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The Henryk Niewodniczański Institute of Nuclear Physics, 40-years of Activity

In 1955, after the first Geneva Conference on Peaceful Use of Atomic Energy, the Government of Poland decided to enter the field of nuclear research. It was decided at the time to buy in the Soviet Union two large installations: a 10 MW swimming pool reactor and a 120 cm classical cyclotron. The reactor, named Ewa, was located in a small village Świerk 30 km out of Warsaw and the U-120 cyclotron was situated at its site in Bronowice, a suburb of Kraków. In the autumn of 1955 a team of physicists and engineers under the leadership of Professor Henryk Niewodniczański began the planning and construction work. In November 1958 we celebrated the extraction of 13 MeV deuteron beam from the then new 120 cm "Large Cyclotron".

At first, the Institute consisted of only four Departments: The Department of Nuclear Reactions, The Department of Nuclear Spectroscopy, The Department of Structural Research and Department of Theoretical Physcis. Since at that time research equipment for nuclear physics was not available on the market, from the very beginning of our Institute the mechanical and electronics shops were crucial for our operation. Soon, thanks to international cooperation, research performed at the Institute attained a recognized world standard. In 1970 the Cracow High Energy Group led by Professor Mięsowicz joined the Institute, considerably broadening the scope of our research.

We meet the 40-th anniversary of the operation of the Henryk Niewodniczański Institute of Nuclear Physics with a staff of 600 employees and over 200 research papers published anually in refereed journals of international reputation. Every year the Institute hosts two or three international conferences attended by physicists from all over the world. The annual "Zakopane School" in theoretical and experimental physics has by now been well established within the international community of physicists.

Over the last few years the Institute has opened itself widely to the needs of the society and of the environment of Kraków, our home town. We provide dosimetry services and monitor radiation levels in the soil and air. Our laboratories are available to everybody who wishes to test any product for radioactive contamination or to seek advice on the level of radon concentration in his home. Using various nuclear and nonnuclear methods developed at our Institute, often unique in Poland, we also provide services in the areas of material and enviromental studies, nuclear medicine, radiobiology and radiotherapy, extensively collaborating with the scientific community of our city. During the first fourty years of its activity, the Henryk Niewodniczański Institute of Nuclear Physics (or IFJ, by its Polish acronym) has gained a respectable position in the world, a leading position in Poland, and has firmly established itself in the scientific, cultural and social life of Kraków. .

Research carried out at the Henryk Niewodniczański Institute of Nuclear Physics through 1994 has resulted in 211 papers published in refereed journals of international reputation, 43 invited talks and 115 contributions to international conferences. The Institute hosted 6 international and 4 local conferences, workshops and summer schools.

In the field of high energy physics we exploited intensively the Delphi, Zeus and H1 detectors harvesting new data. We also participated in muon experiments at FNAL in Batavia and relativistic heavy ion experiments at CERN, Brookhaven, as well as in the JACEE and Hegra cosmic ray projects. We entered fully into new projects: at LHC within Atlas and Alice collaborations and into the Phobos collaboration at RHIC. All these experiments were strongly supported by theoretical studies on subjects such as physics of small x, heavy quark physics and studies of radiative corrections.

Within the COSY 10 collaboration we obtained the first physical data on pion production in the p+p reaction close to threshold. New data concerning multifragmentation of highly excited ^{197}Au nucleus were obtained within the Faza collaboration (JINR Dubna).

We have provided the EUROGAM collaboration with the Recoil Filter Detector which is now being installed at the Vivitron accelerator in Strasbourg. The new approach to study DIC with coincidence gamma spectroscopy developed in collaboration with Legnaro has led to the discovery of the doubly magic ^{58}Ni nucleus.

Using neutron beams from the reactors at Frank Laboratory of Neutron Physics JINR (Dubna) and at Kjellar (Norway) we have finished studies of phase transitions on a series of liquid crystal, molecular crystal and polimer compounds. These studies were supported by calorimetic and infrared spectroscopy measurements.

Applying the technique of nuclear magnetic resonance, we have completed research on tunneling of amonium ions substituted by deuterons.

In the field of nuclear geophysics we found an effect of selfcleaning of mine brines from Ra and Ba. We developed a theoretical method for calibrating neutron logs.

The physical and chemical properties of A=106 elements have been established in collaboration with FLNR (Dubna) and INP (Orsay).

PIXE and SRIXE methods have been widely used in studies of heavy element concentration in cancer tissues. Chromosome abberations and DNA defects were studied using alkaline electrophoresis of blood lymphocytes. Mutation induced by radiation was further investigated using Tradescantia as a model plant. A NMR microtomograph developed on-site was used to study the anatomy ot the bee. A large number of material studies were performed using nuclear methods such as ion implantation, positron anihilation, and RBS.

Monitoring of the radiation level in the environment has been an important task of our Institute. We have upgraded the facilities of the Radiative Pollution Laboratory to be able to rapidly detect ^{7}Be, ^{40}K, ^{137}Cs, ^{226}Ra and ^{210}Pb. The dynamics of the activity of ^{137}Cs, ^{7}Be, ^{40}K in wood biosphere was studied.

Ultrasensitive LiF:Mg,Cu,P thermoluminescence detectors were produced in large quantities and applied in environmental and personal monitoring. Biophysical models of radiation effects were further developed and appied in studies of radiobiological properties of beams of charged particles and of fast neutrons in radiotherapy.

The 120 cm cyclotron was intensively exploited for neutron therapy, isotope production and

in research on fusion fission reactions and the giant resonance of excited nuclear states. The 3 MeV pressurized Van de Graaf accelerator was used for material, medical and environmental studies. The Cockroft Walton pulsed neutron generator was used for studies of neutron scattering in rocks. The 144 cm isochronous cyclotron AIC 144 was equipped with a new dee. We have upgraded our computer network with new workstations of the HP715 and Silicon Graphics Challenge class.

A new and exciting experience for us was the Open Day of the Institute which we organized for the first time. We had a full house and believe this effort has substantially contributed to the development of our public relations with the authorities and the citizens of Cracow. We also paid more attention to our teaching activities in various fields including basic sciences, environmental and material studies as well as efficient energy consumption.

This year we suffered a great loss. Our colleague, Professor Zygmunt Chyliński. Member of our Scientific Council and an eminent Polish theoretical physicist, has suddenly passed away on November 29.

Our traditional collaboration partners were: the CERN Organization in Geneva, the Hahn-Meitner Institute in Berlin, the Jülich Kernforschungszentrum, the University of Münster, GSI Darmstadt, CRN Strasbourg, Laboratoire du GANIL Caen, DESY Hamburg, KfK Karlsruhe, LNL Legnaro, Argonne National Laboratory, Purdue University, Brookhaven National Laboratory, Fermilab, Louisiana Univeristy at Baton Rouge, the JINR in Dubna, the Kurchatov Institute in Moscow and the Institute of Nuclear Physics of the Ukrainian Academy of Sciences in Kiev. New promising contacts with the Korean Atomic Energy Research Institute and the KEK Research Center in Japan have been established.

Prof. A. Budzanowski

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Head of The Polish Atomic Agency.

† – deceased.

CONTENTS:

Section I

Department of Nuclear Reactions

Section I

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GRANTS:

1. *Prof. A. Budzanowski*,
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   "Investigation of Resonances in $(^{16}O,^{12}C)$ System",
   1. 10. 1991 – 30. 09. 1994;
2. *Prof. S. Drożdż*,
   grant No 224099102 (The State Committee for Scientific Research),
   "Investigation of Strong Interactions in Nuclear Many-Body Systems",
   10. 03. 1993 – 31. 12. 1994;

3. *Prof. S. Drożdż,*
   grant No 2P30215704 (The State Committee for Scientific Research),
   "Nonlinear and Topological Effects in Nuclear Dynamics",
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4. *Dr S. Kliczewski,*
   grant No 2P30202505 (The State Committee for Scientific Research),
   *"Experimental Investigation of Low-Lying States of Pionic Atoms Using
   the COSY Accelerator" (Jülich),*
   1. 10. 1993 – 30. 09. 1996;

5. *Dr A. Adamczak,* grant US National Science Foundation No INT 91-19223,
   "Theory of Scattering of Muonic Hydrogen Atoms on Molecular Targets",
   1. 10. 1992 – 1. 10. 1995.

OVERVIEW:

The highlights of the research on nuclear reactions in 1994 may be characterized as follows. We have measured the ratio of the cross sections for the symmetric ($^{16}O,^{16}O$) and asymmetric ($^{20}Ne,^{12}C$) fission like outgoing reaction channels resulting from the α + ^{28}Si collisions. The experimental ratio 1:2.4 which could not be explained by the statistical decay of the compound ^{32}S nucleus was beautifully reproduced in terms of the α cluster classical molecular dynamical model calculations.

In cooperation with physicists from the Institute of Nuclear Physics of the Ukrainian Academy of Sciences in Kiev and the Kurchatov Institute in Moscow we have obtained new data on transfer reactions in light heavy ion system. The GEM spectrometer operating at COSY accelerator in Jülich produced first data on the p + p → d + π^+ cross section at 800 MeV/c.

In the frame of the FASA collaboration new results on the multifragmentation of the nuclei with relativistic alpha particles were obtained. The experimental data indicate on the low ($1/3\rho^o$) density of the excited nucleus and short time of the multifragment decay.

New results on the existence of the meson cloud in barions were obtained. Semiinclusive cross-sections for the deep inelastic lepton scattering on nucleon were calculated. The influence of the meson cloud on these cross sections was shown. The analysis of the isospin asymmetry of the see quarks in terms of the Drell-Yan process confirmed the existence of the virtual meson cloud.

Further studies on quantum chaos in nuclear dynamics were performed. A new model of excitation and decay of nuclear states based on the space of one-particle one-hole and two-particles two-holes excitations was elaborated. It was found for the case of chaotic background that the small components of the wave function are ruled by the scaling low analogous to the selforganizing systems in critical state. A new model was formulated which enabled to study classical dynamics of the fermion system. It was shown that antisymmetrization leads to the chaotic scattering in spite of the absence of the interaction between constitents fermions. New theoretical data on muon transfer and scattering of muonic atoms were obtained. New method of preparing thin (10μ) semiconductor detectors based on etching of the epitaxial Si slices was elaborated.

Our traditional partners were: KFA Jülich, HMI Berlin, JINR (Dubna), GANIL (France), Urbana (Illinois), INP NASU (Kiev), KI (Moscow).

Professor A. Budzanowski

REPORTS OF RESEARCH:

On Fractal Nature of the Compound Nucleus

A. Budzanowski, S. Drożdż, J. Okołowicz, and T. Srokowski

Molecular dynamical approach [1] (MDA) study of the scattering processes based on the concepts of the transport theory [2] allows to determine the classical survival probability $P_{ij}(E, t)$ for a system to remain in the interaction region with respect to a $j \to i$ transition. This is a quantity which, according to the semiclassical considerations determines, via the Fourier transform, the energy autocorrelation function C_{ij} of an S-matrix element, $C_{ij}(\epsilon) = \langle S_{ij}^*(E)S_{ij}(E + \epsilon)\rangle_E$, and thus makes a link between the quantum and the classical picture. Chaotic scattering connected with the existence of only unstable periodic trajectories (hyperbolic chaotic scattering) results in an exponential decay:

$$P(E, t) \sim \exp(-\gamma t). \tag{1}$$

The resulting autocorrelation function has a Lorenzian form: $C(\epsilon) \sim \hbar/(\epsilon + i\hbar\gamma)$, a characteristic of Ericson fluctuations observed in the decay of compound nuclei.

The decay rate in eq. 1 is predicted [3] to be described by:

$$\gamma = \Sigma_i \lambda_i (1 - D_i), \tag{2}$$

where λ_i and D_i denote the positive Lyapunov exponents and the partial fractal dimensions, respectively. For $^{12}C + ^{12}C$ collision (18-dimensional problem) all positive λ_i, calculated according to the prescription of ref. [4], are shown in Fig. 1.
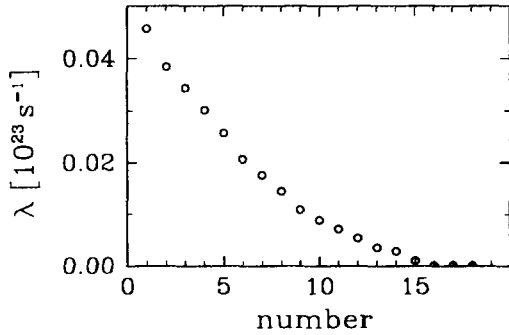
Fig. 1: Spectrum of positive Lyapunov exponents for $^{12}C + ^{12}C$ head on collision at 20MeV incident energy.

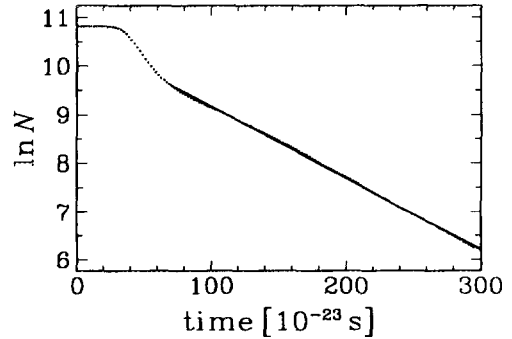Fig. 2: A number of two body events N living until a given time and leading to an α-particle emission following collision as described in Fig. 1. Straight line represents exponential fit for times longer than $7 \cdot 10^{-22}$s.

There exist no well defined methods to calculate the partial fractal dimensions D_i for multidimensional problems. Because more particles are involved and any of them can escape from the interaction region, typical D_i in the present case is, however, expected to be significantly closer to unity than the fractal dimension (~ 0.65) corresponding to the simplified version of the same model [5] in the region of hyperbolic instabilities. In fact, a simple estimate based on the scaling relation between the difference in initial impact parameter for a pair of the scattering events and the resulting fraction of events uncertain in the decay mode or emission angle (uncertainty exponent technique [6]) gives a value of 0.9. This, most probably, does not correspond precisely to any of the D_i but provides a reasonable indication for some average value. Via eq. 2, the above values of λ and D give an estimate which agrees with $\gamma \approx 0.015$ as extracted from the time

dependence of the survival probability shown in Fig. 2. This provides direct evidence that in the classical limit the physics of compound nuclei is governed by the positive Lyapunov exponents and the structure of instabilities is fractal.

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5. S. Drożdż, J. Okołowicz and T. Srokowski, Phys. Rev. E **48** (1993) 4851,
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Antisymmetrization Induced Chaos

S. Drożdż, J. Okołowicz, M. Płoszajczak[1], E. Caurier[2], and T. Srokowski

[1] *GANIL, BP 5027, F-14021 Caen Cedex, France*

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Dynamics of classical scattering in the system of fermions is studied. The model is based on the coherent state representation and the equations of motion for fermions are derived from the time-dependent variational principle [1].

Schematic models [2], based on the scattering of a particle on the target composed of three particles at the corners of an equilateral triangle located in the reaction plane (x, y), proved very instructive in studying various aspects of the collision processes. Thus, each particle represents a fermion described by the Gaussian wave packet:

$$\phi_i(\mathbf{r}) \equiv \langle \mathbf{r} | \phi_{\mathbf{Z}_i} \rangle = \left(\frac{1}{\pi b^2} \right)^{3/4} \exp\left[-\frac{(\mathbf{r} - \mathbf{Z}_i)^2}{2b^2} \right] \tag{1}$$

where $\mathbf{Z}_i$ is the location of the center of gravity of the packet. The target is given by a three fermion configuration forming an equilateral triangle of side equal to 4 (the units are specified by setting $\hbar = b = m = \hbar\omega = 1$). We begin by entirely discarding the interaction term in the Hamiltonian in order to elucidate on the role of antisymmetrization itself.

Fig. 1 shows dependence of deflection angle θ of the particle scattered off the target on the impact parameter for the three different energies. For energies either small ($E = 0.2$) or large ($E = 0.6$) compared to the height of the effective Pauli potential this dependence is essentially continuous. At $E = 0.4$ and for the impact parameters between 0 and 1, one observes behavior characteristic of the chaotic scattering. The succesive blow-ups in this region show that the singularities develope a regular self-similar structure.

Very interestingly, this scattering process carries all characteristics of the hyperbolic chaotic scattering [3]. For this type of scattering, theory predicts the survival probability, *i.e.* number of trajectories remaining in the interaction region up to time t follows $N(t) = N_0 \exp[-\lambda(1 - D)]$, where λ is the Lyapunov exponent and D is the fractal dimension. The determination of Lyapunov exponent is presented in Fig. 2a ($\lambda = 0.22$). Furthermore, the set of singularities seen in Fig. 1 for $E = 0.4$ posesses a well defined fractal dimension D and one finds $D = 0.591$ (Fig. 2b). By uniform random sampling of the whole interval of impact parameters one determines the survival probability $N(t)$. In our case, as is shown in Fig. 2c, one observes asymptotically an exact exponential dependence, characteristic of the hyperbolic chaotic scattering. Using the above values of λ and D yields the straight line in Fig. 2c which perfectly reproduces the survival probability $N(t)$ determined directly (dots) by numerical experiment.
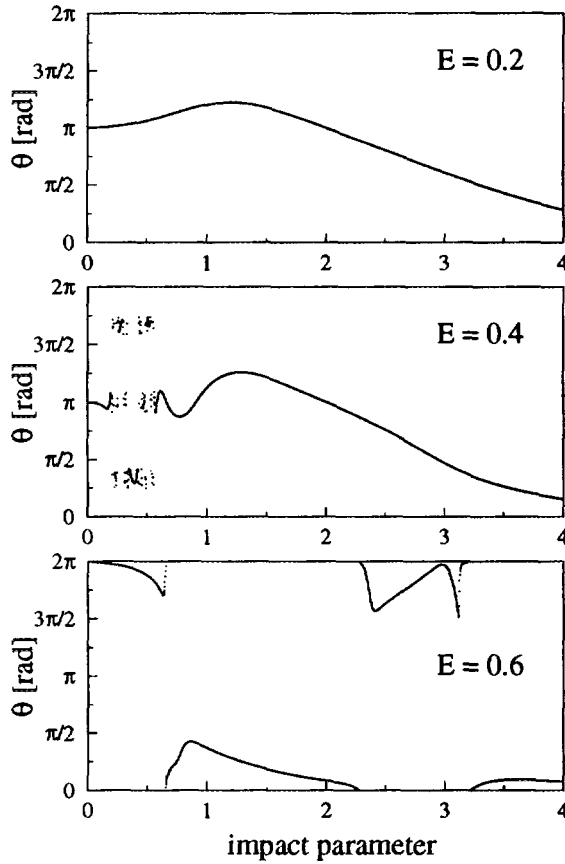
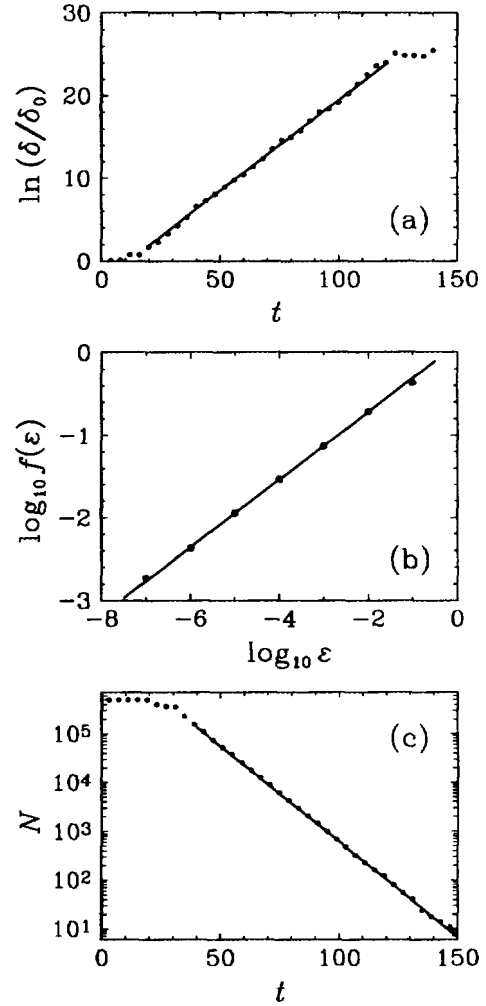*Fig. 1: Deflection angle θ as a function of the impact parameter for three different energies.*

Fig. 2: (a) Separation ratio between the neighbouring trajectories for the scattering process at $E = 0.4$. Dots denote the dynamically determined values and the straight solid line represents a fit whose slope corresponds to the Lyapunov exponent $\lambda = 0.22$.

(b) Dependence of the fraction $f(\epsilon)$ of uncertain pairs of trajectories as a function of the difference ϵ in initial values of the impact parameters. According to the uncertainty exponent technique the corresponding fractal dimension is $D = 0.591$.

(c) Survival probability expressed as a number of the scattering trajectories remaining in the interaction region up to time t. The straight line represents the theoretically determined dependence.

We thus conclude that the fermionic nature of particles may drastically change the structure of the corresponding classical phase space. We identify the chaotic behaviour in absence of any interaction at all.

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Screening of Interaction by Pauli Blocking

S. Drożdż, J. Okołowicz, M. Płoszajczak[1], E. Caurier[2], and T. Srokowski

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One of the central issues in the theory of complex dynamical systems is the classical-quantum correspondence for classically chaotic motion. Classically, chaos is a well defined concept but a way it manifests itself on the quantum level still remains a matter of controversy. One of the reasons of this controversy is the quantum mechanical symmetry related to the identity of particles. Of particular interest and importance in this context are the effects resulting from antisymmetry of an underlying wave function for fermionic systems.

The system of A fermions is described by a Slater determinant. Then the time development of the dynamical variables can be determined by the time-dependent variational principle [1]. For the two particle system, an exact transformation can be performed to the canonically conjugate variables [2]. These canonical variables can never get closer than $\sqrt{2}$. Thus a topological hole, existing also for $A \geq 3$, corresponds to the Pauli forbidden region [2, 3].

In the preceeding contribution we have shown that the correlations resulting from Pauli blocking may lead to a significant modification of the particle dynamics. Namely they may even convert free motion in the gas of non-interacting particles into the strongly chaotic one. In general, this is more likely to occur when the mean kinetic energy of particles in the gas is comparable with the height of the effective Pauli potential. At very low energies, the range of Pauli blocking for sufficiently dense system extends to such a size that different topological holes start overlapping and the dynamics becomes more regular again. In a more realistic case of *interacting fermions*, this effect may thus screen out the short range components of the two-body interaction. This dynamical screening may be especially important for the hard, short-range interactions like the one between the nucleons. Classically, such an interaction generates strongly chaotic behaviour. However, its appearence inside the Pauli forbidden region may restructure and even eliminate the corresponding irregularities.

For a somewhat more quantitative illustration of this point, we present in Fig. 1 the equienergy surfaces in the configuration of three fermions fixed at the corners of equilateral triangle as seen by a fourth particle in the triangle plane. The constituents interact with the spherically symmetric, repulsive two-body interaction:

$$V(r) = V_0 \exp\left[-(r/r_0)^2\right] \tag{1}$$

with $V_0 = 10^{5/2}$ and $r_0 = 10^{-1/2}$. For these parameters the above interaction is comparatively hard and short-ranged. Upper panels of Fig. 1 corresponds to the situation with no antisymmetrization included. The side of the triangle equals 3 in the left panel and it equals 4 on the right. In both cases the three hill structure shows up and, consequently, the scattering will be chaotic in the corresponding energy intervals. Larger separation of the scattering centers in (d) extends these intervals in the direction of lower energies. Including antisymmetrization changes the picture completely, especially in the case (b) of Fig. 1. Here, not only the energy is reduced by almost two orders of magnitude but also the three hill structure, previously responsible for chaotic behaviour disappears. Increasing momentum, slowly recovers the original shape of the energy surfaces, as is shown in Fig. 1c and Fig. 1f for momentum of $2\sqrt{10}$, but they still remain about one order of magnitude lower.

We thus conclude that the fermionic nature of particles may drastically change the structure of the corresponding classical phase space. As the two extreme possibilities we identify the chaotic behaviour in absence of any interaction (*c.f.* preceeding contribution) and the regularization of motion for strongly interacting particles.
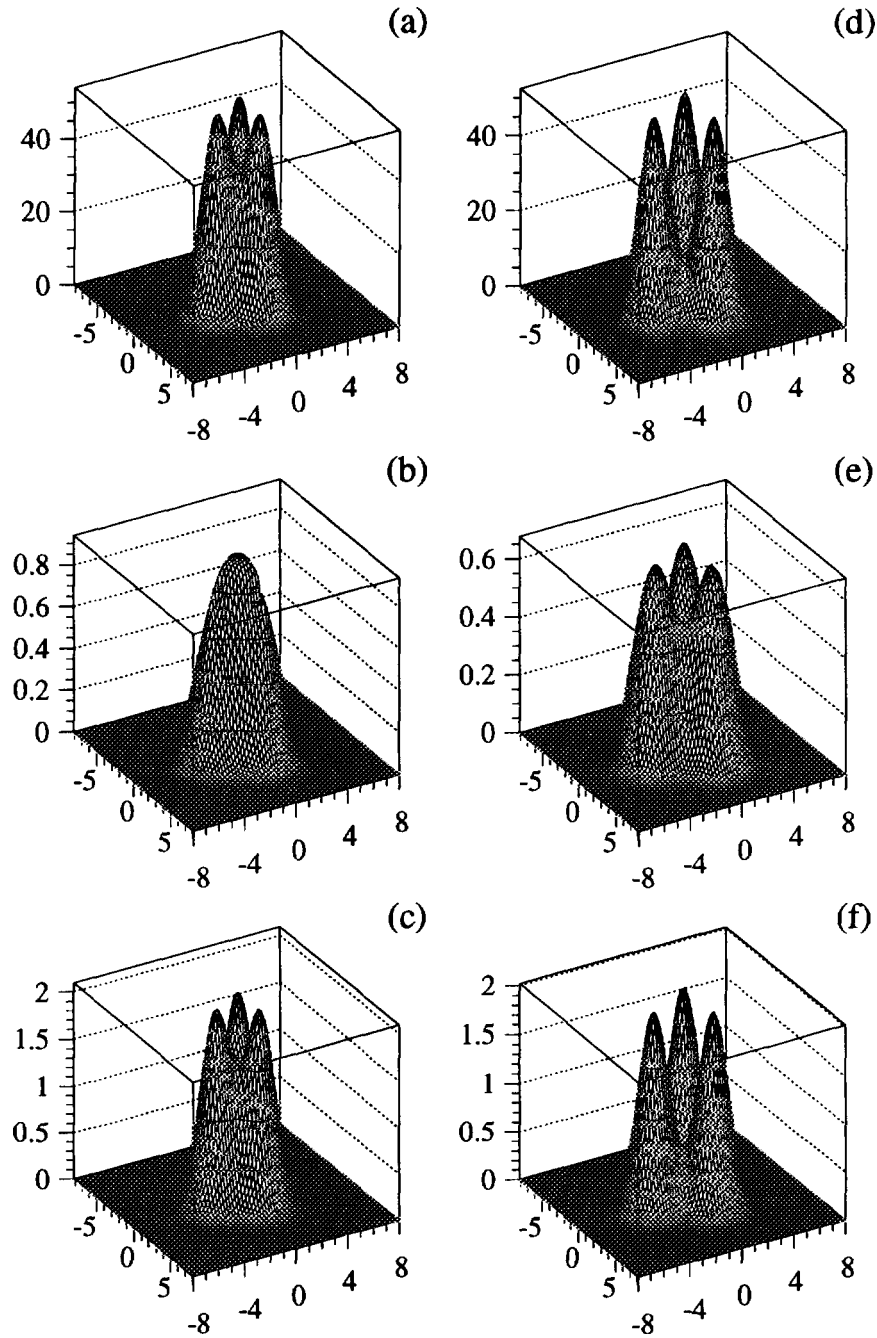
Fig. 1: Equienergy surfaces for the three fermion configurations forming an equilateral triangle of side equal to 3 (left panels) and 4 (right panels) respectively: a) and d) represent the potential energy without antisymmetrization for the two-body interaction defined by eq. (1), b) and e) the total energy with antisymmetrization, c) and f) the total energy with momentum of $2\sqrt{10}$.

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Temporal Correlations in Nuclear Giant Resonance Decay

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The study of chaos in nuclear physics has been mostly based – so far – on level statistics. In practical terms this is rather restrictive since a reliable statistical analysis requires very precise energy resolution. It also does not provide firm means for investigating the role of collectivity and mechanisms of its coexistence with chaos. In this respect the study of temporal correlations between an initially prepared non-stationary state and a state to which it evolves seems to be much more appropriate. Nuclear giant resonances are of central interest in this connection because they are located in a region of high level density which is expected to be dominated by chaotic dynamics. To make the theoretical studies meaningful one needs a scheme which incorporates the relevant elements, such as the possibility of defining a physical collective state, a realistic modeling of the background states whose complexity is consistent with the Gaussian orthogonal ensemble (GOE) of random matrices and, finally, the realistic coupling between the two.

The recently developed model [1], based on a diagonalization of the full nuclear Hamiltonian consisting of a mean field part and a residual interaction

$$\hat{H} = \sum_i \epsilon_i a_i^\dagger a_i + \frac{1}{2} \sum_{ij,kl} v_{ij,kl} a_i^\dagger a_j^\dagger a_l a_k, \tag{1}$$

in the basis of 1p-1h and 2p-2h states

$$|1\rangle \equiv a_p^\dagger a_h |0\rangle; \quad |2\rangle \equiv a_{p_1}^\dagger a_{p_2}^\dagger a_{h_2} a_{h_1} |0\rangle \tag{2}$$

fulfills these requirements and proves numerically manageable [6]. A prediagonalization of the two-body interaction v in the 1p-1h and 2p-2h subspaces defines $|\tilde{1}\rangle = \sum_1 C_1^{\tilde{1}}|1\rangle$ and $|\tilde{2}\rangle = \sum_2 C_2^{\tilde{2}}|2\rangle$, and the coupling is mediated by the off-diagonal elements $\langle \tilde{1}|v|\tilde{2}\rangle$ and their complex conjugate. An initially excited state, in response to an external one-body field $\hat{F} = \sum_{ij} F_{ij} a_i^\dagger a_j$ can be represented as:

$$|F\rangle = \hat{F}|0\rangle = \sum_{\tilde{1}} F_{\tilde{1}} |\tilde{1}\rangle. \tag{3}$$

As soon as the coupling between the subspaces $|\tilde{1}\rangle$ and $|\tilde{2}\rangle$ is taken into account, the state originally localized in the 1p-1h subspace, as defined by eq. (3), starts leaking into the 2p-2h space. The degree of mixing depends not only on the magnitude of v but also on the nature of the energy fluctuations in the 2p-2h space. The most natural quantity for describing the leakage is the survival probability, defined as:

$$P(t) = |\langle F(0)|F(t)\rangle|^2. \tag{4}$$

The physical significance of $P(t)$ can be identified from its relation to the spectral autocorrelation function $G(E)$ [3]

$$P(t) = \int dE e^{-iEt/\hbar} G_F(E), \tag{5}$$

where

$$G_F(E) = \int dE' S_F(E') S_F(E' + E) \tag{6}$$

and $S_F(E)$ is the transition strength distribution $S_F(E) = \Sigma_n |F_n|^2 \delta(E - E_n)$. Thus $P(t)$ can be obtained from experiments which measure $S_F(E)$.

The calculations presented below for quadrupole excitations in ^{40}Ca are performed in the same basis as in ref. [6], *i.e.* including all 1p-1h and 2p-2h states up to 50 MeV and using the same residual interaction. Since the present study concentrates on the phase-space exploration and the role played by chaotic dynamics, we distinguish three cases corresponding to different classes of the spectral fluctuations in the 2p-2h subspace. As established in ref. [1] one finds: a) with no residual interaction in the 2p-2h subspace there are many degeneracies in $|\tilde{2}\rangle$ ($= |2\rangle$) and the nearest-neighbor spacing is strongly peaked near zero; b) inclusion of particle-particle and hole-hole matrix elements in $\langle 2|v|2'\rangle$ removes all degeneracies and leads to a Poissonian distribution of the nearest-neighbor spacings, characteristic of generic integrable systems; and c) use of the full residual interaction yields GOE fluctuations, characteristic of chaotic dynamics.

The initial state $|F(0)\rangle = \hat{F}|0\rangle$ (eq. (3)) is already non-stationary in the 1p-1h subspace and therefore oscillates within the limits set by this subspace. Including the mixing with 2p-2h states and looking at $\bar{P}(t) = \int_0^t dt' P(t)/t$ (Fig. 1) shows that the isovector excitation mixes much more efficiently with the background 2p-2h states. The asymptotic value of the survival probability $P(t)$ systematically decreases with increasing degree of complexity in the background states (going from a) to c)). Most interestingly, for the isovector excitation in the chaotic case c), $P(t) \cdot N$ where N denotes the total number (3040) of states in our space, reaches - on average - a value close to 3 (3.08). This effect, is characteristic of quantum ergodicity [4].

An additional requirement for chaoticity is the initial dephasing of $P(t)$ below its asymptotic value [3]. Such a dephasing, indeed, takes place for the isovector case, as can also be seen from Fig. 1. As a consequence of the high density of states the corresponding 'correlation hole' extends over a time interval, four orders of magnitude longer than the characteristic 'excitation time' of $\sim 10^{-22}$sec. The isoscalar excitation (right panel of Fig. 1) only shows a trace of such a behavior and the asymptotic values of $P(t)$ are systematically larger even though the initial state is coupled to the same background.
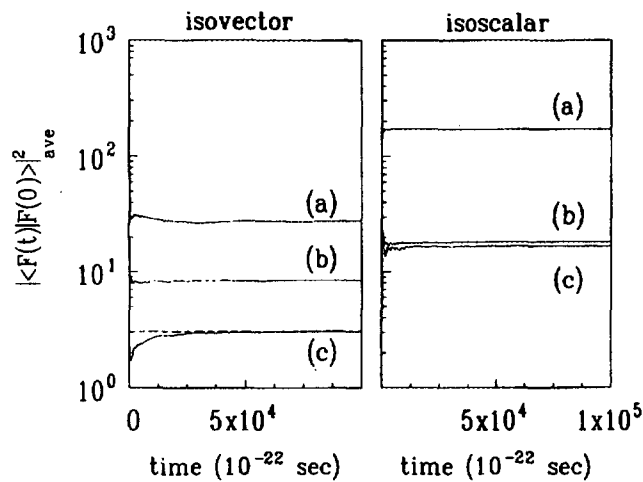
Fig. 1 *The time-averaged survival probability $\bar{P}(t)$ in units of $1/N$ (N is the number of vectors spanning the space, 3040 in the present case) for the isovector (l.h.s.) and isoscalar (r.h.s.) quadrupole resonances: a) no residual interaction in 2p-2h subspace; b) including only particle-particle and hole-hole matrix elements in the diagonalization of the 2p-2h subspace; c) diagonalization of the full residual interaction in the 2p-2h subspace.*

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Generalized Entropy Analysis of Phase-Space Exploration in Nuclear Giant Resonance Decay

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One of the most interesting results of the previous study [1] is that the isoscalar state remains much more localized than the isovector state even though they evolve in the same phase-space. Is it a manifestation of stronger collectivity of the isoscalar state or, perhaps, is it that the specific properties of the coupling matrix elements block certain regions of the phase space and ergodization only occurs in the unblocked regions? A quantity which appears helpful in resolving this question originates from the concept of entropy. The information entropy of the state $|F\rangle$ can be defined, in a given basis $|k\rangle$, as:

$$K = -\sum_k p_k \ln p_k, \qquad (1)$$

where $p_k = |\langle k|F\rangle|^2$. It provides a quantitative measure of the complexity of the state $|F\rangle$ and its localization length in the basis $|k\rangle$ [2]. The so-defined K is, in principle, basis dependent, but the physically preferred basis is determined by the mean field. As the most smooth component of the nuclear Hamiltonian [3] it provides a natural reference for quantifying local GOE-type fluctuations.

In our case the mean field basis corresponds to the unperturbed basis of states $|1\rangle$ and $|2\rangle$. Calculating $K(t)$ along the 'trajectory' $|F(t)\rangle$ for the isovector and isoscalar states, we obtain asymptotically values of 7.10 and 6.53, while the corresponding initial values are 2.56 and 2.40, respectively. This is to be compared to $K^{GOE} = 7.29$ ($K^{GOE} = \psi(N/2 + 1) - \psi(3/2)$) [2], where ψ is the digamma function and N is the number of basis vectors). A comparison of these numbers indicates non-uniformities in the p_k distribution, especially for the isoscalar excitations. Actually, even the GOE-type fluctuations result in a gaussian distribution which is non-uniform (a uniform distribution maximizes the entropy and corresponds to $p_k = 1/N$ which, for $N = 3040$, gives $K \approx 8.02$).

In view of the above mentioned non-uniform phase-space exploration, we find it instructive to calculate the spectrum of q-moments for $\{p_k\}$ and to introduce a generalized entropy [4]

$$K_q = \frac{1}{1-q} \ln \sum_{k=1}^{N} p_k^q. \qquad (2)$$

From this definition it follows that $K_{q_1} \leq K_{q_2}$ if $q_2 < q_1$ (provided $\Sigma_k p_k = 1$). Equality holds for the uniform distribution. For $q \to 1$ eq. (2) yields the information entropy (eq. (1)). The most important property of K_q is that with increasing q a higher weight is given to the largest

components in the set $\{p_k\}$. For $q \to 0$, on the other hand, K_q just counts the number of sites (here the basis vectors $|k\rangle$) visited, irrespective of how frequently they are sampled. For this reason eq. (2) also constitutes a basis for defining the multifractal dimensions of non-uniform fractal sets [5].

For selected q-values Fig. 1 compares the time evolution of $K_q(t)$ for the isovector and isoscalar excitations when the background states have GOE fluctuations (case (c)). As one can see from the large-q behavior of $K_q(t)$, which are systematically smaller for the isoscalar excitation, the large components of these remain much more localized (larger) than those of the isovector excitation. Since, by probability conservation, the number of significant components is smaller in the former case, the amplitude of oscillations is larger in the corresponding $K_q(t)$. On the other hand, the dynamics starts to look similar in both cases as q decreases and, for $q \to 0$, K_q approaches a value of 8. This signals that, on the level of small probabilities, the whole space spanned by 3040 states is visited. This aspect of the dynamics is consistent with the scaling properties of the transition strength distribution for the isovector and isoscalar states discussed in ref. [6]. On the level of small components they both scale.

For the purpose of addressing specific questions concerning the quantum-mechanical phase space exploration of collective modes, the full set of "generalized entropies" appears to be a useful theoretical tool.
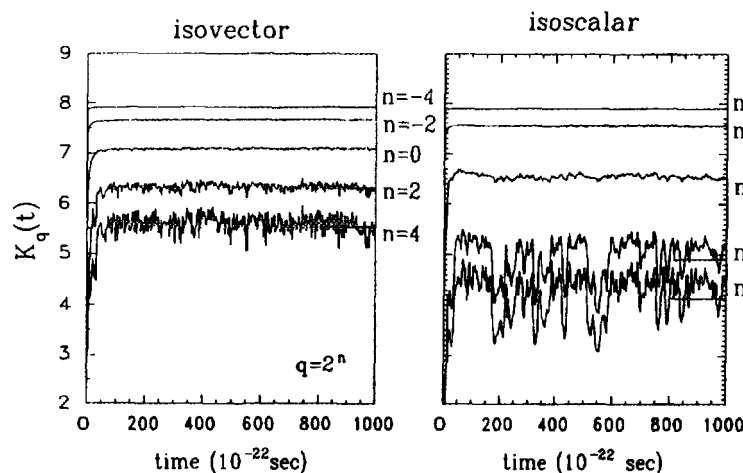

Fig. 1 *The time evolution of the generalized entropies defined by eq. (2) for the isovector (l.h.s) and isoscalar (r.h.s) giant quadrupole resonances in ^{40}Ca coupled to the background characterized by GOE fluctuations. The horizontal marks on the left hand side of each panel denote the asymptotic values of K_q for $q = 4$ and $q = 16$.*

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Heavy Fragment Emission from the ^{32}S + ^{58}Ni Reaction at 30 AMeV Studied with the QMD Model

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We studied heavy fragment emission from the ^{32}S +^{58}Ni reaction at 30AMeV with the QMD model. The velocity and mass distributions of evaporation residues, fission fragments and fragments from 3-fragment emission were previously extracted [1] from the experimental data and compared with the predictions of two statistical fragmentation models [3, 4] and sequential fission simulations [2]. As a starting point for these calculations we took an equilibrated hot compound system with the excitation energy calculated from a simple heavy transfer model. The main drawback of these calculations was complete omission of reaction dynamics. In order to take into account the entrance channel dynamics we applied the QMD model described in the ref. [5]. The calculations were performed in two steps. First, the dynamical phase of the reaction was calculated, starting at the point where two colliding nuclei are 3 fm apart, and ending after 300 fm/c. The final configuration was then stored and used subsequently as an input for the "cooling" procedure which calculates the decay of the excited fragments produced in the first stage of the reaction. Finally, the results were filtered with the detector acceptance and compared with the experimental data.

Fig. 1 Comparison of results of the GROSS(dashed line) and QMD(solid line) models with experimental data (dots). a) Relative azimuthal angle between the IMF3 registered in phoswich array in coincidence with IMF1 registered in trigger detector at 23.5° b) Polar angle distribution of the IMF33 registered in phoswich array in coincidence with IMF1 registered in trigger detector at 23.5°.

Here we compare the QMD results with the predictions of the GROSS model presented already in [1] and [2]. From abundant experimental data we took the azimuthal correlation and

polar angle distribution of fragments from multifragmentation process triggered by the semiconductor detector placed at 23.5 degrees (Fig. 1) as well as the mass and velocity distributions of fragments registered in the trigger (Fig. 2).

In Fig. 1 one can see some (not very pronounced) differrences. Taking into account the data from the other two triggers one can conclude the following:

- The QMD model gives better position of the maximum in ϕ distribution.

- The θ distribution is better described by the QMD model, whereas the GROSS model gives for each trigger values increasing monotonically with θ.

- Finally, the normalization applied for trigger at $23.5°$ cannot be used in case of the GROSS model for the other triggers.

Mass and velocity distributions (Fig. 2) show distinctly that the QMD model gives a much better description of experimental data. This conclusion is strongly supported by the data from detectors placed at other angles and for other processes (evaporation, fission). In case of mass and velocity distributions calculated with the QMD model, one can use again the same normalization for all detectors and processes, which is not true for the GROSS model.
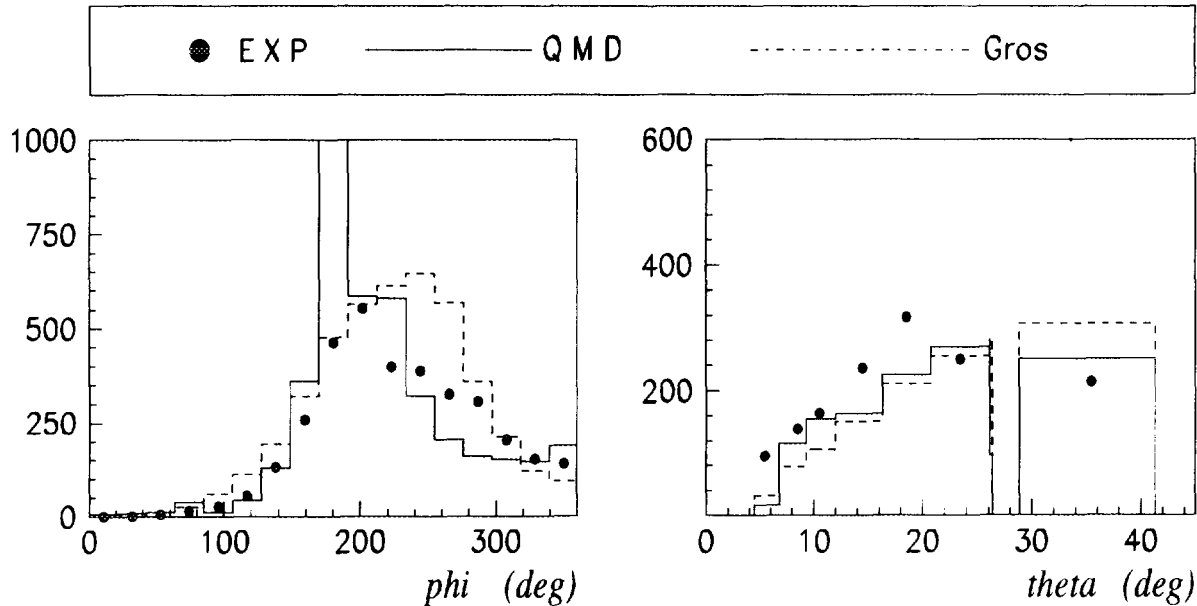

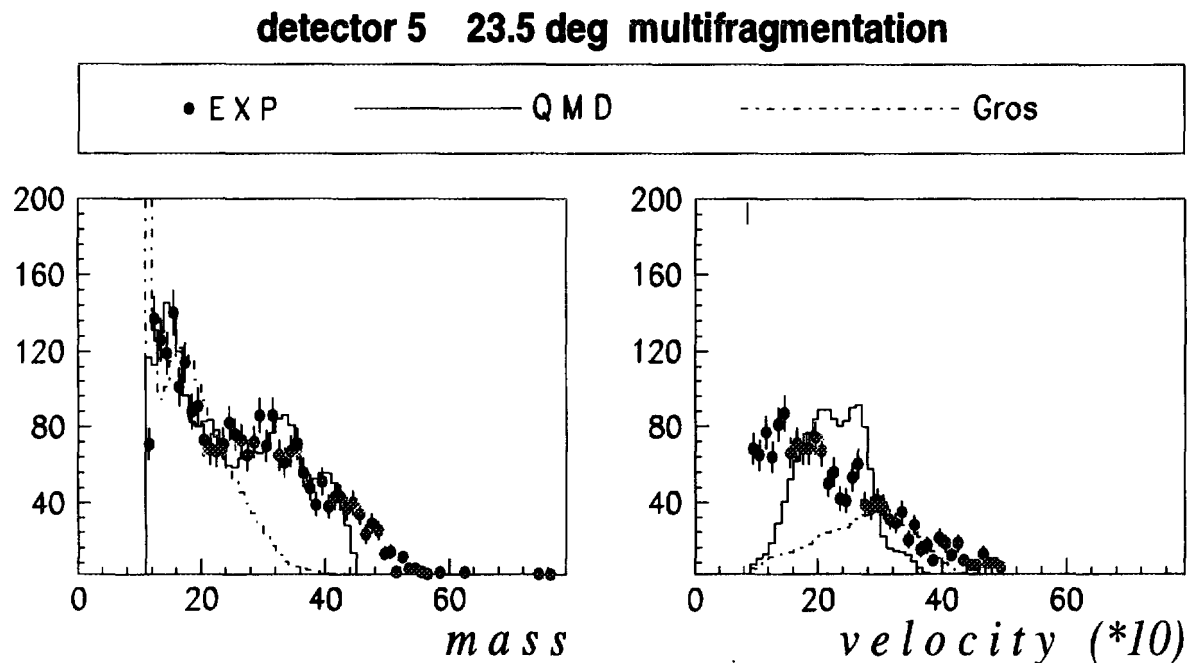**detector 5   23.5 deg multifragmentation**

Fig. 2 Comparison of results of the GROSS(dashed line) and QMD(solid line) models with experimental data (dots). a) Mass distribution of the IMF1 registered at 23.5° in coincidence with two other IMF's detected in phoswich array. b) Velocity distribution of the IMF1 registered at 23.5° in coincidence with two other IMF's detected in phoswich array.

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One-and Two-Step Processes in ^{6}Li(^{7}Li,^{7}Be)^{6}He Reaction at E(^{7}Li) = 78 MeV

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Charge-exchange reactions are natural and very effective tools to study isobaric nuclear states. Reliable information about the spin-isospin structure can only be obtained if the direct one-step mechanism dominates in these reactions and the effective interaction is well known.

The charge-exchange (^{6}Li,^{6}He) and (^{7}Li,^{7}Be) reactions have been studied for 20 years since the first publications [1, 2]. The analysis of experimental data showed that one-step mechanism is dominant even at 30-50 MeV projectile energies, especially for transitions to the unnatural parity states [3], and the contribution of this mechanism increases with increasing beam energies [4]. However, the strength of spin-isospin central interaction extracted from microscopical DWBA analysis has large spread in values for different states and nuclei [3]. The M3Y effective NN-interaction potential gives calculated cross-sections for the (^{7}Li,^{7}Be) reactions 2$-$8 times lower than experimental data [5].

The ^{6}Li(^{7}Li,^{7}Be)^{6}He reaction was studied at the projectile energy of 78 MeV for transitions to the ground and first excited states of ^{6}He and ^{7}Be nuclei. The measured angular distributions were analyzed in the framework of the direct one-step charge-exchange process and two-step sequential np-transfer using DWBA and Coupled Reaction Channel methods. In the calculation of the charge-exchange process the one-pion exchange potential was used as interaction. The analysis showed that direct charge-exchange process dominates at small angles. The cross-section of two-step sequential nucleon transfers increases with increasing angle and gives meaningful contribution at angles larger than 40 deg. for transition to the ground state and at angles > 25 deg. for transition to the first excited state of ^{6}He. At larger angles (> 80 deg.) experimental cross-sections for ^{7}Be emission are determined mainly by the one-proton transfer (^{7}Li,^{6}He) reaction. For the transitions studied, the tensor interaction is very important. The central part of the interaction affects the cross-section at extremely forward angles only. The measured cross-sections can be explained using strength parameter $V_{\sigma\tau}^c = V_\tau^t = 3.9$ MeV for the transition to the ground state, and to the 2.6 MeV excited state respectively.
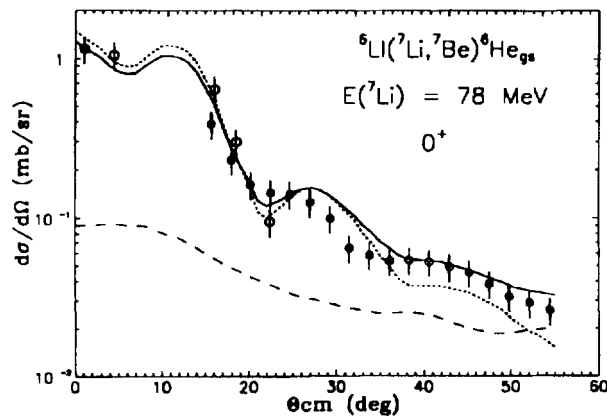
Fig. 1 Angular distribution of the ^{6}Li(^{7}Li,^{7}Be)^{6}He reaction at the ^{7}Li energy of 78 MeV (filled circles) and 82 MeV [6] (open circles) for transitions to the ground state of ^{6}He and the ground and first excited states of ^{7}Be. Dashed lines represent one-step charge-exchange (short dashed line) and two-step (long dashed line) calculations. Solid line is an incoherent sum of both processes.

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Fission of Light Nuclei

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We measured angular distributions of the symmetric ($^{16}O + ^{16}O$) and asymmetric ($^{12}C + ^{20}Ne$) output channels of the $^{28}Si + \alpha$ reaction at 24.9 and 25.9 MeV energies of alpha particles. The heavy-ion spectra were measured in 4° steps from 28° to 64° in the lab system[1].

The data were compared with Hauser-Feshbach calculations using the optical model and level density parameters from ref. [1]. Experimental and calculated differential cross-sections were integrated over the measured angular range. The ratio of integrated cross-sections for $^{12}C + ^{20}Ne$ and $^{16}O + ^{16}O$ output channels was 2.4 ± 0.6 and 0.6 ± 0.03 for experimental data and Hauser-Feshbach calculations respectively. This ratio is not explained in the framework of statistical model.

The dynamics of this reaction was investigated in the framework of the classical dynamical model [2,3] taking into account the alpha particle degrees of freedom only. The model predicts that the equilibrium of the 8-alpha composite system will be attained after $0.9 - 1.2 10^{-20}s$ (Fig. 1) and the lifetimes for $^{12}C + ^{20}Ne$ (Fig. 2a) and $^{16}O + ^{16}O$ (Fig. 2b) decays $1.2 10^{-20}s$ and $1.7 10^{-20}s$ respectively. Thus, most of the decays in question occur during the pre-equilibrium phase and the cross-sections are governed by dynamics rather than by statistics, even at such low energy.

The model predicts the $\sigma_{C+Ne}/\sigma_{O+O}$ ratio to be equal to 2.7 ± 0.8. Good agreement with the experimental value indicates that phenomena beyond the statistical model, e.g. pre-equilibrium emission and the alpha-clusterisation of colliding nuclei, play an important role in explaining the emission of heavy fragments.

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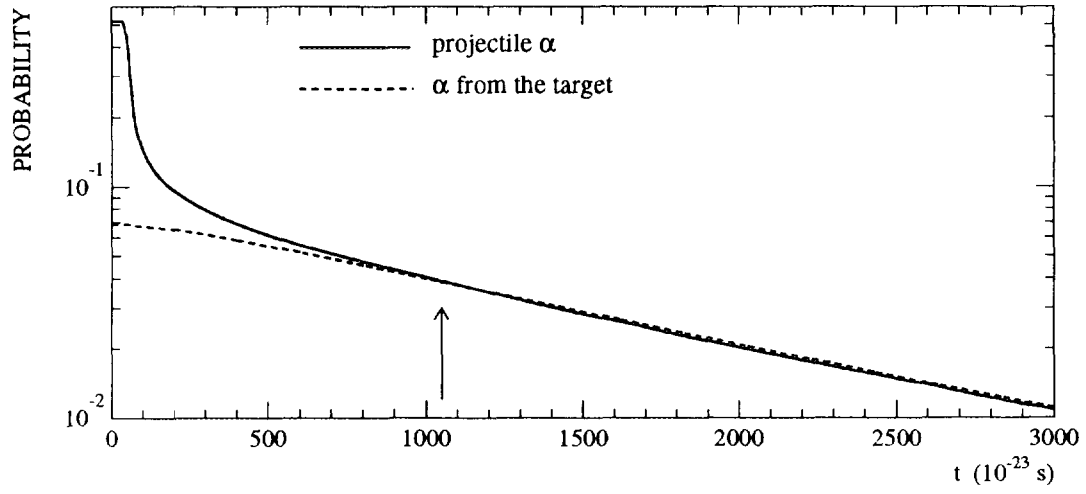
Fig. 1 Angular momentum averaged survival probability for a single α-particle emission vs time.
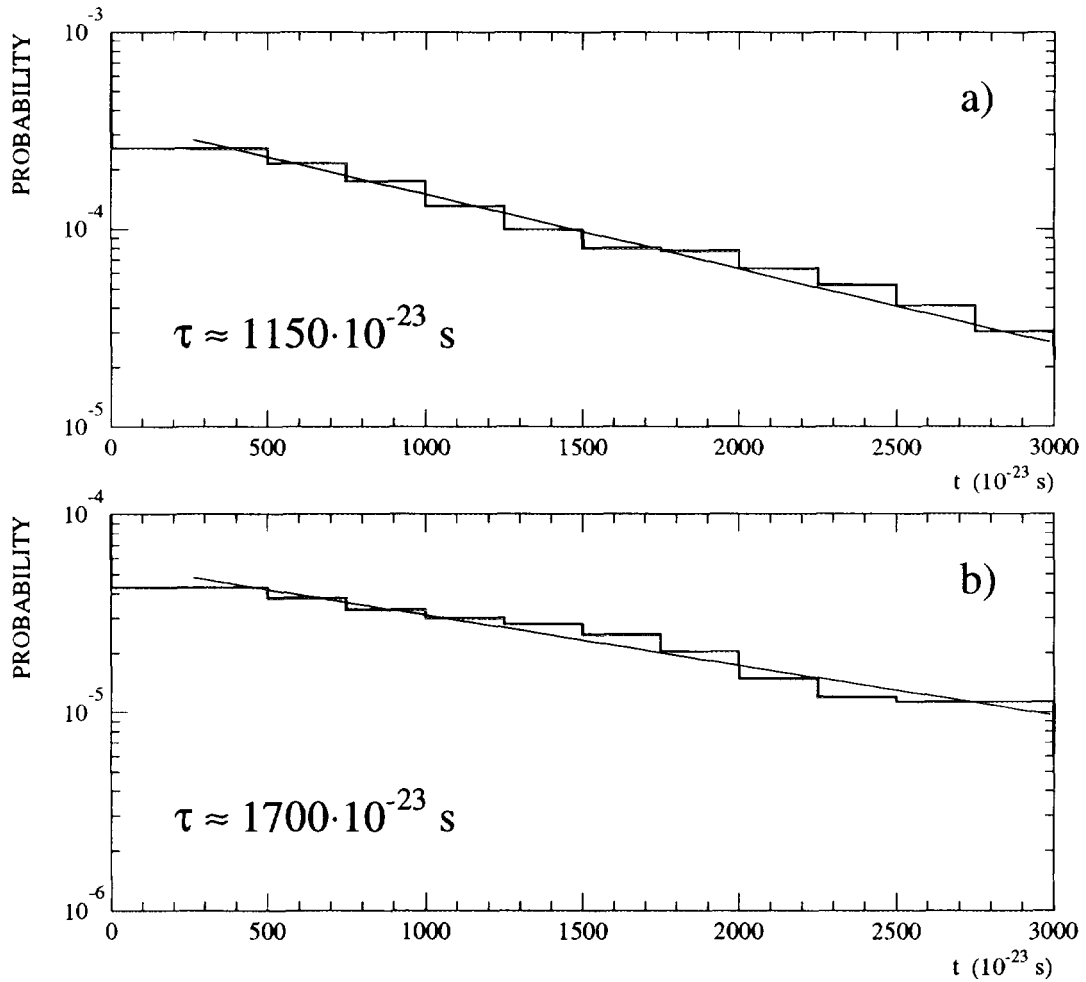

Fig. 2 Angular momentum averaged survival probability for: a) $^{12}C+^{20}Ne$ and b) $^{16}O+^{16}O$ emission vs time. Slope of the best fit lines defines lifetimes τ.

Pion Production from High Energy Proton Scattering at the GEM Facility[1]

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Pion production close to threshold and calibration of the BIG KARL facility constitued subsequent experimental steps of the GEM (GErmanium wall and Magnetic spectrometer) programme using high energy proton beam from the COSY accelerator at KFA, Jülich [1]. In 1994, experiments were performed using magnetic spectrometer BIG KARL only [2]. Simultaneously, the development of the Germanium Wall detector was continued. The Germanium Wall has been designed to increase the angular acceptance of the GEM detector system by a factor of ten as compared to the Big Karl spectrometer alone. The Germanium Wall is described in more detail elsewhere [3].

The main goal of our experiments was to study the $p + p \rightarrow d + \pi^+$ reaction. The experimental setup consisted of a liquid hydrogen target [4], a beam-defining scintillation detector in front of the target and a second scintillation ring detector behind the target, detecting pions and giving a stop signal for the time-of-flight measurement. Deuterons passing through the magnetic spectrometer were measured in coincidence with pions with two stacks of Multi Wire Drift Chambers (MWDC) together with the hodoscope consisting of four layers of scintillation detectors. The second layer produced a start signal for the time-of-flight measurement. Between the third and fourth layers an aluminum absorber was mounted, of thickness sufficient to stop deuterons allowing protons close to the beam momentum to pass through and to be vetoed in the fourth layer. Tracks and momenta of the registered particles were reconstructed using the MWDC's events. Our deuteron measurements agree with the kinematical loci calculated for

beam momentum of 799 MeV/c. Beam intensity was measured using two scintillation detectors (similar to those used in the hodoscope) close behind the scattering chamber which will be used to determine absolute cross-sections.
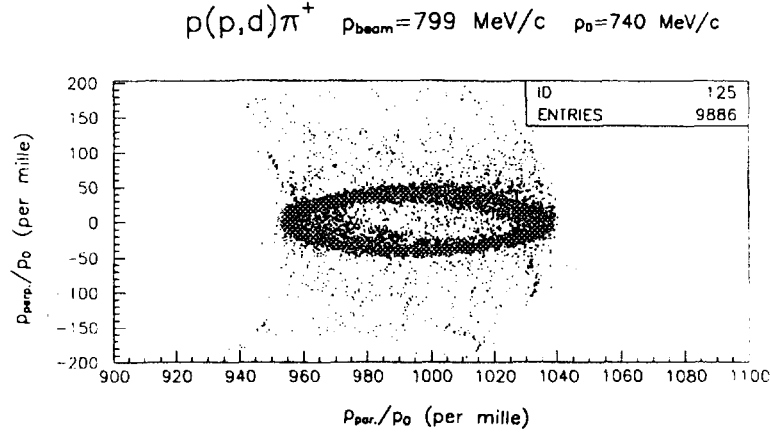
$$p(p,d)\pi^+ \quad p_{beam}=799 \text{ MeV/c} \quad p_0=740 \text{ MeV/c}$$

Fig. 1 *Reconstructed deuteron momenta from* $p + p \rightarrow d + \pi^+$ *reaction at 799 MeV/c incident proton momentum. Deuteron momenta are shown in polar diagram as a function of momenta parallel and perpendicular to the beam axis.*

Cross-section for the $p + p \rightarrow d + \pi^+$ reaction was measured for 799 MeV/c incident proton momentum. Small changes in the experimental setup allowed us also to study near-threshold pion production from $p +^{27} Al \rightarrow X + d + \pi^+$, $p + p \rightarrow p + p + \pi^0$ and $p + p \rightarrow p + n + \pi^+$ reactions.

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Excitation Energy Division in Dissipative Heavy-Ion Collisions ^{159}Tb(^{40}Ar,HI xn), E$_{lab}$= 380 MeV, θ_{HI} = 14.5$^{\circ}_{lab}$, Z$_{HI}$ = 6 - 20

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The PLF energy spectra obtained in coincidence with neutrons were used to construct neutron multiplicity distributions for the E_{LOSS} bins in the region of 20 - 220 MeV. The calculations were performed under the following assumptions: i) two-body kinematics, ii) binary division of excitation energy, iii) most of the detected neutrons arise from TLF.

The numbers of neutrons from the sequential de-excitation of TLF were compared with those obtained by using evaporation code PACE II [1].

The calculations assuming excitation energy sharing proportional to the mass of PLF and TLF [2] describe the experimental data better than those assuming equal energy division [3], even in the low excitation energy domain. Observation of equal temperatures for light and heavy fragments suggests that nearly complete equilibration of the excitation energy is reached in damped heavy-ion collisions already for short interaction time. Assuming that the charge/mass ratio of the fragments is equilibrated to the charge/mass ratio of the composite system for the short interaction time [4], PACE II predictions come near the experimental results.

The results of the statistical model calculations using code PACE II and the experimental data for $Z_{PLF} = 19$ are shown in Fig. 1.
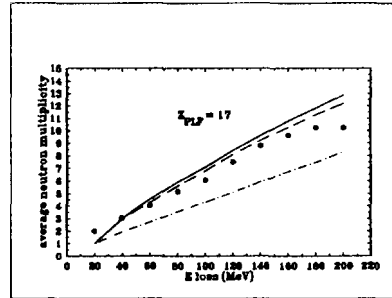

Fig. 1 Neutron multiplicities (filled circles) plotted versus E_{LOSS} for $Z_{PLF} = 17$. The solid and dashed lines represent evaporation calculations assuming N/Z value corresponding to the valley of β -stability and the value equilibrated towards N/Z of composite system, respectively, for equal temperature energy sharing. The dotted-dashed line represents calculations assuming equal energy division.

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Pion Content of the Nucleon as Seen in the NA51 Drell-Yan Experiment

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With the advent of high precision data on deep inelastic scattering, the understanding of the nonperturbative flavour structure of the nucleon is becoming one of the burning issues where the interests of particle and nuclear physics converge. Perturbative QCD describes only the Q^2-evolution of parton densities starting with certain nonperturbative input. At large Q^2 the perturbative QCD evolution is flavour-independent and, to leading order in log Q^2, it generates an equal number of $\bar{u}$ and $\bar{d}$ sea quarks. The $\bar{u}$-$\bar{d}$ asymmetry resulting from effects of interference between the u and d quarks from the perturbative sea of $\bar{u}u$ and $\bar{d}d$ pairs and the valence u and d quarks of the nucleon was found to be negligible [1].

A renewed interest in $\bar{u} - \bar{d}$ asymmetry in nucleons was initiated by experimental evidence for the Gottfried Sum Rule violation observed by the NMC collaboration at CERN [1].

Recently the CERN NA51 collaboration [3] has presented the first direct measurement of the $\bar{u}/\bar{d}$ ratio

$$\frac{\bar{u}(x)}{\bar{d}(x)} = 0.51 \pm 0.04 \pm 0.05 \qquad \text{at } x = 0.18. \tag{1}$$

We interpret the NA51 result as a strong piece of evidence for the pion-induced nonperturbative sea in the nucleon. The pion-nucleon interaction leads naturally to an admixture of a πN Fock

component in the physical nucleon. In the simplest approximation, the Fock state expansion of the light-cone proton reads:

$$|p\rangle_{phys} = \frac{1}{\sqrt{Z}}\Big[|p\rangle_{core}$$

$$+ \int dy d^2\vec{k}_\perp \phi(y, \vec{k}_\perp)\Big(\sqrt{\frac{1}{3}}|p\pi^0, y, \vec{k}_\perp\rangle + \sqrt{\frac{2}{3}}|n\pi^+, y, \vec{k}_\perp\rangle\Big)\Big], \qquad (2)$$

with Z being the wave function renormalization constant which can be calculated by imposing the normalization condition $\langle p|p\rangle = 1$. $\phi(y, \vec{k}_\perp)$, is the light-cone wave function of the πN Fock state, where y is the longitudinal momentum fraction of the π and $\vec{k}_\perp$-its transverse momentum.

The π^0 quark distributions are symmetric functions of up and down quarks. The quark content of the $\pi^+(u\bar{d})$ implies, however, that $\bar{u} < \bar{d}$. Ever since the NMC data on the GSR [1] became available, there have been attempts to accommodate the observed GSR violation into the parton model analysis of structure functions invoking different parametrizations of the asymmetry [2]. Here we wish to emphasize that in contrast to the experiment-driven parametrizations, the dynamical model of the pion-induced sea gives a unique prediction for the $\bar{u}$-$\bar{d}$ difference, provided the pion-nucleon interaction parameters are inferred from low and high energy hadronic interactions [9, 5, 10]. Furthermore, we show that the region of $x \sim 0.2$ is precisely the region where the nucleon sea is dominated by the pion-induced nonperturbative sea.

Before the NA51 result, the experimental evidence for the $\bar{u}$-$\bar{d}$ asymmetry came from an analysis of the Gottfried-Sum-Rule (GSR) violation [1]. The GSR analysis gives integrated asymmetry only, and does not allow one to identify the region of x from which the asymmetry comes. Furthermore, the extraction of F_2^n from the deuteron structure function is biased by the uncertainties due to the nuclear shadowing effects at small $x < x_{shad} \simeq 0.05$ [9, 10]. The NA51 determination of the $\bar{u}/\bar{d}$ ratio from the comparison of the Drell-Yan production in pp and pn collisions [11, 12] also uses a deuteron target, but the $x \simeq 0.2$ region is free of shadowing effects.

The new NA51 result can be explained naturally by the presence of pionic (mesonic) Fock components in the nucleon wave function. The observed asymmetry can, in principle, be reproduced by suitably modified parametrizations which allow for stronger asymmetry placed at somewhat larger x as compared to the MSR (D_0', D_-') parametrizations [2]. In contrast to parametrizations, our results are predictions from a dynamical model which gives nonperturbative sea distributions without free parameters and a correct description of the GSR violation. Furthermore, our model of the nucleon makes a link between low energy meson-nucleon couplings, high energy hadron-hadron collisions and deep inelastic scattering of leptons. Some authors discuss the pionic dressing of the constituent quarks in the nucleon [13], which is also capable of generating the $\bar{u}$-$\bar{d}$ asymmetry [14]. In contrast to our approach, however, these models are unable to make any link to the high energy production of baryons. New experiments at larger x are necessary to give more insight into the pionic (mesonic) cloud of the nucleon.

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How to Measure the Pion Structure Function at HERA

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Up to now the only feasible method to extract the deep-inelastic pion structure function $F_2^\pi(x)$ is the πN Drell-Yan production of dilepton pairs. The disadvantages of this method are that the attainable luminosity is low and that only the valence part of the pion structure function at rather large x can be studied. An extension of our knowledge of the pion structure function is possible by using virtual pions around the nucleon as targets in deep inelastic scattering. These pions arise naturally as a consequence of the pion-nucleon coupling which leads to an admixture of the πN Fock state in the light-cone nucleon [1]. Interaction of high-energy projectiles (nucleons, pions, leptons) with the virtual pion of the πN Fock state of the proton is a typical stripping reaction, in which the momentum distribution of the spectator nucleon reflects the momentum distribution in the πN (meson-baryon) Fock state.

We suggest a method of determination of the pion structure function down to $x \simeq 10^{-4}$ based on semi-exclusive deep inelastic scattering of protons. The idea is to exploit the nonperturbative πN and $\pi \Delta$ Fock components of the nucleon, which contribute significantly to deep inelastic scattering and dominate the fragmentation of protons into fast neutrons and deltas. The intrinsic factorization properties of semi-exclusive cross-section should provide a good test of the validity of our approach. We find that a large part of phase space is populated predominantly through the one-pion exchange mechanism.

In the suggested mechanism of the semi-inclusive neutron production, the differential cross-section is a product of the universal flux factor which only depends on z – the longitudinal momentum fraction carried by the outgoing nucleon, and the structure function $F_2^\pi(x_\pi, Q^2)$ which is a function of $x_\pi = x/(1-z)$. This factorization property allows an important crosscheck of the model. Binding the semi-inclusive cross-section data as a function of z at different fixed values of x_π, one can verify that the shape of the flux factor as a function of z does not depend on x_π.

From the purely experimental point of view, the semi-inclusive reaction $ep \to e'nX$ is being studied already by the ZEUS collaboration which has installed a test forward neutron calorimeter (FNC) to complement its leading proton spectrometer [2]. This FNC was tested with neutrons from inclusive proton-beam gas interactions, and an excellent agreement between the measured spectra and the pion-exchange predictions was found.

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Slow Proton Production in Semi-Inclusive Deep Inelastic Scattering and the Pion Cloud in the Nucleon

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Inclusive deep inelastic lepton scattering of nucleons is a well-established tool for investigating parton distributions. Hadrons, which are not measured in inclusive experiments, are produced mainly in the colour neutralization process, the string models being the state of art.

In semi-inclusive deep inelastic scattering (SIDIS) one observes one or more hadrons in coincidence with the scattered lepton. In the past, the study of semi-inclusive deep-inelastic lepton scattering was restricted mainly to the detection of high energy hadrons which originate from the fragmentation of the leading (struck) quark. Production of slow protons in coincidence with muons was studied in the (anti)neutrino-induced charged-current reactions at CERN [1, 2]. In a more recent analysis of the CERN experiment WA21 [2], the fraction of slow ($p < 0.6$ GeV/c) protons was determined.

We have calculated the semi-inclusive cross-section for producing slow protons in charged-current deep-inelastic (anti-) neutrino scattering on protons and neutrons as a function of the Bjørken x and the proton momentum. Standard hadronization models based upon the colour neutralization mechanism appear to underestimate the rate of slow proton production on hydrogen. The presence of virtual mesons (pions) in the nucleon leads to an additional mechanism for proton production, referred to as spectator process. It is found that at low proton momenta both mechanisms compete, whereas the spectator mechanism dominates at very small momenta, while the colour neutralization mechanism dominates at momenta larger than 1-2 GeV/c. The results of the calculations are compared with the CERN bubble chamber (BEBC) data. The model of the meson cloud constructed in Refs. [3, 4, 5, 6] gives good description of the data for proton production on the neutron as obtained from the deuteron data [7]. The spectator model predicts a sharp increase of the semi-inclusive cross-section at small x due to sea quarks in virtual mesons, which may, however, be difficult to identify experimentally in the (anti)neutrino-induced reactions.

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Light-Cone Description of Pionic (Mesonic) Corrections to Nucleon (Baryon) Electromagnetic Properties

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In the last few years experiments on deep inelastic scattering have demonstrated that the internal structure of the nucleon is more complicated than previously expected. Strong violation of the Gottfried Sum Rule observed by the New Muon Collaboration [1] weakened our belief in a $\bar{d} - \bar{u}$ symmetric sea. The new fits of parton distributions to the deep-inelastic and Drell-Yan world data [2] seem to confirm the asymmetry. The preliminary results of the CERN dedicated NA51 experiment [3] on the dilepton production in the proton-proton and proton-deuteron scattering confirms the asymmetry, which can be well understood by the presence of virtual pions (mesons) in the nucleon [4].

In order to create a consistent picture of the nucleon, all phenomena of nucleon structure should be studied consistently, on the same footing, with the same degrees of freedom included. In the light of the success of the meson cloud model in understanding the Gottfried Sum Rule violation it seems obligatory to consider its role in other phenomena.

Another traditionally important source of our knowledge about the nucleon structure are electromagnetic form factors. Non-relativistic constituent quark models have been successful in describing electromagnetic form factors for four-momentum transfer squared up to $Q^2 <$ $0.5 GeV^2$ only. Rough agreement with the experimental data can be extended to higher Q^2 in relativistic quark models [5, 6, 7, 8]. It remains difficult, however, to explain all static electromagnetic properties of nucleons with the same set of parameters.

We have calculated mesonic corrections to the nucleon electromagnetic form factors in the light-cone approach in a consistent way. The parameters of the model have been determined by the analysis of spectra of high energy $p \rightarrow n$ fragmentation processes [9, 10]. The violation of the Gottfried Sum Rule has been described with this set of parameters [10]. The $\bar{u} - \bar{d}$ asymmetry obtained from our model [4] is consistent with recent CERN NA51 results for dilepton production in proton-proton and proton-deuteron collisions [3]. Our approach yields results for mesonic corrections to nucleon electromagnetic form factors and magnetic moments quite different from the standard static approach.

Properties of the nucleonic core cannot be derived within our model and have to be parametrized. Inspired by the success of the standard dipole parametrization, we parametrize $G_E(Q^2)$ and $G_M(Q^2)$ of the core by a dipole form factor. The ratio of the magnetic moments of the bare neutron and proton found from the analysis is very close to the $SU(6)$ value, $-2/3$. We find that with a reasonable choice of parameters for the bare nucleons, one can fit the available experimental data for electromagnetic form factors in a broad range of transferred momenta.

The electromagnetic radii obtained from the analysis are almost identical to those obtained from the dipole parametrization and slightly smaller than those obtained by the Höhler analysis [11]. The neutron charge radius results solely from the effect of the meson cloud, and it is around 0.3 fm as compared to the experimental value of 0.346 ± 0.003 fm [12]. We find that the bare nucleon electromagnetic radius is only about 10 - 15 % smaller than the proton electromagnetic radius. Of course, the actual, often called hadronic, size is smaller than that seen by the electromagnetic probe, where part of the effect comes from virtual fluctuation of the photon into vector mesons.

We have studied pionic corrections to both the Dirac and Pauli electromagnetic form factors. The light-cone description gives specific cancellations and Q^2 dependence of pionic corrections. While for the Dirac form factors the pionic corrections are important for low Q^2 only, for the Pauli form factors the pionic corrections survive to considerably higher Q^2.

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Status of the COSY-11 Installation

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COSY-11 is an internal experimental setup (see Fig. 1) for threshold measurements of the production of mesons or mesonic pairs [1, 2], presently installed in the COSY-ring. The experiments will be performed using a cluster target in front of a COSY dipole acting as a magnetic separator for the ejectiles which will be registered by several tracking and timing detectors.

The standard COSY vacuum chamber in dipole no. 8 was replaced by a special chamber with large windows for undisturbed transport of reaction products to the detectors. The main window is covered by a 300-μm-thick foil of carbon fibres with a 30-μm aluminum layer on the inner side to guarantee UHV conditions in the ring.

The cluster target and all detectors are ready for installation which will take place at the end of February 1995. The target was mounted outside of the ring and extensive tests have been made which have demonstrated stable operation of the system. All detectors have been tested and calibrated with cosmic radiation, i.e. minimum ionizing particles. For these tests the drift chambers and scintillation counters S1, S2 and S3 were positioned close together so that cosmics may pass through all units simultaneously. For calibration of the scintillation detectors, the particle tracks extracted from the drift chamber data were used. The function and energy resolution of the silicon-pad detector was checked with cosmic rays independently of the other systems. In all silicon elements the minimum ionizing peak was well separated from the noise.

The data acquisition system for COSY-11 is operational. It was used for the cosmic ray measurements.
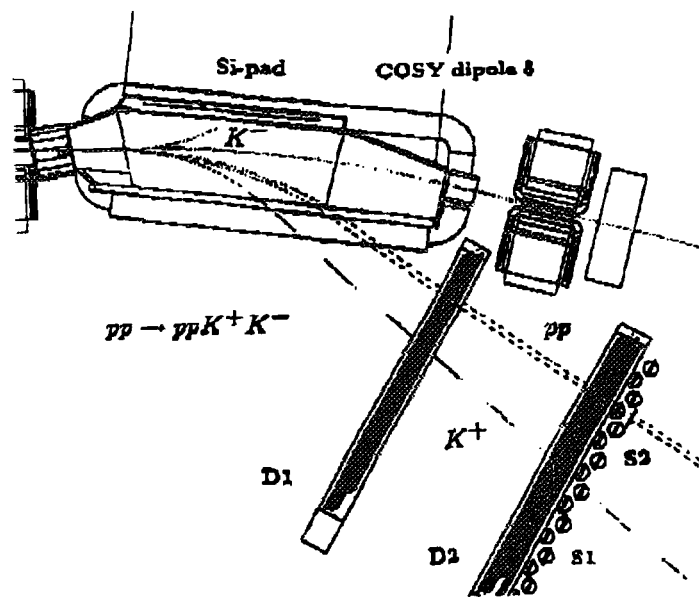
PL9700115

Fig. 1 Sketch of the COSY-11 installation at a COSY dipole. For positively charged particles, drift chambers D1, D2 and scintillators S1, S2 and S3 are used. S3 is positioned 10 m apart from S2, and thus not shown in the figure. Silicon-pad detectors combined with a long scintillator bar was mounted in the dipole gap for detection of negatively charged particles.

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Muon Catalyzed Fusion in Solid Hydrogens

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Muon-catalyzed fusion of hydrogen isotopes is usually studied in gases or liquids. A new target system, developed at TRIUMF [1], allows experiments on muonic hydrogen isotopes in solid hydrogen layers at 3 K. Muonic deuterium or muonic tritium [2] atomic beams with energies of the order of 1 eV are emitted to vacuum from solid protium-deuterium (protium-tritium) layers via Ramsauer-Townsend mechanism, and then strike a thin layer of hydrogen isotopes. That enables direct time-of-flight measurements of different processes of the muon-catalyzed fusion cycle. The most important processes are resonant formation rates of muonic molecules $dd\mu$ and $dt\mu$ at energies below 1 eV.

The target allows observation of electrons, gamma quanta, charged particles from fusion as well as neutrons. To determine reliable values of rates of the investigated processes and to compare theory with experiment, detailed Monte Carlo simulations are essential. An appropriate Monte Carlo program has been developed. It describes accurately the transport of muonic hydrogen atoms in molecular hydrogen targets.

The experiments performed at TRIUMF show that the crystalline structure of solid hydrogens influences significantly the process of thermalization of muonic atoms.

Therefore, solid-state effects (Bragg scattering, phonon scattering) should be taken into account in calculations of differential cross-sections for scattering of muonic atoms on solid hydrogens. The method of calculations of these cross-sections is being developed. These investigations are supported in part by a NATO linkage grant.

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Reactions of Muon Transfer from Muonic Hydrogen to Elements with Z>1

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The main subject of our investigations is muon transfer process from muonic hydrogen and deuterium to elements with charge Z>1. It takes place in gaseous targets at 300 K. We observe X-ray time-spectra due to cascades in excited $Z\mu$ atoms. The experiments performed at Paul Scherrer Institute, Willigen, Switzerland, showed unexpected structures in these time distributions in case of several muonic atoms — $O\mu$, $C\mu$ and $F\mu$ [1, 2]. It turns out that muon transfer to these elements cannot be described in terms of a single transfer rate, connected with thermalized atoms $p\mu$ or $d\mu$. New theoretical research [3] shows that initial energy distributions of $p\mu$ and $d\mu$ atoms in gases have high-energy (a few tens electron volts) components. Therefore, unexpected features of the X-ray spectra can be ascribed to muonic transfer from non-thermalized $p\mu$ and $d\mu$ atoms. This enables us to determine muon transfer rates for higher energies, as well as the initial energy distributions of muonic hydrogen. In March 1994 we performed high-statistic measurements of X-ray time spectra in mixtures H_2+O_2, D_2+O_2 and $H_2+D_2+O_2$. The gas mixtures were measured at total pressures of 7 bars and 15 bars at room temperature. The muonic oxygen X-rays were registered by two Ge-detectors with high energy resolution.

Interpretation of the experimental data requires Monte Carlo calculations. Monte Carlo code HD was written and tested during the year. We also calculated all differential cross-sections for scattering of $p\mu$ and $d\mu$ in mixture H_2+D_2 at 300 K. Therefore, the process of muonic atom deceleration is described accurately. Now we can compare theory with experiment and extract information about energy dependence of the investigated transfer rates.

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Atlas of Cross-Sections for Muonic Atom Processes.
Muonic Hydrogen ($p\mu$, $d\mu$, or $t\mu$) Scattering from Molecular Hydrogen Isotope Targets (H$_2$, HD, HT, D$_2$, DT, or T$_2$)

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(submitted to Atomic and Nuclear Data)

We present a new extensive atlas of total cross-sections for scattering of 1S-state muonic hydrogen atoms on hydrogen molecules. Tables and figures are provided which contain cross-section information for all possible combinations of hydrogen isotopes in both hydrogenic targets and muonic hydrogen atoms. Effects of spin composition in the targets and in the incident muonic atoms are also included.

Usefulness of muonic hydrogen atoms ($p\mu$, $d\mu$ and $t\mu$) is well established in studies of atomic, nuclear and weak interaction physics, as well as quantum electrodynamics. Muonic hydrogen atoms can also be used as probes of material surfaces and interiors because they can penetrate ordinary atoms and molecules in a way forbidden to ordinary hydrogen atoms.

The interpretation of experiments in these cases depends on understanding of the behaviour of such atoms in material targets, which are most often composed of mixtures of hydrogen isotopes. Muonic hydrogen atoms (neutral entities which in their ground state have a muonic Bohr radius of 2.5×10^{-11}cm) will scatter both elastically and inelastically within a medium, and can also enter into nuclear reactions such as muon-catalyzed fusion, which are not observed for normal hydrogen atoms. The behaviour of muonic hydrogen atoms in hydrogenic media is therefore determined by cross-sections for a variety of processes, and theoretical calculation of these cross-sections is important in the interpretation of experiments [1, 2]. This Atlas presents the latest (as of November 30, 1994) theoretical results on cross-section calculations for muonic hydrogen atoms in the ground 1S state, interacting with hydrogenic media.

The energy of muonic atom $a\mu$ ($a=p$, d, t) formed in gaseous hydrogen targets ranges from thermal energies (e.g. ~ 0.04 eV at room temperature) to 1–100 eV for "hot" atoms [3]. In this energy range the following muonic atom scattering processes are possible

elastic scattering: $\qquad a\mu + BC \rightarrow a\mu + BC,$ $\qquad\qquad$ (1)

spin-flip: $\qquad a\mu(F) + BC \rightarrow a\mu(F') + BC,$ $\qquad$ (2)

isotopic exchange: $\qquad a\mu + BC \rightarrow b\mu + AC,$ $\qquad\qquad$ (3)

where a and b are hydrogen isotope nuclei, AC and BC are electronic molecules of hydrogen isotopes , F and F' denote the hyperfine state of $a\mu$ before and after collision. The 1S states of muonic atoms $p\mu$, $d\mu$ and $t\mu$ are split into two sublevels F due to the interaction of the muon and nuclear spins. The hyperfine splitting ($\Delta E_{p\mu} = 0.182$ eV, $\Delta E_{d\mu} = 0.0485$ eV and $\Delta E_{t\mu} = 0.2373$ eV) exceeds many times the fine splitting of muonic atom energy levels ($\sim 10^{-3}$eV), which allows us to withdraw spin-orbit coupling from consideration. Thus, both total orbital momentum **J** and total spin $\vec{S} = \vec{S}_a + \vec{S}_b + \vec{S}_\mu$ of the three-particle system are conserved during the interaction.

In isotope exchange reactions (3), energy difference between thresholds of the two channels $a\mu + b$ and $b\mu + a$ is equal to the isotopic shift of the ground state energy level of a muonic atom due to the replacement of nucleus a with nucleus b ($\Delta E_{p-d} = 134.7$ eV, $\Delta E_{p-t} = 182.8$ eV,

$\Delta E_{d-t} = 48.04$ eV). Accurate results in case of low-energy ground-state muonic hydrogen atom scattering by hydrogen nuclei have already been calculated [4, 5] within the framework of the multichannel adiabatic method [6]. However, in experiments one usually deals with molecular hydrogen targets, and therefore it is necessary to take into account molecular binding and electron screening at collision energies below a few electron volts. Computational schemes for such calculations were developed in Ref. [7].

Based on the computations [4, 5, 7], in this paper we present the complete set of total cross-sections for processes (1–3) in the collision energy range 0.001 eV$\leq \varepsilon \leq$ 100 eV. Correlations between neighbouring hydrogen molecules are neglected. Therefore, the results are valid for gaseous targets and for liquid and solid hydrogens at energies much greater than that corresponding to the Debye temperature ($T_D \approx$ 100K). All possible rovibrational excitations and de-excitations of molecules have been taken into account. It has been assumed that vibrations are harmonic, and that there are no correlations between the rotational and vibrational degrees of freedom. The cross-sections are averaged over the Boltzmann distribution of rotational states and over the Maxwell distribution of molecular kinetic energy in the laboratory system for temperatures 30 K, 100 K, 300 K and 1000 K.

The total cross-section data are presented in 78 tables and 78 figures [8]. The data files are available from (adamczak@bron.ifj.edu.pl) or R.T. Siegel (siegel@muon.physics.wm.edu).

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Experimental Method for Measurement of Hyperfine Splitting of Muonic Hydrogen

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We report results of a recent theoretical study of feasibility of an experiment to measure hyperfine splitting of muonic hydrogen using a tunable infrared laser [1]. The latest values of differential cross-sections for the scattering process $p\mu+H_2$ were used [2]. We also evaluated the required features of the laser. The Monte-Carlo simulations show that the efficiency of the proposed method is high enough to allow measurement of hyperfine splitting of the ground state of muonic hydrogen with an accuracy of 10^{-4}, the main difficulty being the need for a powerful pulsed-beam muon source. The list of physics motivations in the field of muonic hydrogen spectroscopy includes tests of QED corrections (especially vacuum polarization) in a lepton-hadron bound system, study of corrections due to the proton finite size and tests of μ-e universality [3].

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Multifragmentation of Nuclei Induced by Relativistic Light Ions
(FASA Project)

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Scientific Goal

The aim of this project is investigation of the mechanism of nuclear multifragmentation which takes place in nucleus–nucleus collisions at intermediate and high energies. This is a new decay process in which many fragments (IMF) with masses heavier than α particles and lighter than fission fragments are observed. It is now established as the main decay mode of highly excited nuclei. This process is likely to occur when the nucleus has expanded and lower density is reached. Detailed knowledge of this new de-excitation mechanism will give fundamental information on properties of nuclear matter at low densities relevant also for the understanding of astrophysical processes. It is under discussion whether this process is related to a liquid-gas phase transition in nuclear matter.

Over the last years experimental studies of multifragmentation have been conducted by a number of research groups using mainly heavy-ion beams. In this project we use light projectiles from protons to carbon ions at relativistic energies to investigate multifragmentation decay of a heavy target. Our choice has two main advantages: 1. All fragments originate from the target nucleus. 2. Compression of nuclear matter is very small in contrast to heavy-ion induced collisions, and the decay of the excited nucleus proceeds in an apparently statistical manner ("thermal multifragmentation"). Our study gives complementary information to that obtained from heavy-ion collisions and the comparison will allow one to extract the influence of compression and rotation on the multifragmentation decay.

Results Achieved by the FASA Collaboration

The first experimental studies of nuclear multifragmentation have been performed by the FASA collaboration. For these experiments, carried out at the JINR Synchrophasotron, the new 4π setup FASA was built [1].

At present the FASA setup consists of 5 telescope-spectrometers which serve as a trigger for the system, and 64 CsI(Tl)-counters composing a multiplicity detector for IMF's. One module of the setup (6 counters) can be replaced by a large position-sensitive avalanche chamber for correlation measurements.

The study of target multifragmentation in the ^{4}He(14.6 GeV)+Au collision leads to the following conclusions [2 - 5]:

- Multifragment emission is a dominant decay mode of the highly excited target spectator.

- Mean multiplicity for the intermediate mass fragments is $< M_{IMF} > = 5.1 \pm 0.8$. From comparison of the experimental data and the statistical model calculation one can conclude that the excitation energies reached are higher than 1 GeV.

- The mass spectrum of IMF's is fitted well by a power law distribution $A_{IMF}^{-\tau}$. Parameter τ shows "critical behaviour" (a minimum) as a function of multiplicity.

- The break-up density of the system is at least three times smaller than the normal one. It was estimated from the relative velocities of the coincident fragments at large correlation angles.

- The mean lifetime of the fragmenting system is less than 100 fm/c $(3 \cdot 10^{-22}$ s). It was found analysing the distribution of the relative angles between the coincident IMF's, showing strong suppression of small angles caused by the Coulomb interaction in a final state (Fig. 1).
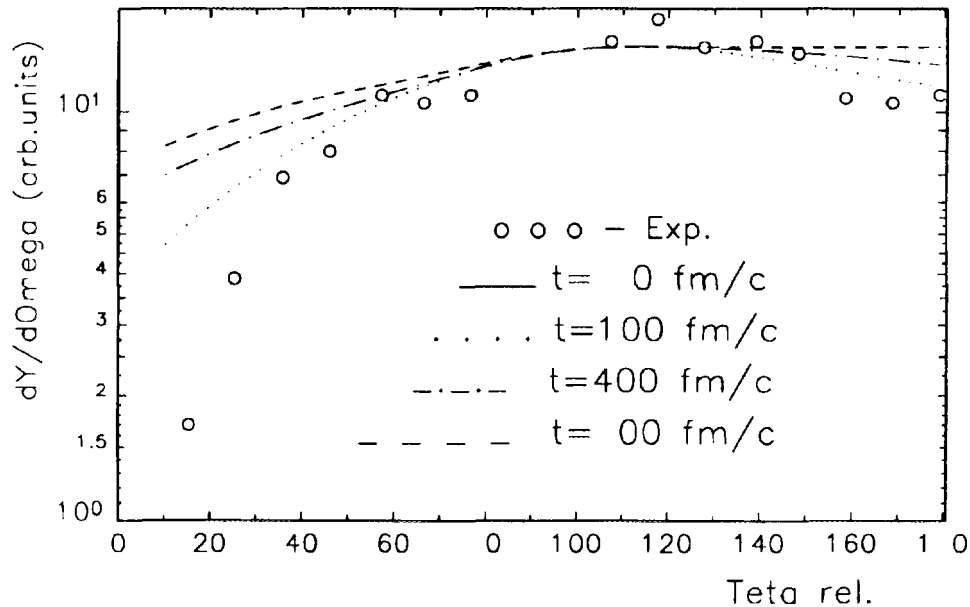

Fig. 1 Distributions of relative angles between coincident IMF's. Solid circles: experiments. Lines: calculations for different mean life-times of the fragmenting system.

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Coincidence Detector Camac Module PROCOD [1]

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Programmable Camac module PROCODE was developed to detect the coincidence of logical input pulses.

The module has two sets of 16 inputs:

$I01$ - $I16$ (NIM) logical pulse inputs,

$I17$ - $I32$ (NIM) logical pulse inputs

and two outputs:

G (TTL) gate output; low/high (jumper selectable) level means that the module has open inputs and is waiting for the pulses,

R (TTL) fast reset output; at this output a fast pulse is generated when the module detects "bad" coincidence.

Module PROCODE works with the data acquisition system through the CAMAC bus.

Module development was based on the fact that every analog output from the preamplifier is accompanied by a fast logical pulse. These logical pulses are used to trigger the module and are connected to the I inputs. It is provided that the logical pulses appear before the analog pulse reaches its peak. The T1 time is used to analyze the event and in the "good" event case the system knows the bit pattern of "fired" channels well before the conversion is finished. The G output signal is used as a gate input to the ADC modules. In case of the "bad" coincidence pattern the module clears itself and all the ADCs. This is done with the R output signal. After that the module is ready for the next event. The data acquisition system is not notified about the "bad" event.

Before starting the acquisition the module must be opened with the F9A0 function. After that the module watches the state of input lines I. A change at any of the I line starts internal time gate T1. When the gate is opened, all logical inputs are stored in input register IR. When the gate is closed, the pattern stored in the input register is analyzed. When it is a "good" coincidence, the module sets the LAM and the computer system can read the stored pattern with the F1A0 and F1A1. When it is a "bad" coincidence, the system clears itself as well as the connected ADC's and opens again.

Before using the module the coincidence and the anticoincidence must be programmed in the module. The main part of the module is fast memory MC. The pattern from the input register is used as the address to MC. The memory content says if it is a "good" or "bad" event. F17A0 function is used to program the MC memory before using the module. Input gate timer T1 is programmed with the F17A1 function.

Two other timers T2 and T3 can be set with jumpers and trimpots. The block diagram shows the module, and the time diagram explains the module operation.

The main features of the module are:

* the module is fast (total delay in the module is: programmed timer + 100ns),
* flexibility in programming coincidence and anticoincidence,
* there is a possibility to cascade a number of modules,
* the module can register groups of very frequent events, counting not every event but every n-th event.

The PROCODE module was used as a part of 32-parameter data-acquisition system in the measurements of $^{28}Si(\alpha,^{16}O)^{16}O$ reaction [3].

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Diagnostic System for Fragment Separator COMBAS

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Magnetic separator COMBAS (1) has been designed to operate alternatively as a monochromator for primary beams accelerated in the U-400 M cyclotron, or as a separator for fragments (radioactive beams) produced in interactions of primary beams with target nuclei.

Because of low intensity of secondary beams, the COMBAS separator has been planned to accept beams with widely distributed momenta and angles, the largest one among other separators of this type. Therefore, magnets with large apertures have to be used to fulfill this condition. For proper operation of COMBAS and for experimental purposes it is necessary to know the characteristics of the beam, e.g. its profile, intensity and mean velocity in case of primary beams, or velocity of each particle in case of secondary ones.

Beam diagnose will be carried out at three locations: near to the focus of the primary beam, close to the intermediate dispersive focal plane of the separator and at its final focus. The system of diagnosis consists of two sets of detectors. The first one will only be used during the initial setting-up of operation conditions. Gas-filled multiwire detectors will monitor beam profile. Depending on the intensity of the beam they will work in the ionisation or in the gas multiplication mode. In the latter case intensities as high as 10^9 pps can be registered.

The second set of detectors will be used during the normal work of the COMBAS separator. Their thicknesses are so small that they will not affect beam characteristics, as they are nearly completely transparent for it.

The principle of detector operation (2) is based on the ionisation of the residual gas and there is practically no limitation to the beam intensity.

The areas of these two detectors, positioned at the entrance and at the exit of the COMBAS system, are equal to 40x65 mm^2. Their spatial resolution has been estimated to be about 0.2 mm.

The distance of 14 m between those detectors and their expected time resolution 1 ns or better will allow one to measure energies of beam particles with accuracy better than 1% for the energy of 25 MeV/n.

The third detector-profilometer will be placed in the intermediate focal plane. Its entrance and exit windows are large because the dimension of the dispersed secondary beams are large, being equal to 380x70 mm^2. The profilometer consists of two identical drift chambers, positioned in such a way that the first of them stands in front of the other one. The drift volumes of the chambers are surrounded by special, wedge-like cathodes. The anodes, made of thin wire and mounted near the wide ends of the wedges are surrounded by grounded grids. The drift chambers are mounted in such a way that the direction of the electrical field in the first one is opposite to the direction of the electrical field in the other one. Such construction of the profilometer allows one to determine the vertical coordinate of a passing particle because the ratio of lost energies in the first and second chamber depends on the distances from the ends of the chambers. The vertical coordinate can be also determinated, from the drift time of electrons to the anode. A delay line placed close and parallel to the anode wire allows one to determine the horizontal

coordinate from the time difference of signals arriving at its ends. The positional resolution of the profilometer is expected to be better than 2 mm.

The profilometer is movable and, if necessary can be removed from the path of the beam.

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SCIENTIFIC DEGREES

1. *Stanisław Drożdż* – professor of physics
2. *Artur Siwek* – Ph.D. degree

   "Evaporation Fission and Multifragmentation in The Reaction ^{32}S + ^{58}Ni at 30 AMeV".

LECTURES, COURSES AND EXTERNAL SEMINARS:

A. Budzanowski

1. "Selected Topics in Theoretical Physics"
   Lectures for students of physics at the Jagellonian University, Cracow.
2. Seminars for students of physics (fifth year course).

S. Drożdż

1. "Nuclear Decays: Ergodicity and Self-Organisation"
   Seminar at the Jagellonian University, Cracow, March 1994.
2. "How Chaotic is Chaos in Physics?"
   Talk at the Polish Physical Society Meeting, Cracow, April 1994.
3. "Self-Organizing Nuclear Decays", Seminar IKP-KFA Jülich, April 1994.

A. Górski

1. "The Chiral Soliton Model of the Nambu-Jona-Lasinio Type"
   Seminar at Theoretical Department of INP, Cracow, December 1994.

A. Szczurek

1. "New Aspects of the Old Meson Cloud in Nucleon"
   Seminar at the Theoretical Department of INP, Cracow, June 1994.

A. Siwek

1. "Multifragmentation in Reaction ^{32}S+^{58}Ni at the Energy of 30 MeV", Seminar at the Heavy Ion Laboratory, Warsaw, April 1994.
2. "Evaporation Fission and Multifragmentation in Reaction ^{32}S+^{58}Ni at the Energy of 30 MeV", Jagellonian University, Cracow, March 1994.

A. Adamczak

1. "Thermalization of Muonic Hydrogen and Muon Transfer to Elements Z>1"
   Physics Department, University of Fribourg, Switzerland, June 1994.
2. "Scattering of Muonic Hydrogen on Solid Hydrogens"
   TRIUMF meson factory, Vancouver B.C., Canada, November 1994.

J. Okolowicz

1. "Chaotic Scattering in Nuclear Physics"
   Seminar GANIL Caen, France, January 1994.

INTERNAL SEMINARS:

1. *J. Golak:* "Final State Interaction in Reaction ^{3}He(e,e'p)".
2. *M. Wolf:* "Multifractality".
3. *L. Leśniak:* "Investigation of the Strong Meson Interaction".
4. *R. Siudak* "Meson Production near Threshold in Nuclear Collisions".
5. *Yu.E. Penionzhkevich - JINR Dubna, Russia:* "Investigation of Properties of Very Neutron Rich Isotopes of Lighest Elements".

6. *A. Rudchik - Kiev University, Ukraine:* "One and Two-Step Processes in Light Nuclei Reactions".

7. *K. Golec:* "Deep Inelastic Electron Scattering on Protons for Small x-Bjorken".

8. *S. Jadach:* "What New in Particle Physics?".

9. *M. Kutschera:* "Nuclear Energy of Symmetry for Light Density".

10. *Ch. Goodman - Bloominghton, USA;* "How Can We Measure Gamov–Teller Transition Strenghts that are not Accesible to Beta Decay?".

11. *A. Wieloch:* "Multifragmentation Process in Reaction ^{28}K+^{197}Au, 60 MeV/A, Statistical Characteristics or Dynamical One?".

12. *M. Wójcik:* "Solar Neutrino Puzzle. Experiment GALLEX".

13. *A.G. Artiuch - JINR Dubna, Russia:* "Fragment Separator COMBAS and Planned Experiments".

14. *A. Kozela:* "η' and ϕ Meson Production in the Reaction ^{2}H(p,x)^{3}He near Threshold".

15. *T. Chmaj:* "Gamma Flashes - the Greatest Sky Puzzle".

16. *S.A. Fayans - Kurchatov Institute, Moscow, Russia:* "Soft Nodes in the Halo Nuclei".

17. *V.L. Aksenov - JINR Dubna, Russia:* "Present Status and Trends of Reactor Neutron Sources".

18. *L. Jarczyk:* "Experiments at COSY Accelerator".

19. *S.A. Sakuta - Kurchatov Institute, Moscow, Russia and A. Rudchik - Institute for Nuclear Research, Kiev, Ukraina:* "Charge-Exchange Reactions on Light Nuclei".

20. *M. Gąsior:* "Photon Structure. Is the Photon a Corpuscule?".

21. *P. Żenczykowski:* "Weak Decays of Barions".

22. *W. Broniowski:* "Physics at the CEBAF Accelerator".

23. *N.M. Shumeiko - Minsk University, Bielarussia:* "Physics of Radiative Effects in Deep Inelastic Lepton-Nucleon Scattering".

24. *Z. Sosin:* "Excitation Energy Pastitioning in Heavy Ion Binary Reactions Induced by N-N Collisions".

SHORT TERM VISITORS TO THE DEPARTMENT:

1. *V. Zaglobin* - JINR Dubna, Russia,
2. *Yu. E. Penionzhkevich* - JINR Dubna, Russia,
3. *G. Lippert* - Forschungszentrum Jülich, FRG,
4. *S. Sakuta* - Kharkov University, Ukraine,
5. *A. Rudchik* - Kiev Institute of Nuclear Research, Ukraine,
6. *V. Pirmak* - Kiev Institute of Nuclear Research, Ukraine,
7. *V. Ziman* - Kiev Institute of Nuclear Research, Ukraine,
8. *I. Stephan* - Forschungszentrum Jülich, FRG,
9. *H. Machner* - Forschungszentrum Jülich, FRG,
10. *H. Fuchs* - HMI Berlin, FRG,
11. *Yu. Mashkarov* - Kharkov University, Ukraine,
12. *K. Scho* - Forschungszentrum Jülich, FRG,
13. *G. Kemmerling* - Forschungszentrum Jülich, FRG,
14. *H. Nüsser* - University Bonn,
15. *J. Heinrich* - University Bonn,
16. *S. Fayans* - Kurchatov Institute, Moscow,
17. *H. Holtmann* - Forschungszentrum Jülich, FRG,
18. *Ch. Goodman* - Bloominghton, US,
19. *FOBOS WORKSHOP* - 51 persons.

Department of
Nuclear Spectroscopy

Section II

DEPARTMENT OF NUCLEAR SPECTROSCOPY

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Deputy Head of Department: *Professor Jan Styczeń*
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Marian Gąsior	Marta Marszałek	Paweł Wodniecki
Maria Kmiecik	Witold Męczyński	Jacek Wrzesiński
Jan Kormicki	Tomasz Pawlat	Kazimierz Zuber
Wojciech Królas*		

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Laboratory of the Applied Nuclear Spectroscopy

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PL9700122

GRANTS:

1. *Prof. R. Broda*
   Grant No 224319203 (The State Committee for Scientific Research),
   "Heavy-Ion Reaction Mechanism Studied by Discrete Gamma-Radiation"
2. *Dr Z. Stachura*
   Grant No 2P30204505 (The State Committee for Scientific Research),
   "Modification of Solid Surfaces and their Investigation by Methods of Nuclear Spectroscopy"
3. *Dr J. Dryzek*
   Grant No 2P30202804 (The State Committee for Scientific Research),
   "Studies of Positron Resonance Trapping in Solids"
4. *Prof. A. Hrynkiewicz*
   Grant No 204579101 (The State Committee for Scientific Research),
   "PAC Studies of Hyperfine Interactions in Hf and Ce Compounds"
5. *Prof. A. Hrynkiewicz*
   Grant No 2P30213207 (The State Committee for Scientific Research),
   "Studies of the Properties and Formation Processes of Intermetallic Compounds with the Perturbed Angular Correlation Method".
6. *Dr A. Gil (AGH) and Dr Bogusław Rajchel (IFJ)*
   Grant No 773269203 (The State Committee for Scientific Research),
   "Investigation of High-Temperature Corrosion in Metals Doped by the Ion-Implantation"
7. *Prof. J. Styczeń*
   Grant No 204519101/P01 (The State Committee for Scientific Research),
   "Properties of "Hot" Atomic Nuclei Studied by Means of Gamma Rays"
   Grant nr 204519101/P02 (The State Committee for Scientific Research),
   "Investigations of High-Spin Excitations and Superdeformation in Nuclei"
8. *Dr J. Kwiatkowska and Dr F. Maniawski* also participate in the following grants:
   Grant No 201829101 (The State Committee for Scientific Research),
   "The Studies of Time Correlations a Spatial Properties of Matter in Microscopic and Real Time Scale"
   Grant nr 223509102 (The State Committee for Scientific Research),
   "The Studies of Electronic Structure of Transition Metals by Means of Compton Spectroscopy".
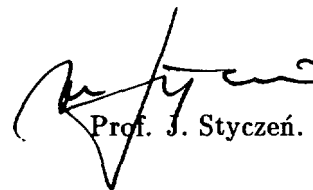
OVERVIEW:

The 1994 year activity in the Nuclear Spectroscopy Department was like in previous years spread over a large variety of subjects concerned with the in-beam nuclear spectroscopy and many nucleon transfer reactions, properties of highly excited nuclear states, and the applied nuclear spectroscopy.

The studies in the first two groups were mostly carried out in a vast international collaboration which enabled us to carry out experiments on highly sophisticated experimental facilities abroad like EUROGAM, GASP, HECTOR or OSIRIS, and others. Some preparations for "home" experiments have been carried out on the very much looked forward and recently obtained heavy ion beam from the cyclotron at the Warsaw University.

The applied nuclear spectroscopy works, on the other hand, were mainly based on using our own installations: an elaborated set-up for perturbed angular correlations, the RBS and PIXE set-ups at the Van de Graaff accelerator, the implanter, an atomic force microscope and several others.

Much of the effort manifests itself in several valuable results which are summarized in the following pages. It is to be underlined that those results, as well as some new intstrumentation developments were possible due to additional financial support via special grants and the promotion of our international cooperation by the State Committee for Scientific Research (KBN).

Prof. J. Styczeń.

REPORTS ON RESEARCH:

Lifetimes of the High Spin States in ^{45}Sc

P. Bednarczyk, J. Styczeń, R. Broda, M. Lach, W. Męczyński, D. Bazzacco[1],
F. Brandolini[1], G. de Angelis[2], S. Lunardi[1], L. Müller[1], N. Medina[1], C. Petrache[2],
C. Rossi-Alvarez[1], F. Scarlassara[1], G.F. Segato[1], C. Signorini[1], and F. Soramel[3]

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Our recent investigation of the ^{45}Sc high spin structure has indicated the competition between collective and single particle modes of excitation in this nucleus [1]. In order to prove the collectivity of the band-like sequence of the positive parity levels based on the $d_{3/2}$ proton-hole state, the lifetime measurements were performed at the LNL Tandem Laboratory in Legnaro. Gamma-rays emitted in the bombardment of a thick ^{12}C target with ^{35}Cl projectile at 75, 95 and 120 MeV were recorded in the multidetector array GASP. The selected beam energies lead to a population of three different regions of spin and excitation energy in ^{45}Sc, which arises in 2p CN evaporation. This enabled a well controlled extraction of lifetimes by the DSAM analysis of the γ-lineshapes observed at different angles in respect to the beam direction. The stopping power necessary to calculate the lineshapes was taken from ref. [2]. The examples of the best fits to the shapes for some transitions in the positive parity band are shown in Fig. 1. In this band, the γ-transitions between the highest lying states reveal full Doppler shifts which correspond to lifetimes shorter than 0.1ps. The obtained lifetimes point strongly to the collective character of this band and imply the deformation with $\beta \approx 0.25$.
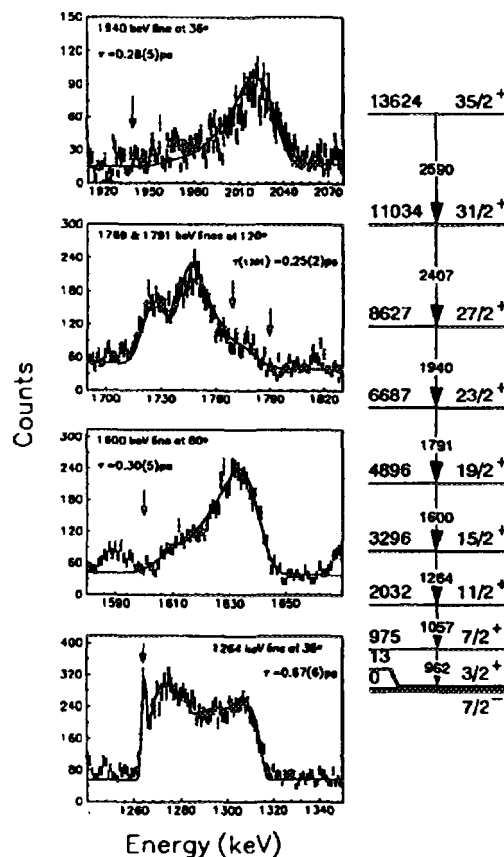

Fig. 1: The best fits for the lineshapes of the positive parity band (shown to the right) in ^{45}Sc. The 2407 and 2590 keV transitions are fully shifted. The arrows indicate the unshifted positions of the lines.

References:

1. P. Bednarczyk et al., IFJ Ann. Rep. 1993, also Nucl. Phys. **A** (in print),
2. J.F. Ziegler, The Stopping and Range of Ions in Matter (Pergamon, New York, 1985).

The $\nu g_{9/2} \to \nu f_{5/2}$ M2 Isomers in Neutron-Rich Ni and Fe Nuclei

B. Fornal, R. Broda, W. Królas, T. Pawłat, D. Bazzacco[1], S. Lunardi[1],
C. Rossi-Alvarez[1], G. de Angelis[2], P.J. Daly[3], H. Grawe[4], and K.H. Maier[4]

[1] Dipartimento di Fisica dell'Universitá and INFN, Padova, Italy; [2] INFN Laboratori Nazionali di Legnaro, Italy; [3] Purdue University, West Lafayette, Indiana, USA; [4] Hahn-Meitner Institute, Berlin, Germany.

In heavy Fe and Ni isotopes the neutron Fermi level is localized within the low j-negative parity orbitals $p_{3/2}$, $f_{5/2}$ and $p_{1/2}$ and it moves towards the $g_{9/2}$ orbital as the number of neutrons approaches N=40. As a result, in odd-A neutron-rich Fe and Ni nuclei the $9/2^+$ level comes down in energy and the M2 transition to the $5/2^-$ state becomes its only way of decay.

These $\nu g_{9/2} \to \nu f_{5/2}$ M2 isomers are known in Zn, Ge and Se nuclei in which the neutron $p_{3/2}$, $f_{5/2}$ and $p_{1/2}$ orbitals are close to being filled. Similar $\pi g_{9/2} \to \pi f_{5/2}$ M2 isomers occur in nuclei around N=50 in which the number of protons approaches Z=40.

In the past, heavy Fe and Ni nuclei could not be reached in processes suitable for γ-ray yrast spectroscopy and among them only in ^{63}Ni the $\nu g_{9/2} \to \nu f_{5/2}$ M2 isomer was identified [1]. Recently we studied the neutron-rich Fe and Ni species in deep-inelastic reactions of ^{64}Ni beam on thick ^{208}Pb (HMI Berlin) and ^{130}Te (INFN Legnaro) targets. The γ-γ coincidence data obtained with the OSIRIS germanium multidetector array (Berlin) allowed us to identify the $\nu 9/2^+$ isomer in ^{65}Ni and ^{67}Ni nuclei [2]. We measured the half-life in ^{65}Ni to be 25 (5) ns and we set a lower limit 0.3 μs for ^{67}Ni.

In the reaction ^{130}Te + ^{64}Ni (Legnaro), using data from the GASP germanium array, we located the $\nu 9/2^+$ state in ^{61}Fe decaying by an isomeric 654 keV transition to the known level at 207 keV which must be then a $5/2^-$ state. The assignment of ^{61}Fe was fixed by delayed γ cross coincidences; by setting a gate on delayed 654 and 207 keV lines the prompt γ-rays from the reaction partner Xe nuclei with A = 128 - 133 were displayed.

A second GASP measurement, which had as a main objective the half-life determinations [3, 4], was performed for the same ^{130}Te + ^{64}Ni system with various beam pulsing conditions. The half-lives of the $\nu 9/2^+$ states were measured, yielding 0.22 μs and 12 μs in ^{61}Fe and ^{67}Ni, respectively.

In Table 1 the $B(M2, \nu g_{9/2} \to \nu f_{5/2})$ values extracted for heavy Ni and Fe isotopes are shown. The similarity of the B(M2)'s in all examined nuclei is striking. Search for other isomers of this kind, which is in progress, will allow us to look at these M2 transitions in a more systematic way.

Table 1. The $\nu g_{9/2} \to \nu f_{5/2}$ M2 isomeric transitions in Fe and Ni nuclei.

nucleus	transition energy [keV]	half-life	B(M2) $(e\hbar/2M_p c)^2 fm^2$
^{63}Ni	1204	9.3(3) ns	2.1(1)
^{65}Ni	1017	25(5) ns	1.9(4)
^{67}Ni	313	12(2) μs	1.4(2)
^{61}Fe	654	0.22(2) μs	1.9(2)

PL9700125

References:

1. W. Müller et al., *Phys. Rev.* **B 40** (1989) 7633,
2. T. Pawłat et al., *Nucl. Phys.* **A 574** (1994) 623,
3. R. Broda et al., *Phys. Rev. Lett.* in press,
4. R. Broda et al., contribution to this Annual Rep.

Yrast Isomers in Odd-A Tins Produced in Deep-Inelastic Collisions

R.H. Mayer[1], D. Nisius[1], I.G. Bearden[1], L. Richter[1], M. Sferrazza[1], Z.W. Grabowski[1],
P.J. Daly[1], R. Broda, B. Fornal, M. Carpenter[2], R.V.F. Janssens[2], T.L. Khoo[2],
T. Lauritsen[2], and J. Blomqvist[3]

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In the γ-γ coincidence experiment at ATLAS, in which the lead-backed ^{124}Sn target was bombarded with pulsed beams of ^{76}Ge and ^{80}Se ions, we identified the long-lived $(\nu h_{11/2})^n$ 10^+ isomers in ^{122}Sn and ^{124}Sn (but not ^{126}Sn) products [1]. These results almost completed a series of B(E2) determinations for $(\nu h_{11/2})^n$ states in even-A $^{116-130}$Sn isotopes and located half-filling of the neutron $h_{11/2}$ subshell close to N = 73.

In the data from the ^{124}Sn + ^{80}Se experiment new γ-rays deexciting previously unknown $(\nu h^2_{11/2} s_{1/2}) 19/2^+$ isomers in ^{119,121,123}Sn and $(\nu h_{11/2})^n$ seniority 3, $27/2^-$ isomers in ^{119}Sn and ^{121}Sn have also been identified [2] - Fig. 1.
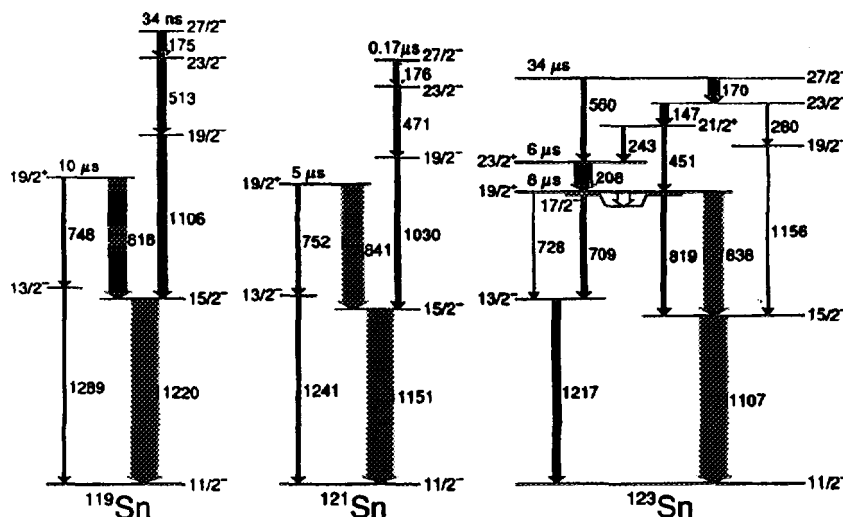

Fig. 1 Isomeric decay schemes for ^{119}Sn, ^{121}Sn and ^{123}Sn nuclei.

In the follow-up experiment we extended the ATLAS investigations by studying the system ^{124}Sn + 655 MeV ^{136}Xe. We expected on the basis of N/Z equilibration considerations that the ^{136}Xe beam would favor production of neutron-rich nuclei more than the ^{76}Ge and ^{80}Se beams. Indeed, the overall experimental yield distribution in the Z = 50 region was definitely shifted towards higher neutron numbers; for example, the ^{126}Sn 10^+ isomer, with a 7 μs half-life, was finally observed.

The high quality prompt and delayed γ-ray coincidence data allowed us to establish a very complete ^{123}Sn level scheme up to a 34 μs isomeric level at 2713 keV [3] - Fig. 1. This isomer and the level at 2543 keV are, without doubt, the $(\nu h_{11/2})^n$ $\nu = 3$ $27/2^-$ and $23/2^-$ states. Very low B(E2, $27/2^- \rightarrow 23/2^-$, ^{123}Sn) value - less than 0.002 W.u. - reflects the half-filling of the $\nu h_{11/2}$ subshell at N = 73, and is a striking illustration of the impact of subshell occupation on transition probabilities.

References:

1. R. Broda et al., *Phys. Rev. Lett.* **68** (1992) 1671,
2. R.H. Mayer et al., *Z. Phys.* **A 342** (1992) 247,
3. R.H.Mayer et al., *Phys. Lett.* **B 336** (1994) 308.

Trend Towards N/Z Ratio Equilibration in ^{208}Pb + ^{64}Ni Collisions

W. Królas, R. Broda, B. Fornal, J. Grębosz, T. Pawłat
M. Schramm[1], H. Grawe[1], J. Heese[1], K.H. Maier[1], and R. Schubart[2]

[1] Hahn–Meitner–Institut Berlin, Germany, [2] Universität Göttingen, Germany.

Fragmentary results of the study of ^{208}Pb + ^{64}Ni colliding system at 350 MeV projectile energy have been presented in a number of previous reports [1, 2]. It turned out that the detailed analysis of γ-γ coincidence data and of radioactive decays gave nearly complete distribution of secondary product nuclei. Moreover information needed to reconstruct the map of primary reaction fragments was obtained. This result allows us to look in rather detailed way at the N/Z equilibration process in massive transfer reactions which was considered to be an important issue since the beginning of heavy ion physics. Attempts to describe this effect theoretically were presented as early as in 1972 [3]. An analytical formula for the optimum N/Z ratio for nuclei of a fixed mass produced in such processes was obtained assuming two spherical product nuclei at a given distance and calculating the minimum of total energy of the system with respect to the charge division.
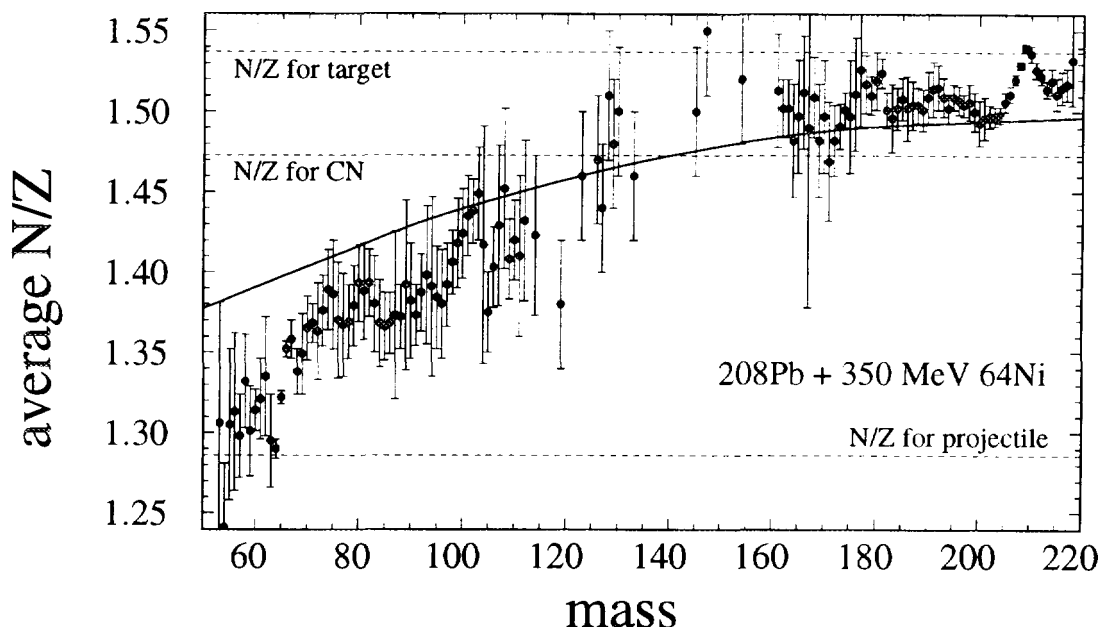

Fig. 1 Average N/Z for reaction products. Solid curve is a result of theory based calculation - see text.

In Fig. 1 we present the most probable N/Z ratios obtained from experiment for each mass of reaction products. The solid curve represents the model prediction calculated according to the formula of Ref. [3]. The general trend of the distribution is reproduced by the calculation. However, to obtain the quantitative agreement apparently the deformation effects of the colliding nuclei have to be included. Within the same simple calculation increase of the distance of two fragments can reproduce the experimental N/Z.

References:

1. W. Królas et al., IFJ Cracow Annual Report 1993, p. 36,
2. W. Królas et al., *Acta Phys. Pol.* **B25** (1994) 687,
3. W.J. Swiatecki, *J. Phys.* **C5** (1972) 45.

The 5⁻ Isomeric State in 68Ni

R. Broda, B. Fornal, W. Królas, T. Pawłat, P. Bednarczyk,
D. Bazzacco[1], S. Lunardi[1], C. Rossi-Alvarez[1], R. Menegazzo[1], G. de Angelis[2], J. Rico[2],
D. de Acuña[2], P.J. Daly[3], R.H. Mayer[3], M. Sferrazza[3], H. Grawe[4], K.H. Maier[4], and
R. Schubart[5]

[1] Universitá di Padova e INFN, Italy, [2] Laboratori Nazionali di Legnaro, INFN, Italy
[3] Purdue University, West Lafayette, Indiana, USA, [4] Hahn–Meitner–Institut, Berlin, Germany; [5] Universität Göttingen, Germany

Recently we have identified three new states in the $^{68}_{28}\text{Ni}_{40}$ which indicated a substantial subshell closure at the neutron number $N = 40$ [1, 2]. This result was a natural extension of our more systematic study of the neutron–rich Ni isotopes performed with the use of deep–inelastic heavy–ion reactions [3]. The important feature established in ^{68}Ni [1] is a presence of a long–lived isomeric state which on the basis of shell–model expectations was tentatively assigned as the $(\nu g_{9/2} p_{1/2}^{-1})$ 5⁻ particle–hole excitation. We have performed now a new experiment aimed at this isomer half–life determination. The half–life value was expected to clarify the 5⁻ assignment by establishing the E3 character of the 814 keV isomeric transition. On the other hand the direct comparison of the $B(\text{E3})$ transition probability with a similar E3 transition known in ^{90}Zr could indicate structural differences at the neutron $N = 40$ and proton $Z = 40$ numbers.
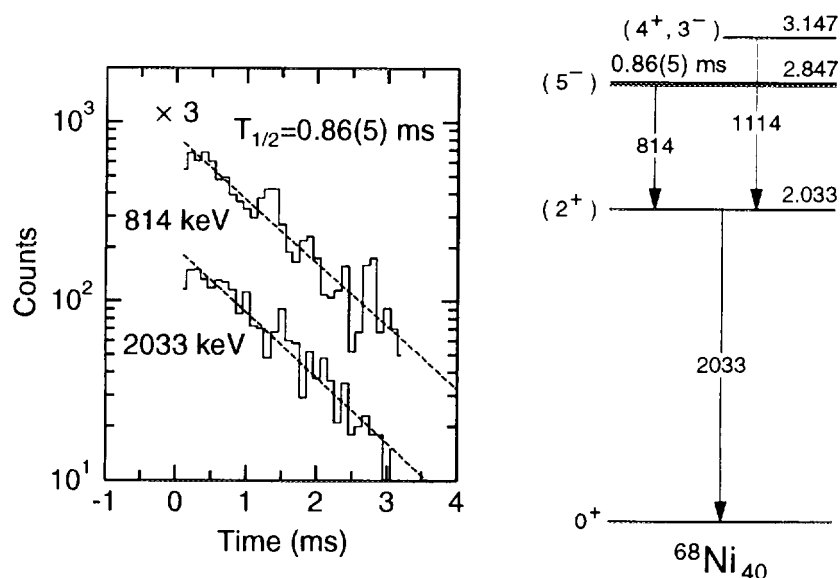

Fig. 1 The 5⁻ isomer decay curves and new established level scheme of ^{68}Ni.

The experiment was performed with the GASP array at the LNL Legnaro, using the 275 MeV ^{64}Ni beam pulsed in the range from micro– to milliseconds which bombarded a thick ^{130}Te target. The singles GASP detector data were clean enough to observe the isomeric decay and to select the beam pulsing condition (3 ms – on, 10 ms – off) for the main run which gave the isomeric half–life of $T_{1/2} = 0.86(5)$ ms. The obtained decay curves and the ^{68}Ni level scheme is shown in Fig. 1.

This result confirms the E3 character of the 814 keV isomeric transition. However, the $B(E3)$ value is very small (0.022 W.u.) indicating that $5^- \rightarrow 2^+$ E3 in ^{68}Ni is ten times slower than the similar E3 transition known in ^{90}Zr.

References:

1. R. Broda et al., IFJ Annual Report 1993, p. 40,
2. R. Broda et al., Proceedings of the Conference on Physics from Large γ-Ray Detector Arrays, Berkeley 1994,
3. T. Pawlat et al., *Nucl. Phys.* **A574** (1994) 623.

Determination of Product Distribution in ^{130}Te + 275 MeV ^{64}Ni Collisions

W. Królas, R. Broda, B. Fornal, T. Pawlat, P. Bednarczyk,
D. Bazzacco[1], S. Lunardi[1], C. Rossi-Alvarez[1], G. de Angelis[2], and P.J. Daly[3]

[1] Universitá di Padova e INFN, Italy, [2] Laboratori Nazionali di Legnaro, INFN, Italy,
[3] Purdue University, West Lafayette, Indiana, USA

The discrete gamma–ray analysis of the gamma radiation accompanying heavy–ion collisions can provide an important new information for the study of deep–inelastic processes [1]. A possibility to reconstruct a complete distribution of primary reaction products allows one to look in a very detailed way at the N/Z equilibration process. Recently we have performed such an analysis for the ^{208}Pb + 350 MeV ^{64}Ni reaction [2, 3].

We are analyzing now the ^{130}Te + 275 MeV ^{64}Ni system which starts our comparative studies of deep–inelastic reactions. The characteristics given in Table 1 show that for both target-projectile combinations the important initial parameters are similar; in particular the projectile is identical and the N/Z ratio of target nuclei is very close to one another. However, there are also distinct differences. Firstly, the ^{130}Te + ^{64}Ni is a much less assymetric system and, unlike the ^{208}Pb, the heaviest stable tellurium isotope ^{130}Te is a neutron rich nucleus. Secondly, even more important difference is that for ^{130}Te + ^{64}Ni system the fusion process represents a significant part of the total reaction cross section. Whereas at 350 MeV ^{64}Ni projectile energy the fusion with ^{208}Pb almost does not happen, the compound nucleus is easily formed in central collisions of ^{130}Te and ^{64}Ni leading to subsequent decay by particle evaporation or by fission. The aim of our analysis is to find how these differences will affect the N/Z equilibration process.

Table 1. The characteristics of two investigated target–projectile combinations.

target	projectile	beam energy	above the barrier	N/Z numbers for projectile	compound	target
208Pb	64Ni	350 MeV	11 %	1.29	1.47	1.54
130Te	64Ni	275 MeV	12 %	1.29	1.43	1.50

PL9700129

In the experiment performed at the Laboratori Nazionali di Legnaro γ–γ coincidences were measured using the GASP array. All the produced nuclei were stopped in the thick target (1.2 mg/cm^2 of Te placed on a 14 mg/cm^2 Pb backing). After the experiment the target radioactivity was measured for several months at the Institute of Nuclear Physics in Cracow. The analysis of the radioactivity spectra lead to the identification of 56 isotopes with lifetimes in the range from few hours to three hundred days. The investigation of in– and off–beam coincidences that is still in progress will give main information on product yields.

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Multinucleon Transfer in ^{208}Pb + ^{58}Ni Collisions

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One of the most important features observed in collisions of very heavy ions at energies above the Coulomb barrier is the trend to equilibrate the N/Z ratio of two colliding nuclei. In an assymetric system, the lighter nucleus has a smaller N/Z value and during the collision time easily picks up neutrons from the heavy reaction partner. In the same time the flow of protons is directed the opposite way and the two resulting fragments separate in the exit channel with much closer N/Z ratios.

In our recent study we used the high resolution in–beam γ–γ coincidence data and measured the long–lived radioactivity to reproduce almost complete distribution of the primary reaction products for the ^{208}Pb + 350 MeV ^{64}Ni colliding system [1, 2]. The observed variation of the N/Z ratio with fragments mass indicated that even for a neutron excessive ^{64}Ni projectile the N/Z equilibration trend determines the isospin composition of the transferred mass. With an expectation to observe a significant enhancement of this effect for the system involving neutron deficient projectile we proposed a similar experiment for the ^{208}Pb + ^{58}Ni collisions.

The ALPI Linac accelerator test at the LNL Legnaro gave us an opportunity to perform this experiment. The 345 MeV ^{58}Ni beam extracted for the first time to the GASP array area bombarded a thick ^{208}Pb target placed in the array center. The 36 hours run gave sufficiently good statistics for the quantitative analysis of the γ–γ in–beam and off–beam coincidence data. Although the analysis aimed at the extraction of the production yields is still in progress the initial results already demonstrate a spectacular effect of the N/Z equilibration process.
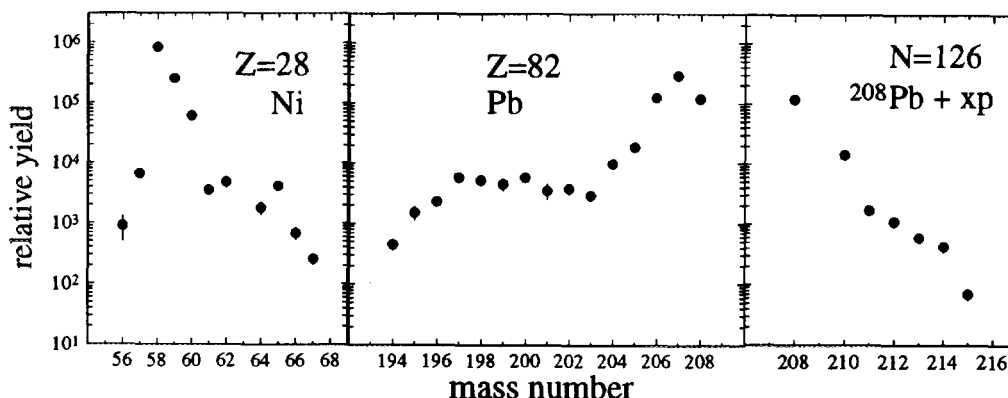

Fig. 1 The distribution of Ni and Pb isotopes and of $N = 126$ isotones produced in ^{208}Pb + 345 MeV ^{58}Ni collisions as observed by selected γ–γ coincidences.

Fig. 1 shows the observed production yields for Ni and Pb isotopes as well as for $N = 126$ isotones produced by the transfer of protons from the projectile to ^{208}Pb target nucleus. The populations extend to ^{67}Ni and ^{215}Ac isotopes which corresponds to the transfer of 9 neutrons and 7 protons respectively. The distribution of Pb isotopes which spans even broader mass region down to the ^{194}Pb isotope emphasizes a role of the neutron evaporation from the excited primary fragments. After completing our analysis this process will be taken into account in reconstruction of the primary fragment distribution.

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2. W. Królas et al., contribution to this Annual Report.

Study of Nuclei around ^{56}Ni by Recoil -γ-γ- Coincidences

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The γ-spectroscopy of ^{56}Ni and its neighbours has been difficult, because the compound nucleus emits neutrons, protons and alpha-particles with comparable probabilities, and therefore many final nuclei are produced and the spectra are complex. Also the momentum of the evaporated charged particles is about 10% of that of the compound nucleus. This leads to a wide velocity distribution of the γ-emitting nuclei and consequently to the Doppler broadening of the fast high-energy transitions.
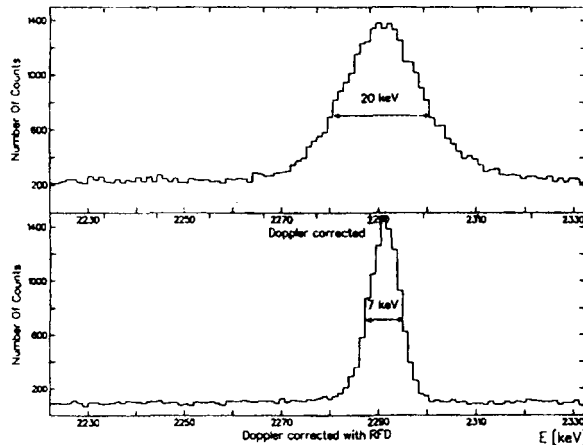

Fig. 1: The 2290 keV line in ^{57}Co with the usual Doppler correction for the average velocity of the nuclei (upper part) and with individual corrections for the velocity vector measured by the RFD (lower part).
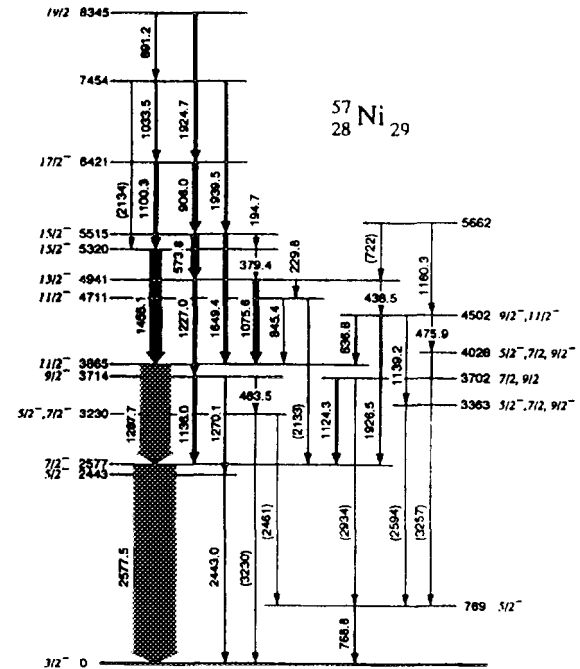

Fig. 2: Preliminary level scheme of ^{57}Ni.

The γ-γ-RFD coincidences have been measured for the reactions of 68 MeV ^{20}Ne with a 1 mg/cm^2 ^{40}Ca-target, using the standard OSIRIS-RFD-setup at ISL. The RFD serves here primarily to determine the velocity vector of the γ-emitting nucleus. The γ-energies can then be corrected for the corresponding Doppler shift. Fig. 1 shows that the line width can be reduced

by a factor 3. The efficiency of the RFD for ^{57}Co can also be directly determined from this figure as 30%. Data evaluation has so far concentrated on ^{57}Co and ^{57}Ni. A preliminary scheme of ^{57}Ni is shown in Fig. 2. New level spins have been assigned from DCO-ratios. The yrast line is very steep, it takes about 1 MeV to gain one unit of spin. The spin of the 3702 keV level is limited to 7/2 or 9/2, it is a good candidate for the $g_{9/2}$ single neutron state.

Shell Model States in the $^{157}_{72}Hf_{85}$ Nucleus

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So far, the only knowledge on the N = 85 nucleus ^{157}Hf is the 110ms half life of the ground state observed in its α-decay [1].

In-beam $\gamma\gamma$- and $\gamma\gamma$n-measurements at the VICKSI cyclotron have for the first time identified the ^{157}Hf excited states up to 6.5 MeV and I = (51/2). The obtained experimental high-spin level scheme is presented in Fig. 1. Configuration assignment of the observed excitations is based on the results of parameter-free shell model calculations for the 11 valence particles ($\pi^8\nu^3$) outside the ^{146}Gd core with empirical two-body interactions compiled in Ref. [2]. From the systematics of the N = 85 isotones we assign the ^{157}Hf ground state as $(\nu f^3_{7/2})_{7/2}$. The level sequence up to $21/2^-$ at 1.86 MeV represents the yrast $\nu f^2_{7/2}h_{9/2}$ excitations. Above 2.5 MeV, where $h_{11/2}$ protons contribute to the spin, the negative parity levels are interpreted as members of the $\pi h^8_{11/2}\nu f^3_{7/2}$ or $\pi h^8_{11/2}\nu f^2_{7/2}h_{9/2}$ multiplets. Only the $23/2^{(-)}$ state at 2.29 MeV is not predicted by the calculation. We tentatively assign it as the maximum aligned $(\nu f_{7/2}h^2_{9/2})_{23/2}$ state since no other $23/2^-$ level is expected at this low excitation. The 52ns isomer at 2.88 MeV is the fully aligned $f_{7/2}h_{9/2}i_{13/2}$ three-neutron state; the analogous state is known [3] in the ^{153}Er isotone. In conclusion, we have established a fairly complete yrast level scheme of the previously unknown ^{157}Hf proton-rich nucleus. In spite of a rather complex situation, with 11 valence nucleons, the results of shell model recoupling calculations are in excellent agreement with experiment.
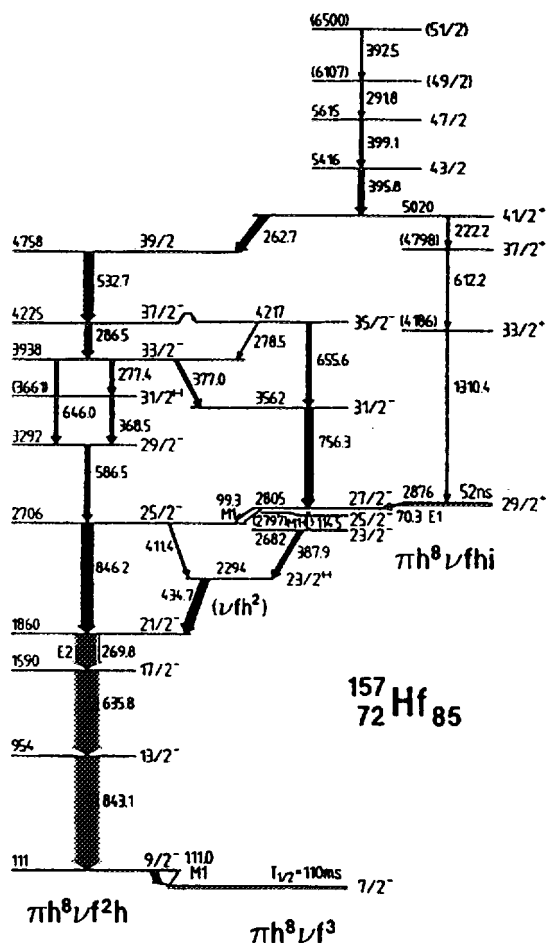

Fig.1: The ^{157}Hf yrast states populated in ^{106}Cd(^{54}Fe,2pn) at 255 MeV. Levels of specified multiparticle configurations are arranged in columns.

PL9700132

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Gamma–Ray Angular Distributions in Deep–Inelastic Reactions

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We have recently studied the neutron-rich $^{64-67}$Ni isotopes using quasi- and deep-inelastic reactions of ^{64}Ni with ^{208}Pb [1]. For a number of new states observed in those nuclei we gave tentative spin-parity assignments basing on the observed γ-decay and on theoretical expectations.

We are now inquiring whether the spin alignment obtained in the binary reactions used in our experiments is large enough to produce measurable γ-ray anisotropies thereby providing input to spin-parity assignments by angular distribution measurements. We use the high-statistics $\gamma-\gamma$ coincidence data obtained with the GASP array in experiment performed at the LNL Legnaro, in which the thick ^{130}Te target was bombarded with 275 MeV ^{64}Ni beam. In these ^{130}Te + ^{64}Ni collisions the neutron-rich Ni isotopes are abundantly produced and data from that experiment allowed us to extend earlier study [1] including the identification of the ^{68}Ni $N = 40$ closed subshell nucleus [2]. However for the present purpose important feature of the reaction used is, that fusion-evaporation process also happens quite frequently. It leads to the well known ^{190,191}Hg isotopes [3, 4] where the long γ-transitions cascades provide us with an excellent chance to control the procedure of the angular distribution analysis.
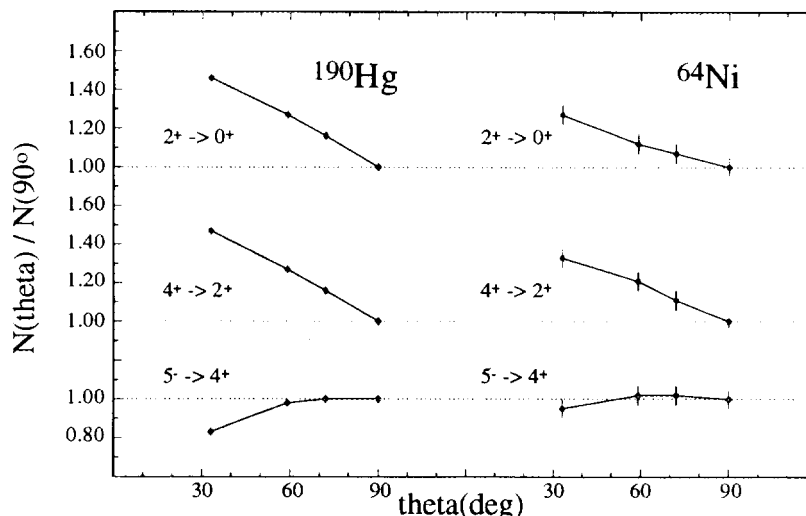

Fig. 1: Examples of γ–ray angular distributions obtained in the ^{130}Te + ^{64}Ni collisions for fusion–evaporation (left) and inelastic processes (right).

The coincidence data were sorted into separate matrices corresponding to rings of detectors at $33°, 59°, 72°$ and $90°$ angles with respect to the beam direction. Selecting by appropriate coincidence gates transitions in a specific nucleus and using an adequate normalization, the angular

distributions could be extracted. Fig. 1 shows examples of the obtained results with the ^{190}Hg transitions clearly showing the expected anisotropies. Few examples shown for nuclei produced in binary reaction indicate that the spin alignments involved are significantly smaller. Nevertheless in many cases it will be possible to get meaningful results for spin-parity assignments. The detailed analysis is in progress.

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Energy Levels in $^{147}_{65}$Tb$_{82}$ from GT Decay
of its $^{147}_{66}$Dy$_{81}$ 1/2$^+$ and 11/2$^-$ Parents

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It is difficult to identify the low-lying phonon excitations in $^{147}_{65}$Tb$_{82}$ which are of particular interest in this one-valence proton nucleus. These levels cover the spin range from 1/2 to 17/2. Most of them occur more than 1 MeV above the yrast line, and even a dedicated in-beam experiment at the Coulomb barrier with ^{6}Li beam fails to populate the states with I≤5/2. Alternatively, ^{147}Tb above-yrast levels can also be excited in β-decay of the 1/2$^+$ and 11/2$^-$ $^{147}_{66}$Dy$_{81}$ isomers. In both cases ^{147}Tb excited states are populated in GT-decay of a paired ^{147}Dy $h_{11/2}$ proton to the empty $h_{9/2}$ neutron shell above N = 82, proceeding as $(\pi h^2_{11/2})_{0^+}+(\pi h_{11/2}\nu h_{9/2})_{1^+}$ transition and leading to two partcile - one hole excitations of $\nu h^{-1}_{11/2}$ x 1$^+$ and $\nu s^{-1}_{1/2}$ x 1$^+$ character in ^{147}Tb above 3.5 MeV. These high-lying GT-resonances can populate in their γ-decay above-yrast states up to I = 15/2, among them also the particle x phonon states.

Our original ^{147}Dy β-decay experiments [1] utilized HI-compound evaporation production with 4.5 MeV/u ^{58}Ni beam on ^{92}Mo at the GSI on-line mass separator where standard $\gamma\gamma$- and γX-coincidences and timed γ- and p-singles spectra were measured. Later, additional data were obtained with the high yields of the ISOLDE and ISOCELE II mass separators; a miniorange electron spectrometer, Compton-suppressed γ-detectors, and a cooled Si(Li)-detector for proton measurements were employed.

These data gave the decay schemes of Fig. 1 (see next page). Firm attribution of the γ-rays to the respective parent activity is obtained from their decay characteristics. While the 11/2$^-$ decay shows the pure 56s half-life of the ^{147}Dy M4 isomer, a consecutive 56s $\rightarrow$ 49s decay curve identifies the transitions following 1/2$^+$ decay. Else, coincidence data and energy relations were used to build the level schemes.

The two ^{147}Dy decays both reveal quite sharp GT-resonances in ^{147}Tb, which lie 2.33 and 2.42 MeV below their respective $\nu s^{-1}_{1/2}$ and $\nu h^{-1}_{11/2}$ parent states of ^{147}Dy. We note that the $\pi h_{11/2}\nu h_{9/2}\nu h^{-1}_{11/2}$ resonance at 4.70 MeV excitation contains the $h_{9/2} - h_{11/2}$ neutron particle-hole excitation across N = 82 and thus specifies the splitting of the neutron l = 5 spin-orbit pair except for contributions from residual interactions.

Fig. 1: The decay scheme of ^{147}Dy. Configuration assignments as proposed for the ^{147}Tb levels up to 2.35 MeV are included. In many cases, angular distribution information from the in beam study [R. Collatz et al. to be published] was vital to assign the level spins, but several states with I = 1/2 and 3/2 could only be observed in the present β-decay experiment.

Finally we mention that the precise level energies of low-spin resonance states together with the energies of the discrete lines in the proton spectrum have determined the ground state mass of ^{147}Tb [2].

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Lifetime of Hot Superheavy Nuclei

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Recent research has provided evidence that fission of the compound nucleus is a far slower process than predicted by the statistical model [1]. Measurements of γ-rays, evaporated neutrons and charged particles from fissile nuclei indicate a significant fission hindrance. γ-ray spectra from fissioning systems reveal both a pre-fission and a post-fission giant dipole resonance component. This occurs at different γ-energies due to the different radii of the heavy fissile nucleus and its fragments. Studies of the pre-fission GDR radiation offer insight into nuclear behaviour under extreme conditions with respect to temperature, spin and nucleon number, a region which was previously closed to direct inspection. In this work we use the GDR radiation as a tool for investigating the superheavy nucleus ^{272}Hs and its evaporation daughters at temperatures of the order of 2.5 - 3.3 MeV.

At the SARA Cyclotron Laboratory in Grenoble, the superheavy nucleus $^{272}_{108}$Hs has been synthesized employing the reaction ^{40}Ar + ^{232}Th $\rightarrow$ ^{272}Hs. A pilot experiment was carried through by the HECTOR collaboration in 1989, using beam energies of 6.8 and 10.5 MeV/A [2]. The main experiment was performed in 1991, with beam energies of 10.5 and 15.0 MeV/A. Excitation energies introduced by the three beams were about 92, 218 and 371 MeV respectively. The observed cross-sections include both compound fission and the faster quasi-fission process.

The experimental set-up and a part of the results were reported in [2, 4]. Here we present estimates of the lifetime of hot superheavy nucleus before fission.

The energy differential method, first described in ref. [3], has been employed in order to obtain information about the earliest decay steps. We have normalized the coincident γ-spectra from the 15.0 and 10.5 MeV/A runs to the same number of symmetric fission events. The difference spectrum shows a well-defined pre-fission component [4]. In the energy region above 15 MeV, associated with the fission fragment GDR radiation, the difference spectrum reveals no significant contribution. This indicates that the onset of fission takes place after cooling the system down to an excitation energy below that initially introduced by the 10.5 MeV/A beam.

The relative yield of GDR radiation in the difference spectrum is somewhat reduced compared to that expected from simple statistical model arguments. This may suggest that the initial excitation energy introduced by the 15.0 MeV/A beam approaches the limiting temperature for collective vibration in hot nuclei.

The fact that no post-fission contributions are present in the difference spectrum allows us to extract a lower limit for the lifetime of the hot fissile superheavy system in this reaction. In Figure 1 the average evaporation time τ_n for neutrons, which represent the dominant decay mode for the heated system, is plotted as a function of compound nucleus excitation energy. Level density parameter $a = A/8$ has been chosen. Relations between the excitation energy

varying during the decay sequence and the total elapsed time since the start of the cascade, given as $\sum \tau_n$, are also shown for the three different beam energies. Starting at 371 MeV, the excitation energy of 218 MeV, corresponding to the lower beam energy, is exceeded after $8 - 9 \cdot 10^{-21}$s. Since no fission fragment GDR decay is observed before this point, the duration of the fission process must be at least equal to this elapsed time. An upper limit can be extracted by taking into account the fact that a post-fission component is indeed observed in the difference between the γ-spectra for 10.5 and 6.8 MeV/A beam energy [2]. Here, the corresponding elapsed time is about $4 \cdot 10^{-20}$s. This estimate agrees well with values found by other authors.
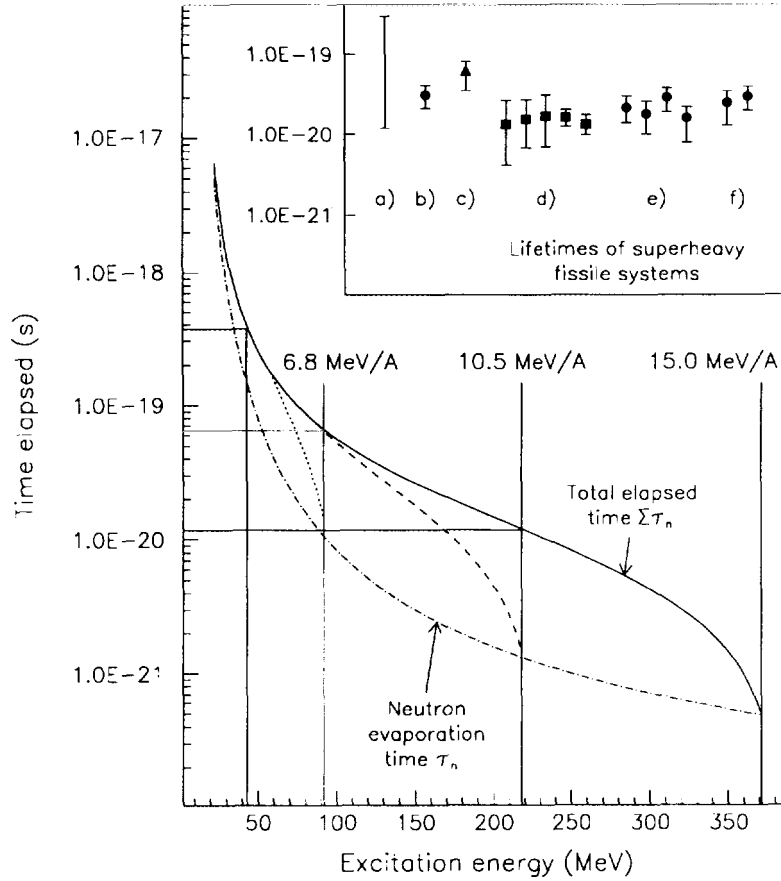
Fig. 1: Individual neutron decay times (dash-dotted curve) and total elapsed time as a function of excitation energy during decay for reactions at 15.0 (solid) 10.5 (dashed) and 6.8 MeV/A (dotted curve). Horizontal lines: Limits on fission (or quasifission) lifetime, extracted from data of ref. [2] and this work. The insert shows data on fission lifetimes for various target-projectile combinations, available in literature: a) ^{40}Ar+^{232}Th (this work); b) ^{28}Si+^{232}Th [6]; c) ^{32}S+^{208}Pb [7]; d) ^{238}U+^{27}Al,^{32}S,^{35}Cl,^{40,48}Ca [5]; e) ^{64}Ni+^{175}Lu,^{197}Au,^{208}Pb,^{238}U [8]; f) ^{40}Ar +^{208}Pb,^{238}U [8].

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PL9700135

Fission – γ-Ray Angular Correlation
in GDR Decay from Hot Nielsbohrium Nuclei

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As a continuation of research on GDR decay in hot superheavy nuclei [1, 2], an experiment at Stony Brook has been performed in which hot ^{269}Ns (with Z=107) was formed. The reaction used was ^{37}Cl+^{232}Th at 7.3 MeV/A bombarding energy. Fission fragments were detected in PPAC counters, while high-energy gamma rays were picked up by BaF$_2$ detectors from the HECTOR array. Fig. 1a shows two-dimensional spectrum of total kinetic energy in the output channel versus mass of measured reaction fragment. The gamma spectra, obtained by setting narrow gates on the 2-dimensional spectrum, are shown in Fig. 1b. By gating on pairs of approximately mass-symmetric fission fragments (gate #1), we selected events connected with complete fusion or quasi-fission reactions. In such a spectrum the GDR bump is clearly visible, while in the two other gates the spectra show mostly exponential behaviour, typical for rather cold nuclei.

The spectra were measured at 0° and 90° with respect to the spin axis (defined by fission fragments), which allowed us, after correcting for neutron pile-up, to establish angular anisotropy W($0°$)/W($90°$) as a function of gamma-ray energy. This fission - γ-ray angular correlation pattern is shown in Fig. 1c with full squares, in comparison to the results obtained earlier in Grenoble for a similar system at higher bombarding energies. All spectra show a pattern typical for dipole emission from a very heavy system, indicating either a prolate, collectively rotating or an oblate, non-collectively rotating compound nucleus. At these elevated temperatures, however, the angular correlation is most likely the result of averaging over an extensive shape ensemble. One can see an increase of the magnitude of the W($0°$)/W($90°$) ratio around 9 MeV with increasing bombarding energy, most probably a result of increasing contribution of the pre-fission component.
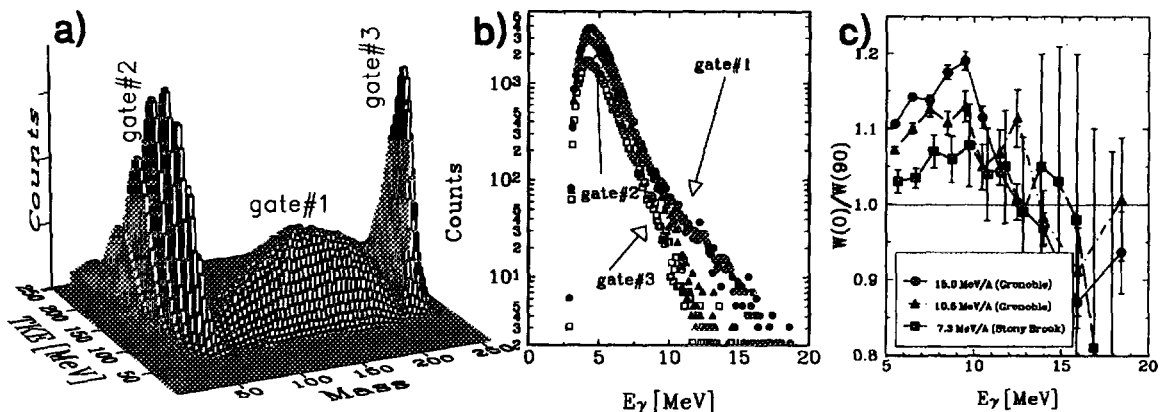

Fig. 1: a) Total kinetic energy of reaction products as a function of the mass of one detected fragment, with indicated regions where gates were set on; b) Gamma-ray spectra obtained in coincidence with the 3 different gates; c) Comparison of obtained anisotropy pattern with results obtained previously in Grenoble experiments.

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2. T.S. Tveter et al., IFJ Ann. Rep. 1993 (1994) 51; and this Ann. Rep.

Detecting High Energy γ-ray with HPGe Detectors

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The "Adding Mode" technique has been applied [1] to measure the response of a HPGe (82%) detector (manufactured by Intertechnique Strasbourg) with a BGO anti-Compton shield to the 15.1 MeV gamma-rays produced by the reaction $D(^{11}B,n\gamma)^{12}C$ and to the 6.13 MeV gamma-rays from ^{238}Pu-^{13}C source. In this technique the energy deposited in the HPGe and in the BGO is summed together to enhance the full energy peak efficiency. The spectra obtained this way are shown in the top row of Fig. 1. The escape peaks and the Compton shoulder which dominate the "single" spectra (bottom row) are no more clearly visible. The response function in the summed spectrum is very well concentrated in the full energy peak. It is especially evident for the 15.1 MeV peak (shifted to 14.84 MeV because of the Doppler effect: the detector was placed at an angle of 110° relative to the ^{11}B-beam direction and the recoil velocity was $\beta \simeq 0.05$). FWHM for this peak was found to be 210 keV (about half of this width was due to the Doppler broadening), a value much better than that usually obtained with scintillators. For the 6.13 MeV peak from the source, the FWHM was 130 keV. This very good resolution of the added-back spectrum is related to the fact that the largest fraction of the gamma energy is deposited in the HPGe while only a small part of the energy is left in the BGO shield.

Measurements of high energy γ-rays with such a good energy resolution (using for example large detector arrays such GA.SP, EUROGAM or EUROBALL, originally designed for standard low-energy γ spectroscopy) offer the possibility of a new generation of experiments, e.g. study of structure of strength function of Giant-Resonance gamma decay.
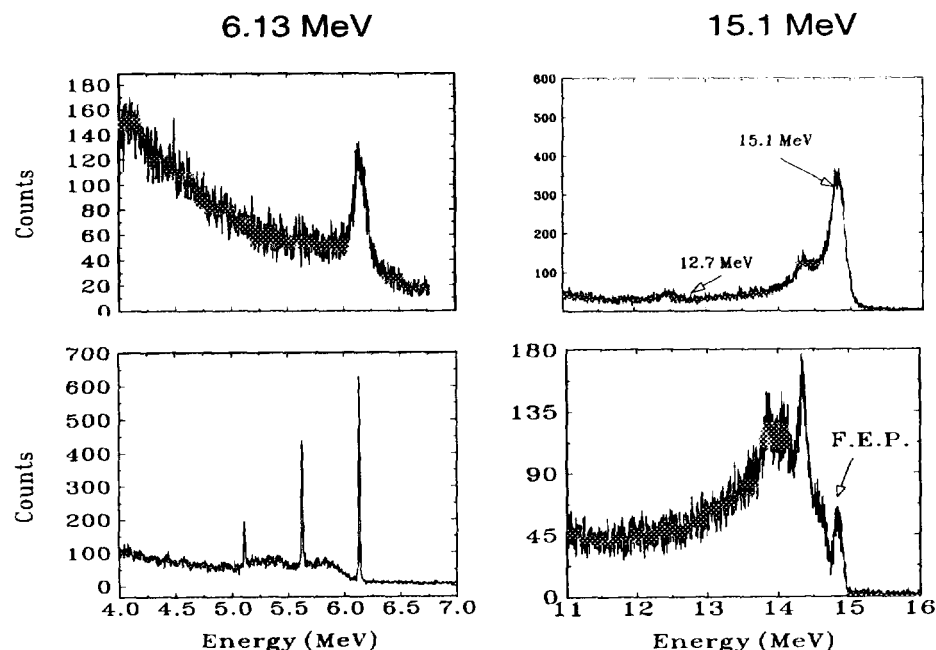

Fig. 1: The left column shows spectra for 6.13 MeV γ-ray, the right one those for 15.1 MeV. The upper row shows spectra from the "adding mode" (HPGe+BGO) procedure, the bottom row - single HPGe spectra.

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Experimental Setup for High–Energy γ-Ray Studies at the Warsaw Cyclotron

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In this report we would like to present the current status of the experimental setup built at the Warsaw Cyclotron in collaboration between physicists from Warsaw, Cracow and Świerk, in order to study high-energy γ-rays from heavy-ion collisions. The planned studies fall into two major groups. The first one involves investigations of statistical γ-ray emission from the thermally-equilibrated compound nucleus. High-energy photons are then emitted in competition with neutrons, protons and α-particles, and are associated with statistical decay of the giant dipole resonance (GDR) built on highly excited states. Owing to the stability of the GDR in hot nuclei [1, 2], the statistical GDR decay may be used as a tool for studying hot, fast-rotating nuclei. Studies of non-statistical, ultradipole (bremsstrahlung) emission in nucleus-nucleus collisions form the second group of our interests. Here, photons are produced mainly in collisions between individual projectile and target nucleons. The relative motion of these nucleons couples with the Fermi motion of nucleons in colliding nuclei. Therefore, probability of γ-ray production in such processes, and thus the measured cross-section, carry information about phase space distribution of nucleons in projectile and target nuclei [3]. To study these effects in detail we need to measure high-energy γ-ray spectra and angular distributions, both in inclusive as well as in exclusive (e.g. in coincidence with γ-ray multiplicity) experiments.

At its present stage, our high-energy γ-ray spectrometer consists of a 10 cm × 10 cm cylindrical bismuth germanate scintillator from INP Cracow. Due to high atomic number and high density of bismuth germanate, such detector has large full-energy absorption and may be used for γ-rays of energy up to about 50 MeV. Its energy resolution ($\approx$ 13% at 661 keV, 2.2% at 17.4 MeV [4]) is comparable to that of large NaI(Tl) detector in Seattle or large BaF_2 detectors in Copenhagen. Time resolution of our BGO was determined to be 6 ns, which, however, is worse than the typical time resolution of NaI(Tl) (2-3 ns) or BaF_2 (0.6 ns)

In order to define the angular momentum of the decaying compound nucleus or to discriminate against non-fusion processes, we constructed a γ-ray multiplicity filter. It is an array of 28 cylindrical scintillators: 10 BaF_2's (5 cm × 5 cm) from Chalmer Techniska Hogskala in Göteborg and 18 NaI(Tl)'s (8 crystals of 3 cm × 3 cm and 10 crystals of 2 cm × 2.5 cm) from Sołtan Institute for Nuclear Studies at Świerk. All detectors are mounted on a special stand which allows various configurations of the filter. Efficiency callibration for 1.17 MeV γ-rays in a configuration where detectors were placed 16 cm from the target was performed by a standard method [5] using ^{60}Co source. The total filter efficiency obtained was 10%.

The target chamber is made of aluminum with a movable target holder (four target positions) surrounded by a copper cold shroud (at liquid-nitrogen temperature) connected with the isolated copper cold-finger, which inhibits the build-up of hydrocarbons on the target surface.

The first GDR experiment using this setup is scheduled for February 1995. We plan to measure high-energy γ-rays from the ^{12}C+^{27}Al reaction at 50 MeV carbon beam energy, in order to study properties of the hot rotating ^{39}K nucleus.

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Correlation Table for HECTOR-HELENA Multi–Detector Array

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The HECTOR-HELENA array is a multi-detector system for detecting high-energy gamma rays (up to 100 MeV). At present it is operating at the Niels Bohr Institute, Copenhagen, Denmark, and it is used mostly for hot Giant Dipole Resonance (GDR) experiments. It consists of 8 large-volume BaF_2-detectors to measure gamma-ray energy and 38 small BaF_2-crystals for angular momentum determination [1]. The HECTOR collaboration (NBI Copenhagen, INFN and University of Milan, INP Cracow) have decided to move this detection system to Legnaro (Italy) in 1996, where an experimental programme using beams from ALPI accelerator is planned. For implementation of the existing HECTOR system to particle detectors from Legnaro and for making it more flexible to carry out different types of experiments, a new mechanical support was needed. In particular, it was of great importance to be able to perform precise angular correlation experiments, in which the angle between the detectors and the beam can vary with good accuracy. Such a construction, consisting of correlation table and detector supports, is being built at INP, in collaboration with INFN and the University of Milan.
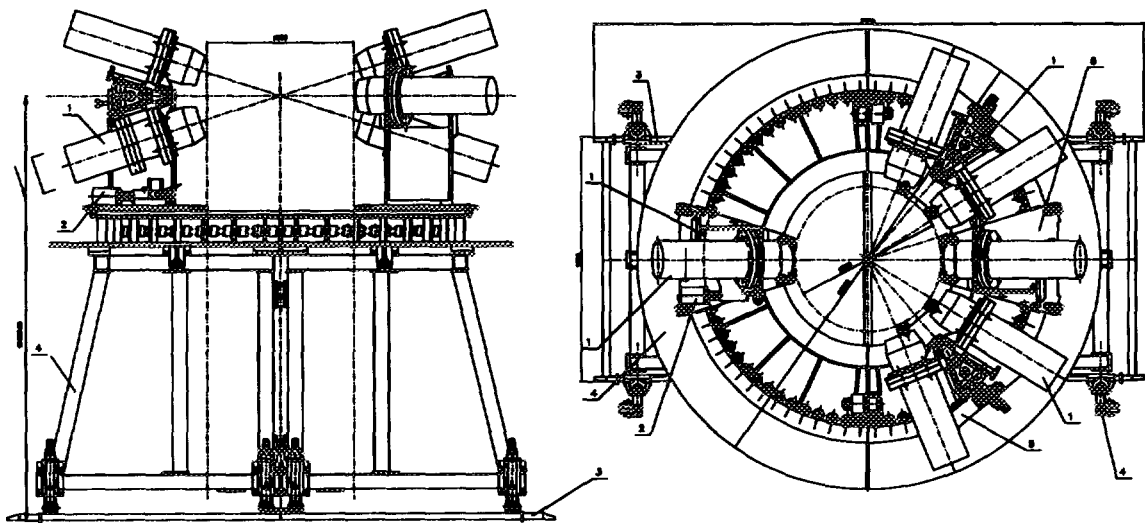
Fig. 1: A schematic view of the correlation table design for the HECTOR-HELENA array. In the left panel the table is seen from the front and in the right panel - from the top. The pair of BaF_2 detectors on the left and the opposite pair on the right are arranged in vertical geometry. The two other pairs on the right are twisted to horizontal geometry.

The correlation table for HECTOR-HELENA array has been designed, manufactured and assembled at the Department of Mechanical Construction of INP. It consists of two parts: a base frame and a table on which detector carrying carriages are arranged (see Fig. 1). The base frame is a light welded construction divided in two symmetrical parts to ensure proper access to the experimental space. In the experimental region, each part of the table can be moved independently, in the direction perpendicular to the table symmetry plane, by using rollers fastened to the base frame legs and running on rails supported on the floor. The base frame is also equipped with additional rubber wheels which enable the movement of the table beyond the experimental region. The roller units include mechanisms enabling the adjustment of height of the whole construction. Each part of the base frame is equipped with adjustable buffer to

ensure proper position in relation to the other part. End stops are also provided on the rails to define table position in relation to beam axis. The upper part of the correlation table is designed to support, move (rotate) and define the position of 8 large-volume BaF_2-detectors. This part, called the table, consists of two concentric collars. The internal collar is formed like a gear wheel, and the external one has angular scale marked at its circumference and holes for fixing detector carriages in required positions. The collars are divided in two symmetrical parts by the same symmetry plane which divides the base frame. There are 4 carriages, each of them carrying two BaF_2-detectors which are placed on the table and can be moved along the circumference of the external collar and fixed every 5 degrees. Three of the carriages are operated only manually and their position has to be pre-defined before running the experiment. The fourth carriage is driven by a DC motor and a gear-box in a mesh with the internal toothed collar mentioned. It can be remote controlled and it can change its position during the experiment. BaF_2-detectors are placed in tubular housings arranged radially, usually in a horizontal plane at the angle of 36 degrees to one an other. The housings can be moved along their axe by a distance of 140 mm, which allows approaching and withdrawing the detectors to and from the beam target. Each pair of the detectors can be twisted by 90 degrees from horizontal to vertical position. In spite of partitioning the table with the mentioned symmetry plane, all carriages carrying BaF_2-detectors can be moved along the whole circumference (360 degrees) of the table.

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Tests of FIDIAS, Fifteen-Parameter Data Acquisition System

J. Grębosz, W. Męczyński, and M. Ziębliński

FIDIAS, the fifteen-parameter data acquisition system [1] developed for in-beam gamma-spectroscopy measurements at the Cracow cyclotron, has been tested extensively. The tests were performed using events obtained from a multidetector setup for variuos γ-ray standard sources. The setup consisted of 3 NaI scintillator counters and 2 HPGe detectors. Data processing capabilities of FIDIAS are shown in Fig. 1. Fig. 1a shows the efficiency of the system (the ratio of the number of registered events to number of input events) versus trigger frequency. Fig. 1b shows the efficiency of the system versus the number of parameters handled.
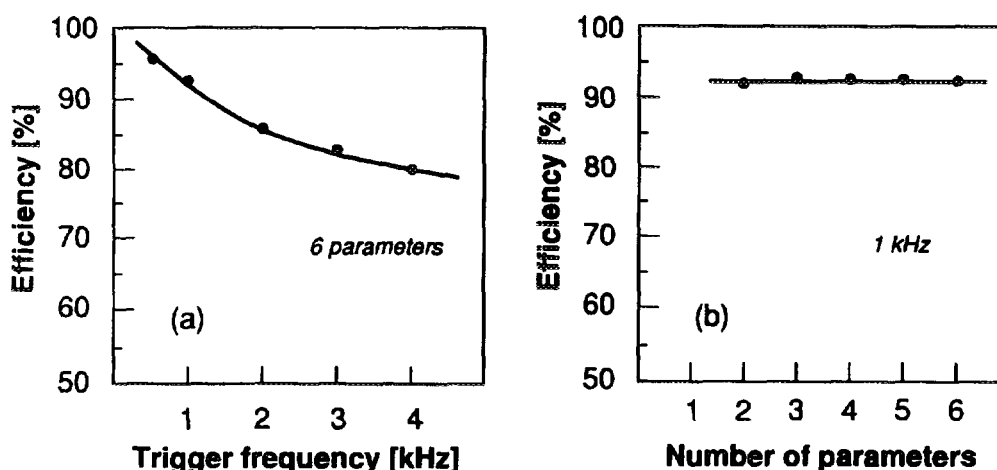

Fig. 1: Efficiency of the FIDIAS acquisition system versus trigger frequency (a) and the number of parameters handled (b).

The γ-γ coincidences were measured for ^{152}Eu standard γ-source. 2-fold Ge-Ge events were stored on magnetic tape. In order to sort (off-line) the data and create 2-dimensional matrices, the software running under the Ultrix operating system was written. Using this program the energy-energy and energy-time matrices were constructed. The evaluation of the data indicated a positive outcome of the tests, both for the acquisition system and for the sorting software.

Reference:

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Electric Quadrupole Interaction at ^{181}Ta Probes in Hexagonal TiNi$_3$-type Phases

B. Wodniecka, P. Wodniecki, M. Marszałek, and A.Z. Hrynkiewicz

In the course of systematic studies of quadrupole interactions in binary transition metal compounds, we report the results for hexagonal DO_{24} (space group D_{6h}^4, $P6_3$/mmc) TiNi$_3$-type intermetallic compounds of Zr and Ti with Pd. In these compounds the Zr and Ti atoms occupy $2(a)$-D_{3d} and $2(c)$-D_{3h} positions with axial symmetry and Pd atoms $6(g)$-C_{2h} and $6(h)$-C_{2v} positions without axial symmetry. Our former PAC studies of HfPd$_3$ are presented in [1]. The hafnium-doped ZrPd$_3$ and TiPd$_3$ samples were prepared by argon-arc melting, followed by a 4-day annealing at 1100 K in an evacuated and sealed quartz tube. The powder X-ray diffraction patterns confirmed the DO_{24} structure of the investigated compounds. The samples were neutron-irradiated in order to produce the ^{181}Hf (β^-) ^{181}Ta probes. To remove irradiation defects they were annealed for 2 days at 1000 K prior to measurements. The quadrupole interaction was measured by the time differential perturbed angular correlation method (TD-PAC). The PAC spectra were recorded in the temperature range of 45 K - 1100 K using a four BaF$_2$-detector setup.

The room-temperature spectra for ZrPd$_3$ and TiPd$_3$ samples are presented in Fig. 1 together with the Fourier transforms of the data. The samples show a nonrandom orientation of the crystallites.
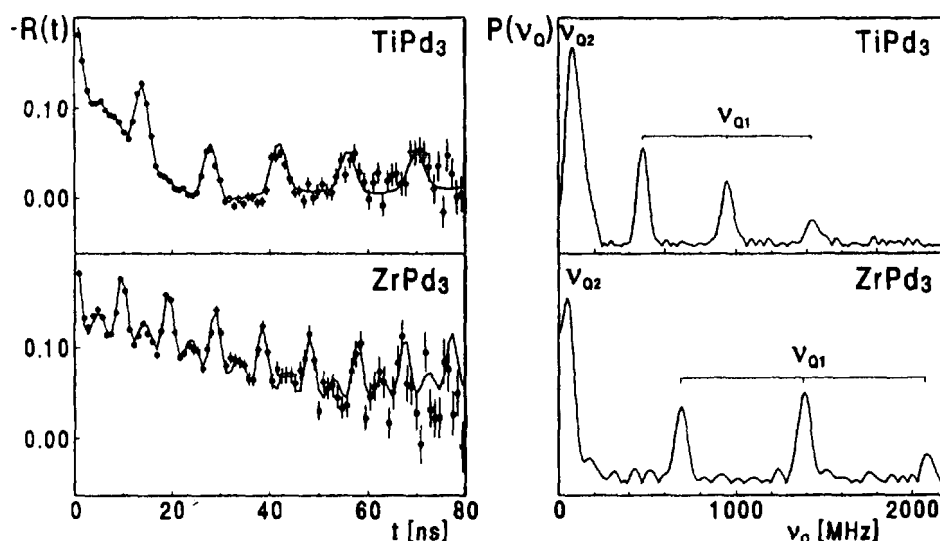

Fig. 1: Room temperature PAC spectra (with corresponding Fourier transforms) of ^{181}Ta in TiPd$_3$ and ZrPd$_3$ samples.

The experimental PAC spectra for each sample exhibit two equal fractions of probe atoms exposed to different axially-symmetric electric field gradients corresponding to quadrupole frequencies ν_{Q_i} and asymmetry parameters $\eta_i = 0$. These two fractions reflect the existence of two nonequivalent axially symmetric 2(a) and 2(c) probe sites in the DO_{24} structure of the investigated samples. The fitted quadrupole interaction parameters for $ZrPd_3$ and $TiPd_3$ compounds are collected in Table 1.

For both compounds the frequency distributions are very narrow, which indicates a well-defined nearest neighbourhood of the probe atoms. The substitution of Zr and Ti sites by probe atoms in $ZrPd_3$ and $TiPd_3$ compounds seems to be obvious.

The measured temperature dependence of quadrupole frequencies in $HfPd_3$ [1], $ZrPd_3$ and $TiPd_3$ samples is shown in Fig. 2.

Table 1: Quadrupole interaction parameters of ^{181}Ta in $ZrPd_3$ and $TiPd_3$.

compound	probe fraction	$\nu_Q(300\ K)$ [MHz]	η	V_{zz} [10^{17} V/cm^2]	attributed lattice site
$ZrPd_3$	0.52(1)	692(1)	0.0	$\pm 11.40(2)$	2(a)
	0.48(1)	29(1)	0.0	$\pm 0.47(2)$	2(c)
$TiPd_3$	0.45(1)	476(1)	0.0	$\pm 7.84(2)$	2(a)
	0.55(1)	55(2)	0.0	$\pm 0.90(3)$	2(c)

As it turned out, slope parameters for quadrupole frequencies attributed to different probe lattice locations are different. Similar temperature behaviour was observed also in some other intermetallic compounds [2, 3]. It should be noticed that temperature changes are relatively small for higher frequency component, especially in the case of the $HfPd_3$ compound [1].
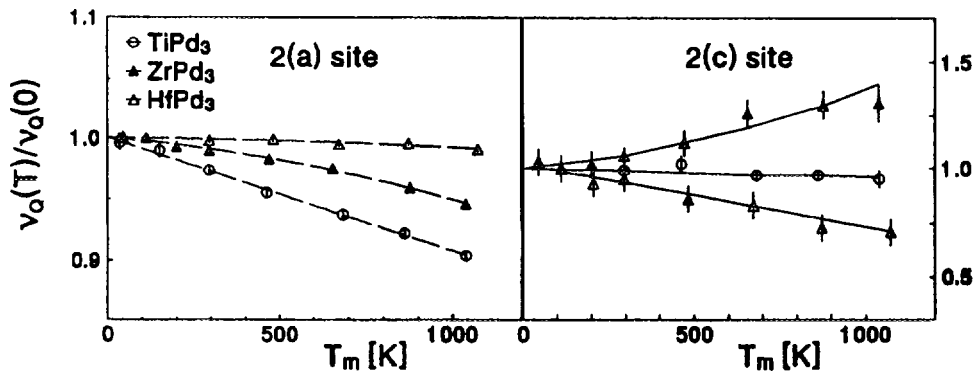
Fig. 2: Temperature dependence of quadrupole interaction frequencies measured at ^{181}Ta in $TiPd_3$, $ZrPd_3$ and $HfPd_3$ [1] samples.

The magnitude of the EFG temperature dependence is attributed to thermal vibrations of the probe and lattice atoms which tend to reduce the EFG at high temperatures. Thus, one would expect the temperature dependence of the EFG to be related to $(M\Theta_D^2)^{-1}$, M being the mean atomic mass and Θ_D-the Debye temperature of the crystal. The $(M\Theta_D^2)^{-1}$ values, estimated from the Lindemann equation (equal to 0.94×10^{-7} K^{-2}, 1.04×10^{-7} K^{-2} and 1.12×10^{-7} K^{-2} for $HfPd_3$, $ZrPd_3$ and $TiPd_3$ respectively) are very low which can explain the observed very weak temperature dependence of the EFG. The rising trend of temperature variation of the low quadrupole frequency in $ZrPd_3$ sample is very interesting. For metals with large densities of

states at the Fermi level, as in transition metals, the Fermi surface contribution to EFG seems to be decisive. Our results suggest that electrons at the Fermi surface, where thermally induced repopulation can occur, play a dominant role. Experiments concerning compounds of the same crystallographic structure with Pt and Ni are planned.

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PAC Studies of Aluminum Implanted with Noble Gases

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The formation of vacancy voids (cavities) in metals after implantation of noble gases has been investigated with the perturbed angular correlation (PAC) method for a few years [1-3]. The implanted rare-gas atoms preserve their chemically inert nature also in metallic environment. The repulsive interaction results in segregation of the rare-gas atoms into open volumes inside metal (vacancies, grain boundaries). It causes the appearance of rare-gas bubbles.
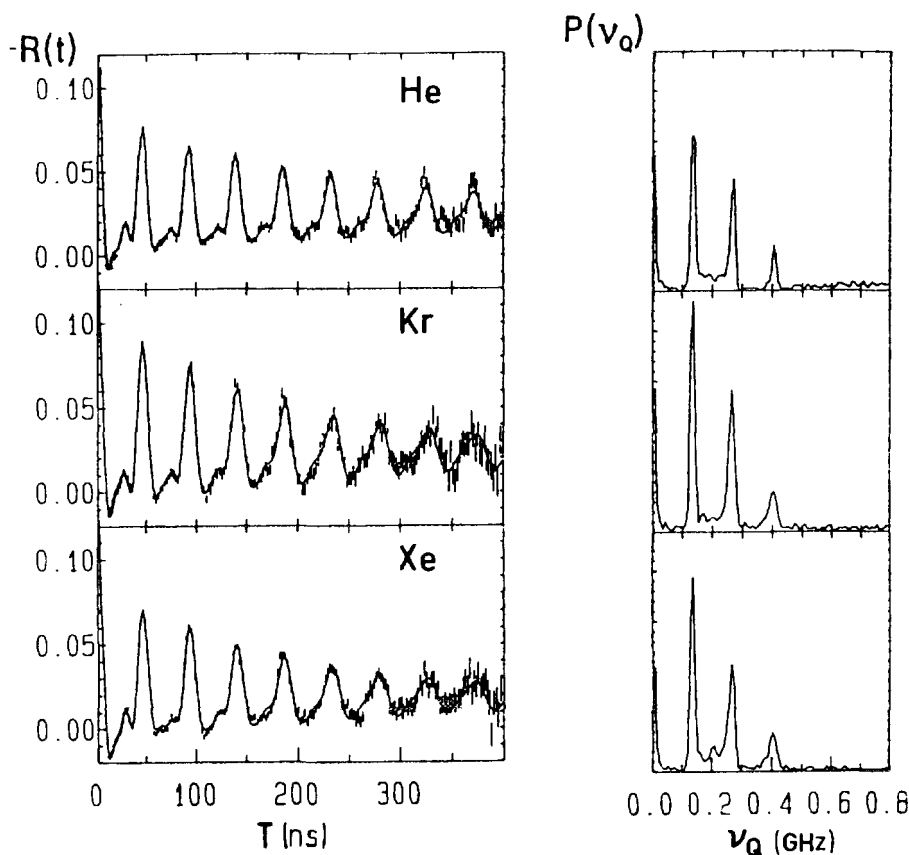
Fig. 1: PAC spectra with the Fourier transforms for ^{111}In-doped Al irradiated with He, Kr and Xe ions.

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Moreover, the presence of gas atoms in crystal lattice strongly affects and enhances the agglomeration of radiation-induced vacancies and the creation of three-dimentional clusters called cavities [4]. The results of PAC measurements have indicated that ^{111}In probes are situated on the inner surface of these vacancy clusters and are exposed to the electric field gradient (EFG) which does not depend on the implanted gas.

Our investigations, performed at II. Physikalisches Institut der Universität Göttingen, concerned the Al samples doped with ^{111}In probes and implanted with He, Kr and Xe ions. The implantation energies of ^{111}In and gas ions were chosen appropriately to create overlapping range profiles, and thus to achieve a large ^{111}In fraction placed in cavities. The PAC spectra (Fig.1), taken after annealing the samples at 200 °C for 30 min, demonstrate that 70 - 90 % of the probes feel the same EFG, characteristic for the cavity inner surface in aluminum.

The corresponding quadrupole frequencies ν_Q measured after additional annealing at 500 °C are identical for all implanted gases and equal to 135.7(1) MHz, 134.9(1) MHz and 136.0(1) MHz for krypton, helium and xenon respectively. These values agree with the frequency of 135.7 MHz measured by Schumacher and Vianden [3] after argon implantation into Al. Furthermore, it turned out that the sequence of ^{111}In and gas ion implantations has essential influence on the observed ^{111}In-cavity fraction. Gas implantation prior to radioactive probes increases this fraction, which indicates that the vacancies correlated with ^{111}In implantation play an important role in the cavity formation near the probe atoms.

In an additional RBS experiments we found that a decrease in ^{111}In-cavity fraction after annealings above 200 °C is not caused by the out-diffusion of implanted gas atoms but by the annihilation of vacancies in cavities. More detailed information on the thermal stability of the ^{111}In-cavity complexes will be published soon.

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PAC Experiment with [181]Ta Probe in Hf2Ag MoSi2-Type Intermetallic Compound

M. Marszalek, P. Wodniecki, B. Wodniecka, and A.Z. Hrynkiewicz

The PAC studies of Hf2Pd and Zr2Pd [1,2] started our systematic investigation of [181]Ta quadrupole interaction in MoSi2-type intermetallic phases (space group 4I/mmm). Although the phase diagram of Ag-Hf system is not known, the Hf2Ag compound was found to crystallize in the Cl1$_b$ MoSi2-type of structure [3]. In this compound the Hf atoms occupy the unique 4e (4mm) site and the Ag atoms - the 2a (4/mmm) lattice positions.

The sample was prepared by argon-arc melting at Centro Brasileiro de Pesquisas Físicas in Rio de Janeiro, while the neutron irradiation and all measurements were performed in Poland. The powder X-ray analysis showed the Cl1$_b$ structure of the main phase of the sample and an admixture of another unknown phase. The electric quadrupole interaction of [181]Ta probes in Hf2Ag was studied by the perturbed angular correlation method (PAC) in the temperature range of 24 K - 900 K using the 4 BaF2 detector setup.

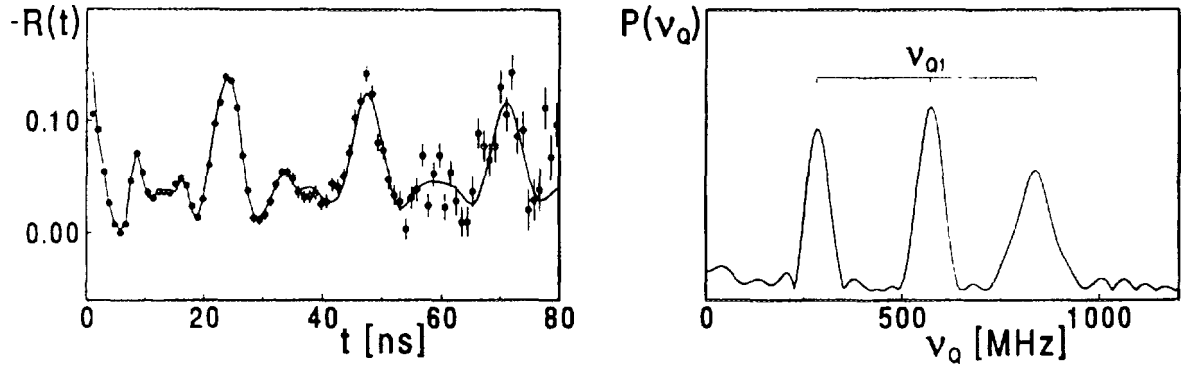The room-temperature PAC spectrum and its Fourier transform is presented in Fig. 1.

Fig. 1: Room-temperature PAC spectrum (with its Fourier transform) for ^{181}Ta in the Hf$_2$Ag sample.

The PAC pattern exhibits nonrandom orientation of crystallites in the sample. Fitting the perturbation factor to the experimental data yields two fractions of probe atoms. The 70 % fraction is characterized by an axially symmetric field gradient (EFG) corresponding to a well-defined quadrupole frequency $\nu_Q = 288(1)$ MHz and the asymmetry parameter $\eta = 0$. The remaining probe atoms interact with the EFG described by $\nu_Q = 823(8)$ MHz and $\eta = 0$. The lower frequency component was attributed to ^{181}Ta probes situated in $4(e)$ unique sites of the C11$_b$-type Hf$_2$Ag phase. The fact that the fraction of higher frequency is two-times smaller can be interpreted as being connected with the second additional phase of the sample detected by X-ray analysis, not excluding the HfAg phase.

The temperature dependence of the 288 MHz quadrupole frequency shown in Fig. 2 is very week with the slope of $0.4(1) \times 10^{-4}$ K^{-1}, i.e. about 10 times smaller than that observed in Hf$_2$Pd and Zr$_2$Pd MoSi$_2$-type compounds [1, 2]. Further experiments with ^{181}Ta and ^{111}Cd probes in Hf$_2$Ag and HfAg compounds are planned.
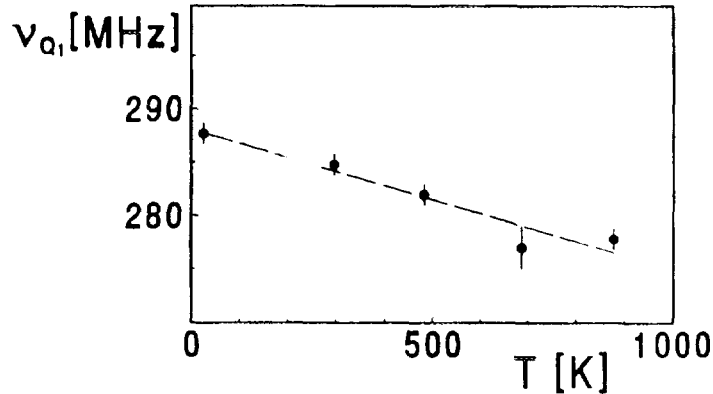
Fig. 2: Temperature dependence of quadrupole interaction frequency for ^{181}Ta in Hf$_2$Ag sample.

References:

1. B. Wodniecka, P. Wodniecki, and A.Z. Hrynkiewicz, *INP Annual Report* 1993, p. 56,
2. B. Wodniecka, M. Marszalek, P. Wodniecki, H. Saitovitch, P.R.J. da Silva, and A.Z. Hrynkiewicz, *J. of Alloys and Compounds*, (1995), in press.

Trapping Implantation–Induced Vacancies by ^{111}In Atoms in Palladium

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Hyperfine interaction methods have proven to be very useful for studying point defects in metals because they probe the formation of impurity-point defect complexes on a microscopic scale. In the implantation process an incident ion produces a displacement cascade with a number of vacant lattice sites and an equal number of interstitial atoms. It is found that in the core of the cascade (where the implanted ion finally stops) a high concentration of vacancies occurs. These can be trapped by the impurity atom.

We report on PAC studies of ^{111}In-monovacancy pairs created in palladium after ^{111}In implantation. In the experiments performed at II. Physikalisches Institut der Universität Göttingen the 400 keV ^{111}In ions from IONAS ion implanter were introduced into the Pd foil at room temperature. Fig.1 shows the PAC spectra obtained for the "as implanted" sample (upper curve) and after annealing at 200 °C for 30 min. The unique quadrupole frequency of 87.0 (2.0) MHz observed directly after implantation with the fraction of 8(1) % is attributed to the vacancy-^{111}Cd pairs (^{111}Cd is the daughter of ^{111}In in radioactive decay). This complex dissappears after annealing at 200 °C due to the recombination of the Frenkel pairs.
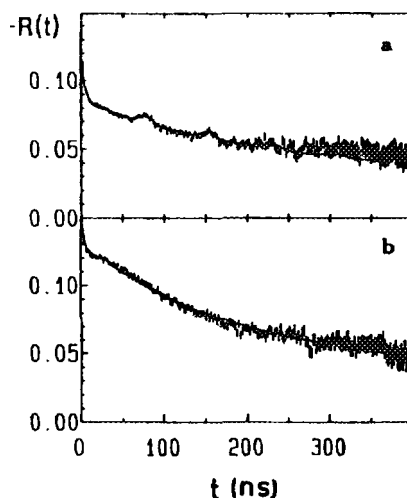

Fig. 1: PAC spectra for ^{111}In-implanted Pd foil directly after implantation (a) and after additional annealing at 200 °C (b).

Our results agree perfectly with the data reported by R. Butt et al. [1] who showed that the vacancies were created by the ^{111}Pd atoms recoiled after (n,γ) reaction. Their PAC measurements on ^{111}Cd probes obtained in ^{111}Pd $\longrightarrow$ ^{111}Ag $\longrightarrow$ ^{111}Cd β-decays yielded the quadrupole frequency corresponding to the monovacancy-^{111}Cd complexes of 86.5 (1.5) MHz, which dissappear at 157 °C.

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1. R. Butt, H. Haas, T. Butz, W. Mansel, and A. Vasquez, *Phys. Lett.* **64A** (1977) 309.

Local Atomic Environment in C11$_b$ Intermetallic Compounds as Characterized by PAC Method

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We report the studies on the nearest-neighbourhood characterization in C11$_b$ intermetallic compounds by perturbed angular correlation (PAC) method. The method was applied to study electric field gradient (EFG) on the ^{181}Ta probe nuclei in tetragonal Hf$_2$Au, Zr$_2$Ag and Zr$_2$Au intermetallic compounds.

The samples were prepared by argon-arc melting of stoichiometric amounts of elements together with neutron-irradiated hafnium (less than 2 at. %), containing ^{181}Ta probe atoms. Next they were annealed at 1100 K in evacuated and sealed quartz tubes. The powder X-ray diffraction patterns confirmed the C11$_b$ structure of the investigated compounds.

For measurements of the perturbed angular correlation of the 133 to 482 keV $\gamma - \gamma$ cascade of ^{181}Ta, a conventional four-detector system of slow-fast coincidence type, providing time resolution of 1.8 ns (FWHM), was used. PAC spectra were recorded in temperature range of 77 K - 1100 K. Room temperature spectra for investigated compounds are shown in Fig.1.

Fig. 1. Room temperature PAC spectra for C11$_b$ compounds.

For each compound one electric field gradient V$_{zz}$ with asymmetry parameter $\eta = 0$ was observed, corresponding to the 4e crystallographic position of probe atoms in the C11$_b$ structure of the investigated samples. Electric field gradient values and asymmetry parameters at room temperature for the studied compounds together with the EFG value for Hf$_2$Ag [1] are collected in Table 1 .
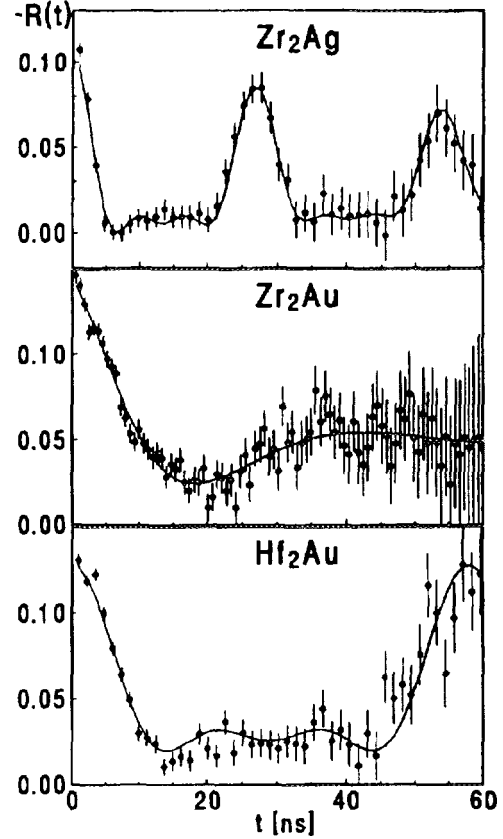
Table 1: Electric field gradients at ^{181}Ta in C11$_b$ compounds.

compound	V$_{zz}$(300 K) [10^{17} V/cm^2]	η	lattice site
Hf$_2$Ag [1]	5.05(3)	0.0	4(e)
Hf$_2$Au	1.91(9)	0.0	4(e)
Zr$_2$Ag	4.41(2)	0.0	4(e)
Zr$_2$Au	1.37(9)	0.0	4(e)

It can be noticed that the magnitude of electric field gradient for compounds containing silver is much higher than for those containing gold. The electric field gradient temperature dependence measured for Hf$_2$Au, Zr$_2$Au and Zr$_2$Ag compounds was very weak as it was already observed in other intermetallic compounds [2]. However, for Zr$_2$Ag compound EFG decreases

slightly with temperature, whereas for both remaining compounds it shows a raising trend. We are not able to explain the reasons for this appearance of the temperature dependence of EFG.

Acknowledgement:

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Determination of Phase Decomposition in Zr$_2$Fe Compound Studied by PAC

45

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The phase diagram of the zirconium-iron system has been studied over many years. However, there remains still some uncertainity about the compounds present in this system and the temperature region of their existence. To investigate the stability of Zr$_2$Fe phase we performed perturbed angular correlation (PAC) measurements. Samples of Zr$_2$Fe were prepared by argon-arc melting of stoichiometric amounts of component elements with a small addition of hafnium (less than 2 at.%), containing radioactive ^{181}Ta probe atoms. It is known [1] that Zr$_2$Fe is a high-temperature phase, existing between 1050 K and 1250 K. Because of peritectoid decomposition of this phase at 1250 K long annealing (480 hours) at 1173 K was performed and the samples were then quenched to the liquid nitrogen temperature as quickly as possible. Next, the PAC spectra were measured at room temperature and the electric field gradient (EFG) related to Zr$_2$Fe phase [2] was observed. Prepared samples were treated in two different ways. One of them, after measurement at room temperature, was heated successively in steps of the order of 100 K/day and PAC spectra were taken at each temperature up to 1273 K.
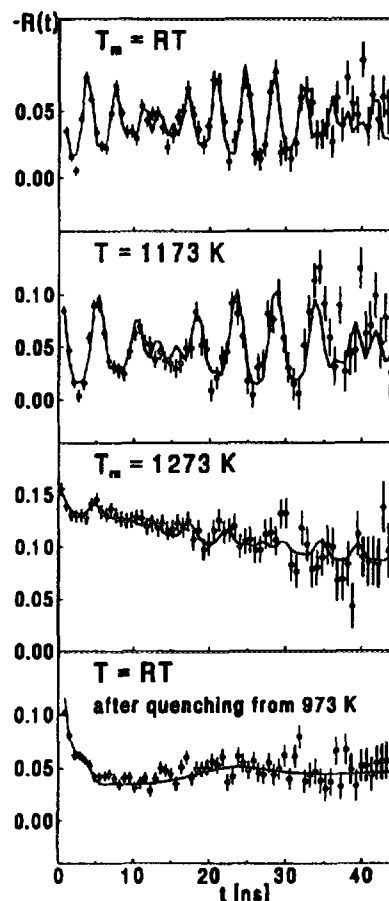

Fig.1. PAC spectra for Zr$_2$Fe compound taken at different stages of sample annealing.

Surprisingly, PAC spectra showed that Zr$_2$Fe phase decomposes only at 1273 K, but even then there existed a small fraction (about 10%) of ^{181}Ta probes related to Zr$_2$Fe phase.

The remaining 90% of probe atoms showed broad distribution of electric field gradient around the 0 value, which can be related to the presence of cubic $ZrFe_2$ phase, according to the assumptions of the phase diagram.

The other sample after the measurement at room temperature was annealed for 24 hours at 973 K (i.e. below the temperature known from the phase diagram [1]), and then rapidly cooled to liquid nitrogen temperature. Next, PAC measurement at room temperature was performed. The spectrum showed a very small fraction of probe atoms in Zr_2Fe compound and a broad distribution of electric field gradient, confirming the decomposition of Zr_2Fe phase.

These results confirm the temperature range of Zr_2Fe existence, but at the same time new questions arise as to the thermodynamics of the decomposition process and phase stability conditions.

Acknowledgement:

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Positron Annihilation in Carbon Fibers

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Preliminary results on positron annihilation in carbon fibers produced from polyacrylonitrile precursor are presented. Systematic studies of various kinds of carbon materials, e.g. highly oriented pyrolytic graphite (HOPG), isotropic fine-grained nuclear graphite (AXF-5Q1, IG- 110) and non-graphitizable carbon called glassy carbon (GC-10, 20, 30) using the angular correlation of annihilation radiation and positron lifetime spectroscopy have been performed by Hasegawa et al. [1]. We intend to develop these studies for another type of carbon material, namely carbon fibers which are intensively investigated by various methods since they are used in advanced technology materials [2]. Numerous types of carbon fibers are commercially available for different applications.
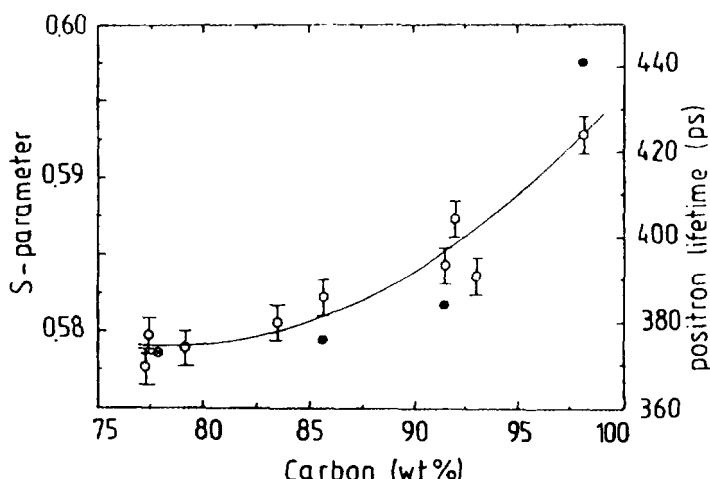

Fig. 1: Dependences of the S-parameter (left axis and open circles) and positron lifetime (right axis and closed circles) vs carbon content for investigated carbon fibers. (Solid line presents a parabolic line fitted to the data points).

In order to characterize the fibers, X-ray diffraction, electrical resistivity measurement and elemental analysis have been used. S-parameter measurements were performed using the HPGe

detector ($1.66 keV$ resolution at $511 keV$). The S-parameter is defined as the ratio of the area under fixed central channels to the total area of the annihilation line after background correction. The parameter defined in that way is extremely sensitive to the low-momentum electrons that exist in open volume defects like vacancies, their clusters and pores. Lifetime spectra were registered by means of the fast-slow spectrometer with time resolution of ca. FWHM=$270 ps$. Only one component in positron lifetime spectra ranging from $373 \pm 1 ps$ to $441 \pm 1 ps$ has been found. It was observed that the positron lifetime and the S-parameter increase with the temperature of heat treatment of carbon fibers and with the amount of carbon (Fig. 1). Correlation of the Doppler broadening of annihilation line and positron lifetime indicates a possibility of positron trapping in pores existing in the fibers.

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Mössbauer Study of Magnetic Ordering in Intermediate Valent $EuCu_{2-x}Ag_xSi_2$ Phases

4 7

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Substitutional single-phase solid solutions in the $EuCu_{2-x}Ag_xSi_2$ system are formed for the whole range of $0 < x < 2$ [1]. With increasing silver concentration the time-averaged of 4f-electronic configuration europium is driven closer toward the divalent state (Fig. 1) with magnetic order occurring at low temperatures [2].

The effects of the local environment on the intermediate valence behaviour of europium are visible but not as pronounced as in $EuCu_2Si_2$ modified with iron and cobalt substitutions [3]. The influence of the near-neighbourhood on the europium ion causes the rearrangement of the compound conduction band in a self-consistent way [4]. In consequence, the ^{151}Eu Mössbauer absorption spectra of samples of intermediate composition at room temperature may be analyzed in terms of two components with average position varying along the series of phases (Fig. 1). The primary objective of the present work is to acquire microscopic insight into magnetic ordering occurring in silver-substituted $EuCu_2Si_2$ compounds.
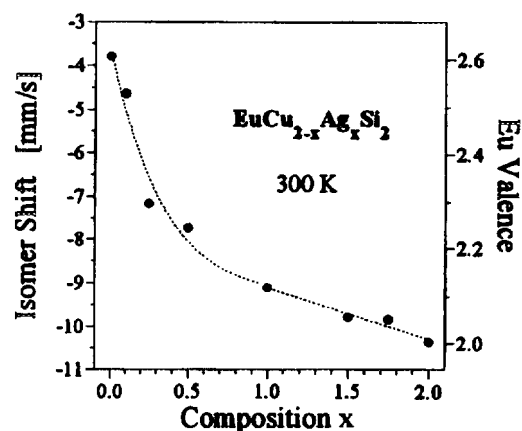

Fig. 1. Mean isomer shift of the Eu^{151} Mössbauer spectra and the europium time-averaged valence state plotted versus silver content in $EuCu_{2-x}Ag_xSi_2$ samples.

From the microscopic point of view, the process of losing the magnetic order with increasing temperature proceeds by gradual shrinking of magnetic regions rather than only by degradation of moments spatial correlations. It might be argued that distinguishing between the two

types of regions (magnetically ordered and disordered) is a matter of relation of their respective correlation times to a characteristic time set by the Mössbauer method (ME). The latter quantity is determined by the period of Larmor precession of nuclear moment in a local field, and is of the order of $\nu_L^{-1} = 10^{-8}$ s. However, the temperature variation of the hyperfine field indicates that the system remains in the fast relaxation limit, i.e. for both types of domains the moment fluctuation rate is definitely greater than ν_L. In general, time-dependent aspects of these phenomena are of importance as may be observed with the ^{151}Eu ME spectroscopy in the demagnetization process of the $EuCu_{0.5}Ag_{1.5}Si_2$ sample (to be discussed elsewhere). It has to be stressed that when defining critical magnetic temperature as the point of disappearance of any hyperfine split components in the ME spectrum, this parameter does not substantially differ between the samples of the investigated series of phases and remains in the range of about 9 to 10 K. However, species of low silver content (e.g. $EuCu_{1.9}Ag_{0.1}Si_2$) simply do not have a magnetically ordered fraction down to 1.8 K.
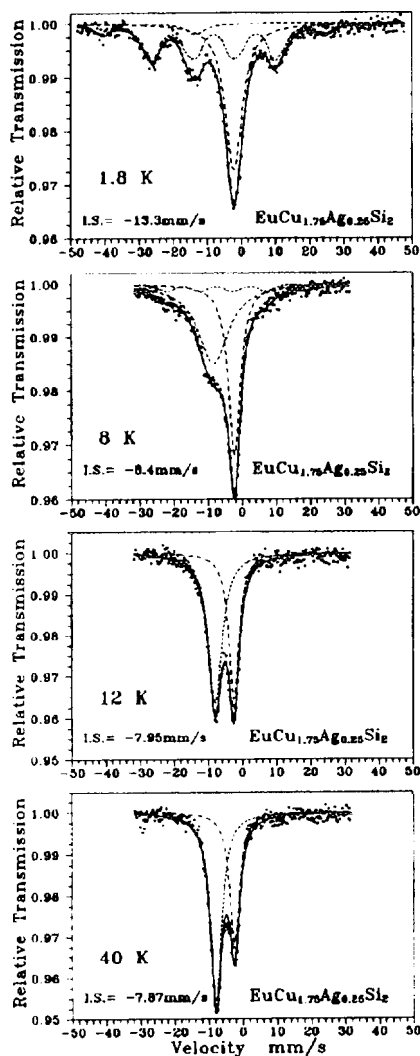
In silver-richer phases, where it is present, extinction of the magnetic phase takes place before the hyperfine field disappears. In order to determine the temperature of the onset of the magnetic order, γ-ray transmission through the $EuCu_{1.75}Ag_{0.25}Si_2$ absorber has been recorded as a function of temperature (Fig.2). Progressive development of the magnetic state results in decreasing intensity of the single unsplit line and increasing, at its expense, of a hyperfine split component upon temperature lowering. For the sample of $x = 1.5$, magnetic ordering extends over the whole volume of the sample, whereas the saturation hyperfine field is distinctly smaller than that for low silver content samples, e.g. with $x = 0.25$. Concluding, the magnetization process in $EuCu_{2-x}Ag_xSi_2$ phases develops via growth and percolation between magnetically-ordered volumes.

Fig. 2. Disappearance of the magnetic ordering in $EuCu_{1.75}Ag_{0.25}Si_2$ sample proceeds with increasing temperature via successive vanishing of the magnetically-ordered domains.

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Compton Profile Studies of Ni–Cu Single Crystals

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Compton profile measurements with using the of 662 keV ^{137}Cs source were performed for a single crystal of the 0.76Ni–0.24Cu alloy in the spectrometer at Warsaw University Branch in Białystok . The profiles were obtained for the three crystallographic directions [100], [110] and [111] under experimental conditions essentially described in [1] but with higher precision (statistical errors less than 0.25%). The raw experimental data collected for the above specimens were the subject to the usual corrections; for the background, detector response function, detector efficiency, the sample absorption, Compton scattering cross section and the multiple scattering in the sample. In the experiment particular attention was given to the existence of some additional background observed earlier [1, 2] and postulated by the authors to be the bremsstrahlung radiation from photoelectrons excited in the sample.
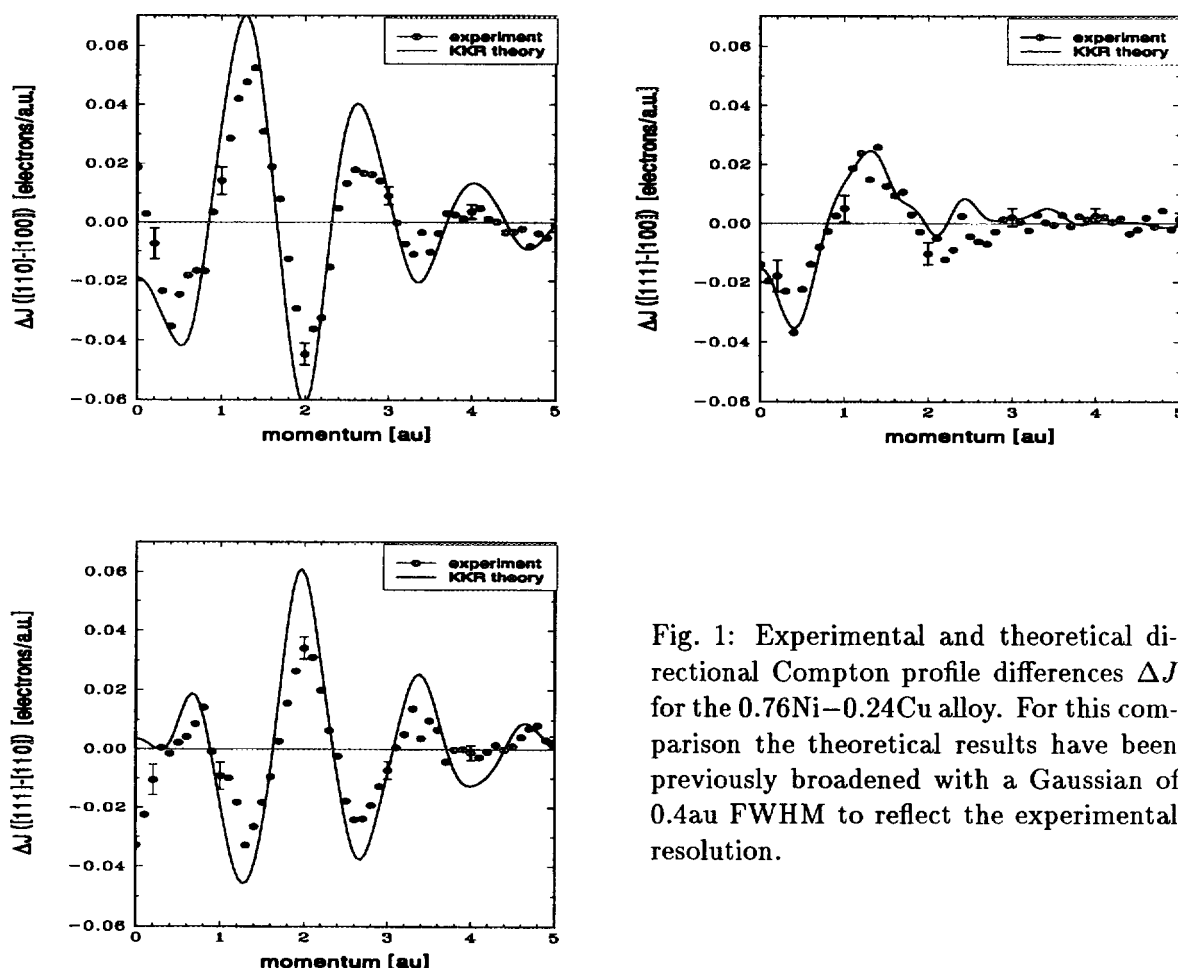

Fig. 1: Experimental and theoretical directional Compton profile differences ΔJ for the 0.76Ni–0.24Cu alloy. For this comparison the theoretical results have been previously broadened with a Gaussian of 0.4au FWHM to reflect the experimental resolution.

This backround is undetectable with the sample removed from the scattering chamber, thus its intensities are estimated from the difference between high-energy tails of experimental and theoretical profiles with the latter beeing the free-atom profile [3]. All profiles were normalised to 13.119 electrons from 0 to 10au.

Similar measurements have already been made for Ag and successfully compared with the relativistic Korringa-Kohn-Rostoker band structure calculations [1]. The study of the Ni-Cu alloy was motivated by the development of the theory of electronic structure for disordered alloys. Using the KKR-CPA formalism, the Compton profiles were calculated for a number of alloy compositions and reported in [3]. The present experimental results and the calculated profiles are compared in Fig. 1. The figure shows differences between the profiles measured in different crystallographic directions, thus revealing anisotropy of the Compton profile. The predicted anisotropy reproduces this profile not only with respect to the shape, but also to the amplitude. Good overall agreement between theory and experiment is claimed for momentum above 1au. The discrepancy in lower region is the subject of further analysis.

The present experiment proved that alloying and disorder in Ni-Cu can be described by the KKR-CPA theory equally well as pure metals. For a more detailed discussion on the agreement between theory and experiment, see the paper on the Compton profile of silver [1].

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Investigation of Trace Elements in Cancer Kidney Tissues by SRIXE and PIXE

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In November 1994 we performed some preliminary studies on cancer kidney tissues. The objective of the measurements was to find a difference in trace element concentrations between normal and cancerous kidney tissue. All targets were prepared as pellets of more or less the same weight and thickness. Kidney samples were obtained during surgical operations done at the Clinic of Urology in Cracow. All kidneys were subject to removal due to cancer disease. Samples for analysis were taken from the cancerous part of the kidney and the non-cancerous one. All samples were analyzed by means of SRIXE (Synchrotron Radiation Induced X-ray Emission) at the NSLS (National Synchrotron Light Source) in BNL (Brookhaven National Laboratory) and by means of PIXE, at INP (Institute of Nuclear Physics) in Cracow.

According to physicians' investigations, cadmium plays a role in oxidation process during tumor growth. Other elements, i.e. selenium, play here a significant role, too. The results obtained so far seem to be interesting and may confirm our hypothesis about the cancer process in the kidney. The hypothesis will be the subject of a further study. The applied analytical technique enables us to analyze even a small region of samples with high precision.

The elemental analyses by means of SRIXE and PIXE allow us to determine trace element concentrations with high accuracy. The concentration of trace elements varies with regard to sample type. Synchrotron radiation has many advantages that make SRIXE measurements very attractive. It gives excellent results in microanalysis. Along with the Trace Element Analysis biochemical studies have been performed and the data are being evaluated.

The same set of samples was analyzed with the PIXE technique at the Institute of Nuclear Physics in Cracow in order to perform primary measurements and to compare sensitivity of those two techniques. Beam energy was 2.6 MeV and its size was about 3 mm in diameter.

The PIXE technique is quite sufficient for analysis of elements at increased concentration level. Table 1 sumarizes primary results. Since the project is in progress, final results may differ from those presented in the table.

Table 1: Trace element concentrations in cancerous and non-cancerous part of kidneys measured by means of SRIXE and PIXE. (Concentrations are given in ppm)

Sample	S	Cl	K	Ca	Fe	Cu	Zn	Se	Sr	Cd
SRIXE measurements										
cancerous	1030	400	2940	1220	210	5.4	52	4.2	2.2	16
mean error	77	27	163	205	27	0.6	4	0.6	0.3	3.5
non-cancerous	895	450	4960	820	100	10	185	5.9	3.1	180
mean error	100	50	1240	220	18	1.8	35	1.1	0.9	45
PIXE measurements										
cancerous	–	–	1300	610	260	8.1	68	1.1	1.3	53
mean error	–	–	480	240	100	3.0	22	0.4	0.3	32
non-cancerous	–	–	2210	980	230	6.3	112	1.5	1.0	110
mean error	–	–	430	440	70	2.0	46	0.5	0.2	45

Lead Concentration in Renal Stones

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Urolithiasis is a disease that has been studied for many years and the ethiopatogenesis of the stone formation is still not very well known. Since trace elements interact with organs and play a significant role in life processes, it is important to know their concentration level in analyzed materials. Trace elements, especially toxic ones, may cause some diseases. The existence of toxic elements in organism may be caused either by environmental pollution or by chemical interactions between the other elements that exist in the organism. In this study the authors show correlation between the renal stone phases and lead concentration.

The samples were obtained from 250 patients aged 20 - 70 years. The calculi were removed from kidneys during surgical operations done at the Urological Clinic in Cracow. All information about patients' professions and living conditions was filed prior to the operation. The stones

were analyzed with respect to of chemical (phase determination) and elemental composition. For this study different analytical methods have been appplied. Phase determination was established by Fourier Transform InfraRed Spectroscopy (FTIR) at the Regional Laboratory of the Jagellonian University, Cracow. Lead concentration was analyzed by both the Proton Induced X-ray Emission (PIXE) technique performed at the Institute of Nuclear Physics, Cracow, and by the Atomic Emission Spectrography (AES) performed at the Department of Chemistry of the Jagellonian University. The last two techniques were chosen to confirm the results.

All samples for both phase and lead determination were prepared from the same stone material.

The Bio-Rad Spectrometer was applied for analysis of phase composition of the stones in the wavelengths region from 400 to 4000 cm^{-1} with a 2 cm^{-1} resolution and 200 scans.

The PIXE method, lead concentration was analyzed with 2.5 MeV proton beam collimated down to 1 mm^2. The spectra were collected for 10 min each and detected with Si(Li) detector with energy resolution of 200 eV.

The AES method, concentration of lead was determined using PGS2 spectrograph. Each sample portion was excited from anode by direct-current arc (10A, 300V). The spectra were recorded on Wu-1 (ORWO) photographic plates and then blackenings of line (Pb 283.29 nm) were measured with the microphotometer MD100.

By means of FTIR analysis, the calculi were divided into 6 different groups according to their phase composition:

group 1 – magnesium amonium phosphate hexahydrate [$MgNH_4PO_4*6H_2O$],

group 2 – calcium phosphates [$Ca(PO_4)_3(OH)$, $Ca_3(PO_4)_2$],

group 3 – mixture of phosphates and oxalates,

group 4 – calcium oxalate monohydrate and/or dihydrate [$CaC_2O_4*nH_2O$],

group 5 – mixture of oxalates and uric acid, and

group 6 – pure uric acid [$C_5N_4O_3H_4$].

Table 1: Pb concentration in different kind of kidney stones.
(Concentrations and errors are given in ppm)

Group No	Percentage of population	Pb conc.	Mean error	Group No	Low Pb population (%)	Low Pb conc.	Low Pb error
1	10	7.3	0.9	1	11	7.3	0.9
2	6	42.5	10.5	2	7	20.5	4.2
3	40	37.9	4.6	3	34	21.0	1.6
4	23	17.2	2.5	4	24	12.8	1.4
5	7	7.0	1.3	5	8	7.1	1.3
6	14	2.2	0.6	6	16	2.2	0.6

Lead concentration for each group is shown in Table 1 which also shows mean Pb concentrations called "Low Pb conc." calculated for groups with patients who had been exposed to environmental pollution. It is shown that Pb concentration strongly depends on chemical composition of the stones. Significance of mean differences between groups was tested with the Student T-test with a significance level of $\alpha = 0.05$. The test confirmed important differences between all mean values exept for the differences between mean values calculated for the 3rd and 4th group of stones.

Local Lead Pollution in the Antarctic

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Man has been active in Antarctic for many years. Antarctic bases, transport, power stations obviously introduce pollution to that otherwise clean area. In order to protect one of the last clean bastions in the world, the scientific Environmental Monitoring System in Antarctica has to be organized on a broad scale.

Among the great variety of organisms which are good indicators of environmental conditions, lichens have been found to be particularly sensitive to anthropogenic changes of the environment. They have avery high capacity to accumulate many airborne inorganic ions because they draw nutrients almost entirely from the air by the whole surface of their thalli. The ability of lichens to cumulate pollutants and the application of multi-elemental analytical capacity of PIXE/PIGE make these methods powerful tools for comparative studies of air pollution and its time dependence.

Such monitoring is proposed by the authors and the study on trace element analysis has been carried out since 1988. The first results were published in 1990.

Table 1: Pb contents (ppm) in lichens sampled in 1988.

Sampling place	Usnea antarctica	Usnea aurantiaco-atra
Livingston Island		
South Bay region		
near Antarctic station	11.0	12.9 ; 14.6
King George Island		
Maxwell Bay region		
near Antarctic station	–	13.0 ; 24.0
near road to airport	–	33.0 ; 51.0
near airport	–	19.0 ; 44.0
King George Island		
Admiralty Bay region		
Antarctic station	13.0 ; 9.5	–
Jersak Hills	–	5.0

Here, we would like to present results obtained in an experiment of transplantation of lichens from clean sites and polluted locations close to the base. Material was sampled after 1, 3, 6, and 12 months. The long-term integrating ability of lichens is clearly visible. Dangerous Pb concentrations of up to 90 ppm were found close to the road to the power station.

The measurements were performed at the Institute of Nuclear Physics in Cracow using the Proton Induced X-ray Emission (PIXE) technique. The proton beam of energy 2.5 MeV was obtained from the Van de Graaff accelerator. On target beam current of about 5 - 10 μA and beam of about 1 - 5 mm in diameter were applied for this study.

Table 2: Pb contents (ppm) in lichens sampled in 1990.

Sampling place	Usnea antarctica	Usnea aurantiaco-atra
King George Island		
Maxwell Bay region		
near Antarctic station	–	8.4 ; 6.0 ; 7.8
near road to airport	–	44.0
King George Island		
Admiralty Bay region		
Antarctic station	4.1	–
Ubocz hill	0.0 ; 0.5	–
Hala hill	3.7 ; 3.0	–
Admiralty Bay region		
Keller Peninsula		
near Antarctic station	4.3	–
King George Bay region	1.8	3.7

Table 3: Pb contents (ppm) in Usnea antarctica close to the road to the power station. Samples collected in 1990, 3 and 12 months after transplantation of lichens, and samples collected in 1992, 1, 3, and 6 months after transplantation of lichens.

Distance from power station:	Exposition time (months)				
	0	1	3	6	12
1990					
1 m	0.2	–	4.0 ; 5.8	–	47.0 ; 90.0
4 m	0.2	–	2.6 ; 7.2	–	14.0 ; 26.0
16 m	0.2	–	0.6	–	4.8
1992					
1 m	3.2	12.0	60.0	–	.
4 m	3.2	4.7	12.6	102.0	..
16 m	3.2	3.3	–	10.8	–

These results prove the need for continuous environment pollution monitoring of Antarctica. The PIXE/PIGE technique is very powerful, and thanks to a small amount of samples required it is very valuable for this type of research.

First Measurements Using Scanning Force Microscope (SFM)

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The SFM instrument was built at the Institute of Nuclear Physics of the University of Münster and then successfully installed in Cracow. Detailed description of the instrument construction is presented in [1, 2]. The first experiments were performed using a callibration standard. Dimensional callibration of the instrument was performed using a standard delivered by Nanosensors GmbH. The standard was a silicon disk with a small (500 μm × 500 μm) area covered by a regular pattern of inverted pyramides. The depth of the pyramides was 70 nm, the

period of the pattern-200 nm, and the accuracy of manufacturing was ±5 nm. Force calibration is the result of multiplication of the cantilever bending magnitude and the cantilever force constant. For the measurements a cantilever with 0.1 N/m spring constant was used, thus 100 nm deflection corresponds to a force of 10^{-8} N.
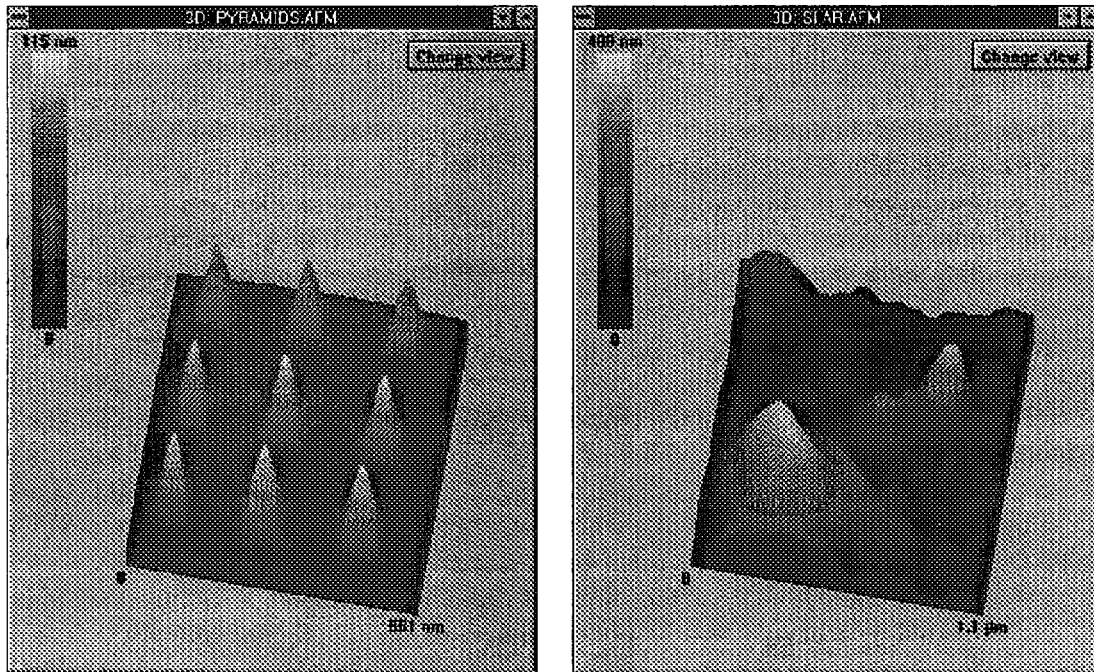

Figure 1: Left: 3D image of the inverted pyramides standard. Right: 3D image of the topography of the wear track region of Ar-implanted Si crystal. Both images show normal force scans with the resolution of 256 × 256 pixels. No corrections have been made. Data were smoothed out using a 5 × 5 median filter.

The actual height resolution of SFM was estimated to be below 10 nm. Up to the end of 1994 the atomic resolution using our SFM was still not achieved. In the nearest future we anticipate application of the modified current-to-voltage converters and amplifiers, which should provide a much higher signal-to-noise ratio, and therefore a better resolution of the SFM.

The instrument was subsequently used for studies of microtribological properties of implanted silicon crystals, where the implantation process introduced significant changes in friction and wear behaviour [3]. SFM measurements show that the average size of the wear particles present in the wear track of Ar-implanted samples is by an order of magnitude smaller than in the case of non-implanted crystals, despite the total removal of implanted ions. This fact supports a hypothesis that the defect structure formed by implantation migrates into the bulk during wear process.

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Ion-Beam-Assisted Deposition of Carbon Coatings by Means of Dual Beam Device

B. Rajchel, M. Drwięga, E. Lipińska, and A. Sellmann

Ion Beam Assisted Deposition (IBAD) is the most useful technique for growing adherent coatings with special physical, chemical, mechanical, optical, or electrical properties on surfaces of metals, ceramics, composites and other material. The two-beam-line ion implanter of the Institute of Nuclear Physics in Cracow is an excellent tool for materials modification by means of ion engineering methods, especially for the ion-beam-assisted deposition technique[1, 2]. At the ion implantation laboratory, coatings are prepared by the ion beam sputter deposition of atoms onto a modified substrate and the simultaneous ion bombardment of the created film by means of the mass-analyzed second ion beam. Careful choice and measurements of the parameters of the two ion beams make control of the IBAD process possible (e.g. the ratio of number of bombarding ions and number of sputter deposited atoms, energy of ions, vacuum conditions etc.). The IBAD method is applied to prepare carbon layers (so-called DLC, diamond - like coating or a-C:H, hard amorphous carbon coating) on substrates of special Co-Ni-Cr-Mo alloys (PROTASUL-10 and ISODUR) used for endoprostheses. So far, a preliminary series of < 111 > Si samples coated with carbon films of different thickness, structure and impurity content was prepared by a proper selection of conditions of the IBAD processes (Si is favourable as a substrate for preparatory measurements). Various research methods are applied to find out the features of ion-beam-assisted deposited coatings. Electron microscopy methods were used to find morphology (granularity, texture etc.) of these layers. In Fig. 1 and 2 microphotographs of the layers obtained by means of a scanning electron microscope are shown.
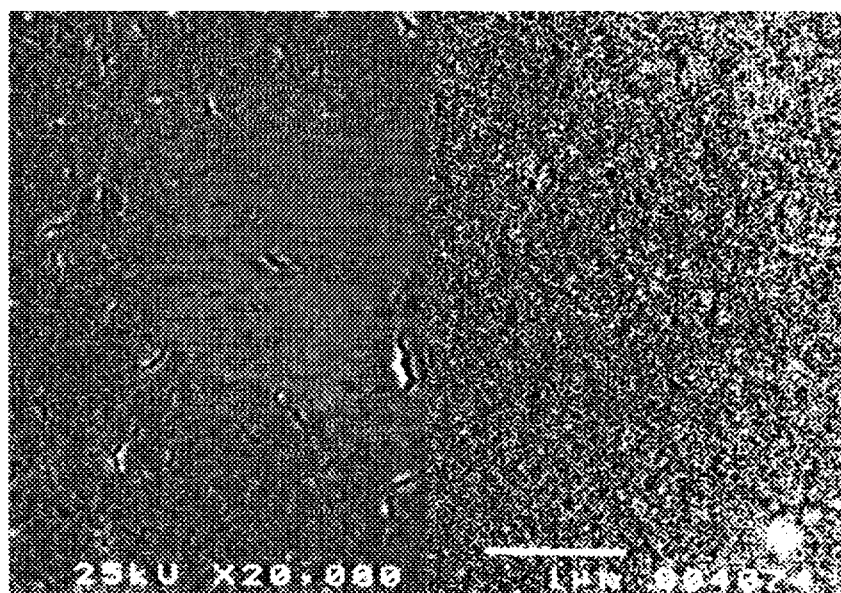

Fig. 1: The SEM microphoto of two samples: glass (left) and a thin carbon — IBAD layer (right) created by sputter deposition of carbon atoms and bombarded by C^+-ions beam.
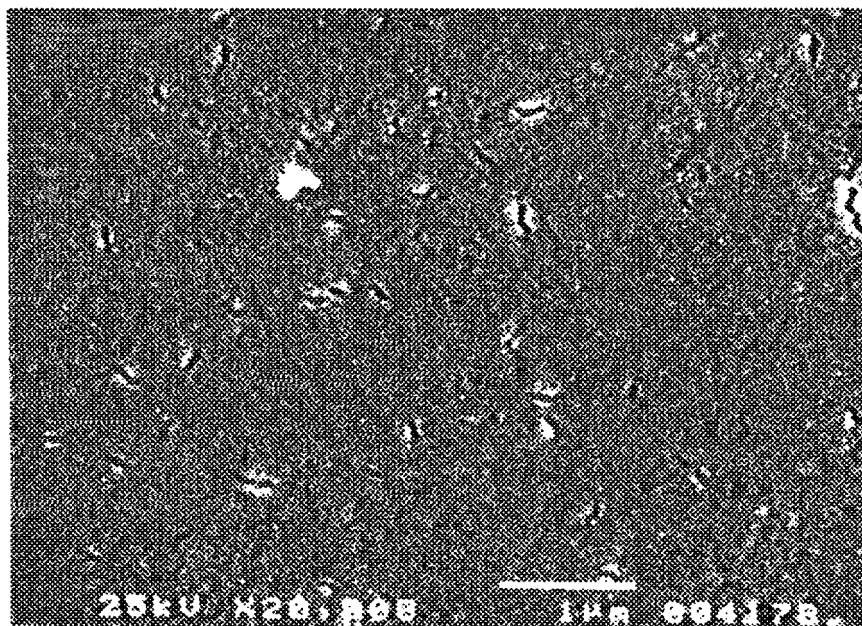
Fig. 2: The SEM microphoto of the thin carbon layer created only by sputter deposition of carbon atoms.

Non - destructive measurements (internal structure, defects, composition and thickness of layers) are carried out by the RBS - Rutherford Backscattering Spectroscopy. The 3 MV Van de Graaff accelerator is used to provide an analysing beam of protons. The Raman Spectroscopy method is applied for characterization (distribution and local concentration of sp2 and sp3 bonding - domains of graphite, diamond - like and diamond structures) of different, thin carbon layers. Mechanical properties (hardness, contact rigidity and stresses) as well as functional behaviour (friction, wear, grindability, fatigueability, corrosivity) of test samples will be studied. The results of investigations of the material features and the functional quality of the special alloy specimens modified by the carbon layers (DLC, a-C:H) by means of the IBAD method, will be published.

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Development of the 75kV INP Ion Implanter

B. Rajchel, M. Drwięga, E. Lipińska, J. Ligocki, and A.Sellmann

Technical specifications of the 75 kV INP ion implanter satisfactory for typical ion engineering methods (ion implantation, ion mixing, ion etching etc.) were, to some extent, inadequate for novel ion engineering techniques such as the Ion Beam Assisted Deposition (IBAD) method. That is why in 1992 we started adaptating the ion-implanter facility to the IBAD technique [1]. The first modernization stage (installation of the second beam line) was finished in 1993. Then the first targets using the IBAD method (simultaneous sputtering deposition and ion bombardment) were prepared, and the results were reported at the ECCART-3 conference [2]. Using this IBAD technique, one can create thin surface layers on modified samples, for example Li -Ni films resistant to high-temperature corrosion or carbon layers of special properties (DLC, diamond - like coating). At present, projects are under way to increase the capabilities of the ion implanter.
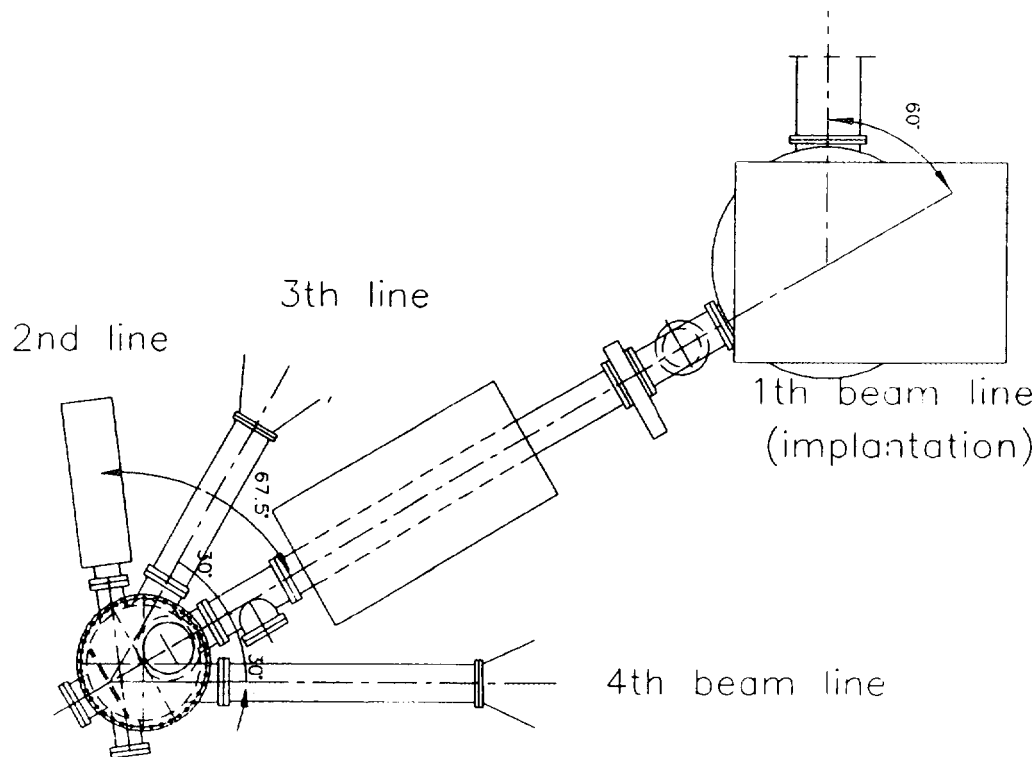
Fig. 1: Schematic diagram of the new geometry of the 75kV INP ion implanter.

We propose to replace the existing target chamber by a new one that ensures better vacuum conditions (10^{-9} mm Hg) and is equipped with a precise goniometer. Additionally, a third ion beam line (for material modification) will be connected and a fourth, analysing beam line, will be used for diagnostics of surface layers using the backscattering technique. After the final modernization, the ion implanter will work with four ion beam lines: one used to sputter deposition of atoms onto a modified substrate, two used for simultaneous, independent bombardment of the growing layer by ions of a chosen element, and the fourth one used for structural analysis (a schematic diagram of the arrangement is shown in Fig. 1). The setup will make possible to form more complex layers of materials for technical and research applications. So far, a comprehensive idea of the development of the INP ion implanter has been put forth. Detailed designs of the modernized device will be completed in 1995.

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Simulation of Dechannelling Processes by CRBS Code

B. Rajchel

For many years, dechannelling of charged particles in single crystals has been frequently used to study crystal structures. Interaction of the charged-particle beam moving through a single crystal is very complex. Therefore, there does not exist any general computer code for simulation of dechannelling processes and for analysis of experimental data collected in dechannelling experiments. Channelling/dechannelling effects are used at INP to study the structures of single crystals with thin surface layer changed by ion beam (implantation, IBAD -
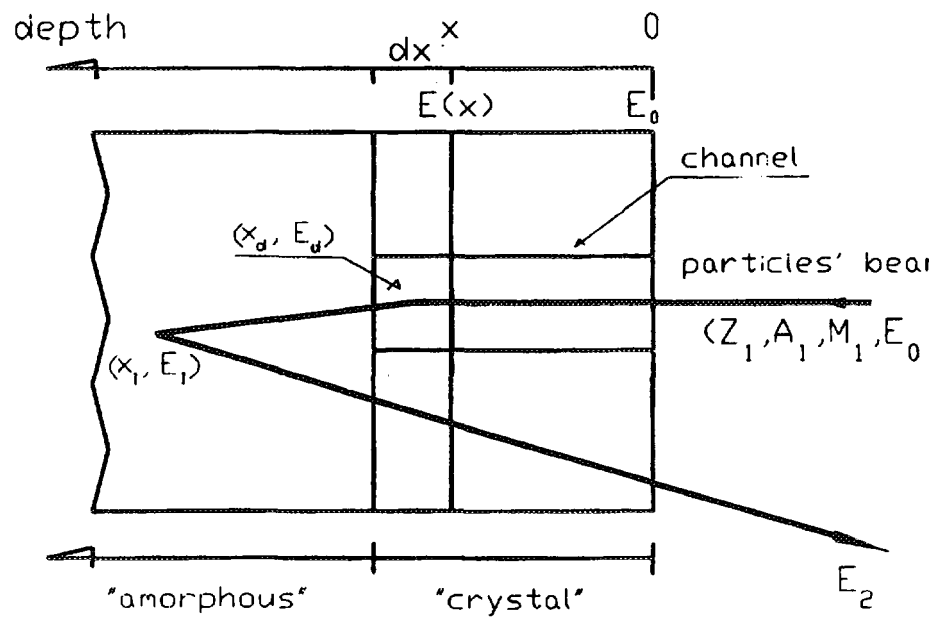
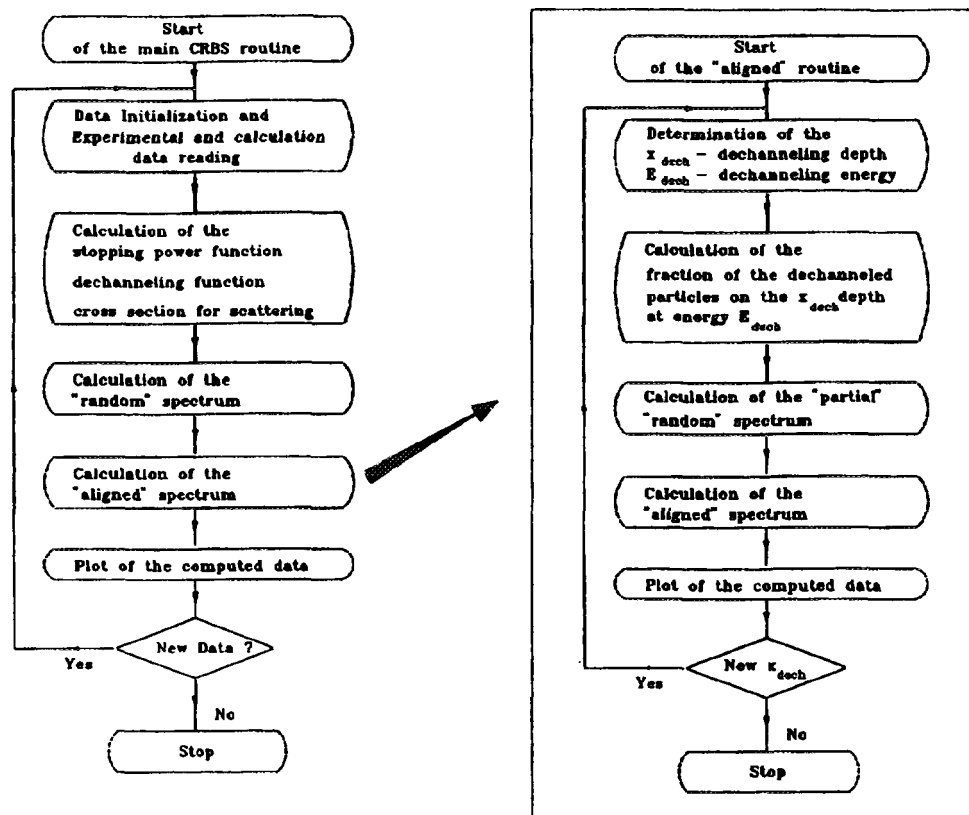*Fig. 1:* Basic physical idea of the CRBS code.
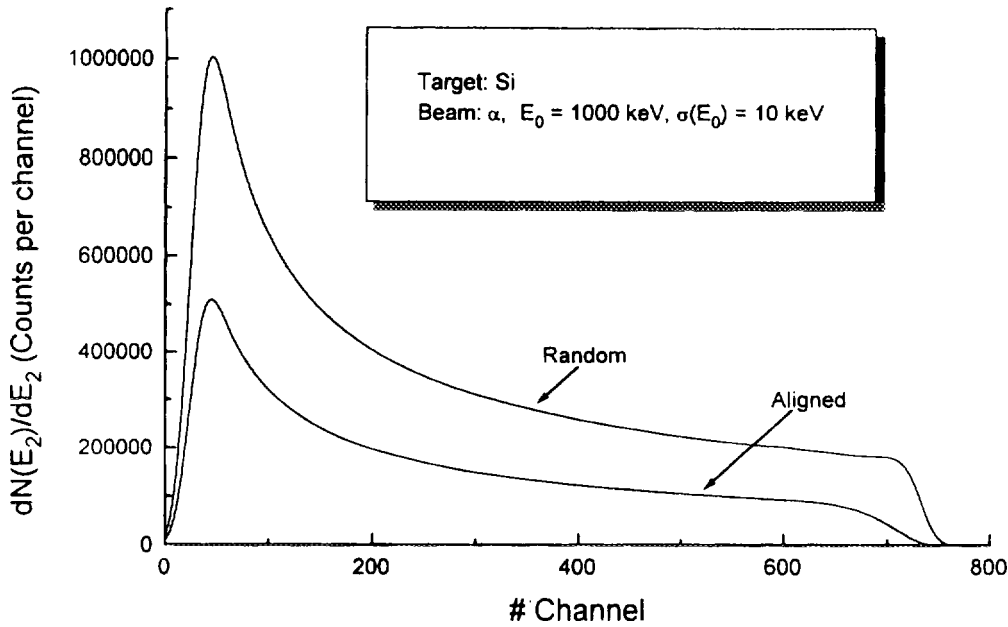

Fig. 2: Block scheme of the CRBS code.

Fig. 3: The "aligned" and the "random" spectra, calculated by the CRBS code, for the single *Si* crystal, bombarded by α-particle beam with initial energy $E_0 = 1000$ keV.

Ion Beam Assisted Deposition, etc.). In experiment, two spectra of backscattered particles are collected. One spectrum, called "aligned", is collected when the single crystal is bombarded by a proton or α-particle beam parallel to the main crystallographic axis. The other one, called "random", is collected when the angle between the main crystal axis and the beam direction is larger than ψ_c, a critical angle for channelling. To simulate the dechannelling processes and also to calculate the "aligned" and the "random" spectra, the CRBS code (Channeling Rutherford Backscattering Spectroscopy) was prepared. The first version of the CRBS code was presented at the ECAART'3 conference. A new version of this computer program is now ready. In this new version, calculations of the theoretical "aligned" and "random" spectra are more effective. In Fig. 1 and 2 the basic physical idea of the CRBS code and the block diagram of this code are respectively presented. In Fig. 3 the "aligned" and "random" spectra calculated by the CRBS code for the α-particle beam bombarding the single Si crystal are shown. The CRBS code can work on the IBM PC (386 or 486) compatible computers (the DOS version), on the VAX machines (the VMS version) or on the UNIX computers (CONVEX and IBM RISC/6000 machines).

L-Subshell Resolved REC Investigations

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Uranium ion beam pre-accelerated at the *UNILAC* (GSI, Darmstadt) was injected to and accelerated in the *SIS* synchrotron, and after a slow exctraction mode it was directed to an *Al* stripper foil. Beam energy after passing the stripper was 89 MeV/u. The *He*-like ions in charge state of 90^+ were selected by magnets of the Fragment Separator (*FRS*) and focused on a 400 μg/cm^2 carbon foil tilted by $30°$ with respect to the beam axis. Charge states of the emerging

beam were analysed magnetically once again in the *FRS*. Ions in primary charge state (90^+) and those which captured one electron (89^+) were registered in scintillator detectors. X-rays emitted from the target were registered by a set of solid state $Ge(i)$ detectors in coincidence with the detected ions.

The experiment was dedicated to experimental study of the radiative electron capture process into the L-subshells (L-REC) [1, 2]. In Fig. 1 the L-REC spectra are shown, measured at the various observation angles in coincidence with ions which captured one electron (89^+).
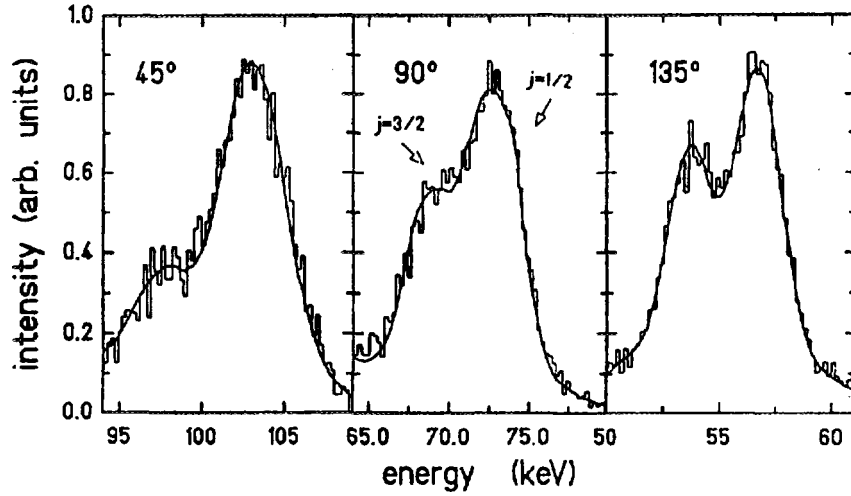

Figure 1: L-REC spectra in coincidence with electron pick-up of the projectile, measured at different observation angles in the laboratory frame. For presentation purposes, intensities were normalized to one common scale.
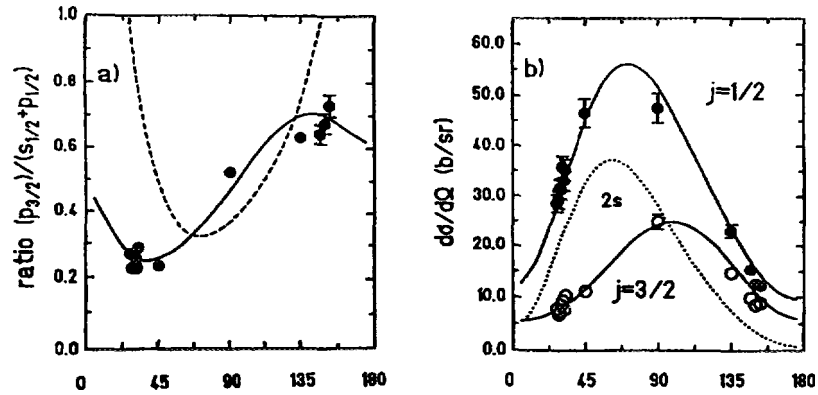

Figure 2: (a) Measured intensity ratios (full points) as a function of the observation angle in comparison with exact relativistic calculations [3] (solid line). The dashed line gives the results of the dipole approximation including the lowest-order retardation effect [4]. (b) Experimental angular distribution for REC into the $2s_{1/2}$ and $2p_{1/2}$ states (full circles) and for REC into the $2p_{3/2}$ level (open circles) in comparison with exact relativistic calculation. For capture into the $2s_{1/2}$ state the dipole approximation calculations are also presented (dashed line). See text for the normalization of experimental data.

In spite of spectral shape broadening due to the Doppler shift and to the Compton profile of carbon-target electrons, the L-subshell splitting is clearly visible. The spectra manifest a very strong variation of relative intensities of different j-components (j = 3/2 and j = 1/2) with respect to the observation angle.

Full points in Fig. 2 present the measured cross-section ratio for REC into the j = 3/2 state and into the j = 1/2 levels as a function of the observation angle. The experimental points are in agreement with the theoretical predictions based on a rigorous relativistic treatment of the REC process [3], as shown by the solid line. The results of non-relativistic dipole approximation calculations, including the lowest-order retardation effects [4] are shown by the dashed line. The non-relativistic calculations predict the angular distribution in the laboratory frame as $\sim sin^2\Theta$ for s-states or $\sim (1 - 2 \cdot v/c \cdot cos\Theta \cdot sin^2\Theta)$ for p-states (v is the projectile velocity). It is obvious that this approach fails completely in describing the experimental data.

Experimental data presented in Fig. 2b are multiplied by a factor of 0.65. for normalization to the theoretical cross-section as calculated by the exact relativistic theory (solid line). The normalization factor is within the total absolute normalization uncertainty of the experiment, estimated to be 50 %. The exact relativistic calculations and extrapolation of the experimental data presented in Fig. 2b show nonvanishing values of the cross-section at 180° and at 0° observation angle. This can be attributed to spin-flip transition only, not considered in a non-relativistic theory.

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Radiative Double Electron Capture (RDEC) in Heavy-Ion Atom Collisions

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The dominance of the single radiative electron capture (REC) in fast collisions of fully stripped Z_1 ions with light Z_2 atoms is established for charge-exchange processes [1]. Here, theory [2] as well as experiments [1] clearly show that single REC into the projectile K-shell (K REC) is the dominant REC channel. Double radiative electron capture (DREC) has been addressed only theoretically [3]. In this case, if the independent electron model (IEM) is assumed, filling of both K-shell vacancies in one collision via electrons from a multi-electron target-atom can be discussed as two independent transitions followed by the emission of two single REC photons with energy $\hbar\omega$. Going beyond the IEM, a certain fraction of transitions of two target electrons into the projectile K-shell should occur with the emission of one photon ($\hbar\omega'$) with twice the energy of single REC photons ($\hbar\omega' \approx 2\hbar\omega$). Hence, by taking into account the electron-electron interaction, an exotic double charge-exchange process can be discussed—radiative double electron capture (RDEC)—a process similar to the time-reversed photoionization. Within the RDEC process, the two quasi-free continuum (target) electrons jump into the projectile K-shell.

The first dedicated RDEC experiment was performed with bare Ar-ions at 11.4 MeV/u from the UNILAC (*GSI, Darmstadt*). Solid-state carbon targets were chosen with thickness of 4-10 $\mu g/cm^2$. At 11.4 MeV/u this low-Z_2 target ensured a considerable contribution of REC to the

total charge exchange. Two x-ray detectors facing each other and mounted perpendicularly to the beam axis, viewed the beam-target interaction region. After passing through the target, the ion beam was charge-state analysed in a dipole magnet. The projectiles which captured two electrons were registered in a plastic scintillator detector. The x-rays associated with these projectiles were recorded event-by-event. In order to avoid pile-up effects, which is crucial for the experiment, x-ray absorbers (50 μm, stainless steel) were inserted between the target and the x-ray detectors.

No significant line structure which could be attributed to the investigated process was observed in the RDEC region of the measured x-ray spectra associated with the double charge exchange. The background present in this spectrum region is most probably due to the secondary electron bremsstrahlung and/or Compton scattering of high energy γ rays. The number of counts, collected in the expected RDEC energy window, provides an upper limit estimate for RDEC cross section (σ_{RDEC}) of 0.25 mb at a confidence level of 95% ($\sigma_{RDEC} \leq 0.25$ mb). The most reliable theoretical estimate of σ_{RDEC} is obtained by considering RDEC as the time reversal of double photoionization [4]. Within the principle of detailed balance the cross-section for REC and for RDEC are given by [4]:

$$\sigma_{REC}(\beta) = Z_2 \cdot (\frac{\hbar\omega}{\gamma\beta mc^2})^2 \cdot \sigma_{ph}(\hbar\omega) \tag{1}$$

$$\sigma_{RDEC}(\beta) = A \cdot Z_2 \cdot (Z_2 - 1) \cdot (\frac{\hbar\omega'}{2\gamma\beta mc^2})^2 \cdot \sigma_{dph}(\hbar\omega') \tag{2}$$

where $\hbar\omega$ and $\hbar\omega'$ are the corresponding energies for single and double photoionization (energy of single or double REC photons), m-electron rest mass, c-the speed of light, β-projectile velocity in units of c, γ-the Lorentz factor, σ_{ph} and σ_{dph}-cross-sections for single and double photoionization respectively. Factor A ($A \leq 1$) describes the phase-space fraction accessible for RDEC. It depends on the energy distribution and on the angular distribution of the two photoelectrons. Factor $A = 1$ implies that the two photoelectrons are emitted collinearly with the same kinetic energy. The most favorable conditions, with A as close to one as possible, are reached for $Z_1 \gg 2$ in the high-energy limit, where the photon energy exceeds considerably the threshold for double photoionization [5, 6, 7]. However, even in these cases the angular distribution of the two photoelectrons is nearly isotropic, thus always keeping A smaller than one. In Fig. 1 the prediction of the $\sigma_{RDEC}/\sigma_{REC}$ ratio, given by Eq. 1 and Eq. 2, is plotted for $A = 1$ in the high-energy limit according to [4, 5].
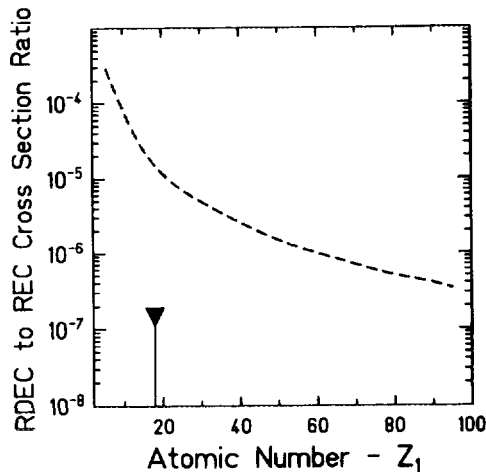

Figure 1. Dashed line - calculated $\sigma_{RDEC}/\sigma_{REC}$ ratio plotted for $Z_2 = 2$ and $A = 1$. Full triangle - upper-limit estimate obtained in the present experiment for $Z_1 = 18$.

Within this picture the limit $\sigma_{RDEC} \leq 0.25$ mb obtained in the experiment provides an upper-limit estimate for the $\sigma_{RDEC}/\sigma_{REC}$ ratio of $1.5 \cdot 10^{-7}$ (see Fig. 1). From this estimate,

an upper-limit estimate for $A \leq 1.1 \cdot 10^{-2}$ was extracted. Albeit negative, these results can be put in good use both for planning a new experiment with an improved sensitivity as well as for theoretical investigations of RDEC.

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Design of UHV Stand for Surface Analysis

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A modular UHV stand for surface studies of new materials has been designed. The setup will be used in microtribological studies of ion-implanted samples and in studies of structural properties of thin films. The stand consists of four independently pumped chambers:

- *preparation chamber for cleaning, baking and annealing of samples*

- *AES chamber for depth-profile analysis with Auger Electron Spectroscopy*

- *AFM chamber with Atomic Force Microscope used for microtribology studies and for characterization of surface topography*

- *PAC chamber with $\gamma - \gamma$ Perturbed Angular Correlations Spectrometer used for diagnostics of thin films.*

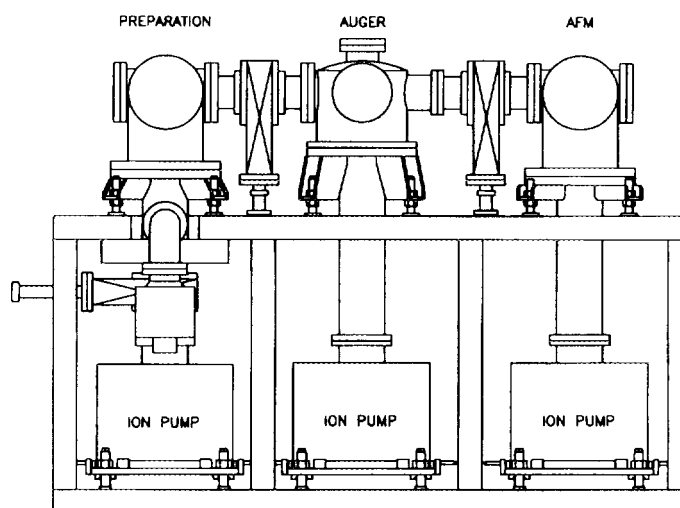A schematic view of the design is presented in Fig. 1.

Figure 1: Front view of the UHV stand.

The preparation chamber is pumped with an ion pump and a turbomolecular pump. In order to protect the system against oil contamination, all other chambers will be pumped by their own ion pumps in combination with two adsorption pumps for each chamber.

The preparation-, AES- and AFM chamber will be aligned to one axis, which enables the transport of samples between chambers using a simple axial transfer rod. The PAC chamber will be equipped with its own transfer rod, so that radioactivity-doped samples will never be mixed with non-contaminated ones. Manipulation of samples within the chambers will be done using wobble-sticks or simple manipulators.

In the setup we used second-hand standard Perkin-Elmer chambers separated by Riber gate valves. The chambers are fixed in a stable steel frame.
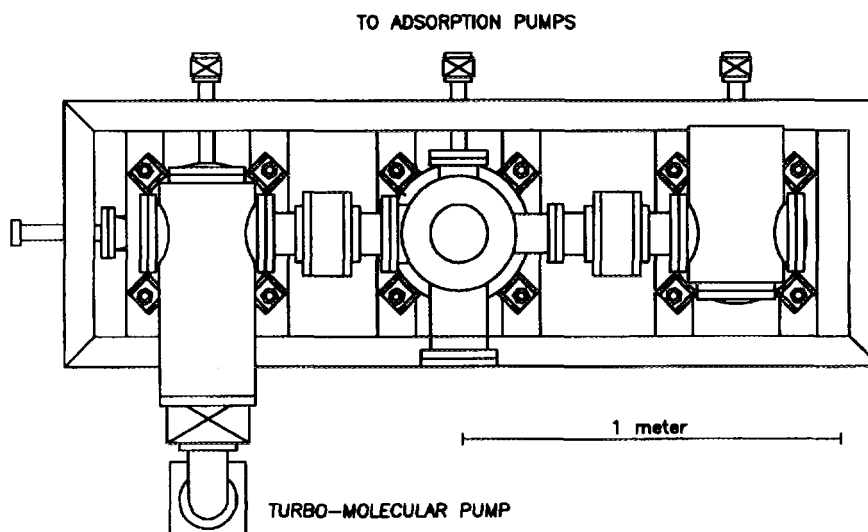

Figure 2: Top view of the UHV stand. The PAC chamber is not shown.

The UHV stand has been designed with the help of the Division of Mechanical Construction at our Institute. The manufacturing of the frame, vacuum connections and transfer systems, and the assembling of the setup will be done by this Division as well.

Van de Graaff Accelerator Status Report

S. Lazarski, T. Nowak, Z. Stachura, and Z. Szklarz

A second-hand Van de Graaff accelerator of type *KN-3000*, produced by the High Voltage Engineering Co., was purchased from the VIVIRAD Company (France) in 1990. The accelerator replaced an old, home-made cyclotron C-48 and became the main tool of the Department of Nuclear Spectroscopy in its investigations in the fields of:

- *solid state physics*
- *materials engineering*
- *biology and medicine*
- *environment protection*

studied by nuclear methods.

The machine delivers a beam of protons, α-particles and He^+ ions accelerated by the terminal voltage of up to 3 MV. So far the full pressure of insulating gas (2.5 MPa of the $H_2 + CO_2$

mixture) has not been used. With the lower pressure of 1.75 MPa, the highest terminal voltage used for experiments was 2.8 MV. The first scientific programmes realized at the Van de Graaff did not require high intensity beams, therefore the development work was concentrated on improving energy stability of the beam only. Stability better than 7 keV for 2.5 MeV protons was achieved.

The accelerator crew includes one physicist working half-time, one full-time engineer and one full-time technician. At the beam lines of the machine, it was planned to install the following experimental facilities:

- *stand for trace-element analysis by PIXE and PIGE methods*
- *stand for depth profiling by methods of RBS, NRA, FRS and channelling*
- *scanning proton microprobe with beam focused down to less than 1 μm diameter*
- *stand for high-energy ion implantations*
- *experimental area dedicated for extemporary measurements*

The experimental area at the accelerator is still at a temporary site. The small area for experiments permits putting into operation two short beam lines only, where stands for PIXE/PIGE and RBS/channeling experiments are installed. As a further development, the installation of the scanning proton microprobe was started. The focusing system for the microprobe (a quadruplet of quadrupoles) has been ordered from the University of Melbourne. The final installation of the microprobe will be possible after a new experimental hall is available. The new experimental site will also make it possible to install the stand for ion implantation and the beam line dedicated for extemporary experiments or for experiments performed by groups from other institutes.

In 1994, after allowing for vacation time, there were 247 accelerator working days. These were used as follows:

- *for service, repairs and development work*   85 days
- *for trace-element analysis by PIXE method*   67 days
- *for depth profile analysis by RBS method*   35 days
- *not used*   60 days

Investigations using the RBS method were performed with a beam of protons or α-particles of various energies, depending on the experimental needs. PIXE measurements were performed with proton beam energy of 2.0 - 2.8 MeV (usually 2.4 MeV).

Better utilisation of accelerator time is expected when the new experimental area is available. This will permit experiments using the scanning proton microprobe, ion implantations and other experiments which cannot find place at present.

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44. Z. Żelazny, (A. Maj) et al.,
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II. Contributions to Conferences:

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Conf. on Physics from Large γ-Ray Detector Arrays, Berkeley (1994) 20;

3. P. Bednarczyk, (J. Styczeń, R. Broda, M. Lach, W. Męczyński) et al.,
"Collective High Spin States in ^{45}Sc",
Conf. on Physics from Large γ-Ray Detector Arrays, Berkeley (1994) 132;

4. D. Bialic, R. Kruk, R. Kmieć, K. Tomala,
"^{155}Gd and ^{119}Sn Mössbauer Effect Investigation of the GdTSn Intermetallic Compounds (T= Ni, Pd, Cu, Au)",
Abstr. of the Int. Conf. on Magnetism, Warsaw, 22-26 August (1994) 567;

5. A. Bracco, (A. Maj) et al.,
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6. R. Broda, (B. Fornal, W. Królas, T. Pawłat, P. Bednarczyk) et al.,
"The N=40 Neutron Subshell Closure in the ^{68}Ni Nucleus",
Conf. on Physics from Large γ-Ray Detector Arrays, Berkeley (1994) 109;

7. F. Camera, (A. Maj) et al.,
"Spin and Temperaature Effects in the Width of the GDR in Hot Tin Isotopes",
Proc. of the "7th Int. Conf. on Nuclear Reaction Mechanisms", Villa Monastero, Varenna,
Italy, 6-11 June (1994);

8. B. Fornal, (R. Broda, W. Królas, T. Pawlat, P. Bednarczyk) et al.,
"Spectroscopy of Neuton-Rich A=93-97 Zr Nuclei",
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9. M. Galka, W.M. Kwiatek et al.,
"Lead Concentration in Renal Stones", XXIV Meeting of Polish Urological Society, Cracow, Poland, 1-3 September, to be published in Urology;

10. J.J. Gardhøje, (W. Królas, A. Maj) et al.,
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11. E.A. Görlich, R. Kmieć, K. Lątka,
"Magnetism of $Eu_{2-x}Ag_xSi_2$ Phases Studied with ^{155}Eu Mössbauer Effect", Proc. of Int.
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12. E.A. Görlich, R. Kmieć, K. Lątka, E.M. Levin,
"Local Picture of the Magnetism of Intermediate Valence $EuCu_{2-x}Ag_xSi_2$ Phases",
Abstr. of the Int. Conf. on Magnetism, Warsaw, 22-26 August (1994) 909;

13. M. Gąsior, S. Wiktor, H.A. Eliseeva, K.F. Komarovskij,
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14. H. Grawe, (R. Broda, W. Królas, A. Maj, T. Pawlat, M. Ziębliński) et al.,
"Nuclear Structure Studies in Neutron Rich Ni Isotopes",
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15. R. Julin, (A. Maj) et al.,
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16. T. Kandler, (Z. Stachura) et al.,
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17. T. Kandler, (Z. Stachura) et al.,
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18. W. Królas, (R. Broda, J. Grębosz, A. Maj, T. Pawlat) et al.,
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Int. Conf. on Solid Compounds of Transition Elements, Wrocław, 5-8 July (1994) 48;

21. R. Kruk, R. Kmieć, K. Lątka, K. Tomala, R. Troć, V.H. Tran,
"Investigation of Magnetic Properties of UTSn Intermetallic Compounds (T= transition

or noble metals) by the Mössbauer ^{119}Sn Spectroscopy",
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22. W.M. Kwiatek,
"Bio-Medical Applications of Synchrotron X-Ray Fluorescence",
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Conference on the Application of Accelerators in Research and Industry, Denton, Texas,
USA, 7-10 November, to be published in Nucl. Instr. and Meth. B;

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25. R. Mayer, (R. Broda, B. Fornal) et al.,
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26. T. Pawłat, (R. Broda, W. Królas, A. Maj, M. Ziębliński) et al.,
"High Spin State in Neutron Rich Ni Isotopes", Proc. of XXIII Mazurian Lakes Summer
School, Piaski, Poland, 18-28 August 1993, in: Acta Phys. Pol. **B25** (1994) 731-735;

27. K. Spohr, (W. Męczyński, M. Lach, A. Maj, J. Styczeń) et al.,
"Gamma Spectroscopy with the Recoil Filter Detector - Recent Results and Perspectives",
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"Radiative Electron Capture in Relativistic Heavy-Ion Atom Collisions",
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29. J.P. Vivien, K. Zuber,
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30. A. Warczak, (Z. Stachura) et al.,
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The VII-th Int. Conf. on the Physics of Highly-Charged Ions, Vienna, 19-23 Sept. 1994,
in: GSI preprint **GSI-94-80** (1994) 132;

31. G.W. Weselov, (A.W. Potempa) et al.,
"Metod opredelenia granicznykh energij pozitronnykh spektrov, izmerennykh detektorom
iz sverkhhistogo germanija" (The Method of β^+ Spectra Energy Determination Using
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Spektroskopia i Struktura Atomnogo Jadra", Sankt-Petersburg, 17-20 May 1994;

32. B. Wodniecka, M. Marszałek, P. Wodniecki, H. Saitovitch, P.R.J. da Silva, A. Hrynkiewicz,
"PAC Measurements at ^{181}Ta in Hf_2Pd Tetragonal $MoSi_2$-Type Phases", Abst. of XI-th
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33. B. Wodniecka, P. Wodniecki, M. Marszałek, A. Hrynkiewicz,
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"PAC Studies of Isostructural Ag_5Zn_8 and Ag_5Cd_8", Abst. of XI-th Int. Conf. on Solid
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III. Reports:

1. D. Bazzacco, (B. Fornal) et al.,
   "Probing Entrance Channel Effects in Low Energy Fussion: the Reaction ^{64}Ni + ^{92}Zr —
   ^{156}Er Studied with GASP", LNL Annual Report 1993, Legnaro 1 (1994);

2. R. Broda, (B. Fornal, W. Królas, T. Pawłat, P. Bednarczyk) et al.,
   "The N=40 Neutron Subshell Closure in the ^{68}Ni Nucleus",
   LNL Annual Report 1993, Legnaro 3 (1994);

3. Z. Drebi, (A. Maj) et al.,
   "Bremsstrahlung and GDR Decay in ^{12}C + ^{24,26}Mg Collision",
   NPL, Univ. of Washington, Seatle, Annual Report (1994);

4. M. Drwięga, E. Lipińska, S. Lazarski, M. Wierba,
   "Adaptacja implantatora IFJ do metody IBAD - Ion Beam Assisted Deposition, w wersji
   układu dwóch wiązek jonów - Dual Beam Technique" (Adaptation of the INP Implanter
   to the IBAD (Iom Beam Assisted Deposition) Technique - Version of Two Ion Beams Line
   (Dual Beam Technique)) , Raport IFJ 1660/AP (1994);

5. J. Dryzek,
   "Badania defektów sieci krystalicznej metodą anihilacji pozytonów" (Studies of Crystal
   Lattice Defects by the Positron Annihilation Method), Raport IFJ 1672/PS (1994);

6. O. Files, (J. Dryzek) et al.,
   "Analysis of Crystal Structures and Thin-Films with XRD",
   Inst. für Kernphysik, Univ. Münster Annual Report 1992/93, p. 72 (1994);

7. B. Fornal, (R. Broda, W. Królas, T. Pawłat) et al.,
   "Spectroscopy of Neutron-Rich A=93-97 Zr Nuclei",
   LNL Annual Report 1993, Legnaro 2 (1994);

8. T. Kandler, (Z. Stachura) et al.,
   "Resonant Electron Capture Determined via X-Ray Emission in U^{90+} →C-Collisions",
   GSI Scientific Report p. 148 GSI-94-1 (1994);

9. B. Kharraja, (K. Zuber) et al.,
   "Unfavoured Signature Partner Superdeformed Bands Associated with Proton Excitations
   in ^{151}Tb", CRN Strasbourg preprint CRN 94-11; Phys. Lett. B (in print) (1994);

10. G.J. Möllerberndt, (J. Lekki, Z. Stachura) et al.,
    "Tribological Investigations of Different Materials",
    Inst. für Kernphysik, Univ. Münster Annual Report 1992/93, (1994) 74;

11. Th. Stöhlker, (Z. Stachura) et al.,
    "Investigation of Radiative Electron Capture in Relativistic Heavy-Ion Atom Collisions",
    GSI Scientific Report p. 147 GSI-94-1 (1994);

12. G.V. Veselov, (A.W. Potempa) et al.,
    "The Method of Decay Energy Determination for Short-Lived Nuclei in On-Line Experi-
    ments", JINR Dubna preprint P6-94-272 (1994).

PARTICIPATION IN CONFERENCES AND WORKSHOPS:

1. R. Broda, P. Bednarczyk,
   "Physics from Large Gamma–Ray Detector Arrays", Berkeley, California, 2-6 August 1994;

2. R. Broda, P. Bednarczyk,
   "Heavy–Ion Fusion: Exploring the Variety of Nuclear Properties", Padova, Italy, 25-27 May 1994;

3. R. Broda, A. Maj, J. Styczeń, K. Zuber,
   "EUROBALL Users Meeting", Strasbourg, France, 21-23 September 1994;

4. R. Broda et al.,
   "Zakopane School of Physics – Trends in Nuclear Physics", Zakopane, Poland, 5-14 September 1994;

5. A. Hrynkiewicz,
   "Combined Meeting of the European Atomic Energy Society", Interlaken, Swiss, May 1994;

6. A. Hrynkiewicz,
   "European Atomic Energy Society 98th Working Group Meeting", Budapest, Hungary, October 1994;

7. A. Hrynkiewicz,
   Second conference "Racjonalizacja użytkowania energii i środowiska" (Rationalisation of the Use of Energy and Environment), Szczyrk, Poland, October 1994;

8. A. Hrynkiewicz,
   "General meeting of the Polish Academy of Sciences", Warsaw, Poland, May 1994;

9. A. Hrynkiewicz,
   "Meeting of the Poznań branch of Polish Academy of Sciences", Poznań, Poland, December 1994;

10. A. Hrynkiewicz,
    Scientific session "Czy kryzys idei postępu naukowo–technicznego i racjonalizmu?", (Crisis of the Idea of Scientific and Technological Progress and Rationalism ?), 50th Anniversary of the Maria-Skłodowska Curie University in Lublin, October 1994;

11. A. Hrynkiewicz,
    Seminar "Współpraca międzynarodowa a zarządzanie współczesną szkołą wyższą" (International Collaboration and Management of Contemporary High School);

12. W.M. Kwiatek,
    "Second International School on Synchrotron Radiation", Jaszowiec, Poland, 17-26 May 1994;

13. W.M. Kwiatek,
    "Workshop on Accelerator Based Techniques in Mineral Prospecting and Exploration", RER/04/008 Programme "Small Accelerators for Science and Technology", Denton, Texas, USA, 4-6 November 1994;

14. W.M. Kwiatek,
    "Workshop on Policy and Promotion of Nuclear Technology Based on Low Energy Accelerators Used in Industry, Environment and Other Applications", RER/04/008 Programme "Small Accelerators for Science and Technology", Vienna, Austria, 3-5 May;

15. W.M. Kwiatek,
    "Thirteen International Conference on the Application of Accelerators in Research and Industry", Denton, Texas, USA, 7-10 November 1994;

16. M. Marszałek,
    XI th International Conference on Solid Compounds of Transition Elements, Wrocław,
    Poland, 5-8 July 1994;
17. W. Męczyński,
    "EUROGAM Collaboration Meeting", CRN Strasbourg, France, 6-7 January 1994.

INVITED TALKS:

1. P. Bednarczyk,
   "Collective High Spin States in ^{45}Sc",
   Conf. on Physics from Large Gamma-Ray Detector Arrays, Berkeley 1994;
2. R. Broda,
   "Neutron-Rich Ni Isotopes Studied in Deep-Inelastic HI Collisions",
   Euroball Users Meeting, Strasbourg, France, Sept. 1994;
3. R. Broda,
   "The N=40 Neutron Subshell Closure in the ^{68}Ni Nucleus", Conference on Phys. from
   Large Gamma-Ray Detector Arrays, Berkeley, California,
   2-6 August 1994;
4. R. Broda,
   "Neutron-Rich Ni Isotopes Studied in Deep-Inelastic Heavy-Ion Reactions",
   University of Liverpool, UK, 16 February 1994;
5. R. Broda,
   "The $h^{n}_{11/2}$ Neutron States in Sn Isotopes Produced via Deep-Inelastic HI Reactions",
   The Schuster Laboratory, University of Manchester, UK, 17 February 1994;
6. B. Fornal,
   "Deep Inelastic Reactions - a New Tool for Nuclear Spectroscopy",
   XXIX Zakopane School on Physics, Zakopane 4-15 September 1994;
7. A. Hrynkiewicz,
   "Energia jądrowa – szanse i zagrożenia" (Nuclear Energy – Chances and Threats),
   Second Conference "Racjonalizacja użytkowania energii i środowiska" (Rationalisation of
   the Use of Energy and Environment), Szczyrk, Poland, October 1994;
8. A. Hrynkiewicz,
   "Energia jądrowa - szanse i zagrożenia" (Nuclear Energy – Chances and Threats),
   lecture at General Meeting of Polish Academy of Science, May 1994;
9. A. Hrynkiewicz,
   "Czy Polsce potrzebna jest energetyka jądrowa" (Does Poland Need Nuclear Energy),
   lecture at the meeting of Poznań branch of Polish Academy of Science, Poznań, Poland,
   December 1994;
10. A. Hrynkiewicz,
    "Uwagi o istocie praw fizyki" (Remarks on the Essence of Physics Laws),
    lecture at scientific session "Czy kryzys idei postępu naukowo-technicznego i racjonaliz-
    mu?" (Crisis of the Idea of Scientific and Technological Progress and Rationalism ?), 50th
    Anniversary of the Maria-Skłodowska Curie University in Lublin, October 1994;
11. A. Hrynkiewicz
    "Rola KBN w kreowaniu polityki szkół wyższych" (The Role of the State Comittee for
    Scientific Research in the Creation of the High School Policy),
    introducing lecture to the discussion at the seminar "Współpraca międzynarodowa a
    zarządzanie współczesną szkołą wyższą" (International Collaboration and Management
    of Contemporary High School);

12. A. Maj,
    "Hot Superheavy Nuclei Seen with the GDR Gamma-Decay",
    XXIX Zakopane School on Physics, Zakopane, 4-15 September 1994;

13. A. Maj,
    "Preliminary Results from Latest HECTOR-NORDBALL Experiment",
    Tandem Accel. Lab., NBI Riso, Denmark, 16 December 1994;

14. W. Męczyński,
    "Physics with the Recoil Detector",
    EUROGAM Collaboration Meeting, CRN Strasbourg, France, 6-7 January 1994.

LECTURES AND COURSES:

1. J. Dryzek,
   "Scattering and Trapping of Positrons in Solids",
   26th Positron Annihilation Seminar, Pokrzywna, Poland, September 1994;

2. A. Hrynkiewicz,
   "Metody fizyczne w medycynie, biologii i ochronie środowiska" (Physical Methods in Medicine, Biology and Environment Protection),
   lectures at the Institute of Physics of Jagellonian University;

3. W.M. Kwiatek,
   "Trace Element Analysis Using Synchrotron Radiation",
   WSP Kielce, Poland, 1 December 1994;

4. W.M. Kwiatek,
   "Proton Induced X-Ray Emission (PIXE)" and "Synchrotron Radiation Induced X-Ray Emission (SRIXE)", lectures at the Institute of Physics of Jagellonian University;

5. J. Lekki,
   "Construction of the Atomic Force Microscope",
   Institut für Kernphysik, Münster, Germany, 13 February 1994;

6. A. Maj,
   "Angular Distribution of the Gamma Ray in the Decay of Hot Superheavy Nucleus ^{269}Ns",
   Milano, Italy, 28 June 1994; "

7. B. Rajchel,
   "Oddziaływanie wiązki naładowanych cząstek z ciałem stałym" (The Interaction of Charged Particles Beam with the Solid Body),
   lectures at the Institute of Physics of Jagellonian University;

8. P. Wodniecki,
   "PAC Studies of Aluminium Implanted with Noble Gases",
   Seminar at Second Institute of Physics, University Göttingen, Germany.

INTERNAL SEMINARS:

1. Andrzej Warczak (Institute of Physics, Jagellonian University, Cracow),
   "Najnowsze badania procesów atomowych w zderzeniach ciężkich jonów", (Recent Investigations of Atomic Processes in Heavy Atoms Collisions), 5 January 1994;

2. Janusz Frąckowiak (University of Silesia),
   "Badanie zjawiska uporządkowania atomowego w stopach metali metodą spektroskopii mössbauerowskiej", (Investigation of the Atomic Ordering Effect in Metal Alloys Using Mössbauer Spectroscopy), 13 January 1994;

3. Jan Kownacki (Heavy Ion Laboratory, Warsaw),
   "Eksperymenty planowane przy cyklotronie the U-200", (Experiments Planned at U-200 Cyclotron), 19 January 1994;

4. Andrzej Budkowski (Jagellonian University, Cracow),
   "Badanie własności fazowych mieszanek polimerów za pomocą techniki wiązki jonowej", (Investigation of Phase Properties of Polymer Mixtures Using Ion Beam Technique), 2 February 1994;

5. Tomasz Czosnyka (Heavy Ion Laboratory, Warsaw),
   "Wzbudzenie kulombowskie dziś i jutro", (Coulomb Excitation Today and Tomorrow), 9 February 1994;

6. Małgorzata Sowa,
   "Mikroskop sił atomowych (AFM) i jego wykorzystanie do badań biologicznych", (Atomic Force Microscope and its Application to Biological Investigations), 23 February 1994;

7. Marta Marszałek,
   "Gradienty pól elektrycznych w związkach międzymetalicznych metali przejściowych", (Electric Field Gradients in Intermetallic Compounds of Transition Metals), 8 March 1994;

8. Jan Czerniawski (Jagellonian University, Cracow),
   "Dwie interpretacje teorii względności: rzeczywiste i pozorne punkty sporne", (Two Interpretations of Relativity Theory: Real and Spurious Controversies), 16 March 1994;

9. Artur Siwek,
   "Mechanizm multifragmentacji w reakcji ^{32}S + ^{58}Ni przy energii 30 AMeV", (Mechanism of Multifragmentation in ^{32}S + ^{58}Ni Reaction at the Energy of 30 AMeV), 23 March and 13 April 1994;

10. Elżbieta Marczewska,
    "Badanie zanieczyszczeń powietrza metodą próbek aerozolowych i modelowanie źródeł zanieczyszczeń", (Studies of Air Pollution by the Method of Aerosol Samples and Modelling of Pollution Sources), 20 April 1994;

11. Hugo Maier (Hahn-Meitner Institute, Berlin, Germany),
    "Spectroscopy of ^{208}Pb with Inelastic Heavy Ion Scattering, mbox(d, pγ) and (t, $\alpha\gamma$)", 11 May 1994;

12. Marta Kicińska-Habior (Warsaw University),
    "Promieniowanie ultradipolowe w zderzeniach ciężkich jonów o energiach kilka-kilkanaście MeV/u", (Ultradipol Radiation in Heavy Ion Collisions at Energies of Several MeV/u), 1 June 1994;

13. Henryk Figiel and Krzysztof Turek (Academy of Mining and Metallurgy, Cracow),
    "Zastosowanie magnesów typu Nd-Fe-B do wytwarzania pól magnetycznych o zadanej konfiguracji", (Application of Nd-Fe-B Magnets to Production of Magnetic Fields with Required Configuration), 8 June 1994;

14. Zbigniew Lodziana (Academy of Mining and Metallurgy, Cracow),
    "Jak odczytujemy informację niesioną przez elektrony w fizyce powierzchni", (How Do We Read the Information Brought by Electrons in Surface Physics), 22 June 1994;

15. Marian Cholewa (University of Melbourne and INP),
    "Mikrowiązka protonowa - zastosowania i nowe pomysły", (Proton Microbeam - Applications and Ideas), 27 September 1994;

16. Paweł Tomczyk (Jagellonian University),
    "Symulacja eksperymentu PIXE", (Simulation of PIXE Experiment), 5 October 1994;

17. Rafał Broda,
    "Nowe jądro podwójnie magiczne ^{68}Ni", (New Doubly Magic Nucleus ^{68}Ni), 12 October 1994;

18. Andrzej Bałanda (Institute of Phycics, Jagellonian University, Cracow),
    "Ściśliwość materii jądrowej a gigantyczny rezonans monopolowy", (Compressibility of Nuclear Matter and Giant Monopole Resonance), 19 October 1994;

19. Erazm M. Dutkiewicz,
    "Preparatyka próbek PIXE i mikro-PIXE", (Preparation of PIXE and Micro-PIXE Samples), 26 October 1994;

20. Piotr Salabura (Institute of Phycics, Jagellonian University, Cracow),
    "HADES - spektrometr dileptonów dla SIS", (HADES - a Dileptons Spectrometer for SIS), 9 November 1994;

21. Jerzy Dryzek,
    "Zjawisko rezonansowego wychwytu pozytonów na wakancjach", (Resonance Positron Trapping at Vacances), 16 November 1994;

22. Igor V. Bondariev (University of Minsk),
    "Positronium Research at INP, Minsk, Beylorussia", 23 November 1994;

23. Nikolai Maksimovich Shumeiko (Beylorussian University, Minsk, Beylorussia),
    "Physics of Radiative Effects in Deep-Inelastic Lepton-Nucleon Scattering", 12 December 1994.

SHORT TERM VISITORS TO THE DEPARTMENT:

Dr M. Bentaleb, ULP Strasbourg, France,
Dr I. Bondariev, University of Minsk, Beylorussia,
Dr B. Cleff, University of Münster, Germany,
W. Grewer, University of Münster, Germany,
Dr M. Kaci, CSNSM Orsay, France,
Dr P. Kleinheinz, Institute of Nuclear Physics, Jülich, Germany,
Dr S. Lebed, Institute of Applied Physics, Sumy, Ukraine,
Dr K.H. Maier, Hahn–Meitner Institute, Berlin, Germany,
O. Metelitsa, University of Minsk, Beylorussia,
Ing. J.L. Pedroza, Centre d'Etudes Nucleaires de Bordeaux–Gardignan, France,
Prof. C.A. Quarles, Texas Christian University, USA,
MSc. T. Stegemann, University of Münster, Germany,
Prof. N.M. Shumeiko, University of Minsk, Beylorussia,
V.I. Voznij, Institute of Applied Physics, Sumy, Ukraine,
MSc. E. Wasiliewa, Joint Institute of Nuclear Research, Dubna, Russia.

Section III

Department of Structural Research

Section III

DEPARTMENT
OF STRUCTURAL RESEARCH

Head of Department: . *Jerzy Janik, Professor*
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PERSONNEL:

Neutron Laboratory:

Research Staff:

Jerzy Janik, Professor	Jerzy Hubert, Assoc.Prof
Jan Krawczyk, Ph.D.	Maria Massalska-Arodź, Assoc.Prof.
Jacek Mayer, Ph.D.	Ireneusz Natkaniec, Ph.D.
Ewa Ściesińska, Assoc.Prof.	Jan Ściesiński, M.Sc., Eng.
Wacław Witko, Ph.D.	Wojciech Zając, Ph.D.
Piotr Zieliński, Assoc.Prof.	

Technical Staff:

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Janusz Sokołowski, M.Sc., Eng.	Eugeniusz Lisiecki
Tadeusz Sarga	

Administration:

Władysława Lisiecka	Maria Magdalena Mayer

Laboratory of Magnetic Research:

Research Staff:

Maria Bałanda, Ph.D.	Andrzej Pacyna, Ph.D.
Tadeusz Wasiutyński, Assoc.Prof.	Tomasz Mayer, M.Sc., Eng.

Technical Staff:

Waldemar Witek, M.Sc., Eng.

GRANTS:

OVERVIEW:

The activity of the Department continued to be carried out in three main areas:

1. Phase situation and motions in crystals containing molecules and/or molecular fragments and also in liquid crystals,
2. Magnetic structure and magnetic relaxation also in relation to high temperature superconductors,
3. Physics of chaos and nonequillibrum thermodynamics as related to interdisciplinary problems.

In the first area, an extensive study of rotational slowing down was completed for two substances with reorienting NH_3 groups: $Ni(NH_3)_6(NO_3)_2$ and $Mg(NH_3)_6(NO_3)_2$. The quasi-elastic neutron scattering data from two spectrometers — one with broad energy resolution (Kjeller, Norway) and one with narrow energy resolution (Dubna, Russia) — were analyzed and the elastic incoherent structure factors were determined. Both substances showed slowing down of four out of six NH_3 groups when approaching phase transition at 110 K. Moreover, an additional quasi-elastic component showed up close to the transition, which may be connected with critical effects. Another possibility, however, is that it might be connected with an increasing anharmonicity or a phonon branch when the transition is approached.

In the field of liquid crystals, the studies of phase situation of TCDCBPh were concluded. The results of differential scanning calorimetry and polarizing microscopy allowed us to interpret and support suggestions from quasi-elastic neutron scattering (QNS). The existence of intermediate phase between solid and smectic A was confirmed and additional monotropic phases on cooling were discovered. Experimental results of the thermoelectrooptic studies in glass-forming liquid-crystal mixtures were also interpreted. The changes of orientation of molecules after local heating by laser beam suggest the possibility of a new write – erase procedure in displays with glassy state at room temperature and nematic phase above. Dependence on layer thickness and electric field parameters was also studied. Dielectric relaxation data of PBBA molecules reorienting in smectic G and in glass of smectic G phases were analyzed, and quantitative differences have been found.

The activity of the laboratory of physics of magnetism was concentrated in two main fields: magnetic properties and the phase diagram of solid solutions of orthoferrites and orthoaluminates of rare earth elements, and magnetic properties of superconductors. An extensive study was performed for the $TbFe_{1-x}Al_xO_3$ system (x=0, 0.03, 0.06, 0.1, 0.2, 0.4, 0.6, 0.8, 1.0). Although spin reorientation was not seen, new phase transition was observed for large Al concentration (particularly at x=0.40 and 0.60). Its nature is not clear, however. The study is continued for the other elements: Er, Tm. The study of magnetic susceptibility of single crystals of $Nd_xLa_{1-x}F_3$ was performed for a wide range of concentration x. The investigation of magnetic properties of superconductors was the continuation of earlier work. The magnetic susceptibility

of gold-substituted HT_c superconductors of the $YBa_2Cu_3O_{7-\delta}$ type was studied for temperature range $T < T_c$ and $T > T_c$ for both superconducting and deoxygenated samples. Magnetic properties of the normal state were analyzed in detail. The study of magnetic susceptibility and magnetization was also performed for $HgBa_2Ca_2Cu_3O_{8-\delta}$. The other study concerns time dependence of susceptibility for the new class of intermetallic superconductors: YNi_2B_2C and $ErNi_2B_2C$. A new type of metastable state, which reduces diamagnetism, was observed. The relaxation to the state of full diamagnetism and its dependence on thermal and magnetic history were analyzed.

The third area of activity of the Department was devoted to general synergetic and social synergetic, thermodynamical aspects of physics of the environment and ecological problems, thermodynamics of complex systems in application to the theory of evolution of macroscopic structures in physical systems.

Most of the experimental work of the Department was done by means of the following methods: neutron scattering, infrared spectroscopy, adiabatic and scanning calorimetry, X-ray diffraction, polarized microscopy and magnetometry. The method of neutron scattering plays a leading role in this research. In this respect international collaborations with the I.M. Frank Neutron Laboratory of Joint Institute of Nuclear Research at Dubna, Russia as well as with the Institute for Energy Technology at Kjeller, Norway, and with the Rutherford Appleton Laboratory, England, are important. The majority of research was done with the cooperation with other groups in Poland. The most important are: the Chemical Physics Laboratory of the Faculty of Chemistry of the Jagellonian University in Cracow, the Solid State Physics Laboratory of the Faculty of Physics of the Jagellonian University in Cracow, the Institute of Physics and Nuclear Technology of the Academy of Mining and Metallurgy in Cracow.

for Tadeum Waninbyil

Prof. Jerzy Janik

REPORTS ON RESEARCH:

Slowing down of Molecular Reorientation in Ni(NH$_3$)$_6$(NO$_3$)$_2$

J.A. Janik, J. Mayer, J. Krawczyk

H. Niewodniczański Institute of Nuclear Physics, Cracow

T. Riste, K. Otnes

Institute for Energy Technology, Kjeller, Norway

J.M. Janik, and T. Stanek

Faculty of Chemistry of Jagellonian University, Cracow, Poland

Quasi-elastic neutron scattering experiments were performed with two different resolutions of $\sim 140~\mu eV$ and $\sim 30~\mu eV$. For temperature far above the phase transition at ≈ 110 K, a good agreement with a model assuming NH_3 reorientation was obtained. However, when approaching the phase transition (on cooling), a systematic deviation from such a model was observed. The hypothesis that rotational diffusion of NH_3 groups is more probable than NH_3 jumps was analyzed. Some NH_3 groups slow down, whereas other continue to rotate fast. There exists a quasi-elastic component of scattering in additions to the reorientational one, either caused by quasi-critical effects or a softening of the phonon branch.

Unusual Magnetic Properties
of Superconducting $ErNi_2B_2C$ and YNi_2B_2C

M. Bałanda, A. Bajorek, A.W. Pacyna, W. Witek

H. Niewodniczański Institute of Nuclear Physics, Cracow

N.X. Phuc

on leave from Institute of Materials Science, Nghia do, Hanoi, Vietnam

Recently discovered intermetallic superconductors $RENi_2B_2C$ (RE - rare earth ion) present an interesting example of the coexistence of antiferromagnetism and superconductivity. Time dependence of the dc magnetic susceptibility measured by means of Faraday-type electrobalance for several samples of $ErNi_2B_2C$ and YNi_2B_2C (T_c = 10.2 K and 15.6 K respectively) showed some unusual properties of these materials. After relatively fast cooling in zero magnetic field (ZFC), the samples showed an incomplete flux screening, which, depending on magnetothermal history, equaled to 15% - 80% of the ideal $\chi = -1/4\pi$ value. In all cases susceptibility relaxed towards a stronger diamagnetism, and this diamagnetic relaxation process lasted over tens of minutes. The two time regimes, of the measurements, i.e. the continuous field-on regime and the intermittent field-on-off regime, revealed some characteristic features of the process and its dependence on magnetic field and temperature. The development of two related fragmentary processes with opposite directions of magnetic response was studied using the intermittent measuring regime. Fig. 1 presents time dependence of the ZFC susceptibility for YNi_2B_2C measured in H = 1000 Oe at T = 4.5 K. In order to achieve the perfect diamagnetic state, a prolonged waiting time (for the case of small measuring field) or an additional heat treatment (for the stronger field) were needed. Fig. 2 shows the typical ZFC and FC branches of temperature dependence of susceptibility registered after the relaxation measurement. The values obtained at the lowest temperature correspond to the ideal diamagnetism.

The origin of the unusual magnetization behaviour may be ascribed to the existence of the novel glassy state of spontaneous orbital moments [1] created in the superconductor *via* negative Josephson π-junctions [2].
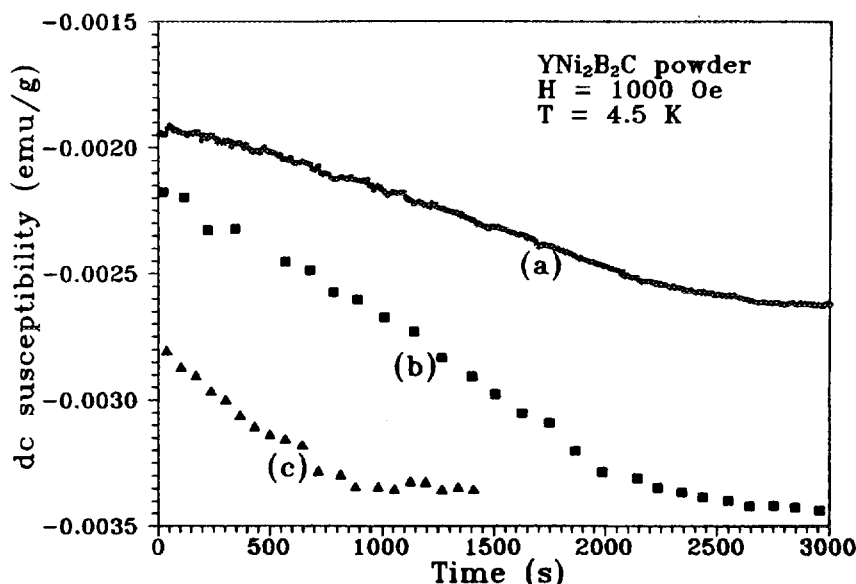

Fig.1. Time dependence of ZFC susceptibility for YNi_2B_2C: a) continuous field-on regime, b) intermittent field-on-off regime, c) intermittent regime, curve obtained after a) and quick heating up to 60 K and cooling back.
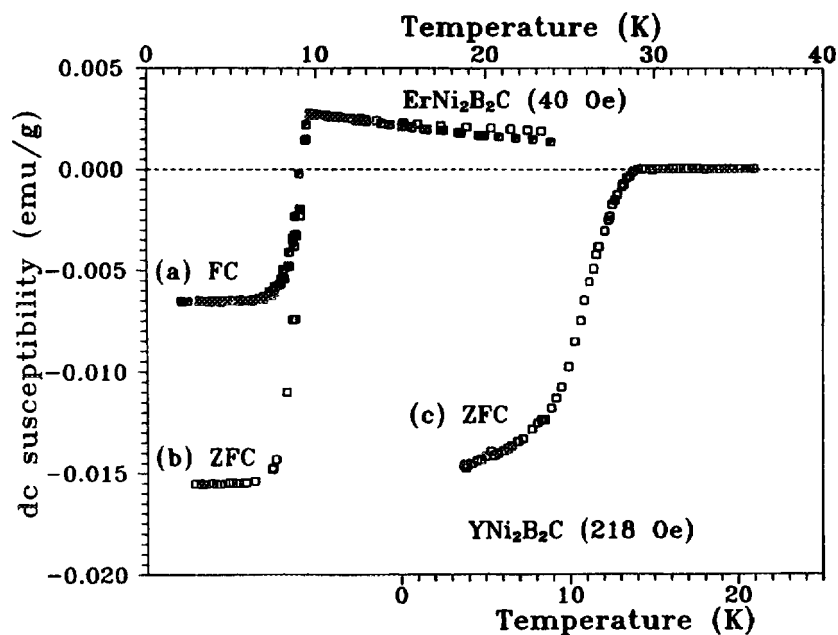
Fig.2. Temperature dependences of ZFC and FC susceptibility for $ErNi_2B_2C$ and YNi_2B_2C measured after the termination of the diamagnetic relaxation process.

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   "Quasielastic Scattering of Neutrons - A Real or an Illusory Success of Many Years of Research in Liquid Crystals?",
   in: Modern Topics in Liquid Crystals, ed. A. Buka (World Scientific) (1994) 1;

2. R. Podsiadły, J.M. Janik, T. Stanek, J.A. Janik, K. Otnes,
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   "On Exchange Mechanism in $Hg_{1-x}Mn_xS$",
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4. A. Bombik, A.W. Pacyna, W. Witek,
   "Phase Transitions in $ErFe_{1-x}Al_xO_3$ System ($x \leq 0.1$)",
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5. G. André, F. Bourée, A. Bombik, A. Oleś, W. Sikora, M. Kolenda, A. Szytuła, A.W. Pacyna, A. Zygmunt,
   "Magnetic Structure of $RNiGe$ and $RPdSn$ Compounds",
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6. A. Bombik, B. Leśniewska, A.W. Pacyna,
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7. L. Bobrowicz, K.Holderna-Natkaniec, M. Mroz, I. Natkaniec, W. Nawrocik,
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   nium Hydrogen Sulphate",
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8. K. Holderna-Natkaniec, I. Natkaniec, S. Habryło, J. Mayer,
   "Comparative Neutron Scattering Study of Molecular Ordering in d-Camphor and
   dl-Borneole",
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9. K. Holderna-Natkaniec, I. Natkaniec,
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    "Neutron and Raman Scattering Studies of the Lattice and Methyl Group Dynamics in
    Solid p-Xylene", Mol. Cryst. Liq. Cryst. (1994) in press;

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    Comparison with Ih and VI",
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13. M. Massalska-Arodź,
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    "Search of the Self-Similarity in a Nematic Liquid Crystal",
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15. A. Pawlukojc, L. Bobrowicz, I. Natkaniec, J. Leciejewicz,
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    Spectrochimica Acta (in press) (1994);

16. E.F. Sheka, V.D. Khavryutchenko, E. Nikitina, I. Natkaniec, I. Markichev, N. Goncharova,
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    ing",
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18. E.F. Sheka, I. Natkaniec, V.D. Khavryutchenko, I.V. Markichev, A.Yu. Muzychka,
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19. L.S. Smirnov, V.A. Goncharova, E.L. Gromnitskaya, G.G. Il'ina, I. Natkaniec, A.I. Soloviev,
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20. J. Hubert,
"Elements of Social Synergetics" (in Polish),
Transformacje, Kwartalnik Interdyscyplinarny **1-2 (3-4)** (1994);

21. J.A. Janik,
"Science - Religion - History - 7-th Meeting" (in Polish),
Nauka-Religia-Dzieje: VII Seminarium Interdyscyplinarne w Castel Gandolfo, 3-5 August 1993, ed. J.A. Janik (Jagellonian University) (1994) 5;

22. J.A. Janik, R. Podsiadły,
"Systemic Aspect of the World - A Critics of the Paradigm Concerning Proportionality of Effects to Cause" (in Polish),
Nauka-Religia-Dzieje: VII Seminarium Interdyscyplinarne w Castel Gandolfo, 3-5 August 1993, ed. J.A. Janik (Jagellonian University) (1994) 7;

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24. R. Podsiadły, J. Mayer, W. Witko,
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25. J. Stanek, A. Szytuła, Z. Tomkowicz, A. Bajorek, M. Bałanda, M. Guillot,
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II. Contributions to Conferences:

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"Magnetic Relaxation in 1-2-3 and 1-2-4 HT_c Superconductors Substituted by Pr",
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"Magnetization of $TmFe_{1-x}Al_xO_3$ (x≤0.1)",
Int. Conf. on Magnetism, Warsaw, 22-26 August 1994;

3. J. Chruściel, W. Zając, C.J. Carlile,
"Bayesian Analysis of Quasielastic Neutron Scattering Data in Liquid Crystalline Phases of $\overline{7}S5$",
15 Int. Liquid Crystal Conf., Budapest, 3-8 July 1994;

4. J. Hubert,
"Physical Description and Determinants of Evolution of Structures",
3rd Int. Symposium "Evolution of Natural Structures", Stuttgart Univ., 4-7 October 1994;

5. J. Hubert, S. Taczanowski,
"Physicists' Contribution to an Environment Friendly Philosophy of Man and Society",
VI ISU Symposium "The Role of Philosophy and Sciences in the Prevention of Ecological and Economic Catastrophe", London, 15-18 March 1994;

6. J.A. Janik, J. Mayer, J. Krawczyk, T. Riste, K. Otnes, J.M. Janik,
"Slowing Down of Molecular Reorientations in $Ni(NH_3)_6(NO_3)_2$",
Int. Conf. "Neutron Scattering in Material Science", Boston, 28 Nov. - 2 Dec. 1994;

7. M. Massalska-Arodź,
"Statistical Self-Similarity in Liquid Crystalline Phases",
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8. I. Natkaniec, S.I. Bragin, J. Brańkowski, J. Mayer,
"Multicrystal Inverted Geometry Spectrometer NERA-PR at the IBR-2 Pulsed Reactor",
ICANS-XII, 24-28 May 1993, Abingdon, U.K.;

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11. Z. Tomkowicz, J. Stanek, A. Szytuła, A. Bajorek, M. Bałanda, M. Guillot,
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Proc. of the Int. Symp. "Properties of f-electron Compounds", Jagellonian University,
Cracow, 27-30 June 1994;

12. B. Trzcińska, J. Ściesiński,
"New Possibilities of Ball-Pen Ink Analysis Using Infrared Spectroscopy for Questioned
Document Examinations",
Criminalistic Traces, Cracow, 20-23 Sept. 1994;

13. W. Witko, Ch. Selbmann, H.D. Koswig,
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Mixtures",
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Poland, 23-27 Oct. 1994;

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drogen Sulfate",
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17. K. Holderna-Natkaniec, I. Natkaniec,
"Neutron Scattering Studies of Disorder in Camphor-like Plastic Crystals in the Tempera-
ture Range 10-300K",
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lutions",
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19. K. Holderna-Natkaniec, I. Natkaniec, J. Wąsicki,
"Structural Phase Transitions and Molecular Dynamic in Bornyl Chloride Studied by
Neutron Scattering and NMR Methods",
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20. L. Bobrowicz, S.I. Briagin, I. Natkaniec, T. Sarga,
"Neutron Scattering Studies of Pressure Induced Phase Transitions in NH_4HSO_4",
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21. K. Hołderna-Natkaniec, I. Natkaniec, S. Habryło,
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    by Neutron Scattering",
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    Solutions",
    Int. Conf. on Neutron Scattering, ICNS'94, Sendai, Japan, 11-14 October 1994;

23. A.I. Kolesnikov, V.V. Sinicyn, E.G. Ponyatovsky, I. Natkaniec, L.S. Smirnov,
    "Similarity of Vibrational Spectra of High Density Amorphous Ice and High Pressure
    Phases Ice VI",
    Int. Conf. on Neutron Scattering, ICNS'94, Sendai, Japan, 11-14 October 1994:

24. A.I. Kolesnikov, (I. Natkaniec), et al.,
    "Neutron Scattering Studies of Structural Transformations and Vibrational Spectra od Ice
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25. C. Cachet, A. Belushkin, I. Natkaniec, F. Fillaux, L.T. Yu,
    "Characterization with Inelastic Neutron Scattering of Various Protonic Species in Man-
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    Int. Conf. on Neutron Scattering, ICNS'94, Sendai, Japan, 11-14 October 1994;

26. T. Wasiutyński, J. Ściesiński, J. Mayer, E. Ściesińska,
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27. T. Wasiutyński,
    "Phase transitions and glassy states in cyclooctanol",
    Phase Transformations and Dynamics of Molecular Materials,
    Saint-Malo, France, 12-16 September 1994;

III. Reports:

1. M.L. Paradowski, A.W. Pacyna, A. Bombik, W. Korczak, S.Z. Korczak,
   "Magnetic Susceptibility of $La_xNd_{1-x}F_3$ Single Crystals",
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2. L.S. Smirnov, I. Natkaniec, S.I. Bragin, J. Brańkowski, A.I. Solovev, V.A. Goncharova,
   E. Gromnitskaja, G.G. Il'ina, O.V. Stalgorova,
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   Phase Diagram, Comm. JINR, E14-94-266, Dubna, 1994;

3. M. Massalska-Arodź,
   "Unusual Properties of Granular Materials" (in Polish),
   Foton **29** (1994).

SCIENTIFIC DEGREES:

1. *Maria Massalska-Arodź*, habilitation
2. *Piotr Zieliński*, habilitation
3. *Tomasz Mayer*, M.Sc.

INTERNAL SEMINARS:

1. dr J. Krawczyk,
   "Genetic Programming";
2. prof. dr J. Janik,
   "Recent History of Physics: Physicist and the Problem of Real and Potential Existing";
3. dr W. Otowski, Technical University, Cracow, Poland,
   "Magnetocaloric Effect in Gadoline";
4. dr W. Zając,
   "Bayesian Analysis of QENS Spectra of Liquid Crystalline Phases 7S5";
5. dr W. Otowski, Technical University, Cracow, Poland,
   "Anisotropic Heat Flow in Liquid Crystals - Mięsowicz–Jeżowski Experiment";
6. mgr K. Rohleder, Technical University, Wrocław, Poland,
   "The Modelling of the Disorder in Molecular Crystals";
7. mgr R. Podsiadły, Jagellonian University, Cracow, Poland,
   "The Study of the Phase Situation in TCDCBPh";
8. prof. dr hab. Nguyen Xuan Phuc, Institute of Materials Science, Hanoi, Vietnam,
   "The Magnetic Properties of the Superconducting Materials";
9. prof. dr J. Błocki, Institute of Nuclear Problems, Świerk, Poland,
   "From Order to Chaos in Nuclear Physics";
10. prof. dr J. Janik,
    "March Meeting of American Physical Society in Pittsburgh 1994";
11. T. Mayer,
    "The Study of Ammonium – Potassium Thiocyanates by Differential Scanning Calorimetry";
12. prof. E. Kluk, Dickinson State University, North Dakota, USA,
    "The Structure and Dynamics of the American Business – Education System";
13. prof. H. Kresse, Martin Luter University, Halle, Germany,
    "Dielectric Behavior of Liquid Crystalline Oligomers";
14. prof. dr J. Janik,
    "New Version at the Critical Slowing down of Rotation in $Ni(NH_3)_6(NO_3)_2$ and $Mg(NH_3)_6(NO_3)_2$";
15. dr M. Bałanda , prof. dr hab. Nguyen Xuan Phuc,
    "The New Metastable Magnetic Phase in Superconducting Borocarbides";
16. dr A. Bombik, dr A.W. Pacyna,
    "The Influence of the Magnetic Vacancies on Properties of $ReFe_{1-x}Al_xO_3$";
17. dr J. Krawczyk,
    "Prisoner's Dilemma - Evolution of Cooperation".

SHORT TERM VISITORS TO THE DEPARTMENT:

1. prof. Nguyen Phuc, Institute of Materials Science, Hanoi, Vietnam, 6 months;
2. prof. V. Aksenov, dr A. Belushkin, Frank Laboratory of Neutron Physics, JINR, Dubna, Russia, 7 days;
3. Eng. S. Briagin, Frank Laboratory of Neutron Physics, JINR, Dubna, Russia, 4 weeks;
4. M.Sc. L. Paradowski, IF UMCS Lublin, 12 days;
5. dr N.M. Hong, Technical University, Wien, Austria, 4 days;
6. dr D. Rodić, Institute of Nuclear Sciences, Vinča, Jugoslavia, 2 days.

Department of Theoretical Physics

Section IV

DEPARTMENT
OF THEORETICAL PHYSICS

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Leonard Leśniak	Assoc. Professor
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Mariusz Michalec	M.Sc.
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[3] Associated Editor of Zeitschrift für Physik C - Particles and Fields

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GRANTS:

1. *Dr W. Broniowski*
   Theoretical Studies of Nucleons and Nuclear Matter,
   no: PAN-NSF 9313988;   1. 01. 1994 - 31. 12. 1996;

2. *Dr W. Broniowski*
   Theoretical Studies in Hadronic Physics Related to CEBAF,
   no: PAA/NSF-94-158; Maria Skłodowska-Curie Fund II,
   1. 01. 1994 - 31. 12. 1996;

3. *Prof. E. Kapuścik*
   grant No: 2 0342 91 01 (State Committee for Scientific Research),
   The Meaning of the Galileo Relativity Principle in Quantum Mechanics;

4. *Assoc. Prof. M. Kutschera*
   grant No: 2 0204 91 01 (State Committee for Scientific Research),
   Dense and/or Hot Hadron Matter;

5. *Prof. J. Kwieciński*
   grant No: 2 0198 91 01 (State Committee for Scientific Research),
   Structure of Hadrons Studied in Particle and Nuclear Interactions;

6. *Prof. J. Kwieciński*
   grant No: 2 P302 062 04 (State Committee for Scientific Research),
   Analysis of Lepton Inelastic Scattering on Nucleons and on Atomic Nuclei;

7. *Prof. J. Kwieciński*
   grant No: F0408 (British - Polish Joint Research Collaboration Programme),
   Proton Structure and Small x Physics;

8. *Prof. J. Kwieciński*
   grant No: ERBCHRXCT 920004; supplementary agreement No: ERBCIPDCT
   940016 (within the network coordinated by the University of Grenada, Spain),
   Phenomenology of the Standard Model and Alternatives for Present and Future High Energy Colliders.

OVERVIEW:

Research activity of the Department of Theoretical Physics spans a wide variety of problems in theoretical high-energy and elementary-particle physics, theoretical nuclear physics, theory of nuclear matter, quark-gluon plasma and relativistic heavy-ion collisions, theoretical astrophysics, as well as general physics. Some topics, like theoretical astrophysics, have interdisciplinary character requiring theoretical tools of high-energy physics together with the knowledge of the theory of nuclear matter and the theory of condensed matter. There is some emphasis on the phenomenological aspect of the theoretical research, yet more formal problems are also considered.

Theoretical research in high energy and elementary particle physics is concentrated on the theory of deep inelastic lepton scattering in the region of low x and its phenomenological implications for the ep collider HERA at DESY, on the theory of nonleptonic decays of hadrons, and on low energy $\pi\pi$ and $K\bar{K}$ interactions and scalar meson spectroscopy.

Our activity in the theory of relativistic heavy-ion collisions is focussed on the study of quark condensate fluctuations, on the analysis of critical scattering near the chiral phase transition, and on Bose-Einstein correlations in heavy-ion collisions.

Theoretical studies in nuclear physics and in the theory of nuclear matter concern analysis of models, with dynamical symmetry based on group $Sp(6, R)$, for the description of collective modes of atomic nuclei, analysis of the Goldstone bosons in nuclear matter and analysis of saturation properties of nuclear matter.
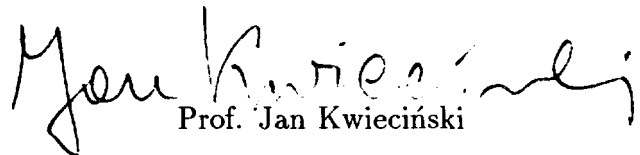
Research in theoretical astrophysics is mainly devoted to the analysis of magnetic properties of hadronic matter in neutron stars with proton admixtures.

Studies in general physics concern problems related to the Galilean covariance of classical and quantum mechanics.

The detailed results obtained in various fields are summarised in the abstracts listed below.

Our Department collaborates actively with other departments of our Institute and with several laboratories in Poland and abroad.

Besides pure research, members of our Department are also involved in graduate and undergraduate teaching activity, both at our Institute as well as at other academic institutions in Cracow.

Prof. Jan Kwieciński

REPORTS ON RESEARCH:

Multiparticle Correlations in High Energy Collisions

P. Bożek, M. Płoszajczak[1], and R. Botet[2]

[1] GANIL, Caen, France

[2] Laboratoire de Physique des Solides, Université Paris-Sud, Orsay, France

The power–law multiparticle correlations between particles produced in high energy collisions were studied [1]. The implications of the structure of the emitting source on the Bose-Einstein correlations was addressed in ultrarelativistic nuclear collisions. The role of hadronization on the observed correlations was studied in a simple model as well.

Reference:

1. P. Bożek, M. Ploszajczak, and R. Botet, Two and Many Particle Correlations in Nuclear and High Energy Physics, GANIL preprint **P-94-13**, *to appear in Physics Reports.*

Subthreshold Particle Production in Heavy Ion Collisions

P. Bożek and M. Płoszajczak [1]

[1] GANIL, Caen, France

The subthreshold production of particles in intermediate–energy heavy–ion collisions was studied. The model of instabilities was applied to the production of mesons and high–energy photons. The data of the TAPS group on energetic photon production (E_γ >pion mass) were reproduced for the first time. The model was also improved by the inclusion of the Fermi motion.

Low-Energy Sum Rules and Large-N_c Consistency Conditions

W. Broniowski

The large-N_c consistency conditions for axial-vector and isovector magnetic couplings of pions to baryons have been derived from the point of view of low-energy current-algebra sum rules (Adler-Weisberger, Cabibbo-Radicati). In particular, we have shown how the result that ratios of axial vector and isovector magnetic coupling constants get corrections only at the order $1/N_c^2$ follows from the N_c-counting of the appropriate cross sections. This counting is performed using various approaches at the quark and hadronic level [1].

Reference:

1. W. Broniowski, Low-Energy Sum Rules and the Large-N_c Consistency Conditions, Nucl. Phys. **A580** (1994) 429.

Pseudo-Goldstone Modes in Nuclear Medium

T.D. Cohen[1] and W. Broniowski

[1] Department of Physics and Astronomy, University of Maryland, College Park, MD 20742, USA

We have shown that in a uniform medium, the vanishing of a particular condensate along with spontaneously broken symmetry imply the existence of an anomalously light pseudo-Goldstone mode. The consequences for a vanishing chiral condensate in nuclear matter are discussed [1]. We have also analyzed the chiral limit in dense isospin-asymmetric nuclear matter, and shown that the pseudo-Goldstone modes in this system are qualitatively different from the case of isospin-symmetric matter [2].

References:

1. T. D. Cohen and W. Broniowski, Vanishing Condensates and Anomalousy Light Goldstone Modes in Medium, Univ. of Maryland preprint **DOE-ER-40762-043** (1994), to appear in Phys. Lett. **B**,
2. T. D. Cohen and W. Broniowski, Pseudo-Goldstone Modes in Isospin-Asymmetric Nuclear Matter, Report **INP 1683/PH** (1994).

Effective Local Interactions and the Equation of State for Nuclear Matter and Finite Nuclei

P. Czerski, H. Müther[1], and W.H. Dickhoff[2]

[1] Institut für Theoretische Physik der Universität Tübingen, D-72076 Tübingen, Germany

[2] Department of Physics, Washington University, St. Louis, MO 63130, USA

Differences in the evaluation of the saturation properties of infinite nuclear matter and finite nuclei are discussed. It is demonstrated that ground-state properties of finite nuclei are much more affected by the finite range of realistic nucleon - nucleon interactions than the saturation point of nuclear matter. Due to surface effects, a large incompressibility for finite nuclei is obtained as compared to nuclear matter. Local nucleon - nucleon interactions are determined, which simulate the main features of the Brueckner G - matrix

and allow for a simple calculation and analysis of the ground - state properties. These effective local interactions of finite range could be very useful in dynamical calculations of heavy - ion scattering [1].

Reference:

1. P. Czerski, H. Müther, and W.H. Dickhoff, J. Phys. **G20** (1994) 425.

Large Time-Scale Fluctuations of the Quark Condensate at High Temperature

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The transport theory for a quark-antiquark plasma is used to study large time-scale fluctuations of the quark condensate. The interactions between quarks are assumed to be of the NJL type. We restrict ourselves to the mean field (Vlasov) approximation. The space-time behaviour of the fluctuations of the mean field and, consequently, of the condensate depends strongly on the form of the initial conditions for the quark distribution function. If the latter can be initially represented as a sum of the thermal background distribution and a perturbation which is broad in momentum, then the fluctuations are suppressed in time by a mechanism analogous to that of Landau damping. On the other hand, if we add a perturbation which is peaked in momentum to the thermal background distribution, the fluctuations are not damped and behave similarly to Van Kampen modes in ordinary plasmas.

Critical Scattering at the Chiral Phase Transition and the Low p_T Enhancement of Mesons in Ultra-Relativistic Heavy-Ion Collisions

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[3] INP Cracow, Poland

The enhancement of pions and kaons observed at small transverse momenta in ultra-relativistic heavy-ion collisions may at least partly reflect critical scattering expected in the neighbourhood of a second–order phase transition. In order to study this connection, the kinetic equations in the relaxation time approximations are proposed for the time evolution of the quark and pion distribution functions. Relaxation times for thermalization and hadronization processes are functions of momenta and approach zero in the limit $p \to 0$, a consequence of criticality at the phase transition.

Gluons from Logarithmic Slopes of F_2 in the NLL Approximation

K. Golec-Biernat

We perform a critical, next–to–leading order, study of the accuracy of the "Prytz" relation, which is frequently used to extract the gluon distribution at small x from the logarithmic slopes of the structure function F_2. We find that the simple relation is not genarally valid in the HERA regime. It is shown that it is a reasonable approximation only for gluons which are sufficiently singular at small x.

Reference:

1. K. Golec-Biernat, Phys. Lett. **B328** (1994) 495.

Recombination Effects in the Structure Function Evolution at Low x. Can They be Observed at HERA?

K. Golec-Biernat, M.W. Krasny[1], and S. Riess[2]

[1] L.P.N.H.E, IN2P3-CNRS, Paris VI and VII Universities, Paris, France

[2] II. Institute for Experimental Physics, Hamburg University, Germany

Can the non-linear QCD effects resulting from parton recombination be detected at HERA by the H1 and ZEUS detectors? We argue that an extension of the low x domain of the proton structure function F_2 measurements to small electron scattering angle is essential before such effects can be ruled out. If, on the other hand, they are large, we find that their magnitude cannot be determined unambiguously from the measured Q^2 and x dependence of F_2. This is due to large correlations between the size of recombination effects and the gluon distribution which is very weakly constrained at low x by the F_2 evolution.

Reference:

1. K. Golec-Biernat, M.W. Krasny, and S. Riess, Phys. Lett. **B337** (1994) 367.

Transverse Energy Flow at HERA

K. Golec-Biernat, J. Kwieciński, A.D. Martin[1], and P.J. Sutton[2]

[1] Dept. of Physics, University of Durham, DH1 3LE, England

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We calculate the transverse energy flow accompanying small x deep inelastic events and compare with recent data obtained at HERA. In the central region between the current jet and the remnants of the proton we find that BFKL leading $\ln(1/x)$ dynamics gives a distinctively large transverse energy distribution, in approximate agreement with recent data.

Reference:

1. K. Golec-Biernat, J. Kwieciński, A.D. Martin, and P.J. Sutton. Phys. Lett. **B335** (1994) 220

QCD Predictions for the Transverse Energy Flow in Deep-Inelastic Scattering in the DESY HERA Small x Regime

J. Kwieciński, A.D. Martin[1], P.J. Sutton[2], and K. Golec-Biernat

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The distribution of transverse energy E_T, which accompanies deep-inelastic electron-proton scattering at small x, is predicted in the central region away from the current jet and proton remnants. We use BFKL dynamics, which arises from the summation of multiple gluon emissions at small x, to derive an analytic expression for the E_T flow. One interesting feature is an $x^{-\epsilon}$ increase of the E_T distribution with decreasing x, where $\epsilon = \left(\frac{3\alpha_s}{\pi}\right) 2 \ln 2$. We perform a numerical study to examine the possibility of using characteristics of the E_T distribution as a means of identifying BFKL dynamics at DESY HERA.

Reference:

1. J. Kwieciński, A.D. Martin, P.J. Sutton, and K. Golec–Biernat, Phys. Rev. **D50** (1994) 217.

Implications of Scaling Violations of F_2 at HERA for Perturbative QCD

A.J. Askew [1], K. Golec-Biernat, J. Kwieciński, A.D. Martin [1], and P.J. Sutton [2]

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The QCD predictions for the Q^2 dependence of electron-proton deep-inelastic structure function $F_2(x, Q^2)$ in the small x region, which is being probed at HERA, are examined. The standard results based on next-to-leading order Altarelli-Parisi evolution are compared with those that follow from the BFKL equation, which corresponds to the resummation of the leading $\log(1/x)$ terms. The effects of parton screening are also quantified. The theoretical predictions are confronted with each other, and with existing data from HERA [1].

Reference:

1. A.J. Askew, K. Golec-Biernat, J. Kwieciński, A.D. Martin, and P.J. Sutton, Phys. Lett. **B325** (1994) 212.

Properties of the BFKL Equation and Structure Function Predictions for DESY HERA

A.J. Askew [1], J. Kwieciński, A.D. Martin [1], and P.J. Sutton [2]

[1] Department of Physics, University of Durham, Durham, England
[2] Department of Physics, University of Manchester, Manchester, England

The general properties of the Balitzkij-Fadin-Kuraev-Lipatov (BFKL) equation are reviewed. Modifications to the infrared region are proposed. Numerical predictions for the deep- inelastic electron-proton structure functions at small x are presented and confronted with recent DESY HERA measurements [1].

Reference:

1. A.J. Askew, J. Kwieciński, A.D. Martin, and P.J. Sutton, Phys. Rev. **D49** (1994) 4402.

Dijet Production at HERA as a Probe of BFKL Dynamics

A.J. Askew [1], D. Graudenz[2], J. Kwieciński, and A.D. Martin [1]

[1] Department of Physics, University of Durham, Durham, England
[2] Theoretical Physics Division, CERN, Geneva, Switzerland

The rate for the deep-inelastic electroproduction of dijets at HERA was calculated. The weakening of the azimuthal (back-to-back) correlation between the jets with decreasing x was studied in order to see whether it can be used to identify BFKL dynamics from conventional fixed-order QCD effects. It was shown how this may give information on the transverse (k_T) dependence of the gluon distribution in the proton [1].

Reference:

1. A.J. Askew, D. Graudenz, J. Kwieciński, and A.D. Martin, Phys. Lett. **B 338** (1994) 92.

Shadowing in the Deuteron and the New F_2^n/F_2^p Measurements

B. Badełek[1] and J. Kwieciński

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The quantity $2F_2^d(x, Q^2)/F_2^p(x, Q^2) - 1$ is calculated in the region of low x and low and moderate Q^2 relevant for the recent NMC and E665 measurements as well as for the expected final results of the precise NMC analysis of their low x data. The calculations include nuclear shadowing effects and a suitable extrapolation of the structure functions of free nucleons to the low Q^2 region. The theoretical results are in good agreement with the NMC data. The shadowing correction to the experimental estimate of the Gottfried sum is quantified [1].

Reference:

1. B. Badełek and J. Kwieciński, Phys. Rev. **50** (1994) R4.

Low Q^2, Low x Region in Electroproduction - an Overview

B. Badełek[1] and J. Kwieciński

[1] Department of Physics, Uppsala University, Uppsala, Sweden and Institute of Experimental Physics, Warsaw University, Warsaw, Poland

The existing experimental and theoretical knowledge on the structure function F_2 in the region of low Q^2 and low x is summarised. The constraints on the behaviour of structure functions in the limit $Q^2 = 0$ are listed. Phenomenological low Q^2 parametrisations of F_2 are collected and their dynamical content is discussed. The high energy photoproduction and nuclear shadowing are also briefly described. Recent update of the low Q^2, low x experimental data is given [1].

PL9700181 PL9700180

Reference:

1. B. Badelek and J. Kwieciński, Low Q^2, Low x Region in Electroproduction - an Overview, Warsaw University preprint IFD/1/1994.

Physics at Low x

J. Kwieciński

The QCD expectations concerning the deep inelastic lepton - hadron scattering at low x and their phenomenological implications for HERA are summarised. Theoretical predictions for the structure function $F_2(x, Q^2)$ based on the leading $\log 1/x$ resummation are presented and compared with the results obtained from the Altarelli–Parisi equations. The theoretical predictions are confronted with the recent data from HERA. The role of studying the final states in deep inelastic scattering for revealing the dynamics at low x is emphasised and some dedicated measurements, like deep inelastic plus jet events, transverse energy flow and dijet production in deep inelastic scattering, are discussed [1,2].

References:

1. J. Kwieciński, QCD Predictions for Deep Inelastic Scattering at Small x and their Phenomenological Imolications for HERA, invited talk presented at the XIX Rencontre de Moriond, March 1994, Méribel, France, Report **INP 1674/PH** (1994);

2. J. Kwieciński, Physics at Low x, invited talk presented at the Workshop "QCD94", July 1994, Montpellier, France, Report **INP 1681/PH** (1994).

Galilean Covariance in Classical and Quantum Mechanics

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We have continued to study the properties of the Galilean covariant formulation of classical mechanics as well as its consequences for Galilean covariant formalism of quantum mechanics. Our aim has been to construct the Galilean covariant description of the single particle classical dynamics. It has been achieved within a new formalism where the fundamental concept, leading to the Galilean covariant single particle dynamics, is based on the rejection of the notion of force laws. The standard identification of forces with force laws which used to be non-covariant expressions giving the forces in terms of particle position and velocity, cannot describe the acting forces (except for the constant one) in a covariant way. In our approach the acting forces are considered as physical objects with their own time evolution, and they may be expressed in terms of force laws in only one, chosen, reference frame. It means that for a complete and consistent description of a physical system, a new degree of freedom has to be introduced and that we have always to describe a particle together with its environment. The formalism admits Lagrangean and Hamiltonian formulations, the formal technical aspects of which are similar

to that applied in models of one–dimensional field theory. However, its interpretation needs new ideas. In particular, many physical quantities, identified within standard, non-covariant approach, must be distinguished in the new formalism. The differences between covariant and non-covariant formalisms are most easily seen in the framework of the co-variant canonical formalism which gives unexpected results. The most important of them is a different form of the uncertainty principle (caused by the fact that the canonical and mechanical momenta must be distinguished) and a different Galilean transformation rule for the total and kinetic energies. The connection between covariant and non-covariant formalisms can be analysed in the framework of Dirac's theory of constrained systems which shows how the covariant formalism reduces to the standard one in a reference frame in which the force law is satisfied.

References:

1. A. Horzela, E. Kapuścik, and J. Kempczyński, Hadr. J. **17** (1994) 160;

2. A. Horzela, E. Kapuścik, and J. Kempczyński, Hadr. J. **17** (1994) 207;

3. E. Kapuścik, Turkish J. Phys. **12** (1994) 137;

4. E. Kapuścik, Physics without Physical Constants, in *Frontiers in Fundamental Physics*, eds. F. Selleri and M. Barone, Plenum Press (1994) p. 387;

5. A. Horzela, On the Connection between Classical and Quantum Mechanics, in *Frontiers in Fundamental Physics*, eds. F. Selleri and M. Barone, Plenum Press, (1994), p. 443.

Physical Theories in Discrete Space–Time

A. Horzela, E. Kapuścik[1], and Ch. A. Uzes[2]

[1] INP and Cracow Pedagogical University
[2] University of Georgia, Athens, 30602 Georgia, USA

The aim of this research is the formulation of quantum mechanics in the configuration space given by the finite, discrete set of allowed positions, and a further study of the properties of quantum mechanical models formulated in such way. In contradistinction to any discretization of the physical theory defined primarily on a continuum, our approach realizes the concept of the physical theory defined from the very beginning on a discrete set. The approach proposed previously demands new mathematical methods. The algorithms based on the theory of discrete Fourier transforms allows one to perform theoretical investigations as well as numerical calculations. The analysis of the problem of one–dimensional quantum mechanical scattering has been performed for various quantum mechanical potentials and its results have been compared with standard quantum mechanical calculations. The method shows that discrete space calculations are fairly close to those of the standard continuum ones even for a relatively small number of points, which makes it possible to use the method on a typical PC computer both as a calculation tool as well as a simple illustration used in education.

Reference:

1. C. A. Uzes, E. Kapuścik, and A. Horzela, Turkish J. Phys. **12** (1994) 180.

Properties of Classical Electrodynamics

E. Kapuścik[1]

[1] INP and Cracow Pedagogical University

A non–standard formulation of classical electrodynamics is proposed. In this scheme electromagnetic fields $\vec{D}$ and $\vec{H}$ as well as polarization $\vec{P}$ and magnetization $\vec{M}$ vectors must be distributions while electromagnetic fields $\vec{E}$ and $\vec{B}$ are test functions. The mathematically precise description of all these quantities gives the possibility to avoid the troubles of the conventional electrodynamics connected to the problem of the distribution-valued sources, like for example the point charge.

Constrained Systems in Mechanics and Field Theory

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[2] INP and Cracow Pedagogical University
[3] Dep. of Marine Sciences, Univ. of Georgia, Athens, USA

The problem of connecting systems with different number of degrees of freedom is discussed. Constraints appropriate for "Bose" and "Fermi" quantization are used to construct algebras of Dirac brackets associated with special solutions of the nonlinear complex oscillator. The constraints are shown to provide a basis for characterizing the elementary excitations of the oscillators. An alternative notion of quantization through a correspondence with an enveloping algebra of the Dirac brackets is introduced, a notion which simplifies the operator-ordering problem implied by the original Dirac brackets. The infinite and two-dimensional representations of the subalgebra are utilized to illustrate the quantization technique.

References:

1. E. Kapuścik, C.A. Uzes, and A.O. Barut, Phys. Rev. **49A** (1994) 2260;
2. E. Kapuścik, C.A. Uzes, and A.O. Barut, Turkish J. Phys. **12** (1994) 227.

Threshold Amplitudes for Pseudoscalar Meson Interactions

R. Kamiński and L. Leśniak

Coupled channel $\pi\pi$ and $K\overline{K}$ interactions in the $I^G(J^{PC}) = 0^+(0^{++})$ state have been studied using a separable potential formalism [1]. A very good description of the experimental data on the interactions in both channels has been achieved in a wide energy range from the $\pi\pi$ threshold up to 1.4 GeV. The parameters of the effective range expansions in both channels have been evaluated up to the order $O(k^6)$ [2]. A comparison of the parameters obtained in the relativistic and nonrelativistic approaches has been done. The interactions in both channels are attractive. The strong interaction between the kaons leads to an appearence of the $K\overline{K}$ quasibound state $f_0(980)$. A single pole of the scattering amplitude corresponding to this state has crucial influence on the threshold parameters in the kaon channel. The M–matrix formalism has also been used. The

threshold amplitude expansion written in terms of the M-matrix elements has a larger convergence radius than the ordinary effective range expansion.

The wave functions of both pairs of mesons have been evaluated using the coupled Lippmann–Schwinger equations. The coupling constants of the resonances (found in our analysis [1]) for decays into the $\pi\pi$ and $K\overline{K}$ pairs have been evaluated.

Analogous calculations have been performed in the $I = 2$ $\pi\pi$ channel, where a non-resonant behaviour of the scattering amplitude was found. A good description of the experimental data has been obtained. The data allow for the existence of two solutions for the scattering amplitudes. However, the χ^2 test favours the solution with an attractive interaction over the repulsive one.

References:

1. R. Kamiński, L. Leśniak, and J.-P. Maillet, Phys. Rev. **D50** (1994) 3145;
2. R. Kamiński and L. Leśniak, Threshold Parameters of the $K\overline{K}$ and $\pi\pi$ Scalar-Isoscalar Interactions, Phys. Rev. **C**, in press.

Dense Matter in Neutron Star Cores

M. Kutschera

Knowledge of the proton fraction of neutron star core matter as a function of density is very important for various astrophysical properties (cooling, magnetic properties) of neutron stars. Models of nuclear matter give different predictions. In particular, there exists a striking discrepancy between the variational many-body models which predict decreasing proton fraction and the relativistic mean-field models which predict the increase of proton fraction with increasing density. In Ref. [1] the origin of this contradiction is explained.

In Ref. [3] formation of regular lattice structure by localized protons is studied. For simplicity, the structure is assumed to have cubic lattice symmetry. Neutrons are described by variational Bloch functions. Neutron density is modulated with minima occurring at the lattice sites which correspond to potential wells localizing the protons. This structure forms a selfconsistent proton crystal immersed in the modulated neutron background. In calculations Skyrme forces were used.

As a by-product of the above crystal construction we have found that certain Skyrme force parametrizations, often used in astrophysical calculations, give unphysical ferromagnetic instability for pure neutron matter, Ref. [2]. In Ref. [2] we show how this defficiency can be removed and we give a parametrization which fits well microscopic neutron matter calculations.

Localization of protons in neutron matter of sufficiently high density is the result of a general tendency to separate protons and neutrons in high-density neutron star matter [4]. In Ref. [4] two separation mechanisms, bulk separation and localization of individual protons, are discussed. In the neutron star core matter the latter mechanism is more likely to occur.

In Ref. [5] we construct the equation of state for quark matter with pion condensate.

References:

1. M. Kutschera, Z. Phys. **A348** (1994) 263;
2. M. Kutschera and W. Wójcik, Phys. Lett. **B325** (1994) 271;
3. M. Kutschera and W. Wójcik, Nucl. Phys. **A581** (1995) 706;
4. M. Kutschera, Phys. Lett. **B340** (1994) 1;
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New Trends in Kinetic Fragmentation Theory

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Recent theoretical developments in kinetic fragmentation theory are presented, with a particular emphasis of the newly proposed Fragmentation-Inactivation Binary (FIB) cascading model. We also discuss the origin of scale-invariant, intermittent fluctuations in cluster fragmentation models such as the percolation model and the binary cascading models.

Quantum Tunneling in the Driven Lipkin N - Body Problem

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Quantum tunneling is investigated in the quantum and semiclassical limits using a periodically driven Lipkin N - body model. The time-dependent driving changes the tunneling rate by orders of magnitude as compared to the unperturbed system, leading to its enhancement in a somewhat similar way as found recently in simple one-dimensional anharmonic oscillator model for one particle. Taking different values of driving amplitude and frequency, one can influence the quantum tunneling that takes places between the HF minima in the nonperturbed system. Oscillatory and coherent tunneling of the N - particle wave-function between two degenerated Hartree-Fock minima is found when the initial wave-function is localized in one doublet of quasi energy states of different parity. The tunneling time is determined exactly by the splitting of quasi energy doublet. Our results suggest the existence of a new mechanism of quantum tunneling in strongly interacting many-body systems, which involves the transport of wave-function between symmetric, stable regions of the classical phase-space due to the coupling with chaotic levels. The coherent suppression of tunneling is also found for specific parameters of the driving force. This quantum effect can be observed when the two quasi energy eigenstates of opposite parities which dominate in the initial state cross each other exactly. A phenomenon of tunneling assistance by external-field drive, due to the under-barrier absorption of the quanta from the external field, has been discussed before only for independent particles (electrons) in the external field, while neglecting any correlations between those particles. In this work we show for the first time that a similar phenomenon can be found in the system of strongly coupled fermions, and therefore it could be relevant for the studies of atomic nuclei.

Tunneling Control
in the Driven SU(2) N-Body System

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Quantum tunneling is investigated using an exactly soluble, periodically driven Lipkin N - body model. The coherent suppression of tunneling is found for specific parameters of the driving force. This exotic quantum phenomenon can be observed when the two quasi-energy eigenstates which dominate in the initial state cross each other exactly. The simple, analytically solvable two-level model explains the behaviour of the system in some ranges of the driving amplitude and frequency. In this model, these crossings form a straight line in the amplitude-frequency planar for the driving force. For many-level models, like the driven quartic oscillator or the driven Lipkin SU(2) model, this linear dependence, and also the presence of crossings in the quasi-energy spectrum, occurs in a finite range of frequencies only. The experimental test of this interesting effect could be carried out in any bistable tunneling system, e.g. in molecular or solid-state physics.

Anomalous Diffusion in Chaotic Scattering

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Anomalous diffusion is found for peripheral collisions of atomic nuclei, described in the framework of molecular dynamics. Similarly as for chaotic billiards, the long free paths are the source of long-time correlations and anomalous diffusion. For a fixed angular momentum, the predicted energy spectrum has a peak at relatively low energy. The mass and atomic numbers of ejectiles are similar to those of the projectile and target. An integration over angular momentum has a smoothing effect and broadens the peak. Such a picture is typical for deep-inelastic heavy-ion collisions. For near-grazing collisions in light and medium heavy-ion nuclei, one has the evidence for an orbiting di-nuclear system which is formed after damping the initial energy and angular momentum and evolves through the exchange of nucleons (α - particles) into different configurations of a di-nuclear system. The dependence of the internal energy on the average lifetime can be measured directly, utilizing experimental techniques of atomic and nuclear physics. This would help to verify the anomalous diffusion mechanism. Independently, the detailed analysis of the shape of experimental spectra would give information about the decay probability $p(t)$ of the rotating system.

The divergence of the dissipation rate may have important consequences for the semi-phenomenological description of heavy-ion collisions and, in particular, hot fission process. Going from central to peripheral collisions or from saddle to scission in the fission process, one usually employs the same model of diffusion changing only the geometrical constraints such as the size of the 'window' or the deformation of the system. In view of the above results, this alone may not be sufficient as the change of the time scales involved modifies the nature of the dissipation process. Consequently, for peripheral collisions or for

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strongly elongated shapes from saddle to scission, it is more appropriate to use the time- or coordinate-dependent diffusion coefficient.

The similarity of the diffusive behaviour for systems as different as the MD and the Lorentz gas of hard discs, follows from the fact that the powerlaw tail of the velocity autocorrelation function is due to the existence of long free paths. This behaviour is insensitive both to the details of the potential, in particular to its short distance features, and to the existence of the topological holes induced by the Pauli blocking. Hence, one expects that the above results should hold for a broad class of systems, including those of the Antisymmetrized Molecular Dynamics and the Quantum Molecular Dynamics.

Quark and Pole Models of Nonleptonic Decays of Charmed Baryons

P. Żenczykowski

Quark and pole models of nonleptonic decays of charmed baryons were analysed from the point of view of their symmetry properties. It was shown that the symmetry structure of parity conserving amplitudes that corresponds to the contribution of the ground-state intermediate baryons differs from the one hitherto employed in the symmetry approach. It was pointed out that the "subtraction" of sea quark effects in hyperon decays leads to an estimate of W-exchange contributions in charmed baryon decays that is significantly smaller than that naively expected on the basis of $SU(4)$. An $SU(2)_W$ constraint questioning the reliability of the factorization technique was also exhibited [1].

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Weak Hyperon Decays: Quark Sea and SU(3) Symmetry Breaking

P. Żenczykowski

An explanation of the difference in the values of the apparent f/d ratios for the S- and P- wave amplitudes of nonleptonic hyperon decays was proposed. The argument was formulated in the framework of the standard pole model with $(56, 0^+)$ ground-state and $(70, 1^-)$ excited baryons as the intermediate states for the P- and S- waves respectively. On the assumption that the dominant part of the deviation of $(f/d)_{P-wave}$ from -1 is due to large quark–sea effects, $SU(3)$ symmetry breaking in energy denominators was shown to lead to a prediction for $(f/d)_{S-wave}$, which is in excellent agreement with experiment. This corroborated previous unitarity calculations which indicated that the matrix elements $< B|H^{p.c.}_{weak}|B' >$ of the parity–conserving weak Hamiltonian between the ground-state baryons are characterized by $f_0/d_0 \approx -1.6$. A brief discussion of the problem of the relative size of the S- and P- wave amplitudes was also given [1].

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Nonleptonic Charmed-Baryon Decays: Symmetry Properties of Parity-Violating Amplitudes

P. Żenczykowski

Effects of pole-model-induced SU(4)-symmetry breaking in parity violating amplitudes of Cabibbo-favoured nonleptonic decays of charmed baryons were studied in some detail. A simple technique generalizing the expressions of current algebra to the case of flavour symmetry breaking in the intermediate states was applied to sum the contributions from all intermediate excited $1/2^-$ baryons of given charm. The technique permits easy discussion of departures from current algebra for any values of $\Delta c/\Delta \omega$ (Δc - charm-noncharm mass difference, $\Delta \omega$ - $1/2^- - 1/2^+$ mass difference). It was found that, in the pole model, the symmetry structure of parity violating amplitudes of charmed baryon decays into an octet baryon and an octet pseudoscalar meson consists of two parts: (i) a term proportional to the standard current algebra expression but much smaller and of the *opposite* sign, and (ii) a term proportional to the factorization contribution, interfering with it destructively. Symmetry structure of parity-violating amplitudes for decays with vector meson production was also given. The full pole model was applied to the description of available data, and compared with the results of current algebra. Possible places of good discrimination between the pole model and current algebra were indicated [1].

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   Z. Phys. **A348** (1994) 17;

2. A.J. Askew, K. Golec-Biernat, J. Kwieciński, A.D. Martin, and P.J. Sutton:
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3. A.J. Askew, D. Graudenz, J. Kwieciński, and A.D. Martin:
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4. A.J. Askew, J. Kwieciński, A.D. Martin, and P.J. Sutton:
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   "Shadowing in the Deuteron and the New F_2^n/F_2^p Measurements",
   Phys. Rev. **D50** (1994) R4;

6. R. Botet and M. Płoszajczak:
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9. T.D. Cohen and W. Broniowski:
   "Pseudo-Goldstone Modes in Isospin-Asymmetric Nuclear Matter",
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    "Vanishing Condensates and Anomalously Light Goldstone Modes in Medium",
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13. W. Florkowski and B.L. Friman:
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14. K. Golec-Biernat:
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22. R. Kamiński and L. Leśniak:
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23. E. Kapuścik:
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    "Electric Polarizability of the Nucleon in the Nambu–Jona-Lasinio Model",
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32. T. Srokowski and M. Płoszajczak:
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33. C.A. Uzes, E. Kapuścik, and A. Horzela:
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II. Contributions to Conferences:

1. W. Florkowski and B.L. Friman:
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5. A. Horzela:
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6. E. Kapuścik:
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8. M. Kutschera and W. Wójcik:
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   Magnetism and Magnetic Materials, to be published;

9. L. Leśniak:
   "Aspects of $f_0(975)$ Analysis",
   Proc. of the Int. Europhysics Conf. on High En. Phys., ed. J. Carr and
   M. Perrottet, Editions Frontiers (1994) p. 65;

10. L. Leśniak:
    "J/Psi Coherent Production on Nuclei by High Energy Muons or Photons",
    Proc. of the XIII International Conference PAN XIII - "Particles and Nuclei",
    Perugia, Italy, June 28 - July 2, 1993, ed. A. Pascolini, World Scientific, 1994,
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11. L. Leśniak:
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    20-24, 1994, Como, Italy, eds. G.M. Prosperi and N. Brambilla, World Scientific,
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    "Threshold Expansions of the $\pi\pi$ and $K\overline{K}$ Scalar Isoscalar Amplitudes",
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III. Reports:

1. B. Badełek and J. Kwieciński:
   "Low Q^2, Low x Region in Electroproduction – an Overview",
   Univ. of Warsaw preprint **IFD/1/1994** (1994);

2. J. Dolejší, W. Florkowski, and J. Hüfner:
   "Critical Scattering at the Chiral Phase Transition and Low-p_T Enhancement of
   Mesons in Ultra-Relativistic Heavy-Ion Collisions",
   Univ. of Heidelberg preprint **HD-TVP-94-18** (1994);

3. W. Florkowski:
   "Large Timescale Fluctuations of the Quark Condensate at High Temperatures",
   Univ. of Heidelberg preprint **HD-TVP-94-12** (1994);

4. R. Kamiński and L. Leśniak:
   "Low Energy Parameters of the $K\overline{K}$ and $\pi\pi$ Scalar-Isoscalar Interactions",
   Report INP No **1675/PH** (1994);

5. J. Kwieciński:
   "QCD Expectations for Deep Inelastic Scattering at Small x and their
   Phenomenological Implications for HERA",
   Report INP No **1674/PH** (1994);

6. J. Kwieciński:
   "Physics at Low x",
   Report INP No **1681/PH** (1994).

CONFERENCES, WORKSHOPS AND EXTERNAL SEMINARS:

P. Bożek:

1. "Correlations, Scaled Factorial Moments and Intermittency",
   International Workshop on Fluctuations in Nuclear Dynamics", Trento, Italy,
   January/February 1994.

W. Broniowski:

1. "Large N-Consistency Conditions",
   University of Maryland, USA, May 1994,
2. "Low-Enegy Sum Rules and Large N-Consistency Conditions",
   CEBAF, USA, May 1994,
3. "Goldstone Bosons in Nuclear Medium",
   University of Bochum, Germany, November 1994,
4. "Physics of CEBAF",
   Department of Nuclear Reactions, INP, Cracow, Poland, December 1994.

W. Florkowski:

1. "Screening of the Meson Fields in the Nambu–Jona-Lasinio Model",
   Institute of Physics, Heidelberg University, Germany, January 1994,
2. "Towards a Chiral Transport Theory",
   Heidelberg-Rostock Workshop, Oberflockenbach, Germany, March 1994,
3. "Dynamic Stability of the Nambu–Jona-Lasinio Gap Equation",
   Institute of Physics, Heidelberg University, Germany, May 1994,
4. "Screening of the Meson Fields in the Nambu–Jona-Lasinio Model",
   Landau-Heisenberg Workshop, Rostock University, Germany, May 1994,
5. "Critical Scattering at the Chiral Phase Transition and Low p_T Enhancement of Mesons in Ultrarelativistic Heavy-Ion Collisions",
   Heidelberg University, Germany, October 1994.

K. Golec-Biernat:

1. "Hot Spots Scenarios for HERA",
   College de France, Paris, March 1994 – invited talk,
2. "Deep Inelastic Electron-Proton Scattering at Small x-Björken",
   Department of Nuclear Reactions, INP, Cracow, Poland, April 1994,
3. "Nonlinear Effects at Small x",
   Rencontres de Blois, France, June 1994 – invited talk.

E. Kapuścik:

1. "New Maxwell Electrodynamics",
   International Conference on Electron Theory
   and Quantum Electrodynamics, NATO Advanced Study Institute, Edirne, Turkey,
   September 1994.

M. Kutschera:

1. "Epoch of Quark-Hadron Transition in the Early Universe",
   CAMK, Warsaw, April 1994,
2. "Nuclear Symmetry Energy at High Densities",
   Department of Nuclear Reactions, INP, Cracow, Poland, May 1994,
3. "Quark-Hadron Transition in the Early Universe",
   Institute of Physics, Jagellonian University, Cracow, Poland, May 1994,
4. "Neutron Stars",
   INP, Cracow, June 1994 – invited talk,

5. "Neutron Stars – Laboratory of Condensed Baryon Matter",
   Polish Physical Society, Cracow, November 1994,

6. "How Many Protons in the Neutron Star ?",
   Institute of Physics, Jagellonian University, Cracow, November 1994.

J. Kwieciński:

1. "QCD Expectations for Deep Inelastic Scattering at Small x and their
   Phenomenological Test at HERA",
   XXIX Rencontre de Moriond – QCD and High Energy Hadronic Interactions,
   Meribel, France, March 1994 – invited talk,

2. "Deep Inelastic Lepton Scattering and Quantum Chromodynamics",
   Theoretical Physics Seminar, Institute of Physics, Jagellonian University, Cracow,
   April 1994 – invited talk,

3. "QCD Expectations for Deep Inelastic Scattering at Small x and their
   Phenomenological Test at HERA",
   Centre de Physique Théorique, Luminy, Marseille, France, April 1994 – invited
   talk,

4. "Physics at Low x",
   QCD 94 Workshop – Quantum Chromodynamics, Montpellier, France, July 1994
   – invited talk,

5. "Three Problems in Electroproduction",
   Collaboration Meeting of E665, Collaboration from FNAL, High Energy Physics
   Department, INP, Cracow, Poland, September 1994.

L. Leśniak:

1. "Study of Strange Mesons Interactions",
   Department of Nuclear Reactions, INP, Cracow, Poland, January 1994,

2. "Scalar Meson Decays: $K\bar{K}$ and $\pi\pi$ Threshold Expansion Parameterss",
   International Conference on Quark Confinement and the Hadron Spectrum, Como,
   Italy, June 1994,

3. "Threshold Expansions of the $\pi\pi$ and $K\bar{K}$ Scalar-Isoscalar Amplitudes",
   International Conference: "1994 Annual Fall Meeting of the American Physical
   Society Division of Nuclear Physics", Williamsburg, USA, October 1994,

4. "Couple Channel Model of Pseudo-Scalar Meson Interactions",
   North Carolina State University, Raleigh, USA, November 1994,

5. "Scalar Meson Structure and Intermeson Interactions",
   CEBAF, Newport News, USA, November 1994,

6. "Production Mechanics and Properties of Scalar Mesons",
   High Energy Physics Department, INP, Cracow, Poland, December 1994.

P. Żenczykowski:

1. "Weak Decays of Baryons",
   Department of Nuclear Reactions, INP, Cracow, Poland, November 1994.

LECTURES AND COURSES:

W. Czyż

1. "Quantum Mechanics",
   lectures for graduate students of Physics at the Institute of Physics, Jagellonian University and Institute of Nuclear Physics.

E. Kapuścik

1. "Introduction to Nuclear and Elementary Particle Physics",
   lectures for students of physics at the Cracow Pedagogical University, Cracow 1994,
2. "Classical Electrodynamics",
   lectures for students of physics at the Cracow Pedagogical University, Cracow 1994,
3. "General Properties of Spacetime",
   lectures for physics teachers at the Cracow Pedagogical University, Cracow 1994.

M. Kutschera

1. "Introduction to Theoretical Astrophysics",
   lectures for students of physics at the Jagellonian University, Cracow, 1994.

J. Kwieciński

1. "Recent Developments in Particle Physics",
   advanced lectures for physics teachers at the Cracow Pedagogical University, Cracow 1994,
2. "Small x Physics",
   Educational Workshop – Basics of the Hadron Structure,
   Warsaw, April 1994 – invited lectures.

INTERNAL SEMINARS:

1. *H. Arodź* (Jagellonian University):
   "Vortices in Relativistic Field-Theoretical Models";
2. *A.O. Barut* (University of Colorado, USA):
   "Electromagnetic Interactions at Short Distances";
3. *P. Bożek* :
   "Subtreshold Production, Experiment and Model of Instabilities in Heavy Ion Collisions";
4. *M. Cerkaski* :
   "Introduction to Geometric Formulation of the Dynamics on the Base of the Dirichlet-Riemann Model";
5. *M. Cerkaski*:
   "Investigation of the Stationary Solutions in the Sympletic Model for Determining of the Nuclear Rotational Bands";
6. *T. Chmaj* (CAMK Warsaw) :
   "Gravitating Solitons";

7. *W. Czyż*:
   "Antishadowing and Nuclear Optics";

8. *S. Fayans* (Kurchatov Institute of Nuclear Energy, Russia):
   "Novel Density - Functional Approach to Nuclei";

9. *W. Florkowski*:
   "Critical Scattering at the Chiral Phase Transition and Low-p_T Inhancement of Mesons in Ultrarelativistic Heavy-Ion Collisions";

10. *K. Golec-Biernat*:
    "Nonlinear QCD Effects in DIS at Small x";

11. *A. Horzela* :
    "Galilean Covariant Generalization of the Harmonic Oscillator Lie Algebra";

12. *A. Horzela*:
    "Hydrodynamical Aspects of Wave Mechanics";

13. *P. Kamiński* (Department of Nuclear Reactions):
    "Tunneling Effects in SU(2) Models";

14. *E. Kapuścik*:
    "Who is right: Ylmaz or Einstein ?";

15. *E. Kapuścik*:
    "Some Remarks on Gravitation and Electromagnetism";

16. *M. Kutschera*:
    "Symmetry Energy at High Densities";

17. *J. Kwieciński*:
    "Structure of Hadronic Final State in Electroproduction";

18. *L. Leśniak*:
    "Threshold Parameters of $\pi\pi$ and $K\bar{K}$ Interactions";

19. *M. Michalec*:
    "Field Theoretical Aspects of Mechanical Forces";

20. *E.N. Nikolov* (University of Bochum, Germany):
    "Nucleon Polarizabilities in the NJL Model";

21. *S. Riess* (University of Hamburg, Germany):
    "Electroweak Physics Processes at HERA";

22. *S. Stachniewicz*:
    "Models of Stars with Very Dense Cores";

23. *A. Staruszkiewicz* (Jagellonian University):
    "Quantum Mechanics of Electrical Charge";

24. *P.J. Sutton* (Durham University, England):
    "QCD Predictions for the Transverse Energy Flow in Deep-Inelastic Scattering at Small x";

25. *A. Szczepaniak* (North Carolina State University, USA):
    "The Constituent Quark Structure";

26. *A. Szczurek* (Department of Nuclear Reactions):
    "New Aspects of the Old Meson Cloud in the Nucleon";

27. *J. Wosiek* (Jagellonian University):
    "Critical Properties of State Density in Statistical Physics";

28. *S. Wycech* (Soltan Institute for Nuclear Studies, Warsaw):
    "Meson Production near Threshold";

29. *V.S. Yarunin* (ZIBJ Dubna):
    "Path Integrals for Quantum Dynamics";
30. *K. Zalewski* (Jagellonian University):
    "Inclusive Decays of Particles with *b* Quark";
31. *P. Żenczykowski*:
    "Weak Decays of Hyperons".

SHORT- AND LONG-TERM VISITORS TO THE DEPARTMENT:

1. *Dr E. Nikolov* – Department of Theoretical Physics, University of Bochum, Bochum, Germany, April 1994;
2. *Prof. A.D. Martin* – Department of Theoretical Physics, University of Durham, England, April 1994;
3. *Dr P.J. Sutton* – Department of Theoretical Physics, University of Manchester, England, April, September and November/December 1994;
4. *Prof. A. Jannussis* – Department of Theoretical Physics, University of Patras, Greece, April 1994;
5. *Prof. A.O. Barut* – Department of Theoretical Physics, University of Colorado, Boulder, USA, May 1994;
6. *Dr A. Steiner* – Department of Theoretical Physics, University of Regensburg, Germany, June 1994;
7. *Prof. Ch.A. Uzes* – Department of Theoretical Physics, University of Georgia, Athens, USA, June 1994;
8. *Prof. V.S. Yarunin* – JINR, Dubna, Russia, June 1994;
9. *Dr A. Szczepaniak* – North Carolina State University, Raleigh, USA, September 1994;
10. *Dr S. Riess* – Department of Experimental Physics, University of Hamburg, Germany, September/October 1994.

Department of High Energy Physics

Section V

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Piotr Gruszecki, M.Sc.
Lidia Görlich, Ph.D.
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H1 ($e+p$ interaction 30 GeV x 820 GeV at HERA), DESY, Hamburg

NA32 (π^-Cu interactions at 200 GeV at SPS), CERN, Geneva

ATLAS (Preparation of the experiment at the LHC 7 TeV x 7 TeV), CERN, Geneva

BELLE (Preparation of experiment at "B-factory", e^+e^- interactions at KEK), Tsukuda, Japan

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Janusz Chwastowski, Ph.D.   Maciej Przybycień, M.Sc. - research student
Jan Figiel, Assoc. Professor   Piotr Stefański, Ph.D.
Ewa Gładysz-Dziaduś, Ph.D.   Piotr Stopa, Ph.D.
Zbigniew Jakubowski, Ph.D.   Maciej Zachara, Ph.D.
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E665 (μ^+p interactions at 500 GeV, TEVATRON), Fermilab, Batavia, USA

NA35/NA49 (heavy ion interactions on nuclear targets at 60 and 200 GeV/nucleon, SPS), CERN, Geneva

ALICE (preparation of the experiment with ultrarelativistics heavy ions at the LHC 3 A TeV x 3 A TeV), CERN, Geneva

NA22-EHS ($\Pi^+, K^+, p-p$ interactions at 250 GeV, SPS), CERN, Geneva

WA59 ($\nu,\bar{\nu}$ interactions at 250GeV, SPS), CERN, Geneva

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Monika Szarska, Ph.D.   Krzysztof Woźniak, Ph.D.
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Technical Staff (6):

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Experiments and International Collaborations of HENI:

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KLMM (^{16}O,^{28}Si,^{32}S - emulsion interactions at 15, 60 and 200 GeV/nucleon), BNL-Brookhaven, CERN - Geneva
KLMT (π^- - emulsion interactions at 525 GeV), Fermilab, Batavia, USA
PHOBOS (Preparation of the experiment at the Relativistic Heavy Ion Collider 100A GeV x 100A GeV), Brookhaven, USA.

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Zofia Kawula

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participation in H1, ZEUS, ATLAS, DELPHI Collaborations.

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(on leave of absence, the group is presently   Marek Stodulski, M.Sc.Eng.
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Administration:

Mrs Ewa Bukała[1]
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Ms Maria Mielnik, M.A.[1]

GRANTS:

A. From the State Committee for Scientific Research (KBN)

1. Prof. R. Hołyński
Grant No 203419101, 1991–94
"*Composition, Energy Spectra and Nuclear Interactions of Cosmic Rays*".

2. Prof. J. Bartke, together with Prof. E. Skrzypczak of the Warsaw University
Grant No 204369101, 1991–94
"*Collisions of Relativistic Nuclei*".

3. Prof. R. Hołyński
Grant No 203799101, 1991–94
"*Study of Nucleus–Nucleus Interactions at Highest Accelerator Energies*".

4. Prof. S. Jadach
Grant No 223729102, 1992–94
"*Predictions of Standard Model for Future Colliders*".

5. Assoc. Prof. J. Figiel
Grant No 2P30204104, 1993–94
"*Investigation of Muon-Nucleon and Muon-Nucleus Interactions at the TEVATRON (Experiment E665)*".

6. Prof. T. Coghen
Grant No 2P30215104, 1993–95
"*Participation in the PHOBOS Experiment: Study of Correlations and Fluctuations of Low p_t Particles Produced in Heavy Ion Interactions in the Future RHIC Collider at BNL*".

7. Dr Eng. K. Pakoński
Grant No 3P40700604, 1993–96
"*Technology of Manufacturing Extremely Stiff Thin Shells Made of Carbon-Carbon Composites*".

8. Prof. M. Jeżabek
Grant No 2P30225206, 1994 -96
"*Production of Short-Lived Heavy Particles in the Standard Model and its Generalization*".

9. Dr Z. Hajduk
Grant No 2P30204706, 1994-96
"*Triggering Systems for High Energy Experiments at High Luminosity Collider*".

10. Dr A. Zalewska
Grant No 2P30211206, 1994-96
"*Study of Baryons Containing the b Kwark in the Hadronic Z^0 Decays*".

11. Prof. M. Turała, together with Prof. D. Kisielewska of the Academy of Mining and Metallurgy, Cracow, and Prof. J. Królikowski of the Warsaw University
Special grant No 343/SPUB/P3/201/94, 1994
"*Preparation of the Physics Programme and Detectors for Studying Proton–Proton Interactions at 16 TeV in the LHC Collider*".

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12. Dr H. Pałka together with Prof. R. Sosnowski from the Institute of Nuclear Problems, Warsaw
    Special grant No 621/E-78/SPUB/P3/210/94, 1994
    "Participation in the DELPHI Experiment".

13. Prof. A. Eskreys and Prof. K. Rybicki together with Prof. D. Kisielewska from the Academy of Mining and Metallurgy and Prof. J. Zakrzewski from the Warsaw University
    Special grant No 113/E-343/SPUB/P3/202/94, 1994
    "Investigation of Electron-Proton Interactions in the ZEUS and H1 Experiments at HERA, Hamburg".

B. From the German–Polish Foundation

1. Prof. A. Eskreys and Prof. K. Rybicki, together with Prof. D. Kisielewska of the Academy of Mining and Metallurgy, Cracow, and Prof. J. Zakrzewski of the Warsaw University
   Grant No 506/92, 1993–95
   "Experiments ZEUS and H1 at the HERA Collider in DESY".

2. Prof. J. Bartke, together with Prof. E. Skrzypczak of Warsaw University
   Grant No 565/93/LN, 1993–95
   "Experiment NA49 with Ultrarelativistic Heavy Ions at the CERN SPS".

C. From other sources

1. British Council/KBN
   No WAR/992/012, 1994, Dr Z. Hajduk
   Personnel exchange.

2. French-Polish Convention IN2P3

   a) No 72, LAPP-Annecy 1994, Prof. S. Jadach

   b) No 89-54, LAL Orsay 1994, Dr G. Nowak

   c) No 92-66, LPN Univ. Nantes, 1994, Prof. J. Bartke together with Prof. J. Petykiewicz from Warsaw Technical University

   d) No 92-70, CRN Strasbourg, 1994, Dr G. Polok

   e) No 94-CS3, CRN Strasbourg, 1994, Dr G. Polok

3. Deutsche Forschungsgemeinschaft DFG 436 POL 173 193 S, 1994, Prof. M. Jeżabek together with Prof. J.M. Kühn from the Karlsruhe University.

OVERVIEW:

The Department originated from a group of cosmic ray and high energy physicists created by the late Prof. M. Mięsowicz in the early fifties. This group consisted of people originally employed and housed at the Academy of Mining and Metallurgy. In 1955 some of them were transferred to the so-called Cracow Branch of the High Energy Physics Department of the Institute of Nuclear Studies in Warsaw, which rapidly increased in number and in 1970 became a Department in the Institute of Nuclear Physics in Cracow. The Department is located in a separate building at the campus of the Academy of Mining and Metallurgy, which facilitates the close collaboration with the research groups from the latter as well as with the theorists from the Jagellonian University. Joint weekly seminars represent a more than 30-years old tradition of this high energy physics community, where the theorists from the Department of Theoretical

Physics of our Institute also play an important role. An important part of the activities of the Department is teaching and training of students from the academic community in Cracow on the M.Sc. and Ph.D. level.

Joint research, teaching and academic training in high energy physics are carried out within the M. Mięsowicz Inter-Institute Centre for High Energy Physics, which was formed by an agreement between the Academy of Mining and Metallurgy, the Jagellonian University and our Institute to honour the late Prof. Marian Mięsowicz, the founder and leader of the high energy physics community in Cracow, as well as to formalize and facilitate the collaboration between the participants from the above-mentioned institutions. Thus in addition to the staff of our department listed above, several task teams working on some projects such as DELPHI, H1, ZEUS, and the future ATLAS, and PHOBOS experiments include people from other departments of our Institute and other institutions forming the M. Mięsowicz Centre for High Energy Physics.

In 1994, the research in the Department continued to cover a variety of problems of experimental and theoretical high energy elementary particle physics: hadronic and leptonic interactions with nucleons and nuclei (mainly characteristics of particle production, including heavy quark physics), e^+e^- interactions and tests of the Standard Model (also evaluation of radiative corrections), ultrarelativistic heavy ion interactions and search for the quark-gluon plasma, as well as spectra, composition and interactions of high energy cosmic ray particles. Research on detectors and development of apparatus for high energy physics experiments at future accelerators such as LHC or RHIC were also carried out.

The experiments in which the Department participates are mainly carried out within the framework of large international collaborations formed at the leading laboratories where large accelerators have been or will be constructed: the European Laboratory for Nuclear Research CERN in Geneva, DESY in Hamburg, Brookhaven National Laboratory, and Fermilab, Batavia in the USA. In addition in 1994 our Department joined the D0 Collaboration at the TEVATRON in Fermilab and the BELLE Collaboration at KEK. In 1994 this work brought the publication of further very interesting results from the e^+e^- experiment DELPHI at CERN and gave new physics results from the e^-p experiments H1 and ZEUS at DESY, the μp E665 experiment in Fermilab and important results on heavy ion collisions from BNL and CERN. Some of these can be found by the reader in the following pages together with interesting results obtained in other experiments and by our Theory Group.

It should be pointed out that our research would be practically impossible without the financial support of the State Committee for Scientific Research in Poland, the German-Polish Foundation and last not least the generous help of DESY - Hamburg which for several years has been funding most of the per-diem expenses of our staff and students in Hamburg as well as the purchase of computer equipment. We have also been helped by other institutions, such as CERN, Fermilab, KEK, MIT, and MPI-Munich. Their support is gratefully acknowledged.

Prof. T. Coghen

REPORTS ON RESEARCH:

THE DELPHI EXPERIMENT AT LEP [1]

The DELPHI Collaboration [2]

Cracow DELPHI group:
P. Brückman, P. Gruszecki, Z. Hajduk, P. Jałocha, K. Korcyl, W. Krupiński,
W. Kucewicz, T. Lesiak, J. Michałowski, B. Muryn, G. Polok, H. Pałka, K. Rybicki,
M. Witek, and A. Zalewska

Physicists, engineers and technicians contributing to the project:
A. Adamski, J. Błocki, B. Dąbrowski, M. Despet, A. Florek, B. Florek, K. Gałuszka,
T. Gdański, J. Godlewski, E. Kochan, M. Stodulski, Z. Stopa, A. Strączek, M. Stręk,
and M. Turała

DELPHI (Detector for Electrons, Leptons, Photons and Hadrons Identification) is one of four multi-purpose detectors installed at the LEP accelerator at CERN.

In 1993 LEP was working since May till December at the Z^0 mass peak. During this time about 1,500,000 Z^0 events have been collected by the DELPHI detector. A total number of about 3,700,000 Z^0 particles has been collected by DELPHI since the LEP startup in 1989 till the end of 1994.

The analysis of the data taken since 1990 till 1993 resulted in more than 20 publications and in tens of conference contributions. They cover a wide range of physics: precise tests of the standard model, search for new particles, e.g. Higgs bosons, studies of the quark hadronisation processes, studies of heavy quarks and τ leptons and studies of the $\gamma\gamma$ interactions. Physicists from the Cracow group have participated in the study of Λ_b baryons and in the study of $\gamma\gamma$ interactions. A study of the resonance production in $\gamma\gamma$ interactions and a discussion of the b quark polarization measurement are presented below as separate contributions.

Apart from the data analysis, the Cracow DELPHI group has helped during the data tak-
ing period and was co-responsible for three subdetectors: the Microvertex Detector, the Inner
Detector and the Ring Imaging Cherenkov detectors (RICH).

The data acquisition, the safety of the detector, the quality of the data and the data process-
ing had to be controlled during runs. The Cracow group had more than 60 shifts, participating
in first three kinds of controls.

Last year was crucial for the Microvertex Detector. An almost completely rebuilt detector
was installed in the experiment in February 1994. The Cracow group has contributed to this
project working on the data acquisition and the online analysis programs as well as on the
detector simulation program and the detector data base for simulation. The group took also
part in running the Microvertex Detector and preparing it for the data taking. The 1994 detector
is a part of an even bigger upgrade, initially planned for 1995 and now forseen in 1996. The
contribution of our group consists of the tests of silicon detectors, building reinforcement bars
for two new layers, participating in mounting of the inner layer modules and building additional
voltage supplies for silicon detectors. A more detailed description of the work done in Cracow
for the actual Microvertex detector and for its upgrade is given below as a separate contribution.

The Inner Detector, working in the experiment since 1989 till 1994 was a common respon-
sibility of the DELPHI group from the NIKHEF Institute in Amsterdam and of the Cracow
DELPHI group. As every year, both groups were preparing the detector and the data ac-
quisition programs for running, took shifts during runs and performed the calibration of the
detector using collected data. In parallel, the new, longer Inner Detector has been constructed
and tested. It will be installed in the experiment before the data taking period in 1995 and
will upgrade the DELPHI capability to analyse data at LEP200. As before, the Inner Detector
consists of two parts: the jet chamber and the trigger layers. The jet chamber was constructed
by the NIKHEF group in Amsterdam. The trigger layers, being a common responsibility of
CERN, Liverpool and Cracow, were constructed at CERN. They are described more in detail
in a separate contribution below.

In 1994 the RICH detectors have been working during the whole data taking period, what
should result in larger possibilities of the data analyses. The Cracow group has contributed by
working on the detector programs.

The $\gamma\gamma$ Resonance Production in the DELPHI Experiment

B. Muryn

By now the two-photon exclusive physics was only a small domain within the extensive Z°
physics program of the DELPHI Collaboration. The main reason is that the DELPHI detector
has rather limited possibilities to detect low energy particles, which additionally are peaked
forwards due to the frequent boost along the z-axis, typical for $\gamma\gamma$ interaction. Several channels
have been investigated to answer a question if such a specific final states can be reliably observed.
The results presented here have been obtained from data taken with the DELPHI detector at
the LEP electron-positon storage ring in 1992. The integrated luminosity for this period is
$28.7\ pb^{-1}$. One field of the study is the $f_2(1273)$, the most representative resonance produced
in untagged $\gamma\gamma \rightarrow \pi^+\pi^-$ final state. Four body final states $\gamma\gamma \rightarrow \pi^+\pi^-\pi^+\pi^-$ and $\gamma\gamma \rightarrow K\pi\pi\pi$
have also been studied where $\rho^0\rho^0$ vector meson pair production and $\eta_c(2980)$ bottomium state
are observed. The full analysis of all above-mentioned channels is presented in [1]. Here an
example of analysis of $\gamma\gamma \rightarrow f_2(1273) \rightarrow \pi^+\pi^-$ is presented.

Selected events had to pass selection criteria concerning the total energy $E_{tot} < 9\ GeV$,
the total electric charge $Q = 0$ and good primary vertex fit. All tracks taken into account were
reconstructed owing to information from tracking detectors (summary of the principal properties

is presented in [4]). Very steep p_t^2 distribution, characteristic for the $\gamma\gamma$ interactions (see Fig. 1a), suggests that selected events are predominantly produced in $\gamma\gamma$ collisions. The invariant mass distribution shows a clear signal of the $f_2(1273)$ resonance (see Fig. 1b).
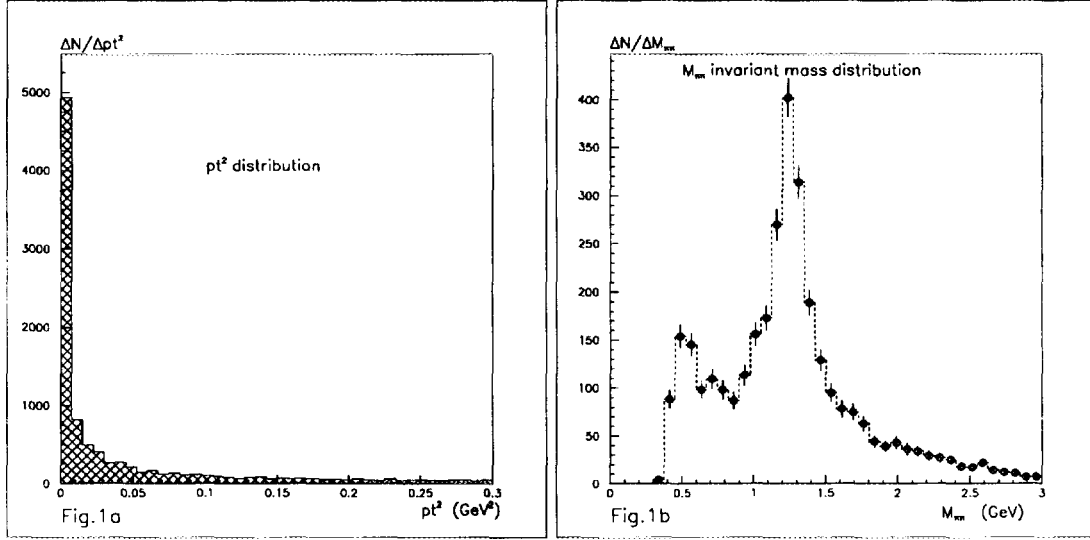
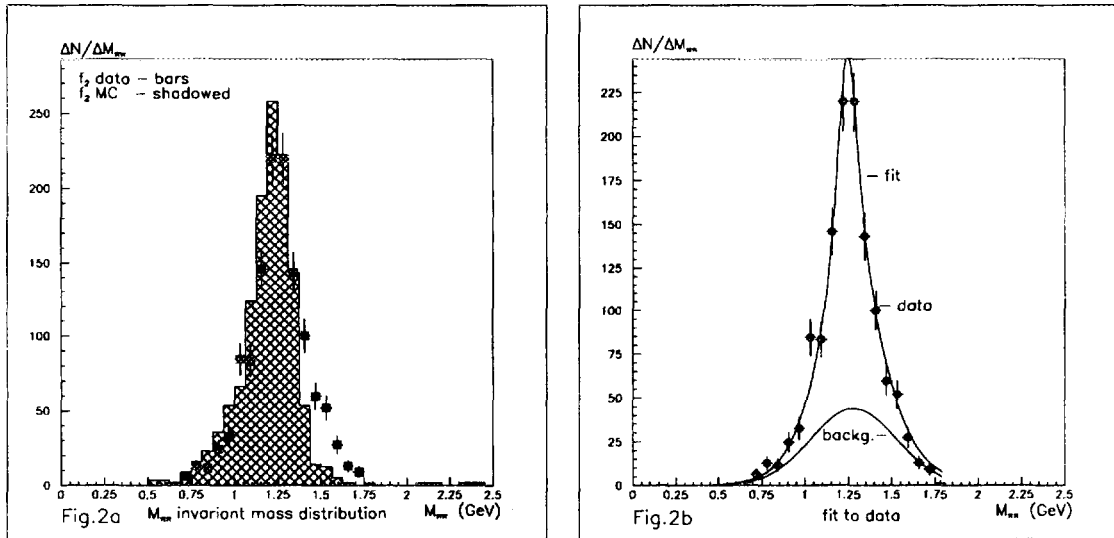Figure 1: a) p_t^2 distribution, b) Invariant mass distribution, $M_{\pi^+\pi^-}$.

Figure 2: Invariant mass distributions, $M_{\pi^+\pi^-}$ a) after all cuts together with the MC prediction, b) Result of the fit (see text).

Further subtraction of $\gamma\gamma \to K^+K^-$, $\gamma\gamma \to e^+e^-$ and $\gamma\gamma \to \mu^+\mu^-$ background events has been done using mainly the dE/dx from TPC. The $M_{\pi^+\pi^-}$ invariant mass distribution for events which passed additional cleaning cuts are shown in Fig. 2a together with MC generated events after identical kinematical cuts. The Breit-Wigner function [2] together with residual non-resonant $\gamma\gamma \to \pi^+\pi^-$ contribution has been fitted, yielding parameters which are in agreement with those obtained from other $\gamma\gamma$ experiments and listed in Particle Data. The result of the fit and the shape of the continuum are plotted in Fig. 2b.

To investigate the origin of the background the angular distributions of $cos(\theta^*)$ (θ^* is the angle of one of the f_2 decay products calculated in $\gamma\gamma$ reference frame) was plotted for both, the f_2 resonance and events with $M_{\pi^+\pi^-}$ invariant mass outside the resonance region. The comparison of both is consistent with a hypothesis [3] that observed $\pi^+\pi^-$ non-resonant background has a similar helicity structure as $\pi^+\pi^-$ system originating from f_2 decay.

Our preliminary studies show that the DELPHI detector is well suited to explore the exclusive, low multiplicity, final states produced in $\gamma\gamma$ interactions. The simple selection criteria lead to clean untagged $\gamma\gamma$ sample.

References:

1. B. Muryn, *Proceedings of the Workshop on Two-Photon Physics at LEP and HERA - Lund*, **26-28 May 1994, p. 64**;

2. M. Poppe, *Int. Journ. Mod. Phys.* **A1** (1986) 545., also DESY 86-014;

3. H. Krasemann and J. Vermaseren, *Nucl. Phys.* **B184** (1981) 265, 296;

4. P. Aarnio et. al., *Nuclear Instruments and Methods in Physics Research* **A303** (1991) 233-276.

An Attempt to Study the Λ_b Polarization

P. Brückman

LEP is an excellent accelerator for exploring reactions in which b and c quarks take part. Z^0 decays in 15.4% to $b\bar{b}$ pair and in 11.9.% of cases to $c\bar{c}$ pair.

In particular, the analysis of baryons containing heavy quark b has been of growing interest to all LEP experiments over last few years. A substantial majority of results on b baryons, especially on the lightest baryonic state – Λ_b^0, come from the LEP experiments.

Heavy baryon studies offer a unique possibility of investigating a series of phenomena inaccessible in case of heavy mesons. One of such interesting effects is a strong longitudinal polarization of Λ_b being a direct consequence of the b ($\bar{b}$) polarization in Z^0 decay. The latter is precisely determined in the framework of the Standard Model and equals 0.936. Its full transfer to the ground baryonic state Λ_b makes an important prediction of the Heavy Quark Effective Theory (HQET). The indirect hadronization through heavier Σ and Σ^* states could lead to a substantial depolarization of the heavy quark. Therefore, Λ_b polarization measurement should give an important hint about heavy barion hadronization processes and constitutes a subsequent test of HQET.

The subject of interest are semileptonic decays of Λ_b^0 with Λ_s^0 in the final state. Hence the studied inclusive decay channels are the following:
$$\Lambda_b^0 \rightarrow \Lambda_c^+ + e^- + \overline{\nu_e} \rightarrow \Lambda_s^0 + e^- + \overline{\nu_e} + X$$
or
$$\Lambda_b^0 \rightarrow \Lambda_c^+ + \mu^- + \overline{\nu_\mu} \rightarrow \Lambda_s^0 + \mu^- + \overline{\nu_\mu} + X$$
and the charge coupled ones.

The inclusive semileptonic decays have been chosen for two reasons. First of all, there is a relatively easy way of Λ_b^0 tagging through Λ^0–lepton correlations. Besides, the branching ratios for these decay modes are fairly high. Secondly, for the semileptonic decay there is a precise Standard Model prediction on the double-differential (θ angle & energy) distribution of decay products in the Λ_b^0 rest frame. Not going into details, we may say that polarization introduces an asymmetry in angular distributions of all decay products. Unfortunately the strongest dependence on the b quark polarization lies in a neutrino which is experimentally the most difficult to access. Besides, since we are not able to fully reconstruct a Λ_b^0 we are effectively limited to the laboratory frame observables. However, from the data we can extract

energy spectra of both charged lepton and neutrino. The latter is reconstructed using the hemisphere missing energy method and hence has a considerable error. Since the mean values of the above spectra are respectively correlated and anticorrelated with polarization, the variable defined as:

$$y = <E_l> / <E_\nu>,$$

turns out to be highly sensitive to Λ_b^0 polarization. Moreover, this observable is practically independent of fragmentation uncertainties which allows us to overcome the substantial problem of Λ_b^0 energy evaluation.

Such a measurement has already been performed by the ALEPH collaboration and the result on the polarization which they got, is:

$$P_{\Lambda_b} = -0.30^{+.32}_{-.27}(stat.) \pm 0.04(sys) \text{ [1]}.$$

This result, although not precise, indicates the existence of a strong depolarization mechanism in the Λ_b^0 hadronization. The analysis has been based on over 1.5 million Z^0 events coming from 1991–1993 data-taking periods.

The aim of my analysis is to perform similar measurement on the DELPHI data. Up to now I have performed extensive analysis based on the pure LUND generations and on the full DELPHI Monte Carlo simulation (DELSIM). I also prepared a routine introducing polarization for Λ_b^0 semileptonic decays in DELSIM. Using this tool over 20,000 polarized Λ_b^0 events have been generated so far. Now I am working with the DELPHI real data coming from the years 1991–93.

References:

1. ALEPH Collaboration: Measurement of the Λ_b Polarization at LEP, contribution to the Glasgow ICHEP 94 Conference.

The Microvertex Detector

J. Blocki, P. Brückman, B. Florek, T. Gdański, J. Godlewski, P. Jalocha, W. Kucewicz, J. Michalowski, B. Muryn, H. Palka, and A. Zalewska

Since its first installation in 1990 the DELPHI silicon strip Microvertex detector has proven to be an essential tool to study short lived particle decays and to improve charged particles track reconstruction. The measurement capabilities of the detector have been increasing through the years of its operation.

The first detector consisted of two concentric layers (at R = 9 and 11 cm) of single sided silicon detectors which provided two high precision points on a track in the plane transverse to the beam.

After the reduction of LEP beam pipe diameter in 1991, the addition of a third single sided layer (at R = 6.3 cm) became possible. A third measurement point close to the interaction region together with the new lighter beam pipe have increased considerably track and vertex reconstruction capabilities of the detector.

The 1994 Vertex Detector

The new Microvertex detector for 1994 data taking has been constructed to allow for three coordinate readout (Rϕ and z) [1]. Two of the three layers (the innermost and the outermost) have been equipped with double sided detectors providing simultaneous measurements of Rϕ and z coordinates of a track with a precision of 8 μm and 11 μm respectively. This increases the accuracy of lifetime measurements and improves the efficiency for reconstruction and identification of heavy quark final states. Fig. 3 shows a hadronic Z^0 decay event recorded in the new detector.
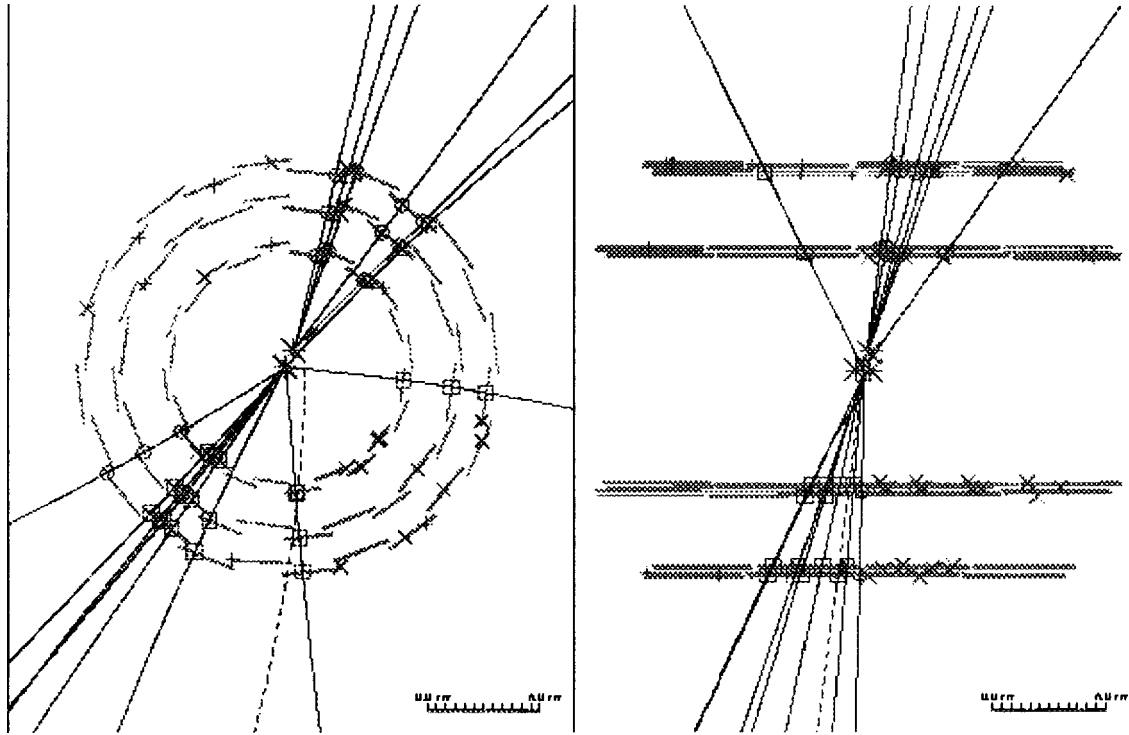
Figure 3: Z^0 decay to hadrons observed in the new Delphi Microvertex detector in both projections : Rϕ (left) and z (right). Circles and squares denote hits associated to tracks, crosses correspond to unassociated hits.

The on-line data acquisition system is under responsibility of the Cracow group. It has been expanded to 96 DSP's (Digital Signal Processors of DSP56001 type manufactured by Motorola) and the total number of analog channels being analyzed reached 125952 for the 1994 Microvertex detector. The data selection criteria of the DSP's analysis were widened to accommodate wider clusters and negative polarity of signals on the detector n-side.

Larger data size due to more analog channels and wider selection criteria, as well as higher trigger rate due to increased LEP luminosity and harder background conditions, demanded improved performance of the data acquisition system. This required rewriting of the code supervising the DSP farm and modifying the readout strategies.

For fast event viewing of the two-dimensional detectors the graphics part of the on-line event display was completely rewritten allowing for viewing the microvertex detector in three dimensions, as well as in various cross-sections. For example, Fig. 4 shows signal amplitudes as a function of the readout channel index.

Physicists from the Cracow DELPHI group have prepared the full simulation program and the detector ideal data base for the 1994 Microvertex detector. The full simulation program, called VDSIM, is one of the constituents of the whole detector simulation package (DELSIM). VDSIM controls tracking in the material, generates charge due to electron-hole pair creation process in silicon and simulates charge transport and charge collection on the detector strips. Further, charge collected on strips is expressed in terms of signal pulses and assigned to corresponding channels of the front-end electronics. Finally VDSIM converts all the information collected for a given event into the format identical with the real data format.

The major change of the full simulation program for the Microvertex detector in 1994, as compared to the previous version, consisted in the introduction of signal collection on the detector n-side. The present VDSIM has more than 4300 lines of FORTRAN code divided into
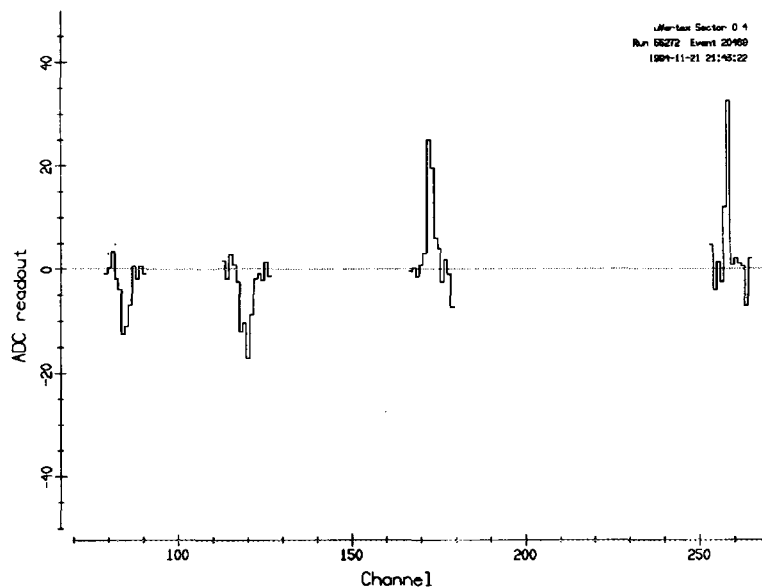
Figure 4: Signals of particles being output of the on-line analysis. Positive signals come from the detector p-side, negative - from the detector n-side.

42 subroutines. Currently the program is used in the production of the 1994 Monte Carlo events for the DELPHI experiment.

Future upgrade

The new upgrade of the Microvertex detector started in 1994 to meet requirements of physics program of high energy phase of LEP (LEP200). Its main physics motivation is to improve further the b tagging capabilities and to increase the efficiency of Higgs boson searches by increasing the solid angle coverage. The middle and outermost layers are being rebuilt and extended in length to 48 cm to cover polar angles down to 25° while the innermost 28 cm long layer remains intact. Except for the barrel extension, three discs of silicon detectors in the forward/backward region are introduced to cover the angles between 15° and 25°. The Cracow Delphi Group participates in the upgrade of the barrel part of the detector. The new outermost layer is composed of doublets of single sided detectors measuring $R\phi$ and z coordinates separately. This solution was chosen instead of double-sided detectors because of its better signal-to-noise performance for long readout layers. The middle layer is of hybrid type with 24 cm long single-sided sector close to right incidence angles and two 12 cm long double-sided sectors at the ends. The arrangement of single-sided and double-sided detectors in the three layers allows at least two space points to be measured for the majority of tracks.

The long readout layers impose strict requirements on the quality of the detectors used. Thorough acceptance tests have been performed in the Cracow laboratory for more than 100 single sided $R\phi$ detectors. The acceptance criteria included such detector parameters as leakage current from active area, depletion voltage, coupling capacitance, bias resistance and a number of defective channels. The tested detectors (from Hamamatsu Photonics, Japan) appeared to be of very good quality, with a typical leakage current below 100 nA from active area of $\approx$ 20 cm^2 (640 readout strips).

For the first time the assembly of the silicon detectors has been possible in Cracow thanks to new equipment in our silicon laboratory : high precision movable stages and a manual wedge

bonder which was adapted in-house to allow automatic bonding. The quarter modules (i.e. detector pairs) for a half of the middle layer have been assembled in our lab (see Fig. 5). The assembly included precise alignment of strips on both detectors, joining the detectors and making electrical connections between the strips by ultrasonic bonding.
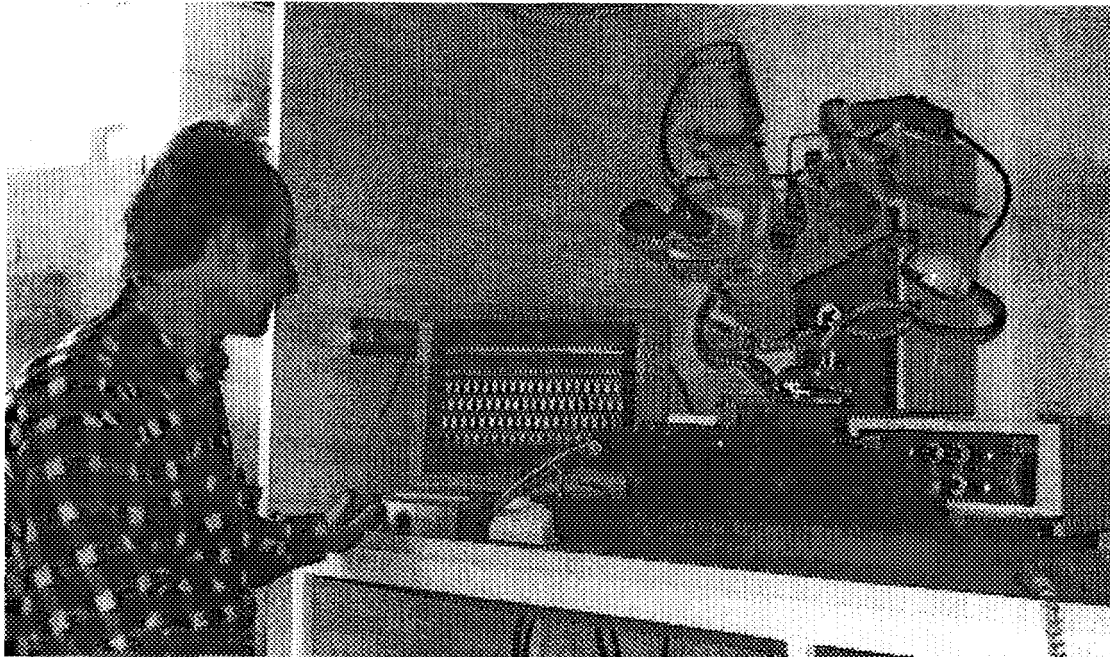
Figure 5: Mr Bogdan Florek doing bonding of the detectors.

Cracow was also responsible for designing, prototyping and constructing of module supports for the new long layers. The necessary stiffness of the 48 cm long silicon modules has been achieved by use of U-shaped support beams made of kevlar-carbon fibre composite. They ensure the module deflection below 3 μm per gram of load, while the additional material constitutes 0.15 % of a radiation length.

The new detector was scheduled to be ready for LEP startup in March 1995. However, due to problems with manufacturing of Rz detectors its insertion to DELPHI is postponed till the next LEP shutdown.

References:

1. DELPHI Collaboration: The DELPHI Silicon Strip Microvertex Detector with Double Sided Readout, contribution to the Glasgow ICHEP'94 Conference.

Straw Tube Tracker in DELPHI Experiment

From INP Cracow: A. Florek, Z. Hajduk, and J. Michalowski

As part of an upgrade of the inner tracking system of DELPHI, a straw tube detector has been built to replace the ID Trigger Layers. The main reason was to extend polar angle coverage from $\theta = 30^\circ$ down to 15° for triggering. However, since in WW physics a substantial number of tracks goes in forward direction (where DELPHI suffers from moderate quality of tracking) a possibility of tracking with straws in that region has been investigated as well. To exploit the tracking capabilities of straws we foresee to use a drift time measurements. The idea has been checked with the prototype studies in the test beam. The detector is going to be installed within DELPHI during the winter shutdown '94/'95.

The straw detector is cylindrical with active length of 210 cm. It consists of 5 concentric layers at radii between 24 cm and 27 cm. Each layer has 192 straws (thin walled tubes) and the diameter of straws changes gradually from layer to layer to ensure minimal dead spaces. The tubes in each subsequent layer are staggered relative to initial layer in order to reduce dead spaces and improve double track resolution of the detector. The straws have walls of 30 μm mylar covered double sided with 1000 Å of aluminium.

The straws were mounted on a support structure consisting of two aluminium end flanges glued onto central carbon fiber cylinder[1] of 47.8 cm diameter and 1.6 mm thickness. Into the carbon cylinder were incorporated two 40 μm thick aluminium meshes to ensure good electro-magnetic shielding properties.

Each straw was then glued with conductive epoxy to special coaxial endplugs. The role of endpieces was to hold axially a sense wire and mount the straw into endflanges. The wire was held in position by means of special crimped pins. To eliminate the gravitational sag, straws have been tensioned to 1.2 kg on a jig and then equipped with wire 40 μm strung to 200 g tension. Then whole assembly of each counting tube has been tested with Fe-55 source for uniformity of gains (Fig. 6) and possible defects, and glued onto the carrying structure.

The electronic chain of the detector consists of:

- on the chamber: coupling network (HV decoupling) and fast preamplifier,
- in the counting room: fast active split, multiplexer and TDC (for drift time measurements), shaper, trigger module and FADC (for triggering and BCO determination).

To assess the expected performance of the detector we have conducted a beam test of the 5*8 tubes prototype. The detector has been exposed to 145 GeV pion beam in North Area at CERN.
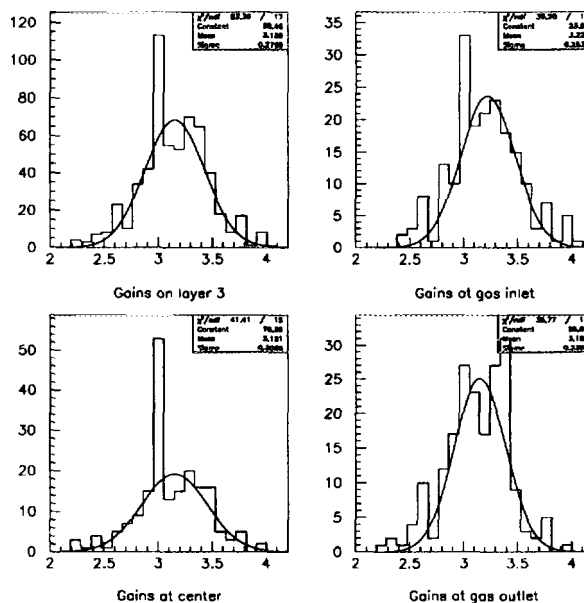
Figure 6: Distribution of gaseous gains for straws in layer 3; example of test results (the gains uniformity is better than 10%).

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[1]due to straw tension the cylinder has to carry a force of 1200 kg's
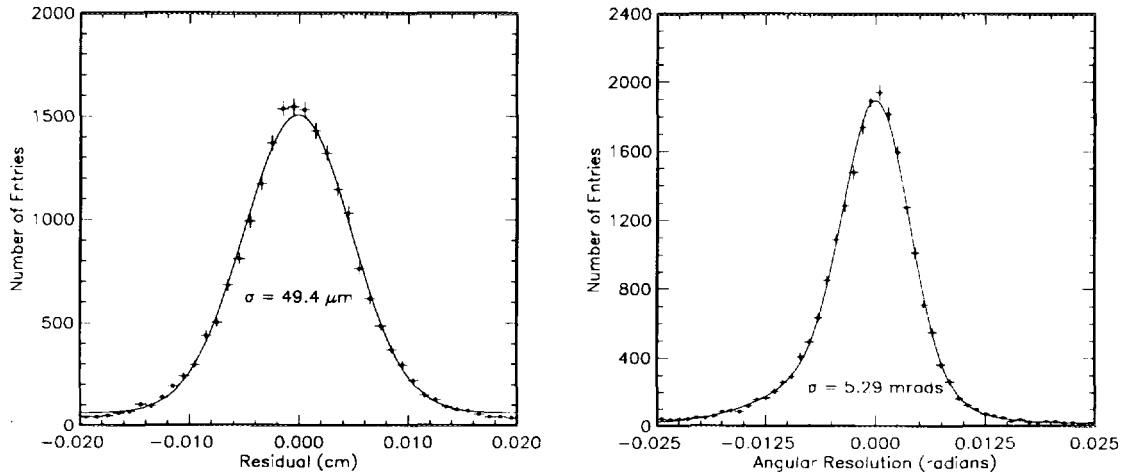
Figure 7: Spatial and angular resolutions of Straw Tube prototype detector.

The reference detector consisted of eight planes of silicon microstrip detectors with spatial resolution of 5 μm. The efficiency found for the prototype assembly was **99.09** % **±0.03**% with track angular resolution **5.29±0.04** mrads and position resolution of **49.4** **±0.5**μm (Fig. 7). These results are very encouraging and show that straw tubes can bring substantial improvement to DELPHI tracking due to their excellent resolution and position close to vertex region (in front of all heavy material which introduces interactions and scattering).

References:

1. Proposal for the Upgrade of DELPHI in the Forward Region - DELPHI 92-142 GEN 135, 16 October 1992;

2. Nucl. Instr. and Meth. **A225** (1987) 486-492.

THE H1 EXPERIMENT AT HERA

The H1 Collaboration [1]

During 1994 the H1 experiment collected about 4 pb^{-1} of high quality data at electron (positron)-proton collider HERA in DESY/Hamburg. The data from 1993 corresponding to an integrated luminosity of 530 nb^{-1} have been analysed and the results presented in 6 publications [1 - 6] and at the 27th International Conference on High Energy Physics at Glasgow [7]. The most important results are:

- **The first measurement of the charged current cross section at HERA [5].** The weak charged current processes were extensively investigated in neutrino experiments. The observed linear increase in the total neutrino cross section was expected to be finally damped due to the $W^{\pm}$ propagator but the available energies of neutrino beams were by far too low. The cross section for the crossed process $e^- p \rightarrow \nu_e + hadrons$ was measured for the first time at HERA by the H1 collaboration at the energy corresponding to E_ν

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[1]Cracow H1 group: L. Görlich, L. Hajduk, J. Martyniak, S. Mikocki, E. Mroczko, G. Nowak, K. Rybicki, and J. Turnau; engineers and technicians contributing to the project: E. Banaś, A. Cyz, B. Dulny, M. Dziaduś, B. Florek, J. Godlewski, and W. Janczur; The H1 Collaboration includes 37 institutes. The Cracow H1 group has especially close collaboration with DESY (Hamburg), LAL (Orsay, France), and University of Liverpool.

50 TeV. The size of the cross section clearly exhibits the W propagator effect, as shown in Fig. 1.

• **A measurement of the proton structure function** $F_2(x, Q^2)$ **with tenfold higher statistics than previously available** [7]. Observation of a rapid rise of F_2 with decreasing x at a given Q^2 was confirmed. This behaviour led to many theoretical papers.
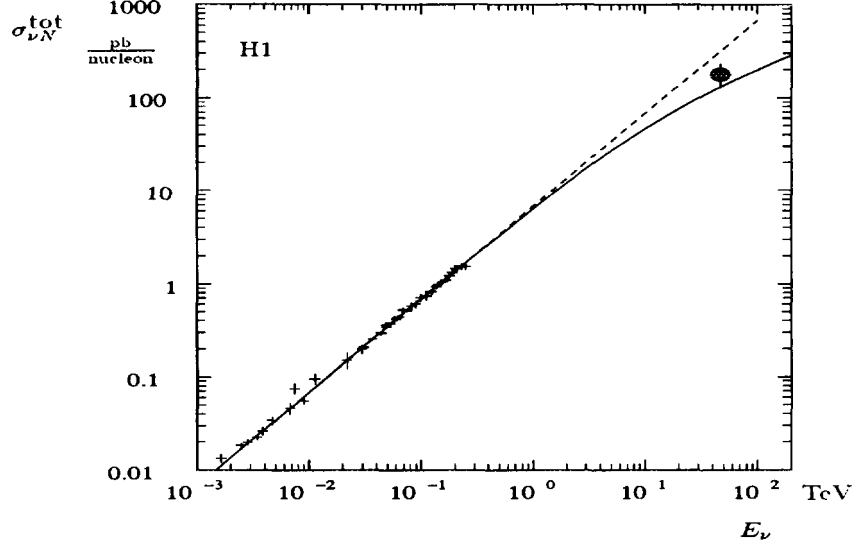
Figure 1: The energy dependence of the νN cross section. The crosses represent the low energy neutrino data while the full circle refers to the result of the H1 analysis. The experiment at HERA corresponds to an equivalent fixed target energy about 50 TeV. The full line represents the predicted cross section including the W propagator. The dashed line is the linear extrapolation from low energies.

• **Determination of the strong coupling constant from jet rates in deep inelastic scattering.** It was shown that jet rates in deep inelastic electron proton scattering can be quantitatively described by perturbative QCD in next to leading order making use of the parton densities of the proton and with strong coupling constant α_s as a free parameter. This allowed the measurement of α_s at several energies in a single experiment. The extrapolated value, $\alpha_s(M_Z^2) = 0.123 \pm 0.018$, is in agreement both with determinations from e^+e^- annihilation at LEP using the same observable and with the world average. The agreement between the α_s values determined in deep inelastic ep scattering and e^+e^- annihilation again demonstrates the coherence and consistency of the underlying QCD picture. angle=90

• **Observation of an** $e^+p \rightarrow \mu^+ X$ **event with high transverse momenta at HERA** [9]. This event (see Fig. 2) has been registered in a total integrated luminosity of $4pb^{-1}$. Although the event kinematics is compatible with the interpretation of a W^+ production, the cross section estimate within the standard model yields 0.03 events of this type. This small probability leaves room for further speculations on the origin of the event. In Fig. 2 we present the display of the event. The isolated muon track is measured in the central track detector, the barrel liquid calorimeter and in the instrumented barrel iron return yoke. A muon signature can be faked by pion, however the probability that a pion traverses 14 absorption lengths compatible with the behaviour of a muon (energy deposition, track extrapolation match, hit multiplicity) is smaller than 10^{-4}.

Members of the H1 Cracow group have participated in the analysis of data and significantly
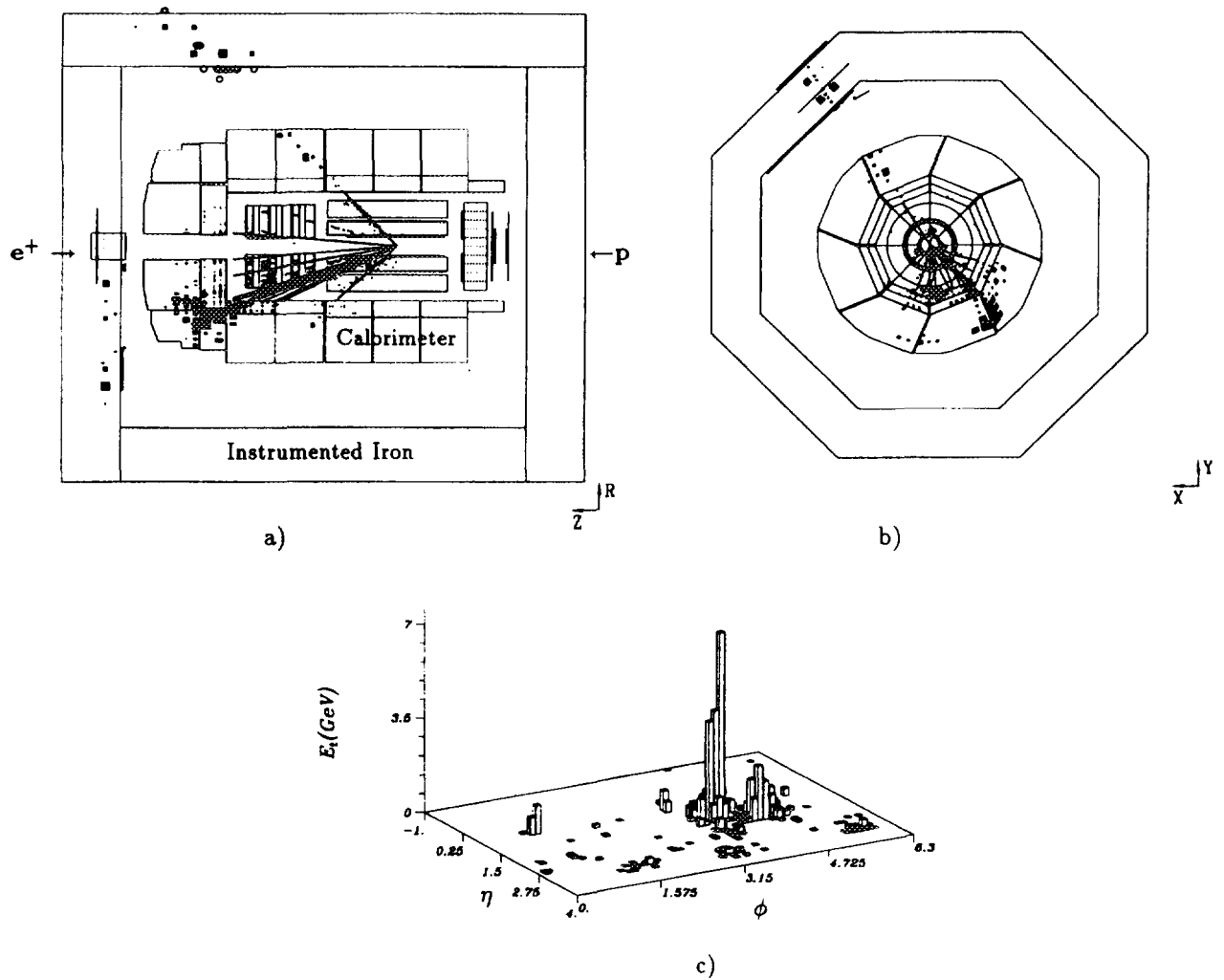
Figure 2: Event display : a) $R - z$ view b) $R - \phi$ view and c) transverse calorimetric energy.

contributed to the activities of the following physics working groups:

- DIS working group
- heavy quark group

They have also participated in the H1 run shifts.

Cracow contribution to physics analysis and the H1 detector upgrade covers several topics:

- Studies of local parton density fluctuations (hot spots) at low x, based on the ideas of Müller [8] have been continued. The clear signature of the "hot spot" process is the production of a high energy jet in the direction close to the incoming proton.

The event topology with the associated jet very close to the beam pipe in the proton beam direction represents a real experimental challenge. Results based on the 1993 data were encouraging although not conclusive. We have found excess of the forward-jet events in comparison to the prediction of the standard Monte-Carlo, in which Altarelli-Parisi evolution was assumed. However statistical significance of this effect was not very large.

In 1994 our efforts were devoted to establishing relations between parton, hadron and reconstruction levels of the Monte Carlo sample and to the analysis of the 1994 data. In general the result from 1993 was confirmed but many problems of the analysis and interpretation of the data still remain.

At the meeting held at Cracow with participation of physicists from DESY and Durham the outline of further collaborative efforts has been agreed upon. Thanks to the upgrade of the SGI-server to six R-4400 processors which was financed by Bundesministerium für Forschung und Technologie through the DESY administration, a dedicated simulation of a large sample of the DIS events with forward jet was started at Cracow. Also work on new DIS generator based on the Webber program for small x has been initiated here.

- The most important result of the H1 Heavy Quarks Group in 1994 was the extraction of the J/ψ in both $\mu^+\mu^-$ and e^+e^- channels and the estimation of the total photoproduction cross section [10] of

$$\sigma(\gamma p \to J/\psi + X) = (56 \pm 13 \pm 14)nb$$

where the second error is due to the systematic uncertainties. The Cracow group has contributed to their estimation.

- In 1994 the LAL-Cracow project of the topological second level trigger has been pursued. Having hardware testing almost finished and the final version of the simulation program ready we are prepared to the trigger installation at the H1 experiment. Also the final version of the documentation for monitoring application program on McIntosh was prepared at Cracow.

- Most important upgrade of the H1 detector, replacement of the present backward calorimeter by the spaghetti type calorimeter with better resolution for both electrons and hadrons, has taken its final steps in 1994. The complete rack for SPACAL electronics, with Faraday boxes for cards and with the cooling system, was designed and constructed in Cracow and then assembled at DESY. Technicians and engineers from Cracow worked at many SPACAL construction and assembly tasks at DESY.

References:

1. H1 Collaboration; I. Abt et al.: A Measurement of Multi-jet Rates in Deep Inelastic Scattering at HERA, Z. f. Physik, **C61** (1994) 59-66;

2. H1 Collaboration; I. Abt et al.: Energy Flow and Charged Particle Spectra in Deep Inelastic Scattering at HERA, Z. f. Physik, **C63** (1994) 377-389;

3. H1 Collaboration; I. Abt et al.: Scaling Violations of the Proton Structure Function F2 at Small x, Physics Letters **B321** (1994) 161-167;

4. H1 Collaboration; I. Abt et al.: Inclusive Charged Particle Cross Section in Photoproduction at HERA, Physics Letters **B328** (1994) 177-186;

5. H1 Collaboration; T. Ahmed et al.: First Measurement of the Charged Current Cross Section at HERA, Physics Letters **B324** (1994) 241-248;

6. H1 Calorimeter Group; B. Andrieu et al.: Electron/Pion Separation with the H1 LAr Calorimeters, Nucl. Instrum. Meth **A344** (1994) 492-506;

7. V. Brisson, H. Hufnagel, C. Kleinwort, T. Köhler, G. Rädel: New Results from HERA on Deep Inelastic Scattering at Low x, the Proton Structure Function, Jets in Photoproduction, Heavy Flavour Production and Searches for New Particles, **DESY 94-187**;

8. A.H. Müller: Nucl. Phys. **B** (Proc.Suppl.) 18C (1990) 125;

9. H1 Collaboration; T. Ahmed et al.: The event, DESY 94-248;

10. H1 Collaboration; T. Ahmed et al.: Photoproduction of J/ψ, Physics Letters **B338** (1994) 507.

THE BELLE EXPERIMENT AT KEK

The BELLE Collaboration [1]

The BELLE experiment [2] will be performed at KEK on an e^+e^- collider operating at the energy corresponding to the formation of the $\Upsilon(4s)$ resonance and with the luminosity reaching $10^{34} \mathrm{cm}^{-2}\mathrm{sec}^{-1}$. The machine of this type is a pure source of $B\bar{B}$ pairs and is called "B-factory". B-factories are experimentally the most straightforward approach to study rare processes involving b quarks.

The main goal of the experiment is to study CP violation in B meson decays. The study of CP asymmetries in B decays will give an important contribution to our understanding of CP violation in weak decays. In particular measurement of asymmetries in $B^0, \bar{B}^0$ decays to CP eigenstates will allow us to test quantitatively the Standard Model explanation of CP violation, which relates it to the complex phase in the Kobayashi-Maskawa (KM) matrix. Studying B decays will also allow us to measure precisely other KM matrix elements. Testing relations among them is a very sensitive test of the Standard Model and is a promising method to look for phenomena beyond it.

The experimental program demands a detector system able to register big variety of decay channels with high efficiency. The particular requirements are:

secondary vertex detection with $90\mu m$ resolution along the z axis,

good momentum resolution for charged particles with p_t down to 100 MeV/c,

efficient photon detection in the energy range from 20 MeV to 4 GeV,

K/π separation up to 4 GeV/c,

lepton identification over wide momentum range.

The triggering and data acquisition system has to be capable to handle huge event rates.

The Cracow group has joined the BELLE Collaboration in June 1994 and is involved in the project of the vertex detector, which will be double sided silicon strip counter (SVD) and in particular in the trigger design using the SVD detector information to reject beam associated background.

The data taking is foreseen to start in 1998.

PL9700202

ATLAS EXPERIMENT AT LHC [1]

From INP Cracow: J. Błocki, A. Czermak, S. Gadomski, J. Godlewski, Z. Hajduk, W. Iwański, P. Jurkiewicz, M. Kajetanowicz, J. Kapłon, B. Kisielewski, K. Korcyl, A. Kotarba, P. Malecki, A. Moszczyński, J. Olszowska, W. Ostrowicz, A. Sobala, and M. Turała

The ATLAS collaboration is a group of more than 130 institutes and universities[2] preparing experimental programme and a large spectrometer[1] for the studies of proton–proton interactions at the energy of 14 TeV (center of mass) at the LHC accelerator at CERN. At the end of 1994 the LHC project has been unanimously approved by the CERN Council for financing. The main effort of ATLAS collaboration this year has been the preparation of Technical Proposal [2] which has been finished by December 15.

The Cracow groups from the Institute of Nuclear Physics and the Faculty of Physics and Nuclear Techniques were taking part in that effort contributing to the following areas:

- simulation studies of physics processes, designing of the spectrometer and simulation of its performance, prototyping work on the detectors, electronics and the programming. Special attention has been paid to the B-physics sector of the programme.

- participation in the CERN R&D programme on the development of detectors for the LHC experiments, in particular, in the following projects:

  - RD6 'Integrated transition radiation and tracking detector for the LHC' [3]
  - RD11 'Embedded architectures for 2nd level triggering in the LHC experiments' [4]
  - RD20 'Development of high resolution Si strip detectors for experiments at the LHC' [5]
  - RD28 'Development of gas micro-strip chambers for high radiation rate detection and tracking' [6]
  - RD41 'An Object Oriented software R&D project' [7].

References:

1. ATLAS Letter of Intent for a General-Purpose pp Experiment at the Large Hadron Collider at CERN, CERN/LHCC/92-4, LHCC/I2 (1992);
2. ATLAS technical proposal, CERN/LHCC/94-43, LHCC/P2, 15 December 1994;
3. RD-6 Status Report, CERN/DRDC/93-46, 1993;
4. RD11 Status Report, CERN/DRDC/94- , 1994;
5. RD20 Status Report, CERN/DRDC/94-39, 1994;
6. RD28 Status Report, CERN/DRDC/94-45, January 1995;
7. Object Oriented Approach to Software Development for LHC experiments - CERN/DRDC/94-9, CERN/P55, 1994.

[2] Here we list only institutes closely collaborating with us: NIKHEF Amsterdam, LAPP Annecy, HEP Lab. Bern, Univ. Birmingham, LBL Berkeley, Univ. Bratislava, Cambridge Univ., Univ. Clermont-Ferrand, NBI Copenhagen, Univ. Dortmund, INFN Frascati, Freiburg Univ., CERN Geneva, Univ. Geneva, Univ. Glasgow, CNRS Grenoble, Univ. Hamburg, Univ. Heidelberg, SEFT Helsinki, Univ. Jena, IEP Kosice, LIFEP Lisbon, Univ. Liverpool, QMWC Univ. London, RHBNC Univ. London, Univ. College London, Lund Univ., Univ. Madrid, Manchester Univ., Mannheim Univ., CPPM Marseille, ITEP Moscow, FIAN Moscow, MEPI Moscow, Moscow Univ., Univ. Munich, MPI Munich, LAL Orsay, Oslo Univ., Oxford Univ., Pittsburgh Univ., Paris VII Univ., Pavia Univ., Pisa Univ., Prague Univ., IHEP Protvino, RAL, DAPNIA Saclay, Univ. Sheffield, MSI Stockholm, Stockholm Univ., Tel-Aviv Univ., Univ. Uppsala, IHOAW Vienna, WIS Rehovot, Univ. Wuppertal.

B-PHYSICS IN ATLAS

B_s^0 Mixing Measurement in ATLAS

S. Gadomski

Studies of the B-physics capabilities of the ATLAS experiment were continued in 1994. A recently considered measurement of the B_s^0 mixing can be made using the following decay:

$$b\bar{b} \to \mu \ (p_T^\mu > 6 \ \mathrm{GeV}/c, \ |\eta| < 1.6) + \mathrm{X}$$
$$\hookrightarrow B_s^0 \to D_s^- \pi^+$$
$$\hookrightarrow \phi^0 \pi^-$$
$$\hookrightarrow K^+ K^-$$

The muon provides the first level trigger. It is predicted that the distribution of the B meson decay times will have the form $e^{-t/\tau}(1 \pm D\cos(x_s t/\tau))$ where τ is the B_s^0 meson lifetime. The sign of the cos term is positive for the like-sign combination of the trigger muon and $D_s^\pm$ and negative for opposite signs. The measurement of the oscillation frequency x_s will enable us to calculate unknown parameters of the Standard Model. An excellent resolution in B decay proper times is necessary to make this interesting measurement.

The dedicated vertexing layer placed close to the interaction point (see next section) enables the precise reconstruction of B decay positions. It has been calculated that the resolution of 0.07 ps in the proper time of the ·B decay can be reached [1, 2, 3]. The result was obtained using full GEANT simulation, which includes all the effects introduced by the interaction of produced particles with detector material, followed by track reconstruction, including the dilu-
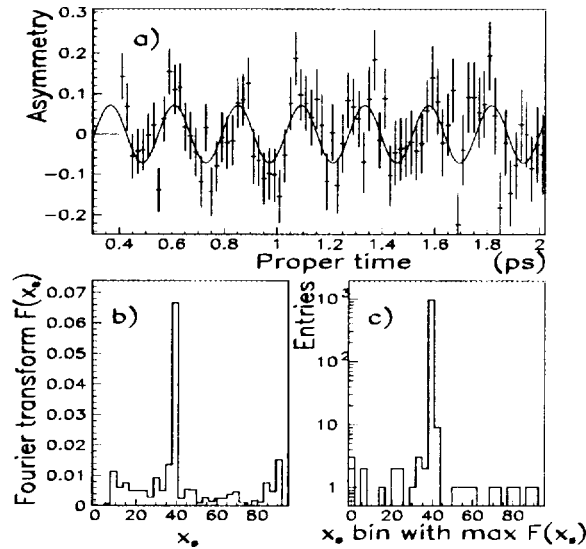
Figure 1: Simulation of the B_s^0 mixing measurement for $x_s = 40$: (a) time-dependent asymmetry distribution (single experiment); (b) power spectrum of the Fourier transform of the asymmetry distribution given in (a); (c) distribution of x_s giving the highest value of $F(x_s)$ when the experiment was repeated 1000 times.

tion introduced by the background, wrong sign tagging and the proper time resolution. Fig. 1c shows the distribution of x_s bins giving the highest value of the Fourier transform when the experiment was repeated 1000 times. The correct x_s bin can be identified in $> 95\%$ of the cases when $x_s < 40$.

Acceptance for signal events and background rejection were also calculated. The experiment will collect 2650 signal events after one year of low luminosity ($L = 10^{33}$ cm^{-2}s^{-1}) operation. An upper limit on the background, given by the available Monte-Carlo statistics is 1140 events under mass peak. After one year (integrated luminosity 10^4 pb^{-1}) x_s values up to 30 can be precisely measured in ATLAS. For an integrated luminosity of $6 * 10^4$ pb^{-1}, corresponding to the lifetime of the vertexing layer at $R = 6$ cm due to radiation damage, x_s values up to 40 are within reach.

The asymmetry distribution and the Fourier transform of the asymmetry distribution are shown in Fig. 1a and b for $x_s = 40$.

The present experimental limit is $x_s > 8.5$. LEP experiments, which are limited by low event rates, can reach x_s values up to ~ 10. The sensitivity range of the ATLAS experiment covers the preferred region of the theoretical predictions.

Vertex Detector for the ATLAS Experiment

J. Blocki and S. Gadomski

In order to exploit the potential of the LHC for b and t-quark physics it is essential to equip the tracking system with the best possible vertex detector, capable of identifying b-quark decays. For an initial period of the low luminosity running a layer of silicon microstrip detectors can be placed at the radius of $R = 6$ cm [4]. Such an addition gives a major improvement of the impact parameter resolution of the ATLAS tracking system.

Due to comparatively large cross-sections heavy quark processes can be studied at low luminosity of $\sim 10^{33}$ cm^{-2}s^{-1}. Present radiation damage predictions indicate that the layer of silicon strip detectors placed at $R = 6$ cm can survive 6 years at $L = 10^{33}$ cm^{-2}s^{-1}. Because of the small area the layer could also be replaced at an affordable cost.
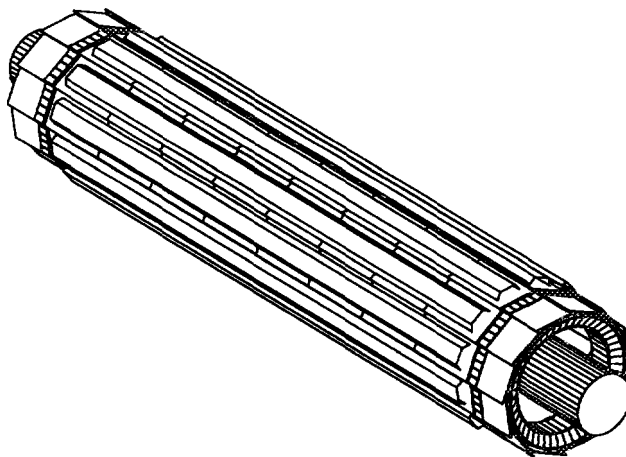
Figure 1: A view of the silicon strip vertex detector.

In order to achieve the optimal impact parameter resolution it is necessary to minimize the multiple scattering contribution to the measurement error. The technical solution based on experience from DELPHI Vertex Detector assures minimum material of the vertex detector and, as a consequence, minimal multiple scattering. There will be no electronics and almost no support structure in the active region of the detector. All the electronics together with its cooling will be placed near the supporting end rings.

The layer will be made of 12 identical modules. Each module will consist of 8 silicon microstrip detectors and will have a total length of 52 cm. Mechanical stability is given by the lightweight kevlar fiber rail glued to detectors. A schematic drawing of the vertex detector is shown in Fig. 1. Supporting end-rings can be made of carbon composite. As a backup solution aluminium can be used as in the DELPHI VD.

The heat dissipated by the electronics is removed by a cooling liquid flowing inside the end-rings. It is expected that the detector will have to be operated at a low temperature of 0 to 5 degrees C in order to slow down the effects of radiation damage and to limit the leakage current. This concerns also the main silicon tracker. In order to maintain a constant low temperature of the detectors the vertexing layer will have to be integrated with the entire tracker in the flow of cooling gas.

The basic sensors will be 6.5×3.3 cm^2 double sided silicon microstrip detectors. 50 μm pitch p-type strips will be used to measure the $R\varphi$ coordinates. Perpendicular strips on the back side of the detectors will measure the z coordinate. The readout pitch may vary with the distance from the center of the module. A constant 200 μm readout pitch was tentatively assumed for the resolution calculations. A second layer of metal lines or capton fanouts will be used to connect the z strips to their readout at the module ends.

Design of the layer is a challenge for the readout electronics. Four detectors will be connected in chain to form 26 cm long $R\varphi$ strips. Such long strips have large capacitance, which is a source of noise for the fast readout electronics of the LHC experiment. Thanks to the recent progress in preamplifiers it is possible to readout such long strips with modest power consumption [5]. The detailed simulations of the realistic readout scheme show that the resolutions of 10 μm in $R\varphi$ and 20 μm in z can be reached.

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Development of Silicon Detectors Using ToSCA Simulation Package

A.S. Moszczyński

Last year, the Cracow group has continued investigating of the n-side test structures designed at CERN for RD20. The preliminary results have been reported [1, 2].

The Cracow group has presented some ideas on improvements of radiation hardness of silicon strip detectors [3]. In particular, an idea of compensating acceptor-like postradiation defects in silicon microstrip detectors by means of drifted lithium ions has been presented. Some possible, negative consequences of nuclear reactions of thermal neutrons with boron and lithium atoms in silicon crystal lattice have been considered.

The ToSCA simulations of silicon strip detectors have been continued [4, 5]. The simulations of interstrip capacitances have led to idea of "deep p-stop" made by Al deep diffusion (instead

of B ions implantation). Introduction of "deep p-stops" should decrease capacitances "seen" by inputs of read-out electronics, what should lead to better performance of detection system.
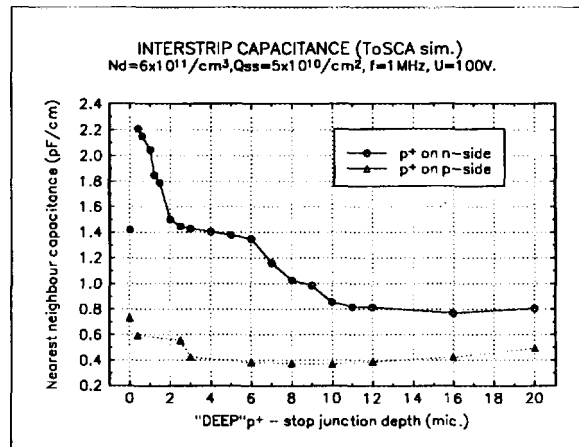

Figure 1: Simulated dependence of interstrip capacitance on p-stop junction depth. The values for junction depth = 0 were calculated for detector without p-stop.

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Studies of Triggering System Architectures for LHC Experimentation

K. Korcyl and Z. Hajduk

In 1994 we continued studies on evaluation of different architectures as candidates for second level trigger in LHC experiments. The system is split into local and global parts. In the local part, guidance is taken from the level-1 system to extract fine grain raw data from specific, small region of detector (Region of Interest) stored in the level-2 buffers. The data are processed in feature extractors (FEX) to produce a feature (well defined physical, topological or quantitative characteristics). The resulting features from all detectors participating in the level-2 system are then gathered in a global processor. Certain physical quantities are then evaluated and result in a decision as to accept or reject the event.

Other characteristics of the architecture described above are:

- reduction of required level-2 system input bandwidth,
- parallel processing in both local and global subsystems to achieve a design decision frequency of 10^5 Hz, but with processing time of a few milliseconds for each event,
- system scalability to track the evolution of algorithms and corresponding physics goals.

Our results contributed to the ATLAS Technical Proposal [1].

Figure 1: Beam test setup.

We verified our modelling methods [2] on the behaviour of the small test system assembled and put into operation in ATLAS test beam line at CERN (Fig. 1). The local part was built around commercially available VME boards with Texas Instrument T320C40 DSP [3] chips. The global part of the system was composed of four SCI nodes. The main goal of that exercise was to feed assembled architecture with 'live' detector data. As a source for our data we selected Transition Radiation Tracker (TRT) [4]. Data were derived from a Spy Unit (made in Cracow) placed in the readout path of a TRT. Two channels were equipped to feed data into two level-2 buffers under the supervision of a C40 managed buffer (T2B). Data were moved through a link unit to enable routing of data to the appropriate FEX (again both C40 based). After feature extraction (a null algorithm in initial tests) the data were concentrated in the global gateway (another C40) and were sent on to a SCI [5] node for final processing by a global processor. Events were recorded at the global gateway by an OS9 system and at the target SCI node. The whole system was self-triggered by the passage of an event and generation of a RoI-like message to the RoI-builder (C40 based). The C40 sub-system (7 processors running in parallel) was controlled from a PC through a daisy-chained JTAG interface. A very simple skeleton software was loaded into all C40's performing all necessary phases of tasks assigned to every part of an architecture.

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Tests of the TRT Frontend Electronics Daughter Boards

Z. Hajduk, B. Kisielewski, A. Kotarba, P. Malecki, J. Olszowska, and W. Ostrowicz

New Daughter Boards for the TRT detector sector prototype had to be tested, and set up before the '94 beam test run. There were two versions of DB's - one of them was equipped with the 'old' versions of ASIC's (the same like the ones used during '93 beam tests), while the second one had the ROC (readout chip) replaced by the DTM ROC (readout chip with the drift time measurement). We have upgraded our VME-based test system dedicated for TRT readout electronics tests (the new versions of digital cards were built, the analogue card was improved, and the software was updated) to be able to test functionally both versions of DB's (we are skipping the DTM information while testing DB's with DTM ROC). The set of functional tests helped to find and repair DB's with 'soldering problems'. The evaluation of offset resistors for all channels of each DB was done to set the offsets to the value 5 ±1 of the low threshold level. Tests of the uniformity of gain for 5.5 fC and 55 fC input pulses showed ± 15% differences between channels. Block diagram of the system setup can be found elsewhere [1]. No measurable crosstalk effects were observed in neighbouring channels on the DB.

It is known that DB's are extremely sensitive to external fields. They require very careful shielding during measurements. A series of tests and measurements were done to understand the noise and pickup effects. Careful investigations of interference effects resulted in many valuable hints for redesign of daughter boards. Detailed results are given in [2].

Some tests have also been performed with eight mini-straws connected to DB inputs and irradiated with the X-ray source. This has proven wider usefulness of our read-out system.

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2. RD6 Note No 59, CERN, 13 October 1994.

ZEUS EXPERIMENT AT HERA [1]

ZEUS Collaboration [2]

Group from the Institute of Nuclear Physics includes:
P. Borzemski, J. Chwastowski, A. Eskreys, K. Piotrzkowski, M. Przybycień,
M. Zachara, L. Zawiejski (physicists)
and
J. Andruszków, B. Dąbrowski, W. Daniluk, P. Jurkiewicz, A. Kotarba, K. Oliwa. W. Wierba
(engineers and technicians)

Third year of HERA operation was a very successful one for the HERA crew. Experiments (ZEUS and H1) collected more than $3pb^{-1}$ of the integrated luminosity compared to $600nb^{-1}$ in the previous year. Higher luminosity means also higher rates and higher background. That created new problems for our experiment at the beginning of the running period. The common effort of all groups taking care of the different detector components resulted in a smooth and successful running of the ZEUS experiment.

The main responsibility of the Cracow group is the reliable performance of the Luminosity Monitor, which has been designed and built by our group. That means the maintenance of the detector, continuous development of the online and offline software tools and the luminosity measurement itself. A very detailed offline analysis of the 1993 luminosity data was done in 1994. This resulted in much better understanding of the systematic effects influencing the luminosity measurement. The systematic error in the determination of the integrated luminosity is now below 2.5%. Modification of the hardware setup, especially replacement of the photomultipliers in the calorimeters, made during the 1993/1994 winter shutdown, allowed for more stable operation in the 1994 running period. Much improvement has also been achieved in both offline and online software. Several corrections for the systematic effects have been included into the online luminosity measurement scheme what makes this measurement much more accurate. The offline procedure, including calibration of the calorimeters and the luminosity recalculation, has been automatized. Much effort has been put into the development of the Monte Carlo simulation of the beam line structure.

Members of the Cracow INP group have been taking part in the ZEUS data taking shifts. They have also contributed to the development of the general ZEUS online and offline software. Our physicists have actively participated in the physical analysis of the collected data and have significantly contributed to studies of the photoproduction processes, where the luminosity monitor used for tagging of almost real photons plays a very important role.

Both HERA experiments (ZEUS and H1) have continued studies started with small data samples from 1992, using much larger data samples collected in 1993. This enriched statistics

allowed also new analyses of the processes with smaller cross-sections to be made. Results of the ZEUS physics analysis, based mainly on the data collected in two previous years, have been published in 9 papers. New interesting data concern many aspects of the electron proton interactions and the much larger data sample permits more accurate measurements. We would like to review here briefly on the published results of two different analyses dealing with different type of processes: photoproduction and deep inelastic scattering.

Observation of Direct Processes in Photoproduction at HERA [3]

ZEUS Collaboration

M. Derrick et al. [4]

Electron proton scattering is dominated by the exchange of almost real photons. Although most of the photoproduction cross section is due to soft processes, a fraction of the γp collisions at HERA energies is expected to contain high-p_T processes. In lowest-order QCD, these hard processes are of two main types [1, 2], as shown in Fig. 1. In the *direct* processes, the photon participates as a point-like particle, interacting with a gluon ($\gamma g \to q\bar{q}$, photon gluon fusion) or a quark ($\gamma q \to gq$, QCD Compton scattering). In the *resolved* processes, the photon behaves as a source of partons which can scatter off those in the proton. The unscattered constituents of the photon then give rise to a hadronic system, known as the photon remnant, going approximately in the direction of the original photon.
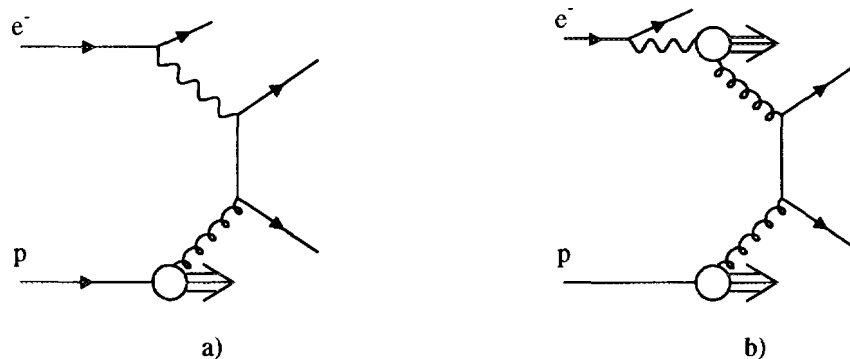
Figure 1: *Schematic diagrams showing examples of (a) a direct process and (b) a resolved process.*

Hard scattering in photoproduction should produce multi-jet structures with features similar to hadron-hadron collisions [3]. QCD-based models of these processes predict that the resolved processes should dominate over the direct for a wide range of jet transverse energy [2, 4]. The presence of hard scattering in γp collisions has already been observed at HERA [5, 6], with evidence for multi-jet structures and for the presence of the resolved contribution.

The main components of the ZEUS detector [5, 7] used in this analysis are the high resolution uranium-scintillator calorimeter, the central tracking detector and the luminosity monitor. The analyzed data were collected during 1992, when 820 GeV protons were colliding with 26.7 GeV electrons. The hard photoproduction data sample was selected using criteria described in [5] and

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in the original reported paper. The final sample of photoproduction events with a total transverse energy deposition in the calorimeter larger than 10 GeV consists of 19,589 events. For this sample the γp centre-of-mass energy (W) ranges from 130 GeV to 250 GeV. A Monte Carlo simulation for the direct processes gives a median value of $Q^2 = 0.001$ GeV^2. The median Q^2 is expected to be similar for the resolved processes. Monte Carlo studies are crucial for the analysis of data collected with such complicated detector as ZEUS. Two independent Monte Carlo generators, HERWIG5.7 [8] and PYTHIA5.6 [9], were used to simulate the hard photoproduction processes. In these generators, the direct and resolved processes are each simulated using leading order matrix elements, with the inclusion of initial and final state parton showers. The generated events were passed through detailed detector and trigger simulation programs based on the GEANT package [10]. They were reconstructed using standard ZEUS off-line programs and passed through the same analysis chain as the data.
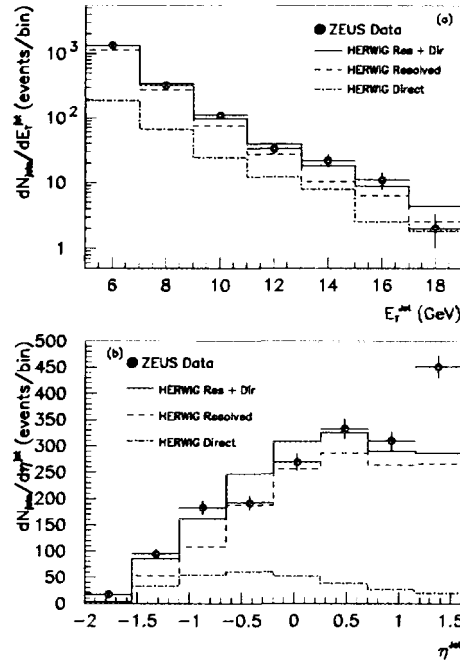
Figure 2: *Inclusive jet distributions for: a) transverse energy of jets, b) pseudorapidity of jets, where the Monte Carlo distribution is normalised to the data in the region $\eta^{jet} < 1.2$. The relative contributions of the direct and resolved processes as predicted by the Monte Carlo simulation are also shown.*

The search for jet structure in the selected data sample was done using a jet finding algorithm in pseudorapidity (η) - azimuth (ϕ) space [11, 12]. Calorimeter cells were grouped into clusters; those clusters with transverse energy (E_T^{jet}) larger than 5 GeV were called jets. The transverse momentum-weighted mean pseudorapidity (η^{jet}) was evaluated and jets were accepted for the present analysis if η^{jet} was less than 1.6.

Of the sample of 19,589 hard photoproduction events, 6.5%, 1.4% and 0.1% of the events were of the one-jet, two-jet and three-jet type, respectively. A total of 1548 events with jets was found. From a comparable number of Monte Carlo events, a QCD based simulation using the HERWIG generator predicts the fractions to be in the range 6.3 - 9.8% and 0.7 - 1.9% for

the one-jet and two-jet categories, respectively. The quoted ranges indicate the spread of the values obtained with the different proton and photon parton distributions mentioned above. The inclusive jet sample consists of 1850 jets. The E_T^{jet} distribution, shown in Fig. 2a, falls steeply, reaching values as high as 18 GeV. The Monte Carlo distribution (normalised to the data) for HERWIG is shown as a full line. The shape of the data is well described. The expected relative contributions of direct and resolved photon processes are also shown.

Fig. 2b shows the inclusive η^{jet} distribution, together with the Monte Carlo distribution from HERWIG. The data require a substantial resolved component.
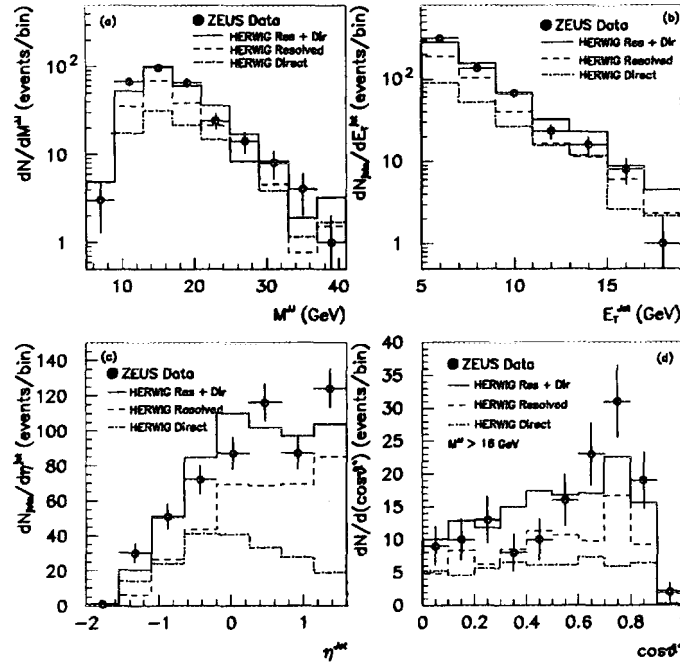
Figure 3: *Kinematic distributions for events with two or more jets. The Monte Carlo is normalised to the data, and in all cases the relative contributions of the direct and resolved processes, as predicted by the Monte Carlo simulation, are shown. a) Jet-jet invariant mass for jet pairs, b) Transverse energy of jets, c) Pseudorapidity of jets, d) $\cos\theta^*$ of jet angles in the jet-jet c.m.s. measured with respect to the proton momentum.*

Di-jet production has been studied by selecting events with two or more jets in the accepted rapidity range ($\eta^{jet} \leq 1.6$). In the case of events with three or more than two jets, the two jets with highest E_T^{jet} are taken. The di-jet sample consists of 284 events. The di-jet invariant mass (M^{jj}) spectrum, shown in Fig. 3a, extends up to values of 40 GeV. The E_T^{jet} spectrum of the di-jet sample, which reaches values as high as 18 GeV, is shown in Fig. 3b. The jet pseudorapidity distribution is shown in Fig. 3c. In all cases, the data and Monte Carlo distributions are in reasonable agreement. Fig. 3c shows again the need for a large contribution from resolved processes. The angular distribution is displayed in Fig. 3d. The QCD-based simulations again acceptably reproduce the data.

These results show, for several independent distributions, agreement of the data with QCD simulations which include hard processes involving the partonic content of the photon. The selected di-jet sample was used to separate the contribution of the direct and resolved pho-

ton processes. In two-to-two parton scattering, the momenta of the incoming partons can be calculated from the two partons in the final state.

Assuming that the observed jets originate from fragmentation of the two final partons, the approximate expresions for the fraction of the initial proton (x_p) and photon (x_γ) momenta carried by the final parton should hold :

$$x_p^{meas} = \frac{\sum_{jets}(E + p_z)_{jet}}{2E_p},$$

$$x_\gamma^{meas} = \frac{\sum_{jets}(E - p_z)_{jet}}{\sum_i(E - p_z)_i},$$

where the sum in the denominator runs over all calorimeter cells.
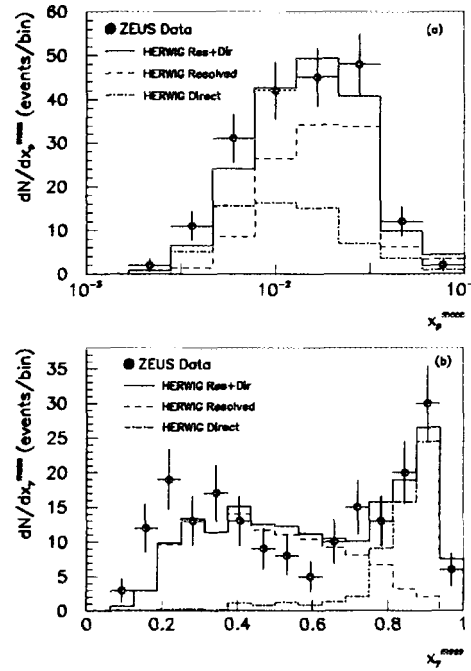
Figure 4: *Kinematic distributions for events with two or more jets. a)* x_p^{meas} *distribution for the final sample, b)* x_γ^{meas} *distribution for the final sample. For both figures, the Monte Carlo distributions are the result of the fit to the data shown in Fig. 4b (see text).*

From Monte Carlo studies it is found that imposing the requirements $|\eta^{jet_1} - \eta^{jet_2}| \leq 1.5$ and $|\phi^{jet_1} - \phi^{jet_2}| > 120°$ improves the x_γ^{meas} resolution and these cuts are applied in the following analysis. The number of events surviving these cuts is 193. The distribution of x_p^{meas} is shown in Fig. 4a. The Monte Carlo distributions describe the data well and are insensitive to the choice of proton parton distributions.

The x_γ^{meas} distribution shown in Fig. 4b rises at both low and high values. The Monte Carlo simulations of the resolved and direct processes, shown in the same figure, have very different characteristics. The resolved processes show a rise towards low x_γ^{meas} , as observed in the data, but cannot account for the rise at high x_γ^{meas} . This is the case for both HERWIG and PYTHIA and for all the parton distributions studied. It has been checked that the peak at the high end

of the x_γ^{meas} distribution cannot be reproduced from resolved processes by experimental and acceptance effects, and that means that it results from the direct processes.

In Fig. 4b the sum of the independently normalised contributions from the resolved and direct processes was fitted to the x_γ^{meas} distribution using the shapes predicted by Monte Carlo simulation. From the fit we obtain a contribution of 65 ± 17 events from the direct processes. We subtract this number from the total 193 events in the sample, and attribute all the remaining events to resolved interactions.

The clear separation between resolved and direct contributions allows us to measure the di-jet cross sections for each of the two processes in the kinematic region defined by the cuts used in the analysis. The detailed studies of the systematic effects concerning both, experimental measurements and Monte Carlo simulations, are described in the original paper. Finally the di-jet ep cross sections involving the exchange of almost real photons in the region defined by $0.2 \leq y \leq 0.7$, jets with transverse energies greater than 5 GeV and pseudorapidities less than 1.6 are measured to be 21.1 ± 5.2(stat.) ± 5.7(syst.) nb for the resolved, and 9.4 ± 2.7(stat.) ± 2.7(syst.) nb for the direct processes.

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Extraction of the Gluon Density in the Proton at Small x [5]

ZEUS Collaboration

M. Derrick et al. [6]

The determination of the gluon density $g(x, Q^2)$ in the proton as a function of Bjorken-x and the momentum transfer squared, $-Q^2$, is a difficult task, despite the known fact that gluons carry about half of the proton's momentum. The main difficulty in the measurement of the gluon
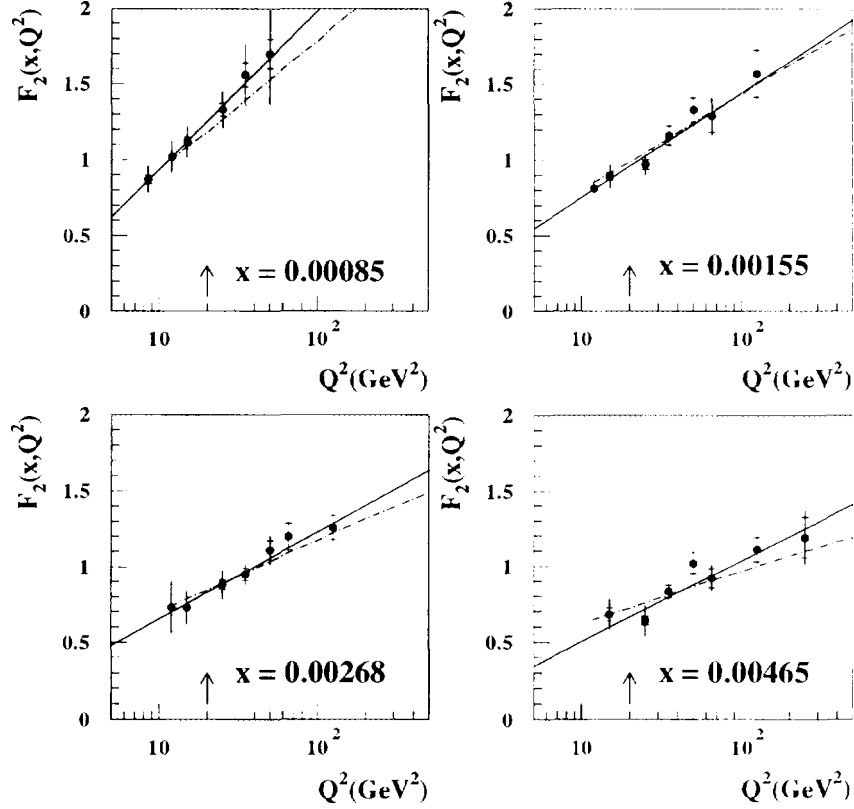
ZEUS 1993

Figure 5: *The F_2 structure function measurements of ZEUS together with the linear fits using equation (1), (solid lines), and the result from the global NLO fit. (dashed-dotted lines). The error bars show the statistical (inner error) and systematic error added together in quadrature. The arrow indicates the Q^2 value at which the slope and F_2 are determined in order to extract the gluon distribution using the approximate methods.*

density in the deep inelastic scattering is related to the fact that gluons do not contribute to the cross section in zero-th order QCD, where the structure functions do not depend on Q^2. Scaling violations occur in the next order (leading order: LO) through gluon bremsstrahlung from quarks and quark pair production from gluons, and the latter process dominates at $x < 10^{-2}$ [1]. That allows a direct extraction of the gluon density from the slope $dF_2/d\ln Q^2$ of the proton structure function F_2 in LO and in next-to-leading order (NLO) using the approximations of Prytz [2, 3]. A different method, based on the solution of the QCD evolution equations (GLAP) [5] up to the next-to-next-to-leading order (NNL), has been proposed by Ellis, Kunszt and Levin (EKL) [4].

In this analysis the F_2 data have been used to extract the gluon density at $Q^2 = 20$ GeV^2 using the Prytz and EKL methods. A global QCD fit to F_2, making use of the full NLO GLAP equations in the $\overline{\text{MS}}$ scheme [7], has also been performed in order to determine the gluon density. The NMC data [8] were used to constrain this fit at large x.

It should be mentioned that in the EKL scheme the gluon momentum density and F_2 are assumed to behave as $x^{-\omega_0}$ and the obtained results turned out to be very sensitive to the choice of ω_0 value, especially in the higher orders.

The F_2 values used here were obtained with the double-angle method [6]. Since the gluon density is to be extracted at $Q^2 = 20$ GeV^2, only those x bins which have data both below and above $Q^2 = 20$ GeV^2 and, where the errors allow a reliable determination of the slope are
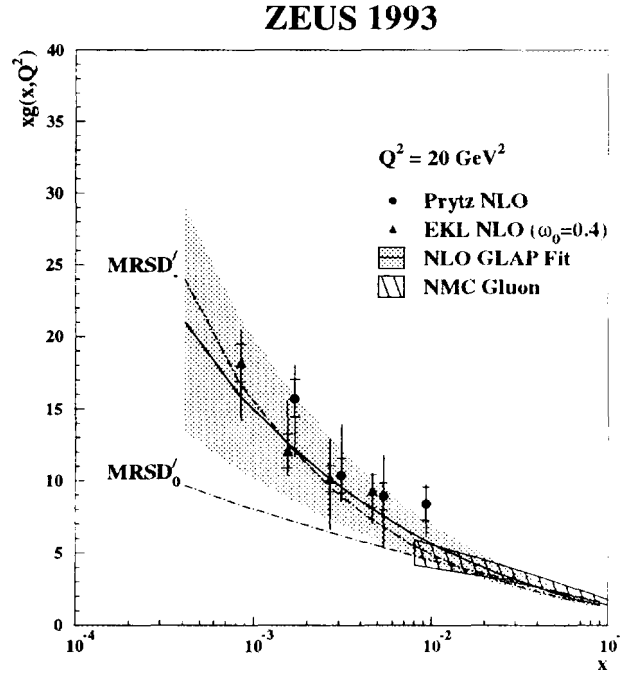
ZEUS 1993
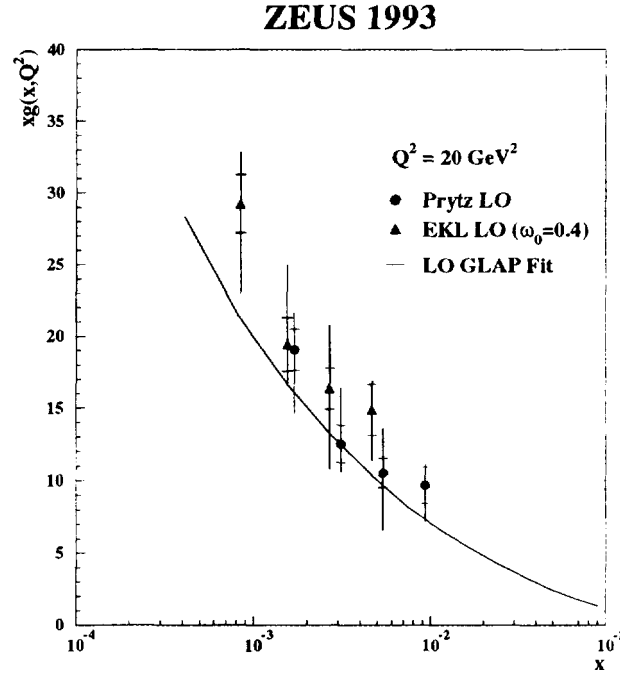
Figure 6: *The gluon momentum density as a function of x at $Q^2 = 20\,GeV^2$ determined from the ZEUS data using the methods of Prytz and EKL in LO. The error bars show the experimental statistical (inner error) and systematic error added together in quadrature. Also shown, as a solid curve, is the LO GLAP global fit.*

considered (see Fig. 5).

The value of the structure function F_2 and its slope $dF_2/d(\ln Q^2)$ were determined for each x bin using a linear fit of the form:

$$F_2(x, Q^2) = c_1(x) + c_2(x)\ln(Q^2/20 \text{ GeV}^2). \tag{1}$$

The fit parameters are $c_1 = F_2(x, Q^2 = 20 \text{ GeV}^2)$ and $c_2 = dF_2(x)/d\ln Q^2$. These fits give a good representation of the data as shown in Fig. 5. From the fitted parameters and the value of α_s (and of ω_0 for EKL) one can evaluate the gluon density.

The extracted gluon momentum densities are shown in Fig. 6 (LO) and in Fig. 7 (NLO) together with the results of the global QCD fit. Also shown in Fig. 7 is the result obtained by NMC for $x \geq 10^{-2}$. A substantial increase in xg is seen as x decreases from the region of the NMC measurement to the low x region of the ZEUS data. For completeness the parametrisations MRSD$'_0$ and MRSD$'_-$ [9] are shown in Fig. 7. The results of the analysis can be summarized as follows:

- The gluon momentum density was extracted at $Q^2 = 20\text{GeV}^2$ down to x values of $\sim$ 4×10^{-4}, using a NLO GLAP global fit to the ZEUS F_2 data. The global fit was constrained at larger x using F_2 data from NMC. A good description of the data was obtained.

- Two independent approximate methods were also used to extract $xg(x, Q^2)$ in NLO. Both methods agree with the global fit. Scaling violation is dominated by the gluon contribution.

- A substantial increase in $xg(x, Q^2)$ is observed as x decreases from the NMC data region to the low x region covered by this analysis.

Figure 7: *The gluon momentum density as a function of x at $Q^2 = 20 \, GeV^2$ determined from the ZEUS data using the methods of Prytz and EKL in NLO. The error bars show the experimental statistical (inner error) and systematic error added together in quadrature. The solid line shows the result of the NLO GLAP global fit with the associated error indicated by the shaded region. The gluon parameterisations of $MRSD'_-$ and $MRSD'_0$ are shown as dash-dotted lines. The hatched region shows the gluon distribution determined by the NMC experiment.*

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FNAL E665 EXPERIMENT

The Inelastic μ^+p and μ^+-Nucleus Interactions

The E665 Collaboration[1]

The INP E665 group: A. Eskreys, J. Figiel, P. Malecki, K. Olkiewicz, B. Pawlik, and P. Stopa [2]

In 1994 the reduction of the data from the 1991 run was finished and the necessary Monte Carlo samples were generated. In this way the complete data on μ^+p, d, C, Ca, Pb, Xe interactions at about 490 GeV were made available for further study. The analysis of various physical subjects was our main activity this year. The following problems were studied:

a) The intermittency in deep-inelastic muon- nucleon interactions,

b) The relation between nuclear shadowing and diffractive scattering in muon- xenon interactions,

c) Nuclear transparency from exclusive ρ production,

d) Proton structure function F_2,

e) Ratio of neutron and proton structure functions,

f) Nuclear shadowing on various nuclei.

In 1994 five papers were published and further two were accepted for publication. Some of them are presented briefly below.

Nuclear Shadowing, Diffractive Scattering and Low Momentum Protons in the μ^+Xe Interactions at 490 GeV [3]

The E665 Collaboration

The nuclear shadowing has been already observed in μ^+Xe interactions at low x_{Bj} (< 0.02) [1]. On the other hand the multiplication of the slow hadrons in the nuclear cascade was also found [2]. The question was raised if these two phenomena are related. To answer it the x_{Bj} - dependence of three hadronic quantities, specially sensitive to nuclear effects, was studied. They were: total hadronic charge in μ^+Xe interactions $< Q_t >_{Xe}$, average multiplicity of "grey" tracks (slow protons) $< n_g >_{Xe}$ and the difference of backward charged multiplicity on xenon and deuterium targets $< n_B >_{Xe} - < n_B >_d$. All of them were found to increase with increasing x_{Bj} which means weaker hadron cascading in the shadowing region than in the non-shadowing. Investigating the origin of this behaviour we have found that events with large rapidity gaps (> 2.0, called LRG) between the recoil nucleon and the rest of the charged hadrons are responsible for it (see Fig. 1). The LRG events contain the diffractive scattering of the virtual photon which is enhanced at low x_{Bj} (in the shadowing region). For the complementary class of events with small rapidity gaps (SRG) the strength of cascading does not depend on x_{Bj}.

These observations support the hypothesis that diffractive fluctuation of a virtual photon into hadronic state and its scattering in the nucleus are responsible for nuclear shadowing.
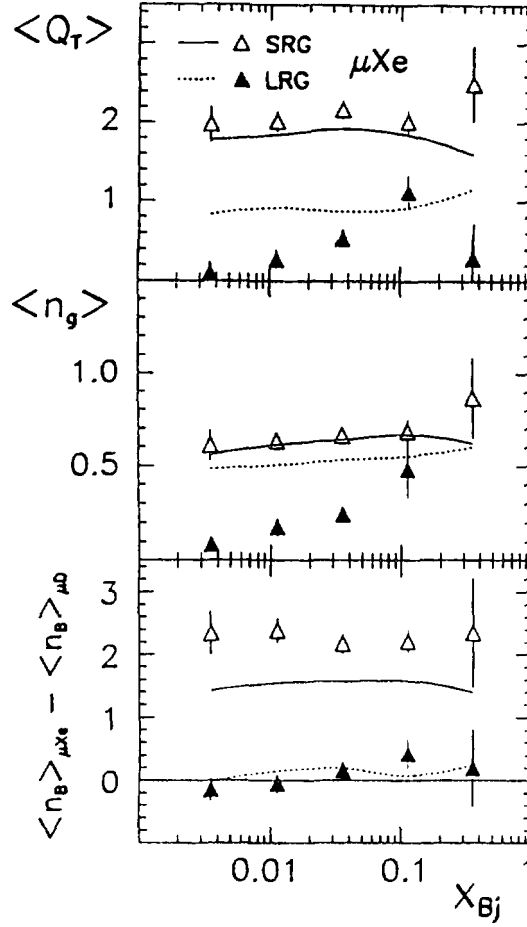

Figure 1: $< Q_T >_{Xe}$, $< n_g >_{Xe}$ and $< n_B >_{Xe} - < n_B >_D$ as a function of x_{Bj} for the SRG and LRG event samples. The lines represent the predictions of the Venus model.

The Proton Structure Function F_2

The E665 Collaboration

The behaviour of the structure function F_2 is expected to be very different in the extreme limits of the kinematic variables. For big Q^2 (DIS limit) $F2$ almost scales with x_{Bj} and has only logarithmic Q^2 dependence from QCD radiative effects. In the photoproduction limit ($Q^2 \rightarrow 0$) F_2 should vanish proportionally to Q^2. The E665 data cover the very interesting transition domain between these limits: $8 \times 10^{-4} < x_{Bj} < 0.12$, $0.2 < Q^2 < 40.0 \, GeV^2$. The x_{Bj} range is comparable with that of experiments at HERA while the Q^2 values are considerably lower. The preliminary results on F_2 are presented in Fig. 2. The expected trends in the structure function behaviour are really observed.
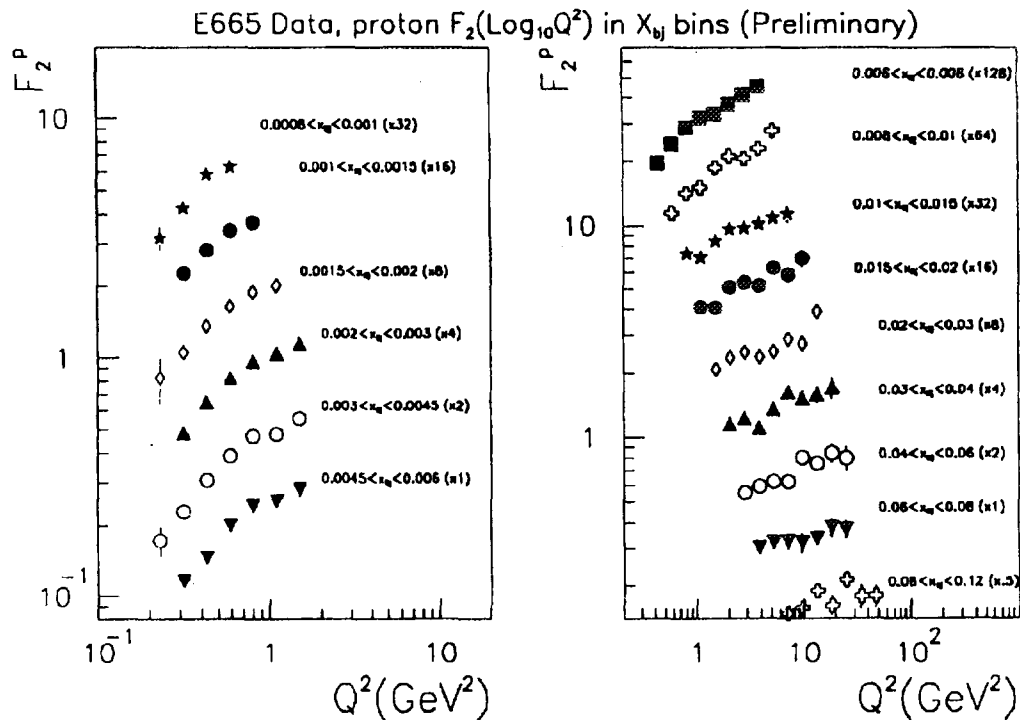
Figure 2: F_2^p as a function of Q^2 in x_{Bj} bins. The errors shown are statistical only.

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CERN NA22 EXPERIMENT

The EHS-NA22 Collaboration[1]

From the Institute of Nuclear Physics: K. Olkiewicz

The experiment has been performed with the European Hybrid Spectrometer (EHS), using a meson enriched positively charged beam from the SPS accelerator. Tracks of secondary charged particles are reconstructed from hits in the wire and drift chambers of the spectrometer and from the measurements in the hydrogen filled rapid cycling bubble chamber RCBC, used as an active vertex detector. The momentum resolution is about 1.5% in the whole momentum range. Ionization information is used to identify protons up to 1.2 GeV/c and electrons (positrons) up to 200 MeV/c. The sample consists of about 86000 well reconstructed inelastic non single diffractive $\pi^+ p$ events.

Transverse Momentum Compensation in π^+ Interactions at 250 GeV/c (Ref. [1])

It is known that important information about production mechanism can be deduced from the distribution, correlations etc. observed in the transverse plane of a high energy collision. Of

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[1]Participating institutions in: Antwerp, Brussels, Cracow, Moscow, Nijmegen, Protvino, Rio de Janeiro, Tbilisi, Yerevan.

particular interest for construction of parton models is the way in which transverse momentum p_t is compensated within the final state of collision. The data are compared to the predictions of FRITIOF6.0, FRITIOF7.0 and the Quark-Gluon-String (QGSM) models. All the three models give reasonable description of the gross features of the data in terms of multiplicity, single particle p_t and rapidity distributions, however in p_t compensation important differences are observed.

The main conclusions of the analysis are the following:

1. Significant transverse momentum transfer is observed between the two cms hemispheres. The transfer is larger than predicted by the models (see Table 1). The transfer is mainly absorbed by the large number of particles in the central region.

2. Non trivial correlations (beyond multiplicity effect) exist between the total p_t of charged particles in the forward and backward hemispheres.

3. Transverse momentum compensation with respect to the sphericity axis is observed essentially inside one hemisphere.

Table 1. Average values of transverse momenta in the forward Q_f and backward Q_b hemispheres and in the central region:

$$\vec{Q}_b = \sum_{j=1}^{k} \vec{p}_{t,j}, \quad \vec{Q}_f = \sum_{j=k+1}^{n} \vec{p}_{t,j},$$

where n is the total number of charged particles in the whole event and k is that of charged particles in the backward hemisphere.

| | total hemispheres | | $|x_F| < 0.2$ | |
	$< Q_f > GeV/c$	$< Q_b > GeV/c$	$< Q_f > GeV/c$	$< Q_b > GeV/c$
experiment	1.028 ± 0.004	0.974 ± 0.003	0.936 ± 0.004	0.885 ± 0.004
QGSM	0.684 ± 0.002	0.676 ± 0.002	0.628 ± 0.002	0.628 ± 0.002
FRITIOF6.0	0.619 ± 0.002	0.595 ± 0.002	0.551 ± 0.002	0.517 ± 0.002
FRITIOF7.0	0.649 ± 0.002	0.633 ± 0.002	0.648 ± 0.003	0.631 ± 0.003

Collective Sea-Gull Effect in $\pi^+ p$ Interactions at 250 GeV/c (Ref.[2])

This analysis is related to that published in [1] in terms of the collective longitudinal and transverse variables. A dependence of the collective average transverse momentum $< p_t > = |\sum p_t|$ on the collective longitudinal variable $X_F = \sum x_F$ (where the sums include the charged particles in the beam or the target fragmentation regions) is studied. The corresponding plot for single particles is not well reproduced by the models. It has a characteristic sea-gull shape and its "wings" are rising with increasing energy $\sqrt{s}$. This effect is attributed to the presence of hard-like processes. By using the collective variables the differences between the data and the models should be reduced if they come from the fragmentation phase of interaction.

Two cases seem to be distinguished by the data:

1. For system of hadrons produced at small cms angle $\theta^0 < 9°$ or $\theta^0 > 171°$ the collective sea-gull effect can be described by the FRITIOF models,

2. However, when including larger emission angles ($\theta^0 > 21°$) the collective sea gull effect is underestimated by these models. This suggests that hard-like processes yielding particles with comparatively large cm emission angles take place in the collision phase, but are not properly included in the models.

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EXPERIMENTS NA35 AND NA49 AT THE CERN SPS[1]

The NA35/NA49 Collaboration[2]

Group from the Institute of Nuclear Physics includes:
J. Bartke, E. Gładysz-Dziaduś, M. Kowalski, P. Stefański (physicists),
and E. Górnicki (engineer)

The aim of these experiments is to study the production of charged hadrons and neutral strange particles in collisions of ultrarelativistic nuclei with nuclear targets. Single-particle spectra of various particles as well as two-particle correlations (boson interferometry) are investigated in a search for the phase transition of nuclear matter to the Quark-Gluon Plasma predicted by the Lattice QCD.

In the experiment NA35 the 2 m long streamer chamber placed in a magnetic field served as the main tracking detector. A time projection chamber (TPC) was added to the set up at the later stage, allowing significantly higher statistics and precise momentum analysis for particles emitted into the forward hemisphere to be obtained. The energy flowing in the forward direction was measured by a set of calorimeters. Data with oxygen and sulphur beams of 60 and 200 GeV/nucleon were taken in several runs at the SPS in the years 1986-92 and their analysis is still being continued. Nine papers were published in 1994.

Experiment NA49 is a continuation of NA35 using the lead beam of 160 GeV/nucleon. The experimental set up is shown in Fig. 1.
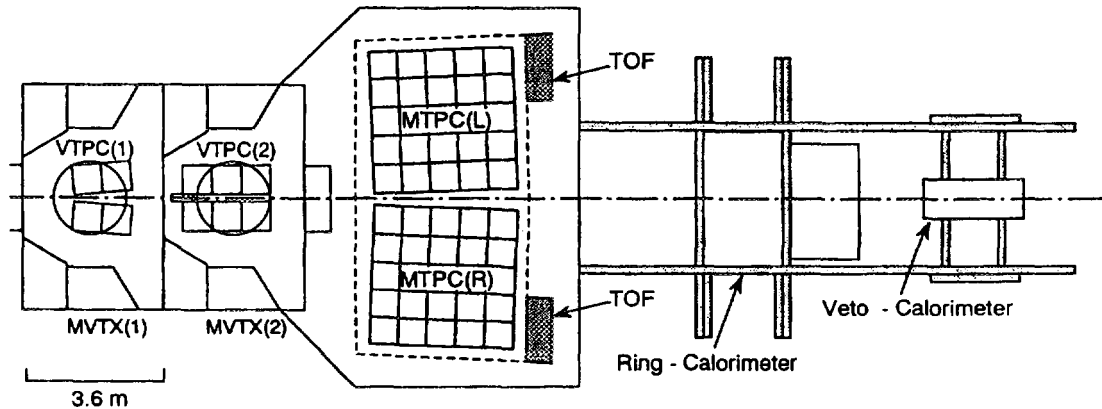
Figure 1: The layout of the NA49 detector (full configuration).

The major detector components are a large volume, fine granularity time projection chamber MTPC with a total of about 100 000 electronic channels, and two high resolution intermediate size time projection chambers VTPC placed in the magnetic field. The hadron identification system is completed by a high resolution time of flight wall TOF. The forward angle calorimeters of NA35 are also employed here for energy flow measurements.

Large acceptance of the detector system allows to study global dynamical observables at the event by event level which is a new, promising feature.

To this experiment we contributed the mechanical manipulator/extractor for handling the TPC readout chambers for the MTPC (a more detailed description can be found in the activity report of the Division of Mechanical Constructions), regulator boards for the low-voltage power system for time projection chambers (130 boards made) and some other electronics, developed in Cracow. Computer simulation of the TPC performance was also made - a short account of this work is presented below.

In Autumn 1994 one Vertex TPC and one half of the Main TPC were ready to take data in the 160 A GeV lead beam from the SPS. This first run was successful. the detector performance met the expectations. The detector should be expanded to its full configuration in 1995.

Space Charge Calculations for NA49 Vertex TPC-s

M. Kowalski

In Time Projection Chambers (TPC) working in the environment of high multiplicities and/or high event rates one can expect a large current in the readout chamber and a significant positive charge build up in the drift volume. Thus, the detailed calculation of the space charge becomes of great importance for the proper design of electronics and the field cage.

The space charge in the TPC used in heavy ion collisions originates from the ionization caused by primary particles as well as from δ electrons generated by a multicharged beam particles. Some of δ-s can enter not only the TPC drift volume, but also the proportional chamber of the readout module which is especially harmful, because such ionization is magnified by a gas gain and, unlike the ionization generated in the drift volume, cannot be gated out.

Calculation have been performed in several steps:

- for δ-s, events consisting of δ-s and the vertices of their generation have been created assuming an exponential probability distribution of distances between subsequent collisions leading to release of a δ

$$P(s) = \frac{1}{\bar{s}} \exp \frac{-s}{\bar{s}}, \tag{1}$$

where $s = \frac{1}{N_\delta}$, $N_\delta = 2.39$ m^{-1}
- for vertex Pb-Pb events the VENUS 4.12 generator has been used
- each track has been followed through the simplified NA49 setup using GEANT; in the sensitive volume the step length for each tracking step has been calculated using the probability distribution of distances between subsequent collisions leading to the ionization energy loss as in Formula 1 with $\bar{s} = \frac{1}{N_{prim}}$, where N_{prim} is the number of primary ionization electrons per cm , equal to 14.2
- from the energy loss due to ionization, the charge density has been calculated
- assuming gas multiplication of 5000, the magnitude of current has been calculated
- assuming the ion drift velocity equal to 500 cm/s the build-up of positive charge density has been obtained
- the Poisson equation has been solved to obtain potential distribution
- distortions due to the space charge have been calculated.

Below are listed values of the charge integrated over half of the VTPC (one side, 3 sectors) as well as the corresponding current of different origin, assuming the beam rate 10^5 s^{-1} and the central event rate 30 s^{-1}:
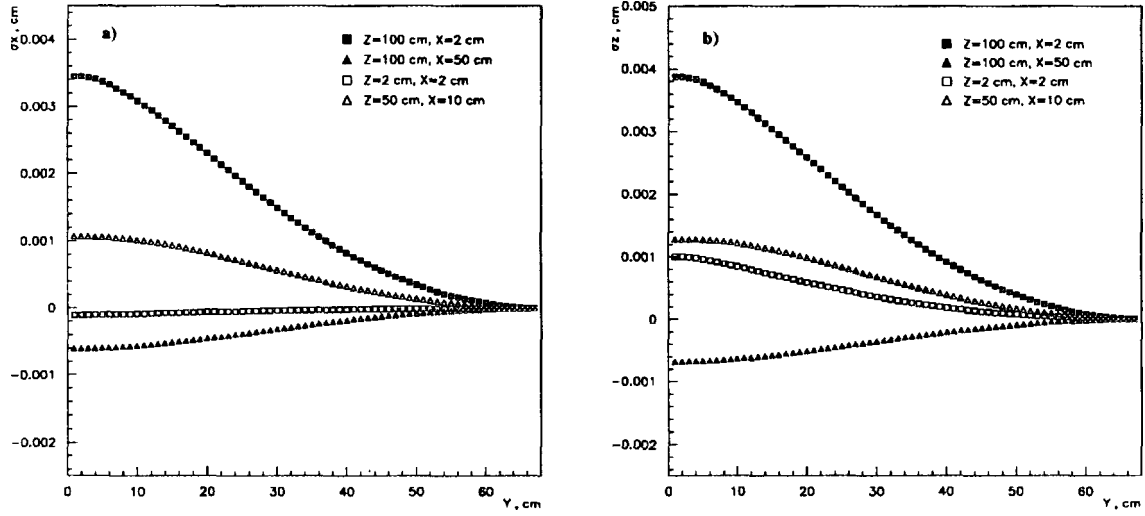
Figure 1: Distortions in the X (a) and Z (b) directions due the positive charge build-up from the ionization caused by δ-s as a function of Y coordinate (drift length is equal 68 cm - Y) for different values of Z and X. The origin of the coordinate system is in the left lower corner of the TPC, the beam is along the Z axis.

1. δ-s entering the proportional chamber:
   $Q=1.4*10^{-11}$ C,
   $I\approx70$ nA

2. δ-s in the drift volume:
   $Q=1.4*10^{-9}$ C,
   $I\approx7$ μA;
   in this case one has to take into account that most of this charge is gated out. Assuming open gate time 50 μs and averaging over 1 s one finally gets:
   $I\approx10$ nA.

3. central vertex event:
   $Q=5.9*10^{-13}$ C,
   $I\approx60$ μA for a single event;
   averaged over 1 s:
   $I\approx90$ nA

One can see that the signal (vertex event) and background (δ-s) are of the same order what has been confirmed during the November-December '94 Pb ion run.

The positive charge built from the ionization caused by δ-s and background minimum bias events is a source of an extra electric field in the drift volume and leads to distortions of tracks. Distortions due to minimum bias events do not exceed few microns and thus can be neglected. Distortions due to δ-s are shown in Fig. 1. They do not exceed 50 microns and are within the experimental resolution of the NA49 vertex TPC.

ALICE - the Detector for Heavy Ion Physics at the LHC

The ALICE Collaboration[1]

Group from the Institute of Nuclear Physics includes:
J. Bartke, E. Gladysz-Dziaduś, M. Kowalski, and P. Stefański

The heavy ion community proposes to build a dedicated, general purpose detector ALICE for the LHC. In collisions of heavy ion beams of about 3 TeV/nucleon each one should get all parameters relevant to the formation of the quark-gluon plasma much more favourable than at the SPS, and also at RHIC: the average energy density should be well above the deconfinement threshold and the central rapidity region will have nearly vanishing baryon number density. The Letter of Intent for the ALICE detector, presented in March 1993, obtained a positive recommendation of the LHC Committee in April 1994, and the ALICE Collaboration has been requested to proceed towards the Technical Project by the end of 1995.

Our contribution at this stage are computer simulations for the large cylindrical TPC, performed within the CERN RD32 development project. In particular the single point accuracy and double track resolution have been studied for different readout chamber geometry. The momentum resolution and the resolution in HBT variables have also been investigated. The possibility of using TPC with divided drift volume has been checked as well. Also the pattern recognition algorithm for track finding in the TPC has been proposed and tested. Simulation of a full TPC event for the development of DAQ has been started. All these activities will be continued in 1995.

BNL 868 EXPERIMENT[2]

The KLMM Collaboration[3]

from Cracow:
A. Dąbrowska, R. Hołyński, A. Olszewski, M. Szarska, B. Wilczyńska, and W. Wolter

Interactions of 10.6 GeV/n Gold Nuclei with Light and Heavy Target Nuclei in Nuclear Emulsion

In 1992 we exposed a number of stacks of BR-2 nuclear emulsion to a beam of gold nuclei accelerated at the Brookhaven AGS to the kinetic energy of 10.6 GeV/n. The general characteristics of these interactions on emulsion target have been shown and compared with those observed previously at lower energies, < 1 GeV/n [1]. It was found that the breakup of the projectile gold nuclei at high energy is appreciably more severe than that observed at lower energies. The results discussed here concern the study of the multiparticle production and fragmentation

of nuclei participating in the interactions of 10.6 GeV/n gold nuclei with different nuclear targets. We have developed [2] a method of selecting unbiassed samples of gold interactions with the light (H, C, N, O) and heavy (Ag, Br) target nuclei in the emulsion. This has allowed the study of different processes as a function of the mass of the target nucleus.

The multiplicity distributions of created charged particles, n_π, for the two samples of gold interactions are shown in Fig. 1. The average number of created particles is 17.4 ± 1.0 in interactions of gold with the light target nuclei, and 92 ± 4 in interactions with the heavy nuclei. These multiplicities are proportional to the mean numbers of intranuclear nucleon-nucleon collisions in agreement with the predictions of simple superposition models. The pseudorapidity distributions of all singly charged relativistic particles show strong forward asymmetries, particularly for the interactions with the light target nuclei [2]. These asymmetries are caused by the presence of the many released protons among the singly charged relativistic particles and by the asymmetry in mass of the colliding nuclei.
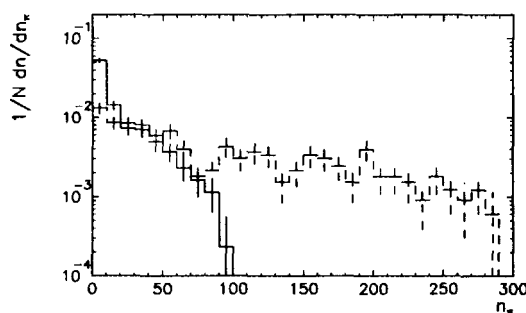

Fig. 1: Multiplicity distributions of created charged particles n_π in interactions of 10.6 GeV/n gold nuclei in light (—) and heavy (- - -) target nuclei.
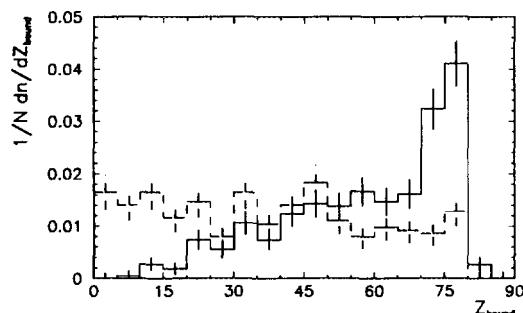
Fig. 2: The distributions of the total charge Z_{bound} in interactions with light (—) and heavy (- - -) targets.

The fragmentation of the projectile gold nucleus after an interaction with different target nuclei has been also investigated. The probability distributions for the emission of the total charge, Z_{bound} bound in multicharged projectile fragments are shown in Fig. 2 for the two targets. We see that in interactions with the light target nuclei the probabilities for events with small Z_{bound} are very small, and that the highest probabilities are for events with most of the charge still bound, i.e. Z_{bound} close to the charge of the projectile. In contrast, in interactions with the heavy target nuclei the probabilities are almost independent of Z_{bound}. The effects shown in Fig. 2 and also other features of the gold fragmentation reported in [2] indicate that heavy target nuclei produce a more violent breakup of the projectile gold nucleus than in the case of the lighter targets.

We have also studied the correlations between parameters describing nuclear fragmentation processes and the particle production. As a parameter describing the production process we have chosen the number of created charged particles which is a measure of the degree of centrality of the collision. In Fig. 3 we present the dependence of the average number of fragments emitted from the target nucleus, $< N_b >$, on the number of created charged particles. We see that for both samples, in contrary to the results obtained for light (proton, oxygen, sulphur) projectiles [3, 4, 5], the mean number of target fragments generally decreases with increasing n_π with the exception for very peripheral collisions on heavy targets. In Fig. 4 we show the dependence of the mean number of multicharged projectile fragments, $< N_{tot} >$, on n_π. The number of projectile fragments initially increases with increasing centrality of the collision. Then, after reaching a certain degree of centrality, $< N_{tot} >$ decreases with the further increase of n_π. This decrease of $< N_{tot} >$ with increasing n_π is particularly clearly seen for the heavy target nuclei. The correlations shown in Fig. 3 and 4 may be due either to a large number of intranuclear nucleon-nucleon collisions which result in less and less of the residual target nucleus being left

as an entity, or it may indicate that a violent explosion of the target nucleus occurs in which the nuclear remnants are no longer emitted as slow particles in the rest system of the nucleus.
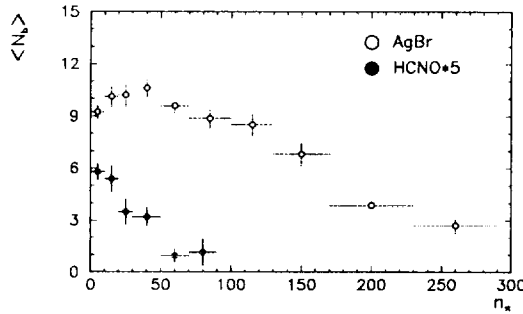

Fig. 3: The relation between the mean number $\langle N_b \rangle$ of heavy-ionizing particles and the number n_π of created charged particles in interactions with light ( ) and heavy ( ) targets. The $\langle N_b \rangle$ values are shown scaled by 5 for the sample of interactions with light target nuclei.
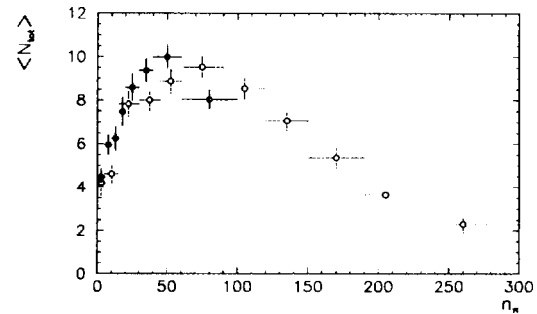
Fig. 4: The relation between the average total number $\langle N_{tot} \rangle$ of projectile fragments and the multiplicity of created charged particles n_π in interactions with light ( ) and heavy ( ) targets.

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5. E.G. Boos et al., Nucl. Phys. **B143** (1978) 232.

CERN - EXPERIMENT EMU07[1]

The KLM Collaboration[2]

from Cracow:
A. Dąbrowska, R. Hołyński, A. Jurak, A. Olszewski, M. Szarska, A. Trzupek, B. Wilczyńska, H. Wilczyński, W. Wolter, B. Wosiek, and K. Woźniak

Phase Space Dependence of the Correlations Among Particles Produced in High Energy Nuclear Collisions[3]

Correlations between charged particles produced in central collisions of p, ^{16}O and ^{32}S at 200 GeV/nucleon with Ag/Br targets have been analysed. A search for the effect of nonstatistical fluctuations has been performed by means of the factorial moments [1] and correlation integrals [2]. Correlations have been studied in different phase space regions, thanks to the full phase space coverage attainable in emulsion detectors. The results of the analysis of the factorial moments are compatible with those obtained from the study of the correlation integrals in the one-dimensional phase space.
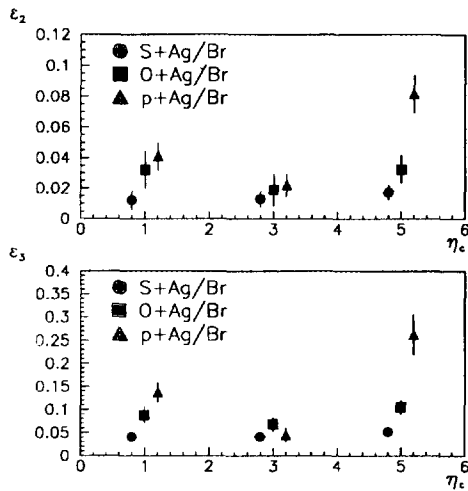
Fig. 1 Dependence of the intermittency indices ϵ_q obtained from power law fits to the correlation integrals in the azimuthal angle space on the location of pseudorapidity window η_c for the three data samples. For clarity, the intermittency indices for p and S data are slightly shifted in η_c with respect to $\eta_c = 1, 3$ and 5.
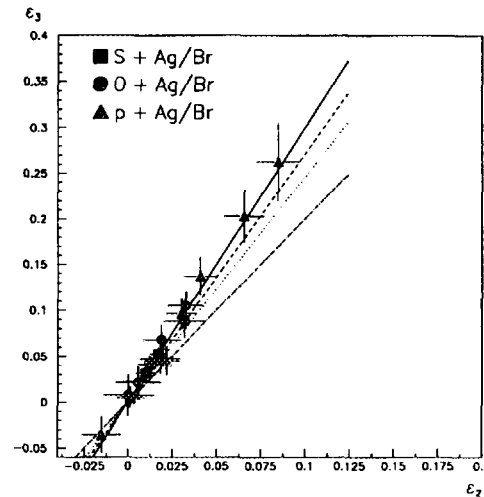
Fig. 2 Correlation between ϵ_3 and ϵ_2 obtained from one-dimensional analyses in η and φ variables in different pseudorapidity intervals. Lines correspond to: self-similar cascade model (solid and dashed); to the monofractal structure (dashed-dotted); and to the Ginzburg-Landau description of the second order phase transition (dotted).

The moments exhibit a power-law rise with decreasing size of the phase space cell in the one-dimensional analyses, thus showing the effects of intermittency. Also in the one-dimensional analysis a stronger effect is seen in the azimuthal angle φ than in the pseudorapidity η. This indicates that bulk of the events responsible for the one-dimensional effect are *fan-like*, i.e. with strong correlations in $\delta\varphi$ diluted over the whole interval in η, and not *ring-like*, which would be characterized by strong correlations in η uniformly distributed over the entire 2π interval in φ. The correlations weakly depend on the location of pseudorapidity region (see Fig. 1). Somewhat larger indices are obtained in the forward pseudorapidity range. In the target and projectile fragmentation regions the intermittency indices decrease with increasing mass of the projectile, however more slowly than $(dN/d\eta)^{-1}$ expected in superposition models [3]. In the central pseudorapidity region no systematic dependence on the projectile mass is seen. The dependence of the intermittency indices on the rank of the moments (see Fig. 2) is consistent with that derived from a self-similar cascade process [4] but disagrees with the behaviour expected in the case of a single fractal dimension [5]. The present data do not allow to rule out the possibility of the occurrence of the second order phase transition described in terms of Ginzburg-Landau theory [6].

In the two-dimensional analysis the effect is stronger than in the one-dimensional case, however, the dependence of the factorial moments and correlation integrals on the cell size is not compatible with a simple power-law in the full range of cell sizes. The long range two-dimensional correlations seem to be suppressed and then faster than power-law increases are seen. It is shown, however, that the two-dimensional data seem to obey more generalized power behaviour. This generalized power-law is shown to be independent of the reaction type and the location of the analyzed phase space region.

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CERN - EXPERIMENT EMU13[1]

The KLMM Collaboration[2]

from Cracow:
A. Dąbrowska, R. Hołyński, D. Kudzia, A. Olszewski, M. Szarska, A. Trzupek, B. Wilczyńska, H. Wilczyński, W. Wolter, B. Wosiek, and K. Woźniak

Particle Production and Nuclear Fragmentation in Interactions of 158 GeV/nucleon Lead Nuclei with Lead and Nuclear Emulsion Targets

In December 1994 emulsion chambers with lead targets as well as conventional emulsion pellicle stacks were exposed to the beam of 158 GeV/nucleon lead ions at CERN SPS. Each emulsion chamber consisted of three sections (see Fig. 1): section A, containing Pb foils as a target and nuclear emulsions separated by air gaps, S, to perform angular measurements of charged particles produced in nuclear interactions; section B, composed of nuclear emulsions and large air gaps, S, to measure the divergence of projectile fragments and section C, containing three nuclear emulsion pellicles where the charges of projectile fragments are measured.
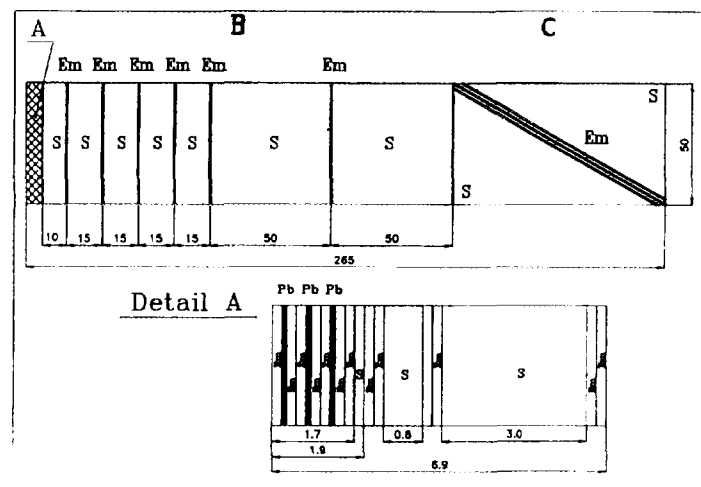

Fig. 1 The basic design of emulsion chamber.
Distances are given in milimeters.

The aim is to study the characteristics of particle production and nuclear fragmentation modes in ultrarelativistic Pb ion interactions with Pb nuclei as well as with hydrogen, light (C, N, O) and heavy (Ag, Br) nuclei of nuclear emulsion. About one thousand interactions with various targets and different impact parameters will be analysed using the semiautomatical devices designed and constructed in Cracow.

Measurements of multiplicity and pseudorapidity, η, distributions of charged relativistic hadrons produced globally and in limited regions of η will be performed, together with the multiplicity and angular distributions of nuclear fragments. We anticipate multiplicities of more than one thousand singly charged particles produced in one central Pb-Pb collision. This will make possible to study event-by-event the structure and the relevant signatures of quark-gluon plasma, e.g., pseudorapidity density distribution and its fluctuations.

The data will be compared with similar ones obtained from the analysis of ^{32}S and ^{16}O interactions at 200 GeV/nucleon (experiment CERN EMU07) and ^{197}Au interactions at 10.6 GeV/nucleon (experiment BNL 868). This will allow us to make studies of multiparticle production and fragmentation processes as function of energy and mass of the multicharged projectile.

JACEE EXPERIMENT[1]

from Cracow:

R. Hołyński, B. Wilczyńska, H. Wilczyński, and W. Wolter

The JACEE Collaboration continues to study cosmic ray composition, energy spectra and nuclear interactions, using emulsion chambers which are exposed to cosmic rays in balloon flights at high altitude. Primary particle charge and energy are measured, thus elemental composition and spectra can be obtained at energies in the 1–100 TeV/nucleon energy range.

1 Cosmic Ray Spectrum

Cosmic rays coming at the Earth have a very broad energy spectrum – from about 10^7 eV to at least 10^{20} eV. The all-particle spectrum falls with energy according to the power law $E^{-\gamma}$. A pronounced break in this spectrum (a "knee") is observed at energies $10^{15} - 10^{16}$ eV. Below 10^{15} eV the differential spectrum depends on energy as $E^{-2.7}$, while above 10^{16} eV – as $E^{-3.1}$. It is generally believed that the knee in the cosmic ray spectrum is a result of a change in acceleration mechanism or in propagation of cosmic rays in the galaxy. Understanding these processes is one of most important problems in astrophysics. In recent years a theory of cosmic ray acceleration by shock waves in supernova remnants has been developed. The energy spectrum resulting from this process agrees with that actually observed at energies below the knee. The acceleration in supernova remnants has an upper limit on energy to which particles can be accelerated. This limit is expected to be about 10^{14} eV for protons and about $3 \cdot 10^{15}$ eV for iron nuclei. If this theory is valid, cutoffs should be observed in spectra of various cosmic ray nuclei at energies increasing with their charges.

The most recent data from the JACEE experiment [1, 2] indicate a possible kink in proton spectrum at energy $4 \cdot 10^{13}$ eV. This agrees well with the expectation from acceleration in supernova remnants mechanism. However, within the accuracy of presently available data the kink is not observed in the helium spectrum up to about 10^{14} eV/nucleon.

New JACEE emulsion chambers were exposed in balloon flights in Antarctica in December'93/January'94. Two flights were performed which circumnavigated the Antarctic continent, as shown in Fig. 1. The new data from these flights are now being accumulated.
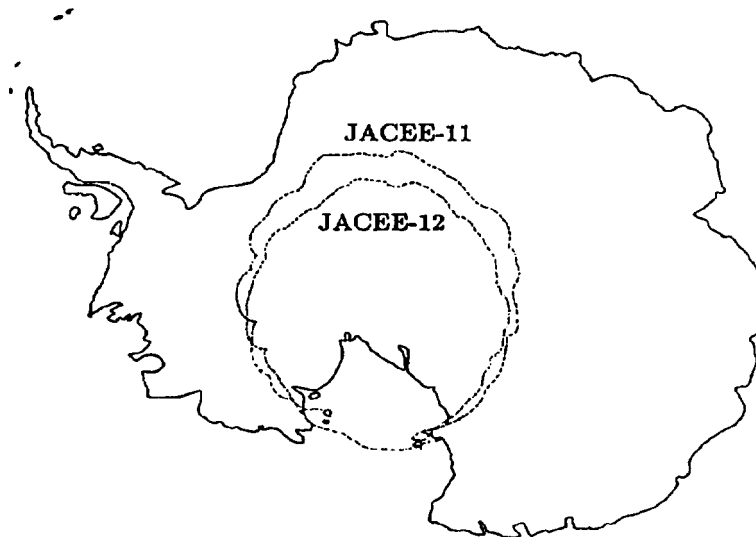
Figure 1: Paths of JACEE-11 and JACEE-12 Antarctic balloon flights.

2   High Energy Interactions

Among the interactions recorded by JACEE so far two events were found which contain heavy (most probably bottom) particle decays and which were studied in detail [3]. These decays show a striking similarity: a singly charged heavy particle decays into just one charged particle and at least four photons. Four of these photons converted within 0.38 and 0.59 conversion length, respectively in the two events. The probability of such early conversions is small $(4 \cdot 10^{-4})$ if there were just four photons emitted in each decay. The observed small conversion distances indicate that there should have been of the order of 10 photons emitted at each decay vertex. On the other hand, observation of two such multiphoton decays is incompatible with branching ratios of known decays of bottom and charmed particles with the observed topology. Larger photon multiplicities are likely to imply larger parent particle masses, thus enabling their strong or electromagnetic decays, which would contradict the observation.

The decaying particle in one of the events was identified to be a bottom particle. The simplest decay mode compatible with the data is $B^- \to D_s^- \eta \eta$, with $b \to u$ quark transition. Finding two such decays in event sample so small would be incompatible with $e^+ e^-$ data on charmless b quark decays. The decaying particle in the second event is either bottom or charmed particle and its decay channel cannot be identified. In view of the above it is unlikely that the second decay is also a $b \to u$ decay, but this channel cannot be ruled out.

It may be posssible that not all decay products of particle 1 were recorded in the decays discussed. However, those decay products which were detected already allow one to make a conclusion that what is observed is either (i) four-photon decays — but the photons convert unusually early in both cases (if both decays represent a $b \to u$ transition, this would in addition be inconsistent with $e^+ e^-$ data), or (ii) decays with photon multiplicities considerably larger than 4 — but this would be incompatible with branching ratios of known bottom and charm decays, or (iii) decays with charged multiplicity larger than 1, with only one charged particle emitted at small angles — but this would imply masses of decaying particles larger than those of known bottom particles, or (iv) emission of new, light neutral particles, which in turn decay into $e^+ e^-$ — but the available evidence is too weak to be accepted, or (v) the observed secondary vertices are actually due to nuclear interactions — but their observed features make this hypothesis improbable, or (vi) decays so far unknown.

The close similarity of the two decays may suggest that these are examples of the same, relatively frequent, decay channel of a bottom particle. Since the observed features do not agree

with characteristics of known decays, this may be an indication of a new decay channel of a heavy particle.

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BNL - EXPERIMENT PHOBOS AT RHIC[1]

The PHOBOS Collaboration[2]

From Cracow:

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The aim of the PHOBOS experiment [1] is to explore the new physics of nuclei collisions at the Relativistic Heavy Ion Collider (RHIC) in Brookhaven. RHIC accelerator with the energy of heavy ions beams of 100 GeV/nucleon will open a new area of research where the conditions for the creation of the Quark Gluon Plasma (QGP) will be well fulfilled according to the present theoretical estimates. There are several sensitive observables to probe the existence of the QGP. The PHOBOS detector is designed to study a number of this specific signatures like, e.g., structures in the p_t distributions, multiparticle correlations, abundant production of some species of particles, change in properties of some particles (e.g. ϕ-mesons) and other. Some of those observables can be investigated on an event-by-event basis, the other will be obtained from the inclusive high statistics measurements.

In the last year (1994) efforts of the PHOBOS collaboration focussed on the technical issues to be solved prior to full construction of the PHOBOS detector. A major progress has been made on technical issues of PHOBOS subsystems (silicon detectors, silicon front-end electronics, data acquisition and trigger, magnet, cooling system, and detector support structures) and on PHOBOS detector simulations (multiplicity measurements, tracking proof-of-principle, HBT measurement capability, particle identification, ϕ mass, and width measurements). The presentations of results on these issues resulted in a full construction approval by Brookhaven's Technical Advisory Committee (TAC). Cracow part of PHOBOS collaboration participated in both kinds of efforts [2, 3, 4]. Some of them are presented in the next two sections.

Particle Identification in the PHOBOS Detector [3]

The particle identification (PID) algorithm has been constructed to determine the particle identification performance of the PHOBOS detector. To accomplish this, the standard PHOBOS Monte Carlo (PMC) code was used to generate and trace large samples of π^+, K^+, p and e^{+-} particles (about 50000 particles of each type) uniformly distributed in the cosine of the polar angle (with the azimuth $\phi = 0$) and in the initial particle momentum. The large PMC samples of particles were used for defining the algorithm but later, for testing the algorithm and the results, standard HIJET events were used. Energy losses of these PMC particles traversing different components of the PHOBOS detector were described by the standard GEANT option (the Landau distribution) using the most accurate descriptions of the detector geometry and materials.

Data from simulations have been analysed to obtain PID bands. To construct them we made scatter plots of dE/dx versus momenta for a large sample of each type of particle. The dE/dx was calculated out of 10 hits in the spectrometer silicon plains. Because large fluctuations in energy loss due to the Landau tail smear the PID performance we have tested different kinds of truncations, i.e. different numbers (from 0 up to 4 out of 10 dE/dx values per particle) of biggest dE/dx values were rejected while calculating the average. The scatter plots were sliced in the momentum range from 0 GeV/c to 1 GeV/c in 50 bins 20 MeV/c each. Each slice projected on the dE/dx axis had tails cut off in such a way that the fraction of entries inside the cut-off tails was 2.5 % on each side. The lowest and the biggest values of the tailored dE/dx distributions for hadrons were fitted with 5-parameters functions. A graphical presentation of obtained functions is shown in Fig. 1 for four truncations.
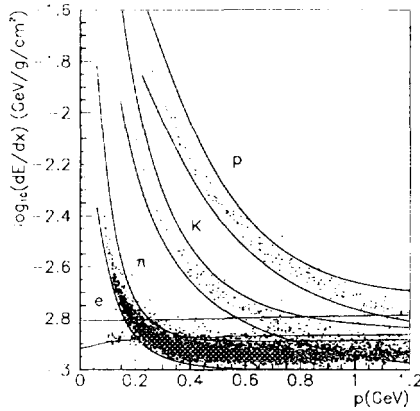
Fig. 1 PID bands (solid lines) in the dE/dx vs the particle momentum scatter plot. Dots are PHOBOS Monte Carlo results for dE/dx for one hundred central Au(100 GeV/nucl) - Au(100 GeV/nucl) events from HIJET.

In terms of the obtained PID bands the algorithm for particle identification was defined as follows: when a particle with dE/dx and the momentum p is inside one and only one PID band corresponding to a particle of the type A then the particle is identified as A. The above definition excludes all areas (in the dE/dx vs p plot) outside bands and also those where PID bands overlap. To gain on the pion, kaon and proton efficiencies we do not exclude the areas were the electron band overlaps with the pion, kaon and proton bands since the electron abundance (which is due to background particles) in these regions is small.

Fig. 2 Efficiencies of identification of π and K for two (open circles), three (full circles) and four (triangles) truncations as a function of the particle initial momentum.

We have applied the PID algorithm to the sample of 100 central HIJET events to find the efficiencies for particle identifications and contaminations in the identified samples of particles by other particles. We have selected only those particles hitting the spectrometer planes (in

two arms) which traversed through the first 10 planes. The energy losses of the particles are presented in Fig. 1 as dots. In Fig. 2 the efficiencies (probabilities $P(A \rightarrow A)$ that a particle of type A is identified as a particle of the same type A) for π and K versus the particle momentum for 2, 3, and 4 truncations are shown as an example. The contaminations (probabilities that a particle identified as A is in fact a particle of a type different than A) in samples of particles identified as π and K are shown in Fig. 3. From probabilities shown in Fig. 2 (and also for protons and electrons - not shown here) we can see that efficiencies for identifying π, K and p is 100 % below 0.2, 0.4, and 0.6 GeV/c regardless of the type of the truncation. In the momentum range 0.2-0.7 GeV/c for π and K the efficiencies are about 95 % (due to cutting of the tails of the dE/dx distributions). For protons this is the case up to 1.2 GeV/c in momenta. For higher momenta (above 0.7 GeV/c for π and K, and above 1.2 GeV/c for protons) the efficiencies sharply fall down. Using four truncations this upper limit in momenta can be extended by about 200 MeV/c to higher values as compared to the case of two truncations.
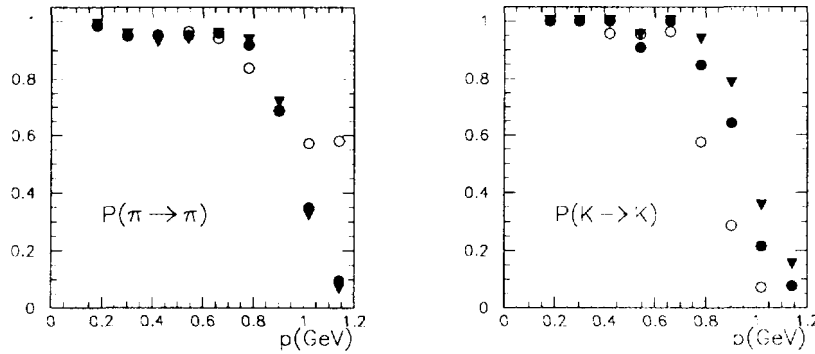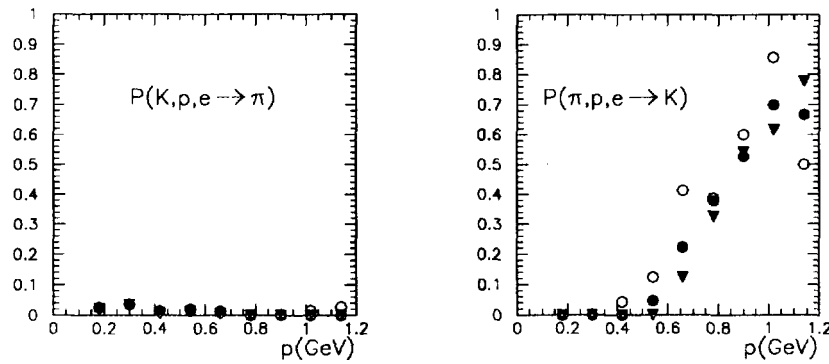

Fig. 3 Contaminations in the samples of identified π and K for two (open circles), three (full circles) and four (triangles) truncations as a function of the particle initial momentum.

In Fig. 3 (and also in figures for protons and electrons - not shown here) we can see small (less then 5 %) contamination in the pion sample in the momenta range 0 - 0.6 GeV/c due to electrons. There is no contamination in the kaon sample up to about 0.4 GeV/c for two truncations (for four truncations up to 0.6 GeV/c). Then the contamination starts to increase to about 90 % at 1 GeV/c (60 % for 4 truncations) mainly due to pions. There is also a contamination in the kaon sample up to 15 % from electrons in the momentum range 0.7 - 1.2 GeV/c. There is no contamination in protons in the range 0 - 1.0 GeV/c. At 1.1 GeV/c for 2 truncations there is a 15 % contamination from pions. For more truncations the contamination is smaller.

The study of the PHOBOS PID performance with the help of the PID algorithm shows that for well defined tracks and correctly measured particle momenta we will be able to identify non-stopping particles in the detector with a very good efficiency.

Water Cooling of Silicon Detectors

Cooling efficiency of the silicon detectors has been intensively investigated. The test model of the PHOBOS silicon detector described in [4] was built basing on the design presented in [1]. Preamplifiers and pipeline chips existing in the design are here simulated by resistive heaters. Heat generated by the heaters is taken away by water flowing inside circular channels. Heat sources and water are separated by ceramic layers and aluminum detector plate glued one to another with thermoconductive glue Thermopox 35. To improve the heat contact between detector plate and cooling frame thermoconductive paste Silpox was used. Fig. 4 (left) illustrates the vital role of the heat contact between the detector plate and cooling frame. It presents the

results of the tests performed in two situations: first, the detector plate was placed directly on the cooling frame (upper curve) and next, with the thermoconductive paste put between them (lower curve). As one can see, in the first case the temperature difference between cooling water and heat generating elements is equal to about 32 deg and in the second case only 18 deg. Thus the heat resistance of the contact between detector plate and cooling frame can increase the temperature difference almost twice. The heat resistance of the contact is in this case equivalent to an air layer having thickness of about 0.015 mm. Therefore the use of thermoconductive paste is necessary. Fig. 4 (right) presents the results obtained for two cooling frames 20 and 30 mm wide. It shows that in case of the detector plate 2 mm thick made of a good heat conductor (e.g. aluminum alloy) the temperature distributions are practically the same for both types of the cooling frames.
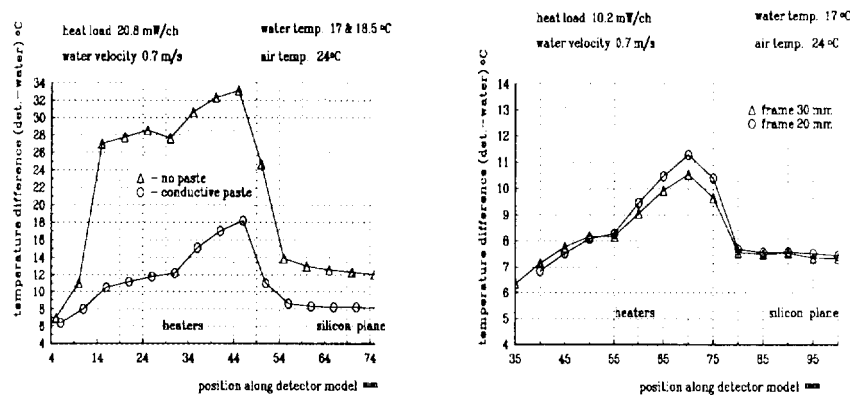
Fig. 4 Results of tests for different contacts (left) and for different cooling frames (right).

The theory of heat exchange is well known in the case of one-phase flow inside a pipe and in the case of heat conduction in the solid state, and theoretical predictions are in good agreement with the experimental results. To calculate the heat transfer coefficient (HTC) for water flowing inside a cooling channel the Haussen equation for the flow in the transient range, i.e. between a laminar and turbulent flow, was used. HTC values determined in such a way were used as boundary conditions for finite element calculations of temperature distributions. Finite element model of the detector is shown in Fig. 5.
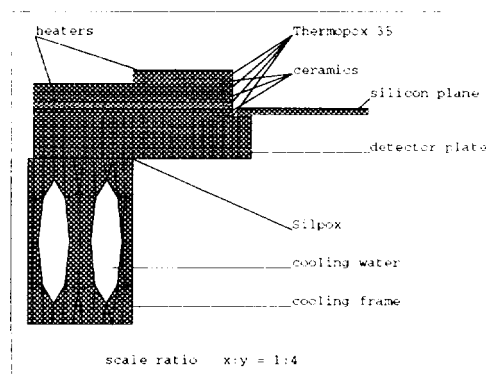
Fig. 5 Finite element model of the PHOBOS detector module.

The detector was covered with the grid of 519 elements and 589 nodes. The calculations were performed using the ANSYS system for the two-dimensional case. Heat exchange in the direction of water flow was neglected. The finite element thermal modelling and the tests were performed with heat conductive paste between the detector plate and the cooling frame. The comparison of the results of the calculations and the measurements was done at various water flow velocities and heat loads. Fig. 6 presents two chosen cases:

- heat load of 10.4 mW/channel, water flow velocity of 0.7 m/s,
- heat load of 10.3 mW/channel, water flow velocity of 0.31 m/s.

Theoretical predictions are in good agreement with the result of tests along the whole length of the detector. The maximum discrepancies do not exceed 2 deg for hybrids and 2.5 deg for silicon plate and are acceptable for both electronics and silicon detector requirements.
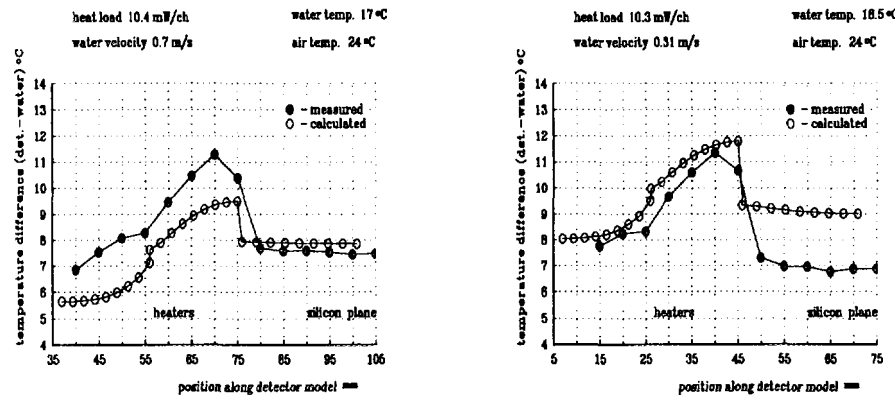
Fig. 6 Comparison of the simulation and the test results

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3. A. Trzupek, Non-Stopping Particle Identification in the PHOBOS Detector, PHOBOS report 95, MIT, January 1995;
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THEORY GROUP

The studies performed by the theory group concentrated on the consequences of the standard model of quarks and leptons and its extensions. The results obtained are directly related to ongoing experiments at LEP, SLC, CESR, BEPC, Tevatron and other accelerators as well as to studies at future machines. In 1994 the members of the group wrote 17 articles which have been published or accepted for publication in journals. In addition 9 other papers appeared as contributions to conferences and preprints. In below we list the most important results on production and decays of heavy flavors, Z boson physics, τ lepton physics, and radiative corrections which were obtained in this year.

1. QCD corrections to semileptonic decays of polarized heavy quarks have been calculated. These belonged to the few uncalculated first order radiative corrections in the Standard Model. The results are employed by ALEPH and OPAL collaborations in experimental analyses of polarization in Λ_b production at LEP. Further applications are in polarization studies for decays of polarized top quarks.

2. QCD corrections to inclusive $b \to \tau X$ decays have been calculated including mass effects.

3. A method of measurement of $bWc(u)$ coupling was proposed. This method was then used by the $L3$ collaboration.

4. The decay constants for B and D mesons have been studied.

5. Higher order (three-loop) corrections to production of heavy quarks in Z decays have been obtained.

6. A substantial upgrade of the BHLUMI Monte Carlo for luminosity measurements at LEP was done. The new version 4 features the second order matrix element. This in turn allows us to reduce BHLUMI total error from 0.25% to 0.16%. It is of crucial importance since the experimental accuracy of the luminosity measurement at LEP is about 0.1%.

7. The family of the Monte Carlo programs KORALZ, KORALB and TAUOLA for production and decays of $\tau^+\tau^-$ in e^+e^- annihilation has been further developed. These programs are used by several collaborations all over the world (eg. LEP, ARGUS, CLEO).

8. A new version of the Monte Carlo program PHOTOS for single and double bremsstrahlung in decays has been published and successfully used by numerous collaborations.

9. Cross sections and polarizations for top quark pair production in e^+e^- annihilation close to threshold have been calculated for polarized beams. The results are applicable in polarization studies at future linear e^+e^- colliders.

QCD Corrections to Decays of Polarized Charm and Bottom Quarks

A. Czarnecki, M. Jeżabek, J.G. Körner, and J.H. Kühn

Distributions of leptons in semileptonic Λ_c and Λ_b decays can be used as spin analysers for the corresponding heavy quarks. QCD corrected charged lepton spectra are known for polarized up-type quarks. The analogous formulae are derived for polarized down-type quarks. These results are applied to the decays of polarized charm and bottom quarks. For charged leptons in charm decays the corrections to asymmetries are small. For bottom decays they exhibit a non-trivial dependence on the energy of the charged lepton.

Distributions of Leptons in Decays of Polarized Heavy Quarks

A. Czarnecki and M. Jeżabek

Analytic formulae are given for QCD corrections to the lepton spectra in decays of polarized up and down type heavy quarks. These formulae are much simpler than the published ones for the corrections to the spectra of charged leptons originating from the decays of unpolarized quarks and polarized up type quarks. Distributions of leptons in semileptonic Λ_c and Λ_b decays can be used as spin analysers for the corresponding heavy quarks. Thus our results can be applied to the decays of polarized charm and bottom quarks. For the charged leptons the corrections to the asymmetries are found to be small in charm decays whereas for bottom decays they exhibit a non-trivial dependence on the energy of the charged lepton. Short life-time enables polarization studies for the top quark. Our results are directly applicable for processes involving polarized top quarks.

V-A Tests through Leptons from Polarized Top Quarks

M. Jeżabek and J.H. Kühn

Angular-energy distributions are studied for charged leptons and neutrinos from the decays of polarized top quarks. A small admixture of V+A interactions is incorporated. The polarization-dependent part of the neutrino distribution which can be measured experimentally through the missing momentum is particularly sensitive towards deviations from the V-A structure. This result remains unaffected by QCD corrections which, however, cannot be neglected in a quantitative analysis.

PL9700229 PL9700228 PL9700227

QCD Corrections to Inclusive Distributions of Leptons in Decays of Polarized Heavy Quarks

M. Jeżabek

Compact analytic expressions have been obtained for the first order perturbative QCD corrections to the inclusive spectra of the leptons in the semileptonic decays of polarized heavy quarks. Charmed and beautiful Λ baryons from Z^0 decays can be viewed as sources of highly polarized charm and bottom quarks. Charged leptons and neutrinos from Λ_b and Λ_c decays can be used in the polarization studies for the corresponding heavy quarks. Thus our results are applicable for the b quark polarization measurements at LEP. Short lifetime enables polarization studies for the top quark. The angular-energy spectra of the charged leptons are particularly useful in this respect whereas the distributions of the neutrinos are sensitive to deviations from the V-A structure of the charged weak current in the decay.

Radiative Corrections to $b \to c\tau\bar{\nu}_\tau$

PL9700230

A. Czarnecki, M. Jeżabek, and J.H. Kühn

Analytical calculation is presented of the QCD radiative corrections to the rate of the process $b \to c\tau\bar{\nu}_\tau$ and to the τ lepton longitudinal polarization in $\tau\bar{\nu}_\tau$ rest frame. The results are given in the form of one dimensional infrared finite integrals over the invariant mass of the leptons. We argue that this form may be optimal for phenomenological applications due to a possible breakdown of semilocal hadron-parton duality in decays of heavy flavours.

How to Measure the Structure of the Weak Charged Current in Semileptonic b Decays

M. Dittmar and Z. Wąs

We propose a new method to measure the structure of the weak charged-current in semileptonic b-hadron decays using the energy spectrum of the neutrinos. This method allows us to distinguish experimentally between the V–A×V–A, V×V–A and V+A×V–A form of the charged current interaction.

The Ratio of Decay Constants f_B/f_D

PL9700231

S. Narison and K. Zalewski

The result $f_B \approx f_D$, which had been obtained from sum rules and lattice calculations, and which contradicts the načhar16ve prediction $f_P \sim 1/\sqrt{M_P}$, is rederived using a simple argument based on semilocal parton-hadron duality. It is argued that both here and in sum rules the key point is the use of semilocal duality instead of the bound-state wave function.

Hadron Radiation in Leptonic Z Decays

A. Hoang, M. Jeżabek, J.H. Kühn, and T. Teubner

The rate for the final state radiation of hadrons in leptonic Z decays is evaluated, using as input experimental data for $\sigma(e^+e^- \to hadrons)$ in the low energy region. Configurations with a lepton pair of large and a hadronic state of low invariant mass are dominant. A relative rate $\Gamma_{\ell\bar{\ell}had}/\Gamma_{\ell\bar{\ell}} = 6.3 \times 10^{-4}$ is calculated. This result is about twice the prediction based on a parton model calculation with a quark mass of 300 MeV. The rate for secondary production of heavy qaurks is calculated in the same formalism.

Radiation of Heavy Quarks

A. Hoang, M. Jeżabek, J.H. Kühn, and T. Teubner

The rate for the production of massive fermions radiated off a pair of massless fermions is calculated analytically. Combined with the analytic calculation of the corresponding virtual contribution one obtains the order α^2 correction to the cross section which is induced by the real and virtual radiation of a pair of massive fermions by massless fermions. Approximations valid for large and for small masses are derived and shown to agree with earlier calculations.

Higher-Order Radiative Corrections to Bhabha Scattering at Low Angles: YFS Monte Carlo Approach

S. Jadach, M. Melles, W. Płaczek, E. Richter-Wąs, M. Skrzypek, B.F.L. Ward, Z. Wąs, and S. Yost

In this contribution we present new results on the QED second-order radiative corrections to the low-angle Bhabha cross section. The presented results will be essential in the future reduction of the overall theoretical uncertainty in the measurement of the luminosity at LEP below the present 0.25% level.

Soft Pairs Real and Virtual Infrared Functions in QED

S. Jadach, M. Skrzypek and B. F. L. Ward

We calculate the soft pairs production analoga of the Yennie-Frautschi-Suura (YFS) real and virtual infrared functions B_γ and $\tilde{B}_\gamma$, where the latter describe the respective infrared singularities in QED to all orders in α via YFS exponentiation. In our work, we extend the discussion of B_γ and $\tilde{B}_\gamma$ by YFS to treat the case of soft pairs. The respective pairs versions of B_γ and $\tilde{B}_\gamma$ are exhibited explicitly. We also discuss some possible applications to high precision Z^0 physics at SLC/LEP.

Role of A_{LR} in High Precision Z Physics

S. Jadach and B.F.L. Ward

In view of the recent high integrated luminosity at CERN LEP on unpolarized e^+e^- colliding beams Z^0 physics, we discuss the physics role of a realistic measurement of A_{LR} at the SLC with 10^4 60% polarized incoming electrons. Presuming LEP will reach $\approx 2.3 \times 10^6$ Z^0's/experiment by the spring of 1994 we find that the SLC measurement is not redundant—it provides input to the high precision Z^0 physics which is not accessible at LEP.

KORALB – An Upgrade to Version 2.4

S. Jadach and Z. Wąs

An upgrade of the Monte Carlo program for τ pair production including τ mass, spin and QED $O(\alpha)$ effects is presented. Its main feature is the interface to the new τ decay Monte Carlo library TAUOLA, new coding of the final states and implementation of the Z exchange at the Born level.

The Monte Carlo Program KORALZ, Version 4.0, for the Lepton or Quark Pair Production at LEP/SLC Energies

S. Jadach, B.F.L. Ward, and Z. Wąs

The Monte Carlo program for τ pair production and decay applicable to the experiments in e^+e^- colliders in the Z resonance energy range is presented. The program includes initial and final state bremsstrahlung corrections up to the $O(\alpha^2)$ (with exclusive exponentiation), and $O(\alpha)$ electroweak corrections. More than twenty distinct τ decay modes can be generated: (a) leptonic modes $\tau^- \to \bar{\nu}\nu e^-(\gamma)$ and $\bar{\nu}\nu\mu^-(\gamma)$; (b) one-meson modes, $\nu\pi^-$ and νK^-; (c) two-meson modes, $\nu\{\pi^-\pi^0\}_{\rho-}$, $\nu\{K^-\pi^0\}_{K*-}$ and $\nu\{K^0\pi^-\}_{K*-}$; (d) three-meson modes, $\nu\{\pi^-2\pi^0\}_{a_1^-}$, $\nu\{2\pi^-\pi^+\}_{a_1^-}$, $\nu K^+K^-\pi^-$, $\nu \bar{K}^0 K^0\pi^-$, $\nu K^- \bar{K}^0\pi^0$, $\nu K^-\pi^0\pi^0$, $\nu K^-\pi^-\pi^+$, $\nu K^0\pi^0\pi^-$ and $\nu\eta\pi^-\pi^0$; (e) four-pion modes, $\nu\pi^-3\pi^0$, and $\nu2\pi^-\pi^+\pi^0$ (including the $\omega\pi^-$ contribution); (f) multi-pion modes, $\nu n\pi^{\pm,0}$ with $n > 4$; and finally the decay $\tau^- \to \nu\pi^-\pi^0\gamma$ from the $\omega \to \pi\gamma$. Complete $O(\alpha)$ QED corrections are included in the leptonic decay channels, and for other decay channels an interface is provided to the PHOTOS Monte Carlo generator for approximate simulation of the QED corrections. The program includes three libraries of the pure electroweak corrections from the three independent groups of authors.
The program can be also used for generation of the final states different from $\tau^+\tau^-$ pairs, i.e., it is able to generate $\mu^+\mu^-$, $\nu\bar{\nu}$, and under some restrictions $u\bar{u}$, $d\bar{d}$, $c\bar{c}$, $s\bar{s}$ and $b\bar{b}$ final states.

PHOTOS–A Universal Monte Carlo for QED Radiative Corrections: Version 2.0

E. Barberio and Z. Wąs

This paper documents an update of the PHOTOS algorithm, by E. Barberio, B. van Eijk and Z. Wąs, for the Monte Carlo simulation of QED photon radiative corrections in decays. The algorithm is implemented as an independent package written in FORTRAN 77. The program is universal, i.e. it allows for easy interface with *any* program generating decays of *any* particle. The program can be used to estimate the size of the QED bremsstrahlung in the leading-logarithmic (collinear) approximation, but it provides final states with their full topology, including kinematical effects due to massive particles. The proper soft photon behaviour is also reproduced. The algorithm is designed in such a way that the inclusion (if necessary) of the exact, process-dependent, matrix element subgenerator is *possible* and straightforward. This update of PHOTOS provides new options to improve the performances of the program in some specific cases: the interference for two-body particle-antiparticle decays, the double bremsstrahlung, and refinements important for the decays into massive non-relativistic decay products. The comparison of the program with the exact matrix-element calculation for the process $Z \to \mu^+\mu^-(\gamma)$, $W \to e\nu(\gamma)$, $\tau \to e\nu(\gamma)$, $B^\pm \to D^0 e^\pm\nu(\gamma)$ and $gg \to t\bar{t}(\gamma), t\bar{t}(\gamma\gamma)$ is also discussed.

Polarization in Top Quark Pair Production and Decay near Threshold

R. Harlander, M. Jeżabek, J.H. Kühn, and T. Teubner

Theoretical results are presented for top quarks produced in annihilation of polarized electrons on positrons. Polarization studies for $t\bar{t}$ pairs near threshold are free from hadronization ambiguities. This is due to the short lifetime of the top quark. Semileptonic decays are discussed as well as their applications in studying polarization dependent processes involving top quarks.

The Green function formalism is applied to $t\bar{t}$ production at future e^+e^- colliders with polarized beams. Lippmann–Schwinger equation is solved numerically for the QCD chromostatic potential given by the two-loop formula at large momentum transfers and Richardson ansatz at intermediate and small ones. The polarization dependent momentum distributions of top quarks and their decay products are calculated.

Top Quark Physics

M. Jeżabek

Top quark studies at future e^+e^- colliders are considered. Two issues are discussed: a – Some results are presented on the decays of top quarks. Energy distributions of charged leptons and neutrinos in $t \to bW \to be^+\nu$ and jets in $t \to bW \to b\bar{d}u$ decays are sensitive to the structure of tbW vertex. Distributions of charged leptons from top decays are particularly useful in polarization studies whereas neutrinos are sensitive to deviations from the Standard Model. b – Recent calculations are reviewed on the top quark pair production in e^+e^- annihilation. The differential cross sections in the threshold region can lead to an accurate determination of the top quark mass and the interquark potential. The effects of the top-Higgs Yukawa coupling and some higher order QCD corrections are also under control.

Oxygen Ionizer for Inhalation of the Individual Patient

B. Niziol

A live organism consisting of the atoms with electromagnetic forces connection, continuously evolving under the influence of an external agent, cannot be insensitive to the changes which occur in the environment, especially in the earth atmosphere. One of these problems is the influence of air-ions on live organisms. Research (e.g.[1, 4-9]) has shown the influence of air-ions on the metabolism of live organisms.

The animals living in air with positive ions concentration showed higher blood contents of glucose, pyruvic and lactic acid. The activity of lactic hydrogenase and the content of free fats were also elevated. Esterified fatty acids and trigliceride remained at an unchanged level. In the brain the contents of dopamine and noradrenaline was elevated and the adrenals was lower. The elevating of activity of the iso-citrate dehydrogenase in mitichondrial fraction of hepatic cells and decrease of the total protein content was observed. The examination of excised tracheal strips and exposed tracheas of living rabbits, mice, rats, guinea pigs, and monkeys has indicated a decreased ciliary activity after positive ions application.

The application of negative ions results in the increase of pH (0.02 - 0.04)% of blood, an increase in hemoglobin contents and the number of erytrocytes, increased stabilization of colloidal system of blood (decreased OB), and decreased blood thromboembolism. The latter phenomenon is used to avoid post - operative thromboembolism.

The research on ions measurement [2, 3, 10], ionizer construction and the results achieved contribute to the scientific collaboration contact with the University in Kassel and with enterprise "Bork - Medizintechnik". The result of this collaboration is an instrument for oxygen ionization which can be seen in Fig. 1. The electronic part was made in Kassel. The ionizer (Fig. 2.) was made in Cracow. The ionizer works in the dark discharge range and ought to produce only minimal quantity of ozone. Therefore the high voltage for every ionizer must be always experimentally determined. On the outlet of the ionizer flux density of ions equals 10^7 ion $cm^{-3}s^{-1}$. The ionizer is designed for inhalation of the individual patient. Therefore, the outlet of the ionizer is connected with an inhaling mask. The flux density of ions in the inhaling mask depends on dimensions and the chemical constitution of the pipe connecting the ionizer

with an inhaling mask. In this case the maximum value of the flux density of ions in the inhaling mask is about $5 \cdot 10^4$ ion $cm^{-3}s^{-1}$ and can be decreased to the value registered in the free air. The ionizer has received the attestation [11] and can be distributed in the Western Europe.
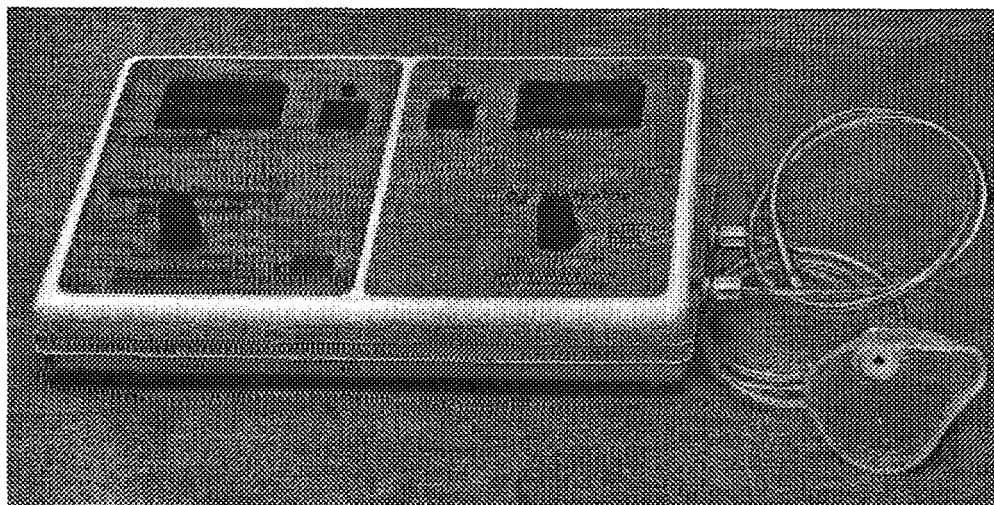

Figure: 1 The instrument for iontophorese and for oxygen ionization.
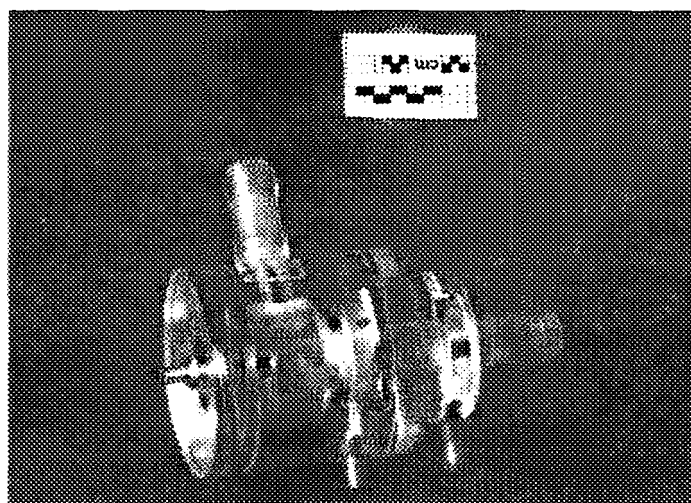
Figure 2: The ionizer.

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ENGINEERING AND TECHNICAL SUPPORT OF HIGH ENERGY PHYSICS EXPERIMENTS

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The ATLAS Experiment

The group has had a notable contribution to the ATLAS Technical Proposal. A supporting structure for the vertexing layer of silicon microstrip detectors was proposed. Moreover, the group has had a share in design work of the Tile Hadronic Calorimeter.

The DELPHI Experiment (the Microvertex Detector)

Due to the length of inner and outer layers modules (around $0.5\,m$) they require stiffening. The optimization of the shape and the materials used for stiffening beams was done using Finite Element Analysis. For chosen solution (kevlar U-shaped beams with carbon composite reinforcement) 1:1 scale modules were built and tested. The deflection of modules is less than 3 microns per 1 Gram force applied in the middle of the model for inner layer and around 1 micron/Gram for outer layer. Kevlar beams and carbon based composite stiffeners are currently produced.

Design Study of the LHC

Strain-stress analysis of elements of superconducting magnets was performed in collaboration with the Mechanical Technologies Division at CERN.

An attempt to quantify mechanical properties of superconducting cables at room temperature has been done. It is assumed that the mechanical properties of cable components, i.e. insulation, impregnation and superconducting wires are known. A numerical method was proposed to determine the mechanical properties of the superconducting wires.

An ANSYS program was built to calculate strain and stress distributions in end heads of the superconducting magnets (Fig. 1). The program allows for easy change of the head geometry what is crucial at the present stage of their design.
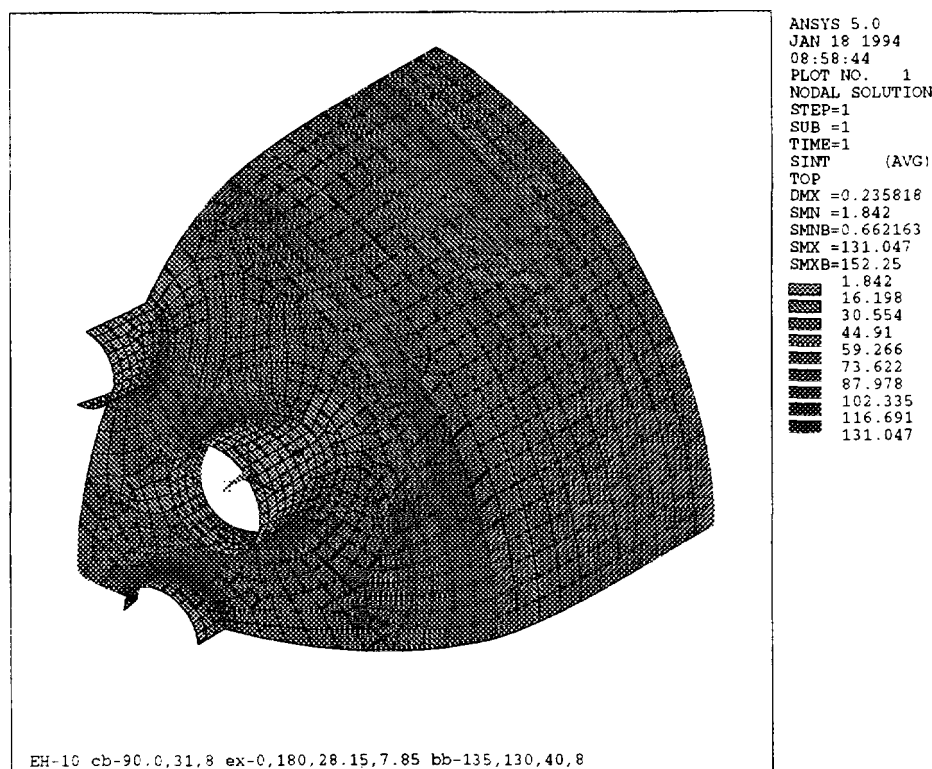
```
ANSYS 5.0
JAN 18 1994
08:58:44
PLOT NO.   1
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
SINT      (AVG)
TOP
DMX =0.235818
SMN =1.842
SMNB=0.662163
SMX =131.047
SMXB=152.25
       1.842
       16.198
       30.554
       44.91
       59.266
       73.622
       87.978
       102.335
       116.691
       131.047
```

```
EH-10 cb-90.0,31,8 ex-0,180,28.15,7.85 bb-135,130,40,8
```

Figure 1: Finite Element Model of the superconducting magnet end head.

The PHOBOS Experiment

Research and developing works on the mechanical structure and cooling system were continued. Technical documentation of the detector elements (spectrometer cooling frames, detector modules, ring multiplicity detector supports) was prepared. Full scale model of the spectrometer two arms and the magnet structure fabricated accordingly to the documentation was made and sent to Brookhaven National Laboratory. Numerical simulation of the spectrometer arm deflection showed that the supporting structure should be designed as a "box structure" to keep its displacement within acceptable range. Cooling efficiency of the pad detector module was numerically simulated and experimentally verified on a model for various qualities of thermal contact, width of the cooling frames, heat loads, and water velocity.

RD20 - Gas Cooling for Silicon Strip Detectors

The possible use of gas cooling of silicon detectors is immensely appealing since it offers removal of unwanted heat for virtually no extra material. Some of its other advantages are that it permits a wide choice of operating temperature, simple control and distribution and stable reliable cooling with an intrinsically radiation hard medium. To investigate these schemes, finite element thermal modelling and experimental tests of gas cooling systems have been carried out. The calculations have been carried out using the ANSYS package. A laminar boundary layer theory was applied to calculate the heat transfer coefficient, the values of which were used as boundary conditions for the heat transfer model. The results of these theoretical calculations were compared with experimental values. The results indicate that gas cooling of silicon detectors is feasible and gives acceptable temperature distributions.

Carbon/Carbon Composites for Special Applications

The project is aimed to develop a method of manufacturing thin carbon/carbon composite elements. This material should have very high stiffness, high radiation hardness, low coefficient of thermal expansion, and in addition, high thermal conductivity.

Using ultra high modulus carbon fibers (Thornel P-100S 2K) some carbon/carbon composite samples about 0.5 mm thick have been produced. Their Young's moduli were higher than those for steel and they are to be used as stiffening elements for silicon strip detectors.

(The project is supported by the State Committee for Scientific Research (grant No 3 P407 006 04)).

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12. DELPHI Collab., P. Abreu, (P. Brückman, Z. Hajduk, P. Jałocha, W. Krupiński, W. Kucewicz,
    B. Muryn, H. Pałka, G. Polok, A. Zalewska) et al.,
    "Measurement of the $\Gamma_{b\bar{b}}/\Gamma_{had}$ Branching Ratio of the Z by Double Hemisphere Tagging",
    CERN preprint **CERN-PPE/94-131** (1994);

13. DELPHI Collab., P. Abreu, (P. Brückman, Z. Hajduk, P. Jałocha, W. Krupiński, W. Kucewicz,
    B. Muryn, H. Pałka, G. Polok, A. Zalewska) et al.,
    "Measurement of Time Dependent $B_d^0 - \bar{B}_d^0$ Mixing",
    CERN preprint **CERN-PPE/94-132** (1994);

14. DELPHI Collab., P. Abreu, (Z. Hajduk, P. Jałocha, K. Korcyl, W. Krupiński, B. Muryn,
    H. Pałka, G. Polok, K. Rybicki, M. Turała, A. Zalewska) et al.,
    "A Study of Radiative Muon-Pair Events at Z^0 Energies and Limits on an Additional Z'
    Gauge Boson", CERN preprint **CERN-PPE/94-121** (1994);

15. DELPHI Collab., P. Abreu, (Z. Hajduk, P. Jałocha, K. Korcyl, W. Krupiński, B. Muryn,
    H. Pałka, G. Polok, K. Rybicki, M. Turała, A. Zalewska) et al.,
    "First Evidence of Hard Scattering Processes in Single Tagged $\gamma\gamma$ Collisions",
    CERN preprint **CERN-PPE/94-163** (1994);

16. E665 Collab., M.R. Adams, (A. Eskreys, J. Figiel, P. Malecki, K. Olkiewicz, B. Pawlik,
    P. Stopa) et al.,
    "Density and Correlation Integrals in Deep-Inelastic Muon-Nucleon Scattering at 490
    GeV", MPI **PhE/94-12** (1994);

17. E665 Collab., M.R. Adams, (A. Eskreys, J. Figiel, P. Malecki, K. Olkiewicz, B. Pawlik,
    P. Stopa) et al.,

"Measurement of Nuclear Transparencies from Exclusive ρ^0-Meson Production in Muon-Nucleus Scattering at 490 GeV", FNAL **FERMILAB-PUB-94/233-E** (1994);

18. P. Eerola, (S. Gadomski) et al.,
    "B Physics in ATLAS", ATLAS Internal Note, CERN **PHYS-NO-041** (1994);

19. P. Eerola, S. Gadomski, B. Murray, "B_s^0 Mixing Measurement in Atlas", ATLAS Internal Note, CERN **PHYS-NO-39** (1994);

20. J. Godlewski, M. Stodulski,
    "Mechanical Structure and Cooling System",
    MIT, PHOBOS Internal Report **94-2** (1994);

21. M. Stodulski,
    co-authorship in "Laboratory of Machine Design" (in Polish), ed. by J. Rys, A. Trojnacki, Cracow Technical University, Cracow, 1994;

22. H1 Calorimeter Group, B. Andrieu, (L. Görlich, L. Hajduk, M.W. Krasny, J. Martyniak, S. Mikocki, K. Rybicki, J. Turnau) et al.,
    "Beam Tests and Calibration of the H1 Liquid Argon Calorimeter with Electrons",
    DESY preprint **DESY 94-055** (1994);

23. H1 Collab., T. Ahmed, (L. Görlich, L. Hajduk, M.W. Krasny, J. Martyniak, S. Mikocki, G. Nowak, K. Rybicki, J. Turnau) et al.,
    "Observation of Hard Processes in Rapidity Gap Events in Gamma-Proton Interactions at HERA", DESY preprint **DESY 94-198** (1994);

24. H1 Collab., T. Ahmed, (L. Görlich, L. Hajduk, M.W. Krasny, J. Martyniak, S. Mikocki, G. Nowak, K. Rybicki, J. Turnau) et al.,
    "Determination f Strong Coupling Constant from Jet Rates in Deep Inelastic Scattering",
    DESY preprint **DESY 94-220** (1994);

25. Z. Hajduk, W. Iwański, K. Korcyl,
    "Modelling of Local/Global Architectures for Second Level Trigger at LHC Experiment",
    CERN **DAQ/T 61** (1994); ATLAS Internal Note, CERN **DAQ-No-13** (1994);

26. J. Harton, (Z. Wąs) et al., "Combining the LEP τ Polarisation Results",
    LEPTAU/**94-01** Internal note for all LEP experiments (1994);

27. HEGRA Collab., A. Karle (M. Różańska) et al.,
    "Search for Isotropic Gamma Radiation of Cosmological Origin between 65 and 200 TeV",
    MPI-PhE/94-28;

28. S. Jadach, Z. Wąs,
    "How to Measure the Lifetime of the Z or Perform a Test of the Uncertainty Principle",
    CERN preprint CERN **TH-7232/94** (1994);

29. A. Karle (M. Różańska) et al.,
    "Design and Performance of the Angle Integrating Cerenkov Array AIROBICC",
    MPI-PhE/94-29;

30. D. Loukas, (M. Turała) et al.,
    "Developments at High Luminosity at LHC - Status Report to the DRDC",
    Status Report to the DRDC **CERN/DRDC 94-39** (1994);

31. S. Martinez (M. Różańska) et al.,
    "Monte Carlo Simulation of the HEGRA Cosmic Ray Detector Performance",
    MPI-PhE/94-29;

32. NA35 Collab., Th. Alber, (J. Bartke, E. Gładysz-Dziaduś, M. Kowalski, P. Stefański, B. Wosiek) et al.,
    "Transverse Momentum Dependence of Bose-Einstein Correlations in 200A GeV/c S+A Collisions", LBL preprint **LBL-36062** (1994);

33. S. O'Neale, (A. Sobala) et al.,
    "Object Oriented Approach to Software Development for LHC Experiment",
    CERN Report **DRDC/94-9 CERN/P55** (1994);

34. RD20 Collab., W. Dąbrowski, (A. Moszczyński, M. Turala) et al.,
    "Some Ideas on Improvements of Radiation Hardness of Silicon Strip Detectors",
    CERN Report **RD20/TN35** (1994);

35. RD20 Collab., D. Loukas, (A. Czermak, S. Gadomski, J. Godlewski, P. Jałocha, J. Kapłon,
    M. Kajetanowicz, A. Moszczyński, K. Pakoński, M. Turala) et al.,
    "Development of High Resolution Silicon Strip Detectors for Experiments at High Luminosity at LHC",
    RD20/STATUS REPORT 1994; CERN Report **DRDC 94-39** (1994);

36. A. Trzupek, "PID Algorithm (1st Order)", MIT, PHOBOS Internal Report **94-34** (1994);

37. A. Trzupek, "Particle Identification Plans", MIT, PHOBOS Internal Report **94-35** (1994);

38. K. Woźniak, "Ghosts", MIT, PHOBOS Internal Report **94-32** (1994);

39. K. Woźniak,
    "Occupancy in the Spectrometer", MIT, PHOBOS Internal Report **94-37** (1994);

40. K. Woźniak,
    "Analysis of the Possibility of the Particle Identification by the TOF Detector in the PHOBOS Experiment", MIT, PHOBOS Internal Report **94-41** (1994);

41. K. Woźniak,
    "Computer Simulation of the Detector in PHOBOS Experiment - (Acceptance and Background Calculations)", MIT, PHOBOS Internal Report **94-42** (1994);

42. A. Zalewska,
    "Krzemowy detektor wierzchołka w eksperymencie DELPHI; od pomysłu do wyników z fizyki", Raport IFJ **1682/PH** (1994);

43. ZEUS Collab., M. Derrick, (P. Borzemski, J. Chwastowski, A. Eskreys, K. Piotrzkowski, M. Zachara, L. Zawiejski) et al.,
    "A Search for Excited Fermions in Electron-Proton Collisions at HERA",
    DESY preprint **DESY 94-175** (1994);

PARTICIPATION IN CONFERENCES AND WORKSHOPS:

1. *J. Turnau*, 10th Aspen Winter Physics Conference on Particle Physics Before the Year 2000, Aspen, 16-23 January 1994;

2. *K. Piotrzkowski*, International Workshop on Deep Inelastic Scattering and Related Topics, Eilot, Israel, February 1994;

3. *K. Piotrzkowski*, DPG - Fruehjahrstagung, Dortmund, March 1994;

4. *S. Jadach*, Moriond Conference, Meribell, March 1994;

5. *M. Jeżabek*, DESY-Zeuthen Workshop LEP200 and Beyond, Teupitz, 13 April 1994;

6. *J. Chwastowski, A. Eskreys, J. Figiel, L. Görlich, E. Mroczko, J. Turnau, M. Zachara, and L. Zawiejski*, Educational Workshop on Basics of the Hadron Structure, Warszawa, 22-26 April 1994;

7. *M. Turala*, 2nd Int. Workshop on Front End Electronics for Tracking Detectors at Future High Luminosity Colliders, Perugia, April 1994;

8. *J. Godlewski, M. Stodulski, and R. Hołyński*, PHOBOS Conceptual Design Review, BNL Uptown, 6-7 May 1994;

9. *P. Brückman, S. Gadomski, R. Hołyński, M. Jeżabek, H. Pałka, G. Polok, M. Różańska, K. Rybicki, M. Turała, and H. Wilczyński*, Cracow-Munich Seminar, Cracow, 10-12 May 1994;

10. *T. Lesiak*, XVII Kazimierz Meeting on Elementary Particle Physics, Kazimierz, Poland, 23-27 May 1994;

11. *R. Hołyński and B. Wosiek*, Nucleus - Nucleus Collisions V, Taormina, 30 May - 4 June 1994;

12. *M. Jeżabek and K. Zalewski*, Cracow School of Theoretical Physics, Zakopane, Poland, 9 June 1994;

13. *K. Rybicki*, chairman of session, Physics in Collision Conference, Tallahassee, U.S.A., 15-17 June 1994;

14. *J. Bartke and A. Olszewski*, European Research Conference on Physics of High Energy Heavy Ion Collisions, Helsinki, 17-22 June 1994;

15. *A. Eskreys*, VI-th Recontre de Blois "The Heart of the Matter", Blois, 20-25 June 1994;

16. *S. Jadach* , The Tennessee International Symposium on Radiative Corrections, Tennessee, June 1994;

17. *K. Zalewski*, QCD 94 Workshop, Montpellier, 7-13 July 1994;

18. *L. Görlich, M. Jeżabek, S. Mikocki, M. Turała, and P. Stopa*, XXVII International Conference on High Energy Physics, Glasgow, 20-27 July 1994;

19. *E. Gładysz-Dziaduś*, Symposium on Strangeness and Quark Matter, Kolymbari, Krete, 1-5 September 1994;

20. *J. Bartke*, International Workshop on Multiparticle Correlations and Nuclear Reactions, CORINNE-2, Nantes, 6-10 September 1994;

21. *J. Godlewski*, International Workshop on Advanced Materials for High Precision Detectors, Archamp, 28-30 September 1994;

22. *M. Jeżabek*, XI International Symposium on High Energy Spin Physics SPIN'94, Bloomington, September 1994;

23. *Z. Wąs*, Third Workshop on Tau Lepton Physics, Montreaux, September 1994;

24. *J. Godlewski and K. Pakoński*, First International Workshop on Electronics and Detectors Cooling, Lausanne, 4-10 October 1994;

25. *K. Zalewski*, Workshop on Heavy Quark Physics, Bad Honnef, December 1994;

INVITED TALKS:

1. P. Brückman - "A_b Polarization at LEP", Cracow-Munich Seminar;

2. A. Eskreys - "Photon Properties from ZEUS Experiment,VI-th Recontre de Blois";

3. J. Figiel - "Nuclear Shadowing and Properties of Hadronic Find State in μ^+Xe Interactions at 490 GeV", Educational Workshop on Basics of the Hadron Structure;

4. S. Gadomski - "B_s Mixing Measurement in ATLAS", Cracow-Munich Seminar;

5. E. Gładysz-Dziaduś - "Strangelet Formation in "Centauro" Cosmic Ray Events", Symposium on Strangeness and Quark Matter;

6. R. Hołyński - chairman of session at the Cracow-Munich Seminar;

7. S. Jadach - "QED Corrections to Luminosity Measurements at LEP", Moriond Conference;

8. S. Jadach - "Higher-Order Radiative Corrections to Bhabha Scattering at Low Angles: YFS Monte Carlo Approach", The Tennessee International Symposium on Radiative Corrections;

9. S. Jadach - "Radiative Corrections, Status and Outlook", Gatlinburg;

10. M. Jeżabek - "Top Quark Physics", DESY-Zeuthen Workshop LEP200 and Beyond;

11. M. Jeżabek - "Decays of Polarized Heavy Quarks", Cracow-Munich Seminar;

12. M. Jeżabek - "Semileptonic Decays", Cracow School of Theoretical Physics;

13. M. Jeżabek - "QCD Corrections to Semileptonic Decays of Heavy Quarks", XXVII International Conference on High Energy Physics;

14. M. Jeżabek - "Polarization in Top Pair Production and Decay near Threshold", XI International Symposium on High Energy Spin Physics SPIN'94;

15. T. Lesiak - "Lifetimes and Masses of b-Hadrons at LEP", XVII Kazimierz Meeting on Elementary Particle Physics;

16. H. Pałka - "DELPHI Vertex Detector for LEP 200", Cracow-Munich Seminar;

17. H. Pałka - invited talks in KEK and Osaka University;

18. K. Piotrzkowski - "Luminosity Measurement fo the ZEUS Experiment at HERA", DPG - Fruehjahrstagung;

19. G. Polok - "DELPHI Experience with RICH Counters", Cracow-Munich Seminar;

20. K. Rybicki - invited talk at Nara University;

21. K. Rybicki - chairman of session at the Cracow-Munich Seminar;

22. K. Rybicki - chairman of session, acting chairman of the International Advisory Committee at Physics in Collision Conference;

23. M. Turała - "Inner Detector for the ATLAS Experiment", 2nd. Int. Workshop on Front End Electronics for Tracking Detectors at Future High Luminosity Colliders;

24. M. Turała - "New Detectors and New Technologies", XXVII International Conference on High Energy Physics;

25. M. Turała - "Semiconductor Technologies", Cracow-Munich Seminar;

26. J. Turnau - "Jet Physics at HERA", 10th Aspen Winter Physics Conference on Particle Physics Before the Year 2000;

27. K. Zalewski - invited lectures at the Cracow School of Theoretical Physics;

28. K. Zalewski - "Problems Related to the Heavy Quarks", QCD 94 Workshop;

29. K. Zalewski - "Nonrelativistic Model of $b - \bar{b}$ Quarkonia", Workshop on Heavy Quark Physics.

SCIENTIFIC DEGREES:

M.Sc. degrees

Piotr Gruszecki (supervisor: H. Pałka)   Paweł Kmiecik (supervisor: Z. Hajduk)
Paweł Hachaj (supervisor: J. Turnau)   Maria Olko (supervisor: Z. Hajduk)

Ph.D. degrees

Janusz Martyniak (supervisor: J. Turnau)
Krzysztof Piotrzkowski (supervisor: D. Kisielewska)

Professorship

Stanisław Jadach

LECTURES AND COURSES:

The HEPD staff participates in the education process of physics at the Jagellonian University in Cracow. The following staff members participated in this activity in 1994:

1. "Experimental High Energy Physics", undergraduate course led by J. Bartke;
2. "Theoretical High Energy Physics", undergraduate course led by Z. Wąs;
3. "Experimental High Energy Physics", undergraduate course led by K. Rybicki;
4. "Selected Topics of the Experimental Techniques of High Energy Physics", undergraduate course led by P. Malecki, M. Turała, and Z. Hajduk;
5. "Experimental High Energy Physics", undergraduate course led by M. Różańska and H. Pałka;
6. "e^+e^- Interactions at the Z^0 Mass", series of monographic lectures, undergraduate course led by A. Zalewska;
7. Student's Seminar on Experimental High Energy Physics, led by J. Turnau, B. Pawlik, G. Nowak, and A. Trzupek;
8. High Energy Physics Laboratory, led by T. Coghen.

INTERNAL SEMINARS:

Joint seminars with the Theoretical Physics Department
of the Jagellonian University

1. *A. Białas* (Univ.): "Production of Heavy Quarks by a Double Pomeron", 14 January 1994;
2. *M. Praszałowicz* (Univ.): "The Solar Neutrino Puzzle", 21 January 1994;
3. *K. Zalewski* (Univ. and INP): "Heavy Quarks", 28 January 1994;
4. *K. Rybicki* (INP): "Hadronic Production of Heavy Quarks - Theory and Experiment", 18 February 1994;
5. *J. Turnau* (INP): "Tests of QCD at HERA", 25 February 1994;
6. *A. Stocchi* (LAL Orsay): "Physics of b-Quarks at LEP", 4 March 1994;
7. *K. Fialkowski* (Univ.): "Solar Neutrinos", 11 March 1994;
8. *K. Fialkowski* (Univ.): "Two-Particle Correlations", 18 March 1994;
9. *S. Jadach* (INP): "Evidence (not Discovery) of the t-Quark", 28 April 1994;
10. *J. Wosiek* (Univ.): "Functions of the Brain", 6 May 1994;
11. *K. Zalewski* (Univ. and INP): "Update on Heavy Quarks", 20 May 1994;
12. *K. Fialkowski* (Univ.): "XXIV Colloquium on Multiparticle Dynamics, Vietri sul Mare", 30 September 1994;
13. *E. Richter-Wąs* (Univ.): "Is the Channel $H \to b\bar{b}$ Observable at LHC?", 7 October 1994;
14. *K. Fialkowski* (Univ.): "Total Cross Sections ", 14 October 1994;
15. *G. Nowak* (INP): "Events with Large Rapidity Gap Observed at HERA", 21 October 1994;
16. *K. Fialkowski* (Univ.): "Intermittency in UA1 and PYTHIA with BE - Effect", 28 October 1994;
17. *J. Wosiek* (Univ.): "Hyperintermittency", 4 November 1994;
18. *J. Turnau* (INP): "Handedness of Jets and their Correlations", 18 November 1994;
19. *K. Zalewski* (Univ. and INP): "New Results on Kobayashi-Maskawa Matrix Elements", 25 November 1994;

20. *L. Leśniak* (INP): "Production Mechanism and Properties of Scalar Mesons", 2 December 1994;

21. *A. de Roeck* (Brussels): "Physics Analysis of Events with Large Rapidity Gap at HERA", 9 December 1994;

22. *K. Fiałkowski* (Univ.): "Comparison of Proton-Nucleus and Muon-Nucleus Interactions", 16 December 1994.

Internal seminars

1. *K. Miller* (Techn. Univ. Warsaw): "Two-Particle Correlations in Hadron-Nucleus and Nucleus-Nucleus Collisions", 12 January 1994;

2. *L. Suszycki* (Academy of Mining, Cracow): "Search for "Dark Matter" in the Universe", 19 January 1994;

3. *M. Turała* (INP): "Development of New Experimental Techniques for LHC - R&D Programme at CERN", 16 February 1994;

4. *T. Matsuda* (KEK): "The B-Factory Project at KEK", 23 February 1994;

5. *S. Mikocki* (INP): "Upgrade of the H1 Detector", 2 March 1994;

6. *J. Turnau* (INP): "Physics of Jets at HERA", 9 March 1994;

7. *K. Rybicki* (INP): "Experimental Particle Physics in Poland. A Short Course", 23 March 1994;

8. *M. Winter* (Strasbourg): "Desperately Seeking for the Standard Model Limits", 30 March 1994;

9. *L. Görlich* (INP): "First Measurements of Charged Current Cross Section at HERA", 13 April 1994;

10. *P. Brückman* (INP): "What Do We Know about Polarization of Baryons with c or b Quarks", 20 April 1994;

11. *D. Kiełczewska* (Univ. Warsaw): "Investigations of Neutrinos and Proton Stability in the "Super-Kamiokande" Experiment", 27 April 1994;

12. *P. Roudeau* (LAL Orsay): Tau/Charm Factory Project as a Possibility to Study Strong Interactions in Systems with a Heavy Quark", 31 May 1994;

13. *A. Eskreys* (INP): "Hard Interactions of Photons Observed in the ZEUS Detector", 5 October 1994;

14. *T. Tymieniecka* (Univ. Warsaw): "Search for New Solutions in Calorimetry for Electrons and Hadrons", 12 October 1994;

15. *J. Bartke* (INP): "What is New in Physics of Relativistic Nuclei" (conferences in Helsinki and Nantes), 19 October 1994;

16. *P. Stopa and L. Görlich* (INP): "News from the XXVII ICHEP Conference" (Glasgow, July 1994), 26 October 1994;

17. *S. Mikocki* (INP): "News from the XXVII ICHEP Conference" (Glasgow, July 1994), 2 November 1994;

18. *A. Sandacz* (INS - Warsaw): "Diffractive Production of Vector Mesons in Deep Inelastic Scattering", 9 November 1994;

19. *P. Zalewski* (INS - Warsaw): "Search for Λ_b Baryon through Lepton-Baryon Correlations", 16 November 1994;

20. *E. Rondio* (INS - Warsaw): "Parton Distributions in the Nucleon from the NMC Experiment", 23 November 1994;

21. *J. Figiel* (INP): "Muon-Nucleon/Nucleus Interactions at Low and Medium Values of x_{Bj} and Q^2 (Experiment E665)", 30 November 1994;

22. *M. Turala* (INP): "New Technologies and New Detectors for High Energy Physics", (review talk at XXVII ICHEP at Glasgow), 7 December 1994;

23. *P. Salabura* (Univ. Cracow): "HADES - the Dilepton Spectrometer for SIS", 21 December 1994.

SHORT TERM VISITORS TO THE DEPARTMENT:

Prof. J.E. Augustin - CERN, Switzerland
Dr M. Baker - Massachusetts Institute of Technology, USA
Dr B. Baller - FNAL, USA
Prof. J. Bizot - LAL Orsay, France, (twice)
Dr H. Braun - Wuppertal University , Germany
Dr T. Carroll - MPI, Munich, Germany
Dr H. Hennenkamp - DESY/Zeuthen, Germany
Prof. M. Hasumi - University Osaka, Japan
Dr E.D. Kolganova - Institute of Theoretical and Experimental Physics, Russia
Dr S. Kurokawa - KEK, Japan
Dr T. Matsuda - KEK, Japan, (twice)
Dr J. Morfin - FNAL, USA
Prof. H. Nanjo - Hirosaki University, Japan.
Dr E.A. Pozharova - Institute of Theoretical and Experimental Physics, Russia
Dr A. De Roeck - University Antwerp, Belgium
Prof. P. Roudeau - LAL Orsay, France
Dr H. Sadroziński - CERN, Switzerland
Dr H. Schellman - Northwestern University , USA
Prof. N. Schmitz - MPI, Munich, Germany
Dr W. De Silva - University Paris VI, France
Prof. T.Yu. Skorodko - Institute of Theoretical and Experimental Physics, Russia.
Prof. G. Snow - University of Maryland, USA
Dr A. Stocchi - LAL Orsay, France
Prof. C.J. Waddington - University of Minnesota, USA
Prof. B. Wiik - Director General DESY, Germany
Prof. R. Wilson - Harvard, USA
Prof. M. Winter - CRN Strasbourg, France
Dr W. Wittek - MPI, Munich, Germany
Dr S. Wolbers - FNAL, USA
Prof. B. Wysłouch - Massachusetts Institute of Technology, USA.

PATENTS:

B. Niziol: "Construction of an Oxygen Ionizer for Individual Inhalation",

Polish patent: PL 164230,
German attest: NDL Frankfurt a/M, No 03.300.3.013/01.

Department of Environmental and Radiation Transport Physics

Section VI

DEPARTMENT OF ENVIRONMENTAL AND RADIATION TRANSPORT PHYSICS

Head of the Department: *Professor Jerzy Loskiewicz*
Secretary: *Ewa Lipka*
telephone: (48)-(12)-37 02 22 ext. 345
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PERSONNEL:

Jerzy Loskiewicz, Professor - Head of the Department

Research staff:

Jan A. Czubek, Professor	Dominik Dworak, M.Sc.
Jan Lasa, Professor	Joanna Dąbrowska, M.Sc.
Andrzej Zuber, Professor	Barbara Gabańska, M.Sc.
Urszula Woźnicka, Assoc.Professor	Andrzej Igielski, M.Sc., E.Eng.
Krzysztof Drozdowicz, Ph.D.	Ewa Krynicka, M.Sc.
Jan Swakoń, Ph.D.	Jadwiga Mazur, M.Sc.
Ireneusz Śliwka, Ph.D.	Edward Mnich, M.Sc., E.Eng.
Joanna Bogacz, M.Sc.	Grzegorz Tracz, M.Sc.
Teresa Cywicka-Jakiel, M.Sc.	Jarosław Płaszczyca, M.Sc.
Bogdan Drozdowicz, M.Sc.	

Technical staff:

Tadeusz Zaleski, Ph.D.	Ryszard Haber
Jacek Burda, Eng.	Antoni Rościszewski
Władysław Kowalik	Tadeusz Zdziarski

Administration:

Ewa Lipka

GRANTS:

Grants from the Governmental Committee for Scientific Research:

1. "Investigations of Noble Gases in Some Mineral Waters of Southern Poland"
   - grant No 0 9602 030 04, Prof. A. Zuber;
2. "Measurements of Atmospheric Trace Gases - Greenhouse Effect"
   - grant No 6-040591-01, Prof. J. Lasa;
3. "Physics of Radiation Transport in Nuclear Well Logging"
   - grants No 6-631891-02 and 9-060691-01, Prof. J.A. Czubek;
4. "Determination of Influence of Humidity and Ash Content Changes on Neutron Measurement of Coal Calorific Value"
   - grant No 2-026091-01, Prof. J. Loskiewicz;

5. "Implementation of a New Model of Synthetic Neutron-Scattering Function for Calculation of Diffusion Parameters in Finite Hydrogenous Media"
   - grant No 2 P302 074 05, Dr K. Drozdowicz;

6. "System for an Effective Measurement of the Decay Constant of Non-Stationary Neutron Fields"
   - grant No 2 P302 021 05, A. Igielski, M.Sc.

Participation in application grants (together with industrial companies):

1. Cracow Geophysical Co. and Institute of Geophysics, Academy of Mining and Metallurgy, "Modernization of Radiometric Probe Calibration Facility", grant No 99211 93C/1142

2. Institute of Geophysics, Academy of Mining and Metallurgy, Cracow, "Protecting Earth Surface and Natural Environment in Mining Regions Using Geophysical Research Methods", grant No 9 9047 91 02

Grants from the International Atomic Energy Agency, Vienna (Austria):

1. Prof. J.A. Czubek, Technical Assistance Project POL/8/010, "Analysis of Methods for Calibration of Well-Logging Tools";

2. Prof. J. Loskiewicz, Research Contract 5807/RB, "Determination of the Influence of Humidity and Ash Content Changes in Polish Coals on their Calorific Value as Measured Using Neutron Inelastic Scattering".

OVERVIEW:

Research activity in the Department is carried out by the three Laboratories:

1. Laboratory of Environmental Physics (head: Prof. Andrzej Zuber),

2. Laboratory of Neutron Transport Physics (head: Assoc. Prof. Urszula Woźnicka),

3. Laboratory of Physics and Modelling of Radiation Transport (head: Prof. Jerzy Loskiewicz).

The Department employs: 4 professors, 1 associated professor (docent), 3 Ph.D. research associates, 10 research physicists, 2 electronic engineers and 6 technicians of different specialities. The Department is engaged in theoretical and experimental research in the following areas:
1. Tracer transport and flow in porous (geological) media,
2. Studies on pollutants in atmospheric air,
3. Physics of molecular phenomena in chromatographic detectors,
4. Studies on neutron transport in heterogenous media,
5. Studies on evaluation of neutron cross-sections in the thermal region,
6. Studies on theory and utilization of neural networks in data evaluation,
7. Numerical modelling of particle cascades for particle accelerator shielding purposes.

The following problems were studied during 1994:
1. Development of deterministic theoretical approaches of solute transport in porous and fractured media for the improvement of the interpretation of artificial tracer experiments and environmental tracer data (in close cooperation with the GSF-Institut fuer Hydrologie, Neuherberg, Germany).

Studies related to the determination of the origin of formation waters. Determining vulnerability of some important aquifers to anthropogenic pollution by environmental tracer methods (in close cooperation with GSF-Institut fuer Hydrologie, Neuherberg, Germany and the Faculty of Physics and Nuclear Techniques, Academy of Mining and Metallurgy, Cracow).

2. Concentrations of freons (F-11, F-12), CO, CH_4 and CO_2 in samples taken in Cracow, Maków Podhalański, and Kasprowy Wierch measured for investigations of greenhouse effect. For the determination of the source of methane, the $^{13}C/^{12}C$ and D/H ratios are measured.

Concentrations of methane and carbon dioxide were measured in samples taken in Cracow and a brown-coal mine site in western Poland. A line for extraction of methane from air for isotope ratio determination was improved and the $^{13}C/^{12}C$ and D/H ratios were measured to determine the source of that gas.

3. A new method for Electron Capture Detector calibration was developed. This method allows one to use an ECD detector for direct measurements of freon concentrations in the air without enrichment of samples. The basic conditions for the calometric effect to occur in a ECD detector were determined.

4. Theoretical, experimental and applied research in neutron transport physics developed in the Department concern the phenomena of slowing down, scattering and absorption of neutrons in different media. The research is done both on basic theory and on particular applications for heterogeneous models and geological formations. The following main problems were studied last year:

4.1 Neutron transport in environmental geological formations.

The theory of calibration procedures for neutron well logging methods has been solved for two-region cylindrical geometry. A first industrial application of the method has been implemented in a Polish geophysical company.

4.2 Applied research on PGNAA and the utilization of neutron inelastic scattering for instrumental analysis of coal has resulted in pronounced progress due to the use of multielemental correction algorithms. Using neutron inelastic scattering allows a precise measurement of coal calorific value using smaller isotopic neutron sources compared to those used, in commercial PGNAA equipment. Despite the smaller neutron sources used, it is also possible to determine other parameters important for assessing the quality of coal such as ash and moisture content as well as concentrations of chlorine, sodium, and silicon.

4.3 Modernization of the experimental set-up at the 14 MeV pulsed neutron generator.

The modernization includes both the mechanical and the electronic equipment as well as research on the method of measuring the decay constant of non-stationary neutron fields in bounded heterogeneous systems. The statistical analysis of experiments conducted on the pulsed neutron generator is developed for the time decay constant determination and macroscopic absorption cross-section measurement.

5. Diffusion of thermal neutrons in hydrogeneous media. A new model of the synthetic neutron scattering function for calculating diffusion parameters in finite hydrogeneous media was tested. The research is developed in collaboration with the Bariloche Atomic Center, Argentina and will be continued over the next years.

6. Study of the theory and applications of neural networks has resulted in Ph.D. Thesis of J. Swakoń "Numerical methods of gamma spectra analysis and their application to rock examination". It was shown possible to describe the complicated dependence of neutron absorption cross-section on concentrations of potassium, uranium and thorium in rocks using slightly modified backpropagation algorithm. The research results have important application potential for the estimation of Σ_a in the wellbore.

7. Calculations of neutron dose outside the accelerator tunnel of HERA at DESY were performed using a modified version of the FLUKA92 and MORSE codes. These studies were performed together with the Radiation Protection Group of Dr Klaus Tesch from DESY. The effort was

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directed towards identification of two prominent peaks in neutron experimental energy spectrum. The first, in the energy range of between 2 and 3 MeV, was shown to be due to evaporation particles from high energy collisions. The second one, between 80 and 100 MeV, is under study now.

Prof. Jerzy Loskiewicz

REPORTS ON RESEARCH:

Experiment for Water-Flow Measurement by Pulsed Neutron Activation

Krzysztof Drozdowicz

Under collaboration with the Chalmers University of Technology in Göteborg, Sweden, an experiment was performed at the Reactor Physics Department as a feasibility study on applying the neutron activation method for measurement of water mass transport in pipings. Such a method can be utilized e.g. in nuclear power stations. The idea of the experiment comes from Professor Imre Pázsit and Dr Gudmar Grosshög from the Reactor Physics Department.

The fast neutron generator was used as a pulsed-neutron activation source for oxygen O^{16} in water which circulated in a closed piping system. The γ radiation [$E_\gamma = 6.134$ MeV (68%) and $E_\gamma \cong 7.121$ MeV (4.9%)] of the nitrogen product isotope N^{16} was measured by scintillation detectors placed in two positions at the piping. Detailed results are presented in plots of time distributions obtained and in tables in [1]. The method has been found useful for application under consideration.

Reference:
[1] K. Drozdowicz, Report CTH-RF-106, Chalmers University of Technology, Göteborg, 1994.

PUBLICATIONS:

I. Articles:

1. J.A. Czubek, "Neutron Tool Calibration by a Scaling Procedure",
   Nucl. Geophys. **8** (1994) 261-279;

2. J.A. Czubek, "Dead Time of Dual Detector Tools",
   Nucl. Geophys. **8** (1994) 317-326;

3. T. Cywicka-Jakiel, J. Loskiewicz, and G. Tracz,
   "The Hydrogen Signal Use in Correcting the Neutron Measurements of Calorific Value of Coal", J. of Coal Quality **12** (1994) No 2-3, 351-359;

4. E. Krynicka,
   "Correlation Between Thermal Neutron Absorption and Time Decay Constant in Bounded Sample-Moderator System", Nucl. Geophys. **8** (1994) 79-84;

5. J. Lasa, B. Drozdowicz, I. Śliwka, and J. Rosiek,
   "Measurements of Concentration of the Trace Gases Active in the Greenhouse Effect", Geographia Polonica **62** (1994) 47-59;

6. J. Lasa, B. Drozdowicz, and A. Korus, "Determination of the Nitrogen Concentration in Argon on ppm Level by Gas Chromatography with a Thermal Conductivity Detector", Chem. Anal. (Warsaw) **39** (1994) 735-739;

7. J. Lasa, I. Śliwka, and B. Drozdowicz,
"A Theoretical Model of the Electron Capture Detector",
Chromatographia **38** (1994) 304-312;

8. J. Motyka, S. Witczak, and A. Zuber,
"Migration of Lignosulfonates in a Karstic-Fractured-Porous Aquifer: History and Prognosis for Zn-Pb Mine, Pomorzany, Southern Poland",
Environmental Geology **24** (1994) 144-149;

9. A. Zuber and J. Motyka,
"Matrix Porosity as the Most Important Parameter of Fissured Rocks for Solute Transport at Regional Scales", J. Hydrol. **158** (1994) 19-46;

10. J.A. Czubek,
"Methodology and Coding of Semi-Empirical Calibration of Neutronic Probes",
Zeszyty Naukowe (Scientific fascicles) AGH, Quarterly "Geologia" **2** (1994) 121;

11. J.A. Czubek, "Dead Time of Two Detector Probes",
Zeszyty Naukowe (Scientific fascicles) AGH, Quarterly "Geologia", **2** (1994) 201;

12. J.A. Czubek, "Dead Time of Radiation Detectors", Geologia **T. 20, Z. 2** (1994) 185;

13. J.A. Czubek,
"Semi-empirical Calibration Method of Porosity Measuring Neutron Probes",
Nafta-Gaz (Oil-Gas) **9** (1994) 378;

14. I. Śliwka, B. Drozdowicz, J. Lasa, and A. Korus,
"The Results of Measurements of the Halogenated Compounds Concentrations in the Air around KZF "POLFA" in Cracow", Polish Academy of Sciences, Cracow Branch, Mineralogical Papers, 83, ISBN 83-86077-15-8, pp. 79-82 (in Polish);

15. J. Lasa,
"Gaia Hypothesis: a Global Cybernetic Ecological System",
Polish Academy of Sciences, Cracow Branch, Mineralogical Papers, 84,
ISBN 83-86077-20-4, pp. 13-15 (in Polish);

16. J.A. Czubek, K. Drozdowicz, B. Gabańska, A.I. Igielski, E. Krynicka, U. Woźnicka,
"Thermal Neutron Macroscopic Absorption Cross Section Measurement (Theory, Experiment and Results) for Small Environmental Samples",
Nuclear Data for Science and Technology, Proceedings of the International Conference, Gatlinburg, Tennessee, 9-13 May (1994) 170-172.

II. Reports:

1. T. Cywicka-Jakiel,
"Ecological Aspects of Using Nuclear Methods for Coal Quality Monitoring",
INP Report No **1661/PL**, Cracow 1994;

2. K. Drozdowicz,
"Experiment for Water-Flow Measurement by Pulsed-Neutron Activation",
Report CTH-RF-106, Chalmers Univ. of Technology, Sweden (1994);

3. T. Cywicka-Jakiel, J. Loskiewicz, and G. Tracz,
"Inelastic Neutron Scattering Method in Hard Coal Quality Monitoring",
INP Report No **1678/PL**, Cracow 1994;

4. J. Bogacz, T. Cywicka-Jakiel, J. Mazur, J. Loskiewicz, J. Swakoń, and G. Tracz,
"Analysis of the Radioactivity of Some Building Materials from Małopolska Region (Southern Poland)",
INP Report No **1687/AP**, Cracow 1994.

PARTICIPATION AND CONTRIBUTIONS TO CONFERENCES AND WORKSHOPS:

Professor Andrzej Zuber

Advisory Group Meeting on "Isotopic Techniques in the Hydrological Appraisal of Radioactive Waste Disposal Sites", IAEA Vienna, 1994,

Lecture: "Some Important Problems in the Interpretation of Environmental Tracer Data of Old Groundwater Systems".

Assoc. Professor Urszula Woźnicka

"International Conference on Nuclear Data for Science and Technology", May 1994, Gatlinburg Tenn., USA,

Lecture: "Thermal Neutron Macroscopic Absorption Cross-Section Measurement (Theory, Experiment and Results) for Small Environmental Samples".

Professor Jan A. Czubek

4-th International Conference on Application of Nuclear Techniques "Neutrons and their Applications", Crete, Greece, June 1994,

Lecture (invited): "Neutron Logging Tool Readings and Parameters of the Formations".

Joanna Dąbrowska

participation in "Workshop on Variance Reduction Methods", Bolonia, Italy, 1994.

Professor Jerzy Loskiewicz

IAEA Research Coordination Committee Meeting on "Nuclear Techniques in Exploration and Exploitation of Coal", Cracow, May 1994,

Lecture: "Inelastic Neutron Scattering Method in Hard Coal Quality Monitoring".

Professor Jan Lasa

Symposium on "Organic Compounds in the Environment and Methods of their Assessment", Jachranka, May 1994, National Environment Preservation Authority (Poland),

Lecture: "Concentration and Isotopic Composition of Methane in Earth's Atmosphere".

Professor Jan Lasa

Polish Scientific Seminar on "Chromatography and Associated Techniques in Environmental Chemistry", Toruń, October 1994,

Lecture: "Philosophical Aspects of Environment Chemistry".

VI National Conference on Science and Technology in Wellbore Geophysics, Dobczyce (Poland), September 1994,

Lectures:

1. *Prof. Jan A. Czubek,*

" Methodology and Coding of Semi-Empirical Calibration Method of Neutron Probes" and "New in Detector Dead Time Calculations".

2. *Ass. Prof. Urszula Woźnicka,*

"Utilization of Time Application of the Thermal Neutron Time-Decay of Pulsed Neutron Flux for Measuring Macroscopic Neutron Absorption Cross Section of Rock Samples".

3. *Dr Jan Swakoń,*

"Neuron Network Utilization for Estimation of Macroscopic Thermal Neutron Cross Section Based on Measured Values of K, U, Th Concentrations".

Regional Conference on "Ecology in Mining and the Geophysics", Ustroń (Poland), October 1994,

Lectures:

1. *Professor Jerzy Loskiewicz (plenary):*

"Neural Network Assistance in Interpretation of Geophysical Data".

2. *Professor Jan A. Czubek*:
"Programs for Implementation of Semi-Empirical Calibration Method for Neutron Well-Logging Probes".
3. *Professor Jan A. Czubek*:
"Determination of Dead-Times of Two-Detector Neutron Probes".
4. *Ass. Prof. Urszula Woźnicka*:
"Measurement of Macroscopic Absorption Cross-Section of Thermal Neutrons in Rock Samples Using a Pulsed Neutron Generator".
5. *I. Pluta, A. Zuber, and J. Lączny*:
"Investigation of the Origin of Brines Can be Useful for their Planned Underground Discharge Taking the "Silesia" Mine as an Example", in: Ekologia w górnictwie a geofizyka, edited by "Centrum" Polish Academy of Science, Cracow, pp. 237-241 (in Polish).
6. *J. Szczepańska and A. Zuber (plenary)*:
"Determining the Direction of Water Inflows to Coal Mines in the Upper Silesia Coal Basin from the Chloride Concentration Ratios in Pore and Inflowing Waters", in: Ekologia w górnictwie a geofizyka, edited by "Centrum" Polish Academy of Science Cracow, pp. 237-241 (in Polish).

V Conference on Ecological Problems in Mining:
1. *J. Szczepańska and A. Zuber*:
"Chloride Concentration Ratios in Pore Water and Inflowing Water to Indicate the Direction of Inflows to Coal Mines in the Upper Silesia Coal Basin", edited by "Infograf", Katowice,
pp. 299-309 (in Polish).
2. *I. Pluta, A. Zuber, and M. Pytlak*:
"Purification Possibility of Discharged Brines by Flow through Mine Workings", as above,
pp. 347-353 (in Polish).

Members of Organizing Committee:
Professor *J. Loskiewicz*
IAEA Research Coordination Meeting on "Nuclear Methods in Exploitation and Exploration of Coal", Cracow, May 1994.

Chairmen of the Session (organizers):
1. *Prof. J.A. Czubek*
VI National Conference on Wellbore Geophysics, Dobczyce (Poland), September 1994.
2. *Prof. J. Loskiewicz*
IAEA Research Coordination Meeting on "Nuclear Methods in Exploration and Exploitation of Coal", Cracow (Poland), May 1994.

SCIENTIFIC DEGREES:

J. Swakoń
Ph.D. Thesis on "Numerical Methods of Gamma-Ray Spectrum Analysis for Rock Assay".
A. Drabina
M.Sc. Thesis on "Development of the Adsorption Method for the Sample Air Enrichment in Measurements of the Halogenated Compounds".

LECTURES AND COURSES:

Prof. J. Lasa
Course "Physicochemical Methods Employed for Air Pollution Determination", Faculty of Environmental Protection, Jagellonian Univ., Cracow.

Prof. A. Zuber
Course "Tracers Methods in Hydrogeology", Sect. Hydrology, Faculty of Geology and Geophysics, Academy of Mining and Metallurgy, Cracow.
Ass. Prof. U. Woźnicka
Lab. Exercises "Measurement of Macroscopic Cross Section of Rocks", Faculty of Geology and Geophysics, Academy of Mining and Metallurgy, Cracow.
dr K. Drozdowicz
Lecture: "Water-Flow Measurements by the Pulsed Neutron Activation method", Centro Atomico Bariloche, Argentina.
Prof. J. Lasa
Lecture: "A Simplified Model of the ECD" presented at the Seminar in Institute of Environmental Physics, Univ. of Heidelberg, Germany.

INTERNAL SEMINARS:

1. J. Lasa, "Gaia Hypothesis";
2. B. Gabańska, "Concentration Measurements of Fissionable Materials in a Sample Using the Neutron Coincidence Counter";
3. N.G. Sjöstrand, "Homogenization of Simple Slab Lattices";
4. J. Lasa, "Current Research of Environmental Physics Group";
5. U. Woźnicka, J. Dąbrowska, "Tittle's Method of Σ_a Measurement and its Optimization";
6. J. Bogacz, J. Mazur, "Activated Charcoal Method of Measuring Radon Concentrations";
7. K. Tesch, "Shielding of High Energy Accelerators";
8. J. Loskiewicz, "Neural Network Recognition of Well-Model from Pressure Change Data in the Wellbore";
9. J.A. Czubek, "What's New in Calculation of Dead-Time of Neutron Probes";
10. U. Woźnicka, "Using Pulsed Neutron Generator to Measure Absorption Cross Section of Thermal Neutrons in Rock Samples".

SHORT TERM VISITORS TO THE DEPARTMENT:

1. Prof. Nils G. Sjöstrand - Chalmers Univ. of Technology, Goeteborg, Sweden;
2. Dr Klaus Tesch - DESY, Hamburg, Germany;
3. Dr B. Zatolokin - IAEA, Vienna, Austria;
4. Dr P. Arikan - Saraykoey Res. Center, Ankara, Turkey;
5. Mr Yang Hongchang - Tangshan Coal Research, China;
6. Dr M. Borsaru - CSIRO Menai, Australia;
7. Dr M. Millen - CSIRO Menai, Australia;
8. Dr Vo Dac Bang - Nat. Atomic Energy Commission, Vietnam;
9. Mrs Marzieh Nezamzadeh - Atomic Energy Organization, Iran;
10. Prof. St. Cierpisz - Politechnika Gliwicka, Poland.

Department of Radiation and Environmental Biology

Section VII

DEPARTMENT OF RADIATION AND ENVIRONMENTAL BIOLOGY

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GRANTS:

1. *Doc. dr hab. A. Cebulska-Wasilewska*

Environmental Studies:

    a) PECO 10964 CIPDCT 925100 (Joint Research CEC Project)

    b) WEST/EAST Grant PECO ERB3510PL920811

Radiobiology:

    a) PECO 2992 CIPDCT 925008 (Joint Research CEC Project)

    b) ERBCIPDCT 930110 (Joint Research CEC Project)

2. *Dr B. Lazarska*

    Joint grant No 550079102 (State Committee for Scientific Research) with the Academy of Agriculture, Cracow, Poland.

OVERVIEW:

Year 1994 might be called the "Comet Year". It resembles the picture of DNA damage, seen in a fluorescent light under the microscope in a COMET assay. The brightest aspects of the year were: numerous scientific events partly reflected in the pages to follow, a strong will to maintain research standards equal to those of highly advanced partners in Europe, minds filled with new ideas and big hopes for modernization. There were also other features of this year reminding a comet: hopes fading fast because of hard financial circumstances, and a long tail behind created by the work still to be done.

We devoted year 1994 mainly to the activities concerning the following goals:

a) fulfilling the requirements and expectations of CEC in the issues of three research projects,

b) modernization of our methodology,

c) participation in an effort to firm up future applications of neutrons and protons to cancer therapy.

Perceiving the research as our primary duty, we were very busy both in the environmental and radiobiology fields. We have successfully completed all parts of field research on the geno-toxic damage caused by benzene related compounds and early markers of cancer diseases. The research was sponsored and supported by CEC. A part of the samples of biological material collected was transferred to the laboratory of BIBRA in Carshalton, UK, for further studies on presence of ras oncogene proteins. Cytogenetics studies on those samples are performed in our laboratory, and the first results of our measurements are presented here.

In the radiobiology field, our research involved two ongoing CEC projects affiliated to the CLINCT Programme. This programme is aiming at the application of fission neutrons to cancer therapy. We finished comparative studies on neutron efficiency to induce mutations and chromosomal damage. With the use of our best bioassays, gene mutations in TSH-assay and chromosome aberrations, we have established good dose-response curves for X-ray, and 5.6 MeV neutrons from our U-120 cyclotron. Our first attempt to compare experimentally the biological effectiveness of fission and fast neutrons resulted in a dose-response relationship for chromosome aberrations induced in human lymphocytes by neutrons from HFR JRC reactor in Petten (EC-NICE), the Netherlands. In cooperation with the Radiobiology Group from Petten we performed another irradiation exposure and now we are improving the statistics in cytogenetic measurements for dose-response curve for fission neutrons. We are still working on finding the formula for alteration of the repair process observed in case of gene mutations in TSH assay. We have

also paid a significant amount of time and effort in order to establish new methods for more accurate measurements of molecular and cellular damage caused by radiation and environmental agents. We are approaching that goal hoping that our new research tools could combine value, modernity and economy. Now we are almost sure that the "Comet assay" will at least partly fulfill our expectations in terms of detection of DNA damages. We hope to develop another method for cytogenetics studies. The third part of our effort concerned possible improvement in the applications of different radiation sources to clinical cancer therapy. We wish success to our colleagues from the Health Physics Laboratory who have attempted to obtain financial support to get a new cyclotron working. We are keen on doing our best to help them. In the meantime, we continued our work on the old U-120 performing irradiation of patients from the Oncological Centre in Cracow. Year 1994 was also very attractive in the sense of many interesting visits of important people to our Department. We were honoured to host Dr Diana Anderson from BIBRA International, Carshalton, UK. We hope that her visits will become a habit, of great value for both our friendship and programmes. We were also excited by the visits of Prof. S. Tano from JAERI, Japan and Dr Jim Kyu Kim from KAERI, South Korea. We are looking forward to continuing our collaboration with those groups. That could bode well for the years to come.

Doc. dr hab. Antonina Cebulska-Wasilewska

REPORTS ON RESEARCH:

Biomonitoring of Human Population Exposed to Petroleum Fuel with Total Consideration of Benzene Genotoxic Component

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The paper presents the preliminary data from CEC collaborative research programme CIPDCT 925100 aimed to investigate the relationship between the exposure to genotoxic chemicals and the induction of genetic damage in human cells and living organisms. The development, evaluation and application of biomonitoring procedures were planned for environment exposed to genotoxic substances that result from petrochemical combustion or processing. Blood sampling strategies were discussed and tested. Questionnaires considering health conditions, types of genotoxic risk and lifestyle have been correlated with interviews of other contractors in the project, and with the sociologists from the Cracow School of Economy. Two petroleum plants in central and southern parts of Poland that differ in the total amount of production (Table 1) were chosen for blood sampling of two groups exposed (Table 2: codes 1 and 2). The second plant is in the area close to the most polluted region, under the studies reported in Nature [1]. Two groups of unexposed controls (Table 2: codes 3 and 4) were taken:
a) from the region of southern Poland selected on the basis of low level of pollution (3), and low level of total cancer cases (4), and no reported exposures to benzene related compounds,

b) from administrative staff at the second petroleum plant and from individuals in urban locations.

A potential seasonal factor was taken into account by drawing blood samples in pairs [exposed group (code 1) and control (code 4)] and [exposed group (code 2) and control (code 3)] in the Winter and Summer seasons respectively. Chromosome Aberration (CA) and Sister Chromatid Exchange (SCE) analyses in human blood lymphocytes were applied to cytogenetic studies of the samples. Chromosomal and chromatid aberrations were scored at the first metaphase following stimulation. The culturing protocol was the same as for the analysis of the dose-assessment of exposure to ionizing radiation. Sister chromatid exchanges and high frequency cells were measured and evaluated following the procedure described in ICPEM publications concerning population monitoring using cytogenetic techniques. The highest level of all biological points studied was observed in the exposed group from petroleum plant in Southern Poland. However, only the difference between chromosome aberration rates (excluding gaps) measured in samples from Central (code 1) and Southern (code 2) Poland was statistically significant. The percentage of aberrant cells was also much higher in exposed group 2 than in the others, and was correlated strongly with the total aberration frequency. There was no significant variation between SCE measurements observed for all groups. So far, the results of cytogenetic studies of blood samples from persons exposed and unexposed to benzene related compounds reveal a slight influence of exposure on the biological end-points observed, but a final conclusion can be made when all the cytogenetics is completed.

Table 1. Comparison between production and emission of two tested Polish petroleum plants.

	Central /Mg/	Southern /Mg/
Oil processed	10.000.000	135.434
Emission:		
SO$_2$	48.113	310
CO	7.354	31
NO$_2$	5.867	183
H$_2$S	65	3.5
Aromatic		
Hydrocarbons	784	5.2
Aliphatic H.	6.172	231.7
benzoαpyrene	0.002	0.004
gaseous in total	?	782
dust in total	411	286

Table 2. Characteristics of exposed and unexposed control groups.

Group	No of Indiv.	Age	SEX F %	SEX M %	Smok. %	Cancer history %
1	14		14	86	71	0
2	10		10	90	90	20
3	17	40	90	10	50	20
4	20	39	35	65	45	10

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1. F.P. Pevera et al., Molecular and Genetic Damage in Humans from Environmental Pollution in Poland, Nature Vol **360**, 256-258 (1992);

2. A.V. Carrano and A.T. Natarajan, Mutat. Res.**204**, 379-406 (1988);

3. W. Zatonski et al., The Geography of Cancer in Poland, Warszawa, PAN, Vol. **3-4**, 17-30 (1990);

4. Ambient Air Pollution in Poland in 1987, (in Polish), Ed. M. Nowicki, Warszawa, 1990, Inst. Env. Protection;

5. IAEA, Technical Report Series No **260**;

6. S. Wolff, in: Ed. Wolff S., Sister Chromatid Exchanges, John Wiley, New York, p. 41-57 (1982);

7. A.D. Tates et al., Mutat. Res. **250**, 483-497 (1991);

8. A. Cebulska-Wasilewska, H. Pluciennik, A. Wierzewska, E. Kasper, and B. Krzykwa, Annual Rep., INP , Cracow, 311-313 (1992);

9. A. Cebulska-Wasilewska, H. Pluciennik, and A. Wierzewska, Proc. of Conf. on Env. Mutagenesis in Human Populations at Risk, Cairo, p. 41 (1992).

Interaction Between Deltamethrin and Radiation in Induction of Chromosomal Aberrations in Human Blood Lymphocytes

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Our previous studies (1, 7) of combined treatment demonstrated in general synergistic interactions between radiation and various types of chemicals (including pesticides) in the induction of gene mutation in somatic cells of Tradescantia (TSH assay). However, an antagonistic effect was observed after a combined treatment by deltamethrin and X-rays. This paper presents the results of combinations of treatments by X-rays and deltamethrin studied in human blood lymphocytes in terms of the presence of chromosomal aberrations induced. Heparinized whole blood was collected from a young and healthy male donor. For each exposure the blood cultures were set up, fixed, stained and scored for chromosomal and chromatid type of aberrations according to published procedures (3, 4). Cells were stimulated and incubated for 24 h to ensure their growth. Then 50 μl of deltamethrin in DMSO was added to the cultures selected for chemical pretreatment. After 4 h of further incubation the medium in all cultures was replaced with the new standard medium and samples were incubated for another 20 h, then selected samples were irradiated with acute (1Gy) and split (0.5Gy) doses of radiation. After 52 hours of culture, 0.1ml of colcemid was added and the samples were incubated for additional 2 hours. Doses splitted into two parts had a 2-hour-interval between irradiations. The X-ray machine (1, 2) from the Radiation and Environmental Department in the Institute of Nuclear Physics was used as the radiation source. Chemical and radiation treatments and screening data are shown in Table 1. Table 2 represents the mean values of the biological end-points observed. Figure 1 demonstrates the efficiency of various types of treatment in the induction of all types of aberrations tested. Percentages of aberrant cells observed are presented in Figure 2. As far as the effects of radiation exposures are concerned, the results alone revealed much lower efficiency of given doses in the induction of chromosome type of aberrations (dicentrics and rings) while showing elevated frequency of fragments, triradials and quadriradials. The results also demonstrate a higher level of induced chromosome damage after the split dose than after the acute one. Our previous studies on the induction of chromosome aberration after irradiation in G_0 phase with different radiation doses of X-rays and fast neutrons showed a good agreement with the expectations based on the data published elsewhere and on the radiobiological models (2, 3, 6). The decrease in the induced chromosome aberration rate observed in those studies is understood because the irradiation took place at the end of the culture, when most of the cells were supposed to be in G_2 phase. In this phase the individual chromatids are already present, and become the units of aberration formation leading to chromatid type rather than to full aberrations (9). The second

finding demonstrates that the more cells in the G_2 cell cycle phase, the more efficient the radiation in the induction of chromatid type of aberrations, and the later in G_2 phase is the cell, the more sensitive it is to the radiation.

Table 1. Chemical (deltamethrin) and radiation treatment conditions as well as cell screening data.

Code	treat /ppm/	Dose 1 /Gy/	time /h/	Dose 2 /Gy/	Cells anal.	Cells norm.	Cells aber.	AbI
1	-	-	-	-	186	185	1	1.0
2	2.5	-	-	-	335	313	22	1.09
3	2.5	1.0	-	-	113	87	26	1.23
4	2.5	0.5	2	0.5	115	107	8	1.13
5	-	1.0	-	-	236	183	54	1.15
6	-	0.5	2	0.5	186	135	51	1.31

anal. norm. aber.: analyzed, without aberration and aberrant cells respectively, AbI aberration index (No of aberration/No aberrant cells)

Table 2. Mean number of chromosome and chromatid aberrations per cell and percentage of aberrant metaphases (AbcF).

Code	CAbF	FF	GF	QF	AbF	TAbF	SD +/-	AbcF %
1	.000	.000	.005	.000	.000	.005	.005	0.5
2	.003	.042	.027	.000	.045	.072	.015	7.0
3	.009	.212	.062	.000	.221	.283	.050	23.0
4	.000	.052	.026	.000	.052	.078	.026	7.0
5	.004	.203	.055	.004	.212	.267	.033	23.0
6	.000	.269	.097	.016	.285	.382	.047	27.0

CAbF, FF, GF, QF chromosome, fragments, gaps tri- and quadriradial frequency respectively, AbF - aberration frequency exluding gaps, TAbF - total aberration frequency (including gaps), SD - standard deviation.

Frequencies of aberrations observed after irradiation of chemically pretreated cells are lower than values expected on the basis of an additive effect observed after individual treatments. The most visible protective effect of the chemical pretreatment in cases of acentric aberrations and a number of aberrant cells induced by combined treatment of deltahametrine and fractionated irradiation is observed (Fig. 2). Differences between the additive levels expected and those observed are statistically significant for all the cytogenetic end-points measured except dicentrics and rings. Our results with TSH assay reported earlier already suggested that deltamethrin pretreatment may increase cell resistance to radiation (1, 7). An adaptive response in which exposure to a very low level of an alkylating agent or a very low radiation dose induces resistance to damage caused by subsequent exposure to the same chemical or radiation respectively, was observed in many bacterial, mammalian and plant cells. It was also found that it takes place mainly in the cells irradiated in phase G_1 and G_2, and not in the G_0 (4-6, 8).

Human blood lymphocytes
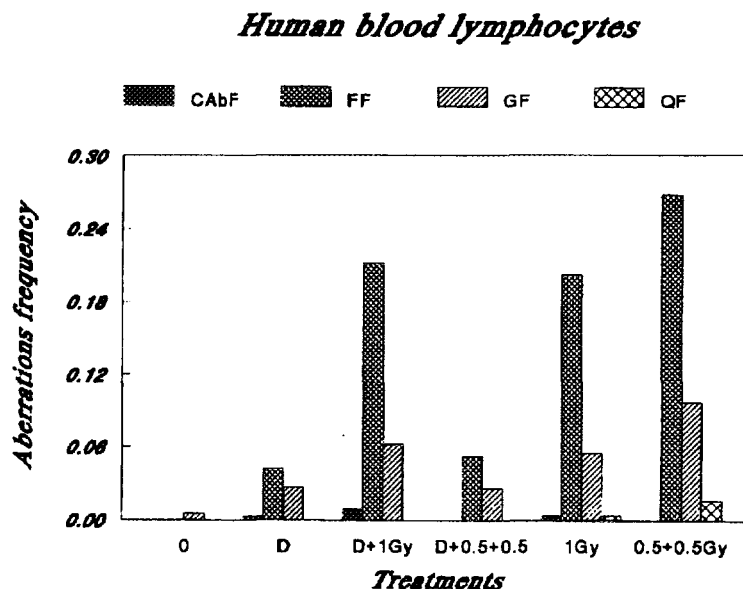
Figure 1: Different types of aberrations induced by various treatments.

Human blood lymphocytes
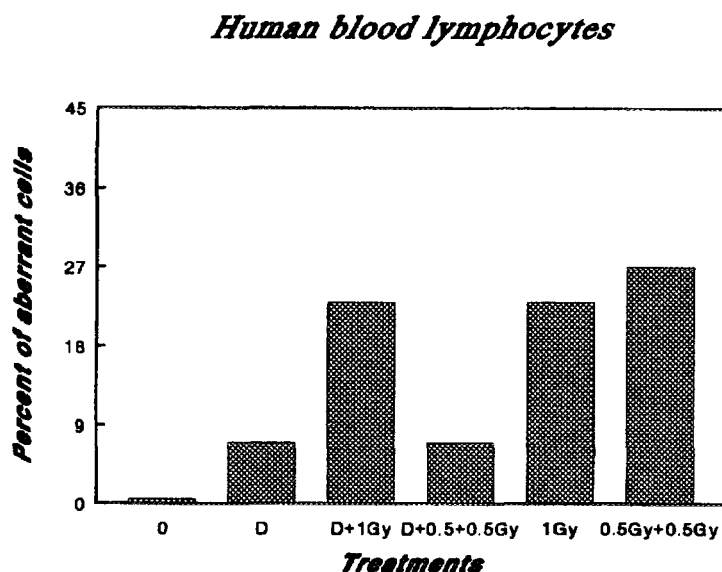
Figure 2: Percentage of aberrant cells induced by various treatments.

Our results are in good agreement with those findings, and suggest that deltamethrin pretreatment induces resistance to, or stimulates a repair mechanism against subsequent damage caused by radiation also in mammal cells.

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Comparative Studies of Genotoxic Effects in TSH Assay, CA and SCE Tests

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Wide use of pesticides in modern agriculture and their genotoxic effects might be hazardous to the environment and human health. We have already reported the data from the studies of some pesticide mutagenicity carried out with TSH assay (1, 2, 4, 5). In this paper we present a comparison on the mutation rate in TSH assay and the yield of chromosomal aberrations (CA) and sister chromatid exchanges (SCE) in human blood lymphocytes induced by various agrochemicals. The results of genotoxicity test with the use of *Tradescantia* are shown in Table 1. Concentrations of pesticides employed for TSH assay were within the range of those used in agriculture. Three of the tested compounds revealed only a weak mutagenicity, whereas Aminopielik and deltamethrin were quite effective in the induction of mutations in TSH assay. The studies of agrochemicals with the application of TSH assay enabled us to compare genotoxic effectiveness of those chemicals with radiation. The values of Rad-equivalents shown in the last column of Table 1 indicate X-ray doses which induce the same level of mutant frequency in TSH assay as was observed after treatment with pesticides. It is worth to notice that for all chemicals tested these values greatly exceed the permissible annual effective dose. Moreover, comparisons of genotoxic action of tested pesticides with genotoxicity of a known mutagen like EMS indicate that prudence is required while using some agrochemicals. Aminopielik, Decis and deltamethrin were tested also with the use of CA and SCE tests in human blood lymphocytes. For all three pesticides tested the number of SCE is higher than in control samples (Table 2). Results of chromosome aberration studies revealed the genotoxicity of the chemical action in case of one Aminopielik batch (1988) only (Table 3). The results obtained confirm assumption that some pesticides can be genotoxic to mammalian cells, as was reported also on the basis of epidemiological studies (9,10) and as we reported earlier on the basis of our previous studies with other bio-assays (3,6-8).

Table 1. Gene mutation frequency and Rad-equivalent values in TSH assay after mutagenic treatment.

Mut. Agent	Treatment	PF^a (-control)	Rad-equiv. /cGy/
X-Rays	1 cGy	0.045	1.0
EMS	20μl-0.045%	0.60	13.3
Aminopielik 88	10μl-0.004%	0.30	6.7
Aminopielik 89	10μl-0.004%	0.24	5.3
Decis	10μl-0.1%	0.01	0.2
Deltamethrin	20μl-0.01%	0.26	5.8
Benomyl*	10μl-0.004%	0.04	0.9
Carbofuran*	10μl-0.004%	0.05	1.1
2,4 - D*	10μl-0.004%	0.05	1.1
Methoxychlor*	10μl-0.004%	0.02	0.4
Parathion-methyl*	10μl-0.004%	0.16	3.6

a - pink mutation frequency
* - chemicals kindly provided by Prof. J.M. Gentile from Hope College, Holland, MI 49423, U.S.A.

Table 2. Sister chromatid exchange (SCE) frequency in human blood lymphocytes *in vitro* after treatment with pesticides.

Aminopielik ppm	SCE	SD	Decis ppm	SCE	SD	Deltamethrin ppm	SCE	SD
0	5.640	.242	0	7.269	.323	0	6.792	.281
100	8.053	.261	3	7.624	.356	10	7.964	.317
150	7.887	.149	10	8.291	.339	50	7.881	.295
200	9.793	.577	20	8.228	.256	100	8.823	.492
300	11.646	1.053	40	10.043	.504			

Table 3. Chromosome aberration (CA) frequency in human blood lymphocytes *in vitro* after treatment with different batches of Aminopielik.

	ppm	MitA^a	CA
Aminopielik batch 88	0	1000	.000
	100	621	.047
	200	573	.028
	300	1066	.059
Aminopielik batch 89	0	1000	.000
	100	1000	.001
	200	1000	.007
	300	1000	.001

a - mitosis analyzed

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Genotoxicity of Adduct Forming Mutagen Benzo(a)pyrene in *Tradescantia*

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Polycyclic aromatic hydrocarbons (PAH) are present among other by-products of combustion processes and they are ubiquitous pollutants of our environment. Benzo(a)pyrene (BaP) belonging to this class of compounds is a widely distributed environmental carcinogen that has DNA-damaging and mutagenic properties. Mutations that are formed as a consequence of induced DNA damage are very important for the process of cancer development. Since the relationship between DNA damage and mutation fixation is not always clear, there is a need to investigate a correlation between genotoxic effects on molecular and cellular levels.

DNA adducts are formed as the result of covalent binding of metabolically activated carcinogens to the DNA molecules (1). The most essential step for DNA-adduct detection is the isolation of good quality DNA which has a high molecular weight and is RNA- and protein-free. A fast and simple method for genomic DNA isolation from stock plants of *Tradescantia* 4430 has been already developed. With the use of this method DNA isolation has been successfully performed for different *Tradescantia* tissues: flowers, leaves and roots, both fresh and frozen (2). The purity and quality of extracted DNA was sufficient for DNA-adduct detection. Samples of DNA isolated from control and benzo(a)pyrene-treated tissues were subjected to DNA-adduct analysis using ^{32}P-postlabelling assay (3). However, preliminary data have shown only slight differences between the adduct pattern of control and treated samples.

The aim of our studies was to look for the induction of mutations in relation to the DNA-adduct formation in the same test system. Therefore, we have also chosen the *Tradescantia* 4430 plant for mutation studies of acute and chronic exposures to BaP. Pink mutation frequency (PF), lethal mutation frequency, i.e. hair stunting (STF) and cell cycle factor (CCF) were the end points studied in *Tradescantia* stamen hair (TSH) assay (4). The data of acute treatment are shown in Table 1. BaP dose dependence was not observed, although the mutational effect was significant. The doubling of mutation frequency indicates the mutagenicity of the compound tested. The results of chronic treatment were very similar, and lethality (hair stunting) for both exposures was relatively low indicating that in further studies treatment time can be prolonged or BaP concentrations can be higher, and that should allow us to attain a larger uptake of carcinogen. The investigations will be continued as the possibility to perform experiments that detect DNA-adducts and mutations after chemical exposure of *Tradescantia* offers a powerful tool for studies of environmental mutagenesis since *Tradescantia* is a very sensitive indicator of genotoxic agents.

Table 1. Mean values of biological effects measured by TSH assay after acute exposure to BaP.

Treatment	NOH[1]	PF±SD	STF±SD	CCF	Rad-equiv[2] /cGy/
20μl 1%	26340	0.352±0.130	1.136±0.474	0.37	3.1
20μl 0.1%	27800	0.317±0.112	0.412±0.251	0.38	2.3
20μl 0.01%	22710	0.400±0.189	0.867±0.501	0.31	4.2
Control	25320	0.212±0.094	0.697±0.400	0.32	-

[1] - number of scored hairs

[2] - values calculated for pink mutations after subtracting of the control data

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Radiation Damage of Mouse Skin, Lung and Kidney after Fractionated Local X-ray Irradiation Performed with the Use of Various Schedules

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In radiotherapy, before clinical use of new schedules, careful mathematical analysis using LQ model must be provided. It is needed to get information as to the total dose acceptable in the new schedule, i.e. as to the level of normal tissue damage not worse than before (using the clinically proven schedule). Such analysis must be done taking into account possible reaction of both early and late reacting tissues. The parameters needed for the LQ model calculations (α / β and T1/2) could be taken from animal experiments; sometimes these parameters are available in clinical radiobiology.

An alternative way is the examination of the new schedule expected for clinical use by performing animal experiments with this schedule and measuring the early and late damage of various animal tissues after local irradiation. Such programme of studies is performed in Cracow. The schedules under examination are: 10 fractions of X-ray irradiation once a day over 12 days (with a break for the weekend), 20 fractions, twice a day over 12 days (every fractions is divided into two subfractions with time intervals between them of 3 or 6 hours), and the schedule

in which the course of treatment (20 fractions over 12 days with 3 hours between subfractions) is preceded by a large 10 or 15-Gy introductory dose given on Friday (the normal course starts on Monday, 3 days later).

The results obtained with all the schedules, mentioned above applied to the early reacting tissue (mouse skin), were presented in our Prog. Rep. 1992 and 1993 and by Dr Huczkowski at a seminar at St. Mary Hospital in April (see: Seminars). It is worth-while to state that the results of animal experiments are slightly different from LQ calculations. In all experiments no difference in the total dose giving the same level of skin damage after irradiation performed with 3 or 6-hour intervals between subfractions was observed. According to the LQ calculation, 2.5-Gy "gap" between both curves was expected. Both introductory doses also provoked more damage to the skin than that expected from LQ model calculation (equivalent to about 6 and 8 Gy for 10 and 15 Gy introductory doses respectively). If these slight but important differences for the examined schedules are observed also in the clinic, then examination of new schedules "straight away" with the help of animal experiments could be advantageous.

To start the work with the animal model for the late-reacting tissues it was necessary to determine the irradiated area properly, especially for local kidney irradiation. Previously we used jigs obtained from the Gray Laboratory but CBA animals of the same age (12 - 16 weeks old) from a Polish breeder were distinctly smaller. As a result, an area larger than necessary was exposed to irradiation. It increases animal mortality in the first weeks after irradiation. After checking the situation using X-ray examination (Figures 1 and 2 represent Polish mice in English jigs), we have been modifying the jigs to start a new series of experiments.

There was no problem with the lung system (CBA males), and we have obtained the first data on 20 fractions over 12 days with 3-hour intervals between fractions. There is a clear dependence between the respiration rate (% of control) and the total dose (Fig.3). Lung damage measured in this system is well correlated with animal survival measured one year after irradiation (Fig.4).

Due to a complication caused by mortality of animals irradiated over a bigger area than necessary, we have not obtained the whole curve of radiosensitivity (haematocrit and the urea level in blood versus total dose) for kidney damage of animal system as yet. However, the first data obtained show that the steep sigmoidal curve of kidney damage starts at the total dose of about 34-36 Gy (20 fractions over 12 days with 3-hour interval between subfractions).
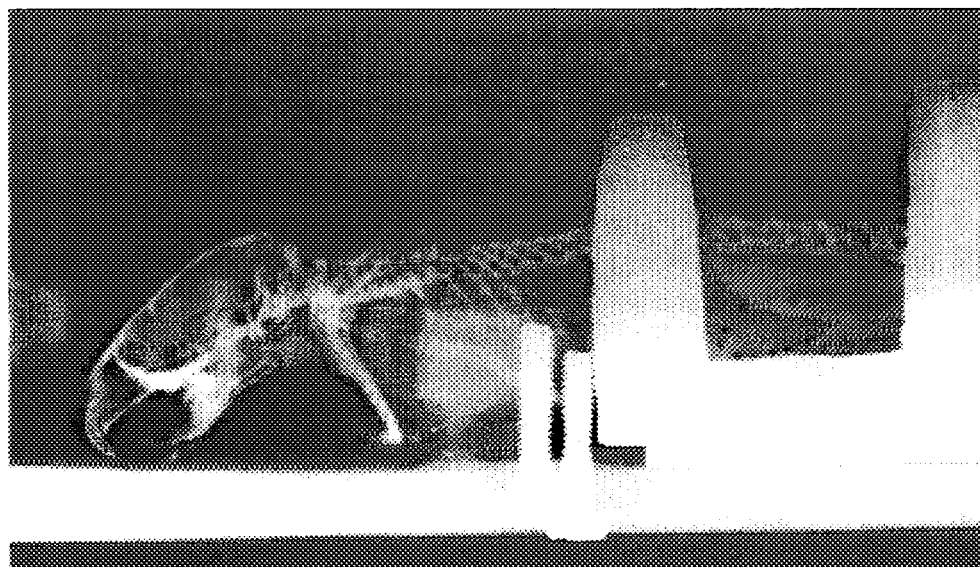
Fig.1: Kidney position - lateral view.
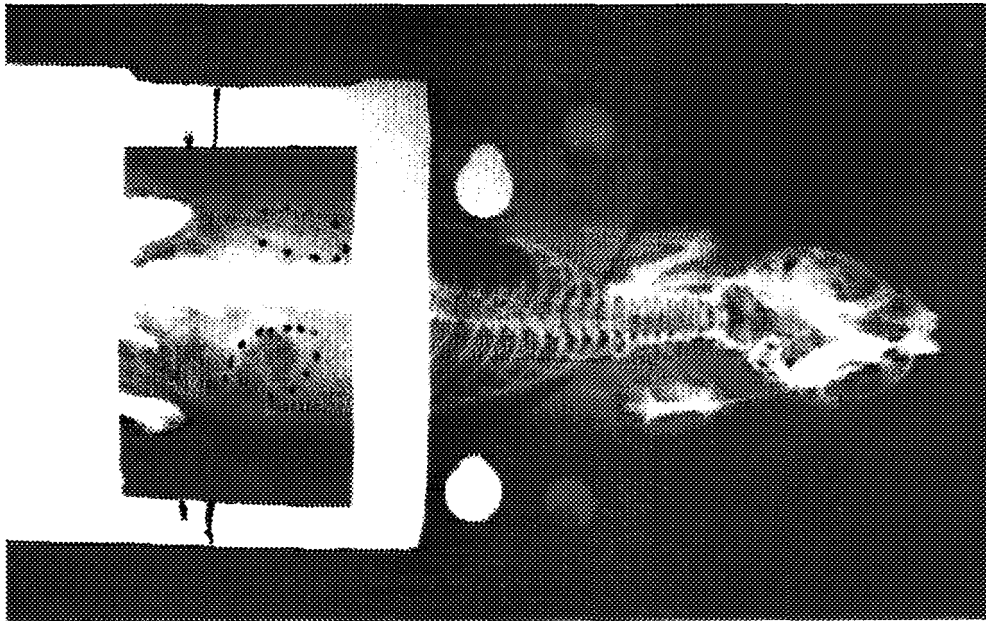
Fig.2: Kidney position - dorsal view.
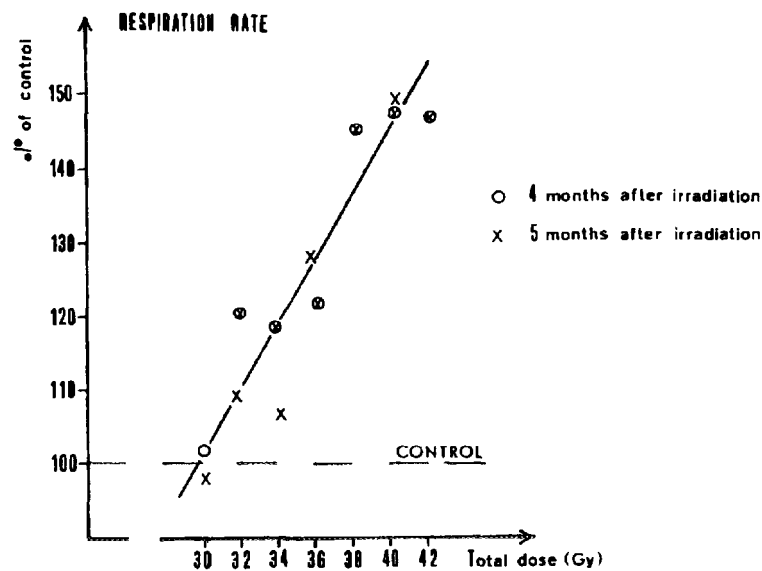
Fig.3: Respiration frequency as a function of total dose measured 4 and 5 months after X-ray irradiation.

Comparing the results obtained with the skin model system with these, only preliminary, results obtained with lung and kidney animal systems we notice that serious, clinically not acceptable, skin damage starts at the total dose of 70-75 Gy. This dose is about 2.5 times higher than that causing a serious level of lung (about 30 Gy) or kidney (about 31-32 Gy) damage.

The main topic of further research is to obtain kidney and lung results for all examined schedules so as to make it possible to perform intercomparison between the early and the late normal tissue damage for these schedules and to compare the obtained results with the LQ model calculations.
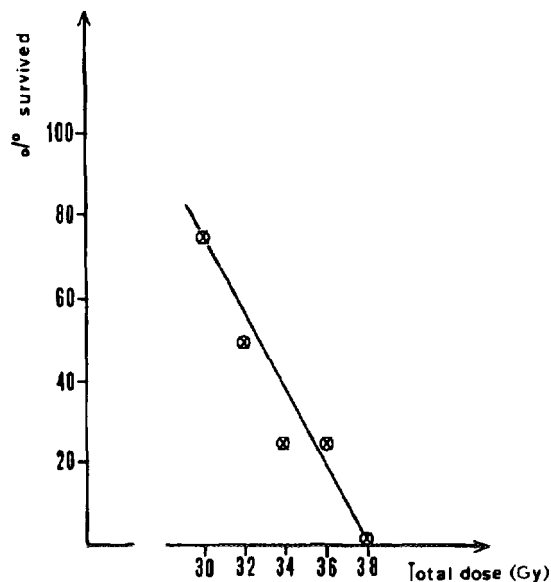
Fig.4: Mice survival measured
1 year after X-ray irradiation.

The Role of Poly(ADP-Ribose)Polymerase in the Induction *in Vitro* of Micronuclei in Down's Syndrome Lymphocytes by Mitomycin-C.

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Poly(ADP-ribose) is a nuclear polymer. This polymer is rapidly synthetised from cellular nicotinamide (NAD) by poly(ADP-ribose)polymerase in response to DNA strand breaks (1, 4). These breaks can be produced directly by agents such as X-rays and this DNA damage induces repair processes in which poly(ADP-ribose)polymerase plays an important role (3, 4). In order to understand better the function of poly(ADP-ribose)polymerase, 3-aminobenzamide (3-AB) has been used to inhibit this enzyme (2). The inhibition of polymerization by 3-AB permits a mutagenic agent (mitomycin-C) to attack the nuclear DNA, resulting in further damage and strand breaks of nuclear DNA (4).

The cytokinesis-blocked (CB) micronucleus assay has been used as a simple method of scoring damage to chromosomal material. This test consists of scoring micronuclei in lymphocytes having undergone one division after exposure to chromosome breaking (5, 6).

Blood was obtained from:
- healthy middle-age donors (normal I, normal II),
- mother of Down's syndrome patient (normal III),
- Down's syndrome patients (Down I, Down II),

Lymphocytes were cultured and cells were harvested and scored according to conditions described by Fenech and Morley (5). 3-AB was added at the beginning of cultures and mitomycin-C was added 24 hours later.

The level of micronuclei in cytokinesis-blocked normal and Down's syndrome lymphocytes after mitomycin-C treatment in the absence and the presence of 3-aminobenzamide is shown in Fig. 1.

Normal I

Normal II

Normal III

Down I

Down II
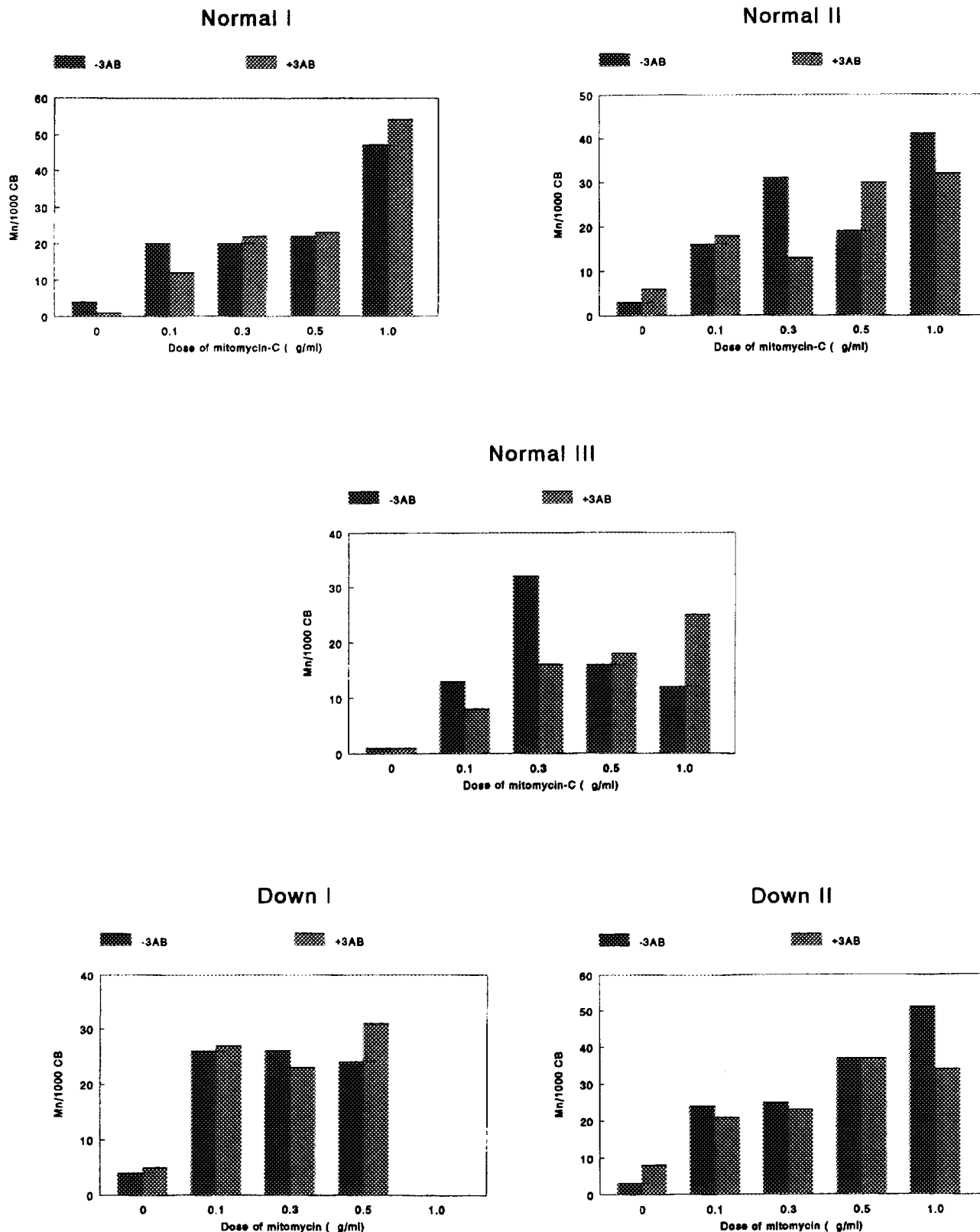
Fig.1 The level of micronuclei in cytokinesis-blocked normal and Down's syndrome lymphocytes after treatment with mitomycin-C in absence and presence of 3-Aminobenzamide.

The obtained results have shown that the level of micronuclei in Down's syndrome patients and in healthy donors is not elevated after adding 3-AB. However, a combined treatment with 3-AB and mitomycin-C revealed a higher level of micronuclei in both groups of donors as compared to the damaging effect of the same doses of mitomycin-C.

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   Book of Abstracts, Workshop "Monitoring of Exposure to Genotoxic Substances", Sosnowiec, 27-28 October 1994;

7. A. Cebulska-Wasilewska, B. Pałka, M. Litwiniszyn,
   "Ambient Air Genotoxicity in Comparison with Genotoxicity of Known Mutagens",
   Book of Abstracts, Workshop "Monitoring of Exposure to Genotoxic Substances", Sosnowiec, 27-28 October 1994;

8. A. Cebulska-Wasilewska, M. Litwiniszyn, A. Wierzewska, E. Kasper, B. Pałka,
   "Comparative Genotoxicity Studies of Pesticides Using Different Bio-assays",
   Book of Abstracts, Workshop "Monitoring of Exposure to Genotoxic Substances",
   Sosnowiec, 27-28 October 1994.

II. Contributions to Conferences:

1. J. Huczkowski,
   Animal Models Systems in Radiation Oncology,
   International Meeting on the Management of Head and Neck Carcinomas, England,
   April 1994;
2. A. Cebulska-Wasilewska,
   Genotoxic Effects of Benzene Related Compounds,
   CEC Projects Contact Meeting, Corfu, Greece, May 1994;
3. A. Cebulska-Wasilewska, E. Kasper, B. Krzykwa, A. Wierzewska,
   *Comparison Between Deltamethrin and Radiation in the Induction of Chromosome
   Aberrations in Human Blood Lymphocytes,*
   24th European Environmental Mutagen Society Annual Meeting, Poznań, September 1994;
4. A. Cebulska-Wasilewska, E. Kasper, B. Krzykwa, B. Pałka, A. Wierzewska,
   *Chromosome Aberrations and SCE in Human Blood Lymphocytes induced in vitro
   by exposure to pesticides,*
   24th European Environmental Mutagen Society Annual Meeting, Poznań, September 1994;
5. A. Cebulska-Wasilewska, E. Kasper, L. Koziara, B. Pałka, A. Wierzewska,
   *Biomonitoring of Human Population Exposed to Petroleum Fuel with Total Consideration
   of Benzene Genotoxic Component,*
   WHO Sponsored International Workshop, Sosnowiec, October 1994;
6. A. Cebulska-Wasilewska, E. Kasper, M. Litwiniszyn, B. Pałka, A. Wierzewska,
   Comparative Genotoxicity Studies of Pesticides Using Various Bio-assays,
   WHO Sponsored International Workshop, Sosnowiec, October 1994;
7. A. Cebulska-Wasilewska, B. Pałka, M. Litwiniszyn,
   *Monitoring of Exposure to Genotoxic Substances. Ambient air genotoxicity in comparision
   with genotoxicity of known mutagens,*
   WHO Sponsored International Workshop, Sosnowiec, October 1994.

PARTICIPATION IN CONFERENCES AND WORKSHOPS:

1. *A. Cebulska-Wasilewska*
   - 24th European Environmental Mutagen Society Annual Meeting, Poznań,
   September 1994;
   - WHO Sponsored International Workshop, Sosnowiec, October 1994;
   - CEC Projects Contact Meeting, Corfu, Greece, May 1994;
2. *J. Huczkowski*
   - International Meeting on the Management of Head and Neck Carcinomas,
   England, April 1994;
3. *M. Litwiniszyn*
   - WHO Sponsored International Workshop, Sosnowiec, October 1994;
4. *B. Pałka*
   - 24th European Environmental Mutagen Society Annual Meeting, Poznań,

September 1994;
- WHO Sponsored International Workshop, Sosnowiec, October 1994;
5. *A. Wierzewska*
- WHO Sponsored International Workshop, Sosnowiec, October 1994.

LECTURES AND COURSES:

1. *A. Cebulska-Wasilewska*
   - Postgraduate One-week Course on Radiation and Chemical Mutagenesis for IAEA Fellows;
   - Radiation Biology and Chemical Mutagenesis Course (IV course of Medical Physics and Dosimetry, AGH - lectures);
   - Environmental and Chemical Mutagenesis Course (V course of Medical Physics and Dosimetry, AGH - lectures and labs);
2. *B. Pałka*
   - *Tradescantia* stamen hairs: a test system for genetic effects at low radiation and chemical exposures;
   (a lecture at the Institute of Plant Genetics and Crop Plant Research, Gatersleben, Germany, June 1994).

INTERNAL SEMINARS:

1. D. Anderson (U.K.), January 1994,
   "Human Monitoring Studies";
2. B. Lazarska, January 1994,
   "Methods of Mutation Induction in Rape-Seed Cultures *in Vitro*";
3. B. Pałka, February 1994,
   "Cancer Biomarkers in Epidemiological Studies";
4. U. Rytwińska, March 1994,
   "Mutations in *Tradescantia* Induced by Filter Dusts Cellected in the Płock Area";
5. A. Cebulska-Wasilewska, April 1994,
   "Prospects of the Development of Cytogenetic Methods";
6. A. Cebulska-Wasilewska, April 1994,
   "Preliminary Results of Studies Carried out for Research Programmes in Collaboration with European Communities";
7. H. Płuciennik, May 1994,
   "Mutagenic Activity Testing of Pesticides with the Use of Chloropyll Mutations in Chlorella Vulgaris";
8. H. Płuciennik, June 1994,
   "Mutagenic Activity Testing of Pesticides with the Use of Mitochondrial Mutations in *Saccharomyces Cerevisiae*";
9. J. Kyu Kim (Korea), June 1994,
   "Serum Enzymes as Indicators of Radiation Exposure in Rat";
10. S. Muszyński, June 1994,
    "Environmental Mutagenesis - Teratologic Changes";
11. D. Nowak, August 1994,
    "Application of *in Situ* Hybridization (FISH) for Cytogenetic Studies";

12. W. Niedźwiedź, August 1994,
    "Application of DNA Electrophoresis in Human Blood Lymphocytes for Radiation Damage Evaluation (Comet Assay)";
13. S. Tano, September 1994,
    "Heavy Ion Beams and *Arabidopsis thaliana*";
14. B. Pałka, October 1994,
    "Detection of Adducts as the Method of DNA Damage Evaluation";
15. A. Cebulska-Wasilewska, November 1994,
    "Perspectives of Fluorescent Methods Applications for Environmental and Radiobiological Studies";
16. J. Smagała, November 1994,
    "Differences in the Induction of Lymphocyte Micronuclei in Down Syndrom Patients and Normal Healthy Subjects by Mitomycin-C in the Presence of 3-Aminobenzamide - an Inhibitor of Poly (ADP-Ribose) Polimerase";
17. W. Niedźwiedź, December 1994,
    "Comet Assay - an Introduction to the Method and Applications in DNA Damage Studies".

SHORT TERM VISITORS TO THE DEPARTMENT:

1. *Dr D. ANDERSON* - BIBRA Toxicology International, Carshalton, U.K., January 1994;
2. *Dr J. KYU KIM* - Korea Atomic Energy Research Institute, Taejon, South Korea, June 1994;
3. *International Atomic Energy Agency Fellows:*
   Golam Ahmed - Bangladesh,
   Bon-Cheol Koo - South Korea,
   Assefa Kebebew - Ethiopia,
   Masoud Rahimi - Iran,
   Conely Yagole - Tanzania,
   Cognamjil Dolgar - Mongolia,
   Jorge Jimenez Davalos - Peru,
   Agripina Roldan - Peru,
   Ihsan Tutluer - Turkey,
   Nasseri Tafti - Iran,
   Abadi Khaled - Libya,
   - partcipants of Postgraduate One-week Course on Radiation and Chemical Mutagenesis: August 1994;
4. *Dr S. TANO* - Japan Atomic Energy Research Institute, Takasaki, Japan, September 1994;
5. *Dr R. CREBELLI* - Instituto Superiore di Sanita, Viale Regina Elena, Italy, October 1994;
6. *Dr I. RODRIGEZ* - University of Lisbon, Lisbon, Portugal, November 1994.

PATENTS:

Dr B. Łazarska
Patent: PL 164154, Poland.
"Sposób uzdatniania wody dla intensyfikacji organizmów żywych, zwłaszcza roślin i urządzenie dla uzdatniania wody dla intensyfikacji wzostu organizmów żywych, zwłaszcza roślin" (Water Purification Method for the Intensification of Living Organism Growth...).

Department of Nuclear Radiospectroscopy

Section VIII

DEPARTMENT
OF NUCLEAR RADIOSPECTROSCOPY

Head of Department: *Prof. Jacek W. Hennel*
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PERSONNEL:

Magnetic Resonance Laboratory

Research Staff:
    Artur Birczyński, Ph.D.
    Jerzy Blicharski, Professor
    Jacek W. Hennel, Professor, Head of Department and Laboratory
    Zdzisław T. Lalowicz, Ph.D.
    Zbigniew Olejniczak, Ph.D.
    Stanisław Sagnowski, Ph.D.
    Robert Serafin, M.Sc.

Administration:
    Secretary: Magdalena Zych

Magnetic Resonance Imaging Laboratory

Research Staff:
    Andrzej Jasiński, Assoc. Professor, Head of Laboratory
    Jacek Kibiński, Ph.D.
    Stanisław Kwieciński, M.Sc.
    Artur Krzyżak, M.Sc.
    Piotr Kulinowski, Eng.
    Tomasz Skórka, M.Sc.
    Zenon Sułek, Ph.D.
    Krzysztof Szybiński, M.Sc.,Eng.
    Bogusław Tomanek, Ph.D.

Laboratory of Solid State Physics and Computer Simulations

Research Staff:
    Krzysztof Parliński, Professor, Head of Laboratory,
    Małgorzata Sternik, Ph.D.

GRANTS:

1. *Dr Z.T. Lalowicz,*

   grant No 2 033649 91 01 (The State Committee for Scientific Research),

   "Studies on Quantum and Classical Reorientation of ND4$^+$ Ions by Means of NMR Spectroscopy" (01. 10. 1991 - 30. 09. 1994);

2. *Assoc. Prof. A. Jasiński,*

   grant No 2 244291 02 (The State Committee for Scientific Research),

   "Nuclear Magnetic Resonance Microscopy" (01. 06. 1992 - 31. 05. 94);

3. *Assoc. Prof. A. Jasiński,*

   grant No 628/IA/620/93 i 838/IA/620/94 (The State Commitee for Scentific Research),

   "Investment Subsidy, Magnetic Resonance Imaging System";

4. *Dr Z. Olejniczak,*

   Grant EWG nr 92 - 0066 (Oct. - Dec. 1994);

5. *Prof. K. Parliński and Dr M. Sternik,*

   grant No 2 2377 92 01 (The State Committee for Scientific Research),

   "The Mechanisms of Structural Phase Transitions".

OVERVIEW:

Research at the Department of Nuclear Radiospectroscopy of the H. Niewodniczański Institute of Nuclear Physics concerns various problems of nuclear magnetic resonance (NMR) and its applications in different areas of science, with molecular dynamics in the first place. The Department is equipped with a 1.5 T, 6cm-gap electromagnet, a 6.4 T superconducting magnet, an XP4-100 Bruker spectrometer, a home-made 270 MHz MR microscope system and a home-made Zero-Field NMR spectrometer of unique design permitting work at helium temperatures. The Department cooperates closely with the NMR group of Prof. J.S. Blicharski at the Department of Physics of the Jagellonian University in Cracow.

Current research programme covers three areas: magnetic resonance, magnetic resonance imaging, and solid state physics by computer simulations.

MAGNETIC RESONANCE LABORATORY

We apply magnetic resonance methods in studies of molecular rotations in solids. We can distinguish two ways of rotations: tunnelling through the potential barriers and random jumps between distinct orientations. The former is responsible for orientational delocalisation at liquid helium temperatures, causing so-called tunnelling splitting of the ground torsional energy level and therefore strongly influencing the NMR spectrum. Random jumps are possible at higher temperatures since the molecule needs a sufficient amount of energy to overcome the potential barrier. This type of motion can be treated classically. This also influences the NMR spectrum but in a manner quite different from that of tunnelling. In particular, the deuteron NMR spectra provide explicit evidence of the type of motion. Moreover, measurements of tunnelling frequency and reorientation rate are possible. Both supply data on height and symmetry of the potential. Theoretical fits to deuteron NMR spectra of $(ND_4)_2SnBr_6$ at 4.2 K gave the ground torsional level structure and estimates of splittings within it. Ammonium ions perform tunnelling rotation at relatively low frequences in a low-symmetry potential.

In the case of ammonium tetrachloroplatinate, combined analysis of powder and single crystal samples as well as, proton and deuteron relaxation, guided us among several possible motional

models. The current interpretation involves existence of domains of differently ordered ions and exceptional mobility of ions within domain walls.

Deuteron NMR spectra of tunnelling CD_3 groups in the single cristal of aspirin were measured and analysed. Tunnelling frequency temperature dependence was established and explained by jumps between all torsional levels within the potential well.

Studies of deuteron NMR spectra and spin-lattice relaxation were continued for partially deuterated rotors CH_3D and NH_3D^+.

MAGNETIC RESONANCE IMAGING LABORATORY

Work on the construction of a MR microscope based on a 6.3 T superconducting magnet was completed. Each part of the system was tested. Software written in the Laboratory was used for the MR microscope testing, optimization and running the experiment. Multi-slice multi-echo with pilot scan sequence was implemented. A special probe with integrated, actively shielded gradients coils, a set of custom-designed rf coils and a temperature control system were built. MR images of phantoms with in-plane resolution of 15 μm x 15 μm with slice thickness of 100 μm were obtained.

The MR microscope was used for small-plant imaging (e.g. *Dactylis glomerata*) to study water distribution and water transport by applying diffusion-weighted imaging sequences. MR microscope was also used for visualisation of internal structure of the honeybee *in vivo*. Most of the organs have been identified. Reproductive organs of honeybee queen and drone were imaged and their size measured noninvasively for the first time. Our results show that MR microscopy is a very promising tool for research in insect biology.

In collaboration with the FORENAP Foundation in Rouffach, France, new 3-dimensional T_1 weighted FLASH and Magnetisation Transfer FLASH sequences were implemented and tested on 3 T whole-body system.

LABORATORY OF SOLID STATE PHYSICS AND COMPUTER SIMULATIONS

In the Laboratory of Solid State Physics and Computer Simulations the work was concentrated around the following topics:

Consequences of tetragonal-orthorhombic phase transition, experimentally observed in high-T_c superconducting material $YBa_2Cu_3O_{7-\delta}$, have been studied extensively on a 2d model by molecular-dynamics simulation. The model has been supplemented with a term of external field which could be coupled to oxygen concentration, and with the second nearest neighbour interaction. That allows one to establish temperature-oxygen concentration phase diagram with the tetragonal - orthorhombic phase boundary, and with new incommensurate phase, known as a OII phase. The corresponding microstructure pattern shows a tiny grid of domains in this case. A MD simulation of the same model with substitutional impurities in place of copper showed influence of these atoms on the microstructure pattern. The impurity atoms pin the domain walls, and therefore hinder formation of a single domain.

The ground state of our hexagonal model contains one-dimensional $1q$ and two-dimensional $3q$ modulations. That model has been extensively simulated by the MD method in order to elucidate phase transition mechanisms between different types of modulated phases. The simulations have shown that: (i) The $1q$ commensurate $\frac{1}{4} \to 1q$ incommensurate phase transition is driven by stripple mechanism, with stripples built up from four discommensuration planes. (ii) At the $3q \to 1q$ phase transition, the columns of $3q$ phase merge together to form a stripe of $1q$ incommensurate phase.

Another activity in the simulation of incommensurate phases was related to the question of coupling of the order parameter to the crystal strain. A simple three-dimensional model

specially constructed for this purpose showed that elastic domain walls can serve as a source of nucleation of discommensurations. Moreover, the modulated phase induces some modulation also in the crystal strain. We have also proved the existence of stripples with a complicated structure consisting of six discommensuration planes. Such defects are responsible for driving the phase transition from commensurate phase $k = \frac{1}{3}$ to the incommensurate one.

The domain patterns are consequences of the phase transition. The microstructure in the molecular crystal of KSCN has been studied along this line. This crystal undergoes an order-disorder phase transition, which has been simulated by the molecular-dynamics technique. Evolution during the annealing process shows that ferroelastic domain walls keep fixed orientation of matching lattice directions, while antiphase domain walls are oriented arbitrarily.

Prof. Jacek W. Hennel

REPORTS ON RESEARCH:

Deuteron NMR of Methyl Groups in Tunneling Regime. Single-Crystal Study of Aspirin-CD$_3$

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Max–Planck–Institut für Medizinische Forschung, Jahnstraße 29, 69120 Heidelberg, Germany
and
Z. Olejniczak and Z.T. Lalowicz

We report the first single-crystal deuteron NMR spectra of CD$_3$ groups which display the so-called $\pm\beta$, $\pm(|\alpha| \pm \beta)$ and $\pm(2|\alpha| \pm \beta)$ lines characteristic of rotational tunnelling in a higher sufficiently clear to allow a quantitative comparison with theory developed in 1988 by the group of W. Müller-Warmuth. The molecular system we study is aspirin-CD$_3$. We recorded spectra for differently oriented single crystals and we measured spin-lattice relaxation times T$_1$ in a wide temperature range. At 12.5 K we used dependence of the $\pm(|\alpha| \pm \beta)$ and $\pm(2|\alpha| \pm \beta)$ lines on the orientation of applied field B$_0$ for determining the equilibrium orientation of the CD$_3$ group in the crystal lattice. The spectra display features which by comparison with simulated spectra allow to measure of tunnel frequency ν_t. Its low temperature limit is (2.7 ± 0.1) MHz. It allows one to infer height V_3 of potential $V(\varphi)$ in which the CD$_3$ group moves, provided that this potential is purely threefold. We get $V_3 = (47.2 \pm 0.5)$ meV. Transition from the tunnelling to the classical, fast reorienting regime occurs in the $15 \text{ K} \lesssim \text{T} \lesssim 35 \text{ K}$ temperature range. In this range we observe broadening, merging and eventually narrowing of the $\pm|\alpha|$ and $\pm 2|\alpha|$ lines in very much the way predicted by Heuer. His theory, however, must be extended by taking into account all librational levels. The behaviour of the $\pm\beta$ lines in the transition temperature range signalizes reduction of the *observable* tunnel frequency with increasing temperature. This reduction allows an independent measurement of the potential height and represents a test of the assumption of a purely threefold potential. From the T$_1$-data we derive temperature dependence of correlation time τ_c of the reorientational jumps. The plot of $\log \tau_c$ vs $1/T$ follows a straight line for more than five decades. From its slope we get yet another independent number for the potential height. It agrees well with the other ones, confirming the assumption of essentially threefold potential $V(\varphi)$ in aspirin CD$_3$.

(accepted for publication in Z. Naturforsch.)

PL9700255   PL9700254

Deuteron NMR Spectra of ND_4^+ Tunnelling at Low Frequencies in $(ND_4)_2SnBr_6$

14 8

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and

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Deuteron NMR spectra of slowly tunnelling ND_4^+ ions are analysed. Spectra are calculated as a function of tunnelling parameters, i.e. tunnelling frequencies about symmetry axes C_2 and C_3 of the tetrahedral ion. The structure and splittings within the ground torsional level (GTL) are obtained by fitting the spectra of $(ND_4)_2SnBr_6$. As a final result we obtain the tunnelling parameters : $\Delta(4) = 20$ kHz, $\Delta = \Delta(1) = \Delta(2) = \Delta(3) = 13$ kHz, $\pi = \pi_x = \pi_y = \pi_z = 1$ kHz, where $\Delta(n)$ and π_α are tunnelling frequencies about C_3 and C_2 symmetry axes of the ammonium ion respectively. Comparing the tunnelling splittings for protonated and deuterated compounds we obtain the isotope reduction factors X = 219 for the T levels splitting and X = 287 for the A - T tunnelling splitting. Up to about 30 K no changes in the spectra were observed. At higher temperatures decreasing amplitude of the innermost doublet was seen, leading to its disappearence above 34 K. Subsequently, other doublets undergo motional narrowing as well and the central narrow component increases. At about 45 K fast reorientation limit was achieved.

The paper has been accepted for publication in Z. Naturforsch.

Magnetic Resonance Microscopy Study of Honeybee Internal Structure

14 3

B. Tomanek, A. Jasiński, Z. Sułek, S. Kwieciński, T. Skórka, A. Krzyżak, J. Kibiński,

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and

J. Muszyńska

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Non-invasive investigation of internal insect structure is a nontrivial problem. All the work reported so far was done *post mortem*, after killing the insect. In most cases internal organs are studied after extraction from insect body. Optical microscope images of anatomical cross-sections of thin slices are very rare in literature because hard chitin outer shell of insects makes slice cutting very difficult. Magnetic resonance imaging (MRI), widely used in medical diagnostics, offers a non-destructive way of imaging internal insect structure. Intensity of MR images is proportional to water concentration in tissue, water mobility and to MR parameters such as relaxation times T_1, T_2. In this work we applied MR microscopy to image honey bees of all casts to see whether physiologically useful information can be obtained from MR images. Honey bees of all casts were imaged using a home-made MR microscope based on a 6.4 T vertical bore magnet. Custom-made temperature-regulated MR probe head with integral actively shielded gradient coils in one hour produced images with in-plane resolution of 20 μm x 20 μm and slice thickness of 80 μm. Honey bees were immobilised by lowering the temperature to about $+10^0$ C. Experiments on all casts of honey bee showed that cooling down the insects for about 2 hours has little effect on their survival and subsequent activity. In the experiments reported here insects fully recovered even after 6 hours of cooling. During Spring and Summer of 1994 we recorded hundreds of MR microimages of individuals from all casts, i.e. workers, drones and queens. These images corresponding to thin cross-section slices through the insect show details

PL9700256

of internal structure allowing identification of organs. As an example, two MR microimages are shown below: a) a sagittal cross-section through the abdomen of a queen, where intestine, ovary and spermatocyst are clearly visible, b) a coronal cross-section through the abdomen of a drone, where testis and spermatic ducts can be recognised. In conclusion we can say that honey bee imaging *in vivo* is possible and can be used for studying some problems of honey bee physiology.
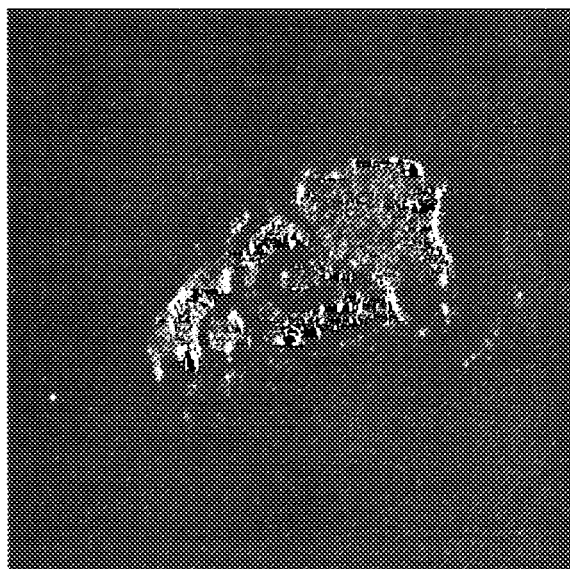
Fig. a MR microimage of a sagittal cross-section through the abdomen of a queen: 1 - spermatocyst, 2 - ovaries, 3 - intestines.
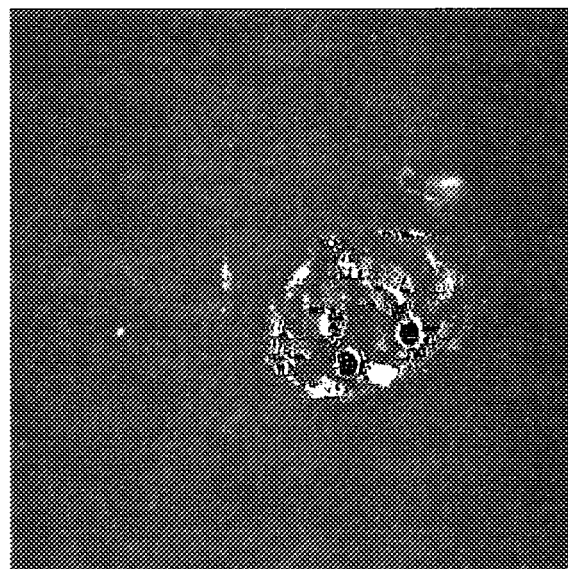
Fig. b MR microimage of a coronal cross-section through the abdomen of a drone: 1 - testis, 2 - spermatic ducts.

Tetragonal Model with 1q and 2q Modulated Phases

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The majority of experimentally observed incommensurate phases occurs in orthorhombic crystals and the modulation propagating along its high-symmetry directions, is found to be one-dimensional ($1q$). Two-dimensional modulation ($2q$) is rather rare. The best known example is a crystal of barium sodium niobate, $Ba_2 Na Nb_2 O_{15}$.

In the referred paper [1] we discuss a three-dimensional tetragonal model, which exhibits stable $1q$ and $2q$ modulated phases. In the model, each particle with a displacive degree of freedom is subjected to the fourth-order site potential and is coupled harmonically and anharmonically up to third nearest-neighbours and via three-body interaction to the nearest-neighbours. The molecular-dynamics technique has been applied to analyse a structural rearrangement in the system consisting of 24x24x12 particles. Distribution of displacement amplitudes in the XY, XZ and YZ planes was recorded in a form of particle configuration maps after each simulation step. The modulation wave vector was detected through the scattering function.

The calculated temperature-potential energy parameter phase diagram (Fig. 1) of the model exhibits normal, commensurate $k = \frac{1}{2}$, one-dimensional ($1q$) and two-dimensional ($2q$) incommensurate phases. We have demonstrated that the $1q$ phase could be easy converted to the $2q$ phase just by increasing the magnitude of three-body interaction. The mechanism of ($1q - 2q$) phase transition is the same for both commensurate and incommensurate phases, and it relies

on the creation of anisotropic gaps nucleated equidistantly on the modulation stripes of the $1q$ phases.

Fig. 1 Calculated phase diagram of the tetragonal model for 4 sets of the potential energy parameters as a function of the potential energy parameter A and temperature.
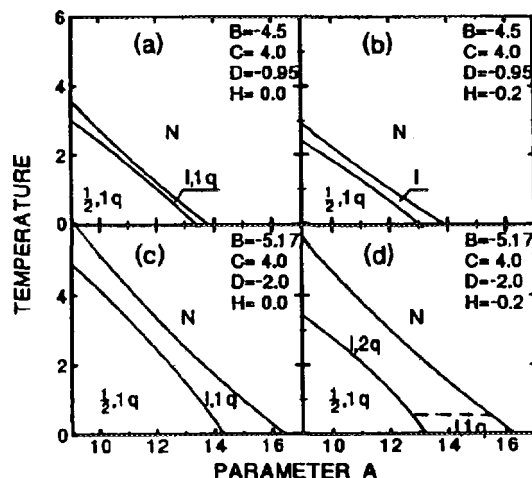
Reference:

1. M. Sternik and K. Parliński, *Phys. Rev.* B **50**, 9086 (1994).

Computer Simulation of Domain Formation in the Order-Disorder Phase Transition of KSCN Model

K. Parliński

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The tetragonal-orthorhombic improper ferroeleastic phase transition and domain formation of the order-disorder KSCN model is studied by molecular-dynamics simulation. On quenching from the disorder phase and subsequent annealing, a tweed texture is obtained, which later evolves to a stripe phase with well oriented ferroelastic domain walls and arbitrarily oriented antiphase boundaries.

Orientational order-disorder phase transitions can occur in crystals consisting of molecular units. In such a case the disorder is manifested by occupation of distinguishable orientations of the molecules. The disorder can be induced either by the dynamical reorientations or by random occupations of the different states. As a rule the orientation of molecule is coupled to the lattice deformation. Here, the orientational degree of freedom η is coupled bilinearly $\eta^2 \rho$ to the strain ρ, leading to the improper ferroelasticity. In KSCN the transition instability occurs at the Brillouin zone. The KSCN crystal exhibits a tetragonal-orthorhombic phase transition at 415 K. The low-temperature orthorhombic unit cell with symmetry $Pbcm(D_{2h}^{11})$ contains four molecular units $(Z = 4)$ [1]. All SCN^- molecules are aligned along $< 1, 1 >$ crystal direction with a definite head-tail orientation. The high-temperature tetragonal phase is characterized by the space group $I4/mcm(D_{4h}^{18})$ $(Z = 2)$. In this phase the SCN^- molecules become orientationally disordered because of rotational motion.

Due to the symmetry reduction from $I4/mcm$ to $Pbcm$, four domain states appear in KSCN below transition temperature. Two of the states are related by a 90° rotation and the other two by a translational shift. Two orientational domain states differ in spontaneous strain. Thus, the wall separating two domains is termed a ferroelastic domain wall. Two translational domains differ in the phase of the order parameter and are named antiphase domains with an antiphase boundary between them.

A two-dimensional model is proposed [2] to simulate the rotational motion of molecules coupled bilinearly to the strain. The model represents a single xy layer of KSCN crystal.

Our choice of variables and potential parameters guarantees correct symmetry reduction at the tetragonal-orthorhombic phase transition, and satisfies the symmetry of all four domains. The crystallite consisted of 105×105 unit cells, with 21841 particles. Free boundary conditions were used.

The domain formation depends on many factors, in particular, time, quench and annealing temperature. Here, we report results of the following process: The system equilibrated initially in tetragonal phase has been quenched to the annealing temperature. After the quench, isothermal conditions were imposed and the system was left to relax towards equilibrium.
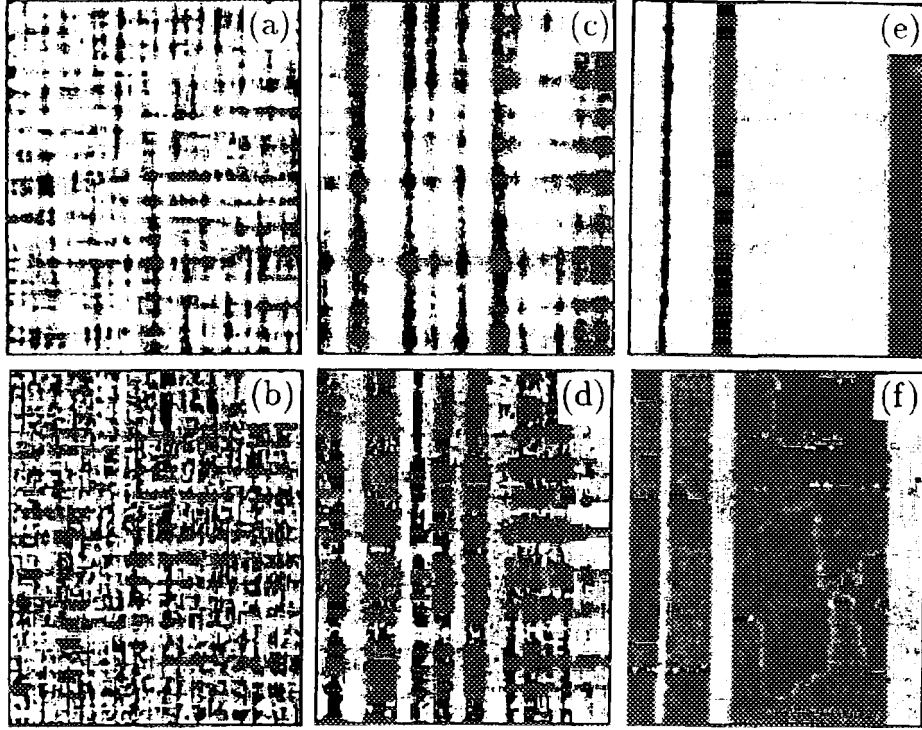
Fig. 1: Maps of the strain (a, c, e) and orientational (b, d, f) order parameters obtained during annealing at temperature $T_a = 0.63\ T_c$ after quenching from $T = 1.25\ T_c$. Maps (a, b), (c, d) and (e, f) correspond to annealing time of $0.20, 0.76$ and $4.13\ \tau_o$, respectively. The maps show system of 105×105 unit cells.

The results of two typical runs quenched from temperature $1.25\ T_c$ to the annealing temperature $T_a = 0.63\ T_c$ are shown on the maps of strain and orientational order parameters in Fig. 1. In each case the degree of undercooling is large, therefore, the domain walls are narrow and the thermodynamic driving force towards equilibrium is strong. Already the first snapshots of Fig. 1a and b taken after short annealing time show a definite, although very fine domain microstructure. In course of time tweed texture evolves with a number of right-angle domain wall junctions between ferroelastic domains.

The number of junctions reduces rapidly, indicating that junction energies are high and prohibit wall crossing. After annealing time of $0.76\ \tau_o$ a pattern of locally stripe structure of ferroelectric domains has been developed. Each stripe, however, consists of antiphase domains. Later on, the junctions between ferroelastic domain walls disappear completely and each stripe consists of antiphase domains with antiphase boundaries with no prefered orientations.

The analytical theory which indicates the way of calculating the transition temperature, gave a very good quantitative agreement when the translation rotation coupling vanishes. It also correctly describes the shift of the transition temperature when the coupling constant remains finite.

References:

1. W. Schranz, Phase Transitions **51**, 1 (1994);
2. K. Parliński, Phys. Rev. **B50**, 59 (1994).

Mechanisms of Phase Transitions in a Hexagonal Model K. *'52*

Parliński[1] and G. Chapuis[2]

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A number of dielectric and ferroelectric crystals possess incommensurately modulated phases, which could be seen as a sequence of discommensuration planes. Using simple hexagonal microscopic model the nucleation of topological defects responsible for creation of discommensurations, has been studied. Example of the collective nucleation mechanism in the commensurate $\frac{1}{4} \rightarrow$ incommensurate phase transition driven by stripples will be discussed. During the phase transition from $3q$ two-dimensional modulated phase to $1q$ stripe commensurate phase formation of domain-like texture has been observed.

A rather complete information on the crystallite system, its properties and behavior would have been drawn from the computer simulation by a molecular-dynamics technique. Knowing potential energy of the crystal and applying laws of dynamics and statistical physics, the structure, phase states, dynamics, kinetics, phase transitions, and domain structures, etc. can be, in principle, derived. But even nowadays fast supercomputers are able to handle MD simulations of systems of order of 10^4 particles, which is far not sufficient for studying the incommensurability or the domain textures of the crystals. One way of solving this problem is to reduce the number of degree of freedom of the crystallite to a model and to simulate only this simplified model with a few but essential degree of freedom. The computer time needed normally to calculate the forces between many neighbors in the unit cell, is then considerably reduced, and it can be used to calculate effects appearing over much more unit cells. Such models will be useful if they would be able to reproduce phenomena occuring on mesoscoping scale, where any interesting object needs at least several lattice constants to be defined.

The existence of incommensurate phases in quartz [1, 2] inspired to set down a hexagonal model which could generate either one-dimensional or two-dimensional modulated phases. The model [3, 2, 3] consists of particles having only one displacement degree of freedom and occupying sites of simple hexagonal lattice. The ground state phase diagram of this model shows a number of modulated phases propagated along [1, 0] or equivalent directions. The commensurate $q = 0, \frac{1}{4}, \frac{1}{3}$ and $\frac{1}{2}$, and incommensurate phases of ($1q$) one- and ($3q$) two-dimensional character cover a considerable area of the phase diagram.

Generally, the mechanism of $1q$ commensurate $\rightarrow$ $1q$ incommensurate phase transition is well understood and can be conveniently described in terms of discommensurations and stripples [6, 7, 4, 9]. This is also the case for the commensurate $\frac{1}{4} \rightarrow$ incommensurate phase transition which is driven by stripples built up from four discommensuration planes. Example of the simulation maps are shown in Fig. 1. Indeed, the commensurate phase $\frac{1}{4}$ of the model may exist in four antiphase domains $\uparrow\uparrow\downarrow\downarrow$, $\uparrow\downarrow\downarrow\uparrow$, $\downarrow\downarrow\uparrow\uparrow$, $\downarrow\uparrow\uparrow\downarrow$. The incommensurate modulation can be described as an ordered cyclic sequence of these domains. The stripples appear in the metastable crystal by conventional nucleation mechanism. They resemble disks which in this case are build up from four discommensuration planes, meeting at closed deperiodization lines.
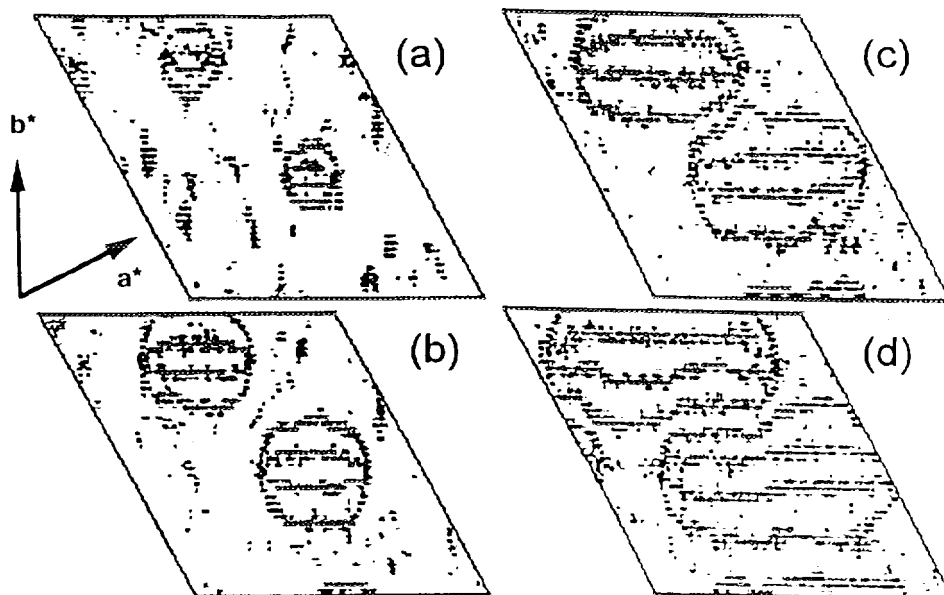
Fig. 1: Maps of discommensurations at the phase transition from the commensurate $\frac{1}{4}$ to incommensurate phase. The crystallite consisted of $88 \times 88 \times 5$ unit cells.
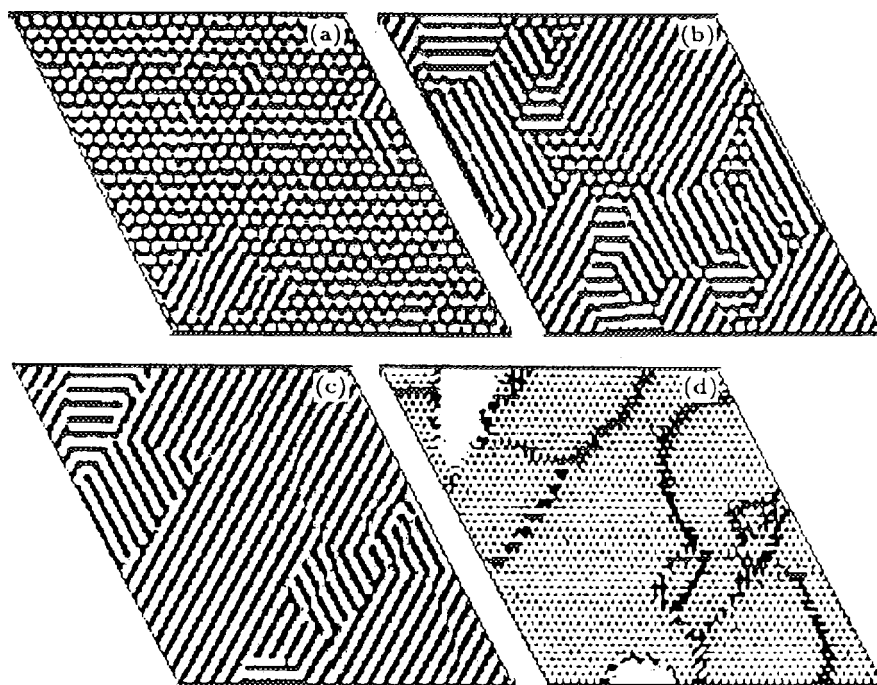
Fig. 2: (a-c) Maps of particle displacements in the crystallite of $88 \times 88 \times 5$ unit cells of the hexagonal model and at the phase transition from two-dimensional $3q$ incommensurate $k = 0.2727$ to one-dimensional commensurate $k = \frac{1}{4}$ phase. (d) Domain boundaries corresponding to particle configuration of Fig. 2c.

Experimentally, it has been found that the majority of the incommensurate phases occur in crystals with frame symmetry being orthorombic and that the modulation is one-dimensional and propagates as a rule along the high-symmetry lattice direction. A two dimensional modulation, which arrises as a result of superposition of three static modulated waves $(3q)$, propagating along three different, but equivalent directions occurs rather seldom. In two hexagonal crystals

a two-dimensional $3q$ incommensurate phase has been reported. Quartz [1, 2] and $AlPO_4$ [10] belong to that class of crystals. There are not many attempts to study models with the two-dimensional modulations, perhaps, because of existance of a very few samples which exhibit such type of the modulation.

Our hexagonal model [3, 2, 3] has $3q$ modulated phases. The $3q$ incommensurate phase can be visualized as a sequence of columns, oriented along the unique hexagonal axis. The quantity which is modulated consists of particle displacements, what means that the displacement amplitudes are large and small inside and outside the columns, respectively.

Of some interest could be the phase transition mechanism from the two-dimensional column like incommensurate phase $3q$ to the one-dimensional commensurate phase $\frac{1}{4}$. Fig. 2a, b, c show such phase transition from $q = 0.2727 \rightarrow \frac{1}{4}$. In the beginning some of neighboring columns merge, forming first column dimers and later stripes of the modulation. Neighboring columns have a strong tendency to merge along the direction of the first stripe, forming a single orientational stripe domain. Finally, a texture of three kinds of orientational stripe domains is formed. The incommensurate separation within the domains, driven by a slower process, is now readjusted to the commensurated value $q = \frac{1}{4}$, by annihilating the excess of periods in the domain boundaries. Fig. 2d shows as well an antiphase domain boundary between two domains of the same orientation. At the beginning of the phase transition the neighboring domains started to readjust the incommensurate spacing changing their phases in different ways. When the two domains met they had already different phases and therefore they formed the antiphase domain boundary. Upon long simulation time only single one-dimensional commensurate $\frac{1}{4}$ domain remains.

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Commensurate-Incommensurate Phase Transition in the Deformed Crystal

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Using simple orthorhombic microscopic models the commensurate - incommensurate phase transition has been studied. Coupling of the order parameter with spontaneous strain may lead to process which uses the ferroelastic domain walls to introduce the discommensurations to the incommensurate phase.

The leading modulation in the crystal consists of degree od freedom which form the order parameter. And as a rule the order parameter is not a spontaneous strain. The order parameter can, however, couple to the spontaneous strain. Namely, the symmetry of the order parameter

could be the same as the symmetry of one of the acoustic branch. This would lead to a linear coupling of the modulation with the local spontaneous strain mode. In such case, the effect of unit cell deformation will cummulate over long distances, therefore the coupling to spontaneous strain may play essential role in incommensurate phases involving long wavelentgh modes, i.e. in the commensurate $q = 0 \rightarrow$ incommensurate phase transitions. The situation is relatively simple for crystals with a one-dimensional modulation.

Very little effort has been made to simulate properties of incommensurate phases in the models which take into account the coupling of the order parameter with the spontaneous strain. We refer here some results of K. Parliński, Y. Watanabe, K. Ohno, and Y. Kawazoe [1], where a model of a simple three-dimensional orthorhombic lattice with one molecular object in the unit cell was considered. Each object, one per unit cell, has four degrees of freedom; three coordinates and the soft spin-like variable, which describes the molecular orientation. Owing to direct interaction between nearest and next nearest soft-spins the subsytem may form modulated phases. The coupling is set so that when the modulation is directed along Z axis then the accompanying shear mode will be of YZ type.

This model has been studied by the molecular-dynamics technique [1]. The simulated crystallite had a shape of rectangular parallelpiped and consisted of $26 \times 26 \times 48 = 32448$ unit cells. The restricted volume boundary conditions were used. That means that the simulated crystallite was inserted into a cavity of fixed volume and fixed shape.
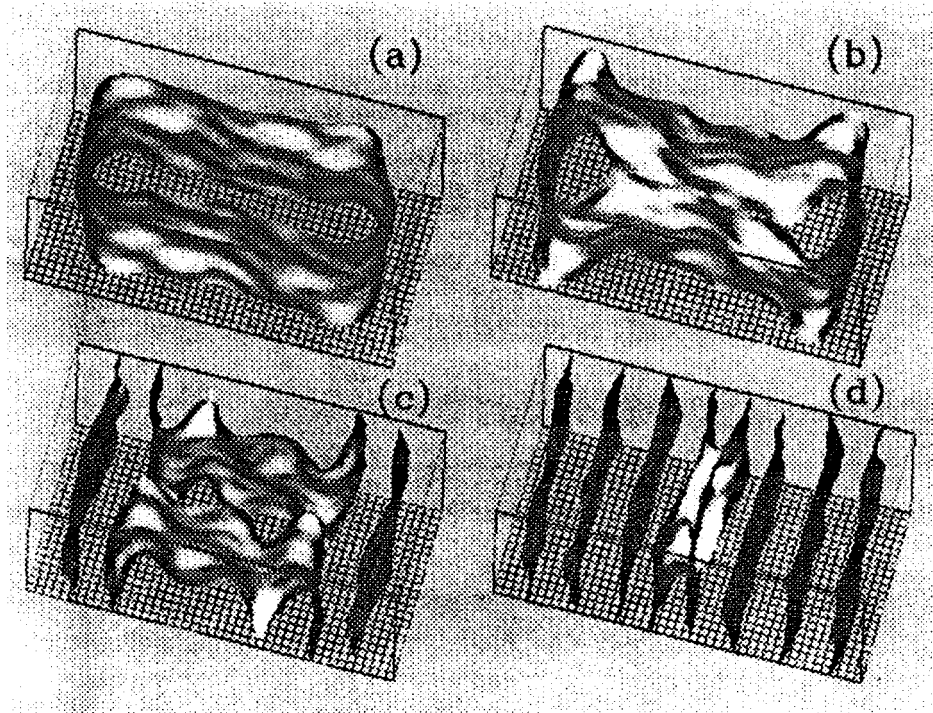
Fig. 1: Volume representation of (a) ferroelastic domain walls which are transformed to (d) the discommensuration planes at the commensurate $q = 0 \rightarrow$ incommensurate phase transition in the orthorhombic model.

Fig. 1 shows the soft-spin configurations during the commensurate $q = 0 \rightarrow$ incommensurate phase transition. The commensurate $q = 0$ state is a monoclinic phase which possesses two ferroelastic domains. Due to restricted volume conditions the initial configuration consists of two domains, Fig. 1a, separated by the ferroelastic domain wall of cylindrical shape. Such a shape of domains reduces remarkably the macroscopic deformation. The ferroelastic domain walls are oriented mainly along the coherent matching planes. Next the crystallite was put into metastable conditions in order to initiate the phase transition, and hence the domain walls,

which were parallel to the modulation direction, started to wave, as shown in Fig. 1b. The outer tips of these waves went to crystal surfaces, there they split off and formed discommensuration planes, Fig. 1d.

This result then indicates that the phase transition from a $1q$ commensurate phase to $1q$ incommensurate one can be driven by different mechanisms. It can be either a stripple mechanism as demonstrated in [2, 3, 4], or the mechanism which uses already existing ferroelastic domains walls. However, to cause the last mechanism to function, there should exist a linear coupling of the order parameter to the acoustic phonon branch, and a network of ferroelastic domains walls must be already present in the initial configuration of the commensurate phase.

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PUBLICATIONS:

I. Articles:

1. C. Dimitropoulos, Z. Lalowicz,
   "NMR and NQR Spin-Lattice Relaxation in Partially Deuterated $(NH_4)_2SnCl_6$",
   Phys. Rev. **B49** (1994) 644-646;

2. Z. Lalowicz,
   "Tunnelling Spectroscopy Proton and Deuteron NMR",
   INP Report **1673/PL**, 1994 (rozp. habilitacyjna);

3. Z. Lalowicz, R. Serafin, M. Punkkinen, A.H. Vuorimki, and E.E. Ylinen,
   "Deuteron NMR Spectra of ND_4 Tunnelling at Low Frequencies in $(ND_4)_2SnBr_6$",
   Z. Naturforsch. (in print);

4. A. Detken, P. Focke, H. Zimmermann, U. Haeberlen, Z. Olejniczak, and Z.T. Lalowicz,
   "Deuteron NMR of Methyl Groups in the Tunnelling Regime. A Single Crystal Study of
   Aspirin-CD_3", Z. Naturfosch (in print);

5. K. Parliński and M. Sternik,
   "Computer Simulation of Tweed Microstructure in High T_c Superconductors",
   J. Phys: Condensed Matter C **6**, 237-252 (1994);

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   "Phase Transitions Mechanisms between Hexagonal Commensurate and Incommensurate
   Structures", Phys. Rev. B **49**, 11643-11651 (1994);

7. K. Parliński,
   "Computer Simulation of Domain Formation in the Order-Disorder Phase Transition of
   KSCN Model", Phys. Rev. B **50**, 59 (1994);

8. M. Sternik and K. Parliński,
   "Computer Simulation of $1q$ and $2q$ Modulated Phases in Tetragonal Model",
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10. K. Parliński and M. Sternik,
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11. K. Parliński,
    "Discommensuration Pattern and Phase Transition Mechanisms in Hexagonal Incommensurate System", Molecular Physics Report **6**, 87-96 (1994);

12. K. Królas and M. Sternik,
    "Rhodium Segregation in Dilute Silver-Rhodium Alloys",
    Acta Metallurgica et Materialie (in print);

13. K. Parliński, Y. Watanabe, K. Ohno, and Y. Kawazoe,
    "Commensurate-Incommensurate Phase Transition in the Presence of Crystal Deformation", Phys. Rev. **B** (in print);

14. K. Parliński, K. Ohno, and Y. Kawazoe,
    "Mechanism of Commensurate $k = 1/3$ Incommensurate Phase Transition" (in print).

II. Contribution to Conferences:

1. T. Skórka, A. Jasiński,
   First Nottingham Symp. on Mag. Res. in Med., Nottingham, 6-8 April 1994, UK;

2. B. Tomanek, A. Jasiński, Z. Sułek, J. Muszyńska, S. Kwieciński, T. Skórka, A. Krzyżak, J. Kibiński, "Noninvasive Investigation of Honey Bee in MR Microscopy",
   XXXI Bees Conference, Puławy 1994, p. 64 (in Polish);

3. J. Muszyńska, A. Jasiński, Z. Sułek, B. Tomanek,
   "Safety Technique of Immobilisation of Honey Bee for MRI Investigation",
   XXXI Bees Conference, Puławy 1994, p. 43 (in Polish);

4. J. Muszyńska, A. Jasiński, Z. Sułek, B. Tomanek,
   "Technique of Preservation of Three Kinds of Honey Bee in Periods between MRI Investigations", XXXI Bees Conference, Puławy 1994, p. 44 (in Polish);

5. B. Tomanek, A. Jasiński, Z. Sułek, J. Muszyńska, S. Kwieciński, T. Skórka, A. Krzyżak, J. Kibiński,
   "Application of MR Microtomography to Investigation of Honey Bee and Honey Bee Queen *in Vivo*", 2nd NMR School, Zakopane, 30 May - 4 June, 1994, p. XXVI;

6. B. Tomanek, A. Jasiński, Z. Sułek, J. Muszyńska, S. Kwieciński, T. Skórka, A. Krzyżak, J. Kibiński, "Magnetic Resonance Microscopy Study of Honey Internal Structure",
   Sallus Apis Mellifera. Polish-German Symp., Oberusel, 19 - 23 September 1994, Germany;

7. K. Parliński,
   "Workshop on Magnetic Structure and Phase Transitions", 26 - 30 August 1994, Cracow;

8. B. Tomanek, A. Jasiński, Z. Sułek, J. Muszyńska, S. Kwieciński, T. Skórka, A. Krzyżak, J. Kibiński,
   "Application of MR Microimaging to Honey Bee and Honey Bee Qeen *in Vivo* Research",
   II Summer NMR School, 30 May - 4 June 1994, Zakopane, p. XXVI;

9. Z.T. Lalowicz, Z. Olejniczak, R. Serafin,
   "NMR Relaxation Dispersion in NH_4ClO_4 at Low Temperatures",
   12-th EENC, Oulu, 1994, Finland;

10. B. Tomanek, A. Jasiński, Z. Sułek, J. Muszyńska, S. Kwieciński, T. Skórka, A. Krzyżak, J. Kibiński, "MR Microscopy of Honey Bee Morphology *in Vivo*",
    XXVII Ogólnopolskie Sem. nt. MRJ i Jego Zastosowań, Cracow (also as a talk);

11. B. Tomanek, A. Jasiński, Z. Sułek, J. Muszyńska, S. Kwieciński, T. Skórka, A. Krzyżak, J. Kibiński, "MR Microscopy of Plants",
    XXVII Ogólnopolskie Sem. nt. MRJ i Jego Zastosowań, Cracow;

12. Z. Sułek, B. Tomanek, A. Jasiński, K. Szybiński, S. Kwieciński, T. Skórka, A. Krzyżak, J. Kibiński, "Modular MR Microscope",
    XXVII Ogólnopolskie Sem. nt. MRJ i Jego Zastosowań, Cracow;

13. Z.T. Lalowicz, M. Punkkinen, E.E. Ylinen,
    "Spectacular History of Molecular Dynamics in $(ND_4)_2PtCl_4$ (ibid)", (a talk);

14. A. Birczyński, Z.T. Lalowicz, L.P. Ingman, M. Punkkinen, E.E. Ylinen,
    "Restricted Jumps of NH_4^+ Ions in Ammonium Perchlorate (ibid)";

15. T. Skórka, A. Jasiński, "Symmetrical Shielded Head Gradinet Coil",
    First Symp. on Mag. Res. Applied to Psychiatry, Rouffach, France, p. 36.

SCIENTIFIC DEGREES:

1. *Piotr Kulinowski* - Ing. degree

INVITED TALKS:

1. K. Parliński,
   Japanese Metallurgical Society Meetting, 30. 03 - 1. 04. 1994, Tokyo, Japan, invited talk:
   "Molecular-Dynamics Simulation of Incommensurate Phases";

2. K. Parliński,
   Supercomputting Meetting, 26 - 27 May 1994, Sendai, Japan,
   "Evolution of Microstructure and Incommensurate Patterns";

3. K. Parliński,
   International Conference on Aperiodic Crystals, 18 - 22 September 1994, Les Diablerets, Switzerland,
   "Computer Simulation of Phase Transition Mechanisms between Incommensurate Phases";

4. K. Parliński,
   3-rd International Symposium on Domain Structure of Ferroelastic Materials, 6 - 9 September 1994, Zakopane, "Domain Formation in Crystals";

5. K. Parliński,
   Komputerowe Obliczenia Dużej Skali, 1. Szkoła Fizyki Komputerowej,
   21 - 23 February 1994, Cracow, "Przejścia Fazowe i Mikrostruktura Kryształów" (Phase Transitions and Crystal Microstructure - in Polish);

6. Z. Sułek,
   II Summer NMR School, 30 May - 4 June 1994, Zakopane,
   "MR Imaging - What EPI Is?";

7. A. Jasiński,
   II Summer NMR School, 30 May - 4 June 1994, Zakopane, "MR Microscopy *in Vivo*";

8. Z. Sułek,
   Sallus Apis Mellifera. Polish-German Symp., Oberusel, 19 - 23 September 1994, Germany,
   "Magnetic Resonance Microscopy Study of Honey Internal Structure".

LECTURES AND COURSES:

1. A. Jasiński,
   "MR Microscopy of Honey Bee *in Vivo*", Department of Biochemistry and Molecular Biology, College of Medicine University of Florida, Gainsville, Fl USA;

2. J.W. Hennel,
   Nuclear Magnetic Resonance, Chemistry Dept., Jagellonian University;
3. B. Tomanek,
   "MR microscopy *in Vivo*", University of Poznań.

ORGANIZED CONFERENCES:

1. "Komputerowe Obliczenia Dużej Skali", I Szkoła Fizyki Komputerowej,
   21 - 23 February 1994, Cracow, Przewodniczący: K. Parliński;
2. XXVII Ogólnopolskie Seminarium na temat Magnetycznego Rezonansu Jądrowego,
   Cracow, IFJ, 1 - 2 December 1994.

INTERNAL SEMINARS:

1. S. Kwieciński: "Flash - Fast MR Imaging Method"
2. Z. Olejniczak: "The School in Portoroz - Part I"
3. W. Węglarz, UJ: "NMR Study of Hydratation in Bark"
4. R. Serafin: "The School in Portoroz - Part II"
5. Z. Olejniczak: "Literature Review"
6. T. Skórka: "Shielded Gradient Coils for a Head"
7. B. Tomanek: "Multislice Imaging"
8. M. Sternik: "Structural Phase Transitions by Computer Simulations"
9. A. Jasiński: "1-st Nottingham Conference on Magnetic Resonance in Medicine", part I
10. A. Jasiński: "1-st Nottingham Conference on Magnetic Resonance in Medicine", part II
11. A. Jasiński: "Rf Selective Pulses"
12. Z. Lalowicz: "Tunnelling of CD3 Groups in Aspirine Single Cristal"
13. I. Jeżowska, UJ: "The Effect of Exchange on MR Spectra under Cross-Relaxation"
14. A. Birczyński: "The Temperature Dependence of Tunnelling CD3 Group Spectra"
15. J. Kibiński: "ADC"
16. J.W. Hennel: "Cross - Polarization"
17. B. Blicharska, UJ: "Water Studies in Polimers"
18. Z. Lalowicz: "The Spectacular History of Molecular Dynamics in $(ND_4)_2PtCl_4$"
19. S. Kwieciński: "Is Magnetic Field Harmfull?"
20. B. Tomanek: "MR Imaging of Biological Systems "

SHORT TERM VISITORS:

1. Prof. T. Takui, Osaka City University, Osaka, Japan;
2. Prof. W. Müller-Warmuth, Universität Münster, Münster, Germany;
3. Prof. W. Sobol, University Hospital, Birmingham, Ala. USA;
4. Dr P. Jonsen, Chemagnetics, Harrogate, UK;
5. Dr A. Ejchart, Universität Bayreuth LS Biopolymere, Bayreuth, Germany;
6. Prof. A.N. Veselkov, Sevastopol State Technical University, Sevastopol, Ukraine;
7. Ing. K. Bartusek, Institute of Scientific Instruments, Brno, Czech Republic;
8. Dr P. Kamasa, Research Institute for Solid State Physics, Budapest, Hungary.

Department of Nuclear Physical Chemistry

Section IX

DEPARTMENT
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Mirosława Jasińska, M.Sc., Head of Laboratory
Krzysztof Kozak, Nucl.E., M.Sc.
Piotr Macharski, M.Sc.
Jerzy Wojciech Mietelski, Ph.D.

GRANTS:

1. Head: Prof. J. Mikulski

   Research grant no 202599101 - *Neutron-deficient isotopes for medicine. Optimization of radiometric and analytical methods.* - Completed in September 1994, positively evaluated by the State Committee for Scientific Research (KBN) in December 1994.

2. Head: Dr hab. Z. Szeglowski

   Research grant no 226129102 (KBN) -*Studies on the chemical properties of transactinium elements (Z>104) in aqueous solutions in model systems with their homologues (Zr, Hf, Nb, Ta, W)* - completed in December 1994.

OVERVIEW:

The Department consists of three laboratories whose common or specific interests are pure and applied problems of nuclear, physical and analytical chemistry. The laboratories are presented below in order corresponding to the chronology of their establishment.

Laboratory of Physical Chemistry of Separation Processes

In 1994, a further effort was made towards routine production of neutron-deficient isotopes for nuclear medicine. New regulations for the registration of pharmaceuticals were studied, the required data and documents collected, and a revised application for registration of ^{67}Ga citrate re-submitted to the Drug Institute. The analytical and gamma-spectrometric part of the project was supported by the State Committee for Scientific Research (grant no 202599101).

Small activities of ^{111}In were produced regularly by alpha bombardment of silver targets. Radioactivity was separated from the targets by means of thermal methods. The nuclide was used by the physicists in the PAC experiments performed in this Institute and at the Jagellonian University.

In order to obtain ^{111}In in a more efficient nuclear reaction, experiments on deuteron bombardment of cadmium were continued. The distribution of beam intensity on the target was checked by mapping the activity of ^{24}Na produced via the ^{27}Al (d, αp) reaction in the catcher foil. Some improvements were introduced into preparation of targets from compressed CdO powder.

In cooperation with the Institute of Zoology of the Jagellonian University, several batches of ^{67}Ga were used in preliminary experiments on animal cell labelling. Some problems of cell labelling were discussed during medical conference held in Cracow in May.

To prepare material for calibrated ^{139}Ce sources, several portions of this nuclide were produced by deuteron bombardment of lanthanum oxide. Only some problems of separating of ^{139}Ce from chemically and physically similar lanthanum have been solved. The experiments on chemical separation of ^{139}Ce from La will be continued in 1995.

To control non-radioactive trace impurities in radiopharmaceuticals, the atomic absorption spectrometer has been adapted for safe handling of radioactive samples. The efficiency of air filters in the spectrometer exhaust system turned out adequate. The filters (kindly supplied by the Environmental Radioactivity Laboratory) were checked radiometrically using home-made ^{24}Na tracer.

One atomic absorption scientist participates also in research on trace elements in human organisms, organized by the Department of Bromatology at the Medical College of the Jagellonian University. He also cooperates with the Laboratory of Environmental Radioactivity of

this Department in their studies on trace elements in various ecosystems. The experimental data are analyzed and interpreted by means of pattern recognition methods.

Another project in this Laboratory is the use of the Langmuir-Blodgett films in preparation of thin sources for alpha and electron spectroscopy. Some of such sources were prepared for the Laboratory of Environmental Radioactivity.

Laboratory of Chemistry and Radiochemistry

The 1994 was another year of studies on physicochemical properties of transactinoid elements 104, 105, 106 in model systems with their lighter homologues Hf, Ta and W. The problem to investigate was the sorption of Hf, Ta, W, rare earths and trivalent actinide elements from oxalic and oxalic-hydrochloric acid solutions onto ion-exchange resin. The investigations resulted in determining optimum conditions for the separation of Zr, Hf, Ta and Nb from some lanthanides and trivalent actinides. Model experiments with short-lived isotopes of Hf, Ta and W produced in the bombardment of ^{144}Sm with ^{24}Mg ions on the U-400 cyclotron have shown that the oxalic-hydrochloric acid system is the promising one for the separation and identification of trans-actinium elements.

The research was supported by the State Committee for Scientific Research (grant no 226129102). Foreign groups involved in the cooperation were: the G. N. Flerov Laboratory of Nuclear Reactions at the Joint Institute of Nuclear Research in Dubna (Russia), the Institute of Nuclear Research in Orsay (France) and the Institute of Geochemistry and Analytical Chemistry of the Russian Academy of Sciences in Moscow.

Laboratory of Environmental Radioactivity

The Laboratory takes part in the National Network of Early Detection of Radioactive Contamination in Air, performing continuous monitoring of the atmosphere at ground level. Since October 1994, a new and improved ASS-500 station, let out free of charge by the Central Laboratory of Radiation Protection (CLOR), has replaced the prototype which had been in continuous use on the premises of the Institute during the last four years. Weekly reports on the content of ^{7}Be, ^{40}K, ^{137}Cs, ^{226}Ra and ^{228}Ac have been sent regularly to CLOR as well as to the National Atomic Agency (PAA). Some numerical programs on experimental data processing have been upgraded recently. A procedure for determining of ^{210}Pb in the air filters is being developed.

A project on the geographical distribution of Pu and gamma-radioactive elements in forest ecosystems, started in 1991, has been completed. In 1994, about 40 alpha-spectrometric measurements were added to almost 800 gamma - spectrometric measurements performed earlier. The results and their interpretation were the subject of a Ph.D. thesis defended in October 1994. The results were also presented as an invited talk at an international conference in Ottawa.

In cooperation with the Department of Forest Ecology at the Hugo Kołłątaj Academy of Agriculture in Cracow, the dynamics of caesium contamination in selected ecosystems was studied. Using a low-background spectrometer, eighty samples from experimental fields in the Carpathian and Sudeten Mountains were measured. The samples were collected at the same sites and in the same manner as those collected in 1987-1988 in a pilot project. The recent results, analyzed in reference to the 1987-1988 data, will be published soon.

In cooperation with the Institute of Geography of the Jagellonian University, spatial variation of caesium ^{137}Cs contamination in the Carpathian Foothills is being studied. Gamma-spectrometric analyses of 64 soil samples from the area between the Raba and the Uszwica rivers will be completed and interpreted by the end of 1995.

Two expert appraisals have been made on natural radioelements occurring in coal mining waste stockpiles near Przezchlebie and Racibórz.

The Laboratory participates also in an intercalibration programme organized by the US

Environmental Protection Agency (Las Vegas, USA). Determinations of traces of ^{106}Ru, ^{137}Cs and ^{60}Co confirm the reliability of measurements performed in the Laboratory.

for Dr hab. Zdzisław Szeglowski

REPORTS ON RESEARCH:

A Novel Aproach to the Problem of Highly-Sensitive Regular Analyses for Man-Made Plutonium in Environment and Human Body

Yu. T. Chuburkov[1], V. P. Perelygin[1], I. Zvara[1], Z. Szeglowski, S. P. Shtanko[1],
G. V. Buklanov[1], Yu. P. Kharitonov[1], A. G. Belov[1], T. P. Drobina[1], V. N. Bugrov[1],
B. Bisplinghoff[2], and R. Brandt[2]

[1]Laboratory of Nuclear Reactions, JINR, Dubna, Russia;
[2]Kernchemie, F.B. 14, Philipps-Universität, Marburg, Germany.

A method of determining sub-picogram quantities of plutonium in soil, mud, water, plant, and animal tissues is proposed. Plutonium is chemically isolated from the samples, while α-active ^{236}Pu is used to control the yield. Plutonium fraction deposited on a backing is put in contact with solid-state track detectors (SSTD) - polyethylene terephtalate foils. The samples as well as a uranium-containing standard are irradiated by thermal neutrons of approximately 10^{15} cm^{-2} fluence.

After chemical etching, the content of ^{239}Pu in the samples is determined by scanning the fission fragment tracks in the SSTD. To control possible uranium impurities in the plutonium fraction, the latter and the standard (in contact with a fresh SSTD) are bombarded by a high fluence of γ-quanta with energies < 25 MeV (microtron bremsstrahlung). We have succeeded in determining the lower limit of ^{235}U impurities at a level <10^{-13}g, owing to similar photofission cross-section of all Pu isotopes.

The proposed method provides the determination of ^{239}Pu content in routine analyses with sensitivity at a level of 10^{-13} g/g. More than one hundred assays of ^{239}Pu content in specimens of the above-mentioned media from Ukraine, Belorussia, the Ural region and Germany have been performed. In the future, sensitivity of 10^{-14} - 10^{-13} g/g will hopefully be reached.

Cross Sections of the (*HI*, αn) Channel in the Cold - Fusion - Type Reactions ^{209}Bi + ^{40}Ar and ^{208}Pb + ^{37}Cl

Yu. A. Lazarev[1], Yu. Ts. Oganessian[1], Z. Szeglowski, V. K. Utyonkov[1],
Yu. P. Kharitonov[1], O. Constantinescu[1], Dinh Thi Lien[1], I. V. Shirokovsky[1], and
S. P. Tretyakova[1]

[1] Laboratory of Nuclear Reactions, JINR, Dubna, Russia.

By using an off-line radiochemistry technique, production cross-sections of ^{240}Cm ($t_{1/2}$ = 27 d) in the ^{209}Bi + ^{40}Ar and ^{208}Pb + ^{37}Cl reactions at the bombarding energy of

$E_{lab} < 230$ MeV were determined to be 0.5 ± 0.2 and 0.6 ± 0.3 nb respectively. The production of ^{240}Cm was attributed to the 1n-de-excitation channel of composite systems ^{249}Md and ^{245}Es. The measured ^{240}Cm production cross-sections represent upper cross-section limits for the (HI, αn) channel of reactions under study. These limits are about 100 times lower than the cross-section values reported by Nomura et al. for the (^{40}Ar, α, xn) channels with x=1.2 of ^{209}Bi + ^{40}Ar reaction at $E_{lab} = 208$ MeV. In this connection, we present and discuss an up-to-date summary of the available data on cross-sections of the (HI, α, xn) channels in cold-fusion-type reactions induced by projectiles ^{37}Cl to ^{50}Ti on targets of ^{203,205}Tl, ^{208}Pb and ^{208}Bi.

Appreciable EC/β^+ - delayed fission effects were detected in the ^{209}Bi + ^{40}Ar and ^{209,208}Pb + ^{37}Cl reactions. In particular, our data reveal the occurrence of EC/β^+ - delayed fission in the decay chains

$$^{242}\text{Es} \xrightarrow[7s]{EC} \ ^{242}\text{Cf} \quad \text{and} \quad ^{248}\text{Bk} \xrightarrow[2min]{EC} \ ^{238}\text{Cm}$$
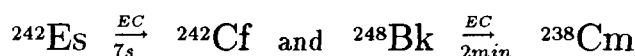
Obtaining and Preparation of Carrier-Free Cerium ^{139}Ce

R. Misiak and E. Ochab

Obtaining ^{139}Ce from lanthanum targets in a cyclotron was evaluated as a mean of preparing calibrated sources for gamma spectrometry.

A thick target yield for the formation of ^{139}Ce in the La(d,n)^{139}Ce reaction was determined. The practical yield for the U-120 cyclotron at the on-target energy of 12.5 MeV is 4.6 μCi/μAh.

Separation of carrier-free cerium from the target material (La$_2$O$_3$) was achieved using the extraction technique. The quadrivalent cerium was extracted with diisopropyl ether from 9M nitric acid medium with a small addition of sodium bromate. Two consecutive extractions should remove 96% of cerium from the aqueous phase. Finally, the activity is transferred quantitatively by back extraction into a dilute hydrogen peroxide solution.

During this work some problems of target preparation and separation conditions were solved. The influence of the nitric acid concentration in the range of 1-10M on cerium extraction is still to be determined.

Use of Pattern Recognition Methods in the Interpretation of Heavy Metals Content (Pb, Cd) in Children's Scalp Hair

J. Chłopicka[1], P. Zagrodzki[1,2], Z. Zachwieja[1], M. Krośniak[1], and M. Folta[1]

[1]Department of Food Chemistry and Nutrition, Collegium Medicum, Jagellonian University, Podchorążych 1, 30-084 Cracow;
[2]H. Niewodniczański Institute of Nuclear Physics, Radzikowskiego 152, 31-342 Cracow.

The aim of the study was to determine the exposure to toxic metals and correlate it with possible adverse effects in children's scalp hairs from various rural and industrial areas in southern Poland. The population studied consisted of school children aged 7-12. The concentrations of Pb and Cd in children's hair were analysed by GF-AAS. The mean Pb and Cd content in the hair of the sampled individuals was found to be 4.85 ± 5.91 mg/g and 0.430 ± 0.569 mg/g respectively. The hair of boys (especially of those living in the areas of greater industrial contamination) exhibited statistically significant higher levels of Pb and Cd than the hair of girls from

the same areas. The data were subject to factor analysis and the first two common factors were extracted. The plot of factor pattern, modified by means of Varimax rotation technique, showed that there were three tight clusters of variables: 1° metal contents (Cd, Pb), 2° anthropometric indices (W/H, H/A) and 3° educational achievements. Finally estimated communalities indicate that the variances of the variables are accounted for in most part by the common factor. No relationship was revealed between metal content (Pb or Cd) and either anthropometric indices (W/H or H/A) or educational achievements. We conclude that, at relatively low levels of exposure to toxic metals, there was about no retarding effect on parameters expressing body growth and intellectual scores.

(Accepted for publication in *The Analyst*)

Use of Pattern Recognition Methods in Preparation of Map of Natural Radioactivity (^{40}K, ^{226}Ra, ^{228}Ra) in Poland

J. W. Mietelski and P. Zagrodzki

The aim of this work was to find out if there is any difference in radioactivity of ^{40}K, ^{226}Ra, ^{228}Ra between the areas seriously influenced by industry and the not polluted ones. In statistical analysis 8 parameters were taken into account: the activity of ^{40}K, ^{226}Ra and ^{228}Ra in two upper layers of forest litter (A0 - holorganic, A1 - hemiorganic), and the density of these layers. Stepwise discriminant analysis was used to evaluate the results. All calculations were performed using the STATISTICA package. The first two discriminant functions were statistically significant. Cumulated percentage of parameter variance explained by them is 91%. Factor structure matrix is consistent with standardized coefficients for canonical variables. Linear discriminant analysis (LDA) allowed us to classify correctly only the samples of soil originating from eastern and central Poland. The heavily polluted region in southern Poland does not have any distinct radioactive isotope content which could be detected with the help of LDA. Probably, the geological basis has a bigger influence on the soil content than the industrial emission.

A Program for Interactive Calculation of Radionuclide Activities

P. Grychowski

To calculate absolute radioactivities measured with germanium detectors in various geometries, a program AKT has been written and tested. The activity is calculated basing on calibrated efficiency of the detector. The calibration data, are stored in parametric form, in an external file. Calibrations can be performed for any geometry, and the efficiency functions *Ef(En)* can be fitted for each geometry and stored in separate files. Each file represents a particular geometry of the measurement.

The activity of a sample is calculated basing on the correlation between the measured intensity of the line with quantum yield of the corresponding transition known from the tables. Input data for the AKT program are the files containing, in subsequent records, information about the number of counts in each peak of interest.

Energetic calibration of the gamma spectrum is not necessary because the analytical line is selected interactively on the computer screen. The program displays contents of the input file and the appropriate record can be selected from the screen using the cursor. Table data can be grouped in sub-libraries, each of which containing just the data on the nuclides of interest. The library data are also selected interactively from the screen.

The activity can be calculated for the day of the measurement as well as for any other date, e.g. for EOB. The half-life data required for the calculation are collected in another library.

Recently, a new algorithm has been added to the program, giving the user more freedom in choosing a function to describe the efficiency of the detector. The function and its parameters can be put in by the user, at any time and in any form that corresponds to the best fit of the calibration data. The program is written in the C++ language. It is planned to prepare a file transporting the algorithm to other programming languages.

Time-Changes of Radiocaesium Contamination in Selected Parts of Mountain Forest Ecosystems (Case Study for the Carpathian and the Sudeten Mountains)

M. Jasińska, K. Kozak, P. Macharski, J. W. Mietelski, J. Barszcz[1], and J. Greszta[1]

[1]Forest Ecology Department, The H. Kołłątaj Academy of Agriculture, Cracow, 29 Listopada Avenue.

In a pilot project in 1988, soil and forest litter samples collected the year before at 19 sites located in forested mountains of southern Poland, were examined for the content of gamma-emitters [1,2]. Of all detected radionuclides, two isotopes of caesium ^{137}Cs ($t_{1/2}$ =30 y) and ^{134}Cs ($t_{1/2}$ = 2.02 y) showed the highest activity. Six years later, similar samples were collected at the same sites and analyzed for radiocaesium (^{137}Cs and ^{134}Cs) content, using the same or equivalent gamma-spectrometric high-resolution low-background detection system. To compare the data from both projects, all measured activities were decay-corrected for the same date.

The analysis of the data shows that radiocaesium contamination in the mountains of southern Poland originates mainly from the Chernobyl NPP disaster, with a minor contribution from global ^{137}Cs fallout. The total amount of contaminants in forest litter turned out to be similar in both sets of samples, the decay-corrected activity of the more recent ones being slightly higher. We explain this rise by the accumulation of radioactivity brought into the litter by dead needles.

The decay-corrected radiocaesium isotope ratio was the same in both sets of observations which suggests that the chemical forms of both caesium isotopes are identical [3]. Vertical distribution of radioactivity has changed since the earlier project with the maximum activity shifting, as expected, towards deeper layers.

Transfer of radiocaesium to plants (ferns, *Athyrium* species) showed larger variations in 1993 than in 1987. This is probably due to differences in the fraction of unexchangeable (bound on clay particles) caesium, which must strongly depend on the mineral composition of the soil. In general, transfer of caesium into plants seems to be slower at higher altitudes but not all reasons for this trend have been elucidated as yet.

References:

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2. M. Jasińska, K. Kozak, J. W. Mietelski, J. Greszta, J. Barszcz - *J. Radioanal. Nucl. Chem., Letters* **146** (1990) 1-13;

3. P. Carbol, G. Skarnemart, M. Skalberg, - Speciation of the Chernobyl fallout by sequential chemical separation - *The Science of the Total Environment* **130/131** (1993) 129-137.

Spatial Distribution of ^{137}Cs Contamination in the Vicinity of the Town of Bochnia

W. Chełmicki[1], K. Krzemień[1], M. Jasińska, K. Kozak, P. Macharski, and J. W. Mietelski

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The research on a middle scale spatial distribution of radioactive caesium in soils of the Carpathian Foothills was a part of the project entitled *Circulation and Transformation of Anthropogenic Contaminants in Geoecosystems of the Edge Zone of the Carpathian Foothills* carried out at the Jagellonian University, Institute of Geography, Research Field Station at Lazy (Grant: PB 0389/P2/93/04).

Sixty-four samples of 10-cm-deep soil cores were collected at semi-regular network covering a 30-km-long and 10-km-wide area situated between the Raba and the Uszwica rivers. The samples were analyzed for gamma-emitters with low-background gamma-rays spectrometers. Some mechanical and chemical properties of the samples, namely grain-size distribution, pH, potassium and humus content, were also analyzed.

The study is still in progress and will be continued in 1995.

LIST OF PUBLICATIONS:

I. Articles:

1. Z. Szeglowski, H. Bruchertseifer, V.B. Brudanin, G.V. Buklanov, O. Constantinescu, Dinh Thi Lien, V.P. Domanov, L. . Guseva, M. Hussonnois, Yu. Ts. Oganessian, I. Zvara, G.S. Tikhomirova,
"Chemical Isolation of Element 106 from Aqueous Solutions According to The Model Experiments with Short Lived Tungsten Isotopes",
J. Radioanal. Nucl. Chem., Letters **186** (1994) 353-359;

2. Z. Szeglowski, M. Hussonnois, O. Constantinescu, B. Kubica, Dinh Thi Lien, S.A. Karamian,
"Hafnium Decontamination from Microquantities of Some Elements of Groups I, II and III",
J. Radioanal. Nucl. Chem., Letters **186** (1994) 233-236;

3. Z. Szeglowski, O. Constantinescu, M. Hussonnois, A. Abdul-Hadi, G.J. Ardisson,
"Continuous Purification of ^{223}Fr from its Decay Products on a Nickel Hexacyanoferrate (II) Composite Ion Exchanger",
Radiochim. Acta **64**, (1994) 57-59;

4. Z. Szeglowski, O. Constantinescu, M. Hussonnois,
"Sorption Behaviour of I to V Group Elements on a Nickel Hexacyanoferrate (II) Composite Ion Exchanger",
Radiochim. Acta **64** (1994) 127-130;

5. Yu.A. Lazarev, Yu.Ts. Oganessian, Z. Szeglowski, V.K. Utyonkov, Yu.P. Kharitonov, Dinh Thi Lien, O. Constantinescu, I.V. Shirokovsky, S.P. Tretyakova,
"Cross Sections of the *(HI,αn)* Channel in the Cold -Fusion-Type Reactions ^{209}Bi + ^{40}Ar and ^{208}Pb + ^{37}Cl",
Nucl. Phys. A, in press;

3. K. Skarżyńska, E. Zawisza, M. Jasińska, M. Waligórski,
"Investigation of Radioactivity of Coal Mining Wastes Stockpile in Przezchlebie
near Gliwice" (in Polish),
Przegląd Górniczy (Mining Review) **6** (1994) pp. 31;

4. B. Petelenz,
"From Nuclear Chemistry to Nuclear Medicine" (in Polish),
Foton, Bulletin of the Teachers' Section of the Polish Physical Society, 7-13 March 1994,
7-16 April 1994.

PARTICIPATION IN CONFERENCES AND WORKSHOPS:

1. L.I. Gusiewa, G.S. Tichomirowa, Z. SZEGLOWSKI,
"Studies on Chemistry of Short-Lived Radionuclides in Solutions by Means of Fast Ion-
Exchange Chromatography",
First Russian Radiochemical Conference, Dubna 17-19 May 1994;

2. J. Chłopicka, P. ZAGRODZKI, Z. Zachwieja, M. Krośniak, M. Folta,
"Use of Pattern Recognition Methods in the Interpretation of Heavy Metals Content
(Pb, Cd) in Children's Scalp Hair",
The 5th Nordic Symposium on Trace Elements in Human Health and Disease, Loen,
Norway, 19-22 June 94, poster presentation;

3. Z. SZEGLOWSKI,
"Continuous Decontamination of ^{223}Fr from its Decay Products Using a Composite Nickel
Ferrocyanide Sorbent",
First Polish Radiochemical Symposium, Jachranka near Warsaw, 9-12 May 1994;

4. Z. SZEGLOWSKI, B. Kubica,
"Studies on Chemical Properties of Transactinoid Elements in Model Systems with their
Homologues Hf, Ta and W",
First Polish Radiochemical Symposium, Jachranka near Warsaw, 9-12 May 1994;

5. Z. SZEGLOWSKI,
"Rapid Method of *on-line* separation of Element 104 from Aqueous Solutions",
First Polish Radiochemical Symposium, Jachranka near Warsaw, 9-12 May 1994;

6. B. KUBICA, Z. Szeglowski,
"Radiochemical Separation of Pure ^{178m2}Hf Isomer from Nuclear Reaction
Products",
First Polish Radiochemical Symposium, Jachranka near Warsaw, 9-12 May 1994;

7. E. OCHAB, P. Grychowski, J. Mikulski, R. Misiak,
"Production of I-123 from Tellurium Targets",
First Polish Radiochemical Symposium, Jachranka near Warsaw, 9-12 May 1994;

8. R. MISIAK, A.F. Novgorodov, A. Kołaczkowski, J. Mikulski,
"Thermal Separation of Ga, In and Tl from Thick Ge, Sn and Pb Targets",
First Polish Radiochemical Symposium, Jachranka near Warsaw, 9-12 May 1994;

9. B. PETELENZ, R. Misiak, E. Ochab, J. Mikulski, P. Grychowski,
"Methods of Production of ^{111}In, a Comparison",
First Polish Radiochemical Symposium, Jachranka near Warsaw, 9-12 May 1994;

10. J.W. MIETELSKI, B. Wąs,
"Isotopes of Plutonium in Forest Litter",
First Polish Radiochemical Symposium, Jachranka near Warsaw, 9-12 May 1994;

6. Yu.T. Chuburkov, V.P. Perelygin, I. Zvara, Z. Szeglowski, S.P. Shtanko, A.G. Belov, G.V. Buklanov, Yu.P. Kharitonov, T.P. Drobina, V.N. Bugrov, B. Bisplinghoff, R. Brandt, "A Novel Aproach to the Problem of Highly-Sensitive Regular Analyses for Man-Made Plutonium in Environment and Human Body", *Radiochim. Acta*, in press;

7. P. Zagrodzki, J.W. Mietelski, M. Krośniak, B. Petelenz, "Accumulation of Caesium and Radiocaesium in Forest Litter in Selected Regions of Poland and its Influence on Litter-to-Mushroom Transfer Factor", *Biol. Trace Elem. Res.* **43/44** (1994) pp. 273-277;

8. P. Zagrodzki, M. Schlegel-Zawadzka, P. Malec, E. Dutkiewicz, M. Krośniak, A. Bichoński, "Flour Characteristics by Means of Pattern Recognition Methods", *Food Chemistry* (1994), in press;

9. W. Chełmicki, J.W. Mietelski, P. Macharski, J. Święchowicz, "Natural Factors of ^{137}Cs Distribution in Soil on the Example of Forested Slope in the Carpathian Foothills", *Studia Geomorphologica Carpatho-Balcanica*, **27-28** (1993-1994) pp. 71-86;

10. J.W. Mietelski, "Gamma and Alpha Radioactive Contamination of Forest Litter in Poland" (in Polish: "Skażenia gamma i alfa promieniotwórcze ściółek leśnych w Polsce"), *Progress in Nuclear Technology (Postępy Techniki Jądrowej)* **37** (1994) pp. 15-33;

11. J.W. Mietelski, M. Jasińska, B. Kubica, K. Kozak, P. Macharski, "Radioactive Contamination of Polish Mushrooms", Proceedings of the Seminar on the Dynamic Behaviour of Radionuclides in Forests, Stockholm, 18-24 May 1992, *The Science of the Total Environment* **157** (1994) pp. 217-226;

12. J.W. Mietelski, P. Macharski, M. Jasińska, R. Broda, "Radioactive Continuation of Forests in Poland", *Biol. Trace Elem. Res.* **43/44** (1994), in press.

II. Contributions to conferences:

1. J.W. Mietelski, B. Wąs, "Plutonium from Chernobyl in Poland", an invited talk on the International Symposium on Pu in the Environment, 6-8 July 1994, Ottawa; Proceedings in press in *Applied Radiation and Isotopes*, special volume, Pergamon Press.

III. Reports and other papers:

1. D. Schumann, S. Fischer, St. Taut, R. Dressler, A.F. Novgorodov, R. Misiak, M. Schadel, N. Trautmann, H. Bruchertseifer, "Sorption Studies of Subgroup IV, V and VI Elements on Ion Exchangers from Weak HCl/HF Solutions. Model Experiments for the Separation of Element 106", *GSI Scientific Report* No **94-1** (1994) 241;

2. J.W. Mietelski, "Radioactive Contaminations in Forests" (in Polish), *Forest Echoes (Echa Leśne)* No **6** (1994) pp. 14, 15, 23; No **7** (1994) pp. 8-10;

11. J.W. MIETELSKI, M. Jasińska, K. Kozak, P. Macharski,
    "Long-Lived Gamma-Radioactive Nuclides in Forest Litter in Poland",
    First Polish Radiochemical Symposium, Jachranka near Warsaw, 9-12 May 1994;

12. B. WĄS,
    "Monomolecular Langmuir-Blodgett Films in Precision Alfa and Beta Spectroscopy",
    First Polish Radiochemical Symposium, Jachranka near Warsaw, 9-12 May 1994;

13. P. ZAGRODZKI, M. Schlegel-Zawadzka, M. Krośniak, P. Malec, A. Bichoński,
    E.M. Dutkiewicz,
    "Characterization of Flour by Means of Pattern Recognition Methods",
    First National Congress "Food, Nutrition and Health", Warsaw, Poland, 30 May - 1 June
    1994, poster presentation;

14. P. ZAGRODZKI,
    "Use of Pattern Recognition Methods in Preparation of Map of Natural Radioactivity
    (^{40}K, ^{226}Ra, ^{228}Ra) in Poland",
    30th Congress of Polish Biochemical Society, Szczecin, 14-16 Sept. 1994, poster presenta-
    tion;

15. B. PETELENZ,
    First Workshop on Hadron Therapy Centre, Institute of Nuclear Physics, Cracow,
    30 November 1994;

16. B. PETELENZ,
    Fourth Congress of the Polish Society of Nuclear Medicine, Cracow, 24-26 May 1994, no
    presentation;

17. P. ZAGRODZKI,
    East European Furnace Symposium, Warszawa, 4-7 Sept. 1994, no presentation;

18. P. ZAGRODZKI,
    Seminar "Recent Trends in Chemometrics", Rzeszów, Poland, 28 Sept. 1994, no presen-
    tation;

19. P. ZAGRODZKI,
    Seminar "Problems of Quality of Trace Elements Analysis of Soils and Plants", Warsaw,
    Poland, 4 Nov. 1994, no presentation;

20. K. KOZAK,
    Special Seminar on RODOS (Real-time On-line Decision Support System) Project, War-
    saw, Poland, 17-18 Nov. 1994, no presentation.

INVITED TALKS:

1. K. KOZAK,
   "Proposal of a Monitoring System",
   an invited contribution to the discussion during *The Second International Meeting on Low-
   Level Air Radioactivity Monitoring* (organized by the Central Laboratory of Radiation
   Protection, Poland and PTB Braunschweig, Germany), Mądralin near Warsaw, Poland,
   14-18 February 1994;

2. K. KOZAK,
   "Monitoring of Radioactivity in Air",
   an invited talk on the Symposium *Atmospheric dusts as health hazard* organized by the
   Biometeorological Section of the Social Health Comission, Cracow Branch of the Polish
   Academy of Sciences, Cracow, Poland, 9 June 1994;

3. J.W. MIETELSKI, B. Wąs,
"Plutonium from Chernobyl in Poland",
an invited talk on the *International Symposium on Pu in the Environment*, 6-8 July 1994,
Ottawa.

SCIENTIFIC DEGREES:

A Ph.D. thesis *Radioactive Contamination of the Forests of Poland* has been completed by
Jerzy W. Mietelski, M.Sc. under the supervision of Professor Rafał Broda.

The thesis has been defended on 14 October 1994, approved by the Scientific Board of the
Institute on 14 November 1994.

LECTURES AND COURSES:

Popular presentations of environmental radioactivity problems to high school students
(several groups per month, Environmental Radioactivity Laboratory).

INTERNAL SEMINARS:

I. In the Institute:

1. J.W. Mietelski - "Estimation of after-Chernobyl radiation doses";
2. K. Kozak - "ASS-500 station - continuous monitoring of radioactivity in air";
3. P. Zagrodzki - "Biochemical role of selenium";
4. B. Petelenz - "New trends in nuclear medicine";
5. D. Schumann - "Sorption of Subgroup IV, V, and VI Elements on Ion Exchanger from HCl-HF Solutions";
6. K. Kozak - "RODOS - a Sytem of Early Detection of Radioactive Contamination".

II. In other Polish institutions:

1. J.W. Mietelski - "Estimation of Post-Chernobyl Radiation Doses"
   - at Central Laboratory of Radiation Protection (CLOR), Warsaw, 21 March 1994;
2. J.W. Mietelski - "Radioactive Contaminations in Polish Forests"
   - at the Department of Nuclear Physics and its Applications, Silesian University, Katowice, 22 November 1994;
3. K. Kozak - "ASS Station as an Element of the System of Early Detection of Radioactive Contaminations in Air"
   - at the Department of Nuclear Physics and its Applications, Silesian University, Katowice, 29 November 1994;
4. B. Petelenz- "Radioisotopes for Biomedical Sciences"
   - invited talk at the meeting of the Polish Immunological Society, Jagellonian University, Cracow, Poland, 24 March 1994.

III. Abroad:

1. J.W. Mietelski - "Geographical Distribution of Radioactive Contamination in Poland (Based on Measurements in Forests)"
   - at Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany, 14 December 1994;
2. K. Kozak - "Early Warning Network for Radioactive Contamination Monitoring in Poland"
   - at Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany, 14 December 1994.

SHORT TERM VISITORS TO THE DEPARTMENT:

1. *Mrs Alicja Józkowicz*, M.Sc., Laboratory of Immunology, Institute of Zoology, Jagellonian University, February - June 1994;
2. *Dr Sueo Michi*, IAEA Deputy Director General for Research and Isotopes, 24 May 1994;
3. *Dr Andovic Feriz*, Pristina University, Department of Mathematic and Natural Sciences, Pristina, Yugoslavija, 24 May 1994;
4. *Dr Zofia Gołąb-Meyer*, Institute of Physics, Jagellonian University, 23 June 1994;
5. *Prof. Christian G. Reinhardt*, Department of Chemistry, College of Science, Rochester Institute of Technology, Rochester, New York, USA, 23 June 1994;
6. *Mrs Kimberley Heinz*, USA and Institute of Geography, Jagellonian University, June 1994;
7. *Mrs Barbara Niemiec*, M.P. and persons delegated by the President of the Polish Senate, 6 July 1994;
8. *Dr A. Ćwierz*, Education Methodical Centre in Cracow, 16 September 1994;
9. *Prof. Julian Liniecki*, Department of Nuclear Medicine, Medical Academy in Łódź, 26 September 1994;
10. *Dr Dinh Thi Lien*, G. N. Flerov Laboratory of Nuclear Reactions, Joint Institute of Nuclear Research, Dubna, Russia, September 1994;
11. *Dr V. P. Domanov*, G. N. Flerov Laboratory of Nuclear Reactions, September 1994;
12. *Prof. C. Loos-Neskovic*, Laboratoire d'Analyse par Activation Pierre Süe, C.E.N. Saclay, France, September 1994;
13. *Dr Dorothea Schumann*, Technische Universität, Dresden, Germany, 17 October 1994;
14. *Dr A. E. Val'kov*, Institute of Nuclear Research, Ukrainian Academy of Sciences, Kiev, Ukraine, November 1994;
15. About 350 high school students with their teachers;
16. About 500 people during the Institute Open Day in June 1994.

OTHER:

A revised (according to the new registration rules) application for registration of [Ga-67] gallium citrate has been submitted to the Drug Institute.

Section X

Health Physics
Laboratory

Section X

HEALTH PHYSICS LABORATORY

Head of Laboratory: *Assoc. Prof. Michael P.R. Waligórski*
Deputy Head: *Dr Paweł Olko*
Secretary: *Irena Lipeńska*
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PERSONNEL:

Research Staff:

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Maciej BUDZANOWSKI, M.Sc., E.Eng. (Technical Physics) - Assistant,
Radiation Safety Inspector
Tadeusz NIEWIADOMSKI, Ph.D., Assoc.Prof. (Physics) - Part-Time, Consultant
Małgorzata NOWINA-KONOPKA, M.Sc. (Physics) - Assistant
Paweł OLKO, Ph.D. (Physics), E.Eng. (Nucl.Eng) - Adjoint, Deputy-Head of
Laboratory
Michał WALIGÓRSKI, Ph.D., Assoc. Prof. (Physics) - Head of Laboratory

Research Staff, on Leave of Absence (since 1991):

Maryla OLSZEWSKA-WĄSIOLEK, Ph.D., E.Eng. (Nucl.Eng) - on leave of absence
to the New Mexico Institute of Mining and Technology, Socorro, NM, USA
Piotr WĄSIOLEK, Ph.D. (Physics) - on leave of absence to the New Mexico Institute
of Mining and Technology, Socorro, NM, USA

Technical Staff:

Józef DYBEL - Technician
Jerzy IBKOWSKI - Technician, Radiation Safety Officer
Irena LIPEŃSKA - Laboratory Assistant, Secretary
Bronisław MOTYKA - Technician, Radiation Protection Officer
Anna NOWAK - Technician
Elżbieta RYBA, E.Eng. - Chief Specialist, Chief Radiation Safety Officer, INP
Marta WOŹNIAK, M.Sc., Ch.Eng. (Chemistry) - Chemist

GRANTS:

1. *M. Waligórski*
   grant No 607359101 (The State Committee for Scientific Research),
   Analysis of microdeposition of energy for determination of radiation hazard,
   including that from radon (completed 31 March 1994);
2. *M. Waligórski*
   grant No 224309203 (The State Committee for Scientific Research),
   Modelling of interaction of nuclear radiation in nanometre volumes;
3. *T. Niewiadomski*
   grant No 607379101 (The State Committee for Scientific Research),
   Investigation of the concentration of radon in dwellings over southern Poland
   (completed 31 December 1994);
4. *M. Waligórski*
   EEC grant No FI3P-CT92-0018 (European Union),
   The measurement of environmental radiaton doses and dose rates;
5. *P. Olko*
   EEC grant No FI3P-CT920032 (European Union),
   Dosimetry of beta and low-energy photon radiations.

INTERNATIONAL COLLABORATION PROGRAMMES:

1. Polish-German Collaboration: Quantitative Assessment of Radiation Hazard, with
   Prof. Müller-Gärtner/Dr Th. Schmitz, Institute of Medicine, KFA Jülich;
2. Polish-German Collaboration: Neutron Dosimetry with TL Detectors, with
   Dr Piesch, HSD, KfK Karlsruhe.

OVERVIEW:

The activities of the Health Physics Laboratory at the Institute of Nuclear Physics
in Cracow are principally research in the general area of radiation physics, and radia-
tion protection of the employees of the Institute of Nuclear Physics. Theoretical research
concerns radiation detectors, radiation protection (modelling of radiation effects in bio-
logical and physical systems) and studies of concepts in radiation protection. Experimen-
tal research concerns solid state dosimetry, mainly thermoluminescence (TL) dosimetry
(present thrust: development of thin TL detectors for beta-ray and mixed neutron field
dosimetry, development of ultra-sensitive LiF: Mg, Cu, P phosphors) and environmental
radiation measurements (radon in dwellings, low-level natural radiation). The Laboratory
provides expert advice on radiation protection regulations at national and international
levels. Routine work of the Health Physics Laboratory involves design and maintenance
of an in-house developed TL-based personnel dosimetry system for over 200 radiation
workers at the INP, monitoring and supervision of radiation safety on INP premises, and
advising other INP laboratories on all matters pertaining to radiation safety. Over the
years, under the earlier leadership of Prof. Tadeusz Niewiadomski (now retired, Con-
sultant to the Laboratory), considerable expertise in TL dosimetry has been gained at

the Laboratory: sintered TL detectors, based on LiF (Mg, Ti-doped, equivalent to HAR-SHAW TLD-100, TLD-600 and TLD-700, and Mg, Cu, P-doped, of properties similar to those of ultra-sensitive "Chinese" GR-200 phosphors) are produced, as well as gamma-irradiators and annealing ovens. A new micro-processor controlled laboratory TL reader, model RA94, is produced by the MICROLAB company in close collaboration with our Laboratory. The Health Physics Laboratory is able to accept not only commercial orders for production of large quantities of TL detectors and of TL laboratory equipment, but also to produce on request non-standard TL detectors according to specification, and to train and advise in the applications of TL dosimetry.
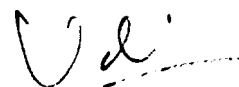
1994 was another year of intense activity in our Laboratory. We were especially pleased to be offered collaboration within two European Community grants: The measurement of environmental radiation doses and dose rates and Dosimetry of beta and low-energy photon radiations, coordinated by Dr Botter-Jensen and Dr Christensen, both from the Risoe National Laboratory, Denmark. Together with three other research grants from the Polish State Committee for Scientific Research, our finances were considerably easier than those of our colleagues in other research groups who suffer to a far greater extent from our Government's policy towards science and education. We are investing a large proportion of this external support into research equipment, especially into TLD hardware, such as annealing ovens and TL readers, and computer software and hardware (including a small laboratory computer network interfaced to the main network of the Institute). A major publication on the TL efficiency of our MCP-N (LiF: Mg, Cu, P) phosphors to photons, beta-electrons, alpha particles and thermal neutrons, summarizing our work on this subject, has been published in Radiation Protection Dosimetry. We have prepared and submitted abstracts of about ten papers to the 11th International Conference on Solid State Dosimetry (Budapest, 1995). Mr Budzanowski and Mr Bilski took part in an environmental dosimetry intercomparison organized at Risoe National Laboratory in June 1994 and presented two papers at the LUMDETR'94 International Conference in Tallin (Estonia). We continued our long collaboration with the Institute of Medicine of the KFA Juelich and the Radiation Protection Laboratory of the KfK Karlsruhe (both in Germany). Dr Olko and I travelled to China (Beijing and Guangzhou) and to Kharkov (Ukraine) to establish new collaborations in the areas of application of TL dosimetry, radiobiological modelling and radiation protection. Dr Olko was heavily engaged in the activities of the European Dosimetry Group EURADOS, as participant of the EURADOS meeting in Strasbourg, as contributor to the Workshop: Advances in Radiation Measurements at Chalk River (Canada) and as author of a chapter on Tissue-Equivalent Proportional Chambers in a major Working Group 10 EURADOS publication. I was honoured to be invited by Prof. Jaworowski, Delegate of Poland, to act as his Consultant at the 43rd Session of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) in Vienna. I also took part in the work of the Standing Committee of the International Conferences on Solid State Dosimetry, preparing the 11th SSDC to be held in Budapest in 1995, and regularly attended the meetings of the Scientific Council of our Institute and of two Sub-Committes of the National Board for Atomic Energy. Prof. Niewiadomski was actively pursuing research in the area of radon measurements: apart from completing the second part of the survey of radon concentration in houses in the Southern region of Poland and submitting a publication on this subject to NUKLEONIKA, he edited a brochure Radon - Properties, Hazard and Prevention (in Polish) intended for lay readers and state administration. Together with Ms. Ryba, the Chief Radiation Protection Officer for the INP, Prof. Niewiadomski also prepared a new edition of Ionizing Radiation, its Sources and Effects (also in Polish), a compendium

of information on radiation protection used to train the personnel of the INP. I gave a regular undergraduate course on Radiation Dosimetry in Oncology to the students of the Academy of Mining and Metallurgy and Prof. Niewiadomski and Dr Olko gave a number of lectures on the general topics of radiation protection, environmental dosimetry and radiobiological medelling. Two students are preparing their M.Sc. projects in our Laboratory. Dr Pawel Olko is working on his habilitation thesis, and Mr Pawel Bilski, together with Mr Krzysztof Kozak (Environmental Radioactivity Laboratory, Department of Nuclear Physical Chemistry) and Mr Janusz Gajewski (Department of Radiation and Environmental Biology) are working on their Ph.D. projects under my supervision.

Two members of our research staff, Dr Olszewska-Wąsiolek and Dr Wąsiolek, are continuing their leave of absence from the INP for the third consecutive year and are now at the New Mexico Institute of Mining and Technology, Socorro, NM, USA.

We have began to be actively involved in developing medical applications for the new AIC-144 cyclotron presently being tested at the INP. Inspired by Prof. Budzanowski, Director of our Institute, over the second half of 1994, Dr Olko, Dr Taraszkiewicz (Cyclotron Division) and I became heavily engaged in preparing a Hadron Radiotherapy Centre Proposal for the Polish-German Cooperation Foundation and the State Committee for Scientific Research. Work on this project involved collaboration with the Centre of Oncology in Cracow, the Clinic of Ophtalmology, the Institute of Molecular Biology (both Jagellonian University) and the Department of Physics and Nuclear Techniques of the Academy of Mining and Metallurgy, and with several Divisions and Departments of our Institute, to design a facility for proton therapy of eye melanomas and fast neutron radiotherapy facilities and the supporting pre-clinical, clinical and research programs which could utilize the 60 MeV proton and neutron beams to be produced by the AIC-144 cyclotron. This 6 million DM project was submitted to the Polish-German Cooperation Foundation and the Polish State Committee for Scientific Research at the end of 1994, after its positive evaluation by several foreign experts during a short International Workshop on Hadron Radiotherapy which we organized at the INP on 30 November 1994. We keep our fingers crossed, hoping now for a positive reaction from our sponsors. With our colleagues at KFA Jülich we co-authored a paper on modelling the radiobiological properties of therapeutical proton beams, which was presented at the meeting of the Proton Therapy Co-Operative Group (PTCOG) at Chiba, Japan in November 1994.

Since the beginning of 1993, apart from leading the Health Physics Laboratory, I also head the Medical Physics Department of the Cracow Division of the Maria Skłodowska-Curie Centre of Oncology. Managing two excellent and hard-working teams is no easy task. I hope to move some of the research activities of the Health Physics Laboratory closer to physics in radiotherapy and, in particular, to applications of TL and alanine dosimetry in clinical measurements and in Quality Assurance procedures for radiotherapy.

Assoc. Prof. Michael P.R. Waligórski

REPORTS ON RESEARCH:

A. Environmental Radiation Protection

Long-Term Investigations of Self-Irradiation and Sensitivity to Cosmic Rays of TL Detector of Types TLD-200, TLD-700, MCP-N, and New Phosphate Glass Dosemeters

M. Budzanowski[1], B. Burgkhardt[2], P. Olko[1], W. Pessara[3], and M.P.R. Waligórski[1,4]

[1] Institute of Nuclear Physics, ul. Radzikowskiego 152, 31-342 Cracow, Poland

[2] Karlsruhe Nuclear Research Centre, Postfach 3640, D-76021 Karlsruhe, Germany

[3] PTB, Postfach 3345, D-38023 Braunschweig, Germany

[4] Centre of Oncology, ul. Garncarska 11, 30-115 Cracow, Poland

(*submitted to the 11th International Conference on Solid State Dosimetry, Budapest, 10-14 July 1995*)

The cosmic component of background gamma radiation, the intrinsic background or "self-dose" and the fading of TLD-600, TLD-700 and TLD-200 from HARSHAW, MCP-N (LiF: Mg, Cu, P) from the INP Cracow and phosphate glass dosemeters (TOSHIBA GLASS) were measured over a period of 557 days at different locations: in the Asse saltmine (Braunschweig, Germany) 775 m below ground level, in a steel shielding at the KfK laboratory, and in a buoy placed on the surface of an artificial lake (Baggersee, Karlsruhe, Germany). The self-dose is mainly due to the dosimeter capsules and is negligibly small in the detecors. Assuming a reference cosmic dose rate of 289 micro Gy/a at the lake surface, the relative response to cosmic rays was found to be 0,82 and 0,84 for the LiF: Mg, Ti and CaF_2: Dy detectors and 0,91 and 0,95 for the phosphate glass and LiF: Mg, Cu, P detectors, respectively. The difference in the LET response of the detector appears to be the main reason for the different cosmic ray response of the two detector groups. The fading of all detector types did not exceed 5%/year including the results of long-term storage at 33 C in the salt mine.
(Work partly supported by the Polish-German cooperation programme).

A Regional Survey of Indoor Radon Concentration in South-Eastern Poland

T. Niewiadomski

(*submitted to Nukleonika*)

The Central Laboratory for Radiological Protection and the Institute of Nuclear Physics began in 1991 a country-wide study of radon concentration in dwellings in which CR-39 track-etch detectors located in diffusion cups were used. South-Eastern Poland (a geo-morphologically diversified area constituting 17% of Poland's territory) was assigned to the INP and two surveys were performed between November 1991 and November 1993. A total of 350 cups were randomly placed on the territory of 10 voivodships and about 300 cups were returned to the laboratory for chemical etching of plastics and optical track density counting. A computer data base was set up to store and process the

results. Using the calibration factor of 4.2 tracks.cm^{-2} per (kBq.h.m^{-3}) it was found that the radon concentration over the investigated area exhibits an approximately log-normal distribution with an arithmetic mean of 70 Bq m^{-3} in the first and 80 Bq m^{-3} in the second measurement series (which was longer by a few autumn-winter months). In about 3% of housing stock which were monitored (i.e. 60 000 households with about 250 000 inhabitants) the radon concentration exceeded 200 Bq m^{-3}. If these results are extrapolated to the population, the mean annual effective dose due to radon inhalation is equal to 1.5 mSv while the above-mentioned 3% of the population receive from this source doses higher than 5 mSv per year. Houses with higher radon concentration indoors have been found mainly in the southern, mountainous part of the area surveyed by the INP. Analysis of two measurement series allowed sources of uncertainty in these measurements, which originate both in the laboratory and in the field, to be assessed.

(Research partly supported by grant No 607379101 from the State Committee for Scientific Research).
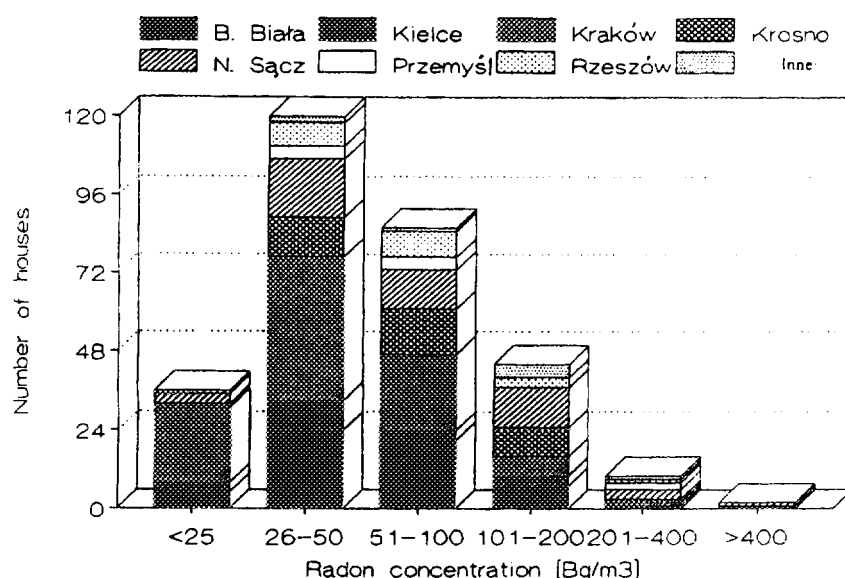
Figure 1: Frequency distribution of radion concentration for the surveyed voivodships.

Comparison of LiF: Mg, Cu, P (MCP-N, GR-200) and Al203 (TLD500) TL Detectors in Short-Term Measurements of Natural Radiation

M. Budzanowski[1], P. Bilski[1], L. Boetter-Jensen[2], M. Delgado[3], P. Olko[1], J.C. Saez-Vergara[3], and M.P.R. Waligórski[1,4]

[1] Institute of Nuclear Physics, ul. Radzikowskiego 152, 31-342 Cracow, Poland

[2] Riso National Laboratory, P.O. Box 49, DK-4000 Roskilde, Denmark

[3] CIEMAT, Adva. Complutense 22, E-28040 Madrid, Spain

[4] Centre of Oncology, ul. Garncarska 11, 30-115 Cracow, Poland

Within the EU-sponsored Intercalibration Experiment at RISO National Laboratory (June 1994) Chinese GR-200 (LiF: Mg, Cu, P), Polish MCP-N (LiF: Mg, Cu, P) and

Russian TLD-500 (Al2O3) TL detectors were tested for their capability of performing short-term measurements of natural radiation. The response of these TL detectors to the natural environmental photon spectrum was evaluated at the Natural Environment Measurement Station recently established at Riso, under partial EU sponsorship. The total environmental radiation dose rate was measured by detectors placed 1 m above ground level, exposed over 3, 5 and 8 hours. Excellent agreement and accuracy was found for all detectors, even after 3-hour exposures. To assess the cosmic component of natural radiation, detectors were exposed for three days on a wooden pier at Roskilde Fjord with a Reuter-Stokes high pressure ionization chamber as a monitor. The average cosmic-ray dose rates determined by LiF: Mg, Cu, P materials (MCP-N and GR-200) was about 32 nGy/h and about 38 nGy/h for TLD-500, while the average dose rate assessed with the ionisation chamber was about 40 nGy/h. Estimating the shortest exposure period required to evaluate the natural photon dose-rate with MCP-N, GR-200 and TLD-500 detectors, we found that they were all capable of reliably measuring natural environmental doses after an exposure of about 3 hours. Procedures required to determine these ultra-low doses will be described.

B. Development of new TL materials and model analyses of the response of TL detectors

Thermoluminescent Eficiency of LiF: Mg, Cu, P (MCP-N) Detectors to Photons, Beta-Electrons, Alpha-Particles and Thermal Neutrons

P. Bilski[1], P. Olko[1], B. Burgkhardt[2], E. Piesch[2], and M.P.R. Waligórski[1,3]

[1] Institute of Nuclear Physics, Cracow, Poland
[2] Nuclear Research Centre Karlsruhe, Germany
[3] Centre of Oncology, Cracow, Poland

The thermoluminescent efficiency, η, of LiF: Mg, Cu, P (MCP-N detectors, commercially produced at the INP, Cracow, Poland), relative to 662 keV Cs-137 gamma rays, has been measured for (i) 1250 keV Co-60 gamma-rays, (ii) filtered X-ray beams of average energies in the range 15 - 300 kVp, (iii) Pm-147 beta-electrons, (iv) thermal neutrons and (v) stopping alpha-particles of initial energies in the range 0.5 - 5 MeV. A rapid decrease of TL efficiency with decreasing mean photon energy from $\eta = 1.04 \pm 0.02$ for Co - 60, $\eta = 0.93 \pm 0.02$ for 300 kVp X-ray to $\eta = 0.59 \pm 0.016$ for 15 kVp X-ray was observed. The measured value of relative efficiency for Pm - 147 beta-electrons was $\eta = 0.90 \pm 0.02$. The relative efficiency for alpha particles decreased from $\eta = 0.06 \pm 0.004$ to $\eta = 0.03 \pm 0.007$ for particles of initial energies of 5 MeV and 1 MeV, respectively.

The measured response of MCP-N detectors after doses of thermal neutrons was equal to 0.72 1010 Gy $n^{-1}cm^2$, which corresponds to $\eta = 0.104 \pm 0.012$. The efficiency for 2.73 MeV ^3H tritons was found to be $\eta = 0.155 \pm 0.02$. The rapid decrease of sensitivity of LiF: Mg, Cu, P with increasing ionization density is a microdosimetric effect, resulting

from the saturation of the TL signal from high energy deposits. An empirical relationship between the mean lineal energy, y_F, and η has been found which can be used to predict the TL efficiency of MCP detectors for photons and electrons. However, TL efficiency η is not a unique function of $y_{F'}$, so this relationship cannot be used to predict the value of η over the whole range of ionization densities (LET) of heavy charged particles stopping in the detector.
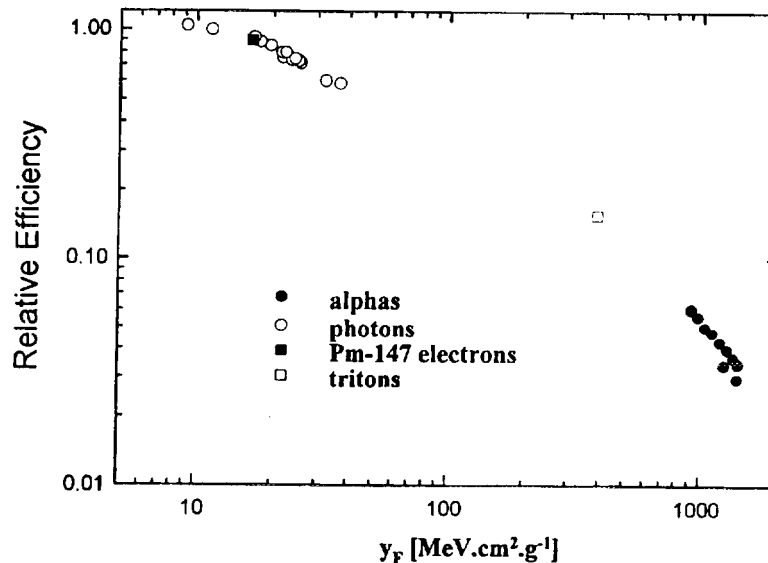
Figure 1: Relative TL efficiency η for photons (o), 147-Pm beta electrons (■) and tritons (□), plotted against mean lineal energy y_F, calculated for target diameter of 100 nm for water of unit density.

A Systematic Evaluation of the Dependence of Sensitivity and Glow-Curve Structure on Dopant Concentration and Thermal Treatment in LiF: Mg, Cu, P

P. Bilski, M. Budzanowski, and P. Olko

Institute of Nuclear Physics, Radzikowskiego 152, 31-342 Cracow, Poland

(submitted to the 11th International Conference on Solid State Dosimetry, Budapest, 10-14 July 1995)

A systematic multi-parameter investigation of the dosimetric properties of LiF: Mg, Cu, P is being performed with respect to the concentration of Mg (0.1 - 0.5 mol%), Cu (0 - 0.5 mol%) and P (0 - 5 mol%) activators, preparation procedures (melting, sintering), and thermal treatment. Over one hundred different samples of LiF: Mg, Cu, P material were prepared using uniform batches of chemical substrates. From each material a group of sintered chips was produced. The TL signal after gamma irradiation is measured in powdered material and in pellets. Total sensitivity and glow-curve parameters are analysed. Considerable attention is paid to the high-temperature structure of the glow-curves. On selected samples a series of thermal treatment experiments will be performed, including different annealing temperatures (from 200°C to 600°C) and different cooling rates. TL

glow-curves are analysed and the influence of thermal treatment on detectors with various dopant composition studied. The aims of this work are to discuss: (i) optimum proportions of dopant concentration and the possible role of particular activators; (ii) optimum annealing procedures and the thermal susceptibility of materials with different activator concentration; and (iii) to propose a thermal treatment which could restore TL properties after overheating of the detector.

[6]LiF Sandwich-Type Detectors for Low-Dose Individual Monitoring in Mixed Neutron-Photon Fields

P. Olko[1], M. Budzanowski[1], P. Bilski[1], B. Burgkhardt[2], and E. Piesch[2]

[1] Institute of Nuclear Physics, Cracow, Poland
[2] Kernforschungszentrum Karlsruhe, Germany

ICRP Publication 60 recommends the reduction of the annual dose limit for occupational exposure from 50 mSv to 20 mSv and doubling the value of the quality factor for medium energy neutrons. If occupational doses are evaluated every month (which is obligatory, e.g. in Germany and in Poland), the individual neutron dosemeter will have to measure neutron doses in the range of 100 μSv. No commercially available, automatic individual dosimetry monitoring system exists which fulfils this requirement.

We studied some of the parameters which influence the evaluation of the neutron dose from readings of TL dosemeters in order to decrease the variance of the measured neutron signal. In mixed neutron-photon fields, clear separation of the neutron component from the total reading depends also on the uncertainty of the gamma dose measurements. While the thermal albedo neutrons are absorbed mostly at the surface of the [6]LiF detector, the reduction of the detector thickness results in decreasing its photon sensitivity while maintaining its neutron sensitivity almost constant. In concequence, the uncertainty of gamma dose determination contributes with a lower weight to the variance of the evaluated neutron signal. First tests of an optimised 200 μm sandwich detector and 0.9 mm thick standard LiF chips were made at low neutron and photon dose ranges using different readers, in order to find out the uncertainty versus dose for different neutron/photon combinations. We demonstrate conditions under which the new sandwich-type detectors may improve albedo neutron dosimetry.

C. Theoretical Radiobiology, Microdosimetry and Radiation Protection

Recalculation of Thyroid Doses after the Chernobyl Accident in an Iodine Deficient Area

P. Olko[1], T. Niewiadomski[1], M. Budzanowski[1], and Z. Szybiński[2]

[1] Institute of Nuclear Physics, Radzikowskiego 152, 31-342 Cracow, Poland

[2] Chair and Department of Endocrinology, Jagellonian University, Collegium Medicum, Kopernika 17, 31-034 Cracow, Poland

(presented at the Congress of the Polish Society of Nuclear Medicine, Cracow, 12 June 1994)

Thyroid doses were estimated in Poland shortly after the Chernobyl accident under the assumption of stable iodine consumption for the reference man over areas with "standard" stable iodine consumption. These estimates are not representative for the southern part of Poland which is known to be an iodine-deficient area. Therefore the thyroid doses were now recalculated basing on the real and differentiated stable iodine intakes for groups of people of different age with and without thyroid blockage after the accident.

Calculations of RBE for Proton Beams with Energies Between 70 and 250 MeV Using the Response Function Model

H. Paganetti[1], P. Olko[2], H. Kobus[3], D. Filges[3], Th. Schmitz[1], H.W. Müller-Gärtner[1], and M.P.R. Waligórski[2,4]

[1] Institute of Medicine IME, Forschungszentrum Jülich GmbH, Jülich, Germany

[2] Institute of Nuclear Physics IFJ, Cracow, Poland

[3] Institute of Nuclear Physics IKP, Forschungszentrum Jülich GmbH, Jülich, Germany

[4] Centre of Oncology, Cracow, Poland

(presented by H. Paganetti at the Proton Therapy Co-Operative Group Meeting PTCOG XXI, Chiba, Japan, 14-16 Nov. 1994)

The biological effectiveness of therapeutic pencil proton beams was studied with regard to the initial energy distribution of an extracted beam and to the depth of the beam penetration in water. Such data will be useful in assessing the biological effectiveness of protons in future therapy installations with electronically modulated scanned beams, which are planed to be applied on some modern accelerators, e.g. the COol SYnchrotron at Jülich, Germany. Proton transport calculations in water for proton energies ranging from 70 to 250 MeV were performed using the PTRAN Monte Carlo code in order to obtain proton energy spectra at a given depth in water on the beam axis. The momentum spread of the input semi-monoenergetic proton beam, dp/p, was varied from 0 to 0.003. Next, the microdosimetric response function approach was applied to calculate the biological effectiveness of the proton beam at a depth of interest. The biological response function, R, describes the probability of occurence of a given biological effect after an event of energy deposition with a given lineal energy, y, which is a parameter characterizing ionization density. In the calculation of relative biological effectiveness for protons. RBE_0, the whole

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distribution of possible energy deposition events (i.e. the so-called yd(y) microdosimetric distribution) was taken into account and normalized to the effect of Co - 60 gamma-rays. yd(y) distributions were calculated from proton energy distributions at a given depth, assuming Continuous Slowing Down Approximation (CSDA) of protons in spherical targets of 1 μm in diameter and disregarding delta-ray effects. Two biological end-points were considered i.e. early intestinal tolerance assessed by crypt regeneration in mice, and inactivation of T1 cells. The results show that calculated RBE values for both considered end-points depend on the initial energy spread of the input proton beam and on the depth of beam penetration. RBE for intestinal tolerance in mice approaches 1 in the plateau region and gradually increases with the proton penetration depth. In the center of the Bragg peak RBE values range from about 1.1 (250 MeV beam) up to 1.9 (70 MeV beam). At the end of Bragg peak RBE was found to be even higher (1.5 for 250 MeV beam to about 2.4 for 70 MeV beam) but only less than 1% of dose is delivered with such high RBE values. The above results indicate that for therapy planning with electronically modulated pencil proton beams it would be necessary to account for the increase of proton RBE, especially for low-penetrating beams.

Multi-Level Modelling of the Response of the Ultraminiature Proportional Coutner: Gas Gain Phenomena and Pulse-Height Spectra

P. Olko[1], C. Moutarde[2], and P. Segur[2]

[1] Institute of Nuclear Physics, Radzikowskiego 152, 31-342 Cracow, Poland
[2] University Toulouse, Toulouse, France

The ultraminiature proportional counter, UMC, a unique radiation detector to monitor high intensity therapy fields, designed by Kliauga and operated at Columbia University (USA), has yielded a number of pulse-height distributions for photons, neutrons and ions at simulated diameters of 5 - 50 nanometers. Monte Carlo calculations of the gas gain in such a counter questioned the possibility of achieving proportionality at such low simulated diameters. We have now modelled the response of the UMC taking into account both fluctuations of energy deposited in the counter volume and its calculated gas gain. Energy deposition was calculated using the MOCA-14, MOCA-8 and TRION codes, whereby distributions of ionizations d(j) after irradiations with Cs-137, 15 MeV neutrons and 7 MeV/amu deuterons were obtained. Our Monte Carlo calculations of electron avalanches in UMC show that the size of the single-electron avalanche P(n) reaching the anode wire strongly depends on the location of the primary ionization within the counter volume. Distributions of the size of electron avalanches for higher numbers of primary ionizations, $P^{*j}(n)$, were obtained by successive convolutions of P(n). Finally, the counter response was obtained by weighting $P^{*j}(n)$ over d(j) distributions. On comparing the measured and calculated spectra we conclude that the previously proposed single-electron peak calibration method might not be valid for the UMC due to the excessive width and overlap of electron avalanche distributions. Better agreement between the measured and calculated spectra is found if broader electron avalanche distributions than those used in the present calculations, are assumed.

Microdosimetric Interpretation of Thermoluminescence Efficiency of LiF: Mg, Cu, P (MCP-N) Detectors for Weakly and Densely Ionizing Radiations

P. Olko[1], P. Bilski[1], M. Budzanowski[1] and M.P.R. Waligórski[1,2]

[1] Institute of Nuclear Physics, ul. Radzikowskiego 152, 31-342 Cracow, Poland
[2] Centre of Oncology, ul. Garncarska 11, 30-115 Cracow, Poland

Track Structure Theory (Horowitz et al., Waligórski et al.) explains the decrease of TL efficiency of LiF: Mg, Cu, P with increasing LET of heavy charged particles as a saturation effect due to the high radial dose close to the ion's path, offering no explanation for different TL efficiency of this one-hit detector for photons or electrons of different energies (Waligórski et al.).

We now analyse recent X-ray, gamma-ray, beta electron, thermal neutron, alpha particle and cosmic-ray data obtained with LiF: Mg, Cu, P (MCP-N, Institute of Nuclear Physics, Cracow, Poland) detectors (Bilski et al., 1994) using a micro-dosimetric model which is a modification of the single-hit detector model, where interpretation of the value of relative TL efficiency, η is possible for a broad spectrum of radiations including weakly ionising modalities. Microdosimetric distributions applied in model calculations were obtained for photons, beta-electrons, tritons and alpha-particles from published measurements with low pressure proportional counters or calculated using MOCA-8 and MOCA-14 track structure codes. The marked decrease of η for weakly ionising radiations is now also explained by saturation of TL response in the small (40 nm diameter) sensitive site (target) representing TL traps in LiF: Mg, Cu, P.

D. Studies of Concepts in Radiation Protection

Radon - Properties, Hazard and Prevention

T. Niewiadomski (Editor),
M. Budzanowski, P. Olko, and M. Waligórski

Summary

This 83-page publication contains basic information on radon, its progeny and consequences of their inhalation for the general public. It is intended for the lay reader, and principally for workers and advisors to the local governement who have no background in physics or radiation protection. The booklet contains five main chapters describing the following subjects:
- description of radon sources in the earth crust, radon availability and transport from

soil to buildings as well as interactions of radon progeny in air,
- description of the mechanisms of lung cancer induction due to radon progeny inhalation and of the risk associated with radon exposure,
- information on radon levels in dwellings in different countries,
- description of the main methods for measuring the concentration of radon and of its progeny, the uncertainties of results and methods of reducing these uncertainties,
- the strategy and methods of reducing the hazards of indoor radon inhalation, including a programme for informing the public, introducing legislation, and for bringing together different institutions which should cooperate in such a programme, safety standards, methods of finding radon - prone areas, and building techniques for radon control and reduction.

E. Miscellaneous

Project of the Hadron Radiotherapy Centre at the Institute of Nuclear Physics in Cracow

Health Physics Laboratory
in collaboration with

The Centre of Oncology, Cracow Division
The Clinic of Ophthalmology,
Collegium Medicum, Jagellonian University,
The Institute of Molecular Biology, Jagellonian University,
and
The Department of Physics and Nuclear Techniques,
University of Mining and Metallurgy (AGH), Cracow

*(A Proposal submitted to The Polish-German Cooperation Foundation
and The State Committee for Scientific Research, December 1994)*

The aim of the Project is to establish in Cracow a modern centre of radiotherapy which would exploit beams of protons and neutrons (i.e. hadrons) produced by the AIC-144 isochronous cyclotron of the Institute of Nuclear Physics in Cracow. The Centre of Hadron Radiotherapy created as a result of this Project would be the only centre in Poland in which clinical work in this area would be carried out. This centre would satisfy national needs for treating ocular melanoma and clinically indicated fast neutron radiotherapy, and produce selected medical radioisotopes. The Centre would also offer research and training opportunities to teams of physicians, physicists, biologists, and engineers and allow them to actively develop modern techniques of treating cancer in close cooperation with laboratories abroad. We estimate that a sum of about 6 million German Marks, of which about a half would be provided by Polish-German Cooperation Foundation, invested over a period of four years into the present infrastructure of at least the same value, in order to finally adjust the AIC-144 cyclotron at the Institute of Nuclear Physics in Cracow, to equip the proton ocular therapy and fast neutron radiotherapy facilities, and to partially support the necessary research work in this area, would allow us to treat about 300 patients a year, to produce selected medical radioisotopes and to provide about 50 research staff with research opportunities. We believe that establishment of the Hadron

Radiotherapy Centre at the Institute of Nuclear Physics in Cracow is justified by the many years' clinical and research experience of the teams engaged in this Project and especially by the fact that for almost twenty years neutron radiotherapy and ocular brachytherapy have been carried out in Cracow, that the main accelerator infrastructure already exists, significantly easing the financial burden of creating this Centre, and that the siting of the Institute of Nuclear Physics in Cracow is convenient for out-patient treatment.

The proposed Hadron Radiotherapy Centre in Cracow is a serious research undertaking in the field of health care which, if realized together with German physicists, physicians and engineers, would serve to further bring these two nations together. It is therefore an undertaking which serves the interests of Poland and Germany and as such, it is suitable for presentation to the Polish-German Cooperation Foundation to seek support under the statutory terms of operation of this Foundation.

LIST OF PUBLICATIONS:

I. Articles:

1. P. Bilski, P. Olko, M. Waligórski et al.,
   "Thermoluminescence Efficiency of LiF: Mg, Cu, P (MCP-N) Detectors to Photons, Beta Electrons, Alpha Particles and Thermal Neutrons",
   Radiat. Prot. Dosimetry **55**, 31-38 (1994);

2. R. Katz, M.P.R. Waligórski,
   On the Linear Extrapolation to Low Doses",
   Radiat. Prot. Dosimetry **52**, 197-199 (1994);

3. K. Morstin, P. Olko,
   "Calculation of Neutron Energy Deposition in Nanometric Sites",
   Radiat. Prot. Dosimetry **52**, 89-92 (1994);

4. P. Olko, M. Budzanowski, P. Bilski, B. Burghardt, E. Piesch,
   "^{6}LiF Sandwich-Type Detectors for Low-Dose Individual Minitoring in Mixed Neutron-Photon Fields",
   Radiat. Prot. Dosimetry **54**, 349-352 (1994);

5. P. Olko, P. Bilski, V.M. Michalik,
   "Microdosimetric Analysis of the Response of LiF Thermoluminescent Detectors for Radiations of Different Qualities",
   Radiat. Prot. Dosimetry **52**, 405-408 (1994);

6. M.P.R. Waligórski,
   "Track Structure Analysis of Survival of Two Mouse Lymphoma L5178Y Cell Strains of Different Radiation Sensitivity",
   Radiat. Prot. Dosimetry **52**, 207-210 (1994);

II. Reports:

1. M. Skarżyńska, E. Zawisza, M. Jasińska, M.P.R. Waligórski,
   "Complex Investigations of Gamma-Ray Doses and of Radioactivity of Coal Wastes and Ashes at the Przezchlebie Stockpile" (in Polish),
   Przegląd Górniczy (Mining Review) **31**, No 6 (1994).

2. T. Niewiadomski,
   "Building Materials and their Impact on Radon Indoors" (in Polish),
   Opracowanie SPOPP, red. T. Niewiadomski, IFJ, Cracow (1994);

3. T. Niewiadomski, A. Budzanowski, P. Olko, M.P.R. Waligórski,
   "Radon - Properties, Hazard, Prevention" (in Polish),
   Opracowanie SPOPP, red. T. Niewiadomski, IFJ, Cracow (1994);

4. T. Niewiadomski, E. Ryba,
   "Ionizing Radiation, its sources and effects" (in Polish),
   Opracowanie SPOPP, red. T. Niewiadomski, IFJ, Cracow (1994).

PARTICIPATION IN CONFERENCES AND WORKSHOPS:

1. *M.P.R. Waligórski*
   Member of the International Scientific Advisory Board of the 11th International
   Conference on Solid State Dosimetry, Budapest 1995,
   Member of the Subcommittee on Radiation Protection of the National Board for
   Atomic Energy,
   Member of the Subcommittee on Medical Applications of Ionizing Radiation of the
   National Board for Atomic Energy,
   Member of the INP Scientific Council;

   M. Wasilewska-Radwańska, B. Gwiazdowska, M. Waligórski
   "Biomedical Physics Teaching Program in Poland", Proc. International Workshop
   on Advanced teaching in Biomedical Radiation Physics, Archamps (France), 12-14
   October 1994 (presented by M. Wasilewska-Radwańska);

   M. Wasilewska-Radwańska, M.P.R. Waligórski
   "The Curriculum of Medical Physics in Cracow", Proc. European Conference on
   Post-Graduate Education in Medical Physics, Budapest (Hungary), 12-14 November
   1994 (presented by M. Wasilewska-Radwańska);

   H. Paganetti, P. Olko, H. Kobus, D. Filges, Th. Schmitz, H.W. Müller-Gärtner,
   M.P.R. Waligŕski,
   "Estimation of Radiobiological Effectiveness of Proton Beams with Energies Between
   60 and 250 MeV", PTCOG XXI, Chiba, Japan, 14-16 Nov. 1994 (presented by
   H. Paganetti).

2. *P. Olko*
   Vice-President of the Cracow Division of the Polish Medical Physics Society, Member
   of EURADOS WG 10 Group;

   P. Olko, "Evolution of the Radiation Quality Factor", Seminar of the Polish Medical
   Physics Society, Warsaw, 15 May 1994;

   P. Olko, T. Niewiadomski, Z. Szybiński, "Recalculation of Thyroid Doses After the
   Chernobyl Accident in an Iondine-Deficient Area", Congress of the Polish Society of
   Nuclear Medicine, Cracow, 12 June 1994;

   P. Olko, "Multilevel Modelling of Ultra-Miniature Proportional Counter", International Workshop: Modern Methods in Dosimetry, Chalk River, Canada, 5-8 October
   1994;

H. Paganetti, P. Olko, H. Kobus, D. Filges, Th. Schmitz, H.W. Müller-Gärtner, M.P.R. Waligórski, "Estimation of Radiobiological Effectiveness of Proton Beams with Energies Between 60 and 250 MeV", PTCOG XXI, Chiba, Japan, 14-16 Nov. 1994 (presented by H. Paganetti).

3. *M. Budzanowski*

M. Budzanowski, B. Burgkhardt, "Thin$^{6-7}$LiF: Mg, Cu, P and $^{6-7}$LiF: Mg, Ti Detectors for Automatic Albedo Neutron Dosimetry", Proc. of Int. Symposium: "Luminescent Detectors and Transformers of Ionizing Radiation LUMDETR '94", Tallin, Estonia, 25-29 Sept. 1994.

4. *P. Bilski*

Member of European Dosimetry Group, EURADOS, Working Group 12 "Environmental Dosimetry"

P. Bilski, (M. Budzanowski, P. Olko) et al., "Properties of New Thin Sandwich Detectors for Beta and Neutron Dosimetry", Konf. Strahlenschutz: Physik und Messtechnik, Karlsruhe, 24-26 May 1994;

P. Bilski, P. Olko, B. Burgkhardt, E. Piesch, "Ultra-Thin LiF: Mg, Cu, P Detectors for Beta Dosimetry", Proc. of Int. Symposium "Luminescent Detectors and Transformes of Ionizing Radiation LUMDETR '94, Tallin, Estonia, 25-29 Sept. (1994) 2.

LECTURES AND COURSES:

1. *M. Waligórski*,
   undergraduate course: "Radiotherapy, Radiobiology and Dosimetry in Oncology", given to 4th year students of the Department of Physics and Nuclear Techniques, Academy of Mining and Metallurgy, Feb. - May 1994;
2. B. Schaeken (Antwerp) and *M. Waligórski*,
   "The Dialogue Between the Physicist and the Clinician", lecture given at the ESTRO TEMPUS Network Meeting on the Restructuring of Radiotherapy in Central and Eastern Europe, Cracow, 21 Jan. 1994;
3. *M. Waligórski*,
   "Safe Use of Ionizing Radiation", public lecture given during the Open Day of the Institute of Nuclear Physics, 18 June 1994;
4. *M. Waligórski*,
   "Design and Perspectives of the Hadron Radiotherapy Centre in Cracow", lecture given at the International Workshop on Hadron Radiotherapy, INP, 30 Nov. 1994.

INTERNAL SEMINARS:

1. Dr F. Pernicka
   "Dosimetry of Cosmic Rays at Commercial Air Flight Altitudes",
   14 March 1994;
2. E. Ryba
   "Application of MCP Detectors in Measuring Environmental Dose Rates",
   27 October 1994.

SHORT TERM VISITORS TO THE DEPARTMENT:

1. Dr H. Hlawacz-Martinez
   University of Caracas, Venezuela;
2. Dr F. Pernicka
   Institute of Radiation Protection, Prague, Czech Republic;
3. Dr H. Paganetti
   Institute of Medicine, Research Center Jülich, Germany;
4. Dr Th. Schmitz
   Institute of Medicine, Research Center Jülich, Germany;
5. Dr D. Filges
   Institute of Nuclear Physics, Research Center Jülich, Germany;
6. Dr H. Homayer
   Hahn-Meitner Institute, Berlin, Germany;
7. Dr A. Kacperek
   Clatterbridge Hospital, Great Britain;
8. Dr E. Egger
   PSI Villingen, Switzerland;
9. Dr H. Hese
   Hahn-Meitner Institute, Berlin, Germany.

Section XI

Cyclotron Laboratory

Cyclic Accelerator R & D Laboratory

Electronics Laboratory

Computing and Networks

Division of Mechanical Constructions

Energy Efficiency Center

Section XI

CYCLOTRON LABORATORY

Head of Division: *Edmund Bakewicz, M.Sc.E.E.)*
telephone: (48)-(12)-37 02 22 ext.: 365
e-mail: bakewicz@bron.ifj.edu.pl

PERSONNEL:

U-120 Cyclotron Section:

Head of the Section: Bronisław Wojniak, M.Sc.

Józef Cora	Tadeusz Francuz
Mieczysław Kubica	Maria Mirek
Stanisław Papierz	Zbigniew Pazdalski
Bogusław Sałach	Bogdan Sułek
Jacek Sulikowski, M.Sc.	Marek Tałach, M.Sc.E.E.
Ryszard Tarczoń	Lucyna Włodek

AIC-144 Cyclotron Section

Head of the Section: Henryk Doruch, M.Sc.E.E.

Krzysztof Daniel, M.Sc.E.E.	Leszk Dzieża
Jerzy Korecki, M.Sc.E.E.	Janusz Lagisz
Tadeusz Norys	Wojciech Pyzioł
Marek Ruszel	Jerzy Starzewski, M.Sc.E.E.
Ryszard Taraszkiewicz, Ph.D.	

OVERVIEW:

Cyclotron techniques have been developed in our Institute from the very beginning of its existence. The first cyclotron we had was a small cyclotron C-48, built in Cracow over 40 years ago. The second one, U-120 cyclotron has been used in Institute since 1958. Two years ago the constructing a new isochronous cyclotron – AIC-144 was finished.

The main parameters of the cyclotrons are as follows:

U-120 Cyclotron

Magnet pole diameter:	120 cm
Magnetic field:	13–15 kGs
Number of dees:	2 ($\alpha = 180^0$)
R–F system:	8–16 MHz/120 kW
Dee voltage:	150 kV
Extraction radius:	52,5cm
Ion sources:	PIG, internal
Extraction system:	electrostatical, $U_d = 60$ kV (+magnetic channel)

Particles	Energy	Intensity
deuterons	12 – 14 MeV	60 μA
H_2–ions	12 – 14 MeV	40 μA
^3H–ions	29 – 32 MeV	3 μA
alpha	24 – 28 MeV	20 μA
Emittance:	$\varepsilon_x = 50$ mm·mrad	$\varepsilon_z = 35$ mm·mrad

AIC-Cyclotron

Magnet pole diameter:	144 cm
Magnetic structure:	4 sectors with spiral angle of 54^0
Magnetic field:	8.5 – 18 kGs
Field variation:	$B_4/<B> = 0.2$
Frequency of betatron oscillators:	$Q_x = 0.42$; $Q_z = 0 - 1.06$
Number of concentric coils:	20
Number of azimuthal coils:	8
Number of dees:	1 ($\alpha = 180^0$)
Radiofrequency generator:	8 – 26 MHz/150 kW
Dee voltage:	50 kV
Extraction radius:	62 cm
Ion source:	internal, PIG type
Acceleration coefficient:	K = 60
Range of energy:	
Protons:	10 – 60 MeV
Deuterons:	15 – 30 MeV
α–particles:	30 – 60 MeV
Emittance:	$\varepsilon_x = 25$ mm·mrad, $\varepsilon_z = 20$ mm·mrad.

The general activity of our Laboratory was connected with the U-120 and AIC-144 cyclotrons.

A. The U-120 cyclotron was used generally for:
   1) radionuclide production
   2) radiobiological research
   3) physical experiments
   4) radiotherapy

Therapy was offered to the patients of the Maria Skłodowska-Curie Centre of Oncology in Cracow. Ten sessions of therapy with fast neutron beams from U-120 (a one-week-per-month cycle) were run in 1994.

B. In 1994, the AIC-144 cyclotron was not used for acceleration. The activity of the AIC-144
   Cyclotron Section encompassed two topics:
   1) modernization and renovation of some parts of the cyclotron
   2) measurements and investigations of magnetic fields, especially for higher levels
   of excitation currents.
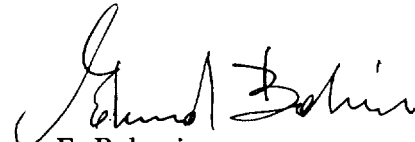
As for the first part, in 1994 we manufactured one new dee (in order to replace the damaged one); then use constructed an apparatus to measure dee peak voltage and the phase of acceleration voltage. We also constructed an arrangement for compensation of the coupling loop between the resonator and the H.F. generator.

The main aim of our Laboratory is now to convert cyclotron AIC-144 for medical purposes. This situation is connected with the intention to create the Hadron Radiotherapy Centre in Cracow. It means that we ought to obtain proton beam with energy up to 60 MeV, and up to 30 MeV for deuterons.

In order to understand all the possibilities of our machine in this range we had to measure many characteristics of magnetic fields, especially in the upper range of excitation currents. In the range of 400A - 600A of the excitation current we measured many maps of magnetic field distribution (see Fig. 1), influences of concentrical trimming coils on the main magnet fields (for example, Fig. 2). Additional investigations of the magnet characteristics (as in Fig. 4 and Fig. 5) were also performed. After a Fourier analysis of measurement data (see example, Fig. 3) we have started computation and elaboration of the results to obtain all the parameters needed (isochronous fields, phase shift, Qr, Qz oscillations etc).

Together with the Health Physics Laboratory we took part in the organization of the international workshop "The Hadron Radiotherapy Centre in Cracow - Development and Perspectives".

In 1994 we began close collaboration with the Cyclotron Division of the Institute for Nuclear Research in Kiev (Ukraine).

E. Bakewicz
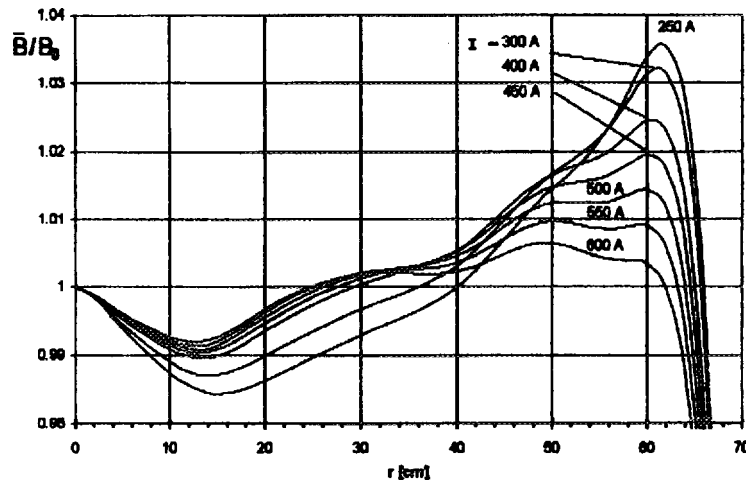
Fig. 1 Dependence of the relative magnetic fields $(\bar{B}/B_0$ vs. radius $\bar{B}$ - average magnetic fields, B_0 - magnetic fields in the center (r = 0), I - excitation current).
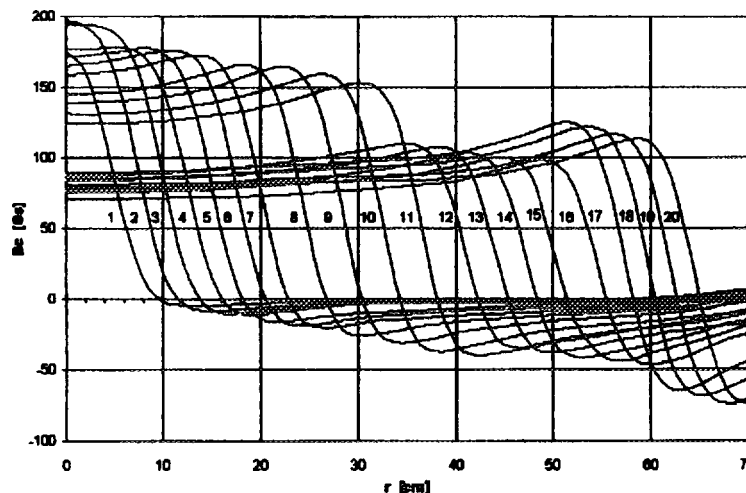
Fig. 2 Magnetic field contribution of each concentrical trimming coil at a base field $B_0 = 18.11$ kGs ($I_0 = 600$ A). Coils current $I_C = 400$ A.
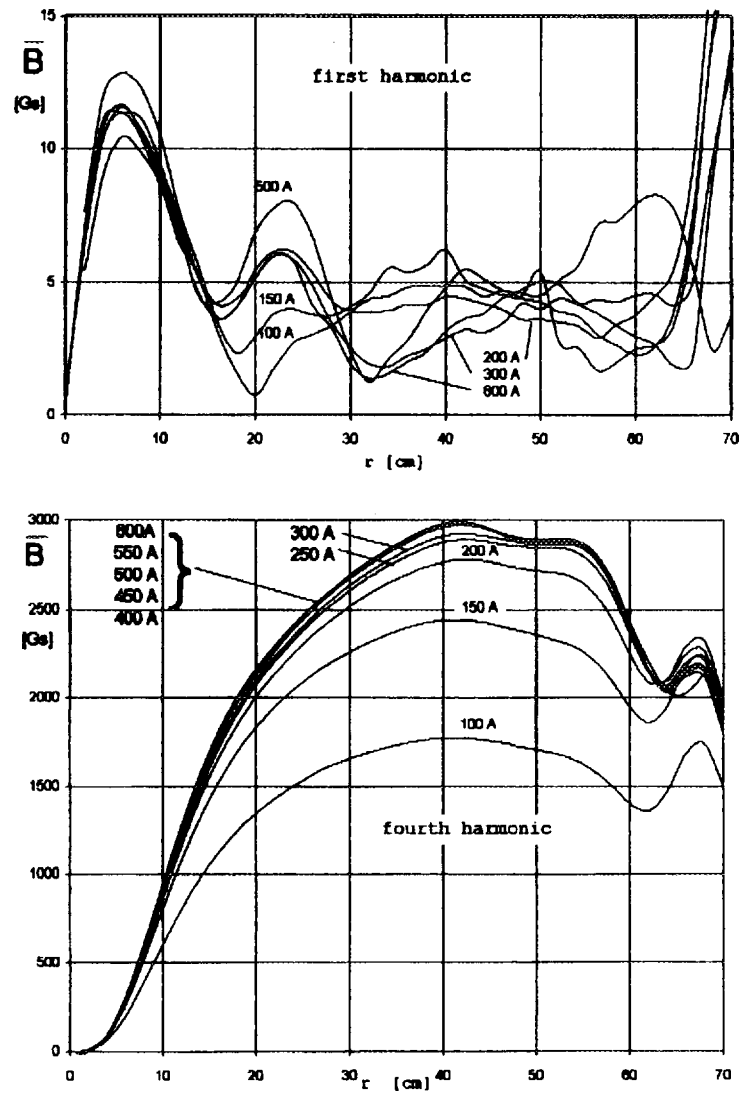
Fig. 3 Results of a Fourier analysis of measurement data from magnetic field with an azimutal period of 2π vs. radius (for some levels of excitation current).
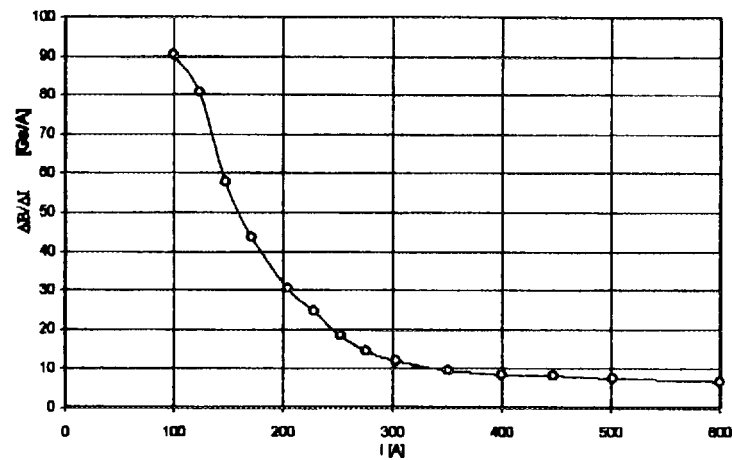
Fig. 4 Dependence of $\Delta B/\Delta I$ vs. excitation current (for point: $\Theta = 0^0$, $R = 39.25$ cm).
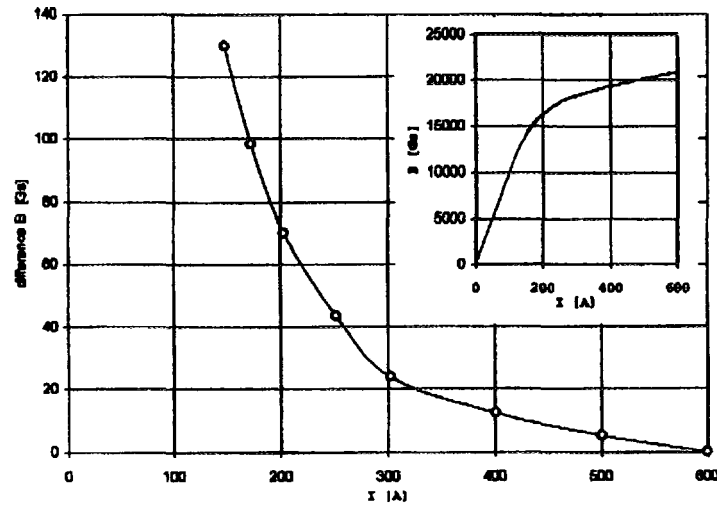
Fig. 5 Difference between upper and lower brauch of histeresis loop for the AIC-144 magnet (for point: $\Theta = 0^0$, $R = 39.25$ cm).

PARTICIPATION IN CONFERENCES AND WORKSHOPS:

1. E. Bakewicz
   - participation in the "International Workshop: The Hadron Radiotherapy Centre in Cracow - Development and Perspectives", 30 October 1994, Cracow;

2. R. Taraszkiewicz
   - member of the Organization Comitte of the "International Workshop: The Hadron Radiotherapy Centre in Cracow - Development and Perspectives", 30 October 1994, Cracow;

3. H. Doruch
   - participation in the 29 European Cyclotron Progress Meeting, 20-23 June 1994, Dubna, Russia.

INTERNAL SEMINARS:

1. Dr A.A. Valkov (Institute for Nuclear Research, Kiev, Ukraine),
   "The Algorithms of Magnetic Fields of U-240 Cyclotron";

2. H. Doruch, M.Sc.,
   "The 29 European Cyclotron Progress Meeting in Dubna";

3. Dr R. Taraszkiewicz,
   "The Main Characteristics of Magnetic Fields";

4. Dr A.A. Papash (Institute for Nuclear Research, Kiev, Ukraine),
   "The "Rezim" - Program for Calculation of the U-240 Characteristics";

5. J. Sulikowski, M.Sc.,
   "Arrangement for Measurements Dee's Peak Voltage and Phase of Acceleration Voltage".

SHORT TERM VISITORS TO THE DEPARTMENT:

1. Dr Emmanuel Egger - Paul Sherrer, Institut Villigen, Switzerland;
2. Dr Detlef Filges - Institute of Nuclear Physics, Research Centre Jülich, Germany;
3. Dr Jurgen Heese - Hahn-Meitner Institut Berlin, Germany;
4. Prof. dr H. Homeyer - Hahn-Meitner Institut Berlin, Germany;
5. Dr Andrzej Kacperek - Clatterbridge Centre for Oncology, Bebington, U.K.;
6. Mr Hubert Kobus - Institute of Nuclear Physics, Research Centre Jülich, Germany;
7. Dr Harald Paganetti - Research Centre Jülich, Germany;
8. Dr Thomas Schmitz - Research Centre Jülich, Germany;
9. Dr M. Nezamzadeh - Nuclear Research Center AEOI, Teheran, Iran;
10. Prof. dr W.L. Aksionow - Join Institute for Nuclear Research, Dubna, Russia;
11. Dr A.E. Valkov - Institute for Nuclear Research, Kiev, Ukraine;
12. Dr A.A. Papash - Institute for Nuclear Research, Kiev, Ukraine;
13. Dr W.I. Grantsev - Institute for Nuclear Research, Kiev, Ukraine.

Chapter XI

CYCLIC ACCELERATOR R&D LABORATORY

Head of the Research Group: *Assoc.Prof. Jerzy Schwabe*
Secretary: *Halina Szymańska*
telephone: (48)-(12)-37 02 22, ext.: 371, 381
e-mail: schwabe@bron.ifj.edu.pl

PERSONNEL:

Research Staff:	**Administration:**
Jerzy Schwabe	Halina Szymańska
Andrzej Balmas	
Helena Godunowa	
Maria Potempa	

OVERVIEW:

Our group is engaged in investigating and developing the physics and techniques of cyclic accelerators.

The main subjects of our interest concern improving the operation parameters of cyclotrons that are at present operating in the world.

The AIC-144 S (automatic isochronous cyclotron) is the basic tool for some experimental investigations here. Theoretical studies of acceleration processes are based on computer codes developed in our laboratory.

Cooperation with cyclotron divisions:

JINR Dubna
NPhI Reź near Prague
PINPh Gatchina–St. Petersburg
KFK Karlsruhe

Topics theoretically developed in 1994:

- Converting AIC-144 S for medicine and other applications (60 MeV protons), Report No **1672/AP**,
- Investigation of the Beam Orbit Storage (BOS) effect, application of which permits to achieve high particle beam intensity (up to several mA) on Isochronous Cyclotrons (IC), Report No **1677/AP**; the paper was originally presented at the 29th ECPM held in Dubna in June 1994,
- H^-, D^- beam acceleration with IC - magnetic dissociation, Report No **1689/AP**,
- Magnetic field measurements on AIC-144 S to achieve 60 MeV protons,
- Problems of high-efficiency extraction from the IC, Report No **1676/AP**.

Topics under development:
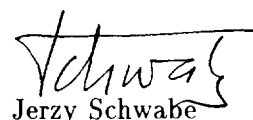
- Vacuum dissociation conditions for H⁻, D⁻ beam acceleration on IC,
- Vacuum system of AIC-144 S for H⁻, D⁻ beam acceleration,
- Studying acceleration parameters for multicharged ion acceleration on IC,
- Designing a target bombardment station for radioisotope production at the AIC-144 S.

Computer codes developed in 1994:

Name of Program	Programming Language	Nature of the Physical Problem Solved	Hardware Requirements
MAG1	C	Mechanical system and Hall probe control for magnetic field measurements	PC IBM
MF1/V01	TBASIC	Magnetic field analysis	PC IBM
H/V01/94	TBASIC	Magnetic dissociation of H^-	PC IBM
H/V02/94		ions during their acceleration	
RES.5/V02	TBASIC	Cavity calculations	PC IBM

Experimental work carried out:

Magnetic field measurements at 500 A, 550 A, 600 A values of main-magnet current.

Jerzy Schwabe

REPORTS ON RESEARCH:

The Most Economical Operation Conditions of IC for Proton Beam Acceleration up to 60MeV

J. Schwabe, A. Balmas, and H. Godunowa

The design concerns modifications of the AIC-144 S construction that are aimed at improving the two operating parameters:

1. Increasing the maximum energy of protons up to 60 MeV,
2. Minimizing excitation power losses of resonator cavity.

In principle, the above-mentioned requirements preclude each other, thus presenting some difficulties in their realization. Nevertheless, it is possible to make simple low-lost modifications in the RF system construction of the AIC-144 S that allow one to solve this problem in general.

Conditions required for providing 60-MeV protons

Two basic conditions are pointed out here:

a. Increasing the average magnetic field value up to 18.2 kGs at the extraction radius (62.5 cm),

b. Extending the upper band of RF generator frequency range from 24.8 MHz to 26.1 MHz and obtaining the conditions for cavity tuning at this frequency.
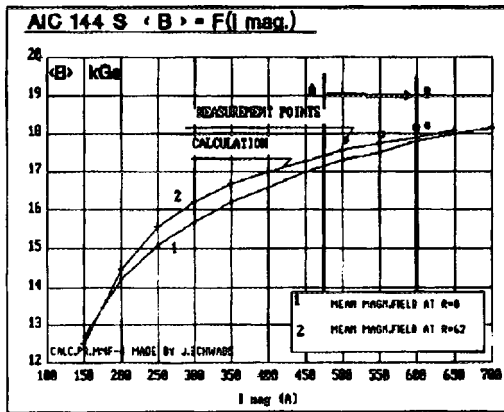
Fig. 1 Mean magnetic field as function of AIC-144 S main magnetic current.
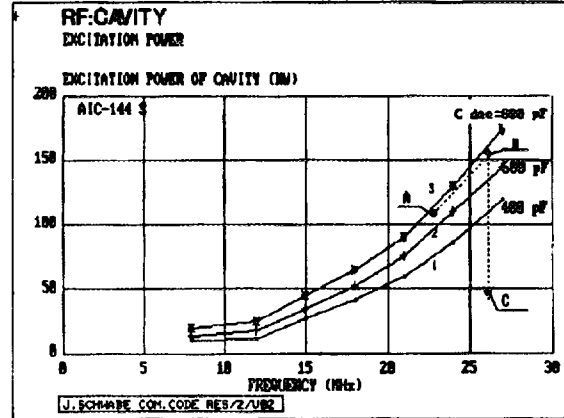
Fig. 2 Excitation power cavity as function of main current.

To satisfy the condition pointed out in (a), the value of main magnet current has to be increased by about 130 A, wheras for (b), the design resonator cavity must be slightly modified.

Regarding the AIC-144 S magnetic system, it is possible to attain proton energy values up to 60 MeV in case of forced the operation conditions (see Fig. 1, points A, B). The average magnetic field generated by ferro–magnetic elements in the acceleration plane was computed as a function of the main magnet current, the results are given in Fig. 1 for two regions:

1 – in the centre
2 – in the extraction region
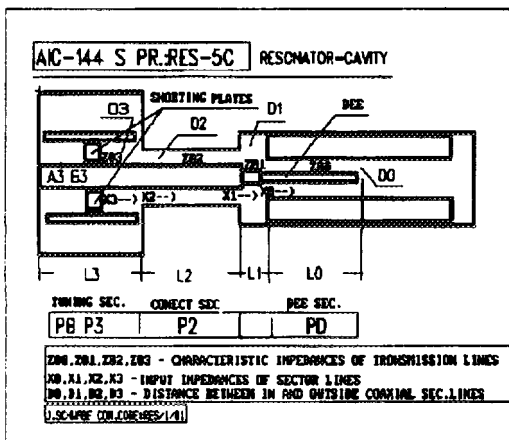
Fig. 3: Draft of resonator cavity, conversion proposal. Here P2, P3, PD, PB are power losses in different resonator sections.

Fig. 4: Table of calculation results for power losses in different sections.

The magnetic field measurement data are dotted in Fig. 1. In accordance with the design, the cavity and RF generator operate in the frequency range of 4–25.5 MHz. The maximum excitation power evaluated for 24.8 MHz is about 135.5 kW for 50 kV dee voltage. Expanding the frequency range up to 26.1 MHz will cause power increase up to 156.4 kW (see Fig. 2, point B). It is very well known the cavity excitation power depends on its design, which enables one to tune the resonator cavity in a wide frequency range (3.1-fold). The resonator excitation power changes in similar proportions. The possibility of cavity tuning is one of the advantages of the

AIC-144 S universal design, which makes it possible to work in a wide energy range (K = 20 - 55 p) and to accelerate a wide assortment of particles and ions in the range of Z/A = 1 - 0.285.

However, it has been shown in ref. [3] that, if the modified cavity is excited at **the frequency of 26.1 MHz only**, the maximum excitation power consumption will decrease from 150 kW to 45 kW. Computation results using computer codes [1,2] are given in the table (Fig. 4) where power losses in the different sections of the cavity are presented (see also Fig. 3). The proposal of cavity conversion is shown in Fig. 3. In this case the cavity tuning in the energy range of 10 - 26 MeV is obtained by moving up the panels. The possibility of wide-band cavity tuning will not be limited by the proposed changes at any rate.

References:

1. Flat Coaxial Cavity for Isochronous Cyclotrons, /HFCIC/ computer code developed by J. Schwabe,
2. Resonator 5C, /RES.5C/ computer code developed by J. Schwabe,
3. J. Schwabe, A. Balmas, H. Godunowa, Report No **1672/AP**, INPh, Cracow (1994).

Magnetic Dissociation while Accelerating H^-, D^- Beams on Isochronous Cyclotrons (AIC-144 S)

J. Schwabe

Problems of H^- ions acceleration, are considered in this report for the case of the AIC-144 S type of cyclotron. Conditions required to realize such acceleration are also given; more details can be found in [2]. Methods presented in [2] may be also used to determine parameters for other types of isochronous cyclotrons (IC) .

It is very important to examine H^- losses during the acceleration process at different radii (energies). This knowledge is needed to avoid the undesirable activation of cyclotron construction elements by neutralized H^- particles. For the case of AIC-144 S, the remainder of H^- vs acceleration radius and the corresponding energy are presented in Fig. 1 at different parameters (B_k, B_m, B_0). The beginning of H^- losses is marked by (A) in Fig. 1. The curves are obtained with computer code H/V01/94 [1]. The code is based on calculations performed iteratively for each step of acceleration radius.
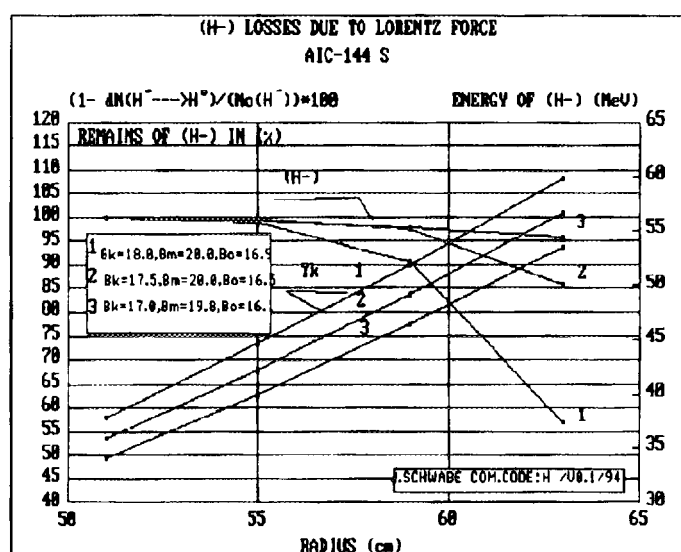
Fig. 1: Remainder of H^- ions and their energy vs acceleration radius in relation to AIC-144 S cyclotron.
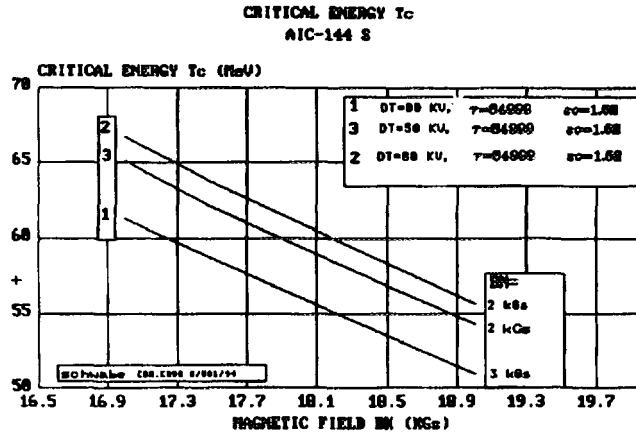
Fig. 2: Critical energy of H^- ions in different acceleration and magnetic field conditions vs isochronous magnetic field B_k in relation to AIC - 144 S. Energy at which some H^- ions are neutralized and H^- beam intensity decreases by a factor of e is denoted by T_c.

As it has been shown by analysis, H^- losses up to 50% caused by magnetic dissociation are to be expected for extreme operation parameters, i.e. mean magnetic field of 18.2 kGs, at 60 MeV protons. The neutralized part of H^- beam inside the cyclotron (for instance, when H^- beam intensity is 100 μA and more) will induce the accelerator activation, and therefore it is undesirable. For this reason optimum conditions must be found for which maximum acceleration energy of H^- may be reached with minimal neutralization. Investigating this problem has provided us with some methods, thus allowing us to correct the critical situation.

The way to minimize neutral particle H at a given value of mean magnetic field ($B = 18.2$ kGs) in the region of extraction is as follows:

1) Decrease, by as much as possible, the maximum value of magnetic field by decreasing the flatter in the region (however, that leads to decreasing the amplitude of magnetic field variation B_N from 3 kGs to 2 kGs, Fig. 2).

2) Increase the energy gain per turn as much as it is allowed, i.e.

from 60 kV to 80 kV in case of AIC-144 S (Fig. 2).

By applying these conditions it is possible to achieve minimal induced radioactivity inside the cyclotron. Besides, the H^- losses may be reduced by up to 10 - 15%. Otherwise, the intensity of accelerated beam should be decreased considerably. It must be pointed out that it is difficult to provide any protection against this kind of irradiation from the inside.
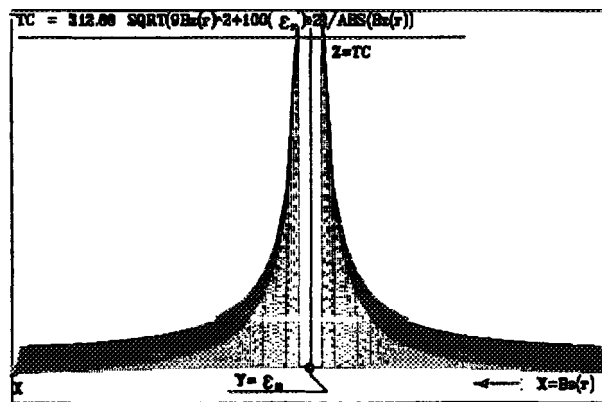
Fig. 3: Critical energy of H^- ions, T_c, against isochronous magnetic field $B_z(r)$ and dissociation force ϵ. The ϵ axis is perpendicular to the plot.

References:

1. J. Schwabe, H/V01/94, H/V02/94 computer codes are available in Cyclic Acceleration R&D Laboratory, INP,
2. J. Schwabe, Report No **1689/AP** (1994), INP, Cracow.

Beam Orbit Storage Effect in Isochronous Cyclotrons

J. Schwabe

The effect was observed for the first time while extracting the beam from the AIC-144 S cyclotron by means of magnetic channels [2]. Analysis of measurement results as well as computer simulation of the process have corroborated this phenomenon, see Fig. 1.
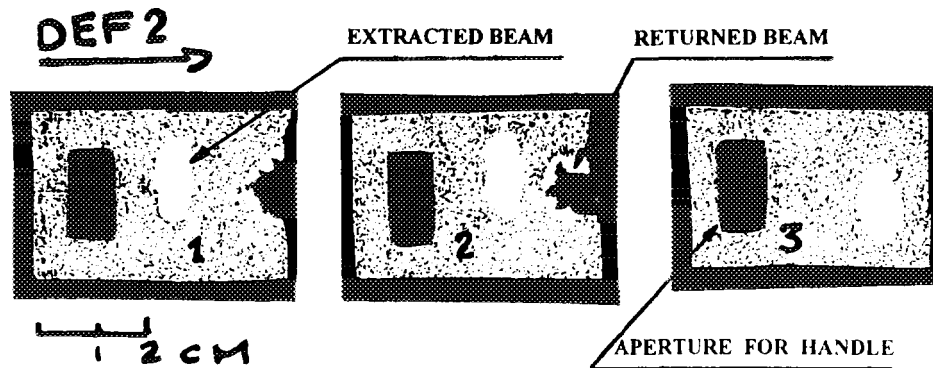
Fig. 1: Photograph of returned and extracted beam tracks taken during experiments on AIC-144 S.

As the simulations on the Mathematical Analogue of the Isochronous Cyclotron (MAIC) [1] have shown, it is possible to obtain storage effect for some orbits in the extraction region of isochronous cyclotrons.

In this report the results of mathematical simulations of the process as well as the dynamic conditions for obtaining such a phenomenon are concisely presented, for details see ref. [3]. Some designs to obtain this effect are proposed. All input data for computer calculations have been taken for the AIC-144 S magnetic structure presented in Fig. 2.
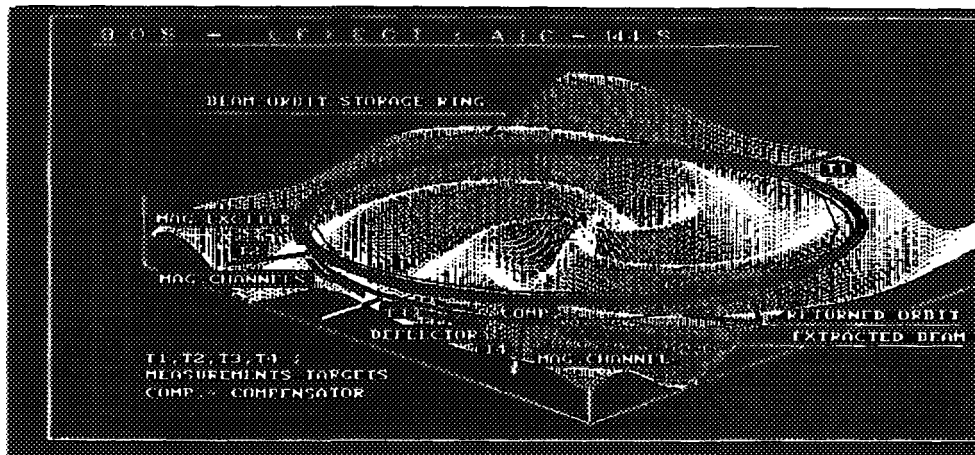
Fig. 2: Magnetic structure of AIC-144 S with last equilibrium and returned orbits.

General Description of BOS Effect

In general the storage effect is based on the compensation of orbit drift caused by magnetic field perturbations (MFP) in the extraction zone (see Fig. 3).

The fundamental condition needed to achieve this successfully is a very rapid decrease in the energy gain of beam during its returning into the acceleration zone.

The following conditions are required to obtain the storage effect:

1. After the beam passes into the extraction zone (where $n < 0$, $Q_r \leq 1$), it must be returned to the acceleration region (where: $n \geq 0$, $Q_r > 1$) by means of MFP.
2. Maximum increase of the acceleration phase in the returned beam up to the deceleration moment (Fa $\simeq 1.57$ rad) must be obtained by using orbit deformation control system.
3. Stability conditions of acceleration should be protected during all of the returning process.
4. Special shape of the isochronous field and its slope must be formed because of control phase shift.

The first two conditions are easy to satisfy by introducing the first subharmonic magnetic perturbation in a given place in the extraction space, see Fig. 3. Satisfying the third condition depends on the magnitude and position (azimuth at given radius) of such a perturbation. The isochronous magnetic field shape and slope gradient may be controlled by a system of correction coils.
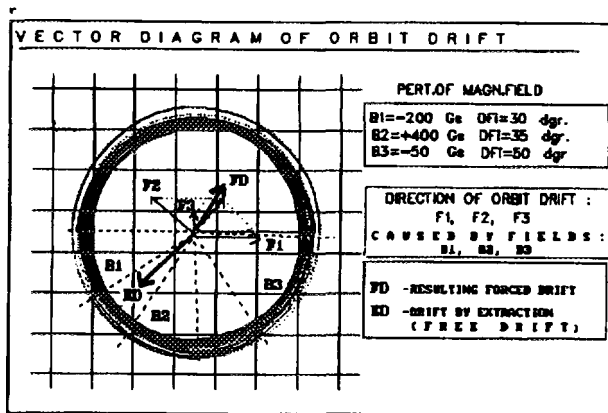
Fig. 3: Proposed location of magnetic perturbations in AIC-144 S and orbit drift directions induced by them.
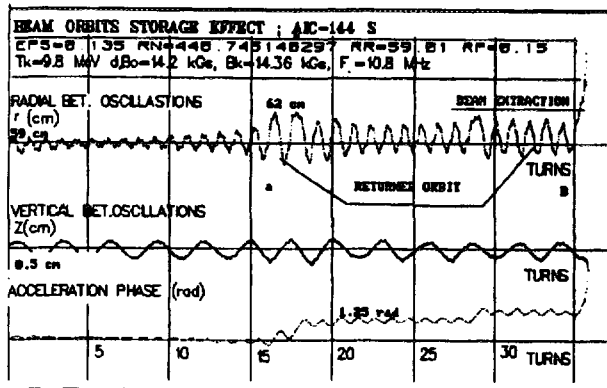
Fig. 4: Radial and vertical betatron oscillations as well as acceleration phase vs turns in accumulation zone.

Practical Ways to Satisfy BOS Conditions

The simplest way to achieve useful MFP may be obtained by using moving magnetic channels. In this case one must take into account the influence of such a perturbation on the isochronous field and thereby on the acceleration phase, see Fig. 4. In the conventional solution it is possible to use a very well-known effect of passive magnetic channels. In this case the channels may satisfy both conditions: perturbation and extraction.

In case of practical application on AIC-144 S, one prefers to use the above-proposed solution. The location and value of MFP are presented in Fig. 3, and in space field plot in Fig. 2.

It is useful to apply the BOS-effect in many isochronous cyclotrons operating today. Some general advantages are pointed out below:

1. The BOS effect may be used to increase the internal space charge in a given extraction zone (for instance, medical isotope production and other applications on internal beam).

2. Returning the unextracted beam to the space of quasi-stable acceleration region ($n \geq 0$) will cause decreasing activity of construction elements of the cyclotron. This is a very important problem during exploitation on high intensity internal beams.

3. Because of avoiding internal beam losses on construction elements, as well as longitudinal extension of the beam and also a change in the angle of radial emittance during the second acceleration process, increase of the extracted beam is to be expected.
   The results of BOS-effect simulation in accumulation zone obtained by MAIC codes [1] are presented in [3].

References:

1. Mathematical Analogue of Isochronous Cyclotron, MAIC-1, MAIC-II, MAIC-III - computer codes, developed by J. Schwabe,
2. J. Schwabe, Report No **1676/AP**, INP, Cracow (1994),
3. J. Schwabe, Report No **1677/AP**, INP, Cracow (1994) .

The AIC-144 S Magnetic Field Measurements

M. Potempa, J. Potempa,[1] and J. Schwabe

The measurements of magnetic field structure were performed with supply current of the main magnet coils: of 600 A, 550 A, 500 A as well as with supply current of 400 A of selected correction coils. The measurements, including their preparation, lasted 14 days in November 1994. This work is related to the possibility to obtain proton beam energy of up to 60 MeV, needed for Hadron Radiotherapy Program at INP. To achieve this, new computer code MAG1 [1] working on a PC/AT/286 was developed and used to control the following operations during magnetic field measurements: position of the Hall probe, measurement time, dead time, and recording data in special output code format into a given file. Because of wide possibilities of MAG1 and its working without fail, the measurements were finished quickly. The measurement data were analyzed by means of new computer code MF1/V01 [2]. Some results of the analysis are given in Figures: 1, 2, 3, 4, 5, 6 below.

As seen in Fig. 3 above, the first subharmonics amplitude at 600 A current value of the main coils begins to increase, which may be caused by a large drift of beam orbits in the extraction zone. On the other hand, the average magnetic field still has a positive gradient

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against acceleration radius, which allows one to get the isochronous field for proton acceleration up to the energy of 60 MeV.
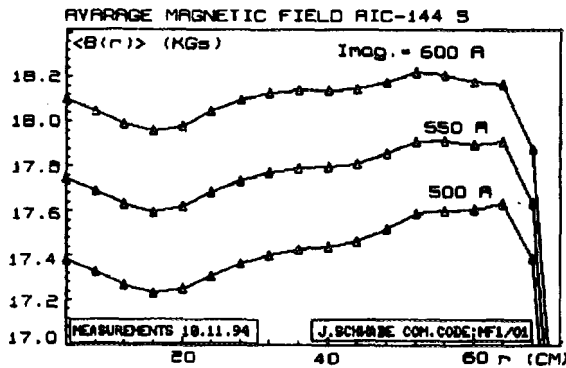
Fig. 1: Average magnetic field $< B_z >$ vs acceleration radius.
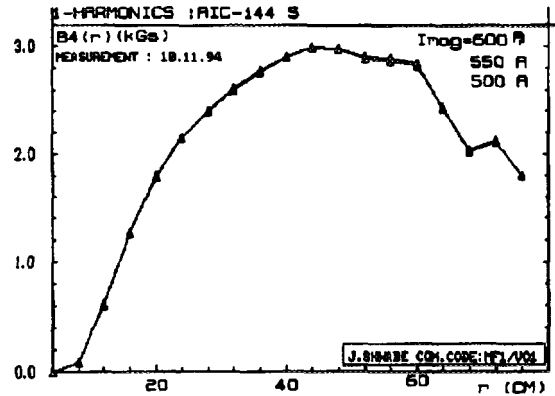
Fig. 2: Amplitudes of the 1st harmonics vs acceleration radius.
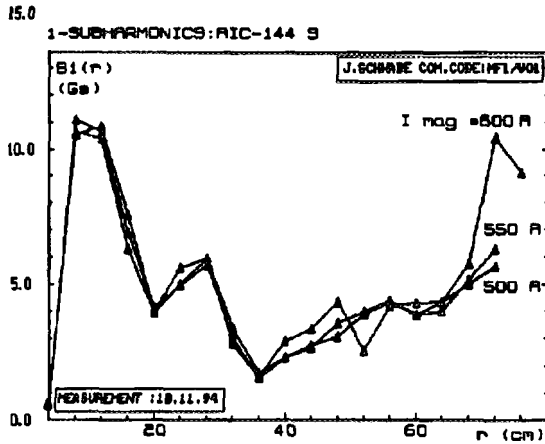
Fig. 3: Amplitudes of the 1st subharmonics vs acceleration radius.
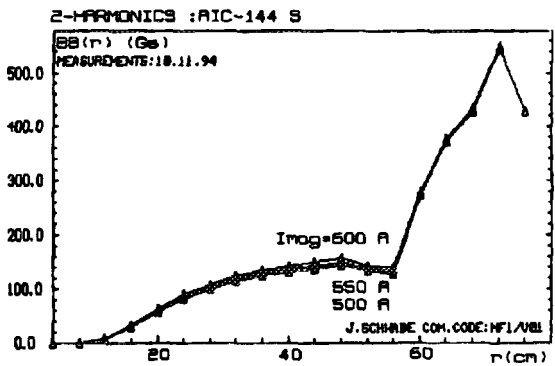
Fig. 4: Amplitudes of the 2nd harmonics vs acceleration radius.
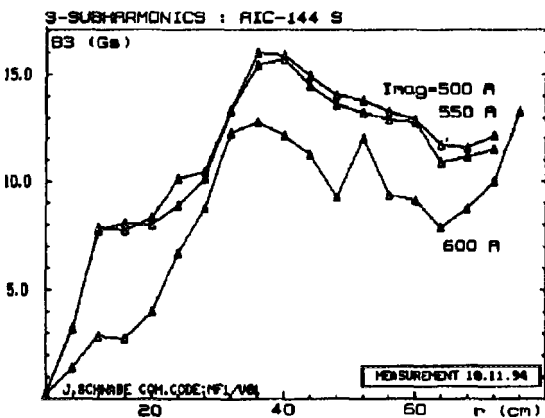
Fig. 5: Amplitudes of the 3rd subharmonics vs acceleration radius.
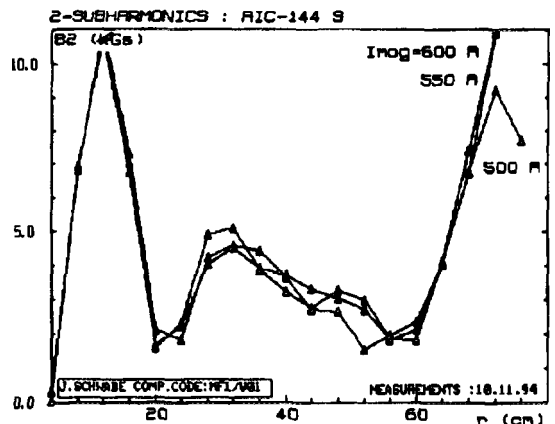
Fig. 6: Amplitudes of the 2nd subharmonics vs acceleration radius.

References:

1. MAG1 - Managing Computer Code, developed by M. Potempa, J. Potempa,
2. MF1/V01 - Computer Code, developed by J. Schwabe.

High-Efficiency Extraction Problems for Isochronous Cyclotrons

J. Schwabe

Some possible methods of extraction to achieve high-efficiency extraction (HEE) have been considered. The problem of HEE $\eta > 50\%$ from IC (except for the stripping method) has not been completely solved so far. This problem is especially important because these cyclotrons are being applied in isotope and radio pharmaceutical production, hadron therapy, and machine industry, and therefore high-efficiency extracted beam is required. In this paper we propose to solve this problem in the following stages:

1. Procurement of maximum orbit separation.
2. Extraction of separated beam with minimal emittance deformation at maximum intensity.

One prefers to obtain orbit separation either by coherent excitation of the beam in the extraction region ($Q_R \simeq 1, n \leq 0$) or by resonance excitation in this zone. Computer simulation and such an orbit separation process are considered in detail in [2]. Besides, analytical expression of beam separation per turn for different methods of beam excitation is given there, too. To achieve high-efficiency extraction, either magnetic field perturbations with the first subharmonics of the magnetic field in the strictly defined place may be applied, or non-linear resonance excited by the working amplitude of magnetic structure may be used. Both methods as well as some experimental results obtained during extraction experiments on AIC-144 S are also presented in [2].
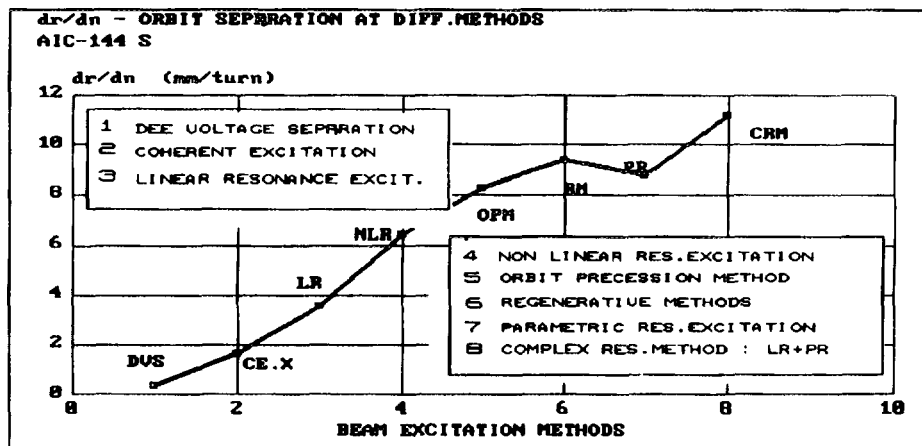
Figure 1: Orbit separation for different beam excitation methods.

References:

1. A.C. Paul, B.T. Wright, IEEE Trans. on Nuclear Sci. NS-13 (1966) 74,
2. J. Schwabe, Report No **1676/AP**, (1994), INP, Cracow,
3. W. Joho, Fifth International Cyclotron Conference, Oxford, (1969) 159,
4. V. P. Dmitrijevski, V. V. Kolga et al., Report JINR P9-6733, Dubna, (1972),
5. J. Schwabe et al., Report No **1069/PI** (1978), NP, Cracow.

LIST OF PUBLICATIONS:

Submitted for publication:

1. *J. Schwabe*
   "Beam Orbit Storage Effect in Isochronous Cyclotrons",
   contributed to Nuclear Instr. and Meth. in November 1994,

2. *J. Schwabe*
   "Problems of High Efficiency Extraction from Isochronous Cyclotrons",
   contributed to IEEE Trans. on Nuclear Sci. in November 1994.

Contributions to conferences:

1. *J. Schwabe,*
   29th European Cyclotron Progress Meeting, 20-24 June 1994, Flerov Laboratory of Nuclear Reactions JINR:

   (a) "Status of the AIC-144 S. The Problems of High Efficient Extraction",
   (b) "Beam Orbit Storage in Isochronous Cyclotrons".

Reports:

1. *J. Schwabe, A. Balmas, H. Godunowa,*
   "AIC-144 S Isochronous Cyclotron Conversion for Medicine and other Applications (60 MeV p)",
   Report No **16722/AP**, INP, Cracow,

2. *J. Schwabe*
   "The Problems of High Efficiency Extraction from the Isochronous Cyclotron",
   Report No **1676/AP**, INP, Cracow,

3. *J. Schwabe*
   "Beam Orbit Storage Effect in the Isochronous Cyclotrons",
   Report No **1677/AP**, INP, Cracow,

4. *J. Schwabe*
   "Magnetic Dissociation at Acceleration of H^- D^- Beams on the Isochronous Cyclotrons (AIC-144 S)", Report No **1689/AP**, INP, Cracow.

LECTURES AND COURSES:

1. *J. Schwabe,*
   lectures given in INP Reź near Prague, April 1994:

   (a) "Proposal for Cavity Performance Aimed at Decreasing Excitation Power for U-120M Isochronous Cyclotron",
   (b) "AIC-144 S Isochronous Cyclotron Conversion (60 MeV p)".

2. *J. Schwabe,*
   lectures given in JINR, Dubna, June 1994:

   (a) "Around Proposal of Mounting and Applying Isochronous Cyclotron ALPHA (the Model Prototype of that is AIC-144 S) in JINR Dubna",
   (b) "Status of the AIC-144 Cyclotron in Cracow".

INTERNAL SEMINARS:

1. *J. Schwabe*,
   "The Problems Appearing at Increasing Energy of Accelerated Particles on Isochronous Cyclotrons", 11 March 1994,
2. *J. Schwabe*,
   "AIC-144 Conversion Aimed at Obtaining 60 MeV Accelerated Proton Energy for Application in Tumor Proton Therapy", 19 March 1994,
3. *J. Schwabe*,
   "Beam Orbit Storage Effect in Isochronous Cyclotrons", 31 May 1994,
4. *J. Schwabe*,
   "New Trends of Investigations in Cyclotron Techniques - presented on 29 ECPM", June 1994, Dubna.

PATENTS:

Patents submitted for approval:
A. Balmas, J. Schwabe,
"The Method of Energy Increasing of Accelerated Particles in Isochronous Cyclotrons with Wide Range of Energy Tuning, Especially for AIC-144 S Type", **No 1/94/P**.

Chapter XI

ELECTRONICS LABORATORY

Head of Laboratory: *M. Kajetanowicz, M.Sc.E.E,*
Deputy Head of Laboratory: *F. Kościelniak[1], M.Sc.E.E,*
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Jolanta Olszowska	Wacław Ostrowicz
Wojciech Reklewski	Robert Szczygieł

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Head of the Section: Franciszek Kościelniak, M.Sc.E.E.

Engineers:

Ryszard Lerch	Maria Wąsik

Technicians:

Wacław Kozub	Edward Kochan
Bogdan Lipka	Artur Włodarczyk

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[1] on leave of absence to JINR, Dubna.
[2] on leave of absence to CERN, Geneve.

OVERVIEW:

The main activities of the Electronics Laboratory are:

- designing and testing electronic equipment for physical experiments,
- developing software for data acquisition and trigger systems,
- maintenance of electronic equipment in the Institute.

Laboratory designers, together with physicists, take part in large international collaborations set up for the preparation of physical experiments. Our main partners are CERN in Geneve and DESY in Hamburg.

At CERN we participate in the DELPHI experiment on the LEP accelerator and in the future ATLAS experiment on the new LHC accelerator. We take part in four research and development programs for LHC experiments: RD6, RD11, RD16 and RD20.

- DELPHI: the work concerned Inner Detector software development. The main area of our activity was optimization and maintenance of on-line data acquisition system as well as local third-level triggering system,

- ATLAS:

  - RD6: The second version of the VME test system for the new front-end electronics for the Transition Radiation Tracker (TRT) was designed and manufactured. It was extensively used for setting up and testing the TRT readout boards before the beam tests at CERN (July - September); TRT is one of the future ATLAS detectors,
  - RD11: Modelling of local and global architectures for second-level triggering at the ATLAS experiments using MODSIM II language. Study of algorithms for the local second-level trigger system for the calorimeter in the ATLAS experiment,
  - RD16: Modelling of architecture of the ATLAS calorimeter readout board,
  - RD20: Tests of the ATLAS silicon tracker front-end electronics; participation in the design of a chip comprising whole front-end readout electronics for the ATLAS silicon tracker. Study on readout architecture for the silicon tracker in the ATLAS experiment. Design of a hybrid board for readout electronics for the silicon strip detector.

At DESY our engineers were involved in upgrading of the H1 experiment.

At MPI, Munich, the main part of the electronic system of the H1 LAr Calorimeter Trigger has been redesigned to get better sensitivity and resolution by providing lower and individual threshold for every channel.

The control part of the monitoring software for the H1 second-level trigger system has been developed in cooperation with LAL, Orsay, France.
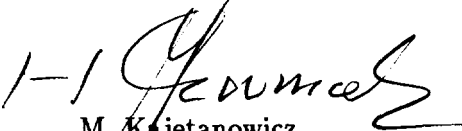
In 1994 our Institute became a member of the EUROCHIP - service organization being a part of the ESPRIT VLSI Design Training Action launched by the European Commission. The Institute purchased the Cadence CAD package for full custom integrated-circuit design. The Institute signed the agreement with Austrian company AMS - a foundry manufacturing integrated circuits. That agreement enables INP engineers to design circuits in AMS 1.2 μm CMOS technology.

A general-purpose data-acquisition module in the VME standard has been designed in our Laboratory. The module is equipped with Motorola 96002 digital signal processor for data processing. It will be initially used for tests of readout electronics for silicon particle detectors.

Three university students wrote their M.Sc. theses at the Electronics Laboratory.

Two university students served their Summer apprenticeship at the Electronics Laboratory.

M. Kajetanowicz

REPORTS ON RESEARCH:

Sparse Data Readout Chip for Silicon Particle Detector

A. Czermak, M. Kajetanowicz, and J. Kaplon, R. Szczygieł

The silicon strip particle detector is a set of long diodes manufactured on common silicon substrate. The diodes are parallel to one another and their typical dimensions are 50 μm x 6 cm. Silicon wafer is usually 300 μm thick. The diodes, called strips, are connected to a circuit collecting the electrical charge generated in silicon volume by an ionizing particle passing through it. This information is the basis for particle track reconstruction.

The most probable number of strips hit by particles after each beam collision is at the level of 2% of all strips. Having that level of occupancy and a tremendous number of channels, data reduction in the detector readout chips is necessary to avoid transmitting this information out of the detector. To meet this goal a circuit described here has been designed.

The circuit serves 128 detector strips and contains 128 identical channels at its input. Each channel is composed of the following parts:

- sample and hold circuit,
- comparator.

Then circuits common for all channels follow:

- 128-bit input register,
- 128-to-1 analog multiplexer,
- sparsifying logic - priority encoder,
- flash ADC logic,
- output register.

The state of the detector strips after particle beam collisions is remembered in the sample and hold circuit and then presented to the comparator inputs. The threshold voltage is common for all comparators. Few comparators have a signal at the output, meaning that a given strip was hit by a particle. The state of comparator outputs is written into the register. Basing on the contents of the register, the priority encoder controls the multiplexer which selects the outputs of the sample and hold circuits. Only the strips hit by a particle are processed. Priority encoder logic supplies also the address (number) of the selected input channel. The multiplexer output is connected to the input of the flash ADC. The ADC is built of the same comparators which are used for finding hits. The function of comparators is changed by switches after having their output written to the register. Such a solution results in adding no additional power dissipation for the analog-to-digital conversion. The ADC gives a 7-bit result which is presented at the chip output together with a 7-bit strip number.

Some circuit elements like sample and hold circuit, fast comparator and analog multiplexer have been already manufactured and tested as separate chips. For the first time all elements
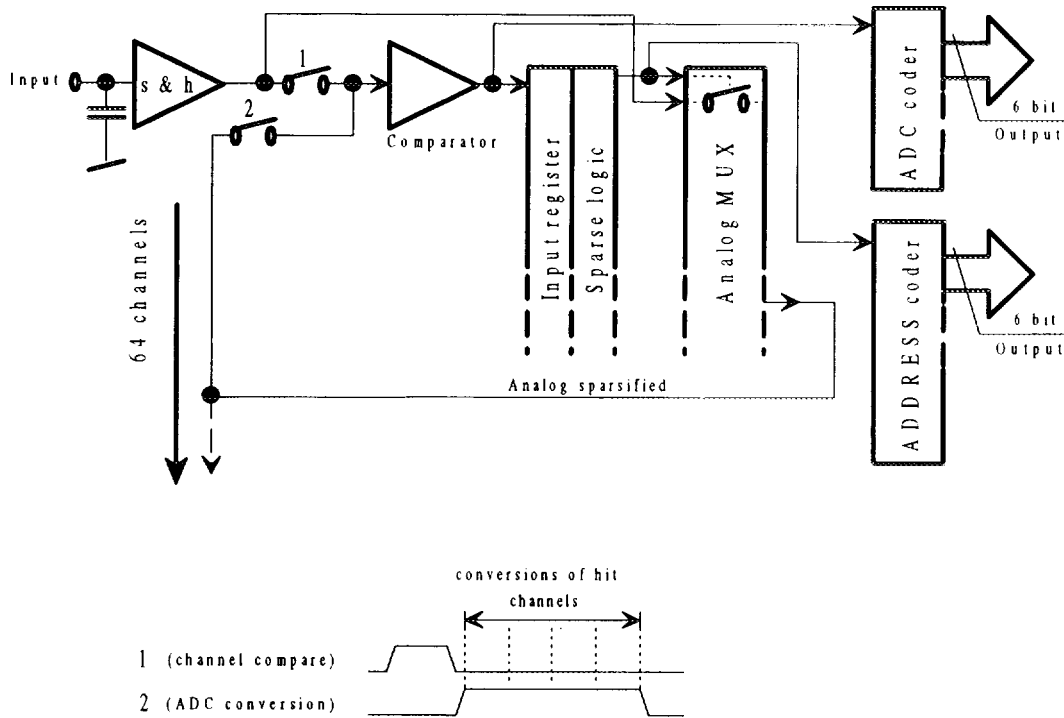
Figure 1: Block diagram of a full sparse chip.

will be put together in the presented chip. The chip will be manufactured in the AMS foundry in 1.2 μm CMOS technology. The next step is to integrate a FIFO memory buffer on to the chip.

64x8 CMOS FIFO Memory

A. Czermak, M. Kajetanowicz, and R. Szczygieł

64-byte First-In First-Out Memory has been designed using Cadence software. The memory is going to be used to derandomize data flow in silicon strip detector readouts.

Dual Port RAM architecture has been used, thus a static memory cell with twin-bit lines (separate for reading and writing) has been applied. The FIFO memory consists of static RAM matrix, Read Pointer, Write Pointer, Flags block, input and output buffers.

The RAM matrix contains 64 8-bit words; each bit is an 8-transistor cell. The Read Pointer indicates current word to be read, and the Write Pointer indicates current word to be written. Flag block generates two signals: Empty Flag (EF) and Full Flag (FF) to show current FIFO status. The RESET, READ and WRITE inputs are provided. Data is transferred in the following way: after resetting, both the Read Pointer and the Write Pointer indicate the same word. Empty Flag is active. Data is written with the WRITE signal, then the Write Pointer is increased. Empty Flag switches to inactive - there exists data to be read. Next, the data is read with the READ signal and the Read Pointer is increased. If no more data has been written, the Empty Flag switches to active. Reading and writing processes are completely independent. The memory has the capacity of 64 words of data. If the number of words is exceeded, the Full Flag is switched to active.

The FIFO Memory was designed for 1.2 μm CMOS technology process.

Fast Low-Power Analogue MUX for Readout of Multichannel Electronics

J. Kapłon

An analogue multiplexer chip (AMUX) dedicated to the readout of silicon strip detectors was designed and manufactured in 1.2 μm n-well CMOS AMS technology. Since in the experiment a very large number of sensors and readout electronics is placed in a small volume, low-power consumption at the given speed is the driving force for the presented design. A great number of electronic channels placed in a small volume requires the use of low-power technique for building a fast analogue multiplexer. Our goals were to design a 32-channel analogue multiplexer with the following parameters:

- power dissipation less than 50 mW for 32 channels,
- readout speed 20 MHz,
- dynamic range at the input $0 - 1$ V, power supply ± 2 V.

The analogue multiplexer chip contains 32 input channels with sample and hold circuits. Each channel consists of an input switch, a storage capacitor and an input buffer designed as a source follower based on a NMOS transistor biased with 20 μA. Because the n-well technology is used, the gain at this stage is about 0.8. The multiplexing function is implemented as a simple array of 32 switches connected by analogue bus line to the output buffer. Since the parasitic capacitance of this line is about 4 pF for 32 channels, it is necessary to increase the current in the readout channel. We can obtain this simply by adding a pull-up NMOS resistor connected to the VSS. In addition to the 32 input channels one extra channel is used to cancel the offset and the cross-talk from the digital part. The output of this channel is used as a reference for the differential output.
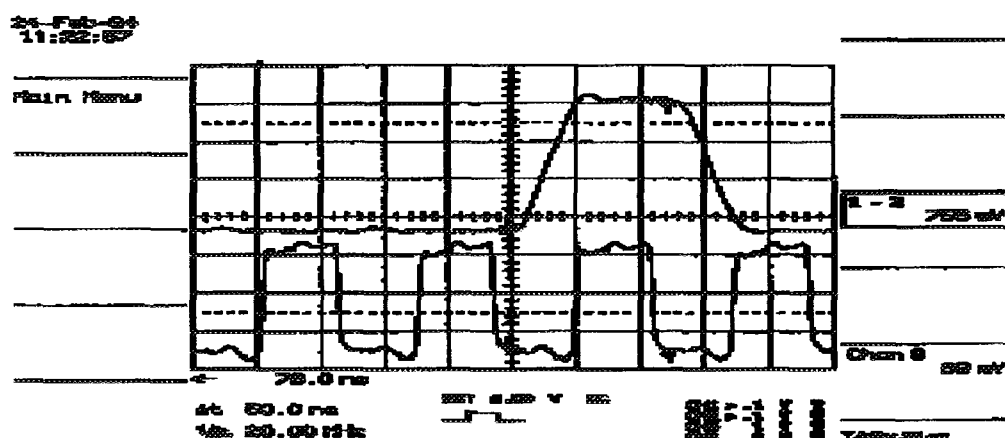
Figure 2: Performance of the multiplexer with 1V step of one channel and 20 MHz read-out clock.

Quasi-complementary configuration used in the output buffer provides good DC performance. The combination of the error amplifier and the common source device gives low output impedance and high signal swing at the output of the buffer. Capacitors used in the feedback provide compensation for load capacitance of up to 30 pF. The -3 dB bandwidth of the buffer is equal to 115 MHz and the settling time for a 1 V signal step at the input is 25 ns.

The multiplexer gain of 0.75 is obtained. The power dissipated by the multiplexer is about 25 mW. Settling time for 1 V step at the input is about 30 ns which shows that we have a

good safety margin of 20 MHz operation. Maximum nonlinearity of the MUX analogue is less than 1 percent, which is acceptable for this application. The channel offset spread together with the cross-talk from neighbouring channel is less than 5 mV. The 128-channel version has been designed and is expected to be manufactured soon.

Readout System for Silicon Strip Detector Based on DSP56001

A. Czermak and W. Reklewski

Silicon strip detectors for X-rays with orthogonal X-Y strips have been constructed lately. To collect and process data from such detectors specialized readout devices are needed. This project is the first attempt at constructing such a device.

The detector itself is controlled by specialized VLSI Front End circuit. The same circuit prepares signals from strips for further processing. The output signals from FE circuit (for one coordinate) are: central, lower, upper strip amplitude, number of simultaneous hits registered, address of central strip. These signals are read by readout device by 12 - 14-bit ADCs. Four 11-bit DACs supply signals to control and adjust the detector. The possibility to read the amplitude in the neighbouring strips allows one to increase both spatial and energetic resolutions.
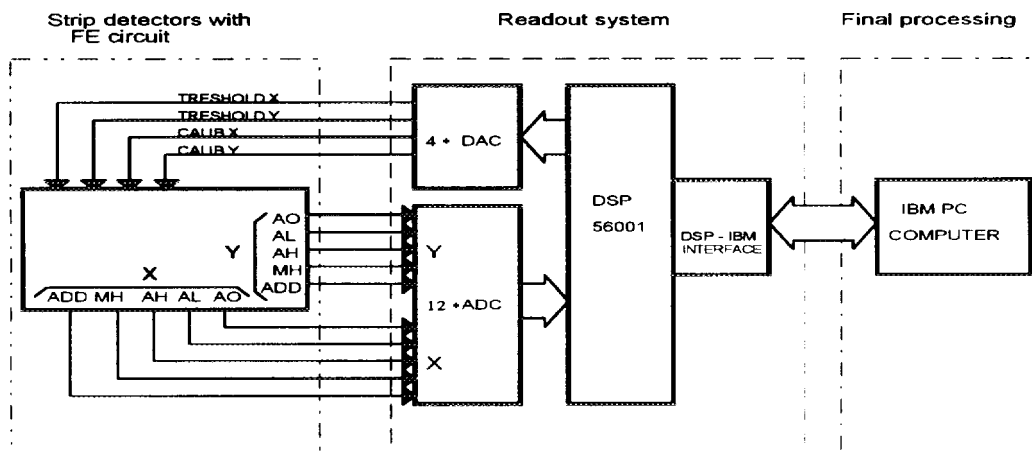
Figure 3: Block diagram of a detector.

The device has the following features:

- data acquisition speed of up to 80 kHz from 12 analog inputs. This allows one to collect pictures consisting of 50000 events per second,
- on-board memory to store temporary data and correction tables. Due to strip-to-strip differences each strip must have the amplitude correction factor evaluated. By multiplying amplitude by the factor we receive corrected amplitude,
- 8-bit parallel DMA link to IBM PC for fast data transfer,
- DSP56001 Digital Signal Processor allows one to conduct all math ematical operations very efficiently.

VME Data-Taking Module

M. Kajetanowicz and P. Kapusta

A general-purpose DSP-based VME data acquisition module has been designed and built in the Electronics Laboratory. It is designed as the VME 6U slave module equipped with an exchangeable input board. Digital input signals are scheduled to control data acquisition. The module prototype is dedicated as an intelligent readout controller during microstrip detector tests.

The main features of the module are as follows:

- 96002 Motorola DSP processor running at 33MHz for data processing,
- 56002 Motorola DSP processor running at 33MHz for input queue handling,
- 64k x 32 static memory, shared among the 96002 and VME,
- 32k x 32 of program memory and 32k x 32 of working memory connected to the 96002,
- two 64k x 32 static memory pages working as interface between 56002 and 96002,
- microcontroller (μC), responsible for booting the DSP and all "slow control" tasks on the board,
- exchangeable input daughterboard controlled by byte-wide bus directed by the microcontroller,
- 32k-deep 18-bit FIFO between the input daughterboard and the 56002.

Data flow goes from the input board, through the FIFO, the 56002, one of the memory pages, the 96002, to the shared memory. This memory shared between the 96002 and the VME interface is accessible directly from the VME.

The module is equipped with an exchangeable input board. The following types of input boards are considered:

- 1 analog input,
- 8 analog inputs,
- 16 digital inputs with selectable threshold level (TTL, ECL),
- mixed input: e.g. 1 analog + 5 digital inputs.

The input board is attached to the main board by two connectors:

- "fast" - with data bus, data enable signal and Acquisition Clock. The Acquisition Clock is used either as a convert signal for an ADC or as a clock for latching digital data. It can be delayed on the input board.
- "slow" - with extension of an 8-bit-wide bus of the μC for slow controls.

The prototype input daughterboard will be equipped with a 10-bit 18-MSPS ADC accompanied by a 12-bit DAC (for adjusting the DC level of input signal) and by a programmable delay generator (for trimming conversion timing). Four control signals are received at the module. These are:

- Acquisition Clock;
- Start of Event;
- Stop of Event;
- External Convert;

All control signals are differential at TTL level. The Start/Stop signals, together with the Acquisition Clock, are used for generating the two MSB's passed to the FIFO (event marking) and the FIFO "write" signal. The mechanism for skipping initial pulses and limiting event size is implemented in a programmable logic (Xilinx 4005). Event size and number of skipped pulses can be programmed (the μC or VME).

Short and fast procedure in the internal program memory of the 56002 transfers data from the FIFO to one of memory pages. "Stream oriented" calculations (calculating mean value and standard deviation, finding minimum and maximum value, event size and event numbering) are performed during this step.

The 96002 performs intensive computational tasks on events appearing in page memories and puts results in to the output memory, shared with VME. The 96002 has two-port architecture. Port B is connected to the shared memory and VME interface. Pages, program and working memory are on port A. On-chip program memory of the 96002, loaded by the microcontroller, should contain programs ("firmware") which make it possible:

- to access all memories on port A "through the chip",
- to manage pages properly,
- to load and execute user programs.

PADEL - Data Acquisition Package

E. Banaś and M. Kajetanowicz

The PADEL controls the operation and reads data from a multiparameter data acquisition system. CAMAC crate controlled by IBM PC/AT computer contains the following modules: a crate controller, Silena 4418/V analog-to-digital converter, Polon 712 analog-to-digital converter, 401 binary counter and a coincidence module. The data read from the detectors are sent via Ethernet to the VAX 4000/60 work station and written to the disk. Another IBM PC connected to the VAX by Ethernet is used for monitoring the collected data.

The tasks of the PADEL package are given below:

- loads configuration parameters from VAX file to PC memory and shows them on the screen,
- programs the CAMAC modules (coincidence module, ADC's and counters),
- starts the measurement,
- suspends and resumes data collection,
- stops the measurement.

The coincidence module and ADCs are programmed and counters are cleared at the beginning of the experiment. The coincidence module selects interesting coincidences and then the ADC's are read and an event is formed. The events are written to the file on the VAX disk. The counters are read both on user's demand and automatically at the end of the measurement. When data acquisition is suspended, the events in PC memory are automatically transferred to the VAX. During data acquisition, PADEL offers the basic file-handling functions like viewing the file or deleting it.

PADEL has been written in object-oriented C++ language. The Turbovision graphic library has been used to provide windows and menu system. The CAMAC crate controller used in the system is a custom design of the INP Electronics Laboratory.

Fig. 4 presents the logical structure of the PADEL package.
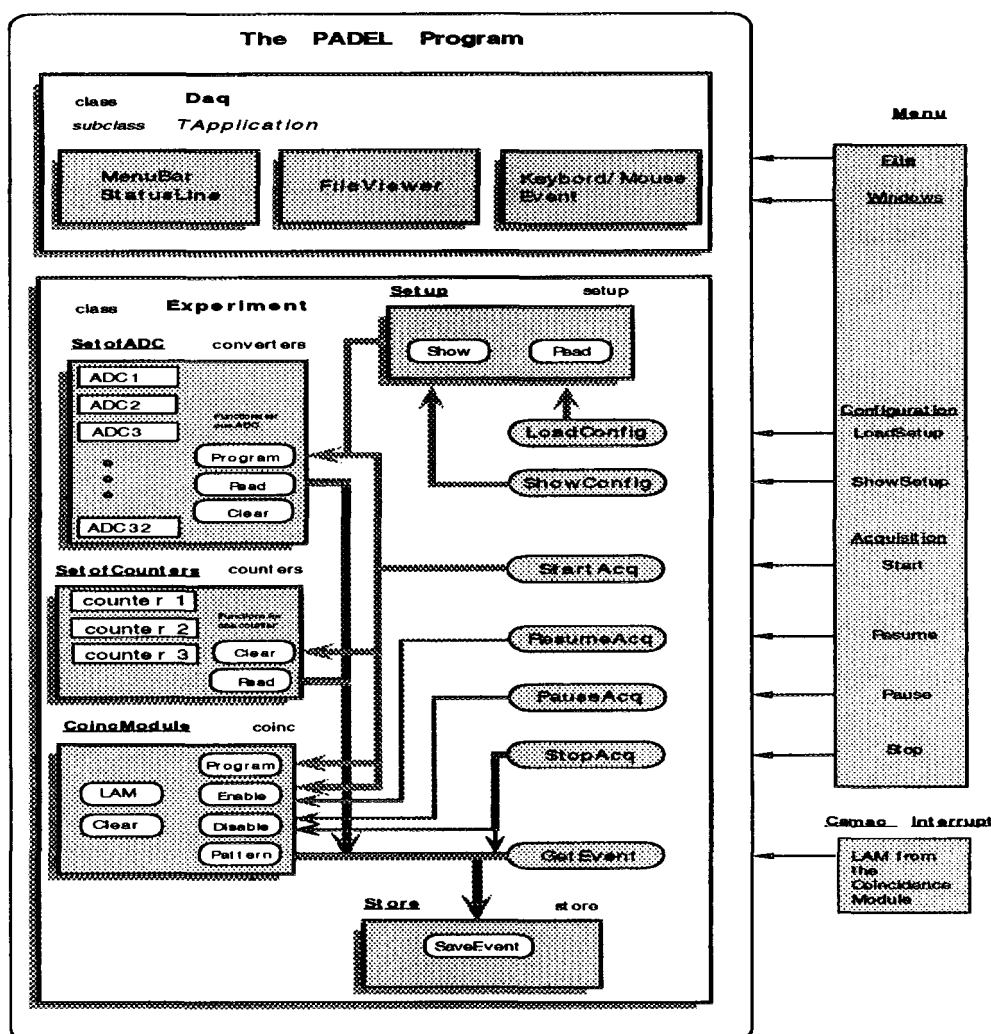
Figure 4: Logic structure of the PADEL package.

T-0 Board. Version 1.1

/ 2:

B. Dulny

T-0 Module is the main part of the LAr Calorimeter Trigger System.
Sampled and shaped signals are compared here with the programmed thresholds, and under
specified conditions the digital pulse called T-0 is given. This pulse is synchronized with the
HERA clock and is used later in the system as the first-level LAr Trigger.
The Module operates with 16 T-0 channels. They have one common Noise-threshold, one common Overflow-threshold and each of them has a separate Sigma-threshold. Sigma and Overflow thresholds are accessible as 8-bit digit registers and can be programmed from the VME-controlled system via Analog Crate Controller.
The Overflow threshold resolution is 1/256 out of 2.56 V Reference Voltage (e.g. 10 mV).
The Sigma-threshold resolution is 1/256 out of 640 mV Reference Voltage (e.g. 10 mV).

The internal comparator Reference Voltage is used as the Overflow-threshold Reference.
The Sigma-threshold Reference Voltage can be adjusted manually on the board as well as the Noise-threshold.
The module can be configured easily in 3 different modes used in the system. It can provide:

- 16 trigger signals (16 Trigger Tower = 16 TT) from 16 channels,
- 8 trigger signals (8 TT) from next 8 channels summed together,
- 4 trigger signals (4 TT) from next 4 channels summed together.

The operation of the T-0 Module is shown in the picture below.
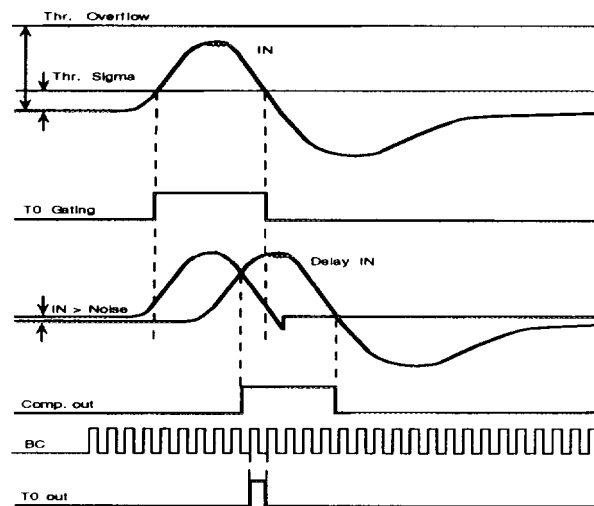
Figure 5: Principle of operation of the T-0 Module.

The shaped signal called "IN" is compared with the window thresholds, Sigma and Overflow. The output of this comparison is the gating pulse. The "IN" signal delayed by constant time is compared with the original "IN" signal. At the output of that comparator the crossing point fixed in time is obtained. The last step is to synchronize it with the HERA clock (BC) and normalize the width of every T-0 trigger pulse (one BC i.e. 96 ns). Time tolerance between 16 t-0 output signals is 5% of BC.

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   The 4th European Symposium & Exhibition on Semiconductor Engineering and Materials
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   Warsaw University of Technology, Warsaw, 25-28 April 1994;

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Ph.D. Thesis:

Adam Czermak
"Paskowe detektory krzemowe z elektroniką odczytu VLSI dla eksperymentów fizycznych"
("Silicon Strip Detectors with VLSI Readout Electronics for Experimental Physics").
Supervisor: Prof. Michał Turała.

M.Sc.E.E. Thesis:

1. Tomasz Mnich
   "Badania i ocena specjalnych układów VLSI dla odczytu informacji z detektorów półprzewodni-
   kowych"
   (Tests and Evaluation Specific VLSI Circuits for Readout of Semiconductor Detectors).
   Graduated with honours.

2. Wojciech Reklewski
"Układ do odczytu krzemowych detektorów paskowych oparty na procesorze DSP56001"
(The Readount Circuit for Readount of Silicon Strip Detectors Based on Processor DSP56001).
Graduated with honours.

3. Robert Szczygieł
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1.2 μm" (Design of 64 Words x 8 Bits FIFO Memory Integrated Circuit in 1.2 μm CMOS
Technology).

SHORT TERM VISITORS TO THE LABORATORY:

1. Jurgen Fent
Max PLanck Institut, Münich, Germany, February 1994;

2. Prof. Jean-Claud Bizot
Laboratoire de l'Accélérateur Linéaire, Orsay, France, May and December 1994;

3. Dr Masashi Hazumi
Osaka University and KEK Laboratory, Japan, November 1994;

4. Marcello Givoletti
Adriano Bigongiari
CAEN (Costruzioni Apparecchiature Eletroniche Nucleari S.p.A) Viareggio, Italy,
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Section XI

COMPUTING AND NETWORKS

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OVERVIEW:

Computing support and computer network are maintained by the Computing Group at the Institute's main site and the Electronic and Computing Group of the High Energy Physics Laboratory at Kawiory. This division is "geographical" and somewhat traditional but in 1994 members of both groups worked more closely than in the past, particularly as regards sharing responsibilities. The following working subgroups have formed:

- VAX/VMS support,

- UNIX Work Stations support,

- Local Area Network support

- Wide Area Network support,

- Object-Oriented Analysis, Design and Programming studying group.

In 1994 the activities of computer services were dominated by running Vax/VMS clusters, increasing the number of Unix Work stations, upgrading the Silicon Graphic Server Challenge L.

Local Area Network has been increased by installations of new ETHERNET lines. The total length of LAN exceeds 4 km. In addition, about 60 terminals are connected via serial lines. An important change in our Wide Area Network followed the decision to cut the leased line between Cracow and Geneva and to use the TCP/IP connection to the national academic and research network NASK.

Our two clusters of Vax servers and Vax stations continued running under the control of VMS operating systems. We are still using the leased 9600 bps telephone line as the main computer cluster connection between the Institute's main site and the HEP Laboratory at Kawiory. We run DECNET protocol and TCP/IP over it. This is certainly the weakest point of the system. Fortunately, the fiber optic line connecting the main location of the Institute to the Metropolitan

Area Network has recently reached our premises, and thus we hope to complete the project by Summer 1995.

The main computer server in the HEP Laboratory at Kawiory, SGI Challenge L, installed with the basic configuration of 2 processors and 128 MB RAM has been recently upgraded to 6 processors and 256 MB RAM. This upgrade nearly tripled its computational power. A further upgrade is planned. There are also new SGI Indy workstations installed with appropriate software tools. In the near future, Indys and Challenge will form a cluster, that is one virtual machine. For now, the NIS and NFS services are used for a more effective sharing of resources, e.g. disks, CD-ROMs, exabytes, printers etc. Installation of Network Queuing System is in progress.

Basic software tools like CERN program library and LaTeX were installed on the UNIX platform. Some other software products were installed and tested, in particular GNU Emacs working environment, GNU C and C++ compilers, interactive mail systems (elm and pine). For the purpose of WWW access, two WWW browsers - lynx and xmosaic were also successfully installed. The number of X terminals grew up as well. Appropriate software for X terminals was installed on some other UNIX machines.

Bugs and errors in the original configuration of UNIX machines were quickly detected and fixed. There was a serious security hole in the rlogin service, but the patch fixing this bug was provided by the SGI and applied immediately.

Hardware problems were very rare. The most serious one was disk failure which caused a system crash. Fortunately, the system was quickly brought up and there were no serious data loses.

Certain importance has been attached to the creation of the Object-Oriented Analysis, Design and Programming subgroup. Some earlier activities resulted in joining, by this group, a CERN R&D project dedicated to study Object-Oriented Persistency. It is assumed that the activity of this subgroup will allow us to be in touch with new world-wide accepted software technologies.

Section XI

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Ryszard Pyzioł	Maciej Rachwalik	Józef Rogowski
Roman Romanow	Andrzej Seweryn	Maciej Sowiński
Władysław Szwaja	Henryk Świerk	Zbigniew Toch
Zygfryd Trulka	Jerzy Wcisło	Ryszard Zając
Zbigniew Zasadzki	Bogusław Zięba	Jan Zwoliński

The Department of Mechanical Construction was established three years ago, joining the Design Group and the Central Mechanical Workshop.
The activity of the Department includes the following:

- designs of devices and equipment for experiments in physics along with their mechanical construction and assembly, particularly vacuum chambers and installations for HV and UHV,
- maintenance and upgrading of the existing installations and equipment in our Institute,
- participation of our engineers and technicians in design, equipment assembly and maintenance for experiments in foreign laboratories.

The Design Group is equipped with PC-486 microcomputers and AutoCad graphic software, its latest version (release 12) which allows making drawings and mechanical documentation meeting world standards. At the end of 1994 the latest version of ANSYS, a software for mechanical, heat and magnetic calculations using finite-elements methods was bought and will be applied in near future.
The Mechanical Workshop can offer a wide range of machining and treatment methods with satisfactory tolerances and surface quality. The services offered by our Mechanical Workshop include:

- turning – cylindrical elements of length up to 2000 mm and diameter up to 400 mm, and also disc-type elements of diameter up to 600 mm and length not exceeding 300 mm,
- milling – elements of length up to 1000 mm and gear wheels of diameter up to 300 mm,
- grinding – flat surfaces of dimensions up to 300 mm × 1000 mm and cylindrical elements of diameter up to 200 mm and length up to 800 mm,
- drilling – holes of diameter up to 50 mm,
- welding – electrical and gas welding in argon, vacuum-tight welding,
- soft and hard soldering,
- mechanical work including precision engineering,
- plastics treatment – machining, modelling, lamination of various shapes, polishing; technology of forming plexiglas and scintillators is under development,
- painting – paint spraying with possibility of using furnace-fired drier of internal dimensions of 800 mm × 800 mm × 800 mm.

Last year our department has been equipped with a welding machine enabling welding of elements for Ultra High Vacuum possible. At the end of 1994 we ordered a CNC milling machine that can be used for machining of elements up to 500 kg. The machine ensures the following tool movements: X - 1000 mm, Y - 500 mm, Z - 500 mm, controlled by HEIDENHAIN 407 Control System. Its start-up is planned for March '95.

In 1994 the Department of Mechanical Construction designed, manufactured and assembled equipment for the following laboratories:

1. Deutches Elektronen Synchrotron, Hamburg, FRG,
2. Paul Scherrer Institut, Villigen, Switzerland,
3. Joint Institute of Nuclear Research, Dubna, Russia,
4. Instituto Nazionale di Fisica Nucleare, Milano, Italy,
5. Niels Bohr Institute, Copenhagen, Denmark,
6. European Organization for Nuclear Research, Geneva, Switzerland,
7. Jagellonian University, Cracow,
8. Academy of Mining and Metallurgy, Cracow.

Jerzy Halik

REPORTS ON ACTIVITY:

In this report the most important installations and devices designed at manufactured at the Department of Mechanical Construction are shown. The description " Correlation Table for HECTOR – HELENA Multi – detector Array" concerning, the largest construction of 1994, is among the reports of the Department of Nuclear Spectroscopy.

Manipulator for Handling Read-out Chambers for the Main TPC of NA49 Experiment at CERN SPS

The aim of the NA49 experiment is to study interactions of 160 A GeV lead ions in search for the phase transition of nuclear matter to the quark-gluon plasma. The Main Time Projection Chamber (MTPC) is one of the most important components of the NA49 detector and consists of 2 × 25 read-out chambers, mounted in two 5 × 5 m^2 common frames. Each of the read-out chambers has dimensions of 720 mm × 720 mm × 150 mm and weight of about 70 kg. The process of putting these chambers in place into the MTPC frames is complicated and consists of the following sequence of steps:

- read-out chamber is positioned near the frame window to which it should be fastened,
- from this position it is lifted by about 500 mm,
- next it has to be rotated from horizontal to vertical position,
- then the chamber is rotated by 45 degrees around the vertical axis,
- afterwards it is moved in x- and y-directions to find its position exactly above the diagonal of the frame window,
- in this position the chamber is lowered by about 1100 mm through the window to the position in which the upper edge of the chamber is below the lower edge of the MTPC frame,
- subsequently the chamber is re-rotated by 45 degrees around the vertical axis,

- later it is re-rotated from vertical to horizontal position,
- finally, the read-out chamber is lifted to the edge of the frame window to which it is fastened using bolts and nuts; this step can also include some precise movements in x- and y-directions to ensure proper position of the chamber before fastening the screws.

A special device, called a manipulator (see Fig. 1), has been built for handling the read-out chambers during the assembly process to fulfil all the above-mentioned requirements. It has been designed, manufactured and assembled in our Department according to the general fore designs and the design of rotating head made at CERN. The manipulator is a light construction of a U-shaped carrying frame supported on base plate, of 2067 mm in height and 930 mm in width. It consists of four vertical columns connected with an upper plate. The rear hollow columns serve as supporting elements of the carrying frame only, while the front shafts are used simultaneously as guiding elements. One of the front shafts has a rack on its surface which ensures vertical movement of a movable frame carrying the rotating head to which the read-out chamber is fixed.

The movable frame is equipped with four precise ball-bushes surrounding the front shafts to ensure precise vertical movement. The horizontal elements of the movable frame play also a role of a driving screw (the upper one) and a guiding shaft (the lower one), thus enabling horizontal movement of the rotating head.
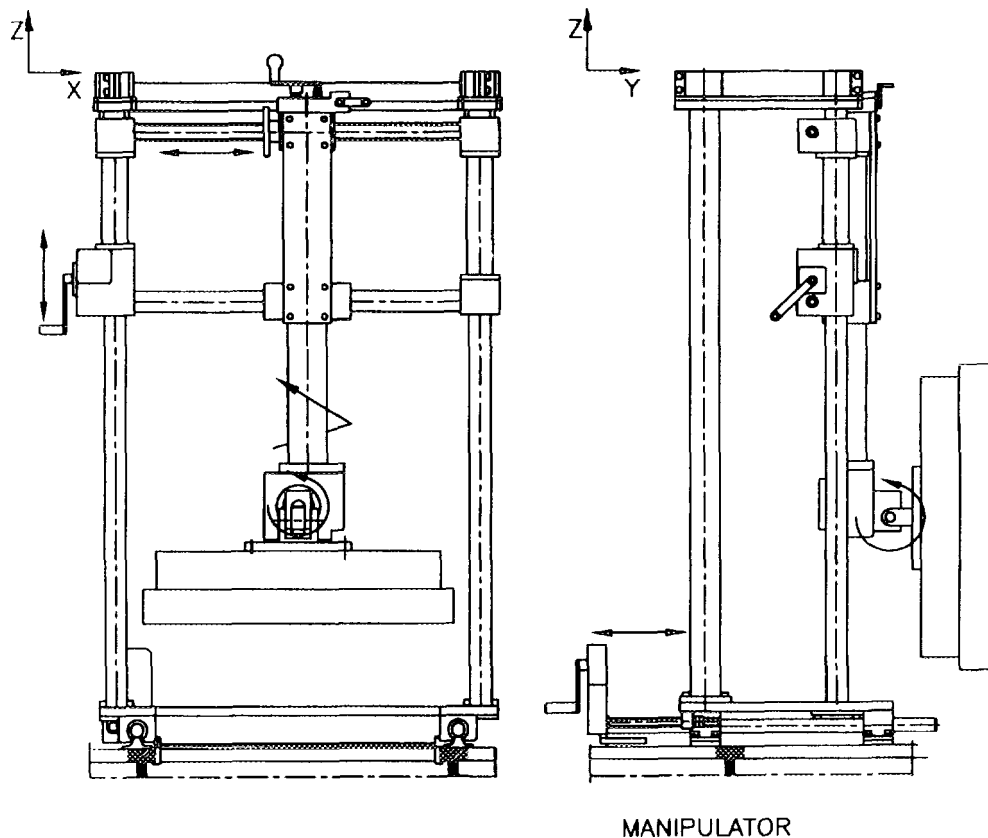
MANIPULATOR

Fig. 1 The manipulator for handling read-out chambers.

The horizontal screw and shaft support the rotating head by using a hollow housing which contains the shaft, driving the rotating head. The main frame together with the movable frame can be also moved perpendicularly to the horizontal movement of the movable frame by using precise ball-bushes fastened to the base-plate and supported by precise shafts.

All rotations and movements in x, y, and z axes are operated manually using two mechanisms of screw-and-nut type (x and y axes), a rack-and-pinion mechanism (z axis) and toothed segments driven by a worm gear. Precise guiding (shafts and ball-bushes) and driving mechanisms ensure the accuracy of positioning of ± 0.05 mm that is required in the assembly process of the MTPC.

Stand with Movable Targets for Experiment on Meson-Factory at PSI, Villigen

The project on "Time-Even Correlation in μ^--capture on Nuclei" is carried on in the collaboration between the Jagellonian University (Cracow); Eidg. Technische Hochschule (Zürich), Universite Catholique (Luvain-la-Neuve), Universite of Silesia (Katowice) and Paul Scherrer Institute (Villigen). The aim of the Factory Meson experiment at PSI, Villigen, is to extract pseudo-scalar form factor F_p from the longitudinal and average recoil nucleus polarization induced by the μ^--capture on ^{16}O.

For this purpose, a new version of a stand with movable targets has been designed and manufactured in our Department according to the fore designs of Assoc. Prof. K. Bodek from the Jagellonian University, the spokesman for the experiment.

Generally, the stand consists of two components: a base frame and a movable frame. The movable frame carries two replaceable target units which can be transferred with high speed from the Activation Stand to the β- Polarimeter. The distance between target centre is 1500 mm. The frame (together with the targets) moves periodically every 10 seconds and movement duration is about 0.5 second. While the first target is inside the β-Polarimeter, the other one remains inside the Activation Stand. The first target is placed between two coils which move together with it in order to keep the target in constant magnetic field during its journey from the Activation Stand to the β- Polarimeter.

The frames are light, welded constructions made of alu-alloy profiles. The movable frame has two toothed bars fastened to its lower part of length of 1650 mm, meshed with two gear wheels fastened to a driving shaft supported in the base frame by ball-bearings. The end of the shaft is coupled with an electric motor by using a universal joint. The toothed bars play simultaneously the role of elements guiding the movable frame during its fast movements. The grooves made on both sides of each bar engage the guiding rollers arranged every 405 mm along the movement path. The rollers are rotatable and supported in the base frame. The base frame supports also two magnetic coils 760 mm in diameter, which surround the target inside the Activation Stand. The movable frame is driven by a DC flywheel motor and its movement is controlled by a computer control system which ensures target positioning accuracy of 0.1 mm.

Magnetron for Depositing Thin Layers on Large Surfaces

The Chair of Electronics of the Academy of Mining and Metallurgy carries research and development work on "Studies on technology of thin-layer spraying on large surfaces by using a magnetron and tests of optical parameters" which forms a part of the grant "Development of glass panel (sheet) technology with coatings of controlled optical transmittance".

Within this work, three prototypes of a linear magnetron of dimensions 1360 mm × 280 mm have designed and manufactured in our Department. They are used for depositing thin layers of different metals and their compounds (oxides and nitrides) on substrates of large surfaces in ion sputtering process. In this process, ionized gas (Ar) kept under low pressure in electric field bombards a target and knocks out metal atoms which are then deposited on a substrate, creating a layer of required thickness (from 300 Å to 2000 Å).

The prototype consists of a long yoke to which magnet elements are glued. It is surrounded by

a light housing to which an upper cover and a lower one (the target and its clamping frame) are bolted. The frame (together with covers) defines a kind of pressure vessel filled with water under a pressure of about 5 bars and placed in vacuum chamber, where glass sheets are moved. The water stream inside the vessel is used for cooling the magnet yoke.

The magnetron is equipped with a yoke cooling system and cables supplying the yoke with electricity to create electric field. The upper cover of the magnetron is simultaneously a kind of a blind flange for the vacuum chamber.

Besides these large detectors and systems described above, some interesting designs have been made for the departments of our Institute.

Compensator of Coupling Loop Inductance for AIC 144 S Cyclotron

This device compensates the inductance of a coupling loop between the resonator and the high-frequency generator of AIC 144 cyclotron. The compensating element is a vacuum capacitor connected in series between the coupling loop and the feeder. The capacitor is placed in a housing equipped with clamping rings which engage electric outlets of the capacitor. Capacitance of the capacitor can be changed by using the adjusting rod engaged by a knob equipped with the position indicator, placed outside the housing.

Implantation Chamber

The implantation chamber is a part of the vacuum installation of 75 kV ion-implantation system working in IBAD geometry. The chamber has the following inlets:

- main beam inlet,
- spraying beam inlet,
- low energy beam inlet,
- analyzing beam inlet,

and a spectrometry track of backscattered particles. The target mechanism ensures the transfer of the target, its rotation about the main beam axis and a change of angle between the implantation surface and the implantation beam.

Furthermore, the following topics can be mentioned:

- Magnetic shielding for magnetic resonance investigations,
- Design and construction work for isochronic cyclotron AIC 144 S,
- Designs for the Van de Graaff accelerator.

Within the activity of the Department of High Energy Physics, our engineers participated in research work for the PHOBOS experiment on the RHIC accelerator at Brookhaven National Laboratory, and our technicians took part in assembly and maintenance for the H1 experiment at the HERA accelerator at DESY, Hamburg and the NA49 experiment at CERN.

We have also installed the ARGUS – FOBOS Intermediate Detector at JINR, Dubna, that was manufactured at our Department in previous year.

Section XI

ENERGY EFFICIENCY CENTRE

Head of Centre: *Assoc.Prof. Edward Obryk*
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OVERVIEW:

The main activities of the Energy Efficiency Centre (EEC) have been carried out within the framework of the Energy Efficiency Scheme (Poland), sponsored by the Government of Norway in close cooperation with Institutt for energiteknikk, Kjeller, Norway (IFE). EEC activities covered industrial sector, apartment and public buildings.

Knowledge and experience gained by the EEC staff during professional courses given by the Norwegian specialists and through practical activities allows us to establish EEC as a centre of competence and to extend its activities into promoting energy efficiency.

General experience shows that one obstacle in energy efficiency activities in Poland is lack of channels for dissemination of information. EEC, in collaboration with IFE, has started preparations for establishing the Industrial Energy Efficiency Network in Poland.

The EEC work in 1994 included:

- Energy Studies
- Housing Project
- Show-room
- Interactive Programme

ENERGY STUDIES:

In 1994 staff of the EEC carried out extensive energy studies for two dairies and one hospital with the assistance of Norwegian consultants. The Reports on the studies have been favourably reviewed by the Norwegian experts.

HOUSING PROJECT:

Monitoring of parameters related to the heat supply to the centrally-heated apartment building has been continued, supplying interesting information about the importance of modernizing the heating centre. The experience gained on this topic over the last two years has been the basis for the study on "Thermal Energy Management in Apartment Buildings" and the seminar organized by EEC for directors of apartment building cooperatives and managers of municipal building administrations.

SHOW-ROOM:

The Show-room serves as a place for meetings of professionals engaged in energy efficiency activities (e.g. seminars, conferences).

EEC has initiated activities addressed to the general public. Student excursions and organized exhibitions (e.g. "Energy Saving in Buildings" for the Open House at the Institute) have been received at the EEC Show-room. The booklet: "What is Worthwhile to Know about Energy" was written within these activities.
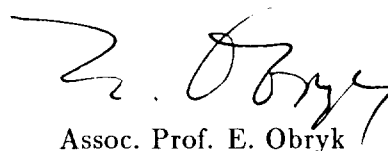
INTERACTIVE PROGRAMME:

EEC, in collaboration with IFE, has organized the Interactive Programme. The main objective of this Programme is to initiate energy efficiency activities in selected plants. Eleven companies from Cracow and its region, representing different industrial sectors, are participating in the Programme.

The Programme consists of four parts:

a) seminar for general managers,

b) seminar for energy managers,

c) collaboration of EEC specialists with individual companies,

d) seminar on financing energy efficiency projects in Poland.

The first part was organized in December 1994 and the rest will take place during the first quarter of 1995.

Assoc. Prof. E. Obryk

REPORTS ON STUDIES:

Thermal Energy Management in Apartment Buildings

Edward Obryk, Marek Ćwikilewicz, and Barbara Obryk

This is an extensive study published as Report COWE/S/1 (in Polish), Cracow, 1994. This study is intended to act as a practical manual which enables apartment building managers to make savings in energy expences. The Table of Contents may serve as a brief abstract.

Table of Contents

Company Energy Management and Energy Efficiency Measures

Marek Ćwikilewicz, Barbara Obryk, and Edward Obryk

This is an extensive study published as Report COWE/S/2 (in Polish), Cracow, 1994. This study is intended to act as a practical manual which enables of general managers companies to make savings in energy expenses. The Table of Contents may serve as a brief abstract.

Table of Contents

What is Worthwhile to Know about Energy

Barbara Obryk and Edward Obryk

This booklet has been written with the purpose of informing the general public about the possibilities to reduce energy expences at home through both technical and behavioural measures. It also contains general information on energy and environmental topics. The Table of Contents gives a good general idea about the booklet.

Table of Contents

Note to the reader
Introduction

- Exceptional status of energy among other resources

Energy in a household

- What we use energy at home for

    - space heating
    - domestic hot water
    - meal preparation
    - lighting
    - electrical appliances

- What energy carriers we use in our household

    - energy units
    - energy prices
    - energy conversion efficiency

- How to reduce energy consumption

    - improving the efficiency of converting delivered energy into useful energy
    - reducing heat losses in space heating

        * space heating and energy losses
        * main measures for reducing heat losses
        * simple ways to reduce heat losses
        * means for energy efficiency in new-built houses

    - producting hot water effectively and ways of saving it
    - changing the bad habits related to consumption of useful energy

        * bad habits related to hot-water consumption
        * wasteful and harmful habits related to meal preparation

    - optimizing the lighting
    - choosing and maintaining properly electrical domestic appliances

- How to control air exchange rate

Energy and Environment

- Energy sources and energy carriers
- Energy consumption and quality of life
- Individual efficient energy usage important to all
- Risks related to meeting the energy needs of mankind
- Risks connected with satisfying the energy needs of mankind
- Need for complex building designs

LIST OF PUBLICATIONS:

I. Reports:

1. E. Obryk, M. Ćwikilewicz, B. Obryk,

   "Thermal Energy Management in Apartment Buildings",

   Report COWE/S/1, Cracow, 1994, (in Polish);

2. M. Ćwikilewicz, B. Obryk, E. Obryk,

   "Company Energy Management and Energy Efficiency Measures",

   Report COWE/S/2, Cracow, 1994, (in Polish);

3. M. Ćwikilewicz, A. Jakubowski,

   "Energy Study Report for the Dairy "Krakowska Spółdzielnia Mleczarska" in Cracow",

   Report COWE/A/1, Cracow, 1994;

4. M. Ćwikilewicz, A. Jakubowski,

   "Energy Study Report for the Dairy "Okręgowa Spółdzielnia Mleczarska" in Cracow",

   Report COWE/A/2, Cracow, 1994;

5. M. Ćwikilewicz, A. Jakubowski,

   "Energy Study Report for the Hospital "Szpital Specjalistyczny im. J. Dietla" in Cracow",

   Report COWE/A/3, Cracow, 1994;

6. B. Obryk, E. Obryk,

   "What is Worthwhile to Know about Energy",

   Report COWE/P/1, Cracow, 1994, (in Polish).

II. Books:

1. E.Obryk, contribution to experts' report,
   "Kierunki Rozwoju Energetyki Kompleksowej w Polsce do 2001 r." (in Polish),
   Polish Academy of Science, Warsaw, 1994.

PARTICIPATION IN CONFERENCES AND WORKSHOPS:

E. Obryk

1. "Regional Energy Policy in Poland and European Union Countries Experience", Sosnowiec, Poland, 28-29 April 1994,
2. "Energy for the Future", Vision EUREKA, Lillehammer, Norway, 14-16 June 1994,
3. "Energy Management in Cracow", Cracow, Poland, 28 June 1994.

LECTURES AND COURSES:

E. Obryk,
"Energy and Environment", Academy of Agriculture, Cracow (postgraduate course).

SEMINARS FOR EXTERNAL PARTICIPANTS:

1. "Thermal Energy Management in Apartment Buildings",
   for apartment buildings' owners and administrators, 26 April 1994,
2. "Company Energy Management and Energy Efficiency Measures",
   for companies' general managers, 15 December 1994.

SHORT TERM VISITORS TO THE DEPARTMENT:

From Norway: From USA:

Thor Gulbrandsen   James R. Myers
Olof Karnell   John S. West
Paul R.A. Piché
Ole Veiby

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INP Author Index

INP AUTHOR INDEX: