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The Andrzej Sołtan
INSTITUTE FOR NUCLEAR STUDIES

ANNUAL REPORT 1996

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ANNUAL REPORT 1996

The Andrzej Sołtan INSTITUTE FOR NUCLEAR STUDIES

INSTYTUT PROBLEMÓW JĄDROWYCH im. Andrzeja Sołtana

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Zakład Graficzny Uniwersytetu Warszawskiego
zam. 350/97

CONTENTS

FOREWORD

The year 1996 was not an easy one for our Institute. The good scientific output, which we can show with certain pride, seems to defy the laws of economics. There were 214 articles published in international journals, 85 communications presented at conferences, several staff members were invited to give major presentations at international meetings, to chair sessions, to serve on advisory boards etc.

We can note a number of important scientific and/or technical results in each of the main subfields of our activity: in the elementary particle and the cosmic rays physics, in the nuclear physics in a wide energy range, from the lowest, of astrophysical interest through the extreme relativistic heavy ions, in the hot plasma physics, in the materials research and in the various measuring techniques, notably the detector development and the nuclear electronics. Brief resumes of these activities are given in this Report by the Department leaders. Here we can highlight only few examples. Thus we mention: the further predictions of the properties of the heaviest elements, the work which has last year brought the leader of the group, professor Adam Sobiczewski, the prestigious prize of the Polish Science Foundation; the theoretical work on the quantum approach to the classical formula of one body dissipation; the experimental work (within the CERN collaboration) on the deep inelastic scattering of muons, which has brought interesting information on the spin- dependent and spin-independent parton structure of free and bound nucleons; the work on the propagation of strange matter in the atmosphere; the project of a new accelerating structure for the medical accelerator COLINE; the work on the polarization of X-rays emitted in the Plasma-Focus systems; the already highly quoted work on measuring the absolute quantal efficiency of various scintillation materials; the highly promising work on the use of plasma technology for modifications of surfaces of various technically important materials; the patent on a method to measure the dose in the field of mixed n + gamma radiation; etc.

Our production unit ZdAJ (Establisment for Nuclear Equipment) has continued to serve the medical community with the installation of the COLINE accelerator in the hospital in Lublin and Simax simulator in the Oncological Centre in Łódź.

We note with satisfaction the progress with the k=160 cyclotron at the Heavy Ion Laboratory in Warsaw. One of the joint projects with the Warsaw University has been to transfer the isotope separator from Świerk and to put it on line at the cyclotron with the intention to study short lived neutron rich fission products.

Most of the work described throughout this Report has been carried out as joint efforts of various international collaborations. Along with the traditional strong involvement of our groups in several CERN projects we can list here the close contacts with the GSI Darmstadt (notably the pursuit of the heaviest elements and the high energy atomic physics), the traditionally good connections of the nuclear physicists with various French Laboratories (GANIL, Saclay, Orsay, Strasbourg), the strengthened ties with Rossendorf, the technical as well as scientific involvement in several large and medium scale European projects (EUROBALL, WASA, KASCADE, ... etc.). We also note with great satisfaction that one important new European facility has become operational: the superconducting cyclotron AGOR at the KVI in Groningen. We are looking forward to many a good piece of work together in the future, as it has been in the past.

One of the welcome side-effects of the international collaboration is the enrollment of foreign students, notably those from Ukraine, in our Ph.D. programme. This programme, supervised by professor Leszek Łukaszuk, has visibly gained momentum.

There were some setbacks. We have had to limit some of otherwise promissing activities because of the financial reasons, we had to reduce personnel and to take some other painful economic measures.

There were two very sad events. We, and with us the world science, have suffered the painful loss of two of our leading, internationally known scientists. On August 26 professor Ryszard Rączka, the Chairman of the Scientific Council of our Institute, has passed away leaving behind his graduate students, his unfinished research in the field theory, and the likewise unfinished reform of our Institute, which he had so strongly advocated.

Soon after, on September 6, we were mourning the equally untimely passing away of professor Jerzy Wdowczyk, worldwide known for his research on the cosmic radiation (especially the high energy components). Also in this case death has brutally interrupted a number of ambitious plans, projects, large scale international collaborations.

There were some organisational changes. The (second) term of office of one of us (W.R.) has ended on September 15. Professor Marian Jaskóła, the Deputy Director and the Editor of the many previous Annual Reports, has stepped down on the same date. It is the pleasant duty of both of us to use this opportunity to thank him for the many years of untired work for the good of the Institute.

One of the new initiatives at the Institute is the formation of the Department of Training and Consulting. Professor Ludwik Dobrzyński has undertaken the difficult task of creating this Department with the characteristic enthusiasm, zest and vision. We hope that this invigorating activity will provide a much needed connection with the educational system.

One of the lessons we have yet to learn is how to gain financial means from sources other than our main sponsor, the State Committee for Scientific Research. How to earn money, in plain words. We have to learn how to convince our potential industrial partners to use some advanced technologies which we can offer, how to sell our produce and services, etc. Noting that our Institute has an excess of the office and laboratory space in Świerk we have started a campaign to attract high-technology to move in. One possible measure to promote this process is to create a Special Economic Zone in Świerk, offering tax privileges etc. to those who would settle there.

May the year 1997 mark the turning point, after which the staff of our Institute will stop shrinking in numbers, will gain young blood and achieve new scientific successes.

Professor Wojciech Ratyński | Professor Ziemowid Sujkowski

I. GENERAL INFORMATION

The Andrzej Sołtan Institute for Nuclear Studies was formed on 1 January 1983 after partition of the former Institute of Nuclear Research (established in 1955).

It is named after Andrzej SOŁTAN, a pioneer of nuclear science in Poland.

The main site of the Institute is Świerk near Otwock, but some of its departments (P-I, P-VI, P-VIII) are in Warsaw, PL-00-681 Warsaw, 69 Hoża street, and one (P-VII) in the city of Łódź, PL-90-950 Łódź, 5 Uniwersytecka street.

The main fields of activity are: nuclear physics, elementary particle physics, plasma physics, accelerator physics and technology (notably accelerators for nuclear medicine), material research with nuclear techniques, the development of spectrometric techniques and of nuclear electronics, and also applied research (e.g. applications of the methods of nuclear physics to environmental research, nuclear medicine etc.).

Apart from the scientific departments, there is a separate production unit operating within the Institute, ZdAJ (the Establishment for Nuclear Equipment). The unit specializes in medical equipment, notably in the production of linear electron accelerators for oncology.

1. MANAGEMENT OF THE INSTITUTE *

Director	Professor Ziemowid SUJKOWSKI phone: (22) 779-89-48 e-mail sujkowsk@iriss.cyf.gov.pl
Deputy Director, Research and Development	Assoc.Professor Michał NADACHOWSKI phone: (22) 779-91-34
Deputy Director, Economy and Marketing	Assoc.Professor Zbigniew WERNER phone: (22) 779-91-62 e-mail p09zw@cx1.cyf.gov.pl
Scientific Secretary	Dr. Danuta CHMIELEWSKA phone: (22) 779-82-88 e-mail danka@iriss.cyf.gov.pl

* since September 17, 1996

until then:	Director:	Professor Wojciech Ratyński
	Deputy Director:	Professor Marian Jaskóła

2. SCIENTIFIC COUNCIL

The Scientific Council was elected on the 23rd of May 1995 by the scientific, technical and administrative staff of the Institute. The Council has the right to confer PhD and *habilitation* degrees in physics (DSc).

Chairman: Professor Ryszard Sosnowski *
Deputy Chairmen: Professor Marek Moszyński
Dr Tadeusz Kozłowski
Assoc.Prof. Stanisław Kuliński

* since September 1996

Representatives of scientific staff::

Helena Białkowska, Assoc.Prof.
Stanisław Gębalski, MSc.
Michał Gryziński, Assoc.Prof.
Andrzej Hilger, MSc.
Marian Jaskóła, Professor
Rościsław Kaczarowski, Assoc.Prof.
Leszek Łukaszuk, Professor
Stanisław Mrówczyński, Assoc.Prof.
Michał Nadachowski, Assoc.Prof.
Adam Nawrot, Eng.
Jerzy Piekoszewski, Professor
Jacek Pracz, MSc.
Stanisław Pszona, Dr
Ryszard Rączka, Professor †
Marek Sadowski, Professor
Adam Sobiczewski, Professor
Ziemowid Sujkowski, Professor
Andrzej Turos, Professor
Zbigniew Werner, Assoc.Prof.
Sławomir Wycech, Professor

† deceased 26 August 1996

Representatives of technical personnel:

Jerzy Bigolas, Eng.
Genowefa Fajkowska, Eng.
Edward Fronczak, technician
Andrzej Guliński, technician
Jan Kopeć, Eng.
Jacek Stanisławski, MSc.
Iwona Żawrocka, MSc.
Zbigniew Żero, Eng.

External members:

Andrzej Budzanowski, Professor - Institute of Nuclear Physics, Cracow
Andrzej Czachor, Professor - Institute of Atomic Energy
Tomasz Czosnyka, Assoc.Prof. - Heavy Ion Laboratory, Warsaw University
Jan Kownacki, Professor - Heavy Ion Laboratory, Kielce University
Ewa Skrzypczak, Professor - Institute of Experimental Physics, Warsaw University
Józef Tołwiński, Professor - Institute of Onkology, Warsaw
Andrzej K. Wróblewski, Professor - Institute of Experimental Physics, Warsaw University
Jan Żylicz, Professor - Institute of Experimental Physics, Warsaw University

3. DEPARTMENTS OF THE INSTITUTE

- DEPARTMENT OF NUCLEAR REACTIONS (P-I)
  Head of Department - Dr. Krzysztof RUSEK

- DEPARTMENT OF NUCLEAR SPECTROSCOPY (P-II)
  Head of Department - Dr. Tadeusz KOZŁOWSKI

- DEPARTMENT OF NUCLEAR ELECTRONICS (P-III)
  Head of Department - Professor Marek MOSZYŃSKI

- DEPARTMENT OF RADIATION SHIELDING AND DOSIMETRY (P-IV)
  Head of Department - Dr. Stanisław PSZONA

- DEPARTMENT OF PLASMA PHYSICS (P-V)
  Head of Department - Professor Marek SADOWSKI

- DEPARTMENT OF HIGH ENERGY PHYSICS (P-VI)
  Head of Department - Professor Joanna STEPANIAK

- DEPARTMENT OF COSMIC RADIATION PHYSICS (P-VII)
  Head od Department - Professor Jerzy GAWIN

- DEPARTMENT OF ATOMIC NUCLEUS THEORY (P-VIII)
  Head of Department - Professor Sławomir WYCECH

- DEPARTMENT OF RADIATION DETECTORS (P-IX)
  Head of Department - Professor Jerzy PIEKOSZEWSKI

- DEPARTMENT OF ACCELERATOR PHYSICS AND TECHNOLOGY (P-X)
  Head of Department - MSc Marian PACHAN

In addition to the research departments:

- DEPARTMENT OF TRAINING AND CONSULTING
  Director of Department - Professor Ludwik Dobrzyński tel.779-98-37

Semi-independent:

- ESTABLISHMENT FOR NUCLEAR EQUIPMENT (ZdAJ)
  Director, MSc Jacek PRACZ tel.779-87-22

and

- SERVICES AND TRANSPORT DIVISION (ZOIT)
  Director, Civ.Eng.Jerzy BABIK tel.779-82-03, Fax 048-22-779-82-44

4. SCIENTIFIC STAFF OF THE INSITUTE

PROFESSORS

1. DĄBROWSKI Janusz	Theoretical Nuclear Physics
2. DOBRZYŃSKI Ludwik	Solid State Physics
3. INFELD Eryk	Plasma Physics and Nonlinear Dynamics
4. JASKÓŁA Marian	Nuclear Physics
5. ŁUKASZUK Leszek	Particle Physics
6. MARCINKOWSKI Andrzej	Nuclear Physics
7. MOSZYŃSKI Marek	Nuclear Electronics, Technical Physics
8. NASSALSKI Jan	Particle Physics
9. PIEKOSZEWSKI Jerzy	Solid State Physics
10 . RATYŃSKI Wojciech	Nuclear Physics
11. RĄCZKA Ryszard †	Theory of Field and Particle Physics
12. SADOWSKI Marek	Plasma Physics
13. SIEMIARCZUK Teodor	Particle Physics
14. SOBICZEWSKI Adam	Nuclear Theory
15. SOSNOWSKI Ryszard	Particle Physics, Member of the Polish Academy of Sciences
16. SUJKOWSKI Ziemowid	Nuclear Physics
17. SZEPTYCKA Maria	Particle Physics
18. SZYMAŃSKI Zdzisław (**)	Theoretical Nuclear Physics
19. TURKIEWICZ Jan	Nuclear Physics
20. TUROS Andrzej	Nuclear Solid State Physics
21. WDOWCZYK Jerzy † †	Cosmic Ray Physics
22. WILCZYŃSKI Janusz	Nuclear Physics
23. WYCECH Sławomir	Nuclear and Particle Physics

† deceased 26 August 1996
†† deceased 06 September 1996

CONTRACT PROFESSORS

1. BŁOCKI Jan	Theoretical Nuclear Physics
2. GAWIN Jerzy	Cosmic Ray Physics
3. MOROZ Zbigniew	Nuclear Physics
4. ŻUPRAŃSKI Paweł	Nuclear Physics

ASSOCIATE PROFESSORS

1. BIAŁKOWSKA Helena	Particle Physics
2. DELOFF Andrzej	Particle Physics
3. FIRKOWSKI Ryszard (**)	Cosmic Ray Physics
4. GRYZIŃSKI Michał	Plasma Physics and Atomic Physics
5. GUZIK Zbigniew	Nuclear Electronics
6. KACZAROWSKI Rościsław	Nuclear Physics
7. KAZIMIERSKI Adam (**)	Electron Technology
8. KIEŁSZNIA Robert (**)	Accelerator Techniques and Physics
9. KULIŃSKI Stanisław	Accelerator Techniques and Physics
10 . MRÓWCZYŃSKI Stanisław	Particle Physics

11. NADACHOWSKI Michał	Nuclear Electronics
12. PIOTROWSKI Antoni	Technical Physics
13. RONDIO Ewa	Particle Physics
14. RONDIO Janusz	Nuclear Physics
15. SŁAPA Mieczysław	Solid State Physics
16. SOWIŃSKI Mieczysław (**)	Nuclear Physics
17. STEPANIAK Joanna	Particle Physics
18. SURA Józef	Accelerator Techniques and Physics
19. SZCZEKOWSKI Marek	Particle Physics
20. TRECHCIŃSKI Roman (**)	Nuclear Electronics
21. WERNER Zbigniew	Solid State Physics
22. WILK Grzegorz	Particle Physics
23. WÓJTOWICZ Stefan	Nuclear Electronics
24. WRZECIONKO Jerzy	Nuclear Theory
25. ZWIĘGLIŃSKI Bogusław	Nuclear Physics

RESEARCH ASSOCIATES (PhD)

1. ADAMUS Marek
2. AUGUSTYNIAK Witold
3. BIAŁKOWSKI Jacek (*)
4. BIELIK Mirosław
5. BIEŃKOWSKI Andrzej (*)
6. BOGDANOWICZ Jerzy (*)
7. BOUŻYK Jacek
8. CHMIELEWSKA Danuta
9. CZARNACKI Wiesław
10. CZYŻEWSKI Tomasz
11. DUDA-GŁOWACKA L.
12. FILIPKOWSKI Andrzej
13. GOKIELI Ryszard
14. GOLDSTEIN Piotr
15. GÓRSKI Maciej
16. HAHN Grzegorz
17. JAKUBOWSKI Lech
18. KOCIĘCKA-MECHANISZ K.
19. KORMAN Andrzej
20. KOZŁOWSKI Tadeusz
21. KULKA Zbigniew
22. KUPCZAK Radomir
23. KUPŚĆ Andrzej
24. LANGNER Jerzy
25. LUDZIEJEWSKI Tomasz (*)
26. MACISZEWSKI Wiesław
27. MARIAŃSKI Bogdan
28. MYSŁEK-LAURIKAINEN B.
29. PATYK Zygmunt
30. PAWŁOWICZ W. (**)
31. PIECHOCKI Włodzimierz
32. PŁAWSKI Eugeniusz
33. PŁÓCIENNIK Weronika
34. POCHRYBNIAK Cezary (**)
35. POLAŃSKI Aleksander
36. PREIBISZ Zygmunt
37. PSZONA Stanisław
38. RABIŃSKI Marek
39. ROŻYNEK Jacek
40. RUCHOWSKA Ewa
41. RURARZ Edward
42. RUSEK Krzysztof
43. RYMUZA Piotr
44. RZYMKOWSKI Krzysztof (*)
45. SANDACZ Andrzej
46. SENATORSKI Andrzej
47. SERNICKI Jan
48. SKALSKI Janusz
49. SKŁADNIK-SADOWSKA E.
50. SKORUPSKI Andrzej
51. SZABELSKA Barbara
52. SZABELSKI Jacek
53. SZYDŁOWSKI Adam
54. SZYMANOWSKI Lech (*)
55. SZYMAŃSKI Piotr
56. SZYMCZYK Władysław
57. TRZCIŃSKI Andrzej
58. WIŚLICKI Wojciech
59. WOJTKOWSKA Jolanta
60. WOLSKI Włodzimierz
61. ZABIEROWSKI Janusz
62. ZYCHOR Izabella

(*) on leave of absence
(**) part-time employee

5. VISITING SCIENTISTS

1	Chebotarev V.V.	Inst. of Plasma Physics, Kharkov, Ukraine	Jan.3 - Feb.16	P-V
2	Solyakov D.G.			
3	Pieczerski O.	NIIEFA, St.Petersburg, Russia	Jan.21 - 24	P-V
4	Kullander S.	University of Uppsala, Sweden	Jan.27 - 31	P-VI
5	Czernobrovin V.	NIIEFA, St.Petersburg, Russia	Feb.19 - 25	P-V
6	Rudczik A.	Inst. for Nuclear Research, Kiev, Ukraine	March 4 - 6	P-I
7	Momotiuk O.			
8	Skliarow W.	Inst. for Nuclear Research, Moscow, Russia	March 20 - April 19	P-VII
9	Stiepanow W.			
10	Garkusha I.	Inst. of Plasma Physics, Kharkov, Ukraine	March 15 - April 15	P-V
11	Makhlaj V.			
12	Janin A.F.	Inst. for Nuclear Research, Moscow, Russia	April 2 - May 21	P-VII
13	Walczenko W.I.			
14	Aleshin V.	Inst. of Nuclear Research, Kiev, Ukraine	April 25 - 28	P-II
15	Sidorenko B.			
16	Gherghescu R.	Inst. of Atomic Physics, Bucarest, Romania	April 16 - Sept.15	P-VIII
17	Gärtner K.	Friedrich Schiller Univ., Jena, Germany	April 24 - 27	P-I
18	Radvanyi P.	Lab. Nat. Saturne Inst. de Phys. Nucl., Orsay, France	May 10 - 14	P-I
19	Ramstein B.			
20	Farhi L.			
21	Hennino Th.			
22	Soyer M.			
23	Pavlichenko O.S.	Inst. of Plasma Physics NSC, Kharkov, Ukraine	May 15 - 18	P-V
24	Krupnik L.I.			
25	Tereshin V.I.			
26	Taran V.S.			
27	Makarenko V.	Kurchatov Inst. of Atomic Energy, Moscow, Russia	May 19 - June 2	P-II
28	Yu Pik-Pichak			
29	Landau R.	Oregon State Univ., USA	May 9	P-VIII
30	Glazunov G.	Kharkov Inst. of Technology, Ukraine	May 24 - June 23	P-V
31	Rudchik A.	Inst. for Nuclear Research, Kiev, Ukraine	June 10 - 22	P-I
32	Ziman V.			
33	Pouzo J.	IFAS, Tandil, Argentyna,	June 16 - July 7	P-V
34	Milanese M.			
35	Carrido F.	Centre de Spectr. Masse et Spectr. Nucleaire, Orsay, France	June 24 - July 7	P-I
36	Minfang LU	Inst. of Physics, ChAS, China	June 14 - 20	P-V
37	Savelov A.S.	State Engineering Physics Inst. Technical University, Moscow, Russia	June 17 - 22	P-V
38	Capdeville J.N.	Univ. of Bordeaux, France	July 5 - 19	P-VII
39	Klapdor-Kleingrothous H.V.	Max Planck Inst. Heidelberg, Germany	July 24 - Aug.1	P-VIII
40	Nioradze M.	JINR, Joint Inst. for Nuclear Research, Dubna, Russia	July 24 - Aug.1	P-VI
41	Kullander S.	University of Uppsala, Sweden	July 24 - Aug.3	P-VI

42	Garsevanishvili V.	Georgian Academy of Sciences, Georgia	July 24 - 30	P-VI
43	Dahmen U.	University of Siegen, Germany	July 24 - 31	P-VIII
44 45	Mazonka V. Aleshin V.	Inst. of Nuclear Research, Kiev, Ukraine	Aug.18 - Sept.1	P-II
46	Makarenko V.	Kurchatov Inst. of Atomic Energy, Moscow, Russia	Aug.31 - Sept.3	P-II
47 48	Garg U. Kharraja B.	Notre Dame, Indiana, USA	Sept.11 - 12	P-II
49	Lepone A.	Inst. de Fisica del Plasma (INFiP), Buenos Aires, Argentyna	Aug.25 - Sept.31	P-V
50	Świątecki W.	Lawrence Berkeley Laboratory, USA	Aug.28 - Sept.3	P-II
51	Jarzyński Ch.	Los Alamos, USA	Aug.29 - Sept.3 Sept.15 - Oct.28	P-II
52	Kretschmer R.	University of Siegen, Germany	Sept.16 - 29	P-VIII
53	Gudowski W.	Royal Inst. of Technology, Stockholm, Sweden	Sept.21 - 27	P-IV
54	Klamra W.	Royal Inst. of Technology, Stockholm, Sweden	Sept.30 - Nov.	P-III
55 56	Aleshin V. Sidorenko B.	Inst. of Nuclear Research, Kiev, Ukraine	Oct.6 - 19	P-II
57	Glazunov G.	Inst. of Plasma Physics., Kharkov, Ukraine	Oct.26 - Nov.11	P-V
58 59	Sun MU Li Bing	Inst. of Physics, ChAS, China	Oct.18 - 31	P-V
60 61	Voevodski A.V. Lidvanski A.S.	Inst. of Nuclear Research, Moscow, Russia	Nov.5 - 12	P-VII
62	Dołgov A.N.	Moscow State Engineering Physics Inst., Russia	Nov.3 - 30	P-V
63 64	Baronova E.O. Vichrev V.	Inst. for Nucl. Fusion RSC, Kurchatov Inst. Moscow, Russia	Nov.3 - 18	P-V
65	Cabot H.	University Perpignan, France	Nov.4 - 9	P-VII
66 67	Remnev G. Kowal N.	High Current Electronics Inst. Russian Academy of Sciences, Tomsk, Russia	Nov.18 - 22	P-V
68	Kirko D.L.	Moscow State Engineering Physics Inst., Russia	Nov.25 - Dec.18	P-V
69	Rudchik A.	Inst. for Nuclear Research, Kiev, Ukraine	Nov.28 - Dec.4	P-I
70	Ziman V.	Inst. for Nuclear Research, Kiev, Ukraine	Nov.24 - Dec.14	P-I
71	Uzhinski V.	JINR, Joint Inst. for Nuclear Research, Dubna, Russia	Nov.19 - 30	P-IV
72	Bětak E.	Inst. of Physics of the Slovak Academy of Sciences, Bratislava, Slovakia	Nov.18 - 23	P-II
73 74	Czerniajew A.B. Stenkin J.V.	Inst. of Nuclear Research, Moscow, Russia	Dec.3 - 18	P-VII
75	Günzel R.	Research Center Rossendorf Inc. Germany	Nov.25 - Dec.10	P-IX
76	Parfenov A.N.	JINR, Inst. for Nuclear Research, Dubna, Russia	Nov.27 - Dec.11	P-VI
77	Kretschmer R.	University of Siegen, Germany	Dec.9 - 16	P-VIII
78	Kullander S.	University of Uppsala, Sweden	Nov.27 - 29	P-VI

6. GRANTS

LIST OF RESEARCH PROJECT (GRANTS) REALIZED IN 1996

1. INVESTIGATION OF NON-EQUILIBRIUM EMISSION OF NUCLEONS AND COMPLEX PARTICLES IN FUSION-LIKE REACTIONS WITH HEAVY IONS
   Principal Investigator: **Professor J.Wilczyński**
   Grant No. 2 P302 211 04

2. STUDIES OF THE Δ- RESONANCE EXCITED ON NUCLEONS OF ATOMIC NUCLEI BY THE (^{3}He,t) REACTION USING THE SATURN ACCELERATOR IN SACLAY
   Principal Investigator: **Professor P.Żuprański**
   Grant No. 2 P302 04604

3. PHOTON FIELD ANALYSIS FOR AIR MONITORING OF A CONTAMINATED AREA
   Principal Investigator: **MSc K.Wincel**
   Grant No. 0 S001 013 04

4. INTERACTIONS OF HIGH ENERGY PARTICLES AND IONS WITH ATOMS OF HEAVY ELEMENTS
   Principal Investigator: **Professor Z.Sujkowski**
   Grant No. 2P 302 119 0710

5. THE DESIGN OF NEW-TYPE MULTICHANNEL CERENKOV DETECTORS TO ANALYSE ELECTRON FLUX FROM HIGH-TEMPERATURE PLASMA
   Principal Investigator: **Dr L.Jakubowski**
   Grant No. 2P 302 058 06

6. MONITORING OF THE GROUND LEVEL AIR POLLUTION USING THE ASS-500 AIR SAMPLER AND NATURAL BIOINDICATORS OF RADIOACTIVE AND INDUSTRIAL CONTAMINATION OF FOREST ECOSYSTEMS
   Principal Investigator: **Dr B.Mysłek-Laurikainen**
   Grant No. 4S 40107207

7. ELABORATION OF METHOD FOR FORMATION OF INTERMEDIATE LAYERS (Ti) UPON MELTED LAYERS (Ti N) WITH MODIFIED PLASMA GUN
   Principal Investigator: **Dr J.Kuciński**
   Grant No. 7T 08C00708

8. CHANNELING STUDY OF SEMICONDUCTOR CRISTALS CONTAINING POINT DEFECTS AND EPITAXY LAYERS
   Principal Investigator: **Professor A.Turos**
   Grant No. 2 PO3B17509

9. PROPERTIES OF RADIOACTIVE NUCLEI
   Principal Investigator: **Professor A.Sobiczewski**
   Grant No. 2 PO3B15608

10. STUDY OF MULTIPLE IONIZATION PROCESSES WITH HIGH RESOLUTION CRYSTAL SPECTROMETERS
    Principal Investigator: **Professor Z.Sujkowski**
    Grant No. 2 PO3B02709

11. STRUCTURE OF DOUBLE MAGIC NUCLEI AROUND 56Ni AND 100Sn AND POPULATION AND DE-EXCITATION HIGH SPIN STATES
    Principal Investigator: **Professor Z.Sujkowski**
    Grant No. 2P 03B04709

12. NONEQUILIBRUM QUANTUM FIELDS
    Principal Investigator: **Assoc. Prof. St.Mrówczyński**
    Grant No. 2P 03B19509

13. EXPERIMENTAL STUDIES ON THE CP BREAKING IN THE DECAY OF K^0 MESONS
    Principal Investigator: **Assoc. Prof. E.Rondio**
    Grant No. 2P 03B09110

14. INVESTIGATION OF THE HEAVY ION DYNAMICS
    Principal Investigator: **Professor J.Błocki**
    Grant No. 2P 03B14310

15. INVESTIGATION OF RARE DECAYS AND MESON PRODUCTION MECHANISM IN THE WASA EXPERIMENT
    Principal Investigator: **Assoc. Prof. J.Stepaniak**
    Grant No. 2P 03B07910

16. A MODEL FOR FUNDAMENTAL INTERACTION OF ELEMENTARY PARTICLES WITH NO HIGGS PARTICLE INVOLVED
    Principal Investigator: **Professor E.Kapuścik**
    Grant No. 2P 03B18310

17. K_α HYPER-SATELITE X-RAYS SPECTRA OF MEDIUM Z ATOMS IONIZED BY ENERGETIC HEAVY IONS
    Principal Investigator: **Dr. P.Rymuza**
    Grant No. 2P 03B00711

18. DEVELOPMENT OF THE METHOD OF THE MEASUREMENT OF PLASMA-PULSE SHAPE IN THE MW ENERGY RANGE
    Principal Investigator: **Assoc. Prof. Z.Werner**
    Grant No. 703/T10/96/11

19. OPERATION AND IMPROVEMENT OF THE C-30 CYCLOTRON OF THE SOLTAN INSTITUTE FOR NUCLEAR STUDIES
    Principal Investigator: **Dr. J.Wojtkowska**
    Grant (SPUB) No. 621/E-78/SPUB/P3/211/94

20. PARTICIPATION IN THE DELPHI EXPERIMENT
    Principal Investigator: **Professor R.Sosnowski**
    Grant (SPUB) No. 621/E-78/SPUB/P3/210/94

21. MEASUREMENTS OF THE NUCLEAR STRUCTURE FUNCTIONS G_1,F_2 AND R IN NMC AND SMC EXPERIMENTS
    Principal Investigator: **Professor J.Nassalski**
    Grant (SPUB) No. 621/E-78/SPUB/P3/209/94

22. CONTRIBUTION TO EU 1525 SUBLATO PROJECT (SURFACING OF BLANKING TOOLS)
    Principal Investigator: **Assoc. Prof. Z.Werner**
    Grant No. 621/E-78/SPUB-EUREKA/T-08/DZ012/96/97

In addition to the above, several of our scientists are principal investigators in grants co-ordinated by other Warsaw institutions.

LIST OF RESEARCH PROJECTS GRANTED BY INTERNATIONAL ORGANIZATIONS

1. EXOTIC SHAPES OF NUCLEI
   Principal Investigator: **Assoc. Prof. R.Kaczarowski**
   Maria Skłodowska-Curie Joint Fund II (USA-PL)
   Grant No. PAA/DOE-93-153

2. TRANSEUROPEAN MOBILITY PROGRAMME FOR UNIVERSITY STUDENTS (TEMPUS)
   Principal Investigator: **Assoc. Prof. J.Stepaniak**
   Contract No. JEP-4329-92/1

3. SPECIFICATION OF RADIATION QUALITY AT NANOMETER SCALE
   Principal Investigator: **Dr. S.Pszona**
   Grant No. ERB CI PDCT 930407; ERB F13 PCT 920041

4. TECHNICAL DOCUMENTATION OF SCINTILLATING DETECTOR UNITS, TECHNOLOGY OF THE PRODUCTION PROCESS OF THE DETECTOR COMPONENTS
   Principal Investigator: **Assoc. Prof. J.Stepaniak**
   WASA Collaboration Uppsala, No. 535, S-75121

5. UNTERSUCHUNG VON ELEMENTARTEILCHEN UNDER HOHEN BARYON - UND ENERGIEDICHTEN
   Principal Investigator: **Professor T.Siemiarczuk**
   Polish-German Foundation Grant No. 1151/94/LN

6. S SEMI-EMPIRICAL THEORY OF NUCLEAR DYNAMICS
   Principal Investigator: **Professor J.Błocki**
   Grant No. PAA/NSF-96-253

7. EUROBALL III - CONSTRUCTION OF A EUROPEAN GAMMA-RAY FACILITY
   Principal Investigator: **Professor Z.Sujkowski**
   Contract No. ERBCIPDCT 940029

8. HERA COUPLER (DESIGN OF TWO TYPES OF MODIFIED HERA INPUT COUPLERS AND TECHNOLOGICAL DESIGN AND PRODUCTION OF CERAMICS WINDOWS
   Principal Investigator: **Professor S.Kuliński**
   Agreement of cooperation between DESY and Institute for Nuclear Studies, 10 May 1995

7. SCIENTIFIC DEGREES

PhD theses

1. JAN KACZANOWSKI, DEPARTMENT P-I
The channeling studies of GaAs crystals containing point defects, precipitates and crystal layers.

2. TOMASZ LUDZIEJEWSKI, DEPARTMENT P-II
The study of multiple inner shell ionization processes by means of high resolution X-ray spectroscopy.

3. JAROSŁAW BARANOWSKI, DEPARTMENT P-V
Influence of experimental conditions on ion-plasma fluxes emission in RPI devices.

4. MARIAN KOWALSKI, DEPARTMENT P-V
A comparison of quantum, semiclasical and clasical methods of the descripton of p + H and e^+ + H, e^- +He collisions.

5. MICHAŁ SZLEPER, DEPARTMENT P-VI
Precision measurement of the structure function ratio F^{Sn}_2 / F^{C}_{2n}.

6. ROBERT SMOLAŃCZUK, DEPARTMENT P-VIII
Properties of heaviest atomic nuclei.

DSc theses

1. ZBIGNIEW KULKA, DEPARTMENT P-III
Some important aspects of the amplitude, charge and shape analog signals digitization in nuclear physics experiments.

2. ANDRZEJ SANDACZ, DEPARTMENT P-VI
Production of vector mesons in deep inelastic scattering.

3. JANUSZ SKALSKI, DEPARTMENT P-VIII
The effects of reflection symmetry in atomic nuclei.

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II. REPORTS ON RESEARCH

1. DEPARTMENT OF NUCLEAR REACTIONS

Head of Department: Dr. Krzysztof Rusek
phone: 6213829
e-mail: rusek@fuw.edu.pl

Overview

Research activities of the Department concentrated in 1996 on nuclear, atomic and material physics.

As far as the nuclear physics research programme is concerned the collaboration with GSI Darmstadt and CEA Saclay yielded various new results.

Activities within the ALADIN collaboration at GSI concentrated on the dependence of temperature on the excitation energy (caloric curve) for highly excited nuclear matter, following the discovery of the liquid - gas phase transition by this collaboration in 1995. The Z_{bound} universality obeyed by the fragment multiplicities and correlations, observed in the multifragment decays of ^{129}Xe, ^{197}Au and ^{238}U projectiles in collisions with Be, C, Al, Cu, In, Au and U targets at energies between 400 and 1000 MeV/nucleon, strongly suggested that the decaying pre-fragment is a relatively long-lived object in thermal equilibrium (experiment S114). This conclusion justified applicability of thermodynamic concepts, such as phase transition, to the finite nuclear systems. The results of experiment S117, devoted to a comparative study of different methods of thermometry, revealed an unexpected disagreement between the measurements of the temperature using the isotope and the population-ratio methods.

The SPES4-π large detection system was completed and put into operation. Using this detection system, the first exclusive experiments on the emission of coherent pions in the charge-exchange reactions and the excitation of the Roper resonance were carried out.

The light ion reaction mechanism was investigated in collaboration with INR Kiev and INP Kraków. Analysis of experimental data from multi-nucleon transfer reactions induced by a 50 MeV deuteron beam on ^6Li was completed. The results suggest an important role of the two-step transfer processes in the reactions.

The charge-exchange reaction $^{28}Si(n,p)$ was experimentally studied at 18.5 MeV. Fast neutrons were generated in the $^3H(d,n)^4He$ reaction induced by the 2 MeV deuteron beam from the 3 MV Van der Graaff accelerator at the Department.

In collaboration with Florida State University (FSU) and the University of Birmingham, the breakup of $^{6,7}Li$ was investigated at many energies around the Coulomb barrier. The experiment was performed at FSU.

Two and three nucleon transfer reactions were experimentally studied in collaboration with Milano, Padova, München and Tübingen Universities in order to investigate homology states in ^{88}Y and Sn isotopes.

Apart from nuclear physics experiments, the 3 MV Van der Graaff accelerator was extensively used for ion beam analysis of solid states. The Rutherford Backscattering Spectroscopy and channeling methods were successfully applied for various materials. The lattice localisation of Er atoms doped in Si and GaAs crystals was investigated. Galium nitride (GaN) single crystals produced by high pressure in the Centre of the Polish Academy of Science were studied. Different types of semiconductor heterostructures were also investigated. A wide collaboration with the Institute of Electronic Materials Technology has to be acknowledged.

Atomic physics studies were performed in collaboration with the Pedagogical University of Kielce, Basel University and the University of Erlangen. Cross sections for M,L-shell ionization of Th, U, Bi and Au atoms were measured in experiments with S ions accelerated up to 41.6 MeV, using the tandem accelerator at the University of Erlangen. The analyses of present and previous data indicate that, ion charge equilibrium in the target and multiple ionization, play an important role in L- and M - shell ionization of atoms induced by heavy ions.

REPORTS ON RESEARCH

1.1 Liquid - gas phase transition in finite nuclear systems

The ALADIN Collaboration at GSI - Darmstadt
by A.Trzciński and B.Zwięgliński

The Collaboration activities were aimed at answering a broad range of questions raised by the discovery of the liquid-gas phase transition in 1995 [1]. This was inferred from the temperature vs excitation energy dependence (caloric curve) measured for the *projectile residues* in the Au + Au collisions at 600 MeV/u (experiment S114). The first question is related to thermal equilibrium. Multifragment decays of ^{129}Xe, ^{197}Au and ^{238}U projectiles in collisions with Be, C, Al, Cu, In, Au and U targets at energies between 400 and 1000 MeV/u have been studied with the ALADIN forward spectrometer at SIS. The dominant feature of the systematic set of data is the Z_{bound} universality that is obeyed by the fragment multiplicities (see Fig. 1) and charge correlations [2]. This finding provides a strong argument in favour of the hypothesis that the multifragmenting projectile residue is a relatively long - lived object, most probably in thermal equilibrium - a conclusion justifying the applicability of thermodynamical concepts, such as phase transition, to finite nuclear systems.

The temperature determination in [1] was based on *measurements of the double* ratio of ($^3He/^4He$)/($^6Li/^7Li$) isotope yields (He - Li thermometer). A dedicated experiment S117 was run in 1995 to compare this $T_{He\text{-}Li}$ with temperatures obtained using alternative methods. The experimental set up employed three hodoscopes of closely packed Si - CsI(Tl) telescopes, consisting altogether of 216 individual units to infer temperature from the measurement of the population ratio of ^5Li unstable resonances $^5Li_{16.66}/^5Li_{gs}$ with the aid of particle interferometry. Moreover, a set of seven four - element telescopes, placed at selected angles, measured the yields of isotopically resolved light fragments ($Z \leq 3$), which were combined into double ratios giving the temperatures $T_{He\text{-}Li}$, $T_{He\text{-}pd}$ and $T_{He\text{-}dt}$. Collisions of Au + Au were studied at 1 GeV/u to investigate *target spectator* decays following peripheral and mid - central collisions, and at 50, 100, 150 and 200 MeV/u in order to examine central collisions which are known to exhibit a considerable collective flow.

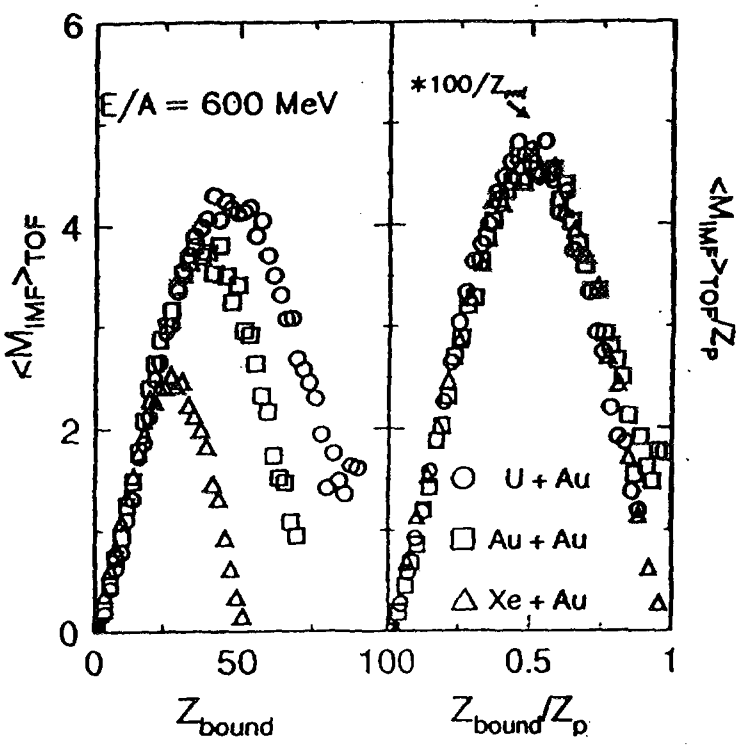

Fig.1 Universality (right panel) of the mean fragment multiplicity, when expressed in terms of the reduced variables $<M_{IMF}>/Z_p$ vs Z_{bound}/Z_p

Break up temperatures $T_{He\text{-}Li}$, $T_{He\text{-}pd}$ and $T_{He\text{-}dt}$ at 1000 MeV/u were found to be in agreement with $T_{He\text{-}Li}$ measured at 600 MeV/u in S114 [1] for the projectile residue at excitation energies corresponding to the liquid - gas coexistence. For the region of gas phase the agreement is less satisfactory with $T_{He\text{-}dt}$ not following the rise of the former two temperatures with excitation energy. Unexpectedly enough, the temperatures measured with the population ratio method show rather constant values at a low level of around 4 - 5 MeV, independent of the excitation energy both in the central collisions in the 50 - 200 MeV/u range and in the peripheral collisions at 1000 MeV/u. These results were presented at the Conference [3,4], attracting considerable interest. Collisional deexitation of the 16.66 MeV level in ^5Li by nucleon impact is suggested as the possible reason of temperature underestimation with the latter method (Bondorf et al).

The SINS team advanced the work on the Monte - Carlo code MSX, used to simulate the neutron detection process in a large - volume, Gd - loaded, liquid scintillation detector [5]. This detector is planned to be used in the forthcoming experiment to determine the excitation energy of the *target residue* by combining the measurements of neutron and light charged - particle multiplicities.

[1] J.Pochodzalla, ..., A.Trzciński, ..., B.Zwięgliński, Phys. Rev. Lett. 75 (1995) 1040
[2] A.Schüttauf, ..., A.Trzciński, ..., B.Zwięgliński, Nucl. Phys. A607 (1996) 457
[3] G.Imme, ..., A.Trzciński, ..., B.Zwięgliński, Proc. of the 1st Catania Relativistic Ion Studies: Critical Phenomena and Collective Observables, Acicastello (Italy), May 27-31, 1996 (submitted for publication)
[4] J.Pochodzalla, ..., A.Trzciński, ..., B.Zwięgliński, *ibid.* (submitted for publication)
[5] A.Trzciński and B.Zwięgliński, Proc. of the XXXI Zakopane Summer School, *Physics*, Sept. 3 - 11, 1996, Acta Phys. Polon. B (in press).

PL9800587

1.2 Study of coherent pion emission using the SPES4-π detection system*

by W.Augustyniak and P.Żupranski for the SPES-π Collaboration[1)]

Measurements of coherent pion emission in the charge exchange (^{3}He,tπ^+) reaction on ^{12}C, ^{40}Ca and ^{208}Pb targets have been carried out [1]. The experiment is to answer the question whether the following picture of the reaction holds: An off the mass shell pion produced in a charge exchange reaction initiates a chain of Δ - hole states propagating the excitation energy throughout a nucleus. As a result of the Δ - hole correlations, the virtual pion can be brought onto the mass shell and will appear as a real pion with the residual nucleus taking up the recoil and being left in its ground state. Angular distribution of the emitted pions reflects the structure of the vertex of the primary interaction producing a virtual pion. The Δ - hole correlations in the spin longitudinal channel have a structure $\vec{S}\cdot\vec{q}$ ($\vec{S}$ is the spin operator of the nucleon - Δ transition, N $\rightarrow$ Δ), the Δ decay has a structure ($\vec{S}^+\cdot\vec{p}_\pi$). Angular distribution of the emitted pion will then have a structure ($\vec{S}\cdot\vec{q}$) $\cdot$ ($\vec{S}^+\cdot\vec{p}_\pi$) $\rightarrow$ ($\vec{p}_\pi\cdot\vec{q}$), i.e. it will be strongly peaked along the transferred momentum $\vec{q}$. The energy loss spectrum corresponding to the coherent pion emission reflects the collectivity of the spin - isospin excitations propagating throughout the nucleus. An attractive Δ - hole potential in the spin longitudinal channel will soften the spectrum, i.e. it will move it towards smaller energy losses.

In the experiment the excitation energy of the residual ^{12}C nucleus was determined with an accuracy (FWHM) of about 5 MeV, which was not good enough to separate the ground and first excited state of ^{12}C. Preliminary analysis of the data shows a softening of the energy loss spectrum pointing to an attractive potential of the Δ - hole interaction. Work on a better reconstruction of pion and triton momenta resulting in an improved resolution of the residual nucleus excitation energy is under way.

[1] L.Fahri, ..., W.Augustyniak, ... and P.Żupranski, Acta Phys. Pol. B27 (1996) 3035

1) The SPES4π Collaboration comprises the following institutions: Laboratoire National Saturne, France; Institut de Physique Nucleaire, France; Niels Bohr Institute, Denmark, Saint Petersburg Nuclear Physics Institute, Russia; Soltan Institute for Nuclear Studies, Poland

* This work was supported in part by the Polish Committee for Scientific Research under Grant No 2P302 04604 and the French-Polish Convention IN2P3 - Polish Laboratories

PL9800588

1.3 Collective excitations in inelastic neutron scattering

by A.Marcinkowski, B.Mariański, P.Demetrion[1)], P.E.Hodgson[1)]

It was found that realistic effective interaction provides multistep direct reaction cross sections (MSD) which are too low to fit the experimental (n,xn) reaction data. The shortfall was ascribed to the strong isoscalar collective contributions to the continuum of states. This conjecture was confirmed by detailed calculation of the cross sections for excitation of surface vibrations of various multipolarities including the giant resonances thus showing that (n,xn), (p,xn) and (n,xp) reactions can be described in a fully consistent way. This result implies that the direct reaction exciting collective vibrations of the nucleus constitutes a new reaction type. These collective reactions contribute throughout the entire spectra of scattered nucleons and show angular distributions that differ from the angular distribution of the MSD reactions. They can be extended to include two-phonon excitations and viewed as a separate preequilibrium reaction mechanism [1,2]. This is the fourth type of reaction besides the incoherent MSD, the multistep compound (MSC) and compound nucleus (CN) reactions that contribute to nucleon scattering.

[1] A.Marcinkowski, B.Mariański, P.Demetrion, P.E.Hodgson, Phys Rev.C52 (1995) 2021

[2] P.Demetrion, A.Marcinkowski, P.E.Hodgson, Nucl. Phys. A596 (1996) 67

[1] University of Oxford, Nuclear Physics Laboratory, Oxford OX1 3RH

1.4 Channel couplings in the ^{9}Be + ^{12}C interaction at E(^{12}C) = 65 MeV

by L.Głowacka, J.Turkiewicz, A.T.Rudchik[1], O.A.Momotyuk[1], V.K.Chernievsky[1], A.V.Mokhnach[1], E.I.Koshchy[2], A.Budzanowski[3], A.Szczurek[3], R.Siudak[3], I.Skwirczyńska[3]

Angular distributions of elastic and inelastic scattering of ^{12}C ions by ^{9}Be nuclei were measured in the large angular range at the energy of 65 MeV for the transitions to the ground and 2.429 MeV ($5/2^-$) + 2.8 MeV ($1/2^-$) excited states of ^{9}Be and 4.439 MeV (2^+), 9.641 MeV (3^-) excited states of ^{12}C. The experimental data were analyzed using the coupled reaction channels (CRC) model. This model includes elastic and inelastic scattering, the spin target reorientation process and one- and two-step cluster transfers. It was found that the channel couplings strongly modified the elastic scattering cross section at large angles. The experimental distribution of the elastic scattering together with the CRC calculations (solid line) is shown in the figure, where: <OM>, <reor>, <^{3}He> and <pd + dp> denote the optical model, spin target reorientation process, one-step transfer and two-step transfers, respectively.

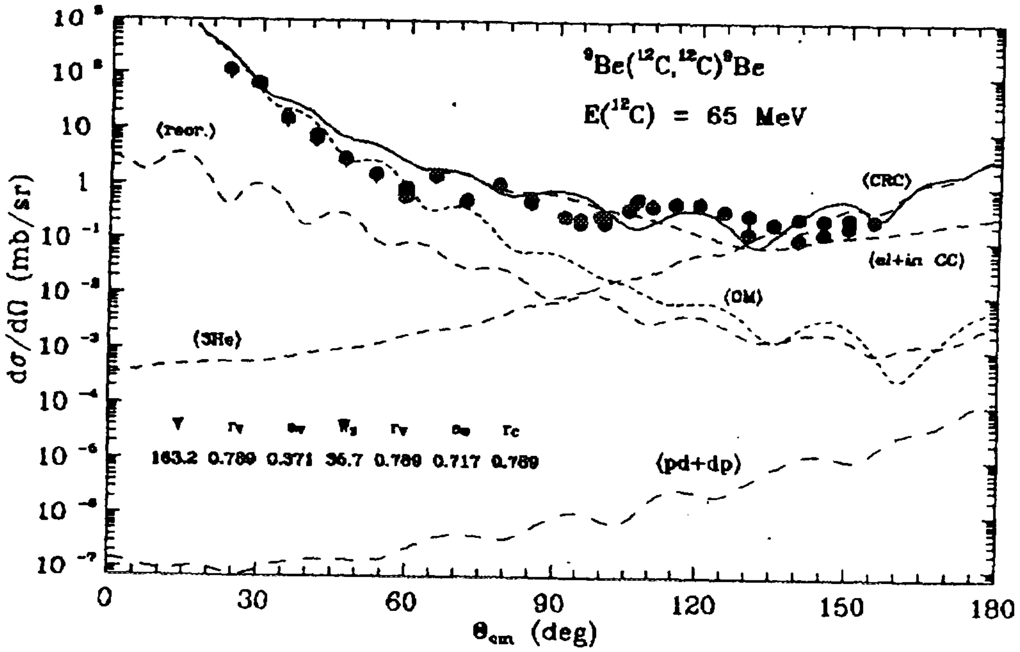

Fig.1

[1] Institute for Nuclear Research, 252028 Kiev, Ukraine

[2] Kharkiv State University, 310077 Kharkiv, Ukraine

[3] H.Niewodniczański Institute of Nuclear Physics, PL-31-342 Cracow, Poland

1.5 Strong coupled-channel effects in the $^{9}Be(^{3}He,^{3}He)$, $^{9}Be(^{3}He,^{7}Be)$ and $^{9}Be(^{3}He,^{6}Li)$ reactions at $E(^{3}He)$ = 60 MeV

by A.T.Rudchik[1)], E.I.Koshchy[2)], A.Budzanowski[3)], R.Siudak[3)], A.Szczurek[3)], I.Skwirczyńska[3)], Yu.G.Mashkarov[2)], L.Głowacka, J.Turkiewicz, I.I.Zalyubovsky[2)], V.A.Ziman[1)], N.T.Burtebayev[4)], A.D.Duysebayev[4)], V.V.Adodin[4)]

The angular distributions of the $^{9}Be(^{3}He,^{7}Be)^{5}He$ and $^{9}Be(^{3}He,^{6}Li)^{6}Li$ reactions were measured at the energy of 60 MeV for the transitions to the ground states of ^{5}He and ^{6}Li and 2.185 MeV (3^+), 5.37 MeV (2^+) + 5.65 MeV (1^+) excited states of ^{6}Li. The experimental data were analyzed using the coupled reaction channels (CRC) model including one- and two-step cluster transfers and cluster spectroscopic amplitudes calculated in the framework of the translation-invariant shell model [1]. It was found that the coupling with inelastic channels and reorientation process modified the elastic scattering cross section at large angles. The $^{9}Be(^{3}He,\alpha)^{8}Be$ reaction was included in the analysis to determine the optical potential of the intermediate α + ^{8}Be channel in a two-step transfer. It was found that in the $^{9}Be(^{3}He,^{7}Be)^{5}He$ reaction the α-transfer dominates only at small angles while the transfer of the 2n-cluster at large angles. In the angular range $\theta_{cm} \approx 30° - 80°$ the cross sections are determined by the sequential transfers of the neutron and ^{3}He-cluster as well as deuteron and deuteron. The transitions to highly excited states of the intermediate ^{8}Be and ^{7}Li nuclei give large contributions to the cross sections.

As an example, the angular distribution of the $^{9}Be(^{3}He,^{6}Li)^{6}Li$ reaction for the transition to the ground state of ^{6}Li nucleus is presented in the figure. The dashed lines show the CRC cross sections for the individual transfers, the names of which are placed in the brackets < >. The solid line shows the coherent sum of CRC cross sections of individual transfers.

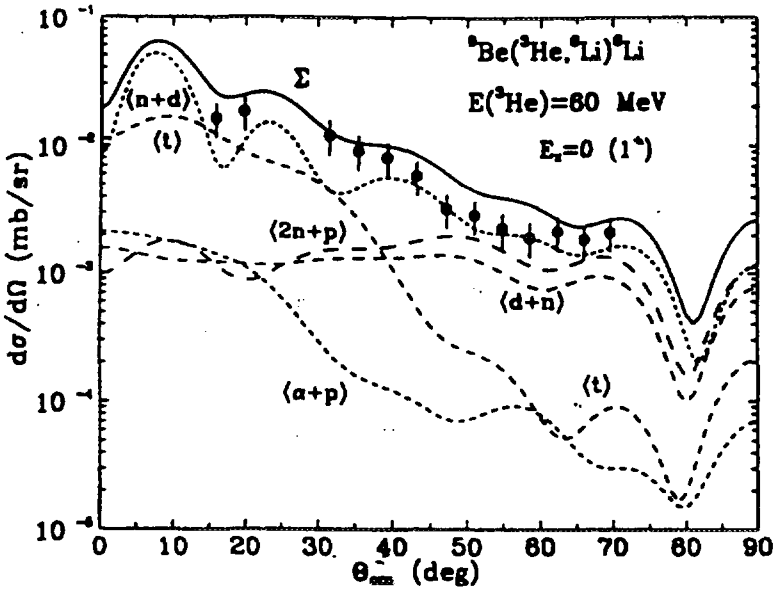

Fig.1

[1] A.T.Rudchik et al., Nucl. Phys. A609 (1996) 147

1) Institute for Nuclear Research, 252028 Kiev, Ukraine
2) Kharkiv State University, 310077 Kharkiv, Ukraine
3) H.Niewodniczański Institute of Nuclear Physics, PL-31-342 Cracow, Poland
4) Institute of Nuclear Physics, Alma Ata, Kazakhstan

1.6 One- and two-step processes in the ^{6}Li(d,^{6}Li), (d,^{7}Li) and (d,^{7}Be) reactions at E_d = 50 MeV

by A.T.Rudchik[1)], A.Budzanowski[2)], E.I.Koshchy[3)], L.Głowacka, Yu.G.Mashkarov[3)], M.Makowska-Rzeszutko[2)], V.M.Pirnak[1)], R.Siudak[2)], A.Szczurek[2)], J.Turkiewicz, V.V.Uleshchenko[1)], V.A.Ziman[1)]

The cross sections for the (d,^{6}Li), (d,^{7}Li) and (d,^{7}Be) reactions on ^{6}Li nuclei were measured at a deuteron energy of 50 MeV for transitions to the ground state of ^{6}Li and to the ground and first excited states of ^{7}Li and ^{7}Be nuclei. The experimental data were analyzed with the coupled reaction channel model [1]. It was found that both one- and two-step cluster transfers gave substantial contributions to the cross sections.

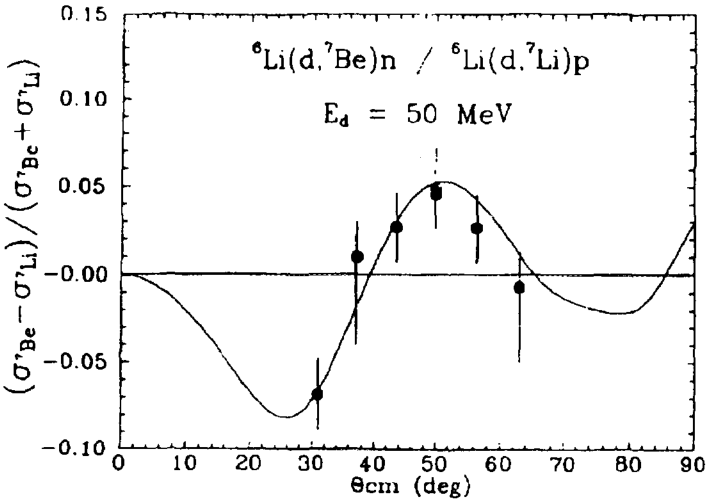

Fig.1 Angular dependence of the charge symmetry function $A(\theta) = (\sigma_{7Li}(\theta) - \sigma_{7Be}(\theta))/(\sigma_{7Li}(\theta) + \sigma_{7Be}(\theta))$ for the ^{6}Li(d,^{7}Be)n and the ^{6}Li(d,^{7}Li)p reactions at E_d = 50 MeV. The cross sections for the transitions to the ground and first excited states of ^{7}Be and ^{7}Li nuclei are summed up. The solid line shows the result of the CRC calculations.

The asymmetry in the angular distribution between the mirror symmetric (with respect to the isospin ^{6}Li(d,^{7}Li)p and ^{6}Li(d,^{7}Be)n) reactions was observed experimentally. The asymmetry shown in Fig. 1, does not exceed 10%. Despite the smallness of the effect we find a remarkably good agreement between the theoretical (calculated from the CRC cross sections) and experimental asymmetry.

[1] A.T.Rudchik et al., Nucl. Phys. A602 (1996) 211

[1)] Institute for Nuclear Research, 252028 Kiev, Ukraine
[2)] H.Niewodniczański Institute of Nuclear Physics, PL-31-342 Cracow, Pola
[3)] Kharkiv State University, 310077 Kharkiv, Ukraine

PL9800592

1.7 The Warsaw ion guide isotope on - separator line (IGISOL)

by A.Korman and A.Wojtasiewicz[1)]

In 1995 the decision was taken to move the SINS mass separator from Świerk to the Heavy Ion Laboratory in Warsaw in order to construct the Ion Guide Isotope Separator on Line (IGISOL)of the Warsaw heavy ion cyclotron. The separator is of so called Scandinavian type with a mean ion radius of 150 cm, mass resolution up to 1000 and average intense ion separated current [1]. During the year 1996 the major experimental setup in OFF-LINE regime was completed. The mass separator operates well, but the efficiency, as well as the mass resolution are still below the values we expect, hence technical and ion optical improvements are still needed to construct a competitive experimental setup working both in the IGISOL regime, as well as with a standard (FEBIAD - type) ion source.

[1] A.Piotrowski, Z.Kozłowski, Mat. Inter. Meeting on Ion Implantation Equipment, Świerk, 24- 26 Sept. 1973

[1)] Institute of Experimental Physics, Warsaw University

1.8 Contribution of GDR excitation to the (p,α) reaction

by J.Rondio, S.V.Khlebnikov[1], M.Mutterer[2], M.V.Rozhkov[3], G.P.Tiourine[1] and W.H.Trzaska[4]

The differential cross sections of the ^{27}Al(p,α)^{24}Mg reaction were measured for 6 proton energies from 18.4 MeV to 23.4 MeV. The proton beam was accelerated in the Jyväskylä K = 130 cyclotron. Alpha particles, protons and other reaction products were identified by two independent methods: Time of Flight analysis and Pulse Shape Discrimination. The second method took advantage of rise time differences for different particles in a reversed PIN diode. In addition, for alpha particle spectra of energie above 7 MeV there was no interference from protons due to a small detector thickness of 0.38 mm. The α spectrum measured at 90° for proton energy 18.9 MeV is shown in Fig. 1.

Transition to the 9.5 MeV T = 1 excited state in a residual nucleus is expected to be enhanced at a bombarding proton energy for about 18.9 MeV. This enhancement is expected due to the of isospin selection rules which make the GDR excited in a doorway state of the reaction to deexcite by α emission to the state with T = 1 only. In fig. 2 is presented excitation function of the 9.5 MeV state which is the lowest one with T = 1. One can see that the excitation function has a maximum at about 18.9 MeV, confiming the suggestion that the α particle emission is due to the GDR deexcitation.

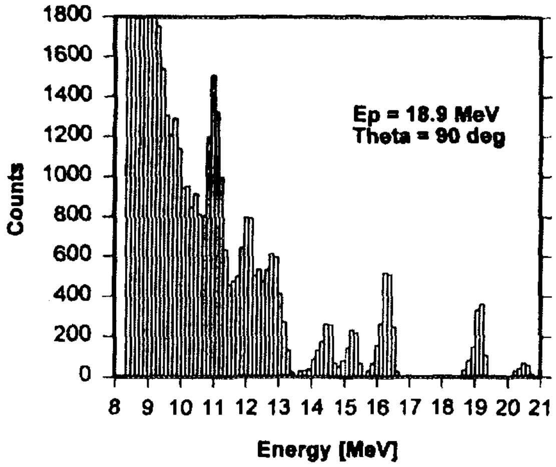

Fig.1 Spectrum of α particles from the ^{27}Al(p,α)^{24}Mg reaction at 18.9 MeV.

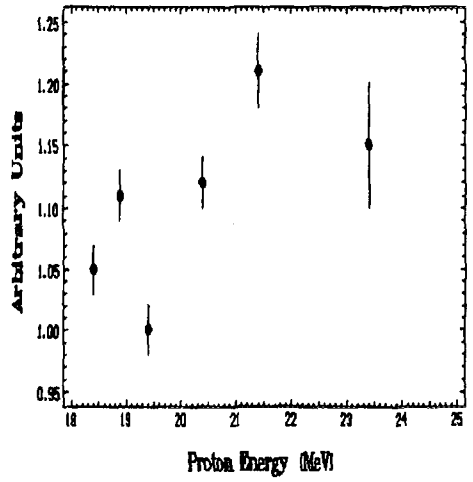

Fig.2 Excitation function of the 9.5 MeV T=1 state excited in the ^{27}Al(p,α)^{24}Mg reaction.

1) Khloplin Radium Institute, St. Petersburg, Russia
2) Technical University Darmstadt, Germany
3) On Leave from Kurchatov Institute, Moscow, Russia
4) University of Jyväskylä, Finland

1.9 Polarized ^{6}Li scattering from ^{4}He; test of the CDCC method

by K.Rusek and K.Kemper[1]

Data for the elastic scattering of 27.8 MeV polarized ^{6}Li from ^{4}He and for inelastic scattering leading to the 3^+, 2.18 MeV and 2^+, 4.31 MeV resonant excited states of ^{6}Li were analyzed using the coupled - channels method. The central and coupling potentials were derived from the realistic d - ^{4}He and α - ^{4}He interactions via the cluster - folding procedure. In the calculations the non-resonant continuum states of ^{6}Li were taken into account by means of continuum - discretized coupled - channels (CDCC) technique. The analysis showed a dominant role of the projectile breakup into α + d in the ^{6}Li + ^{4}He elastic scattering. The deuteron transfer process, indistinguishable experimentally from the elastic channel, was found to affect the scattering only at very backward angles. Predictions made for the direct ^{6}Li $\rightarrow$ α + d breakup near the breakup threshold did not support a suggestion [1,2] that the differential cross section drops suddenly at forward scattering angle corresponding to the momentum transfer of about 117 MeV/c.

[1] C. Samanta et al, Phys. Rev. C45 (1992) 1757
[2] C. Samanta et al, Phys. Rev. C50 (1994) 1226

1) Department of Physics, Florida State University, Tallahassee, USA

1.10 Breakup of ^{6,7}Li above the Coulomb barrier

by R.P.Ward[1], N.M.Clarke[2], B.R.Fulton[2], G.Tungate[2], N.Keeley[3], J.S.Lilley[3], K.Kemper[4] and K.Rusek

The breakup of ^{6,7}Li into α + d,t, on ^{208}Pb target was experimentally studied at energies above the Coulomb barrier. The experiment was performed at the Superconducting Accelerator Laboratory, Florida State University. The data will be analyzed by means of the continuum - discretized coupled - channels method in order to investigate the differences in behaviour of these two isotopes found in a recent analysis of the elastic scattering of ^{6}Li and ^{7}Li by ^{208}Pb [1].

[1] N. Keeley et al, Nucl. Phys. A571 (1994) 326

[1] School of Physics, Staffordshire University, Stoke-on-Trent, UK
[2] School of Physics, University of Birmingham, Birmingham, UK
[3] Department of Physics and Astronomy, University of Manchester, Manchester, UK
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PL9800596

1.11 The role of breakup in near barrier ^{6}Li + ^{208}Pb scattering

by N.Keeley[1] and K.Rusek

Continuum-discretized coupled-channels calculations for the ^{6}Li + ^{208}Pb system were performed at several near-barrier energies using a cluster-folding model description of the ^{6}Li - target interactions. Good agreement with the elastic scattering angular distributions was obtained without the need for re-normalization of the cluster-folding potentials. Decomposition of the calculated ^{6}Li sequential breakup cross section into Coulomb and nuclear components showed that the forward angle cross section was dominated by the Coulomb amplitude at near-barrier energies.

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PL9800597

1.12 Study of polarized ^{7}Li scattering from ^{208}Pb at 33 MeV

by K.Rusek, J.Gomez-Camacho[1], I.Martel-Bravo[1] and G.Tungate[2]

Elastic and inelastic scattering of polarized ^{7}Li from ^{208}Pb at 33 MeV was investigated by means of the continuum-discretized coupled-channels method, using diagonal and coupling potentials derived from empirical α,t - target Optical Model potentials. The effects of the projectile breakup into α + t as well as target excitation and one-neutron transfer reaction were studied. A good description of the experimental data was obtained. The scattering of ^{7}Li from ^{208}Pb at 33 MeV was found to be of similar nature to the scattering of ^{6}Li from the same target and at the same energy [1].

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[1] Departamento de Fisica Atomica, Molecular y Nuclear, Universidad de Sevilla, Sevilla, Spain
[2] School of Physics, University of Birmingham, Birmingham, UK

1.13 Responses of the CR-39, PM-355 and PM-500 track detectors to 14.9 MeV neutrons

by T.Czyżewski, M.Jaskóła, A.Korman, S.Pszona, M.Sadowski and A.Szydłowski

The response of Poly-Allyl-Diglicol Carbonate thermosetting plastics known as CR-39 and PM-355 solid state nuclear track detectors (SSNTD), to protons, alpha particles, nitrogen and oxygen ions, have recently been studied at SINS [1,2]. The CR type detectors are sensitive to protons, therefore their applications for the neutron registration are of interest especialy as long term fluence detectors.

Neutrons of 14.9 MeV energy were produced in a reaction of 2.3 MeV deuterons with a thin titanium tritide target (1.1 mg/cm^2, containing 5.8 Ci of tritium) using the Van de Graaff accelerator at SINS. The neutron flux was measured by counting recoil protons emitted from a polyethylene foil

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(66.6 mg/cm^2) using a 1.2 mm thick CsI(Tl) scintillator followed by a photomultiplier. The counter was calibrated to give absolute values of neutron fluence by using the Monte Carlo method for the solid angle determination,

The CR-39, PM-355 and PM-500 samples were situated at 90^0 to the incident deuteron beam at distances of 21, 30 and 41 cm from the neutron source. The SSNTDs, cut in a form 4 cm^2 squares of 0.4 mm thickness were divided into four fields named A, B, C and D. Part A was a bare detector, part B and C were covered by polyethylene radiators of 1 mm and 2 mm in thicknesses, respectively and part D was covered by 1 mm polyethylene and 0.75 mm-thick Al filter.

The irradiated SSNTDs were etched under standard conditions during 4 hours and then were scanned with an optical microscope at magnification of 500 or 1250, respectively. The readings of tracks for the samples irradiated, normalized to neutron monitor and averaged over three irradiated detectors sets, are shown in Fig.1. As seen from Fig.1, the effects of the polyethylene radiator are very distinct for each type of the investigated material. The most pronounced effect (described by a factor of>3.5) is observed for PM-500 plastics. It is equal to 1.7 for CR-39 and 3 for PM-355. The lower efficiency of CR-39 than that of PM material is the result of a low detectability of protons at 4 hours etching time as shown in our papers [1,2].

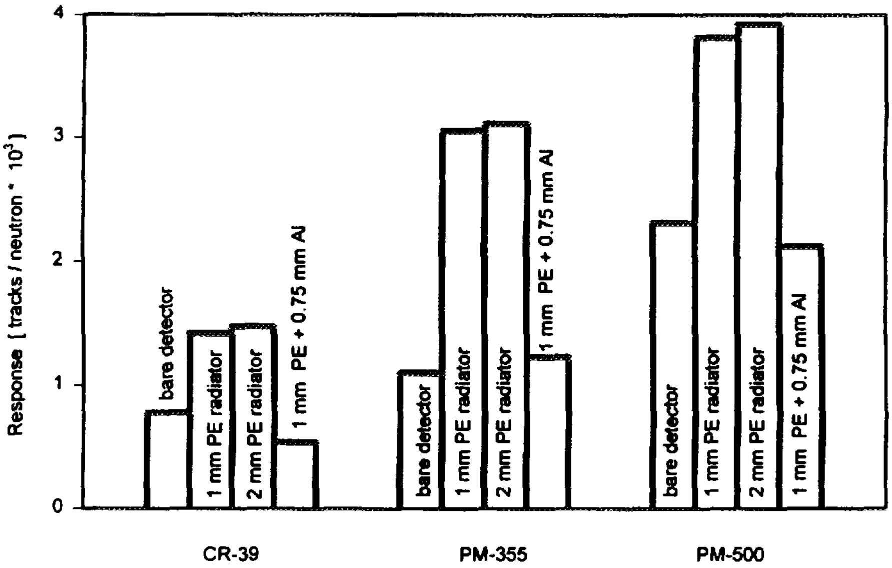

Fig.1

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PL9800599

1.14 Lattice location of erbium atoms in GaAs crystal structure

by J.Kaczanowski, Y.Yamamoto[1)], Y.Kido[1)], J.Nakata[1)], K.Takahei[1)]

The Monte Carlo program was developed for calculation of ion trajectories and channeling spectra [1]. The program was adapted for the analysis of channeling spectra of compound crystals containing point defects and crystalline precipitates. The program was applied to the structure analysis of GaAs crystals doped with Er and codoped with C and O.

Erbium in its trivalent state exhibits luminescence around 1.54μ m [2]. This wavelength corresponds to the minimum absorption of silica-based fibers [3], making GaAs:Er a promising material for optoelectronic devices. The efficiency of Er luminescence strongly depends on its lattice location [4].

We investigated three samples of GaAs crystals doped with Er grown by metalorganic chemical vapour deposition (MOCVD) technique on (100)-oriented GaAs substrates at 500° C. The first crystal was grown as a layered structure as follows: undoped GaAs layer, 55 nm GaAs doped with Er (0.54 % maximum concentration), 79 nm undoped GaAs layer, 62 nm GaAs layer doped with Er (0.62 % maximum concentration) and 63 nm surface GaAs layer. The Er doped layers were unintentionally codoped with C due to the use of organic source materials. The second one consisted of a GaAs substrate layer, 50 nm layer doped with Er to a maximum concentration of 0.15 % and unintentionally codoped with C and 20 nm GaAs surface layer. The third one contained the GaAs substrate, 60 nm layer doped with Er to a maximum concentration of 0.06 % with intentional codoping of oxygen (the same order of concentration as Er) and 20 nm GaAs surface layer. These crystals were investigated by the ion channeling technique. The first crystal was analysed with 2.5 MeV He+ ion beams, and the second and third crystals were analysed with 2.0 MeV He+ ion beams. The spectra were collected for three main axes, [100], [110] and [111]. The corresponding random spectra were also collected. The crystals were oriented by a three-axis goniometer. The experimental channeling spectra were simulated using the Monte Carlo method.

The first analysed sample was a two layer Er doped structure. The best agreement between experimental and simulated spectra was achieved assuming the existence of ErAs crystalline precipitates in a NaCl structure with its three [100] axes aligned with those of the host GaAs in a zinc-blende structure [1].

The second analysed sample was a GaAs crystal doped with Er and unintentionally codoped with C. The Er concentration is about a quarter of the former sample. The best agreement between simulation and experimental results was achieved assuming uniformly dispersed Er atoms occupying a site shifted in the [100] direction by 0.05 nm from a tetrahedral interstitial position [1].

The third analysed sample was a GaAs crystal doped with Er and intentionally codoped with O. The intentional O doping obviously changes atomic sites. In the present analysis, the best agreement between simulated and observed spectra was achieved assuming the Er position to be shifted from Ga substitutional position in [100] direction by 0.09 nm [1].

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[1] Ritsumeikan University in Kyoto, Japan

PL9800600

1.15 Quasi-epitaxial ingrowth of a monoclinic phase on UO_2 single crystals upon leaching in H_2O

by L.Nowicki, A.Turos, C.Choffel[1], F.Garrido[1], L.Thomé[1], J.Gaca[2], M.Wójcik[2] and Hj.Matzke[3]

Nuclear waste management is one of the most important technological and ecological problems involved in the use of nuclear power reactors. In the direct storage scenario, the used fuel is stored in safe, deep geological repositories. However, an accidental contact with water can lead to the loss of integrity of the waste form, which in turn would produce leaching of radioactive material and its transport to the geosphere with the groundwater. Since today's nuclear fuel is UO_2, the study of the corrosion mechanism of this material in aqueous solutions is of primary interest. Although considerable effort has been spent to investigate this problem, questions about phase relationships and structural transformations in the uranium-oxygen-water system still remain [1].

Surface oxidation of (110)-oriented UO_2 single crystals leached in demineralized water at 180°C for 24 h has been studied by means of the backscattering/channeling technique. The O sublattice was analyzed using the $^{16}O(^4He,^4He)^{16}O$ resonance at 3045 keV. X-ray diffractometry (XRD) was also used to study the orientation of (110) atomic planes of the transformed layer with respect to the bulk crystal and to measure the change of the (110) interplane distance.

Quasi-epitaxial ingrowth of an oxidized surface layer was observed and attributed to the phase transformation from the cubic UO_2 to a monoclinic UO_r phase with r=2.28 ± 0.05 [2]. Fig.1 shows the geometrical model of the transformed layer linked to the crystal bulk. The drawing demonstrates an observed peculiar feature of this quasi-epitaxial ingrowth: one of the crystalline axes of both (transformed and non-transformed) structures is common however, this axis is not normal to the crystal surface but it makes an angle of ~ 45° with the normal.

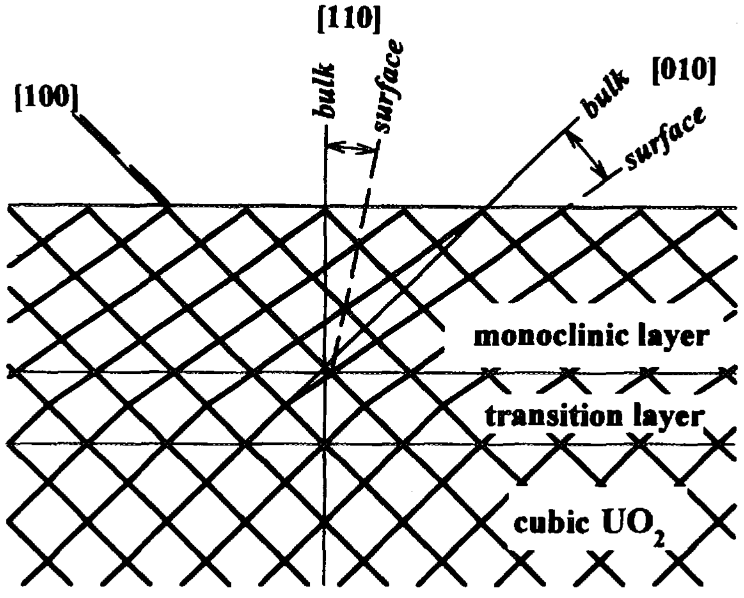

Fig.1 Structural model of the quasi-epitaxial monoclinic surface layer grown on the cubic UO_2 structure.

Channeling experiments performed for four low-index axes combined with XRD measurements enabled us to determine the structure of the formed monoclinic phase as consisting of cells described by: a = 542.8 pm, b = 550.0 pm, c = 546.3 pm, a=b=90.0° and g = 90.75°. The phase belongs to the family of polymorphic structures existing in the $UO_{2.24}$-$UO_{2.50}$ region. It remains unknown whether the obtained a , b and c lengths concern an elementary cell or a sub-cell of a larger structure.

Monte Carlo simulations of ion-channeling in the transformed monoclinic layer linked to the crystal bulk were performed. They enabled us to state that incorporation of additional oxygen atoms into the UO_2 structure results not only in the monoclinic deformation of the elementary cells but also in displacements of uranium and matrix oxygen atoms from their lattice sites. The simulations also showed that uranium atoms were displaced preferentially in one of the crystalline planes.

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1) Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, IN2P3-CNRS, France
2) Institute of Electronic Materials Technology, Warsaw, Poland
3) European Commission, JRC, Institute for Transuranium Elements, Karlsruhe, Gerı

1.16 M-shell ionization of atoms by C, N and O ions

by T.Czyżewski, L.Głowacka, M.Jaskóła, J.Braziewicz[1], M.Pajek, J.Semaniak, M.Haller[2], R.Karschnick, W.Kretschmer, A.P.Kobzev[3], D.Trautman[4], G.Łapicki[5]

The existing data K-, L- and M-shell ionization by light ions can be reproduced quite well by theoretical models based on the plane wave Born approximation (PWBA) or the semiclasical approximation (SCA), when the corrections for higher-order effects are included in these approaches.

For heavy ions perturbing stronger the initial electronic state , these theories cannot describe the data so well. In this case, substantial discrepancies were reported mostly for M- and L-shells. We summarize our systematic studies of M-shell ionization in heavy elements (Au, Bi, Th and U) by C, N and O ions [1]. Results for a $O^{q+} \rightarrow$ Au system, for energy range 0.1 - 2 MeV/u (performed in INR Dubna and Erlangen University), are compared with the predictions of the ECPSSR theory discribing both the direct ionization (DI) and the electron capture (EC), and with the SCA calculations for DI, performed in the separated (SCA - SA) and the united (SCA - UA) atoms limit. Two importent effects, the ion charge equilibrium in the target and the multiple ionization, are discussed.

In experiments using the targets of intermediate thicknesses, 20 - 40 $\mu g/cm^2$, the equilibrium charge state distribution is reached. So essentially, the equilibrium X-ray production and ionization cross sections are measured. Such equilibrium ionization cross sections σ_{eq} are calculated for the equilibrium charge state distribution [2]: $\sigma_{eq} = \Sigma\ F(q)\ \sigma(q) = \sigma_{DI} + \Sigma\ F(q)\ \sigma_{EC}$. Fig. 1 shows theoretical M-shell cross sections for DI and EC for $O^{q+} \rightarrow$ Au calculated according to the ECPSSR theory for 0.1 and 1 MeV/amu vs charge state q for thin target ($< 1\ \mu g/cm^2$). From Fig. 1 we concluded that electron capture contributions for high energies are important. Another important aspect is the multiple ionization effect. In this case the atomic parameters should be known for the multi-vacancy configuration, but practically, only their single-vacancy values are available. To correct this effect the energy shifts of L -X - ray lines can be measured to estimate the probabilities of ionization of M-, N- and O-shells, which in turn allow one to correct approx. the atomic parameters for the multiple ionization effect. In Fig. 2 differences between the L_γ peaks from Au bombarded by O^{q+} and p (3MeV) are shown. The peaks are shifted, independent of the ion energy, of about 100 eV for $L_{\gamma 1,2,3,5}$ ($N_{4,3,2,1} \rightarrow L_{2,1}$), 200 eV for $L_{\gamma 4,4'}$ ($O_{3,2} \rightarrow L_1$) and 320 eV for $L_{\gamma 6}$ ($O_4 \rightarrow L_2$) transisions. Using these results, and relating the observed energy shifts [3] we can estimate the ionization probability. The corrected data for the multiple ionization effects are accurate, within 20-30 %.

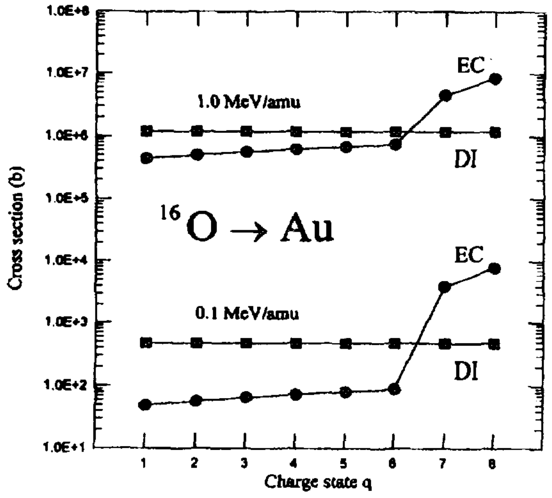
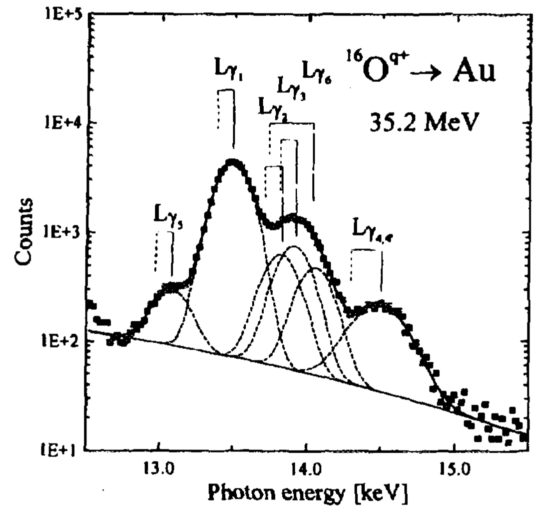


Fig.1



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2) Physicalisches Institut, Uniwersität Erlangen- Nürnberg, D-91058 Erlangen, Germany
3) Joint Institute for Nuclear Research, Dubna, Russia
4) Institute of Physics, University of Basel, CH-4056 Basel, Switzerland
5) Department of Physics, East Carolina University, Greenville, NC 27858, USA

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W.Atzrott, G.Cata-Danil, P.Guazoni, G.Graw, J.Gu, R.Hertenberger, **M.Jaskóła**, P.Schiemenz, G. Staudt, A.Vitturi and L.Zetta
EPS-10 Trends in Physics, Sept. 9-13, 1996 Sevilla

MSX - A MONTE - CARLO CODE FOR NEUTRON EFFICIENCY CALCULATIONS FOR LARGE-VOLUME Gd - LOADED LIQUID SCINTILLATION DETECTORS
A.Trzciński, B.Zwięgliński for the ALADIN Collaboration at GSI-Darmstadt
XXXI Zakopane School of Physics - Trends in Nuclear Physics, Zakopane, 3-11 Sept. 1996

LECTURES, COURSES and EXTERNAL SEMINARS

Van de Graaff Accelerator in Heavy Ion Laboratory: What for?
A.Turos, April 10, UW Warsaw

Physics with Polarized Lithium Beams
K.Rusek, Sept. 5, Triangle Universities Nuclear Laboratory, Durham, N.C.

GaN the Way to the Blue Light
A.Turos, Sept. 19, Max-Planck-Institut fur Kernphysik, Heidelberg, Germany

Studies of the Ionisation Cross Sections Induced by Charged Particle
M.Jaskóła, Oct. 18, Institut of Phys. Milano University, Italy

Particle Induced X-ray Emission as a Tool for Trace Element Analysis
M.Jaskóła, Oct. 21, Institut of Phys. Milano University, Italy

The Light Ion Spin Spectrometer Project at Indiana University
P.Żuprański, Nov. 22, Atomic Nucleus Department of the Institute of Experimental Physics of Warsaw University

Lattice Location of Er Atoms in Semiconductor Crystals
J.Kaczanowski, Nov. 23, UW Warsaw

Preequilibrium Effects in Light-Particle Emission in Light - and Heavy - ion Induced reactions at the Intermediate Energies
B.Zwięgliński, Dec. 10, GSI - Darmstadt, Germany

Defektstrukturen in III-V Halbleitern
A.Turos, Dec. 13, Forschungszentrum Rossendorf, Germany

INTERNAL SEMINARS

Breakup of ^{6,7}Li
K.Rusek, Febr. 6, IPJ Warsaw

Report on a Conference on Pre-equilibrium Reaction Smolenice 1995
B.Mariański, Febr. 27, IPJ Warsaw

Report on a Conference of Meson - Nucleus Interaction
W.Augustyniak, June 4, IPJ Warsaw

Investigation of Nucleon Transfer in a ^{58}Ni + ^{18}O Reaction
J.Rondio, Oct. 29, IPJ Warsaw

Strong Coupled Channel Effects in Nuclear Reactions and Structure of Light Nuclei
A.Rudchik, IBJ UAN, Kiev, Dec.3, IPJ Warsaw

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Tomasz Czyżewski, Dr.
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2. DEPARTMENT OF NUCLEAR SPECTROSCOPY AND TECHNIQUE

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Overview

Departamental at activity was concentrated on two different regions according to the Department's name: "spectroscopy" (basic research) and "technology" (applications). Simultaneously, some effort was focused on teaching. At present, three Ph.D and two M.Sc. students are working for their degrees under supervision of members of the Department. In 1996 one Ph.D was obtained and one M.Sc. student was graduated.

Our research was activated by cooperation with several Polish, European and USA centres and by access to their experimental facilities like the C200 heavy ion cyclotron of the Warsaw University, the heavy ion accelerator complex at GSI in Darmstadt (Germany), PSI cyclotrons in Villigen (Switzerland), NORDBALL, ANL-UND BALL and GAMMASPHERE detectors. However, some results were also obtained using our C30 proton cyclotron, the crystal X-ray spectrometer installed on the SINS EAK electron accelerator and our low background gamma detection facility.

Our mass separator has finally been moved to the C200 cyclotron area after more than twenty years of work on a new start on heavy ion beams. On-line radioactive ion sources are under preparation in cooperation with our Department.

The reader can find short abstracts of our activity and a list of publications in this Annual Report. Nevertheless, it is worthwhile to stress some highlights of 1996.

i) Calculations of heavy ion collision dynamics were performed in cooperation with the SINS Theory Department and LBL at Berkeley (USA). It has been shown that the experimental data on the mean kinetic energies of fission fragments are not sufficient to distinguish between one- and two-body dissipation. The mass flow seems to be more sensitive to the dissipation mechanism.

ii) A final analysis of the NORDBALL experiments on the excited states of nuclei in the vicinity of ^{100}Sn. The level structures of ^{99,101,102,103}Cd, ^{101,103,105}In and ^{105}Sn are reasonably well described by the shell model. This gives predictions for the structures of other nuclei in this exotic region.

iii) The discovery of two high spin isomers in ^{183}Ir and two superdeformed bands in ^{149}Tb in experiments at LBL on ANL-UND BALL and GAMMASPHERE detectors.

iv) Determination of radionuclide concentration in the air, some plants and soil. In particular, the map of concentration of ^{210}Pb in our soil is an unique achievement.

v) Participation in the project of the flue gas treatment plant using the electron beam method for the "Pomorzany" coal power plant coordinated by the Institute of Nuclear Chemistry and Technology under the supervision of the IAEA in Vienna.

Financial support received from the State Committee for Scientific Research and Maria Skłodowska-Curie Polish-American Foundation is acknowledged.

REPORTS ON RESEARCH

2.1 Nuclear friction deduced from mass equilibration measurements in strongly damped reactions

by J.Błocki, J.Wilczyński

We continue our program of testing nuclear friction by comparing a variety of experimental data on fusion-fission and strongly damped reactions with predictions of the dynamical model based on the classical Rayleigh-Lagrange equations of motion. In a recent study [1] we analyzed a selected set of precise measurements of the mean kinetic energy of fission fragments. Both alternative dissipation mechanisms, one body dissipation and two-body viscosity have been tested. Our analysis has indicated an effect of increasing strength of the dissipation with increasing mass of a composite system. However, we found that the kinetic energy released in fission depends only very weakly on the strength of the assumed nuclear dissipation. The fission fragment mean kinetic energies measured in modern experiments with a high accuracy of 1-2 MeV can give at best an accuracy of the deduced dissipation coefficient within a factor of 2.

In the present study we have analyzed existing data on the equilibration of the mass asymmetry degree of freedom in strongly damped reactions studied in GSI Darmstadt by Shen et al. [2]. From the measured dependence of the mass distribution on the angle, one can deduce a value of the average final mass split of a composite system as a function of time in which the dinuclear system rotates before reseparation of the fragments. The rotation time can be deduced from the deflection angle, assuming a certain value of angular momentum for a selected region in the measured mass-angle distribution. In Ref. [2] Shen et al.. demonstrated a universal correlation between the mean normalized mass drift towards symmetry, $\Delta A/\Delta A_{max}$ and the reaction time t determined from the angles of rotation of the intermediate (di-nuclear) complex:

$$\Delta A/\Delta A_{max} = 1 - \exp(-t/\tau),$$

where ΔA is the drift of mass from projectile (or target) to the observed fragment, and ΔA_{max} is the maximum possible drift corresponding to a symmetric split of the composite system. For all systems studied , irrespective of the target-projectile combination and the bombarding energy, the above relation holds for the time constant $\tau=(5.3\pm1)\cdot10^{-21}$ s.

We performed calculations of the mass drift $\Delta A/\Delta A_{max}$ as a function of time for systems studied experimentally in Ref. [2]. The calculations have been done assuming both one-body and two-body dissipation. In the case of one-body dissipation we observed good agreement of the predicted mass drift with the data for collisions characterized by low angular momenta and nearly symmetric split of mass, but for more peripheral collisions (corresponding to a smaller mass transfer ΔA) the one-body dissipation seems to be too strong.

Assuming two-body dissipation (for outgoing trajectories characterized by "sticking" rotation), we found that, in order to reproduce the experimentally determined relation between the mass drift and time, the nuclear viscosity μ cannot be kept constant. Our analysis shows that the postulated viscosity has to considerably increase with decreasing angular momentum (approximately from 0.04 TP to 0.2 TP for nearly central collisions) that can be interpreted as an effect of the dependence of μ on the thermal excitation energy. A phenomenological temperature dependence of the viscosity coefficient has been deduced.

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2.2 Nuclear viscosity determined from prescission neutron multiplicities in fusion-fission reactions

by K.Siwek-Wilczyńska[1)], J.Krzyczkowski[1)], J.Wilczyński, R.H.Siemssen[2)], H.W.Wilschut[2)]

In Ref. [1] we reported unexpectedly large values of the coefficient of nuclear dissipation deduced from prescission neutron multiplicities [2] in *fast fission* reactions which we had analyzed in terms of the deterministic model of nuclear dynamics combined with time-dependent evaporation calculations. In this contribution we report on our recent study aimed at obtaining information on the nuclear dissipation in a different way, namely from an analysis of the prescission neutron multiplicities [2] in *fusion-fission* reactions which (in comparison with the fast fission reactions) clearly represent a different class of nuclear processes.

Nuclear dissipation is taken into account in the Kramers diffusion theory of compound-nucleus fission, in which the diffusion process of the fission degree of freedom over the fission barrier is expressed in terms of the Fokker-Planck equation. The viscous diffusion process results in a fission width Γ^K that is reduced relative to the nonviscous Bohr-Wheeler width Γ^{BW} (calculated with the transition-state method):

$$\Gamma^K = \Gamma^{BW}\left(\sqrt{1+\gamma^2}-\gamma\right).$$

Here γ is the dimensionless friction coefficient describing the damping of oscillations of the fissioning nucleus. The oscillations are overdamped for $\gamma > 1$ and underdamped for $\gamma < 1$.

In our approach we follow the Grangé-Weidenmüller method of estimating the time needed for the system to build up the quasistationary probability flow over the fission barrier (i.e., to attain the Kramers width Γ^K). We parametrize the fission width as a function of time,

$$\Gamma_f(t) = \Gamma^K[1-\exp(-t/\tau_0)],$$

with a time constant τ_0 that is related to the transient time τ between initiation of the diffusion process and the attainment of quasistationarity. In the case of overdamped motion ($\gamma > 1$), Grangé and coworkers estimated the time needed for the system to reach 90% of the asymptotic value Γ^K:

$$\tau = \frac{\gamma}{\omega}\ln(10E_B/T),$$

where ω is the oscillator frequency in the potential well of the fissioning nucleus (typically $\omega \approx 10^{21}$ s^{-1}), and E_B is the height of the fission barrier. Thus the time constant $\tau_0 = \tau/\ln 10$.

We have included the friction-dependent fission width $\Gamma_f(t)$ into our Monte Carlo code SEQ [1] that calculates, event-by-event, a sequence in time of the statistical light-particle emission from the composite system until fission is drawn. Therefore, for a fixed value of γ and a given value of angular momentum, one can calculate the average number of neutrons, $\nu_{presaddle}$, evaporated before the instant of time when fission is decided and the system starts its no-return way from saddle to scission. In a separate procedure, we calculate using the DYNSEQ program [1], the average number of neutrons emitted during that final stage of the fission process, $\nu_{saddle\text{-}to\text{-}scission}$. Since fission is decided beyond the saddle point, the fission channel is then excluded from the competition (Γ_f=0). The light-particle emission is continued, starting with the value of the excitation energy that the system possessed at the saddle point. The process of generating the excitation energy during the descent from saddle to scission is calculated with the HICOL code [3] and coupled with the evaporation cascade calculation. Thus the actual excitation energy during the post-saddle cascade is continuously adjusted during the descent.

We have found that for the majority of reactions analysed, a deduced value of the friction coefficient strongly depends on the upper limit of angular momentum l_{max} assumed to confine (on the average) the fission and fission-like processes taken in a given experiment as a trigger for coincidences between neutrons and fission fragments. In our calculations, the prescission neutron multiplicity is averaged over the angular momentum:

$$\nu_{presaddle} = \frac{\sum_{l=0}^{l_{max}} (2l+1)\nu(l)N_f(l)}{\sum_{l=0}^{l_{max}} (2l+1)N_f(l)}$$

Here $N_f(l)$ is the number of cascades which end in fission for a given value of angular momentum (for a fixed total number of cascades) and $\nu(l)$ is the corresponding presaddle neutron multiplicity. In the above averaging procedure we took for l_{max} the limiting angular momentum for fusion, l_{fu}, in the Feldmeier code [3] or the angular momentum for which the fission barrier for a given composite system vanishes, $l_{B=0}$ (if $l_{B=0} < l_{fu}$). In fact, the fission-like component, taken in the experiments as a trigger, may contain some fast-fission events (corresponding to larger l values). This would lead to significant errors in determination of the dissipation coefficient γ.

We have begun systematic calculations for the whole set of prescission neutron multiplicities measured by Hinde et al. [2]. The results will help us to verify the strange temperature dependence of the friction coefficient deduced from giant dipole resonance data in fusion-fission reactions [4] and neutron multiplicities in fast fission reactions [1].

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PL9800605

2.3 Testing of lepton flavour conservation in neutrinoless nuclear μ-e conversion

by T.Kozłowski (SINDRUM II Coll.)

A violation of Lepton Flavour Conservation (LFC) would be a direct indication for the new physics beyond the Standard Model. One of the most stringent tests of LFC is the search for coherent μ^--e^- conversion in muonic atoms without neutrino emission as it is carried out at PSI in Villigen, Switzerland with the SINDRUM II spectrometer.

The data obtained on the μE1 negative muon beam have been finally analysed which resulted in new upper limits for the branching ratio $B_{\mu e}$ of the conversion $\mu^-(A,Z) \rightarrow e^-(A,Z)$ relative to the normal muon capture $\mu^-(A,Z) \rightarrow \nu_\mu(A^*,Z-1)$:

$$B_{\mu e}(Ti) < 8.4 * 10^{-13} \text{ (90\% CL)[1]}$$

$$B_{\mu e}(Pb) < 4.6 * 10^{-11} \text{ (90\% CL)[2]}$$

The new limit for titanium improves on the previous one by a factor of five, and for lead by an order of magnitude. These values put very stringent limits on the masses of hypothetical supersymmetric particles.

The sensitivity is expected to be increased by another factor of ten when a newly developed πE5 beam line with the PMC (Pion Muon Converter) at PSI will be put into operation.

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2.4 Investigations of neutron deficient nuclei close to the doubly magic ^{100}Sn

by M.Palacz, J.Kownacki[1], Z.Sujkowski (NORDBALL Coll.)

Nuclei in the region of doubly-magic ^{100}Sn have been a subject of extensive investigations for decades. Recently, substantial progress has been made in *in-beam* studies of very neutron deficient tin, indium and cadmium isotopes. Excited states have been observed for the first time in ^{102}Sn [1], ^{101}In [2], ^{98}Cd [3] and ^{99}Cd [4]. Knowledge of excited states of many other nuclei in the region has been extended.

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The analysis of data from an experiment performed in the Tandem Accelerator Laboratory, Risø, Denmark has been continued. This experiment employed the NORDBALL detector array together with light charged particle and neutron detectors and was described in [2,4,5,6,7,8]. Final results were obtained for ^{101,103}Cd [5,6].

A package of Shell Model computer programs RITSSCHIL [6] was installed, tested and used on a DEC Alpha Station 200 4/233 workstation placed at the Heavy Ion Laboratory in Warsaw. Calculations for the $^{101-106}$Sn, $^{99-104}$In and $^{98-103}$Cd were done using a set of single particle energies and two body matrix elements from [10], in a full $\pi(g_{9/2},p_{1/2})$, $\nu(d_{5/2},g_{7/2},d_{3/2},s_{1/2},h_{11/2})$ configuration space. The calculations have been used to interpret the obtained experimental level schemes and to discuss selected properties of nuclei in the region.

A new method of detection and correction of shifts and gain changes observed in experimental spectra was developed [7]. The method is based on the calculation and minimization of the sum of squared differences between two spectra and can be used for discrete gamma - ray spectra as well as for various spectra from ancillary detectors. The method was used in the analysis of data from the NORDBALL experiment.

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1) Heavy Ion Laboratory, Warsaw University.

PL9800607

2.5 First investigation of the ^{115}In nucleus in the high spin regime

by S.Naguleswaran[1)], U.Garg[1)], S.S.Ghugre[1)], B.Kharraja[1)], R.Kaczarowski, E.Ruchowska, A.Galindo-Uribarri[2)], V.P.Janzen[2)], D.C.Radford[2)], D.B.Fossan[3)], S.Gundel[3)] and J.M.Sears[3)]

The ^{115}In nucleus was studied by means of γ-ray spectroscopic measurements. High-spin states in ^{115}In were populated with the ^{100}Mo(^{18}O, p2n)^{115}In reaction at an incident beam energy of 65 MeV. The ^{18}O beam was provided by the Tandem Accelerator Superconducting Cyclotron (TASCC) facility at Chalk River Laboratories. The target consisted of two self supporting foils of 350 μg/cm^2 thickness each. γ-γ coincidence data were acquired by means of the 8π spectrometer, which comprises 20 Compton-suppressed HPGe detectors and a 71-element BGO inner ball. Channel selection was provided by gating on charged particles detected in the Chalk River charged-particle array, ALF [1], which for this experiment comprised 44 CsI(Tl) detectors arranged in near 4π geometry. A rather clean selection of the proton channel afforded by ALF provided for identification of transitions belonging to the ^{115}In nucleus which were otherwise overwhelmed in the spectra by the γ-rays from the much stronger pure neutron evaporation channels. The data were sorted into proton-gated E_γ - E_γ matrices, and analyzed using standard techniques, including the software package, RADWARE [2]. A DCO analysis was performed in order to determine the multipolarities of the observed γ-ray transitions.

Prior to the present study, only the 1291 keV ($13/2^+ \rightarrow 9/2^+$) transition was known in the high-spin regime of this nucleus [3]. Seventeen new transitions were observed in the present study and have been placed in the level scheme using coincidence relationships and intensity arguments. The resulting level scheme extends to a spin of J=(31/2) and an excitation energy of 4716 keV. The main features of the level scheme are two structures coincident with the ground state transition. One of these structures is based on the 2310-keV level which decays via the 1019 keV, E2 ($17/2^+ \rightarrow 13/2^+$) transition. The second structure is based on the 846-keV transition, which is most likely of a pure dipole (E1) character, in analogy with a similar transition in ^{113}In [4]. Overall, the level scheme of this nucleus appears quite similar to the corresponding parts of the level schemes observed in the ^{109,111,113}In nuclei [4,5]. However, no structures analogous to the "intruder-type" rotational bands recently observed in the lighter-mass In nuclei [4,5] could be identified in this nucleus. However although, at first glance, the positive-parity structure does appear to have some resemblance to a proposed $(g_{9/2})^{-1}$ band in ^{113}In [4]. This non-observation is, most likely, a result of these structures not being populated with any discernible strength in the reaction employed in this work (because of the rather low maximum angular momentum at the beam energy needed for maximizing the p2n reaction channel) rather than an indication of any changes in the nuclear structure.

Theoretical calculations were performed in the framework of the particle+core coupling model wherein the odd particle (hole, or quasiparticle) motion is coupled to the collective surface vibrations of the core. The details of the model and the calculations are provided in Ref. [6]. For this nucleus, the theoretical levels were obtained by coupling a proton $g_{9/2}$ hole to a Sn (Z=50) core. Agreement between the experimental results and theoretical predictions is quite reasonable for the low-lying levels (up to spin 17/2), for both positive- and negative-parity levels. For states above the $19/2^{+}$ level, however, the deviations between experimental and theoretical levels become large. This discrepancy between theory and experiment could be due to the restrictions imposed by a mainly harmonic vibrational core. For example, in the Sn nuclei [7], high-spin, broken-pair states appear at excitation energies of 2.0 - 2.5 MeV and these non-collective, one-broken pair states are expected to play a major role in determining the nuclear structure in the odd-A In nuclei at high spins. Therefore, the comparison between the calculations presented here and the experimental level energies becomes less valid at those spins.

To summarize, an extensive level scheme in the high-spin regime has been constructed for the first time for ^{115}In. While the overall structure of the level scheme is similar to that of the lighter-mass, odd-A In nuclei, no "intruder" structures analogous to those recently observed therein have been identified in this nucleus. The low-lying, high spin levels of ^{115}In could be characterized by the particle+core model.

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2.6 Detailed investigation of superdeformation in ^{149}Tb

by B.Kharraja[1], U.Garg[1], H.Jin[1], R.Kaczarowski, M.P.Carpenter[2], S.Fisher[2], R.V.F.Janssens[2], T.L.Khoo[2], T.Lauritsen[2], D.Nissius[2], I.M.Govil[3], R.Kruecken[4], A.Machiavelli[4], R.MacLeod[4], F.A.Beck[5], Th.Byrski[5] and B.Haas[5]

To extend our investigation of the superdeformation (SD) phenomenon in the neutron gap N = 86, we have performed an experiment to study in detail the superdeformed bands in $^{149}_{65}$Tb$_{84}$, the (p,n)-exchange counterpart of the widely studied nucleus $^{149}_{64}$Gd$_{85}$. Our aims for this experiment were to: search for SD bands in ^{149}Tb; measure lifetimes to determine quadrupole moment Q_0 and, hence, the deformation β_2 associated with the observed SD bands in this nucleus; compare the observed properties of these bands with predictions of Hartree-Fock-Bogolubov cranking calculations in order to identify the intruder configurations associated with these bands in ^{149}Tb and explore their "identical-band" relationship with bands in its isotope ^{150}Tb and isotone ^{149}Gd; and look for evidence (or lack thereof) for the C_4 symmetry.

The experiment was performed at GAMMASPHERE, which, at that time, comprised 90 Compton-suppressed Ge detectors. The ^{128}Te(^{27}Al, 6n) reaction was employed at a beam energy of 155 MeV from the LBNL cyclotron in Berkeley. The target was enriched ^{128}Te (1.0 mg/cm^2 thick) and evaporated onto a sandwich of Al and Au foils to facilitate DSAM measurements. Only quadruple and higher-multiplicity coincidences were registered with event rate of about 14,000/sec. Thirty five high-density EXABYTE of tapes containing the data events and an additional two tapes with calibration data have been recorded during 8 shifts (64 hours) of experiment.

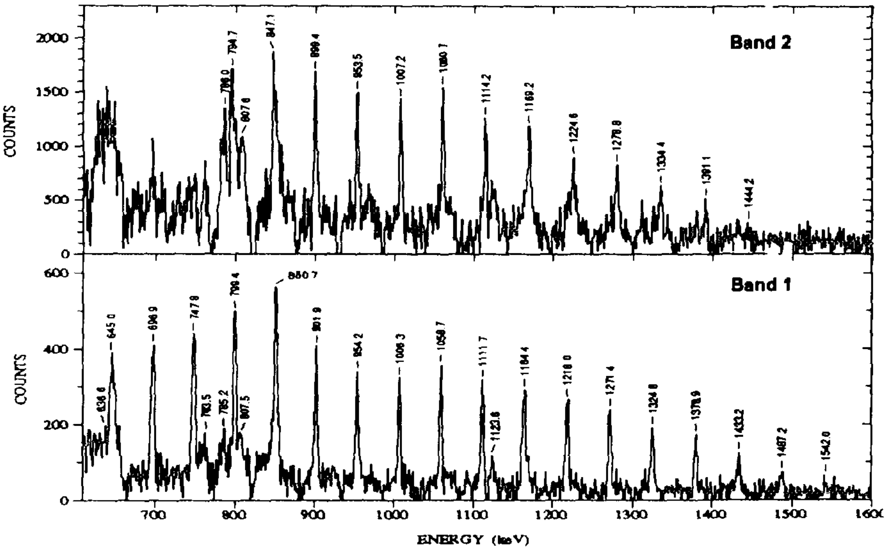

Fig.1 SD bands 1 and 2 in ^{149}Tb.

Prior to this study no SD band was known in ^{149}Tb. We have observed two superdeformed bands in this nucleus for which the observed coincidence relationships between the known γ-rays in ^{149}Tb and SD intra-band transitions make the assignment of these band unambiguous. These SD bands are shown in figure 1. In addition, three more SD bands have been observed which can also be assigned to this nucleus (detailed studies are still in progress). The newly found band 1 in ^{149}Tb and previously observed band 1 in ^{150}Tb nucleus have nearly equal transition energies (and, therefore, similar $\mathfrak{I}^{(2)}$) over a large range of rotational frequencies - they are so called "identical bands". This occurrence suggests that band 1 in ^{149}Tb has a configuration involving a hole in the [651]1/2 neutron orbital (α = -i), and one neutron in the N = 7 intruder orbital. Band 2 in ^{149}Tb is also "identical" to these two bands, except that the highest transitions begin to shift toward higher energies. A possible explanation might be that this band is the signature partner of the yrast band (band 1), involving a hole in the positive parity branch of the [651]1/2 neutron orbital. Other multi-particle excitations involving a proton and/or neutron are also expected in ^{149}Tb and may explain the existence of the remaining three bands. The search for additional SD bands is in progress.

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2.7 Investigation of high spin isomers in ^{180}Os

by R.Kaczarowski, E.Ruchowska, R.M.Lieder[1], W.Gast[1], A.Georgiev[1], H.M.Jäger[1], H.J.Jensen[1], T.Morek[2], C.Ender[3], T.Härtlein[3], D.Schwalm[3] and G.Sletten[4]

It is well known that for deformed, axially-symmetric prolate nuclei, the projection K of the total angular momentum on the symmetry axis is approximately conserved. This leads to the existence of isomeric states when the angular momenta of a few valence nucleons are aligned along the symmetry axis forming an excited state with a sufficiently high K quantum number. Half-lives of isomers with relatively low excitation energies with respect to the yrast line are found to increase approximately by two orders of magnitude for each degree of K-forbiddenness defined as $\nu = |\Delta K - \lambda|$, where λ is the multipolarity of the de-exciting γ-transition [1]. Thus, high-K isomers decay preferentially via small changes in K, eventually reaching the K$\approx$0 states of the ground band at low spins. According to the rule mentioned above, the direct decay from an isomeric state with a K quantum number of the order of 20 to an yrast band state (K=0) via a single transition of low multipolarity would violate the K-selection rule by many orders of magnitude, leading to partial half-lifes of the order of the age of the Universe. Unexpectedly, such direct decay paths have been found [2], indicating the breakdown or inapplicability of the K selection rule. One of the examples is the decay of the K≥ 20 isomeric state in ^{180}Os [1]. A detailed investigation of this unexpected phenomenon was the motivation for the present study.

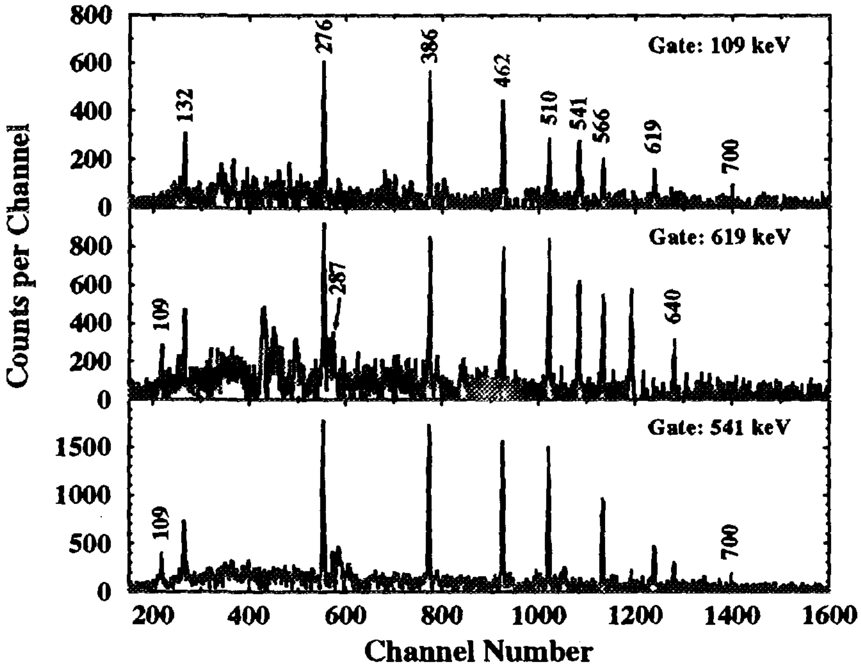

Fig.1 Spectra obtained by gating on the 109, 619 and 541 keV transitions, respectively, of ^{180}Os in the prompt-prompt E_γ-E_γ matrix.

The ^{180}Os nuclei were produced in the ^{150}Nd(^{34}S,4n) reaction at a beam energy of 153.5 MeV. The ^{34}S beam was provided by the tandem accelerator Emperor of the MPI in Heidelberg. A recoil-shadow technique has been used in the experiment to shield the detectors from the prompt γ-radiation emitted from the target. The delayed γ-radiation from the recoiling nuclei stopped at the catcher were detected by six CLUSTER detectors, each of them consisting of seven large-volume hexagonal-tapered Ge detectors. A description of the experimental setup and details concerning the experiment are given in ref. [3]. Only coincidental events with a multiplicity ≥3 were accumulated. During the off-line analysis, 219x10^6 multi-fold events were sorted into prompt-prompt, delayed-delayed and prompt-delayed E_γ-E_γ matrices as well as into an E_γ-time matrix. Additionally, gated E_γ-E_γ matrices were produced from triple γγγ events, requiring a coincidence with one of the strong yrast transitions of ^{180}Os with the aim to suppress the background of γ-rays caused by Coulomb excitations, Compton-scattering and n-γ reactions in the Ge detectors. This background was an undesirable result of the high beam current used in the experiment to produce enough feeding of the isomeric states.

Spectra obtained by gating on the 109, 619 and 541 keV transitions of ^{180}Os in the prompt-prompt E_γ-E_γ matrix are shown in fig. 1. A preliminary analysis of the data confirms that the 16$^+$ level of the yrast band and the 18$^+$ level of the yrare band are populated in the decay of the 5848 keV isomer [1] (cf. fig. 1). In addition, evidence for the feeding of the 20$^+$ level in the yrare band in the decay of this isomer has been found. The previously known 109 keV transition [1] de-exciting the 5848 keV isomer was found to feed both the 18$^+$ levels of the yrast and yrare bands (cf. fig. 1) by a cascade of weak transitions which were not yet identified. A new transition of 577 keV was observed in a similar way to feed the 18$^+$ level of the yrast band. Both transitions are not in coincidence with the 287 and 1427 keV transitions deexciting the 5848 keV isomer into the 18$^+$yrare state. Our preliminary results indicate that the isomeric decay path is highly fragmented, with the exception of the strong 287-1427 keV cascade.

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[2] J.Pedersen et al., Z. Phys. A321 (1985) 567
[3] R.M.Lieder et al., MPI-K Heidelberg Annual Report 1995

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PL9800610

2.8 Study of the high spin isomers in ^{183}Ir

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Several high-spin isomers have been observed in neutron-deficient Re - Pt nuclei, especially in N=104 and N=106 isotones, at an excitation energy of 1.7-2.0 MeV. In $^{181}Ir_{104}$ an isomer at 2034 keV with half life of about 25 ns and spin $23/2^+$ has been recently found [1,2], while in N=104 isotone, ^{180}Os, two isomeric states with spin and parity of 7^- and of the order of 20 ns were found at excitation energies 1863 keV and 1929 keV, respectively [3]. Isomeric states with spin and parity of 8^- and much longer halflives (780 ns and 1.01 ms, respectively) are observed in the even-even N=106 isotones, ^{182}Os and ^{184}Pt, at excitation energies 1831 keV and 1839 keV, respectively [4]. To gain further insight into this phenomenon, an experiment was carried out at the ATLAS facility at Argonne National Laboratory, Argonne. High spin states of the ^{183}Ir and ^{182}Ir nuclei were populated with the ^{150}Nd (^{37}Cl, 4n) ^{183}Ir and ^{150}Nd (^{37}Cl, 5n) ^{182}Ir reactions, respectively, at a beam energy of 170 MeV. The Argonne-Notre Dame Gamma-ray Facility (an array of 12 high-efficiency Compton-suppressed HP Ge spectrometers surrounding a (nearly) 4π-geometry, 50-element BGO-detector multiplicity array) was employed to measure the emitted γ-radiation. The target was enriched ^{150}Nd (1.7 mg/cm^2 thick) evaporated onto a 20 mg/cm^2-thick gold foil and covered by a thin (0.27 mg/cm^2) Au layer to prevent oxidation. About 114 million γ-γ and higher fold coincidence events were recorded during 128 hours of the beam time; only events with *fold* $K \geq 5$, as registered in the BGO array, and a Ge-multiplicity of 2 (and higher) were collected.

The events were unfolded and sorted into eight 2K×2K γ-γ matrices (in-beam and out-of-beam, prompt and delayed coincidences) with different conditions set on the *fold* to enhance the reaction channels of interest. The events were also sorted into a 2K×256 γ-t matrix for determination of lifetimes of the excited levels with the use of a computer program for lifetime analysis, described elsewhere in this Annual Report, which fits complex time curves employing convolution of the prompt response function. Additional sorting into six γ-γ matrices, where γ-rays were selected according to the respective detector-beam angles, was done for extraction of DCO ratios for the individual γ-transitions.

A preliminary analysis of the prompt and delayed γ-γ matrices allows us to identify for the first time in ^{183}Ir the existence of two isomers with halflives of about 4 ns and 22 ns at excitation energy ≥ 1.6 MeV and with spin $I \geq 19/2$. They decay primarily by a strong cascade of 197, 253, 339 and 210 keV transitions to the 9/2-[514] bandhead at 645 keV. In addition, decay branches via 565 keV and 895 keV transitions and via 1608 keV transition to the ground state rotational band built on the 1/2-[514] Nilsson orbital has been found. Several time curves for γ-transitions in ^{183}Ir also exhibit two additional time components with lifetimes of about 10 ns and 32 ns, respectively, indicating a possible existence of other isomers in this nucleus. Our preliminary results show that the decay paths of these isomers are complex and, probably, highly fragmented. Further analysis is in progress.

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[2] G.D.Dracoulis et al, Nucl.Phys. A554 (1993) 439
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[4] R.B.Firestone et al, Table of Isotopes, 8th edition, John Wiley and Sons, New York (1996)

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PL9800611

2.9 Lifetime measurements in ^{180,182,184}Pt beyond the backbend

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Pt - Hg nuclei lie in the transitional region between well-deformed, prolate, rare-earth nuclei, and the slightly-to-moderately deformed oblate Hg and Pt with N > 108. In particular, $^{180-184}$Pt nuclei lie near the center of this transitional region where the coexistence of prolate and oblate structures have already been established. This shape coexistence is an indication that the cores of these nuclei are "soft" with respect to deformation and one can expect a change in the nuclear shape due to the alignment of quasi-particles at high spins. In all the even-even mass $^{180-186}$Pt nuclei [1-4], one observes a sharp increase in the transition quadrupole moment, Q_t, at low frequencies, followed by a rapid and significant decline in the backbending region. The initial sharp increase in the Q_t can be explained in terms of mixing at low spins of two bands with very different deformations [1-3]. The decline in the backbend region has been attributed to the transition to triaxial shape. The next obvious question is: what happens beyond the backbending region? We have performed DSAM measurements to explore the behaviour of Q_t beyond the backbending region in $^{180-184}$Pt.

The nuclei of interest were populated via $^{120-124}$Sn(^{64}Ni,4n)$^{180-184}$Pt reactions at a bombarding energy of 285 MeV. DSAM lifetime measurements were carried out at the Early Implementation GAMMASPHERE at LBNL, Berkeley. The targets were isotopically enriched foils (~1 mg/cm^2 thick), on a Pb backing (~75 mg/cm^2 thick). During the analysis, the γ-γ-γ coincidences were sorted into angle-dependent gated matrices. The computer code LILIFI [5] was used to extract lifetimes from Doppler-broadened lines. Lineshapes were calculated using the slowing-down histories, nuclear decay schemes, detector geometries, and side-feeding (to each state, approximated by a single rotational cascade of 5 transitions). Incidentally, from the γ- γ coincidence data, it has been possible to identify two new transitions in the yrast band of ^{182}Pt, extending this band up to $J = 30\ \hbar$.

Lifetimes have been extracted for states in ^{180,182,184}Pt at and above the backbending; the corresponding Q_t values from this and previous experiments [1-4] are summarized in Table 1. It should be noted that the DSAM analysis reproduces the Q_t values of some states which had earlier been measured using the RDM technique, testifying to the validity of the procedures and assumptions employed in the analysis. For ^{184}Pt the comparison between the experimental Q_t values and those obtained from standard TSR calculations shows an overall reasonable agreement and, on a qualitative level, quite good, indeed. In particular, the behavior of Q_t at and beyond the backbend is reproducible only by employing a large negative triaxial deformation ($\gamma \approx -15^0$) which corresponds to the alignment of a pair of $\nu i_{13/2}$ particles. Our measurements, therefore, clearly imply that the origin of the first backbend in these nuclei lies in $\nu i_{13/2}$ (and, not $\pi h_{9/2}$) alignment.

Table 1: Experimental Q_t's of states in the yrast band of ^{180,182,184} Pt

Ji → Jf	Q_t		
	^{180}Pt	^{182}Pt	^{184}Pt
$2^+ \rightarrow 0^+$	6.8 (±0.2)	5.77 (±0.17)	5.9 (±0.8)
$4^+ \rightarrow 2^+$	5.5 (±0.2)	6.37 (±0.19)	6.8 (±0.1)
$6^+ \rightarrow 4^+$	7.3 (±1.2)	7.45 (±0.24)	6.7 (±0.2)
$8^+ \rightarrow 6^+$	6.4 (±0.8)	6.88 (±0.27)	7.2 (±0.3)
$10^+ \rightarrow 8^+$	5.4 (±0.3)	6.95 (±0.28)	7.5 (±0.4)
$12^+ \rightarrow 10^+$	4.2 (±0.4)	5.33(±0.30)	5.8 (±0.3)
$14^+ \rightarrow 12^+$	5.1 (±0.4)	4.33 (±0.38)	$5.6^{(+0.51)}_{(-0.40)}$
$16^+ \rightarrow 14^+$	2.6 (±0.3)		$6.0^{(+0.58)}_{(-0.45)}$
$18^+ \rightarrow 16^+$	2.9 (±0.3)		$5.4^{(+0.40)}_{(-0.50)}$
$20^+ \rightarrow 18^+$	5.0 (±0.5)		$6.73^{(+0.23)}_{(-0.35)}$
$22^+ \rightarrow 20^+$	5.7 (±0.7)	5.07 (±0.5)	$6.02^{(+0.40)}_{(-0.30)}$
$24^+ \rightarrow 22^+$	6.6 (±1.0)	≥ 6.16 (±0.5)	$5.84^{(+0.52)}_{(-0.41)}$
$26^+ \rightarrow 24^+$			≥ 5.23 (±0.5)

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[2] J.Wei et al, BAPS 35 (1990) 1016 and University Notre Dame Nuclear Structure Laboratory Progress Report, 1987-1990, p.79
[3] J.C.Walpe et al, University Notre Dame Nuclear Structure Laboratory Triennial Report, 1990-1993, p.62
[4] R.K.Noorman, Ph.D. thesis, Rijksuniversiteit Groningen, 1991 (unpublished)
[5] H.Emling et al, Phys.Lett. B217 (1989) 33

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PL9800612

2.10 Computer program for analysis of the time spectra obtained in the delayed coincidence measurements employing convolution of the prompt response function

by R.Kaczarowski and W.Płóciennik

A computer program for the analysis of time spectra of delayed coincidences has been developed. The program permits to analyse time curves (γ-transition intensity v.s. time) resulting not only from single isomeric level decay but also a superposition of up to three "independent" time curves, when two or three gamma transitions from different levels or nuclei have very close energies. In this case resulting time curve is simply a sum of three exponential curves.

The program allows also for analysis of more complicated case: time curve for γ-transition deexciting the lowest level in a "sandwich" of up to three isomers (isomeric cascade decay). In this case the time dependence of the transition intensity is given by the following formula:

$$N'(t)=N_{03}e^{-\lambda_3 t}+N_{02}\frac{\lambda_2}{\lambda_2-\lambda_3}[e^{-\lambda_3 t}-e^{-\lambda_2 t}]+N_{01}\lambda_2\lambda_3[\frac{e^{-\lambda_1 t}}{(\lambda_2-\lambda_1)(\lambda_3-\lambda_1)}+\frac{e^{-\lambda_2 t}}{(\lambda_1-\lambda_2)(\lambda_3-\lambda_2)}+\frac{e^{-\lambda_3 t}}{(\lambda_1-\lambda_3)(\lambda_2-\lambda_3)}]$$

In order to take into account a finite time resolution of the detectors and the electronics the convolution method with the use of an experimental time-resolution curve $P(t)$ was employed [1]. Now the theoretical delayed coincidence time curve is described by equation:

$$N(t)=\int_0^\infty P(t-\tau)N'(\tau)d\tau$$

For discrete spectra the above formula can be rewritten as:

$$N(t_i) = \sum_{x_j=t_1}^{t_i} P(x_j)N'(t_i-x_j)$$

The program reads data (energy slices) from an experimental two-dimensional Eγ-time matrix (up to 4096×4096 channels, however, the true time dimension may be smaller) written in standard RADWARE binary format. Transition energy limits as well as energy regions chosen as prompt and (optionally) background have to be defined by user before the beginning of fitting procedure. During the analysis a fitted region and number of parameter of theoretical function $N(t)$ can be changed. The minimization is performed using slightly modified MINUIT minimization program [2]. The fitted parameters are halflives and intensities of decay components and intensity of prompt component - altogether up to seven independent parameters.

The program works in an interactive mode and user can watch on computer display a progress of each step of minimization in numerical form and on graphic display. An example of graphic display is presented on Fig.1. The results are saved on hard disk. The program is written in FORTRAN language and uses a standard X-window computer library as well as the "minig_x.a" RADWARE library. The program runs on any UNIX workstation, especially on Silicon Graphic INDY or SUN.

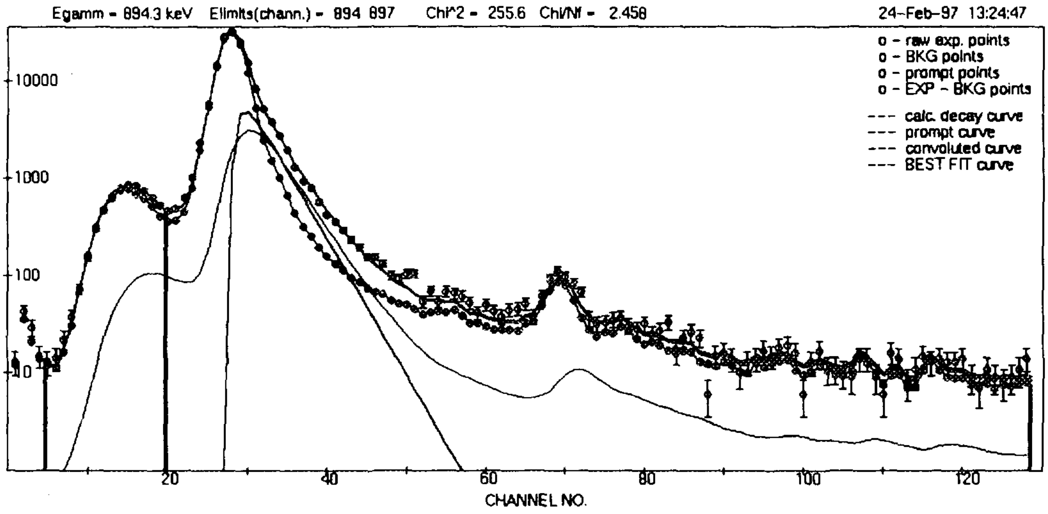

Fig.1 Example of fit results

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[2] F.James and M.Ross, Comp.Phys.Comm. **10** (1975) 343

2.11 Preequilibrium mechanisms in (p,xp) reactions at about Ep = 26 MeV

by Z.Moroz, J.Wojtkowska, A.Marcinkowski, B.Mariański

In 1996, a study of the continuous proton spectra from a (**p,xp**) reaction using 26 MeV protons from the C-30 cyclotron was continued. Further experimental data on double differential cross sections were obtained for the natural **Ni** and ^{26}**Mg** enriched targets respectively. Contrary to reported in 1995 case of ^{93}**Nb(p,xp)** [1], proton spectra were measured in the range from 30 to 150 degs LAB in steps of 5 degs.

All data are, at present, subject to extensive theoretical analyses using suitable "pre-equilibrium" codes. In general it is assumed that the spectrum of outgoing particles consist of four independently calculated contributions, namely COLL + MSD + MSC + EQU. Direct collective contribution COLL is calculated in the microscopic DWBA approximation, using a fenomenological deformed form-factor. Coupling of the GDR with the continuum was also included. The collective level density of the final nucleus was taken from experiments.

The multistep direct part (MSD) was calculated using microscopic DWBA with a 2-body form-factor and particle-hole interaction replaced by effective particle-particle interaction. Energy levels and their quantum numbers were taken according to the standard shell model. In general, the effective interaction of the NN collision in the nucleus was taken to be central, of the Yukawa radial form with standard value of r_0=1 fm. Both, the multistep compound (MSC), in FKK approximation, and thermodynamically equilibrated (EQU) contributions were calculated using our computer code EMPIRE.

During the calculations, special attention was paid to comparison between (**n,xn**) and (**p,xp**) reactions. Calculations of ^{93}**Nb(p,xp)** using the one-component version of the preequilibrium code (protons and neutrons in the target nucleus are not distinguishable) have shown that for incident energy 26 MeV, the high energy part of MSD contribution appeared to be signifficantly lower than that needed to explain the experimental data. It is in clear contradiction to the case of ^{93}**Nb** (**n,xn**) where this agreement is very good.

In search for a reason of this discrepancy, new calculations of the MSD of the two-component type were performed. Radial form-factors of the effective interactions for **pp** and **pn** were kept identical, taking into account a proper isospin normalization factor only. For real NN form-factors some improvement was observed in comparison with the calculations of the one-component type, but still a discrepancy with experimental data is not fully removed.

Assumption of the pure real effective NN form-factor may be oversimplified, as was shown already in some analyses of the elastic and direct inelastic proton scattering of relative low energy, made by other authors [e.g.M.A.Franey, W.G.Love [2]]. Therefore we tried a simple generalization, of our calculations, taking the effective interaction to be complex, with the same radial form for both real and imaginary parts, and treating only the phase angle as a free parameter. We found a significant dependence of the result on the value of the phase angle, but relatively large increase of the MSD proton spectra is obtained for rather large phase angles (close to 90 degs), which seems to be rather hard to justify physically.

To approach this problem in a more physically correct way, one should adapt in MSD calculations a more sophisticated form of the effective NN interaction in a nuclear medium, which can be obtained from the g-matrix calculations using the coresponding Bethe-Goldstone equations. Another way is to use complex effective interaction which, in principle, can be obtained from the fit of the experimental data on elastic and direct inelastic scattering, using corresponding folded form-factors. The practical applicability of such methods have not been not tested, as yet. At present, both approaches are now considered by us.

Another generalization of the effective interaction concept comes if one takes into account a finite size nucleus. Quite recently, it was shown by M.Avrigeanu et al. [3] in the semi-classical and local-density approximation that the effective interaction is trajectory dependent and this, to some extent, may explain experimentally observed difference between strengths **pp** and **nn** effective interactions in preequilibrium reactions. Of course, correct calculations for relatively low incident energies we have dealing with require quantum-mechanical rather than semiclassical calculations. This makes this problem much more difficult and, to our knowledge, not as yet attacked.

[1] Z.Moroz, J.Wojtkowska, A.Marcinkowski, B.Mariański, W.Czarnacki, RAPORT SINS - 16/II
[2] M.A.Franey, W.G.Lowe, Phys. Rev. C31 (1985) 488
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2.12 Study of the $^{25}Mg(p,d)^{24}Mg$ reaction at 26 MeV

by J.Wojtkowska, Z.Moroz, J.Turkiewicz and W.Czarnacki

PL9800614

Using a 26 MeV proton beam from the C-30 cyclotron in Świerk, the differential cross sections of (p,p_0), (p,d_0) and (p,d_1) reactions on a ^{25}Mg target have been measured [1]. The experimental data were analyzed in the frame of the CRC method using the FRESCO code. The results of the calculations are plotted in Figs 1 - 3 together with experimental distributions.

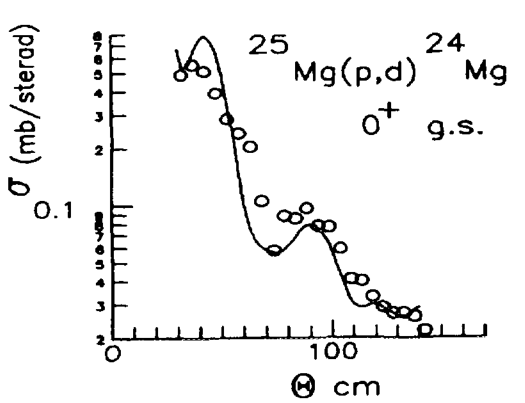

Fig.1 Deuteron angular distribution for the ground state of ^{24}Mg.

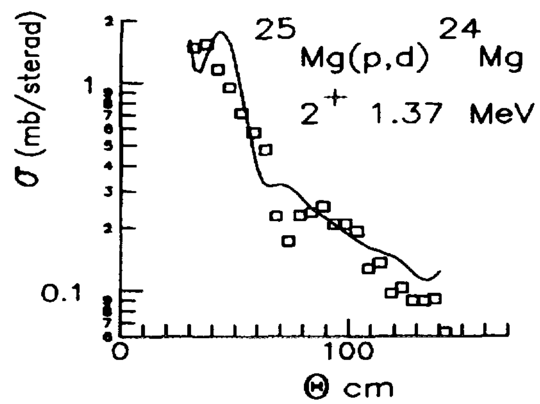

Fig.2 Deuteron angular distribution for the 1.37 MeV level of ^{24}Mg.

As can be seen from the figures, the CRC calculations give a good description of the investigated reaction leading to low-lying states of the final nucleus ^{24}Mg. There is evidence from our data that for the high excited states of ^{24}Mg this description is not so good. We also observe a very strong transition to the 9.52 MeV (4^+,T=1) state of ^{24}Mg. This transition is probably connected with the excitation of ^{24}Na ground state isobaric analogue. Therefore we continue the experimental data processing to obtain deuteron angular distributions for higher excited levels of ^{24}Mg.

[1] J.Wojtkowska, Z.Moroz, J.Turkiewicz, W.Czarnacki, SINS Annual Report 1995, p.20

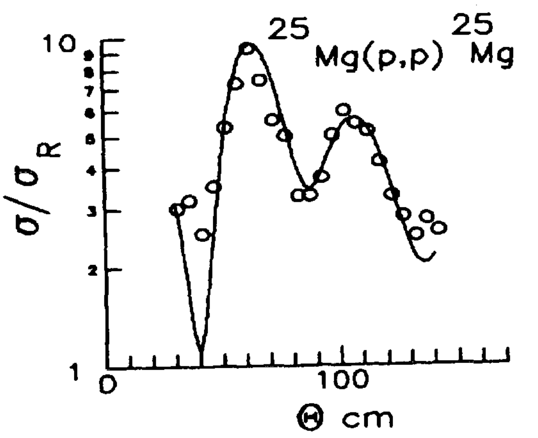

Fig.3 The differential cross section divided by the Rutheford cross section for elastic scattering of protons.

2.13 High resolution study of Kα hypersatellites spectrum of $_{42}Mo$ atoms induced by 17 MeV/u ^{16}O beam

by P.Rymuza, D.Chmielewska, T.Ludziejewski, Z.Sujkowski, D.Castella[1)], D.Corminboeuf[1)], J.-Cl.Dousse[1)], B.Galley[1)], Ch.Herren[1)], J.Hoszowska[1)], J.Kern[1)], M.Polasik[2)], M.Pajek[3)]

Measurements of K X-ray spectra with resolution comparable to the natural width of the emission lines provide rich and valuable information about the structure of singly and multiply ionized atoms. Satellites appearing in such spectra arise as a consequence of the reduced screening of the nuclear charge due to additional holes in inner electron shells. If the initial state of an atom is doubly ionized in the K-shell, the radiative $K^{-2} \rightarrow K^{-1}L^{-1}$ decay is characterized by the emission of so-called hypersatellite X-ray $K^h\alpha$. A measurement of the energies of the X-ray transitions between multivacancy states offers a possibility to test the atomic structure models under unique conditions. Moreover, since the $K\alpha_1$ hypersatellite transition is forbidden in the pure L-S coupling scheme, the relative yields of the $K^h\alpha_1$ and $K^h\alpha_2$ hypersatellites strongly differ from those of the corresponding diagram lines. Thus the measured $K^h\alpha_1$ / $K^h\alpha_2$ intensity ratios directly reflect the influence of mixing between j-j and L-S coupling schemes which occurs for medium Z atoms. They are further influenced by the Breit interaction [1].

The measurement was carried out at the PSI variable energy cyclotron in Villigen, Switzerland, using a 277 MeV ^{16}O beam. The X-ray were measured with a high resolution crystal spectrometer in the modified Du Mond slit geometry. The Kα X-ray spectrum is shown in the figure.

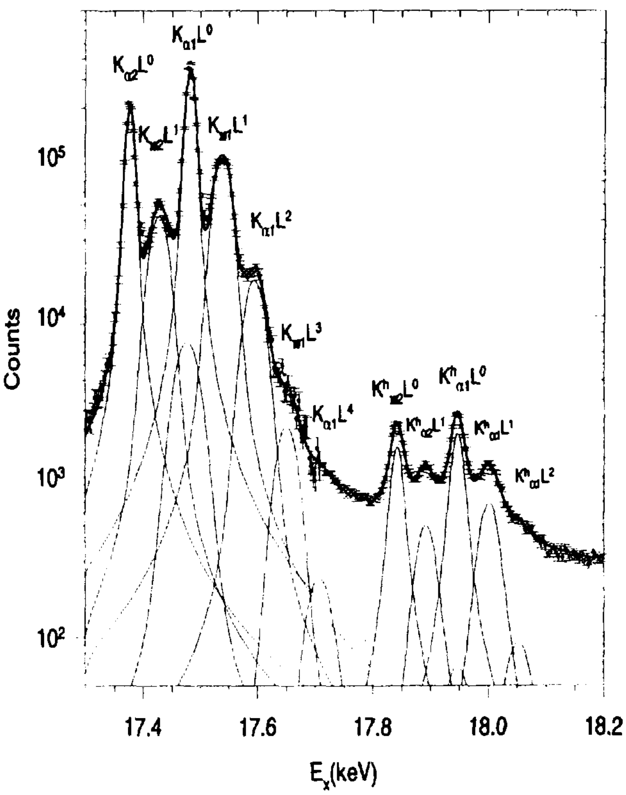

Fig.1 Crystal spectrometer K X-ray spectrum of molybdenum induced by 17 MeV/u ^{16}O ions.

The experimental $K^h\alpha_1$ and $K^h\alpha_2$ hypersatellite energies and relative yields were determined and compared with theoretical predictions [2]. A good agreement with the MCDF calculation including the proper Breit term was obtained. A more detailed discussion of these results is presented in Ref. 3 and 4.

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[2] Polasik M., *Phys.Rev.* **A40**, 4361 (1989)
[3] Boschung B. et al. *Phys.Rev.* **A51**, 3650 (1995)
[4] Rymuza P. et al., *CAARI'96, AIP Conf. Series*, in press

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PL9800616

2.14 A tubular ionizer as a high efficiency negative fluorine ion source

by A.Piotrowski, T.Kozłowski and M.Laskus

The study [1] of the tubular ionizer has been continued with a tantalum tube. In order to examine the efficiency of negative ion production by the tubular ionizer, a SF_6 gas was used. Decomposition and desorption of thermal SF_6 molecules have been observed.

The tubular ionizer was made from a tantalum tube with inner diameter 3 mm, outer diameter of 5 mm and length 30 mm. The principle and construction of this ion source has been described in [2]. Fig.1 shows the desorbed negative ion currents of SF_6 and SF_6 decomposed molecules as a function of the ionizer temperature. One interesting result is the formation of SF_6 ions which confirms the existence of low-energy (<0.2eV) electrons with sufficient concentration for production of SF_6 ions by electron capture and permits us to conclude the low energy spread of ions produced by tubular ionizer. To obtain a reasonable efficiency for negative ion formation, the work function of the ionizer surface should be small. This is usually established via adsorption of a submonolayer of electropositive atoms. The influence of the negative fluorine ion current is shown in Fig. 2.

The estimated increasing factor of the fluorine current is of the order of $4*10^4$ at maximum, leading to the production efficiency of fluorine ions of up to 40% defined as the ratio of the measured current of F^- ions to the number of SF_6 molecules. Thus this kind of ion source seems to be a good candidate to produce radioactive fluorine ion beams for the RBF (Radioactive Beam Facility). Such beams are needed to study astrophysical processes; an inhomogeneous Big Bang and explosive hydrogen burning, for example.

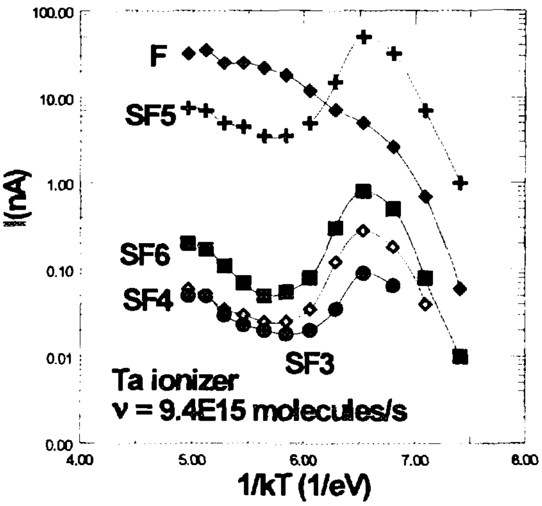

Fig.1 The temperature dependence of the F, SF_5, SF_6, SF_4, and SF_3 ion currents

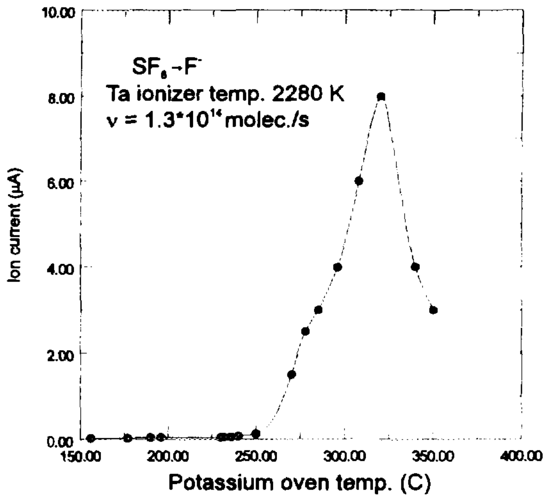

Fig.2 The fluorine ion current as a function of the potassium oven temperature.

[1] A.Piotrowski, T.Kozlowski and M.Laskus, SINS Annual Report 1995, p.35.
[2] A.Piotrowski, T.Kozlowski and M.Laskus, "Study of negative ion emission from the tubular ionizer" Nucl. Instr. Meth. submitted.

2.15 Practical data on the first Townsend coefficient of organic vapour in avalanche counters

by J.Sernicki

The first Townsend coefficient (α), defined as the ionization number per unit path length, is still a subject of interest for scientists conducting research on detectors operating with gas amplification. One reason for conducting this research is the undoubted fascination with the subject, but to the common user of the detector the main wish is to have the fullest applicable data on α. It is true that at present there is generally insufficient data available on α under high reduced electric field intensity (K/p) values; the α coefficient is a function of the K/p ratio, where K specifies the field intensity while p refers to the gas pressure. On the other hand, the rapid growth of parallel-plate avalanche counters (PPAC) has created a qualitatively new demand for data on the α coefficient - principally of organic vapours - under high K/p values. It is understandable that the most wanted solution would be a simple analytic representation of α by a universally applicable formula.

Today the solution nearest to fulfilling these requirements is undoubtedly Townsend's classic formula $\alpha/p = A \exp[-B/(K/p)]$, where A and B are a pair of characteristic gas constants. Unfortunately, among the available data on A and B just a few are intended for use with avalanche counters; as is shown in refs. [1-4] the appropriate value of α can only be obtained under the actual operating conditions of these detectors. That is why refs. [1,2,4] remain the only source of useful data on the α coefficient (under high K/p values) of organic vapours commonly used in avalanche counters; the data was obtained by the PPAC method using Townsend's α/p formula and a PPAC detector.

The purpose of the undertaken investigation is the optimal use of Townsend's formula for the estimation of gas amplification of avalanche counters. The gas constants, A and B, were determined by the PPAC method [1], implemented this time at pressures, p, successively increasing by 1 Torr. Parallel-plate avalanche counters, filled with n-heptane vapour, were used. From three very precisely determined - at different boundary conditions - variants of data on the first Townsend coefficient of n-heptane in PPAC detectors, the optimal solution was chosen, justifiable in the range of K\p-values from 172.2 to 940 V/cm·Torr, which includes the largest spans of applicable PPAC operating voltages. The obtained results were compared with the author's previous solutions [1,2].

The most appropriate - from the practical point of view - set of data is given in table 1. The character of the variability of veracity of the present gas constants vs p (fig. 1) has generally remained the same as presented in ref. [1]; the spread presented in the figure is considered to be a measure of veracity of the gas constants as well as of the absolute gas amplification value of avalanche counters. The values of the spread, however, have generally become a little larger.

Table 1. Gas constants of n-heptane in PPAC, A and B, and their resultant values, A_r and B_r, justifiable over given intervals of reduced electric field intensity (K/p) at the individual electrode spacings d. The constants were determined based upon the semiempirical $(\alpha d)_s$ equations at the given values of pressure p; U is expressed in Volts.

d [cm]	$(\alpha d)_s$	p [Torr]	K/p [Vcm^{-1} $Torr^{-1}$]	A [cm^{-1} $Torr^{-1}$]	B [Vcm^{-1} $Torr^{-1}$]	A_r [cm^{-1} $Torr^{-1}$]	B_r [Vcm^{-1} $Torr^{-1}$]
0.1	$-0.596p+0.0172U+0.002130pU-0.000062p^2U$ $p\leq 18$ Torr	5 - 18	249 - 940	30.3	577		
0.2	$-1.21p+0.0283U+0.001399pU-0.000049p^2U$ $p<10$ Torr $-1.21p+0.0363U+0.000115pU$ $p\geq 10$ Torr	5 - 30	221.7 - 570	35.1	580		
0.3	$-1.69p+0.0396U+0.000064pU$	5 - 25	184.9 - 400	43.4	573	44	580
0.4	$-2.28p+0.0386U+0.000191pU$	5 - 22	172.2 - 330	42.8	576	44	580

The obtained data on the first Townsend coefficient of n-heptane in avalanche counters should be adequate for those who use their PPACs as timing detectors [5] as well as those trying to use them as elementary detecting devices [6].

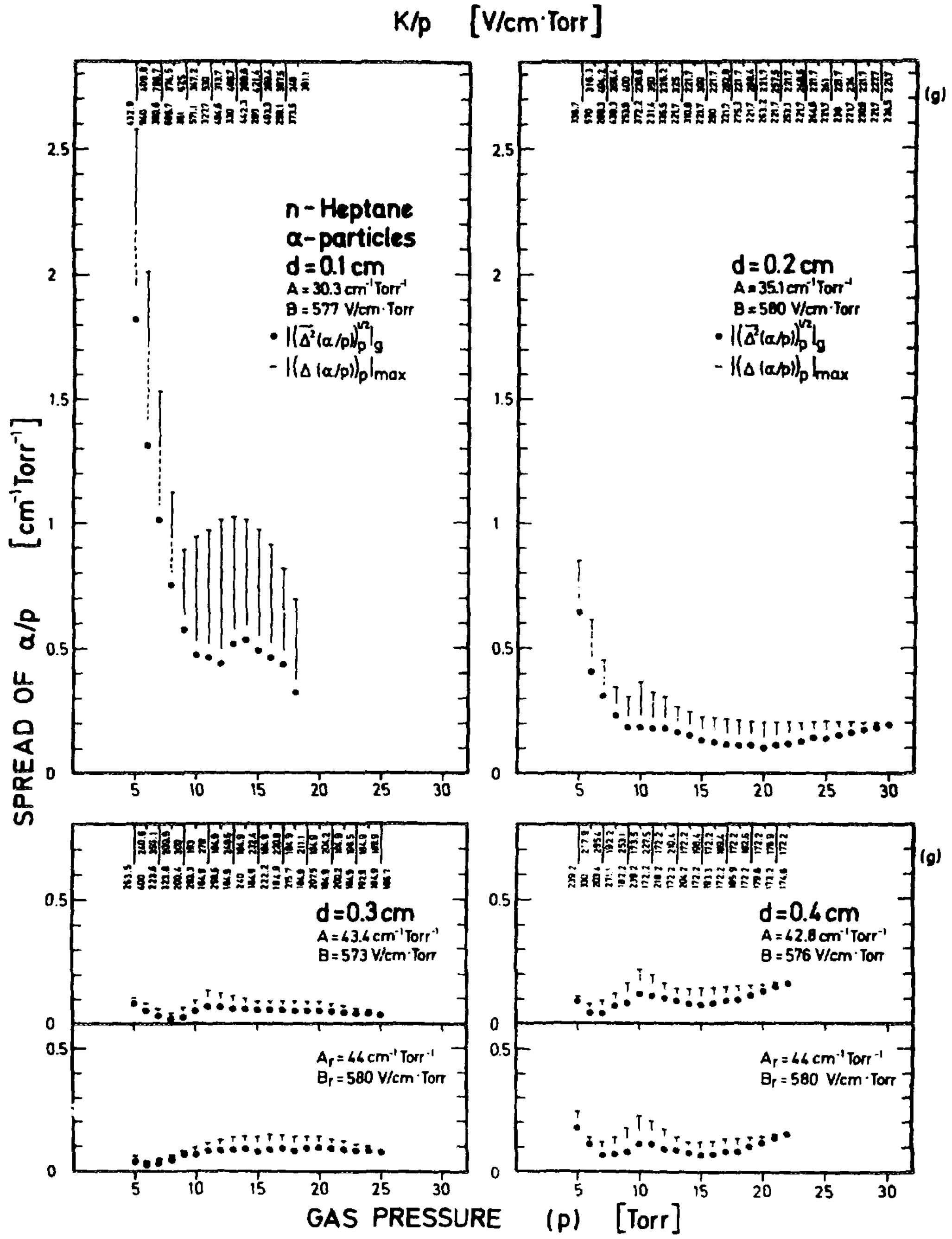

Fig.1. Spreads of specific $(\alpha/p)_s$ curves with respect to the respective general $(\alpha/p)_g$ curve, the latter determined by the gas constant pairs (A,B and A_r,B_r); the specific curves are determined by $(\alpha d)_s$ equations from table 1. The spreads at the individual pressures have been assessed for the respective K/p intervals specified in the plots, where the gas constants are claimed to be justifiable. The remaining symbols denote: $\overline{(\alpha/p)}$ is the mean square spread of α/p; $|(\Delta(\alpha/p))_p|_{max}$ is the maximum difference between the values of the curves.

[1] J.Sernicki, Nucl. Instr. and Meth. A288(1990)555.

[2] J.Sernicki, Nukleonika 40(4)(1995)67.

[3] P.P.Shakkeeb, A.Joseph, A.M.Vinodkumar, K.M.Varier and B.R.S.Babu, Nucl. Instr. and Meth. A366(1995)320.

[4] G.Brunner, Nucl. Instr. and Meth. 154(1978)159.

[5] J.Sernicki, Nucl. Instr. and Meth. A251(1986)81.

[6] J.Sernicki, Nucl. Instr. and Meth. A263(1988)446.

2.16 Contribution to the projects of flue gas cleaning from NO_x and SO_2 contaminations using electron irradiation.

by M.Sowiński, J.Boużyk*, J.Licki**, M.Kowalski, Z.Moroz, J.Wojtkowska

Recently, the technology of cleaning flue gas from ecologically dangerous contaminations of NO_x and SO_2 by means of the electron irradiation method is being introduced to the industrial applications. During the last few years, the method was successfully studied in laboratory and semi-industrial conditions by the Institute of Nuclear Chemistry and Technology in Warsaw, with a significant contribution of the Institute of Atomic Energy as well as of our Institute. At present, a big project of the demonstration installation is in preparation for the Electric Power Plant in Pomorzany. The installation will enable us to reduce SO_2 and NO_x emission to values less than the limits described by Polish Standards valid from 1997 (870 g/GJ-SO_2, 170 g/GJ-NO_x). This project is supervised and partially financed by IAEA in Vienna.

Our activity was concentrated this year on a few subjects closely connected with these problems.

(i) Because a fuel cleaning problem is closely related to the correct environmental monitoring system which, in fact, should be an important part of the whole installation, our first task was to install and test an experimental computerized system for monitoring of NO_x and SO_2 contaminations. This was done in EP "Kawęczyn". The system is based on the gas analyzer MIR 9000. A full monitoring system was already installed and preliminarily tested outside the boiler.

The monitoring system is controlled from a standard IBM compatible PC. For this purpose a special program MANAGER was written and installed, which allows us to run the system by the operator from the PC console and perform basic measurements, as well as tests and calibrations needed to control effectively the work of the monitoring device. Tests are planned to be continued in 1997. They should allow us to estimate the effectiveness of the continuous monitoring of the flue gas contaminations and its economical impact on the whole EP station operation.

(ii) A second direction was to build a computer program MODEL, devised as a tool for theoretical estimation of the process parameters, such as electron beam currents, gas temperature, its humidity and flow needed to obtain a given level of the NO_x and SO_2 removal from the flue gas, being irradiated by the electron beam. The basic formalism was published in [1] and [2]. The program MODEL is a computer implementation of this method, generalized to a form suitable for use by an operator of the flue gas cleaning installation. It is written in the form of the menu driven dialog between an operator and computer, which allows one to fix needed process parameters, for given values of the initial contaminations of the flue gas and needed final level of the NO_x removal. The theoretical model contains a few free parameters, which at present can be only very crudely estimated, taking experimental data obtained in the past in such installations as being installed in Kawęczyn and in a few foreign laboratories, such as JAERI(Japan) and KfZ Karlsruhe (Germany). Comparison of the results obtained in different laboratories shows that these parameters are rather installation dependent and finally can be fixed after completion of the testing runs preformed with a given installation. At present using the MODEL program different sets of model parameters are tested in the hope to understand the domains of their applicability in technological conditions present in different installations.

(iii) A third direction of our activity was to prepare a conceptual project of the computerized monitoring and control system for the Demo Industrial Installation in EP Pomorzany. This system is assumed to play a significant role during the installation implementation as well as during its exploitation. The system will perform the following main tasks:

1. continuous supervision of the process parameters and the installation control (automatically and manually) in normal, emergency and damage situations;
2. continuous monitoring of the emission levels of SO_2, NO_x, NH_3 and dust in order to fulfill the requirement of the "Administrative Decision" delivered by the County Office in Szczecin;
3. continuous control of the effectivity of electrofilters;
4. current optimization of the installation exploitation;
5. demonstration to outside visitors of the functioning of the installation without stopping its operation.

Besides this, the system will be equipped in a special simulating program. The first version of such a program, named MANAGER_P, was already written and successfully run, enabling us to get experience in solving various particular problems met by an operator.

(iv) A separate task was the preparation of the project of the internal electron beam monitor, which can be installed in the centre of the irradiation chamber and is used to measure the electron beam in the centre of the tank and estimate the dose levels in the whole chamber. The model of such a monitor was invented by us some time ago. Its first version was tested successfully in 1995 in the experimental installation working in EP "Kawęczyn" [3]. The present version of the monitor which is planned for EP "Pomorzany", is essentially similar to that tested in Kawęczyn. However, it fulfils many other rather complicated mechanical requirements needed in fully industrial applications and is planned to be automatized and remotely controlled by a computer. At present, all the technological requirements and general project are determined.

[1] M.Sowiński, J.Boużyk, Report SINS - 7/II (1994)
[2] M.Sowiński, J.Boużyk, Report SINS - in print
[3] E.Kulczycka*, M.Kisieliński*, Z.Moroz*, M.Sowiński*, J.Wojtkowska*, A.Chmielewski, S.Hashimoto, JAERI-Research 96-053, p86

**) Institute of Atomic Energy in Świerk
*) Institute of Nuclear Studies in Świerk

PL9800619

2.17 Modelling and simulation of real e-beam industrial gas treatment for an advisory process in a computer control system

by J.Boużyk, Z.Moroz, M.Sowiński

Our previous notes in SINS Annuals [1,2] briefly reported on a path-way used to describe e-beam processes in exhaust gas by a relatively simple model well approximating a real industrial process. This approach is based on simplified models of both NO_X and SO_2 radiation removal processes and an identification procedure adjusting proper coefficients to the linear dependence of the efficiencies of those processes on such technological parameters as gas temperature and its humidity, ammonia content and inlet NO_X/SO_2 concentrations. A coefficient matrix in the first approximation is determined using radiochemical data base and experimental dependencies of NO_X/SO_2 removal on technological parameters gathered during operation of various pilot plants. In Figs. 1 and 2, NO_X/SO_2 total efficiencies η calculated with our model are presented with their respective radiative parts η_0. Final values of the model coefficients will be set during a physical start-up process of the pilot plant and in that sense the elaborated model is attributed to a given installation. The model is incorporated in the computer code called MODEL which is an instrument of the whole computer control system to evaluate a proper accelerator current and the level of other technological parameters needed for operation on assumed NO_X/SO_2 removal efficiencies. Current NO_2/SO_2 inlet concentrations and other technological parameters measured autonomously by a data acquisition system are the input values for the computer code. The MODEL code continuously computes NO_X/SO_2 decay when a gas mixture flows through a process chamber and fits a proper accelerator current to yield in process chamber output assumed NO_X/SO_2 concentrations. Technological parameter levels may also be varied, and again a respective accelerator current is recommended to a control desk. If the cost of technological media is known an actual cost of radiative decontamination lowering NO_X/SO_2 content in exhaust gas to an assumed level may also be estimated on line.

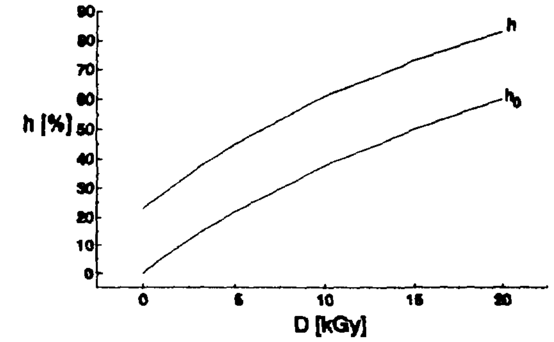

Fig.1 NO_x removal efficiencies vs absorbed dose yielded by elaborated model.

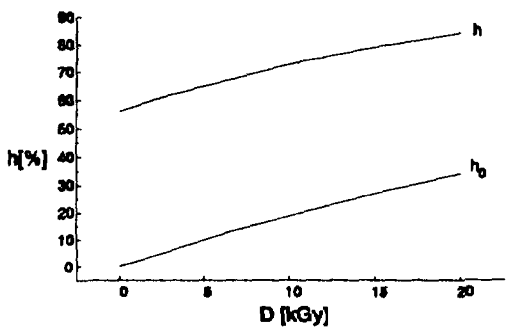

Fig.2 SO_2 removal efficiencies vs absorbed dose yielded by elaborated model.

[1] J.Boużyk, M.Sowiński - SINS Annual Report, 1994.
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2.18 Exotic radioactivity of nuclei

by J.Błocki, O.Mazonka[1], Yu.Pik-Pichak[2] and B.Sidorenko[1]

Branching ratios of the radioactive decay of nuclei by the emission of heavy clusters with respect to an alpha decay are examined. The assumption made earlier by Shi and Swiatecki [1] and Poenaru et al.[2] that the decay of the nucleus by the emission of heavy clusters can be treated as a very asymmetric fission was adopted in the calculations. The parametrization of the shape of the fissioning system was taken as two spheres connected smoothly by a second degree polynomial in cylindrical coordinates [3]. In this way we have a prametrization of the shape which is more relevant for fission than just two spheres without a neck [1,2]. Branching ratios are calculated as a ratio of the Gamow penetrability factors without any preformation factors. In order to calculate a Gamow factor, one has to decide what mass tensor and potential to take. For the mass tensor we have taken a hydrodynamical mass in the Werner-Wheeler approximation. The potential energy is calculated as a Coulomb one for a uniformly charged drop and a folding part [4].

Until now all experimentaly discovered cluster radioactivities lead to a heavy daughter nuclei close to ^{208}Pb or to ^{102}Sn, as recently discovered decay of ^{114}Ba nucleus. That means that closed shell nuclei as daughter ones are very strongly bound and therefore the most preferable for such exotic decays. It is necessary then to take into account shell corrections in calculations of the potential energy. For this we have adopted shell corrections in a phenomenological form proposed by Myers and Świątecki [5] with an attenuation factor depending on deformation. As we go from a compound sphere through fission channel to two separated nuclei (spheres) we have two different shell corrections in entrance and exit channels. It is assumed that the shell correction for one compound nucleus is going smoothly to the shell corrections for two nuclei, a daughter one and a cluster, depending on the size of the neck. In Fig.1 there is a potential energy plot for the decay of ^{222}Ra into ^{208}Pb + ^{14}C with shell corrections included.

There are two lines drawn in Fig.1 corresponding to a minimization of the Gamow penetrability factor. One of them (dotted) corresponds to a minimization of the integral of the square root of the potential only and therefore it takes a shortest way through the lowest barrier (saddle point) from the compound sphere (left hand corner) to the two separated spheres. The other line (dashed) corresponds to a minimization of the integral of the square root of a product of the potential and the mass tensor. Gamow factors calculated in this way for the decay of different nuclei by heavy cluster emission vary from 10^{30} to 10^{50}. The same procedure is repeated for alpha decay. After that we can define the branching ratios which are of the order of 10^{-10}. The agreement with experimental data is within 2-3 orders of magnitude.

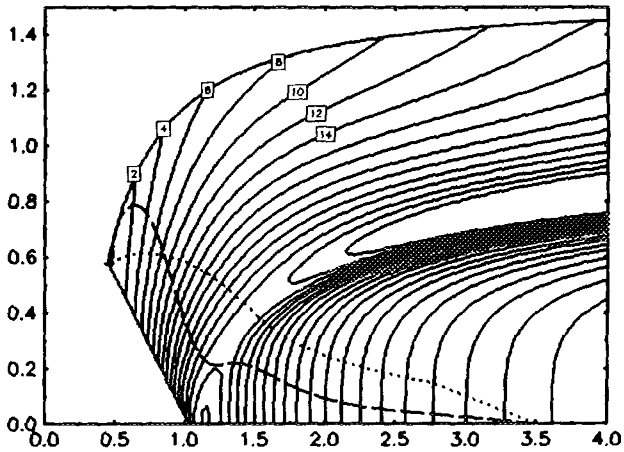

Fig.1 Potential energy for the decay ^{228}Ra→^{208}Pb + ^{14}C.

[1] Y.J.Shi and W.J.Świątecki, Phys.Rev.Lett.54(1985)300
[2] D.N.Poenaru et al., Phys.Rev.C32(1985)572
[3] J.Błocki and W.J.Świątecki, report LBL-12811(1982)
[4] H.J.Krappe, J.R.Nix and A.J.Sierk, Phys.Rev.C20(1979)992
[5] W.D.Myers and W.J.Świątecki, Nucl.Phys.81(1966)1

[1] Institute of Nuclear Research, Kiev, Ukraine
[2] Kurchatov Institute of Atomic Energy, Moscow, Russia

2.19 Excitation of an independent-particle gas by a time-dependent potential well. Part II

by J.Błocki, J.Skalski and W.J.Świątecki[1)]

A systematic comparison is carried out between quantal and classical computer simulations of the excitation of independent particles in a time-dependent, diffuse potential well undergoing one cycle of oscillation. This paper continues the studies reported in [1], denoted from now on as Part I. The background and motivation for these studies are described in Part I. Here we shall only repeat our conviction that in order to understand the collective dynamics of the intricate nuclear many-body system it helps to understand thoroughly the simpler problem of particles moving in a time-dependent external potential.

Eleven values of the diffuseness, up to 25 values of the oscillation frequency, and five Legendre polynomial deformations P_2, P_3, P_4, P_5, P_6 were examined. Oscillations around the spherical shape as well as around a P_3 deformed shape were considered. The results are compared with the one-body dissipation theory in the form of the wall formula [2], including corrections for the heating up of the gas, the diffuseness of the surface, the wave-mechanical suppression of dissipation and the reduction in the effective volume available to a quantal gas in a container whose diffuseness is small compared to the particle wavelengths.

[1] J.Błocki, J.Skalski and W.J.Świątecki, Nucl.Phys.A594(1995)137
[2] J.Błocki, Y.Boneh, J.R.Nix, J.Randrup, M.Robel, A.J.Sierk and W.J.Świątecki, Ann. of Phys.113(1978)330

[1)] Nuclear Science Division, Ernest Orlando Lawrence Berkeley National Laboratory, University of California, Berkeley, California 94720, USA

PL9800622

2.20 Upper limit of the Lyapunov exponent calculated from the potential

by J.Błocki, O.Mazonka[1)] and B.Sidorenko[1)]

The Lyapunov exponent is a measure of the average rate of exponential divergence (or convergence) of two trajectories with nearby identical initial conditions. For an N-dimensional phase space there are N characteristics average divergence (convergence) rates, given by N Lyapunov exponents λ_i, $i=1,...N$. If positive exponents are present, the largest of them λ_m will dominate the divergence between trajectories and it will control the exponential instability leading to chaos (in the case of regular trajectories all exponents of Hamiltonian systems are zero). We present a simple analitic method of calculation of the upper limit of this largest Lyapunov exponent λ_m. Let us consider a system for which the time evolution in phase space is described by a set of differential equations:

$$\frac{d}{dt}\vec{x}=F(\vec{x}) \tag{1}$$

The equation for a small variation δx of the orbit x(t) can be written as $\delta\dot{x}=J\delta x$, where J is the matrix $\frac{\partial F_i}{\partial x_j}$. The solution of this equation is: $\delta x(t)=L(t)\delta x_0$, where $L(t)=T\int_0^t Jdt$ and T is time ordering operator. The Lyapunov exponents λ_i are now defined as:

$$\lambda_i=\lim_{t\to\infty}\frac{1}{t}\ln E_i \tag{2}$$

where E_i are the module of eigenvalues of the matrix L: $E_i=\|A_i(L(t))\|$. The largest Lyapunov exponent λ_i corresponds to the largest eigenvalue $E_m=\|A_m(L(t))\|$, and taking into account an expression (2):

$$\lambda^m=\lim\frac{1}{t}\ln E_m=\lim\frac{1}{t}\ln\|A_m(T\int Jdt)\| \tag{3}$$

The upper limit of the largest Lyapunov exponent λ_m will then be equal to :

$$(\lambda^m)^{up}=\lim\frac{1}{t}\ln\ \exp\int ReA_m(J)\,dt=\lim\frac{1}{t}\int ReA_m(J)\,dt \qquad (4)$$

which is the limit of the average over time of the largest eigenvalue of matrix J when time tends to infinity $(\lambda^m)^{up}=\overline{ReA_m(J)}$. If we take an average over the phase space the expression (4) for the Newtonian system becomes equal to:

$$\overline{(\lambda^m)^{up}}=\frac{\int ReA_m(J(r))\rho(v)\,drdv}{\int\rho(v)\,drdv}=\frac{\int ReA_m(J(t))\,dr}{\int dr}=\frac{\int D\,dr}{\int dr} \qquad (5)$$

(the integrals are taken over E>V), and for two dimentional case:

$$D=\sqrt{-\frac{1}{2}(Tr\Delta V-\sqrt{(Tr\Delta V)^2-4\det(\Delta V)}} \qquad (6)$$

As an example we have taken a two dimentional potential:

$$V=x^2+y^2+2\exp(-3((x-0.1)^2+y^2)) \qquad (7)$$

Results are presented in Fig.1 where Lyapunov exponents as a function of the energy of particles are shown. Points correspond to numerical calculations of the largest Lyapunov exponents[1)] and a solid line is their average. The dashed curve corresponds to the upper limit of the largest Lyapunov exponent.

[1] G.Benettin, L.Galgani and G.M.Strelcyn, Phys. Rev., A14 (1986), 2338.

[1)] Institute for Nuclear Research, Kiev, Ukraine.

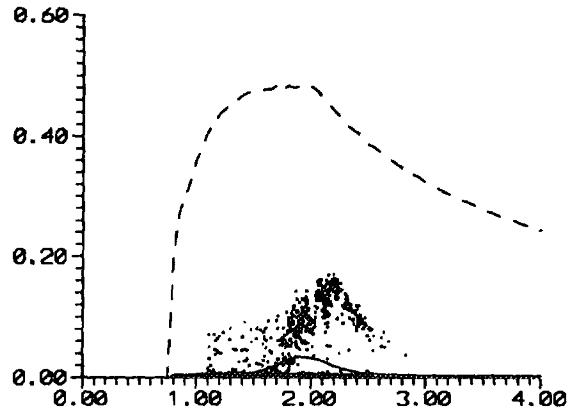

Fig.1

PL9800623

2.21 Monitoring of ground-level air pollution in the vicinity of Świerk in 1996

by E.Droste, M.Matul, S.Mikołajewski, B.Mysłek-Laurikainen, H.Trzaskowska.

1996 was the sixth year of operation the high volume aerosol sampling station type ASS-500 which is situated 6 km West of Świerk at the S.Kalinowski Geophysical Observatory of the Institute of Geophysics, Polish Academy of Science, Świder near Otwock. The monitoring network of the ASS-500 stations in Poland consisted of 11 stations in 1996. This network is supervised by the Central Laboratory of Nuclear Protection and State Inspection of Environmental Protection. The weekly reports are spread through internet and continuous, systematical exchange of data are provided. The sampling and measurement procedures were described in SINS Annual Reports 1992, 1993. In 1996 the ground-level air pollution was without any accidental events and the concentration of natural and artifical origin radionuclides is shown on Fig 1. Every year airborn ^{7}Be is the dominating radionuclide in the average level 2230 $\mu Bq/m^3$ with max 7300 and min. 760 $\mu Bq/m^3$. The ^{210}Pb is the decay product of the ground exhalated Rn and some amount is the remnant of nuclear tests and nuclear accidents in the atmosphere. The average value was 365 $\mu Bq/m^3$ the max. 1900 $\mu Bq/m^3$ and min. 65 $\mu Bq/m^3$. The presence of the most common component of the soil ^{40}K

is in the level 2-3 orders of magnitude lower. The ^{137}Cs which is mainly of Chernobyl origin is on the level of several $\mu Bq/m^3$. The average value is 2.59 max.(16,9±0,9)$\mu Bq/m^3$ min.(0,0±0,3)$\mu Bq/m^3$.

The average dust concentration was 41.75 $\mu g/m^3$ what was slightly higher then in 1994 and 1995 Table 1. Weekly data show typical seasonal dependence:
higher for winter, when coal and gas burning brings more pollution to the air.

Table 1. The average dust concentration in air:

YEAR	AMOUNT OF DUST		
	TOTAL	WINTERS	UMMER
1991	48,5 $\mu g/m^3$	62,6 $\mu g/m^3$	39,6 μg/m3
1992	46,7 $\mu g/m^3$	54,1 $\mu g/m^3$	36,1 μg/m3
1993	40,8 $\mu g/m^3$	48,5 $\mu g/m^3$	35,0 $\mu g/m^3$
1994	37,9 $\mu g/m^3$	38,6 $\mu g/m^3$	37,4 $\mu g/m^3$
1995	39,2 $\mu g/m^3$	42,4 $\mu g/m^3$	35,7 $\mu g/m^3$
1996	41,7 $\mu g/m^3$	46,4 $\mu g/m^3$	36.8 $\mu g/m^3$

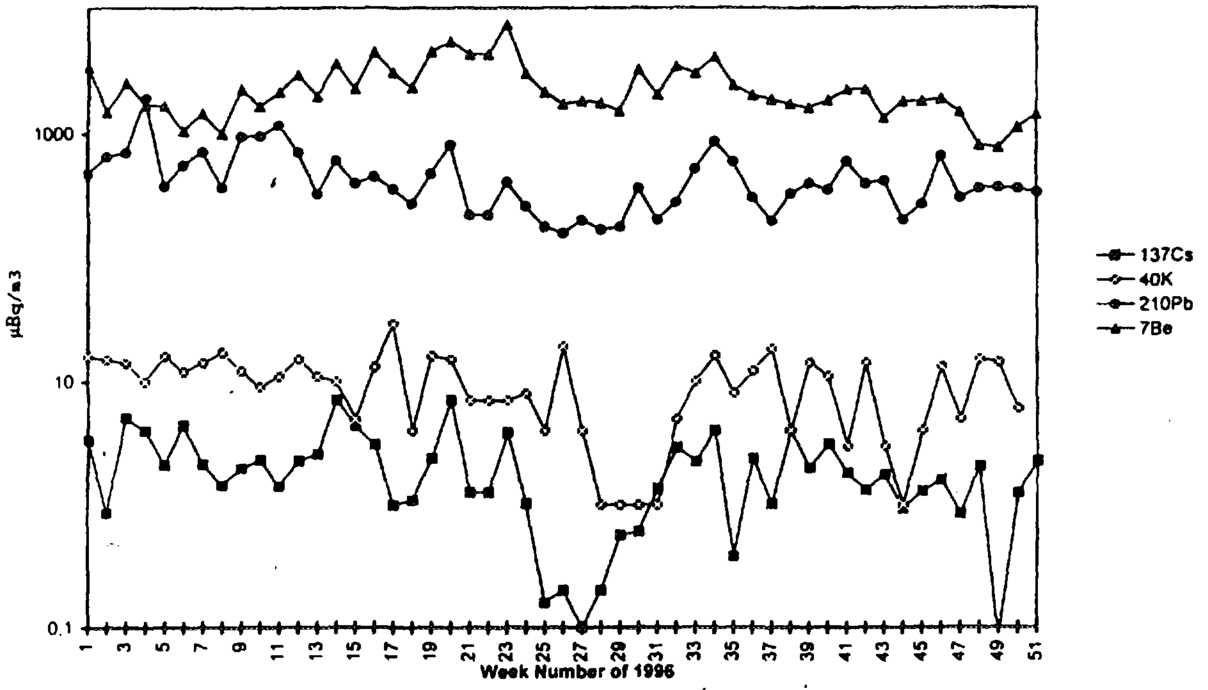

Fig.1 The concentration of radioactive isotopes in ground level air at the Świder sampling station.

PL9800624

2.22 Map of ^{210}Pb concentration in the soil in Poland

by E.Droste, M.Matul, S.Mikołajewski, B.Mysłek-Laurikainen, H.Trzaskowska.

^{210}Pb is one of the most common radionuclide in nature. The presence of ^{210}Pb in air gives the main contribution to inhalated doses. The short-lived decay products of ^{222}Rn decay to ^{210}Pb which has a radioactive half-life of 22 years and decays:

^{210}Pb(22 years)→ ^{210}Bi(5days)→ ^{210}Po (138days)→ ^{206}Pb (stable)

The ^{222}Rn exhalated from the earth's surface are redeposited as short-lived decay products, but most decay in the atmosphere to ^{210}Pb.The mean residence time of ^{210}Pb is short in comparison to its half-life, so the downwords flux of ^{210}Pb expressed as the number of atoms per square meter per sec. should be equal to the upwords flux of ^{222}Rn. It has been suggested that ^{210}Pb was formed in nuclear bomb tests but there is no evidence that concentrations were higher in the period (1955-1965) of frequent bomb tests in the air. There is some evidence that volcano activity may contribute to ^{210}Po and ^{210}Pb in the air. ^{210}Po was released to the atmosphere from the Windscale reactor in 1957. In the top soil, ^{210}Pb and ^{210}Po are in equilibrium and with dust they became in aerosol form the component of ground level air radioactivity. In this work the distribution of ^{210}Pb in topsoil in Poland was determined. About 90 soil samples were taken from the places used for soil sampling for the Radiological Atlas of Poland done by the Central Laboratory of Radiation Protection. The concentration was determined by measurement of 46 keV γ-line accompanying ^{210}Pb decay. Samples were taken according to IEAE requirements. The measurements were performed using a HPGe detector placed in a low-background chamber. Samples were measured using Marinelli geometry. The concentration of ^{210}Pb changes in the range from 7.9±1.3 to 91.2±1.2 Bq/kg with the average concentration of about 20 Bq/kg.The map of ^{210}Pb distribution in Poland is presented on Fig.1.

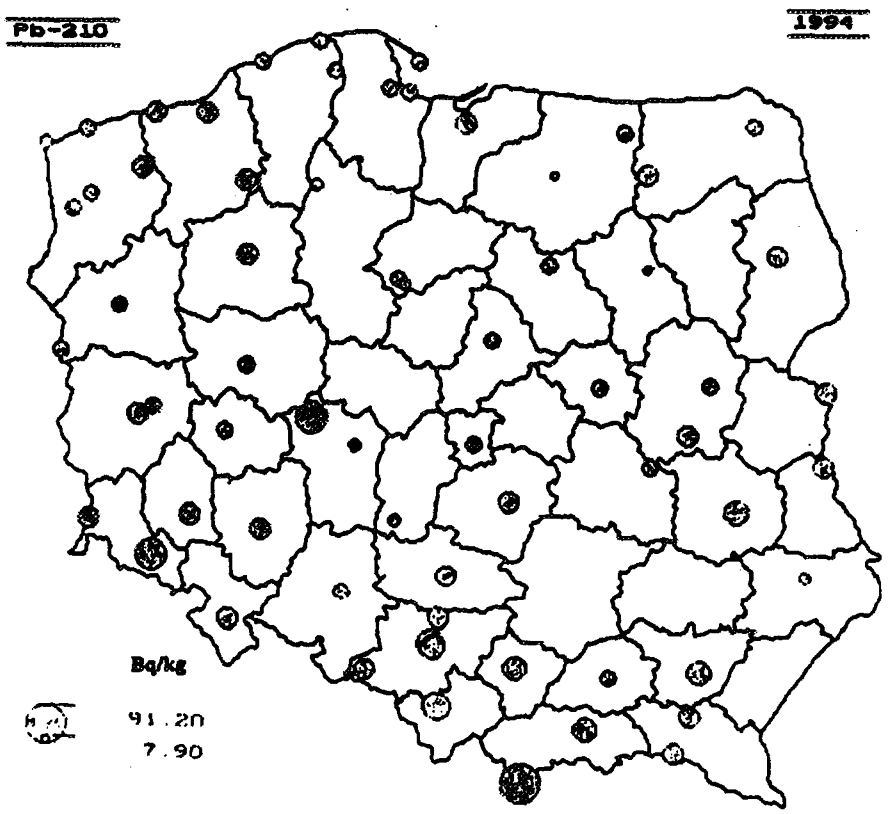

Fig.1 Map of ^{210}Pb concentration in the soil in Poland.

LIST OF PUBLICATIONS

ISOSPIN DEPENDENT p-n MULTIPLETS IN THE REGION OF DOUBLY MAGIC ^{100}Sn
Kownacki,...,**M. Palacz**, et al.
Proceedings of XXIV Mazurian Lakes School of Physics, Piaski, August 1995,
Acta Physica Polonica B27 (1996) 87

SPECTROSCOPY OF ^{57}Co BY γ-γ RECOIL COINCIDENCES WITH THE ^{40}Ca(^{20}Ne,3pγ)-REACTION AND THE ^{55}Mn(α,3nγ)-REACTION
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Danuta Chmielewska, Dr., since Sept.17,1996
Scientific Secretary of the Institute
Tadeusz Kozłowski, Dr.
Tomasz Ludziejewski, Dr.,on leave, till Sept.1997
Bogumiła Mysłek-Laurikainen, Dr
Zbigniew Moroz, Contract Professor
Marcin Palacz, MSc.
Weronika Płóciennik, Dr.
Antoni Piotrowski, Assoc.prof.
Zygmunt Preibisz, Dr.
Wojciech Ratyński, Professor, till Sept.16,
Director of the Institute
Ewa Ruchowska, Dr.
Edward Rurarz, Dr.
Piotr Rymuza, Dr.
Mieczysław Sowiński, Assoc.prof., 4/5
Ziemowid Sujkowski, Professor, since
Sept. 17, 1996, Director of the Institute
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Marian Laskus
Maria Matul
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3. DEPARTMENT OF NUCLEAR ELECTRONICS

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Overviev

The main activities of the Department of Nuclear Electronics were focused on five groups of problems:

- a study of new scintillation techniques,
- a contribution to the EUROBALL project,
- electronics for experiments in high energy physics,
- further development of hardware and software for IBM-PC based multichannel analyzers,
- technical support for the Institute as a whole.

Many results have been obtained, and construction and development projects have been furthered by the staff of the Department. The most important are:

- measurements of the absolute light output of several standard and new Ce doped scintillators and the development of a new approach to the light output measurement,
- a study of the avalanche photodiodes in scintillation detection
- a development of the front-end electronics for the EuroSiB, silicon ball for light charged -particles detection and identification in the EUROBALL project. This is the first electronics system that realizes a pulse shape discrimination with reversed Si detectors,
- development of electronics for a data acquisition system for the NA48 experiment at CERN and front-end electronics for the SPHERE experiment on the superconducting accelerator Nuclotron in JINR Dubna (commercial contract),
- development of a quantitative γ-ray analysis system.

The scientific activities of the Department were summarized in four published papers, four papers in press and one submitted paper. (All in IEEE Trans. on Nucl. Sci. and Nucl. Instr. and Meth.) Moreover, our scientists presented five contributions at international conferences and meetings, three of them at the IEEE Nucl. Sci. Symp. in Anaheim, USA. One of our colleagues got his DSc degree and then the position of Assoc. Professor in our Department. One of us has got the Soltan prize, first class for 1996.

The construction activity of the Department should be pointed out. Nine new electronics modules were developed, within them complex electronics modules for pulse shape discrimination with Si detectors (for EUROBALL) and FASTBUS modules for a data acquisition system in the NA48 CERN experiment.

The technical support of the Department for the Institute covers a large undertaking such as the project of the local network for the computer system at the Institute in Świerk (being under construction) and a number of hardware and software consultancies.

The Department was involved in scientific collaborations with a number of international centers. Among them is CERN, FZ Rossendorf, the Royal Institute of Technology in Stockholm, Boston University, JINR in Dubna and EUROBALL collaboration. We got support of foreign nuclear industry for our scientific activity. Philips Photonics in France has offered us calibrated XP2020Q photomultiplier tubes, Bicron in USA delivered a special set of BGO and CsI(Tl) crystals, both for work on the absolute light output of scintillators. Advanced Photonix in Camarillo, USA is supplying us with unique avalanche photodiodes which allow us to carry out a study of the future of scintillation detectors.

REPORTS ON RESEARCH

3.1 Absolute light output of scintillators

by M.Moszyński, M.Kapusta[1)], M.Mayhugh[2)], D.Wolski, S.O.Flyckt[3)]

The absolute light outputs of BGO, CsI(Tl) and some new Ce-doped crystals have been measured to an accuracy of about ±5 % using calibrated XP2020Q photomultipliers and standard S3590-03 and S2740-03 photodiodes, see Table 1.

Table 1
Absolute light output of tested scintillators

Absolute light output [ph/MeV]						
BGO	CsI(Tl)	GSO:Ce	LSO:Ce	YAG:Ce	YAP:Ce	LuAP:Ce
8500±350	61000±3000	7620±380	27300±1400	16700±660	18000±900	11300±450

The use of small crystals, 9 mm in diameter and 1 mm thick, reduces the corrections for imperfections in the light collection process and in the photoelectron collection by the photomultipliers. The measured light output of 8500±350 ph/MeV (photons/MeV) for BGO crystals well agrees with the earlier measurement done by Holl et al [1]. The study highlighted the importance of the spread in the published emission spectra of the crystals which seems to limit the measurement accuracy. Finally, a simple comparative method of measuring light output to an accuracy of ±10 %, is proposed using an uncalibrated XP2020 photomultiplier and a 1 mm thick BGO crystal as a standard.

Presented at IEEE Nucl. Sci. Symp. Anaheim, USA, November 1996. IEEE Trans. on Nucl. Sci. in press.

[1] I. Holl, E. Lorenz, G. Mergas, "A measurement of the light yield of common inorganic scintillators", IEEE Trans. on Nucl. Sci. 35(1988)105.

1) University of Warsaw, Institute of Experimental Physics, Hoża 69, PL 00-681 Warsaw, Poland,
2) Bicron, 12345 Kinsman Road, Newbury, OH 44065, USA,
3) Philips Photonics, BP520, F-19106 Brive, France,

3.2 Investigation of some scintillation properties of YAG: Ce crystals *)

by T.Ludziejewski, M.Moszyński, M.Kapusta[1)], D.Wolski, W.Klamra[2)]

Light output expressed in the photoelectron number, a relative light yield for α-particles and light pulse shapes for γ-rays and α-particles excitation of the YAG:Ce crystals with different Ce doping between 0.012 mol% and 1.08 mol% were studied. The highest light output of 1420±70 phe/MeV was measured for the sample doped with 0.21±0.03 mol% Ce, while the fastest pulse was observed for the sample doped with 1.08±0.08 mol% Ce showing, however, a light yield lower by 10%. The relative light yield for α-particles of 0.21±0.03 as compared to γ-rays was approximately the same for all the samples studied. In conclusion the YAG:Ce crystal doped with about 1 mol% of Ce is the most appropriate for different applications. For this crystal, the α-γ discrimination by the digital charge comparison method was studied. Although a clear separation was observed with the YAG crystal coupled to the XP2020Q photomultiplier for 5.49 MeV α-particles from ^{241}Am source, and 6.04 MeV and 8.77 MeV from ThC source, see Fig.1, it is inferior compared to the separation given by CsI(TI) crystal.

Submitted to Nucl. Instr. and Meth.

1) University of Warsaw, Institute of Experimental Physics, Hoża 69, PL 00-681 Warsaw, Poland,
2) Royal Institute of Technology, Department of Physics, Frescati, S-104 05 Stockholm, Sweden.

*) Support for this work was provided by the Polish Committee for Scientific Research, Grant No. 2-P302-096-07

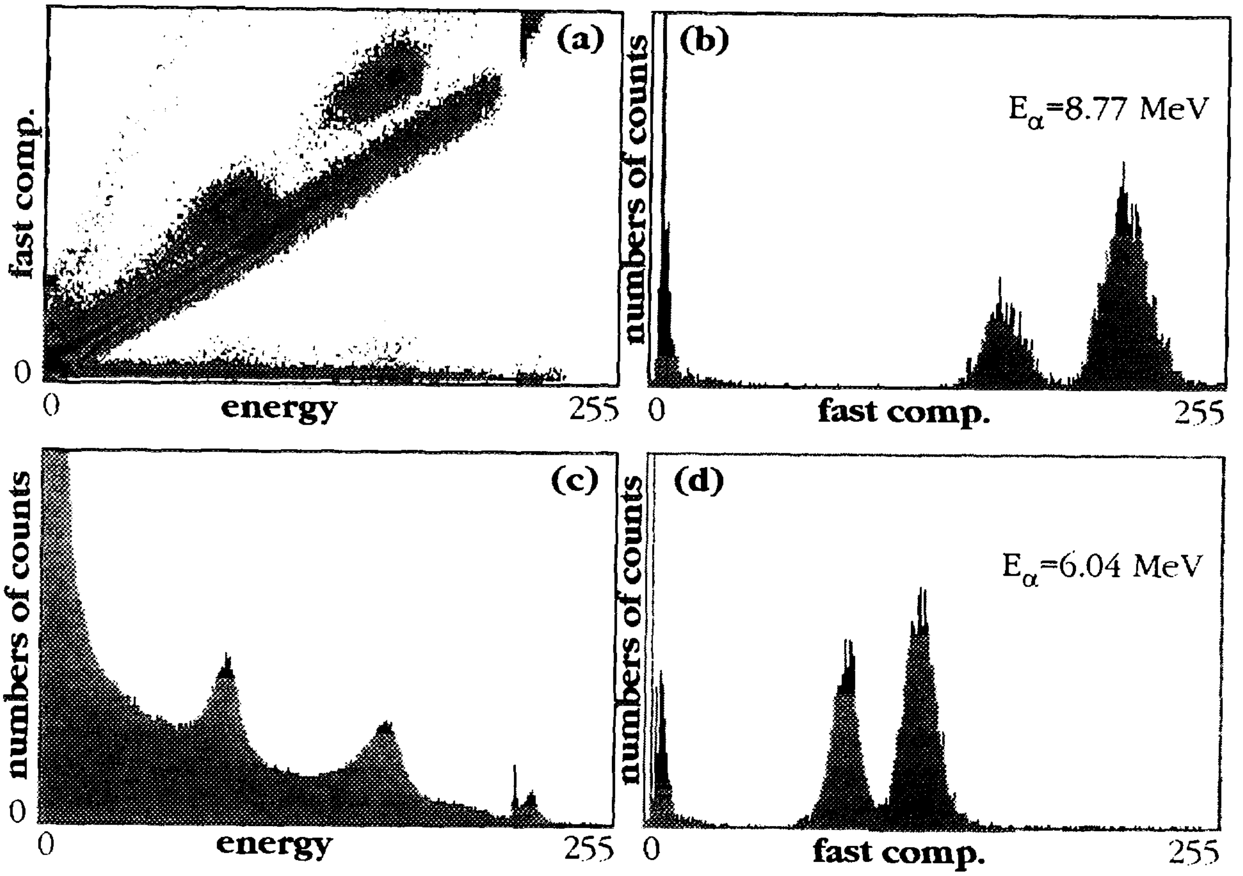

Fig.1 Two-dimensional spectrum of the charge under the fast component versus total charge showing separation of α-particles from a ThC source and γ-rays from Pu-Be neutron source, (a) 2-D spectrum, (b) and (d) one dimensional spectra corresponding to the gates at the 8.77 MeV and 6.04 α-peaks, respectively, (c) energy spectrum of α-particles and γ-rays.

3.3 Blue enhanced large area avalanche photodiodes in scintillation detection with LSO, YAP and LuAP crystals

by M.Moszyński, M.Kapusta[1], D.Wolski, M.Szawłowski[2], W.Klamra[3]

Scintillation detectors consisting of LSO, LuAP and YAP crystals fitted to bevelled-edge large area avalanche photodiodes of 10 mm in diameter characterised by a high quantum efficiency up to 68% at 350 nm wavelength were studied. Among the properties measured were the number of electron-hole pairs, energy resolution and noise contribution of the LAAPDs at shaping time constants down to 20 ns at different gains. High electron-hole pair numbers of 11000±550 e-h/MeV and 19500±9500 e-h/MeV for the YAP and LSO crystals were measured, respectively. The energy resolution for ^{137}Cs γ-rays of 5.9% (FWHM) for the YAP crystal, see Fig.1, much better than that of 9.8% for the LSO crystal were measured at 0.5 μs shaping time constant and the APD gain of 40. The same study done with a fast shaping of 20 ns and the APD gain of 160 showed the energy resolution of 6.7%, see Fig.2.

Presented at IEEE Nucl. Sci. Symp. Anaheim, USA, November 1996. IEEE Trans. on Nucl. Sci. in press.

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[2] Advanced Photonix, Inc. 1240 Avenida Acaso, Camarillo, CA 93012, USA,
[3] Royal Institute of Technology, Department of Physics, Frescati, S-104 05 Stockholm, Sweden,

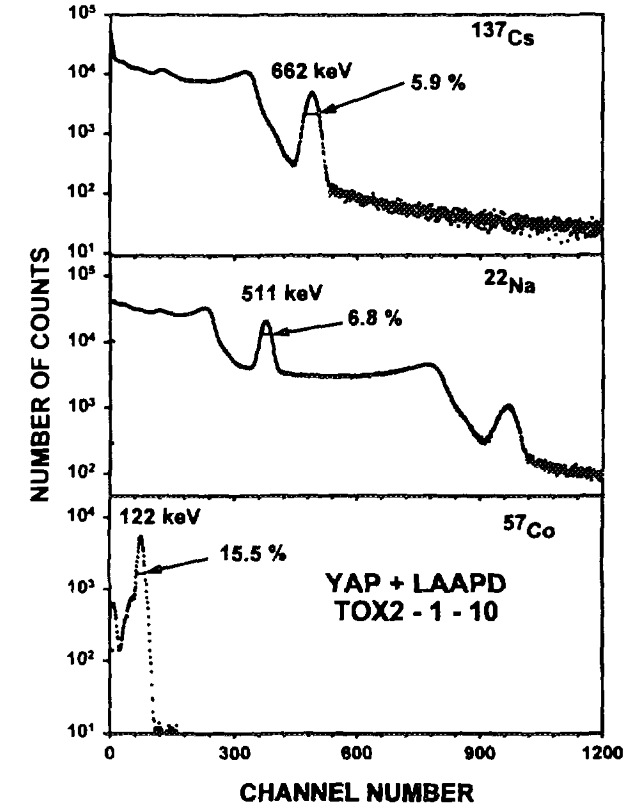

Fig.1 Energy spectra of γ-rays from ^{137}Cs, ^{22}Na and ^{57}Co sources measured with the YAP crystal at 0.5 μs shaping and APD gain of 40.

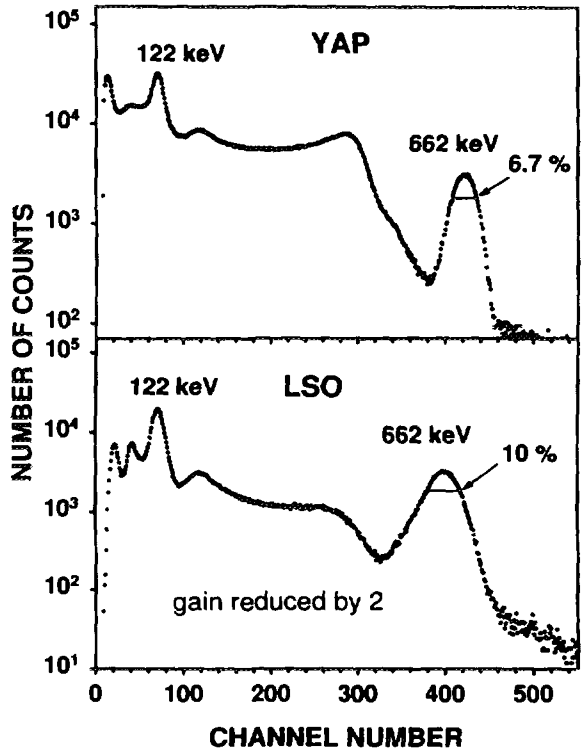

Fig.2 Energy spectra of γ-rays from ^{137}Cs and ^{57}Co sources measured with YAP and LSO crystals at 20 ns shaping and APD gain of 160.

PL9800629

3.4 Properties of the YAP: Ce scintillator

by M.Moszyński, M.Kapusta[1)], D.Wolski, W.Klamra[2)] and B.Cederwall[2)]

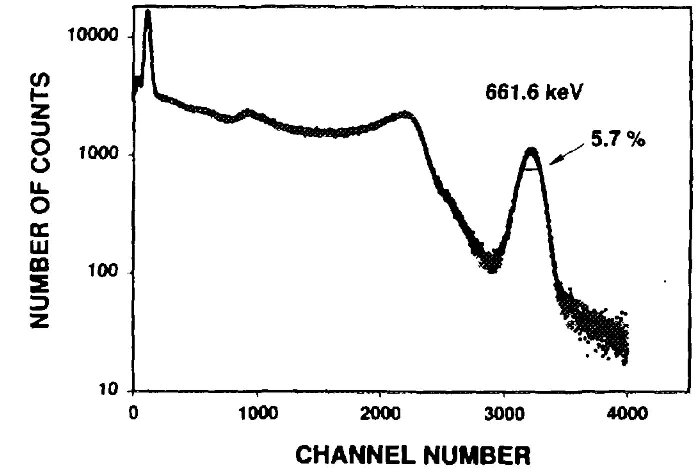

Fig.1 Energy spectrum of γ-rays from a ^{137}Cs source measured with YAP crystal coupled to XP2020Q photomultiplier.

Light yield, light pulse shapes due to γ-rays and α-particles, energy and time resolutions for the YAP crystal of 10x10x5 mm^3 coupled to the XP2020Q photomultiplier were studied. The light output of 17000±850 ph/MeV, as seen by PMT, was measured due to the known calibrated quantum efficiency of the XP2020Q. The fast component of the light pulse with the decay time constant of 26.7±0.12 ns also shows a finite rise time described by the time constant of 350 ps. The studied YAP crystal exhibited a very good energy resolution of 5.7% for 662 keV γ-rays from a ^{137}Cs source, see Fig. 1, due to a good intrinsic energy resolution of 3.4% of the crystal itself. This quantity together with a good time resolution for ^{60}Co γ-rays measured at a threshold of 1 MeV equal to 160 ps suggest a wide application of the YAP crystal in different fields.

To be published in Nucl. Instr and Meth.

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3.5 Front-end electronics for EuroSiB: silicon ball in EUROBALL *)

by M.Moszyński, D.Wolski, S.Borsuk and G.Pausch[1)]

EuroSiB, the 4π silicon ball for charged-particles detection inside of EUROBALL consists of 40 individual Si detectors of 500 μm thickness. It exploits the pulse-shape discrimination technique for proton-alpha discrimination with reversed n-type Si detectors. Fig. 1 presents a simplified block scheme of the EuroSiB electronics.

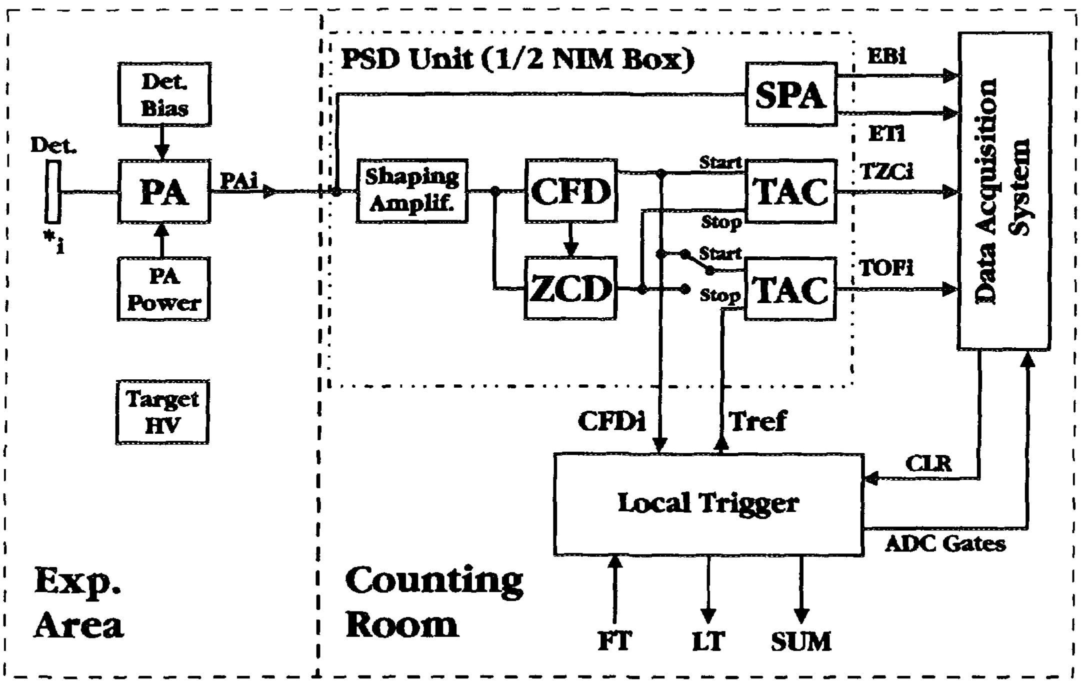


Fig.1 A simpified block schme of the EuroSiB electronics.

It consists of:

- a charge sensitive preamplifier with a large dynamic range of output pulses, fast rise time of 20 ns and a low gain of ≈ 2mV/MeV. In the preamplifier a small load resistor of (1 + 1) MΩ is used to reduce the variation of the detector bias caused by a non-constant leakage current,
- a zero-crossing channel with a bipolar shaping amplifier, a constant fraction discriminator, a zero-crossing discriminator, and a time-to-amplitude converter which measures the zero-crossing time distribution used to identify different particles,
- a spectroscopy amplifier with a quasi-trapezoidal shaping to reduce a ballistic deficit of the detector pulses caused by the variation of the charge collection times for particles of different range,
- a local trigger and a second TAC circuit used to identify the correlated events. The TAC circuit can be started by the CFD or ZCD outputs and stopped by the local trigger (timing is controlled by the fast trigger pulse of EUROBALL).

The design of front-end electronics exploits stick-on cards in SMD technology for separate functions like shaping amplifier, CFD etc. The whole electronics for 1 detector channel occupies ½ of NIM box. Since the prototype electronics successfully passed a number of tests on the beam of the Berlin cyclotron, 20 NIM boxes and 40 preamps were produced to be used in the EUROBALL electronics.

1) Forschungszentrum Rossendorf, Inst. für Kern- u. Hadronenphysik, Postfach 510119, D-01314 Dresden, Germany.

*) Support for this work was provided by the CEC-Contract No. ERBCIPDCT940029

3.6 Comparison of YAP: Ce and BGO for high resolution PET detectors

by M.Kapusta[1)], J.Pawelke[2)], M.Moszyński

Currently, most commercially available positron emission tomography (PET) systems use BGO block detectors, which consist of many crystals coupled to a smaller number of photomultiplier tubes (PMTs). The aim of this work was to evaluate the potential of small YAP:Ce crystals for high resolution PET systems. This scintillator is already commercially available and is used in applied studies for animal tomographs. For this, we directly compared the scintillator properties of 3x3x20 mm^3 crystals of YAP with those of BGO. The light output, energy resolution, detection efficiency and timing properties for the irradiation using ^{137}Cs and ^{22}Na sources were investigated. Special attention was focused on the influence of the reflector coating on light output as well as the characterization of the quality of the crystals studied. All the measurements were carried out for YAP and BGO crystals coupled to an XP2020Q PMT.

Fig.1 presents a comparison of the 662 keV γ-rays spectra from a ^{137}Cs source measured with the YAP and BGO crystals. It shows a dramatically higher light output of the YAP for the perpendicular position of the crystal. The light output of the YAP and BGO, tested in their position parallel to the PMT, showed their good quality. The same spectra also reflect a good energy resolution of the YAP crystal even in its perpendicular position. Note also the higher light output observed with both the crystals for a Teflon tape used as a reflecting coating. The original reflector, an evaporated aluminum layer, gives almost a factor of two lower light output.

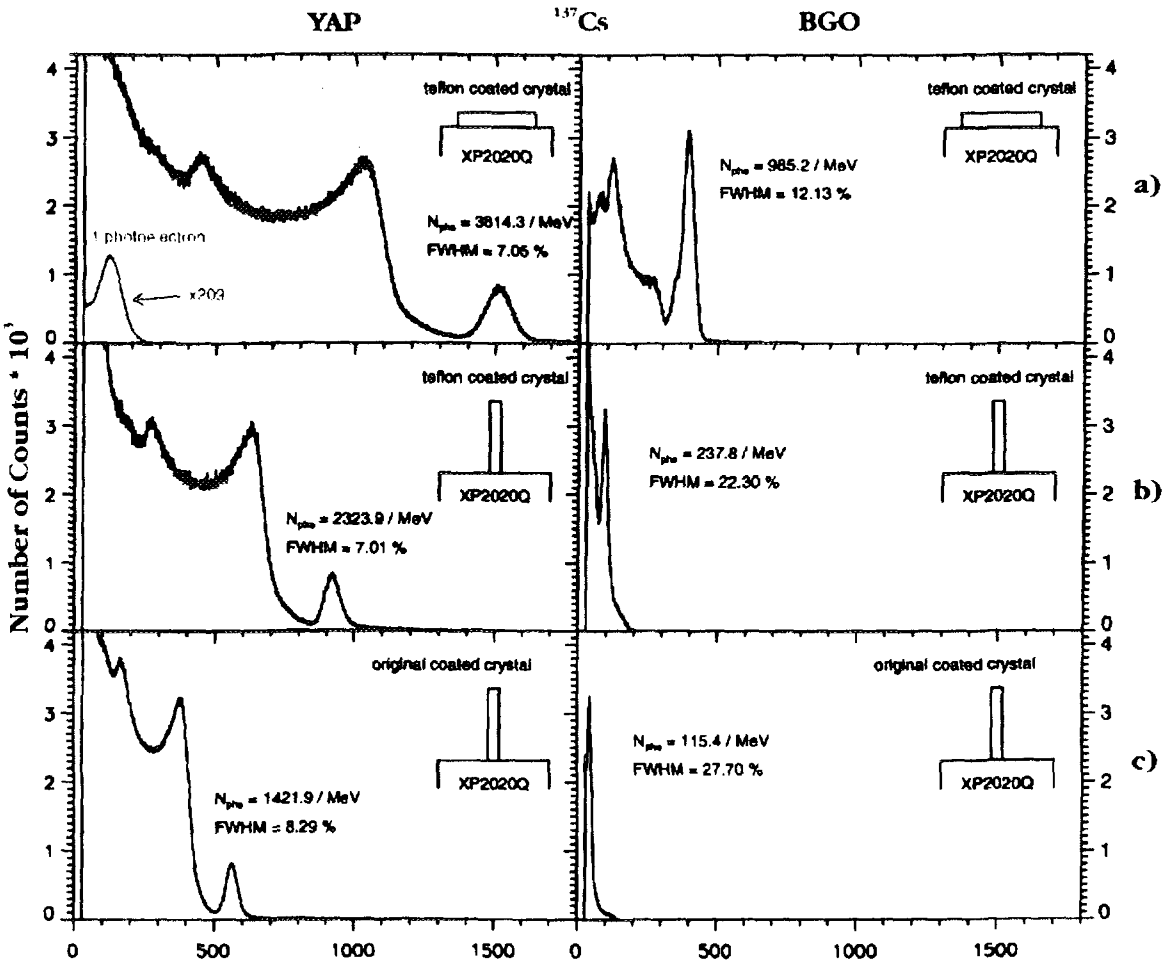


Fig.1 A comparison of the 662 keV γ-rays spectra from a ^{137}Cs source measured with the YAP and BGO crystals.

The tests of time resolution carried out for 511 keV annihilation quanta also shows better properties of the YAP. Its time resolution for the energy threshold set at 200 keV of 600 ps is more than an order of magnitude better than that observed with BGO (10 ns). This is due to a much faster light pulse with a decay time constant of 25 ns and a higher light output as presented above.

Unfortunately, the detection efficiency of the YAP crystal is lower by a factor of 3 than that of BGO, as measured at energy threshold 200 keV. It shows that a YAP crystal can only be applied in the animal PETs. The human PET requires crystals with a high detection efficiency for 511 keV.

[1] University of Warsaw, Institute of Experimental Physics, Hoża 69, PL- 00 681 Warsaw
[2] Forschungszentrum Rossendorf, Institu für Kern- u. Hadronenphysik, PF 510119, D-01314 Dresden, Germany.

3.7 Contract for apparatus for the SPHERE experiment on nuclotron in Dubna (JINR)

by Z.Guzik, J.Charuba, A.Chłopik

According to the contract signed with the Laboratory of High Energies in Dubna (JINR), Russia, two types of electronic modules were designed for the SPHERA experiment located on the NUCLOTRON accelerator in Dubna. The first module is the high speed front-end discriminator connected directly to the photomultipliers. The second module is a multichannel coincidence register/latch providing data storage and used in the fast first level trigger. Their goal is to provide a readout chain for the hodoscope detector. The first approach had been to design the modules in Fastbus standard. But after discussion, in order to reduce total cost, the CAMAC standard was chosen.

The project is divided into two phases. During the first phase the prototypes of modules were designed and tested. The second phase, which is planned for 1997, will be the mass production of modules. The work has been financed on the basis of the Polish contribution to JINR.

Main characteristics of the 16-channel, 200 MHz discriminator (DR16A):

Number of inputs:	16 LEMO
Input impedance:	50 Ω
Minimum input width:	4 ns
Maximum rate:	200 MHz
Time slewing:	< 500 ps
Time jitter:	30 ps
Input threshold:	-1.023 V to -10mV adjusted by F-P potentiometer in local mode or by 12 bit DAC in remote mode via CAMAC F(16).A(1)
Operation modes:	Updating/Non-updating with and without Burst Guard
Outputs:	Twisted pair ECL (two per channel)
Output width:	From 5 ns to 100 ns adjusted by F-P potentiometer in local mode or by 12-bit DAC in remote mode via CAMAC F(16).A(2)
Additional features:	Masking inputs (software), test input, vetoinput, current summing output

The module is functionally compatible with the LeCroy discriminator type 3412.

Main characteristics of the 48-channel coincidence register (CO48A):

Input signals:	Number of inputs: 48, all identical; differential ECL, resistance : 100 Ω direct coupled. Minimum width = 4 ns; Double-Pulse Resolution: 6 ns max.
Coincidence width:	from 2 ns, determined by gate and input pulse durations.
Gate input:	One on the front panel, Lemo-type connector; Minimum duration at full logic level: 4 ns.
Clear inputs:	Two on the front panel, bridged for cascading; Lemo-type connectors; minimum duration: 4 ns.
Summing outputs:	3 identical on the back panel; Lemo-type connectors; One for each of the three groups (A, B or C) of 16 bits each. 100 mV into 50 Ω is presented for each bit latched in the corresponding group of 16.
CAMAC commands:	Reading registers, reading and clearing, clearing, LAM handling.

The module is functionally compatible with the LeCroy coincidence register type 4448.

3.8 Electronic support for the NA48 experiment at CERN

by Z.Guzik, A.Chłopik

The SINS contribution to the NA48 experiment ("A Precision Measurement of ε/ε' in CP Violating $K^0 \to 2\pi$ Decays"), conducted in CERN, was to provide three types of electronic modules designated for the Krypton Calorimeter readout system.

- Isolated Clock Fanout (NA48CKFO-F6916) - Fastbus,
- Optoisolated Cluster Interconnect (OPTOCI-F6915) - Fastbus
- FOL-RIO Interface - VME.

The designing phase of the project was realized in 1995 - a more detailed description of these units can be found in the previous issue of SINS Annual Report. Our activities in 1996 were concentrated on tuning the modules for particular experimental needs and proposed modifications, testing apparatus in an entire experimental environment and providing mass production of units necessary for running the NA48 experiment. These are the demands for the volume of our electronics:

NA48CKFO	-	60 Fastbus modules
OPTOCI	-	50 Fastbus modules + 250 Daughter boards
FOL-RIO	-	30 modules

Additionally, two extra modules were designed to support proper testing and debugging of the apparatus - one generating various serial patterns simulating central experiment control facilities (necessary for testing Clock Fanout module), and the second providing indispensable tools for debugging OPTOCI Daughter Boards.

A big effort was made to provide appropriate checking of the operational characteristics of the FOL-RIO module, which serves as a event builder. Several software packages in C++ under OS-9 operating system were written in cooperation with our colleagues from the collaboration.

At the begining of 1997 we are going to prepare the entire apparatus and install it into the experimental area - data taking will start in the middle of April 1997.

3.9 Electronic equipment for NA49 experiment at CERN

PL9800634

by A.Chłopik

Our collaboration with the CERN NA49 Experiment started in 1993. During these years, electronic equipment was developed and tested for use in Slow Control and Laser Control. The following CAMAC modules were built for Slow Control:

- Gas Chambers Control,
- NIM Clock Generator,
- Quad High Voltage.

The purpose of the Gas Chamber Control Unit is to output a NIM trigger signal based on input analog signals. These signals control the mixture of gases in the chambers.There are four such trigger channels on one board. Twenty five such units are used in the experiment.

NIM Clock Generator CAMAC modules are used to trigger a set of analog-to-digital converters in Slow Control of the NA49 Experiment. At the output of a unit an asynchronous square wave of NIM standard levels is generated. This signal can be gated from the CAMAC Bus using standard commands. Four such modules are in use in the experiment.

Quad High Voltage CAMAC units are used to produce high voltage which goes to Gas Chambers. Each module has four high voltage outputs. They are controlled via CAMAC Bus using 16-bit words. The voltage can be changed in the range from 50V to 1,7kV. Four such modules are used in the experiment.

Another group of electronic equipment made for the NA49 Experiment are units used for Laser Control. The following modules were developed for these purposes:

- Triple High Voltage,
- Laser Valves Control,
- Laser Singnal Converters.

The Triple High Voltage module is based on Quad High Voltage Module. The difference is that it has three outputs and each of them can produce voltage in the range from -50V to 250V. The output voltages are changed with 16-bit digital word sent via CAMAC Bus. The module is purposed to control piezoelectric crystal dimensions in the NA49 Experiment which can precisely position the lasers (with 100μm resolution). Four such modules are used in the experiment.

A rough position of the lasers can be set with use of Laser Valve Control CAMAC Unit. Each laser table is connected to two valves. One of them turns the table to the left and another to the right. To switch a valve on the power of 6W must be delivered. Thus each output is able to deliver a current of 0,5A with 12V. The unit has a double CAMAC width and consists of two identical boards. Each board has sixteen outputs. Each output works independently of the others and is opened and closed by appropriate CAMAC commands. Two such units are used in the experiment.

The signals which control the lasers are square waves with logical levels of 0V and 15V. It is necessary to convert them to NIM levels to use standard electronic equipment. Four converters are placed on one NIM board: laser-to-NIM-non-inverting, laser-to-NIM-inverting, NIM-to-laser-non-inverting and NIM-to-laser-inverting.

PL9800635

3.10 Design of semicustom ICs for the PC based MCA

by S.Borsuk, A.Chłopik, Z.Kulka

A few years ago the multichannel analyzer (MCA) type SWAN based on PC XT/AT computers was developed. It has a form of a set of two cards plugged into slots of an IBM PC XT/AT or a compatible one. One card was a built-in 12-bit successive approximation spectroscopy analog-to-digital converter (ADC), the second one included an 8k 24-bit buffer memory. In the data acquisition mode, these cards could operate autonomously, making the computer free for other tasks including software offered acquisition control, visualisation, data handling and different modes of presentation of results.

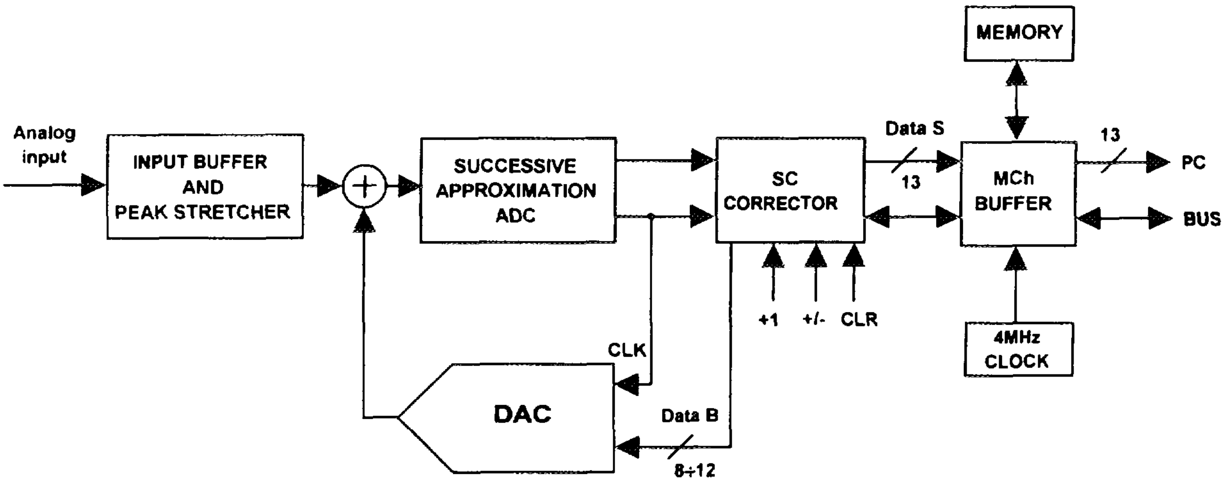


Fig.1 Simplified block diagram of the ADC-Buffer plug-in card which converts IBM PC, or compatible, into multichannel pulse-height analyzer.

Lately the main effort has been taken to construct a new, 13-bit ADC, as well as to improve the software. In effect (concerning hardware) the 13-bit spectroscopy ADC, successive approximation type was designed. It is based on a low cost, audio, 16-bit/5μs, serial output ADC (Burr-Brown's PCM-78P chip). The low differential nonlinearity which is important in high resolution spectroscopy applications is achieved through a special correction system based on a sliding scale principle. The executive element of such a system is also a low cost audio, 16-bit, serial input DAC (Burr-Brown's PCM 56P chip).

In order to reduce the costs, the size of the PCB card, power and complexity of interconnections, two semicustom digital integrated circuits „MCh Buffer" and „SS Corrector" were designed last year. Both of them use Altera's CMOS CPLD (Complex Programmable Logic Device) chips. The simplified block diagram of the ADC-Buffer plug-in card (under development) is shown in Fig. 1.

MCh Buffer

The idea of the construction of the MultiChannel Buffer is to place all control logic into one programmable chip. Additionally, the buffer card should comprise the following chips: memory, transfer gates (to buffer the signals of computer bus) and few flip-flops and logic gates. An Altera's chip type EPM7192E will to be used. This device consists of 192 programmable macrocells and it has 160 pins. The new MCh Buffer will be a universal unit with which 1k, 2k, 4k and 8k of 24-bit word MCAs may be realized. The type of working mode will be set by an on-card switch. In Fig. 2 the block diagram of the new MCh Buffer chip is shown.

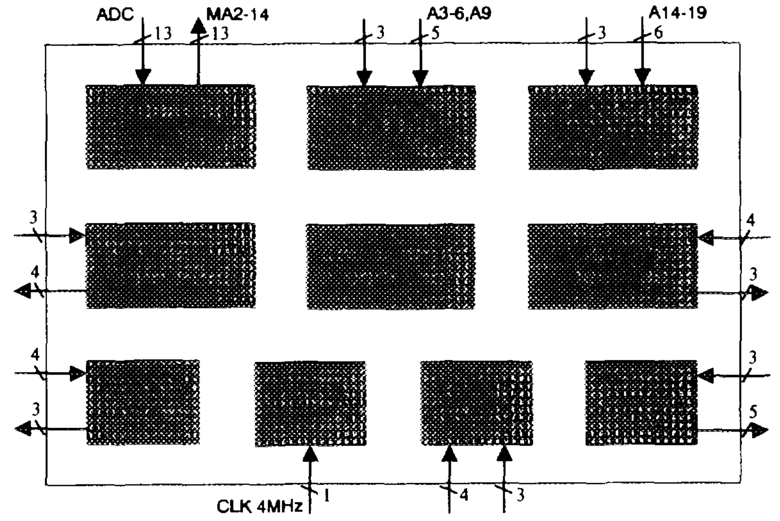


Fig.2 Functional block diagram of the MCh Buffer chip.

SS Corrector

The fully universal Sliding Scale Corrector chip (Fig. 3) together with audio DAC will perform the differential nonlinearity correction using a sliding scale principle. The new chip consists of the following main circuits: 13-bit input register A, adder/subtractor (C1-C13) of two 13-bit digital words (depends on the external on-card switch position +/-), 13-bit counter B (its contents is incremented by the pulse +1 after each summing/subtracting operation) and 13-bit output register S. These circuits can be arranged by external connections depending on the width of spanning, i.e. on the number of averaging bits (8, 9, 10, 11 or 12). In this case an Altera's chip type EPM7064E is planned.

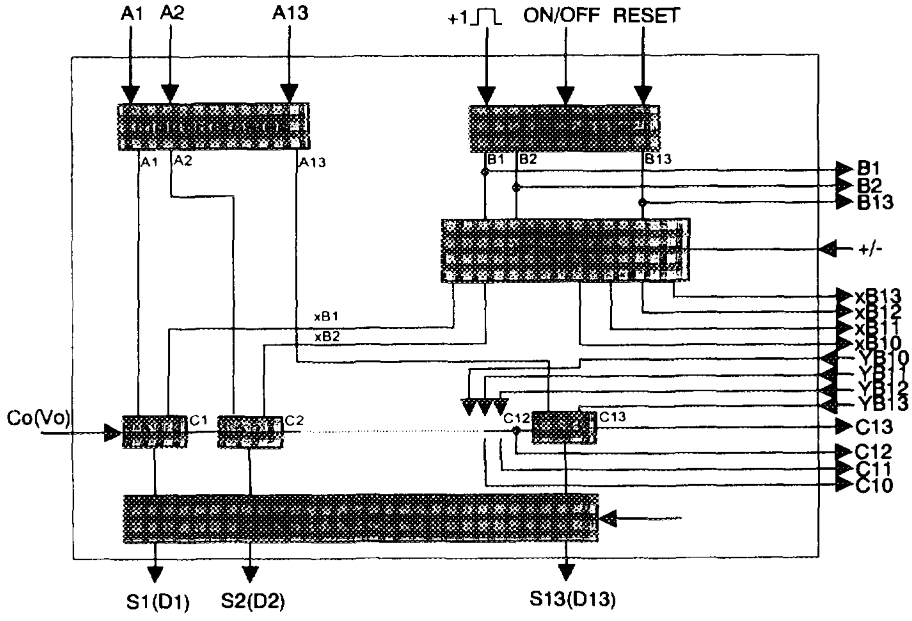


Fig.3 Functional block diagram of the SS Corrector chip.

Conclusion

The designed chips should be passed for practical implementation when the performance testing of the 13-bit ADC is completed. The applied technique of improvement of the channel width uniformity gives the full dynamic range of ADC and does not limit the number of averaging bits. So, with new designed semicustom ICs it will be possible to make a very compact, built on one card, high resolution PC based MCA.

PL9800636

3.11 Standardisation activities

by J.Charuba, Z.Guzik

The Department is involved in the standardisation process of electronics in Poland and electronics for physics research in the world research community. The Institute is a member of the Executive Group of the ESONE (European Studies on Norms for Electronics) Standardisation Committee. In 1996 Polish editions of the VME and SCSI-2 standards were prepared on the basis of ISO/IEC standards. Some effort was made to promote PCI and SCI standards in Poland. We are taking part in the work of the ESONE Committee for use the VME standard in physics.

PL9800637

3.12 Driver for IBM PC-based Multichannel Analyzer card

by M.Płomiński

A driver is a part of the software of the Multichannel Analyzer which is responsible for communication between the main program and the analyzer card. It is a TSR type program which should be loaded before the main program. It can reside either in the base or in the high (above 640K) computer memory. Although designed for DOS, it can be run as DOS application under Windows 95 environment. Due to the low level language used to build the code (TASM version 3.2), it occupies only 9K memory. Its construction together with the TSR feature makes it possible to start data acquisition, leave the main program and apply a computer for any other purpose with data acquisition taking place in the background under rules set at the starting time.

The driver performs the following functions: it starts and stops data acquisition, card reset, preset set parameters, buffer clear, access to collected data, reading of the current parameters of the analyzer card, time flow, CPS and Dead Time calculation. After installing, the driver takes control under a timer (08h) and TSR search (2Fh) interrupts in the computer system. To communicate with the main program, (2Fh) interrupting with a dynamically set parameter distinguishing the driver from other TSR is performed. On demand of the main program, a transfer of acquisition parameters and experimental data is performed by sending a package of fixed or variable data length to the address in the memory pointed out by the main program.

The driver has been designed to give maximum flexibility. The screen built-in configuration allows us to achieve and set all user dependent driver parameters. In particular, it allows us to indicate if the program should control one or more analyzer cards at the same time. On-line help together with self explanatory error messages make its use easy and efficient.

The driver can be removed from memory, when needed, without restarting the computer.

The program interface has been prepared in Polish and in English.

PL9800638

3.13 Multichannel Analyzer system for γ-ray spectroscopy

by S.Borsuk, I.Obstój[1], M.Płomiński, K.Traczyk

The gamma spectra control and analysis system consists of a Pulse Height Multichannel Analyzer constructed in the form of a card to be plugged in a PC type computer and the program performing data acquisition, visualisation and full analysis of collected spectra.

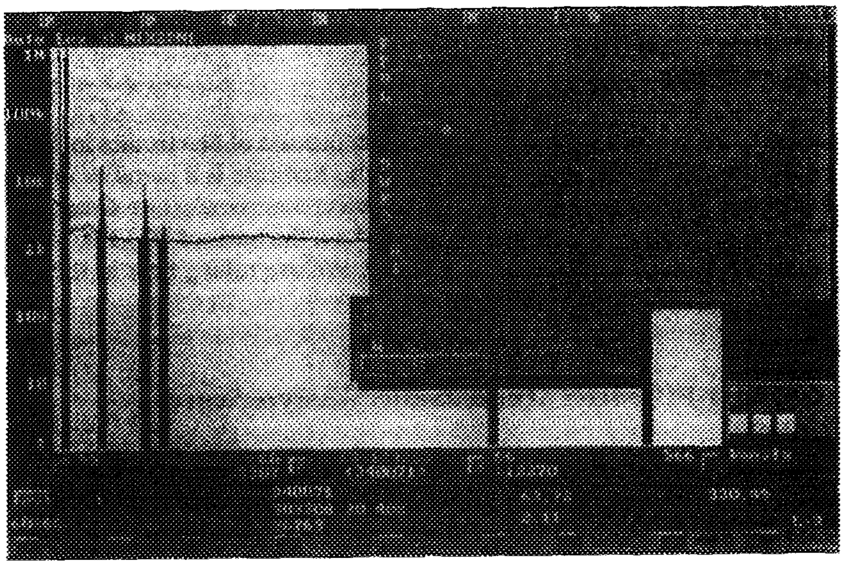
The system can be installed in a wide range of IBM-PC type computers from AT to 200 MHz Pentium. A computer can be equipped with any graphic card (except CGA) and a monochrome or color monitor.

The analyzer card is equipped with a spectrometric ADC of 4096 channels (constant conversion time equal to 5 μs) and a memory buffer with capacity of about $16x10^6$ events.

The data analysis program can be run in the same computer where the analyzer card is installed or in any other computer equipped with the special hardware security key. It allows performing off-line spectra analysis in a different place from that where data was collected.

One of the main advantages of the system is its "transparency" for the user. It means that a computer can be run for any other purposes, while data acquisition is being performed in the background. This is possible due to the special initialized TSR program (driver).

The collected spectra can be saved on a disk in binary or ASCII form. It allows us to interface the results of measurements with a wide range of plotting, spreadsheet and other programs.



The mathematical analysis consists of addition and substraction of direct spectra or with time normalization, smoothing and compressing, energy and efficiency calibration (see [1]), peak search and nuclide identification based on a set of nuclide libraries saved in separate files. The program is equipped with a specialized editor which enables editing or creating user's own libraries. The results of the analysis can be presented in user configurable special reports saved on a disk or else printed.

Although the program can perform many functions with a variety of parameters, it is very easy to operate due to the pull down menu and help system .

In 1996 the spectra analysis system was finished and became an integral part of the main program. A "User's Guide" containing a detailed description of the analyzer and "Operator's Tutorial" containing examples of typical operations are also available.

[1] I.Obstój et al., SINS Annual Report 1995, p.90

[1)] APEXIM S.A.

3.14 Network project and installation in SINS-Świerk

by M.Kapusta, K.Leśniewski, B.Moszyński, B.Woźnica

The heart of the distributed control system of the SINS-Świerk was an old fashion LAN (Local Area Network) called "yellow Ethernet" (thick Ethernet) Fig.1. On the one cable we had connected about 150 devices: workstations, servers, printers. Due to this topology, the network was often malfunctioning because of collisions. Complete reorganization of the network was needed. A basic concept based on the idea of a partly micro segmented collision domain was accepted. Finally, the network layout is sketched in Fig.2; the completed description of the solution foreseen will be given in internal report of SINS. This structure of the network was designed taking into account the peculiar needs of the Institute and to optimize these features.

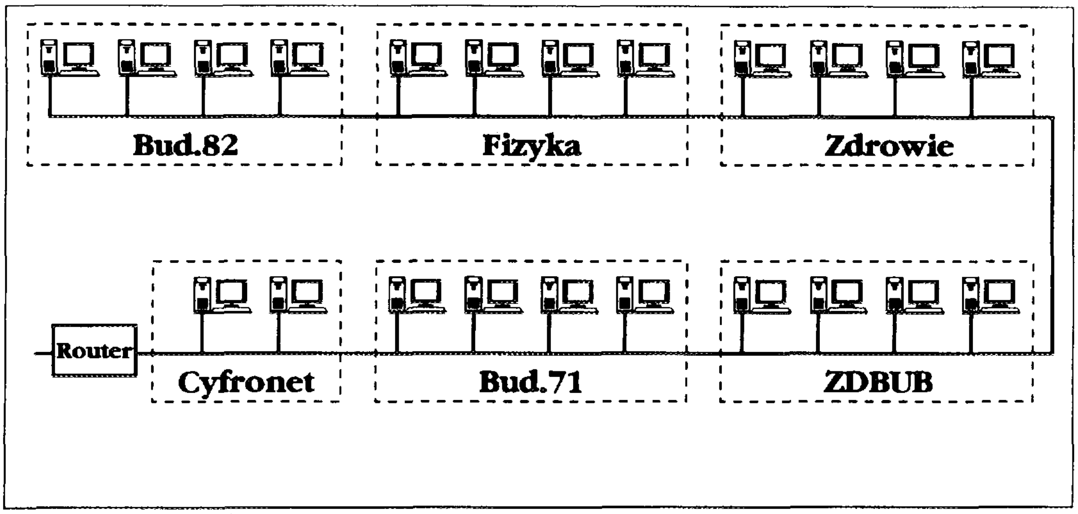


Fig.1 Previous instalation.

The most important factors are:

* the continuous flow of data in each department
* sharing data and network resources between computers

Another key factor was the need of a long and faultless operating life and the minimalisation of both capital and maintenance. Because of this we have had to minimize the ratio/costperformance. We chose as main components two SMC switches EZ006 supporting connection up to 10Mb/s, SMC Tiger Hub and COMPEX hubs. The whole Institute was divided into 6 domains (P-3, 2x P-2, DYREKCJA, P-5, P-10). This topology fulfills the requirements operation flexibility and allows easy reconfiguration in case of any change of design parameters. For transmitting medium a twisted pair cable assuring the class 5 10-Base-T in this topology was chosen.

All in all we installed 2.5 km cables (Belden, Rydex) and plastic line wire covers in two buildings, 130 wall plates Telegarten and about 400 plugs RJ-45. The total cost of cabling, hardware, installations, project, configurations of the workstations amounted to 30 000 PLN. SINS workers did all this work.

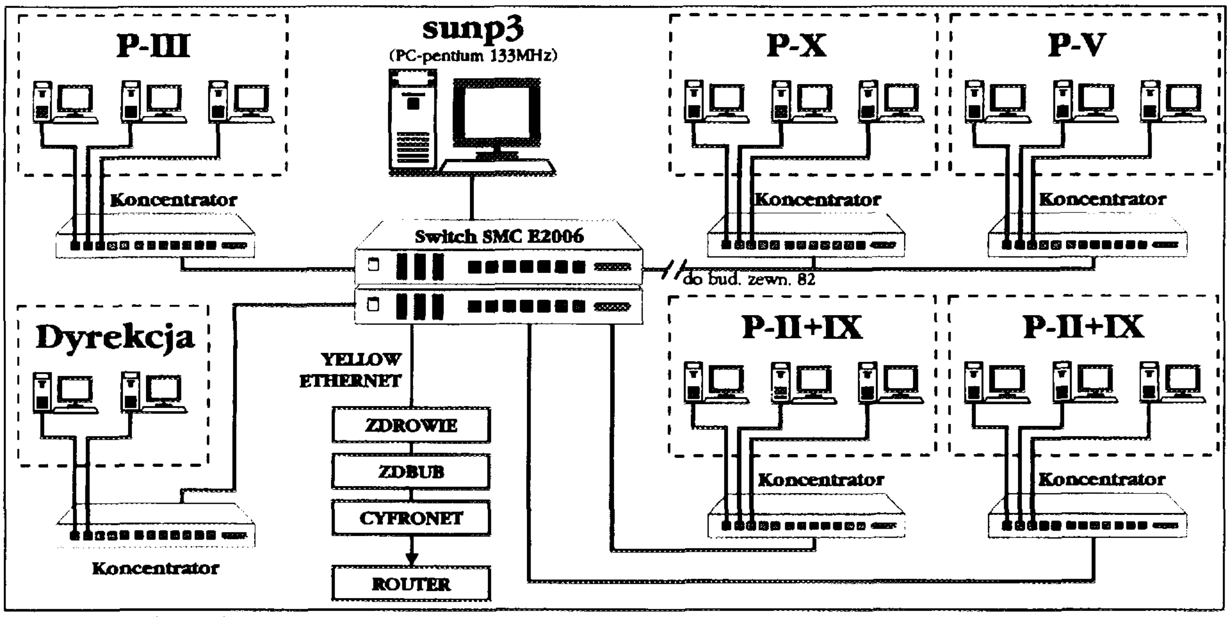


Fig.2 Current instalation.

LIST OF PUBLICATIONS

TIMING PROPERTIES OF GSO, LSO AND OTHER Ce DOPED SCINTILLATORS
M.Moszyński, T.Ludziejewski, D.Wolski, W.Klamra, V.V.Avdi...ikov,
Nucl. Instr. and Meth. A372 (1996) 51, (listed also in Department P-II)

A 1-GHz FLASH-ADC MODULE FOR TAGGING SYSTEM OF THE CP-VIOLATION EXPERIMENT NA-48
H.Bergauer, M.Jeitter, **Z.Kulka**
Nucl. Instr. and Meth. A 373 (1996) 213-222

SUBNANOSECOND TIMING WITH LARGE AREA AVALANCHE PHOTODIODES AND LSO SCINTILLATORS
M.Moszyński, T.Ludziejewski, D.Wolski, W.Klamra, M.Szawlowski, M.Kapusta,
IEEE Trans. on Nucl. Sci. 43 (1996) 1298, (listed also in Department P-II)

IDENTIFICATION OF LIGHT CHARGED PARTICLES AND HEAVY IONS IN SILICON DETECTORS BY MEANS OF PULSE-SHAPE DISCRIMINATION
G.Pausch, W.Bohne, G. de Angelis, M. de Poli, H.Grawe, D Hilscher, **M.Moszyński**, H.G.Ortlepp, **D.Wolski**
IEEE Trans. on Nucl. Sci. 43 (1996) 1097

PROPERTIES OF THE NEW LuAP:Ce SCINTILLATOR
M.Moszyński, D.Wolski, T.Ludziejewski, M.Kapusta, A.Lempicki, C.Brecher, D.Wisniewski, A.J.Wojtowicz,
Nucl. Instr. and Meth., (listed also in Department P-II), (in press)

ABSOLUTE LIGHT OUTPUT OF SCINTILLATORS
M. Moszyński, M. Kapusta, M. Mayhugh, S.O. Flyckt
IEEE Trans. on Nucl. Sci. (in press)

BLUE ENHANCED LARGE AREA AVALANCHE PHOTODIODES IN SCINTILLATION DETECTION WITH LSO, LuAP AND YAP CRYSTALS
M.Moszyński, M.Kapusta, **D.Wolski**, M.Szawlowski, W.Klamra,
IEEE Trans. on Nucl. Sci. (in press)

LIMITATION OF THE PULSE-SHAPE TECHNIQUE FOR PARTICLE DISCRIMINATION IN PLANAR Si DETECTORS
G.Pausch, **M.Moszyński**, W.Bohne, J.Cederkall, H.Grawe, W.Klamra, M.O.Lampert, P.Rohr, R.Schubart, W.Seidel, **D.Wolski**
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PARTICIPATION IN CONFERENCES AND WORKSHOPS

ABSOLUTE LIGHT OUTPUT OF SCINTILLATORS
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IEEE Nucl. Sci. Symp. 1996, Aneheim, USA

BLUE ENHANCED LARGE AREA AVALANCHE PHOTODIODES IN SCINTILLATION DETECTION WITH LSO, LuAP AND YAP CRYSTALS
M.Moszyński, M.Kapusta, **D.Wolski**, M.Szawlowski, W.Klamra,
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G.Pausch, **M.Moszyński**, W.Bohne, J.Cederkall, H.Grawe, W.Klamra, M.O.Lampert, P.Rohr, R.Schubart, W.Seidel, **D.Wolski**,
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D.Wolski, M.Moszyński
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J.Charuba
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Z.Guzik
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Z.Kulka, M.Nadachowski
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Z.Kulka, M.Nadachowski
Elektronizacja, nr 5 (1996) 14

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Z.Kulka, M.Nadachowski
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A.Chłopik
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N.Nadachowski
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M.Nadachowski
Radioelektronik, nr 10 (1996) 11

NEW TYPES OF OPERATIONAL AMPLIFIERS
M.Nadachowski
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MICROPROCESOR SYSTEM - VME
Z.Guzik J.Kołosowski
Polish Standard PrPN-1-43000

SMALL COMPUTER SYSTEM INTERFACE -2 (SCSI)
Z.Guzik, J.Charuba
Polish Standard PrPN-ISO/IEC 6316-1

LOCAL BUS - PERIPHERAL COMPONENT INTERCONNECT (PCI)
J.Charuba
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Translations

R. van de Plassche
INTEGRATED ANALOG-TO-DIGITAL AND DIGITAL-TO-ANALOG CONVERTERS
Kluwer Academic Publishers (1994) -
translation **Z.Kulka, M.Nadachowski**
for WKŁ, 1996 r

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ISO/IEC 9613-1: 1995(E)
translation **J.Charuba, Z.Guzik**

LECTURES, COURSES and EXTERNAL SEMINARS

Prospects for scintillation detectors with APD light readout[b)]
M.Moszyński, Nov. 11, Advanced Photonix. Inc. Camarillo, USA, 3

New scintillators in positron emission tomography[a)]
M.Moszyński, Jan. 8, Institute of Experimental Physics, Warsaw University

FASTBUS Cluster Innterconnection in NA48[b)]
Z.Guzik, June 3, NA48 Collaboration Seminar, CERN Genewa

Optical Link between Data Concentrator and Data Merger in NA48[b)]
Z.Guzik, Nov. 6, NA48 Collaboration Seminar, CERN Genewa

INTERNAL SEMINARS

New scintillation techniques[a)]
M.Moszyński, Oct. 28, IPJ, Świerk

[a]) in Polish
[b]) in English

PERSONNEL

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Jacek Białkowski, Dr. on leave till Dec. 31, 1997
Stanisław Borsuk, Dr.
Andrzej Bogdanowicz, Eng.
Jacek Charuba, Dr.
Arkadiusz Chłopik, MSc.
Zbigniew Guzik, Assoc.prof.
Zbigniew Kulka, Assoc.prof.
Marek Moszyński, Professor
Michał Nadachowski, Assoc.prof., since Sept. 17, Deputy Director of the Institute
Jacek Szlachciak, Eng. on leave till March 2000

Technical and administrative staff

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Andrzej Dziedzic		Michał Płomiński
Cezary Górny		Krystyna Traczyk
Wiesław Karnicki	1/2	Marek Uzdowski
Maciej Kapusta	1/2	Błażej Woźnica
Wojciech Kelarz		Stanisław Żardecki
Jerzy Kucharski		Iwona Żawrocka
Krzysztof Leśniewski		Artur Żyrda

4. DEPARTMENT OF RADIATION SHIELDING AND DOSIMETRY

PL9800640

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phone: 7798481
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Overview

Research activities of the Department concentrated in 1996 on the following areas:
- Numerical modeling of interaction of radiation with matter;
- Metrology of absorbed dose in macro and microscopic scale;
- Methods for low-level neutron monitoring.

Within these activities the following specific research works were carried out:

MCNP code has been adapted for range of the tasks for radiation shielding purposes. Gamma radiation field above fallout-contaminated ground has been studied using the ANISN transport code. The numerical code system WIDMA for aerial monitoring of contaminated area has been developed.

Interactions of protons and high energy ions with the spallation targets were investigated in collaboration with JINR Dubna. Nuclear interactions and particle transport for uranium, thorium and lead targets with high energy ion beams and secondary hadrons were simulated using Monte Carlo method. The results were used to study a heavy ion beam driven electronuclear process. In collaboration with the Royal Institute of Technology in Stockholm, the mathematical model of nuclear physics processes occurring in the spallation targets was developed.

A new experimental set up, JET COUNTER, to study the ion creation pattern in the gas cavities equivalent to nanometer sizes in unit density scale has been assembled and tested. Activities within "nanodosimetry" are in collaboration with INFN, Legnaro under the IV CEC Framework programme.

A linear array of 32 ionization chambers, for studying of the radiation beam performances, has been assembled and are under tests.

The new method for the simultaneous measurements of gamma and neutron radiation especially for low-level monitoring, based un use of ^3He and BF_3 proportional counters has been devised.

The results of research were published in the literature, in the reports of the Joint Institute for Nuclear Research (Dubna) and in the internal reports.

REPORTS ON RESEARCH

4.1 Ionization measurements in nanometre size sites with JET COUNTER

by S.Pszona

Attempts to find an experimental method which is able to characterize the interaction pattern of radiation with different quality at nanometre size sites started in the early 70-ies [1-3]. This approach was based on a differential pumping technique for simulating nanometre sizes (SNS) and single ion counting. It has been quickly learnt that with this technique SNS of less than 1nm can be achieved. To overcome this barrier the pulsed flow of gas through an orifice instead of constant flow has been devised [4]. The practical implementation of this concept appeared difficult. Just recently, the differential pumping technique is revived by a group from Legnaro and Rehavot [5]. Another approach using a pulsed expanded flow of gas, JET COUNTER, (JC), has been proposed by Pszona and Gajewski [6] for studying the delta electron spectra escaping from nanometre sites when irradiated by charged particles. By this method a nondirect estimate of the mean value of restricted LET for low energy electrons was obtained. In this first JET COUNTER, presented at the 11-th Microdosimetry Symposium, the gas jet expanded to a large dimension of an interaction chamber. In the present paper a description of a modified JET COUNTER is presented.

The principle of the operation of the modified JET COUNTER, is explained in Fig. 1. A simulated nanometre - size, SNS, is obtained by a short lasting gas jet (nitrogen in this case). This jet is created due to a pulse-operated valve, PZ, which injects gas from a volume, R, over a valve, through a nozzle with a 1 mm diameter orifice to an interaction chamber, IC, below a nozzle. The interaction chamber is a cylinder, dia. 10 mm, made of tissue equivalent plastic or other material when a secondary particle equilibrium spectrum of incoming radiation has to be investigated. The ions created at the specific volume of this chamber during the gas flow, are removed from that volume by an electric field created by a grid, G. The ions are then guided in an electric field Eh to a counting device, CH2. The effective thickness of a SNS is controlled by a gas pressure inside chamber R as well as by the electrical parameters of valve PZ. The scaling procedure applied for the SNS needs to have an electron gun, EG, as well as the electron counting detector, CH1 are installed inside the device.

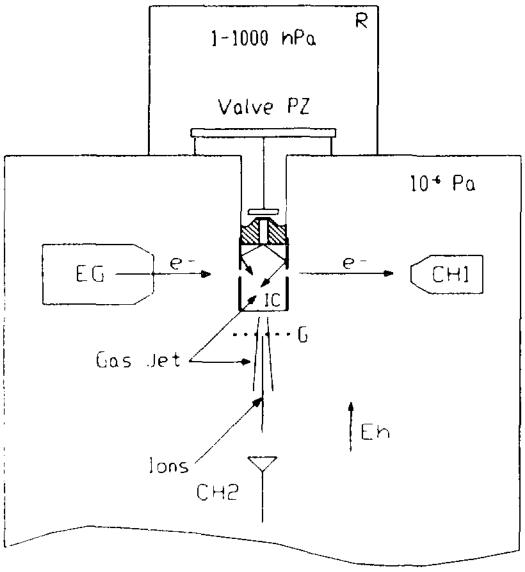

Fig. 1 Schematic view of the modified Jet Counter. G - grid, IC - interaction chamber, EG - electron gun, CH1 and CH2 - channeltrons

The modified JET COUNTER differs from the previous one in the build of the interaction chamber IC. In modified JC an interaction chamber has a cylindrical shape made of TE material which provides the particle equilibrium, necessary for dosimetric experiments, especially for photons and neutrons. Special attention has been paid to the scaling procedure for the 2 - 10 nm dia. cylindrically shaped SNS. For this purpose a 100eV electron beam generated by EG enters through a slit to the IC chamber, crosses a SNS and exits through another slit to a channeltron, CH1, where electrons are detected. The effective thickness of the nitrogen volume has been derived from the known Rao [7] transmission function and taking the Groswendt [8] data for practical range of 100eV electrons equal to 3,2 nm in unit density scale. The 2 nm SNS corresponds to an attenuation of 0.55 which is attained at 42 Torr of nitrogen in R chamber. Presented at 12 Symposium on Microdosimetry, Oxford, 1996.

Support by ECC under the subcontract ERBCIPDCT 930407 is appreciated.

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4.2 New method for ambient dose equivalent measurement

PL9800642

by S.Pszona

A new method for measuring of the ambient dose equivalent in mixed neutron - gamma fields has been devised [1]. It has been shown that the moderator technique, used up to now only for neutron monitoring can be adjusted for monitoring both gamma and neutron radiation. The relative response to photons of a device consisting with a ^{3}He proportional counter placed inside a 203mm diameter polyethylene sphere has been evaluated. It has been shown that the relative response to gamma radiation is within 30% acceptable limits in the energy range from 50 keV to 10 MeV.

[1] S.Pszona, Radiat. Prot. Dosim., 1996, 70, 132.

4.3 Linear array of 32 ionization chamber for radiotherapy

PL9800643

by A.Dudziński, J.Kula, S.Marjańska and S.Pszona

A linear array of detectors composed of 32 flat ionization chambers has been assembled together with an electronic system. Ionization currents of the chambers are amplified by the charge amplifiers and through the multiplexers fed to a 12 bit ac converter. The reading and controlling process as are operated by a 537 microcontroler. The later one is operated by a PC. The whole system is now under tests.

4.4 MCNP transport code installation

PL9800644

by K.Wincel

Due to the current state of the art of neutron, photon and electron calculations, a new version of MCNP executable and cross section data libraries were installed on PC-Pentium computer. MCNP.EXE file was replaced by MCNP6.EXE, which allows calculations of large problems. In a new executable the MDAS parameter is 6000000 and it requires at least 32 MB of RAM memory. Also significant sources of cross section data for use with MCNP code were adopted. These data are MCNPDAT and MCNPDAT6 from RSICC Data Library Collection. A standard set of sample problems and some examples proposed in "Training Course on the Use of MCNP in Radiation Protection and Dosimetry" (Italy, Bologna, 1996) were run.

4.5 Photon fields above an air-ground interface

PL9800645

by K.Wincel and B.Zaręba

The work is part of the program which aim's to carry out a methodology of aerial monitoring of a contaminated area. In order to correlate aerially measured data with a quantitative assessment of ground level gamma-ray spectrum the WIDMA code system was developed. The WIDMA code system consists of SGLIB data set, WIDMA1, WIDMA2 and WIDMA3 numerical codes. The SGLIB library includes angular and energy gamma-ray distributions in air up to 2000 meters above the ground. The SGLIB library was calculated for three cases of the gamma source distribution using the ANISN transport code. The first case was the plane source placed on the ground surface. The second and the third ones were volumetric distributed sources. The purpose of the volumetric source was to imitate of fallout migration to the ground and fallout material storage on the trees in the case of a wooded area. For each type of source six energy groups, in the range from 0.2 MeV to 5.0 MeV were assumed. Basing on SGLIB data set, the WIDMA1 code calculates the gamma-ray spectra for required flight altitude and given energy distribution and type of gamma-ray source. The WIDMA2 code allows us to perform calculations of absorbed doses, mean energy of gamma-ray, gamma-ray density flux and doses buildup factors in the air above a given gamma source. Finally, the WIDMA3 code fixes the correlation between aerial data and the flux energy spectrum at positions near the air-ground interface. The WIDMA code system was written in Turbo Pascal 6.0 and runs on PC computers.

4.6 Interactions of proton and heavy ion beams with spallation targets

by V.S.Barashenkov[1)] and A.Polański.

A mathematical model of interactions of protons and heavy ions with a spallation target was developed. Using of inter- and intranuclear cascades (INC) a series of mathematical simulations was performed. Hadron production and heat generation initiated in uranium, thorium and lead targets by ions (H-2, He-4, C-12) [1-4] was calculated. However, the reliability of INC models is questionable in particular at energies above a few GeV where little data on hadron production exist [5]. The dependence of level density parameters on energy and on the type of interacting nuclei was considered while simulating the intranuclear cascades. At present we try to improve the parameters of the INC model. High energy particle propagation in a spallation target was calculated using Monte Carlo techniques taking into account: the decrease of energies of cascade particles due to the ionization process along their trajectories, decay of created pions, after cascade preequlibrium process, evaporation and fission of excited residual nuclei.

Ion-nucleus cross sections were calculated by means of phenomenological formulas [6]. Hadron-nucleus cross sections at energies E>10.5 MeV were interpolated using a library of estimated experimental data [6]. Low energy neutrons were calculated using the 26-group neutron data library [7]. The results were compared with calculated data for the proton-induced spallation source.

The number of neutrons with energies below 10.5 MeV from a surface of cylindrical lead target vs energy of incident proton is presented in Fig.1. As one can see, the peak is observed for incident proton energy about 1 GeV. A fall in neutron yield at energies less then 1 GeV is determined by energy ionization losses of primary protons. Neutron yield decrease at energies greater than 1 GeV is connected with competetive pion production. Therefore the optimal energy for generation of neutrons is about 1 GeV.

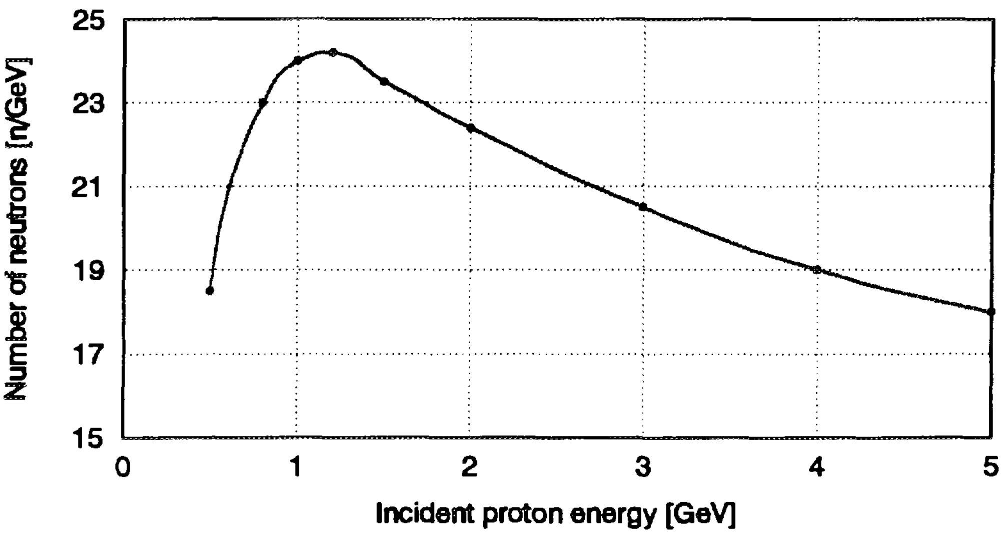

Fig.1 Number of low energy neutrons (below 10.5 MeV) per incident proton energy from surface of cylindrical lead target (d=20 cm,l=60 cm).

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PL9800647

4.7 Mathematical model of nuclear-physics processes in spallation targets

by A.Polański

A mathematical model of nuclear-physics processes in spallation targets was developed. The following processes were enclosed in this model:

- nuclear reactions and high energy particle transport;
- low energy neutron transport;
- transmutation of radioactive nuclides.

The hadron-nucleus and nucleus-nucleus generator includes the following models:

- Dubna version of the intranuclear cascade model (CASCADE code [1-2]) - for intermediate energy;
- QCD string model (FRITIOF code [3-6]) - for high energy;
- nuclear deexcitation model (BOTFRA code [7-8]) considering the multifragmentation of highly excited nuclei, equilibrium particle emission involving evaporation/fission competition for heavy nuclei and Fermi break up for light nuclei.

High energy particles transport and transmutation in spallation target being prepared using cross sections CROSEC code [9], energy losses TEION code [10] and for the transmutation of radioactive nuclides BISON code [11].

This mathematical model will be used for the study of nuclear energy generation and radionuclides transmutation using Accelerator Driven Systems (ADS).

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NEUTRON PRODUCTION IN FISSILE TARGETS UNDER ION BEAM IRRADIATION
V.S.Barashenkov, **A.Polański**, A.N.Sosnin and V.P.Filinova
Kerntechnik, Vol.61, No.2-3, May 1996.

A NEW APPROACH TO LOW-LEVEL MONITORING IN MIXED RADIATION FIELDS
S.Pszona
Radiat. Prot. Dosim. Vol. 70, (1996)

MONTE CARLO MODELING OF ELECTRON-NUCLEAR PROCESSES WITH NON-LINEAR EFFECTS
V.S.Barashenkov, A.N.Sosin, **A.Polański**
Proceedings of the International Workshop , Dubna, Russia, 1996
"Nuclear Methods for transmutation of nuclear waste", World Scientific, 1996, p.77

PARTICIPATION IN CONFERENCES AND WORKSHOPS

HEAVY-ION-DRIVEN ELECTRONUCLEAR PROCESS
V.S.Barashenkov, **A.Polański**, A.N.Sosnin, V.P.Filinova
Preprint E2-96-211, JINR, The Eight International Conference on Emerging Nuclear Energy Systems, June 24-28, 1996, Obnińsk, Russia

NEW METHOD FOR MONITORING OF MIXED RADIATION IN NATURAL ENVIRONMENT
S.Pszona
Proc. of 1996 International Congress on Radiation Protection, Vol.2. 280, 1996

NEW METHOD FOR NEUTRONS AND PHOTONS SIMULTANEOUS MEASUREMENTS IN NATURAL RADIATION ENVIRONMENT
S.Pszona
International Symposium on Ionizing Radiation, Stockholm, 1996

IONIZATION MEASUREMENTS IN NANOMETER SIZE SITES WITH JET COUNTER - RECENT EXPERIMENTAL RESULTS
S.Pszona
12th Symposium on Microdosimetry, 29 Sept. - 4 Oct. 1996, Oxford

LECTURES, COURSES AND EXTERNAL SEMINARS

Photon Fields Analysis for Air monitoring of Contaminated Area*)
K.Wincel, Dec. 4, Institute of Atomic Energy, Otwock-Świerk

Application of Accelerators in Nuclear Energy*)
A.Polański, Febr. 6, Institute of Atomic Energy, Otwock-Świerk

New High Sensivity Method of Measuring Neutron and Gamma Equivalent Dose*)
S.Pszona, June 19, Institute of Atomic Energy, Otwock-Świerk

*) in Polish

PERSONNEL

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5. DEPARTMENT OF PLASMA PHYSICS AND TECHNOLOGY

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PL9800648

Overviev

In 1996 the main activities of Department P-V (until December 1996 known as the Department of Thermonuclear Research) were concentrated on 5 topics:
1. Selected problems of plasma theory,
2. Studies of phenomena within high-current plasma concentrators,
3. Development of plasma diagnostic methods,
4. Studies in the field of fusion technology,
5. Research on new plasma-ion technologies.

Theoretical studies mainly concerned elementary processes occurring within a plasma, and particularly those within near-electrode regions of microwave discharges as well as those within near-wall layers (SOL) of tokamaks. We also developed computational packages for parameter identification and modelling of physical phenomena in pulse plasma coaxial accelerators. Some theoretical studies, e.g. the modelling of a cathode sheath in a magnetron sputtering device, were performed within the frame of a scientific collaboration with the Institut für Plasmaforschung at Stuttgart University, Germany.

Experimental studies were concentrated on the generation of a dense magnetized plasma in different high-current PF (Plasma Focus) facilities and small Z-Pinch devices. We carried out investigations of X-rays, relativistic electron beams (REBs), accelerated primary ions, and fast products of fusion reactions for deuterium discharges. Some experimental studies of high-temperature plasma were performed within the framework of the scientific collaboration with the Institute of Plasma Physics and Laser Microfusion in Warsaw, the Czech Technical University in Prague, the INFIP and IFAS Laboratories in Argentina, and the Institute of Plasma Physics in Kharkov, Ukraine.

Research on plasma diagnostics comprised the development of methods and equipment for studies of X-ray emission, pulsed electron beams, and fast ions, by means of classical and new techniques, e.g., using special Čerenkov-type detectors of electrons and solid-state nuclear track detectors (SSNTDs) of ions. New diagnostic techniques were developed within the frame of the collaboration with the Kurchatov Institute in Moscow, Russia, and the INFIP at the Buenos Aires University, Argentina.

Studies in the field of fusion technology concerned the design, construction, and testing of different high-voltage pulse generators. Those generators were used as pulsed power supply systems as well as simulation devices for studies of electromagnetic compatibility. We also developed special opto-electronic systems for control and data transmission. Research on high-voltage surge generators was supported by contracts with industrial laboratories (Institute of Energetics, APENA, and ELTEST).

Research on plasma-ion technology concentrated on the generation of pulsed high-power plasma-ion streams and their applications for the surface modification of different materials (semiconductors, pure metals and alloys). The material engineering studies were carried out in close collaboration with our P-IX Department and other domestic and foreign research centers, e.g. the Institute of Plasma Physics in Kharkov, Ukraine, and the Institute of Physics Ch.A.S. in Beijing, China. These studies are described in a separate chapter of this Annual Report.

The most important achievements of Department P-V in 1996 can be summarized as follows:
1. The development of a new model for the description of dynamic phenomena in a coaxial plasma accelerator and the adaptation of a conducting fluid model for the analysis of magnetron-type discharges.
2. Experimental investigations of correlations between the formation of hot-spots within a pinch column and the emission of X-ray pulses and fast e-beams, and in particular the empirical demonstration of X-ray polarization.
3. Detailed calibration measurements of different nuclear track ion detectors and the development of new Čerenkov-type electron detectors equipped with radiators made of diamond or rutil in order to decrease the energy threshold level down to about 50 keV.

Achievements in the field of plasma-ion technologies are described in another chapter prepared together with Department P-IX.

REPORTS ON RESEARCH

Selected problems of plasma theory

PL9800649

5.1 Computational package for parameter identification
by M.Rabiński

Experimental device complexity in the field of controlled fusion results in a growing need for mathematical models of plasma behaviour. Simultaneously, there is a continually growing demand for validation of plasma codes by comparison with measured data and for solutions of complex inverse problems during the interpretation of experiments. Therefore, parameter identification becomes an important tool in reducing the discrepancy between observations and theoretical predictions.

System identification is understood as determination (on a basis of all available information about the inner structure, observations, boundary and initial conditions) of a model system to which the real object (process or device) is equivalent. The equivalence is usually defined in terms of some performance criterion which is a functional of the measurements and the adequate model response. When the considered model system is given by the mathematical equations evaluated up to a set of unknown parameters, the problem becomes a subject of parameter identification. A model equivalent in the above described sense to the real system is the one minimizing the performance criterion. In other words, a model whose responses are closest to the observations of the real object is the best substitute. Consequently, parameter vector minimizing the criterion is the solution of the parameter identification problem.

Among all theoretical models those characterized mathematically by partial differential, integral or integro-differential equations are of direct relevance to computational plasma physics. Moreover, the equations describing the process are known up to a finite set of parameters which should be identified. The sophistication of a mathematical model and the high computational costs of the numerical solution require extremely efficient methods relevant to the minimization of the performance criterion.

The PARIDEN computational program for the solution of the parameter identification problem in complex systems has been evaluated. The methodology and computational method [1], based on modified Gauss-Newton [2] and Marquardt [3] minimization techniques, has been applied.

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PL9800650

5.2 Modelling of cathode sheath in magnetron sputter device
by M.Rabiński

Sputtering magnetrons are commonly used devices in industry and research for sputter etching and thin film deposition [1, 2]. Specific configurations of magnetic fields used to trap electrons in the region close to the cathode allows magnetron operation at lower pressures and voltages than with the other devices.

A one-dimensional fluid model has been developed for modelling of plasma behaviour in a magnetron. The model includes continuity, momentum transfer, energy balance for electrons and ions as well as a Poisson equation for the potential. A conception of taking into account two-temperature electron populations has also been worked out. Numerical schemes and elements of the GRAD_1D [3] computational package for tokamak edge plasma transport will be used to accelerate the phase of magnetron code evaluation.

For comparison with experimental results, a project of cooperation with Institut für Plasmaforschung - Universität Stuttgart has been developed [4].

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[2] B.Window, G.L.Harding, J.Vac. Sci.Technol. A 8 (1990) 1277

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5.3 Explanation of discharge phenomena in an impulse plasma coaxial accelerator

by M.Rabiński and K.Zdunek[1)]

A coaxial impulse plasma accelerator [1, 2] is used in surface engineering (Impulse Plasma Deposition [3]) as an efficient source of mass and energy in the synthesis and deposition of various materials in the form of layers. An impulse plasma is generated within the working gas by a high-voltage high-current discharge ignited in the inter-electrode space. Electroerosion during the discharge enriches the plasma with the electrode material.

On the basis of earlier observations and a snow-plow model of current sheet motion, a physical model of phenomena in such devices has been proposed [4]. The self consistent model combines the dynamics of the current carrying sheet driven by the Lorentz force with the balance of magnetic and fluid pressures at the contact interface, as well as the discharge of a condenser bank. The even phases of current flow in the accelerator (second and fourth half-period) occur with the change of electrode polarization. Because of a significant difference in the discharge pattern caused by a polarity change as well as lowering current consecutive amplitudes, plasma approaches nearer and nearer range along the electrodes. At the end of each phase, the weakening magnetic piston slows the current sheet motion, stops it or even causes its reverse movement. This leads to massive electroerosion at the sheet foot and after many discharges one can observe a characteristic form of the eroded central rod (Fig.1). Moreover, the alternating direction of the current flow during the termination of consecutive discharges tends to alternate the direction of central electrode magnetization (Fig.2). The physical model also explains other experimental observations. For example, the plasma velocities obtained from the snow-plow model ($1.8\text{-}2.7 \cdot 10^4$m/sec) correspond strictly with the value ($2.0 \cdot 10^4$m/sec) measured in the device.

This work has been supported by the Polish State Committee for Scientific Research within the project KBN 3 P407 027 06.

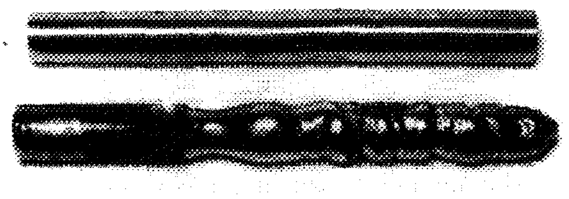

Fig.1 The external appearance of the central electrode after 5000 discharges [5].

Fig.2 Arrangement of iron filings observed on the central electrode.

[1] A.Rusek, K.Zdunek, Vacuum, 39 (1989) 55
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1) Institute of Material Science and Engineering, Warsaw University of Technology, 85 Narbutta, 02-524 Warsaw, Poland

5.4 First step to a classical description of scattering of charged particles from solids

by M.Gryziński

In view of the fact that a lot of atomic collision problems have been successfully solved on the basis of classical dynamics [1, 2] and the latter was succesfully used for a description of molecular systems [3] we have undertaken efforts to describe in similan way collisions of charged particles (electrons, protons) with solids. In this approach solids are considered as systems of regularly spaced positively and negatively charged centers.

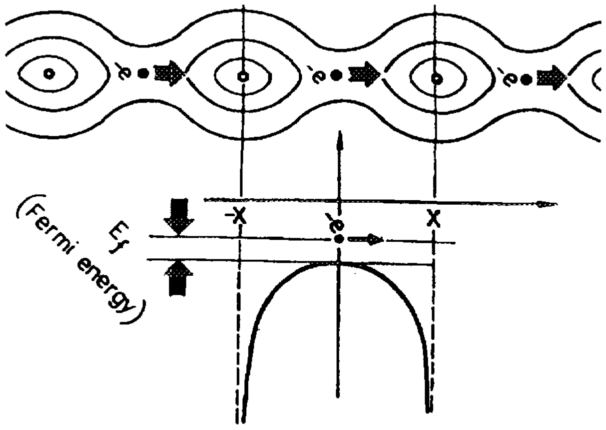

Fig.1 One-dimensial dynamical model of the lattice.

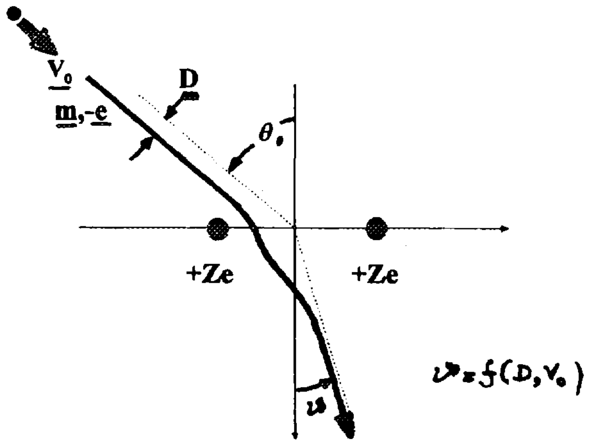

Fig.2 An element of the lattice with a moving electron may be considered as a two fixed center problem.

The two fixed center problem (TFC) was chosen as a starting point for a formulation of a entirely new classical multi-center scattering theory. A known solution of the two-fixed center problem was transformed to a form suitable for analysis of the scattering problem - in the planar case they have a form as shown below

$$\int_{\lambda_0}^{\lambda} \frac{d\lambda}{\sqrt{(\lambda^2-1)\,L(\lambda)}} = U - U_0$$

$$\int_{\mu_0}^{\mu} \frac{d\mu}{\sqrt{(\mu^2-1)\,M(\mu)}} = U - U_0$$

where

$$L(\lambda) = \lambda^2 + 2(Z/\mathrm{E})\lambda - (\sin^2\Theta_0 + \delta^2)$$

$$M(\mu) = -\mu^2 + (\sin^2\Theta_0 + \delta^2)$$

and

$$\mathrm{E} = m V_0^2 D/(2e^2) \qquad \delta = D/d$$

In the planar case integration can be effectively carried out and a relation between the impact parameter δ and the scattering angle ϑ can be given in analytical form. It has been found that, using the derived relations the main features of back scattered electrons from a crystal lattice can be quite well reproduced.

To give a more realistic description, a numerical program for scattering from a single layer of a lattice was developed. In this program electrons, accordingly to the recently formulated dynamical theory of molecular bonds are represented by localised electrons situated between nuclei.

[1] M.Gryziński, Phys. Rev. A138 (1965) 305
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Studies of phenomena within high-current pulse plasma facilities

5.5 Influence of gas-puffed targets on the dynamics and emission characteristics of neutrons and X-rays within the POSEIDON plasma focus

by M.Sadowski, L.Jakubowski, E.Składnik-Sadowska, J.Stanisławski, A.Szydłowski and H.Schmidt[1)]

In 1996 we finished the final elaboration of a paper on results of a recent series of experiments, as carried out with a large POSEIDON plasma-focus facility, within the frame of the scientific cooperation with the Institut für Plasmaforschung at Stuttgart University. Those experiments concerned research on the influence of a gas-puffed target (see Fig.1) on the dynamics of plasma-focus discharges and characteristics of the X-ray and neutron emission. It was found that with pulsed injection of deuterium one could observe a consirable increase (by about 80%) of the neutron yield (see Fig.2).

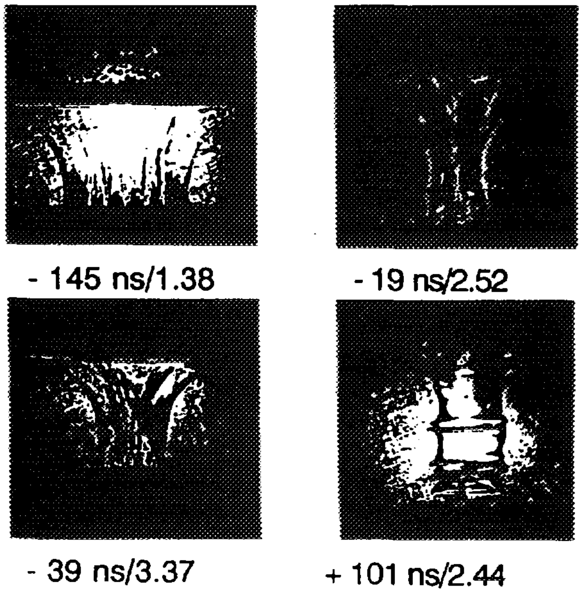

Fig.1 Schlieren pictures (exposure 1 ns) of 135-kJ PF discharges, performed with the D_2 puffing. Times of exposure as well as neutron yields ($Y_n/10^{10}$ in the whole solid angle) are given below each picture.

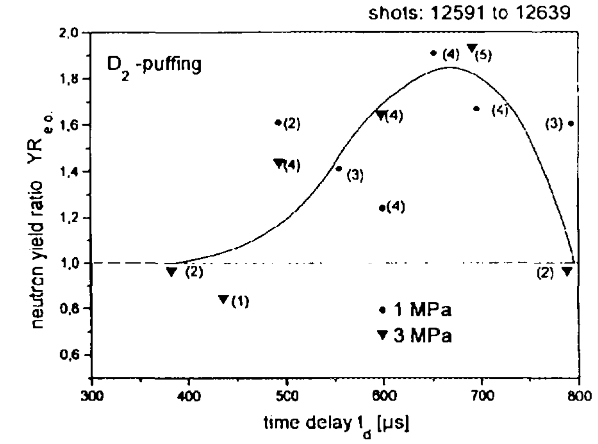

Fig.2 Neutron yield ratio $YR_{e.o}$, as registered end-on for 135-kJ PF shots with additional D_2-gas puffing at the initial pressure 1 hPa D_2. Numbers of averaged shots are given in brackets. The total neutron yield $Y_{e.o}$ without gas puffing was 1.86×10^{10}.

Detailed time-integrated and time-resolved measurements, as performed by means of several different diagnostic techniques, made possible to determine exact time correlations and characteristics of X-ray pulses as well as neutron pulses. The results of the gas-puffed experiments reported above can be summarized as follows. It has been shown that the new titled gas-nozzles, applied for the first time in the POSEIDON facility, enable axially convergent conical gas targets to be formed within the focus region. Such gas-puffed targets considerably influence the dynamics and emission characteristics of the compression phase. Nevertheless, PF discharges can be performed in a controlled way [1].

[1] H.Schmidt, M.Sadowski, L.Jakubowski, E.Składnik-Sadowska, J.Stanisławski, and A.Szydłowski; J. Techn. Phys. 38 (1997) 121-140.

[1)] Institut für Plasmaforschung, Universitaet Stuttgart, 70569 Stuttgart, Germany.

PL9800654

5.6 Study of deuterium ion emission from PACO-PF device under different gas conditions

by J.Baranowski, M.Sadowski, E.Składnik-Sadowska, M.M.Milanese[1)], R.Moroso[1)] and J.Pouzo[1)]

Within the framework of the scientific collaboration with the Institute of Plasma Physics at the University of Tandil (IFAS) we performed studies of the emission of deuterium ions generated by the PACO-PF device [1-2]. The experimental chamber, after pumping, was filled with pure deuterium to 1.0, 1.5, and 2.0 mbar. The emission of ion streams was measured with a Faraday cup collector (FC) equipped with polarized grids [3]. The PIN-diode, as used for X-ray measurements, was equipped with a 12-μm-thick

Be-filter and it was placed side-on in the focus region. Signals from hard X-rays were registered with an NE102A scintilator covered with a 5-μm-thick Al-foil. The Rogowski coil was used to register the total current derivative dI/dt, that was applied to control the quality of PF discharges.

The ion emission along the z-axis was investigated with FC collectors placed at different distances (64 cm and 84 cm) from the focus center. For pressures 1.5 mbar and 2 mbar the entrance of the FC diaphragm was covered with a 0.75-μm Al-foil. The ion signals were registered by a digital oscilloscope (see Fig.1).

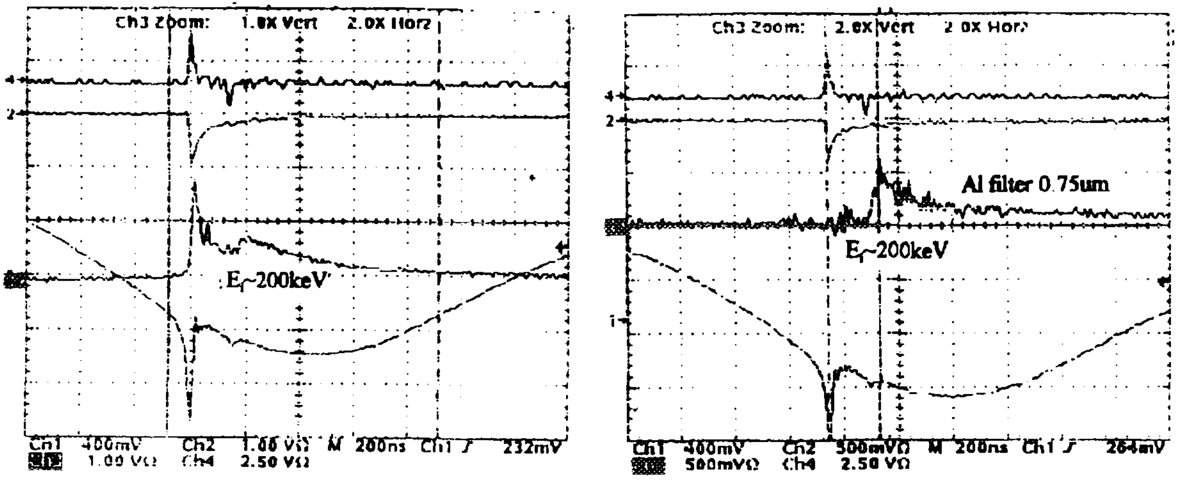

Fig.1 Time-resolved signals from the FC collectors (3), as registered by means of the FC without the Al-foil (on the left) and with the 0.75μm-thick Al-foil (on the right), in comparison with hard X-rays (2), soft X-rays (4), and dI/dt signals (1). The ion flight path was about 84cm.

A quantitative analysis of the signals has shown that for initial pressure of 1.5 mbar D_2 the main ion signals corresponded to the ion fluxes of about 10^{11} ions/cm^2 and the ion kinetic energy value, as measured with the TOF method, was about 280 keV. It was found that for the initial pressure equal to about 1 mbar D_2 the ion signal peak corresponded to the ions of energy equal to about 30 keV. Under such conditions we also observed a strong negative signal correlated in time with the PIN-diode, hard X-ray and dI/dt signals. At 1 mbar D_2 the neutron yields were relatively high in comparison with those from shots performed at 2 mbar D_2. Since the peak plasma density appears at the maximum compression, and the dense plasma emits intense UV radiation, during the ion measurements by means of the FC without Al-foils, it can produce secondary electrons on the FC collector and generate strong interference.

[1] J.Pouzo et al.; Proc. Symp. on Small Scale Labor. Plasma Experiments (Trieste 1987).
[2] M.Milane, M.Moroso, J. Pouzo, M.Sadowski, E.Składnik-Sadowska; submitted for Int. Symp. PLASMA'97.
[3] J.Baranowski, Ph.D.Thesis (SINS, Warsaw 1996) - in Polish.

1) Instituto de Fisica Arroyo Seco (IFAS), UNCPBA, 7000 Tandil, Argentina.

5.7 Time-resolved measurements of deuterium and nitrogen ions from different plasma devices

by J.Baranowski, M.Sadowski, E.Składnik-Sadowska, J.Żebrowski, H.Kelly[1], A.Lepone[1] and A.Marquez[1]

Within the framework of the scientific collaboration with the Institute of Plasma Physics at the University of Buenos Aires (INFIP) we performed studies of the emission of nitrogen and deuterium ions emitted from the IONOTRON-93 and PF-360 facilities at SINS, as well as from the PF-II device at INFIP.

The IONOTRON-93 facility of RPI-type [1] was filled with nitrogen by means of a fast electromechanical gas-valve operated before each discharge. The emission of ion streams was investigated with two Faraday cups (FC); the first one was placed on the z-axis at a distance of 110 cm from the electrode ends, and the second one was oriented at a small angle (about 15°) to the z-axis, at a distance 55 cm. An average energy value of the ion beam, as calculated on the basis of TOF measurements, was found to be about 4 keV. The current density at the FC surface was estimated to reach several tenths of A/cm^2, and the total ion flux - about 10^{14} ions/cm^2.

The PF-360 facility [2] was operated at 130 kJ/30 kV with the initial D_2 filling up to 3.0 mbar. For electrical measurements we applied a voltage divider and Rogowski coil, and for X-ray measurements we used scintillator + photomultiplier sets. The FC was placed on the z-axis at a distance of about 140 cm from the focus center. It was been observed that for PF shots under the initial pressure of 3 mbar D_2 - several ion pulses were generated. The energy value corresponding to the first ion pulse was about 0.6 MeV (assuming deuterons only).

The PF-II device in INFIP [3] was operated at 5 kJ/30 kV with the deuterium filling up to 0.5-2.5 mbar or with the nitrogen filling up to 0.4-1.0 mbar. The emission of ions was measured with a double coaxial FC. The distance from the focus center to the double FC was about 90 cm, and to reduce the ion stopping the pressure value inside the drift tube was reduced to 10^{-3} mbar. Simultaneously, we registered the current derivative signals (dI/dt) from a Rogowski coil, and soft X-ray signals from a PIN-diode covered with a 12 μm-thick Be-filter. The ion signals were compared with other diagnostic signals, as shown in Fig.1.

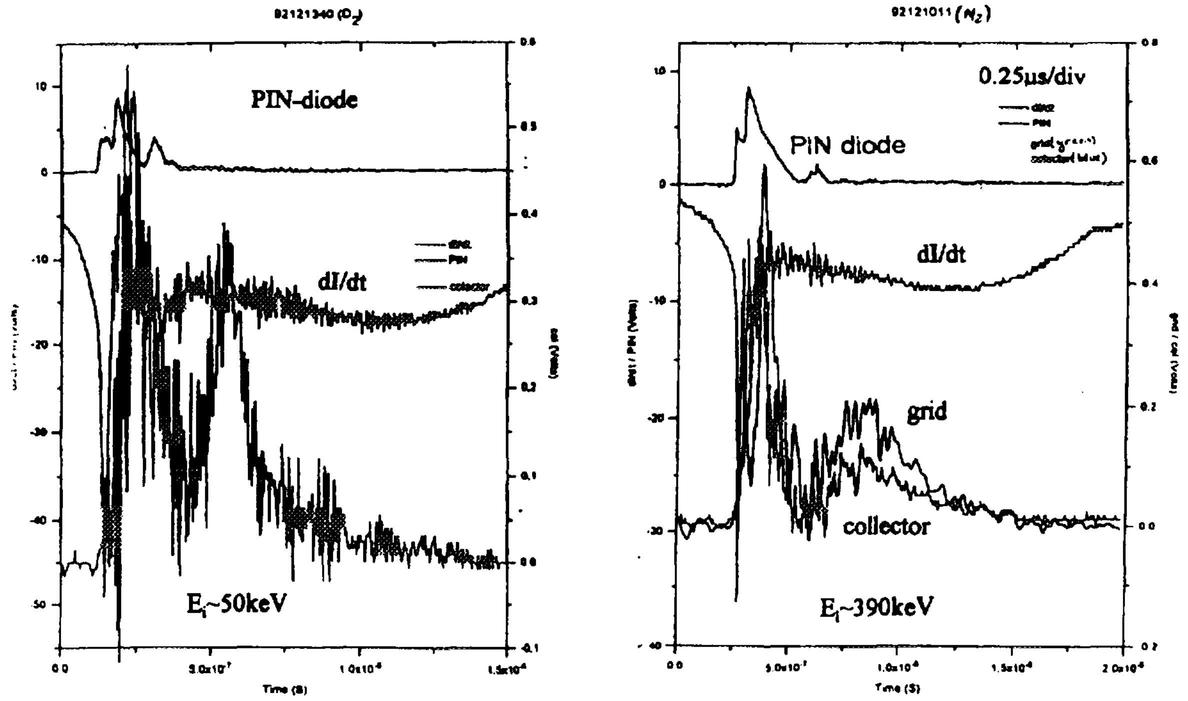

Fig.1 Time-resolved signals from the PIN-diode (X-rays), the Rogowski coil (dI/dt), and the double coaxial FC collector (ions), as registered at the PF-II device. The ion flight path was about 90 cm (on the left, with the deuterium filling) or 120 cm (on the right, with the nitrogen filling).

A quantitative analysis of the signals registered has shown that for shots with the deuterium filling - under the initial pressure of 0.5 mbar and 1 mbar - the main ion signals corresponded to kinetic ion energy 100 keV. With the nitrogen filling - for shots performed at initial pressure of 0.4 mbar - kinetic energy of nitrogen ions was about 400 keV, and at the initial pressure of 1.0 mbar it was equal to about 140 keV.

[1] J.Baranowski, Ph.D.Thesis (SINS, Warsaw 1996) - in Polish
[2] M.Sadowski, J.Baranowski, L.Jakubowski, S.Kienle, H.Schmidt, E.Składnik-Sadowska, and J.Żebrowski, Proc. 21st EPS Conf. Controlled Fusion and Plasma Physics (Montpellier 1994), Pt.III, 1320.
[3] H.Kelly, and A.Marquez.; Meas. Sci. Technol. 6 (1995) 400.

[1] Instituto de Fisica del Plasma (INFIP), 1428 Buenos Aires, Argentina.

5.8 Studies of X-ray polarization and e-beams generation during hot-spots formation in PF-discharges

by L.Jakubowski, M.Sadowski, J.Żebrowski, E.O.Baronova[1)] and V.V.Vikhrev[1)]

Spectral measurements of X-rays emitted from plasma discharges in the MAJA-PF facility, as carried out previously (vide SINS Annual Report 1995), showed that apart from intercombination and resonance lines of He-like Argon ions there were also emitted K_α-lines of weakly-ionized Argon (i.e. ArXIII-ArXV). The emission of the K_α-lines, registered also during experiments performed in 1996, can be explained by interactions of suprathermal electrons, which were observed in different dense Z-pinch devices too. The relativistic electron beams (REBs) were registered as well in the MAJA-PF facility and it was shown that nanosecond X-ray pulses corresponded to hot-spots, i.e. microregions of high-density and high-temperature plasma. It was also observed that the hot-spots are formed along the Z-axis in a determined sequence, starting from the front plane of the inner electrode and moving towards the maximum compression region.

Recent experimental studies [1] have confirmed the time correlation between the emission of REBs and the formation of individual hot-spots. The appearance of suprathermal electrons means that the electron distribution function is anisotropic, and it can induce some polarization of X-ray lines emitted by highly-ionized ions. It means that He-like intercombination and resonance lines can demonstrate different polarization, depending on components of electron velocities. The reflection of such a radiation from a crystal depends on a relative orientation of the crystal surface and the polarization plane.

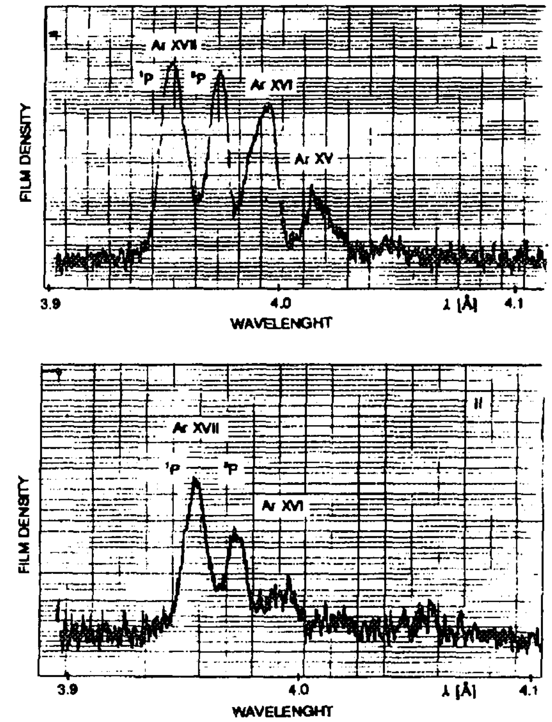

Fig.1 Relative intensities of selected X-ray lines, as registered with two crystal spectrometers oriented perpendicularly.

To investigate X-ray polarization effects we constructed a second X-ray spectrometer equipped with a concave quartz crystal. The device was calibrated in the Kurchatov Institute in Moscow, and it has recently been installed and adjusted at the MAJA-PF facility. X-ray spectrograms obtained so far have shown some polarization effects, i.e. different ratio of given X-ray lines registered with two spectrometers (see Fig.1).

It should be noted that parameters of the REBs, i.e. length of electron pulses, instant of their emission, and their energy spectra, as measured with the Čerenkov-type detectors, are found to be in rough agreement with the results of theoretical computations performed by V.V.Vikhrev [2] for experimental conditions similar to those observed within the MAJA-PF facility. Results of these preliminary studies will be presented at PLASMA'97.

[1] L.Jakubowski, M.Sadowski and E.O.Baronova; Proc. 1996 Int. Conf. on Plasma Phys. (Nagoya 1996) - in press.
[2] V.V.Vikhrev and E.O.Baronova; ibid.
[3] L.Jakubowski, M.Sadowski, E.O.Baronova and V.V.Vikhrev; submitted for Int. Symp. PLASMA'97.

[1)] Nuclear Fusion Institute, RRC Kurchatov Institute, 123182 Moscow, Russia.

5.9 Investigation of plasma-focus phenomena and time correlations of X-rays and charged particles in the PF-360 facility

by J.Żebrowski, M.Sadowski, J.Baranowski, E.Składnik-Sadowska, M.M.Milanese[1], J.Pouzo[1], I.Garkusha[2] and V.Makhlaj[2]

In 1996 time-resolved measurements of the emission of high-energy ions, relativistic electrons and hard X-rays, carried out in the PF-360 facility, were supplemented by new ion measurements performed by means of Faraday-type collectors and a magnetic analyzer. Additionally, to monitor X-rays of different energy a two-channel XET analyzer was applied. A comparison of signals corresponding to low- and medium-energy X-rays, as obtained from different regions of the dense plasma column, and the ion signals obtained from the ion-pinhole camera, has demonstrated that the ion emission is characterized by a complex fine structure, as shown in Fig.1A. The time-resolved ion signals, as obtained from the Faraday-type collector placed at the distance of about 140 cm from the focus region, were reletively low in comparison with interference signals, and they corresponded to ions of energy equal to about 600 keV only. The use of a magnetic analyzer, equipped with 0.5 T permanent magnets, made it possible to register time-resolved signals from 500-700 keV and 3-5 MeV ions. The preliminary results of both diagnostic equipments are shown in Fig.1B and 1C, respectively. The results of these studies are now under elaboration [1].

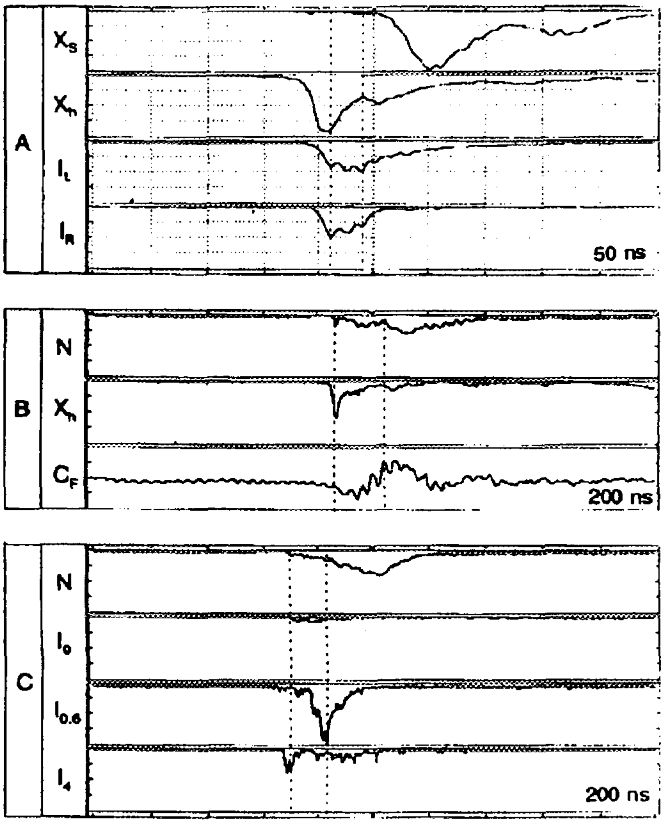

Fig.1 Correlation measurements performed within the PF-360 device operated at: E_0 = 113 kJ, p_0 = 4.6 mbar (A and C), or at E_0 = 130 kJ, p_0 = 4.0 mbar (C). X_s and X_h are X-rays of energy 0.4-2.0 keV and >5keV, respectively; I_l and I_p are ion signals with the same 1.3-MeV treshold, but obtained from different detectors (r = ±10 mm); N denones neutrons; I_∞, $I_{0.6}$, and I_4 are ion signals from the magnetic analyzer (corresponding to ∞, 0.6 MeV, and 4 MeV ions, respectively), and C_F denotes ions registered with the Faraday-type collector.

Within the framework of the scientific collaboration with the Institute of Physics at the University of Tandil, a comparative analysis of experimental and theoretical values of neutron yields and the maximum discharge currents as registered at different working gas pressures p_o and charging voltages U_o within the PF-360 facility, was performed. Experimental data were compared with a two-dimensional MHD-model. It was concluded that the both upper and lower pressure limits of the DPF neutron production correspond to a low and high value of the internal plasma energy, respectively [2].

[1] J. Żebrowski, J. Baranowski, M.Sadowski, E. Składnik-Sadowska, I. Garkusha and V. Makhlaj; submitted for Int. Symp. PLASMA'97.

[2] M. Milanese, J. Pouzo, M. Sadowski, E. Składnik-Sadowska and J. Żebrowski; Proc. 81st Annual Meeting of Argentine Physical Association AFA'96 (Tandil 1996).

1) Instituto de Fisica Arroyo Seco (IFAS), UNCPBA, 7000 Tandil, Argentina.
2) Institute of Plasma Physics, NSC KhIPT, Kharkov, Ukraine.

PL9800658

5.10 Optimization of high-current plasma discharges within the PF-1000 facility

by M.Scholz[1)], M.Borowiecki[1)], L.Karpiński[1)], M.Sadowski, A.Szydłowski, W.Romanova[2)], S.A.Pikuz[2)] and Y.A.Faenov[3)]

In 1996 plasma-focus experiments within the large PF-1000 facility at IPPLM were continued. Some modernizations and changes in the high-pressure system made it possible to fill spark-gaps up to a relatively higher pressure and to keep it for a longer time. Due to that, the condenser bank could be charged up to a voltage higher than 30 kV in order to supply electric energy of about 500 kJ (the highest value achieved so far).

Electrical measurements of the discharge development have been performed with a Rogowski coil, and recently also by means of miniature magnetic probes placed at the ends of the electrodes. Discharge current traces, as obtained from the Rogowski coil, have been compared with hard X-ray pulses registered by means of a scintillation detector. It has been observed that in some shots, particularly in those with very strong current pecularities, also appear other characteristic singularities on the current waveforms. Such singularities were accompanied by separate hard X-ray pulses.

In general, two different types of current waveforms have been observed; the first one with the discharge current decreasing monotonically after the main peculiarity, and the second one with the discharge current decreasing again after the collapse phase. In the second type of discharges there were ususally observed two hard X-ray pulses, the first one synchronized with the main peculiarity and the second one appearing a few microseconds later.

The soft X-ray emission was investigated with a pinhole camera equipped with two separate pinholes (each of about 100 μm in diameter) covered with Be-filters of 10μm and 25μm in thickness, respectively. A new version of the X-ray pinhole camera, constructed at SINS, has also been applied in order to take magnified pictures. The new camera can be oriented at any angle to the electrode axis, and its replacable pinhole can be placed at different distances from the plasma focus region. This camera can also be equipped with thin scintillators and optical cables in order to make possible time-resolved measurements of the soft X-ray emission.

To study selected X-ray lines, use was made of a crystal spectrometer, applicable particularly for measurements of Ar-lines emitted from discharges performed with the Ar admixture. An electron temperature of the plasma column, as estimated from the registered Ar-lines, has been found to reach 400-800 eV.

For ion studies, a Thomson-type analyzer, as constructed at SINS, has been equipped with a new entrance system consisting of an appropriate skimmer and a long drift tube pumped to facilitate ion transfer. Using an additional pumping stand and a special vacuum valve, to be opened for a short time after discharge, it will be possible to perform the ion measurements under reduced pressure and to detect ions of lower energy. Preliminary ion measurements have been carried out with some samples of the NTDs (nuclear track detectors) placed at a distance of about 30 cm from the electrode ends, and the PF-1000 facility has been prepared for the installation of the whole Thomson spectrometer.

Data obtained from the preliminary experiments have been elaborated for presentation at PLASMA'97 [1].

[1] M.Scholz, M.Borowiecki, L.Karpiński, M.Sadowski, A.Szydłowski, W.Romanova, S.A.Pikuz and Y.A.Faenov; submitted for Int. Symp. PLASMA'97.

[1)] Institute of Plasma Physics and Laser Microfusion, 00-908 Warsaw, Poland.
[2)] Lebedev Institute, 117924Moscow, Russia.
[3)] VNIIFTRII, Mendeleevo, Russia.

Development of plasma diagnostics methods

PL9800659

5.11 Research on the influence of experimental conditions on the emission of plasma-ion streams from RPI facilities

by J.Baranowski, M.Sadowski and E.Składnik-Sadowska

The paper presents the most important results of many years of studies on the dynamics of plasma-ion streams generated by plasma devices of the RPI-type (Rod Plasma Injectors). We investigated [1-3] mostly pulsed corpuscular streams (i.e., ions and electrons). The main aim of this paper is to present a phenomenological explanation of the observed phenomena connected with ion emission, and in particular to interpret mass- and energy-spectra of ions, their average kinetic energy, and neutron yield from discharges performed with deuterium filling [4].

Three different regimes (modes) of the RPIs' operation are considered taking into account a time delay value, i.e., the delay between the triggering of a pulsed gas-valve (injecting the working gas into the interelectrode region) and the application of high-voltage to the electrodes. Particular attention was paid to an increase in the neutron yield from deuterium shots in a case of relatively long time delays. In such cases we found that the kinetic energy of deuterons was several times lower than that in the case of short time delays.

For discharges performed with a nitrogen filling we observed an analogous effect, but apart from a decrease in the average kinetic energy value multiply ionized ions were generated. It was found that, for those ions, the ratio of kinetic energy to electric charge is constant. This can be explained by their thermal origin.

The paper also presents useful practical comments for the application of corpuscular diagnostic methods to studies of pulsed plasma injectors. Such injectors are used for application research on the plasma-ion implantation and the plasma-ion modification of solid surfaces, as well as for basic research on different gas discharges.

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[3] E.Składnik-Sadowska, J.Baranowski, et al.; Proc. XXth ICPIG (Pisa 1991), Vol.3, pp. 843-844.
[4] J.Baranowski; Ph.D. Thesis (SINS, Otwock-Świerk 1996) -in Polish.
[5] J.Baranowski, M.Sadowski, and E. Składnik-Sadowska; submitted for Int. Symp. PLASMA'97.

5.12 Calibration of CN - and CR-39 track- detectors for measurements of fast deuterons and nitrogen ions

PL9800660

by M.Sadowski, J.Baranowski, E.Składnik-Sadowska, A.Szydłowski, H.Kelly[1], A.Lepone[1] and A.Marquez[1]

Within the frame of the scientific collaboration between SINS and INFIP we performed two series of ion studies at the IONOTRON-93 facility in Świerk and the PF device in Buenos Aires. The main aim of those experiments was to determine responses of different track detectors, and - based on those - to measure mass- and energy-spectra of different ion species emitted from the plasma facilities investigated. To perform the ion analysis, use was made of Thomson-type spectrometers. On the basis of the registered ion parabolae we determined calibration diagrams of CN-LR115A, CN-80, and CR-39 track detectors for deuterons within an energy range from about 100 keV to 500 keV and for N^+ ions of energy from 200 keV to 2 MeV. The results of these calibration studies were presented at the 18th ICNTiS in Cairo and submitted for publication [1]. At that time only preliminary data on responses of CR-39 detectors to N^{+2} and N^{+3} ions were obtained, while such nitrogen ion species are also observed, particularly in PF discharges with the pure nitrogen filling.

Results of recent research on responses of different CN-type track detectors to N^+, N^{+2}, and N^{+3} ions (see Fig.1), as emitted from the plasma facilities operated in Świerk and Buenos Aires, have been elaborated for PLASMA'97 [2].

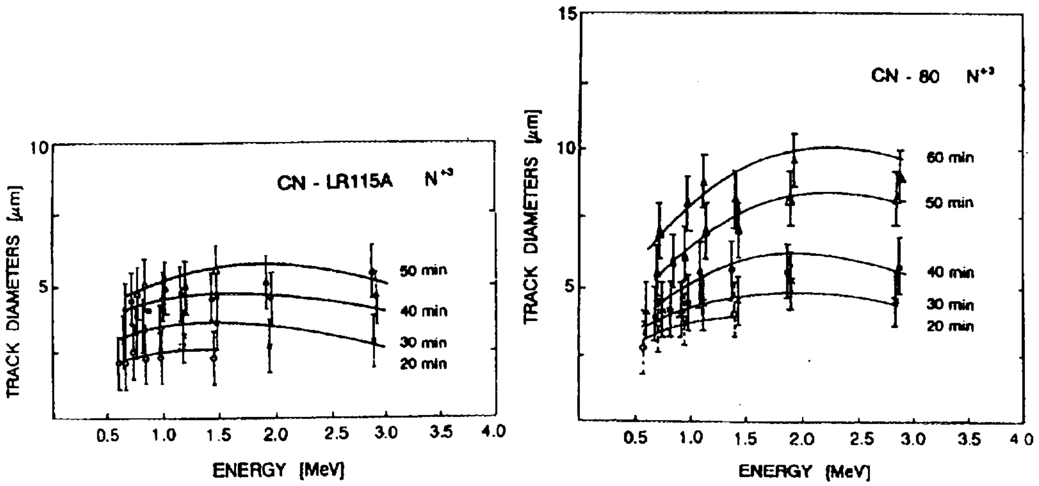

Fig.1 Comparison of calibration diagrams for CN-LR115A and CN-80 track detectors, as obtained from N^{+3} ions measurements performed with a Thomson analyzer at the PF facility.

To separate different nitrogen ion species, use was made of the Thomson spectrometer, and on the basis of its known operational characteristics we determined mass- and energy-scales for the registered ion parabolae. Using an optical microscope, a detailed analysis of track dimensions was performed in chosen points along the parabolae in question, and the calibration diagrams, (i.e. track diameters versus ion energy for different etching times) were drawn. The results of the calibration procedure may be applied for quantitative measurements of fast N^{+}, N^{+2}, and N^{+3} ions in various plasma- or ion- facilities, as used for basic research and technological applications. Using these results one can determine the total number and total energy of the nitrogen ions as well as their energy spectra (within the 0.2-3MeV range).

[1] M.Sadowski, J.Baranowski, E.Składnik-Sadowska, A.Szydłowski, H.Kelly, A.Lepone and A.Marquez; Proc. 18th ICNTS, Cairo 1996; Radiation Measurements - in press.
[2] M.Sadowski, J.Baranowski, E.Składnik-Sadowska, A.Szydłowski, H.Kelly, A.Lepone and A.Marquez; submitted for Int. Symp. PLASMA'97.

1) Instituto de Fisica del Plasma (INFI), Univ. of Buenos Aires, Argentina

PL9800661

5.13 Calibration studies of different nuclear track detectors for measurements of fast ions and fusion products

by M.Sadowski, A.Szydłowski, T.Czyżewski, M.Jaskóła and A.P.Kobzev[1)]

In 1996 the calibration measurements of dielectric track detectors were continued, two types of cellulose-nitrate films (CN-80 and CN-LR115A) as well as new plastic detectors (CR-39 and PM-355) were studied. Samples of the chosen detectors were exposed to monoenergetic particle beams taken from different accelerators, and then diameters of tracks were determined as a function of the ion species, ion energy, and etching time of the samples.

Nuclear track detectors are often used in high-temperature plasma diagnostics. The calibration data obtained facilitate the elaboration and interpretation of experimental results. In many cases one can identify the registered particles, and discern the tracks from microdamages and the background. Moreover, the calibration measurements make possible the determination of the detector sensitivity range and the assessment of the detection efficiency versus the particle energy value. In 1993-1995 the calibration diagrams were determined for CR-39 and PM-355 track detectors irradiated with protons, deuterons, and alpha particles [1]. In 1996 the same detectors, and additionally some cellulose-nitrate films, were exposed to monoenergetic nitrogen-, oxygen, and carbon-ions of energy within the 0.9-2.8 MeV. Such ion beams were obtained from the EG-5 accelerator operated at the JINR in Dubna. After irradiation, the detector samples were etched in the NaOH water solution under controlled conditions. The etching procedure was stopped every 2 hrs, and the track diameters were measured by means of an optical microscope. The calibration data were presented and published at ICNTS [2]. The most important results were also presented at the IAEA meeting [3]. Some examples of diagrams, as obtained for nitrogen ions, are shown in Fig.1.

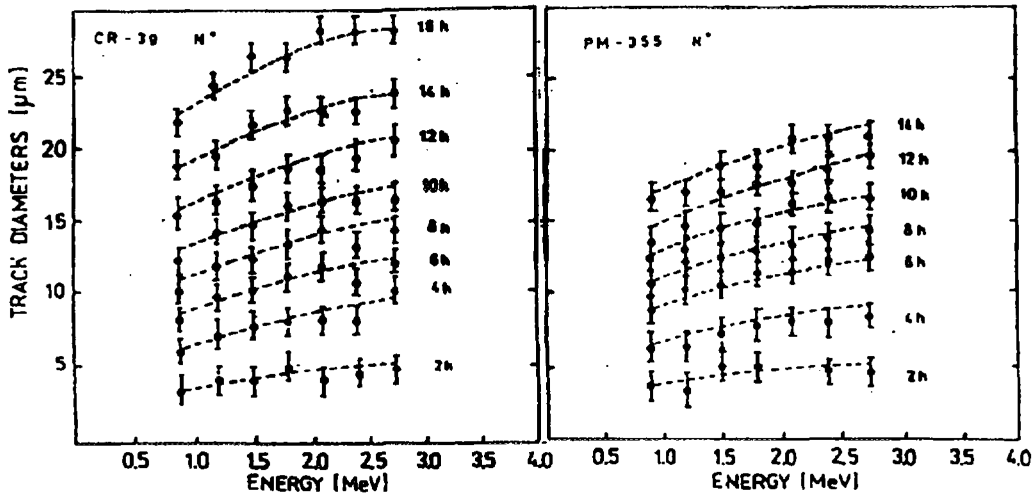

Fig.1 Calibration diagrams of the investigated nuclear track detectors, as obtained for monoenergetic nitrogen-ions.

In 1996 we also performed some preliminary studies on the application of the CR-39, PM-355, and new PM-500 plastic track detectors for the registration of fast protons and neutron dosimetry [4].

[1] M.Sadowski, A.Szydłowski, M.Jaskóła and T.Czyżewski, Proc. 23rd Europ. Conf. CF&PP (Kiev 1996) - in press.

[2] M.Sadowski, S.Szydłowski, M.Jaskóła, T.Czyżewski and A.P.Kobzev, Proc. 18th ICNTS (Cairo 1996), Radiation Measurements - in press.

[3] M.Sadowski, Proc. IAEA Techn. Comm. Meetinmg (Prague 1996).

[4] T.Czyżewski, M.Jaskóła, A.Korman, S.Pszona, M.Sadowski and A.Szydłowski, Nucl. Instrum. Methods - in press.

5.14 Investigation of new Čerenkov-type detectors for studies of fast electron beams emitted from a hot plasma

by L.Jakubowski, M.Sadowski and J.Żebrowski

The main aim of studies undertaken within the framework of a special research project (grant KBN-2-P302-058-06) was the design, construction, and testing of new diagnostic equipment for measurement of pulse electron beams of energy above 50 keV. For this purpose the authors proposed to exploit the Čerenkov effect, and in order to reduce an energy threshold level - to apply radiators made of transparent materials characterized by a high refractive index value, e.g. diamond or rutil [1-2]. Within the frame of the project three detection heads were constructed. They were equipped with two or three measuring channels of an active diameter equal to 10 mm, or a single axial channel of 14 mm in diameter (see Fig.1).

Within the measuring channels thin metal foils were placed. They constited electron energy filters and shields against visible light. Behind the filters were located the Čerenkov radiators made of diamond or rutil. Light pulses from the radiators were transmitted through separate optical cables to fast photomultipliers coupled with a digital oscilloscope. Tests of the whole diagnostic system have been performed at the MAJA-PF facility operated at 44 kJ. Pulse electron beams were extracted from the plasma focus region through an axial channel within the central electrode (anode) and they were registered at a distance of about 50 cm from the focus region. Time-resolved measurements have demonstrated the appearance of

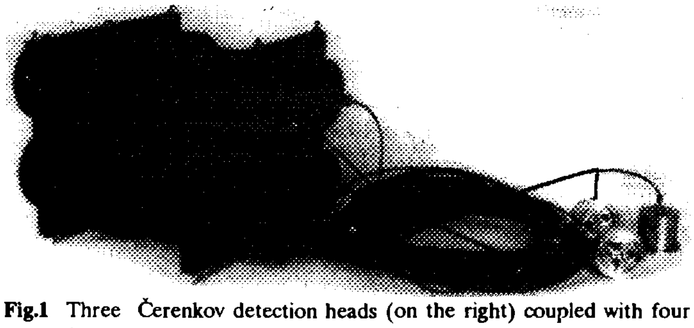

Fig.1 Three Čerenkov detection heads (on the right) coupled with four fast photomultiplier sets (on the left) by means of optical cables.

electron pulses with a complex multi-spike structure. Detailed measurements have shown that the diagnostic system developed makes it possible to register electron pulses with a rise time of about 2 ns and the length of 5-8 ns. The application of the diamond or rutil radiators with very thin metal filters enables an electron energy threshold level to be lowered to about 40 keV.

Within the frame of the project we also developed a computer code which made it possible to calculate an electron range within different materials and to compute their energy loss during the penetration through the selected foil filter. It also enables the determination of changes in the electron energy distribution after their penetration through absorbers made of various materials and different thicknesses.

[1] L.Jakubowski, M.Sadowski and J.Żebrowski, Proc. VI Symp. on Application of Electromagnetism (Poraj 1996).

[2] L.Jakubowski, M.Sadowski and J.Żebrowski, J. Techn. Phys. 38 (1997) 141-150.

5.15 Research on electromagnetic and corpuscular radiation from a Z-pinch discharge

by L.Jakubowski, M.Sadowski, J.Żebrowski, J.Kravarik[1] and P.Kubeš[1]

In 1996, within the framework of the collaboration with the Department of Physics at the Czech Technical University (ČVUT) in Praque, correlation measurements at a small 0.5-kJ Z-pinch device were performed. We studied X-rays, as registered with XET analyzers within different energy ranges, relativistic electron beams, as investigated by means of the Čerenkov-type detectors, and the UV radiation, as measured with PIN diodes. The reverse polarization of the electrode system was applied in order to make

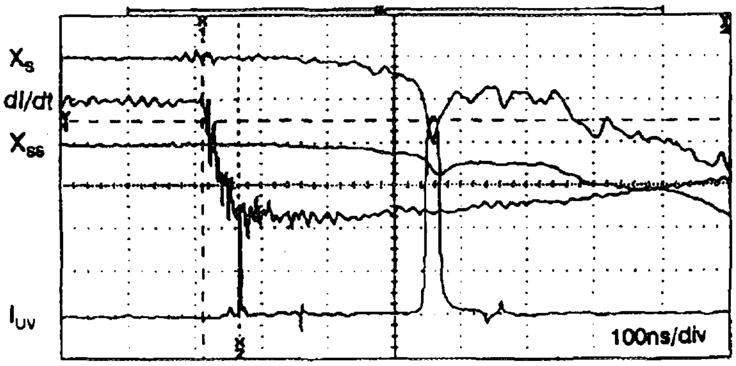

Fig.1 Discharge current derivative (dI/dt), soft X-rays registered behind a 1.5-μm Al-filter (X_s), very soft X-rays registered behind a 0.75-μm Al-filter (X_{ss}), and UV signal (I_{UV}) from a PIN diode, as obtain from a z-pinch discharge performed with a carbon fiber.

possible the registration of electrons accelerated toward the anode direction. Although many z-pinch discharges were performed, we registered no electron beams of energy higher then 40keV. The emission of extremely short X-ray signals within the 20 eV energy range was corroborated by a series of measurements with PIN diodes and the XET analyzers. For that purpose amplitudes of X-ray signals were measured simultaneously behind two filters of a different thickness (see Fig.1). Most z-pinch discharges were performed with a 6-μm carbon fiber, but some test shots were carried out with a 20-μm molybdenum wire [1].

[1] L.Jakubowski, M.Sadowski, Żebrowski, P.Kubeš, J.Kravarik and L.Pina; to be submitted for 18th Int. Symp. PPT (Prague 1997).

[1] Dept. of Physics, Czech Technical University (ČVUT), Prague, Czech Republic.

Special electronic- and HV-systems

PL9800664

5.16 Design of special fiber-optic on-off modules for control systems of fusion experiments

by M.Bielik

One of the main problems in complex fusion experiments is to ensure an appropriate electrical insulation between the control and diagnostic systems on one side, and pulsed power generators on other side. Hardwired systems used so far cause a strong feedback coupling and partial loss of control signals because of strong interference. Such interference is usually connected with switching processes in spark-gaps or HV pulsed thyratrons [1].

In order to reduce electromagnetic interference, special fiber-optic on-off modules have been designed and tested. These modules enable several functions to be performed with the confirmation of their realization, e.g. switching on (off) a surge generator, switching on (off) a grounding system, switching on (off) the charging process. The modules developed have been applied and tested in the Lightning Laboratory at IPPLM in Warsaw, in order to control a system of 5 surge generators. Another module system (see Fig.1) was applied to control the LAE-10 electron accelerator at the IChNT in Warsaw. Other applications of the developed modules have been presented at the IEAE meeting in Prague [2].

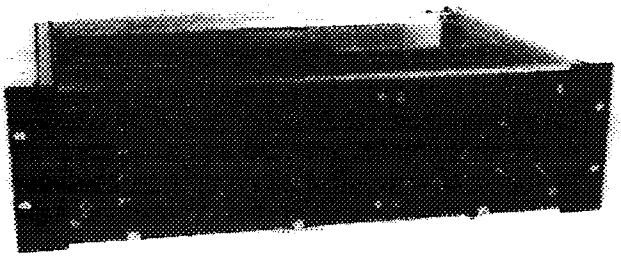

Fig.1 General view of a FO ON-OFF system for the LAE accelerator.

In 1996 we also realized a contract connected with the design and construction of a 10-channel fiber-optic transmission system for slow transients. That system was designed and manufactured at SINS for the NIIEFA in St. Petersburg in order to control an ANGARA-type facility exported to China. The whole system was tested against strong interference in Russian laboratories within the framework of bilateral cooperation [3].

Within a frame of preparations to EMC testing a special Burst Generator 5/30 ns was designed. It will be used for testing electronic equipment for immunity against switching processes within a 50 Hz power network, giving the possibility of synchronization within a $0\text{-}360^0$ range.

[1] M.Bielik, SINS Techn. Docum. (Swierk 1996).
[2] M.Bielik, Proc. IAEA Techn. Comm. Meeting (Prague 1996).
[3] M.Bielik, Manual for NIIEFA (Swierk 1996) - in Russian.

PL9800665

5.17 Design and construction of HV supply systems

by A.Jerzykiewicz, K.Kocięcka, J.Witkowski, and R.Mirowski

Theoretical studies in the field of numerical simulation of transient processes in electrical circuits with non-linear elements have been continued [1-4]. Some efforts were made to improve a model of the MO-varistor. This type of varistor will in the future replace silicon carbide varistors, used presently for oscillation damping in almost all high current supply systems. The best results have been obtained using a model consisting of inductance, capacitance, current dependent resistance calculated from the expression $u=K_1*i^{\alpha_1}$, and time dependent resistance R_2 varying in accordance with the formula

$$R_2(t)=R_{20}-(R_{20}-R_{2e})^{-t/T}.$$

Detailed results will be presented in Palermo [5].

Within a framework of the modernization of supply systems we designed, built, and tested the following devices [6]:

1. HV triggering pulse generators of UI-70 and UI-70a type (shown in Fig.1). They can produce pulses of both polarities, with crest values 30 kV and rise-times of about 300 ns. The UI-70 type is switched on by means of an electrical relay and it is designed especially for triggering trigatrons in simple circuits of the HV generators used mainly in industry. The UI-70a type generator is equipped with a krytron and it will replace the oldest US-4 type pulser within the circuits which should be switched on with a low jitter.

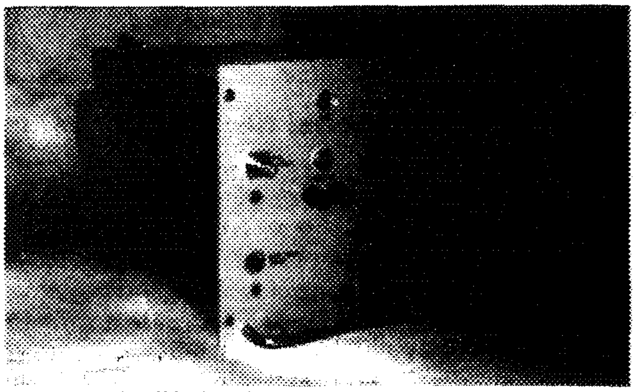

Fig.1 UI-70a HV triggering generator.

2. A capacitor bank charging unit, consisting of a 0.22/25 kV transformer and a two-stage cascade rectifier. The charged capacitors are placed in the second stage of the rectifier and the capacitance of the first stage capacitor is adjusted to a required charging time. The steady state power of the unit is 2.5 kW, and the highest charging voltage is about 60 kV.
3. Control desks and electrical control systems. They have been adjusted to the use of a motor-driven sliding contact transformer, supplying the charging unit.
4. New 60 kV voltage dividers of the resistive- and capacitive-type have also been developed and tested.

[1] A.Jerzykiewicz and K.Kocięcka, Proc. III Symposium on HV Engineering IW-96 (Poznań-Kiekrz 1996), p.259.
[2] M.Bielik, A.Jerzykiewicz, K.Kocięcka and J.Witkowski; ibid, p.274.
[3] K.Kocięcka , Przegląd Elektrotechniczny 72 (1996) 149.
[4] K.Kocięcka, Przegląd Elektrotechniczny 72 (1996) 240.
[5] A.Jerzykiewicz and K.Kocięcka, to be published in Proc. of ISTET'97 (Palermo 1997).
[6] A.Jerzykiewicz, K.Kocięcka and J.Witkowski, SINS Dept. P-V Intern. Report (Otwock-Swierk, 1996).

PL9800666

5.18 Studies of electromagnetic compatibility

by A.Jerzykiewicz, K.Kocięcka, J.Witkowski

Problems connected with the organization of a laboratory, designed for testing the electromagnetic immunity of electronic and electrical equipment, have been analyzed [1-3]. It has been shown that costs of the laboratory stands could be significantly diminished if the basic simulators of interference signals are designed and manufactured at SINS. This conclusion was confirmed by computations of circuits and testing of models for the following simulators:
- a surge, high-energy generator,
- a damped oscillating pulse generator,
- an electrostatic discharges simulator,
- a fast transient (burst) generator,
- the main drop-out simulator.

[1] K.Kocięcka, A.Jerzykiewicz and J.Witkowski, Proc. VI Symposium on Applied Electromagnetism in Modern Technics and Technologies (Poraj 1996).
[2] A.Jerzykiewicz, K.Kocięcka and J.Witkowski, Proc. Seminar on Tests and Certification Problems of Electronic and Electrical Equipment (Jachranka 1996).
[3] A.Jerzykiewicz, K.Kocięcka and J.Witkowski, SINS Dept. P-V Intern. Report (Otwock-Swierk 1996).

PL9800667

5.19 Design and construction of HV generators

by A.Jerzykiewicz, K.Kocięcka, J.Witkowski and R.Mirowski

Within the framework of research on new HV generators we designed, constructed, and tested different surge generators:

1. New HV pulse generator of the GUs-60 type [1-2]. That generator was designed and built for inducing short-circuiting in power cable lines, according to the order from the Institute of Power Engineering.

It can produce pulses with 1.2/30 μs shape on a load that consists of three parallel branches, each including a 0.5 μF coupling capacitor and a 20 Ω tested cable connected in series. The generator can be adapted for two versions of nominal voltage.
The technical data are as follows:

version	I	II
nominal voltage [kV]	60	50
pulse crest value [kV]	50	40
capacitance [μF]	2.5	3
energy [kJ]	4.5	3.75
pulse repetition rate	6/min	

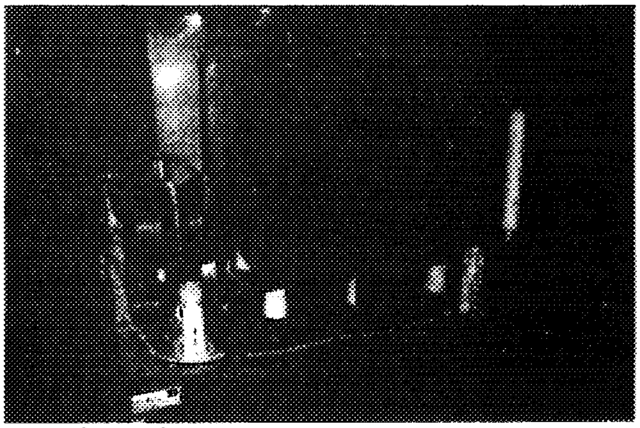
Fig.1 GUs-60 Generator.

The generator is equipped with two voltage dividers: a resistive one - for measuring the pulse outgoing from the generator, and a capacitive one, for measuring the pulse on the cable impedance. Detailed investigations of the influence of the cable impedance and coupling capacitance on the pulse shape were performed. The view of the generator is shown in Fig.1

2. A surge generator of the GUN-8/1 type [3-4]. That generator has been designed and built according to the order from the ELTEST Laboratory and it will be used for testing of electronic and electric equipment. It can produce pulses of both polarities with 1.2/50 μs shape and crest values within the range 0.3 - 6.8 kV on a capacitive load up to 5 nF, according to requirements given in the IEC 60 Publication. A general view of this generator, equipped with an automatic charging voltage regulation system and a pulse counter is shown in Fig. 1.

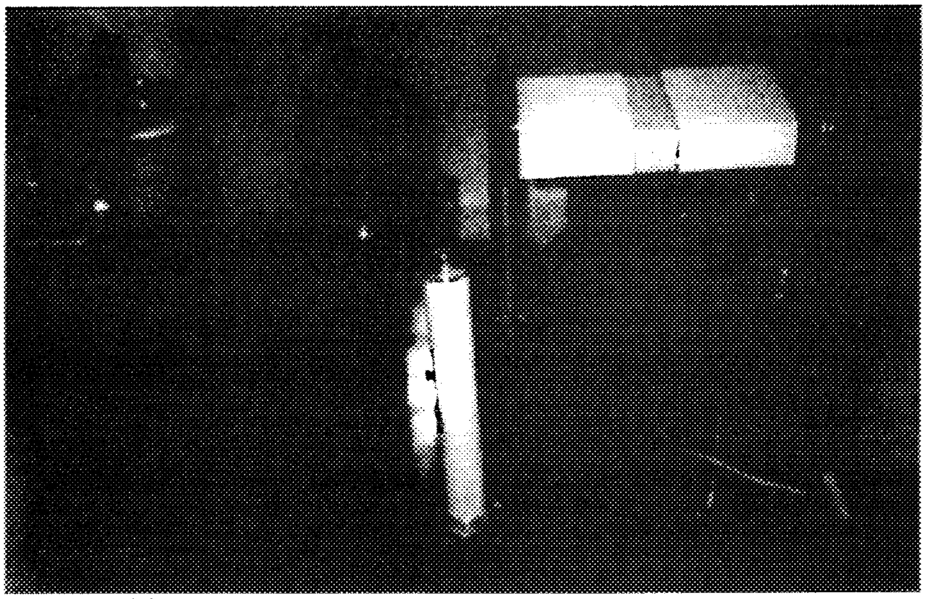
Fig.2 GU-70 Surge generator.

3. A surge generator of the GU-70 type [5-6]. This generator (Fig.2), producing 1.2/50 μs pulses with the crest value within the range 0.8 - 65 kV, has been put in operation in industry.

[1] A.Jerzykiewicz, J.Witkowski, K.Kocięcka and R.Mirowski, GUs-60 Generator Design (Swierk 1996).
[2] A.Jerzykiewicz, J.Witkowski, K.Kocięcka and R.Mirowski, GUs-60 Manual (Swierk 1996).
[3] A.Jerzykiewicz, J.Witkowski, K.Kocięcka and R.Mirowski, GUN-8/1 Generator Design (Swierk 1996).
[4] A.Jerzykiewicz, J.Witkowski, K.Kocięcka and R.Mirowski, GUN-8/1 Manual (Swierk 1996).
[5] A.Jerzykiewicz, J.Witkowski, K.Kocięcka and R.Mirowski, GU-70 Generator Design (Swierk 1996).
[6] A.Jerzykiewicz, J.Witkowski, K.Kocięcka and R.Mirowski, GU-70 Manual (Swierk 1996).

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Proc. XIth International Conference on High-Power Particle Beams BEAMS'96 (Prague 1996), Vol.II, p. 860 (listed also in Department P-IX)

ELECTRICAL BREAKDOWN AND EVOLUTION OF HIGH-CURRENT PLASMA DISCHARGE OF PLASMA-FOCUS TYPE
M. Sadowski;
Proc. of VI Symposium on Applied Electromagnetics in Modern and Technologies, Poland, Poraj 13-15 May, 1996.

STUDY OF NEW, MULTICHANNEL CERENKOV-TYPE DETECTORS FOR ANALYSIS OF ELECTRON BEAMS FROM HIGH-TEMPERATURE PLASMA, PART II;
L.Jakubowski, M.Sadowski, J.Żebrowski;
Proc. of VI Symposium on Applied Electromagnetics in Modern and Technologies, Poland, Poraj 13-15 May, 1996.

LECTURES, COURSES AND EXTERNAL SEMINARS

Plasma research in Poland[b)];
M. Sadowski; April 18, Kharkov Institute of Physics .

Recent pf experiments with gas puffing[b)];
E. Składnik-Sadowska; April 18, Kharkov Institute of Physics .

Correlation of x-ray and particle emissions from PF facilities[b)];
J. Żebrowski; April 18, Kharkov Institute of Physics.

Technological applications of plasma-ion streams[b)];
J. Langner; April 18, Kharkov Institute of Physics.

Fluid model for magnetron plasma;
M. Rabiński; Nov.13, Institut für Plasmaforschung w Stuttgarcie, Germany.

Some Experimental facilities and diagnostic equipment for studies of dense plasmas;
M. Sadowski; Nov.14, Research Center ENEA, Brasimone, Włochy.

Status of plasma research and applications in Poland;
M. Sadowski; Nov.15, Ferrara University , Italy.

Corpuscular diagnostics on RP devices at SINS[b)];
J. Baranowski; Nov.25, Institute of Plasma Physics (INFIP) University in Buenos Aires, Argentina.

True and false achievements of modern physics - Deterministic alternative to quantum mechanics[c)]
M. Gryziński; Dec.10, Kurchatov Institut , Moscow, Russia,

To see the electron[c)];
M. Gryziński; Dec. 11, Moscow Institute, Rosja.

True and false achievements of modern physics - Deterministic alternative to quantum mechanics [c)]
M. Gryziński; Dec.13, Moscow Institue, Russia.

Ion diagnostics on plasma devices at SINS;
J. Baranowski; Dec.14, Institute of Physics (IFAS) Tandill, Argentina.

Classical collision theory and the structure of the atom[c)];
M. Gryziński; Dec.15,1996, Lebiediev Institute, Moscow, Russia.

Classical collision theory and the structure of the atom and molecule[c)];
M. Gryziński; Dec.16, Moscow University, Moscow, Russia.

INTERNAL SEMINARS

Recent results on controlled nuclear fusion [a)];
M. Sadowski; May 6, SINS-Świerk.

[a)] in Polish
[b)] in English
[c)] in Russian

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6. DEPARTMENT OF HIGH ENERGY PHYSICS

PL9800668

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Overview

The interest of the High Energy Physics Department is focused on Experimental Particle Physics and High Energy Nuclear Physics. In both fields, physicists work in large international teams formed around a few physical goals. Few accelerators and detector systems in the world give opportunities to attack such goals. The complex and expensive instrumentation has to be built and run over a long timescale.

For several years the Department has been involved in the DELPHI experiment at LEP, muon experiments (EMC, NMC, SMC) and relativistic ions studies at SPS in CERN.

In 1996 the main effort of the DELPHI Collaboration was focused on searches for new particles: Higgs bosons and supersymmetric particles in the new energy window accessible at increased energies of the lepton beams.

The New Muon Collaboration (NMC) has published final results on the high accuracy measurements of nuclear effects for structure functions and on the ratio of cross sections for the absorption of virtual photons polarised longitudinally and transversely. The Spin Muon Collaboration (SMC) continued the work on the scattering of polarised muons on a polarised proton target in order to understand the origin of proton spin. New results have been obtained from semi-inclusive spin asymmetries.

In the interactions of heavy ions at extremely high energies both in running experiments at SPS (NA35, NA49, WA98) as well as at the future LHC accelerator (ALICE) the main goal is the search for a new phase of matter, the quark-gluon plasma.

New results on the production of antiprotons, antilambdas and Ξ and $\bar{\Xi}$ hyperon production were obtained in NA35 and NA49 experiments.

From the WA98 experiment, data on production of photons and neutral pions in Pb-Pb collisions appeared.

In the intermediate energy physics domain we are working on the international WASA project at the CELSIUS Storage Ring in Sweden, devoted to rare decays of pseudoscalar mesons. The Plastic Barrel Detector was built in Warsaw for the 4π WASA apparatus (under construction).

New challenges are connected with the high intensity of beams and growing number of emitted particles at new large accelerators. At present, preparations are in progress for CMS and ALICE experiments at the future Large Hadron Collider (LHC).

The Resistive Plate Chamber prototype has been successfully tested and a muon trigger electronic prototype has been constructed and tested for the CMS experiment at LHC.

The need for collaborations to share the large volume of data and to exchange sophisticated computer codes triggered a further development of the computer network in the laboratory.

In 1996, several physicists from the HEP Department participated in the organisation of the biennial, 28-th International Conference of High Energy Physics held in Warsaw at the end of June.
The attendance at the Conference was about 800 physicists and a joint effort was made, by both experimentalists and theorists, to understand not only accelerator data, but also implications for gravitation, astrophysics and cosmology.

PL9800669

REPORTS ON RESEARCH

6.1 The NA48 experiment on direct CP violation

by A.Chłopik, Z.Guzik, J.Nassalski, E.Rondio, M.Szleper and W.Wiślicki

The NA48 experiment [1] was built and tested on the kaon beam at CERN. It aims to measure the effect of direct violation of the combined CP transformation in two-pion decays of neutral kaons with precision of 0.1 permille. To perform such a measurement beams of the long-lived and short-lived K's are produced which decay in the common region of phase space. Decays of both kaons into charged and neutral pions are measured simultaneously.

The Warsaw group contributed to the electronics of the data acquisition system, to the offline software and took part in the data taking during test runs in June and September 1996.

The hardware contribution of the group consisted of design, prototype manufacturing, testing and production supervision of the data acquisition blocks: RIO Fiber Optics Links, Cluster Interconnectors and Clock Fanouts. These elements are described in a separate note of this report.

We worked on the following software related issues:

(i) reconstruction of data and Monte Carlo in the magnetic spectrometer consisting of four drift chambers, the bending magnet and the trigger hodoscope. Energy and momentum resolution and background sources were carefully studied.

(ii) decoding and undecoding of the liquid kryptonium calorimeter data. This part of the equipment is crucial for the measurement of neutral decays.

(iii) correlated Monte Carlo to use the same events to simulate K_L and K_S decays and thus speed up simulation considerably.

(iv) study of the charged decay trigger efficiency. This work is underway in Warsaw and is the MA thesis of a student of Warsaw University. The whole off line software was installed on the local cluster of workstations and data processing is enabled by using exabyte streamers.

In 1996, two test runs were performed. The first run in June was mainly devoted to test some elements of the magnetic spectrometer, as e.g. the fourth drift chamber which was missing in 1995. The second run in September was concentrated on testing the liquid krypton calorimeter. This detector was not yet fully equiped. The data were read out from 16-cell clusters and were analysed. About 0.5 TByte of data was taken.

[1] The NA48 Collaboration, G.D.Barr et al., CERN/SPSC/90-22, SPSC/P253

PL9800670

6.2 Preparations for the CMS experiment on LHC

by M.Górski, P.Zalewski

In the year 1996 the activities concerning the preparations for the CMS (Compact Muon Solenoid) experiment on the LHC (Large Hadron Collider) accelerator at CERN concentrated on two subjects:

1) Detailed studies of the RPC (Resistive Plate Chamber) prototypes and
2) Construction and tests of the muon trigger electronics prototype.

ad 1)

The studies of the RPC prototypes concentrated on the chamber behaviour as a function of the applied high voltage and gas mixture composition. We constructed a 20*20 cm prototype using melamine plates and equipped it with 20 1-cm wide readout strips. In the tests two readout schemes were used: readout with a charge ADC and TDC module which was principally used to investigate the signal properties of the streamer mode discharges and readout with a Tektronix digital oscilloscope, where information was digitised with the time interval down to 4 nanoseconds. This second method permitted us to clearly distinguish between streamer and avalanche modes of operation. It was possible to register signals with amplitude as small as about 1 mV. We were able to determine that practically all events contained a small avalanche type pulse, possibly followed later by a streamer discharge. The probability of appearance of the streamer pulse was found to be a decreasing function of the proportion of the freon gas.

The chamber behaviour was described using the GARFIELD chamber simulation program, while the signal formation on the readout strips was studied with the circuit analysis program SPICE. Good agreement was found between the simulation results and obtained data.

ad 2)

A prototype of the muon trigger device (PAC - Pattern Comparator) for the CMS was constructed at the Institute of Experimental Physics of Warsaw University in collaboration with the University of Bari. The prototype was built using Altera and Xilinx FPGAs (Field Programmable Gate Arrays).
It incorporates all functional elements of the final design, namely:
- input signal synchronisation,
- detection of muons and their momentum estimate,
- sorting tree to select four highest momentum candidates from among all possible ones.

The prototype was first tested in a laboratory using a programmable generator providing up to 32 signals. In October it was tested in Bari with four planes of RPC's using cosmic rays. Instead of momentum, which could not be measured due to the lack of a magnetic field, the muon angle with respect to the vertical direction was used.

The prototype performed correctly. In 1997 a specially designed integrated circuit will be produced, which will then replace FPGAs and the final prototype will be constructed and tested.

6.3 Deuteron charge exchange disintegration

by A.Deloff

PL9800671

The exclusive reaction $^3He(d,pp)^3H$ at 3.9 MeV/c incident momentum has been considered. The model applied assumes a one-pion-exchange mechanism followed by a virtual $\pi^+ d \rightarrow pp$ process the amplitude of which has been obtained from a one-nucleon-exchange diagram. With the form factors determined from other experiments there are no adjustable parameters in the transition amplitude. The calculated cross sections are found to be in very good agreement with recent Saclay data.

6.4 Color fluctuations in ultrarelativistic heavy-ion collisions

by S.Mrówczyński

PL9800672

Using kinetic theory, fluctuations in quark-gluon plasma have been studied. When the plasma is in thermodynamic equilibrium the fluctuations are poissonian and consequently small. The situation changes drastically when the non-equilibrium plasma is considered. We have demonstrated that the fluctuations can be very large in such a case. Then they can play a significant role in the system dynamics.

We paid particular attention to the color fluctuations in the plasma with strongly anisotropic momentum distribution of partons. Such a plasma is expected to appear at the early stage of heavy-ion collisions at the Relativistic Heavy-Ion Collider (RHIC) or Large Hadron Collider (LHC). Then, the average parton momentum along the beam is much larger than the average transverse momentum. By solving the dispersion equation, we have shown that there are unstable modes in such an anisotropic plasma which exponentially grow in time. The fluctuations, which initiate these modes, have been studied and we have demonstrated that these fluctuations are indeed large and very probable. The physical mechanism responsible for the fluctuation growth has been also discussed. Finally, we have considered how the color fluctuations, which are the characteristic feature of the deconfined phase, can show up in heavy-ion collisions at RHIC and LHC.

6.5 Deep inelastic muon scattering experiments at CERN

by J.Nassalski, E.Rondio, A.Sandacz, M.Szleper, W.Wiślicki

PL9800673

In 1996 our group was involved in three experiments at CERN concerning deep inelastic muon scattering: NMC, SMC and COMPASS.

The New Muon Collaboration (NMC) final results have been published or were accepted for publication. They include high accuracy measurements of nuclear effects for structure functions; A dependence and Q^2 dependence of the structure function ratio F_2^A/F_2^C (with respect to carbon nuclei) [1,2].

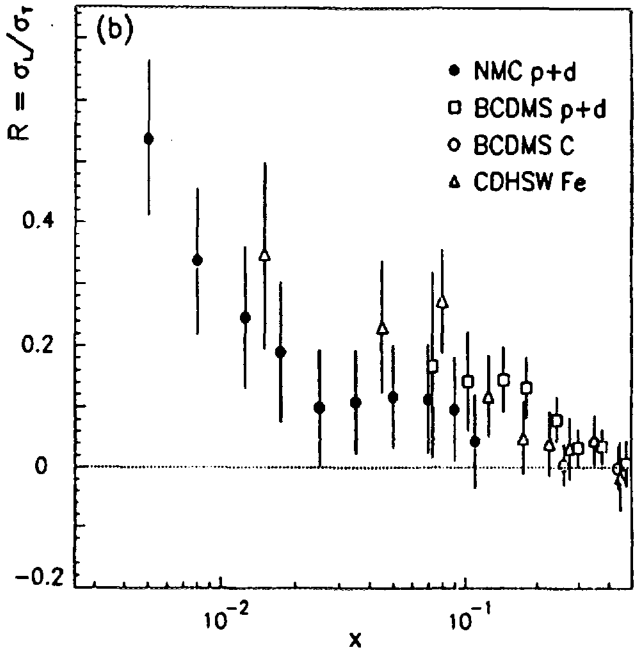

Fig.1

The are also two publications of measurements of structure functions F_2^p and F_2^d, of the ratio $R^{p,d}$ of cross sections for the absorbtion of virtual photons polarised longitudinally and transversely, and very precise measurements of the F_2^d/F_2^p ratio[3,4].

The NMC result on the R (averaged over p and d) covering a previously unexplored range of small x is shown in Fig.1 together with earlier measurements.

The NMC estimate of the ratio F_2^n/F_2^p as a function of x is shown in Fig.2 (a). At small x it is consistent with a small shadowing in deuteron predicted by various models (b).

In 1996 the Spin Muon Collaboration (SMC) finished the experimental part of its program. During the last year the data were taken with the polarised proton target. The collected statistics is about 10 million events after cuts; two times more than taken previously with the proton target by the SMC in 1993. The data analysis is in progress. Among the SMC publications of 1996 is the first experimental result concerning the polarisation of valence, $\Delta u_v(x)$ and $\Delta d_v(x)$ [5], as well as non-strange quarks, $\Delta q(x)$, in the nucleon obtained from semi-inclusive spin asymmetries.

In 1996 a proposal of a new experiment was submitted [6]. The experiment is called COMPASS (Common Muon and Proton Apparatus for Structure and Spectroscopy). The main aim of the "muon" part is the determination of the gluon polarisation in the nucleon, $\Delta g/g$ (x). Beginning of the data taking is foreseen in 2000. The proposal was recommended by SPSLC and approved by the Research Board of CERN.

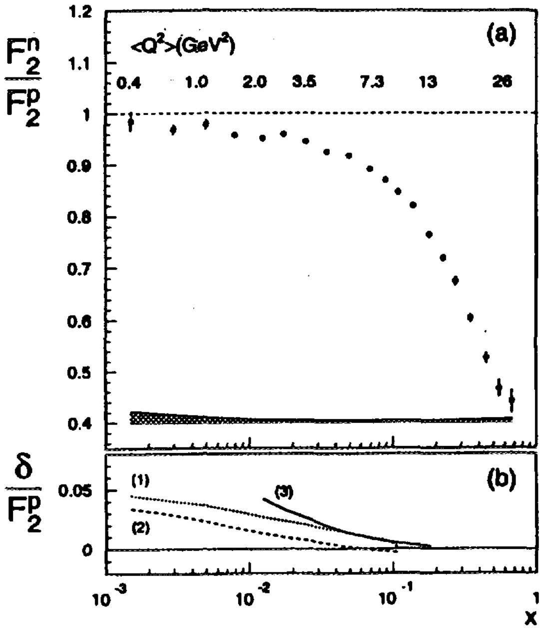

Fig.2

[1] M.Arneodo et al., (NMC) Nucl.Phys. B481 (1996) 3.
[2] M.Arneodo et al., (NMC) Nucl.Phys. B481 (1996) 23.
[3] M.Arneodo et al., (NMC) Submitted to Nucl.Phys., hep-ph/9610231.
[4] M.Arneodo et al., (NMC) Submitted to Nucl.Phys., hep-ph/9611022.
[5] B.Adeva et al., (SMC) Phys.Lett. B369 (1996) 93.
[6] G.Baum et al., (COMPASS) CERN/SPSLC 96-14, SPSLC/P297.

PL9800674

6.6 Experiments with relativistic heavy ions - NA35 and NA49

by H.Białkowska

A study of NA35 continued, with published new results on pion correlations, and antiproton and antilambda production in sulphur - nucleus collisions at 200 GeV/M.

The $\bar{\Lambda}/\bar{p}$ ratio near mid-rapidity is significantly larger than for pp and p-nuclear collisions. A study of ksi hiperon production in S - Au collisions (performed in Warsaw) yielded the Ξ/Λ and $\bar{\Xi}/\bar{\Lambda}$ ratios, an important quantity for hot nuclear matter diagnosis. Fig.1 shows the reconstructed Ξ hyperon mass spectrum.

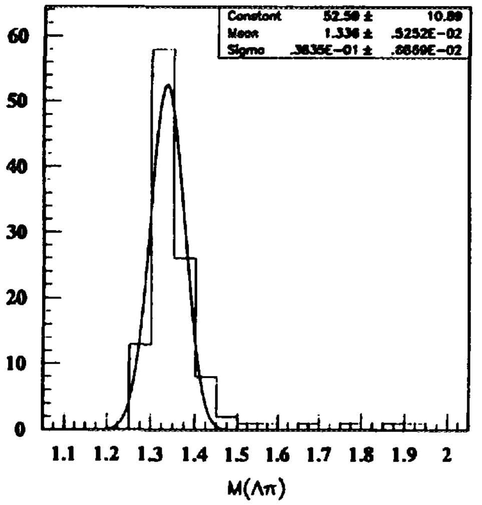

Fig.1 The invariant mass of the $(\Lambda\pi)$ system (after subtraction of the combinatorial background).

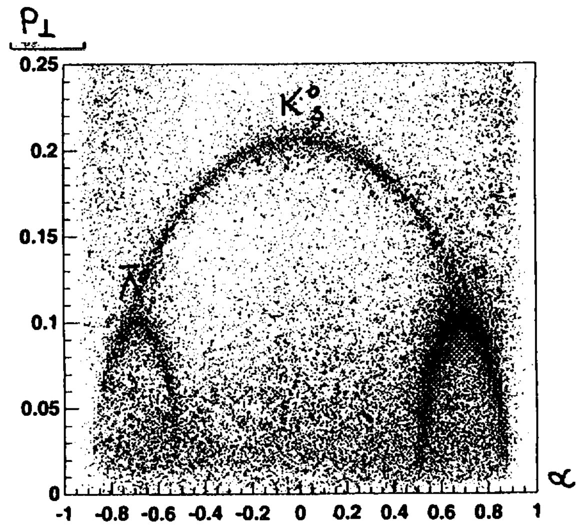

Fig.2 Armenteros plot for V^0's.

The analysis of NA49 data on Pb - Pb collisions at 160 GeV/N first yielded information on produced particle multiplicity, spectra and pion correlations. A study of strange particle production (performed in part in Warsaw) is in progress. In spite of large overall multiplicity, it allows for good discrimination between K^0, Λ, and $\bar{\Lambda}$ signals, as illustrated in Fig.2.

6.7 DELPHI experiment in 1996 (Highlights)

by R.Gokieli, K.Nawrocki, R.Sosnowski, M.Szczekowski, M.Szeptycka, P.Zalewski

The upgrade of the LEP accelerator opened a new energy window for search of expected and/or possible new particles. In 1996 the main effort of the DELPHI collaboration was devoted to looking for the Higgs boson (s) and supersymmetric particles. Searches were performed for the collision energy of $e^+ e^-$ equal 130, 161 and 172 GeV. No evidence has been found for new particles with masses accessible at these energies. New data collected at higher energies will allow us to continue searches of objects with higher masses.

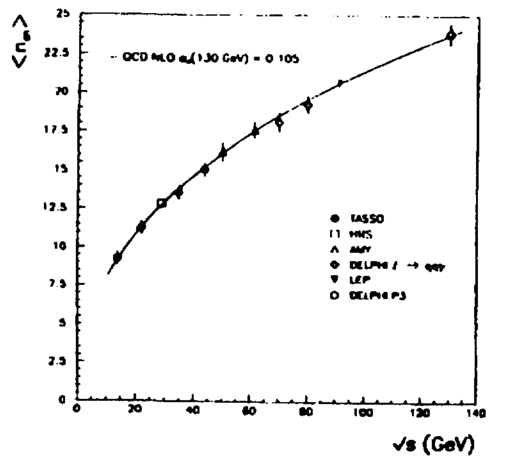

Fig.1 Measured multiplicity at 130 GeV, compared with lower energy measurements and with a fit to a pradiction from QCD in next-to-leading order.

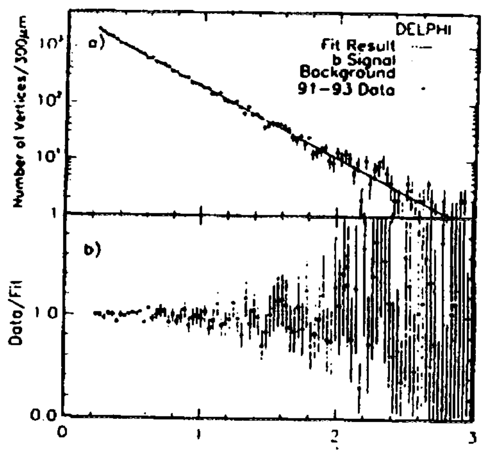

Fig.2 The decay length distribution of B hadrons.

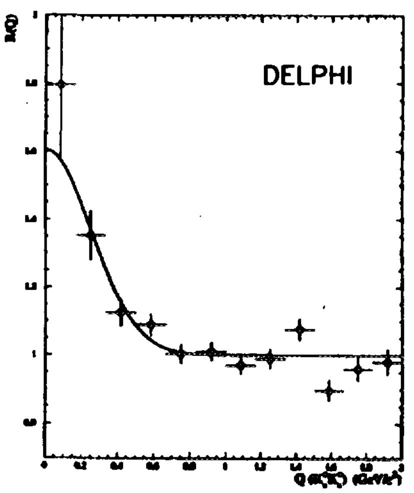

Fig.3 Bose-Einstein correlation for pairs of neutral kaons.

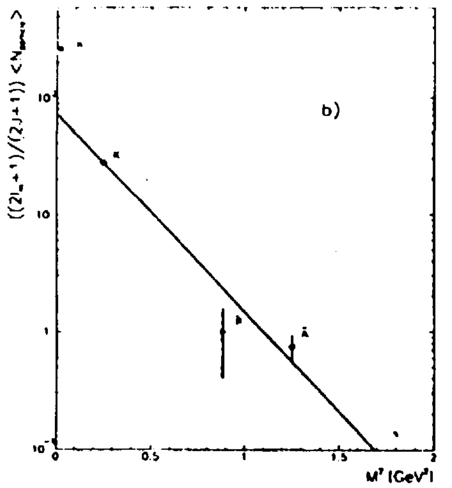

Fig.4 Inclusive cross-section for hadrons produced S + Ag at 200 Ax200 GeV compared with the fit from e^+e^- processes.

In addition to the above searches, the analysis of data at the energy of the Z^0 peak was continued. Among numerous results presented e.g. to the 28-th International Conference on High Energy Physics in Warsaw (65 papers submitted) a few examples are given below.

The first measurements of the charged particle multiplicity was performed for 130 GeV collision energy (Fig.1). The fit to the data gave the value of the strong coupling constant at 130 GeV, $\alpha_s(130\ \text{GeV}) = 0.105 \pm 0.003\ (\text{stat}) \pm 0.008\ (\text{syst})$.

The average lifetime of B hadrons was measured with high precision using the data from 1991 - 1993. The fit to the decay length distribution (Fig.2) gave $\tau_B = 1.582 \pm 0.011$ ps.

The Bose-Einstein correlation was used to determine the size of the K meson source. This was done for both charged and neutral kaons. In either case the measured size is about 0.5 fm (0.48 ± 0.04 ± 0.07 fm for charged and 0.55 ± 0.08 ± 0.12 for neutral kaons).

The universal mass dependence for meson and baryon inclusive cross-sections (advocated recently in e^+e^- annihilation and in hadronic reactions) was shown to also be consistent with heavy ion collisions data (Fig.4) [M.Szczekowski and G.Wilk, Phys.Lett.B374(1996)225]. The dependence can be used as a reference for quark-gluon plasma studies.

PL9800676

6.8 The D-state probability of the deuteron

by T.Siemiarczuk for Dubna-Košice-Moscow-Tbilisi-Warsaw Collaboration

A method is proposed [1] for direct determination of the deuteron D-state probability based on the analysis of the d↑p→ppn reaction. Using known results on the vector analyzing power in elastic NN scattering, the overall nucleon polarization, the deuteron vector polarization and the probability of the deuteron D-state have been estimated.

[1] V.V.Glagolev et al. Z.Phys. A356(1996)183

PL9800677

6.9 Spatial correlations in deuteron break-up with allowance for final-state interaction

by T.Siemiarczuk for Dubna-Košice-Moscow-Tbilisi-Warsaw Collaboration

Experimental results on dp inelastic collisions obtained with a 100 cm hydrogen bubble chamber exposed to a 3.35 GeV/c deuteron beam [1] are compared with a nonrelativistic model based on the Lippmann-Schwinger equation. Final-state interaction is shown to play an important role in the deuteron break-up.

[1] V.V.Glagolev et al., Physics of Atomic Nuclei 59(1996)2125

6.10 Azimuthal correlations in the target fragmentation region of high-energy collisions

by T.Siemiarczuk for WA80 Collaboration

Results on the target mass dependence of proton and pion pseudorapidity distributions and of their azimuthal correlations in the target rapidity range $-1.73 \le \eta \le 1.32$ are studied [1]. The data have been taken with the Plastic-Ball detector set-up for 4.9 GeV p+Au collisions at the Berkeley BEVALAC and for 200 AGeV/c p-, 0-, and S-induced reactions on different nuclei at the CERN-SPS. The yield of protons at backward rapidities is found to be proportional to the target mass. Although protons show a typical "back-to-back" correlation, a "side-by-side" correlation is observed for positive pions, which increases both with target mass and with impact parameter of a collision. The data can consistently be described by assuming strong rescattering phenomena including pion absorption effects in the entire excited target nucleus.

[1] T.C.Awes et al., Physics Letters B381(1996)29

6.11 First results on 158 AGeV Pb+Pb collisions from CERN WA98 experiment

by K.Karpio, T.Siemiarczuk, G.Stefanek and L.Tykarski for WA98 Collaboration

The WA98 experiment [1] consists of large acceptance hadron and photon spectrometers. It allows us to study a variety of observables in heavy-ion reactions via inclusive distributions and also event-by-event. It is unique in its capabilities to measure photons and neutral mesons in these reactions.

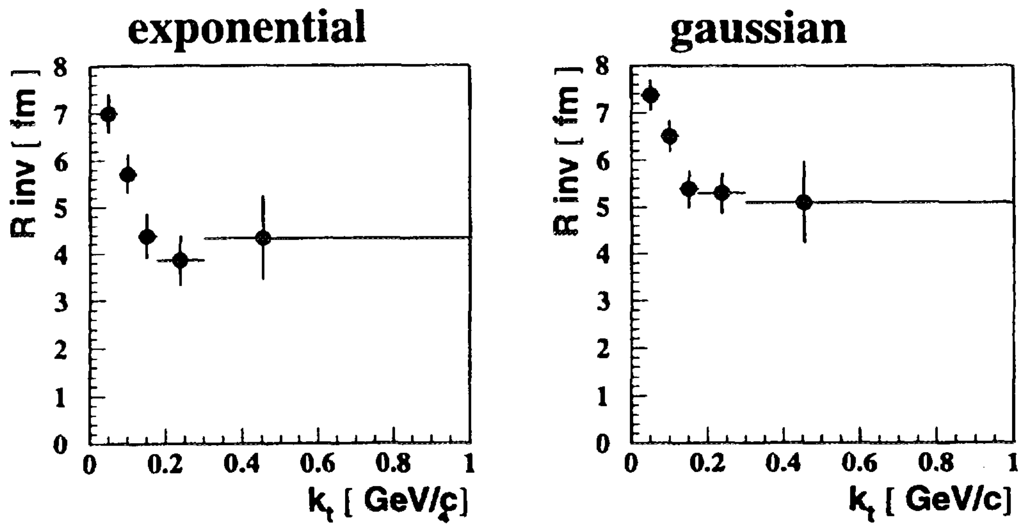

Fig.1 Radii obtained by 1-dimensional Gaussian and exponential fit as a function of K_T.

The analysis based on less than 10 % of the total data sample [1,2] of the 1995 beam-time can be summarized as follows:

- Transverse energies produced in 158 AGeV ^{208}Pb induced collisions exhibit a similar scaling as 200 AGeV ^{16}O and ^{32}S induced reactions. Volume averaged energy densities reach values of $\epsilon = 2.5$ GeV/fm^3.
- Photon multiplicity distributions for ^{208}Pb+Pb indicate slightly larger fluctuations than expected from Poisson statistics.
- Inclusive photon and neutral pion p_T spectra are flatter for central than for peripheral reactions. Inverse slopes are similar to ^{32}S+Au. VENUS 4.12 tends to overpredict the yield in the high p_T region.
- The variations of the event-by-event mean-p_T are largely governed by statistical fluctuations.
- Events of extremely high photon multiplicity in LEDA show indications of a flatter inclusive photon spectrum than average central events.
- The neutral pion production is consistent with the charged particle yield without a drastic low p_T enhancement beyond a Bessel function with T = 155 MeV.

- The interferometry analysis for negative particles gives fitted radii of about 6 fm for Pb + Pb collisions at 158 AGeV.

The Q_{inv}, Q_3 correlations are not Gaussian. They are better represented by exponentials. This study is based on the tail of the distributions and not on the first bins which might be subject to systematics. One possible hypothesis is that this behaviour is due to resonance effects. Fitting Gaussians to these correlation functions may then produce different results depending on the acceptance of the experimental setup.

A clear dependence of the radius parameters on k_T is observed (Fig.1).

[1] M.Aggarwal et al., WA98 Collaboration, Nuclear Physics A610(1996)200c
[2] L.Rosselet et al., WA98 Collaboration, Nuclear Physics A610(1996)256c

6.12 Correlations and single particle spectra in S + Au reactions at 200 A*GeV.

by T.Siemiarczuk and G.Stefanek for WA93 Collaboration

The WA93 experiment combined a large acceptance, highly granular lead-glass Photon Spectrometer and a large area Photon Multiplicity Detector with a Charged Particle Spectrometer providing tracking and momentum reconstruction of negatively charged particles. The incident beam passed through a thin start detector before impinging on a gold target at the entrance of a dipole magnet. A Zero Degree Calorimeter and a Mid-Rapidity Calorimeter allowed the selection of central reaction events. The charged particle spectrometer used for the correlation studies consisted of a $\int Bdl = 1.8$ Tm dipole magnet with circular pole pieces of 2 m diameter and an air gap of 1.6 m. The charged particles, deflected mainly in the horizontal X-Z plane, were detected in four 1.2 x 1.6 m^2 Parallel Plate Avalanche Chambers which were optically read out via CCD cameras equipped with image intensifiers. These tracking chambers were placed at a relative distance of 1.3 m in the field free region downstream of the magnet. The acceptance of the spectrometer comprised a region in rapidity $2.2 < y < 4.4$ and transverse momentum $0 < p_T < 3.0$ GeV/c where complete coverage in p_T was achieved for $3.0 < y < 3.5$.

Below we list the main topics studied by the Collaboration in 1996:

- Inclusive photon spectra have been measured for $p_T < 1$ GeV/c in central S + Au reactions with a small acceptance BGO detector. The redundant photon identification possibilities from both the dispersion method and the forward/total method allow us to study the photon production down to very low transverse momentum.
  The assumption of an exponential shape of meson spectra at low m_T with an inverse slope of T = 210 MeV fails to reproduce the spectral shape of the photons. A second component of T = 100 MeV improves the description but fails for the lowest p_T.
- The mean transverse momentum of photons has been determined on an event by event basis in S + Au collisions at 200 A*GeV from the ratio of the measured electromagnetic transverse energy (E_T^{em}) to the photon multiplicity (N_γ). The average value obtained is similar to that determined for the same system using spectroscopic technique. The central dependence of the measured values are in agreement with the predictions of the VENUS event generator.
- The photon multiplicity has been measured for the first time in S + Au collisions at 200 A*GeV over a wide pseudorapidity range ($2.8 \le \eta \le 5.2$) employing a fine granularity preshower detector. The pseudorapidity density is determined over a varying range of centralities and shows an increasing behaviour with centrality, reaching ~ 200 at the highest centrality studied. The results are compared with the measurements of charged particle multiplicity and with the predictions of the VENUS event generator.
- Single particle transverse mass distributions and two-particle correlations have been measured for negatively charged particles (dominantly π^-) from 200 A*GeV S + Au reactions. The transverse mass distributions are found to have a concave shape with a slight enhancement of particles at low m_T. The enhancement is largest for central interactions. Radii extracted from interferometry increase with the centrality of the collision. The dynamical evolution of the source size of negative particles is studied by analysing the dependence of the invariant radius on the transverse momentum of the correlated pairs. A decrease of the invariant radius with increasing transverse momentum is observed satisfying a $1/\sqrt{m_T}$ parametrization.

PL9800681

6.13 The forward muon spectrometer of ALICE

by K.Karpio, T.Siemiarczuk, C.Sobczyński, G.Stefanek, L.Tykarski and G.Wilk for ALICE Collaboration

ALICE (A Large Ion Collider Experiment) is the only detector dedicated to the study of nucleus-nucleus interactions at the LHC. It will investigate the physics of strongly interacting matter at extreme energy densities. where the formation of a new phase of matter, the quark-gluon plasma (QGP), is expected. For the central part, which allows a comprehensive measurement of hadrons. photons and lower-mass electron pairs, the ALICE collaboration submitted its Technical Proposal [1] at the end of 1995.

In early 1995, we proposed to upgrade our central detectors with a forward muon arm in order to measure the complete spectrum of heavy quark vector mesons, i.e., J/ψ, ψ',Υ, Υ', and Υ'', via their muonic decay in pp and heavy-ion collisions. The dissociation of these resonances in a deconfining medium is one of the most promising signatures of quark-gluon plasma formation, and its investigation therefore forms an essential part of the LHC heavy-ion program.

Hard, penetrating probes, such as heavy quarkonium states, provide an essential tool to study the earliest and hottest stages of heavy-ion collisions. They can probe the strongly interacting matter created in these reactions on short distance scales and early times, and are sensitive to the nature of the medium (i.e. confined versus deconfined).

Heavy quarks (c,b) are produced in hard partonic scattering processes during primary nucleon-nucleon interactions at the very beginning of a nucleus-nucleus collision. Some of these quarks will eventually form quarkonium resonances. The effect of the colliding nuclei on the preresonance stage can be extracted from p-A collisions and must be taken into account when studying the effect of the medium produced on the fully formed physical quarkonium states.

The original idea of suppressed quarkonium production in the presence of a deconfining medium, i.e. a QGP, is based on colour screening. The screening radius in the medium is inversely proportional to the density of colour charges and therefore to the energy density. When it becomes smaller than the size of a resonance, the range of the strong force is so reduced that a bound state can no longer exist. The resonance dissolves' and the quarks separate in space to appear late, after hadronization, as two hadrons with open charm or beauty.

This macroscopic picture has recently been corroborated by microscopic considerations. The large binding energy of the quarkonium ground states J/ψ and Υ prevents their dissociation by low-momentum gluons. Gluons confined to hadrons are restricted to rather low momenta, as is known from the parton distribution functions measured in deep inelastic scattering. As a result, the cross-section for the dissociation of ground state quarkonia by hadronic collisions is strongly damped. In contrast, a deconfined medium, even at comparatively low temperatures, contains sufficiently hard gluons. Hence the dissociation of quarkonium ground states is a clear evidence of deconfinement.

In 1996 a technical proposal of the ALICE forward muon spectrometer has been completed [2].

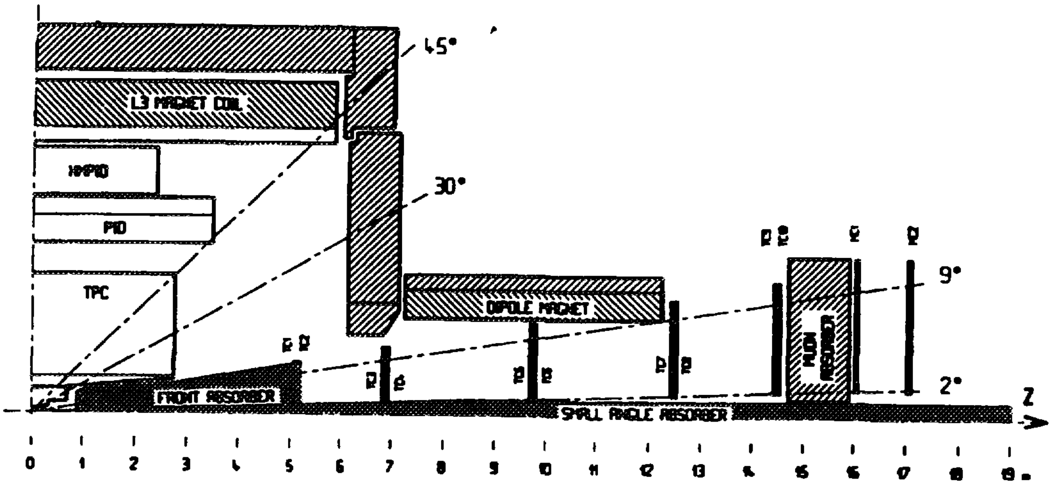

Fig.1 Principal layout of the forward muon spectrometer, including absorbers, dipole magnet, chambers, and the muon identifier.

The principle layout of the forward muon arm and its integration with the central detectors is shown in Fig.1 and Fig.2. The angular acceptance of the muon spectrometer goes from 2^0 to 9^0 (η = 2.5-4).

Its mass resolution will be better than 100 MeV at around 10 GeV, sufficient to separate all resonance states. It consists of a composite absorber ($\sim$ 10 λ_{int}), made with layers of both high and low Z materials, starting 90 cm from the vertex, a large dipole magnet with a 3 Tm field integral placed outside the L3 magnet, and 10 planes of thin, high-granularity tracking stations. A second absorber ($\sim$ 7.2 λ_{int} or iron) at the end of the spectrometer and four more detector planes are used for muon identification and triggering. The spectrometer is shielded throughout its length by a dense absorber tube, of about 60 cm outer diameter, which surrounds the beam pipe.

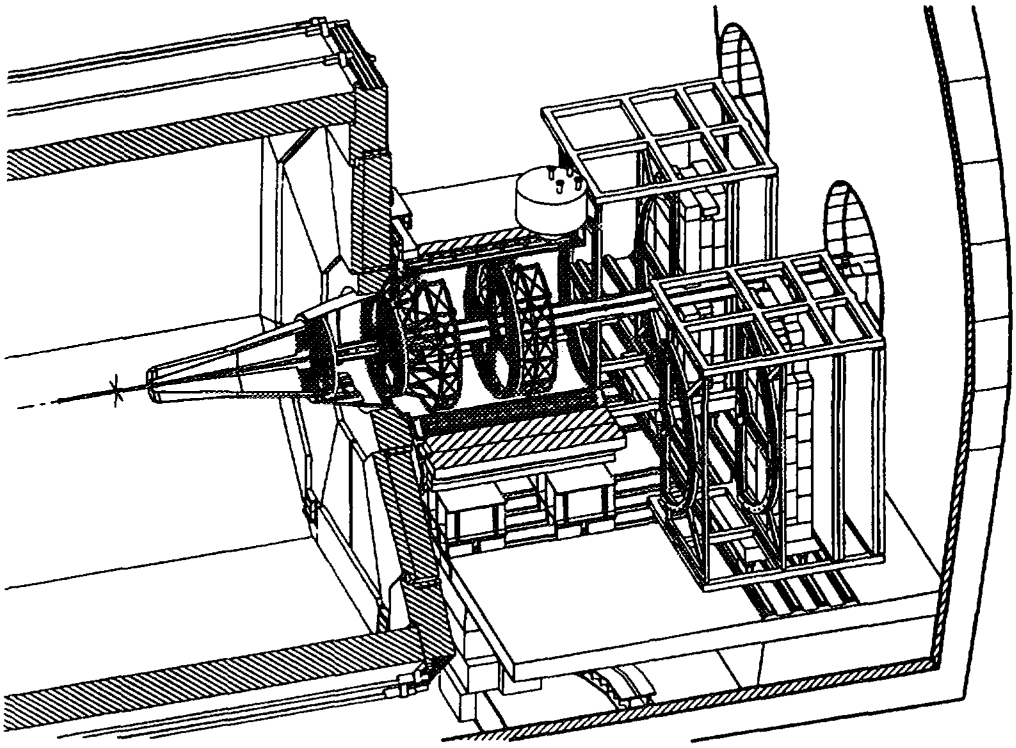

Fig.2 Conceptual layout of the muon arm integrated into ALICE.

[1] ALICE Collaboration, Technical Proposal, CERN/LHCC 95-71, 1995
[2] ALICE Collaboration, The Forward Muon Spectrometer of ALICE, CERN/LHCC 9632, 1996

6.14 The WASA project at CELSIUS accelerator

by A.Kupść, P.Marciniewski, A.Nawrot, J.Stepaniak for WASA/PROMICE Collaboration

The main aim of the international WASA Collaboration at the CELSIUS Storage Ring in Uppsala is the study of rare decays of π^0 and η mesons. These decays give knowledge about fundamental symmetries, meson form factors and chiral perturbation theory. The mesons will be produced in the interactions of the circulating proton beam with a frozen hydrogen or deuteron pellet target.

Extensive simulation studies have been made of both production and decay processes. We also took part in the mechanical design of the CsI calorimeter and the supports. A multi input trigger logic unit based on the programmable logic chip has been designed and built. The device was used with the new amplifier-discriminators to perform the multiplicity trigger. [4].

In Warsaw the 146 detectors which will be arranged in the form of a barrel for 4π WASA apparatus were manufactured and tested (Fig.1). The Plastic Scintillator Barrel will be placed after the vertex drift chamber inside a superconducting coil. The detector will provide a signal for a fast trigger and will give information about the energy loss for charged particle identification.

At present the near threshold of η meson production has been studied [1] in the first stage of the detector setup called WASA PROMICE [2]. It consists of a forward spectrometer, which covers scattering angle less of than 22 degrees, with respect to the beam and two side telescopes consisting of 56 CsI(Na) crystal each. The Collaboration measured the pp $\rightarrow$ ppη cross section at six energies close to threshold using an internal cluster gas jet target. It permits us to determine the cross section energy dependence that gives new information on ηp and ηpp interaction.

In the same set-up the first exclusive measurement was performed of the two charged pions production in proton - proton collisions at 750 MeV. In this experiment a narrow peak was observed in the $pp\pi^-$ invariant mass spectrum at 2063 ± 2 MeV [3]. The position of the peak is in agreement with the hypothesis of the exotic d'dibaryon. The existence of such a state explains in a natural way the peculiarities observed in double charge exchange reactions on nuclei. The analysis of new data collected at 725 MeV and 775 MeV is in progress.

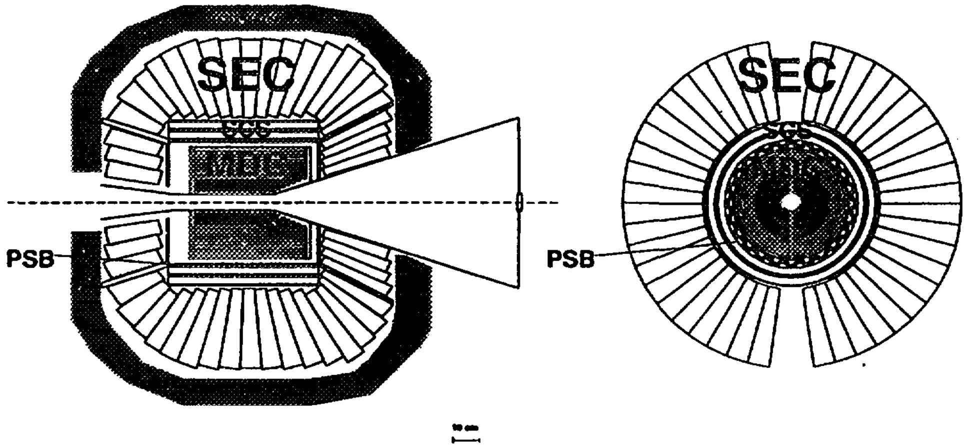

Fig.1 Schematic view of the WASA 4π detector. PSB stands for Plastic Scintillator Barrel.

In 1996 a run was performed with 1037 MeV energy of the incident protons. The protons interacted with a cluster jet deuteron target. The data analysis of pd → npp, pd → $ppp\pi^-$ and pd → $ppn\gamma$ reactions are in progress in the kinematics far from the quasi-free interaction region.

A new low cost amplifier discriminator for use with vertex chambers, proportional multiwire fast chambers fast plastic scintillating detectors has been constructed. The prototypes have been successfully tested with the new ΔE detectors during Spring and Autumn'96 WASA runs.

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DESY 96-183 (August 1996) Z. f. Phys., (in press)

MEASUREMENT OF THE F_2 STRUCTURE FUNCTION IN DEEP INELASTIC e^+p SCATTERING USING 1994 DATA FROM THE ZEUS DETECTOR AT HERA
M.Derrick, **M.Adamus**,et al.
DESY 96-076 (June 1996) Z. f. Phys., (in press)

COLOR FILAMENTATION IN ULTRARELATIVISTIC HEAVY-ION COLLISIONS
St.Mrówczyński
Phys. Lett. B, (in press)

SEARCH FOR LEPTON FLAVOR VIOLATION IN EP COLLISIONS AT 300 GeV CENTER OF MASS ENERGY
M.Derrick, **M.Adamus**, et al.
DESY 96-161 (August 1996) Z. f. Phys. C, (in press)

SEARCH FOR EXCITED LEPTONS IN e^+e^-COLLISIONS AT $\sqrt{s}$ = 161 GeV
P.Abreu, **R.Gokieli, M.Górski, R.Sosnowski, M.Szczekowski, M.Szeptycka, P.Zalewski**, et al.
CERN-PPE-96-169, Nov. 1996. 22pp. Phys. Lett. B393, (in press)

A PRECISE MEASUREMENT OF THE B^0_D MESON LIFETIME USING A NEW TECHNIQUE
P.Abreu, **R.Gokieli, M.Górski, R.Sosnowski, M.Szczekowski, M.Szeptycka, P.Zalewski**, et al.
CERN-PPE-96-139, Oct. 1996. 25pp. Z. Phys. C74, (in press)

MEASUREMENT OF EVENT SHAPE AND INCLUSIVE DISTRIBUTIONS AT $\sqrt{s}$ = 130 GeV AND 136 GeV
P.Abreu, **R.Gokieli, M.Górski, R.Sosnowski, M.Szczekowski, M.Szeptycka, P.Zalewski**, et al.
CERN-PPE-96-130, Sep. 1996. 23pp. Z. Phys. C73, (in press)

SEARCH FOR LEPTON FLAVOR NUMBER VIOLATING Z^0 DECAYS
P.Abreu, **R.Gokieli, M.Górski, R.Sosnowski, M.Szczekowski, M.Szeptycka, P.Zalewski**, et al.
CERN-PPE-96-129, Sep. 1996. 21pp. Z. Phys. C73, (in press)

PARTICIPATION IN CONFERENCES AND WORKSHOPS

ELECTROMAGNETIC Δ DECAYS AND DILEPTON PAIR PRODUCTION AT CELSIUS
J.Stepaniak
Presented at the Int. Conf. Sätra Brun 17-19 June 1996

LIGHT MESON PRODUCTION IN THE pd INTERACTIONS AROUND 1 GeV
J.Stepaniak
Presented at the VI Int. Conf. Oberjoch Meeting on Meson-Nuclear Physics, September 2 - 7 1996

MESON PRODUCTION IN ^{3}He INTERACTIONS WITH PROTONS
J.Stepaniak
Presented at the Conf. MESON'96, Cracow 10-14 May 1996

SPIN STRUCTURE OF THE NUCLEON
J. Nassalski
Invited talk on plenary session "XXVIII International Conference on High Energy Physics", 25-31 July, 1996. Warsaw, Poland, SINS-17/V, hep-ph/9612352, to be published in the Proceedings

RESULTS ON F_2 AND R MEASUREMENTS FROM NMC
E. Rondio
Presented at the QCD96, 4-12 July, 1996, Montpellier, France

THE MUON TRIGGER FOR THE CMS DETECTOR AT LHC
M. Górski
Presented at the Indiana University, Bloomington, USA, 9 Sept.1996

COLOR FILAMENTATION IN ULTRARELATIVISTIC HEAVY-ION COLLISIONS
St.Mrówczyński
Presented at the "XXVIII International Conference on High Energy Physics", 25-31 July 1996, Warsaw, Poland

COLOR FILAMENTATION IN ULTRARELATIVISTIC HEAVY-ION COLLISIONS
St.Mrówczyński
Presented at the "Workshop on Phase Transitions in Nuclear Collisions", Copenhagen, Dec. 1996

PHYSICS OF QUARK-GLUON PLASMA
St. Mrówczyński
Presented at the Conf. "Quark Matter and Heavy-Ion Collisions", Dera Ismail Khan, Pakistan, Jan. 1996

PION CORRELATION AND DEUTERON FORMATION - TWO SIDES OF THE SAME MEDAL
St. Mrówczyński
Presented at the "Workshop on Interferometry in High Energy Heavy-Ion Collisions" Trento, Italy, Sept. 1996

WIGNER FUNCTIONAL APPROACH TO QUANTUM FIELDS
St. Mrówczyński
Presented at the "Workshop on Disoriented Chiral Condensates" Trento, Italy, Oct. 1996

HADRON YIELDS AND HADRON SPECTRA FROM THE NA49 EXPERIMENT
P. Jones, **H. Białkowska** et al.
Conf. Quark Matter'96, Heidelberg, May, 1996

STOPPING AND COLLECTIVE EFFECTS AT SPS ENERGIES
T. Wienold, **H. Białkowska** et al.
Conf. Quark Matter'96, Heidelberg, May, 1996

PARTICLE CORRELATIONS IN Pb - Pb COLLISIONS AT THE CERN SPS - NA49.
K. Kadija, **H. Białkowska** et al.
Conf. Quark Matter'96, Heidelberg, May, 1996

CELSIUS AS AN η FACTORY
R.Bilger, **A.Kupść**, **J.Stepaniak** et al.
14th Int. Conf. on Particles and Nuclei (PANIC), Wiliamsburg, VA, 1996

FIRST EXCLUSIVE MEASUREMENT of η PRODUCTION IN QUASIFREE P-N COLLISIONS
R.Bilger, **A.Kupść**, **J.Stepaniak** et al.
14th Int. Conf. on Particles and Nuclei (PANIC), Wiliamsburg, VA, 1996

MEASUREMENT OF THE pd $\rightarrow$ $^3He\eta$ REACTION AT CELSIUS
R.Bilger, **A.Kupść**, **J.Stepaniak** et al.
14th Int. Conf. on Particles and Nuclei (PANIC), Wiliamsburg, VA, 1996

COLOR FILAMENTATION IN ULTRARELATIVISTIC HEAVY-ION COLLISIONS
St.Mrówczyński
Poster session on Conf. "Quark Matter 96", Heidelberg, May 1996

PHOTON AND NEUTRAL MESON PRODUCTION IN 158 AGeV ^{208}Pb + Pb COLLISIONS
M.M.Aggarwal, **K.Karpio**, **T.Siemiarczuk**, **G.Stefanek**, et al.
Conf. "Quark Matter 96", Heidelberg, May 1996

NEW EXPERIMENTS WITH A DEUTERON BEAM
V.V.Glagolev, **T.Siemiarczuk**, et al.
Conf. XIII Int. Symposium on High Energy Physics, Dubna, 1966

LECTURES, COURSES AND EXTERNAL SEMINARS

WHAT WE INTEND TO MEASURE AT CELSIUS STORAGE RING IN UPPSALA - SWEDEN*)
J. Stepaniak, Feb. 23, Warsaw University, Poland

INVESTIGATION OF PROTON STRUCTURE IN HIGH ENERGY MUON COLLISIONS*)
E. Rondio, March. 22, Warsaw University, Poland

COLOR FILAMENTATION IN ULTRARELATIVISTIC HEAVY-ION COLLISIONS*)
St. **Mrówczyński**, Nov., IFJ, Cracow

EMC EFFECT IN THE NEW MUON COLLABORATION DATA*)
M. Szleper, Jan. 24, IFJ, Cracow

INTERNAL SEMINARS

THE RADII OF NUCLEI AND RADII OF STARS*)
H. Białkowska, Feb., SINS, Świerk

LEPTONIC SIGNALS FROM HIGH ENERGY RELATIVISTIC ION COLLISIONS*)
H. Białkowska, Oct. 10, Seminar of Hight Energy Physics, Warsaw University and SINS, Warsaw

PRELIMINARY RESULTS FROM LEP 1.3*)
M. Szczekowski, Jan. 5, Seminar of Hight Energy Physics, Warsaw Uniwersity and SINS, Warsaw

*) in Polish

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Maciej Górski, Dr.
Andrzej Filipkowski, Dr. 3/4
Andrzej Kupść, Dr.
Stanisław Mrówczyński, Assoc.Prof. 3/4
Jan Nassalski, Professor
Adam Nawrot, Dr.
Ewa Rondio, Dr.
Andrzej Sandacz, Dr.
Teodor Siemiarczuk, Professor
Ryszard Sosnowski, Professor
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7. DEPARTMENT OF COSMIC RADIATION PHYSICS

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Overview

The Department of Cosmic Ray Physics in Łódź is involved in basic research in the area of high energy physics and cosmic ray physics related to:

- Studies of the asymptotic properties of hadronic interactions from the analysis of cosmic ray propagation in the atmosphere.
- Studies of structure and properties of Extensive Air Showers induced by cosmic ray particles.
- Search for point sources of high energy cosmic rays.
- Studies of cosmic ray propagation in the Galaxy and mechanisms of particle acceleration.
- Studies of the mass composition of cosmic rays in the energy range 10^{15} - 10^{17} eV.

Theoretical and experimental studies of nuclear interactions for energies exceeding those obtained by modern particle accelerators are performed employing results obtained by the Łódź Extensive Air Shower Array. The Łódź hodoscope can register electromagnetic components of cosmic ray showers in the atmosphere as well as muons at two energy thresholds.

Data collected by the Łódź array are also used to study mass composition of cosmic rays in the energy range 10^{15} - 10^{17} eV.

The Łódź group collaborates with foreign institutes and laboratories on construction and data interpretation of cosmic ray experiments. Our most important partners are: Forschungszentrum Karlsruhe (Germany), Collège de France, the Institute for Nuclear Studies of the Russian Academy of Sciences, the University of Durham, and the University of Perpignan.

REPORTS ON RESEARCH

Extensive air showers (EAS) of high energy cosmic rays (CR).

PL9800684

7.1 Łódź EAS Array

by R.Firkowski, J.Gawin, S.Kowalczyk, S.Pachała, J.Szabelski and A.F.Janin[1)], W.J.Poddubny[1)], W.W.Skliarow[1)], W.I.Stiepanow[1)]

The Łódź EAS array has been rebuilt and modernized. With the help of specialists from the Institute of Nuclear Studies of the Russian Academy of Sciences we have re-arranged part of our array, which detects EAS muons and electrons on the ground. We have installed new photomultipliers (supplied by our Russian colleagues) and changed the configuration of the data registration system by introducing new CAMAC blocks and modernizing some existing ones. Now we perform tests of our array, which has been collecting data since the 1st of June.

[1)] Institute for Nuclear Research of Russian Academy of Science

PL9800685

7.2 KASCADE EAS experiment

by J.Wdowczyk, J.Zabierowski

The collaboration within the KASCADE project has been continued. This currently biggest in Europe cosmic ray experiment, covering primary energy range 10^{15} - 10^{17} eV, has been under construction since 1990 in Forschungszentrum Karlsruhe, Germany.

The main aim of the KASCADE project [4] is the determination of the chemical composition in the energy range around the knee of the primary cosmic ray spectrum [Refs.1 - 3]. The main advantage of the installation is the simultaneous measurement of a large number of observables for each individual event. This is achieved by the combination of various advanced detection techniques for the electromagnetic, muonic and the hadronic components of the EAS.

The apparatus has been built with significant participation of the Łódź cosmic ray group and the data taking with a large part of the experiment has started at the end of 1995.

We are engaged in the developement of the CORSIKA code (for EAS simulation) as well as preparations of the independent software routines for data reconstruction and interpretation. The Łódź based cosmic ray group has been given the task of independent experimental data handling, based on software procedures different from those being used in Karlsruhe. This approach may assure better uderstanding of the obtained data and should minimize possible software errors.

We also participate in the developement of the electronics for the Muon Tunnel (600m^2 of limited streamer tubes) [4].

[1] J.Wdowczyk, A.W.Wolfendale, Nuovo Cimento Suplemento in press
[2] J.Wdowczyk, A.W.Wolfendale, Nuovo Cimento Suplemento in press
[3] J.Wdowczyk, J.Kempa, Nuovo Cimento Suplemento in press
[4] G.Schatz, W.D.Apel, K.Bekk, J.Wdowczyk, J.Zabierowski,..et al, Nucl. Phys. B Proc.Suppl. in press

PL9800686

7.3 EAS of high energy CR and nucleus-nucleus interactions

by B.Szabelska and J.Szabelski

The Russian EAS experiment at Baksan has been enlarged by adding the array for registration of the soft component of EAS above the muon telescope. ADC channels from outside detectors have been connected to the "Karpet" array. Nearby a 100 m^2 detector for muons above 1 GeV has been built and put into operation. A mirror for registration of Čerenkov radiation from EAS is under construction. We have supplied some components of the on-line system for the Russians and we have together performed calculations which will be used in data analysis. Based on the results of Monte-Carlo simulations of EAS development in the atmosphere we studied the influence of a nucleus-nucleus interaction model used in calculations on the observed characteristics. We compared the superposition model widely used in EAS studies with a more realistic model, taking into account fragmentation, excitation and evaporation of the primary nucleus. The calculations were performed in collaboration with prof. Capdevielle from Collège de France.

The description of the nucleus-nucleus interaction model and its influence on the interpretation of some experimental data has been published [1].

[1] R.Attallah, J.N.Capdevielle, C.Meynadier, B.Szabelska, J.Szabelski, J. Phys. G: Nucl. Part. Phys. 22 (1996) 1497-1506.

PL9800687

7.4 Čerenkov radiation from EAS

by J.Gawin, B.Szabelska, J.Szabelski

In collaboration with the Group of Fundamental Physics from the University of Perpignan we studied the possibility of experimental discrimination between electromagnetic and hadronic showers in measurements of Čerenkov radiation of EAS in the French Pyrenees (THEMISTOCLE). We have found out that analysing the time profile of the Čerenkov impulse in a fast photomultiplier in many cases we can identify the signal due to high energy muons, which is a signature of the hadronic nature of the shower. The results have been presented during the 15th ECRS in Perpignan and discussed with specialists from Collège de France. The necessity of using 'Flash ADC' has been underlined. A publication summarizing the results of these studies has been prepared.

PL9800688

7.5 Monte Carlo simulations of EAS development in the atmosphere

by A.Wasilewski and J.Wdowczyk

We studied distributions of the electromagnetic component of EAS simulated with our own Monte Carlo program and we compared them with the distributions obtained using CORSIKA. Our program is much more specialized in calculating EM component and Čerenkov radiation from EAS, and is quicker than the more universal CORSIKA. Both programs use different algorithms for calculating Coulomb scattering of particles. The comparison of results obtained using our program and CORSIKA showed that both versions of Coulomb scattering are correct.

PL9800689

7.6 Participation in the WASA experiment

by J.Zabierowski

Participation in experiments in the Institute of Radiation Sciences in Uppsala University, has been continued for many years. It has been devoted to the WASA/PROMICE projects on the CELSIUS storage ring in Uppsala. In 1996, activity was devoted to further developement of the WASA 4π vertex detector as well as to the analysis of data obtained in previous experimental runs and publication of the results [Refs. 1, 3 - 10]. Moreover, the existing WASA PROMICE experimental setup [Ref.2] was used for data taking in experiments for studying d+p -> d+p+ π^0 reactions as well as search for diprime dibaryon [Refs. 4,5,9].

Several tasks in the field of nuclear electronics were fulfilled. In the collaboration we are responsible for the light pulser monitoring system of the experiment. The design work on the system for the full WASA detector has been started. The Light Source for the CsI part of the WASA 4π vertex detector (1200 channels) has been built and the production of a Z light distribution system is in progress. In Fig.1, a schematic diagram of the light distribution system for the electromagnetic calorimeter part of WASA is shown. The system is now being constructed in Łódź.

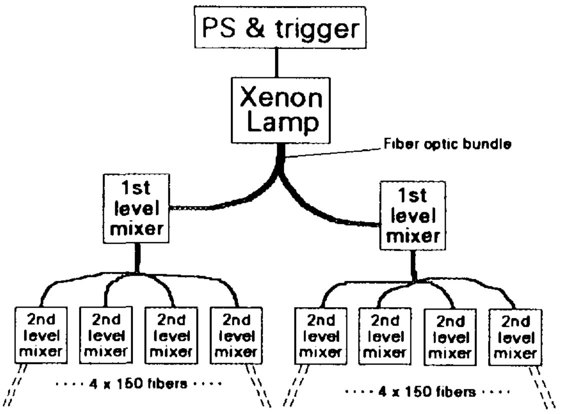

Fig.1. Light Distributions System for CIs calorimeter in WASA vertex detector.

The collaboration with Uppsala also benefited from the TEMPUS MJEP-9006 project.

[1] H.Calen, J.Stepaniak, J.Zabierowski, et al.., Physics Letters B366 (1996) 39 - 43

[2] H.Calen, A.Kupsc, P.Marciniewski, A.Nawrot, J.Stepaniak, J.Zabierowski, et al., Nuclear Instruments and Meth. A379 (1996) 57-75.

[3] D.Akimov, A.Kupsc, P.Marciniewski, A.Nawrot, J.Stepaniak, J.Zabierowski et al., TSL Progress Report 1994-1995, Uppsala,1996 p.64 - 92

[4] W.Brodowski, A.Kupsc, P.Marciniewski, J.Stepaniak, J.Zabierowski et al., Zeitschrift fuer Physik A, A355, 5-8, (1996)

[5] R.Bilger, A.Kupsc, J.Stepaniak, J.Zabierowski et al., Prog.Part.Nucl. Phys., Vol.36, pp.379-381, 1996.

[6] T.Johansson, A.Kupsc, P.Marciniewski, J.Stepaniak, J.Zabierowski et al., (PROMICE-WASA Collaboration) TSL/ISV Report -96-0155, Uppsala University, Oct. 1996. ISSN 0284-2769

[7] R.Bilger, A.Kupsc, P.Marciniewski, A.Nawrot, J.Stepaniak, J.Zabierowskiet al., PANIC96, XIV International Conference on Particles and Nuclei, 22-28 May 1996,12-9, 692

[8] A.Bondar, A.Kupsc, J.Stepaniak, J.Zabierowski et al., PANIC96, XIV International Conference on Particles and Nuclei, 22-28 May 1996, 12-125, 268

[9] W.Brodowski, A.Kupsc, P.Marciniewski, J.Stepaniak, J.Zabierowski, et al.,PANIC96, XIV International Conference on Particles and Nuclei, 22-28 May 1996, 12-15, 158

[10] R.Bilger, A.Kupsc, P.Marciniewski, J.Stepaniak, J.Zabierowski, et al., MESON 96 - Workshop on Production, Properties and Interaction of Mesons, Cracow, Poland 10-14 May 1996. Proceedings will be published in Acta Physica Polonica.

PL9800690

7.7 Origin of the highest energy CR

by J.Wdowczyk

The problem of origin of the highest energy CR (above 2×10^{19} eV) has been studied. Analysis of correlations between arrival directions of highest energy EAS with distributions of different extragalactic objects was performed. The possibility that highest energy particles originate in collisions of galaxies was suggested. Results of these studies have been published [1],[2],[3].

[1] S.S.Al-Dargazelli, A.W.Wolfendale, A.Śmiałkowski, J.Wdowczyk⁺, J.Phys. G: Nucl. Part. Phys. 22 (1996) 1825-1838.

[2] J.Wdowczyk⁺, A.W.Wolfendale, Nuovo Cimento Suplemento in press

[3] J.Wdowczyk⁺, A.W.Wolfendale, Nuovo Cimento Suplemento in press

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THE PP->PPη REACTION NEAR THE KINEMATICAL THRESHOLD.
H.Calen, S.Carius, K.Fransson, **J.Zabierowski**,.. et al.
Phys.Lett.B366 (1996) 39-43 , (listed also in Department P-VI)

DETECTOR SETUP FOR A COOLER STORAGE RING WITH AN INTERNAL TARGET.
H.Calen, S.Carius, K.Fransson, **J.Zabierowski**,.. et al.
Nuclear Instr.and Methods A349 (1996) 57-75, (listed also in Department P-VI)

A SIGNAL OF A NARROW π-NN RESONANCE IN $pp \rightarrow pp\pi^-\pi^+$.
W.Brodowski, R.Bilger, H.Calen ,**J.Zabierowski**,.. et al.
Z.Phys.A, A355, 5-8, 1996, (listed also in Department P-VI)

SEARCH FOR A NARROW π-NN RESONANCE IN $pp \rightarrow pp\pi^-\pi^+$.
R.Bilger, W.Brodowski, H.Calen ,**J.Zabierowski**,.. et al.
Prog.Part.Nucl.Phys., Vol.36, pp.379-381, 1996, (listed also in Department P-VI)

THE ORIGIN OF COSMIC RAYS OF THE HIGHEST ENERGIES.
S.S.Al-Dargazelli, A.W.Wolfendale, A.Śmiałkowski, **J.Wdowczyk**
J. Phys. G: Nucl. Part. Phys. 22 (1996) 1825-1838.

A MONTE CARLO GENERATOR FOR COSMIC RAY NUCLEI INTERACTIONS.
R.Attallah, J.N.Capdevielle, C.Meynadier, **B.Szabelska**, **J.Szabelski**
J. Phys. G: Nucl. Part. Phys. 22 (1996) 1497-1506.

RECENT MEASUREMENTS OF THE η PRODUCTION IN pd COLLISIONS AT CELSIUS.
R.Bilger, W.Brodowski, H.Calen, **J.Zabierowski**,..et al.
MESON 96 - Workshop on Production, Properties and Interaction of Mesons, Cracow, Poland 10-14 May 1996.
Acta Physica Polonica, B27 (1996)

PARTICIPATION IN CONFERENCES AND WORKSHOPS

HIGH ENERGY COSMIC RAYS
J.Wdowczyk i A.W.Wolfendale
Vulcano Conf. (27.V - 1.VI.96), to be published in Nuovo Cimento Supplemento

COSMIC RAYS OF THE HIGHEST ENERGIES.
J.Wdowczyk i A.W.Wolfendale
Vulcano Conf. (27.V - 1.VI.96), to be published in Nuovo Cimento Supplemento

COSMIC RAYS MASS COMPOSITION FROM FRACTAL ANALYSIS.
J.Wdowczyk and J.Kempa
Vulcano Conf. (27.V - 1.VI.96), to be published in Nuovo Cimento Supplemento

THE KASCADE EXPERIMENT
G.Schatz, W.D.Apel, K.Bekk, **J.Wdowczyk**, **J.Zabierowski**,..et al.
XVth Cracow Summer School of Cosmology, 15-19 lipca 1996, Łódź.

EAS-1000: STATUS 1996.
S.S.Ameev, **J.Wdowczyk** et al.
XV-ECRS, Perpignan, France, 26-30 August 1996.

MEASURABLE DIFFERENCE IN CHERENKOV LIGHT BETWEEN GAMMA AND HADRON INDUCED EAS.
G.Debiais, C.Meynadier, D.Sobczyńska, **B.Szabelska**, **J.Szabelski**, T.Wibig
XV-ECRS, Perpignan, France, 26-30 August, 1996.

CELSIUS AS AN η FACTORY.
R.Bilger, M.Blom, D.Bogoslavsky, **J.Zabierowski**,.. et al.
PANIC96, XIV International Conference on Particles and Nuclei, Williamsburg, VA, 22-28 May 1996, 12-9, 692

THRESHOLD PRODUCTION OF π^0 AND η MEZONS IN P+P COLLISIONS.
A.Bondar, H.Calen, S.Carius, **J.Zabierowski**,..et al.
PANIC96, XIV International Conference on Particles and Nuclei, Williamsburg, VA, 22-28 May 1996, 12-125, 268

A SIGNAL OF A NARROW πNN RESONANCE IN $pp \rightarrow pp\pi^-\pi^+$.
W.Brodowski, R.Bilger, H.Calen, **J.Zabierowski**,.. et al.
PANIC96, XIV International Conference on Particles and Nuclei, Williamsburg, VA, 22-28 May 1996, 12-15, 1583.

THE KASCADE EXPERIMENT
G.Schatz, W.D.Apel, K.Bekk, **J.Wdowczyk**, **J.Zabierowski**,..et al.
IXth International Symposium on Very High Energy Cosmic Ray Interactions, 18 Aug. 1996, Karlsruhe, Germany. Proceedings will be published in Nuclear Physics B (Proc.Suppl.).

THE KASCADE EXPERIMENT
G.Schatz, W.D.Apel, K.Bekk, **J.Wdowczyk**, **J.Zabierowski**,..et al.
XVth European Cosmic Ray Symp. , Perpignan, France, 26-30 Aug. 1996.

LECTURES, COURSES AND EXTERNAL SEMINARS

Multiple Scattering in CORSIKA[a)]
D.Sobczyńska, Dept. of Experimental Physics, University of Łódź, March 28, 1996

Light Pulser Monitoring System for 4π WASA Apparatus[b)]
J.Zabierowski, June, WASA Main Meeting Uppsala

INTERNAL SEMINARS

ZEBRA, PAW, HIGZ[a)]
J.Szabelski, March 14, IPJ Łódź

Studies of Cosmic Ray Mass Composition[a)]
J.Gawin, April 11, IPJ Łódź

Rearangement of the Łódź EAS Array[a)]
J.Szabelski, May 9, IPJ Łódź

Report from the 15th ECRS in Perpignan[a)]
B.Szabelska, Oct. 17, IPJ Łódź

Comparison of the Results from CORSIKA with Experimental Data[a)]
J.Gawin, Oct. 31, IPJ Łódź

[a)] in Polish
[b)] in English

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8. DEPARTMENT OF ATOMIC NUCLEUS THEORY

PL9800691

Head of Department: Prof. Sławomir Wycech
phone: 6216085
e-mail: wycech@fuw.edu.pl

Overview

This department consists of 16 scientists working on aspects of low energy, high energy and plasma physics. Most of the effort is phenomenologically oriented. Specific topics are:

- Studies of strangeness in nuclei that stem from a long Warsaw tradition of hypernuclear physics. These include attempts to understand the elusive Σ-hypernuclei, studies of nuclear bound states of η-mesons that introduce hidden strangeness into nuclei, and work on interactions of strangelets - the hypothethical large quasi-nuclear objects.
- Systematic studies have been devoted to understanding the structure of heavy deformed - nuclei. These were successful in predicting properties of superheavy elements. Now we continue calculations of collective motion, neutron haloes and energy dissipation in heavy ion collisions. An increasing effort is devoted to the research of nuclear collisions at high energies.
- Studies in high energy physics are devoted to - investigating and modelling multiparticle production processes especialy correlations, productions of strange matter, and their universality properties, understanding of deep inelastic lepton scattering, and also of formal properties of contour gauge theories.
- Theoretical studies of soliton solutions in several branches of physics are performed. Methods testing instabilities of the soliton solutions have been developed. Soliton metamorphosis from 2D to 3D has been followed. Work on protein dynamics is in process.

Collaboration with several universities has been maintained. Joint publications involve the Universities of: Warsaw, Bucarest, Kielce, T.U. Münich, Oxford, Siegen, Helsinki, São Paulo, Matsumoto, Lipsk, Berkeley, Brussels, St.Petersburg, I.C.London, Warwick, U.C.London.

REPORTS ON RESEARCH

PL9800692

8.1 Theory of the inclusive strangeness exchange reaction

by J.Dąbrowski and J.Rożynek

The theory of the inclusive (K^-, π^+) reaction, in which only the pion spectrum is measured, is presented. The hyperon in the final state - either Σ^- or Λ (produced via Σ conversion) - is described in the effective two-channel approach, and the cross section is calculated in the coupled-channels impulse approximation. The theory is applied to the (K^-, π^+) reaction on the ^{16}O target and compared with existing data [1], [2].

[1] J.Dąbrowski, J.Rożynek, Few Body Systems, Supplementum 9 (1996)141-144
[2] J.Dąbrowski, J.Rożynek, Acta Physica Polonica B27 (1996) 985

PL9800693

8.2 Poles of the S-Matrix for a complex potential

by J.Dąbrowski

Previous work [1] on the trajectories of S-matrix poles in the complex k plane resulted in a simple rule for predicting the effect of adding a small absorption to a real potential. Presently the work is extended to include the case of very strong absorption.

[1] J.Dąbrowski, Phys. Rev. C 53 (1996)2004

PL9800694

8.3 Properties of radioactive nuclei

by R.A.Gherghescu[1)], Z.Patyk, J.Skalski, R.Smolańczuk and A.Sobiczewski

The stability of spherical superheavy nuclei, situated around the doubly magic nucleus 298-114 (i.e. the nucleus with proton number Z=114 and the neutron number N=184), has been studied [1-3]. Alpha-decay and spontaneous-fission half-lives have been analyzed in a multidimensional deformation space.

The results indicate that alpha decay is expected to be the main decay mode of these nuclei. Thus, the picture is similar to that obtained for deformed superheavy nuclei, situated around the doubly magic deformed nucleus 270-108 (270-Hs).

[1] R.A.Gherghescu, Z.Patyk, A.Sobiczewski, Acta Phys. Pol. B28(1997), in press
[2] R.A.Gherghescu, Z.Patyk, J.Skalski, A.Sobiczewski, Proc. Int. Workshop: "Research with Fission Fragments", Benediktbeuern (Germany) 1996 (World Scientific, Singapore 1997), in press
[3] Z.Patyk, R.Smolańczuk, A.Sobiczewski, Nucl.Phys. A (1997), in press

[1)] Institute for Atomic Physics, Bukarest, Romania

PL9800695

8.4 Non-abelian flux algebras in Yang-Mills theories

by L.Łukaszuk

Contour gauges are discussed in the framework of the canonical formalism. We find flux operator algebras with structure constants of the underlying Yang-Mills theory [1].

[1] L.Łukaszuk, Proceedings of XXVIII ICHEP'96, in press.

8.5 Coupling of the giant dipole resonance to low lying octupole modes - generator coordinate method study

by P.-H.Heenen[1)] and J.Skalski

The effect on the properties of low lying octupole modes of coupling with the giant dipole resonance is studied within the Generator Coordinate Method. Results are presented for ^{152}Sm which is deformed in its ground state and for the superdeformed state of ^{190}Hg. A basis is first generated by Hartree-Fock+BCS calculations with constraints on the octupole and dipole moments. The same Skyrme SkM* effective interaction used in the mean field is then diagonalised by GCM. For the octupole K=0 mode, the effect of the coupling is marginal and the dipole properties of low lying states are satisfactorily described by pure octupole calculations. For the K=1 mode, the dipole-octupole coupling slightly reduces the E1 transition strength.

[1)] Service de Physique Nucléaire Théorique, U.L.B. CP229, 1050 Brussels, Belgium

PL9800697

8.6 The excitation of a quantum gas of independent fermions in a deforming cavity - periodicity of driving vs. Landau-Zener transitions

by J.Skalski

The numerically calculated excitation of a quantum gas of 112 non-interacting fermions in a hard-walled cavity changing its shape is analysed for one and half of the oscillation cycle. Spheroidal and Legendre polynomial distortions, P_2,P_3,P_4,P_5 and P_6, around the sphere and the octupole deformed shape are considered. Oscillations of the excitation energy as a function of the driving frequency, especially pronounced for low frequencies, are related to quantum interference between Landau-Zener transitions at successively traversed, avoided crossings. This irregular component of excitation may be linked to the periodicity of the driving motion since it is strongly suppressed for one-half of the oscillation period. It is argued that the wall formula has a better chance to describe properly the one-body dissipation in aperiodic processes in which at most half of the full cycle is performed.

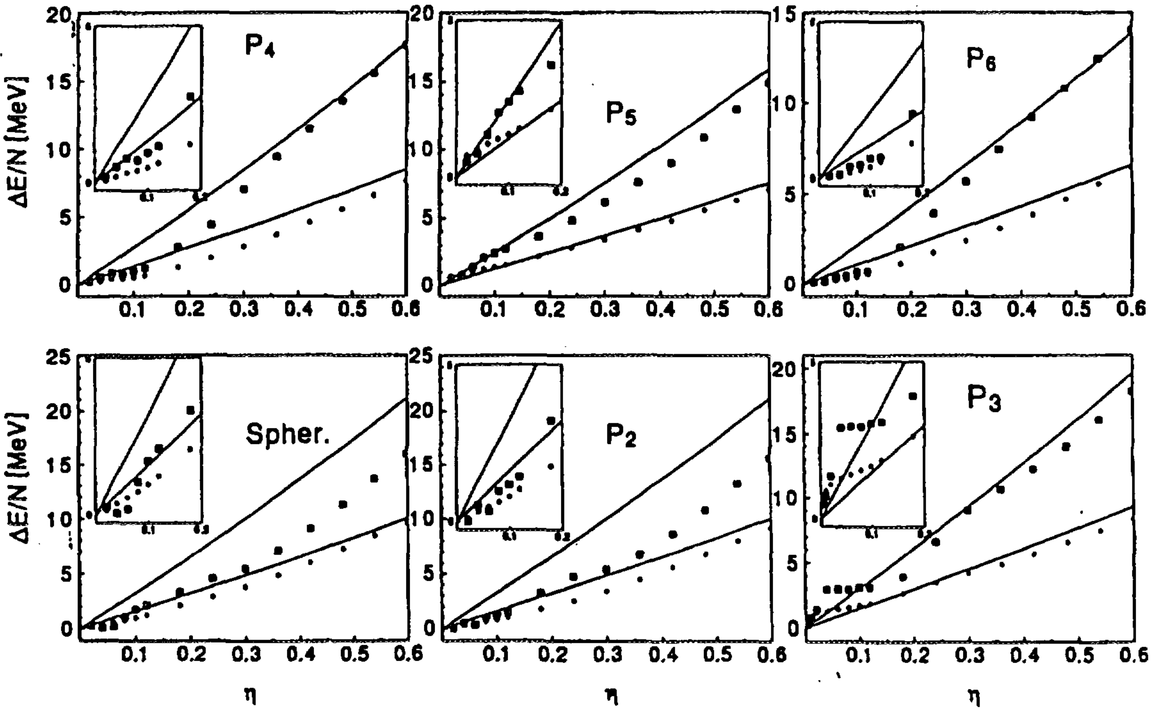

Fig.1 The excitation energy per particle, ΔE/N, after half-period T/2 (dots) and full period T (open squares) of shape oscillations around the sphere are shown as functions of the adiabacity parameter η (or the oscillation frequency $\hbar\omega$). Thin solid lines are the result of the wall formula with corrections. Six panels correspond to six types of shape oscillations (notice different scales on the ordinate). The detailed low-frequency part of each plot is shown in the inset.

8.7 The excitation of a quantum gas of independent particles under periodic perturbation in integrable or ion-integrable potentials

by P.Magierski[1,2], J.Skalski, J.Błocki

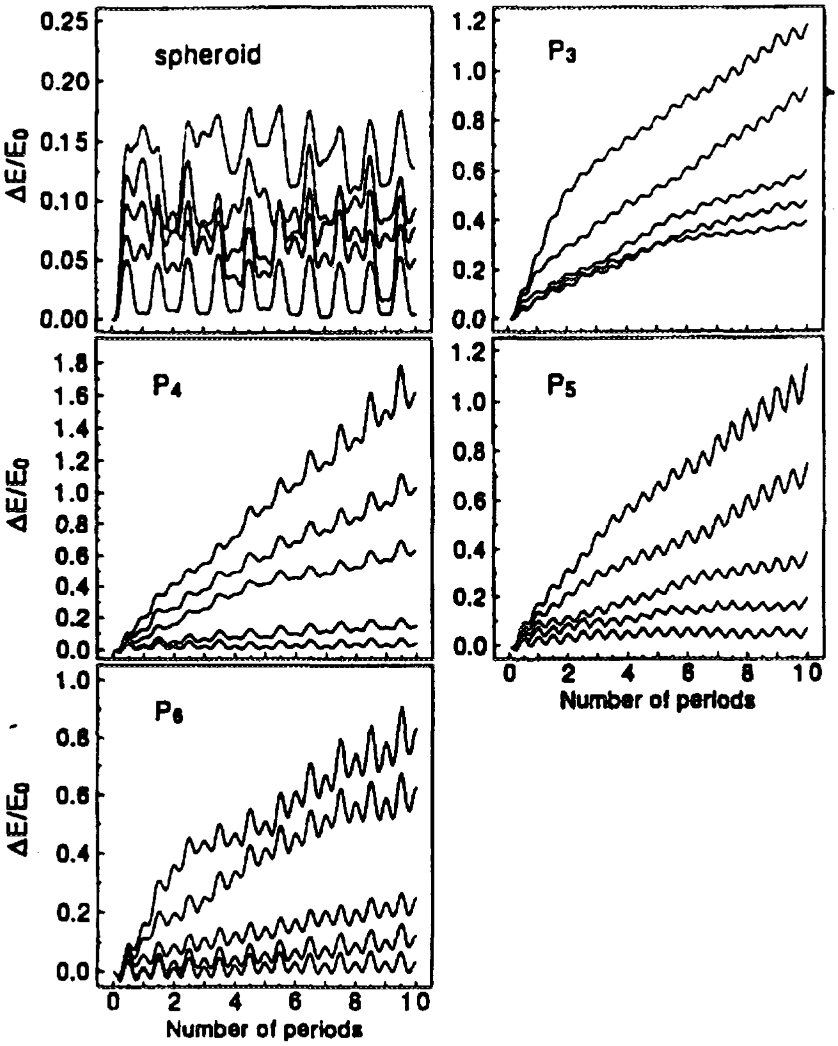

Fig.1 The relative excitation energy $\Delta E/E_0$ of 112 fermions in five types of cavities plotted as a function of oscillation cycles around the spherical shape. Different curves in each subfigure refer to different values of the adiabaticity parameter η = 0.06, 0.12, 0.18, 0.24, 0.30. The excitation energy increases with η.

The excitation of a quantum gas of 112 independent fermions in the time-dependent potential well, periodically oscillating around the spherical shape, was followed over 10 oscillation periods. Five different oscillation frequencies are considered for each of the five types of deformations: spheroidal and Legendre polynomial ripples: P_3,P_4,P_5 and P_6. For two types of potentials studied, the hard-walled cavity and the diffused Woods-Saxon well, the excitation energy is found to be at least two times smaller than the wall formula predictions. The details and possible origins of this deviation are discussed as well as the consequences for the one body dissipation model of nuclear dynamics.

1) The Royal Institute of Technology, Physics Department Frescati, Frescativägen 24, S-10405 Stockholm, Sweden
2) Institute of Physics, Warsaw University of Technology, ul. Koszykowa 75, PL-00662 Warsaw, Poland

8.8 Quark single particle degrees of freedom in the nuclei

by J.Rożynek

Departures from the Momentum Sum Rule in deep inelastic scattering in a medium was discussed and explained in the Relativistic Mean Field Approach [1]. The main advantage is the inclusion of the nuclear vector mean field by taking into account the interference term in the electron-nucleus scattering amplitude [2]. Finally it was concluded that a good fit to the data can by obtained only by strong Pauli correlations between quarks in the nucleus.

[1] J.Rożynek, Proc. of the Conf. Baryons 95, Santa Fe 1995, World Scientific, p.523
[2] J.Rożynek, sent to Nucl. Phys., preprint IFNS/Th/2

8.9 Kadomtsev-Petviashvili soliton dynamics in 3D

by E.Infeld and A.Senatorski

PL9800700

We performed 3D simulations that follow exact, z symmetric soliton solutions to an important equation of plasma physics and fluid dynamics. The solitons break up when perturbed along z. Some fairly robust, 3D entities are subsequently produced [1]. We now believe that they are the 3D solitons of Jones and Roberts [2]. This work may have implications for reconnection in superfluid helium (4HeII).

[1] E.Infeld and A.Senatorski Phys. Rev.Lett. 77 (1996)2855-2858

[2] C.A.Jones and P.H.Roberts, J.Phys. A15 (1982) 2599-2619

8.10 Stability of light beams in nonlinear photorefractive media

by E.Infeld, T.Lenkowska-Czerwińska

PL9800701

We investigate the stablity of both bright and dark beams propagating in bulk media with a photorefractive nonlinear response, such as crystals. The beams are seen to be unstable with respect to perturbations along the initially homogeneous coordinate. Our analysis is based on a k expansion for the perturbation. Agreement with recent numerical calculations is obtained. Growth rates obtained extend previous results into the small k region. In the case of bright beams the extension is straightforward, whereas for dark beams an interpretation is needed. We suggest an improvement of dark beam laser-crystal devices, resulting in better stability of the beam. We comment on some recent experiments [1].

[1] T.Lenkowska-Czerwińska and E.Infeld, accepted by Phys. Rev. E m 1997

8.11 Strange results from cosmic ray data

by G.Wilk and Z.Włodarczyk[1)]

PL9800702

Continuation of research on *strange results* from cosmic ray data. We have obtained two new results in this field:

We have proposed a new mechanism of the propagation of so called *strangelets* (i.e., hypothetical particles composed in roughly equal proportion with u, d and s quarks and being therefore realization of strange quark matter) through the Earth's atmosphere. It allows for the propagation of those objects through thick layers of the atmosphere and for the first time allows for a consistent description of all available data and also provides new predictions which can be tested in future experiments with cosmic rays [1,2,3,4].

We have shown that the production of the so called *Centauros* (i.e., events with extreme imbalance between charged and neutral components) will not - contrary to the prevailing opinion - lead to a discovery of regions of physical vacuum with different than normal orientation of the isospin (the so called disoriented chiral condensates or DCC's). On the other hand, it was shown that this can be used to investigate the, so called, penetrating component of the cosmic rays [5].

[1] G.Wilk, Z.Włodarczyk, J.Phys. G22 (10) (1996) L105-L111

[2] G.Wilk, Z.Włodarczyk, Heavy Ion Physics 4 (1996) 395-402

[3] G.Wilk, Z.Włodarczyk, to be published in the proceedings of the 28th Int. Conf. on High Energy Physics, 25-31 July, 1996, Warsaw, Poland

[4] G.Wilk, Z.Włodarczyk, to be published in the proceedings of XV Cracow Summer School of Cosmology, Łódź, Poland, July 15-19, 1996

[5] G.Wilk, Z.Włodarczyk, to be published in the proceedings of the IX Int. Symp. on Very High Energy Cosmis Ray Int., Karlsruhe, Germany, August 19-23, 1996: Nucl. Phys. B Proc. Suppl.(1997) in press

[1)] Institute of Physics, Pedagogical University, Kielce, Poland

PL9800703

8.12 Bose-Einstein correlations

by M.Biyajima[1)], N.Suzuki[2)], G.Wilk, Z.Włodarczyk[3)]

We have provided a new possible physical interpretation of the so called *chaoticity parameter* λ arguing that it is not so much connected with the actual coherent or chaotic character of reaction under consideration, but rather it provides an estimate of the number of independently emitting hadronic sources [1].

[1] M.Biyajima, N.Suzuki, G.Wilk, Z.Włodarczyk, Phys. Lett. B386 (1996) 297-303

[1)] Department of Physics, Shinshu University, Matsumoto, Japan
[2)] Matsumoto Gauken Junior College, Matsumoto, Japan
[3)] Institute of Physics, Pedagogical University, Kielce, Poland

PL9800704

8.13 Final state Coulomb interactions

by M.Biyajima[1)], T.Mizoguchi[2)], T.Osada[1)], S.Sanol), G.Wilk

We have continued work on the final state Coulomb interactions between pairs of produced secondaries (mostly $\pi^{\pm}$ providing a new method of their calculation [1,2,3]. It was then applied to the recent data for the π^+/π^- yield ratios measured in heavy ion collisions for very small momenta of produced π's. In particular we have investigated the Coulomb interaction between the produced secondaries and the charge of nearly stopped protons in the central part of the phase space. Here we have obtained an interesting and novel result indicating the existence of a kind of quasi-scaling between the charge of the nucleonic cluster Z_{eff} and the parameter describing the size of the source emitting finally observed secondaries β [4].

[1] M.Biyajima, T.Mizoguchi, T.Osada, G.Wilk, Phys. Lett. B366 (1996) 394-400

[2] M.Osada, S.Sano, M.Biyajima, G.Wilk, Final State Interactions for Bose-Einstein Correlations in S+Pb $\rightarrow \pi^+\pi^-$ + X Reaction at Energy 200 GeV/nucleon; Proc. of the ICRR Workshop on Hadron Interactions in 10^{15} - 10^{17} eV Region, Univ. of Tokyo, 4-5 Jan. 1996.

[3] M.Biyajima, T.Mizoguchi, T.Osada, G.Wilk, Final State Interactions in Bose-Einstein Correlations, presented at the 7[th] International Workshop on Fluctuation and Correlations, June 30- July 6, 1996, Nijmegen, The Netherlands; to be published in the proceedings (World Scientific)

[4] T.Osada, S.Sano, M.Biyajima, G.Wilk, Phys. Rev.C54 (1996) 2167R

[1)] Department of Physics, Shinshu University, Matsumoto, Japan
[2)] Toba National College of Maritime Technology, Toba, Japan

PL9800705

8.14 Universality of multiparticle processes

by M.Szczekowski and G.Wilk

We have demonstrated that the universality in the distributions of masses of produced secondaries observed recently in the e^+e^- annihilation processes and in the hadronic collisions also extend to heavy ion collisions. This finding is important for the searches of the new state of the hadronic matter (the so called Quark-Gluon Plasma) which is currently going on in all heavy ion collisions [1].

[1] M.Szczekowski, G.Wilk, Phys.Lett. B374 (1996) 225-230

PL9800706

8.15 Further development in the applications of the interacting gluon model

by F.O.Durães[1)], F.S.Navarra[1)], C.A.A.Nunes[1)], G.Wilk

We have continued work on applications of the Interacting Gluon Model (IGM) developed by us some time ago to new physical processes of particle production. This time we have applied it successfully to the production of the so called *charm* and *bottom* containing hadrons [1]. Our approach is the first which describes this process both in the central and fragmentation regions of reaction and does not violate the energy-momentum constraints. This comes from the two component feature of the IGM and from the fact that conservation law constraints are built in, prior to any other dynamical mechanisms.

[1] F.O.Durães, F.S.Navarra, C.A.A.Nunes, G.Wilk, Phys. Rev. D53 (1996) 6136-6143

[1] Institute of Physics, University of São Paulo, São Paulo, Brazil

PL9800707

8.16 Nuclear states of η mesons

by S.Wycech

Threshold production of η-mesons with light systems (η, d) (η He) (η p,p) performed by SATURNE and CELSIUS indicate possibilities of quasibound states. Such states were studied [1,2] and related to as yet uncertain properties of η nucleon interactions. In order to develop a quasibound or virtual state in the η deuteron system one needs the η-nucleon scattering length to be as large as .7-.8 fm. Our recent analysis of (η, N) (π, N) (γ, N) systems performed via a $\hat{K}$ matrix analysis shows that this indeed happens.

[1] A.M.Green, J.Niskanen, S.Wycech, Phys.Rev.C54(1996)1770
[2] S.Wycech, Acta Physica Polonica 27(1996)2981

PL9800708

8.17 Antiprotonic atoms

by J.Kulpa, R.Smolańczuk, J.Skalski, S.Wycech

The PS-209 experiment at the Low Energy Antiproton Ring at CERN was completed with measurements of X-ray transitions in some antiprotonic atoms. For the first time the absolute intensities of the atomic cascade were measured. These confirm a correlation of the X-ray intensities with the atomic radius.

The main motivation was to determine atomic orbitals of the most likely nuclear capture. First analyses show the capture probability to be strongly localised on two angular momentum states, with a large dispersion over the main quantum number. These confirm theoretical calculations [1,2] done previously to discuss the "neutron haloes" found in some heavy atomic nuclei.

[1] S.Wycech, J.Skalski, R.Smolańczuk, J.Dobaczewski and J.Rook, Phys. Rev. C54(1996)1832-1842
[2] J.Jastrzębski et al., Nucl. Phys. A - in press

PL9800709

8.18 Small x behaviour of the chirally odd parton distribution h_1(x, Q ,

by R.Kirschner, L.Mankiewicz, A.Schaefer, L.Szymanowski

The small x behaviour of the structure function $h_1(x, Q^2)$ is studied within the leading logarithm approximation of perturbative QCD. There are two contributions relevant at small x. The leading one behaves like $(1/x)^0$ i.e. it is just a constant in this limit. The second contribution, suppressed by one power of x, includes the terms summed by the GLAP equation. Thus for $h_1(x, Q^2)$ the GLAP asymptotics and Regge asymptotics are completely different, making $h_1(x, Q^2)$ an interesting quantity for the study of small x physics.

PL9800710

8.19 Coupling gravity and the standard model: a conformal approach

by M.Pawłowski

We have studied a mechanism which extends the symmetry group of the Standard Model. Adding a new local conformal symmetry we obtained a model which unifies gravity with other fundamental interactions. The physical interpretation of the scalar sector is reexamined [1].

[1] M.Pawłowski, to appear in proceedings of International Conf. "Gravitational Energy and Gravitational Waves", Dubna 1996.

8.20 Consistency test of the standard model

by M.Pawłowski and R.Rączka

If the "Higgs mass" is not the physical mass of a real particle but rather an effective ultraviolet cutoff then an energy dependence of this cutoff must be admitted. Precision data from at least two energy scale experimental points are necessary to test this hypothesis. The first set of precision data is provided by the Z-boson peak experiments. We argue that the second set can be given by 10-20 GeV e^+e^- colliders. We pay attention to the special role of tau polarization experiments that can be sensitive to the "Higgs mass" for a sample of 10^8 produced tau pairs. We argue that such a study may be regarded as a negative self-consistency test of the Standard Model and of most of its extensions [1].

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G.Wilk, Z.Włodarczyk
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Proceedings of the II-German-Polish Symposium, Acta Physica Polonica, B27 vol. 10 (1996)

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LECTURES, COURSES AND EXTERNAL SEMINARS

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W.Piechocki, XVth Workshop on Geometric Methods in Physics, Białowieża, July 1996

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"Totally chaotic poissonian-like sources in multiparticle production processes"
G.Wilk, Physics Dept. of Tohoku University, Sendai, (Prof. F.Takagi), September 17, 1996

"HBT effect in multiparticle production physics"
G.Wilk, Physics Dept., Faculty of Education, Yamagata University, (Prof. N.Masuda), September 18, 1996

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G.Wilk, Yukawa Inst. for Theoretical Physics, Kyoto University, Kyoto, (Prof. T.Matsui), September 25, 1996

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Miscellanous

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A.Sobiczewski
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NONLINEAR DYNAMICS CHAOTIC AND COMPLEX SYSTEMS
Editors: **E.Infeld**, R.Żelazny, A.Gałkowski
Cambridge University Press, (in press)

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9. DEPARTMENT OF RADIATION DETECTORS

PL9800712

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Overiew

Work carried out in 1996 in the Department of Radiation Detectors concentrated on three subjects: (i) Semiconductor Detectors (ii) X-ray Tube Generators (iii) Material Modification Using Ion and Plasma Beams.

SEMICONDUCTOR DETECTORS

Semiconductor detectors of ionizing radiation are among the basic tools utilized in such fields of *research and industry as nuclear physics, high energy physics, medical radiotherapy (oncology), radiological* protection, environmental monitoring, energy dispersive X-ray fluorescence non-destructive analysis of chemical composition, the nuclear power industry.

The Departamental objectives are:

- a search for new types of detectors
- adapting modern technologies (especially of industrial microelectronics) to detector manufacturing
- producing unique detectors tailored for physics experiments
- manufacturing standard detectors for radiation measuring instruments.

These objectives were accomplished in 1996 by:

- research on unique detectors for nuclear physics (e.g. a spherical set of particle detectors "silicon ball", detectors for particle identification)
- development of technology of high-resistivity silicon detectors HRSi (grant proposal)
- development of thermoelectric cooling systems (grant proposal)
- research on p-i-n photodiode-based personal dosimeters
- study of applicability of industrial planar technology in producing detectors
- manufacturing detectors developed in previous years
- re-generating and servicing customer detectors of various origin.

In accomplishing the above, the Department cooperated with groups of physicists from SINS P-I and P-II Departments, Warsaw University, Warsaw Heavy Ion Laboratory and with some technology Institutes based in Warsaw (ITME, ITE). Some detectors and services have been delivered to customers on a commercial basis.

X-RAY TUBE GENERATORS

The Department conducts research on the design and technology involved in producing X-ray generators based on X-ray tubes of special construction. Various tube models and their power supplies were developed. Some work has also been devoted to the detection and dosimetry of X-rays.

X-ray tube generators are applied to non-destructive testing and are components of analytical systems such as:

- X-ray fluorescence chemical composition analysis
- gauges of layer thickness and composition
- stress measurements
- on-line control of processes
- others where an X-ray tube may replace a radio-isotope source.

In 1996, the Department:

- reviewed the domestic demand for X-ray generators
- developed an X-ray generator for diagnosis of ostheroporosis of human limbs
- prepared a grant proposal for the development of a new instrument for radiotherapy, the so-called needle-like X-ray tube.

In accomplishing the above, the Department cooperated with the Institute of Physics of the Jagiellonian University in Cracow and with Polon IZOT and Dora Power Systems companies.

MATERIAL MODIFICATION USING ION AND PLASMA BEAMS

See Chapter PLASMA AND ION TECHNOLOGY IN SURFACE ENGINEERING of this Review.

REPORTS ON RESEARCH

9.1 Spherical set of DE silicon detectors silicon ball - part II

by E.Belcarz, W.Czarnacki, B.Sawicka, T.Sworobowicz, K.Kostrzewa

The manufacture and testing of silicon detectors for a "silicon ball" set have been completed. The set is to be used in experiments planned on the U-200 Warsaw cyclotron in the frame of the Warsaw University Heavy Ion Laboratory subject "Gamma spectroscopy on heavy ion beams with determination of reaction channels by help of a set of semiconductor detectors".

To complete the final part of the task:
- 48 silicon wafers with parallel faces and thickness around 240 μm have been prepared;
- 15 detectors have been manufactured;
- the detector assembly mechanical construction has been modified;
- the vacuum chamber for testing has been elaborated.

The parameters of all produced detectors fall within the following ranges:
- thickness 127-162 um;
- active area 130-140 mm^2;
- bias voltage 20-50 V;
- energy resolution 24-50 keV FWHM for alpha particles (from Pu-239, Am-241, Cm-244 sources).

The parameters obtained conform with the projected values. Within 2 years of accomplishing the task, 35 detectors have been manufactured and tested. According to the requirements of the first phase of in-beam testing, 16 of the total number of detectors have been assembled within the silicon ball supporting construction. The set is ready for physical experiments.

9.2 Research on detection structures made of the n-type high purity germanium (HPGe)

by W.Czarnacki, B.Sawicka, T.Sworobowicz, K.Kotlarski

Development of technology of producing highly pure Ge monocrystals resulted in the availability of n-type monocrystals. This made it possible to produce detectors with a thinner entrance window as well as more radiation damage resistant as compared to the formerly manufactured p-type detectors. The task objective was to test our Department capabilities to produce n-type HPGe detectors. Tests were performed on a monocrystal with the following parameters:

- impurity concentration N_D-N_A <= 2.2 x 10^{10} cm^{-3}
- dislocation density (EPD) <= 5000 cm^{-2}
- mobility μ_n >= 17 000 cm^2/Vs
- point defects density (as measured by the DLTS technique) < 5 x 10^8 cm^{-3}.

10 circular samples of diameter 12 mm and thickness 5 mm have been cut out of the monocrystal. The n^+ contact of 6 mm diameter has been produced by diffusing lithium at a temperature 350 °C to a depth 400-600 μm. The rectifying junction has been produced by some chemical surface treatment and evaporation of a gold contact. Six working detecting structures have been obtained.

The obtained detecting structures were placed within a LN_2 cryostat (T = 80 K), where their I-V characteristic and energy resolution were tested. The structure leakage currents were below 10^{-12} A at 300 V reverse bias. The obtained energy resolution ranged from 197 to 230 eV FWHM for 5.9 keV photons.

PL9800715

9.3 Research on the applicability of three-component commercially available semiconductors to X and gamma radiation detection

by M.Słapa, M.Traczyk

Electrical, spectral and noise characteristics of several types of GaAsP photodiodes manufactured commercially by Hamamatsu have been measured. The charge carrier transport parameters, e-h pair production energy and low energy X- and gamma-ray detection efficiency have been evaluated.

9.4 Development of an X-ray generator for the diagnosis of human limb ostheroporosis (U_a = 50 kV, I_a = 500 μA)

by M.Słapa, M.Traczyk

PL9800716

The X-ray generator satisfying the requirements of applicability in medicine (compact and easily portable X-ray tube, high level of protection against an electrical shock or radiation hazard) has been designed and produced. The tube is equipped with a temperature sensor and overheat protection circuits. The source is computer-controlled. The generator operates in cycles: power on - measurement - power off - data computation - next patient. The generator stability in such a mode is no worse than ±0.3%.

PLASMA AND ION TECHNOLOGY IN SURFACE ENGINEERING
(Departments P-V and P-IX)

9.5 Metallization of ceramics with intense pulsed plasma beams

by J.Piekoszewski, J.Langner, J.Stanisławski, J.Białoskórski and K.Czaus

PL9800717

1. Introduction

Ceramic materials, in view of their resistance to high temperatures, corrosion and large hardness draw ever growing attention of engineers from various fields as engineering materials of the XXI century. They are capable of replacing traditionally used materials based on iron and alloys of other metals. At least two directions of research on ceramic materials may be distinguished. One is a search for methods of improving their mechanical properties. It is well known that the energy necessary to initiate microcracking is larger than the energy necessary to propagate defects originating usually on the surface of a material. Therefore many papers have been devoted to modifying surfaces of ceramic materials with the help of ion implantation (and related methods, as ion mixing IBAD) as well as with irradiation by laser beams. In both cases (although differently approached) the objective is to introduce to the surface layer some impurities which might improve the material. Another direction is to search for methods of improving the quality of ceramic-metal joints, in particular their resistance to shear stress.

The results of research done so far on interactions of intense plasma beams with condensed matter (metals, semiconductors) indicate that it might be fruitful to extend the research on ceramic materials in both abovementioned aspects. The reserach on ceramic-metal joints has been undertaken by the Institute of Nuclear Chemistry and Technology (INCT) and is now conducted in close collaboration with SINS and Warsaw University of Technology.

2. Titanium on Al_2O_3 using Ti-N plasma pulses

The choice of Al_2O_3 as the substrate material was dictated by two factors. First, Al_2O_3 may be a liquid at normal pressure (at approximately 2000°C). Second, from previous experiments it was known that plasma pulses generated in the IBIS accelerator working in the PID mode (plasma rich in working gas ions) definitely melt the surface layer of this material at a typical energy density from the range 6-7 J/cm^2. Selection of titanium as the plasma constituent was also directed by two factors. It is known that this metal easily diffuses into Al_2O_3 even in the condensed phase. On the other hand, both attempts to mix the Ti-Al_2O_3 set - by ion bombardment (the ion mixing technique), as well as by laser beam melting of a thin Ti layer deposited previously on the substrate, have failed, according to the literature.

The following facts have been discovered during the first phase of the experiments (the unexpected findings concern both the research described in points 2 and 3 of this contribution as well as that accomplished in the INCT i.e. on the ceramic-metal joints):

i) All samples irradiated by plasma pulses show a mass deficit which is not related to conditions of generation of pulses (in the entire range of ignition time delay, from the PID mode to the DPE mode).

ii) All the samples contain a significant amount of metal impurities which were not expected in the plasma.

It was also learned from the literature that mixing of substrate material with a previously deposited metal layer may take place by pulsed melting (with proton beams) only if the surface tension of both the constituents is similar. Otherwise the metallic layer forms microdrops falling apart from the irradiated surface. To explain the range of unknowns related to the above facts a series of additional experiments had to be done. The results formed two separate papers (accepted for publication) and allowed us to avoid some mistakes made in the first series of experiments.

The subsequent irradiation has been performed at the following settings: main battery voltage 35 kV; valve voltage 10 kV; energy density 6-7 J/cm^2; number of pulses n=10; delay time τ=160, 170, 180 and 200μs. The irradiation was repeated 3 or 4 times nominally at the same set of settings with different sets of samples. The preliminary characterization of samples showed that:

i) Like in the first series of experiments, one observes the mass deficit Δm_t which is the least for τ=160 μs. In other cases no correlation Δm_t, τ could be observed. This fact confirms such critical conditions appearing in the entire range of delay times τ in which the effectiveness of ablation is governed by some small fluctuations of thermal evolution of the substrate material, definitely related to its physical properties.

ii) For τ= 160 and 170μs one observes a measurable electrical conductivity on the surface of all the samples (10^4/R = 1 - 20 Ω^{-1}). For other delays τ conductivity appears only on same samples.

iii) The 2.5MeV α particle spectra obtained in the FZR Rossendorf show a sequential drop of the Ti line intensity with increase of τ in the delay time range 160 - 180μs. Unexpectedly, the largest intensity of the Ti line was observed for 200μs. In the lower energy range, the efficiency of scattering of Y for 160 and 200μs is significant, whereas it is very low for 170 and 180μs. A saddle-like spectrum in the lowest energy range indicates decomposition of the material; it is a natural phenomenon in the PID mode. Increase of Y in the middle energy range often indicates introduction of foreign atoms into the substrate. However, the trustworthiness of this indicator depends on homogeneity of the surface structure. The latter must be verified by scanning electron microscope observations and microanalyses of various surface fragments. Such investigations are to be conducted in ZFR in 1997. The course of our reserach will depend on these findings.

3. Nickle on Si_3N_4 using Ni-N plasma pulses

Tests on doping Si_3N_4 ceramics with metal atoms (Cr,Ni,Ti) have been suggested by our partners from FZR, in connection with their research on the possibility of improving the tribological properties of this material by ion implantation. It seemed interesting to compare the effects of applying the technique based on a quite different mechanism of mass transport. During testing it was decided to abandon tests with the Cr plasma, in view of difficulties in producing rod electrodes made of this material. Covering other metals with chromium did not guarantee a sufficient purity of the deposit. The tests were conducted in conditions analogous to that described in p.1, with series of 2-3 samples for particular delay times from the range 160 - 200 μs.

A preliminary characterization has been done analogously. The mass deficit amounted to 35 μg/cm^2 imp on the average. All the samples except those irradiated at τ=200μs showed a measurable electrical conductivity, highest for 160μs. The dependence of RBS spectra on τ is different compared to the Ti/Al_2O_3 case. Both Ni and Y line intensities in the range of middle energies decrease with increase of τ. Tails visible on Ni lines may not be regarded as a sufficient proof of mixing of Ni ions with the substrate, because microscopic investigations revealed some microdroplets rich in Ni on the surface of samples. The tails may arise from those microdrops and not from Ni introduced into the substrate. This observation does not exclude the possibility that mixing occurs in the area between the microdroplets. Investigation of that area by the AES microanalysis technique is planned for 1997. Wear resistance of the irradiated samples has been measured in FZR by the ball-on-disk method. It turned out that plasma irradiation results in a significant increase of the wear resistance in all the samples in spite of some increase of the their friction coefficient. Cross-section profiles of the tested samples indicate a 10-fold decrease of wearing after 10000 cycles. This fact is even more interesting taking into account that close results have been obtained in FZR by Cr and Ti ion implantation. Explanation of mechanisms of the observed phenomena requires further research.

9.6 Use of high intensity pulsed plasma beams in formation of ceramic/metal joints

by J.Piekoszewski, J.Langner, A.Krajewski[1)], L.Waliś[2)], W.Włosiński[1)]

Interest in using ceramics has increased in the past ten years in many structural applications. Due to specific desirable properties, ceramics are selected for various components of systems which are largely made of metallic materials. The successful performance of such systems depends on the quality and reliability of ceramic-to-metal joints. In a number of studies, brazing with active filler metal were used to form joints with a high sheer strength. One of the difficulties in bonding ceramic to metal may arise as a result of differences in their interatomic bonding and physical properties. The low surface tension of various ceramics makes it unlikely for many molten metals to satisfy the wetting conditions necessary for reaction to take place at the ceramic interface. The key concept of the present work is to alloy a metallic coating into a ceramic surface to serve as an intermediate layer between the surfaces to be joined. To form metallic coatings, high intensity plasma beams were used as described elsewhere. The plasma pulses of duration in the microsecond range and of 6-7 J/cm^2 energy densities used in our experiments rapidly heat the near surface layer of the substrate to a high temperature (well in excess of the melting point of even refractory metals) and simultaneously deposit the metallic layer. It could have been expected that such conditions will produce a good adhesion at the metal-ceramic interface. In the course of the first series of experiments it was believed that the metallic component of the plasma beam originated exclusively from the outer set of the rod-type electrodes in the IBIS facility. Therefore only these electrodes were varied in the experiments, whereas the inner electrodes made of molybdenum were fixed. The metals selected for alloying were: Mo, Ni, Cu, Ti. The working gas was N_2 of technical purity. The delay time τ was set on 170 μs to attain the metal-rich plasma regime (DPE). The substrates were platelets of polycrystalline ceramics: Al_2O_3, Si_3N_4, SiC and graphite -35. Using a variable number of pulses (from 5 to 40) the following structures were formed: Ni/Mo/Al_2O_3, Cu-Ti/Al_2O_3, Ni/Mo/SiC, Ni/Si_3N_4 and Cu/graphite.

Table 1. Parameters of processing and results of tests of Ti/graphite joints

Pulsed Plasma Processing			Number of Samples	Brazing Parameters		Joint Tests	
τ [μs]	Number of Pulses	Cu Density [μg/cm^2]		T_b [°C]	t_b [min]	Joint Formed Yes/No	Shear Strength [MPa]
200	10	990	1/II	800	10	No	-
180	10		2/II	800	10	No	-
160	60		3/II	850	5	No	-
			4/II	850	5	Yes	7
200	20	750	1/V	800	10	No	-
180	10		2/V	800	10	No	-
160	60		3/V	850	5	Yes	29
			4/V	850	5	Yes	23
Not Processed			1/0	800	10	No	-
			2/0	800	10	No	-
			3/0	850	5	No	-
			4/0	850	5	No	-

Out of over 40 structures prepared as outlined above, several specimens were selected for brazing with 0.15-0.2 mm thick FeNi42 foils under the load of 1.3 kPa. Two brazing thermal cycles with different filler metals were adopted. In one cycle (C1) the sandwich of metallized ceramic plus FeNi42 foil with the AgCu28 filler in between was heated in the vacuum furnace up to 500 °C at a rate of 30°C/min., kept at 500 °C for 10 min., heated up to the brazing temperature T_b=850 °C, kept at this temperature for 20 min. and then cooled down at a rate of 10°C/min. before the furnace was switched off. The other cycle (C2) was modified in respect to the C1 one by using AgCu19 Ti3 In5 filler, adding additional constant-temperature step before reaching the brazing temperature T_b (750 °C for 10 min.), and shortening the brazing time t_b

to 5 min. No metal-ceramic joints were obtained using the C1 cycle, whereas all the structures processed according to the C2 cycle - except the Cu/graphite - have been well joined.

The EDXRF analysis revealed unexpectedly that all the metal coatings were contaminated by molybdenum originating from the inner set of electrodes. Therefore, in subsequent series of experiments conducted with the Cu/graphite structures, both the outer and the inner electrodes were made of Cu rods. 99.996% pure (instead technical purity) N_2 was used as a discharge gas. Also, the metallization process was modified by using a sequence of pulses at different τ, i.e. of different metal-nitrogen ratio, as indicated in Table 1. The brazing process was performed according to the C2 procedure with two values of both T_b and t_b, and Ti-platelets as the base metal. The most important data concerning this part of the experiments are summarized in Table 1. The real values of the shear strength of the joints are certainly larger than those given in the table, because in all 3 cases a fracture occurred in the bulk of the graphite and not in the joint. As is obvious from these data, more detailed investigations are necessary to clarify the dependence of quality of metal-ceramic joints on processing with pulses of plasma.

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[2] Institute of Nuclear Chemistry and Technology, 16 Dorodna str., PL-03-145 Warszawa, Poland

9.7 Irradiation of silicon with pulsed plasma beam containing Mo ions

by J.Piekoszewski, Z.Werner, J.Langner

The paper presents preliminary results of a new approach to forming a refractory metal (Mo) layer on silicon using intense pulses of Mo-N plasma. The new approach overcomes an inherent difficulty of mixing two materials with dissimilar surface tension in liquid state when using proton beam pulses for melting the pre-deposited surface layer of refractory metal [1]. Previous attempts to mix a refractory metal with silicon using the latter pulses were unsuccessful owing to a tendency of the pulse-melted refractory metal layer to collect into droplets and splash off. Since in the new approach the plasma-born Mo atoms "sink" in the molten silicon layer, there is no opportunity for them to form a separate Mo layer and an effective mixing between Mo and Si takes place. This mixing is demonstrated by the Mo in Si profiles obtained by Auger electron spectroscopy as shown in the figure. For clarity, only Mo and Si profiles are plotted, although the surface layer also contains significant amounts of Co, O, and N. The most important observation is that the profile of Mo extends into the Si substrate to a depth far exceeding a depth resolution of the method which amounts in our case about 5Å.

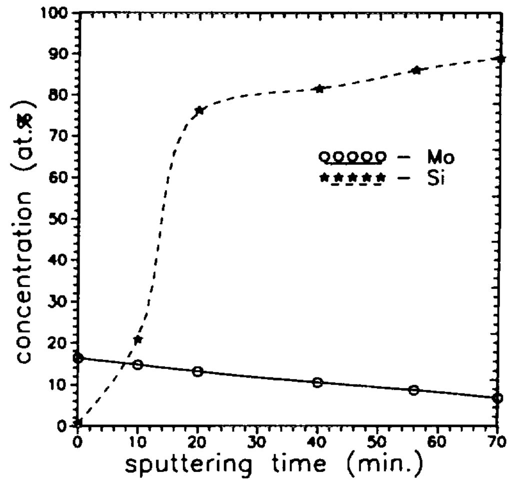

Fig.1 AES profiles of Mo and Si in the surface layer of Si sample treated with 10 pulses of Mo-N plasma.

The paper was accepted for publication in Surf. Coat. Technol.

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9.8 Intense plasma pulses; two modes of the use for surface processing purposes.

by J.Piekoszewski, J.Langner, L.Waliś[1] and Z.Werner

Pulsed ion and plasma beams under appropriate conditions can modify the surface properties of materials by melting their near-surface regions and simultaneously doping it with portions of foreign atoms reaching in a single pulse doses as large as 10^{17} atoms/cm^2. Such processes can be accomplished using Rod Plasma Injector (RPI) type of generators [1]. These devices can operate in two modes. The plasma pulses are generated as a result of a low-pressure, high-current plasma discharge between two concentric, cylindrical sets of rod-type electrodes. The discharge is initiated by applying high voltage after some delay time $\Delta\tau$ from the moment of injection of working gas into the interelectrode space. If $\Delta\tau$ is sufficiently long, the plasma contains almost exclusively elements from the gas (PID mode). For short $\Delta\tau$, the beam is a mixture of elements of working gas and metallic electrodes chosen deliberately for a given purpose (DPE mode). The process was conducted with: nitrogen as the working gas, copper as the electrode material, and stainless steel as the substrate. The energy density of pulses amounts to about 6 J/cm^2, pulse duration is in the microsecond range. The samples were characterized by: weighing before and after processing to determine the total mass change Δm_t (μg/cm^2 pulse); energy dispersive x-ray fluorescence (EDXRF) on CuK_α line measurements to determine the copper contribution to mass change Δm_{Cu}(μg/cm^2 pulse); Auger Electron Spectroscopy (AES) to follow the mixing of the plasma and substrate elements.

The figure illustrates the comparison between the total mass change Δm_t (as determined by weighing) and copper mass contribution Δm_{Cu} (as determined by the EDXRA method) in samples processed with copper-nitrogen plasma pulses at various delay times τ ranging from 160 up to 210 μs. The principal features which emerge from these data are as follows:

(i) The largest total mass gain Δm_t is observed for shortest τ i.e. definitely for the DPE regime. When τ rises, the Δm_t decreases, changes the sign at about τ= 190 μs and with a further rise of τ the mass loss increases reaching the largest value for the longest τ, i.e. for 210 μs.

(ii) For short τ (160-175 μs), the total mass change equals the amount of Cu deposited on the surface. For further rise of τ the values of Δm_t and Δm_{Cu} diverge, Δm_{Cu} being non negligible even for the longest τ, i.e. for nominally PID regime.

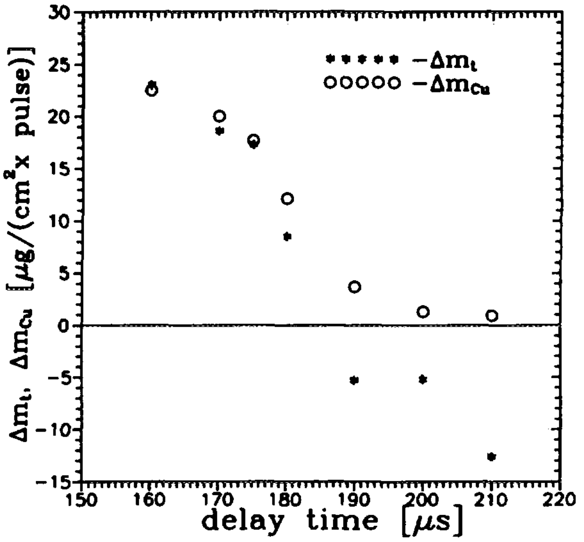

Fig.1

This last fact makes it impossible to state unambiguously that, in the τ range where the loss of total mass is observed, there is a pure PID regime, in spite of the fact that the nitrogen dose is about 4 times as large as the Cu dose for τ =210 μs. The PID regime manifests itself more clearly when electrodes are made of more refractory material, like molybdenum. In the case of molybdenum after 5 pulses for τ=200 μs, the surface concentration of Mo is below the detection limit, i.e. below 1x10^{16}, whereas the surface concentration of N amounts to 1.6x10^{17} at.N/cm^2. The facts pointed out in (i) and (ii) make it obvious that for delay times $\tau \geq 180$ μs ablation dominates over deposition. This means that an effective mixing between substrate and coating constituents occurs, otherwise the plasma supplied Cu would be completely removed by ablation. This mixing effect is even more evident in our AES results. For short delay time the AES spectrum reveals only the presence of Cu, N, C, and O lines. For longer delay times one observes a progressive growth of N line and a decrease of Cu lines.

In conclusion: The most effective mass deposition occurs for short delay times, i.e. for metal-rich plasma pulses. The most effective mixing takes place for long delay times, i.e. for working-gas rich plasma pulses. It is therefore possible to adjust the discharge parameters in the same equipment to form first the well mixed intermediate layer, and then to continue the layer formation at the parameters favoring an effective coating.

The paper was accepted for publication in Surf. Coat. Technol.

[1] J.Piekoszewski et al., Nucl. Instr. Meth. B53 (1991) 148

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9.9 A method of creating functional tin layers by using the modified plasma gun

by J.Kuciński, J.Langner, J.Piekoszewski

Two different stages of the project were successively accomplished in 1996. Within the first one 10 samples with some Ti-interlayer deposited on the melted surfaces have been produced on PF046 plasma device working in the HIPIB-DPE mode (after optimization of the device). The roller-shaped specimens were made of speed steel SW7m, hardened and tempered up to HRC of 64. The samples have been produced by exposing polished steel specimens to titanium-nitrogen plasma pulses. The time between injection of the working gas and switching on of the high voltage (the delay time) was varied in the range 180-220μs. The preliminary characterization of samples prepared this way consisted of the following measurements:

- Ti distribution on the specimen surface by means of electron microprobe (TiKα-line)
- HV001 and HV microhardness at different loads (20 - 100G)
- roughness
- microscopic study of the sample surfaces
- X- ray analysis

Some of the experimental results obtained at the first stage of the project are as follows:

Nr	τ[μs]	Ti relative concentration (TiKα line)			Roughness			Microhardness HV001		Mass variation
		N_{Ti}	σN_{Ti}	$\frac{\sigma N_{Ti}}{N_{Ti}}$	R_a [mm]	σR_a	$\frac{\sigma R_a}{R_a}$	HV001 [kG/mm²]	HV001 (HV001)°	Δm[μg]
1	2	3	4	5	6	7	8	9	10	11
37	180	0.395	0.076	2	0.22	0.027	12	863	0.719	130
38		0.340	0.039	11	0.22	0.029	13	859	0.716	40
35	190	0.320	0.009	3	0.32	0.076	24	848	0.707	320
36		0.321	0.026	8	0.26	0.020	9	830	0.692	380
33	200	0.448	0.038	8.5	0.09	0.025	26	876	0.730	60
34		0.360	0.035	10	0.14	0.032	23	881	0.734	-3.0
31	210	0.119	0.017	14	0.15	0.08	5	759	0.632	220
32		0.187	0.018	9.7	0.14	0.022	16	837	0.679	-510
26	220	0.220	0.031	14	0.11	0.012	11	876	0.730	40
27		0.190	0.013	6.5	0.15	0.029	12	857	0.714	?

For the second batch of experiments the plasma device has been switched to the "Plasma-Gun" regime and optimized (gas pressure, electrode geometry, electrode-target distance, working voltage, gas injection-voltage switching delay time, etc.) in order to obtain the best TiN coating on the irradiated steel specimens. The samples coated with a hard, yellow layer, but roughness of the surface was not good enough for any industrial application. This could be attributed to deposition of too high energy on the specimen surface. In order to decrease the working voltage, the high voltage generator needs a slight reconstruction. In the meantime the plasma device has been additionally equipped with the PVD-Arc machine, which substantially improved the roughness of the coating.

9.10 Studies of angular dependence of erosion of tungsten wires caused by high-power pulses of hydrogen plasma

by G.P.Glazunov[1)], J.Langner, M.Sadowski, J.Stanisławski and V.I.Tereshin[1)]

Tungsten, as one of the candidate materials for target plates of the ITER's divertor, has been extensively studied to determine its erosion rate under irradiation by high-power pulsed fluxes of hydrogen plasma. Particular attention has been paid to conditions in which the metal surface melts and some new mechanisms of erosion—different from sputtering—can appear. Effects of shielding the plasma with a metal vapor near the target may decrease the erosion rate [1], whereas volume bubble boiling within the melted layer increases loss of the material [2]. For objects with a small radius of curvature (e.g. metal wires) a strong dependence of the erosion rate on the wire diameter has been observed at normal (perpendicular) irradiation. To identify erosion mechanisms of such objects, measurements of erosion rates for W-wires with various diameters irradiated by pulsed hydrogen plasma streams at various angles of incidence have been performed.

Irradiation of samples was carried out within the SOWA-400 plasma accelerator [4]. The plasma pulse duration was about 1 μs, energy flux achieved ca. 5 J/cm^2, and the number of pulses for different samples was 5-10. The erosion was determined as a decrease in the sample weight measured with 10 μg accuracy. The erosion mechanisms observed at the normal irradiation and at the angular one were different. In the former case the erosion rate decreases from 10^{-2} g/cm^2 per pulse to 10^{-6} g/cm^2 per pulse with an increase in the W-wire diameter from 0.1 mm to 9 mm. This behavior can be explained by partial melting of the wire surface and by the difference in the carry-over of melted particles. At the angular irradiation the erosion depends to a lesser extent on the wire diameter (variation within one order of magnitude), but the absolute values of the erosion rate for wires of bigger diameter are larger than those observed at the normal incidence. This can be explained by the absence of any melted layer on the wire surface, which results from a lower energy density and simultaneously from the angular-enhanced sputtering and radiation-enhanced sublimation.

Apart from the simulation studies on the influence of plasma disruption on the fusion reactor structure, the results of this work are also of importance for other technological applications, e.g. for determining or modifying the dimensions and weight of plasma-treated samples, for the design of an emission plasma probe with W-wire as a working element, etc.

[1] N.I.Arkhipov et al., Sov. Phys. Plasma 13 (1987) 632
[2] A.Hassenein et al., J. Nucl. Mat. - in press
[3] V.G.Kotenko et al., Zh. Tehh. Phys. - in press
[4] M.Gryziński et al., Proc. 14th EPS Conf. CFPP (Madrid 1987) Pt. II, p. 645

[1] Institute of Plasma Physics, NSC KIPT, 310108 Kharkov, Ukraine

PL9800723

9.11 Deposition and mixing of cobalt, titanium and tungsten on the pulse-melted surfaces of substrates

by J.Langner, J.Piekoszewski, J.Stanisławski and Z.Werner

In 1994 a new method of forming thin metallic coatings on steel substrates, based on the use of high intensity plasma pulses generated in the IONOTRON device, was proposed [1]. In the methods ions and metal vapors produced by an additionally installed pulsed source of metal plasma are deposited upon a melted surface layer of a processed material. Depending on the choice of operational conditions of the device it is possible to form pulses containing either both nitrogen and metal plasma, or pure metallic plasma. It was found that the most effective conditions for melting and mixing deposit components with a substrate prevail when nitrogen and metal ions reach the substrate simultaneously.

Plasma pulses of Ti, Co and W were used simultaneously with high intensity nitrogen streams in the present experiments. Energy density in the plasma stream was in the range 3.5-5 J/cm^2 at the distance of 50 cm from the end of the electrodes (where the samples were positioned). The substrates were cut out of AISI 321 stainless steel in the form of discs of 50 mm in diameter, and with surface roughness of R_a=0.2 μm. As a rule, each sample was irradiated with 5 pulses. Some of them were additionally subjected to the deposition of 10 pure metallic plasma pulses without heating by nitrogen ions. The elemental profiles and the chemical composition in the layers as well as the surface morphology were analyzed using Glow Discharge Spectrometry (GDS), Auger Electron Spectroscopy and Scanning Electron Microscopy, respectively.

The surfaces of all samples exhibit granular morphology, characteristic of arc-based deposition techniques. The mean roughness expressed by R_a ranged from 0.2 μm to 0.6 μm, depending on the energy density in the pulse. The in-depth profiles of Ti, Co and W in AISI 321 s/s as well as the results of AES analysis provide strong evidence that mutual mixing of the substrate and the deposit is taking place at pulsed metallic plasma beams. It was observed that the mixing efficiency is different for various elements; that may be attributed to different diffusion coefficients for various elements in liquid steel. The GDS in-depth profiles shown in fig.1 refer to structure in which an additional cobalt layer was formed after mixing. This result demonstrates feasibility of forming a substrate/mixed-layer/deposit structure and of building up a metallic layer of practically unlimited thickness. This work was presented at the International Workshop on Beam Surface Technology, Tomsk, May 1996, and will be published in Surface and Coating Technology (in press).

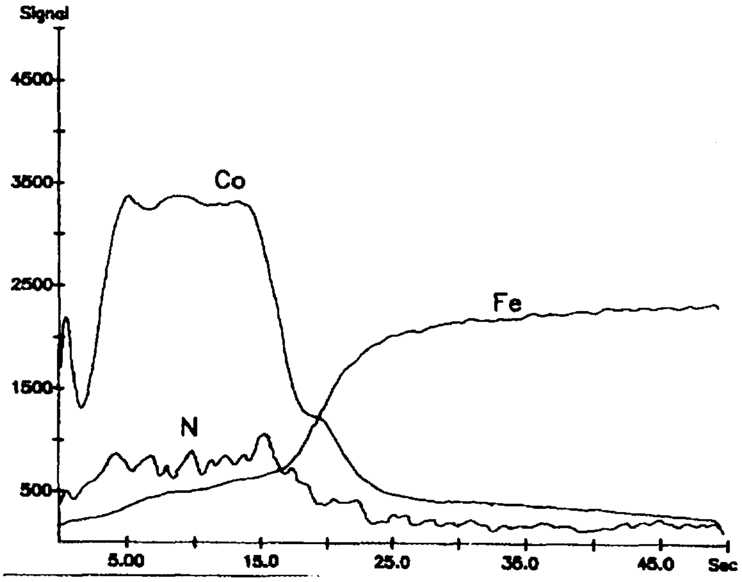

Fig.1 GDS elemental profile of the structure in which an additional cobalt layer was formed after mixing. The sputter rate was approx. 50 nm/s.

[1] J.Langner, J.Stanisławski, J.Piekoszewski, Proc.2nd Nat. Symposium PLASMA'95 on Research and Applications of Plasmas, Warsaw 1995, Vol.1., pp.121-124

PL9800724

9.12 High-current nitrogen ion implanter

by J.Langner, K.Czaus, E.Górski, J.Piekoszewski, E.Pławski, Z.Werner

In 1996, efforts were put into the design and construction of a high current implanter. The aim of this work is to construct and put into operation a nitrogen ion implanter for basic research in surface engineering as well as for industrial applications. The main parameters and features of this implanter are as follows:

- ion energy - 80 keV
- ion current - several mA
- no mass separation
- large working chamber
- use of duoplasmotron ion source
- low cost of the installation.

For these purposes various combinations of extracting, forming and accelerating sets have been analyzed. The two-electrode system with 35 kV extraction voltage and 80 kV acceleration voltage has been chosen. Supply units and a vacuum system for the implanter have been designed. Main technological efforts connected with the construction of the device have been concentrated on assembling the working chamber (0,5 m^3) together with the pumping units (5000 l/s + 2000 l/s) and the high voltage power supply (80 kV). We hope to finish the task in 1997.

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GLAZING OF CERAMIC SURFACES WITH HIGH INTENSITY PULSED ION BEAMS
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Surface and Coating Technology 84 (1996) 329-333, (listed also in DepartmentrP-V)

ALLOYING OF AUSTENITIC STAINLESS STEEL WITH NITROGEN USING HIGH-INTENSITY PULSED BEAMS OF NITROGEN PLASMA
J.Piekoszewski, L.Waliś, J.Langner, Z.Werner, J.Białoskórski, L.Nowicki, M.Kopcewicz, A.Grabias
Nucl. Instr. Meth. in Physics Research B 114 (1996) 263-268, (listed also in Department P-V)

A NEW CONCEPT OF DOSIMETER WITH SILICON PHOTODIODES
M.Słapa, M.Traczyk
IEEE Transactions on Nuclear Science, Vol. 43 No. 3 (June 1996) 1855

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DEPOSITION AND MIXING OF COBALT, TITANIUM AND TUNGSTEN ON THE PULSE MELTED SURFACES OF SUBSTRATES
J.Langner, J.Piekoszewski, J.Stanisławski, Z.Werner
Surface and Coating Technology, (listed also in Department P-V), (in press)

SURFACE MORPHOLOGY OF NITROGEN-ALLOYED STEELS USING HIGH INTENSITY PULSED PLASMA BEAMS
J.Piekoszewski, L.Waliś, J.Langner
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IRRADIATION OF SILICON WITH PULSED PLASMA BEAM CONTAINING Mo IONS
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Surface and Coating Technology, (listed also in Department P-V), (in press)

CONTINUOUS PROTON SPECTRA FROM THE $_{93}$Nb(p,xp) REACTION AT 216 MeV
Z.Moroz, J.Wojtkowska, A.Marcinkowski, B.Mariański, W.Czarnacki
Raport SINS-16/II 17 czerwiec 1996

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CORROSION RESISTANT Al-REFRACTORY METAL GLASSY ALLOYS
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J.Piekoszewski, Z.Werner, J.Langner, M.Janik-Czachor
Int. Workshop on Plasma Based Ion Implantation, September 1996, Drezno

INTENSE PLASMA PULSES: TWO MODES OF USE FOR SURFACE PROCESSING PURPOSES
J.Piekoszewski, J.Langner, L.Waliś, Z.Werner
Int. Workshop on Plasma Based Ion Implantation, September 1996, Drezno

APARATUROWE ŹRÓDŁO PROMIENIOWANIA X W BADANIACH NIENISZCZĄCYCH
M.Słapa, W.Straś, M.Traczyk, J.Dora, R.Gutowski
Krajowa Konferencja Badań Nieniszczących, Szczyrk, październik 1996 (materiały konferencji str. 99)

WYKORZYSTANIE IMPULSÓW PLAZMY METALICZNEJ DO WYTWARZANIA CIENKICH POWŁOK W WARUNKACH PRZETOPIENIA POWIERZCHNI PODŁOŻA
J.Langner, J.Piekoszewski, J.Stanisławski
Materiały VI Sympozjum Środowiskowego Zastosowań Elektromagnetyzmu w Nowoczesnych Technikach i Technologiach, Poraj, May 1996 (listed also in Department P-V)

OPRACOWANIE METODY WYTWARZANIA WARSTW POŚREDNICH (Ti) NA PRZETOPIONYM PODŁOŻU ORAZ WARSTW UŻYTKOWYCH (TiN) PRZY UŻYCIU ZMODYFIKOWANEGO DZIAŁA PLAZMOWEGO
J.Kuciński, J.Langner, J.Piekoszewski
Materiały VI Sympozjum Środowiskowego Zastosowań Elektromagnetyzmu w Nowoczesnych Technikach i Technologiach, Poraj, May 1996 (listed also in Department P-V)

INTERNAL SEMINARS

ODDZIAŁYWANIE INTENSYWNYCH IMPULSÓW WIĄZEK PLAZMOWYCH Z CIAŁAMI STAŁYMI: MODYFIKACJA WŁAŚCIWOŚCI POWIERZCHNIOWYCH
J.Piekoszewski
Konwersatorium z fizyki i techniki jądrowej IPJ, wrzesień 96

"PHOTON NEEDLE" - A NEW TOOL OF RADIOTHERAPY*)
M.Słapa, *December 3, IPJ Warsaw*

*) in Polish

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10. DEPARTMENT OF ACCELERATOR PHYSICS AND TECHNOLOGY

PL9800725

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Overview

The current activity of the Department in '97 was focused on three main branches:

- the development of a scientific background and computational capabilities in accelerator physics, and in particular of accelerating structures, beam dynamics and interactions of particles and fields, beam focusing and transport etc..
- maintaining and further development of the experimental basis and metrological method and instrumentation; this comprises measurements of electron and ion optics, beam profiles and emmitance, accelerated beams intensity, energy and energy spectra, dosimetric measurements and r.f. fields distributions in accelerating structures;
- initiative and participation in new design projects of various types of accelerators for applications in science, and practical radiation technology, medicine, agriculture, environmental protection.

In the past year, our main attention was given to the following:

- maintenance and modification of the C-30 compact cyclotron, for operation with internal ion-sources and internal or external targets. The development of the external ion-source and axial injection line was continued;
- design and model measurements of a new solution of the "supershort" accelerating structure for a 4 MeV medical electron accelerator with SID (Source Isocentre Distance) 100cm;
- theoretical and computational work for the design of the 15-18 MeV accelerating structure for a new generation of medical accelerator with a broad variation of electron energy and two energies of the photon beam;
- adaptation and completion of the 20 MeV test-bench for experimental measurements of electron and photon beams;
- theoretical study of a possible solution for the proton linear accelerator for future applications in nuclear waste transmutation and energy generation (collaboration with INFN-Milan);
- the design and construction of coaxial-waveguide couplers for superconducting cavities in HERA accelerators, within the frame of the General Agreement with DESY-Hamburg;
- computation of the excitation of Higher Order Modes in superconducting structures for the TTF-project (TESLA Test Facility), in collaboration with DESY.

REPORTS ON RESEARCH

PL9800726

10.1 An experimental setup for studies in the field of RF electron linacs' technology in the energy range of up to 20 MeV

by W.Maciszewski, M.Pachan, J.Pszona, B.Daniel, A.Stępiński, S.Stępniak, and H.Wojnarowski

The experimental setup is based on utilization of subunits of the Saturn medical linac, retired from clinical exploitation at the Institute of Oncology and installed in our laboratory. The machine is equipped with an S-band RF system based on a klystron, capable to delivering RF pulse and average power of 6 MW and 6 kW respectively. Such parameters enable the carrying out of works concerning research and development of accelerating structures for medical and industrial linacs.

The aim of the work planned for 1996 was to examine and restore the whole infrastructure of the Saturn machine and to create the possibility of its normal operation. The first stage of the work concerned reconstruction of several accelerator systems, such as the water system, electrical connections of all accelerator blocks, and the waveguide. In the next stage, the testing of the heating and H.V. chains, adjusting of all protection systems, inspection and adjustment of the RF driver and computer control system were done. After a short training of the vacuum system of klystron and accelerating structure, first without and next with RF power, a readiness for normal machine operation has been achieved. The waveforms of: the envelope of RF driver's output signal, klystron current and voltage, and the output of a forward wave detector placed in the waveguide, are shown in fig.1. The values of klystron current and voltage shown in fig.1 with the assumption of klystron efficiency of 50% give the RF pulse power of about 6 MW. This value is sufficient to obtain an electron beam with energy at the level of 20 MeV.

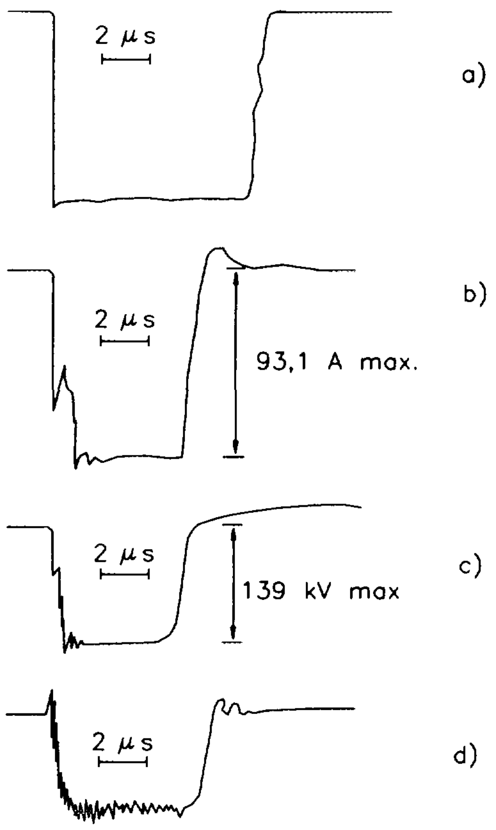

Fig.1 a - envelope of RF driver's output signal, b - klystron's pulse current, c - klystron's pulse voltage, d - signal from forward wave detector placed at the klystron's output.

All procedures described above were done without heating of the electron gun, because up to now the radiation shielding of the laboratory is not sufficient to produce the beam. After completion of radiation shielding, we will have the possibility to run the stand in the full range of its parameters. The stand is intended to be used for the following purposes:

1 - R&D for RF linacs' technology (both medical and industrial) in an energy range up to 20 MeV, with emphasis on accelerating structures' testing and measurements;

2 - metrology needed in RF linacs technology, including RF high power measurements, metrology of electron and photon beam and dosimetry;

3 - shaping of narrow photon beams for special kinds of medical applications (e.g. stereotactic radiosurgery).

PL9800727

10.2 Radiation measuring system for 20 MeV accelerators test-stand.

by J.Pszona

Reconstruction & development of accelerators test-stands that started in 1996 at the Department of Accelerator Physics has led to interest in methods and systems used in radiation protection. Monitoring of the radiation level in the area close to an accelerator shelter and in a control room is essential for safety of both the technical staff and of others. From this point of view, even the simplest monitoring system should consist of 3 to 5 "ground" detectors and, if necessary, of "sky shine" ones.

A practical dosimetry system is composed of the following items:

1.remote detectors with solid-state X-Ray dose sensors,
2.computer with special counting hardware and software,
3.interface circuits.

For the dose sensor a special, commercially available, hybrid circuit has been chosen [1]. The circuit consists of a semi-conductor detector, a charge sensitive preamplifier, a pulse amplifier and a discriminator. Its technical parameters are as follows:

sensitivity	0.25 imp/s/μGy/h (variant I)
	50 imp/s/mGy/h (variant II)
energy range	20 keV...1.3 MeV (variant I)
	20 keV...8 MeV (variant II)
output pulse	amplitude 3 V, duration 8 μs
operating temperature range	-30...+50^{0}C
dimensions	30 x 9 x 5.5 mm

For the sensor a two-wire supply and pulse transmitting circuit has been constructed and tested. The circuit is based on the current loop principle and is highly immune to external noise. All electronic components of detectors will be placed in water-resistant housings made of polycarbonate. Signals from detectors will be counted and displayed by a PC class computer with counting board [2]. The board has 10 channels of 16-bit counter-timers and 16 digital input-output lines. Software included with the board has definitions of functions in high level programming language. The rest of the electronic equipment (the interface) adjusts signals from detectors to the requirements of the computer board and separates the two circuits. The separation, made with opto-couplers is necessary for safe operation of a computer. The designed interface has modular construction and a special wall-mounting enclosure has been chosen for it.

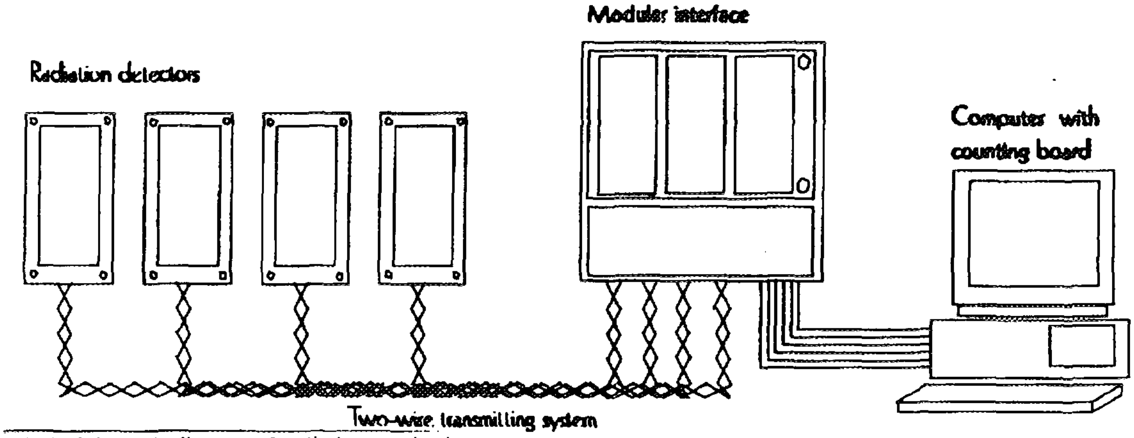

Fig.1 Schematic diagram of radiation monitoring system.

[1] X-Ray-Gamma-Dose-Sensor; VACUTEC Messtechnik Specifications.
[2] PC-TIO-10, Timing I/O Board for the IBM PC/XT/AT; National Instruments Catalogue 1995 pg.3-61.

10.3 Upgrading of "doorknob" couplers for HERA electron accelerator

by J.Olszewski, S.Kuliński, M.Pachan, E.Pławski, J.Pszona

PL9800728

The coaxial RF couplers of the HERA accelerator are used for RF power transmission between a klystron and a superconducting 4-cell RF cavities. They are equipped with the WR-1800 waveguide to the coaxial line transition part of so called "doorknob" type. This part serves as a mode transducer from TE_{10} in WR-1800 waveguide to TEM in coaxial line and as an impedance transformer at the same time.

The couplers work at a frequency of 500 MHz and at continuous power of 70 kW. At present the RF power transmission is frequently accompanied by the electron multipactoring phenomenon. To cope with this problem it was decided to introduce the modifications listed below.

a) The inner conductor of the coupler will be biased at about 2 kV in order to avoid multipactoring.

b) For this purpose a 25 μm thick capton foil with 35 μm copper layers on both sides will be used as the doorknob insulator. The total copper coated area equals 85 mm^2 and the unit pressure - 20 N/mm^2. The insulator should be synchrotron radiation resistant.
c) The RF power transmitted will be increased up to 100 kW.
d) Air-cooling system of the inner conductor will be introduced.
e) The light concomitant to the multipactor or a discharge in the region of RF vacuum window of the coupler will be monitored using a sapphire window and a photodiode. The transmitted light wavelengths will be confined between 0.4 and 0.9 μm and the attenuation should be less than 6 db.
f) For safety reasons the external part of the doorknob will be enclosed in metal housing.

The doorknob prototypes (Fig.1) have been manufactured at SINS and working conditions of the modified transmission line tested. The preliminary tests made at DESY, Hamburg show that multipactoring effects disappear at the coupler's bias exceeding 1.2 kV, and the coupler works properly.

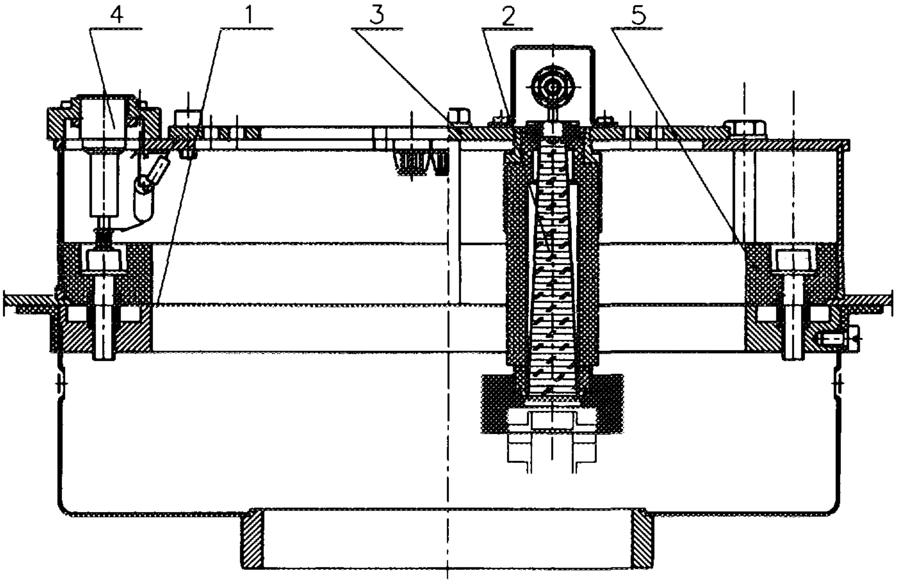

Fig 1. K–F "doorknob" type waveguide to coaxial transition part of main coupler for HERA accelerator
1 – kapton insulator, 2 – lightguide, 3 – metal container,
4 – HV connection, 5 – insulating ring of acetal

PL9800729

10.4 Electron RF GUN for DESY TESLA test facility

by S.Getka, S.Kuliński, E.Pławski, J.Sekutowicz[1)]

To fix the final design parameters of an RF type electron gun, the models of a gun described in [1] were equipped with RF power couplers and underwent low level signal tests.

The RF gun is essentially composed of laser excited photocathode (Cu) and a high electric field RF accelerating cavity. The burst of emitted electrons is accelerated very rapidly, thus reducing the time dependent degradation of electron beam quality.

In our case the accelerating cavity is made of two strongly coupled cells (Fig.1) resonating on TM_{01}, π mode at the frequency of 1299.9 MHz. The 4.5 MW of pulsed RF power which has to excite the effective accelerating field of more than 50 MV/m on the gun axis, is delivered to the cavity through the coaxial coupler (CL). The inside of the inner conductor of the coupler serves as an electron beam guide and also as the laser light guide. The optimal coupling coefficient can be obtained by the change of the length ΔL of the inner conductor of the model.

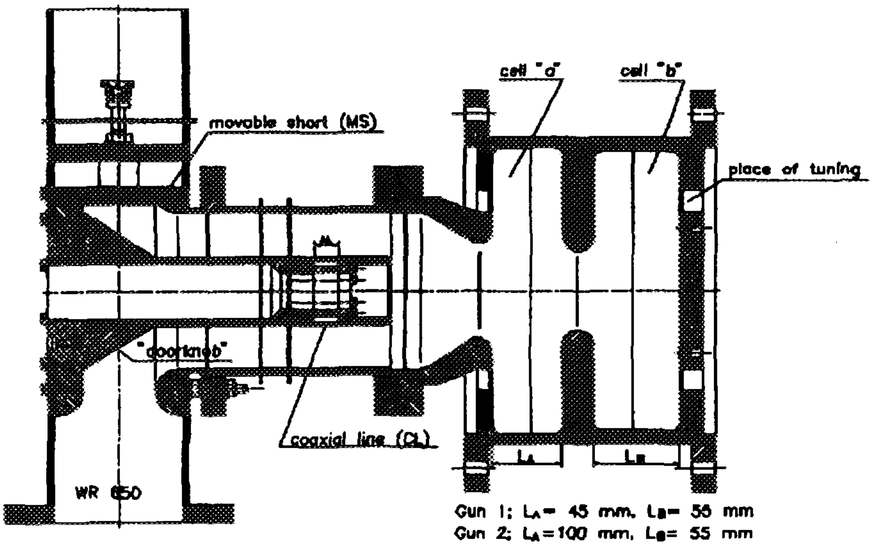

Fig.1 Gun No 1 and with coaxial - waveguide transition.

A proper matching in the region of mode transducer (TE_{10} in WR 650 feeding waveguide to TEM coaxial mode in the coupler) is accomplished by the "doorknob" type transition at the base of the coaxial line. The minimum of SWR (Standing Wave Ratio) can be obtained by the adjustment of the position of the movable short (MS) at the end of feeding waveguide.

The measured frequencies of π modes of both cavities were within 0.06% of calculated values. To measure the axial electric field distribution, the field perturbation method [2, 3] was applied where the relation (1) between the field perturbed by a small perturbing object of volume Δv and frequency shift is given by the relation:

$$\frac{\omega^2-\omega_0^2}{\omega_0^2} = \frac{const}{2W}\iiint_{\Delta v}(\mu H^2-\epsilon E^2)dv \tag{1}$$

ω is the frequency, W the energy stored in cavity.

A small metallic needle of diameter 0,8 mm and length of 5 mm was moved on the axis of cavity perturbing thus only the **E** component. In fact, what was measured was the phase shift of the reflected wave as a function of the needle position. The sample result of such measurement is shown in Fig.2.
Both cells were tuned in steps up to the moment where the phase shift in both cells were the same. The HP 8753C network analyser was used for all measurements.

The measurement and correction of the SWR of the waveguide to coaxial line transition is not a trivial task because the coaxial coupler is of not a standard impedance. The procedure known as Deschamp's method [3] depicted in Fig.3 was applied to solve this problem. The scattering matrix parameters are determined in this method on the basis of bilinear transformation

$$\Gamma_1 = S_{11} + \frac{S_{12}^2 \cdot \Gamma_2}{1 - S_{22}\Gamma_2} \tag{2}$$

where scattering matrix elements and both reflection coefficients are complex values. By Γ_2 we denote the reflection coefficient at the position of shorting plunger and Γ_1 at the input of network. The movable plunger is moved in steps of $\lambda_g/16$ and the input impedance and hence the reflection coefficient corresponding to each position of the plunger is measured. The measurements are repeated for positions of the plunger changed by $\lambda/4$ and connecting of proper points l_1, l_2, l_3 with l_1', l_2', l_3' on a Smith chart enable determination of impedance at the input of the coupler. The results of the measurements for the range of frequencies from 1.2 GHz to 1.36 GHz and two arbitrary positions of movable short MS are shown in Fig.4. The coupling coefficient of the coaxial line to the cavity was found to vary in the range 0.45 ÷ 1.63 for GUN No 1 and 0.37 to 1.27 for Gun 2 when ΔL was varied from 15 to 30 mm.

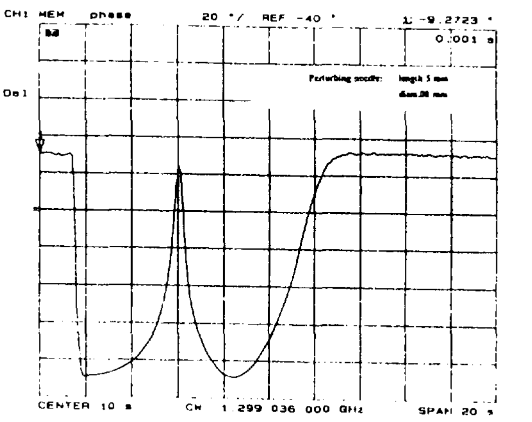

Fig.2 GUN No 1. Phase perturbation. β = 1.08; ΔL = 25 mm.

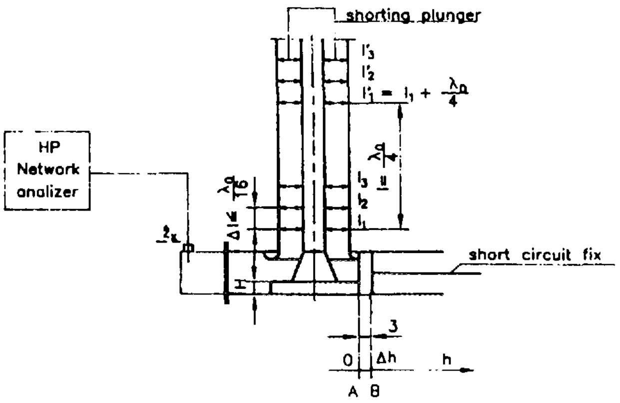

Fig.3 Impedance measurements of coaxial-waveguide transision with Deschamps method.

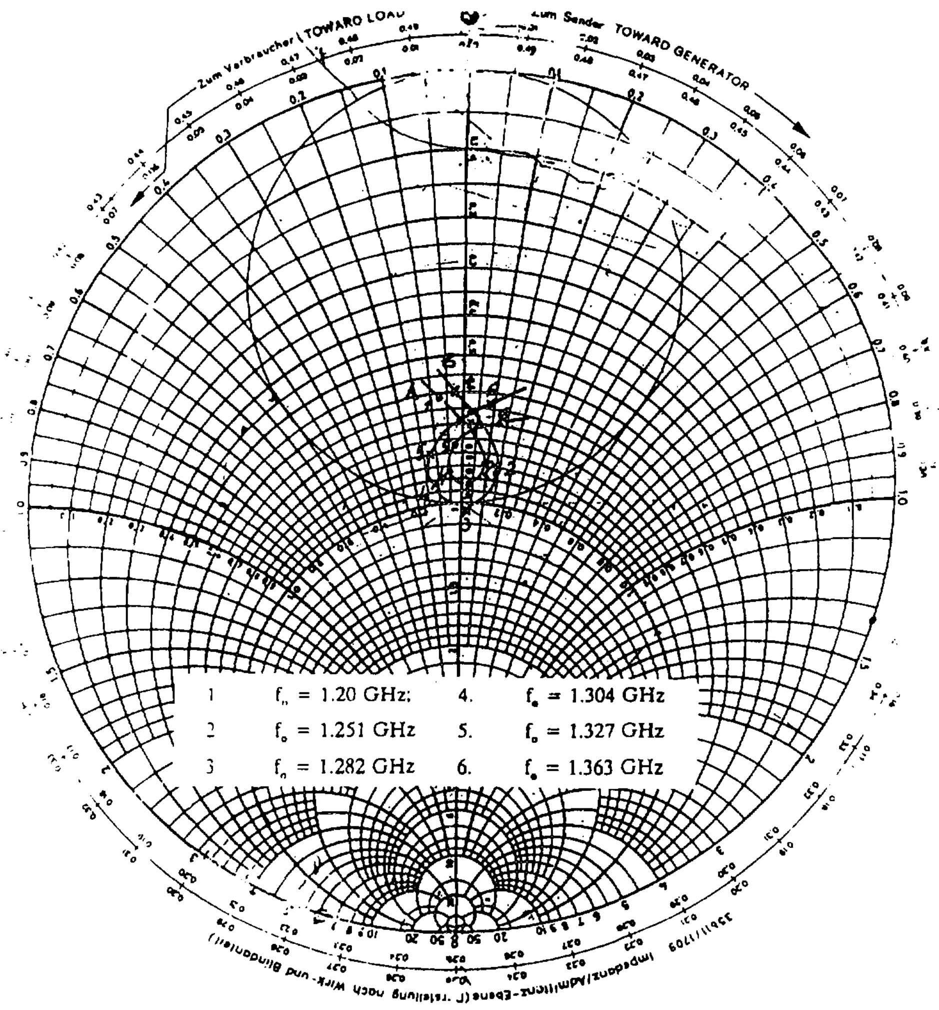

Fig.4 Impedance loci for measurements of coaxial-waveguide transition with Deschamps method.

[1] SINS, Annual Report 1995
[2] J.Müller, Zeitung für Hochfrequnztechn. Electroacount. 54, 1939
[3] E.L.Ginzton, Microwave Measurements, Mc Graw-Hill Book Co., Inc 1957
[4] G.A.Deschamp, Proc. I.R.E., 42, 859, 1954; J.Appl.Phys. 24, 1046, 1953

[1] DESY Deutsches Elektronen Synchrotron

10.5 Numerical simulations and experimental studies of the electron beam - RF field interaction in the Uppsala CMC device

by S.Kuliński, J.Lorkiewicz, A.Jansson[1)], J.Pszona

PL9800730

Recently H.Ikegami proposed a new method of cooling of accelerated relativistic electron and ion beams - Cyclotron Maser Cooling (CMC) [1]. According to him, in the scheme of CMC, cyclotron radiation is enhanced by a high frequency electromagnetic field which stimulates a radiation exchange leading to very short cooling times of both transverse and longitudinal energy dispersion. Classically the stimulated emission or absorption mechanism is explained as the relativistic change of the cyclotron frequency of gyrating particles $\omega_c = qB/mo\gamma_{\perp}$. (q-charge, B-magnetic field, m_0 - particle mass, $\gamma_{\perp}$ -coefficient of relativistic increase of mass). It is supposed that, in the vicinity of cyclotron resonance due to the relativistic change of mass, there will be a bunching of phases of gyrating particles with respect to the field, leading to rapid energy exchange between the RF field and particles resulting in cooling. In a quantum mechanical approach, the gyrating particles are described as relativistic Landau oscillators [1,2] with the level spacing $\hbar\omega_c$. The coherent emission or absorption of photons is due to non-equal, level spacing $\hbar_1\omega_c$. A similar mechanism has been utilized in high power cyclotron maser amplifiers.

To prove the principle of CMC an experimental device was built at Uppsala University (described below [3]). In the frame of TEMPUS, SINS and especially Accelerator Department has been invited by Prof.S.Kullander and H.Ikegami to collaborate both in theoretical and experimental aspects of this problem.

To check theoretically the first preliminary experimental results [1,3] and especially the supposition of relativistic phase bunching in the vicinity of cyclotron resonance, relativistic equations of motion of charged particles in a constant homogeneous magnetic field and a transverse, standing, circularly polarized electromagnetic wave close to cyclotron resonance have been written out and solved numerically. Preliminary results of these calculations are:

Equations can rather closely simulate experimental conditions. In the vicinity of cyclotron resonance a standing electromagnetic wave creates some kind of potential barrier to axially travelling particles. The hight of the barrier is proportional to the RF electric field intensity. Existance of this barrier determines the transit time of a particle through the RF field region. For the Uppsala CMC experiments, depending upon the entrance phase of a particle, its transit time through a half-wavelength long cavity can vary from ten to many hundreds of RF periods. (Fig.3). All this time, a particle, besides being decelerated and then accelerated (if it passes the barrier), also gains or looses transverse energy. (Fig.4).

In fact starting from 10 keV of transverse input energy, output energies above 20 keV can be easily obtained. No phase bunching was observed (Fig.5).

Since particles (electrons) are weakly relativistic, these results are close to those obtained analytically for the nonrelativistic case [4].

The CMC device at Uppsala University consists of an electron gun with a beam forming system, magnetic deflectors, a solenoid and four RF cavities excited in the TE_{018} standing wave mode. An electron beam is deflected and introduced into the solenoid. After crossing the solenoid fringe field electrons travel along helical paths, defined by their transverse and longitudinal kinetic energies and interact with the RF field.

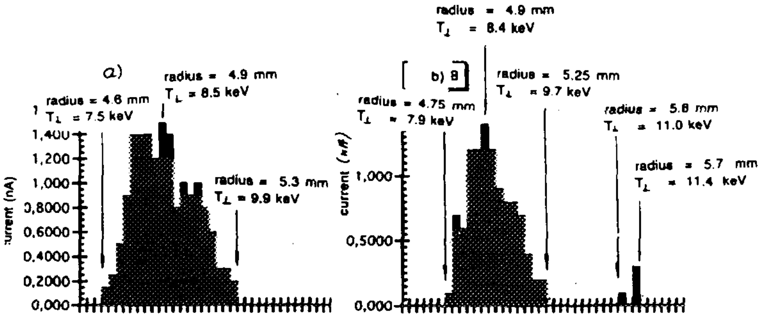

Fig.1 The radial distribution of the current density of a 10 keV electron beam before a), and after applying RF field b). The mean electric field amplitude was 12 kV/m.

So far CMC effects were studied experimentally using a luminescent screen [1,3]. It was found difficult, however, to investigate electron current density distribution with this instrument, since the energy deposited on the screen and the observed intensity of luminescence depends not only on the current density but also on the fractional longitudinal energy [3]. To cope with this problem, a simple diagnostic device for the longitudinal and transverse energy distributions has been manufactured and tested in the Uppsala CMC device [5]. A luminescent screen was complemented with a portable copper blade, which defined the external size of the helical electron trajectories, a Faraday cup and a cylindrical stopping electrode. The new diagnostics allowed determination of both longitudinal and transverse electron energy distributions.

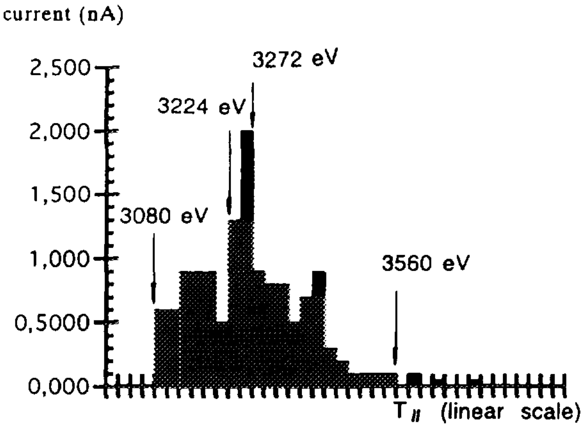

Fig.2 The longitudinal energy distribution of a 10 keV electron beam interacting with RF field. The peak in the centre corresponds to the external ring shown in Fig. 1b.

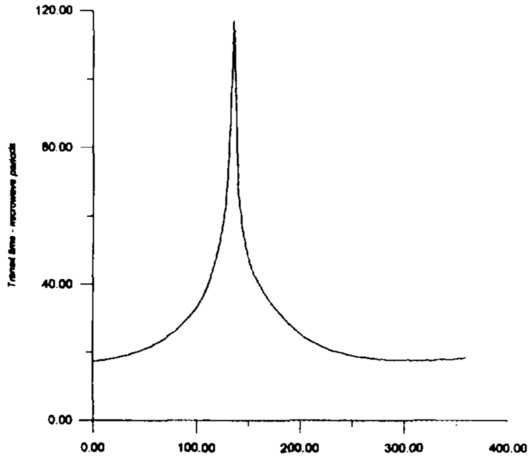

Fig.3 input phase - degrees
f = 1.665 GHz, Bo = 607 Gs, Em = 26.42 kV/m

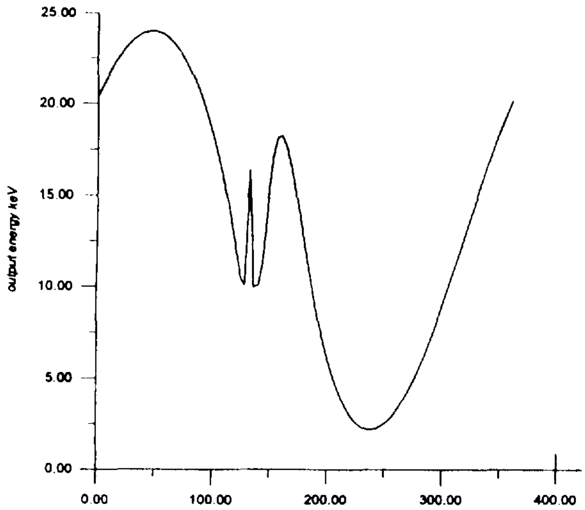

Fig.4 input phase - degrees
Eko = 10 keV, Ektr = 9.85 kV,
Bo = 607 Gs, Em = 26.42 kV/m

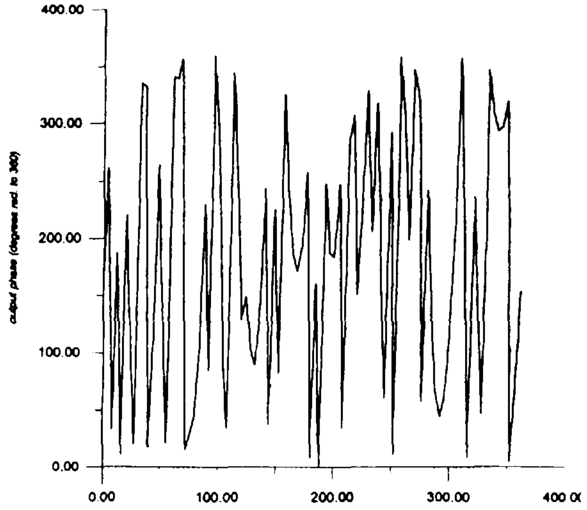

Fig.5 input phase - degrees
Eko = 10 keV, Ektr = 9.85 keV, f = 1.665 GHz,
Bo = 607 Gs, Em = 26.42 kV/m

Energy distributions of 10 keV beams were measured for different RF powers and deflection magnet settings. For the RF input powers below 2 W the radial distribution of a beam current density had a gaussian form with its boundaries and maximum shifted by 0.1 - 1 keV towards high energies, compared with a beam not influenced by a microwave field. For higher RF input powers, the beams were often composed of several groups of electrons seen on a luminescent screen as double or multiple "rings" (see for example Fig. 1b). Determination of the longitudinal energy distribution for a beam interacting with an RF field, revealed that the external ring, produced as a result of this interaction, consisted of the electrons of longitudinal energies confined to a band of width not exceeding 25 eV. It can be seen as a narrow peak in the longitudinal energy distribution shown in Fig.2. The peak is situated about 190 eV above the minimum longitudinal energy. The obtained results are of importance from the CMC theory point of view.

[1] H.Ikegami, Phys.Rev.Lett. 64, 1737 (1990); 64, 2593,(1990) Proc.of the CERN School on Beams Cooling, 81 (1993);

[2] J.Schnaider, Phys.Rev.Lett. 2, 504, 1959
[3] F.Kullander, Cyclotron Maser Cooling, Thesis, Osaka University, Nov 1992.
[4] S.Kuliński, The Motion of the Charged Particle in a Constant Homogeneous Magnetic Field and a Transverse Standing Electromagnetic Wave at Cyclotron Resonance. Rijnhuizen Re. 63-14. Rijnhuizen 1963.
[5] J.Lorkiewicz, A.Jansson, J.Pszona, Electron Beam Structure Studies in the Uppsala CMC Device with a New Diagnostic, (Nov 1996), unpublished.

[1] TSL/ISV Uppsala University, Box 535, S-75121 Uppsala, Sweden

10.6 Works on the external H⁻ source and injection line of the C-30 cyclotron

by J.Lorkiewicz, R.Morozowicz, E.Pławski

The status of the external H⁻ source and the injection system of the C-30 cyclotron at the end of 1995 was described in [1, 2]. In 1996, measures were taken to increase and stabilize the intensity of the H⁻ ion beam in the transport line and to increase the cathode filament life-time. The development programme was strongly limited by financial restrictions.

In order to stabilize the extraction voltage, an additional electron suppressor electrode was installed between the plasma electrode and the extractor. It intercepted part of the electrons extracted from the source when being biased at +1 kV respective to the plasma electrode. The rest of the electron beam was transported in the beam line. In order to avoid the vacuum system damage due to electrons impinging on the walls, a beam collimator was mounted 0.5 m downstream of the source. An extra steering magnet was installed upstream of the bending magnet (see [1]) to correct the H⁻ beam direction. The beam current reached 580 μA and about 300 μA downstream of the einzel lens and bending magnet, respectively.

Currently the cathode life-time does not exceed 15 hours. To increase the life-time of the cathode filament, its diameter was changed from 0.75 mm to 1 mm. An appropriate emission current could be reached by increasing the filament heating power. An extra filament power supply was manufactured at SINS for that purpose. Its schematic drawing is given in Fig. 1. It is equipped with a 3-phase rectifier and a keyer with a set of power transistors.Some basic working parameters of the power supply are listed below

- output voltage keying frequency - 5 kHz (constant),
- duty factor control range - 1 - 98%,
- output power control range - 100 W - 2.5 kW,
- mean current control range - 2 A - 120 A.

It will be installed at the ion source test-stand in the beginning of 1997.

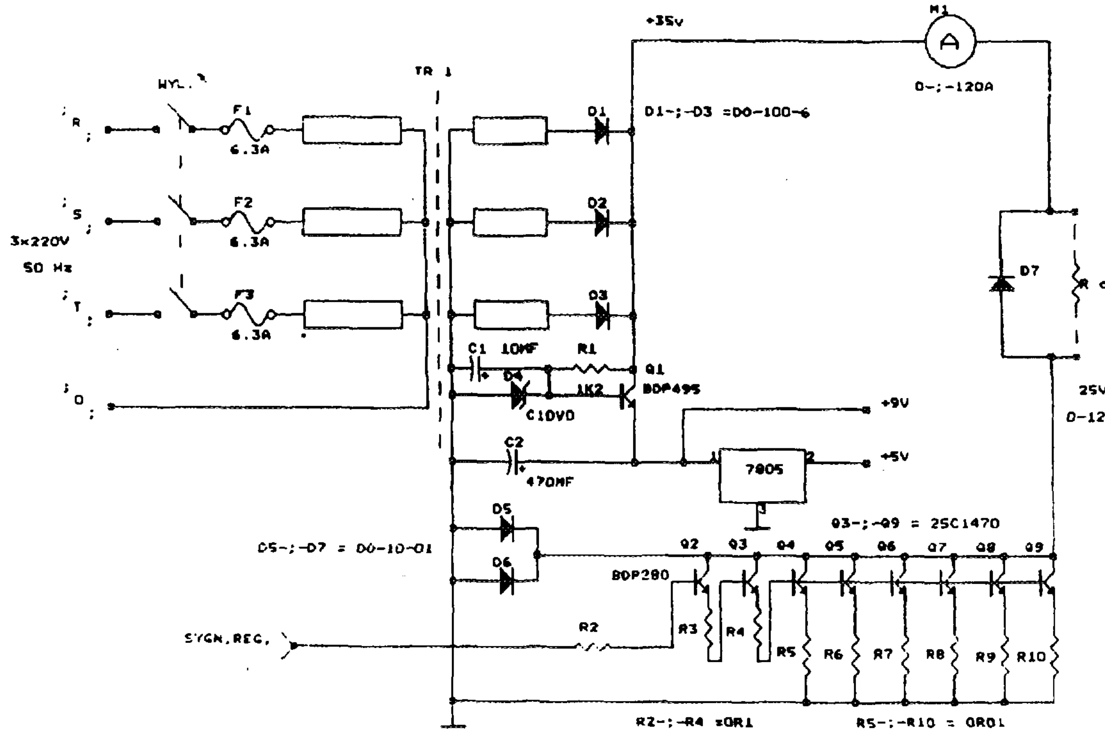

Fig.1 Schematic drawing of the 3-phase rectifier and set of regulation transistors.

[1] J. Lorkiewicz et al., SINS Annual Report 1995, p. 72
[2] J. Lorkiewicz, Proc. Fifth. European Particle Accelerators Conference, Sitges (Barcelona), 10 - 14 June 1996, p.1528

10.7 Calculated and measured proton beam parameters for the COSY-13 experiment in Jülich

by I.Zychor and O.W.B.Schult[1)]

The COSY (COoler SYnchrotron) accelerator complex in Jülich consists of several ion sources, the isochronous cyclotron, a 100 m long injection beam line, the COSY ring with a circumference of 183.47 m and extraction beam lines to the external experiments. It provides proton beams with energies from 40 MeV to 2.6 GeV. The COSY ring is made up of two 40 m long straight sections (which act as a telescope with 1:1 imaging, giving either a 1π or 2π phase advance) and of two 52 m long arc sections with mirror symmetry.

In 1996, the COSY-13 experiment "Production of Very Heavy Λ-Hypernuclei at Energies Below the Nucleon-Nucleon Threshold" was continued with proton beams of energies 1.0 GeV, 1.5 GeV and 1.9 GeV [1]. The internal targets made of uranium and bismuth were used at the TP1 target position placed in the target telescope straight section at a distance of 24.87 m from the injection point to the COSY ring [2]. For optimal experimental conditions the ring acceptances should be large and the beta functions at the target position should be small. We define the following figure of merit:

$$FOM = \frac{1}{\frac{\beta_x^T}{a_x} + \frac{\beta_y^T}{a_y}}$$

where: πa_x, πa_y - the horizontal and vertical acceptances of COSY, respectively; β_x^T, β_y^T - the beta functions at the target position [2]. Good experimental conditions are achieved for large values of *FOM*.

The MAD code [3] was used to calculate the ion-optical COSY beam parameters. By use of calculated β functions for horizontal and vertical planes the ring acceptances and the figure of merit were derived.

In Table 1 the measured and calculated tunes Q_x and Q_y are shown as well as the difference between calculated and measured values. For the vertical tune Q_y the difference agrees within the error but the difference for horizontal tune Q_x is much higher. We suppose that for this discrepancy not enough accurate calibration of the COSY quadrupoles is responsible. This effect is now examined more carefully at the COSY ring. In addition, in Table 1 the data are given about proton beam intensity, the full COSY cycle length and the time when the beam was in use after acceleration at the flat top.

Table 1. Beam parameters for the COSY-13 experiment

	MARCH 1996	SEPTEMBER / OCTOBER 1996		
	1.0 and 1.5 GeV	1.0 GeV	1.5 GeV	1.9 GeV
Q_x^{meas} (± 0.01)	3.687	3.592	3.636	3.610
Q_y^{meas} (± 0.01)	3.521	3.597	3.660	3.676
Q_x^{MAD}	3.620	3.544	3.560	3.521
Q_y^{MAD}	3.529	3.601	3.676	3.699
$\Delta Q_x = Q_x^{MAD} - Q_x^{meas}$	-0.067	-0.048	-0.076	-0.089
$\Delta Q_y = Q_y^{MAD} - Q_y^{meas}$	0.008	0.004	0.016	0.023
number of protons	$1 \div 2 \cdot 10^{10}$	$1.3 \cdot 10^{10}$	$1.3 \cdot 10^{10}$	$<10^{10}$
COSY cycle	36 sec	6 sec	10 sec	12 sec
at flat top	30 sec	2.5 sec	5 sec	5 sec
FOM at target TP1	0.8	1.6	1.6	0.7
target	^{238}U (UF_4)	^{209}Bi		

[1] T.Hermes et al., "Search for Heavy Hypernuclei Produced in the $^{238}U(p,K)$ $_{\Lambda}A$+X Reaction at COSY Jülich", Proc. of the 3rd Int. Conf. on Nuclear Physics at Storage Rings (STORI 96), Bernkastel, Germany, 30.09 - 3.10.1996, ed. by F.Bosch and P.Egelhof (Nuclear Physics A, in print)

[2] I.Zychor, "Beam Parameters at Internal Target Positions for Experiments in COSY-Jülich", SINS Report-15/X (1996)

[3] H.Grote, F.Ch.Iselin, "The MAD Program", CERN/SL/90-13

1) Institut für Kernphysik, Forschungszentrum Jülich, Germany

10.8 Design study of a high energy chopper

by J.Sura and L.Calabretta[1)]

Some physical experiments done with the LNS Superconducting Cyclotron require a time structure of the accelerated beam which is different from the cyclotron time structure. The required time structure may be obtained using a beam chopper, working in the range of frequencies from 2 to 9 MHz. To sweep a beam of particles accelerated up to 100 MeV/nucleon in realistic beam line geometry, the length of the chopper plates should be about 1 meter and the amplitude voltage reaching 50 kV.

To get this voltage on chopper plates we considered two solutions:

1 - lumped LCR resonant circuit,

2 - cavity resonator.

The first solution can basically meet the requirements in the full frequency range. Detailed technical studies are under way.

The alternative second solution is based on the idea of Split Coaxial Resonator - SCR by R.W.Mueller [1]. A model 39 MHz cavity chopper has been built and measured [2] (see Figure). The main measured parameters are: Q-factor = 2320, shunt impedance = 327 kOhm. The plates have the following dimensions: thickness 5 mm, width 50 mm, length 857 mm, and gap between the plates 8 mm.

The scaled results proved that the SCR system may be realistic at least at the upper frequency limit. Cost estimates of the whole system, including the RF power amplifier (up to 10 kW) will determine the final solution.

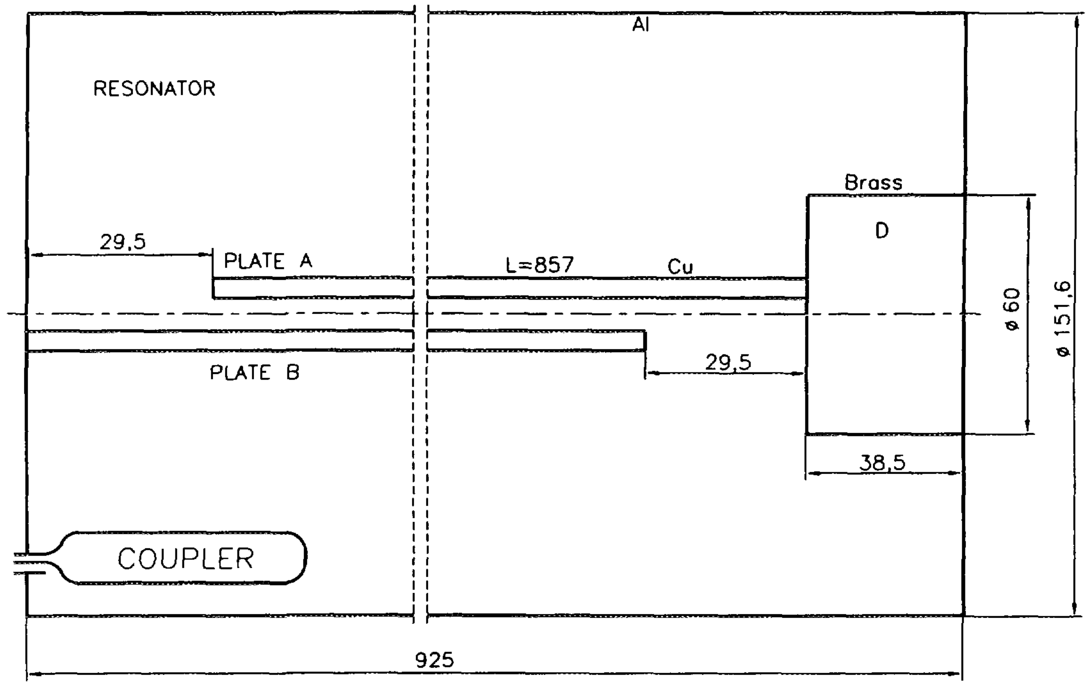

Fig.1 Schematic cross-section of the 39 MHz model SCR resonator.

[1] R.W.Mueller, GSI Report 79-7, Darmstadt.

[2] J.Sura, L.Calabretta and E.Zappalà, LNS, Catania, July 1996

1) INFN LNS Catania, Italy

10.9 Recent trends in methods and techniques of purifications of flue gases by electron induced plasma processing.

by W.Drabik, M.Bielik, A.Jerzykiewicz

PL9800734

There are two main methods of electron induced processing of flue gases:

1. radiation by electron beam:
   - direct current (DC) electron beam
   - pulsed electron beam

2. electrical discharges in gas:
   - direct current (DC) driven discharges
   - alternating current (AC) driven discharges
   - pulsed voltage driven discharges

Electron beam processing, being tested and optimized in many pilot plants in USA, Japan, Germany and Poland, mainly in the DC regime, is established by IAEA as a method which may be used on an industrial scale. However, the main disadvantage of this method is the energy cost of oxidation.

Laboratory experiments with pulsed electron beams showed that the energy cost for current density less than $10^{-4}A/cm^2$ is equal to 10 eV/mol, but for higher current densities the energy cost may be drastically reduced up to 0.3 eV/mol due to a chain ion-molecule mechanism of SO_2 oxidation. The results suggest the use a pulsed electron beam, where it is relatively easy to obtain high-current density in one pulse.

Among many methods of electrical discharges, special attention is paid to a pulsed corona discharges. Very intense corona discharges can be produced by applying a fast rising, narrow-pulse high voltage, to electrodes with different geometries: point-to-plane, point-to-point, wire-to-cylinder, wire-to-plane, which are placed in a gas reactor. During the narrow pulse much higher voltage may be applied without spark breakdown in the reactor comparing to DC regime. It is generally assumed that the energy of reactive electrons produced by a pulse corona discharge increases with the time derivative of the applied voltage. In practice these factors mean that larger volumes are penetrated by the discharge and less energy goes into heating, leading to an increase in the removal efficiency of pollutants. It has been shown that the pulsed corona method is effective, both in the laboratory and industrial scale, for removal of many types of pollutants: SO_2, NO_x, hydrocarbons etc.

Small scale experiments of pulsed plasma discharge processes (PPDP) showed that the optimal condition for PPDP requires a pulse modulator which generates a pulse voltage of 150 kV at peak, with pulse length 500 ns, operating at repetition rates between 100-300 Hz. It is obvious that long life-time and reliability of such a driven system is a necessary requirement for industrial implementation. Actually the best candidate fulfilling the demands is the magnetic pulse compressor (MPC). In the MPC circuit a low power pulse is generated in a primary circuit using a classical repetitive switch such as thyratron, thyristor or rotating spark gap. After that, the pulse is transmitted through a chain of condensers and saturable inductors (magnetic switches), which reshape it to the short rise and duration time and to higher power level.

Up to now, many MPC systems have been constructed all over the world, for applications in high-power particle beams, high-power lasers, intense X-ray sources, using max. 100 kW average-power level.

[1] E.I.Baranchicov et.all, Investigation of SO_2 oxidation in humid air stream by high current density pulsed electron beam Radiat. Phys. Chem. Vol. 45, No. 6, pp.1063-1066, 1995

[2] J.Mizeraczyk,Plasma equipment for gaseous pollution destruction, 2-nd National Symposium Plasma-95, Warsaw, June 26-28, 1995

[3] M.Rea, A.Dono, Plasma catalysis in Italy, 2-nd National Symposium PLASMA-95, Warsaw, June 26-28, 1995

[4] R & D Activities, Pohang Light Source NewsLetter/July 1996/ No. 8

[5] N.Georgescu, V.Zoita, R.Presura, Magnetic pulse compression circuits for plasma devices, 11-th International Conference on High Particle Beams, Praque, Czech Republic, June 10-14, 1996

PROTON AND ION ACCELERATORS

PL9800735

10.10 C-30 Isochronous cyclotron of SINS
by E.Pławski, M.Pachan, J.Sura

The cyclotron in its actual state characterised by the parameters given in the Table 1 is operational and is used occasionally for nuclear physics study and target activation on an internal or extracted beam.

Table 1

	Goal	Achieved	Achieved
Particle accelerated	H^-	H^-	H^+
Ion source	-	PIG internal	PIG internal
Ion source external	multicups	not finished	
Energy, internal beam	30.0 MeV	31.5 MeV	31.5 MeV
Energy, extracted beam	30.0 MeV	28.0 MeV	-
Beam intensity	50 μA aver.	0.1-1.0μ A aver.	15 μA aver.
Beam losses in accel. process		70 ÷ 80%	5%
Internal beam intensity in pulse	-	up to 15 μA	150 μA
Extracted beam intensity in pulse		up to 8 μA	-

The actual H^- beam losses between R = 10 ÷ 44 cm result from dissociation on gas particles (mainly from internal ion source) and are connected with the present state of the vacuum system. It was installed during running-in, only for initial operation, and should be changed as soon as possible. Vacuum improvement will radically diminish beam losses.

For further development, and achieving commercial isotope production capability, one should increase a duty factor and approach to c.w. operation. For this purpose, an external ion source, axial injection and new RF resonators ought to be installed. As this involves costs, these works can be undertaken only when real interest in isotope production exists in our country.

10.11 Wakefields induced by the relativistic electron beam in TESLA superconducting accelerating cavities

PL9800736

by E.Pławski

In the frame of a wide international collaboration, a future linear electron-positron supercollider is under study. The main efforts are concentrated in DESY Hamburg where the TESLA Test Facility is under construction in order to verify and to prove the feasibility of the superconducting version of a collider. The work carried out at SINS Świerk were already reported in 1995 Annual Report [1]. The computations of wakefields excited by the electron beam in accelerating cavities and beam lines were continued through 1996. The influence of the cavity length and shape as well as of electron bunch length on excited wakes were investigated.

The resulting longitudinal energy loss factors and transverse loss factors (the measure of the transverse momentum kick received by the bunch particle when the bunch passes off the axis) are summarised in Table 1. The influence of the bunch length on these factors is given in Table 2.

The physics of wakefield generation and detailed procedures of computational evaluations are described in report [2].

Table 1.
The loss factors as a function of the number of cells of TESLA 1.3 GHz structure. The values were computed for sigma = 1 mm of Gaussian bunch.

Number of cells	monopole loss factor [V/pC]	transverse loss factor [V/pC/m]
1	1.558	3.511
2	2.870	6.344
3	4.073	8.880
4	5.222	11.25
5	6.347	13.510
7	8.608	17.87
9*	10.620	21.99
9**	11.05	20.6

*)End cells non compensated; **)end cells compensated

Table 2. Loss parameters of 9-cell cavity

σ_{bunch}(mm)	$k_{Lmonop.}$(V/pC)	$k_{\perp dipole}$(V/pC/m)
2	7.63	25.31
1	11.05	20.60
0.5	15.58	12.96

[1] SINS Annual Report 1995, page 66.
[2] E.Pławski, Wake-fields induced by the electron beam passing TESLA accelerator system (to be published).

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THE C-30 COMPACT ISOCHRONOUS CYCLOTRON AT ŚWIERK AS A POTENTIAL SOURCE OF SHORT LIFE-TIME ISOTOPES
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A MINIATURE H SOURCE FOR THE C-30 COMPACT CYCLOTRON AT ŚWIERK
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Proc.of the 3rd International Conference on Nuclear Physics at Storage Rings (STORI 96), Bernkastel, Germany, September 30 - October 3, 1996. Edited by F. Bosch and P. Egelhof (Nuclear Physics A, special issue)

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A Preliminary Estimation of the Economic Impact of Accelerator Driven Nuclear Reactors*)
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*) in Polish

PERSONNEL

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11. SECTION FOR STANDARD AND PATENTS

PL9800737

Standardization and Patents

by S.Wójtowicz, R.Trechciński, M.Rybka, A.Ryszkowska, J.Wardaszko

The most important tasks of the Section in 1996 were:

- preparation of national standards and program of future work on standards for nuclear instrumentation and electronic equipment in nuclear engineering;
- organization of activities and participation in the meetings of the Commissions for Standardization No 173 - Microprocessor Systems, No 266 - Nuclear Instrumentation;
- giving opinions and expertises on national and international standards for equipment in nuclear engineering;
- cooperation with the Commission for Standardization No 246 - Radiological Protection;
- control of inventiveness activity;

The quality of the technical products is being improved by:

a) selection of the proper types of interface systems, technical coordination and quality control;
b) creation of standards at a high technical level;

The Section works mainly for the Polish Committee for Standardization, the National Atomic Energy Agency, Association of Polish Electrical Engineers and Research Institutes in Poland. The activity of the Section is useful for all national institutions where backplane busses and nuclear electronic equipment is produced or used.

The Section participates in the following international organizations:

- IEC - (International Electrotechnical Commission) TC 45 - (Nuclear Instrumentation);
- ISO/IEC Joint Technical Committee - ISO/IEC JTC1 SC26 (Microprocessor systems);
- ESONE - (European Studies on Norms for Electronics);

The section takes part in popularization of nuclear technology and instrumentation in the following ways:

- distribution of standards and technical documentation to national institutions dealing with nuclear apparatus;
- collecting and distributing technical information from international organizations (e.g. ESONE);
- organization of technical and scientific, national and international conferences (New Generation Nuclear Power Plants - September 96, QNX in Real World - January 96);
- participation in the technical conference organized by the Polish Committee for Standardization;
- cooperation with the Patent Office Republic of Poland in the areas of inventiveness and patents;

International Electrotechnical Vocabulary
Chapter 394:
Nuclear Instrumentation:
Instruments
M.Rybka, R.Trechciński, S.Wójtowicz
Polish Standard PN-IEC 394

MICROPROCESSOR SYSTEM PCI
Z.Guzik, M.Rybka, R.Trechciński, S.Wójtowicz
Recommendation APEE /Association of Polish Electrical Engineers/
K SEP-I-0003

MICROPROCESSOR SYSTEM SCSI-2
J.Charuba, M.Rybka, R.Trechciński, S.Wójtowicz
Recommendation APEE /Association of Polish Electrical Engineers/
K SEP-I-0004

Standardization of Nuclear Instruments
J.Roszij **R.Trechciński, S.Wójtowicz**
Normalizacja No 7, 1996, pg. 22-24

12. ESTABLISHMENT FOR NUCLEAR EQUIPMENT

Head of Establishment: MSc. Jacek Pracz
phone: 779-82-77

Overview

In 1996 Establishment for Nuclear Equipment continued working on the development of the diagnostic and tumour therapy equipment. The results of the work were applied in the following equipment installed in 1996:

- Co-line accelerator in Lublin,
- Simax simulator in Łódź.

The microprocessor systems used in this equipment control all the equipment's parameters: they measure them and they monitor and control the operation of the safety and interlock circuits. They also ensure data processing and recording, they simplify the maintenance and repairs, the latter thanks to modem communication.

The research and develpoment works include the following:

- amelioration of cooling of the accelerating devices in accelerators,
- control system of the position of the filter disk in accelerators,
- development of a measurement correcting system of the dose rate depending on the temerature, humidity and pressure in the dosimetric systems used in accelerators,
- development of a new type of simulator with larger radiation field, more precise reading of mechanic positions and a micropocesssor control system with an anticollision system.

In 1996 the interest in therapeutic tables produced by our Establishment has increased. They can both be installed together with radiotherapy equipment or with patient immobilising outfit in prototype workshops.

In 1996 the deliveries to the health service amounted to 51% of all sales, while 26% of the output was exported, mainly to Siemens and to the CERN centre.

REPORTS ON RESEARCH

12.1 Correction of influence of the environmental temperature and atmospheric pressure changes on the meteorology characteristics of open air ionisation chamber KMA-10

by E.Jankowski

An analysis has been carried out on the influence of environmental temperature and atmospheric pressure on the volume of ionisation power of the KMA-10 chamber used as a line detector for monitoring systems of the dose and dose density in medical accelerators manufactured in ZdAJ (Institute for Nuclear Equipment). We observed the constant character of the eco-positional dose the power of ionisation in an open air ionisation chamber under the influence of radiation is directly proportional to the atmospheric pressure and reversibly proportional to the environmental temperature:

$I_K = C \times P/T$, whereas C - constant,

The following has been assumed: margin of temperature changes: 283° - 333°K (10° - 60°C),
normal temperature: $T_n = 293°K$
margin of pressure changes; 900 - 1113 hPa,
normal pressure: $P_n = 1013$ hPa.

The percentage changes of the dose density as a function of temperature changes have been calculated for the normal atmospheric pressure P_n as well as a function of the pressure, for constant temperature T_n for NEPTUN PC accelerator. The results are presented in Fig. 1:

T (°C)	T (°K)	dose density dD (MU)	dD %
10	283	310.34	103.45
20	**293**	**300**	**100**
30	303	289.86	96.62
40	313	280.6	93.53
50	323	271.91	90.64
60	333	263.75	87.92

P(hPa)	dose density dD (MU)	dD (%)
900	266.31	88.77
925	273.71	91.24
950	281.11	93.7
975	288.51	96.17
1000	295.9	98.63
1013	**300**	**100**
1025	303.3	101.1
1050	310.7	103.57
1075	318.1	106.03
1113	329.34	109.78

Modification of the dose density depending on the temperature changes amounts approximately to 3.3%/10°C, while in case of atmospheric pressure changes it amounts to 1%/10 hPa.

Correction of the dose density (chamber current) consists of the determination of the correction coefficients: k_T - depending on the changes in environmental temperature and k_p - changes in atmospheric pressure and their consideration in the basic equation:

$dD_N = dD \times k_T \times k_p$, whereas dD - dose density before compensation.

The coefficients are calculated on a programme base from the equation:

$k_T = 3.413E - 03 \times T\ (°C) + 0.93174$,

$k_P = -1.0140 - 03 \times P\ (hPa) + 2.0318$.

The current value of temperature and pressure is determined on the basis of tension signals, resulting from the transformers : 'temperature - current' and 'absolute pressure - tension', after re-scaling and approximation;

T (°C) = 12.5 x U_T (V) - 25,

P (hPa) = 37.1050 x U_P (V) + 794.9559.

The sensibility of the transformer 'temperature - pressure' is equal to 80 mV/°C, of the transformer 'pressure - tension' is equal to 27.5 mV/hPa. These values aresufficient for the measurements with 12-bite transformers of the Computer Managing System. The temperature and pressure are displayed on the operator screen.

Fig. 2 shows some values of the coefficients for selected temperature and pressure:

T (°K)	283	**293**	303	323	323	333
k_T	0.9667	**1.000**	1.035	1.0691	1.1033	1.1375

P (hPa)	900	925	950	975	1000	**1013**	1025	1050	1075	1113
K_P	1.1192	1.0939	1.695	1.0432	1.018	**1.000**	0.9925	0.9671	0.9418	0.9033

12.2 Results of tests of the CO-LINE PC medical accelerator

PL9800740

by R.Kiełsznia, E.Jankowski

The CO-LINE PC medical accelerator which has been produced since 1995, was tested in agreement with IEC 976 (International Electrotechnical Commission) International Standard and IEC 977 Technical Report.

The parameters of the accelerator are as follows:

1. X-Ray beem energy 4 MV,
2. Absorbed dose rate in build-up 2 Gy/min,
3. Source diameter < 3 mm,
4. Source-isocenter distance (NTD) 80 cm,
5 Radiation field from 3 × 3 cm up to 30 × 30 cm,
6. Both stationary and arc therapy,
7. Light field indicator,
8. Numerical field indicator.

Results of tests are given situated in Table 1 and compared with appropriate data, suggested by IEC 977. Obtained outcomes for the CO-LINE accelerator are superior to those suggested by IEC 977 in the scope of the tests.

Table 1

No.	Designation of test	Results of tests	Values suggested by IEC 977
	Dose Monitoring System		
1	Reproducibility	0,26 %	0,5 %
2	Proportionality	1,27 %	2 %
3	Dependence on angular positions	1,45 %	3 %
4	Dependence on gantry rotation	0,8 %	2 %
5	Dependence on the shape of radiation field	it do not depend of	-
	Stability of Calibration		
6	Stability after high absorbed dose delivered	1,3 %	2 %
7	Stability throughout the day	1,1 %	2 %
8	Stability throughout the week	1,15 %	2 %
9	Stability in moving beem radiotherapy	2 %	3 %
10	Flatness of square X-ray fields		
	10 cm × 10 cm (H)	105 %	106 %
	10 cm × 10 cm (V)	105 %	106 %
	30 cm × 30 cm (H)	103 %	106 %
	30 cm × 30 cm (V)	102 %	106 %
11	Deviation of dose distribution of square X-ray fields with angular positions	2,28 %	3 %

12	Symmetry of square X-ray fields		
	10 cm × 10 cm (H)	102 %	103 %
	10 cm × 10 cm (V)	102 %	103 %
	30 cm × 30 cm (H)	102 %	103 %
	30 cm × 30 cm (V)	102 %	103 %
13	Penumbra of radiation fields		
	10 cm × 10 cm (H)	9,0 mm; 9,0 mm	
	10 cm × 10 cm (V)	8,0 mm; 8,0 mm	
	30 cm × 30 cm (H)	13,0 mm; 14,5 mm	
	30 cm × 30 cm (V)	14,0 mm; 15,0 mm	
14	Numerical field indication	max 1,25 %	1,5 %
15	Reproducibility of numerical field indication		
	20 cm × 20 cm (H)	0,5 mm	2,0 mm
	20 cm × 20 cm (V)	0,5 mm	2,0 mm
16	Light field indicator	max 0,8 %	1,0 %
17	Geometry of the beem limiting system for X-radiation, nonparallel of fields	max 0,48 °	0,5 °
18	Indication of the radiation beem axis on entry to the patient	max 1,76 mm	2,0 mm

PL9800741

12.3 New Roentgen simulator "SIMAX"

by M.Górski, J.Marjanowski

In 1996, a new, fully computerised roentgen simulator called SIMAX was designed and put into operation at the Institute for Nuclear Equipment IPJ.

The main purpose of the computerisation of the simulator was, together with the improvement of the precision of medical care planning, to increase the average number of patients examined with the assistance of the simulator during the year. In comparison with the POLEX simulator manufactured hitherto, the new design has the following advantages:

1. Better mechanical parameters: the size of the radiation field in the plane of the isocenter has been increased from 40 x 40 cm to 43 x 45 cm, while the margin of the cross movement of the image amplifier was increased from 26 to 30 cm. The scope of the movement of the amplifier in the Z axis has been increased from 50 to 60 cm, which facilitates the simulation of radiation being applied, the distance between the source and skin equal to 100 cm (also for thick patients).
2. Better precision of the read out of the geometric parameters:

	POLEX	SIMAX
Distance source-isocenter	+/- 2mm	+/- 1mm
Distance film-isocenter	+/- 2mm	+/- 1mm
Dimension of simulated radiation field	+/- 3mm	+/- 1.5mm
Arm rotation angle	+/- 1°	+/- 0.5°
Angle of table isocentric rotation	+/- 1°	+/- 0.5°

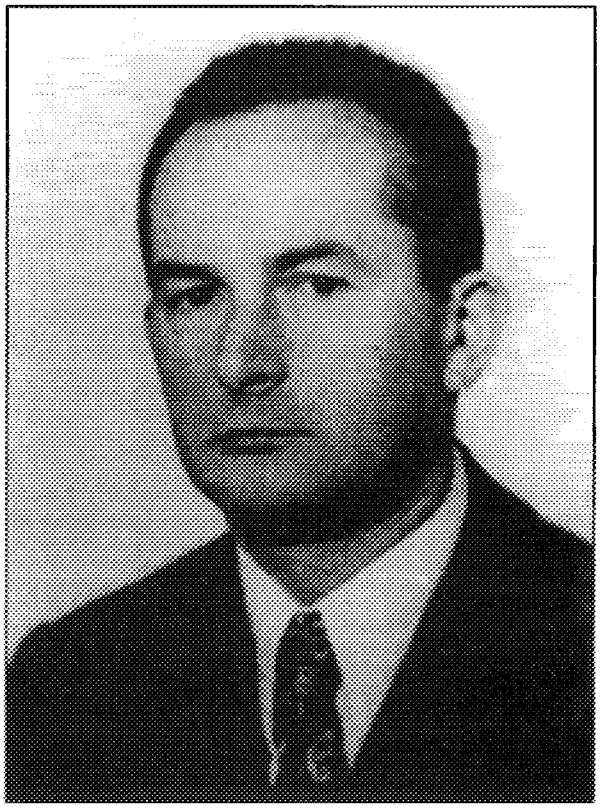
3. The possibility of co-operation with the Care Planning Division. The geometrical parameters initially planned may be copied automatically from the database as set values. Also the data concerning patients are subject to automatic copying. All set values are realised simultaneously after pressing the button. After the correction of these parameters during the examination the final set-up is recorded - also automatically - as the result of the simulation.
4. The possibility of carrying out standard settings pre-defined by the user in the radiation of particular organs.
5. Signalling of operator errors in the case of recording of the parameters incorrect for the selected therapeutic appliance or installation of improper screen shelves.

6. Rapid service procedures: loading and unloading of the patient, realisation of opposite fields.
7. A computer anti-collision system acting on the basis of the analysis of read-outs of the situation.
8. A digital memory of the image integrated with managing and data recording systems, facilitating the recording on the disk of the images of roentgen photo together with the data concerning the patient to be copied automatically, session and field number as well as date of image freezing.

It is possible to measure the real distances, angles and surfaces in the isocenter plane on the stopped image, while considering the situation of the roentgen lamp and image amplifier memorised in the moment of stopping.

III. OBITUARIES

PROFESSOR RYSZARD RĄCZKA (1931-1996)



Ryszard Rączka died on August 26, 1996. At the time he was the Chairman of our Scientific Council.

Ryszard was born in Warsaw in 1931, where he was also educated. His stay at Warsaw University was interrupted in 1953 for political reasons that are difficult to understand in a free society. However, he finally completed his studies and spent two years at the Dubna Nuclear Institute near Moscow. Since 1965 he was closely associated with the International Centre of Theoretical Physics in Trieste. Here began his collaboration with Asim Barut, resulting in work on the geometrical modelling of relativistic particles. This developed into, a comprehensive study of the use of group theory in physics. Ryszard co-authored the important book Theory of group representations and applications, in 1977. This monograph was a standard reference book for a long time and was reprinted in 1988.

Ryszard's later work was in field theory and particle physics. He was intellectually ambitious, hoping to improve on perturbative QCD by formulating a superior, nonperturbative model. He visited France, Germany and Italy on a regular basis, establishing broad collaborations between Poland and Western Europe. In particular, he organized a series of Polish-German symposia on fundamental interactions.

Although Ryszard's research and especially his book with Barut will keep his name alive for a long time to come, many people will remember him foremost as a splendid person. Although persecuted in his youth, he was completely devoid of spite. He had deep feelings of sympathy for the suffering of others and often managed to help. As head of the Nuclear Theory Department under martial law he tried desperately to keep our group together. Against all odds, he was partially successful.

Ryszard Rączka was that rare combination, a first rate scientist and an active, humane man.

Eryk Infeld

PROFESSOR JERZY WDOWCZYK (1935 - 1996)

Professor Jerzy Wdowczyk, a distinguished cosmic ray physicist, died in Łódź on September 6, 1996.

Jerzy Wdowczyk was born in Sośnica in central Poland on July 28, 1935. He finished the Pedagogical High School in Krotoszyn and worked as a teacher in a primary school for three years. Afterwards he began to study physics at the University of Łódź, where he graduated in 1960. After completing his studies he joined the extensive air shower (EAS) group led by Professor Aleksander Zawadzki, who started cosmic ray research in Łódź.

Studies of different aspects of EAS development in the atmosphere became one of the main areas of J. Wdowczyk 's scientific research. The aim of his work was to get information about the nature of the particle which initiated the shower and about properties of high energy interaction. In 1964 he got his PhD for work on the muon content in showers induced by a photon. Next he worked on fluctuations of the muon and electron densities observed on the ground and their dependence on the mass of the primary particle. This work was the basis of his habilitation in 1972. When in 1968 Prof. Aleksander Zawadzki was forced to stay abroad, J. Wdowczyk took over the leadership of the Łódź cosmic ray group. Since then he worked in the Institute for Nuclear Research (and then Soltan Institute for Nuclear Studies), from 1972 as an associate professor and from 1978 as a professor. All the time he was closely bound with Łódź University, where he gave lectures and seminars. He was the supervisor of many PhD and MA theses. He was the Chairman of the Scientific Council of SINS in the period 1987 - 1991. From 1992 he held the Chair of the Experimental Physics Division of Łódź University.

He collaborated with many cosmic ray laboratories in England, France, Germany and Russia. Among all his collaborations the most important one was with prof. Arnold Wolfendale's group at the University of Durham (England). The research performed with the Durham group related to all aspects of cosmic ray physics, from properties of high energy interactions to astrophysics (famous scaling breaking hypothesis' of Wdowczyk and Wolfendale).

J.Wdowczyk published around 180 scientific papers and gave around 150 contributions to different international cosmic ray conferences and symposiums, many of which he organized or chaired. He actively worked in the Cosmic Ray Commission of IUPAP, first as its member from 1981 to 1987, then its Secretary (1987-1990) and finally as its Chairman (1990-1993). From 1960 he was a member of the Polish Physical Society, where he served for several years as a member of the Main Council. He was a member of the British Royal Astronomical Society and the American Physical Society. He was awarded the Maria Curie-Skłodowska prize in 1979 and the prize of the Committee for Atomic Energy in 1976. In 1985 the University of Durham awarded him the degree of Doctor of Science *(honoris causa)*.

J. Wdowczyk was a man of great enthusiasm for science and of high personal authority. He was one of the founders of cosmic ray research in Poland. He left a group of collaborators and pupils, who shall continue his work. This will be the best tribute that can be paid to his memory.

Jerzy Gawin

IV. AUTHOR INDEX