

INSTYTUT PROBLEMÓW JĄDROWYCH im. Andrzeja Sołtana THE ANDRZEJ SOŁTAN INSTITUTE FOR NUCLEAR STUDIES





INIS-PL- - 2005-0004

INSTYTUT PROBLEMÓW JĄDROWYCH im. Andrzeja Sołtana The Andrzej Sołtan INSTITUTE FOR NUCLEAR STUDIES

ANNUAL REPORT 2004

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Printed by

ISSN 1232-5309

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FOREWORD

There is always a temptation while writing a Foreword to the Annual Report of a big research institute to address the big issues of the scientific policy in the country in which you operate. The declared policy in our country is to follow the Lisbon declaration, to increase the funding of research at an accelerating pace, so as to reach soon the goal of 3% of GNP. Along with that declaration, there is a steady decrease of the funding, the present state budget providing about 0,3% GNP with some wishful thinking about the private industry doing the rest. No comments. We can invite foreigners for various survival courses, fashionable in extreme sports but less attractive in normal daily life.

There is a question of mission for a large, multi-disciplinary institute like ours in a country like Poland to-day, undergoing the convulsions of transformation and urgently trying to catch-up with the world of wealth , the world of hi-tech. Personally, I am convinced that we have such a mission, that there is an important role to fill in a modern society for an institute of our type: a fair size national laboratory with a fifty-fifty share of basic research and of R&D, being a natural research back-up for high technology development as well as an important contributor to the cultural and educational advancement of the country.

Within the present organization of scientific research in Poland our mission should and could best be carried out under the auspices of the Polish Academy of Sciences. I hope that the rather artificial difficulties in the transfer of our Institute from our present formal supervising body, the Ministry of Economic Affairs and Labour, to the Academy will eventually be removed and the transfer will finally take place.

We try to pursue our mission within the limited resources we have, the best we can. I invite the reader to glance through the pages of this Report to hopefully find confirmation of this. A few highlights as well as some trends worth noting are listed below:

• There were 217 papers published in the high ranking journals listed by the Philadelphia Institute of Physics. Our yearly internal awards in the basic research category were won by the work on Majorana neutrinos (Contrib. 8.7), on timing the nuclear reactions (contrib. 2.2) and on plasma spectroscopy (contrib. 5.7). In the technical category the winning work was that on detectors for astrophysical observations (contrib. 6.18), on the jet counter for measuring ionization clusters (contrib.4.2), on the new techniques of coating bulk copper of various shapes with thin superconducting layers (contrib. 5.8) and on the network of detectors for high energy cosmic ray showers (contrib. 7.6). These are placed in various secondary schools in the Łódź district and are operated by school pupils which in itself is a major sociological and educational achievement.

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- We note some success in gaining the EU contracts, notably those for technical applications of plasma techniques, for developing new methods of detecting the illicit traffic of dangerous or strategic materials and for contributing to new detectors at CERN.
- The age structure of our staff has slightly improved thanks to hiring twelve junior scientists, four of them on international contracts
- There are a few research trends at our institute worth noting. On the one hand, we wish to strengthen our involvement in such fields of applied nuclear sciences as the medical physics, the environmental issues and, last but not least, the boarder controls and safety problems. All these fields have rather obvious social priorities, well recognized by the EU and gaining recognition also in Poland. As a measure in this direction we have formed a new department of "Interdisciplinary Physics Implementation". This was achieved by fusion of the former departments of nuclear spectroscopy and techniques and of radiation shielding and dosimetry. The work envisaged is no doubt a major challenge for all the colleagues of the new department. But it also offers an important opportunity. I wish the new leader of this group, dr. Piotr Szymański, a big success in using this opportunity.
- A major trend in the basic research in subatomic physics is to join forces with astrophysicists and astronomers. Responding to this trend we take active part in building large neutrino detectors or in hunting for the extra galactic Gamma-Ray-Bursts (see our previous Annual Report as well as the cover of this one).
- An active group of our theoreticians led by Włodek Piechocki has embarked on a new ambitious cosmological project. We all wish them quick progress!

I have begun this Foreword with revoking *our mission*. This mission gets an added dimension recently in view of the planned return to the nuclear energy in Poland. For the years to come, this task has a mainly educational character. With the expertise we have, with the large team of researchers of highest qualifications, with our very active department of Training and Consulting I daresay we are well prepared to undertake this task.

Have a good reading!

Fremenist Suy las noto

Professor Ziemowid Sujkowski

I. GENERAL INFORMATION

The Institute is a state owned laboratory. It conducts pure and applied research on subatomic physics, i.e. elementary particle, low and high energy nuclear physics, plasma physics and related fields.

The Institute specializes in accelerator physics and technology, material research with nuclear techniques, the development of spectrometric techniques, nuclear electronics and also in applications of nuclear techniques to environmental research, nuclear medicine etc.

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

The main site of the Institute is Świerk near Otwock, but some of its departments (P-I, P-VI, P-VIII) are located 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.

1. MANAGEMENT OF THE INSTITUTE

Director

Professor Ziemowid SUJKOWSKI phone: (22) 718-05-83 e-mail: sujkowsk@ipj.gov.pl

Deputy Director, Research and Development

Professor Marek MOSZYŃSKI phone: (22) 718-05-86 e-mail: marek@ipj.gov.pl

Scientific Secretary

Dr. Danuta CHMIELEWSKA phone: (22) 718-05-85 e-mail: danka@ipj.gov.pl

2. SCIENTIFIC COUNCIL

The Scientific Council was elected on the 28th of October 2003 by the scientific, technical and administrative staff of the Institute. The Council has the right to confer PhD and habilitation degrees in physics (DSc).

Representatives of scientific staff:

Helena Białkowska, Assoc.Prof., Deputy Chairman Ludwik Dobrzyński, Professor Marian Jaskóła, Professor Rościsław Kaczarowski, Assoc.Prof. Robert Kiełsznia, Dr. Ryszard Kisiel, Dr. Leszek Łukaszuk, Professor, Deputy Chairman Marek Moszyński, Professor

Jan Nassalski, Professor Krzysztof Rusek, Assoc. Prof. Adam Sobiczewski, Professor Ryszard Sosnowski, Professor, Chairman Ziemowid Sujkowski, Professor Sławomir Wronka, Dr. Janusz Wilczyński, Professor, Deputy Chairman

Representatives of technical personnel:

Robert Hornung, MSc. Jan Kopeć, Eng. Jerzy Marjanowski, MSc. Jacek Pracz, MSc. Krystyna Traczyk, MSc.

External members:

Andrzej Budzanowski, Professor	-	Institute of Nuclear Physics, (IFJ-PAN), Cracow
Katarzyna Chałasińska-Macukow, Professor	-	Institute of Geophysics, Warsaw University
Tomasz Czosnyka, Assoc.Prof.	-	Heavy Ion Laboratory, Warsaw University
Danuta Kisielewska, Professor	-	University of Minning and Metalurgy, Cracow
Wojciech Królikowski, Professor	-	Institute of Theoretical Physics, Warsaw University
Zbigniew Kulka, Professor	-	Warsaw Technical Institute
Julian Malicki, Assoc. Prof.	-	Greatpoland Cancer Center, Poznań
Marek Pajek, Professor	-	Institute of Physics, Świętokrzyska Academy, Kielce
Stanisław Rohoziński, Professor	-	Institute of Theoretical Physics, Warsaw University
Michał Waligórski, Professor	-	Institute of Oncology, Cracow

Institute of Oncology, Cracow

3. DEPARTMENTS OF THE INSTITUTE

- NUCLEAR REACTIONS (P-I) Head of Department – Assoc. Prof. Krzysztof RUSEK
- NUCLEAR SPECTROSCOPY AND TECHNIQUE (P-II) Head of Department - Dr Jan SERNICKI
- DETECTORS AND NUCLEAR ELECTRONICS (P-III) Head of Department – Assoc. Prof. Zbigniew GUZIK
- RADIATION SHIELDING AND DOSIMETRY (P-IV) Head of Department - Dr Stanisław PSZONA
- PLASMA PHYSICS AND TECHNOLOGY (P-V) Head of Department - Professor Marek SADOWSKI
- HIGH ENERGY PHYSICS (P-VI) Head of Department - Assoc. Prof. Helena BIAŁKOWSKA
- COSMIC RAY PHYSICS (P-VII) Head of Department – Dr Jacek SZABELSKI
- NUCLEAR THEORY (P-VIII) Head of Department – Professor Grzegorz WILK
- MATERIAL STUDIES (P-IX) Head of Department – Assoc. Prof. Zbigniew WERNER
- ACCELERATOR PHYSICS AND TECHNOLOGY (P-X) Head of Department – Dr Eugeniusz PŁAWSKI

Other units:

- DEPARTMENT OF TRAINING AND CONSULTING Director - Professor Ludwik DOBRZYŃSKI tel.718-06-12, 718-05-71
- ESTABLISHMENT FOR NUCLEAR EQUIPMENT (ZdAJ) Director, MSc. Jacek PRACZ tel.718-05-00, 718-05-02
- TRANSPORT DIVISION (ZTS) Director, Civ. Eng. Bogdan GAS

tel.718-06-16, fax 048-22-718-06-15

4. SCIENTIFIC STAFF OF THE INSITUTE

PROFESSORS

BŁOCKI Jan (**)
 DĄBROWSKI Janusz (**)
 DOBRZYŃSKI Ludwik
 INFELD Eryk
 JASKÓŁA Marian
 ŁUKASZUK Leszek
 MARCINKOWSKI Andrzej
 MOSZYŃSKI Marek
 MRÓWCZYŃSKI Stanisław (**)
 NASSALSKI Jan
 PIEKOSZEWSKI Jerzy
 SADOWSKI Marek
 SIEMIARCZUK Teodor
 SOBICZEWSKI Adam

15. SOSNOWSKI Ryszard

STEPANIAK Joanna
 SUJKOWSKI Ziemowid
 SZEPTYCKA Maria
 TUROS Andrzej (**)
 WILCZYŃSKI Janusz
 WILK Grzegorz
 WYCECH Sławomir

CONTRACT PROFESSORS

1. ŻUPRAŃSKI Paweł

Theoretical Nuclear Physics Theoretical Nuclear Physics Solid State Physics Plasma Physics and Nonlinear Dynamics Low Energy Nuclear Physics Particle Physics Low Energy Nuclear Physics Nuclear Electronics, Technical Physics **Particle Physics** Particle Physics Solid State Physics **Plasma Physics** Particle and High Energy Nuclear Physics Theoretical Physics, Member of the Polish Academy of Sciences Particle Physics, Member of the Polish Academy of Sciences High Energy Nuclear Physics Nuclear and Particle Physics **Particle Physics** Solid State Physics Low Energy Nuclear Physics **Particle Physics** Nuclear and Particle Physics

High Energy Nuclear Physics

ASSOCIATE PROFESSORS and DSc

- 1. BIAŁKOWSKA Helena
- 2. DELOFF Andrzej (**)
- 3. GUZIK Zbigniew
- 4. JAGIELSKI Jacek (**)
- 5. KACZAROWSKI Rościsław
- 6. KIEŁCZEWSKA Danuta (**)
- 7. PIECHOCKI Włodzimierz
- 8. RONDIO Ewa
- 9. RUSEK Krzysztof
- 10. SANDACZ Andrzej
- 11. SKALSKI Janusz
- 12. SŁAPA Mieczysław (**)
- 13. SZCZEKOWSKI Marek
- 14. SZYMANOWSKI Lech
- 15. WERNER Zbigniew
- 16. WIBIG Tadeusz (**)

High Energy Nuclear Physics Particle Physics Nuclear Electronics Solid State Physics Low Energy Nuclear Physics Particle Physics Particle Physics Particle Physics Low Energy Nuclear Physics Particle Physics

Theoretical Nuclear Physics Solid State Physics

Particle Physics

Theoretical Nuclear Physics Solid State Physics

Cosmic Ray Physics

- 17. WIŚLICKI Wojciech
- 18. WROCHNA Grzegorz
- 19. ZABIEROWSKI Janusz
- 20. ZWIĘGLIŃSKI Bogusław

RESEARCH STAFF

- 1. ADAMUS Marek
- 2. AUGUSTYNIAK Witold
- 3. BALCERZYK Marcin
- 4. BARLAK Marek (**)
- 5. BATSCH Tadeusz
- 6. BIEŃKOWSKI Andrzej (**)
- 7. BORSUK Stanisław
- 8. CHARUBA Jacek
- 9. CHMIELEWSKA Danuta
- 10. CHMIELOWSKI Władysław (*)
- 11. CZARNACKI Wiesław
- 12. GIERLIK Michał
- 13. GOKIELI Ryszard
- 14. GOLDSTEIN Piotr
- 15. GÓRSKI Maciej
- 16. JAKUBOWSKI Lech (**)
- 17. KORMAN Andrzej
- 18. KOWAL Michał
- 19. KOZŁOWSKI Tadeusz
- 20. KUPŚĆ Andrzej (*)
- 21. KUREK Krzysztof
- 22. LANGNER Jerzy
- 23. MARIAŃSKI Bogdan
- 24. MUNTYAN Igor
- 25. MYSŁEK-LAURIKAINEN Bogumiła
- 26. NAWROT Adam (**)
- 27. NOWICKI Lech
- 28. PATYK Zygmunt
- 29. PAWŁOWSKI Marek
- 30. PŁAWSKI Eugeniusz
- (*) on leave of absence
- (**) part-time employee
- (†) deceased Dec.25

- Particle Physics Particle Physics Cosmic Ray Physics Nuclear Physics
- 31. PŁÓCIENNIK Weronika (†)
- 32. POLAŃSKI Aleksander (*)
- 33. PREIBISZ Zygmunt (**)
- 34. PSZONA Stanisław
- 35. RABIŃSKI Marek
- 36. ROŻYNEK Jacek
- 37. RUCHOWSKA Ewa
- 38. RZADKIEWICZ Jacek
- 39. SENATORSKI Andrzej (**)
- 40. SERNICKI Jan
- 41. SKŁADNIK-SADOWSKA Elżbieta (**)
- 42. SKORUPSKI Andrzej (**)
- 43. SMOLAŃCZUK Robert
- 44. SOWIŃSKI Mieczysław (**)
- 45. SPALIŃSKI Michał
- 46. STONERT Anna
- 47. SZABELSKA Barbara
- 48. SZABELSKI Jacek
- 49. SZLEPER Michał (*)
- 50. SZYDŁOWSKI Adam
- 51. SZYMAŃSKI Piotr (*)
- 52. SZYMCZYK Władysław
- 53. TRZCIŃSKI Andrzej
- 54. UTYUZH Oleg
- 55. WINCEL Krzysztof
- 56. WOJTKOWSKA Jolanta (**)
- 57. WOLSKI Dariusz
- 58. WYSOCKA Anna
- 59. ZALEWSKI Piotr
- 60. ZYCHOR Izabella

5. VISITING SCIENTISTS

1.	Petkov V.B.	Inst. for Nuclear Research, RAS, Moscow, Russia	Jan.17-Feb.15	P-VII
2.	Dzaparova I.M.	Inst. for Nuclear Res. RAS, Moscow, Russia	Jan.17-Feb.15	P-VII
3.	Chomaz P.	GANIL, France	Jan.26-Feb.1	P-I
4.	Giot L.	GANIL, France	Jan.26-Feb.1	P-I
5.	Romanyshyn V.	Inst. for Nucl. Research, Kiev, Ukraine	Jan.19-Feb.8	P-I
6.	Koshchy E.	Kharkiv State University, Ukraine	Jan.19-Feb.12	P-I
7.	Tsarenko A.	Inst. of Plasma Physics, Ukraine	Feb.16-March 27	P-V
8.	Romanyshyn V.	Inst. for Nucl. Research, Kiev, Ukraine	March 18-April 16	P-I
9.	Klamra W.	Royal Inst. of Technology, Stockholm, Sweden	March 23-April I	P-III
10.	Garrido F.	Centre de Spectrométrie Nucléaire et de	May 3-23	P-I
		Spectrométrie de Masse, Orsay, France		
11.	Willis B.	Oxford University, Oxford, UK	May 3-4	P-I
12.	Cooper R.	Oxford University, Oxford, UK	May 3-4	P-I
13.	Morsch P.	Forschungszentrum Jülich GmbH, Germany	May 18-19	P-III
14.	Kilian K	Forschungszentrum Jülich GmbH, Germany	May 18-19	P-III
15.	Werner G	Forschungszentrum Julich GmbH, Germany	May 18-19	P-III
16.	Schnell G.	DESY, Hamburg, Germany	May 24-29	P-I
17.	Lavoute P.	Photonis, Brive, France	June 13	P-III
18.	Roy A.	Centre de Seclay, France	June 23	P-V
19.	Capdevielle J.N.	Collège de France, Paris, France,	June 16-30	P-VII
20.	Cohen F.	Collège de France, Paris, France	June 16-28	P-VII
21.	Rowlands G.	University of Warwick, UK	July 9-15	P-VIII
22.	Marmonier C.	Photonis, Brive, France	July 13	P-III
23.	Jorjadze G.	Tbilisi State University, Georgia	July 27-Aug. 8	P-VIII
24.	Tsarenko A.	Institute of Plasma Physics, Kharkiv, Ukraine	Sept.6-10	P-V
25.	Pavilchenko O.	Institute of Plasma Physics, Kharkiv, Ukraine	Sept.6-10	P-V
26.	Weisen H.	Politechnique Federale de Lausanne, Switzerland	Sept.15	P-V
27.	Baluc N.	Politechnique Federale de Lausanne, Switzerland	Sept.15	P-V

28.	Keeley N.	Centre d'Etudes de Saclay, Saclay, France	Sept.20-27	P-I
29.	Amato E.	University di Messina, Italy	Sept.29	P-V
30.	Jacobsson R.	CERN, Geneva, Switzerland	Sept.21-24	P-III
31.	Enberg R.	Ecole Politechnique Saclae, France	Sept.27-Oct.2	P-VIII
32.	Klamra W.	Royal Inst. of Technology, Stockholm, Sweden	Nov.2-10	P-III
33.	Tsarenko A.	Institute of Plasma Physics Ukraine	Nov.2-Dec.16	P-V
34.	Petrotchenkov S.A	. JINR, Dubna, Russia	Nov.16-Dec.17	P-VII
35.	Trautmann W.	GSI, Darmstadt, Germany	Nov.18–22	P-1
36.	Capdevielle J.N.	Collège de France, Paris, France	Nov.28-Dec.12	P-VII
37.	Guryna W.	Brookhaven National Laboratory, USA	Dec.5-12	P-VI
38.	Morozov	Inst. of Theoretical and Experimental Physics,	Dec-5-12	P-VI
		Moscow, Russia		
39.	Hancke K.	Target, Solingen, Germany	Dec.17	P-III
40.	Pausch G.	Target, Solingen, Germany	Dec.17	P-III

6. GRANTS

LIST OF RESEARCH PROJECTS (GRANTS) REALIZED IN 2004 Granted by State Committee for Scientific Research (KBN)

- INTERACTION OF HIPERONS WITH ATOMIC NUCLEI AND THE HYPERON-NUCLEON INTERACTION Principal Investigator: Prof. J. Dąbrowski No. 2P03B07522
- PROPERTIES OF HEAVY AND SUPER-HEAVY NUCLEI Principal Investigator: Prof. A. Sobiczewski No. 2P03B03922
- THEORY OF NUCLEAR SYNTHESIS Principal Investigator: Dr. R. Smolańczuk No. 2P03B04622
- DYNAMICS OF RELATIVISTIC NUCLEAR AND HADRONIC COLLISIONS IN THE CERN SPS ENERGY RANGE. EXPERIMENT NA49 Principal Investigator: Prof. H. Białkowska No. 2P03B13023
- EXPERIMENTAL AND CALCULATIONAL ANALYSIS OF ABSORBED DOSE DISTRIBUTION IN CORONARY TISSUE OF THE PATIENTS TREATED WITH P-32 RADIOACTIVE SOURCE Principal Investigator: Dr. St. Pszona No. 3P05C06522
- 6. INFLUENCE OF MULTIPLE IONISATION AND SHELL COUPLINGS ON L SERIES X RAY EMISSION EXCITED WITH HEAVY IONS Principal Investigator: Prof. M. Jaskóła No 2P03B03824
- DETERMINATION OF GLUON POLARISATION IN PROTON ON THE BASIS OF EXPERIMENT COMPASS Principal Investigator: Prof. J. Nassalski No 2P03B11425
- SELECTION OF PHOTO-GLUON FUSION IN MION-NUCLEON INTERACTIONS WITH PRODUCTION OF HADRONS WITH GREAT TRANSVERSE MOMENTUM Principal Investigator: Prof. E. Rondio No 2P03B10725
- INVESTIGATION OF OPTICAL FLASHES ACCOMPANYING GAMMA-RAY BURSTS Principal Investigator: Assoc. Prof. G. Wrochna No. 2P03B03825
- REGISTRATIONS OF DELAYED PARTICLES IN EXTENSIVE AIR SHOWERS: STUDIES OF THE HADRONIC COMPONENT AND SEARCH FOR EXOTIC PARTICLES Principal Investigator: Dr. J. Szabelski No. 1P03B01426
- INVESTIGATION OF COSMIC RADIATION IN THE PRIMARY ENERGY RANGE 10¹⁵ 5x10¹⁷ eV WITH EXTENSIVE AIR SHOWERS REGISTERED BY KASCKADE-GRANDE EXPERIMENT, OPERATING IN FORSCHUNGSZENTRUM IN GERMANY Principal Investigator: Assoc. Prof. J. Zabierowski No. 1P03B03926

- A STUDY OF NEUTRINO PROPERTIES IN THE SUPER-KAMIOKANDE DETECTOR Principal Investigator: Assoc. Prof. D. Kiełczewska No 1P03B03826
- STUDY OF ENERGY RESOLUTION OF SCINTILLATON DETECTORS FOR NUCLEAR RADIATION Principal Investigator: Prof. M. Moszyński No. 3T10C01026
- SYNTHESIS AND FISSION DYNAMICS OF THE HEAVIEST NUCLEI Principal Investigator: Assoc. Prof. J. Skalski No. IP03B06427

In addition to the above, several of our scientists are principal investigators in grants coordinated by other institutions.

RESEARCH PROJECTS GRANTED BY FOREIGN INSTITUTIONS

- DESIGN, CONSTRUCTION AND TESTING OF A PROTOTYPE OF A LINEAR ARC SOURCE FOR COATING OF COPPER CAVITIES WITH NIOBIUM Principal Investigator: Dr. J. Langner Agreement with DESY, Hamburg, Appendix No 6
- COLLABORATION IN THE THEORETICAL AND EXPERIMENTAL STUDIES OF SUPERHEAVY NUCLEI Principal Investigator: Prof. A. Sobiczewski JINR Dubna, Order 438, 18
- PARTICIPATION IN DESIGNING AND TESTING OF PHOTOMULTIPLIERS Principal Investigator: Prof. M. Moszyński Contract of PHOTONIS, Brive, France
- DESIGN AND TESTING OF A STRIPE DETECTOR Principal Investigator: Dr. T. Batsch Order No. 110/41537762/251
- COMPARATIVE STUDY OF NEW SCINTILLATION MATERIALS IN APPLICATION TO THE BORDER DETECTION EQUIPMENT Principal Investigation: Prof. M. Moszyński Contract IAEA No. 12596/NSM-donors F
- THE CONSULTANCY IN THE FIELD OF SCINTILLATOR CRYSTAL ANALYSIS BY NUCLEAR SPECTROMETRY Principal Investigator: Prof. M. Moszyński Contract No Sc 186697, Agreement with Photonic Materials Ltd., Glasgow
- THE EXPLORATION OF CWO AS A POSSIBLE SCINTILLATOR MATERIAL FOR HANDHELD ISOTOPE IDENTIFIERS Principal Investigator: Prof. M. Moszyński Contract target systemelectronic gmbh, Solingen
- NEUTRON PULSE SHAPE DISCRIMINATOR BOX Principal Investigator: D. Wolski Order No. 200392

RESEARCH PROJECTS (INDIRECT ACTIONS) GRANTED BY THE EUROPEAN COMMISSION

- DEVELOPMENT OF GRID ENVIRONMENTAL FOR INTERACTIVE APPLICATIONS (CROSS GRID) Responsible for the work: Assoc. Prof. W. Wiślicki No. IST-2001-32243, The Fifth Framework Programme of EU
- NUPEX: A WEB-BASED SCIENCE COMMUNICATION SYSTEM FOR NUCLEAR SCIENCE AND ITS APPLICATIONS Responsible for the work: Prof. L. Dobrzyński Contract No HPRP-CT-2002-00006, The Fifth Framework Programme of EU
- RESEARCH AND DEVELOPMENT ON SUPERCONDUCTING RADIO-FREQUENCY CAVITIES FOR ACCELERATING SYSTEMS Task Leader: Dr. J. Langner Responsible for the work: Prof. M. Sadowski Contract No. RII3-CT-2003-506395, The Sixth Framework programme of EU
- RECOIL DETECTOR PROTOTYPE FOR COMPASS Task Leader and Responsible for the work: Prof. J. Nassalski Contract No. RII3-CT-2004-506078/JRA5, The Sixth Framework programme of EU
- MOLECULAR IMAGING FOR BIOLOGICALLY OPTIMIZED CANCER THERAPY "BIO-CARE" Responsible for the work: Prof. M. Moszyński Contract No. LSHC-CT-2004-505785, The Sixth Framework programme of EU
- EUROPEAN ILLICIT TRAFFICKING COUNTERMEASURES KIT "EURITRACK" Responsible for the work: Prof. M. Moszyński Contract No. STREP-2004-511471, The Sixth Framework Programme of EU
- PROTOTYPE OF THE ELECTROMAGNETIC CALORIMETER FOR THE PANDA DETECTOR Responsible for the work: Assoc. Prof. B. Zwięgliński Contract No. RII3-CT-2004-506078/JRA2, The Sixth Framework programme of EU

7. DEGREES

PhD theses

- BOŻENA BOIMSKA (Institute for Nuclear Studies, Otwock-Świerk) Transverse characteristics of hadron production in elementary and nuclear collisions at the CERN SPS energies.
- 2. JAROSŁAW CHOIŃSKI (Heavy Ion Laboratory, Warsaw University) Electromagnetic structure and beam dynamics of the Warsaw U-200P cyclotron.
- 3. KRZYSZTOF KARPIO (Institute for Nuclear Studies, Otwock-Świerk) Bose-Einstein correlations of π^+ - mesons from Pb+Pb collisions at 158 A GeV.
- KATARZYNA KOWALIK (Institute for Nuclear Studies, Otwock-Świerk)
 Selection of the photon gluon fusion process by requiring high-p_T hadrons in muon nucleon scattering.

DSc theses

1. WŁODZIMIERZ PIECHOCKI (Institute for Nuclear Studies, Otwock-Świerk) Quantum dynamics of test particle in curved space - time.

8. CONFERENCES AND WORKSHOPS ORGANIZED OR COORGANIZED BY IPJ

- 1. HERMES COLLABORATION MEETING Kazimierz Dolny, Poland, June 25 – July 1, 2004
- 2nd GERMAN-POLISH CONFERENCE ON PLASMA DIAGNOSTIC FOR FUSION AND APPLICATIONS Cracow, Poland, September 8 – 10, 2004

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II. REPORTS ON RESEARCH

1 DEPARTMENT OF NUCLEAR REACTIONS

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Overview

It is surprising how so few under-paid scientists could do so much. During 2004 the number of papers published or being in press exceeded fifty, making almost three papers per person employed in our department. Furthermore, among these papers one was published in *Nature*, the World's highest-ranked scientific journal. This is a result that will be difficult to beat. It is my pleasure to mention that one of our PhD students, Mr Sergiy Mezhevych, won a prestigious Heavy Ion Laboratory Prize founded by Prof. Inamura, for his experimental work using a beam from the Warsaw Cyclotron.

Thanks to the effort of our colleagues the Hermes Collaboration Meeting organized by IPJ in Kazimierz Dolny (June 25 – July 1) turned out a success.

The following short reports cover the three major domains of our scientific activities: nuclear, materials and atomic physics.

Nuclear physics

The structure of light nuclei, including exotic radioactive isotopes, was investigated both experimentally and theoretically. Some experimental studies were performed at the Heavy Ion Laboratory of Warsaw University in collaboration with scientists from the Institute of Nuclear Research in Kiev, Ukraine. The two reports present interesting results for the rare carbon isotope, ¹⁴C.

In the framework of Feshbach, Kerman and Koonin theory the multistep emission of one particle as well as more complicated direct processes were studied. It was found that these more complex processes play an important role in proton induced reactions.

Experimental data from projectile-multifragmentation experiments with stable and radioactive beams were analysed. Some preliminary results are presented.

Using a proton beam provided by the C-30 compact cyclotron at Świerk, detectors consisting of a PWO scintillator coupled to avalanche photodiodes were tested. The aim of these tests was to find the best detectors for the large electromagnetic calorimeter which will be used in future PANDA Collaboration experiments.

In the series of four short contributions, recent experimental results from the HERMES Collaboration are presented. Particulary important are the results on the quark transverse spin polarisation in the nucleon. The Hermes experiments have found evidence of nonvanishing quark transverse polarisation and have provided an indication for a nonzero orbital angular momentum of quarks in the nucleon.

Atomic physics

The L-shell ionisation cross sections for atoms of some heavy elements were measured. The results are presented and compared to different model calculations.

Materials research

Our group of scientists performed many experimental studies using low-energy p-, d- and α - beams from the van de Graaff accelerator of the Department which were commissioned by other institutions. In this Annual Report the results of experiments devoted to studying damage buildup and recovery of compound semiconductors are presented. The experiments were performed at the Friedrich Schiller University of Jena, in collaboration with local scientists.

Our involvement in education and science popularization has become a tradition. Students of Warsaw High Schools and of Warsaw University attended in 2004 many lectures given by Dr. Andrzej Korman & Dr. Lech Nowicki on nuclear physics, accelerators, detectors and nuclear methods in solid state physics.

Our contribution to the 8th Scientific Picnic and the 11th Science Festival is also worth mentioning.

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1.1 Quadrupole Deformation of ${}^{14}C$ from the ${}^{11}B + {}^{14}C$ Scattering

by S.Yu.Mezhevych¹⁾, K.Rusek, A.T.Rudchik¹⁾, A.Budzanowski²⁾, B.Czech²⁾, J.Choiński³⁾, L.Głowacka⁴⁾, S.Kliczewski²⁾, E.I.Koshchy⁵⁾, V.M.Kyryanchuk¹⁾, A.V.Mokhnach¹⁾, A.A.Rudchik¹⁾, S.B.Sakuta⁶⁾, R.Siudak²⁾, I.Skwirczyńska²⁾, A.Szczurek²⁾

Angular distributions for ${}^{11}\text{B} + {}^{14}\text{C}$ elastic and inelastic scattering for transitions to a few excited states of ${}^{14}\text{C}$ were measured at $E_{lob}({}^{11}\text{B}) = 45$ MeV over the full angular range. The beam of ${}^{11}\text{B}$ ions was accelerated in the cyclotron U-200P of the Heavy Ion Laboratory of Warsaw University. The experimental data were analyzed within the coupled-channels method (CC).

The collective model for the transitions to the excited states of ¹⁴C was assumed. The optical model (OM) potential for the ${}^{11}B + {}^{14}C$ system was taken to be of the standard complex form V(r)+iW(r), with the real part generated by means of the double folding method using known densities of the ¹¹B and ¹⁴C nuclei. Nucleon-nucleon interaction was taken to be of the standard M3Y form. The imaginary part of the potential was assumed to be of the Woods-Saxon form with the parameters: W = 5.3 MeV, $r_w = 1.450$ fm and $a_w = 0.670$ fm. The coupling scheme used in the CC calculations is shown in Fig. 1, reorientation of the $^{11}B_{g.s.}$ was also included. Form factors for collective model transitions were chosen as the first derivative of the OM potential multiplied by the deformation length δ_{λ} . The values of the deformation lengths for transitions to the excited states of ¹⁴C were deduced from the fit to the experimental data at forward angles.

The results of the CC calculations for the transition to the 2⁺ (7.012 MeV) state are shown in Fig. 2. Following Ref. [1], this state was assumed to be the member of the ground state rotational band with the positive quadrupole deformation. From the fit to the experimental data at forward angles (short-dashed curve in Fig. 2) a value of $\delta_2 = 0.8$ fm was deduced. However, a phase mismatch was observed between the short-dashed curve and the experimental data in the angular range 30 - 80 deg.



Fig. 1 Coupling scheme used in the CC calculations.

Calculations performed in Ref. [2] within the antisymmetrized molecular dynamics (AMD) model predicted an oblate shape for the distribution of protons and spherical shape for the distribution of neutrons in ¹⁴C. Thus, according to these predictions, the matter distribution of the ¹⁴C ground state should

be oblate with respect to the symmetry axis. When the sign of the quadrupole deformation was changed to negative in the present CC calculations, the phase agreement was significantly improved. The best fit to the experimental data was obtained with $\delta_2 = -0.6$ fm (solid curve in Fig. 2). Excellent agreement was obtained in the forward hemisphere.

We also performed calculations for the transition to the 2⁺ (7.012 MeV) state of ¹⁴C in the framework of a simple dineutron, ¹⁴C_{g.s.,2+} = ¹²C_{g.s.} + ²n, model. Spectroscopic amplitudes $S_x(1d_2) = 0.3$ for the 2⁺ excited state and $S_x(2s_0) = 0.615$ for the ground state were used in the calculations. The ¹¹B + ¹⁴C interaction potential was folded from the projectilecore (¹¹B + ¹²C) and projectile-particle (¹¹B + ²n) empirical interactions. The results of the singleparticle calculations are plotted in Fig. 2 by the longdashed curve. This curve underestimates the data in the angular range 30 - 80 deg. Our calculations suggest that the 2⁺ (7.012 MeV) state of ¹⁴C has a predominately collective nature.



Fig. 2 Angular distribution of the ${}^{14}C({}^{11}B,{}^{11}B){}^{14}C'$ inclastic scattering for the transition to the 2^- (7.012 MeV) excited state of ${}^{14}C$. See text for the description of the curves.

- [I] V.Burjan et al., Z. Phys. A 354(1996)163
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Supported by KBN Joint Projects with Ukraine No. 1243 and 2689.



PL0501103

1.2 Halo Nature of the 1⁻ (6.094 MeV) State of ¹⁴C Deduced from the ¹¹B + ¹⁴C Inelastic Scattering

by S.Yu.Mezhevych¹⁾, K.Rusek, A.T.Rudchik¹⁾, A.Budzanowski²⁾, B.Czech²⁾, J.Choiński³⁾, L.Głowacka⁴⁾, S.Kliczewski²⁾, E.I.Koshchy⁵⁾, V.M.Kyryanchuk¹⁾, A.V.Mokhnach¹⁾, A.A.Rudchik¹⁾, S.B.Sakuta⁶⁾, R.Siudak²⁾, I.Skwirczyńska²⁾, A.Szczurek²⁾

In this contribution we present the results of a coupled-channel (CC) analysis of the ${}^{11}B + {}^{14}C$ inelastic scattering leading to the 1⁻ (6.094 MeV) state of ${}^{14}C$. The experimental data were obtained in the same experiment as the data presented in our previous contribution.

CC calculations with the assumption that the 1⁻ (6.094 MeV) state is of collective nature did not lead to a good description of the measured angular distribution. The parameters of the optical potential as well as the coupling scheme were the same as in the previously described analysis. With the value of the dipole deformation length $\delta_1 = 0.4$ fm chosen from the fit to the experimental data at very forward scattering angles the calculated angular distribution did not reproduce well the experimental data (long-dashed curve in Fig. 1).



Fig. 1 Angular distribution of the ${}^{14}C({}^{11}B,{}^{11}B){}^{14}C^{*}$ inclastic scattering for the transition to the 1⁻ (6.094 MeV) excited state of ${}^{14}C$. See text for the description of the curves.

Next, we performed CC calculations in the framework of a single-particle model, in which the ${}^{14}C_{g.s.,1-} = {}^{13}C + n$ structure was assumed [1]. Spectroscopic amplitudes $S_x(2s_{1/2}) = -0.994$, $S_x(1d_{3/2}) = 0.105$ for the ${}^{14}C_{1-} = {}^{13}C_{g.s.} + n$ projection and

 $S_x(1p_{1/2}) = 1.094$ for the ground state projection were used. The ${}^{11}B + {}^{14}C$ interaction potential was constructed from the projectile-core $({}^{11}B + {}^{13}C)$ and projectile-particle $(^{11}B + n)$ empirical interactions. The short-dashed curve in Fig. 1 shows the results of calculations with ¹³C + n binding potential radius set at the conventional value of $R_{\nu} = 1.25 \cdot 13^{1/3}$, and diffuseness parameter of $a_V = 0.65$ fm. The behaviour of the short-dashed curve in the backward angle region is oscillatory, while the experimental data, within the error bars, show rather smooth dependence on the scattering angle. When, following the method proposed in [2], we increased the binding potential radius to $R_V = 1.7 \cdot 13^{1/3}$ fm, the fit to the experimental data in the backward angle region was significantly improved (solid curve in Fig. 1). In this case the rootmean-square radius of the valence neutron wave function in the 1⁻ (6.094 MeV) state was found to be equal to 5.157 fm, which makes this a good candidate for a neutron halo state [3].

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- [3] Z.H. Liu et al., Phys. Rev. C68(2003)024305
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Supported by KBN Joint Projects with Ukraine No. 1243 and 2689



1.3 Multistep Emission of One Particle and the More Complicated Direct Processes by A.Marcinkowski, P.Demetriou¹⁾

Unbound 1plh states are excited together with bound ones in one-step direct reactions induced by nucleons of energy greater than the particle binding energy. The cross sections of the one-step reactions to bound final states (1SD_{bound}) are folded into a convolution integral to obtain the multistep cross sections (MSD_{bound}). This is done in the framework of the theory of Feshbach, Kerman and Koonin (FKK) [1] that describes the emission of one particle. The processes to unbound final 1p1h states ($1SD_{unbound}$) give rise to more complicated direct reactions. At low incident energies $1SD_{unbound}$ describes the emission of one particle followed by damping transitions of the low-energy unbound particle that ends in a quasi-

bound state embedded in the continuum. Such processes contribute to absorption into the compound states of the A-nucleus. On the other hand, at energies higher than the potential well, i.e. above 40 MeV, the unbound particle in the final state will be emitted even after one or a few rescattering collisions with the bound nucleons of the nucleus. In such case 1SD_{unbound}

describes a knockout reaction (a, ab), i.e. the emission of two particles. Since the 40 MeV limit is not sharp, both the one-particle emission followed by damping and the two-particle emission coexist over a wide energy interval. Both processes are also out of scope of the FKK theory.

Table 1

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The integrated cross sections for the ${}^{90}Zr(p,n){}^{90}Nb$ reaction including enhanced MSD_{bound} contributions calculated with non-DWBA matrix elements. All cross sections are in mb. The calculated cross sections are verified by comparison with experimental data [3].

Incident energy	25 MeV	45 MeV	80 MeV	120 MeV	
Reaction					Emission
1 SD _{bound}	60	57	34	24	one particle
MSD_{bound}	13	123	456	355	one particle
1SD _{bound} +MSD _{bound}	73	180	490	379	one particle
1SD _{unbound}	39				one particle + damping
1SD _{unbound}		89	199	232	two particle

The 1SD_{unbound} cross section is obtained by subtraction of ISD_{bound} from 1SD, the one-step cross section to both the bound and the unbound final 1p1h states [2]. The ISD_{unbound}, integrated over angle and energy, then provides the total cross section for the more complicated direct processes, e.g. at the higher energies for the emission of two particles. With increasing energy the integrated 1SD_{unbound} increases. However, the total 1SD_{unbound} remains practically constant with respect to the total one-particle emission of FKK, i.e. with respect to the total 1SD_{bound}+MSD_{bound}. This is shown in Table 1. The total one-particle emission of FKK amounts to approximately 65% (third row) of the total flux involved in the direct reactions, independent of the incident energy. The remaining 35% of the flux (fours and fifth rows) is due to the 1SD_{unbound} and is mostly either one particle emission followed by damping or involved in the two-particle emission, depending on the incident energy. This means that the theory of FKK, that describes only the one-particle emission, leaves out of description 35% of the direct reactions contributing to the 90 Zr(p,n) 90 Nb reaction.

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- [2] A.Marcinkowski, P.Demetriou, Eur. Phys. J. A 21(2004)287
- [3] P.Demetriou, A.Marcinkowski, Nucl. Phys. A 714(2003)75
- ¹⁾ Institute d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, CP-226 Campus La Plain, B-1050 Brussels, Belgium

1.4 Preliminary Data Analysis from the S254 Experiment at GSI-Darmstadt by A.Mykulyak and B.Zwięgliński for the ALADIN Collaboration at GSI-Darmstadt



Fig. 1 Limiting temperature as a function of N and Z of the system of interest. Empty circles indicate the systems used in the S254 experiment.

The experiment S254 at GSI was undertaken to study isospin effects in the process of projectile multifragmentation [1]. During two runs, in March and July 2003, beams of stable (124Sn, 197Au) and secondary radioactive (107Sn, 124La) isotopes at energies E=600 MeV/A on targets 12C, Ninat, Snnat and 197Au were used to investigate observable consequences of the predicted [2] dependence of limiting temperatures (see Fig. 1) on isotopic composition (124Sn, N/A=1.48, 197Au, N/A=1.49, 124La, N/A=1.18 and 107Sn, N/A=1.12) of the system.

The experimental setup included the upgraded ALADIN spectrometer and, for producing secondary beams, the fragment separator FRS. The spectrometer

and the mass separator are described in detail elsewhere [3, 4].

During 2004 we performed a preliminary analysis of the experimental data, whose main part was the development of track reconstruction algorithms.



Fig. 2 Reconstructed particle masses for fragmentation products of the 124Sn projectile on a 197Au target.

For track reconstruction we used the scheme similar to the one described in Ref. [5]. Track candidates were defined using the information from the MUSIC ionization chamber. Using them as a first approximation to the true particle tracks, we traced them back to the target spot, varying only the rigidity (in contrast to the usual scheme of tracing particles from the target down to the ionization chamber) which gave us well-defined criteria for the convergence of the fitting process. Using the information from the TOF wall we were able to reconstruct particle masses.

In Fig. 2 the spectra of reconstructed particle masses of the low-charge $(2 \le Z \le 10)$ multi-fragmentation products of 124Sn on 197Au are presented.

Although for low Z values one can see good mass resolution, for $Z \ge 7$ the resolution systematically worsens. This calls for better calibration of the overall detector geometry, which will be the subject of further work.

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- [4] ALADIN Web Page at GSI http://www-kp3.gsi.de/www/kp3/aladinhome.html
- [5] J.C.Hart, D.H.Saxon, Track and vertex fitting in an inhomogeneous magnetic field, Nucl. Instr. and Meth. A 220(1984)309

1.5 Amplitude- and Time-response Studies of PWO+LAAPD Combination to Low-energy Protons from the C-30 Cyclotron at Świerk

by D.Melnychuk, M.Kisieliński, T.Kozłowski, A.Mykulyak, J.Wojtkowska, and B.Zwięgliński for the ECAL-PANDA Collaboration at GSI

Open-charm and gluonic excitation studies, which are of primary interest in the PANDA physics program, require incorporation of a fast and compact electromagnetic calorimeter (ECAL) into the detector.

These requirements are fulfilled by PbWO₄ as a scintillation material, which has already been used in CMS and ALICE detectors at CERN. In those both an operation of ECAL in magnetic field exceeding 1T is forseen, hence the necessity of readout with avalanche photodiodes (APDs). PANDA's additional requirement is an attainment of the detection threshold below 20 MeV, which necessitates supplementary R&D work to improve the scintillation light yield and the readout efficiency in comparison with the above mentioned predecessors. This work is a two-stage process. The first stage consists in modification of production technology by the producers of PWO [BTCP (Russia) and SICCAS (China)] and APDs [Hamamatsu (Japan) and API (USA)]. The second stage is testing the consequences of the current modification using probes covering in the range forseen in PANDA: from energy 1.5 GeV down to the MeV range. The high energy part is covered with 800

to 80 MeV photons from the tagging facility at the Mainz microtron (MAMI) [see the next research note], whereas for inspection of the low energy response it was decided to employ protons. The test conclusions are fed back to the producers to make them execute the next iteration in production technology.



Fig. 1 Spectrum of 22 MeV protons detected with PWOI readout with a cooled APD 630-70-73-510 of API.

Fig. 1 presents the amplitude spectrum from an APD 630-70-73-510 of Advanced Photonix Inc. (API) and PWOI scintillator excited with 22 MeV protons



scattered by 30° on the Au target. Fig. 2 is the TAC spectrum taken in the same measurement. The data have been acquired as a two-dimentional timeamplitude spectrum taken in coincidence, of which Figs. 1 and 2 are the projections. The APD temperature was -30° C. One may conclude that the time resolution of the order of 1ns is achievable from the PWOI+APD(cooled) combination at these moderate light levels. At higher light levels obtained with 25 MeV protons from the plastic scintillator BC-408, the time resolution (FWHM) of 400 ps has been achieved, demonstrating that the APD readout is not a limiting factor. This observation corroborates our previous result of 600 ps obtained [3] with BC-408 readout with an APD 630-70-74-510 of the same producer, excited with beta-rays from a source with 2.3 MeV end-point energy. On the other hand, the energy resolution (see Fig. 1) worsened in comparison with $\sigma/E\sim17\%$, which we have observed previously with 26 MeV protons [2] for PWOI readout with the latter APD. Unfortunately, production of 630-70-74-510, which evidently presented by its spectral sensitivity a better match to the PWO emission spectrum, has been abandoned by API. We intend, therefore, to continue our study of low-energy PWO response with the Hamamatsu S8664-1010, a prototype avalanche photodiode of 1x1 cm² sensitive

area, taylored specially by Hamamatsu Photonics to our needs. This study will be extended to BGO, which represents an alternative scintillation material, considered for PANDA-ECAL.



Fig. 2 TAC spectrum of delayed coincidences between APD and PMT showing FWHM of 0.95 ns.

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- [2] D.Melnychuk et al., IPJ Annual Report 2003, p. 23
- [3] A.Mykulyak et al., Nucl. Instr. and Meth. A 523 (2004)425



1.6 Study of PbWO₄ Scintillator Performance at MAMI by K.Makony¹, R.Novotny¹, M.Thiel¹, D.Melnychuk, T.Kozłowski and B.Zwięgliński for the ECAL-PANDA Collaboration at GSI

Current design of the electromagnetic calorimeter (ECAL) for the PANDA detector is based on the experience of the CMS detector at CERN. PWO (PbWO4) crystals have been chosen as the main option for the detector material with large area avalanche photodiodes (LAAPD) readout due to strong magnetic field in the volume of ECAL. However, in contrast to CMS the PANDA experiment will concentrate on energies well below 1 GeV and ECAL behaviour at the low energy threshold is of special interest. According to this requirement the main R&D work is concentrated on improvement of crystal quality to increase light output and to study improvement in energy resolution due to cooling down to -25°C which should increase light output and decrease APD dark current as well.

A series of measurements has been performed at MAMI (Mainz Microtron) with the goal to study an impact of the above two factors on energy resolution. Second generation PWO scintillators (PWOII) have been used. PWOII is expected to give about 50% higher light output than the standard CMS material (PWOI) due to special doping and crystal growth control by the producer (BTCP-Bogoroditsk, Russia).

The arrays were installed in a thermoisolated box and cooled with a steady flow of dry air via thermoisolated pipes from a cooling machine. The machine forced automatically the flow velocity to keep the temperature of the array at the predetermined level. The tagging photon facility at MAMI provides a collimated beam of (quasi) monoenergetic photons in the energy range form 50 to 850 MeV. In our measurements 8 discrete energies have been selected in the range from 50 to 850 MeV by selecting momenta of the magnetically deflected electrons after bremsstrahlung in a thin target. The experiment had runs taken at T=-25°C and at room temperature to determine the net effect of cooling on energy resolution at different photon energies. Energy resolution was inferred from a run in which the central scintillator was illuminated with a collimated beam of photons. The amplitudes of pulses in all 9 scintillators, their arrival times relative to the tagging signal and the momentum of the electron have been registered event wise by the acquisition system, which allowed reconstructing the total energy deposited by the photon-electron shower in the array. This could be accomplished by calibrating each scintillator in energy by inserting them one-by-one into the photon beam with the aid of a remote control system.



Fig. 1 Energy response of 3x3 PWO array of 200 mm long crystals at T=-25° readout with photomultipliers.

Fig. 1 is the spectrum of total energy deposited in the 3x3 array obtained by summing the individual scintillator contributions when the beam is directed at the central one. The decreasing height of individual peaks reflects energy dependence of the elementary bremsstrahlung cross section which favours large energy loss between the radiating electron and the emitted photon. There is an additional loss of intensity caused by leakage of the electron-photon avalanche through the lateral surfaces of the array, which is reflected also in the increasing peak asymmetry with the increasing photon energy. We intend to repeat the reported experiment with an array of 5x5 scintillators of the same size to verify this conclusion.

1.7 The Hermes Collaboration^{*)} Reports:

Fig. 2 presents the energy dependence of the width parameters σ of Gaussians fitted to the individual peaks in Fig.1. Comparing the spectra of the central crystal measured under identical conditions of the photomultiplier bias and electronics settings at T=+10°C and T=-25°C we note the gain factor of 2.6 of the overall luminescence yield upon cooling, giving a factor 1.6 of improvement in resolution. With the 5x5 matrix of cooled scintillators we expect to reach the best resolution ever measured for PWO.



Fig. 2 Energy resolution of 3x3 PWO array of 200 mm long erystals at T=-25° readout with photomultipliers.

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1.7.1 Quark Helicity Distributions in the Nucleon for *up*, *down*, and *strange* Quarks from Semi-inclusive Deep-inelastic Scattering

by W.Augustyniak, B.Mariański, A.Trzciński, P.Żuprański

Polarised deep-inelastic scattering data on longitudinally polarized hydrogen and deuterium targets have been used to determine double spin asymmetries of cross sections. Inclusive and semiinclusive asymmetries for the production of positive and negative pions from hydrogen were obtained in re-analysis of previously published data. Inclusive and semi-inclusive asymmetries for the production pf negative and positive pions and kaons were measured on a polarized deuterium target. The separate helicity densities for the *up* and *down* quarks and the *anti-up*, *anti-down* and *strange* sea quarks were computed from these asymmetries in a 'leading order' QCD analysis. The polarization of the *up* quark is positive and that of the *down* quark is negative. All the extracted sea quark polarizations are consistent with zero, and the light quark sea helicity densities are flavour symmetric within the experimental uncertainties.

 *) The HERMES Collaboration comprises 32 institutions from 11 countries at Deutches Elektronen-Synchrotron (DESY) Hamburg, Germany.

1.7.2 Search for an Exotic S=-2, Q=-2 Baryon Resonance at a Mass Near 1862 MeV in Quasi-real Photoproduction

by W.Augustyniak, B.Mariański, A.Trzciński, P.Żuprański

A search for an exotic baryon resonance with S=-2, Q=-2 has been performed on a deuterium target through the decay channel $\Xi^-\pi^- \rightarrow \Lambda\pi^-\pi^- \rightarrow p \pi^-\pi^-\pi^-$.

No evidence for a previously reported Ξ^{--} (1860) resonance is found in the $\Xi^{--}\pi^{--}$ invariant mass

spectrum. An upper limit for the photoproduction cross section of 2.1 nb is found at the 90% confidence level. The photoproduction cross section for the Ξ^0 (1530) is found to be between 9 and 24 nb.



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1.7.3 Hard Exclusive Electroproduction of p^+p^- Pairs

by W.Augustyniak, B.Mariański, A.Trzciński, P.Żuprański

Hard exclusive electroproduction of $\pi^+ \pi^-$ pairs off hydrogen and deuterium targets has been studied by the HERMES experiment. Legendre moments $\langle P1 \rangle$ and $\langle P3 \rangle$ of the angular distributions of π^+ mesons in the centre of mass frame of the pair have been measured for the first time. Their dependence on the $\pi^+ + \pi^-$ invariant mass can be understood as due to the interference between relative P-wave (isovector) and S,D-wave (isoscalar) states of the two pions. The rise of $\langle P_1 \rangle$ with the Bjorken variable × is interpreted in the framework of Generalised Parton Distributions as an enhancement of flavour non-singlet qq exchange for larger values of ×, which leads to a sizable admixture of isoscalar and isovector pion pairs. In addition, the interference of the P-wave with the D-wave states for longitudinal and transverse pairs separately has been studied. The data indicate that in the f2 (1270) region at $\langle Q^2 \rangle = 3 \text{ GeV}^2$ higher twist effects can be as large as the leading twist longitudinal component.

1.7.4 Single-spin Asymmetries in Semi-inclusive Deep-inelastic Scattering on a Transversely Polarized Hydrogen Target

by W.Augustyniak, B.Mariański, A.Trzciński, P.Żuprański

Single-spin asymmetries for semi-inclusive electroproduction of charged pions in deep-inelastic scattering of positrons are measured for the first time with transversely polarized target. Two different phenomena that have been indistinguishable in experiments not employing transversely polarized proton target contribute to this asymmetry. Their separate signals have been extracted for the first time as distinctive Fourier components of the dependence of the target spin asymmetry on the azimuthal angles of both the pion (ϕ) and the target spin axis (ϕ_s) about the virtual photon direction and relative to the scattering plane. The signal for the so called Collins moment can arise from the transverse polarization of quarks in the target revealed by its influence on the

fragmentation of the struck quark has been found to amount to 0.021 +/- 0.007 (stat) for π^+ and to -0.038 +/- 0.008 (stat) for π^- . It appears that fragmentation that is disfavoured in terms odd quark flavour has a surprising importance, and enters with a sign opposite to that of the favoured case. The other signal for the Sivers moment can arise from a correlation between the transverse polarization of the target nucleon and the intrinsic transverse momentum of quarks, and could provide another indication for nonzero orbital angular momentum of quarks in the nucleon. The averaged Sivers moment measured in the experiment is positive and equal to 0.017 +/- 0.004 (stat) for π^+ and consistent with zero [0.002 +/- 0.005] for π^- .

1.8 Multiple Ionisation and Coupling Effects in L Shell Ionisation of Heavy Atoms by S-ions

by I.Fijał, M.Jaskóła, A.Korman, D.Banaś¹, J.Braziewicz¹, U.Majewska¹, M.Pajek¹, J.Semaniak¹, S.Chojnacki², W.Kretschmer³, G.Lapicki⁴, T.Mukoyama⁵, and D.Trautmann⁶

We have studied L subshell ionisation of Ta, Os, Au, Bi, and U atoms by S⁹⁺ ions in the energy range 9.6 - 120 MeV. The L-x-rays excited in thin targets $(10-40 \ \mu g/cm^2)$ were measured by a Si(Li) detector placed at 90s to the beam direction with energy resolution of about 200 eV at 6.4 keV. The L-x-ray production cross section was normalized to the elastically scattered projectiles measured by Si detector kept at angles of 150s and 20s. In order to study the L-subshell ionisation cross sections, the xray production cross sections for $L_{\alpha_{1,2}}(L_3-M_{4,5})$, $L\gamma_1(L_2-N_4), L\gamma_2(L_1-N_2)$ and $L\gamma_3(L_1-N_3)$ x-ray transitions were obtained. The L x-ray spectra were analysed using the method [1] accounting for multiple-ionisation effects, such as x-ray line shifting and broadening which one enables to obtain the ionisation probabilities for outer shells. The ionisation cross sections of L_1 , L_2 , and L_3 subshells have been obtained from the measured x-ray production cross sections using the L shell fluorescence and Coster– Kronig yields being modified by the multiple ionisation in the M and N shells. In particular, the effects of closing the strong $L_1-L_3M_{4,5}$ Coster–Kronig transitions in multiple-ionised atoms were evidenced and taken into consideration [2]. The experimental ionisation cross sections values for the L_1 , L_2 , and L_3 subshells have been compared with the predictions of the SemiClassical Approximation within the United-Atom limit (SCA–UA) [3] and the ECUSAR (projectile Energy Ioss, Coulomb deflection from straight–line, United or Separated Atom binding

PL0501111



energy, Relativistically increased mass effect) [4,5] theories.

Taking into account the "coupled subshells model" CSM of Sarkadi et al. [6] we have obtained much better agreement with the experimental data, as is presented in Fig. 1, particularly when it is further modified to include the saturation of the binding effect [7].

Our account for the coupling effects improves drastically the agreement of the ionisation cross sections at low energies for the L₂ subshell of studied elements, and results in better agreement with the ionisation cross sections for the L_1 and L_3 subshells.



Fig. 1 The ratios of experimental to theoretical ionisation cross sections for L1, L2, and L3 subshells of heavy atoms bombarded by S-ions versus the relative projectile to L-shell electron velocity v1/v2. The theoretical SCA-UA, ECUSAR, (open symbols, dashed lines) contrasted with SCA-CSM, ECUSAR-CSM calculations (closed symbols, solid lines).

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Damage Buildup and Recovery in III-V Compound Semiconductors at Low 1.9 Temperatures

by A.Turos, A.Stonert, L.Nowicki, R.Ratajczak, E.Wendler¹⁾, and W.Wesch¹⁾

A broad recovery stage at low temperatures exists for III-V semiconductor compounds. It is attributed to the recombination or reconfiguration of a variety of defects with different activation energy. Thus, the investigation of thermally activated processes can be decisive for identification of defects. Defect mobility at 295 K can also lead to important defect transformation after ion implantation and subsequent storage at room temperature. Hence, structure, distribution and reproducibility of radiation defects are of great scientific and technological interest.

Epitaxial layers InP, $In_{0.53}Ga_{0.47}As$, of $In_{0.82}Ga_{0.18}As_{0.52}P_{0.48}$ compound semiconductors were Layers of such compositions are lattice studied. matched to InP substrates and are not strained due to the pseoudomorphic growth. Experiments were carried out using the two beam facility at the Institute of Solid State Physics, FSU Jena. The beams delivered by the ion implanter were used to produce defects, while the tandem accelerator equipped with a 3-axis goniometer was applied for in situ ion channeling (RBS/c) measurements. The Monte Carlo computer



code McChasy was used for the evaluation of the channeling data.

There is only a small difference in damage buildup between the studied compounds. Damage recovery at low temperatures reveals important differences: the fastest recovery was observed for InGaAsP whereas it is slowest in InP (cf. Fig. 1). For all studied compounds, the broad recovery stage begins at approximately 100 K and extends above 295 K. Prolonged storage at 295 K leads to the further reduction of the defect content. Defects that anneal below 295 K belong to the group III sublattice whereas the group V interstitials become mobile at approximately 500 K. The presence of defects directly influences the conductivity and the defect induced strain modifies the energy bandgap. Due to these facts the defect mobility has profound consequences on properties of ion implanted semiconductor structures during the shelf storage at room temperature.

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Fig. 1 Defect recovery in various semiconductor compounds during warming from 15 K up to 295 K. The lines are drawn to guide the eye. Result of storage of GaAs at room temperature is marked by the arrow.

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LECTURES, COURSES AND EXTERNAL SEMINARS

Reactions with exotic helium isotopes^{b)} K.Rusek, University of Sevilla, Spain, July15 2004

a) in Polish

b) in English

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DIDACTIC ACTIVITY

MATHEMATICAL STATISTICS Warsaw Agricultural University (lecture) B.Mariański

M.Jaskóła - Supervisor of Ph.D. studies of Mrs. I. Fijał (IPJ)

K.Rusek - Supervisor of Ph.D. studies of Mr. S. Mezhevych (IPJ)
A.Turos - Supervisor of Ph.D. studies of Mr A.M. Abdul-Kader (IPJ)

B.Zwięgliński - Supervisor of Ph.D. studies of Mr. A.Mykulyak (IPJ)

B.Zwięgliński - Supervisor of Ph.D. studies of Mr. D.Melnychuk (IPJ)

11th Science Festival, Warsaw, Poland L.Nowicki, R.Ratajczak, A.Stonert

8th Science Pienic, Warsaw, Poland A.Korman, S.Mezhevych, L.Nowicki, R. Ratajczak, A.Stonert, W.Mielczarek

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1/2 1/5

2 DEPARTMENT OF NUCLEAR SPECTROSCOPY AND TECHNIQUE

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Overview

Research activities in our Department in the last year were focused on traditional domains of nuclear physics: heavy-ion reactions and nuclear spectroscopy, but also on medium-energy elementary particle physics, neutrino physics, as well as atomic physics. Along with the group of nuclear and atomic physicists, our Department encompasses a team working on medical physics and another team engaged in ecology and environmental physics.

We maintain our collaboration with FZ Jülich (Germany) continuing experiments on the COSY storage ring, aimed at studying heavy hyperons produced in pp collisions. Recently, evidence for a new hyperon has been obtained.

At PSI Villigen (Switzerland) rare pion- and muon decays have been studied using the large PIBETA detector. The branching ratio for the pion beta decay was measured with six times better accuracy than previously. From the precise measurements of the radiative pion decay the pion axial form factor was evaluated (four times more precisely). Some anomaly, which can not be explained by the Standard Model, was observed in this process.

In the field of neutrino physics, data collected with the T600 module of the cosmic ray detector ICARUS in Pavia (Italy) have been analysed. In collaboration with the Department of Nuclear Theory, conditions to observe the fascinating process of neutrino-less double electron capture were further examined from the point of view of the fundamental question of the neutrino nature and mass.

Our involvement in the CHIMERA/ISOSPIN Collaboration resulted in interesting studies of semi-peripheral nucleus-nucleus collisions at the Fermi energy range. In particular, a new method of determination of the time scale of the emission of intermediate mass fragments was developed.

We continued the collaboration with LBNL Berkeley (USA) and IEP Warsaw University on a theoretical model of the synthesis of super-heavy elements. A comprehensive description of the model with extensive predictions of the production cross sections and optimum bombarding energies for "cold fusion" reactions (used to produce transfermium elements) has been published.

Our nuclear spectroscopy studies concentrated on life-time measurements of low energy levels and high spin states in various nuclei. The experiments were carried out in collaboration with the ISV Studsvik (Sweden), ISOLDE at CERN and with Warsaw University. Nuclear shapes, octupole correlations and other properties of nuclei in excited states have been examined.

Two subjects have been pursued by the high energy atomic physics group. Studies of multiple inner shell ionization in medium Z atoms have been continued in collaboration with groups from the Universities of Fribourg (Switzerland), Toruń and Kielce. Of particular interest are the lifetimes of "hollow atoms" (atoms doubly ionized in the K shell) which were found to be nearly independent of the strong hindrance of the K_{α}^{h} transition. The other subject concerns interactions of semi relativistic helium ions with solid targets, studied in collaboration with the RCNP, Osaka. Cross sections for electron capture to the vacant state of He⁺⁺ ions as well as for stripping of the last electron from He⁺ ions were determined for targets ranging from carbon through gold.

The team working on medical physics has developed a method of dose rate anisotropy reduction for X-ray beams produced in the *Photon Needle* generators. The X-ray dose-rate angular distributions have been measured and simulated in Monte Carlo calculations.

The environment protection group of our Department participated in the state-wide system of air sampling stations. Radioactivity measurements of nuclides in the ground level airborne dust were carried out. Filters from the air sampling station in Hornsund (Spitsbergen) are systematically analysed. Measurements of the underground water radioactivity in our institute have also been carried out by the group. In collaboration with local authorities, the group constructed a mobile air sampling station (AZA-400) for suspended dust measurements. The group elaborated and investigated a model of short-time variation of pollutants concentration based on the wavelet analysis algorithms and neural networks method.

No-carrier-added ¹⁸F fluorine was produced using our C-30 cyclotron for applications in nuclear medicine. Tests of the avalanche photo-diodes, expected to be applied in the PANDA project at GSI Darmstadt (Germany), were continued.

SemicBi

PL0501114

2.1 Temperature (in) Dependence of One-body Dissipation by L.Shvedov, J.Błocki, J.Wilczyński

One-body dissipation [1, 2] is the main mechanism of energy dissipation in nuclear reactions at low energies. This is due to the long mean free path of nucleons resulting from the fact that the phase space available for final states of two-body collisions is strongly limited by the Pauli principle.

There are two extreme situations for which simple formulae for the rate of the dissipated energy can be derived. The first one is a case of the so called "wall formula" describing the rate of energy dissipation in the mononuclear regime – for nucleons treated as the Fermi gas with isotropic velocity distribution. The exchange of energy between collective and microscopic degrees of freedom proceeds through collisions of particles (nucleons) with a moving boundary of the system, followed by the equilibration of the perturbed single-particle energies with the bulk of nucleons.

In the second extreme situation of the di-nuclear regime, typical for nucleus-nucleus collisions, the system can be represented by two Fermi gases having isotropic velocity distributions, but shifted in the phase space by the relative velocity. When the two nuclei are in contact, a window between them opens and the collective energy of relative motion can dissipate due to the exchange of nucleons between both colliding nuclei. This leads to the so called "window formula" for energy dissipation.

For both the wall and window mechanisms, the expressions for the rate of energy dissipation contain a factor of the mean velocity of nucleons $\overline{\nu}$, which for the Fermi gas model at zero temperature equals $\overline{\nu} = \sqrt[3]{4}\nu_F$ where ν_F is the Fermi velocity.

It is generally assumed that the mean nucleonic velocity is practically independent of temperature and thus the one-body dissipation mechanism is temperature independent. In this report we analyse to what extent this assumption is correct in the framework of the Fermi gas model (for the Fermi surface diffused thermally by the Fermi distribution function).

In a calculation of the dependence of the mean velocity of nucleons on the temperature, we approximated the Fermi distribution function $[1+\exp(E-E_F)/T]^{-1}$ by linear dependence and obtained the following expression:

$$\overline{v} = \frac{5T(16T^2 + 3m^2 v_F^4)}{m^3 \left[\left(v_F^2 + \frac{4T}{m} \right)^{\frac{4}{2}} - \left(v_F^2 - \frac{4T}{m} \right)^{\frac{4}{2}} \right]}$$

where T is the temperature and m is the mass of the nucleon. In the first order approximation the above expression simplifies to:

$$\bar{\nu} \approx \frac{3}{4} v_F \left(1 + \frac{5}{6} \frac{T^2}{E_F^2} \right)$$

where E_F is the Fermi energy.



Fig. 1 The mean velocity of particles \overline{V} as a function of the temperature T of the system calculated for the Fermi velocity $v_F = 8 \text{ fm}/(10^{-22} \text{ scc})$.

The calculated dependence of the mean velocity of nucleons on the nuclear temperature is presented in Fig. 1. It is seen that for nuclear temperatures of about 1-3 MeV, typical for nuclear reactions at low energies, the mean velocity of nucleons varies by less than 1% with respect to the velocity for zero temperature, and thus also the rate of one-body dissipation varies by the same amount. Therefore the result of our calculation well supports the commonly accepted assumption that the one-body dissipation mechanism is practically independent of the temperature. It should be remembered, however, that at higher temperatures the one-body dissipation mechanism breaks down due to shortening of the mean free path of nucleons, independently of the value of the mean velocity discussed above. At these higher temperatures, the two-body dissipation mechanism takes over and the wall- and window formulae cease to be valid.

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PL0501115



2.2 Determination of the Time Scale of Emission of Intermediate Mass Fragments by J.Wilczyński and CHIMERA/ISOSPIN Collaboration

Semi-peripheral nucleus-nucleus collisions at intermediate energies of about 20-40 MeV/nucleon are basically binary. However, along with projectilelike fragments (PLF), target-like fragments (TLF) and evaporated light charged particles, reaction products of a new type – intermediate mass fragments (IMF) – are also produced, especially at higher energies. Usually all fragments of $Z \ge 3$ (which cannot be recognized as PLF's or TLF's) are classified as IMF's. It is rather well established that IMF's originate mostly from the neck region during re-separation of the colliding system, but the time scale of this process is not known.

We proposed [1, 2] to deduce information on the time scale of IMF production from an analysis of relative velocity correlations in ternary events, in which along with the PLF and TLF only one IMF is produced. In so events selected, the relative velocities in the IMF+PLF and IMF+TLF sub-systems, $V_{rel}(IMF,PLF)$ and $V_{rel}(IMF,TLF)$, can be determined experimentally in the event-by-event mode. For convenience, the relative velocities V_{rel} can be expressed in units of the velocity V_{Viola} corresponding to the Coulomb repulsion energy of a given subsystem.

Fig. 1 shows results of our analysis [2] of semiperipheral collisions in the ¹²⁴Sn + ⁶⁴Ni reaction at the beam energy $E(^{124}Sn) = 35$ MeV/nucleon studied at the Laboratori Nazionali del Sud in Catania using the CHIMERA multidetector array [3]. A selected class of almost completely reconstructed ternary events involving a PLF, a TLF and one IMF was analyzed. The relative velocities $V_{rel}/V_{Viola}(IMF,PLF)$ and $V_{rel}/V_{Viola}(IMF,TLF)$ were calculated in the event-byevent mode and the correlation between these two quantities is displayed in Fig. 1 separately for four selected IMF's: $Z_{IMF} = 4$, 8, 12 and 18. As suggested above, the correlation between $V_{rel}/V_{Viola}(IMF,PLF)$ and $V_{rel}/V_{Viola}(IMF,TLF)$ gives information on the scenario of the IMF formation.

In order to "calibrate" the time scale of the observed IMF emission we carried out simple calculations of relative motion of three fragments: PLF, TLF and IMF assuming that the IMF is the neck remnant produced in a two-step process, i.e., released either by the projectile fragment P' or target fragment T' after an assumed time interval Δt elapsed from the binary re-separation of the colliding system.



Fig. 1 Correlation between relative velocities $V_{rel}/V_{Viola}(IMF,PLF)$ and $V_{rel}/V_{Viola}(IMF,TLF)$ for different intermediate mass fragments of $Z_{IMF} = 4$, 8, 12 and 18. The experimental distributions are compared with simple model calculations assuming that the IMF is released at times $\Delta t = 40$, 80 or 120 fm/c after re-separation of the primary binary system. Two branches of the calculated correlation correspond to either projectile breakup (squares) or target breakup (circles). The shortest indicated time $\Delta t = 40$ fm/c corresponds to the location near the diagonal.

It is seen from Fig. 1 that the majority of light IMF's are produced within 40-80 fm/c after the system starts to re-separate. Heavy IMF's are formed at times of about 120 fm/c or later, and can be viewed as resulting from two-step (sequential) neck rupture processes.

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PL0501117

2.3 Fusion by Diffusion II: Synthesis of Transfermium Elements in Cold Fusion Reactions

by W.J.Świątecki¹⁾, K.Siwek-Wilczyńska²⁾, J.Wilczyński

Following our early work [1], a theoretical study of the synthesis of super-heavy elements in cold fusion reactions has been completed.

In Ref. [2] we describe a method of estimating cross sections for the synthesis of very heavy nuclei by the fusion of two lighter ones. The cross section is considered to be the product of three factors: the cross section for the projectile to overcome the Coulomb barrier, the probability for the resulting composite nucleus to reach the compound nucleus configuration by a shape fluctuation treated as a diffusion of probability in one dimension, and the probability for the excited compound nucleus to survive fission.



Fig. 1 Comparison of the theoretical excitation function for the $^{64}Ni+^{20K}Pb \rightarrow ^{271}110 + n$ reaction with measurements [4, 5].



Fig. 2 The lowest line shows the logarithms of the calculated peak cross sections for the synthesis of elements with atomic numbers Z=102 to Z=119, in one-neutron-out reactions using targets of ^{20K}Pb and ²⁰⁹Bi bombarded with the projectiles listed along the Z axis. The uppermost curve shows the calculated cross sections for overcoming the Coulomb barrier; the middle curve, the cross sections for forming a compound nucleus.

Semi-empirical formulae for the mean Coulomb barrier height and the height distribution around the mean are constructed. After overcoming the Coulomb barrier [3] a rapid growth of the neck between the target and projectile at approximately frozen asymmetry and elongation is assumed to inject the system into an "asymmetric fission valley". Diffusion in the elongation coordinate in this valley can occasionally bring the system over the saddle separating the injection point from the compound nucleus configuration. This is the stage that accounts for the hindrance to fusion observed for very heavy reacting systems. The competition between deexcitation of the compound nucleus by neutron emission and fission is treated by standard methods, but an interesting insight allows one to predict in an elementary way the location of the maximum in the resulting excitation function (see Fig. 1). After adjusting one parameter in the theory, the calculated peak cross sections (see Fig. 2) agree within about a factor of two or so with twelve measured or estimated values for "cold" one-neutron-out reactions where targets of ²⁰⁸Pb and ²⁰⁹Bi are bombarded with projectiles ranging from ⁴⁸Ca to ⁷⁰Zn [4, 5]. The centroids of the excitation functions agree with theory to within one or two MeV for the six cases where they have been determined and their widths are reproduced. "Hot" fusion reactions, where several neutrons are emitted, are not treated, apart from a comparison made between the hindrance factors in cold and hot reactions to make elements with atomic numbers 112 to 118. The calculated diffusive hindrances in the hot reactions are less unfavourable by 4 to 5 orders of magnitude.

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2.4 Charge Exchange Processes for Semi-relativistic Helium Ions ($\beta = 0.51$) in Solid Gold

by A.Gójska, D.Chmielewska, J.Rzadkiewicz, Z.Sujkowski, T.Adachi¹⁾, H.Fujita¹⁾, Y.Fujita¹⁾, K.Hara¹⁾, Y.Haruyama¹⁾, J.Kamiya¹⁾, H.Ogawa¹⁾, M.Saito¹⁾, Y.Shimizu¹⁾, Y.Shimbara¹⁾, M.Tanaka¹⁾, H.P.Yoshida¹⁾, I.Katayama²⁾

Interactions of 150 MeV/amu ³He⁺⁺ projectiles with solid C, Ni, Ag and Au targets have been studied at the isochronous cyclotron of the RCNP in Osaka. The yield ratio of singly to doubly ionized helium ions emerging from thin foils, $R = Y(He^+)/Y(He^{++})$, has been measured as a function of the foil thickness (fig.1). By fitting the function R = a[1-exp(-bx)], the cross section values for electron stripping from ³He⁺ ions and for electron capture to ³He⁺⁺ ions were determined separately. The results are compared with basic theories (table 1, 2).



Fig. 1 The $Y({}^{3}Hc^{-})/Y({}^{3}Hc^{++})$ yields as a function of target thickness for an Au target. The solid line represents the fit.

The experimental values of electron stripping cross sections are compared in Table 1 with the theoretical predictions based on the Bohr and Gillespie approximations [1].

Table 1

Experimental and theoretical electron stripping cross sections for 150 MeV/amu ³He ions. Z_T is the target atomic number, BLZ, BMZ, BHZ are the Bohr approximations for low, mid and high Z, respectively, G is the Gillespie theory. All values *10⁻¹⁷cm².

Z	Exp	BLZ	BMZ	BHZ	G
6	0.08(1)	0.08	0.21	8.79	0.04
28	0.35 (3)	1.48	0.58	8.79	0.45
47	1.20 (25)	4.12	0.82	8.79	1.01
79	1.05 (19)	11.50	1.17	8.79	2.12



Fig. 2 The experimental and theoretical electron stripping cross section for 150 MeV/amu 3 He vs. Z_T.

The data for total capture cross sections for He interacting with solids are collected in Table 2 and illustrated with fig. 3. A comparison of the data with the OBK, B2, Nikolaev [2] and eikonal [3] – type calculations shows that the first two overestimate the effect dramatically.

Table 2

Experimental and calculated electron capture cross sections for 150 MeV/amu 3 He ions as a function of Z_T. All values ${}^{*}10^{-28}$ cm²

Ζ	Exp	OBK	B2	Nik	Eik
6	1.1 (2)	0.92	0.27	0.01	1.5
28	80.3 (9.3)	2030	599	70.5	146
47	365 (99)	27100	7980	301	505
79	1120 (269)	363000	107000	1000	1590



Fig. 3 The experimental and theoretical (Nikolaev, cikonal) electron capture cross sections for 150 MeV/amu ³He vs. Z_T . The calculated Radiative Electron Capturecross section is also shown.

The interaction of relativistic helium ions with atoms as well as with free electrons are of primary astrophysical interest [4]. Likewise, information on the charge exchange process involving fast light ions is much needed in hot plasma diagnostics.

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2.5 Natural Widths of Hypersatellite K X-ray Lines and Lifetimes of Double K-hole States in Mid-Z Atoms

by J.Rzadkiewicz, D.Chmielewska, A.Gójska, Z.Sujkowski, J-Cl.Dousse¹⁾, M.Polasik²⁾, K.Słabkowska²⁾, J.Hoszowska³⁾, M.Pajek⁴⁾

K X-ray spectra of Zr, Nb, Mo and Pd targets bombarded with 250 MeV C and 360 MeV O ions were studied with high resolution diffraction spectrometry. The natural widths of the $K^h\alpha_{1,2}$ hypersatellite lines and lifetimes of the K^{-2} states were determined and compared with theoretical predictions. The strengths and natural widths of the $K^h\alpha_1$ and $K^h\alpha_2$ hypersatellite transitions are determined by the coupling scheme dominating in the atom (see Fig. 1).

PL0501119



Fig. 1 Energy diagram showing the decay of double K-shell ionized states via the $K^{h}\alpha_{1,2}$ hypersatellite X-ray transitions.

In Fig. 2 the experimental natural widths Γ_1 of the $K^h\alpha_1$ lines are compared with values calculated with the phenomenological laws corresponding to the *jj* coupling: $\Gamma(K^h\alpha_1)=3\Gamma_K+\Gamma_{L3}$, [1] (solid line) and intermediate coupling: $\Gamma(K^h\alpha_1)=(3-4/3K_{LS})\Gamma_K+\Gamma_{L3}$, [2].



Fig. 2 Γ_1 natural widths of the K^h α_1 lines compared with the results given by the phenomenological formulas based on the jj coupling (dashed line) and intermediate coupling (solid line), respectively. X represents results of MCDF calculations performed for Zn and Kr [3], \blacklozenge experimental data taken [4].

The experimental widths significantly exceed the phenomenological values for intermediate coupling. The lifetimes of the double K-hole states shown in Fig. 3 were deduced from the natural widths of the K⁻² states, which can be determined from: $\Gamma_{KK} = \Gamma(K^h \alpha) - \Gamma(K \alpha)$.



Fig. 3 Experimental double K shell vacancy lifetimes compared with the values obtained from the phenomenological formulas based on the jj coupling (dashed line) and the intermediate coupling (solid line). ♦ represents experimental data taken [4].

The experimental lifetimes are close to those predicted by the phenomenological law for *jj* coupling (dashed line in Fig. 3) but significantly shorter than the values determined by means of the phenomenological law based on the intermediate coupling (dashed line), although the latter should be the most appropriate coupling scheme for the investigated mid-Z atoms.

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- ¹⁾ Physics Department, University of Fribourg, CH-1700 Fribourg, Switzerland
- ²⁾ Faculty of Chemistry, Nicholas Copernicus University, 87-100 Toruń, Poland
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2.6 Total Routhian Surface Calculations for ^{183,185}Ir Nuclei

by R.Kaczarowski and W.A.Płóciennik*

Extensive total Routhian surface (TRS) calculations [see ref. 1] were continued for ¹⁸³Ir and ¹⁸⁵Ir nuclei with the aim to compare theoretical predictions with the results of experimental studies of the high spin states in these nuclei [2-4].

The examples of calculated equilibrium deformation parameters of the negative- and positiveparity rotational bands (with positive signatures α =+1/2) at $\hbar\omega$ =0.050 MeV (below backbending region) and $\hbar\omega$ =0.400 (above backbending) are shown in Table 1 (¹⁸³lr) and Table 2 (¹⁸⁵lr).

Table 1

Equilibrium deformations in ¹⁸³Ir.

Π, α	ħω	β2	β4	γ
-,+	0.050	0.234	-0.036	0.3°
	0.400	0.221	-0.047	-12°
+, +	0.050	0.236	-0.038	8°
	0.400	0.268	-0.024	12°
	0.400	0.192	-0.054	-18°

Table 2

Equilibrium deformations in ¹⁸⁵Ir.

π, α	ħω	β2	β4	γ
-, +	0.050	0.229	-0.047	1.6°
	0.400	0.207	-0.053	-17°
+,+	0.050	0.219	-0.050	10°
	0.400	0.183	-0.059	-24°

The calculated values of the total angular momentum as a function of the rotational frequency are compared with experimental data in Figs. 1 and 2. Calculations indicate that the lowest observed backbending in negative parity bands in both nuclei is caused by alignment of a pair of neutrons. In the ¹⁸³Ir nucleus the calculated and experimental critical frequencies for the first backbending are quite close ($\hbar\omega^{calc}c=0.32$; $\hbar\omega^{exp}c=0.28$), but the observed second backbending at $\hbar\omega^{exp}c=0.42$ is not predicted by calculations. Both values are significantly different in ¹⁸⁵Ir ($\hbar\omega^{calc}c=0.34$; $\hbar\omega^{exp}c=0.40$).

For the positive-parity rotational band in ¹⁸³Ir, calculations predict at low h ω two close lying configurations, the lower one with γ =+8° and higher with γ =-6° and, at higher rotational frequencies, S-band with γ =-17° which at h ω =0.32 become yrast band.

According to the calculations, the backbendings in positive parity band in ¹⁸³Ir are more complicated. They involve initially an alignment of both proton and

neutron pair at $\hbar\omega_c^{calc} = 0.25$ and then alignment of proton pair at $\hbar\omega_c^{calc} = 0.325$ for configuration with $\gamma \approx 6 \div 9^\circ$. For configuration with $\gamma = -18^\circ$ only alignment of neutron pair is predicted at $\hbar\omega_c^{calc} = 0.25$. The values observed in experiment are $\hbar\omega_c = 0.214$ and 0.317.



Fig. 1 Calculated and experimental values of the total angular momentum as a function of rotational frequency for both signatures of the lowest negative- parity bands in ¹⁸³Ir and ¹⁸⁵Ir.



Fig. 2 Calculated and experimental values of the total angular momentum as a function of rotational frequency for both signatures of the lowest positive parity band in ¹⁸³Ir.

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PL0501120



2.7 Lifetimes of Rotational Levels in Supposed Chiral Bands in Odd-odd ¹²⁸Cs Nucleus by E.Grodner¹, 1.Zalewska¹, T.Morek¹, J.Srebrny¹, Ch.Droste¹, M.Kowalczyk^{1,2}, J.Mierzejewski¹, M.Sałata¹, A.A.Pasternak², J.Kownacki³, M.Kisieliński, A.Kordyasz³, P.Napiorkowski³, M.Wolińska-Cichocka³, S.G.Rohoziński⁴, R.Kaczarowski, W.A.Płóciennik, E.Ruchowska, A.Wasilewski and J.Perkowski⁵

Lifetimes of the high spin states in ¹²⁸Cs have been investigated via the ¹²²Sn(¹⁰B,4n)¹²⁸Cs reaction using the DSA method. A 55 MeV ¹⁰B beam was provided by the Warsaw U-200P cyclotron at HIL. The measurements were performed using the OSIRIS II multidetector array consisting of 10 Comptonsuppressed HPGe detectors. Lifetimes of the excited levels were determined from the γ -line shape of deexciting transitions. Lifetimes of thirteen rotational levels in the supposed chiral partner bands in ¹³²La have been already determined in our previous studies [1, 2]. The level scheme of ¹²⁸Ce has already been studied [3-5]. In the present experiment the lifetimes of seven rotational levels in bands built on the $\pi h_{11/2} \theta v h_{11/2}^{-1}$ configuration in a ^{128}Cs nucleus have been found. The deduced values of the B(E2) and B(MI) reduced transition probabilities in both nuclei are presented in Fig. 1.

The preliminary results for ¹²⁸Cs show that the B(E2) values for the side band are only about three times smaller than those in the yrast band. This observation is in striking contrast with results obtained for similar bands in a ¹³²La nucleus, where much larger differences (about 20÷30 times) between the B(E2) values in the side and yrast bands built on the $\pi h_{11/2} \theta v h_{11/2}^{-1}$ configuration were found. The values of B(M1) intraband transition probabilities in both bands in ¹²⁸Ce and ¹³²La nuclei are not so dramatically different (Fig. 2). However, still some

differences between the behaviour of the B(M1) transition probabilities in bands of interest in ¹²⁸Ce and ¹³²La nuclei can be noted.

A comparison of the electromagnetic properties and energy splitting between the side and yrast bands built on the $\pi h_{11/2} \theta v h_{11/2}^{-1}$ configuration in ¹²⁸Cs and ¹³²La seems to suggest that ¹²⁸Cs is a better candidate for the presence of chiral bands than ¹³²La. A discrepancy between the measured and calculated electromagnetic properties in the case of ¹³²La presents a challenge for further investigations, since the question whether we really observe the chiral bands in this nucleus is still open.

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Fig. 1 Reduced transition probabilities in the partner and yrast bands versus spin. Top-left: B(E2) values in ¹³²La. Top-right: B(M1) values in ¹³²La. Bottom-left and bottom-right: B(E2) and B(M1) values, respectively, in ¹²⁸Cs.

2.8 New Structure Information on the ³⁰⁻³²Mg Nuclei*

by H.Mach¹⁾, L.M.Fraile^{2,3)}, O.Tengblad⁴⁾, R.Boutami⁴⁾, C.Jollet⁵⁾, W.A.Płóciennik^{*}, D.T.Yordanov⁶⁾, M.Stanoiu⁷⁾, M.J.G.Borge⁴⁾, P.A.Butler^{2,8)}, J.Cederkäll^{2,9)}, Ph.Dessagne⁵⁾, B.Fogelberg¹⁾, H.Fynbo¹⁰⁾, P.Hoff¹¹⁾, A.Jokinen¹²⁾, A.Korgul¹³⁾, U.Köster²⁾, W.Kurcewicz¹³⁾, F.Marechall⁵⁾, T.Motobayashi¹⁴⁾, J.Mrazek¹⁵⁾, G.Neyens⁶⁾, T.Nilsson²⁾, S.Pedersen¹⁰⁾, A.Poves¹⁶⁾, B.Rubio¹⁷⁾, E.Ruchowska and the ISOLDE Collaboration

Very exotic neutron-rich ³⁰Mg, ³¹Mg and ³²Mg nuclei have been studied using the Advanced Time Delayed $\beta\gamma\gamma(t)$ method [1, 2]. These nuclei belong to the so called 'island of inversion' [3, 4] where indications of a disappearance of the N=20 shell gap between the sd and fp shells have been found. As a result the fp intruder configurations appear at low excitation energies or even dominate ground states of these nuclei.

The excited states in ³⁰Mg and ³¹Mg were populated in the β decay and in the β delayed neutron decay of ³⁰Na and ³¹Na, and of ³¹Na and ³²Na, respectively, while levels in ³²Mg were populated in the β decay of ³²Na. The activity of Na was produced in the reaction of ²³⁸U with the 1.4 GeV protons from the PS booster and extracted from other reaction products by the HRS mass separator at ISOLDE. It was deposited onto an aluminium foil placed at the center of the experimental setup.

The experimental setup consisted of a thin plastic NE111A β detector, two fast response BaF₂ detectors and two large HPGe detectors. All detectors were placed in a close geometry at the deposition point. Mainly triple β -Ge-Ge and β -Ge-BaF₂ coincident events have been collected.

The analysis of experimental data from these measurements is still in progress, but already a number of new states have been identified in ³⁰Mg and ³¹Mg and their level schemes have been revised. In particular, no evidence has been found in our data for the 1820 keV level in ³⁰Mg. No confirmation was found that the 1789 keV line de-excites the 1789 keV level in ³⁰Mg as it was reported in earlier studies [4] and precluded interpretation of this level as the intruder 0⁺ state. In ³¹Mg a new level at 1154 keV has been established which is a good candidate for the 11/2⁻ 1p1h state.

A preliminary lifetime value of 3.9(4) ns (see Fig. 1) determined for the 1789 keV level in ³⁰Mg is consistent with its interpretation as the 0⁺ intruder state. In the case of ³¹Mg preliminary lifetimes of 133(8) ps and 10.5(8) ns have been obtained for the 221 and 461 keV levels, respectively. The B(E2) value of 67(6) e²fm⁴ obtained for the 240 keV transition connecting these two levels supports their interpretation as the 1p1h intruder states. The preliminary lifetime of 16.0(42) ps obtained for the 885 keV 2+ level in ³²Mg (see Fig. 2) yields B(E2) value of 327(87) e²fm⁴ which indicates that the ground state of this nucleus is dominated by the intruder configurations.



Fig. 1 Time-delayed $\beta\gamma(t)$ spectrum due to the lifetime of the 1789 keV level in ³⁰Mg. The lifetime value has been determined from the slope fitting.



Fig. 2 Centroid shift analysis for 32Mg: lifetime of the 885 keV level has been determined from the shift of the 885 keV time peak position relative to the prompt reference curve.

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- * Published in the memory of Weronika Płóciennik deceased on December 25, 2004. She was young and a talented researcher in both experimental and theoretical physics.

2.9 Rare Pion and Muon Decays

by T.Kozłowski for the PIBETA Collaboration

Using a large PIBETA calorimeter [1] and a stopped pion beam we made precise measurements of the pion beta $\pi^+ \rightarrow \pi^0 e^+ \upsilon$ decay (π_β) branching ratio, the radiative pion $\pi^+ \rightarrow e^+ \upsilon \gamma$ decay and the radiative muon $\mu^+ \rightarrow e^+ \upsilon \upsilon \gamma$ decay.

We evaluated the pion beta decay branching ratio by normalizing the number of π_{β} decays to the number of observed $\pi^+ \rightarrow e^+ v$. We find this value of $\Gamma(\pi^+ \rightarrow \pi^0 e^+ v)/\Gamma(\text{total}) = [1.036 \pm 0.004(\text{stat}) \pm 0.004(\text{syst}) \pm 0.003(\text{norm})]*10^{-8}$, where the first uncertainty is statistical, the second systematic, and the third is normalization uncertainty [2]. Our result agrees well with the Standard Model prediction, and represents a sixfold improvement in accuracy over the previous measurement.

We studied radiative pion $\pi^+ \rightarrow e^+ \upsilon \gamma$ decay in three broad kinematic regions. Based on Dalitz distributions of 41601 events, we evaluated absolute branching ratios in these three regions. Integral and differential (E_e.E_{γ}) distributions result in the axial-to-vector form factors ratio of $\gamma = F_A/F_V = 0.443(15)$, or $F_A = 0.0115(4)$ with $F_V = 0.0259$ (4 times more accurate than the previous result) [3].

The overall good agreement between our data and predictions based on Standard Model (SM) calculations was spoiled by a statistically significant (7σ) deficiency in the measured branching ratio in the low positron energy region.

A similar, albeit statistically less significant deviation was reported by the ISTRA collaboration

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and attributed to a nonzero pion tensor form factor, F_T . Inclusion of $F_T = 0.0018(3)$, clearly at variance with the Standard Model, would account for this anomaly. However, we saw no analogous effect in radiative muon decays $\mu^+ \rightarrow e^+ \nu \nu \gamma$.

While all our attempts to find an experimental cause for the observed discrepancy failed, we decided to repeat our experiment in the conditions optimized for this particular pion decay channel. Using the same setup, except for a redesigned target counter, we collected new data during 4 months of 2004, running at a reduced pion stop rate. In this way we were able to lower the accidental background by a factor of 10, and collect the same number of events as before.

In addition, we collected a large clean sample of radiative muon decay events to test for non - (V-A) interaction terms without the complications of hadronic structure effects.

In summary, this new run has achieved all of its proposed goals. The new data set will enable us to resolve the anomaly observed in the radiative pion decay.

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2.10 Reduction of Anisotropy of X-ray Beams Produced by the "Photon Needle" X-ray Generator

by M.Słapa, W.Straś, M.Snopek, M.Talejko, M.Traczyk, K.Wincel, B.Zaręba

The electron beam in the X-ray tube of the *Photon Needle* (IF) generator developed by our team is focused down to a spot of about 0.3 mm diameter, nominally located in the central region of the tube anode (Au target). Due to machining accuracy of the tube constructional elements, as well as due to external electromagnetic interferences, electrons may strike the target outside its central region. To compensate for that effect, a special set of deflection coils has been used. However, measurements of angular distribution of the produced radiation have shown a considerable anisotropy of the X-ray beam, even in the case when electrons strike the target precisely at its center. The anisotropy is caused by absorption in the thick Au target.



Fig. 1 Angular distribution of X-ray dosc rates in PMMA measured using Gafchromic foils.

To reduce the anisotropy, the beam deflection coils have been biased with an AC waveform suitable to sweep electrons across the target surface. The angular distribution of the X-ray dose rates measured in polymethyl methacrylate (PMMA) located 15 mm from the tube end in a plane parallel to the tube axis is shown in Fig. I. Angles were measured about electron beam direction. Doses were measured using the Gafchromic foils. Measurements were performed at the tube anode bias 40 kV, anode current 20 μ A, for both swept and non-swept electron beams.

The X-ray dose rates predicted in the used tube geometry and for the used tube operational parameters have been simulated using the MCNP5 computer code based on the Monte Carlo technique. Scanning the electron beam was simulated as a wide electron beam of 1.98 mm diameter. The calculated and experimental results have been compared in Fig. 2 and 3 for the case of non-swept/swept electron beam, respectively.

The developed X-ray beam dose rate anisotropy reduction method has been applied in the IF generator designed for clinical testing to be performed at the Collegium Medicum Neurotraumatology Clinic of the Jagiellonian University in Cracow.

The results of this work were presented at the 14th International Conference on Solid State Dosimetry held in New Haven, CT, USA, June 27 and July 2, 2004.



Fig. 2 Calculated and measured angular distribution of X-ray dose rate in PMMA. Non-swept electron beam.



Fig. 3 Calculated and measured angular distribution of X-ray dose rate in PMMA. Swept electron beam.

2.11 Investigation of Changes in Air Contamination by Neural Networks and Wavelet Decomposition (the Case of NO₂ as an Example)

by M.Sowiński, K.Garanty¹⁾, J.Wojtkowska, B.Mysłek-Laurikainen, M.Kowalski, S.Mikołajewski, H.Trzaskowska, K.Szymańska²⁾, T.Kołakowski²⁾

The temporal distribution of air contamination (Fig. 1) exhibits high concentration dynamics (up to 2 orders of magnitude) as well as high irregularity in time (from 0.5 hour to many days). The investigation of concentration correlations for many measurement stations points to the fact that some maxima cover very vast space (the whole agglomeration or its substantial part). Another maxima have a local character (contain several or only one station). Such spatio-temporal distribution of contaminants suggests either great complexity of these phenomena or incidental character of changes. It remarkably limits the modelling possibilities when the neural network is applied [1].



Fig. 1 Temporal distribution of NO_2 contaminant in February 2003 in AM1 station in Gdańsk with 0.5 hour sampling.



Fig. 2 Signal after the high frequency wavelet algorithms were applied.

Some of the results presented indicate an important improvement of prediction when wavelet algorithms are used for identification accuracy of temporal characteristics. The transformed data formed an input to neural network of a MLP (multi line perception) type. The wavelet analysis leads to minimisation of information necessary for signal description [2]. It also helps to separate the appropriate signal from casual noise. Wavelet algorithm is a new tool for transforming nonstationary signals, in particular. Fig. 2 presents the signal after the high frequency wavelet algorithms have been applied. With such signals we deal in the analysis of air contamination for two selected days in summer and winter season of NO₂ contamination. Fig. 3 presents the original signal after the subtraction of the high frequency component and this is a properly



Fig. 3 Example of daily original signal of NO_2 contaminant (a) in comparison with resulting curve (b).

defined signal to be used for teaching the neural network prediction.

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2.12 Wavelet Decomposition and Neural Networks Application to Daily Changes Prediction of NO₂ Concentration Based on Manual Measurement Data from Otwock

by K.Garanty¹⁾, M.Sowiński, J.Wojtkowska, B.Mysłek-Laurikainen, M.Kowalski, S.Mikołajewski, H.Trzaskowska

The pollution monitoring station in Otwock collects weather data similar to those that are collected by automatic stations in Gdańsk [1] but with different recording method. For a manual station the recording period is one day. Separation of the appropriate signal from casual noise using the wavelet analysis [2] is not needed. The daily average does not reflect casual variations of measurements performed every 0.5 hour. Weather data (wind direction, wind velocity, atmospheric pressure, temperature, and humidity) as well as two artificial vectors (month number, the day number) and contaminant (NO₂) being investigated constituted the input to the neural network. It was assumed that weather forecast for the day for which we perform our prediction is known. The signal NO₂ decomposed to wavelets was introduced to the output of the network. This idea appeared to be a good solution. The network learned to resolve the given problem with high accuracy. Results are shown in Fig. 1 and Fig. 2.



Fig. 1 Network training error and difference between real signal and network response.



Fig. 2 Network testing error and difference between real signal and network response.

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2.13 New Generator Method of Pure¹¹¹In Production in the Proton Induced Nuclear Reactions with Enriched¹¹²Sn

by E.Běták¹⁾, E.Rurarz, S.Mikołajewski, J.Wojtkowska

We have measured activation cross-sections using gamma-ray spectroscopy with high purity germanium detectors for 7 reactions induced by (23.6 ± 0.8) MeV energy protons in the enriched ¹¹²Sn sample.

The cross-sections are:

$$\begin{split} &\sigma[^{112}\text{Sn}(p,n)^{112}\text{Sb}] = (4\pm0.8)\text{mb};\\ &\sigma[^{112}\text{Sn}(p,2n)^{111}\text{Sb}] = (182\pm26)\text{mb};\\ &\sigma[^{112}\text{Sn}(p,pn)^{111}\text{Sn}] = (307\pm35)\text{mb};\\ &\sigma[^{114}\text{Sn}(p,2n)^{113}\text{Sb}] = (442\pm52)\text{mb};\\ &\sigma[^{117}\text{Sn}(p,n)^{117}\text{Sb}] = (15\pm3)\text{mb};\\ &\sigma[^{117}\text{Sn}(p,p`\gamma)^{117\text{m}}\text{Sn}] = (0.37\pm0.06)\text{mb};\\ &\sigma[^{115}\text{Sn}(p,2p)^{114\text{m}2}\text{In}] = (0.01\pm0.002)\text{mb}. \end{split}$$

The values of the cross-sections were compared with theoretical calculations based on the hybrid model of nuclear reactions using the well developed computer code Overlaid Alice.

We have undertaken experimental efforts to find out a simple and reliable way of ¹¹¹In production with highest purity from its grand parent ¹¹¹Sb and parent ¹¹¹Sn produced by the reactions ¹¹²Sn(p, 2n)¹¹¹Sb and ¹¹²Sn(p,pn)¹¹¹Sn, respectively.

The target (20.6 mg) was 84% enriched, metallic ¹¹²Sn sample. The contamination of ¹¹¹In by the undesired nuclide ^{114m2}In was determined and belongs to the smallest in the published literature. The expected yield of ¹¹¹In production is 1.2 mCi/µAh (46MBq/µAh). We also identified in proton beam monitoring Ni foils the activities of ⁵⁵Co (T_{1/2}=17.5h) and ⁶⁰Cu (T_{1/2} = 23.4m) induced in the ^{nat}Ni (p,X) ⁵⁵Co and ^{nat} Ni(p,X) ⁶⁰Cu reactions at 22.8 MeV proton energy. The determined cross sections for these reactions are: σ [^{nat}Ni (p, X) ⁵⁵Co] = (36.6 ± 4)mb; and σ [^{nat}Ni(p,X) ⁶⁰Cu] = (64.4 ± 7)mb.

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2.14 The C-30 Proton Beam Energy Measurement by the Time of Flight Method by M.Kisieliński and J.Wojtkowska

Our knowledge of the ion beam energy from the extraction radius is often inaccurate [1]. Thus other beam energy measurements are needed.

The C-30 cyclotron uses 52 MHz rf electrical field to accelerate protons. The extraction geometry and magnetic field of 1.7 Tesla give the possibility to obtain the range of proton velocities from 0.2c to 0.24c what corresponds to energies from 19 MeV to 28 MeV. During every rf period, a bunch of protons is injected into the beam line. Subsequent bunches are spatially separated by a distance L proportional to proton velocities v according to the simple formula:

$$L = v^*(1/f)$$
 (1)

where f is the rf field frequency; and L varies from $L_{min} = 110$ cm to $L_{max} = 140$ cm for minimal and maximal proton energies available.

A convenient way to determine the proton velocity is to measure the time of flight over a well defined base between two probes recording the time of passage of one bunch. If no more than one bunch travels the base, the determination of the time of flight is unambiguous. Then, however, the base has to be short and the precision is low. A longer base offers higher accuracy, but involves a number of bunches k. It is easy to show, that if the probes are separated by base D fulfilling the relation:

$$(k-1)*L_{max} < D < k*L_{min}$$
 (2)

then every k-th signal in the second probe following the signal in the first one is the true one, i.e. both signals originate from the same bunch. With growing k the lower and upper limits of D become closer and meet around $k = k_{max}$

$$k_{max} = L_{max}/(L_{max} - L_{min})$$

In C-30 cyclotron $k_{max} = 4$.

The above reasoning fixes the base between probes in the middle of the range (2), i.e.

$$D = ((k-1)*L_{max} + k*L_{min})/2$$

where $k < k_{max}$.

It turned out convenient to put D=170 cm with k=2.

The probes have the shapes of cylindrical capacitors 10 cm long with inner and outer diameters of 3 cm and 9 cm, respectively. They are closed on both sides by diaphragms with central apertures of 2 cm diameter. Their symmetry axis is collinear with the proton beam. Additionally, they are equipped with the pin electrodes stimulating response of the probes to the capacitively coupled 1 ns wide reference signal from Tektronix 109 Pulse Generator. The reference signal is splitted and sent to probes through cables matched in length. Signals from the probes are amplified by wideband amplifiers made from two monolithic amplifiers ERA-3SM manufactured by

Mini Circuits Inc. The 40 dB amplified signals are sent to fast discriminators built from LeCroy 400MHz quad comparators, type MVL407. The fast NIM logical pulse is triggered at zero crossing of input signal. This corresponds to the crossing of the bunch centroid the middle of the probe. The intervals between logical pulses from the discriminators are measured with ORTEC TAC 566. The first peak in the time spectrum originates from the reference pulser. It marks the absolute zero time span, within 100 psec. The following peaks originate from protons and intervals between them correspond to the rf field period known precisely from the frequency synthesizer. These peaks give precise TAC calibration checked earlier for integral nonlinearity to be less than 0.1%. The proton velocity is determined from the separation between Ist (reference pulser) peak and 3th peak (k=2), in the time spectrum, Fig. 1.



Fig. 1 T-O-F spectrum. The energy of the proton beam $E_0 = 24$ MeV was obtained from the measured velocity.

The beam energy can be also measured with the protons scattered by ${}^{12}C$ target, (see Fig. 2). Using well known energies of excited states of ${}^{12}C(Q_1,Q_3)$ the energy of the beam is simply determined.



Fig. 2 The energy of proton beam E_0 was obtained from the spectrum of protons scattered on ${}^{12}C$ target.

Although both methods of energy measurements are equivalent, the T-O-F has the advantage that is non intrusive. It can be also useful for continuous monitoring of the beam energy during long irradiation times.

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2.15 On Gas Gain at Characteristic Voltages of Spectrometric Mode of Conventional Avalanche Counters at Moderate Specific Ionization

by J.Sernicki

The spectrometric properties of avalanche counters may be evaluated based only upon partial data on the detector energy resolution (see e.g. refs. [1-4]). At present, there are generally insufficient data available on the spectrometric properties of parallel-plate avalanche counters (PPAC).

It should be fully realized that the counter spectrometric properties depend not only upon the statistical fluctuations of the charge generated in the interelectrode space, which are affected by the basic ionization processes (primary ionization process and gas gain process), but also upon the additional factors (see ref. [4]). However, the effect of additional factors can be minimized [4, 5].

In ref. [6], the empirical curve of the PPAC energy resolution is shown. The PPAC was filled with n-heptane vapour. In turn, the resolution variability as a function of the gas pressure is shown in refs. [6-8]. It has been found that the empirical curves of PPAC energy resolution have some plateau range. This plateau range falls within that section of the gas gain curve which has a strictly linear course in semilogarithmic coordinate system. This means that the fluctuations of the charge generated in the gas gain process are – within a determined plateau of energy resolution – approximately constant.

The fluctuations of the charge generated in the gas gain process depend upon the gas gain mean value. Thus, it is interesting to meet the values corresponding to the plateau range of the PPAC energy resolution.

The purpose of this investigation is to determine absolute values of effective gas amplification (M_{abs}) for the characteristic voltages which correspond to ends of the plateau range of energy resolution of PPAC detectors at moderate (see ref. [5]) specific ionization. General equations of the absolute gas gain characteristics, which are justifiable for PPAC filled with n-heptane vapour, were used [9]. The equations are obtained, generally, under measurement conditions, which are typical for the majority of physical experiments in which the PPAC detectors are used. The equations describe the linear characteristics in the semilogarithmic coordinate system.

The gas gain values – for individual plateau ranges – are given in Figs. 1 - 3. The determined values, generally, lie between 46 and 29110. In Figs. 2 - 3, the critical values of effective gas amplification (at U_{sch} voltage), above which the space charge effect may in fact accour, are shown too. The most dynamical variation of the gas gain occurs at the voltages which correspond to the lower end of the plateau, when interelectrode gap is changed (see Fig. 1).



Fig. 1 Actual gas gain values at voltages U_i – relating to lower end of PPAC energy resolution plateau range – vs. n-heptane pressure. The PPAC has an interelectrode gap of d.



Fig. 2 Actual gas gain values at voltages U_n – relating to upper end of PPAC energy resolution plateau range – vs. n-heptane pressure. The PPAC has an interelectrode gap of d=0.2 cm.



Fig. 3 Actual gas gain values at voltages U_u – relating to upper end of PPAC energy resolution plateau range – vs. n-heptane pressure. The PPAC has an interelectrode gap of d=0.3 cm.

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MEASUREMENT OF THE MUON DECAY SPECTRUM WITH THE ICARUS T600 LIQUID ARGON TPC S.Amuroso,, **T.Kozłowski** et al. *Eur. Phys. J. C33(2004)233*

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DESIGN, COMMISSIONING AND PERFORMANCE OF THE PIBETA DETECTOR AT PSI E.Frlcz,, **T.Kozłowski** et al. *Nucl. Inst. Meth. A 526(2004)300*

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ISOTOPE CORRELATIONS AS A PROBE FOR FREEZE-OUT CHARACTERIZATION: CENTRAL ¹²⁴Sn + ⁶⁴Ni, ¹¹²Sn + ⁵⁸Ni COLLISIONS E.Geraci,, **J.Wilczyński** et al. (REVERSE/CHIMERA Collaboration) *Nucl. Phys. A 734(2004)524*

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ATOMIC RESONANCES IN NUCLEAR RADIATIVE ELECTRON CAPTURE AND POSSIBILITY TO MEASURE THE MAJORANA NEUTRINO MASS **Z.Sujkowski**, S.Wyccch *Nucl. Inst. Meth. B (in press)*

NATURAL WIDTHS OF HYPERSATELLITE K X-RAY SPECTRA AND LIFETIMES OF DOUBLE K-HOLE STATES IN MID-Z ATOMS

J.Rzadkiewicz, D.Chmielewska, A.Gójska, Z.Sujkowski, M.Berset, ..., M.Polasik, K.Słabkowska, J.Hoszowska, M.Pajek, et al. Nucl. Inst. Meth. B (in press)

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ACTIVATION CROSS SECTIONS FOR REACTIONS INDUCED BY 14 M¢V NEUTRONS ON NATURAL TIN AND ENRICHED ¹¹²Sn TARGETS WITH REFERENCE TO ¹¹¹In PRODUCTION VIA RADIOISOTOPE GENERATOR ¹¹²Sn(n,2n)¹¹¹Sn→¹¹¹In E.Bctak, R.Mikołajczak, J.Staniszcwska, **S.Mikolajewski, E.Rurarz** *Radiochimica Acta (in press)*

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Oral presentations:

SURVIVAL PROBABILITY IN DEEXCITATION OF HEAVY NUCLEI <u>1.Skwira</u>, K.Siwek-Wilczyńska, **J.Wilczyński** XXXIX Zakopane Int. Symp. "Atomic nuclei at extreme values of temperature, spin and isospin", Zakopane, Poland, Sept. 2004

SHELL CORRECTION ENERGIES IN CALCULATIONS OF THE SURVIVAL PROBABILITY <u>K.Siwck-Wilczyńska</u>, I.Skwira, **J.Wilczyński** 11th Nuclear Physics Workshop 'Marie and Pierre Curie', Kazimierz Dolny, Poland, 23 – 26 September 2004

DEFORMATION ENERGIES OF NUCLEAR SYSTEMS <u>J.Blocki</u>, L.Shvedov, J.Wilczyński 11th Nuclear Physics Workshop 'Marie and Pierre Curie', Kazimierz Dolny, Poland, 23 – 26 September 2004

TESTS OF DYNAMICS OF DEEP INELASTIC COLLISIONS <u>L.Shvedov</u>, J.Błocki, J.Wilczyński 11th Nuclear Physics Workshop 'Marie and Pierre Curie', Kazimierz Dolny, Poland, 23 – 26 September 2004 HOW TO CALIBRATE THE TIME SCALE OF EMISSION OF INTERMEDIATE MASS FRAGMENTS? <u>J.Wilczyński</u>, E.Dc Filippo, A.Pagano, F.Amorini et al. (REVERSE/CHIMERA Collaboration) 11th Nuclear Physics Workshop 'Marie and Pierre Curie', Kazimierz Dolny, Poland, 23 – 26 September 2004

NATURAL WIDTHS OF HYPERSATELLITE K X-RAY SPECTRA AND LIFETIMES OF DOUBLE K-HOLE STATES IN MID-Z ATOMS

J.Rzadkiewicz

12th International Conference on the Physics of Highly Charge Ions (HCI 2004), Vilnius, Lithuania, 6-11 September, 2004

NEW STRUCTURE INFORMATION ON ³⁰Mg, ³¹Mg AND ³²Mg <u>H.Mach</u>, L.M.Fraile, ..., C.Jollet, **W.A.Plóciennik**, B.Rubio, **E.Ruchowska**, et al. (ISOLDE Collaboration) *International Conference ENAM04, Callaway Garden, Pine Montain, USA, 12 – 16 September 2004* Presentation is placed in <u>https://www.phy.ornl.gov/enam04/WebTalks/</u>

LIFETIME MEASUREMENTS IN ¹²⁸Cs AND ¹³²La AS A TEST OF CHIRALITY E.Grodner, ..., <u>J.Srebrny</u>, Ch.Droste, M.Kisicliński, A.Kordyasz, **R.Kaczarowski, W.A.Plóciennik, E.Ruchowska, A.A.Wasilewski**, J.Perkowski et al. *11th Nuclear Physics Workshop 'Marie and Pierre Curie', Kazimierz Dolny, Poland, 23 – 26 September 2004*

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Program Advisory Committee, Juelich, Germany, 8 November 2004

COMPUTERIZED SET FOR RADIOTHERAPY WITH *PHOTON NEEDLE* X-RAY TUBE **M.Slapa**, **W.Straś**, **M.Snopek**, **M.Talejko**, **M.Traczyk**, H.Roguszczak, T.Zawada *III Medical Engineering Workshop*, *Cracow*, *Poland*, *13 – 14 May 2004*

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NEUTRINO-LESS DOUBLE ELECTRON CAPTURE – A TOOL TO SEARCH FOR MAJORANA NEUTRINOS Z.Sujkowski, S.Wyccch

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ATOMIC RESONANCES IN NUCLEAR RADIATIVE ELECTRON CAPTURE AND POSSIBILITY TO MEASURE THE MAJORANA NEUTRINO MASS

Z.Sujkowski, S.Wycceh

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CHARGE EXCHANGE PROCESSES FOR SEMI-RELATIVISTIC HELIUM IONS (β = 0.51) IN SOLID GOLD **A.Gójska, D.Chmielewska, J.Rzadkiewicz, Z.Sujkowski,** T.Adachi, H.Fujita, Y.Fujita, K.Hara, Y.Haruyama, J.Kamiya, H.Ogawa, M.Saito, Y.Shimizu, Y.Shimbara, M.Tanaka, H.P.Yoshida, I.Katayama *12th International Conference on the Physics of Highly Charge Ions (HCI 2004), Vilnius, Lithuania, 6 – 11 September 2004*

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DOSE DISTRIBUTION AROUND A NEEDLE-LIKE ANODE X-RAY TUBE: DYE-FILM VS PLANAR THERMOLUMINESCENT DETECTORS

M.Budzanowski, P.Olko, B.Marczewska, Ł.Czopyk, M.Slapa, W.Straś, M.Traczyk, M.Talejko 14th International Conference on Solid State Dosimetry, New Haven, CT, USA, 27 June – 2 July 2004 RADIOACTIVE AIR POLLUTION ANALYSIS AS A BASE FOR CREATION OF INTELLIGENT SYSTEM OF AIR QUALITY ASSESSMENT AND MANAGEMENT

B.Mysłek-Laurikainen, K.Garanty, M.Sowiński, J.Wojtkowska, Z.Moroz, K.Szymańska, Z.Preibisz, M.Kowalski, M.Matul, H.Trzaskowska, S.Mikołajewski

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SPATIAL AND TEMPORAL AIR POLLUTION MODELING USING NEURAL NETWORK AND WAVELET METHOD BASED ON THE MONITORING DATA FOR GDAŃSK AND OTWOCK REGION B.Mysłek-Laurikainen, K.Garanty, M.Sowiński, J.Wojtkowska, K.Szymańska, Z.Preibisz, M.Kowalski, M.Matul, H.Trzaskowska

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RECENT RESULTS OF THE CHIMERA-REVERSE EXPERIMENTS G.Politi,, J.Wilczyński et al. (REVERSE/CHIMERA Collaboration) Proc. Int. Workshop on Multifragmentation and Related Topics, IWM2003, Caen, France, Nov. 2003, (Eds. G.Angello, A.Pagano, S.Pirrone), Tipolitografia Bonanno, Catania, 2004, p. 95

DYNAMICAL ASPECTS OF FRAGMENT PRODUCTION IN THE REACTIONS ¹²⁴Sn + ⁶⁴Ni, ²⁷Al AND ¹¹²Sn + ⁵⁸Ni AT 35 A MeV E.De Filippo,, **J.Wilczyński** et al. (REVERSE/CHIMERA Collaboration) Proc. Int. Workshop on Multifragmentation and Related Topics, IWM2003, Caen, France, Nov. 2003, (Eds. G.Angello, A.Pagano,

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LECTURES, COURSES AND EXTERNAL SEMINARS

NEUTRINO BETA BEAMS *)

T.Kozłowski, Warsaw University Seminar, Warsaw, Poland, 15 December 2004

NEUTRINO-LESS DOUBLE BETA DECAY – A FUNDAMENTAL EXPERIMENT OF MODERN NEUTRINO PHYSICS ^{a)} Z.Sujkowski (lecture) UMCS, Lublin, Poland, 22 January 2004

HAVE WE ENTERED THE DECADE OF BIG DISCOVERIES IN NEUTRINO PHYSICS ^{bi} Z.Sujkowski (lecture) Department of Physics, University of Jyväskylä, Finland, 7 October 2004

RESEARCH AT THE INSTITUTE FOR NUCLEAR STUDIES^{b)} Z.Sujkowski (lecture) Kharkov Institute of Physics and Technology, Kharkov, Ukraine, 24 September 2004

LIFETIMES OF HOLLOW ATOMS^{a)} J.Rzadkiewicz, Warsaw University Seminar, Warsaw, Poland, 20 October 2004

NATURAL WIDTHS OF HYPERSATELLITE K X-RAY SPECTRA AND LIFETIMES OF HOLLOW MID-Z ATOMS^{b)} J.Rzadkiewicz, (lecture) GSI, Darmstadt, 8 December 2004

a) in Polish

b) in English

INTERNAL SEMINARS

NEUTRINO BETA BEAMS T.Kozlowski, Institute for Nuclear Studies, 8 October 2004

DEVELOPMENT OF "PHOTON NEEDLE" COMPUTERIZED SET FOR RADIOTHERAPY M.Słapa, M.Tałejko, M.Traczyk, Institute for Nuclear Studies, 1 July 2004

HAVE WE ENTERED THE DECADE OF BIG DISCOVERIES IN NEUTRINO PHYSICS Z.Sujkowski, Institute for Nuclear Studies, 29 January 2004

CHARGE EXCHANGE PROCESSES FOR SEMI-RELATIVISTIC HELIUM IONS IN SOLID A.Gójska (PhD seminar), Institute for Nuclear Studies, 30 November 2004

NUCLEUS-NUCLEUS COLLISIONS IN ONE-BODY DYNAMICS L.Shvedov (PhD seminar), *Institute for Nuclear Studies, January 2004*

PARTICIPATION IN SCIENTIFIC COUNCILS AND ORGANISING COMMITIES OF CONFERENCES

J.Wilczyński - Member of the "CHIMERA Advising Committee" at LNS, Catania, Italy

J.Wilczyński – Member of the International Advisory Committee for the "World Consensus Initiative 2004" on nuclear reaction dynamics and thermodynamics in the Fermi-energy regime

Z.Sujkowski - Member of the Nuclear Physics Board European Physical Society

DIDACTIC ACTIVITY

J.Błocki - Supervisor of PhD studies of Mr. L. Shvedov (INS)

R.Kaczarowski - Supervisor of PhD studies of Mr. A. Wasilewski (INS)

Z.Sujkowski - Supervisor of PhD studies of Mr. J. Rzadkiewicz (INS)

Z.Sujkowski - Supervisor of PhD studies of Mrs. A. Gójska (INS)

SCIENCE POPULARIZATION ACTIVITY

ENTHUSIASM UNDER DRIP Z.Sujkowski (Interview by W.Bielski), Przegląd Techniczny, 27.06.2004

PERSONNEL

Research scientists			
Jan Błocki, Professor	4/5 since June	Jan Sernicki, Dr.	
Danuta Chmielewska, Dr.		Mieczysław Słapa, Assoc. Professor	4/5
- Scientific Secretary	of the Institute	Mieczysław Sowiński, Assoc. Prof.	1/3 till June 30
Rościsław Kaczarowski, Asso	c. Professor		3/5 from July 1
Tadeusz Kozłowski, Dr.		Ziemowid Sujkowski, Professor	
Bogumiła Mysłek-Laurikainer	n, Dr.	- Director of the Institute	
Weronika Płóciennik†, Dr.	till De	c. Janusz Wilczyński, Professor	
25		Jolanta Wojtkowska, Dr.	3/4
Zygmunt Preibisz, Dr.	1/5	Izabella Zychor, Dr.	
Ewa Ruchowska, Dr		•	

PhD students

Aneta Gójska, MSc. Leonid Shvedov, MSc.

Technical and administrative staff

Andrzej Fronczak	from Nov. 1	Tomasz Pławski, Eng. (on leave)	
Konrad Garanty	1/2	Jacek Rzadkiewicz, MSc. Dr. from O	
Stanisław Gębalski, MSc.		Mirosław Snopek	
Marek Kowalski, MSc.		Włodzimierz Straś	till Aug. 22
Alicja Kurdej	2/5	Marcin Talejko	Ũ
Marian Laskus	2/5 from June 1	Marek Traczyk, MSc.	
	l from Nov. 1	Halina Trzaskowska	
Maria Matul, MSc.	3/5 till Aug. 31	Katarzyna Tymińska, MSc.	from Dec. I
	2/5 from Sept. 1	Adam Wasilewski, MSc.	¹ / ₂ till June 30
Stefan Mikołajewski		Anita Zych, MSc.	from Oct. 1

Weronika Anna Plóciennik (1967 – 2004)

Commemoration





Dr. Płóciennik – for us Weronika – joined our Department at the Andrzej Sołtan Institute for Nuclear Studies in 1996. She was with us for nine years and to our deep sorrow she left us on December 25, 2004 at her best age – she was only 37 – and at her full creative potential. There is no shade of exaggeration in these words. Extremely fruitful were the last years.

Weronika had a strong personality and her own characteristic style of work. She worked seemingly without effort, with ease. She had her own working hours – evidently preferring to work evenings. Not showing it, Weronika was very ambitious, and she devoted a lot of time, energy, and heart to her work. She had very deep knowledge of physics and computer techniques. Many of us benefited from her knowledge and experience. Weronika was always ready to give advice and help in professional and even personal problems. She was able to contribute significantly in both experimental and theoretical nuclear physics. These rather exceptional abilities were appreciated by many physicists who always eagerly invited her to participate in various research projects in the field of nuclear spectroscopy.

Weronika loved flowers and cultivated her garden outside the city. Very often she shared with us fruits which she gathered from her garden. We remember excellent plums and medlars. Her illness and death were a complete surprise for us. We will always miss her. She will remain in our best memories.

Colleagues

3 DEPARTMENT OF DETECTORS AND NUCLEAR ELECTRONICS

Head of Department: Dr. Zbigniew Guzik phone: (22) 718-05-49 e-mail: zbig@ipj.gov.pl



Overview

The basic activities of the Department of Nuclear Electronics in 2004 were concentrated on the following areas:

- studies of new scintillation techniques,
- contribution to the FWVI European projects,
- scientific contracts with European industry in respect to detection techniques
- electronics for experiments in High Energy Physics,
- development of γ-ray spectrometry apparatus,
- development of new generation State of the Art USB based and PCI based multi-channel analysers,
- electronics and software support for nuclear plants (i.e. IGISOL setup for Warsaw University)
- development, investigation and production of silicon detectors
- technical support for the Institute as a whole with special emphasis on networking,
- normalisation activities.

Most of the scientific achievements of the Department were summarized in 16 publications (released or in press) and 9 submitted publications. The papers were published mainly in IEEE Trans. Nucl. Sci. and Nucl. Instr. Methods. Besides that, our scientists presented 8 contributions at international conferences -7 presentations on IEEE Nuclear Science Symposium and Medical Imaging 2004 in Rome, Italy. We also stress our normalization activity in preparation of Polish versions of European Standards in electronics.

Studies of new scintillation techniques were concentrated mainly on the new crystals for the border monitoring application as CdWO₄ and Lil(Eu), as well as on those important for nuclear medicine (LuAP and LSO). Measurements of the non-proportionality of the light yield versus gamma ray energies and energy resolution allowed us to collect new data and observations important for understanding of a scintillator itself contribution to the energy resolution.

In the last year we have started realization of three European projects within FWVI. The EURITRACK project is addressed to the development of a neutron activation analysis system to detect explosive materials at border crossings. The BioCare project is dealing with new developments in Positron Emission Tomography. Finally, in the third project, guided by the High Energy Physics Department, we contribute to the development of the recoil detector for COMPASS experiment at CERN.

The Department was involved in scientific collaborations with a number of international centers, such as CERN, Royal Institute of Technology in Stockholm, FZR Rossendorf, FZ Juelich, GSI Darmstadt and companies as Saint-Gobain, Photonis Materials in Scotland, Scionix in Holland, Photonis in France and Target in Germany. Additionally, collaboration with IAEA in Vienna concerning monitoring of State borders was continued. Several scientific contracts were realized for European industry.

The collaboration with the High Energy Physics Department of our Institute was focused on the LHCb experiment in CERN. It covered design, fabrication and test of four kinds of hardware modules – Readout Supervisor (ODIN), TFC Switch (THOR), Throttle Switch (MUNIN) and Throttle OR (HUGIN). In 2004 the final production versions of ODIN and THOR were released and final prototype version of MUNIN and HUGIN were prepared and tested.

Our work on the development of a new generation State of the Art PCI based and USB based multi-channel analysers was very promising. Many PCI based analysers were sold while a USB based device in the form of autonomous miniature screened box is under production tests and finalization of supporting software.

In the field of semiconductor detectors, besides continuation of previous works, the modification of the production method of drift Si(Li) detectors was started. Also, works concerning ion implantation for creation of n-p and p-n junctions in HP-Ge germanium monocrystals was initialized.

The technical support for the Institute covers a lot of different types of activities, as supervising the Institute computer network, maintaining internal data base and so on.

Zh fi



3.1 CdWO₄ Crystal in Gamma-ray Spectrometry

by M.Moszyński, M.Balcerzyk, M.Kapusta, A.Syntfeld, D.Wolski, G.Pausch¹⁾, J.Stein¹⁾, P.Schotanus²⁾

The properties of CdWO₄ (CWO) crystals [1] in gamma ray spectrometry were studied. Several small samples of 10x10x3 mm size, typically used in CT X-ray detectors, were tested and then compared to the performance of a larger crystal of 20 mm in diameter and 20 mm in height. The light output, energy resolution, and non-proportionality of the CWO response versus gamma-ray energy, were measured and compared with those of a small BGO to discuss further the origin of the intrinsic resolution of pure undoped scintillating crystals.

A high light output of 6500 ± 200 phe/MeV and a good energy resolution of $6.6 \pm 0.2\%$ for 662 keV gamma rays from a ¹³⁷Cs source were measured for the small samples coupled to an XP3212 photomultiplier, see Fig. 1.



Fig. 1 Energy spectra of 662 keV γ -rays from a ¹³⁷Cs source, as recorded with the 10 x 10 x 3 mm³ CWO (bottom panel) and with the Ø25 mm x 30 mm Nal(Tl) (upper panel). An escape peak of K X-rays of Tungstate is seen at the 662 keV peak in the CWO spectrum.

Note the comparable photofractions of 26% and 23% in both spectra for the CWO and the Nal(Tl) crystals, respectively, while the volume of the Nal(Tl) crystal is 50 times larger.

Fig. 2 presents the non-proportionality characteristics of the small CWO 1L in comparison to that of a BGO crystal, according to Ref. [2].



Fig. 2 A comparison of the non-proportionality curves measured for the small CWO and BGO crystals. The curve for BGO follows that of [2].

Common non-proportionality curves and consequently common intrinsic resolutions of small CWO and BGO suggest that they represent fundamental characteristics of the heavy oxide scintillating material themselves.

A good energy resolution and a high photofraction measured for CWO crystals confirmed the high potential of CWO crystals for application in the border monitoring equipment.

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- [2] M.Moszyński, M.Balcerzyk, W.Czarnacki, M.Kapusta, W.Klamra, A.Syntfeld, M.Szawlowski, IEEE Trans. Nucl. Sci., Vol. 51, No. 3, pp. 1074-9, June 2004

Presented at IEEE Nuclear Science Symposium and Medical Imaging Conference, Roma, Italy, October 2004, IEEE Trans. Nucl. Sci., in press.

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DEPARTMENT OF DETECTORS AND NUCLEAR ELECTRONICS

3.2 Non-proportionality and Thermoluminescence of LSO:Ce.

by M.Kapusta, P.Szupryczynski¹⁾, C.L.Melcher, M.Moszyński, M.Balcerzyk, A.A.Carey¹⁾, W.Czarnacki, M.A.Spurrier¹⁾, A.Syntfeld

This work presents the results from experiments, performed on Lu₂SiO₅:Ce (LSO:Ce). We look for potential correlations of light yield scintillation non-proportionality and other properties, including intrinsic energy resolution with thermoluminescence properties. Samples were chosen from various crystal batches that were known to have significantly different properties. Single crystal LSO:Ce samples were coupled to an XP2020Q photomultiplier and to large area avalanche photodiodes and measured as a function of gamma-ray energy between 14.7 and 1770 keV at room temperature and also near liquid nitrogen temperature. In order to explain the experimental results obtained from spectrometric methods, the properties of the samples were further studied using thermoluminescence techniques in the temperature range from 250 to 600 K.

In the spectrometry measurements at LN₂ temperature the best LSO sample showed a high light output of 39500 ph/MeV and an energy resolution of 7.5±0.3% for 662 keV γ -rays from a ¹³⁷Cs source. The study of non-proportionality and intrinsic resolution for this sample as a function of gamma energy exhibited common curves in dependent of temperature. The properties of other samples depended on temperature. Their nonproportionality and energy resolution were worse than those of the best LSO sample assuming that the non-proportionality curve of LSO-L is disturbed due to its inhomogeneities. The shapes of the non-proportionality curves for those samples were related with ionization densities of the incident radiation. The large intrinsic resolution of LSO comparing with other crystals suggested that this part of energy resolution covers more then nonproportionality.

On the bases of the thermoluminescence data, we found that in all the samples used in the experiments is the same type of defect. The yellow defect in the LSO – M crystal does not show up in thermoluminescence data in the temperature regime used. The role of these yellow centers in the scintillation process remains unknown. However, the defect concentration detected by thermoluminescence is different for each sample.

As shown in Fig. 1, the afterglow of the crystals is related to the thermoluminescence intensity. Fig. 2 shows that also the light output of the crystals is related with thermoluminescence intensity. Thus, we conclude that the concentration of the traps is inversely related to the scintillation light yield and proportional to their afterglow as measured at room temperature.



Fig. 1 A comparison of the dependency of the afterglow of the samples measured at RT on thermoluminescent integrated intensity.

In all samples, the defects showed by thermoluminescent studies might be related to oxygen vacancies generated in the material during the crystal growth. The oxygen vacancies remove some of the electrons generated by ionizing radiation and remove them from the scintillation process. It might be that there are some mechanisms related to the traps which affect nonproportionality curves and influence the intrinsic component of the energy resolution. However the nature of this process is still unknown and further studies are necessary.



Fig. 2 A comparison of the dependency of the light output at RT on integrated intensity of the thermoluminescent for tested samples.

As shown in Fig. 2, there is still room to improve LSO by reducing a number of defects.

 CTI Molecular Imaging, Inc., 810 Innovation Dr., Knoxville, TN. 37932, USA



3.3 Perspectives for High Resolution and High Light Output LuAP:Ce Crystals

by M.Balcerzyk, M.Moszyński, Z.Galazka¹⁾, M.Kapusta, A.Syntfeld and Jean-Luc Lefaucheur¹⁾

After its introduction as a new scintillator in 1994, LuAlO₃:Ce (LuAP:Ce) encountered problems of (1) a low light output, (2) self-absorption of scintillation light, (3) non-proportionality of light output versus energy and (4) a poor energy resolution (5) small nonuniform crystals. The recently available large size boules of LuAP (up to 50 mm in diameter) from Photonic Materials (PM) present important progress in overcoming all the listed drawbacks of LuAP. The aim of this work was to study gamma-ray detection and optical properties of LuAP.



Fig. 1 Non-proportionality of LuAP:Cc: diamonds and triangles – samples of Photonic Material crystals A and B of 2 mm×2 mm×10 mm, squares – Litton Airtron sample 1 mm thick of 1993.

The non-proportionality characteristics of LuAP from PM of the light yield versus gamma rays energy are shown in Fig. 1, in comparison with the similar measurements performed using the earlier sample from Litton Airtron. The curves measured for PM crystals are certainly flatter compared with earlier LA crystals and more flat than those reported by C.Kuntner *et al.* for LuYAP crystals – 95% for 32 keV compared to 85% in Kuntner paper.

The dependence of the total energy resolution, intrinsic resolution and statistical contribution on energy is shown in Fig. 2.

The number of photoelectrons was measured for all the rectangular-prism-shaped samples of different thickness. Light attenuation versus sample thickness exhibits an exponential character, with the exponent constant of 0.90 ± 0.04 cm⁻¹. The 10 mm thick sample showed about $45\pm2.5\%$ of the light measured for the 1 mm sample; see Fig. 3.

The integration of the light pulse over a 100 μ s period suggests an increase of the light output by a factor of about 2 in comparison with that measured at 0.25 μ s shaping. Comparing these values with the light output of YAP:Ce, one can deduce that the

ultimate LuAP:Ce light output integrated over 100 μ s may be close to the YAP, which has light output of 5300 phe/MeV.



Fig. 2 Energy resolution of LuAP:Cc 2x2x10 mm pixel of crystal B PM. Diamonds - FWHM, triangles - statistical term, squares - intrinsic resolution.



Fig. 3 Light yield vs. thickness for Cc-doped and undoped LuAP (PM).

Current samples of LuAP from PM are characterized by: (i) excellent energy resolution (6.8% at 662 keV), (ii) intrinsic energy resolution (2.8% at 662 keV), close to that of YAP:Ce, (iii) excellent non-proportionality (same as YAP:Ce), (iv) significantly reduced self-absorption to 0.9 cm^{-1} , (v) possibility of doubling of light yield if long components are shifted to fast Ce emission.

Self-absorption of LuAP is the same for Ce-doped and undoped samples, suggesting that it is not connected with Ce, but rather with crystal properties.

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3.4 Studies of ⁶LiI(Eu) Scintillator in Neutron Spectrometry

by A.Syntfeld, M.Moszyński, R.Arlt¹⁾, M.Balcerzyk, M.Kapusta, M.Majorov²⁾, R.Marcinkowski, P.Schotanus³⁾, M.Swoboda¹⁾ and D.Wolski

A Europium activated ⁶LiI crystal (enriched to 96% ⁶Li) of the size of \emptyset 50 mm×5 mm has been studied in neutron spectrometry. The crystal was coupled to a calibrated Photonis XP5200 photomultiplier. A response of ⁶LiI(Eu) to neutrons has been investigated and the thermal neutron peak has been found to be located at Gamma Equivalent Energy (GEE) of about 3.5 MeV. Due to the high sensitivity to thermal neutrons and good proportionnality against γ -ray energy [1], the ⁶LiI(Eu) crystal was brought under testing with a few samples of fissile nuclear materials. Moreover, ⁶LiI(Eu) was tested with a strong γ source to inspect a neutron response of the crystal disturbed by a pileup effect.

A Pu-Be neutron source was used to measure neutron spectra. The source emitted neutrons up to about 11 MeV with an intensity maximum in the 3-5 MeV range [2]. Since the ⁶Li nuclei have a large cross-section for thermal neutron capture, the Pu-Be source was surrounded with paraffin blocks to slow down the fast neutrons and, therefore, increase the total detection efficiency. A neutron monitor Nuclear Enterprises NM2B was used to control a dose equivalent (DE) expressed in both μ S/h units and counts of neutrons per second registered in the monitor.



Fig. 1 Measured linear dependence of the number of neutron detected in ⁶Lil(Eu) (left Y-axis) on dose equivalent (bottom X-axis) and counts of neutrons (top X-axis), both registered by the neutron monitor NM2B.

The high sensitivity of the detector is illustrated in Fig. 1 where almost linear dependence of the number of neutrons detected by ⁶Lil(Eu) on the dose equivalent goes down to very low DE values. ⁶Lil(Eu) is able to detect neutrons at a rate as low as 10⁻² counts/s registered in the neutron monitor.

Due to the very high sensitivity of ${}^{6}\text{Lil}(\text{Eu})$ to neutrons, samples of fissile materials were measured. Three fissile samples were used: an enriched (4.46%) uranium, a low burnup ${}^{239}\text{Pu}$ (93%) and a high burnup ${}^{239}\text{Pu}$ (61%). The first sample contained 7.6 g of 235 U, the second one consisted of 6.2 g of 239 Pu, 0.4 g of 240 Pu, and other small impurities. The high burnup 239 Pu (61%) contained 4.2 g of 239 Pu and 1.7 g of 240 Pu. Each of the plutonium samples weighed about 6.6 g with all impurities included. Fig. 2 shows radiation of the low and high burnup samples of Pu shielded with a 30 mm thick Pb brick.



Fig. 2 The γ -ray and neutron spectra of the low burnup Pu (bottom) and high burnup Pu (top) samples measured with ⁶Lil(Eu).

A further test was done to show neutron detection with overloading of a 6Lil(Eu) crystal by a strong γ background. The crystal has been irradiated with a very strong ⁶⁰Co source of several MBq activity and with the moderated Pu-Be source at the same time. The shaping time of 1 µs was set. The very high γ -detection rate (about 10⁵ counts/s registered in ⁶Lil(Eu)) caused a neutron peak to shift by about 140 channels to the right. Nevertheless, the peak can be easily recognized even though the background is increased due to pileup effects.

- ⁶Lil(Eu) in Neutron and γ-ray Spectrometry a High Sensitive Thermal Neutron Detector A.Syntfeld, M.Moszyński, R.Arlt, M.Balcerzyk, M.Kapusta, M.Majorov, R.Marcinkowski, P.Schotanus, M.Swoboda, D.Wolski submitted to IEEE Trans. Nucl. Sci.
- [2] Neutron Energy Spectra of Different Size
 ²³⁹Pu Be(α,n) Sources M.E. Anderson and R.A. Neff Nucl. Instr. Meth. 99 (1987) 231
- International Atomic Energy Agency (IAEA), Wagramer Strasse 5, PO Box 100, 1400 Vienna, Austria
- ²⁾ Nuclear Physics Researches, Scientific Engineering Center, St. Petersburg, Russia
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3.5 Evaluation of New Photonis XP1472 Nine-Channel Photomultiplier

by M.Moszyński, D.Wolski, M.Kapusta, M.Balcerzyk, A.Syntfeld, C.Fontaine¹, P.Lavoute¹, P.Bascle¹, C.Moussant¹, S.O.Flyckt¹

The performance of a new Photonis XP1472 nine-channel photomultiplier (PMT) was studied with the main emphasis on the photoelectron numbers and photoelectron collection efficiency, as measured with a 10 mm in diameter NaI(Tl) crystal coupled to the separate channels.

Fig. 1 shows a photograph of the PMT input structure as seen through its window. Note the specific design of the focalization electrodes, which divide the photocathode to 9 equal areas and provide a good photoelectron collection for each channel.



Fig. 1 Photograph of the XP1472 PMT input optic, as seen through the glass window.

Simultaneously, energy resolution and crosstalk were measured for all channels with a ¹³⁷Cs source. Fig. 3 shows a map of the channels in the PMT no. 59.

1.01	1.25	0.54
1.06	0.97	0.97
10.8 %	10.7 %	10.8 %
1.57	1.00	1.20
1.00	0.94	0.97
10.7 %	12.6 %	12.7 %
0.74	1.00	0.47
1.09	0.82	1.18
11.6 %	12.8 %	11.5 %

Fig. 2 Relative gain, photoelectron number, and energy resolution (measured for 122 keV gamma rays in a small Nal(TI) erystal coupled to each channel) in the XP1472.

The numbers presented correspond to the relative gain of the channels in comparison to the central one, the number of photoelectrons compared to the mean number over all the channels, and energy resolution of the 122 keV peak of ⁵⁷Co gamma rays, as measured on each channel with the small NaI(TI) crystal.

The time jitter and time resolution for an LSO crystal coupled to the different channels were measured for 511 keV annihilation quanta and compared to those measured earlier with XP2020Q PMTs.

Fig. 3 presents time spectra measured with two LSO crystals coupled to the central channel, P5, of the XP1472, no. 83. It shows regular Gaussian spectra with FWHM of 740 ± 200 ps and 1.0 ± 0.2 ns for the square and PET crystals, respectively.



Fig. 3 The time spectra measured with LSO crystals coupled to the central channel of XP1472, No. 83 for ²²Na γ -rays. Note that in the reference detector a BaF₂ crystal coupled to the XP20Y0Q/DA was used.

Our studies confirmed high photoelectron collection efficiency in the PMT due to a new design of the input focalisation system. A good time resolution measured with the finger like LSO crystal pointed out further a good capability of the XP1472 for PET block detectors.

Photonis, Av. Roger Roncier, B.P. 520, F 19106 Brive La Gaillarde, Cedex, France



PL0501134

3.6 Tests of the 3" x 3" NaI(Tl) Detector in a High Energy γ-spectrometry, as a Potential Detector of Choice for the EURITRACK Project

by M.Gierlik, T.Batsch, M.Moszyński, and D.Wolski

The EURITRACK project defines its basic γ detector as an affordable and widely available unit, characterized by high efficiency and satisfactory time and energy resolution. Here we report on some rudimentary tests of a potential detector of choice, consisting of a 3"x3" Nal(Tl) scintillator coupled to a Photonis XP4312/B PMT.

A high light output is essential for good energy and time resolutions and is related to the minimum quantity of detectable material required for triggering the positive response of the system. The number of $(6.8 \pm 0.3) \times 10^3$ photoelectrons per 1 MeV at an energy of 662 keV of ¹³⁷Cs was determined by a comparison to the single photoelectron spectrum, see Fig. 1.



Fig. 1 Energy spectra of 137Cs (right panel) and corresponding single photoelectron peak (left panel)) measured with the 3"x3" NaI(Tl) crystal coupled to XP4312/B PMT. Full width at half maximum (fwhm) for the energy of 662 keV is marked in the pieture.

Since detection of explosives is generally related to the identification of high energy γ transitions such as 3.93 and 4.44 MeV of carbon or 6.16 and 6.91 MeV of oxygen, it becomes vital to achieve sufficiently good energy resolution at a possibly wide energy range. By using a Pu-Be radioactive source we were able to measure the desired characteristic up to the energy of 4.4 MeV, see Fig. 2.

The crystal investigated displays fwhm as low as 7.4% at an energy of 662 keV. This value is slightly but not unexpectedly worse, considering the size of the crystal, than 6.5% commonly cited for NaI(TI) scintillators. Fig. 2 presents the energy spectrum of γ -rays from ⁵⁶Co source (lower panel) and energy resolution plotted versus energy (upper panel).

Among other project requirements, the ability to determine the position of the suspected sample inside a standard container is considered to be of the utmost importance.



Fig. 2 Upper panel: FWHM as a function of the γ -energy. Lower panel: An example of a complex ⁵⁶Co energy spectrum.

The Time of Flight (TOF) technique is considered to be most suitable for this purpose; however, it demands a detector of sufficiently high time resolution. We measured γ - γ coincidences in ⁵⁶Co and ⁶⁰Co as well as γ -n in Pu-Be source, applying a fast BaF₂ scintillator coupled to a XP20Y0 Q/DA PMT as a reference detector. In order to cut off low energy events and thus enhance the quality of the time spectra, energy gates were set on relevant parts of energy spectra by means of single channel analysers (SCA). The obtained value of 1.1 ns corresponds to about 15 cm and is well within the project's constraints.



Fig. 3 Left panel: The time spectrum of γ - γ and γ - ν coincidences from Pu-Be source. Energy spectra corresponding to set gates are presented in the insert. Right panel: The time spectrum of γ - γ coincidences from ⁶⁰Co. Gates were set on 1333 and 1172 keV lines.

PL0501135

3.7 Peltier-cooled Avalanche Photodiode-scintillator Sets

by W.Czarnacki, M.Moszyński, T.Sworobowicz, A.Kotlarski

Two Peltier-cooled avalanche photodiode (APD)-scintillator sets have been built and tested as ionizing radiation spectrometers. Single stage thermoelectric coolers and 1 cm dia x 1 cm high CsI and NaI crystals were used. The hot cooler junction in one of the sets equipped with CsI was cooled by a fan. The junction in the other set equipped with NaI was cooled by tap water. Depending on the ambient temperature, the

temperature of the CsI-APD set could be lowered to -15° C...-10°C, that of the NaI-APD set could be lowered to -21° C...-15°C.

Long-term stability of peaks and energy resolution (FWHM) were tested for 5.9 keV X-rays from the ⁵⁵Fe source and 662 keV γ -rays from the ¹³⁷Cs source. The measurements were conducted at the APD gain M=100. The preliminary results are as follows:

	5.9 keV X-ray peak		662 keV γ-ray peak	
	stability	FWHM	stability	FWHM
CsI-APD	5%	14%	-	12%
NaI-APD	0.5% (6 hrs)	10-12%	0.5%	10%

The tests are to be continued.

3.8 Timing Properties of 512 Microstrips 3 Inch Silicon Detector Assembly^{*})

by T.Batsch, A.Dziedzic, M.Kisieliński, K.Leśniewski, M.Moszyński, T.Sworobowicz, I.Żawrocka

The final part of the contract "Assembling and testing of the microstrip silicon detector" concentrates on measurements of the timing properties of the detector assembly built in Świerk in accordance to previously worked out and agreed specification. The tests performed off-line in Świerk had to extend and systematize the preliminary measurements done earlier.

The aim of the work was to check the correctness of the detector assembly. The results of the measurements should not only help in proper planning of the future on-line experiments but also show the weak points in the detector assembly that can be possibly improved later.

The 500 µm thick detector manufactured by Micron Semiconductors Ltd. was delivered by FZ Julich for testing. The measurements were done with use of a laser diode HL6501MG produced by Thor Labs Inc. The light beam diameter of the laser installed in a special experimental set-up was smaller then 30 µm. The diode was powered by TEKTRONIX type 109 pulse generator. The pulses were 8 ns wide with rise time better then 3 ns. The energy calibration was done by means of ORTEC spectroscopic Am-241 source. K-MAX data acquisition system α manufactured by Sparrow Corp, USA was used for data collection. The especially written program made it possible to work with 40 parameters.

The time resolution of 170 ps at the energy corresponding to 20 MeV α particles was achieved. The result is satisfactory as for such a compact system with leading edge discrimination when compared with 70 ps measured with standard NIM fast amplifier and constant fraction discriminator.



The examination of the timing properties of each system component has shown that the better timing characteristics of the "fast" version of the preamplifier are illusive.

The detailed results of the measurements are available in the form of an internal report. Further tests with use of C-30 accelerator in Świerk are planned.

*) work contracted by FZ Julich

3.9 Current Status of Works for the LHCb Experiment at CERN by Z.Guzik and R.Jacobsson¹⁾

LHCb is a hadron collider experiment planned for running on the LHCb machine at CERN. The main purpose of this experiment is to search for new physics through precise tests of the heavy flavor sector of the Standard Model. P-3 Department (together with P-6 Department) is involved in the project since spring 1999 and participates in designing several vital elements of the Data Acquisition System in particular of the Timing and Fast Control (TFC) of the experiment.



Fig. 1 View of the final version of basic LHCb module - the Readout Supervisor.

The status of the work for the end of 2004 is as follows:

- The final version of the basic LHCb control module, the "Readout Supervisor - ODIN" (see figure below) has been designed, debugged and tested. Now the module is equipped with several new functions, advised by physicists and required by the updated experimental environment. The module is in the mass production stage (required quantity – 50 copies).
- 2. We designed, debugged and tested the final version of the basic TFC clock distribution module, the "TFC Switch THOR". The module is in mass production stage (required quantity 10 copies).
- 3. We designed, debugged and tested the final version of the "Glue Light Mezzanine" with 40 MHz local bus speed. This mezzanine serves as an interface between Credit card PC and the rest

of the module in LHCb experimental boards. The module is in mass production stage (required quantity – 500 copies).

- 4. We designed and debugged the last prototype version of the "Throttle Switch MUNIN". This module serves as throttles (inhibits) re-distributor from the experiment front-end partitions. This module will be produced in 20 copies.
- 5. We designed and debugged the first prototype version of the "Throttle OR HUGIN". This module is a sub-circuitry of Throttle switch and serves as the throttles (inhibits) collector located at the experiment front-end partitions. This module will be produced in 300 copies.
- 6. We wrote, simulated and pre-tested software instances of all hardware FPGA entities located on mentioned boards (VHDL language).
- ¹⁾ CERN, Geneva, Switzerland

PL0501137

3.10 New Peak Detect and Hold Circuitry for New Generation of TUKAN Analyzers by Z.Guzik and S.Borsuk

The new generation of our TUKAN analyzers is characterized by very low power consumption (USB based variants), low component count and exceptional parameters in sense of linearity, stability and performance.

The peak-detect and hold circuit is a crucial element in high-resolution spectroscopy. Low quality stretchers use voltage amplifiers to charge the hold capacitor through a diode. In order to provide circuit linearity the feedback loop must take up a nonlinear device. This introduces stability problems. This makes such a solution useless in high-speed applications. The analog stretcher of this module is based on diamond transistor as shown in fig.1. The presented solution shifts a pole of the feedback deep loop into the safe region and edges with rise times of down to 100 ns and covering the full dynamic range may be accepted. It is a tracking circuitry with a very small pedestal, an exceptionally low drop rate and good thermal characteristics (the tracking mode means that the voltage on the storage polypropylene capacitor follows the analog input waveform). The stretcher circuitry is changed over to "Peak Detect & Hold" mode when the HOLD/TRACK switch is open.



Fig. 1 Simplified diagram of peak detect & hold circuitry.

The "Diamond Transistor" is a voltage controlled current source or Operational Transconductance Amplifier (OTA). It can be viewed as an "ideal transistor" having, like a transistor, three terminals – a high impedance input (base), a low impedance input/output (emitter), and current output (collector). The OTA, however, is self-biased and bipolar. In presented solution the OPA660 diamond transistor from Burr-Brown was chosen. A typical transconductance of this OTA is 125 mA/V.

Peak detection is accomplished by monitoring the summing point of the circuitry (point A in Figure 1).

3.11 Tukan8k USB Software

by M.Płomiński, K.Traczyk

In the Department of Detectors and Nuclear Electronics, a new project developing a stand-alone multi-channel pulse height analyzer is under realization. Communication between the analyzer and the host computer is performed via USB. Concise set of "commands" (requests send from the host to

The summing point voltage is amplified ten times to provide adequate levels for very low input amplitudes. The zero level crossing appears when the input amplitude starts to fall. This moment is detected by a fast comparator. This is signaled by issuing a PEAK DETECT pulse.

The presented module allows the differential nonlinearity of our multi-channel analysers to drop below a "magic" 1 %. They can also accept now rising pulse edges from 100 ns to infinity.



apparatus) was developed. A fixed format for "commands" and "responses" (information transmitted from apparatus to the host) was defined. Program modules for constructing commands and for "response" analysis were already developed and tested.



3.12 Monitoring IGISOL Set-Up at U-200 Cyclotron

by Z.Guzik, S.Borsuk, M.Kisieliński, M.Płomiński and K.Traczyk

The IGISOL isotope separator installed on the beam of the U-200 Warsaw cyclotron requires precise diagnostic information for proper tuning of its operation. The measurements involve: primary ion beam current and ion kinetic energy,

- 1 mass of magnetically separated ions as a function of magnetic field and accelerating voltage,
- 2 secondary beam profile (scanner),
- 3 time of flight of secondary ions.

In the normal mode the following values are measured:

- a) Intensity of magnetic field measured by DTM 151 teslameter (RS-232 link)
- b) Intensity of magnetic field measured by means of another teslameter (analog output)
- c) Acceleration voltage (analog input)
- d) Current of primary beam (optical input)
- e) Energy of primary beam (output from TAC)
- f) Time-of-Flight of secondary beam (fast digital inputs)



Fig. 1 Block diagram of the main acquisition module.

In the scanning mode we measured the current of the secondary beam by means of the needle. The needle is moved across the beam by a special carriage driven by stepping motor. The apparatus for monitoring purposes consists of three basic units: main acquisition module (see Fig. 1) designed in the CAMAC standard, a device for measurement of primary beam current located at



30 kV potential and a carriage for secondary beam current scanning. Data flow from the device monitoring the primary beam current to the main module is realized via an optical fibre.

The main acquisition module is supervised by DS 89C420 micro-controller and is connected to the host computer via USB interface. Most of the measurements need very high accuracy. For this

3.13 Program IGISOL

by Z.Guzik, S.Borsuk, M.Kisieliński, M.Płomiński and K.Traczyk

The main goal of the IGISOL program is to control the apparatus for monitoring IGISOL (Ion Guide and Isotope Separator On-Line) on the beam of U-200 cyclotron managed by Heavy Ion Laboratory, the Warsaw University. The apparatus was developed in Department of Detectors and Nuclear Electronics (see 3.12). The program performs visualization, analysis and archiving of experimental data.

The apparatus operates in two independent modes: normal and scanner. Consequently, two independent programs were created, one for each mode of running. The programs were developed in Borland Delphi 7 (Pascal) environment and were tested under Windows 98/2000/XP operating systems.

Advancet or.
7 Acquisition Register 0
7 State Register 0
7 Parameter Register 0
DDDDDDDDDDD
RUNE JOICH BRITH DUISE MUCH HART BAILS STOL
Other
Jumper O position: 🖓
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✓ Hall 2 compensation mode
Communication
Buffer CMD 98/98/ 0,00%
Buffer RSP 0/0/ 0,00%
Filo bin 0/0/ 0,00%
Fito ordered 0/0/ 0.00%
Curt {Imp} U
Curr (V) 0.0000
je bidel, bil d, i bie ladd Sadded, j
Debug (data dump to liles)
Level 0
Umd (\$ On/Off
Rsp I⊽ On/Off Clear
Rsp IV On/Off Clear
Debug mes part
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Data transmission between the apparatus and the host computer is performed via USB. A set of 8 commands was defined, like "acquisition start", "acquisition stop", "get histogram memory contents", "get control Registers" etc. Communication is always initiated by the host by sending so called "Command". Every command is analyzed by the apparatus and confirmed by responding to the host so called "Response". To achieve high reliability of transmission, a fixed format of "Commands" and "Responses" was defined consisting of identification characters, control characters and main data block.

The program allows turning on and off each controlled parameter separately or all together. purpose the precise integrating ADC's HI-7159 are used. All module logic is glued together by means of Altera 10KE50 Flex FPGA.

The apparatus works on-line with the host computer. Measurements are controlled and data is acquired, visualized and archived by specially written sophisticated software which is the subject of another presentation.



Because the real acquisition signals were not easily available for developers (equipment was accessible in Heavy Ion Laboratory only), it was necessary to create a simulation mode which allowed the program to be developed outside the Laboratory.

In addition, a special module for tracing communication between the host computer and the apparatus was developed, which allows us to obtain text files containing a complete, bi-directional data transmission history enriched with time stamps. Analysis of the information contained in those files allows us to perform off-line verification of functionality of both, the hardware and the software.

The IGISOL Program - normal mode

The main screen of the program consists of an acquisition data display panel, intensity of current histogram field and a control panel. For user convenience, a set of various display options of histogram are available, e.g. automatic scale switch. In that mode the following parameters are measured: intensity of magnetic field (available from two sources), acceleration voltage, current of primary beam, energy of primary beam and time of flight of secondary beam. Based on those parameters, the program allows us to perform: calibration of mass ions as a function of intensity of magnetic field and accelerating voltage and ion energy calculation. Those two functions are performed in independent dialogue windows. In another, the histogram of time of flight of secondary beam can be observed.

The program is equipped with a data archiving engine. Data archiving includes: calibration data files (it is possible to renew calibration from archive file), experimental data dump to text files performed automatically with selected frequency and experiment description file.

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Fig. 1 Auxiliary control panel for normal mode.


Fig. 2 Main screen for scanner mode.

The IGISOL program - scanner mode

In scanner mode of running, current of secondary beam is measured by means of unique apparatus designed in our Department, equipped with a set of needles fastened to a carriage driven by stepping motor. The current is taken from two probes and is transformed into voltages SCAN1 and SCAN2. The main screen of the program (see Fig. 2.) consists of acquisition a data display panel, two histogram fields with scale control suit and control panel.

After performing start of acquisition, carriage position in mm and three experimental data are displayed. The program allows us to perform either manual or automatic scanner control.

3.14 Improvements in the Computer Infrastructure

by J.Szlachciak, C.Górny, K.Leśniewski, P.Lorencki, M.Płomiński

The development of computer infrastructure in 2004 was mainly focused on installing a new computer equipment and upgrading operating system to Microsoft Windows XP Professional on users' computers. Due to governmental support, the Institute purchased 32 computers, 3 workstations, 2 servers and 11 printers. At the end of 2004 45% computers have been migrated to Windows XP. Maintenance of a good level of security and reliability of the network has been continued.

The Institute continued a process of acquiring required software licenses. The number of licenses for Norton Enterprise and Corporate Antivirus, Symantec Gateway Security SGS 5420 firewall and Adobe Acrobat 6.0 CE has been increased. New licenses for the following utility programs have been purchased:

- Aleksander Simonic WinEdt - an ASCII editor and a shell for MS Windows for creation of [La]TeX documents; - Christian Ghisler TotalCommander – a file manager for MS Windows;

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- RARLAB WinRAR – an archive manager with ability to backup data, reduce size and decompress of files.

In addition a server version of OriginLab Corporation Origin (professional graphing and data analysis software for scientists and engineers) has been implemented.

The functionality of the system for dynamic collection of hardware and software inventory based on logon scripts has been extended by detection of installed Anti-virus software, registration of date of virus signature files, registration of version of selected Windows components, ability of automatic detection of lack of proper system updates and notification of available updates.

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M.Moszyński, M.Balcerzyk, A.Syntfeld

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M.Balcerzyk, M.Moszyński, Z.Gałązka, M.Kapusta, A.Syntfeld, J.L.Lefaucher IEEE NSS-MIC Conference, Roma, Italy, 18-22 Oct. 2004

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4 DEPARTMENT OF RADIATION SHIELDING AND DOSIMETRY

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Overview

The research activities of the Department in 2004, similarly to the previous year were concentrated on the following tasks:

Track structure experiments with the JET COUNTER;

Experimental and computational radiation dosimetry for medical purposes;

Numerical modeling for different aspects of electro-nuclear processes.

Track structure experiments with the JET COUNTER: The preparatory works for new experiments with track structure for low energy electrons have been carried out. Study of gas jet profiles in an interaction chamber has been initiated. The experimental analysis of mass and charge spectra of ions generated by an ion source has been opened. The collaboration under the TARI program with LNL Legnaro PTB has been continued. A new area of collaboration under COST Action P9 – Radiation Damage to Biomolecular Systems has been accessed.

Experimental and computational radiation dosimetry for medical purposes: Studies on the use of a ring ionization chamber, RIC, for standardizing of the absorbed dose from beta-radioactive wires and seeds used for the endovascular brachytherapy have been continued. The new models of RIC for dose uniformity measurements for Sr/Y –90 radioactive sources were designed and tested. The Dose Volume Histogramms were calculated using a MCNP5 code based on intravascular ultrasonographic studies of coronary arteries of real patients.

This activity was supported by The State Committee for Scientific Research (Grant KBN Nr 3P05C065 22.)

Numerical modeling for different aspects of electro-nuclear processes

The following tasks have been realized:

- Development of QMD models for mathematical modeling of electronuclear processes,
- Wavelet analysis of angular distributions of secondary particles in high energy nucleus-nucleus interactions.
- Simulation of production of radioactive isotopes in a lead target exposed to 660 MeV protons.
- Monte Carlo modeling of advanced reactor systems.

The year 2004 was the last year of functioning of this department in its present form. We will continue our research as a group within the newly created Department of Interdisciplinary Applied Physics, P-II.

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4.1 Ionization Cluster Distribution at Nanometre Track Segments – State of the Art of the Experimental Approaches. Part I – Single Ion Counting

by S.Pszona, B.Grosswendt¹⁾, P.Colautti²⁾ L.De Nardo²⁾. G.Garty³⁾, A.Bantsar, J.Kula

Three different experimental approaches based on a single pulse mode have been devised up to now for measuring the ionization cluster-size distributions for single charged particles crossing a nanometre target.

All approaches are based on the use of gas cavities for simulating nanometre sites, SNS, on a unit density scale. A short overview of these methods is given, which describes the common methodological tasks like deconvolution of the measured spectra and scaling from gas to water.

Differential gas pumping technique

The first attempt was reported in 1973 [1] and a first complete system named "Track Ion Counter" was described in 1976 [2]. A novel development and extensive measurements were reported by a team of the Weizmann Institute of Science [3].

The idea of this technique is presented in Fig. 1, and selected results of are shown in Fig. 1a.



Vacuum pumping

Fig. 1 Schematic view of ion counting device based on differential gas pumping technique. Shadowed area corresponds to different ion extraction efficiencies.



Fig. 1a Cluster-size distributions for pencil beams of various particles crossing 4.6 nm diameter sensitive volume in propane.

Performances of this technique: a) sensitive volume and physical dimensions; 1mm diameter (orifice) x 50 mm height at 0.9 Torr in propane which corresponds to 3.7 nm diameter x 90 nm SNS at unit

density in the case of an ion extraction efficiency of 50% at the contour border; b) beam alignment necessary due to strong dependence of ion extraction efficiency with beam position; c) wal l-less geometry; d) high counting mode; e) deconvolution to true cluster-size distributions necessary.

Gas jet technique

Set up known as JET COUNTER developed at the Soltan Institute for Nuclear Studies [4].

The idea is presented in Fig. 2. Cluster-size distributions for alpha particles are shown in Fig. 2a.



Fig. 2 Schematic view of the Jet Counter: A-configuration for the experiments with alpha particles; PZ-piczoelectric valve; CH1-electron detector, DM205IG-ion detector, SI alpha particle detector, IC interaction chamber.



Fig. 2a Cluster size distributions for 4.6 MeV alpha particle crossing different diameter of simulated volumes in nitrogen between 4.9 nm (\Box), 8.8 nm (•) and 13 nm (o). Solid lines Poisson distribution, broken line Monte Carlo calculations.

Performances: a) - sensitive volume and physical dimensions; 10 mm diameter x 10 mm height which corresponds to up to 13 nm diameter x 13 nm height of SNS, depending on nitrogen pressure in the volume above the PZ valve; b) - walled geometry; c) - low counting mode; d) - experiments with low penetrating radiation possible (low energy electrons); e) - deconvolution to true cluster-size distributions necessary.

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- Physikalish-Technische Bundesanstalt, Braunschweig, Germany
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4.2 Ionization Cluster Distribution at Nanometre Track Segments - State of the Art of the Experimental Approaches. Part II - Single Electron Counting

by S.Pszona, B.Grosswendt¹, P.Colautti², L.De Nardo², G.Garty³, A.Bantsar and J. Kula

Single electron counting measuring device:

Technique developed at LNL/Legnaro [1].

The idea is presented in Fig. 1. The first moment of cluster-size distributions as a function of the impact parameter is shown in Fig. 1a.



Fig. 1 Schematic view of the single electron counting device. SV-22.5 nm diameter cylindrical simulated volume (350 Pa in propane); SSD-solid state detector for trigger signal, MSAC-multi step avalanche chamber.



Fig. 1a First moments values of cluster distributions for a 244Cm alpha particle beam as a function of the impact parameter d. Open and closed circles - measurements for SV with 22.5 nm diameter. Solid line Monte Carlo calculations.

Performances: a) sensitive volume and physical dimensions; 3.7 mm diameter x 3.7 mm height; b) investigated range of SNS in propane: 20-25 nm diameter cylinder of the same height; c) low extraction efficiency (25%) of electrons from a SNS; d) high counting mode; e) suitable for studying of delta ray effects; f) deconvolution to true cluster-size distributions necessary.

Deconvolution of the measured spectra:

All methods presented are characterized by an overall efficiency of single ion or electron collection which is less than 100% and needs a deconvolution of measured cluster-size distributions to the true ones. This deconvolution is based on Bayesian analysis and provides a powerful tool to perform a good estimation of the true ionization cluster-size distribution [2].

Gas to liquid water scaling:

Grosswendt [3] provides the formulas for scaling the material equivalence gas to liquid water. It can, therefore, be stated that measurements in gases can also be used to determine ionization cluster-size distributions in specified volumes of liquid water if the sizes of the target volumes in the gas are chosen adequately.

Conclusions

The described methods for measuring cluster-size distributions cover the simulated nanometer sites from less than 1 nm to 25 nm (diamters) on a unit density scale.

The frequency distribution of ionization cluster size per single charged particle crossing a nanometre target is a new description of radiation action at nanometre levels.

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- ¹⁾ Physikalish-Technische Bundesanstalt, Braunschweig, Germany
- ²⁾ Laboratori Nazionali di Legnaro, Legnaro, Italy
- ³⁾ Weizmann Institue of Science, Israel

4.3 An Electron Discriminator for Low Energy Electrons (for Jet Counter) by A.Bantsar

The Electron Analyzer (EA) is an essential part of the Jet Counter (JC) set up. It was installed for studying gas flow (timing and instant density) as well as for investigating the ionization cluster formations at nanometre levels. The EA cuts off the scattered electrons from the primary electron beam. The performances of the EA seen in Figure 1 has been investigated and examined. The EA is based on retarding field principle, so it is a high energy-pass



Fig. 1 Schematic view of EA and electron detector, G-grid, Ch-Channeltron.



Fig. 2 Transmission of mono-energetic electron through analyzer vs applying voltage on analyzer.



Fig. 3 Electron transmission through analyzer vs. energy of electron.

filter. Transmission of mono-energetic electrons through analyzer vs applying voltage on Grid G is shown in Figure 2. And electron transmission through analyzer vs. energy of an electron is shown in Fig. 3.

The JC configuration for such studies is shown in Figure 4. The JC, consists of a pulse-operated valve which injects an expanding jet of gas into an interaction chamber where a sensitive volume in the form of a cylinder is created. The gas density is measured by electron beam attenuation. The electron transmission with and without EA is shown in Fig. 5. It can be see that 8-10% differences in electron transmission (at local minimum) is observed.



Fig. 4 Schematic view of the Jet Counter to measure electron transmition.



Fig. 5 Electron transmission with and without analyzer.

Conclusion

A simple, one grid electron analyzer was built and installed in Jet Counter set up. The energy resolution of EA for total cut off is around 0.65 %.

4.4 Monte Carlo Computations of the Absorbed Dose Distributions in the Tissue Like Materials from ³²P Sources

by K.Wincel, B.Zaręba and S.Pszona

The absorbed dose profiles in polycarbonate (lexan), polymethylmethacrylate (PMMA), plastic

scintillator, polyethylene, polyethylene terepthalate (mylar), polystyrene, and water were calculated for ³²P



theoretical point source and real ³²P brachytherapy wire source. The data for selected materials were specified as in ICRU Publication 49. Calculations were performed using the MCNP5 - A General Monte Transport Code with Carlo N-Particle the MCNP5DATA cross-sections library [1]. The Monte Carlo method is considered to be one of the most accurate techniques for simulation of radiation transport. The transport of electrons is characterized by a large number of individual interactions. To simulate electron transport, the MCNP Monte Carlo code uses the so-called "condensed history" technique, where a large number of collisions is grouped together into a single energy step that is randomly sampled.

The calculations were performed for two geometric models, namely: spherical and cylindrical. For the spherical model, i.e. a material sphere with ³²P point source is placed at the geometrical centre. For the cylindrical model, a wire source is placed at its axis. A modelled beta radiation source is related to catheter-based ³²P endovascular brachytherapy source wire produced by Guidant Company [2]. The active part of the cylindrical ³²P source is 27 mm in length and 0.24 mm in diameter and is encapsulated in a NiTi tube. The NiTi tube wall thickness is 0.076 mm. The outside diameter of the source wire is 0.46mm. A tungsten wire marker with dimensions of 1 mm in length and 0.25 mm in diameter is distal to active source and NiTi plug is welded into the distal end of the wire cavity. The electrons energy spectrum emitted by ³²P source was taken from ICRU Report 56. Maximum electron energy emitted by the source is 1.710 MeV. The source wire is centrally positioned within water or other material. Annuli are introduced as volumetric detectors for tallying the energy deposition. The detectors have length of 20 mm and thickness of 0.1mm in case of radial dose distribution calculations. The *F8 option of the MCNP5C code was applied to calculate absorbed dose radial distributions. The *F8 option provides energy deposition in a cell that represents a volumetric detector. Doses were calculated up to 4.5 mm distance from the source in the radial directions. The number of realized histories was 20 milions for each considered material. The electron and gamma history was terminated when the particle reached energy below 20 keV.

Number of substeps equal to 12 was assumed for all materials as a result of testing runs. Calculated absorbed dose distributions are shown on Fig. 1 and Fig. 2.



Fig. 1 Radial absorbed doses distribution in different materials from point source P32.



Fig. 2 Radial absorbed doses distribution in different materials from linear source P32.

- Monte Carlo simulations were performed using personal computer with Pentium IV 2.4 GHz processor
- [2] MCNP-A General Monte Carlo N-Particle Transport Code, X-5 Monte Carlo Team, Los Alamos 2003



4.5 Simulation of "Photon Needle" X-ray Generator Using MCNP5 Transport Code by K.Wincel, B.Zaręba and M.Traczyk

The Monte Carlo MCNP5 [1] transport code was used to calculate angular dose distribution in PMMA from X-ray generator [2]. The geometrical model used for calculation is shown in Fig. 1. Energy deposition was calculated for annuli volumetric detectors placed on spherical surface of 30 mm diameter. Simulation was performed for both a narrow and wide 40 keV electron beam of 0.3 mm and 1.98 mm diameter respectively. The assumed thickness of golden target was 1.5 μ m and 0.5 mm of beryllium cup. Inside diameter of the cylindrical part of beryllium cup was taken to be 2 mm.



Fig. 1 A sketch of the geometrical model used in the simulation for estimating energy deposition in PMMA from X-ray generator.



Fig. 2 Angular absorbed dose rate distribution in PMMA calculated for X-Ray generator assuming electron energy 40 keV, an electron current 20 μ A and Au target thickness 1.5 mm.

The basic parameters that are directly related with the presented MCNP calculations are as follows:

Tally: *F8	(energy deposition tally)
Mode: e p	(the transport of electrons and
	photons)
Ecut: 0.001	(energy cut off, in MeV)
Substep: 10, 25, 36	(for Be, Au and PMMA
	respectively)
NPS: 500 000 000	(number of electron histories)

Calculated angular dose rate distribution normalized to 20μ A electron current is shown in Fig. 2. Standard deviation for presented results is varied from 0.014 to 0.085 depending on volume and position of a detector. Similar calculations were realized for X-ray generator with golden target of thickness 1.0 µm. It should be noted that in MCNP code no electromagnetic interaction is considered. Simulations were performed on personal computer with a Pentium IV 2.4 GHz processor.

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4.6 Wavelet Analysis of Angular Distributions of Secondary Particles in High Energy Nucleus-nucleus Interactions by A.Polański

Experimental data on sulfur and oxygen nuclei interactions with photo emulsion nuclei at the energies of 200 and 60 GeV/nucleon are analyzed with the help of a continuous wavelet transform. Irregularities in pseudo rapidity distributions of narrow groups of secondary shower particles in the pointed interactions are observed at application of the second order

derivative of Gaussian as a wavelet. The irregularities

can be interpreted as an existence of the preference emission angles of the group particles. Such effect is expected at emission of Cherenkov's gluons in nucleus-nucleus collisions. Some of the positions of the observed peculiarities on the pseudo rapidity coincide with the ones found by I. M. Dremin et al. (Dremin I. M. et al., Phys. Lett. B 499(2001)97).

4.7 Development of QMD Models for Mathematical Modeling of Electro-nuclear Processes

by A.Polański

The QMD model [1, 2] for description of the nucleon spectra and the residual nuclei mass distribution at low and intermediate energy hadronsnucleus interactions was developed. We included evaporation model for calculations of the second stage of nuclear interaction [3, 4]. The results of calculations of nuclear interactions using QMD with evaporation GEM2 and Cascade Evaporation Model are presented in Fig. 1. QMD model + evaporation GEM2 model allows to describe p+A reactions at energy about 250 MeV and quite good agreement with cascade-evaporation model and with experimental data is indicated. However at high energies it is needed to take into account the generation of pions.





The modified QMD model can be useful for calculations of neutron and proton spectra and the residual nuclei mass distribution at low and intermediate energy hadron-nucleus interactions.



Fig. 1 Comparison of experimental data on cross sections for neutron production with calculations using QMD model and Dubna Cascade Model.



Fig. 2 Comparison of the experimental mass distribution of the nuclides produced in the reaction p(100 MeV) + 238U(circles) with calculations by the QMD+GEM2 model.

In [4] we present the spectra of neutrons and residual nuclide mass and charge distributions in proton and neutron reactions with U-238, calculated using QMD+GEM2 model.

As we can see, the reaction cross sections calculated in the QMD+GEM2 model agree quite well with the experimental data. Merging QMD with GEM allows us to describe many fission and fragmentation reactions. The production of fission fragments is weakly dependent on the energy of interacting particles. The production of light fragments and heavy nuclei essentially depends on the energy of interaction neutrons

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- [2] A.Polański, V.V.Uzhinsky, M.Baznat, Residual nuclide production induced by neutrons and protons between 20 and 200 MeV in framework of the QMD model, Workshop on Nuclear Data for the Transmutation of Nuclear Waste GSI-Darmstadt, Sept. 1-5, 2003
- [3] A.Polański, ..., V.V.Uzhinsky, et al., Development of Quantum Molecular Dynamic (QMD) Model to Describe Fission and Fragment Production, Proc. of the Conference ICRS-10 – RPS 2004, Madeira Island, Portugal, from 9-14 May 2004, Radiation Protection in press
- [4] V.Amirkhanov, ..., A.Polański, V.V.Uzhinsky, et al., Use of quantum molecular dynamics models for analysis of particle – nuclei interactions, JINR Preprint (2004)

4.8 Simulation of Production of Radioactive Isotopes in the Leaden Target Exposed to 660 MeV Protons by A.Polański

Designing an accelerator driven system needs a thorough evaluation of the build-up of long-lived radioactivity and changes in the elemental composition in construction materials. This data can be calculated with the use of experimentally verified computer codes and data libraries. In the experiment performed in DLNP the activation detectors and track detectors with heavy metal radiators - Bi, Pb, Au, W, Ta were irradiated inside and/or on the surface of a cylindrical Pb targets with 660 MeV protons [1]. Activities of several radionuclides in Pb and Bi samples were determined and compared with the values obtained from LAHET, MCNPX [2] calculations.

- W.Pohorecki, ..., A.Polański, et al., Spatial distributions of reaction rates inside and next the spallation neutron source, XI Int. Seminar on Interaction of Neutrons with Nuclei, Dubna, May, 2003
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4.9 Monte Carlo Modeling of Features of Advanced Reactor Systems by A.Polański

The Monte Carlo method was used to simulate a new full scale electronuclear system consisting of cascade sub-critical zones: fast reactor, which is used as a booster, and a thermal liquid-metal reactor, where most of the energy is released [1, 2, 3]. Reactors of the type MSBR-1000, and CANDU-6 are considered. The systems considered, functioning in the safe regime $(k_{eff}=0.94-0.98)$, possess much higher maximum power in the entire range of k_{eff} than similar systems without an intermediate fast booster reactor. At the same time, for high neutron flux and with both fast and thermal zones present nuclear wastes can be efficiently transmuted in them, decreasing the required proton current in the beam by approximately a factor of 10. This is especially important when the molten

salt thermal reactors are considered as the main power production zone.

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- [2] S.A.Bznuni, ..., A.Polański, et al., Bireactor Electronuclear Systems with Liquid Cadmium Valve, Atomnaya Energia, 94, 2 (2003), in russian
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ANGIOGRAPHIC PATTERN OF RECURRENT IN-STENT RESTENOSIS FOLLOWING INTRAVASCULAR BRACHYTHERAPY DOES NOT CORRELATE WITH DELIVERED DOSE. A STUDY WITH DOSE VOLUME HISTOGRAMS

A. Witkowski, ..., W.Bulski, A.Kulik, C.Kępka, M Kruk, T.Deptuch, J.Owezarczyk, S.Pszona, W.Rużyłło, et al. Cardiovascular Radiation Medicine 4, 4 (2004)192

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PARTICIPATION IN CONFERENCES AND WORKSHOPS

Oral presentations:

JET CONTER – AN OVERVIEW OF THE EXPERIMENTS <u>S.Pszona</u> Mini workshop on Current trends in Nanodosimetry and Track Structure Calculations, Stockholm, Sweden, December 2004

CZYNNIKI WPŁYWAJĄCE NA ROZKŁAD DAWKI OD LINIOWYCH ŹRÓDEŁ P-32 STOSOWANYCH W BRACHYTERPII NACZYŃ WIEŃCOWYCH

S.Pszona, <u>W.Bulski</u>, C.Kçpka, A.Witkowski, K.Wincel, B.Zaręba, M.Kawczyńska, D.Garmol *III Zjazd Polskiego Towarzystwa Radioterapii Onkologicznej, Bydgoszcz, 2004*

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W.Pohorccki, J.Janczyszyn, S.Taczanowski, I.V.Mirokhin, A.G.Molokanov, T.Horwacik, <u>A.Polański</u> Euradwaste '04, 6th Eur. Commission Conf. on the Management and Disposal of Radioactive Waste; 29-31 March 2004, Luxembourg OBSERVATIONS OF NEUTRONS DURING SEVERAL MSECONDS AFTER SAL A.Polański, S.Petrochenkov, J.Shabelski, et al. 28th Russian Conference on Cosmic Rays, 7-11 June 2004

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IONIZATION CLUSTER DISTRIBUTION AT NANOMETREE TRACK SEGMENTS – STATE OF ART. OF THE EXPERIMENTAL APPROACHES S.Pszona B.Grosswendt, L.Dc Nardo, P.Colautti, G.Garty, A.Bantsar and J.Kula RADAM conference, 24 – 27 June 2004, Lyon, France

DIDACTIC ACTIVITY

S.Pszona -Supervisor of MSc. diploma of Mr. M.Janecki (Warsaw University)

PERSONNEL

Research scientists Jacek Kula, MSc. Aleksander Polański, Dr, on leave until Dec. 2005 Stanisław Pszona, Dr.

Krzysztof Wincel, MSc. Barbara Zaręba, MSc.

PhD students Aleksander Bantsar, MSc.

Technical and administrative staff Adam Dudziński Elżbieta Jaworska

5 DEPARTMENT OF PLASMA PHYSICS AND TECHNOLOGY

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Overview

In 2004 our research activities in Dept. P-V were concentrated on the continuation of previous studies in the field of plasma physics and controlled nuclear fusion. New investigations were also undertaken, particularly in the field of plasma technology. The main tasks of the research activities were as follows:

1. Studies of physical phenomena in pulsed discharges producing dense magnetized plasma;

3. Development of methods and tools for high-temperature plasma diagnostics;

3. Research in the field of plasma technologies.

In a frame of the first task the correlation of pulsed X-rays and e-beams was investigated in PF-type discharges, mostly in the MAJA-PF facility. Measurements of instants when X-ray spectral lines are emitted from different hot-spots, enabled us to perform an analysis of changes in the polarization of those lines, to correlate selected spectral peaks with the appearance of corresponding hot-spots, and to estimate changes of the electron temperature. It was shown that the highly-ionized Ar-lines are really emitted from individual hot-spots, and the maxima of these lines are well correlated with the appearance and duration of such dense plasma micro-regions.

In collaboration with IFPiLM in Warsaw and CVUT in Prague experimental research on the pulsed emission of X-rays and fusion-produced neutrons was performed with the use of different solid targets within the PF-1000 facility. A summary of our joint research on physics of PF-type discharges was presented at an international conference in Prague. A detailed analysis of the main problems connected with high-current pulsed discharges of the PF-type was presented at a conference in Tomsk, and progress in studies carried out with the large PF-1000 facility was summarized in an invited talk given at the conference in Alushta. To initiate an active participation in the EURATOM fusion program, we elaborated a proposal of the adaptation of some diagnostic techniques to studies of high-temperature plasma within magnetic traps. That proposal was presented at the conference in Prague and at a seminar at Cadarache. Also a detailed study of characteristics of discharges within PF-360 and PF-1000 facilities was performed, and temporal changes of the neutron emission anisotropy were investigated.

Another experimental task was the development of plasma diagnostic techniques. Investigations of selected solid-state nuclear track detectors (SSNTDs) were continued. Calibration studies were extended to measure the depth of micro-craters produced by various ions. The SSNTDs were applied in different plasma experiments, e.g. in the TEXTOR machine in Juelich and the PALS experiment in Prague. Additional calibration measurements were also performed by means of mono-energetic ion beams from an accelerator. The calibrated detectors were used for preliminary measurements of fast (3 MeV) protons from fusion reactions in the PF-1000 facility. The calibration measurements for low-energy (50-300 keV) protons were carried out by means of a Thomson-type spectrometer at the IBIS facility. Results were reported at international conferences in Uppsala, Barcelona, Kudowa Zdroj and Cracow. The development of diagnostic methods also included time-resolved optical spectroscopy of pulsed plasma-ion streams. In cooperation with researchers from KIPT in Kharkov and CVUT in Prague, two series of detailed spectroscopic measurements were performed within the PF-1000 facility and "exploding-wire" experiment at IFPiIM in Warsaw. An interaction of the pulsed plasma-ion streams with different targets, and particularly with hydrogen getters, was studied in the RPI-IBIS facility in Świerk. Results of spectroscopic studies were reported at international conferences in Kiev, Prague, St. Petersburg and Alushta.

As for technological studies, efforts were devoted to develop ultra-high vacuum arc-technology for deposition of thin Nb-layers upon internal surfaces of RF accelerator cavities. The modernization of a prototype set-up (equipped with a cylindrical cathode) was performed and a new triggering system (based on Nd-YAG laser) was tested in Świerk. In the bilateral collaboration with the Tor Vergata University in Rome, experimental studies were performed with the use of a planar-cathode system. A magnetic filter system was tested and the Nb-coated samples were compared with the samples of bulk Nb. Technological research also included studies of a coaxial accelerator with squirrel-cage electrodes used for the impulse plasma deposition (IPD). Other studies of plasma-ion techniques for material engineering were performed in collaboration with the P-IX Department (see chapter IX of this Report).

The most important achievements of the P-V Department in 2004 were as follows: 1. Detailed spectroscopic measurements of plasma discharges in different experimental facilities (IBIS, PF-360 and PF-1000), and the demonstration that impurities appear with a delay depending on the electrode configuration, gas conditions and target parameters; 2. Measurements of the emission anisotropy of fast neutrons emitted from fusion reactions in PF-360 and PF-1000 devices, and a comparative analysis of discharges within those experimental facilities; 3. The modernization of the ultra-high vacuum system equipped with a cylindrical arc-plasma source, as designed for the deposition of thin superconducting Nb-layers, and the development of arc triggering methods, as well as successful tests performed with the planar arc-plasma source in Rome.

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5.1 Research on Correlation of Pulsed X-ray and Electron-beam Emission in Different PF Discharges

by L.Jakubowski, M.J.Sadowski, E.O.Baronova¹⁾

In pulsed discharges of the Plasma-Focus (PF) type, the accelerated current sheath (after reaching the electrode ends) undergoes radial collapse and forms a dense plasma pinch column. Inside this column one can observe numerous micro-regions of increased X-ray emission which are called hot-spots. It was observed that the hot-spots are formed successively, starting from the electrode outlet and developing along the z-axis. This makes it difficult to determine some characteristics of PF discharges, e.g. the polarization of X-ray spectral lines cannot be measured synonymously, because there are several microsources of their emission. Since different hot-spots are formed along the z-axis in various instants [1], to determine accurate values of the electron concentration and temperature it is necessary to perform measurements of the chosen X-ray lines as a function of space and time.

Temporal changes in the emission of highly ionized argon lines were recorded within the MAJA-PF device by means of a relatively simple measuring technique. These changes were correlated with hot-spots formed inside the pinch column, as well as with the emission of pulsed electron beams oriented towards the anode and perpendicularly to the z-axis [2]. It was found that the emission of highly-ionized argon lines originates from the observed hot spots. The maximum emission of the investigated spectral lines is well correlated with the appearance and lifetime of hot-spots formed during the discharge.

Time-resolved measurements of the chosen spectral lines make it possible to determine changes in the electron concentration and temperature as a function of time, and particularly during the formation and development of individual hot-spots, as shown in Figs. 1 and 2.

Precise measurements of time instants, when the observed spectral lines are emitted from individual hot-spots, should enable the accurate determination of the polarization of those lines to be performed. The aim of the reported studies was to carry out timeresolved measurements of the X-ray lines recorded by means of two crystal spectrometers with mutually perpendicular dispersion planes. The main aim was to correlate the selected spectral peaks with corresponding hot-spots and to determine the polarization of the X-ray emission from the investigated hot-spots.



Fig. 1 Temporal changes of the chosen X-ray lines and a computed change in the electron concentration.



Fig. 2 Temporal changes of the chosen X-ray lines and a computed change in the electron temperature.

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- ¹⁾ RRC Kurchatov Institute, Moscow, Russia



PL0501155

Research on Modifications of the Emission of X-rays and Fusion-produced 5.2 Neutrons in PF-type Facilities by Means of Special Targets

by M.J.Sadowski, M.Scholz¹⁾, P.Kubes²⁾

Studies of the influence of different targets on development and yield of PF-type discharges were performed within the frame of the collaboration with the Institute of Plasma Physics and Laser Microfusion in Warsaw, and with the Czech Technical University in Prague. In the large PF-1000 facility (operated at IPPLM) there were performed joint experiments with the use of targets made of a CD₂ fiber. Behavior of such a fiber during the interaction of a current sheath, as produced in PF-discharges with pure hydrogen or deuterium, was investigated, as shown in Fig. 1.



Fig. 1 Streak picture showing the VR emission of the plasma corona formed around a CD₂ fiber (100 µm in dia., 7.5 cm in length) placed at the top of anode [1].

It was shown that in the both cases the emission of soft as well as hard X-rays is smaller than in the case when a pure C- or Al-fiber is applied [1]. On the basis of an analysis of the CIII and CIV lines it was estimated that the plasma concentration amounted to above 10^{19} cm⁻³, but the temperature was below 5 eV.

Within the frame of the collaboration at the PF-1000 facility we also investigated the emission of fast neutrons originated from nuclear fusion reactions. For pure deuterium shots with maximum current of about 2 MA, use was made of scintillation detectors and a time-of-flight method, and it was found that neutrons emitted towards the anode (upstream direction) have energies of 2.6-3 MeV, while neutrons perpendicular to the discharge axis have energies of only 2.4-2.5 MeV. This was evidence of the neutron emission anisotropy and motion of dense plasma regions, which are sources of the nuclear fusion reactions [2].

In addition, to facilitate an active participation in the fusion program of EURATOM, we prepared a

special proposal concerning the possibility of the adaptation of some diagnostic methods to studies of high-temperature plasma within magnetic traps [3]. Details of the Polish proposal, as regards a transfer of the measuring techniques from pulsed plasma experiments to the magnetic traps of the Tokamak type, were presented in an invited talk given by M.J. Sadowski at the plasma seminar in the CEN-Cadarache [4]. An example is shown in Fig. 2.



Fig. 2 Scheme of the equipment proposed for time-resolved measurements of ions escaping from a magnetic trap, by means of NTD samples irradiated during different phases of a discharge [6-7].

Problems connected with the generation of fast (runaway) electrons in magnetic traps as well as possibilities of their measurements were discussed in a talk given by M.J. Sadowski at the General Plasma Seminar in Warsaw [5].

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- [4] M.J.Sadowski; Plasma Seminar at Association Euratom-CEA, Cadarache, France, Sept. 8, 2004; CD Issue
- [5] M.J.Sadowski;General Plasma Seminar, Warsaw, Poland, Oct. 19, 2004
- \mathbf{D} Institute of Plasma Physics and Laser Microfusion, Warsaw, Poland 2)
- Czech Technical Univ., Prague, Czech Rep.

5.3 Comparison of Discharge Characteristics within PF-360 and PF-1000 Devices (collaboration with IPPLM in Warsaw, Poland)

by J.Żebrowski, K.Czaus, M.J.Sadowski, M.Scholz¹⁾

In 2004 we performed studies of discharge characteristics connected with an analysis of the neutron anisotropy within the PF-360 and PF-1000 facilities. Additionally, a system of silver activation counters was modified. The whole neutron diagnostics system (consisted of two scintillation probes, cables,



silver-activation counters, light-pipes and data acquisition unit) was moved from the PF-360 device to the PF-1000 facility, and several series of measurements were carried out in order to obtain comparative data. The two sets of time-resolved signals obtained during experiments with the PF-1000 facility are shown in Fig. 1.

It was found that the neutron anisotropy coefficients within both devices were within the same range and the first small peak, as observed within time-resolved neutron signals in the PF-360 device, had also been observed in some PF-1000 discharges. The two simple procedures were developed in order to control the quality of the silver-activation counters and to eliminate the defective GM-tubes during the experiments.

¹⁾ Institute of Plasma Physics an Laser Microfusion, Warsaw, Poland



Fig. 1 Two sets of time-resolved signals from NP1 and NP2 probes (located at the distance about 700 cm from the inner electrode outlet), as recorded within the PF-1000 facility at the conditions: $A-p_0=4.0$ hPa, $U_0=26$ kV, $E_0=450$ kJ, $Y_n=1.8 \times 10^{10}$; $B-p_0=5.3$ hPa, $U_0=27$ kV, $E_0=486$ kJ, $Y_n=2.9\times 10^{10}$. There are shown the anisotropy coefficients (A_{Ni}) for the analyzed neutron peaks.

5.4 Investigations of Detection Characteristics of Selected Solid-state Nuclear Track Detectors and Applications of Such Detectors in Different High-temperature Plasma Experiments

by A.Szydłowski, A.Banaszak, B.Sartowska, A.Korman, M.Jaskóła and M.J.Sadowski

Solid-state nuclear track detectors (SSNTDs) have found numerous applications in high-temperature plasma studies. They were also used in plasma experiments carried out at the IPJ and IPPLM. In the frame of this task some results of those investigations were summarized in three papers published in 2004 [1-3]. To make these detectors more useful for ion diagnostics, detailed calibration measurements of the CR-39 detector and its derivatives (PM-355, PM-500, and PM-600) were continued. The main aim of these measurements was to determine the diameters of tracks produced in the detectors by different charged particles (p, d, α , C⁺ⁿ, N⁺ⁿ, S⁺ⁿ, Ar⁺ⁿ) as a function of their atomic numbers and energies. The calibration diagrams, which were determined in our laboratory, can be useful in the identification of the detected particles and in the estimation of their energies.

In 2004 we also investigated the influence of some external factors on the tracks formation. Taking into account that in many plasma experiments the detectors are operated under harsh conditions (a high temperature, intense electron streams, intense X-ray pulses, etc.), we tested the immunity of tracks (recorded upon the CR-39 and PM-355 detectors) to some of these factors. In order to determine the resistance of the tracks to a heat impact some detector samples, which were irradiated previously with He-ons, were heated up to 200 $^{\circ}$ C in an oven. After that, those samples were etched and the recorded craters were analyzed. The influence of fast electrons

and X-ray pulses on the track development in the PM-355 detectors was also investigated. To perform these investigations, some detector samples were irradiated with intense X-ray and electron beams, and track diameters were measured as a function of the absorbed doses. By a comparison of characteristics of the selected old and new detectors we also investigated the so-called aging effect [3].



Fig. 1 Shape of tracks (micro-craters) produced by 5.5-MeV alpha particles in the PM-355 detector, as observed by means of an electron microscope after 4-hour (A) and after 8-hour (B) etching of the irradiated sample.



In 2004, the main effort of the calibration studies was to investigate the possibility of their applications for mass- and energy-analysis of ions [4]. Bearing in mind that also pit depths may provide information on parameters of the recorded particles, we decided to extent our calibration measurements and to measure the depths of craters produced by different ion species [5]. The calibration diagrams related to pith depths can be used to estimate ion energy with a better resolution [6]. An example of changes in tracks profiles is shown in Fig. 1.

Up to now we used the SSNTDs mainly in Plasma-Focus experiments, but recently we have made an attempt to extend their application to other hightemperature plasma experiments. The PM-355 detectors have been used in the TEXTOR experiment (Juelich, Germany) to measure fusion reaction protons, and in the PALS experiment (Prague, Czech Republic) to measure fast ions emitted from different targets (Al, Ta, C, Ge), which were irradiated with a powerful iodine-laser beam of energy up to 1 kJ. Recently, SSNTDs have also been used in the PALS experiment to determine mass-spectra of fast ions, which were recorded by means of a Thomson parabola analyzer.

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5.5 Calibrations of Selected Solid-state Nuclear Track Detectors by Means of Mono-energetic Beams from Accelerator and Applications of these Detectors for Measurements of High-energetic Ions within PF-1000 Facility

by A. Banaszak, A. Szydłowski, M.J. Sadowski, M. Scholz¹⁾, H. Schmidt²⁾, A. Korman and M. Jaskóła

Solid-state nuclear track detectors (SSNTDs) have been used for ion measurements in different fields of science, e.g. geology, dosimetry, etc. The SSNTDs have also found applications in various hightemperature plasma experiments. To use SSNTDs for quantitative diagnostics it is necessary to perform their calibration with mono-energetic particles, e.g. those provided by a charged-particle accelerator.

In 2004, in order to perform detailed calibration studies of SSNTDs of the PM-355 type, the samples of that detector were exposed to mono-energetic protons and deuterons provided by a Van de Graff accelerator operated at the SINS in Warsaw [1]. After irradiation the detector samples were etched under standard conditions (in the 6.25–N water solution of NaOH, at a temperature of 70° C). The etching procedure was stopped every hour and the samples were scanned with an optical microscope. The diagrams have been consistent with results of previous calibration studies. The PM-355 type plastic appeared to be the most suitable for the detection of light ions within energy range from 0.1 keV up to a dozen MeV, and also for high-temperature plasma experiments.

In 2004, measurements of fusion reactions products were carried out within the PF-1000 facility

in Warsaw [2-3]. Important ion characteristics were measured, e.g. angular distributions, energy spectra and ion sources location.



Fig. 1 Example of micro-craters, which were placed side-on (A) and end-on (B) the electrode outlet. The visible tracks were developed after 4-hour etching.

To determine angular distributions and the fusion proton yield, several samples of those detectors were located inside the discharge chamber at different angles to the electrode axis. Those samples were covered with 78- or 82- μ m thick Al-foils, which protected the detectors from direct plasma interaction and stopped almost all fast primary deuterons emitted from the plasma. Examples of tracks (micro-craters), which were produced by fusion-originated protons emitted from PF-1000 plasma at different angles, are presented in Fig. 1.

To investigate locations of ion sources within the pinch column, samples of the calibrated PM-355 detector were located inside pinhole cameras located at different angles to the electrode axis. The cameras were equipped with 1-mm- or 3-mm-diameter diaphragms. An ion pinhole picture is shown in Fig. 2.



Fig. 2 Typical ion pinhole image, as obtained in PF-1000 facility.

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- Institute of Plasma Physics and Laser Microfusion, Warsaw, Poland
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5.6 Calibration of Selected Nuclear Track Detectors by Means of a Thomson Spectrometer and Their Applications to Low-energy Ion Beams Measurements by K.Malinowski, E.Składnik-Sadowska, M.J.Sadowski

In 2004 within a frame of research on diagnostic methods we performed the calibration of selected solid-state nuclear track detectors (LR115A, CR39 and PM355) for low-energy protons (50-300 keV), because such protons appear in many plasma and technology experiments. For that purpose use was made of a Thomson type mass-spectrometer. A source of hydrogen plasma-ion streams was the RPI-IBIS facility operated with the hydrogen puffing. The hydrogen ions (mostly protons), which were separated as regards their masses and energies within the Thomson spectrometer, were recorded upon samples of the detectors to be calibrated. After the etching of the irradiated samples, under conditions typical for the investigated detectors, the obtained ion tracks (microcraters) were analyzed qualitatively and quantitatively. For that purpose use was made of an experimental set which consisted of an optical microscope coupled with a CCD camera and a PC unit equipped with the appropriate software.

Using this technique it was possible to determine a dependence of dimensions (e.g. diameters) of the analyzed tracks on energy of the recorded protons as a function of the etching time, i.e. to perform the calibration of the investigated nuclear track detectors.

On the basis of the obtained results we determined an energy spectrum of the analyzed proton streams. The measured energy spectra of protons ranged from about 50 keV to 300 keV. The measurements enabled also a lower energy threshold for the registration of low-energy protons to be determined for the investigated detectors. The results of the detailed measurements were presented at two scientific meetings: the Workshop on Ion Track Technology at Uppsala University [1] and the International Workshop and School in Kudowa Zdroj [2], as well as at the International Conference on Nuclear Tracks in Solids in Barcelona [3]. During the next stage the calibrated track detectors were used for studies of the spatial structure of plasma-ion streams emitted from the RPI-IBIS facility (Figs. 1 and 2).



Fig. 1 Ion pinhole picture (B), as recorded within the RPI-IBIS experiment, and enlarged images (A) of different parts of this picture.



Fig. 2 Colored pinhole image, which shows the spatial structure of the investigated proton streams.

The results of the studies described above are of importance for the verification of the detector characteristics and for practical measurements of lowenergy ions under different experimental conditions.

As the continuation of these investigations we plan to apply the same technique for measurements of lowenergy nitrogen ions generated within the RPI-type devices, which are used for various technological applications, e.g. material engineering.

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5.7 Time-resolved Spectroscopic Measurements of Pulsed Plasma-ion Streams and Study of their Interactions with Different Targets

by E.Składnik-Sadowska, M.J.Sadowski, K.Malinowski, K.Czaus, A.V.Tsarenko¹⁾, M.Scholz²⁾, M.Paduch²⁾, K.Tomaszewski²⁾, P.Kubes³⁾

In the framework of this topic, during the first semester of 2004 the editorial improvements of papers on studies within the PF-360 facility and the interaction of plasma streams with hydrogen getters were finished [1-4]. The results of those studies were elaborated in the collaboration with a team from KIPT in Kharkov.

In March and November 2004 we performed two series of time-resolved spectroscopic measurements at IPPLM in the PF-1000 facility and in separate experiments performed with exploding-wires. An example of time-resolved optical spectra is presented in Fig. 1.



Fig. 1 Temporal changes in the emission of the deuterium Balmer lines and impurity lines from plasma produced in PF-1000 facility.

Particular attention was also paid to the application of optical diagnostics methods to research on the dynamics of pulsed plasma streams generated within the RPI-IBIS facility, which is often used for studies in the field of material engineering. A separate task was a detailed study of different operational modes of the RPI-IBIS facility. That research was performed within a frame of the Polish-Ukrainian collaboration. An example of the optical spectra measured within the RPI-IBIS facility has been presented in Fig. 2.



Fig. 2 Optical spectra recorded for different operational modes of the RPI-IBIS device, which are determined by HV-pulse delay time.

In cooperation with the Baykov Institute in Moscow, there was performed editorial elaboration of a paper on changes in optical properties of sapphire under interaction of pulsed hydrogen-ion streams [5].

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- Institute of Plasma Physics KIPT, Kharkov, Ukraine
- ²⁾ Institute of Plasma Physics and Laser Microfusion, Warsaw, Poland
 ³⁾ Creater Technical Univ. Proceeding Creater
- ³⁾ Czech Technical Univ., Prague, Czech Rep.



5.8 Deposition of Superconducting Films upon RF Accelerating Cavities^{*})

by J.Langner, L.Catani¹⁾, A.Cianchi¹⁾, K.Czaus, R.Mirowski, D.Proch²⁾, R.Russo³⁾, M.J.Sadowski, P.Strzyżewski, S.Tazzari¹⁾, F.Tazzioli⁴⁾, J.Witkowski

Ultra-high-vacuum (UHV) arc technology was proposed in 2000 as an alternative for depositing thin superconducting films of pure niobium upon internal surfaces of RF cavities for charged particle accelerators [1, 2]. At that time, research efforts on that technology were undertaken within the framework of the collaboration between the University of Rome "Tor Vergata", the Andrzej Soltan Institute for Nuclear Studies (IPJ) at Świerk, Poland, and at DESY in Hamburg, Germany. In recent years a number of experimental devices based on the UHV arc have been designed and constructed in Rome and Świerk, and very promising results with the deposition of superconducting Nb-films have been obtained [3, 4, 5]. Since the beginning of 2004 this task is realized in the frame of the so-called CARE European Project under contract No RII3-CT-2003-506395,

In Świerk a prototype set-up with a linear (cylindrical) cathode, as designed especially for the deposition of niobium films, was constructed and put into operation in mid 2003. In 2004 a through modernization of this set-up was performed. The modification of the prototype facility included an exchange of the whole pumping system, important improvements in the control unit and baking system, as well as the installation of a new Nd-YAG laser for triggering of arc discharges. The whole experimental facility, which was equipped with the linear (cylindrical) cathode, is presented in Fig. 1.



Fig. 1 General view of the modified UHV system and supply units.

In Rome the experimental studies, performed mainly with a so-called planar cathode, were focused on the deposition of niobium films at various conditions [6]. In 2004 particular attention was paid to experiments with magnetic filtering of niobium plasma [7]. The most important result was the confirmation that the Nb-coated samples show the same behavior as bulk Nb at DC conditions. The results of preliminary RF measurements are shown in Fig. 2.



Fig. 2 $\,$ Quality factors measured for the bulk Nb and Nb-film samples.

These results show that the superconducting niobium films obtained with the magnetic filtering appear to be the best ones.

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- ²⁾ DESY-Hamburg, Germany
- ³⁾ Universitr di Roma "Tor Vergata" and INFN Roma 2, Italy
- ⁴⁾ INFN-LNF, Frascati, Italy
- *) Collaboration with Universita Tor Vergata in Rome, INFN in Frascati, Italy and DESY in Hamburg, Germany (within a frame of the CARE Program)



5.9 Studies of a Squirrel-cage Type Coaxial-accelerator for the IPD Process by M.Rabiński, K.Zdunek¹⁾

During the impulse plasma deposition (IPD) process plasma is generated in a working gas due to a high-voltage high-current pulse discharge, triggered within an inter-electrode region of a coaxial accelerator [1]. This plasma discharge can be applied for synthesizing the amorphous and nanostructured high-melting materials, as thin layers deposited on different substrates. Coatings made of diamond, titanium nitride, multicomponent metallic alloys and aluminium oxide, have been obtained by means of this technique implemented in the surface engineering.

The electrode system usually consists of an internal rod and external tube, which are insulated from one another by a ceramic insulator. In the reported study, the outer electrode had the form of a squirrel cage, which was composed of stainless steel rods fixed symmetrically around the inner electrode.

It has been found that the electrode modifications introduce significant changes in plasma dynamics and in a phase composition of the coatings [2]. For a set of rods, the plasma is released outside the electrode, which prevents the formation of a swept mass reservoir close to outer electrode surface. The applied modification of the outer electrode also changes the shape of the plasma sheath and prevents 'climbing' of the electric current sheath up the metallic wall of the vacuum chamber. Contrary to the solid tube electrodes, the shape of the current sheath becomes much more symmetrical.

A sequence of plasma discharge images is shown in Fig. 1. The pictures demonstrate the most characteristic change of IPD discharge phenomena. Using a squirrel-cage electrode set, one can distinguish the characteristic snow-plow structure during the first half-period only. During later phases of the accelerator operation (the second, third and fourth half-periods) with the change of electrode polarization the current sheath is not formed on the isolator surface. The pinch column formed during the first half-period of the discharge transforms into a continuous arc. Some evolution of the pinched column disintegration process can be observed, but the main pattern of arc discharge remains constant.

The transformation of the plasma consecutive pinching into the nearly stable arc (during the next stages of discharge) influences a process of the material coating, synthesis and deposition.

Analysis of the obtained results suggests the direction of IPD accelerator design changes. Conclusions confirm the previously investigated role of the Rayleight-Taylor instability upon the snow-plow interface. The findings also indicate a reason for the negative features of some coatings produced by means of the IPD process.



Fig. 1 High-speed images of nitrogen plasma in a visible spectrum for the IPD accelerator with squirrel cage electrodes $(U=3 \text{ kV}, C=100 \text{ }\mu\text{F}, p=20 \text{ Pa})$, electrodes' length – 10 cm. Internal electrode partially hidden behind the outer electrode rods.

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MEASUREMENTS OF PULSED ELECTRON BEAMS EMITTED FROM PLASMA-FOCUS DEVICES L.Jakubowski, M.J.Sadowski

Proc. 10th Int. Conference and School on Plasma Physics and Controlled Fusion, Alushta, Ukraine, Sept. 13-18, 2004.P.5-9

HYDROGEN DYNAMICS UNDER PULSED PLASMA STREAMS INTERACTION WITH REVERSIBLE HYDROGEN GETTERS

V.N.Borisko, ..., V.I.Tereshin, A.V.Tsarenko, J.Baranowski, E.Składnik-Sadowska, M.J.Sadowski, et al. Proc. 10th Int. Conference and School on Plasma Physics and Controlled Fusion, Alushta, Ukraine, Sept. 13-18, 2004.P.5-11 EXPERIMENTAL STUDIES OF THE INTERACTION OF ION- AND PLASMA-STREAMS WITH CARBON-BASED TARGETS PLACED NEAR A CATHODE OF PLASMA-FOCUS FACILITY <u>V.A.Gribkov</u>, ..., Yu.E.Ugaste, **M.J.Sadowski**, **E.Składnik-Sadowska**, **K.Malinowski**, A.V.Tsarenko, et al. *Proc. 10th Int. Conference and School on Plasma Physics and Controlled Fusion, Alushta, Ukraine, Sept. 13-18, 2004, P.5-12*

LECTURES, COURSES, AND EXTERNAL SEMINARS

Why we study plasmas? - Possibilities of the construction of a thermonuclear reactor ^{a)} **M.J.Sadowski** – invited lecture General Seminar, The Andrzej Soltan Institute for Nuclear Studies (IPJ), Świerk n. Warsaw, Poland, February 19, 2004.

Nuclear fusion^{a)} **M.Rabiński** – invited lectures Series of courses at the Department of Training and Consulting of IPJ, Świerk, Poland

Progress in research on controlled nuclear fusion ^{a)} M.J.Sadowski -- invited lecture Seminar at the Institute of Physics, Polish Academy of Sciences, Warsaw, Poland, March 30, 2004

Application of diagnostics from pulsed plasma experiments to magnetic confinement fusion^{b)} **M.J.Sadowski** – invited lecture *Plasma Seminar at CEN-Cadarache, France, October 8, 2004*

Problems connected with the generation of fast runaway electrons within magnetic traps; possibilities of measurements ^{ab} M.J.Sadowski – invited lecture General Plasma Seminar, The Andrzej Soltan Institute for Nuclear Studies, Warsaw, October 19, 2004

a) in Polish

b) in English

PARTICIPATION IN PROGRAM AND ORGANIZING COMMITTEES OF CONFERENCES

M.J.Sadowski - Member of the International Scientific Committee 21st Symposium on Plasma Physics and Technology, Prague, Czech Rep., June 14-17, 2004

M.J.Sadowski - Member of the International Scientific Committee 13th International Symposium on High Current Electronics, Tomsk, Russia, July 25-30, 2004

J.Langner - Member of the International Scientific Committee 7^{th} International Conf. on Modification of Materials with Particle Beams and Plasma Flows, Tomsk, Russia, July 25-30, 2004

M.J.Sadowski - Chairman of the International Scientific Committee and Co-Chairman of the Local Organizing Committee 2nd German-Polish Conference on Plasma Diagnostics for Fusion and Applications, Cracow, Poland, September 8-10, 2004

M.J.Sadowski - Member of the International Scientific Committee 10th International Conf. and School on Plasma Physics and Controlled Fusion, Alushta (Crimea), Ukraine, September 13-18, 2004

M.Rabiński – Member of Local Organizing Committee

5th International School and Symposium on Physics in Materials Science – Application of nuclear methods in multi-modality diagnostics and radioecology, studies of large molecules, bio–compatible materials and surface modification, ISSPMS'2004, Ustron-Jaszowiec, Poland, September 19-25, 2004

M.Rabiński – Mcmber

Joint ENS/Foratom Information Committee

MEMBERSHIP IN SCIENTIFIC SOCIETES

M.J.Sadowski - a member of the Polish Physical Society (since 1967)

M.J.Sadowski - a member of the European Physics Society (since 1968)

M.J.Sadowski - a member of the Polish Society of Applied Electromagnetism (since 1990)

M.Rabiński - a member of the Polish Nuclear Society and European Nuclear Society (since 1990)

M.J.Sadowski - Fellow of the Institute of Physics, London, UK (since 2004)

PERSONNEL

since Oct. 1	Marek Jan Sadowski, Professor	
3/5	Elżbieta Składnik-Sadowska, Dr.	3/5
3/5	Adam Szydłowski, Dr.	
	Jan Witkowski, B.Sc.E.E.	3/5
	Jarosław Żebrowski, MSc.	
taff		
	Józef Kloch	till Jan. 31
	Mirosław Kuk	
	Krzysztof Michalik	till Jan. 31
since Sept. 1	Robert Mirowski, M.Sc.E.E.	
	Paweł Strzyżewski, M.Sc.E.E.	since Sept. 1
	Andrzej Trembicki	
till Sept. 30	Andrzej Wiraszka	
	since Oct. 1 3/5 3/5 taff since Sept. 1 till Sept. 30	since Oct. 1 3/5 3/5 3/5 Marek Jan Sadowski, Professor Elżbieta Składnik-Sadowska, Dr. Jan Witkowski, B.Sc.E.E. Jarosław Żebrowski, MSc. taff Józef Kloch Mirosław Kuk Krzysztof Michalik since Sept. 1 Robert Mirowski, M.Sc.E.E. Paweł Strzyżewski, M.Sc.E.E. Andrzej Trembicki till Sept. 30 Andrzej Wiraszka

6 DEPARTMENT OF HIGH ENERGY PHYSICS

Head of Department:Assoc. Professor Helena Białkowskaphone:(22) 621-28-04e-mail:Lena.Bialkowska@fuw.edu.pl



Overview

The activities of the Department are centered around experiments performed at large accelerator laboratories:

I. At CERN, the European Laboratory for Particle Physics in Geneva, Switzerland:

Data taking experiments:

COMPASS (Compact Muon and Proton Apparatus for Structure and Spectroscopy) - studies of the gluon polarization in the nucleon.

Experiments that completed data taking but continue the analysis:

DELPHI - using the data from LEP e+e- storage ring - studies of the Standard Model, Higgs and Supersymmetry searches;

NA49 and WA98 - heavy ion experiments, study hadronic and nuclear interactions, searching for the quark-gluon plasma.

- II. The 'Pi of the Sky' experiment, searching for optical flashes associated with Gamma Ray Bursts has started taking data with a set of CCD cameras mounted in the Chile Observatory Station.
- III. WASA experiment, at the CELSIUS storage ring in Uppsala, studies near threshold resonance production.
- IV. ZEUS experiment at HERA in Hamburg studies of proton structure functions and diffractive interactions.
- V. Neutrino experiments at SuperKamiokande and K2K in Japan studies of neutrino oscillations.
- VI. Preparations for future experiments:
 - a) ICARUS in preparation for the neutrino beam from CERN, to study neutrino oscillations,
 - b) Experiments at the future Large Hadron Collider at CERN:
 - CMS Compact Muon Solenoid,
 - LHCb study of b-quark production,
 - ALICE study of heavy ion collisions.

There is also a small group involved in theoretical work on the phenomenology of quark-gluon plasma formation and the low energy hadronic reactions.

A well equipped mechanical workshop is now involved in a large scale production of the straw tube modules for the LHCb detector.

Several physicists from our department are involved in popularization.

A close collaboration with the Division of Particles and Elementary Interactions from the Institute of Experimental Physics is maintained. This also involves supervising students.

A large group (12) of PhD students works under the supervision of physicists from our department.

1Brischowsh



6.1 The Delphi Experiment

by M.Bluj, R.Gokieli, J.Hoffman, K.Nawrocki, R.Sosnowski, M.Szeptycka, P.Zalewski

In the period 1990 - 2000 a large amount of data on e^+ - e^- collisions have been accumulated with the DELPHI detector installed at the LEP Collider. They cover collision energies from 90 to 207 GeV. The results obtained from the data have been presented in nearly publications and in conference papers. Nevertheless, the published results do not exhaust all questions which can be answered using the obtained data. Moreover, new questions are generated. One of the basic ones is whether there exists in nature the missing component of the Standard Model – the Higgs Boson. The effort to solve this basic problem has been

6.2 ZEUS Experiment in 2004 by M.Adamus

During 13 years of operation HERA delivered few hundred inverse picobarn of integrated luminosity. Significant progress in this field was made after luminosity upgrade (see Fig. 1).



Fig. 1

The four ZEUS physics groups concentrated their attention on data analysis. They are:

continued during 2004. The studies of the variety of possibilities of the nature of the Higgs boson still do not allow us to exclude the possibility that it can exist in the mass region accessible to the DELPHI data.

To assure the access to the data in the future requires the creation of a software system which will enable an analysis. The fast changing hardware may create a situation when data accumulated with older carriers will not be accessible for modern tools. A significant effort to avoid such a situation is being carried on by the DELPHI team.

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- *High Q2 Group* (measurement of the charged and neutral current deep inelastic scattering (DIS) cross sections at high values of Q2, searching particles such as leptoquarks, supersymmetric quarks or excited leptons, exploring sub-structure of quarks using the DIS processes at very high Q2)
- *QCD/Hadronic Final States Group* (studies of hard QCD processes, which usually give rise to the production of high energy jets)
- *Diffraction and Vector Mesons Group* (studies a wide variety of diffractive processes)
- *Heavy Flavour Physics Group* (focusing on the production of charm and beauty quarks at HERA)

Our institute is responsible for the VETO WALL detector. VETO WALL detector is a very important component in the data acquisition process. Aside from common activities repeatedly mentioned in previous years, two trigger electronics boards for first level trigger purposes - GFLT and SCANNER (Fig. 2 a, b) were produced and assembled. They help to improve the VETO WALL performance.





Fig. 2b

Fig. 2a

6.3 Weak Decays of Neutral Kaons and Hyperons in NA48 and NA48/1 Experiments at CERN

by J.Nassalski, E.Rondio, M.Szleper, S.Wronka and W.Wiślicki

The NA48 and NA48/1 Collaborations at CERN performed measurements and published results of analyses of the following decay channels:

 $K_s \rightarrow \pi^0 \gamma \gamma$ [1]

For this rare decay channel 31 candidates were observed for the first time, with estimated background of 3.2 events. This leads to the branching ratio for this decay $Br = (4.9\pm1.6_{stal}\pm0.9_{syst})\times10^{-8}$, in agreement with the chiral perturbative QCD predictions.

$$K_{L} \rightarrow \pi^{\circ} \pi^{*} e^{+} V_{e}$$
 [3]

The branching ratio for this decay channel was determined to be $Br = (5.21\pm0.7_{stal}\pm0.09_{syst})\times10^{-5}$ from the sample of 5464 events with 62 background events. The form factors, f_s , f_p , λ_g and h were found to be in agreement with previous measurements but were obtained with higher accuracy. The coupling parameter of the chiral Lagrangian L_3 =-(4.1±0.2)×10⁻³ was evaluated from the data.

$$K_{l} \rightarrow \pi^{\pm} e^{\mp} \boldsymbol{\mu}_{e} [4, 5, 6]$$

The branching ratio for this channel, relative to all other decays with two charged tracks, was found to be R=0.4978±0.0035. From this the branching fraction and the weak coupling parameter $|V_{us}|$ of the Cabibbo-Kobayashi-Maskawa (CKM) matrix was determined. The value $|V_{us}|/f_+(0)=0.2146\pm0.0016$ was found, where f_+ is the form factor for this decay. This value is 2.4 standard deviation lower than required by the 3rd generation unitarity of the CKM matrix.

Form factors for this decay were determined from a sample of 5.6 million reconstructed decays, by fitting the Dalitz plot density. The values $|f_s/f_*(0)| = 0.015^{+0.007}_{-0.010} \pm 0.012$ and

$$|f_r / f_+(0)| = 0.05_{-0.04}^{+0.03} \pm 0.03$$

were found, both compatible with zero. Assuming pure vector-axial coupling the slope parameter $\lambda_{+}=0.0288\pm0.0004\pm0.0011$ was determined.

In addition, the branching ratio for radiative K_{e3} decay was determined based on a sample of 19,000 radiative events.

 $K_s \to \pi^0 e^+ e^- [7]$

Using data collected at the high-intensity K_S beam 7 events were found with the background of 0.15 event. Using the vector matrix element and the form factor equal to one, the branching fraction was found to be $(5.8^{+3.9}_{-2.4}) \times 10^{-9}$.

$$K_s \to \pi^0 \mu^+ \mu^- [8]$$

In search for this decay six events were found with a background expectation of 0.22 events. The branching ratio, determined using the vector matrix element and unit form factor, was found to be $Br = (2.9^{+1.5}_{-1.2}(stat) \pm 0.2(syst)) \times 10^{-9}$.

$$\Xi^{\circ} \to \Lambda \gamma \ [2]$$

For this weak hyperon decay 730 candidates have been found with an estimated background of 58 events. From these events the decay asymmetry was determined $\alpha(\Xi^0 \rightarrow \Lambda \gamma)=-0.78\pm0.18\pm$, which is the first evidence of a decay asymmetry in this channel. The branching fraction of the decay has been measured to be $Br = (1.16\pm0.05_{stst}\pm0.06_{syst}) \times 10^{-3}$.

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- [2] NA48, A.Lai et al., Phys. Lett. B584(2004)251
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- [6] NA48, A.Lai et al., Phys. Lett. B605(2004)247
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- [8] NA48/1, J.R.Batley et al., Phys. Lett. B 599 (2004)197

PL0501167

6.4 Hadron Production in Elementary and Nuclear Collisions: the NA49 Experiment at the CERN SPS

by H.Białkowska, B.Boimska, W.Trubnikow

The NA49 experiment studies hadron production in hadron-hadron, hadron-nucleus and nucleusnucleus collisions at CERN SPS energies. Although the data taking is finished, large ammount of data already taken offers large possibilities for physics analysis. The most important physics result, based on the common effort of the whole NA49 team, concerns the system size dependence of strangeness production in nucleus-nucleus collisions at 158 GeV/c [1].

This complements the simultaneously studied energy dependence of strangeness production. The production of pions, kaons, phi mesons and lambda hyperons was studied in p-p, S – S and central Pb – Pb collisions.

The fast rise and the saturation observed at about 60 participating nucleons can be understood as an onset of the formation of coherent system of increasing size [1]. Fig. 1 illustrates the effect.

As for the INS team, the effort was concentrated on the study of the nuclear modification factor and other transverse characteristics of particles produced in p - Pb collisions. The results indicate an onset of effects.

Observed in d - Au collisions at RHIC. These results formed the basis of BB PhD Thesis, defended in May 2004. Concurrently, a study of peripheral Pb – Pb collisions is pursued (a subject of WT thesis in preparation). The first results on pion production indicate an important role of the Coulomb effects in the π^+/π^- ratio.



[1] C.Alt et al., (H.Białkowska, B.Boimska, W.Trubnikow), PRL 94, 052301 (2005)

6.5 A High Resolution Electromagnetic Calorimeter Based on Lead-tungstate Crystals for ALICE Experiment

by A.Deloff, K.Karpio, T.Siemiarczuk, G.Wilk for ALICE-PHOS Collaboration

prototype PHOS А large-scale of the electromagnetic spectrometer, which is part of the ALICE detector, has been built and tested using electron and hadron beams of the CERN PS and SPS accelerators [1]. This prototype has 256 detector channels and is operated at -25°C. Each detector channel is a lead tungstate crystal coupled to an Avalanche Photo-Diode with low-noise а preamplifier. The prototype includes a 16 x 16 crystal matrix photo-detectors, analog and digital electronics, a thermo-stabilized cooling system, a light-emitting diode monitoring system, and a charged-particle detector acting as veto counter.

[1] D.V.Aleksandrow et al., to appear in Nucl. Instr. and Methods in Physics Research



Fig. 1 The PHOS-256 calorimeter: A - detector and cooling system, B - closed detector with CPV on top, C- crystal matrix, D - close-up of the CPV.

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6.6 ALICE at LHC – Physics Performance Report

by A.Deloff, K.Karpio and T.Siemiarczuk and G.Wilk for ALICE Collaboration

One of the central problems addressed at the LHC is the connection between phase transitions involving elementary quantum fields, fundamental symmetries of nature and the origin of mass. Theory draws a clear distinction between symmetries of the dynamical laws of nature (i.e. symmetries and particle content of the Lagrangian) and symmetries of the physical state with respect to which these dynamical laws are evaluated (i.e. symmetries of the vacuum or of an excited thermal state). The experimental programme at the LHC addresses both aspects of the symmetry breaking mechanism through complementary experimental approaches. ALICE will study the role of chiral symmetry in the generation of mass in composite particles (hadrons) using heavy-ion collisions to attain high energy densities over large volumes and long timescales. ALICE will investigate equilibrium as well as nonequilibrium physics of strongly interacting

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density regime the energy in matter ϵ =1 1000 GeV/fm³. In addition, the aim is to gain insight into the physics of parton densities close to phase - space saturation, and their collective toward hadronisation evolution dynamical (confinement) in a dense nuclear environment. In this way, one also expects to gain further insight into the structure of the QCD-phase diagram and the properties of the OGP phase [1].

[1] P.Cortese et al., ALICE Physics Performance Report, Journal of Physics G 30(2004)1517

Interferometry of Direct Photons in Central ²⁰⁸Pb + ²⁰⁸Pb Collisions at 158 A GeV 6.7 by K.Karpio and T.Siemiarczuk for WA98 Collaboration

Two-particle correlations of direct photons were measured in central ²⁰⁸Pb + ²⁰⁸Pb collisions at 158 AGeV. The invariant interferometric radii were extracted for $100 < K_T < 300$ MeV/c and compared to radii extracted from charged pion correlations. The vield of soft direct photons, $K_T < 300$ MeV/c, was

extracted from the correlation strength and compared to theoretical calculations [1, 2].

- [1] M.M.Aggarwal et al., Phys. Rev. Lett. 93 (2004)022301
- [2] M.M.Aggarwal et al., J. Phys.G 30(2004)1065

Centrality and Trensverse Momentum Dependence of Collective Flow in 6.8 158 A GeV Pb + Pb Collisions Measured by Inclusive Photons by K.Karpio and T.Siemiarczuk for WA98 Collaboration

Directed and elliptic flow of inclusive photons near mid-rapidity in 158A GeV Pb+Pb collisions has been studied. The data have been obtained with the photon spectrometer LEDA of the WA98 experiment at the CERN SPS [1]. The flow strength has been measured for various centralities as a function of p_T and rapidity over $0.18 < p_T < 1.5$ MeV/c and 2.3 < y < 2.9. The angular anisotropy has been studied relative to an event plane obtained in the target fragmentation region that shows the elliptic flow to be in-plane. The elliptic flow has also been studied using two-particle correlations and shown to give similar results. A small directed flow component is observed. Both the directed and elliptic flow strengths increase with p_{T} . The photon flow results are used to estimate the corresponding neutral pion flow.

[1] M.M.Aggarwal et al., nucl-ex/0410045, 2004; submitted to Nucl. Phys. A

Azimuthal Anisotropy of Photon and Charged Particle Emission in ²⁰⁸Pb + ²⁰⁸Pb 6.9 **Collisions at 158 A GeV**

by K.Karpio and T.Siemiarczuk for WA98 Collaboration

The azimuthal distributions of photons and charged particles with respect to the event plane are investigated as a function of centrality in $^{208}Pb + ^{208}Pb$ collisions at 158 AGeV/c in the WA98 experiment at the CERN SPS [1]. The anisotropy of the azimuthal distributions is characterized using a Fourier analysis. For both the photon and charged particle distributions the first two Fourier coefficients are observed to

decrease with increasing centrality. The observed anisotropies of the photon distributions compare well with the expectations from the charged particle measurements for all centralities.

[1] M.M.Aggarwal et al., nucl-ex/0410045, 2004; submitted to EPJ

6.10 Three-pair Fnal-state Interaction in the pp \rightarrow pp η Reaction Close to Threshold by A.Deloff

We present a three-body formalism describing the final-state interaction effects in the pp \rightarrow pp η reaction close to threshold. We derive a three-body enhancement factor devised in such a way that all three pairwise interactions are regarded on equal footing. The enhancement factor is obtained by expanding the







to reproduce the effective mass distributions at an excitation energy Q=15.5MeV in good accord with the data.

[1] A.Deloff, Schriften des Forschungzentrums, Jülich, Vol. 21, p. 206

6.11 Phenomenology of the pp-ppŋ Reaction Close to Threshold

by A.Deloff

The recent high statistics measurement of the $pp \rightarrow pp\eta$ reaction at an excess energy Q=15.5MeV has been analysed by means of partial wave decomposition of the cross section. Guided by the dominance of the final state ${}^{1}S_{0}$ pp interaction (FSI), we only keep terms involving the FSI enhancement factor. The measured pp and ηp effective mass spectra can be well reproduced by lifting the standard on-shell

6.12 Study of Meson Production and Eta Decays in PP and PD Interactions with WASA **Detector at CELSIUS Storage Ring**

by A.Kupść, A.Nawrot, J.Stepaniak

The WASA (Wide Angle Shower Apparatus) is a detector set-up (Fig. 1) built by the international CELSIUS/WASA Collaboration around the internal pellet target at the CELSIUS Storage Ring in Uppsala The detector was designed to measure both photons and charged particles with a detection coverage close to 4π sr. The detector consists of three main parts: Forward Detector, Central Detector and Zero Degree Spectrometer. The forward detector covers scattering angles from 3 to 18 degrees. It provides a fast trigger for meson production tagging.





PL0501175

The Central Detector consists of a drift chamber, plastic barrel and electromagnetic calorimeter made of 1012 sodium-doped CsI crystals. The moment of the charged particles are measured in the drift chamber embedded in a strong magnetic field provided by the extremely thin-walled superconducting solenoid. A calorimeter provides information on the energies of approximation in the enhancement factor and by allowing for linear energy dependence in the leading ${}^{3}P_{0} \rightarrow {}^{\prime}S_{0}$, s partial wave amplitude. Higher partial waves seem to play only a marginal role.

[1] A.Deloff, Phys. Rev. C 69(2004)035206

both charged and neutral reaction products emitted at large angles.

In the year 2004, the data were collected with the hydrogen target and proton beams of energy 1100 and 1360 MeV. The production of two and three pions both from nucleon isobars and η meson decays was studied. The cross section for the $pp \rightarrow pp 3\pi^{0}$ and $pp \rightarrow \pi^+ \pi^- \pi^0$ was found to be equal to $1.5 \pm 0.5 \ \mu b$ and 4.6 \pm 1.2 μb , respectively, after subtraction of η production. Several events of $\eta \rightarrow \pi^+ \pi^- e^+ e^-$ decay were observed [1].

The data were also collected at the incident proton energy 893 MeV. The proton beam interacted with deuteron pellet target. The η mesons were produced in $p+d \rightarrow \eta + {}^{3}He$ reaction at incident energy of 893 MeV The trigger was based on the 3He registration [2]. Such trigger has an advantage of independence of the particular η decay channel.

- [1] J.Stepaniak for CELSIUS/WASA Collaboration, Observation of $\eta \rightarrow \pi^+ \pi^- e^+ e^-$ decay with WASA at CELSIUS, talk at MESON 2004, 8th Int. Workshop on Production, Properties and Interaction of Mesons, 4-8 June 2004, Cracow, Poland, to be published in Int. J. of Modern Physics A: High **Energy Physics**
- [2] A.Kupść for CELSIUS/WASA Collaboration, Studies of η meson decays with WASA detector, talk at MESON 2004, 8th Int. Workshop on Production, Properties and Interaction of Mesons, 4-8 June 2004, Cracow, Poland

PL0501174

Annual Report 2004


PL0501176

6.13 Participation in the CMS Experiment at the LHC Accelerator at CERN

by M.Bluj, R.Gokieli, Ł.Gościło, M.Górski, P.Traczyk, G.Wrochna, P.Zalewski

The Warsaw group participates in the preparations of the CMS experiment at the future LHC accelerator at CERN. Present planning foresees that the accelerator should provide its first proton-proton collisions in the year 2007. The experiment is currently being assembled at CERN. Our group is mainly concerned with the construction of the electronics of the muon triggering system based on the Resistive Plate Chambers and with the simulation of its work.

We continued simulation studies concerning various processes and new particles proposed by current extensions of the Standard Model which may be observed at the LHC, such as the predictions concerning the extra spatial dimensions and Gauge Mediated Supersymmetry Breaking. The aim of the simulation is to determine the possibility of discovery of those phenomena and to define the best strategy for their analysis. During 2004 we refined our simulation, using the most up-to-date, realistic CMS simulation software. The results obtained confirm our expectations based on more primitive simulation techniques. We also tested our trigger electronics components at the Jyvaskyla Accelerator Laboratory proton cyclotron in Finland with the 50 MeV and 30 MeV beams. We tested the Link Boards - devices used to compress the data originating from the RPC's before transferring them to the trigger electronics system itself. The main components of the LBs are the XILINX FPGAs (Field Programmable Gate Arrays). The SEU rate (Single Event Upset - events, where a single bit of the FPGA firmware was changed) in the Link Boards is shown in the Figure. Using our data, we estimate, that less than 0.3% of the total system

6.14 The LHC-b Experiment at CERN

by K.Brzozowski, P.Gawor, A.Nawrot, A.Średnicki, K.Syryczyński and M.Szczekowski

LHC-b is a hadron collider experiment in preparation at CERN. The main goal of the LHC-b experiment is to search for new physics through precise tests of the heavy-flavour sector of the Standard Model. The most stringent test is expected to be provided by a combination of precise measurements of CP violation in the B meson system. The unitarity of the Cabibbo - Kobayashi - Maskawa matrix implies relations between matrix elements that can be graphically represented as so-called unitarity triangles. The LHC-b experiment intends to measure all the parameters of the two triangles relevant for the B - meson system with a very good precision. will suffer readout errors, which is an acceptable result. No errors in the data bits during processing were observed. We observed no permanent damage of the components after irradiation corresponding to 10 years of operation in the CMS environment.



Fig. 1 Number of SEUs for two frequencies of the FPGA clock.

number of SEUs

2

3 4 5 6 7 8 9

 K.Bunkowski, G.Wrochna et al., Radiation tests of CMS RPC muon trigger electronics components, NIM A 538 (2005) 708



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To fully exploit the high forward bb production cross-section at LHC energies, the LHC-b experiment has been designed as a single-arm, forward spectrometer running in collider mode. The important characteristics of the experiment are:

• An excellent hadronic particle identification over a large momentum range (from 1 to 150 GeV/c) provided by three Ring Imaging Cherenkov (RICH) detectors. This is essential both for the exclusive reconstruction of hadronic B decay modes and to tag the neutral B hadrons initial flavour. • In addition to high - p_i lepton triggers, there will be a high - p_i hadron trigger. This trigger, as well as the low thresholds for the lepton triggers, ensures a high trigger efficiency also for purely hadronic *B* decays.

• A good proper time resolution, necessary to resolve the fast $B_s^0 - \overline{B}_s^0$ oscillations, is provided by the vertex detector. This device will provide a 40 μ m resolution on the interaction point along the beam axis.

• A good mass resolution is provided by the tracking system. Because of high particle density close to the beam axis, the tracking system is split into outer and inner subsystems at a radius of approximately 0.5 m.



Fig. 1 Straw preparation tool.



Fig. 2 Wiring of straws.

The Warsaw group is involved in the production of about 1/3 of the straw chamber modules for the LHCb tracking system. The modules should be produced in a clean environment with constant temperature and humidity. To fulfill these conditions, a clean room has been built in the laboratory of High Energy Physics Department. A sophisticated, automated air conditioning system (VTS CLIMA) maintains the temperature within $\pm 1^{\circ}$ and the humidity within ± 15 %. A very fine grained filter provides clean room class 100000 specifications. All these conditions are necessary to maintain the high quality of the produced modules.

39 modules have been constructed in Warsaw SINS laboratory until the end of 2004. They consist of 128 straws of 5 mm diameter and 250 cm length. Various tests are routinely performed indicating that the produced modules fulfill stringent quality assurance requirements (Fig. 3).



Fig. 3 Mechanical tension test for 64 wires on a panel.

Electronics engineers from the 3rd department of the Institute are involved in the design and tests of the Readout Supervisor, the main control unit for the Data Acquisition system of the LHC-b experiment.

- [1] LHCb–Trigger System Technical Design Report, R.Antunes et al. CERN/LHCc 2003-31, 2003
- [2] LHCb–Reoptimization Detector Design and Performance, R.Antunes et al., CERN/LHCc 2003-30, 2003
- [3] K.Brzozowski et al., "Tests of mechanical wire tensions in the 2.5 m prototype module of straw drift chamber for Outer Tracker detector in LHCb experiment", Report SINS/VI/LHCb-1/2004, 15 March 2004
- [4] K.Brzozowski et al., "Test results for the first production modules of straw drift chambers for the Outer Tracker detector in LHCb experiment", Report SINS/VI/LHCb-2/2004, 8 June 2004
- [5] K.Brzozowski et al., "Test of the first production modules of straw drift chambers for the Outer Tracker detector in LHCb experiment with a Fe⁵⁵ ionization source" Report SINS/V1/LHCb-3/2004, 14 Sept. 2004



6.15 COMPASS Experiment

by O.Grajek, K.Klimaszewski, K.Kowalik, K.Kurek, A.Mielech, J.Nassalski, E.Rondio, A.Sandacz and W.Wiślicki

The COMPASS (NA-58) experiment at CERN was set up to study the spin structure of the nucleon and the spectroscopy of charmed hadrons [1]. Due to its universality it is well suited to investigate other physical issues, i.e. exclusive vector meson production, or searching for pentaquarks, which is a hot topic since the summer of 2003. A main goal of COMPASS is to determine the gluon polarization $\Delta G/G$ in the nucleon. For this we use a beam of polarized (76%) muons and a polarized (up to 57%) nuclear target filled with ⁶LiD material. The gluon polarization will be measured in two independent ways, using: I) events with open charm $(D^0 \text{ and } D^*)$ mesons) production; 2) events with production of pairs of oppositely charged hadrons with high p_{μ} . In both cases we measure the double-spin longitudinal asymmetries of cross sections for the mentioned processes.

Description of the COMPASS spectrometer can be found in [1, 2], its brief version was also given in the SINS Annual Report 2003. Here we will concentrate on the physics results obtained in 2004.

One of these results was a measurement of the inclusive double-spin longitudinal asymmetry A_1^{d} from 2002 and 2003 data. From this asymmetry the $xg_{1}^{d}(x)$ quantity was determined in the kinematical range $1 < Q^2 < 100 \text{ GeV}^2$ and 0.004 < x < 0.7. Here g_1^{d} is the spin-dependent structure function of the deuteron, $x = Q^2/(2M\nu)$ is the Bjorken scaling variable, $-Q^2$ is the squared four-momentum of the virtual photon, M is the nucleon mass, and v is the virtual photon energy in the laboratory frame. This analysis is similar to that performed by SMC predecessor of COMPASS, but now it is based on a much larger data sample (overall 2002 and 2003 sample corresponds to 1500 pb^{-1}), which allows significantly better statistical precision. Results of this analysis are published in [3], and xg_1^d is shown in Fig. 1.



Fig. 1 xg_1^d as a function of *x*, for COMPASS 2002 and 2003 data and SMC whole data sample. Statistical errors are shown with vertical bars, systematic ones – with bands at the bottom (shaded for COMPASS, white for SMC).

Both analyses concerning determination of $\Delta G/G$ are well advanced. Preliminary result of the analysis, based on 2002 and 2003 data sample, is presented in Fig. 2. It shows $\Delta G/G$ as a function of x_g , where x_g is a fraction of the nucleon momentum, carried by the gluon participating in the photon-gluon fusion reaction, which produces events with the high- p_t hadron pairs.



Fig. 2 $\Delta G/G$ from an analysis of high- p_i hadron pairs production, as a function of x_g . Preliminary results from COMPASS 2002 and 2003 data are shown vs. results of SMC (whole data sample) and HERMES. COMPASS and SMC results were obtained with $Q^2>1$ GeV² cut, whereas HERMES one is based on the events mostly concentrated at $Q^2<1$ GeV². The ranges of x_g are shown with horizontal bars, whereas vertical bars represent statistical errors. LO QCD predictions at $Q^2 = 2$ GeV², with 3 different parton distributions, are also presented.

There are also other analyses being carried at COMPASS at present. The most advanced ones are: 1) determination of the Sivers and Collins single-spin transverse asymmetries, based on 2002 and 2003 data taken with transversely polarized target, with the aim of studying the transversity distributions (the publication will be sent to Phys. Rev. Lett. in mid-February); 2) searching for the pentaquark $\Phi(1860)$ (preparation of the publication is almost finished); 3) studying of the spin effects in exclusive ρ^0 meson production, with determination of $R = \sigma_L/\sigma_T$, elements of the ρ^0 spin density matrix, and the double-spin longitudinal asymmetry A_1^{ρ} ; 4) studying of the spin effects in semi-inclusive production of Λ and $\overline{\Lambda}$ hyperons.

Last 2 weeks of the run 2004 were devoted to collect data with hadronic (charged pions) beam and modified hadronic setup. Such data were taken at COMPASS for the first time. At the end of year 2004 first preliminary results of the analysis of these data were shown to the collaboration. These results concern the Primakoff reaction (see [1] for details) – one of the main items of the COMPASS hadronic program.

6.16 Experiment PP2PP at RHIC by A.Sandacz

The experiment PP2PP studies elastic scattering of polarized protons at Relativistic Heavy Ion Collider (RHIC). In 2004 a first determination of the single-spin asymmetry A_N , or the analyzing power, at the highest available energy $\sqrt{s} = 200 \text{ GeV}$ and in the four-momentum transfer t range $0.011 < |t| < 0.029 \text{ GeV}^2$ was obtained.

The analyzing power is defined as the cross section asymmetry for transversly polarized protons, $A_{N} = (\sigma^{\dagger} - \sigma^{\perp})/(\sigma^{\dagger} + \sigma^{\perp})$, where the arrows correspond to the spin orientations for the protons from one of the colliding beams.

PP2PP measures A_N for pp elastic scattering at the energy which is an order of magnitude higher than energies available for fixed target experiments. For the covered t range the interference of the electromagnetic and hadronic amplitudes plays a significant role. Even in the absence of a spin dependence of the hadronic amplitude, a non-zero value of A_N is expected. This is due to the interference of non-spin flip hadronic amplitude with the single spin-flip electromagnetic amplitude (related to the magnetic moment of the proton). For this case A_N is predicted to be equal to about 0.02 in the considered t range. Any departure of the measurements from this prediction will signal an existence of single spin-flip hadronic amplitude. An observation of such a contribution will shed a new light on the role of the spin in diffractive scattering and on the spin structure of a mediator of the diffractive interactions, the pomeron.

The first precise measurements of A_N in pp scattering at much lower energy $\sqrt{s} = 14$ GeV [1] indicate that no spin-flip hadronic amplitude is needed to desribe the data. However, it is speculated [2] that it may be accidental, and at this particular energy a cancellation of contributions from various exchanges occurs.

The preliminary measurements of A_N from PP2PP were shown at several conferences in 2004, see e.g. [3], and are presented in Fig. 1. The curve represents

- [2] G.Mallot, The COMPASS Spectrometer at CERN, Nucl. Instr. Meth. A 518(2004)121
- [3] E.S.Ageev et al., (COMPASS Coll.), Measurement of the spin structure of the deuteron in the DIS region, hep-ex/0501073, CERN-PH-EP-2005-001, submitted to Phys. Lett. B



predictions assuming no hadronic spin-filp amplitude and is at variance with the measurements which suggest a contribution of the hadronic single spin-flip amplitude. Understanding of the energy dependence of A_N presents a challenge for the theory. Clearly more experimental results at high energies would be helpful.



Fig. 1 The single spin analyzing power A_N . Vertical error bars show statistical errors. Curves represent the theoretical calculations without hadronic spin flip.

- H.Okada, "Measurement of the analyzing power in pp elastic scattering in the peak CNI region at RHIC", to appear in the proceedings of the 16th Intern. Spin Physics Symp., Trieste, Italy, 2004
- [2] T.L.Trueman, "Energy dependence of *pp* and *p*-Carbon CNI Analyzing Power", to appear in the proc. of the 16th Int. Spin Physics Symp., Trieste, Italy, 2004
- [3] W.Guryn, "Preliminary result of A_N measurement in *pp* elastic scattering at RH1C at $\sqrt{s} = 200$ GeV", to appear in the proceedings of the Intern. Workshop on Diffraction in High Energy Physics, Cala Gonone, Sardinia, Italy, 2004
- [4] N.H.Buttimore et al, Phys. Rev. D 59 (1999) 114010



6.17 Neutrino Experiments

by D.Kiełczewska, T.Kozłowski, P.Przewłocki, E.Rondio, J.Stepaniak, M.Szeptycka, and J.Zalipska

The neutrino IPJ group is working in collaboration with other institutions from Warsaw (University and Technical University) as well as from Cracow, Katowice and Wrocław. The main field of activity for the whole group is a participation in ICARUS experiment; a part of the group is active in K2K experiment in Japan.

The activity of our institute in this field started in 2000 and during last year the basic aims were:

Experiment ICARUS

The preparation to ICARUS installation in an underground laboratory in Gran Sasso is under way and the main step is transportation of the tested detector (600 t) into the laboratory in December 2004.



Fig. 1 The T300 ICARUS module in Hall B of the Gran Sasso underground laboratory.

The detector will be enlarged and preparation of the inner readout chambers will take place in Poland. This task requires preparation of 57 000 wires and a construction of a special, high precision "table" was the first step. Such a table was constructed in Warsaw (Fig. 2). This table will be used for wire production in Cracow and later on in Warsaw and Katowice.



Fig. 2 The table for readout wire production.

Other activities of the group concentrate on the analysis of test data where the first results were published [1-5] and preparation for the analysis of neutrino interactions. In particular studies of neural network application to the v_{τ} interaction were finished and published as an ICARUS note. The analysis of the effect of τ polarization is in progress. Further analysis of test data is in progress. It includes studies of electromagnetic component associated with high energy muons, and π^0 production.

K2K experiment

The v oscillation was discovered in experiments with atmospheric neutrinos. It was therefore crucial to test it in a long base experiment with a v_{μ} beam. The beam is produced at KEK accelerator and the neutrino interactions are measured at near detectors for normalization purposes and the SuperKamiokande detector located 250 km away. An important question in v physics is the measurement of the oscillation parameters in an appearance experiment $v_{\mu} \rightarrow v_e$. In the K2K experiment near detectors control the admixture of v_e in a v beam at the production target. Ms J. Zalipska from our group is in charge of running a H₂O detector and analyzes the data to establish the selection criteria of v_e CC interaction and their admixture in the primary v beam.

The first results of the search for electron neutrino appearance have been published [6]. No signal has been found and limits on the mixing parameter θ_{13} have were determined us a function of the difference of neutrino mass states.

- M.Antonello et al., "Detection of Cherenkov Light Emission in Liquid Argon", Nucl. Instr. Meth. A 516 (2004) 348
- [2] S.Amoruso et al., "Analysis of The Liquid Argon Purity in the Icarus T600 TPC", Nucl. Instr. Meth. A 516 (2004) 68
- [3] S.Amoruso et al., "Measurement of the O decay spectrum with the ICARUS liquid argon TPC", Eur. Phys. J. C 33 (2004) 233
- [4] S.Amoruso et al., "Study of Electron Recombination in Liquid Argon with the ICARUS TPC", Nucl. Instr. Meth. A 523 (2004)275
- [5] S.Amerio et al., "Design, Construction and Tests of the ICARUS T600 detector", Nucl. Instr. Meth. A 527 (2004) 329
- [6] M.H.Ahn et al., "Search for electron neutrino appearance in a 250 km long-baseline experiment", Phys. Rev. Lett. 93 (2004) 051801

PL0501181

6.18 Experiment ,, π of the Sky"

by M.Górski, K.Nawrocki, M.Sokołowski and G.Wrochna for " π of the Sky" Collaboration^{*})

The ", π of the Sky" experiment [1] is designed to search for short optical flashes in the sky. The main motivation is to look for optical counterparts of Gamma Ray Bursts (GRB) [2]. GRBs are 0.1-100 s short pulses of gamma rays emitted by extragalactic sources. Intensity of the burst is often higher than the total background from all other gamma ray sources in the sky. So far, phenomena responsible for GRB have not been unambiguously identified. There are hints that certain types of supernovae explosions could be the source of burst energy. Among other hypotheses are neutron star collisions leading to black hole creation or quark star collapse. In order to proceed with understanding the physics of GRB one needs to observe them also in wavelengths different from gamma rays [3].

The " π of the Sky" project is an attempt to apply experimental techniques of particle physics for detection of cosmic optical flashes. The apparatus to be built in 2005 was designed to cover most of the visible sky down to about 20° over horizon. It consists of two sets of 16 camera lenses of focal length 50mm. Each lense is attached to a CCD camera with 2000×2000 pixels. Most of the analysis is performed in real time (*on-line*). Multilevel trigger system searches 60MB/s data stream for optical flashes of 11 12 magnitudo and duration of the order of 10 s.



Fig. 1 Prototype apparatus tested in Poland.



Fig. 2 Installation at Las Campanas.

In 2004 a prototype system is built and tested in Poland. In summer, it was installed at Las Campanas Observatory (LCO) in Chile to profit from high altitude, clean atmosphere and clear sky over most of the year. It consists of two CCD cameras and a robotic mount, which can move to any point in the sky in < 1min. During the operation of the apparatus in LCO from July 2004, over 700 000 images have been taken. 58 optical flashes of unknown origin have been detected. They have not been confirmed by other observations and one cannot exclude, the possibility that they are caused by sunlight reflexes from artificial satellites.

During this period, 36 GRBs were detected by satellites. The " π of the Sky" observations are summarized below:

- 1 apparatus was switched off
- 7 on the North hemisphere
- 19 during daytime
- 1 below horizon
- 7 outside field of view
- 1 inside field of view

For the GRB 040825, the only one so far which has happened within the field of view, no optical flash has been observed and upper limits have been established. These were the first limits ever obtained during and just before the GRB. For several GRBs the apparatus has moved automatically and the limits were given shortly after the bursts. In four cases, when " π of the Sky" observation was faster than any other telescope, the limits were published in GCN Circulars [4]. In addition, regular photometric measurements of variable stars are conducted (Fig. 3).



Fig. 3 Example of a variable star light curve for one night; brightness (magnitudo) vs time (truncated Julian days).

- [1] A.Burd et al., "π of the Sky" all-sky, real-time search for fast optical transients, astroph/0411456, to be published in the New Astronomy
- [2] B.Zhang and P.Meszaros, astro-ph/0311321
- [3] B.Paczyński, astro-ph/0108522
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PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited talks:

REPORT FROM NA49 <u>M.Gazdzicki</u>, **H.Białkowska**, **B.Boimska**, et al. 17th Int. Conf. on Ultra Relativistic Nucleus-Nucleus Collisions (Quark Matter 2004), Oakland, California, USA, 11-17 Jan 2004

THREE-PAIR FINAL-STATE INTERACTION IN THE pp-ppη REACTION CLOSE TO THRESHOLD <u>A.Deloff</u>

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 ΔG FROM HIGH p_T AT SMC

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RESULTS FROM SUPER-KAMIOKANDE AND K2K EXPERIMENTS **D.Kielczewska** (for the collaboration) Cracow Epiphany Conference on Astroparticle Physics, Cracow, Poland, 8-11 Jan 2004

SMC HIGH-pT ANALYSIS <u>K.Kowalik</u> XII International Workshop on Deep Inelastic Scattering (DIS 2004), Strbske Pleso, Slovakia, 14 April 2004

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DIFFRACTIVE ρ^0 PRODUCTION AT COMPASS EXPERIMENT

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COMUNICATIONS PUBLISHED IN CONFERENCES MATERIALS

EXPERIMENT PP2PP AT RHIC

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LECTURES, COURSES AND EXTERNAL SEMINARS

P_T Spektra Evolution with System Size and Energy B.Boimska, International Workshop: Future of Nuclear Collisions at High Energies, Kielce, Poland, 17 Oct. 2004

Measurements of the Spin Asymmetries for Events with High-p_T Hadrons in SMC Experiment K.Kowalik, *Brookhaven National Laboratory, USA, 23 March 2004*

Determination of the Gluon Polarization from Spin Asymmetries for Events with High-p_T Hadrons in DIS K.Kowalik, Lawrence Berkeley National Laboratory, USA, 25 March 2004

Preparation for Wire Production for Inner Detector in Poland **E.Rondio**, *Workshop Icarus, Gran Sasso, 24 June 2004*

Status of Module Productions M.Szczekowski, NIKHEF, Amsterdam, 20 April 2004

Experimence from Production of 1 m and 2,5 m Prototypes in Warsaw M.Szczekowski, Heidelberg, Germany, 12 June 2004

Production of Outer Tracker Modules in Warsaw M.Szczekowski, CERN, Genewa, Switzerland, 25 May 2004

b) in English

INTERNAL SEMINARS

Evolution or Revolution? From Elementary to Nuclear Collisions H.Białkowska, UW, Warszawa, 22 Oct. 2004

Transverse Characteristics of Hadron Production in Elementary and Nuclear Collisions **B.Boimska**, *INP, Cracow, 6 April 2004*

Transverse Characteristics of Hadrons Produced in High Energy Elementary and Nuclear Collisions **B.Boimska**, UW, Warsaw, 21 May 2004

Systematic uncertainties in the analysis of atmospheric neutrino oscillations **D.Kielczewska**, UW, Warsaw, 16 Jan. 2004

Last half a year of neutrino oscillation D.Kielczewska, UW, Warsaw, 5 March 2004

Neutrino oscillations and proton decay: current status and plans for future **D.Kielczewska**, UW, Warsaw, 8 March 2004

Determination of gluon polarization from asymmetries measured in muon-nucleon interactions with pairs of hadrons with high transverse momentum **K.Kowalik**, *IFJ*, *Cracow*, 6 April 2004

New results from Compass experiment E.Rondio, HERMES COLLABORATION MEETING, Kazimierz Dolny, 29 June 2004

Cosmological Measurements M.Szeptycka, UW, Warsaw, 20 Feb. 2004

Supernowa – Observations and Interpretations M.Szeptycka, Konwersatorium IPJ, Świerk, 18 March 2004

Search for Optical F;ashes Accompanyning Extragalactic Gamma Bursts – Experiment 'Pi of the Sky' G.Wrochna, Konwersatorium IPJ, Świerk, 18 Nov. 2004

Scarch for extragalactic flashes - Experiment 'Pi of the Sky' apparatus in action G.Wrochna, Warsaw, 29 Oct. 2004

Gamma Bunts - the Largest Cataclisms in the Universe G.Wrochna, Warsaw, 17 July 2004

CP violation measurements via LHCb Experiment M.Szczekowski, PW, Warsaw, 21 Jan. 2004

An Outline of Equilibrium Thermodynamics for Network Gamet W.Wiślicki, FENS, Warsaw, 19-20 Jan. 2004

Choice Models and Games on Graphs W.Wiślicki, Polish Academy of Sciences, 22 June 2004

Rarc dccays of neutral kaons W.Wiślicki, UW, Warsaw, 9 Jan. 2004

SCIENCE POPULARIZATION TALKS AND ARTICLES

J.Nassalski

"One day in the factory of knowledge", Polityka nr 41, 9.10.2004,

"From what is the world built?", Rzcczpospolita, 19.10.2004,

"Polish participation in the MON experiments at CERN", published in "Polska w Europejskiej Organizacji Badań Jądrowych CERN", Polska Akademia Umiejętności, Kraków 2004, TVP3 – interview on the subject of CERN, 21.10.2004.

T.Siemiarczuk

"Experiments with relativistic heavy ions, WA80, WA93, WA98", in the book 'Poland at CERN', Cracow 2004 "Big Bang in a laboratory", J.Bartke, T.Siemiarezuk in "Rzeczpospolita", 19.10.2004

W.Wiślicki

Radio interview on "Grid computing" Rzeczpospolita newspaper interview on "Grid computing"

G.Wrochna

Webcam presentation "Astronomic webcam", Fete des Seiences, Paris et Le Mans

Internet presentations: "Particle Physics for Everybody", http://hcp.fuw.cdu.pl/ems/edu/edu.htm "CMS experiment", http://hep.fuw.edu.pl/ems/pub/lhc pub.htm "CCD Astronomy - between hobby and science" http://eed.astronet.pl

P.Zalewski

13 articles in popular science magazine DELTA,

V-ce editor in chief of a popular monthly Delta devoted to mathematics, physics, and astronomy, primarily aimed at high-school students.

Physics and astronomy expert at EduSeck website, Participation in a tv programme "Science for you" broadcasted by polish tv channel TVP3 devoted to the physics of sport, Interview broadcasted by polish radio channel Radio Plus about the physics of sport.

PARTICIPATION IN SCIENTIFIC COUNCILS AND ORGANISING COMMITTEES OF **CONFERENCES**

H.Białkowska

Member of the Scientific Council of the SINS, chair of the Program Commission, Member of the SPS Committee, CERN, Member of the Physics Panel, Human Potential Networks C, Brussels 2004, Secretary General of the Polish Physical Society.

R.Gokieli

Member of DELPHI Directorate and DELPHI Executive Committee (DEC).

J.Nassalski

Member of the "Programme Advisory Committee for Particle Physics", Joint Institute for Nuclear Research, Dubna, Member of the "Extended Scientific Council", DESY, Hamburg, Member of the CERN Council - from December 2004, Member of the Scientific Council, SINS.

R.Sosnowski

Chairman of the Scientific Council of the SINS, Chairman of the Scientific Council of the High Pressure Centrum of Polish Academy of Sciences, Council for Nuclear Science and Technology - vice chairman, chairman of the High Energy Physics Commission, a member of the Commission for Collaboration with JINR in Dubna, Polish delegate to the CERN Council, Polish representative to International Union of Pure and Applied Physics, Member of the Scientific Council of JINR in Dubna, Chairman of the Committee of Physics of the Polish Academy of Sciences.

T.Siemiarczuk

International Advisory Committee of International Conference HYPERONS, CHARM and BEAUTY HADRONS, Polish group coordinator in the ALICE CERN experiment, Member of the Collaboration Board of the ALICE CERN experiment, Polish group coordinator in the WA98 CERN experiment, Polish group coordinator in the STRELA experiment at Dubna NUCLOTRON.

J.Stepaniak

Member of Executive Committee of the CELSIUS/WASA Collaboration, Spokesperson of CA83 experiment at CELSIUS accelerator.

G.Wrochna

Advisory Committee of the symposium "Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments II", Wilga, 26-30 May 2004, Coordinator of the Muon Trigger System of the CMS Experiment.

PERSONNEL

Research scientists			
Marek Adamus, Dr.		Krzysztof Nawrocki, Dr.,	1/2
Helena Białkowska, Assoc.Prof.		Adam Nawrot, Eng.	3/5
Bożena Boimska, MSc.		Ewa Rondio, Assoc.Prof.	
Andrzej Deloff, Assoc.Prof.	1/3	Andrzej Sandacz, Assoc.Prof.	
Ryszard Gokieli, Dr.		Teodor Siemiarczuk, Professor	
Maciej Górski, Dr.		Ryszard Sosnowski, Professor	
Julia Hoffman, Dr.	(on leave)	Joanna Stepaniak, Professor	
Krzysztof Karpio, MSc.		Maria Szeptycka, Professor	
Danuta Kiełczewska, Assoc. Prof.	1/5	Michał Szleper, Dr.	(on leave)
Katarzyna Kowalik, MSc.		Marek Szczekowski, Assoc.Prof.	
Andrzej Kupść, Dr.	(on leave)	Piotr Szymański, Dr.	(on leave)
Paweł Marciniewski, Dr.	(on leave)	Andrzej Średnicki, MSc.	
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Stanisław Mrówczyński, Professor	2/3	Grzegorz Wrochna, Assoc. Prof.	
Jan Nassalski, Professor		Piotr Zalewski, Dr.	

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Michał Bluj, MSc. Oleg Grajek, MSc. Łukasz Gościło, MSc. Liu Han, MSc. Konrad Klimaszewski, MSc. Marcin Przewłocki, MSc. Marcin Sokołowski, MSc. Krzysztof Syryczyński, MSc. Piotr Traczyk, MSc. Wiktor Trubnikov, MSc. Joanna Zalipska, MSc.

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7 DEPARTMENT OF COSMIC RAY PHYSICS

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Overview

The Department of Cosmic Ray Physics in Łódź is involved in basic research in the high energy Cosmic Ray field. Cosmic Rays are energetic particles from outside the Solar System. The energy spectrum (power law energy dependence) suggests a non-thermal origin of these particles. Most studies of Cosmic Rays address fundamental problems:

- the nature of the physical and astrophysical processes responsible for high energies of particles (up to about 10²⁰ eV/particle),
- estimation of the astrophysical conditions at the acceleration sites and/or search for sources of Cosmic Rays,
- properties of high energy particle interactions at very high energies (nuclear interactions at energies exceeding energy available in laboratories).

Some Cosmic Ray studies might have practical (commercial) implications, e.g.

 "cosmic weather" forecast - predictions of geomagnetic disturbances related to Solar activity changes (due to large Solar Flares / events of Coronal Mass Ejection); these are important for large electricity networks, gas pipes, radio-wave connections, space missions and satellite experiments.

Presentation of Cosmic Ray registration to high school students is a popular way to introduce particle physics detectors and elementary particle detection techniques to young people.

Energetic Cosmic Ray particles produce cascades of particles in the atmosphere, called Extensive Air Showers (EAS). Registering the EAS and their properties is the main way of experimental studies of very high energy Cosmic Rays. In our Łódź Department we run an Extensive Air Shower array where EAS are continuously being registered. We concentrate on the studies of detection of neutrons correlated with EAS and interpretation of this phenomenon.

In 2004 we started realisation of the Roland Maze Project, the network of EAS detectors placed on the roofs of high schools in $\pounds \dot{o} d\dot{z}$. We received funds from the City of $\pounds \dot{o} d\dot{z}$'s budget to make a pilot project and equip 10 high schools, each with four $1m^2$ detectors and GPS. The network is connected on-line using internet infrastructure and precise time registration. This allows us to correlate detection of the same EAS in a few schools. High schools students are involved.

In the underground (15 meters) laboratory we register muon (5 GeV energy thresholds) flux with the multidirectional telescope. We have observed several disturbances (Forbush Decreases related to Solar activity) in muon counting rates.

International collaborations are very important: the Department was a KASCADE member and now is a member of KASCADE-Grande Collaboration – the large classical experiment for very high energy EAS. We collaborate in EAS data interpretation, detection techniques and basic Cosmic Ray studies with Collège de France, Institute for Nuclear Research of the Russian Academy of Sciences, JINR Dubna and Cosmophysical Institute in Yakutsk (Russia).

In the area of high energy particle physics the Department is a member of the CELSIUS/WASA Collaboration (Uppsala, Sweden), and participates in the ZEUS experiment at DESY (Hamburg, Germany).

Jack Suckeld:





7.1 Łódź Extensive Air Shower Array

by K.Jędrzejczak, J.Karczmarczyk, S.Petrochenkov¹⁾, A.Polański, J.Swarzyński, J.Szabelski and T.Wibig

Registrations of extensive air showers (EAS) of cosmic rays at energies above 10^{15} eV are continued. Studies of delayed signals correlated with showers are in progress. We assume the hypothesis that the EAS hadron interactions in the lead block produce MeV neutrons, which then undergo thermalization and are detected as delayed signals in Geiger-Müller counters, boron counter and other detectors registering time structure of signals (10 MHz FADC, 8-bit converters, 32 kB memory). The hypothesis that these registrations are due to a great number of neutrons produced in the lead block by the EAS hadrons seems very probable.

Together with our collaborators from JINR in Dubna we performed simulations of neutron diffusion in the detector surroundings. We used the MCNP code, which we introduced into a very detailed geometry of the apparatus and its nearest vicinity (including hydrogen abundance in the soil). Simulated neutrons started their diffusion from the lead block or from the surrounding ground. Time distributions of slow neutrons obtained from simulations agree quite well with those registered in the boron counter. The only problem is the requirement of a great number of neutrons produced at the time of shower passage. We have obtained a one year financial support for these studies (Polish Science Committee grant 1 P031B 014 26)

We have collected 26 helium counters with polyethylene blocks and cadmium sheets for neutron registrations. We plan to study in more details the spatial distribution of neutrons in EAS. From our computer simulations it comes that the effective range of neutrons is equal to 1.5 - 2.5 meters.

We construct electronics for helium counters (FADC - 24 channels) and systems for individual registrations of signals from G-M counters together with the time structure of signals. These works will be completed soon.

 Joint Institute for Nuclear Research, Dubna, Russia



7.2 KASCADE: Astrophysical Results and Tests of Hadronic Interaction models by A.Risse and J.Zabierowski

KASCADE [1] is a multi-detector setup, operating at the site of Forschungszentrum Karlsruhe, Germany, to get redundant information on single air shower basis.

The information obtained by KASCADE is used to perform multiparameter analyses to solve the threefold problem of the reconstruction of (i) the unknown primary energy, (ii) the primary mass, and (iii) to quantify the characteristics of the hadronic interactions in the air-shower development. During the last year some results have been obtained.

Investigation of anisotropies in the arrival directions of the cosmic rays give additional information on their origin and propagation. No large scale anisotropy has been found in KASCADE data set [2]. The limits on anisotropy obtained out of our data already exclude some model predictions.

We have looked for the evidence of an existence of near-by point sources of cosmic rays in KASCADE data. No such evidence has been found [3].

Using the world-best data on cosmic ray hadrons – in this case single hadrons - obtained with KASCADE hadron calorimeter the primary proton spectrum between $E_0 = 300$ GeV and I PeV has been determined [4]. It corroborates former results and in the lower energy end the proton flux compares well with the results of recent direct measurements.

Investigation of the energy spectra of individual mass groups of primaries by means of unfolding procedure applied to KASCADE data [5] provided conclusive evidence that the knee in the spectrum is caused by a decrease of the flux of light primaries, where positions show a dependence on the primary mass group. Systematic uncertainties for an estimate of the elemental composition are dominated by the inadequacy of the hadronic interaction models underlying the reconstruction of energy spectra of single mass groups. Hence, there are still only weak constraints for detailed astrophysical models to explain the knee in the primary cosmic ray energy spectrum.

Test of hadronic interaction models has been one of the key activity in KASCADE. Redundant information on all shower components is used for these purposes.

Using data supplied by the hadron calorimeter the investigation of geometric structures of hadronic cores of EAS in the hadron calorimeter [6] continued throughout the whole 2004. We found that the widely used alignment parameter λ_4 contrary to the existing claims, shows no sensitivity to the features of hadronic interaction, such as primary type and transverse momentum transfer. It was shown, that another geometric parameter, dependent on the

relative distance of hadrons in the core, shows such sensitivity and can be used for tests of the models. Results will be published in 2005 [7].



Fig. 1 Pseudorapidity of muons registered on ground compared with the pseudorapidity of their mother hadrons.

Hadronic interactions have been investigated also using data on the muonic EAS component. In particular, the method [8], utilizing the excellent angular resolution of the KASCADE Muon Tracking Detector, allows to investigate momenta and pseudorapidities of hadrons generated in high-energy hadronic interactions [9]. This is still an open question and an important parameter for the model building. As it is seen in Fig.1 there is a strong correlation between the pseudorapidity of muons measurable in the Muon Tracking Detector and of the parent hadrons. Comparisons of the measured muon pseudorapidies and predictions given by different models have shown inadequacy of their description of hadronic interactions in the atmosphere.

Similar conclusions, that none of the present hadronic interaction models is able to describe all the KASCADE data consistently (on a level a a few percent) are made based on the investigation of other parameters of hadronic and muonic EAS component. However, the more recent models or improved versions of the previous ones reproduce the data better than a few years ago.

- [1] T.Antoni et al., Nucl. Instr. Meth A513 (2003) 429
- [2] T.Antoni et al., Astrophys. J. 604 (2004) 687
- [3] T.Antoni et al., Astrophys. J. 608 (2004) 865
- [4] T.Antoni et al., Astrophys. J. 612 (2004) 914
- [5] H.Ulrich et al., Eur. Phys. J. C33 (2004) s944
- [6] A.Iwan et al., Proc. 28 ICRC, Tsukuba 2003, 1595
- [7] T.Antoni et al. submitted to Phys. Rev.D, 2005
- [8] J.Zabierowski et al., Nucl. Phys. B122 (2003) 275
- [9] J.Zabierowski et al., Proc XIII ISVHECRI, Pylos, Greece, 2004; to appear in Nucl. Phys. B, 2005

7.3 KASCADE-Grande EAS Experiment and LOPES Collaboration by A.Risse and J.Zabierowski



PL0501185

The KASCADE-Grande extensive air shower experiment (EAS) [1], located in Germany at the site of Forschungszentrum Karlsruhe, has been taking data since the middle of 2003. It comprises the KASCADE multi-detector facilities and the two new detectors: Grande and Piccolo, with the respective aims of providing a large acceptance area (0.5 km²).

The major goal of KASCADE-Grande is the observation of the 'iron knee' in the cosmic-ray energy spectrum at around 100 PeV, which is expected due to the recent KASCADE and EAS-TOP observations where the positions of the knees of individual mass groups suggest a rigidity dependence [2,3]. The main observable characteristics of hadron interactions to be compared with the expectations from the simulations used will be investigated as well.

In 2004, an effort was put into development of data analysis software and the calibration of the whole experiment. The new, digital front-end electronics to be used in parallel to the analogue one has been designed and introduced [4].

Recently, with the tremendous progress in digital electronics, an increased interest in the investigation of radio signals generated by EAS has been observed. Radio pulses emitted in the atmosphere during the EAS development were measured during the late 1960ies in the frequency range from 2 to 520 MHz. Due to the short-falls of analog electronics in those days, the measurements were very cumbersome and did not lead to useful relations between radio emission and air shower parameters. As a consequence, the method was not pursued for a long time and the historic results came into question.

However, inspired by the new developments in radio astronomy, it was recently suggested that the new generation of digital radio arrays, such as Low-Frequency Array (LOFAR), could be ideal for detecting radio emission from EAS induced by cosmic rays (including neutrinos) [5]. Radio dipoles can be cheaply produced in large numbers creating thus a cheap alternative to the traditional detectors in building arrays for detection of the highest energy cosmic rays ($\sim 10^{20}$ eV), like Auger.

In order to explore this technique a LOPES (LOFAR Prototype Station) [6] experiment has been built in conjunction with KASCADE-Grande in Forschungszentrum Karlsruhe in Germany. On the 1st of January 2004 *The LOPES Collaboration* was established by all member institutes of KASCADE-Grande (so, SINS, as well), four radio-astronomy institutes from Germany and Netherlands and ASTRON – Netherlands Foundation for Research in Astronomy.

LOPES comprises at present 30 antennas operating in the frequency range of 40-80 MHz. It is triggered by a large event trigger from the KASCADE-Array. Using digital beam-forming technique it is possible to assign the measured radio pulse to the large air showers (primary energy 10¹⁷ eV and more). So far we have collected some tens of candidates and investigation is under way. A publication on the clear detection of radio signal from EAS is expected very soon.

The Auger Collaboration has also recently decided to equip the Southern Site in Argentina with radio antennas to test the technique with larger showers. There are plans to use the radio-detection technique in

7.4 Results of Collaboration with Prof. A.W.Wolfendale by T.Wibig

In the 2004 we started to analyse data from the WMAP experiment. The map the of Cosmic Microwave Background (CMB) published at the end of 2003 showing results of the first year of measurements by WMAP probe analysed by the WMAP group gave estimations not only of the age of the Universe and the dark matter density, but also other significant cosmological parameters. The problem with WMAP data was to extract from the measured fluxes the true 'cosmological CMB'. Together with prof. Wolfendale we tested the possible correlation of CMB with the spatial distribution of cosmic rays. First results were presented by Prof. Wolfendale at the CRIS 2004 conference "GZK and Surroundings" and European Cosmic Ray Symposium in Florence. Recent findings are submitted to the Monthly Notices of the Royal Astronomical Society.

The works on Ultra-High Energy Cosmic Rays (UHECR) were also continued with results presented

7.5 EAS Registrations on the Board of Airbus A380

by K.Jędrzejczak, B.Szabelska, J.Szabelski and T.Wibig

Prof. J.N. Capdevielle from Collège de France put forward the idea of using test flights of Airbus A380 for EAS registrations at an altitude of 10 km. (Prof. Capdevielle has realised the project of cosmic ray registrations on board of Concorde at an altitude of 16 km). A380 has enough space for placing detectors of electromagnetic component of EAS, and its carrying capacity (80 tons) allows for placing also detectors of the Northern Site of Auger Laboratory, which deployment of which is going to start in 2007.

- K-H.Kampert et al., Nucl. Phys. B (Proc. Suppl.) 122 (2003) 422
- [2] H.Ulrich et al., Eur. Phys. J. C33 (2004) 944
- [3] B.Alessandro et al., Proc. 27th ICRC, Vol.1, (2001) 124
- [4] W.Walkowiak et al., to appear in IEEE Trans. on Nucl. Sci. 2005
- [5] H.Falcke, P.W.Gorham, Astropart. Phys. 19 (2003) 477
- [6] A.Horneffer et al. Proc. SPIE Conf. 5500, to be published; astro-ph/0409641



in Florence and CRIS 2004. The important result of this work is to show the significance of the role of enhancement of infra-red photon radiation field and magnetic fields in regions surrounding possible UHECR sources (quasars and/or colliding galaxies in galactic clusters).

The new data of the largest arrays measuring UHECR (Hi-Res, Akeno, Yakutsk) published in 2003 were analysed and summarised in the way described in the paper by J.Szabelski, T.Wibig and A.W.Wolfendale, Astropart. Phys. 17, 125 (2002) "Cosmic Rays of the Highest Energies: the Case for Extragalactic Heavy Nuclei". The updated fluxes were used to support the statement of Galactic origin of CR up to about 10^{18} eV. The problem of where the extragalactic component starts to predominate is recently re-analysed by many authors.



muons and neutrons. Test flights of Airbus are planned for $5\ 000 - 10\ 000$ hours.

Computer simulations performed in Łódź show that measurements at such high altitude should give the possibility to register and identify showers produced by heavy nuclei up to an energy of 10^7 GeV, that is much above the "knee" in primary spectrum of cosmic rays.



PL0501188

7.6 The Roland Maze Project – Cosmic Ray Registrations at Schools

by J.Feder, K.Jędrzejczak, J.Karczmarczyk, R.Lewandowski, P.Tokarski, J.Swarzyński, B.Szabelska, J.Szabelski and T.Wibig

The idea of the project is to construct a large area network of cosmic ray detectors using town infrastructure of high schools in Łódź. The main goal of the experiment is studies of extensive air showers of cosmic rays at the highest observed energies (above 10^{18} eV). Introducing high school students to the project will have an important educational impact and seems to be an efficient way of science popularization.

Last year we got financial support from the City authorities in Łódź. A sum of 300 000 PLN was accepted in the Łódź City budget for "Education of young people to realisation of tasks in the high technology area". The funds will allow us to cover expenses for detector installation in 10 high schools (out of 30 that expressed their will to participate in the Project). After many tests of different kinds of scintillator probes, photomultipliers from PHOTONIS in Brieve (France) and reemitting fibers Bicron we have chosen suitable equipment: scintillator plates 10cm x 12cm x 5mm produced in Protvino, PHOTONIS tubes XP1912 and 1mm Bicron fibers. By the end of year 2004 we nearly completed acquiring all necessary equipment and materials. In parallel to experimental works on detector construction details we collaborate with high school students and their teachers as follows:

- groups of students construct Geiger-Muller cosmic ray telescopes for their schools; the first such device was presented during the First Scientific Session of the Maze Project organised in the XXVI High School;
- students have prepared a computer program for EAS reconstruction with a graphical interface;
- the works on idea of data collection software in school detection points and sending them to the main server in IPJ in Łódź are in progress;
- international Web page of the Maze Project has been designed; students are also working on many languages dictionary for cosmic ray physics based on *mysql*.

Contacts with schools have caused our greater activity in science popularization and great interest from television, radio and local newspapers.

7.7 Experiments with WASA Detector at CELSIUS in Uppsala by J.Zabierowski



During 2004, several experimental runs with the WASA Detector were performed. They utilized a newly introduced deuterium pellet target as well as upgraded CELSIUS energy from 1360 MeV to 1450 MeV. Improvements of the eta trigger efficiency were obtained.

Among others, the reaction $pd \rightarrow He$ eta at 893 MeV has been investigated. It gives the quasibackground-free eta tagging.

In the investigating of multi-pionic final states an upper limit on $\sigma(pp \rightarrow pp3\pi^0) = 1.5 \ \mu b$ was found by comparing prompt and resonant $3\pi^0$ production. This and several other results were reported at MESON 2004 conference in Cracow and some others.

Based on previously collected data, the result of the measurement of the pd \rightarrow pd eta cross section in complete kinematics has been published [1].

In view of the shutdown of CELSIUS in June 2005 and the moving of WASA to Juelich afterwards a new <u>WASA@COSY</u> collaboration has been founded. The proposal of the experiments at COSY with WASA apparatus has been prepared.

- [1] R.Bilger et al. Phys. Rev. C69 (2004) 014003
- [2] H.-H.Adam et al., arXiv: nucl-ex/0411038

7.8 Participation in ZEUS Experiment by P.Pluciński

We participate in the ZEUS experiment at DESY (Hamburg) in the works on the Backing Calorimeter (BAC). Mr. Paweł Pluciński, who works in DESY, played a role of an "on-line" expert for BAC, took part in data acquisition in the ZEUS control room and was responsible for monitoring of data registered by the BAC detector. Last year he was mainly involved in the works on the first level trigger of the Backing



Calorimeter in ZEUS experiment, gathering materials for his PhD thesis.

He developed the diagnostic system for BAC and made some actualisation of software used for data acquisition. He organised service works during the shutdown of BAC in July and August 2004. During service works he performed several tests of trigger system in BAC detector.

LIST OF PUBLICATIONS

COSMIC RAYS IN THE "KNEE" REGION - RECENT RESULTS FROM KASCADE K.-H.Kampert, ..., A.Risse, J.Zabierowski et al. Acta Phys. Pol. B 35 (2004) 1799

ASTROPHYSICS OF THE KNEE IN THE COSMIC RAY ENERGY SPECTRUM A.Haungs, ..., A.Risse, J.Zabierowski ct al. Acta Phys. Pol. B 35 (2004) 331

TEST OF HADRONIC INTERACTION MODELS WITH KASCADE J.Milke, ..., A.Risse, J.Zabierowski, et al. Acta Phys. Pol. B 35 (2004) 341

LARGE SCALE COSMIC RAY ANISOTROPY WITH KASCADE T.Antoni, ..., A.Risse, J.Zabierowski ct al. The Astrophys. J. 604 (2004) 687

SEARCH FOR COSMIC-RAY POINT SOURCES WITH KASCADE T.Antoni, ..., A.Risse, J.Zabierowski et al. The Astrophys. J. 608 (2004) 865

THE PRIMARY PROTON SPECTRUM OF COSMIC RAYS MEASURED WITH SINGLE HADRONS AT GROUND LEVEL T.Antoni, ..., A.Risse, J.Zabierowski et al. The Astrophys. J. 612 (2004) 914

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ENERGY SPECTRUM AND ELEMENTAL COMPOSITION OF COSMIC RAYS IN THE PcV REGION H.Ulrich, ..., A.Risse, J.Zabierowski ct al.

Eur. Phys. J. C 33 (2004) 94

SEARCH FOR OCD-INSTANTON INDUCED EVENTS IN DEEP INELASTIC EP SCATTERING AT HERA S.Chckanov,..., P.Pluciński, ct al. (ZEUS Collaboration) Eur. Phys. J. C 34 (2004) 255

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PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited talks:

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INDIRECT MEASURMENT AROUND THE KNEE - RECENT RESULTS FROM KASCADE <u>H.Ulrich</u>, ..., **A.Risse**, **J.Zabierowski** et al. 19th ECRS, Florence (Italy), 30 Aug. – 3 Sept. 2004, to be published in the International Journal of Modern Physics A

Oral presentations:

MYONPRODUKTIONHOHEN <u>R.Obenland</u>, C.Buettner, K.Daumiller, P.Doll and J.Zabierowski DPG Fruehjahrstagung 2004, Mainz 29.03-01.04.2004 STABILITAET DES MYONEN SPURDETEKTORS <u>P.Doll</u>, C.Bucttner, K.Daumiller, R.Obenland and **J.Zabierowski** DPG Fruehjahrstagung 2004, Mainz 29.03-01.04.2004

INVESTIGATION OF THE MUON MOMENTA IN EAS WITH THE KASCADE MUON TRACKING DETECTOR **J.Zabierowski**, C.Buettner, K.Daumiller, P.Doll and R.Obenland *DPG Fruehjahrstagung 2004, Mainz 29.03-01.04.2004*

THE KASCADE-GRANDE EXPERIMENT

A.Chiavassa, ..., A.Risse, J.Zabierowski et al. Vulcano Workshop 2004, 24-29 May 2004, Vulcano, Italy

EAS EXPERIMENT ON BOARD OF THE AIRBUS A380 J.N.Capdevielle, F.Cohen, K.Jędrzejczak, B.Szabelska, J.Szabelski, T.Wibig XIII ISVHECRI, Pylos (Greece), 6 – 12.1X.2004, to be published in Nuclear Physics B

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INVESTIGATION OF THE PSEUDORAPIDITY AND MOMENTUM OF MUONS IN EAS WITH THE KASCADE MUON TRACKING DETECTOR J.Zabierowski, ..., A.Risse ct al.

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MUON ANGLES IN KASCADE-GRANDE J.Zabierowski KASCADE - Grande Workshop 6 -7.12.2004, Institut fuer Kernphysik, Forschungszentrum Karlsruhe, Germany

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CONNECTION BETWEEN HIGHEST ENERGY COSMIC RAYS AND COSMOLOGY **T.Wibig**, A.W.Wolfendalc CRIS 2004 , GZK and Surroundings", Catania, Italy, 31 May – 4 June 2004

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RECONSTRUCTION OF TOTAL MUON NUMBER IN KASCADE-GRANDE J. van Buren, ..., A.Risse, J.Zabierowski et al. 19th ECRS, Florence, Italy, 30 Aug. – 3 Sept. 2004, to be published in the International Journal of Modern Physics A

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A FADC-BASED DATA ACQUISITION SYSTEM FOR THE KASCADE-GRANDE EXPERIMENT W.Walkowiak, ..., A.Risse, J.Zabierowski ct al. IEEE Nuclear Science Symposium, 16 – 22 Oct. 2004, Rome, Italy

KASCADE-GRANDE: AN EXTENSION OFTHE KASCADE EXPERIMENT TO MEASURE EASs UP TO 10¹⁸ cV <u>A.Haungs</u>, ..., **A.Risse, J.Zabierowski** ct al. XXII Texas Symposium on Relativistic Astrophysics, Stanford University, USA, 13 – 17.12.2004

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COMUNICATIONS PUBLISHED IN CONFERENCE PROCEEDINGS

FIRST LEVEL TRIGGER OF THE BACKING CALORIMETER FOR THE ZEUS EXPERIMENT K.T.Późniak, **P.Pluciński**, G.Grzelak, K.Kierzkowski, M.I.Kudła Proc. SPIE Vol. 5484, p. 186-192, Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments II; Ryszard S. Romaniuk; Ed. (Jul 2004)

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MEASUREMENT AND RECONSTRUCTION OF EXTENSIVE AIR SHOWERS WITH THE KASCADE FIELD ARRAY G.Maicr, J.Zabierowski et al. Relativistic Astrophysics and Cosmology (Editors: M. Shapiro, T. Stanev, J.Wefel), World Scientific 2004, 243

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LECTURES, COURSES AND EXTERNAL SEMINARS

Statistical model of hadronic interactions – high transversal momentum problem^a) **T.Wibig** Experimental Physics Department, University of Łódź, 11 Mach 2004

Cosmic rays: origin and propagation in the Galaxy ^{b)} **T.Wibig** Technical University of Łódź, 20 April 2004

Cosmic rays: propagation in the interplanetary plasma^{b)} J.Szabelski Technical University of Łódź, 20 April 2004

a) in Polish

b) in German

DIDACTIC ACTIVITY

T.Wibig – supervisor of PhD thesis of Mrs. I. Kurp (IPJ)

"Thermodynamical description of particle production processes in ultra-high energy collisions"

PARTICIPATION IN POLISH AND INTERNAL SCIENTIFIC COUNCILS AND SOCIETIES

J.Zabierowski

Member of the CELSIUS/WASA Collaboration Board Voting Member of the KASCADE-Grande Collaboration Steering Committee Coordinator of Polish group in the KASCADE-Grande Collaboration

SCIENCE POPULARIZATION ACTIVITY

T.Wibig

2+2=4 (Un) natural history of human mind Lecture during the 4th Science Festival, Łódź, 22 April 2004

K.Jędrzejczak, J.Karczmarczyk, I.Kurp, B.Szabelska, J.Szabelski, T.Wibig Demonstration of air shower array and cosmic ray registrations during the 4th Science Festival, Łódź, April 2004

J.Feder, K.Jędrzejczak, I.Kurp, B.Szabelska, J.Szabelski, T.Wibig Organization of two Masterclass sessions in Łódź High Schools (27 and 28 April 2004)

K.Jędrzejczak, J.Szabelski, T.Wibig

Organization of the First Scientific Session of the Maze Project in XXVI LO in Łódź, 23 Nov. 2004

J.Szabelski

interview for Radio Plus about the Maze Project (7 July 2004) TVP3 – short report abot the Maze Project (7 July 2004) talk for Radio Łódź (28 Oct. 2004) talk about the Maze Project and the First Scientific Session in XXVI LO for TVP3 and TOYA television (23 Nov. 2004) interview for Radio Łódź 99.2 MHz about the Maze Project (30 Nov. 2004)

T.Wibig

three short talks in the local Radio Łódź

J.Szabelski

Polish outreach activities - presentation during the EPOG (European Particle Physics Outreach Group) meeting in CERN, Geneva, 28 Oct. 2004

PERSONNEL

Ryszard Lewandowski

Research scientists Anna lwan-Rise 1/21/3Tadeusz Wibig, DSc., Janusz Zabierowski, DSc. Barbara Szabelska, Dr. Jacek Szabelski, Dr. **PhD students** Karol Jędrzejczak Technical and administrative staff Jadwiga Feder Paweł Pluciński Jacek Karczmarczyk 1/2Józef Swarzyński

Przemysław Tokarski

8 DEPARTMENT OF NUCLEAR THEORY

Head of Department: Prof. Grzegorz Wilk phone: (22) 621-60-85 e-mail: wilk@fuw.edu.pl

Overview

The Department of Nuclear Theory consists of 21 physicists and 2 PhD students working on different aspects of low energy, high energy, plasma and nonlinear physics as well as on general problems of quantization of particle dynamics and astrophysics. In addition collaborations with experimental groups: COMPASS, ASACUSA/ACOL and ALICE at CERN, and participation in the EURIDICE (European CHP Program) should be emphasized. The results of our work in 2004 are presented in 41 regular published papers (plus some conference proceedings) and in 20 papers already accepted for publication. They were also presented in numerous seminars, both in Poland and abroad. Worthy of special emphasis are results of studies on:

- properties of superheavy and exotic nuclei;
- strange nuclear matter;
- search for the Majorana Neutrino;
- nonextensivity in hadronic and nuclear collisions and application of stochastic networks to elementary particle physics;
- fluctuations as signal of the phase or formation to QGP form of matter;
- some problems connected with parity violation;
- diffractive production processes in QCD;
- studies of exotic mesons and pentaquarks;
- confirmation of Feynman's hypothesis in BE condensates.

Other topics covered include studies on the entrance channel in fusion reactions, studies of a nuclear surface by antiprotons, topology of canonical variables and solitons in media. A theoretical group for the study of astrophysical problems has been formed (dr. hab. W.Piechocki i M.Spaliński i dr. M.Pawłowski).

Collaborations with several universities and institutions have been maintained. These include the Universities of Warsaw, Kielce, the Polish Academy of Sciences, München, Paris, Liege, Helsinki, São Paulo, Berkeley, St. Petersburg, Regensburg, Lipsk, London, Warwick and the Institutes at: CERN, GSI and JINR.

Shill

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PL0501191

8.1 Properties of Heavy and Superheavy Nuclei

by I.Muntian, A.Parkhomenko, Z.Patyk and A.Sobiczewski

Studies of the properties of the heaviest nuclei have been continued. Calculations of the masses of the heaviest nuclei have been performed within a macroscopic-microscopic approach [1]. Attention has been given to an analysis of the (static) fission-barrier height of these nuclei [2-4]. In particular, the role of higher-multipolarity deformations of a nucleus, taken in the analysis, has been studied for both spherical and deformed (in their ground state) nuclei. The problem of existence of superheavy nuclei which are superdeformed in their ground state, predicted in the literature, has been checked with the use of a macroscopic-microscopic model [5]. Our results do not support these predictions. To meet the needs of experimental physicists recently performing α - and γ spectroscopic studies of odd-A heaviest nuclei, singleparticle spectra of these nuclei have been calculated [6, 7]. The results indicate that the calculations reasonably reproduce the ground state of the nuclei



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and the sequence of the lowest excited states, while the average deviation between calculated and measured excitation energies is about 300 keV.

- [1] I.Muntian, Z.Patyk and A.Sobiczewski, APH N.S., Heavy Ion Physics 19(2004)139
- [2] A.Sobiczewski and I.Muntian, Nucl. Phys. A 734 (2004) 176
- [3] I.Muntian and A.Sobiczewski, Int. J. Mod. Phys. E 14 (2005) in press.
- [4] A.Sobiczewski and I.Muntian, Int. J. Mod. Phys. E 14 (2005) in press
- [5] 1.Muntian and A.Sobiczewski, Phys. Lett B 586 (2004) 254
- [6] O.Parkhomenko and A.Sobiczewski, Acta Phys. Pol. B 35 (2004) 2447
- [7] A.Parkhomenko and A.Sobiczewski, Int. J. Mod. Phys. E 14 (2005) in press

8.2 Pairing Properties of Exotic Nuclei Far from the Stability Line by Z.Patyk

Studies of the pairing properties, especially for new measured [1, 2, 3] neutron-deficient nuclei far from the stability line, have been performed. We compared an experimental pairing Δ_3 extracted from 3-mass formula, with the BCS pairing Δ_{BCS} calculated with the Woods-Saxon single particle energy spectrum. Strong dependence of the pairing Δ_3 on nuclear isospin, experimentally observed for deformed exotic nuclei from Sn up to Pb isotopes, has been supported by theoretical analysis. As a result, the new pairing strength was parameterized with two constants for protons (p) and neutrons (n) $G_{p(n)}=g_0/A+(-)g_1(N-Z)/A^2$

with $g_0=20.8$ MeV and $g_1=22.4$ MeV [3]. With this paring parameterization the rms, the quantity reflecting an agreement between the experimental Δ_3 and the theoretical pairing Δ_{BCS} was reduced to 130 keV.

- A.H.Wapstra, G.Audi and C.Thibault, Nucl. Phys. A729(2003)129
- [2] T.Radon et.al., Nucl. Phys. A 677(2000)75
- [3] Yu.A.Litvinov et. al., Nucl. Phys. A 734 (2004)473

8.3 Theoretical Research on Properties and Formation of Superheavy Elements by R.Smolańczuk

Theoretical investigations of shell structures, magic numbers, energies, shell corrections, masses, deformations and decay properties of superheavy elements have been performed [1]. Theoretical investigations of the formation probabilities for superheavy nuclei have been performed as well [2]. Predictions for future experiments have been given [1, 2]. ²⁹³118 and ²⁹⁴119 have been predicted [2] to be the best isotopes for the discovery of the superheavy elements with atomic numbers 118 and 119, respectively.

These reactions might also give an opportunity for the discovery and measurements of the properties of the variety of spherical and deformed superheavy elements that could be obtained through the consecutive decays of elements 118 and 119.

- [1] R. Smolańczuk, Phys. Rev. C56 (1997) 812
- [2] R. Smolańczuk, Proceedings on Fusion Dynamics at the Extremes, Dubna, Russia, 2000, edited by Yu. Ts. Oganessian and V.I. Zagrebaev (World Scientific, 2001), p.200



8.4 The Associated Σ Production and the Σ-Nucleus Potential by J.Dąbrowski and J.Rożynek

The kaon spectrum from the (π, K^{+}) reaction on a ²⁸Si target in the region of Σ production is analyzed in the impulse approximation for different strengths of the Σ single particle potential. It is concluded that this potential is repulsive, and its strength is consistent

8.5 Σ^{-} Atoms

by J.Dąbrowski and J.Rożynek

Our work on the strong-interaction shifts ε and widths Γ of the Σ atomic levels, reported in [1, 2], was continued. Our previous results [3] obtained for ε and Γ are sensitive to the nucleon densities assumed in the calculations. We use this sensitivity to determine these densities. We consider the case of the Σ -Pb atom for which the most precise experimental data are available. Comparison of these data with our results

with the Nijmegen model F of the hyperon-nucleon interaction [1].

 J.Dąbrowski, J.Rożynek, Acta Phys. Pol. B 35 (2004)2303



suggest modifications in the nucleon densities in ²⁰⁸Pb, obtained in the Hartree-Fock calculations.

- J.Dąbrowski, J.Rożynek, in Condensed Matter Physics, Vol.18, Eds M.de Llano et al., Nova Scotia Publishers, Huntington, N.Y. 2003, p. 347
- [2] J.Dąbrowski, Acta Phys. Pol. B 35(2004)971
- [3] J.Dąbrowski, J.Rożynek, G.S.Agnostatos, Europ. Phys. J. A 14(2002)125

8.6 Selfconsistent Nuclear Energies at Large Deformations by J.Skalski

Methods for selfconsistent calculations of nuclear energy at extreme deformations and for two-fragment configurations (resulting from fission or heading towards fusion) have been improved upon. This consisted in taking into account the two-body part of

the center-of-masss kinetic energy correction, including pairing correlations, and allowing for a continuous change of interfragment distances. The codes developed are presently used for calculations of fission and fusion barriers.

8.7 Search for Majorana Neutrino - a Problem for Atomic Physics by Z.Sujkowski and S.Wycech

Recent oscillation experiments provide evidence on non-zero mass differences between neutrinos of various flavours. They thus prove that at least one of the three neutrino species has a non-vanishing rest mass and that the lepton flavour is not conserved. The information most needed now concerns the actual value of the neutrino mass of at least one of the neutrinos and the transformation properties of neutrinos under charge conjugation. The Majorana hypothesis that the neutrino is identical to its antiparticle makes the neutrinoless double beta decay possible. The rate of such a process depends in a direct way on the electron neutrino mass, thus providing the observable needed. An attractive alternative to the double β decay, 0 v2 β , is to search for the radiative neutrinoless double electron capture, 0v2EC. While in the general case this process is much slower than the $0v2\beta$ one, it might be enhanced by several orders of magnitude by the atomic resonance effect. The

PL0501198 resonance is expected to occur when the energy release equals the 2P-1S atomic level energy difference. The present work [1-3] presents the theory of the atomic resonance in the radiative electron capture applied to the double capture case. Candidates

An alternative way to determine the Majorana nature of neutrinos may be offered by the neutrino beta beam factories. Chances for such determination are being studied.

for such processes are considered. Experimental

feasibility is discussed and found encouraging.

- [1] Z.Sujkowski and S.Wycech. Phys. Rev. C 70 (2004)052501
- [2] S.Wycech and Z.Sujkowski, Acta Phys. Pol. B 35 (2004)1223
- [3] Z.Sujkowski and S.Wycech. NIM, in press



PL0501197

PL0501195

8.8 Antiprotonic Atoms and Studies of Nuclear Surface

by S.Wycech and R.Smolańczuk

The analysis of X-ray transitions in antiprotonic atoms, measured by the PS 209 Collaboration at CERN has been continued [1]. The purpose of that experiment, recently discussed in [2], was to study the neutron density distributions at large nuclear radii. The atomic X-ray data collected so far by the PS209 and other experiments allows us to determine a new form of the antiproton optical potential. It is dominated by antiproton annihilation and becomes nonlinear in the nuclear density due to three effects: dependence on the angular momentum of the nucleons, sensitivity to the longest nucleonantinucleon force range and the existence of nucleonantinucleon resonances [3].



An interesting by-product of this search is the finding of a nuclear, Coulomb assisted, state of antiproton circulating with a high angular momentum around the nucleus of Te [1].

We participate in antiprotonic experiments FLAIR and AIC planned at the future GSI facility, a few related questions have been discussed.

- [1] B.Klos et al, Phys. Rev. C69(2004)044311
- [2] J.Jastrzebski et al. Int. J. Mod Phys. E 13 (2004)343
- [3] S.Wycech, Nucl Instr. Meth. B 214(2004)164

8.9 Stochastic Networks and their Application to Elementary Particle Physics by G.Wilk, Z.Włodarczyk¹⁾

We have demonstrated that the process of formation of scale-free stochastic networks can in a natural way be described by means of statistical physics using nonextensive statistics (defined by Tsallis entropy) [1]. In particular, in this manner one obtains the characteristic power-like dependence of the number of links k formed in such a network and at the same time a correct description of the situation when the number of links is small. Connecting in this way the description of scale-free networks with a statistical approach we have then shown that some intriguing results obtained in elementary particle physics (namely power-like instead of simple exponential distributions in transverse masses of produced particles apparently observed experimentally) can be simply explained as due to the growth of some specific network composed of quarkantiquark pairs (forming its nods) and gluons (representing its links) [2].

- G.Wilk and Z.Włodarczyk; Acta Phys. Pol. B 35 (2004)871
- [2] G.Wilk and Z.Włodarczyk; Acta Phys. Pol. B 35 (2004)2141
- Institute of Physics, Świętokrzyska Academy, Kielce, Poland

8.10 Description of Single Particle Distributions by Means of Information Theory Approach

by F.S.Navarra¹⁾, O.V.Utyuzh, G.Wilk, Z.Włodarczyk²⁾

Using information theory (IT) in its extensive and nonextensive versions we were able, for the first time, to obtain a model independent description of nuclear collisions [1, 2] as well as elementary collisions $e^+e^- \rightarrow hadrons$ [2, 3]. The later reaction has also been compared to results of simple cascade model developed by us recently. We have shown that whereas nuclear data can be described reasonably well by methods of IT, the same is not true for data on $e^+e^- \rightarrow hadrons$ and this fact indicates that in this case there are some other dynamical mechanisms not yet accounted for.

 F.S.Navarra, O.V.Utyuzh, G.Wilk,
 Z.Włodarczyk; contribution to NEXT2003 (Second Sardinian Conf. on News and Expectations in Thermostatistics), Villasimius, Cagliari, Sept. 2003; Physica A340 (2004) 467

- F.S.Navarra, O.V.Utyuzh, G. Wilk,
 Z.Włodarczyk; contribution to Int. Workshop on: Trends and Perspectives in Extensive and Non-Extensive Statistical Mechanics, November, 2003, Angra dos Reis, Brazil; Physica A344(2004)568
- [3] F.S.Navarra, O.V.Utyuzh, G.Wilk, Z.Włodarczyk; contribution to Second Warsaw Meeting on Correlations and Resonances in Heavy Ion Collisions, Warsaw, October 2003, Poland; Nukleonika 49 (Supplement) (2004) S19
- ¹⁾ Inst. de Fisica, Universidade de São Paulo, Brazil
- ²⁾ Institute of Physics, Świętokrzyska Academy, Kielce, Poland

PL0501201

8.11 Fluctuations as Signal of the Phase Transition to Quark-gluon Plasma Form of Matter

by M.Rybczyński¹⁾, Z.Włodarczyk¹⁾, G.Wilk

We have shown that recent experimental data from heavy ion collisions concerning all kinds of fluctuations of the number of produced secondaries can be explained in a natural way together if one assumes that these fluctuations are caused by the critical point on the phase diagram describing different types of matter: normal hadronic matter, quark matter and the quark-gluon plasma.

PL0501202

PL0501204

- [1] M.Rybczyński, Z.Włodarczyk, G.Wilk; Acta Phys. Pol. 35 (2004)819
- I) Institute of Physics, Świętokrzyska Academy, Kielce, Poland



8.12 Superconvergence Relations and Parity Violating Analogue of GDH Sum Rule by K.Kurek and L.Łukaszuk

Sum rules of a superconvergence type for parity violating amplitudes (p.v. analogue of Gerasimov-Drell-Hearn sum rule) [1] have been discussed [2]. Examples illustrating the validity of p.v. sum rules in the lowest order of electroweak theory are given. The parity violating photon-induced processes for a proton target are considered within the frame of effective low energy theories and phenomenological models based on p.v. nucleon-meson effective interactions. Assuming the saturation of the p.v. sum rule, the possibility to limit the range of parameters, poorly known from existing experimantal data and used in

these models is discussed. The photon's energy dependence of asymmetries for p.v. p0 and π^4 production are predicted for models satisfying saturation. It is argued that the verification of the sum rule in future high intensity polarized beam experiments is feasible.

- [1] L.Łukaszuk Nucl.Phys. A 709(2002)289
- [2] K.Kurek, L.Łukaszuk Phys. Rev. C 79 (2004) 065204

8.13 The Single Particle Sum Rules in the EMC Effect by J.Rożynek and G.Wilk

We have modelled the parton distribution in nuclei using a suitably modified [1] nuclear Fermi motion. The modifications concern the nucleon rest energy which changes the Björken x in a nuclear medium. We also introduce final state interactions between the scattered nucleon and the rest of the nucleus. The energy-momentum sum rule is saturated. Good agreement with experimental data of the EMC effect for x>0.15 and nuclear lepton pair production data has been obtained. The connection to the chiral restoration scenerio is suggested [2].

- [1] J.Rożynek, G.Wilk, submitted to Phys. Rev. C
- [2] J.Rożynek, The Nuclear Sum Rule in Deep Inelastic Scattering, Nucl. Phys. A - in press

8.14 Diffractive Production of Vector Mesons in Quantum Chromodynamics (QCD) by D.Y.Ivanov¹, A.Schafer², L.Szymanowski and G.Krasnikov^{2.3}

The exclusive production of vector mesons is a subject of experimental studies at DESY. These processes are well suited for probing the nonperturbative generalized parton distribution in a target. For that a precise estimation of the perturbatively calculable coefficient function is necessary. Ref. [1] and [2] contain the first results of calculations of this function for light r and heavy JY mesons within the (collinear) QCD factorization approach at the next-to-leading order (NLO). The obtained NLO corrections turned out to be

surprisingly large. This requires new ideas in their interpretation and of the QCD factorization approach.

- [1] JETP Lett. 80(2004)226; (Pisma Zh. Eksp. Teor. Fiz.80(2004)255)
- [2] Eur. Phys. J. C34(2004)297
- 1) Institute of Math., Novosibirsk, Russia 2)
- Regensburg University, Germany
- 3) St. Petersburg State Univ., Russia



8.15 Studies of Exotic Hybrid Mesons and Pentaquarks

by M.Diehl¹⁾, I.V.Anikin^{2,3)}, B.Pire⁴⁾, L.Szymanowski, O.V.Teryaev³⁾ and S.Wallon²⁾

The studies of exotic particles are subject of many investigations whose aim is a better understanding of the structure of elementary particles.

The process best suited for probing the partonic structure of these particles is their exclusive electroproduction. In Ref. [1] we developed a theoretical framework - based on the generalized parton distributions describing the hard electroproduction of the θ^+ pentaquark. In Ref. [2] we put in doubt a popular belief about strong suppression of the hybrid meson electroproduction. We derive the twist-2 distribution amplitude for such a meson and

compare the resulting cross section for its production with the cross section for production of non-exotic pmeson.

- [1] M.Diehl et al., Phys. Lett. B 584(2004)58
- [2] M.Diehl et al., Phys.Rev. D 70(2004)011501
- I) DESY, Germany
- 2) LPT, Univ. Paris-Sud, Orsay, France
- 3) Dubna, JINR, Russia 4)
 - CPhT École Polytechnique, France

8.16 Dipole Model of Diffractive Processes and its Generalizations

by Y.V.Kovchegov¹⁾, L.Szymanowski and S.Wallon²⁾

The dipole model is actually the most popular model of diffractive scattering. Due to its simplicity it shows many limitations in describing processes with other than Pomeron exchanges. In Ref. [1] we generalized the dipole model for exchanges of the Odderon, being an odd charge parity partner of the Pomeron with quantum numbers of the vacuum.

- [1] Phys. Lett. B 586 (2004) 267
- 1) Univ. of Washington, Seattle, USA
- 2) LPT, Univ. Paris-Sud, Orsay, France



PL0501207

8.17 Studies of Quantum Mechanical Models with Non-hermitean Hamiltonians by R.Kretschmer¹⁾ and L.Szymanowski

Models based on non-hermitean hamiltonians having real spectra are the subjects of many studies attempting to generalize conventional quantum mechanics. In Ref. [1] we critically reanalyzed several such models proposed recently pointing out their shortcomings and limitations.

- [1] Phys. Lett. A 325(2004)112
- J) University of Siegen, Germany



8.18 One Parameter Family of Additive Energies and Momenta in 1+1 Dimensional STR

by M.Pawłowski

The velocity dependence of energy and momentum was studied. It was shown that in the case of STR in the space-time of only one spatial dimension the standard energy and momentum definition can be naturally modified without loss of local Lorenz invariance, conservation rules and additivity for multiparticle system. A one parameter family of energies and momenta has been constructed and it was shown that within natural conditions there is no

further freedom. Choosing a proper family parameter one can obtain energy and momentum increasing with velocity faster or slower in comparison with the standard case, but almost coinciding with them in the wide velocity region [1].

[1] M.Pawłowski, Concepts of Physics - in press



8.19 Topology of Canonical Variables

by W.Piechocki

In our quantization procedure of particle dynamics in de Sitter space, we use the idea of taking the canonical variables in a form compatible with their topologies. Such a choice enables a solution of the problems of self-adjointness of quantum observables

8.20 Coherent State Realization of the Principal Series Representation of SO(1,2) Group

by J-P.Gazeau¹⁾ and W.Piechocki

The principal series representation (PSR) of the SO(1,2) group may be found within the canonical quantization method [1]. We present the coherent state realization of PSR, in order to compare the effectiveness of both quantization methods [2]. The latter method, in contrast to the former one, does not suffer from the ordering problem of canonical operators appearing in the process of mapping classical observables into the corresponding quantum operators.

8.21 Two-dimensional Dispersion-managed Light Bullets in Kerr Media

by M.Matuszewski¹⁾, M.Trippenbach¹⁾, B.A.Malomed²⁾, E.Infeld and A.A.Skorupski

We propose а scheme for stabilizing spatiotemporal solitons (STSs) in media with cubic self-focusing nonlinearity and "dispersion management", i.e., a layered structure inducing periodically alternating normal and anomalous groupvelocity dispersion. We develop a variational approximation for the STS, and verify results by direct simulations. A stability region for the two-dimensional (2D) STS (corresponding to a planar waveguide) is identified. At the borders between this region and that of decay of the solitons, a more sophisticated stable object, in the form of a periodically oscillating bound state of two subpulses, is also found. In the 3D case (bulk medium), all the spatiotemporal pulses spread out or collapse.

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 Dep. of Interdisciplinary Science, Tel Aviv University, Israel

8.22 Enhancement of Third Harmonic Generation by Wave Vector Mismatch to Counter Phase-modulation

by M.Trippenbach¹⁾, M.Matuszewski¹⁾, E.Infeld, V.Cao Long²⁾, R.S.Tasgal³⁾, Y.B.Band³⁾

Recent experimental developments in material sciences have generated hope that it will be possible to devise optical media where the difference in group velocity between the fundamental and third harmonic mav be strongly suppressed. Under these circumsances both pulses would travel together over a long distance. This would lead to an enhancement of the generation process, and hence strong focusing and/or using ultra-short pulses might not be crucial. If the perfect phase matching condition is assumed, the only remaining mechanisms to decrease efficiency are self and cross phase modulation. Here we suggest that,

instead of exactly matching wave vectors, we admit a small mismatch and show how it can be tailored to compensate for the cross phase modulation of the third harmonic by the fundamental during the generation process. This is very beneficial for the efficiency of third harmonic generation, even increasing it by a factor of two or more.

- ¹⁾ Physics Department, Warsaw University, Poland
- ²⁾ Inst. of Physics, Univ. of Zielona Góra, Poland
 ³⁾ Department of Chemistry and Electro-Optics,
 - Ben-Gurion University of the Negev, Israel



PL0501211

[1] W.Piechocki, Class. Quantum Grav. 20 (2003) 2491

and time-reversal invariance of the system already at

the level of canonical variables algebra [1].

[1] W.Piechocki, Class. Quantum Grav. 21

(2004)331

- [2] J-P.Gazeau and W.Piechocki, J. Phys. A: Math. Gen. 37 (2004) 6977
- ¹⁾ University of Paris 7, Astroparticle and Cosmology Institute, Paris, France





8.23 Theoretical Confirmation of Feynman's Hypothesis on the Creation of Circular Vortices in Bose-Einstein Condensates: II

by A.Senatorski and E.Infeld

In a recent paper [1] we confirmed Feynman's hypothesis on how circular vortices can be created from an oppositely polarized linear pair in a Bose-Einstein condensate. This was done by perturbing the original pair numerically, so that a circular vortex (or array of identical circular vortices) was created as a result of reconnection. These circular vortices were then checked against known theoretical relations binding velocities and radii. Agreement to a high degree of accuracy was found. Here in part 11, we give examples of the creation of several different vortices from one linear pair. All are checked as above. We also confirm the limit of separation of the line vortices below which mutual attraction, followed by annihilation, prevents the Feynman metamorphosis. Other possible modes of behaviour are illustrated.

 E.Infeld and A.Senatorski, J. Phys.: Condens. Matter 15 (2003)5865

8.24 Eigenvalue Problem for a set of Coupled Schrödinger like ODEs by A.A.Skorupski and E.Infeld

Numerical solving of the eigenvalue problem for N coupled Schrödinger like ODEs [1] (N>1) was illustrated by two such equations describing small vibrations of a linear vortex in a Bose-Einstein condensate. A complication of the problem was due to the following facts: the infinite interval of the independent variable r, the presence of an unknown function in the differential equations (vortex radial profile) described by a nonlinear differential equation, and looking for the solutions in the long wavelength limit. To solve numerically the problem in question it was necessary to find appropriate asymptotics for large r, which were a generalization of the well known

phase integral approximation for one equation. Furthermore, in most critical cases, numerical precision in excess of 100 decimal digits was necessary. The results of our calculations fully confirmed earlier theoretical predictions of the authors [2].

- [1] A.A.Skorupski and E.Infeld, App. Num. Anal. Comp. Math. - in press
- [2] E.Infeld and A.A.Skorupski, J. Phys.: Condens. Matter, v.14, (2002) 13717

8.25 Conditions for Existence of Solitons in the Propagation of a Laser Beam Interacting with its Second Harmonic

by V.Cao Long¹⁾, P.P.Goldstein and S.Vu Ngoc²⁾

Equations governing the propagation of a monochromatic laser beam coupled to its second harmonic, previously shown to be partially integrable for some values of its parameters, are checked for the existence of Hirota type solitons. The Hirota scheme is found to work merely for exact resonance, i.e. for the ratio of the dispersion coefficients equal to the ratio of frequencies.

Similarly to the third harmonic case [1], these conditions may only be satisfied by single envelope travelling waves. Unlike the third harmonic coupled to the fundamental mode, which satisfies the nonlinear Schrödinger equation with the usual cubic nonlinearity, the nonlinearity is of the form |Y|Y in the second harmonic case. The envelope of the second harmonic has locally the shape of the Weierstrass P function [2].

- V.Cao Long, P.P.Goldstein and M.Trippenbach, Acta Phys. Pol. A105 (2004) 437
- [2] V.Cao Long, P.P.Goldstein and S.Vu Ngoc, Acta Phys. Pol. A106 (2004) 843
- Institute of Physics, Univ. of Zielona Góra, Poland
- ²⁾ Faculty of High Technology, Vinh University, Nghe AN, Vietnam



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A.Sobiczewski - two chapters in a nuclear physics textbook for students of the Physics Department of Warsaw University

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- DECAY OF ATOMIC NUCLEI

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PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited talks:

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MAY WE EXPECT SUPERDEFORMED GROUND STATE OF SUPERHEAVY NUCLEI? A.Sobiczewski Symposium "Future Research of Superheavy Elements", Darmstadt, Germany, Feb. 2004

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K MATRIX ANALYSIS OF eta – ³He SYSTEM **S.Wycech** MESON 2004 Cracow, Poland, June 2004

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MULTIPARTICLE PRODUCTION PROCESSES FROM THE NONEXTENSIVE POINT OF VIEW O.V.Utyuzh, <u>G.Wilk</u> and Z.Włodarczyk The HS 2004, Smolenice Castle, Slovakia, Aug.30 – Sept. 3, 2004

COSMOLOGICAL SINGULARITIES AND DARK ENERGY W.Piechocki 5th Int. Workshop on the Identification of Dark Energy, Edinburgh, Great Britain, Sept. 6-10, 2004 NUMERICAL MODELING OF QUANTUM STTISICS IN HIGH-ENERGY PHYSICS O.Utyuzh, G.Wilk, Z.Włodarczyk Sixth Int. Symp. On Frontiers of Fundamental and Computational Physics (FFP6), Voline, Italy, Sept. 16-29, 2004 ROLE OF HIGHER-MULTIPOLRITY DEFORMATIONS IN THE HEIGHT OFFISSION BARRIER OF A DEFORMED HEAVY NUCLEUS A.Sobiczewski XI Nuclear Physics Workshop "Physics of Exotic Nuclei", Kazimierz Dolny, Poland, Sept. 23-26, 2004 DELTA G FROM HIGH pT events at SMC and high pT ANALYSIS AT COMPASS K.Kurek BARYON 04, Palaiseau, Ecole Polytechnique, France, Oct. 25-29, 2004

PARITY VIOLATING ANALOGUE OF GDH SUM RULE L.Łukaszuk Baryon 2004, Paris, France, Oct. 25-29, 2004

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DIRECT MASS MEASUREMENTS OF SHORT-LIVED NEUTRON-RICH FISSION FRAGMENTS AT THE FRS-ESR FACILITY AT GSI M.Matoš, ..., Z.Patyk, B.Pfeiffer, M.Winkler, H.Wollnik, T.Yamaguchi, et al. International Symposium on Exotic Nuclei, EXON 2004, Peterhof, Russia, July 5-12, 2004

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ARE THERE STRANGELETS IN COSMIC RAYS M.Rybczyński, Z.Włodarczyk and G.Wilk 19 ECRC, Florence, Italy, Aug. 31 - Sept. 3, 2004

EFFECTS OF NON-AXIAL SHAPES ON THE HEIGHT OF FISSION BARRIERS OF HEAVIEST NUCLEI LMuntian

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MULTIPLICITY FLUCTUATIONS IN HIGH ENERGY HADRONIC AND NUCLEARCOLLISIONS M.Rybczyński, Z.Włodarczyk, O.V.Utyuzh, and G.Wilk XIII ISVHECRI, Pylos, Greece, Sept. 6-12, 2004

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BABIE LATO ALBERTA EINSTEINA E.Infeld Świat Nauki, Oct. 2004

LECTURES, COURSES AND SEMINARS

THEORETICAL DESCRIPTION OF THE FUSION REACTIONS^{al} **R.Smolańczuk** XII Seminar in Miedzyzdroje, University of Szczecin, May 2004

DESCRIPTION OF THE ENTRANCE CHANNEL IN THE COLD REACTIONS OF NUCLEAR SYNTHESIS^{a)} R.Smolańczuk

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ON COSMOLOGICAL SINGULARITIES PROBLEM^{a)} W.Piechocki Cosmology Seminar, IFT UW, March 16, 2004 ON WAVE WAVE COUPLING^a) E.Infeld Theory Department Seminar, IPJ, January 2004

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a) in Polish

FELLOWSHIPS

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E.Infeld – Fellow of the Institute of Physics (UK)

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EDITORSHIPS

E.Infeld - Assoc. Editor, Plasma Physics, Cambridge

A.Sobiczewski - Editor, Postępy Fizyki, Warsaw

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Michał Kowal, Dr.	since Nov. 25	Robert Smolańczuk, Dr.
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9 DEPARTMENT OF MATERIAL STUDIES

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Overview

The technology of modifying surfaces of practical-use materials by means of continuous and pulsed energy and particle beams has been intensely studied for more than 20 years. In some fields it is presently utilized on a wide scale in industry. Continuous or pulsed ion and plasma beams play a significant role among various approaches used in this area. The research carried at by Department P-IX is centered around the use of two ion implantation machines (ion implanters) of different kinds and several unique sources of high-intensity intense plasma pulses, utilized jointly with Department P-V. The Department cooperates with Forschungszentrum Rossendorf (FZR, Dresden, Germany) in the field of ion-beam-based analytical techniques and the use of ion implantation facilities. The main objectives of the Department are:

- A search for new ways of modifying the surface properties of solid materials by means of continuous or pulsed ion and plasma beams and
- implementation of ion implantation techniques in national industries as a method of improving the lifetime of machine parts and tools utilized in industry.

In 2004 these objectives were being accomplished in many ways, particularly by research on:

- interaction of nitrogen atoms in expanded austenite formed in pure iron
- formation of superconducting MgB₂ phases
- surface layer modification of ion-bombarded HDPE
- nanolayers in AIN for direct bonding with copper
- surface alloying of titanium with nickel and palladium for increased corrosion resistance
- nanolayers in alloys and ceramic coatings for improved resistance to high-temperature corrosion
- improvement of cutting tools lifetime by means of nitrogen implantation.

The research was conducted in cooperation with Department P-V of IPJ, Institute of Nuclear Chemistry and Technology (Warsaw), Warsaw University of Technology, Institute of Technology of Materials for Electronics (Warsaw), Forschungszentrum Rossendorf FZR (Dresden, Germany), as well as with some industrial companies.

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9.1 Interaction of Nitrogen Atoms in Expanded Austenite Formed in Iron by Intense Nitrogen Plasma Pulses

by J.Piekoszewski, B.Sartowska¹⁾, L.Waliś¹⁾, Z.Werner, M.Kopcewicz²⁾, F.Prokert³⁾, J.Stanisławski, J.Kalinowska²⁾, W.Szymczyk

Several authors [e.g. 1, 2] have shown that it is possible to nitride stainless steel in such a way that a metastable phase is formed, in which nitrogen in solid solution increases the surface hardness and wear resistance without compromising corrosion behavior. This phase is referred to as nitrogen-expanded austenite and is denoted as γN . Some authors [e.g. 3, 4] claim that the γN phase can only be formed if Fe, Cr and Ni are available in the system, but the initial material needs not be of fcc austenite structure. However, it has been also demonstrated [5] that high intensity nitrogen plasma pulses can form γN phase even in pure α -iron (ARMCO). On the other hand, it has been shown [6] that γN in carbon steels also improves their tribological properties.

In the present work we tried to determine the character of interaction between nitrogen atoms in γN phase formed in pure iron treated by high-intensity nitrogen plasma pulses. ARMCO samples were irradiated with 20 intense nitrogen plasma pulses of about 1 µs duration each. At about 5 J/cm² deposited energy the pulses were melting sample surface to about 1-2 µm and doping the molten layer with nitrogen. Retained dose after 20 pulses was 5.5x1017 N/cm², and nitrogen concentration was 6.5-8.5 at% as found by nuclear reaction analysis (NRA). Samples were also examined by X-ray diffraction in grazing incident geometry (ω =2°) using CuK_a rays (XRD analysis depth≈500 nm), and by conversion electron Mössbauer spectroscopy (CEMS depth≈300 nm).

Table 1

XRD parameters of ARMCO sample treated with 20 pulses of nitrogen plasma.

(64)	20 FWHM a	$(a-a_0)/a_0(\%)$			
	(deg)	(deg)	(nm)	a ₀ (1)	a ₀ (2)
(200)	50.180	0.622	0.36332	2.056	1.29
(220)	73.652	0.838	0.36349	2.104	-
(311)	89.276	1.189	0.36361	2.138	-

 $a_0(1)=0.356$ nm extrapolated for pure austenit [7]

a₀(2)=0.3587 nm for untreated 310 stainless steel [8]

Expansion of the crystal lattice is confirmed [7, 8]. However, lattice transformed to austenite from α -Fe by us is less susceptible for expansion than that of an originally austenite steel (e.g. compare lattice parameter *a* relative change (a-a₀)/a₀ $\approx 2\%$ with 2.9% observed in [8] for 310 steel containing 8at.% of nitrogen). The difference is due to different structures and compositions of both materials.

CEMS spectra were fitted with spectra of various phases. $F\gamma_0/F\gamma_N$ fraction ratio derived from the fit was used to semi-qualitatively estimate character of interactions between nitrogen atoms present in the

austenitic phases. Two models discussed in [9] were considered: (i) occupation of each of 6 octahedral sites occurs randomly, i.e. there is no interaction between nitrogen atoms (model A) and (ii) strong repulsive forces act between both first- and second-nearest nitrogen atoms, so they tend to separate from each other (model B).



Fig. 1 The box represents value of F γ_0 /F γ_N fraction ratio observed experimentally in ARMCO sample treated with 20 pulses of nitrogen plasma. The horizontal sides represent the range of experimentally measured concentrations, the vertical sides represent the estimated error of the F γ_0 /F γ_N fraction ratio. The solid lines show theoretical predictions assuming no interaction and strong repulsion between nitrogen atoms in the nearest-neighbour positions.

The experimental result is much closer to model B than to A. Therefore, we conclude that strong repulsion forces act between nitrogen atoms in the fcc austenitic structure formed as a result of nitriding of pure iron by intense nitrogen plasma pulses.

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9.2 Ion Implanted Nanolayers in AIN for Direct Bonding with Coper

by M.Barlak, W.Olesińska¹), J.Piekoszewski, M.Chmielewski¹), J.Jagielski¹), D.Kaliński¹), Z.Werner, B.Sartowska²)

Direct bonding (DB) of conductors to ceramics (especially AlN) is considered as the most promising technology of packaging electronic devices used in high power density applications. In the DB technique, metal is bonded directly to the ceramics with only a very thin transition layer at their interface. One of the pioneering works [1] proved that satisfactory bonding of Cu to AlN can be achieved if 1-1.5 at% of oxygen is added to the system as an active element – even if the surfaces of the joined components have not been intentionally modified.

In our preliminary experiments with implantation of Ti, Fe and O ions into AlN substrates we tried to replace the conventional process of thermal oxidation. The results [2] suggested that the best shear strength could be expected for relatively low energy of Ti ions.

In the present work, we implanted Ti, Fe and O ions. 10^{16} - 10^{18} Ti and Fe ions/cm² were implanted in the MEVVA-type TITAN direct beam implanter [3] at 15 or 70 kV into commercial (Goodfellow) AlN substrates of 12x3x0.63 mm³ with roughness of about R_a=0.1 µm. Oxygen was implanted in a home-made semi-industrial implanter with non-mass separated beam. To avoid overheating, samples were clamped onto a water-cooled stainless steel plate mounted in both implanters. The ion current densities were kept below 10 µA/cm², and the substrate temperature did not exceed 200°C during the entire run.

Metallic components of the joints, i.e. 30x3x0.3 mm³ strips of oxygen-free Cu were annealed at 600°C for about 30-40 min in flowing nitrogen containing 1.5 ppm oxygen. The components were subsequently oxidized in air at 380°C for 3 min and directly bonded to the ceramics in a conventional DB process.

Mechanical properties of the obtained joints were examined. Careful SEM observations were performed on fractured surfaces of both components of the joints to reveal the joint microstructure.



Fig. 1 Comparison of various AlN pre-treatment techniques for Direct Bonding of AlN-Cu joints.

Shear strengths between 20 and 70 kG/cm² have been obtained. Oxygen implantation gave consistently better results than implantation of iron. For all elements implanted at 15 kV shear strength was greater by a factor of about 2 than that obtained at 70 kV. The best shear strength obtained for 5×10^{16} cm⁻² Ti (70 kG/cm²) exceeds by a factor of 5 typical values (14 kG/cm²) obtained using conventional isothermal oxidation AlN pre-treatment process [2].

Microstructure inspections showed that the strongest joints are of adhesive type over the entire surface. Over 90% of the copper surface in contact with the ceramics exhibited neither changes, nor inhomogeneities – its structure was continuous and homogeneous. Insignificant copper grooves observed at grain boundaries can be associated with copper oxidation prior to the joining process.

The ceramic surface had a homogeneous compact grain structure homogeneously covered with nanoprecipitates. At higher Ti doses larger numbers of needle-shape precipitates were seen and a new phase of multifaceted crystals appeared. On the other hand, the grain-like phase increases with both energy and dose of Ti ions.

Fe and O implantations did not lead to substantial changes of the microstructures at the joint surfaces of ceramics and copper for different implantation conditions. Such effects were seen only for Ti.

To conclude, ion implantation seems to be ideally suited for Direct Bonding process. Optimized implantation process leads to much better results than a conventional process at a comparable processing time. Advantages of ion implantation include:

- potentially fast processing time (several minutes at 100 mA beam current instead of tens of minutes in the conventional process)
- accuracy in creating an appropriate dopant content
- flexibility in tailoring the desired distribution of the introduced atoms at nanometer depth range
- ability to form non-equilibrium compounds.
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9.3 Superconductivity of MgB₂ Thin Films Prepared by Ion Implantation and Pulsed Plasma Treatment

by J.Piekoszewski, W.Kempiński¹⁾, B.Andrzejewski¹⁾, Z.Trybuła¹⁾, L.Piekara-Sady¹⁾, J.Kaszyński¹⁾, J.Stankowski¹⁾, Z.Werner, E.Richter²⁾, F.Prokert²⁾, J.Stanisławski, M.Barlak

The superconductive phase of inter-metallic MgB_2 compound discovered in 2001 by Nagamatsu et al. [1] has attracted a considerable interest due to its relatively high transition temperature $T_C=39K$ and potential application on the industrial scale. The new material has been studied along two paths: solid MgB_2 and thin films formed on various substrates. We try to form superconducting MgB_2 layer grown on substrates with surfaces molten by intense plasma pulses.

In our preliminary experiments [2] Mg substrates were implanted with 5×10^{18} B ions per cm² at energy of 100 keV an melted by two µs duration H plasma pulses of energy 1.9 and 3.0 J/cm². Magnetically Modulated Microwave Absorption (MMMA) and four point probe (FPP) methods were used to detect superconductivity. The highest obtained transition temperature was $T_C=31$ K. However, macroscopic percolation chains did not occur and MMMA signals were very weak.

In the present work, the number of pulses was increased (2-4), and H plasma was replaced by Ar one. Mg substrates were implanted with 3×10^{18} B ions per cm² at energy of 80 keV. Samples were characterized by MMMA, FPP, XRD and RBS techniques.

XRD data indicate that the *a* lattice constant decreased with respect to the as-implanted samples by $\Delta a/a = -$ 0.71%, whereas the *c* lattice constant increased by $\Delta c/c = 0.37\%$. According to theoretical predictions given by Wan [3] this should lead to an increased density of states near the Fermi level and therefore to an increased T_c. On the other hand, the highest value of T_c was observed when the c lattice constant had the smallest value with respect to the bulk $\Delta c/c = -0.2\%$ [4]. However, some authors claime that T_c rises with lattice expansions [5-7].



Fig. 1 RBS spectra of as-implanted and pulse-treated samples.

A pronounced valley centered around channel 400 appeared in the RBS spectrum of as-implanted sample (a). Samples (b) and (c) were treated with 2 H pulses with energy density 2 and 3 J/cm², respectively. It may be seen that the width of the valley (related to the width of the boron profile) grows with the pulse fluence. For sample (c) the boron profile seems to be spread over the greatest depth. On the other hand, the Mg signal value at the minimum of the spectrum does not change significantly. Rough estimations based on SIMNRA simulations indicate that the Mg content at the peak of boron profile amounts to no more than 15-25%. It means that boron concentration is no less that 75-85% - far in excess of the stoichiometric composition of MgB₂. However, this excess of boron does not preclude the existence of MgB₂ phase, as evidenced by the XRD spectra (not shown here).

The strongest MMMA signal hysteresis (higher by an order of magnitude with respect to samples (b) and (c)) has been obtained for the sample treated with 4 pulses of Ar plasma at the fluence of about 2 J/cm². However, T_C for that sample had a rather disappointing value of about 12K, probably due to lack of stoichiometry. The highest T_C has been obtained for high-energy pulses, but the highest superconducting phase content has been obtained for the largest number of pulses, corresponding to a long time of diffusion in the molten phase.

Still no breakthrough has occurred with respect to the macroscopic percolation of the superconductive regions.

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PL0501221

9.4 The Effect of Nitrogen Implantation on Lifetime of Cutting Tools Made of SK5M Tool Steel

by J.Narojczyk¹⁾, Z.Werner, J.Piekoszewski

A number of tools used presently in industry for cutting and forming are made of high speed steels (HSS). To increase wear resistance of such cutting tools, hard coatings of nitrides, borides, carbides or oxides of such elements like Al, Cr, Ta, Ti and Fe are used [1]. Nitrogen ion implantation has for a long time been used as an alternative to coatings [2, 3, 4, 5]. This report describes the results of such application in the ball-bearing industry.

The tested form tool made of the SK5M steel and heattreated to 65 HRC is shown in Fig. 1. $1-5 \times 10^{17} N_2$ at/cm² were implanted into the tool flank face at 80 keV, 4×10^{-4} Pa. The tool temperature did not exceed 1500°C during the entire treatment. 6-35 tools were implanted at the same conditions.

The implanted tools were used to form inside hole and curvature radii of the internal ring of type 608 bearing made of annealed LH 15 bearing steel. Machining was performed at a cutting speed of 24.5 m/min and a feed rate of 0.02 mm/rev. The tool lifetime was expressed in terms of the number of bearing rings manufactured until the tool wear resulted in exceeding the tolerance

limit of the product. Each tool was re-sharpened 6x on the average. Results of the tests are presented in Fig.2. The optimum dose corresponds to about 3×10^{17} N₂ at/cm² yielding on the average 1.6 x lifetime increase as compared to the unimplanted tools.



Fig. 1 Form tool elected

for the tests

To clarify the nature of the observed lifetime improvement, a number of characterisations have been undertaken. Nanohardness was measured in the 150-400 nm indentation depth range. N₂ profiles were

analyzed by the glow discharge optical emission GDOES spectroscopy, phase composition of surface layer by the conversion Mössbauer electron spectroscopy in backscattering geometry.



Fig.3 presents the results of nanohardness tests. They are inconclusive.

The obtained nitrogen profiles were in fair agreement with theoretical calculations except for some tail, observed particularly for higher doses. The tail may result from radiation-enhanced diffusion processes not accounted for in calculation [6]. The results demonstrate that the GDOES technique may reveal shallow nitrogen profiles (this have been under dispute for some time).



Fig. 4 Results of phase composition fitting to the obtained CEMS spectra. Curves denoted x=0.33 and x=0.5 represent E-Fe_{3-x}N with x=0.33 and x=0.5, respectively.

Results of fitting the phase composition to the obtained spectra are shown in Fig. 4. Amount of ε-Fe_{2.5}N initially grows during the implantation process at the expense of α and α ' phases, but at doses around 4×10^{17} N/cm² starts to decrease and ξ -Fe₂N develops. The latter phase is correlated with decreasing wear resistance observed for nitrogen doses exceeding 3×10^{17} cm⁻². Transformation of ε -Fe_{3-x}N into ξ -Fe₂N does not result exclusively from accumulation of N, but also from an accompanying change of stress field in the implanted layer [7]. Stress relaxation occurs for implanted nitrogen dose leading to the onset of E-Fe₂N phase presence. Analysis of phase composition in surface layer of the SK5M HSS confirms this mechanism. In conclusion, wear resistance of nitrogen-implanted tools made of SK5M HSS is to a large extent associated with quantitative relations within the ferric nitride system in the surface layer.

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BOOKS

ION IMPLANTED NANOLAYERS IN ALLOYS AND CERAMIC COATINGS FOR IMPROVED RESISTANCE TO HIGH-TEMPERATURE CORROSION

Z.Werner, W.Szymczyk, J.Piekoszewski

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PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited talks:

FROM MICRO TO NANOTRIBOLOGY; SCALING DOWN THE MECHANICAL PROPERTIES J.Jagielski

1st Workshop of Advanced Materials, Doha, Katar, April 2004

SUPERCONDUCTIVITY OF MGB2 THIN FILMS PREPARED BY ION IMPLANTATION AND PULSED PLASMA TREATMENT

J.Piekoszewski, W.Kcmpiński, ..., J.Stankowski, Z.Werner, E.Richter, F.Prokert, J.Stanisławski, M.Barlak, et al. 5th Intern. Conf. ION 2004, Kazimierz Dolny, June 14-17, 2004 (accepted for publication in Vacuum)

FRICTION PROPERTIES OF ION-BEAM MODIFIED MATERIALS: WHERE CAN WE SEARCH FOR PRACTICAL APPLICATIONS OF ION IMPLANTATION? J.Jagielski

5th International Conference ION 2004, Kazimierz Dolny, June 14-17, 2004

ION IRRADIATION OF CERAMIC OXIDES: DISORDER PRODUCTION AND MECHANICAL PROPERTIES J.Jagielski

European Conf. on Accelerators in Applied Research and Technology, Paris, France, September 2004

Oral presentations:

MODIFICATION OF THE NEAR SURFACE LAYER OF CARBON STEELS WITH INTENSE ARGON AND NITROGEN PLASMA PULSES

B.Sartowska, J.Piekoszewski, L.Waliś, W.Szymczyk, J.Stanisławski, L.Nowicki, R.Ratajczak, ..., F.Prokert, et al. 5th International Conference ION 2004, Kazimierz Dolny, June 14-17, 2004

THE EFFECT OF NITROGEN IMPLANTATION ON THE LIFETIME OF CUTTING TOOLS MADE OF SK5M TOOL STEEL J.Narojczyk, Z.Werner, J.Piekoszewski

5th International Conference ION 2004, Kazimierz Dolny, June 14-17, 2004

QUANTITATIVE ANALYSIS OF RADIATION-INDUCED DISORDER IN SPINEL CRYSTALS J.Jagielski

Ion Beam Modification of Materials, Monterey, USA, September 2004

Posters:

ION IMPLANTATION AS A PRE-TREATMENT METHOD OF AIN SUBSTRATE FOR DIRECT BONDING IN COPPER **M.Barlak**, W.Olcsińska, **J.Piekoszewski**, M.Chmiclcwski, **J.Jagielski**, D.Kaliński, **W.Szymczyk**, **Z.Werner** 5th International Conference ION 2004, Kazimierz Dolny, June 14-17, 2004

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DIDACTIC ACTIVITY

Z.Werner - Supervisor of PhD studies of Mr .R. Narojczyk (Technical University of Radom)

J.Piekoszewski - Supervisor of PhD studies of Mrs. B.Sartowska (IChTJ)

PARTICIPATION SCIENTIFIC COUNCILS AND ORGANIZING COMMITTEES OF CONFERENCES

J.Piekoszewski – Member of International Scientific Committee and Chairman of Tu 13 – Tu 17 sessions on 5th International Conference ION 2004, Kazimierz Dolny, Poland, June 14-17, 2004

J.Jagielski - Chairman of a session I Workshop of Advanced Materials, Doha, Katar, April 2004

PERSONNEL

Research scientists

Jerzy Piekoszewski, Professor	
Zbigniew Werner, Assoc. Prof.	
Jacek Jagielski, Assoc. Prof.,	1/2
Marek Barlak, Dr.	4/5
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10 DEPARTMENT OF ACCELERATOR PHYSICS AND TECHNOLOGY

PL0501222

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Overview

The work of Department P-10 in 2004 included the following subjects:

- development of radiographic 4 MeV electron accelerator,
- physical and technological problems related to the development of accelerating and deflecting types travelling and standing wave RF structures and their subsystems,
- MC simulations applied to radiotherapy; continuation study of photon beams with the use of BEAMnrc Monte Carlo codes,
- minor works concerning the C-30 cyclotron: the modifications of an H⁻ external ion source and actualisation our list for cyclotron upgrading.

The compact 6 MeV electron linac constructed in Department P-10 was mounted on an experimental stand, equipped with necessary auxiliary systems (pulsed high power RF supply, focusing and beam measuring system, cooling and temperature stabilising and safety system) and put into preliminary operation. The output energy and current intensity of the structure were measured and compared with the calculated values. The computational codes written in our Department during realisation of the 6/15 MeV project were used for that purpose, giving satisfactory agreement of calculations with measurements.

The accelerator can be operated in electron or X-ray mode depending on demand. In 2004 all sub-units of the accelerator were operationally tested and intensity optimisation for $e^{-1}X$ -ray conversion was made. As the linac is thought primarily as a tool for radiographic services which may be offered by the Department, a number of X-ray exposures to radiographic films has been made in order to check its usability and the quality of pictures. The MC calculations of photon beams produced on the $e^{-1}X$ converter were made to complete the design of radiographic facility. Apart from radiography, the output beams of electrons and/or X-rays can also be used for studies in dosimetry, radiation effects in electronic components, neutron production in RT low energy linacs and so on.

The TiN coating of accelerator components, in particular of ceramic RF power vacuum windows, is nowadays the common technological procedure in accelerator construction. For that purpose in 2004 the big sublimation setup was designed and partially made in our Department. It will undergo a technological test, including coating quality next year.

The triode gun, originally thought of as part of the6/15 MeV medical accelerator is still on long term tests showing very good performance; a new pulse modulator for that sub-unit was preliminary tested.

The Monte Carlo calculations of narrow photon beams are continued. Our principal researcher continued collaboration with DKFZ Heidelberg, where she participated in the development of scanning a photon beam system for intensity modulated radiation therapy and also in some works related to heavy ion therapy.

Time was also devoted to the C-30 cyclotron. The H⁻ multicusp ion source planned for a future axial injection system to cyclotron underwent some modification. The aim of these modifications was a considerable increase of source cathode life-time.

As a result of contacts with foreign laboratories (CERN, INFN-Frascati, INFN-Milano, and ENEA-Frascati) a series of contracts for delivery of RF accelerating equipment was under negotiation; they are likely to be signed in early 2005.

Eigenen Ptarin

PL0501223

10.1 6 MeV Radiographic Facility in IPJ Świerk

by J.Bigolas, W.Drabik, J.Bogowicz

Introduction

Table 1

The accelerator test stand for 6 MeV electron beam irradiatin and X-ray irradiation is described. The electron beam and X-ray beam from the accelerator may be used for experimental work as well as for nondestructive material testing on laboratory scale. After some modifications the stand may be useful for radiographic inspection on industrial scale.

The design of the accelerator

The radiographic facility consists of an electron accelerator and e-X conversion units placed in a concrete radiation shielded room, equipped additionally with 10 cm lead shields surrounding the conversion head and the exposure compartment.

The construction of the accelerator was preceded by computational optimisation of electron gun and RF accelerating structure. The basic parameters of the accelerator are listed in below:

Electron gun:
Diode, Pierce geometry type, thermionic tungsten cathode,
Energy/Intensity: 30keV/200mA in pulse 4 µsec; variable repetition 50-300 Hz
RF accelerating structure:
11 cell, on axis coupled, $\pi/2$ mode,
Resonant frequency:2997.85 MHz ; Quality factor: 12 500
Nominal output energy: 6 MeV; Output electron current : 100 mA in pulse
Structure length (total): 50 cm ; Working temperature 40 ± 1°C
Beam Focusing :
Solenoid surrounding the accelerating structure
Maximum attainable axial magnetic field 700 Gs.
Magnetic quadrupole dublet on structure output
e/X conversion unit (tungsten target) - radiographic parameters:
Electron beam energy: 6 MeV; Focal spot: 2 mm max.; X-ray dose rate: 500 R/min/m
Flaw detectability: 0.4%

Spectra measurements and calculations

Results of radiographic imaging

In the electron mode the measurements of electron beam spectra were performed using magnetic spectrometer. The experimental data were the basis for Monte Carlo calculations of X-ray spectral distribution, mean energy distribution and fluence versus position.



Fig. 1 Image of electron gun

For taking the radiographic imaging the Kodak Industrex AA 400 film was chosen and experiments with different expositions and filters were performed to obtain the good radiographic contrast.

The radiographic images of two different specimens are presented below:



Fig. 2 Image of vacuum valve



PI 0501224

10.2 Radiographic Facility in IPJ Świerk Computational Simulations of Electron **Accelerating Structure**

by E.Pławski

The accelerator section of the radiographic facility built in P-10 Dpt. of Institute is a short, RF, 11 cell "on axis" coupled structure excited in the $\pi/2$ mode at a frequency of 3GHz. It is equipped with conventional diode type electron gun operated at 30 kV. The solenoidal, iron screened coil surrounding the structure ensures proper focusing of the beam in gunstructure region. An additional magnetic quadrupole arrangement on output of the structure ensures the precise focusing on e⁻/X converter which is essentially thick tungsten target.

The list of essential facility parameters is given elsewhere in this Annual Report. The construction of the accelerator was preceded by thorough computational optimisation of electron gun and successive RF accelerating structure. The computational DC [1] and RF [2] codes, followed by beam dynamics codes developed in our Institute were used to get the optimum shapes of the structures. The RF code (Superfish) simulations gives the power lost in walls 1.2 MW in pulse if the peak field in the cell is 23MV/m (14 MeV/m in actual structure), what corresponds to 6 MeV of electron output nominal energy.

Samples of computational results are presented in Figs 1 to 3.



It is visible from the calculations (see Fig. 1) and from experiments, that good beam focusing calls for fairly high axial magnetic field of solenoid (600 Gs in 10cm inner dia coil of 45cm length with iron screening, surrounding the accelerating structure). The beam focusing is a strong function of the ratio of cell gap g to total cell length L and also of the bunching

efficiency of the first cell of structure. Large number of performed simulations have shown that for single energy machine the correct choice of g/L and correct cell tuning the structure can be operated without a focusing solenoid.



Fig. 2 Electron beam transmission through RF accelerating structure at optimal input phase 95" RF.



Fig. 3 Calculated electron energy spectrum on W target of radiographic 6 MeV accelerator.

The output energy of electron beam was measured using magnetic spectrometer. The results obtained were in good agreement with computational results presented here.

- W.B.Herrmamsfeld ,"E-Gun Code", SLAC-[1] 331/1988 Rep.
- [2] J.H.Billen, L.M.Young, "Poisson- Superfish" Los Alamos LA-ur-96-1834 Rep.



10.3 Monte Carlo Calculation of Parameters for a Photon Beam Used at the Radiographic Facility at IPJ Świerk

by A.Wysocka

The Monte Carlo code BEAMnrc/EGSnrc [1], was used to calculate spectral distribution, mean energy distribution and fluence versus position for a photon beam in the radiographic accelerator.

Calculations were done for 7×10^7 particles, using electron transport cutoff ECUT=0.7 MeV, and photon transport cutoff PCUT=0.01 MeV. For the maximum fractional electron energy loss per step (ESTEPE), a value of 0.25 was used. Relativistic spin effects have been included in nuclear elastic scattering for accurate calculations near high Z interfaces. The electron step algorithm PRESTA-II (an essential requirement for accurate high–Z interface simulations) and the exact boundary crossing algorithm BCA PRESTA-I were implemented.

A "Parallel Circular Beam with 2-D Gaussian X-Y Distribution" was used as the source type of incident electron beam in the BEAMnrc code. The value of FWHM of the Gaussian distribution was set to 2 mm. The energy spectrum of the electron beam was set from 2.345 to 6.125 MeV. A Tungsten target of 6mm diameter and 1 mm thickness was put as the e⁻/X conversion unit.



Fig. 1 Energy spectrum of a photon beam in air for the field area with a radius of 10 cm at a distance of 100 cm from the tungsten target.

The influence of different energy spectra of electrons was investigated.

Phase space files (PHSP) were generated for scoring planes at different distances from the tungsten target. PHSP contains data relating to particle position, direction, charge, etc. for every particle crossing a scoring plane. The BEAMDP program was used for processing phase space files and to derive spectral distribution, means energy distribution and fluence versus position of a photon beam in air.

Figures 1 and 2 show the energy spectrum and the fluence versus position of a photon beam for the field area with a radius of 10 cm at a distance of 100 cm from the tungsten target. Photon fluence is normalized by the energy bin width, number of incident particles and the area of the field being considered. The mean energy of photon beam changed from 1.18 MV to 1.14 MV at a distance of 10 cm from the beam axis.

 I.Kawrakow and D.W.O.Rogers "The EGSnrc Code System: Monte Carlo Simulation of Electron and Photon Transport", "National Research Council of Canada Report PIRS-701, (2001)



Fig. 2 Fluence versus position of a photon beam in air for the field area with a radius of 10 cm at a distance of 100 cm from the tungsten target.

10.4 A Pulse Modulator for Triode Gun Used in Electron Accelerators by K.Kosiński, E.Pławski

A triode pulsed electron gun oriented for use in linac accelerating structure has been under lifedurability tests in P-10 Department since 2001.

PL0501226

The advantages of triode over diode type guns are well known. The most important in medical electron linac is the possibility of dynamic change of beam intensity during exposure. In our triode gun the HWEG 1079 cathode-grid unit bought from HeatWave Co. used.

The guaranteed parameters and technical data of this unit are as follows:

- Cathode type-Dispenser; BaO, CaO, Al₂O₃
- Emission current-up to 1.4A
 - Permitted values of Ugun=100V

Uanod=20kV

 Guaranteed life-time under proper vaccum conditions over 10000 hours

The supply system developed for this gun consists of:

- Pulsed grid voltage control unit (modulator), part of which is placed on cathode voltage terminal and controlled from ground potential through optical waveguide system [1],
- Anode, high voltage regulated DC unit adjustable for optical focusing at each value of emitted cathode current.



Fig. 1 Measuring stand.



Fig. 2 The pulse modulator of triode elektron gun.

Measuring stand is shown in (Fig. 1) and the prototype version of total supply in (Fig. 2).

The gun was opened twice (in 2003 and 2004) to air dry nitrogen to check the efficiency after cathode recovery.

As it is illustrated in Fig. 3 and Fig. 4 there is no change in gun performance after those operations.



Fig. 4 Measuring results-May 2004.

 K.Kosiński "Autonomous Pulse Modulator for Triode Gun used in Electron Linacs" Annual Report 2003



10.5 TiN Coating at DESY and the IPJ in 2004

by J.Lorkiewicz, H.Wojnarowski, J.Bogowicz, A.Łubian, A.Kucharczyk, M.Wojciechowski

Evaporation anti-multipactor TiN coating of RF power components has been reported in detail in [1, 2]. In 2004 two complete coaxial couplers from AMAC Company (Newport News, USA) were TiN coated by evaporation at DESY in the region of ceramic windows. A special sublimation setup has been designed to overcome the problems arising from space restrictions. The average layer thickness reached 6-7 nm. TiN coating of complete components after brazing prevents the surface layer from oxidation during brazing. vacuum chamber sublimation setup vertical litanium filament cut-off valve valv

Fig. 1

A new device for TiN coating has been designed and manufactured at the Soltan Institute for Nuclear Studies in 2004 (see Fig. 1 below). A typical sublimation setup consisting of a set of vertical titanium wires is installed in a 100 l vacuum chamber connected to an oil-free turbo pumping unit. The wires, l mm diameter, are fed with 16A dc current. Two gas feeding lines deliver pure nitrogen for venting the system and 99.95% purity dry ammonia as a reactive atmosphere. Two alumina samples: one in a form of a cylinder and another having a shape of a flat disc have been TiN coated in the new device. The obtained surface layers of 8 nm were uniformly yellow in color and transparent. In order to coat more complex components the sublimation setup can be easily modified.

- J.Lorkiewicz, et al., "Anti-multipactor TiN Coating of RF Components for TESLA at DESY", TESLA Report, DESY 2002-2
- [2] J.Lorkiewicz, J.Kula, S.Pszona, "Anti-Multipactor TiN Coating of Power RF Components Using Evaporation Method" Report SINS 30/X, December 2004

10.6 Works on H⁻ Source for C-30 Cyclotron at Świerk by J.Lorkiewicz and H.Wojnarowski

H⁻ ions are generated in hydrogen plasma in "volume" sources as a result of attachment of thermal electrons (of ca. 1 eV kinetic energy) to highly vibrationally excited hydrogen molecules. The volume of a multicusp H⁻ source is typically divided by a localised magnetic field into two regions: 1) a "driver region" that contains a cathode which generates fast electrons of kinetic energy of the order of 100 eV and "hot" plasma with electron temperature within 3-6 eV; 2) a "target region" filled with plasma diffusing across the magnetic field. Inelastic processes like ionisation and excitation of atoms and molecules take place in the driver region whereas in the target region, filled with plasma of low temperature (typically 1 eV); electron attachment to H₂ is enhanced.

Originally in the miniature multicusp H⁻ source designed and manufactured for the C-30 cyclotron a typical "hairpin" cathode of a single tungsten wire (see Figure 1a) has been used. It was installed in the centre of the driver region which resulted in reduction of the cathode lifetime in hot plasma to ca 50 hours. Two new designed and manufactured cathodes of tungsten and tantalum wires consist of two wire loops each, connected in parallel (Fig. I b), placed in the cusp magnetic field next to the chamber wall. The cusp field comes from an array of 12 permanent magnets surrounding the source chamber. Apart from the expected rise of the cathode lifetime, placing the cathode in the magnetic field of average value of ca. 10 mT should further reduce electron temperature in the target region and enhance H⁻ ions production. The new source configuration has not been tested yet.











PL0501229

10.7 Superconducting (Nb and NbN) and Tungsten Layers Generation at Tor Vergata University/INFN

by J.Langner, A.Cianchi¹⁾, J.Lorkiewicz, R.Russo²⁾, S.Tazzari¹⁾

Although superconducting accelerator cavities are so far mainly manufactured from bulk niobium, interest for Nb/Cu technology has grown since the beginning of the previous decade. Copper cavities with surface niobium films have numerous merits compared to the bulk niobium ones like simple manufacturing, higher heat conductivity or lower material costs.

Niobium surface layers on copper cavities obtained by magnetron sputtering suffer from degradation of quality factor at electric fields exceeding 15 MV/m. An alternative method which makes use of vacuum arc deposition is being developed since the beginning of the present decade at the Soltan Institute for Nuclear Studies and Tor Vergata University/INFN in Rome in collaboration with DESY (Hamburg) [1]. Unlike sputtering techniques, the latter method is characterised by the absence of gases (discharge is initiated in vaporized cathode material), highly ionized states of evaporated material and high energy of ions reaching the substrate surface (typically 50 eV). The latter results in high layer density and fewer defects. The biggest disadvantage of the vacuum arc method is connected with generation of micro droplets which can be deposited on the substrate surface.

Three experimental stands for generation of surface layers using vacuum arc have been manufactured within last years:

- a planar arc stand for deposition of niobium or other materials (Fig. 1),
- a stand equipped with a magnetic filter able to reduce the number of micro-droplets,
- a planar arc structure equipped with a pure nitrogen laminar flow installation aimed at producing superconducting NbN layers.

In the second half of 2004, a series of more than ten test coatings have been performed on planar sapphire plates using the latter system in order to calibrate the NbN deposition rate at different values of arc current, nitrogen pressure and substrate bias. Using sapphire substrate enable RRR measurements of the reached surface layers. Thickness of the layers was contained between 0.2 μ m to 2.7 μ m. Nitrogen pressure in the arc chamber was varied from 10⁻⁴ to 10⁻² mbar. A specially designed copper sample has been coated with niobium in the arc stand with the magnetic filter. The sample will be further tested for its surface resistivity in RF field.

A series of UHV arc studies with a tungsten cathode has been performed including the dependence of metallic ions current to the substrate on arc current, the substrate bias and the strength of the magnetic field in the arc chamber. Tungsten layer depositions have been performed on planar samples of sapphire, tungsten and tantalum. One of the sapphire samples has been preheated to 150°C prior to the deposition. Substrate preheating was aimed at avoiding a columnar growth of the surface layer and improving its structure and properties. The tungsten coating has been ordered by CERN.

The above activities will be continued in 2005 and followed by the studies of chemical, structural, and superconducting properties of the reached surface layers.



Fig. 1

- J.Langner et al., Czechoslovak Journ. of Physics 52 (2002), Suppl. D, p. D289
- Tor Vergata University, Rome/INFN, Italy
 University of Naples, Italy

⁹ University of Naples, Italy

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10.8 A Scanning Photon Beam System for Intensity-modulated Radiation Therapy by A.Wysocka, G.H.Hartmann¹⁾

PL0501230

Intensity-modulated radiation therapy (IMRT) is almost exclusively realised using a multi-leaf collimator (MLC). In this work, we investigated alternative approaches to realise an IMRT- scanning photon beam system [1].

Technical realisation of this concept required investigating the influence of various design parameters on the final small photon beam. This was done using Monte Carlo Simulation methods. The photon beam to be scanned required a diameter of less than 10mm at SSD distance, with a penumbra that was as small as possible.

A first draft for this system, based on the PRIMUS 6MV DKFZ accelerator, was proposed and modelled using the BEAMnrc/EGSnrc Monte Carlo code [2]. In the second part of our calculations a new geometry for the source- target-collimator system was proposed and investigated.

Calculations were done for 10^8 particles, using ECUT = 0.7 MeV, and PCUT = 0.01 MeV. The influence of different collimator parameters, different target construction and various incident electron beam characteristics were then studied. Calculations of the dose absorbed in water were performed for 8 different collimators at a distance of 40 cm from the collimator exit, which is the medical requirement.

Results of the dose distribution calculations are presented as photon beam profiles with the values of FWHM (full width at half maximum) and of PM (penumbra) for each beam profile. The influence of target construction was studied for different thicknesses of target and material minimizing electron contamination. The influence of the following characteristics of the incident electron beam was also investigated: size of electron beam, energy, displacement of the beam from the axis of the targetcollimator system, shape of the electron beam profile. The field dose distribution of the photon beam was calculated for eight types of collimators giving the beam profiles.

In the second stage of these simulations, a "new geometry" was introduced into the system of target, collimator, and chamber. (1) A new distance between target and collimator was introduced, and (2) the ionization chamber was moved behind the collimator.

(1) The collimator was put at a distance of 0.5 cm from the target. This ensured that more photons from the target would enter the collimator than would be the case for a distance of 5.6 cm.

(2) Placing the ionization chamber behind the collimator at a distance of 0.5 cm made it possible both to measure the photon beam dose behind the

collimator and to control the correlation between the scanning of electron beam and the scanning of collimator.

In this "new geometry", the water phantom was added in at a distance of 40 cm from the collimator. The water-absorbed dose was calculated in the voxels of this phantom at a depth of between 1 and 1.5 cm.

In the second part of these simulations, the DOSXYZ nrc code was used for calculating dose distribution. This code is an EGSnrc-based Monte Carlo simulation code for calculating dose distributions in a rectilinear voxel phantom.

A "Parallel Circular Beam with 2-D Gaussian X-Y Distribution" was used as the source type of incident electron beam in the BEAMnrc code. The value of FWHM of the Gaussian distribution was set to 1 mm. The energy of electron beam was set to 6 MeV.

Three types of collimators were simulated with BEAMnrc code in this part of the project. The phase space files that were generated for these collimators in BEAMnrc, were used as source input data for the DOSXYZ code. Parameters of these collimators as well as results for FWHM and PM of the obtained photon beam are given in tables and in figures in the paper being prepared.

A program allowed to determine the required intensity of each single beam in the case, when single beams are moved in a raster-scan motion across a given field size to arrive at a desired dose distribution. The intensity weights were optimized in such a way that the obtained superimposed dose distribution matches a given input distribution of intensity.

The single photon beam profile was expressed as a 15x15 matrix, each element representing the dose at isocenter distance in a 1mm x 1mm pixel element. The raster scanning was performed in a quadratic point raster with 1 mm spacing.

Basing on the work performed in this investigation, it will be possible to define adequate parameters for the target-collimator system as well as on the scanning electron beam for new IMRT system.

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- ¹⁾ Medizinische Physik, Heidelberg, Germany



10.9 Photon Beam Transport Through a Solid Phantom for an X-ray Computed Tomography Scanner (CT): A Preliminary Monte Carlo Study

by A.Wysocka, S.Qamhiyeh¹⁾, O.Jakel¹⁾

Radiotherapy with heavy ion beams enables high spatial accuracy of the delivered dose, as ions deposit most of their energy in a narrow region near the end of their range (Bragg peak). However, the transport of ions in tissue, and therefore their range, depends on tissue composition, which can only be measured with reasonable spatial resolution using X-ray computed tomography (CT).

To calculate ion ranges from CT data, an empirical relation between measured Hounsfield Units (HU) and ranges is used. The overall inaccuracy of treatment beam delivery is estimated to be 3mm in depth for tumors in the head and neck area [1]. CT-HU measurements with a standard deviation reaching up to 5% of the HU value in bone-like materials are the main source of this inaccuracy [2].

In heavy ion treatment planning an empirical scanner-dependent calibration relation between HU and ion range is used [1]. Any deviation in the HU values causes a drift in the calibration curve of the CT scanner.

This project is part of a larger study of the effects of different measurement parameters, reconstruction algorithms and image artifacts on both HUmeasurements and the HU-to-range relation currently used for heavy ion therapy at GSI. To accomplish this, the interactions of X-rays (attenuation and scattering) in the solid-state phantoms that are used for the calibration, are simulated numerically by a Monte-Carlo method. Since the phantom geometry is radial symmetric, the first step is to build line-projections of the phantom, as measured by the CT detectors. Then the expected HU will be calculated using different reconstruction filters and measurement parameters. Finally, the calculated HU will be compared with values measured for phantoms and real tissues.

The objective of this work was to calculate and analyze the characteristics of photon beam transport of an X-ray computed tomography scanner (CT), along its path from the X-ray tube, through beam filters and collimators and through the phantom up to the signal production in the CT detectors. To characterize the beam, the energy spectrum and energy fluence distribution were used.

The calibration phantom is a solid state phantom with different inserts that are made of tissue equivalent material, which are used for measurement and simulations.

In this work, the MC code BEAMnrc/EGSnrc was used to build the model of a CT unit and a phantom with different inserts. Calculated photon fluence spectra for different phantom inserts were then generated.

These calculations were done for 10^8 particles, using ECUT=0.521 MeV and PCUT=0.001 MeV. An ECUT=0.516 MeV was used to ensure more accurate electron transport, ECUT=0.561 MeV for saving the calculation time in individual regions of system.

A new PEGS4 file had to be created, which included every material used in the present simulations.

MC simulations were performed using the following options:

- bound Compton scattering
- Rayleigh scattering
- atomic relaxation
- relativistic spin effects
- fractional electron energy loss per step (ESTEPE)= 0.25
- electron step algorithm PRESTA II
- exact boundary crossing algorithm (BCA)

The system of CT unit and phantom was divided into 3 parts: CT1, CT2, and CT3, each of which terminated in a so-called scoring plane. Phase space files were calculated for each scoring plane. Each file contained data relating to particle position, direction, charge, etc. for every particle crossing a scoring plane. The phase space file (PHSP1) obtained in CT1 was then used as the source file for the second part CT2. From the PHSP2 obtained in the CT2, new data were derived. Spectral distribution for different inserts of the phantom (lung, cortical bone, muscle, CB2 30%, IB) was then calculated.

The BEAMDP program was used for processing phase space files and to derive spectral distributions, energy fluence distributions and energy fluence as a function of the position of the photon beam.

Initial results and observations from the calculations were of some interest. The most significant preliminary finding were the values of spectra shifted to higher energies (beam hardening) for higher electron densities of the insert material. Work on this project will continue in the next year.

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¹⁾ Medizinische Physik, Heidelberg, Germany

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10.10 Preliminary Design of Power Couplers for SPARC Compressor Section

by E.Pławski, S.Kuliński, M.Wojciechowski, A.Kucharczyk, C.De Martinis¹⁾, D.Giove¹⁾, M.Mauri¹⁾

Coherent, soft X-ray sources based on the FEL-SASE mechanism, are of increasing interest for many fields of applications, from basic science to industrial and medical applications. FEL's based on SASE (Self Amplified Spontaneous Emission) effect are able to generate coherent radiation with unique features. In principle the brilliance of the source is several order of magnitudes higher than the Synchrotron Radiation Sources of third generation, and it is possible to reach the x-ray spectrum region with ultra-short pulses of hundreds femto-seconds.

The Italian accelerator dedicated to the FEL-SASE source (SPARX Project) has the task of accelerating ultra-brilliant electron bunches up to an energy of 2.5GeV.As the preliminary step a dedicated R&D program (SPARC Project) is under realisation in INFN laboratories Frascati and Milano. Its aim is the generation of electron beams with ultra-high peak brightness and the generation of resonant higher harmonics in the SASE-FEL process. The proposed scheme consists of 6 MeV RF gun operated at S-band (2.856GHz) followed by 3 accelerating sections of the SLAC type (S-band, travelling wave). These 3 sections increase the energy to 150 MeV. Two of these sections are of special design; they accelerate beam, effectuating simultaneously bunch compression without deteriorating its normalized 6D phase space volume. An unusual feature of these compressors is very high, temperature regulated, group velocity which demands very high input RF power to produce necessary accelerating field, but allows for acceleration of very high bunch currents without field distortions. Part of design works on compressors is realized in P-10 Dpt. on basis of cooperation with INFN Milano.

Compressor parameters

Frequency - 2856 MHz; Type - forward TW; Mode - $2\pi/3$; v_g/c - 0.034; ExT average - 20MV/m; β input - 0.9969.



Fig. 1 Calculated dispersion diagram of compressor.

The compressor structure dimensions for the desired group velocity were found from SUPERFISH simulations. The resulting dispersion curve is shown in Fig. 1. Tuning sensitivity, machining accuracy, numbers of dimpling points were also calculated from SF simulations. Machining accuracy 0.01 mm produce frequency error $\Delta f=\pm 190$ kHz. At Q=12000 $\Delta f=\pm 110$ kHz at 3 dB power points. Dimpling should cure at least 80 kHz $\rightarrow 25$ mm³.

The numerical computations concerning non symmetrical parts of compressor were executed using 3D codes. The simulations were performed using 3D CST MWS (www.cst.com) code with the following criteria of quality:

- minimization of SI1,

- proper phase advance per cell at working mode,

- proper E-field pattern on n cell structure.

The free parameters were: a) taper in the feeder waveguide (cannot be avoided in chosen solution dictated by the design of complete compressor structure), b) coupling cell diameter, c) width of coupling aperture.

The final values of these 3 parameters were found as a compromise of the above criteria. The technical and technological documentation of 4-cell coupler assembly for RF high power tests is in the course preparation (Fig. 2).



Fig. 2 Mechanical layout of experimental coupler assembly.

This assembly will be produced by P-10 the low RF power and vacuum will be tested in 2005 in Świerk. Power vacuum windows equipped with RF power input/output will undergo high power tests (20MW peak) in Frascati. If these tests are successful the whole compressor structure of 50 cells will be produced.

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10.11 A New RF System for the CEBAF Normal Conducting Cavities by T.Pławski, C.Hovater¹⁾, H.Dong¹⁾, A.Hofler¹⁾, G.Lahti¹⁾, J.Musson¹⁾

Abstract

The CEBAF Accelerator at Jefferson Lab is a 6 GeV five pass electron accelerator consisting of two superconducting linacs joined by independent magnetic transport arcs. CEBAF also has numerous normal conducting 499 MHz cavities for beam conditioning in the injector and for RF extraction to the experimental halls. For these cavities, a new, digital RF system is under development, using an FPGA containing the feedback algorithm. The system is based on digital down-conversion, quadrature under-sampling of 70 MHz IF frequency with 56 MHz clock. Long studies demonstrated effectiveness of this method. The VXI bus/crates were chosen as the operating platform.

RF System

The new RF system will control the chopper and separator, (both beam deflecting) cavities. The field control requirement is relatively undemanding at 1% and 1 ps phase accuracy. In the case of the chopping cavities, the field is rarely changed in contrast to the separator where amplitude is adjusted according to the deflection needed for different beam energies. Figure 1 shows a block diagram of the low level RF control system (LLRF). This type of architecture has become a common model for single cavity control system equipped with a number of RF inputs and outputs, utilizing a modern field programmable gate array (FPGA). VXI platform was chosen because of good RFI/EM1 properties and EPICS (software) control system compatibility. In RF front/end system 499 MHz cavity frequency is converted down to IF=70 MHz. This assures compatibility with existing CEBAF LLRF system. The IF signal is quadrature demodulated using harmonic under-sampling 56 MHz, processing in the FPGA, digitally recombined, filtered and up-converted to the cavity frequency. The feedback loop is equipped with PI algorithm and the entire system operates as a digital generator driven resonator (GDR). To assure system stability over 360 deg phase range, rotation matrix for I and Q vector is implemented.



Fig. 1 RF system block diagram.

RF Receiver/transmitter

RF front/end had to fulfill number of strict requirements concerning linearity, dynamic range, temperature drift, noise, group delay. Thus, high IP3 and high dynamic range FET mixer WJ HMJ5 was chosen. To minimize temperature related drifts a product called Thermopads is being considered (attenuator with selectable tempcos). 70MHz commercial bandpass filter, was selected for its low~80 ns group delay. Isolation channel is also a concern; we specified this to be at least 60 dB for the cavity transmitted power and 50 dB for all other channels. The receiver has been modeled and tested in a variety of ways e.g. with System View (commercial software for RF design).

VXI Motherboard

The VXI motherboard contains the electronics necessary to process digital signals, interface to VXI bus and 10/100 Ethernet. The board features one Altera Startix FPGA, 64x16 DPRAM, 1Mx32 RAM, 1Mx32 FLASH, 56 MHZ PLL based clock generator, 6 x 16 -bits/ 500 Ksamp. DACs, 10/100 Ethernet, digital I/O, Infrared I/O. We chose Altera Stratix FPGA with 18000-25000 logic elements (basic blocks), electronics building 80 - 8bit multiplier/accumulator, supporting both hard coding and a soft microprocessor core (NIOS). Various operating systems including Linux can be loaded and with Ethernet support, the board can communicate with EPICS directly. Care was taken in the design of the 56 MHz clock /PLL The characterization of phase noise (timing jitter) of clocking sources has become crucial due to their direct impact on the performance of the data conversion devices (ADC and DAC). Special phase noise measurement with Vector Signal Analyzer was developed and tested [2].

Model & system control

System control was modeled and tested for a variety of cavity scenarios e.g. separator cavity with $Q_L=2500$ or chopper cavity with $Q_L=10^4$. This ultimately affects the loop bandwidth and hence the gain parameters of the LLRF system. We used Matlab and Simulink to model the step response of RF system. The model of warm cavity contains a controller, a cavity and cable/digital delay. The cavity is modeled by its fundamental mode using the resonant cavity equivalent circuits equations.

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PARTICIPATION IN CONFERENCES AND WORKSHOPS

VERIFICATION OF MEASURED CT NUMBERS FOR HEAVY ION THERAPY S.Qamhiych, O.Jäkel, **A.Wysocka** (poster) 40th Particle Therapy Cooperative Group Conference, Paris, France, 16-18 June 2004

COMMUNICATIONS PUBLISHED IN CONFERENCE MATERIALS

VERIFICATION OF MEASURED CT NUMBERS FOR HEAVY ION THERAPY S.Qamhiych, O.Jäkcl, A.Wysocka (postcr) Proc. 40th Particle Therapy Cooperative Group Conference, Paris, France, 16-18 June 2004

LECTURES, COURSES AND EXTERNAL SEMINARS

Monte Carlo Simulation of Photon Beam Transport Through a Solid Phantom for an X-ray Computed Tomography Seanner (CT)^{b)} A.Wysocka, Deutsches Krebsforschungszentrum (DKFZ), Heidelberg, Germany, 5 Oct. 2004

Accelerator Physics Activities at A. Soltan Institute in Świerk^{b)} E.Pławski, Laboratorio Acceleratori e Supercoductivita Applicata, LASA/INFN Milano, Italy, 25 Nov. 2004

Preliminary Design of Power Couplers for SPARC Compressor Section^{b)} E.Pławski, Laboratorio Acceleratori e Supercoductivita Applicata, LASA/INFN Milano, Italy 26 Nov.2004

Radiographic Facility in INS Świerk,^{a)}

J.Bigolas, W.Drabik, E.Plawski, A.Wysocka, XIII Scientific and Technical Conference Technologies for Tubes Production in Non-Ferrous Metals Industry, Cracow, Poland, 25 Nov. 2004/

a) in Polish

b) in English

PERSONNEL

Research scientists Eugeniusz Pławski, Dr. Anna Wysocka, Dr.

Technical and administrative staff

Jerzy Bigolas	4/5
Krzysztof Bigolas	
Józef Bogowicz	
Wojciech Drabik	3/5
Konrad Kosiński	

Jerzy Lorkiewicz (on leave) Andrzej Łubian Marek Śliwa Marcin Wojciechowski

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11 DEPARTMENT OF TRAINING AND CONSULTING

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Overview

The Department of Training and Consulting is regularly serving secondary school pupils and teachers, university students and the public. As usual we have been visited by more than 5000 visitors, mainly students from secondary schools.

Since January 2003, the Department participated in a European program called NUPEX (from Nuclear Physics Experience) that aimed at creating an internet platform of educational material from nuclear physics and its applications. The platform was finally prepared in eight languages (English, French, German, Italian, Flemish, Greek, Hungarian and Polish) and is dedicated to pupils from secondary schools and to science teachers. The whole material can be found at <u>http://www.nupex.org</u>. The Polish part is displayed additionally at <u>http://ipi.gov.pl/pl/szkolenia/nupex</u>. It is worth mentioning that the Polish group played an important role in the whole project. Seven modules were fully prepared by us; we also were active in helping the other Project's participants to understand technicalities connected with preparation of the material for internet.

New educational posters have been designed by the Department. The titles of these posters are: *Energy and its transformations; typical electric power plants; Nuclear Power Plants; Nuclear Power Plants in Europe and in the World.* The posters are offered to visiting schools.

The number of possible experiments at our Laboratory of Atomic Physics is still increasing. Recently a computer simulation of the process of start-up of the nuclear reactor was prepared. Although it can be considered as a game, in fact the animation reflects the reality of the process and can be used for training of nuclear reactor's operators.

For the first time one, of the leading secondary schools in Warsaw, the Stefan Batory School, participated in a Summer School of Physics organized at our Department, which lasted 10 days. Most of the educational program was filled with the basics of nuclear physics with emphasis on experimentation. This event was also extraordinary because there were about 25 pupils who decided to use 10 days of their vacations to learn modern physics. Another non-typical event was a course on radiation and radioactivity organized by us for geography teachers.

The year 2004 was also productive for research: we published 8 papers and one chapter in a monograph concerned with X-Ray Compton Scattering (Oxford University Press).

Jobnyniski'

PL0501235

11.1 Electronic Structure and Magnetism of Fe_{3-x} (Cr,Mn)_x(Si,Al) Alloys by A.Go¹⁾, M.Pugaczowa-Michalska²⁾, L.Dobrzyński

Electronic and magnetic properties of the transition metal alloys based on Fe₃Si and Fe₃Al are investigated by polarised TB-LMTO and KKR-CPA methods. The main goal of the studies is to understand how magnetic moments are formed, what kind of magnetic structure appears when transition metal is substituted for iron, and, last but not least, which of the two symmetry inequivalent sites is preferred by the transition metal atom. An influence of the local environment on the distribution of hyperfine magnetic fields is another problem of our interest. All the

11.2 Hyperfine Fields in Fe₄₈Al₅₂

by K.Szymański¹⁾, D.Satuła¹⁾, L.Dobrzyński, E.Yelsukov²⁾, E.Voronina²⁾

Fe₄₈Al₅₂ alloy presents interesting material in which magnetic moment values and configurations are largely debated. In particular, systematic Mossbauer studies show that the system exhibits complicated distribution of hyperfine magnetic field as well as distribution of orientations of these fields. The effect of nearest surrounding is crucial for understanding magnetic phenomena. Happilly, the EXAFS measurements showed unambiguously what is the configuration of the nearest neighbour shell of iron. This greatly facilitates interpretation of the spectra.

11.3 Mössbauer Investigations of UFe₅Sn

by D.Satuła¹⁾, K.Szymański¹⁾, L.Dobrzyński and V.H.Tran²⁾

The UFe₅Sn intermetallic alloy was investigated by means of Mössbauer spectroscopy in the temperature range of 13 K – RT. The measurements have been carried out with the use of unpolarized as well as a circularly polarized beam. It was revealed that the average hyperfine field is gradually increasing with decreasing temperature. The analysis resulted in obtaining a set of hyperfine parameters for various local environments of iron present in the system. In addition to the classical spectra analysis, the Maximum Entropy Method was used. We used socalled ignorant prior and next a distribution which was obtained from the best fit of the hyperfine field nearest neighbours' atomic configurations corresponding to the observed sextets contributing to the Mössbauer spectra are analysed.

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Nevertheless, in order to gain good insight into the problem one has to perform the measurements not only at various temperatures but also in various magnetic fields and polarization states of the beam.

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parameters to the spectra obtained. This analysis showed that the distribution of h.m.f. is much more complicated. In particular one deals with a relatively wide distribution of the quadrupole splitting and isomer shifts, which suggests the presence of a variety of defects in the structure.

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11.4 Toward Nuclear Polarimetry with Circularly Polarized SR

by K.Szymański¹⁾, D.Satuła¹⁾, L.Dobrzyński, J.Waliszewski¹⁾, B.Kalska-Szostko²⁾ and W.Olszewski¹⁾

Circularly polarized radiation can be used for detection of the sign of local magnetization. Nuclear resonance scattering additionally offers element selective determination of the orientation of the hyperfine magnetic field. In order to transform linear to circular polarization, one can use the Bragg scattering from a quarter plate [1, 2]. The first experiments with nuclear resonant scattering of circularly polarized radiation obtained with diamond quarter plate were described in [3].

The experiments were performed at the BW4 station of DORIS ring at Hasylab with silicon quarter plates. The Si plate was inserted at angle corresponding to Si(400) Bragg peak. Symmetrical Bragg geometry in transmission mode was used. The desired phase shift of the quarter plate was realized by selecting the Bragg angular position of the plate. Time spectra were measured with two perpendicular inplane directions of magnetization. All measurements were done at room temperature. Well-known hyperfine structure of the ⁵⁷Fe nucleus was used as a probe of the beam polarization. The foil surface was oriented perpendicular to the photon k vector. In case of linearly polarized radiation, the time spectrum depends on the in-plane direction of the foil magnetization. On the contrary, scattering of the circularly polarized photons should not depend on the in- plane magnetisation. Experimental details were published in [4, 5] and presented during the Workshop on Synchrotron Radiation for the study of Magnetic Nanosystems Leuven, 18-19 November, 2004 [6].

Results of the measurements clearly indicate, that Si plate changes polarization state of beam. However, the condition that time spectra do not depend on the in-plane direction of magnetization was not found and the spectra are different from the simulated ones, predicted for circularly polarized beam. This happens because of too large horizontal beam divergence.

Simulations based on dynamical theory shows that asymmetrical Bragg geometry results in larger angular

acceptance of the plate. Recently scattering experiments with to Si(2 2 0) Bragg peak in asymmetrical Bragg geometry were performed and are subject of evaluation.

The experiments were performed as scientific projects AB (II-03-003) and (I-01-042) under IHP-Contract HPRI-CT-1999-00040/2001-00140.

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11.5 Mössbauer Studies of Fe-Ni Alloys with Compositions Range Characteristic for the Invar Behavior

by D.Satuła¹⁾, K.Szymański¹⁾ and L.Dobrzyński

Mossbauer studies have been carried out for FelxNix alloys (x = 0.30, 0.32, 0.34, 0.36, 0.38, 0.40). The experiments have been carried out using both unpolarized as well as circularly polarized beams. In the composition range of interest a structural phase transition BCC FCC takes place. This transition has an essential impact on the magnetic properties of iron atoms and leads to so-called Invar effects. The measured spectra exhibit a distribution of the hyperfine magnetic field characterised by the presence of two maxima: a narrow one in the vicinity of 30 T, and the broad distribution around B = 12 T. The analysis of spectra measured with circularly polarized beam has shown that the magnetic moments contributing to the two aforementioned maxima have the same angular distributions of iron magnetic moments.

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J. Magnetism and Magn. Mat. 272-276 (2004) 217

PARTICIPATION IN CONFERENCES AND WORKSHOPS

L.Dobrzyński, participation in UNSCEAR meeting, Vienna, Austria, May 2004

L.Dobrzyński, participation in NUPEX' meetings in Malta, May 2004 and Kazimierz, Poland, October 2004

Invited talks:

BAYESIAN LOGIC OF SCIENCE L.Dobrzyński XVI International School on Physics and Chemistry of Condensed Matter, Białowieża, Poland, July 1-10, 2004

BAYESIAN ANALYSIS OF THE SPECTROSCOPIC DATA L.Dobrzyński XVI International School on Physics and Chemistry of Condensed Matter, Bialowieża, Poland, July 1-10, 2004

BAYESIAN ANALYSIS OF EXPERIMENTAL DATA L.Dobrzyński All-Poland Seminar on Mössbauer Spectroscopy, Wisła, Poland, June 6-9, 2004

Oral presentations:

MÖSSBAUER STUDIES OF SINGLE CRYSTAL γ-Mn-Fe K.Szymański, W.Olszcwski, **L.Dobrzyński**, D.Satuła and J.Jankowska-Kisiclińska All-Poland Seminar on Mössbauer Spectroscopy, Wisła, Poland, June 6-9, 2004

Posters:

ELECTRONIC STRUCTURE AND THE SITE PREFERENCE OF CHROMIUM IN FE3AL ALLOY BY THE TB-LMTO-ASA METHOD A.Go, M.Pugaczowa-Michalska, **L.Dobrzyński**

General Conference of the Condensed Matter Division, EPS, Prague, Czech Rep., July 19-23, 2004

HYPERFINE FIELDS IN NANOCRYSTALLINE Fc0.48Al0.52

K.Szymański, D.Satuła and L.Dobrzyński, E.Voronina and E.P.Yclsukov XIII Int. Conf. on Hyperfine Interactions and XVII Int. Symp. on Nuclear Quadrupole Interaction, Bonn, Germany, 23-27 August 2004

QUARTER WAVE PLATES FOR NR SCATTERING OF CIRCULARLY POLARIZED SR K.Szymański, D.Satuła1, L.Dobrzyński, J.Waliszcwski, B.Kalska-Szostko and W.Olszcwski Workshop on Synchrotron Radiation for the study of Magnetic Nanosystems, Leuven, Belgium, 18-19 November, 2004

A STUDY OF ELECTRON MOMENTUM DENSITY IN Ni0.75C00.25 AND Ni0.75CU0.25 DISORDERED ALLOYS BY HIGH RESOLUTION COMPTON SPECTROMETRY

A.Andrejczuk, L.Dobrzyński, C.Bellin, J.Kwiatkowska, F.Maniawski, E.Żukowski, S.Kaprzyk, A.Shukla Int. School and Symposium on Synchrotron Radiation in Natural Science (ISSRNS'2004), Zakopane, Poland, 8-13 June, 2004

ELECTRON MOMENTUM DENSITY OF HEXGONAL CADMIUM STUDIED BY COMPTON SCATTERING H.Reniewicz, A.Andrejczuk, M.Brancewicz, E.Żukowski, **L.Dobrzyński** and S.Kaprzyk XVI Int. School on Physics and Chemistry of Condensed Matter, "Structural Aspects of Solids", Białowieża, Poland, July 1-10, 2004; Conference of Chemists, Białystok, Poland, February, 2004

COMMUNICATIONS PUBLISHED IN CONFERENCES MATERIAL

RAISING PUBLIC AWARENESS OF NUCLEAR SCIENCE IN ACTION L.Dobrzynski Proceedings of Int. Conf. on Nuclear Knowledge Management: Strategies, Information Management and Human Resource

Development, IAEA (2004); <u>http://www.iaea.org/km/cnkm/index.html</u>

LECTURES, COURSES AND EXTERNAL SEMINARS

Neutron optics as a checking tool for quantum mechanics' predictions^{a)} L.Dobrzyński, Institute of Nuclear Energy, 8.01.2004

Maximum entropy method in physics and technology^{a)} L.Dobrzyński, Maria Słodowska-Curie University, Lublin, 11.03.2004

Public awareness of nuclear science^{a)} L.Dobrzyński, Polish Physical Society, Lublin, 11.03.2004

Logic in the circle of bayes theorem^{*)} L.Dobrzyński, Institute of Experimental Physics, Białystok, 16.03.2004

Elements of the maximum enropy method in physics and technology^a) L.Dobrzyński, *Institute of Theoretical Physics, University of Warsaw, 19.03.2004*

On public awareness of nuclear science^{a)} L.Dobrzyński, Institute of Experimental Physics, Białystok, 26.10.2004

Bayesian analysis of the spectroscopic data^{a)} L.Dobrzyński, Institute of Physics, Polish Academy of Sciences, Warsaw, 3.11.2004

Bayesian analysis of the spectroscopic data^a) L.Dobrzyński, Faculty of Physics and Applied Informatics, Academy of Mining and Metallurgy, Cracow, 8.12.2004

Introduction to physics of magnetics^{a)} L.Dobrzyński, 60 hours course at the University of Białystok (October 2004 – January 2005)

Physical principles of nuclear medicin^{a)} L.Dobrzyński, 30 hours course at the University of Białystok (February 2004 – June 2004)

a) in Polish

PARTICIPATION IN PROGRAM AND ORGANIZING COMMITTEES OF CONFERENCES CHAIRMENSHIP

L.Dobrzyński - chair of the Organizing Committee of the 16th International Summer School on Physics and Chemistry of Condensed Matter, "Structural Aspects of Solids", Białowicza, Poland, July 1-10, 2004

DIDACTIC ACTIVITY

L.Dobrzyński delivers regularly academic courses and seminars of solid state physics at the University of Białystok. He serves also as an adviser of the Polish Delegate to United Nation Scientific Committee of the Effects of Atomic Radiation (UNSCEAR), and in Editorial Board of Physica Scripta. Currently he is supervising two Ph.D. Thesis.

W.Trojanowski is conducting seminars and takes active part in education of radiographers in the Medical Academy in Warsaw.

L.Dobrzyński is a member of the international group Public Awareness of Nuclear Science (activity ended in 2003) and Polish Physical Society.

E.Droste is member of the Polish Physical Society.

All staff is involved in popularization of nuclear physics and its applications (see Overview).

PERSONNEL

Research scientists	
Ludwik Dobrzyński, Professor,	Director of the Department
Ewa Droste, MSc.,	3/4
Wojciech Trojanowski, MSc.	(since October, 3/5)

Technical and administrative staff

Tadeusz Ostrowski2/5Teresa Piotrowska

12 ESTABLISHMENT FOR NUCLEAR EQUIPMENT

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Overview

The research and production performed in the Establishment for Nuclear Equipment (ZdAJ IPJ) is focused mainly on two branches: medical and industrial.

Nowadays, in the face of Polish participation in the EU, the most important challenge on the market is the CE sign for all products produced in ZdAJ IPJ. Therefore in 2004 quite a big effort has been put on measurements, tests and necessary documents required by official authorities. This activity benefits the satisfactory – therapeutic table POLKAM 16 and a medical accelerator Co-LINE. They are prepared in agreement with all requirements and the audit procedure is being started.

Progress in the new medical 15 MeV accelerator project can be observed. The difficult conversion from model to final medical machine is being done within a friendly and helpful cooperation with Polish radiologists and the Medical Physicist's Society.

One of the strongest points of this machine is its modern and sophisticated additional equipment, for example the Portal Imaging system based on an amorphous silicon matrix. One such unit was successfully tested by the 9 MeV Neptun PC machine.

Similar visualization systems were tested to operate with industrial accelerators for radiography purposes. The resolution achieved is better than 1-2T in the range of 5 - 30 cm of steel.

Our mission citation:

"The Establishment for Nuclear Equipment takes on developmental works, designing, production, installation and service of devices able to elaborate on ionization radiation as well as all concurrent accessories, intended to uses in medicine (diagnostics and therapy), industry and other fields."

12.1 The Investigation of Functional Performance Characteristic of the Therapeutic Table Polkam 16

by A.Zając, A.Baczewski, K.Gryn, R.Kisiel, J.Kopeć, L.Kotulski, A.Kuciak, Z.Kuciak, A.Polak, R.Szymański

The therapeutic table Polkam 16 is used for a precise positioning of patient in radiation field during radiotherapy session. The table can be used with different radiation sources like: accelerators, cobalt units or simulators. The basic movements of the therapeutic table are: isocentric rotation of the table base (the axis of table and accelerator are the same); vertical, longitudinal and horizontal movements.

PL0501241

The modular concept was applied during the table design. It permits us to integrate the table with the control system of different types of radiotherapy devices. So, the steering of table movements and positions is possible by control system of radiotherapy devices. Such solutions permit a precise control of patient position before treatment. The table position is displayed on computer screen.

The aim of the functional table investigation is to confirm if the table fulfils design parameters. The scope of investigation covered:

- Checks of the range of displacements and the functioning of edge switches as well as of mechanical bumpers,
- Checks of the maximum movement speed,

- Checks of the functionality of "O" and "H" type inserts in table top,
- Checks of the force of the brakes,
- Checks of the longitudinal and horizontal rigidity,
- Checks of the table geometry.

By proper design the longitudinal and horizontal rigidity was significantly improved in comparison with Polkam 15, see Figure 1.



Polkam 15 🗖 Polkam 16

Fig. 1 Comparison of longitudinal and horizontal rigidity of Polkam 15 and 16 therapeutic tables.

Parameters	Polkam 15	Polkam 16	Varian	Siemens
Vertical movement range [cm]	68÷135	60÷150	64÷169	65÷175
Horizontal movement range [cm]	±20	±25	±25	±25
Longitudinal movement range [cm]	80	100	108	90
Isocentric table rotation [°]	±120	±120	±100	±120
Table top rotation [°]	Yes	No	No	Yes
Horizontal movement speed [cm/s]	1,33	3	2	0,8 and 3
Table top movement speed [cm/s]	2,33	5	4	0,8 and 2,5
Table angle speed rotation [°/s]	6	7	Option	0,7 and 3,2

Table 1

The data from Table 1 show that technical parameters of Polkam 16 table are superior to parameters of Polkam 15 and to those of competitory tables. The therapeutic table was designed and manufactured according to European Union Directive 93/42/ECC and fulfills the requirements of actual technical and quality standards.

12.2 Implementation of PLC Driver for Steering the Therapeutic Table Polkam 16 by A.Baczewski

The programmable driver PLC (Programmable Logic Controller) is a modular industrial computer designed to control objects with a number of twostage inputs and outputs as well as analog inputs and output. The code recorded in memory of programmable driver checks periodically the signals at all the entries of the PLC from supervised industrial object or device and generates proper output signals. Programmable drivers are used in automatic industrial systems, manufacturing process, technological lines,


intelligent buildings etc. The main tasks for the PLC in therapeutic table Polkam 16 are: the realization of suitable algorithm of steering of the executive components in the table, read-out and recalculation of voltage levels from measuring potentiometers and sending data via RS 232.

The main requirements for the selection of PLC for therapeutic table Polkam 16 are:

- the possibility of connecting to PLC a defined number of input signals as well as - after their analysis by controller – generation of a number of output signals,
- small external dimensions,
- low price.

Many offers from manufacturers of drivers on the market have been analyzed, among them: SIEMENS, IDEC (representative - COMPART), TOSHIBA (representative - KONTECH), GE FANUC (representative - ASTOR), Allen - Bradley (representative - INTROL), ABB, MITSUBISHI (representative - MPL) and SAIA BURGESS (representative - SABUR).

All requirements for PLC are fulfilled in the case of the MicroSmart series from IDEC Izumi (Japan) company. The MicroSmart driver is an innovatory conception for controlling small and medium systems. Its main advantage is very simple configuration of the system with the functions directly fitted to object requirements due to the modular constructions and wide offer of optional functions. Programming of the MicroSmart driver can be done on PC-computer with WindLDR program. This code can be sent afterwards from PC to PLC through serial port RS 232. The external dimensions of the driver are 14 x 9 x 7cm. Internal composition of MicroSmart PLC includes: the basic module: FC4A-D20RS1 (12 two-stage inputs, 6 relay outputs, 2 transistor outputs) and additional modules: FC4A-N08B1 - 8 two-stage inputs module, FC4A-T08S1 - 8 transistor outputs PNP module and FC4A-J2A1 - two analog module with two inputs.

In the selected PLC driver digital inputs and outputs are separated from internal circuits of the driver by the optoisolators. LED's on front panel of the driver realizes the signalization of logical in-out states.



Fig. 1 The view of driver MicroSmart installed in table therapeutic Polkam 16.

The presented concept of steering for the therapeutic table Polkam 16 based on programmable driver PLC has been realized in practice, Fig. 1. It was found that it is possible to control the table movement and the reading of table position in full range of movement. The applied solution permits an easy modification of the master program, and makes permanent improving of the therapeutic table parameters possible.

PL0501243

12.3 Simulations of the 4MeV Co-line Accelerator by T.Benamara¹, G.Couderc¹, E.Jakubowska, S.Wronka



Fig. 1 The influence of the shaping electrode geometry on the electrons' trajectories.

The modern scientific software together with fast computers give us new perspectives and possibilities to provide quite complicated calculations in a reasonably short time. A verification of the accelerating structure as well as the electron gun of the 4 MeV Co-line machines produced by ZdAJ has been

performed to check if some improvements are possible. The main goal of this work was to increase the dose rate by optimizing electron trajectories, thus minimizing losses of electrons in the cavities walls. In this project SUPERFISH [1] and GPT [2] software were used.

By changing the geometry of the diode electron gun it was found that the distance between the cathode and the shaping electrode should be minimized to achieve better emitance. After the whole construction process the new electron gun has been manufactured in special technique to fulfill this requirement and is actually under testing in ZdAJ to confirm theoretical results.

Simulations of the composition of cavities in the accelerating structure showed that by increasing the length of the first cavity one can transmit more electrons through the structure with the same phase acceptance (Fig. 2) due to a better geometrical acceptance. This advantage should be visible in higher dose rate with the same h.f. power delivered.

New accelerating structure with the length of first cavity increased by 5.25mm has been manufactured in ZdAJ in 2004 and is presently tested. Pure geometrical acceptance is expected to be more than 30% better.



Fig. 2 Phase acceptance of the 4 MeV Co-line accelerators.

- [1] LANL (Los Alamos National Laboratory), USA
- [2] M.J. de Loos, S.B. van der Geer, FOM-Instituut voor Plasmafysica 'Rijnhuizen', The Netherlands, <u>www.pulsar.nl/gpt</u>
- ¹⁾ Ecole des Mines de Nantes, France

12.4 Monte Carlo Simulations of Electron Beam in 15 MeV Medical Accelerator by J.Harasimowicz, S.Wronka

Monte Carlo simulations have been used to verify construction of an electron applicator of 15 MeV medical accelerator. Initial literature studies have shown that materials of prepared applicator prototype (aluminum and lead) can fulfill the requirements for medical devices [1].



Fig. 1 Electron fluence at the phantom surface (SSD 100cm, field size: 10x10 cm) simulated with BEAMnre. Results are presented for the applicator (1 cm layer of aluminum) with and without additional 2 mm layer of lead.

In this work BEAMnrc Monte Carlo code has been used. Preliminary results for monoenergetic 12 MeV electron beam have shown that 1 cm aluminum shelves of the applicator are not enough to minimize dose outside the treatment field. Nevertheless, additional 2 mm layer of lead can highly decrease electron fluence outside the region of interest (Fig. 1). The next step is to calculate dose profiles and percentage depth doses and to compare them with experimental results. To achieve this the real energy spectrum of initial electron beam is needed. Unfortunately, the experimental measurement of energy spectrum with high resolution is not trivial and could not be satisfactory realized in our Institute. Therefore, an indirect energy spectrum measurement is being developed. This technique is one of the inverse Monte Carlo methods and consists of three steps:

- Monte Carlo simulations of percentage depth doses (PDD) for different monoenergetic electron beams (for example, in a range from 10 MeV to 14 MeV with a step of 0.1 MeV for so called 12MeV electron beam);
- calculation of previously simulated monoenergetic beams contribution to measured real percentage depth dose (simulated PDDs weighted-sum fit to the real PDD);
- final Monte Carlo simulation of beam with fitted energy spectrum and comparison with measurements.

Presently, the first step of the method is being developed, i.e. percentage depth doses for monoenergetic beams are being simulated.

 L. J. van Battum, W. van der Zee, H.Huizenga: Scattered radiation from applicators in clinical electron beams; Phys. Med. Biol. 48(2003)2493

PL0501244

12.5 Progress in New 15 MeV Medical Accelerator

by E.Jakubowska, J.Harasimowicz, R.Hornung, J.Pracz, S.Wronka, J.Wysokiński

A new 15 MeV medical accelerator is being prepared in ZdAJ. The main beam parameters have been fixed: one can expect five electron energies from 6 up to more than 13MeV and one 9MV X beam. Presently the main goal is to adapt the existing model to final medical unit.

In 2004, a new 270ş deflection magnet was mounted together with the deflection chamber. Two additional coils in this component, QH and QV, were prepared to control the beam position and direction. Two additional measuring slits were located inside the deflection chamber to monitor changes of the energy. All those new elements have been tested and verified during experiments. The results and conclusions are as follows:

- coils QV and QH work properly,
- additional slits help in on-line monitoring of the energy beam, however can decrease the dose rate

Tek Stop

 therefore a construction with one movable slit will be used in the future.

by cutting a part of the energy spectrum),

Thus, the whole chain of the beam optics is checked and set for proper work.

ZdAJ has an ambitious plan to finish this accelerator in 2005. Still there is some work to be done:

- computer system of steering safety systems required by official norms
- hard and soft covers
- electron applicators
- whole documentation in agreement with the CE requirements
- portal Imaging, MLC as additional options in the future.

[1] IPJ Annual Report 2003



Fig. 3 Beam current seen after 270s deflection unit (left) and before (right). First part of the pulse is lost on the slits inside the deflection system due to different energy composition.

12.6 Electron Beam Deflection with Movable Slits in 15 MeV Accelerator by J.Olszewski, J.Wysokiński, S.Wronka

The electron deflection system in a 15 MeV accelerator with slits was elaborated in 2003 (see Annual Report, p.173). Slits permit to control the energy spectrum in electron beam.

After measurements and experimental works on the 15 MeV accelerator with elaborated slits, it was decided to design a new deflection system with the following elements:

1. The movable outside slit, water-cooled, without a signal from the electron beam output. The primary slit position was at 2 mm from the theoretical trajectory of electron beam. The movement of movable slit is 2 mm in the

direction of electron trajectory and 4 mm in the outside direction. There is a possibility of slit positioning.

- 2. The fixed inside slit, water-cooled, without a reading of the signal of electron beam. The slit position is at 2 mm from the theoretical trajectory of electron beam.
- 3. The air gap between poles is 16.4 mm instead of 12.4 mm in previous version.
- The exit window of the deflection chamber has a diameter of 12 mm instead of 16 mm. Titan foil of a thickness of 50 μm is used for the window.

PL0501246



The assumption mentioned above has made the construction of the electron beam deflection system simple and permit for precise adjustment of electron beam in 15 MeV.

The drawing of the deflection system was prepared. The computer simulation for temperature field was done for Cu movable slit and for fixed slit made of Cu or 1H18N9T steel. The temperature of steel and copper slits was estimated to be 2900 K and 1170 K, respectively. On base of the simulation it was decided to:

- Develop technical documentation of the Cu movable slit, according to design shape.
- Develop technical documentation of the Cu fixed slit. Especially elaborated vacuum brazing has been found necessary for the slit assembly.

Technical documentation of deflection system was prepared and delivered to the workshop of ZdAJ, Fig. 1.



Fig. 1 Deflection system for 15 MeV accelerator.

12.7 Verification of a:Si Matrix for Digital Imaging System by S.Wronka, J.Wysokiński

Modern digital imaging systems in radiotherapy and industrial radiography for non-destructive testing in a range of up to 30 MeV are based on amorphous silicon technology. Construction of such units is much simpler than solutions with CCD camera.

The tests of IRIS system with a:Si flat-panel proposed by BioScan[®] were performed in ZdAJ in 2004. Parameters of the detector:

Canaan

Sensor.	
Total pixel number	1024x1024
Pitch	400 μm
Total area	409.6x409.6mm ²
Saturation charge	84 pC
Dark current	<1 pA/Pixel
Electronics:	
Charge amplifier:	16 x 128 channel ASIC
ADC	16bit
Saturation charge of ASIC	5/25 pC
Integration time (minimum)	285 ms
Detector:	
Dynamic range	> 80 dB
Non-linearity $< \pm 2\%$	(10 % to 90 % of FSR)
Radiation energy	400 keV - 30 MeV

To verify quality of radiograms ASTM E-142 penetrameters were used. As an example one of the obtained pictures is presented in Fig. 1.

It was found that **1-2T** resolution is achieved in a range of 3cm÷10cm of steel and **1-1T** resolution is

achieved in a range of 10cm ÷ 30cm of steel.

PL0501247



Fig. 1 The image of 1cm steel and 0.4mm, 0.5mm, 1mm, 1.5mm, 2mm, 3mm, 4mm ASTM E-142 penetrameters.



PL0501248

12.8 Measurement Methodology and Results of 15 MeV Accelerator Shielding

by E.Jakubowska, J.Harasimowicz, L.Kotulski, J.Marianowski, J.Wysokiński

The permissible absorbed dose of outside radiation field and measurement methodology was described in IEC 60601-2-1 standard, § 29.3 and 29.4. The standard described two main area of leakage radiation in the patient plane outside the radiation field and outside the patient plane.

The dosimeter Ionex 2500/3 with the built-in radiation detector type 2571-0.6 cm² (Farmer Ionisation Chamber), density 551 mg/cm² and diameter 27 mm was used for measurement of outside X radiation. The device with a precise angular movement of radiation detector at established radius and angle speed was applied. TV camera and PC were used for dose rate registration in measurement points.

The beam limiting devices ought to attenuate X radiation such that the absorbed dose due to leakage radiation should not exceed 2 % of the maximum absorbed dose measured on the reference axis at NTD,

in any case the average absorbed dose due to leakage radiation through the beam limiting devices should not exceed 0.5%. It is connected with M area, which is defined as the area at NTD on the plane perpendicular to the reference axis of the geometrical projection of the distal end of that primary BLD, as seen from the center of the front surface of the target electron radiation window, Fig. 1.

The absorbed dose outside the patient plane caused by leakage radiation in a distance of 1 m from the electron gun and target should not exceed 0.5 % dose rate measured at NTD, Fig. 2.

The attenuation of the dose rate by the beam limiting devices fulfils the requirements of IEC standard. The deviation and solenoid shielding must any way reduce by a factor of 10 the leakage radiation around the accelerator arm.



Fig. 1 The spectrum of dose rate in M area, r=21.5 cm (up).



Fig. 2 The spectrum of dose rate directly after deviation, accelerator arm angle position 270° Ad.10.



III. OBITUARIES

MICHAŁ GRYZIŃSKI (1930-2004)



Michał Gryziński left us on June 1 2004 after a short struggle with cancer. He leaves two children.

Michał was an unusual man. He was born to Jan and Stefania in Warsaw-Anin in 1930. Michał was educated at the Władysław IV school in Warsaw and graduated from the Warsaw Polytechnic in 1955. He had a short spell as an assistant in the Nuclear Chemistry Department of Warsaw University, followed by joining the newly created Institute of Nuclear Research at the Świerk site. Here he worked under the first director, Andrzej Soltan. He sent his first paper, "Stopping power of a medium for heavy charged particles" to the Physical Review in 1957. This was an unusual thing to do in the Poland of the fifties. In this and successive papers into the mid sixties, (also published in Phys. Rev.) he developed a classical theory of binary collisions that has made the textbooks. These papers were quoted over 100 times a year for a while. He raised classical methods in nuclear physics to new heights. Many specialists I have talked to agree that more can be done classically, the success of quantum theory notwithstanding. Unfortunately, in the view of most scientists, Michał took his reasoning further, advocating the superiority of classical over quantum methods in the nuclear context. I once asked him why his calculations had not been carried out sooner, given the basic nature of binary collisions. His answer, if controversial, gave insight into the workings of his mind. He said that one had to believe in the relevance of classical nuclear physics more strongly than the masters did to obtain these results. True or false, it was a revealing answer. His results earned him numerous invitations, largely to the US.

In 1965 Michał obtained his PhD, followed by submission of a DSc thesis. He based it on his classical calculations and would have had every chance of its being accepted, had it not gone on to criticise quantum mechanics. The thesis was rejected. This unfortunately estranged this very gifted and dedicated man from many of his elders in the Warsaw physics community. No DSc meant no professorial importance of his early title, the work notwithstanding. Many of us felt that this was unfortunate. Michał went on to devise a "free fall" model of an electron in its atom. (Its motion is envisaged as roughly following a "triangle" with concave sides). This time few physicists followed him, though he did manage to publish in established journals from time to time. Towards the end of his life he published a book pointing out some weaknesses of quantum mechanics ("The story of the atom" in Polish). It is a good read, but fails to address the many unquestionable successes of quantum theory. It also includes some interesting observations about the state of the world. The whole tone is extremely pessimistic, about the state of science, Poland, and our civilisation!

There was a second aspect to Michał's professional life. Early on he realised that plasma physics would be an important field in the developed world. He instigated research on medium sized devices such as the Plasma Focus. He led the plasma group since 1959, and when a plasma physics department was created in 1973, was appointed its head, a position he held until Solidarity initiated elections to the post in 1981. Michał's group collaborated with the Bemowo institute in north Warsaw in building one of the largest Plasma Focus devices in the world (PF-1000). His group also utilised ion beams to modify the surfaces of solid bodies. Michal's mixed luck with his theoretical physics career was to some extent mitigated by recognition of his plasma experiments by the authorities. He was awarded the Chevalier's Cross of Polonia Restituta. He also participated in a State Prize (first class). Upon retiring from our Institute he was awarded the Soltan Medal. Michał also had interests outside physics. He was keen on many sports, long canoe journeys and mountain hiking.

Michał Gryziński was an interesting man in many ways. When I was abroad as a young man, people would ask me about him as soon as they learned where I worked. Controversial, yes; boring, never. Many of us will miss him, no one will expect to ever see anyone quite like him again.

Eryk Infeld

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