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FOREWORD

With dwindling means Polish science struggles for survival. To survive means to keep contributing to the world knowledge on a worthy level and to assure the continuation of this process, i.e. to at least reproduce the human and technical resources. We did our part in this struggle during the difficult year 1998 as well as we could. Let the Reader of this Annual Report judge how well did we manage.

We have published 237 papers in international journals, 76 of which are jet in press. (207 in journals from the so-called “Philadelphia list”, 30 in other recognised journals). These were supplemented with 154 communicates and 27 invited talks presented at various international conferences. Ten members of our staff served on the Advisory Boards to some of these conferences, many have chaired sessions. We have co-organized the “International Workshop on Plasma – Focus Research PF’98” in Kudowa in July 1998. As a contribution to the on-going discussion we have organised a symposium on the perspectives of nuclear physics at our Institute (Mądralin, June 1998). Nineteen of our staff members have spent long (above two months) stays in various research centers throughout Europe and the US. A permanent exhibition “Nuclear wastes: problems, solutions” prepared by the Department of Training & Consulting has been opened in the fall. The steady flow of visitors, notably the school youth, brings satisfaction to all of us and shows the need for such activities (cf. § II. 11).

The Reports on Research presented below are grouped in ten chapters corresponding to the ten scientific departments of our Institute. Chapters eleven and twelve give reports of activities of the Training Department and of the production unit ZdAJ, correspondingly. Each of these chapters begins with a short overview written by the head of the department; these are followed by short accounts of the work in progress and lists of publications and other output of each of the departments. The samples of these activities presented below are to whet the appetite of the Reader and to encourage Her/Him to read further.

The activities of our Institute concentrate on the nuclear physics (low, medium and high energy), the particle physics, the cosmic radiation and the hot plasma physics on one hand and on such domains of the applied research and instrumentation as the accelerator development, the materials science (notably the surface properties), the development of detectors and of specialised, short-series electronics. Therapeutical accelerators and diagnostic devices feature highly on our technical output list.

There is a clear shift of interest of our nuclear physics experts towards higher energy accelerator experiments. There is still, however, a worthy output concerning the more traditional low energy nuclear physics. An example to mention is the work on the $^6$He nucleus with the suggested two-neutron halo structure (cf. § II.1).

Our high energy nuclear and particle physics groups are increasingly involved in preparations for the “next century physics”, be it at CERN or elsewhere. The long term projects, such as, e.g., the CMS and ALICE experiments planned for the Large Hadron Collider or COMPASS for the SPS at CERN, require an early technical and instrumental effort of many teams. As a consequence, the instrumental developments feature highly on the priorities of our groups (cf. e.g., § II.6).

The two modest and aged nuclear accelerators: the 2MV van de Graaff and the 30 MeV proton cyclotron, serve successfully the solid state related research. Examples: the work on defects in GaAs crystals, one of the most studied material in the recent years because of its technological potential (§ II.1) or the radiation-induced modification of optical properties of various materials (§ II.2).

Our plasma physics group continues the work on their discovery of a couple of years ago of the polarisation of X-rays emitted during the PF - type discharges. They gained a new insight to the effect by observing it for discrete X-ray lines. A noteworthy also is their methodical work on the track detectors and their use in plasma research.
Our Institute has always had quite a strong nuclear electronics group, developed years ago to partly offset the shortages of ready-made electronics on the Polish market and partly to assist the physics oriented groups. It is satisfying to see how our electronics experts find appreciation of their skills today. The work on the front-end electronics for the Euroball system or on the acquisition system for the NA 48 experiment at CERN (cf. § II.3) bear witness to this.

One hallmark of our Institute over many years has been the development, construction and implementation of linear electron accelerators for cancer therapy (cf. § II.10 and II.12). Last year we have been honoured by the award “Teraz Polska”, the prestigious prize for the best industrial product made in Poland and based on Polish technology, for the therapeutical range SACON (cf. § II 12).

The latest pride of our detector experts is a very thin Si ΔE detector (cf. § II.9) and a tiny (1 mm x 1 mm) scintillation probe for dosimetry (cf. § II.4). The Reader of this Report should also not miss the work on the high energy atomic physics (cf. § II.1 and II.2), on the implantation techniques to modify the surface properties of materials (§II.5 and II.9) and many other “goodies”.

My somewhat bitter opening phrase can unfortunately be illustrated in number of ways. One such illustration is the steady flow of talented and already accomplished researchers out of science. It is normal when this happens to the fresh Ph.D’s., it is not normal when this concerns the tenured staff members who do this against their wish, being forced by the daily needs. The generation gap in the ranks of scientists, which ensues, is clearly worrisome. To end on a more optimistic tone, the weakly seminar of the PhD students shows that there is still enthusiasm for science among our youngest colleagues.

Professor Ziemowid Sujkowski
I. GENERAL INFORMATION

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

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@iriss.cyf.gov.pl

Deputy Director, Research and Development
Professor Marek MOSZYŃSKI
phone: (22) 718-05-86
e-mail marek@ipj.gov.pl

Deputy Director, Economy and Marketing
Assoc.Professor Zbigniew WERNER
phone: (22) 718-05-56

Scientific Secretary
Dr. Danuta CHMIELEWSKA
phone: (22) 718-05-85
e-mail danka@iriss.cyf.gov.pl
2. SCIENTIFIC COUNCIL

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

Chairman: Professor Ryszard Sosnowski
Deputy Chairmen:
  - Professor Sławomir Wycech
  - Dr Tadeusz Kozłowski
  - Professor Stanisław Kuliński

Representatives of scientific staff:

Helena Białkowska, Assoc.Prof.
Stanisław Gębalski, MSc.
Michał Gryźiński, Assoc.Prof.
Marian Jaskóla, Professor
Różaśław Kaczerowski, Assoc.Prof.
Jerzy Langner, Dr.
Leszek Łukaszk, Professor
Stanisław Mrówczyński, Assoc.Prof.
Michał Nadachowski, Assoc.Prof.
Adam Nawrot, Eng.
Jerzy Piekoszewski, Professor
Stanisław Pszona, Dr.
Marc Sadowski, Professor
Adam Sobieczewski, Professor
Ziemowit Sujkowski, Professor
Andrzej Turos, Professor
Zbigniew Werner, Assoc.Prof.
Sławomir Wycech, Professor

Representatives of technical personnel:

Jerzy Bigolas, Eng.
Genowefa Fajkowska, Eng.
Edward Fronczak, technician
Andrzej Hilger, MSc.
Danuta Jastrzębska, economist
Jan Kopec, Eng.
Jacek Pracz, MSc.
Jacek Stanisławski, MSc.
Iwona Zawrocka, MSc.
Zbigniew Zero, Eng.

External members:

Andrzej Budzanowski, Professor
Andrzej Czachor, Professor
Tomasz Czosnyka, Assoc.Prof.
Jan Kownacki, Professor
Ewa Skrzypczak, Professor
Józef Tolwiński, Professor
Andrzej K. Wróblewski, Professor
Jan Żylicz, Professor

- Institute of Nuclear Physics, Cracow
- Institute of Atomic Energy
- Heavy Ion Laboratory, Warsaw University
- Heavy Ion Laboratory, Warsaw University
- Institute of Experimental Physics, Warsaw University
- Institute of Oncology, Warsaw
- Institute of Experimental Physics, Warsaw University
- Institute of Experimental Physics, Warsaw University
3. DEPARTMENTS OF THE INSTITUTE

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

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

- DEPARTMENT OF NUCLEAR ELECTRONICS (P-III)
  Head of Department - Dr. Zbigniew GUZIK

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

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

- DEPARTMENT OF HIGH ENERGY PHYSICS (P-VI)
  Head of Department - Professor Jan NASSALSKI

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

- DEPARTMENT OF NUCLEAR THEORY (P-VIII)
  Head of Department - Professor Grzegorz WILK

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

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

In addition to the research departments:

- DEPARTMENT OF TRAINING AND CONSULTING
  Director - Professor Ludwik Dobrzyński  tel.718-05-70, 718-05-71, 718-05-72

Semi-independent:

- ESTABLISHMENT FOR NUCLEAR EQUIPMENT (ZdAJ)
  Director, MSc Jacek PRACZ  tel.718-05-00, 718-05-02

and

- SERVICES AND TRANSPORT DIVISION (ZOIT)
4. SCIENTIFIC STAFF OF THE INSTITUTE

PROFESSORS

1. DĄBROWSKI Janusz (**)
2. DOBRZYŃSKI Ludwik
3. INFELD Fryk
4. JASKÓŁA Marian
5. KULINSKI Stanisław
6. ŁUKASZUK Leszek
7. MARCINKOWSKI Andrzej
8. MOSZYŃSKI Marek
9. NASZALSKI Jan
10. PIEKOSZEWSKI Jerzy
11. RATYŃSKI Wojciech
12. SADOWSKI Marek
13. SIEMIARCZUK Teodor
14. SOBIĆZEWSKI Adam
15. SOSNOWSKI Ryszard
16. STEPANIAK Joanna
17. SUJKOWSKI Ziemowid
18. SZEPITKA Maria
19. TURKIEWICZ Jan, until July 31
20. TUROS Andrzej
21. WILCZYŃSKI Janusz
22. WYCECH Sławomir

Theoretical Nuclear Physics
Solid State Physics
Plasma Physics and Nonlinear Dynamics
Low Energy Nuclear Physics
Accelerator Techniques and Physics
Particle Physics
Low Energy Nuclear Physics
Nuclear Electronics, Technical Physics
Particle Physics
Solid State Physics
Low Energy Nuclear 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
Low Energy Nuclear Physics
Particle Physics
Low Energy Nuclear Physics
Nuclear and Particle Physics

CONTRACT PROFESSORS

1. BLOCKI Jan
2. GAWIN Jerzy
3. MOROZ Zbigniew
4. ZUPRANSKI Paweł

Theoretical Nuclear Physics
Cosmic Ray Physics
Low Energy Nuclear Physics
High Energy Nuclear Physics

ASSOCIATE PROFESSORS and DSc

1. BIAŁKOWSKA Helena(*)
2. DELOFF Andrzej
3. GRYZIŃSKI Michał
4. GUZIK Zbigniew
5. JAGIELSKI Jacek(**)
6. KACZAROWSKI Rościsław
7. KIELSZNIA Robert(**)
8. KULKA Zbigniew(**)
9. MRÓWCZYŃSKI Stanisław(**)
10. PIOTROWSKI Antoni
11. RONDIO Ewa
12. SANDACZ Andrzej

High Energy Nuclear Physics
Particle Physics
Plasma Physics and Atomic Physics
Nuclear Electronics
Solid State Physics
Low Energy Nuclear Physics
Accelerator Techniques and Physics
Nuclear Electronics
Particle Physics
Technical Physics
Particle Physics
Particle Physics
13. SKALSKI Janusz
14. SŁAPA Mieczysław (**)
15. SOWIŃSKI Mieczysław (**)
16. SURA Józef
17. SZCZEKOWSKI Marek
18. SZYMANOWSKI Lech
19. WERNER Zbigniew
20. WILK Grzegorz
21. WÓJTOWICZ Stefan
22. WRZECIONKO Jerzy
1. ZWIEGLIŃSKI Bogusław

Theoretical Nuclear Physics
Solid State Physics
Applied Nuclear Physics
Accelerator Techniques and Physics
Particle Physics
Theoretical Nuclear Physics
Solid State Physics
Particle Physics
Nuclear Electronics
Theoretical Nuclear Physics
Nuclear Physics

RESEARCH ASSOCIATES (PhD)

1. ADAMUS Marek (*) till Oct. 9
2. AUGUSTYNIAK Wrold
3. BALCERZYK Marcin
4. BARANOWSKI Jarosław
5. BIAŁKOWSKI Jacek (*)
6. BIELIK Mirosław †
7. BIEŃKOWSKI Andrzej
8. BOGDANOWICZ Jerzy (*)
9. BORSUK Stanisław
10. CHARUBA Jacek
11. CHMIEŁOWSKI Władysław (*)
12. CHMIELEWSKA Danuta
13. CZARNACKI Wiesław
14. CZYŻEWSKI Tomasz
15. FILIPKOWSKI Andrzejj (**)
16. GAWLIK Grzegorz (**)
17. GOKIELI Ryszard (*)
18. GOLDSTEIN Piotr
19. GÓRSKI Maciej
20. JAKUBOWSKI Lech
21. JERZYKIEWICZ Andrzejj
22. KOCIĘCKA-MECHANIŃSKA K.
23. KORMAN Andrzejj
24. KOWALSKI Marian (*)
25. KOWŁOWSKI Tadeusz
26. KUPŚĆ Andrzejj (*)
27. KUREK Krzysztof
28. LANGNER Jerzy
29. LUDZIEJEWSKI Tomasz (*)
30. MACISZEWSKI Wiesław
31. MARIŃSKI Bogdan
32. MYSŁEK-LAURIKAINEN B.
33. NOWICKI Lech
34. PATYK Zygmunt
35. PIECHOCKI Włodzimierz
36. PŁAWSKI Eugeniusz
37. PŁOŚCIEŃNIK Weronika
38. POLANSKI Aleksander
39. PREJBISZ Zygmunt (**)
40. PSZONA Stanisław
41. RABİŃSKI Marek
42. RÓŻYNEK Jacek
43. RUCHOWSKA Ewa
44. RURARZ Edward (**)
45. RUSEK Krzysztof
46. RYMUZA Piotr, untill Oct. 31
47. SENATORSKI Andrzejj
48. SERNICKI Jan
49. SKŁADNIK-SADOWSKA E. (**)
50. SKORUPSKI Andrzejj
51. SMOLANČUK Robert (*), from Nov. 31
52. SUROWIEC Alicja (*)
53. SZABELSKA Barbara
54. SZABELSKI Jacek
55. SZLEPER Michal
56. SZYDŁOWSKI Adam
57. SZYMAŃSKI Piotr (**)
58. SZYMČZYK Władysław
59. TRZCIŃSKI Andrzejj
60. WIŚLIŃKI Wojciech
61. WOJTOWSKA Jolanta (**)
62. WÓLSKI Dariusz
63. ZABIEROWSKI Janusz
64. ZALEWSKI Piotr
65. ZYCHOR Izabella

(*): on leave of absence
(**): part-time employee
(†): deceased July 6
5. VISITING SCIENTISTS

1. Kretschmer R. University of Leipzig, Germany Feb. 23 – March 7 P-VIII
3. Momotik A. Inst. For Nuclear Research, Kiev, Ukraine March 23 – 26 P I
5. Piervushin V. Joint Inst. for Nuclear Research, Dubna, Russia April 24 – May 9 P-VIII
6. Van Beverena University Coimbra, Portugal May 4 – 17 P-VIII
7. Petridis A. Iowa University, USA May 13 – 16 P-VIII
8. Zhan Fu Rui Hebei University, China May 22 – 2 P-V
9. Lei Tianliang
10. Lu Mingfang
12. Czerniejewski W. Inst. For Nuclear Research, Kiev, Ukraine June 1 – 20 P-I
13. Gareev F. Joint Inst. For Nuclear Research, Dubna, Russia June 2 – 4 P-V
14. Smirnow D. Joint Inst. For Nuclear Research, Dubna, Russia June 3 – 16 P-VII
15. Garrido F. Centre de Spectrometrie de Masse et Spectrometrie Nucleare Orsay, France June 4 – 24 P-I
17. Zimman V.
18. Groetzschel R. Forschungszentrum Rossendorf, Germany June 15 – 16 P-I
19. Mrothschek I.
20. Nuss E. University of Perpignan, France July 1 – 14 P-VII
22. Jarzyński C. Los Alamos, USA Aug. 29 – Sept. 19 P-II
23. Świątecki W. Lawrence Berkeley Laboratory, USA Sept. 1 P-II
25. Stodel J. P. Laboratoire de Physique Corpusculaire, Caen, France Sept. 1 – Oct. 9 P-II
27. Pervushin V. Joint Inst. for Nuclear Research, Dubna, Russia Sept. 20 – Oct. 20 P-VII
28. Trzaska W. University of Jyvaskyla, Finland Sept. 21 – 26 P-I
29. Hoffman C. Lawrence Berkeley Laboratory, USA Sept. 25 – 28 P-VIII
30. Hoffman M.
32. Nezavibatko Y.
33. Ivanow Mathematical Inst. Novosybirsk, Russia Oct. 25 – Nov. 7 P-VII
34. Jorjadze G. Rozmadze Mathematical Inst., Tbilisi, Georgia Nov. 1 – 3 P-VIII
35. Abrosimow V. Inst. for Nuclear Research, Kiev, Ukraine Nov. 4 – 6 P-II
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<td>Sidorenko B.</td>
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<td>Parfionov A</td>
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6. GRANTS

LIST OF RESEARCH PROJECT (GRANTS) REALIZED IN 1998

1. PROPERTIES OF RADIOACTIVE NUCLEI
   Principal Investigator: Professor A. Sobieczewski
   Grant No. 2P 03B15608

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

3. INVESTIGATION OF RARE DECAYS AND MESON PRODUCTION MECHANISM IN THE WASA EXPERIMENT
   Principal Investigator: Professor J. Stepianiak
   Grant No. 2P 03B07910

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

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

6. INTERACTION OF STRANGE PARTICLES WITH ATOMIC NUCLEI
   Principal Investigator: Professor J. Dąbrowski
   Grant No. 2P 03B04812

7. MUONS IN COSMIC RAY SHOWERS IN THE KASKADE EXPERIMENT
   Principal Investigator: Dr. J. Zabierowski
   Grant No. 2P 03B16012

8. PHOTON NEEDLE FOR RADIOTHERAPY
   Principal Investigator: Dr. M. Słapa
   Grant No. 8T 11E00913

9. DEVELOPMENT OF A NEW TYPE, THERMEOLECTRICALLY-COOLLED SILICON DETECTOR FOR SPECTROMTRY OF X-RAY RADIATION, ESPECIALLY FOR FLUORESCENCE ANALYSIS
   Principal Investigator: Dr. W. Czarnacki
   Grant No. 8T 11B01913

10. STUDY OF THE DECAY OF b QUARK INTO s QUARK AND GLUON USING THE DELPHI DETECTOR
    Principal Investigator: MSc. K. Nawrocki
    Grant No. 2P 03B12913

11. STUDY OF THE ATOMIC INNER-SHELL (L,M) IONISATION INDUCED BY IONS WITH Z ≥ 3 IN HEAVY ELEMENTS
    Principal Investigator: Prof. M. Jaskóla
    Grant No. 2P03B06514
12. ANALYSIS OF $G_1$ STRUCTURE FUNCTION MEASUREMENTS FROM THE SMC EXPERIMENT AT CERN
   Principal Investigator: Dr. W. Wiślicki
   Grant No. 2P03B081114

13. STUDY OF STRUCTURE OF STRONGLY IONISED HEAVY IONS AND DYNAMICS OF THEIR INTERACTION WITHATOMS.
   Principal Investigator: Dr. P. Rymuza
   Grant No. 2P03B116115

14. OPTICAL POTENTIAL FOR ANTIPROTONS.
   Principal Investigator: Prof. S. Wycech
   Grant No. 2P03B09915

15. PRODUCTION MECHANISM OF SUPERHEAVY ELEMENTS.
   Principal Investigator: Dr. R. Smolańczuk
   Grant No. 2P03B09915

16. BOSE-EINSTEIN CORRELATION OF $\pi^+$ MESONS FROM $^{207}$Pb+$^{207}$Pb AND $^{207}$Pb + $^{59}$Ni INTERACTIONS AT 158A GEV/C
   Principal Investigator: Mgr K. Karpio
   Grant No. 2P03B 6815

17. INVESTIGATION OF NEW SCINTILLATION TECHNICS AS USED IN SPECTROMETRY OF NUCLEAR RADIATION IN PHYSICS, NUCLEAR TECHNICS AND IN NUCLEAR MEDICINE.
   Principal Investigator: Prof. M. Moszyński
   Grant No. 8T10C00515

18. PRECISE MEASUREMENT OF CP VIOLATION IN K° DECAYS.
   Principal Investigator: Dr E. Rondio
   Grant No. 2P03B07615

19. NEW HIGH EFFICIENCY SCINTILLATORS FOR GAMMA AND X-RAYS DETECTION IN POSITRON EMISSION TOMOGRAPHS AND DIGITAL RADIOGRAPHY.
   Principal Investigator: Dr M. Balcerzyk
   Grant No. 8T11E02515

20. STUDIES OF RADIOACTIVE NUCLEI.
    Principal Investigator: Prof. A. Sobiczewski
    Grant No. 2P03B11715

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

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

23. SEARCHES FOR NEW PHYSICS AT LEP2.
    Principal Investigator: Prof. R. Sosnowski
    Grant (SPUB) No. 621/E-78/SPUB/P03/023/97
    No. 621/E-78/SPUB/P03/178/98

24. COMPASS EXPERIMENT – CONSTRUCTION OF DETECTORS AND SOFTWARE PREPARATIONS.
    Principal Investigator: Prof. J. Nassalski
    Grant (SPUB) No. 621/E-78/SPUB/P03/021/97
    No. 621/E-78/SPUB/P03/178/98
25. RADIATION QUALITY ACTIVE MONITORING BASED ON NANOMETRIC MEASUREMENTS.  
Principal Investigator: Dr. S. Pszona  
Grant (SPUB) No. 621/E-78/SPUB-UE/P-03/DZ-24/97

26. APPLICATION OF MeV ION BEAMS FOR DEVELOPMENT AND CHARACTERIZATION OF  
SEMICONDUCTOR MATERIALS  
Principal Investigator: Prof. A. Turos  
Grant (SPUB) No. 621/E-78/SPUB-IAEA/P-03/DZ-98

In addition to the above, several of our scientists are principal investigators in grants co-ordinated by other Warsaw institutions.
LIST OF RESEARCH PROJECTS GRANTED BY INTERNATIONAL ORGANIZATIONS

1. SEMI-EMPIRICAL THEORY OF NUCLEAR DYNAMICS
   Principal Investigator: Professor J. Blocki
   Grant No. PAA/NSF-96-253

2. TRANSEUROPEAN MOBILITY PROGRAMME FOR UNIVERSITY STUDENTS (TEMPUS)
   Principal Investigator: Professor J. Stepianiak
   Contract No. MJEP-9006/91

3. TECHNICAL DOCUMENTATION OF SCINTILLATING DETECTOR UNITS, TECHNOLOGY OF THE PRODUCTION PROCESS OF THE DETECTOR COMPONENTS
   Principal Investigator: Professor J. Stepianiak
   WASA Collaboration Uppsala, No. 535, S-75121

4. SPECIFICATION OF RADIATION QUALITY AT NANOMETER SCALE
   Principal Investigator: Dr. S. Pszona
   Grant No. ERB CI PDCT 930407
   ERB F14 P-CT 96-044/Sub.1.

5. APPLICATION OF MeV ION BEAMS FOR DEVELOPMENT AND CHARACTERIZATION OF SEMICONDUCTOR MATERIALS
   Principal Investigator: Professor A. Turos
   IAEA Contract No. 10035

6. DESIGN AND CONSTRUCTION OF A ROOM TEMPERATURE MODEL OF A NEW SHAPE TESLA ACCELERATING SUPER STRUCTURE
   Principal Investigator: MSc. M. Pachan
   Contract No 1957833

7. DESIGN AND CONSTRUCTION OF PULSED MICROWAVE POWER GENERATOR
   Principal Investigator: MSc. J. Bigolas
   Italy, Commission No PO/1820

8. A COMPACT, PORTABLE AND ECONOMICAL HIGH POWER INDUCTIVE ENERGY STORAGE GENERATOR – DEVELOPMENT AND APPLICATION
   Principal Investigator: Professor M. Sadowski
   Contract No. IC15-CT97-0705

9. COMPILATION AND EVALUATION OF HIGH ENERGY GAMMA-RAY STANDARDS FROM NUCLEAR REACTIONS
   Principal Investigator: Professor A. Marcinkowski
   Contract No. 10314/RBF
7. SCIENTIFIC DEGREES

Phd theses

1. MARCIN BALCERZYK, DEPARTMENT P-III
   New scintillating materials for $\gamma$-ray detection and spectroscopy.

1. JAROSŁAW BOGUSZYŃSKI, DEPARTMENT P-VIII
   Asymptotically collinear dynamics in quantum field theory.

3. LECH NOWICKI, DEPARTMENT P-I
   Transformations of oxygen sublattice in uranium dioxide single crystals.

DCs theses

1. JÓZEF ANDRZEJEWSKI (ŁÓDŹ UNIVERSITY)
   Study of averaged parameters of slow neutron induced reactions on selected nuclei with the emission of $\alpha$-particles and protons.

2. WOJCIECH WISLICKI, DEPARTMENT P-VI
   Spin structure of the nucleon in polarized deep inelastic muon – nucleon scattering.

3. KRZYSZTOF RUSEK, DEPARTMENT P-I
   Scattering of polarized $^{6,7}$Li.
II. REPORTS ON RESEARCH

1 DEPARTMENT OF NUCLEAR REACTIONS

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Overview

The Department of Nuclear Reactions had a very productive year. The following reports cover three major domains of our activities: nuclear, material and atomic physics.

One of the current questions in modern nuclear physics is question of the phase transitions in nuclear matter. Our physicists, the members of the ALADIN Collaboration at Gesellschaft für Schwerionenforschung, participated in new experiments exploring properties of highly excited nuclear matter and the phenomenon of the liquid – gas phase transition. The experiments yielded a number of important results. Details can be found in the three short reports presented in this volume.

Structure of a nucleon is another important subject of nuclear science research. In the last year energy region of $\Delta$ resonance has been investigated by means of charge exchange reaction. The experiment was performed at Laboratory National Saturne in Saclay by SPESIV-α collaboration consisting of physicist from Institute of Nuclear Physics Orsay, Niels Bohr Institute Copenhagen and from our Department. The main achievement of the experiment was evidence for a $\Delta$ - hole attraction in the spin longitudinal channel.

Reactions induced by radioactive ion beams such as $^6$He recently attract a lot of interest. There exist some evidences that the $^6$He nucleus has a two-neutron halo structure similar to that well established for $^{11}$Li. An analysis of $^6$He + $^4$He scattering data reported in this volume revealed some similarities between the loosely bound $^6$Li nucleus and the neutron rich $^6$He.

Research in material physics has focused on two basic topics: a crystallographic model of uranium dioxide, a material currently used as a nuclear fuel and transformations of defects in GaAs crystals at low temperature. The investigations have been carried out in a wide collaboration with scientists from the University of Jena, Research Center Karlsruhe and Centre de Spectrometrie Nucleaire Orsay. Some experiments have been performed at the Department using microbeams provided by the Van der Graaff accelerator. The results have been presented at many conferences and workshops.

As far as atomic physics is concerned, the studies of ionisation of M-, N- and O-shell by heavy ions have been continued in collaboration with the Pedagogical University of Kielce and the University of Erlangen. Among others, new results have been obtained for Au, Bi, Th and U nuclei bombarded by oxygen ions. The PIXE method has been used to determine the concentration of trace elements in several biological samples (mainly honey samples) in order to test if those samples as an indicator of soil and air pollution could be used. Moreover, application of solid state nuclear track detectors for detection of heavy ions has been studied using carbon beam of energy ranging from 1 up to 15 MeV. Those detectors are used in various fields of experimental physics.
1.1 Temperatures of Exploding Nuclei
by A. Trzcinski, and B. Zwieglinski. The ALADIN Collaboration at GSI – Darmstadt

The ALADIN Collaboration activities in 1998 concentrated on the three main issues:

(i) Interpretation of experimental data accumulated in the SI 17 experiment performed in 1995 and preparation of the pertaining publications,
(ii) Running two experiments (SI85-LII) in collaboration with the French equipe from GANIL (Caen), IPN (Orsay), LPC (Caen), CEA DAPNIA/SPhN (Saclay) and IPN (Lyon) using INDRA, the most advanced among the existing $4\pi$ multidetectors,
(iii) Upgrading of the ALADIN spectrometer detecting system intended to meet the requirements of Collaboration forthcoming experiments.

The experiment SI 17 was devoted to a comparative study of the two methods of nuclear thermometry - the isotope ratio and the excited state population ratio methods, in different regimes of the collision centrality. To this end two multidetector hodoscopes, consisting of 96 and 64 Si-CsI(Tl) telescopes in closely packed geometry, were placed on opposite sides with respect to the beam axis. In addition, seven four-element telescopes were used to measure the isotopically resolved yields of light charged particles and fragments. For central $^{197}\text{Au}^{+}\text{Au}$ collisions temperature measurements were performed for beams of $^{197}\text{Au}$ with energies of 50, 100, 150 and 200 MeV/u, provided by the heavy-ion synchrotron SIS. The associated charged particle multiplicity, measured simultaneously in the azimuthally symmetric array of 36 CaF$_2$-plastic phoswich detectors, covering the range of $\theta_{\text{lab}}=6$ to 20 deg., was used as the centrality filter.

The obtained values [1] for two isotopes (full symbols) and three excited state temperatures (open symbols) are compared in Fig. 1. The dashed line indicates the linear rise assuming a complete stopping of the incident nuclei and a classical gas with 3x2A degrees of freedom, carrying a thermal energy component of 50% of the collision energy. The last assumption is in line with the recent observations [2] that 40-60% of the center-of-mass energy is converted into collective radial flow energy, suggesting an explosive scenario of disassembly of the joined system of nearly 400 nucleons in these central collisions. The isotope temperatures reflect this trend of increase, however it must be admitted, that agreement on the quantitative level is far from perfect. The excited state temperatures, on the other hand, appear to be virtually independent of the bombarding energy, with the average $T$ of about 6 MeV. The observed differences suggest that these two types of thermometers are sensitive to different stages of evolution of the system. The freeze-out time of a nuclear state is correlated with the cross section, with which it is populated or destroyed in collisions with other nucleons during the expansion phase. Since excited states can be destroyed by almost any inelastic collision, they will freeze-out very late and reflect the temperature of the system at a late time.

For the in-depth study of phenomena occurring in central collisions two dedicated experiments were performed in 1998, using the multidetector INDRA. The first one, S185-I, was aimed to provide multifragmentation systematics in $^{197}\text{Au}^{+}\text{Au}$ collisions in the energy range 40-150 MeV/u, covering the maximum in intermediate mass fragment production at $\sim$100 MeV/u [3]. The second one, S185-II, was intended to provide insight into isospin effects. Tilt collisions of $^{132}\text{Xe}$ and $^{129}\text{Xe}$ ions with $^{112}\text{Sn}$ and $^{124}\text{Sn}$ targets, widely differing in neutron number, were studied in the same energy range. An analysis of the accumulated data and energy calibrations of the INDRA modules are in course.

![Fig.1. Measured isotope temperatures (full symbols) and excited state temperatures (open symbols) as a function of the incident energy per nucleon. The meaning of the dashed line is explained in the text.](image-url)


* This work was supported in part by the Scientific and Technological Cooperation Joint Project with Germany for the years 1997-2000 ("Elementary Reactions", FKZ - Nr: POL - 196 - 96)
1.2 Nonequilibrium Features of the Nuclear Liquid-Gas Phase Transition Revealed in Proton Spectra Emitted in Au+Au Collisions at 1 GeV/u*

by A. Trzcinski and B. Zwieglinski. The ALADIN Collaboration at GSI-Darmstadt

The applicability of thermodynamical concepts, such as liquid-gas phase transition to multifragmentation requires that the residue is in thermal and chemical equilibrium at the instant of its disassembly. Implicit to this requirement is an assumption that the residue lifetime, throughout which the constituent nucleons form a self-bound system, is sufficient for equilibration to occur. The proton spectra (open points on the left panel in Fig. 1) emitted by the target residue, measured with the aid of high resolution four element telescopes in the experiment S117 (see [1] and the preceding research note) reveal that equilibration ceases to be reached at high excitation energies, corresponding to the gas branch of the caloric curve [2].

The spectra are labeled with \( Z_{\text{bound}} \) (\( Z_{\text{bound}} = Z_i + Z_f + 2 \)) of the products of projectile fragmentation, simultaneously detected with the ALADIN forward spectrometer. There is a one-to-one correspondence between \( Z_{\text{bound}} \) and the residue average excitation energy \( \langle E_0 \rangle \), such that decreasing \( Z_{\text{bound}} \), correspond to increasing \( \langle E_0 \rangle \) values (correspondingly decreasing average residue masses \( \langle A_0 \rangle \)).

The spectra are fitted with a sum of two Maxwell-Boltzmann distributions with different slopes, typified by the inverse-slope parameters, \( T_{\text{slop}} \). The low temperature component \( \sigma_0(E_p) \), corresponding to the equilibrium proton emission, is indicated with the dotted line, while the high temperature component \( \sigma_0(E_p) \), corresponding to the pre-equilibrium one, with the dashed line for the spectrum in bin 70<\( Z_{\text{bound}} \)<80. Solid lines represent their sum for this and the remaining \( Z_{\text{bound}} \) bins in Fig. 1. The total yields \( Y_{\text{bin}} \) result from integration of \( \sigma_0(E_p) \) over \( E_p \). The three panels on the right-hand side of Fig. 1 summarize the parameters derived from the fits for the low-(solid points) and high-temperature (open points) components, respectively. The relative intensity of the low-temperature component \( Y_{\text{bin}}/Y_{\text{bin}} \) (lower panel) decreases rapidly with decreasing \( Z_{\text{bound}} \) to become hardly discernible in the experimental spectra with \( Z_{\text{bin}} \geq 30 \).

A further insight into the interplay of pre-equilibrium and equilibrium phenomena, as evidenced by light charged particles, will be gained in the \( ^{12}\text{C} + ^{197}\text{Au} \) studies at 1 and 2 GeV/u with the INDRA multidetector, scheduled for February - March 1999.


* This work was supported in part by the Scientific and Technological Cooperation Joint Project with Germany for the years 1997-2000 ("Elementary Reactions", FKZ - Nr: POL - 196 - 96)
1.3 Upgrading of the ALADIN Spectrometer Detecting System for Experiments in the Collaboration Long-Term Research Program

by A. Bietikowski, U. Lynen\textsuperscript{1}, W. F. J. Müller\textsuperscript{11}, A. Trzcinski and B. Zieliński, for the ALADIN Collaboration at GSI-Darmstadt

An upgrade of the ionisation chamber MUSIC-III aimed at improving Z resolution and fragment trajectory reconstruction is underway. For the latter purpose it appeared mandatory to improve on precision of the y-coordinate determination, the function fulfilled by the proportional counters installed in the device. Till now a prototype of the new proportional counter has been built and tested, demonstrating improved position resolution. Moreover, an effort to improve and simplify the associated electronic chains is pursued. The latter two goals will be achieved by replacing the previously used charge-sensitive preamplifiers with the current-sensitive ones. They will provide signals of the proper shape and magnitude to be fed directly into flash-ADCs, thus avoiding the need for shaping amplifiers as an intermediate amplification stage. Also the foreseen application of twisted-pair cables, instead of the coaxial ones, is expected to cut substantially on the cabling costs.

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A prototype of low-noise, current-sensitive preamplifier, based on best current-feedback operational amplifiers available on the market, has been built and successfully tested. It employs three amplification stages. The second and third stage provide preamp output signals differing in amplitude by a factor of 8. This permits to cover with two flash-ADCs, the entire fragment Z range from 2 to 82, occurring in multifragmentation. A single integrating RC filter is inserted between the input and the second amplification stage for pulse shaping. Because of a direct galvanic coupling used between the input and the outputs, the preamp demonstrates remarkably short double-pulse resolution time. This feature is vital to resolve two fragments widely differing in Z, emitted in the same event. Some of its characteristics have already been tested. As an example, Fig. 1 presents full width at half maximum of the output noise as a function of ambient temperature.

The question of limiting excitation energy above which thermalization ceases to be seen, posed in the previous research note, will benefit from the study of neutrons emitted by the target residue. An obvious advantage of neutrons is in that their low energy part, which carries the thermalization signature, is not distorted by energy losses in a target material. Moreover, neutrons are more abundantly produced, because of the target N/Z, making them apparently a more sensitive probe than protons. In the planned experiment peripheral to semicentral \( ^{197}\text{Au} + ^{197}\text{Au} \) collisions will be studied at 600 and 1000 MeV/u. Excitation energy of the residue will be tagged with the aid of Z\(_{\text{bott}}\), lc\(_j\) of the coincident projectile fragments, detected with the ALADIN spectrometer, whose detection performance will be upgraded taking advantage of the measures described above. Two conceivable systems are treated as alternatives for the coincident neutron detection: a large-volume Gd-loaded liquid scintillation detector ("Neutron Ball") and the multidetector DEMON, consisting of 96 separate organic liquid scintillators.

\textbf{Fig. 1} Full-width at half-maximum (FWHM) of the output noise spectrum as a function of ambient temperature for the preamp prototype.

\textbf{Fig. 2} Number of neutrons balance for the "Neutron Ball". The meaning of different curves is explained in the insert. Arrows mark the position of the group of resonances in the \( ^{12}\text{C}(n,a)^{10}\text{Be} \) reaction, centred at \( E_\text{n} \approx 9 \text{ MeV} \).
A Monte-Carlo code, dubbed MSX, has been written to perform a comparative study of these two systems, aimed to select the more suitable from the point of view of the above application. The novel feature, employed for the first time in MSX, is a recursive calling of the tracking subroutine. This resulted in a substantially improved tracking efficiency, permitting to include into simulations many effects not covered by the concurrent code DENIS [1] and its later modifications, introduced in several intermediate energy heavy ion laboratories. In particular, a simultaneous tracking of two and more neutrons produced in the n+^{12}C interaction, an exact sampling of the radiative capture cross sections in the relevant energy range and gamma-ray cascades in ^{156,158}\text{Gd} have been implemented. Last but not least, a simulation of the scintillation light transport, the stage entirely missing from DENIS, has been incorporated into MSX. The latter permits to evaluate the detector performance in regimes utilising the full amplitude information carried by the prompt and the delayed signals. A detailed account of the physics input, the principle of recursive calling and many results of simulations for the "Neutron Ball" which fulfils constraints imposed by the existing ALADIN instrumentation are contained in [2]. Fig. 2 presents neutron capture efficiency as a function of neutron energy for this detector.


* This work was supported in part by the Scientific and Technological Cooperation Joint Project with Germany for the years 1997-2000 ("Elementary Reactions", FKZ - Nr: POL - 196 - 96).

1.4 Coherent \pi^+ Production in the ^{12}\text{C}(^{3}\text{He},t) Reaction at an Incident Energy of 2.0 GeV

by W. Augustyniak and P. Żuprański for the SPESIV-II Collaboration

Charge exchange reactions have proved to be the a particularly useful tool in the investigation of the nuclear response in the A resonance energy region. In contrast to pion and electron probes, inclusive (p,n) and \(^{3}\text{He},t\) reactions display a universal downward shift of the A peak on all targets. It is now generally accepted that only a fraction of that shift can be attributed to a collective softening of the response due to the residual \(\Delta - \text{hole attraction}\) in the spin longitudinal channel. An exclusive \(^{12}\text{C}(^{3}\text{He},t)\) experiment performed at Laboratory National Saturne in Saclay at an incident \(^{3}\text{He}\) energy of 2.0 GeV has shed new light on this issue. In the experiment the decay products were measured in coincidence with momentum analysed tritons. Particular attention was paid to the decay channel in which a single pion is emitted and the nucleus remains in its ground state. This channel, producing the so called "coherent pions", has been found theoretically to be most sensitive to the collective softening of the response.

The pion momentum and emission angle were measured in a magnetic spectrometer consisting of two multiwire proportional chambers and a scintillation hodoscope placed in a magnetic field. The energy and momentum transferred to the target, \((\omega, \vec{q})\) were obtained from the triton emission angle and momentum. The excitation energy of the residual \(^{12}\text{C}\) nucleus was measured with an resolution (FWHM) of 4.7 MeV. The \(^{12}\text{C}\) excitation energy spectrum is dominated by the \(^{12}\text{C}\) ground state, contributing by more than 90% to the spectrum. The angular distribution of pions leaving the residual nucleus in its ground state shows a correlation with the transferred momentum \(\vec{q}\). For the spin longitudinal channel the \(\Delta\) excitation is proportional to \(\vec{S} \cdot \vec{q}\), where \(\vec{S}\) is the \(\Delta - N\) spin transition operator, while the \(\Delta\) decay has a structure \(\vec{S}^+ \cdot \vec{p}_x\) In consequence, the longitudinal cross section for the coherent pion production will be characterised by a \((\vec{p}_x \cdot \vec{q})\) dependence on the momentum vectors. The width of the angular distribution gives a measure of the longitudinal to transverse ratio [1] of the cross sections. The measured angular distribution exhibits a strong peaking of coherent pions along the momentum transfer.

The width of the distribution depends on the energy transfer and amounts to \((32 \pm 2)\) FWHM for \(\omega = (215 \pm 15)\) MeV and \((20 \pm 1)\) FWHM for \(\omega = (295 \pm 15)\) MeV.
The spectrum of the transferred energy corresponding to the coherent pion emission exhibits a peak shifted by 30 MeV below the peak position in the inclusive channel. This is a clear evidence for an $\Delta-\text{hole}$ attraction in the spin longitudinal channel.


1.5 Coupled-Channels Analysis of $^6$He + $^4$He Elastic Scattering at 151 MeV
by K. Rusek and K. Kemper

Analysis of elastic scattering of the radioactive $^6$He beam from $^4$He target measured recently at energy of 151 MeV in Dubna [1] provided empirical evidence for the "di-neutron" configuration in $^6$He nucleus. This neutron rich nucleus has much in common with the loosely bound $^6$Li. If the main component of the $^6$He ground state wave function corresponds to the cluster $\alpha + \text{"dineutron"}$ configuration, similar to the well known $^6$Li = $\alpha + d$ cluster structure, the sequential and direct breakup of $^6$He could considerably affect elastic scattering as it was found for $^6$Li [2].

In this contribution we report on results of coupled-channels (CC) calculations for $^6$He + $^4$He elastic scattering at 151 MeV. The calculations are based on our experience with $^6$Li + $^4$He system [3]. The aim of the calculations is to test the extent to which a simple two-body $\alpha + \text{"dineutron"}$ model of $^6$He, analogous to the previously used $\alpha + d$ model of $^6$Li, could account for experimental results. The nucleus $^6$He is assumed to have a two-body cluster $\alpha + \text{"dineutron"}$ structure with the spin of the "dineutron" cluster set to $s = 0$. The geometry of the Woods-Saxon potential between the clusters is taken to be the same as was previously used for $^6$Li = $\alpha + d$ [4]. In the calculations performed by means of coupled-discretized-continuum-channels method [5], couplings to the $2^+$ resonance an excitation energy of 1.80 MeV as well as to the non-resonant continuum are taken into account. All the central and coupling potentials used in the calculations are derived from $\alpha - ^4$He and "dineutron" - $^4$He potentials by means of single-folding method. The $\alpha - ^4$He potential is purely real while the parameters of the "dineutron" - $^4$He real potential are assumed to be the same as for $d - ^4$He [6]. Moreover a small imaginary part is added to this potential with the depth of $W = 2.5$ MeV and the geometry as for the real part. The calculations are performed using version FRXP-15 of the coupled-reaction channels code FRESCO [5].

The results of the Optical Model (OM) calculations with the $^6$He - $^4$He central potential consisting of the real part predicted by the single-folding model and the imaginary part taken from Ref. [1] are plotted by the dashed curve in Figure 1. The calculations describe the forward angle scattering data but generate too small values of the differential cross section at scattering angles larger than 125 degrees. These large empirical values were interpreted by Ter-Akopian et al. [1] as a contribution from a two-neutron exchange process, indistinguishable experimentally from the elastic scattering.

CC calculations with the central and coupling potentials derived from single folding model reproduce forward angles scattering data as well as the OM but in addition predict a rise of the $^6$He + $^4$He elastic scattering differential cross section at backward angles. This rise emerges mainly from coupling to the L = 2 breakup states.

Concluding, the present analysis of $^6$He + $^4$He elastic scattering data supports a suggestion of Ter-Akopian et al. [1], that the experimental data can be described in terms of a simple two-body model of $^6$He. However, a two-neutron exchange process may have a much smaller contribution to the $^6$He + $^4$He elastic scattering.
1.6 Elastic and Inelastic Scattering of $^{12}$C ions by $^{9}$Be Nuclei at $E^{(12C)} = 65$ MeV


The angular distributions of elastic and inelastic scattering of $^{12}$C from $^{9}$Be nuclei were measured on the Kiev (INR) cyclotron U-240 at the energy of 65 MeV. The transitions to the ground and 1.68 MeV (1/2$^+$), 2.429 MeV (5/2$^-$), 2.8 MeV (1/2$^+$) + 3.06 MeV (5/2$^-$), 4.7 MeV (3/2$^-$), 6.8 MeV (7/2$^-$) excited states of $^{9}$Be nucleus and to the ground and 4.439 MeV (2$^-$), 7.654 MeV (0$^+$), 9.641 MeV (3$^-$), 10.84 MeV (1$^-$), 11.83 MeV (2$^+$), 12.71 MeV (1$^-$), 13.35 MeV (2$^+$), 14.08 MeV (4$^+$), 15.11 MeV (1$^+$), 16.107 MeV (2$^+$), 16.58 MeV (2$^-$) excited states of $^{12}$C nucleus were investigated. The experimental data were analysed within the optical - and coupled-reaction-channels (CRC) models. The elastic transfers were included in the coupling scheme. The strong coupled-channels effects were observed and deformation parameters for the $^{9}$Be and $^{12}$C nuclei obtained. Good agreement between measured and calculated cross sections was achieved.

As an example the measured angular distributions of the differential cross section for elastic and inelastic $^{9}$Be($^{12}$C,$^{12}$C)$^{9}$Be* scattering are compared to the CRC calculations in Figure 1.

Fig.1 Results of CRC calculation compared to the experimental data for elastic and inelastic scattering of $^{12}$C + $^{9}$Be.
1.7 Sum Rule Analysis of Low Energy Direct Reactions
by A. Marcinkowski and B. Mariański

Analysis of inclusive nonelastic nucleon emission is usually described as an onestep direct (1SD) reaction followed by gradual absorption of the remaining flux into the quasibound particle-hole states of the multistep compound reaction chain. This approach is conceptually inconsistent, although quantitatively the 1SD reaction cross sections together with the cross sections of the one-phonon direct reactions to the collective states describe adequately the nucleon emission spectra and angular distributions at higher outgoing energies. We have presented a sum rule analysis of the cross sections calculated in the framework of the practicable version [1] of the quantal theory of Feshbach, Kerman and Koonin which shows that the experimental data cannot be explained by onestep direct reactions only. The calculated 1SD cross sections for incoherent population of the particle-hole states were found to exceed the limits of the multipole energy-weighted sum rules (EWSR’s) the more the higher the projectile energy is. The figures in Table 1 show that the cross sections for transferred orbital angular moment \( L = 1, 2, 3 \) and \( 4 \) cannot be absorbed within the uncertainty of the EWSR’s limits and therefore must be to a large extent due to multistep reactions. We concluded that in neutron scattering on \(^{93}\text{Nb}\) the contribution of the incoherent multistep direct reactions exceeds one half of the mainly coherent onephonon cross section to the collective states already at an incident neutron energy as low as 20 MeV and further increases with energy [2]. The multistep direct reactions are mainly two step although the contribution of threestep direct processes is not negligible [3]. This finding reconciles at least qualitatively the contradiction between the calculated “1SD” reactions and the multistep compound absorption.


Table 1 The excess \( F_L \) of the 1SD-\( L \) cross sections calculated according to refs. [1,2] in terms of the EWSR’s limits for different multipolarity \( \lambda=L \) and projectile energy.

<table>
<thead>
<tr>
<th>( ^{93}\text{Nb}(n,xn) )</th>
<th>projectile energy</th>
<th>20 MeV</th>
<th>26 MeV</th>
<th>32 MeV</th>
</tr>
</thead>
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<td>( \lambda^* )</td>
<td>( \sigma_{1SD} )</td>
<td>( F_L )</td>
<td>( \sigma_{1SD} )</td>
<td>( F_L )</td>
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</tr>
</tbody>
</table>
1.8 Structural model of the $\text{U}_3\text{O}_7$ polymorphs
by L. Nowicki, A. Turos, F. Garrido$^1$ and L. Thome$^1$

Due to technological and ecological reasons the oxidation mechanism of uranium dioxide ($\text{UO}_2$), a material currently used as a nuclear fuel, is an important research object. Recently our activity was focused on elaboration of a crystallographic model of oxygen-excess structural derivatives of $\text{UO}_2$.

The cubic (fluorite-type) structure of $\text{UO}_2$ reveals a peculiar ability to accommodate a quite large amount of extra oxygen atoms: several oxygen-excess crystalline modifications based on the matrix structure have been reported [1]. They are known as polymorphs of the $\text{U}_4\text{O}_9$ and $\text{U}_3\text{O}_7$ oxides. Their structures can be briefly described as $\text{UO}_2$ matrix lattice enriched with large amount (up to 19%) of extra oxygen atoms. Due to this oxygen excess the fluorite-type matrix lattice is altered. For $N_0/N_U$ concentration ratio lower than 2.25 the lattice is contracted while the higher excess of oxygen results in transformation of the cubic lattice to tetragonal or monoclinic system. This fact is illustrated in Fig.1, where the $a$ and $c$ lattice parameters are plotted as a function of the $N_0/N_U$ ratio.

![Fig.1 Lattice parameters $a$ and $c$ as a function of $N_0/N_U$ concentration ratio in oxygen-excess derivatives of $\text{UO}_2$ according to experimental data published in refs. [2],[3] and [4]. Greek letters denote $\text{U}_4\text{O}_9$ polymorphs (as listed in ref. [1]).](image)

For elucidation of the changes presented in Fig.1 a structural model of $\text{U}_3\text{O}_7$ oxide was elaborated. The model is based on the concept of cuboctahedral clusters formation [5]. A single cuboctahedral cluster (shown in Fig.2) contains five excess oxygen atoms: large concentration of clusters explains well the $N_0/N_U = 7:3$ stoichiometry. The defects are spatially arranged due to their mutual Coulomb interaction and due to the interaction of them with uranium and oxygen ions of the matrix structure. High concentration of the defects and their various arrangements explain the tetragonal and monoclinic deformations of the structure typical for the described crystals.


1$^1$ Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, CNRS-IN2P3, Orsay, France
1.9 Low Temperature Transformations of Defects in GaAs and AlGaAs
by A.Turos, A.Stonert, B.Breeger, E.Wendler, W.Wesch, and R.Fromknecht

Defect recovery in GaAs and AlGaAs is principally governed by two annealing stages occurring at 235 K and 280 K that are attributed to the defect mobility in the Ga(Al) sublattice. To elucidate to what extent the defect clustering can suppress the damage recovery, GaAs single crystals and AlGaAs epitaxial layers were implanted at 77 K with 150 keV N- and Se-ions to fluences ranging from $5 \times 10^{13}$ to $2 \times 10^{14}$ at/cm$^2$. Implanted crystals were analyzed in situ using the RBS/channeling technique. Successive measurements were performed during warming up of the sample to room temperature.

A summary of these experiments is presented in Fig. 1, where the normalized defect content $N(T)/N_0$ is plotted vs. temperature; $N$ is the integral over a selected defect profile, and $N_0$ is that for the as implanted crystal. The principal damage recovery occurred in both cases in the stage II, i.e. at temperatures in vicinity of 290 K. What is surprising, is that even for such large defect concentrations (≥50 at.%) the low defect mobility at 77 K almost completely precluded formation of clusters and extended defects. For crystals that were driven amorphous, the amorphized region remained unchanged upon warming up. Defect annealing occurred only in the tail region of the defect distribution.

The results of the similar experiments performed for AlGaAs epitaxial layers confirmed the well known fact that the regrowth of amorphized III-V compounds is difficult. At such low temperatures only part of defect distribution that contains remnants of the crystalline structure can recover at temperatures where simple defects become mobile. Besides the higher sensitivity to radiation damage of GaAs, no important differences in the annealing behavior of the studied materials was noticed.

1.10 Multiple Ionisation in M-, N- and O-Shell in Collisions of O-, Si and S Ions with Heavy Atoms

In collisions of heavy energetic ions with atoms, due to the interaction of strong Coulomb field of projectile with target electrons, more than one electron can be ejected. Such multiple ionisation, by reducing a nuclear charge screening, leads to occurring of the satellite transitions in emitted x-ray spectra. Consequently, the structure of the satellite transitions contains information on a degree of multiple ionisation in different atomic shells and by applying high resolution x-ray spectroscopy the ionisation probabilities can be measured.

We demonstrate that almost the same information on the ionisation probabilities in outer shells can be obtained by using conventional Si(Li) detectors. This can be done by including the multiple ionisation effects in fitting procedure [1] to resolve the measured x-ray spectra. The developed method of x-ray spectra analysis was applied to study the multiple ionisation effects in M-, N- and O-shells in collisions of O, Si and S ions with selected heavy atoms (Au, Bi, Th and U). By analysing measured $L_{\gamma}$ x-rays, the ionisation probabilities for M- and N-shell were derived.
The ionisation probabilities for O-shell were derived from the measured ratios $L_{\gamma}/L_{\alpha}$, which indicated a reduction of a degree of ionisation in O-shell, as compared to theoretical predictions. This finding indicates an importance of the solid state effect for weakly bound electrons in O-shell.

The measurements were performed at the Institute of Physics of the University Erlangen-Nürnberg. Thin (10-30μg/cm$^2$) solid targets of Au, Bi, Th, and U were bombarded by $^{16}$O$^{q+}$, $^{28}$Si$^{q+}$ and $^{32}$S$^{q+}$ (q ranged between 3 and 6) ions of energy 0.4-2.0 MeV/amu from the EN tandem accelerator.

Fig. 1 Derived ionisation probabilities for M- and N-shell in comparison with the predictions of the geometrical model using the projectile nuclear charge (dashed line) and effective projectile charge (solid line).

The measured data are compared to the ionisation probabilities for M- and N-shell (Fig. 1) at the zero impact parameter predicted by the geometrical model [2,3]. The effective projectile charges $Z_{\text{eff}}^{M,N}$ for a charge equilibrated projectile were calculated by weighting the screened charges for a given projectile charge state $Z_{\text{eq}}^{M,N}$(q) by the equilibrium charge state fractions F(q) [4]. For the studied energies the effective charge of the projectile seen by M-shell electrons is close to the projectile nuclear charge $Z_{\text{nuc}}$, whereas for N-shell it is substantially smaller.

Fig. 2 Measured $L_{\gamma}$-subshell ionisation cross sections for Au, Bi, Th and U targets bombarded by O ions normalised to the predictions of the ECPSSR theory [5]. The result are plotted versus scaled velocity. The data marked by closed symbols were obtained by applying the new fitting method, while the open symbols were obtained using standard fitting procedure.


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1.11 PIXE and TRXRF Analysis of Honey Samples


The main aim of this work was to compare the capability of the PIXE and XRF methods, for relative and quantitative measurements of honey samples and to test if the honey may be used as an bioindicator of soil or air pollution and if it is polluted, e.g. by lead. Standard PIXE and total reflection x-ray fluorescence (TRXRF) measurements were carried out. The different kinds of honey samples were collected in the period of spring-summer in two places of Poland: in the centre of Warsaw (a highly polluted region) and about 100 km east of Warsaw (a region free from industrial and transport pollution).

The PIXE and XRF measurements were performed at the Van de Graaff accelerator in the Nuclear Reaction Department of the SINS in
Warsaw and at the Holycross Cancer Center in Kielce, respectively.

The samples of honey to be analysed by PIXE and TRXRF were prepared by the same procedure. The simplest but suitable and useful procedure was used which met the requirement of the preparation of a large number of honey samples [1,2,3].

Using PIXE method the honey samples were placed in a target chamber and irradiated using 2 MeV proton beam with a diameter of 4-5 mm.

The concentrations of K, Ca, Cr, Mn, Fe, Cu, Zn and Pb in different kinds of honey samples are presented in Table 1.

The errors in the PIXE measurements were estimated to be between 15-25% and the average error of TRXRF measurements was less than 10%.

In the present work some advantage was found for the total reflection XRF method. This method does not require an expensive accelerator and also the preparation of a thin target is more simple. For the PIXE method the sample preparation takes a somewhat longer time, and also the measurement time is longer. By optimising the irradiation conditions in the PIXE method to measure certain elements and applying a special sample preparation (such as honey incineration after dehydration in an oxygen oven) the lower detection limits can be obtained. In this case the sample preparation is more complicated and the sample contamination can increase. It appears that the detection limits for the TRXRF method for most elements studied are better than for the PIXE case.

On the basis of these measurements one can point out that the honey samples collected in the centre of Warsaw (bee-hives were located 80 m from a heavy traffic street) and in a nonpolluted region have similar elemental composition. Two conclusions can be drawn: i) honey is not useful as a bioindicator of air or pollution, and ii) plants and bees purify the products from which the honey is produced. Also the content of lead, which was also the subject of our studies in the two kinds of honey samples, was below the detection limits in both applied methods.

The analysis of the honey samples indicates that the contents of trace elements were in accordance with the Polish honey standard of the Polish Committee for Standardisation (and in accordance with the European standards too).

<table>
<thead>
<tr>
<th>Method</th>
<th>K</th>
<th>Ca</th>
<th>Cr</th>
<th>Mn</th>
<th>Fe</th>
<th>Cu</th>
<th>Zn</th>
<th>As</th>
<th>Pb</th>
<th>Sn</th>
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<tbody>
<tr>
<td>Multiflower honey</td>
<td>TRXRF</td>
<td>2546</td>
<td>87.2</td>
<td>2.92</td>
<td>2.09</td>
<td>6.23</td>
<td>2.34</td>
<td>4.24</td>
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<tr>
<td>Honeydew honey</td>
<td>TRXRF</td>
<td>6798</td>
<td>243</td>
<td>3.14</td>
<td>2.50</td>
<td>18.2</td>
<td>1.47</td>
<td>4.52</td>
<td>&lt;0.1</td>
<td></td>
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<tr>
<td>Multiflower honey</td>
<td>PIXE</td>
<td>2243</td>
<td>45.0</td>
<td>2.45</td>
<td>3.98</td>
<td>4.63</td>
<td>1.12</td>
<td>2.22</td>
<td>&lt;0.1</td>
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<tr>
<td>Acacia honey</td>
<td>PIXE</td>
<td>1950</td>
<td>36.0</td>
<td>1.32</td>
<td>2.02</td>
<td>3.11</td>
<td>2.33</td>
<td>6.68</td>
<td>&lt;0.1</td>
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<tr>
<td>Buckwheat honey</td>
<td>PIXE</td>
<td>2040</td>
<td>60.0</td>
<td>1.26</td>
<td>2.51</td>
<td>6.47</td>
<td>1.85</td>
<td>3.21</td>
<td>&lt;0.1</td>
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<td>Polish honey standard PN-88/A-77626</td>
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2 Heavy Ion Laboratory, Warsaw University, 02-097 Warsaw, Poland
3 Holycross Cancer Centre, 25-734 Kielce, Poland
1.12 M-Shell X-Ray Production Cross Sections for PIXE Applications


M-shell x-ray production cross sections by protons were studied for a number of heavy elements (Ta, W, Re, Os, Ir, Pt, Au, Bi, Th) in the energy range 0.1-4.0 MeV, using thin targets [1,2].

Due to a steep dependence of x-ray detector efficiency on photon energy for low-energy x-rays, precise estimation of the detector efficiency was very crucial for accurate estimation of M-x-ray cross sections. Adopted efficiency calibration procedure [3] allowed us to estimate detector efficiency within 3-5%. Overall uncertainties of measured M$_{\alpha\beta}$, M$_{\gamma}$ and M$_{\delta\gamma}$ x-ray lines are 5-10%.

The general features of M-shell ionisation cross sections by charged particles can be derived using the first order theories of inner shell ionisation, namely the PWBA, SCA and BEA approaches. In this work the PWBA approximation will be used to establish the scaling rules for M-shell ionisation by ion impact. According to the PWBA approximation M$_i$-shell ionisation cross sections [4] are expected to scale with corresponding scaled velocity

$$\xi_{M_i} = (2/\sqrt{\theta_{M_i}}) \cdot v_1 / v_{2M_i}$$

and outer screening constant $\theta = 9E_M/Z_{2M_i}^2 R$, where $E_i$ and $Z_{2i}$ are the electron binding energy and screened target atomic number, respectively. In this formula $v_{2M_i} = (2E_M/m_i)^{1/2}$ is electron velocity in M$_i$-subshell, $m_i$ is the electron mass and R is the Rydberg constant.

The universal M-shell x-ray production cross sections shown in Fig. 1 were fitted using a simple parameterisation of the cross sections of the following form:

$$\ln \sigma_{M_{\alpha\beta}} = \sum_{k=0}^s a_k \left( \ln \xi_{M_{\alpha\beta}} \right)^k$$  \hspace{1cm} (2)

Generally, the proposed parameterisation of M-shell x-ray production cross sections allows to derive the universal empirical cross sections being accurate within ±5% for proton energies 0.1-4.0 MeV.

Observed discrepancies justify the idea of using the empirical M-x-ray production cross sections for protons qualitative PIXE analysis of heavy metals. As we mentioned already, the advantage of using M-shell x-rays in PIXE analysis due to their high x-ray production cross sections for protons, can sometimes be limited by the interference with other low-energy x-rays.

However, for selected types of samples the analysis of M-shell x-rays can substantially improve the detection limits of the PIXE method.

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Fig. 1 Measured M-x-ray production cross section for M$_{\alpha\beta}$ and M$_{\gamma}$ (left scale) and M$_{\delta\gamma}$ (right scale) transitions in studied targets exhibiting universal behaviour versus the scaled velocity $\xi_M$. The data are compared with the predictions of the ECPSSR [4], the SCA-UA [5] and the RPWBA-BC [6] calculations. Solid curve shows fitted (Eq. 2) empirical x-ray production cross section for protons.

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1.13 Investigation of Response of CR-39, PM-355, and PM-500 Types of Nuclear Track Detectors to Energetic Carbon Ions

by A. Szydłowski, T. Czyżewski, M. Jaskoła, M. Sadowski, A. Korman, J. Kędzierski and W. Kretschmer

Solid state nuclear track detectors (SSNTDs) for many years have found wide applications in the particle detection, and especially they have become very convenient tools for corpuscular diagnostic of various high-temperature plasma objects. In order to investigate detection characteristics and to take advantage of such applications for their properties thorough studies of selected types of the SSNTDs have been undertaken at the SINS [1, 2, 3]. Until now we have gathered a quite comprehensive collection of diagrams showing diameters of the track induced in the detectors by different ion species. Recently we have examined the responses of the CR-39, PM-355, and PM-500 plastic detectors to fast carbon ions of energy from 1 to 15 MeV. The carbon ions were provided by tandem accelerator operated at the Erlangen-Nurmberg University. After the irradiation those samples were etched in a 6.25 N water solution of NaOH, at a temperature of 70±1°C. The results of detailed measurements of the track diameters in CR-39, PM-355, and PM-500 detectors, as performed for carbon ions of different energies and selected values of etching times are presented in Fig. 1. Practically, there is no difference between the tracks induced in all plastics by carbon ions of equal energy, provided that they are etched under identical conditions. The observations refer, however, to relatively heavy and energetic ions only. Recently we have developed an automatic scanning system consisted of an optical microscope, CCD camera and PC computer. The operation produces a track image in which edges are bright and flat-fields are dark. In this image the etch-pits appear to be nearly uniform circular rings. The numerical code [4] makes possible the analysis of several diameters (Φ) of the same track measured in different directions. To eliminate the overlapped tracks only the tracks with Φ_{min}/Φ_{max} ≥ 0.8 are accepted. Comparison of the values of the etch-pits diameters, measured with our automated scanning system and those measured manually, showed that the average values were the same (within an experimental error limits).

![Calibration diagrams presenting track diameters as a function of particle energy and etching time for (a) CR-39, (b) PM-355, and (c) PM-500 track detectors. (*- the data for 10 hrs were obtained after the continuous etching).](image)

The diagrams of the track diameters resented in this paper as determined for the three modern SSNTDs i.e., the CR-39, PM-355, and PM-500 plastics enrich our collection of the calibration data. These data facilitate the interpretation of experimental results obtained by means of various track detectors. They also shed some new light on the processes of the track formation in different plastic materials. The computational processing of tracks registered by the modern SSNTDs is progressively developed in our laboratory.


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2) Physikalisches Institut, Universität Erlangen-Nürnberg, D-91058 Erlangen, Germany
LIST OF PUBLICATIONS

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A. Turowski, A. Stonert, B. Breger, E. Wendler, W. Wesch, and R. Fromknecht
Nucl. Instr. and Meth. B. (in press)

ION BEAM MIXING OF THE ZrO2/Fe SYSTEM
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STUDY OF MICROMECHANICAL PROPERTIES OF ION BEAM MIXED LAYERS
J. Jagiełło, G. Gawlik, A. Turowski, A. Pietkowska, D. Drzeha, L. Starewski, and M. Szwedowicz
Nucl. Instr. and Meth. B. (in press)

STRUCTURAL ANALYSIS OF Si/Fe AND Mo/Fe ION-BEAM MIXED LAYERS
J. Jagiełło, M. Kopocicz, A. Turowski, and F. Eichhorn
Nucl. Instr. and Meth. B. (in press)

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E. Kaminska, A. Piotrowska, K. Golaszewska, A. Stonert, A. Turowski, E. Dynowska, B. Misera

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A MONTE-CARLO CODE FOR NEUTRON EFFICIENCY CALCULATIONS FOR LARGE VOLUME Gd-LOADED LIQUID SCINTILLATION DETECTORS
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A. Marcinkowski, B. Mariński
Report-P1/98/01, November 1998

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Proc. MRS Fall Meeting, Boston 1997

THE CALORIC CURVE OF HOT NUCLEI
U. Lynen, A. Trzcinski, B. Zwieglinski

NUCLEAR CALORIC CURVE
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PARTICIPATION IN CONFERENCES AND WORKSHOPS

ELASTIC Recoil DETECTION WITH HEAVY ION BEAMS
A. Turos (invited talk)
Int.Conf. Accelerators and Isotopes in Science and Technology Warsaw, 2-4 February 1998

THERMALLY ACTIVATED DEFECT TRANSFORMATION IN III-V COMPOUND SEMICONDUCTORS
A. Turos, A. Stonert, B. Breeger, E. Wendler, and W. Wetsch (invited talk)
II Int. Symposium on Ion Implantation and Other Application of Ions and Electrons, Kazimierz Dolny, 19-19 June 1998

EXPERIENCE GAINED IN PRACTICAL IMPLEMENTATION OF FKK AND TUL APPROACHES
A. Marcinkowski (invited talk)
Workshop on Open Problems in Quantum – Mechanical Approaches to Multistep Direct Nuclear Reactions held at European Centre for Theoretical Studies in Nuclear Physics and Related Areas, Trento, Italy, Juny 27 – August 1, 1998

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NONEQUILIBRIUM FEATURES OF THE NUCLEAR LIQUID-GAS PHASE TRANSITION
B. Zwieglinski (invited talk)
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POLYGONISATION OF IONIC SINGLE CRYSTALS - A NEW EFFECT OF SWIFT ION BOMBARDMENT
A. Turos, L. Nowicki, F. Garrido, L. Thomé, and J. Domagala (oral)
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W.Wierzchowski, K.Wieteska, A.Turos, W.Graeff, R.Groetzschel (poster)
Int. Conf. on Semiconducting and Insulating Materials, Berkeley, Ca., USA 1-5 June 1998

DEFECT MOBILITY IN AlxGa1-xAs AT LOW TEMPERATURES
A.Turos, A.Stonert, J.Kaczanowski, R.Fromknecht, E.Wendler, and W.Wesch (poster)
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E.Kaminska, A.Piotrowska, K.Golaśewska, A.Stonert, A.Turos, E.Dynowska, E.Mizera (poster)
XXVII Int. School on Physics of Semiconducting Compounds „Jaszowiec ‘98”, Jaszowiec, 7-12 June 1998

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INVESTIGATION OF RESPONSE OF CR-39, PM-355, AND PM-500 TYPES OF NUCLEAR TRACT DETECTORS TO ENERGETIC CARBON IONS

MULTIPLE IONIZATION OF M- AND O-SHELLS IN HEAVY ATOMS BY O, SI AND S IONS

STRUCTURAL MODIFICATIONS INDUCED IN UO2 SINGLE CRYSTALS BY HIGH-ENERGY ION IRRADIATION
P.Garrido, C.Coffot, L.Thomé, L.Nowicki, A.Turos, and S.Kluemétner (poster)
Int. Conf. on Ion Beam Modification of Materials. Amsterdam, September 1998

LOW TEMPERATURE TRANSFORMATIONS OF DEFECTS IN GaAs AND AlGaAs
A.Turos, A.Stonert, R.Breeker, E.Wendler, W.Wesch, and R.Fromknecht (poster)
Int. Conf. on Ion Beam Modification of Materials. Amsterdam, September 1998

ION BEAM MIXING OF THE ZrO2/Fe SYSTEM
A.Turos, A.Stonert, R.Breeker, E.Wendler, W.Wesch, and R.Fromknecht (poster)
Int. Conf. on Ion Beam Modification of Materials. Amsterdam, September 1998

STUDY OF MICROMECHANICAL PROPERTIES OF ION BEAM MIXED LAYERS
J.Jagielski, G.Gawlik, J.Jagielski, A.Stonert, W.Matz, and R.Groetzschel (poster)
Int. Conf. on Ion Beam Modification of Materials. Amsterdam, September 1998

STRUCTURAL ANALYSIS OF Si/Fe AND Mo/Fe ION-BEAM MIXED LAYERS
J.Jagielski, M.Kopećwicz, A.Turos, and F.Eichhorn (poster)
Int. Conf. on Ion Beam Modification of Materials. Amsterdam, September 1998
WHAT IS THE ROPER RESONANCE?
H.P. Morsch and P. Żuprański (poster)
*International Conference “Baryon 98”, Bonn 1998*

COHERENT PION PRODUCTION IN CHARGE EXCHANGE REACTION WITH SPES IV-π
L. Fahri, ..., W. Augustyniak, ..., and P. Żuprański (poster)
*International Conference on Nuclear Physics INPC98, Paris 1998*

LECTURES, COURSES AND EXTERNAL SEMINARS

- Transitions of oxygen sublatice in U3O7
  L. Nowicki, April 21, UW Warsaw

- Backscattering spectrometry and channeling technique
  L. Nowicki, Oct. 13, UW Białystok

- A low noise large dynamic range current sensitive preamplifier
  A. Biełkowski, Nov. 23, Darmstadt, Gesellschaft fuer Schwerionenforschung mbH (GSI), Germany

- Particle Induced X-ray Emission (PIXE)
  M. Jaskóla, Nov 26, Erlangen, Physikalisches Institut der Universität Erlangen-Nürnberg

INTERNAL SEMINARS

- Polarization observables in intermediate energy nuclear physics
  P. Żuprański, Feb. 3, SINS Warsaw

- Nuclear halo
  K. Rusek, March 17, SINS Warsaw

- The man in the ice
  K. Rusek, April 28, SINS Warsaw

- Phase transitions in UO2 single crystals
  L. Nowicki, April, SINS Świeciek

- Fullerens and fullerites: A history of a discovery
  K. Rusek, May 19, SINS Warsaw

- Nuclear physics with polarized heavy ions
  K. Rusek, May 25, SINS Świeciek

- Borromean nuclei
  K. Rusek, June 8, Małopolska

- Multifragmentation in relativistic heavy ion collisions and nuclear liquid – gas phase transition
  B. Zwieglinski, June 8, Małopolska

- Nonequilibrium features of the nuclear liquid – gas phase transition
  B. Zwieglinski, Nov. 10, SINS Warsaw

- Study of baryon resonances with COSY 2.5 GeV protons
  P. Żuprański, June 8, Małopolska
PERSONNEL.

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Tomasz Czyżewski, Dr.
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Krzysztof Rusck, Dr.

Anna Stonert, MSc.
Jan Turkiewicz, Professor, untill July 31.
Andrzej Turos, Professor
Andrzej Trzcinski, Dr.
Bogusław Zwiegliński, Assoc. prof.
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Overview

During the last year, the activity of our department was spread over basic research in nuclear physics (standard spectroscopy, more exotic regions close to the elementary particle physics, theoretical studies of heavy ion interactions), high energy atomic physics, applications of and nuclear physics (environmental studies, effects of irradiation, ion production). Some effort was focused on teaching – actually, four Ph. D. students are working for their degrees. Some of us were involved in organisation and further activity of the "Radioactive Waste" exhibition in Swierk.

Our research is performed on our facilities (C30 cyclotron, low background detection facility), and in close co-operation with the Heavy Ion Laboratory of the Warsaw University, Jagellonian University in Cracow, Military Technical Academy in Warsaw, Institute of Electronic Technology and Materials in Warsaw and some foreign centers like GSI in Darmstadt, MPI in Heidelberg and KFA in Julich (Germany), PSI in Villigen (Switzerland), University of Notre Dame, Argonne National Lab., Lawrence Berkeley Lab. and Los Alamos National Lab. (USA).

The reader is invited to find some of our recent results on the next pages, together with a list of publications. Nevertheless some activities are worth mentioning:

Nuclear spectroscopic studies were concentrated on Z or N = 50 nuclei – determination of excited level schemes of $^{182,183}$Ir, $^{180,181,182}$Os and $^{116}$Sn and $^{132}$Ce was continued and some new effects found.

The most precise lifetime of the Λ hyperon in very heavy hypernuclei was measured (COSY#13 project). The search of muon number forbidden nuclear $\mu - e$ nuclear conversion was continued (SINDRUM II coll.).

Heavy ion interactions leading to fusion or fission processes were studied theoretically, and the experiments are in preparation.

The experimental studies of atomic effects in bare, H- and He-like very heavy atoms and X ray spectroscopy of heavy ion atomic collisions were continued at GSI and PSI.

The study of radiation-induced modification of optical properties using the C30 proton beam was found to be a very interesting subject and resulted in many publications.

A new idea of application of the artificial neural nets technique into calculations and control of the industrial exhaust gas purification systems employing electron beam irradiation has been invented and the results seem to be encouraging.

Financial support received from the State Committee for Scientific Research and Maria Skłodowska-Curie Polish-American Foundation is acknowledged.
2.1 High Resolution Study of Kα Hypersatellite Spectra of Medium Mass Atoms

High-resolution measurements of the K-hypersatellites of Kα₂ transitions were performed for zirconium, niobium, molybdenum and palladium. The x-ray spectra were induced by oxygen ions and measured with a transmission-type bent crystal spectrometer in modified DuMond slit geometry [1]. The Breit interaction, as well as the QED corrections were discussed in view of their possible effects on the energies of the Kα₂ transitions and the I(Kα₁) / I(Kα₂) intensity ratios. These effects are much stronger for the hypersatellite transitions than for the diagram lines. The experimental results are compared with the multiconfiguration Dirac-Fock (MCDF) calculations with the inclusion of the Breit interaction and QED corrections. The Breit interaction, i.e., the interaction between any two electrons due to the exchange of the single transverse photon, substantially affects the multiplet splitting of double vacancy configurations in atom [2]. The calculated relative contribution of the Breit interaction to the total energy is different for the different vacancy configurations.

The Breit interaction influences the transition energies as well as the transition probabilities.

![Fig.1 Ratio of the experimental to theoretical (ΔEexpt/ΔEmcdf) MCDF calculations energy shifts vs the atomic number for Kα2 induced by 280 MeV O.](image)

For medium-mass atoms the relative contribution of the Breit interaction to the energy shift of Kα hypersatellites was estimated to be 5-6% [3]. The QED (self-energy and vacuum polarization) corrections were estimated to be less than 0.1%.

Another test of theoretical description is the measurement of I(Kα₂)/I(Kα₁) intensity ratio. For diagram transitions the I(Kα₂)/I(Kα₁) intensity ratios are close to two and their variation with the atomic number is small, but for doubly ionized atoms the I(Kα₂)/I(Kα₁) intensity ratio varies strongly with Z. Indeed, considering light atoms where the L-S coupling is dominant, the Kα₁ spin flip transition 1S⁰ → 1P₁ is forbidden.

For that reason, this transition is strongly delayed for light atoms and the relative yields I(Kα₁)/I(Kα₂) are nearly zero. In heavy atoms, where the jj coupling is predominant, the Kα₁ transitions are no longer hindered and the intensity ratio I(Kα₁)/I(Kα₂) tends to two as in the case of the diagram transitions. For medium-mass atoms this ratio represents thus a sensitive tool to check the intermediate coupling model. The influence of the Breit interaction for the I(Kα₁)/I(Kα₂) intensity ratio is less then 0.1%, whereas for I(Kα₁)/I(Kα₂) it is about 5-6%. Our experimental results for hypersatellites are compared with the calculations with the MCDF method in fig. 1 and fig. 2. The scattering of the values is larger than that expected from the experimental uncertainties. This may suggest the presence of other effects, not included in the calculation, e.g. breaking of the atomic shell closures in M-shell ionized atoms or the role of nucleus in relaxing the L-S selection rule. In our experiments it was shown that we obtained very precise experimental results of the values energy shifts and intensity ratio of Kα hypersatellite transitions. This was possible because of the high K-shell ionization probability in collisions of high-energy heavy ions with medium Z atoms. With such good statistics our data provide a sensitive test of the MCDF calculations including the proper Breit and QED terms. We also find that the additional M-shell holes play an important role for an accurate calculation of the energies of Kα₂ transitions and the I(Kα₂)/I(Kα₁) intensity ratios. The effect of increased statistics however is partly offset by uncertainties due to the additional M-shell ionization effect. The separate experiment is planned in the near future in order to determine these values.

![Fig. 2 Ratio of the experimental to theoretical (MCDF calculations) intensity ratios I(Kα₂)/I(Kα₁) expt/ theory for 280 MeV O beam.](image)


1) University of Fribourg, Switzerland
2) University of Torun, Poland
3) Pedagogical University, Kielce, Poland
2.2 Lifetime Measurement of the High-spin States in $^{182}$Ir
by A.Wasilewski, R.Kaczarowski, E.Ruchowska, I.Ahmad$^1$, D.Blumenthal$^1$, M.P.Carpenter$^1$, B.Crowell$^2$, U.Garg$^2$, S.S.Ghugre$^2$, R.V.F.Janssens$^1$, T.L.Khoo$^1$, T.Lauritsen$^1$, S.Naguleswaran$^2$, D.Nissius$^3$

Lifetime measurements were performed using the Notre Dame "plunger" device in conjunction with the Argonne-Notre Dame Gamma-ray Facility consisting of 12 high efficiency Compton-suppressed HPGe detectors and 50 BGO detectors working as multiplicity filter. Ge detectors were placed at 34, 90 and 146 degrees relative to the beam direction. The nuclei of interest were produced in $^{15}$O$^{37}$Cl$(5n)^{183}$Ir reaction at a beam energy of 169 MeV from the Argonne Tandem Superconducting Linear Accelerator System (ATLAS). The target was enriched $^{150}$Nd (0.9 mg/cm$^2$ thick) evaporated onto stretched 1.5 mg/cm$^2$ Au foil and covered with thin (0.06 mg/cm$^2$) Au layer to prevent oxidation. Runs of approximately 3 hours were taken at 23 target-stopper distances, ranging from 20 μm to 10420 μm. The events were stored on magnetic tapes and sorted offline into individual spectra for different Ge detector angles and different target-stopper distances.

Only events with multiplicity M>5 were registered. In order to clean the $^{182}$Ir γ-spectra from γ-transitions originating from other reaction channels only events with multiplicity 6≤M≤13 are taken into account during further offline analysis. Further cleaning of the resulting spectra from γ-transitions originating from $^{183}$Ir can be done by subtracting normalized γ-spectra registered with multiplicity condition 15≤M≤25 (see Fig. 1).

2.3 Highly K-forbidden Transitions in $^{180}$Os
by E.Ruchowska, R Kaczarowski, R.M.Lieder$^1$, W.Gast$^1$, A.Georgiev$^1$, H.M.Jäger$^1$, H.J.Jensen$^1$, T.Morek$^2$, Ts. Venkova$^3$, C.Ender$^4$, T.Härtlein$^9$, D.Schwalm$^6$, G.Sletten$^5$

The decay of isomers in $^{180}$Os was investigated with use of the CLUSTER cube setup at the MPI, Heidelberg, employing recoil-shadow technique to suppress prompt (γ-radiation from the target. The experimental setup and first results were already described in refs. [1,2]. The analysis of the data on the decay of high-spin isomers in $^{180}$Os has been finished.

Most of the high K isomers preferentially decay stepwise through lower K levels in order to minimise differences in the K quantum number. The nucleus $^{180}$Os is one of the nuclides from the A=180 region in which a strongly K-violating decay mode of high spin isomers has been discovered [3]. In this mode the decay of an isomer with high K proceeds directly to the high-spin states of a low-K bands violating the K-selection rule by many orders of magnitude. In $^{180}$Os the anomalous K-forbidden transitions constitute the predominating decay paths of the 5845.1 keV K$^=$(21$^+$) isomer.

A good way to compare K-forbidden transitions in a quantitative manner is through the hindrance factor F and through the hindrance factor per degree of K-forbiddenness, $f_v$ [3]. Table 1 lists the hindrance factors F and $f_v$ for the γ-transitions deexciting the K$^=$7$^-$ isomers at 1861.8 keV and 1928.0 keV and K$^=$2(21$^+$) isomer in $^{180}$Os. In case of E1 transitions the hindrance factors F were divided by 10$^4$ to take into account the generally stronger E1 hindrance compared with the Weisskopf estimate and thus to facilitate the comparison with transitions of other multipolarities.
Table 1 Partial half-lives \(^{1}\)) and hindrance factors \(F\), degrees of K-forbiddness \(v\) and hindrance factors per degree of K-forbiddness \(f_v\) for the \(\gamma\) transitions deexciting the 7\(^+\) isomers and for the highly K-forbidden transitions deexciting the high-spin isomer in \(^{180}\)Os. In case of the E1 transitions the hindrance factors \(F\) were divided by \(10^4\).

<table>
<thead>
<tr>
<th>(E_{\nu}) (keV)</th>
<th>(K^{\pi}_{\nu})</th>
<th>Final level (E_{\nu}) (keV)</th>
<th>(\gamma)</th>
<th>Mult</th>
<th>(T_{1/2}) (ns)</th>
<th>(F)</th>
<th>(v)</th>
<th>(f_v)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1861.8</td>
<td>7</td>
<td>6(^+) (\gamma)</td>
<td>235.7</td>
<td>E1</td>
<td>183</td>
<td>1.3\times10^{-3}</td>
<td>4</td>
<td>5.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5(\beta)</td>
<td>258.0</td>
<td>E2</td>
<td>46</td>
<td>5.62</td>
<td>(2)</td>
<td>(2.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6(^{gsb})</td>
<td>483.6</td>
<td>E1</td>
<td>114</td>
<td>6.09\times10^{-3}</td>
<td>6</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6(^{gsb})</td>
<td>604.9</td>
<td>E1</td>
<td>51</td>
<td>5.32\times10^{-3}</td>
<td>6</td>
<td>4.2</td>
</tr>
<tr>
<td>1928.0</td>
<td>7</td>
<td>6(^{g})</td>
<td>(14.6)</td>
<td>(M1)</td>
<td>(7.1)\times10^{-3}</td>
<td>(1.0)\times10^{-4}</td>
<td>(0.79)</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6(^{g})</td>
<td>51.4</td>
<td>E1</td>
<td>90</td>
<td>5.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6(^{g})</td>
<td>301.2</td>
<td>E1</td>
<td>928</td>
<td>1.20\times10^{-4}</td>
<td>4</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5(\beta)</td>
<td>324.0</td>
<td>E2</td>
<td>200</td>
<td>75.9</td>
<td>(2)</td>
<td>(8.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6(^{gsb})</td>
<td>549.9</td>
<td>E1</td>
<td>761</td>
<td>5.96\times10^{-4}</td>
<td>6</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8(^{gsb})</td>
<td>671.1</td>
<td>E1</td>
<td>274</td>
<td>3.91\times10^{-4}</td>
<td>6</td>
<td>5.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6(^{gsb})</td>
<td>1133.6</td>
<td>E1</td>
<td>198</td>
<td>1.36\times10^{-3}</td>
<td>6</td>
<td>7.2</td>
</tr>
<tr>
<td>5845.1</td>
<td>(21)</td>
<td>21(^{-})</td>
<td>(800.0)</td>
<td>(M1)</td>
<td>(324)</td>
<td>(7.6)\times10^{-6}</td>
<td>(13)</td>
<td>(\leq3.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20(^{0})</td>
<td>(867.1)</td>
<td>(M1)</td>
<td>(706)</td>
<td>(2.1)\times10^{-7}</td>
<td>(13)</td>
<td>(\leq3.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20(^{0})</td>
<td>(1025.4)</td>
<td>(M1)</td>
<td>(1500)</td>
<td>(7.4)\times10^{-7}</td>
<td>(20)</td>
<td>(\leq2.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19(^{-})</td>
<td>(1076.4)</td>
<td>(M1)</td>
<td>(222)</td>
<td>(1.3)\times10^{-7}</td>
<td>(17)</td>
<td>(\leq2.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19(^{0})</td>
<td>(1195.6)</td>
<td>(M1)</td>
<td>(343)</td>
<td>(2.7)\times10^{-7}</td>
<td>(13)</td>
<td>(\leq3.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20(^{0})</td>
<td>(1304.9)</td>
<td>(M1)</td>
<td>(444)</td>
<td>(4.5)\times10^{-7}</td>
<td>(20)</td>
<td>(\leq2.4)</td>
</tr>
</tbody>
</table>

Only two direct decay branches were observed in case of the high-spin isomer at 5845.1 keV. The isomer deexcites via a 286.1 keV transition to a level, which is subsequently depopulated through the 1425.7 and 739.0 keV transitions to the 18\(^{g}\) and 20\(^{g}\) levels of the yrast band. In the decay of this isomer the yrast band and \((-1)_{1g}, (-1)_{2g}, (-1)_{1h}, (-1)_{1h}\) and \((-1)_{1h}\) bands are also populated. However, the decay paths to these bands are too weak to be established within statistics of our experiment. In Table 1 hindrance factors are given for the 286.1 keV transition deduced assuming E2 multipolarity and \(K=0\) for the final level. For the unobserved decay paths leading to each of the rotational bands the upper limits for hindrance factors are given. They were calculated assuming that the deexcitation to each band proceeds via one transition with a \(\gamma\) ray energy equal to the energy difference between the isomer and the highest observed level of the band and with intensity equal to the \(\gamma\) ray feeding of this level. The highest of the values obtained for the E1, E2 and M1 multipolarities were chosen as the upper limits.

For all decay branches of the high-spin isomer the values of hindrance factors \(f_v\) are very small, lower than 4, indicating that the decay of this isomer is another example of nearly unhindered K-isomeric decay.

References:

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5) Niels Bohr Institute, Copenhagen, Denmark
2.4 High Spin States in $^{110}$Sn


A $^{110}$Sn isotope is one of the nuclei in which high-spin, rotational-like intruder band has been observed [1,2]. It is likely that this band results from the excitation of a proton pair through the closed major shell. The levels in the intruder band with spins ranging from $(12^+$) to $(20^+)$ are connected by stretched E2 transitions. The lowest state of the band decays to the $10^+_2$ presumably spherical ($h_{11/2}^2$) state. The consecutive decay of the latter state is complex and up to now not yet firmly established.

To resolve ambiguities concerned with the level scheme of $^{110}$Sn, an experiment was carried out at the Heavy Ion Laboratory in Warsaw. High spin states in $^{110}$Sn were populated in the $^{98}$Mo($^{16}$O,4n)$_{110}$Sn reaction at beam energy of 80 MeV. The $^{16}$O beam was provided by the U200P cyclotron. The target was enriched to 92%, 5 mg/cm$^2$ thick Mo foil. The $\gamma$-$\gamma$ coincidence events were measured with the use of the OSIRIS multidetector array which comprised six Compton-suppressed HP Ge detectors and one four-sector Compton polarimeter. The detectors were placed at 25, 90 and 65 degrees with respect to the beam direction. The $\gamma$-$\gamma$ coincidence data were acquired by the SMAN acquisition system. Data were collected in the list-mode and sorted off-line into several $\gamma$-$\gamma$ matrices. Unfortunately the statistics of our experiment appeared to be too low to resolve all existing ambiguities in the $^{110}$Sn level scheme. The $\gamma$-$\gamma$ coincidence matrix contained only 5 millions events. The deduced level scheme (see Fig. 1) generally is in agreement with level schemes published previously [1,2]. Further measurements are planned to obtain complete $^{110}$Sn level scheme and to gain further insight into the intruder band phenomenon.


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4) Institut für Kernphysik, Forschungszentrum Jülich, Germany
5) Heavy Ion Laboratory, Warsaw University, Warsaw, Poland

2.5 The DCO Measurements in $^{183}$Ir


The properties of the high spin states of the $^{183}$Ir nucleus have been investigated using the Argonne-Notre Dame Gamma-ray Facility at ANL in Argonne. Twelve Ge detectors, placed at angles of $\pm34.5^\circ$, $\pm90^\circ$ and $\pm145.5^\circ$ with respect to the beam direction, were used for data collection (see ref.[1]). The DCO (directional correlation from oriented states) analysis has been performed to determine the multipolarities of observed $\gamma$ transitions. Two $\gamma$-$\gamma$ coincidence matrices nf and nb, (where f, n and b denote detectors at angles 34.5°, 90°, 145.5°, respectively) have been used in order to deduce the DCO ratios for several $\gamma$ transition. The DCO ratios were defined as $R=I_f/I_n$. Here $I_f$ denotes the intensity of transition of interest measured at angle of 34.5° or 145.5° gated by stretched E2 transition registered at 90° and $I_n$ is intensity obtained when angles of measured and gating E2 transitions are
reversed. Unfortunately, only total efficiency of the whole detector system has been measured. In consequence, peak areas have been used instead of transition intensities and results have been normalised in order to obtain $R=1.0$ for known stretched E2 transitions. The above procedure increases uncertainty of $R$ by $\leq 6\%$ for the yrast band transitions and by $\leq 15\%$ for transitions in $[402]5/2^+$ band.

The average DCO values extracted from two coincidence matrices are listed in Tables 1 and 2. To improve statistics, sums of the coincident spectra gated by the E2 transitions from the ground state and the positive parity bands have been used in analysis.

Our results suggest E2 character for the 997.5 and 1351 keV transitions deexciting 2974.5 and 2269 keV levels, respectively. Therefore spin and parity of $I=25/2^+$ has been tentatively assigned to the first level and of $I=33/2^+$ to the second one.

The multipolarity E1 has been assigned based on the systematic [2,3] to the transition 307.0 keV deexciting the $[402]5/2^+$ level to the g.s.b. The DCO ratio for this transition is equal to 0.8±0.1. The values of R calculated for $\Delta I=1$ in-band transitions in the positive parity $[402]5/2^+$ band vary from 0.4±0.1 (probably pure M1) to 0.8±0.2 (strong E2/M1 mixing).

Table 1 DCO ratio for γ-transitions in $^{183}$Ir (gates on g.s.b. transitions)

<table>
<thead>
<tr>
<th>$E_\gamma$ [keV]</th>
<th>$R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>253.6</td>
<td>0.73(8)</td>
</tr>
<tr>
<td>267.5</td>
<td>0.70(25)</td>
</tr>
<tr>
<td>283.1</td>
<td>0.61(7)</td>
</tr>
<tr>
<td>296.9</td>
<td>0.78(10)</td>
</tr>
<tr>
<td>332.0</td>
<td>0.56(6)</td>
</tr>
<tr>
<td>337.1</td>
<td>0.76(10)</td>
</tr>
<tr>
<td>628.5</td>
<td>0.41(7)</td>
</tr>
<tr>
<td>668.4</td>
<td>0.71(8)</td>
</tr>
<tr>
<td>816.2</td>
<td>1.19(17)</td>
</tr>
<tr>
<td>895.5</td>
<td>0.39(8)</td>
</tr>
<tr>
<td>997.5</td>
<td>1.12(15)</td>
</tr>
<tr>
<td>1050.2*$</td>
<td>1.37(33)</td>
</tr>
<tr>
<td>1053.2*$</td>
<td>0.87(28)</td>
</tr>
<tr>
<td>1351.0</td>
<td>1.12(17)</td>
</tr>
</tbody>
</table>

*Unresolved doubled

Table 2 DCO ratio for γ-transitions in $^{183}$Ir in 5/2$^+$ band.

<table>
<thead>
<tr>
<th>$E_\gamma$ [keV]</th>
<th>$R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>307.0</td>
<td>0.79(11)</td>
</tr>
<tr>
<td>129.7</td>
<td>0.41(10)</td>
</tr>
<tr>
<td>152.9</td>
<td>0.53(16)</td>
</tr>
<tr>
<td>172.8</td>
<td>0.51(10)</td>
</tr>
<tr>
<td>190.4</td>
<td>0.63(12)</td>
</tr>
<tr>
<td>202.1</td>
<td>0.60(11)</td>
</tr>
<tr>
<td>213.5</td>
<td>0.77(14)</td>
</tr>
<tr>
<td>215.0</td>
<td>0.58(12)</td>
</tr>
<tr>
<td>225.5</td>
<td>0.62(10) *</td>
</tr>
<tr>
<td>225.8</td>
<td>0.80(16) *</td>
</tr>
<tr>
<td>246.3</td>
<td>0.77(19) *</td>
</tr>
<tr>
<td>246.6</td>
<td>0.76(18) *</td>
</tr>
<tr>
<td>272.1</td>
<td>0.56(14) *</td>
</tr>
</tbody>
</table>

* For single E2 gates.

2.6 Determination of the $\Lambda$ Lifetime in Hypernuclei Produced in the 1.9 GeV p + Bi Reaction

by I. Zychor for the COSY-13 Collaboration (Jülich)

The lifetime of the heavy $\Lambda$ hypernuclei was measured by the observation of delayed fission using the recoil shadow method in the p + Bi reaction. The measurements were performed at 1.9 GeV proton energy and the background was determined at 1.0 GeV. From the distribution of the fission fragments in the shadow region the lifetime

$$\tau = [161 \pm 7 \text{ (statist.)} \pm 14 \text{ (system.)}] \text{ ps}$$

was obtained.
measured 146 events. In the wire range from 41 to 54 we have recorded 1418 events at 1.9 GeV and 140 events at 1.0 GeV. This gives a statistical error in the lifetime determination equal to 7 ps.

The shape of the drop-off around the shadow edge is predominantly caused by absorption of fission fragments in the target and by small–angle scattering of fission fragments in a window foil at the bottom of the experimental chamber. These effects were simulated assuming a Gauss distribution with $\sigma_{\text{Gauss}}$ as parameter. The parameter was varied until the drop-off curve (dashed line in Fig. 1) fitted the data points. The target deformation was a parameter in our lifetime calculations and it was assumed that the lower edge of the target was shifted up to 0.4 mm in the direction of the proton beam.

The following contributions were included to the systematic error of the lifetime:

- target deformation: 2 ps,
- different wire ranges: 3 ps,
- small angle scattering described by the Gauss distribution: 5 ps,
- the error of measured lengths and distances in the experimental set up (e.g. a target length, a distance from the detectors to the shadow edge etc.): 6 ps,
- uncertainty in the recoil momentum distribution and its modification caused by the absorption in the target: 8 ps,
- uncertainty where the COSY protons hit the target in vertical direction: 6 ps,
- four different cuts in the event selection during the track reconstruction for 1 $\sigma$, 1.5 $\sigma$, 2 $\sigma$ and 3 $\sigma$ values for both horizontal (x and y) directions: 2 ps,
- normalizing and shifting of spectra from different runs: 1 ps.

Assuming independent contributions from different errors we get a total systematic error equal to 14 ps.

![Fig. 1](image-url)

**Fig. 1.** The experimental points shown for channels = 54 (the shadow region) were obtained by subtracting the normalized background measured at 1.0 GeV. The full line presents the result of the fit of delayed fission fragments for a hypernucleus lifetime of 161 ps. The dashed line is the distribution of prompt fission events modelled taking into consideration absorption and scattering of fission fragments in the target and in window foils. The abscissa is the distance (in 1 mm wide channels) along the lower MWPC, parallel to the COSY beam direction.

2.7 Influence of the Background Shape on Hypernucleus Lifetime Measured in the 1.9 GeV p + Bi Reaction

by I. Zychor for the COSY-13 Collaboration (Jülich)

The background in the COSY-13 experiments, using the recoil shadow technique, is measured at 1.0 GeV proton energy. At this energy hypernucleus production in reactions induced on heavy targets is very small.

After normalization of the 1.0 GeV spectrum to the 1.9 GeV in the plateau region (for wire numbers > 70) the background was subtracted from the 1.9 GeV spectrum in the shadow region (< 55). The lifetime $\tau$ of the $\Lambda$ hyperon was then obtained from a fit to the number of net events in the shadow region. It was found to be equal to

$$\tau = [161 \pm 7 \, \text{(statist.)} \pm 14 \, \text{(system.)}] \, \text{ps}.$$
For different shapes of the "step background" (in steps of 10 wires) we have got the lifetime values from 156 to 161 ps.

So, the largest difference between lifetime values obtained for different shapes of included background is 12 ps, then it differs less than 7.5% from the value obtained with normalized background subtracted wire by wire.

For calculations with the constant background the total number of counts in wire range from 1 to 54 was used as a parameter changing from 5.4 (0.1 count/wire) up to 54 (1 count/wire) events. The lifetime decreases with the increasing number of subtracted background counts from 158 to 149 ps.

2.8 Feynman's Ratchet and Pawl: an Exactly Solvable Model
by C.Jarzynski\textsuperscript{1}, O.Mazonka

Feynman's ratchet and pawl system [1] is a well known (but not the earliest! [2]) example of a proposed "mechanical Maxwell's demon", a device whose purpose is to convert into useful work the thermal motions present in a heat reservoir.

Since the failure of the ratchet and pawl system to perform work arises from thermal fluctuations of the pawl, a natural solution to the problem is to reduce these fluctuations by externally cooling the pawl to a temperature below that of the gas. In this case the device does indeed operate as designed, but this no longer constitutes a violation of the Second Law: the ratchet and pawl is now effectively a microscopic heat engine, capitalizing on a temperature difference to extract useful work from thermal motions. While the ratchet and pawl was introduced in Feynman's Lectures primarily for pedagogical purposes, recent years have seen a renewed interest in this system [3], largely due to the fact that analogous mechanisms have been proposed as simple models of motor proteins.

We would like to introduce an exactly solvable model of Feynman's microscopic heat engine. This model is discrete rather than continuous, but it captures two essential features of the original example: (1) a periodic but asymmetric interaction potential between the ratchet and the pawl corresponding to an asymmetric sawtooth shape for the ratchet's teeth, and (2) two "modes" of interaction corresponding to the pawl being either engaged or disengaged from the ratchet.

Consider a particle which moves via discrete jumps between neighboring sites along a one-dimensional regular lattice. We assume that the particle is coupled to a heat reservoir at temperature $T_B$, and that its jumps are thermal in nature. Next, we assume that the potential energy function has two possible modes, and that it changes stochastically...
between these two. In the first mode, the potential energy of each site is zero. In the second mode, the potential energy is periodic, with period 3. The second mode is a discrete version of an asymmetric sawtooth potential. We assume that the stochastic process governing the changes between modes is also a thermal process, driven by a heat reservoir at temperature $T_A$. So there are altogether 6 possible states of the system.

Two stochastic processes are involved into the dynamics, the one governing the jumps of the particle, the other governing the change between modes. We assume that the processes are independent of one another, and that each is a Poisson process occurring at a rate $P$. The Metropolis algorithm [4] is used to satisfy detailed balance: the attempt is either accepted or rejected according to the Metropolis weights (at temperature $T_A$).

Given this model, we would like to know whether a current arises: in the long run, will there be a net drift of the particle — corresponding to a non-zero angular velocity of the wheel in the original ratchet and pawl — and if so, what will be the rate and direction of the drift?

Let $p_n$ denote the probability that the system is found in state $n$ at time $t$. Then the evolution of these probabilities is governed by the following set of coupled equations:

$$\frac{d\bar{p}}{dt} = \Gamma \cdot R \cdot \bar{p}$$

where $\bar{p} = (p_1, ..., p_6)$ and $R$ is the transition matrix deduced from Metropolis weights. The exact solution of the equation $R\bar{p} = 0$ for the steady-state distribution can be found in terms of two temperatures. Knowing $\bar{p}$ one can easily find the net drift of the particles as well as the net rate at which the system absorbs energy from reservoir.

The presence of an external load allows the system to perform work. In Feynman's example, this load is a flea, attached by a thread to the ratchet wheel: when the wheel rotates in the appropriate direction, the creature is lifted against gravity. In our model, we add a slope to the discrete potential. Our approach to solving for the steady-state behavior is the same as before. We are interested in the quantities net drift and rate of heat flow, which describe that behavior. The only difference is in the potential changes the elements of $R$, and therefore the vector of steady-state probabilities $\bar{p}$. All the exact solutions and full analysis are given in [3].

There are two different scenarios in which our system acts as a "useful" device: (1) the system is a heat engine, causing the particle to drift up the potential energy slope; (2) the system is a refrigerator, the particle drifts down the potential slope, and the resulting energy liberated allows for a net transfer of heat from the colder to the hotter reservoir, without violating the Second Law.


2.9 In Search of an Explanation of Near-Treshold Fusion of Heavy Systems
by O.Mazonka, J.Blocki, J.Wileczynski

Energy dependence of the (fusion,xn) cross section for a heavy system $^{86}$Kr + $^{136}$Xe was measured recently by Stodel et al. [1]. Theoretical explanation of these unique data extending to the threshold energy at $E_{cm} = 195$ MeV (where the deduced fusion probability is as low as $P_{fus} = 10^{-4}$), is of great importance because extrapolation of the theoretical predictions to still heavier systems may help to optimize experiments aimed to produce new super-heavy elements in the magic region of $Z = 114$.

The near-threshold processes which occur with low probability need to be described in terms of nuclear dynamics with fluctuations. In our attempts to describe fusion of the $^{86}$Kr + $^{136}$Xe system we use the 4-dimensional configuration-space model which includes:

(i) three geometrical parameters defining the shape of the system [2] and one parameter corresponding to charge asymmetry;

(ii) the conservative driving forces calculated from the Coulomb interaction energy and the "Yukawa-plus-exponential" nuclear interaction potential [3], modulated by shell effects [4];
(iii) the one-body dissipation forces expressed by the „wall-plus-window“ formula [5];
(iv) the inertia tensor calculated with the Werner-Wheeler method;
(v) the stochastic Langevin force determined by the dissipation-fluctuation theorem. The fusion probabilities were calculated using the importance sampling method [6] which is a new, very effective tool for simulating rare processes in the Langevin dynamics.

As seen from Fig. 1, our calculations [7] show that for energies $E_{\text{cm}} > 215 \text{ MeV}$ the calculated fusion probability agrees with that deduced from the experiment. However, at lower energies, the calculated fusion probability falls much faster than observed in the experiment. Looking for possible sources of the disagreement, we considered the role of sub-barrier fusion. However estimates of the penetrability through the barrier show that the contribution of the sub-barrier fusion is negligible for such heavy systems. We plan to carefully investigate the role of fluctuations caused by the exchange of particles, not accounted for in the present calculations. (Only thermal fluctuations were applied). The non-thermal sources of fluctuations may be especially important in the near-threshold fusion, when the composite system is cold.

The non-thermal fluctuations can be viewed as arising from the fact that the number of non-interacting particles located in a region of a container is described by the binomial distribution [8]. Both the „window“ and „wall“ formulae contain the factor $p_v \Delta \sigma$ [5] which can be rewritten as $m_0 \Delta n/\Delta t$, where $m_0$ is the mass of a particle and $\Delta n$ is the average number of particles located inside the layer with the base $\Delta \sigma$ and the width $v \Delta t$. The fluctuations can be taken into account by replacing the average number of particles $\Delta n$ with the varying number $\Delta n$ taken from the Poisson distribution.

We do not exclude that apart from the magnitude and nature of fluctuations, also other constituents of the dynamical model will need to be reconsidered in order to fully understand the near-threshold fusion of heavy systems.

![Fig. 1. Experimental [1] and calculated [7] energy dependence of the fusion probability in the $^{88}\text{Kr} + ^{133}\text{Xe} \rightarrow (\text{fusion, xn})$ reaction.](image)

2.10 Studies of the Properties of Materials Using Proton Beam from Cyclotron C-30 by J. Wojtkowska

Proton beam with energy 21 MeV was used for the production of the radioactive isotope $^{172}\text{Yb}$ ($T_{1/2}=6.7d$) (via the reaction $^{172}\text{Yb}(p, n)$), in different compounds of Yb as $\text{YbBa}_2\text{Cu}_3\text{O}_7$, $\text{Yb}_3\text{Ga}_5\text{O}_{12}$ and $\text{YbNiBC}$.

Among about one hundred $\gamma$ transitions in the decay of $^{175}\text{Lu}$ to $^{175}\text{Yb}$, two cascades 91-1094 keV and 1094-79 keV, give the possibility of using $^{175}\text{Lu}$ as a PAC (perturbed angular correlation) probe for investigation of different physical properties of ytterbium compounds. In particular the $^{175}\text{Lu}$ PAC probe is applied to the studies of Yb atom charge states in solids, which are being carried out in the Institute of Physics of the Jagiellonian University in Cracow.

For about two years in collaboration with Military Technical University in Warsaw and the Institute of Electronic Technology and Materials in Warsaw the proton beam from the cyclotron has been used to study radiation induced modification of such crystals as active laser radiators and materials for optical wafers. The analysis of various observed
effects was first reported in Annual Report IPJ 1997. In 1998 this collaboration was continued and following crystals doped with rare-earth elements and metals were irradiated by 21 MeV proton beam:

- Ce:YAG, Ce:Mg:YAG, Nd:YAG, Er:YAP, Cu:LiNbO$_3$, Cr:LiNb, Cr:SrGa$_2$O$_7$, and Gd$_3$Ga$_5$O$_{12}$.

After crystals irradiation their optical properties were observed by measuring crystal transmission, luminescence and thermoluminescence spectra. Significant changes of the optical properties of the crystals were registered. The colour centres which appeared after the irradiation created additional absorption bands in the wavelength range characteristic for transitions in Ce$^{3+}$ ions (from about 250 to 1000 nm), or shift the short-wave absorption edge towards the longer wavelengths by a few hundreds nm. Also a change of the shape of luminescence spectra under proton irradiation was observed. It is due to the density change of active centres by recharging process. This change depends on a type of dopant and its concentration in crystal.

Different types of radiation can induce changes in the operation of optoelectronic devices. The influence of proton radiation on Cu:LiNbO$_3$ wafer was investigated. After material irradiation with up to $10^{14}$/cm$^2$ protons, the changes in its transmission of visible and IR light were examined as well as changes of the birefringence and its dispersion. It has been found that irradiation induces undesirable changes in the optical characteristics of investigated wafer. Thermal annealing can remove radiation effects.

Detailed analyses of different changes induced in crystals under proton irradiation were reported in nine publications [1-9] and presented on conferences [10-12]. Further studies of observed effects are in progress.

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2.11 Determination of the Adsorption Delay Time of Fluorine on Tantalum Surface

by A. Piotrowski, T. Kozlowski

One of the most important isotopes for the RIB (Radioactive Ion Beam) Facilities is the radioactive fluorine, which is necessary to study several astrophysical processes. In our study of the tubular ionizer [1,2] we found that in this source the negative fluorine ions are produced with the high efficiency if the vapors of alkaline metals are introduced.

For these applications any time delays comparable to the isotope half-life can result in significant losses of the RIB intensity. Here we present the results of the measurements of the adsorption delay time of the negative fluorine ions produced in dissociation of the SF$_6$ in the tantalum ionizer at 2395 K.

A definite (1.35*10$^5$ mbar*litre/s) SF$_6$ flux had been applied to the ionizer from the reference leak and it was found that the F$^-$ current was saturated after 70 min. The time dependence of the current
after switching off of the gas is shown in Fig. 1. The exponential fit (straight line) gives the decay time of 13.6 min.

![Fig. 1. Time dependence of the F current after switching off the SF6 gas.](image)

In the tubular geometry this time is affected (multiplied) by the number of collisions before the ion can leave the source volume. Because in our case (inner diameter of 3 mm and total length of 30 mm) this number is equal to 40, the adsorption delay time on the tantalum surface is $\tau_a = 20.4$ s. This number can be compared to the half-life time of the $^{17}$F (65 s) and $^{19}$F (110 m).

The temperature dependence of the adsorption time is described by the Frenkel equation\[3\]:

$$\tau_a = \tau_1 \exp(\Delta H/kT)$$

where $v$ is the attempt frequency with which the adsorbed particle tries to escape from the adsorption surface, $\Delta H$ is the enthalpy of adsorption and $T$ is the surface temperature. Assuming the typical value $v = 10^{13}$ one obtains $\Delta H = 6.8$ eV. This value has been determined for the first time and can be useful in estimation of the fluorine production efficiency for different ion sources.


2.12 Artificial Neural Nets for the Process Control of the Flue Gas Electron Beam Irradiation.

by Z. Moroz, M. Sowiński, J. Bouzyk

The artificial neural nets (ANN) technique have been studied as a tool for model calculations and control of the industrial exhaust gas purification systems employing the electron beam irradiation. The electron irradiation method was recently applied in few foreign installations and at present, is planned to use in Pomorzany Electric Power Station.

In short, this process proceeds as follows: technological fuel gas heavily contaminated by SO$_2$, CO and CO$_2$ admixtures is cooled down in the humidifying column to the temperature of about 65-85 °C and its humidity level is increased to 10-15% vol. Then, to enable the formation of solid ammonia salts, the ammonia is added to the flue in the quantity approximately corresponding to the stoichiometric acid ratio. The flue gas prepared in such way is irradiated by the electron beam. As a result the solid salts are formed which are then separated from the cleaned gas in the filtering device.

In reality, the process is very complicated because there is about few hundreds of different physico-chemical reactions, which participate in the process. Any of the phenomenological models has some internal parameters to be fixed, which are very difficult to calculate from the first principles and are to be found purely phenomenologically. Also there are many external technological parameters, such as initial NO, and SO$_2$ concentrations, temperature, humidity, ammonia concentration, flue gas flow, electron energies and beam currents. Therefore, each set of the final pollutants of three essential gases (NO, NO$_2$ and SO$_2$) in the output of the installation is, in fact, a highly non-linear multiparameter event.

It is just a situation, where application of the ANN technique should have advantage over standard calculations and modelling in which computer expert methods are used. This method have been studied having in mind its future applications for the control of the process in the Pomorzany Electric Power Station as well as in other installations of a similar kind.

The ANN net was trained to respond to the set of three initial concentrations and ten input technological parameters giving desired values of the concentrations of the final pollutants.

As a training set data values obtained from the simplified theoretical model published elsewhere \[1\] were used. Though the output of this particular model is only approximate, it was shown that
2.13 An Attempt to Apply Short Lived $^{44}$K Activity Induced in the $^{44}$Ca(n,p)$^{44}$K Reaction Using 14 MeV Neutrons for Total Body Calcium Assessment in Human Subject
by Z. Haratym$^1$, T. Kempisty$^2$, and E. Rurarz

The status of in vivo neutron activation analysis techniques for measurement of total body calcium in human subject is reviewed. Relevant data on the nuclear characteristics of calcium isotopes during interaction with neutrons ranging from slow up to 14 MeV neutrons are presented. Physical aspects of the measurement of in vivo total body calcium (TBCa) using $^{44}$K activity induced in the $^{44}$Ca(n,p)$^{44}$K ($T_{1/2} = 22.3$ min) reaction by 14 MeV neutrons are discussed. The measurement of delayed $\gamma$-rays emitted during decay of activities induced in enriched $^{44}$Ca, $^{40}$Ca, phantom filled with water solution of natural calcium and skeletal arm are considered. Results of measurements on the phantom and skeletal arm indicate that it should be possible to measure the TBCa using $\gamma$-rays from the $^{44}$K activity.

$^1$ Institute of Atomic Energy, PL-05-400 Świerk, Poland
$^2$ Radioisotope Centre, PL-05-400 Otwock-Świerk, Poland

2.14 Pre-equilibrium Cluster Emission: Some Examples
by E. Betáč$^{1,2}$, Ľ. Čaplar$^3$, and E. Rurarz

Several co-existing models of pre-equilibrium cluster (complex particle) emission are currently in use. They are quite different in their physical assumptions, but in some cases they yield rather close results. We apply current pre-equilibrium models to the isotopic effect of (n,$\alpha$) reactions and illustrate some possible future modifications of the existing models for complex particle emission.

$^1$ Institute of Physics, Slov. Acad. Sci., 84228 Bratislava, Slovakia
$^2$ Faculty of Philos. and Nat. Sci. Silesian Univ., 74601 Opava, Czech Rep.
$^3$ R. Bošković Inst. POB. 1016, 10001 Zagreb, Croatia.
2.15 Local Space Charge Effect in Parallel-Plate Avalanche Counters at Moderate Specific Ionization

by J. Sernicki

Under a strong electric field in an avalanche counter, the charge carrier multiplication process (i.e., the gas gain process) is obstructed by local space charge effects if a large number of primary carriers is generated by ionizing radiation which initiates the discharge in the interelectrode gap. Under these conditions the avalanche discharge grows at values of the first Townsend coefficient (the ionization number per unit path length) lower than those calculated from the actual value of interelectrode voltage because of the dynamic distortion of the electrical field by the charge created. It is represented in the semilogarithmic plot of the counter pulse amplitude and gain characteristics by a section of nonlinear variability of the individual curves [1]. Thus, a critical value of effective gas amplification, above which the space charge effect may in fact occur, corresponds to the lower bound of voltages, which belong to the section. In practice, the product of the critical absolute value of gas amplification ($M_{abs}$) and the energy ($\Delta E$) which is lost in the detector by detected radiation is used as a criterion of this effect to occur. However, the value of the $M_{abs}\times\Delta E$ product is undoubtedly dependent upon the widely understood measurement conditions.

The determination of the criterion of the space charge effects in avalanche counters consists of a numerical determination of the above-mentioned, product which now takes the form of:

$$M_{abs}\times\Delta E = M_{abs}\times(dE/dx)_{d} = M_{abs}\times dE/dx \times d,$$

where $dE/dx$ is the specific particle energy loss (stopping power) and $d$ is the interelectrode gap. It should be noted that the relation holds under the following assumptions:
- the particles pass the counter perpendicular to the detector electrodes;
- the charge density resulting from the primary ionization process (specific ionization) is constant throughout the entire interelectrode gap of the counter, i.e., $(dE/dx)/W = \text{const}$, where $W$ is the ionization work.

The purpose of this investigation is to determine a simple analytic representation of the criterion of local space charge effects in parallel-plate avalanche counters (PPAC) at moderate specific ionization (fig. 1). The investigation was realized, generally, under measurement conditions, which are typical for the majority of physical experiments in which the PPAC detectors are used [3].

![Fig. 1. Mean effective energy $E$ of alpha particles and the corresponding particle energy loss in the gas space between the PPAC electrodes, determined for actual measurement conditions. See ref. [2] for data on the front electrodes of the PPAC.](image)

The final results obtained are given in Table 1. In order to simplify the use of formulas from this Table, the analytic representations of $M_{abs}$ (obtained by author) are given in Table 2.

**Table 1** Product of the critical absolute value of gas amplification ($M_{abs}$) and the actual particle energy loss ($dE/dx$), as a criterion of space charge effects in PPAC with electrode spacing $d$, at given value of $p$. Pressure $p$ is expressed in Torrs.

<table>
<thead>
<tr>
<th>$d$ [cm]</th>
<th>$M_{abs}\times(dE/dx)_{d}$ [keV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>$7.193 \times 10^{5}/p^{0.05}$</td>
</tr>
<tr>
<td>0.3</td>
<td>$6.817 \times 10^{5}/p^{0.06}$</td>
</tr>
<tr>
<td>0.4</td>
<td>$2.443 \times 10^{5}/p^{0.81}$</td>
</tr>
</tbody>
</table>

The formulas of Table 1 clearly indicate that they are function of the pressure ($p$) of the gas as well as of the size ($d$) of the interelectrode gap.

Table 2 General equations of the absolute PPAC gas gain characteristics ($M_{abs}$). They are justifiable in the ranges of n-heptane vapour pressure values $p$ given in the table. $U$ is expressed in Volts.

<table>
<thead>
<tr>
<th>$d$ [cm]</th>
<th>$M_{abs}$</th>
<th>$p$ [Torr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,2</td>
<td>$1,22 \exp(-1,19p+0,0283U+0,000791pU+0,0206p^2-0,000049p^2U)$</td>
<td>&lt; 10</td>
</tr>
<tr>
<td></td>
<td>$1,22 \exp(-1,19p+0,0363U-0,000493pU+0,0206p^2)$</td>
<td>$\geq 10$</td>
</tr>
<tr>
<td>0,3</td>
<td>$0,0410 \exp(-1,36p+0,0396U-0,000717pU+0,0278p^2)$</td>
<td>5 - 30</td>
</tr>
<tr>
<td>0,4</td>
<td>$0,00528 \exp(-1,50p+0,0386U-0,000952pU+0,0417p^2)$</td>
<td>5 - 30</td>
</tr>
</tbody>
</table>

2.16 Monitoring of Ground-Level Air Pollution in the Vicinity of Świerk in 1998

by B. Mystek-Laurikainen, M. Matul, S. Mikolajewski, H. Trzaskowska

The ground level air, its composition and the processes which take place there have the main influence on the total effective inhalation dose received by man. The radioactive elements carried into atmosphere are due to the numerous natural phenomena as well as the anthropogenic radionuclides released to the environment in the industrial processes or nuclear accidents.

West of Świerk at the S. Kalinowski Geophysical Observatory of the Institute of Geophysics, Polish Academy of Science in Świeradów near Otwock. This station operates since 1991. The sampling and measurement procedures were described in SINS Annual Reports 1992, 1993. The weekly reports of 1998 can be found in Internet on the page of our Institute as: [http://india.ipi.gov.pl/rad/raptvg.htm](http://india.ipi.gov.pl/rad/raptvg.htm)

Fig. 1 The concentration of radionuclides in the ground level air at the Świeradów sampling station.

The summary of results for 1998 shows Fig. 1. Every year the air born $^7$Be is the dominating radionuclide in the average level 2230 $\mu$Bq/m$^3$ with max. 5523 and min. 1017 $\mu$Bq/m$^3$.

The anthropogenic $^{137}$Cs being mainly the remnant of nuclear weapon tests carried out in atmosphere in 1963-1980 and partially originating from Chernobyl is on the level of several $\mu$Bq/m$^3$.

The average value is 37.1 max 95.56 and min 15.25 $\mu$Bq/m$^3$. The dust level during 1991-1998 is presented in Fig. 2 and shows some systematic decreasing tendency.

Fig. 2 The dust level in 1991-1998
LIST OF PUBLICATIONS

K-SHELL EXCITATION STUDIED FOR H- AND H-like HIGH-Z IONS IN COLLISIONS WITH LOW-Z TARGETS ATOMS
Th. Stochlker, D.C. Ionescu, P. Rymuza,..., T. Ludziejewski et al.

INTERFERENCE BETWEEN ELECTRIC AND MAGNETIC AMPLITUDES FOR K-SHELL EXCITATION OF HIGH-Z H-LIKE PROJECTILES
Th. Stochlker, D.C. Ionescu, P. Rymuza,..., T. Ludziejewski, et al.

ELECTRON BREMSSTRAHLUNG IN COLLISIONS OF 223 MeV/u Ha-LIKE URANIUM IONS WITH GASEOUS TARGETS
T. Ludziejewski,..., P. Rymuza et al.

PROBABILITIES FOR M-SHELL IONIZATION IN INTERMEDIATE-VELOCITY COLLISIONS OF MEDIUM-MASS ATOMS WITH Ha IONS
Ch. Herenc,..., T. Ludziejewski, P. Rymuza, Z. Sujkowski

CHARGE-EXCHANGE CROSS SECTIONS AND BEAM LIFETIMES FOR STORED AND DECELERATED BARE URANIUM IONS
Th. Stochlker, T. Ludziejewski,..., P. Rymuza, et al.

LEVEL STRUCTURES OF 199Mo AT HIGH ANGULAR MOMENTUM
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RECOIL DISTANCE LIFETIME MEASUREMENTS IN 131Xe
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NUCLEAR STRUCTURE OF 196Mo AT HIGH SPINS
B. Kharraja,..., R. Kaczarowski

QUADRUPOLE MOMENTS AND IDENTICAL SUPERDEFORMED BANDS IN 195Tb
B. Kharraja,..., R. Kaczarowski

DEFORMED INTRUDER BANDS IN 132Sn
J.M. Szmul,..., R. Kaczarowski

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J. Blocki, J. Wilczyński

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L. Zychor
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B. Myslek-Laurikainen
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I Międzynarodowa Konferencja Naukowa: Teoria i Praktyka Ochrony Powietrza, Szczecin, 2-4 czerwca 1998

NEW METHOD OF CALCULATING VERY SMALL FUSION CROSS SECTIONS
O. Mazonka, C. Jarzynski, J. Blöckl

COMPUTING PROBABILITIES OF VERY RARE EVENTS FOR LANGEVIN PROCESSES IN NUCLEAR DYNAMICS
O. Mazonka (oral)

NEW METHOD OF CALCULATING VERY SMALL FUSION CROSS SECTIONS
O. Mazonka (poster)
Conference: Nuclear Physics Close to the Barrier, 30 June - 4 July 1998

CHANGES IN LUMINESCENCE OF Ce:YAG CRYSTALS UNDER IONIZING RADIATION TREATMENT
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RADIATION DEFECTS IN OXIDE COMPOUNDS
S.M. Kaczmarek, R. Jabłoński, Z. Moroz, J. Pracza, T. Łukasiewicz
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CHANGE OF OPTICAL PROPERTIES OF Ce:YAG SINGLE CRYSTALS DUE TO CODOPING AND IONIZATION
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LECTURES, COURSES AND EXTERNAL SEMINARS

P. Rymuza
Oddziałanie magnetyczne w relatywistycznych zderzeniach ciężkich jonów z atomami
IFD UW, Warszawa, 11 marca 1998

P. Rymuza
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RCNP, Osaka University, Osaka, 19 April 1998, (39th Nuclear Science 1C Seminar)
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GANIL, Caen, France, 16 October 1998

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Los Alamos, New Mexico, June 1998

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O. Mazonka
Stochastic Model of Heavy Ion Collision
Jyväskylä, University of Jyväskylä, Finland, January 1998

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Jyväskylä, University of Jyväskylä, Finland, January 1998

O. Mazonka
Brownian engine, refrigerator: exactly solvable model
Kraków, Institute of Nuclear Physics, 29 Dec. 1998

Z. Sajkowski
Fizyka jądrowa A.D. 1998; migawki
PERSONNEL

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Danuta Chmielewska, Dr.
- Scientific Secretary of the Institute
Rościsław Kaczarowski, Assoc. Prof.
Tadeusz Kozłowski, Dr.
Tomasz Ludziejewski, Dr. on leave
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Overview

The basic activities of the Department of Nuclear Electronic were concentrated on the following areas:

- studies of new scintillation techniques,
- contribution to the EUROBALL project,
- electronics for experiments in High Energy Physics,
- development of spectrometry apparatus,
- development of new generation State of the Art PC based multichannel analyzer,
- technical support for the Institute as the whole with special emphasis on networking support,
- normalisation activities.

Most of the scientific achievements concerning the Department were summarized in 8 publications (released or being in press). All papers mentioned were published in IEEE Trans. On Nucl. Sci. and Nucl. Instr. and Methods. Besides that our scientists presented two contributions at international conferences (IEEE Nucl. Sci. Symp. 1998 in Toronto, Canada). One of our colleagues obtained his PhD degree.

The Department was involved in scientific collaborations with a number of international centres, such as CERN, Royal Institute of Technology in Stockholm, FZR Rosendorf Boston University, GSI Darmstadt, York University and LNFN Legnaro. The collaboration with High Energy Physics Department was focused on experiments in CERN (NA 48 experiment) and in Dubna (SPHERA experiment).

In 1998, work concerning the development and implementation of electronics for silicon ball EuroSiB (EUROBALL) were completed. Positive tests were passed in experimental conditions in Heidelberg. Also, input electronics for EUROBALL neutron detectors was finished. Our acquisition system for the NA48 experiment in CERN, which contained more than 140 large electronic modules (mainly FASTBUS), was working an entire year without a single failure. The Dubna contract for delivery of CAMAC blocks for the SPHERA experiment is continued, however on a lower scale, because of financing problems.

The technical support for the Institute covers a lot of different types of activities, among them an installation of a new worldwide network.

The main results of our activities are:

- development and implementation of a readout electronic system for NA48 experiment in CERN,
- continuation of a study of energy resolution of scintillation detectors with avalanche photodiodes light readout showing excellent energy resolution in the low energy range of γ-rays,
- successful test of the RoSiB(EuroSiB) silicon ball and its electronics in the commissioning experiment in Heidelberg,
- successful implementation of the front-end electronics for the neutron detectors in EUROBALL,
- advanced studies and preparation of a technical project for the new generation PC based or stand alone multichannel analyzer.
3.1 Feasibility Study of the Semiconductor Detectors for Particle Identification in In-Beam Experiment


Precise determination of the particles emitted in nuclear reaction is an important part of each nuclear physics experiment. Very promising results obtained by M.M. and G. Pausch prompt us to further effort to improve the particle discrimination techniques and to study different types of semiconductor detectors. First experiments had been performed in 1997 at JYFL, the second one was done in 1998. During this experiment, 380μ thick PIN detectors, surface barrier 1150μ microns thick detectors and 3mm and 1mm thick Si(Li) detectors were used. PIN and SBD detectors were used in different configurations: rear side in front and in normal mode operation. The sandwich detectors were used also by means of combining two PIN detectors as a dE-E telescope. Additionally special detector dE-E telescope was used with very thin front detector (dE). In experiment the pulse shape discrimination methods based on zero-crossing techniques and rise time of the fast output from the preamplifier has been applied. Best results were obtained with PIN diodes in reverse mode operation and rise time methods.

Fig. 1 Particles from reaction registered with best PIN diodes.

Fig. 2 The same data as in Fig. 1 extended to zoom low energy region.
Figure 1 shows particles registered with best PIN diodes originating from the reaction 150 MeV$^1$N$^+$\textsuperscript{12}C. Figure 2 shows data from the same experiment extended to expose the low energy region. Note very good quality of the particle discrimination and isotope resolution. These results are still under discussion and further effort is needed. The next in-beam experiment is planned in 1999.

3.2 First Experiments with the Rossendorf Si-Ball RoSiB

RoSiB is a 4π Silicon detector array based on a N=42 ball with 12 pentagons and 30 hexagons \[1\]. It is designed for the detection of light charged particles inside modern 4π γ-ray spectrometers (e.g. EUROBALL) and exploits the pulse shape discrimination technique for particle identification \[2\]. Two experiments have been performed at the MP tandem accelerator of the MPI Heidelberg, using the fusion evaporation reactions $^{58}$Ni (220 MeV) + $^{46}$Ti and $^{16}$O (95 MeV) + $^{38}$Ni. The setup consisted of the Rossendorf Cluster detector, 3 individual HPGe detectors, RoSiB and reduced version of the EUROBALL neutron wall \[3\]. Fig 1 shows a 2D-plot of zero-crossing time versus energy deposition for one Si-detector. By defining gates in such matrices different exit channels of the fusion evaporation reaction are selected as illustrated in Fig.2

Fig. 1 Color image of matrix zero-crossing time (ZCT) versus energy deposition (E) for a Si-detector of RoSiB in forward direction, showing the particle discrimination between protons and alphas. The data has been taken in the reaction $^{16}$O + $^{38}$Ni at 95 MeV.

[3] University of Jyvaskyla, Jyvaskyla, Finland
[4] V.G. Khlopin Radium Institute, St. Petersburg, Russia
[5] Technical University, Darmstadt, Germany
[6] Kurchatov Institute, Moscow, Russia
[7] St. Petersburg State University, St. Petersburg
3.3 Low Energy $\gamma$-rays Scintillation Detection with Large Area Avalanche Photodiodes

by M. Moszyński, M. Kapusta, J. Zalipska, M. Balcerzyk, D. Wolski, M. Szawlowski

Energy resolution of NaI(Tl), CsI(Tl), LSO and YAP crystals coupled to 16 mm diameter Large Area Avalanche Photodiodes (LAAPD) was studied for low energy $\gamma$-rays. Table 1 summarizes the results of the measurements carried out with all crystals for 662 keV, 122 keV and 59.6 keV $\gamma$-rays.

Table 1  Energy resolution measured with the studied crystals

<table>
<thead>
<tr>
<th>Crystal</th>
<th>$\tau$ [µs]</th>
<th>662 keV</th>
<th>122 keV</th>
<th>59.6 keV</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaI(Tl)$^a$</td>
<td>0.5</td>
<td>6.5±0.2</td>
<td>8.4±0.3</td>
<td>11.3±0.3</td>
</tr>
<tr>
<td>CsI(Tl)$^b$</td>
<td>2</td>
<td>5.5±0.2</td>
<td>8.9±0.3</td>
<td>12.7±0.4</td>
</tr>
<tr>
<td>LSO$^b$</td>
<td>0.25</td>
<td>10.9±0.3</td>
<td>21.5±0.6</td>
<td>29.4±0.9</td>
</tr>
<tr>
<td>YAP$^b$</td>
<td>0.25</td>
<td>4.9±0.2</td>
<td>13±0.4</td>
<td>21.2±0.6</td>
</tr>
</tbody>
</table>

$^a$ measured with a blue-enhanced LAAPD  
$^b$ measured with a uv-enhanced LAAPD

Excellent energy resolutions of 11.3% and 8.4% were obtained for 59.6 keV $\gamma$-rays from $^{54}$Am and 122 keV $\gamma$-rays from $^{57}$Co sources, respectively, as measured with a 10 mm diameter by 10 mm high NaI(Tl) crystal, see Fig. 1. These results are comparable to those measured with the best scintillators coupled to a photomultiplier. The optimization of the LAAPD performance is presented, being essential for improvement of energy resolution at low energy $\gamma$-rays. Measured numbers of primary electron-hole pairs produced in LAAPDs and evaluation of noise contribution of these devices allowed for a quantitative discussion of the results. Particularly, the intrinsic energy resolution of the crystals vs. energy of $\gamma$-rays has been evaluated. Data for NaI(Tl) crystal showed good agreement (within 30%) with calculated component due to nonproportional light yield for energies above 50 keV.

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


$^*)$ Support for this work was provided by the Polish Committee for Scientific Research, Grants No 8T 10C 005 15 and No 8T 11E 025 15
3.4 Avalanche Photodiodes in Scintillation Detection for High Resolution PET

by M. Kapusta, M. Moszyński, M. Balcerzyk, K. Leśniewski, M. Szawlowski

The data characterizing general properties of APDs, scintillators, and LSO-APD, YAP-APD and BGO-APD detectors reported by our group and other authors in recent years have been experimentally verified and analyzed towards better understanding and characterization of the complex phenomena involved in such structures. Our study clearly demonstrates that the detector assemblies comprising the beveled-edge APDs and such inorganic scintillators as YAP:Ce, LSO:Ce or BGO can be successfully used in PET. This study demonstrates that detectors containing beveled-edge APD and inorganic scintillator such as YAP:Ce, LSO:Ce or BGO can be used successfully in Positron Emission Tomographs. A high number of e-h pairs, above 10,000 e-h/MeV for LSO, a good energy resolution, for BGO (13.9 %) and LSO (11.2 %) and an excellent time resolution for LSO of 1.26 ns were measured.

The high number of generated e-h pairs, good energy resolution (particularly for BGO), and excellent time resolution for LSO point directly towards feasibility of such application. The results obtained with APDs and BGO scintillators commonly used in commercial PET scanners reveal the possibility of replacement the PMTs by contemporary APDs. The BGO-APD detector produced a superior energy resolution, which is so important in decreasing the probability of registering false events coming from Compton scattering. On the other hand, the results obtained for YAP crystals coupled to APD show that such detectors would have limited usage in further PET applications due to their low detection efficiency. However, the results obtained with LSO:Ce scintillator and APDs show that there is no doubt that this is a winning combination and the best available choice for developing future PET scanners. Superiority of LSO-APD over LSO-PMT is manifested by its ability to work efficiently at high counting rates, resulting in significantly lower dead times of the PET process, which in turn should allow a true 3D scanning to be performed.

We need to report, though, that high resolution PET requirements are still twice as high as the results obtained by the authors. Thus further effort is needed to develop better scintillation crystals and photodetectors to fulfil these requirements.


![Time spectra measured with LSO:Ce and YAP:Ce crystals.](image)

1) Advanced Photonix, Inc. 1240 Avenida Acaso, Camarillo, CA 93012, USA

* Support for this work was provided by the Polish State Committee for Scientific Research, Grant No 8T 10C 005 15.
3.5 Intrinsic Energy Resolution and Nonlinearity of Some Contemporary Scintillators

by M. Balcerzyk, M. Moszyński, M. Kapusta

Nonproportional light output versus energy (Fig 1.), energy resolution and intrinsic energy resolution (Fig 2.) have been measured for pairs of scintillators: NaI(Tl) and CsI(Tl); GSO (Gd₂SiO₅:Ce) and LSO (Lu₂SiO₅:Ce); YAP (YAlO₃:Ce) and LuAP (Lu₃Al₂O₅:Ce); YAG (Y₃Al₅O₁₂:Ce) and LuAG (Lu₃Al₅O₁₂:Ce). Measured oxide scintillators exhibit increasing nonproportionality for energies below characteristic Kα X-ray line. Among them YAP is excellently linear within 3% down to energy of 10 keV. It also has very good energy resolution of 4.36% for 662 keV γ-line of $^{137}$Cs and corresponding intrinsic energy resolution of 1.4%. Measured iodides, perovskites and garnets show characteristic step-like curve on log-log plot of intrinsic energy resolution versus energy. Measured orthosilicates exhibit straight line behaviour on the above mentioned plot.

![Linearity of YAP and LuAP](image1)

![Linearity of YAG (XP) and LuAG (Adit)](image2)

![Linearity of NaI (Tl) and CsI(Tl)](image3)

![Linearity of GSO and LSO crystal](image4)

Fig. 1 Linearity of light output of a) YAP and LuAP, b) YAG and LuAG, c) NaI(Tl) and CsI(Tl), and d) GSO and LSO in units of light output at 662 keV.

Despite the same crystal structure LuAP and YAP linearity curves are strikingly different. While YAP is almost perfectly linear down to 5 keV, LuAP at 17 keV has only 70% of light output of 662 keV value. Since the crystal structures of YAP and LuAP are the same (Pbnm) one would expect the same nonlinearity. For the YAG - LuAG pair the difference in linearity is negligible; both crystals show a constant drop of linearity with decreasing energies. One would expect that if a crystal contains only light elements then it should be linear. The above two pairs of scintillators show that the case is not that simple. Following the reasons of Murray and Meyer [1] that can be caused by different electron and hole capture properties of Ce³⁺ center in garnets (YAG and LuAG) and perovskites (YAP and LuAP). Although GSO and LSO has slightly different crystal structures (P₂₁/c and C2/c respectively [2]) linearity curves are almost identical.

Intrinsic energy resolution is correlated with linearity of the scintillator. For crystals with almost perfect linearity (YAP) intrinsic energy resolution has low values for energies above 100 keV (1.4% for 662 keV). The shape of the curve is slope-plateau-slope for iodides and bump-plateau-slope for other scintillators.
3.6 Properties of ZnSe(0.2%Te) Scintillator

by M.Moszyński, M.Balcerzyk, M.Kapusta, M.Szawlowski, W.Klamra

We have studied the scintillation properties of ZnSe: 0.2%Te scintillator. It is a low-density crystal (5.42 g/cm$^3$). Peak emission of the crystal is at 610 nm.

The light output is $28000 \pm 1500$ photons/MeV, comparable to LSO. The electron-hole yield is 26500 e-h pairs/MeV and the energy resolution for 662 keV $\gamma$ line is 5.37%, when measured with avalanche photodiode. The intrinsic energy resolution for 662 keV is 3.26%. ZnSe(0.2%Te) has linear light output - energy dependence within ±5% down to 16 keV (see fig. 1). At 5.7 keV light output per unit energy is 85% of the light output per unit energy at 662 keV. We have also observed the increase of the values of intrinsic energy resolution with lowered shaping time constant (fig 2). According to contemporary models of intrinsic energy resolution, such an effect should not be observed. Nevertheless this effect was observed by us also in CsI(Tl) NaI(Tl). The properties of ZnSe(0.2%Te) scintillator point toward its use as a low energy X-ray detector.


Fig. 1 Linearity of light output of ZnSe(Te) in units of light output at 662 keV.

Fig. 2 Energy resolution $\Delta E/E$, intrinsic energy resolution $\Delta E$, statistical contribution to energy resolution $\Delta N/N$, and noise contribution to energy resolution $\Delta N_{noise}$ of ZnSe(Te) at 662 keV versus shaping time. Measurements done with avalanche photodiode.

Fig. 3 Energy resolution $\Delta E/E$, intrinsic energy resolution $\Delta E$, statistical contribution to energy resolution $\Delta N/N$ versus energy. Measurements done with photomultiplier.

Support for this work was provided by the Polish Committee for Scientific Research, Grants No 8T 10C 005 15 and No 8T 11E 025 15.

To be published in Nuclear Instruments and Methods Section A.

3.7 A Design of Complete Multichannel Analyzer on the PC Card

by S. Borsuk, Z. Guzik, Z. Kalka

A new version of complete PC based Multichannel (MCA) Card excluding only the detector-preamplifier assembly was designed. The MCA Card has the form of a PC plug-in motherboard equipped with four daughter modules, five DC/DC converters and PC Bus connector.

The simplified block diagram of the PC based MCA Card is shown in Fig. 1.

The daughter modules include spectroscopy amplifier, high speed and high resolution spectroscopy ADC, histogramming memory and MCA microcontroller. One of five DC/DC converters gives the high-voltage bias supply for the photomultiplier tube (PMT) and the rest of them provide low voltages for the external detector-preamplifier (converters 1 and 2) and for on-board amplifier – ADC modules (converters 3 and 4). The parameters, control and operational functions of all four modules and high voltage supply are fully programmable via software.

A unique feature of the new designed MCA Card is the totally galvanic isolation high voltage supply, amplifier and ADC modules by opto-couplers (control, data and programming signals) and by transformers built-in to the DC/DC converters. With this feature, all circuits which are responsible for spectroscopy performance of the MCA PC Card will be insensitive to a high level of noise and disturbances usually existing in computer ground and power supply lines.
High voltage supply
The on-board high-voltage module provides positive supply from 0 to 1.25 kV for PMTs, suited for most scintillation detector operations. The feedback feature is introduced to control the output voltage. High voltage is computer programmable in 10V steps with ramp up/down rate of 50V/s.

The PMT high-voltage module can be easily removed in order to exchange it for the module suitable to bias a semiconductor detector of any kind.

Amplifier
The amplifier is optimized for high resolution gamma spectroscopy with Ge detectors. It has a gated integrator with gaussian prefilter which completely eliminates the ballistic deficit.

The main amplifier specifications are following:
- equivalent to 3us gaussian shaping time
- gain from 5 to 1500, computer programmable
- P/Z cancellation adjustment
- Automatic noise discr imination threshold
- Rejection of pile-up pulsces.

ADC
The spectroscopy ADC, successive approximation type is very similar to the previously developed conception [1]. It is based on a low cost, audio, 16-bit/4us, serial output ADC (Burr-Brown's PCM 78P chip) and a 16-bit, audio, serial input DAC (also Burr-Brown PCM 56P chip). The low differential nonlinearity which is important in high resolution spectroscopy is achieved by using a special channel averaging system which does not limit the dynamic range, including developed sliding scale corrector chip. The suitable length of data words is obtained by a rounding technique.

The most important features of ADC are following:
- 13-bit resolution (8 k channels)
- 5us conversion time (fixed)
- < +/- 0.5% differential nonlinearity over 98% of full scale
- < +/- 0.05% integral nonlinearity over 98% of full scale
- input base-line restoration
- computer programmable low level discrimination threshold.

Histogramming memory
A histogramming memory is a complex system consisting of an incremente and a router which are made with semicustom VLSI digital integrated circuits (Altera's CMOS CPLD), spectrum memory and address decoder (GAL). The configuration of Altera's chips is achieved using two serial EEPROMs.
The Z_592B Mezzanine board is a heart of the system. Its main functions could be summarized as follows:

- global supervising of the system behaviour,
- configuration of PLD devices after power-up,
- optional saving of the histogramming memory content,
- realization of an algorithm for HV setting,
- non-volatile saving and presetting of the system parameters,
- partial spectra pre-processing,
- system timing (starting, stopping, pausing, real time calculation),
- organization of fast computer network (CAN fieldbus) in the case when the system is working as an autonomous device not connected to the PC.

The Z_592B contains P08C592 Microcontroller from Philips working with 16 MHz clock, fast static memory (128 kB), on-line programmable EEPROM memory (128 kB), 100 ns access time and other auxiliary logic. It is also equipped with networking capabilities by means of a PCA82C250 CAN controller located on the microcontroller itself. Besides that the RS-232 serial communication facilities are also included. The size of the four layers Z_592B board was minimized to the highest extent (68 x 53 mm).

The basic embedded programming tool is a specially designed ASSIST1 monitor with a lot of features, which make the debugging process fast and easy. However, a target programming kernel, an MULTIX Real-Time Operating System, is under development.


3.8 Development Principles of Communication Protocol Between Multichannel Analyser and Visualisation Software
by M. Plominski

A new version of the software is being developed concurrently to the new model of Multichannel Pulse Amplitude Analyser. One of the fundamental problems during the first phase of both is to precisely define physical and logical communication layers. For the first version of the project the following assumption was made: PC internal ISA bus for physical layer and 16-channel compact area in I/O address space for logical layer. To achieve maximum universality, the basic address for communication will be hardware selected by a set of micro-switches (in a range from 000 to FF0) at one side and program selected at another end. Limitation of the communication layer to narrow window in I/O space was developed to isolate measuring part of the card from the environment (computer). In particular it is not possible to reach the buffer (memory) containing collected experimental spectra directly from the program.

Communication takes place by sending a command to the hardware and scanning selected channels for return information. The list of commands and their syntax was initially defined, but can be still modified during the development process of both hardware and the software. The command sent to the card besides its unequal identification code can contain one or more supplementary parameters. In effect of one command sent to the card analyser one or more sequential values in specified address channels can be prepared by the card to be read by the program.

From a technical point of view, communication between 32-bit application and the analyser card will occur thanks to 16-bit library (DLL) connected to 32 bit application via "quick-thinking" mechanism. This mechanism relies on calling unpublished procedures placed in Microsoft's Kernel32.dll library element of every Win 95/98 installation. For Windows NT environment, a special driver in VxD technology is being expected.

For testing the developed communication protocol a special program was created. Its functionality highly exceeded the primary intention and can be utilised for many other purposes.
3.9 Multichannel Analyser Software for Windows – Program Structure
by K. Traczyk, M. Płomiński

In the Department of Nuclear Electronics a new version of the multichannel pulse amplitude analyser is developed. In the same time software running in Windows 95/98/NT environment is prepared. The modular, object structure of the program has already been defined.

Every module in the system will realise a strictly defined rule. So, there will be a module for acquisition control, database services, spectra visualisation, data analysis, reports etc. The system is developed in Delphi Integrated Development Environment (IDE) based on Object Pascal. In the object structure of the program every element is equivalent to a certain object and every object is a member of a certain class of objects. Every object will contain a set of properties and functions possible to be performed on it and a set of functions and rules based on which other objects can profit. Thus the object “Acquisition Series” will contain the sub-object “Spectrometry path” (including “detector type”, “amplification value” etc.), “Measure”, “Analysis parameters”, “Calibration”, “Nuclide library”. Therefore it will group a complete set of information related to measurements performed in specified conditions.

All data (i.e. experimental and related to measurement conditions and parameters of analysis) will be collected in a database which is an integrated part of the system. Every spectrum placed in this database will contain full information: experimental data, spectrometry path type, date, analysis parameters suitable for it and other.
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M. Moszyński, Advanced Photonix, Inc. Cupertino, USA Nov., 1998

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Trends and directions in Positron Emission Computer Tomography development\(^c\)
M. Kapusta, IPD UW, Sep., 1998

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\(^b\) in English
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Błażej Woźniak
Iwona Zawrocka
Overview

The research activities of the Department in 1998, similarly to the previous year were focused on the following problems:

- Dosimetry for medical purposes;
- Microdosimetry at the nanometre level;
- Numerical modelling of interaction of radiation with matter;

**DOSIMETRY:** Based on experience gained in previous years in absolute and relative measurements of absorbed dose for $^{105}$Ru applicators, the detectors and methods for dosimetry of $\beta$ radiation applied in intravascular brachytherapy have been undertaken. A new, small size scintillation probe with NE102A scintillator 1 mm dia. by 1 mm coupled to a 30 cm long flexible light guide and to a 95245 photomultiplier has been assembled and tested. The GAF Chromic foils, MD55, have been found to be very promising detectors for intravascular and ocular brachytherapy. A miniature ionisation chamber for Kerma in air measurements in radiation field of a "photon needle" (small size X-ray tube operated at 30 KV) has been assembled and tested.

**MICRODOSIMETRY:** The absolute efficiency of two types of electron multipliers, i.e. discrete dynode electron multiplier DM205IG and channel electron multiplier X719BL for Ar+ ions in energy range 1 keV to 10 keV has been determined in an experiment performed in cooperation with the Weizmann Institute of Science. These electron multipliers are used in the set up "JET COUNTER" as detectors for ion cluster studies. A method for measuring the spectra of ion clusters created along a charged particles track has been proposed. The ion clusters spectra produced by alpha particles $^{241}$Am source passed a distance of 3.6 to 10 nm (in units of density scale) in nitrogen have been measured. Also, preliminary measurements of ion clusters created by low energy electrons 50 and 100 eV have been carried out. Activities in this field were supported by IV CEC Framework Programme as well as by the Polish State Commission for Scientific Research.

**NUMERICAL MODELLING:** Monte Carlo simulation is direct and the most versatile method of investigation of electron transport throughout matter in respect to the irradiation conditions encountered in practice. MCNP-A General Monte Carlo N Particle Transport Code and MCNPDAT6 Photon Interaction and Electron Data Libraries have been used to compute electron transport for medical applications. The absorbed dose distributions were calculated for $^{106}$Ru ophthalmic applicator and $^{90}$Y source used in intravascular brachytherapy. The evaluated cross sections for interaction of 10 MeV to 1 TeV neutrons with hydrogen to californium nuclei have been calculated for the purposes of transport mathematical modeling. Numerical calculations for the project of an experimental setup for study of electronuclear method of energy generation based on the use of a subcritical fast plutonium reactor and 650 MeV proton accelerator have been performed.
4.1 Ion Cluster Spectra at Nanometre Track Created by Alpha Particles
by S.Pszona, J.Kula and S.Marjańska

The interaction of charged particles with matter over a nanometre distance is of interest for biological science (DNA structure). For such "nanometre" sites, instead of deposited energy it is more meaningful to focus the attention on the distribution of the number of ionisations (cluster of ions) within such structures. The distribution of the ion clusters, occurring at the nanometre track length irradiated by alpha particles in the set up called JET COUNTER was measured. The description of Jet Counter has been given in previous Annual Report (1) as well as in (2-3).

Applying the MCS, the time of flight pattern of ions is simultaneously recorded. The registered number of counts is read out between the consecutive gas pulses. A number of counts spectrum for a given diameter of nitrogen gas layer, for 1000 alphas in coincidence with gas jet is collected. To convert the measured count number spectra, to the true number of ions spectra, the efficiency of a CH2 detector to single ions has been determined in a separate experiment (see this Annual Report) The ion cluster spectra for 3.6, 7.4 and 10 nm are shown on Fig.2.

Two maxima can be seen i.e. first one for clusters containing between 2 and 3 counts and another around a cluster of 7 counts. The existence of two maxima for 10 nm of alpha particle track can be explained by an assumption that the first maximum is due to the delta electrons only.

Fig. 1 The block diagram of set up for ion cluster measurements

Fig. 1 shows the block diagram of set up for ion cluster measurements for alpha particles of $^{241}$Am source. Only these ionisation events created in an interaction chamber by single alpha particle, which are in coincidence with gas jet are selected by the gate GATE initiate the multiscaler (MCS) 914T. The input signal to MCS is formed by an electron multiplier, CH2, (operated in a mode for positive ion detection) then amplified by fast preamplifier VT 120. The MCS type 914T ORTEC, has 10 ns resolution and is programmed to run only through 200 μs i.e. time necessary to allow all ions created in interaction chamber to reach the detector CH2.

Applying the MCS, the time of flight pattern of ions is simultaneously recorded. The registered number of counts is read out between the consecutive gas pulses. A number of counts spectrum for a given diameter of nitrogen gas layer, for 1000 alphas in coincidence with gas jet is collected. To convert the measured count number spectra, to the true number of ions spectra, the efficiency of a CH2 detector to single ions has been determined in a separate experiment (see this Annual Report) The ion cluster spectra for 3.6, 7.4 and 10 nm are shown on Fig.2.

Two maxima can be seen i.e. first one for clusters containing between 2 and 3 counts and another around a cluster of 7 counts. The existence of two maxima for 10 nm of alpha particle track can be explained by an assumption that the first maximum is due to the delta electrons only.

[1] Support by CEC under the subcontract, FI4P-CT96-0044 is appreciated.

4.2 Absolute Efficiency of the Discrete and Channel Electron Multipliers.
by S.Shchemelinin”, S.Pszona

The absolute efficiency of single ion counting is an important parameter in many experiments. An example of such experiment is simultaneous detection of all ions formed (as ion cluster) along a track of a charged particle. One of the most important prerequisites for such ion cluster measurements is known and possibly high efficiency ion detection. The available literature data on
efficiencies of electron multipliers, EM, for ions of 1–10 keV are reported exclusively for channel EM. On the other hand, a discrete dynode EM, recently commercially available, seems to be promising for the ion cluster study as having an uniform input sensitivity and designed to resist large beam intensity. Lack of the literature data on the efficiency of these devices for ions was one of the motivations of this work intended to study the absolute efficiency of to Ar⁺ for ions for two EM: a discrete EM type DM205IG (produced by ETP) and a X719BL channel EM (Phillips). The absolute efficiency of a discrete dynode electron multiplier was measured by the direct method i.e. by the ion beam current from the Faraday cup and the counting rate of the pulses from the EM were measured in turn, typically, 5 - 10 times. The ratio of these values was used for the evaluation of ion counting efficiency using the very conventional formula. The counting efficiency of X719BL channel EM was evaluated by comparison of its counting rate with that of discrete EM. The preliminary results of the absolute efficiency of X719BL and DM205IG multipliers are shown in Table I.

Table 1 Counting efficiency of X719BL and DM205IG electron multipliers for Ar⁺ ions.

<table>
<thead>
<tr>
<th>Ion energy, keV</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>6</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency, DM205IG</td>
<td>0.34</td>
<td>0.67</td>
<td>0.83</td>
<td>0.86</td>
<td>0.93</td>
<td>0.98</td>
</tr>
<tr>
<td>Efficiency, X719BL</td>
<td>0.36</td>
<td>0.69</td>
<td>0.81</td>
<td>0.84</td>
<td>0.95</td>
<td>0.95</td>
</tr>
</tbody>
</table>

4.3 Detectors for Beta Radiation Brachytherapy
by B.Kocik , S.Pszona and W.Czarnacki

Beta radiation sources are widely used in medical treatment of intraocular tumours ($^{106}$Ru) and recently in intravascular irradiation of blood arteries after angioplasty ($^{90}$Y, $^{188}$Re). The difficulties encountered in dosimetry of these sources are due to high dose gradient near the surface as well as to the depth of tissue. The depth dose gradient is depending upon geometrical factors as well as upon attenuation of beta radiation in tissue. In practice of dosimetry for the applicators (ophthalmologic and intravascular) these difficulties are manifested in two ways: first - in necessity of having enough "thin" detectors for relative depth dose measurements and second -in the necessity of having a method for calibrating these detectors in terms of absorbed dose in tissue (water). In presented approach two different type detectors for relative depth dose measurements in water phantom were tested, namely:

- scintillation detector 1mm long and 1 mm diameter of NE 102A scintillation fibre coupled to an optical guide and to a photomultiplier
- semiconductor detector-Si-pin photodiode with area of 4mm², assembled in IX Dept. of ASIN.

The relative depth doses in water for $^{106}$Ru applicator of CCA type, measured with these detectors are shown in Fig.1. Both detectors show identical dependence versus depth in water. The scintillation detector has been selected for further studies as the most suitable for depth dose measurements mainly due to its tissue equivalence and a better signal to noise ratio.

Fig. 1. Relative readings (normalised at 0.2 cm) of function of scintillator detector, Sc, and Si diode, Si, as a function of depth in water for a Ru applicator.

1) Co-operation with Department IX IP
4.4 Dosimetry for a "Photon Needle"
by S. Marjańska and S. Pszona

The miniature ionisation chamber for Kerma in air measurements radiation field of a "photon needle" (small size X ray tube operated at 30 kV) has been assembled and tested. The assembled chamber has the following technical performances:
- air equivalent material TG 43,
- window active diameter 8 mm,
- active volume 0.1 ccm,
- leakage current < 10fA
- sensitivity, approx. 0.3 Gy/nC.

Work supported by State Committee for Scientific Research (Grant No PB681/T11/97/13)

4.5 Monte Carlo Calculations of the Dose Distributions for 106Ru and 90Y Sources Used in Brachytherapy
by K. Wincel and B. Zareba

Calculations of energy deposition distributions for CCA 106Ru ophthalmic applicator and 90Y inner vein source have been performed using MCNP-A General Monte Carlo N-Particle Transport Code and MCNPDAT6 - Photon Interaction and Electron Data Libraries. The transport of electrons is dominated by the long range Coulomb forces resulting in large number of small interactions. This large number of small interactions makes a single-collision Monte Carlo method unfeasible for most situations of practical interest. For electron transport calculations MCNP code uses "condensed history" of the Monte Carlo method. This method is based on the replacement of the effects of many individual collisions with single step sampled probabilistically.

Geometrical model of the eyeball and CCA ophthalmic applicator used in calculations is shown in Fig. 1.

Fig. 1 Geometrical model of eye ball and 106Ru ophthalmic applicator used in MCNP calculations.

The shell shaped applicator consists of 1 mm thick pure silver sheet and has spherical radius of 12 mm. Calculated absolute values and measured relative values of absorbed dose (energy deposition) [1] for water are shown in Fig. 2, as a function of the distance from CCA applicator.

Fig. 2. Calculated absolute and measured normalised values of energy applicator used in MCNP calculations

Fig. 3 shows energy deposition as a function of theta at the 1mm distance from the applicator calculated for two detectors of different volumes (3.05 and 1.44 mm³). There are differences between the results for these two detectors due to strong gradient of the absorbed dose profile.

Calculations have been performed with 166MHz Pentium PC. Typical running times were of an order of 20 hours and involved five detectors and 500000 electron histories. The statistical uncertainties of calculated absorbed dose distributions are of an order of 2.5% near the applicator and less than 1% at the distances of 10 mm.

Using the MCNP code, absorbed doses in water have been calculated for beta source concept specially developed for intravascular brachytherapy. 90Y isotope, which emits beta rays of maximum energy 2.281 MeV, is applied as a source.
Calculations have been performed for a cylindrical source of 0.36 mm in diameter and 29 mm in height incorporated into "centering balloon" which is placed on central axis of water cylinder with dimensions 20 mm and 50 mm respectively. Number of primary electron histories was 100000. Fig. 4 shows comparison of calculated results and measured data [2] for a source activity of 1 mCi/mm.

Statistical relative error for calculated results is less then 3%.

Fig. 3 Energy deposition at a depth of 1 mm water for different detector volumes

Fig. 4 Absorbed dose rate distribution in water for \(^{90}\)Y cylindrical source; activity 1 mCi/mm length.

4.6 Integral High-Energy Nucleon-Nucleus Cross Sections for Mathematical Modeling

by A. Polański V. S. Barashenkov\(^{13}\), W. Gudowski

Several methods for the parameterisation of nucleon cross-section were compared with optical model for medium-energies results. It is shown that the methods are, on the average, very consistent over the medium-energy range for masses from carbon to lead.[1] The evaluated integral cross-sections of elastic and inelastic interactions of neutrons and protons with the nuclei H, D, Li, Be, C, N, O, Na, Al, S, Ca, Ti, Fe, Cu, Br, Cd, Sn, Ba, W, Ph, U, Cf have been tabulated on basis of the known experimental data and theoretical models in the energy intervals 10 MeV - 1 TeV for neutrons [2] and 1 MeV - 1 TeV in the case of protons. To describe the cross sections at the energies higher than several dozens MeV the quasioptical and Glauber models with fitted parameters are used. For smaller energies the phenomenological approximation is applied. The tables are used as a frame for an interpolation calculation of cross-sections at intermediate energies and other values of target nuclei mass and charge numbers. The results are compared with the experimental data. The frame tables and the interpolation procedure have been put into a FORTRAN code which can be used in the CASCADE code.


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\(^{21}\) Royal Institute of Technology, Lindstedsvagen 30, 10044, Stockholm, Sweden
4.7 An Experimental Accelerator Driven System Based on Plutonium Subcritical Assembly and 660 MeV Protons Accelerator

t by A.Polański, V.S.Barashenkov, I.V.Puzynin, A.Sissakian

The aim of the studies was to define parameters of the Accelerator Driven System, which employs plutonium subcritical assembly and the 660-MeV proton accelerator, operating in the Laboratory of Nuclear Problems (LNP) of the JINR (Dubna, Russia). Fuel designed for the IREN pulsed neutron source for the Frank Laboratory of Neutron Physics will be adopted for the core of the assembly. The importance of research on the plutonium Accelerator Driven System (ADS) set up from the viewpoint of ecological safety and economic efficiency of finding a use for plutonium accumulated in the course of operating the nuclear power plants has been experimented. As a first step in the studies of peculiarities of plutonium ADS it was proposed to combine the core of the plutonium fast reactor IBR-30 and 660 MeV proton accelerator [1],[2],[3],[4]. Now a similar set up with plutonium of the IREN - new pulsed neutron source is considered [5].

The following measurements on the test assembly are planned: energetic gain and its variation for different target material compositions, neutron multiplication $k_{en}$ and its variation, neutron spectra etc. The kinetic of the processes in the Pu- subcritical assembly by the proton-neutron flash in the target inside the Pu-zone from 650-660 MeV protons, will be investigated. One of the interesting questions is the stability of the neutron multiplication coefficient value for subcritical assembly at the different energy and intensity of the proton beam.


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PHOTON NEEDLE FOR RADIOTHERAPY
M. Słapa, S. Pszona, W. Straś, M. Traczyk, J. Dora, R. Gutowski

PHOTON NEEDLE AS NEW TOOL FOR BRACHYTHERAPY
M. Słapa, J. Dora, R. Gutowski, S. Pszona, W. Straś, M. Traczyk (oral presentation)
II Symposium "Problems in Medical Physics" (in Polish), 15-16 November 1998

LECTURES, COURSES AND EXTERNAL SEMINARS.

Mathematical modeling of spallation reactions
A. Polański, 26.01 1998. Faculty of Physics and Nuclear Techniques, University of Mining and Metallurgy, Cracow

Energy amplifiers based on proton accelerators and subcritical reactors
A. Polański, 26.02 1998 Institute of Atomic Energy, Świerk

Energy production and nuclear transmutation using accelerator driven systems
A. Polański, 23.04 1998 Institute of Plasma and Nuclear Micro synthesis, Warsaw

New concepts safety nuclear reactors
A. Polański, 9.06 1998 Electrical Department, Warsaw Technical University, Warsaw

Study of physical aspects nuclear transmutation using Dubna proton phasotron
A. Polański, 23.10 1998 Faculty of Physics and Nuclear Techniques, University of Mining and Metallurgy, Cracow

High energy integral neutron-nucleus cross-sections
Jet counter-description and recent results\footnote{S.Pszona, 21.10.1998, Weizmann Institute of Science, Rehovot, Israel.}
S. Pszona, 21.10.1998, Weizmann Institute of Science, Rehovot, Israel

Ion cluster spectra at nanometer sites for alpha particle and electrons\footnote{S. Pszona, 9.12.1998, Genome Stability Unit, Harwell, England}
S. Pszona, 9.12.1998, Genome Stability Unit, Harwell, England

Ion cluster spectra at nanometer sites for alpha particle and electrons\footnote{S. Pszona, 17.12.1998, Gray Laboratory, Northwood, England}
S. Pszona, 17.12.1998, Gray Laboratory, Northwood, England

\footnote{in Polish}
\footnote{in English}

INTERNAL SEMINARS

Energy production and nuclear transmutation
A. Polański, 19.01 1998 Soltun Institute for Nuclear Study, Świerk

PERSONNEL

Research scientists

Aleksander Polański, Dr., on leave
Stanisław Pszona, Dr.
Krzysztof Wincel, MSc.
Barbara Zaręba, MSc.
Jacek Kula MSc.
Sabina Marjanska MSc.

Technical and administrative staff

Adam Dudziński
Adami Górski
Elżbieta Jaworska
Bogdan Kocik
Jan Piętka
Overview

In 1998 research activities were mostly continuations of previous studies, but we also undertook some new research aims. Theoretical studies comprised a development of the model of processes occurring at electrodes within a plasma system with magnetron discharges. Also developed was an improved model of phenomena within coaxial plasma injectors. Within a framework of the collaboration with the Warsaw Technical University we analyzed plasma dynamics in the coaxial gun used for the IPD process. We also carried out theoretical studies of proton-atom collisions (using a quasi-classical approach), different atomic experiments, and X-ray spectra. It was shown that some effects, interpreted so far on the basis of quantum mechanics, could be explained by the interaction of electrons moving along “rosette-type” trajectories.

Experimental studies of phenomena within PF-type discharges were concentrated on measurements of particle emission and polarization effects within the MAJA-PF device in Swierk (in cooperation with the Kurchatov Institute in Moscow). Also performed were studies of ions, neutrons, fast electrons and X-rays within the PF-360 facility in Swierk, an analysis of low-energy deuterons within PF-II device at INFIP in Buenos Aires (Argentina), as well as studies of ion beams with the PACO-PF device at IFAS in Tandil (Argentina). Within the framework of studies within the large PF-1000 facility at IPP/LM in Warsaw, we continued experiments with a thin liner compressed by a collapsing current sheet, optimization tests of PF discharges and measurements of emission characteristics. We performed measurements of VR with high-speed cameras, studies of X-rays with pinhole cameras and crystal spectrometers, as well as high-energy ion measurements with nuclear track-detectors (NTDs). In collaboration with the CVUT and IPP ČAS in Prague (Czech Rep.) we initiated new Filamentary Z-Pinch experiments within the large PF-1000 facility.

Studies connected with the development of plasma diagnostic methods concerned the calibration of new types of NTDs (particularly of PM-355, PM-500, and PM-600 plastic detectors) with beams of protons, alphas, deuterons, nitrogen- and carbon-ions. We also performed tests of NTDs for ion measurements in the TEXTOR facility in Juelich (in cooperation with the ERM group from Brussels). We also continued the elaboration of improved crystal spectrometers for measurements of X-ray polarization (the collaboration with the Kurchatov Institute in Moscow). In addition, we constructed miniature magnetic spectrometers for studies of electron beams, and a nitrogen laser for interferometry (the collaboration with the MFTI in Moscow).

Technological studies concerned modeling of HV pulse generators, and particularly systems with pulse transformers were used for pulse shaping. The PSPICE program was applied for computations of one-stage pulsed generators, multi-stage Marx-type systems, HV supply systems, and triggering units. Also designed was a high-energy simulator for studies of electromagnetic compatibility. Studies in the field of plasma-ion techniques used for material engineering were carried out in collaboration with Dept. P-IX in Swierk, and other research centers: the Warsaw Technical University, the Institute of Nuclear Chemistry and Technology in Warsaw, the FZR in Rossendorf (Germany), the Institute of Physics ČAS in Beijing (China), and the Institute of Plasma Physics NSC KhIPT in Kharkov (Ukraine). In addition we realized a contract with the Ecole Polytechnique in Palaiseau (France) connected with an INCO-COPERNICUS grant. It concerned measurements of overvoltages generated within plasma devices of the PF- and RPI-type. We also realized several contracts with industrial laboratories, concerning the design, manufacturing, and tests of special pulse generators.

The most important achievements of the Dept. P-V in 1998 were as follows:

1. The collection and elaboration of new experimental data showing changes in the polarization of X-ray lines emitted from the PF-type discharges, and studies of their correlation with pulsed beams of fast electrons.
2. The development of diagnostic methods, and in particular the calibration and use of modern NTDs, as well as the design and application of modernized Faraday-type collectors and miniature magnetic spectrometers.
3. The design of new pulse generators and simulators of electromagnetic interference as well as studies in the field of plasma-ion techniques applicable for the material engineering.

The studies described above were presented in 24 published papers (or accepted for the publication) in scientific journals, and in 38 papers presented at international conferences. Scientists from Dept. P-V also gave 9 invited lectures at different seminars in other research centers in Poland and abroad.
5.1 Modelling of Magnetron Sputter Device
by M. Rabinski

Magnetron sputtering is widely used in industry and research for sputter etching and thin film deposition [1, 2]. In all types of magnetrons, a specific configuration of an external magnetic field, applied to trap electrons in the region close to the cathode, allows the magnetron operation at lower pressures and voltages than within the other devices.

Investigation of the spatial structure of the magnetron discharge is a way to understanding discharge dynamics and has important implications for controlling nonuniformity of the target sputtering. Since a principal virtue of the magnetron is its ability to operate effectively at low neutral pressures and voltages, it is worthwhile to study mutual relations of discharge phenomena and plasma transport.

A one-dimensional three-fluid model has been developed for the modeling of plasma behavior in the magnetron [3]. The model includes continuity, momentum transfer, energy balance for electrons and ions as well as the Poisson equation for potential. A conception of taking into account two-temperature electrons has also been worked out.


5.2 Investigation of Discharge Phenomena in IPD Accelerator
by M. Rabinski, K. Zdunek

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

On the basis of earlier observations and a snow plow model of the current sheet motion, a physical model of phenomena in such devices has been proposed [2]. The selfconsistent model combines the dynamics of the current carrying sheet driven by the Lorentz force, with the balance of magnetic and fluid pressures at the contact interface, as well as the discharge of a condenser bank. The even phases of current flow in the accelerator (the second and fourth half-period) occur with the change of electrode polarization. Because of a significant difference in the discharge pattern caused by the polarity change as well as lowering current consecutive amplitudes, the plasma approaches nearer and nearer the range along the electrodes. At the end of each phase a weakening magnetic piston slows the current sheet motion, stops it or even causes its reverse movement. This leads to massive electro-erosion at the sheet foot and after many discharges one can observe a characteristic form of the eroded central rod.

A detailed analysis of the current sheet dynamics has been carried out for different discharge conditions (see Fig. 1) [3]. Conditions favourable for evaluation of the Rayleigh-Taylor instability on the current sheet surface have been found. The plasma configuration following this instability explains formation of a toroidal ring of dense plasma observed in front of the central electrode, as well as the nonuniformity of coating phase composition and morphology. By proper modification of the plasma accelerator design, for the first time we succeeded in reducing substantially the R-T instability and in obtaining $\alpha$-$\text{Al}_2\text{O}_3$ coatings instead of common $\gamma$-$\text{Al}_2\text{O}_3$ [4].

Fig. 1. Time evolution of the current sheet shape (plotted with 1 usec interval) for several discharge conditions ($C=100\,\mu\text{F}$, $U=6\,\text{kV}$, argon pressure $p=20/40/60\,\text{Pa}$). Radial and axial coordinates in cm.
5.3 On Nature of the Atom
by M.Gryziński

I gave a synthesis of many years lasting investigations on application of classical dynamics to atomic and molecular processes [1-4].

I gave arguments that electrons in the ground-energy-state always come in a close vicinity of the nucleus where they are back scattered by a spin magnetic field, see Fig. 2.

![Fig. 1. Electronic skeleton of matter](image)

The main conclusions of this research is that the thesis on the inapplicability of classical dynamics to the description of atomic and molecular, systems thesis formulated at the beginnings of quantum mechanics, is not true. In particular, it has been shown that within Newtonian dynamics and the Coulomb law, a large number of atomic and molecular problems can be quite accurately described. Among them are elastic and inelastic atomic collisions, atomic and molecular diamagnetism, the Stark effect, elasticity and thermal expansion of a solid body. A broad confrontation of theoretical calculations with experimental data has led to a conclusion that orbits of electrons in atoms, molecules and in a solid body have a radial character, see Fig. 1.

![Fig. 2. Spin of radially moving electrons is a factor which keeps order in matter](image)

A commonly accepted thesis on the excellent agreement of quantum theory, with experiment is questioned. I presented examples showing that quantum mechanics gives wrong results or is unable to solve many problems. In particular, it has been shown that Quantum Mechanics for seventy years failed to solve the simplest problem of atomic collision physics – that is the collision of a simple charged particle with a hydrogen atom. The shaky philosophical basis of quantum theory has led on one hand to a quite misleading interpretation of the Ramsauer effect and to formulation of an entirely wrong theory of the Stark effect. Arguments were presented that Quantum collision theory is a formal fitting procedure deprived of any real physical meaning. The Schroedinger equation was identified with the equation of classical dynamics describing stability of atomic system in the presence of oscillatory electromagnetic perturbations having origin in spin properties of the electron. The need to come back to the deterministic laws of classical dynamics forms this essence of the research.

5.4 Investigation of Charged Particle Emission and X-Ray Polarization on MAJA - PF Device
by L.Jakubowski, M.Sadowski, J.Zebrowski

New interesting X-ray spectra from the MAJA-PF device was obtained during an investigation performed with two mutually perpendicular spectrographs. These X-ray measurements of highly ionized argon lines show the polarization of the X-ray emission from PF discharges. This polarization can be explained by the appearance of strong local electric fields or by the anisotropy of the electron velocity distribution function [1,2]. The generation of such e-beams within PF discharges has been confirmed by means of different diagnostic techniques. The most important results can be summarized as follows:

- The pulsed e-beams emitted mainly in the upstream direction, through the tubular inner electrode (anode) contain electrons of energy ranging from several keV to above 500 keV.
- The electron energy spectrum is not smooth. It reveals many peaks which can be combined with the formation of numerous hot spots. Individual hot spots during a single PF discharge can emit electrons within different (relatively narrow) ranges of energy.
- The measurements performed recently make it possible to attribute to individual hot spots the emission of pulsed e-beams, synchronized in time and correlated in space (Fig.1). These e-beams are characterized by given energy distributions [3,4].

In general, it seems that such pulsed e-beams are accountable for the two mechanisms inducing the polarization of the X-ray emission from PF discharges.


5.5 Investigation of Charged Particles Emission and X-Ray Pulses from PF–360 Facility
by M.Sadowski, E.Skladnik-Sadowska, J.Zebrowski and L. Jakubowski

Experimental studies of the emission of the charged particles, neutrons and X-ray were continued in 1998 within the PF–360 facility. The analysis of results of the previous correlation measurements of the emission was performed and all these measurements were summarized in several papers [1,2].

In order to measure an ion beam divergence there was applied a set of three ion pinhole cameras placed one behind the other along a common z-axis. Changes in the deuterons flux density and the deuterons beam cross-sections were measured along the beam path in one of the cases [Fig.1.].

Time integrated measurements of energy spectra of the fast electron beams were carried out with a miniature magnetic analyzer placed inside the inner electrode of the PF–360 facility. It was found that the energy maximum of the spectrum appeared within the 70 - 90 keV energy range. This value was significantly lower in a comparison with the maximum of the electron spectrum measured with the second magnetic analyzer placed behind the main collector plate.

In 1998, we also performed preliminary measurements of energy spectra of ion beams inside the experimental chamber by means of a prototype.
of a miniature Thomson spectrometer with strong permanent magnets.

![Image](image_url)

Fig. 1. Maps of ion beams registered with three ion pinhole cameras placed one behind the other, as obtained from PF shots at $E_n = 113$ kJ, $p_e = 4.2$ mbar $D_2$. The CN-films were placed at a distance: A — 545 mm, B — 671 mm, C — 797 mm from the electrodes, respectively.

The PF-360 was also prepared for measurements of the X-ray and visible radiation with an ultra-high speed camera equipped with four micro-channel plates. Two series of X-ray measurements by means of an X-ray pinhole camera with the high magnification were carried out. In addition two turbomolecular vacuum pumps were assembled and tested for future vacuum X-ray measurements.

5.6 Measurements of Energetic Distribution of Low-Energy Deuterons in the PF-II Plasma Focus Device (collaboration with INFIP, Buenos Aires Argentina)

by J. Baranowski, M. Sadowski, E. Składnik-Sadowska, J. Zebrowski, H. Kelly, A. Lepone, and A. Marquez

Within the framework of the scientific collaboration with the Instituto de Fisica del Plasma (INFIP) at the University of Buenos Aires, we performed several series of ion measurements. The main aim of those studies was the determination of a low energy deuteron spectrum. The measurements of low energy deuterons ($E_d < 100$ kV) within plasma facilities are of particular importance because such deuterons play an important role in nuclear fusion reactions and in fast neutrons generation.

We measured an absolute value of the ion stream detected by means of a Faraday type collector. Low-energy deuteron interactions with a working gas filling up the PF-II experimental chamber were taken into account. The measured energy spectrum of deuterons was compared with an energetic distribution determined earlier by means of a Thomson-type spectrometer (Fig. 1).

Using the Faraday-type ion collector, operating within the so-called secondary electron (SE) emission mode, it was possible to register deuterons of energy equal to a dozen or so keV. Next studies are to be concentrated on the search of a correlation between the ion beam characteristics and the neutron production.

![Graph](image_url)

Fig. 1. Final spectrum of the nitrogen (including elastic scattering effect) calculated either from the FC grid signal or from the FC collector signal. For a comparison, the nitrogen spectrum obtained with a Thomson spectrometer is also shown.

The results were presented at the Intern. Workshop on Plasma-Focus Research and published in two scientific journals [1-3].
5.7 Studies of a Structure of Ion Beams Emitted From a Small PACO PF-Device

(collaboration with IFAS in Tandil, Argentina)


Within the framework of the collaboration with IFAS we performed experimental investigations of a structure of ion beams of different energies, and those of an angular distribution of ions emitted from the PF-PACO device operated with an initial static D₂-filling.

Fig. 1 Angular distribution of high-energy deuterons emitted from PACO device: with a 6 μm Al-filter there were registered deuterons of energy above 700 keV, and with a 10 μm Al-filter—those of energy above 1.3 MeV.

In order to analyze high-energy deuteron beams emitted mostly along the z-axis, the use was made of an ion pinhole camera equipped with solid-state nuclear track detectors (NTDs) and appropriate absorption filters. The applications of the absorption filters of different thickness enabled the ion pictures of different energy to be obtained, e.g. deuterons of energy: \( E_D > 80 \text{ keV} \), \( E_D > 220 \text{ keV} \), \( E_D > 700 \text{ keV} \), and \( E_D > 1.3 \text{ MeV} \), respectively. Characteristic ring-shaped ion images were explained as the tracks induced by deuterons deflected within an azimuthal magnetic field produced around a pinch column.

The anisotropic angular distribution of fast deuterons (Fig. 1) was registered by means of NTDs, covered with narrow strips of different filters, placed upon a special semicircular support at the same distance from the pinch center, but at different angles to the z-axis. The anisotropic character of that distribution was explained by a stochastic formation of ion micro-sources within the pinch column. The local minimum, usually observed near the z-axis, was interpreted by numerous reflections of accelerated deuterons within a tunnel formed by the collapsing current sheath. Deuterons of energy equal to 10-100 keV can be trapped inside such a plasma tunnel.

Registered ion images suggest the appearance of two different types of PF discharges. For PF shots with a low neutron yield one can observe numerous well-collimated deuteron beams. For PF discharges with high neutron yield distinct bunches of deuteron beams of energy above 80 keV are emitted. Primary deuterons of lower energy cannot be observed because they are stopped by a dense plasma region and partially lost in nuclear fusion reactions.

The results of the studies were presented at the Intern. Workshop on Plasma Focus Research [1] and published [2].

[1] Intern. Workshop on PF Research, Kudowa, Poland, July 8-10, 1998

1) Instituto de Fisica Arroyo Seco (IFAS), UNCPBA, 7000, Tandil, Argentina
5.8 Studies of X-Ray and Corpuscular Emission from Different Plasma Discharges of Axial Symmetry
by E.Skladnik-Sadowska, J.Baranowski, M.Sadowski, J.Stanislawski, and J.Zebrowski

The review presents the most important results of studies of X-ray emitting regions and corpuscular emission from plasma streams generated by an injector with coaxial multi-rode electrodes of the IONOTRON-type, as well as devices of the Plasma-Focus type. Recently, time-resolved measurements of ion pulses and energy spectra have been carried within a Hall-type injector ISEX, which was designed specially for active experiments in of the ionosphere (Fig. 1) [1].

Different diagnostic techniques for studies of X-ray, ions, and fast electrons, have been developed at the IPJ in Swierk. They have successfully been applied for investigation of of the IONOTRON- and PF-type facilities.

Time-integrated measurements of pulsed ion beams are carried out by means of pinhole cameras (Fig.2) and Thomson-type analyzers equipped with NTDs [2]. For studies of X-rays, use is made of pinhole cameras with thin metal foil filters and X-ray films (Fig3) or microchannel plates [3].

Time-resolved measurements of X-rays are performed with miniature filter-scintillator detector sets or gated microchannel plates.

To study ion and electron pulses, use is made of magnetic analyzers equipped with appropriate films or scintillation detectors.

In order to improve spatial- and temporal-resolution in the studies of X-rays and corpuscular beams, further development of diagnostic methods is needed. In particular a modern electronic equipment should be applied, e.g. microchannel amplifiers of a new generation.

Fig.1. Ion energy spectra of Xe-ions emitted from the ISEX device, as measured with Faraday cups placed at different angular position.

Fig.2 Time-integrated ion pinhole picture and time-resolved ion signals from PF device for two different discharges. M-markers, X-rays, n-neutrons, d-deuteron pulses.

Fig.3 Series of X-ray pinhole pictures from the MAJA facility, as obtained for three successive shots performed at \( U_0 = 40 \) kV, \( t = 250 \) us with the D2 filing.

The main results were presented at three conferences [1-3].


5.9 Measurements and Comparison of Overvoltage Waveforms within PF- and RPI-Type Facilities (first stage of the INCO-COPERNICUS contract) by M. Sadowski, J. Baranowski, K. Czaus, E. Skladnik-Sadowska, and J. Żebrowski

In a framework of the EC contract with the Ecole Polytechnique in Palaiseau, France we performed experimental studies of voltage peaks appearing upon collectors and free ends of the coaxial electrodes within PF (Plasma Focus) and RPI (Rod Plasma Injector) devices.

It has been supposed that during such peaks the acceleration of charged particles is intensified. Recently, it has been proposed to intensify the POS (Plasma Opening Switch) operation and to use such overvoltage pulses in order to accelerate ions between especially shaped electrodes, forming the HV-diode configuration.

The main aim of this work was to study experimental conditions within different PF- and RPI-type facilities, constructed and operated at the IFJ in Swierk, when high overvoltage peaks can be generated. In order to measure waveforms of voltages between the electrodes, we applied several voltage dividers (Fig.1).

It has been confirmed that between coaxial electrodes of the RPI- and PF-type facilities overvoltage peaks appear. If the RPI-IBISEK is operated under standard initial gas conditions (i.e., under a static initial pressure) the voltage peaks on the inner electrode are lower. They amount to 15-27 kV only, although the maximum discharge current is considerably higher (at the initial charging voltage $U_0 = 30$ kV within the PF-360 device it is possible to obtain $I_{max} = 1.6 - 1.8$ MA).

It was observed that if the PF-360 facility is operated under standard gas conditions (i.e., under a static initial pressure) the voltage peaks on the inner electrode are lower. They amount to 15-27 kV only, although the maximum discharge current is considerably higher (at the initial charging voltage $U_0 = 30$ kV within the PF-360 device it is possible to obtain $I_{max} = 1.6 - 1.8$ MA).

It was concluded that to increase the overvoltage peaks within the PF-360 facility it is necessary to apply gas puffing and to optimize electrode shapes. To supply an appropriate amount of the working gas a fast electromagnetic gas-valve can be used, but to facilitate the formation of a current sheath it is better to apply miniature plasma injectors placed close to the main tubular insulator.

The main results of the studies were presented at the International Workshop [1] and published in [2-3].

[1] Plasma-Focus Research, Kudowa, Poland, July 6-8, 1998; oral C-2;
[3] Partner progress report on the realization of the first year activities under the contract No. IC15-CT97-0705

*) This work was supported by the European Commission contract No. IC15-CT97-0705.
5.10 Optimization of Discharges and Measurements of fast Particles and X-Ray Emission Characteristics in PF-1000 Facility at Increased Energy by M. Sadowski, A. Szydlowski, M. Scholz, M. Borowiecki

Results of the experiment performed in 1997 within the PF-1000 facility (at the IFPJ in Warsaw) in which the collapsing current sheath was used as a driver of a foam-agar liner were elaborated and two papers on the plasma-focus-liner interaction were prepared. The first paper was submitted for publication [1], and the second one was presented at the international conference in Haifa [2].

In 1998 we also continued experiments with the optimization of PF-1000 discharges. In particular, evolution of the discharges of the increased charging voltage and initial pressure, as well as various compositions of the working gas, was investigated. Based on the streak camera pictures taken in such experiments, a detailed analysis of the current sheath dynamics was performed. The X-ray emission was also investigated by means of time-resolved and time-integrated pinhole cameras, an X-ray spectrometer equipped with a bent mica crystal, and by means of scintillation probes. A Thomson parabola analyzer (hired from IPJ) was adapted for diagnostics of fast ion beams emitted from the PF discharges. A special drift tube (so-called skimmer) with a differential pumping was designed and manufactured. It allowed ion beams to be extracted from the discharge chamber and to be propagated under a relatively low pressure. The ion pinhole cameras equipped with nuclear track detectors were also used. Average radial- and axial-speeds of the current sheath were measured during the collapse phase of the discharge. They were equal to ~ 1.3 \times 10^7 \text{ cm/s} and ~ 1.7 \times 10^7 \text{ cm/s} respectively. When the hydrogen discharges were admixed with argon, the plasma column appeared to be less stable and soft X-ray emission was about one order of magnitude higher than that from the pure hydrogen discharges.

Fast ion fluxes (of energy > 400 keV) were measured by means of an ion pinhole camera installed on the end flange of the discharge chamber (~ 200 cm from the electrode end). The ion flux was estimated to be about $10^6 \text{ ions/cm}^2$. Ion beam pictures as taken with the pinhole camera fixed at a distance of 40 cm from the inner electrode end, showed quite complex and complicated structures of the ion sources. Energetic spectra of fast electrons emitted in the upstream direction were measured with a small magnetic spectrometer equipped with a permanent magnet, and placed on the electrode axis behind the main collector of the PF-1000 facility. The fast electron spectrum showed two maxima (at electron energies of 60 keV and 160 keV), and it extended up to energy of 300 keV. The results of those experiments were presented at three international conferences: in Prague [3], in Kudowa [4], and in Besancon [5].

At the end of 1998, a new experiment was started within the PF-1000 facility. Within the framework of Polish-Czech cooperation we performed investigations of interaction of the PF current sheath with a metallic liner (thin wire) installed at the inner electrode end.

[1] Phys. Letters A, manuscript number PLA # 2084, – in press


Detailed studies of selected types of solid-state nuclear track detectors (SSNTDs) have been performed at the IPJ for many years. Up to now responses of such detectors were, however, investigated mainly for ion energy ranging from 0.3 to 4.5 MeV. Those studies were motivated by the application of these detectors for plasma experiments. Recently we have examined the characteristics of the SSNTDs for ions of a relatively low energy (70 - 250 keV), as well as for high energy of a dozen or so MeV. The main aim of these measurements was to find low energy registration limits of the modern CR-39, PM-355, and PM-600 track detectors irradiated with protons.
deuterons, and $^4$He ions of energy within the range of 70-250 keV. Diagrams of the track diameter evolution as a function of particle energy, and etching times were determined.

![Diagram showing track diameter evolution](image)

**Fig.1.** Diagrams presenting track diameter evolutions as a function of particle energy and etching time for the PM-355 plastic detector.

The experimental set-up and the procedure used in the experiment were the same as those used in our previous calibration studies [1]. Protons, deuterons, and helium-ion beams were obtained from a Van de Graaff accelerator operated at IPJ. A thin (about 10 $\mu g/cm^2$) carbon foil was used as a scattering target of the incident ion beam. A SB Si- detector was used to determine spread and an effective energy value of the scattered projectiles, as well as to control the counting rate (track densities) at the detector sample surface. Samples of the SSNTDs, cut in narrow strips (5x30 mm), were placed inside the scattering chamber at 150° to the accelerator beam and about 85 mm from the carbon foil target. The particles backscattered from the foil hit the samples almost perpendicularly. After irradiation, the SSNTD samples were etched in a 6.25-N water solution of NaOH, at a temperature of 70 $\pm$ 1° C. The etching procedure was stopped every hour, the samples were washed and dried, and track diameters were measured with an optical microscope. After that, the etching procedure of the samples was renewed, and it was continued for a next hour.

In general, tracks induced by relatively low energy particles (protons, deuterons, and helium-ions) in the modern plastic detectors take the form of very shallow craters. The diagrams showing track diameters in the PM-355 plastic as a function of particle energy and etching time, are presented in Fig.1. One should admit that the value of 70 keV is the lower energy limit for protons, deuterons, and helium ions which can be still registered by the CR-39, PM-355, and PM-600 plastics, provided that these detectors are etched under typical etching conditions. The PM-355 plastic appeared to be best for the detection of low energy protons, deuterons, and helium-ions. Tracks induced in the PM-355 samples, especially by particles of energy not much higher than 70 keV, are better visible and less diffuse than those produced in the two other plastics investigated. The paper was submitted for the publication [2].


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**5.12 Development of Crystal Spectrometers for X-Ray Polarization Measurements (cooperation with Kurchatov Institute) and of Equipment for Plasma Dynamics Studies (cooperation with the MSEPhI in Moscow)**

by L.Jakubowski, M.Sadowski, E.O.Baronova¹, and E.D.Vovchenko²

In order to prepare new equipment for research on plasma dynamics a nitrogen laser system was designed and assembled. After preliminary voltage tests the laser system was used in a series of measurements performed to determine the main characteristics of laser pulses (Fig.1).

To investigate energy spectra of fast electron beams, as emitted from PF discharges, we designed two miniature magnetic spectrometers. They are characterized by a 180° deflection angle and they make possible time-resolved measurements of electrons within given energy range.
In order to improve methods of the experimental data processing a new setup for the scanning of transparent film was completed and assembled. Using selected computer programs a new method of X-ray film analysis was used. It makes possible computer processing of registered X-ray and electron spectra.

1) RRC “Kurchatov Institute”, Moscow, Russia.
2) MSEPhI, Moscow, Russia

5.13 Modeling of HV-Pulse Generators Containing Transformers for the Pulse Shaping
by A.Jerzykiewicz, K.Kocięcka, and J.Witkowski

Several numerical programs simulating the generation of current- and voltage-pulses in the circuits switched by means of controlled spark-gaps described recently in paper [1] were elaborated at the INS in the years 70s. Among them were: ISKRA, SPARK, ROZRZUT, G1, G2, TWICCAP, designed for calculations of one-stage generator of various configurations, and two-stage MARX generators. There was also GENRAT for multisectional current generators. Results of calculations were compared with the results of measurements to verify the simulation methods.

The access to the PSpice program enabled the solving of various electrical circuits by means of node matrix equations to be performed. Some efforts have been made to check the usefulness of this program for preliminary calculations of one-stage voltage and current surge generators [2], multistage Marx generators, HV charging units (including the capacitive cascade rectifiers), resistive and capacitive voltage dividers, and spark-gap triggering systems (including pulse transformers).

Appropriate schemes were elaborated and described in the PSpice language. Basing on the results of these calculations the EMC simulators (burst, surge, ESD) of the EM 10-1 test system were built. Also designed was the voltage surge (1.2/50) and oscillating current generator of the GUN-25/2s type. Sufficiently good agreement was achieved between results of the calculations and measurements performed during the laboratory tests.


5.14 Design and Construction of Pulse Generator for EMC Surge Immunity Tests
by A.Jerzykiewicz, K.Kocięcka, R.Mirowski, and J.Witkowski

A special pulse generator was designed and built according to the demands of the IEC1000-4-5 standard "Electromagnetic Compatibility (EMC), Part 4: Testing and measurement techniques - Section 5: Surge immunity test" [1-2]. It was a part of EMC modular test system of the EM10-1 type [3]. A HV-supply system of the generator as well as coupling and decoupling networks were placed in the central unit of the test system. After investigation of the model a surge generator of the S-1 type was assembled. It was equipped with two inserts (G and T). In a case when the G insert was used the generator was working as a hybrid generator producing normalized current- and voltage-surges 8/20μs up to 2kA, and 1.2/50μs up to 4kV, appropriately. In the case when the T insert was applied voltage surges of 0.5/700, 10/700, 100/700μs (both polarities, with crest values from 0.5 to 4kV) were generated. In the shortcircuited circuit generating voltage surges 10/700 μs as well as current surges with the front time 4μs and crest value 100A, were measured at 4kV charging voltage.

The pulse circuit was switched on by means of a trigatron. To adjust the breakdown voltage of the trigatron to the working voltage the distance between electrodes was changed by means of a setting-knob on the front panel. The generator was equipped with three floating outputs: the first - direct from the generator, and two others through a 9 μF and 18 μF capacitors, respectively. It could be
triggered from a phase shifter synchronizing the pulse generation with a phase of the network voltage. The generator was tested and the results were presented in the report [4].

[1] Proc. of IV Symp. on HV Engineering IW-98, Poznań, Poland, pp. 57-62
[2] Design of surge generators (hybrid 1.2/50, 8/20, 10/700 μs), A.Jerzykiewicz, K.Kocięcka,

5.15 Testing of the High Current Implantator of Nitrogen Ions
by K.Czaus, J.Langner, J.Stanislawski, and J.Zebrowski

In 1997 the construction and assembling of a high current ion source for nitrogen implantation purposes were finished. Last year all the units of the device were tested and the implantator was put into operation. The nitrogen ion beam of intensity higher than 1 mA, and energy of 80 keV, was obtained. For a stable operation of the ion source at a voltage higher than 50 kV, some modification of the vacuum system and cooling circuit were performed. During the 3-hour operation of the implantator a change on stability of the ion current was below 10%.

A radial distribution of the ion current density was measured by means of miniature collectors, (Fig.1).

5.16 Design and Testing Device for Production of the Metallic and Ceramic Coatings
by J.Stanislawski and J.Langner

The method of physical vapour deposition (PVD) is one of the most intensively developed methods of surface technology. One of these methods is the arc plasma condensation. The method provides hard coatings which have found applications as wear-resistant layers on different tools, and as decorative coatings.

In the framework of the task considered a complete device for the production of metallic and ceramic coatings upon conducting surfaces has been designed, constructed, and tested.

The device consists of a vacuum chamber equipped with a metallic plasma source as well as a supply system for this source. The chamber of about 250 l capacity is pumped out by means of a pumping stand of the SP-2000 type. The metallic plasma is generated by a vacuum or a low pressure arc discharge. Motion of the arc spot on the cathode surface is constrained with the use of the 100 Gs axial magnetic field (steered arc). The supply system contains three main DC supply units with parameters as follows: 50V, 60A – for the arc discharge; 30V, 5A – for the magnetic field, and 2kV, 1A – for irradiated substrates bias.

Tests of a titanium nitride (TiN) coating upon the stainless steel substrates has been performed.
The deposition procedure sequence was as follows:
- mechanical and chemical cleaning,
- physical cleaning with an argon glow discharge,
- sputter-etching with 1keV titanium ions originated from the vacuum arc,
- TiN coating deposition with an arc discharge in a nitrogen atmosphere.

The coatings were investigated using a X-ray diffraction technique. Texture of TiN coatings depends strongly on substrates bias voltage. In general, they have a (111) preferred orientation with a significant (200), (220) and (222) components (Fig.1).

Performed tests demonstrated that the device operates correctly.

5.17 Contracts
by M.Bielik, A.Jerzykiewicz, K.Kociecka, R.Mirowski, and J.Witkowski

1. The ZS-60 type Station for testing of electrical breakdown strength of insulating gloves
The station built, as according to the order from the SECURA B.C.Co.Ltd., was equipped with HV transformers (6 and 60kV), a control desk, the measuring system of test voltage and currents, a test stand enabling simultaneous tests of 6 gloves and a computer aided control and data acquisition stand [1,2].

2. Modular EMC test system of the EM10-I
The system consisted of a central unit type C-1, a phase shifter (PS-1), an electrical fast transient/burst simulator (B-1), an electrostatic discharge simulator (ESD-1), a surge generator (S-1), a voltage dips & short interruptions simulator, and an auxiliary equipment. The system was built according to the order from the ELTEST Laboratory [3-9].

3. Withstanding voltage tester of the ZS-4a type
The tester was designed especially for alternating voltages tests of distribution boards, with nominal voltages up to 690V. It produced voltages up to 4kV at continuous power of 0.5kVA [10-11].

4. Voltage and current surge of the generator GUN-25/2s
The generator produced a surge voltage with the shape 1.2/50μs and a crest value up to 20kV for testing of electrical equipment according to demands of the PN standards (PN-88/E-88605, PN-90/E-06150/10 and PN-IEC 1008-1+A#:1996), or dumped, oscillating current pulse with the first amplitude 200A according to demands of the standard PN-IEC 1008-1+A#:1996.

The procedure of tests can be fully automatized and controlled with a computer.
A preliminary design was made in 1998 [12].

LIST OF PUBLICATIONS

ANALYSIS OF THE NITROGEN ION BEAM GENERATED IN A LOW-ENERGY PLASMA FOCUS DEVICE BY A FARADAY CUP OPERATING IN THE SECONDARY ELECTRON EMISSION MODE;
H. Kelly, A. Legpne, A. Marquez, M. Sadowski, J. Baranowski, E. Składniak-Sadowska;

ISLEDOVANYE POLARIZATSl LINEYCHTOVO IZLUCHENIYA MNOGO-ZARYADNYKH YONOV
MIKROPINCHEVYHO RAZRYADA;
E.O. Baronova, V.V. Vikhrov, A.E. Gurchi, A.N. Dolgov, K.T. Karayev, M. Sadowski, O.G. Semenyov, A.A. Tihomirov, and
L. Jakubowski;

EROSION BEHAVIOUR OF BORON CARBIDE UNDER HIGH-POWER PULSED FLUXES OF HYDROGEN PLASMA

MODIFICATION OF SILICON NITRIDE CERAMICS WITH HIGH INTENSITY PULSED ION BEAMS;
E. Brenschel, J. Piekoszewski, E. Wieter, J. Langner, R. Grotechen, H. Reuther;

MODIFICATION OF THE SURFACE PROPERTIES OF MATERIALS BY PULSED PLASMA BEAMS;
J. Piekoszewski, Z. Werner, J. Langner, L. Walit;
Surface Coating Techn. 106 (1998) 228

THEORETICAL STUDY OF ION MOTION WITHIN A PLASMA-FOCUS REGION;
A. Pasternak and M. Sadowski;

THE HEIBE PROJECT; HIGH ENERGY ION BEAM ENGINEERING
J. Larour, P. Choi, J. Lunney, V. Brac, A. Kim, P. Chraska, I. Raicu, I.R. Smith,
M. Sadowski, and C.S. Wong;

MEASUREMENTS AND COMPARISON OF OVERVOLTAGE WAVEFORMS WITHIN PF- AND RPI-TYPE FACILITIES;
M. Sadowski, J. Baranowski, K. Czaus, E. Składniak-Sadowska, and J. Zebrowski;

STUDIES OF NONCYLINDRICAL PINCH DYNAMICS AND CHARGED PARTICLE EMISSION WITHIN PF-1000 FACILITY;

MEASUREMENTS OF ION BEAMS WITHIN THE PF-1000 FACILITY BY MEANS OF NUCLEAR TRACK DETECTORS;
A. Szydlowski, M. Sadowski and M. Scholz;

X-RAYS AND ELECTRON BEAMS EMISSION FROM MAJA-PF DEVICE;
L. Jakubowski, M. Sadowski and E.O. Baromova;

FARADAY-CUP MEASUREMENTS OF DEUTERON BEAMS GENERATED BY A SMALL PLASMA-FOCUS DEVICE;
H. Kelly, A. Legpne, A. Marquez, M. Sadowski, J. Baranowski and E. Składniak-Sadowska;

STRUCTURE OF ION BEAMS_EMITTED FROM A SMALL PACO PF-DEVICE;
M. Sadowski, E. Składniak-Sadowska, J. Baranowski, M. Milanese, R. Maroso and J. Pouzo;

DIAGNOSTIC METHODS OF EXPERIMENTAL STUDIES ON EMISSION OF PULSED DEUTERON AND ELECTRON BEAMS FROM THE PF-360 FACILITY;
M. Sadowski and J. Zebrowski;

DIAMOND GROWTH ON STEEL SUBSTARTES WITH Al-N INTERLAYER PRODUCED BY HIGH POWER PLASMA STREAMS;
Ying-Bing Jiang, Xiang-Jun He, Bin Liu, Hong-Xia Zhang, Si-Ze Yang, J. Baranowski, J. Langner, M. Sadowski, E. Składniak-Sadowska, and J. Stanisławski;
PHYSICAL AND COMPUTATIONAL MODELS OF DYNAMIC PHENOMENA WITHIN IPD ACCELERATOR;
M. Rabinski and K. Zdunek;

SCIENTIFIC STATUS OF PLASMA-FOCUS RESEARCH;

STUDIES OF NEUTRON EMISSION FROM DIFFERENT PLASMA-FOCUS FACILITIES IN POLAND; A REVIEW;
M. Sadowski;
J. Moscow Phys. Soc. 8 (1998) 197

PULSED PLASMA BEAM MIXING OF Ti AND Mo INTO Al₂O₃ SUBSTRATES;
J. Piekoszewski, E. Wieser, R. Grotzschel, H. Reuther, Z. Werner, J. Langner,
Nucl. Instrum. & Methods B (in press)

FOAM LINER DRIVEN BY A PLASMA FOCUS CURRENT SHEATH;
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FORMATION OF SURFACE Pd-Ti ALLOYS USING PULSED PLASMA BEAMS;
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RESEARCH ON DENSE MAGNETIZED PLASMAS IN POLAND: HISTORY, STATUS, AND PROSPECTS;
M. Sadowski;
VANT: Plasma Physics (in press)

STUDIES OF X-RAY AND CORPUSCULAR EMISSION FROM PULSED PLASMA FACILITIES;
E. Słudnik-Sadowska, J. Baranowski, M. Sadowski and J. Zebrowski;
VANT: Plasma Physics (in press)

DYNAMICS OF PULSE PLASMA IN COAXIAL ACCELERATOR;
K. Zdunek (coauthor: M. Rabinski) – Invited talk;
Polish Vacuum Society Congress, Cracow, Poland, 25-30 May, 1998 – in press

DIAGNOSTICS OF PULSED PLASMA-ION BEAMS FROM DIFFERENT COAXIAL INJECTORS
E. Składnik-Sadowska (coauthors: J. Baranowski, M. Sadowski, J. Stanisławski and J. Zebrowski) – Poster;
BEAMS'98, 12th International Conference on High Power Particle Beams, Heifa, Israel, June 8-12, 1998 – in press

LINE FORMATION AND POLARIZATION ANALYSIS OF HIGHLY CHARGED IONS RADIATED FROM DENSE PINCHING PLASMAS;
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FOAM LINER PREIONISATION BY EXTERNAL CURRENT SHELL ON “PF-1000” AND “ANGARA-S-1”;
BEAMS'98, 12th International Conference on High Power Particle Beams, Heifa, Israel, June 8-12, 1998 – in press

ELECTRON BEAMS AND X-RAY POLARIZATION EFFECTS IN PLASMA-FOCUS DISCHARGES
L. Jakubowski (coauthors: M. Sadowski, E.O. Baranova, and V.V. Vikhrev) – Poster;
BEAMS'98, 12th International Conference on High Power Particle Beams, Heifa, Israel, June 8-12, 1998 – in press
FORMATION OF SURFACE Pd-Ti ALLOYS USING PULSED PLASMA BEAMS;

PULSE GENERATOR Gus-60 FOR LOCALIZATION OF INTERMITTENT FAILURES MEDIUM VOLTAGE UNDERGROUND CABLES;

PULSE SIMULATORS OF ELECTROMAGNETIC INTERFERENCES

CONTROLLED SPARK-GAPS OF HV GENERATORS;

CALIBRATION AND APPLICATION OF NUCLEAR TRACK DETECTORS FOR HIGH-TEMPERATURE PLASMA DIAGNOSTICS

STUDIES OF ION EMISSION FROM DIFFERENT PLASMA DISCHARGES OF AXIAL SYMMETRY

ANALYSIS OF ION TRAJECTORIES WITHIN A PINCH COLUMN OF A PF-TYPE DISCHARGE

FLUID MODEL OF PLASMA IN MAGNETRON SPUTTER DEVICE

NUMERICAL MODELLING OF PLASMA IN IPD PROCESS

STUDY OF CURRENT SHEATH DYNAMICS AND CHARGED PARTICLE EMISSION FROM PF-1000 FACILITY

RESEARCH ON EMISSION OF CHARGED PARTICLE BEAMS FROM PF-360 FACILITY

FARADAY CUP MEASUREMENTS OF DEUTERON BEAMS GENERATED BY A SMALL PLASMA-FOCUS DEVICE
J. Baranowski (coauthors: H. Kelly, A. Lupecz, A. Marquez, M. Sadowski, and E. Skladnik-Sadowska) - Oral; International Workshop on Plasma-Focus Research PF'98, Kraków Zdroj, Poland, July 8-10, 1998

X-RAYS AND ELECTRON BEAMS EMISSION FROM MAJA-PF DEVICE

THEORETICAL STUDY OF ION MOTION WITHIN A PLASMA-FOCUS REGION

PHYSICAL AND COMPUTATIONAL MODELS OF DYNAMIC PHENOMENA WITHIN IPD ACCELERATOR

STUDIES OF NONCYLINDRICAL PINCH DYNAMICS AND CHARGED PARTICLE EMISSION WITHIN PF-1000 FACILITY
MEASUREMENTS AND COMPARISON OF OVERVOLTAGE WAVEFORMS WITHIN PF- AND RPI-TYPE FACILITIES
M. Sadowski (coauthors: J. Baranowski, K. Czaus, E. Skladnik-Sadowska, and J. Żebrowski)
International Workshop on Plasma-Focus Research PF'98, Kudowa Zdrój, Poland, July 8-10, 1998

DIAMOND GROWTH ON STEEL SUBSTRATES WITH Al-N INTERLAYER PRODUCED BY HIGH POWER PLASMA STREAMS
M. Sadowski (coauthors: Ying-Bing Jiang, Xiang-Jun He, Bin Liu, Hong-Xia Zhang, Si-Ze Yang, J. Baranowski, J. Langner, E. Skladnik-Sadowska, and J. Stanisiawski)
International Workshop on Plasma-Focus Research PF'98, Kudowa Zdrój, Poland, July 8-10, 1998

STRUCTURE OF ION BEAMS EMITTED FROM A SMALL PACO PF-DEVICE
E. Skladnik-Sadowska (coauthors: M. Sadowski, J. Baranowski, M. Milanese, R. Moreno, and J. Pouzo)
International Workshop on Plasma-Focus Research PF'98, Kudowa Zdrój, Poland, July 8-10, 1998

MEASUREMENTS OF ION BEAMS WITHIN THE PF-1000 FACILITY BY MEANS OF NUCLEAR TRACK DETECTORS
A. Szydlowski (coauthors: M. Sadowski, and M. Scholz)
International Workshop on Plasma-Focus Research PF'98, Kudowa Zdrój, Poland, July 8-10, 1998

DIAGNOSTIC METHODS OF EXPERIMENTAL STUDIES ON EMISSION OF PULSED DEUTERON AND ELECTRON BEAMS FROM THE PF-360 FACILITY
J. Żebrowski (coauthor: M. Sadowski)
International Workshop on Plasma-Focus Research PF'98, Kudowa Zdrój, Poland, July 8-10, 1998

APPLICATION OF SOLID-STATE NUCLEAR TRACK DETECTORS FOR STUDIES OF FAST ION BEAMS WITHIN PF-1000 AND OTHER PLASMA-FOCUS FACILITIES
Szydlowski (coauthors: M. Sadowski, M. Scholz, H. Kelly, A. Marquez, and A. Legone)
19th International Conference on Nuclear Tracks in Solids, Besançon, France, August 31 – September 4, 1998

INVESTIGATION OF RESPONSE OF CR-39, PM-355, AND PM-500 TYPES OF NUCLEAR TRACK DETECTORS TO ENERGETIC CARBON IONS

PULSED PLASMA BEAM MIXING OF Ti AND Mo INTO Al2O3 SUBSTRATES;

NON-LINEAR ELECTROMAGNETIC PHENOMENA IN HIGH-VOLTAGE HIGH-CURRENT DISCHARGES
M. Sadowski – Invited lecture;

INFLUENCE OF PLASMA DYNAMICS ON MATERIAL SYNTHESIS PRODUCT OF IPD PROCESS;
M. Rabinski, (coauthor K. Zdzieńek) – Poster
III International School and Symposium on Physics in Material Science, Jaroszowic, Poland, September 13-19, 1998 (in press)

COMPUTER SIMULATIONS OF IMPULSE PLASMA DYNAMICS DURING IPD PROCESS;
K. Zdzieńek (coauthor: M.Rabinski) – Poster
Sixth Int. Conf. on Plasma Surface Engineering, Garmish-Parten Kirchen, Germany; September 14-18, 1998 ( in press)

RESEARCH ON DENSE MAGNETIZED PLASMAS IN POLAND; HISTORY, STATUS, AND PROSPECTS
M. Sadowski – Invited lecture;
VI Ukrainian Conference and School on Plasma Physics and Controlled Fusion, Alushta, Ukraine, September 14-20, 1998 (in press)

STUDIES OF X-RAY AND CORPUSCULAR EMISSION FROM PULSED PLASMA FACILITIES
E. Skladnik-Sadowska (coauthors: J. Baranowski, M. Sadowski, and J. Żebrowski) – Invited lecture
VI Ukrainian Conference and School on Plasma Physics and Controlled Fusion, Alushta, Ukraine, September 14-20, 1998 ( in press)

DOPING, COATING AND GLAZING THE SOLID SURFACES BY INTENSE PLASMA PULSES
VI Ukrainian Conference and School on Plasma Physics and Controlled Fusion, Alushta, Ukraine, September 14-20, 1998 ( in press)

CHANGES OF SURFACE STRUCTURE INDUCED BY PULSED PLASMA STREAMS PROCESSING
I.E. Garkusha (coauthors: V.V. Chebotarev, J. Langner, J. Piekoszewski, M. Sadowski, V.I. Tereshin, and N.T. Derepovski) - Invited lecture;
VI Ukrainian Conference and School on Plasma Physics and Controlled Fusion, Alushta, Ukraine, September 14-20, 1998 (in press)

PLASMA-FOCUS EXPERIMENTS ON PF-1000 FACILITY – NEW IDEAS
LECTURES, COURSES AND EXTERNAL SEMINARS

Status and Prospects of Dense Magnetized Plasma Studies in Poland;
M. Sadowski;
Plasma Seminar at INFIP, University of Buenos Aires, Argentina, March 13, 1998

Progress in Diagnostics of Pulsed Plasma Streams;
E. Skladnik-Sadowska;
Plasma Seminar at INFIP, University of Buenos Aires, Argentina, March 13, 1998

Investigation of Electron Beams and Polarization X-rays in Plasma Focus Discharges;
L. Jakubowski;

Old and New Problems of Plasma Focus Studies;
M. Sadowski;
Plasma Seminar at IFAS, University of Tandil, Argentina, March 25, 1998

Results of Gas-Puffed Experiments with Plasma-Focus Devices;
E. Skladnik-Sadowska;
Plasma Seminar at IFAS, University of Tandil, Argentina, March 25, 1998

Studies and Applications of Plasma-Focus Facilities;
M. Sadowski;
General Colloquium at Dept. of Physics, Pontificia Universidad Catolica de Chile, Santiago, Chile, March 31, 1998

Detection and Analysis of Pulsed Plasma-Ion Streams;
E. Skladnik-Sadowska;
Plasma Seminar at Dept. of Physics, Pontificia Universidad Catolica de Chile, Santiago, Chile, April 1, 1998

Applications of High-Temperature Plasmas;
M. Sadowski;
Seminar for Ph.D. Students of Masaryk University, Brno, Czech Rep., September 11, 1998

Investigations of Pulsed Plasma Streams with Aid Faraday Collectors;
J. Baranowski;
Plasma Physics Section, Warsaw, 17 November, 1998 - in Polish

The Methods of Books Deacidification;
J. Baranowski
Heavy Ion laboratory, Warsaw, October 7, 1998 - in Polish

PARTICIPATION IN PROGRAM AND ORGANIZING COMMITTEES OF CONFERENCES, CHAIRMENSHIP

M. Sadowski - Member of International Advisory Committee;

M. Sadowski - Chairman of Oral Session Or.21-23;

M. Sadowski - Chairman of International Scientific Committee & Conference Chairman;
International Workshop on Plasma-Focus Research PF’98, Kudowa Zdroj, Poland, July 8-10, 1998
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6 DEPARTMENT OF HIGH ENERGY PHYSICS

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Overview

The main activity of our Department is experimental high energy physics with accelerators. Experiments are carried using large facilities:

- at CERN, the European Laboratory for Particle Physics in Geneva,
- at Celsius Storage Ring in Uppsala and
- in Desy laboratory in Hamburg,

where several groups of physicists from our Department are members of international collaborations. They are listed below together with the main physics interests:

- **At CERN**
  - Delphi at LEP - tests of the Standard Model, b-quark physics, SUSY search,
  - NA48 - CP-violation in K⁰ decays, rare decays,
  - SMC - spin dependent nucleon structure function, the Bjorken sum,
  - NA49 and WA98 - heavy ion physics.
- **At CELSIUS**
  - WASA - threshold production of light mesons, rare meson decays.
- **At DESY**
  - ZEUS - proton and photon structure functions, diffractive production.

In most of these experiments our Department also contributed to the instrumentation of detectors and is presently involved in data collection, detector supervision and in data analysis.

At the same time the Department is also involved in preparation of new experiments:

- CMS (Compact Muon Solenoid) and ALICE at the LHC (Large Hadron Collider) at CERN,
- COMPASS (Compact Muon and Proton Apparatus for Structure and Spectroscopy) at the SPS at CERN,
- WASA-Promice - an upgrade of the present detector at Celsius,
- hyperfragment experiment at JINR, Dubna.

The department has small workshop which was recently involved in an upgrade of the WASA detector.

In our Department there are also two physicists working on the phenomenology of a quark-gluon plasma and on the low energy hadron-hadron interactions.

Physicists from our Department collaborate with the Department of the Experimental Physics of Warsaw University. They are also involved in teaching and in supervision of diploma students. There is a group of 9 PhD students.
6.1 Experiment DELPHI

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

The year 1998 was the best one in the LEP history. Despite that the luminosity delivered by the LEP accelerator to the DELPHI detector was the lowest among all four LEP experiments and that the level of accelerator noise was there the highest, we recorded nearly 160 inverse picobarns at $e^+ - e^-$ energy of 188.7 GeV, the highest ever achieved.

one of the most interesting topologies are those with only photons produced in the final state, like the event shown in fig.1. The trigger for such events is based on signals from the scintillation counters designed and built in Warsaw.

For searches for new effects the ability of the DELPHI electromagnetic calorimeter called HPC to reconstruct the direct photons is very important. The calorimeter was built with the Warsaw important contribution. It allows to establish upper limits on non-pointing to the interaction vertex gamma quanta which may originate from decays of heavy long-
lived particles. The existence of such particles is predicted eg. by supersymmetry.

The most intensive searches have been performed looking for Higgs boson(s). A benchmark plot for this activity is shown in fig.2. As one can see the very promising tanβ MSSM scenario has been excluded at the 95 % confidence level. At Warsaw we are trying to elaborate more general approach to the Higgs searches. This should allow to set almost model independent limits on its production or even to find a Higgs boson where it not yet has been looked for. For this purpose also the data from LEP1 are not fully exploited so far. The another activity which uses the LEP1 data are measurements of the amount of the penguin b decays. These results will help to constrain eg. supersymmetric models.

Apart from the searches the LEP2 data continue to provide several crucial results. Determination of $e^{-} - e^{+}$ cross-section, precise measurements of the mass of W boson (fig.3) and the triple boson couplings are the most prominent examples. In 1998 we took data at collision energies above the ZZ mass so it was possible to observe the production of a pair of $Z^{0}$ bosons decaying in the DELPHI detector. A display of such an event is shown in fig.4. We are looking forward to still more fruitful operation of DELPHI next year.

6.2 The SMC experiment at CERN

Polarized deep inelastic lepton-nucleon scattering is an important tool to study the structure of the nucleon. Our group has been involved in this program for many years. In 1998 most of the final results from Spin Muon Collaboration were published. These include measurements of inclusive asymmetries $A_{T}$ and $A_{d}$ [1] as well as results from semi-inclusive asymmetries and valence quark distributions [2]. The analysis of events collected with a special trigger, which requires a signal from the hadron calorimeter in addition to the detection of a scattered muon, and allows measurements down to $x = 0.0001$, mainly for $Q^{2} < 1$ GeV$^{2}$, is in progress. Preliminary results were presented at conferences.

The final results [1] of the spin asymmetries $A_{T}$ and the spin structure functions $g_{1}$ of the proton and deuteron cover the kinematic range $0.0008 < x < 0.7$ and $0.2 < Q^{2} < 100$ GeV$^{2}$. For $x < 0.02$ we use a new method which minimizes the radiative background by selecting events with at least one hadron in the final state and for higher $x$ we use the usual inclusive method. In this way one gets optimal precision on the $A_{T}$ measurements. The results are compared with other measurements in Fig.1.

In the perturbative QCD analysis in next-to-leading order (NLO) [3] of all available measurements of $A_{T}$ we obtained the first moments of spin dependent structure functions $g_{1}$ and have verified the Bjorken sum rule [4], which is a fundamental relation of QCD.

![Fig.1 Optimal set of spin asymmetries $A_{T}$ for proton and deuteron from the SMC data compared to the published data from other experiments.](image)

![Fig.2 Polarized parton distribution functions determined from the pQCD analysis at $Q^{2} = 1$ GeV$^{2}$. Their statistical uncertainty as obtained from the QCD fit is shown by a band with crossed hatch. The experimental systematic uncertainty is indicated by the vertically hatched band, and the theoretical uncertainty by the horizontally hatched band.](image)

The Bjorken sum rule has been tested in two different ways: in a global pQCD analysis and in an analysis restricted to the non-singlet part of $g_{1}$. In both cases, the sum rule is found to be verified within an accuracy of about 10% for the global fit and 15% for the non-singlet fit. The polarised parton distributions with their uncertainties are shown in...
Fig. 2 for singlet and gluon. The impact of each experimental data set and the sources of theoretical uncertainties were studied. The singlet and nonsinglet (not shown) quark distributions are well determined, while the gluon first moment is found to be positive but has an error of the order of 100% of its value. Improved determination of the polarised gluon distribution requires a dedicated measurement.

6.3 Search for Glueballinos in the NA48 Experiment

The NA48 experiment performed a direct search for hypothetical light gluinos in a decay of the gluon $g$ and gluino $\tilde{g}$ bound state $R^0$ into the eta meson $\eta$ and the photino $\gamma$ [1]. Eta mesons were expected to have relatively high transverse momenta. They were identified through decays $\eta \rightarrow 3\pi^0$ in the vacuum decay volume of the NA48 detector, under the assumption that $\gamma$ is not detectable. In order to select the high-$p_T$ $\eta$'s a dedicated trigger was implemented.

The $\pi^0$'s were detected through their decays into photons giving electromagnetic showers in the liquid crypton calorimeter. Trigger conditions included the total energy deposit in the calorimeter to be greater than 40 GeV, the first moment of showers greater than 1500 GeV cm, the center of gravity of showers greater than 20 cm and at least four distinguishable clusters in at least one projection of the calorimeter. These requirements limit the $p_T$ of $\eta$'s to be greater than 0.15 GeV/c.

The data were taken during 3 weeks in 1997. We found one candidate event within a lifetime range of $10^{-9}$ - $10^{-3}$ s and another one between $10^{-10}$ - $10^{-9}$ s. Both events are consistent with the expected background from neutrons in the beam, produced by 450 GeV protons impinging on the Be targets, which interact with the residual air in the tank. From the data we estimated limits on the $R^0$ mass and lifetime and on the ratio of the $R^0$ to $K_L$ flux as functions of the mass ratio $r = m_{R^0}/m_{\gamma}$. Our results are summarized in the figures. We present the upper limits at 95% confidence level on the flux ratio between $R^0$ and $K_L$ production in p - Be interactions for $r = 2.2$. The second plot shows the $10^{-6}$ contours limits for the NA48 experiment and the KTeV experiment at Fermilab [2].


Fig. 1 Upper limits at 95% CL on the flux ratio between $R^0$ and $K_L$ production in p-Be interactions for $r= 2.2$. The second plot shows the $10^{-6}$ contours limits given by the analysis presented here and by the KTeV collaboration. In both cases a 100% branching ratio in the analysed decay mode $R^0 \rightarrow \eta \gamma$ was assumed.
6.4 Hadron Production in Nuclear Collisions at 158 GeV/c  
by H. Bialkowska

The NA49 experiment, designed to search for possible signatures of phase transition at high energy density, registers and identifies produced hadrons within wide acceptance range. In 1998 final results were published on a number of subjects studied in central Pb-Pb collisions: baryon stopping and charged particle distributions, projectile fragmentation, cascade hyperon production. This last topic is of great significance, as a very strong enhancement (about one order of magnitude) of cascade hyperon production in Pb-Pb collisions over elementary hadronic interaction has been observed. Fig.1 shows the measured invariant mass spectra for cascade hyperons. An important new domain of NA49 investigations in 1998 was a study of proton-proton and proton-nucleus interactions at 158 GeV/c. A recoil proton trigger allowed for centrality selection, and a refined calibration of TPC detectors made possible excellent particle identification in wide acceptance. New results on baryon stopping, transverse momentum structure, and strangeness production in hadron-nucleus collisions are being prepared for presentation at the nearest Quark Matter Conference.

6.5 Multiplicity and Pseudorapidity Distribution of Photons in S + Au Reaction at 200 A GeV  
by T. Siemiarczuk, G. Stefanek for WA93 Collaboration

The photon multiplicity has been measured [1] for the first time in S + Au collisions at 200 A GeV over a wide pseudorapidity range (2.8 = η < 5.2) employing a fine granularity preshower detector. The pseudorapidity density of photons increases with centrality, reaching ~ 200 at the highest centrality studied. The results are compared with measurements of the charged particle multiplicity and with predictions of the VENUS event generator.

6.6 Directed Flow in 158 A GeV $^{208}$Pb + $^{208}$Pb Collisions
by K. Karpio, T. Siemiarczuk, G. Stefanek and L. Tykarski for WA98 Collaboration

The directed flow of protons and $\pi^+$ has been studied in 158 A GeV $^{208}$Pb + $^{208}$Pb collisions. A directed flow analysis of the rapidity dependence of the average transverse momentum projected onto the reaction plane is presented for semi-central collisions with impact parameters $b = 8$ fm, where the flow effect is largest. The magnitude of the directed flow is found to be significantly smaller than observed at AGS energies and than RQMD model predictions.

6.7 Centrality Dependence of Neutral Pion Production in 158 A GeV $^{208}$Pb + $^{208}$Pb Collisions
by K. Karpio, T. Siemiarczuk, G. Stefanek and L. Tykarski for WA98 Collaboration

The production of neutral pions in 158 A GeV $^{208}$Pb + $^{208}$Pb collisions has been studied [1] in the WA98 experiment at the CERN SPS. Transverse momentum spectra are presented for the range $0.3 \text{ GeV/c} < p_T < 4.0 \text{ GeV/c}$. The results for central collisions are compared to various models. The centrality dependence of the neutral pion spectral shape and yield is investigated. An invariance of the spectral shape and a simple scaling of the yield with the number of participating nucleons is observed for centralities with greater than about 30 participating nucleons.


6.8 Search For Disoriented Chiral Condensates In 158 AGeV Pb + Pb Collisions
by K. Karpio, T. Siemiarczuk, G. Stefanek and L. Tykarski for WA98 Collaboration

The restoration of chiral symmetry and its subsequent breaking through a phase transition has been predicted to create regions of Disoriented Chiral Condensates (DCC). This phenomenon has been predicted to cause anomalous fluctuations in the relative production of charged and neutral pions in high-energy hadronic and nuclear collisions. The WA98 experiment has been used to measure [1] charged and photon multiplicities in the central region of 158 AGeV Pb + Pb collisions at the CERN SPS. In a sample of 212646 events, no clear DCC signal can be distinguished. Using a simple DCC model, we have set a 90 % C.L. upper limit on the maximum DCC production allowed by the data.


6.9 WASA Project at CELSIUS Storage Ring
by A. Kupś, P. Marciniewski, A. Nawrot, K. Przestrzelska, J. Stepiąk, WASA Collaboration

In 1998 the CELSIUS/WASA Collaboration continued the study of the near threshold mesons production in nucleon-nucleon interactions using the PROMICE-WASA set-up. The differential cross sections were measured for the $p + p \rightarrow p + p + 0$ and $p + p \rightarrow p + p + B^0$ reactions [1]. It has been shown that the admixture of the meson production in D wave is seen at the energies much closer to the threshold, than it was commonly believed.

The threshold structure of the quasi-free $p + n \rightarrow d + 0$ reaction was studied much closer to the threshold than before [2]. The very forward going deuterons were extracted from the beam region and detected in a special telescope placed at the third bending magnet of the accelerator. The photons were measured in CsI (Na) matrices. The observed behaviour of the cross section seems to support the hypothesis of the existence of a quasi-bound state or a resonance in the $0d$ system.

Polish team actively participated in the work on the project of the whole mechanical construction and assembling. The mechanical assembling of the WASA - 4B detector was finished in November 1998. Designed and produced in Warsaw Plastic...
Scintillator Barrel, designed and produced in Warsaw, was successfully installed between the Mini Drift Chamber and Superconducting Solenoid. The Barrel was not supported by either MDC or SCS, which created a challenging problem. Finally, the whole set-up was installed at the accelerator around the pellet target after successful tests of superconducting solenoid. The work on the data acquisition system is in progress.


Fig. 1 Assembling of the WASA - 4B detector

6.10 Self-similarity in light nuclei collisions
by T.Siemiarczuk for Dubna - Košice - Moscow - Tbilisi - Warsaw Collaboration

Light nuclei fragmentation in a 1 m hydrogen bubble chamber have been studied [1] by means of the new invariant representation in the 4-velocity space. A self-similarity behaviour of the reactions studied has been observed.


6.11 Bose - Einstein Correlation in $\pi^0 - \pi^0$ System
by A.Deloff and T.Siemiarczuk

We argue that the $\pi^0 - \pi^0$ correlation function can be extracted from the experimentally measured $\gamma - \gamma$ correlation function. It has been explicitly shown how the $\pi^0 - \pi^0$ source parameters can be inferred from the correlation function of two-gammas originating from the decaying $\pi^0$.

6.12 Strong Interaction Effects in Kaonic Deuterium
by R.C.Barrett and A.Deloff

High precision measurements of kaonic hydrogen x-rays and also, for the first time, of kaonic deuterium are under way in the DEAR project using the $e^+e^-$ storage ring at Frascati. The values of the strong interaction $1s$ level shift and width in kaonic deuterium cannot be simply
predicted by relating them, via the Deser-Trueman formula, to the \( K'd \) scattering length because the latter is not known experimentally: it cannot be obtained by adding the \( Kp \) and \( Kn \) scattering lengths but involves the solution of a complicated multi-channel three-body problem. We give results of calculations of the kaonic deuterium strong interaction shift and width using an \( \langle N K, Y\pi \rangle \) interaction \( (Y=\Lambda,\Sigma) \) that fits the available low-energy scattering data. The 1s level shift in kaonic deuterium comes out negative and both the shift and the width are estimated to be about 1 keV. The 2p capture rate is estimated to be smaller than the \( 2p \rightarrow 1s \) x-ray transition rate. This information is of importance for the planned experiment as it indicates that most of the kaons should reach the lowest 1s level.

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### 6.13 M-Measure of Event-by-Event Fluctuations in High-Energy Heavy-Ion Collisions
by S. Mrówczyński

The fluctuation measurements is a potential source of valuable information on the dynamics of heavy-ion collisions. For example, the multiplicity fluctuations determine the compressibility [1] of the (equilibrium) hadronic matter at freeze-out. In the experimental realization of such ideas one has to disentangle however the "dynamical" fluctuations of interest from the "trivial" geometrical ones due to the impact parameter variation. The latter fluctuations are very sizable and dominate the fluctuations of all extensive event characteristics such as multiplicity or transverse energy.

A specific solution to a problem was given in our paper [2], where we introduced the measure of fluctuations or correlations which was later called M. It is constructed in such a way that M is exactly the same for nucleon-nucleon (N-N) and nucleus-nucleus (A-A) collisions if the A-A collision is a simple superposition of N-N interactions. On the other hand, M equals zero when the correlations are absent in the collision final state. The measure manifests very interesting properties in the equilibrium ideal gas [3], where \( t \) is negative for fermions, positive for bosons and zero for the classical particles.

The M-measure has been successfully applied to the NA49 experimental data and the fluctuations of transverse momentum, which are observed in N-N collisions, have been found to be significantly reduced in the central Pb-Pb collisions at 158 GeV per nucleon. In this way we have got the model independent proof that the central heavy-ion collision is not a superposition of N-N interactions. The theoretical analysis of the result has also provided a valuable insight into the collision dynamics.


### 6.14 Preparation of the CMS Experiment
by R. Gokieli, M. Górski, P. Zalewski

In the year 1998 the activities of the Warsaw CMS group were devoted to the following questions:

1) Construction and testing of a full scale RPC (Resistive Plate Chamber) prototype. The RPCs in the CMS experiment at the Large Hadron Collider at CERN will be used as the main detectors in the muon trigger system. The chamber built is a final prototype of the RPC which is to be used in the forward area, where radiation is the highest. It is trapezoidal in shape, its height is about 100 cm and width about 40 cm. The chamber was extensively tested in the GIF (Gamma Irradiation Facility) at CERN. It showed good timing properties and excellent efficiency at highest particle fluxes available at GIF. The preliminary results were already reported at two international conferences. Our design has been accepted by the collaboration for the final version of the detector (with possible minor modifications).

2) The study of the possibilities of registering heavy supersymmetric particles in the CMS was continued.

3) Monte Carlo studies of the CMS muon trigger performance were continued. The new developments in the final design of the structure of the experiment have to be incorporated in the simulation software and their influence on the triggering system are studied.

4) The work on the hardware implementation of the triggering device - the Pattern Comparator
6.15 The COMPASS experiment at CERN

One of the main aims of the COMPASS experiment [1] is the determination of the gluon polarisation, $\Delta G/G$, in the nucleon. The photon-gluon fusion process will be tagged by open charm production [1,2] and oppositely charged high-$p_T$ hadron pairs [3,2]. The experiment will be performed using high-energy polarised virtual photons from an intense polarised muon beam impinging on a double cell polarised solid-state target. Open charm production will lead to an accuracy of $\delta(\Delta G/G) \approx 0.11$. A complementary method using high-$p_T$ hadron pairs yields $\delta(\Delta G/G) = 0.05$ and is presently limited by systematic uncertainties.

The experiment will also provide high statistics data for the spin structure function $g_1$, semi-inclusive muon scattering, and the transverse structure function $h_T$. In addition a broad physics program with hadron beams is envisaged.

Presently the experiment is in the phase of building and assembling detectors, testing the apparatus with the test beams and preparing the experiment's software. The commissioning of the experiment is planned during the year 2000.

The Warsaw group contribution to the preparation of the experiment during 1998 included work on the algorithms and programs to reconstruct particles momenta in inhomogeneous magnetic field, investigation of the background in detectors which originates from the electromagnetic interactions in the target, investigation of the combinatorial background for the detection of $D^0$ mesons, and estimates of the precision of determination of $\Delta G/G$ from the spin dependent diffractive $p^0$ production [4]. The precision of the latter determination is estimated to be comparable to the precisions of the two previously mentioned methods.

[1] G.Baum et al., CERN/SPSLC 96-14, CERN/SPSLC 96-30

6.16 Search for Anomaly at High $x$ in Polarized Deep Inelastic Scattering Data
by W. Wiślicki

We examined an idea [1] of possible axial anomaly contribution of nonperturbative origin to the nucleon spin by analyzing data on spin asymmetries in polarized deep inelastic scattering of leptons on nucleons [2]. The anomaly was expected to screen colour fields of quarks in the nucleon and affect the spin-dependent quark distributions.

In order to estimate such effect we analyzed existing data on the inclusive and semi-inclusive asymmetries in the region of Bjorken $x$ larger than 0.15. In the region of high $x$ the non-strange sea, the strange sea and the ratio of the transverse to the longitudinal photoabsorption cross sections are negligible. The spin-dependent quark distributions were modified by adding an anomaly term which contributes with opposite signs to quarks polarized parallel and antiparallel to the nucleon spin. The anomaly fragmentation function was determined by comparing the inclusive and semi-inclusive asymmetries for any hadron for deuteron target.

Asymmetries were assumed to be independent of the four momentum transfer $Q^2$, consistent with experimental observations. Any possible effects of scale mixing by anomaly were neglected. Three unknown spin distributions, $\Delta u(x)$, $\Delta d(x)$ and the anomaly term $k(x)$, were evaluated from the system of equations for asymmetries. Contributions from the unmeasured region of $x > 0.7$ were estimated from the extrapolations of a simple analytic function fitted to data points.

We observe that the anomaly distribution $k(x)$ does not exhibit any significant deviation from zero. The integral $\int_{0.15}^{1} \delta k(x) = 0.015 \pm 0.013 \pm 0.002$ is consistent with zero within one standard deviation, where the first error is statistical and the second one is systematic.

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SEARCH FOR SELECTRON AND SQUARK PRODUCTION IN e+p COLLISIONS AT HERA
DESY 98-069 (June 1998)
J. Breitweg, M. Adamus, et al.

MEASUREMENT OF ELASTIC (PHOTOPRODUCTION AT HERA
DESY 98-089 (July 1998)
J. Breitweg, M. Adamus, et al.

SEARCH FOR DISORIENTED CHIRAL CONDENSATES IN 158A GeV Pb+Pb COLLISIONS

POLARISED QUARK DISTRIBUTIONS IN THE NUCLEON FROM SEMI-INCLUSIVE SPIN ASYMMETRIES

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MEASUREMENT OF THE CHARGED PARTICLE MULTIPLICITY OF WEAKLY DECAYING B HADRONS

MEASUREMENT OF TRILINEAR GAUGE COUPLINGS IN e+ e- COLLISIONS AT 161 GeV AND 172 GeV

SEARCH FOR CHARGED HIGGS BOSONS IN e+ e- COLLISIONS AT \sqrt{s} = 172 GeV

m_\gamma AT \sqrt{s}

MEASUREMENT OF THE INCLUSIVE CHARMLESS AND DOUBLE-CHARM B BRANCHING RATIOS

CHARGED PARTICLE MULTIPLICITY IN e+ e- \rightarrow q\bar{q} EVENTS AT 161 AND 172 GeV AND FROM THE DECAY OF THE W BOSON

RAPIDITY CORRELATIONS IN \lambda BARYON AND PROTON PRODUCTION IN HADRONIC Z DECYPS

A STUDY OF THE HADRONIC RESONANCE STRUCTURE IN THE DECAY \tau \rightarrow 3\pi +

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MEASUREMENT OF |v_{c\bar{c}}| USING W DECAYS AT LEP-2

A SEARCH FOR HEAVY STABLE AND LONG-LIVED SQUARKS AND SLEPTONS IN e+ e- COLLISIONS AT ENERGIES FROM 130 TO 183 GeV
TWO-PARTICLE ANGULAR CORRELATIONS IN e⁺ - e⁻ INTERACTIONS COMPARED WITH QCD PREDICTIONS

A SEARCH FOR γγ PRODUCTION IN PHOTON-PHOTON FUSION AT LEP

PIONIC, D-WAVE EFFECTS IN pp → ppγγ NEAR THRESHOLD

UPPER LIMITS FOR A NARROW DIBARYON IN pp COLLISIONS AT 200 AND 310 MeV

MEASUREMENT OF THREE-JET DISTRIBUTIONS IN PHOTOPRODUCTION AT HERA
DESY 98-162 (October 1998)
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HADRONIC MATTER COMPRESSIBILITY FROM EVENT-BY-EVENT ANALYSIS OF HEAVY-ION COLLISIONS
S. Mrowczyński

TRANSVERSE MOMENTUM AND ENERGY CORRELATIONS IN THE EQUILIBRIUM SYSTEM FROM HIGH-ENERGY NUCLEAR COLLISIONS
S. Mrowczyński

DIRECTED AND ELLIPTICAL FLOW IN 158 GeV/N Pb-Pb COLLISIONS
H. Appelshauser, H. Białkowska, et al.

CENTRALITY DEPENDENCE OF NEUTRAL PION PRODUCTION IN 158 AGeV Pb + Pb COLLISIONS

DENSITY FLUCTUATIONS IN THE QUARK-GLUON PLASMA
S. Mrowczyński

MULTIPICITY AND PSEUDORAPIDITY DISTRIBUTION OF PHOTONS IN THE S+Au REACTION AT 200 A GeV

MEASUREMENT OF THE QUASI-FREE p + n → p + n + η REACTION

SPIN ASYMETRIES A1 AND STRUCTURE FUNCTIONS g1 OF THE PROTON AND THE DEUTERON FROM POLARIZED HIGH ENERGY MUON SCATTERING

A NEXT-TO-LEADING ORDER QCD ANALYSIS OF THE SPIN STRUCTURE FUNCTION g1

SEARCH FOR ANOMALY AT HIGH X IN POLARIZED DEEP INELASTIC SCATTERING DATA
W. Wiślicki

NEW DEVELOPMENT ON RESISTIVE PLATE CHAMBERS FOR HIGH RATE OPERATION
H. Czyrko, M. Górski, et al.
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MEASUREMENT OF PROTON AND NITROGEN POLARIZATION IN AMMONIA AND A TEST OF EQUAL SPIN TEMPERATURE
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SPIN STRUCTURE OF THE NUCLEON - EXPERIMENTAL RESULTS
E. Rondio

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DETERMINATION OF ΔGG IN COMPASS EXPERIMENT AT CERN
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H. Appelshauser, H. Bialkowski, et al.

SEARCH FOR CHARGINOS, NEUTRALI OnS AND GRAVITONS AT LEP

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MEASUREMENT OF THE W-PAIR CROSS-SECTION AND OF THE W MASS IN e+ e- INTERACTIONS AT 172 GeV

$\pi^0$, K L P AND ANTI-P PRODUCTION IN $Z \rightarrow q\bar{q}, Z \rightarrow b\bar{b}, Z \rightarrow u\bar{u}, d\bar{d}, s\bar{s}$

INVESTIGATION OF THE SPLITTING OF QUARK AND GLUON JETS

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DESY 98-085 (July 1998)
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V. V. Glogolev, T. Siemiarczuk, et al.
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FUTURE RESEARCH IN HIGH ENERGY EXPERIMENTAL PHYSICS AND ITS POLISH PARTICIPATION
R. Sosnowski

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A. Deloff, T. Siemiarczuk

DETECTOR FOR HIGH MOMENTUM particle IDENTIFICATION
S. Bede, T. Siemiarczuk, et al.

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SINGLE PARTICLE CORRELATIONS IN EVENTS WITH TOTAL DISINTEGRATION OF NUCLEI

INCLUSIVE SPECTRA OF PROTONS AND I π-MESONS EMITTED IN He+C AND C+C INTERACTIONS WITH TOTAL DISINTEGRATION OF NUCLEI
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V. A. Belyakov, J. Bogdanowicz
BnR Communication P1-98-289 (1998), Dubna

DIRECT SEARCH FOR LIGHT GLUINOS

X-ray AND ANTI-X-ray PRODUCTION IN 158 GeV/NUCLEON Pb + Pb COLLISIONS
H. Appelshauser, H. Bialkowska, et al.
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BARYON STOPPING AND CHARGED PARTICLE DISTRIBUTIONS IN CENTRAL Pb+Pb COLLISIONS AT 158 GeV PER NUCLEON

DIRECTED FLOW IN 158 AGeV Pb + Pb COLLISION

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SEARCH FOR PAIR-PRODUCED NEUTRALIONS IN EVENTS WITH PHOTONS AND MISSING ENERGY FROM e+ - e-
COLLISION AT \sqrt{s} = 130 - 183 GeV

SEARCH FOR COMPOSITE AND EXOTIC FERMIONS AT LEP 2

SEARCH FOR SCALAR FERMIONS AND LONG-LIVED SCALAR LEPTONS AT CENTRE-OF-MASS ENERGIES OF 130 GeV TO 172 GeV

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TOPICS IN THE TRANSPORT THEORY OF QUARK-GLUON PLASMA
S.Mróczynski

OBSESSION OF STRONG FINAL-STATE EFFECTS IN \pi^+ PRODUCTION IN pp COLLISIONS AT 400 MeV
Phys. Lett B (in press)

HIGHER PARTIAL WAVES IN p + p -> p + p + \eta NEAR THRESHOLD

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FILAMENTATION INSTABILITY IN ULTRARELATIVISTIC HEAVY-ION-COLLISION
Stanisław Mróczynski (invited talk)
Workshop on Nuclear Matter in Different Phases and Transitions, Les Houches, April 1998

ELEMENTARY ATOM INTERACTION WITH MATTER
Stanisław Mróczynski (invited talk)
NONEQUILIBR1UM QUARK-GLUON PLASMA
Stanislaw Mrowczyński (invited talk)
XXXVIII-th Cracow School of Theoretical Physics, Zakopane, June 1998

EQUILIBRIUM EVENT-BY-EVENT FLUCTUATIONS
Stanislaw Mrowczyński (invited talk)

TRANSPORT THEORY OF MASSLESS FIELDS
Stanislaw Mrowczyński (invited talk)
Workshop Quantum Fields In and Out Equilibrium, Brookhaven, Oct. 1998

EVENT-BY-EVENT FLUCTUATIONS MEASURED BY PHI
Stanislaw Mrowczyński (invited talk)
International Workshop Phase Transition in Nuclear Collisions, Copenhagen, Nov. 1998

M-MEASURE OF EVENT-BY-EVENT FLUCTUATIONS
Stanislaw Mrowczyński (invited talk)
Workshop "Phase Transitions in Nuclear Collisions", Copenhagen, Nov. 1998

PROPOSAL FOR MASS AND LIFETIME DETERMINATION OF CHARGED AND NEUTRAL NLSP's WITHIN GMSB MODELS IN THE CMS
Piotr Zalewski
First European Meeting "From Planck Scale to Electroweak Scale", Kazimierz, 24-30 May 1998

SPIN DEPENDENT STRUCTURE FUNCTIONS
Ewa Rondio (invited talk)
The Structure of Mesons, Baryons and Nuclei and Workshop "Meson 98", Cracow, 28 May - 2 June 1998

POLARISED QUARK DISTRIBUTIONS IN THE NUCLEON FROM SEMI-INCLUSIVE SPIN ASYMMETRIES
Andrzej Sandacz
"Workshop on Deep Inelastic Scattering and QCD", Brussel, Belgium, 4-8 April 1998

DETERMINATION OF D/G IN COMPASS EXPERIMENT AT CERN
Jan Nassalski

SEARCH FOR A LIGHT GLUINO IN NA48 AT CERN
Michal Szleper
Sasy 98, Oxford, United Kingdom, 11-17 July 1998

MEASUREMENTS OF THE SPIN STRUCTURE OF THE NUCLEON FROM SMC EXPERIMENT
Ewa Rondio

HEAVY ION COLLISIONS AT HIGH ENERGY
Plenary talk by Helena Bialkowska

THRESHOLD η PRODUCTION IN pN REACTIONS AT CELSIUS
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RECENT RESULTS FROM THE CELSIUS/WASA COLLABORATION ON MESON PRODUCTION IN PROTON-HYDROGEN COLLISIONS

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SEARCH FOR DISORIENTED CHIRAL CONDENSATES AN EXPERIMENTAL PERSPECTIVES

NEW DEVELOPMENTS ON RESISTIVE PLATE CHAMBERS FOR HIGH RATE OPERATION
M. Cwiok, M. Gdrski, et al.
8-th Vienna Wire Chamber Conference, Vienna, Austria, 22-27 Feb. 1998

A HIGHLY EFFICIENT RESISTIVE PLATE CHAMBER (RPC) FOR HIGH RATE ENVIRONMENT
W. Dominik, M. Gdrski, et al.
6-th International Conference on Advanced Technology and Particle Physics, Villa Olmo, Italy, 5-9 October 1998

A HIGHLY EFFICIENT RESISTIVE PLATE CHAMBER (RPC) FOR HIGH RATE ENVIRONMENT
W. Dominik, M. Gdrski, et al.
3-rd International Workshop on Ring Imaging Cerenkov Detectors (RICH98), Ein Gedi, Dea Sea, Israel, 15-20 Nov. 1998

CENTRALITY OF COLLISIONS AND TOTAL DISINTEGRATION OF NUCLEI
M. K. Suleimanov, J. Bogdanowicz, A. A. Kuznetsov

LECTURES, COURSES AND EXTERNAL SEMINARS

Determination of $\Delta G/G$ in COMPASS Experiment at CERN
Jan Nassalski, University of Durham, United Kingdom, 3 March 1998

CP Violation in Neutral Kaon Decays
Wojciech Wislicki, Vrije Universiteit, Amsterdam, Netherlands, 10 March 1998

Diffractive $p^0$ Polarised Leptoproduction in COMPASS and SMC Experiments
Andrzej Sandacz, Free University, Amsterdam, Netherlands, 31 March 1998

Gluon Polarisation from Exclusive $p^0$ Polarised Leptoproduction
Andrzej Sandacz, University of Torino, Italy, 16 June 1998

Gluon Polarisation from Exclusive $p^0$ Polarised Leptoproduction
Andrzej Sandacz, CERN, COMPASS collaboration meeting, 30 June 1998

Neutral $\eta$ Decays: $\eta \to 3\pi^0$ and $\eta \to 4\gamma$
Andrzej Kupś, Uppsala University, 23 March 1998

Update on $\eta$ Decays (Experiments)
Andrzej Kupś, Uppsala University, 23 March 1998

Status of the CsI Calorimeter
Andrzej Kupś, Uppsala University, 22 March 1998

Multiple Pion Prompt Background to 0 Meson Decays
Joanna Stepaniak, Uppsala University, 23 March 1998

Stanisław Mróweckiński, CERN, Geneva, 1 Oct. 1998

Filamentation Instability in Ultrarelativistic Heavy-Ion Collisions
Stanisław Mróweckiński, State University of New York in Stony Brook, Stony Brook, 2 Nov. 1998

Course: Classical Mechanics, Quantum Physics, Statistical Mechanics, Introduction to Quantum Field Theory at Pedagogical University, Kielce, S. Mróweckiński

INTERNAL SEMINARS

Why we Study the Near Threshold Production and Decays of B and D Mesons
Joanna Stepaniak, IFJ, Warsaw University, Warsaw, 20 February 1998

Parton Structure of the Nucleon
Jan Nassalski, University of Silesia, Katowice, 20 March 1998
Spin Structure of the Nucleon
Jan Nassalski, Maria Curie-Skłodowska University, Lublin, 2 June 1998

Seven Years of Poland's CERN Membership
Ryszard Sosnowski, Council for Nuclear Problems, Warsaw, 6 March 1998

Experiments in High Energy Physics with Polish Participation - at Present and in the Future
Ryszard Sosnowski, IFJ, Warsaw University, Warsaw, 3 April 1998

The Smallest Grains of Matter, what is the Universe Made of?
Ryszard Sosnowski, PFF, Białystok, 16 April 1998

Spin Structure of the Nucleon
Wojciech Wislicki, IFJ, Warsaw University, Warsaw, 17 April 1998

What do We Know About Nucleon Spin?
Ewa Rondio, Warsaw University, Warsaw, 8 May 1998

Symmetries and Decoherence in Physics
Wojciech Wislicki, Warsaw University, Warsaw, 22 May 1998

Spin Structure of the Nucleon
Wojciech Wislicki, IFJ, Cracow, 10 June 1998

What is Inside - How Physicists Check Internal Structure of the Nucleon
Ewa Rondio, Festival of Science, Warsaw, Sept. 1998

Conference in Vancouver - Experimental Results
Ewa Rondio, Warsaw University, Warsaw, 16 Oct. 1998

Determination of Gluon Polarisation in the Nucleon - COMPASS Proposal at CERN
Jan Nassalski, Warsaw University, Warsaw, 23 Oct. 1998

Experiment NA48 at CERN
Michal Szlepcr, Warsaw University, Warsaw, 4 Dec. 1998

High Energy Heavy Ion Collisions
Helena Biaikowska, Warsaw University, Warsaw, 6 Nov. 1998

New Results from WASA Experiment in Uppsala
Joanna Stepniak, Warsaw University, Nuclear Physics Department, 18 Dec. 1998

SCIENCE POPULARIZATION TALKS AND ARTICLES

S. Mrówczyński
11 articles in weekly "Polityka"

P. Zalewski
12 articles in "Delta"

R. Sosnowski
1 article in "Wprost", 1998

J. Nassalski

Jan Nassalski
Radio - Bia, 20-24 lipca 1998 - 5 days by 8 minutes
Mysteries of a Neutrino
PERSONNEL

Research scientists

Marek Adamus, Dr. (on leave till Oct.9)
Helena Bialkowska, Assoc.Prof. (on leave)
Andrzej Dehoff, Assoc.Prof.
Tomasz Gadaj, MSc. (on leave)
Ryszard Gokieli, Dr. (on leave)
Maciej Górski, Dr.
Andrzej Filipkowski, Dr. 1/2
Andrzej Kupsć, Dr. (on leave)
Pawel Marciniowski, MSc. (on leave)
Stanisław Mrówczyński, Assoc.Prof. 2/3
Jan Nassalski, Professor
Adam Nawrot, Eng.

Ewa Rondio, Assoc.Prof.
Andrzej Sandacz, Assoc.Prof.
Teodor Siemiarczuk, Professor
Ryszard Sosnowski, Professor
Joanna Stepaniak, Professor
Maria Szeptycka, Professor
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PhD Students

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Overview

The Department of Cosmic Ray Physics in Łódź is involved in basic research in the area of high energy physics and cosmic ray physics related to:
- Studies of asymptotic properties of hadronic interactions based on the analysis of cosmic ray propagation in the atmosphere.
- Experimental and phenomenological studies of Extensive Air Showers induced by cosmic ray particles.
- Search for point sources of high energy cosmic rays.
- Studies of cosmic ray propagation in the Galaxy and mechanisms of particle acceleration.
- Studies of mass composition of cosmic rays in the energy range $10^{15} - 10^{17}$ eV.

Theoretical and experimental studies of Extensive Air Shower properties are performed mostly based on the results obtained by the Łódź Extensive Air Shower Array. We analysed nearly 100,000 events of energies above $10^{15}$ eV registered by the Łódź hodoscope. We have developed the method of data analysis which allows us to verify different models of cosmic ray mass composition.

In our research in high energy cosmic rays we also used experimental data from other collaborating experiments in Karlsruhe, Baksan and THEMISTOCLE.

The Łódź group collaborates with many foreign institutes and laboratories in construction and data interpretation of cosmic ray experiments. Our most important partners are: Forschungszentrum in Karlsruhe (Germany), Collège de France, Institute for Nuclear Studies of the Russian Academy of Science, University of Perpignan and Uppsala University (Sweden).
Extensive Air Showers (EAS) of High Energy Cosmic Rays (CR).

7.1 Łódź EAS Array
by J.Gawin, S.Pachula, J.Swarzynski, J.Szabelski

Łódź hodoscopic array has been registering EAS for most part of the year. Continuous monitoring of array's work has been performed and the faults which appeared sporadically were removed. We performed the analysis on data collected until 1998. In a first step the periods of correct work of the array were chosen. The data gathered from 7th July 1997 to 26th January 1998 which contained 90470 EAS registered during 2204 hours have been taken for further analysis. We applied our original method of physical analysis, basing on comparison of the results of EAS registrations in our hodoscope with the simulated registrations predicted for different assumed primary cosmic rays mass composition and high energy nucleus-nucleus interaction model.

The principles of our analysis and preliminary qualitative results have been summarized in the internal report. We conclude that interpretation of the Łódź EAS data allows for verification of existing models of CR mass composition above $10^{16}$ eV. Different models assumed in simulations give significant differences in distributions of measurable EAS characteristics between experimental and simulated registrations. For mass composition adopted, consistent with the data, we can study the influence of assumed high energy interaction model on the registered EAS parameters. We showed that numerical analysis of the data allows for selecting models consistent with experimental results.

7.2 Investigation of EAS in KASCADE Experiment
by J.Zabierowski for KASCADE Collaboration

1998 was the second year of routine data taking for KASCADE (KArlsruhe Shower Core and Array Detector) experiment, in which scientists from Lodz Cosmic Ray Research Group (both from Lodz University and Soltan Institute) have been participating since nine years. KASCADE, located in Forschungszentrum Karlsruhe, Germany, is currently the biggest in Europe, and in some aspects, also in the world, EAS experiment, covering primary energy range $10^{15} - 10^{17}$ eV. More than 150 millions of showers have been collected so far.

The main aim of the KASCADE project [1] is the determination of the chemical composition of cosmic rays in the above mentioned energy range, where the, so called, “knee” in the primary cosmic ray spectrum has been observed. This, in turn, will allow us to better understand the origin and propagation mechanisms of the cosmic rays. The main advantage of the installation is the simultaneous measurement of a large number of observables for each individual event. This is achieved by the combination of various advanced detection techniques for the electromagnetic, muonic and hadronic component of EAS.

It is well known that many parameters of EAS depend on the energy per nucleon of the primary nucleus, notably the ratio of electron to muon numbers, the energy of the hadrons in the shower, the shapes of the lateral distributions of the various components of the shower, the arrival times of the particles, etc. The basic concept of the KASCADE experiment is to measure a large number of these parameters in each individual event, in order to determine both the energy and mass of the primary particles.

During the last year, based on the data collected so far, the methods of multiparameter analyses of EAS continued to be developed. Several of the above mentioned parameters of EAS have been determined. The preliminary estimation of the primary particle mass, on the basis of the ratio of muon to electron number in EAS [2], the time structure of the muonic shower component [3] and hadron/muon structure of the shower core, [4] has been done. For the first time ever the electron, muon and hadron number spectra in extensive air showers were simultaneously measured. In all three kinds of spectra the „knee” has been observed [5], which position on the energy scale depends on the zenith angle of the showers. The spectral indices, however, do not depend on the zenith angle.

The change in the spectral index was observed also in the EAS muon density spectrum [6], determined independently in Lodz on the KASCADE data sample which we have here.

Results of the analyses have been reported at the two main cosmic ray international conferences in 1998, in Spain (Alcala) and in Italy (Gran Sasso). The preparation of the papers for scientific journals is on the way, however this requires in some cases
the analysis of a bigger data sample, in order to minimize the statistical errors. The tuning and further development of the interaction models used in simulations, as well as of the reconstruction codes, aimed at the understanding and minimization of the systematical errors is in progress.

In 1998 the assembly of the Central Calorimeter was completed. Since the middle of the year, 100% of the detector area (320 m² - 10 000 ionization chambers) has been in operation.

During 1998 in the Muon Tunnel the assembling of the detectors and front-end electronics, built according to the design made in Lodz, was continued. The detector towers are incorporated into the detector system one by one and this hardware/software process will continue until the end of 1999. About 45% of the total detecting area is already included in the data collection system of KASCADE.

Preliminary analysis of this detector performance is in progress. Some of the first experiences with this new detector were reported at the conference in Vienna [7].

7.3 Registration of Hadrons in EAS
by J. Szabelski

We studied the possibility to apply neutron monitors for detection of hadrons in EAS. Hadrons from EAS can knock off neutrons, which after thermalization are registered, even several microseconds after EAS arrival. The number of neutrons is proportional to the sum of energy of hadrons falling on the neutron monitor. Preliminary experimental studies performed in the Tien-Shan experiment and confirmed in Baksan showed the extremely long delay time of neutrons as compared to the time of shower front arrival in cases, when energy of registered EAS exceeded $10^{17}$ eV and the shower core fell close to the neutron monitor. Physicists at Baksan performed a series of measurements in different experimental configuration of neutron monitor and scintillation counters.

In collaboration with the Russians we have started to prepare programs for simulation of neutron registration in the neutron monitor. We used the program GEANT which describes "geometry" and neutron interactions down to energy 1 MeV. We are going to write programs for neutron thermalization (below 1 MeV) and to include them into the geometrical part of GEANT. High energy processes relating to EAS development in the atmosphere and especially to the hadron component are known and described in the CORSIKA code. We have prepared the hadron component generator at the observation level, taking into account protons, neutrons and pions, correlations between them, and their lateral distributions. Financial problems in Russia caused delays in continuation of these studies this year.

7.4 Cosmic Ray Astrophysics.

Cosmic Ray Muons Correlated with Solar Flares.
by J. Szabelski

We are working on a trigger system for a muon telescope built of 4 layers of Geiger-Müller tubes. We performed several tests on a model of telescope consisting of 8 GM counters, coincidence system and registration system (CAMAC blocks 303 and 305, computer PC). Due to prototype studies we can
precisely predict requirements and appearing difficulties. The muon telescope will register muon flux from different directions. We shall look for the muon flux changes correlated with solar activity (flares). These studies are connected with the search for muon flux changes in the experiment "L3 + cosmics" in CERN.

7.5 Search for Point Sources of High Energy Gamma Rays
by M.Matraszek, B.Szabelska and J.Szabelski

A search for discrete sources of TeV gamma rays is one of important areas of cosmic ray origin studies. Emission of high energy photons from astrophysical objects is the direct evidence of the process of CR particles acceleration. Gamma rays of energies from 100 GeV to several tens of TeV are observed on the ground due to registration of Cherenkov light produced in the atmosphere by the photon induced cascade of particles. Interpretation of such measurements is not straightforward, as photon registrations are contaminated by the much more frequent cascades induced by CR protons and heavier nuclei. We continued our work leading to better recognizing of hadron induced events. In particular we studied Cherenkov light produced directly or indirectly by EAS muons, the presence of which suggests hadronic origin of an event. Muons of energies exceeding several GeV can arrive at an observation level a few nanoseconds before the Cherenkov light produced by EAS particles several kilometers higher. Cherenkov light produced just above the detector from such an energetic muon can indicate hadronic origin of EAS. Results of these studies have been published in Astroparticle Physics, [1].

We analysed the data from the Cherenkov experiment THEMISTOCLE in order to identify the effects caused by muons in measurements of Cherenkov photon arrival time with accuracy better than 1 ns. We have chosen a sample of registrations from the direction of the source Markarian 501, thus enriched in photon induced events. We also worked on the method of improving the localization of EAS core and finding its direction. We also studied indirect production of Cherenkov light by EAS muons. Muons of energies below the threshold for Cherenkov light production can decay to electrons and produce a "new" electromagnetic cascade, which will emit Cherenkov light. Photons from such cascades can arrive several microseconds after the bulk of EAS Cherenkov emission. Detailed computer simulations with the CORSIKA code confirmed these predictions. The intensity of such a "muonic tail" of Cherenkov radiation can be comparable to the night sky background and cannot be detected by current experiments, which register the Cherenkov signal in time from several to several tens of nanoseconds.


7.6 Participation in the WASA Experiment
by J. Zabierowski for WASA/PROMICE Collaboration

1998 was the last year of experiments with the WASA/PROMICE experimental setup at the CELSIUS storage ring in Uppsala University. This was also the year of assembly of the 4π WASA Detector in one of the straight sections of the CELSIUS machine. The existing setup will serve as a forward part of the WASA Detector. The beginning of the measurements with the new device is foreseen in late spring of 1999. The WASA/PROMICE Collaboration has changed its name into CELSIUS/WASA. Assembling and tests of the subparts of WASA Detector have dominated experimental activity of the collaboration during last year. In our laboratory in Lodz a complete Light Pulser Monitoring System for all scintillation counters of the WASA Detector (over 1600 channels) has been built and tested. It delivers several types of light pulses, matched to the type of scintillator counter being used. The system will be shipped to Uppsala and installed in the experimental setup during early spring of 1999. In parallel to the above mentioned activity the intensive data analysis and physics exploitation from the previous measurements took place. During the last years we have made measurements of the production cross sections of pi and eta mesons close
to kinematical threshold in pp [1,2] and pd [3,4] collisions.

We have also made the first exclusive measurements of the charged $2\pi$ production in pp collisions near threshold [5].

LIST OF PUBLICATIONS

MEASURABLE DIFFERENCE IN CHERENKOV LIGHT BETWEEN GAMMA AND HADRON INDUCED EAS
H. Cabot, C. Meynial, D. Sobczyńska, B. Szabelska, J. Szabelski, T. Wibig,
Astroparticle Physics v.9 (1998), 269

HIGH ENERGY HADRONS IN EAS AT MOUNTAIN ALTITUDE
J. N. Capdevielle, J. Gawin, D. Sobczyńska, B. Szabelska, J. Szabelski, T. Wibig,

ON THE EXTENSIVE AIR SHOWER DENSITY SPECTRUM
A. Zawadzki, T. Wibig, J. Gawin

THE KASCADE EXPERIMENT,
G. Scharz, J. Zabierowski et al.,

THRESHOLD STRUCTURE OF THE QUASIFREE P+N->D+ETA REACTION
H. Calen, J. Zabierowski et al.,

UPPER LIMIT FOR A NARROW DIBARYON IN PP COLLISIONS AT 200 AND 310 MeV
H. Calen, J. Zabierowski et al.,

PIONIC D-WAVE EFFECTS IN PP -> P+P+ZERO NEAR THRESHOLD
J. Złomanczuk, J. Zabierowski et al.,

HUNTING THE DIBARYON d' (2065)
G. J. Wagner, J. Zabierowski et al.,

MEASUREMENT OF THE QUASI-FREE PN+->PN+ETA REACTION
H. Calen, J. Zabierowski et al.,

THE COMPOSITION OF ULTRA COSMIC RAYS - THE NEW KASCADE EXPERIMENT.
H. O. Klages, J. Zabierowski, et al.,

HIGHER PARTIAL WAVES IN pp+->pp+eta NEAR THRESHOLD
H. Calen, J. Zabierowski et al.,

OBSESSION OF STRONG FINAL-STATE EFFECTS IN PIPLUS PRODUCTION IN PP COLLISIONS AT 400 MEV.
A. Betsch, J. Zabierowski et al.,

REPORTS

CORE STRUCTURE OF EXTENSIVE AIR SHOWERS AT PRIMARY ENERGIES AROUND THE KNEE BY A MULTIFRACTAL MOMENTS ANALYSIS.
A. Haungs, J. Zabierowski et al.,
Report Forschungszentrum Karlsruhe FZKA-6105, May 1998. 21pp

HIGHER PARTIAL WAVES IN pp+->pp+eta NEAR THRESHOLD
H. Calen, J. Zabierowski et al.,
Report series ISSN 0284-2769 of The Svedberg Laboratory and Department of Radiation Sciences, Uppsala University, TSL/ISV - 98-0198, 1998

PIONIC D-WAVE EFFECTS IN pp+->pp+pi0
J. Złomanczuk, J. Zabierowski et al.,
Report series ISSN 0284-2769 of The Svedberg Laboratory and Department of Radiation Sciences, Uppsala University, TSL/ISV - 98-0196, 1998

THE WASA AND PROMICE PROJECTS
D. Akimov, J. Zabierowski et al.,
MEASUREMENT OF THE QUASI-FREE PN\rightarrow PNETA REACTION
H. Calen, J. Zabierowski et al.
Report series ISSN 0284-2769 of The Svedberg Laboratory and Department of Radiation Sciences, Uppsala University, TSL/ISV - 98-0195, May 1998

EXPERIMENTAL INVESTIGATION OF THE TIME STRUCTURE OF THE EAS MUON COMPONENT
I.M. Brancus, J. Zabierowski et al.
Forschungszentrum Karlsruhe Wissenschaftliche Berichte FZKA 6151, FZK GmbH, Karlsruhe 1998

PARTICIPATION IN CONFERENCES AND WORKSHOPS

ADRONY WYSOKICH ENERGII W SZAL NA WYSOTE GOR
J.N. Capdevielle, J. Gawin, D. Sobczyńska, B. Szabelska, J. Szabelski, T. Wibig,
25 Rosyjska Konferencja po Kosmiczkom Luczam, Moskwa, 22-27.06.1998

RAZLICZUJE W NABLUDAJEMOM Czerenkovs Kom SWIETE W SZAL OT ADRONOV I GAMMA KVANTOV
C. Meynader, D. Sobczyńska, B. Szabelska, J. Szabelski, T. Wibig,
25 Rosyjska Konferencja po Kosmiczkom Luczam, Moskwa, 22-27.06.1998

MEASURABLE DIFFERENCE IN CHERENKOV LIGHT BETWEEN GAMMA AND HADRON INDUCED EAS
H. Cabot, C. Meynader, D. Sobczyńska, B. Szabelska, J. Szabelski, T. Wibig
16th ECRS, Alcala de Henares, Spain, July 20-25, 1998

HIGH ENERGY HADRONS IN EAS AT MOUNTAIN ALTITUDE
J.N. Capdevielle, J. Gawin, D. Sobczyńska, B. Szabelska, J. Szabelski, T. Wibig
16th ECRS, Alcala de Henares, Spain, July 20-25, 1998

ON POSSIBLE OBSERVATION OF "DOUBLE-FRONT" EXTENSIVE AIR SHOWERS
V. V. Alekseenko, A. B. Chernyaev, S. Kh. Ozorkov, Yu. V. Sten’kin, J. Szabelski
Proc. of the Xth ISVHECR112-17 July 1998, Gran Sasso, Italy

THE EXTENSIVE AIR SHOWER EXPERIMENT KASCADE - FIRST RESULTS
H. O. Klages, J. Zabierowski et al. KASCADE Collaboration

RESULTS FROM THE MUON TRACKING DETECTOR IN THE AIR SHOWER EXPERIMENT KASCADE
I. Atanasov, P. Doll, J. Zabierowski et al.
Presented at 8th Wire Chamber Conference, Vienna, Feb. 1998

THRESHOLD ETA PRODUCTION IN pN REACTIONS AT CELSIUS
R. Bilger, J. Zabierowski et al.
Presented at MESON workshop, Cracow, Poland, May 26- June 2, 1998

LIGHT PULSER MONITORING SYSTEM FOR THE 4% WASA DETECTOR - - STATUS REPORT
J. Zabierowski
WASA/PROMICE Collaboration Main Meeting, March 20-23, 1998, Uppsala

THE KASCADE EXPERIMENT: STATUS AND PHYSICS OVERVIEW
K.-H. Kampert, J. Zabierowski et al. KASCADE Collaboration
Proc. of XVth ECRS 1998, Alcala Spain

EXTENSIVE AIR SHOWERS MUON DENSITY SPECTRUM
T. Wibig, J. Zabierowski et al. KASCADE Collaboration
Proc. of XVth ECRS 1998, Alcala Spain

THE TIME STRUCTURE OF THE EAS MUON COMPONENT IN THE KASCADE EXPERIMENT
M. Brancus, J. Zabierowski et al. KASCADE Collaboration
Proc. of XVth ECRS 1998, Alcala Spain,

ELECTRON, MUON AND HADRON SIZE SPECTRA OF EAS IN THE „KNEE” REGION
R. Glasstetter, J. Zabierowski et al. KASCADE Collaboration
Proc. of XVth ECRS 1998, Alcala Spain

ESTIMATION OF THE CHEMICAL COMPOSITION IN THE „KNEE” REGION FROM THE ELECTRON/MUON RATIO IN EAS
J. Weber, K.-H. Kampert, J. Zabierowski et al. KASCADE Collaboration
Proc. of XVth ECRS 1998, Alcala Spain
NONPARAMETRIC METHODS FOR DETERMINING ENERGY AND ELEMENTAL COMPOSITION OF COSMIC RAYS FROM EAS OBSERVABLES
A. Chillingarian, J. Zabierowski et al.
Proc. of XVIIIth ECRS 1998, Alcala Spain

ANALYSIS OF EAS OBSERVABLES OF THE KASCADE EXPERIMENT BY NONPARAMETRIC METHODS FOR DETERMINING ENERGY AND ELEMENTAL COMPOSITION OF COSMIC RAYS
M. Roth, J. Zabierowski et al.
Proc. of XVIIIth ECRS 1998, Alcala Spain

2PI-PRODUCTION AND D+ SEARCH IN PP-COLLISIONS
R. Bilger, J. Zabierowski et al. WASA/PROMICE Collaboration

ELECTRON, MUON AND HADRON SIZE SPECTRA OF EAS IN THE „KNEE” REGION,
R. Glasstetter, J. Zabierowski et al. KASCADE Collaboration
Xth ISVHECRI, 12-17.07.1998, Gran Sasso, Italy

ESTIMATION OF THE CHEMICAL COMPOSITION IN THE „KNEE” REGION FROM THE MUON/ELECTRON RATIO IN EAS
J. Weber, J. Zabierowski et al., KASCADE Collaboration
Xth ISVHECRI, 12-17.07.1998, Gran Sasso, Italy

LECTURES, COURSES AND EXTERNAL SEMINARS

HIGH ENERGY MUONS CORRELATED WITH SOLAR FLARES
J. Szabelski
CAMK, Warszawa, 15.04.1998 r.

POMIARY ZMIAN NALEŻENIA PROMIENIOWANIA KOSMICZNEGO SKORELOWANYCH Z ROZBŁYSKAMI SLONECZNYMI
J. Szabelski
CBK PAN, Wroclaw, 23.02.1998 r.

SOME INSTRUMENTAL PROBLEMS IN HIGH ENERGY PHYSICS EXPERIMENTS
J. Zabierowski
Faculty of Physics and Chemistry, University of Łódź, Łódź, 18.11.1998

in Polish
PERSONNEL

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Overview

The Department of Nuclear Theory consists of 18 physicists and 3 graduate students working on different aspects of low energy, high energy, plasma and nonlinear physics. Most of the effort is phenomenologically oriented. Close collaboration with SMC, LEAR and ALICE Collaborations at CERN must be also emphasized. The specific topics are:

Studies of strangeness in nuclei stem from a long Warsaw tradition of hypernuclear physics. These include attempts to understand the elusive Σ-hypernuclei, studies of nuclear bound states of η-mesons that introduce hidden strangeness into nuclei. Some studies have been devoted to the structure of superheavy elements, which resulted in predicting properties of deformed superheavy nuclei. They are continued with calculations of collective motion, neutron haloes and energy dissipation in heavy ion collisions. An increasing effort is also devoted to research on nuclear collisions at high energies. Much attention is paid to the study of the mass of exotic nuclei.

Studies in high energy physics are devoted to understanding deep inelastic lepton scattering, formal properties of the contour gauge theories, the phenomenology of high energy multiparticle and production processes in both hadronic and nuclear collisions, (especially the systematics of leading particle production in these processes). A new approach to the standard model via conformed unification of general relativity has been attempted.

The new attempt at quantization of nonlinear theories has been undertaken and first positive and interesting results obtained.

Theoretical studies of soliton solutions in several branches of physics are performed. Methods of testing the stability and metamorphosis of these soliton solutions have been developed. Results have implications in solid state physics as well as for plasmas and hydrodynamics.

Collaborations with several universities have been maintained. These include the Universities of: Warsaw, Bucharest, Kielce, T.U. Munich, Liege, Siegen, Helsinki, São Paulo, Matsumoto, Lipsk, Berkeley, Brussels, St.Petersburg, Tbilisi, I.C. London, U.C. London, Warwick and the Institutes: GSI-Darmstadt, Joint Institute of Nuclear Research – Dubna.
8.1 Production of Σ Hypernuclei in the (K⁻, π⁺) Reaction and the ΣN Interaction

by J.Dąbrowski and J.Rozynek

Pion spectra from (K⁻, π⁺) on ¹⁶O and ⁹Be targets in the region of Σ production are analyzed in the impulse approximation for different strengths of the Σ single-particle potential. A comparison with the recent BNL (K⁻, π⁺) spectra favors model F of the Nijmegen barion-barion interaction as a realistic representation of the Σ-nucleon interaction.


8.2 The Single-Particle Potential of a Σ Hyperon in Nuclear Matter

by J.Dąbrowski

The connection between the baryon-baryon interaction and properties of Σ hypernuclear states are investigated. The single-particle Σ potential fitted to the pion spectrum measured in (K⁻, π⁺) reaction appears to be repulsive. A comparison with the (K⁻, π⁺) suggests a much less repulsive single-particle potential. Thus the comparison with both (K⁻, π⁺) and (K⁻, π⁺) spectra is sensitive to the isospin dependence of the Σ single-particle potential. This work is now in progress. Some of these problems have been mentioned in [1].


8.3 Instability and Oscillations of One and Two Dimensional Kadomtsev-Petviashvili Waves and Solitons

by E.Infeld, G.Rowlands¹, A.Senatorski

We investigated the stability and dynamics of nonlinear structures that arise from the Kadomtsev-Petviashvili equation (KPI). For initially flat, propagating cnoidal waves and solitons the region of instability in perturbed wavevector K space is found. This is done by combining information obtained by both approximate and exact calculations. Growth rates are found. It might seem strange that this should be necessary when the problem has been "solved" exactly by Kuznetsov and co-workers. However, as those authors admit, their treatment is extremely difficult to apply to any but two specific limits. So much so that they miss a stability boundary even in one of those limits. Here, by combining all our results, we are able to present a reasonably complete picture. Formulas are explicit and simple. Once the instability develops, two-dimensional "lumps" are produced, as well as a new, diminished cnoidal wave. We will concentrate on the lumps and their further fate. The two-dimensional solitons or lumps are then investigated in three dimensions by numerical simulations. A distortion in a plane perpendicular to the motion leads to an oscillation of the lumps. This result is in contradistinction to the one of a perturbation in a plane containing the direction of motion. In that simulation of Senatorski & Infeld, lumps were destroyed completely and three dimensional solitons were formed [1]. We thus have an initially two dimensional soliton that can either produce a three dimensional decay product or exhibit a new oscillation. This will depend on the plane of the perturbation. This dichotomy may be the first of its kind for two dimensional solitons in the three dimensional world.


¹ Department of Physics, University of Warwick, Coventry CV4 7AL., UK
8.4 Growth of the Normal Flow Instability of a Vortex Array in Two Component HeII
by E. Infeld, T. Lenkowska-Czerwińska

We investigate the instability of a rotating, vortex permeated superfluid HeII. Growth rates were formed. Our theory gives the one fluid limit [1]. However, it should not be used in general, as it is internally inconsistent. Our results proved important in view of recent experiments in which the superfluid matches the vorticity of the normal fluid.


8.5 The Problem of Pattern Recognition and Momenta Determination in COMPASS Experiment Spectrometer
by K. Kurek

The new Polarized Deep Inelastic Scattering experiment – COMPASS is now under construction at CERN laboratory. One of the goals of COMPASS program is measurement of gluon polarization $A_G$ using polarized muon beam scattered off polarized target. The polarized open charm lepto production is one of the processes which allow us to access $A_G$. To detect and reconstruct $D^0$ mesons as well as other particles needed for correct kinematics reconstruction the efficient algorithm for pattern recognition and momenta reconstruction are needed. The COMPASS spectrometer consists of complicated set of detectors of different types (including RICH), a polarized long target with solenoid magnetic field and two magnets with complicated fringe field.

Therefore the efficient and fast (high intensity muon beam) reconstruction is a real problem especially for small momenta particles, the reconstruction of which is needed. The three different theoretical approaches have been tested as a prototype pattern recognition algorithm: the standard projections method, the projection method with Kalman Filter and Space Points method. For particles, momenta determination the Chebyshev polynomials method has been also tested [1]. The first results have shown that the most promising method is the Space Points reconstruction algorithm. However, tuning of parameters and tests of different setups (spectrometer optimization) are needed and will be continued.


8.6 Spin Asymmetries in Polarized Muon Scattering at Low $Q^2$
by K. Kurek

We continued research on the calculations of the asymmetries of spin dependent cross sections for polarized lepton scattering off a polarized target. The detailed calculations including radiative corrections from QED and QCD processes are needed for SMC experiment analysis as well as for future COMPASS experiment. The last SMC analysis contains data taken with a specially dedicated hadron trigger (see SMC results in this report) allowed to measured $A_1$ asymmetry in very low $x$ and $Q^2$ kinematical regime. For these data the decomposition used for the measured asymmetry $A$ as a product of so-called depolarization factor $D$ and virtual photon-proton asymmetry $A_1$ (related to structure function $g_1$) requires explanation because for small $Q^2$ and $x$ the factor $D$ is greater than 1. The effect is caused by the mass correction from lepton (muon in our case). The simple physical meaning of $D$ (part of polarization from lepton taken by photon what implies that $D$ should be smaller than 1) is dependent on the definition of virtual photon-proton spin dependent cross sections and in consequence of the definition of $A_1$. To keep a naive interpretation of $D$ the redefinition of the virtual photon cross sections are needed. Also relations between $R$, $F_2$ and $F_1$ structure functions are affected. Such redefinition is not wanted because the redefined structure functions depend on the mass of the lepton. On the other hand, such dependence is also hidden in the standard definitions in the smallest values of $Q^2$ allowed by kinematics which depends on lepton mass. The physical quantity measured in experiment, $A$, is defined in unique way (as should be) but the decomposition is not. The discussion of the definition of $A_1$ and $D$ will be published in SMC paper dedicated to low $Q^2$ and $x$ analysis. The
COMPASS experiment is focused on the measurement of asymmetries in very low Q^2 regime - quasi-photoproduction (muon program) and different types of corrections (also muon mass corrections) should be carefully studied and determined. This work is now in progress.

### 8.7 Nambu and Jona Lasinio Model Beyond the Hartree Approximation

by A. Okopińska, J. Rozynek

Nonperturbative treatment which go beyond the self-consistent mean field Nambu and Jona-Lasinio model was investigated with the generating functional for one-particle-irreducible Green's functions. An approximation to this functional generates a consistent set of approximation for all Green's functions of the theory [1].

We discuss also [2] various nonperturbative expansions obtained in the path integral formulation of the generating functional which offer systematic approximation.


### 8.8 Production Mechanism of Heaviest Atomic Nuclei

by R. Smolańczuk

We propose the model [1] describing cold fusion reactions leading to deformed superheavy nuclei [2-5]. We assume that the compound nucleus is formed due to the quanta! tunneling through the Coulomb barrier. The competition between neutron emission and fission is described statistically. Within the proposed model, we calculate optimal bombarding energies and formation cross sections of the hypothetical spherical superheavy nuclei. Presently our model is extended for the description of fusion reactions with different target-projectile-energy combinations.


### 8.9 Properties of SuperHeavy Nuclei

by I. Muntian, Z. Patyk, A. Sobieczewski

Rotational properties of even-even deformed superheavy nuclei, situated around the nucleus 270-Hs in the nuclear chart, have been studied theoretically. The energy \( E_{2+} \) of the first rotational state has been calculated. Small values of this energy, obtained for some of the nuclei, are interpreted as coming from large deformations of these nuclei and from lowered pairing correlation, caused by large energy gaps.

For spherical superheavy nuclei with the neutron number N close to N=184, the effect of the surface diffusenesses of the proton and neutron density distributions on the properties of these nuclei has been investigated. Properties such as single-particle spectra and masses of the nuclei have been considered. Instead of being fixed, as they were up to now, the diffusenesses are treated as degrees of freedom in the macroscopic-microscopic calculations. Their values are established by minimization
of the energy of a nucleus. It is found that such treatment may decrease the energies (masses) of the studied nuclei by up to about 2 MeV [2].


8.10 Small-\(x\) Behaviour of the Polarized Structure Function \(F_3^y(x,Q^2)\)

by B. Ermolaev, R. Kirschner\(^1\), L. Szymanowski

We study the small \(x\) behaviour of the polarized photon structure function \(F_3^y\), measuring the gluon transversity distribution, in the leading logarithmic approximation of perturbative QCD. There are two contributions, both arising from two-gluon exchange. The leading contribution to small \(x\) is related to the BFKL pomeron and behaves like

\[ x^{\alpha_0} \approx 0(\sqrt{S}) \]

The other contribution includes in particular the ones summed by the DGLAP equation and behaves like

\[ x^{\alpha_0^{(s)}} \approx 0(\sqrt{S}) \quad \text{[1]} \]


\(^1\) Leipzig Univ., Germany

8.11 The BFKL Pomeron in (2+1) Dimensional QCD

by D. Yu. Ivanov\(^1\), R. Kirschner\(^2\), E. M. Levin\(^3\), L. N. Lipatov\(^4\), L. Szymanowski, M. Wusthoff\(^5\)

We investigate the high-energy scattering in the spontaneously broken Yang-Mills gauge theory in 2+1 space-time dimensions and present the exact solution of the leading \(\ln s\) BFKL equation. The solution is constructed in terms of special functions using the earlier results of two of us (L. N. L. and L. S.). The analytic properties of the \(t\)-channel partial wave as functions of the angular momentum and momentum transfer have been studied. We find in the angular momentum plane: (i) a Regge pole whose trajectory has an intercept larger than 1 and (ii) a fixed cut with the rightmost singularity located at \(j=1\). The massive Yang-Mills theory can be considered as a theoretical model for the (non-perturbative) Pomeron. We study the main structure and property of the solution including the Pomeron trajectory at momentum transfer different from zero. The relation to the results of M. Li and C.-I. Tan for the massless case is discussed.

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\(^2\) Leipzig Univ., Germany
\(^3\) Durham Univ., UK.
\(^4\) Tel Aviv Univ. & St. Petersburg, INP, Russia

8.12 Next to Leading Gluonic Reggeons in the High Energy

by R. Kirschner\(^1\), L. Szymanowski

We study the next-to-leading gluon exchange in the high-energy scattering that contributes to the amplitude to order \(\mathcal{O}(\alpha_s^n)\) up to logarithmic corrections. Similar to the leading gluon exchange these contribution can be described in terms of reggeon exchanges. There are several gluonic reggeons at the next-to-leading level. Some of them transfer parity or gauge group representation different from the leading gluonic reggeon. Unlike the leading one they are sensitive to the helicity and transverse momenta of the scattering partons. We extend the high-energy effective action and derive from the action of gluodynamics the terms describing the next-to-leading reggeons and their interaction in the multi-Regge approximation.[1]


\(^1\) Leipzig Univ.
8.13 \(\eta\)-Nucleon Interactions
by J.Kulpa and S.Wycech

An analysis of the coupled \(\eta N\), \(\pi N\), \(\eta\pi N\), \(\gamma N\) channels was updated with several models for \(K\) matrix [1]. The coupling to \(\pi\pi\) channel was found to be very small.

Nuclear states of \(\eta\)-mesons are found to exist. Their widths are affected mildly by the absorption of \(\eta\) by two-nucleon [2].

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8.14 Pionium
by J.Kulpa and S.Wycech

Chances to produce pionium – an atomic state of two \(\pi\) mesons – in nuclear collisions are calculated. One finds a sizable probability to produce pionium in 2P states. The latter are generated by Coulomb fields of the colliding nuclei [1].

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8.15 Magnetic Mixing of Nuclear States
by S.Wycech

A unique possibility to detect the mixing of nuclear states in magnetic field exists in highly ionized \(^{229}\text{Po}\text{^*}\) atoms. The magnetic field is provided by the IS electron. The chances to see this effect via the X-ray transitions are discussed [1].

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8.16 Antiprotonic Atoms
by J.Kulpa, R.Smolańczuk, S.Wycech

The analysis of Polish-German PS209 experiment performed at Low Energy Antiproton Ring at CERN is going on [1,2]. It was found that at very large distances antiprotons are repelled by the nucleus. That is contrary to all previous expectations, one possible explanation might be due to the \(^{13}\text{Po}\) nucleon-antinucleon quasibound state [3].

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8.17 Systematics of Leading Particle Production
by F.O.Duraes\(^{5}\), F.S.Navarra\(^{6}\), G.Wilk

Using a QCD-inspired model developed by our group for particle production, the interacting gluon model (IGM), we have made a systematic analysis of all available data on leading particle spectra [1]. These data include diffractive collisions and photoproduction at DESY HERA [2,3,4]. With a small number of parameters (essentially only the nonperturbative gluon-gluon cross section and the fraction of diffractive events) good agreement with data is found. We show that the difference between
pion and proton leading spectra is due to their different gluon distributions. We predict a universality in the diffractive leading particle spectra in the large momentum region, which turns out to be independent of the incident energy and of the projectile type.


8.18 Multiparticle Production Phenomenology
by N.Suzuki\textsuperscript{1),} M.Biyajima\textsuperscript{2),} G. Wilk, Z.Włodarczyk\textsuperscript{3)}

We have analysed cumulant moments of negatively charged particles observed in hadron-nucleus collisions [1]. Our goal was to demonstrate that fluctuations seen in those moments do not bear information of the fundamental aspects of multiparticle production processes (as has been repeatedly argued recently on many occasions) but result from the natural truncation of the observed multiplicity distributions.


8.19 HBT Interferometry
by G.Wilk

The perspectives of Bose-Einstein correlations (known also as HBT interferometry) for the foreseen measurements of photons and neutral pions in the ALICE experiment at LHC have been discussed and summarized for the use of the ALICE collaboration [1].


8.20 Global Geometry of Spacetime and Quantization
by W.Piechocki and G.Jorjadze\textsuperscript{1)}

We consider classical and quantum dynamics of a relativistic particle in two-dimensional Lorentzian spacetimes with constant curvature. It turns out that specification of the Lagrangian of a system and its local symmetries are not sufficient for finding an unique quantum system corresponding to the classical one. To quantize the system it is necessary to specify the topology and global symmetries of the spacetime[1-8].

LIST OF PUBLICATION

SINGULARITIES OF THE S-MATRIX FOR A COMPLEX SQUARE WELL POTENTIAL
J. Dąbrowski

PRODUCTION OF SIGMA HYPERNUCLEI IN THE \((K^-, \pi^+)\) REACTION AND THE SIGMA INTERACTION
J. Dąbrowski, J. Rożynek

PROBLEMS IN HYPERNUCLEAR PHYSICS
J. Dąbrowski

STRUCTURE OF HEAVIEST NUCLEI
A. Sobieczwski

OPTIMIZED EXPANSION FOR THE NAMBU AND JONA LASINIO MODEL
A. Okopinska, J. Rożynek

THE \(\rho^2\) OPTICAL POTENTIAL FOR ETA MESONS
J. Kulpa and S. Wycech

LEADING PARTICLE EFFECT IN THE J/PSI ELASTICITY DISTRIBUTION
F. O. Duras, F. S. Navarra and G. Wilk

DYNAMICAL AMBIGUITIES IN SINGULAR GRAVITATIONAL FIELD
G. Juszkiewicz, W. Piechociński
Class. Quantum Grav. 15 (1998) L41

MEAN-FIELD ON A 3-DIMENSIONAL MESH

DIFFRACTIVE MESON PRODUCTION FROM VIRTUAL PHOTONS WITH ODD CHARGE - PARITY EXCHANGE
R. Englert, D. Yu, Ivanov, R. Kirschner, L. Szymański

PROPER TIME DYNAMICS IN GENERAL RELATIVITY AND CONFORMAL UNIFIED THEORY
L. N. Gyngazov, M. Pawlowski, V. N. Pervushin, V. I. Smirichinski

SHELL STRUCTURE AND SHAPES OF SUPERHEAVY NUCLEI
Z. Patyk, J. Skalski, R. A. Gherghesca, A. Sobieczwski
Heavy Ion Physics 7 (1998) 913

J/PSI ELASTICITY DISTRIBUTION IN THE VECTOR DOMINANCE APPROACH
F. O. Duras, F. S. Navarra and G. Wilk

MEASUREMENT OF PROTON AND NITROGEN POLARIZATION IN AMMONIA AND A TEST OF EQUAL SPIN TEMPERATURE
K. Kurek with SMC Collaboration

POLARIZED QUARK DISTRIBUTIONS IN THE NUCLEON
K. Kurek with SMC Collaboration

GLUONIC REGGEONS
R. Kirschner, L. Szymański

CONFORMAL UNIFICATION OF GENERAL RELATIVITY AND STANDARD MODEL
M. Pawlowski, V. V. Papoyan, V. N. Pervushin, V. I. Smirichinski
CUMULANT MOMENTS IN HADRON-NUCLEUS COLLISIONS AND STOCHASTIC PROCESSES
N.Suzuki, M.Biyajima, G.Wilk and Z.Wlodarczyk

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POLARIZED HIGH ENERGY MUON SCATTERING
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A NEXT-TO-LEADING ORDER QCD ANALYSIS OF THE SPIN STRUCTURE FUNCTION Gl
K.Kurek with SMC Collaboration

THE BFKL POMERON IN (2+l)-DIMENSIONAL QCD

NEXT-TO-LEADING GLUONIC REGGEONS IN THE HIGH-ENERGY EFFECTIVE ACTION
R.Kirschner, I.Szczepaniak

BREAKUP OF 2D INTO 3D KADOMTSEV-PETVIASHVILI SOLITONS
A.Senatorski, E.Infeld

GROWTH RATES OF THE NORMAL FLUID FLOW INSTABILITY IN HEII
E.Infeld, T.Lenkowska-Czerwińska

RATES OF TRANSITIONS BETWEEN THE HYPER-FINE-SPLITTING COMPONENTS OF THE GROUND-STATE AND
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THE ENERGIES AND RESIDUES OF THE NUCLEON RESONANCES N(1535) AND N(1650)
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GROUND-STATE ROTATIONAL ENERGIES OF DEFORMED SUPERHEAVY NUCLEI
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SURFACE DIFFUSENESS AND PROPERTIES OF SPHERICAL SUPERHEAVY NUCLEI
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SMALL X BEHAVIOR OF THE POLARIZED PHOTON STRUCTURE FUNCTION $F^7_3(x, Q^2)$
E. Ermolaev, R. Kisscher, L. Szymanowski

A MODEL FOR LANGMUIR AND UPPER HYBRID TURBULENCE IN THE MAGNETOSPHERE
P. Goldstein
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MASSES AND RADIi OF SPHERICAL NUCLEI CALCULATED IN VARIOUS MICROSCOPIC APPROACHES
Z. Putyk, A. Baran, J. P. Berger, J. Decharge, J. Dobaczewski, P. Ring, A. Sobieczewski

NUCLEAR INTERACTIONS OF ANTI-PARTRONS: THEORY
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GEOMETRIC QUANTIZATION OF FIELD THEORY ON CURVED SPACETIME
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**Books**

LAGRANGIAN PICTURE OF PLASMA PHYSICS
E. Infeld, G. Rowlands
*PWN E. Infeld, G. Rowlands, 1998 book*

**PRESENTATIONS AT CONFERENCES AND WORKSHOPS**

a) Published in conferences proceedings

PROBLEMS IN HYPERNUCLEAR PHYSICS
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PIONIUM IN EXTERNAL ELECTRIC FIELDS
J. Kulpa and S. Wycech

THE NAMBU AND JONA LASINIO MODEL BEYOND THE HARTREE APPROXIMATION
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RELATIVISTIC PARTICLE IN SINGULAR GRAVITATIONAL FIELD
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MASSLESS PARTICLE IN CURVED 2D SPACETIME
G. Jorjadze, W. Piechocki

GLOBAL PROPERTIES OF 2D SPACETIME AND QUANTIZATION
G. Jorjadze, W. Piechocki
PARTICLE IN CURVED 2D SPACETIME
G.Jorjadze, W.Piechocki

STABILITY OF HEAVIEST ELEMENTS
A.Sobiczewski
Proc. 2nd Int. Conf. On Exotic Nuclei and Atomic Masses, Shanty Creek USA (199) (in press)

INELASTICITY FOR HADRON-CARBON NUCLEUS COLLISIONS FROM EMULSION CHAMBER
G.Wilk, Z.Wlodarczyk

DO WE OBSERVE LEVY FLIGHTS IN COSMIC RAYS?
G.Wilk, Z.Wlodarczyk

CONFORMAL SYMMETRY AND UNIFICATION
M.Pawlowski

b) Oral presentations:

FORMFACTOR OF $\pi^0 \rightarrow \gamma \gamma$ AT DIFFERENT PHOTON VIRTUALITIES
L.Lukaszuk

THE NAMBU AND JONA LASINIO MODEL BEYOND THE HARTREE APPROXIMATION
A.Okoprniska, J.Rozynek
6th International Conference on Path Integrals, Florence

RELATIVISTIC PARTICLE IN SINGULAR GRAVITATIONAL FIELD
G.Jorjadze, W.Piechocki
International Conference “Particles, Fields and Gravitation”, 1998, Lódź

MASSELESS PARTICLE IN CURVED 2D SPACETIME
G.Jorjadze, W.Piechocki
International Seminar in Physics and Mathematics 1998, Tbilisi

Global properties of 2d spacetime and quantization
G.Jorjadze, W.Piechocki
XVIIth Workshop on Geometric Methods in Physics, 1998, Białowieża

FORMATION OF HEAVIEST ELEMENTS
A. Sobiczewski
Plenary talk at the „Krajowa Konferencja Radiochemii i Chemii Jądrowej: w stulecie odkrycia poloniu i radu”, Kazimierz Dolny 1998

STRUCTURE OF HEAVIEST NUCLEI
A. Sobiczewski
Plenary talk at the „NATO Advanced Research Workshop: The structure of mesons, baryons and nuclei”, Kraków 1998.

STABILITY OF HEAVIEST ELEMENTS
A. Sobiczewski

STABILITY AND PROPERTIES OF SUPERHEAVY NUCLEI
A. Sobiczewski

SYNTHESIS OF NEW ELEMENTS
A. Sobiczewski
Int. Conf.: „The discovery of polonium and radium – its scientific and philosophical consequences” Polish Academy of Sciences, Warsaw 1998
DECAY PROPERTIES OF SUPERHEAVY NUCLEI
R. Smolarzczuk
MEP Conference, Woodbury, New York, 1998

COUPLING OF PIONIUM TO TWO PHOTONS
S. Wycech

PIONIUM IN EXTERNAL ELECTRIC FIELDS
S. Wycech
International Workshop on EXOTIC ATOMS AND QCD, Dubna, June 1998.

NUCLEAR INTERACTIONS OF ANTIPOTONS: THEORY
S. Wycech
International Conference LEAP (Low Energy antiprotons), Srodula, September 1998.

THEORETICAL ASPECTS IN THE ANTIPOTONIC ATOMIC STUDIES
S. Wycech
Ps 269 CERN/LEAP Experiment Workshop, September 1998, Munich.

QUASIBOUND STATES IN \( \pi NN \) AND \( \pi NNN \) SYSTEMS
S. Wycech
International Conference MESON, Krakow, June 1998

CONFORMAL SYMMETRY AND UNIFICATION
M. Pawlowski

LECTURES, COURSES AND EXTERNAL SEMINARS

WLASNŚCI SI SYNTEZA JADER SUERCIĘŽKICH
A. Sobiczewski
IFT UW, Warszawa 1998

SUPERCIEŽKIE PIERWIASTKI
A. Sobiczewski
Odolanów 1998

SEMI-INCLUSIVE DEEP INELASTIC SCATTERING
K. Kurek
Warsaw University, May 1998

\( C C \) PRODUCTION AND PROTON SPIN
K. Kurek
Jagiellonian University, Kraków, September 1998
Free University Amsterdam, February 1998
Durham University, May 1998
University in Uppsala, July 1998

EXPERIMENT COMPASS
K. Kurek
University in Białystok

Course in QUANTUM MECHANICS II
K. Kurek
Białystok University

Course in QUANTUM FIELD THEORY
K. Kurek
Białystok University

Course in MATHEMATICAL METHODS IN PHYSICS
K. Kurek
Białystok University

POLON BYL PIERWSZY
A. Snieczewski
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PERSONNEL

Dąbrowski Janusz, Professor 2/5
Goldstein Piotr, Dr.
Infeld Eryk, Professor
Kurek Kurek, Dr.
Łukaszuk Leszek, Professor
Patyk Zygmunt, Dr.
Pawłowski Marek, M.Sc
Piechocki Włodzimierz, Dr.
Rożynek Jacek, Dr.

Senatorski Andrzej, Dr.
Skorupski Andrzej, Dr.
Skalski Janusz, Assoc. Professor
Smolańczuk Robert, Dr., on leave since Oct. 1998
Sobiczewski Adam, Professor
Szymanowski Lech, Assoc. Prof.
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9 DEPARTMENT OF RADIATION DETECTORS

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Overview

Work carried out in 1998 in the Department of Radiation Detectors concentrated on three subjects: (i) Semiconductor Detectors (ii) X-ray Tube Generators (iii) Material Modification Using Ion and Plasma Beams.

SEMICONDUCTOR DETECTORS

Semiconductor detectors of ionizing radiation are among the basic tools utilized in such fields of research and industry as nuclear physics, high energy physics, medical (oncology) radiotherapy, radiological protection, environmental monitoring, energy dispersive X-ray fluorescence non-destructive analysis of chemical composition, nuclear power industry.

The departmental objectives are: a search for new types of detectors; producing unique detectors tailored for physics experiments; manufacturing standard detectors for radiation measuring instruments; scientific development of the staff. These objectives were accomplished in 1998 particularly by:

• research on unique thin silicon detectors for identification of particles in E-AE telescopes
• modernization of technology of manufacturing Ge(Li) detectors capable of detecting broader range of gamma energies
• manufacturing detectors developed in previous years
• re-generating and servicing customer detectors of various origin.

In accomplishment of the above the Department co-operated with groups of physicists from IPJ, PAN Institute of Physics (Warsaw), and with some technology Institutes based in Warsaw (ITME, ITE). Some detectors and services have been delivered to customers on a commercial basis.

X-RAY TUBE GENERATORS

The Department conducts research on design and technology of manufacturing X-ray generators as well as on imaging and dosimetry of X-ray beams. Various models of special construction X-ray tubes and their power supplies are under construction. In 1998 work concentrated on:

• completing laboratory equipment for manufacturing X-ray tubes and their components
• developing technology of manufacturing X-ray tubes and their components
• completing a laboratory set-up with CCD camera for imaging X-ray beams.

In accomplishment of the above the Department cooperated with Dora Power Systems company.

MATERIAL MODIFICATION USING ION AND PLASMA BEAMS

The technology of modifying surfaces of industrially used materials by means of continuous and pulsed energy beams has been intensely studied for more than 20 years. In some fields it is presently utilized on a broad scale in industry. A significant role among various methods is played by continuous or pulsed ion and plasma beams. The P-IX Department jointly with the P-V Department utilizes some unique sources of intense ion-plasma pulses, and makes use of intense continuous ion beams available in the P-I Department.

The main objectives of the Department in this field are:

• searching for new, original ways of modifying surface properties of solid materials by means of pulsed plasma beams
• implementation in the Institute and thus in the country the ion implantation technique as a method of improving the quality of parts of machinery and tools applied in industry.

These objectives were in 1998 accomplished particularly by:

• advancing the construction of ion source built to improve quality of parts of machinery and tools applied in industry
• research on metal-ceramic mixing (aimed at improving their tribological properties)
• reconnaissance on the market of commercial implantation services in industry
• advancing diagnostics of pulsed plasma beams (power vs time measurement).
9.1 Formation of Surface Pd-Ti Alloys Using Pulsed Plasma Beams

Surface alloying of Pd into Ti is known as an effective way of achieving passivation against reducing acid environments. Such alloys used to be formed by electroplating in combination with diffusion annealing, ion implantation of Pd into Ti, and ion or laser beam mixing of Pd film pre-deposited on a substrate. We demonstrate a new approach to formation of Pd-Ti alloys using intense plasma pulses containing Pd ions.

This technique has some features of ion implantation (mass transport takes place) and some features of laser processing (melting of near-surface layer occurs). In our experiments Ti-foil substrates were exposed to irradiation by Pd-N and Pd-Ar plasma pules of energy density 4-5 J/cm² and duration in the microsecond range. Plasma pulses were generated in the rod plasma injector (IBIS) type of accelerator developed at IPJ. The number of pulses was: 5, 10, and 20.

![Fig. 1 RBS spectra of the irradiated samples](image)

RBS spectra of irradiated samples show a substantial mixing of Pd into Ti substrate. A sharp surface Pd peak accompanied by a tail in the low energy range indicates that Pd has diffused quite far into the substrate. The range of mixing for both N₂ and Ar working gases (as estimated from the spectra) amounts to about 0.5 µm for 5 pulses, and over 1.3 µm for 20 pulses.

![Diagram](image)

The pure Pd layer on top on the processed substrate originates from the inherent features of the mechanisms governing the process. Ions of the working gas which are accelerated during the discharge to an energy of the order of 1-10 keV arrive at the substrate in microseconds. They heat and melt its near surface layer. The melted phase lasts from few to several microseconds before solidification takes place. The evaporated metallic atoms of a kinetic energy on the level of fraction to few eV reach the surface with a delay much longer (>10 µs) then the duration of liquid state. Therefore, the metallic vapour only condenses on the re-solidified surface without mixing with the substrate. The subsequent pulse melts both the metallic layer (pre-deposited by the former pulse) and the near surface region of the substrate, so an effective mixing via diffusion can occur. Each next pulse repeats the pattern outlined above.

The results of the remaining characterizations are collected in the table:

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>No. of pulses</th>
<th>Δm₁ [µg/cm²]</th>
<th>Δm₂ [µg/cm²]</th>
<th>Vₙ [m/V]</th>
<th>I [mA/cm²]</th>
<th>Rₘ [Ω]</th>
<th>R₂ [Ω]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pd-N plasma: T=170 µs, U₀=30 kV, L=300 mm</td>
<td>010</td>
<td>5</td>
<td>47.5</td>
<td>36.3</td>
<td>672</td>
<td>0.37</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>013</td>
<td>5</td>
<td>37.5</td>
<td>36.3</td>
<td>672</td>
<td>0.37</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>08</td>
<td>10</td>
<td>70</td>
<td>75</td>
<td>660</td>
<td>0.93</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>09</td>
<td>10</td>
<td>87.5</td>
<td>-</td>
<td>660</td>
<td>0.93</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>014</td>
<td>20</td>
<td>180</td>
<td>-</td>
<td>647</td>
<td>1.78</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>015</td>
<td>20</td>
<td>165</td>
<td>153</td>
<td>647</td>
<td>1.78</td>
<td>0.25</td>
</tr>
<tr>
<td>Pd-Ar plasma: T=190 µs, U₀=30 kV, L=300 mm</td>
<td>06</td>
<td>5</td>
<td>97</td>
<td>97.5</td>
<td>679</td>
<td>0.36</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>07</td>
<td>5</td>
<td>92.5</td>
<td>97.5</td>
<td>679</td>
<td>0.36</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>05</td>
<td>10</td>
<td>197</td>
<td>196.5</td>
<td>703</td>
<td>1.05</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>016</td>
<td>20</td>
<td>307.5</td>
<td>307.8</td>
<td>682</td>
<td>0.31</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>017</td>
<td>20</td>
<td>285</td>
<td>-</td>
<td>647</td>
<td>1.78</td>
<td>0.23</td>
</tr>
<tr>
<td>Refer.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>492</td>
<td>0.45</td>
<td>0.22</td>
<td>1.54</td>
</tr>
</tbody>
</table>

Δm₁ is the total mass change, Δm₂ is the Pd thickness, Vₙ, I, are corrosion potential and current.

The principal features of the pulse plasma processing that emerge from this work:

1) Efficiency of Pd deposition for 5 Pd-N plasma pulses on the average is 8.5 µg/cm² per pulse and is smaller than that for Pd-Ar plasma (19 µg/cm²) by a factor of about 2.2. This relation decreases substantially for 20 pulses, i.e. to a factor of about 1.7.

2) Values of Δm₁ and Δm₂ do not differ within the accuracy of EDX measurements (~7%). Therefore, the difference between them can not be ascribed neither to the ablation of the sample nor to additive of Ti eroded from titanium part of the electrodes.

3) There are no essential differences in appearance of the roughness profiles and parameters of Ra and Rz for different processing conditions. The surface roughness is caused mainly by post-rolling features on the unprocessed substrates, whereas on the processed ones the post-rolling features are smeared out or absent at all.

4) Preliminary corrosion tests show the corrosion potential increases substantially in all Pd alloyed
samples. However, a decrease of corrosion current occurs only for some samples.

9.2 Kinetics of the Pulsed Erosion Deposition Process Induced by High Intensity Plasma Beams

by J. Piekoszewski, J. Stanislawski, R. Grötzsche, E. Wieser, Z. Werner

Over the past several years we conducted a number of experiments on modification of surface properties of materials using high intensity pulsed plasma beams. This technique has some features of ion implantation since a mass transport takes place, and some features of laser processing since heat transport and hence melting of the near surface layer occurs. High-intensity short-duration pulses of plasma deposits its energy on the surface of the substrate; the energy is transformed into heat. At sufficiently high density of the beam power (on the order of $10^6 \text{ W/cm}^2$ or more) a rapid temperature rise occurs in the irradiated region, leading to melting of it. Once the surface layer is molten, a rapid inward diffusion of the pulse delivered on/at pre-deposited atoms takes place. If the pulse is in the micosecond range, then the near surface layer remains molten for a period of few to several microseconds. In many cases it is enough to enable the deposited atoms to penetrate the substrate to a depth in $\mu$m range. The plasma pulses capable to induce such a process are generated in rod plasma injector (RPI) type of generators described in details elsewhere. Briefly, the plasma pulses are generated as a result of a low-pressure, high current discharge between two concentric sets of electrodes. A high voltage pulse delayed some time $t_d$ with respect to the moment of the injection of the working gas into the inter-electrode space ignites the discharge.

If $t_d$ is set long enough to allow the injected gas to expand over the whole inter-electrode space, the plasma contains almost exclusively the elements of the working gas. This mode of operation is referred to as Pulse Implantation Doping (PID), typically occurring for $t_d = 190-210 \mu$s (for nitrogen as working gas). For short $t_d$ there is a steep gradient of the gas concentration in the inter-electrode space, and effective erosion of metallic electrodes occurs. This regime is referred to as Deposition by Pulsed Erosion (DPE). In both regimes plasma carries sufficient energy to melt surface layer of substrate. DPE leads to formation of well adhering metallic films and in some cases to long range mixing of the deposit-substrate system. Up until recently, we used to assume that in the PID regime plasma pulses are rich in ions of the working gas, whereas in the DPE regime plasma contains mostly metal ions. Such belief was strongly supported by results of Auger analysis of steel substrates processed with Cu-N beams [1], since the PID-processed near-surface layers were rich in N atoms, whereas Cu dominated in the DPE layers.

Although there is no doubt about the PID case, the situation of the DPE is not so clear. In our recent experiments with Mo and Ti electrodes, sapphire substrates and nitrogen as the working gas [2], in the case of Mo electrodes and 5 pulses of DPE treatment the resulting structure consisted of micro droplets with a homogeneous thin film of metal in between. Formation of droplets as a result of a large difference in the surface tension between metallic deposit and substrate was already observed and explained in [3]. In the case of Ti apart from the surface film also mixing of Ti atoms with the substrate was observed. The simplest explanation of presence of the film is that metal ions and/or atoms reach the surface when it is already solidified after the last pulse. In order to get insight into the kinetics of the DPE process, in the present work we performed a series of experiments under the following conditions: energy density $\sim 6 \text{ J/cm}^2$, 3 different working gases (N, Ar and Xe with optimized $t_d$ equal to 160, 190 and 240 $\mu$s respectively), Ti electrodes, and $\text{Al}_2\text{O}_3$ substrates placed 30cm away of the electrodes. Ti-$\text{Al}_2\text{O}_3$ is miscible in the DPE process [2]. Samples were processed with 1, 2 or 3 pulses, next analyzed by RBS technique. Unexpectedly no mixing of Ti into the substrate was observed after 1 pulse, whereas after 2 and 3 pulses mixing was quite evident. Principle conclusions emerging from these facts are as follows:

(i) Metal atoms ablated from electrodes do not undergo acceleration during discharge along with the working gas atoms. Time-of-flight to the substrate $t_f$ of Ti ions accelerated to energy $\sim 1\text{ kV}$ would be $\sim 5\mu$s i.e. only 2 $\mu$s longer than that of N ions. Molten phase at the substrate surface lasts about 10$\mu$s – enough for ions to get mixed by diffusion in liquid phase. The situation should be even more favorable for Ar or Xe working gases when $t_f$ of Xe ions is about 1.6 times greater than that of Ti ions, whereas Ar arrives practically at the same time as Ti ions do.

(ii) A likely mechanism of ablation is bombardment of ends of the electrodes by electrons...
yielding evaporation of particles with thermal energies. Ceramic substrate surface remains hot (>1000°C) for at least 100μs and is "fresh", so electrode particles (in vapor or ion state) reaching the surface may form a very well adhering film. The subsequent pulse melts both metallic film and the near-surface layer that leads to mixing — as in the case of the Ti/Al₂O₃ system.

References

9.3 Double Interfacial Layers for Ceramic/Metal Braze Joints Made by High Intensity Pulsed Plasma Beams and Arc PVD Techniques
by J.Piekoszewski, J.Stanislawski, R.Grötzschel

Fabrication of ceramic joints is complicated by the fact that most metals would not wet the ceramics unless certain conditions are met. The key concept of our studies conducted over the past 3 years is to metallize the ceramic surface prior to actual brazing by alloying it with some chosen metal in the liquid state using intense plasma pulses generated in the so-called DPE regime (see our preceding contribution). Our experiments conducted with Mo and Ti [1] and recently (1998) with Cu metals show that of these three metals only Ti exhibits long range mixing with Al₂O₃ substrates after the DPE processing. Therefore, we decided to fabricate double layers based on Ti brought to an intimate contact with the ceramic surface. Four experimental setups have been used on two facilities: IONOTRON 46 (I-46) and IBIS. The former one comprises two sources: DPE plasma pulses (titanium electrodes) with energy densities on the level of 3 J/cm², and ARC PVD gun capable of formation of Cu, Ti and TiN coatings. Switching from the DPE to the PVD processing does not require breaking of vacuum in the facility. In the latter (IBIS) facility the procedure of switching electrodes that serve as a metal source from one type to another needs breaking of vacuum. Energy densities of pulses generated in IBIS were about 6 J/cm². The sintered Al₂O₃ samples intended for vacuum seal joints had the form of cylinders with 25 mm outer diameter, 15 mm inner diameter, and 13 mm height. Both flat parallel surfaces were exposed to processing. To each sample a small witness sample was added for further structural characterization of the metallized layer. The preparation of samples in four different setups is outlined in Table 1.

The witness samples were characterized by the EDX, SEM and RBS techniques (the latter one at FZR Rossendorf). The most important information emerging from the characterization can be summarized as follows:

Average thickness of the Ti layers formed with the use of DPE process in the I-46 and the IBIS facilities is 25 μg/cm² and 50 μg/cm², respectively. Thickness of the Cu layer formed with the use of DPE process in the IBIS facility equals to about 85 μg/cm², and thickness of the layer deposited by ARC PVD technique in the I-46 facility is about 1800 μg/cm².

1. There is a substantial difference in appearance of the SEM micrographs taken on the Ti/Al₂O₃ samples prepared by DPE in I-46 with the nitrogen working gas and that taken on samples prepared in IBIS with the argon working gas. The former one resembles the morphology observed earlier by us on the same kind of samples processed in IBIS with nitrogen, whereas the latter one exhibits a large non-homogeneity of the thickness and craters.

2. There is definitely no mixing within the Ti-Al₂O₃ system processed in the I-46 facility — in spite of the fact that the surface layer melts. No unambiguous conclusion in regard to the question of mixing within the Ti-Al₂O₃ system processed in the IBIS facility with Ar working gas can be drawn from the RBS spectra of the system. The low energy tails may be accounted for either by non-homogeneity of thickness of the surface layer, or by a long range mixing. Coexistence of both mechanisms cannot be excluded.

Some cylindrical samples of the 5th, 6th 7th and 8th series (5 items in each batch) are still under brazing experiments conducted at the Warsaw Technical University.
Table 1 Preparation of samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>Batch No.</th>
<th>Process</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>DPE 1-46</td>
<td>—</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>Ti+N</td>
<td>Vacuum sustained between process 2 and 3</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>ARC PVD 1-46</td>
<td>—</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>Ti+N</td>
<td>Vacuum sustained between process 2 and 3</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>TiN</td>
<td>—</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>Cu</td>
<td>Vacuum broken between process 4 and 5</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Ti+Ar</td>
<td>—</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>—</td>
<td>Vacuum broken during process 4 for replacement of electrodes</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Cu</td>
<td>—</td>
</tr>
</tbody>
</table>

Thin silicon detectors find their use in E-ΔE telescopes for heavy charged particle identification. Several detectors with thickness below 13 μm have been manufactured. Starting material for the detectors were silicon wafers with epitaxial (EPI) layer, characterized as follows:

- EPI layer thickness — 4.2 to 12.9 μm
- EPI layer resistivity — app. 36, 40 and 200 Ωcm
- Silicon bulk resistivity — 0.005 to 0.01 Ωcm
- Total wafer thickness including the EPI layer — 200 and 400 μm.

Laboratory technology of manufacturing the thin detectors has been worked out. The crucial technological steps concern thinning of the wafers and producing surface barriers on them. 25 detectors of thickness from 2.4 to 12.6 μm and active surface from 15 do 100mm² have been obtained. The obtained useful working biases were from 5 to 10 V at leakage currents from 10 to 20 nA.

The detectors have been tested with alpha particles from a mixed ²⁴¹Am + ²³⁹Pu + ²⁴⁴Cm source. Top to bottom the spectra (Fig.1) were taken by a thick E detector in front of which no thin detector, and detectors of about 2.4, 4.3, 7.6, and 11μm thickness (respectively) have been placed.

The other figure presents homogeneity of thickness measured by means of alpha particles (²³⁹Pu source, alpha energy 5.155 MeV) along diameter of one of the detectors of 8.6 μm thickness. The presented data indicate the thickness is constant within ± 0.2 μm i.e. around ± 3%.

Fig.1 Top to bottom: alpha particles spectra taken by a thick E detector in front of which no thin detector, and detectors of about 2.4, 4.3, 7.6, and 11μm thickness have been placed.

Fig.2 Thickness measured by means of alpha particles along the diameter of one of the thin detectors of 8.6 μm average thickness.
9.5 Coaxial Ge(Li) Detectors with Thin Entrance Windows

by W.Czarnacki, E.Belcarz, A.Kotlarski, B.Sawicka, T.Sworobowicz

Coaxial Ge(Li) detectors produced according to the standard technology can detect gamma radiation of energies from 60 keV upwards. The technology of coaxial Ge(Li) detector with thin n+ contact, beryllium entrance window on the cryostat, and cooled first stage of amplification has been worked out. Such a detector provides for gamma radiation spectrometry in the energy range from 30 keV upwards. The starting material was p-type germanium monocystal characterized as follows:
- Room temperature resistivity — about 20 Ωcm
- Minority carriers lifetime — at least 1000 μs
- Dislocation density (EPD) — 2 x 10^3 cm^-2

In order to obtain detectors with thin contacts the existing Ge(Li) detector technology has been modified. Crucial modifications include changes of the method of producing n+ contact on the front face of the detecting structure. The field-effect transistor (2N4393) and the feedback resistor (1 GΩ) have been placed inside the cryostat. The obtained detectors were able to detect gamma radiation with the following resolutions (FWHM):
- 2.45 keV for the energy 30 keV (^{133}Ba)
- 1.73 keV for the energy 356 keV (^{133}Ba)
- 2.39 keV for the energy 1332.5 keV (^{60}Co)

The low-energy part of the obtained spectrum is shown in the figure below.

The charge collection efficiency has been determined for the above energies. The experimentally determined Fano factor amounted to F=0.127. By comparison with the Fano factor observed for detectors made according to the standard Ge(Li) and HPGe technology (in both cases F=0.11) one can draw conclusion that the technology modernization did not introduce any substantial deterioration of the detector quality.

![Figure 1](image-url)

Fig.1 Low-energy part of the ^{133}Ba spectrum taken with the developed detector

9.6 Experimental Set-Up with CCD Camera for Real Time X-Ray Beam Imaging

by M.Traczyk, M.Slapa

A laboratory set-up suitable for real-time imaging of X-ray beams based on a CCD camera has been developed. The minimal requirements on the camera, lens, frame grabber extension card, and PC computer have been established. A measurement chamber optically linked with the camera lens has been designed and machined. The chamber design provides for testing various phosphors (lumines-
cence screens). A suitable software for computing images from the camera has been written. The software’s capabilities include integration of successive video frames into a single image. Images may be digitally saved for subsequent processing.

The imaging set-up has been completed and put into operation. The set-up consists of:

- 65 cm long optical bench
- the GNS 3 X-ray tube
- measuring chamber with 31 mm diameter mylar entrance window
- phosphor
- black and white MTV-1802 CB camera (Mintron) with 1/2" CCD device (6.4 x 4.8 mm², 795 x 596 pixels)
- 1614-2/3 Ernitec lens with focal length 16 mm and brightness 1:1.4
- Tekram C210 frame grabber card (8 bit A-D conversion)
- PC computer
- Intrana imaging software
- a dosimeter with a miniature ionization chamber.

The first X-ray images have been obtained with help of the ZnS(Cu) phosphor. The set-up will find its applications in the diagnostics of X-ray tubes manufactured in the P-IX IPJ Department, especially in monitoring of angular distributions of X-ray beams produced by the “photon needle” type tubes.

9.7 Photon Needle for Radiotherapy


"Photon needle" - a new type of X-ray tube designed for radiotherapy of brain tumors - was developed at the beginning of the last decade [1]. The target for electrons was placed at the very end of a specially modeled needle-like anode of the tube. Such target may be surgically entered into a tumor. Electron-to-X-ray conversion takes place inside a tumor. A high dose of radiation sufficient for
destroying malignant cells may in this way be deposited locally within the tumor. At typical operating parameters of the tube (anode voltage 40 kV, anode current 10 μA) the indispensable dose of 20 Gy may be deposited within a single radiation session lasting from 10 to 30 minutes, depending on the tumor dimensions.

First phase of clinical tests began at the turn of 1992 and 1993. The objective of that phase was to check the feasibility of the "photon needle" radiotherapy procedure and its safety for patients. Research on effectiveness of the procedure has been undertaken in selected hospitals since 1995, after obtaining favorable results of tests during the first phase [2].

The work on the "photon needle" started in the P-IIX Department of IPJ at the turn of 1997 and 1998 within the frames of KBN grant PB 681/T11/97/13. In 1998 research was directed on:

- developing of construction and technology of X-ray tubes with needle-like anodes
- developing construction and technology of a laboratory high-voltage power supply
- setting-up a laboratory set-up for imaging X-ray beams with a high spatial resolution
- designing a low-dimension ionization chamber for dose monitoring.

Laboratory facilities for manufacturing components and assembling X-ray tubes have been built and put into operation. Technology of manufacturing components and complete tubes has been developed. Model of a tube with the acceleration chamber suitable for accelerating voltages up to 50 kV has been designed and fabricated. The tube fulfills all the electrical requirements of the "needle-like" anode tube. Research on technology of joining stainless steel thin-wall tubes with beryllium caps is in progress.

Laboratory high-voltage power supply for the "needle-like" anode X-ray tubes has been built and put into operation. The laboratory instrument is indispensable for testing the tubes, electrical isolating components, and antimagnetic shields. Designing of the final make of power supplies for the tubes is in progress.

The laboratory set-up suitable for real-time imaging of X-ray beams based on a CCD camera with a high spatial resolution has been developed [3]. The set-up is in its testing phase.

Low-dimension ionization chamber for X-ray dose and dose-rate measurements in the energy range 1–50 kV has been designed and built. The chamber is read-out by a microprocessor-controlled read-out circuit with the built-in temperature and pressure compensation correction algorithms.

This work has been presented at two conferences:
- National Symposium "Technika Jądrowa w Przemysle, Medycynie, Rolnictwie i Ochronie Środowiska", Kraków, September 16-18, 1998

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June 1, 1998

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IGLA FOTONOWA DO RADIOTERAPII
M.Słapa, J.Dora, R.Gutowski, S.Pszona, W.Straś, M.Traczyk

IGLA FOTONOWA JAKO NOWA METODA BRACHYTERAPII?
M.Słapa, J.Dora, R.Gutowski, S.Pszona, W.Straś, M.Traczyk
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Overview

As presented at the overview seminar held on December 1998, the activities of the Department were shared among several directions of accelerator applications, as well as research and development works on new accelerator techniques and technologies.

In the group of proton and ion accelerators, two main tasks were advanced. The first was a further step in the optimization of operational parameters of multicusp ion-source, prepared for axial injection system in C-30 cyclotron. Another one is the participation in important modifications of r.f. acceleration system in heavy-ion accelerator C-200 of Warsaw University.

In the broad field of electron accelerators our main attention was directed at medical applications. Most important of them was the designing and construction of a full scale technological model of a high-gradient accelerating structure for low-energy radiotherapy unit CO-LINE 1000. Microwave measurements, and tuning were accomplished, and the technical documentation for construction of radiation unit completed. This work was supported by the State Committee for Scientific Research.

Preparatory work was continued to undertake in the year 1999 the design of two new medical accelerators. First is a new generation radiotherapy unit, with 15 MeV electron beam and two selected energies of X-ray photons. This accelerator should in future replace the existing Neptun 10 MeV units. The work will be executed in the frame of the Project-Ordered commissioned by the State Committee for Scientific Research.

The next type of accelerators in preparation is the mobile, self-shielded electron-beam unit for interoperative irradiation. The specification of parameters was completed and study of possible solutions advanced.

The programme of medical accelerator development is critically dependent on the existence of metrological and experimental basis. Therefore the building of a former proton linear accelerator was adopted to the new function as electron accelerators' laboratory. Additional radiation shielding was constructed and the computer assisted system for dosimetric monitoring was installed.

Three experimental set-ups for electron and photon beam diagnostics are in course of installation and running - at: 4-5 MeV, 10-15 MeV, and 20 MeV. The 20 MeV unit will also be used for generation and metrology of narrow photon beams applicable in stereotactic radiosurgery.

Preliminary design works are advanced, oriented, undertaken on an important project – high-power electron accelerators for radiation technology (10 MeV, 20-50 kW). Financial support for this task is still pending.

A substantial part of the Department's activity was oriented to an international collaboration with accelerator physics centres. Two works completed in 1997 were extended in 1998: microwave pulsed generator destined for short beam bunches diagnostics was installed and put in operation at INFN-Frascati; 27 pieces of polarized "door-knob" r.f. couplers for superconducting cavities in HERA ring were installed and put in operation. In the course of 1998 we got the message from DESY, that couplers are working well and brought desirable improvement in operation reliability.

The new item of collaboration with DESY, is design, construction and r.f. measurements of a copper model of accelerating “superstructure” for TESLA collider. If successful, the use of niobium “superstructure” can shorten by about a few kilometres the length of the TESLA linear accelerator. First four 1 m sections of model structures were sent to DESY at the end of 1998. The next four are in preparation.

Some results of work done in 1998 were presented at conferences in Caen, Stockholm and Cracow.

M. Pachan
10.1 Optimization Process of the Miniature Multicusp H\(^{+}\) Ion Source for C-30 Cyclotron's Axial Injection System

by J. Lorkiewicz, E. Prawski

Works an external H\(^{+}\) source were continued in 1998 [1]. The typical measured 18 keV beam current of the source is shown in Fig. 1. In order to reveal the source performance limitation factors, a series of plasma diagnostic tests were done. Plasma electron density, temperature and plasma potential were measured at different arc powers using a cylindrical Langmuir probe located both in the discharge and in the extraction region of the source plasma chamber. The obtained electron energy distributions consisted of two quasi-maxwellian components. Typically above 80% of electrons were thermalized at temperatures 1.3-5eV, depending on arc power and gas flow rate (cold electrons). Energy distribution of the rest of electrons may be approximated by a maxwellian distribution (corresponding temperatures 20-70eV), truncated at the high energy end, due to a finite value of discharge voltage.

The measured cold electron densities in the discharge region rise with discharge current at low current values and saturates at 10\(^{12}\) cm\(^{-3}\) for currents exceeding 5A. The intensity of the H\(^{+}\) current in the following beamline exhibits a similar tendency to saturate. The increase of arc voltage delays the onset of this saturation. The effect can be attributed to variation of the fast electron temperature with arc voltage. Increasing the latter from 75V up to 135V increases the temperature from about 30eV to above 60eV which corresponds to a considerable increase of ionization rate coefficient in the discharge region. Apart from this effect, the arc voltage growth raises the concentration of highly vibrationally excited hydrogen molecules which participate in H\(^{+}\) production.

If the decision on PET radionuclides production in C-30 is made, the beam intensity of multicusp source should be further increased to make this production economically efficient. We propose raising the arc voltage with possible cathode modification to avoid plasma breakdown. Increasing the size of the emission aperture along with raising the pumping speed in the system are also considered.


![Fig. 1 Beam current of the source.](image)
10.2 Complex Revision and Resulting Modifications in the r.f. Accelerating System and the Central Region Heavy-ion Cyclotron of the Warsaw University
by J. Sura, J. Dworski

The U-200P cyclotron is undergoing a procedure aimed to improve the reliability and beam stability. This procedure implied to check the whole chain of the r.f. system and the central region, due to operate with installed ECR-ion source. The first stage was the solid-state preamplifier – SSPA. A cross-check of the SSPA showed its vulnerability against the reflected waves appearing at any mistuning effect in the resonators. If the effort to improve the reliability of the SSPA will fail, then it might become necessary to turn back to vacuum-tube preamplifiers. The actually used computerized amplitude and phase-stability systems do not meet the stability requirements. For the moment, we are going to use again the analogue system which was being used, while the PIG-ion source was operating.

The control system of the panel-resonators needed improved trimmers. We replaced the inductive low-range trimmers by capacitive trimmers having at least 6-times larger range (70kHz instead of 11kHz). Their design showed very good performance (Figure 1).

Fig.1 Large-range capacitive tuning trimmer.

A substantial improvement of the cyclotron is the installation of a new central region shown in the Figure 2.

Some main features of this central region are:
- it may operate at harmonics two and three or four, just turning the inflector by 180 degrees
- it permits to exchange any type of inflector or source without lifting up the upper part of the magnet
- the ion-optical properties are optimized and should increase the beam intensity.

The technological solutions and the design were found and realized by J. Dworski.

1) Heavy Ion Laboratory, Warsaw University
10.3 Full Scale Microwave Model of the Compact High-Gradient Accelerating Structure for 4 MeV Medical Unit CO-LINE 1000
by S. Getka, S. Kulinski, J. Olszewski, E. Plawski, J. Pszona

In low energy medical accelerators, the accelerating structure is typically located in the radiation head, directly on the output beam axis, what allows us to avoid bending of the beam and simplifies the construction. In this solution, the mechanical length of the structure must be sufficiently small, to enable rotation of radiation head around the patient, and to keep the distance from radiation source to the isocentre at a desirable value. In the present solution of CO-LINE accelerator, the achievable length of the structure, permits for Source-Isocentre Distance (SID) of 80 cm. To match modern therapy standards, this distance should be 100 cm. It requires in turn a shortening of the accelerating structure from present 45 cm to below 30 cm. Such value is practically not attainable in “classical” design of standing-wave, JT/2, on-axis coupled S-band structure. Therefore it was necessary to look for a new type of structure with a very high accelerating field gradient.

The adopted solution is the configuration composed of two interlaced chains of resonators, with off-axis coupling cavities, and the shapes of accelerating cavities destined for high field intensity. In this configuration, the ratio of maximum to average field in the structure is close to unity, and the field gradient along the beam axis approaches 30 MV/m. Both chains of resonators are fed with microwave power from the same magnetron, throughout a special coupler which splits the power into two halves, and with phase-shift between them 90° (electrical). In this way during transmission of bunched accelerated beam, in all cavities accelerating fields of proper phase exist.

The designing process consists the following main steps:
- theoretical study
- numerical calculations of electromagnetic fields, microwave circuits, beam dynamics, focusing and transport
- mechanical design and construction of subsequent models, approaching the final technological solution
- experimental investigating of models, and measurements of principal r.f. fields' parameters.

In 1998, the full scale copper model of complete structure was executed, which after testing should serve as a specimen for manufacturing of a prototype, and also verify assembling and tuning procedures.

Accelerating structure composed of several accelerating and coupling cavities is equivalent to a series of coupled resonance circuits, excited by an external r.f. signal of defined frequency. In such a system, electromagnetic fields of different modes are generated, and the frequencies of modes are ascribed to phase-shift angles between adjacent cavities. The relation between frequencies and phase-shifts forms a dispersion curve.

The measurement and tuning procedure of multiresonator structure encloses checking of frequencies of separated cavities, and then tuning of assembled structure to get a continuous dispersion curve (without stop-band), uniform field distribution along structure’s axis, proper coupling to feeding waveguide, high quality factor Q, and proper effective shunt-impedance.

Basic r.f. measurements, were executed on the full-scale model, using Hewlett-Packard Network Analyzer.

Fig. 1 Calculated and measured dispersion curve of high-gradient structure

Fig. 2 Copper full-scale model of the structure, with waveguide ports
10.4 Specific Design and Technology Problems in Construction of High-gradient Structure
by S.Getka, J.Olszewski, E.Ptawski, J.Pszona

A high-gradient accelerating structure forms an integral unit connected with electron gun and waveguide coupler.

It is composed of two interdigital chains of resonators independently fed with r.f. power from the same magnetron, through power coupler and transient section matching an impedance of waveguide to the resonance structure.

Each chain consists of three accelerating cells and two coupling cells. Feeding waveguide is coupled to a middle cell in both chains. The coupling cells are located off-axis of the accelerating cells and machined in common copper blocks. There are seven copper slices of cylindric form and thickness 25 mm. Every slice has on both sides the halves of accelerating and coupling cavities (slices 2,3,4,5,6). Slices 1 and 7 have half cavities on one side. To these slices stainless steel flanges are brazed. The position of dividing planes between slices ensures:
- precision machining of complicated shapes of cavities
- precise correction of cavities’ frequency during tuning.
Proper positioning of half cells during assembling is done with three fixing plugs.

Heat generated during operation of the structure, is transmitted to cooling channels with water flow in closed circuit equipped with temperature control.

Vacuum tightness of the structure is achieved by two step brazing in vacuum furnace, with the help of silver based alloys. The final tuning of the structure is realized in several steps:
- shape correction of cavities by machining before brazing
- shape correction of coupling cavities with tuning pegs done after first brazing
- shape deformation of accelerating cavities after second brazing.

The electron gun is connected to the accelerating structure in a detachable way and sealed with metal sealing rings. The gun body is formed by a corrugated insulator of alumnum ceramic with metal flange with current feedthrough on one end, and vacuum joint on the other. The electron emitter is a dispenser type cathode of small dimensions, what with proper designed optics gives narrow electron beam with proper current intensity. The copper anode of the gun is fastened to the first structure’s cell.

The waveguide coupler is made from stainless steel, and connected to the structure’s flanges with gold sealings. It divides the input power from magnetron into two equal halves, with 90° phase shift. At the input port, and the side port for water load, there are located standard ceramic waveguide windows. An additional port in the coupler is provided for connection of a vacuum ion-pump. All connections on the ports are sealed with high-vacuum gold sealing rings.

![Fig.1 Construction of high-gradient accelerating structure.](image-url)
10.5 Experimental Set-up for e Beam Diagnostics and Metrology of 4 MeV High-gradient Accelerating Structure.

by J. Bigolas, R. Morozowicz, J. Pszona, H. Wojnarowski

In parallel to construction of a new high-gradient accelerating structure, an engineering group was working on a design of a new modern experimental set-up dedicated to testing its parameters. An existing old experimental set-up which has been extensively used in the past, was insufficient for new demands.

Therefore, a new ensemble has been constructed, tested and prepared for experimental operation. The new arrangement consists of a number of completely new modules, as well as some old - but improved ones. Among them are:

- a microwave guide with MG-5249 high-power pulse magnetron and ferrite circulator
- new modulator synchronisation system, with improved noise immunity
- new oil-less pumping system
- new equipment for electron beam measurements with inductive beam monitors from PEARSON ELECTRONICS.

Basic parameters of the present experimental stand are as follows:

- Peak output microwave power: 2.8 MW;
- Magnetron anode voltage: 51 kV;
- Operation frequency (tuned by AFC): 2998±2 MHz;
- AFC correction time: 15s, max;
- Repetition frequency: 200, 150, 100, 50, 25, 12.5 Hz;
- Rough pumping: DRYTEL-100 & turbo-molecular pumping set;
- High-vacuum pump: Varian ion pump 20 l/s;
- Electron beam, energy and spectrum measurement system: magnetic spectrometer;
- Beam measurement by absorption: Faraday cup;
- Sensitivity of inductive beam monitor: 1 V per 1 A;
- Rise time of beam current monitor: 10 ns.

At the designed shunt-impedance of the structure, the above indicated microwave power should allow to attain accelerating field gradient in a range of 30 MV/m. To avoid discharges at such field, a special procedure of high-vacuum technology must be applied.

**Fig. 1** Schematic diagram of experimental set-up for e beam diagnostics and metrology.
In the IPJ-DESY collaboration, a new task was initiated in 1996, oriented on substantial modification of coaxial r.f. couplers for HERA superconducting cavities. The main aim was introduction of d.c. polarisation, to suppress multipactoring resonance discharges. This work was continued in 1997, and completed in 1998.

A series of 27 polarized “door-knob” couplers were designed and manufactured at Świerk, and in December 1997 delivered to DESY. There, these units produced by IPJ were assembled with existing parts dismantled from the HERA ring. In January 1998, complete units were submitted to long time polarisation tests, with applied high-voltage of 5kV. This test took about 2 months of continuous operation. Then, one-week test was carried out on the special stand, with simultaneous application of high-voltage, and flow of helium gas cooling the coupling antenna. Both tests gave positive results. In March 1998, all door-knob couplers were installed in the HERA tunnel. Dismantling and assembling operations were done with participation of IPJ group. In April 1998 a two-week operation was effectuated with feeding r.f. power through the couplers into superconducting cavities of HERA, without an electron beam. This test was also positive.

From June till the end of November, the HERA accelerator was operated with the beam. During this period all couplers worked without damage. The harmful multipactoring effects which existed previously, were completely suppressed. As the result, utilization time factor of HERA for physics' experiments was noticeably improved.
10.7 Design, technology and RF measurements of copper model of 1300 MHz accelerating "superstructure" for TESLA collider

by E.Plawski, J.Sekutowicz, J.Olszewski, W.Pęcilo

The new idea proposed by J. Sekutowicz in DESY[1] and discussed since over the year on regular international TESLA meetings is the modification of superconducting 1300 MHz cavities in a way to reduce substantially the cost of a TESLA collider to be build in future. The interconnections between niobium 9-cell cavities actually fabricated and used in TTF (TESLA Test Facility at DESY) have 3λ/4 length and cut-off frequency above the fundamental frequency passband. This arrangement was motivated and chosen at the very beginning of TTF project[2] to avoid the risk of mode overlapping due to intercavity coupling. As a result, the accelerator fill factor (active cavity length/total cavity length) is 75% reducing by this factor the effective accelerating field (from 25MV/m to 18.8 MV/m). Each cavity is equipped with the input fundamental mode RF power coupler and two HOM couplers dissipating the RF power deposited by an electron beam in higher resonant modes of the cavity. The new proposed layout is a string of 4 or 8 intercoupled cavities forming so-called superstructure. Each cavity is made of 7 strongly coupled cells. Interconnecting beam tubes are shortened to λ/2 length and increased in diameter to make the coupling of FM pass-band possible. The gain of such an arrangement is straightforward. The reduced number of cells per cavity assure better field flatness. Owing to reduction of the interconnections length the accelerator fill factor is increased from 75% to 86% which corresponds to ~10% reduction of total collider length (18km instead of 20km). The main gain is fourfold decrease of the number of FM and HOM couplers.

The idea discussed though theoretically realizable, needs to be proved experimentally. For this purpose the room temperature full scale model of superstructure composed of 4 to 8 cavities is under development. On the basis of the data from DESY the copper model is designed, manufactured and measured in our Institute. Further measurements and tuning will be performed at DESY. In 1998 the necessary simulations, design of single cavity, design and manufacture of precise tools to produce the cavity cells were done. The sample result of RF simulations and the single cavity general layout are shown in Fig.1 and Fig.2. The cavity is a string of 14 half-cell cups welded together in equator region and iris region. The technique of electron beam welding was chosen as giving the most homogenous and lossless structure.

![Fig.1 The SUPERFISH simulation of accelerating mode in 7-cell cavity.](image1)

Fig.1

![Fig.2 The general layout of 7-cell 1300 MHz cavity.](image2)

Fig.2

Since the tolerances on shape are very high (order of tens of micrometer), all steps of production procedure were thoroughly studied. The numerous tests of EBW were made to fix the parameters assuring the high repeatability of series production of cavities. The cups of 3 types necessary to make the cavities were produced, measured and tuned to desired frequencies. The part of half-cells already produced, were welded on iris diameter to form the “dumb-bells” of adjoining cells. The measured RF characteristics are satisfactory (Fig.3). The mass production of 8 cavities (two “superstructures”) should be finished at the beginning of 1999.

In Fig.4 the welded fragments of cavity and interconnecting tube are shown.

![Fig.3 The RF characteristics of half-cell cavity.](image3)

Fig.3

1) MHF Group, DESY, Hamburg
Fig. 3 The measured frequencies of single cup and of welded dumb-bell of 1300 MHz cavity.

Fig. 4 Fragment of 1300 MHz copper model of cavity and λ/2 interconnection


10.8 Installation, and Experimental Operation of Microwave Pulsed Generator for $e^-$ Beam Diagnostics Stand in INFN-Frascati

by J.Bigolas, S.Kulinski, M.Pachan, J.Pszona

In the research centre INFN – Frascati, the experimental investigations are conducted in frame of international TESLA collaboration, concerning photocathodes excited by laser light pulses. The measuring method is based on the observation of electron bunches emitted by the cathode. As the beam pulses are very short, an interesting set-up has been applied.

The electron beam is accelerated in an electrostatic field, and then undergoes deflection by two azimuthally shifted magnetic fields, generated in microwave resonator excited in the mode $TM_{110}$.

As the r.f. power source for feeding of resonator, the pulse microwave power generator, with high frequency stability and peak power 3kW is used. This generator was designed and constructed in Andrzej Sołtan Institute during 1997, and tested at Świerk in November 97.

Early in 1998, the device was transported to Frascati, and experimentally operated to check the main parameters. Afterwards, long term operation was started for frequency and power stability measurements, with the aim to match the generator to operation conditions of the whole set-up.

All measured generator’s parameters were within specification, and frequency stability appeared 3-times better than demanded. This performance confirmed the usefulness of generator for laboratory operation.

Basic parameters obtained during testing:
- Peak output power - 3 kW;
- Operation frequency - 2460 MHz;
- Frequency stability - 150 kHz/h;
- Standing-wave factor - < 1.1;

Pulse length - 9 μs;
Repetition rate - 10 Hz.

Photocathodes measured and optimized by the use of above described arrangement, will be applied in a high-gradient r.f. e-gun prepared for TESLA collider accelerating structure. Two models of r.f. guns were also designed at Świerk in collaboration with DESY.
10.9 Radiation Shielding and Dosimetric Monitoring in Electron Accelerators’ Laboratory
by A. Wysocka, J. Pszona, M. Śliwa

The department of Accelerator Physics has four experimental set-ups for study of the 4.18 MeV energy electron linacs placed in the laboratory constructed for proton linear accelerator. It was necessary to design and build additional radiation shielding and dosimetric monitoring.

The project was performed for legal requirements of radiation protection and was consulted with qualified experts and governmental authorities. In assessing shielding requirements, the following factors were taken into account which affect the average weekly dose equivalent to individuals in occupable areas: the accelerator workload W, the beam orientation (use) factor U and the area occupancy factor T. Radiation protection needs were calculated for the nearest point of the area to be protected.

The barrier towards which the useful beam cannot be directed is called a secondary barrier. Two sources of photon radiation were considered in the design of these barriers: bremsstrahlung at wide angles (“leakage” radiation) and photons scattered from objects placed in the direct bremsstrahlung beam. Some economies were achieved by the fact that the radiation at 90° to the useful beam is somewhat less penetrating. We assumed the shielding parameters of materials for bremsstrahlung at 90° to be the same as those for bremsstrahlung produced at 0° by electrons of energy 2/3E₀. We used ordinary concrete, steel and lead as shielding materials (see Fig. 1). The main considerations in this choice were cost and availability of space. Shielding barriers were calculated using the most accurate information available. For the final design we augmented the preliminary design by a safety factor of two, in the form of an additional HVL (Half-Value Layer) of shielding material on all sides.

The purpose of dosimetric monitoring is to provide an information about the level of radiation in the various places around the protected region as well as control of an access to it. The system named SM-4 is built using hybrid modules with semiconductor detectors as radiation sensors and a computer with specialised add-on card as the system supervisor. The card is equipped with eight 16-bit counters and two 8-bit input/output ports. The number of counters in the card defines the maximum quantity of external detectors connected to the system. There are four detectors and counters in use, at present. Four input lines are used to control doors. In order to carry signals from detectors and door switches to the card, a cable system was worked out. The cable used is 4-pair screened one and it allows to double a number of detectors from four to eight. During its work the SM-4 presents measured radiation levels on the computer screen in the form of a scrolling line plot and stores radiation values on hard drive for later inspection. Average radiation is calculated and stored after each measuring cycle and is presented as bar graph for each channel. Such data as the name of the operator and date and time of measurement are added to saved file, also.

![Building's plan of the electron linear accelerator laboratory.](image-url)
10.10 Accelerating Systems for High-Power, Heavy-Duty Accelerators for Radiation Technology
by J. Bigolas, S. Kulinski, W. Maciszewski, M. Pachan, E. Plawski

As already reported last year, the presumed development of radiation sources for radiation technology in Poland should be based on electron accelerators with $e^-$ beam energy 10 MeV and average output power - 10-20kW (for S-band solution) and 20-50kW (for 200-300MHz solution). This evaluation emerges from operational and economical comparison between isotope ($^{60}$Co) and machine (resonance linear accelerator) sources, taking also into account scientific and technological preparation for accelerator manufacturing and on the other hand all problems with cobalt purchase, transport and storing. For the current needs in existing and planned e-beam treatment facilities in the country, most useful and well suited for easy implementation is the 10MeV/20kW unit. Therefore current efforts were focused on studying in detail such project, with particular emphasis on main subunit – the accelerating system. The standing wave, S-band accelerating structure is taken as basic solution, and more close attention was given to heavy-duty operation of this type of structure.

As the result of these considerations, the following specifications were formulated:
- high-current, dispenser cathode, electron-gun (1A pulse current)
- long accelerating structure, to get high operating shunt–impedance ($2 \times 75 \Omega/m = 150 \, \Omega$)
- r.f. power supply in the middle of the structure for short energy filling time
- high time duty-factor at pulse operation ($P_{av} = (2\%) \, P_{pulse}$)
- long pulse operation of klystron (100μs, 100 Hz-200Hz)
- over-critical coupling waveguide –structure for matching at high beam-loading ($\beta_c \approx 3$)
- high thermal capacity of cooling system (efficient heat flow, temperature control)
- high efficiency focusing system (two separated solenoids)
- sensors and feed-back loops for energy and beam current control.

Such a project is included as first priority level in the Strategic Programme – “Isotopes and Accelerators”.

Fig. 1 Control loops in power accelerator
The frequency distribution system for the TESLA linear collider must deliver a highly phase stable rf signal to the 616 rf stations over a length of 33 km. At the operating frequency of 1300 MHz a short term and long term phase stability of the order of 1 degree with respect to the accelerated beam is required. Our solution involves three coherent oscillators, a 9 MHz low loss coaxial cable distribution, 1.3 GHz fiber optics, and continuous calibrations based on beam phase measurements. This system is transparent to beam operation and will continually monitor and correct slow phase drifts.

The overall layout of the TESLA linac [1] is sketched in Figure 1. The main elements are two linacs with a length of 2x12 km, the damping rings which make use of the linac tunnel, the source for electrons (laser driven rf photocathode gun), the source for the positrons which is based on the concept of high-energy photon conversion into e^+e^-, and a 3 km region for the beam delivery system in between the two linacs. The photons are generated by the spent high-energy electron beam passing a wiggler. The acceleration system in each linac consists of 9856 superconducting cavities which are powered by 308 klystrons (32 cavities per 10 MW klystron).

The various rf systems that must be phase synchronized with picosecond stability over the full accelerator length are:
- the 616 rf systems operating at 1300 MHz in the two superconducting linacs.
- the 433 MHz rf systems for the damping rings
- the 1300 MHz rf system providing power to the photocathode rf gun of the electron source and the associated laser for illumination of the photocathode.

The timing system must guarantee that the bunches which are spaced by 337 ns (3 MHz repetition rate) arrive at the same time at the interaction region.

The phase stability requirements for the accelerating field in the linac cavities are dictated by the low beam energy spread requirement of \( \sigma_E/E < 7 \times 10^{-4} \) and the timing requirements for the bunch arrival at the interaction point. Assuming that a third of the energy spread contribution originates from phase fluctuations of the accelerating field a correlated phase error of only \( \sigma_\phi = 0.4^\circ \) at 1300 MHz corresponding to a timing error of 0.8 picoseconds can be tolerated. The phase stability of the 433MHz rf systems of the damping rings determines arrival
time of the bunches at the interaction point. The interaction position error should not exceed one bunchlength (1 mm) resulting in the same timing stability requirements as dictated by the low energy spread. In addition to the rf phase reference system a timing system with event coding capability is required to allow for real time synchronization of the various rf and other subsystems. The electron and positron bunches must be accelerated in selected rf buckets (every 438th bucket, this number is given by the ratio of bunch spacing and the period of one rf cycle) to guarantee that the collision takes place in the center of the detector. A misplacement by 1 bucket would result in a collision position error of 23 cm (λ=v/τ=23 cm). Therefore the timing system for the rf gun must guarantee a trigger signal stability of better than 770 ps. The timing system clock will also be synchronized to the master oscillator and can therefore provide phase stable timing for the digital feedback and rf system monitors.

The design of a rf phase reference and timing system for the TESLA linear collider is a challenging task due to the tight timing stability requirements of about 1 picosecond over a distance of more than 30 km. It should be possible to meet these requirements if a combination of coaxial distribution, optical fiber distribution, coherent oscillators and beam based calibration is used. It is planned to evaluate the performance of such a scheme at the TESLA Test Facility.


1) DESY, Hamburg
REPORTS

A SMALL MAGNETIC MULTIPLE H+ ION SOURCE, BEAM EXTRACTION MEASUREMENTS
J.Lorkiewicz

STEREOTACTIC RADIOSURGERY WITH LINEAR ACCELERATORS
A.Wysocka
TERRA memo, Fondazione per Androterapia Oncologica, June 1998, Italy

PHYSICAL ASPECTS OF TREATMENT PLANNING IN A LINAC-BASED RADIOSURGERY OF INTRACRANIAL LESIONS
A.Wysocka
Reports of Practical Oncology and Radiotherapy (in press)

PARTICIPATION IN CONFERENCES

UPGRADING OF A SMALL H+ CUSP SOURCE FOR THE C-30 CYCLOTRON AT ŚWIERK
J.Lorkiewicz, E.PIawski /poster/
Proc. 15th International Conference on Cyclotrons and their Applications, Caen, France, June 15 – 19, 1998

ACCELERATING STRUCTURE WITH SEPARATED MODULAR RESONATORS WORKING IN 300MHz FREQUENCY BAND, FOR HIGH POWER ELECTRON ACCELERATOR, ATENA
J.Bigolas, W.Maciejowski, S.Kulinski, M.Pachan, E.PIawski /poster/
Proc. EPAC98, Sixth European Particle Accelerator Conference, Stockholm, June 22-26, 1998

NEW SOLUTION OF HIGH-GRADIENT ACCELERATING STRUCTURE FOR MEDICAL ACCELERATOR CO-LINE/1000-4 MeV
Proc. Nuclear Techniques in Industry, Medicine, Agriculture and Environmental Protection, Polish Symposium, Cracow, 16-18 Sept. 1998

ELABORATIONS IN THE ANDRZEJ SOLTAN INSTITUTE OF ELECTRON ACCELERATORS FOR RADIATION TECHNOLOGY
J.Bigolas, S.Kulinski, M.Pachan, E.PIawski /poster/
Proc. Nuclear Techniques in Industry, Medicine, Agriculture and Environmental Protection, Polish Symposium, Cracow, 16-18 Sept. 1998

THE POSSIBILITY OF ADAPTATION OF C-30 COMPACT CYCLOTRON FOR APPLICATION TO PET – SCANNER FACILITY
S.Kulinski, L.Królicki, J.Lorkiewicz, M.Pachan, E.PIawski, Z.Sujkowski, J.Sura /poster/
Proc. Nuclear Techniques in Industry, Medicine, Agriculture and Environmental Protection, Polish Symposium, Cracow, 16-18 Sept. 1998

APPLICATION OF ACCELERATOR BASED R.F. TECHNIQUE IN THE AGRICULTURE
J.Sura /oral presentation/
Proc. Nuclear Techniques in Industry, Medicine, Agriculture and Environmental Protection, Polish Symposium, Cracow, 16-18 Sept. 1998

TUBE TECHNOLOGIES IN PARTICLE ACCELERATORS
M.Siwa
Scientific and Technical Conference „Technologies of tube production in nonferrous metals industry” Mining and Metallurgy University – Cracow Nov.26-27, 1998
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Maria Zielińska
Overview

1998 was the year when, after one year of preparation, the Department started its educational activity. On October 23rd, a permanent exhibition "Nuclear wastes: problems, solutions" was opened at the Centre of Education and Information (bldg. 67) of the Soltan Institute for Nuclear Studies at Świerk. The exhibition is divided into two parts: first, some introductory information about nuclear radiation displayed, next the problem of nuclear wastes and procedures used for processing, transporting and storing them shown in a series of photographs, drawings, models and descriptions. The exhibition soon became a place of interest to numerous primary and secondary schools even from such distant places from Świerk as Gliwice, students of various universities and the Institute's visitors. At the moment, our Department offers, additionally to the exhibition, introductory lectures to nuclear physics, sightseeing to the reactor MARIA in the neighboring Institute of Atomic Energy and to the experimental laboratories of SINS. We also wrote and are able to supply four educational texts on radioactive materials and their use, on ionising radiation and on nuclear waste.

Another part of our educational activities was concerned with the medical technicians involved in nuclear medicine. The Department prepared two lectures (also in written form for the distribution) on nuclear radiation (mainly X-ray and γ) and its interaction with matter, as well as on the basic principles of the radiological protection in nuclear medicine. Other "hands-on" experiments, dedicated to this professional group, are under preparation.

Last but not least, a group of 60 students from the University of Warsaw (Interfaculty Study of Environmental Protection) asked for appropriate training in ecoradiology. Such a training, on an introductory level, was prepared and conducted successfully. It seems that this group of problems will become a permanent position in our teaching activities.

Independently of the educational and popularisation undertakings, we are personally involved in various research activities, mainly based on the research potential of the Institute of Physics of the University at Białystok. Among them two seem to deserve special mention: an experimental proof that the negative magnetic moments observed for electrons with low momenta must be due substantially to d-electrons and not uniquely to conduction electrons as often though previously, and confirmation of the apparently different two chemical Ga-N bonds in GaN. Two PhD students are currently involved in studies of the interfaces by means of the Conversion Electron Mössbauer Spectroscopy (CEMS) at the Institute of Physics of the University of Uppsala, and studies of structural and magnetic properties of the Cr₃Si alloy doped with iron by means of the X-ray, magnetization and Mössbauer techniques.
11.1 Electron Momentum Density Distribution in Cobalt Disilicide and Silicon: Analysis by the Maximum Entropy Method

by L. Dobrzyński\(^1\), Ch. Bellin\(^2\), H. Kouba\(^3\), X\(^1\)

Three-dimensional electron momentum density distribution in CoSi\(_2\) (experimental data from ESRF) and Si (experimental data from LURE) are studied mainly by the Maximum Entropy Method (MEM). Detailed comparison of the results obtained for a 3-dimensional electron momentum density reconstruction by means of MEM and the Fourier Transformations (FT) is carried out for CoSi\(_2\). MEM analysis only has been carried out for much more limited data set measured for Silicon crystal.

It is shown that both methods of analysis deliver essentially similar results. However, some advantages of MEM are pointed out.

The electron momentum density is slightly contracted along the [111] direction in CoSi\(_2\). In Silicon there are two regions in which the asphericity is different. The distribution at low momenta is contracted along the [100] direction. At larger momenta (above approx. 0.9 a.u.) one observes contraction of the distribution along the [110] direction. This shows that two electron systems are present, the difference between them being sought mainly in their degree of localisation. The overall shape of the momentum density in Si resembles the atomic one expected for the sp\(^3\) configuration of the outer shell, while the distribution in CoSi\(_2\) is generally wider and much closer to what one expects for nearly-free electrons. The comparison of both substances leads to the conclusion that 3d type electrons play an important role in the anisotropy of the electron momentum density distribution in CoSi\(_2\), the contraction along [111] axis indicating on their predominantly e\(_g\) character.

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\(^3\) LURE, bat. 209, Universite Paris-Sud, 91405 Orsay Cedex, France

11.2 Reconstruction of the Uncompensated Electron Momentum Density Distribution by the Maximum Entropy Method

by L. Dobrzyński\(^1\), E. Zukowski\(^1\)

Application of the Maximum Entropy Method (MEM) to the reconstruction of the 3-dimensional electron momentum density for electrons with uncompensated spins is described. The case of iron, for which the largest collection of experimental data is available, is presented in detail. The analysis of the distributions in Fe\(_3\)Si and Cu\(_2\)MnAl alloys is carried out based on measurements of the Magnetic Compton Profiles along only three high-symmetry crystallographic directions. It is shown that the general density distribution in Fe and Fe\(_3\)Si are very much alike, while the data for Cu\(_2\)MnAl can be interpreted with a single strictly positive distribution. It is postulated that the crater-like structure of the Magnetic Compton Profiles may be due to both, conduction and d-band polarizations. In such a case one could reconcile the results of the neutron and Compton experiments.

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\(^2\) Laboratoire de Mineralogie-Cristallographie, Université de Paris VI, 4 place Jussieu, 75252 Paris Cedex 05, France and The Soltan Institute for Nuclear Studies, 05-400 Otwock-Swierk, Poland
11.3 Iron Moment Projection in UFe$_4$Al$_8$ Investigated by Monochromatic Circularly Polarized Mössbauer Source

by K.Szymański$^1$, L.Dobrzyński$^{1,2}$, K.Recko$^1$, D.Satula$^1$, J.Waliszewski$^1$, W.Suski$^3$

UFe$_4$Al$_8$ was investigated using a monochromatic, circularly polarized Mössbauer source. The measurements are sensitive to the sign of the hyperfine magnetic field. The iron magnetic moment component along the direction of applied magnetic field was determined. Quantitative analysis shows that the configuration of iron moments is not uniaxial and, on average, only about one fourth of the atomic iron moment contributes to the total magnetization in randomly oriented powder exposed to the field of 1 T at T=12 K. The presence of ferromagnetic clusters in an otherwise antiferromagnetic ordering is discussed. In the course of the interpretation of the neutron data the Debye temperature $\theta_D = 605(24)$ K was determined.

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11.4 Polarized Source Mössbauer Spectroscopy Applied to Pd-Ti-Al:$_{57}$Fe Alloy

K.Szymański$^1$, D.Satula$^1$, L.Dobrzyński$^{1,2}$, K.U.Neumann$^3$, K.R.A.Ziebeck$^3$

The Heusler alloy Pd$_3$TiAl is claimed to exhibit magnetic order with a relatively high transition temperature and a small magnetic moment, of the order of hundredth Bohr magnetons. $^{57}$Fe impurity was admixed into the alloy in order to carry out Mössbauer measurements with circularly polarized monochromatic radiation. The results show that most iron atoms are located on Ti or Al sites surrounded by eight Pd atoms while a small part occupies Pd sites. An external magnetic field applied to the sample induces an additional field acting on the $^{57}$Fe nucleus. The induced field direction is parallel to the external field and originates from conduction electron polarization. An upper limit for the static hyperfine field intensity was determined to be of the order of $10^{-3}$ T in zero applied field. The fluctuating hyperfine field of the order of a tenth of tesla is considered as a mechanism responsible for observed line broadening.

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11.5 On the Magnetism of Pd$_2$TiAl

by M.Biernacka$^1$, L.Dobrzyński$^{1,2}$, W.Mac$^3$, K.U.Neumann$^3$, K.Perzyńska$^1$, A.Stachow-Wójcik$^3$, K.Szymański$^1$, S.Tarasenko$^1$, J.Waliszewski$^1$, P.Zaleski$^1$, K.R.A.Ziebeck$^3$

The unusual magnetic properties of Pd$_2$TiAl and Pd$_2$TiAl:Fe are described. It is shown that the Pauli paramagnetism observed for the bulk material with a small addition of iron turns to a mixture of ferromagnetic and paramagnetic components when the sample is crushed to a powder. Annealing exerts different effects on the samples with and without iron. In all cases, however, it is observed that an increase of the ferromagnetic moment is accompanied by a decrease of the paramagnetic susceptibility.

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11.6 Pd$_2$TiAl:$^{57}$Fe Investigated by Monochromatic, Circularly Polarized Mössbauer Source
by K. Szymański$^1$, D. Satuła$^1$, L. Dobrzyński$^{1,2}$, K. U. Neumann$^3$, K. R. A. Ziebeck$^3$

The Heusler alloy Pd$_2$TiAl is claimed to exhibit magnetic order with a relatively high transition temperature and a small magnetic moment, of the order of a hundredth of Bohr magneton. $^{57}$Fe impurity was admixed into the alloy in order to carry out Mössbauer measurements with circularly polarized monochromatic radiation. The results show that most iron atoms are located on Ti or Al sites surrounded by eight Pd atoms while a small part occupies Pd sites. An external magnetic field applied to the sample induces an additional field acting on the $^{57}$Fe nucleus. The induced field direction is parallel to the external field and originates from conduction electron polarization. An upper limit for the static hyperfine field intensity was determined to be about $5 \times 10^{-2}$ T in zero applied field and room temperature. The fluctuating hyperfine field of the order of a tenth of tesla is considered as a mechanism responsible for the observed line broadening.

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11.7 Electron Density Distribution in GaN
by J. Waliszewski$^1$, T. Lippmann$^2$, L. Dobrzyński$^{1,4}$, S. Porowski$^3$, I. Jun$^5$

The semiconductors with wide energy gap raise particular interest as solid optical devices. The blue light-emitting diode (LED) of high brightness and long life time has already been realised using GaN compound [1]. Although the crystal structure of wurtzite GaN is known and there are some theoretical studies of valence charge density distribution [2,3], experimentally the bonding nature of GaN has not been widely studied.

Here we report the electron density distribution (EDD) in GaN as can be inferred from single crystal synchrotron radiation diffraction data. The details of the experiment can be found elsewhere in this Report. The single crystal was prepared in High Pressure Research Center UNIPRESS in Warsaw.

The Maximum Entropy Method [4], modified for phaseless problem solution [5], has been used. After data reduction process, 125 experimental structure factors have been taken into account during EDD calculations.

![Fig.1 The (-1 10)-plane electron density distribution in GaN. The contour ranges are from 0.0 to 370.25 with intervals of 5.70 eÅ$^{-3}$ and from 0.0 to 10.0 with intervals of 0.1 eÅ$^{-3}$ for Figs. (a) and (b) respectively. The two types of Ga-N bonds are visible.](image-url)
axis. The electron density in another three equivalent Ga-N bonds was found to be equal to 0.75 eÅ$^{-3}$. These values are consistent with the bond lengths, that in the investigated crystal are equal to about 1.96 Å and 1.94 Å for the weaker and stronger bond respectively. Our earlier investigations of EDD in powdered GaN [6] showed the antisymmetric distortion of electron density distribution near N atom. This was considered as antisymmetric thermal vibrations of N atom restricted by Ga-N bond. This observation is not confirmed by experiment reported here, which shows nearly spherical symmetry of EDD around Ga and N atoms and a small distortion with the electron density of the order of about 0.75 eÅ$^{-3}$ is seen in the vicinity of each N atom. The origin of this distortion remains to be cleared up.

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L. Dobrzyński
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L. Dobrzyński
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X- AND $\gamma$-RAYS: CREATION AND INTERACTION WITH MATTER
L. Dobrzyński
VIth Scientific Meeting of the Polish Nuclear Medicine Society, Łódź, Sept., 23-25, 1998

FOUNDATIONS OF THE RADIOPHYSICAL PROTECTION IN NUCLEAR MEDICINE
L. Dobrzyński
VIth Scientific Meeting of the Polish Nuclear Medicine Society, Łódź, Sept., 23-25, 1998

RECONSTRUCTION OF THE 3-DIMENSIONAL MOMENTUM DENSITY DISTRIBUTION FROM THE COMPTON PROFILES BY THE MAXIMUM ENTROPY METHOD. THE CASE OF CoSi$_2$
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L. Dobrzyński, Seminar of the Polish Physical Society, Cracow division, 19$^{th}$ of Nov., 1998, Kraków

X-rays and neutrons in metal studies
L. Dobrzyński, 4$^{th}$ of Oct., 1998, University of Białystok

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L. Dobrzyński, 3$^{rd}$ of Nov., 1998, University of Białystok,

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Služba Zdravie, Elektroradiologija Medyczna Nr 1(3), 29.01-2.02 (1998)

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Overview

In 1998 ZDAJ was mainly involved in the production of accelerators, simulators and tables ordered by the domestic market or destined for export. ZDAJ produced 28 POLKAM 15 therapeutic tables, 7 SIMAX X-ray simulators, 2 Coline soft accelerators and 2 Neptun accelerators. In addition, the 2D ALFARD treatment planning system was introduced for sale and five planning systems were installed in Polish hospitals. An order was received for the delivery of target chambers for the Isolde experiment carried out by CERN European Laboratory in Geneva.

It is noteworthy that we got the 1998 “Teraz Polska” prize, a reward for the best industrial product of the year based on Polish technical solutions, for the SACON cancer treatment therapeutic range. The SACON therapeutic range includes SIMAX diagnostic simulator with POLKAM 15 table, ALFARD treatment planning system, as well as Coline and Neptun accelerators.
12.1 Side-Coupled Linear Accelerator Structure
by J.Bąbik, K. Gryn, E. Jakubowska, W. Wolski

A side-cavity-coupled standing wave accelerating structure for a low energy S-band electron linac has been developed. The structure is 273,5 mm long and consists of 6 accelerating cavities, the first of which is designed to obtain the maximum phase acceptance and minimum energy spread. All cavities, including turning pins and internal cooling system, are jointed by 3-step brazing technique to assure vacuum tightness. The shunt impedance of the structure corresponds to 82,6 MΩ.

12.2 New Version of the SIMAX Simulator Software
by M. Górski

A new version of the software for SIMAX Simulator has been introduced. This software provides:
- improved procedures for "patient load in" and "patient load off",
- improved procedures for control of the image intensifier movements,
- extended information for the stuff about X-Ray graphy and scopy conditions,
- extended emergency procedures.

12.3 The Mamobus Project
by A.Kazimierski, Z.Sienkiewicz

A system of mobile mammography has been developed. The mammography unit MAMO will be located on the bus-chassis Jelcz. To provide full examination process the mammobus will be equipped with a film processor, negatoskop installed in the medical cabinet, washbasin and WC. For X-Ray protection the shielding calculation has been made.

12.4 New Design of the Shielded Door
by Z.Rusak, Z.Kuciak

New construction of the slight protected door has been worked out in 1998. The door does not demand any niche over the door frame. Hanging system is made of commercial elements. All movements are controlled by microprocessors. System is equipped with photoelectric and radar barriers as safety elements.

12.5 Solid Phantoms and Mechanical Device Set for Quality Test of Medical Accelerators
by E.Byrski A.PołaK

Two solid phantoms have been developed: one mounted directly at the accelerator’s head for checking photon beam parameters and another placed on the treatment coach for checking electron beam as well as radiation field symmetry and uniformity.

For the purpose of checking the mechanical and geometric parameters a set of devices was designed including mechanical pointer of isocenter location and the device for checking the location of side positioning lasers, in the range of ±20 cm in respect to the isocenter, as well as for controlling the telemeter and rotating screen.
PROFESSOR WŁODZIMIERZ KUSCH (1919-1998)

Professor Włodzimierz Kusch, born on June 29, 1919 in Vyaz'ma (Russia), died on April 8, 1998 in Warsaw.

He completed his studies at the Physics Faculty of Łódź University in 1949. Earlier, in 1947, W. Kusch started his work as assistant at the Chair of Experimental Physics of the Łódź University and then continued his academic career as assistant professor. In 1956 W. Kusch joined the Institute of Nuclear Research (INR) at Otwock – Świerk where he rose from assistant professor to associate professor in 1962. In the period 1957 – 1962 he headed the Nuclear Reaction Group and in the years 1963 – 1965 the Department of Nuclear Physics at Świerk. During the time 1956 – 1966 he took part in the designing and constructing of the rf ion source for a proton linear accelerator, a neutron generator and other technical equipment applied in experimental nuclear physics (among them in neutron activation methods).

In 1966 he joined the Department of Nuclear Reactions of the INR in Warsaw and in 1983 the same Department in the Institute for Nuclear Studies. He retired on October 1, 1985.

In 1957 he earned his doctorate at Łódź University with the PhD thesis „Measurements of absorption in graphite of electrons from muon decay”, and in 1972 in the Institute of Nuclear Research he completed his “habilitation” on the basis of „Nuclear levels structure studies of heavy elements near double magic nuclei Z=82, N=126 (neutron deficient isotopes of Pb and Bi)”.

In the period 1957 – 1959 and 1966 – 1971 he worked at the Joint Institute for Nuclear Research in Dubna (JINR). In 1964 he spent a few months at the Rutherford High Energy Laboratory. In 1975 – 1976 he became a visiting scientist at the Gesellschaft für Schwerionenforschung Darmstadt (GSI). Professor Kusch was the author of many scientific papers on nuclear physics published in international journals. He gave many contributions to different international conferences and symposia. They mainly concerned meson physics, fast neutron physics (neutron induced reactions, neutron scattering, neutron activation analyses), nuclear levels structure examined by means of Heavy Ions induced nuclear reactions.

After his retirement in 1985 he wrote many popularized scientific articles (published in scientific magazines) for the general public and popularized scientific text books about radioactivity and astrophysics.

Professor Kusch was a teacher for many generations of students at Łódź University, Warsaw University and Warsaw Technical University. He was a supervisor of many MSc theses. Prof. Kusch was active in international organizations such as the JINR in Dubna and the IAEA in Vienna. He was a member of many scientific councils and committees in Poland.

He was one of the founders of nuclear physics research in Poland, a distinguished academic teacher, a soldier of the Polish Army in September 1939 and at the war time a soldier of the Polish Underground Army (AK). In 1964 he was awarded the Knight’s Cross of the Polonia Restituta Order.

In the memory of his collaborators and colleagues he remains a man of great knowledge, a critical mind and extreme culture.

Marian Jaskóla
On May 4 1998 Józef Werle, professor emeritus at the Physics Department of Warsaw University and member of the Polish Academy of Sciences was killed in a car accident. In 1957 - 1969, he was employed in our Institute.

Józef Werle was born in 1923 in Margonin in the Chodzież district. During the German occupation, he worked as a locksmith in the Cegielski factory. In 1944 - 1950 in Poznań, he studied physics and also chemistry. He wrote his MA thesis in theoretical physics under the supervision of prof. Szczeniowski.

In 1950 prof. Leopold Infeld employed him in his Chair of Electrodynamics and Theory of Relativity. This initiated the lasting connection of Józef Werle with theoretical physics at Warsaw University. In 1954, he received his PhD degree (at that time called candidate of science degree) - his PhD thesis was supervised by prof. Leopold Infeld.

In 1956, he went for one year to Manchester, to prof. Rosenfeld. After the Stalin period of absolute isolation, this was the first visit abroad by a theoretical physicist from Poland. At that time it was possible entirely thanks to the successful efforts of prof. Leopold Infeld.

In 1960, he passed the Doctor of Science proceedings (habilitacja) at the Physics Department of Warsaw University. For reasons which now are beyond comprehension, this Doctor of Science degree was officially never approved.

His organizational and administrative activity was remarkable. It ranged from committees in the Polish Academy of Sciences, various scientific councils, editorial committees, up to involvement in construction work at Hoża Street.

With the passing of time, he was more and more interested in philosophical problems. No doubt, the circle of philosophers could profit from his sound approach of a physicist.

He had an open character and was able to tell point-blank what he thought. He had civil courage. The best of his character was demonstrated during the "March events" in 1968.

The death of Józef Werle is a heavy loss for the physics community in Warsaw and also in all of Poland.

Janusz Dąbrowski
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