ANNUAL REPORT

1997
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1997

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CONTENTS

I. GENERAL INFORMATION ....................................................... 7
1. MANAGEMENT OF THE INSTITUTE ....................................... 7
2. SCIENTIFIC COUNCIL ....................................................... 8
3. DEPARTMENTS OF THE INSTITUTE ..................................... 9
4. SCIENTIFIC STAFF OF THE INSTITUTE ............................... 10
5. VISITING SCIENTISTS .................................................... 12
6. GENERAL MONTHLY COLLOQUIA AT THE IPJ IN ŚWIERK .......... 14
7. THE XXV MAZURIAN LAKES SCHOOL OF PHYSICS .................. 15
8. GRANTS ................................................................. 17
9. SCIENTIFIC DEGREES ................................................... 20

II. REPORTS ON RESEARCH ..................................................... 21
1. DEPARTMENT OF NUCLEAR REACTIONS ............................... 21
2. DEPARTMENT OF NUCLEAR SPECTROSCOPY AND TECHNIQUE .... 39
3. DEPARTMENT OF NUCLEAR ELECTRONICS ........................... 73
4. DEPARTMENT OF RADIATION SHIELDING AND DOSIMETRY ....... 87
5. DEPARTMENT OF PLASMA PHYSICS AND TECHNOLOGY .......... 95
6. DEPARTMENT OF HIGH ENERGY PHYSICS ............................. 117
7. DEPARTMENT OF COSMIC RADIATION PHYSICS .................... 137
8. DEPARTMENT OF ATOMIC NUCLEUS THEORY ....................... 145
9. DEPARTMENT OF RADIATION DETECTORS .......................... 161
10. DEPARTMENT OF ACCELERATOR PHYSICS AND TECHNOLOGY ... 171
11. DEPARTMENT OF TRAINING AND CONSULTING .................. 189
12. ESTABLISHMENT FOR NUCLEAR EQUIPMENT .................... 195

III. OBITUARIES ............................................................ 197

IV. AUTHOR INDEX .......................................................... 199
FOREWORD

The year 1997 was marked for us by the hundredth birthday anniversary of professor Andrzej Soltan, the first director of our Institute and the pioneer of nuclear physics in Poland. It is also about hundred years since nuclear physics has begun with the discovery of Polonium and Radium by Maria Skłodowska-Curie and Pierre Curie. In honour of these anniversaries we have organized an Exhibition entitled "Nuclear Physics and Nuclear Technique in Service of Medicine - from Radium Needle to Accelerators".

The Exhibition was first shown in Świerk in June and then reopened in September at the Museum of Technique in Warsaw. Some 16000 viewers, mainly school pupils, have seen it there. Some lectures, radio broadcasts, popular level articles have supplemented this effort to bring the present day nuclear sciences closer to the general public (the Hugon Steinhaus award for Stanisław Mrówczyński in recognition of his popularization work should be noted here).

Andrzej Soltan, as I remember him, has never been fond of solemn celebrations. The best way to give tribute to his memory is to do a good piece of research. I take the liberty therefore to dedicate the scientific output of our Institute in the year 1997 to the memory of Andrzej Soltan.

We have published this year 227 articles in international journals, supplemented by 24 invited talks and 219 communications at conferences. The lists of these publications are given separately for each of the Research Departments throughout this Annual Report. They are preceded by articles on the work in progress and by the brief overviews written by the Department Heads. The Reader will have noticed the differences in style of these resumé's. Personally, I was struck by one thing which they seem to have in common, a rather unexpected one, I daresay: a note of optimism in describing how good the situation in their Departments is. In this spirit, let me select a few highlights of the past year.

The good progress in materials science, notably that of deep surface layers, can best be illustrated with the work of Lech Nowicki and Andrzej Turos on transformation of uranium lattice induced by water corrosion. The related work on modification of surface properties by hot and cold ion implantation develops well and we hope it will soon become one of the hallmarks of our Institute.

In nuclear physics the careful study of polarization phenomena in the decay of light, weekly bound nuclei has resulted in a series of elegant publications. This has brought the main author, Krzysztof Rusek, a measure of international recognition as well as the habilitation thesis (DSc). The continued work on the properties of the heaviest elements continues to bring Adam Sobiczewski prestigious international prizes: in 1997 he has been awarded the Alfred Jurzykowski prize in New York and the Flerov prize in Dubna (this one jointly with experimenters from GSI and Dubna). The good publication crop of the nuclear physics related sub-field of high energy atomic physics is also worth noting.

Marek Moszyński has scored again with his group's studies on new scintillation techniques. The highlight this time is the demonstration of advantages offered by avalanche diodes for the light output readout.

Our particle physicists continue their involvement in various international projects. This year they managed to give a noteworthy instrumental and technical input to some of these projects, notably on the Resistive Plate Chambers capable of operating in the high flux environment for the Compact Muon Solenoid (CMS) at the LHC in CERN and on the development of the WASA system at CELSIUS, Uppsala.
In plasma physics we welcomed last year the presumably highly consequential event: the decision to establish in Warsaw the International Centre of Dense Magnetized Plasma. This is one result of the increased international activities of our plasma group lead by Marek Sadowski and a measure of recognition the Polish plasma physics has gained in the international plasma community.

Our accelerator physics group and the production unit ZdAJ have embarked on a new project of a 15 MeV therapeutical accelerator. They also managed to export some high technology work to DESY (Hamburg) and to CERN.

As usual most of our scientific effort is based on various international collaborations. One visible result of these collaborations was the half a year visit at our Institute of Dieter Fick, the renown expert on polarization phenomena in nuclear physics as well as in applied research. This was made possible by the Alexander von Humboldt Honorary Fellowship awarded to professor Fick by the Foundation for Polish Science.

A regular, every second year accent on the international exchanges is the International Mazurian Lakes School of Physics. This has been organized in 1997 for the 25th time; it has had the symmetries in micro- and macro- worlds as the main subject.

Most of our very fruitful international collaborations are based on personal contacts rather than formal agreements. Occasionally, however, it is expedient to formalize these ties to gain favours with our and for our partner's sponsors. This year we welcomed such Agreements with the GSI Darmstadt, the University of Roma "Tor Vergata", the Razmadze Mathematical Institute in Georgia and Institute of Plasma Physics in Kharkov, Ukraine.

The program of PhD studies at our Institute is gaining momentum. The enrollment has nearly doubled last year.

Michał Nadachowski, the Deputy Director till the end of 1997, has resigned and left the Institute to fill the important position of the Editor-in-Chief in "Radioelektronik" monthly journal on electronics. It is my pleasant duty thank him warmly for his service for our Institute during the difficult year 1997. Equally warmly I welcome Marek Moszyński as his successor at the Deputy Director post.

With my thanks to all the Colleagues who have contributed to the Institute's activities in 1997 and with the best wishes for the year 1998.

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) 779-89-48
e-mail sujkowsk@iriss.cyf.gov.pl

Deputy Director, Research and Development
Assoc.Professor Michał NADACHOWSKI*
phone: (22) 779-91-34

Deputy Director, Economy and Marketing
Assoc.Professor Zbigniew WERNER
phone: (22) 779-91-62
e-mail p09zw@cx1.cyf.gov.pl

Scientific Secretary
Dr. Danuta CHMIELEWSKA
phone: (22) 779-82-88
e-mail danka@iriss.cyf.gov.pl

* since January 1, 1998:

Professor Marek Moszyński
phone: (22) 779-91-34
2. **SCIENTIFIC COUNCIL**

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

- **Chairman:**
  - Professor Ryszard Sosnowski
- **Deputy Chairmen:**
  - Professor Marek Moszyński
  - Dr Tadeusz Kozłowski
  - Professor Stanisław Kuliński

### Representatives of scientific staff:

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<thead>
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<th>Title/Position</th>
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<tr>
<td>Helena Białkowska</td>
<td>Assoc.Prof.</td>
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<tr>
<td>Stanisław Gębalski</td>
<td>MSc.</td>
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<td>Michał Gryziński</td>
<td>Assoc.Prof.</td>
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<td>Marian Jaskóła</td>
<td>Professor</td>
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<td>Rościsław Kaczarowski</td>
<td>Assoc.Prof.</td>
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<td>Jerzy Langner, Dr.</td>
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<td>Leszek Łukaszuk</td>
<td>Professor</td>
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<tr>
<td>Stanisław Mrówczyński</td>
<td>Assoc.Prof.</td>
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<td>Michał Nadachowski</td>
<td>Assoc.Prof.</td>
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### Representatives of technical personnel:

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<tr>
<td>Jerzy Bigolas, Eng.</td>
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<td>Genowefa Fąjkowska, Eng.</td>
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<td>Edward Fronczak, technician</td>
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<td>Andrzej Guliński, technician</td>
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<tr>
<td>Andrzej Hilger, MSc.</td>
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<td>Danuta Jastrzębska, economist</td>
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<td>Jan Kopeć, Eng.</td>
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<td>Jacek Pracz, MSc.</td>
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<td>Jacek Stanisławski, MSc.</td>
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<td>Iwona Zawrocka, MSc.</td>
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<td>Zbigniew Żero, Eng.</td>
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† deceased 22 June 1997
* since 23 September 1997

### External members:

- Andrzej Budzanowski, Professor
- Andrzej Czachor, Professor
- Tomasz Czosnyka, Assoc.Prof.
- Jan Kownacki, Professor
- Ewa Skrzypczak, Professor
- Józef Tołwiński, 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 - Professor Marek MOSZYŃSKI

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

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

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

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

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

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

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

In addition to the research departments:

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

Semi-independent:

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

and

- SERVICES AND TRANSPORT DIVISION (ZOIT)
  Director, Civ. Eng. Jerzy BABIK  tel. 779-82-03, Fax 048-22-779-82-44
4. SCIENTIFIC STAFF OF THE INSTITUTE

PROFESSORS

1. DĄBROWSKI Janusz  
   Theoretical Nuclear Physics  
2. DOBRZYŃSKI Ludwik  
   Solid State Physics  
3. INFELD Eryk  
   Plasma Physics  
4. JASKÓŁA Marian  
   Plasma Physics and Nonlinear Dynamics  
5. ŁUKASZUK Leszek  
   Low Energy Nuclear Physics  
6. MARCINKOWSKI Andrzej  
   Particle Physics  
7. MOSZYŃSKI Marek  
   Low Energy Nuclear Physics  
8. NASSALSKI Jan  
   Nuclear Electronics, Technical Physics  
9. Piekoszewski Jerzy  
   Particle Physics  
10. RATYŃSKI Wojciech  
    Solid State Physics  
11. SADOWSKI Marek  
    Low Energy Nuclear Physics  
12. SIEMIARCZUK Teodor  
    Plasma Physics  
13. SOBICZEWSKI Adam  
    Particle Physics and High Energy Nucl. Phys.  
14. SOSNOWSKI Ryszard  
    Theoretical Nuclear Physics  
15. STEPANIAK Joanna  
    Particle Physics, Member of the Polish Academy of Sciences  
16. SUJKOWSKI Ziemowid  
    High Energy Nuclear Physics  
17. SZEPTYCKA Maria  
    Low Energy Nuclear Physics  
18. TURKIEWICZ Jan  
    Particle Physics  
19. TUROS Andrzej  
    Nuclear Solid State Physics  
20. WILCZYŃSKI Janusz  
    Low Energy Nuclear Physics  
21. WYCECH Slawomir  
    Nuclear and Particle Physics

CONTRACT PROFESSORS

1. BŁOCKI Jan  
   Theoretical Nuclear Physics  
2. GAWIN Jerzy  
   Cosmic Ray Physics  
3. KULIŃSKI Stanisław  
   Accelerator Techniques and Physics  
4. MOROZ Zbigniew  
   Low Energy Nuclear Physics  
5. ŻUprański Paweł  
   High Energy Nuclear Physics

ASSOCIATE PROFESSORS and DSc

1. BIAŁKOWSKA Helena  
   High Energy Nuclear Physics  
2. DELOFF Andrzej  
   Particle Physics  
3. FIRKOWSKI Ryszard (**)  
   Cosmic Ray Physics  
4. GRYZIŃSKI Michał  
   Plasma Physics  
5. GUZIK Zbigniew  
   Plasma Physics and Atomic Physics  
6. JAGIELSKI Jacek  
   Nuclear Electronics  
7. KACZAROWSKI Rościsław  
   Stylet State Physics  
8. KIELSZNIA Robert (**)  
   Low Energy Nuclear Physics  
9. KULKA Zbigniew  
   Accelerator Techniques and Physics  
10. MRÓWCZYŃSKI Stanisław  
    Nuclear Electronics  
11. NADACHOWSKI Michał  
    Particle Physics  
12. PIOTROWSKI Antoni  
    Nuclear Electronics  
13. RONDIO Ewa  
    Technical Physics  
14. RONDIO Janusz  
    Particle Physics  
15. SANDACZ Andrzej  
    Low Energy Nuclear Physics
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<td>SKALSKI Janusz</td>
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<td>Applied Nuclear Physics</td>
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<td>Accelerator Techniques and Physics</td>
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<td>Theoretical Nuclear Physics</td>
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<td>Nuclear Electronics</td>
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<td>WRZECIONKO Jerzy</td>
<td>Theoretical Nuclear Physics</td>
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<td>27.</td>
<td>ZWIEGLIŃSKI Boguslaw</td>
<td>Nuclear Physics</td>
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**RESEARCH ASSOCIATES (PhD)**

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<td>1.</td>
<td>ADAMUS Marek (*)</td>
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<td>AUGUSTYNIAK Witold</td>
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<td>BARANOWSKI Jaroslaw</td>
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<td>BIAŁKOWSKI Jacek (*)</td>
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<td>CHARUŁA Jacek</td>
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<td>DUDA-GŁÓWACKA L.</td>
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<td>KACZANOWSKI Jan till Oct.31</td>
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<td>KOCIĘCEK-MECHANISZ K.</td>
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<td>NAWROT Adam</td>
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<td>PALACZ Marcin till Nov.31</td>
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<td>PATYK Zygmunt</td>
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<td>SZLEPER Michał (*)</td>
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<td>SYDŁOWSKI Adam</td>
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<td>61.</td>
<td>SYMAŃSKI Piotr</td>
<td></td>
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<tr>
<td>62.</td>
<td>SYMCEZYK Władysław</td>
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<td>63.</td>
<td>TRZCIŃSKI Andrzej</td>
<td></td>
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<tr>
<td>64.</td>
<td>WIŚLICKI Wojciech</td>
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<tr>
<td>65.</td>
<td>WOJTKOWSKA Jolanta</td>
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<td>66.</td>
<td>WOLSKI Dariusz</td>
<td></td>
</tr>
<tr>
<td>67.</td>
<td>ZABIEROWSKI Janusz</td>
<td></td>
</tr>
<tr>
<td>68.</td>
<td>ZALEWSKI Piotr</td>
<td></td>
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<tr>
<td>69.</td>
<td>ZYCHOR Izabella</td>
<td></td>
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</tbody>
</table>

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


### 5. VISITING SCIENTISTS

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Institution</th>
<th>Dates</th>
<th>Room</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sidorenko B.</td>
<td>Inst. on Nuclear Research, Kiev, Ukraine</td>
<td>Feb. 2 - 21</td>
<td>P-II</td>
</tr>
<tr>
<td>2</td>
<td>Gherghescu R.</td>
<td>Inst. of Atomic Physics, Bucharest, Romania</td>
<td>Feb. 17 - April 17</td>
<td>P-VIII</td>
</tr>
<tr>
<td>3</td>
<td>Trzaska W.</td>
<td>University of Jyväskylä, Finland</td>
<td>Feb. 21 - 27</td>
<td>P-I</td>
</tr>
<tr>
<td>4</td>
<td>Jorjadze G.</td>
<td>Razmadze Mathematical Inst., Tbilisi, Georgia</td>
<td>Feb. 23 - 25</td>
<td>P-VIII</td>
</tr>
<tr>
<td>5</td>
<td>Keeley N.</td>
<td>University of Manchester, U.K.</td>
<td>March 11 - Sept. 11</td>
<td>P-I</td>
</tr>
<tr>
<td>6</td>
<td>Rudchik A.</td>
<td>Inst. for Nuclear Research, Kiev, Ukraine</td>
<td>April 1 - 4</td>
<td>P-I</td>
</tr>
<tr>
<td>7</td>
<td>Ziman V.</td>
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<tr>
<td>8</td>
<td>Capdeville J.N.</td>
<td>University of Bordeaux, France</td>
<td>April 1 - 15</td>
<td>P-VII</td>
</tr>
<tr>
<td>9</td>
<td>Carrido F.</td>
<td>Centre de Spectrometrie de Masse et Spectrometrie Nucleaire, Orsay, France</td>
<td>April 28 - May 17</td>
<td>P-I</td>
</tr>
<tr>
<td>10</td>
<td>Zlomańczuk J.</td>
<td>University of Uppsala, Sweden</td>
<td>May 17 - 24</td>
<td>P-VI</td>
</tr>
<tr>
<td>11</td>
<td>Taran V.S.</td>
<td>Inst. of Plasma Physics, NSC, Kharkov, Ukraine</td>
<td>June 12 - 14</td>
<td>P-V</td>
</tr>
<tr>
<td>12</td>
<td>Lapshin V.I.</td>
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<td>Tereshin V.I.</td>
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<tr>
<td>14</td>
<td>Kelly H.</td>
<td>Inst. de Fisica del Plasma (INFiP), Buenos Aires, Argentyna</td>
<td>June 12 - 15</td>
<td>P-V</td>
</tr>
<tr>
<td>15</td>
<td>Pouzo J.</td>
<td>Instituto de Fisica Arroyo Seco, Tandil, Argentyna</td>
<td>June 12 - 15</td>
<td>P-V</td>
</tr>
<tr>
<td>16</td>
<td>Burke R.R.</td>
<td>Laboratoire d'Electrostatique, Grenoble, France</td>
<td>June 13 - 16</td>
<td>P-V</td>
</tr>
<tr>
<td>17</td>
<td>Sing Lee</td>
<td>Nanyang Technological University, Singapore</td>
<td>June 11 - 13</td>
<td>P-V</td>
</tr>
<tr>
<td>18</td>
<td>Si-Ze Yang</td>
<td>Inst. of Physics, Beijing, China</td>
<td>June 12 - 15</td>
<td>P-V</td>
</tr>
<tr>
<td>19</td>
<td>Kovol N.</td>
<td>High Current Engineering Inst., Russian Academy of Sciences, Tomsk, Russia</td>
<td>June 12 - 15</td>
<td>P-V</td>
</tr>
<tr>
<td>20</td>
<td>Remnev G.</td>
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<tr>
<td>21</td>
<td>Baronova E.O.</td>
<td>Inst. for Nuclear Fusion, RSC, Kurchatov Inst., Moscow, Russia</td>
<td>June 12 - 16</td>
<td>P-V</td>
</tr>
<tr>
<td>22</td>
<td>Vichrev V.</td>
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<tr>
<td>23</td>
<td>Rudchik A.</td>
<td>Inst. for Nuclear Research, Kiev, Ukraine</td>
<td>June 23 - 30</td>
<td>P-I</td>
</tr>
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<td>24</td>
<td>Czernijevskiy W.</td>
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</tr>
<tr>
<td>25</td>
<td>Barashenkov V.</td>
<td>Joint Inst. for Nuclear Research, Dubna, Russia</td>
<td>July 6 - 18</td>
<td>P-IV</td>
</tr>
<tr>
<td>26</td>
<td>Cugnon J.</td>
<td>University of Liege, Belgia</td>
<td>July 21 - 28</td>
<td>P-VIII</td>
</tr>
<tr>
<td>27</td>
<td>Byajima M.</td>
<td>Shinshu University, Matsumoto, Japan</td>
<td>Aug. 20 - Sept. 10</td>
<td>P-VIII</td>
</tr>
<tr>
<td>28</td>
<td>Rebel H.</td>
<td>Forschungszentrum Karlsruhe, Germany</td>
<td>Aug. 21 - 27</td>
<td>P-VII</td>
</tr>
<tr>
<td>29</td>
<td>Aleshin V.</td>
<td>Inst. for Nuclear Research, Kiev, Ukraine</td>
<td>Aug. 22 - 27</td>
<td>P-II</td>
</tr>
<tr>
<td>30</td>
<td>Jarzyński Ch.</td>
<td>Los Alamos, USA</td>
<td>Aug. 23 - Sept. 19</td>
<td>P-II</td>
</tr>
<tr>
<td>31</td>
<td>Meyers W.</td>
<td>Lawrence Berkeley Laboratory, USA</td>
<td>Aug. 24 - Sept. 13</td>
<td>P-II</td>
</tr>
<tr>
<td>32</td>
<td>Świątek W.</td>
<td>Lawrence Berkeley Laboratory, USA</td>
<td>Aug. 25 - Sept. 13</td>
<td>P-II</td>
</tr>
<tr>
<td>33</td>
<td>Ivaniuk F.</td>
<td>Inst. for Nuclear Research, Kiev, Ukraine</td>
<td>Aug. 26 - 27</td>
<td>P-II</td>
</tr>
<tr>
<td>34</td>
<td>Jorjadze G.</td>
<td>Rozmadze Mathematical Inst., Tbilisi, Georgia</td>
<td>Aug. 1 - Sept. 27</td>
<td>P-VIII</td>
</tr>
<tr>
<td>35</td>
<td>Makarenko V.</td>
<td>Kurchatov Ins. Atomic Energy, Moscow, Russia</td>
<td>Sept. 6 - 10</td>
<td>P-II</td>
</tr>
<tr>
<td>36</td>
<td>Muntian I</td>
<td>Inst. for Nuclear Research, Kiev, Ukraine</td>
<td>Sept. 8 - 11</td>
<td>P-VIII</td>
</tr>
<tr>
<td>37</td>
<td>Konoleva N.</td>
<td>Joint Inst. for Nuclear Research, Dubna, Russia</td>
<td>Sept. 8 - 28</td>
<td>P-VIII</td>
</tr>
<tr>
<td>38</td>
<td>Zlomańczuk J.</td>
<td>University of Uppsala, Sweden</td>
<td>Sept. 11</td>
<td>P-VI</td>
</tr>
<tr>
<td>39</td>
<td>Suzuki N.</td>
<td>Matsusho Gauken Junior College, Matsymoto, Japan</td>
<td>Sept. 22 - Oct. 6</td>
<td>P-VIII</td>
</tr>
<tr>
<td></td>
<td>Name</td>
<td>Institution</td>
<td>Dates</td>
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<tr>
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<td>Kretschmer R.</td>
<td>University of Siegen, Germany</td>
<td>Sept.24 - Oct.8</td>
<td>P-VIII</td>
</tr>
<tr>
<td>41</td>
<td>Haungs A.</td>
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<td>Sept.24 - Oct.1</td>
<td>P-VII</td>
</tr>
<tr>
<td>42</td>
<td>Popova L.</td>
<td>Inst. of Physics, Sofia, Bulgaria</td>
<td>Sept.29 - Oct.1</td>
<td>P-VII</td>
</tr>
<tr>
<td>43</td>
<td>Klamra W.</td>
<td>Royal Inst. of Technology, Stockholm, Sweden</td>
<td>Oct.6 - 19</td>
<td>P-III</td>
</tr>
<tr>
<td>44</td>
<td>Fick D.</td>
<td>Philipps Universität, Marburg, Germany</td>
<td>Oct.15 - Dec.31</td>
<td>P-I</td>
</tr>
<tr>
<td>45</td>
<td>Trzaska W.</td>
<td>University of Jyväskylä, Finland</td>
<td>Oct.28 - Nov.3</td>
<td>P-I</td>
</tr>
<tr>
<td>46</td>
<td>Piervushin V.</td>
<td>Joint Inst. for Nuclear Research, Dubna, Russia</td>
<td>Nov.2 - 4</td>
<td>P-VIII</td>
</tr>
<tr>
<td>47</td>
<td>Baronova E.O.</td>
<td>Inst. for Nuclear Fusion RSC, Kurchatov Inst.,</td>
<td>Nov.4 - 24</td>
<td>P-V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moscow, Russia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Chernikov N.</td>
<td>Joint Inst. for Nuclear Research, Dubna, Russia</td>
<td>Nov.16 - 26</td>
<td>P-VIII</td>
</tr>
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<td>Shevohina N.</td>
<td></td>
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</tr>
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<td>Rudchik A.</td>
<td>Inst. for Nuclear Research, Kiev, Ukraine</td>
<td>Nov.23 - Dec.8</td>
<td>P-I</td>
</tr>
<tr>
<td>51</td>
<td>Czernijevski W.</td>
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</tr>
<tr>
<td>52</td>
<td>Dahmen H.</td>
<td>University of Siegen, Germany</td>
<td>Nov.30 - Dec.6</td>
<td>P-VIII</td>
</tr>
<tr>
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<td>Sidorenko B.</td>
<td>Inst. for Nuclear Research, Kiev, Ukraine</td>
<td>Dec.1 - 14</td>
<td>P-II</td>
</tr>
<tr>
<td>54</td>
<td>Stenkin J.V.</td>
<td>Inst. for Nuclear Research, Moscow, Russia</td>
<td>Dec.2 - 20</td>
<td>P-VII</td>
</tr>
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<td>Tsyabuk A.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>Duraes F.</td>
<td>Inst. of Physics, University of Sao Paulo, Brasil</td>
<td>Dec.8 - 21</td>
<td>P-VIII</td>
</tr>
<tr>
<td>57</td>
<td>Navarra F.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>Piervushin V.</td>
<td>Joint Inst. for Nuclear Research, Dubna, Russia</td>
<td>Dec.18 - 19</td>
<td>P-VIII</td>
</tr>
</tbody>
</table>
6. GENERAL MONTHLY COLLOQUIA AT THE IPJ IN ŚWIERK

1. 27 January 1997
NUCLEON SPIN STRUCTURE
J. Nassalski (Dept. P-VI IPJ)

2. 24 February 1997
LINEAR SUPERCONDUCTING ELECTRON ACCELERATOR LISA AT FRASCATI
S. Kuliński (Dept. P-X IPJ)

3. 24 March 1997
PROTONS, QUARKS AND...
J. Zakrzewski (IFD-Warsaw University)

4. 28 April 1997
ACCELERATOR TECHNIQUES IN MATERIALS RESEARCH
A. Turos (Dept. P-I IPJ)

5. 5 May 1997
THE PROBLEMS OF QUANTIFICATION OF SCIENTIFIC MERITS IN LIGHT OF THE ASSESSMENT SYSTEM AT THE INSTITUTE OF CHEMISTRY OF THE WARSAW UNIVERSITY
L. Piela (Institute of Chemistry - Warsaw University)

6. 19 May 1997
FROM RADIAUM NEEDLE TO ACCELERATORS
B. Myslek-Laurikainen (Dept. P-II IPJ)

7. 20 October 1997
EDUCATIONAL PROGRAMME AT THE IPJ
L. Dobrzyński (Dept. of Training and Consulting)

8. 17 November 1997
THE COMPACT MUON SOLENOID (CMS) EXPERIMENT AT CERN
M. Górski (Dept. P-VI IPJ)

a) in Polish
7. THE XXV MAZURIAN LAKES SCHOOL OF PHYSICS

This International Conference, called a School for reasons of a certain precious tradition, is organized every second year. It is devoted to Nuclear Physics and related fields. This year the title was:

"TOPICS IN NUCLEAR PHYSICS, 1997 - Symmetries in micro- and macro-worlds"

It was organized at a summer resort Piaski on the Beldany Lake, August 2 - September 6, 1997.

The selection of topics for the 1997 School was focused on "Symmetries".

"...Considerations of symmetries of physical systems play a fundamental role in understanding the forces and constituents of our Universe. They start with an orientation on the strong belief in the PCT invariance, telling us that our world is symmetric under simultaneous space inversion, charge conjugation and reversal in time. However, breaking of these particular symmetries occurs already in the early history of the Universe, developing towards matter rather than to antimatter, to the left handed weak interaction, but with strict invariance for the strong, electromagnetic and gravitational forces, at least at the present level of our knowledge..." wrote prof. Heinigerd Rebel in his concluding remarks of the XXV Mazurian Lakes School.

There were 162 participants from 16 countries.

The list of lectures, seminars and short contributions selected for oral presentation is given below.

The panel discussion led by prof. Wolfram von Oertzen and Witek Nazarewicz on "Unconventional physics with big Ge arrays" has also to be mentioned.


The School, chaired by professor Ziemowid Sujkowski, was organized jointly by colleagues from various departments of our Institute and of the Warsaw University. There was also a special TEMPUS Workshop on Symmetries organized jointly with the School.

The main Sponsors were: The State Committee for Scientific Research and the National Energy Agency.

<table>
<thead>
<tr>
<th>Lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fritz Bosch (Darmstadt)</td>
</tr>
<tr>
<td>Peter Butler (Liverpool)</td>
</tr>
<tr>
<td>Jerzy Dudek (Strasbourg)</td>
</tr>
<tr>
<td>Hiroejuu Ejiri (Osaka)</td>
</tr>
<tr>
<td>Hans Enfling (Darmstadt)</td>
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<td>Amand Faessler (Tübingen)</td>
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<td>Mamoru Fujikawa (Osaka)</td>
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<td>John Hardy (Texas A&amp;M)</td>
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<td>Norbert Herrmann (Darmstadt)</td>
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<td>Zenon Janas (Warsaw-UW)</td>
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<td>Johan van Klinken (Groningen)</td>
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<td>Tadeusz Kozlowski (Świerk)</td>
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<td>Sven Kullander (Uppsala)</td>
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<td>Marek Kutschera (Cracow)</td>
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<td>Marek Kutschera (Cracow)</td>
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<td>Gines Martinez (Caen-GANIL)</td>
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<td>William Myers (Berkeley)</td>
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<td>Erich Ormand (LSU)</td>
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<td>Erich Ormand (LSU)</td>
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<td>Heinigerd Rebel (Karlsruhe)</td>
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<td>Olaf Scholten (Groningen)</td>
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<td>Carsten Schwarz (Darmstadt)</td>
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<td>Peter Senger (Darmstadt)</td>
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<tr>
<td>Ryszard Sosnowski (Warsaw-IPJ)</td>
</tr>
</tbody>
</table>
Bernard Tamain (Caen-LPC)
Hans Wilschut (Groningen)

Dynamical and statistical aspects in nucleus-nucleus collisions around the Fermi energy.
Nuclear bremsstrahlung in proton induced reactions at 190 MeV. (New results for p+p, p+d, p+A).

INVITED SEMINARS
Exclusive measurements on the excitation of baryonic resonances.
High precision spectroscopy of pionic and muonic X-rays to extract a new upper limit for the muon-neutrino mass.
Hypothesis of tachyonic neutrinos.
Opening the yrast spectroscopy of the $^{132}$Sn region.
Physics with polarized photons at SP-Ring8.
The plans for a superconducting electron linac and a Free-Electron Laser at Rossendorf.
Two photon interference in micro- and macro-systems.
Two center structure in light neutron rich nuclei.
Coulomb fission.
Antihydrogen as a testbench for the symmetry of the antiworld.
Supersymmetry and exotic nuclei.
An experiment to look for Jacobi-like superdeformed nuclei.

SHORT CONTRIBUTIONS
Muon signals of cosmic ray interactions.
Singularities of the S-matrix for a complex square well potential.
Meson exchange currents.
Nuclear Structure of $^{228}$Th.
New $\mu$-isomers from heavy ion fragmentation.
The $^{40}$Ca + $^{40}$Ca reaction at E = 35 MeV/nucleon binary collisions.
Warm nuclei: the transition from independent particle motion to collisional dominance.
Unexpected octupole properties of $^{186}$Nd.
Charged kaons in central $^{58}$Ni on $^{58}$Ni collisions at 2AGeV. Identification and studies.
Thermalisation and stopping in relativistic heavy ion collisions. Testing equilibration - colliding nuclei with different N/Z.
Observation of $\Delta + p^*$ decay in nuclear matter.

High resolution (d,t) study of $^{197}$Au and IBM supersymmetry.
Fock-space diagonalization of the state-dependent pairing Hamiltonian with the Woods-Saxon mean field.

Decay of hot nuclei produced in energetic antiproton annihilation.
Optimized expansion for the Nambu and Jona-Lasinio model.
Neutron emission from $^{197}$Ru produced via $^{12}$C + $^{16}$O reaction at 53 MeV.
New direct proton emitter $^{125}$Tm (T1/2 = 3.5 $\mu$s - shortest ever observed for proton radioactivity).
Analysis of pre-scission neutron multiplicities in terms of statistical model with Kramers dissipative fission.
Neutron and proton distribution in nuclei in relativistic mean field theory.
Nuclear friction deduced from mass equilibration measurements in strongly damped reactions.
8. GRANTS

LIST OF RESEARCH PROJECT (GRANTS) REALIZED IN 1997

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

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

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

4. NONEQUILIBRUM QUANTUM FIELDS
   Principal Investigator: Assoc. Prof. St. Mróweczyński
   Grant No. 2P 03B19509

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

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

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

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

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

10. 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

11. INTERACTION OF STRANGE PARTICLES WITH ATOMIC NUCLEI
    Principal Investigator: Professor J. Dąbrowski
    Grant No. 2P 03B04812
12. MUONS IN COSMIC RAY SHOWERS IN THE KASKADE EXPERIMENT  
Principal Investigator: Dr. J.Zabierowski  
Grant No. 2P 03B16012

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

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

15. 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

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

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

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

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

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

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

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

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

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

5. 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.

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

7. DESIGN AND CONSTRUCTION OF A ROOM TEMPERATURE MODEL OF A NEW SHAPE
   TESLA ACCELERATING SUPER STRUCTURE
   Principal Investigator: Professor S.Kuliński
   Contract No 1957833/0.000

8. DESIGN AND CONSTRUCTION OF PULSED MICROWAVE POWER GENERATOR
   Principal Investigator: MSc. J.Bigolas
   Italy, Commision No PO/1820
9. **SCIENTIFIC DEGREES**

**PhD theses**

1. **MARCIN PALACZ, DEPARTMENT P-II**  
   Study of nuclear structure in the vicinity of doubly magic neutron deficient nuclei and of the quasi-continuum radiation in $^{143}$Eu.

2. **SLAWOMIR KWIATKOWSKI, DEPARTMENT P-I**  
   Study of thermal stability of the metal - $A^{III}B^V$ compound semiconductor system.

**DSc theses**

1. **JACEK JAGIELSKI (ITME)**  
   Ion beam induced amorphisation of metals.

2. **JANUSZ BRAZIEWICZ (WSP - KIELCE)**  
   Atomic L-subshell ionisation by light ion bombardment.
II. REPORTS ON RESEARCH

1. DEPARTMENT OF NUCLEAR REACTIONS

Head of Department: Dr. Krzysztof Rusek
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Overview

During the last year our activities were spread over the three major domains: nuclear, atomic and material physics.

The nuclear physics experimental programme covered a broad range of nuclear reactions induced by light and heavy ions. New experiments were performed at the compact C-30 cyclotron at Świerk, at University of Jyväskylä, GSI Darmstadt, LN Saturne. Prospects for future experiments on nucleon structure at Forschungszentrum Jülich were open. The collaboration with INR Kiev was tightened and work was done in order to prepare experiments at the C-200 heavy ion cyclotron in Warsaw. An effort to install the ion guide isotope separator on line (IGISOL) at the C-200 cyclotron has also to be mentioned. A half a year stay of Dr. Nicholas Keeley in the Department, who received The Royal Society/Polish Academy of Science grant, resulted in many interesting results on breakup of light nuclei. Details can be found in the short abstracts presented in this report.

As far as atomic physics is concerned, the activity of a research group lead by Prof. Marian Jaskóla yielded various new results. The experiments were performed at the University of Erlangen, in close collaboration with the Pedagogical University in Kielce and the University of Basel. Fast neutrons generated in the $^3$H(d,n)$^4$He reaction induced by the 2 MeV deuteron beam from the Van der Graaff accelerator at the Department were used to calibrate solid-state-nuclear-track detectors.

This was a very good year for material physics research. Jan Kaczanowski and Sławomir Kwiatkowski received Ph.D. degrees based on dissertation research performed in the material physics research programme, while Paweł Kołodziej completed his M.Sc. thesis. In collaboration with the Institute of Electronic Materials Technology in Warsaw, Research Center Karlsruhe, University of Jena and CSNSM Orsay many results were obtained. Lech Nowicki and Prof. Andrzej Turos were awarded by the Director of the IPJ prizes for their scientific activities in 1997.

Last but not least, we had the honour to host Prof. Dietrich Fick from Philips University of Marburg, Germany. He was awarded the first Alexander von Humboldt Honorary Fellowship by Foundation for Polish Science.
1.1 Nucleon Scattering to the Continuum in Terms of the Two-Fermion Theory of Multistep Direct Reactions
by A. Marcinkowski, B. Mariański, Z. Moroz and J. Wojtkowska

Cross sections of the \((p, xp)\) reaction on \(^{93}\text{Nb}\) were measured at an incident energy of 26.5 MeV and analysed together with existing data for nucleon scattering between 18 MeV and 26 MeV. This experiment was performed at the compact C-30 cyclotron of SINS in Świerk. The aim of this work was to remove the drawback in consistent description of different nucleon reaction channels [1] by improving the calculations of the multistep direct reaction cross sections. Actually the \((p, p')\) and \((n, n')\) inclusive emission spectra and angular distributions have been described consistently using the two-fermion theory of Feshbach, Kerman and Koonin for multistep direct reactions [2]. In these calculations adequate normalisation of reaction amplitude in the DWUCK-4 code and improved averaging of the DWBA angular distributions over final shell model \(lplh\) configurations of the same orbital angular momentum transfer were applied. The parity distribution of the density of \(lplh\) states was allowed for. The results of calculations agree with the experimental data (e.g. see fig.1). This result confirms the prediction of our earlier analyses that the strength of the effective interaction as determined from the folding model does not vary with reaction channel provided all mechanisms of preequilibrium reactions, namely the multistep compound (MSC), the multistep direct (MSD) and the direct collective reactions (DCR) are allowed for. This conclusion is different from results of previous reports in which the effective interaction strengths were adjusted to fit separately the neutron scattering, the proton scattering and the charge-exchange reaction data.


1.2 Excitation Function of the 9.3 MeV \(T=0\) State Measured for the \(^{27}\text{Al}(p, \alpha)\text{Mg}\) Reaction
by J. Rondio, S. V. Khlebnikov\(^{1}\), M. Mutterer\(^{2}\), W. H. Trzaska\(^{3}\) and G. P. Tiourine\(^{1}\)

GDR excited in a doorway state of the \(^{27}\text{Al}(p, \alpha)\text{Mg}\) reaction can deexcite by \(\alpha\) emission only in two cases: when the state in residual nucleus \(^{24}\text{Mg}\) has isospin \(T=1\) or when GDR is built on a state in compound nucleus \(^{28}\text{Si}\) with isospin \(T=1\). In our previous study [1] we have measured the excitation function to two unresolved states: one at an excitation energy of 9.5 MeV and \(T=1\) and the other at 9.3 MeV and \(T=0\). It is meaningfull to know the excitation functions of these two states separately for a proper interpretation of the investigated process.
To resolve the above mentioned closely lying states a thinner aluminium target and smaller solid angles were used. To compensate for a loss of efficiency more detectors were placed in the scattering chamber. The obtained results are presented in figure 1. One can see that the excitation function of the 9.3 MeV T=0 state reproduces the shape of the GDR excited in compound nucleus $^{28}$Si. This indicates that GDR is built on a 9.4 MeV T=1 state in the compound nucleus and, to obey the isospin selection rules, its isospin has to be coupled with that of GDR to T=0. This result confirms our suggestion that collective states, such as GDR, excited in doorway state, participate in multistep compound processes.

Fig.1 Excitation function of GDR excited in the $^{28}$Si nucleus. The points represent cross sections of the 9.3 MeV T=0 state measured for the $^{27}$Al(p,a)$^{26}$Mg reaction.

1.3 Study of the (d,$^6$Li) and (d,$^7$Li) Reactions on the $^{12}$C at 50 MeV

The energy and angular distributions of the $^{12}$C(d,$^6$Li)$^7$Be and $^{12}$C(d,$^7$Li)$^7$Be reactions were measured at a deuteron energy of 50 MeV for the ground state of $^6$Li and for the ground and first excited states of $^7$Li and $^7$Be nuclei. The energy resolution of about 1% (mainly due to the energy spread of the beam) does not allow the $^7$Li and $^7$Be ground and first excited states to be resolved. Due to those facts the measured cross sections contain the sums of contributions from the transitions to the ground and first excited states of $^7$Li and $^7$Be nuclei. The experimental data were analysed in the framework of coupled reaction channels (CRC) model using the computer code FRESCO. The cluster spectroscopic amplitudes needed in the CRC analysis were calculated with a translationary invariant shell model. The one- and two step cluster transfers (Fig. 1) were taken into account in the CRC calculations. The parameters of Woods-Saxon optical potentials for the entrance, exit and intermediate channels were obtained by fitting the $^{12}$C + d, $^3$B + $^3$He, $^6$Be + $^6$Li and $^7$Be + $^7$Li data known from the literature.

Fig.1 Diagrams of one- and two-step transfers for the $^{12}$C(d,$^7$Li)$^7$Be and $^{12}$C(d,$^7$Li)$^7$Be reactions.
The data of the $^{12}$C($d,^7Li)^7$Be reaction at an energy of 50 MeV, 52 MeV and 54 MeV were included in the CRC analysis as one of the important intermediate channel among different two-step processes leading to the $^7$Li + $^7$Be exit channel. It was found that small differences between most important $^5$He - cluster and n + α transfer at forward hemisphere and $^7$Li - cluster and p + α transfers at backward hemisphere are due to Coulomb effects. A good agreement between measured and calculated cross section is shown in Fig. 2 together with the individual contributions to the cross section (the dashed lines with the names in brackets < >). The solid line shows a coherent sum of the individual contributions.

Fig. 2 Angular distribution of the $^{12}$C($d,^7Li)^7$Be reaction for the transition to the ground and first excited states of the $^7$Li and $^7$Be nuclei.

1.4 **Mechanism of the $^{12}$C($^{14}$N,$^{13}$C)$^{13}$N Reaction at 116 MeV**


The angular distribution for the $^{12}$C($^{14}$N,$^{13}$C)$^{13}$N reaction at an incident ion energy 116 MeV, measured earlier, were analysed using the coupled reaction channels (CRC) model. Both p and sequential (d + n) - transfer processes were included in the coupled reaction channels scheme. In Fig. 1 the measured angular distribution is compared with the CRC calculations. As can be seen the p -transfer is dominant in the $^{12}$C($^{14}$N,$^{13}$C)$^{13}$N reaction and the two - step d + n - transfer is unimportant.

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1.5 Breakup of Light Projectiles Near the Coulomb Barrier
by N. Keeley and K. Rusek

Recent optical model analysis of $^6$Li + $^{208}$Pb elastic scattering data at near barrier energies found a marked difference in the energy dependence of the surface strength of the real part of the best fit optical model potentials for the two isotopes [1]. This effect is studied by a set of continuum - discretised - coupled - channel (CDCC) calculations with included couplings to the non-resonant continuum of $\alpha + t$ ($\alpha + d$) cluster states above the respective breakup thresholds for $^7$Li ($^6$Li).

The calculated total $^6$Li breakup cross sections are somewhat smaller than the measured $\alpha$ emission cross section of Speth et al. [2] (see the figure). However, the measured $\alpha$ cross sections were not taken in coincidence with the deuterons and hence may include $\alpha$ - particles from sources other than breakup. Thus, the measurements represent an upper limit for the total breakup cross section. Based on this, we believe that our model space provides a reasonable description of the total breakup cross section, at least in the near-barrier region.

From the calculations total (bare plus polarisation) effective potentials are derived, whose surface strengths show the same qualitative behaviour as a function of energy as the empirical optical model potentials obtained in the original analysis [1]. The calculations show that the real parts of the $^7$Li polarisation potentials at energies near the Coulomb barrier are less repulsive than those for $^6$Li. This is mainly because of the higher breakup threshold of $^7$Li. This explains why the two isotopes both show similar behaviour at higher energy, where the difference in breakup thresholds becomes less important, while in the vicinity of the Coulomb barrier they show marked difference.

Optical model analyses of near-barrier $^7$Li + $^{208}$Pb elastic scattering data found a peak in the energy dependence of the strength of the imaginary part of the optical model potential at the strong absorption radius. It was speculated [3] that this might be due to the polarization potentials produced by couplings to the $^{208}$Pb($^7$Li,$^6$Li)$^{209}$Pb transfer channels. A series of coupled-reaction-channel calculations is carried out in order to show explicitly that such couplings do indeed produce polarisation potentials with the same energy dependence as the observed for the empirical optical model potentials.

A test CDCC calculations are performed for a near barrier scattering of $^9$Be from several targets. The $^3$He + $\alpha$ cluster model of $^9$Be is assumed providing a good description of the measured values of the ground-state spectroscopic quadrupole moment and reduced transition probabilities $\text{B}(E2; g.s. \rightarrow 5/2^-)$ and $\text{B}(E2; g.s. \rightarrow 7/2^-)$. In the calculations couplings to the two resonant states of $^9$Be at 2.43 (5/2) and 6.76 (7/2) MeV are included. The breakup threshold for $^3$He + $\alpha$ is 2.47 MeV, thus the 5/2$^-$ resonance is bound with respect to this threshold and is treated as such while the 7/2$^-$ resonance is treated as an unbound bin of width $\Delta E = 3$ MeV.

We are able to obtain good agreement with the optical model fits to elastic scattering data, provided that the real and imaginary depths of the input $^3$He-target and $\alpha$-target empirical potentials are substantially reduced. This is probably due to the omission of any continuum cluster states, which we expect to produce a positive real polarisation potential similar to those for $^6$Li and $^7$Li. The angular distribution predictions for breakup via the 5/2$^-$ resonance indicate that the Coulomb breakup completely dominates at forward angles near the barrier, thus providing a good regime for studies of astrophysical interest.

1.6 The Warsaw Ion Guide Isotope Separator on Line (IGISOL)
by A. Korman, A. Wojtasiewicz

In 1997 we continued our efforts to install the isotope separator on line of the Warsaw 200 cm heavy ion cyclotron. During the year we improved the main experimental parameters of the separator in off-line regime. A special attention was paid to ion optics corrections and mass resolution of the separator. New elements of the IGISOL system, as a high efficiency pumping installation based on the 8000 m³/h Root's pumps, the He gas supply system, target chamber, high voltage supply, general control system were designed and made. We plan mounting and testing all the elements in near future to get a full operation stage of the facility in 1998.

1) Institute of Experimental Physics, Warsaw University

1.7 Temperature Measurements in Au + Au Collisions at Relativistic Energies*
by A. Trzcinski and B. Zwieglinski
The ALADIN Collaboration at GSI - Darmstadt

The simultaneous measurements of the temperature and the excitation energy for excited projectile spectators in $^{197}$Au + $^{197}$Au collisions at 600 MeV/u (experiment SI14) resulted in a caloric curve for finite nuclear systems [1]. The temperature determination was based in [1] on the double ratio $(^3\text{He}/^4\text{He})/(^6\text{Li}/^7\text{Li})$ of isotope yields (He - Li thermometer). The curve consists of the liquid and vapor branches, where temperature rises with increasing excitation energy, separated by a phase-coexistence region of nearly constant temperature $T = 5$ MeV - a behavior strikingly reminiscent of macroscopic Van-der-Walls liquids. These results and, in particular, the apparent rise of the breakup temperature at excitation energies exceeding 10 MeV/u have triggered a widespread discussion which addressed both methodological aspects and questions of interpretation.

![Fig.1 Temperatures $T_{\text{HeLi}}$, $T_{\text{HeHe}}$, and $T_{\text{LiLi}}$ in the residue excitation energy range from about 0 ($Z_{\text{bound}} = 79$) to 15 MeV/u ($Z_{\text{bound}} = 0$).](image)

![Fig.2 Energy spectra of light charged particles measured at $\theta_{\text{lab}} = 150^\circ$ (black dots). Open dots are the statistical model calculations.](image)

Our contribution to this discussion was a dedicated experiment SI17, run in 1995, aimed at comparing the above $T_{\text{HeLi}}$ with temperatures for target spectators obtained using alternative methods. The experimental set-up incorporated three multidetector hodoscopes for correlated light - particle detection, consisting of a total of 216 Si - Cs(Tl) telescopes. In addition, seven four-element telescopes, placed at selected angles, were used to measure the isotopic yields of light charged particles ($Z<2$) and fragments ($Z\geq3$). This system supplied information on hydrogen isotopes, unavailable in [1], because of the detection threshold of the ionization chamber MUSIC-III at $Z=2$. The hodoscope data were used to infer temperatures from the population ratio of pairs of widely separated states in $^5\text{Li}$, $^7\text{He}$ and $^7\text{Be}$. On the other hand, with the aid of telescopes emission temperatures were deduced from the double ratios of yields measured for pairs of neighboring H, He and Li isotopes. Collisions of Au + Au were studied in two centrality domains. Peripheral to midcentral collisions were selected...
DEPARTMENT OF NUCLEAR REACTIONS

at 1 GeV/u, using the quantity \( Z_{\text{baml}} \) of the coincident projectile decay, measured with the TOF wall of the ALADIN spectrometer. Fig. 1 compares the temperatures given by three different isotope - ratio thermometers in the \( Z_{\text{baml}} \) range corresponding, as in [1], to the excitation energy range 0 - 15 MeV/u of the target residue [2]. The results agree rather well, with \( T_{\text{Hedt}} \) lying systematically somewhat lower than the other two temperatures.

A striking feature of the light - particle spectra (Fig. 2) is the preequilibrium component as exemplified by the difference between the experimental (black dots) and the statistical - model predicted (open points) spectra. Its magnitude increases systematically with decreasing particle mass (\( A=3 \) not shown) and excitation energy of the residue (decreasing \( Z_{\text{baml}} \)). Part of the results pertaining to central collisions in Si17 is presented in [3].

1.8 Study of Pre-breakup Light Particle Emission in HI Collisions at Relativistic Energies

by A.Bieńkowski, W.F.J.Müller\(^1\), A.Trzciński and B.Zwieglinski for the ALADIN Collaboration at GSI - Darmstadt

Light charged particle (\( Z = 1,2 \)) spectra emitted in peripheral to semicentral Au + Au collisions at 1 GeV/u (see [1] and the preceding research note) revealed significant components emitted prior to attainment of statistical equilibrium by the target residue, the stage at which multifragmentation most probably occurs. Since these serve for diagnostic purposes in all thermometers in current use, a due account needs to be taken of the contributions coming from each of the pre-breakup and evaporative stages of the residue disassembly. This goal imposes stringent requirements on the instrumentation of low energy thresholds, wide dynamic range and good energy resolution.

The short - term program of the ALADIN Collaboration will address the spectra of light charged particles in the joint experiment with the French laboratories, using INDRA multidetector - the most advanced of the presently existing instruments possessing multiparticle detection capability. To this end target residue disassembly products will be studied in \(^{12}\text{C} + ^{197}\text{Au} \) collisions at 1 and 2 GeV/u. The experiment is foreseen for late 1998.

The long - term program focuses on neutrons emitted by the target residue in peripheral to semicentral \(^{197}\text{Au} + ^{197}\text{Au} \) collisions at 600 and 1000 MeV/u. Excitation energy will be tagged with the aid of \( Z_{\text{baml}} \) of the coincident projectile fragments with the ALADIN forward spectrometer. A Monte - Carlo program MSX was written [2] to perform a comparative study of conceivable neutron detecting systems: a large - volume Gd - loaded liquid scintillation detector ("Neutron - Ball") with the multidetector DEMON consisting of 96 separate organic liquid scintillators.

An upgrade of the detection capability of the ionization chamber MUSIC - III is underway. This includes construction and installation of the new proportional counters and the associated electronic chains. An application of the current sensitive preamplifiers will permit to feed signals from the counters directly to flash - ADC's, eliminating the shaping amplifiers, thus simplifying considerably the electronic system. The gained simplicity will permit to increase significantly the number of cathode pads, thereby leading to increased accuracy of the \( y \)-coordinate determination of the detected fragments. Tests of several types of current - feedback operational amplifiers, available on the market, will be performed to select for the preamplifiers the optimum one from the point of view of the forseen application.

\(^1\) GSI - Darmstadt

* This work was supported in part by the Scientific and Technological Cooperation Joint Project with Germany for years 1997 - 2000 ("Elementary Reactions", FKZ - Nr: POL - 196 - 96)
1.9  Mass Distribution of the N*(1/2,1/2)+ Resonance at about 1400 MeV from Alpha - Proton Scattering
by H.P. Morsch\textsuperscript{1)}, P. Żuprański

Data on N* excitation in α-p scattering at E\textsubscript{a}=4.2 GeV were reanalysed assuming projectile and target excitation and their interference. It has been found that the description of the spectrum is sensitive to details of the N* mass distribution around 1400 MeV. Using P\textsubscript{\textsigma} cross sections of elastic T\textsubscript{C}-N scattering, which show a resonance at about 1440 MeV (Roper resonance), a quantitative description of the data is not obtained. However, the data are well described by a 2π - threshold modified Breit - Wigner shape (with M=1380±20 MeV and \Gamma=230±30 MeV) consistent with π-N \to 2π(s)-N (with the same quantum numbers as α-p excitation). Pole positions and speed plot analyses of π-N scattering give quite similar resonance parameters.

Evidently, the N* structures observed in α-p and π-N are not identical. The differences can be explained by a different isospin selectivity in the two systems. This can be tested in exclusive α-p experiments which should exhibit a N* decay pattern different from π-N.

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* Submitted for publication in Zeitschrift für Physik C

1.10  Analysing Powers for Inclusive Reactions of Deuterons on Carbon at Energies between 0.75 and 1.6 GeV
by P. Żuprański

Using the polarized deuteron beam of Laboratoire National Saturne a new calibration of the POMME polarimeter for deuteron energies 0.175 - 1.6 GeV has been carried out. The present calibration gives, together with previous ones, a complete set of vector analysing powers in the energy range 0.175 - 1.8 GeV. The results have been described in terms of two sets of empirical parameters which give the vector analysing powers for deuteron energies from 0.175 GeV to 0.571 GeV and from 0.7 GeV to 1.8 GeV, respectively \cite{1}.

*) Accepted for publication in Nucl. Inst. and Meth.

\cite{1} V.P. Ladygin, E. Tomasi-Gustafsson, …, P. Żuprański, Nucl. Instr. Meth., accepted for publication

1.11  Multiple Ionization of M-, N-, and O-shell by Energetic Heavy Ions
by T. Czyżewski, M. Jaskóla, A. Korman, M. Pajek\textsuperscript{1)}, D. Banaś\textsuperscript{1)}, J. Braziewicz\textsuperscript{1)}, W. Kretschmer\textsuperscript{2)}, J. Semaniak\textsuperscript{3)} and D. Trautmann\textsuperscript{1)}

In collisions of energetic heavy ions with atoms multiple vacancy configurations are formed. For heavy ions with energies in the MeV range this effect is particularly pronounced for outer M-, N- and O-shells, for which a condition of equal electron and projectile velocities is better fulfilled. Multiple ionization causes energy shifts and line broadening of K- and L-x-rays emitted in such collisions due to a presence of additional spectator vacancies in outer shells. The multiple ionization is usually studied by means of high-resolution x-ray spectroscopy using crystal spectrometers. In such experiments x-ray satellite structure caused by the multiple ionization is measured, giving information on the ionization probabilities for different shells. In the present study we demonstrate that almost the same information on the ionization probabilities in outer M-, N- and O-shell can be obtained performing a careful analysis of the L-x-ray line energy shifts and widths measured with commonly used semiconductor x-ray detectors, having energy resolution typically in the range of 200 eV.

Taking into account a binomial character of intensities distribution of x-ray satellites and their Gaussian energy spreads in semiconductor detector, the energy shift of the x-ray line reads:

\[ \Delta E = \Sigma \frac{\Gamma}{\Gamma} \delta E \]
where \( n \) is a number of electrons in \( i=M, N, O \)-shell, \( p_i \) is a ionization probability, and \( \delta E_i \) stands for the energy shift per electron. Within this formalism we found additionally, that the shifted and broadened x-ray peaks still have Gaussian shapes with the widths given by the following formula:

\[
w = \left[ w^2_G + 8 \ln 2 \Sigma n \cdot p_i (1 - p_i) (\delta E_i)^2 \right]^{1/2}
\]

where \( w_G \) denotes a width of the Gaussian curve not influenced by the multiple ionization effects. This finding allows to perform a very accurate fitting of the measured L-x-ray spectra due to a substantially reduced number of free parameters, being for instance only \( p_M, p_N, w_G \) and peak areas for the Ly group consisting of six dominating transitions (fig. 1). The analysis of the L-x-ray spectra performed in this way yields the ionization probabilities \( p_M, p_N, \) and \( p_0 \), giving thus a full description of the multiple ionization in \( M-, N-, \) and \( O- \) shells [1].

![Diagram](image1)

**Fig. 1** a) Calculated energy shift and line broadening for \( L_{\gamma 1} \) transition.

![Diagram](image2)

**Fig. 1** b) Resolved L transitions in Au for 35.2 MeV \( O^{16+} \) ions. Vertical lines shown the energy shifts.


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### 1.12 Isotopic Effect in M-shell Ionization by Slow H and He Ions

by T. Czyżewski, L. Glowacka, M. Jaskóla, D. Banaś, J. Braziewicz, G. Lapicki, M. Pajek and D. Trautmann

It is well proved experimentally that the existing theories of inner-shell ionization by charged particles generally fail in a good description of the data for very low energies. In this regime a realistic description of the projectile trajectory and perturbation of the electronic wave function, due to a relatively long collision time and small impact parameters dominating the ionization process, have to be accounted for. For these reasons, investigation of the ionization process using projectiles of different isotopes, having the same nuclear charge, gives a possibility to study discussed effects in a much more detailed way. Substantial discrepancies were reported earlier for the M-shell ionization, both by light [1] and heavy ion [2] impact. We chose light ions because their isotopes have the largest mass ratio, e.g. a factor of two for \( ^2H \) and \( ^1H \), to display the isotopic effect.

The isotopic effect in the ionization of the M-shell by slow hydrogen and helium ions, down to an energy of 100 keV/amu, was studied by measuring the M-x-ray production cross sections in selected heavy atoms by \( ^1H, ~^2H, ~^3He \) and \( ^4He \) ions. The measured M-x-ray cross sections ratios, \( \sigma(^2H)/\sigma(^1H) \) and \( \sigma(^4He)/\sigma(^2He) \) (fig.1), which give a magnitude of the isotopic effect, were compared with the predictions of the existing theoretical approaches describing direct ionization process, namely the first Born approximation (PWBA), the
ECPSSR theory [3] and the semiclassical approximation (SCA). A contribution of the electron capture to M-shell vacancy production was found to be small for light ions studied. The role of approximations used in these approaches to account for the projectile deflection and a change of electron binding energy, as well as electronic wave functions effects, are discussed. It is shown that the magnitude of isotopic effect is very well reproduced by the ECPSSR theory, in spite of a difference by a factor of three between the predicted and measured absolute cross sections at the lowest energy of 100 keV/amu. Possible explanation and consequences of this observation are discussed by contrasting the predictions of the ECPSSR theory with the SCA calculations.

![Fig. 1: M-x-ray cross sections ratios 
$\sigma$(2H)/$\sigma$(1H) and 
$\sigma$(4He)/$\sigma$(3He) for Au versus projectile energy per mass. Theoretical predictions are shown by solid line.]


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1.13 Lattice Location of Oxygen Atoms in UO$_2$ Single Crystals Leached in Water

by L. Nowicki, A. Turos, F. Garrido$^1$, C. Choffel$^1$, L. Thome$^1$, J. Jagielski$^2$

Uranium dioxide is used as a fuel in the majority of nuclear power stations. The burnt out fuel management is one of the most important technical and ecological problems limiting the further development of nuclear energy plants. In the direct storage scenario the burnt out fuel is stored in safe, deep geological repositories. An accidental contact with water can produce leaching of radioactive material and its transport to the geosphere via the groundwater. Thus, to obtain more basic data on the phase relationship and structural transformations of UO$_2$ upon leaching the backscattering/channelling studies were carried out. Previous works showed that the leaching of UO$_2$ single crystals in water of temperature over 160°C and containing dissolved oxygen produces substantial changes in the surface region of the crystals. These effects are due to the formation of higher oxides at the surface, characterized usually by a O/U = 2.3 ratio. The incorporation of oxygen into a UO$_2$ cubic elementary cell (fluorite structure) induces modifications of the crystalline structure [1,2]. The aim of this work was to study the changes in the lattice location of oxygen atoms induced by the wet oxidation of UO$_2$. The samples were (001)-oriented UO$_2$ single crystals. Leaching was made in water of pH = 6 at 180°C. The backscattering/channelling analysis of the UO$_2$ single crystals was performed at the ARAMIS facility of the CSNSM Orsay with a $^4$He beam of 3070 keV to take advantage of the $^{16}$O($^4$He,$^4$He)$^{16}$O resonant scattering at 3045 keV.
The performed measurements showed that the O/U ratio in the crystal surface layer rose to 2.35. Its thickness is ~130 nm after 13 h of the leaching process. The yield of backscattering on the oxygen nuclei contained in this layer displays high flux-peaking for the channelling in the (100) plane and also in the vicinity of the [001] axis (fig. 1). The yield of backscattering signal normalized to the random direction reaches 1.5. This effect was interpreted as a result of substantial changes in the oxygen sublattice due to the incorporation of the excess oxygen atoms. These changes include formation of oxygen cuboctahedral clusters [3] and the displacement of the oxygen atoms in their surroundings. The performed Monte Carlo computer simulations of the ion channeling gave strong support for the presented model. They indicated also that cluster arrangement in the leached layer reveals a superstructure since not all of uranium [001] rows are disturbed to the same extend. See ref. 4 for more extensive discussion of the results.


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1.14 Defect Mobility in Al$_x$Ga$_{1-x}$As at Low Temperatures
by A.Turos, J.Kaczanowski, R.Fromknecht\(^1\), E.Wendler\(^2\), and W.Wesch\(^2\)

The properties of defects in III-V semiconductor compounds have been extensively studied by various techniques over the last few decades. The irradiation induced defects have been principally identified by measurements of their electrical [1,2] and optical [3,4] characteristics. The important limitation of the usually used spectroscopic methods is due to the fact that they can only detect defects in appropriate charge states. Thus, they are virtually "blind" to interstitial atoms. Since the RBS/channeling is almost exclusively sensitive to displaced atoms it has been expected that the application of this technique will provide valuable and complementary information on the defect structures in III-V compounds.

Al$_x$Ga$_{1-x}$As epitaxial layers grown on semi-insulating GaAs substrates with $x = 0.25$ were implanted at 77K with 150 keV N ions to the fluxes $0.7 \times 10^{14}$ and $1 \times 10^{14}$ at/cm$^2$. Implanted crystals were analyzed in situ with 2 MeV $^4$He ions using the RBS/channeling technique.

The kinetics of the defect recovery at 77K is shown in Fig. 1. The total amount of displaced atoms, $n_d$, was calculated as an integral over the corresponding defect distribution determined using Monte Carlo simulations of the measured channeling spectra [5,6]. Next part of the experiment consisted of the warming the sample up...
to room temperature. During the warming-up, the aligned spectra were measured; the measurements time was 10 min, and the corresponding temperature change was smaller than 4K. There were essentially no changes in the shape until the temperature of about 200K was reached. From this temperature a continuous decrease of the de channeling and the damage peak was observed. The dramatic changes were noticed above 270K: the damage peak completely disappeared already at 295K. The residual defect concentration was approximately 1 at%. The results of this part of experiment are summarized in Fig.2 where the isochronal (holding time $\Delta t = 10$ min) annealing curve, $n_d(T)$, is shown.

There is a general agreement that defects which anneal below room temperature are related to the Ga sublattice whereas the As interstitials become mobile at approximately 500K [7]. Our results can be interpreted as the observation of Frenkel pairs (FP's) and/or small defect complexes containing displaced atoms. Our paper presents the first detailed study of the annealing stage at 77K. The plausible explanation is that at this stage the recombination of close FP's occurs with the constant recombination probability. There is still an open question whether they belong only to the Ga sublattice or whether the As sublattice FP's are also involved. Since practically no damage peaks were observed at the end of the stage III the As-interstitials have to disappear at much lower temperatures.


1) Research Center Karlsruhe, INFP, Germany
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LIST OF PUBLICATIONS

QUASIEPTAXIAL GROWTH OF A MONOCLINIC PHASE ON UO₂ SINGLE CRYSTALS UPON LEACHING IN H₂O
L.Nowicki, A.Turos, C.Choffel, F.Garrido, L.Thome, J.Gaca, M.Wójcik, Hj.Matzke

STUDY OF POLARIZED ⁷Li FROM ²⁰⁹Pb AT 33 MeV
K.Rusek, J.Gomez-Camacho, J.Marcel-Bravo and G.Tungate

CHANNEL COUPLINGS IN THE ⁶⁵Cu(⁴N,X) REACTIONS AT E(⁴N) = 116 MeV
V.A.Ziman, A.T.Rudchik, A.Budzanowski, V.K.Chernievsy, L.Głowacka, E.I.Koshchyi, S.Kliczewski, M.Makowska-
Rzeszutko, A.V.Mokhann, O.A.Momotyuk, O.A.Ponkratenko, R.Siudak, I.Skwirczynska, A.Szczurek and J.Turkiewicz

CDCC ANALYSIS OF ⁴Li + ⁴He SCATTERING AT E_CM = 11.1 MeV
K.Rusek, P.V.Green, P.L.Kerr and K.W.Kemper

HOMOLOGOUS STATES AND THE STRUCTURE OF NUCLEI IN THE LEAD REGION

POLARIZATION POTENTIALS FOR THE ²⁰⁹Pb(⁷Li,⁶Li)²⁰⁹Pb TRANSFER REACTION
N.Keeley and K.Rusek

SPECTROSCOPY OF ⁶⁸Y HOMOLOGOUS LEVELS
P.Guazzoni, M.Jaskóla, L.Zetta, J.Gu, A.Vitturi, G.Graw, R.Hertenberger, D.Hofer, P.Schiemenz,
B.Valtne, U.Atzrott, G.Staudt, G.Cata-Danil

FORWARD PEAKING OF NEAR COULOMB ENERGY PROTONS IN (n,p) REACTIONS AT 14.1 MeV
S.Y.Kahn, A.V.Vagov, A.Marciukowski

BREAK-UP TEMPERATURES OF TARGET SPECTATORS IN ¹³⁷Au + ¹⁹⁷Au COLLISIONS AT E/A = 1000 MeV
Hongfei Xi, X.T.Odeh, R.Bassini, M.Begemann-Blaich, ..., A.Trzcinski, ..., B.Zwieglinski

STRUCTURAL MODIFICATION IN URANIUM DIOXIDE IRRADIATED WITH SWIFT HEAVY IONS
F.Garrido, C.Choffel, J.-C.Dran, L.Thome, L.Nowicki, A.Turos

CORROSION PROPERTIES OF SILICON-ON STEEL ION BEAM MIXED LAYERS
J.Jagielski, J.Baszkiewicz, A.Turos, G.Gawlik
Nucl. Instr. and Meth. B127 (1997) 961

ON THE INTERPRETATION OF CR-39, PM-355 AND PM-500 TRACK DETECTORS RESPONSE TO 14.9 MeV
NEUTRONS

COMPARISON OF RESPONSES OF CR-39, PM-355 AND CN TRACK DETECTORS ENERGETIC HYDROGEN-,
HELIUM-, NITROGEN-, AND OXYGEN- IONS
M.Sadowski, A.Szydlowski, M.Jaskóla, T.Czyżewski A.P.Kobzev
Radiation Measurements 28 (1997) 207

MSX - A MONTE-CARLO CODE FOR NEUTRON EFFICIENCY CALCULATIONS FOR LARGE VOLUME Gd-
LOADED LIQUID SCINTILLATION DETECTORS
A.Trzciński, B.Zwieglinski for the ALADIN Collaboration

ION CHANNELING STUDY OF GaN SINGLE CRYSTALS
A.Turos, L.Nowicki, A.Stonert, M.Leszczynski, I.Grzegory, S.Porowski

SPREŻYSTE I NIESPREŻYSTE RZEPRAZANIE JONÓW ¹³C NA JADRACH ³²Be PRZY ENERGII 65 MeV
A.Budzanowski, I.Skwirczynska, A.Szczurek and R.Siudak
PRESENT STATUS OF THE CALORIC CURVE OF NUCLEI
U.Lynen, R.Bassini, M.Begemann - Blaich, Th.Blaich, ..., A.Trzcinski, ..., B.Zwieglinski

ANALYSIS OF PROTON TRANSFER IN POLARIZED 7Li SCATTERING BY 208Pb at 33 MeV
A.M.Moro, M.W.Bailey, C.O.Blyth, N.M.Clarke, K.A.Connell, N.J.Davis, P.R.Dee, B.R.Fulton,
J.Gomez-Camacho, I.A.R.Griffith, S.J.Hall, N.Keeley, J.S.Lilley, I.Martel, K.Rusek and G.Tungate

NUCLEON SCATTERING TO THE CONTINUUM IN TERMS OF THE TWO - FERMION THEORY OF MULTISTEP
DIRECT REACTIONS
A.Marcinkowski, B.Marianski, Z.Moroz, J.Wojtkowska

ANALYSING POWERS FOR THE INCLUSIVE REACTION OF DEUTERONS ON CARBON AT ENERGIES BETWEEN
0.175 AND 1.6 GeV
V. P.Ladygin, ..., P.Zuprański, et al.
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ION BOMBARDMENT INDUCED RELAXATION OF STRAINED AlGaAs/GaAs HETEROSTRUCTURES STUDIED BY
THE COMPLEMENTARY USE OF RBS-CHANNELING AND X-RAY SYNCHROTRON RADIATION
A.Turos, K.Wite ska, W.Wierzchoski, W.Graeff, E.Wendler, W.Wesch, W.Strupinski, R.Grott schel

LATTICE LOCATION OF OXYGEN ATOMS IN UO2 SINGLE CRYSTALS SUBJECTED TO LEACHING
L.Nowicki, A.Turos, C.Choffel, F.Garrido, L.Thomé, Hj.Matzke

A CHANNELING STUDY OF THE STRUCTURAL MODIFICATION IN URANIUM DIOXIDE SUBMITTED TO SWIFT-
ION IRRADIATION AND AQUEOUS CORROSION
F.Garrigo, C.Choffel, J.C.Dran, L.Thomé, L.Nowicki, A.Turos

A STUDY OF THE 90Zr(p,t)92Zr REACTION

A 4He + ALPHA CLUSTER MODEL OF 9Be
N.Keeley and K.Rusek

STUDY OF THE 90Zr(p,n)91Y REACTION AT 22 MeV
G.Staudt

SYNCHROTRON X-RAY STUDIES OF AlGaAs EPITAXIAL LAYERS IMPLANTED WITH Selenium IONS
K.Wite ska, W.Wierzchoski, A.Turos W.Graeff, R.Grottschel
Universtatis Jagiellonicae Folia Physica, (in press)

PARTICIPATION IN CONFERENCES AND WORKSHOPS
A CONSISTENT ANALYSIS OF THE (p,p') AND (n,n') MULTISTEP REACTION USING THE FESHBACH-KERMAN-
KOONIN THEORY
A.Marcinkowski (invited talk)
8th Int. Conference on Nuclear Reaction Mechanisms, Varenna, 8-4 czerwiec 1997

ANALYSIS OF THE SUBSTRATE CRYSTALS SURFACES: SELECTED METHODS
A.Turos (invited talk)
Third Symposium of Polish Society of Crystal Growth, Warsaw, June 1997

ACCELERATOR TECHNICS FOR SURFACE LAYERS MICROANALYSIS
A.Turos (invited talk)
Symposium of Polish Vacuum Society, Ustron, September 1997

ION BOMBARDMENT INDUCED DAMAGE IN ZrO2 SINGLE CRYSTALS AND ITS THERMAL ANNEALING
Hj.Matzke, ..., A.Turos (invited talk by A.Turos)
Int. Conf. on Radiation Effects in Insulators, Knoxville (USA), September 1997

DOPING, ACTIVATION OF IMPURITIES, AND DEFECT ANNHI LATION IN GaN BY HIGH PRESSURE ANNEALING
T.Suski, ..., A.Stonert, A.Turos (invited talk by A.Turos)
MRS Fall Meeting, Boston (USA), December 1997
DOPING, ACTIVATION OF IMPURITIES, AND DEFECT ANNIHILATION IN GaN BY HIGH PRESSURE ANNEALING

MULTIPLE IONIZATION OF M-, N-, AND L- SHELL BY ENERGETIC HEAVY IONS
M. Pajek, D. Banaś, I. Braziewicz, T. Czyżewski, M. Jaskóła, W. Krechmer and J. Semaniak
XX International Conference on the Physics of Electronic and Atomic Collisions, July 23 - 29, 1997, Vienna, Austria

ISOTOPIC EFFECT IN M-SHELL IONIZATION BY SLOW H AND He IONS
D. Banaś, J. Braziewicz, T. Czyżewski, M. Jaskóła, G. Lapicki and M. Pajek
XX International Conference on the Physics of Electronic and Atomic Collisions, July 23 - 29, 1997, Vienna, Austria

EFFECTS OF THE DIPOLE ELECTRIC POLARIZABILITY IN POLARIZED 7Li SCATTERING
I. Martel, J. Gomez-Camacho, K. Rusek and G. Tungate (poster)
XXV Mazurian Lakes School of Physics, Piaski 1997

A 1He + ALPHA CLUSTER MODEL OF 18Be
N. Keesey and K. Rusek (poster)
XXV Mazurian Lakes School of Physics, Piaski 1997

A STUDY OF THE 207Zr(l,p)208Zr REACTION
XXV Mazurian Lakes School of Physics, Piaski 1997

A CHANNELING STUDY OF THE STRUCTURAL MODIFICATION IN URANIUM DIOXIDE SUBMITTED TO SWIFT-ION IRRADIATION AND AQUEOUS CORROSION
F. Garrido, C. Choffel, J.-c. Dran, L. Thomé, L. Nowicki, A.Turos
Int. Conf. on Ion Beam Analysis, Lisbona, July 1997

ION BOMBARDMENT INDUCED RELAXATION OF STRAINED AlGaAs/GaAs HETEROSTRUCTURES STUDIED BY THE COMPLEMENTARY USE OF RBS - CHANNELING AND X-RAY SYNCHROTRON RADIATION
Int. Conf. on Ion Beam Analysis, Lisbona, July 1997

LATTICE LOCATION OF OXYGEN ATOMS IN UO2 SINGLE CRYSTALS SUBJECTED TO LEACHING
L. Nowicki, A. Turos, C. Choffel, F. Garrido, L. Thomé, Hj. Matzke
Int. Conf. on Ion Beam Analysis, Lisbona, July 1997

SYNCHROTRON X-RAY STUDIES OF AlGaAs EPITAXIAL LAYERS IMPLANTED WITH SELENIUM IONS
K. Witeska, W. Wierzchowski, A. Turos, W. Graeff, R. Grötzschel
Fourth Symposium of Synchrotron Radiation Users, Krakow, September 1997

OTHER PAPERS

NEW TEMPERATURE MEASUREMENTS IN 197Au + 197Au COLLISIONS
W. Trautmann, R. Bassini, M. Begemann-Blaich, A.S. Botvina,..., A. Trzcinski, ..., B. Zwieglinski

SOURCE TEMPERATURES AND SIZES IN CENTRAL COLLISIONS
C. Schwartz, R. Bassini, M. Begemann-Blaich, A.S. Botvina,..., A. Trzcinski, ..., B. Zwieglinski

EMISSION TEMPERATURES AND FREEZOUT DENSITIES FROM LIGHT PARTICLE CORRELATION FUNCTIONS IN Au + Au COLLISIONS AT 1A GeV
S. Fritz, R. Bassini, M. Begemann-Blaich, A.S. Botvina,..., A. Trzcinski, ..., B. Zwieglinski

MULTIFRAGMENTATION AND THE SEARCH FOR THE LIQUID - GAS PHASE TRANSITION IN NUCLEAR MATTER
U. Lynen, R. Bassini, M. Begemann - Blaich, Th. Blaich,..., A. Trzcinski, ..., B. Zwieglinski

THE NUCLEAR LIQUID - GAS PHASE TRANSITION: PRESENT STATUS AND FUTURE PERSPECTIVES
J. Pochodzalla, G. Imme, V. Maddalena, C. Nociforo, ..., A. Trzcinski, B. Zwieglinski
DETERMINATION OF CRITICAL EXPONENTS IN NUCLEAR SYSTEMS
W.F.J. Müller, R. Bassini, M. Begemann-Blaich, Th. Blaich, ..., A. Trzciński, ..., B. Zwieglinski

LAST MINUTE FROM ALADIN: TEMPERATURE MEASUREMENTS IN Au + Au REACTIONS AT RELATIVISTIC ENERGIES
G. Imme, V. Maddalena, C. Nociforo, G. Raciti, ..., A. Trzciński, ..., B. Zwieglinski

NUCLEAR CALORIC CURVE
G. Raciti, R. Bassini, M. Begemann-Blaich, S. Fritz, ..., A. Trzciński, ..., B. Zwieglinski

A CONSISTENT ANALYSIS OF THE (p,p') AND (n,n') MULTISTEP REACTIONS USING THE FESHBACH-KERMAN-KONNIN THEORY
A. Marcinkowski, B. Mariariski, Z. Moroz, J. Wojtkowska

RESPONSE OF CR-39, PM-355 AND PM-500 NUCLEAR TRACK DETECTORS TO FAST NEUTRONS
Proc. of Int. Symp. Plasma 97, Jarosławek near Opole, June 10-12, 1997

LECTURES, COURSES AND EXTERNAL SEMINARS

Nuclear Physics with Polarized Heavy Ions*  
K. Rusek, May 23, UW Warsaw

Two Nucleon Transfer Reactions in Zr Nuclei*  
M. Jaskoła, June 5, Inst. of Physics, Milano University, Italy

The Fluorite - Like Family of UO_3 and UO_2 Oxides*  
L. Nowicki, Nov. 10, Institute for Transuranium Elements, Karlsruhe, Germany

Decay of GDR Induced by ^27Al(p,α)^24Mg Reaction*  
J. Rondio, Dec. 3, UW Warsaw

INTERNAL SEMINARS

Study of the Homology States in Zr and Pb Nuclei*  
M. Jaskoła, Jan. 7, IPJ Warsaw

Liquid - Gas Phase Transition in Finite Nuclear Systems - Illusion or Reality?*  
B. Zwieglinski, Febr. 20, IPJ Warsaw

Deexcitation of GDR excited in doorway state of ^27Al(p,α)^24Mg reaction*  
J. Rondio, Oct. 31, IPJ Warsaw

Multistep Direct Reactions in the Continuum*  
A. Marcinkowski, Nov. 25, IPJ Warsaw

* in Polish  
* in English

PARTICIPATION IN CONFERENCE COMMITTEES, SESSION CHAIRMEN

XXV MAZURIAN LAKES SCHOOL OF PHYSICS, PIASKI, AUGUST 1997  
K. Rusek - member of the Organizing Committee
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Overview

According to the Department's name, our activity is focused on "spectroscopy" (basic research) and "technique" (applications). Our Department is also involved in the new subject in our Institute, namely Training and Consulting. The exhibition commemorating the 100 anniversary of the birth of Prof. Andrzej Soltan and the discovery of Polonium and Radium was presented with a strong support of our Department. At present, three Ph.D and five M.Sc. students are working for their degrees. In 1997 one Ph.D was obtained.

Many results obtained profited by cooperation with Polish, European and USA centres like the Heavy Ion Laboratory at Warsaw University, GSI in Darmstadt (Germany), PSI in Villigen (Switzerland) etc. Our own equipment: C-30 proton cyclotron, electromagnetic mass-separator and low background gamma detection facility has allowed us to obtain new results.

The Theory Group was involved in further studies of nuclear dynamics, particularly of the nature and strength of nuclear dissipation in compound-nucleus fission and strongly damped nucleus-nucleus collisions. A comprehensive program for studying nucleus-nucleus collision dynamics with inclusion of fluctuations and shell effects has been started.

In-beam spectroscopic studies have been continued in collaboration with Argonne National Lab., University of Notre Dame, USA and KFA Jülich (Germany). Level schemes of several nuclei in the vicinity of Z,N=50 have been extended to very high spins. New evidence of shell-breaking effects has been found in some Ru nuclei. New isomers have been discovered in heavy $^{187,189}$Ir nuclei. In collaboration with Heavy Ion Lab. a study of high spin states in $^{136}$Sn and several high spin isomers in this region was undertaken.

A search for lepton flavour violating nuclear processes has been continued at PSI- new data for the Au target have recently been collected.

Many new results in high energy atomic physics have been obtained in collaboration with PSI and GSI. A systematic study of K$\beta$ spectra emitted from medium Z atoms by an $\alpha$ beam allowed us to deduce the average M-shell ionization probabilities. The Bremsstrahlung process was investigated for He-like U ions and substantial discrepancies between the data and first order Born calculations were found. The electron excitation process was investigated for H- and He-like ions and the radiative electron capture to excited L level - for bare U ions.

On our C-30 Cyclotron new data were obtained for continuous energy spectra and angular distributions of secondary protons from $^{48}$Ni and $^{25}$Mg targets under proton bombardment to study pre-equilibrium emission in nuclear reactions. Theoretical analysis is in progress.

The proton beam of this cyclotron was used to study radiation-induced modifications of optical properties of laser radiators in collaboration with the Military Technical Academy and Institute of Electronic Technology and Materials in Warsaw.

The study of the negative ion source for Radioactive Beam Facilities have been continued and new results for the graphite ioniser are obtained.

Determination of the ground-level air radioactivity within the frame of the air sampler network is continued and the concentrations of $^7$Be, $^{40}$K, $^{137}$Cs and $^{210}$Pb are routinely measured every week.

Our Department is participating in the project of the flue gas treatment plant using the electron beam method for the "Pomorzany" coal power plant coordinated by the Institute of Nuclear Chemistry and Technology in Warsaw under the supervision of IAEA in Vienna.

Strong financial support received from the State Committee for Scientific Research and Maria Skłodowska-Curie Polish-American Foundation is acknowledged.
2.1 Shell Effects in Heavy Ion Collisions
by J. Blocki, O. Mazonka, and W. J. Świątecki

The importance of shell effects was demonstrated in the fusion process where one can see an enhanced probability of fusion when using Pb or Pb-like targets as compared to targets from the transuranic region. In our dynamical approach developed from some time ago [1]. We did not have shell effects included and therefore we could look only at the average behaviour of Heavy Ion Collisions and not at the behaviour of specific combinations of target and projectile. We have decided to include shell effects in our calculations in a phenomenological form proposed by Myers and Swiatecki [2]. In their approach the shell correction $S_0(N,Z)$ in MeV to the potential energy is written in the form:

$$ S_0(N,Z) = 5.8 \left( \frac{F_N + F_Z}{(A/2)^{2/3}} - 0.325A^{1/3} \right) $$

where

$$ F_N = q_N(N-N_{j-1}) - 0.6(N^{5/3} - N_{i-1}^{5/3}) $$

and

$$ q_N = 0.6 \frac{N_{i-1}^{5/3} - N_{j-1}^{5/3}}{N_{i-1} - N_{j-1}} $$

In here $N_{j-1}$ and $N_j$ correspond to the numbers of closed shell neutrons and $N$ is the actual number of neutrons being between $N_{j-1}$ and $N_j$ for a given system with $A$ being its mass. The same formulae for $F_Z$ and $q_Z$ are for protons. For neutron and proton numbers $N$ and $Z$ corresponding to closed shells $N_M$ and $Z_M$ the shell effect is the strongest and is equal to:

$$ S_0(N=N_{j-1}, Z=Z_{j-1}) = -5.8 \cdot 0.325 \cdot A^{1/3} $$

which for instance for $^{208}$Pb corresponds to about -11.2 MeV.

This shell correction $S_0(N,Z)$ holds for spherical shapes. When shapes get deformed the actual shell correction diminishes exponentially due to the deformation:

$$ S(N,Z) = S_0(N,Z) \cdot (1 - 2\frac{\text{dist}^2}{a^2}) \exp\left(-\frac{\text{dist}^2}{a^2}\right) $$

where:

$$ \text{dist}^2 = \int (r(\theta,\phi) - R_p)^2 d\Omega / 4\pi $$

and $r(\theta,\phi)$ is a radius vector of the given shape calculated with respect to its mass center and $R_p$ is a radius of an equivalent sphere.

The problem which remains here to be solved is how to connect in a smooth way shell corrections $S_i$ and $S_j$ of colliding ions in an entrance channel with one shell correction $S_0$ for the compound shape. It was decided to take a so called window opening $\alpha$ [3] distinguishing between dinuclear and mononuclear shapes. The final formula for shell correction reads:

$$ S = (S_i \cdot S_j) (1-\alpha) \cdot S_0 \cdot \alpha $$

For separated shapes ( below scission line ) $\alpha$ is equal to zero and we have only $S_i + S_j$. When neck degenerates to a cone $\alpha$ reaches the value equal one and we put $\alpha = 1$ also above and then there appears only one shell correction $S_0$ for a mononuclear shape.
As a test of our model we have taken recently measured reaction \([4]^{86}\text{Kr} + ^{136}\text{Xe}\) for which we have closed neutron shells in both ions. For this reaction fusion takes place at the barrier. The energy in the center of mass system for which probability of fusion reaches the value 1/2 is equal to 224 MeV. In Fig.1 an excitation function for this reaction calculated with a model with shell and stochastic effects included is shown. These are preliminary results with rather poor statistics, so the errors are relatively big. Nevertheless the experimental point at 224 MeV, where fusion probability is equal to 1/2 is very nicely reproduced. If one makes the same calculations without shell effects the probability of fusion at 224 MeV is about zero.


2.2 Numerical Computations of Small Fusion Cross Sections for Langevin Models of Nuclear Dynamics

by O.Mazonka, J.Blocki and C.Jarzynski

Langevin method provides a powerful tool for a numerical simulation of a wide variety of physical phenomena where stochastic noise is present in the equations of motion. The ability to simulate a process, in turn, allows one to study numerically its details, with an eye to answering questions of physical interest. The application which will concern us here is the use of Langevin approach to compute probabilities of particular outcomes of a given process. This approach becomes doubtful, however, when the interesting outcome is very rare. Then prohibitively many simulations may be needed in order to compute the desired probability with decent statistical accuracy.

Here we develop a method for using Langevin simulations to compute efficiently the probabilities of very rare outcomes. In this method we modify the dynamics so that the probability for that outcome is greatly enhanced. We then run a number of Langevin simulations to collect statistically accurate information about the modified dynamics. Finally, from this information, we extract the desired information regarding the original dynamics.

Suppose we are interested in the stochastic process

\[ \dot{x} = \nu(x) + \eta(x,t) \]

with initial condition \(x(0) = A\), and we want to use Langevin trajectories to determine what is the probability for finding \(x(t)\) in \(B\), where \(B\) is some region on the \(x\)-axis. Assume that this probability is very small, so direct simulation of the stochastic process is inefficient. Now suppose we have another stochastic process with

\[ \dot{y} = \nu(y) + \varphi \]

where \(\varphi\) is an additional force

\[ \dot{x} = \nu'(x) + \eta(x,t) \]
with the same initial condition \( x(0) = A \), and suppose that under this process the probability of finding \( x(t) \) in \( B \) is reasonably large. How can we use simulations of the second Langevin process to determine information about the first one?

The probability distribution of obtaining a trajectory \( x(t) \) under a stochastic process is given by

\[
p[x(t)] = N^{-1} \exp -S[x(t)]
\]

where \( S \) is a Langevin action[1]. As normalization factor \( N^{-1} \) is the same in both cases we get immediately:

\[
p_0[x(t)] = e^{\Delta S_1} p_1[x(t)]
\]

where \( \Delta S = S_1 - S_0 \) (indexes 0 and 1 correspond to the first and the second process, respectively). So finally the probability that a trajectory, evolving under the first process, will end up in \( B \), is given by

\[
p(B) = \int_{x(t) \in B} \mathcal{D}[x(t)] p_0[x(t)] = \int_{x(t) \in B} \mathcal{D}[x(t)] e^{\Delta S_1} p_1[x(t)]
\]

\[
= \lim_{N \to \infty} \frac{1}{N} \sum_{x(t) \in B} \exp \Delta S \left[ x(t) \right]
\]

The last line means the following: simulate \( N \) Langevin trajectories evolving under the second stochastic process, then take the sum of the values \( \exp(\Delta S) \) for those trajectories that end up in region \( B \).

The effectiveness of such kind of calculations (the convergence with number of simulations) has big dependence on final distribution values \( \Delta S(T) \) which in turn depend on additional force. To calculate probability of very rare events we should take pretty big additional force, but it does not mean that the width of the distribution \( \Delta S \) will be also big.

We have taken a simple model of Heavy Ion Collisions [3] to test our method. This model was already used in 1990 [2] where in addition to deterministic trajectories in the deformation space stochastic effects in the form of "kicks" were added. The original model [3] is a simplified one where one assumes the parametrization of the shape as two spheres connected by a cone. After some approximations for the potential, dissipation and kinetic energy terms one ends up in a set of two coupled differential equations for the time evolution of the given symmetric system. We have followed symmetric collisions and as an example we have taken a collision of two \(^{109}\)Zr nuclei.

In Fig.1 dynamical trajectories of such a collision are shown. Trajectories are presented in \((\rho, \alpha)\) space, where \( \rho \) is the relative distance between sphere centers and \( \alpha \) is so called window opening [4]. Our trajectories start at two touching spheres \((\rho = 1, \alpha = 0)\) and go either to the right (reseparation of two colliding nuclei) or to the left (fusion) depending on the initial energy over the interaction barrier \( E_x \). In Fig 1 we have three full lines of deterministic trajectories which
correspond to 3 different initial energies $E_x$: 0 MeV (reseparation), 8 MeV (fusion) and 3.385 MeV leading right to the saddle point. Two dashed lines represent trajectories with stochastic force and $E_x=3.385$ MeV. In Fig 2 excitation function (probability of fusion) is shown. In the box inside there is a part of the function in the small probabilities region. The dashed line corresponds to direct calculations and the full line to calculations where our method was used.


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2.3 Radiative and Nonradiative Electron Capture by Relativistic $^3$He$^{++}$ Ions


A fast ion traversing a solid undergoes multiple electron stripping and capture processes. The capture to a vacant electron shell in the projectile proceeds mainly via two mechanisms: the non-radiative electron capture [1], NREC, occurring mainly at the velocity matching condition $v_{\text{projectile}} = v_{\text{sr}}$, where $v_{\text{sr}}$ is the velocity of the bound target electron, and the radiative electron capture, REC, in which the excess energy is carried away by a photon.

Measurements of the REC for He$^{++}$ and very light targets correspond in principle to measuring the photo-electric effect for singly ionized He, provided that the target electrons can be considered as free. No such data exist.

A 450 MeV $^3$He$^{++}$ beam extracted from the the ring cyclotron of the RCNP Osaka was used to bombard thick targets ranging from Be through Pb. The typical beam intensity was 20 nA.

Singly ionized $^3$He$^+$ ions together with tritons from the ($^3$He,t) reaction were detected in the focal plane of the magnetic spectrometer Grand Raiden, set at 0° with respect to the beam, with vertical and horizontal opening of 40 mrad each. The $^3$He$^{++}$ beam was fully intercepted by a Faraday cup placed in the first dipole magnet of the spectrometer.

The present data have been obtained as a by-product of the systematic study of the Gamov-Teller strength distribution in the ($^3$He,t) charge exchange reactions.

We have analyzed the measured yields, $Y(^3\text{He})$, in terms of the yield ratio

$$\frac{Y(^3\text{He}^+)}{Y(^3\text{He}^{++})} = \frac{\sigma_{\text{EC}}}{\sigma_{\text{stripping}}}$$

valid at equilibrium, where $\sigma_{\text{EC}} = \sigma_{\text{REC}} + \sigma_{\text{NREC}}$ is the sum of radiative and nonradiative electron capture cross sections, $\sigma_{\text{stripping}}$ is the cross section for stripping of the single electron from the $^3$He$^+$ ions and $Y(^3\text{He}^{++})$ is the beam intensity. The targets used were a few mg/cm$^2$ thick which means that the charge equilibrium condition was safely fulfilled.

Fig.1 shows the results together with the calculated yield ratios. No fitting has been done. For high Z targets the capture is dominated by the nonradiative process. The decreasing trend of the calculated curve in this region is presumably mainly due to the approximations used in calculating the $\sigma_{\text{stripping}}$ function (see below). The excess of the capture yield for low Z targets is only explainable if the radiative capture is included.

The cross sections $\sigma_{\text{REC}}$ and $\sigma_{\text{NREC}}$ were calculated using the high energy approximations [1] with corrections for relativistic kinematics [2]. The ionization...
cross sections, $\sigma_{\text{ripping}}$, were obtained with semiempirical formulae [3] in high energy Born approximation. This method describes well the ionization cross sections of He in collisions with low Z targets but overestimates those for high Z targets. This explains the deviation of the calculated curve for high Z. Experimental results on the $\sigma_{\text{ripping}}$ NREC process dominates even for light targets. No evidence for REC could be seen.

Information on REC for relativistic He ions is of direct astrophysical interest [4],


2.4 Compressibility of Nuclear Matter Nuclear and Astrophysical Evidence by Z.Sujkowski

The nuclear incompressibility modulus, $K_\omega$, is the primary ingredient of the Equation - Of - State of nuclear matter, EOS. This is still poorly known. In fact only the values of the coordinates of one point on the energy per nucleon versus the density plane are known, that is the saturation density, $\rho_0=0.16 \text{ fm}^3$, and the binding energy per nucleon at this density, $E_\omega=-16\text{MeV}$. Known also, though with much inferior accuracy, is the curvature at this point, i.e. $K_\omega$.

The present constraints on the value of $K_\omega$ stem from the nuclear physics data on cold, finite nuclei as well as from the data on unequilibrated and/or very dense systems, e.g. on the nucleus-nucleus collisions, the neutron stars and supernovae explosions [1]. The intuitively most promising information on $K_\omega$ is that obtainable from data on the breathing mode in finite nuclei (the Giant Monopole Resonances, GMR), [2].

Recently [3] a simple relationship has been proposed between the incompressibility moduli, $K_{\omega}$ and $K_m$, and the binding energy per nucleon, $E_{\omega}$ and $E_{m}$ for the finite nuclei and for the nuclear matter, respectively. For uncharged finite nuclei the relationship is

$$ K_{\omega} / K_m = E_{\omega} / E_0 $$

The resonance energies given by this formula (Coulomb corrected) are overestimated and the deviations increase with $A$ decreasing. A two mode model proposed in [4] predicts two energy solutions for the GMR due to the coupling of the surface mode to the bulk mode. The low energy solution, corresponding to the observed resonance concentration, is pressed down increasingly with lower mass values. The high energy component escapes observation. The main lesson of the coupled mode analysis is a warning: the identification of the observed GMR centroid with the unperturbed energy may lead to false results for the deduced $K_\omega$ value.

A possible recipe [5] to obtain the range of allowed $K_\omega$ values is to calculate $K_\omega$ microscopically, e.g. with a good Gogny or Skyrme force [2]; to use this value as an input to the Coupled Mode Model and deduce corrections to $E_{\text{GMR}}(AZ)$ from a fit to the data; to compare the corrected $E_{\text{GMR}}(AZ)$ values with microscopic calculations; to iterate.

2.5 Systematics of the Dissipation Coefficient Deduced from Pre-Scission Neutron Multiplicities in Fusion-Fission Reactions
by K.Siwek-Wilczyńska, J.Krzyczkowski, J.Wilczynski, R.H.Siemssen, H.W.Wilschut

In the last Annual Report we outlined our method of calculating pre-scission neutron multiplicities in terms of the statistical model, in which the fission decay channel is hindered due to the nuclear dissipation and described in framework of the diffusion model of Kramers (later refined by Grané and Weidenmuller).

At the beginning of the 80s a new experimental technique called "source analysis" was developed which made it possible to extract the pre-scission component $v_{\text{pre}}$ of the neutron multiplicity in fusion-fission reactions. It was found that the measured values of $v_{\text{pre}}$ are larger than predicted by the statistical model with the standard Bohr-Wheeler fission width $\Gamma_{\text{BW}}$. This has led to the revival of the Kramers’ theory of dissipative fission, in which the fission width is reduced by a factor depending on the dimensionless dissipation coefficient $\gamma$:

$$\Gamma^K = \Gamma_{\text{BW}}(\sqrt{1 + \gamma^2} - \gamma)$$

The dependence of the Kramers fission width on the dissipation coefficient $\gamma$ gives a unique possibility to determine the strength of nuclear dissipation, obviously one of the basic properties of nuclear matter.

We carried out comprehensive simulations of the existing data on pre-scission neutron multiplicities for about 15 fusion-fission reactions studied by Hinde et al. [1] and Rossner et al. [2]. Calculations were performed with our statistical model Monte Carlo program [3] adapted for inclusion of the Kramers-Grané-Weidenmuller fission width, and complemented with our scheme of calculating the saddle-to-scission contribution to $v_{\text{pre}}$ values by using a hybrid of the time-dependent statistical code with the dynamical model HICOL.

The deduced values of the dissipation coefficient $\gamma$ are shown in Fig. 1. The collection of these reactions covers a wide range of temperatures and seems to contradict the suggested [4] increase of $\gamma$ with the temperature. Admitting the fact that the deduced values of the dissipation coefficient are quite dispersed, we can only state that we do not observe a clear trend in the temperature dependence of $\gamma$ and that on average these values remain in agreement with the strength of one-body dissipation which is equivalent to $\gamma$ in a range from 4 to 5.


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2.6 Predictions of the Mass Drift in Strongly Damped Reactions with the Classical One-Body Dissipation Model
by J.Blocki, J.Wilczyński

We carried out comprehensive simulations of the mass flow between reaction partners in nucleus-nucleus collisions by using a dynamical model based on the Rayleigh-Lagrange equations of motion [1,2]. Our analysis was focused on correlations between the mass division of a composite system, the loss of the kinetic energy and the emission angle of the reaction products, measured by Shen et al. [3] in reactions of $^{238}$U beam with different
targets. From the measured angles of rotation of the di-nuclear system, Shen and co-workers could deduce the time $t$, during which the di-nuclear complex remains in contact. It was found in Ref. [3] that there is almost a universal correlation between the mean normalized mass drift towards symmetry, $\Delta A/\Delta A_{\text{max}}$, and the reaction time $t$. (Here, $\Delta A$ is the observed drift of mass, and $\Delta A_{\text{max}}$ is the maximum possible drift corresponding to symmetric split.) The dependence of $\Delta A/\Delta A_{\text{max}}$ on $t$ can be directly calculated with our dynamical model and thus compared with experimental results.

An example of our simulation for the $^{48}\text{Ca} + ^{232}\text{U}$ system is shown in Fig.1. The standard "wall-and-window" formula which describes the rate of one-body dissipation was applied in these calculations, but in order to quantitatively demonstrate discrepancies between the model predictions and experimental data, calculations with the one-body dissipation scaled by a factor $k_s$ are also shown. It is seen that the standard calculation ($k_s = 1$) gives too long time scales, especially for peripheral collisions corresponding to a smaller mass transfer $\Delta A$. For an energy of 7.5 MeV/nucleon a better agreement with the data is obtained for the one-body dissipation reduced by a factor $k_s = 0.6$. Comparison of the curves for 5.4 and 7.5 MeV/nucleon shows that the theoretically predicted dependence on energy is significant, while the experimental results seem to be almost independent of the collision energy.

The same set of data was analysed assuming two-body dissipation. However, deduced values of the nuclear viscosity $\mu$ of about 0.1TP are much larger than those deduced from our analysis [4] of the mean kinetic energies of the fission fragments. This inconsistency of the results for two-body dissipation can be used as an argument in favour of the dominance of the one body dissipation mechanism in nucleus-nucleus collisions at the studied range of energies (below 10 MeV/nucleon).


2.7 Nuclear Structure of $^{94,95}\text{Mo}$ at High Spins


The high-spin level structures of $^{94,95}\text{Mo}$ (N = 52,53) have been investigated via the $^{65}\text{Cu}(^{65}\text{S}, \alpha p n)^{95}\text{Mo}$ and $^{64}\text{Cu}(^{64}\text{S}, \alpha p n)^{94}\text{Mo}$ reactions at a bombarding energy of 142 MeV. Even though the incident beam energy was not optimized (according to statistical model calculations) for the $^{94,95}\text{Mo}$ reaction channels, it was still possible to obtain substantial information on the higher angular momentum states in these nuclei, as can be seen below. The $^{64}\text{S}$ beam was provided by the 88-inch Cyclotron facility at the Ernest O. Lawrence Berkeley National Laboratory. Two stacked, self-supporting, isotopically enriched $^{64}\text{Cu}$ target foils (-0.5 mg/cm$^2$ thick) were used. Triple- and higher-fold coincidence events were measured using the early implementation phase of the Gammasphere array, which at that time comprised 36 Compton-suppressed Ge detectors. A total of about 400 million events were accumulated and stored onto magnetic tapes for further analysis.

The data were sorted into 3-dimensional histograms ($E_{\gamma}, E_{\gamma}, E_{\gamma}$ cubes) using the Radware [1] and Kuehner [2] formats. The coincidence cube with Radware-format was analyzed with the Radware software package [3] which uses the generalized background subtraction algorithm of Ref. [4] to extract spectra corresponding to two coincidence gates (the so-called "double-gated spectra"). Such double-gated spectra were also obtained from the Kuehner cube using the FUL method of background subtraction[ben]. More experimental details, including
procedures for constructing level schemes and for multipolarity assignments, are given in Ref. [5]. In particular, multipolarity assignments were based primarily on intensity ratios extracted from angle-sorted matrices. Coincidence gates were placed on transitions detected in the forward-angle (32 and 37 degrees) detectors.

...
multipolarities of gamma transitions. The experimental data are being analysed with the use of standard techniques.


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2.9 Investigation of High Spin Isomer in $^{132}$Ce

Isomeric states with K,I$^*$ = 8,8 have been found in several even-even N = 74 isotones [1]. In the case of the $^{130}$Ba, $^{134}$Nd $^{136}$Sm and $^{138}$Gd nuclei, these states decay by K-forbidden, El transitions to the 8$^+$ state of the ground state band with K = 0. The K-hindrance factor per degree of K forbiddenness, $f_v$, is of the order of 25 for $^{134}$Nd, $^{136}$Sm and $^{138}$Gd nuclei and increases significantly to the value of 44 for $^{130}$Ba isotope. Two possible explanations of this phenomenon have been proposed [1]: the first one is the change of shape and structure of the isomeric state itself and the second one is the change of ratios of the s-band and ground state band admixtures to the final state of the isomer decay. The investigation of $^{132}$Ce nucleus, which lies just at the region of the large changes of the hindrance factor, has been undertaken in order to get more information on this subject. The 8$^+$ isomeric level at 2338 keV was already known in this nucleus [2]. The value of 13±2 ms for the halflife of the isomeric state was reported [2]. Prior to the present studies only one decay branch, via the 796 keV, M2 transition to the 6$^+$ yrast state, has been known.

The $^{132}$Ce nuclei were produced in the $^{16}$O($^{10}$Be,4n)$^{132}$Ce reaction at a beam energy of 80 MeV. The $^{16}$O beam was provided by the U200P cyclotron at Heavy Ion Laboratory in Warsaw. The time profile of the beam was 1.5 ms on and 8.5-28.5 ms off. Gamma-gamma coincidences were measured with the use of the OSIRIS multidetector array which consisted of 6 Compton-suppressed HP Ge detectors. Off-beam coincident events were sorted into $E_g$-$E_g$ and $E_g$-$t$ coincidence matrices in the aim to deduce halflives of the respective transitions and to establish coincidence relationship between γ-rays associated with the decay of the isomer.

Preliminary decay scheme of the 8$^+$ isomer deduced from this experiment is presented in fig. 1. The isomer halflife $T_{1/2} = (9.4\pm0.3)$ ms has been determined in this experiment. A weak 788 keV gamma-transition observed in the off-beam coincidence spectra proves the existence of ~11 keV, El transition connecting the 8$^+$ isomer with the 8$^+$ member of the ground state rotational band. The value of hindrance factor, $f_v = 35\pm2$, deduced for this transition agrees very well with the results of band mixing calculations for this region of nucleus presented in ref. [1]. Another new isomer decay path was also established. It proceeds via weak 525 keV transition to a new level at 1813 keV with a tentative spin and parity assignment of 5$^+$. This level deexcites via 614, 432 and 955 keV transitions to the 3$^+$ and 4$^+$ levels of the gamma band and to 4$^+$ level of the ground state band, respectively. According to systematics the new level at 1813 keV seems to
be a better candidate for the $5^+$ rotational state of the gamma band than the $1656$ keV level quoted in the literature [3]. Data analysis is still in progress.


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2.10 Investigation of the High Spin Isomers in $^{180}$Os


The decay of $^{180}$Os isomers was investigated with use of the CLUSTER cube setup at the MPI, Heidelberg, employing recoil-shadow technique to suppress prompt $\gamma$-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 continued.

The $^{180}$Os nucleus is one of a few nuclides from the A=180 region in which a strongly $K$-violating decay mode of high spin isomers has been discovered [3]. The decay of such an isomer with high $K$ proceeds directly to the high spin states of the low-$K$ bands (including the yrast and yrare bands with $K=0$) without going through the intermediate $K$ states. Moreover, $^{180}$Os together with $^{176}$W represent the only two unique cases [3,4] where this anomalous decay constitutes the predominating decay path of the isomer.

The recoil-shadow setup allowed to suppress prompt $\gamma$-radiation emitted from the target but did not reduce the $\gamma$-radiation from (n,$\gamma$) reactions in the Ge detectors and the tungsten shielding. A serious problem in the data analysis was a huge background from these reactions that obscured weak $\gamma$-lines from the isomeric decay. To suppress this background, different "cleaning tools" such as the use of various types of time gates, multiplicity conditions and coincidence conditions, were used during the sorting procedures. The most useful $\gamma-\gamma$ matrices were obtained from three- and higher-fold events. However, the number of such events was too small to establish the complex deexcitation of the isomers.

Only two direct decay branches from the high spin isomer at $5845$ keV were observed. The first one leads to the $18^+$ yrare state via strong $286-1426$ keV cascade, established already in ref. [3], and the second one, being much weaker, leads to the $20^+$ yrare state via the $286-739$ keV cascade. The observed intensity ratio of the $739$ and $1426$ keV transitions suggests that the level deexcited by them has $I = 19$. The isomer may then have a spin of $20$ or $21$. In addition to the yrast, yrare and (.,1), (.,0), (.,0) bands, as previously established [3], four other negative parity bands are weakly fed in the decay of the high spin isomer. The decay paths to these bands were too weak to be established within statistics of our experiment. Even the reasonably strong $109$ and $577$ keV lines, reported earlier [3,5], which feed the $16^+$ yrare and $18^+$ yrast levels, respectively, could not be placed with certainty in the level scheme.
The distribution of the feeding intensities to the individual bands is shown in fig. 1 together with the summed feeding intensities to levels of given spin and positive or negative parity, respectively. The fact that the $16^+, 17^+$ and $19^+$ states receive the strongest feeding and that levels up to $I = 21$ are populated indicates that the cascades depopulating the isomer into these levels are rather short. The high-spin isomer depopulates mainly ($\approx 52\%$) by highly K-forbidden transitions into the low-K bands at high spins. Only about 30% of the decay goes to the K=7 bands built on the two 7$^+$ isomers.


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2.11 Decay of the High Spin Isomer in $^{183}$Ir


The high spin states of the $^{183}$Ir nucleus has been investigated with the use of the Argonne-Notre Dame Gamma-ray Facility at ANL, Argonne. Details of the experiment were already described in ref. [1]. An analysis of the prompt and delayed $\gamma-\gamma$ matrices allowed to identify, for the first time in $^{183}$Ir, a high spin isomer at an excitation energy of $\approx 1647$ keV and with spin $I=17/2$. The time spectra of deexciting transitions have been studied with the use of computer program VERA especially developed for $E\gamma$-t matrix analysis. The program allows for de-convolution up to three consecutive isomer decays [2]. A halflife of about 22 ns was established for the isomer. An additional weak time component, found in the time curves for several transition, may indicate an existence of another high spin isomer with halflife of about 2 ns. Although the isomer is quite weakly populated, an analysis of delayed $\gamma-\gamma$ matrices permitted a very sensitive identification of weak $\gamma$-transitions which are nearly fully obliterated by stronger transitions and $\gamma$-background in the prompt spectra. Several new levels have been identified in this way. The levels populated by the isomeric decay are shown in the level scheme of fig. 1. A few levels above isomer are also indicated. The available experimental data do not allow to conclude which of the levels at 1647 keV and 1743 keV is isomeric one. The spin assignments above the 1647 keV level are only tentative.

The isomer populates primarily the level structure above the already known K,I$^+=9/2^+$ level at 646 keV. Weak decay branches into low-K bands have been also found despite of very high K-forbiddenness of the respective $\gamma$-transitions. The main decay path goes by a strong cascade of 211, 339, 253 and 197 keV transitions to the $9/2^+[514]$ bandhead at 646 keV. Another, much weaker path, goes via 538, 306, 243 and, unseen, 13 keV transitions to the same level. For the most intense, 211 keV $\gamma$-transition an E1 multipolarity was assumed. This is the unique choice consistent with intensity balance considering that the $9/2^+$ level at 646 keV decays by the mixed M1/E2 transitions. Under this assumption a predominant M1 multipolarity has been deduced for the three remaining strongest transitions, 339, 253 and 197 keV, from total intensity balance for the respective levels.
This, together with the coincidence relations, allowed for consistent spin/parity assignments for the level structure feeding the 9/2 state. This structure can be understood in terms of two rotational bands, strongly mixed by Coriolis interaction, built on the 9/2[514] and 11/2[505] Nilsson orbitals. The latter one is for the first time identified in the light Ir isotopes with $A < 185$. The theoretical calculations with the use of the CORIOLIS program [3] support this interpretation. The calculated undisturbed moment of inertia for the rotational band built on the 11/2[505] state is about 30% lower than the respective moment for the 9/2[514]. Considering that moment of inertia is roughly proportional to squared quadrupole deformation parameter, $\beta_2^2$, it indicates about 15% lower quadrupole deformation for the former orbital. This result is in a good agreement with theoretical calculations (see the next contribution to this Annual Report).


2.12 Equilibrium Deformation Calculations for $^{183}$Ir
by W.A.Plöciennik and R.Kaczarowski

Non-collective properties of atomic nuclei can be explained in the framework of the nuclear shell model. The coexistence between oblate and prolate states at low spins and low excitation energies in the neutron-deficient nuclei near closed shell $Z=82$ is well established both experimentally and theoretically. Moreover, different single-particle orbitals in the same nucleus can have quite different deformation parameters in this nuclei region. In this work systematic calculations of potential energy minima have been carried out for various orbitals in several odd-A Ir nuclei with the use of realistic microscopic-macroscopic model. Shell correction approach with the axially deformed Woods-Saxon potential was employed for microscopic part of the model. Standard collection of the W-S potential parameter values, so called universal set, has been used. The macroscopic part is described by Möller-Nix formula with surface density diffuseness taken into account. For the residual particle-particle interaction a standard seniority pairing force with approximate particle number projection was used. The shape of nuclear surface has been defined in terms of standard $\beta_2$, $\beta_4$ and $\beta_6$ parameters. An orbital occupied by non-paired nucleon has been blocked in calculations performed for odd-A nuclei. Energies of local minima in the potential energy surface and corresponding deformation parameters were obtained by performing a multi-parameter minimization of the total energy with respect to $\beta_2$, $\beta_4$ and $\beta_6$ parameters. For more detailed description of the model see ref. [1,2].

![Fig.1](image_url)
The results of calculations for several single-particle proton orbitals in $^{181}$Ir and $^{183}$Ir nuclei show that the absolute minima in the potential energy appear only for prolate shapes of this nuclei. Values of the static quadrupole deformation parameter, $\beta_2$, vary from 0.19 for $[400]1/2^+$ and $[505]11/2^-$ to 0.23 for $[514]9/2^-$. The values of hexadecapole deformation, $\beta_4$, are about -0.04 for all states and values of $\beta_6$ change from -0.007 for $[514]9/2^-$ to 0.006 for the ground state $[541]1/2^+$ orbital. Search for oblate equilibrium minima has also been performed for these nuclei and the respective deformation parameters, $\beta_4$, have been calculated. The secondary oblate minima have been found for all orbitals, however, they lie from 2 to 4 MeV above the prolate ones. The respective values of quadrupole deformation parameter, $\beta_2$, vary from -0.13 for $[505]11/2^-$ to -0.24 for $[514]1/2^+$ while the values of $\beta_4$ and $\beta_6$ parameters are between -0.42 and 0.025 and between 0.003 and 0.03, respectively.

An appearance of well-defined, secondary prolate minimum for the $1/2^+, i_{13/2}+i_{11/2}$ proton state in $^{181}$Ir ($\beta_2=0.31, \beta_4=-0.014, \beta_6=-0.007$) is one of the interesting results. Indeed, a highly deformed rotational band with deduced value of $\beta_2=0.30\pm0.01$ has been recently found in this isotope [3]. It is worth to note that this secondary minimum disappears in $^{183}$Ir. The considerable different quadrupole deformation parameters, $\beta_2=0.19$ and 0.23 were found for the $[505]11/2^-$ and $[514]9/2^-$ orbitals, respectively, also in a good agreement with the recent experimental data [4]. The calculated Woods-Saxon deformation energy, defined as $E_{\text{def}} = E(\beta_2,\beta_4,\beta_6) - E(\beta_2=0,\beta_4,\beta_6=0)$, as a function of quadrupole deformation $\beta_2$ is shown in the figure below for two orbitals of interest. The values of $\beta_2$ and $\beta_6$ parameters were calculated independently for each $\beta_2$ value and correspond to the respective energy minimum in the $\beta_4-\beta_6$ plane.

4. R. Kaczarowski et al, "Decay of the high spin isomer in $^{183}$Ir", this Annual Rep

2.13 Search for Total Lepton Number Violating $\mu^-\text{e}^+$ Conversion on Titanium
by T.Kozlowski (SINDRUM II Coll.)

Within the Standard Model a total lepton number is strictly conserved and a violation of this symmetry would be a direct indication for a new physics. Processes like neutrinoless double $\beta$-decay or charge-changing $\mu(A,Z) - e^+(A,Z-2)$ conversion require complex mechanisms involving two nucleons. Recent estimates of the latter process resulted in values for the branching ratio $B_{\text{ee}}$ of the conversion relative to the normal muon capture $\mu(A,Z) - e^-(A,Z)$ which could be as large as $10^{-12}$ for a supersymmetric model with R-parity breaking [1] or $10^{-14}$ for a left-right symmetric model [2]. Since the nucleus changes from the initial to final state no coherent enhancement of the ground state (GS), as contrary to in the case of $\mu(A,Z) - e^-(A,Z)$, is expected. Usually one assumes a giant resonance (GR) for the daughter nucleus with both a mean energy and a width of 20 MeV resulting in a broad momentum distribution for the emitted positron.

The measurement was done at the $\mu$E1 negative muon beam line at PSI in Villigen, Switzerland with the SINDRUM II spectrometer. Detailed information can be found in [3]. The beam intensity was 12 MHz and the total number of muons stopped in the titanium target during the effective measuring period of 60 days was $(2.95\pm0.13)\times10^{13}$.

No candidate coming from the total lepton number violating $\mu^-\text{e}^+$ conversion was found. The obtained data yielded the new upper limits for the branching ratios:

$$B_{\mu}(Ti^{60}) < 1.7\times10^{-12} \text{ (90\% CL)}$$

$$B_{\mu}(Ti^{60}) < 3.6\times10^{-11} \text{ (90\% CL)}$$

These results improve on our previous best limits [4] by a factor of 2.5.
Meanwhile first data-taking has started at a new dedicated πE5 beam line. Thanks to increased beam intensity the sensitivity is expected to be increased by another factor of ten.


2.14 Magnetic and Higher-Order Effects Studied for K-Shell Excitation of High-Z Projectiles


Recently, the process of K-shell excitation of high-Z H-like ions has attracted particular interest due to its sensitivity to magnetic effects occurring in relativistic collisions [1]. This process is almost equivalent to projectile ionization except that the active electron is excited into a bound state and not into a continuum state of the projectile. By a j-subshell resolved measurement of the ground-state transitions in one- and two-electron high-Z ions, the formation of excited projectile states by Coulomb K-shell excitation can be studied uniquely. First experimental data for K-shell excitation for high-Z ions were found to be in agreement with the predictions of a fully relativistic first-order perturbation approach which considers the Lienard-Wiechert potential without any further approximations [1]. The results of these calculations show that the complete consideration of the magnetic interaction leads to a strong reduction (of almost 30 %) of K-shell excitation cross-sections which can only be explained by a destructive interference between the amplitudes for the electric and the magnetic part of the Lienard-Wiechert interaction.

During one of the last runs performed at the ESR storage ring we applied the same experimental technique for an investigation of K-shell excitation of He-like uranium ions in collisions with gaseous targets [2]. Here, for the first time at the ESR, also heavy targets such as Kr and Xe were used. The main interest focused on a study of the Ka and Kβ x-ray production which essentially reflects the $n,l,j$ - population distribution of the excitation process. For the experiment, the He-like ion species were chosen because here the emission of a Ka photon is a clear signature of an excitation process whereas single electron capture cannot produce such characteristic photons. Moreover, by using particle detectors mounted behind the next dipole magnet, x-rays in coincidence with down-charged (89+) and up-charged (91+) ions were measured in addition. This technique allowed us to study also higher-order effects. Here, one has to consider capture plus excitation (CE), ionization plus excitation (IE), and ionization plus capture (also called transfer ionization) (TI). The signature for CE is the production of Ka photons in coincidence with a change of the projectile charge from 90+ to 89+. In the case of IE, the emission of a characteristic projectile photon is associated with a change of the projectile charge from 90+ to 91+. Therefore, we were able to identify unanimously IE and EC from single excitation and from single electron capture. Only TE cannot be separated directly from the single excitation channel. We like to stress that until now no such data are available for high-Z ions because in standard
single-pass experiments and for solid targets, effects due to multiple collisions cannot be excluded.

In Fig. 1, the x-ray spectra recorded for He-like uranium at 223 MeV/u colliding with Ar, Kr, Xe gaseous targets are shown. As can be observed in the figure, the relative strength of the Ka lines changes considerably with the nuclear charge of the target which cannot be described within first order-perturbation theory. Whereas for low-Z targets (e.g. Ar) the requirements of first order-perturbation theory are fulfilled ($Z_t << Z_p$, where $Z_t$ and $Z_p$ are the nuclear charges of the target and the projectile), transfer ionization may play a considerable role for high-Z targets.


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2.15 Electron Bremsstrahlung in Strong Coulomb Fields Studied at the Internal Gas Target of the ESR Storage Ring

by T. Ludziejewski1, Th. Stohlker1, S. Keller2, H. F. Beyer1, F. Bosch1, C. Kozhuharov1, A. Krämer1, D. Liesen1, P. H. Mokler1, R. H. Pratt1, P. Rymuza, C. D. Shaffer4, Z. Stachura5, P. Swiat6, A. Warczak6

The bremsstrahlung emission has been studied, almost exclusively in conventional electron - atom scattering experiments. It has been established that for low-Z systems, the first-order Born approximation describes fairly well experimental data in a broad range of electron energies. However, for high-Z systems, this model fails, necessitating the use of a non-perturbative approach for the description of electron-electromagnetic field interaction [1].

Here, we report on an experiment carried out at the ESR storage ring, where electron bremsstrahlung was studied for 223.2 MeV/u $^{90+}$ ions impinging on gaseous N$_2$ and Ar targets. In such collisions, electron bremsstrahlung occurs in inverse scattering kinematics, i.e. the target electrons, which are initially at rest, are inelastically scattered from a projectile nucleus giving rise to the production of bremsstrahlung photons. The main advantages of electron bremsstrahlung studies for highly charged heavy-ions colliding with gas-targets over electron-scattering experiments with solid targets are the following:

Fig. 1 Cross sections for bremsstrahlung in collisions of 223.2 MeV/u $^{90+}$ with N$_2$ (left) and Ar (right) gaseous targets.
Inverse scattering kinematics gives an opportunity to use highly charged or even bare high-Z ions. Such systems allow to study bremsstrahlung in the domain of strong Coulomb fields in absence of nuclear charge screening effects.

Gaseous targets reduce the background associated with secondary electron bremsstrahlung as compared to solid target experiments.

The absolute cross-sections for bremsstrahlung were determined by normalizing the bremsstrahlung intensity to that of radiative electron capture to the projectile L-shell (L-REC). The description of the experimental details and data analysis can be found elsewhere [2]. In Fig.1 the doubly differential cross sections are presented for bremsstrahlung in collisions of U\(^{90+}\) ions with N\(_2\) and Ar targets at observation angles of 132\(^\circ\) and 90\(^\circ\), respectively. The experimental data are compared to the predictions of relativistic first-order Born calculations (Bethe-Heitler-Elwert formula, dotted line), and to rigorous relativistic calculations (solid line). The latter take into account the exact scattering electron wave-functions in a static potential, and include the lowest non-zero term in the interaction between the emitted photon field and the electron [3].

The figure shows, that both models underestimate the experimental data for photon energies up to the vicinity of the end-point energy of the bremsstrahlung. However, at the end-point region the "exact" calculations lead to almost quantitative agreement with the experimental data. This energy domain is in particular sensitive to the final-state Coulomb interaction, since high-energy photons originate from collisions in which the final electron kinetic energy is small as compared to the electron-nucleus interaction potential. It demonstrates the importance of a rigorous non-perturbative description of the electron - electromagnetic-field interaction in the domain of strong Coulomb fields.


2.16 Preliminary Results for the Inner Shell Ionization Cross Sections of the Rare Earth Elements in Collisions with HI at Subbarrier Energies

by A.Undynko, D.Chmielewska, P.Kaszyński, M.Ksielniński\(^4\), M.Palacz\(^5\), P.Rymuza, J.Rzadkiewicz, Z.Sujkowski, A.Surowiec\(^2\), T.Czosnyka\(^1\), A.Iwanicki\(^1\), P.Napiórkowski\(^1\), P.Koczoń\(^^6\)

The K-shell ionization process induced by charged particles at energies below the Coulomb barrier has been the subject of the intensive experimental and theoretical studies during the last decades[1-3]. However for the projectiles heavier than α-particles the experimental data are till comparatively poor, in particular for high Z-targets.

The present work is aimed at obtaining the total cross sections for the K-shell ionization induced by \(^{12}\)C ion collisions at projectile energies far below the Coulomb barrier. These can be determined from the measured intensity ratios of the K X-ray and the 2\(^{+}-0^{+}\) transitions in some rotational nuclei. According to the expression[1]:

\[
\sigma_{IR} = \frac{I_{12} - \omega_k (I' a_k)_{12} - \omega_k (I' a_k)_{14}}{\omega_k (I' (1 + \omega_{ke})}_{12} - \omega_k (I' (1 + \omega_{ke})}_{14}) \sigma_{CE}(2^{+})
\]

where \(\sigma_{CE}\) is the nuclear CE cross sections (Coulomb excitation) and \(I^{\pm}\) and \(I'\) are measured K x-ray and γ-ray 2\(^{+}-0^{+}\) and 4\(^{+}-2^{+}\) intensities of the respective transitions, correct for detector efficiency and the angular distributions for the γ-rays. The \(\sigma_{CE}\) values are precisely calculable as long as the projectiles energy is well under the Coulomb barrier of the system. \(\omega_{ke}\) is the fluorescence yield of the target element, and \(a_k\) and \(\alpha\) are the K and total internal conversion coefficients, respectively.

The experiment was performed at the U200 Cyclotron of the Warsaw University Heavy Ion Laboratory. The Coulomb Excitation set-up CUDAC together with a three high-purity germanium detectors for registration
of X-rays and γ-rays were used. To reduce the effect of γ-ray angular anisotropy, the X-ray detector with active diameter 2.5 cm and 1.3 cm thick was placed at the angle 45° relative to the beam direction. The 55° location was not available. The other two γ-detectors were located at 140° and 144°, respectively.

The computer code GOSIA[4] was used in the calculations. There are two theories with which the results are compared. The first one (RSCA) is the semiclassical approximation in the United Atom limit and the second is the PWBA with binding, polarization, Coulomb deflection, and relativistic corrections. On Fig.1 the experimental and theoretical K-shell ionization cross sections as function of the reduced velocity \( \eta_k \) for the projectiles with energy 38 MeV are presented. For this projectile energy (about 30% of the safe bombarding energy for all used combinations projectile - target) the results are in good agreement with theory. For the energy 52 MeV there is no such an accordance, presumable of the onset of the interference Coulomb with the nuclear forces. Therefore an appropriate theoretical mechanism should be used to deduce the \( \sigma_{K}\text{ values} \) from the experimental data.

![Diagram](image)

Fig.1 The experimental and theoretical K-shell ionization cross sections depending on the reduced velocity \( \eta_k = (V_1/V_2)^2 \).

References:

2.17 Activation Cross Sections for Reactions Induced by 14.7 MeV Neutrons on Natural Calcium and Enriched \(^{44}\text{Ca}\) Targets

by E. Betak\(^1\), E. Droste, S. Mikolajewski, W. Ratynski, E. Rurarz, T. Kempisty\(^2\), S. Raman\(^3\)

Using 14.7 MeV neutrons and γ-ray spectroscopy with HPGe detectors, the activation cross sections have been measured for the following nuclear reaction: (i) \(^{44}\text{Ca}(n,p)^{44}\text{K}\), \(\sigma = (39 \pm 4)\text{mb} \), (ii) \(^{44}\text{Ca}(n,\gamma)^{45}\text{K}\), \(\sigma = (3.0 \pm 0.3)\text{mb} \), (iii) \(^{44}\text{Ca}(n,\gamma)^{45}\text{Ar}\), \(\sigma = (31 \pm 3)\text{mb} \), (iv) \(^{44}\text{Ca}(n,\gamma)^{45}\text{K}\), \(\sigma = (138 \pm 12)\text{mb} \), (v) \(^{44}\text{Ca}(n,\gamma)^{46}\text{K}\), \(\sigma = (90 \pm 9)\text{mb} \), and (vi) \(^{44}\text{Ca}(n,2n)^{47}\text{Ca}\), \(\sigma = (613 \pm 60)\text{mb} \). A 98.6% enriched \(^{44}\text{Ca}\) target was used for reactions (i)-(iii) and a natural calcium target for reactions (iv)-(vi). The cross sections listed above have been compared with some earlier published experimental values and with some results of calculations. The latter includes those based on semiempirical formulas and those given by the pre-equilibrium plus compound-nucleus code GNASH. When applied to the reactions (i),(iv),(v), and (vi), this code gives cross-section values that are consistently above our measured values.

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2.18 New Experimental Data on Inelastic Scattering of 26 MeV Protons to the Continuum

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

Our previous measurements of the energy spectra of the protons inelastically scattered to the continuum carried out for the $^{93}$Nb (p,p') $^{93}$Nb* reaction [1], have proved their usefulness as tests of the present preequilibrium models. Such models, should be able to describe simultaneously (n,n') (p,p') and (p,n) reactions on the same target and at about the same incident energy. Our previous measurements showed, however, that even for such target like $^{93}$Nb, for which many experimental data already exist and which is the target nucleus commonly employed in theoretical calculations, some of the implantations of the FKK preequilibrium models do not fulfill this consistency condition for all three reaction channels in consideration. It was shown that to get reasonably consistent results one must use the two-fermion version of the FKK theory instead of the routinely used one-fermion version. Also, the problem of the collective sum rule exhausting in the preequilibrium reactions, which at present seems to be one of the most important topics in the understanding of preequilibrium reactions, requires comparisons of different reactions with different degrees of the collectivity. The applicability domains of various preequilibrium models are not clear either. In particular, the number of the reaction steps participating in the MSD chain, as well as the ratio of MSD and MSC contributions are still being discussed. It is believed that to elucidate these points in the energy region about 30 MeV more data for for (p,p') reactions for targets much lighter than the most frequently analysed should be very useful.

For this purpose new experimental data were obtained for continuous energy spectra and angular distributions of protons emitted in the inelastic scattering of 26 MeV protons on natural Ni and $^{25}$Mg targets. Energy spectra were measured in the range from 3 to 25 MeV and angular distributions from 25 to 125 degrees in steps of 5 degrees. Some of the experimental data are shown in Fig. 1 and Fig. 2.

Detailed theoretical analysis of energy spectra and angular distributions using available versions of preequilibrium codes based on the FKK model is in progress.

2.19 Modification of the Optical Properties of some YAG Crystals Doped with Rare-Earth Elements by Irradiation with 26 MeV Protons.
by J. Wojtkowska, Z. Moroz and S. Kaczmarek

In collaboration with Military Technical University in Warsaw and the Institute of the Electronic Technology and Materials in Warsaw the proton beam from C-30 compact cyclotron was used to study radiation induced modifications of optical properties of some crystals used in the production of laser radiators.

In particular samples of YAG, Er:YAG, Nd:YAG, Ce,Nd:YAG, Er:YAP and Dy:SiLaG₃O₇ were used. The proton fluences varied from 10¹² to 10¹⁶ particles/cm². These modifications were studied by looking at the additional absorption spectra of the crystals in the wavelength range from about 230 to 1100 nm, as and at the luminescence and thermoluminescence spectra under various conditions of annealing of the samples (in oxygenized or reductive atmospheres, at different temperatures etc.). Significant changes of the optical properties of the samples were registered. Some of the color centers in the crystals responsible for the observed optical changes were identified. The results were compared with those obtained during gamma (⁶⁰Co) and electron (1 MeV) irradiations.

In this way, by proton irradiation, an additional independent factor has been included to the set of methods used to study the radiation induced modifications of crystals, some of which are used in the laser technique. The ratio of energy losses for ionization in the crystal and for knock-out of ions from their crystal sites is different for protons and for electrons or fast neutrons. This provides a very interesting comparison of proton induced effects and those due to electron or fast neutron bombardment.

Knowledge of the proton induced effects, except for its use in the physics of the radiation induced production of the color centers or their disappearance, has a direct practical importance for construction of some optical devices irradiated by protons e.g. installed in space rockets crossing van Allen belts or, in space missions, subjected to a long term bombardment by cosmic rays.

As an example proton induced additional absorption spectra for Ce,Nd:YAG are shown in Fig.1. Detailed analysis of various observed effects was published elsewhere [1] and is still in progress.


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2.20 Response of 50 μm Thick Self-Biased Silicon Strip Detector for Light Charged Particles
by A. Kordyasz and J. Wojtkowska

Self-biased silicon epitaxial detectors were first developed by Kim at al [1]. The aim of our work was to test this type of the detector as a stripped ΔE-E telescope. The ΔE strip detector was made using a silicon epitaxial n⁺-n structure produced in the Institute of Electronic Materials Technology in Warsaw. The high resistivity (1800 Ωcm) n-type epitaxial layer 50 μm thick was deposited on the 250 μm thick n⁺ substrate of 0.01 Ωcm resistivity, which was then partially removed by anodic dissolution [2]. The details of ΔE technology will be described separately [3]. The large difference of carriers concentration between substrate (n⁺ = 5*10¹⁸ cm⁻³) and epitaxial layer (n = 3.5*10¹² cm⁻³) creates the built-in potential defined as:

\[ V = - \frac{kT}{q} \ln \left( \frac{n^+}{n} \right) \]

where \( k \) is the Boltzmann constant, \( T \) is absolute temperature and \( q \) is electron charge. From this equation the built-in electric field on interface n⁺ - n is 720 V/cm. This pseudo-potential replaces an external bias voltage so that charge preamplifiers can be simplified. A ΔE 50 μm thick detector with spiral (right bent) strips and the hole for the beam, was followed by a 450 μm thick E detector with spiral strips bent to the left. The intersections of ΔE and E strips create 'local' ΔE-E telescopes. This type of the detector is useful for light charged particles identification as well as for the measurement of their position. In Fig.1 the shape of ΔE strips and an intersection of strips for a pair of detectors is shown.

The 2" diameter ΔE-E telescope was tested on the 22 MeV proton beam from the C-30 cyclotron in IPJ, Świerk. As a source of different charge particles the reaction p+⁹Be was chosen. The particles from the ⁹Be(p,p'), ⁹Be(p,d)⁸Be, ⁹Be(p,t)⁷Be, ⁹Be(p,a)⁶Li and some break-up reactions are emitted in an energy range broad enough for ΔE-E coincidences. The telescope was placed at 90° to the proton beam. The particles emitted from the target were collimated by a thick Al diaphragm of 3 mm diameter, so that only one pair of ΔE-E strips was illuminated. The ΔE-E hyperbolas corresponding to p, d, t and α particles are shown in Fig.2. A good separation of hydrogen isotopes was obtained.

Fig.1 (a) Spiral strip geometry of ΔE and (b) intersection of strips for ΔE-E detectors.

Fig.2 Two-dimensional ΔE vs E spectrum.


¹) Heavy Ion Laboratory, University of Warsaw
2.21 Graphite Tubular Ionizer as a Negative Carbon Cluster Ion Source
by T. Kozlowski and A. Piotrowski

There is a growing theoretical and experimental interest in carbon clusters. They play a significant role in processes ranging from catalysis and combustion to interstellar opacity (some of these species can be abundant in the space).

![Graphite Ionizer](image)

\[
\frac{(C_{\text{tot}})}{100} = 1 \times 10^{-8} 
\]

Fig.1 The temperature dependence of the anion cluster currents.

Negatively ionized clusters are usually produced by a laser vaporization or in standard sputter ion sources. In our studies [1] of negative ion emission from a tubular ionizer we replaced the Ta or W tube by a tube made of graphite and observed negative carbon clusters (up to C_{10} - the anion fullerenes have not been observed). This tube with an inner diameter of 3 mm, outer one of 5 mm and a length of 30 mm was inserted into a thin walled Ta tube.

Fig.1 shows the currents of intense singly charged anion clusters as a function of the inverse of the ionizer temperature. One can see that they are proportional to the total number of C atoms emitted from the tube orifice calculated from the total evaporation rate [2] and multiplied by elementary charge, which is shown in the same figure (dotted line). In Fig.2 the yields (defined as the ratio of the anion current to this total atom "current") of all observed negative clusters at 2450 K (1/kT=4.73) are presented.

Vaporization of negative C clusters from a graphite surface was observed already in 1954 [3], but our results show that the tubular geometry strongly enhances the yields. We found that these yields are increased by two orders of magnitude if potassium vapour of some precisely defined pressure is additionally present in the ionizer as it was observed before by us for other negative ions [1]. Then approximately 20% of all atoms are emitted in a form of anion clusters.

Thus this kind of ion source can be useful in further studies of the anion clusters and can be applied as an ion source of radioactive carbon beams for the RBF (Radioactive Beam Facility).


2.22 Monitoring of the Ground-Level Air Pollution in the Vicinity of Swierk in 1997
by E. Droste, M. Matul, S. Mikolajewski, B. Myslek-Laurikainen, H. Trzaskowska

The ground-level radioactive air pollutions have been investigated since 1991 using the high volume aerosol sampling station type ASS-500 which is situated 6 km West of Swierk at the S. Kalinowski Geophysical Observatory of the Institute of Geophysics, Polish Academy of Science, Swider near Otwock.
The concentration of radioactive isotopes in ground level air at the Świdr sampling station.

![Graph](image)

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

The monitoring network of the ASS-500 stations in Poland consisted of 11 stations in 1997. This network is supervised by the Central Laboratory of Nuclear Protection and State Inspection of Environmental Protection. The weekly reports are spread through Internet and continuous, systematical exchange of data are provided with most of European countries. The sampling and measurement procedures were described in IPJ(SINS) Annual Report 1992, 1993. In 1997 our station did not register any accidental events or random radioactivity release which were seen in Finland, Sweden and Northern Poland. As every year an airborne \(^{7}\)Be is the dominating radionuclide in the average 2798\(\mu\)Bq/m\(^3\) with max 6200\(\mu\)Bq/m\(^3\) and min 1060\(\mu\)Bq/m\(^3\). The \(^{210}\)Pb is the decay product of the ground exhalated Rn and some amount is the remnant of some nuclear accidents in the atmosphere which took part in the past. The average value was 398\(\mu\)Bq/m\(^3\) with respect to max 1114\(\mu\)Bq/m\(^3\) and min 140\(\mu\)Bq/m\(^3\). The presence of the most common component of the soil \(^{40}\)K is in the level 2-3 orders of magnitude lower and does not show seasonal changing. The \(^{137}\)Cs which is mainly of Chernobyl origin is on the level of several \(\mu\)Bq/m\(^3\). The average dust concentration was 39.3 \(\mu g/m^3\), in winter 42.3 \(\mu g/m^3\), in summer 35.9\(\mu g/m^3\).

![Graph](image)

**Fig.2** The dust level in 1991-1997 in \(\mu g/m^3\) for winter and summer sampling seasons.
2.23 Accumulation of Heavy Metals and Radionuclides in the Odra River Stream Sediments
by E.Droste, M.Matul, B.Myslek-Laurikainen, I.Bojakowska, G.Sokolowska, T.Gliwicz

Great loads of heavy metals and radionuclides together with other contaminations are brought into the Odra river and its tributaries by industrial waste water and municipal sewages, and surface run-off as well. Most of the heavy metal loads carried to the river are accumulated in the river bed sediments as the effect of self-purification processes in the water. 153 samples of the Odra river sediments were collected every 5 km along the course and 103 samples of its tributaries sediments were taken near their mouths. The Ag, As, Ba, Cd, Cu, Cr, Co, Ni, Pb, Sr, V, Ti and Zn concentrations were determined by using the inductively coupled plasma emission spectrometry (ICP-ES). For Hg analysis the method of atomic absorption spectrometry with the cool vapours technique were used. The concentration of U, Cs, Th were determined with gamma spectrometry. Heavy metals concentration in the upper and the middle course of the Odra river sediments exceeds many times the background values for these elements in river sediments in Poland.

The sediments of the Odra river in its lower course, below the mouth of the Warta tributary contain lower amounts of heavy metals. High concentrations of As, Ba, Cu, Hg, Pb and Zn were found in the sediments of the upper and the middle course of the Odra river. The concentration of heavy metals in the Odra river sediments are the result of an impact of waste water discharge from coal mines (barium), from mines and processing of the lead and zinc ores (zinc, lead), copper deposits (copper, arsenic, lead, zinc) also of the industrial waste water discharge from chemical industry (mercury). The stream sediments of the upper and middle Odra river contain higher amounts of uranium, cesium and thorium than the stream sediments of the lower Odra river. Higher concentrations of uranium are noticed in the sediments of the Odra river tributaries such as Psina river, Pśeńica river, Śłąza river, Rudzica river and Rów Główny river, thorium- instream sediments of Olza river, Łęgoń river, Psina river, Czarnka river and Rów Główny river, and cesium - in sediments of Mala Panew river, Łęgoń II river, Dzielnica river and Czarnka river. All sampling work of this project was done before the summer flood in 1997 and one can expect the dramatical changes of heavy metals and radioactive elements distribution as a result of water movement during and after flood. An example of the $^{137}$Cs distribution is shown in Fig. 1.

![Fig.1 The $^{137}$Cs concentration in Bq/kg in water sediments in Odra river.](image)

2.24 Contribution to the Projects of the Flue Gas Cleaning from NO$_x$ and SO$_x$ Contaminations Using Electron Irradiation
by M.Sowiński, Z.Moroz, M.Kowalski, J.Licki, R.Kupczak

In 1997 our Institute together with Institute of Nuclear Chemistry and Technology, BP "Proatom" and BP "Energoprojekt" contributed to the development of technical project for the industrial installation planned for EPS "Pomorzany".
In particular, studies of the computerized monitoring and control system were completed. The final report establishes the main requirements for the measuring devices, for the localization of various measuring points, proposes the methods, which should be applied for measurement of various complex process parameters, both continuous and periodical, and methods of the data storage, processing and presentation (see fig.). It takes into account not only industrial but also demonstrative functions of the projected installation.

The data acquisition system will measure:

i) the SO$_2$, NO$_x$, CO$_2$, O$_2$ and dust contaminations in four measuring places,
ii) the NH$_3$ contamination in one place,
iii) the flue gas flows in three places,
iv) the flue gas humidity in 2 measuring places,
v) the temperature and pressure of the gas in many places and
vi) the electron dose for all four accelerators.

Also measurements of the ammonia level, ammonia water, water steam pressure and compressed air pressure are required. Altogether, the monitoring system includes data taking of various analogue quantities in about 200 measuring points and of bistable signals in about 300 measuring points. It contains also about 20 systems of the automatic regulation. Analogue or digital signals from these points will be sent to a system of modular processors.

The selected measuring devices fulfill high precision requirements (2-5%), accessibility (> 95 %), short response time (< 60 s). The instruments should be dedicated to work in severe environmental conditions (high humidity, low temperatures, presence of acids and salts). The main goal of this system is to assure proper values of the following processing parameters: electron dose, flows of water, steam, ammonia and ammonia water and compressed air. Both feedback and feedforward methods will be applied in the control system.

The corresponding software should assure proper real-time presentation of the status of the installation as well as on line automatization of a great majority of functions of the automatic control.

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2) ELLEK, Warsaw

2.25 Concept of the Demonstration and Simulation System
by M. Sowiński, Z. Moroz, J. Boużyk

The installation for cleaning of the flue gas from NO$_x$ and SO$_2$ contaminations by electron irradiation planned to be built in Pomorzany Electric Power Station has still experimental character, which will require many further studies on the running installation. One of very important goals which is expected to be achieved during the exploitation is a final verification of the process of the radiative cleaning on full industrial scale and its technical optimization. During the run of the installation the Pomorzany EPS is expected to host many visitors e.g. experts from foreign institutes working on this subject or other guests from the member countries of the IAEA.
Therefore a proposal has arisen to build in the EPS Pomorzany a special computer subsystem working in parallel with the main operating system, however fully separated, used for information and teaching of visitors, without disturbing the work of the operators of the installation. Visitors should have maximum insight into the details of running process however without a possibility to influence actively the process itself.

Also, there are two situations when a numerical simulation of the process is desirable. They are: 1) necessity to recalculate the input parameters of the installation when it is known in advance that some parts of the installations should be switched-off or in the case of an emergency shut down of some elements of the installation (e.g. one accelerator), and 2) training of the personnel to operate the installation, which can be made on a system numerically simulating the work of the installation.

In other institutes various dynamical models of the radiation cleaning are worked out and they are expected to be tested in the EPS Pomorzany. It is very desirable to have a possibility to install such theoretical models in the computer in such a way, that the impact of different parameters contained in these models can be studied directly by comparison with the output measured in the running installation.

For this purpose a detailed concept of such demonstration/simulation program was worked out by us and some of more critical details were programmed and tested on a standard PC.

Minimum hardware configuration is the following: a dedicated computer connected to the main computer of the operating system and a large display screen identical with that installed in the main operation room. If necessary, an external standard PC computer can be connected as well.

It is assumed that the system has the following options:

1) Display of the status of the running installation. This will be done by a direct parallel connection of the large display screen to the main manager computer in the operation room. On request, various parameters of the installation can be shown in detail on the same screen.

2) Simulation of the installation run. For this purpose a special program simulating the irradiation process in the reaction chamber has been developed and implanted into a more general scheme, in which an interplay of three independent cleaning lines takes place. Two of these lines contain their own reaction chambers with two accelerators installed. The third line, parallel with the two former ones, sends some part of the uncleaned gas to the common point and the mixture of these three streams of gas is finally sent to the chimney. The main simulating routine is an extended implementation of the theoretical model which was developed previously and was published elsewhere [1]. Special acquisition loop installed in the demonstration computer asks every minute for the data produced partly by the running installation and partly by the simulation program. The data of such simulated process are displayed on the main display screen in exactly the same way and in the same graphical mode as in the real installation on the main operator screen. In this way various running situation may be simulated and presented on the screen.

3) Off-line model calculations. When certain bigger changes in the working installation are anticipated to occur, they can be modelled and optimized, to instruct operator on desirable settings of various process parameters. For this purpose a special program has been developed. Its operation in the form of a dialogue between operator and computer enables to calculate necessary beam currents of the accelerators for differently chosen main process parameters, namely: ratio of the beam currents, gas temperature, humidity, amount of ammonia and flow of the gas through the reaction chamber.

All these options were programmed in a special experimental PC program, which serves for further studies of the details of the simulation system.


### 2.26 Construction and Operation Principle of the Electron Beam Monitor


The device is dedicated for the measurements of the electron beam current inside the processing chamber in conditions of normal exploitation of the installation for elimination of SO and NO, with the electron beam. It is predicted to work in dusty, wet and contaminated atmosphere, with aggressive substances, like ammonia, ozone etc. present. It consists of the following components:

- Movable protecting tube housing the beam measuring probe
- Driving unit
- Ball valve with pneumatic driving system
— System of orifices and rotating and locking mechanism
— Electron charge meter
— Manual control unit
— Programmable steering unit for computer control

Fig. 1 presents the general scheme of the device. In the initial rest position the tube with the charge measuring probe (1) placed at its end is housed in the protecting tube in the position parallel to the wall of the process chamber. The ball valve (6) is closed and the lock (9), which blocks the position of the protecting tube, is released. When the start of measurement is ordered, the protecting tube is rotated by 90 degrees and locked in the position perpendicular to the chamber axis. The ball valve (6) is opened by the pneumatic cylinder (8). This position being signalled by the limit switch allows the run of the driving mechanism (7) which outriggers the tube with the measuring probe to its working position. In this position, the measuring probe is placed in the geometrical centre of the process chamber.

During the measuring phase, the electron charge collected on the probe is measured by means of the electronic charge integrator and the output signal is converted to a variable frequency digital train of pulses counted during 1 second by the scaling unit and subsequently sent to the register of the integrator.

The accuracy of the measurement of the charge dependent frequency of the signals is about 2%. After performing the suitable calibration procedure, which should be periodically carried out, the corresponding absorbed electron dose can be estimated from this measurement. During this phase the stream of air under over pressure of about 1 atmosphere is blowing against the measuring probe to protect it from dust.

After the measurement is completed, the pneumatic cylinder is activated, which withdraws the arm with the measuring probe back to the protecting tube and closes the ball valve. The blocking mechanism of the position is released and the whole assembly is turned back by 90 degrees to its rest position.

All the positions of the arm with the measuring probe are signalled by a suitable system of light signals. Electric blocking devices protect against an incidental start of the driving mechanisms, what can cause a damage of the elements.

The mechanical construction of the device allows relatively easy and fast disassembling of the instrument for periodical maintenance or service.

1) Institute of Atomic Energy, Świerk
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M. Palacz, ..., Z. Sujkowski, et al.

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Z. Sujkowski

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LEVEL STRUCTURES OF $^{97,99}$Ru AT HIGH ANGULAR MOMENTUM
B. Kharraya,..., R. Kaczarowski

SOME PRACTICAL DATA ON THE FIRST TOWNESECONDS COEFFICIENT OF ORGANIC VAPOUR IN AVALANCHE COUNTERS
J. Sernicki

STUDY OF NEGATIVE ION EMISSION FROM A TUBULAR IONIZER
A. Piotrowski, T. Kozłowski, M. Laskus

RADIATION INDUCED RECHARGING OF CERIUM IONS IN Nb, Ce; Y$_3$Al$_2$O$_7$ SINGLE CRYSTALS
S. Kaczmarek,..., Z. Moroz, et al.

RADIATION DEFECTS IN SrLaGa$_3$O$_7$ CRYSTALS DOPED WITH RARE-EARTH ELEMENTS
S. Kaczmarek,..., Z. Moroz, et al.

MASS DRIFT IN STRONGLY DAMPED REACTIONS AS A TOOL FOR STUDYING NUCLEAR DISSIPATION
J. Blocki, J. Wilczyński

ANALYSIS OF PRE-SCISSION NEUTRON MULTIPLECITIES IN TERMS OF THE STATISTICAL MODEL WITH KRAMERS DISSIPATIVE FISSION

A SEARCH FOR A "NEW PHYSICS" IN LEPTON FLAVOUR VIOLATION PROCESSES
T. Kozłowski

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S. Kaczmarek, ..., Z. Moroz, et al.
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E. Rurarz

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Z. Sujkowski
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PARTICIPATION IN CONFERENCES AND WORKSHOPS

COMPRESSIBILITY OF NUCLEAR MATTER, NUCLEAR AND ASTROPHYSICAL EVIDENCE
Z. Sujkowski (invited talk)
8th Int. Conf. on Nuclear Reaction Mechanisms, Varenna, June 9-14, 1997

RADIATIVE AND NONRADIATIVE ELECTRON CAPTURE BY RELATIVISTIC *He ++ IONS
D. Chmielewska (invited talk)
8th Int. Conf. on Nuclear Reaction Mechanisms, Varenna, June 9-14, 1997

A SEARCH FOR A "NEW PHYSICS" IN LEPTON FLAVOUR VIOLATION PROCESSES
T. Kozłowski (invited talk)
XXV Mazurian Lakes School of Physics, Piaski, Poland, Aug. 1997

REVIEW AND EXPERIENCE OF THE CONTROL AND MONITORING SYSTEM OF THE KAWECZYŃ PILOT PILOT PLANT
M. Sowiński, (invited talk)

PROCESS AND ENVIRONMENT MONITORING SYSTEM,
M. Sowiński, (invited talk)

CHAOS STUDY BY THE LYAPUNOV METHOD
J. Blocki (oral presentation)
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MASS DRIFT IN STRONGLY DAMPED REACTIONS AS A TOOL FOR STUDYING NUCLEAR DISSIPATION
J. Wilczyński (oral presentation)
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A. Marcinkowski, B. Mariński, Z. Moroz, J. Wojtkowska (presented by A. Marcinkowski)
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J. Block, J. Wilczyński (poster)
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K. Siwek-Wilczynska, J. Krzyczkowski, J. Wilczyński, R.H. Siemssen, H.W. Wilschut (poster)
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NUCLEAR VISCOSITY DETERMINED FROM PRE-SCISSION NEUTRON MULTIPlicITIES IN FUSION-FISSION REACTIONS
K. Siwek-Wilczynska,..., J. Wilczyński et al. (poster)
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STRONG ALIGNMENT OBSERVED FOR THE TIME-REVERSED TWO-STEP PHOTOIONIZATION PROCESS
Th. Stoehlker,..., T. Ludziejewski, P. Rymuza, et al. (poster)
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PROJECTILE EXCITATION STUDIES FOR HIGH-Z H- AND He-LIKE IONS
Th. Stoehlker,..., T. Ludziejewski, P. Rymuza, et al. (poster)
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NON-DIPOLAR EFFECTS IN RELATIVISTIC ION-ATOM COLLISIONS
Th. Stoehlker,..., T. Ludziejewski, P. Rymuza, et al. (poster)
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TOTAL AND SUBSHELL DIFFERENTIAL CROSS-SECTIONS MEASURED FOR ELECTRON CAPTURE INTO DECELERATED BARE URANIUM IONS
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STRONG ALIGNMENT OBSERVED FOR THE TIME-REVERSED TWO-STEP PHOTOIONIZATION PROCESS
Th. Stoehlker,..., T. Ludziejewski, P. Rymuza, et al. (poster)
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P. Rymuza,..., T. Ludziejewski, et al. (poster)
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15th Mazurian Lakes School of Physics, Piaski, August 1997

ELECTRON BREMSSTRAHLUNG FOR U²⁶⁺ IMPACT ON GAS TARGETS
T. Ludziejewski,..., P. Rymuza et al. (poster)
15th Mazurian Lakes School of Physics, Piaski, August 1997
LECTURES, COURSES AND EXTERNAL SEMINARS

PRINCIPLES OF SPACE SPECTROSCOPY USING NUCLEAR DETECTORS
Z. Moroz
Institute of Experimental Physics, University of Warsaw, 17. 10. 1997

K-SHELL IONIZATION WITH HEAVY IONS AT ENERGIES CLOSE TO THE COULOMB BARRIER
P. Rymuza
Heavy Ion Laboratory, University of Warsaw, 20. 03. 1997

CYCLOTRON C-30 AT DEPT. OF NUCLEAR SPECTROSCOPY, IPJ - POSSIBILITIES OF APPLICATIONS
R. Kaczarowski
Institute of Physics, Technical University of Warsaw, 15. 01. 1997

MISTERIES OF HIGH SPIN ISOMERS - ARE THEY ANY WAY RELATED TO SUPERDEFORMED STATES AT ATOMIC NUCLEI?
R. Kaczarowski
Institute of Experimental Physics, University of Warsaw, 12. 03. 1997

STUDY OF NUCLEAR SHAPES
R. Kaczarowski
Institute of Experimental Physics, University of Warsaw, 12. 12. 1997

DETECTION AND SPECTROMETRY OF NUCLEAR RADIATION (lectures)
Z. Moroz, M. Mostyński, Z. Sujkowski
University of Warsaw, Faculty of Physics, II semester 1996-1997

METHODS AND MEASUREMENTS TECHNIQUES IN ENVIRONMENTAL RESEARCH (lectures)
B. Myslek-Laurikainen
University of Warsaw, Faculty of Physics - Environmental Physics Section (14 h)

MEDICAL PHYSICS, RADIOMETRY AND RADIOECOLOGY (lectures)
B. Myslek-Laurikainen
University of Warsaw, Faculty of Physics - Environmental Physics Section (30 h)
PARTICIPATION IN CONFERENCE COMMITTEES, SESSION CHAIRMEN

25th MAZURIAN LAKES SCHOOL OF PHYSICS, PIASKI, AUGUST 1997
Z. Sujkowski (Chairman of the Organizing Committee)
D. Chmielewska (Scientific Secretary)

INTERNATIONAL SYMPOSIUM ON EXOTIC NUCLEAR SHAPES, DEBRECEN, MAJ 12-17, 1997
Z. Sujkowski (Member of the International Advisory Board)

8th INT. CONF. ON NUCLEAR REACTION MECHANISMS, VARENA, JUNE 9-14, 1997
Z. Sujkowski (chairman of session)

6th INT. CONF. ON NUCLEUS-NUCLEUS COLLISIONS, GATLINBURG, USA, JUNE 1997
J. Wilczyński (chairman of session)

PERSONNEL

Research scientists
Jan Biocki, Contract Professor
Danuta Chmielewska, Dr. - Scientific Secretary of the Institute
Rościsław Kazarowski, Assoc. Professor
Tadeusz Kozłowski, Dr.
Tomasz Łudzielewski, Dr., on leave
Bogumiła Mystek-Laurikainen, Dr.
Zbigniew Moroz, Contract Professor
Marcin Palacz, Dr., till Nov.31.
Antoni Piotrowski, Assoc. Professor
Weronika Płoćciennik, Dr.
Zygmunt Preibisz, Dr., since March 13, 1/2
Wojciech Ratyński, Professor
Edward Rurarz, Dr., since April 1, 1/2
Piotr Rymuza, Dr.
Mieczysław Sowiński, Assoc. Professor
Ziemowid Sujkowski, Professor - Director of the Institute
Janusz Wilczyński, Professor
Jolanta Wojtkowska, Dr., since March 1, 3/4

PhD Students
Oleg Mazonka, MSc.
Jacek Rzadkiewicz, MSc.
Alexander Undynko, MSc.

Technical and administrative staff
Zofia Bogusławska, since Oct.1, 1/2
Ewa Droste, MSc.
Kazimierz Głębicki
Maciej Kisieliński, Eng. 1/5
Marek Kowalski
Marian Laskus
Stefan Mikołajewski
Maria Matul, MSc.
Tomasz Pławiński, Eng., on leave
Jan Sernicki, Dr.
Alicja Surowiec, Dr., on leave
Halina Trzaskowska, 3/4
Overview

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

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

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

- evidence that the energy resolution of scintillation detectors with avalanche photodiode light readout is better than that measured with photomultipliers,
- a study of new Ce doped scintillators in an application to the positron emission tomography (PET),
- development of front-end electronics for neutron detectors in the EUROBALL project,
- development of electronics and its implantation to the data acquisition system in NA48 experiment at CERN,
- development of scintillation detectors for a spectrometry equipment.

The scientific activities of the Department were summarized in six published papers and three papers in press. (All in IEEE Trans. on Nucl. Sci. and Nucl. Instr. and Meth.) Moreover, our scientists presented two contributions at international conferences, one of them at the IEEE Nucl. Sci. Symp. in Albuquerque, USA. One of our colleagues has completed his PhD thesis and submitted to the Scientific Council of our Institute.

The construction activity of the Department should be pointed out. The complex front-end electronics for EUROBALL neutron detectors is in the last phase of development. The electronics for a data acquisition system in the NA48 experiment was successfully implanted and the prototypes of electronics for SPHERE experiment in JINR Dubna was delivered.

The technical support of the Department for the Institute covers a large undertaking such as the project of the local network for the computer system in the Institute and a number of hardware and software consultancies.

The Department was involved in scientific collaborations with a number of international centers. Among them are CERN, FZ Rossendorf, Royal Institute of Technology in Stockholm, GSI Darmstadt, Boston University, JINR in Dubna and EUROBALL collaboration. The collaboration with Advanced Photonix, Inc. in Camarillo, USA helps us get unique avalanche photodiodes and to carry out a study of the future of scintillation detectors.
3.1 Energy Resolution of Scintillation Detectors Readout with Large Area Avalanche Photodiodes and Photomultipliers

by M. Moszyński, M. Kapusta, D. Wolski, M. Szawlowski\(^1\), W. Klamra\(^2\),

The energy resolution of small NaI(Tl), CsI(Tl), BGO, GSO, YAP and LSO crystals has been studied using 16 mm diameter large area avalanche photodiodes (LAAPD) produced recently by Advanced Photonix, Inc. and a Philips XP2020Q photomultiplier. The best result of 4.8% for 662 keV γ-rays from a \(^{137}\)Cs source was obtained with a 9 mm in diameter by 9 mm high CsI(Tl) scintillator coupled to an LAAPD, see Fig. 1. The energy resolutions measured with all the crystals coupled to the LAAPDs are comparable to, or significantly better than, those obtained with the photomultiplier, see Table 1. At energies above 100 keV, the energy resolution measured with the majority of crystals and the LAAPD was weakly affected by the photodiode noise contribution. Measuring the number of primary electron-hole pairs produced in the LAAPD and photoelectrons in the photomultiplier, as well as the noise contribution of the LAAPD, allowed a quantitative discussion of the results. The intrinsic resolution of the crystals was determined, reflecting the contribution of the scintillator to the measured energy resolution. The advantages and limitations of LAAPDs in energy spectrometry with scintillation detectors are also discussed.

Table 1
Energy resolution for 662 keV γ-rays from a \(^{137}\)Cs source measured with the LAAPD and XP2020Q PMT

<table>
<thead>
<tr>
<th>Crystal</th>
<th>LAAPD</th>
<th>PMT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\tau) [μs]</td>
<td>(\Delta E/E) [%]</td>
</tr>
<tr>
<td>CsI(Tl)</td>
<td>6</td>
<td>4.8±0.14</td>
</tr>
<tr>
<td>NaI(Tl)</td>
<td>1</td>
<td>6.5±0.19</td>
</tr>
<tr>
<td>BGO</td>
<td>0.75</td>
<td>7.8±0.23</td>
</tr>
<tr>
<td>GSO</td>
<td>0.25</td>
<td>7.4±0.22</td>
</tr>
<tr>
<td>LSO</td>
<td>0.25</td>
<td>10.6±0.31</td>
</tr>
<tr>
<td>YAP</td>
<td>0.25</td>
<td>5.5±0.16</td>
</tr>
</tbody>
</table>

IEEE Trans. on Nucl. Sci. in press

\(^1\) Advanced Photonix, Inc. 1240 Avenida Acaso, Camarillo, CA 93012, USA
\(^2\) Royal Institute of Technology, Department of Physics, Frescati, S-104 05 Stockholm, Sweden
3.2 A High Energy Resolution of YAP:Ce Scintillator
by M.Kapusta, M.Moszyński, J.Pawelke, M.Balcerzyk

The study of the properties of a 3x3x20 mm YAP:Ce crystal coupled horizontally to the XP2020Q has shown an extremely good energy resolution of 4.5 ±0.11% for 662 keV γ -peak from a $^{137}$Cs source, see Fig. 1. This is one of the best results ever obtained with a scintillator. The quoted number represents the mean value of several measurements. The measured number of photoelectrons of $5350\pm100$ phe/MeV allows us to calculate the resolution expected from photoelectron statistics equal to $4.3\pm0.4\%$ and then to determine the intrinsic energy resolution of $1.7\pm0.4\%$ for the tested YAP crystal. This quantity is the lowest one observed with scintillators, about three times lower than that observed for a NaI(Tl) crystal equal to $5.7\pm0.2\%$.

To be published in Nucl. Instr. and Meth.

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2) Forschungszentrum Rossendorf, Institut für Kern-u. Hadronenphysik, PF 510119, D-01314 Dresden, Germany

3.3 Properties of the LuAG:Ce Scintillator
by M.Moszyński, M.Kapusta, A.Lempicki, W.Klamra

A growing interest in digital X-ray radiography which uses a scintillator with a CCD light readout prompts this study of the properties of the LuAG:Ce crystal. Its high density of 6.71 g/cm$^3$ and a high atomic number of Lu (Z=71) assure a good detection efficiency of X-rays in the range of 20-60 keV not affected by the K-edge of absorption. A peak emission at 510 nm fits well to the CCD and may allow getting a high signal at the CCD output. The sample of LuAG:Ce doped with 0.2% Ce, with a diameter of 12 mm and a height of 10 mm was tested coupled to the XP2020Q photomultiplier and Hamamatsu S3543 photodiode. The number of photoelectrons produced in the XP2020Q of $1200\pm60$ phe/MeV was measured comparing the position of the 662 keV peak of γ-rays from a $^{137}$Cs source with that of the single photoelectron. The energy spectrum of γ-rays from a $^{137}$Cs source shows a poor energy resolution of 16% mainly because of a number of imperfections in the tested crystal. Fig. 1 presents the light pulse shape observed by means of HP4542C digital scope. It shows the decay with two components with the time constants of $460\,\text{ns}$ and $1.9\,\mu\text{s}$. The measurements carried out with the S3543 photodiode was not successful, suggesting that the expected emission at $510\,\text{nm}$ is rather weak. Further study with the samples having a larger doping of Ce is necessary.

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3.4 New Scintillating Materials for γ-ray Detection and Spectroscopy
by M. Balcerzyk, Ph.D. dissertation (submitted)

Scintillators that are currently used and developed show imperfections in applications (Positron Emission Tomography, fast γ-ray detection and digital X-ray imaging). These flaws are low detection efficiency and scintillation light output, long luminescence pulse, nonlinearity, afterglow and high a price. The aim of the dissertation is to propose new, yet not existing, scintillating materials for γ-ray detection and spectroscopy. The proposal is based on research on existing compounds. To predict the usefulness of the newly proposed scintillators, the phenomenological model of light output is presented. It is based on crystallographic properties of double oxides (DO) doped with cerium. About 40 new potential scintillators in two groups are proposed. They

Luminescence and scintillation properties of YAlO\textsubscript{3}:Ce, Y\textsubscript{2}Al\textsubscript{2}O\textsubscript{5}:Ce, ScPO\textsubscript{4}:Ce, YPO\textsubscript{4}:Ce, YbPO\textsubscript{4}:Ce, LuPO\textsubscript{4}:Ce, Ce\textsubscript{3}La\textsubscript{5}F\textsubscript{3} and ceramics of Lu\textsubscript{2}O\textsubscript{3}:Ce and Y\textsubscript{2}O\textsubscript{3}:Ce are presented. These materials are efficient and fast scintillators in UV or visible light (Y\textsubscript{2}Al\textsubscript{2}O\textsubscript{5}:Ce). The exceptions are transparent ceramics of Lu\textsubscript{2}O\textsubscript{3}:Ce and Y\textsubscript{2}O\textsubscript{3}:Ce. They show only weak luminescence and scintillation. Besides aluminum DO, also boron DO are efficient luminophors. That property gives special attention to the IIIB group in the periodic table of elements, which contains indium and thallium. We have compared scintillation properties of scandium, yttrium, ytterbium and lutetium orthophosphates. They share the same crystallographic structure and phosphate group. Yb\textsuperscript{3+} ion is optically active, since YbPO\textsubscript{4} and YbPO\textsubscript{4}:Ce showed luminescence with doublet splitting characteristic to Yb\textsuperscript{3+}. YPO\textsubscript{4} has moderate light output and LuPO\textsubscript{4}:Ce high. The excitation spectra of cerium luminescence and graphs of light output vs. cerium concentration show that the scintillation mechanism is based on sequential carrier capture by cerium ions. ScPO\textsubscript{4} and ScPO\textsubscript{4}:Ce showed excitonic luminescence and a different scintillation mechanism based on the transfer of energy from excitons to cerium ions. The analysis of data available in the literature shows that transfer of energy from self-trapped excitons to cerium ions can explain scintillation mechanism of scintillation in Ce\textsubscript{3}La\textsubscript{5}F\textsubscript{3}. Ce\textsubscript{3}La\textsubscript{5}F\textsubscript{3} has low light output, too low for medical applications. The fast component of the luminescence is connected with the transfer from cerium ions in regular crystallographic sites to those in perturbed sites.

Crystallographic and light output data at known cerium concentration on scintillators has been collected for DO of aluminum compounds, orthophosphates and orthosilicates. These data were the foundation of a phenomenological model of light output on crystallographic data. We define the δ-radius as the difference between the shortest distance from the ion, for which cerium is substituted, to the oxygen ion and the radius of the oxygen ion. We postulate that when the cerium ion is put into a site where δ-radius is substantially smaller than Ce\textsuperscript{3+} ion radius, the light output of such a scintillator is high. The δ-radius is a parameter of the model. Figure 1 shows known light output data vs. δ-radius and the calculated light output for newly proposed scintillating compounds based on In\textsubscript{2}O\textsubscript{3} and Tl\textsubscript{2}O\textsubscript{3}. For In\textsuperscript{3+} and Tl\textsuperscript{3+} we predict high light output for the compounds containing indium and low light output for the compounds containing thallium. However, thallium compounds will have much higher detection efficiency than indium compounds. The new compounds will have an important use in Positron Emission Tomography, digital X-ray detection in dentistry and mammography and γ-ray detection.
3.5 Comparison of Commercially Available LSO Crystals for High Resolution PET Detectors with Those of YAP and BGO

by M. Kapusta, J. Pavelka, M. Moszyński

The goal of this work was to evaluate the influence of the geometry, size, and reflector coating on the light output as well as on the overall performance of the quality of the crystals studied. The light output, energy resolution, detection efficiency and timing properties for the irradiation using $^{137}$Cs and $^{22}$Na sources were investigated.

For the studies we used: YAP fully polished crystal 3x3x20 mm (two samples); LSO: 3x3x20 mm fully polished (one sample), 3x3x20 mm unpolished (two samples), 2x2x15 mm unpolished (two samples), 2x2x15 mm polished (two samples); BGO 3x3x20 mm polished (four samples), 3x3x20 unpolished (two samples), 1.7x1.7x15 mm polished (four samples), 1.7x1.7x10 mm polished (six samples), unpolished (six samples). Due to our studies of the crystals preparations we obtained very best results as for LSO 7.2 % FWHM, YAP 4.3 % FWHM. These results allow as predicting how the crystals should be prepared before they will be used in PET detector to perform the best quality of the studied cases.

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3.6 Performance Tests of Neutron Detectors for the EUROBALL Neutron Wall
by M. Moszyński, Z. Sujkowski, D. Wolski and M. Kapusta and Neutron Detector Subgroup of EUROBALL

The EUROBALL Neutron Wall consists of 15 pseudohexagonal detector units subdivided into three hermetically separated segments of 150 mm height covering a 1 \( \pi \) solid angle at 150 mm distance from a target, see Fig. 1. The smaller central pentagonal unit is subdivided in 5 segments viewed by Philips XP4312B photomultipliers. The detectors are filled with Bicron BC501A liquid scintillator. Each hexagonal section is viewed by a 130 mm diameter Philips XP4512PA photomultiplier. The measured number of photoelectrons of about 1000 phe/MeV of recoil electron energy confirmed a good quality of home made scintillating cells. The performed tests of \( n-\gamma \) discrimination by zero-crossing and time-of-flight methods show a full separation of \( \gamma \)-and neutron events down to 50 keV recoil electron energy, see Fig. 2. The tests also showed excellent timing properties of the detectors reflected in the time resolution of 1.6 ns. The factors determining the efficiency of neutron detectors are discussed leading to the total efficiency of the detector equal to 0.29.

![Fig.1 The neutron wall mounted to the EUROBALL frame.](image)

![Fig.2 The \( n-\gamma \) discrimination by simultaneous measurements of the zero-crossing time and time-of-flight. The Z/C time versus energy (a). The time-of-flight versus energy (b). The Z/C time versus the time-of-flight (c). Note that the analysis of the 2D spectrum of the Z/C versus the time-of-flight allows selecting very clearly both the neutron and \( \gamma \)-events. The energy threshold corresponding to 50 keV recoil electrons was set in constant fraction discriminator.](image)

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3.7 Front-End Electronics for the EUROBALL Neutron Wall

by D. Wolski, M. Moszyński

The front-end electronics for the neutron wall in the EUROBALL system is under development. It consists of a pulse shape discriminator based on a zero-crossing principle, a time-of-flight channel and energy channel, see Fig. 1. Moreover, the output signals corresponding to the neutron and γ-ray multiplicity are produced. A prototype of the electronics for two detector channels was designed and assembled in a NIM box in the form of a stick-on card. The electronics was designed using 6 layer printed board and SMD technology. The first test of n-γ discrimination using 5"x5" BC501A liquid scintillator coupled to an XP4512B photomultiplier and a Pu-Be neutron source show excellent performances of the electronics.

Fig. 1 Block scheme of the front-end electronics.

3.8 Set-up for Spectroscopy Measurements

by A. Dziedzic, C. Górny, A. Grajda, W. Karnicki, J. Kucharski, M. Moszyński, D. Wolski

The spectrometry equipment for an environmental study is under development. The model of the detector with 2" x 2" NaI(Tl) scintillator and XP 3212 photomultiplier was designed and constructed. Test measurements showed the energy resolution of 6.8 % for the 662keV γ-rays from a $^{137}$Cs source. A high voltage power supply with the voltage of 0 to 1.5 kV and a current output up to 2mA was designed. A spectroscopy amplifier is under development.

3.9 Electronic Support for NA48 Experiment at CERN

by Z. Guzik and A. Chlopik

SINS contribution to NA48 experiment ("A Precision Measurement of $g/g'$ in CP Violating $K^o \rightarrow 2B$ Decays"), conducted actually in CERN, was to provide the experiment with three types of sophisticated electronic modules designated for the main part of experiment apparatus, i.e. the Krypton Calorimeter readout system.
These modules are: Isolated Clock Fanout (NA48CKFO-F6916) - Fastbus, Optoisolated Cluster Interconnect (OPTOCI-F6915) - Fastbus, and FOL-RIO Interface - VME. The designing phase of the project was realised in 1995. Prototypes and modules testing in real experimental conditions were performed in 1996. A more detailed description of these modules and phases can be found in previous issues of SINS Annual Report. Our activities in 1997 were concentrated on mass production of modules, final testing and participation of data acquisition. More than 150 modules in total were produced and put into operation. Fig.1 presents the block diagram of the experiment's electronics. Our contributions are denoted by CI (Optoisolated Cluster Interconnect), CK FANOUT (Isolated Clock Fanout) and RIO (FOL-RIO Interface).

The installed apparatus behaves very stably and reliably. Our further plans are concerned with maintaining that apparatus in proper operational conditions.

3.10 Contract for Apparatus for SPHERE Experiment on the Nuclotron in Dubna (JINR)
by Z. Guzik, J. Charuba, A. Chlopik

According to the new contract with the Laboratory of High Energy Physics in Dubna JINR, Russia signed in 1997, CAMAC modules of the multichannel coincidence register/Latch providing data storage in the fast first level trigger were produced on the basis of the prototype module designed and tested by us. We were taking part in the design of Data Acquisition System for SPHERE experiment. Work has been financed on the basis of Polish contribution to JINR.
3.11 Standardisation Activities
by J.Charuba, Z.Guzik

The department is involved in the standardisation process of electronics and Information processing systems in Poland and Bus systems for physics research. We took part in the ESONE (European Studies on Norms for Electrones) Standardisation Committee activities. During ESONE General Assembly at Beaune in France, in September our Institute was chosen as the organizer of the seminar "Software applications for control systems" and of the ESONE XG/TCC (Executive Group and Coordination Committee) meeting in Warsaw in November 2-3, 1998. In 1997 Polish Edition of VIC standard was prepared on the basis of ISO/IEC standard. The summaries of ISO/IEC 9316-1 SCSI-2 and PCI Local Bus,Rev.2.0 standards were prepared by us and published by the Polish Association of Electrical Engineers. During the conference Medica-Controla-Optica,97 in Warsaw in September 22-24 we presented a paper "Application of PCI bus for microprocessor measurement and control systems". We were taking part in the works of ISO/IEC JTC 1/SC 26 Committee on microprocessor systems.

3.12 A Design of Portable, Microprocessor Controlled Partial Discharge Analyzer (PDA) for on-Line Testing the State of Insulation of High-Voltage Rotating Machines
by S.Borsuk, A.Chlopik, Z.Kulka

Partial discharge (PD) testing during high-voltage rotating machine operation is used to identify abnormal conditions or deterioration of insulation in stator windings. These problems may lead to serious failure of such generators (if not monitored, detected and corrected).

Very short pulses are typical for PD-generated ionization processes in HV insulation. These pulses are detected, shaped and measured.

A wideband, PD analyzer type MSAA-1 for measuring integrated distributions, i.e. the number of pulses per unit time (N) against charge magnitude (Q) was designed. On-line measuring with a portable instrument is usually sufficient for the state of insulation to be evaluated. The crucial point is that changes in the PD characteristics rather than their magnitudes are important.

The MSAA-1 is able to record up to 100 of N(Q) distributions, each with 128 maximal measuring points. It consists of an active passband filter from 1 MHz to 100 MHz, a wideband amplifier with adjustable gain from 0 to 10 and other circuitry. The number of measuring points (8, 16, 32, 64 or 128), as well as measuring time (1, 10, 50, 100 or 1000) x 20 ms are programmable. All operations in MSAA-1 are controlled by microprocessor M68HC16Z1 from Motorola. The MSAA-1 is battery operated unit.

Data collected in the local memory of microprocessor can be transferred to PC computer via RS-232 interface. Usually data transmission and processing are executed in a laboratory room, far from place where HV generator is situated.

The information processing uses statistical criteria and regression analysis. First, the differential distribution n(Q) is calculated from N(q). Next some statistical factors, like mathematical operations, dispersion and others are calculated. The values are compared with the admissible levels. When taking periodic N(Q) measurements the trends and observations can be studying (degrees of deterioration). The measuring system with MSAA-1 is presented in Fig.1.
3.13 Multichannel Analyser System for γ-ray Spectroscopy
by K.Traczyk, M.Płomiński

Our gamma spectra control and analysis system is under permanent development during few last years.
In general, in 1997 the following innovations were performed:
- compare analysis was added to already existing energy and efficiency analysis,
- new version of manuals: "User's Guide" and "Tutorial" was prepared,
- English language version of the program was prepared containing on-line help system describing in
details all functions of the program available for the user,
- English language version of both manuals mentioned above was written,

Taking into consideration actual trends in the market of Pulse Height Multichannel Analyzers, computer
technique and client expectation, a new project for hardware and software running under Windows'95 system
is being prepared.

3.14 Computers, Software and Additional Equipment in the Institute for Nuclear
Studies (IPJ) - Data Base
by M.Uzdowski

The Data Base described below including information regarding computers, software and additional
equipment (printers, scanners, plotters etc.). The reason of preparing this Data Base was to define all the
equipment which is in our Institute. It will help in the future in the proper selection when planning the purchase
of the new equipment and software as well.

All particulars are in the relationship data base form. The table including information about employees
(.forename, surname, division, phone number etc.) is the basis. Other tables which include information about the
equipment and software are connected to the basis table through "employee number".
The series of form were created as the user's interface. The first form enabling one to select the mode:
"Preview" - making possible to look through the equipment and software of the selected employee;
"Edition" - making possible to introduce any change for buying new equipment,
"Diagrams" - enabling one to see information in diagram forms,
"Close" - exit from Data Base.

The form containing personal data is opened after selecting "Preview" or "Edition". Bottoms on the
personal data form are opening the next forms with the specific type of information and depending on option
selected i.e. "Review" or "Edition" edition of Data Base or preview is possible.
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AND YAP CRYSTALS
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PARTICIPATION IN CONFERENCES AND WORKSHOPS

ENERGY RESOLUTION OF SCINTILLATION DETECTORS WITH LARGE AREA AVALANCHE PHOTODIODES AND
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Z. Kulka
SAT-Audio-Video, Nr 2 (1997) 52

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Z. Kulka
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XRCD - EXTENDED RESOLUTION CD
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SAT-Audio-Video, Nr 4 (1997) 62

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Z. Kulka
SAT-Audio-Video, Nr 5 (1997) 72

DISTORTIONS IN AUDIO AMPLIFIERS
Z. Kulka
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Z. Kulka
SAT-Audio-Video, Nr 7-8 (1997) 69

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Z. Kulka
SAT-Audio-Video, Nr 9 (1997) 70
LG ELECTRONICS ON WORLD'S COURSE
Z. Kulka
SAT-Audio-Video, Nr 9 (1997) 78

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Z. Kulka
SAT-Audio-Video, Nr 10 (1997) 75

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SAT-Audio-Video, Nr 11 (1997) 73

DIGITAL RADIO DURING IFA'97
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A. Chlopik
CADCAM Forum, Nr 1 (1997) 51

CADSTAR FOR WINDOWS - PCD DESIGN
A. Chlopik
CADCAM Forum, Nr 2 (1997) 31

CADSTAR FOR WINDOWS - BASIC VERSION EXTENTIONS
A. Chlopik
CADCAM Forum, Nr 3 (1997) 67

ADVANCED PLD 3
A. Chlopik
CADCAM Forum, Nr 5 (1997) 49

MAX+PLUS II
A. Chlopik
CADCAM Forum, Nr 6 (1997) 65

ADVANCED PCB 3
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A. Chlopik
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A. Chlopik
Elektronik, Nr 3 (1997) 22

PROGRAMMABLE LOGIC DEVICES. PART 3 - CPLD
A. Chlopik
Elektronik, Nr 4 (1997) 10
PERSONNEL

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Stanisław Borsuk, Dr
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Jacek Charuba, Dr
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Krystyna Traczyk
Marek Uzdowski
Błażej Woźniak
Artur Zyda
Stanisław Żardecki
Iwona Żawrocka
Overview

As reported in previous annual reports, in 1997 the research activities of the Department were concentrated on the following areas:

Dosimetry and Microdosimetry;
Numerical modelling of interaction of radiation with matter;

The main achievements in 1997 can be summarised as:

- **DOSIMETRY**: Our activities in metrology of absorbed doses were focused on absorbed dose standardisation problems connected with use of $^{106}$Ru and $^{125}$I applicators for ophthalmological purposes. The metrological chain for absorbed dose determination in water phantom for a $^{106}$Ru applicator is based on the use of a small size, parallel plate, ionisation chamber calibrated against Co in a SSDL laboratory and a scintillation detector NE102A. The scintillation detector (4mm$^3$ size) is used for relative dose depth determination. Measurements of depth dose in water phantom for 14 seeds of $^{125}$I (ropes applicator) were carried out using the same scintillation probe as for Ru applicators.

- **MICRODOSIMETRY**: Works to optimise a JET Counter device for nanometric experiments have been progressing. The time of flight spectra of nitrogen ions for a wall-less condition were measured. The new method for absolute counting efficiency of the channeltrons for electrons with 50-1500 eV has been devised. The absolute efficiency of B419BL and KPE 07 channeltrons was determined. The preliminary results of ion cluster formation in a nanometre nitrogen cavity irradiated by 100eV electrons were obtained. Activities in this field were supported by IV CEC Framework Programme as well as by the Polish State Commission for Scientific Research.

- **THE ENERGY RESPONSE** of a HPGE detector was calculated using the MNCP code with MNCDAT, 6 libraries for gamma photons emitted by $^{137}$Cs and $^{60}$Co isotopes. The calculated spectra were compared with measured ones as tests of the quality of the calculations. The MNCP code was used for modelling the influence of a large mass of scattered material, placed in the vicinity of this detector in the energy spectrum.

- **EVALUATED CROSS SECTIONS** for high-energy transport codes for neutrons above 10 MeV, calculated by FLUKA, LAHET and CROSEC codes, have been compared with experimental data. Rather large differences were observed and, not surprisingly, this has led to further research recommendations. Work was done with Royal Institute of Technology in Stockholm (Sweden) and Joint Institute for Nuclear Research in Dubna (Russia).
4.1 Nanodosimetry of Low-Energy Electrons with JET Counter-Status Report
by S.Pszona, J.Kula and S.Marjańska

The JET counter (description has been given in a previous annual report and also elsewhere [1-2] discussed below) is a laboratory device which is capable of providing the type of basic radiation data needed to support development of the NANDET detector [3]. The data are needed on the stochastic grouping of charge, known to be produced in nanometre volumes along the tracks of ionising particles. The charge group may occur as clusters of ionizations formed in successive individual collisions or as multiple ionisation in a single collision or as ionizations produced by low energy delta rays associated with primary ionizations. Clustering is thought to be of special relevance to the yields of chromosome dicentrics. Experimental data are needed on the yields and bio-effectiveness of low energy electrons, especially at energies below 300eV where delta ray spectral shapes are not adequately known in tissue-equivalent gases and in condensed phase, tissue-like materials. Evaluation of the proportion of damage due to synergistic action between primary ion tracks and the associated delta rays at tissue interfaces, remains an important interdisciplinary challenge.

The activities during the first year of NANDET project have been focused on the basic objectives for this period of study: i) to test the ion detector and to develop the electronic set-up of the detector for registering the frequencies of single and multiple ions created in a nanometre site by charged particles. After improvements (vacuum system), the JC set-up has been running for collecting the operational characteristic of the overall system as a preparatory stage for an experiment with electrons of 100-300 eV range. The time of flight experiment for nitrogen jets irradiated by electrons were studied to elucidate the time pattern of the ion movement towards the detector. The set-up for measurement of the frequency distribution of ion groups for electron irradiation is based on use a multiscaler technique with externally triggered single channel steps. For each electron gun pulse, the counts from the ion channeltron, which is presumed to be able to detect all ions created in a nanometre volume, is registered in a separate channel in the multiscaler within a selected dwell time. The multiscaler is externally controlled by a pulse, which controls the electron beam. After progressively switching over the 4096 channels, the relative frequencies of recording zero, one, two and more counts are calculated. If the efficiency of ion counting is close to 1, this result is equivalent to the spectrum of the different integer number of ions produced in the investigated nanometre site. The preliminary results of such measurements for 100 eV electrons in a nitrogen jet are presented in Figure 1. (It should be noted that these are 'first results' yet to be substantiated). As can be seen from this figure, the results depend on the intensity of the electron beam. This means that the overlap of ionisations from different electron traversals is occurring and it is necessary to find a method for analysis of the results.


![Figure 1](image-url)
4.2 New Method for Determination of the Counting Efficiencies of the Channeltrons for Electrons
by S. Pszona

In the nanometric experiment with sub 300 eV electrons, a known counting efficiency for electrons is important. This is because it is essential that the nanometric gas jet be irradiated with a known electron flux to enable accurate evaluation of the integrally charged ion yield per electron traversing the sensitive volume. In practice, it is necessary to work with a low flux to avoid superposition of ions from successive traversing electrons (see the preliminary results of recording of frequency of a different number of counts created by 100 eV electrons irradiating a 2 nm site as a function of electron beam intensity, Fig. 1, section 4.1 this report). Within the scope of the objectives for this period, a new method for measuring the absolute counting efficiencies for the channeltrons for electrons has been devised [1]. It was shown that an investigated channeltron B419BL counted 250 -350 eV electrons with close to 100% efficiency. It was discovered that the efficiency of a B419BL channeltron for these electrons depends on place of hitting the entrance cone of the channeltron by electrons. Due to this effect, the reproducibility of the results of the efficiency measurements is of 12%. The results of the measurements for two channeltrons i.e. B419BL (Mullard) and KPE 07 (Gdansk Technical University) are shown in Fig. 1

![Efficiencies of B419BL (dots) and KPE07 (squares) channeltrons versus electron energy](image)

Fig.1 Efficiencies of B419BL (dots) and KPE07 (squares) channeltrons versus electron energy


4.3 Dosimetry of the Ru 106 Ophtalmological Applicators
by S. Pszona, B. Kocik, S. Marjańska

The 106 Ru/Rh beta applicators (clinics in Poland have in use the applicators produced by BEBIG, Germany, also OBRI, Poland, claimed to open such production soon) are commonly used in intraocular tumours radiation therapy. The BEBIG's applicators [1], are characterised in a certificate by total activity of Ru, relative dose depth in a phantom as well as the absorbed dose at the surface of an applicator. The claimed accuracy of dose determination is +- 30%. It is evident that the accuracy of dose determination is very low and would have the negative influence in the tumour treatments. The aim of this work is to establishing a system of absolute dose measurements based on use of ionisation method as well as a scintillation method in order to substantially increase the accuracy of absorbed depth dose determinations.

A parallel plate ionisation chamber „pipe” type has been used for absorbed dose determination of the ophthamological applicators. The chamber has flat electrodes with 8 mm dia. collecting electrode distanced of 2mm from the voltage electrode. The electrodes are made of polyamide foils with thin layer of Al. The chamber window is made of polyamide foil thick. The sensitive volume is of 0.1cm³. The chamber body was made of tissue equivalent conducting plastic ended with Al stem. The pipe chamber has been standardised in the field of Co-60 in SSDL of Oncology Centre in Warsaw in terms of exposure.
A scintillation probe consists of an NE102A organic scintillator, 3 mm dia. and 2 mm thick, PMMA light quide 150 mm long and EMI9524S photomultiplier.

A scintillation detector output current is compared with the absorbed dose rate as measured by a flat small size ionisation chamber at the same distance in air from an investigated applicator. In this way a scintillation detector can be directly calibrated in terms of the absorbed dose rate.

![Graph](image)

**Fig. 1** Relative absorbed dose in water and air for ROA 015 and 192 applicators as a function of distance from the centre of the applicator. Data of the BEBIG applicator are shown.

The absorbed dose rates in water as a function of distance from the surface of an applicator have been measured using a calibrated scintillation detector. The results for two applicators (ROA 015 and 192) are shown in Fig. 1. The data taken from a certificate issued by BEBIG for the CCA applicator (the same dimensions as ROA 015) are shown in Fig. 1 for comparison. Fig. 1 also presents the dose rate in air for ROA 015 applicator. As seen from this figure the results obtained for ROA 015 applicator of OBRI, agree well with the results for CCA applicator of BEBIG. The dose profiles at different depth in water, normalised at a dose at the surface of 192 applicator are shown in Fig. 2. The numbers above a curve indicate a depth in water.

![Graph](image)

**Fig. 2** Dose profiles in rel. units for 192 applicator for different distances from surface as a function of horizontal displacement. Numbers above curves indicates a distance form a central point surface

4.4 Evaluated Neutron Cross Sections for High Energy Transport Codes

by A.Polański and W.Gudowski

We have updated the total and elastic cross sections for neutrons for twenty of the most important isotopes in accelerator driven technologies: He, Be, C, N, O, Na, Al, Ar, Ti, Fe, Cu, Br, Mo, Cd, Sn, Ba, W, Pb, U, Pu. Our evaluations cover energies from 10 MeV to 1 TeV. Below 20 MeV the relevant data were taken from the JEF and EB6 library. For high energy the experimental data were taken from the compilations of Barashenkov [1], Carlson [2], and the National Nuclear Data Center [3]. We compare the neutron cross sections determined by the CROSEC code [4], [5], FLUKA code, and LAHET code [6], [7]. Rather large differences are observed leading to further research recommendations for nucleon-nucleus cross sections calculations. We describe the details of the implementation of the neutron total end elastic cross sections parameterization [8], for CROSEC usage and extensions of the method to stable light nuclei with 1 < A < 4. The use of evaluated cross sections from CROSEC code in the merge LAHET - MCNP code [9] is commented upon.

[1] V.S.Barashenkov, Cross Sections of Interactions of Particle and Nuclei with Nuclei, JINR, Dubna, 1993

1) RIT, Stockholm, Sweden

4.5 Plutonium Energy Amplifier Concept

by V.S.Barashenkov1), A.Polański, A.N.Sosnin1)

Recent studies of the proton 650 MeV accelerator driven subcritical fast reactor IBR-30 which are being carried out at JINR in Dubna are briefly described [1]. The subcritical reactor has a form of a multi-layer cylinder with a tungsten target having radius R=1.5 cm, length L=14 cm and surrounded by a plutonium blanket with dimension R*L=7.5*14 cm and average density to 8 g/cm3. The device is covered with a tungsten reflector of the thickness 2.4 cm and a steel reflector of thickness 10 cm.

Fig.1 Dependence of the energy gain vs. proton energy for K-eff=0.94

Fig.2 Dependence of the energy gain vs. neutron multiplication factor (K-eff ) for 0.65 GeV proton energy.

The beam of the accelerated protons with energies varying from 100 MeV to 2 GeV is brought into an axial split with the depth of 1 cm. The calculated quantity was the neutron multiplication and the energy gain of the system. A graphic illustration of dependence of the energy gain $G$ of the system is presented in Fig.1. As one
can see, the maximum \( G = 22.12 \) is observed for incident proton energy about 1 GeV. For considered proton energy (650 MeV) the energy gain is only 5\% less than for 1 GeV. The results of the calculations of the energy gain vs. the multiplication factor \( K_{\text{eff}} \) for proton energy \( E = 0.65 \) GeV are shown in Fig.2. Inspection of Fig.2 shows there are large possibilities to increase the energy gain by increasing the neutron multiplication factor.


4.6 HPGE Detector Response Function Calculations

by K.Wincel and B.Zareba

The radiation response function of the high purity germanium detector was calculated using MCNP-A General Monte Carlo N-Particle Code for photons emitted by Co-60 and Cs-137 isotopes. The pulse height tally, which is analogous to a physical detector, and energy deposition tally have been used. Calculations were performed for a HPGE coaxial detector produced by Canberra with 59mm of diameter and 61.5mm length. Binary cross-section files for photons and electrons were generated based on MCNPDAT6 (MCNP4A Standard Neutron Cross-Sections, Photon Interactions and Electron Libraries). Two geometries were considered to investigate the following cases:

- unshielded detector
- detector located inside an ellipsoidal cell bounded by an aluminium layer of 3mm thick; an inside cell stainless steel cylinder was placed.

Geometry of the second cause is shown in Fig.1. In both cases gamma sources were placed on the detector axis at 100cm distance from the detector window. The purpose of performing response function calculations for such geometries was to find the effect of the cabin and engine of a helicopter on measurements. Results of the calculations on the case of the unshielded detector can be treated also as a test of proper use of the MCNP code. Calculated peak-to-Compton ratio is 56.5:1. The measured value of the peak-to-Compton ratio given by Canberra is 55.1:1 the calculated energy distribution of pulses for Co-60 source is shown in Fig.2. The values presented in this picture were determined for 10 keV energy bins and photon source yield \( 1 \times 10^5 \)
LIST OF PUBLICATIONS

A NEW APPROACH TO LOW-LEVEL MONITORING IN MIXED RADIATION FIELDS
S. Pszona

IONISATION MEASUREMENTS IN NANOMETER SIZE SITES WITH JET COUNTER-RECENT EXPERIMENTAL RESULTS
S. Pszona
Royal Soc. for Chemistry, 204 (1997) 395

ON THE INTERPRETATION OF THE RESPONSE OF THE CR-39 TRACK DETECTORS TO 14.9 MeV NEUTRONS,
T. Czyżewski, M. Jaskóla, A. Korman, S. Pszona, M. Sadowski, A. Szydlowski

NEW APPLICATION OF HE-3 AND BF PROPORTIONAL COUNTERS IN POLYTHENE MODERATOR
S. Pszona

EVALUATED CROSS SECTIONS FOR HIGH ENERGY TRANSPORT CODES. PART 1. CROSS SECTIONS FOR NEUTRONS
A. Gadowski, A. Polański

PARTICIPATION IN CONFERENCES AND WORKSHOPS

NEUTRONS IN NATURAL ENVIRONMENT
S. Pszona (poster and oral presentation)
Proceedings of IRPA Regional Symposium on Radiation Protection, Prague, 1997, 157

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S. Pszona (oral presentation)
Workshop of NANDET research group, Legnaro, June 1997

RESPONSE OF CR-39, PM355 AND PM500 NUCLEAR TRACK DETECTORS TO FAST NEUTRONS
T. Czyżewski, M. Jaskóla, A. Korman, S. Pszona, M. Sadowski, A. Szydlowski,

INTERACTIONS OF PROTON AND HEAVY IONS WITH URANIUM AND THORIUM TARGETS
V. S. Barashenkov, A. Polański, A. N. Sosnin (oral presentation by V. S. Barashenkov)
Proc. Sec. Intern. Conf. on Accelerator Driven Transmutation Technologies and Applications, Kalmar, Sweden, June, 1996,
Editor Henry Conde, Uppsala University (1997) 723

LECTURES, COURSES AND EXTERNAL SEMINARS

Interaction of proton and ion beams with fissile media
A. Polański, 22.01.1997, Dep. of Neutron and Reactor Physics, Royal Institute of Technology Stockholm, Sweden

Neutron sources in accelerator driven systems
A. Polański, 5.02.1997, Institute of Atomic Energy, Świern

Nuclear energy generation and waste transmutation using accelerator driven systems
A. Polański, 4.04.1997, Institute of Physics, Technical University in Warsaw

Plutonium energy amplifier
A. Polański, 5.12.1997, Dep. of Neutron and Reactor Physics, Royal Institute of Technology Stockholm, Sweden

Radiation at high altitude flight-radiation protection aspects
S. Pszona, 10.04.1997, Polish Academy of Science, Radiobiology and Radiation Protection Committee
INTERNAL SEMINARS

Neutrons in earth atmosphere *
S.Pszona, 06.10.1997, IPJ P-VII ŁÓDŹ

Accelerator-driven transmutation technologies *

* in Polish
* in English

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Overview

In 1997, theoretical studies mainly concerned the verification of physical models on the basis of experimental data, an analysis of plasma behaviour within regions close to electrode surfaces during quasi-continuous discharges induced by microwaves (collaboration with the IPF at the Stuttgart University), as well as modelling of a discharge development within coaxial plasma injectors (collaboration with the Warsaw Technical University). Another direction of theoretical studies concerned elementary processes of importance for plasma research, and in particular those taking into consideration the role of spin within a classical model of proton - hydrogen atom collisions.

Experimental studies comprised measurements of pulsed electron beams and effects of the polarization of X-rays emitted from Plasma Focus (PF) facilities (collaboration with the Kurchatov Institute in Moscow), research on emission characteristics of different PF devices (collaboration with the IFAS at the University of Tandil, Argentina), as well as measurements of pulsed electron and ion-beams emitted from various devices of the PF and Z-Pinch type (collaboration with the IPP-NSC in Kharkov and the INFIP in Buenos Aires). An important direction of experimental studies concerned X-ray and ion measurements at a large PF-1000 facility (collaboration with the IPPLM in Warsaw).

In the field of plasma diagnostics, efforts were devoted to an analysis of the results obtained from time-resolved measurements of nitrogen ions and deuterons within PF-type devices (collaboration with the INFTP and IFAS). Within a frame of diagnostics, a substantial achievement was also the design and construction of a new measuring equipment for studies of plasma dynamics and X-ray emissions (collaboration with the Kurchatov Institute and MFTI in Moscow). Particular attention was also paid to studies connected with the calibration of various solid-state nuclear track detectors (NTDs), particularly modern plastic detectors of the CR-39, PM-355, and PM-500 type.

Studies in the field of fusion technology concerned the design and construction of a special pulse generator for the simulation of electromagnetic interference, as well as other efforts connected with research on electromagnetic compatibility of electronic and electrotechnical devices. Research on new types of HV pulse generators were carried out partially under contracts with industrial laboratories (the Institute of Energetics, APENA, and ELTEST). In order to modernize experimental facilities the IONOTRON-SW device was equipped with new electrodes made of pure aluminum, which were used to perform expositions of samples made of different materials (collaboration with the IPP-NSC in Kharkov and the Institute of Physics, Chinese Academy of Sciences, in Beijing).

In the field of new plasma-ion technologies a team from Dept. P-V and Dept. P-IX performed numerous experiments on the doping of aluminium plates with molybdenum ions and on the treatment of ceramic targets with pulsed streams of titanium-nitrogen or hydrogen plasmas. Results of those experiments (elaborated in cooperation with the INChT in Warsaw and the FZR in Rossendorf) are presented in another chapter prepared together with Dept. P-IX. A separate task, realized only by Dept. P-V, concerned the construction and laboratory tests of a high-current source of nitrogen ions. From other efforts of Dept. P-V, one should mention the design, assembling, and testing of a special plasma injector (ISEX), designed especially for active experiments in space (collaboration with the Space Research Centre, PAS, in Warsaw). A substantial result was also the mastering of a new technological method for the deposition of Ti or TiN layers by the means of a modified plasma gun (realized in a frame of a KBN grant).

The most important achievements of Dept. P-V can be formulated as follows:

1. Experimental confirmation of the polarization of X-rays from PF discharges (discovered in 1996) and the demonstration that there is a distinct correlation between this effect and the generation of pulsed electron beams.
2. Detailed elaboration of the calibration measurements performed for different nuclear track detectors (NTDs) exposed to protons, deuterons, helium-, nitrogen- and oxygen-ions (several papers), as well as the performance of new calibration measurements of NTDs exposed to fast (14.9 MeV) neutrons (in the cooperation with the Dept. P-I and Dept. P-IV).

3. Design and construction of new HV-pulse generators as well as the elaboration of an extended documentation of systems for the simulation of electromagnetic interferences.

4. Investigation of new plasma-ion technologies applicable to material engineering (in collaboration with the Dept. P-IX, IPP-NSC in Kharkov, and IP-ChAS in Beijing).
5.1 Computational Package for Parameter Identification
by M. Rabiriski

The complexity of fusion devices results in a growing need for mathematical models of phenomena governing plasma behaviour. Simultaneously, one can observe constantly increasing demand for validation of plasma codes by comparison with measured data, and for the solution of complex inverse problems during the interpretation of experiments. Therefore, the parameter identification becomes an important tool in reducing the discrepancy between observations and theoretical predictions.

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

High computational costs of the numerical solution of plasma models require extremely efficient methods relevant to the minimization of the performance criterion. It should be pointed out that calculations of the model response to every set of parameter values are the most time-consuming steps in the whole algorithm. Therefore, the high efficiency of a minimization technique is a basis to meet with success when attempting to determine unknown values in a complex model. Commonly used optimization methods usually have to complete several hundred evaluations of the minimized function (i.e. solutions of the mathematical model) before the extremum is achieved. Their rates of convergence are evidently unacceptable for the considered application.

For the solution of the parameter identification problem in the complex plasma systems a PARIDEN computational program has been worked out. The methodology and computational method [1, 2], based on the modified Gauss-Newton [3] and Marquardt [4] minimization techniques, have been applied. Numerical tests and practical applications have proved that the introduced methodology and computational methods are both efficient and accurate for the solution of inverse problems in plasma physics. The considered set of methods can be recommended also for the cases when some parameters may lose their influence on the performance criterion. The computational program in question has been applied for the interpretation of experimental data obtained from magnetic spectrometer. The occurrence of relativistic electrons resulting in a complex formula precludes the use of the popular fitting techniques.


5.2 Modelling of Magnetron Sputter Device
by M. Rabiriski

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

In the magnetron discharge, ions created in a plasma are accelerated by an electric field toward the cathode surface. The impact of ions striking the cathode leads to sputtering as well as the emission of
secondary electrons. These help sustain the discharge. These electrons are accelerated back into the plasma and trapped in the ExB drift loop. These trapped electrons create ions from a neutral background gas before being lost.

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. Numerical models commonly use one of two basic approaches: kinetic or fluid. Kinetic particle-in-cell (PIC) Monte Carlo simulations of the discharge require considerable computer time and memory. Most of this time is consumed by determining the motion of particles and their collisions with neutral species. Hydrodynamic models significantly reduce computational costs of numerical simulations in comparison with Monte Carlo codes. Soon a better understanding of the phenomena may be achieved.

A one-dimensional three-fluid model has been developed for the modelling of a plasma behaviour in a magnetron [3]. The model includes continuity, momentum transfer, energy balance for electrons and ions as well as the Poisson equation for the potential. A conception of taking into account two-temperature electrons has also been worked out. Numerical schemes and elements of a GRAD_1D [4] computational package for the tokamak edge plasma transport will be used to accelerate the phase of the magnetron code evaluation.

For a comparison with experimental results a project of scientific cooperation with the Institut für Plasmaforschung, Universität Stuttgart, has been developed.


5.3 Investigation of Discharge Phenomena in an Impulse Plasma Coaxial Accelerator
by M.Rabinski and K.Zdunek

A coaxial impulse plasma accelerator [1-2] is used in surface engineering, e.g. the Impulse Plasma Deposition [3], as an efficient source of mass and energy in the synthesis and deposition of various materials in the form of layers. 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 current sheet motion, a physical model of phenomena in such device has been proposed [4-5]. 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 lower current consecutive amplitudes, the plasma approaches nearer and nearer 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. Moreover, the alternating direction of the current flow during the termination of consecutive discharges leads to change in the direction of a central electrode magnetization.

A detailed analysis of the current sheet dynamics has been carried out for different discharge conditions (see Fig.1). Results of these computations explain some phenomena observed in the device, e.g. the occurrence
of a toroidal ring of a dense plasma in the front of the central electrode. The influence of external electrode geometry on the parameters of Al₂O₃ coatings was found.


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5.4 Spin of the Electron in Proton – Hydrogen Atom Collision Theory Based on Free-Fall Atomic Model Concept

by M.Gryziński

Investigation based on a classical theory of a localised electron moving according to the laws of Newtonian dynamics were undertaken to disclose the role of the spin of electron in proton-hydrogen atom collisions. At first, however, to close many years lasting discussions on the applicability of classical dynamics to the description of an internal structure of atomic systems, a proof was given that an electron in the hydrogen atom, as well as in an ionized hydrogen molecule, must be considered as a well defined point like particle, moving along well defined orbits. Moreover, it has been shown that in the ground state the hydrogen atom electron moves along almost exactly radial "free-fall" orbits, while in the ionized hydrogen molecule the electron moves along the shortest distance between the two nuclei [1].

Arguments were presented that a spinless free-fall atomic model is insufficient to describe correctly slow collisions of heavy charged particles (protons) with a hydrogen atom.

To determine the shape of the ground-state atom, that is to define correctly initial conditions for a collision problem, the motion of a spinning electron in the Coulomb field of nucleus was carefully investigated. In a particular case of electron motion in the equatorial plane of the electron an analytical solution has been found describing a free-fall orbit. By performing numerical integrations of equations of motion for a spinning electron in a more general case, it has been found that a few basic closed quasi-free-fall orbits over which motion can be periodic exist. Therefore, the orbit can represent the hydrogen atom in the ground state [2]. Two basic orbits are shown in Fig.1.

The conclusion was drawn that further research aimed at the correct description of collisions with hydrogen atoms need an extension of the mathematical formalism on Euler equations of motions for spin coordinates of the electron.


5.5 Investigation of Pulse Electron Beams and X-ray Polarization in the MAJA-PF Facility

by L.Jakubowski, M.Sadowski, E.O.Baronova and V.V.Vikhrev

Measurements of X-rays made it possible to evaluate plasma concentration and electron temperature values within the hot-spot region. These values were found to be: \(10^{20}\) cm\(^{-3}\), 1 keV respectively. As a result of the spectral measurements, performed with two mutually perpendicular X-ray spectrographs, there appears to be an evident difference between intensities and shapes of the intercombination and resonance lines (ArXVII\(^{3+}\),
This difference can be explained by the polarization of X-rays, caused by the appearance of high-energy electron beams. The additional evidence of the existence of such suprathermal electrons is the emission of the $K_a$ lines corresponding to of low-ionized argon ions (ArXIII-Ar XV).

The generation of relativistic electron beams was also proved by direct measurements. On the basis of many oscillograms it can be concluded that fast e-beams emitted along the z-axis, were generated within hot-spots or in their close vicinity. In recent experiments, the emission of relativistic e-beams was also observed at 45° (Fig. 1.) and 90°. The studies of energy spectra of e-beams, as performed within the frame of the collaboration with MSEPI (Moscow), make it possible to determine electron energy within a range of 10-500 keV. Some results of these studies were presented at the International Conference in Vancouver [1] and at the International Symposium PLASMA’97 [2].


5.6 Emission Characteristics of Small PF-PACO Experiment (at IFAS in Tandil, Argentina)
by E. Składnik-Sadowska, M. Sadowski, M.M. Milanese 1, R. Moroso 1 and J. Pouzo 1

Experimental studies performed last year at the Institute of Physics (IFAS) in Tandil mostly concerned measurements of the emission of soft X-ray and ion beams. Results of those investigations were elaborated in details during the first quarter of 1997. A quantitative analysis of the measurements of soft X-rays of energy < 1.5 keV, which were performed by means of a multipinhole camera with Al- and Be-filters, was carried out. The X-ray pinhole pictures made possible studies of a pinch structure. The soft X-ray pictures obtained demonstrated the fine structure of a pinch column and the appearance of hot spots in spite of small energetics of the PACO device. The observed correlation between intensity of the X-ray pinhole picture with the neutron yield, can be evidence that the plasma density is possibly more relevant for the fusion neutron production than its temperature.

The ion emission along the z-axis (Fig. 1.) was investigated by means of an ion pinhole camera with variable magnification, using nuclear track detectors of the CN- and CR39-type. The application of Al absorption filters of different thickness enabled the energy of the analyzed ions of to be estimated. We observed relatively intense deuteron fluxes of about $1.2 \times 10^{11}$ ions/cm$^2$ at a distance of 13 cm from the electrodes outlet. Those ions measurements showed (similarly to larger PF experiments) that within relatively intense ion fluxes numerous well-collimated microbeams of high-energy (up to 2 MeV) deuterons are emitted. It can be concluded that mechanisms of the X-ray and ion emission in low-energy PF devices seem to be the same as those in larger-scale PF facilities. The main results were presented at the International Symposium PLASMA’97 [1] and 18th Symposium of Plasma Physics and Technology [2].
5.7 Experimental Studies on Electron and Ion Pulse Beams from the PF and Z-pinch Type Facilities


In 1997 the correlation measurements of the emission of high-energy ions, relativistic electrons, neutrons, and X-rays within the PF-360 facility were continued. The magnetic analyzer equipped with \( B = 0.5T \) permanent magnets, which was constructed within the framework of the scientific collaborations with IPP-NSC Kharkov in 1996, was applied in order to make possible the registration of time-resolved ion signals within two energy ranges. Results of these measurements and correlation studies were presented at the Int. Symposium PLASMA'97 [1].

The results of the Faraday-type collector measurements of the ion emission, which were performed at two different plasma-focus facilities within the IPJ - INFIP scientific collaboration were also presented at the same Symposium [2].

During the first quarter of the 1997, we also performed preliminary measurements of the ion beam power by means of a pyroelectric detector obtained from the IPP-NSC in Kharkov.

Within the collaboration with the Department of Physics at the Czech Technical University (CVUT) in Prague, we elaborated results of measurements of the X-ray radiation from a small 0.5-kJ Z-pinch device. It was possible to estimate the energy of successive pulses of the X-ray radiation. The results of these studies were presented at the Prague Symposium [3].

In 1997 we also performed preliminary measurements of the spreading of high-energy ion beams. The use of miniature electron spectrometer made it possible to measure energy spectra of the relativistic electron beams inside the inner electrode of the PF-360 facility (see Fig.1).
5.8 Measurements of X-rays and Ions Within a Large PF-1000 Facility (cooperation with the IPPLM in Warsaw)
by M.Scholz, W.Stepniewski, L.Karpinski, M.Sadowski, A.Szydlowski and V.M.Romanova

Within the scientific collaboration between the Soltan Institute for Nuclear Studies and the Institute of Plasma Physics and Laser Microfusion in 1997 we performed two new experiments with the PF-1000 facility. In the both experiments, particular attention was paid to X-ray diagnostics. With additional help of scientists from the Institute for Innovation and Fusion Research in Troick by Moscow, Russia, an attempt was undertaken to implode thin-walled liners made of an agar gel. The implosion was an effect of the interaction of a PF current-sheath with the liner surface. The liners, identical to those used previously in the ANGARA experiment, were placed on the electrode symmetry axis, near the outlet of the inner electrode. During the collapse phase of the PF discharge kinetic energy and discharge current (of intensity reaching 1 MA) were transferred from the current-sheath to the liner material. Using a fast streak camera, sensitive to visible light, it was demonstrated that the 20-mm-diam. liner may be compressed by the current-sheath with a radial velocity of $2 \times 10^4$ m/s. Contrary to that, the same camera showed that the liners of a smaller diameter (i.e. of 5.4 mm) were not compressed the same way. However, on pictures taken with an X-ray pinhole camera, one can observe a plasma column of 2 mm in diameter, having a more intense core of about 1 mm in diameter. That dense plasma was evidently produced from the liner material [1-3].

In the second PF experiment, as performed with an argon admixture to the working gas (hydrogen), time-integrated X-ray spectra were measured by means of a spectograph equipped with a mica crystal bent spherically. The crystal with $2d=19.94$ A had a radius of curvature equal to 180 mm. The PF-1000 facility was operated at an initial $H_2$-filling pressure of $p_o=3-5$ mbar, using a small admixture of Ar gas. The X-ray spectra were registered in the plane of the PF-facility axis or in the perpendicular plane. In the first case, the direction of dispersion coincided with the pinch axis and the spectograph operated with a space-focusing and an increased luminosity. In the second case, the spatial resolution was ensured by the focusing in the plane perpendicular to the dispersion plane (i.e. in the meridional plane to the crystal). In that way it was possible to register spectral lines of highly ionized argon ions in a function of a distance from the electrode ends. The results of that experiment were presented at two international conferences [4-5].
Within the scientific collaboration, we also designed and constructed a new X-ray pinhole camera with variable magnification and adjustable direction of observation.


1) Institute of Plasma Physics and Laser Microfusion, Warsaw
2) Lebedev Physical Institute, Moscow, Russia

5.9 Time Resolved Measurements of Nitrogen and Deuteron Ions From PF-II Device (at INFIP in Buenos Aires, Argentina) and PACO Device (at IFAS in Tandil, Argentina)

by J.Baranowski, M.Sadowski, E.Składnik-Sadowska, J.Żebrowski, H.Kelly¹, A.Lepone¹, A.Márquez¹, M.M.Milanese¹, R.Moroso² and J.Pouzo²

Within the scientific collaboration with the Institute of Plasma Physics (INFIP) at the University of Buenos Aires, we performed several series of ion measurements at the PF-360 facility in Świerk and at the PF-II device in Buenos Aires. The main aim of these measurements was to determine the kinetic energy of nitrogen ions, and to measure the duration of ion pulses. For this purpose, use was made of Faraday-type collectors equipped with polarized grids to cut off "primary electrons" coming from a discharge plasma [1]. For soft X-ray measurements, used as time markers, we used PIN diodes. Signals from the diode and collector were compared with $dl/dt$ traces. It was estimated that the energy of nitrogen ions was within a range $40 \text{ keV} < E < 1 \text{ MeV}$, and their HWHM values were below $1 \mu$s. The energy spectra of nitrogen ions, as obtained with a time of flight (TOF) method, were used as supplementary information (for low energy) to the energy spectra measured with a Thomson spectrometer (Fig.1). The results obtained were presented at the International Symposium PLASMA'97 [2] and they will be published in a separate paper [3].

Within the collaboration with the Institute of Plasma Physics at the University of Tandil (IFAS) we performed studies of the emission of deuterium ions generated within the PACO-PF device. Energy of deuterons, and the duration of the ion pulses were determined. The data obtained from these preliminary experiments were presented at the International Symposium PLASMA’97 [4].
Fig.1 Typical FC, X-ray, and dl/dt signals (on the left), as obtained from a single discharge within the PF-II device operated at the initial nitrogen filling $p_0=0.4$ mbar, and the corresponding nitrogen ion spectrum (on the right), as calculated on the basis of the presented FC signal.


1) Instituto de Fisica del Plasma (INFIP), Univ. of Buenos Aires, Argentina
2) Instituto de Fisica Arroyo Seco (IFAS), UNCPBA, 7000 Tandil, Argentina

5.10 Elaboration and Application of A New Diagnostic Equipment for Plasma Dynamics and X-ray Emission Studies
by L.Jakubowski, M.Sadowski, E.O.Baronova$^{1)}$ and A.S.Savelov$^{2)}$

Reliable measurements of the polarization of the X-ray emission need two identical focusing spectrographs to be applied. The construction of such spectrographs was initiated in the P-V Department in 1996. In 1997 one such device was calibrated with a pulse X-ray tube equipped with an iron anticathode which was made available at the Institute of Physics of the Warsaw University of Technology. This spectrograph has been prepared for routine operation. The second device is still under construction in the mechanical workshop of the P-V Department. The design work was carried out in collaboration with the Kurchatov Institute in Moscow.

Knowledge of the electron energy spectra is important, because of a strong dependence of the X-ray polarization on the e-beam emission from a plasma. The first series of electron energy spectra measurements was carried out with a magnetic spectrometer which was constructed at the MSEPI in Moscow and modified for the MAJA-PF experiments. The appearance of e-beams of energy within the 10-500 keV range has been confirmed. A new version of the magnetic spectrometer, adopted for time-resolved measurements, has been prepared.
Within the framework of the scientific collaboration with the MSEPI, the construction of a new nitrogen laser has been initiated. This laser will be used for plasma probing by means of interferometry and shadowgraphy.

1) RRC Kurchatov Institute, Moscow, Russia
2) Moscow State Engineering Physics Institute (MSEPI), Moscow, Russia

5.11 Calibration and Application of Solid State Nuclear Track Detectors for Plasma Diagnostics (cooperation with Departments P-I and P-IV of IPJ)
by A. Szydłowski, M. Sadowski, T. Czyżewski, M. Jaskóła, K. Korman and S. Pszona

In 1997 the final corrections of the two papers accepted for publication in Radiation Measurements, which concerned problems of the calibration of nuclear track detectors, were completed [1-2]. The calibration measurements of selected track detector materials were continued. Among other questions, diameters of tracks induced in the CR-39, PM-355, and PM-600 detectors by relatively low-energy protons and He ions (i.e., those from 70 keV to 220 keV) were determined as a function of the ion energy and etching time. It was found that 70 keV is the lowest energy value of protons and He ions, which can be registered by the detectors in question, and that detector samples irradiated with such low-energy particles need rather a short etching time (3 or 4 hours). After a longer etching time the tracks are removed from the detector together with a thin surface layer of the detector, which is always washed out during the etching procedure. In 1997 the calibration measurements were also performed for the CR-39, PM-355 and PM-600 track detectors exposed to carbon ions of energy ranging from 1.2 MeV to 15 MeV. The ions were provided by a tandem accelerator (Institute of Physics in Erlangen – Nürnberg University). The measurements aimed at determining neutron registration efficiency for selected track detectors were also continued. In 1996 neutron registration efficiencies of the CR-39, PM-355, and PM-500 materials were determined for 14.9 MeV neutrons in our Institute [3]. In 1997 additional measurements were performed for 5.2 MeV neutrons [4]. The calibration data obtained from the experiment carried out for the Polish-Argentinean cooperation, were also elaborated [5].

In 1997, track densities on the detector samples irradiated with 2.5 MeV neutrons generated within the Textor Tokamak were also defined. The aim of these measurements was to evaluate a neutron background level to be expected during ion diagnostics realized by means of track detectors within the tokamak facility. In 1998, we intend to measure the ion flux in the Textor facility using a set of nuclear track detectors.


5.12 Design and Realization of Burst Generator for the Simulation of Electromagnetic Fast Transients (EFTs)
by M. Bielik

The design, construction, and tests of a burst generator were performed in order to prepare equipment needed for research on electromagnetic compatibility (EMC) of different electronic and electrotechnical devices. The main task of this generator is the simulation of electrical fast transients (EFTs), as produced within different systems, e.g. in switching devices, thyatron and ignitron switches, power distribution switch-gears, etc. The designed Burst Generator fulfilled requirements of the PN-IEC 801-4 program (for Electromagnetic Compatibility of devices performed in measurements and control of industrial processes).

Technical Data of constructed Burst Generator
Pulse amplitude.................. 0.25-4.0 kV on 50 ohm
Energy of pulse.................. 4 mJ
Polarity of pulse.................. + or - (selectable)
Form of generated pulse........ 5/50 ns on 50 ohm
DC cutting off capacity...... 10 nF
Burst repetition............... 300 ms
Burst duration................. 1-20 ms /15 ms/ 
Burst frequency.............. 2.5 kHz, 5.0 kHz, 10 kHz
One series time of operation.. ≤ 60 sec
Coupling with power network... L1.0

According to the technical data given above, the designed Burst Generator can be controlled with a phase of the power network within a range of the full period (360°). The designed scheme can also be switched into a single-shot mode of the operation.

A high-voltage part of the Burst Generator is based on high-voltage fast transistors of the HTS 80-07 type, which permit an anode supply voltage to be increased to 8 kV DC. The HV output pulses are introduced directly into equipment under testing (EUT) but the power supply of the EUT is performed through a power filter (F) with attenuation of about 60 dB.

The output pulses with amplitude of the order of 250 V are performed in telecommunication lines for measurements of mutual couplings. The tests may be used in symmetric or unsymmetric modes. The logic and HV parts are realized on the basis of micro electronics, e.g. MCY 74047 in logic and HTS 80-07 of BEHLKE-ELECTRONICS in HV part. Application of these chips permits full miniaturization of designed Burst Generator.


5.13 Modernization of Optoelectronic Transmission Data Lines
by M.Bielik

Up to now, the optoelectronic transmission data lines used at IPJ have been equipped with solid junctions made of a fibre-optic cable with a LED or PHD. The main disadvantage of this solution was the difficulty of repairing after a damage to one of the FO connector parts.

Now, in an optoelectronic practise we often apply the FO connectors, where a LED or PHD with a premature amplifier are exchangeable parts.

During the 18th Symposium on Plasma Physics and Technology, held in Prague in 1996, the Institute of Plasma Physics (IPP), Czech Academy of Sciences, expressed interest in such new optoelectronic transmission lines. It was agreed that, within a scientific collaboration program Dept. P-V would lend to IPP two converters of the VFC and FVC type for some laboratory tests, as soon as two modern FO connection with LEDs and PHDs are delivered from the HP company.

After this supply, the converters were adapted to new requirements and installed in the IPP laboratory for a new Capillary Discharge experiment [1]. They were used in measuring circuits of HV blocks of a Marx-type Generator, and in those of a system used for the gas filling of a capillary tube.

[1] M.Bielik; Data Transmission Lines with a Galvanic Separation (in Czech); An invited talk at a Plasma Seminar at the IPP CzAS, as held in Prague on Nov.9, 1997

5.14 Research on Electromagnetic Compatibility of Electrical Equipment
by K.Kocięcka, J.Witkowski, A.Jerzykiewicz and R.Mirowski

Theoretical studies in the field of numerical simulation of transient processes in electrical circuits have been continued. The results of MO-varistor modelling [1] were presented during the ISTET'97 symposium in Palermo. Studies concerning the equivalent inductance of pulse high-current generators [2] were included in the proceedings of the International Symposium PLASMA'97. Equivalent circuits of the pulse generators used for electromagnetic compatibility tests were analyzed and calculated [3]. Circuits of a two-stage high-voltage surge generator were calculated and the influence of starting switches jitter on a pulse shape was investigated.
The International and European Standards related to the immunity requirements and the test methods have been analyzed as part of the electromagnetic compatibility studies. Based on the results of this analysis, requirements for a modular set of the simulation systems have been determined. The set should consist of the following panels:
- a combination wave (hybrid) generator,
- a long wave generator (according to CCITT),
- a fast transient (burst) generator,
- an electrostatic discharge generator,
- a phase shifter,
- a generator of voltage dips and short interruptions,
- a central unit comprising supply and measuring systems,
- the coupling and decoupling networks.

Models of the generators mentioned above have been built and tested. An invited paper concerning these activities was presented at the Seminar on Testing and Certification Problems of Electronic and Electrical Equipment [4].


5.15 Design, Assembling, and Testing of Special Surge Current and Voltage Generators (industrial contracts) by A.Jerzykiewicz, K.Kociecka, R.Mirowski and J.Witkowski

Exploitation tests of a HV pulse generator of GU-60 type have been successfully performed in cooperation with the Institute of Power Engineering. This generator was designed and built in 1996 for tests of breakdowns in power cable lines.

According to the order from the APENA factory the crest value of voltage surges produced by the GU-70 pulse generator has been increased to 130 kV (nominal voltage to 140 kV). To reach this aim the second stage was built and the generator was rebuilt to the two-stage Marx-type system [1-2]. The charging circuit was also modified and the voltage measurement range was enlarged.

The surge voltage generator of SIP-010 type was adapted to requirements of the Polish Standard PN-88/T-06250 [3] according to the order obtained from the ELTEST Laboratory. The characteristics of that generator were also tested. The same Laboratory supported also the design and construction of a modular set of simulators for EMC immunity tests (as described in 5.14).

A control and supply system of a 15 kV / 2.5 kVA test-transformer was designed and built for the TAZBET Co. Ltd [4].

Other 60 kV / 10 kVA test-transformers were inspected for the SECURA BC Co. Ltd. A station for the voltage testing of insulating gloves is under design and construction for the same company [5]. The station will be equipped with test-transformers up to 60 kV, a computer aided control and data acquisition system. Six gloves will be tested simultaneously during the continuous manufacturing process. This task should be finished June 1998.

Modernization and Tests of IONOTRON Device Equipped with Aluminium Electrodes for Technological Purposes (cooperation with Academia Sinica Institute of Physics in Beijing, China)

by J. Baranowski, J. Langner, J. Piekoszewski, M. Sadowski, E. Składnik-Sadowska, J. Stanisławski, Si-Ze Yang, Xiang-Jun He and Ying-Bing Jiang

Within the scientific cooperation with the ASIP in Beijing, China, during the first semester of 1997 we elaborated the samples made of a constructional steel and a titanium alloy. They were previously exposed within the IONOTRON-SW device equipped with titanium electrodes and a fast electromagnetic valve for pulsed injection of a working gas (nitrogen). Surface layers of those samples, modified by pulsed plasma-ion streams, were analyzed by means of XRD and AES methods, and after that they were subjected to microhardness tests. Results of those studies were presented at the Intern. Symposium PLASMA’97 [1], and afterwards they were elaborated to be published [2].

In the second semester we organized a two-week scientific stay of two Polish researchers at the ASIP laboratories. During that stay we performed preliminary measurements of ion streams emitted from a coaxial plasma gun used for material engineering by means of gas-puffed nitrogen discharges. The irradiated nuclear track detectors of CR-39 type have been prepared for a quantitative analysis, and its results (together with comparative materials) are to be presented in a paper. To perform a modernization of plasma devices used for material engineering, the IONOTRON-SW was equipped with new multirod electrodes made of pure (99.9%) aluminium. Within the system we first there were carried out preliminary measurements of pulsed plasma-ion streams by means of multi-grid collectors of the Faraday type. It made it possible to collect data about parameters of the generated ion streams (Fig. 1.).

A two-week scientific staff of two researchers from ASIP was organized in Święrk, and during that visit studies of the ion streams were supplemented by routine measurements of voltage and current waveforms as well as by detailed measurements of a power flux by means of thermocouples. The tests performed have shown that the IONOTRON-SW with aluminium electrodes operates within the whole range of exploration parameters. Subsequently we performed irradiations of several series of samples made of different materials (silicon, constructional steel, stainless steel, NaCl crystals). The samples irradiated by aluminium and nitrogen ions will be analyzed in Poland and China, and results are to be published next year.


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5.17 Operating and Testing of the High-Current Nitrogen Ion Source
by K. Czaus, E. Gorski, J. Langner and J. Stanisławska

In 1997, design studies and construction of high-current nitrogen ion sources for ion implantation of metals purposes were finished.

At first, the assembling and testing the implantator vacuum system were performed. This vacuum system contains two independently pumped vacuum chambers separated by a gate valve. Such a construction enables easy and fast change of irradiated samples to be achieved. The first vacuum chamber of about 60 l capacity contains an ion source of duoplasmotron type, equipped with an acceleration and focusing electrode system. This chamber is pumped out by means of a pumping stand of SP-2000 type. The second vacuum chamber is designed for the exposition of irradiated samples. Its capacity is 200 l and it is pumped out with a pumping stand of the SP-6000 type. The use of a gate valve makes possible an exchange of irradiated samples without opening the chamber.

Other efforts have been connected with the final assembling and putting into operation of a supply system for the ion source. This system contains two main HV-DC supply units of parameters: 80 kV, 10 mA - for acceleration, and 30 kV, 15 mA - for focusing. It also contains an insulating transformer made of a coaxial cable, which can transmit 3 kVA power at 80 kV potential difference, as well as an optoelectronic system controlling supply units of the duoplasmotron, which are operated at a high potential.

All subsystems of the high-current nitrogen ion source were put to exploitation tests which have demonstrated that they operate correctly.

5.18 Construction of a Special Plasma Injector ISEX in the Final Version and Performance of Its Laboratory Tests

Within the contract with the Space Research Centre, Polish Academy of Science (SRC-PAS), Warsaw, we prepared a technical documentation of the ISEX special plasma injector the Hall type. Basing on this documentation a team from the Dept. P-V constructed and put into operation the ISEX device in the final (flight) version [1-2], which was designed for the installation on a satellite board in order to perform active plasma experiments in space.

In 1997, the SRC-PAS delivered supply- and control-units, the ISEX device (Fig.1) was subjected to a final examination. We performed measurements of discharge characteristics, studies of efficiency of electron “freezing” and of the compensation of generated xenon ion streams. We achieved the required parameters of a plasma-ion stream, i.e., its complete charge compensation, an average ion energy value at a level of 400 eV, ion current intensity of about 1 A, and ion pulse length equal to 1 sec. Detailed investigations of the ion stream parameters were presented in a separate paper [3].
The main diagnostic tool was a set of several ion collectors of the Faraday type. They were adapted to measurements within dense plasma streams. Those collectors made possible time-resolved measurements of the ion component. Results of these measurements demonstrated a strong dependence of the ion energy distribution on the maximum value of a magnetic field strength. In all the cases investigated, the energy distribution of xenon ions had a maximum close to 400 eV (Fig. 2), according to requirements of future experiments planned to be performed with the ISEX device.

![Fig.2 Energy distribution of Xe ions emitted from an ISEX device, as measured at different states of the discharge.](image1)

![Fig.3 Angular distribution of Xe ion stream intensity, as measured at distance of 165 cm from the ISEX outlet.](image2)

On the basis of the measured angular distribution and the divergence of the investigated ion stream (Fig. 3), taking into consideration the geometry of the measuring system and data from the Faraday collectors, it was estimated that the total current intensity of the xenon ions was 1.1 A at a distance of 165 cm from the injector outlet. Waveforms of the main discharge current, values of uncompensated stream intensity, and those of the ion component, which were registered for pulses of different length (i.e., duration time ranging from 0.4 sec to 1.0 sec), confirmed the correct operation of the ISEX device. A quantitative analysis of the data obtained has proved that the required values for the main parameters of the generated ion streams were achieved.


5.19 Investigation of the Coating of Type: Metallic Layer - Interlayer (Ti) - Ceramic Layer (TiN), Produced with Use of Modified Plasma Gun

by J. Kuciński, J. Langner and J. Piekoszewski

1997 was the third and the last period of the project. In this period we carried out a combination of Ti-interlayer deposition on a melted specimen surface by HIPID-DPE method with deposition of TiN final layer by means of Impulse Plasma Deposition (IPD) method and/or Steered-Arc Evaporation (St-Arc) method.
The IPD method has been realised by using a modified plasma gun with inner electrode diameter of 65 mm and outer electrode diameter of 20 mm, both covered with a thin layer of titanium. The half period of the condenser bank discharge was of the order of 90\mu s. The current amplitude was of the order of 30kA. The St-Arc technology was based on utilisation of a metallic plasma source with cylindrical electrode diameter of 40mm.

The deposition time for a TiN layer of several microns thickness was of the order of 10 min. for arc discharge current 60A. The TiN functional layers have been deposited on a cold target as well as on the target heated up to 400°C. The results obtained show that utilisation of the HIPIB-DPE method combined with IPD technology and/or with St-Arc technology much improve adhesion and the thickness of TiN layers. The coatings produced in the project are characterised by thickness (2-3mm) and microhardness (critical load of 20-50 N) sufficient to their application to industry.

Application of the HIPIB method for ceramic surfaces glazing has been presented at the 9th Int. Conference on Surfaces with High Intensity Pulsed Ion Beams, San Sebastian, Spain 1995 [1], and the results obtained during the project realisation were published in the II-nd All-Polish Scientific Conference INZYNIERIA POWIERZCHNI'96 [2] as well as in the International Symposium PLASMA'97 [3].

LIST OF PUBLICATIONS

INFLUENCE OF GAS-PUFFED TARGETS ON THE DYNAMICS AND EMISSION CHARACTERISTICS OF NEUTRONS AND X-RAYS WITHIN THE POSEIDON PLASMA FOCUS

INVESTIGATION OF NEW CERENKOV-TYPE DETECTORS FOR STUDIES OF FAST ELECTRON BEAMS EMITTED FROM A HOT PLASMA
L.Jakubowski, M.Sadowski, J.Zebrowski

COMPARISON OF RESPONSES OF CR-39, PM-355, AND CN TRACK DETECTORS TO ENERGETIC HYDROGEN-, HELIUM-, NITROGEN-, AND OXYGEN-IONS
M.Sadowski, A.Szydłowski, M.Jasikola, T.Czyżewski, A.P.Kobzev
Radiation Measurements 28 (1997) 201

CALIBRATION OF CN- AND CR39-TRACK-DETECTORS FOR MEASUREMENTS OF FAST DEUTERONS AND NITROGEN IONS
M.Sadowski, J.Baranowski, E.Składnik-Sadowska, A.Szydłowski, H.Kelly, A.Lepone, A.Marquez
Radiation Measurements 28 (1997) 207

ON THE INTERPRETATION OF CR-39, PM-355 AND PM-500 TRACK DETECTORS RESPONSE TO 14.9 MeV NEUTRONS
T.Czyżewski, M.Jasikola, A.Korman, S.Pszona, M.Sadowski, A.Szydłowski

SURFACE MORPHOLOGY OF STEEL NITROGEN-ALLOYED USING HIGH INTENSITY PULSED PLASMA BEAMS
J.Piekoszewski, L.Walit, J.Langner
Material Letters 32 (1997) 49

INTENSE PULSED PLASMA PULSES; TWO MODES OF THE USE FOR SURFACE PROCESSING PURPOSES
J.Piekoszewski, J.Langner, L.Walit

IRRADIATION OF SILICON WITH A PULSED PLASMA BEAM CONTAINING Mo IONS
J.Piekoszewski, Z.Werner, J.Langner, M.Janik-Czachor

PHYSICAL MODEL OF DYNAMIC PHENOMENA IN IMPULSE PLASMA COAXIAL ACCELERATOR
M.Rabieński, K.Zdynia
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J.Langner, J.Piekoszewski, J.Stanisławski, Z.Werner

AN ELECTRON IN THE ATOM (IN THE MOLECULE) AND CLASSICAL DYNAMICS
M.Gryziński

SPIN OF THE ELECTRON AND STEREOCHEMISTRY OF THE ATOM
M.Gryziński

MODIFICATION OF SILICON NITRIDE CERAMICS WITH HIGH INTENSITY PULSED ION BEAMS
F.Brenschel,E.Piekoszewski, E.Wiener, J.Langner, R.Groetzbach, H.Reuther
Material Science & Engineering (1997), (in press)

MODIFICATION OF THE SURFACE PROPERTIES OF MATERIALS BY PULSED PLASMA BEAMS
J.Piekoszewski, Z.Werner, J.Langner, L.Walit
PARTICIPATION IN CONFERENCES AND WORKSHOPS

DIAGNOSTICS AND MODELLING OF A PLANAR MAGNETRON SPUTTER SOURCE
A. Neuffer, M. Rabiszki, A. Lunk (presented by A. Lunk)
Mat. Deutsche Physikalische Gesellschaft E. V. Tagung (Mainz 1997)

EROSION BEHAVIOUR OF BORON CARBIDE UNDER HIGH-POWER PULSED FLUXES OF HYDROGEN PLASMA
Proc. 4th Intern. Symp. on Fusion Nuclear Technology (Tokyo 1997)

X-RAY EMISSION FROM PF-1000 PLASMA-FOCUS DEVICE ADMIXTURED WITH ARGON

DENSE PLASMA-FOCUS RESEARCH IN POLAND
M. Sadowski (invited talk)

THERMAL LOADING OF THIN TITANIUM FOIL DURING ELECTRON BEAM SCANNING
A. Drabik, W. Drabik, M. Rabiszki (presented by W. Drabik)
Proc. 5th Polish-Japanese Seminar on Electromagnetics in Science and Technology (PTZE, Gdansk 1997), pp. 5-8

PLASMA FOCUS CURRENT SHELL IMPLOSION ONTO FOAM LINER
L. Karpinski, M. Scholz, W. Stepniewski, A. Szydlowski, A. V. Branitski, M. V. Fedulov, S. F. Medovshikov, S. L. N. Sadowski, V. P. Smirnov, M. V. Zurin (presented by L. Karpinski)
Proc. Fourth Intern. Conf. on Dense Z-Pinches (Vancouver 1997), Paper A2-06

STUDY OF X-RAY POLARIZATION AND E-BEAMS GENERATION DURING HOT-SPOT FORMATION IN PF-DISCHARGES
L. Jakubowski, M. Sadowski, E. O. Baranowska, V. V. Vakhrev (oral presentation by L. Jakubowski)
Proc. Fourth Intern. Conf. on Dense Z-Pinches (Vancouver 1997), Paper C1-04

COMPUTATIONAL PACKAGE FOR PARAMETER IDENTIFICATION OF A COMPLEX PLASMA MODEL
M. Rabiszki

FLUID MODEL OF A MAGNETRON SPUTTER DEVICE
M. Rabiszki

PLASMA FOCUS CURRENT SHELL IMPLOSION ONTO A FOAM LINER
L. Karpinski, M. Scholz, W. Stepniewski, A. Szydlowski, A. V. Branitski, M. V. Fedulov, S. F. Medovshikov, S. L. N. Sadowski, V. P. Smirnov, M. V. Zurin (presented by L. Karpinski)

EXPERIMENTAL AND THEORETICAL STUDIES OF ELECTRON BEAMS AND HOT SPOT FORMATION IN PF-DISCHARGES
L. Jakubowski, M. Sadowski, E. O. Baranowska, V. V. Vakhrev (oral presentation by L. Jakubowski)

X-RAY EMISSION FROM A MEGAJOULE PLASMA-FOCUS EXPERIMENT

STUDY OF IONS, ELECTRONS, AND X-RAYS EMMITTED FROM PF-TYPE DISCHARGES
J. Zebrowski, J. Bananowski, M. Sadowski, E. Skladnik-Sadowska, I. Garkusha, V. Makhlay

STUDY OF X-RAY AND ION EMISSION FROM PACO PF-DEVICE
M. M. Milanese, R. L. Moroso, J. O. Pouzo, M. Sadowski, E. Skladnik-Sadowska

STUDY OF DEUTERIUM-ION EMISSION FROM PACO PF-DEVICE UNDER DIFFERENT GAS CONDITIONS

MODEL OF DISCHARGE PHENOMENA IN COAXIAL IMPULSE PLASMA ACCELERATOR
M. Rabiszki, K. Zdunik
TRIBOLOGICAL PROPERTIES OF PULSED PLASMA TREATED STEELS; COMPARATIVE STUDIES
V.I.Tereshin, J.Langner, M.Sadowski, J.Fiekszewski, V.V.Chebotarev, N.T.Derepovski, I.E.Garkusha, G.D.Gamulaya,
Y.L.Ostrovskaya, Y.V.Vedensky, T.P.Yukhno

SURFACE MODIFICATION OF Fe-, AND Ti-ALLOYS WITH PULSED PLASMA-ION STREAMS FROM AN
IONOTRON
Si-Ze Yang, Ying-Bing Jiang, Mu Sun, Bing Li, J.Langner, M.Sadowski, J.Stanisławski (oral presentation by Si-Ze Yang)

ANGULAR DEPENDANCE OF TUNGSTEN WIRE EROSION CAUSED BY HIGH-POWER PULSES OF A HYDROGEN
PLASMA

FORMATION OF Ti COATINGS ON METALLIC AND CERAMIC SUBSTRATES USING INTENSE PLASMA PULSES

INVESTIGATION OF THE COATING OF THE TYPE: METALLIC LAYER - INTERLAYER (Ti) - CERAMIC LAYER
(TiN), PRODUCED WITH USE OF A MODIFIED PLASMA GUN
J.Kuceński, K.Czauo, J.Langner, J.Fiekszewski

RESEARCH ON THE INFLUENCE OF EXPERIMENTAL CONDITIONS ON THE EMISSION OF PLASMA STREAMS
FROM RPI FACILITIES
J.Baranowski, M.Sadowski, E.Składnik-Sadowska

TIME-RESOLVED MEASUREMENTS OF DEUTERIUM AND NITROGEN IONS FROM DIFFERENT PLASMA
DEVICES
J.Baranowski, M.Sadowski, E.Składnik-Sadowska, J.Zebrowski, H.Kelly, A.Lepone, A.Máquez (oral presentation by
H.Kelly)

STUDIES OF THE RESPONSE OF CN TRACK DETECTORS TO N+, N+3, AND N+13 IONS WITHIN THE ENERGY
RANGE 0.2-3 MeV
M.Sadowski, J.Baranowski, E.Składnik-Sadowska, A.Szydlowski, H.Kelly, A.Lepone, A.Máquez

RESPONSE OF CR-39, PM-355, AND PM-500 NUCLEAR TRACK DETECTORS TO FAST NEUTRONS

EQUIVALENT INDUCTANCE OF PULSE HIGH CURRENT GENERATORS
A.Jerzykiewicz, K.Kocięcka

BURST GENERATOR FOR EMC TESTING - PART I
M.Bielik

X-RAY DIAGNOSTICS OF FIBER DISCHARGES IN SMALL Z-PINCHES
L.Jakubowski, M.Sadowski, J.Zebrowski, P.Kubes, J.Kravarik, L.Pina
Proc. 18th Symposium on Plasma Physics and Technology (Prague 1997), pp. 80

SOME INEXTRICABLE PROBLEMS OF PLASMA-FOCUS STUDIES
M.Sadowski (invited talk)
Proc. 18th Symposium on Plasma Physics and Technology (Prague 1997), pp. 136

EMISSION CHARACTERISTICS OF SMALL PF-EXPERIMENTS
E.Składnik-Sadowska, M.Sadowski, M.M.Milanese, R.L.Moroso, J.O.Pouzo
Proc. 18th Symposium on Plasma Physics and Technology (Prague 1997), pp. 141

MO-VARISTOR MODEL FOR COMPUTATIONS OF HV PULSE CIRCUITS
A.Jerzykiewicz, K.Kocięcka (presented by K.Kocięcka)
Proc. 9th Intern. Symp. on Theoretical Electrical Engineering (Palermo 1997), pp. 350

TESTING OF LV EQUIPMENT BY MEANS OF STANDARIZED VOLTAGE PULSES
A.Jerzykiewicz, K.Kocięcka, J.Witkowski, R.Mirowski (presented by A.Jerzykiewicz)

NUMERICAL SOLUTION OF INVERSE PROBLEMS IN PLASMA RESEARCH
M.Rabinński
Proc. IAEA TC Meeting on Research Using Small Fusion Devices (Cairo 1997), P. A1-4
FOAM LINER EXPERIMENT WITH THE PF-1000 PLASMA FOCUS FACILITY

UNSOLVED PROBLEMS AND FUTURE PROSPECTS OF PLASMA-FOCUS RESEARCH
M. Sadowski (invited talk)
Proc. IAEA TC on Innovative Approaches to Fusion Energy (Pleasanton 1997), P. Th-10

ANALYSE ENERGÉTIQUE DES IONS DANS LE JET PULSÉ D’UN PROPULEUR COAXIAL
J. Baranowski, M. Sadowski, E. Skladnik-Sadowska (presented by J. Baranowski)
Mat. le 1er Séminaire Franco-Polonais sur les Plasmas Thermiques dans l’Espace et en Laboratoire (Varsovie 1997), P. 4A

LA CONSTRUCTION ET LA MISE EN ACTION DU PROPULEUR ISEX POUR DES EXPÉRIENCES ACTIVES DANS L’ESPACE
Mat. le 1er Séminaire Franco-Polonais sur les Plasmas Thermiques dans l’Espace et en Laboratoire (Varsovie 1997), P. 6A

DIAGNOSTICS DES CARACTÉRISTIQUES DES JETS DE PLASMA DE KSENON PRODUIT PAR LE PROPULEUR ISEX
Mat. le 1er Séminaire Franco-Polonais sur les Plasmas Thermiques dans l’Espace et en Laboratoire (Varsovie 1997), P. 5A

SEMINARS AT OTHER INSTITUTES

Corpuscular diagnostic of ions on RPI facilities
J. Baranowski, Jan. 14, Polish Academy of Science Institute of Fundamental Technological Research, Warsaw

Electronic skeleton of matter
M. Gryziński, April 18, Computational Modelling Inc., Warsaw

Principal characteristics of solid state nuclear track detectors
A. Szydlowski, April 20, Ecole Royale Militaire Brussels, Belgium

Possibility of application of solid state nuclear track detectors for corpuscular diagnostics in tokamak TEXTOR experiments
A. Szydlowski, April 21, Institut für Plasmaphysik, Jülich, Germany

Calibration measurements of solid state nuclear track detectors as performed at the Soltan Institute for Nuclear Studies
A. Szydlowski, April 22, Centre d’Etude de l’Energie Nucleaire, Mol, Belgium

Status and prospects of plasma studies in Poland
M. Sadowski, May 27, Philips Laboratory, Albuquerque, NM, USA

Some unsolved problems in plasma-focus research
M. Sadowski, Sept. 22-24, ICDMP Workshop on Plasma-Focus Neutron Sources, Palaiseau, France

Studies of neutron emisson from different plasma-focus facilities in Poland
M. Sadowski, Sept. 22-24, ICDMP Workshop on Plasma-Focus Neutron Sources, Palaiseau, France

Dynamical model of a molecular bond
M. Gryziński, Oct. 14, Institute of Physics, Białystok

Data transmission lines with a galvanic separation
M. Bielik, Nov. 9, Institute for Plasma Physics, Czech Academy of Sciences, Prague, Czech Republic

Dense magnetized plasma studies in Poland
M. Sadowski, Nov. 7, Institute of Physics, Chinese Academy of Sciences, Beijing, China

Study of X-ray and ion emission from pulsed plasma streams
E. Skladnik-Sadowska, Nov. 7, Institute of Physics, Chinese Academy of Sciences, Beijing, China

Study of neutron emission from PF devices
M. Sadowski, Nov. 12, Gas Discharge Laboratory, Tsinghua University, Beijing, China

Gas-puffed experiments with PF facilities
E. Skladnik-Sadowska, Nov. 12, Gas Discharge Laboratory, Tsinghua University, Beijing, China

Plasma research and applications in Poland
M. Sadowski, Nov. 18, Dept. of Physics, Hebei University, Baoding, China

Diagnostics of ions and x-rays from high-temperature plasma
E. Skladnik-Sadowska, Nov. 18, Dept. of Physics, Hebei University, Baoding, China
Calibration and application of the solid state nuclear track detectors for high temperature plasma
A. Szydlowski, Dec. 16, Plasma Physics Section, Warsaw

1) in Polish
2) in English

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Overview

The main focus of the Department of High Energy Physics is experimental physics, but there is also some activity in theory and phenomenology of high energy interactions.

The main involvement is in large international experiments at CERN, the European Laboratory for Particle Physics, and also in CELSIUS Storage Ring in Sweden:

- At CERN we participate in the DELPHI experiment at LEP, muon experiments NMC (New Muon Collaboration) and SMC (Spin Muon Collaboration) at the SPS, CP-violation experiment NA48 and heavy ion experiments NA49 and WA98,
- At CELSIUS we are involved in the WASA project.

They require contributions in instrumentation and long time scales, which are necessary to collect and analyse data. The department has been involved in CERN experiments for many years. In parallel there is also an increasing activity in preparation for future projects. They are:

- 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 a workshop which recently was involved in an upgrade of WASA detector. It has adequate computing power and networks to contribute to the analysis of experimental data in large collaborations.

Our department collaborates closely by with the Department of Experimental Physics, Warsaw University. The physicists take care of diploma projects and there is also group of PhD students.
6.1 DELPHI Experiment in 1997 (Highlights)
by R. Gokieli, M. Górski, K. Nawrocki, R. Sosnowski, M. Szczekowski, M. Szeptycka, P. Zalewski

In 1997 the further upgrade of the LEP accelerator to the collision energy of $e^+$ and $e^-$ $\sqrt{s} = 183$ GeV allowed the extension of searches for the Higgs bosons and supersymmetric particles in this new energy region. Preliminary results show that no new particles with masses accessible at this energy were found.

The mass of the W boson is one of the important parameters of the Standard Model. The precise measurement of this observable is one of the main goals of the LEP experiments. In the DELPHI detector the W mass was determined from the measurement of the cross-section for W-pair production (Fig. 1) and from the direct reconstruction of W bosons in the final states (Fig. 2).

The combined result is still dominated by statistical errors:

$$M_w = 80.33 \pm 0.30 \text{(stat.)} \pm 0.06 \text{(syst.)}$$

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**Fig. 1** $W^+W^-$ cross-section as a function of centre-of-mass energy. The curve is the Standard Model prediction for $m_w = 80.45$ GeV/c$^2$.

**Fig. 2** The distributions of the reconstructed masses for the semileptonic and fully hadronic channels.
6.2 Nucleon Spin Structure - Results from the SMC

The data taking by the SMC collaboration was finished by the end of 1996. In 1997 we published two results based on all the SMC data. The first one is the determination of the virtual photon-proton asymmetries $A_F^1$ [1] from inclusive deep inelastic muon scattering and the second one is on polarised quark distributions from semi-inclusive spin asymmetries [2]. Both results were obtained by scattering longitudinally polarised muons of approximately 190 GeV energy on longitudinally polarised solid targets.

The inclusive asymmetry $A_F^1$ covers the kinematic range $0.008 < x < 0.7$ and $0.2 \text{ GeV}^2 < Q^2 < 100 \text{ GeV}^2$. The statistical error has improved by approximately a factor of two compared to previous SMC measurements. Using the data with $Q^2 > 1 \text{ GeV}^2$ and $x > 0.003$ the spin dependent structure $g_1$ of the proton was determined. A perturbative QCD evolution in next-to-leading order was used to obtain $g_1^p(x)$ at a constant $Q^2 = 10 \text{ GeV}^2$. The quantity of interest is the first moment of $g_1^p$, as it can be related to the axial charges of the nucleon.

Fig. 1 shows $xg_1^p$ as a function of $x$, where the area under the points represents the integral. In the insert of this figure two versions of the interpolation of $xg_1^p$ to $x=0$, Regge-like and QCD-like, are drawn. It is clear that the value of the first moment will strongly depend on that assumption. The data do not allow to exclude either approach, so the first moments obtained in the two cases are: $\Gamma^p_1 = 0.142$ (Regge) or 0.130 (QCD) ± 0.014, where the total errors include contributions from statistical, systematics, low $x$ extrapolation and QCD evolution uncertainties. The first moment violates the Ellis-Jaffe sum rule [3] independently of the low $x$ extrapolation selected.

Fig. 1 $xg_1^p$ as a function of $x$; SMC data points (squares) with the total error are shown together with the result of the QCD fit (continuous line), both at $Q^2 = 10 \text{ GeV}^2$. For $x < 0.003$ the extrapolation assuming Regge behaviour is indicated by the dot-dashed line. The inset is a close-up extending to lower $x$. 
From the measurements of semi-inclusive spin asymmetries for positively and negatively charged hadrons the polarised quark distributions of the valance u and d quarks and the non-strange sea quarks can be determined. Such a separation is possible because the probability to observe a hadron depends not only on the quark distribution but also on the fragmentation function into a given hadron, which is, in general, different for a quark and anti-quark. The polarisation of the valence u quarks was found to be positive and to increase with x and it was found negative for valence d quarks. For the non-strange sea quarks no polarisation was observed. The difference $\Delta u_d = \Delta d$, was determined from inclusive or semi-inclusive data independently and found consistent.


6.3 Precise Measurement of the Direct CP Violation in NA48

The principal objective of the NA48 experiment is the measurement of direct CP violation in decays of neutral kaons. The quantity to be measured is the double ratio of decay rates of $K_L$ and $K_S$ into two charged and neutral pions. It is related to the parameter $\epsilon'/\epsilon$ as follows:

$$\frac{\Gamma (K_L - \pi^0\pi^0)}{\Gamma (K_L - \pi^+\pi^-)} / \frac{\Gamma (K_S - \pi^0\pi^0)}{\Gamma (K_S - \pi^+\pi^-)} = 1 - 6 Re (\epsilon'/\epsilon)$$

The parameter $\epsilon'/\epsilon$ has to be determined with an accuracy of $2 \times 10^{-4}$. Year 1997 was the first of data taking with completely equipped detector (Fig.1).

To meet all the requirements the following conditions have to be fulfilled:

1. To separate $K_S$ and $K_L$ decays. This is done by using $K_L$ and $K_S$ beams and $K_S$ tagging.
2. To measure $K_{LS} = \pi^+\pi^-$ and $K_{LS} = \pi^0\pi^0$ simultaneously. Charged decays are measured in the magnetic spectrometer and neutral decays in liquid crypton calorimeter.
3. To record a large statistics. In 1997 alone, $10^7$ reconstructed events were collected.

The experiment used a dedicated computer CS2, consisting of 128 processors working in parallel, for the online and offline computing.
The Warsaw group was involved in 1997 in the following tasks:

1. Production supervision and maintenance of DAQ system elements FOL RIO, CLOCK FO and CLUSTER IC.
2. Determination of efficiency of the $K_{\ell,5} - \pi^+\pi^-$ trigger
3. Decoding software for liquid crypton calibration
4. Determination of the $K_s$ lifetime from two-pion decays as a tool for acceptance studies (Fig. 2.)
5. Reconstruction of $K_{\ell,5} - 2\pi^0$ decays.

![Image of the $K_s$ lifetime from $K_\ell \rightarrow \pi^0\pi^-$ decays](image)

**Fig. 2:**

6.4 Study of Hadronic Observables in Heavy Ion Collisions at 158 GeV/c/N

Experiment NA49 at CERN SPS by H. Białkowska

The NA49 experiment was designed to search for predicted phase transition to deconfined quarks and gluons in Pb-Pb collisions, by the study of hadronic observables within large acceptance coverage for momentum measurements and particle identification.

In 1997 the analysis of lead-lead collisions continued, concentrating on the study of baryon stopping, strangeness production and investigation of expansion dynamics of hot and dense matter.

A systematic study of strangeness production results in an observation that strangeness enhancement, previously observed in S-S collisions, is indeed seen in central Pb-Pb collisions, but does not increase for these heaviest systems. The $\phi$ meson enhancement observed in Pb-Pb reaction is even stronger than strange particle enhancement, which is probably related to the two-strange quarks content of the $\phi$.

The main result concerning baryon stopping is shown in Fig. 1. Here the rapidity distribution for net protons (protons minus antiprotons) and for net $\Lambda$ hyperons measured in Pb-Pb is used to evaluate total baryon minus antibaryon spectrum. A strong difference relative to the corresponding spectrum for S-S and a dramatic difference with respect to p-p collision is observed. This is consistent with strong increase of energy density in central collisions of heavy nuclei.

A new direction in the physics programme of NA49 was opened up at the end of 1997 by an exposure of the detector to proton beam at 158 GeV/c, detector registering slow recoil protons allows to select processes with various degrees of centrality.
6.5 Soft Photon Production in Central 200 GeV/nucleon $^{32}$S+Au Collisions
by T. Siemiarczuk, G. Stefanek for WA93 Collaboration

Inclusive photons of low transverse momenta have been measured in 200 GeV/nucleon $^{32}$S+Au collisions at the CERN SPS [1]. Data were taken in the WA93 experiment using a small acceptance BGO detector with longitudinal segmentation. The results are compared to WA80 measurements for the same system and results from hadron decay calculations. An excess of photons over the expectations from neutral meson decays is observed.


6.6 Event by Event Measurement of $\langle p_T \rangle$ of Photons in S+Au Collisions at 200 A GeV
by T. Siemiarczuk, G. Stefanek for WA93 Collaboration

The mean transverse momentum of photons has been determined on an event by event basis in S + Au collisions at 200 A-GeV from the ratio of the measured electromagnetic transverse energy ($E_T^{\text{em}}$) to the photon multiplicity ($N_T$) [1]. The average value obtained is similar to that determined for the same system using spectroscopic techniques. The centrality dependence of the measured values is in agreement with the predictions of the VENUS event generator.


6.7 Azimuthal Anisotropy in S + Au Reactions at 200 A GeV
by T. Siemiarczuk, G. Stefanek for WA98 Collaboration

Azimuthal correlations of photons produced at mid-rapidity in 200 A-GeV S+Au collisions have been studied using a preshower photon multiplicity detector in the WA93 experiment. The Fourier expansion method has been employed to estimate the event plane via anisotropy of the event as a function of centrality. The event plane correlation technique has been used to determine the true event anisotropy, beyond the anisotropy which arises due to finite multiplicity.

The VENUS event generator with rescattering and proper simulation of the detector response can explain only a portion of the observed anisotropy (Fig.1). The residual anisotropy is found to be of the order of 5% for semi-central collisions. This suggests that directed collective flow of the produced particles is present at SPS energies.

6.8 Search for Disoriented Chiral Condensates in 158 A GeV Pb + Pb Collisions
by K.Karpio, T.Siemiarczuk, G.Stefanek, 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 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 charged and photon multiplicities in the central region of 158 A GeV 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 Search for Thermal Direct Photon Production in Sulphur - Sulphur Collision at 19.8 A GeV, CMS Energy
by T.Siemiarczuk, G.Stefanek for WA98 Collaboration

Results are presented of a search for a thermal direct photon signal in collisions between sulphur nuclei at the CERN-SPS at a beam energy of 200 GeV per nucleon. The analysis is performed in the nucleon-nucleon center of mass system by comparison of inclusive photon- and hadron momentum spectra for central and peripheral collisions.

An excess of photons is observed of which the integrated yield amounts to $6.4 \pm 0.9$ (stat.) + $8.2$ (syst.) - $3.1$ (syst.) % of the inclusive photon spectrum of the central event sample.

6.10 WASA Project at CELSIUS Storage Ring
by A.Kupsc, A.Nawrot, J.Stepaniak, WASA Collaboration

The WASA project at the CELSIUS storage ring in Uppsala is aimed at improving limits on $\eta$ and $\pi^0$ meson decay rates. The observation of branching ratios for some rare decays will serve as a test of fundamental symmetries and of physics beyond the standard model [1].

The CELSIUS ring with a pellet target will produce about $10^7$ $\eta$ mesons per day using the $p+p \rightarrow p+p+\eta$ reaction at about 1.3 GeV proton incident momentum. The wide angle detector WASA-4$\pi$ is now being assembled.

The main modules of the apparatus: a CsI (Na) Callorimeter, Plastic Scintillator Barrel (manufactured in our workshop), superconducting solenoid, vertex drift chamber and the iron yoke are now ready for the assembly. The forward part of the detector will be taken from the presently working PROMICE-WASA setup. It was shown, that the clean tagging of mesons can be achieved, using this forward detector [2].

Fig.1 Layout of the PHOS detector.
Fig.2 Detailed view of modules and bars inside a cradle.

In 1997 the study of near threshold mesons production has been continued using the PROMICE-WASA setup. Near threshold meson production involves large momentum transfers and filters-out the short range features of the NN interactions. The cross section for $p+n \rightarrow p+n+\eta$ and $p+n \rightarrow d+\eta$ [3] reaction was
measured, using the deuteron target. In this analysis it was assumed, that the proton in the target deuteron acted as a spectator. The energy in the center of mass of interacting nucleons was calculated event by event.

Further analysis of the data collected with the deuteron target will address the question, whether the reaction mechanism is affected by the presence of other nucleon.

Large sample was collected of the non-spectator deuteron break-up and pd-ppn events. The analysis is in progress.


6.11 Investigation of the Reaction $dp\rightarrow p\pi^0nn$

by T.Siemiarczuk for Dubna-Košice-Moscow-Tbilisi-Warsaw Collaboration

The reaction $dp\rightarrow p\pi^0nn$ induced by 3.34 GeV/c deuterons is investigated under experimental conditions of $4\pi$ geometry [1]. The reaction is shown to proceed mostly via the quasinucleon-nucleon transition $pp\rightarrow pn\pi^+$ accompanied by a spectator neutron. The anisotropy of neutron emission in quasiproton-proton collisions results in the invariant mass of two neutrons (the missing mass for the reaction under investigation) populating two distinct mass regions. Thereby, interactions occurring at the proton and deuteron vertices are naturally separated. As soon as off-mass-shell effects are disregarded, the "neutron mass" estimated from data on quasinucleon-nucleon collisions is found to be significantly distorted in an asymmetric way. The observation that $\Delta$ isobars emitted from the proton and deuteron vertices are characterized by different parameter values is qualitatively interpreted.


6.12 Angular Dependence of Proton Inclusive Spectra from $dp\rightarrow pX$ Reaction at 3.34 GeV/c

by T.Siemiarczuk for Dubna-Košice-Moscow-Tbilisi-Warsaw Collaboration

Inclusive differential cross sections for the $dp\rightarrow pX$ reaction at 3.34 GeV/c are studied [1] for different proton production angles in the deuteron frame. At large angles some irregularities have been observed in the spectra. The obtained angular dependence of the inclusive differential spectra for the backward hemisphere allows a detailed comparison with models describing dp interactions. This comparison shows the importance of the contributions from rescattering processes at production angles around 90°. Conclusion is made about the necessity to include additional mechanisms into existing models in order to describe the angular dependence of the inclusive proton cross sections.


6.13 Color Filamentation in Ultrarelativistic Heavy-Ion Collisions

by S.Mrówczyński

We have studied [1] color fluctuations in the quark-gluon plasma produced at the early stage of nucleus-nucleus collision at RHIC or LHC. The fluctuating color current, which flows along the beam, has been shown to be very large due to the strong anisotropy of the parton momentum distribution. We have argued that a specific fluctuation, which splits the parton system into the current filaments parallel to the beam direction, grows exponentially. The physical mechanism responsible for the phenomenon, which is known as a filamentation instability, has been discussed.

6.14 Transport Theory of Massless Fields
by S.Mrówczynski

Using the Schwinger-Keldysh technique we discuss [1] how to derive the transport equations for the system of massless quantum fields. We analyse the scalar field models with quartic and cubic interaction terms. In the model with quartic interaction the massive quasiparticles appear due to the self-interaction of massless bare fields. Therefore, the derivation of the transport equations strongly resembles that one of the massive fields, but the subset of diagrams which provide the quasiparticle mass has to be resummed. The kinetic equation for the finite width quasiparticles is found, where, except the mean-field and collision terms, there are terms which are absent in the standard Boltzmann equation. The structure of these terms is discussed. In the massless model with cubic interaction the massive quasiparticles do not emerge and presumably there is no transport theory corresponding to this model. It is not surprising since this model is anyhow ill defined.


6.15 Fundamentals in Hadronic Atom Theory
by A.Deloff

The purpose of this work, which is intended to appear in a book form, is to describe some of the major advances in our understanding of the fundamental properties of hadronic atoms within the conventional approach based on a two-body model Hamiltonian in which all strong interaction effects are simulated by an absorptive effective potential representing the complicated interaction between the hadron and the nucleus.


6.16 Participation in the CMS Experiment
by R.Gokieli, M.Górski, P.Zalewski

In 1997 the activities of the Warsaw CMS group concentrated mainly on the following subjects:

1. Construction and testing of two RPC prototypes. The chambers were built with two different types: low resistivity ($5 \times 10^8$ $\Omega$ cm) and high resistivity ($6 \times 10^{11}$ $\Omega$ cm). The chambers were tested at CERN in the hadron and muon beams and the low resistivity one at the GIF (Gamma Irradiation Facility). Especially the low resistivity one showed excellent behaviour when submitted to high radiation level, higher than that expected at the LHC. The chamber efficiency was above 98% and the time spread of the signal was less than 3 ns. The results of those tests were reported during the 4th International Workshop on Resistive Plate Chambers and Related Detectors.

2. The problem of data transmission from the CMS trigger RPC's to the electronics room has been addressed. We plan to transfer the data in a compressed format using optical links. The detailed Monte Carlo study of the compression algorithm was performed and hardware implementation of a prototype device has been undertaken. Results were presented at the 3rd Workshop on Electronics for LHC Experiments.

3. The study of the possibilities of registering heavy supersymmetric particles in the CMS was initiated. It was a subject of a diploma thesis at the Warsaw University.

4. Monte Carlo studies of the CMS muon trigger performance were continued. Special stress was put on finding a solution to the problem of elimination of "ghosts" - track candidates which do not correspond to real muons.

5. Work on the hardware implementation of the muon trigger continued. Software and hardware tools permitting the programming and testing of the muon trigger were developed. The first sample of Pattern Comparator ASIC's is expected in early 1998 which will allow us to study its performance.
6.17 Preparation of the COMPASS Experiment
by K.Kurek, A.Mielech, J.Nassalski, E.Rondio, A.Sandacz, W.Wislicki

The COMPASS experiment [1] was approved about a year ago by CERN Research Board. COMPASS, which stands for Common Muon and Proton Apparatus for Structure and Spectroscopy, will be located in the experimental area of the Spin Muon Collaboration and will start data taking in 2001.

Its initial physics aims will be to continue the work of the SMC into nucleon structure, and to study in detail the hadron spectrum. For this latter task, the muon beamline will be modified to transport hadrons with energies up to 300 GeV as well as muons. The experimental set-up has to be substantially modified to allow high trigger rates and to enable particle identification in a wide kinematics range.

With a muon beam COMPASS will measure the gluon contribution to the proton spin by looking, in particular, for charmed mesons emerging from the scattering events. Using a proton beam the COMPASS will study leptonic and semi-leptonic decays of charmed hadrons, will search for baryons containing two charm quarks and will search for exotic particles (glueballs and gluon-quark hybrids).

The Warsaw group contributions to the preparation of the experiment include the work on design and production of a part of the front-and electronics for the detector read-out, for which a team of electronics engineers from the Warsaw Technical University is responsible, and also Monte Carlo simulation of the experiment. The Monte Carlo studies are done to optimize the experimental set-up in order to achieve good resolutions and a high efficiency of pattern recognition and event reconstruction.

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

6.18 The Alice Photon Spectrometer (PHOS)
by A.Deloff, K.Karpio, T.Siemiarczuk, G.Stefanek, L.Tykarski and G.Wilk for ALICE Collaboration

The PHOS detector has been designed to search for direct photons. Their production and p_t dependence reflect, to a large extent, the initial conditions which will occur in heavy-ion collisions at the LHC.

The second goal of the PHOS is to measure π^0 and η production at the highest momenta, where the momentum resolution is an order of magnitude better (at 25 GeV) than for charged particles measured in the tracking detectors. The spectrum of high momentum ('leading') particles gives information about the propagation of jets in the dense medium created during the collision ('jet quenching').

The direct photons are embedded in a large background of photons from hadron decays (mainly π^0 and η). The ratio of direct to decay photons is of the order of 5 % in the most conservative estimate, but could well be considerably larger up to a few 10 %. We expect to achieve a sensitivity < 5 %, dominated by systematic errors mainly in the γ and π^0 reconstruction efficiencies. If the yield of direct photons has a stronger than linear dependence with multiplicity, the sensitivity can be increased by comparing central and peripheral collisions, because then systematic errors cancel to some extent. A close to quadratic dependence with multiplicity could be expected e.g. for thermal photons.

In order to reach the required sensitivity, we have to measure the rates and the p_t spectra of photons, π^0 and η mesons in the same apparatus. The expected extremely high multiplicity environment implies a high segmentation of the calorimeter, the largest possible distance to the vertex, and use of a very dense active medium with the smallest possible Molière radius.

Fig.1 A half of the iron yoke with one layer of CsI (Na) crystals inside.
In order to have adequate space resolution and to allow separation of overlapping showers, the transverse cell size should be of the order of the Molière radius $R_M$. Little shower overlap is needed in order to ensure reliable reconstruction of photons and mesons.

The particle occupancy should not exceed ~3% (which corresponds to ~15% cell occupancy) in order to be able to determine the photon reconstruction efficiency with high accuracy. At this occupancy, as shown by the SPS heavy-ion experiment WA80, that photon reconstruction efficiency can be measured to an accuracy of ~2%.

A material with a Molière radius of ~2 cm is needed for the PHOS spectrometer (at $r = 4.6$ m) in order to keep the occupancy within the required range in central Pb-Pb reactions (up to $dN_{ch}/dy = 8000$).

In addition to photons, the PHOS also responds to charged hadrons. It is therefore necessary to include a charged-particle veto detector in front of the PHOS detector (fig.1 and fig.2).

Similarly, the PHOS detects $K^0$, $n$ and $n$. All of them are produced abundantly at the LHC. The most disturbing in terms of energy deposited in the PHOS are the antineutrons. Neutral hadron rejection can be achieved by a cut on the shower width, which operates at all energies, and/or by a cut on time of flight. Indeed, over a distance of 4.6 m, a particle of Lorentz factor 2.8 will arrive 1 ns later than a photon. This covers a relevant energy range, especially for antineutrons. Therefore an option of nanosecond time-of-flight measurement in PHOS is currently being investigated.

Finally, the PHOS detector must be able to operate in the full L3 magnetic field up to ~0.5 T, and it should be compact enough to be integrated into the ALICE set-up.

6.19 Relativistic Hypernuclei

by J. Bartke$^1$, A. Filipkowski

The JINR (Dubna), SINS and other institutes in Warsaw, Cracow and Łódź are preparing experiment described in [1].

Physical motivation is given for the experiment which is aimed to investigate decays of hypernuclei and to obtain new information on the four-baryon weak coupling at small momentum transfers. Such information cannot be obtained from other reactions.

It is proposed to carry out the experiment at JINR and to use beams of relativistic heavy ions in the energy range 4–6 GeV/per nucleon which is best suited for such studies.

A specific detector set-up (Fig.1; Fig.2 - presents the trigger system) is proposed.
The experiment will use the equipment which is available at the High Energy Laboratory of JINR, and thus should be relatively inexpensive. Already at the first stage it should yield unique data on non-mesonic decay channels of the beryllium-9 hypernucleus.


b) Institute of Nuclear Physics, Cracow
LIST OF PUBLICATIONS

THE SPIN-DEPENDENT STRUCTURE FUNCTION $g_1(x)$ OF THE DEUTERON FROM POLARIZED DEEP INELASTIC MUON SCATTERING

A LINE-SHAPE ANALYSIS BY SPIN-1 NMR SIGNALS

SPIN STRUCTURE OF THE PROTON FROM POLARIZED INCLUSIVE DEEP INELASTIC MUON-PROTON SCATTERING

ACCURATE MEASUREMENT OF $F_2/F_1$ AND $R^+ - R^-$

MEASUREMENT OF THE PROTON AND DEUTERON STRUCTURE FUNCTIONS $F_1$ AND $F_2$ AND OF THE RATIO $a_0/a_1$

THE SPIN-DEPENDENT STRUCTURE FUNCTION $g_1(x)$ OF THE PROTON FROM POLARIZED DEEP-INELASTIC MUON SCATTERING

ANGULAR DEPENDENCE OF PROTON INCLUSIVE SPECTRA FROM $dp-px$ REACTION AT 3.34 GeV/c
V. V. Glagolev, T. Siemiarczuk, et al.

STUDY OF THE $dp-pn$ REACTION
Yad. Fiz. 60 (1997) 464

SOFT PHOTON PRODUCTION IN CENTRAL COLLISIONS OF 200 AGeV $S+Au$

ABOUT A POSSIBLE EXPERIMENT ON THE SEARCH OF DIBARYON STATES
V. V. Glagolev, T. Siemiarczuk, et al.
JINR Rapid Communications 83 (1997) 9

AZIMUTHAL ANISOTROPY IN $S+Au$ REACTIONS AT 200 AGeV

EVENT BY EVENT MEASUREMENT OF $<p_\gamma>$ OF PHOTONS IN $S+Au$ COLLISIONS AT 200 AGeV

MEASUREMENT OF THE SPIN DENSITY MATRIX FOR THE $\rho^0$, $K^0$ AND $\phi$ PRODUCED IN Z DECAYS
PPE 97-55 (22 May 1997)

OBSERVATION OF CHARGE-ORDERING IN PARTICLE PRODUCTION IN HADRONIC Z$^0$ DECAY
PPE 97-62 (3 June 1997)

MEASUREMENT OF CORRELATIONS BETWEEN PIONS FROM DIFFERENT W'S IN $e^+e^-\rightarrow W^+W^-$ EVENTS
MEASUREMENT OF THE MULTIPLICITY OF GLUONS SPLITTING TO BOTTOM QUARK PAIRS IN HADRONIC Z DECAYS
PPE 97-39 (10 April 1997)

MEASUREMENT OF THE TRANSVERSE SPIN CORRELATION IN Z-+e- DECAYS
PPE 97-34 (27 March 1997)

SEARCH FOR STABLE HEAVY CHARGED PARTICLES IN e+e- COLLISIONS AT SQRT(s) = 130-136, 161 AND 172 GeV

MEASUREMENT OF Bc- Bc OSCILLATIONS
PPE 97-51 (12 May 1997)

SEARCH FOR THE Bc MESON

A STUDY OF THE REACTION e+e- → μ+μ- γH AT LEP AND SEARCH FOR NEW PHYSICS AT ANNIHILATION ENERGIES NEAR 80 GeV
PPE 97-45 (25 April 1997)

MEASUREMENT AND INTERPRETATION OF THE W-PAIR CROSS-SECTION IN e+e- INTERACTIONS AT 161 GeV

RAPIDITY CORRELATIONS IN LAMBDA BARYON AND PROTON PRODUCTION IN HADRONIC Z DECAYS
PPE 97-27 (7 March 1997)

SEARCH FOR EXCITED LEPTONS IN e+e- COLLISIONS AT SQRT(s) = 161 GeV

A PRECISE MEASUREMENT OF THE Bc MESON LIFETIME USING NEW TECHNIQUE

MEASUREMENT OF EVENT SHAPE AND INCLUSIVE DISTRIBUTIONS AT SQRT(s) = 130 AND 136 GeV

SEARCH FOR LEPTON FLAVOUR NUMBER VIOLATING Z DECAYS

SEARCH FOR NEUTRAL HEAVY LEPTONS PRODUCED IN Z DECAYS

MEASUREMENT OF A, FROM THE SCALING VIOLATION IN e+e- ANNHIILATION

SEARCH FOR NEW PHENOMENA USING SINGLE PHOTON EVENTS IN THE DELPHI DETECTOR AT LEP

IDENTIFIED PARTICLES IN QUARK AND GLUON JETS

CHARGED PARTICLE MULTIPLICITY IN e+e- --> q anti-q EVENTS AT 161 GeV AND 172-Gev AND FROM THE DECAY OF THE W BOSON
MEASUREMENT OF THE TRIPLE GLUON VERTEX FROM DOUBLE QUARK TAGGED FOUR JET EVENTS

A NEW COULOMB CORRECTION METHOD FOR BOSE-EINSTEIN CORRELATIONS, BASED ON THE $\pi^+\pi^-$ CORRELATION MEASUREMENTS
T. Alber, H. Bia³kowska et al.

COLOR FILAMENTATION IN ULTRARELATIVISTIC HEAVY-ION COLLISIONS
S. Mrówecki

TRANSPORT THEORY OF MASSLESS FIELDS
S. Mrówecki

MEASUREMENT OF THE QUASI-FREE p+n - d+$\eta$ REACTION NEAR THRESHOLD

MESON PRODUCTION IN LIGHT ION COLLISIONS AT CELSIUS
R. Bitger, A. Kupie, J. Stepniak, et al.,
Nucl. Phys. A626 (1997) 29 c

CELSIUS AS AN $\eta$ FACTORY
Nucl. Phys. A626 (1997) 93 c

D* PRODUCTION IN DEEP INELASTIC SCATTERING AT HERA
J. Breitweg, M. Adamus, et al.

STUDY OF PHOTON DISSOCIATION IN DIFFRACTIVE PHOTOPRODUCTION AT HERA
J. Breitweg, M. Adamus, et al.

MEASUREMENT OF ELASTIC J/$\psi$ PHOTOPRODUCTION AT HERA
J. Breitweg, M. Adamus, et al.
DEST 97-060 (March 1997), Zeit. Phys. MS 655

DIFFERENTIAL CROSS SECTIONS OF D** PHOTOPRODUCTION IN EP COLLISIONS AT HERA
J. Breitweg, M. Adamus, et al.

COMPARISON OF ZEUS DATA WITH STANDARD MODEL PREDICTIONS FOR e+p - e+X SCATTERING AT HIGH $x$ AND $Q^2$
J. Breitweg, M. Adamus, et al.

STUDY OF ELASTIC $\rho^0$ PHOTOPRODUCTION AT HERA USING THE ZEUS LEADING PROTON SPECTROMETER
M. Derrick, M. Adamus, et al.

SEARCH FOR LEPTON FLAVOR VIOLATION IN EP COLLISIONS AT 300 GeV CENTER OF MASS ENERGY
M. Derrick, M. Adamus, et al.

A SEARCH FOR EXCITED FERMIONS IN e+p COLLISIONS AT HERA
J. Breitweg, M. Adamus, et al.

MEASUREMENT OF THE PROTON STRUCTURE FUNCTION $F_2$ AND $a_{uu}^*p$ AT LOW $Q^2$ AND VERY LOW $x$ AT HERA
J. Breitweg, M. Adamus, et al.

OBSERVATION OF ISOLATED HIG ET PHOTONS IN PHOTOPRODUCTION AT HERA
J. Breitweg, M. Adamus, et al.

MEASUREMENT OF INELASTIC J/$\psi$ PHOTOPRODUCTION AT HERA
J. Breitweg, M. Adamus, et al.
SPIN STRUCTURE OF THE NUCLEON
Plenary talk by J. Nassalski

NEW RESULTS ON THE F2 AND R ON THE PROTON AND THE DEUTERON FROM NMC
E. Rondio (on behalf of the NMC)

MEASUREMENT OF PROTON AND NITROGEN POLARIZATION IN AMMONIA AND A TEST OF EQUAL SPIN TEMPERATURE

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

MULTIPOLICY AND PSEUDORAPIDITY DISTRIBUTIONS OF PHOTONS IN S + Au REACTIONS AT 200 AGeV

SEARCH FOR DISORIENTED CHIRAL CONDENSATES IN 158 AGeV Pb + Pb COLLISIONS

SEARCH FOR CHARGINOS, NEUTRALINOS AND GRAVITINOS AT LEP

DIRECTED AND ELLIPTIC FLOW IN 158 GeV/NUCLEON Pb + Pb COLLISIONS
H. Appelshauser, H. Bialkowska, et al.

CHARGED PARTICLE PRODUCTION IN PROTON, DEUTERON, OXYGEN AND SULPHUR NUCLEUS COLLISIONS AT 200 GeV/NUCLEON
T. Alber, H. Bialkowska et al.

DENSITY FLUCTUATIONS IN THE QUARK-GLUON PLASMA
S. Mrówczyński

PION SUPPRESSION IN NUCLEAR COLLISIONS
M. Gaździcki, M. I. Gorenstein, S. Mrówczyński

HADRONIC MATTER COMPRESSIBILITY FROM EVENT-BY-EVENT ANALYSIS OF HEAVY-ION COLLISIONS
S. Mrówczyński

BREAKING THE CP SYMMETRY IN RARE η DECAYS

OBSERVATION OF SCALING VIOLATIONS IN SCALED MOMENTUM DISTRIBUTIONS AT HERA
J. Breitweg, M. Adamus, et al.

MEASUREMENT OF THE DIFFRACTIVE STRUCTURE FUNCTION F2 pT0 AT HERA
J. Breitweg, M. Adamus, et al.

DIJET CROSS SECTIONS IN PHOTOPRODUCTION AT HERA
J. Breitweg, M. Adamus, et al.

FIXED TARGET EXPERIMENTS WITH HEAVY IONS AT CERN
H. Bialkowska
Report SINS (in press)

THRESHOLD STRUCTURE OF THE QUASI-FREE p+n –> d+eta REACTION
Report TSL/ISV-97-0181, September 1997 Uppsala,
PARTICIPATION IN CONFERENCES AND WORKSHOPS

SPIN DEPENDENT STRUCTURE FUNCTIONS IN POLARIZED DEEP INELASTIC SCATTERING
E. Rondio (invited talk)
QULEN 97 International Conference, Osaka, Japan, 20-23 May, (in press)

NEW RESULTS FROM THE SMC
A. Sandacz (invited talk)
VI Conference on the Intersections of Particle and Nuclear Physics, Big Sky, Montana, 27 May - 3 June 1997, (in press)

QUARK SPIN DISTRIBUTIONS AND AXIAL ANOMALY FROM POLARIZED DEEP INELASTIC SCATTERING EXPERIMENTS
W. Wiślicki (invited talk)

WASA/PROMICE EXPERIMENT AT CELESIUS
A. Kupić (invited talk)
Chiral Dynamics Workshop, Mainz, 1-5 Sept. 1997

TRANSPORT THEORY OF MASSLESS FIELDS
S. Mróz wczynski (invited talk)
Presented at the IV Workshop on Nonequilibrium Physics at Short-Time Scales, Rostock, Germany, April 1997

COLOR COLLECTIVE PHENOMENA IN QUARK-GLUON PLASMA
S. Mróz wczynski (invited talk)
Presented at the Workshop on Deconfinement at Finite Temperature and Density, Dubna, Russia, October 1997

THE pp -> p p x REACTION BELOW 1 GeV
J. Stepanski (invited talk)
Presented at the Studies of Mesons and Light Nuclei Using WASA, Zakopane, September 12-15, 1997

SYMMETRY IN ELEMENTARY PARTICLE PHYSICS
R. Sosnowski (invited talk)
The XXV Mazurian Lakes School of Physics, Pia ki 1997

THE FUTURE HIGH ENERGY PHYSICS EXPERIMENTS
R. Sosnowski
Presented at the XXXIV Meeting of Polish Physically Society, Katowice 1997

DISCOVERY OF THE RADIOACTIVITY - THE FIRST STEP INSIDE THE ATOM
R. Sosnowski
Presented at the Symposium "The Hundred Years of the Discovery of Radioactivity", Warsaw 1997

LAMBDA AND ANTI-LAMBDA RECONSTRUCTION DETAILS
T. A. Yates, H. Bialkowski et al.
Submitted to the proceedings of Strangeness in Quark Matter 97
Santorini, Greece, 14-18 April, 1997

CASCADE (OMEGA) PRODUCTION IN Pb+Pb COLLISIONS AT 158 GeV/c
G. Odyniec, H. Bialkowski, et al.
Submitted to the proceedings of Strangeness in Quark Matter 97
Santorini, Greece, 14-18 April, 1997

Φ PRODUCTION IN 158 GeV/n Pb+Pb-COLLISIONS
V. Friese, H. Bialkowski et al.
Submitted to the proceedings of Strangeness in Quark Matter 97
Santorini, Greece, 14-18 April, 1997

KAON-LAMBDA-AND ANT LAMBDA-PRODUCTION IN Pb+Pb- COLLISIONS AT 158 GeV PER NUCLEON
C. Bornmann, H. Bialkowski, et al.
Submitted to the proceedings of Strangeness in Quark Matter 97
Santorini, Greece, 14-18 April, 1997

Ξ HYPERON PRODUCTION IN SULPHUR-GOLD INTERACTIONS AT 200 GeV/n
W. Resyk, H. Bialkowski, et al.
Submitted to the proceedings of Strangeness in Quark Matter 97
Santorini, Greece, 14-18 April, 1997

HADRONIC SPECTRA FROM COLLISIONS OF HEAVY NUCLEI
P. Jacobs, H. Bialkowski, et al.
Submitted to proceedings of ICPAQP97, Jaipur, India, 17-21 March, 1997
FIRST OF THE NA49 EVENT-BY-EVENT ANALYSIS OF Pb+Pb COLLISIONS at the SPS
G.Roland, H.Bialkowska, et al.
Contributed to Hirschegg 97 workshop

RECENT RESULTS FROM THE NA49 EXPERIMENT
G.Roland, H.Bialkowska, et al.
Presented at "Quark Matter’97" conference Tsukuba, Dec., 1997

FIRST EVIDENCE OF DIRECTED FLOW AT CERN-SPS ENERGY FROM WA98 EXPERIMENT
Quark Matter 97 conference, Tsukuba, 1997

ELECTROMAGNETIC SIGNATURES OF QGP (PHOTONS): EXPERIMENTAL STATUS
III Int. Conference on Physics and Astrophysics of Quark Gluon Plasma, Jaipur, India, 1997

COMBINATORIAL BACKGROUND AND CORRELATIONS BETWEEN PHOTONS IN Pb+Pb REACTION AT 158 AGeV
Sixth Int. Conference on Nucleus-Nucleus Collisions, Gatlinburg, USA, 1997

PRODUCTION OF NEUTRAL MESONS IN 158 AGeV HEAVY-ION COLLISIONS AT CERN SPS
III Int. Conference on Physics and Astrophysics of Quark Gluon Plasma, Jaipur, India, 1997

DIRECTED FLOW ANALYSIS IN Pb+Pb COLLISIONS AT 158 GeV PER NUCLEON
Quark Matter 97 Conference, Tsukuba, Japan, 1997

SEARCH FOR DISORIENTED CHIRAL CONDENSATES: AN EXPERIMENTAL PERSPECTIVE
III Int. Conference on Physics and Astrophysics of Quark-Gluon Plasma, Jaipur, India, 1997

RESULTS ON COLLISIONS OF Pb+Pb AND S+Au FROM THE WA98/WA93 EXPERIMENTS
Int. Conference on Gross Properties of Nuclei, Hirschegg, 1997

THE FINAL STATE INTERACTION IN THE DEUTERON BREAK-UP REACTION
V.V.Glagolev, T.Siemiarczuk, et al.

LECTURES, COURSES AND EXTERNAL SEMINARS

Structure Functions from the NMC
E.Rondio, May 15, University of Miazaki, Japan

Search for Direct CP Violation - Experiment NA 48 at CERN
J.Nassalski, May 28, Free University, Amsterdam, The Netherlands

ChPT and the Initial Program of \( \eta \) Decays at WASA
A.Kupsc, Oct. 3, Uppsala University, Department of Radiation Sciences, High Energy Physics section, Sweden

Fixed Target Experiments with Heavy Ions at CERN
H.Bialkowska, June, Lectures given at the XXXVII International School of Theoretical Physics, Zakopane

Why Relativistic Heavy-Ions?
T.Siemiarczuk, April 25, Lund University, Lund, Sweden

Near Threshold \( \eta \) and \( \eta^0 \) Meson Production and Rare Decays at CELSIUS in Uppsala
J.Stepaniak, Jan. 22, IFJ, Krakow

Colorful Quark-Gluon Plasma
S.Mróweczyński, Oct., Institute of Physics, Pedagogical University, Kielce

Colorful Quark-Gluon Plasma
S.Mróweczyński, Nov., Institute of Experimental Physics, Warsaw University, Warsaw

Two Particle Correlations and Bound State Formation
S.Mróweczyński, Nov., Institute of Physics, University of Technology, Warsaw

Relativistic Elementary Atoms
S.Mróweczyński, Dec., Institute of Experimental Physics, Warsaw University, Warsaw
100 Years of the Electron
P. Zalewski, May, Jadwisin

Measurement of the Stau Mass in the GMSB Model via Time of Flight Determination in the CMS
P. Zalewski, Dec. 9, Physics and Detector Simulation Meeting CERN, Geneva, Switzerland

Ghost Buster for the MRPC
P. Zalewski, Nov. 3-6, TRIDAS Review, CERN, Geneva, Switzerland

Course: Classical Mechanics, Quantum Physics and Statistical Physics at Pedagogical University, Kielce,
S. Mrózczynski

INTERNAL SEMINARS

The Mass of the W boson
M. Szeptycka, April 18, Seminar of High Energy Physics, Warsaw University and SINS, Warsaw

Tests of the Standard Model
M. Szczekowski, Oct. 3, Seminar of High Energy Physics, Warsaw University and SINS, Warsaw

Will We Discover the Supersymmetry in the CMS Detector?
P. Zalewski, Nov. 28, Seminar of High Energy Physics, Warsaw University and SINS, Warsaw

Colorful Quark-Gluon Plasma
S. Mrózczynski, Nov., SINS, Warsaw

Heavy Ions at the Crossroad
H. Białkowska, Oct. 24, Seminar of High Energy Physics, Warsaw University and SINS, Warsaw

Participation of the Warsaw Laboratory in the CMS experiment at CERN
M. Górski, Nov. 14, SINS, Świerk

* in Polish
" in English

PARTICIPATION IN CONFERENCE COMMITTEES, SESSION CHAIRMEN

INTERNATIONAL WORKSHOP "STUDIES OF MESONS AND LIGHT NUCLEI USING WASA"
Sept. 12-15, Zakopane
J. Stepaniak, Chairperson

INTERNATIONAL CONFERENCE "SYMMETRY AND SPIN 97",
Praque, Aug. 26-30, 1997
W. Willicki, Chairman of session

SCIENCE POPULARIZATION TALKS AND ARTICLES

S. Mrózczynski
9 articles in weekly "Polityka"
2 articles in monthly "Wiedza i Życie"
Participation in several radio and TV programs
Lecture on nuclear physics for the physics teachers in Kielce
Lecture on nuclear physics at "Science Festival" in Warsaw

P. Zalewski
9 articles in "Dela"

H. Białkowska
6 articles in "Młody Technik"
PERSONNEL

Research scientists

Marek Adamus, Dr. (on leave)
Helena Białkowska, Assoc.Prof.
   1/4, on leave since Nov.1.
Andrzej Deloff, Assoc.Prof.
Tomasz Gadaj, MSc.
   on leave since Dec.4.
Ryszard Gokieli, Dr.
Maciej Górski, Dr.
Andrzej Filipkowski, Dr. 3/4
Andrzej Kupść, Dr. 1/4 (on leave)
Stanisław Mrówczyński, Assoc.Prof. 2/3
Jan Nassalski, Professor

Adam Nawrot, Dr.
Ewa Rondio, Assoc.Prof.
   1/4, on leave till Dec. 31.
Andrzej Sandacz, Assoc.Prof.
Teodor Siemiarczuk, Professor
Ryszard Sosnowski, Professor
Joanna Stepaniak, Professor
Maria Szeptycka, Professor
Michał Szleper, Dr., on leave till Nov. 8.
Marek Szczekowski, Assoc.Prof.
Piotr Szymański, Dr., (on leave)
Wojciech Wiślicki, Dr.
Piotr Zalewski, Dr.

PhD Students

Bożena Boimska, MSc.
Krzysztof Karpio, MSc.
Julia Kurowska, MSc.
Adam Mielech, MSc.
Krzysztof Nawrocki, MSc.
Krystyna Przestrzelska, MSc.
Sławomir Wronka, MSc.

Technical and administrative staff

Krzysztof Brzozowski
Maria Dąbowska 1/2
Piotr Gawor
Janina Krawiec
Paweł Marciniewski (on leave)

Tadeusz Marszał
Fryderyk Perski
Wiesława Pojedyńska
Maria Sobocińska
Teresa Świerczyńska
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.
- Studies of the structure and properties of Extensive Air Showers induced by cosmic ray particles.
- Search for point sources of high energy cosmic rays.
- Studies of cosmic ray propagation in the Galaxy and mechanisms of particle acceleration.
- Studies of mass composition of cosmic rays in the energy range $10^{15} - 10^{17}$ eV.

Theoretical and experimental studies of nuclear interactions for energies exceeding those obtained by modern particle accelerators are performed based on the results obtained by the Łódź Extensive Air Shower Array. The Łódź hodoscope can register the electromagnetic component of cosmic ray showers developing in the atmosphere as well as muons of two energy thresholds.

Data collected by the Łódź array are also used to study the mass composition of cosmic rays in the energy range $10^{15} - 10^{17}$ eV.

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 Karlsruhe (Germany), Collège de France, the Institute for Nuclear Studies of the Russian Academy of Science, the University of Perpignan (France) and Uppsala University (Sweden).
7.1 Łódź EAS Array
by R. Firkowski, J. Gawin, S. Kowalczyk, S. Pachała, J. Swarzyński, J. Szabelski

The Łódź hodoscopic array for EAS registration was working during 1997. More than 600000 showers were registered. The data from the part of array on the surface of the ground were stored. All the Geiger-Müller tubes in this part of the array have been replaced by new ones. The actual experimental setup allows for the control of the state of the array and correctness of its work. Several programs for testing the work of the array have been written. Due to these programs, we manage to find and remove a few faults in the work of the array. Several programs for storing and reading experimental data have been written, which enable quick access to the database and fast data analysis.

7.2 KASCADE EAS Experiment
by J. Zabierowski

The year 1997 was the first year of routine data taking for KASCADE (Karlsruhe Shower Core and Array Detector) - currently the biggest cosmic ray experiment in Europe, covering primary energy range $10^{15}-10^{17}$ eV and situated in Forschungszentrum Karlsruhe, Germany.

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 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 a combination of various advanced detection techniques for the electromagnetic, muonic and the hadronic component of the EAS. By the end of 1997, 90% of the Central Calorimeter was in operation and the build-up of the last big component of the experiment, the Muon Tunnel, was started. This large muon detector, comprising 600 m$^2$ of limited streamer tubes (organised in 16 towers) and more than 25 000 electronics channels, will be brought into full operation during 1998. The design and prototype testing of the tunnel front-end electronics was completed in Łódź during 1997 and after successful test with one tower [2] its mass production was performed in Germany. The development of the data analysis methods for the tunnel has been in progress.

The collaboration activity, in which the Łódź group (from SINS and Łódź University) was participated, was devoted to better understanding of the detectors' performance and development of the analysis procedures which will account for possible systematical errors. Different preliminary spectra and distributions were presented during XXV International Cosmic Ray Conference in Durban (South Africa) in July/August 1997 in 12 contributions (see the publications of our department) and the current status of the experiment was given in the Highlight Talk there [3].


7.3 EAS of High Energy CR and Nucleus-Nucleus Interactions
by J. Szabelski

The collaboration on the EAS studies with physicists from the Institute of Nuclear Studies of the Russian Academy of Sciences was continued. Joint research was mainly devoted to the analysis of muons of energy above 200 GeV detected underground and to studies of time structure of the front of EAS registered at mountain altitudes.
We analysed the data from the muon telescope, studying the frequency of registration of muon groups coming at different angles, i.e. having different threshold muon energies: from 200 GeV to around 3000 GeV. The aim of these studies is the estimation of CR mass composition in a large energy range using data from one experiment. The data are archived on optical disks. A small sample of original data (30 MB), which has been transferred to Łódź, is used for creating and testing of software.

The analysis of shower front time structure can also provide information on primary CR mass composition. The measurements were performed on the Karpet array. Interpretation of results needs detailed simulations of EAS development adjusted to experimental conditions.

7.4 High Energy Hadrons and Cherenkov Radiation from EAS
by J.Gawin, B.Szabelska, J.Szabelski

We continued the EAS development simulations by the Monte-Carlo method using the CORSIKA program. The calculations were concentrated on tasks allowing for comparison of simulation results with experimental data. We have studied two problems: lateral distribution of high energy hadrons measured on mountain altitudes and time structure of Cherenkov light produced by the EAS.

Measurements of hadron lateral distribution in the Tien-Shan experiment seemed to indicate a very rapid rise of transverse momentum of hadrons with energy above 1000 GeV. This result for many years neither has been explained nor confirmed by computer simulations. This discrepancy has served as one of the main arguments for the necessity of building hadron calorimeters. Our calculations showed that the "measured" lateral distribution of hadrons was the result of inappropriate treatment of calorimeter resolution. This influenced the estimation of the number of hadrons and their energy. Now it seems that the discrepancy has been removed. The paper describing the results of our calculations has been submitted to the Journal of Physics [1].

We also continued our studies of a time analysis of impulses from photomultipliers registering Cherenkov light produced in the atmosphere by propagating EAS. The aim is to determine a method of experimental discrimination between electromagnetic and hadronic showers in wave front sampling measurements of Cherenkov radiation (experiments THEMISTOCLE and CELESTE). Determination of the hadronic origin of the shower would improve the ratio of the observed signal due to gamma rays of energy 100 to 3000 GeV to the dominating hadronic background. Our calculations indicated that hadronic showers could be identified by registration of the signal from fast muons coming before the main signal from the electromagnetic component.

The paper summarizing results of these studies was published in the Raports of SINS, released via INTERNET and submitted to Astroparticle Physics [2].

Experimental verification of our calculation became possible due to the application of the Flash ADC system (with frequency 1.3 GHz) in one of the THEMISTOCLE detectors. During our visit in Collège de France we obtained full access to the results of measurements. We have prepared several programs for data analysis, especially the program for scanning the full THEMISTOCLE data simultaneously with the data from Flash ADC. The work is being continued in order to define experimental conditions which would reduce the hadronic background in the THEMISTOCLE experiment. This in collaboration with physicists from Collège de France.


7.5 Participation in the WASA Experiment
by J.Zabierowski

The year 1997 was important for the WASA Collaboration. Missing funding was granted and the final preparations to the installation of the 4π detector setup in the straight section of the CELSIUS storage ring started. At the same time the existing PROMICE / WASA experimental setup was used for the investigation of the near threshold production of π and η mesons in pp and pn reactions [1-5].

We participated in the collaboration physics programme as well as in the build-up of the WASA detector. The Light Pulser Monitoring System for ~1600 channels is being built in Łódź. The installation and tests in the
experiment are foreseen for 1998. The participation in the collaboration benefited also from the TEMPUS MJEP9006 project.


7.6 Preparations to the Detection of CR Background During the Period of Maximal Solar Activity.

by J.Szabelski

PL9900113

In the previous solar maximum activity period (1989 - 1992, 11-years cycle), increases of CR intensity during solar flares were registered. Those changes caused some perturbations on the Earth (mainly in the work of industrial electronics) and also a rise of ionizing radiation important for air transport. From the scientific point of view, such cases are interesting for studies of particle acceleration mechanism to energies above 10 GeV (or may be even above 500 GeV) during the solar flares.

We plan (together with dr. Pszona from Dept. P-IV) to apply a helium neutron counter and a small muon telescope to study those effects. The neutron counter will measure the flux of background neutrons on the ground level, which originates from the CR particles in the upper layers of the atmosphere:
- protons of energies above 10 GeV (for our latitude)
- neutrons of GeV energies.

The muon telescope built of Geiger-Muller tubes will register muons from different directions with angular resolution of ~2 degrees. We want to study changes of muon flux in narrow angular ranges (not necessarily in the direction to the Sun). Both detectors would be synchronized with the EAS array and provide new interesting information on high energy CR.

We also plan to join CR muon studies in the L3 experiment in CERN. At the meeting of "L3 + Cosmics" collaboration we presented a talk about the possibility of using the L3 results to studies of energy and direction of muons correlated with the solar flares [1].

LIST OF PUBLICATIONS

THE KASCADE EXPERIMENT

MEASUREMENTS OF THE QUASIFREE $p+n - d+\eta$ REACTION NEAR THRESHOLD

CELSIUS AS AN $\eta$ FACTORY
Nucl. Phys. A 626 (1997) 93c

MESON PRODUCTION IN LIGHT ION COLLISIONS AT CELSIUS
Nucl. Phys. A 626 (1997) 29c

HIGH ENERGY HADRONS IN EAS AT MOUNTAIN ALTITUDE
J.N.Capdevielle, J.Gawin, D.Sobczyńska, B.Szabelska, J.Szabelski, T.Wibig

REPORTS

MEASURABLE DIFFERENCE IN CHERENKOV LIGHT BETWEEN GAMMA AND HADRON INDUCED EAS
H.Cabot, C.Meynadier, D.Sobczynska, B.Szabelska, J.Szabelski, T.Wibig
(INTERNET in library xxx.lanl.gov as astro-ph/9708236)

COSMIC RAYS: STUDYING THE ORIGIN
J.Szabelski
Raport SINS - 20-VII, 1997
(INTERNET in library xxx.lanl.gov as astro-ph/9710191)

THRESHOLD STRUCTURE OF THE QUASIFREE $p+n - d+\eta$ REACTION
TSL/ISV Report-97-0181, Uppsala, September 1997

$\eta$-MESON PRODUCTION IN LIGHT ION COLLISION AT CELSIUS
T.Johansson, J.Zabierowski, et al.
TSL/ISV-97-0184, Uppsala, September 1997

ON THE DENSITY SPECTRUM - AGAIN (FORTY YEARS LATER)
A.Zawadzki', T.Wibig, J.Gawin
Raport IPJ, (in press)

PARTICIPATION IN CONFERENCES AND WORKSHOPS

THE COMPOSITION OF UHE COSMIC RAYS - THE NEW KASCADE EXPERIMENT
H.O.Klages, ..., J.Wdowczyk', J.Zabierowski et al.

THE STATUS OF THE EXTENSIVE AIR SHOWER EXPERIMENT KASCADE

ESTIMATION OF THE COSMIC RAY COMPOSITION WITH THE KASCADE HADRON CALORIMETER
Proc.XXV ICRC Durban 1997, Vol.6 HE 1.2.27, p.93

ENERGY DEPOSITION OF 10 TeV HADRONS IN THE KASCADE CALORIMETER
Proc.XXV ICRC Durban 1997, Vol.6 HE 1.2.28, p.97

HADRON DISTRIBUTION IN THE CORE OF 100 TeV EXTENSIVE AIR SHOWERS
Proc.XXV ICRC Durban 1997, Vol.6 HE 2.1.2.28, p.145
MEASUREMENTS OF ARRIVAL TIME DISTRIBUTIONS OF EAS MUONS WITH THE FACILITIES OF THE KASCADE CENTRAL DETECTOR
M. Föllner, J. Wdowczyk, J. Zabierowski, ... et al.

THE ELECTRON/MUON RATIO IN EAS AT AND ABOVE THE "KNEE" REGION
J. H. Weber, J. Wdowczyk', J. Zabierowski, ... et al.

ELECTRON AND MUON SIZE SPECTRA OF EAS BELOW AND ABOVE THE "KNEE"
R. Glastetter, J. Wdowczyk', J. Zabierowski, ... et al.

MULTIFRACTAL MOMENTS ANALYSIS OF THE CORE OF PeV SHOWERS FOR AN ESTIMATE OF THE COSMIC RAY COMPOSITION
A. Haungs, J. Wdowczyk', J. Zabierowski, ... et al.

HOW TO INFER THE MASS COMPOSITION FROM EAS OBSERVATIONS DEMONSTRATED WITH KASCADE DATA
A. Chilingarian, J. Wdowczyk', J. Zabierowski, ... et al.

HOW TO INFER THE PRIMARY ENERGY SPECTRUM FROM EAS OBSERVATIONS DEMONSTRATED WITH KASCADE DATA
M. Roth, J. Wdowczyk', J. Zabierowski, ... et al.

RECENT EXTENSIONS TO THE AIR SHOWER SIMULATION PROGRAMM CORSIKA
D. Heck, J. Wdowczyk', J. Zabierowski, ... et al.
Proc. XXV ICRC Durban 1997, Vol. 6 HE 2.3.2, p. 245

INELASTIC CROSS-SECTIONS AND THEIR INFLUENCE ON AIR SHOWER DEVELOPMENT
J. Knapp, J. Wdowczyk', J. Zabierowski, ... et al.
Proc. XXV ICRC Durban 1997, Vol. 6 HE 1.3.3, p. 121

THE EXTENSIVE AIR SHOWER EXPERIMENT KASCADE - FIRST RESULTS
H. O. Klages, J. Wdowczyk', J. Zabierowski, ... et al.
Highlight Talk at XXV ICRC Durban 1997, to be published in World Scientific
 FIRST RESULTS FROM THE KASCADE AIR-SHOWER EXPERIMENT
K. H. Kampert, ... J. Wdowczyk', J. Zabierowski et al.

LIGHT PULSER MONITORING SYSTEM FOR 4π WASA DETECTOR
J. Zabierowski

HIGH ENERGY MUONS CORRELATED WITH SOLAR FLARES
J. Szabelski
Meeting of collaboration "L3 + Cosmics", Amsterdam 20.02.1997

LECTURES, COURSES AND EXTERNAL SEMINARS

Measurements of Cosmic Ray Muons in detector L3 (LEP CERN)
J. Szabelski, March 13, Department of Experimental Physics, University of Łódź

Studies of High Energy Particles Correlated with Solar Flares
J. Szabelski, April 4, Astronomical Observatory of the Jagiellonian University

The Extensive Air Shower Experiment KASCADE
J. Zabierowski, May, Department of Experimental Physics, University of Łódź

INTERNAL SEMINARS

Solar Muons in L3
J. Szabelski, Febr. 14, IPJ Łódź

First Results from the KASCADE Experiment
T. Pytlos, Experimental Physics Dept., University of Łódź, Febr. 21, IPJ Łódź
Production of Nuclear Energy and Transmutation of Radioactive Nuclei Using Accelerators\(^a\)
A. Polanski, Dept. P-IV, ASINS, April 18, IPJ Łódź

Models of Hadronisation Used in EAS Physics\(^b\)
Lilia Popowa, Institute of Nuclear Research and Nuclear Energy, Sofia, July 11, IPJ Łódź

Statistical Properties of Wavelet Spectra\(^b\)
N. Suzuki, Dept. of Physics, Shinshu University, Sept. 26, IPJ Łódź

Measurements of Neutrons in Cosmic Rays\(^a\)
St. Pszona, Dept. P-IV, ASINS, Oct. 28, IPJ Łódź

Hypothesis of Tachionic Neutrino\(^b\)
J. Rembielinski, Theoretical Physics Dept., University of Łódź, Dec. 18, IPJ Łódź

\(^a\) in Polish
\(^b\) in English

**RESEARCH PROJECTS (GRANTS)**

**INVESTIGATION OF THE MUON DISTRIBUTIONS IN EXTENSIVE COSMIC RAY SHOWERS IN THE FRAMES OF POLISH-GERMAN EXPERIMENT KASCADE IN KARLSRUHE (GERMANY)**
Principal investigator: Dr. Janusz Zabierowski
Grant No. 2 P03B 160 12

**UPGRADING OF THE ŁODŻ COSMIC RAY LABORATORY FOR THE PURPOSE OF ENHANCED PARTICIPATION IN KASCADE EXPERIMENT**
Principal investigator: Dr. Janusz Zabierowski
Polish-German Foundation Grant 1720/95/LN

**OTHER GRANTS**

J. Zabierowski
INVESTIGATION OF REAR DECAYS AND MESON PRODUCTION MECHANISM IN THE WASA EXPERIMENT
KBN grant nr 2P 03B07910
Principal Investigator: Prof. J. Stepaniak

J. Gawin, B. Szabelska and J. Szabelski
STUDY OF THE DIFFUSE COSMIC GAMMA RADIATION
Collaboration nr 95-80 between LPC - CDF Paris - IPJ Łódź (in frame of Cooperation between IN2P3 and Polish Laboratories)

J. Gawin, B. Szabelska, J. Szabelski
INTERPRETATION OF THE HIGH ENERGY GAMMA RAYS MEASUREMENTS IN EXPERIMENTS THEMISTOCLE, CAT AND CELESTE
Project nr 086/R96/R97 in frame of French - Polish Scientific and Technological Cooperation Joint Project

**PERSONNEL**

**Research scientists**
Jerzy Gawin, Professor
Barbara Szabelska, Dr.
Jacek Szabelski, Dr.
Andrzej Wasilewski
Janusz Zabierowski, Dr.

**Technical and administrative staff**
Ryszard Firkowski, Dr. 1/5
Stefan Kowalczyk 1/2
Ryszard Lewandowski
Stefan Pachała
Zygmunt Piskor
Józef Swarzyński
Przemysław Tokarski
Overview

This department consists of 17 physicists and 4 graduate students working on some aspects of low energy, high energy, plasma and nonlinear physics. Most of the effort is phenomenologically oriented. The specific topics are:

- Studies of strangeness in nuclei that stem from a long Warsaw tradition of hypernuclear physics. These include attempts to understand the elusive Σ-hypernuclei, studies of nuclear bound states of η-mesons that introduce hidden strangeness into nuclei, and work on the propagation of strangelets - the hypothetical large quasi-nuclear objects - through the atmosphere.

- Some studies have been devoted to the structure of superheavy elements. These were successful in predicting properties of deformed superheavy nuclei. Now we continue calculations of collective motion, neutron haloes and energy dissipation in heavy ion collisions. An increasing effort is devoted to research of 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 (hadronic and nuclear).

- Theoretical studies of soliton solutions in several branches of physics are performed. Methods of testing stabilities of these soliton solutions have been developed. Results have implications in solid state physics as well as for plasmas.

Collaborations with several universities have been maintained. These include the Universities of: Warsaw, Bucharest, Kielce, T.U. München, Liege, Siegen, Helsinki, Sao Paulo, Shinshu (Motsumoto), ICRR Tanashi (Tokyo) Lipsh, Berkeley, Brussels, St.Petersburg, Tbilisi, I.C.London, Warwick and the Institutes: GSI-Darmstadt, Joint Institute of Nuclear Research - Dubna.
8.1 Review of Selected Topics in Hypernuclear Physics
by J. Dąbrowski

A critical review of hypernuclear physics was prepared. In particular the uncertain accuracy of the LOB (Low Order Brueckner) results for hyperon binding in nuclear matter was stressed, and a theoretical description of the production of Sigma hypernuclear states in the inclusive (K-,π+) reaction was discussed [1], [2].


8.2 Poles of the S-matrix for a Complex Square Well Potential
by J. Dąbrowski

The possible connection between the Σ hypernuclear resonances and the poles (in the complex k plane) of the S matrix for the Σ single-particle optical potential was the starting point for a detailed discussion of the trajectories of these poles. The assumed square well shape of the potential leads to analytical expressions for the S matrix. When the absorption increases, the poles, in agreement with a simple criterion, tend either to a finite limit or to infinity. In a preliminary discussion, the case was considered also when the S optical potential was replaced by two coupled channels Σ and Λ. [1], [2]


8.3 On the possible S.P. Nature of the Σ Hypernuclear States Produced in the (K-,π) Reaction
by J. Dąbrowski and J. Rożynek

The possibility of describing observed Σ hypernuclear states with positive energy in terms of a Σ single particle model is discussed. It is pointed out that the states may be explained as resonances of Σ in the s.p. potential with a repulsive bump near the nuclear surface, whose magnitude agrees with microscopic estimates [1].


8.4 Studies on Nuclear Masses and Radii
by Z. Patyk, A. Baran, J. F. Berger, J. Decharge, J. Dobaczewski, J. Muntian, P. Ring, A. Sobiczewski

The quality of the description of nuclear masses and charge radii, calculated in various microscopic approaches, is studied. The Hartree-Fock-Bogoliubov, Extended Thomas-Fermi model with Strutinski Integral, Relativistic Mean Field and Macroscopic-Microscopic approaches are considered [1,2].
A theoretical elaboration of the experimental data on masses of exotic nuclei, obtained with the use of the fragment separator (FRS) and the storage ring (ESR) at GSI-Darmstadt is undertaken \[3,4\]. Studies of the properties of heavy and superheavy nuclei were extended \[5,6\].


1) Maria Curie-Sklodowska University, Lublin, Poland
2) Centre d’Etudes, Bruyères-le-Châtel, France
3) Warsaw University, Warsaw, Poland
4) Technische Universität, München, Germany

8.5 The Role of the Quark Degrees of Freedom in the EMC Effect
by J.Rozynek

The influence of the nuclear medium on the polarization part of the nucleon structure function was calculated in the Convolution Model. The relativistic mean field model was developed. The departures from the momentum sum rule were explained \[1\] with a good fit to the data. The results have been we submitted to Phys. Rev. C.


8.6 The Quark Sub-Structure in the Relativistic Mean Field Approach
by A.Okopińska and J.Rozynek

The optimized expansion is applied to calculate the effective action for the Nambu-Jona-Lasinio model. The method is non-perturbative. The results derived from the effective action calculated to the first order of the optimized expansion correspond to an infinite summation of perturbative Feynman diagrams both in the Schwinger-Dyson equation for propagator and in the two-body Bethe-Salpeter equation. We show that this is equivalent to the mean field (relativistic Hartree plus random phase) approximation. The optimized expansion thus offers a systematic method to improve the relativistic mean field approximation in a consistent way \[1\].


8.7 Non-axial Shapes in Spontaneous Fission of Superheavy Nuclei
by J.Skalski, R.A.Gherghescu, Z.Patyk and A.Sobiczewski

We tested the importance of non-axial nuclear shapes in the spontaneous fission of heavy and superheavy even-even nuclei from a region around the hypothetical doubly magic nucleus \(^{298}_{114}\). Fission half-lives were calculated by finding a dynamical fission path as dictated by the least WKB action principle with the macroscopic-microscopic energy and the cranking masses included. Results show that effects of non-axial shapes in the fission process are weakened by inertia and become important only for the heaviest elements with \(Z \geq 120\).
8.8 Theoretical Investigations of Superheavy Nuclei
by R. Smolotćzuk

Equilibrium deformations, masses, alpha-decay energies and half-lives, as well as fission barriers and spontaneous-fission half-lives, for even-even isotopes of the elements Z = 104-120, were calculated. On the nuclear chart, the area of beta-stable even-even superheavy nuclei was determined. The borders of the region of spherical superheavy nuclei, which should live long enough to be synthesized and detected in a present-day experimental set-up, were also determined. Within the obtained results, conclusions concerning the stability of odd-A and odd-odd nuclei were drawn. Calculations were performed in a multidimensional deformation space and were based on the macroscopic-microscopic model [1-5].


8.9 Geometric Quantization of Field Theory
by M. W. Kalinowski and W. Piechocki

A symplectic structure of classical field theory on globally hyperbolic spacetime and its application to canonical geometric quantization procedure is presented. The developed formalism can be treated in two ways: as a prequantization procedure in a usual sense or as a quantization procedure in a stochastic quantum mechanics approach on a phase space [1,2].


8.10 Relativistic Particle in the Liouville Field
by G. Jorjadze and W. Piechocki

A model of a relativistic particle moving in the Liouville field is investigated. The symmetry group of the system is SL(2,R)/Z. The corresponding dynamical integrals describe a full set of classical trajectories. Dynamical integrals are used for the gauge-invariant Hamiltonian reduction. The new scheme is proposed for quantization of the reduced system. The quantum system obtained reproduces classical symmetry. Physical aspects for the model are discussed [1,2].


8.11 On the Influence of Impurities on Soliton Propagation along Dipole Chains
by E. Infeld, A. Skorupski

Some time ago, Zorski and Infeld introduced a simple model for the propagation of waves and solitons along dipole chains [1]. Using an extension of this model, we investigated the possibility of soliton reflection from an impurity. We found that this is possible only in very exceptional cases.

8.12 Soliton Dynamics in 3D
by E. Infeld, A. Senatorski

Further 3D simulations of soliton breakup were performed. As a result of a more comprehensive study, which was done with increased exactness and for larger times, 3 main corollaries emerge. Firstly, the present computation confirmed last year’s results for formerly reached times. Secondly, a new theoretical and numerical analyses was completed with the result that theoretically found stability curves in the region of their validity agree with numerics. Furthermore, the present computations showed that practical life-times of principally unstable products of 3D soliton breakup are much longer than could be guessed from previous, less exact computations. Thirdly more exact results, including colour illustrations, allowed us to establish a firm quantitative correspondence of the obtained solitons with the ones described by other investigations.

The results were written up and submitted to Physical Review E, 1997 (in press).

8.13 Growth of the Normal Flow Instability of a Vertex Array in 2 Component He II
by E. Infeld, T. Lenkowska-Czerwińska

There is a hydrodynamic instability in 2 component rotating superfluid He II. This instability sets in at a critical relative velocity of the two components (normal and superfluid). Growth rates of this instability are found. Generally speaking, growth rates are different from those found hitherto and presented in the literature [1]. This is important in view of recent experiments in which the superfluid matches the vorticity of the normal fluid [2].

Paper to be published in Phys. Rev. B.


8.14 Description de la Turbulence de Langmuir Dans un Champ Magnétique Fort [1]
by P.P. Goldstein, J.C. Samson [b], G. Rostoker [b]

We continued our research on a theory for description of some quasiperiodic structures, observed in the magnetosphere. Although most such structures develop as a result of lower hybrid turbulence, some of them, especially those which propagate at a small angle to the magnetic field, may be due to Langmuir turbulence. A set of equations describing such turbulence in a strong magnetic field has been derived and some solutions similar to solitons (and periodic nonlinear waves) of the cubic Schrödinger equation have been found. Those solutions differ from their Schrödinger counterparts by larger phase velocities and deeper density depletions. The difference is due to the presence of the strong magnetic field [1].

[1] Communication at I er Séminaire Franco-Polonais sur les Plasmas Thermiques dans l’Espace et en Laboratoire, Warsaw, 8-10 december 1997
[b] Center for Space Research, University of Alberta Edmonton, Alberta, Canada, T6G 2J1

8.15 Multi-channel Regge Behaviour
by L. Lukaszuk

The high-energy behaviour in a multi-channel system was investigated [1] in the framework of collinear asymptotic dynamics for massive particles [2]. The most general trilinear coupling of N different scalar fields was considered. The Regge behaviour and closed expression for the Regge trajectories and couplings have been obtained. The results were corroborated in the multichannel Bethe-Salpether approach.

8.16 Spin Asymmetries in Polarized Deep Inelastic Lepton Scattering
by K.Kurek

Deep inelastic scattering (DIS) of polarized charged leptons off polarized nuclear targets allows us to access the spin-dependent nucleon structure. When interpreted in the framework of the quark-parton model the experimental results show that the quark spins account only for a rather small fraction of the nucleon spin, thus implying an appreciable contribution either of gluons or possibly of angular momentum [1]. The study of semi-inclusive DIS allows us, in addition, to distinguish the role of each individual component and to separate the contributions of different constituents to the nucleon spin. The study of polarized open charm lepto-production allows us to access the gluon polarization $A_G$ in a polarized nucleon. The hard cross sections of the dominant processes in polarized DIS (the leading order parton level process, virtual photo-absorption, the first order in QCD processes: the gluon radiation (Compton) and the photon-gluon fusion (PGF)) were recalculated. The masses of heavy (charm) quarks were taken into account. The fully spin dependent amplitudes for charm quarks were calculated using helicity amplitudes formalism [2].

The calculations were done in a new Monte Carlo program for polarized DIS, POLDIS, [3]. The five-fold differential partonic cross sections and the partonic spin asymmetry are convoluted with the corresponding parton polarization. This procedure provides a polarization weight for each event generated by existing lepto-production event generator LEPTO for DIS and AROMA for Heavy Flavor production. POLDIS is a Monte Carlo code for polarized inclusive as well as for semi-inclusive DIS. The program is now used by SMC and COMPASS experiments.


8.17 Gluonic Reggeons
by R.Kirschner and L.Szymanowski

Contributions from gluon interactions, which are non-leading in high-energy semi-hard processes are studied and represented in terms of reggeon exchanges. Unlike the leading gluonic reggeon, related to the BFKL pomeron, the non-leading reggeons are sensitive to the spin and transverse momentum distributions of scattering partons. There are several gluonic reggeons with poles in the vicinity of angular momentum $j=0$ contributing to the perturbative Regge asymptotics of QCD. We extend the high-energy effective action including sub-leading terms which describe these reggeons and their interactions with scattering quarks and gluons in the multi-Regge approximation.

[2] Leipzig Universität, Germany

8.18 Diffractive Meson Production from Virtual Photons with odd Charge-parity Exchange
by R.Engel, D.Yu.Ivanov, R.Kirschner and L.Szymanowski

We calculated the cross-section of diffractive charge-parity $C=+1$ neutral meson production in virtual photon-proton collision at high energies. Due to the opposite $C$-parities of photon and meson $M^* (M^* = \eta_c\pi^0,a_2)$ this process probes the t-channel $C=-1$ odderon exchange which is described here as a noninteracting three-gluon exchange. Estimates for the cross section of the inelastic diffractive process $\gamma p \rightarrow \eta_cX_c$ are presented. The total cross section of diffractive $\eta_c$ meson photoproduction is found to be 47 pb. The cross sections for the diffractive production of light mesons ($\pi^0,a_2$) in $\gamma p$ collisions are of the same order if the photon virtuality $Q^2$ is $m_{\eta_c}^2$. [1].

[2] Leipzig Universität, Germany
8.19 X-rays in Antiprotonic Atoms
by J. Kulpa, J. Skalski, R. Smolarczyk, S. Wycech

The Polish German experiment PS209 at the Low Energy Antiproton Ring at CERN completed in 1996 brought initial results on the intensities of X rays transitions. The new measurements supply precise energies of some low lying states of antiprotonic atoms with heavy nuclei [1]. This precision will allow a better estimate of antiproton-nucleus optical potentials. When this is known the measurements of atomic level life times will serve as a method to test the neutron distribution on the surface of large nuclei.

The first results allow us to find, by E2 mixing of atomic and nuclear states, some properties of Coulomb assisted nuclear bound states of antiprotons. These indicate a transition of optical potential from a surface attraction to a central repulsion [2].


8.20 Interactions of Nucleons with η-Mesons
by J. Kulpa and S. Wycech

An analysis of coupled ηN, πN, ππN, γN channels was performed in the region close to the η-N threshold. The motivation was to obtain the scattering length in this system and to understand the role of the ηN threshold cusp in few body η interactions.

The length of .75 + i.27 fm [1] turns out to be large enough to support an η-deuteron virtual state. It also indicates possibilities of a very rich spectrum of quasibound states in the η-nucleus systems.


8.21 The QCD-Based Analysis of Kaon Weak Decays
by J. Wrzecionko

Starting directly from the QCD lagrangian an effective action describing the weak kaon decays in different channels has been calculated. Calculated decay rates in the leptonic, semileptonic and two pion decay channels of charges K-mesons, agree with the experimental data. The role of strong interaction effects in the nonleptonic two and three pion decay modes of kaons has been estimated.

The paper will be sent to Phys. Rev. D.

8.22 Strange Results from the Cosmic Ray Data
by G. Wilk and Z. Wlodarczyk

We have continued research on the propagation of strangelets through the atmosphere addressing the problem of their stability this time. First results were presented at a poster session IV-T at Quark Matter'97 conference in Tsukuba, Dec. 1-5, 1997, Japan (G. Wilk and Z. Wlodarczyk: Have strangelets already been observed?). We demonstrated there, on a simple example of Λ production that strangelets propagating through the atmosphere are stable against fragmentation. The origin of this stability is in the higher binding energy per baryon for strange baryons in nuclear matter.

1) Institute of Physics Pedagogical University, Kielce, Poland

8.23 Final State Coulomb Interactions
by T. Osada, M. Biyajima and G. Wilk

We applied the new method of calculation of Coulomb final state interactions developed by us recently to the new data for the π⁺/π⁻ yield ratios. We obtained a very interesting result that there exist strong correlations between the observed charge of the (pion) emitting source and its size [1]. Our method can serve,
in addition to the Bose Einstein correlations, to deduce the proper dimensions of the central fireball produced in high energy heavy ion collisions [1].


8.24 Further Development in the Applications of the Interacting Gluon Model
by F.O.Durães\(^1\) F.S.Navarra\(^1\) and G.Wilk

We continued work on applications of the Interacting Gluon Model (IGM), developed by us some time ago, to new physical processes of particle production, namely to diffractive dissociation processes, both in hadronic collisions [1] and in collisions initiated by high energy photons [2,3]. We have shown that, the characteristic for these processes inverse mass-squared dependence of the measured cross sections, follows automatically from our model. Moreover, the energy dependence of these cross sections agrees with the standard dynamical input of the IGM used in its previous applications. This result shed new light on the problem of the so called Pomeron in the multiparticle (diffractive) production processes and pushes the applicability region of the IGM still further.


\(^1\) Institute of Physics, University of São Paulo, São Paulo, SP, Brazil
### LIST OF PUBLICATIONS

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Journal/Volume/Issue</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRECISION EXPERIMENTS WITH EXOTIC NUCLEI</td>
<td>H.Geissel, G.Bollen, G.Muenzenberg and Z.Patyk</td>
<td>Nuclear Instruments and Methods B 136(1997)351</td>
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A. Bravar, K. Kurek, R. Windmolders
Computer Physics Communications 105 (1997) 42

FORM FACTOR $\eta^{2} - \eta' + \nu'$ AT DIFFERENT PHOTON VIRTUALITIES
A. Anselm, A. Johansen, E. Leader, L. Lukaszuk

THE SPIN DEPENDENT STRUCTURE FUNCTION $g_1(x)$ OF THE PROTON FROM POLARIZED DEEP INELASTIC MUON SCATTERING
K. Kurek with SMC Collaboration

A LINE-SHAPE ANALYSIS FOR SPIN-1 NMR SIGNALS
K. Kurek with SMS Collaboration

PROPERTIES OF THE HYPOTHETICAL SPHERICAL SUPERHEAVY NUCLEI
R. Smolarzczuk

η-NUCLEON SCATTERING LENGTH AND EFFECTIVE RANGE
A. M. Green, S. Wycech

ANTIPROTONIC INVESTIGATION OF NUCLEAR PERIPHERY

THE EXCITATION OF AN INDEPENDENT-PARTICLE GAS BY A TIME-DEPENDENT POTENTIAL WELL. Part II
J. Blocki, J. Skalski, W. J. Swiatecki
Nucl. Phys. A 618 (1997) 1

EQUILIBRIUM SHAPES AND HIGH-SPIN PROPERTIES OF THE NEUTRON-RICH $A=100$ NUCLEI
J. Skalski, S. Manzatori, W. Nazarewicz

THE EXCITATION OF A QUANTUM GAS OF INDEPENDENT FERMIONS IN A DEFORMING CAVITY - PERIODICITY OF DRIVING VS. LANDAU-ZENER TRANSITIONS
J. Skalski

THE EXCITATION OF A QUANTUM GAS OF INDEPENDENT PARTICLES UNDER PERIODIC PERTURBATION IN INTEGRABLE OR NON-INTEGRABLE POTENTIAL
P. Majerciak, J. Skalski, J. Blocki

SMALL $x$ BEHAVIOUR OF CHIRALLY ODD PROTON DISTRIBUTION $h_{c}(x, Q^{2})$
L. Szymanski

DIFFRACTIVE DISSOCIATION IN THE INTERACTING GLUON MODEL
F. O. Duras, F. S. Navarra, G. Wilk

QUASISCALING IN THE ANALYSIS OF THE YIELD RATIO $\pi/\pi^*$: MATHEMATICAL STRUCTURE AND ESTIMATION OF SOURCE SIZE
T. Osada, M. Biyajima, G. Wilk

DIFFRACTIVE MASS SPECTRA AT DESY HERA IN THE INTERACTING GLUON MODEL
F. O. Duras, F. S. Navarra G. Wilk

OPTIMIZED EXPANSION FOR THE NAMBU AND JONA LASINIO MODEL
A. Okopińska, J. Rozynek

GLUONIC REGGEONS
R. Kirschner, L. Szymanski
DIFFRACTIVE MESON PRODUCTION FROM VIRTUAL PHOTONS WITH ODD CHARGE-PARITY EXCHANGE
R.Engel, D.Yu.Ivanov, R.Kirschner, L.Szymanowski

SINGULARITIES OF THE S-MATRIX FOR A COMPLEX SQUARE WELL POTENTIAL
J.Dąbrowski

HYPERNUCLEAR PHYSICS - AN OVERVIEW
J.Dąbrowski

BREAKUP OF 2d INTO 3d KADOMTSEV-PETIAUSHILI SOLITONS
A.Senatorski, E.Infeld

GROWTH RATES OF THE NORMAL FLUID FLOW INSTABILITY IN HE II
E.Infeld, T.Lenkowska-Czerwińska

MEASUREMENT OF PROTON AND NITROGEN POLARIZATION IN AMMONIA AND A TEST OF EQUAL SPIN TEMPERATURE
K.Kurek with SMC Collaboration

POLARIZED QUARK DISTRIBUTION IN THE NUCLEON FROM SEMI-INCLUSIVE SPIN-ASYMMETRIES
K.Kurek with SMC Collaboration

ON WYEL'S EXTENSION OF THE RELATIVITY PRINCIPLE AS A TOOL OF UNIFICATION OF FUNDAMENTAL INTERACTIONS
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E.Infeld, A.Skorupski

LESSONS OF NONLINEAR PLASMA THEORY
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PREDICTED PROPERTIES OF TRANSACTINIDE NUCLEI
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THEORETICAL MASSES AND CHARGE RADII OF STABLE AND EXOTIC NUCLEI
Z. Patyk, A. Baran, J. F. Berger, J. Dechargé, J. Dobaczewski, P. Ring, A. Sobiczewski

PREDICTED PROPERTIES OF DEFORMED AND SPHERICAL SUPERHEAVY NUCLEI
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NON-ABELIAN FLUX ALGEBRAS IN YANG-MILLS THEORIES
L. Lukaszk

GAUGE THEORY OF PHASE AND SCALE
M. Pawlowski

DECAY PROPERTIES OF SUPERHEAVY NUCLEI
R. Smolańczuk

PROPERTIES OF SPONTANEOUS FISSION OF SUPERHEAVY NUCLEI
R. Smolańczuk

MASS SPECTRUM OF STRANGELETS
G. Wilk and Z. Włodarczyk

CAN STRANGELETS BE SEEN IN COSMIC RAYS?
G. Wilk and Z. Włodarczyk

FINAL STATE INTERACTIONS IN BOSE EINSTEIN CORRELATIONS
M. Biayjima, T. Mizoguchi, T. Osada and G. Wilk

CENTAURS AS PROBE OF DEEP PENETRATING COMPONENT IN COSMIC RAYS
G. Wilk and Z. Włodarczyk

J/ψ ELASTICITY DISTRIBUTION IN THE VECTOR DOMINANCE APPROACH
F.O. Darbés, S. Navarra and G. Wilk

STRANGENESS IN NUCLEI
J. Dąbrowski (invited talk)
XVI International Workshop on Nuclear Theory, Rila Mountains, Bulgaria, June 16-21, 1997

SELECTED TOPICS IN HYPERNUCLEAR PHYSICS
J. Dąbrowski (invited talk)
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SINGULARITIES OF THE S-MATRIX FOR A COMPLEX SQUARE WELL POTENTIAL
J. Dąbrowski (oral presentation)
XXV Mazurian School in Physics, Piaski 27 August - 6 September 1997

HYPERNUCLEAR PHYSICS - AN OVERVIEW
J. Dąbrowski (invited talk)
XXI International Workshop on Condensed Matter Theories, Luso, Portugal, 22-26 September 1997

LESSONS OF NONLINEAR PLASMA THEORY
E. Infeld (invited talk, presented by E. Infeld), A. Senatorski, P. Frycz
DEPARTMENT OF ATOMIC NUCLEUS THEORY

SHELL STRUCTURE AND SHAPES OF SUPERHEAVY NUCLEI
Z. Patyk, J. Skalski, R.A. Ghersescu, A. Sobieczwski (invited talk)
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CALCULATED PROPERTIES OF NEUTRON-RICH HEAVY NUCLEI
R.A. Ghersescu, Z. Patyk, J. Skalski, A. Sobieczwski (invited talk)

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A. Sobieczwski (invited talk)
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PREDICTED PROPERTIES OF TRANSACTINIDE NUCLEI
A. Sobieczwski (invited talk)

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Z. Patyk, A. Baran, J. F. Berger, J. Dechare, J. Dobaczewski, P. Ring, A. Sobieczwski
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PREDICTED PROPERTIES OF DEFORMED AND SPHERICAL SUPERHEAVY NUCLEI
Z. Patyk, A. Sobieczwski (invited talk)
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TOPOLOGY OF SOLUTION OF THE LOUVILLE EQUATION
W. Piechocki (invited talk)
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E. Infeld, A. Skorupski
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DYNAMICS OF PROTEIN CHAINS
E. Infeld (invited talk)
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DESCRIPTION DE LA TURBULENCE DE LANGMUIR DANS UN CHAMP MAGNETIQUE FORT
P. Goldstein (invited talk)
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NON-ABELIAN FLUX ALGEBRAS IN YANG-MILLS THEORIES
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CONFORMALLY SYMMETRIC STANDARD MODEL
M. Pawłowski (oral presentation)
"Relativistic Physics and Some of its Applications", Athens, June 1997

GAUGE THEORY OF PHASE AND SCALE
M. Pawłowski (invited talk),
Int. Conference "Macroscopic Electrodynamics", Cracow, November 1997

CONFORMAL SYMMETRY AND Higgs EFFECT IN COSMOLOGY
V. N. Pervushin (oral presentation), M. Pawłowski, V. I. Smirinški
Seminar at Triangle Seminar on Particle Physics, Vienna, November 28-29, 1997

THE ROLE OF THE QUARKS DEGREES OF FREEDOM IN THE EMC EFFECT
J. Rożniewski (oral presentation)
in International Conference on Quarks in Nuclei "QUELEN 97", RCNP, Osaka, (20-24) May 1997

OPTIMIZED EXPANSION FOR THE NAMBU AND JONA LAŠINU MODEL
A. Okopinska, J. Rożniewski (oral presentation by A. Okopinska)
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\( J/\psi \) ELASTICITY DISTRIBUTION IN THE VECTOR DOMINANCE APPROACH
F. O. Durá, S. Navarra and G. Wilk (invited talk)

HAVE STRANGELETS ALREADY BEEN OBSERVED?
G. Wilk, Z. Włodarczyk
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UNIVERSAL MASS DEPENDENCE FOR PARTICLE PRODUCTION RATES: A SIGNAL FOR NON-THERMAL PRODUCTION MECHANISM?
M. Szczekowski, G. Wilk
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DECAY PROPERTIES OF SUPERHEAVY NUCLEI
R. Smolarzczuk (invited talk)
Symposium on Nuclear Physics III, Tours, France, September 1997

STABILITY OF SUPERHEAVY NUCLEI
R. Smolarzczuk (invited talk)
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HF+SkP AND HFB+SkP CALCULATIONS OF NUCLEON DENSITIES AT THE NUCLEAR PERIPHERY
R. Smolarzczuk (invited talk)
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S. Wycech (invited talk)
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R. Smolarzczuk (invited talk)
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A. Sobieczewski
JINR, Dubna (Russia) June 1997

THEORETICAL RESULTS FOR STABILITY OF SUPERHEAVY NUCLEI
A. Sobieczewski
GSI-Darmstadt (Germany), June 1997

\( \eta \)-N SCATTERING LENGTH
S. Wycech
Uppsala University, June 1997

INTERACTING GLUON MODEL
G. Wilk
Shinshu University, Matsumoto, 9.01.1997

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G. Wilk
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G. Wilk
ICRR Tanashi/Tokyo; 28.11.1997

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S. Wycech
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ON SOLITON DYNAMICS
E. Infeld
IPPT PAN (September) 1997

HOW FAR CAN THE PERIODIC TABLE OF ELEMENTS BE EXTENDED
A. Sobiczewski
Warsaw University, May 1997

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R. Smolańczuk
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WHERE DOES THE MENDELEYEV TABLE END?
R. Smolańczuk
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A. Sobiczewski
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XVI INTERNATIONAL WORKSHOP ON NUCLEAT THEORY, RILA, BULGARIA, 16-21.VI.1997
J. Dąbrowski (session chairman)

XXI INTERNATIONAL WORKSHOP ON CONDENSED MATTER THEORIES, LUSO, PORTUGAL, 22-26.IX.1997
J. Dąbrowski (session chairman)

INTERNATIONAL WORKSHOP ON CONDENSED MATTER THEORIES
J. Dąbrowski - Member of the International Advisory Committee

ACTA PHYSICA POLONICA B
J. Dąbrowski - Member of the International Editorial Council
PERSONNEL

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Goldstein Piotr, Dr.
Infeld Eryk, Professor
Krzysztof Kurek, Dr.
Łukaszuk Leszek, Professor
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Skorupski Andrzej, Dr.
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Smolańczuk Robert, Dr.
Sobiczewski Adam, Professor
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Wrzecionko Jerzy, Assoc.prof.
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Jgor Muntian, M.Sc.
Oleg Utyuzh, M.Sc.

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9. DEPARTMENT OF RADIATION DETECTORS

Head of Department: Prof. Jerzy Piekoszewski
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Overview

Work carried out in 1997 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 Department all objectives are:
- search for new types of detectors
- adapting modern technologies (especially of industrial microelectronics) to detector manufacturing
- producing unique detectors tailored for physics experiments
- manufacturing standard detectors for radiation measuring instruments
- scientific development of the staff.

These 1997 objectives were accomplished particularly by:
- research on unique detectors for nuclear physics (e.g. transmission type Si(Li) detectors with extremely thin entrance and exit window)
- development of technology of high-resistivity (HRSi) silicon detectors and thermoelectric cooling systems (KBN grant)
- study of the applicability of industrial planar technology in producing detectors
- manufacturing detectors developed in previous years
- re-generating and servicing customer detectors of various origin.

In accomplishing of the above, the Department cooperated with interested groups of physicists from our Institute (P-I and P-II Departments), Warsaw University, Warsaw Heavy Ion Laboratory and with some technology Institutes based in Warsaw (ITME, ITE). Some detectors and services have been delivered to customers on a commercial basis.

X-RAY TUBE GENERATORS

The Department conducts research on design and technology of producing X-ray generators based on X-ray tubes of special construction. In 1997, work on a special design X-ray tube with "needle-like anode" for therapy of tumors began (KBN grant). In accomplishing the above, the Department cooperated with Polon IZOT and Dora Power Systems companies.

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. Experiments on conventional implantation of ions into engineering components are carried out in cooperation with FZ Rossendorf, (Germany), and ITME (Warsaw). Pioneering of new applications of the pulsed ion beams is thus possible. The processing step in the experiments conducted in cooperation with FZR is carried out in our Institute.

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 of an ion implantation technique as a method of improving the quality of engineering tools.
These objectives were accomplished in 1997 particularly by:

- melting, and attempts of diffusive mixing, of selected metals with ceramic substrates by means of intense plasma pulses (proportion of ions of metal and of working gas varied in a controlled way)
- construction of the source of nitrogen ions
- improving the useful properties of selected machine tools by means of conventional ion implantation
- working-out some diagnostics for pulsed plasma beams (power vs time measurement)

In accomplishing the above the Department cooperated with the P-V Department, the Institute of Ion Beam Physics and Material Research (FZ Rossendorf, Germany), INCT (Warsaw), and ITME (Warsaw).
9.1 Pulsed Plasma Beam Mixing of Titanium and Molybdenum with Sapphire

by J. Piekoszewski, E. Wieser, J. Langner, R. Grötschel, H. Reuter, Z. Werner

A wealth of information was published in the last decade on the results of experiments on formation of alloys and chemical compounds on surfaces of materials by means of ion beams (ion implantation and ion mixing techniques) and laser beams.

In the former case mixing of the alloyed constituent (most often metallic) with the substrate appears as a result of superposition of the three following processes: (i) displacing impacted atoms (ballistic mixing, BM); (ii) diffusion through radiation-generated defects (radiation enhanced diffusion, RED); and (iii) diffusion caused by a chemical potential gradient, leading to formation of a new phase or new phases. The first process is a short-range one (below < 100nm). The other two may lead to a long-range mixing (several micrometers).

In case of laser techniques, the near-surface layer of a metallic film-substrate structure is molten by a continuously scanned or a pulsed laser beam of a power in the range $10^6$-$10^8$ W/cm². Since migration of atoms in liquid phase is by 7 orders of magnitude (or even more) higher than that in solid phase, an effective mixing of a film-substrate structure may take place in time as short as several tens of nanoseconds; it is a consequence of a very effective diffusion of both structure constituents.

As was shown in our previous works devoted to metal-metal structures, the Deposition by Pulsed Erosion (DPE) version of intense plasma pulses technique (under development in the Andrzej Sołtan Institute for Nuclear Studies in Świerk) is potentially capable of alloying (mixing) also the ceramic-metal the structures. The method exhibits some features of both above mentioned techniques (ion beams and laser beams). During the DPE process, a plasma pulse containing ions of a selected metal (e.g. Al, Cu, Ti, Ni, Mo) and ions of a working gas in which the discharge takes place (e.g. N, Ar, H, Xe) supplies to the substrate a portion of energy sufficient to melt its near-surface layer—analogously as in the case of a laser beam treatment. However, a transport of mass takes place simultaneously, as in the case of an ion beam treatment.

A series of experiments to determine the efficiency of metallization of the $\text{Al}_2\text{O}_3$ (sapphire) and polycrystalline $\text{Si}_3\text{N}_4$ ceramics by the DPE method was conducted within the reported period. The main difference between both mentioned materials - from the DPE application point of view - lies in the fact, that the former ceramic melts in 2030°C (in normal conditions), whereas the latter one does not exhibit any liquid phase, and in the temperature of 1900°C decomposes or intensely evaporates. Some results obtained for $\text{Al}_2\text{O}_3$ samples irradiated with Mo-N and Ti-N plasma pulses are briefly discussed below.

Experimental conditions: mean energy density of pulses generated in the rod-type plasma generator IBIS: 5.5 J/cm²; delay times: $t = 160, 180$ and $200 \mu$s (for 160 $\mu$s plasma is rich in metal ions, poor in nitrogen ions, on the contrary for 200 $\mu$s); number of subsequent pulses: 5. The irradiated samples were characterized in FZR by the following methods: secondary and back-scattered electron images observed in SEM, EDX microprobe analysis, RBS spectra, AES measurements.

Computer simulation of thermal evolution in sapphire irradiated with pulses of plasma lasting more than 1 $\mu$s and carrying energy densities of the order of the experimentally encountered ones showed that duration of the molten phase did not depend on the energy level; it amounted to about 10 $\mu$s. On the other hand, the melted depth for pulses of duration 1-5 $\mu$s amounted to 0.7 to 1.7 $\mu$m. Therefore one can easily estimate that during the melt time (50 $\mu$s at 5 pulses) the diffusion range is approximately 0.5 $\mu$m (taking into account a typical value of diffusion constant for impurities in molten phase $D = 5 \times 10^{-5}$ cm²/s). One can then expect that mixing in $\text{Al}_2\text{O}_3$ might occur at a depth of a fraction of a micrometer—provided other necessary conditions are met.

A detailed analysis of results of sample characterization has provided the following observations and conclusions. There is a very pronounced difference in topology of samples irradiated with the Mo-N and Ti-N plasma. In the former case one can see microdroplets, net of microcracks and gaps on the surface. Number and dimensions of microdroplets are the largest for $t = 160 \mu$s and diminish with $t$. Microdroplets consist mainly of Mo. Between them there exists a thin layer also containing Mo with surface concentrations $N_s = 1.6 \times 10^{17}$, $4 \times 10^{16}$ and $2 \times 10^{15}$ cm⁻² for $t = 160$, 180 and 200 $\mu$s, respectively. The $N_s$ values do not vary between gaps and outside of them.
In the latter case (Ti-N) there appears a homogenous layer without microdroplets and with not very abundant gaps, but with a visible net of microcracks. A sub-layer of Ti.N appears down to a depth of 5 nm; the deeper layer is composed of metallic titanium. The surface concentrations of Ti amount to $1.8 \times 10^{17}$, $3.2 \times 10^{16}$ and $3.2 \times 10^{16}$ cm$^{-2}$ for $t=160$, 180 and 200 $\mu$s, respectively.

In case of Ti a distinct mixing of deposit with substrate takes place down to a depth of about 0.5 $\mu$m. It is not yet clear whether the mixing is connected with formation of titanium-oxygen and/or titanium-aluminum compounds or alloys, or if titanium is an impurity dissolved in sapphire.

Conclusions drawn from the above reported results:

- A capability of the DPE version of the intense plasma pulse technique to perform a long-range mixing of deposit with substrate in the Ti/Al$_2$O$_3$ structures has been proved. Previous attempts of other authors aiming at obtaining mixing in this structure by means of ion and laser beams have failed.

Further experiments are required in order to determine chemical state of titanium alloyed into a sapphire substrate and to clarify the question whether the thin metal (Mo, Ti) layer observed on the substrate is formed cumulatively or only during the last pulse.

9.2 Modification of Silicon Nitride Ceramics with High Intensity Ion Pulses

by F. Brentscheidt, J. Piekoszewski, E. Wieser, J. Langner, R. Grötschel, H. Reuter

Samples were irradiated and characterized similarly as in the previous task, but the number of pulses was 10, and the mean energy density was about 6.5 J/cm$^2$. Additionally, some tribological tests were performed during characterization. The results allow to make the following statements.

Microdroplets that are Ni-rich are the more abundant in Ni/Si$_3$N$_4$ structures the shorter the delay time $\tau$. A thin layer exhibiting a strong 1617 eV line in the AES spectra covers the area between the microdroplets; the line is characteristic for nickel silicides. This can be understood taking into consideration the fact that the substrate material decomposes, providing a source of silicon for formation of silicides. The outer sub-layer consists mainly of pure nickel. Because of presence of the microdroplets, broadening of the main line in the low-energy part of the RBS spectra may not be interpreted as a result of mixing.

Long-range mixing does not take place in Ti/Si$_3$N$_4$ structures either. Some narrow surface peaks appear in RBS spectra in case of these structures, whereas the low-energy part of the spectra is even. The presence of Ti only on the surface is confirmed by a sequence of shifts of Si edges; the sequence depends (in agreement with expectations) on the value of time $\tau$. Surface concentrations $N_s$ of titanium amount to $1 \times 10^{17}$ and $2.4 \times 10^{16}$ cm$^{-2}$, for 160 and 170 $\mu$s, respectively. For larger delays the concentration falls below the detection limit of the RBS method. The surface layer consists of a mixture of Ti, TiSi and TiN. The presence of the latter is confirmed by the 416 eV line that appears next to the 419 eV line in AES spectra, whereas the presence of TiSi - by the 1617 eV line that appears next to the 1612 eV Si$_3$N$_4$ line. The differences in morphology of surfaces of the samples bombarded by Ni and Ti plasma may be explained by a larger surface tension of liquid phase Ni (1.74 N/m) than that of Ti (1.57).

In spite of lack of a long-range mixing, structures of both types exhibited in the "ball-on-disk" test (10,000 cycles) an about tenfold increase of the wear resistance. A similar result may be brought about by some conventional ion implantation (according to investigations performed earlier in FZR). Improvement of the wear resistance did not clearly depend on the amount of deposit in the delay time range $\tau = 160-200$ $\mu$s. The improvement was attributed to the following factors:

- melting and distributing the binding component over the microcracks
- formation of new phases generating a squeezing strain that restrains propagation of microcracks
- ablation of surface-defected material.

The above results were presented at the "Modification of ceramics and semiconductors by ion bombardment" International Conference held on May 19-23, 1997 in Il Ciocco, Italy, and accepted for publication in Materials Science and Engineering.

Forschungszentrum Rossendorf, Institut für Ionenstrahlphysik und Materialforschung, Postfach 510119, D-01314 Dresden, Germany
9.3 Implantation of Nitrogen Ions Into Cutting Tools and Machine Parts
by J. Piekoszewski, R. Günzel, M. Przesmycki, J. Langner

Within the scope of preparations aimed at putting into operation for research and commercial purposes a plasma- and ion-treatment laboratory in the Andrzej Soltan Institute for Nuclear Studies in Świerk (ASINS), evaluation of the domestic demand for such type services has been started. The first and basic element of such evaluation must be a verification of the effectiveness of any given treatment in an industrial environment. Laboratory tests provide only some indicative data that are not sufficient to make any business plan.

The task was accomplished by the three cooperating institutions: ASINS—the coordinating institution; Institute of Ion Beam Physics and Materials Research (FZR), Rossendorf—the institution actually performing ion implantation; and POLMOTOR-AGROMETAL—the institution supplying items to be treated and testing the results in a production environment.

The object of the applied treatment was to increase the wear resistance of treated items, i.e. to lengthen their technical lifetime. The method of ion implantation from a plasma source was selected; it is known in the literature as the Plasma Immersion Ion Implantation (PIII) technique. The method is a recently developed variant of the conventional ion implantation technique accomplished by a linear ion accelerator. During the PIII processing the treated item is immersed into a suitably dense plasma and biased by pulses of a high negative potential. Ions contained within the plasma are accelerated towards the treated item and implanted relatively uniformly on the whole surface of it without any need for scanning a beam, that is applied in the conventional implantation technique. The PIII technique advantages—as compared to the conventional implantation—are as follows: lower treatment cost; treated and modified layers are thicker; a capability to treat objects with compound shapes (since the "line-of-sight" effects are limited).

The following items have been treated so far:

- 3 pairs of gears—elements of some oil pumps—made of the 40H steel. Two pairs were thermally improved to a hardness of 28-32 HRC. One pair was not improved and had a hardness of about 20 HRC.
- Fellows cutter made of the high-speed steel SW7M. Thermally improved to a hardness of 64 HRC.
- Hob cutter for cutting gears. Material and treatment as above.

The PIII processing was done in the PII UNIT 2 device in FZR, at the following conditions:

- reaction chamber volume 35 l
- vacuum system: turbo-molecular and rotational pump
- output pressure: 0.2 Pa
- plasma generator: ECR, peak power 800 W
- high voltage pulses generated by a modulator made in FZR
- working gas: nitrogen at the controlled pressure of 0.2 Pa.

In case of the gears the high voltage was 20 kV, pulse duration 5 μs, repetition rate 1 kHz, the object temperature 280°C, processing time 2 x 2 hours (each side 2 hours). Dose of the implanted nitrogen was 2x10^18 cm^-2.

In case of the tools the high voltage was 8 kV, pulse duration 10 ms, repetition rate 3 kHz, the object temperature about 280°C, processing time 2 hours. Dose of the implanted nitrogen was 2x10^18 cm^-2.

Most probably the object temperature was not optimal in either case; it should be closer to 380°C. However, this was impossible in the used set-up since the power supplied by the plasma was too low.

The following tests of the treatment effectiveness are foreseen:

- for the gears: work on an industrial stand at a pressure of 600 atm during 100 hours, then investigation of the profile of the surface cooperating with the tightening element
- for the tools: routine milling the gears in a manufacturing process and logging the yield obtained up to the first sharpening and between successive ones until the tool is completely used up and comparing it with the yield obtained for the non-treated tools. Test of the hob cutter is presently the most advanced; the so-far obtained results are given below.
As can be seen, the yield of the PIII-treated tools was about 83% higher during the time up to the first sharpening, and about 48% higher after the first sharpening. However, during its lifetime a typical tool is regenerated (sharpened) about 20 times. Therefore it is clear that evaluation of the economic feasibility of the PIII process will become possible only after the total yield for the treated tools is summed up and compared to the total yield of the non-treated ones. The work is in progress.

1) Forschungszentrum Rossendorf
2) POLMOTOR-AGROMETAL, Warszawa

9.4 Transmission-Type Si(Li) Detectors
by W. Czarnacki, B. Sawicka, T. Sworobowicz, A. Kotlarski

The object of this task was to manufacture transmission-type silicon lithium-drifted Si(Li) semiconductor detectors that would exhibit possibly thin dead layers (i.e. entrance and exit windows). Starting material was a p-type Si monocrystal characterized as follows:
- resistivity 800-1000 ohm cm
- minority carrier lifetime 500 ms
- dislocation density (EPD) about 1x10³ cm⁻².

The transmission-type detectors were manufactured according to a modified technology of producing standard Si(Li) detectors. Main production phases:
- cutting-out and polishing some silicon disks of thickness around 1 mm and diameter 30 mm, with mesa of diameter 20 mm and thickness around 400 mm on one side of disks
- n⁺-p junction formation by diffusing lithium atoms into the disks to a depth of about 200 mm
- drifting the lithium ions throughout the whole thickness of disks
- complete grinding-out the mesa on disks
- evaporating Au (p⁺) and Al (n⁺) contacts
- mounting in special detector holders.

4 detectors have been manufactured according to the above technology. The following parameters have been obtained:
- thickness of the lithium-doped region 800-1000 µm
- active area 1 cm²
- operating voltage U₀ between 150 and 250 V
- energy resolution below 45 keV FWHM.

Resolution was measured in room temperature by alpha particles of energy 5.8 MeV. No significant differences have been observed between the results obtained at irradiation of detectors from the p⁺ and from the n⁺ side.

The detectors were additionally characterized by means of charge collection efficiency and energy resolution measurements as a function of the operating voltage; the measurements have been performed at room temperature (RT = +18°C) and at temperature around 100°C (−173°C). It was found that the charge collection
efficiency exceeded 98% at both the temperatures when the detectors were irradiated through the $p^+$ (Au) contacts. For irradiation through the $n^+$ (Al) contacts the efficiency amounted only to about 90% at the RT; it recovered to the high level (over 98%) after decreasing temperature down to 100°K. The energy resolution 15-20 keV at $T = 100°K$ indicates a low detector noise level. Perhaps more important is attaining at higher bias voltages and irradiating alpha particles from $n^+$ side a similarly good energy resolution as at irradiating from $p^+$ side. Taking into account that $p^+$ entrance window is usually below 0.1 μm thick, one can conclude that the dead layer in the exit $n^+$ window is similar or thinner.

The above results may be concluded by a statement that a technology of building stacks of transmission-type silicon detectors for detection and spectrometry of high-energy charged particles has been successfully developed. The developed transmission-type Si(Li) detectors must yet be characterized from the point of view of their applicability to identification of charged particles.

9.5 Silicon Telescope for Identification of Charged Particles

by E. Belcarz, W. Czarnacki, B. Sawicka, T. Sworobowicz

A telescope consisting of two silicon detectors (a transmission-type thin ΔE detector, and a thick E detector) has been manufactured for identification of heavy charged particles. The transmission-type thin detector was made of silicon wafer with an epi layer. The wafer was characterized as follows:

- epi layer thickness: about 13 μm
- specific resistivity of the epi layer: about 40 ohm·cm
- substrate thickness: about 200 μm
- specific resistivity of the substrate: about 0.005 ohm·cm

After covering the wafer edges with an acid-resistant material, the wafer was placed in a special device designed for electrolytic etching. The substrate was etched away leaving the epi layer alone. Standard surface-barrier silicon detector was manufactured on the obtained structure; its active surface was 1 cm² and thickness 13 μm. The operational voltage was 10 V; leakage current at this bias stayed at a level below 1 μA, and the capacitance amounted to about 1000 pF.

The thick E detector was made of n-type silicon monocrystal of specific resistivity 3500 ohm·cm. Active area was over 1 cm², energy resolution (for alpha particles of energy 5.8 MeV) amounted to 24.6 keV FWHM. Both detectors (the transmission-type one and the thick one) were mounted about 8 mm apart inside a special holder. Further characterization of the telescope will be performed on heavy ion beams in cyclotrons.
9.6 Implanted Detection Structures Made of High Purity n-Type Germanium
by W. Czarnacki, T. Sworobowicz, A. Kotlarski, B. Sawicka

Developments in technology of manufacturing high purity germanium monocrystals and in consequence appearing n-type monocrystals made possible producing germanium detectors with a thinner entrance window and more radiation-resistant than detectors formerly produced of p-type crystals. The objective of this task was to produce germanium structures with an implanted p⁺-n junction, suitable for detection of X-rays. N-type germanium monocrystal with the following parameters was used:

- Impurity concentration \( N_D - N_A \) \( \leq 2.2 \times 10^{10} \text{ cm}^{-3} \)
- Dislocation density (EPD) \( \leq 5000 \text{ cm}^{-2} \)
- Mobility \( \mu_n \) \( \geq 17000 \text{ cm}^2/\text{V}s \)
- Density of point defects (as measured by the DLTS technique) \( \leq 5 \times 10^8 \text{ cm}^{-3} \).

10 samples of dimensions 5 mm thickness, 12 mm diameter were cut out of the monocrystal. By diffusion of lithium at 350°C into one side of the sample to some depth within the range of 400-600 \( \mu \text{m} \) the n⁺ contact with diameter of 6 mm was produced. To get both a good p⁺-n junction and a good ohmic contact, boron ions was implanted into the other side of the sample in a two-step process: at the energy of about 40 keV to the surface density of \( 1 \times 10^{14} \text{ cm}^{-2} \) and at an energy between 10 and 20 keV to the surface density of \( 3 \times 10^{14} \text{ cm}^{-2} \).

Post implantation defects were annealed in each sample at 200-300°C and at vacuum better than \( 10^{-5} \text{ Torr} \). Annealing was performed in some specially prepared heater placed inside the vacuum chamber of an evaporator. Four fully operational detection structures have been obtained. The work is in progress.

9.7 X-Ray Tube with Needle-Like Anode
by M. Stapa, M. Traczyk, W. Straś

Research and design works on construction of X-ray tube with single drift chamber of 80 mm length and 6 mm inner diameter built in the classical glass-metal technology have been conducted. The tube will form a basis for developing the ultimate construction with a needle-like anode; the latter will have a two-stage drift chamber. The second stage will be 100 mm long and 2 mm thick (inner diameter). Some research on possibility of manufacturing tubes with the needle-like anodes in a ceramic-metal technology has also been conducted.

9.8 "Photon Needle" for Radiotherapy
by M. Stapa, M. Traczyk, W. Straś

The work was conducted according to the KBN grant No. PB 681/T11/97/13, that was granted but was not effectively financed. Literature survey on state-of-the-art and perspectives of application of "photon needles" in radiotherapy, as well as patent survey of this subject have been done. First tests of technology of closing-up enclosures of tubes with single drift chamber have been concluded. Reconnaissance in the field of methods of diagnostics of electron beam inside X-ray tubes and in the field of imaging of X-ray beams by means of CCD cameras has been done.
LIST OF PUBLICATIONS

SURFACE MORPHOLOGY OF STEEL NITROGEN-ALLOYED USING HIGH INTENSITY PULSED PLASMA BEAMS
J.Piekoszewski, L.Walis, J.Langner
Materials Letters 32 (1997) 49

INTENSE PULSED PLASMA PULSES: TWO MODES OF THE USE FOR SURFACE PROCESSING PURPOSES
J.Piekoszewski, J.Langner and L.Walis

IRRADIATION OF SILICON WITH A PULSED PLASMA BEAM CONTAINING Mo IONS
J.Piekoszewski, Z.Werner, J.Langner, M. Janik-Czachor

MODIFICATION OF SILICON NITRIDE CERAMICS WITH HIGH INTENSITY PULSED ION BEAMS
F.Brenscheidt, J.Piekoszewski, E.Wieser, J.Langner, R.Groetzschel, H.Reuther
Material Science & Engineering, (in press)

DEPOSITION AND MIXING OF COBALT, TITANIUM AND TUNGSTEN ON THE PULSE MELTED SURFACES OF
SUBSTRATES
J.Langner, J.Piekoszewski, J.Stanislawski, Z.Werner

MODIFICATION OF THE SURFACE PROPERTIES OF MATERIALS BY PULSED PLASMA BEAMS
J.Piekoszewski, Z.Werner, J.Langner, L.Walis

PARTICIPATION IN CONFERENCES AND WORKSHOPS

EROSION BEHAVIOR OF BORON CARBIDE UNDER HIGH-POWER PULSED FLUXES OF HYDROGEN PLASMA
Proc. Int'l Conf. ISFNT-4, Tokio, April 6-11, 1997

MODIFICATION OF SILICON NITRIDE CERAMICS WITH HIGH INTENSITY PULSED ION BEAMS
F.Brenscheidt, J.Piekoszewski, E.Wieser, J.Langner, R.Groetzschel, H.Reuther
presented on the "Modification of Ceramics and Semiconductors by Ion Bombardment" Conference, May 19-23, 1997, II Ciocco, Italy

TRIBOLOGICAL PROPERTIES OF PULSED PLASMA TREATED STEELS: COMPARATIVE STUDIES
V.I.Tereshin, J.Langner, M.Sadowski, J.Piekoszewski, V.V.Chebotarev, N.T.Deprovski, I.E.Garkusha, G.D.Gamalaya,
Y.L.Ostrovskaya, Y.V.Vvedensky, T.F.Yukino
Proc. Int'l Symp. PLASMA 97, Jarzno/lowek near Opole, June 10-12, 1997 p. 201

FORMATION OF Ti COATINGS ON METALLIC AND CERAMIC SUBSTRATES USING INTENSE PLASMA PULSES

INVESTIGATION OF THE COATING OF TYPE: METALLIC LAYER - INTERLAYER (Ti) - CERAMIC LAYER (TiN),
PRODUCED WITH USE OF MODIFIED PLASMA GUN
J.Kucinski, K.CzauS, J.Langner, J.Piekoszewski
Proc. Int'l Symp. PLASMA 97, Jarzno/lowek near Opole, June 10-12, 1997 p. 221

MODIFICATION OF THE SURFACE PROPERTIES OF MATERIALS BY PULSED PLASMA BEAMS
J.Piekoszewski, Z.Werner, J.Langner, L.Walis
Proc. 10th Int'l Conf. on Surface Modification of Metals by Ion Beams, Gatlinburg, Tennessee, September 21-26, 1997
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1/2 1/2 1/2 1/2 1/2 1/2
Overview

In the context of general discussions concerning the activity of the Institute, it was important to look critically at current and future directions of the Department's activity.

Attention is given to development of basic accelerator knowledge, realized at home and throughout international collaborations. Of importance is a steady improvement of metrological and experimental basis for accelerator research.

Apart of this, some development tendencies were formulated during 1997, oriented to application fields of accelerators.

As examples should be named:

- **medical applications:**
  
a) A serious effort was given to an idea of using the existing compact cyclotron C-30 as a source for creation of a diagnostic centre in Świerk. The proposition was formulated in contact with the Nuclear Medicine Department of the Medical Academy, and the "Bródno" General Hospital. In spite of declared medical interest in such an installation, the project was not approved, due to lack of proper financial support.

b) Model measurements and verification of theoretical assumptions and calculations oriented on the design of a very short, high-gradient acceleration structure for the low energy accelerator COLINE/1000 were done. This project will enable us to achieve "source - isocentre distance", of 1000 mm, instead of existing 800 mm. This is important for therapy.

In 1998, this work will be supported by the State Committee for Scientific Research.

c) Preliminary discussions, and design approach were undertaken in collaboration with the Centre of Oncology, for elaboration of a movable low-energy accelerator with electron beam output, matched to interoperative irradiation during surgical therapy of tumours.

- **applications in radiation technology**

Comparison of isotope and machine radiation sources indicates that, under Polish conditions it is reasonable to use purpose-oriented high power accelerators. The working group composed of specialists from IChTJ and IPJ prepared the Survey Report with a feasibility study on design and construction of such accelerators in Poland.

Two types were defined as necessary:

- S-band linear accelerator 10 MeV, 10-20 kW beam power (TAEL 10/20)
- Modular 300 MHz accelerator 10 MeV, 20-50 kW beam power (ATENA 10/50)

It should also be emphasized that we performed:

- design, manufacturing and testing of 27 pieces of polarized coaxial-waveguide couplers for superconducting resonators in HERA accelerator.

This work was done for the collaboration agreement with DESY, and paid for by DESY.

Preliminary assembling of couplers was done in Hamburg in December 97. Final completion, matched to HERA time schedule will take place in March 98.

- design, manufacturing and testing of Pulsed Microwave Generator dedicated to beam bunches diagnostics of short beam pulses.

This work was done in collaboration with LNF-INFN/Frascati, and was paid for by INFN.

The generator was completed and tested in Świerk in December 97, and shipped to Frascati in January 98.
10.1 Preliminary Study of e'/X Converter for High Power Electron Accelerator Dedicated to Irradiation Technology
by S. Kulinski, W. Maciszewski, M. Pachan, E. Plawski, I. Zychor

A new electron linac for radiation technology is under development. The accelerator is expected to generate an electron beam with energy \( 5 \pm 10 \) MeV and average beam power \( 20 \pm 50 \) kW [1]. An alternative mode of the facility operation is conversion of an electron beam into much more penetrative X-rays (bremsstrahlung).

In the electron conversion into bremsstrahlung it is important to optimise target material and thickness as well as beam energy to get maximal conversion efficiency. One of the best tools to deal with these problems is the application of Monte Carlo methods for electron and photon transport in matter.

All processes observed in the interaction of an electron beam with matter in the energy range up to a few MeV could be divided into two groups:
1. processes involving photons: \((e', e')\) pair production, Compton collision, photoelectric effect, photofission of heavy elements,
2. processes involving electrons and positrons: multiple scattering, ionisation and delta ray production, bremsstrahlung, annihilation of a positron.

In the past the modified GEANT3 code was used to look for electron interaction with matter for use in radiotherapy [2]. The same program could be applied for computer simulation of electron to bremsstrahlung conversion for a high power electron accelerator dedicated to irradiation technology.

In Table 1, the bremsstrahlung yield \( Y_b \) was calculated for four target materials and two electron beam energies \( E_b \) for forward bremsstrahlung \( (\Theta \leq 15^\circ) \) and for target thickness of \( 0.5r_0 \), where \( r_0 \) is equal to the incident electron range. The bremsstrahlung yield \( Y_b \) is defined as the percentage of incident electron energy converted into photon energy.

<table>
<thead>
<tr>
<th>BREMSSTRAHLUNG YIELD ( Y_b )</th>
<th>Al ((Z=13))</th>
<th>Fe ((Z=26))</th>
<th>W ((Z=74))</th>
<th>Pb ((Z=82))</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E_b = 5 ) MeV</td>
<td>3%</td>
<td>5%</td>
<td>12%</td>
<td>9%</td>
</tr>
<tr>
<td>( E_b = 10 ) MeV</td>
<td>6%</td>
<td>11%</td>
<td>19%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Generally, the use of targets made of materials with high atomic numbers, such as lead, tantalum, tungsten or gold, enhances the bremsstrahlung yield. The yield increases with the electron beam energy.

Results presented above and some data from the literature [3-6] have been utilized to elaborate the preliminary target design [7]. Initial requirements for the design of the target are as follows:

- primary beam electron energy: \(-5\) MeV
- with possibility of operation at 7.5 and 10 MeV
- average power of electron beam: \(-20 \div 50\) kW
- average current of electron beam up to: \(-10\) mA at 5 MeV, \(-5\) mA at 10 MeV
- primary beam geometry:
  - linear scanning
  - scan length on target surface: \(-900\) mm
  - scan width on target surface: \(-75\) mm
  - deflection angle of scanned beam: \(\pm 20^\circ\)

**Target material.** Any appropriate material for high bremsstrahlung production efficiency should have large atomic number \( Z \). Also thermal and mechanical properties of the materials should be taken into consideration. Three of them: tungsten \((Z=74)\), tantalum \((73)\) and gold \((79)\) fulfill these requirements. For example, calculations for 5 MeV electrons for these materials have given very close results [4]. Because of the cost of material and easiness of machining, tantalum seems to be most convenient.
Target thickness should be chosen to obtain maximum conversion efficiency. At 5 MeV the optimum value of target thickness is 1 mm for tantalum [4].

A typical target structure is shown in Fig. 1a. It consists of three parallel layers:
1. tantalum converter plate,
2. cooling water layer,
3. stainless steel cover plate.

One of the crucial problems of the beam converter construction is effective cooling. At 5 MeV about 80% of the full power is dissipated in the converter structure, so for primary beam power of 50 kW the heat deposition in converter is 9.6 kcal/s. To remove such an amount of heat at an assumed outlet (5) - inlet (4) temperature difference of 70°C, the water flow needed is about 60 l/min. For water volume in the target 1cmx1cmx100cm = 1000cc, this gives water flow velocity of 1 m/s. This is a rather moderate value, not critical for the strength of the construction. However, some earlier experiments with targets so constructed have proved that calculated water flow for given power loading was insufficient, causing serious thermal troubles and even damage of the target. To improve heat transfer the modified construction of the stainless steel cover plate is proposed. It has been proven in practice, that if diaphragms in the cover are added as shown in Fig. 1b, the heat exchange is much more effective than in a classical scheme. Such a configuration is being considered.

![Diagram of electron beam converter](image)

For electron beam power 50 kW, required absorbed dose 10 kGy, and typical beam absorption coefficients, the estimated mass throughput of the facility is as follows [8]:
- for e-beam mode of operation - 9 000 kg/h;
- for X-ray mode of operation, taking into account the total conversion efficiency (including X-ray absorption in the layers of cooling water and cover) - 1 300 kg/h.

Such a machine used as an X-ray source is equivalent to a Co-60 source with activity at the level of 0.6 MCi. In spite of significantly lower throughput in the X-ray mode, it seems that the accelerator facility with X-ray option at the primary beam power of 50 kW is quite useful, creating the possibility of irradiation of objects of bigger dimensions. Further studies of proposed converter analysis, optimization and construction are foreseen.

10.2 Electron Accelerators with High Average Beam Power Dedicated to Irradiation Technology
by J. Bigolas, S. Kuliński, M. Pachan, E. Plawski

Introduction

Growing interest in the application of various types of radiation technology (material modification, sterilization of medical utensils, protection of agricultural products etc.) evokes increasing demand for high intensity radiation sources matched to current requirements. In 1997 the Polish National Atomic Agency, initiated an elaboration of Survey Report [1] on the current status of radiation technology in Poland and abroad, together with perspectives of its further development.

This work was done in close collaboration of specialists from Andrzej Sołtan Institute for Nuclear Studies, and Institute of Nuclear Chemistry and Technology.

This report consists of:
- summary of application fields for irradiation technology around the world
- comparison of isotope and machine radiation sources
- economical analysis of investment and exploitation costs of irradiation facilities
- evaluation of present and future needs for irradiation installations in Poland
- selection of most useful radiation sources
- estimation of design and construction feasibility of high-power accelerators in Poland

As an effect of this analysis it was decided to undertake preliminary design of two basic types of accelerators:
- Linear S-band standing-wave system, 10 MeV/10-20 kW
- Modular system in 300 MHz - band, 10 MeV/20-50 kW

Both types are purpose addressed machines, matched to processing requirements and well established in existing experience.

10 MeV (10-20)kW S-Band Industrial Electron Linac

As stated above, the need for such a class of accelerators follows from a wide spectrum of applications in radiation processing. The basis for the work on designing this accelerator in the Department of Accelerator Physics and Technology is the well established experience we have in construction of different types of accelerators, especially S-Band Linacs for radiography and oncology. The main difference between the projected industrial accelerator and those for oncology is at least an order of magnitude bigger electron beam average power, and also much bigger radio-frequency power dissipation in the accelerating structure.

To diminish rf. power dissipation in the accelerating guide and avoid an eventual thermal instability of an accelerator, the accelerating electric field is decreased almost twice by making the length of structure almost two times longer: L ~ 200 cm.

Another important parameter was the RF power source capable to give both sufficiently high peak and average power. It seems that for our purposes the most appropriate is the klystron TH 2097A having the following parameters: \( f_r = 2.9985 \text{ GHz} \), peak output power \( P_M = 4 \text{ MW} \), average output power \( P_{av} = 25 \text{ kW} \), pulse length \( \tau_{\text{max}} = 100 \mu\text{s} \).

**Accelerator main parameters**

As mentioned above, the geometry of the accelerator will be based on the accelerating structures used for medical and radiographic accelerators built in IBJ/IPJ. The constructional and technological changes will be limited to those parts of the accelerating guide which, because of much higher average beam power and RF losses in the walls, must fulfill more severe requirements for thermal and mechanical stability.

**Main parameters:**
- Electron energy \( W = 10 \text{ MeV} \)
- Average beam power \( P_b = (10 \div 20) \text{kW} \)
- **Gun:** Type - triode with Pierce’s geometry, maximum current \( I_M = 0.5 \text{A} \), accelerating voltage \( V = (40 \div 50) \text{kV} \), maximum pulse duration \( \tau_{\text{max}} = 100 \mu\text{s} \), repetition frequency \((100 \div 300)\text{Hz} \).
- **Prebuncher:** Gap voltage \( V_g = 4.5 \text{ kV} \), gap length \( g = 0.1 \lambda = 1 \text{cm} \), \( \lambda = 10 \text{cm} \) - RF wavelength) drift space \( d = 20 \text{cm} \).
- **Accelerating structure:** standing wave (SW), biperiodic type \( \pi/2 \), resonant frequency \( f_r = 2.9985 \text{ GHz} \), length \( L \sim 200 \text{cm} \).
The geometry of the unit cell together with the electric field lines is shown in Fig. 1. The results of preliminary dynamic calculations are shown in Fig. 2.

![Electric field lines in cavity](image1.png)

**Fig.1** Electric field lines in cavity 2992MHz - for n/2 mode.

![Distribution energy-phase on accelerator's output.](image2.png)

**Fig.2** Distribution energy-phase on accelerator's output.

### High-power modular accelerator in 300 MHz frequency band - 10 MeV/20-50 kW/ATENA

For industrial scale irradiation treatment facilities, high product throughput is one of the most important technical and economical factors. Therefore it is essential to equip such facilities with possibly high power radiation sources, but at the same time matched to existing infrastructure and material handling capacity. Basic operational parameters of proposed ATENA accelerator are selected to fulfil estimated requirements in the next ten years. Average beam power in the range 20 to 50 kW is a good balance between installation costs and treatment capabilities. An important feature of the adopted solution is a lack of an inherent physical barrier to achieving higher output beam power. The accelerating structure of ATENA is composed of a chain of separated modular resonators working on 1 m. wavelength. Such resonators have a big enough aperture for the transport of an intense beam, and at the same time a high capacity of thermal power. Resonators are fed from individual modules of power amplifiers with grid tubes of transmitter type. These tubes have long life-time and relatively low high-voltage supply. Shape optimization of the accelerating cavity was done with SUPERFISH code.

Results are presented in the Table.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field normalization (NORM=1):</td>
<td>EZEROT = 5.00000 MV/m</td>
</tr>
<tr>
<td>Frequency (starting value = 300.000)</td>
<td>300.49342 MHz</td>
</tr>
<tr>
<td>Particle rest mass energy</td>
<td>0.511003 MeV</td>
</tr>
<tr>
<td>Beta = 0.9900000</td>
<td>Kinetic energy = 3.111 MeV</td>
</tr>
<tr>
<td>Normalization factor(for E₀=5.968 MV/m)</td>
<td>38938.757</td>
</tr>
<tr>
<td>Transit-time factor</td>
<td>0.8378360</td>
</tr>
<tr>
<td>Surface resistance (for 1/μ=1.72410 μΩ-cm)</td>
<td>4.5225 mΩ</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>20.0000°C</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>227.9933 kW</td>
</tr>
<tr>
<td>Q = 49849.2</td>
<td>Shunt impedance = 39.052 MΩ/m</td>
</tr>
<tr>
<td>Rs*Q = 225.443 Ω</td>
<td>Z*T² = 27.413 MΩ/m</td>
</tr>
<tr>
<td>r/Q = 137.480 Ω</td>
<td>Wake loss parameter = 0.06489 V/pC</td>
</tr>
<tr>
<td>Average of H₀, on the outer wall</td>
<td>10350.30 A/m,</td>
</tr>
<tr>
<td>Maximum magnetic field on boundary</td>
<td>13151.83 A/m,</td>
</tr>
<tr>
<td>Maximum electric field on boundary</td>
<td>16.965 MV/m,</td>
</tr>
</tbody>
</table>
10.3 Computer Simulation of Periodic Focusing System for Intense Electron Beam
by W. Drabik

The aim of this work is to prepare the preliminary analysis and computer simulation of a periodic focusing system in electron linacs for energy of 10 MeV and a current of 200-300 mA. Considering the dynamics of an electron beam in a standing or travelling wave linac, we can differentiate five main force components acting on the beam [1]:
- axial component of rf electric accelerating field
- radial defocusing component of rf accelerating field
- radial defocusing component of space charge force
- radial focusing component of magnetic self field
- radial focusing component of external magnetic field

There are three main methods of magnetic focusing in such accelerators: solenoid focusing, quadrupole focusing and periodic focusing with permanent magnets.

The choice of the particular focusing system depends mainly on the magnitude of the magnetic field required to maintain the electron beam within specified limits. However, in some cases additional demands are formulated concerning operating conditions of the accelerator. If the portability and compactness aspect is important, the best solution is periodic focusing with permanent magnets, because this system enables the reduction of weight and power consumption compared to electromagnetic coils as used in solenoids and quadrupoles.

Starting from the theory of classical periodic magnetic focusing [2] (non-relativistic case) we can see that the trajectory of an edge electron depends on two geometrical parameters: initial radius and initial divergence of the beam and three more parameters: space charge parameter, magnetic field parameter and cathode conditions parameter. The computer program OPTICS, integrating the motion equation given in [2], was written and the results are shown in the Fig.1.

Solving a full relativistic Newton equation with defocusing radial rf component it is possible to analyse radial dimensions of an electron beam with a degree of accuracy high enough for practical design of the accelerator. The procedure of course may be applied not only for a periodic magnetic field but also for a multilayer, solenoid focusing structure. Finally the quadrupole periodic focusing is analysed using high energy approximations [3]. The computer program FODO, calculating the optimal parameters of the FODO channel and electron trajectories in two quadrupole planes, was implemented in the IBM PC/486 computer from the VAX/VMS computer. The results of the FODO program are given in Fig.2.

![Fig.1 Electron trajectory in (R,Z) plane.](image1)

![Fig.2 Electron trajectories in (x,z) and (y,z) planes.](image2)

10.4 Preparatory Steps for the Dose Distribution Investigation in Stereotactic Irradiations with Narrow Photon Beams Produced by an Electron Linear Accelerator
by A. Wysocka, J. Olszewski

The goal of radiotherapy is to deliver therapeutic doses of radiation to a lesion (tumour or arteriovenous malformations), while minimizing the dose to surrounding normal tissues. Narrow photon beams produced by an electron linear accelerator deliver a high dose of radiation to limited, stereotactically defined target volumes while avoiding nearby critical structures[1].

Our experimental set-up is based on the Saturn accelerator, retired from clinical exploitation at the Institute of Oncology and installed in Swierk. Preliminary tests of the accelerator have been done and readiness for normal machine operation has been achieved. We have made a project of the biological shielding for our laboratory which is realized now. After completion of the shielding, we will have the possibility to run the stand in the full range of its parameters.

The modification which is needed to adapt our linac to radiosurgery is a set of additional collimators to define the beams with diameters from 5 to 30 mm. We have made constructive design of the collimators and the collimator mount fittable to the head of the linac. Fig. 1 presents the scheme of the linear accelerator treatment head.

Since in the stereotactic radiosurgery the whole dose of the irradiation is transmitted usually in one or only a few fractions, we are preparing very precise dosimetry of narrow beams.

The first dosimetric measurements: (a) relative output factors, (b) dose profiles, (c) percentage depth dose, will be the basic input data for the calculations of the radiation dose distribution with different codes.

The next important step is a very carefully monitored delivery of the radiation dose to the target volume. It is an aim of our project to compare and analyze the calculated and measured dose distributions in the tissue equivalent head phantom [2,3].

Collaboration with the neurosurgery staff from University Schools of Medicine and with the radiotherapy groups from Oncological Institutes is planned.


10.5 Parasitic Wakes in Modified TESLA Superconducting Accelerating Cavities
by E. Plawski, J. Sekutowicz

The TESLA TEST FACILITY (TTF) in DESY Hamburg is being built as a test bed for the performance and cost optimization of superconducting accelerating structures for the TESLA 500 GeV electron positron collider. The TTF linac will deliver 8 mA of electron beam at energy 390 MeV. It will also be used as part of a free electron laser source of coherent photon beams. The accelerating structure is based on superconducting 1.3 GHz cavities made of niobium. The basic parameters of a single cavity are listed in Table 1. In TTF, the 24 cavities arranged in 3 cryomodules will be used at the beginning. In the future TESLA collider, a string of about 20000 sc cavities will form accelerating system.
Most of 32 RF accelerating cavities fabricated for TTF have successfully passed cold tests. The values of accelerating field level of at least 15 MV/m and Q factor above $5 \times 10^9$ were reached which are the values satisfactory for TTF specifications. Some cavities already satisfy the TESLA specification which is 25 MV/m at $Q > 5 \times 10^9$.

Table 1. TESLA RF cavity parameters

<table>
<thead>
<tr>
<th>Frequency</th>
<th>1300 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cells in one cavity</td>
<td>9</td>
</tr>
<tr>
<td>Accelerating field $E_{ac}$ (for TTF 15 MV/m)</td>
<td>25 MV/m</td>
</tr>
<tr>
<td>$E_{peak}/E_{acc}$</td>
<td>2</td>
</tr>
<tr>
<td>Quality factor $Q_0$</td>
<td>$&gt; 5 \times 10^9$</td>
</tr>
<tr>
<td>$R/Q$</td>
<td>1035 $\Omega$</td>
</tr>
<tr>
<td>Iris diameter between cells</td>
<td>0.07 m</td>
</tr>
<tr>
<td>Cell to cell coupling coefficient</td>
<td>1.84</td>
</tr>
<tr>
<td>HOM loss factor - longitudinal (for $\sigma = 1$ mm)</td>
<td>8.5 V/pC</td>
</tr>
<tr>
<td>Cavity length (active, excluding end beam tubes)</td>
<td>1.036 m</td>
</tr>
<tr>
<td>Cavity material</td>
<td>niobium</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>2 K</td>
</tr>
</tbody>
</table>

Cavity shapes as used in TTF were decided [1] to keep a relatively high value of coupling impedance $R/Q$ for the accelerating mode, low ratio $E_{peak}/E_{ac}$ of surface to accelerating fields and a safe separation to higher order modes (HOMs). The small iris aperture between cells satisfies the above criteria. The very important figure of merit is the accelerating mode field flatness in the cavity. The field amplitudes in all cells of the cavity have to be kept with accuracy better than 5% for optimum acceleration in collider. The error of the field amplitude in cavity composed of $N$ cells is proportional to $N^2/k_c$. The small value of $k_c$ makes the field pattern very sensitive to all steps in cavity production and treatment. This increases considerably the number of expensive tuning procedure steps. As one solution to simplify the cavity production and lower the costs, an increase of the iris aperture is considered in [2].

In Fig. 1 the proposed changes of cavity shape are illustrated and details are given in Table 2.
TABLE 2. Proposed modifications of accelerating 9-cell TESLA cavity

<table>
<thead>
<tr>
<th></th>
<th>Old cavity</th>
<th>New cavity</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_{\text{ir}} ) of inner cell</td>
<td>35 mm</td>
<td>51 mm</td>
</tr>
<tr>
<td>( R_{\text{end}} ) of inner cell</td>
<td>103.3 mm</td>
<td>108.08 mm</td>
</tr>
<tr>
<td>( R_{\text{outer}} ) of outer cell</td>
<td>103.30 mm</td>
<td>106.6 mm</td>
</tr>
<tr>
<td>( R_{\text{pole}} ) of end cell</td>
<td>39 mm</td>
<td>55 mm</td>
</tr>
</tbody>
</table>

The consequences concerning the \( k_v \), \( R/Q \) and \( E_{\text{peak}}/E_{\text{acc}} \) are discussed in [2]. The proposed changes also influence significantly the parasitic wakes induced in cavities by the accelerated electron beam. These wakes and related loss factors were calculated and below some results are summarised. The comparison is made also with results [4] obtained earlier for TTF cavity.

The method of calculations of wakes, energy loss factors and transverse loss factors is similar to those used before in [3,4]. The calculations were made assuming the bunch of gaussian shape with standard deviation \( \sigma = 1 \) mm. A comparison of results obtained for a new cavity and TTF cavity is shown in Fig. 2. Results obtained are summarised shortly in Table 3, where the loss factors are also given for the bunch of \( \sigma = 0.5 \) mm.

The outcome is that the proposed increase of iris and beam tube apertures of 9-cell TESLA cavity would bring clear advantage as far as the induced wakes and resulting loss factors are concerned.

Table 3. Longitudinal and transverse loss factors of 9-cell TESLA cavities.

<table>
<thead>
<tr>
<th>( \sigma ) bunch [mm]</th>
<th>( k_v ) [V/pC]</th>
<th>( k_{tr} ) [V/pC/m]</th>
<th>( k_v ) [V/pC]</th>
<th>( k_{tr} ) [V/pC/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>11.05</td>
<td>20.6</td>
<td>6.53</td>
<td>6.21</td>
</tr>
<tr>
<td>0.5</td>
<td>15.58</td>
<td>12.96</td>
<td>10.20</td>
<td>4.74</td>
</tr>
</tbody>
</table>

We find the reduction of \( k_{\text{long}} \) by factor of 1.7 and of \( k_{\text{trans}} \) by factor 3.3 when TTF type and new type cavities are compared.


Deutsches Elektronen-Synchrotron DESY
10.6 Type PMG-3 Pulsed Microwave Generator with 3 kW Peak Output Power for Bunch Length Measurement in the Sfera Experiment in I.N.F.N. Frascati

by J.Bigolas, S.Kuliriski, M.Pachan, J.Pszona

The PMG-3 is a magnetron-based microwave generator with 3kW peak output power designed for laboratory use. In the SFERA experiment, PMG-3 will be used for studying the behaviour of ferroelectric cathodes under pulsed laser excitation. During verification of the cathode time response, the bunch length measurement is important. The technique employed will be based on deflecting the beam in a microwave resonator powered by PMG-3 and analyzing the beam image on a view-screen. The power required to create adequate fields in a resonator is approx. 2 kW. Expected measurement resolution is of about 5 picoseconds.

The PMG-3 generator is powered from a single phase 220V/50Hz AC mains supply and forms a complete, easy-to-use and stable microwave source. From many different kinds of medium power sources used in microwave technique a 2M-247 magnetron from Sanyo has been chosen. The magnetron operates on a quite low cathode voltage (4.1 kV). Such a low potential between cathode and anode is very important as far as X-rays generation and laboratory usage are concerned. The magnetron’s high voltage power supply is based on a high voltage module from Applied Kilovolts Ltd. (Great Britain) and high voltage modulator - on high voltage transistor switch made by Behlke Electronic GmbH (Germany). Control and steering electronics is made with TTL-family integrated circuits and industry standard operational amplifiers. During work of the generator several controlling and supporting systems are active.

These are:
- magnetron cooling system,
- magnetron overcurrent control,
- arcs control,
- magnetron overvoltage control.

Controlling systems are grouped together in a so called "INTERLOCK" system. When one of a faulty condition occurs, the "INTERLOCK" system is activated and both high voltage and filament supply are switched off.

Basic parameters of PMG-3 are as follows:
- Frequency 2460 MHz
- Frequency stability 2.10^-4/hour
- Output power 3 kW
- Pulse length 10 μs
- Pulse flatness better than 1 %
- Pulse rise time less than 1 μs
- Repetition frequency 10 Hz max.
- H.F. power output N-50 Ohm
- Output power monitor Directional coupler with detector and peak power indicator
- Refl. wave protection Coaxial ferrite circulator

General view of the apparatus is shown in Figure 1. External dimensions of its housing are 1.7 x 0.6 x 0.6m (height, depth, width).
10.7 Completion and Preliminary Assembling of Polarized Doorknob Couplers for HERA Superconducting Resonators

by J.Olszewski

In 1996, a collaboration DESY-IPJ was started for modification of the coaxial RF couplers in the HERA accelerator. The C-W "doorknob" type waveguide transition is a part of the coupler. It is used as a mode transformer between TE_{10} in WR-1800 waveguide and TEM in a coaxial line and, at the same time, as an impedance transformer. A cross-sectional view of the waveguide and its working parameters are given in [1]. 27 doorknob waveguides were manufactured at IPJ. To assure reliable operation of the device the following modifications were performed in 1997:

a) The inner conductor of the coupler was biased at above 1.2 kV to avoid multipactoring effects.

b) The air-cooling system used to cool the antenna was not satisfactory and had to be replaced by a system which uses helium gas. A helium feeding line was designed and manufactured at DESY. Formation of a layer of frost on the surface of the helium transport line may result in a high-voltage breakdown. To avoid this problem, an appropriate defroster device was designed at IPJ and accepted at DESY.

c) The stability of dimensions of the acetal insulating ring, used in the waveguide (see Fig.1 in [1]) is vital to proper RF connection. Long-time load tests were performed at IPJ on acetal samples to study the temporal evolution of the strain within this material. The results of the tests indicated that the strain value in the doorknob insulator ring will exceed the doubled minimum acceptable strain after 50 years of operation and RF transmission will be satisfactory during this period.

Preliminary assembling of the RF couplers was carried out at DESY in 1997. The final assembly in the HERA accelerator vault will take place in 1998.


10.8 Proposal of a PET Diagnostic Centre at the Institute for Nuclear Studies in Świerk

by S.Kuliński, L.Królicki, M.Moszyński, M.Pachan, E.Plawski, Z.Sujkowski, J.Sura

In Nuclear Medicine the Positron Emission Tomography (PET) is in many cases superior to anatomical (X-Rays, SPECT, NMR) diagnostic methods. As it uses the "metabolic" isotopes, it permits the regional quantification of metabolic activity and a differentiation of normal and abnormal tissue function. Such virtually invisible processes like uptake of glucose by brain cells or nutrient passage through the intercellular membranes can be observed. The methodology is non-invasive and it employs radiopharmaceuticals produced with a cyclotron. The importance of this relatively new diagnostic technique can be appreciated from the number of PET centres - over 200 in the world and at least 40 in Europe.

Because of very short life-times of the positron emitters involved, the PET diagnostic methods require that the production cyclotron, the radiochemical processing and the positron tomograph scanner are located close to each other.

In spite of its high scientific level in nuclear medicine and nuclear physics, Poland so far has no PET facility due to continuous financial shortages. The need for such an installation is acute, and joint efforts to find financing were made by the Nuclear Medicine Department of the Bródno Hospital and our Institute. The
The dominating part of the total cost of a PET facility is a cyclotron in a shielded building with technological subsystems (stabilized power supplies, demineralized water cooling system, air cooling and conditioning). Such a cyclotron is already available in Świerk. It is a compact isochronous cyclotron C-30, accelerating protons in the range 15-30 MeV, largely enough for producing most of the isotopes used for diagnostics (\(^{11}\text{C}, \, ^{13}\text{N}, \, ^{15}\text{O}\) and \(^{18}\text{F}\)). A proposal to establish a PET diagnostic centre on the basis of this cyclotron is described below.

Table 1. Cyclotron C-30; Parameters 1993 ÷ 1997

<table>
<thead>
<tr>
<th>Accelerated particle</th>
<th>Planned</th>
<th>Obtained</th>
<th>Obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ion source</td>
<td>H(^-)</td>
<td>H(^-)</td>
<td>H(^+(proton))</td>
</tr>
<tr>
<td>Energy of internal beam</td>
<td>30 MeV</td>
<td>31.5 MeV</td>
<td>31.5 MeV</td>
</tr>
<tr>
<td>Energy of extracted beam</td>
<td>30 MeV</td>
<td>28 MeV</td>
<td>-</td>
</tr>
<tr>
<td>Internal beam intensity</td>
<td>50 microampers</td>
<td>1.0 (\mu)A ((10 \mu\text{A in pulse}))</td>
<td>15 (\mu)A ((150 \mu\text{A in pulse}))</td>
</tr>
<tr>
<td>Losses in accel. process</td>
<td>70÷80% between (R=10÷44\text{cm})</td>
<td>5% between (R=10÷44\text{cm})</td>
<td>-</td>
</tr>
<tr>
<td>Extracted beam intensity</td>
<td>up to 50 (\mu)A</td>
<td>up to 1(\mu)A ((8 \mu\text{A in pulse}))</td>
<td>-</td>
</tr>
</tbody>
</table>

Though the present parameters of the cyclotron are in principle sufficient, they can be largely improved at relatively low cost. Thus the H\(^-\) beam intensity will be increased with the installation of the external ion source; this will cancel -90% of the losses caused by H\(^-\) dissociation on residual gas. The replacement of not sufficiently cooled accelerating electrodes will allow for continuous operation of RF system. By these means the average beam intensity above 50 \(\mu\)A will be available. The acceleration of the proton beam (last column in Table 1) verifies experimentally the ability to achieve an average intensity in the range of 100 \(\mu\)A. The provisions were made at an early stage of accelerator construction to make these changes possible. The nuclear reactions commonly used for C, N, O and F production are listed in Table 2.

Table 2. PET radioisotopes produced by proton irradiation of targets.

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Half-life</th>
<th>Nuclear reaction</th>
<th>Proton energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen - 15</td>
<td>2.05 min</td>
<td>(^{16}\text{O}(p,\text{pn})^{15}\text{O})</td>
<td>26 MeV</td>
</tr>
<tr>
<td>Carbon - 11</td>
<td>20.4 min</td>
<td>(^{11}\text{B}(p,\text{n})^{13}\text{C})</td>
<td>15 - 20 MeV</td>
</tr>
<tr>
<td>Nitrogen - 13</td>
<td>10 min</td>
<td>(^{18}\text{O}(p,\alpha)^{14}\text{N})</td>
<td>15 MeV</td>
</tr>
<tr>
<td>Fluorine - 18</td>
<td>112 min</td>
<td>(^{18}\text{O}(p,n)^{18}\text{F}) (_{\text{exc}}\text{Ne}(p,x)^{18}\text{F})</td>
<td>18 MeV  30 MeV</td>
</tr>
</tbody>
</table>

The problem of proper shielding against radiation hazard at high beam intensities has to be considered. This can be solved at a reasonable price by placing the irradiation area in the cyclotron vault and using local heavy shields.

Apart from the cyclotron and irradiation chamber the proposed diagnostic facility will comprise:
- the hot cells system for radiochemical processing,
- the on-line transportation system of isotope-marked radiopharmaceuticals,
- the PET scanner
- the computer assisted data acquisition, processing and visualisation system.

The PET facility in Poland could be used in studies of biological functions, diagnostics and treatment of diseases including cancer, stroke-brain tumours, arteriovenous malformations, schizophrenia, depression and heart disease. This program implies a necessity of local production of positron-emitting radioactive tracers.
The status of the external $^3$H multicusp source of the C-30 compact cyclotron at the end of 1996 was presented in [1]. Upgrading of the device was continued in 1997 in spite of a low budget. Steps were taken to raise the effective operation time of the source and to increase the negative ion beam intensity in the beam transport line. The present status of the source is reported in [2].

To raise the life-time of the source cathode filament, its diameter was increased from 0.75 to 1 mm. In order to reach a proper electron emission from the cathode, the heating power was raised. An appropriate filament power supply was manufactured by the end of 1996. It was tested in 1997. Changing the filament diameter and modifying its shape as well as increasing the heating power resulted in growth of the effective cathode life-time from 15 to 45 hours.

Measurements of $^3$H beam currents in the injection line to the cyclotron were performed at different arc parameters, magnetic filter fields and plasma electrode potentials [2]. The number and position of permanent magnets which generate a transverse magnetic field in the region of the emission hole were optimized. As a result of the above modifications the negative ion current increased by about 100 $\mu$A (up to 370-400 $\mu$A) in the beam transport line downstream of the bending magnet (for the configuration of the beam injection line see [2,3]). The estimated ion current density in the emission hole was close to 4 mA/cm$^2$.

Preliminary plasma diagnostic tests were performed using a Langmuir probe. They included determination of the electron temperature and density, plasma potential and the ionic saturation current in the discharge region of our source. The electron energy distribution in this region can be approximated by two Maxwellian distributions corresponding to two different temperatures. Due to the small size of the source, a relatively high plasma density was reached at a low discharge power. The electron density exceeded $10^{12}$ cm$^{-3}$ for the discharge power of about 600 W. There was a clear correlation between the plasma concentration and the measured ion beam current.

10.10 Studies of Very Short Beam-Pulse Formation at the LNS-Catania Accelerator Facility

by L. Calabretta and J. Sura

The MEDEA experimental facility requires very short beam pulses (below 0.6 ns) of accelerated particles up to 100 MeV/nucleon. This goal may be reached by different technical means. We considered three possibilities: a multi-gap buncher, a fast chopper and a set-up of a debuncher combined with an isochronous magnetic field. All of these solutions could be used, if the technical design was realistic (considering cost and technology).

Although studies are being continued, the solution using the fast chopper based upon the idea of a Split-Coaxial-Resonator seems to be realistic [2].

This idea has been modified for application in a chopper. Instead of a four bar RFQ system loading the SCR, we proposed to place two chopper plates. This proposal has been described and verified by model measurements [3]. The resulting cavity will work in the Superconducting Cyclotron frequency range 15-18 MHz. The power consumption will be up to 5 kW for 50 kV on plates. At present design works are under way and mainly concentrated on the mechanical system which could vary the frequency in the full SC range.


LNS, INFN Catania
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A-HYPERON LIFETIME IN VERY HEAVY HYPERNUCLEI PRODUCED IN THE p+U INTERACTION
H. Ohm, I. Zychor, et al.

COMMISSIONING AND OPERATING EXPERIENCE WITH THE LISA SUPERCONDUCTING ACCELERATOR
A. Castellano, L. Catani, M. Ferrario, S. Kuliński, M. Minestrini, P. Patteri, S. Tazzari, F. Tazzioli

COUPLED EDGE-CORE MODEL OF FUSION REACTOR
R. Zagórski, S. Kuliński and M. Scholz

FIRST OPERATIONS OF THE LNS HEAVY ION FACILITY
L. Calabretta, J. Sura et al.

REPORTS

WAKE-FIELDS INDUCED BY THE ELECTRON BEAM PASSING THROUGH THE TESLA ACCELERATING SYSTEM
E. Plawski
Report DESY-TESLA 97-12, June 1997, Hamburg

A SMALL MAGNETIC MULTIPOLAR ION SOURCE, BEAM EXTRACTION MEASUREMENTS
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E. Plawski
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COMPUTER SIMULATION OF e/X CONVERTER FOR HIGH POWER ELECTRON ACCELERATOR DEDICATED TO IRRADIATION TECHNOLOGY
S. Kuliński, W. Macliszewski, M. Puchan, E. Plawski, I. Zychor
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R. Zagórski, S. Kuliński, M. Scholz (presented by R. Zagórski)

ASSOCIATED TARGETS METHODOLOGY IN STEREOTACTIC RADIOSURGERY
A. Wysocka (oral presentation)
Proc. V Autumn School of Medical Physics, Bydgoszcz, Oct. 20-22, 1997

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A. Caruso, J. Sura, et al. (presented by A. Caruso)
Proc. ECPM XXI - European Cyclotron Progress Meeting, Groningen, Sept. 18-20, 1997,

MEASUREMENT OF THE LIFETIME OF HEAVY HYPERNUCLEI PRODUCED BY THE BOMBARDMENT OF Bi WITH PROTONS
P. Kullessa, I. Zychor, O. W. B. Schult, et al., (presented by O. Schult)
Int. Conf. on Hypernuclear and Strange Particle Physics HY97, Brookhaven, Oct. 13-16, 1997

LIFETIME OF A-HYPERONS IN HEAVY NUCLEI
L. Jarczyk, O. W. B. Schult, I. Zychor, et al., (presented by L. Jarczyk)
Proc. 8th Intern. Conf. on Nuclear Reaction Mechanisms, June 4-14, 1997, Varenna, (Italy)
CONFERENCE COMMUNICATIONS

COMPUTATIONAL MODEL OF RELATIVISTIC ELECTRON BEAM
A. Drabik, W. Drabik
Int. Symp. on Non-Linear Electromagnetic Systems, Braunschweig, May 12-14, 1997, Germany

THERMAL LOADING OF THIN TITANIUM FOIL DURING ELECTRON BEAM SCANNING
A. Drabik, W. Drabik, M. Rabinski

INVESTIGATION OF PRODUCTION AND FISSION DECAY OF HEAVY HYPERNUCLEI AT COSY JÜLICH
I. Zychor
Int. Conf. on Quark Lepton Nuclear Physics, May 20-23, 1997, Osaka (Japan)

LECTURES, COURSES AND EXTERNAL SEMINARS

Network at Świerk
TEMPUS Advanced Course for UNIX System Administrators<sup>a</sup>,
I. Zychor June 18, 1997, Faculty of Physics and Astronomy, Amsterdam (Netherlands)

A Preliminary Estimation of the Economic Impact of the Accelerator Driven Nuclear Reactors<sup>b</sup>
S. Kulikowski, March 21, Institute of Experimental Physics, University of Warsaw, Warsaw

New Perspectives of Nuclear Energy Production<sup>a</sup>
S. Kulikowski, April 30, Pedagogical University Kielce, Institute of Physics, Kielce

Application of accelerators in medical radiotherapy<sup>a</sup>
M. Pachan, May 19, University of Warsaw

The Application of Monte Carlo Method to Electron and Photon Beam Transport<sup>a</sup>
I. Zychor, May 19, Institute of Nuclear Chemistry and Technology, Warsaw

Free Electron Laser (FEL) Constructed on the Basis of Tesla Test Facility (TTF) in DESY (Hamburg)<sup>a</sup>
part I and part II.
S. Kulikowski, Oct. 24 and Nov. 28, University of Warsaw

Associated Targets Methodology in Stereotactic Radiosurgery<sup>a</sup>
A. Wysocka, Oct. 22, V Autumn School of Medical Physics, Bydgoszcz

INTERNAL SEMINARS

Linear Superconducting Accelerator of Electrons LISA in Frascati - Italy - Possibility to Build Free Electron Laser<sup>a</sup>
S. Kulikowski, Feb. 24, IPJ, Świerk

<sup>a</sup> in Polish
<sup>b</sup> in English
PERSONNEL

Research scientists
Stanisław Kulinski, Professor
Wiesław Maciszewski, Dr.
Marian Pachan, MSc.
Eugeniusz Pławski, Dr.
Józef Sura, Assoc.Prof.
Anna Wysocka, MSc.
Izabella Zychor, Dr.

Technical and administrative staff
Jerzy Bigolas
Józef Bogowicz
Eugeniusz Czajka
Wojciech Drabik
Jerzy Lorkiewicz
Jan Nowak
Jerzy Olszewski

Witold Pęcioł
Jacek Pszona
Stanisław Stepniak
Włodzimierz Straś
Marc Śliwa
Maria Zielińska
Overview

The Department was formed by the end of 1995. Its main task was originally thought to propagate achievements of the Institute in basic as well as applied research, to develop better public relations and establish closer links with universities. In particular, educational needs were discussed. It was quickly found that the school programs of physics are leaving the graduates with almost total ignorance of the atomic and nuclear physics. Therefore the last year was dedicated to the analysis of the possibilities of involving the SINS into the mainstream of regular educational activities.

The analysis showed what kind of education can be carried out by the Institute, with special emphasis on the education of school pupils, school teachers and medical technicians (radiographers). The essential idea was that an institute like SINS seemed almost an ideal place for arranging an extraordinary nuclear physics laboratory for schools of various levels. It should be kept in mind that people should be better prepared to cope with the problems of ionising radiation, so to be able to be aware of, yet critical of the information spread out by often irresponsible journalists and paraecologists. Our group does not believe, and can show examples, that a simple popularisation of science can solve this problem. It is our conviction that the work should be done from the very beginning, which means going to the youngest members of society. We plan to form a School of Atomic Phenomena at Świerk and offer ,,hands on" approach to school pupils and teachers of physics. The School should also be prepared to conduct courses on principles and application of nuclear techniques for technicians who will be using this knowledge in their work, e.g. medical technicians working in radiology or nuclear medicine. First proposals of the School programs have been worked out. On the popularisation side, the Department started organisation of the permanent exhibition concerned with the nuclear waste treatment.

Independently of the educational and popularisation undertakings, the following scientific problems and achievements can be mentioned:

- participation in the development of the single line circularly polarised Mössbauer source
- studies of electron momentum density distribution (also spin-dependent) by means of the Compton scattering technique with the use of gamma sources $^{137}$Cs and $^{241}$Am as well as synchrotron radiation
- studies of defects in GaN single crystals and epilayers, and Zn(Mg)Se single crystals, by means of positron annihilation techniques
- studies of an application of the Maximum Entropy Method to the reconstruction of 3-dimensional electron momentum density distributions from Compton Profiles
- determination of crystal and magnetic structures of $\text{UFe}_{2+x}\text{Al}_{2-x}$. 

[Signature]
11.1 Studies of the Extra Weak Ferromagnetic-Like Phenomena in Pd$_2$TiAl by Means of the Mössbauer Spectroscopy
by K. Szymański, L. Dobrzyński, D. Satula, K.-U. Neumann

Pd$_2$TiAl Heusler alloy exhibits magnetic order at relatively high temperatures. Its peculiarity consists in the fact that the molecule magnetic moment is extremely small, of the order of hundredth Bohr magneton. $^{57}$Fe impurity was admixed into the alloy in order to carry out the Mössbauer measurements with circularly polarised monochromatic radiation. The results show that most of iron atoms locate at the Ti or Al sites surrounded by eight palladium atoms, while minute part only enters the Pd sites. An external magnetic field applied to the sample induces additional field acting on the $^{57}$Fe nucleus. Induced field direction is parallel to the external field and originates from conduction electron polarisation. No evidence of existence of a hyperfine magnetic field was found. An upper limit of the hyperfine field intensity at $T=12$ K was determined to be of the order of $10^{-2}$ T in zero applied field.

1) Institute of Physics, University in Białystok, Lipowa 41, 15-424 Białystok, Poland
2) Loughborough Institute of Technology, Loughborough, England

11.2 Charge Density Distribution in Non-Centrosymmetric Solids by the Maximum Entropy Method
by J. Waliszewski, L. Dobrzyński

The phase problem in crystallography is well known. It was approached by many techniques and by many researchers. As a result a variety of solutions were proposed. Nevertheless it seems that the state-of-the-art is still unsatisfactory and algorithms used are not always „user-friendly”. One of the methods which seems well suited for the phase problem is the Maximum Entropy Method. We show that a simple numerical trick in the algorithm devised by Collins and developed by Sakata et al. (MEED package) allows one to obtain phases of all structure factors when starting from a uniform prior. The method was checked on the examples of centrosymmetric (Si, Cr A15, Be) as well as non-centrosymmetric structures (GaN). Although one can show that the algorithm is converging to a proper solution, the general convergence conditions require further studies. What is interesting indeed is that the error distribution is much more uniform than the one obtained when conventional MEED routine is used.

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11.3 Positron Annihilation Studies of ZnSe-MgSe Mixed Crystals

Positron annihilation characteristics are measured and calculated for Zn$_{1-x}$Mg$_x$Se semiconductors with $x<0.6$. The bulk lifetime generally increases with increasing magnesium content and this is shown to be due to the increasing content of divacancies. The latter is hardly connected with neither 2.2 eV nor 1.9 eV bands in luminescence spectra. However, the content of short lifetime component correlates well with thermal and concentration behaviour of the energy band which appears 100-150 meV below the free exciton band.

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2) Institute of Physics, N. Copernicus University, Grudziądzka 5/7, 87-100 Toruń, Poland
3) Institute of Physics, Opole University, ul. Oleska 48, 45-052 Opole, Poland
4) Laboratory of Physics, Helsinki University of Technology, 02150 Espoo, Finland
5) Elektrika eta Elektronika Saila, Euskal Herriko Unibertsitatea, 644 p.k., E-48080 Bilbo, Spain
11.4 Mössbauer Spectroscopy Applied to Synthetic Cu$_{9-x}$Fe$_{9+x}$S$_{16}$
by T. Erriçsson$^1$, B. Kalska, K. Szymaniski$^2$, L. Dobrzyński

Local environments of iron in synthetic Cu$_{9-x}$Fe$_{9+x}$S$_{16}$ alloys were identified. A superparamagnetic-like behaviour was observed at room temperature. Interestingly, it turned out that the low-field part of the spectrum, ascribed to the superparamagnetism, grows at the expense of all the surroundings of iron possible in the structure of the alloys. The intensities of the latter seem to preserve their ratios.

1) Institute of Physics, Uppsala University, Uppsala, Sweden
2) Institute of Physics, University in Białystok, Lipowa 41, 15-424 Białystok, Poland

11.5 Mössbauer Investigations of Fe$_{3-x}$Co$_x$P Alloys
by L. Haggström$^1$, M. Trosko, K. Szymaniski$^3$, L. Dobrzyński

Results of Mössbauer spectroscopy applied to Fe$_{3-x}$Co$_x$P compounds are presented. The measurements were made on powdered samples with $x = 0, 0.3, 0.6$ and $1.0$. EFG tensor and dipolar contribution to the hyperfine field were calculated and compared with the experiment. Intensity of magnetic hyperfine fields varies with Co content. It is shown that cobalt atoms substitute preferentially one iron site.

1) Institute of Physics, University of Uppsala, Sweden
2) Institute of Physics, University in Białystok, Lipowa 41, 15-424 Białystok, Poland

11.6 Electron Momentum Ensay Density Distribution in Lithium: Analysis by the Maximum Entropy Method
by L. Dobrzyński, Y. Tanaka$^2$, Y. Sakurai$^3$, N. Shiotani$^2$, A. Bansil$^3$, S. Kaprzyk$^4$

Maximum Entropy algorithm was applied to the reconstruction of the electron momentum density from the series of Compton profiles measured with a high-resolution for lithium metal. It is shown that the model-free Maximum Entropy Method is a very valuable tool for studying fermiological aspects of the electron momentum density distributions. Using this method with some carelessness one can obtain the distributions relatively free of noise. The experimental data show a small expansion of the Fermi surface along the [110] direction with respect to the [100] one. The Fermi wavevector for the direction [111] is smaller than for both [100] and [110] directions. The value of the renormalisation factor describing the jump of the electron momentum density at the Fermi momentum is estimated. It is 0.24(1) for the [100] and [110] directions, whereas the distribution along the [111] direction seems continuous.

1) Institute of Physical and Chemical Research (RIKEN), Wako, Saitama, 351-01, Japan
2) Tokyo University of Fisheries, Kounan, Minato, Tokyo 108, Japan
3) Department of Physics, Northeastern University, Boston, Massachusetts 02115, USA
4) Academy of Mining and Metallurgy, Cracow, Al. Mickiewicza 30, Poland
LIST OF PUBLICATIONS

HYPERFINE STRUCTURE OF β-FeSi₂
K. Szymański, L. Dobrzyński, D. Szufla, J. M. Greenehe

OBSERVATION OF NATIVE Ga VACANCIES IN GaN BY POSITRON ANNIHILATION

SPIN-DEPENDENT ELECTRON MOMENTUM DENSITIES IN Cu,MnAl STUDIED BY COMPTON SCATTERING

COMPTON PROFILES OF DISORDERED Ni-Cu AND Ni-Co ALLOYS
A. Bansil, S. Kaprzyk, A. Andrejczuk, E. Żukowski, L. Dobrzyński, J. Kwiatkowska, F. Manlawski, L. Dobrzyński

PARTICIPATION IN CONFERENCES AND WORKSHOPS

ELECTRON MOMENTUM DENSITY DISTRIBUTION IN LITHIUM: ANALYSIS BY THE MAXIMUM ENTROPY METHOD
L. Dobrzyński, Y. Tanaka, Y. Sakurai (invited talk)

APPLICATION OF THE MAXIMUM ENTROPY METHOD TO RECONSTRUCTION OF THE ELECTRON MOMENTUM DENSITY
L. Dobrzyński (invited talk)
International Conference on Charge, Spin and Momentum Density Distributions, SAGAMORE XII, Waskesiu, Canada, July 1997, unpublished

WHAT CAN WE LEARN FROM MÖSSBAUER?
L. Dobrzyński (invited talk)
International Meeting on Magnetic X-ray Scattering, Mira, Portugal, April 1997, unpublished

SOME APPLICATIONS OF A 99CO MONOCHROMATIC CIRCULARLY POLARIZED SOURCE
K. Szymański, L. Dobrzyński (poster)

DOUBLE SIDED, DOPPLER TUNABLE, MONOCHROMATIC CIRCULARLY POLARIZED MÖSSBAUER SOURCE

RECENT EXPERIMENTS WITH MONOCHROMATIC CIRCULARLY POLARIZED MÖSSBAUER SOURCE
K. Szymański, L. Dobrzyński, B. Prus, K. Rečko, D. Szufla, J. Waliszewski (poster)
Proc. XXXII Zakopane School on Physics (1997)

OBSERVATION OF NATIVE Ga VACANCIES IN GaN BY POSITRON ANNIHILATION
Proc. MRS Fall Meeting, Boston, December (1997)

LECTURES, COURSES AND EXTERNAL SEMINARS

Wstęp do fizyki magnetyków (Introduction to the Physics of Magnetics)
L. Dobrzyński, 1.10.1997-20.01.1998, Instytut Fizyki Uniwersytetu w Białymstoku

Anihilacja pozytonów w azotku gału (positron annihilation in gallium nitride)
L. Dobrzyński, 22 kwietnia 1997, Instytut Fizyki Uniwersytetu w Białymstoku

INTERNAL SEMINARS

Perspektywy włączenia się IPJ w procesy edukacyjne w Polsce (Prospects of connecting SINS to the educational processes in Poland)
L. Dobrzyński, 20 października 1997, IPJ, Świerk
GRANTS

INVESTIGATIONS OF ELECTRONIC STRUCTURE AND MAGNETIC PROPERTIES OF SOME d-ELECTRON ALLOYS
Principal Investigator: Professor L.Dobrzyński
Grant No. 2 P03B 036 10

ELECTRON MOMENTUM DENSITY INVESTIGATIONS IN METALS AND ALLOYS
Principal Investigator: Professor L.Dobrzyński (in grant coordinated by Dr Eugeniusz Żukowski from the Institute of Physics of the University of Białystok)
Grant No. 2 P03B 061 08

EXTENDED INFORMATION ON PEDAGOGICAL ACTIVITIES

Working at the Institute of Physics of the University in Białystok, prof. L.Dobrzynski delivered various courses for students of physics, and lead weekly seminar on condensed matter physics. It is his permanent duty to lead diploma works (for a magister degree). In 1997 he was delivering a course on Introduction to the Physics of Magnetics.

Two Ph.D. dissertations were finished under supervision of L.Dobrzynski:
- mgr Andrzej Andrejczuk „Compton Profiles of transition metals and their alloys”, and
- mgr Dariusz Satuła, „Distribution of atoms and magnetic moments and hyperfine fields in Fe_{x}Cr, Si and Fe_{x}Cr Al”

Both Ph.D. dissertations will undergo process of defense at the Institute of Experimental Physics, University of Warsaw

OTHERS

WSTĘPNA ANALIZA MOŻLIWOŚCI PROWADZENIA DZIAŁALNOSCI DYDAKTYCZNEJ W INSTYTUCIE PROBLEMÓW JĄDROWYCH
L.Dobrzynski, J.Jablonska, P.Jaracz, B.Myslek-Laurikainen, H.M.Szeptycka
Raport Nr 1 i Nr 1-S (wersja skrócona), Dział Szkolenia i Doradztwa IPJ (1997)

WDRAŻANIE PROBLEMATYKI NORMALIZACJI I KONTROLI JAKOŚCI BADAN RENTGENOWSKICH W REALIZACJACH PROGRAMU NAUCZANIA, MATERIAŁY KONFERENCJI PRZEDMIOTO-WO-METODYCZNEJ DLA PRZEWODNICZYCH ZESPOŁÓW METODYCZNYCH I NAUCZYCIELI WYDZIAŁU ELEKTRO-RADIOLOGII
Łódź 10-11.04.97 r.
Raport Nr 2, Dział Szkolenia i Doradztwa IPJ (1997)

KIERUNKI DZIAŁALNOŚCI DYDAKTYCZNEJ W INSTYTUCIE PROBLEMÓW JĄDROWYCH im. A.SOLTANA
Raport Nr 3, Dział Szkolenia i Doradztwa IPJ (1997)

FIZYKA ATOMU I JĄDRA ATOMOWEGO W SZKOLE PODSTAWOWEJ I ŚREDNIEJ
P.Jaracz
Raport Nr 4, Dział Szkolenia i Doradztwa IPJ (1997)

PROJEKT WYCIECZKI EDUKACYJNEJ DLA UCZNIÓW STARSZYCH KLAS SZKÓŁ PODSTAWOWYCH I ŚREDNICH "PROMIENIOWANIE W ŚRODOWISKU CZŁOWIEKA"
J.Jablonska, B.Myslek-Laurikainen, M.Surala
Raport Nr 5, Dział Szkolenia i Doradztwa IPJ (1997)

PROJEKT EDUKACYJNY PRACOWNI MULTIMEDIALNEJ W INSTYTUCIE PROBLEMÓW JĄDROWYCH
R.Kaczmarowski
Raport Nr 6, Dział Szkolenia i Doradztwa IPJ (1997)

AKREDYTACJA JEDNOSTEK MEDYCyny NUKLARNEJ W POLSCE: ZARYS PROBLEMU
Raport Nr 7, Dział Szkolenia i Doradztwa IPJ (1997)

FIZYCZNE PODSTAWY TECHNIKI RENGENOWSKIEJ, DOZYMETRII I OCHRONY RADIOLOGICZNEJ
P.Jaracz, N.Golnik, J.Jablonska
Raport Nr 8, Dział Szkolenia i Doradztwa IPJ (1997)

SCHEMATY PODSTAWOWYCH ĆWICZEŃ I POKAZÓW Z KAZASU FIZYKI PROMIENIOWANIA JONIZUJĄCEGO I PROMIENIOTWARZCZOŚCI ŚRODOWISKA
L.Dobrzyński
Raport Nr 9, Dział Szkolenia i Doradztwa IPJ (1997)
PERSONNEL

Research scientists
Ludwik Dobrzyński, Professor

PhD Students
Beata Kalska, M.Sc.
Marek Trosko, M.Sc.

Technical and administrative staff
Teresa Piotrowska
Overview

The activity of the Establishment for Nuclear Equipment (ZdAJ) in 1997 concentrated mainly on the preparation of tender documentation and the production of apparatus in answer to tenders called for by the Ministry of Health and Social Welfare. The establishment received orders for the delivery of:

- 6 SIMAX simulators;
- 27 POLKAM 15 therapeutic tables;
- 2 Co-line soft accelerators;
- 5 2D Treatment Planning Systems.

Constant care about the development of technical solutions allows ZdAJ to meet the demands of its customers. In 1997 several important changes and improvements were applied to the ZdAJ products. In March 1997 a new generation SIMAX simulator was implemented. It is a fully computerised apparatus, with an effective anti-collision system, modern freezing and image processing system that offers a full range of possible diagnostic activities.

An emergency table lowering battery system was applied in case of voltage drop and an extra control board which facilitates the service of the machine was provided.

In order to meet the quality assurance Co-line accelerator requirements to the highest degree, an apparatus compensating for the influence of pressure and temperature on the readings in the dosimetric channel was built in. A new visual distance indicator was also constructed.

One of the ZdAJ leading products is a shielding door of a special type which is installed in rooms where there is a danger of ionising radiation. Every year doors of different types are sold. In 1997 a new unified design of the shielding door based on ready-to-use elements available on the market was developed.

The process of implementation of the ISO 9001 standard in the institution is being continued. Two procedures have been implemented:

1. 'Draw up and contract review',
2. Design and development works control.
12.1 Implementation of Production of 'SIMAX' Simulator
by M. Górski

To deliver six simulators to radiotherapy centres in Poland and in response to foreign order, the Establishment commenced preparation to implement small serial production of 'SIMAX' simulator in the second half of 1997.

The main tasks were as follows:
- to draw conclusions from the use of the prototype in Radiotherapy Ward of the M. Kopernik Hospital in Łódź and make necessary modifications;
- to equip the assembly stands with necessary instruments;
- to prepare the production;
- to train the staff.

The following items constitute the changes which resulted from the analysis of the use of the prototype:
- multi-point calibration of the read-out signals to replace the polynomial approximation;
- one-unit travel the size of the simulated radiation field and the angle of rotation of the lever and the collimator with a manual control.

Testing equipment and software for the simulator control system have been prepared.

12.2 Work on the System of Quality Assessment Consistent with the ISO 9001
by R. Kiełsznia

In 1996 the manager of ZdAJ decided to apply the Quality System consistent with the ISO 9001 Standard to institutional organisation. The Standard characterises the Model of Quality Assurance System required in design, development activities, installation and service. The activities concerning the Quality Assurance System in 1997 included:

a) preparation of the documentation of the System,
b) staff training,
c) implementation of the System.

The documentation of the Quality Assurance System comprises the quality manual with specification of the System, Quality System procedures, operation manuals and records. In 1997 the works on the Quality System procedures achieved different levels of advance and are as follows:

- 5 procedures developed and implemented;
- 5 procedures developed and are being implemented;
- 9 procedures developed;
- 8 procedures are being developed.

Five people of the staff have completed the lead quality auditors course organised by Jeff Monk Training, two workers have completed 'Practical documenting of quality assurance systems' course organised by PCBC (Polish Centre of Research and Certification), one worker has completed internal quality auditors' course organised by PCBC.

The implementation of the System involves application of procedures and tests of their functioning out internal. 'Draw up and contract review' procedure and 'design and development works control' procedure were audited.

Work on the development and implementation of the System will be continued in 1998.
III. OBITUARIES

PROFESSOR ALEKSANDER ZAWADZKI (1918-1997)

Professor Aleksander Zawadzki, born on 8 May, 1918 in Łódź, died in Paris on October 10, 1997. He was a former professor of Łódź University, the Institute for Nuclear Studies and College de France, creator of the cosmic ray physics laboratory in Łódź. His scientific activity was preceded by 3-years studies at the Faculty of Science of Paris University and Faculty of Science of Bordeaux University, where he obtained Certificat de Mathematicques Generales and Certificat de Physique Generales in 1939. After the war he continued his studies at the newly established Łódź University, working simultaneously as an assistant in the Experimental Physics Division led by professor Marian Grotowski. In prof. Grotowski’s opinion "Aleksander Zawadzki was one of the most brilliant physicist of the young generation in Poland, deserving special attention and help in his research work as a scientist of deep knowledge and creative mind". Thanks to these qualities and great enthusiasm for work in 1964 Aleksander Zawadzki obtained the title of associate professor.

At the beginning of his scientific activity Aleksander Zawadzki was engaged in teaching, organization and administration of the Division, and preparation for research. In September 1948, at an International Conference in England Aleksander Zawadzki presented the project of a spectrometer for measuring meson mass in crossed fields (electric and magnetic). The project was connected with the controversy which arose from the the existence of two particles in this mass range: pộ-meson and muon. The project was highly appreciated but it was not fully realized due to technical difficulties in Poland. The detection part of the designed spectrometer became the basis for construction of the hodoscope for extensive air shower studies.

Due to the inspiration of Aleksander Zawadzki, a centre of cosmic ray research was established in Łódź. The group consisted of scientists working at the Experimental Physics Division of Łódź University and the Łódź Department of the Institute for Nuclear Research (formed in 1956). The Łódź CR physics laboratory soon became recognized among the best centres in this area. During his visit to Paris, Aleksander Zawadzki made contact with professor Roland Maze from Laboratoire de Physique Cosmique. They put forward a hypothesis about the existence of high energy gamma rays in primary cosmic radiation. This hypothesis was soon confirmed experimentally by the data gathered on the Łódź array. Thanks to numerous publications and contributions to international conferences, Professor Zawadzki and his laboratory became known and respected. Many scientist from abroad visited the Łódź center and organized conferences here.

Professor Zawadzki was known not only as the creator of the laboratory, its director and inspirator of research. He also devoted much of his time and energy to teaching and organization and administration of the Division and the Łódź University. After professor Grotowski’s death, when the Division was led successively by prof. Stanislaw Rouppert and prof. Ludwik Natanson, most duties were in fact performed by professor Zawadzki, who was at the time the spokesman of the Division on the University forum. This was expressed in the opinion of professor Adam Szpunar - Chancellor of the University: "Aleksander Zawadzki distinguishes himself by his numerous abilities and excellent scientific work. He is totally devoted to the University - in all matters related to physics we can rely upon his energy, organizational abilities and assiduity."
For a few months Prof. Aleksander Zawadzki performed the duties of the University Vice-chancellor. The main factor that had influence on further activities of professor Zawadzki were family matters. In September 1968 he leaves to Paris to care for a seriously ill sister. Request for prolonging his leave was denied by the governing body of the Institute of Nuclear Research and the University of Łódź, which dismissed our Professor on 31 December, 1969. After his sister's death in 1969 Aleksander Zawadzki began to work with prof. Maze in the Laboratoire de Physique Cosmique and Collège de France. All the time he served the Łódź cosmic ray centre with his advice and help in continuing the collaboration with the Paris laboratory. In 1995 the Senate of the Łódź University appreciated the activities of professor Zawadzki by awarding him the medal for his services to the University - a symbolic recompensation for moral losses.

A warm patriot, noble man and excellent scientist, he served as a pattern to follow for numerous group of his pupils and collaborators. Working under his supervision was a great honour.

Dr. Ryszard Firkowski
<p>| Author Name                  | Pages       | | Author Name                  | Pages       | |
|------------------------------|-------------|-----------------|------------------------------|-------------|
| Akimune H                    | 43          |                 | Ender C                      | 49          |
| Augsburg M                   | 47          |                 | Engl R                       | 150         |
| Balcerzyk M                  | 75, 76      |                 | Erricsson T                  | 191         |
| Banas D                      | 28, 29      |                 | Filipkowski A                | 127         |
| Bansil A                     | 191         |                 | Firkowski R                  | 138         |
| Baran A                      | 146         |                 | Firszt F                     | 190         |
| Baranowski J                 | 101, 103, 108, 109 | | Fromknecht R                | 31          |
| Barashenkov V.S.             | 91          |                 | Fujita Y                     | 43          |
| Baronova E.O                 | 99, 104     |                 | Fujiwara M                   | 43          |
| Bartke J                     | 127         |                 | Garg U                       | 46, 50      |
| Bednarczyk P                 | 47, 48      |                 | Garkusha I                   | 101         |
| Belcarz E                    | 167         |                 | Garrido F                    | 30          |
| Berger J.F.                  | 146         |                 | Gast W                       | 47-49       |
| Betak E                      | 56          |                 | Gawan J                      | 138, 139    |
| Beyer H.F.                   | 54          |                 | Georgiev A                   | 49          |
| Białkowska H                 | 121         |                 | Ghergescu R.A                | 147         |
| Bielik M                     | 105, 106    |                 | Ghugre S                     | 46, 50      |
| Bieńkowski A                 | 27          |                 | Giagola B                    | 50          |
| Bigolas J                    | 174, 180    |                 | Gilicicz T                   | 62          |
| Bijajima M                   | 151         |                 | Glówacka L                   | 23, 24, 29  |
| Blocki J                     | 40, 41, 45  |                 | Gokiewi R                    | 118, 125    |
| Blumenthal D                 | 50          |                 | Goldstein P.P.               | 149         |
| Bojakowska I                 | 62          |                 | Górny C                      | 79          |
| Borsuk S                     | 81          |                 | Górski M                     | 118, 125, 196 |
| Bosch F                      | 53, 54      |                 | Górski E                     | 109         |
| Boużyk J                     | 63          |                 | Grajda A                     | 79          |
| Braziewicz J                 | 28, 29      |                 | Grötschel R                  | 163, 164    |
| Breitscheidt F               | 164         |                 | Gryfiński M                  | 99          |
| Budzanowski A                | 23, 24      |                 | Gudowski W                   | 91          |
| Calabretta L.                | 184         |                 | Günzel R                     | 165         |
| Carpenter M.P.               | 46, 50      |                 | Guzik Z                      | 79-81, 120  |
| Chabik S                     | 190         |                 | Hagstrom L                   | 191         |
| Charuba J                    | 80, 81      |                 | Härtlein T                   | 49          |
| Chernevsky V.K.              | 24          |                 | Hautojärvi P                 | 190         |
| Chłopik A                    | 79-81, 120  |                 | Infeld E                     | 148, 149    |
| Chmielewksa D.               | 43, 55      |                 | Inomata T                    | 43          |
| Choffel C                    | 30          |                 | Ionescu D.C.                 | 53          |
| Crowell B                    | 46, 50      |                 | Ivanov D.Yu                  | 150         |
| Czarnacki W                  | 166-168     |                 | Iwanicki A                   | 55          |
| Czaus K                      | 109         |                 | Jäger H.M.                   | 49          |
| Czosnyka T.                  | 55          |                 | Jagielski J                  | 30          |
| Czyżewski T.                 | 28, 29, 105 |                 | Jakubowski L                 | 99, 101, 104 |
| Dąbrowski J                  | 146         |                 | Janssens R.V.F               | 46, 50      |
| Dechagé J                    | 146         |                 | Jarzynski C                  | 41          |
| Deloff A                     | 125, 126    |                 | Jaskóla M                    | 28, 29, 105 |
| Dobaczewski J                | 146         |                 | Jensen H.J.                  | 49          |
| Dobrzyński L.               | 190, 191    |                 | Jerzykiewicz A               | 106, 107    |
| Drabik W.                    | 176         |                 | Jorjádze G                    | 148         |
| Droste E                     | 56, 60, 62  |                 | Kaczanowski J                | 31          |
| Droste Ch.                   | 48          |                 | Kaczarowski R                | 46-51       |
| Dunford R.W.                 | 53          |                 | Kaczmarek S                  | 58          |
| Durães F.O.                  | 152         |                 | Kalinowski M.W.              | 148         |
| Dziedzic A.                  | 79          |                 | Kaliska B                    | 191         |</p>
<table>
<thead>
<tr>
<th>Author</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pouzo J</td>
<td>100, 103</td>
</tr>
<tr>
<td>Pratt R.H</td>
<td>54</td>
</tr>
<tr>
<td>Przesmycki M</td>
<td>165</td>
</tr>
<tr>
<td>PsZona J</td>
<td>180</td>
</tr>
<tr>
<td>PsZona S</td>
<td>88, 89, 105</td>
</tr>
<tr>
<td>Rabinski M</td>
<td>97, 98</td>
</tr>
<tr>
<td>Raman S</td>
<td>56</td>
</tr>
<tr>
<td>Ratyński W</td>
<td>56</td>
</tr>
<tr>
<td>Reniewicz H</td>
<td>190</td>
</tr>
<tr>
<td>Reuter H</td>
<td>163, 164</td>
</tr>
<tr>
<td>Revíl W</td>
<td>46</td>
</tr>
<tr>
<td>Riedinger L.L.</td>
<td>46</td>
</tr>
<tr>
<td>Ring P</td>
<td>146</td>
</tr>
<tr>
<td>Romanova V.M</td>
<td>102</td>
</tr>
<tr>
<td>Rondio J</td>
<td>22</td>
</tr>
<tr>
<td>Rondio E</td>
<td>119, 120, 126</td>
</tr>
<tr>
<td>Rostoker G</td>
<td>149</td>
</tr>
<tr>
<td>Rożynek J</td>
<td>146, 147</td>
</tr>
<tr>
<td>Ruchowska E</td>
<td>47-49</td>
</tr>
<tr>
<td>Rudzik A.T</td>
<td>23, 24</td>
</tr>
<tr>
<td>Rurarz E</td>
<td>56</td>
</tr>
<tr>
<td>Rusek K</td>
<td>25</td>
</tr>
<tr>
<td>Rymuza P</td>
<td>43, 53-55</td>
</tr>
<tr>
<td>Rząca-Urban T</td>
<td>47, 48</td>
</tr>
<tr>
<td>Rzadkiewicz J</td>
<td>55</td>
</tr>
<tr>
<td>Saarinen K</td>
<td>190</td>
</tr>
<tr>
<td>Sadowski M</td>
<td>99-105, 108, 109</td>
</tr>
<tr>
<td>Sakurai Y</td>
<td>191</td>
</tr>
<tr>
<td>Samson J.C.</td>
<td>149</td>
</tr>
<tr>
<td>Sandacz A</td>
<td>119, 126</td>
</tr>
<tr>
<td>Satula D.</td>
<td>190</td>
</tr>
<tr>
<td>Savelov A.S.</td>
<td>104</td>
</tr>
<tr>
<td>Sawicka B.</td>
<td>166-168</td>
</tr>
<tr>
<td>Scholz M.</td>
<td>102</td>
</tr>
<tr>
<td>Schwalm D.</td>
<td>49</td>
</tr>
<tr>
<td>Sekutowicz J</td>
<td>177</td>
</tr>
<tr>
<td>Semaniak J</td>
<td>28</td>
</tr>
<tr>
<td>Senatorski A</td>
<td>149</td>
</tr>
<tr>
<td>Shaffer C.D.</td>
<td>54</td>
</tr>
<tr>
<td>Shiotani N</td>
<td>191</td>
</tr>
<tr>
<td>Si-Ze Yang</td>
<td>108</td>
</tr>
<tr>
<td>Siemiarczuk T</td>
<td>122-124, 126</td>
</tr>
<tr>
<td>Siemssen R.H.</td>
<td>45</td>
</tr>
<tr>
<td>Siudak R.</td>
<td>23, 24</td>
</tr>
<tr>
<td>Siwek-Wilczyńska K</td>
<td>45</td>
</tr>
<tr>
<td>Skalski J.</td>
<td>147, 151</td>
</tr>
<tr>
<td>Składnik-Sadowska E</td>
<td>100, 101, 103, 108, 109</td>
</tr>
<tr>
<td>Skorupski A.</td>
<td>148</td>
</tr>
<tr>
<td>Skwirczyńska I.</td>
<td>24</td>
</tr>
<tr>
<td>Słapa M.</td>
<td>168</td>
</tr>
<tr>
<td>Słetten G.</td>
<td>49</td>
</tr>
<tr>
<td>Smolarczyk R.</td>
<td>148, 151</td>
</tr>
<tr>
<td>Sobieczewski A.</td>
<td>146, 147</td>
</tr>
<tr>
<td>Sokolowska G.</td>
<td>62</td>
</tr>
<tr>
<td>Sosnin A.N.</td>
<td>91</td>
</tr>
<tr>
<td>Sosnowski R.</td>
<td>118</td>
</tr>
<tr>
<td>Sowinski M.</td>
<td>62-64</td>
</tr>
<tr>
<td>Srebny J.</td>
<td>48</td>
</tr>
<tr>
<td>Stachura Z.</td>
<td>53, 54</td>
</tr>
<tr>
<td>Stanisławski J.</td>
<td>108, 109</td>
</tr>
<tr>
<td>Starosta K.</td>
<td>48</td>
</tr>
<tr>
<td>Stefanek G.</td>
<td>122, 123, 126</td>
</tr>
<tr>
<td>Stepniak J.</td>
<td>123</td>
</tr>
<tr>
<td>Stepiński W.</td>
<td>102</td>
</tr>
<tr>
<td>Stołiker Th.</td>
<td>53, 54</td>
</tr>
<tr>
<td>Strań W.</td>
<td>168</td>
</tr>
<tr>
<td>Styczeń J.</td>
<td>47, 48</td>
</tr>
<tr>
<td>Sujkowski Z.</td>
<td>43, 44, 55, 78, 181</td>
</tr>
<tr>
<td>Sura J.</td>
<td>181, 184</td>
</tr>
<tr>
<td>Surowieckie A.</td>
<td>55</td>
</tr>
<tr>
<td>Swarzyński J.</td>
<td>138</td>
</tr>
<tr>
<td>Swiatek W.J.</td>
<td>40</td>
</tr>
<tr>
<td>Sworobowicz T.</td>
<td>166-168</td>
</tr>
<tr>
<td>Szabelska B.</td>
<td>139</td>
</tr>
<tr>
<td>Szabelska J.</td>
<td>138-140</td>
</tr>
<tr>
<td>Szatkowski J.</td>
<td>190</td>
</tr>
<tr>
<td>Szawłowski M.</td>
<td>74</td>
</tr>
<tr>
<td>Szczekowski M.</td>
<td>118</td>
</tr>
<tr>
<td>Szczurek A.</td>
<td>23, 24</td>
</tr>
<tr>
<td>Szepietcka M.</td>
<td>118</td>
</tr>
<tr>
<td>Szleper M.</td>
<td>119, 120</td>
</tr>
<tr>
<td>Szydłowski A.</td>
<td>102, 105</td>
</tr>
<tr>
<td>Szymanski L.</td>
<td>150</td>
</tr>
<tr>
<td>Szymański K.</td>
<td>190, 191</td>
</tr>
<tr>
<td>Tamii A.</td>
<td>43</td>
</tr>
<tr>
<td>Tanaka M.</td>
<td>43</td>
</tr>
<tr>
<td>Tanaka Y.</td>
<td>191</td>
</tr>
<tr>
<td>Tchuvil'sky Yu.M</td>
<td>23</td>
</tr>
<tr>
<td>Thomé L.</td>
<td>30</td>
</tr>
<tr>
<td>Tiourine G.P.</td>
<td>22</td>
</tr>
<tr>
<td>Traczyk K.</td>
<td>82</td>
</tr>
<tr>
<td>Traczyk M.</td>
<td>168</td>
</tr>
<tr>
<td>Trautmann D.</td>
<td>28, 29</td>
</tr>
<tr>
<td>Trosko M.</td>
<td>191</td>
</tr>
<tr>
<td>Trzaska W.H.</td>
<td>22</td>
</tr>
<tr>
<td>Trzaskowska H.</td>
<td>60</td>
</tr>
<tr>
<td>Trzciński A.</td>
<td>26, 27</td>
</tr>
<tr>
<td>Turkiewicz J.</td>
<td>23, 24</td>
</tr>
<tr>
<td>Turos A.</td>
<td>30, 31</td>
</tr>
<tr>
<td>Tykarski L.</td>
<td>123, 126</td>
</tr>
<tr>
<td>Undynko A.</td>
<td>55</td>
</tr>
<tr>
<td>Urban W.</td>
<td>47, 48</td>
</tr>
<tr>
<td>Uzdowski M.</td>
<td>82</td>
</tr>
<tr>
<td>Vihrelev V.V.</td>
<td>99</td>
</tr>
<tr>
<td>Waliszewski J.</td>
<td>190</td>
</tr>
<tr>
<td>Warczak A.</td>
<td>53, 54</td>
</tr>
<tr>
<td>Wendler E.</td>
<td>31</td>
</tr>
<tr>
<td>Werner Z.</td>
<td>163</td>
</tr>
<tr>
<td>Wesch W.</td>
<td>31</td>
</tr>
<tr>
<td>Wesołowski E.</td>
<td>48</td>
</tr>
<tr>
<td>Węczorkowski M.</td>
<td>64</td>
</tr>
<tr>
<td>Wieser E.</td>
<td>163, 164</td>
</tr>
<tr>
<td>Wilczynski J.</td>
<td>45</td>
</tr>
<tr>
<td>Wilk G.</td>
<td>126, 151, 152</td>
</tr>
<tr>
<td>Wilschut H.W.</td>
<td>45</td>
</tr>
<tr>
<td>Wincel K.</td>
<td>92</td>
</tr>
<tr>
<td>Wiślicki W.</td>
<td>119, 120, 126</td>
</tr>
</tbody>
</table>
Witkowski J. .......................... 106, 107
Wlodarczyk Z. .......................... 151
Wojnarowski H. .......................... 183
Wojtasiewicz A. .......................... 26
Wojtkowska J. .......................... 22, 57-59, 64
Wolski D. .......................... 74, 78, 79
Wronka S. .......................... 120
Wrzecionko J. .......................... 151
Wycech S. .......................... 151
Wysocka A. .......................... 177
Xiang-Jun He .......................... 108
Ying-Bing Jiang .......................... 108
Zabierski J. .......................... 138, 139
Zalewski P. .......................... 118, 125
Zareba B. .......................... 92
Zbyszynski Z. .......................... 109
Zdunek K. .......................... 98
Ziman V.A. .......................... 24
Zwieglinski B. .......................... 26, 27
Zychor I. .......................... 172
Zebrowski J. .......................... 101, 103
Zupraski P. .......................... 101, 28