Editors:
N. Keeley
J. Skalski

Secretarial work and layout:
A. Odziemczyk

On the front cover, clockwise from the top:
- Cameras of the “Pi of the Sky” project at Las Campanas Observatory, Chile
- Straw drift tubes for LHCb detector, CERN, constructed by the IPJ team
- Plasma discharge in the IBIS device
- Jet Counter for simulations of nanometric targets

Printed by
Stanisław Fuksiewicz
Uslugi Wydawniczo-Poligraficzne

ISSN 1232-5309
# CONTENTS

## FOREWORD

### I. GENERAL INFORMATION

1. LOCATIONS
2. MANAGEMENT OF THE INSTITUTE
3. SCIENTIFIC COUNCIL
4. DEPARTMENTS OF THE INSTITUTE
5. MAIN RESEARCH ACTIVITIES
6. SCIENTIFIC STAFF OF THE INSTITUTE
7. VISITING SCIENTISTS
8. GRANTS
9. PARTICIPATION IN NATIONAL CONSORTIA AND SCIENTIFIC NETWORKS
10. DEGREES
11. EDUCATION AND OUTREACH

## II. DEPARTMENTS OF INSTITUTE

1. DEPARTMENT OF NUCLEAR REACTIONS
2. DEPARTMENT OF INTERDISCIPLINARY APPLICATIONS OF PHYSICS
3. DEPARTMENT OF DETECTORS AND NUCLEAR ELECTRONICS
4. DEPARTMENT OF PLASMA PHYSICS AND TECHNOLOGY
5. DEPARTMENT OF HIGH ENERGY PHYSICS
6. DEPARTMENT OF COSMIC RAY PHYSICS
7. DEPARTMENT OF THEORETICAL PHYSICS
8. DEPARTMENT OF MATERIAL STUDIES
9. DEPARTMENT OF ACCELERATOR PHYSICS AND TECHNOLOGY
10. LABORATORY OF ASTROPHYSICAL APPARATUS
11. DEPARTMENT OF TRAINING AND CONSULTING
12. DEPARTMENT OF NUCLEAR EQUIPMENT “HIGH TECHNOLOGY CENTER – HITEC”

## III. REPORTS ON RESEARCH

- ASTROPHYSICS, COSMIC RAYS & ELEMENTARY PARTICLE PHYSICS
- NUCLEAR PHYSICS
- PLASMA PHYSICS & TECHNOLOGY
- DETECTORS, ACCELERATORS, PHYSICS OF MATERIALS & APPLICATIONS

## IV. LIST OF PUBLICATIONS

- 85
- 87
- 107
- 127
- 141

## V. AUTHORS INDEX

- 167
- 181
FOREWORD

In 2008 IPJ strengthened its position in basic research and opened a new chapter in applied studies. Scientific output exceeded 250 publications, including 232 in reviewed international journals from the ISI Master Journal List. The Hirsch index, taking into account the number of citations in the years 2000-2008, reached about 40, which gives us the seventh place among Polish research units, after two institutes of the Polish Academy of Sciences: Institute of Nuclear Physics and Institute of Physics, Faculties of Physics and Chemistry of Warsaw and Jagiellonian Universities and Warsaw Medical University. The H-index cannot be used as the only measure of the quality of scientific output, as it depends on the size of the institute. However, it gives a good feeling of the “scientific strength”.

This output has been created by a staff of 405 people, including 130 researchers.

Our most spectacular achievement in 2008 was the early optical observation of a gamma-ray burst GRB080319B. The detector “Pi of the Sky” built in collaboration with several other institutes from Warsaw\(^1\) recorded a “movie” of the phenomenon which probably leads to the creation of a black hole. It was the most powerful cosmic explosion ever registered, as it occurred 7 bln light years from the Earth and could be seen by the naked eye. Combining the data with gamma ray measurements by the “Swift” satellite gave a new insight into the mechanism of GRBs, as presented in a paper published in “Nature”.

Two other important results were obtained in nuclear physics. In both cases our theorists explained phenomena observed by experimental groups with IPJ participation. A group in GSI Darmstadt measured electron capture dependence on ionization. Prof. Zygmunt Patyk noticed that the results can be explained by invoking angular momentum conservation. A group in GANIL Caen studied neutron halo structure in \(^{6}\text{He}\) by neutron transfer reactions in the \(^{6}\text{He} + ^{65}\text{Cu}\) system. Dr. Nicholas Keeley provided an interpretation of the data.

IPJ also participated in the most important scientific event of 2008, the startup of the LHC accelerator at CERN. Unfortunately, the breakdown of the machine ruled out the possibility of obtaining interesting results. However, the event as such attracted a lot of attention and gave us a chance to present the beauty and importance of elementary particle physics to a wide audience.

Active participation in the top-tech endeavor of the LHC remains in high contrast with the day-to-day problems caused by the old technical infrastructure of the nuclear center in Świerk. The lack of adequate funding makes an upgrade impossible. Power and water supply suffer from frequent breakdowns and only the strong motivation and high qualifications of the technical staff keeps the center in regular operation.

\(^{1}\) Center of Theoretical Physics PAS, University of Warsaw, Warsaw University of Technology, Space Research Center PAS
Hope for change comes with EU funds available for Poland in 2007-2013. Indeed, we have already obtained the first success. The project “Development of accelerator and detector systems for medicine and security” has 79 mln PLN (~18 mln €) for 5 years which doubles the budget of the institute. It brings a breakthrough in the applied studies conducted by IPJ, but also in the way the institute is managed. Introducing project-driven management is the challenge for 2009. It should result in a boost towards modern and dynamic ways of doing science.

This should be followed by new projects funded from EU programs, including the most ambitious one, which is the free electron laser POLFEL. As a part of a distributed infrastructure EuroFEL it stands for the key element of the European scientific roadmap recommended by the ESFRI committee. In the case of positive decision on funding, the 400 m long accelerator producing 0.2 GW pulses of UV light will be the largest and the most modern research infrastructure in the new Europe. A powerful tool for physicists, chemists, biologists, medical researchers and materials engineers, it should bring scientific research in Poland to a new level. The year 2009 will tell us if this opportunity will be won or wasted.

Grzegorz Wrochna
I. GENERAL INFORMATION

The Institute is a state owned laboratory. It conducts pure and applied research in subatomic physics, i.e. elementary particle, astroparticle, plasma physics, low and high-energy nuclear physics, and related fields. The Institute specializes in accelerator physics and technology, materials research with nuclear techniques, the development of spectrometric techniques, nuclear electronics and also in applications of nuclear techniques to environmental research, nuclear medicine etc.

In addition to the scientific departments, there is a separate production unit operating within the Institute - ZdAJ (the Department for Nuclear Equipment). This unit specializes in medical equipment, notably in the production of linear electron accelerators for oncology and in the production of linear accelerators for industry.

1. LOCATIONS

<table>
<thead>
<tr>
<th>Main site:</th>
<th>Warsaw site:</th>
<th>Łódź site:</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 km SE from Warsaw</td>
<td>(departments P-I, P-VI, P-VIII)</td>
<td>(department P-VII)</td>
</tr>
<tr>
<td>Świerk, 69 Hoża street</td>
<td>5 Uniwersytecka street</td>
<td></td>
</tr>
<tr>
<td>05-400 Otwock</td>
<td>00-681 Warsaw</td>
<td>90-950 Łódź</td>
</tr>
</tbody>
</table>

2. MANAGEMENT OF THE INSTITUTE

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Director</td>
<td>Professor Grzegorz WROCHNA</td>
<td>(22) 718-05-83, (22) 553-22-54</td>
<td><a href="mailto:wrochna@ipj.gov.pl">wrochna@ipj.gov.pl</a></td>
</tr>
<tr>
<td>Deputy Director, Science</td>
<td>Professor Jan NASSALSKI</td>
<td>(22) 718-04-72</td>
<td><a href="mailto:jan.nassalski@fuw.edu.pl">jan.nassalski@fuw.edu.pl</a></td>
</tr>
<tr>
<td>Deputy Director, Research and Development (till August 31)</td>
<td>Professor Marek MOSZYŃSKI</td>
<td>(22) 718-05-86</td>
<td><a href="mailto:marek@ipj.gov.pl">marek@ipj.gov.pl</a></td>
</tr>
<tr>
<td></td>
<td>MSc. Zbigniew GOLEBIEWSKI</td>
<td>(22)718-05-82</td>
<td><a href="mailto:z.golebiewski@ipj.gov.pl">z.golebiewski@ipj.gov.pl</a></td>
</tr>
<tr>
<td>Scientific Secretary (till June 30)</td>
<td>Dr. Danuta CHMIELEWSKA</td>
<td>(22) 718-05-85</td>
<td><a href="mailto:danka@ipj.gov.pl">danka@ipj.gov.pl</a></td>
</tr>
<tr>
<td></td>
<td>Associate Professor Janusz SKALSKI</td>
<td>(22) 718-05-85, (22) 553-2241</td>
<td><a href="mailto:Jskalski@fuw.edu.pl">Jskalski@fuw.edu.pl</a></td>
</tr>
<tr>
<td>Spokesman</td>
<td>Dr. Marek Pawłowski</td>
<td>(22)553-22-36</td>
<td><a href="mailto:rzecznik@ipj.gov.pl">rzecznik@ipj.gov.pl</a></td>
</tr>
</tbody>
</table>
3. SCIENTIFIC COUNCIL

The Scientific Council was elected on 1 April 2008 by the scientific, technical and administrative staff of the Institute. The Council has the right to confer PhD and habilitation degrees in physics (DSc).

Representatives of scientific staff:

Helena Białkowska, Professor, *Deputy Chairperson*  
Robert Kielisznia, Dr.  
Ryszard Kisiel, Dr.  
Tadeusz Kozłowski, Dr.  
Marek Pawłowski, Dr.  
Ewa Rondio, Professor  
Krzysztof Rusek, Prof.

Marek Sadowski, Professor, *Deputy Chairman*  
Adam Sobiczewski, Professor  
Ryszard Sosnowski, Professor, *Chairman*  
Joanna Stepaniak, Professor  
Zbigniew Werner, Assoc. Prof.  
Slawomir Wronka, Dr., *Deputy Chairman*  
Slawomir Wycech, Professor

Representatives of technical personnel:

Jan Kopeć, MSc.  
Jerzy Olszewski, MSc.  
Andrzej Polak, MSc.  
Jacek Pracz, MSc.  
Krystyna Traczyk, MSc.

External members:

Danuta Kisielewska, Professor  
Paweł Kukołowicz, Dr.  
Krystyna Ławniczak-Jabłońska, Professor  
Piotr Malecki, Professor  
Tomasz Matulewicz, Professor  
Krzysztof Meissner, Professor  
Marek Pajek, Professor  
Stanisław Grzegorz Rohożiński, Professor  
Michał Waligórski, Professor  
Janusz Ziółkowski, Professor

AGH University of Science and Technology, Cracow  
Świętokrzyskie Cancer Center, Kielce  
Institute of Physics, Polish Academy of Sciences, Warsaw  
The Niewodniczański Institute of Nuclear Physics Polish Academy of Sciences, Cracow  
Institute of Experimental Physics, Faculty of Physics University of Warsaw  
Institute of Theoretical Physics, University of Warsaw  
Institute of Physics, the Jan Kochanowski University of Humanities and Sciences, Kielce  
Institute of Theoretical Physics, University of Warsaw  
The Maria Skłodowska-Curie Institute, Cracow  
The N. Copernicus Astronomical Centre, Warsaw
4. DEPARTMENTS OF THE INSTITUTE

- NUCLEAR REACTIONS (P-I)
  Head of Department – Professor Krzysztof RUSEK

- INTERDISCIPLINARY APPLICATIONS OF PHYSICS (P-II)
  Head of Department – Dr. Jan SERNICKI

- DETECTORS AND NUCLEAR ELECTRONICS (P-III)
  Head of Department – Assoc. Prof. Zbigniew GUZIK

- PLASMA PHYSICS AND TECHNOLOGY (P-V)
  Head of Department – Dr. Marek RABIŃSKI

- HIGH ENERGY PHYSICS (P-VI)
  Head of Department - Professor Helena BIAŁKOWSKA

- COSMIC RAY PHYSICS (P-VII)
  Head of Department – Dr. Jacek SZABELSKI

- THEORETICAL PHYSICS (P-VIII)
  Head of Department – Professor Grzegorz WILK

- MATERIALS STUDIES (P-IX)
  Head of Department – Assoc. Prof. Zbigniew WERNER

- ACCELERATOR PHYSICS AND TECHNOLOGY (P-X)
  Head of Department – Dr. Eugeniusz PŁAWSKI

- LABORATORY OF ASTROPHYSICAL APPARATUS (LAA)
  Head of Laboratory – Dr. Tadeusz BATŚCH

- TRAINING AND CONSULTING
  Director of Department - Professor Ludwik DOBRZYŃSKI

Other units:

- DIVISION OF INFORMATION TECHNOLOGY
  Head of Division – MSc. Eng. Jacek SZLACHCIAK phone: (22) 718-05-35

- DEPARTMENT OF NUCLEAR EQUIPMENT (ZdAJ)
  Director, MSc. Jacek PRACZ phone: (22) 718-05-00, 718-05-02

- TRANSPORT DIVISION (ZTS)
  Director, Civ. Eng. Bogdan GAS phone: (22) 718-06-16
5. MAIN RESEARCH ACTIVITIES

I. Elementary particle physics, astro- & cosmic ray physics and cosmology
   1. Mechanism of hadron-induced reactions
   2. High-energy $e^+e^-$ interactions
   3. Deep-inelastic $\mu$ interactions
   4. Nucleon structure
   5. Rare decays
   6. Baryon & meson resonances and near threshold meson production
   7. Neutrino physics
   8. Astrophysics: detection of short optical bursts, large-scale structure, dark matter
   9. Cosmic ray physics
   10. Cosmology
   11. Theory of lepton and hadron interactions

II. Nuclear physics
   1. Relativistic ion collisions
   2. Nuclear reactions
   3. Nuclear structure
   4. Properties of heavy and superheavy nuclei (theory)
   5. Theory of nuclear matter, hypernuclei & nuclear structure and dynamics
   6. High-energy atomic physics
   7. Exotic atoms

III. Plasma physics and technology
   1. Development of methods and tools for plasma diagnostics
   2. Studies of light emitted from hot plasma jets and jet interaction with solid targets
   3. Thin Nb and Pb film coating by means of arc discharges under ultra-high vacuum conditions
   4. Nonlinear effects in extended media & Bose-Einstein condensates (theory)

IV. Material studies
   1. Modification of surface properties of solid materials by means of continuous or pulsed ion and plasma beams
   2. Material structure studies by nuclear methods
V. Accelerator physics and techniques
   1. R&D of linear accelerators for high-energy electrons
   2. Accelerators for hadron therapy
   3. Small electron accelerators for X-ray therapy
   4. Optimization of TiN coating processes for accelerating structures

VI. Detector physics and techniques
   1. New detection methods and their application in physics experiments, nuclear medicine and homeland security
   2. Electronics for large-scale experiments in high-energy physics
   3. Systems for nuclear radiation spectroscopy
   4. R&D of special silicon detectors for physics experiments and environmental protection

VII. Nuclear methods for society
   1. Monitoring, modelling and prediction of environmental pollution
   2. Dosimetry and nano-dosimetry
   3. Computer modeling of radiation sources, transport of radiation through matter and radiation dose calculations
   4. X-ray sources for medicine and industry
   5. Detector techniques for nuclear medicine

Each report on research (Part III) bears a signature, in square brackets, referring to the corresponding research activity, e.g.: the Hermes collaboration report on page 101 has the reference I.4, i.e. to Elementary particle physics, astro- & cosmic ray physics and cosmology, item 4 – nucleon structure.
6. SCIENTIFIC STAFF OF THE INSITUTE

PROFESSORS

1. BIAŁKOWSKA Helena
   High Energy Nuclear Physics
2. BŁOCKI Jan
   Theoretical Nuclear Physics
3. DĄBROWSKI Janusz (**)
   Theoretical Nuclear Physics
4. DOBRZYŃSKI Ludwik
   Solid State Physics
5. INFELD Eryk
   Plasma Physics and Nonlinear Dynamics
6. JAGIELSKI Jacek (**)
   Solid State Physics
7. JASKÓŁA Marian
   Low Energy Nuclear Physics
8. MOSZYŃSKI Marek
   Nuclear Electronics, Technical Physics
9. MRÓWCZYŃSKI Stanisław (**)
   Particle Physics
10. NASSALSKI Jan
    Particle Physics
11. PJEKOSZEWSKI Jerzy
    Solid State Physics
12. RONDO Ewa
    Particle Physics
13. RUSEK Krzysztof
    Low Energy Nuclear Physics
14. SADOWSKI Marek
    Plasma Physics
15. SIEMIARZUK Teodor
    Particle and High Energy Nuclear Physics
16. SOBIECZEWSKI Adam
    Theoretical Physics, Member of the Polish Academy of Sciences
17. SOSNOWSKI Ryszard
    Particle Physics, Member of the Polish Academy of Sciences
18. STEPANIAK Joanna
    High Energy Nuclear Physics
19. SZEPYCKA Maria
    Particle Physics
20. TUROS Andrzej (**)
    Solid State Physics
21. WILCZYNSKI Janusz
    Low Energy Nuclear Physics
22. WILK Grzegorz
    Particle Physics
23. WISLICKI Wojciech
    Particle Physics
24. WYCECH Sławomir
    Nuclear and Particle Physics
25. ZABIEROWSKI Janusz
    Cosmic Ray Physics

ASSOCIATE PROFESSORS and DSc

1. DELOFF Andrzej (**)
   Particle Physics
2. GUZIK Zbigniew
   Nuclear Electronics
3. KACZAROWSKI Rościsław
   Low Energy Nuclear Physics
4. KIELCZEWSKA Danuta (**)
   Particle Physics
5. PATYK Zygmunt
   Theoretical Nuclear Physics
6. PIASECKI Ernest (**)
   Low Energy Nuclear Physics
7. PIECHOCKI Włodzimierz
   Cosmology
8. RUSEK Krzysztof
   Low Energy Nuclear Physics
9. SANDACZ Andrzei
   Particle Physics
10. SKALSZKI Janusz
    Theoretical Nuclear Physics
11. SŁAPA Mieczysław (**)
    Solid State Physics
12. SPALIŃSKI Michał
    Particle Physics and Cosmology
13. SZCZEKOWSKI Marek
    Particle Physics
14. SYMANOWSKI Lech
    Theoretical Nuclear Physics
15. SYMANIŃSKI Piotr
    Particle Physics
16. TRIPPENBACH Marek(**)
    Quantum and Nonlinear Optics
17. WERNER Zbigniew
    Solid State Physics
18. WIBIG Tadeusz (**)
    Cosmic Ray Physics
19. WROCHNA Grzegorz   Particle and Astroparticle Physics
20. ZWIEGLIŃSKI Bogusław   Nuclear Physics
21. ŹUPRAŃSKI Paweł   High Energy Nuclear Physics

RESEARCH STAFF

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>ADAMUS Marek</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>AUGUSTYNIAK Witold</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>BARLAK Marek</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>BATŚCH Tadeusz</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>BIEŃKOWSKI Andrzej</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>BLUJ Michał</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>BOIMSKA Bożena</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>CHMIELEWSKA Danuta</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>CHMIELOWSKI Władysław</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>CZARNACKI Wiesław</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>CZUCHRY Ewa</td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>GIERLIK Michał</td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>GOKIELI Ryszard</td>
<td></td>
</tr>
<tr>
<td>14.</td>
<td>GOLDSTEIN Piotr</td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>GÓRSKI Maciej</td>
<td></td>
</tr>
<tr>
<td>16.</td>
<td>HOFFMAN Julia</td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>JAKUBOWSKI Lech</td>
<td></td>
</tr>
<tr>
<td>18.</td>
<td>KAPUSTA Maciej</td>
<td></td>
</tr>
<tr>
<td>19.</td>
<td>KAZANA Małgorzata</td>
<td></td>
</tr>
<tr>
<td>20.</td>
<td>KEELEY Nicholas</td>
<td></td>
</tr>
<tr>
<td>21.</td>
<td>KORMAN Andrzej</td>
<td></td>
</tr>
<tr>
<td>22.</td>
<td>KOWAL Michał</td>
<td></td>
</tr>
<tr>
<td>23.</td>
<td>KOWALIK Katarzyna</td>
<td></td>
</tr>
<tr>
<td>24.</td>
<td>KOZŁOWSKI Tadeusz</td>
<td></td>
</tr>
<tr>
<td>25.</td>
<td>KUPŚC Andrzej</td>
<td></td>
</tr>
<tr>
<td>26.</td>
<td>KUREK Krzysztof</td>
<td></td>
</tr>
<tr>
<td>27.</td>
<td>ŁAGODA Justyna</td>
<td></td>
</tr>
<tr>
<td>28.</td>
<td>MAJCZYNA Agnieszka</td>
<td></td>
</tr>
<tr>
<td>29.</td>
<td>MALINOWSKA Aneta</td>
<td></td>
</tr>
<tr>
<td>30.</td>
<td>MARIAŃSKI Bogdan</td>
<td></td>
</tr>
<tr>
<td>31.</td>
<td>MELNYCHUK Dmytro</td>
<td></td>
</tr>
<tr>
<td>32.</td>
<td>MORSCH Hans Peter</td>
<td></td>
</tr>
<tr>
<td>33.</td>
<td>MYKULIYAK Andriy</td>
<td></td>
</tr>
<tr>
<td>34.</td>
<td>NAWROCKI Krzysztof</td>
<td></td>
</tr>
<tr>
<td>35.</td>
<td>NAWROT Adam</td>
<td></td>
</tr>
<tr>
<td>36.</td>
<td>NIETUBYĆ Robert</td>
<td></td>
</tr>
<tr>
<td>37.</td>
<td>NOWAKOWSKA-LANGIER Katarzyna</td>
<td></td>
</tr>
<tr>
<td>38.</td>
<td>NOWICKI Lech</td>
<td></td>
</tr>
<tr>
<td>39.</td>
<td>PAWŁOWSKI Marek</td>
<td></td>
</tr>
<tr>
<td>40.</td>
<td>PLUCIŃSKI Paweł</td>
<td></td>
</tr>
</tbody>
</table>

(*) on leave of absence
(**) part-time employee
## 7. VISITING SCIENTISTS

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Institution</th>
<th>Start Date - End Date</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>El Belyad M.</td>
<td>Ecole Polytechnique, Paris, France</td>
<td>Feb. 24-29</td>
<td>P-VIII</td>
</tr>
<tr>
<td>2</td>
<td>Koshchy E.</td>
<td>Kharkov State University, Kharkov, Ukraine</td>
<td>March 13-22</td>
<td>P-I</td>
</tr>
<tr>
<td>3</td>
<td>Ladygina M.</td>
<td>Institute of Plasma Physics, Kharkov, Ukraine</td>
<td>March 26 - April 23</td>
<td>P-V</td>
</tr>
<tr>
<td>4</td>
<td>Koshchy E.</td>
<td>Kharkov State University, Kharkov, Ukraine</td>
<td>April 11-26</td>
<td>P-I</td>
</tr>
<tr>
<td>5</td>
<td>Smirnov S.</td>
<td>Joint Institute for Nuclear Research, Dubna, Russia</td>
<td>April 11-26</td>
<td>P-I</td>
</tr>
<tr>
<td>6</td>
<td>Loktev T.</td>
<td>Joint Institute for Nuclear Research, Dubna, Russia</td>
<td>April 11-26</td>
<td>P-I</td>
</tr>
<tr>
<td>7</td>
<td>Mutterer M.</td>
<td>GSI-Darmstadt, Germany</td>
<td>April 11-18</td>
<td>P-II</td>
</tr>
<tr>
<td>8</td>
<td>Kazulin E.</td>
<td>Joint Institute for Nuclear Research, Dubna, Russia</td>
<td>April 12-14</td>
<td>P-I</td>
</tr>
<tr>
<td>9</td>
<td>Chlebnikov S.</td>
<td>University of Petersburg, Russia</td>
<td>April 12-19</td>
<td>P-I</td>
</tr>
<tr>
<td>10</td>
<td>Grosswendt B.</td>
<td>Die Physikalich-Technische Bundesanstalt</td>
<td>May 5-10</td>
<td>P-II</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brunswieg, Germany</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Fisher G.</td>
<td>CERN, Switzerland</td>
<td>May 13-14</td>
<td>P-VI</td>
</tr>
<tr>
<td>12</td>
<td>Capdevielle N.</td>
<td>College de France, Paris, France</td>
<td>May 19-30</td>
<td>P-VII</td>
</tr>
<tr>
<td>13</td>
<td>Doll P.</td>
<td>Forschungszentrum, Karlsruhe, Germany</td>
<td>June 4-7</td>
<td>P-VII</td>
</tr>
<tr>
<td>14</td>
<td>Kucuk Y.</td>
<td>Erciyes University, Kayseri, Turkey</td>
<td>July 3-23</td>
<td>P-I</td>
</tr>
<tr>
<td>15</td>
<td>Stepanenko A.</td>
<td>Engineering Physics Institute, Moscow, Russia</td>
<td>July 20-31</td>
<td>P-V</td>
</tr>
<tr>
<td>16</td>
<td>Macintosh R.</td>
<td>The Open University, UK</td>
<td>July 20-28</td>
<td>P-V</td>
</tr>
<tr>
<td>17</td>
<td>Baronova E.</td>
<td>RRC Kurchatov Institute, Moscow, Russia</td>
<td>July 21-31</td>
<td>P-V</td>
</tr>
<tr>
<td>18</td>
<td>Pathak A.</td>
<td>University of Hyderabad, Hyderabad, Indie</td>
<td>Aug. 18-31</td>
<td>P-I</td>
</tr>
<tr>
<td>19</td>
<td>Grosswendt B.</td>
<td>Die Physikalich-Technische Bundesanstalt</td>
<td>Sept. 7-12</td>
<td>P-II</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brunswieg, Germany</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>El Belyad M.</td>
<td>Ecole Polytechnique, Paris, France</td>
<td>Sept. 21-26</td>
<td>P-VIII</td>
</tr>
<tr>
<td>21</td>
<td>Kulich E.</td>
<td>University of Kiev, Kiev, Ukraine</td>
<td>Sept. 24-28</td>
<td>P-VIII</td>
</tr>
<tr>
<td>22</td>
<td>Trautmann D.</td>
<td>University of Basil, Switzerland</td>
<td>Sept. 30 - Oct. 2</td>
<td>P-I</td>
</tr>
<tr>
<td>23</td>
<td>Garrido F.</td>
<td>Centre de Spectrometrie Nucleaire et de</td>
<td>Nov. 2-9</td>
<td>P-I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spectrometrie de Masse, Orsay, France</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Hungs A.</td>
<td>Forschungszentrum Karlsruhe, Germany</td>
<td>Nov. 16-19</td>
<td>P-VII</td>
</tr>
<tr>
<td>25</td>
<td>Dobrzyński L.</td>
<td>Ecole Polytechnique, Saclay, France</td>
<td>Nov. 26-30</td>
<td>P-VI</td>
</tr>
<tr>
<td>26</td>
<td>Mine P.</td>
<td>Ecole Polytechnique, Saclay, France</td>
<td>Nov. 26-30</td>
<td>P-VI</td>
</tr>
<tr>
<td>27</td>
<td>Abrosimov V.</td>
<td>Inst. for Nuclear Research, Kiev, Ukraine</td>
<td>Dec. 2-5</td>
<td>P-II</td>
</tr>
</tbody>
</table>
8. GRANTS

List of Research Projects Realized in 2008
Granted by Ministry of Science and Higher Education

1. Structure of interaction of few-electron high-z ions in relativistic collisions
   Principal Investigator: Dr. J. Rzadkiewicz
   No. 1P03B04730

2. Studies on the spectra of elementary electric charges induced in nanostructures. Measuring set up and experiment for 1-30 nm nanosites
   Principal Investigator: Dr. S. Pszona
   No. 3 T10C 008 30

3. Relativistic ion physics: from elementary to nuclear collisions and from SPS energies (NA49) to the LHC
   Principal Investigator: Prof. H. Białkowska
   No. 1P03B00630

4. K-fragments
   Principal Investigator: Prof. S. Wycech
   No. 1P03B04229

5. Structure and properties of heaviest atomic nuclei
   Principal Investigator: Prof. A. Sobiczewski
   No. 1P03B04230

6. Influence of weak couplings on the structure of Coulomb barrier distribution: application of coupled channel method
   Principal Investigator: Dr. E. Piasecki
   No. N20215231/2796

7. New experimental method for characterization of physical stage of Auger electrons interaction with nanostructures (DNA, nucleosome, chromatid fibre) based on registration of ionization cluster distribution as a tool for defining the effectiveness of targeted radionuclide (I-125) radiotherapy
   Principal Investigator: Dr. S. Pszona
   No. N N401 216134

8. Study of short time scale astrophysics phenomena
   Principal Investigator: Assoc. Prof. G. Wrochna
   No. N20205231/2798

9. The Milne space as a model of the cosmological singularity
   Principal Investigator: Assoc. Prof. W. Piechocki
   No. N N202 0542 33

10. A study of neutrino, interactions constituting the background to electron neutrino appearance in T2K experiment
    Principal Investigator: Assoc. Prof. D. Kiełczewska
    No. N N202 0299 33

11. Determination of the gluon polarization in the nucleon using events with hadron pairs at high transverse momenta in COMPASS experiment
    Principal investigator: Prof. J. Nassalski
    No. N N202 259534

12. Direct and indirect searches for Dark Matter particles
    Principal Investigator: Prof. E. Rondio
    No. N N202 175735

13. Copper-wettable surfaces of carbon and carbide ceramic produced by high intensity plasma pulses technique
    Principal Investigator: Dr. M. Barłak
    No. N N507394235
14. New neutron detection techniques for industry and border monitoring applications  
   Principal Investigator: Prof. M. Moszyński  
   No. R00-O0054/3

15. Universal spectrometric analyzer for applications in environment protection, security systems and nuclear medicine  
   Principal Investigator: Assoc. Prof. Z. Guzik  
   No. R02 003 03

16. Medical dosimetry of the electronic sources of X rays for brachytherapy. Development of the measuring methods for accredited dosimetry laboratory  
   Principal Investigator: MSc. M. Traczyk  
   No. R13 005 03

17. Optimization of the CMS detector trigger for Beyond Standard Model searches  
   Principal Investigator: Dr. M. Kazana  
   No. PBZ/MNiSW/07/2006/38

18. Statistics of the Large Scale Structure of the Universe: between theory and observations  
   Principal Investigator: Dr. A. Pollo  
   No. PBZ/MNiSW/07/2006/34

19. Verifying dynamical stability of the Cyclic Model  
   Principal Investigator: Dr. E Czuchry  
   No. PBZ/MNiSW/07/2006/37

20. Optimization and calibration of the SMRD detector in the T2K neutrino experiment  
   Principal Investigator: Dr. J. Łagoda  
   No. PBZ/MNiSW/072006/36

21. Studies on track structures of low energy electrons up to 3000 eV  
   Principal Investigator: Dr. S. Pszona  
   No. COST/6/2005 (COST P9)

22. COMPASS experiment - investigation of the spin structure of the nucleon  
   Principal Investigator: Prof. J. Nassalski  
   No. CERN/74/2007 (Program CERN)

23. Production of electron-positron pairs in decays of light mesons and baryonic resonances  
   Principal Investigation: Prof. J. Stepaniak  
   No. DFG/126/2007 (Program DFG)

24. Construction of elements of Neutral Beam Injectors to be used in W7-X stellarator: preparatory phase  
   Principal Investigation: Prof. J.Jagielski  
   No. NW7X/129/2007 (Program W7X)

25. Calculations, design, production and measurements of beam line HOM absorber prototype and prototype of HOM suppression system for superconducting accelerating structures of X-FEL facility  
   Principal Investigator: Dr. E. Pławska  
   No. DWM/N5/XFEL/2008 (Program XFEL)

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

1. Collaboration in the Theoretical and Experimental Studies of Superheavy Nuclei
   Principal Investigator: Prof. A. Sobiczewski
   JINR Dubna, Order 438, 18, Russia

2. Participation in Designing and Testing of Photomultipliers
   Principal Investigator: Prof. M. Moszyński
   Contract of PHOTONIS, Brive, France

3. Additions and Modifications of the Microstrip Detector Assemblies
   Principal Investigator: Dr. T. Batsch
   Order No. 125/41780516, Germany

4. Investigation of detector configurations for gamma and neutron detection with scintillators
   Principal Investigator: Prof. M. Moszyński
   Contract with ICx Radiation GmbH, Solingen, Germany

   Principal Investigator: Dr. E. Pławski
   Order No. Prot. ENEA/2005/14909 FIS-stg., Italy

6. Development of new detectors for the border monitoring based on new scintillators and photodetectors
   Principal Investigator: Prof. M. Moszyński
   Contract No: 14360, IAEA, Vienna, Austria

7. Low Level RF development for X-ray Free Electron Laser
   Principal Investigator: MSc. J. Szewiński
   Contract: 39706, DESY, Germany

Research Projects (Indirect Actions) Granted by the European Commission and Ministry of Science and Higher Education

1. BIO-CARE
   Molecular Imaging for Biologically Optimized Cancer Therapy
   Responsible for the work: Prof. M. Moszyński
   Contract No. LSHC-CT-2004-505785, the 6th Framework Programme of EU

2. EURITRACK
   EURopean Illicit TRAfficking Countermeasures Kit
   Responsible for the work: Prof. M. Moszyński
   Contract No. STREP-2004-511471, the 6th Framework Programme of EU

3. HADRON PHYSICS
   Study of Strongly Interacting Matter
   Responsible for the work: Assoc. Prof. B. Zwięgiński
   Contract No. RI3-CT-2004-506078/JRA2:Fast EM, the 6th Framework Programme of EU

4. DIRACsecondary-Beams
   Internal Target experiments with highly energetic stored and cooled secondary beams at the International Accelerator Facility, Darmstadt Ion Research and Antiproton Center (DIRAC)(DIRACsecondary-Beams) within the framework of the specific research and technological development program
   Responsible for the work: Assoc. Prof. B. Zwięgiński
   Contract No. 515873 (RIDS), the 6th Framework Programme of the EU

5. EURATOM
   Contract of Association between the European Atomic Energy Community (EURATOM) and the Institute of Plasma Physics and Laser Microfusion
   Responsible for the work: Dr. Marek Rabinski
   Contract No. FU07-CT-2007-00061, the 7th Framework Programme of the EU
9. PARTICIPATION IN NATIONAL CONSORTIA AND SCIENTIFIC NETWORKS

NATIONAL CONSORTIUM:

<table>
<thead>
<tr>
<th>National Consortium</th>
<th>Institute representative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.* Nuclear Science Center</td>
<td>G. Wrochna</td>
</tr>
<tr>
<td>2.* National Consortium “XFEL-POLAND” for collaboration with the European X-ray Free Electron Laser - Project XFEL</td>
<td>G. Wrochna/Z. Werner</td>
</tr>
<tr>
<td>4. National Consortium “FEMTOFIZYKA” for collaboration with the FAIR project in GSI Darmstadt</td>
<td>B. Zwieglinski</td>
</tr>
<tr>
<td>5. National Consortium “COPIN” for the scientific collaboration with France (IN2P3 Institute)</td>
<td>K. Rusek</td>
</tr>
<tr>
<td>6. Agreement for scientific collaboration in theoretical research on: “Particles-Astrophysics-Cosmology”</td>
<td>W. Piechocki</td>
</tr>
<tr>
<td>8. National Consortium of scientific Network “Polish calculation system for experiments at LHC-POLTIER”</td>
<td>W. Wiślicki</td>
</tr>
<tr>
<td>9. Warsaw Science Consortium</td>
<td>G. Wrochna / M. Juszczyk</td>
</tr>
<tr>
<td>10. “Polish Synchrotron” Consortium</td>
<td>R. Nietubýé</td>
</tr>
</tbody>
</table>

SCIENTIFIC NETWORK:

<table>
<thead>
<tr>
<th>Scientific Network</th>
<th>Institute representative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.* Polish Astroparticle Physics Network</td>
<td>G. Wrochna</td>
</tr>
<tr>
<td>2.* Polish Neutrino Physics Network</td>
<td>D. Kiełczewska</td>
</tr>
<tr>
<td>3. Polish Nuclear Physics Network</td>
<td>D. Chmielewska</td>
</tr>
<tr>
<td>4. Polish Network of Physics of Relativistic Ion Collisions</td>
<td>St. Mrówczyński</td>
</tr>
<tr>
<td>5. Integrated Large Infrastructure for Astroparticle Science (ILIAS) European Network for Theoretical Astroparticle Physics (ENTApP)</td>
<td>W. Piechocki</td>
</tr>
<tr>
<td>6. Polish Network of Neutrons-emission-detection</td>
<td>J. Szydłowski</td>
</tr>
<tr>
<td>7. Polish Network of Neutron Scatterers (NeutroNET)</td>
<td>L. Dobrzyński</td>
</tr>
<tr>
<td>8. Polish Network of Radiation Protection and Nuclear Safety</td>
<td>L. Dobrzyński</td>
</tr>
</tbody>
</table>

* Coordinator: The Andrzej Sołtan Institute for Nuclear Studies (IPJ)
10. DEGREES

DSc theses

1. ROBERT SMOLAŃCZUK (Institute for Nuclear Studies, Otwock-Świerk)
   Stability and synthesis of spherical superheavy nuclei.

PhD theses

1. ANETA MALINOWSKA (Institute for Nuclear Studies, Otwock-Świerk)
   Investigation of emission of nuclear reaction protons emitted from PF facility.

2. ALEKSANDR PARKHOMENKO (Institute for Nuclear Studies, Otwock-Świerk)
   Single-particle effects in the properties of heavy and superheavy nuclei.

3. PAWEŁ PLUCIŃSKI (Institute for Nuclear Studies, Otwock-Świerk)
   The startup and optimization of the muon trigger system for the ZEUS Backing Calorimeter.

4. MARCIN SOKOŁOWSKI (Institute for Nuclear Studies, Otwock-Świerk)
   Investigation of astrophysical phenomena in short time scales with "Pi of the Sky" apparatus.
11. EDUCATION AND OUTREACH

As in previous years, our Department of Training and Consulting has provided a scientific program for secondary schools, including lectures, demonstrations and exhibitions on contemporary physics. The number of participants amounts to 6600. The Department also organizes a competition for secondary school students: “Physical paths”. For a more detailed description of these activities see the Department’s contribution to this report.

The inauguration of the LHC in CERN was the occasion for introducing the general public to developments in science and technology. To this end, the exhibition “LHC – how does it work?” was organized as a joint initiative by many Polish scientific institutions. It is scheduled to visit 11 (possibly even more) cities in Poland. Our scientists and technicians have prepared several parts of the exhibition. Marek Pawłowski of IPJ is one of the main organizers of this large event which will continue throughout 2009. People involved in these events are: J.Łagoda, M.Kazana, H.Białkowska, P.Zalewski, Ł.Adamowski, E.Droste, T.Ostrowski, U.Kalińska, R.Wolkiewicz, J.Użycki, M.Szczekowski, M.Sokołowski, J.Nassalski, R.Sosnowski, A.Ukleja, Z.Dębicki, J.Feder, K.Jędrzejczak, J.Karczmarczyk, M.Kasztelan, R.Lewandowski, J.Orzechowski, B.Szabelska, J.Szabelski, T.Wibig, A.Majcher and R.Gokieli.

Several educational events of the XII Science Festival in Warsaw and the Scientific Picnic of the Polish Radio were organized in 2008 by Departments I, III, V, VI and VIII. In recent years, Jacek Rożynek and Marek Pawłowski have prepared and presented the program “Physical sandpit” including demonstrations and explanations of physical phenomena for kindergarten- and young schoolchildren. Also, in 2008, their presentations (24 h) were very much frequented, causing curiosity and excitement among the young participants.

Department VII of IPJ participated in the organization of the Masterclass “Hands on Particle Physics” in Łódź and Poznań (ca 160 participants), the Roland Maze session “Skąd Prąd” in Łódź (ca 100 participants) and a Workshop for School Teachers on cosmic rays detectors (14-15.VI.2008). Similar workshops on particle physics and the GRID were organized in Warsaw by Department VI, especially by P.Zalewski and W.Wiślicki. M.Sokołowski and J.Użycki presented popular lectures on astrophysics for secondary school pupils.

Our institute is one of the supervisors of the Polish Ukrainian Physics Contest „Lwiątko” (Lion-Cub). Piotr Goldstein and Marek Pawłowski of IPJ are co-authors of the test questions and members of the Organizing Committee. In 2008, the contest encompassed over 1500 schools and over 27000 participants. In addition to material prizes, the young winners are awarded a one-day trip to our institute, and a visit to the nuclear reactor of the Institute of Atomic Energy.

A number of IPJ employees published didactic or popular articles in “Postępy Fizyki”, “Fizyka w Szkole” (A.Sobiczewski), “Delta” (P.Zalewski – 10, E.Czuchry -1) and “Rzeczpospolita” (A.Pollo). There were many articles on topical scientific subjects in newspapers and journals by M.Pawłowski, J.Nassalski (especially on LHC), and G.Wrochna. They also appeared on many TV and radio programs. T.Wibig was on a local radio program (Łódź, 10 times) on various scientific topics. Other persons who took part in TV or radio programs are: J.Jagielski, A.Nassalski, M.Moszyński, A.Turos, Hamada Sadek Ramadan Koth, Shaaban Mohamed Mahmoud Abd El Aal, K.Nowakowska-Langer and A.Polak. A.Majcher provided articles, data and instructions for astrophysical portals on the internet.
II. DEPARTMENTS OF INSTITUTE

1. DEPARTMENT OF NUCLEAR REACTIONS

Head of Department: Professor Krzysztof Rusek
phone: (22) 621-38-29
e-mail: rusek@fuw.edu.pl

Overview

Our activity in 2008 has focused on well-established domains of research: nuclear and atomic physics, and applications.

- As far as nuclear physics is concerned, our interests are very broad, ranging from the structure of the nucleon to the structure of the nucleus including high-energy multifragmentation studies.

Our colleagues led by Prof. Paweł Żuprański, members of the HERMES collaboration that comprises 32 institutions from eleven countries at the Deutsches Elektronen Synchrotron (DESY) in Hamburg, worked last year on the extraction of Spin Density Matrix Elements of vector mesons from scattering experiments on hydrogen targets. They also studied the distribution of quarks and gluons in nucleon.

A team led by Prof. B. Zwieglinski was involved in the large-scale international collaboration PANDA (antiProton ANnihilation at DArmstadt). They studied the response of cooled PWO scintillators irradiated by gammas in the energy range of 4 – 20 MeV. The gammas were produced radiative proton capture on light by nuclei using a proton beam from the Van de Graaff accelerator of our Department. As a result, an important extrapolation of measurements performed by another group of physicists at much higher γ-ray energies was obtained.

Low energy nuclear physics experiments were continued at the Heavy Ion Laboratory of Warsaw University in collaboration with foreign institutions: the University of Jyväskylä, the Institute of Nuclear Research of the Ukrainian Academy of Science and the Institute de Recherches Subatomique in Strasbourg.

At high energies, a study of the isospin - dependence of the caloric curve was performed by the ALADIN Collaboration in a series of experiments at GSI – Darmstadt using radioactive beams of Sn and La. It was found that the asymmetry due to isospin is very weak.

- Atomic physics studies were devoted to ionisation of heavy atoms by oxygen ions from the tandem accelerator of Erlangen-Nürenberg University. X-rays generated in the process of ionisation of gold atoms were detected and analyzed.

- Radiobiological studies were performed using carbon ions accelerated to energies in the range of 50-100 MeV at the Heavy Ion Laboratory of Warsaw University. In these experiments, the profile of the carbon beam was measured for the first time by means of nuclear track detector. This technique is much easier to use than scanning the beam profile with a (x,y) - movable silicon detector.

- Beams from our Van de Graaff accelerator LECH were used in particle - induced X-ray emission (PIXE) studies of polychromatic decorations in ancient Egyptian tombs. Important findings on the origin and dating of wall paintings at different archeological sites are reported.

Finally, I would like to warmly welcome Mr Hamada Kotb who joined us last year. He will study ancient Egyptian ceramics by means of the PIXE technique.

As always, apart from their purely scientific activities, a few of our colleagues have been involved in lectures and demonstrations prepared and presented for the general public.

Krzysztof Rusek
REPORTS

PANDA - Strong interaction studies with antiprotons
GSI, Darmstadt

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Scattering of weakly bound nuclei in the vicinity of the Coulomb barrier
K. Rusek
Prospects of R&D and training programmes at heavy ion accelerator DC-60 (Astana, Kazakhstan, 2008-10-24 - 2008-10-25)

Spin density matrix elements from diffractive $\phi$ vector mesons production at HERMES
W. Augustyniak
DII08 XVI International Workshop on Deep-Inelastic Scattering and Related Subjects (London, United Kingdom, 2008-04-07 - 2008-04-11)

Near-barrier transfer coupling effects for light exotic nuclei
N. Keeley

Reaction mechanism tools for pair transfer
N. Keeley

Ion beam analysis of ancient Egyptian wall paintings
S. Abd-El-Aal, A. Korman, A. Stonert, F. Munnik, A. Turos
VII International Conference Ion Implantation and Other Applications of Ions and Electrons, ION 2008 (Kazimierz Dolny, Poland, 2008-06-16 - 2008-06-19)
Vacuum (in press)

Chemical effects in Zr- and Co-implanted sapphire
Z. Werner, M. Pisarek, M. Barlak, R. Ratajczak, W. Starosta, J. Piekoszewski, W. Szymczyk, R. Grötzschel
VII International Conference Ion Implantation and Other Applications of Ions and Electrons, ION 2008 (Kazimierz Dolny, Poland, 2008-06-16 - 2008-06-19)
Vacuum (2008)

Modification of UHMWPE by ion, electron and γ-ray irradiation
A. Turos, A.M. Abdul-Kader, R. Ratajczak, A. Stonert
VII International Conference Ion Implantation and Other Applications of Ions and Electrons, ION 2008 (Kazimierz Dolny, Poland, 2008-06-16 - 2008-06-19)
Vacuum (in press)

Strain profiles and defect structure in 6H SiC crystals implanted with 2 MeV As ions
W. Wierzchowski, K. Wieteska, W. Graeff, A. Turos, R. Grötzschel, A. Stonert, R. Ratajczak
VII International Conference Ion Implantation and Other Applications of Ions and Electrons, ION 2008 (Kazimierz Dolny, Poland, 2008-06-16 - 2008-06-19)
Vacuum (2008)

Breakup and transfer coupling effects on near-barrier $^4$He+$^{208}$Pb elastic scattering
N. Keeley
First Workshop on State of the Art in Nuclear Cluster Physics, SOTANCP (Strasbourg, France, 2008-05-13 - 2008-05-16)

Calibration and application of modern track detectors CR-39/PM-355 in nuclear physics and high temperature plasma experiments
A. Malinowska, A. Szydłowski, M. Jaskoła, A. Korman, B. Sartowska
Recent Developments and Applications of Nuclear Technologies (Bułowieża, Poland, 2008-09-15 - 2008-09-17)
Warsaw No.40 (2008)

Improved stability of the Ir and IrO2 Schottky contacts on n-SiC with Ta-Si-N diffusion barrier and Au over layer
M. Guziewicz, N. Kwietniewski, A. Piotrowska, E. Kaminska, R. Diduszko, R. Ratajczak
Materials for Advanced Metallization - MAM 2008 (Dresden, Germany, 2008-03-02 - 2008-03-08)
Stopping power and energy straggling of channeled He-ions in GaN
A. Turos, R. Ratajczak, K. Pagowska, L. Nowicki, A. Stonert
23rd International Conference on Atomic Collisions in Solids - ICACS 2008 (Phalaborwa, South Africa, 2008-08-17 - 2008-08-22)

Poster

Compositional dependence of damage buildup in Ar-ion bombarded AlGaN
K. Pagowska, R. Ratajczak, A. Stonert, A. Turco
VII International Conference on Ion Implantation and Other Applications of Ions and Electrons, ION 2008 (Kazimierz Dolny, Poland, 2008-06-16 - 2008-06-19)
Vacuum (in press)

Proton beam induced luminescence of silicon dioxide implanted with excess silicon
G. Gawlik, J. Jagiełski, A. Stonert, R. Ratajczak
23rd International Conference on Atomic Collisions in Solids - ICACS 2008 (Phalaborwa, South Africa, 2008-08-17 - 2008-08-22)

Structural analysis of distributed bragg reflector mirrors
R. Ratajczak, J. Gaca, M. Wójcik, A. Stonert, K. Pagowska, J. Borysiuk, A. Turco
VII International Conference on Ion Implantation and Other Applications of Ions and Electrons, ION 2008 (Kazimierz Dolny, Poland, 2008-06-16 - 2008-06-19)
Vacuum (in press)

The influence of growth temperature on oxygen concentration in GaN buffer layer
E. Dumiszewska, W. Strupiński, P. Cahan, M. Wesołowski, D. Lenkiewicz, R. Jakiela, K. Pagowska, A. Turco, K. Zdunek
MRS Spring Meeting (San Francisco, USA, 2008-03-24 - 2008-03-28)

Investigations of protons passing through the PM-355 type of solid state nuclear track detectors
B. Sartowska, A. Szyladowski, M. Jaskóła, A. Korman
34th Conference on Nuclear Tracks in Solids (INTIS 2008) (Bologna, Italy, 2008-09-01 - 2008-09-05)
Bologna No. (2008)

Comparative study of n-SiC/Ti with n-SiC/Ni ohmic contacts useful in metallization of high power SiC devices
XXXII International Conference of IMAPS - CPMT IEEE (Pilutzk, Poland, 2008-09-21 - 2008-09-24)

Calibration of PM-355 nuclear track detectors; track diameter and track depth characterization
A. Szyladowski, B. Sartowska, M. Jaskóła, A. Korman, A. Malinowska
24th Conference on Nuclear Tracks in Solids (INTIS 2008) (Bologna, Italy, 2008-09-01 - 2008-09-05)
No. (2008)

Influence of nanocomposite diffusion barrier on the thermal stability of Au metallized Ni2Si/n-SiC ohmic contacts
A. Kuchuk, M. Guziewicz, R. Ratajczak, R.A. Minkayev, M. Worek, A. Stonert, V.P. Kladko, A. Piotrowska
XXXII International Conference of IMAPS - CPMT IEEE (Pilutzk, Poland, 2008-09-21 - 2008-09-24)

Response of cooled PWO scintillators to low-energy gamma-rays and its importance in studies of the b+->eta+gamma transition in charmomion
LEAP08 - Low Energy Antiproton Physics (Vienna, Austria, 2008-09-14 - 2008-09-19)

Long-term stability of Ni-silicide ohmic contact to n-type 4H-SiC
A. V. Kuchuk, M. Guziewicz, R. Ratajczak, V.P. Kladko, A. Piotrowska
Materials for Advanced Metallization - MAM 2008 (Dresden, Germany, 2008-03-02 - 2008-03-08)

Structural characterization of GaN epitaxial layers grown on 4H-SiC substrates with different off-cut
7th European Conference on Silicon Carbide and Related Materials - ECSCRM 2008 (Barcelona, Spain, 2008-09-07 - 2008-09-11)
Mat. Sci. Forum (in press)

On the question of ferromagnetism in proton and He-irradiated carbon
J. Szczytko, P. Juszyniński, L. Teliga, A. Stonert, R. Ratajczak, A. Korman, A. Twardowski
37th annual International School on the Physics of Semiconducting Compounds (Jaszowiec, Poland, 2008-06-07 - 2008-06-13)

Characterization of Ti-based Ohmic contacts compatible with Al wire bonding for high power SiC devices
M. Guziewicz, R. Kisiel, A. Kuchuk, A. Piotrowska, E. Kamińska, W. Paszkowicz, R. Ratajczak, A. Stonert
On the formation of Ni-based ohmic contacts to 4H n-SiC
A.V. Kuchuk, A. Piotrowska, V.P. Kladko, O.S. Lytvyn, R. Ratajczak, A. Turos, R. Jakiela, A. Barcz
7th European Conference on Silicon Carbide and Related Materials - ECSCRM 2008 (Barcelona, Spain, 2008-09-07 - 2008-09-11)

Radiation resistance of fluorite-structured nuclear oxides
F. Garrido, S. Moll, L. Nowicki, G. Sattonnay, L. Thomé, L. Vincent
20th Intern. Conference on the Application of Accelerators in Research and Industry - CARRY 2008 (Fort Worth, USA, 2008-08-10 - 2008-08-15)
AIP Conf. Proc. (in press)

Thermal stability of Au/Ni2Si/n-SiC ohmic contacts: influence of aging ambient
A.V. Kuchuk, M. Guziewicz, R. Ratajczak, R.A. Minikayev, M. Wzorek, V.P. Kladko, A. Piotrowska

LECTURES, COURSES AND EXTERNAL SEMINARS

Channeling study of thermal stability III-V semiconductor compounds\(^a\)
A. Stonert
Warsaw, Institute of Electronic Materials Technology, 2008-03-11

Electroproduction of vector mesons \(\rho^0\) and \(\phi\) at HERMES Collaboration\(^a\)
W. Augustyniak
Warsaw, Theoretical Department of Warsaw University, 2008-03-13

RBS/channeling&HRXRD - Complementary methods analysis of semiconductor superlattices\(^a\)
R. Ratajczak
Warsaw, Institute of Electronic Materials Technology, 2008-03-26

Analysis of semiconductor superlattices by RBS/channeling&HRXRD technique\(^a\)
R. Ratajczak
Warsaw, The Andrzej Soltan Institute for Nuclear Studies IPJ, 2008-04-29

Physics reveals secrets of Ancient Egyptian Mural Paintings\(^a\)
A. Turos
Warsaw, Institute of Electronic Materials Technology, 2008-10-30

Application of the FEMTOFIZYKA Consortium to the Polish Ministry of Research and Higher Education for funding of the common projects for collaboration with the FAIR complex in Darmstadt\(^a\)
B. Zwiegliński
Cracow, WFAiS of the Jagiellon University, 2008-11-29

Further rho colour transparency studies\(^b\)
A. Trzciński
Hamburg, DESY, 2008-03-05

\(\phi\) vector mesons and ... \(^a\)
W. Augustyniak
Hamburg, DESY - Deutsches Electron-Synchrotron, 2008-03-06

K\(^*\) vector mesons at HERMES\(^b\)
W. Augustyniak
Hamburg, Deutches Elecronen-Synchrotron ein Forschungszenterum der Helmholtz-Gemeinschaft, 2008-06-02

Status of rho colour transparency studies\(^b\)
A. Trzciński
Hamburg, DESY, 2008-06-02

Asymmetry in exclusive \(\omega\) production\(^b\)
B. Mariański
Hamburg, Desy, 2008-06-04

K\(^*\) (892) vector mesons at HERMES\(^b\)
W. Augustyniak
Hamburg, Deutches Elecronen-Synchrotron ein Forschungszenterum der Helmholtz-Gemeinschaft, 2008-09-24

Asymmetry in \(\omega\) production at HERMES\(^b\)
B. Mariański
Hamburg, Desy, 2008-09-24

Update colour transparency\(^b\)
A. Trzciński
Hamburg, DESY, 2008-09-24
K*(892), K*(892) and ρ*(770) vector mesons at HERMES

W. Augustyniak
Hamburg, Deutches Elektronen-Synchrotron ein Forschungszentrum der Helmholtz-Gemeinschaft, 2008-11-04

Transverse target spin asymmetry A_{T2} in ω production

B. Mariański
Hamburg, DESY, 2008-11-04

Status of colour transparency analysis

A. Trzciński
Hamburg, DESY, 2008-11-05

INTERNAL SEMINARS

Application of low energy accelerators in research and technology

M. Jaskóła
Kielce, Institute of Physics, Jan Kochanowski University, 2008-04-28

Studies of levels structure in 147,149Nd using the (d,p) and (d,t) reactions

M. Jaskóła
Mediolan, Institute of Physics, Milano University, 2008-05-27

DIDACTIC ACTIVITY

M. Jaskóła - Supervision of a PhD student (A. Bantsar)

B. Mariański - Lectures of mathematics and statistic in Agriculture University
Lectures of statistic and econometry in WSZ-SW

K. Rusek - Supervision of PhD student - I. Strojek,
Supervision of PhD student - L. Standylo

B. Zwinglinski - Supervision of PhD student (A. Mykulyak, D. Melnychuk)

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

M. Jaskóła
Member of the Polish Physical Society
Member of the Scientific Council of the Heavy Ion Laboratory, Warsaw University

E. Piasecki
Member of the Scientific Council of the Heavy Ion Laboratory, Warsaw University

K. Rusek
Deputy chairman of the Scientific Council of the Heavy Ion Laboratory of Warsaw University
The Andrzej Soltan Institute for Nuclear Studies, member

A. Turos
Member of the Materials Research Society

B. Zwinglinski
Coordination Board of the PANDA Detector activities, SINS representative

P. Zuprański
Member of the Scientific Council of the HERMES Collaboration at DESY
## PERSONNEL

### Research scientists
- Witold Augustyniak, Dr.
- Andrzej Bieńkowski, Dr. on leave
- Marian Jaskóła, Professor ¼* from July 1
- Nicholas Keeley, Dr. from Jan. 10
- Andrzej Korman, Dr. 3/5*
- Bohdan Mariański, Dr.
- Dmytro Melnychuk, MSc. ¼ from Oct. 15
- Hans Peter Morsch, Dr. on leave
- Andriy Mykulyak, MSc. 1/4* from July 10
- Lech Nowicki, Dr. 1/2*
- Ernest Piasecki, Assoc. Prof. 1/3*
- Krzysztof Rusek, Professor
- Anna Stonert, Dr.
- Andrzej Trzciński, Dr.
- Andrzej Turos, Professor 3/4*
- Bogusław Zwiegliński, Assoc. Prof.
- Paweł Żuprański, Assoc. Prof. 4/5*

### Volunteers
- Shaaban Abd El Aal, MSc
- Hamada Kotb, MSc from April 21

### PhD students
- Karolina Pagowska, MSc.
- Izabela Strojk, MSc.
- Łukasz Standyło, MSc.

### Technical and administrative staff
- Dorota Dobrowolska
- Ryszard Kacprzak 1/2* from May 1
- Grażyna Kęsik, Eng.
- Władysław Mieczarek 1/2*
- Wiesław Pietrzań 2/5*
- Renata Ratajczak, MSc.
- Zbigniew Szczepaniak

* part-time employee
2. DEPARTMENT OF INTERDISCIPLINARY APPLICATIONS OF PHYSICS

Head of Department: Dr. Jan Sernicki  
phone: (22) 718-04-63  
e-mail: Sernicki@ipj.gov.pl

Overview

The activities of the Department in 2008 were focused on the following areas of application of physics:

- Medical physics:
  - modernization of X-ray generators for applications in medicine and industry;
  - research on new methods of production of pure medical radioisotopes using our 25 MeV proton cyclotron;
- Environmental physics:
  - measurements of the PM10 and PM2.5 dust concentrations in the air in Świerk and its environs;
  - work on air pollution prediction methods using neural networks and wavelet analysis; tests of an advanced version of a pollution predictor;
  - monitoring of the radionuclide concentration in soil and air;
  - Nanodosimetry, radiation field modeling, radiation detectors:
    - study of the ionization clusters produced by low energy electrons (100-2000 eV) within structures of nanometer sizes using the “Jet Counter” facility;
    - mathematical modeling of nuclear radiation sources and calculations of the radiation field parameters: installation and tests of the MCNP transport code (version 5) for various applications;
    - study of some spectrometric properties of Parallel Plate Avalanche Counters.

Basic research was realized in the fields of:

- Elementary particle physics:
  - participation in measurements done with the ANKE spectrometer at COSY-Jülich;
  - participation in the ICARUS and T2K programs to study neutrino physics;
  - participation in experiments at PSI Villigen devoted to new precise measurements of the decay properties of the pion;
- Nuclear physics:
  - theoretical description of nuclear fusion reactions and subsequent compound-nucleus deexcitation cascades leading to synthesis of super-heavy nuclei;
  - studies of the mechanism of nucleus-nucleus collisions at low and intermediate energies at LNS Catania (fast ternary and quaternary breakup of very heavy nuclear systems; neck fragmentation processes at intermediate energies);
  - nuclear spectroscopy (properties of high-spin states, chiral bands, octupole deformations);
  - computational support of experimental and theoretical studies conducted at JINR in Dubna (implementation of Cascade Evaporation and Quantum Molecular Dynamics models for simulations of electro-nuclear processes; modeling photo-nuclear reactions; simulations of energy deposition and neutron spectra from a sub-critical assembly irradiated with proton beams);
- High energy atomic physics:
  - X-ray spectroscopy for investigation of ion stopping processes (a study of silicon K-shell spectra induced by calcium ions penetrating low density SiO2 aerogel).

We collaborate among others with the Jagiellonian University, AGH University of Science and Technology in Cracow, Nicolaus Copernicus University in Toruń, Oncology Institute in Warsaw, Radioisotope Centre POLATOM, local authorities in Otwock, Central Laboratory for Radiological Protection in Warsaw, Institute of Nuclear Chemistry and Technology, Institute of Geophysics of Polish Academy of Sciences, Institute of Physics Warsaw Univ., Foundation ARMAAG in Gdańsk, Voivodship Inspectorates for Environmental Protection in Gdańsk and Warsaw, FZ-Jülich, INFN, PSI Villigen, University of Fribourg (Switzerland), Interdisciplinary Centre for Mathematical and Computational Modeling of Warsaw Univ., LNS Catania, Univ. of Virginia, PTB Braunschweig, LNL Legnaro, LBNL Berkeley, JINR Dubna, Heavy Ion Laboratory of Warsaw Univ., CERN, GSI-Darmstadt, and also other departments of our Institute.

Jan Sernicki
REPORTS

PANDA - Strong interaction studies with antiprotons
S. Borsuk, ... , A. Chłopiński, Z. Guzik, T. Kozłowski, D. Melnychuk, M. Plomiński, J. Szewiński, K. Traczyk, B. Zwięgłański, ... et al.
GSI, Darmstadt

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Search for superheavies - 50 years history
J. Blocki
SHE research - prospects for the next decade (Cracow, Poland, 2008-12-18 - 2008-12-20)

Remarks on muon radiography
M. Szepytka, P. Szymański
Safe Nuclear Energy (Jalta, Ukraine, 2008-09-27 - 2008-10-02)

Knowledge management - customer related activity
P. Szymański
International Atomic Energy Agency Regional Workshop on Knowledge Management for Nuclear R&D Organizations (Karlsruhe, Germany, 2008-05-05 - 2008-05-09)

Remarks on the Nuclear Higher Education in Poland
P. Szymański
International Atomic Energy Agency Technical Meeting on the Status of Education and Human Resources Development in the Nuclear Field (Pavia, Italy, 2008-06-17 - 2008-06-20)

Comments on a frequent error in calculations of the $\Gamma_n/\Gamma_f$ ratio
K. Siwek-Wilczyńska, J. Wilczyński
15th Nuclear Physics Workshop "Matie and Pierre Curie" 70 Years of Nuclear Fission (Kazimierz Dolny, Poland, 2008-09-24 – 2008-09-28)

"Koncentracja radionuklidów kosmopochodnych i antropogenicznych w przyziemnej warstwie powietrza w rejonie polarnym
i w średnich szerokościach geograficznych"
B. Myslek-Laurikainen, M. Kubicki, M. Matul, S. Mikołajewski, H. Trzaskowska
XXXII Międzynarodowe Sympozjum Polarne (Wrocław, Poland, 2008-05-23 - 2008-05-24)

Oral Presentation

Excited hyperons produced in pp collisions with ANKE at COSY
I. Zychor
STORI'08 (Lanzhou, China, 2008-09-13 - 2008-09-19)
Int. J. Mod. Phys. E (in press)

New descriptors of radiation quality based on nanodosimetry
S. Pszona
COST Action BM0607, Targeted Radionuclide Therapy (TRNT) (Cracow, Poland, 2008-06-24 - 2008-06-25)

Nanodosimetry of low energy electrons
S. Pszona

Selected properties of nuclei at the magic shell closures from studies of E1, M1 and E2 transition rates
13th Intern. Symposium on Capture Gamma-Ray Spectroscopy and Related Topics (Cologne, Germany, 2008-08-25 – 2008-08-29)

Structure of heavy Fe nuclei at the point of transition at N~37
Zakopane Conference on Nuclear Physics (Zakopane, Poland, 2008-09-01 - 2008-09-07)

Ensemble of neural predictors for forecasting the atmospheric pollution
K. Siwek, S. Oksowsk, K. Garanty, M. Sowiński
WCCI 2008, 2008 IEEE World Congress on Computational Intelligence (Hong Kong Convention and Exhibition Centre, Hong Kong, 2008-06-01 - 2008-06-06)
Electronics X-ray sources for brachytherapy
M. Słapa, M. Traczyk, M. Talejko, K. Wincel, B. Zaręba
Recent Developments and Applications of Nuclear Technologies (Białowieża, Poland, 2008-09-15 - 2008-09-17)

Predyktor pyłu zawieszonego jako narzędzie zarządzania ochroną powietrza (Suspended dust predictor as a tool of air protection management)
M. Sowiński, M. Traczyk, M. Talejko, K. Wincel, B. Zaręba
VI Międzynarodowa Konferencja Naukowa "Ochrona powietrza w teorii i praktyce" (Zakopane, Poland, 2008-10-16 - 2008-10-18)

Neutralization of the ion track core in SiO₂
O.N. Rosmej, J. Rzadkiewicz, A. Gójska, A.E. Volkov
Seventh International Symposium Swift Heavy Ions in Matter (Lyon, France, 2008-06-02 - 2008-06-05)

Poster

57Cs distribution in soil and plants in the Opole vicinity, 20 years after Chernobyl power plant accident
S. Wołkowicz, M. Matul, B. Myslek-Laurikainen
International Conference on Recent Developments and Applications of Nuclear Technologies Białowieża (Białowieża, Poland, 2008-09-15 - 2008-09-17)

Calculations of the formation cross sections for synthesis of Z=114-118 nuclei in 48Ca induced reactions
K. Siwek-Wilczynska, A. Borowiec, J. Wilczynski
15th Nuclear Physics Workshop "Marie and Pierre Curie" 70 Years of Nuclear Fission (Kazimierz Dolny, Poland, 2008-09-24 - 2008-09-28)

Dozymetria igły fotonowej – Implementacja protokołu TG-43
M. Traczyk, S. Pszona, M. Słapa, M. Talejko
Metrologia Wspomagana Komputerowo (Waplewo, Poland, 2008-05-27 - 2008-05-30)

Nanodozymetria
S. Pszona, A. Bantsar, J. Kula
Metrologia Wspomagana Komputerowo (Waplewo, Poland, 2008-05-27 - 2008-05-30)

Vacancy distribution of the X-ray satellite spectra of SiO₂ aerogel bombarded with calcium ions
A. Gójska, J. Rzadkiewicz, O. Rosmej, M. Polasik, K. Slabkowska
14th International Conference on the Physics of Highly Charged Ions (Tokio, Japan, 2008-09-01 - 2008-09-05)

Neutralization of the ion track core in SiO₂
XXX ECLIM 30th European Conference on Laser Interaction with Matter – Information (Darmstadt, Germany, 2008-08-31 – 2008-09-05)

Baza danych pomiarowych predyktora zanieczyszczeń powietrza (Predictive database of air dust pollution)
A. Jakowiak, P. Urbański, E. Świstowski, B. Machaj, H. Reinholz, G. Röpke, S. Hagman
XXX ECLIM 30th European Conference on Laser Interaction with Matter – Information (Darmstadt, Germany, 2008-08-31 – 2008-09-05)

Response of cooled PWO scintillators to low-energy gamma-rays and its importance in studies of the h,c>eta, + gamma transition in charmonium
LEAP08 - Low Energy Antiproton Physics (Vienna, Austria, 2008-09-14 - 2008-09-19)

Mass and energy correlations in fast ternary break-up of 197Au + 197Au system
I. Skwira-Chalot, K. Skwi-Wilczyńska, J. Wilczyński
15th Nuclear Physics Workshop "Marie and Pierre Curie" 70 Years of Nuclear Fission (Kazimierz Dolny, Poland, 2008-09-24 - 2008-09-28)

LECTURES, COURSES AND EXTERNAL SEMINARS

The Baryon number transfer in hadron-hadron, hadron-nucleus, nucleus-nucleus collisions
P. Szymański
Warsaw, Warsaw University, 2008-02-22

The influence of neutrino flavor nonconservation on the observables and the GSI experiment
T. Koslowski
Warsaw, University of Warsaw and IPJ, 2008-03-07
Big Bang neutrinos - do they exist and is it possible to discover them?
T. Kozłowski
Warsaw, Warsaw University, 2008-04-09

Ionizing radiation detectors based on diamond layers (works 01-05.2008)
M. Ślapa
Warsaw, Warsaw University of Technology, 2008-05-08

Strange oscillations in nuclear decays
T. Kozłowski
Warsaw, University of Warsaw - IPJ, 2008-10-17

Electronics X-ray sources for brachytherapy
M. Ślapa
Świerk, Institute for Nuclear Studies, 2008-10-17

Report on realization of research and development project "Intelligent system of measurement of air pollutant concentrations as instrument of aiding of atmospheric air protection management", No R 14 007 02, in 2008. Task 7. Air Quality Index (AQI)
M. T. Kowalski
Warsaw, The Institute of Nuclear Chemistry and Technology, 2008-12-12

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

A. Gójska
Polish Physical Society

R. Kaczarowski
Member of the American Physical Society

T. Kozłowski
Member of Scientific Council

A. Polański
Member of the Scientific-Technical Council of Laboratory of Information Technologies, JINR, Dubna, Russia.

P. Szymański
Session chairman on SAFE NUCLEAR ENERGY
PERSONNEL

Research scientists
Jan Błocki, Professor
Rościsław Kaczarowski, Assoc. Prof.
Tadeusz Kozłowski, Dr.
Jacek Kula, MSc.
Aleksander Polański, Dr.  on leave
Stanisław Pszona, Dr.
Ewa Ruchowska, Dr.
Jacek Rzadkiewicz, Dr.  on leave
Jan Sernicki, Dr.
Leonid Shvedov, MSc.  on leave
Mieczysław Słapa, Assoc. Prof.  4/5*
Mieczysław Sowiński, Assoc. Prof.  3/5*
Piotr Szymański, Assoc. Prof.
Marek Traczyk, MSc.
Janusz Wilczyński, Prof.
Krzysztof Winkel, MSc.
Jolanta Wojtkowska, Dr.  3/4*
Barbara Zaręba, MSc.
Izabella Zychor, Dr.

Technical and administrative staff
Aliaksandr Bantsar, MSc.
Adam Dudziński, Tech.
Stanisław Gębański, MSc.  1/2
Aneta Gójska, MSc.
Elżbieta Jaworska, Tech.
Marek Kowalski, MSc.
Alicja Kurdej  2/5*
Marek Lasiewicz, MSc.
Marian Laskus, Tech.
Maria Matul, MSc.  1/2*
Stefan Mikołajewski, Tech.  4/5*
Tomasz Pławska, Eng.  on leave
Mirosław Snopek, Tech.
Marcin Talejko
Halina Trzaskowska, Tech.

* part-time employee
3. DEPARTMENT OF DETECTORS AND NUCLEAR ELECTRONICS

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

Overview

The basic activities of the Department of Nuclear Electronics in 2008 were concentrated in the following areas:

- studies of new scintillation techniques and their application to nuclear medicine and border monitoring,
- contribution to the FWVI European projects,
- scientific contracts with European industry in respect to detection techniques
- electronics for experiments in High Energy Physics,
- development of \(\gamma\)-ray spectrometry apparatus,
- development of new generation State of the Art USB based multi-channel analyzers supplied with Ethernet port and wireless connection,
- development, investigation and production of silicon detectors
- properties of European standards in the field of electronics.

Most of the scientific achievements of the Department were summarized in 33 reviewed publications and 6 non-reviewed publications. The papers were published mainly in IEEE Trans. Nucl. Sci. and Nucl. Instr. Methods. Besides that, our scientists presented 29 contributions at international conferences - 9 presentations at the IEEE Nuclear Science Symposium and Medical Imaging 2008 in Dresden, Germany. In addition, normalization activities in the preparation of Polish versions of European Standards in the field of electronics were supported.

The study of new scintillation techniques covered measurements of non-proportionality of organic with scintillators in a comparison BGO, a study of the light pulse decays of CsI(Tl) at low energies and its relation to non-proportionality and the summarizing of earlier measurements showing an influence of slow components of the light pulses on the intrinsic resolution of scintillators. Within the work performed for the BioCare European project, realized within FWVI, wide studies analyzing the influence of different parameters of fast photomultipliers and scintillators on the time resolution of PET detectors for TOF PET were carried out. This study was also supported by a contract with Photonis, France. A further study of the common PET/CT detector based on APD array was carried out.

In studies addressed to homeland security, different measurements carried out with the new LaBr\(_3\) crystals using different photomultipliers and avalanche photodiodes were summarized. Moreover, the BC523A, Boron-10 loaded liquid scintillator was studied for a simultaneous detection of fast and thermal neutrons.

The EURITRACK project was practically completed by a series of blind tests with real containers at Rijeka, the seaport in Croatia. The project was a winner of the “1st Prize of Technological Innovation of the French Trophy of Civil Defense 2007” awarded by the senate of France.

The Department was involved in scientific collaborations with a number of international centers, such as CERN, Royal Institute of Technology and Karolinska Institute in Stockholm, FZR Rossendorf, IKF Juelich, GSI Darmstadt, INFN Padova, CEA Saclay and Cadarache, IRB Zagreb, and companies such as Saint-Gobain, Scionix in Holland, Photonis in France, ICX (former Target) in Germany, Siemens (former CTI) in the USA and Hitachi Chemical, Japan. Additionally, collaboration with IAEA in Vienna concerning monitoring of State borders was continued. Several scientific contracts were realized for European industry.

Collaboration with the High Energy Physics Department of our Institute was focused on the LHCb experiment in CERN, GSI (Darmstadt) - Panda and DESY (Hamburg) - XFEL. In 2008, the modules designed and produced for the LHCb experiment in CERN were tested with real beam in the LHCb pit at Meyrin. In addition, the special module for monitoring the LHC beam phase and intensity was put into operation. We also continued the collaboration with PANDA detector in GSI. Our work focuses on the DCS system for the experiment.

Our work on development of new generation State of the Art USB based multi-channel analyzers is very promising. More than 65 copies of our USB based device have been sold all around the world. A new project concerning new features of the device (Ethernet and wireless ports) is being designed and debugged.

In the field of semiconductor detectors, besides continuation of previous work, our activities concentrated on developing a new method concerning n-p junctions and ohmic contacts with the use of sputtering (with the help of the TITAN implanter) for production of new-type semiconductor radiation detectors.

Zbigniew Guzik
REPORTS

PANDA - Strong interaction studies with antiprotons
GSI, Darmstadt

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Novel scintillator materials for gamma-spectrometry and nuclear medicine
M. Moszyński
Compton Camera for Medical Imaging (Vancouver, Canada, 2008-04-08 - 2008-04-08)

Development of new detectors for the border monitoring based on new scintillators and photodetectors
M. Moszyński

Oral Presentation

New method for measuring of the polarization of gamma-rays from GRB with a uniform array of light scintillators
Workshop on Advanced Gamma-Ray Detectors (Garching, Germany, 2008-06-02 - 2008-06-05)

Detectors for Compton camera - Current systems and new options
Ł. Świderski
Compton Camera for Medical Imaging (Vancouver, Canada, 2008-04-08 - 2008-04-08)

The POLAR experiment
Polarimetry days in Rome: Crab status, theory and prospects (Rome, Italy, 2008-10-16 - 2008-10-17)
Proceedings of Science (2009)

Light yield non-proportionality and energy resolution of praseodymium doped LuAG scintillator
Ł. Świderski, M. Moszyński, A. Nassalski, A. Syntfeld-Każuch, T. Szczeńiak, K. Kamada, K. Tsutsumi, Y. Usuki, T. Yanagida, A. Yoshikawa
SORMA West, Symposium on Radiation Measurements and Application (Berkeley, USA, 2008-06-02 - 2008-06-06)

Demonstration of a dual-range photon detector with SDD and LaBr3(Ce3+) scintillator
G. Pausch, C. Plettner, C.M. Herbach, J. Stein, M. Moszyński, A. Nassalski, Ł. Świderski, T. Szczeńiak, A. Niculae, H. Soltau
SORMA West, Symposium on Radiation Measurements and Application (Berkeley, USA, 2008-06-02 - 2008-06-06)

Scintillation properties of praseodymium doped LuAG scintillator compared to cerium doped LuAG, LSO and LaBr3

A comparative study of silicon drift detectors with photomultipliers, Avalanche photodiodes and PIN photodiodes in gamma spectrometry with LaBr3 crystals
M. Moszyński, C. Plettner, A. Nassalski, T. Szczeńiak, Ł. Świderski, A. Syntfeld-Każuch, W. Czarnacki
G. Pausch, J. Stein, A. Niculae, H. Soltau
SORMA West, Symposium on Radiation Measurements and Application (Berkeley, USA, 2008-06-02 - 2008-06-06)

Energy resolution of calcium co-doped LSO:Ce scintillators
A. Syntfeld-Każuch, M. Moszyński, Ł. Świderski, T. Szczeńiak, A. Nassalski, C.L. Melcher, M.A. Spurrier

Silicon photomultiplier as an alternative for APD in PET – MRI applications
A. Nassalski, M. Moszyński, A. Syntfeld-Każuch, T. Szczeńiak, Ł. Świderski, D. Wolski, T. Batsch
Search for an alpha-decaying isomer in $^{229}$Ac
ENAM 08 The Fifth International Conference on Exotic Nuclei and Atomic Masses (Ryn, Poland, 2008-09-07 - 2008-09-13)

A comparative study of fast photomultipliers for timing experiments and TOF PET
T. Szczeniak, M. Moszyński, Ł. Świderski, A. Nassalski, A. Syntfeld-Każuch, A.G. Dehaine, M. Kapusta
SORMA West, Symposium on Radiation Measurements and Application (Berkeley, USA, 2008-06-02 - 2008-06-06)

Prospects of a dual range detector with SDD and LaBr3(Ce) scintillator

POLAR: a novel gamma-ray burst polarimeter

POLAR: design of a novel X-ray polarimeter based on plastic scintillators and multi-anode photomultipliers
21st European Cosmic Ray Symposium (Kosice, Slovakia, 2008-09-09 - 2008-09-12)

Scintillating block detector coupled to a position sensitive PMT - Preliminary results on positioning and energy resolution optimization
T. Szczeniak, L. Świderski, M. Moszyński
Compton Camera for Medical Imaging (Vancouver, Canada, 2008-04-08 - 2008-04-08)

POLAR: Design of a novel X-ray polarimeter based on plastic scintillators and mapmt

Poster

Universal DOOCS server based on the script language
J. Szwewiński, K. Korzanowicz
11th European Particle Accelerator Conference (EPAC-2008) (Genoa, Italy, 2008-06-23 - 2008-06-27)

Measurement and stabilization of the bunch arrival time at FLASH
11th European Particle Accelerator Conference (EPAC-2008) (Genoa, Italy, 2008-06-23 - 2008-06-27)

An 8K pulse height analyzer and multi-channel scaler with the USB, Ethernet and wireless interfaces featuring internal backup file system
Z. Guzik, S. Borsuk, R. Marcinkowski, M. Płomiński, J. Szwewiński, K. Traczyk

A comparative study of undoped NaI scintillators with different purity
M. Moszyński, W. Czarnecki, A. Syntfeld-Każuch, A. Nassalski, T. Szczeniak, Ł. Świderski, F. Kniest, A. Ilits

Response of cooled PWO scintillators to low-energy gamma-rays and its importance in studies of the $h_c$->eta, +gamma transition in charmonium
LEAP08 - Low Energy Antiproton Physics (Vienna, Austria, 2008-09-14 - 2008-09-19)

A continuous crystal detector for TOF PET
T. Szczeniak, M. Moszyński, Ł. Świderski, A. Nassalski, A. Syntfeld-Każuch, P. Ojala, C. Bohn

Further study of boron-10 loaded liquid scintillators for detection of fast and thermal neutrons
LECTURES, COURSES AND EXTERNAL SEMINARS

**BioCare:- Common PET/CT detector - Optimization of time-of-flight PET detectors**\(^b\)
M. Moszyński
Stockholm, Karolinska Institute, 2008-09-25

**A super-TFC for a super-LHC**\(^b\)
Z. Guzik
Geneve, Switzerland, CERN, 2008-11-28

\(^b\) in English

INTERNAL SEMINARS

**PANDA DCS system**\(^b\)
A. Chlopik
Groningen, Holland, KVI, 2008-02-01

**EMC forward endcap prototype meeting**\(^b\)
A. Chlopik
Bochum, Germany, Ruhr-University Bochum, 2008-05-14

\(^b\) in English

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

**Z. Guzik**
Member of Polish CAMAC Committee
Member of Polish Committee for Standardization

**M. Moszyński**
Session chairman on SORMA West, Symposium on Radiation Measurements and Application in
Session chairman on IEEE Nuclear Science Symposium & Medical Imaging Conference in
Member of Advisory Board on IEEE Nuclear Science Symposium & Medical Imaging Conference in
Fellow of IEEE Nuclear and Plasma Science Society
Member of TransNational Committee of IEEE Nuclear and Plasma Science Society
member
Elsevier
Institute of Physics Publishing
Bentham Science Publishers
Bentham Science Publishers

**A. Syntfeld-Kazuch**
Member of IEEE Nuclear and Plasma Sciences Society

**K. Traczyk**
Member, the A. Soltan Institute for Nuclear Studies

**Ł. Świderski**
Member of IEEE Nuclear and Plasma Sciences Society
PERSONNEL

Research scientists
Stanisław Borsuk, Msc. Eng.
Arkadiusz Chłopik, MSc. Eng.
Wiesław Czarnacki, Dr.
Zbigniew Guzik, Assoc. Prof.
Maciej Kapusta, Dr. on leave
Maciej Kisieliński, MSc. Eng.
Łukasz Świderski, Dr.
Marek Moszyński, Professor
Antoni Nassalski, MSc. Eng. on leave from Nov.3
Michał Plomiński, MSc. Eng.
Agnieszka Syntfeld-Kaźuch, MSc.
Krystyna Traczyk, MSc.
Dariusz Wolski, Msc. Eng.

Technical and administrative staff
Eugeniusz Belcarz, MSc. Eng. 3/5*
Andrzej Dziedzic, Tech.
Urszula Firląg, Tech. 1/2*
Krzysztof Kostrzewa, Tech. 1/2*
Andrzej Kotlarski, MSc. Eng.
Krzysztof Leśniewski, Tech.
Tadeusz Sworobowicz, Tech.
Tomasz Szczęśniak, MSc.
Jarosław Szewiński, MSc. Eng.
Iwona Żawrocka, MSc.

* part-time employee
5. DEPARTMENT OF PLASMA PHYSICS AND TECHNOLOGY

Head of Department: Dr. Marek Rabiński  
phone: (22) 718-05-36  
e-mail: rabiński@ipj.gov.pl

Overview

In 2008, the activities of the Department continued previous studies in the following fields of plasma physics, controlled nuclear fusion and plasma engineering:

- Development of selected methods for high-temperature plasma diagnostics;
- Studies of physical phenomena in pulsed discharges at the Plasma-Focus (PF) and RPI-IBIS facilities;
- Research on plasma technologies;
- Selected problems of plasma theory and computational modeling.

Within the framework of the EURATOM program, efforts were devoted to the development of diagnostics methods for tokamak-type facilities. Such studies include elaboration of a special detection system based on a Cherenkov-type detector. The first measurements of fast electrons within the TORE-SUPRA tokamak at CEA-Cadarache were performed in November 2008. The most important result was the statement that the recorded signals confirm the appearance of a thin fast-electron sheath outside the plasma torus. This electron sheath appeared to be almost quasi-stationary in space during the movement of the Cherenkov detector head into the tokamak scrape-off layer region. In the meantime, the IPJ team was involved in the analysis of run-away electrons at the ISTTOK facility. Other fusion-oriented efforts are connected with the application of solid-state nuclear track detectors to the investigation of protons from tokamak plasma and high-energy beams emitted from ultra-intense laser produced plasmas. In addition, new materials for neutron activation measurements were tested within the JET tokamak at Culham.

As regards the experimental studies, particular attention was paid to the application of nuclear track detectors to measurements of fusion protons emitted from Plasma-Focus facilities. Ion streams from pulsed plasma discharges of the RPI-type were studied by means of corpuscular diagnostic techniques, and particularly of a miniature Thompson-type mass-spectrometer. The interaction of plasma-ion streams with different targets was also investigated.

A field of research activity was related to plasma technology. Efforts were undertaken to improve the ultra-high vacuum (UHV) deposition of thin superconducting layers, e.g. pure niobium film on the surface of copper resonant cavities of accelerators. The vacuum arc deposition technique was also applied to the preparation of superconducting photo-cathodes for electron linacs. In the field of surface engineering, applications of pulsed plasma stream interaction with solid materials were studied. Synchrotron radiation structural studies of vacuum arc deposited metallic films have been launched.

Various physical phenomena were analyzed theoretically, e.g. the influence of filamentation processes within the pinch column on the emission of fast deuterons and protons. Computational studies of plasma dynamics in the coaxial Impulse Plasma Deposition (IPD) accelerator also were continued.

Marek Rabiński
PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

**Plasma-Focus neutron source**
M. Scholz, P. Kubes, M.J. Sadowski
Prague No. (2008)

Current filaments in PF experiments and their influence on motion of fast deuterons and protons
M.J. Sadowski, A. Malinowska, K. Malinowski, M. Scholz, W. Stępniewski
ICDMP-2008 Workshop and Expert Meeting (Warsaw, Poland, 2008-12-01 - 2008-12-02)

Recent attainments of research on plasma and technology at IPJ, Poland
M.J. Sadowski

Oral Presentation

Projekt nadfioletowego lasera na swobodnych elektronach POLFEL w IPJ w Święrku
R. Nietużyłą
IV Kongres PTP i VIII Krajowa Konferencja Techniki Próżni (Janów Lubelski, Poland, 2008-09-21 - 2008-09-24)
Janów Lubelski No.0-38 (2008)

Megajoule plasma-focus facility as generator of intense plasma-ion streams and fast neutron pulses
M.J. Sadowski, M. Scholz, P. Kubes
Germany No. (2008) p. 317

X-ray diffraction studies of the structure of superconducting film deposited by ultra-high vacuum cathodic arc technique
R. Nietużyłą, J. Witkowski, R. Mirowski, A. Trembicki, M. Kuk

Neutron production and fast deuteron characteristics at the Plasma Focus discharge
International Conference Dense Z-pinch. (Aleksandria, USA, 2008-08-17 - 2008-08-21)
Aleksandria No. (2008)

Calibration and application of modern track detectors CR-39/PM-355 in nuclear physics and high temperature plasma experiments
A. Malinowska, A. Szydłowski, M. Jaskóla, A. Korman, B. Sartowska
Recent Developments and Applications of Nuclear Technologies (Białowieża, Poland, 2008-09-15 - 2008-09-17)
Warsaw No.40 (2008)

Megajoule Plasma-Focus facility as a generator of intense fast neutron pulses
M. Scholz, L. Karpiński, P. Kubes, M.J. Sadowski
International Conference Dense Z-pinch. (Aleksandria, USA, 2008-08-17 - 2008-08-21)
Aleksandria No. (2008)

Study of deuterium plasma interaction with a tungsten target within RPI-IBIS facility
E. Składnik-Sadowska, K. Malinowski, M.J. Sadowski, K. Czaus, M. Kubkowska, M. Ladygina, B. Sartowska
Alushta No.6-1 (2008) p. 113

Computational studies of the IPD discharge with internal cathode
M. Rabinski, K. Zdunek
Prague No. (2008) p. 18

Comparative MHD analysis of IPD plasma accelerator work with different electrode polarization
M. Rabinski, K. Zdunek
Alushta No. (2008)
Detection of runaway electrons using Cherenkov-type detectors in the ISTTOK Tokamak
No. (2008)

Nanostructured alloy layers with magnetic properties obtained by the impulse Plasma Desposition
K. Nowakowska-Langier, K. Zdunek
18th International Conference on Plasma Surface Engineering (Garmisch-Partenkirchen, Germany, 2008-09-15 - 2008-09-19)

Electric characterization and selective etching of aluminium oxide
P. Firc, J. Szmidi, K. Nowakowska-Langier, K. Zdunek
18th International Conference on Plasma Surface Engineering (Garmisch-Partenkirchen, Germany, 2008-09-15 - 2008-09-19)
No. (2008)

Calibration of PM-355 nuclear track detectors; track diameter and track depth characterization
A. Szylowski, B. Sartowska, M. Jaskóla, A. Korman, A. Malinowska
24th Conference on Nuclear Tracks in Solids (INTIS 2008) (Bologna, Italy, 2008-09-01 - 2008-09-05)
No. (2008)

Determination of mass- and energy-spectra of ions on the basis of Thomson parabolas recorded in plasma experiments
K. Czaus, M. J. Sadowski, E. Składnik-Sadowska, K. Malinowski, J. Żebrowski

Superconducting niobium layers reached by using vacuum arc technique in INFN-Roma Tor Vergata
IV Kongres Polskiego Towarzystwa Próźniowego oraz VIII Krajowa Konferencja Techniki Próźni (Janów Lubelski, Poland, 2008-09-21 - 2008-09-24)
Janów No. P-23 (2008)

Observations of extreme ultraviolet emission from plasma produced by capillary discharges
K. Nowakowska-Langier, L. Jakubowski, E. O. Baronova, K. Czaus, M. Rabiński
Prague No. (2008)

Behavior of tungsten targets bombared by pulsed plasma-ion streams or laser beams
E. Składnik-Sadowska, K. Malinowski, M. J. Sadowski, J. Wołowski, P. Gasior, M. Kubkowska, M. Rosinski, A. Marchenko, B. Sartowska
18th International Conference on Plasma Surface Interactions (PSI2008) (Toledo, Spain, 2008-05-26 - 2008-05-30)
Toledo No. (2008)

Application of PM-355 track detectors for investigation of the spatial structure of plasma-proton streams
K. Malinowski, E. Składnik-Sadowska, M. J. Sadowski, K. Czaus
24th Conference on Nuclear Tracks in Solids (INTIS 2008) (Bologna, Italy, 2008-09-01 - 2008-09-05)
Bologna No. (2008)

Influence of current filamentation on angular distribution of fusion-produced protons in PF-type experiments
W. Stepniewski, M. J. Sadowski, M. Scholz, K. Malinowski
Prague No. (2008)

The influence of distribution of titanium alloyed into carbon ceramics by the intense plasma pulses on their surface wettability with liquid copper
7th International Conference Ion Implantation and Other Applications of Ions and Electrons, ION 2008 (Kazimierz Dolny, Poland, 2008-06-16 - 2008-06-19)

Measurements of fast deuterons from plasma accelerator by means of PM-355 track detectors
E. Składnik-Sadowska, K. Malinowski, M. J. Sadowski, K. Czaus
24th Conference on Nuclear Tracks in Solids (INTIS 2008) (Bologna, Italy, 2008-09-01 - 2008-09-05)
Bologna No. (2008)

Characterisation of laser-produced tungsten plasma using optical spectroscopy method
M. Kubkowska, P. Gasior, M. Rosiński, J. Wołowski, M. J. Sadowski, K. Malinowski, E. Składnik-Sadowska
Prague No. (2008)

Application of SSSNTD of the CR-39/PM-355 for measurements of energetic protons emitted from plasma produced by an ultra-intense laser
A. Szylowski, J. Badziak, J. Fuchs, M. Kubkowska, M. Rosińska, R. Suchańska, J. Wołowski, P. Antici, A. Manica
24th Conference on Nuclear Tracks in Solids (INTIS 2008) (Bologna, Italy, 2008-09-01 - 2008-09-05)
Bologna No. (2008)
Application of SSNTD for measurements of fusion products in high-temperature plasma experiments
A. Malinowska, A. Szydlowski, K. Czaus, M.J. Sadowski, M. Scholz, J. Żebrowski
24th Conference on Nuclear Tracks in Solids (INTIS 2008) (Bologna, Italy, 2008-09-01 - 2008-09-05)
Bologna No. (2008)

Study of plasma produced from titanium irradiated by intense laser pulses
Prague No. (2008)

Investigations of protons passing through the PM-355 type of solid state nuclear track detectors
B. Sartowska, A. Szydlowski, M. Jaskóła, A. Korman
24th Conference on Nuclear Tracks in Solids (INTIS 2008) (Bologna, Italy, 2008-09-01 - 2008-09-05)
Bologna No. (2008)

Cienkie warstwy nadprzewodzące osadzane z pomocą luku w ultra-wysokiej próżni
R. Nietubyc, M.J. Sadowski, R. Mirowski, J. Witkowski, J. Łorkiewicz
IV Kongres Polskiego Towarzystwa Próżniowego oraz VIII KrajoWA Konferencja Techniki Próżni (Janów Lubelski, Poland, 2008-09-21 - 2008-09-24)
Janów Lubelski No. (2008)

Studies of plasma produced from titanium irradiated by intense laser pulses
Prague No. (2008)

Use of Cherenkov-type detectors for measurements of runaway electrons in the ISTTOK tokamak
22 IAEA Fusion Energy Conference (Geneva, Switzerland, 2008-10-13 - 2008-10-18)
Geneva No.P.EX/P4-11 (2008)

Overview of recent ISTTOK results
Geneva No.P.EX/P4-11 (2008)

Computational studies of plasma dynamics and electrode erosion interdependence in the IPD coaxial accelerator
M. Rabiński, K. Żdunek
Engineering of Biomaterials (2008)

LECTURES, COURSES AND EXTERNAL SEMINARS

Nuclear power plant - chance or threat?\(^2\)
M. Rabiński
Kwidzyn, Eco-Initiative Association, 2008-12-19

\(^2\) in Polish
DIDACTIC ACTIVITY

M.J. Sadowski - Ph.D. thesis of Aneta Malinowska

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

R. Nietuby
Polish Synchrotron Radiation Society

M. Rabinski
Member of the Board of the Polish Nuclear Society, Head of the Information Committee
Member of the European Nuclear Society
Member of the Board of the Environmentalists for Nuclear Energy - Poland (treasurer)
Member of the Editorial Board of the Advances of Nuclear Technique, National Atomic Energy Agency
Member of the Editorial Board of the Nucleonics Bulletin, Polish Nuclear Society

M.J. Sadowski
Member of the European Physical Society (Plasma Physics Division)
Fellow of the Institute of Physics, London, UK
Member of the Polish Physical Society
Member of the Polish Society of Applied Electromagnetics
Member of the Editorial Board of the Journal of Advanced Materials, Cambridge International Science Publishing
Member of the Scientific Council of the Space Research Centre, Polish Academy of Sciences
Vice-chairman of the Scientific Council of the Institute of Plasma Physics and Laser Microfusion
Vice-chairman

PERSONNEL

Research scientists
Krzysztof Czaus, BSc.E.E. 3/5*
Lech Jakubowski, Dr. 3/5*
Aneta Malinowska, Dr.
Karol Malinowski, MSc.
Katarzyna Nowakowska-Langier, Dr.
Robert Nietuby, Dr.
Marek Rabinski, Dr.
Marek Sadowski, Professor
Elzbieta Skladnik-Sadowska, Dr. 3/5*
Adam Szydlowski, Dr.
Jan Witkowski, BSc.E.E. 3/5*
Jaroslaw Zebrowski, Dr.

Technical and administrative staff
Krzysztof Gitarczyk
Alicja Gawronska 4/5*
Krzysztof Gniadek
Marcin Jakubowski
Marek Jedrzejczyk
Pawel Karpinski
Bernard Kolakowski
Miroslaw Kuk
Robert Mirowski, MSc.E.E.
Andrzej Trembicki
Andrzej Wiraszka

* part-time employee
6. DEPARTMENT OF HIGH ENERGY PHYSICS

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

Overview

The main activities of the Department can be grouped into four parts:

I. **An ongoing analysis of data from large accelerator facilities**
   At CERN SPS:
   The Compass experiment, ‘a flagship of the CERN fixed target program’, studies the structure of the nucleon. Gluon polarization analysis was the main subject this year. Compass is an active experiment, and there is an ongoing effort in data taking and detector development.
   Two heavy ion experiments, WA98 and NA49, have finished data taking, but continue analysis. In 2008, important results on transverse momentum spectra were published.
   At COSY:
   The WASA experiment works with low energy (up to 3.7 GeV) beams of protons and deuterons, studying rare decays of eta mesons. New limits on branching ratios for such decays have been determined. This information is important for the theory of C and CP symmetry, and chiral perturbation theory.

II. **Preparations for soon-to-be-operating experiments at the LHC**
   Three teams work on LHC experiments: CMS, LHCb and ALICE.
   The CMS experiment is ready for data taking. The muon trigger system, based on resistive plate chambers RPC, has been installed and tested using cosmic ray muons.
   Simulations of physical processes predicted by some extensions of the Standard Model were performed.
   The LHCb experiment team has worked on the system of the Inner Detector positioning station Rasnik, and the beam phase and intensity monitor (together with a P-III team). Simulations of the B decays into vector mesons, for the High Level Trigger, were performed.
   The ALICE team has worked on the installation of the photon detector PHOS and tests with cosmic muons. Simulations of neutral pion reconstruction were performed.

   Preparation of the computing base for future large experiments – work within the Worldwide LHC Computing Grid was actively pursued by a dedicated team.

   In 2008, many activities were directed at information and popularization of LHC physics. Our department members actively participated in the special Open Symposium on Elementary Interactions in the LHC Era (April 2008), several high school lectures and an exhibition, accompanied with lectures, organized at the Warsaw Technical University.

III. **Preparations for neutrino physics experiments**
   The neutrino team works on preparations for the T2K experiment, which will study neutrino oscillations. Local work concentrates on the Side Muon Range Detector, part of the near detector ND280. This involves calculations of the trigger rates, simulations for the multi pixel photon counters and participation in electronics tests. Participation in the CERN SPS NA61 experiment, already active, will serve for the determination of cross sections for hadron-nucleus processes, important for neutrino physics.

IV. **There is an opening into future diffraction physics experiment at RHIC, starting with participation in test runs of polarized proton beams.**
   A future oriented project is an involvement in the studies of the MAPS vertex detector, for the ILC collider.
   Twelve PhD students work under the supervision of our department members. One degree was granted in 2008.

*Helena Bialkowska*
REPORTS

**ALICE electromagnetic calorimeter TDR**
P. Cortese, ..., A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

**ILC Reference design report volume 4 - Detectors**
T. Behnke, ..., M. Szleper, ... et al.
FERMILAB-APC

**ILC Reference design: ILC Global design effort and world wide study**
J. Brau, ..., M. Szleper, ... et al.
FERMILAB-APC

PARTICIPATION IN CONFERENCES AND WORKSHOPS

**Invited Talk**

Unstable quark-gluon plasma at LHC

St. Mrówczyński
Cracow Epiphany Conference on LHC Physics (Cracow, Poland, 2008-01-04 - 2008-01-06)

Remarks on muon radiography

M. Szeptycka, P. Szymański
Safe Nuclear Energy (Jalta, Ukraine, 2008-09-27 - 2008-10-02)

Poland at CERN

J. Nassalski
Symposium on Physics of Elementary Interactions in the LHC Era (Warsaw, Poland, 2008-04-21 - 2008-04-22)

Fizyka wysokich energii w erze LHC

J. Nassalski
Fizyka Wysokich Energii w Edukacji Szkolnej (Puławy, Poland, 2008-02-29 - 2008-03-01)

Heavy ion physics

H. Bialkowska
Symposium on Physics of Elementary Interactions in the LHC Era (Warsaw, Poland, 2008-04-21 - 2008-04-22)

Wielki Zderzacz Hadronów (LHC) - urządzenie do badania nieznanych terytoriów

J. Nassalski
Konferencja dla młodzieży szkolnej: Od MSC do LHC; od radu i polonu do Wielkiego Zderzacza Hadronów (Warsaw, Poland, 2008-05-29 – 2008-05-29)

Beyond SM searches at LHC

P. Żalewski
Trans-European School of High Energy Physics (Buymervoika, Ukraine, 2008-07-03 - 2008-07-09)

Overview of event-by-event fluctuations

St. Mrówczyński
The Fourth Workshop on Particle Correlations and Femtoscopy (WPCF2008) (Cracow, Poland, 2008-09-11 - 2008-11-14)

Search for heavy stable charged particles at CMS

K. Nawrocki
Physics at LHC - 2008 (Splt, Croatia, 2008-09-29 - 2008-10-04)

Chromodynamic fluctuations in quark-gluon plasma

St. Mrówczyński

Colour instabilities in relativistic heavy-ion collisions

St. Mrówczyński

Gluons polarization in the nucleon

E. Rondio
The 18th International Symposium on Spin Physics (Charlottesville, USA, 2008-10-06 - 2008-10-11)
**Instabilities in non-Abelian plasmas**

St. Mrówczyński  

**The GPD program at a future electron-ion collider facility**

A. Sandacz  

**Chromodynamic fluctuations in quark-gluon plasma**

St. Mrówczyński  
Program on Nonequilibrium Dynamics in Particle Physics and Cosmology, Kavli Institute for Theoretical Physics (Santa Barbara, USA, 2008-01-14 - 2008-03-21)

**Generalized parton distributions - experiment**

A. Sandacz  
Electron-Ion Collider Collaboration Meeting (Berkeley, USA, 2008-12-11 - 2008-12-13)

**Colour instabilities in the quark-gluon plasma**

St. Mrówczyński  
Yukawa International Program for Quark-hadron Sciences "New Frontiers in QCD 2008: fundamental problems in hot and/or dense matter", Yukawa Institute for Theoretical Physics (Kyoto, Japan, 2008-01-28 - 2008-03-21)

**Proton-Carbon data from NA61/SHINE for neutrino experiments**

J. Stepaniak  
Workshop on SHIN(E)ing Physics (Kielce, Poland, 2008-12-06 - 2008-12-07)

**Oral Presentation**

New results on Delta_{G}/G from COMPASS experiment at CERN  
J. Nassalski  
PANIC08 (Eilat, Israel, 2008-11-09 - 2008-11-14)

Measurements and interpretation of registration of large number of neutrons generated in lead  
21st European Cosmic Ray Symposium (Kosice, Slovakia, 2008-09-09 - 2008-09-12)

**Thermal neutron background measurements in the Gran Sasso National Laboratory**

21st European Cosmic Ray Symposium (Kosice, Slovakia, 2008-09-09 - 2008-09-12)

The pp→ΔΔ reaction - a case of ΔΔ excitation without ABC-effect  
10th International Workshop on Meson Production, Properties and Interaction - MESON 2008 (Cracow, Poland, 2008-06-06 - 2008-06-10)  
Int. J. Mod. Phys. A (in press)

**Pi of the Sky introduction and data analysis**

M. Sokolowski, G. Wrochna, K. Nawrocki, D. Rybka, T. Batsch  
Workshop on astronomical image processing (Dublin, Ireland, 2008-08-18 - 2008-08-20)

Quark helicity distributions in COMPASS experiment at CERN  
R. Gazda  
Symmetries and Spin (Prague, Czech Republic, 2008-07-20 - 2008-07-26)

Isospin decomposition of pp→NNππ cross sections - Do we see a sign of Δ(1600) excitation in the mnn′,n′ channel?  
10th International Workshop on Meson Production, Properties and Interaction - MESON 2008 (Cracow, Poland, 2008-06-06 - 2008-06-10)  
Int. J. Mod. Phys. A (in press)

Prompt optical observations of GRBs with "Pi of the Sky" system  
The Sixth Huntsville Gamma-Ray Burst Symposium 2008 (Huntsville, USA, 2008-10-20 - 2008-10-23)
Delta G/G measurements at COMPASS
K. Klimaszewski
34th International Conference on High Energy Physics (ICHEP08) (Philadelphia, USA, 2008-07-29 - 2008-08-05)
EConf (2008)

Poster

Thermal neutrons at Gran Sasso

Construction and performance of a scintillating Fiber detector
M. Ziembicki, A. Nawrot, K. Klimaszewski, P. Żabowski-Żychowicz, M. Dziewiecki, R. Kurjata

LECTURES, COURSES AND EXTERNAL SEMINARS

Hard exclusive processes and partonic structure of the nucleon\(^\text{a)}\)
A. Sandacz
Warsaw, University of Warsaw, Seminar of High Energy Physics, 2008-01-11

The sky in computer\(^\text{a)}\)
M. Sokolowski
Warsaw, Faculty of Mathematics, Informatics and Mechanics, University of Warsaw, 2008-02-21

Heavy ion collisions at the LHC\(^\text{a)}\)
H. Białkowska
Warsaw, Nuclear Physics Seminar, Physics Dept., University of Warsaw, 2008-02-29

The LHCb experiment - first years of data taking and New Physics \(^\text{a)}\)
M. Szczekowski
Warsaw, University of Warsaw, 2008-04-18

On the possible existence of MeV dark matter \(^\text{a)}\)
J. Stepaniak
Warsaw, University of Warsaw, 2008-05-16

Early observation of optically brightest ever gamma-ray burst GRB 080319B, performed by the "Pi of the Sky" detector\(^\text{a)}\)
M. Sokolowski
Warsaw, Department of Nuclear Spectroscopy, Faculty of Physics, Warsaw University, 2008-05-21

Wounded nucleon and wounded quark scaling analysis\(^\text{a)}\)
B. Boimska
Cracow, Institute of Nuclear Physics, PAN, 2008-05-27

"Pi of the Sky" observation of the naked-eye GRB 080319B\(^\text{b)}\)
M. Sokolowski
Warsaw, Nicolaus Copernicus Astronomical Center (CAMK, Warsaw), 2008-06-30

Neutrino oscillations: current status and future\(^\text{b)}\)
D. Kiełczewska
Warsaw, Institute of Theoretical Physics, University of Warsaw, 2008-10-21

Neutrino oscillations: what we know and program for future\(^\text{b)}\)
D. Kiełczewska
Warsaw, Institute of Experimental Physics, University of Warsaw, 2008-11-14

Relativistic ion collisions\(^\text{a)}\)
H. Białkowska
Torun, Copernicus University, 2008-12-18

Resolutions for 'transverse' variables in rho\(^0\) production\(^\text{b)}\)
A. Sandacz
Prevessin, France, CERN, COMPASS analysis meeting, 2008-01-15

Simulations of DVCS and exclusive rho\(^0\) production\(^\text{b)}\)
A. Sandacz
Geneva, CERN, 2008-02-27
Instabilities driven equilibration of the quark-gluon plasma\(^{(b)}\)
St. Mrówczyński
Berkeley, California, USA, Lawrence Berkeley National Laboratory, Heavy-Ion Tea Seminar, 2008-03-25

Full chain MC for exclusive processes with the 'DVCS setup'\(^{(b)}\)
A. Sandacz
Geneva, CERN, 2008-04-23

Instabilities driven equilibration of the quark-gluon plasma\(^{(b)}\)
St. Mrówczyński
Los Alamos, New Mexico, USA, Los Alamos National Laboratory, T-16 Nuclear Physics Seminar, 2008-05-27

Instabilities driven equilibration of the quark-gluon plasma\(^{(b)}\)
St. Mrówczyński
Upton, New York, USA, Brookhaven National Laboratory, Nuclear Theory/RIKEN Seminar, 2008-06-03

Full chain MC simulations for DVCS\(^{(b)}\)
A. Sandacz
Geneva, CERN, 2008-07-02

Search for heavy Stable charge particles in CMS\(^{(b)}\)
M. Kazana
Palaiseau, France, Laboratoire Leprince-Ringuet, 2008-07-28

Recoil proton in the full chain MC for DVCS\(^{(b)}\)
A. Sandacz
Geneva, CERN, 2008-09-08

Polish T2 Federation - Status Report\(^{(b)}\)
R. Gokieli
Karlsruhe, FZK (Forschungszentrum Karlsruhe), 2008-09-26

Simulations for the GPD proposal\(^{(b)}\)
A. Sandacz
Geneva, CERN, 2008-10-15

Overview of event-by-event fluctuations\(^{(a)}\)
St. Mrówczyński
Geneva, NA49 Collaboration Meeting, CERN, 2008-10-19

Wounded nucleon and wounded quark scaling - status report\(^{(b)}\)
B. Boimska
Geneva, Switzerland, CERN, 2008-10-24

Model independent determination of the t-slope for DVCS\(^{(b)}\)
A. Sandacz
Geneva, CERN, 2008-11-19

Azimuthal asymmetry in deep inelastic scattering\(^{(b)}\)
A. Ukleja
Aachen, RWTH Aachen University, 2008-05-16

Large Hadron Collider (LHC) - a vehicle to penetrate new territories\(^{(a)}\)
J. Nassalski
Warsaw, Council of Polish Atomic Energy Agency, 2008-06-06

Poland at CERN\(^{(a)}\)
J. Nassalski
Warsaw, Committee of Physics, Polish Academy of Sciences, 2008-10-29

Status of the LHC at CERN\(^{(a)}\)
J. Nassalski
Warsaw, Council of Polish Atomic Agency, 2008-11-28

\(^{(a)}\) in Polish
\(^{(b)}\) in English
INTERNAL SEMINARS

Constraints on collimation of optical emission from Gamma-Ray Bursts
M. Sokolowski
Warsaw, Institute for Nuclear Studies (IPJ), 2008-01-15

RASNIK monitoring during tests of magnet
K. Syryczyński
Geneva, CERN (LHCb), 2008-01-23

Determination of AG/G from high p_T events at COMPASS
K. Klimaszewski
Warsaw, Soltan Institute for Nuclear Studies, 2008-03-04

Plans for searches of New Physics in the CMS experiment
M. Kazana
Warsaw, Institute of Experimental Physics, University of Warsaw, 2008-03-14

RPC synchronization
M. Kazana
Geneve, CERN, 2008-04-04

Status of RASNIK
K. Syryczyński
Geneva, CERN, 2008-04-23

New chapter of research in high energy physics
J. Nassalski
Lublin, Uniwersytet Marii Curie-Skłodowskiej, 2008-05-08

Status of analysis of trigger PT29 from Apr07
M. Berłowski
Juelich, Institut für Kernphysik, Forschungszentrum Jülich GmbH, 2008-06-10

RASNIK monitoring during tests of magnet
K. Syryczyński
Geneva, CERN, 2008-06-11

RPC trigger and readout - Cruzet II Report
M. Kazana
Geneve, CERN, 2008-06-13

Heavy stable charge particles - Status Report
M. Kazana
Limassol, Cyprus, CERN, 2008-06-27

Another step in analysis of trigger PT29 status
M. Berłowski
Juelich, Institut für Kernphysik, Forschungszentrum Jülich GmbH, 2008-07-20

Status of RPC trigger in recent global runs
M. Kazana
Geneve, CERN, 2008-09-24

In search of light dark matter in p0 and eta decays
M. Berłowski
Warsaw, The Andrzeja Soltan Institute for Nuclear Studies, 2008-10-21

Broadband observations of the naked-eye GRB080319B
M. Sokolowski
Warsaw, The Andrzeja Soltan Institute for Nuclear Studies, 2008-11-18

\(^{(a)}\) in Polish
\(^{(b)}\) in English

DIDACTIC ACTIVITY

H. Białkowska - Supervision of student’s seminar “Some predictions for relativistic ion collisions at LHC”

R. Gokieli - User support in the DELPHI experiment, archived on WWW
J. Nassalski - Contribution to organising 4 courses for polish physics teachers at CERN (NTP programme)
J. Nassalski - Lecture for polish physics teachers at CERN, 2008-09-21
"Poland at CERN"
J. Nassalski - Member of the Organising Committee of the conference for teachers: "High Energy Physics in High School Education", Pulawy, 2008-02-29 to 2008-03-01
J. Nassalski - mgr inż. Konrad Klimaszewski,
"Determination of gluon polarisation in the nucleon from high-p_t hadron pairs in COMPASS experiment"
E. Rondio - co-organizer of the seminar
"Neutrinos in the laboratory and in cosmos"
E. Rondio - Lecture at Physics Department University of Warsaw
"From neutrinos to cosmic sources"
E. Rondio - Piotr Mijakowski
A. Sandacz - Supervising of the diploma thesis of Paweł Sznajder, the student of Physics Department of Warsaw Technical University
T. Siemiarczuk - graduate student: Iryna Ilkiv, tentative subject of the PhD thesis: "Photon production in nucleus-nucleus interactions at the LHC";
graduate student: Podist Kurashvili, tentative subject of the PhD Thesis: "Production of pi-zero and eta-zero mesons in nucleus-nucleus interactions at the LHC"
M. Szeptycka - Discussions of the experimental set up for the measurements of thermal neutron flux in the underground laboratory in Gran Sasso. Discussion of the results, and the first version of the report (not yet finished). First stage.
W. Wiślicki - diploma thesis, Witold Haliniak, UW
W. Wiślicki - Jan Iwaszkiewicz, UW
W. Wiślicki - Karol Wawrzyniak, UW
W. Wiślicki - Rafal Gazda

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

M. Adamski
Member of Organizing Committee on International Linear Collider ECFA Workshop in

H. Bialkowska
Member of the Scientific Council of the Institute of Experimental Physics, Warsaw University
Member of the presidium of the Committee of Physics of the Polish Academy of Sciences
Deputy President of the Scientific Council

St. Mrówecki
The Committee on Physics of Polish Academy of Science

J. Nassalski
Member of the Scientific Council of the Andrzej Soltan Institute for Nuclear Studies
Member of the Programme Advisory Committee for Particle Physics, JINR, Dubna; chairman from September 2007.
Representative of the Polish scientific community to the CERN Council, Geneva, Switzerland
Chairman of the Committee for High Energy Physics, National Atomic Energy Agency
Member of the Scientific Council of Nuclear Physics Division (SPhN), Saclay, France

T. Siemiarczuk
Member of Advisory Board on The 8-th International Conference on Hyperons, Charm and Beauty Hadrons (BEACH 2008) at the University of South Carolina in

R. Sosnowski
Corresponding member of Polish Academy of Learning
Member of the Warsaw Scientific Society
Member of the European Physical Society
Full member of the Polish Academy of Sciences
Member of the Scientific Council of the Joint Institute for Nuclear Research (Dubna)
Chairman of the Council for Atomic Energy Matters
Member Scientific Council of the Institute of High Pressure Polish Academy of Sciences
Member of the Central Commission on Degrees and Titles
PERSONNEL

Research scientists
Marek Adamus, Dr.  
Helena Białkowska, Professor  
Michał Bluj, Dr.  on leave  
Bożena Boimska, Dr.  
Andrzej Deloff, Assoc.Prof.  1/3*  
Ryszard Gokieli, Dr.  
Maciej Górski, Dr.  
Oleg Grajek, Dr.  till 30 Sept.  
Julia Hoffman, Dr.  on leave  
Małgorzata Kazana  
Danuta Kieleczewska, Assoc.Prof.  1/5*  
Katarzyna Kowalik, Dr.  on leave  
Andrzej Kupść, Dr.  on leave  
Justyna Łagoda  
Piotr Marciniowski, Dr.  on leave  
Stanisław Mrówczyński, Professor  2/3*  
Jan Nassalski, Professor  
Krzysztof Nawrocki, Dr.  
Adam Nawrot, Eng.  3/5*  
Paweł Przewłocki, MSc.  1/2* from 1 Dec.  
Ewa Rondio, Professor  
Andrzej Sandacz, Assoc.Prof.  
Teodor Siemiarczuk, Professor  
Ryszard Sosnowski, Professor  
Joanna Stepianiak, Professor  
Krzysztof Syryczeny, MSc.  1/4*  
Marek Szczekowski, Assoc.Prof.  
Maria Szeptycka, Professor  4/5*  
Michał Szleper, Dr.  
Piotr Traczyk, Dr.  on leave  
Artur Ukleja, Dr.  from 1 June  
Wojciech Wiślicki, Professor  
Piotr Zalewski, Dr.  
Joanna Zalipska, MSc.  on leave

PhD students
Marcin Berłowski, MSc.  
Rafał Gazda, MSc.  
Iryna Ilkiv, MSc.  
Karol Jędrezczak, MSc.  
Konrad Klimaszewski, MSc.  
Podist Kurashvili, MSc.  
Piotr Mijakowski, MSc.  
Tomasz Palczewski, MSc.  
Paweł Przewłocki, MSc.  till 30 Sept.  
Marcin Sokołowski, MSc.  till 13 Feb.

Technical and administrative staff
Krzysztof Brzozowski  
Piotr Gawor  
Tadeusz Marszał  
Wiesława Pojedyńska  ¼* from 1 Nov.  
Maria Sobocińska  
Teresa Świerczyńska  ¼*  

* part-time employee
7. DEPARTMENT OF COSMIC RAY PHYSICS

Head of Department:  Dr. Jacek Szabelski
    phone:  (042) 678-64-31
    e-mail:  js@zpk.u.lodz.pl

Overview

The Department of Cosmic Ray Physics in Łódź is involved in basic research in the high-energy Cosmic Ray field. Cosmic Rays are energetic particles from outside the Solar System. Most of the studies of Cosmic Rays address fundamental problems:

- the nature of the physical and astrophysical processes responsible for the high energies of the particles
- an estimation of the astrophysical conditions at the acceleration sites and/or the search for sources of Cosmic Rays,
- properties of high-energy particle interactions at very high energies.

Some Cosmic Ray studies might have practical (commercial) implications, e.g.

- “cosmic weather” forecasting - predictions of geomagnetic disturbances related to Solar activity changes (due to large Solar Flares/Coronal Mass Ejection events); these are important for large electricity networks, gas pipelines, radio-wave connections, space missions and satellite experiments.

Presentation of Cosmic Ray registration to high school students has become a popular way to introduce particle physics detectors and elementary particle detection techniques to young people. We organize in Łódź and Poznań workshops on particle physics for high school students. This is a part of the European activity: EPPOG’s Masterclass – Hands on CERN.

Energetic Cosmic Ray particles produce cascades of particles in the atmosphere, called Extensive Air Showers (EAS). Registering EAS and their properties is the main way of experimentally study’s very high energy Cosmic Rays. Locally in Łódź we concentrate on methodological studies of the detection of neutrons correlated with EAS and the interpretation of this phenomenon. We have also performed two series of neutron background measurements in the deep underground Gran Sasso Laboratory in Italy (within the ILIAS-TA Project).

In 2004, we began the Roland Maze Project, a network of EAS detectors placed on the roofs of high schools in Łódź. The pilot project is to equip 10 high schools, each with four 1m² detectors and GPS. The network is connected off-line using internet infrastructure and precise time registration. Students of the high schools in Łódź are involved in the construction of the array.

International collaborations are very important: the Department is a member of the KASCADE-Grande Collaboration – the large classical experiment for very high energy EAS, extended to EAS radio emission detection as part of LOPES Collaboration. We also became a member of the JEM-EUSO satellite experiment collaboration. We collaborate in EAS data interpretation, detection techniques and basic Cosmic Ray studies with University Paris-VII, Institute for Nuclear Research of the Russian Academy of Sciences and JINR Dubna.

In the area of high-energy particle physics the Department participates in the ZEUS experiment at DESY (Hamburg, Germany), and in the WASA@COSY Collaboration in Juelich, Germany.

Jacek Szabelski
PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Air shower measurements with the LOPES radio antenna array
A. Haungs, W.D. Apel, P. Luczak, J. Zabierowski

The air shower experiment KASCADE-Grande
A. Haungs, P. Luczak, J. Zabierowski

Ultra high-energy interaction of CR protons
T. Wibig
21st European Cosmic Ray Symposium (kosice, Slovakia, 2008-09-09 - 2008-09-12)

Oral Presentation

Measurements and interpretation of registration of large number of neutrons generated in lead
21st European Cosmic Ray Symposium (Kosice, Slovakia, 2008-09-09 - 2008-09-12)

Radio emission of energetic cosmic ray air showers: Polarization measurements with LOPES
P.G. Isar, W.D. Apel, P. Luczak, J. Zabierowski

Thermal neutron background measurements in the Gran Sasso National Laboratory
21st European Cosmic Ray Symposium (Kosice, Slovakia, 2008-09-09 - 2008-09-12)

Isospin decomposition of pp→NNπ cross sections - Do we see a sign of Δ(1600) excitation in the nnn′π′ channel?
10th International Workshop on Meson Production, Properties and Interaction - MESON 2008 (Cracow, Poland, 2008-06-06 - 2008-06-10)
Int. J. Mod. Phys. A (in press)

Hadronic interactions and EAS muon pseudorapidities investigated with the Muon Tracking Detector in KASCADE-Grande
J. Zabierowski, P. Doll, P. Luczak
Search for an alpha-decaying isomer in $^{220}$Ac
ENAM 08 The Fifth International Conference on Exotic Nuclei and Atomic Masses (Ryn, Poland, 2008-09-07 - 2008-09-13)

The LOPES experiment radio detection of extensive air showers
A. Haungs, P. Luczak, J. Zabierowski

Lateral distribution of EAS muon density and pseudorapidity
P. Luczak, K. Daumiller, P. Doll, J. Zabierowski
DPG Frühjahrstagung 2008 (Freiburg, Germany, 2008-03-03 - 2008-03-07)
Deutsche Physikalische Gesellschaft e.V. No. T 84.2 (2008)

Myon produktionshöhe und longitudinale schauerentwicklung bei KASCADE-Grande
P. Doll, K. Daumiller, P. Luczak, J. Zabierowski
DPG Frühjahrstagung 2008 (Freiburg, Germany, 2008-03-03 - 2008-03-07)
Deutsche Physikalische Gesellschaft e.V. No. (2008) p. T 85.1

Carpet 3 - a new experiment to study primary composition around the knee.
21$^{st}$ European Cosmic Ray Symposium (Kosice, Slovakia, 2008-09-09 - 2008-09-12)

The constant intensity cut method applied to the KASCADE-Grande muon data
J.C. Arteaga-Velazquez, P. Luczak, J. Zabierowski

The KASCADE-Grande experiment: an overview
A. Chiavassa, W.D. Apel, P. Luczak, J. Zabierowski
21$^{st}$ European Cosmic Ray Symposium (Kosice, Slovakia, 2008-09-09 - 2008-09-12)

AGASA energy spectrum and GZK cut-off
J.N. Capdevielle, F. Cohen, B. Szabelska, J. Szabelski

Investigation of the S(500) distribution for large air showers detected with the KASCADE-Grande array
G. Toma, P. Luczak, J. Zabierowski

The extensive air shower experiment KASCADE-Grande
Dongwa Kang, W.D. Apel, P. Luczak, J. Zabierowski
International Symposium on Cosmology and Particle Astrophysics CosPA 2008 (Pohang, Korea, 2008-10-28 - 2008-11-01)

Muon production height and longitudinal shower development measured with KASCADE-Grande
P. Doll, P. Luczak, J. Zabierowski

Measurement of attenuation length hadrons in air showers
J.R. Hoerandel, D. Hildebrand, P. Luczak, J. Zabierowski

Brief information about Polish group
J. Szabelski
JEM-EUSO Workshop and the 4th International JEM-EUSO Collaboration Meeting (Torino, Italy, 2008-12-01 - 2008-12-04)

Investigation of muon pseudorapidity in EAS with the MTD
J. Zabierowski, P. Luczak, P. Doll

Very, very high-energy interactions of cosmic ray protons (if there are any)
T. Wibig
Workshop on SHIN(E)ing Physics (Kielce, Poland, 2008-12-06 - 2008-12-07)
Muon lateral distributions with the MTD
P. Łuczak, J. Zabierowski, P. Doll
*KASCADE-Grande Collaboration Workshop (Lauterband, Germany, 2008-07-27 - 2008-07-29)

Muon production height
P. Doll, P. Łuczak, J. Zabierowski
*KASCADE-Grande Collaboration Workshop (Lauterband, Germany, 2008-07-27 - 2008-07-29)

Heavy cosmic ray nuclei from extragalactic sources above 'The Ankle'
T. Wibig, A.W. Wolfendale
21st European Cosmic Ray Symposium (Kosice, Slovakia, 2008-09-09 - 2008-09-12)

Muon tracking in KASCADE-Grande: lateral distributions of EAS muons densities
P. Łuczak, W.D. Apel, J. Zabierowski
21st European Cosmic Ray Symposium (Kosice, Slovakia, 2008-09-09 - 2008-09-12)

Poster

Thermal neutrons at Gran Sasso

Carpet 3 - a new experiment to study primary composition around the knee
V.B. Petkov, J. Szabelski, T. Wibig, K. Jędrzejczak, M. Kasztelan

Lateral distribution function of high energy muons in EAS around the knee
J. Szabelski, V.B. Petkov, I.A. Alikhanov

INTERNAL SEMINARS

The measurements of the neutron background in The Gran Sasso Underground Laboratory
K. Jędrzejczak
Warsaw, The Andrzejs Soltan Institute for Nuclear Studies, 2008-05-20

The measurements of the neutron background in The Gran Sasso Underground Laboratory
K. Jędrzejczak
Katowice, University of Silesia, 2008-06-03

End to the cosmic ray spectrum?
T. Wibig
Warsaw, The Andrzejs Soltan Institute for Nuclear Studies, 2008-07-08

a) in Polish
b) in English

DIDACTIC ACTIVITY

J. Zabierowski - Supervision of PhD student in SINS Mr P. Łuczak

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

J. Szabelski
Member of Organizing Committee on XV International Symposium on Very High Energy Cosmic Ray Interactions (ISVHECRI 2008) in Paris, France
Polish representative in the European Particle Physics Outreach Group (EPPOG)

T. Wibig
Polish Physical Society
J. Zabierowski
Session chairman on KASCADE-Grande Collaboration Workshop in
Member of the KASCADE-Grande Steering Committee (Voting Member in the name of IPJ)- Since 2007 - Chairman of the
Steering Committee
Member of the Polish Physical Society
Chairman of the KASCADE-Grande Collaboration Steering Committee
Member of the WAS@COSY Collaboration Board

PERSONNEL

Research scientists
Paweł Pluciński on leave from Oct. 23
Barbara Szabelska, Dr.
Jacek Szabelski, Dr.
Tadeusz Wibig, Assoc. Prof. 1/3*
Janusz Zabierowski, Professor

PhD students
Paweł Łuczak, MSc.

Technical and administrative staff
Zdzisław Dębiccki 3/4*
Jadwiga Feder, Eng.
Karol Jędrzejczak, MSc. 1/2*
Jacek Karczmarczyk 1/2*
Marcin Kasztelan
Ryszard Lewandowski
Jerzy Orzechowski, MSc. Eng.
Przemysław Tokarski, MSc. Eng.

* part-time employee
8. DEPARTMENT OF THEORETICAL PHYSICS

Head of Department: Professor Grzegorz Wilk
phone: (22) 621-60-85
e-mail: wilk@fuw.edu.pl

Overview

The Department of Nuclear Theory consists of 24 physicists and 3 PhD students working on different aspects of low energy, high energy, plasma and nonlinear physics as well as on general problems of quantization of particle dynamics, astrophysics and cosmology. In addition to this activity, close collaborations with experimental groups: COMPASS and ALICE at CERN, FLAIR, AIC, EXO-ATOM (at RIKKEN, GSI and CERN) AMADEUS (at Frascati) and participation in the projects FLAVIAnet and ILIMA (GSI) should be emphasized. We participate in the European networks LANNIS, EURIDICE and EP-13H. Results of our work in 2008 were presented in 36 regular published papers (plus some conference proceedings), in 13 papers already accepted for publication and in 11 papers sent for publication. To this, one must also add 5 educational papers and our very intensive educational activity, highly recognized by the world physics community. Our work was also presented in numerous seminars, both in Poland and abroad. Our research concentrated on:

- properties of heavy and super heavy nuclei;
- properties of nuclear matter and nuclear collisions;
- exotic atoms;
- collisions of hadrons and leptons and phenomenology of high energy multiparticle production processes;
- parton distributions in nuclei;
- description of diverse production processes in QCD, including application at the AdS/CFT methods);
- some properties of Bose-Einstein condensates;
- nonlinear effect in extended media;
- quantum cosmology.

Of special relevance and interest are works on:

- numerical modeling of viscosity in hadronic fluids;
- K-fragments;
- second order phase transitions in verified gases;
- \(\alpha\) decays of highly ionized neutral atoms;
- gluons polarization in nucleus.

Collaborations with several universities and institutions have been maintained. These include the Universities of Warsaw, Kielce, Polish Academy of Sciences, München, Paris, Liege, Helsinki, London, Tokyo, Warwick and the Institutes at: CERN, GSI and JINR.

Grzegorz Wilk
REPORTS

ALICE electromagnetic calorimeter TDR
P. Cortese, ... , A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Spontaneous symmetry breaking of gap solitons trapped in a double-channel potential
M. Trippenbach, P. Zin
Nonlinear phenomena in quantum degenerate gases Universidad de Castilla-La Mancha, (Toledo, Spain, 2008-04-01 - 2008-04-04)

(Some) Highlights of topological string theory
P. Sułkowski
Kwantowa grawitacja w Krakowie (Cracow, Poland, 2008-01-12 - 2008-01-13)

Bunching of scattered atoms in BEC collision
P. Zin, J. Chwedenczuk, M. Trippenbach, A. Perrin
Euroquant Network Conference (Barcelona, Spain, 2008-04-07 - 2008-04-10)

Nuclear fission within the mean-field approach
J. Skalski
15th Nuclear Physics Workshop "Marie and Pierre Curie" 70 Years of Nuclear Fission (Kazimierz Dolny, Poland, 2008-09-24 - 2008-09-28)

Studies of fission barriers of heavy and superheavy nuclei
A. Sobiczewski

Nonextensive perfect hydrodynamics - a model of dissipative relativistic hydrodynamics?
T. Osada, G. Wilk
International Conference in Statistical Physics, SigmaPhi 2008 (Kolymbari, Greece, 2008-07-14 - 2008-07-18)

Looking for inflation in string theory
M. Spaliński
Kwantowa grawitacja w Krakowie (Cracow, Poland, 2008-01-12 - 2008-01-13)

Exclusive photoproduction of lepton pairs at LHC
B. Pire, L. Szymanowski, J. Wagner

N-Nbar exotics and antiprotonic atoms
S. Wycech, B. Loiseau, J.P. Dedonder
LEAP08 - Low Energy Antiproton Physics (Vienna, Austria, 2008-09-14 - 2008-09-19)
Hyperfine Interact. (in press)

Description of experimental fission barriers of heavy nuclei
A. Sobiczewski, M. Kowal
15th Nuclear Physics Workshop "Marie and Pierre Curie" 70 Years of Nuclear Fission (Kazimierz Dolny, Poland, 2008-09-24 - 2008-09-28)
Int. J. Mod. Phys. E (in press)

γ - p coincidence with twist three accuracy
I.V. Anikin, D.Y. Ivanov, B. Pire, L. Szymanowski, S. Wallon
AIP Conf. Proc. (in press)

Variational calculations of K-few-nucleon states
S. Wycech, A.M. Green
Critical Stability (Erice, Italy, 2008-10-12 - 2008-10-18)
Few Body Syst. (in press)

Spin structure of the nucleon
K. Kurek
XXVIII Physics in Collision (Perugia, Italy, 2008-06-25 - 2008-06-28)
SLAC e-conference No. (2009)
Pomeron-Odderon interference in production of $\pi^-\pi^+$ pairs in ultraperipheral collisions
B. Pire, L. Szymanowski, F. Schwennsen, S. Wallon


Gluon Polarization in the Nucleon from High Transverse Momentum Hadron Pairs at COMPASS
K. Kurek
The 18th International Symposium on Spin Physics Spin 2008 (Charlottesville, USA, 2008-10-06 - 2008-10-11)
American Institute of Physics No. (2009)

A test of the BFKL resummation at ILC
M. Segond, L. Szymanowski, S. Wallon
Summer School on QCD, Low X Physics, Saturation and Diffraction (Calabria, Italy, 2008-07-01 - 2008-07-14)

On quantum phase of the Universe
W. Piechocki
Workshop on Particle Physics and Cosmology: The Interface (Warsaw, Poland, 2008-02-13 - 2008-02-16)

Probing photon structure in DVCS on a photon target
M. ElBeiyad, S. Friot, B. Pire, L. Szymanowski, S. Wallon
PANIC 08 (Eilat, Israel, 2008-11-09 - 2008-11-13)
Israel No. (2009)

K-few- N states. Can one bind two neutrons?
S. Wycech
PANIC 08 - satellite meeting (Jerozolima, Israel, 2008-11-15 - 2008-11-21)

Oral Presentation

Renormalization of the Laurent expansion as a tool in the Hirota bilinear method
P. Goldstein
Second Workshop on Nonlinearity and Geometry (Będlewo, Poland, 2008-04-13 - 2008-04-19)

Cosmic rays from thermal sources
G. Wilk, Z. Wróblewski
PANIC08 (Eilat, Israel, 2008-11-09 - 2008-11-14)
Elsevier No. (2009)

New method of modeling dissipative hydrodynamic
T. Osada, G. Wilk
PANIC08 (Eilat, Israel, 2008-11-09 - 2008-11-14)
Elsevier No. (2009)

Effect of non-axial deformations on the fission barrier of heavy and superheavy nuclei
M. Kowal, A. Sobiczewski
15th Nuclear Physics Workshop "Marie and Pierre Curie" 70 Years of Nuclear Fission (Kazimierz Dolny, Poland, 2008-09-24 - 2008-09-28)
Int. J. Mod. Phys. E (in press)

Two photon distribution amplitudes
M. ElBeiyad, B. Pire, L. Szymanowski, S. Wallon
Joint Meeting Heidelberg-Liege-Paris-Wrocław: Three Days of Strong Interactions and Astrophysics (HLPW08) (Liege, Belgium, 2008-03-06 - 2008-03-08)

On K-few- nucleon states
S. Wycech, A.M. Green
PANIC 08 (Eilat, Israel, 2008-11-09 - 2008-11-15)
Elsevier No. (2009)

Coherent evidence for nucleon-antinucleon quasi-bound states
S. Wycech, B. Loiseau
PANIC 08 (Eilat, Israel, 2008-11-09 - 2008-11-13)
Elsevier No. (2009)

Can one measure time like Compton scattering at LHC?
B. Pire, L. Szymanowski, J. Wagner
Signaling the Arrival of the LHC Era (Trieste, Italy, 2008-12-08 - 2008-12-13)
Poster

Matrix models and Seiberg-Witten theory
P. Sułkowski
Humboldt Meeting (Darmstadt, Germany, 2008-10-08 - 2008-10-10)
Humboldt Foundation No. (2008) p. 32

Transition of extended objects across the cosmological singularity
W. Piechocki
3rd Biennial Leopoldine Conference on Dark Energy (Munchen, Germany, 2008-10-07 - 2008-10-11)
Ludwig-Maximilians-University Munich, Munich, Germany No. (2008)

The corrections to nuclear equation of state from deep inelastic scattering
J. Rożynek
PANIC08 (Eilat, Israel, 2008-11-09 - 2008-11-14)

Nonextensive effects on the Nambu Jona-Lasinio model of strongly interacting matter
J. Rożynek, G. Wilk
PANIC08 (Eilat, Israel, 2008-11-09 - 2008-11-14)

Dissipative or just nonextensive hydrodynamics? -Nonextensive/dissipative correspondence
T. Osada, G. Wilk
Quark matter 2008 (Jaipur, India, 2008-02-04 - 2008-02-10)
Indian Journal of Physics (in press)

Nonextensive/dissipative correspondence in relativistic hydrodynamics
T. Osada, G. Wilk
YITP International Symposium on Fundamental Problems in Hot and/or DenseQCD at Yukawa Institute for Theoretical Physics (YITP) (Kiooto, Japan, 2008-03-03 - 2008-03-06)

The $(\pi, K^+)$ reaction on $^{28}$Si and the $\Sigma$-nucleus potential
J. Dąbrowski, J. Rożynek
PANIC08 (Eilat, Israel, 2008-11-09 - 2008-11-14)

Non-axial octupole deformation of a heavy nucleus
P. Jachimowicz, M. Kowal, P. Rozmej, J. Skalski, A. Sobieczewski
15th Nuclear Physics Workshop "Marie and Pierre Curie" 70 Years of Nuclear Fission (Kazimierz Dolny, Poland, 2008-09-24 - 2008-09-28)
Int. J. Mod. Phys. E (in press)

Quantum big bounce
W. Piechocki
The Origin of our Universe: Seeking links between fundamental physics and cosmology (Oxford, United Kingdom, 2008-09-22 - 2008-09-26)

LECTURES, COURSES AND EXTERNAL SEMINARS

Deuteron structure function $g_1$
K. Kurek
Warsaw, University of Warsaw, 2008-01-10

Quantum tunneling in many-fermion systems within the mean-field theory
J. Skalski
Warsaw, Warsaw University, 2008-01-24

Critical transition in Bose-Einstein condensate
P. Zh
Łódź, Department of Physics, University of Łódź, 2008-04-04

Nuclear fission in the mean-field method: a search for a minimum of the instanton action
J. Skalski
Lublin, UMCS, 2008-04-08

Recent advances in construction of solitons by means of the Hirota method
P. Goldstein
Warsaw, Center for Theoretical Physics Polish Academy of Sciences, 2008-05-21

Orbital angular momentum in the nucleon
K. Kurek
Warsaw, University of Warsaw, Physics Department, 2008-06-06
Density of particles in single experimental realization - theoretical calculations and experimental results

P. Ziński

Warsaw, Department of Mathematical Methods in Physics, Faculty of Physics, Warsaw University, 2008-10-30

Mass and lifetime measurements in FAIR

Z. Patyk

Cracow, Physics Department UJ, 2008-11-29

Supersymmetric Gauge theories, Intersecting branes and free fermions

P. Sułkowski

Bonn, University of Bonn, Physics Institute, 2008-01-09

Instantons on ALE spaces and orbifold partitions

P. Sułkowski

Bonn, University of Bonn, Physics Institute, 2008-01-14

Supersymmetric Gauge theories, Intersecting branes and free fermions

P. Sułkowski

San Diego, University of California San Diego, 2008-04-04

Bethe ansatz and integrability

P. Sułkowski

Bonn, University of Bonn, Physics Institute, 2008-11-21

\(^{a)}\) in Polish

\(^{b)}\) in English

INTERNAL SEMINARS

Gluon polarization in nucleon

K. Kurek

Warsaw, Institute for Nuclear Studies, 2008-01-29

Quantum phase of the universe

W. Piechocki

Warsaw, Institute for Nuclear Studies, 2008-02-19

Nuclear fission within the mean-field theory: a search for a minimum of instanton action

J. Skalski

Warsaw, Institute for Nuclear Studies, 2008-04-24

The proof of existence of the Bose-Einstein condensate in the ground state of dilute gas of interacting bosons

P. Ziński

Warsaw, Centre for Theoretical Physics, Polish Academy of Science, 2008-06-03

Electron capture in H-like ions

Z. Patyk

Swierk, Institute for Nuclear Studies, 2008-11-13

How nonlinear electrodynamics was formulated

E. Infeld

Warsaw, Institute for Nuclear Studies, 2008-11-20

Properties of H-like ions

Z. Patyk

Warsaw, Institute for Nuclear Studies, 2008-11-27

\(^{a)}\) in Polish

\(^{b)}\) in English

DIDACTIC ACTIVITY

J. Dąbrowski - Co-organizer of the INS/UW seminar on Theory of Atomic Nuclei

W. Piechocki - Doctoral Thesis supervisor of Przemysław Małkiewicz

W. Piechocki - Leader of the Cosmology Club (collaboration with A.Pollo, E.Infeld and L.Szymanowski)

W. Piechocki - Leader of the Cosmology Seminar (in collaboration with E.Infeld, A.Pollo and L.Szymanowski)

W. Piechocki - PhD supervisor of Piotr Dzierżak
PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

J. Dąbrowski
Fellow of the American Physical Society
Member of the International Editorial Council of Acta Physica Polonica B

P. Goldstein
Member of the American Mathematical Society
Member of the Polish Physical Society
Member of the Editorial Board of DELTA

E. Infeld
Fellow of the Institute of Physics, London, UK
Member of the Editorial Board of Journal of Technical Physics Institute of Fundamental Technical Research, Polish Academy of Sciences
Editor of the Andrzej Soltan Institute for Nuclear Studies Publications

M. Pawłowski
Member of Organizing Committee on Symposium on Physics of Elementary Interactions in the LHC Era in Warsaw, Poland
member of the Scientific Council

W. Piechocki
Session chairman on Loops and Foams in Zakopane, Poland

A. Sobiczewski
Corresponding Member of the Polish Academy of Sciences
Corresponding Member of Polish Academy of Learning
Honorary editor of “Postępy Fizyki” (Advances in Physics)
Member of the Scientific Council of the Andrzej Soltan Institute for Nuclear Studies
Member of the Scientific Council of the Heavy Ion Laboratory of Warsaw University

M. Spaliński
Member of the Editorial Board, International Journal of Modern Physics A

P. Sulkowski
Bethe Center for Theoretical Physics
Particles and Cosmology Network
Philosphic Nature; Excogitation and Innovation Laboratory (EIL)

M. Trippenbach
Fellow of the Institute of Physics, London, UK

G. Wilk
Member of Scientific Counsel of Andrzej Soltan Institute for Nuclear Studies
Member of the Scientific Council of the Institute of Theoretical Physics
PERSONNEL

Research scientists
Ewa Czuchry, Dr.
Janusz Dąbrowski, Professor 2/5*
Piotr Goldstein, Dr.
Eryk Infeld, Professor
Michał Kowal, Dr.
Krzysztof Kurek, Dr.
Oleksandr Parkhomenko, MSc. 1/4*
Zygmunt Patyk, Assoc. Prof.
Marek Pawłowski, Dr.
Włodzimierz Piechocki, Assoc.Prof.
Jacek Rożynek, Dr.
Andrzej Senatorski, Dr. 1/2*
Janusz Skalski, Assoc.Prof. Scientific Secretary
Andrzej Skorupski, Dr. 1/2*
Robert Smołańczuk, Dr.
Adam Sobiczewski, Professor
Michał Spaliński, Assoc.Prof.
Piotr Śulkowski, Dr. on leave
Lech Szymański, Assoc.Prof.
Marek Trippenbach, Assoc.Prof. 1/5*
Grzegorz Wilk, Professor
Sławomir Wycech, Professor
Paweł Zieliński, Dr.

PhD students
Piotr Dzierżak, MSc.
Przemysław Małkiewicz, MSc.
Viet Hung, MSc.

Technical and administrative staff
Anna Sidor 3/4*

* part-time employee
9. DEPARTMENT OF MATERIAL STUDIES

Head of Department: Assoc. Prof. Zbigniew Werner
phone: (22) 718-05-45
e-mail: wernerz@ipj.gov.pl

Overview

The technology of modifying surfaces of technological materials by means of continuous and pulsed energy and particle beams has been intensely studied for more than 20 years. In some fields, it is currently utilized on a wide scale in industry. Continuous or pulsed ion and plasma beams play a significant role among various approaches used in this area. The research carried by Department P-IX is centered on applications of our two ion implantation facilities (ion implanters) of different kinds and unique sources of high-intensity intense plasma pulses, operated by the Department of Plasma Physics. The Department cooperates closely with Forschungszentrum Rossendorf (FZR, Dresden, Germany) in the field of analytical ion beam techniques and the use of unique ion implantation facilities. The main objectives of the Department are:

• the search for new ways of modifying the surface properties of solid materials by means of continuous or pulsed ion and plasma beams and

• the implementation of ion implantation techniques in national industries as a method of improving the lifetime of machine parts and tools utilized in industry.

In 2008, research was focused on:

• ion implantation/plasma treatment of ceramics aimed at improving their wettability in ceramic-metal joints,

• ion beam synthesis and plasma pulse activation of superconducting MgB2 phases,

• cobalt and zirconium inclusions in conducting layers produced in oxide insulators (Al2O3) by ion implantation and thermal annealing.

Research was conducted in cooperation with Department P-V of IPJ, Institute of Nuclear Chemistry and Technology (Warsaw), Warsaw University of Technology, Institute of Technology of Materials for Electronics (Warsaw), Institute of Molecular Physics, Polish Academy of Sciences (Poznan), Institute of Chemical Physics PAS and Forschungszentrum Rossendorf FZR (Dresden, Germany), as well as with some industrial companies.

Zbigniew Werner
PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Nanomechanical measurements of irradiated layers: methodology, possibilities and pitfalls

**J. Jagielski**, L. Thome, P. Aubert, O. Maciejak, A. Piątkowska, M. Romaniec, S. Moll

VII International Conference Ion Implantation and Other Applications of Ions and Electrons, ION 2008 (Kazimierz Dolny, Poland, 2008-06-16 - 2008-06-19)

*Vacuum* (in press)

Modification of polymer materials by ion bombardment. Case studies

D. Bieliński, **J. Jagielski**, P. Lipiński, D. Pieczyńska, U. Ostaszewska, A. Piątkowska

CAARI 2008 20th International Conference on the Application of Accelerators in Research and Industry (Forth Worth, USA, 2000-08-10 - 2008-08-15)

*AIP Conference Proceedings Series No.* (2009)

Oral Presentation

Meso and macroscopic considerations about damage accumulation process

**J. Jagielski**, L. Thome, M. Romaniec, S. Moll

23rd International Conference on Atomic Collisions in Solids - ICACS 2008 (Phalaborwa, South Africa, 2008-08-17 - 2008-08-22)


Chemical effects in Zr- and Co-implanted sapphire


VII International Conference Ion Implantation and Other Applications of Ions and Electrons, ION 2008 (Kazimierz Dolny, Poland, 2008-06-16 - 2008-06-19)

*Vacuum* (2008)

Poster

The influence of distribution of titanium alloyed into carbon ceramics by the intense plasma pulses on their surface wettability with liquid copper


VII International Conference Ion Implantation and Other Applications of Ions and Electrons, ION 2008 (Kazimierz Dolny, Poland, 2008-06-16 - 2008-06-19)

The effect of Ti preimplantation on the properties of TiN coatings on HS 6-5-2 high-speed steel

**J. Narojczyk**, Z. Werner, M. Barlak, D. Morozow

VII International Conference Ion Implantation and Other Applications of Ions and Electrons, ION 2008 (Kazimierz Dolny, Poland, 2008-06-16 - 2008-06-19)

Niskotemperaturowa charakterystyka nadprzewodnika MgB2 metodami STM/STS


V Seminarium Badania prowadzone metodami skaningowej mikroskopii bliskich oddziaływań (Zakopane, Poland, 2008-11-26 - 2008-11-30)


Proton beam induced luminescence of silicon dioxide implanted with excess silicon

G. Gawlik, **J. Jagielski**, A. Stonert, R. Ratajczak

23rd International Conference on Atomic Collisions in Solids - ICACS 2008 (Phalaborwa, South Africa, 2008-08-17 - 2008-08-22)

Biomedical aspects of ion bombardment of polyethylene

P. Lipiński, D. Bieliński, W. Okrój, W. Jakubowski, Ł. Klimek, **J. Jagielski**

VII International Conference Ion Implantation and Other Applications of Ions and Electrons, ION 2008 (Kazimierz Dolny, Poland, 2008-06-16 - 2008-06-19)

LECTURES, COURSES AND EXTERNAL SEMINARS

Modification of SiC properties using electron beams

J. Piekoszewski

Warsaw, Institute of Electronic Materials Technology, 2008-11-17

* in Polish
PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

J. Jagielski
Session chairman on CAARI 2008 20th International Conference on the Application of Accelerators in Research and Industry
Member of Organizing Committee on CAARI 2008 20th International Conference on the Application of Accelerators in Research and Industry

J. Piekoszewski
Session chairman on VII International Conference Ion Implantation and Other Applications of Ions and Electrons, ION 2008
Member of Advisory Board on VII Intern. Conference Ion Implantation and Other Applications of Ions and Electrons, ION 2008

PERSONNEL

Research scientists
Marek Barlak, Dr. 4/5*
Katarzyna Bocheńska, MSc. 1/2*
Jacek Jagielski, Assoc. Prof.
Jerzy Piekoszewski, Professor
Władysław Szymczyk, Dr.
Zbigniew Werner, Assoc. Prof.

Technical and administrative staff
Jerzy Królik 3/5*
Jerzy Zagórski

* part-time employee
10. DEPARTMENT OF ACCELERATOR PHYSICS AND TECHNOLOGY

Head of Department: Dr. Eugeniusz Pławski
phone: (22) 718-05-40
e-mail: plawski@ipj.gov.pl

Overview

The activity of department P-10 is focused on the development of new acceleration techniques and technology, as well as on applications of particle accelerators. In 2008, the following topics were investigated and/or realized:

1. A linear accelerator for protons called TOP (Terapia Oncologica con Protoni, Oncological Proton Therapy).
   Basically a proton linac of modified Alvarez type working at 3000 MHz frequency and delivering beams in the energy range from 65 MeV to 200 MeV.
   In 2005, a contract was signed between ENEA and INS-Świerk for the design, manufacture and delivery to Frascati of the input section of a 65 MeV linac. This section of SCDTL type will increase the proton energy from 7 to 16 MeV. In 2008, the field distribution in the manufactured structure was measured and optimized using available universal test stand. Measurements were also performed in ENEA/Frascati in October; a small difference in results, around 0.25%, is under investigation.
   Beam dynamics calculations using 3D codes have been started in parallel.

2. Preparation for participation in the international X-FEL project.
   Calculations of the parasitic Higher Order Modes (HOMs) induced in superconducting accelerating structures by very short electron bunches have been continued. Thanks to the special research grant received by department P-10 the design and completion of the HOM elements has been started for two accelerating modules, where each module consists of eight superconducting accelerating structures and focusing/correcting elements.

3. Superconducting layers; studies in INFN-Roma.
   Within the European CARE/JRA1/WP4-2 project, serious modification of the Nb-coating stand for the 1.3 GHz single-cell copper resonators using a vacuum arc was performed. Thanks to this stand the internal surface of the resonator was successfully coated.

4. TiN coating vacuum stand for RF components.
   At this stand the analysis of the TiN layer thickness as a function of reactive atmosphere pressure required for the Ti→TiN transition and as a function of potential distribution around the Ti emitter was performed. Results will help in the future design and manufacture of the power-couplers.

5. “Accelerators and Detectors” Project.
   Calculations of the RF distribution were performed for different types of accelerating structures for S-band and C-band, dedicated to compact medical IORT accelerators and mobile cargo inspection machines. The collection of necessary 2-D and 3-D codes has been started and will be finished in 2009. In 2008, also an R&D program for accelerator development was under evaluation, especially current achievements in medicine and cargo inspection.
   Special accelerator stands have been prepared for future experiments and tests.

6. Radiographic service.
   The 6 MeV accelerator dedicated to high energy X-radiography is continuously available for service, both for internal and external users (for example detector tests for department P-5 in the year 2008).

Slawomir Wronka
PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

New type of hadron therapy accelerator

Współczesne kierunki rozwoju radioterapii hadronowej na świecie
A. Wysoka-Rabin, E. Pławski
IX Jesienna Szkoła Fizyki Medycznej (Bydgoszcz, Poland, 2008-11-12 - 2008-11-13)

Radioterapia hadronowa- aspekty fizyczne i medyczne
A. Wysoka-Rabin
IX Jesienna Szkoła Fizyki Medycznej (Bydgoszcz, Poland, 2008-11-12 - 2008-11-13)

Wpływ różnych parametrów pomiarowych w Tomografii Komputerowej na wielkość Hounsfield Units (HU) i na obliczany zasięg jonów węglę w radioterapii ciężkimi jonami
A. Wysoka-Rabin, S. Qamhiyeh, O. Jaekel
IX Jesienna Szkoła Fizyki Medycznej (Bydgoszcz, Poland, 2008-11-12 - 2008-11-13)

Oral Presentation

The effect of various measurement parameters of a CT scanner and phantom with substitutes on the HU-to-range relation in heavy ion therapy
A. Wysoka-Rabin, S. Qamhiyeh, O. Jaekel
Jakość Leczenia Onkologicznego (Poznań, Poland, 2008-11-05 - 2008-11-07)

Poster

Superconducting niobium layers reached by using vacuum arc technique in INFN-Roma Tor Vergata
IV Kongres Polskiego Towarzystwa Próżniowego oraz VIII Krajoowa Konferencja Techniki Próżni (Janów Lubelski, Poland, 2008-09-21 - 2008-09-24)
Janów No.P-23 (2008)

From X-Ray spectrum to CT-numbers: MC simulation of a CT scanner and phantom with tissue substitutes
A. Wysoka-Rabin, S. Qamhiyeh, O. Jaekel
Medical Physics and Engineering 110 Years after the Discovery of Polonium and Radium (Cracow, Poland, 2008-09-17 - 2008-09-20)
European Conference Medical Physics and Engineering 110 Years after the Discovery of Polonium and Radium, Komitety Fizyki Medycznej, Radiobiologii i Diagnostyki Obrazowej Wydzia³u VI Nauk Medycznych PAN, Kraków, Poland No. (2008) p. 50

Cienkie warstwy nadprzewodzące osadzane z pomocą łuku w ultra-wysokiej próźni
R. Nietubyc, M.J. Sadowski, R. Mirowski, J. Witkowski, J. Lorkiewicz
IV Kongres Polskiego Towarzystwa Próżniowego oraz VIII Krajoowa Konferencja Techniki Próżni (Janów Lubelski, Poland, 2008-09-21 - 2008-09-24)
Janów Lubelski No. (2008)

LECTURES, COURSES AND EXTERNAL SEMINARS

Anti-emission TiN coatings of RF power components reached by evaporation
J. Lorkiewicz
Cracow, Faculty of Physics and Applied Informatics, Academy of Mining and Metallurgy, 2008-01-18

a) in Polish
DIDACTIC ACTIVITY

A. Wysocka-Rabin - "Modern methods of radiotherapy with particle and ion beams" lecture during XII Festival of Science

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

A. Wysocka-Rabin
Session chairman on IX Jesienna Szkoła Fizyki Medycznej in Polish Society of Medical Physics

PERSONNEL

Research scientists
Jerzy Bigolas, MSc. 4/5*
Wojciech Drabik, MSc. 3/5*
Konrad Kosiński, MSc.
Jerzy Lorkiewicz, MSc.
Eugeniusz Pławski, Dr.
Marcin Wojciechowski, MSc.
Anna Wysocka-Rabin, Dr.

Technical and administrative staff
Krzysztof Bigolas
Józef Bogowicz
Andrzej Lubian

* part-time employee
11. LABORATORY OF ASTROPHYSICAL APPARATUS

Head of Laboratory: Dr. Tadeusz Batsch
phone: (22) 718-05-47
e-mail: tadek@ipj.gov.pl

Overview

The Laboratory of Astrophysical Apparatus (LAA) was established in 2007. The aim of this decision was:

1. To intensify the activity of the institute in the field of astrophysical observations,
2. To increase the technical contribution of the institute to the national astrophysical network.

The activity of LAA in 2008 was concentrated on three main projects:

1. The “π of the Sky” experiment (http://grb.fuw.edu.pl) has being carried out by our institute for many years in collaboration with several national and foreign institutes with the aim of detecting short optical counterparts (so called afterglows) of Gamma-Ray Bursts (GRB) and other short time scale (a few seconds) optical astrophysical phenomena. The continual observations are controlled over the Internet by robotized equipment installed in Las Campanas Observatory in Chile. The instrumentation used in the project is systematically developed. In 2008, new versions of the electronics for the CCD cameras together with three containers for cameras were prepared. In collaboration with external firms, new cameras and robots were also manufactured.

2. The LAA is involved in a series of international observational projects aiming to understand the evolution of the Large Scale Structure of the Universe and its relation to the evolution of galaxies. The VIMOS-VLT Deep Survey (VVDS, http://www.oamp.fr/virmos/) is an extensive imaging and redshift survey of the deep universe at redshift between 0 and 5, containing presently more than 50,000 redshifts in four 4-sq.-degree deep and wide fields. In 2008, ESO accepted the new large redshift survey – the VIMOS Public Extragalactic Redshift Survey, which will cover 24 sq.-degrees in the sky and measure a few hundreds of thousands of redshifts of galaxies at z~1. The first observations are on-going now. Yet another important collaboration is with the AKARI project (http://www.ir.isas.jaxa.jp/ASTRO-F/Outreach/index_e.html), a satellite performing a sky survey in the infrared. In 2008, we worked on the correlation function of the data from the AKARI Deep Field South (ADFS) field and on the properties of the galaxies found in this field.

3. The LAA also takes part in the POLAR international project (http://isdc.unige.ch/polar/). POLAR is a space instrument devoted to the measurement of the polarization of gamma rays. It is optimized for the measurement of the polarization of gamma photons coming from GRBs. In 2008, the pilot series of plastic scintillator bars planned to be used in the orbital polarimeter was manufactured and tested.

Members of the LAA contributed in 2008 to 30 publications. Among them the article in NATURE (Vol. 455, No 7210, pp 183-188) on the observation of GRB 080319B, published by the “π of the Sky” group is worth mentioning here.

Tadeusz Batsch
PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Prompt optical observations of GRB 080319B

G. Wrochna

37th COSPAR Scientific Assembly (Montreal, Canada, 2008-07-13 - 2008-07-20)

Oral Presentation

IRES system

S. Koroleczuk, D. Rybka


USB controlled Stepper Motor Driver to be used in didactic laboratory of nuclear techniques in the Institute of Nuclear Studies

Ł. Koniusz, D. Rybka


Pi of the Sky introduction and data analysis

M. Sokolowski, G. Wrochna, K. Nawrocki, D. Rybka, T. Batsch

Workshop on astronomical image processing (Dublin, Ireland, 2008-08-18 - 2008-08-20)

Silicon photomultiplier as an alternative for APD in PET – MRI applications

A. Nassalski, M. Moszyński, A. Syntfeld-Kaźuch, T. Szczerbicki, B. Wołski, T. Batsch


POLAR: A novel gamma-ray burst polarimeter


POLAR: Design of a novel X-ray polarimeter based on plastic scintillators and multi-anode photomultipliers


21st European Cosmic Ray Symposium (Kosice, Slovakia, 2008-09-09 - 2008-09-12)

POLAR: Design of a novel X-ray polarimeter based on plastic scintillators and mapmt


Pi of the Sky introduction and data analysis


The Sixth Huntsville Gamma-Ray Burst Symposium 2008 (Huntsville, USA, 2008-10-20 - 2008-10-23)

Poster

Searching for white dwarfs candidates in Sloan Digital Sky Survey Data

M. Należyty, A. Majczyna, A. Ciechanowska, J. Madej

16th European Workshop on White Dwarfs (Barcelona, Spain, 2008-06-30 - 2008-07-04)


The VIMOS-VLT deep survey: clustering of mass and light at z=1

A. Pollo

When the Universe formed stars (La Martinique, France, 2008-11-18 - 2008-11-21)
Clustering of the far-infrared galaxies in the AKARI Deep Field South (ADFS)
M. Kawada, T.T. Takeuchi, S. Matsuura, M. Shirahata, A. Pollo
When the Universe formed stars (La Martinique, France, 2008-11-18 - 2008-11-21)

Further study of boron-10 loaded liquid scintillators for detection of fast and thermal neutrons

Accretion events in AZ Cas and VV Cep binary system
C. Galan, A. Majcher
"Interacting Binaries: Accretion and Synchronization" (Nauchny, Ukraine, 2008-06-20 - 2008-06-26)

Photometric search of orbital periods in symbiotic stars
M.Wieczek, A. Majcher
"Interacting Binaries: Accretion and Synchronization" (Nauchny, Ukraine, 2008-06-20 - 2008-06-26)

LECTURES, COURSES AND EXTERNAL SEMINARS

Evolution of the large scale structure of the Universe\(^a\)
A. Pollo
Cracow, Jagiellonian University, 2008-01-25

Theoretical model atmospheres of X-ray bursters\(^b\)
A. Majczyna
Torun, Poland, Torun Centre for Astronomy of the Nicolaus Copernicus University, 2008-10-27

\(^a\) in Polish

INTERNAL SEMINARS

Robotic observations of rapid astrophysical phenomena\(^b\)
G. Wrochna
Warsaw, Warsaw University of Technology, 2008-03-13

GRB 080319B - the most powerful cosmic explosion\(^b\)
G. Wrochna
Warsaw, Warsaw University, 2008-10-10

Dark side of the Universe with the observer's eye\(^c\)
A. Pollo
Warsaw, The Andrzejs Sołtan Institute for Nuclear Research, 2008-10-21

GRB 080319B - the most powerful cosmic explosion\(^b\)
G. Wrochna
Świerk, Institute for Nuclear Studies, 2008-12-11

GRB 080319B - the most powerful cosmic explosion\(^b\)
G. Wrochna
Cracow, Polish Academy of Arts and Sciences, 2008-12-12

\(^b\) in Polish

DIDACTIC ACTIVITY

A. Majcher - running lectures for participants of summer astronomical camp of an astronomical club "Almukantarat" (http://www.almukantarat.pl)

A. Majcher - running lectures for youth from junior high school and high school visiting INS and running trainings and consultations for pupils and students as well

A. Majczyna - presented a talk 'Nuclear fusion in Universe' on workshop for a teachers organizing by ASSOCIATION EURATOM-IPPLM

J. Użycki - teaching of Warsaw University of Technology students at Faculty of Physics in subjects: "Basics of Microcontroller Systems" and "Basics of Electronics"

G. Wrochna - Adam Zadrożyń
G. Wrochna - Marcin Sokolowski: Investigation of astrophysical phenomena in short time scales with Pr-of-the-Sky

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

A. Majczyna
Member Polskie Towarzystwo Astronomiczne
komisja rewizyjna, Polish Fireball Network

D. Rybka
Member of Organizing Committee on XXII IEEE-SPIE Joint Symposium on Photonics, Web Engineering, Electronics for Astronomy and High Energy Physics Experiments in
Member of Organizing Committee on XXI IEEE-SPIE Joint Symposium on Photonics, Web Engineering, Electronics for Astronomy and High Energy Physics Experiments in

J. Użycki
Warsaw University of Technology, Faculty of Physics. Function: secretary during master diploma exams

G. Wrochna
Member of the Polish Nuclear Society
Member of the Committee on Nuclear Physics of the Council for Atomic Energy Matters
Coordinator of Polish Nuclear Technology Platform
Member of the Physics Committee PAN
President of the Council of Atomic Center consortium
President of the Council of Polish Astroparticle Physics Network
President of the Council of XFEL-Poland consortium
Member of Scientific Council of Institute for Experimental Physics, Warsaw University

PERSONNEL

Research scientists
Tadeusz Batsch, Dr.
Michał Gierlik, Dr.
Agnieszka Majczyna, Dr.
Radosław Marcinkowski, MSc.
Agnieszka Pollo, Dr.
Marcin Sokolowski, Dr.
Grzegorz Wrochna, Professor
Director of the Institute

Technical and administrative staff
Ariel Majcher
Piotr Pucyk 4/5*
Piotr Rybka, MSc. Eng.
Dominik Rybka, MSc. Eng. on leave
Piotr Sitek, MSc. Eng.
Janusz Użycki 1/2*

* part-time employee
12. DEPARTMENT OF TRAINING AND CONSULTING

Head of Department: Professor Ludwik Dobrzyński
phone: (22) 718-06-12
e-mail: ludwik@ipj.gov.pl

Overview

The Department of Training and Consulting regularly serves secondary schools pupils and teachers, university students and the public. Almost 6600 visitors, mainly students from secondary schools in Poland, visited the Department. In addition to regular lectures, demonstrations, visits to the reactor MARIA and two current exhibitions (on nuclear waste and the WWER reactor model), several laboratory experiments have been organized for secondary schools. A one-day summer workshop on “Basics of nuclear radiation, its properties and use in science, technology and medicine” offered secondary school teachers a general understanding of the problems connected with radioactivity.

The Department is constantly developing experiments that can be conducted by students of secondary schools and universities, as well as by professionals. At the moment, there are about 25 experiments available for the guests of the Department. They cover the measurement of lifetimes, essential elements of radioprotection, absorption of radiation in various materials, excitation of fluorescence radiation, influence of magnetic fields on beta radiation as well as on electrons emitted from a typical electron gun, Compton scattering and elements of gamma spectroscopy, search for radioactive pollutions etc. Three experiments were modernized to enable them to be conducted over the Internet. This project is a bit delayed but should be finished by the end of April 2009.

For the third time the Department organized (together with the Institute of Physics of the Polish Academy of Sciences, Warsaw) “The Physical Pathways” competition for secondary school students. The students could choose one of three possibilities (even all of them): either to submit a scientific paper, to present a demonstration of a physical phenomenon, or to write an essay on the connection between physics and the development of civilization. They could also submit work prepared by a team of up to three persons. The level of the competition turned out to be very high. Its particular value consists in activating teachers and pupils from small villages and towns. Two laureates of the Competition, as a special Prize, could spend two weeks at the Joint Institute of Nuclear Research in Dubna, Russia, within the framework of the Bogolubov-Infeld program.

The Department participates actively in Science Festivals and Picnics for the general public. In all these events, in addition to the series of lectures, many simple demonstrations of the properties of nuclear radiation as well as a simulator of a nuclear reactor control were presented.

The staff of the Department was strengthened in 2008 by employing MSc. Eng. Łukasz Adamowski and a PhD student, MSc. Eng. Krzysztof Wojciech Fornalski.
PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk
Oddziaływanie małych dawek promieniowania elektrowni jądrowej na otoczenie w czasie normalnej pracy
L. Dobrzyński
Krajowa Konferencja Renesans Energetyki Jądrowej 2008 pod hasłem "Ekologiczne aspekty eksploatacji elektrowni jądrowej"
(Kielce, Poland, 2008-03-04 - 2008-03-04)
Spektrum Vol. styczeń (2008) XII

Poster
Ionizing radiation and health of nuclear installations workers
K. Fornalski, L. Dobrzyński
LOWRAD 2008 (Lisbon, Portugal, 2008-11-27 - 2008-11-29)
Int. J.Low Rad. (in press)

DIDACTIC ACTIVITY

L. Adamowski - Give lectures for people who visit DSiD IPJ
L. Dobrzyński - Course on "Physics of Magnetic Materials"
L. Dobrzyński - Introduction to physics
E. Droste - Give lectures for people who visit IPJ
E. Droste - Participation in educational activity (lectures, classes) in Department of Training and Consulting
T. Ostrowski - Give lectures for people who visit DSiD
R. Wolkiewicz - Give lectures for people who visit IPJ
R. Wolkiewicz - Participation in educational activity (lectures, classes) in Department of Training and Consulting

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

L. Dobrzyński
member
Physica Scripta, Institute of Physics
Chairman of the Scientific Council of the Institute of Experimental Physics fo the University of Białystok
Member of the Scientific Council of the Andrzej Soltan Institute for Nuclear Studies
Chairman of the Committee on Nuclear Methods in Condensed Matter Physics of the Council for Atomic Energy Matters
Adviser of the Polish Delegation to UNSCEAR
Institute of Nuclear Energy
Institute of Atomic Energy, Świerk
E.Droste member of the Polish Physical Society

PERSONNEL

Research scientists
Łukasz Adamowski, MSc Eng
Ludwik Dobrzyński, Professor, Director of the Department
Ewa Droste, MSc.
Krzysztof Wojciech Fornalski, MSc Eng., PhD student

Technical and administrative staff
Tadeusz Ostrowski
Robert Wolkiewicz
Urszula Kalińska

* part-time employee
Overview

The main activities of the Department for Nuclear Equipment High Technology Centre in 2008 were focused on the development of specialized systems using linear accelerators for medical applications, realized within the frame of the Innovative Economy Operational Program:

- Calculations, simulations and design of accelerator structures and beam shaping devices
- Design of a model of carrying structures
- Building stands for carrying out critical component examinations and tests

A new evolutionary algorithm has been implemented in a three-dimensional treatment planning system for intensity modulated radiotherapy (IMRT) planning optimization.

A design for a multi leaf collimator, second model, was worked out.

The Department received an Award for the Polkam TBI therapeutic table in the first edition of the “Teraz-Polska” national contest for the best Polish innovative product.

Equipment manufactured by the High Technology Centre and especially for total body irradiation techniques was presented for the first time during the Biennial Meeting of the European Society for Therapeutic Radiology and Oncology in Göteborg, Sweden.

The second edition of the School of Medical Accelerator Physics organized in October 2008 was well received by medical physicists and physicians.

Jan Kopeć
Deputy Head of Dept.
III. REPORTS ON RESEARCH

- ASTROPHYSICS, COSMIC RAYS & ELEMENTARY PARTICLE PHYSICS

- NUCLEAR PHYSICS

- PLASMA PHYSICS & TECHNOLOGY

- DETECTORS, ACCELERATORS, PHYSICS OF MATERIALS & APPLICATIONS
Prompt Optical Observation of the GRB 080319B by the „Pi of the Sky” Detector
by M.Sokołowski, T.Batsch, A.Majcher, A.Majczyna, K.Nawrocki, D.Rybka, J.Użycki and G.Wrochna*

Introduction
The „Pi of the Sky” experiment [1,2] is a system designed to investigate short timescale phenomena in the sky. The main purpose of the experiment is to observe prompt optical emission from Gamma Ray Bursts (GRBs) [3,4]. The GRBs are short (0.1 – 100 s) pulses of gamma radiation coming from point sources in the sky. They are observed in γ-rays by satellites orbiting the Earth. These extragalactic events are the strongest explosions observed in the Universe with energies exceeding $10^5$ ergs. The mechanism powering these extreme events is not yet well understood. Current theories describe long bursts ($T_{90}>2$ s) as a collapse of a very massive star to a black hole, in a so called hypernova scenario [5]. Short bursts ($T_{90} < 2$ s) are described as a coalescence of two compact objects (neutron stars or black holes) in a binary system. Understanding and modeling of GRBs requires multiwavelength observations, which are very difficult because it is impossible to predict when and where the next GRB will occur. This implies a time delay between γ-ray detection and observations in other wavelengths. Optical observations are especially important and most crucial are optical data from the early phase of the event. The current strategy is based on the Gamma ray bursts Coordinates Network (GCN) [6] which passes information about the burst (position and time) to registered ground based observatories as soon as possible. A time delay is inevitable and typically, early optical observations begin several dozens of seconds after the gamma-ray detection. Despite the fact that GRBs were discovered more than forty years ago, there have been only a few events where the optical counterpart was serendipitously observed during the gamma-ray emission phase [7,8].

“Pi of the Sky” system
The „Pi of the Sky” is a system of wide field cameras, designed for early observation of the optical counterparts of GRBs. The final design will consist of two sets of 16 cameras of 20° x 20° field of view [2]. Each set will cover ~1/6 of the sky, which will correspond to the field of view (FOV) of the Swift satellite [9]. Such a system ensures that every GRB detected by the Swift satellite and in the range of the telescope will be observed before, during and after the burst. The final system is currently under construction. It has been estimated that it should allow 1-2 positive detections of an early optical signal from GRBs per year.

Prototype in LCO
The prototype of the system was successfully installed in Las Campanas Observatory (LCO) in Chile in June 2004 [1]. It consists of two CCD cameras equipped with CANON EF f=85 mm, f/d=1.2 photo lenses, FOV~20° x 20°. The cameras work in coincidence. The prototype follows the center of the FOV of the Swift satellite, reacts to GCN alerts and analyses the sky images in real time in search of short optical transients.

On March 19, 2009 at 06:12:49 Universal Time the BAT detector onboard the Swift satellite [10] was triggered by an intense pulse of gamma rays from GRB 080319B [11]. The BAT localization distributed over the GCN at 06:13:06 was received by the “Pi of the Sky” system, while the follow-up of a previous alert (GRB 080319A) was still in progress. The angular distance of GRB 080319B from the position of GRB 080319A was $\alpha \approx 11.76^\circ$, which was small enough to catch GRB 080319B in the relatively large FOV of the telescope. The “Pi of the Sky” telescope had observed the area of interest for 23 min 33 sec before the burst. The first exposure on which an optical signal from GRB 080319B was detected started at 06:12:47 Universal Time, two seconds before the GRB was detected by the BAT. A very bright optical flash was automatically detected by the on-line algorithm searching for short optical transients.

The optical signal was bright enough to be observed by the "Pi of the Sky" telescope for the next 4 minutes (Fig. 1), after that time it faded below the limiting magnitude of the system [12].

Fig. 1 Optical counterpart of GRB 080319B, left image with very bright optical signal in the center (taken at 06:14:03 UT) and right image without optical transient (taken 10 minutes after the burst)
The maximum brightness of the optical transient reached 5.3\textsuperscript{m} which means that the event which occurred at a distance of almost 7.5 billion light years would have been visible to the naked-eye. The optical flux was normalized to V filter magnitude of the neighboring stars using the procedure described in [13].

Fig. 2 Optical light curve of GRB 080319B measured by the "Pi of the Sky" prototype, points are centered in central time of the exposure and the 10 s error bars corresponds to the exposure time.

Fig. 3 Early optical measurements by "Pi of the Sky" and TORTORA with $\gamma$-ray light curve superimposed

The optical lightcurve is shown in Figure 2. Observation of GRB 080319B confirms strongly that wide field cameras are the best and probably the only effective way for observations of prompt optical signals. The unprecedented coverage of the optical lighcurve was the key to understanding the physics of the event. The results of multiwavelength analysis of GRB 080319B show that early optical observations can have a very significant impact on the modeling of these phenomena [14].

As may be seen in Figure 3, the optical signal starts and ends at the same moment as the gamma emission. This proves that the optical signal is produced in the same region as the gamma rays. On the other hand, the optical flux is 3-4 orders of magnitude higher than that of the gamma ray spectrum extrapolated to the optical region, suggesting different production mechanisms. Even an observation of one single GRB can have a large influence on the existing models of these mysterious events [14]. This demonstrates how much understanding GRB of suffers from the lack of early optical data. The final "Pi of the Sky" will hopefully be able to provide much more such data.


Galaxies and the Large Scale Structure of the Universe: from VVDS (VIMOS-VLT Deep Survey) to VIPERS (VIMOS Public Extragalactic Redshift Survey)

by A.Pollo, for the VVDS and VIPERS collaborations

The VIMOS-VLT Deep Survey (VVDS) is a spectroscopic cosmological survey, one of the largest existing today. It now includes more than 40,000 spectra in five fields of the sky, gathered by the VIMOS spectrograph installed at the European Southern Observatory Very Large Telescope. The data reduction of VVDS is almost complete but the scientific analysis is still on-going.

Last year, a large part of the data from the Wide fields of the VVDS [1, 2], as well as the K-band follow-up data for the Deep field [3], were made public.

The scientific outcome of these data, published in 2008, includes 1) the analysis of galaxy mass assembly back to z~1.3 [4]; 2) the analysis of galaxy properties from the multiwavelength photometric data [5]; 3) the discovery of a significant population of faint Active Galactic Nuclei (AGNs), probably in the decaying phase of activity, at 1<z<4.3 [6].

Particularly interesting subjects are related to the structure formation and evolution of clustering of galaxies. Our latest work includes the reconstruction of three-dimensional density fluctuation maps up to z~1.5 and the measurement of the evolution of the probability distribution function over the redshift interval 0.7< z<1.5 [7], as well as the analysis of the dependence of the clustering properties of galaxies on their stellar mass content [8].

In the latter work, we found that at z~1, galaxies with a high stellar mass content, similarly to galaxies of high absolute luminosity [9], are clustered more strongly on small scales than their counterparts today. Together with our recent finding that luminous galaxies with low stellar mass are less clustered on small scales than massive luminous galaxies, this leads to the conclusion that the luminosity history of a galaxy may depend not only on its mass but also on its position in the dark matter halo [11].

What gathered a wide interest was a test of the nature of cosmic acceleration using galaxy redshift distortions measured from one of the VVDS-Wide fields [12]. Observations of distant supernovae indicate that our Universe is presently in a phase of accelerated expansion. However, the physical cause is still unknown: it may be related to some exotic form of energy (a classical “cosmological constant”), but alternative explanations require modifications of the general relativity theory. Luckily, different models predict measurable differences in the growth rate of the large-scale structure with cosmic time, and this can be read from the radial anisotropy in the clustering pattern of the galaxy distribution. Our first measurement of this effect at z~0.8 proved to be consistent with the standard cosmological constant model (Fig. 1). The amount of data in the VVDS is still insufficient to make conclusive statements but simulations suggest that a further factor-of-ten increase in the sampled volume at similar redshift should be sufficient for determination of the correct origin of the cosmic expansion.

Fig. 1 The measurement of the evolution of the growth rate function as a test of the nature of a cosmic expansion (from Guzzo et al., 2008, Nature).

Consequently, in 2008 with a group of authors we submitted a proposal to ESO to conduct the largest ever spectroscopic galaxy survey, aiming to measure ~10^6 galaxy spectra at z~1 in a contiguous area 24 deg^2. The proposal has been accepted and the project received the name VIPERS (VIMOS Public Extragalactic Redshift Survey). The first spectroscopic observations are now ongoing and in a few years we can expect exciting new results.

EAS Measurements of Giant Surface Arrays and GZK Cut-off Prediction
by J.N.Capdevielle, F.Cohen, B.Szabelska, J.Szabelski

The Greisen-Zatsepin-Kuzmin (GZK) cut-off effect seems to be one of the best understood physical features in the highest energy cosmic rays (CR). Observations, of how strongly the predicted cut-off is present in the highest energy cosmic ray spectrum, would have important consequences for studying the origin of high energy particles. However, since 2001 a discrepancy in the determination of the primary energy spectrum above 1019 eV between the HiRes and AGASA experiments, which puts forward the question of the presence of the GZK cut-off.

HiRes experiment is observing atmospheric fluorescence and can register complete EAS (extensive air shower) longitudinal development. The HiRes experiment CR energy spectrum clearly indicates the existence of the GZK cut-off.

AGASA was a very large surface EAS array of about 100 km² area. AGASA registered several CR events with energies above the GZK energy cut-off and their CR energy spectrum contradicts the observation of the GZK cut-off.

In 2001, HiRes and AGASA were the largest experiments with the highest statistics of EAS events at the GZK cut-off energy range. Now, results the Pierre Auger Observatory (PAO) show the energy spectrum with GZK cut-off feature.

We have found that in the highest energy part of the spectrum the energies of many AGASA events were overestimated due to bad treatment of inclined showers. For a large surface detector array (like AGASA) the EAS energy is evaluated from the estimated vertical shower particle density S at a given distance from the EAS core, 600 m for AGASA - S600(0). For real showers at the zenith angle θ particle density S600(0) at 600 m was estimated from the core localization procedure and lateral distribution with agreement with particle densities measured by array detectors at different distances. AGASA used the conversion [1]: S600(0) = S600(θ)*exp[(-sec(θ)-1)0/A1-(sec(θ)-1)20/2], where A1=500 g/cm², A2=594 g/cm², and 0=920 g/cm² (AGASA vertical depth). We have shown that this formula is not valid above 1019eV [2].

The conversion formula essentially describes the EAS development at depths larger than the position of maximum development (larger inclination means longer path). Exponential fall off is a standard description of cascade decay far above maximum development. However, for energies higher than 1019eV, observations made near to the maximum of the EAS development (see Fig. 1) and using exponential fall off lead to energy overestimation up to a factor of 2 (see Fig. 2). We have performed large number of Monte Carlo EAS simulations to find the range (max/min) of the proper conversions of S600(θ) to S600(0).

Table 1 shows examples of the highest energy AGASA events with original and corrected energies.

<table>
<thead>
<tr>
<th>Date</th>
<th>θ</th>
<th>E_AGASA</th>
<th>E_min</th>
<th>E_max</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993/01/21</td>
<td>39</td>
<td>1.01</td>
<td>0.540</td>
<td>0.669</td>
</tr>
<tr>
<td>1993/12/03</td>
<td>22</td>
<td>2.13</td>
<td>1.649</td>
<td>1.711</td>
</tr>
<tr>
<td>1994/07/06</td>
<td>36</td>
<td>1.34</td>
<td>0.769</td>
<td>0.896</td>
</tr>
<tr>
<td>1996/01/11</td>
<td>14</td>
<td>1.44</td>
<td>1.307</td>
<td>1.323</td>
</tr>
<tr>
<td>1996/10/22</td>
<td>24</td>
<td>1.05</td>
<td>0.640</td>
<td>0.733</td>
</tr>
<tr>
<td>1997/03/30</td>
<td>34</td>
<td>1.50</td>
<td>0.704</td>
<td>0.926</td>
</tr>
<tr>
<td>1998/06/12</td>
<td>27</td>
<td>1.20</td>
<td>0.862</td>
<td>0.921</td>
</tr>
<tr>
<td>1999/09/22</td>
<td>35</td>
<td>1.04</td>
<td>0.613</td>
<td>0.714</td>
</tr>
<tr>
<td>2001/04/30</td>
<td>24</td>
<td>1.22</td>
<td>0.934</td>
<td>0.980</td>
</tr>
<tr>
<td>2001/05/10</td>
<td>37</td>
<td>2.46</td>
<td>1.316</td>
<td>1.533</td>
</tr>
<tr>
<td>2002/04/09</td>
<td>22</td>
<td>1.21</td>
<td>0.960</td>
<td>0.999</td>
</tr>
</tbody>
</table>


1) APC - Astroparticles et Cosmologie, Univ. de Paris, 75205 Paris, France
Neutron Background Measurements at the Gran Sasso Laboratory

We have used a set of proportional counters filled with $^3$He to measure the neutron background flux in the deep underground Gran Sasso National Laboratory (LNGS).

The interpretation of signals from cold dark matter or other rare processes detectors placed in deep underground laboratories is strongly limited by the existing neutron background, which is hard to eliminate. Measurements of the neutron flux and energy spectrum would help to improve methods of reduction of the unwanted background.

The Gran Sasso laboratory is placed in a motorway tunnel under 1400 m of rock, where the cosmic muon flux is equal to $1/(m^2 \cdot h)$.

In the helium counter thermal neutrons are registered due to the reaction: $^3\text{He}(n,p)^3\text{H}+764 \text{ keV}$ with cross section inversely proportional to the neutron velocity. In about 60% of events the reaction products, proton and triton, leave all their kinetic energy inside the counter. The amplitude distribution of other events shows the characteristic “wall effect” [1,2] with energy limits 191 keV and 573 keV shown in Fig. 1.

The idea of observing low-level neutron flux is to see the neutron peak at 764 keV above the background level due to $\alpha$ particles emitted inside the detector.

In our measurements, we used the set of 16 helium counters made in ZDĄJ about 20 years ago. Counters consist of steel tubes of 2.5 cm diameter and 50 cm, filled with 4 atm of $^3$He gas and 0.5 atm of krypton (stopping gas). We used our self-made preamplifiers. Signals were registered to 8 FADC channels of 1 byte amplitude, sampling with a rate of 10 MHz.

We made two major series of registrations in the LNGS underground laboratory: one for measurements of thermal neutron flux density and the second for energetic neutron measurements.

The thermal neutron flux measurements we made in two runs. The first run with a large exposure lasted one week and all 16 counters were arranged in line. The second run lasted 10 days and the counters were arranged in two circles partially shielding each other (i.e. the $^3$He gas also had played the role of an absorber). The two setups allowed for cross checking of GEANT4 simulations. From a comparison of neutron counting rates with GEANT4 simulations we obtained the flux density equal to $(5.4\pm1.3)\times10^{-7}$ neutrons/(cm$^2$s). Fig. 3 shows a summary of LNGS neutron background measurements.

Measurements of energetic neutrons were made in October/November 2008. The helium counters were placed inside polyethylene moderator blocks with cadmium sheets. Analysis of the results is in progress.

The authors thank Dr. Wojciech Starosta for the $^3$He neutron counters and Dr. Stanisław Pszona for the AmBe source and valuable discussions.

This work was supported by ILIAS (EU contract RII3-CT-2004-506222) as ILIAS-TA project P2007-12-LNGS, and by IPJ, Poland.

Newest Results from The KASCADE-Grande Experiment
by J.Zabierowski and P.Luczak

The KASCADE-Grande experiment [1], located on site of the Forschungszentrum Karlsruhe in Germany, is a multi-detector extensive air shower (EAS) array. It combines the electron and muon detectors of the KASCADE array [2], a hadron calorimeter, Muon Tracking Detector [3] and an array of 37 scintillators (10 m² each) spread over 0.5 km². Its purpose is to study cosmic rays in the energy range $10^{14.5}$-$10^{18}$ eV and to find an explanation of the “knee” feature in the cosmic ray spectrum, as well as the energy region of the conjectured transition between galactic and extra-galactic cosmic rays.

In 2005, using the unfolding method, for the first time the energy spectra for five elemental groups of cosmic rays were reconstructed out of KASCADE data [4]. It was shown that the “knee” at 3-5 PeV is caused by the steepening in the light element spectra and that none of the two hadronic interaction models used was able to describe the experimental data in a consistent way over the whole investigated energy range. This result, in agreement with findings of other experiments, had immediate impact on the views on acceleration and propagation mechanisms of cosmic rays [5].

Currently, the properties of the models and not the understanding of the KASCADE data are limiting the analysis of air shower data. Therefore, testing the models by means of various EAS parameters is a very important part of KASCADE-Grande activity.

In a recent update of the analysis [6] we applied the unfolding method with a different low-energy interaction model (FLUKA instead of GHEISHA) in the simulations. While the resulting individual mass group spectra (Fig. 1) do not change significantly, the overall description of the data improves. In addition, data a larger range of zenith angles were analyzed. The new results are completely consistent, i.e. there is no hint of any severe problem in applying the unfolding analysis method to KASCADE data.

The successful continuous operation of KASCADE-Grande and accumulation of data on showers above $10^{17}$ eV will soon allow us to apply the unfolding method to this energy region and, hopefully, answer the questions about the energy spectrum there [7].

Exploiting the possibility given by KASCADE data, correlations of various observables are used for detailed consistency tests of hadronic interaction models. Recently [8], predictions of air shower simulations using the EPOS 1.61 model have been investigated, revealing that the predictions of EPOS are not compatible with KASCADE measurements. Most likely, EPOS does not deliver enough hadronic energy to the observation level and the energy per hadron seems to be too small. By that, the number of particles at ground are shifted to lower electron and higher muon numbers relative, e.g. to QGSJet, resulting in the reconstruction of the mass of cosmic rays with a much lighter composition.

EAS measured by KASCADE-Grande have been studied with respect to the arrival times of electrons and muons at the observation level [9]. It has been shown that for core distances > 200 m particles of the muonic shower component arrive, on average, earlier than particles of the electromagnetic component. The difference increases with the core distance from $\Delta(t) = (12.9 \pm 0.2)$ ns at $R > 200$ m to $\Delta(t) = (47 \pm 1)$ ns at $R = 500$ m, where the widths of the muonic and electromagnetic shower disks are comparable. This difference in arrival time is used to separate the electrons and muons dependent on the distance from the shower center. The potential of the method evolves with increasing distance to the shower core and it is thus especially interesting for large EAS arrays.
A.Haungs et al., Nucl. Phys B (Proc. Suppl.) in int, BDN 1137
BDN 1161
BDN 746
Progress in Understanding Radio Pulses from Extensive Air Showers with LOPES
by J. Zabierowski and P. Łuczak

The main goals of the LOPES project [1] are the investigation of the relation between the radio emission from extensive air showers with the properties of the primary particles and the development of a robust, autonomous, and self triggering antenna set-up usable for large scale applications of the radio detection technique [2-4]. In addition, within the framework of LOPES a detailed Monte-Carlo simulation program package is being developed.

We report here on two recently published results from LOPES, where the emphasis is put on the investigation of signal characteristics, namely it is the frequency spectrum [5], and the correlation of registered radio signals with the arrival direction of the primary cosmic ray particle [6].

In [5] the results of the spectral dependence of the radio emission from cosmic-ray air showers around $10^{17}$eV were shown. Short radio pulses were observed in a broad frequency band with the dipole-interferometer LOPES, triggered by particle detector array KASCADE. For the analysis, 23 strong air shower events were selected using parameters from KASCADE. The radio data were digitally beam-formed before the spectra were determined by sub-band filtering and fast Fourier transformation.

![Fig. 1 Comparison of average cosmic-ray electric field spectra obtained with 23 LOPES events by two different methods fitted with one exponential (dashed line) [5].](image)

As demonstrated in Fig. 1, the resulting electric field spectra fall off to higher frequencies. An average electric field spectrum can be fitted with a single exponential. For the analyzed sample, we have not found any significant dependence of the spectral slope on the electric field amplitude, the azimuth angle, the zenith angle, the curvature radius, nor on the average distance of the antennae from the shower core position.

We have shown with two different methods that frequency spectra from air shower radio emission can be reconstructed, on an event-by-event basis, with only two dozen dipole antennae simultaneously over a broad range of frequencies. According to the spectral slopes obtained, maximum power is emitted below 40 MHz. Furthermore, the decrease in power to higher frequencies indicates a loss in coherence determined by the shower disk thickness. Therefore, a broader bandwidth, larger collecting area, and longer baselines, as will be provided by LOFAR, are necessary to further investigate the relation of the coherence, pulse length, and spectral slope of cosmic ray air showers.

The second paper [6] is devoted to studies of the geometry of the air shower radio emission measured with LOPES and to the search for systematic effects between the direction determined on the radio signal and the direction provided by the particle detector array KASCADE.

We have found that maximum radio emission is obtained for curvature radii larger than 3 km, and that the direction of the emission maximum can change when optimizing the curvature radius. This dependence dominates the statistical uncertainty for the direction determination with LOPES. Furthermore, we found a tentative increase of the curvature radius to lower elevations, where the air showers pass through a larger atmospheric depth. The distribution of the offsets between the directions of both experiments is found to decrease linearly with increasing signal-to-noise ratio. Significantly, increased offsets and enhanced signal strengths were found in events, which were modified by strong electric fields in thunderstorm clouds.

We conclude that the angular resolution of LOPES is sufficient to determine the direction, which maximizes the observed electric field amplitude. However, the statistical uncertainty of the direction is not determined by the resolution of LOPES, but by the uncertainty of the curvature radius. We did not find any systematic deviations between the directions determined from the radio signal and from the detected particles.

This result places a strong supportive argument for the use of the radio technique to study the origin of high-energy cosmic rays.

The LHC proton-proton accelerator at CERN in Geneva entered its final construction stage in 2008. The first single beams were injected in September and experimenters awaited beam-beam collisions when an unexpected magnet failure delayed the machine commissioning by at least one year.

The CMS experiment was ready to take data with most of its parts installed and tested. The Warsaw CMS group, consisting of participants from the Institute of Nuclear Studies, Physics Department of Warsaw University and Warsaw University of Technology, performed the final installation of the muon trigger system based on Resistive Plate Chambers. About 80% of the triggering system components were present with the exception of one of the endcap regions, which are currently being installed. The system consists of 12 Trigger Crates housing 108 Trigger Boards, three Sorter Crates and about 700 Link Boards used to transfer data from about 2300 chambers to the electronics through optical fibers. During 2008, several runs using cosmic ray muons to test the performance of the whole detector were undertaken and have shown that its functioning was satisfactory. The runs were especially useful to establish the relative timing of detector elements. During the first days of operation we were able to register muon tracks originating from the LHC beams dumped upstream from CMS.

The patterns of RPC hits used to trigger with the cosmic rays were prepared and used. The cosmic tracks trigger rate from our system was about 150 Hz. We have noted that an important noise in the RPC’s was related to the switching on of big lamps in the experimental cavern giving rise to momentary peaks in the trigger rate. The noise question is currently under study.

We continued work on the preparation of diagnostic software used to monitor the system performance on- and off-line.

We also participate in the simulation of physical processes, which may be registered by our experiment and which are predicted by various extensions of the Standard Model. One of the subjects under study concerns the analysis of the possibility of distinguishing muons moving upwards through the detector based on the timing information of their arrival times at various detector parts. Such tracks could signal the presence of neutrino interactions below CMS in the surrounding rock or decay of heavy particles produced in pp collisions and stopped beyond the detector. An example of a muon track traversing the whole of the CMS is shown in Fig. 1.

We are now well prepared to start data taking in the autumn of 2009 when the LHC starts delivering p+p interactions.

![Fig. 1 An example of a cosmic muon event seen by the CMS.](image)

Electron-positron Pair Production from Decays of $\eta$ Mesons

by M.Berłowski, J.Stepaniak, J.Zabierowski, W.Augustyniak, A.Trzcinek, P.Żuprański (for the WASA Collaboration)

The WASA experiment is at present being carried out at the storage ring COSY in Jülich (Germany) in a collaboration of 25 institutions from 6 countries. The WASA detector was moved from the CELSIUS accelerator located in Uppsala (Sweden). The scientific activity of the collaboration comprises a broad research program, to investigate the decays of light mesons $\eta$ and $\eta'$, to search for a breaking of the fundamental C and CP symmetries in flavor conserving interactions, and to test the applicability of chiral perturbation theory. Other aspects of hadron physics will also be studied.

The WASA detector is particularly well suited to perform such measurements. A more comprehensive view of the WASA detector (Fig. 1) can be found in Ref. [1]. The thin windowless proton or deuteron internal pellet target and the possibility to measure electrons, pions and photons with the same apparatus provide a very good opportunity to detect $\eta$ electromagnetic decays and minimize the background due to external photon conversion.

We studied the decays of the $\eta$ meson, which involves emission of electron-positron pairs. Such decays may provide a sensitive test of C and CP invariance and provide information on the meson form factors.

The $\eta$ mesons were produced in pp and pd interactions at energies of 20-50 MeV above the $pp \rightarrow pp\eta$ or $pd \rightarrow H\eta$ reaction threshold to provide an effective tagging of the two outgoing particles (protons) or the helium nucleus emitted at angles smaller than about 18 degrees for both reactions. The first results based on the 300 thousand eta mesons from pd interactions at 893 MeV proton incident energy were published in [2]. We measured the branching ratio for $\eta \rightarrow e^+ e^- \gamma$ and put a new limit on the branching ratio of the rare $\eta \rightarrow \mu^+ \mu^- \mu^+ \mu^-$, $\eta \rightarrow e^+ e^-$, and $\eta \rightarrow e^+ e^- e^+ e^-$ decays (An example of this decay channel candidate can be found in Fig. 2).

![Event display for $\eta \rightarrow e^+ e^- e^+ e^-$ event candidate.](image)

Much larger statistics have now been collected both in pp and pd interactions and the data are being analyzed. The first publication based on data collected in this period is devoted to $\eta \rightarrow \pi^+ \pi^- \pi^-$ decay and can be found in [3].

Neutrino Group Activity in 2008

ICARUS
The ICARUS Collaboration runs a large Liquid Argon Time Projection Chamber located in the Gran Sasso underground laboratory, Italy. This detector (T600) consists of two 300 t tanks of LAr. It will be irradiated by the neutrino beam produced at CERN at a distance of 735 km. The neutrino argon interactions will be measured. The liquid argon technique is very new and to understand its performance several tests are necessary. One of them is the electromagnetic energy reconstruction. The reconstruction of electromagnetic shower energy in ICARUS was analyzed through the reconstruction of events coming from the pizero recorded in the 2001 Pavia surface test run. The $(\gamma, \gamma)$ invariant mass was found to be consistent with the value of the pizero mass with an energy resolution of 16.1%.

The results are presented in the article: arXiv:0812.2373v1 [hep-ex]. Title: "Energy reconstruction of electromagnetic showers from pizero decays with the ICARUS T600 Liquid Argon TPC" which is being prepared for publication (10 Authors from IPJ: P1503).

ND280
The ND280 Collaboration is constructing the Near Detector in the T2K- from Tokai to Kamioka which is the next generation long baseline neutrino oscillation experiment. The neutrino beam will be produced by the Japanese J PARC accelerator in Tokai. This beam will be directed to the Super Kamiokande detector at 295 km distance. The Near Detector at 280 m (ND280) from the target will control the neutrino beam in the T2K experiment. ND280 consists of several subdetectors. We participate in the construction of the Side Muon Range Detector.

1. Work on the calibration of ND280
   a) Trigger of the ND280: The elements of ND280 detectors, once in the magnet, should be calibrated with relativistic cosmic muons. The trigger will be based on signals from the Side Muon Range Detector counters (SMRD). Calculations of the trigger rates were carried out with the Monte Carlo Geant 4 code. They were performed for the SMRD and for SMRD in coincidence with the pizero detector and the upstream electromagnetic detector. Optimal configurations were chosen. Measurements of trigger rates and calibration of the subdetectors of ND280 will be carried out once all the elements of ND280 are in place and the magnet is closed (beginning of 2010?).
   b) MPPC properties: The signals of the SMRD counters will be read by Multi Pixel Photon Counters (MPPC). Tests of a large number of MPPCs are being performed by the Warsaw Technical University. Our group participated in the software part of this work: simulation of the MPPC and data acquisition programs.

2. Electronics tests of final modules of the front end electronics for SMRD were performed by our PhD student in Tokai.

3. Background studies:
   An important goal of the T2K experiment will be the measurement of the oscillation parameter known as theta 1-3. For its measurement based on the analysis of muon neutrino into electron neutrino oscillations in Super Kamiokande a knowledge of the background from pizero production by muon neutrinos is crucial. Several Monte Carlo codes describe this process. To choose the most reliable code a careful comparison of the predictions of existing codes with available data was performed.

   We collaborate with Institute of Nuclear Physics PAN Cracow, Silesia University, Warsaw Technical University, and Warsaw University.
Spin Density Matrix Elements in Exclusive $\rho^0$ Electroproduction on $^1\text{H}$ and $^2\text{H}$ Targets*

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

In leptoproduction of $\rho^0$ vector mesons, the spin transfer from the virtual photon to the vector meson is commonly described by the helicity amplitudes $T_{\lambda \lambda'}$ defined in the “hadronic” center-of-mass system of the virtual photon and target nucleon. The helicity indices $\lambda$ and $\lambda'$ describe the spin state of the virtual photon and the $\rho$ meson, respectively. The $\rho^0$-spin-density matrix is obtained as a convolution of the helicity amplitudes with the photon spin-density matrix. Because in this experiment the contributions from longitudinal and transverse photons cannot be disentangled only the combination of the $\rho^0$ spin-density matrix elements can be determined directly. These combinations are generally referred to as the Spin Density Matrix Elements (SDMEs). The SDMEs are labeled in the following way: $r_{\lambda \lambda'}$, where $\lambda = 1, 2, \ldots, 8$ denotes the polarization state of the virtual photon and $\lambda'$ the polarization state of the $\rho^0$ meson. To be more specific, $\lambda=0$ refers to an unpolarized photon, $\lambda=1, 2, 3, 4$ to linear and circular polarization states and $\lambda=5, 6, 7, 8$ to interference terms. The values of the SDMEs serve to establish the hierarchy of helicity amplitudes. In this way the relative importance of the various $\gamma^* \rightarrow \rho^0$ transitions is revealed. Two main ordering principles are observed in vector meson leptoproduction, s-channel helicity conservation (SCHC) and the dominance of natural parity exchange (NPE) over the unnatural parity exchange (UPE) mechanism. We present the final results of the SDME measurements at HERMES in the years 1996-2005. (arXiv:0901.0701)

In Fig. 1 the SDMEs are shown multiplied by certain factors in order to allow their comparison at the level of dominant amplitudes.

The presentation of the extracted SDMEs is based on a hierarchy of Natural Parity Exchange (NPE) helicity amplitudes: $|T_{00}|>|T_{11}|>|T_{10}||T_{01}|$. The 23 extracted SDMEs are categorized into five classes according to the hierarchy shown above. Class A comprises SDMEs dominated by the helicity conserving amplitudes $T_{00}$, $T_{11}$ which describe the transitions $\gamma^*_L \rightarrow \rho^0_L$ and $\gamma^*_T \rightarrow \rho^0_T$, respectively. Class B contains SDMEs that correspond to the interference of the above two amplitudes. Class C consists of all those SDMEs in which the main term contains a contribution linear in the s-channel helicity non-conserving amplitude $T_{10}$, corresponding to the $\gamma^*_T \rightarrow \rho^0_L$ transition, except for a term involving $T_{00}$ for which the $T_{01}$ contributions is quadratic. Classes D and E are composed of the SDMEs in which the main term contains a contribution linear in the small helicity-flip amplitudes $T_{01}$ ($\gamma^*_L \rightarrow \rho^0_T$) and $T_{10}$ ($\gamma^*_T \rightarrow \rho^0_L$), respectively. For all classes numerical factors are chosen in such a way that the coefficient of the dominant terms is equal to unity. It can be easily seen from Fig.1 that two polarized SDME of class B have large values, similar to those of class A. This suggests the presence of substantial interference of the two dominant amplitudes $T_{00}$ and $T_{11}$. It is also seen that the values of the elements of class C that contain the dominant term $T_{01} T^*_0$ are similar for the unpolarized SDMEs ($\text{Re}\{r_{04}^0\}$, $\bar{r}_{10}$). Those unpolarized class C elements measured with good accuracy, $\langle\text{Im}\{r_{04}^0\}, \bar{r}_{10}\rangle$ are much smaller than the class B SDMEs, whereas the unpolarized class C elements are much larger than the unpolarized class D and class E SDMEs. This shows that the anticipated hierarchy is supported by the data.

Fig. 1 The 23 SDMEs extracted from $\rho^0$ data: proton (squares) and deuteron (circles) in the entire HERMES kinematics with $<x>=0.08$, $<Q^2>=1.95$ GeV$^2$, $<-t'>=0.13$ GeV$^2$. The SDMEs are multiplied by prefactors in order to represent the normalized leading contribution of the corresponding amplitude. The inner error bars represent the statistical uncertainties, while the outer ones indicate the statistical and systematic uncertainties added in quadrature. SDMEs measured with unpolarized (polarized) beam are displayed in the unshaded (shaded) areas. The vertical dashed line at zero is indicated for SDMEs expected to be zero under the hypothesis of SCHC.

* The HERMES collaboration comprises 32 institutions from 11 countries at the Deutsches Elektronen Synchrotron (DESY) in Hamburg.
The distribution of partons (quarks and gluons) in the nucleon is usually parameterized by the so-called Parton Distribution Functions (PDFs). These functions depend on a resolution scale $Q^2$ and $x_B$, which can be interpreted as the fraction of the nucleon momentum carried by a parton in the nucleon. No information about the transverse distribution of quarks and gluons is encoded in the PDFs. However, in the context of the rapid theoretical development of the last decade, PDFs have been conceptually subsumed within the broader framework of Generalized Parton Distributions (GPDs), which also describe elastic form factors and amplitudes for hard-exclusive reactions leaving the target nucleon intact. GPDs depend on the kinematic variables $x$ and $\xi$ which represent, respectively, the average and difference of the longitudinal momentum fraction of the probed parton in the initial and final states. GPDs also depend on the squared four-momentum transfer $t=(p-p')^2$ to the nucleon, with $p$ ($p'$) the four momentum of the nucleon in the initial (final) state. Strong interest in the GPD formalism has emerged after the moments of certain GPDs were found to relate directly to the total (including orbital) angular momenta carried by partons in the nucleon. This finding offers for the first time a path towards solving the 'nucleon spin puzzle' of how the helicities and orbital angular momenta of quarks and gluons combine to form the spin of the nucleon. Generalized Parton Distributions are accessible through exclusive processes that involve at least two hard vertices, yet leave the target nucleon intact. Among all presently practical hard exclusive probes, the Deeply Virtual Compton Scattering (DVCS) process, i.e. the hard exclusive leptoproduction of a real photon (e.g., $\gamma^*N \rightarrow \gamma'N'$), appears to have the most reliable interpretation in terms of GPDs.

In electroproduction, direct access to the DVCS amplitude $T_{DVCS}$ is provided by the interference between DVCS and the Bethe-Heitler (BH) processes, in which the photon is radiated from a quark and from the lepton, respectively. Since these processes are indistinguishable, the cross section is proportional to the squared photon-production amplitude written as $|T|^2 = |T_{DVCS}|^2 + |T_{BH}|^2 + 2T_{DVCS}^* T_{BH}$.

The BH amplitude $T_{BH}$ is precisely calculable from the measured elastic form factors of the nucleon and provides the dominant contribution in the kinematic conditions of the present experiment. These amplitudes depend on $Q^2$ = $-q^2$ with $q$ = $k-k'$ and $k(k')$ the four momentum of the lepton in the initial (final) state. In addition, the amplitudes depend on $\phi$ and, in the case of a target polarization component orthogonal to $q$, on $\phi_S$, the azimuthal angles about the virtual photon direction that are defined in Fig. 1.

A consequence of the DVCS-BH interference is a transverse target-spin asymmetry, i.e. the azimuthal distribution of the detected photons depends on the target polarization direction. An example of an asymmetry expected to predominantly show a $\sin(\phi-\phi_S)\cos\phi$ dependence on the interference term on the transverse target polarization. The curves are predictions with three different values for the u-quark total angular momentum $J_u$ and fixed d-quark angular momentum $J_d=0$.

A consequence of the DVCS-BH interference is a transverse target-spin asymmetry, i.e. the azimuthal distribution of the detected photons depends on the target polarisation direction. An example of an asymmetry expected to predominantly show a $\sin(\phi-\phi_S)\cos\phi$ dependence on the interference term on the transverse target polarization. The curves are predictions with three different values for the u-quark total angular momentum $J_u$ and fixed d-quark angular momentum $J_d=0$.

* The HERMES collaboration comprises 32 institutions from 11 countries at the Deutsches Elektronen Synchrotron (DESY) in Hamburg.
Measurement of Parton Distributions of Strange Quarks from Charged-kaon Production in Deep-inelastic Scattering on the Deuteron*  
by W.Augustyniak, B.Mariański, A.Trzciński, P.Zuprański

Parton distribution functions (PDFs) form the basis for the description of the flavor structure of the nucleon. The spin-averaged parton distribution functions $q(x)$, of quarks and antiquarks of flavors $q=\{u,d,s\}$, describe the quark momentum distributions, where $x$ is the dimensionless Bjorken scaling variable representing the momentum fraction carried by the parton in a frame where the target has “infinite” longitudinal momentum. They are the sums of the number densities of the quarks with the same and opposite helicity as that of the nucleon. The differences or helicity distributions, denoted here by $\Delta$, describe the flavor dependent contributions of the quark spins to the spin of the nucleon. The features of the parton distributions reflect the QCD dynamics of the constituents. Because strange quarks are objects which reflect directly properties of the nucleon sea, they are of special interest. Their distributions are also important because of their impact on quantitative calculations of certain key short-distance processes at hadron colliders, and their implications for the measurement of the Weinberg angle in deep-inelastic scattering (DIS) of neutrinos.

Much of the information on properties of the helicity distribution of strange quarks is based on the analysis of inclusive DIS and hyperon decay under the assumption of SU(3) symmetry among the structures of the octet baryons. Now for the first time the Hermes experiment has made a direct measurement of the strange quark PDFs. To probe the flavor of strangeness one detects, in coincidence with the scattered lepton, charged K mesons which contain strange and anti-strange quarks.

We report here on a new isoscalar extraction of $s(x)+\bar{s}(x)$ and $\Delta s(x)+\bar{s}(x)$ from polarized DIS on a deuteron target. The data were recorded with a longitudinally nuclear polarized gas target internal to the $E=27.6$ GeV HERA positron storage ring at DESY. The self-induced beam polarization was measured continuously by Compton back scattering of circularly polarized laser beams. The open-ended target cell was fed by an atomic-beam source based on Stern-Gerlach separation with hyperfine transitions. The nuclear polarization of the atoms was flipped at 90s time intervals, while both this polarization and the atomic fraction inside the target cell were continuously measured. The average value of the deuteron polarization was 0.845 with a fractional systematic uncertainty of 3.5%.

Scattered beam leptons and coincident hadrons were detected by the HERMES spectrometer. Leptons were identified with an efficiency exceeding 98% and a hadron contamination of less than 1%. A ring-imaging Cerenkov (RICH) detector was used to identify charged kaons. Events were selected subject to the kinematic requirements: $Q^2>1\text{GeV}^2$, $W^2>10\text{GeV}^2$ and $y<0.85$, where $-Q^2$ is the squared four momentum of the virtual photon, $W$ is the invariant mass of the photon-nucleon system, and $y=V/E$ with $V$ being the photon energy and $E$ the positron beam energy. The Bjorken $x$ range of measurement was $0.02-0.6$. The spin averaged PDFs for the strange quarks were determined from the shape and magnitude of the measured yield of charged kaons for the two beam-target polarization states. The results are presented in Fig. 1.

Fig. 1 The multiplicity (corrected for spectrometer acceptance) of charged kaons from a deuterium target, as a function of the Bjorken scaling variable $x$. The solid curve is the result of the HERMES analysis. The dashed (dash-dotted) curve is the nonstrange (strange) quark contribution to the multiplicity for this fit. The dotted curve is the best fit obtained using previously assumed strange quark PDFs. The error bars are statistical. The band represents the systematic uncertainties. The values of $(Q^2)$ for each $x$ bin are shown in the lower panel.

In the absence of experimental data for strange quarks it has been customary to assume that the shape of the strange quark PDFs is the average of that for the up and down quarks. Attempts to fit the HERMES data using this assumption (see dotted curve in Fig. 1) do not provide a reasonable fit to the observed multiplicity curve. However, by taking the strange quark PDF as an unknown, using known values for the up and down quark PDFs together with known values for the fragmentation functions which describe the conversion of the struck quark into the final kaon, it was possible to obtain a good fit to the data. The improved fit (solid curve in Fig. 1) is an indication that the actual distribution is substantially different from those of the nonstrange quarks.

The differences of the measured multiplicities for the two beam-target polarization states yielded the helicity distribution of the strange quarks. The results indicate that, within experimental uncertainty, the strange quarks are unpolarized and make no contribution to the spin of the proton. Furthermore, in large measure the strange sea is generated by gluons conversion into quark-antiquark pairs. Consequently, the HERMES result suggests that the gluons in the proton are themselves not strongly polarized.

* The HERMES collaboration comprises 32 institutions from 11 countries at the Deutsches Elektronen Synchrotron (DESY) in Hamburg.

\[ I.4 \]
Response of Cooled PWO Scintillators to Low-energy Gamma rays and its Importance in Studies of the $h_c \rightarrow \eta_c + \gamma$ Transition in Charmonium


High precision charmonium spectroscopy is one of the major parts of the physics program for the PANDA experiment [1] in the future FAIR facility in Darmstadt. There are several reasons why the study of gamma rays in the transition between the 3526 MeV, $1^1P_1$, $h_c$ and the ground state $\eta_c$, $1^3S_0$, is of importance for the physics of charmonium. First’s, the expected quantum characteristics $J^{PC} = 1^{−}−$ awaits [2] establishing via determination of the angular distribution of the $\gamma$ engaged in the transition. This will give a firm foundation to the expectation that the vector part in potential models of the charm-anticharm interaction is weak [3]. Secondly, the predicted partial $E_1$-width is of order 350 keV [3], largest among the predicted partial widths in charmonium. Comparison of the experimental partial width with predictions is of interest to elucidate the electromagnetic properties of bound quarks [4] and to shed light on the distribution of the ground state $E_1$-strength in charmonium.

Simulations of the expected efficiency of the exclusive detection of the $\gamma$ in the transition $\bar{p} + p \rightarrow h_c \rightarrow \eta_c + \gamma$, employing hadronic and neutral decay channels of the $\eta_c$ have been performed. Exclusive detection using the $\eta_c \rightarrow \phi_1 + \phi_2$ decay channel appears most promising from the point of view of the efficiency and signal to background ratio.

Protons are accelerated with the SINS/UW Van-de-Graaf accelerator. The results presented here are based on the $^{11}\text{B}(p, \gamma)^{12}\text{C}$ reaction with emission of $\gamma$’s of 3 energies - 16.9, 12.7 and 4.43 MeV and $^{19}\text{F}(p, \gamma)^{16}\text{O}$ with an energy 6.13 MeV.

Fig. 1 Spectrum of $^{11}\text{B}(p, \gamma)^{12}\text{C}$ and $^{19}\text{F}(p, \alpha\gamma)^{16}\text{O}$ (target contaminant) gamma-rays emitted at $E_p=1.39$ MeV, detected with a 20x20x200mm PWO scintillator cooled to $−20^\circ$C.

The results of simulations indicate that, because of the high intensities of $\pi^0$’s produced in nonresonant $\bar{p} + p$ annihilations, it is mandatory to maximize the $\pi^0$ identification capability by detecting both gammas in the $\pi^0$ decay to suppress background relative to $\gamma$’s from the electromagnetic transition in charmonium under consideration. Led by these considerations we have constructed a set-up to measure the response of cooled PWO scintillators in the 4.0 to 20 MeV gamma-ray energy range. The set-up uses discrete gamma rays produced in this energy range by radiative proton capture reactions on light nuclei.

Fig. 2 Measured FWHM resolution (solid points with error bars) compared with the solid curve parametrizing the results obtained in the 50-650 MeV range at MAMI [1].

The scintillator is a rod 20x20 mm in cross section and of length 200 mm, nearly equal to that to be used in the future PANDA EMC. The scintillator is installed on the axis of a cylindrical EJ-200 plastic, whose two halves are optically separated and read out individually with two XP-4312 PMs. Fig. 1 presents the energy spectrum detected in the PWO in anticoincidence mode, i.e. when no signal is detected in the two plastics. A 3 gaussian fit is used to extract the energy resolution for the three indicated energies. However, a contamination due to transitions to states of $^{16}\text{O}$ above 6.13 MeV (appearing between the first and second peaks) increases the systematic uncertainties in the measured energy resolution.

A comparison with the results of PWO resolution measurements using bremsstrahlung photons in the 50-650 MeV range [1] at MAMI demonstrates that our results present a valid extrapolation of the latter towards the lowest energies considered by the PANDA - EMC.

[5] Diploma student, Institute of Physics, Warsaw University of Technology, Poland

[85x797]ASTROPHYSICS, COSMIC RAYS & ELEMENTARY PARTICLE PHYSICS 103
Probing Photon Structure in DVCS on a Photon Target
by M. El Beiyad,2) S.Friot,1) B.Pire,2) L.Szymanowski and S.Wallon3)

Motivation

The parton content of the photon has been the subject of many studies since the seminal paper by Witten [1], which allowed the anomalous quark and gluon distribution functions to be defined. Recent progress in exclusive hard reactions focuses on generalized parton distributions (GPDs), which are defined as Fourier transforms of matrix elements between different states, such as \( \langle N'(p',s')|\gamma(-\lambda)n|N(p,s)\rangle \) and their crossed versions, the generalized distribution amplitudes (GDAs) which describe the exclusive hadronization of a \( q\bar{q} \) or \( gg \) pair in a pair of hadrons, see Fig. 1. In the photon case, these quantities are perturbatively calculable \([2,3]\) at leading order in \( \alpha_{em} \) and leading logarithmic order in \( Q^2 \). They constitute an interesting theoretical laboratory for the non-perturbative hadronic objects that hadronic GPDs and GDAs are.

The diphoton generalized distribution amplitudes

Defining the momenta as \( q = p - \frac{Q^2}{s} n \), \( q' = \frac{Q^2}{s} s', p_1 = \xi p, p_2 = (1-\xi)p \), where \( p \) and \( n \) are two light-cone Sudakov vectors and \( 2p^*n = s \), the amplitude of the process \( \gamma^*(q,\epsilon)\gamma(q',\epsilon') \rightarrow \gamma(p_1,\epsilon_1)\gamma(p_2,\epsilon_2) \) may be written as \( A = \epsilon(i\xi_{\epsilon_1}\epsilon_{\epsilon_2}^*\epsilon_{\epsilon_2}\gamma^{\mu\nu\alpha\beta}T_{\mu\nu\alpha\beta}) \). In forward kinematics where \( q + q' = 0 \), the tensorial decomposition of \( T_{\mu\nu\alpha\beta} \) reads

\[
\frac{1}{4} g_{\mu\nu} g_{\alpha\beta} W_1^q + \frac{1}{8} (g_{\mu\alpha} g_{\nu\beta} + g_{\nu\alpha} g_{\mu\beta} - g_{\mu\beta} g_{\nu\alpha}) W_2^q + \frac{1}{4} g_{\mu\alpha} g_{\nu\beta} T_{\mu\nu\alpha\beta} W_3^q.
\]

At leading order, the three scalar functions \( W_i^q \) can be written in a factorized form which is particularly simple when the factorization scale \( M_F \) equals the photon virtuality \( Q \). \( W_i^q \) is then the convolution \( W_i^q = \int dq' C_{\gamma}^q(z) \Phi_i^q(z,\xi,0) \) of the coefficient function \( C_{\gamma}^q = e^{\frac{1}{q} \left( \frac{1}{z} - \frac{1}{1-z} \right)} \) with the anomalous vector GDA \( (z = 1-z, \alpha = 1-\xi) \):

\[
\Phi_1^q(z,\xi,0) = \frac{N_e e^2}{2\pi^2} \log \frac{Q^2}{m^2} \left[ \frac{\pi(2z-\xi)}{\xi} \theta(z-\xi) + \frac{\pi(2z-1)}{\xi} \theta(z-\xi) \right]
\]

\[
+ \frac{z(2z-1)}{\xi} \theta(z-\xi) \right]
\]

Conversely, \( W_3^q \) is the convolution of the function

\[
C_{\gamma}^q = e^{\frac{1}{q} \left( \frac{1}{z} - \frac{1}{1-z} \right)} \] with the axial GDA:

\[
\Phi_3^q(z,\xi,0) = \frac{N_e e^2}{2\pi^2} \log \frac{Q^2}{m^2} \left[ \frac{\pi(2z-\xi)}{\xi} \theta(z-\xi) - \frac{\pi(2z-1)}{\xi} \theta(z-\xi) \right] - \frac{z}{\xi} \theta(z-\xi) \right] \]

\[
+ \frac{z(2z-1)}{\xi} \theta(z-\xi) \right]
\]

and \( W_2^q = 0 \). Note that these GDAs are not continuous at the points \( z = \pm \xi \). The anomalous nature of \( \Phi_1^q \) and \( \Phi_3^q \) comes from their proportionality to \( \log \frac{Q^2}{m^2} \), which remind us of the anomalous photon structure functions. A consequence is that \( \frac{d}{d \ln Q^2} \Phi_i^q \neq 0 \); consequently the QCD evolution equation of the diphoton GDAs obtained with the help of the ERBL kernel are non-homogeneous ones.

The photon generalized parton distributions

We now look at the same process in different kinematics, namely \( q = -2\xi p + n, q' = (1-\xi)p, p_1 = n, p_2 = p, A = (1-\xi)p \), where \( W^q = \frac{1}{2} \frac{\xi}{2\pi^2} Q^2 \) and \( t = 0 \). The tensor \( T_{\mu\nu\alpha\beta} \) is now decomposed in to different tensors with the help of three functions \( W_i^q \) as:

\[
\frac{1}{4} (g_{\mu\alpha} g_{\nu\beta} W_1^q + \frac{1}{8} (g_{\mu\alpha} g_{\nu\beta} + g_{\nu\alpha} g_{\mu\beta} - g_{\mu\beta} g_{\nu\alpha}) W_2^q + \frac{1}{4} g_{\mu\alpha} g_{\nu\beta} T_{\mu\nu\alpha\beta} W_3^q)
\]

\[
+ \frac{1}{4} (g_{\mu\alpha} g_{\nu\beta} - g_{\mu\beta} g_{\nu\alpha}) W_3^q
\]

These functions can also be written in factorized forms which have direct parton model interpretations when the factorization scale \( M_F \) is equal to \( Q \). The coefficient functions are
\[ C^q_{VA} = -2e^2 q \left( \frac{1}{x - \xi + i\eta} \pm \frac{1}{x + \xi - i\eta} \right) \]

and the unpolarized \( H_{1}^q \) and polarized \( H_{3}^q \) anomalous GPDs of quarks inside a real photon read:

\[
H_{1}^q(x, \xi, \theta) = \frac{N e^2 q}{4\pi^2} \left[ \theta(x - \xi) x^2 + \left( 1 - x \right)^2 \frac{1}{1 - \xi^2} \right] \ln \frac{Q^2}{m^2},
\]

\[
+ \phi(\xi - x) \phi(\xi + x) \frac{x(1 - \xi)}{\xi(1 + \xi)} \frac{x(1 + x)^2 - \xi^2}{1 - \xi^2} \ln \frac{Q^2}{m^2},
\]

\[
H_{3}^q(x, \xi, \theta) = \frac{N e^2 q}{4\pi^2} \left[ \theta(x - \xi) x^2 - \left( 1 - x \right)^2 \frac{1}{1 - \xi^2} \right] \ln \frac{Q^2}{m^2},
\]

\[
- \phi(\xi - x) \phi(\xi + x) \frac{1 - \xi}{1 + \xi} \frac{(1 + x)^2 - \xi^2}{1 - \xi^2} \ln \frac{Q^2}{m^2}.
\]

Similarly as in the GDA case, the anomalous generalized parton distributions \( H_{1}^q \) are proportional to \( \ln \frac{Q^2}{m^2} \). Consequently, the anomalous terms \( H_{i}^q \) supply to the usual homogeneous DGLAP-ERBL evolution equations of GPDs a non-homogeneous term which changes them into non-homogeneous evolution equations.

The formulas for the anomalous diphoton GDAs and for the anomalous GPDs in a photon derived above will be a starting point for construction of the so-called dual parametrization of GPDs in terms of Regge-type exchanges.


1) IPN, CNRS, Orsay, France
2) CPhT, Ecole Polytechnique, CNRS, Palaiseau, France
3) LPT, Université Paris XI, CNRS, Orsay, France
Are High-\(p_T\) Particles Suppressed in Pb+Pb Collisions at the CERN SPS Energy?

by H.Białkowska, B.Boimska and P.Szymański, NA49 experiment at CERN

A sensitive tool to characterize matter created in ultrarelativistic heavy ion collisions, and in particular to detect the possible formation of a quark-gluon plasma (QGP) – a thermalized phase in which quarks and gluons (partons) are the relevant degrees of freedom - is the study of hadron production at high transverse momentum (\(p_T\)). These hadrons originate from parton scatterings with high momentum transfer (“hard scattering”). The scattered quarks and gluons traverse the medium formed and fragment into experimentally observed hadrons. Production of high-\(p_T\) particles in nucleus-nucleus (A+A) collisions was predicted to be suppressed due to the energy loss of the scattered partons in the hot and dense medium (“jet quenching”)[1]. Experiments at the Relativistic Heavy Ion Collider (RHIC) observed the suppression in central Au+Au and Cu+Cu collisions at a center-of-mass energy of \(\sqrt{s_{NN}}=200\text{GeV}\) [2, 3, 4, 5]. However, not much is known about the energy dependence of the phenomenon. In particular, it is an open question whether “jet quenching” plays a role in Pb+Pb collisions at the CERN SPS energy of \(\sqrt{s_{NN}}=17.3\text{GeV}\).

Nuclear effects in particle production can be quantified by the nuclear modification factor - \(R\). In general, the nuclear modification factor of a reaction \(A_1+A_2\) relative to \(A_3+A_4\) is defined as

\[
R_{A_1+A_2/A_3+A_4} = \frac{\langle N_{coll} \rangle_{A_1+A_2}}{\langle N_{coll} \rangle_{A_3+A_4}} \frac{\text{yield}(A_1+A_2)}{\text{yield}(A_3+A_4)}
\]

where: \(\langle N_{coll} \rangle\) is the average number of nucleon-nucleon collisions corresponding to a given reaction and is calculated according to the Glauber model via Monte Carlo methods.

Hadron suppression due to parton energy loss might be compensated by an enhancement due to multiple soft scatterings of the incoming partons prior to the hard scattering process (“nuclear \(k_T\)-enhancement” or “Cronin effect”[6]). In order to subtract this contribution, \(R\) for central A+A data is calculated relative to p+A or peripheral A+A data. Then, if \(R\) (for \(p_T>2\text{GeV/c}\)) is below unity it means hadron suppression is present in the central A+A collisions.

Nuclear modification factors \(R\) for Pb+Pb collisions at the CERN SPS energy were determined (for \(\pi^0\)) using measured p+C and p+Pb reference data [7]. In very central Pb+Pb collisions (0-5% of \(\sigma_{\text{inel}}\)) suppression of high-\(p_T\) \(\pi^0\) was observed (\(R=0.5\)). When the nuclear modification factor for charged pions is studied for central (0-5%) Pb+Pb collisions relative to peripheral (33.5-80%) ones, \(R\) at high \(p_T\) also stays below unity, as shown in Fig.1 [8] (data from NA49). The suppression at the SPS energy is however not as strong as it is at RHIC.

In summary, the suppression of high-\(p_T\) particles is present not only at RHIC energies but also at the SPS energy – the effect is less pronounced. The results reported here may help clarify the behavior of the energy loss of partons in the hot and dense medium created in high energy heavy ion collisions.

Suppression of High-pT Neutral Pion Production in Central Pb+Pb Collisions at √s_{NN}=17.3 GeV

by M.M. Aggarwal, …, (T. Siemiarczuk) et al., WA98 Collaboration

The study of hadron production at high transverse momentum (p_T) is a sensitive tool to characterize matter created in ultrarelativistic heavy-ion collisions, and in particular, to detect the possible formation of a quark-gluon plasma (QGP), i.e., a thermalized phase in which quarks and gluons are the relevant degrees of freedom. Particles at high p_T result from quark and gluon scatterings with high momentum transfer (“hard scattering”) which can be described by perturbative quantum chromodynamics. The scattered quarks and gluons will traverse the created medium and fragment into the observable hadrons. High-p_T particle production in nucleus-nucleus (A+A) collisions was predicted to be suppressed as a consequence of the energy loss of the scattered partons in the dense matter (“jet quenching”). Such suppression was observed by experiments at the Relativistic Heavy Ion Collider (RHIC) in central Au+Au and Cu+Cu collisions at a center-of-mass energy of up to √s_{NN} = 200 GeV.

Within jet-quenching models the suppression can be related to medium properties, such as the initial gluon density or the transport coefficient. A crucial test for the idea of parton energy loss in the hot and dense medium created in A+A collisions is the measurement of the √s_{NN} dependence of high-p_T hadron production. In central Pb+Pb collisions at the CERN SPS energy of √s_{NN} = 17.3 GeV (p_{lab} = 158 AGeV/c) the initial energy density, as estimated from the measured transverse energy, is above the critical value ε ≈ 1 GeV/fm^3 for the transition to the QGP. On the other hand, the initial gluon density and the lifetime of a deconfined phase produced at √s_{NN} = 17.3 GeV will be significantly reduced compared to RHIC energies. Results at SPS energies thereby provide a sensitive test of jet-quenching model predictions. In this note we report on π^0 spectra from p+C and p+Pb collisions at √s_{NN} = 17.4 GeV (p_{lab} = 160 GeV/c) measured in the WA98 experiment. Since the nuclear k_T-enhancement in p+C is expected to be small this measurement should provide a useful substitute for a p+p reference. Information on the magnitude of the nuclear k_T-enhancement may be obtained by comparison of the p+Pb and p+C spectra. The spectra are compared to π^0 spectra measured in Pb+Pb collisions at √s_{NN} = 17.3 GeV with the same WA98 experimental setup. Nuclear effects in π^0 production can be quantified with the nuclear modification factor R_AA defined in ref. [1]. In the absence of nuclear effects R is expected to be unity for p_T > 2 GeV/c where hard scattering is expected to dominate particle production. We have measured the π^0 spectra in minimum bias p+C and p+Pb collisions at √s_{NN} = 17.4 GeV in the range 0.7<p_T<3.5 GeV/c. Based on these spectra the nuclear modification factors R_AA for Pb+Pb collisions at CERN SPS energies could be determined using a measured p+A reference. In very central Pb+Pb collisions (0-1% of σ (Pb + Pb)) a significant suppression of high-p_T neutral pions was observed (R_AA ≈ 0.50 ± 0.14) that is reminiscent of the high-p_T hadron suppression observed in Cu+Cu and Au+Au collisions at RHIC. The pion suppression reported here, together with the results at higher energies from RHIC, constrain jet-quenching models and may help clarify the behavior of the energy loss of partons in strongly interacting matter.

Modelling Hydrodynamics of Viscous Hadronic Fluid

by T.Osada and G.Wilk

Viscous hydrodynamic models successfully reproduce most of the RHIC experimental data. Although very promising, they have many difficulties, both in what concerns their proper formulation and applications. In [1] we demonstrate that one can obtain constitutive equations of causal d-hydrodynamics starting from relativistic perfect nonextensive hydrodynamics (q-hydrodynamics) supplemented by nonextensive/dissipative correspondence (NexDC) taking place between perfect q-hydrodynamics (based on nonextensive Tsallis statistics and described by the nonextensivity parameter q) and the usual d-hydrodynamics (based on extensive Boltzmann-Gibbs statistics (BG) to which Tsallis statistics converges for \( q \to 1 \) [2]. We argue that the d-hydrodynamics emerging from such q-hydrodynamics is causal and preserves the simplicity of the latter which facilitates numerical applications [1] (instead of solving very complicated second order equations of d-hydrodynamics one can solve the much simpler equation of motion of the q-hydrodynamics). In this sense, viscous d-hydrodynamics can be modeled by ideal q-hydrodynamics. This is done in the following steps (we consider only the 1+1 dimensional and vanishing chemical potential case). At first we replace:

\[
\partial_q T^{\mu
u} = 0 \quad \Rightarrow \quad \partial_q T^{\mu
u}_q \text{ where } (1) \quad T^{\mu
u} = (\varepsilon + P)u^{\mu} u^{\nu} + P g^{\mu\nu} \quad \Rightarrow \quad T^{\mu
u}_q \text{ (} \varepsilon_q P_q u_q \text{),}
\]

where \( T^{\mu
u} \) is the corresponding energy-momentum tensor depending on \( \varepsilon \), the energy density, \( P \) is pressure (with \( P = P(\varepsilon) \) being the corresponding equation of state - EoS) and \( u \) denotes the four velocity of the fluid (quantities with \( q \) subscripts are their nonextensive equivalents). It means that the usual assumption of local thermal equilibrium is replaced by the notion of the existence of some stationary state being formed in the collision which already includes some interactions summarized by the parameter \( q \) (in fact by \( q - I > 0 \)). In the second step, because usually \( |q - 1| < 1 \), one decomposes \( \varepsilon_q (T_q) = \varepsilon (T_q) + \Delta\varepsilon_q (T_q) \), \( P_q (T_q) = P (T_q) + \Delta P_q (T_q) \) and \( u^{\mu}_q (x) = u^{\mu} (x) + \Delta u^{\mu}_q (x) \). Here \( T_q \) and \( T \) are, correspondingly, the nonextensive and usual temperatures. Supplementing with what we call the Nonextensive/Dissipative conjecture (NexDC, in short), namely assuming that

\[
P(T) = P_q (T_q) \text{ and } \varepsilon (T) = \varepsilon_q (T_q) + 3 \Pi,
\]

one gets from \( T^{\mu
u}_q \) a new form of energy-momentum tensor evidently resembling its viscous counterpart:

\[
T^{\mu
u} = \varepsilon (T) u^{\mu} u^{\nu} + [P(T)+\Pi] d^{\mu\nu} + 2 W (\mu,\nu) + \Pi^{\mu\nu}
\]

(3)

Here \( \Pi = \frac{1}{3} w (\gamma^2 + 2\gamma) \) is the \( q \)-dependent bulk pressure, \( W^{\mu} = w (1 + \gamma) \Delta T^\lambda_\lambda \Delta u^\lambda_q \) is the \( q \)-dependent energy/heat flow vector and

\[
\pi^{\mu\nu} = \frac{W^{\mu} W^{\nu}}{q} + \Pi \Delta^{\mu\nu} = w \partial_q u^\lambda < \frac{\mu}{q} \partial_q u^\nu > (q)
\]

is the shear (symmetric and traceless) pressure tensor. They depend on the \( q \)-enthalpy \( w_q = r_q + P_q \) and on the variable

\[
\gamma = u^\mu \delta_q u^\mu_q = - \frac{1}{2} \delta_q u^\mu_q \partial_q \varepsilon_q = \frac{1}{\sqrt{1 - q - q^{-1}}} \rangle 0
\]

(4)

where

\[
\delta_q \varepsilon_q = - \frac{\varepsilon_q (T_q) - \varepsilon_q (T_q)}{q - 1} .
\]

(5)

This variable is the most important in our approach as it contains all the very complicated, \( q \)-dependence. The other technical definitions are: \( A^{\mu\nu} = g^{\mu\nu} - u^{\mu} u^{\nu} \),

\[
A^{\mu} B^{\nu} = \frac{1}{2} (A^{\mu\nu} B^{\nu} + A^{\nu\nu} B^{\mu})
\]

and

\[
a^<_{\mu\nu} = \left\{ \frac{1}{2} (\Delta^{\mu\nu}_q + \Delta^{\nu\mu}_q) - \frac{1}{3} \Delta^{\mu\nu}_q \right\} u^\lambda \partial_q \lambda.
\]

With these elements one finally obtains two important consequences:

(1) Even if \( q \)-entropy is strictly conserved,

\[
\sigma^\mu_q (x) = -k \left\{ \frac{d^3}{(2\pih)^3} \int \rho^0 f_q (q - f_q) \right\} = 0
\]

(6)

(2) There is a simple relation between the transport coefficient \( \zeta \) (bulk viscosity) and \( \eta \) (shear viscosity):

\[
\frac{1}{\zeta / s} + \frac{1}{\eta / s} = \frac{w \sigma_{\text{full}}^{\mu}}{\Pi^2}
\]

(7)

where \( s \) is entropy density, \( w \) is enthalpy and \( \sigma_{\text{full}}^{\mu} \) is the full entropy current (see [1] for details and preliminary results).
To see the applications of our proposition one should consult [1]. Here we would only like to close with a short explanation why, knowing from our past experience that in all practical cases $q-1<<0$, why we do not simply expand $\exp_q(x)$ in powers of $(q-1)$ to get that

$$T_{q}^{\mu\nu} = T_{q=1}^{\mu\nu} + (q-1) \tau_{q}^{\mu\nu} \tag{8}$$

where

$$T_{q=1}^{\mu\nu} \equiv \frac{g}{(2\pi)^3} \left[ \frac{d^3p}{p^0} p^\mu p^\nu (-\frac{p \cdot u}{T}) \right]$$

and

$$\tau_{q}^{\mu\nu} \equiv \frac{1}{2} \frac{g}{(2\pi)^3} \left[ \frac{d^3p}{p^0} p^\mu p^\nu (-\frac{p \cdot u}{T}) \exp\left(-\frac{p \cdot u}{T}\right) \right],$$

with $T_{q=1}$ being the usual energy-momentum tensor describing an ideal fluid in the BG approach and $\tau_{q}^{\mu\nu}$ representing a viscous correction caused by the nonextensivity. However, in order for Eq. (8) to be valid over the whole phase space, the $|1-q| \left(\frac{p \cdot u}{T}\right)^2 < 2$ inequality must hold. This means that either such a procedure can be applied only to a limited domain of phase space, or that $q = q(x,p)$, a possibility which is outside the scope of the present work.


1) Theoretical Physics Laboratory, Faculty of Knowledge Engineering, Musashi Institute of Technology, Tokyo, Japan
Coupling Effects at Near-barrier Energies for the System $^6$Li+$^{28}$Si
by K.Rusek, N.Keeley, A.Pakou and N.Alamanos

In a series of experiments aimed at studying the $^6$Li+$^{28}$Si interaction [1-4] it was found that the largest cross section is for one-neutron transfer leading to excited states in $^{29}$Si placed above 1.27 MeV in excitation energy. The value of the cross section at an incident energy of 13 MeV was $113 \pm 29$ mb, more than five times larger than that for $^6$Li$\rightarrow$α+d breakup [2]. How much does this process affect the elastic scattering? The aim of this work is to investigate the contribution of transfer versus breakup to the elastic scattering.

Fig. 1 Coupling scheme used in the calculations.

We performed coupled-reaction-channel (CRC) calculations with couplings to breakup and one-neutron transfer channels explicitly included as indicated in Fig. 1. In these calculations we assumed that the transfer reaction may lead to $^7$Li in its ground and first excited states (both are resonant states in the α+p continuum) and that the final nucleus, $^{29}$Si, could be excited to states up to 6.5 MeV. Eight states of $^{29}$Si from this energy range, with the largest spectroscopic amplitudes, were taken into account. Details of the continuum-discretized coupled-channel (CDCC) calculations for $^6$Li$\rightarrow$α+d breakup as well as DWBA calculations for one-neutron transfer may be found in Refs. [2-3].

The results of our calculations are plotted in Figs. 2-3. The calculations reproduce the experimental data for $^6$Li breakup (dashed curve and open circles, respectively, in Fig. 2). However, they underestimate the measured values of the one-neutron transfer (solid curve and filled circles in Fig. 2). In order to improve the latter agreement, the spectroscopic amplitudes must be renormalized by a factor of two.

The effect of breakup and one-neutron transfer on the elastic scattering is illustrated in Fig. 3. Inclusion of $^6$Li$\rightarrow$α+d breakup affects significantly the elastic scattering, calculated the calculated total reaction cross section by about ten percent (see OM and CDCC curves in Fig. 3). The effect of one-neutron transfer is much smaller, even with renormalized values of the spectroscopic amplitudes. The results of calculations including both processes, breakup and transfer, are plotted as the solid curve. This shows that the coupling effect is not proportional to the cross section of a particular process but rather depends on its nature.

Fig. 2 Results of calculations compared to the experimental data for the $^{28}$Si($^6$Li,$^5$Li)$^{29}$Si n-transfer reaction and for the $^{28}$Si($^6$Li,α+d)$^{28}$Si breakup. The data are from [2,3].

Fig. 3 Angular distribution of the elastic scattering cross section at a lab. energy of 13 MeV. The data are from [1]. The curves show the results of calculations described in the text.

An earlier suggestion that breakup contributes mainly to the real part of the dynamic polarization potential while transfer generates its imaginary part is in agreement with our result.

This work was supported by the Polish-Greek bilateral agreement and by the consortium COPIN.


1) Department of Physics, The University of Ioannina, Greece
2) DSM/IRFU/DIR CEA SACLAY, France
Mass-asymmetry Dependence of the Caloric Curve and its Implications for the Understanding of Multifragmentation of Nuclei
by A. Mykulyak, B. Zwiegiński and the ALADIN2000 Collaboration at GSI-Darmstadt

There exists a controversy concerning the interpretation of the asymmetry dependence (or rather lack thereof) of the caloric curves recently measured by the ALADIN collaboration. Experiment S254, conducted at the SIS heavy-ion synchrotron at GSI Darmstadt, was devoted to the study of isotopic effects in projectile fragmentation at relativistic energies. Besides stable $^{124}\text{Sn}$ beams, neutron-poor secondary Sn and La beams were used in order to extend the range of isotopic composition beyond that available with stable beams alone. The radioactive beams were produced at the FRS fragment separator by fragmenting primary $^{142}\text{Nd}$ projectiles with energies near 900 MeV/nucleon in a thick beryllium target. The FRS was set to select $^{124}\text{La}$ and, subsequently, $^{107}\text{Sn}$ projectiles which were directed onto natSn targets of 500 mg/cm$^2$ areal density at the ALADIN setup. All three beams had a laboratory energy of 600 MeV/nucleon.

Two temperature observables, deduced from the resolved isotope yields, are shown in Fig. 1 as a function of the normalized $Z_{\text{bound}}/Z_{\text{proj}}$. Besides the frequently used $T_{\text{HeLi}}$ (left panel) $T_{\text{BeLi}}$ deduced from Li and Be fragment yields is also displayed (right panel) in Fig. 1. Note that the abscissa is inversely correlated with the excitation energy of the multifragmented residue, so that the highest excitation energies are approached as $Z_{\text{bound}}/Z_{\text{proj}} \rightarrow 0$. The deduced temperatures are consistent with the overall observation that the reaction processes are not strongly affected by a variation of the system isospin asymmetry $X=(N-Z)/A$.

The weak sensitivity of the measured caloric curves to $X$ is in sharp contrast to that found in [1] for limiting temperatures using the thermal Hartree-Fock approach where a difference of about 2 MeV is predicted between $^{124}\text{Sn}$ and $^{124}\text{La}$. Ref. [1] considered the hot nucleus as a charged drop immersed in the surrounding vapor in a finite volume ("boxed approach"). The pressure balance inside the drop is given by $P_{\text{bulk}}+P_{\text{Coul}}=P_{\text{surf}}+P_{\text{vapor}}$, i.e. the sum of the inside bulk pressure and the Coulomb repulsion pressure is counteracted by the combined effect of the surface and the vapor pressures. As the system is heated $P_{\text{bulk}}-P_{\text{vapor}}$ as well as $P_{\text{surf}}$ tend to zero, so that at the limiting temperature the Coulomb pressure becomes unbalanced causing instability of the charged drop. The role of the vapor is questioned in the "mononuclear" approach. It is argued [2] that in fact the system as experimentally prepared is isolated with a fixed total excitation energy. The unbalanced thermal pressure induces expansion of the system in search of maximal entropy where the total pressure vanishes and the system is in equilibrium in a mononuclear configuration. The energy of expansion is derived from the thermal energy, the temperature thereby decreasing. This makes the caloric curve largely insensitive to the isospin asymmetry.

1n and 2n transfer with the Borromean nucleus $^6$He near the Coulomb barrier
by A.Chatterjee,1,2) A.Navin,1) A.Shrivastava,2) S.Bhattacharyya,3) M.Rejmund,1) N.Keeley, V.Nanal,2) J.Nyberg,4) R.G.Pillay,3) K.Ramachandran,2) I.Stefan,1) D.Bazin,6) D.Beaumel,6) Y.Blumenfeld,6) G.de France,1) D.Gupta,6) M.Labiche,7) A.Lemasson,1) R.Lemmon,7) R.Raabe,1) J.-A.Scarpaci,6) C.Simenel,8) and C.Timis9) [H1.2]

A recent experiment at GANIL measured for the first time for a reaction induced by a radioactive beam triple coincidences between $\alpha$ particles, neutrons and $\gamma$ rays from the target-like residue for the interaction of $^6$He with a $^{65}$Cu target at an incident energy of 22.6 MeV [1]. The experimental set-up is shown in Fig. 1 a), where the annular Si telescope used to detect the charged particles may be set just down-stream of the target, surrounded by 11 Compton-suppressed clover detectors of the EXOGAM $\gamma$ array. A neutron array of 45 liquid scintillator elements was placed downstream from the target chamber.

![Fig. 1](image)

Fig. 1 Schematic of (a) the experimental set-up, (b) the reaction mechanism for 1n and 2n transfer.

The coincidences enabled the reaction mechanism for the production of $\alpha$ particles to be determined unambiguously – large cross sections for $\alpha$ particle production in this energy regime have been previously reported for $^4$He incident on $^{209}$Bi [2] and $^{64}$Zn [3] targets. The detection of neutrons and $\alpha$ particles in coincidence with $\gamma$ rays in $^{66}$Cu ensured that breakup of $^6$He could be ruled out as a possible production mechanism in these measurements; the target being a spectator in the breakup process, no $^{66}$Cu is formed. This leaves 1n and 2n transfer (stripping) as possible production mechanisms (1n stripping leaves the unbound $^5$He nucleus in the exit channel, which spontaneously decays into an $\alpha$ particle and a neutron), illustrated schematically in Fig. 1 b).

The 1n and 2n transfer mechanisms could be further distinguished by the angular correlation between the neutron and $\alpha$ particle detected in coincidence. For 1n transfer the detected $\alpha$ particle and neutron arise from decay of the unbound $^5$He nucleus, and are therefore restricted to a narrow cone, see Fig. 1(b). For 2n transfer, the detected neutron arises from evaporation from the $^{67}$Cu nucleus, produced at excitation energies above its 1n emission threshold, and no such correlation in angle with the detected $\alpha$ particle exists. The 1n and 2n transfer cross sections could therefore be separated and are shown in Fig. 2 a).

![Fig. 2](image)

Fig. 2 Angular distributions for $^6$He + $^{65}$Cu. (a) 1n and 2n transfer. Calculations for 1n and 2n transfer are shown. (b) Elastic scattering. Calculations with no coupling (dotted curve), 1n transfer couplings only (dashed line), and both 1n and 2n transfer couplings (solid line) are shown.

Coupled reaction channels calculations were carried out to model the transfer processes assuming direct, one-step transfer for both the 1n and 2n stripping, using the code FRESCO [4]. The basic optical potentials in all partitions were calculated using the double-folding procedure and realistic densities for the real parts, and interior imaginary potentials of Woods-Saxon form to simulate the ingoing-wave boundary condition. Realistic calculations could be performed for the 1n-transfer as the relevant structure of $^{65}$Cu is well-known, including the spectroscopic factors, from (d,p) studies [5]. Due to the high density of states in $^{66}$Cu only the strongest states were included. The 2n transfer is more problematical, as the large positive Q-value for this reaction favors the population of states in $^{67}$Cu in an excitation energy region where nothing is known.

[^1]: A.Chatterjee
[^2]: A.Navin
[^3]: A.Shrivastava
[^4]: S.Bhattacharyya
[^5]: M.Rejmund
[^6]: N.Keeley
[^7]: V.Nanal
[^8]: J.Nyberg
[^9]: R.G.Pillay
[^10]: K.Ramachandran
[^11]: I.Stefan
[^12]: D.Bazin
[^13]: D.Beaumel
[^14]: Y.Blumenfeld
[^15]: G.de France
[^16]: D.Gupta
[^17]: M.Labiche
[^18]: A.Lemasson
[^19]: R.Lemmon
[^20]: R.Raabe
[^21]: J.-A.Scarpaci
[^22]: C.Simenel
[^23]: C.Timis
about the spectroscopy. We therefore took the spin-parities and excitation energies of known states in this region for $^{65}\text{Cu}$, with spectroscopic factors set equal to 1.0. As no $\gamma$ rays in $^{67}\text{Cu}$ were observed we only included transfer to states in $^{67}\text{Cu}$ that were above the 1n emission threshold but below that for 2n emission (population of states above the 2n emission threshold could be ruled out by the coincidence with a $\gamma$ ray in $^{66}\text{Cu}$).

The summed angular distributions for transfers to all states in $^{65}\text{Cu}$ and $^{67}\text{Cu}$ are compared with the data in Fig. 2 a). The 1n transfer calculation describes very well the measured cross section angular distribution, confirming that the mechanism is indeed 1n stripping. The 2n transfer is qualitatively reproduced by the calculation, providing support for the supposition that the main mechanism here is also direct transfer to states in $^{65}\text{Cu}$ that are bound with respect to the 2n emission threshold of $^{67}\text{Cu}$ but unbound with respect to the 1n threshold, and which therefore decay by the emission of a neutron. We therefore were able to conclude that the very large $\alpha$ particle production cross section could be explained by conventional transfer reactions to bound states, with the majority of the cross section arising from 2n stripping. This latter circumstance also provided further support for the conclusion that the “di-neutron” configuration dominates the ground state structure of $^{6}\text{He}$.


1) GANIL, CEA/DSM-CNRS/IN2P3, Bd. Henri Becquerel, BP 55027, F-14076 Caen Cedex 5, France
2) Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai 400085, India
3) DNAP, Tata Institute of Fundamental Research, Mumbai 400005, India
4) Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden
5) NSCL, Michigan State University, East Lansing, Michigan, 48824, USA
6) IPN, IN2P3-CNRS, F-91406 Orsay, France
7) CLRC, Daresbury Laboratory, Daresbury, Warrington, WA4 4AD, United Kingdom
8) DSM/IRFU/SPhN, CEA Saclay, F-91191 Gif sur Yvette, France
9) Department of Physics, University of Surrey, Guildford, GU2 7XH, United Kingdom
Calculations of Cross Sections for Synthesis of $Z = 114$-118 Nuclei in Hot Fusion Reactions
by K. Siwek-Wilczyńska, A. Borowiec, J. Wilczyński

In Ref. [1] we presented results of calculations of the evaporation-residue cross sections for production of super-heavy elements of $Z = 114$-118 in hot fusion (3n and 4n) reactions induced by $^{48}$Ca projectiles on Pu, Am, Cm and Cf targets. Exactly these reactions had been used by Oganessian et al. in their discovery experiments [2].

Fig. 1 Excitation function for production of isotopes of element $Z = 114$ in 3n and 4n channels of the $^{48}$Ca + $^{244}$Pu reaction calculated with the ground-state masses and fission saddle-point energies of Myers-Swiatecki [6] and Sobiczewski et al. [7], compared with the cross sections measured by Oganessian et al. [2] (full circles).

Fig. 2 Difference of energy thresholds for fission and neutron emission, $B_f - B_n$, calculated for nuclei in the range $106 \leq Z \leq 120$ with mass numbers $A = 3Z - 58$. The calculations are done for the ground-state masses and fission saddle-point energies of Myers and Swiatecki [6], Sobiczewski et al. [7] and Möller et al. [8].

The calculations were based on the “Fusion by Diffusion Model” [3] in a Monte Carlo version [4] modified to calculate $x_n$ channels, with phenomenological systematics of the fusion hindrance factor [5]. In Fig. 1 we show a typical example of a calculation for the $^{48}$Ca + $^{244}$Pu reaction (sum of the 3n+4n cross sections) compared with the measured cross sections [2]. The calculations were carried out with two different available theoretical predictions of the ground-state masses and fission barriers: the Thomas-Fermi model of Myers and Swiatecki [6] and the macroscopic-microscopic model of Sobiczewski et al. [7]. While the calculations with the masses and barriers of [7] roughly agree with the measured cross sections, the results for [6] overestimate the experimental cross sections by about 4-5 orders of magnitude.

One can easily check that a crucial factor responsible for large differences in the theoretical such predictions is the difference of the energy thresholds $B_f - B_n$ for fission and neutron decay, respectively. As seen from Fig. 2, the differences between the theoretical $B_f - B_n$ values are largest in the vicinity of $Z = 114$ nuclei (up to about 3-4 MeV) and they convert into 4-5 orders of magnitude in the predicted cross sections. We conclude that among other theoretical predictions, the ground-state masses and fission barriers of Sobiczewski et al. [7] are the most suitable in the range of the heaviest nuclei around $Z = 115$.


1) Institute of Experimental Physics, Warsaw University, Poland
On the Competition between Particle Emission and Fission in the Presence of Shell Effects
by K. Siwek-Wilczyńska,1) W.J. Świątecki,2) J. Wilczyński

In the last decade, some 20-30 publications in leading journals have appeared in which cross sections for production of super-heavy elements are calculated with an erroneous formula for the $\Gamma_n/\Gamma_f$ ratio. A paper by Adamian et al. [1] may serve as an example. The erroneous treatment of shell structure corrections leads to an energy-dependent fission barrier inserted into the expression for the fission width $\Gamma_f$. On the other hand, the shell effect in the residual nucleus after neutron emission is ignored in this erroneous approach.

In Ref. [2] we rederived the relevant transition-state decay rate formulae, thus identifying the abovementioned error, and described how to introduce shell structure corrections in a way consistent with the transition-state theory of Bohr and Wheeler [3].

We also described a novel accurate algebraic method of evaluating certain complicated integrals over nuclear level densities, in particular those introduced by Ignatyuk et al. [4], to accommodate shell structure corrections. The accuracy of the proposed approximate method of calculating the $\Gamma_n/\Gamma_f$ ratios is about 1-2% that by far satisfies the requirements of statistical model calculations. On the other hand, the application of the method considerably accelerates the very time-consuming Monte Carlo calculations of the deexcitation cascades.

In Refs. [2] and [5] we presented comparisons of correct values of the $\Gamma_n/\Gamma_f$ ratio (calculated for Ignatyuk’s level densities) with results obtained with the flawed formula of Adamian, Antonenko and Scheid [1] commonly used by various authors in many papers. One example, for the decay of a super-heavy nucleus $Z=118$, $A=297$ with a large predicted shell effect, is shown in Fig. 1. It is seen that there is reasonable agreement of the curve according to Adamian et al. with the correct result at high excitation energies, but at lower excitation energies the disagreement becomes dramatic, up to three orders of magnitude in the immediate vicinity of the fission threshold. This disagreement must have severe consequences not only for cold fusion reactions (at low excitation energies) but also for hot fusion reactions (for which deexcitation of the compound nucleus starts at higher excitation energies) because the deexcitation cascade must eventually pass through the low energy region where emission of the last neutron is miscalculated by the erroneous formula [1] by several orders of magnitude.

Fig. 1 The ratio $\Gamma_n/\Gamma_f$ for the $Z=118$, $A=297$ nucleus obtained using the erroneous scheme of Adamian et al. with an excitation energy dependent fission barrier (solid curve) compared with the ratio $\Gamma_n/\Gamma_f$ correctly calculated with the transition-state method (dashed line).

1) Institute of Experimental Physics, Warsaw University, Poland
2) Lawrence Berkeley National Laboratory, USA
Observation of Fast Ternary and Quaternary Breakup of the $^{197}$Au + $^{197}$Au System in Collisions at 15 MeV/nucleon

by I.Skwira-Chalot,1) K.Siwek-Wilczyńska,1) J.Wileżyński and CHIMERA Collaboration

The analysis of our experiment on the $^{197}$Au+$^{197}$Au reaction at 15 MeV/nucleon [1] has continued and has revealed new interesting features of the reaction mechanism. The presence of a new reaction mode, a violent breakup of the composite $^{197}$Au+$^{197}$Au system into three or four fragments of comparable size was demonstrated and reported in Ref. [2].

The experiment was carried out at the Laboratori Nazionali del Sud in Catania using beams from the LNS Superconducting Cyclotron. For detection and identification of reaction products the Charged Heavy Ion Mass and Energy Resolving Array (CHIMERA), consisting of 1192 $\Delta E$-E telescopes arranged in a 4$\pi$ geometry was used.

Most probable ternary and quaternary events were selected under the condition of nearly complete balance of mass, allowing, however, for up to 70 mass units to be lost due to evaporation of undetected nucleons and $\alpha$ particles from the excited primary fragments. Thus selected events were reconstructed kinematically event-by-event.

An overview of the ternary and quaternary reactions studied is presented in Figs. 1 and 2, respectively, where the velocities of all fragments in a given event are projected onto a common reaction plane and displayed in the transverse vs. longitudinal velocity space. In this presentation of the data an overview of the geometry of the most probable ternary and quaternary reactions and of the relative energies of the fragments is best visualized.

Fig. 1 Distribution of fragments in ternary events plotted in the common reaction plane as a function of the longitudinal and transverse velocities.

In the case of ternary reactions presented in Fig. 1, the slowest fragment is the remnant of the target nucleus (the target-like fragment, TLF), while the other two (faster) fragments originate from breakup of the projectile-like fragment, PLF. All three fragments are emitted almost co-linearly, excluding a statistical character for the breakup. Detailed analysis of the fragments’ angular correlations enabled us to estimate the time scale of the breakup process to be about 70-80 fm/c.

The quaternary events shown in Fig. 2 display the same astonishing effect of nearly co-linear emission of all four fragments. In these events, not only the PLF, but also the TLF is violently torn apart. A similar time scale estimate as for ternary reactions was obtained.

Comparisons with predictions of the quantum molecular dynamics (QMD) model of Łukasik [3] have shown that the explanation of the observed very fast ternary and quaternary breakup processes may be a real challenge for theoretical models of nucleus-nucleus collisions.


1) Institute of Experimental Physics, Warsaw University, Poland
Properties of Heavy and Superheavy Nuclei
by M.Kowal, A.Parkhomenko and A.Sobiczewski

Our theoretical studies of the heaviest nuclei in 2008 were mainly concentrated on two topics; the fission barriers and the genetic decay chains of these nuclei.

A study of the (static) fission-barrier height, $B^\text{st}_f$, of the heaviest nuclei is motivated by the importance of this quantity in calculations of cross sections, $\sigma$, for the synthesis of these nuclei. The height $B^\text{st}_f$ is a decisive quantity in the competition between neutron evaporation and fission of a compound nucleus in the process of its cooling. The large sensitivity of $\sigma$ to $B^\text{st}_f$ stresses the need for accurate calculations of $B^\text{st}_f$. For example, a change of $B^\text{st}_f$ by 1 MeV may result in a change in $\sigma$ by about one order of magnitude or even more [1].

The height $B^\text{st}_f$ is quite often calculated under the assumption of axial symmetry of the nucleus (e.g. [2,3]). In our present study, the effect of the quadrupole non-axiality $\gamma_2$ of a nucleus on the barrier height $B^\text{st}_f$ has been examined for a large number of nuclei with proton number $92 \leq Z \leq 122$ and neutron number $136 \leq N \leq 188$. To get realistic results a large (8-dimensional) deformation space was used. This space is characterized by the parameters: $\beta_\lambda$ ($\lambda=2,3,4,5,6,7,8$) and $\gamma_2$, the coefficients in the expansion of the nuclear radius (in the intrinsic frame of reference) into spherical harmonics. The main results of the study are given in Fig.1 and Fig.2.

One can see in Fig.1 that the effect of the non-axial deformation $\gamma_2$ on $B^\text{st}_f$ is quite large. It may reduce $B^\text{st}_f$ by up to 2 MeV. Fig.2 shows that, after the inclusion of this effect, the largest values of $B^\text{st}_f$ are about 6.5 MeV for the actinide nuclei and about 6.0 MeV for the superheavy ones. Details of the study may be found in Ref. [4].

The importance of the analysis of the $\alpha$-decay genetic chains of the heaviest nuclei comes from the fact that almost the whole of our knowledge of these nuclei is obtained from these chains, observed experimentally up to the present day. Most of the chains belong to odd-A nuclei. It is important, then, to check how well one is able to describe these chains theoretically.

In our paper, we aimed to perform a detailed and complete analysis of such a chain, also including the effects of the single-particle structure of the nuclei appearing in the chain, an effect disregarded, as a rule, in the literature. Single-particle states are treated as one quasi-particle states. Alpha-decay transitions are assumed to occur only between states with the same structure (the same quantum numbers). A transition from an excited state is a result of the competition between $\alpha$- and $\gamma$-decays. Alpha transition energies and the respective half-lives are calculated. An experimentally well-known decay chain of the $^{260}$Ds ($Z=110$) nucleus is taken for the analysis. The main results are shown in Fig. 3. One can see that the effect of the single-particle structure may be quite large. In the chain analyzed, the effect is especially large in the decay of the $^{252}$Rf ($Z=104$) nucleus to the $^{253}$No ($Z=102$) nucleus, leading to the highly excited 11/2- [725] state. This decreases the decay energy by about 790 keV with respect to decay from ground-state to ground state. Details of the analysis may be found in Ref. [5].

Fig. 1 Contour map of the reduction, $\delta B^\text{st}_f$, of the barrier height due to the non-axial quadrupole deformation $\gamma_2$.

Fig. 2 Same as in Fig.1, but for the barrier height after the inclusion of the effect of $\gamma_2$. 
Fig. 3  Calculated single-particle spectra of nuclei belonging to the α-decay chain of the $^{269}$Ds nucleus. The most likely sequence of consecutive α and γ decays is shown by the arrows. Theoretical values of the α-decay energies $Q^{\alpha}_{\text{th}}$ of the nuclei are also given.

Influence of the Electron Cloud on α-decay Half-lives
by Z.Patyk

The α decay constant has been calculated for bare nuclei and neutral atoms [1]. Calculations were performed in the WKB approximation assuming that the α particle tunnels the nuclear Coulomb barrier. For a neutral atom the electron screening potential on the barrier is added as well.

The electron screening potential at a nucleus was estimated from the Hellman-Feynman (H-F) theorem, which states that the derivative of the binding energy for a fixed number of electrons with respect to the nuclear charge Z equals the expectation value of the derivative of the Hamiltonian with respect to Z. The latter expectation value equals the electron screening potential at the nucleus. The electron binding energies applied in the H-F theorem were published in a paper [2] and were calculated in the Dirac-Fock approximation.

Moreover, it was assumed that the difference between the total kinetic energy of an α particle (with added recoil energy of the daughter nucleus) emitted by a neutral atom and a bare nucleus equals the difference of the electron binding energies between the mother and daughter neutral atoms.

Finally, the influence of the electron cloud on the α decay constant was estimated [1] to be a few per mil with an uncertainty of about one per mil.

Fig. 1 presents an example of the α-decay constant shift \[\delta\lambda / \lambda \equiv 2(\lambda_N - \lambda_B )/(\lambda_N + \lambda_B)\] for several radon isotopes.

The α-decay constants λ for neutral atoms and bare nuclei should be measured with a precision \(\delta\lambda / \lambda\) equal to 0.001 or better. To achieve this sample size of decay times should approximately equal 10^6 and the waiting time on the decay event should not be shorter than 13 T_{1/2}, where T_{1/2} denotes the α-decay half-life.

A few nuclides were suggested for a λ shift measurement in the ESR at GSI-Darmstadt [1, 5].

A.Musumarra et al., E073 GSI proposal (2006)
Nuclear Fission within the Mean-field Approach

by J.Skalski

Calculations of decay rates require an exact knowledge of the wave function asymptotics in the proper decay channel, which is usually very difficult to achieve for many-body systems. Up to now, practical calculations of fission rates used a limited mean-field approach with a few chosen degrees of freedom and arbitrary inertia parameters (usually given by the cranking formula). Overcoming this arbitrariness and applying the mean-field theory in full seems desirable. This can be done by considering mean-field instantons: solutions to the imaginary-time TDHF equations [1, 2].

We cast the instanton method in a form analogous to that of the ATDHF [3] or ATDHFB [4] theory [5]. In the latter case, the HFB instanton density matrix, encoding both the normal and anomalous (pairing) densities, can be represented in terms of the time-even (ordinary) HFB density matrix \( \rho_0 \) and the time-odd hermitian operator \( \hat{S} \) (acting in double space),

\[
R(\tau) = e^{-\hat{S}(\tau)} R_0(\tau) e^{\hat{S}(\tau)}, \quad -T/2 < \tau < T/2.
\]

It satisfies the imaginary-time TDHF equations:

\[
\hbar \partial_\tau R(\tau) + \left[ \hat{h}(\tau), R(\tau) \right] = 0,
\]

with

\[
R(\tau) = \begin{pmatrix} \rho(\tau), & \kappa(\tau) \\ -\kappa^*(\tau), & \Gamma - \rho^*(\tau) \end{pmatrix};
\]

\[
\hat{h}(\tau) = \begin{pmatrix} \hat{i} + \hat{\Gamma}(\tau), & \hat{\Delta}(\tau) \\ -\hat{\Delta}^*(\tau), & \hat{\Gamma} + \hat{i} + \hat{\Gamma}(\tau) \end{pmatrix},
\]

where \( \rho(\tau) = \rho^*(\tau), \kappa(\tau) = -\kappa(\tau), \) \( \hat{i} \) is kinetic energy, self-consistent potentials \( \Gamma_{\rho}(\tau) \) and \( \Delta_{\rho}(\tau) \) satisfy:

\[
\hat{i}(\tau) = \hat{i}^+(\tau) \quad \text{and} \quad \hat{\Delta}(\tau) = \hat{\Delta}^+(\tau)
\]

so that \( \hat{h}(\tau) = \hat{h}^+(\tau) \). Equation (1) conserves the energy overlap \( \langle \Phi(\tau) | \hat{H} | \Phi(-\tau) \rangle \) and the 'generalized unitarity', \( N^{-1}(\tau) = N^+(\tau) \), of the imaginary TDHF transformation. The decay rate \( e^{-A} \) is determined by the periodic solution to Eq. (1) (called bounce) that connects the HFB ground state \( |\Psi_{gs}\rangle \) with some HFB state \( |\Phi(\tau = 0)\rangle \) beyond the barrier via the instanton action

\[
A = -\frac{\hbar}{2} \int_{-T/2}^{T/2} d\tau Tr R_0(\tau) e^{\hat{S}(\tau)} \left( \hat{i} e^{-\hat{S}(\tau)} \right).
\]

It turns out that bounce is fixed as the minimum of the action \( A \) among trial fission paths \( (R_0(\tau), \hat{S}(\tau)) \) that conserve the energy overlap, boundary conditions and fulfill the \( \tau \)-odd part of Eq. (1) connecting \( \partial_\tau R_0 \) and \( \hat{S} \) (the velocity-momentum relations) [5]. When the \( \tau \)-odd part of Eq. (1) is solved to first order in small \( \hat{S} \) (adiabatic limit), action (3) defines the ATDHFB mass: \( \frac{\hbar}{2} Tr (\hat{R}_0 \hat{S}) / \hat{Q}^2 \). Any GCM method that constructs fission paths from \( \tau \)-even HFB states ignores the velocity-momentum constraints and must overestimate the bounce-related fission rate [5].

The \((\pi,K^+)\) Reaction on \(^{28}\text{Si}\) and the \(\Sigma\)-Nucleus Potential

by J.Dąbrowski and J.Rożynek

Recently, a new source of information on the \(\Sigma\) single particle (s.p.) potential \(U_\Sigma = V_\Sigma - iW_\Sigma\) became available: the final state interaction of \(\Sigma\) hyperons in the associated production reaction \((\pi, K^+)\). The first measurement of the inclusive \(K^+\) spectrum from the \((\pi^-, K^+)\) reaction on a \(^{28}\text{Si}\) target was performed at KEK at a pion momentum of 1.2 GeV/c \([1]\). The existing impulse approximation analyses \([1-2]\) of this KEK experiment imply a repulsive \(V_\Sigma\) with a surprisingly large strength of about 100 MeV, inconsistent with previous estimates of about 25 MeV (compatible with the Nijmegen model F of the baryon-baryon interaction). We show \([3-4]\) that the inconsistency may disappear if we consider the additional elastic \(\Sigma N\) contribution \(W_e\) to the width \(W_\Sigma\) (see Fig. 1) and the dependence of \(V_\Sigma\) on the \(\Sigma\) momentum. Then \(W_\Sigma\) is the sum of the elastic part \(W_e\) and the \(\Sigma\Lambda\) conversion part \(W_c\). We calculate in the impulse approximation the inclusive kaon spectrum from the \((\pi^-, K^+)\) reaction on \(^{28}\text{Si}\), and compare in Fig. 2 our results with the KEK experimental results. The strength of \(V_\Sigma\) is obtained from the Nijmegen model F of the baryon-baryon interaction, and the strength of \(W_\Sigma\) is determined by the \(\Sigma N\) cross sections for \(\Sigma\Lambda\) conversion and also for elastic \(\Sigma N\) scattering (this elastic scattering introduces a strong dependence of \(W_\Sigma\) on the \(\Sigma\) momentum). Curve A was calculated with \(W_\Sigma \approx W_c\), and curves B and C with \(W_\Sigma = W_c + W_e\). In curves A and B the momentum dependence of \(V_\Sigma\) was not considered. The effect of this momentum dependence was estimated in curve C by introducing the effective mass \(M_\Sigma^* = 0.7M_\Sigma\). Our spectra B and C agree reasonably with the spectrum measured at KEK (the agreement will certainly improve when we consider the distortion of the kaon and in particular the pion waves, disregarded in the present calculation). The strengths of the real and absorptive \(\Sigma\) potentials used in our calculation appear consistent with earlier estimates (analyses of \(\Sigma\) atoms and strangeness exchange reactions).

\[\text{Fig. 1} \quad \text{The components} \; W_e \; \text{and} \; W_c \; \text{of} \; W_\Sigma.\]

\[\text{Fig. 2} \quad \text{The calculated and measured kaon spectrum on} \; ^{28}\text{Si} \; \text{at} \; \theta_K = 6^\circ \; \text{at} \; p_\pi = 1.2 \text{ GeV/c.}\]

X-ray Study of M-shell Ionization of Heavy Atoms by 8.0-35.2 MeV O$q^+$ Ions
by M.Czarnota,1) D.Banaś,1) J.Braziewicz,1) J.Semaniak,1) M.Pajek,1) M.Jaskóła, A.Korman, D.Trautmann,2) W.Kretschmer,3) G.Lapicki,4) T.Mukoyama5)

M-shell ionization in high-Z (Au, Bi, Th and U) atoms by O$q^+$ ions has been studied systematically in the energy range 8.0-35.2 MeV in order to verify the available theoretical approaches describing M-shell ionization by charged particles in asymmetric collisions. Oxygen beams with intensities 5-20 nA were obtained from the tandem accelerator at the Erlangen-Nürnberg University. The M x-rays excited in the targets (10-30 µg/cm² thick) were detected by a Ge(Li) detector, with an energy resolution of 150 eV at 6.4 keV. The M x-rays production cross sections were normalized to the elastically scattered projectiles measured by a Si detector placed at an angle of 150°. The measured M x-ray spectra were analyzed taking into account the effects of x-ray line shifting and broadening caused by multiple ionization in the M and N-shells [1].

The M-subshell ionization cross sections, derived using the M-shell decay rates modified for multiple ionization effects, were compared with theoretical predictions based on the plane-wave Born approximation (PWBA), the semiclassical approximation (SCA), and the binary-encounter approximation (BEA). In the PWBA - based approach the energy loss (E), Coulomb deflection (C), perturbed stationary state (PSS) and relativistic (R) effects were considered within the ECPSSR theory and its recent modification, ECUSAR, which corrects the description of the electron binding effect to account for the united and separated atoms (U-S-A) electron binding energy limits. In the SCA calculations performed with relativistic hydrogenic wave functions the binding effect was included in the limiting cases of separated-atom (SA) and united-atom (UA) limits. In Fig. 1 the measured M x-ray production cross sections for M$_{5}N_{6,7}$, M$_{4}N_{6}$, M$_{3}N_{5}$, M$_{2}N_{4}$ and M$_{1}O_{2,3}$ x-ray transitions in gold bombarded by oxygen ions are compared with the predictions of the ECPSSR and the SCA theories.

The measured M-subshell ionization cross sections are best reproduced by the SCA-UA and ECPSSR calculations, with the exception of the M$_{2,3}$ (3p-subshell) cross sections which are strongly enhanced and cannot be reproduced by these calculations.

More details about the experimental results for all the elements studied and the theoretical description are presented in our recent paper [2].


1) Institute of Physics, Jan Kochanowski University, 25-406 Kielce, Poland
2) Institut für Theoretische Physik, Universität Basel, CH-4056 Basel, Switzerland
3) Physikalisches Institut, Universität Erlangen-Nürnberg, D-91058 Erlangen, Germany
4) Department of Physics, East Carolina University, Greenville, North Carolina 27858, USA
5) Kansai Gaidai University, Hirakata, Osaka, 573-1001 Japan
Studies of Fast Electron Beams in Tore-Supra and other MCF Devices*

by L.Jakubowski, K.Malinowski, M.Rabiński, M.J.Sadowski, J.Zebrowski, M.Jakubowski and R.Mirowski

The main aim of these studies was to measure fast electrons escaping from a dense plasma region during tokamak-type discharges. Within the framework of the EURATOM collaboration the IPJ team devised a special diagnostic technique based on a Cherenkov-type detector. A new measuring head was designed especially for plasma conditions occurring in the scrape-off-layer within the Tore-Supra tokamak (at CEA Cadarache). In 2008, the measuring head was manufactured and tested at IPJ. In September 2008, the detector was assembled on a new fast, internal reciprocating shaft, specially prepared by the CEA team. The shaft was equipped with a Cherenkov measuring head and after baking and vacuum tests, it passed the authorization for application during the last experimental campaign of 2008.

The first measurements of fast electrons within Tore-Supra, using the complete Cherenkov-type detector, were performed in November 2008. The four-channel Cherenkov detector measuring head, which was mounted on the top of the reciprocating shaft, was inserted into the Tore Supra tokamak chamber. The internal shaft was located in one of the vertical diagnostic ports and it enabled the measuring head to be moved into the SOL region along the tokamak small radius (always outside the LCFS) to the nearest positions, in which the top of the measuring head was placed 80-100 mm from the LCFS.

Signals from four channels of the detector were recorded for about 140 shots performed during the experimental campaign in November. Visible light generated by the Cherenkov effect was detected outside the Tore-Supra hall by means of four separate photomultipliers. The background level of the signals from four photomultipliers was low, but some spikes appeared at the level of a four hundred mV. Therefore, for the recording of Cherenkov signals we had to use a fast digital oscilloscope of the Tektronix type. The measurements were performed for different plasma scenarios and discharge regimes. Six sets of signals were recorded corresponding to shots performed with additional lower hybrid (LH) heating. The Cherenkov-produced signals were observed in two channels (for electron energy above 84 keV, and above 109 keV). The signals obtained were routinely correlated with the inner shaft movement (DENEPR) and other basic TS plasma signals: i.e. LH heating, ICRH heating, plasma current ($I_p$), and the line-averaged plasma density ($n_L$).

It seems that the appearance of the Cherenkov signals, produced by about 150-keV fast-electron beams, was strongly dependent on a sufficiently high level of the LH (and ICRH) heating.

An example of the recorded Cherenkov signals is presented in Fig. 1.

![Fig. 1](image)

The most important result was that the recorded electron signals confirm the appearance of a thin fast-electron sheath outside the plasma torus in the Tore-Supra. The electron sheath appeared to be almost quasi-stationary in space during the movement of the Cherenkov detector head.

Simultaneously with new experimental studies in 2008, the IPJ team was involved in the analysis of results obtained during the preliminary Cherenkov measurements, which were performed within the ISTTOK facility (at IST in Lisbon). The Cherenkov signals, recorded by means of a single channel Cherenkov detector head, were analyzed and presented in three different papers [K868, P1280 and K807]. In those papers, the experimental data obtained were compared with the results of numerical simulations. The most important result was the identification of operational regimes in the low-current ISTTOK discharges where fast run-away electrons are generated. The experimental data collected appeared to be in good agreement with results obtained previously by numerical analysis of macroscopic plasma parameters.

* Collaboration with CEA-Cadarache and the IST-Lisbon within the framework of the EURATOM program
Using of Solid-state Nuclear Track Detectors for Measurement of Fusion-reaction Protons in the TEXTOR Tokamak Plasma*

by A.Szydlowski, A.Malinowska, K.Malinowski, G.Van Wassenhove,1) G.Bonheure,1) B.Schweer and TEXTOR team2)

Solid-state nuclear track detectors (SSNTDs) are particularly suitable and useful for high-temperature investigations because they can be operated under high vacuum conditions and are insensitive to electromagnetic radiation and fast electron fluxes. Therefore, these detectors, especially of the CR-39/PM-355 type, have been used in Plasma Focus experimental studies performed at IPJ and IPPLM for many years [P1506, P1509]. It should, however, be mentioned that the detectors used in each of our experiments have been precisely calibrated with mono-energetic ions (H+, D+, He+-ions etc) [P1510]. Recently, we have proposed using the aforementioned detectors in tokamak and laser produced plasma experiments. In order to place the detector inside the TEXTOR vacuum vessel a special ion pinhole camera was constructed at IPJ, Swierk. The camera was equipped with a detector sample and was attached to a water-cooled manipulator, which enabled the camera to be located at a chosen position within the plasma boundary. In the first experiment the camera was located ~49 cm from the plasma centre and its pinhole was oriented along the major tokamak radius (i.e. at γ=0°). A few series of discharges were performed to record fusion-reaction protons. In the first series (shots Nos 99818-99830) the discharges were executed with a 1.5 MW neutral beam (NBI) injected into the plasma [P674]. This resulted in an average neutron emission of Yn≈1.4•10¹³ neutrons/s. In the second series of shots (Nos 103397-103432) the plasma was heated by microwaves (ICRH) tuned to the 2-nd harmonic of H+ -ions (2 x 1 MW) and by NBI (1.3 MW of H neutrals). The neutron emission in these discharges was low and amounted to merely Y n~10¹² neutrons/day [P1105].

The detectors irradiated with fusion-reaction protons were subjected to the same etching procedure as the detectors used in the calibration experiment i.e. in a 6.25 N water solution of NaOH at a temperature of 70°C [P1509, P1510].

The calibration data obtained (Fig. 1 A) showed that the protons of expected energy in the range from 2.5 MeV to 3.5 MeV could produce tracks of diameters ranging from 6 to 8 µm. The two-dimensional distributions of such craters, as measured on the detector sample irradiated in the first experiment, are shown in Fig. 1 B. Comparing the measured crater diameters with those induced by mono-energetic protons it was also possible to convert the track diameter histograms obtained (Fig. 2 A) into proton energy spectra (Fig. 2 B and C). One can see that the fusion-proton spectra are shifted towards higher energy, suggesting that high-energy reagents were responsible for nuclear fusion reactions occurring inside the TEXTOR plasma. The more subtle character of the spectrum obtained in the second experiment (Fig. 2 C) could suggest that some populations of fast reagents (probably accelerated by different mechanisms, i.e. ICRF and NBI) induced the majority of the observed nuclear reactions. The detectors irradiated in the recent two series of shots are still being analyzed and the results could not be presented yet.

Fig. 1 Calibration curve presenting track diameters as a function of proton energy (A), and two-dimensional distribution of craters of diameters in the range 6 – 8 µm, that is those which were induced by fusion-reaction protons as measured with the PM-355 detector sample (B).

It should be emphasized that these measurements are supported by computation of proton trajectories in the TEXTOR facility vessel as well as the expected efficiency of the measuring set-up for 3 MeV proton detection. The computer simulations were performed with the Gourdon code [P363].
Fig. 2 Histogram of track diameters (A) and proton energy spectra obtained on the basis of the proton track diameters as measured upon detector samples, which were irradiated in the first (B) and second (C) series of shots within the TEXTOR facility.

In Fig. 3 the primary results of these calculations are presented. One can see that in the centre of the detector (circle of radius equal to 2.2 mm) only 3 MeV protons were recorded, these emitted at a definite angle to the toroidal magnetic field (the so called pitch angle). By changing the orientation of the pinhole one can record protons with a given initial pitch angle in this circle. We expect that the calculations will also reveal a similar dependence between the proton birth place (small radius) and the registration position.

Fig. 3 Distribution of detection efficiency as calculated for 3 MeV protons and for different orientations of the pinhole camera with respect to the major TEXTOR chamber radius ($\gamma$).

* Collaboration with the IPP-ERM/KMS, EURATOM – Belgian State Association and IPP Juelich within the framework of the EURATOM program

1) IPP-ERM/KMS, EURATOM – Belgian State Association, TEC, B-1000 Brussels, Belgium
2) IPP, Association EURATOM – Forschungszentrum Juelich, D-52425 Juelich, Germany
Application of Solid-state Nuclear Track Detectors of the CR-39/PM-355 Type to Measurements of Energetic Protons Emitted from Plasma Produced by an Ultra-intense Laser*
by A. Szydłowski, J. Badziak, R. Suchańska, J. Fuchsa

Solid-state nuclear track detectors (SSNTDs), due to their specific properties, have found various applications in different fields of science and technology. At IPJ SSNTDs have been used for corpuscular diagnostics of high-temperature plasmas for many years and detailed calibration studies of the selected detectors (CN, CR-39, PM.355 etc) have been performed [P1510]. The PM-355 plastic appeared to be the best one, especially for the detection of protons, deuterons, and He-ions, and therefore this detector was mainly used in our experiments. This paper describes the application of the PM-355 detector to measurements of fast protons emitted from laser-produced plasmas.

The experiment was performed at the 100 TW LULI Nd-glass laser facility. The laser was operated at a wavelength of 1.05 µm and delivered ~15 J of energy in a pulse duration of 0.35 psec yielding a peak target irradiance up to 2•10¹⁹ W/cm². The laser beam was focused on a thin (0.6 – 3 µm) polystyrene target (PS) or a PS target covered by a 0.05 – 0.2 µm thick Au front layer. To measure effectively the proton emission efficiency and to estimate proton energy spectra about ten samples of the PM-355 detector were used in each laser shot. The samples were covered with Al foils of different thicknesses. Other samples were irradiated with mono-energetic protons provided by a particle accelerator. All the samples were etched under the same etching conditions. Such a procedure enabled proton induced craters to be more easily distinguished from other detector tracks e.g. background, detector structure micro-damage, etc.

Some samples irradiated with protons from the same laser shot appeared to be overexposed, especially those covered with thinner Al foils. However, others masked with thicker foils showed craters pretty well separated one from another. Therefore, it was possible to estimate the flux of relatively fast protons (say Ep > 3 MeV) as a function of filter thickness i.e. versus proton energy. Knowing these counting rates (i.e. track densities) it was possible to estimate the proton energy spectrum.

The determined spectra of fast protons were best modeled by two Maxwellian distributions (Fig. 1.). This two-temperature energy distribution of measured protons was a general feature of laser shots performed at relativistic intensities because such spectra were observed at different laser intensities and for various target structures. It is supposed that the lower temperature component is generated by the Skin-Layer Ponderomotive Acceleration (S-LPA) mechanism whereas the higher temperature part is due to the Target Normal Sheath Acceleration (TNSA) interaction [P1281, P1292].

![Fig. 1 Experimental results of SSNTDs measurements (points) with fits by Maxwellian distributions of temperature Tp (lines).](image-url)

* Collaboration with the IPPLM, Warsaw, Poland
1) IPPLM, Warsaw, Poland
2) LULI, Ecole Polytechnique, CNRS, CEA, UPMC; Route de Saclay, 91128
The main task was to investigate fusion-produced protons emitted from Plasma-Focus (PF) discharges. For this purpose, we decided to use Nuclear Track Detectors (NTD) because they are very useful diagnostic tools for measurements of fast protons and other charged particles.

Acceleration processes occurring in high-temperature plasma often lead to the generation of high-energy ion beams. Such beams induce nuclear reactions and contribute to the emission of fast neutrons, fusion protons and alpha-particles from PF-discharges with deuterium gas. The ion measurements are of primary importance for understanding the mechanisms of the physical processes which drive the charged particles acceleration. The main aim of the studies presented there was to perform more accurate measurements of spatial- and energy- distributions of the fusion-reaction protons within the PF-1000 facility operated at IFPiLM in Warsaw. For measurements of the spatial- and energy- distribution of fusion-reaction protons use was made of ion pinhole cameras equipped with PM-355 NTDs [P675]. Figure 1 presents the arrangement of the ion pinhole cameras, which were located at different angles to the electrode axis in the PF-1000 facility.

Similar arrangements were used earlier in the PF-360 facility operated at IPJ in Swierk [P938]. In both experiments, the NTDs were irradiated during a series of PF discharges and then etched under standard conditions. From a detailed analysis of the recorded proton tracks, it was possible to determine the spatial distribution of the fusion protons emitted at the angles investigated [P675, P938]. The total yields of fusion protons at various angles, \( \Theta \), differed considerably. The fusion-reaction protons were emitted mainly into a narrow cone, with the maximum emission oriented along the electrode axis. This effect has already been observed in earlier PF experiments, but it was necessary to perform more accurate measurements in the PF-360 and PF-1000 machines. It was shown that the observed strong anisotropy in the proton emission could be explained by the influence of local (azimuthally- and axially-oriented) magnetic- and electric-fields on the proton trajectories.

From the recorded track diameters, it was also possible to estimate a proton energy spectrum, because the energy scale was determined on the basis of the previous calibration measurements. Figure 2 presents the energy spectrum determined on the basis of the track detectors exposed within the PF-1000 experiment. It can be seen that the fast protons, emitted from plasmas produced within the PF-1000 facility, had energies ranging from 3.1 MeV to 4.5 MeV. Such high-energy protons could be generated by energetic deuteron beams, which could undergo nuclear-fusion reactions, e.g. \(^2\text{H}(d, p)^3\text{H}\).

From the proton energy spectrum obtained, we could conclude that the fusion reactions were induced by different mechanisms: thermo-nuclear and acceleration. An evident confirmation of this hypothesis was the observation that the second proton (and neutron) pulses were induced by the acceleration of some primary deuterons to energies of the order of several hundreds of keV. It should also be noted that the maximum and half-width of the total spectrum were not shifted significantly, as computed for the beam-target mechanism (Fig. 3).
Spectroscopic Studies of Plasma-ion Streams and Interactions of such Streams for Laser Pulses with Different Targets
by E.Składnik-Sadowska, K.Malinowski, M.J.Sadowski, M.Ladygina, A.Marchenko, M.Kubkowska, and J.Wołowski

The main aim of this topic was to elaborate results of earlier spectroscopic studies and to collect new data about free plasma streams and their interactions with solid targets. In general, plasma-target interactions depend strongly on the plasma parameters and target properties, and they must be investigated for various experimental conditions. Using time-resolved optical spectroscopy we studied the interaction of pulsed plasma streams with carbon (C) and tungsten (W) targets in the PF-1000 facility [P942, P937, P943]. For a C-target, placed 30 cm from the electrode outlet, it was shown that the electron density (estimated from C- and D-lines) decreased from $3 \times 10^{18}$ to $3 \times 10^{16}$ cm$^{-3}$ in about 30 µs. For a W-target the recorded optical spectra contained very intense D$\alpha$ and D$\beta$ as well as CII-CIV lines, which covered the WI and WII lines.

Results of the previous spectroscopic studies of plasma produced from a W-target irradiated with an intense laser beam have been presented in a separate paper [P1126]. We recorded and identified distinct WI and WII lines, as shown in Fig. 1.

The most important results of the spectroscopic studies of W-targets, irradiated by intense plasma-ion streams or laser beams, have been summarized in other papers [P1194, K739]. It was shown that during the W-plasma decay the temperature ($T_e$) was about 1.1 eV, and the density ($n_e$) was about $8 \times 10^{16}$ cm$^{-3}$. Signals obtained from an ion analyzer showed that the W-plasma also emitted higher ionized ions (up to W$^{16+}$). Signals from the ion collector showed that the average energy of these ions was about 4.6 keV.

Other efforts concerned research on the interaction of a hot deuterium plasma stream with a W-target placed inside the RPI-IBIS facility [P1189]. In the first step, we determined the conditions for the generation of a clean deuterium plasma. During measurements performed with the W target, we recorded and identified distinct WI and WII spectral lines, as shown in Fig. 3.

On the basis of the identified W-lines, it was possible to estimate the basic plasma parameters. It was found that the most probable $T_e$ value was about 2-3 eV, which seemed to be realistic for the W-plasma expansion phase. In the second step $n_e$ values were estimated ensuring the best agreement of the computed and observed WI- and WII-lines. From this analysis, it was estimated that the maximum density value amounted to about $10^{17}$ cm$^{-3}$, while the average electron concentration amounted to only $3 \times 10^{16}$ cm$^{-3}$.

The studies described there showed that the RPI-IBIS facility can be used for research on the interaction of hot plasmas with W-targets, of great importance for nuclear fusion facilities.

1) IPP KIPT, Kharkiv, Ukraine
2) IFPiLM, Warsaw, Poland
Studies of Pulsed Plasma-ion Streams during their Free Propagation by Means of Corpuscular Diagnostic Techniques

by E. Składnik-Sadowska, K. Czaus, K. Malinowski, M. J. Sadowski and J. Żebrowski

The main aim of these studies was the accurate determination of energy spectra of ions emitted from pulsed plasma discharges of the RPI type. Mass- and energy-distributions of ions depend strongly on discharge characteristics, and they must be measured for given experimental conditions. In the RPI-IBIS experiment, ion measurements were performed for different operational modes. Use was made of corpuscular diagnostics, and particularly of a miniature mass-spectrometer of the Thomson type [P944]. Attention was paid to measurements of primary protons (from hydrogen discharges) and deuterons (from deuterium discharges). Energy spectra of these ions were determined in the energy range from 20 keV to about 200 keV, as shown in Fig. 1.

![Energy distributions of accelerated protons and deuterons](image1.png)

**Fig. 1** Energy distributions of accelerated protons and deuterons, as measured for a so-called “slow mode” in the RPI-IBIS facility [P944].

In order to perform the accurate calibration of nuclear track detectors of the PM-355 type for deuterons of energy from about 20 keV to about 500 keV, use was made of another Thomson-type spectrometer of larger dimensions, which was placed outside the vacuum chamber. Several points on the recorded deuteron parabola were selected where the deuterons might be treated as monoenergetic and a detailed analysis of the tracks was performed with an optical microscope. Due to this procedure it was possible to achieve an energy resolution of ±0.1 keV for 20 keV deuterons, and ±50 keV for 500 keV deuterons [P904].

Selected measurements of mass- and energy-spectra of ions emitted in pulsed plasma-ion streams within the RPI-IBIS and PF-360 facilities operated at IPJ were analyzed and presented at SPPT-2008 [K733]. Particular attention was paid to the analysis of various factors which determine the accuracy of the described diagnostic technique.

The most important results of research on the application of PM-355 nuclear track detectors to studies of the spatial structure of proton streams, carried out earlier, were summarized in a paper presented at INTIS-2008 [K744]. These studies were performed by means of miniature pinhole cameras placed at a distance of 30 cm from the RPI-IBIS electrodes outlet. In order to eliminate protons of energy below the chosen threshold (e.g. 125 keV, 210 keV and 345 keV), the PM-355 detectors were shielded with absorption filters (Al foils of 0.75, 1.5 or 3.0 µm in thickness). Results of the detailed measurements of track diameters were used to produce histograms of the recorded tracks. On the basis of the calibration diagram and the known characteristics of the filters applied, it was possible to compute the corresponding histograms of proton energies, as shown in Fig. 2.

![Proton-irradiated track detectors with micro-regions chosen for quantitative analysis](image2.png)

**Fig. 2** Proton-irradiated track detectors with micro-regions chosen for quantitative analysis, microscope pictures of proton tracks, and corresponding energy spectra of protons, as computed taking into account the applied absorption filters [K744].

Other measurements concerned streams of deuterons emitted from the RPI-IBIS facility operated with D2 puffing [K745]. The main aim was to investigate the applicability of PM-355 detectors to the recording of deuterons of energy below 200 keV. Using the same Thomson-type spectrometer and detectors, distinct deuteron parabolas were recorded under different operational conditions. Accurate measurements of tracks in different points of the deuteron parabolas enabled histograms of deuteron energy distributions to be obtained [K745]. Simultaneously, it was shown that for a so-called “slow mode” the energy distribution has a maximum near 40 keV, while its tail ranges up to about 150 keV. These measurements confirmed the applicability of the diagnostic technique described here for cross-checking the detector calibration diagrams.
Investigation of Current Filaments in Plasma Discharges of the PF Type and their Influence on the Emission of Fast Deuterons and Protons
by M.J. Sadowski, A. Malinowska, K. Malinowski, M. Scholz and W. Stepniewski

The main aim of this study was to investigate the influence of so-called current filaments on the emission characteristics of Plasma-Focus (PF) discharges. Current filaments were observed in various PF and Z-Pinch experiments, but an analysis of their role was missing. On the other hand, intense (10^5-10^6 A) currents, flowing through narrow plasma channels, generate strong local magnetic fields, which deflect the trajectories of free electrons, primary ions (protons, deuterons) and charged products of fusion reactions (i.e. fast protons and tritons). An analysis of the most important issues in research on dense plasmas, presented in a paper [P1046] highlighted by the IOP, brought attention to the role of current filaments and the necessity modelling them. Attention was also paid to angular distributions of fast (ca. 3 MeV) fusion-protons emitted from PF-discharges [P1046, P938]. Measurements of such fast protons were performed within the PF-360 device at IPJ and the PF-1000 facility at IFPlLM, using miniature pinhole cameras equipped with PM-355 nuclear track detectors and absorption filters (Al-foils of 80 µm in thickness), which eliminated particles of lower energy. These studies showed that the proton emission from PF-discharges depends strongly on the experimental conditions and observation angle [P938, K731]. In addition, an analysis of the energy spectrum of primary deuterons was performed on the basis of fast neutrons from D-D reactions [P938, K741].

Particular attention was paid to an analysis of the influence of local magnetic fields (surrounding current filaments) on the trajectories of the fast fusion-protons emitted from different parts of the plasma column. Several models of the pinch column were considered, e.g. a uniform column, 6 or 12 parallel current filaments and tunnel-like structures [K738]. An example is shown in Fig. 1.

Numerical computations for the fusion protons showed that (independent of the pinch structure) some protons are emitted in the upstream direction, but the maximum emission appears along the z-axis [P1193]. The most important result was to show that the proton emission in the radial directions (around the z-axis) depends strongly on the filament configuration, and the proton azimuthal distribution corresponds to the number filaments (see Fig. 2).

In a recent paper [K889] a review of filamentary structures was presented, a summary of research on fast deuterons and protons as well as new numerical simulations, as shown in Fig. 3.

Recent model computations show that the local minimum of the fast deuteron emission, usually observed at the z-axis, can be explained by the influence of a quasi-spherical plasma structure often formed near the end of the pinch column.

The results of the modeling described there will form the basis for new experimental studies.

1) IPPLM, Warsaw, Poland
Coherent and incoherent radiation sources in the vacuum ultraviolet and the soft X-ray wavelength region have become indispensable for many applications, for example in X-ray microscopy, X-ray lasers or EUV lithography. A promising candidate for the generation of EUV radiation is gas discharges in a capillary. These are quite often studied by various experimental techniques as intense soft X-ray sources and a cheap alternative to laser-plasma, free-electron, synchrotron sources, and sources based on higher harmonics generation. The capillary is a very simple device but it should be treated as a sophisticated multiparametric system. It consists of a non-conductive duct placed between two electrodes which are connected to a bank of low-inductance high-voltage (HV) capacitors charged to several kV. Plasma generated in the capillary has a small size and well-localized position. Driver characteristics (amplitude of capillary current, current rise-time), initial conditions (gas pressure, pre-pulse capillary current) and boundary conditions (capillary length and diameter, material of capillary and electrodes) are important for achieving optimal plasma parameters to provide maximal yield in the EUV region. Capillary discharge plasma sources have the potential advantage that they are simpler in design, compact and cost-effective.

Our experiment [P1191, K737] was aimed at the observation of extreme ultraviolet emission from the plasma produced by capillary discharges. A few kA current was applied across the gas-filled alumina capillary (1 mm diameter and 8 mm long) to produce radiation mostly in the EUV region (12-63 nm). The EUV radiation was characterized by use of a XEUV spectrometer. The results obtained from the EUV spectroscopic measurements provided information about the radiation processes from xenon and argon plasma and testifies that the given capillary is an effective source of EUV emission. We registered lines originating from Xe and Ar ions as well as the spectra generated by excitation of atoms from evaporation of the electrodes and capillary materials (Fig. 1). Radiation was registered in the wavelength range: 12-60 nm for argon and 12-63 nm for xenon.

The phenomenon was studied with the help of a computer program which describes plasma dynamics and the dynamics of the plasma ionization stages in a capillary discharge. Simulations confirmed the presence of ions, which spectra was registered in the experiment (Fig. 2).
We studied stationary states of a two-dimensional Bose-Einstein condensate with both attractive and repulsive nonlinearities in a combination of a double-square-well potential in one direction and a perpendicular optical lattice (see figure 1). We looked for dual-core solitons in this configuration, focusing on their symmetry-breaking bifurcations. For attractive interactions, without the lattice, a similar analysis was performed (M. Matuszewski et al., Phys. Rev. A 75, 063621, 2007), where subcritical bifurcation transforming antisymmetric gap solitons into asymmetric ones was found. Here we focused on the effect of an optical lattice and the thus created gap solitons. We discover that a phase transition occurs when the lattice depth increases and the additional dimension becomes strongly suppressed. The bifurcation type changes from subcritical, typical for a 2D system with hysteresis, to supercritical, typical for a one-dimensional system. An additional advantage of the lattice is that gap solitons exist even for repulsive interactions. In this case we also discover bifurcation of a supercritical type. We predicted the parameter regions admitting asymmetric solitons by means of a restricted variational approximation, which allows us to simplify an otherwise very complicated calculation. These results are verified by numerics. We find the agreement to be surprisingly good, for such a restricted variational model.

Our results are summarized in two figures presenting bifurcation diagrams (see below), one with attractive and one with repulsive nonlinearity.
Pair Correlations of Scattered Atoms from Two Colliding Bose-Einstein Condensates: Perturbative Approach


We study the properties of many body systems looking at the higher order correlations functions. The simplest correlation function is proportional to the conditional probability of detecting a particle at position $r_1$ given that the second particle was detected at $r_2$. It is called pair correlation function. The measurement of pair correlations function recently became possible with ultra-cold atoms of metastable helium-4.

Atoms of $^3$He*, in a highly excited electronic state, collide with the surface of a Microchannel Plate (MCP), and transfer their internal energy to the electrons of the MCP. As a result, a macroscopic current allows the detection of the positions of single atoms.

Using this experimental technique, the pair correlation function was measured in an ultracold gas of weakly interacting bosons and fermions [1]. The pair correlation function was also measured in the case of atoms scattered in the collision of two Bose-Einstein condensates [2].

The aim of our paper was to calculate the pair correlation function in the case of [2] and to compare the theoretical prediction with the experimental data. To this end, we introduced a simplified model for atom scattering during a collision of two Bose-Einstein condensate wave-packets. In this model, we assumed that two counter-propagating wave-packets constitute an undepleted source for the process of scattering. To satisfy this assumption the population of the scattered atoms should be small, as compared to the number of atoms in the condensates. In the regime of experimental parameters, the interaction energy of the scattered atoms was much smaller than their kinetic energy. Hence, we have neglected this energy in the Hamiltonian. With the above approximations, the Hamiltonian became quadratic in the quantum field of the scattered atoms, which enabled us to use standard perturbative methods.

Figures 1 and 2 show the averaged pair correlation function for two atoms scattered in opposite directions and the peak of atoms scattered at small angles. Dots correspond to the experimental data whereas the solid lines were obtained within our model. In the case of the opposite direction correlations (Fig. 1) we notice good agreement between our theoretical model and the data. However, in the case of atoms scattered collinearly (Fig. 2) the agreement is not so good, and indicates that we have to improve our model. We expect that the difference is due to the interaction of scattered atoms with the condensate and these effects are the subject of our current investigations.


1) Institute of Theoretical Physics, Warsaw University, Poland
2) Univ. Paris-Sud Campus Polytechnique, France
A Comparative Study of Silicon Drift Detectors with Photomultipliers, Avalanche Photodiodes and PIN Photodiodes in Gamma Spectrometry with LaBr₃ Crystals*

by M. Moszyński, C. Plettner,¹ A. Nassalski, T. Szczęśniak, L. Świderski, A. Syntfeld-Każuch, W. Czarnacki, G. Pausch,¹ J. Stein¹

Taking full advantage of LaBr₃ scintillators requires an optimal selection of photodetectors like photomultipliers (PMTs), avalanche photodiodes (APD) or p-i-n photodiodes (PD) [1]. Recently the application of silicon drift detectors (SDD) to gamma spectrometry with LaBr₃ was proposed by Fiorini et al. [2]. A high-energy resolution of 2.7% for the 662 keV gamma peak was reported due to high quantum efficiency and a very low dark noise contribution.

The aim of this work was to compare the SDD performance in gamma spectrometry with LaBr₃ to that of PMTs, APDs and PDs. All measurements were made with 6 mm diameter and 6 mm high LaBr₃ crystals coupled directly to the photodetectors under test. In the course of this work, the energy resolution versus energy of the gamma rays was measured for all photodetectors. Statistical contributions to the energy resolution were calculated based on the determined photoelectron number or electron-hole (e-h) pair numbers and together with the dark noise contribution allowed the limitation of energy resolution due to different photodetectors to be discussed.

Fig. 1 presents the energy spectrum of 662 keV γ-rays from a ¹³⁷Cs source, as measured with the LaBr₃ crystal on the SDD. The energy resolution of 2.7±0.1% is the same as reported by Fiorini et al [2].

Fig. 2 presents the energy resolution versus gamma ray energy measured with LaBr₃ coupled to the SDD, XP5212, LAAPD and PD, respectively. It shows that at low energies, below 100 keV, the energy resolution values measured with the photomultiplier and LAAPD are better than with the SDD, while for higher energies, above 300 keV, the SDD is superior over other photodetectors. The energy resolution measured with PD is vastly deteriorated by dark noise up to about 1 MeV.

In Table 1, predictions of the expected energy resolution, with fully optimized LaBr₃ crystal and photodetectors, are estimated. The LaBr₃ crystal, with the best light output of 74000 ph/MeV is considered. For the SDD, a full light collection is assumed along with cooling to –20 °C, to reduce the noise contribution. In the case of LAAPD, a smaller diameter of 10 mm is assumed and a similar cooling. Finally, the PMT with 40% quantum efficiency is taken into account.

Table 1 shows that the best energy resolution is expected for light readout by XP5212 PMT, LAAPD, SDD and S3590-18 photodiode. Note that the best energy resolution is expected for light readout by the SDD. This is due to the lowest contribution of the e-h pair statistics and a negligible noise contribution due to the assumed cooling of the device.


Table 1  The expected energy resolution with fully optimized LaBr₃ crystal and photodetectors.

<table>
<thead>
<tr>
<th>Photodetector</th>
<th>QE [%]</th>
<th>Nₚₑ or Nₑ/MeV</th>
<th>Energy resolution [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMT</td>
<td>40</td>
<td>30000</td>
<td>9.4 5.8 2.50</td>
</tr>
<tr>
<td>LAAPD</td>
<td>67</td>
<td>50000</td>
<td>9.8 6.3 2.54</td>
</tr>
<tr>
<td>SDD</td>
<td>70</td>
<td>52000</td>
<td>8.6 5.3 2.16</td>
</tr>
</tbody>
</table>

Note that the best energy resolution is expected for light readout by the SDD. This is due to the lowest contribution of the e-h pair statistics and a negligible noise contribution due to the assumed cooling of the device.


* This work was supported in part by the International Atomic Energy Agency, Research Contract No. 14360

¹) ICx Radiation, Solingen, Germany
A Comparative Study of Undoped NaI Scintillators with Different Purity* 
by M.Moszyński, W.Czarnacki, A.Syntfeld-Każuch, A.Nassalski, T.Szczęśniak, Ł.Sviderski, F.Kniest1) [VI.1]

A previous study of undoped NaI crystals at liquid nitrogen (LN2) temperatures showed for the best crystals a high light output of about 80000 ph/MeV, an excellent energy resolution of about 4% and a good proportionality of the light yield versus gamma-ray energy [1]. However, the properties of different samples of NaI differed and seemed to be correlated with the purity of the crystals, reflected particularly in the non-proportionality curves [1].

Recently, Saint-Gobain Crystals have developed undoped NaI with 7 N purity for future detectors in the search for dark matter. This provides a rare opportunity to study these crystals and to compare results with the previous ones, presented in Ref [3].

The study covered:
• Inspection of the light output at room temperature with the XP2020Q PMT.
• Light output and energy resolution vs. shaping time constant in a spectroscopy amplifier for 662 keV gamma rays at LN2 temperature.
• Non-proportionality of the light yield and energy resolution versus gamma ray energies.
• Intrinsic resolution of the scintillators vs. gamma ray energies.
• A comparison with the results of the earlier tests of undoped NaI crystals reported in [1].

The performance of an undoped NaI crystal of a high purity of 7 N grade, was studied at liquid nitrogen temperature using an avalanche photodiode. The measured quantities covered light output expressed by the electron-hole (e-h) pair number, non-proportionality characteristics, energy resolution and finally intrinsic resolution of the crystals studied.

In Fig. 1, the non-proportionality curves of ultra-pure NaI 1, and crystals NaI A and NaI B of scintillation-grade purity are plotted.

In contrast to the previous study, the new crystals showed comparable non-proportionality curves to those for NaI(Tl) at room temperature [1] and a poor energy resolution of about 8% for 662 keV gamma rays from a 137Cs source. The study highlights the role of undoped NaI crystals in a better understanding of the limitations of energy resolution in scintillation detectors. High sensitivity to traces of doping may help to find the way to a modification of the non-proportionality of other scintillators by selective doping or co-doping.

A further study of the slow components of the NaI light pulses and their influence on the energy resolution may clear up its possible deterioration caused by defects in the crystal structures.


* This work was supported in part by the International Atomic Energy Agency, Research Contract No 14360

1) Saint-Gobain Crystals, Holland Office, P.O. Box 3093, 3760 DB Soest, The Netherlands
Silicon Photomultiplier as an Alternative for APD in PET/MRI Applications
by A. Nassalski, M. Moszyński, A. Syntfeld-Każuch, T. Szcześniak, Ł. Świderski, D. Wolski, T. Batsch and J. Baszak

Facing the challenge to introduce a solid-state photodetector into different fields of photon detection, from medical to high-energy physics applications, a lot of effort has been made to characterize and develop new multi-pixel photon counters (MPPC). The MPPC is a solid-state photodetector known as the silicon photomultiplier (SiPM). It is based on multiple avalanche photodiodes working in the Geiger mode. Details of the operational characteristics of a SiPM can be found in the literature, for example in [1].

For the case of positron emission tomography (PET) systems, there is a need to develop alternatives for APD arrays in terms of building matrices or arrays for a whole body PET scanner. The MPPC offers the high performance needed in photon counting and is used in diverse applications for detecting extremely weak light at the photon-counting level.

Recently, Hamamatsu Inc. has introduced onto the market a 3x3 mm² MPPC with 3600 and 14400 pixels, respectively, better fitted to test with scintillators.

This paper focuses on two aspects of the characterization of the MPPC detectors, first using a laser diode pulser and in the second part, a study with a 3x3x20 mm³ LSO pixel crystal coupled to the MCCP. A considerable effort has been made to finely discuss the true amount of detected light and a determination of the number of pixels fired (comparable to the photoelectron number in other detectors) and pulse height resolution. In scintillation tests, the measurements covered a determination of the energy resolution, non-proportionality of the light yield and the time resolution for 511 keV annihilation quanta for both types of 3x3 mm² MPPC detector, with 3600 and 14400 pixels, respectively.

Fig. 1 presents the dependence of the FWHM of the light pulser peak on the number of photons detected, measured at different bias voltages, of the 3600 pixel MPPC. It shows that an increase of the bias voltage by 0.3 V, which corresponds to about 70% gain change, does not affect the pulse height resolution of the detector. Moreover, good agreement between the measured pulse height resolution, in the linear part of the MPPC response, to the calculated one, based on the measured number of fired pixels, suggests a lack of processes which may lead to distortion of the resolution. It confirms the precision of the measured number of pixels fired due to the light pulser signal.

Fig. 2 presents the energy spectra of 662 keV gamma rays from a $^{137}$Cs source measured for a LSO crystal with 14400 pixels Hamamatsu MPPC in comparison to the single photoelectron peak.

The present studies showed that the new Hamamatsu S10362-33-025C/050C MPPC could be easily applied in nuclear medicine, in particular in detectors for positron emission tomography combined with magnetic resonance, as an alternative to APD arrays. The large number of pixels in the detector assures a good linearity of the response to light from LSO pixel crystals and a good energy resolution. The slow output pulse of the MPPC associated with the high capacitance of the device limits the time resolution; however, it is still superior in comparison to APDs.


1) Hamamatsu Photonics Deutschland GmbH, Polish Office, 8 Boboli Str., Warsaw, Poland
Energy Resolution of Calcium Co-doped LSO:Ce Scintillators
by A.Syntfeld-Kaźuch, M.Moszyński, Ł.Śviderski, T.Szczęśniak, A.Nassalski, C.L.Melcher1) and M.A.Spurrier1)

Advances in crystal growth processes allow increases in crystal size and light output as well as improved energy resolution of LSO:Ce crystals. The energy resolution of LSO:Ce irradiated by 662 keV γ rays obtained with photomultipliers at room temperature, is presently in the range from 8.5% to 10.5%. Apart from the very attractive features of LSO:Ce such as high light yield (~32 000 ph/MeV) and short decay time (~42 ns) the crystals exhibit intense long decaying phosphorescence called afterglow. The afterglow of LSO:Ce crystals is a serious limitation in the use of these crystals in high counting rate applications. The newly developed LSO:Ce crystals are co-doped with calcium divalent cations and show higher light output and faster light pulses [1] as well as substantially reduced afterglow intensity [2].

In this work the effect of Ca co-doping on the light output and the non-proportional response as well as on the energy resolution of LSO:Ce:Ca is investigated by means of γ spectrometry measurements. An effort to correlate the integral intensity of several-hour afterglow with Ca co-dopant concentration as well as with energy resolution and light output was also made.

Table 1 Light output and energy resolution of LSO:Ce for 662 keV γ rays, as measured with the XP2020Q PMT.

<table>
<thead>
<tr>
<th>Ca (at%)</th>
<th>Size (mm)</th>
<th>Phe number (phe/MeV)</th>
<th>Energy Res. (% FWHM)</th>
<th>Intrinsic Res. (% FWHM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10×10×5*</td>
<td>6100±180</td>
<td>9.8±0.2</td>
<td>9.0±0.45</td>
</tr>
<tr>
<td>0.1</td>
<td>5×5×5</td>
<td>6830±200</td>
<td>7.4±0.15</td>
<td>6.5±0.3</td>
</tr>
<tr>
<td>0.2</td>
<td>5×5×5</td>
<td>6590±200</td>
<td>7.35±0.15</td>
<td>6.3±0.31</td>
</tr>
<tr>
<td>0.3</td>
<td>5×5×5</td>
<td>5260±160</td>
<td>8.2±0.2</td>
<td>7.05±0.35</td>
</tr>
<tr>
<td>0.4</td>
<td>5×5×5</td>
<td>6140±180</td>
<td>8.9±0.2</td>
<td>8.0±0.4</td>
</tr>
</tbody>
</table>

* polished

Five unpolished co-doped 5 mm x 5 mm x 5 mm LSO samples were included in this study. These contained 0.1 atomic % Ce and either 0, 0.1, 0.2, 0.3 and 0.4 atomic % Ca (with respect to Lu) in the starting raw materials. In addition, there was a sixth LSO:Ce sample (0% Ca) with a Ce concentration that is believed to be in the 0.1-0.2 at% range. The dimensions of this selected sample are 10 mm x 10 mm x 5 mm, and it was polished on all sides. For gamma-ray spectrometry the crystals were coated with Teflon tape and coupled to XP2020Q or XP200D0 photomultipliers (PMT) with silicon grease. The afterglow of all of the 5 mm x 5 mm x 5 mm samples was studied in separate measurements. The LSO samples were irradiated by a 13.9 GBq 241Am source positioned axially at a distance of about 14 cm from the crystal.

The photoelectron number per MeV-γ, overall energy resolution and intrinsic energy resolution were measured for each LSO at 3 μs bipolar shaping time in the amplifier and the values obtained for 661.6 keV photons from a 137Cs source are depicted in Table 1. In spite of common non-proportionality curves for all of the crystals, an increase of light output and substantial improvement in energy resolution for the co-doped crystals are observed.

![Fig. 1 The total afterglow per MeV vs. Ca concentration as measured for LSO crystals in the several-hour range.](image)

The intensity of afterglow per 1 MeV-γ measured over a several-hour interval decreases with increasing Ca concentration (Fig. 1) and the effective decay time of this afterglow shortens at higher Ca co-doping. The dependence of intrinsic resolution and light output of the crystals on afterglow intensity, A_{total}, is not straightforward. We hypothesize that the missing part of the afterglow in the micro- and millisecond time range distorts the relation between total afterglow intensity, intrinsic resolution and light output. Further studies are necessary to inspect all afterglow components of LSO scintillators.


1) The Scintillation Materials Research Center, University of Tennessee, Knoxville, USA
Further Study of Boron-10 Loaded Liquid Scintillators for Detection of Fast and Thermal Neutrons*


Boron-10 loaded liquid scintillators offer high sensitivity to fast and thermal neutrons and γ rays simultaneously. In these kinds of detectors, γ rays interact mostly by Compton scattering on electrons, whereas fast neutrons are detected by elastic scattering on protons inside the liquid. Formulas containing 10B are dissolved in the liquid in order to capture thermal neutrons through the reaction:

\[ {^{10}\text{B}} + n \rightarrow {^{4}\text{He}} + ^{7}\text{Li} + \gamma (480\text{keV}), \]

with Q = 2.3 MeV and 94% branching. Sensitivity to various types of radiation can be regarded as an advantage if it is possible to achieve satisfactory discrimination between events generated by different particles.

In the foregoing study of liquid scintillators we have shown a technique based on the zero-crossing (ZC) method for discrimination of fast and slow neutrons from γ rays. The main advantages of our approach are:

- Simplicity of the experimental setup, based on a loaded liquid scintillator coupled to a PMT. The setup does not require coincidence measurements for discrimination between thermal neutrons, fast neutrons and γ rays.
- Low cost, as a high QE spectroscopy PMT with moderate timing capabilities is sufficient to perform the measurements.
- Simplicity of noise rejection.
- The ability to perform discrimination with high counting rates, as the setup is based on analogue electronics.

The aim of this study was to compare various 10B loaded liquid scintillators: BC523A2 (produced by Saint-Gobain), EJ339A2 (an analogous detector by Scionix) and EJ309B5 (a high flash point scintillator by Scionix).

The best results were obtained with EJ309B5. Fig. 1 presents a two-dimensional plot of ZC time vs. energy measured with EJ309B5 under irradiation by Pu-Be and 241Am sources. The tested EJ309B5 scintillator was coupled to a Photonis XP5500B photomultiplier. High quantum efficiency (35%) and cathode blue sensitivity of 13.6 µA/lmF allowed easy registration of capture events that were concentrated between γ rays and neutrons (around ZC time ≈ 190 channels) with energy about 100 keVee. We also registered well separated events from γ rays (lower horizontal line), fast neutrons (upper horizontal line) and noise (bump around ZC time ≈ 130 channels). One can also note that 60 keV γ-rays from the 241Am source are well separated from both noise and fast neutrons. Note that the threshold was set at a pulse height equivalent to about 5 keVee only, in order to emphasize the good separation of the capture events from noise.

---

* This work was supported by the Polish Ministry of Science and Higher Education, Grant No. 8054/R/T00/2007/03

1) Saint-Gobain Crystals, Holland Office, P.O. Box 3093, 3760 DB Soest, The Netherlands
2) Saint-Gobain Crystals, 12345 Kinsman Road, Newbury, OH 77005 USA
3) ICx Radiation GmbH, Koelner Str. 99, D-42651 Solingen, Germany
4) The Royal Institute of Technology, Alba Nova, 106 91 Stockholm, Sweden
5) SCIONIX Holland B.V., 3980 CC Bunnik, The Netherlands
6) Eljen Technology, 2010 E. Broadway, Sweetwater, TX 79556, USA
Light Yield Non-proportionality and Energy Resolution of Praseodymium Doped LuAG Scintillator

by Ł. Świderski, M. Moszyński, A. Nassalski, A. Synfeld-Kaźuch, T. Szcześniak, K. Kamada, K. Tsutsumi, Y. Usuki, T. Yanagida, A. Yoshikawa

The aim of this study was to find a new scintillator for Medical Imaging techniques like time-of-flight positron emission tomography (ToF-PET) or positron emission mammography (PEM). Recently Lutetium Aluminum Garnet (Lu₃Al₅O₁₂) doped with praseodymium was proposed, making use of its fast 5d-4f emission from Pr³⁺ ions. The crystal is characterized by large density (6.7 g/cm³) and a high effective atomic number (Z_eff ≈ 65). Its peak emission appears around 310 nm, making this crystal well fitted to be used with photomultipliers (PMTs).

We have tested 2 samples of LuAG:Pr, delivered by Furukawa Co., Ltd. Each sample was wrapped in several layers of Teflon tape and coupled to Photonis XP5500B photomultiplier (PMT) using silicon grease. An energy resolution of 5.2±0.1% (for 662 keV at 3 µs shaping time – see Fig. 1) was registered, not previously observed with crystals of such high density. The good energy resolution is the outcome of the relatively large light output (4500±300 phe/MeV) and nearly proportional response of this scintillator to γ rays. Fig. 2 presents the non-proportionality of the light yield over a wide energy range from 16.6 keV to 1770 keV. Deviation from proportionality does not exceed 3% at 22 keV for the best sample. Note a dip in the non-proportionality curve around 63 keV, corresponding to the electron binding energy of the K-level in Lu.

As the existence of long decay modes in LuAG:Pr has already been reported, we have repeated all the measurements at 12 µs shaping time, to check whether the ballistic deficit has an important influence on our results. We indeed registered a larger number of photoelectrons, equal to 5600 ± 400 phe/MeV, but the non-proportionality characteristics turned out to be identical, as shown in Fig. 2. Moreover, the measured energy resolution (5.0±0.1%) was not improved as much as expected from the increase in photoelectron statistics.

This is contrary to our earlier observations for alkali halide crystals and ZnSe:Te, which showed an improvement in non-proportionality when the total light pulse was integrated by a long shaping time constant. This indicates that the longest decay mode in LuAG:Pr is of different origin than that of alkali halide crystals, perhaps also different from the fast part of the pulse.

High density, good energy resolution and finally the very fast response of LuAG:Pr makes this crystal a reasonable candidate for use in PET systems.


* This work was performed in cooperation with Materials Research Laboratory, Furukawa Co., Ltd., which supplied us with two samples of LuAG(Pr)

1) Materials Research Laboratory, Furukawa Co., Ltd., 1-25-13, Kannondai, Tsukuba, Ibaraki, 305-0856 Japan
2) IMRAM, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai, Miyagi, 980-8577 Japan
A Comparative Study of Fast Photomultipliers for Timing Experiments and TOF PET*  
by T.Szcześniak, M.Moszyński, L.Świderski, A.Nassalski, A.Syntfeld-Każuch, A.G.Dehaine1) and M.Kapusta1)

New 1 inch and 1.5 inch diameter photomultipliers for timing applications from Photonis and Hamamatsu have been tested. The time resolutions of XP1020, XP3060, R9800 and R9420 were measured with a 10x10x5 mm³ LSO crystal in coincidence experiments with 511 keV annihilation quanta from a ²²Na gamma source. Results were discussed in terms of the measured photoelectron number and time jitter. Single photoelectron spectra were recorded and the excess noise factor for each tube was also calculated. The final comparison of the tested tubes and their timing properties were presented in relation to a large amount of experimental data for various types of PMTs collected over the last few years. Especially, the observed linear dependence between the time resolution normalized to the number of photoelectrons and time jitter was pointed out. Inconsistency of the data collected with the Hamamatsu R9420 PMT resulting from an overestimated photoelectron number was reported and further studied. Additional experiments with an LED light source and different experimental set-ups were discussed and a comparison of the two methods of photoelectron number measurements was performed.

The results of the time jitter measurements, including FWHM and FWTM (Full Width at Tenth Maximum) are collected in Table 1. Note, that the results obtained for the whole photocathode for both Hamamatsu tubes are comparable to those measured in the center of the Photonis PMTs.

Table 1: The time jitters of the tested photomultipliers.

<table>
<thead>
<tr>
<th>PMT</th>
<th>FWHM ps</th>
<th>FWTM ps</th>
<th>FWHM ps</th>
<th>FWTM ps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 inch</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>XP1020</td>
<td>380 ± 20</td>
<td>80 ± 40</td>
<td>565 ± 30</td>
<td>1210 ± 60</td>
</tr>
<tr>
<td>R9800</td>
<td>310 ± 20</td>
<td>610 ± 30</td>
<td>360 ± 20</td>
<td>790 ± 40</td>
</tr>
<tr>
<td>1.5 inch</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>XP3060</td>
<td>440 ± 20</td>
<td>90 ± 50</td>
<td>620 ± 30</td>
<td>1500 ± 80</td>
</tr>
<tr>
<td>R9420</td>
<td>420 ± 20</td>
<td>830 ± 40</td>
<td>460 ± 20</td>
<td>950 ± 50</td>
</tr>
</tbody>
</table>

All the timing data, together with the number of photoelectrons are collected in Table 2. The values corrected for the contribution of the reference detector are presented in the third column. The best tubes, the 1 inch Hamamatsu R9800 and 1.5 inch Photonis XP3060, have a time resolution for a single detector equal to about 200 ps.

In our previous work, the plot of time jitter versus normalized time resolution with a 10x10x5 mm³ LSO crystal was presented for various types of fast photomultipliers. Such a plot is presented in Fig. 1 together with the PMTs tested in this study (diamonds).

Table 2: The time resolution of the tested photomultipliers.

<table>
<thead>
<tr>
<th>PMT</th>
<th>Δt [ps]</th>
<th>Nphe/Mev</th>
<th>Plh for 511 kev</th>
<th>ENF</th>
<th>Δ(ENF) [%/phe] x 10⁶</th>
</tr>
</thead>
<tbody>
<tr>
<td>XP1020</td>
<td>247 ± 7</td>
<td>212 ± 9</td>
<td>4900 ± 100, 2500 ± 100</td>
<td>1.05</td>
<td>10.3 ± 10.0</td>
</tr>
<tr>
<td>R9800</td>
<td>237 ± 7</td>
<td>199 ± 9</td>
<td>6300 ± 200, 3200 ± 100</td>
<td>1.20</td>
<td>10.3 ± 10.0</td>
</tr>
<tr>
<td>XP3060</td>
<td>238 ± 7</td>
<td>200 ± 9</td>
<td>6400 ± 200, 3300 ± 100</td>
<td>1.05</td>
<td>11.2 ± 10.5</td>
</tr>
<tr>
<td>R9420</td>
<td>262 ± 8</td>
<td>229 ± 9</td>
<td>11500 ± 300, 5900 ± 200</td>
<td>1.20</td>
<td>16.0 ± 10.7</td>
</tr>
<tr>
<td>R9420</td>
<td>262 ± 8</td>
<td>229 ± 9</td>
<td>6900 ± 400, 3500 ± 200</td>
<td>1.20</td>
<td>12.4 ± 6.6</td>
</tr>
</tbody>
</table>

* a) corrected for the contribution of the Bász: reference detector of 128 ± 4 ps  
(1) the gain dispersion of the electron multiplier (1)  
(2) e) the result obtained using a different method (see section III-D)

This study showed a comparable performance of the tested photomultipliers. The only point which is completely inconsistent with the data in Fig. 1 is related to the Hamamatsu R9420 (solid diamond). This strange behavior of the Hamamatsu R9420 PMTs, showing an overestimated number of photoelectrons as measured by the standard Bertolaccini method was observed for two R9420 photomultipliers.

Presented at 2008 Sorma West Conference, Berkeley, California, USA, June 2–5, accepted for publication in IEEE Trans Nucl. Sci.

* This work was supported in part by the FP6 Commission "Biocare" (Molecular Imaging for Biologically Optimized Cancer Therapy) under contract number 505785 and by SPUB 621/E-78/SBP/6 PR UE/DIE 458/2004-2007 of the Polish Committee for Scientific Research  
1) Photonis, Av. Roger Roncier, B.P. 520, F 19106 Brive La Gaillarde Cedex, France
A Continuous Crystal Detector for TOF PET*  
by T. Szczępniak, M. Moszyński, Ł. Świderski, A. Nassalski, A. Syntfeld-Każuch, P. Ojala,1) C. Bohm1)  

Most of the current Positron Emission Tomography (PET) systems are based on block-detectors consisting of many scintillating pixels read by a smaller number of photomultipliers (PMTs). An improvement in the time resolution, using a common light readout from a cluster of PMTs, was proposed by Kuhn et al, and previously tested by us with LSO crystals. This triggered an idea to design a new PET detector optimized for Time of Flight (TOF) systems, based on continuous crystals. In the present work, we report on optimization of timing with a 20x20x20 mm³ LYSO crystal coupled to a 16-channel H8711-200MOD photomultiplier from Hamamatsu. First, measurements were performed of the transit time jitter, the number of photoelectrons and the time resolution using a small 10x10x5 mm³ LSO crystal coupled to a H8711-200MOD PMT. The results were compared with data collected from fast timing photomultipliers like Photonis XP1020, XP3060, XP20D0 or Hamamatsu R9800. In the second part of the study, time resolution measurements and optimization of the system were carried out with a continuous LYSO crystal. Simple tests to determine the position of the gamma interactions inside the scintillator were also made. The final results are discussed in terms of the measured photoelectron number and the requirements for TOF-PET scanners.

The results of the time resolution measurements with a 10x10x5 mm³ LSO crystal, together with the number of photoelectrons are shown in Table 1. Data collected from various fast timing photomultipliers with a linear focusing dynode structure are also presented. The timing capabilities of the Hamamatsu H8711 phototube are similar to other candidates for a future TOF PET. However, the Hamamatsu tube suffers from poor electron collection efficiency, which is reflected in the small number of photoelectrons. The excellent value, of 198ps was possibly due to a very high QE of 43%.

Table 1 The Time Resolution Measured with 10x10x5 LSO Crystal.

<table>
<thead>
<tr>
<th>PMT</th>
<th>Time resolution at FWHM, τ [ps]</th>
<th>Nphe/Mev</th>
<th>Nphe for 511keV, N [phe]</th>
<th>Δτ [ps] (Nphe) x 10³</th>
</tr>
</thead>
<tbody>
<tr>
<td>H8711</td>
<td>235 ± 7</td>
<td>198 ± 9</td>
<td>5900 ± 200</td>
<td>3000 ± 100</td>
</tr>
<tr>
<td>XP1020</td>
<td>217 ± 7</td>
<td>184 ± 5</td>
<td>5900 ± 200</td>
<td>3000 ± 100</td>
</tr>
<tr>
<td>XP20D0</td>
<td>247 ± 7</td>
<td>211 ± 9</td>
<td>4500 ± 100</td>
<td>2500 ± 100</td>
</tr>
<tr>
<td>XP20D6</td>
<td>238 ± 7</td>
<td>200 ± 9</td>
<td>6400 ± 200</td>
<td>3800 ± 100</td>
</tr>
</tbody>
</table>

The time resolution of the tested detector based on a continuous 20x20x20 mm³ LYSO crystal along with the number of photoelectrons is shown in Table 2. The data recorded with the same scintillator but with a XP20D0 (QE=35%) photomultiplier were added for comparison. Note a big difference in the number of photoelectrons despite the higher quantum efficiency of the Hamamatsu tube (QE=43%).

Table 2 The time resolution measured with the lyso 20x20x20 coupled to the h8711 and xp20d0 pmts.

<table>
<thead>
<tr>
<th>Position</th>
<th>Time resolution at FWHM, τ [ps]</th>
<th>Nphe/Mev</th>
<th>Nphe for 511keV, N [phe]</th>
<th>Δτ [ps] (Nphe) x 10³</th>
</tr>
</thead>
<tbody>
<tr>
<td>H8711</td>
<td>301 ± 9</td>
<td>272 ± 10</td>
<td>4000 ± 200</td>
<td>2100 ± 100</td>
</tr>
<tr>
<td>XP20D0</td>
<td>260 ± 9</td>
<td>226 ± 10</td>
<td>6400 ± 200</td>
<td>3800 ± 100</td>
</tr>
</tbody>
</table>

In the next part of the study a comparison was made between a continuous crystal detector and a single 4x4x20 mm³ LSO pixel placed in various positions on standard fast photomultipliers (see Fig.1).

In the case of the H8711 photomultiplier, the time resolution is identical at all the three measured positions (around 300ps). The number of photoelectrons in each pixel is also the same. The situation is different in the case of the linear focused PMTs. The values in the middle of the standard fast photomultipliers are better in comparison to the one pixel in the Hamamatsu tested, but the results obtained at the remaining four positions are much worse (up to 350ps). The measured timing for the three channels in the continuous crystal detector shows that the homogeneity of the time resolution over the whole area of the detector is its big advantage.

The time resolution of 272ps measured for the single detector with a monolithic LYSO scintillator corresponds to 385ps for two detectors in coincidence. This value is around 200ps better than the time resolution of commercially available TOF PET scanners.


* This work was supported in part by the FP6 Commission “Biocare” (Molecular Imaging for Biologically Optimized Cancer Therapy) under contract number 505785 and by SPUB 621/E-78/SPB/6 PR UE/DIE 458/2004-2007 of the Polish Committee for Scientific Research

1) Department of Physics, Stockholm University, AlbaNova University Centre, Sweden
The next generation of TUKAN analyzers, TUKAN-8K-NET [ref. Drezno], is equipped with three separate communication channels: USB, Ethernet and radio connection.

During the design of the new analyzer, we have found that the chosen radio link may not provide high enough throughput to transfer spectra data from the analyzer to the host (PC). This observation forced us to elaborate methods to squeeze the amount of data transmitted between the analyzer and the host.

During the design stage, the following limitations and assumptions should be observed:

- client-server mode of communication (PC asks -- analyzer answers),
- limited amount of analyzer memory and “CPU” performance,
- lossless compression.

These constrains have removed known compression methods (zip, bz2, etc.) from our area of interest. After many attempts, simulations and tests on real spectra we have elaborated our own dedicated method of compression that is very effective and uncomplicated. The spectrum to be compressed contains 8192 channels, 3 bytes integer (24 bits) in each channel, giving 24kB of data that should be transmitted to the PC at least once per second.

We divide the raw spectrum into 64 equal segments with 128 channels each. Every compressed segment is transmitted as a separate entity. For each segment:

- we analyze for the minimal and maximal 24-bit channel values,
- we calculate the difference between these values,
- from this difference the code determining the size of the data field for the entire current segment is inferred,
- the minimal value is subtracted from each consecutive real channel value and the result of each subtraction is packed into an output frame obeying nibble boundaries according to the inferred data size.

Each transmitted segment packet is preceded by a 4-byte header where the data field size and minimal segment values are placed.

The described algorithm is already implemented and greatly reduces the amount of data to be transferred and allows squeezing of the data volume up to six times. The average compression gain on real spectra is 65%.
Superconducting Thin Films Resonant Cavities for Linacs
by R. Nietubyć, M. J. Sadowski, R. Mirowski and J. Witkowski

The main aim of CARE (Coordinated Accelerator Research in Europe) was to develop a new method of thin-film coating by means of arc discharges under ultra-high vacuum (UHV) conditions. Instead of RF cavities made of bulk Nb, one could then use employ Cu-cavities coated inside with a thin Nb-layer. Our approach was based on the use cathode-arc discharges under UHV conditions to achieve very high purity films. The main disadvantage of all arc-techniques is inferior adhesion. This weakness was a subject of measures undertaken in 2008 by our group.

Niobium films were deposited on copper plates. In order to study the influence of roughness on the Nb adhesion to Cu, the substrate was prepared for exposure by different polishing procedures resulting in various surface roughnesses.

Subsequently, high pressure water rinsing was carried out on the deposited films in order to test their adhesion. A standard compressor was used to provide a water flux with a pressure up to 120 bar. The pressure at the sample surface was estimated to within an accuracy of 20 % by measuring the distance between the nozzle and the sample.

Cleanliness of the surface was improved by applying an additional pre-treatment before deposition. The cavities were cleaned with 15% citric acid solution directly prior to evacuation. The bath influence on the adhesion was tested with samples of polished copper plates. Results showed that bathed and polished plates can survive 100 bar water rinsing.

The triple Tesla-like cavity was treated in a way similar to the samples described above. A cavity was filled with a 15% citric acid solution and kept annealed at 60°C to avoid precipitation. Next, the cavity was flushed with deionized water and propanol consecutively. The prepared cavity was further treated in an N2 atmosphere. It was mounted in the deposition facility, evacuated and annealed for 14 hours at 120°C – 140°C.

The deposition was carried out at a base pressure in the range of 10–9 mbar, rising to us 10–6 range during the arc discharge in the chamber. A Nb layer was deposited in turns of the steering magnet, performed in a total time of 25 minutes. The cavity temperature measured at the outer side of the wall never exceeded 190°C. Tests with dummy and actual Tesla cavities are in progress and will be continued.

The vacuum arc deposition technique was applied to the preparation of superconducting photocathodes for an electron linac. Development of such injectors is closely related to the proposed IPJ free electron laser operating in continuous wave mode based on an inductive output tube RF power supply system. Lead films a few micrometers thick were deposited onto the back wall of a niobium Tesla–like resonant cavity.

Planar cathode geometry was used for this process. During the process, a UHV deposition stand is settled in the nitrogen flow chamber in order to avoid hydrogen penetration into the warm Nb walls of cavity. Similar deposition processes have been performed for plugs used as photocathodes in electron injectors constructed at the Brookhaven National Laboratory (BNL).

The quantum efficiency and resonant RF properties of the prepared structures were studied at TJNL (Thomas Jefferson National Laboratory –JLab). First results shows show a satisfactorily high value of resonant quality for the accelerating gradient ranged up to 40 MV/m. The above research activity has been accepted as the IPJ contribution to the European Coordination of Accelerator Research and Development programme supported within the 7th Framework Programme of the EU.

Synchrotron Radiation structural studies of vacuum arc deposited metallic films have been launched. The crystalline structure of Nb films deposited onto the inner walls of superconducting RF cavities is one of the crucial issues determining their performance. Systematic studies have been initiated with XRD (X-ray Diffraction) studies of thin Nb layers deposited onto a single crystal sapphire (001) substrate. Films of thicknesses less than 5 nm, 5nm, 15 nm and 400 nm respectively were deposited. The aim of these studies was to recognize the structural forms of Nb films formed in the early stages of growth. The measurements were performed at the wiggler beamline W1 using a photon energy corresponding to a wavelength $\lambda = 0.15406$ nm (Cu Kα characteristic line).
Sharp maxima observed in the diffraction patterns in Fig. 1 originate from the single crystal substrate. The thinnest film shows only one feature in the $\omega$-2$\theta$ pattern. This is a broad diffraction profile at $2\theta \approx 35.5^\circ$, very close to the position of the 110 diffraction line of Nb. No diffraction lines corresponding to Nb are observed for this film in the grazing incidence geometry scans. The broad maximum corresponding to the 110 Nb diffraction line indicates that the Nb film consists of very small crystallites.

The shape of the diffraction profile in the angular position corresponding to the Nb 110 maximum depends on the film thickness (Fig. 2). It results from the superposition of Nb 110 reflections originating from two different forms of Nb: The broad one described above and a narrow one. The narrow peak appears for the film having a thickness of 15 nm. This is Nb 110 reflection typical for Nb crystallites larger than roughly 100 nm. The upper pattern shows that, for a thick film, phases containing small and large crystallites exist together.

For the sample having a thickness of 15 nm, the 110 reflection originating from the large crystallites phase only just appeared in the symmetric scan pattern. Still, no reflection coming from that phase can be observed in grazing incidence geometry. This results from a small amount, thinness and fractional coverage of the layer containing large crystallites. This observation points to a thickness of 15 nm where the large crystallites start to grow.

For a 400 nm thick sample, the large crystallites phase is clearly depicted in the diffraction patterns. Only 110 planes contribute to the diffraction pattern measured in a symmetric scan. Broad and narrow components can be distinguished. This indicates a strong preferred orientation for both phases constituting the Nb/sapphire (001) film.

**Fig. 2** Results of cold tests performed for the superconducting injector structures with lead photocathode deposited at PV. Measurements were performed at J Lab (courtesy of Jacek Sekutowicz).
Single Track Nanodosimetry of Low Energy Electrons*
by A.Bantsar, B.Grosswendt,¹ S.Pszona and J.Kula

It is well established that ionizing radiation induces damage in living tissue through initiation stages, which occur at the DNA level. Since DNA molecules in the form of short segments, nucleosomes, or chromatin fibers are the main radiation sensitive targets of nanometer size, the initiation of radiation damage is predominantly caused by single particle interactions. For a detailed understanding of radiation-induced effects, the precise description of the ionization patterns caused by an ionizing particle within a target volume of nanometer size has to be taken into account. Here, low energy electrons contribute to the initiation of radiation damage for all kinds of ionizing radiation. Therefore, the interaction pattern of electrons at energies up to few keV is of particular importance, especially their ability to form ionization clusters. A modern approach to the combined radiotherapy of particular forms of cancer is to use Auger-electron-emitting radionuclides (for instance, $^{125}$I) with a predominant energy spectrum below 3 keV. Therefore, the need for an adequate description of the action of low energy electrons on nanometric biological targets seems to be unquestionable. The experiments presented in this report belong to a new interdisciplinary field of radiation research – nanodosimetry – in which the radiation action of ionizing radiation on nanometer-sized biological structures is investigated. Experimental track nanodosimetry for low energy electrons has been accomplished with a system called JET COUNTER (JC) [1]. The present report describes, for the first time, nanodosimetric experiments in nanometer-sized cavities of nitrogen using low energy electrons ranging from 100 eV to 2 keV.

The experimentally obtained interaction patterns of low energy electrons within nanometer-sized structures, in the form of frequency distributions of ionization cluster size versus cluster size are presented in Figure 1. Here, the ionization cluster size is defined as the number of ions which are created by a single primary electron upon its penetration through the nitrogen cylinder. The experiments were carried out for mono-energetic electrons at energies of 100 eV, 200 eV, 300 eV, 500 eV, 1 keV and 2 keV, which penetrate through a nitrogen cylinder, 0.34g/cm² in height and 0.34g/cm² in diameter, corresponding to a water cylinder of 0.23µg/cm² × 0.23µg/cm² (2.3nm × 2.3nm at unit density).

Acknowledgements:
This work was supported by grants Nr 3 T10C 00830 and 2161/B/P01/2008/34 of the Ministry of Science and Education of Poland.

Fig. 1 Measured discrete ion cluster frequency distributions created by monoenergetic electrons with energies 100 to 2000 eV crossing a nitrogen cavity with a diameter of 0.33 µg/cm².

* see NIM A 599 (2009) 274 for details
¹) Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany
Ion Beam Profile Measurements by Means of Nuclear Track Detectors

by A. Malinowska, A. Szydłowski, M. Jaskóła, A. Korman, M. Sadowski, J. Braziewicz1), J. Czub1) and Z. Szefliński2)

The irradiation of living matter with charged particles has become increasingly interesting for medical applications like radiotherapy, radioprotection and space radiobiology. In this field, particle accelerators are helpful owing to the wide range of available ions, energies and flux or dose fractionation. Usually, two types of configuration are used: micro beams and broad beams. A micro-beam can precisely target a defined point on a cell or a group of cells. The use of broad beams enables a thousands of cells to be irradiated simultaneously. In the set-up, the beam must have a special uniformity of ± 3% over an approximately 1 cm² surface and be stable during the irradiation. In 2005-2006 the SINS, Institute of Physics of Kielce University and Institute of Experimental Physics of Warsaw University decided to develop an “in vitro” irradiation station using ion beams from the U-200 cyclotron of Warsaw University [1,2].

In the present studies, 12C²⁺ ions were accelerated to energies in the range of 50-100 MeV. The ions were transported from the cyclotron to the exposure set-up and the collimated beam was spread out by scattering from gold foils with a thickness of 9-17 mg/cm². The foils allowed a homogeneous radiation field over an area 10x10 mm² of the exit window to be achieved. The ion beam intensity was controlled on-line by a monitoring system consisting of a Si detector placed at an angle of 20° detecting scattered projectiles. The beam extraction into air occurred through a 1x1 cm² square window, sealed by a 2.3 mg/cm² Havar foil. The intensity and distribution of the scattered ions were measured outside the exit window by means of a surface-barrier Si detector with a 0.5 mm collimator. The Si detector was fastened to a x-y-z sliding table moving across two dimensional array centers. The ion beam profiles, as measured by the 0° Si detector in a two dimensional (x,y) intensity distribution over the 1 x 1 cm² exit window, are presented in Fig. 1A. The measured beam uniformity was better than ± 2.5 %. The beam uniformity was also checked using a nuclear track detector of the PM-355 type. The SSNTD sample was located in air a few mm from the exit window. The irradiation time was about 20 sec. After the irradiation, the detector sample was etched in a 6.25N water solution of NaOH at a temperature of 70° for 2h. In Fig. 2 one can recognize a clear 1x1 cm² collimated beam.

Fig. 1 Profiles of ion beams measured using A) Si detector; B) PM-355 track detector.

Fig. 2 Picture of ion beam profile measured by the PM-355 track detector.

The measured beam profile distribution in two axes (x,y) is presented in Fig. 1B. The beam uniformity achieved was about ±3%, in quite good agreement with the results obtained using a time-consuming surface barrier Si detector.


1) Institute of Physics, Jan Kochanowski University, Kielce, Poland
2) Institute of Experimental Physics, University of Warsaw, Poland
Recent years have witnessed a new wave of interest in X-ray machines built for oncology radiotherapy [1,2]. Progress in materials science and technology has made it possible to develop new types of X-ray tubes specially designed for brachytherapy i.e. to irradiate tumors from inside.

To be useful for brachytherapy, the construction of an X-ray tube must enable its target (anode) to enter the to-be-irradiated object. Besides, it must emit radiation isotropically over the whole 4-pi solid angle.

Currently two approaches are followed:

- X-ray tube with needle-like anode,
- miniature X-ray tube that might be placed completely inside the to-be-irradiated tumor.

The idea of an X-ray tube with a needle-like anode for brachytherapy was brought to the market by Photoelectron Corporation in the early '90s of the last century as the Photoelectron Radiation System (PRS400) aimed at brachytherapy of brain tumors [1].

The Xoft company developed new X-ray tubes for brachytherapy at the beginning of this century (Xoft Axxent). This miniature (2 mm dia, 10 mm long) tube operates at the end of a thin (1.5 mm dia) flexible high voltage cable [2].

Both sources have been FDA-certified for applications in clinical practice to brachytherapy of tumors in all medically justified cases. Their basic properties are compared below:

Since both solutions have some advantages and some disadvantages, one may expect that ESB sources will be further developed.

In 2008 our team:

- Analyzed new developments in construction of EBS sources and the operational parameters attained in published solutions. This work was aimed at finding ways to improve the operational parameters of the Polish Photon Needle developed by us during previous years and helping us to prepare a proposal for the LAXT project (Low-energy Accelerator with X-Ray Tube, a part of the Detectors and Accelerators project).
- Extended our engineering and manufacturing base as regards high-voltage electronics circuitry for X-ray tube power supply, which helped to increase the anode voltage of the tube.
- Looked for optimum X-ray energy spectra from the point of view of some selected brachytherapy treatments.
- Optimized X-ray tube construction details from the point of view of some selected brachytherapy treatments.

On the Interesting Variability of some Curves under the Spectrometric Mode of Conventional Avalanche Counters Filled with n-heptane Vapour

by J. Sernicki

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

When the radiation initiating the discharge growth within the avalanche counter interelectrode gas space generates a sufficiently large number of charge carriers during the primary ionization process, i.e. the gas gain process, will be obstructed by a local space charge effect. Hence, the product of the critical absolute value of the gas amplification ($M_{abs}$) and the energy lost in the counter ($dE/dx \times d$) by the radiation detected, in practice plays the role of a criterion of the effect occurrence [2]; $dE/dx$ is the specific energy loss, and $d$ refers to the electrode spacing.

The criterion for a local space charge effect in conventional avalanche counters was obtained, generally, under measurement conditions which are typical for the majority of physical experiments in which such detectors are used [2]. This criterion was determined at moderate specific ionization in n-heptane. Therefore, it is interesting – from a practical point of view – to obtain the values of the maximum differences of gas gain ($\Delta M_{abs}$) and energy loss ($\Delta (dE/dx \times d)$) corresponding to the critical values of the gas gain at the minimum and maximum supply voltage ($U_{min}$ and $U_{max}$ (see ref. [3]), respectively) at different n-heptane vapour pressures ($p$). The voltages determine the useful range $\Delta U$ for individual values of $p$ and $d$ (Fig. 1).

Hence, the purpose of this investigation is to determine absolute values of effective gas amplification of PPAC detectors filled with n-heptane vapor. General equations of the absolute gas gain characteristics, which are justifiable for these detectors, were used [2].

The $\Delta M_{abs}$ and $\Delta (dE/dx \times d)$ values – for individual PPAC electrode spacings – are given in Figs. 2 and 3. It can be seen that the largest variability ranges occur at lower n-heptane pressures. In turn, the $(dE/dx \times d)$ value variability dynamics within the $\Delta U$-range is shown in Fig. 4. The determined energy loss values provide, within the $\Delta U$-range, a strictly linear course of the gas gain characteristics in a semilogarithmic coordinate system.

Fig. 1 Width of the useful ranges of the PPAC supply voltage; $\Delta U = U_{max} - U_{min}$. The PPAC has an interelectrode gap of $d$.

Fig. 2 Maximum differences of absolute values of the PPAC actual gas gain; $\Delta M_{abs} = M_{abs}(U_{max}) - M_{abs}(U_{min})$.

Fig. 3 Maximum differences of the PPAC ultimate $\alpha$-particle energy losses, determined for $M_{abs}(U_{min})$ and $M_{abs}(U_{max})$ of the detector.

Fig. 4 The PPAC energy losses corresponding to linear courses of $\log_{10}(\Delta M_{abs})$ characteristics of the detector with $d=0.2$ cm.

Suspended dust, especially small grain fraction PM_{2.5} (with aerodynamic diameter up to 2.5 µm) is the atmospheric air pollutant reckoned among the most harmful for human health. An EC Directive [1] obliges Member States including Poland to reduce levels of these particulates.

To fulfil effectively these obligations information on actual and predicted pollutant concentrations is needed. Many types of measurements must be carried out such as instant, periodical and reference to supply information and store it for future reference. Prediction must comprise information on the next few days on a local and regional scale. This information is needed for air protection management purposes, preparation of reports on the environment in the state and in particular about the ambient air by local authorities and organizations.

It is recommended that information on atmospheric air pollutant concentrations be supplied to the general public. To make it more understandable, physical values of measured pollutant concentrations are converted to an Air Quality Index (AQI). For example, in the USA the method of conversion and reporting the AQI is described in [2]. Limit levels of PM_{10}, PM_{2.5}, and some others are described in [1] and it may be used as a basis to define an AQI for Poland.

Instant measurements give information on pollutants and enable the actual AQI to be presented to the general public but knowledge of future conditions obtained from predictions is needed to manage air protection and to report the expected AQI.

From 2007 an interdisciplinary research and development project) has been realized and within this project a predictor for short-term forecasting of atmospheric air pollution has been developed by IPJ in collaboration with Warsaw University of Technology [3-7]. The predictor involves artificial neural networks of MLP (multi layer perceptron) and SVM (support vector machine) types. It operates in real time and may be used to predict concentrations of suspended dust, nitrogen oxides, sulphur oxides and others. A measurement station also has been constructed within this project. The station is equipped with two devices of the AMIZ-2007G type to carry out PM_{10} and PM_{2.5} measurements, meteorological parameters meters and a wireless data transmission system.

The predictor is supplied with:
- historical data from Foundation ARMAAG [2];
- current immission data obtained from automatic monitoring stations managed by the Voivodship Inspectorate for Environmental Protection (VIEP) and data obtained from the Institute of Geophysics of the Polish Academy of Sciences (IGF PAS);
- current data obtained from continuous measurements of PM_{10} and PM_{2.5} concentrations in a pilot station at Otwock (made within the project);
- measured PM_{10}, PM_{2.5} reference values obtained by the gravimetric method (used for verification of data obtained from automatic stations);
- forecasted meteorological data (T – air temperature, M – air humidity, P – air pressure, W_v – wind velocity, W_d – wind direction) obtained from the Warsaw University Interdisciplinary Centre for Mathematical and Computational Modelling (ICM).

The data supply system for the predictor is shown in Fig. 1.

![Fig. 1 Data flow in the system involving prediction of atmospheric air pollutants concentrations.](image)

![Fig. 2 Schematic of the predictor of atmospheric air pollutant concentrations, where d – means today.](image)

The predictor was tested over the last few months of 2008 and very promising results have been obtained. Table 1 shows some prediction accuracy examples.

<table>
<thead>
<tr>
<th>Predicted pollutant</th>
<th>Neural network type</th>
<th>Teaching data</th>
<th>Testing data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MAPE [%]</td>
<td>MAE µg/m³</td>
<td>MAPE [%]</td>
</tr>
<tr>
<td>NO₂</td>
<td>MLP</td>
<td>19.65</td>
<td>2.50</td>
</tr>
<tr>
<td></td>
<td>SVM</td>
<td>12.56</td>
<td>1.99</td>
</tr>
<tr>
<td>PM_{10}</td>
<td>MLP</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>SVM</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

MAPE – Mean Absolute Percentage Error
MAE – Mean Absolute Error
Diagrams illustrating prediction results are shown in Fig. 3.

Accurate analysis of the temporal behaviour of air pollutants shows a remarkable influence of conditions and processes (including meteorological) on prediction quality, especially for suspended dust. The predictor presented here is continuously tested in various conditions. The aim of these tests is optimisation of the predictor in relation with the kind of pollutant and especially for extremely great and fast changes of suspended dust concentration, local meteorological conditions specifics, quality of measurement immission data and other.

![Fig. 3 Preliminary results of prediction of PM\textsubscript{10} suspended dust concentration. Accounts done with use “step-by-step” model and PM\textsubscript{10} data obtained in real time.](image)

[7] K. Siwek et al., Ensemble of Neural Predictors for Forecasting the Atmospheric Pollution. NN0239. WCCI 2008. 2008 IEEE World Congress on Computational Intelligence, Hong Kong, China, June 1-6, 2008

1) This work was funded as a research and development project by Ministry of Science and Higher Education in 2007-2008
2) Data contained in this publication were delivered with no charge and remain the property of Foundation ARMAAG
Modification of Surface Properties of 316L Stainless Steel and Fe-Cr Alloys Using High Intensity Pulsed Plasma Beams


A. Ce/La rare earth elements in 316 stainless steel

Stainless steels are widely used in industry, mainly due to their excellent corrosion resistance. However, in applications that need improved corrosion resistance (sinking pumps for dirty water, flow/temperature/pressure/humidity sensors, medical implants e.g. stents or joints), or improved high temperature oxidation resistance (e.g. interconnectors for solid oxide fuel cells), the qualities of such commercial steels are not completely satisfactory.

In the present work, we have attempted to improve these poor properties by adding some rare earth elements (REE), such as Ce or La. In principle, elements may be incorporated while the bulk material is melted or introduced using some surface treatment technique, like ion implantation, the sol-gel coating process etc. [1-3]. We have employed for the first time some high-intensity plasma pulses generated in a Rod Plasma Injector-type (RPI) device originally developed for nuclear fusion studies and described in detail in [4,5]. In brief, in RPI the high intensity plasma pulses are generated as a result of a low-pressure, high current discharge between two concentric, cylindrical sets of rod-type electrodes. Two modes of operation are possible: if the plasma consists almost exclusively of the working gas ions, the mode is referred to as Pulse Implantation Doping (PID). In the other mode, the plasma also contains ions/atoms eroded from the generator metallic electrodes; this mode is referred to as Deposition by Pulse Erosion (DPE). At sufficiently high energy density, the near surface region of the substrate is melted for a short time and atoms delivered by the beam or earlier deposited on the surface diffuse rapidly toward the bulk.

Scanning electron micrographs of the surface of 1.4401 (AISI 316) steel: untreated (left), DPE-treated (center) and PID-treated (right).
B. Nitrogen expanded austenite phase in Fe-Cr alloys

Several authors have shown that it is possible to nitride stainless steels so that a meta-stable phase containing nitrogen in some solid solution may be formed. The phase increases surface hardness and wear resistance of the steel without deteriorating its corrosion resistance. The phase is referred to as nitrogen expanded austenite, $\gamma_N$.

Two methods have been used to produce the phase: (i) implantation of N ions at 400…600ºC and high dose-rate above 100 $\mu$A/cm²; (ii) nitriding the steel in a PI$^3$ process (plasma immersion ion implantation). Some authors [e.g. 6, 7] have claimed explicitly that regardless of the nitriding method, the $\gamma_N$ phase can be formed only when Fe, Cr (>15 wt%) and Ni (>5 wt%) are available in the system. However, we have shown [8] that $\gamma_N$ may also be formed in carbon steels or even in pure $\alpha$-iron using high intensity (power density $10^6-10^7$ W/cm²) short ($\mu$s duration) nitrogen plasma pulses in a PID mode that melt the near-surface (0.1-2 $\mu$m) layer of the substrate.

We have observed that $\gamma_N$ content reduces with rising Cr concentration [9], which apparently is not in line with the opinions cited above [6,7]. To clarify this issue we decided to prepare some Fe-Cr only samples (3.15, 6.2, 12.5, 25 and 50 wt% Cr, the arc furnace synthesis method), to treat them with N plasma pulses, and to investigate $\gamma_N$ phase content using conversion electron Mössbauer spectroscopy (CEMS) at two Doppler velocities (+/- 7 mm/s and +/- 2 mm/s). We also plan to make some “ab initio” calculations capable of modeling real Fe-Cr-N systems, especially with regard to atomic arrangement and its influence on the dynamics and the mechanisms of phase formation.


1) Institute of Nuclear Chemistry and Technology, Warsaw, Poland
2) Institute of Atomic Energy, Świerk, Poland
3) Institute of Physical Chemistry PAN, Warsaw, Poland
4) Institute of Precision Mechanics, Warsaw, Poland
Selected Properties of thin Anti-multipactor TiN Layers Reached by Evaporation Method  

by J.Lorkiewicz, J.Kula, S.Pszona

In this paper, we try to simulate experimentally changes in secondary electron yield (SEY) that take place in power couplers for superconducting accelerators. Unlike most other authors, we study secondary emission from technical ceramic, which is normally used in RF transmission lines, and we try to approach the real RF processing conditions for TiN coated alumina coupler components. Detrimental multipacting effects on their surfaces occur when certain resonance conditions are fulfilled for trajectories of electrons striking surfaces of SEY>1. Since ceramic windows are usually made of alumina which exhibits an unacceptably high secondary electron yield, thin, low emission coatings are applied to reduce this phenomenon. TiN/TiO\textsubscript{x}N\textsubscript{y} containing layers are preferred due to their low SEY value and stability in an RF field. The deposited TiN layers are oxidized after being exposed to air which creates a 1-2 nm thick TiO\textsubscript{2} – rich sub-layer close to the surface, increasing the SEY. In addition, the surface is covered with water vapor and carbon-containing gases which lower the surface barrier to electron emission. In-situ vacuum baking and electron bombardment that take place while RF elements are processed in vacuum leads to surface water and gases desorption and to surface film modification - production of defects and reduction of oxides to low electron emission sub-oxides. The conditioning effects normally reached on the surface of RF power components were simulated in several steps on TiN-coated ceramic samples and SEY value changes were determined after completing each step. SEY\textsubscript{m} and E\textsubscript{m} values were measured for different energies of primary electrons before and after vacuum baking at 200 oC for 16 hours and next - after additional irradiation with 1100 eV electrons (this value is close to the mean energy of electrons involved in low-order multipacting process in coax lines of TESLA couplers) aimed at reaching cumulated electron doses of 10\textsuperscript{18}/cm\textsuperscript{2} and 10\textsuperscript{19}/cm\textsuperscript{2}. Each plot of SEY dependence on primary electron energy is parametrized by two values: the maximum SEY value SEY\textsubscript{m} and E\textsubscript{m} - the energy limit of primaries above which SEY drops below 1. Table 1 contains SEY\textsubscript{m} and E\textsubscript{m} data for both a ceramic sample coated with 7 nm thick TiN layer in a “standard” way and a TiN coated sample which was subject to additional heat treatment (heating up to 830\textdegree C in clean nitrogen and then cooling down in a natural way - typical hard soldering conditions).

<table>
<thead>
<tr>
<th>as delivered</th>
<th>after baking</th>
<th>el. dose 10\textsuperscript{18}/scm</th>
<th>el. dose 10\textsuperscript{19}/scm</th>
</tr>
</thead>
<tbody>
<tr>
<td>TiN coated</td>
<td>2.02 2.0</td>
<td>1.73 1.5</td>
<td>1.66 1.2</td>
</tr>
<tr>
<td>TiN coated, heat treated</td>
<td>1.9 3</td>
<td>1.67 1.2</td>
<td>1.75 1.0</td>
</tr>
</tbody>
</table>

The maximum SEY value on the TiN coated sample was reduced substantially from 2.02 down to 1.73 during bake-out which corresponds mainly to surface water desorption, whereas E\textsubscript{m} was reduced from 2.0 keV down to 1.5 keV as a result of baking. Using the results of [3] one can estimate that vacuum baking alone protects TESLA coupler coax lines from dangerous first-order one-point multipacting. Electron irradiation up to 10\textsuperscript{18}/cm\textsuperscript{2} and 10\textsuperscript{19}/cm\textsuperscript{2} reduced E\textsubscript{m} further by 300 eV and 500 eV, respectively. The TiN deposited and heat-treated sample reveals, after similar vacuum bake-out, E\textsubscript{m} as high as 3 keV, whereas the maximum SEY value on this curve exceeded the maximum value for the sample which had not been subject to heat treatment by merely 0.17. Unlike the standard TiN coating, the SEY of a heat-treated TiN film depend much stronger on surface layer conditions than on adsorbed gases. After electron irradiation up to a dose of 10\textsuperscript{15}/cm\textsuperscript{2} E\textsubscript{m} dropped dramatically by as much as 1800 eV but further irradiation up to 10\textsuperscript{19}/cm\textsuperscript{2} reduced this energy by only 300 eV. This shows how unstable the shape of the SEY curve can be after heat treatment. Additional XPS studies of the layers showed that heating up to 830\textdegree C brings about oxidation of TiN and a rise of TiO\textsubscript{2} content which greatly exceeds the TiN and TiO\textsubscript{x}N\textsubscript{y} content across the whole layer thickness [1].
Conclusions: SEY values of TiN coated technical alumina surfaces were measured in conditions similar to RF power couplers training. In-situ vacuum bake-out of the surface layer is much more effective if the coated ceramic component was not subject to heat treatment. Moreover, the SEY curve vs. primary electron energy of the heat-treated sample still shows a very high $E_m$ value after bake-out. This SEY curve changes its shape rapidly after absorbing a small dose ($\approx 10^{18}$/cm$^2$) of electron irradiation, whereas further irradiation has a much smaller impact on $E_m$. Due to this instability and irreproducibility of the SEY values during conditioning, heat treatment (as well as hard soldering) of TiN coated ceramic surfaces should be avoided whenever possible.

Polychromatic decoration of ancient Egyptian tombs and temples has a long tradition over three millennia. It has been demonstrated that the ancient color hues cannot be determined from present visual perceptions because many pigments have been subjected to severe chemical reactions, which have entirely changed their original colors. Optical microscopy, PIXE and microbeam-PIXE have been used to determine the nature of the pigments, their chronology, and the identification of domestic and imported materials. Pigments from various archeological sites in Egypt were analyzed: According to optical microscopy observations the paint is composed of grains of sizes typically ranging from 50 µm to 300 µm embedded in a binding material. Optical microscopy also revealed great non-uniformity of pigment depth and lateral distributions and discontinuity of the paint layers. In some places paint flaked off and the supporting plaster became visible. This effect is due to the long exposure of wall paintings to environmental degradation factors. Preliminary analysis using broad beam PIXE has been performed allowing a determination of the average composition both of the support and the pigments. Microbeam PIXE has been used for the mapping of selected grains. Important findings on the origin and dating of wall paintings at different archeological sites are reported. Besides these data, interesting details concerning the painting technique of the ancient masters have been revealed.

Two spectra shown in Fig. 1 were taken for each sample: for the face and back side. After subtraction of the face spectrum from the back one, the paint composition was determined. A µ-PIXE spectrum obtained for one selected pigment grain is shown in the inset. The presence of an intense Fe signal has been attributed to a deep yellow paint layer whose pigment was fine powdered mineral goethite, i.e. α-FeO OH; this so-called yellow ochre was very often used as a pigment, and is commonly present in the Egyptian soil. The signal of As has been attributed to the only known yellow pigment containing this element, namely orpiment As₂S₃. Orpiment is not found in any ore deposit in Egypt and therefore has to be imported. The use of this rare and expensive material was a royal privilege. Due its brightness and gold shiny glaze, the ancient Egyptians recognized orpiment as a superior yellow pigment. Besides its rare use as a principal pigment, orpiment was used to blend yellow ochre, not however simply mixed with it but applied in a distinct painting sequence, usually as a very thin top layer. Such a sequence has been apparently discovered in our study.

1) Forschungszentrum Dresden, Germany
IMRT module for ALFARD Treatment Planning System
by M. Andraśiak, K. Ceglińska, P. Kamiński, A. Szułmejło

The aim of the IMRT (Intensity Modulated Radiation Therapy) technique is to optimize beam intensity in order to provide the most efficient dose distribution. This goal is achieved with a multileaf collimator (MLC) that modulates the beam by changing its shape accordingly to the target volume projection onto the plane of the patient. This kind of therapy requires sophisticated optimization algorithms, as well as an extended planning system for dose calculations. This paper presents the basic concept of the IMRT module for the ALFARD treatment planning system.

In order to perform the necessary calculations the algorithm needs some user defined input data. These are beam energy and machine name, collimator angle, table top positions, table support angle, number of beams that have to be delivered and gantry angle for each beam. At this point in the planning process, there are some structures previously defined at the contouring station but they need parameterization. Each structure needs a minimum, maximum and average dose that should be delivered to the structure volume. For each structure, the user can define as many volume-dose histogram points as required. For each point, a limit can be assigned. There are two possible limits: ‘no more than’ and ‘no less than’ with regard to the average dose assigned to the structure. Furthermore, each point can have an integral number priority assigned.

Each beam consists of n beamlets and each beamlet has a weight which corresponds to its intensity. The algorithm changes the weights of every beamlet available in all of the beams and searches for the result that has the best correlation with the dose distribution defined by the user in histograms. For optimization purposes an evolutionary algorithm that searches for the global minimum, in candidate solution space has been used. Firstly, a random population of different solutions is created. Each individual has all beamlet weights assigned; these values create a genotype. The next generation is created by individual mutation and crossing-over, and then a fitness function is applied to each candidate solution in order to evaluate it. Only a group of the best solutions are allowed for next generation creation. These steps are repeated until no better solution can be found or the process has been interrupted by the user (i.e. the user decides that the solution found is close enough to the optimum). Histogram points priorities, limitations and dose values are used in the fitness function. Priorities can be changed during optimization, which allows the algorithm to be even more flexible.

At the optimization end a 3D beamlet weights landscape is received. Output data are presented as a colored weight map and a set of final histograms. The solution can be either accepted by the user or rejected, in the latter case the user can change the input data and recommence the optimization process.

If a given solution has been accepted, IMRT will produce a sequence of irregular fields which in superposition will give a dose distribution adequate to the beamlet weights landscape generated by the optimization algorithm. The next step will alter the produced fields so that they can be delivered with the defined multileaf collimator according to its capability. At the end, the dose distribution is recalculated for the fields designed for a specific multileaf collimator. After user acceptance a treatment plan is produced.

The IMRT module for ALFARD Treatment Planning System is still under development but first tests show that this solution will reach optimum in a rather short time.
IV. LIST OF PUBLICATIONS

PUBLICATIONS IN JOURNALS WITH THE PEER REVIEW

1. Microstructure and Magnetic Properties of Iron Oxide Nanoparticles Prepared by Wet Chemical Method
   D. Satuła, B. Kałska-Szostko, K. Szymański, L. Dobrzyński, J. Kozubowski

2. On the question of ferromagnetism in proton and He-irradiated carbon.
   J. Szczytka, P. Juszyński, L. Teliga, A. Stonert, R. Ratajczak, A. Korman, A. Twardowski

3. The evolution of superconducting phase MgB$_2$
   S. Łoś, ... , J. Piekoszewski, Z. Werner, M. Barlak, ... et al.

4. Unstable Quark-Gluon Plasma at LHC
   St. Mrówczyński

5. $\Sigma$: Nucleus Potential Studied with the ($\pi$ K') Reaction
   J. Dąbrowski, J. Rożynek

6. A study of levels in $^{149}$Nd using the (d,p) and (d,t) reactions
   M. Jaksóla

7. A test of the BFKL resummation at ILC
   M. Segond, L. Szymanowski, S. Wallon

8. Multi-gluon field approach of QCD
   H.P. Morsch, P. Żupański

9. Nuclear States of Strange Mesons
   S. Wycech, A.M. Green

10. Observation of a new (25/2$^+$) isomer in $^{121}$Sb
    J. Kownacki, ... , M. Kisieliński, E. Ruchowska, A. Korman, ... et al.

11. Orbital electron capture and beta plus decay of H-like $^{149}$Pr ions
    J. Kurcewicz, ... , Z. Patyk, ... et al.

12. Plasma Electromagnetic Fluctuations as an Initial Value Problem
    St. Mrówczyński

    J. Rożynek

    A. Szydlowski, ... , A. Malinowska, M. Jaksóla, A. Korman, M.J. Sadowski, ... et al.

15. Assessment of a 1-D, Multi-colour X-ray Imaging System for the MAST ST
    S. Jabłoński, A. Czarnecka, J. Kaczmarczyk, L. Roż, J. Rzadkiewicz

16. Cherenkov detector for measurements of fast electrons in CASTOR tokamak
    L. Jakubowski, ... , M.J. Sadowski, J. Stanisławski, K. Malinowski, J. Żebrowski, M.J. Jakubowski, ... et al.

17. Cosmic Rays and Cosmology
    T. Wibig, A.W. Wolfendale
18. Damages of carbon-tungsten samples under influence of deuterium ions and dense plasma streams within Plasma-Focus facility
V.A. Gribkov, ..., K. Malinowski, M.J. Sadowski, E. Składnik-Sadowska, ... et al.

19. Diagnostics of fast electrons within CASTOR tokamak by means of a modified Cherenkov-type probe
J. Żebrowski, ..., L. Jakubowski, M.J. Sadowski, K. Malinowski, M.J. Jakubowski, ... et al.

20. Experimental studies of fast protons originated from fusion reactions in Plasma-Focus discharges
A. Malinowska, K. Malinowski, M.J. Sadowski, J. Żebrowski, A. Szydłowski

21. Fast-neutron source based on Plasma-Focus device
M. Scholz, ..., A. Szydłowski, ... et al.

22. Investigation of plasma discharges within MAJA-PF device operated with tungsten inserts in the central electrode
K. Malinowski, E. Składnik-Sadowska, M. Ladygina, L. Jakubowski, M.J. Sadowski

23. Jets in heavy-ion collisions at the LHC with ALICE
A. Morsch, ..., A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

24. Measurements of neutron yield from deuterium plasmas at JET by activation techniques
R. Prokopowicz, M. Scholz, A. Szydłowski, S. Popovichev, JET, EFDA-Contributors

25. MHD modelling of flow phenomena during the Impulse Plasma Deposition process
M. Rabiński, K. Zdunek

26. Modified miniature Thomson-type analyzer for measurements of mass- and energy-spectra of ions within plasma facilities
K. Czaus, K. Malinowski, M.J. Sadowski, E. Składnik-Sadowska

27. Structure of Nb films deposited by means of ultra-high vacuum cathodic arc technique
R. Nietubyć, M.J. Sadowski, P. Strzyżewski, J. Pelka

28. Studies of pulsed plasma-ion streams during their free propagation and interaction with carbon-tungsten targets in PF-1000 facility
E. Składnik-Sadowska, ..., K. Malinowski, M.J. Sadowski, ... et al.

29. Study of D-D Reaction at the Plasma Focus Device
P. Kubes, ..., M.J. Sadowski, ... et al.

30. The influence of the Stark effect on the shape of He-like argon lines in a dense plasma
E.O. Baronova, G.V. Sholin, V.V. Vikhrev, L. Jakubowski

31. Two Photon Distribution Amplitudes
M. El-Beiyad, B. Pire, L. Szymanowski, S. Wallon

32. Sublimation TiN Coating of RF Power Components
J. Lorkiewicz, J. Kuś, P. Pszona, J. Sobczak, A. Bilinski

33. Magnetically modulated microwave absorption study of superconducting MgB2 regions
L. Piekar-Sady, ..., J. Piekoszewski, M. Barlak, Z. Werner, J. Stanisławski, ... et al.

34. A database of prompt gamma-ray spectra for the inspection of cargo containers with 14 MeV neutrons
B. Perot, ..., M. Moszyński, M. Gierlik, ... et al.

35. Direction identification in radio images of cosmic-ray air showers detected with LOPES and KASCADE
A. Nigl, ..., P. Łuczak, J. Zabierowski, ... et al.

36. Frequency spectra of cosmic ray air shower radio emission measured with LOPES
A. Nigl, ..., P. Łuczak, J. Zabierowski, ... et al.
37. The Vimos VLT deep survey. Global properties of 20,000 galaxies in the I_{AB} < 22.5 WIDE survey
B. Garilli, ..., A. Pollo, ... et al. 

38. The VVDS-SWIRE-GALEX-CFHTLS surveys: physical properties of galaxies at z below 1.2 from photometric data
C.J. Walcher, ..., A. Pollo, ... et al. 

39. Applying shower development universality to KASCADE data
W.D. Apel, ..., J. Zabierowski, ... et al. 

40. Time structure of the EAS electron and muon components measured by the KASCADE-Grande experiment
W.D. Apel, ..., P. Łuczak, J. Zabierowski, ... et al. 

41. Enhanced Level of Micronuclei in Peripheral Blood Lymphocytes of Patients Treated for Restenosis with ^{32}P Endovascular Brachytherapy.
A. Wójcik, ..., S. Pszona, ... et al. 

42. First Measurements of the Performance of the Barrel RPC System in CMS
A. Colaleo, ..., M. Bluj, T. Fruboes, M. Górska, M. Kazana, M. Szleper, G. Wrochna, P. Zalewski, ... et al. 

43. A grid infrastructure for parallel and interactive applications
J. Gomes, ..., K. Nawrocki, W. Wiślicki, ... et al. 

44. The interactive european grid: project objectives and achievements
J. Marco, ..., K. Nawrocki, W. Wiślicki, ... et al. 
Comp. Inform. Vol. 27 (2008) 161

45. Propagation Technique for Ultrashort Pulses I: Propagation Equation for Ultrashort Pulses in a Kerr Medium
VanCaoLong, H.NguyenViet, M. Trippenbach, KhoaDinhXuan 

46. Propagation technique for ultrashort pulses II: Numerical methods to solve the pulse propagation equation
VanCaoLong, H.N. Viet, M. Trippenbach, KhoaDinhXuan 

47. Propagation technique for ultrashort pulses III: Pulse splitting of ultrashort pulses in a kerr medium
VanCaoLong, H.N. Viet, M. Trippenbach, KhoaDinhXuan 

48. Gauss-Legendre and Chebyshev quadratures for singular integrals
A. Deloff 

49. Variations In the crystalline deposits formed upon electrochemical oxidation of the anions, [Ir(CO)2X2]^- (X=Cl, Br and I)
K. Winkler, ..., I. Dobrzyński, ... et al. 

50. Critical fluctuations of an attractive Bose gas in a double-well potential
P. Ziń, J. Chwedeńczuk, B. Oleś, K. Sacha, M. Trippenbach 

51. Microscopic *Li and *Si potential from the energy-density functional theory
S. Hossain, ..., K. Rusek, ... et al. 

52. Viscous limitation of large amplitude pulse in two component plasmas
G. Rowlands, E. Infeld 

53. EZ transition probabilities in the decoupled band of the ^{139}La nucleus
I. Sankowska, ..., M. Kisielski, R. Kaczarowski, E. Ruchowska, ... et al.

54. Excitation of the Roper Resonance in single and double-pion production in nucleon-nucleon collisions
T. Skorodko, ..., J. Stepniak, J. Zabierowski, ... et al. 

55. Single p(+) production in np collisions for excess energies up to 90 MeV
P. Żurpański, ..., et al. 

56. Two pion production in proton-proton collisions with a polarized beam
ElBary, ..., P. Żurpański, ... et al. 
57. Diffraction photoproduction of dijets in ep collisions at HERA.
S. Chekanov, M. Adamus, P. Plucinski

58. Higgs boson searches in CP-conserving and CP-violating MSSM scenarios with the DELPHI detector
J. Abdallah, ... , M. Bluji, R. Gokkeli, J. Hoffman, K. Nawrocki, R. Sosnowski, M. Szczekowski, M. Szeptycka, P. Zalewski, ... et al.

59. Measurement of the mass and width of the W boson in e+e- collisions at \( \sqrt{s} = 161-209 \) GeV
J. Abdallah, ... , M. Bluji, R. Gokkeli, J. Hoffman, K. Nawrocki, R. Sosnowski, M. Szczekowski, M. Szeptycka, P. Zalewski, ... et al.

60. New high statistics measurement of \( K_{\ell 4} \) decay form factors and pi pi scattering phase shifts
J.R. Batley, ... , M. Szlepec, ... et al.

61. Study of b-quark mass effects in multijet topologies with the DELPHI detector at LEP
J. Abdallah, ... , M. Bluji, R. Gokkeli, J. Hoffman, K. Nawrocki, R. Sosnowski, M. Szczekowski, M. Szeptycka, P. Zalewski, ... et al.

62. Study of W-boson polarisations and triple gauge boson couplings in the reaction e+e-\( \rightarrow W^+W^- \) at LEP 2
J. Abdallah, ... , M. Bluji, R. Gokkeli, J. Hoffman, K. Nawrocki, R. Sosnowski, M. Szczekowski, M. Szeptycka, P. Zalewski, ... et al.

63. Spin Density Matrix Elements from diffractive \( \phi \) meson production
W. Augustyniak, A. Borissov, S. Manayenkov
Hep-ex Vol. 08 (2008) 0069

64. Advantages of Mössbauer polarimetric methods in material studies
K. Szymański, ... , L. Dobrzyński, ... et al.

65. Application of Hamamatsu S8550 APD array to the Common PET/CT Detector
A. Nassalski, M. Moszyński, A. Syntfeld-Kałuż, Ł. Świderski, T. Żuch, D. Wołski, T. Batsch

66. Boron-10 Loaded BC523A Liquid Scintillator for Neutron Detection in the Border Monitoring
Ł. Świderski, ... , M. Moszyński, D. Wołski, T. Batsch, A. Nassalski, A. Syntfeld-Kałuż, T. Żuch, ... et al.

67. Energy resolution of scintillation detectors - new observations
M. Moszyński, A. Nassalski, A. Syntfeld-Kałuż, Ł. Świderski

68. Light pulse shape dependence on \( \gamma \)-ray energy in CsI(Tl)
A. Syntfeld-Kałuż, M. Moszyński, Ł. Świderski, W. Klamura, A. Nassalski

69. Non-proportionality of organic scintillators and BGO
A. Nassalski, M. Moszyński, A. Syntfeld-Kałuż, Ł. Świderski

70. Scintillation properties of undoped CsI and CsI doped with CsBr
Ł. Świderski, M. Moszyński, A. Nassalski, A. Syntfeld-Kałuż, W. Czarnacki, W. Klamura, V.A. Kozlov

71. Study of LaBr₃ Crystals Coupled to Photomultipliers and Avalanche Photodiodes
M. Moszyński, ... , Ł. Świderski, T. Żuch, D. Wołski, A. Nassalski, A. Syntfeld-Kałuż, W. Czarnacki, ... et al.

72. Breakup and Transfer Effects on Near-Barrier \(^{4}\)He + \(^{208}\)Pb Elastic Scattering
N. Keeley

73. Deformation of multipolarity six at the saddle point of heaviest nuclei
L. Shvedov, S.G. Rohozinski, M. Kowal, S. Belchikov, A. Sobieczewski

74. Entrance-channel effects in suppression of fusion of heavy nuclei
K. Siwek-Wilczyńska, A. Borowiec, I. Skwira-Chalot, J. Wilczyński

75. Influence of entrance channel shell effects on fusion hindrance
J. Bloch, J. Wilczyński
76. Macroscopic dynamical description of rotating Au + Au system
N. Cârjan, K. Siwek-Wilczyńska, I. Skwira-Chalot, J. Wileżyński

77. Re-separation modes of 197Au + 197Au system at sub-Fermi energies
J. Wileżyński, ... , E. Piasecki, L. Świderski, ... et al.

78. Relative motion correction to fission barriers
J. Skalski

79. Saddle-point shapes of heavy and superheavy nuclei
A. Sobiczewski, M. Kowal, L. Shvedov

80. Saddle-point shell effects of heaviest nuclei
M. Kowal, L. Shvedov, A. Sobiczewski

81. Biological effectiveness of 12C and 20Ne ions with very high LET
J. Czub, ... , M. Jaskółka, A. Korman, ... et al.

82. Modyfikacja struktury i właściwości warstw wierzchnich stali węglowych intensywnymi impulsem pльн oraz wyższej węglowej i azotowej
B. Sartowska, L. Waliś, J. Piekoszewski, L. Nowicki, R. Ratajczak, J. Senatorski

83. Ultraintense proton beams from laser-induced skin-layer ponderomotive acceleration
J. Badziak, ... , A. Szydłowski, ... et al.

84. Inflation in DBI models with constant gamma.
M. Spaliński

85. Deformed boson-fermion correspondence, Q-bosons, and topological strings on the conifold
P. Sułkowski

86. Energy dependence of the charged multiplicity in deep inelastic scattering at HERA.
S. Chekanov, ... , M. Adamus, P. Pluciński, ... et al.

87. Evidence for a transverse single-spin asymmetry in lepton production of p(+)p(p)(-) pairs
W. Augustyniak, ... , B. Mariański, A. Trzebiński, P. Żupraniński, ... et al.

88. Instantons on ALE Spaces and Orbifold Partitions
R. Dijkgraaf, P. Sułkowski

89. Measurement of azimuthal asymmetries with respect to both beam charge and transverse target polarization in exclusive electroproduction of real photons
W. Augustyniak, ... , B. Mariański, A. Trzebiński, P. Żupraniński, ... et al.

90. Supersymmetric Gauge Theories, Intersecting Branes and Free Fermions
R. Dijkgraaf, L. Hollands, P. Sułkowski, C. Vafa

91. Phase integral approximation for coupled ordinary differential equations of the Schroedinger type
A. Skorupski

92. Air Shower Radio Detection with LOPES
J. Bluemer, ... , P. Luczak, J. Zahierowski, ... et al.

93. Fabrication and characterization of nickel silicide ohmic contacts to n-type 4H Silicon Carbide
A. Kuchuk, V. Kladko, M. Guziewicz, A. Piotrowska, R. Minikayev, A. Stonert, R. Ratajczak

94. Level-1 RPC Trigger in the CMS experiment - software for emulation and commissioning
M. Konecki, ... , M. Blu, ... et al.
95. Radio detection of cosmic ray air showers with the LOPES experiment
T. Huege, ..., P. Łuczak, J. Zabierowski, ... et al.

96. Status of the KASCADE-Grande experiment
H. Ulrich, ..., P. Łuczak, J. Zabierowski, ... et al.

97. The KASCADE-Grande experiment
J. Bluemer, ..., P. Łuczak, J. Zabierowski, ... et al.

98. Ultrahigh-current proton beams from short-pulse laser-solid interactions
J. Badziak, ..., A. Szydłowski, ... et al.

99. Energy dependence of fluctuations in central Pb+Pb collisions from NA49 at the CERN SPS
M. Rybczynski, ..., H. Białkowska, B. Boimka, St. Mrówecki, P. Szymański, W. Trubnikow, ... et al.

100. Anisotropic flow measurements in ALICE
S. Rainwalla, ..., A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

101. Heavy flavour physics in ALICE
M. Masera, ..., A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

102. Jet and gamma-jet physics with ALICE
A. Morsch, ..., A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

103. Prospect for $\phi$-meson production in the pp collisions in the ALICE experiment
J.D. Tapia-Takaki, ..., A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

104. Search for direct photons in p+Pb collisions at $\sqrt{s_{NN}} =17.4$ GeV
C. Baumann, ..., T. Siemiarczuk, ... et al.

105. Soft physics in ALICE
Ch. Kuhn, ..., A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

106. Study of short-lived resonances in ALICE
A. Badala, ..., A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

107. Study of the ALICE performance for the measurements of beauty production
J. Faivre, ..., A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

108. Study of the $\Lambda(1520)$ production in pp simulated interactions at 14 TeV with the ALICE detector
P. Garnot, ..., A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

109. The ALICE muon spectrometer and related physics

110. ALICE experiment at the CERN LHC

111. The CMS experiment at the CERN LHC
S. Chatrchyan, ..., R. Gokeli, M. Górski, K. Nawrocki, P. Traczyk, G. Wrochna, P. Zalewski, M. Bluß, M. Kazana, M. Szyder, ... et al.

112. The LHCb Detector at the LHC
K. Brzoziowski, ..., A. Chłopik, P. Gawor, Z. Guzik, A. Nawrot, A. Średnicki, K. Syryczynski, M. Szczekowski, ... et al.

113. The Influence of Growth Temperature on Oxygen Concentration in GaN Buffer Layer
E. Dumiszewska, ..., K. Pagowska, A. Turos, ... et al.

114. Fabrication of thin metallic films by means of arc discharges under ultra-high vacuum conditions
P. Strzyżewski, M.J. Sadowski, R. Niewębski, K. Rogacki, W. Paszkowski, T. Paryjczak, J. Rogowski
115. Long-term stability of Ni-silicide ohmic contact to n-type 4H-SiC
A.V. Kuchuk, M. Guziewicz, R. Ratajecki, M. Wzorek, V.P. Kladko, A. Piotrowska

116. Environmental Dependence of the Star Formation in Galaxies from the Joint GALEX/CFHTLS Data
A. Pollo, S. Arnouts, S. Heinis, B. Milliard

117. The VIRMOS-VLT Deep Survey: mass and light clustering in the Universe during the last 8 billion years
A. Pollo, ... et al.

118. A test of the nature of cosmic acceleration using galaxy redshift distortions
L. Guzzo, ... , A. Pollo, ... et al.

119. Broadband observations of the naked-eye big gamma-ray burst GRB 080319B
J.L. Racusin, ... , M. Sokołowski, G. Wrochna, K. Nawrocki, ... et al.

120. The catalog of short periods stars from the "Pi of the Sky" data
M. Jaskółka, A. Korman, A. Stolarz, ... et al.

121. Discriminant analysis and secondary-beam charge recognition
J. Andrzejewski, ... , M. Kisieliński, A. Korman, ... et al.

122. Electron spectrometer for "in-beam" spectroscopy
J. Lukasik, ... , A. Mykulyak, B. Zieliński, ... et al.

123. Estimation of the impurity levels in polyimide foils and the life-time of the foils irradiated by charged projectiles
M. Jaskółka, A. Korman, A. Solorz

124. In field tests of the EURITRACK tagged neutron inspection system
C. Carasco, ... , M. Moszyński, M. Gierlik, ... et al.

125. KASCADE-Grande: an overview and first results
M. Bertaina, ... , P. Łuczak, J. Zabierowski, ... et al.

126. Light transport in long, plastic scintillators
M. Gierlik, T. Batsch, R. Marcinkowski, M. Moszyński, T. Sworobowicz

127. The WASA detector facility at CELSIUS
Chr. Bargholtz, ... , M. Berłowski, A. Kupić, P. Marciniewski, A. Nawrot, J. Stepaniak, J. Zahieowski, ... et al.

128. Charge Cluster Distribution in Nanosites Traversed by a Single Ionizing Particle – An Experimental Approach
S. Pszona, A. Bantsar, J. Kula

129. Analysis of the accumulation of radiation damage in selected crystals
J. Jagiełski, L. Thome, P. Aubert, O. Maciejak, A. Piątkowska, R. Groetzschel

130. Channeling study of thermal decomposition of III-N compound semiconductors
A. Stonert, K. Pagowska, R. Ratajecki, P. Caban, A. Turos

131. Ion beam modification of strained InGaAs/InP characterized by HRXRD, PL and AFM
G. Devaraju, ... , A. Turos, ... et al.

132. Ion beam modification studies of InP based multi quantum wells
S. Dhamodaran, G. Devaraju, A.P. Pathak, A. Turos, D.K. Avasthi, R. Kesavamoorthy, B.M. Arora

133. L-subshell ionization of heavy elements by S ions with energy of 0.4-3.8 MeV/amu
I. Fijał-Kirejczyk, ... , M. Jaskółka, A. Korman, ... et al.

134. Magnetic texture determination by conversion electron Mössbauer spectroscopy with circularly polarized beam
W. Olszewski, K. Szymański, D. Satula, L. Dobrzynski, L. Bottyan, F. Tancziko
135. Multi-step mechanism of damage accumulation in irradiated crystals  
   J. Jagielski, L. Thome  

136. Nitrogen sublattice analysis in GaN by non-rutherford He-ion scattering  
   A. Turos, R. Ratajczak, K. Pagowska, A. Stonert, L. Nowicki, P. Caban  

137. Radiation effects in yttria-stabilized zirconia: Comparison between nuclear and electronic processes  
   S. Moll, ... , J. Jagielski, ... et al.  

138. Radiation stability of fluorite-type nuclear oxides  
   F. Garrido, L. Vincent, L. Nowicki, G. Sattonnay, L. Thomé  

139. Structural and Compositional Analysis of Strain Relaxed InGaAs/InP Multi Quantum Wells  
   S. Dhamodaran, G. Devaraju, A.P. Pathak, A. Turos, D.K. Avasthi, R. Kesavamoorthy, B.M. Arora  

140. Swift heavy ion irradiated InGaAs/InP multi quantum wells: Band structure, interface and surface modification  

141. Visible light emission from silicon dioxide with implanted excess silicon  
   G. Gawlik, J. Jagielski  

142. Nuclear structure studies of short-lived neutron-rich nuclei with the novel large-scale isochronous mass spectrometry at the FRS-ESR facility  
   B. Sun, ... , Z. Patyk, ... et al.  

143. Study of the elastic scattering of $^4$He on $^{208}$Pb at energies around the Coulomb barrier  
   A.M. Sanchez-Benitez, ... , K. Rusek, ... et al.  

144. The ALICE experiment at the LHC  
   E. Vorcellin, ... , A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.  

145. Three- and Four-Jet Final States in Photoproduction at HERA  
   S. Chekanov, ... , J. Łukasik, M. Adamus, P. Pluciński, ... et al.  

146. EAS radio-detection with LOPES  
   A. Haungs, ... , P. Łuczak, J. Zabierowski, ... et al.  

147. Exclusive photoproduction of lepton pairs at LHC  
   B. Pire, L. Szmanykowski, J. Wagger  

148. First physics with heavy-ions with ALICE  
   L. Ramello, ... , A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.  

149. From RHIC to LHC  
   J. Rak, ... , A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.  

150. HERMES Measurements of Hard-Exclusive Processes  
   B. Marianowski  

151. Heavy-ion physics with ALICE  
   F. Antinori, ... , A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.  

152. High energy muon number spectrum detected at Baksan underground scintillation telescope  
   V.B. Petkov, J. Szabelski, D.V. Smirnov, R.V. Novoseltseva  

153. Investigations of muons in EAS with KASCADE-Grande  
   A. Haungs, ... , P. Łuczak, A. Risse, J. Zabierowski, ... et al.  

154. Proton-induced physics with heavy-ion beams in ALICE  
   J. Nystrand, ... , A. Deloff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.  
155. Status of KASCADE-Grande experiment
H. Ulrich, ... , P. Luzak, A. Risse, J. Zarbierowski, ... et al.

156. The ALICE detector and trigger strategy for diffractive and electromagnetic processes
R. Schicker, ... , A. Defoff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

157. Ion implantation followed by laser/pulsed plasma/ion beam annealing: A new approach to fabrication of superconducting MgB₂ thin films
J. Pieczowski, Z. Werner, M. Barlak, A. Kolitsch, W. Szymczyk
Nukleonika Vol. 53 No 1 (2008) 7-10

158. The orbital and physical parameters of the eclipsing binary OW Geminorum
C. Galan, ... , A. Majcher, ... et al.

159. Effects of composition grading at the heterointerfaces and layer thickness variations on Bragg mirror quality
J. Gaca, ... , A. Turos, A.M. Abdul-Kader, ... et al.

160. High-\( p_t \) and jet physics from RHIC to LHC
M. Estienne, ... , A. Defoff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

161. Prospects for strangeness measurements in ALICE
R. Vernet, ... , A. Defoff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

162. Proton-proton physics with the ALICE muon-spectrometer at the LHC
N. Bastid, ... , A. Defoff, I. Ilkiv, P. Kurashvili, T. Siemiarczuk, G. Wilk, ... et al.

163. Sigma meson and phonon-like excitations of the instanton vacuum
G.H. Zinovjev, ... , T. Siemiarczuk, ... et al.

164. Some forgotten features of the Bose-Einstein Correlations
G.A. Kozlov, O. Utyuzh, G. Wilk, Z. Włodarczyk

165. Measurement of the Tau Lepton Polarisation at LEP2
J. Abdallah, ... , M. Bluji, R. Gokieli, J. Hoffman, K. Nawrocki, R. Sosnowski, M. Szczezkowski, M. Szeptycka, P. Zalewski, ... et al.

166. Polarisation of the \( \omega \) meson in the \( pd\rightarrow^3He\omega \) reaction at 1360 and 1450 MeV
K. Schönning, ... , M. Berłowski, A. Kupić, P. Marciniowski, J. Stepiński, J. Zarbierowski, ... et al.

167. Analyzing power \( A(y) \) for omega meson production in proton-proton collisions
P. Żuprański, ... et al.

168. Cross sections for hard exclusive electroproduction of \( \pi^+ \) mesons on a hydrogen target
A. Airapetian, ... , W. Augustyniak, B. Mariański, A. Trzciński, P. Zaprański, ... et al.

169. First observation and measurement of the decay \( K^+\rightarrow\pi^+e^+\gamma \)
J.R. Batley, ... , M. Szleper, ... et al.

170. Lineshape of the Lambda(1405) Hyperon Measured Through its Sigma0 pi0 Decay
I. Zychor, ... et al.

171. Measurement of parton distributions of strange quarks in the nucleon from charged-kaon production in deep-inelastic scattering on deuteror
A. Airapetian, ... , W. Augustyniak, B. Mariański, A. Trzciński, P. Zaprański, ... et al.

172. On AdS/QCD correspondence and the partonic picture of deep inelastic scattering
B. Pire, C. Roiesnel, L. Szymanowski, S. Wallon

173. Source shape determination with directional fragment-fragment velocity correlations
A. LeFèvre, ... , A. Trzciński, B. Zwiągliński, ... et al.
174. The Polarised Valence Quark Distributions from Semi-inclusive DIS
M. Aleksev, ... , R. Gazda, K. Klimeszewski, K. Kurek, J. Nassalski, E. Rondio, A. Sandacz, W. Wiślicki, ... et al.

175. Coupling and binding-saturation effects in L-subshell ionization of heavy atoms by 0.3-1.3 MeV/amu Si ions
I. Fijal-Kirejczyk, ... , M. Jaskółka, W. Czarnacki, A. Korman, ... et al.

176. Pair correlations of scattered atoms from two colliding Bose-Einstein Condensates: Perturbative Approach
M. Trippenbach, A. Perrin, V. Leung, D. Boiron, C.I. Westbrook

177. Second -order quantum phase transition of a homogeneous Bose gas with attractive interactions
P. Ziń, B. Oleś, M. Trippenbach, K. Sacha

C. Alt, ... , H. Białkowska, B. Boimska, St. Mrózcyński, P. Szymański, W. Trubnikow, ... et al.

179. Mössbauer data analysis based on invariants and application to UFe5Sn
D. Satulla, K. Szymański, L. Dobrzyński, V.H. Tran, R. Troć

C. Alt, ... , H. Białkowska, B. Boimska, St. Mrózcyński, P. Szymański, W. Trubnikow, ... et al.

181. Energy Dependence of Multiplicity Fluctuations in Heavy Ion Collisions at 20A to 158A GeV.
C. Alt, ... , H. Białkowska, B. Boimska, St. Mrózcyński, P. Szymański, W. Trubnikow, ... et al.

182. Energy dependence of phi meson production at sqrt(sNN) = 6 to 17 GeV
C. Alt, ... , H. Białkowska, B. Boimska, St. Mrózcyński, P. Szymański, W. Trubnikow, ... et al.

183. 118Sn levels studied by the 120Sn(p,t) reaction: High-resolution measurements, shell model, and distorted-wave
Born approximation calculations
P. Guazzoni, ... , M. Jaskółka, ... et al.

184. 6Li and 6He elastic scattering from 12C and the effect of direct reaction couplings
N. Keeley, K.W. Kemper, O. Momotyuk, K. Rusak

185. Alpha decay half-lives for neutral atoms and bare nuclei
Z. Patyk, H. Geissel, Yu.A. Litvinov, A. Musumarra, C. Nociforo

C. Alt, ... , H. Białkowska, B. Boimska, St. Mrózcyński, P. Szymański, W. Trubnikow, ... et al.

187. Centrality dependence of isospin effect signatures in 124Sn + 64Ni and 112Sn + 58Ni reactions
R. Planeta, ... , E. Piaskecki, L. Świderski, J. Wilczyński, ... et al.

188. Cross sections calculated for cold fusion reactions for producing superheavy nuclei
R. Smoluchczuk

189. High Transverse Momentum Hadron Spectra at s(NN)**(1/2) = 17.3-GeV, in Pb+Pb and p+p Collisions, Measured by CERN-NA49
C. Alt, ... , H. Białkowska, B. Boimska, St. Mrózcyński, P. Szymański, W. Trubnikow, ... et al.

190. Nonextensive hydrodynamics for relativistic heavy-ion collisions
T. Osada, G. Wilk

191. Nuclear fission with mean-field instantons
J. Śkałski

192. Orbital Electron Capture Decay of Hydrogen- and Helium-like Ions
Z. Patyk, J. Kurcewicz, F. Bosch, H. Geissel, Yu.A. Litvinov, M. Pfuetzner


207. 1n- and 2n-transfer with the Borromean nucleus \(^6\)He near the Coulomb barrier A. Chatterjee, ..., N. Keelley, ... et al. Phys. Rev. Lett. Vol. 101 (2008) 032701


213. The main issues of research on dense magnetized plasmas in PF discharges
M.J. Sadowski, M. Scholz
*Plasma Sources Science and Technology* Vol. 17 No 024001 (2008) 13PP

214. Comparative MHD analysis of IPD plasma accelerator work with different electrode polarization
M. Rabieński, K. Zdunek

215. EUV emission spectra from excited Ar, Xe and Sn ions produced in capillary discharges
K. Nowakowska-Langier, ... , L. Jakubowski, K. Czaus, M. Rabieński, J. Witkowski, M.J. Jakubowski, R. Mirowski, ... et al.

216. Recent attainments of research on plasma physics and technology at IPJ, Poland
M.J. Sadowski

217. Study of deuterium plasma interaction with a tungsten target within RPI-IBIS facility
M.J. Sadowski, K. Malinowski, M.J. Sadowski, K. Czaus, M. Kubkowska, M. Ladygina, B. Sartowska

218. Advanced camera image data acquisition system for Pi-of-the-Sky
M. Kwiatkowski, G. Kasprowicz, K. Pozniak, R. Romaniuk, G. Wrochna

219. Multi-channel 2D photometry with super-resolution in far UV astronomical images using priors in visible bands
A. Llebaria, B. Magnelli, S. Arnouts, A. Pollo, B. Milliard, M. Guillaume

220. Period and variability type determination for the stars in the Pi of the Sky data
M. Biskup, A. Majczyna, M. Należyty, L. Mankiewicz, M. Sokolowski, K. Nawrocki, G. Wrochna

221. Single- and double-pion production in nucleon collisions on the nucleon and on nuclei - the ABC effect and its origin in a dyabaryonic resonance
H. Clement, ... , A. Kupiś, P. Marciniowski, J. Stepaniak, J. Zabierowski, ... et al.

222. Nonextensive/dissipative correspondence inrelativistic hydrodynamics
T. Osada, G. Wilk

223. Calibration of PM-355 nuclear track detectors for low-energy deuterons
K. Malinowski, E. Składnik-Sadowska, M.J. Sadowski, K. Czaus

A. Szydłowski, ... , A. Malinowska, M.J. Sadowski, M. Jaskóla, A. Korman, ... et al.

225. Measurements of fusion-produced protons by means of SSNTDs
A. Malinowska, ... , A. Szydłowski, M.J. Sadowski, J. Zebrowski, M. Jaskóla, A. Korman, ... et al.

226. Investigation of laser interaction with tungsten target by means of time-resolved optical spectroscopy

227. Use of Cherenkov-type detectors for measurements of runaway electrons in the ISTTOK tokamak
V.V. Plyusnin, ... , L. Jakubowski, J. Zebrowski, K. Malinowski, M. Rabieński, M.J. Sadowski, ... et al.

228. The Effect of Various Measurement Parameters of a CT Scanner and Phantom with Substitutes on the HU-to-range Relation in Heavy Ion Therapy
A. Wysocka-Rabin, S. Qamhiyeh, O. Jaekel

**PUBLICATIONS WITHOUT PEER REVIEW**

1. Searching for white dwarfs candidates in Sloan Digital Sky Survey Data
M. Należyty, A. Majczyna, A. Ciechanowska, J. Madej
*ArXiv* No 0811.2115 (2008)

2. Direct Measurement of the Gluon Polarisation in the Nucleon via Charmed Meson Production
R. Gazda, ... , K. Klimaszewski, K. Kurek, J. Nassalski, E. Rondio, A. Sandacz, W. Wiślicki, ... et al.
*ArXiv* (2008)
3. Double-Pionic Fusion of Nuclear Systems and the ABC Effect -- Approaching a Puzzle by Exclusive and Kinematically Complete Measurements
M. Baskhano, ..., M. Berloowski, A. Kupić, P. Marciniowski, J. Stepiński, J. zabierowski, ... et al.

4. Measurement of the eta->3p0 Dalitz Plot Distribution with the WASA Detector at COSY

5. PANDA - Strong interaction studies with antiprotons
W. Emi, ..., S. Borsuk, A. Chłopik, Z. Guzik, T. Kozłowski, D. Melnychuk, M. Płomiński, J. Szewiński, K. Traczyk, B. Zwięgłński, ... et al.
ArXiv (2008)

P. Zalewski, ... et al.
ArXiv No 0802.3672 (2008)

7. Calabi-Yau crystals in topological string theory
P. Sulkowski

8. Report from the NA61/SHINE experiment at the CERN SPS.
N. Abgrall, ..., P. Mijakowski, T. Palczewski, E. Rondio, J. Stepiński, ... et al.

9. The physics of nucleus-nucleus fusion and synthesis of super heavy nuclei
W.J. Świątecki, K. Siwek-Wilczyńska, J. Wilczyński

10. Excitation of the Roper resonance in single- and double-pion production
T. Skorodko, ..., J. Stepiński, J. zabierowski, ... et al.

11. Measurement of the ABC-effect in the most basic double-pionic fusion reaction
O. Khakimova, ..., J. Stepiński, J. zabierowski, ... et al.

12. Studies of the Lambda(1405) in proton-proton collisions with ANKE at COSY-JUELICH
I. Zychor

13. σ channel low-mass enhancement in double-pionic fusion - is a dibaryon resonance the reason for the ABC effect?
M. Baskhano, ..., J. Stepiński, J. zabierowski, ... et al.

14. GRB 080129: optical limit by Pi of the Sky
M. Cwiok, ..., A. Majcher, A. Majczyna, K. Nawrocki, D. Rybka, M. Sokolowski, G. Wrochna, ... et al.

15. GRB 080319B light curve by Pi-of-the-Sky
M. Cwiok, ..., A. Majcher, A. Majczyna, K. Nawrocki, D. Rybka, M. Sokolowski, G. Wrochna, ... et al.

16. GRB 080319B prompt optical observation by Pi of the Sky
M. Cwiok, ..., A. Majcher, A. Majczyna, D. Rybka, M. Sokolowski, G. Wrochna, ... et al.

17. GRB080805 optical limit by "Pi of the sky"
M. Cwiok, ..., A. Majcher, A. Majczyna, K. Nawrocki, D. Rybka, M. Sokolowski, J. Użycki, G. Wrochna, ... et al.

18. Times of minima observed by "Pi of the sky"
W. Ogloza, W. Niewiadomski, A. Barnacka, M. Biskup, K. Malek, M. Sokolowski
IBVS Vol. 5843 (2008) 1

19. Dynamical emission of heavy fragments in the 112,124Sm+58,64Ni reactions at 35 AMeV as seen with CHIMERA
P. Rusek, ..., E. Piasecki, L. Świderski, J. Wilczyński, ... et al.

20. Fast ternary fission of 197Au + 197Au system at 15 MeV/nucleon
I. Słowia-Chafot, ..., J. Wilczyński, E. Piasecki, L. Świderski, ... et al.

21. Investigation of the isospin dependences in Sn+Ni and Sn+Al systems
K. Schmidt, ..., E. Piasecki, L. Świderski, J. Wilczyński, ... et al.
22. Present and future activity with the CHIMERA 4π detector
   G. Cardella, ... E. Piasecki, L. Świderski, J. Wilczyński, ... et al.

23. Level-1 RPC trigger in the CMS experiment—software for emulation and commissioning
   M. Bluj, K. Buńkowski, T. Fruboes, A. Kalinowski, M. Konecki, M. Pietrusinski

24. Signals of dynamical multifragmentation as seen by CHIMERA detector
   P. Russotto, ... J. Wilczyński, ... et al.

25. Oddziaływanie małych dawek promieniowania elektrowni jądrowej na otoczenie w czasie normalnej pracy
   L. Dobrzyński
   Spektrum Vol. styczeń (2008) XII

PUBLICATIONS RELATED TO PHYSICS EDUCATION AND POPULARIZATION OF PHYSICS

1. Astronomia cząstek naładowanych, czyli sukces na początek
   P. Zalewski
   Delta No 2 (2008) 9

2. Błysk wszelkich czasów
   P. Zalewski
   Delta No 6 (2008) 20

3. Ciekawe własności (nie)zwykłych substancji
   P. Zalewski
   Delta No 11 (2008) 25

4. Co, kto, gdzie taki pięknie gra?
   P. Zalewski
   Delta No 3 (2008) 11

5. Czarny jak węgiel; Szybki jak węgiel
   P. Zalewski
   Delta No 5 (2008) 20

   P. Zalewski
   Delta No 9 (2008) 25

7. Pierwotna antycypacja
   P. Zalewski
   Delta No 4 (2008) 20

8. Pomiar kwantowy
   E. Czuchry
   Delta Vol. 411 No 8 (2008) 15

9. Pospolite ruszenie
   P. Zalewski
   Delta No 7 (2008) 20

10. Próźnina nie dość próźna; Przesunięta granica
    P. Zalewski
    Delta No 1 (2008) 7

11. Superstar uchwycona w kadrze
    P. Zalewski
    Delta No 8 (2008) 19
## V. AUTHORS INDEX

<table>
<thead>
<tr>
<th>Author Name</th>
<th>Page Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abd El Aal Shaaban</td>
<td>164</td>
</tr>
<tr>
<td>Aggarwal M.M.</td>
<td>110</td>
</tr>
<tr>
<td>Alamos N.</td>
<td>113</td>
</tr>
<tr>
<td>Andrasiai M.</td>
<td>165</td>
</tr>
<tr>
<td>Augustyniak W.</td>
<td>98, 100, 101, 102</td>
</tr>
<tr>
<td>Badziak J.</td>
<td>132</td>
</tr>
<tr>
<td>Banaś D.</td>
<td>125</td>
</tr>
<tr>
<td>Bantsar A.</td>
<td>154</td>
</tr>
<tr>
<td>Barlak M.</td>
<td>160</td>
</tr>
<tr>
<td>Baronova E.O.</td>
<td>137</td>
</tr>
<tr>
<td>Baszak J.</td>
<td>145</td>
</tr>
<tr>
<td>Batsch T.</td>
<td>89, 145, 147</td>
</tr>
<tr>
<td>Bazin D.</td>
<td>115</td>
</tr>
<tr>
<td>Beaumel D.</td>
<td>115</td>
</tr>
<tr>
<td>Berlowski M.</td>
<td>98</td>
</tr>
<tr>
<td>Bhattacharyya S.</td>
<td>115</td>
</tr>
<tr>
<td>Białkowska H.</td>
<td>109</td>
</tr>
<tr>
<td>Bluj M.</td>
<td>97</td>
</tr>
<tr>
<td>Blumenfeld Y.</td>
<td>115</td>
</tr>
<tr>
<td>Bohm C.</td>
<td>150</td>
</tr>
<tr>
<td>Boimbska B.</td>
<td>109</td>
</tr>
<tr>
<td>Boiron D.</td>
<td>139</td>
</tr>
<tr>
<td>Bonheure G.</td>
<td>130</td>
</tr>
<tr>
<td>Borowiec A.</td>
<td>117</td>
</tr>
<tr>
<td>Braziewicz J.</td>
<td>125, 155</td>
</tr>
<tr>
<td>Capdevielle J.N.</td>
<td>92</td>
</tr>
<tr>
<td>Cegińska K.</td>
<td>165</td>
</tr>
<tr>
<td>Chatterjee A.</td>
<td>115</td>
</tr>
<tr>
<td>Chwedeńczuk J.</td>
<td>139</td>
</tr>
<tr>
<td>Cohen F.</td>
<td>92</td>
</tr>
<tr>
<td>Czarnacki W.</td>
<td>103, 143, 144</td>
</tr>
<tr>
<td>Czarnota M.</td>
<td>125</td>
</tr>
<tr>
<td>Czias K.</td>
<td>135, 137</td>
</tr>
<tr>
<td>Czub J.</td>
<td>155</td>
</tr>
<tr>
<td>Dąbrowski J.</td>
<td>124</td>
</tr>
<tr>
<td>Dąbrowski Ł.</td>
<td>160</td>
</tr>
<tr>
<td>de France G.</td>
<td>115</td>
</tr>
<tr>
<td>Dehaine A.G.</td>
<td>149</td>
</tr>
<tr>
<td>Deńicki Z.</td>
<td>93</td>
</tr>
<tr>
<td>El Beiyad M.</td>
<td>104</td>
</tr>
<tr>
<td>Friot S.</td>
<td>104</td>
</tr>
<tr>
<td>Fruboes T.</td>
<td>97</td>
</tr>
<tr>
<td>Fuchsc J.</td>
<td>132</td>
</tr>
<tr>
<td>Gocalek J.</td>
<td>138</td>
</tr>
<tr>
<td>Gokieli R.</td>
<td>97</td>
</tr>
<tr>
<td>Górski M.</td>
<td>97</td>
</tr>
<tr>
<td>Grosswendt B.</td>
<td>154</td>
</tr>
<tr>
<td>Gupta D.</td>
<td>115</td>
</tr>
<tr>
<td>Guzik Z.</td>
<td>151</td>
</tr>
<tr>
<td>Hurbut C.</td>
<td>147</td>
</tr>
<tr>
<td>Infeld E.</td>
<td>138</td>
</tr>
<tr>
<td>Iwanowski J.</td>
<td>147</td>
</tr>
<tr>
<td>Jakubowski I.</td>
<td>129, 137</td>
</tr>
<tr>
<td>Jakubowski M.J.</td>
<td>129, 137</td>
</tr>
<tr>
<td>Jaskośa M.</td>
<td>125, 133, 155</td>
</tr>
<tr>
<td>Jędzejezak K.</td>
<td>93</td>
</tr>
<tr>
<td>Kalicy G.</td>
<td>103</td>
</tr>
<tr>
<td>Kamada K.</td>
<td>148</td>
</tr>
<tr>
<td>Kamiński P.</td>
<td>165</td>
</tr>
<tr>
<td>Kapusta M.</td>
<td>149</td>
</tr>
<tr>
<td>Karczemczyk J.</td>
<td>93</td>
</tr>
<tr>
<td>Kasztelan M.</td>
<td>93</td>
</tr>
<tr>
<td>Kazana M.</td>
<td>97</td>
</tr>
<tr>
<td>Keeley N.</td>
<td>113, 115</td>
</tr>
<tr>
<td>Kęś G.</td>
<td>103</td>
</tr>
<tr>
<td>Kieleczewska D.</td>
<td>99</td>
</tr>
<tr>
<td>Klama W.</td>
<td>147</td>
</tr>
<tr>
<td>Kniest F.</td>
<td>144, 147</td>
</tr>
<tr>
<td>Koman A.</td>
<td>103, 125, 133, 135, 155, 164</td>
</tr>
<tr>
<td>Kowal M.</td>
<td>120</td>
</tr>
<tr>
<td>Kowalski M.</td>
<td>138</td>
</tr>
<tr>
<td>Kozłowski T.</td>
<td>99, 103</td>
</tr>
<tr>
<td>Kretschmer W.</td>
<td>125</td>
</tr>
<tr>
<td>Kubkowska M.</td>
<td>134</td>
</tr>
<tr>
<td>Kula J.</td>
<td>154, 162</td>
</tr>
<tr>
<td>Kusne M.R.</td>
<td>147</td>
</tr>
<tr>
<td>Labiche M.</td>
<td>115</td>
</tr>
<tr>
<td>Ladygina M.</td>
<td>134</td>
</tr>
<tr>
<td>Lapicki G.</td>
<td>125</td>
</tr>
<tr>
<td>Lasiewicz M.</td>
<td>158</td>
</tr>
<tr>
<td>Lemasson A.</td>
<td>115</td>
</tr>
<tr>
<td>Lemmon R.</td>
<td>115</td>
</tr>
<tr>
<td>Lewandowski R.</td>
<td>93</td>
</tr>
<tr>
<td>Lorkiewicz J.</td>
<td>162</td>
</tr>
<tr>
<td>Łagoda J.</td>
<td>99</td>
</tr>
<tr>
<td>Łuczak P.</td>
<td>94, 96</td>
</tr>
<tr>
<td>Majcher A.</td>
<td>89</td>
</tr>
<tr>
<td>Majzyna A.</td>
<td>89</td>
</tr>
<tr>
<td>Malinowska A.</td>
<td>130, 133, 136, 155</td>
</tr>
<tr>
<td>Malinowski K.</td>
<td>129, 130, 134, 135, 136</td>
</tr>
<tr>
<td>Malomed B.A.</td>
<td>138</td>
</tr>
<tr>
<td>Marchenko A.</td>
<td>134</td>
</tr>
<tr>
<td>Marcinkowski R.</td>
<td>151</td>
</tr>
<tr>
<td>Mariański B.</td>
<td>100, 101, 102</td>
</tr>
<tr>
<td>Matuszewski M.</td>
<td>138</td>
</tr>
<tr>
<td>Melcher C.L.</td>
<td>146</td>
</tr>
<tr>
<td>Melnychuk D.</td>
<td>103</td>
</tr>
<tr>
<td>Mijakowski P.</td>
<td>99</td>
</tr>
<tr>
<td>Mirowski R.</td>
<td>129, 137, 152</td>
</tr>
<tr>
<td>Moszyński M.</td>
<td>143, 144, 145, 146, 147, 148, 149, 150</td>
</tr>
<tr>
<td>Mukoyama T.</td>
<td>125</td>
</tr>
<tr>
<td>Munnik F.</td>
<td>164</td>
</tr>
<tr>
<td>Mykulyak A.</td>
<td>103, 114</td>
</tr>
<tr>
<td>Nanal V.</td>
<td>115</td>
</tr>
<tr>
<td>Nassalski A.</td>
<td>143, 144, 145, 146, 147, 148, 149, 150</td>
</tr>
<tr>
<td>Navin A.</td>
<td>115</td>
</tr>
<tr>
<td>Nawrocki K.</td>
<td>89, 97</td>
</tr>
<tr>
<td>Nietuhyć R.</td>
<td>152</td>
</tr>
<tr>
<td>Nowakowska-Langier K.</td>
<td>137</td>
</tr>
<tr>
<td>Nyberg</td>
<td>115</td>
</tr>
<tr>
<td>Oberhaler M.</td>
<td>138</td>
</tr>
<tr>
<td>Ojala P.</td>
<td>150</td>
</tr>
<tr>
<td>Orzechowski J.</td>
<td>93</td>
</tr>
<tr>
<td>Osada T.</td>
<td>111</td>
</tr>
</tbody>
</table>