Warsaw University
Heavy Ion Laboratory

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Contents

Introduction

A. Laboratory overview

B. Experiments and experimental set-ups

C. Experiments using the outside facilities

D. General information on HIL activities

INTRODUCTION

The Heavy Ion Laboratory of the Warsaw University is the „User type" facility, providing heavy ion beams to a number of Polish and foreign research groups and to limited extent for its own research programme. In 2005 the Warsaw cyclotron operated for close to 3000 hours of beam on target. 20 experiments, all recommended by the Program Advisory Committee, were performed by more than one hundred facility users. Their scientific achievements are presented in this Report. Here I would like to mention some highlights of the scientific projects with heavy-ion beams delivered by HIL cyclotron. Search for chirality in medium mass nuclei using OSIRIS-II set-up resulted in vivid discussion among nuclear spectroscopists, both theorists and experimentalists. Studies of the quasi-elastic barrier distributions revealed interesting phenomena, not yet fully explainable. Giant Dipole Resonance project with JANOSIK system yielded many new results. Coulomb Excitation investigation of shape coexistence in nuclei was progressing, providing data complementary to those from radioactive beams from CERN and GANIL. Also interesting results concerning optical-model potential in light nuclei interactions were obtained within Warsaw-Kraków-Kiev collaboration. Besides pure nuclear physics the cyclotron delivered beams for projects in solid-state physics, most notably connected to detector development as well as for biological studies. HIL remained an interdisciplinary user facility, keeping high profile of its scientific output, as can be judged from the list of publications contained in Part D of this Report.

At the end of 2005 our experimental equipment started to be substantially enlarged. Thanks to the collaboration with the CNRS centre IRES in Strasbourg their excellent charged particle multidetector set–up ICARE was installed on the "last–free" beam line of the Warsaw Cyclotron. After the well organized transportation and mechanical mounting by an experts team from IRES in collaboration with our mechanical workshop, this detector is now awaiting to receive the first heavy ion beam and to pass the operation tests.

Besides the heavy ion machine, the Laboratory will soon be equipped with the second, low energy (16.5 MeV, p), high current proton – deuteron cyclotron for the production of short lived radiopharmaceuticals for the Positron Emission Tomography. As already presented in the last year Annual Report, this will allow the creation of an interdisciplinary laboratory, the Warsaw Positron Emission Tomography Centre. This project was launched by the Heavy Ion Laboratory and the Nuclear Medicine Department at the Clinical Hospital of the Medical University in Warsaw in 2001. In 2003 the Warsaw Consortium for PET Collaboration (WCPC) was created and presently it plays an active role in the project preparation. The WCPC will possess a single radiopharmaceuticals production unit located at HIL and will be equipped with a commercial proton/deuteron cyclotron, chemical units and a quality control laboratory. The PET CT, PET or adapted SPECT scanners will be successively located in the Warsaw hospital centers, starting with the medical unit closest (500 m) to the radiopharmaceuticals production place. The participation in the WCPC of numerous University and Polish Academy of Sciences units will promote the Warsaw PET Centre activity in research and educational area. The planned purchase of the micro – PET animal scanner will substantially help in this activity.

After four years of efforts, in 2004 the Warsaw PET project obtained the financial support from the Ministry of Sciences and Informatization, which allocated 10 MPLN (about 2.4 MEUR) for the equipment of the Radiopharmaceuticals Production Department of the Warsaw PET Centre. At the end of the same year the Board of Governors of the International Atomic Energy Agency accepted our project of Technical Cooperation with the Agency and allocated almost 0.9 MUS$ for this project. The same year, Ministry of Health reiterated its written engagement to supply in 2006 the Warsaw PET Centre with a PET CT scanner.

In 2005 the IAEA launched a tender for a turn – key project of the Heavy Ion Laboratory building adaptation and the supply of PET radiopharmaceuticals production equipment (cyclotron, radiochemistry units, quality control). During the common IAEA and HIL experts meeting in November 2005 the tender offers were evaluated and the Company General Electric Healthcare was selected as a best bidder. The official announcement of the tender results was issued by Agency in February 2006 and the contract negotiations started soon after.

In the beginning of 2006 we responded to two calls, asking for the detailed description of our centre to appear in the international surveys of worldwide nuclear or European user type facilities, respectively. The first one was issued by the IUPAP (International Union of Pure and Applied Physics) and the second one by the European Commission, evaluating the European Research Infrastructures. Both questionnaires are included at the end of this Annual Report.

Jerzy Jastrzębski

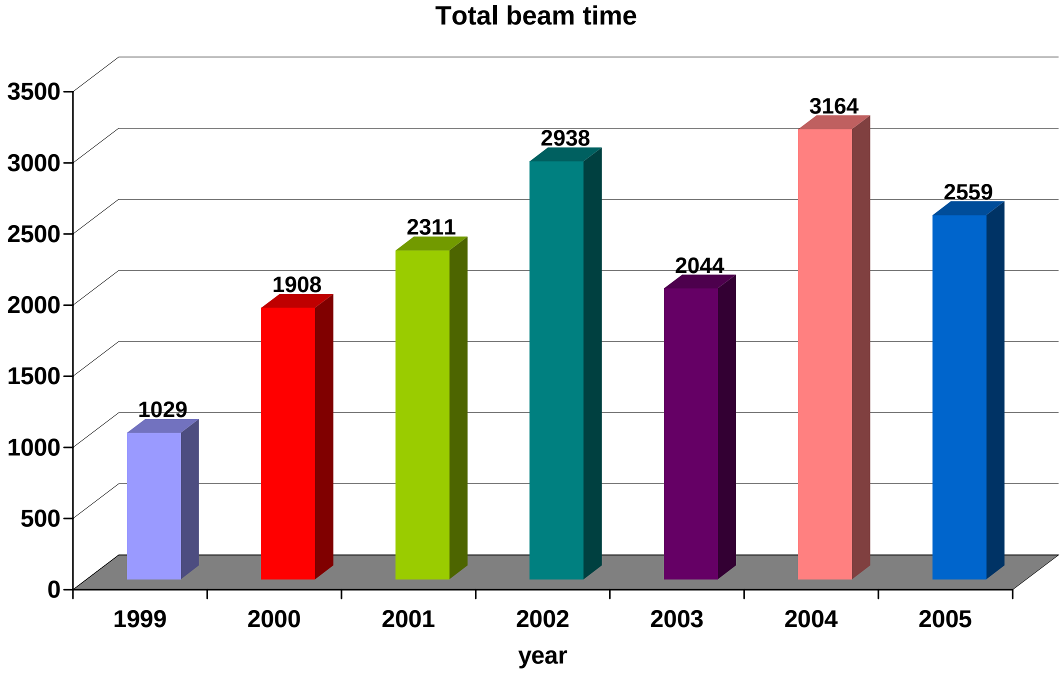
Part A:
Laboratory overview

1. Operation of the cyclotron during 2005

J.Choiński, T.Czosnyka, J.Jastrzębski, W.Kalisiewicz, J.Kownacki, E.Kulczycka, J.Kurzyński, J.Miszczak, B.Paprzycki, J.Sura

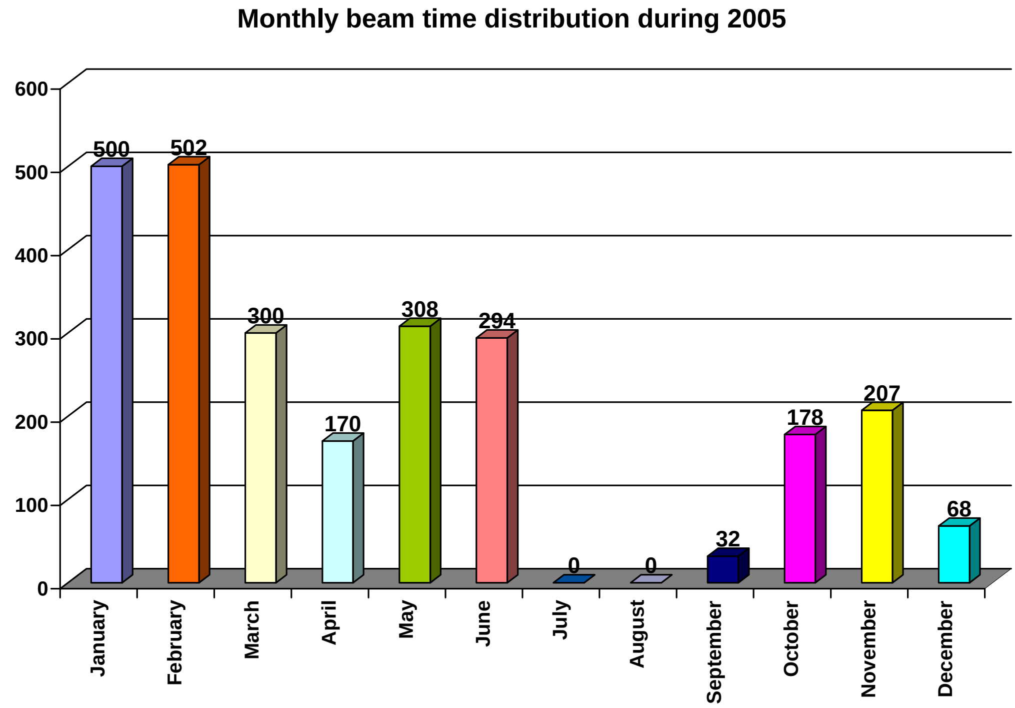
Cyclotron facility

In 2005 the cyclotron delivered a total of 2550 hours of beam-on-target. This number does not include the beam time used for machine testing and development. The figure below shows the usage of cyclotron beams over last six years.

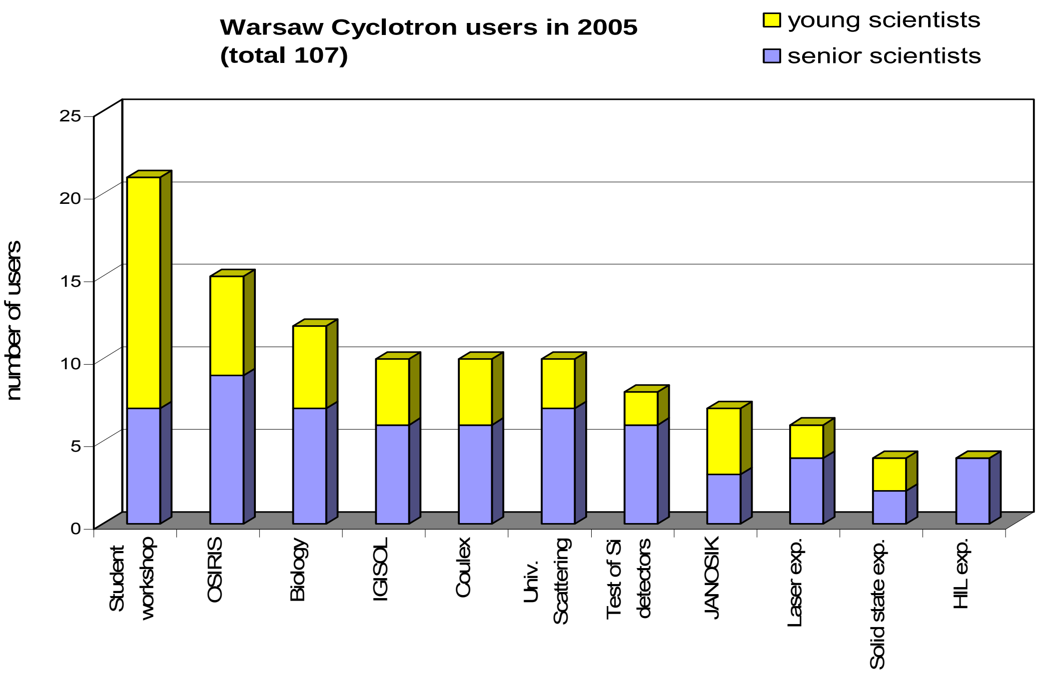


A slight decrease in the number of hours compared to previous year 2004 was due to technical problems which plagued the normal operations of the accelerator and, because of severe financial shortages, were not always possible to be solved immediately. The most important of these problems was the water cooling system which after the first repair turned out to be inefficient. As an effect the Laboratory was forced to curtail some of the experiments scheduled during summer because of overheating of the water-cooled accelerator systems. Another serious issue was maintaining the vacuum in the cyclotron chamber. The cryopumps should have been exchanged, but finding the financing to replace them took almost a year. Only in the end of 2005 appropriate funds were acquired. Similar problem appeared concerning the diffusion pumps and their drivers. Pumping stands are almost 30 years old and suffer from the leaks between the water mantles and interiors of the pumps.

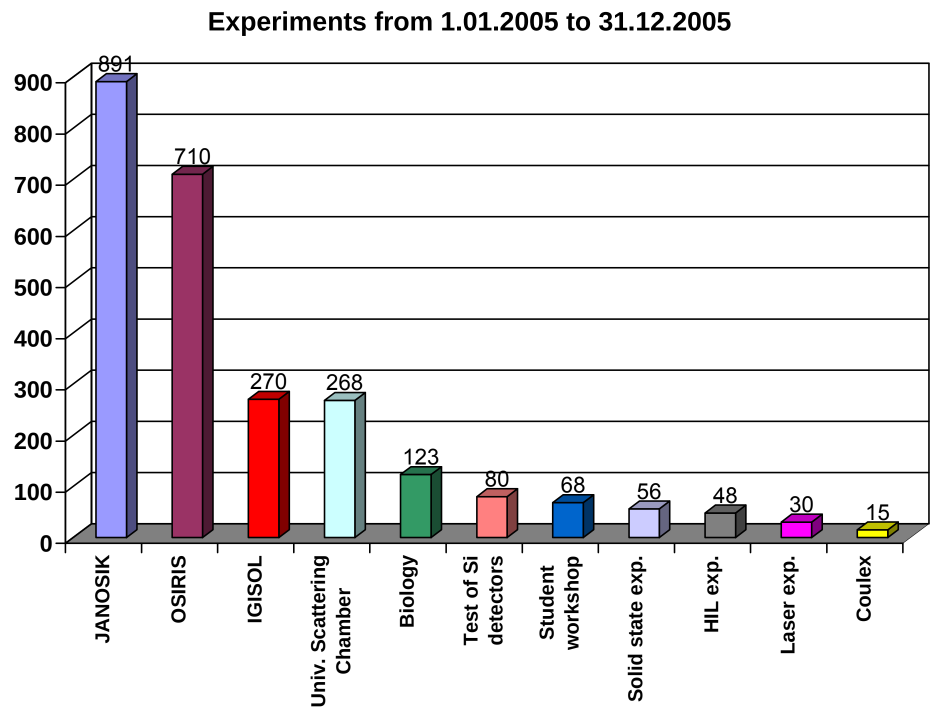
The usage of cyclotron beams during 2005 is shown at the figure below. The numbers represent beam-on-target time only, not including machine tuning.



As can be seen the distribution is uneven. Summer break was caused partly by cooling troubles, but also by the natural preferences of the users unwilling to run experiments during vacation period. Strong involvement of undergraduate and graduate students in the projects is one of the important factors not to favor this period. Participation of young researches is explicitly shown in the figure below which illustrates the beam distribution among the projects accepted by Program Advisory Committee. Detailed description of experimental set-ups can be found on Heavy Ion Laboratory web page:www.slcj.uw.edu.pl



Although basic nuclear physics research consumed most of the beam time a fair share of it was allocated to other areas – biology, solid state physics, atomic physics and applications. More detailed data concerning the beam time usage are summarized in Table 1.



List of experiments performed in 2005 showing the number of hours used. Description of the beam lines can be found in HIL web page.

Table 1. Experiments from 1.01.2005 to 31.12.2005

Dates	Beam line	Ion	Energy [Mev]	Leading institution	Collaborating institutions
3.01 - 23.01	C4	$^{20}Ne^{+3}$ $^{11}B^{+2}$	65 49.5	IEP UW	HIL, INS Świerk
31.01 - 11.02	C3	$^{11}B^{+2}$	50	IEP UW	HIL, INS Świerk, ITME, IPT St. Petersburg
14.02 – 18.02	C1	$^{14}N^{+3}$	82.2	IEP UW	INS Świerk, HIL, IPN Orsay, GSI, JYFL, INR Kiev
21.02 – 4.03	B	$^{18}O^{+4}$	90	INR Kiev	INS Świerk, INP Kraków, HIL, NU Kharkiv
7.03 – 11.03	I section of beam line	$^{40}Ar^{+6}$	128	Student workshop	HIL, IEP UW, FP UAM, IP UŚ
14.03 – 18.03	C1	$^{14}N^{+3}$	82.2	IEP UW	INS Świerk, HIL, IPN Orsay, GSI, JYFL, INR Kiev
21.03 – 23.03	A	$^{14}N^{+3}$	49	HIL	IEP UW
31.03 – 1.04	I section of beam line	$^{16}O^{+3}$	80	FP UAM	HIL
5.04 – 6.04	I section of beam line	$^{16}O^{+3}$	80	TP UAM	HIL
11.04 – 12.04	I section of beam line	$^{16}O^{+3}$	80	HIL	ITME
13.04 – 15.04	A	$^{12}C^{+3}$	108	IP AŚ Kielce	HIL, INS Świerk, IB AŚ Kielce
20.04 – 21.04	A	$^{12}C^{+3}$	108	HIL	IEP UW
Dates	**Beam line**	**Ion**	**Energy**	**Leading**	**Collaborating institutions**

			[Mev]	institution	
21.04 – 22.04	I section of beam line	$^{16}O^{+3}$	80	P UAM	HIL
27.04 – 28.04	Internal	$^{14}N^{+2}$	42	IEP UW	HIL
4.05 – 15.05	C3	$^{11}B^{+2}$	50	IEP UW	HIL, INS Świerk, ITME, IPT St. Petersburg
16.05 – 20.05	C1	$^{14}N^{+3}$	85.6	IEP UW	INS Świerk, HIL, IPN Orsay, GSI, JYFL, INR Kiev
30.05 – 19.06	C4	$^{36}Ar^{+6}$	132	IEP UW	HIL, INS Świerk
20.06 – 25.06	C1	$^{14}N^{+3}$	85.6	IEP UW	INS Świerk, HIL, IPN Orsay, GSI, JYFL, INR Kiev
27.06 – 29.06	A	$^{12}C^{+3}$	108	IP AŚ Kielce	HIL, INS Świerk, IB AŚ Kielce
19.09 – 21.09	D	$^{40}Ar^{+7}$	165	HIL	
28.09 – 28.09	D	$^{40}Ar^{+7}$	165	HIL	
7.10 – 7.10	D	$^{14}N^{+3}$	85.6	HIL	
17.10 – 28.10	C3	$^{40}Ar^{+8}$	194.5	IEP UW	HIL, INS Świerk, IPT St. Petersburg
14.11 – 18.11	C1	$^{14}N^{+3}$	94.7	IEP UW	INS Świerk, HIL, IPN Orsay, GSI, JYFL, INR Kiev
21.11 – 2.12	C4	$^{36}Ar^{+6}$ $^{11}B^{+2}$	130 51	IEP UW	INS Świerk, HIL
12.12 – 16.12	A	$^{12}C^{+3}$	89.6	IP AŚ Kielce	HIL, INS Świerk, IB AŚ Kielce
19.12 – 21.12	C3	$^{12}C^{+2}$	50	HIL	IEP UW, INS Świerk, IP UMCS Lublin

Abbreviations used in the table above:

GSI	GSI, Darmstadt
IB AŚ Kielce	Institute of Biology, Świętokrzyska Academy, Kielce
IP AŚ Kielce	Institute of Physics, Świętokrzyska Academy, Kielce
IEP UW	Institute of Experimental Physics, Warsaw University, Warsaw
FP UAM	Faculty of Physics, Adam Mickiewicz University, Poznań
INP Kraków	The Henryk Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, Kraków
INR Kiev	Inst. For Nuclear Res., Ukrainian Nat. Ac. Of Science, Kiev, Ukraine
INS Świerk	The Andrzej Soltan Institute for Nuclear Studies, Świerk
IPN Orsay	Institute Physique Nucléaire, Orsay, France
IPT St. Petersburg	Ioffe Physical-Technical Institute RAN, St. Petersburg, Russia
ITME	Institute of Electronic Materials Technology, Warsaw
JYFL	Department of Physics, University of Jyvaskyla, Finland
IP UMCS	Institute of Physics, M. Curie Skłodowska University, Lublin
NU Kharkiv	National University, Kharkiv, Ukraine
HIL	Heavy Ion Laboratory, Warsaw University, Warsaw
IP UŚ	August Chełkowski Institute of Physics, University of Silesia, Katowice

Plans of development

		Estimated completion time
<u>1.</u>	<u>Cyclotron</u>	
1.1	Cooling system upgrade	
1.1.1	Exchange of water pulverizes in cooling towers	June 2006
1.1.2	Modernization of heat exchangers	First half of 2006
1.1.3	Inspection of all valves in the system	Summer vacation
1.1.4	Installation and putting into operation the automatic control of water levels in primary and secondary circuits	Sept. 2006
<u>1.2</u>	<u>New experimental set-up ICARE</u>	
1.2.1	Scattering chamber (beam line D)	1-st quarter of 2006
1.2.2	Installation and start-up of the ion guide on line D	2-nd quarter of 2006
1.2.3	Beam profile probes on line D	2-nd quarter of 2006
1.2.4	First experiments with ICARE	4-th quarter of 2006
<u>1.3</u>	<u>RF generators</u>	
1.3.1	Installation and start-up of the new system for automatic tuning of RF resonators	Sep. 2006
1.3.2	Installation and start-up of the modernized phase stability control system	Oct. 2006
<u>1.4</u>	<u>Power supplies</u>	
1.4.1	Design and installation of a new main magnet power supply driver	Apr. 2006
1.4.2	Design of a new quadrupole lenses power supply	First half of 2007
1.4.3	Design of a new driver for existing quadrupoles	First half of 2007
<u>1.5</u>	<u>ECR ion source</u>	
1.5.1	Modernization of source power supplies drivers	First half of 2006
1.5.2	Computerized remote control system	2007
<u>1.6</u>	<u>Vacuum system</u>	
1.6.1	Regeneration of cyclotron chamber cryopumps	First half of 2006

2. Activity report of the ECR ion source group

A.Górecki, B. Filipiak, E. Kulczycka, R. Tańczyk, M. Drabik[1]

1) Institute of Physics, Świętokrzyska Academy

In 2005 ECR ion source worked reliably, providing a wide scope of beams. Exemplary intensities are listed below.

Ion	$^{11}B^{+2}$	$^{12}C^{+3}$	$^{14}N^{+2}$	$^{14}N^{+3}$	$^{18}O^{+4}$	$^{16}O^{+3}$	$^{20}Ne^{+3}$	$^{20}Ne^{+4}$	$^{40}Ar^{+6}$	$^{40}Ar^{+7}$	$^{40}Ar^{+8}$	$^{36}Ar^{+6}$
Ion current [eμA]	14	96	95	135	57	100	96	104	25	57	52	43

The beam currents were measured on the cyclotron inflector before injection.

The O^{+3} ions were used also directly from the source to irradiate polymer membranes during the experiment performed by Institute of Physics, Świętokrzyska Academy. Dedicated chamber for irradiations with various ion currents was designed and built in collaboration with ECR team.

Other activities included:

- The exchange of damaged vacuum turbo molecular pump for another model, including required changes in the connection system.
- The repair of power supply for magnet analyzer
- Routine maintenance and cleaning of the ion source.

3. Activity of the electrical support group

J. Kurzyński, V. Khrabrov, M. Kopka, P. Krysiak, K. Łabęda, Z. Morozowicz, K. Pietrzak

Design projects and implementation:

1. **The design of the steering modules**

a) Main magnet power supply driver was designed. This includes:
   - microcontroller PIC16F628 and 16-bit A/C-C/A converters – concept of the circuit;
   - design of the driver printed board (using PROTEL software tool);
   - placement of an order to manufacture the board according to the project – outside HIL;

b) The functional scheme of automatic control of water level in cyclotron cooling circuits has been prepared, including the level measurements and leak control (Fig.1);

c) Texas Instruments microprocessor MSC1202 based cooling system driver, as well as RS 232 based driver-computer communication protocol were designed;

d) Design of the electrical project of automatics, control and blockades of the water pumps for controlling water levels and leaks. Implementation advanced in 75%;

e) Power supply switchboard for the vacuum pumps in cyclotron vault was designed and manufactured (detailed description in 2005 HIL Internal Report);
f) Power supply system for electronics and vacuum pumps of ICARE set-up was designed and implemented.

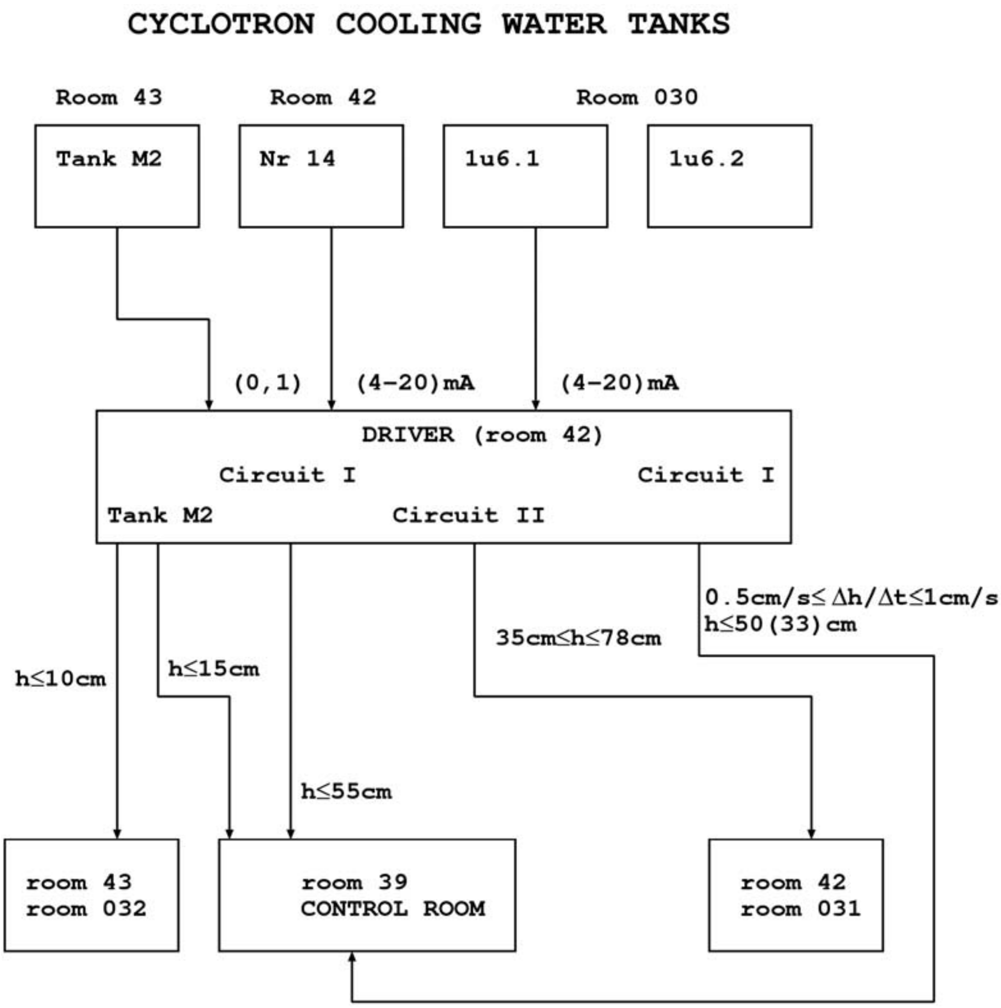


Fig.1. Block scheme of the cooling circuit.

2. Measurements and maintenance

a) Measurements and maintenance of the street lighting in the cyclotron building area;
b) Control, measurements and monitoring of cyclotron electrical circuits (cable network);
c) Continuous maintenance of master and slave cable network switchboards and automation and steering systems, including the small projects concerning interlocks and steering to facilitate cyclotron operations.

4. Beam diagnostics using elastic scattering

J.Iwanicki, A.Jakubowski, E.Kulczycka, K.Wrzosek[1]

1) PhD student at HIL

The variety of beam diagnostics tools available in our laboratory was extended with a dedicated beam scattering device employing a charged particle detector capable to measure the beam energy and its spread. It can also measure the time between particle detection and cyclotron RF reference signal thus collecting time spectrum telling about time structure of the beam.

Mechanics

The beam scattering system has a form of two vacuum extenders attached to a modified standard universal diagnostic box. The device can replace any of several diagnostic boxes used on HIL beam lines.

One of the extenders is the detector housing, with a PiN diode charged particle detector mounted on a holder inside, covering scattering angles around 45° degrees in a forward direction (ensuring that on a gold target scattering is elastic for all the beams delivered by our machine). Rotating system of diaphragms allows for four operation modes: shielded (when not in use), open, collimated and calibration (with an alpha source attached to one of diaphragms).

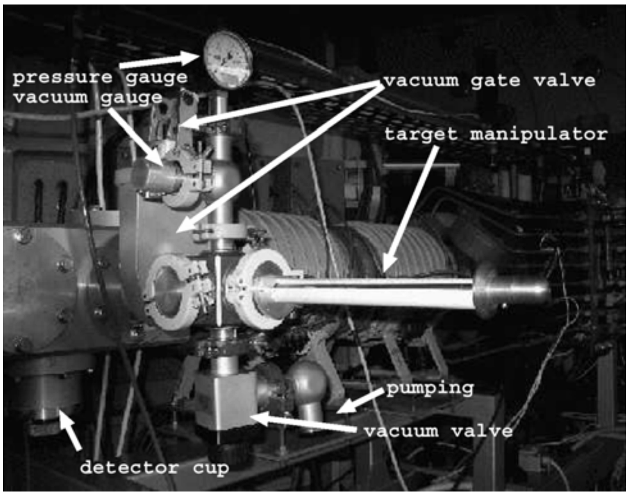


Fig. 1. Beam diagnostics system attached to the diagnostics box. Two main components attached to a diagnostic box can be seen: detector cup (lower left side) and target airlock vacuum system (center).

The other extender is the target airlock which can house up to two targets. It became necessary to protect the targets (typically 100 μg/cm^2 thick) when pressure changes in the beam line. It also allows for target exchange without affecting routine beam line operation.
Target manipulator is introduced horizontally, perpendicular to the beam axis and allows for target rotation.

Electronics

The electronics set-up of the device is shown in Fig. 2. It involves a full particle detector track with time measurement. All the electronics is mounted into CAMAC crate with crate controller and PC-CAMAC interface.

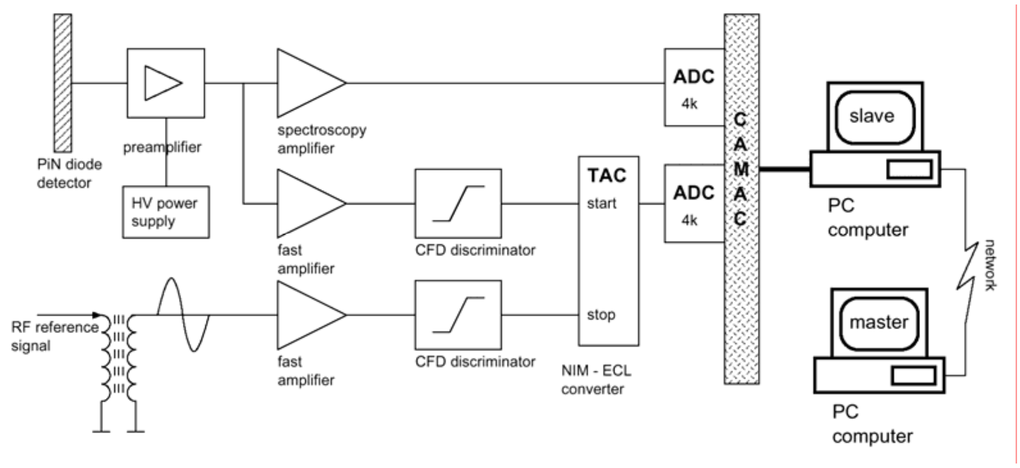


Fig. 2. Electronics for the beam diagnostics system

Acquired data is collected and visualized by the SMAN acquisition system running on the remotely controlled PC machine. Step-by-step instruction manual exists to facilitate the use of the whole system by cyclotron operators.

Summary and outlook

The beam diagnostics set-up suffers from a basic drawback: it is mounted on the first, common section of the beam line, where focusing power is still very limited. This causes problems with beam collimation and geometry, increasing energy spread of the measured spectrum. Mounting the set-up on some other beam line would improve the beam definition with increasing focusing capability but would also limit the universal character of the device.

An accuracy of about 1 MeV was achieved for energy measurements and confirmed by Time-of-Flight set-up when possible, with beam intensity exceeding necessary treshold (beam scattering device is more sensitive). The limiting factor is energy calibration made with α source in the 5 MeV region and extrapolated to ~100 MeV range. Complementary ways of energy calibration are considered.

5. Additional RF Amplitude Control Loop

J.Miszczak, Z.Kruszyński, M.Sobolewski

The RF amplitude and phase control system for the Warsaw Cyclotron performs well since the year 2002 [1]. However, system measuring probes are mounted inside the resonators, so the resonator voltage is stabilized rather than the one on the dees. Since frequency tuning of the resonator is achieved by changing dimensions of the resonator it obviously changes resonator - dee coupling, hence dee voltage, even if a resonator voltage is kept constant. The dee voltage is measured by an independent set of capacitive probes, and displayed to the cyclotron operator on a panel meter. Until the new amplitude control loop was put into operation, it was the task of the operator to control the dee voltage. The new loop, when enabled, stores the first dee voltage reading as a reference. Any subsequent reading is compared against this reference value, and the amplitude setpoint is adjusted accordingly. All this is done by a computer. First, the dee voltage is digitized, and then sent every 2 seconds, over a RS232 link, to the main control computer [2]. It may seem slow (2 sec. interval) but the loop is designed only to account and react for the slow changes in dee voltage, like temperature drifts.

References:
[1] J.Miszczak et al, *Amplitude and Phase Regulation of the RF Cavities*
HIL Annual Report 2002
[2] J.Miszczak, J.Choiński, *Control System for the Warsaw Cyclotron*
HIL Annual Report 2004

6. Activity of the network and web page administrators group

M. Zielińska, M. Palacz, A. Trzcińska, J. Miszczak

The Unix network at HIL consists of about 15 PC computers working with the Linux operating system, and one Digital Unix station (see also earlier HIL Annual Reports [1]). In addition to standard maintenance of the computers, user accounts and services, a few tasks aiming at update and development of the network were undertaken in 2005.

A new firewall computer was installed and configured, which increases security of the entire HIL computer system. All crucial network services (mail server, DNS, WWW server) were transferred from the old Digital Unix station, which became unreliable, to a new dedicated Linux server. Computers which are essential for the functioning of the network, and which do not need to be accessed by the users, were moved to a new secured, air-conditioned room, equipped also with uninterruptible power supplies.

An important, continuous task of the group is also maintenance and development of the HIL webpage (http://www.slcj.uw.edu.pl). In 2005 a new WWW portal of the Warsaw PET Centre was created.

References:
[1] HIL Annual Report 2003, p. 13,
HIL Annual Report 2004, p. 13

7. A new control unit for the SP2000 diffusion pump.

T.Bracha, K. Sosnowski, J. Miszczak

Of all vacuum pumps at the Warsaw Cyclotron – rotary, diffusion, turbo-molecular, cryogenic – the diffusion pumps are the oldest. They owe their longevity to simple design – no moving parts. Only corrosion limits their lifetime. The other limiting factor is reliability of the control electronics. 20+ years old circuits simply fall apart and replacement parts are no longer available, so it was decided to design and build a new control module for the diffusion pump as a replacement. Since control algorithms for the pump are straightforward (for the pump itself and 3 vacuum valves) and reliability is high priority the LOGO PLC (Programmable Logic Controller) was used as the main building block for the new controller. The new controller was successfully tested with the SP2000 pump and put into routine operation. It is also capable of controlling of two other types of diffusion pumps at the Laboratory: SP600 and SP6000.

Part B:

Experiments
and experimental set-ups

1. Fusion barrier distributions

E.Piasecki[1], P.Czosnyka[1], T.Czosnyka, K.Hagino[2], J.Jastrzębski, M.Kisieliński[3], A.Kordyasz, M.Kowalczyk, S.Khlebnikov[4], T.Krogulski[5], M.Mutterer[6], K.Piasecki[1], Ł.Świderski[1], W.H.Trzaska[7], N.Rowley[8]

1) Institute of Experimental Physics, Warsaw University, Poland
2) Tohoku University, Sendai, Japan
3) Institute for Nuclear Studies, Świerk, Poland
4) Radium Institute, St.Petersburg, Russia
5) Institute of Experimental Physics, University in Białystok, Poland
6) Institut fur Kernphysik, Technische Universitat, Darmstadt, Germany
7) Department of Physics, University of Jyvaskyla, Finland
8) Institut de Recherches Subatomiques/Universite Louis Pasteur (UMR 7500), Strasbourg, France

We finished data analysis of the fusion barrier distributions in the ^{20,22}Ne + ^{118}Sn, ^{nat}Ni systems determined by means of the quasielastic backscattering method [1]. The data has been obtained during our 2003 and 2004 campaigns in the Warsaw Cyclotron and published in refs. [2,3]. The most important results, compared with theoretical predictions based on the coupled channels calculations, are compiled in the figure below.

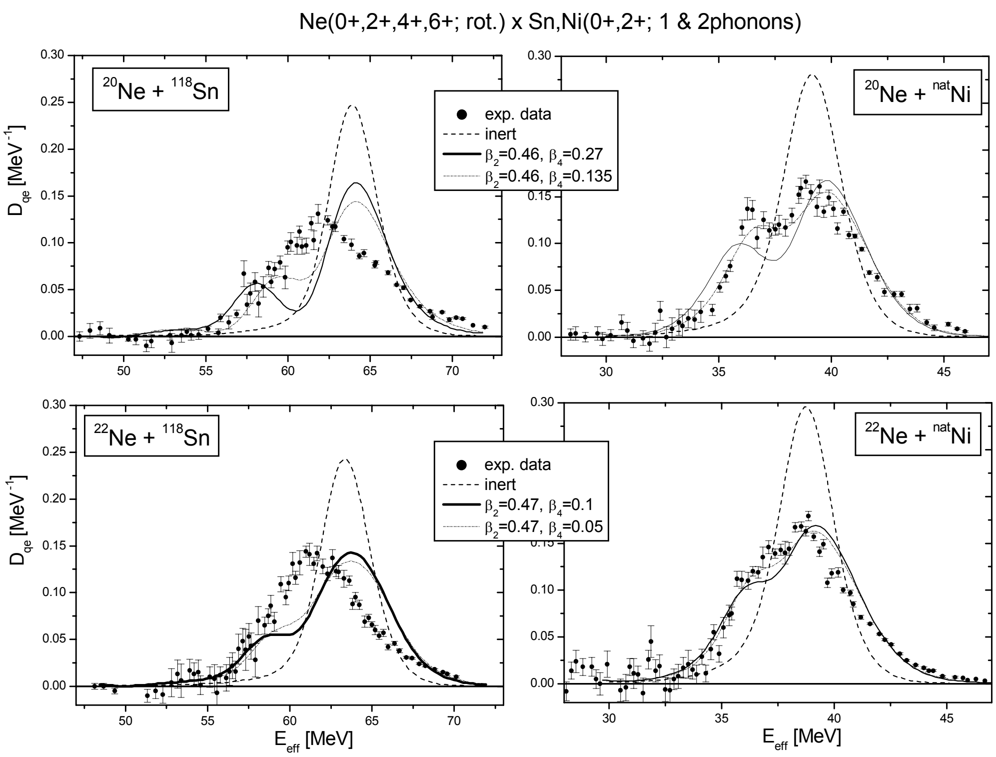


Fig. 1. Experimental barrier distributions D_{qe} for the studied systems compared with theoretical predictions (solid lines). The dotted lines show the no-coupling results. All theoretical distributions are folded with the experimental resolution. The thin line shows the result of reducing the β_4 deformation of the Ne nuclei by the factor of 2 with respect to the values taken from the literature.

The most interesting feature of the predicted distributions consists in their structure, generated by excitation of the rotational levels of neon nuclei. As can be seen in the figure, this structure is experimentally observed in the case of Ni target, while it is absent in the case of the

Sn target. This disagreement between experiment and theory cannot be resolved by any reasonable variation of calculation parameters (mainly optical potential and deformation parameters) nor the calculation scheme. Absence of structure in the ^{22}Ne projectile case shows that smoothing of the distribution is probably not caused by the alpha stripping channels, since even in this case the α-transfer probability is lower by the factor of 5 than in the case of ^{20}Ne, the distribution is still without structure. We presume that smoothing out of the distributions in the Sn target case is caused mainly by the neutron transfer channels, which are probably stronger in this case than in the Ni target one. This hypothesis will be tested in the forthcoming experiments.

The authors wish to thank M.A.Saettel and A.Stolarz for preparing the excellent targets and degraders, and the Warsaw Cyclotron staff for quality of the beam provided. The work was funded in part by the Grant No 2 P03B 026 24 of the KBN and also supported by the cooperation agreement between the IN2P3 (France) and Polish Laboratories.

References:

[1] E. Piasecki, M. Kowalczyk, K. Piasecki, Ł. Świderski, J. Srebrny, M. Witecki, F. Carstoiu, W. Czarnacki, K. Rusek, J. Iwanicki, J. Jastrzębski, M. Kisieliński, A. Kordyasz, A. Stolarz, J. Tys, T. Krogulski, N. Rowley, „Barrier distributions in ^{16}O + ^{116,119}Sn quasielastic scattering", Phys. Rev. C 65 (2002) 054611-1; 054611-11

[2] Ł. Świderski, E. Piasecki, P. Czosnyka, T. Krogulski and N. Rowley „Fusion barrier distributions in ^{20,22}Ne + ^{nat}Ni", Int. Jour. Mod. Phys. E 14 (2005) 341

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2. Giant Dipole Radiation and Isospin Mixing in ^{44}Ti and ^{60}Zn Nuclei

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In this contribution we present continuation of our studies [1] of the isospin mixing in hot nuclei, concerning the ^{44}Ti and ^{60}Zn compound nuclei at the excitation energy of around 50 MeV. In order to extract the isospin mixing probability in self-conjugate nuclei, we have studied the statistical decay of the Giant Dipole Resonance (GDR) built on excited states in those compound nuclei and neighboring N ≠ Z nuclei at the same excitation energy, formed in heavy-ion fusion reactions. The self-conjugate nuclei of ^{44}Ti and ^{60}Zn, were formed in the entrance channel with the isospin T=0. The ^{20}Ne and ^{36}Ar beams of 58 and 123 MeV from the Warsaw Cyclotron at the Heavy-Ion Laboratory of Warsaw University and the self-supporting targets of ^{24}Mg (isotopic 99.94%) were used. The neighboring N ≠ Z nuclei were populated by: ^{20}Ne+^{25}Mg→^{45}Ti and ^{36}Ar+^{25}Mg→^{61}Zn reactions. Gamma rays from the decay of the compound nuclei studied were measured with the multidetector JANOSIK set-up [2].

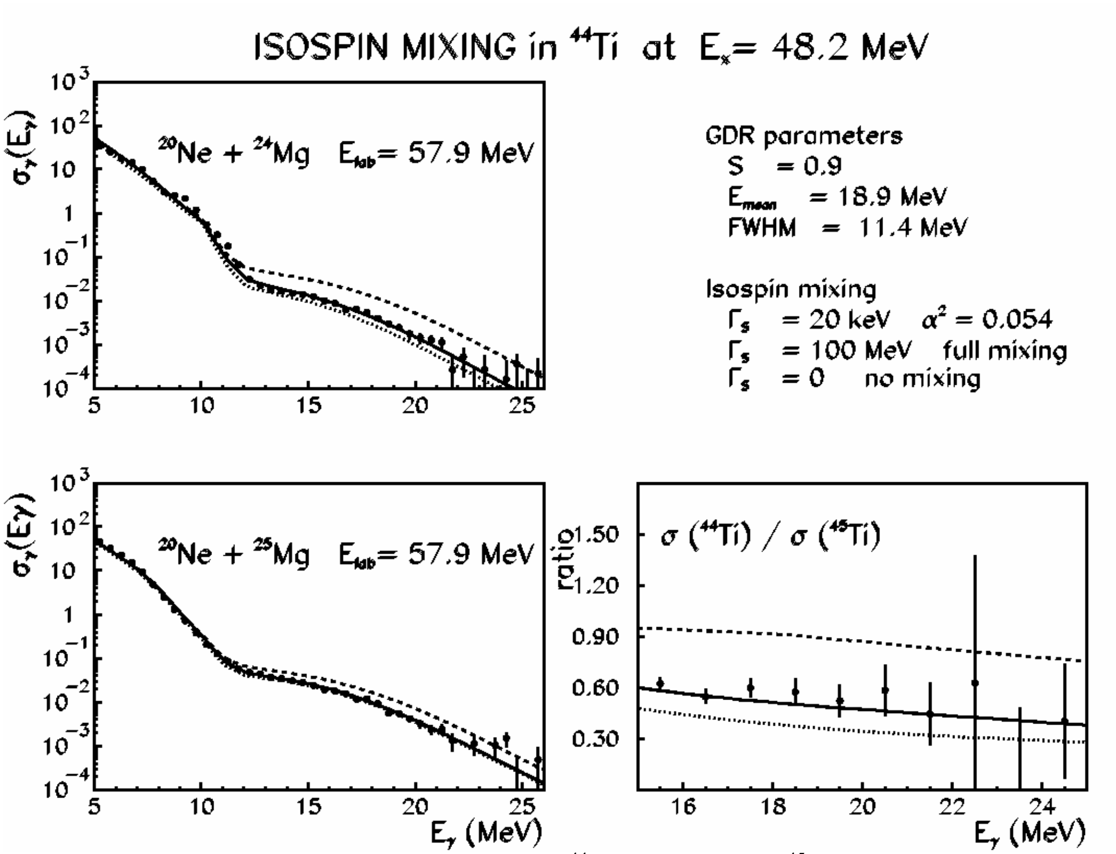

Fig. 1. Spectra of γ-rays emitted during the decay of ^{44}Ti (top-left) and ^{45}Ti (bottom-left) and the ratios of these spectra (bottom-right). The curves - CASCADE fit with different isospin mixing spreading width: $\Gamma_>^{\downarrow}$=0 - no mixing (lowest curve), $\Gamma_>^{\downarrow}$= 20 keV (middle curve) and $\Gamma_>^{\downarrow}$= 100 MeV-full mixing (upper curve).

Measured high-energy γ-ray spectra from the decay of ^{44}Ti and ^{60}Zn are presented in the left top panels in Fig. 1 and 2, respectively. Spectra from the decay of ^{45}Ti and ^{61}Zn are presented in the left bottom panels. Gamma-ray cross sections were calculated within the statistical model by using modified version of the code CASCADE which included the effect of isospin. Statistical model calculations were performed independently for several values of an isospin mixing spreading width $\Gamma_>^{\downarrow}$, assuming that $\Gamma_>^{\downarrow}$ is the same in neighboring nuclei at a given excitation energy. The parameters of the GDR strength function were treated as variables in the least-square fitting of the calculated spectrum to the experimental data. The fits were performed with a single Lorentzian GDR strength function. At first, the GDR parameters were extracted for the N $\neq$ Z nuclei, assuming that there is no mixing and $\Gamma_>^{\downarrow} = 0$. Those parameters values were then used in the least-square fitting of the calculated spectrum to the experimental data for the appropriate N = Z compound nuclei, treating the $\Gamma_>^{\downarrow}$ as variable. After extracting the best value of the isospin mixing spreading width, the fitting was repeated for both, the N $\neq$ Z and N = Z compound nuclei with the best $\Gamma_>^{\downarrow}$ values. This way the best GDR parameters were also extracted.

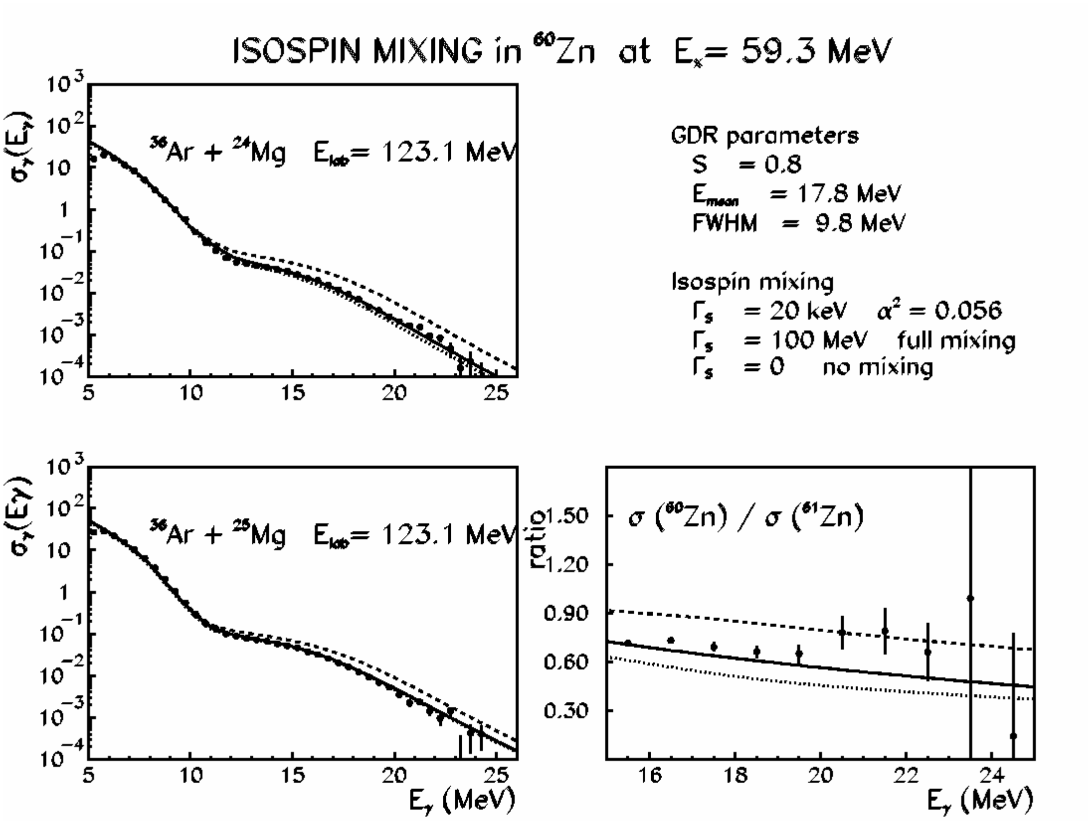

Fig. 2. Spectra of γ-rays emitted during the decay of ^{60}Zn (top-left) and ^{61}Zn (bottom-left) and the ratios of these spectra (bottom-right). The curves - CASCADE fit with different isospin mixing spreading width: $\Gamma_>^{\downarrow}$=0 - no mixing (lowest curve), $\Gamma_>^{\downarrow}$= 20 keV (middle curve) and $\Gamma_>^{\downarrow}$= 100 MeV-full mixing (upper curve).

In order to increase the sensitivity to the isospin mixing we have also analyzed the ratios of γ-ray cross-sections for the reactions forming N = Z and N ≠ Z compound nuclei for the measured and calculated yields. Calculations for several values of isospin mixing parameters: $\alpha_<^2$ = 0 (no mixing), the best value of $\alpha_<^2$ and $\alpha_<^2$ = 0.5 (full mixing) are shown in Fig. 1 and 2 (right bottom panels), for ^{44}Ti and ^{60}Zn, respectively. In both cases, the best reproduction of the ratio of the experimental data is obtained at $\Gamma_>^{\downarrow}$ = 20 ± 4 keV, i.e. $\alpha_<^2$ = 0.054 ± 0.011 and 0.056 ± 0.011, respectively.

This work was partly supported by the Polish State Committee for Scientific Research (KBN Grants No. 1 P03B 160 29*).*

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3. $^{7}Li+^{11}B$ elastic and inelastic scattering in a coupled-reaction-channels approach

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New data for the angular distributions of ^{7}Li + ^{11}B elastic and inelastic scattering at energy $E_{lab}(^{11}B)$ = 44 MeV were measured for transitions to the ground states of these nuclei and to the excited states at energies $E(^{7}Li)$ = 0.478–9.85 MeV and $E(^{11}B)$ = 2.125–8.92 MeV [1] using the ^{11}B beam of Warsaw cyclotron C-200P.

These data and the data for the ^{7}Li + ^{11}B elastic and inelastic scattering at energy $E_{lab}(^{7}Li)$ = 34 MeV [2,3] were analyzed within the optical model (OM) and coupled-reaction-channels (CRC) method. The transitions to the excited states were calculated with the rotational model. Elastic and inelastic channels with reorientations of ^{7}Li and ^{11}B as well as the strong particle transfers were included in the coupling scheme. The energy dependence of the ^{7}Li + ^{11}B OM parameters was taken into account. Some data and corresponding OM- and CRC-calculations are shown in Fig. 1 and 2.

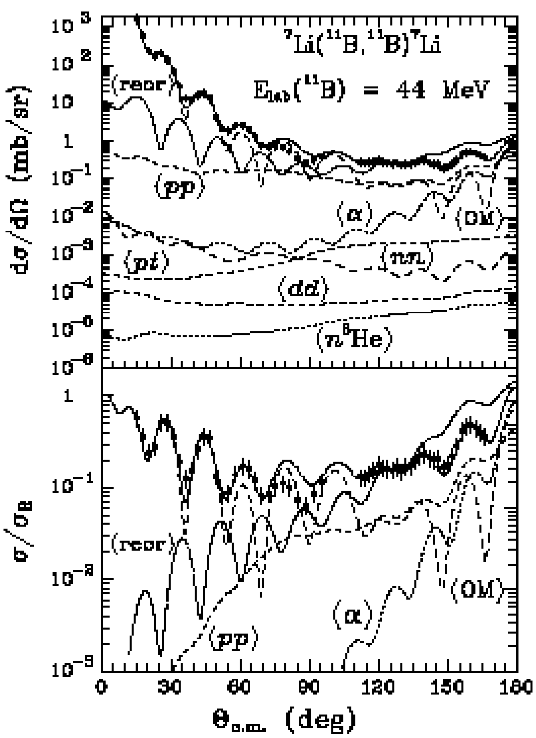

Fig. 1. Angular distributions of ^{7}Li + ^{11}B elastic and inelastic scattering at $E_{lab}(^{11}B)$ = 44 MeV [1]. The curves show the OM and CRC cross section for the potential scattering (curves <OM>), reorientations of ^{7}Li and ^{11}B (<reor>) and transfers (other curves).

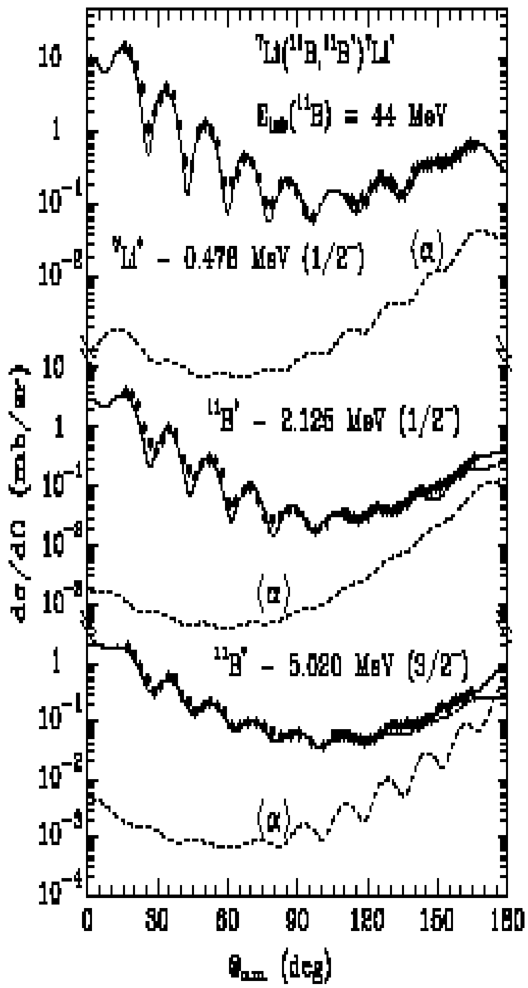

Fig. 2. The same as in Fig. 1 but for excited states of ^{7}Li and ^{11}B.

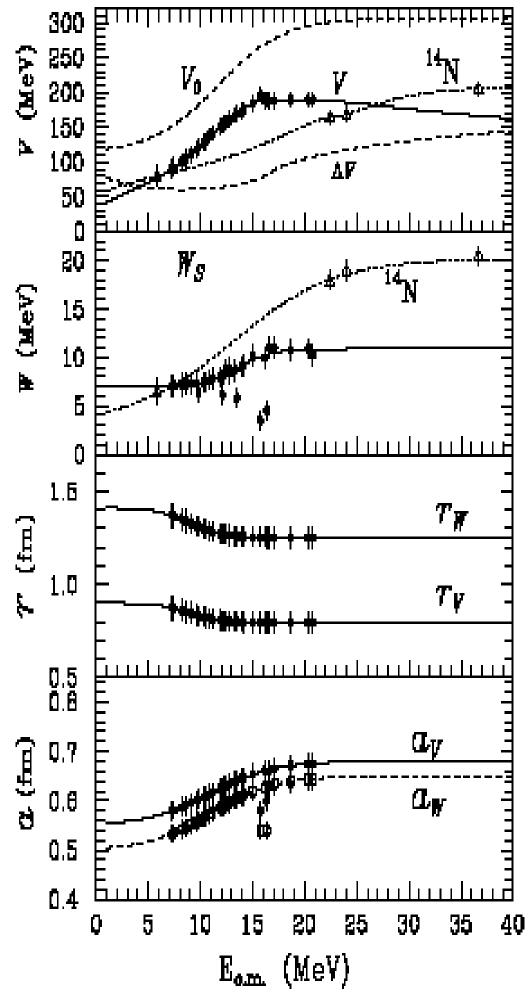

Fig. 3. Energy dependence of the ^{7}Li + ^{11}B OM parameters [1] versus the same for the ^{7}Li + ^{14}N interaction [4].

As a result, the ^{7}Li + ^{11}B OM parameters for the ground and excited states of ^{7}Li and ^{11}B as well as deformation parameters of these nuclei were deduced. The energy dependence of the ^{7}Li + ^{11}B OM parameters for the ground and excited states of ^{7}Li and ^{11}B was obtained.. It was found that this energy dependence is different from that of the ^{7}Li + ^{14}N interaction [4] (Fig. 3).

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4. Quadrupole Deformation of ^{14}C from the ^{11}B + ^{14}C Scattering

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

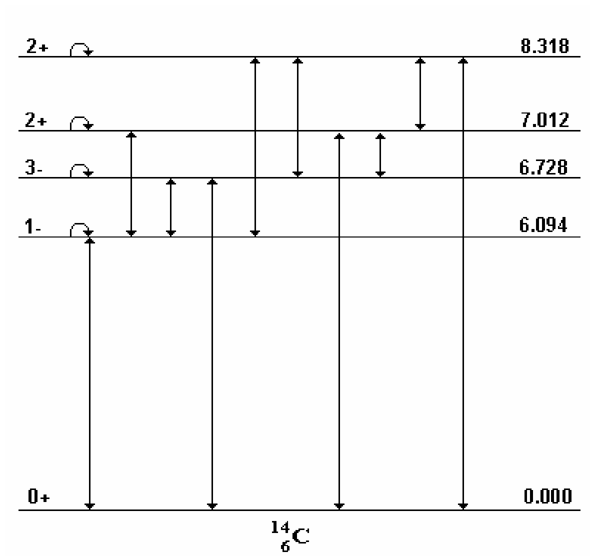

Fig.1 Coupling scheme used in the CC calculations.

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

The results of the CC calculations for the transition to the 2^+ (7.012 MeV) state are shown in Fig. 2. Following Ref. [1], this state was assumed to be the member of the ground state rotational band with the positive quadrupole deformation. From the fit to the experimental data at forward angles (short-dashed curve in Fig. 2) a value of δ_2 = 0.8 fm was deduced. However, a phase mismatch was observed between the short-dashed curve and the experimental data in the angular range 30 – 80 deg.

Calculations performed in Ref. [2] within the antisymmetrized molecular dynamics (AMD) model predicted an oblate shape for the distribution of protons and spherical shape for the distribution of neutrons in ^{14}C. Thus, according to these predictions, the matter distribution of the ^{14}C ground state should be oblate with respect to the symmetry axis. When the sign of the quadrupole deformation was changed to negative in the present CC calculations, the phase agreement was significantly improved. The best fit to the experimental data was obtained with δ_2 = -0.6 fm (solid curve in Fig. 2). Excellent agreement was obtained in the forward angle hemisphere.

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

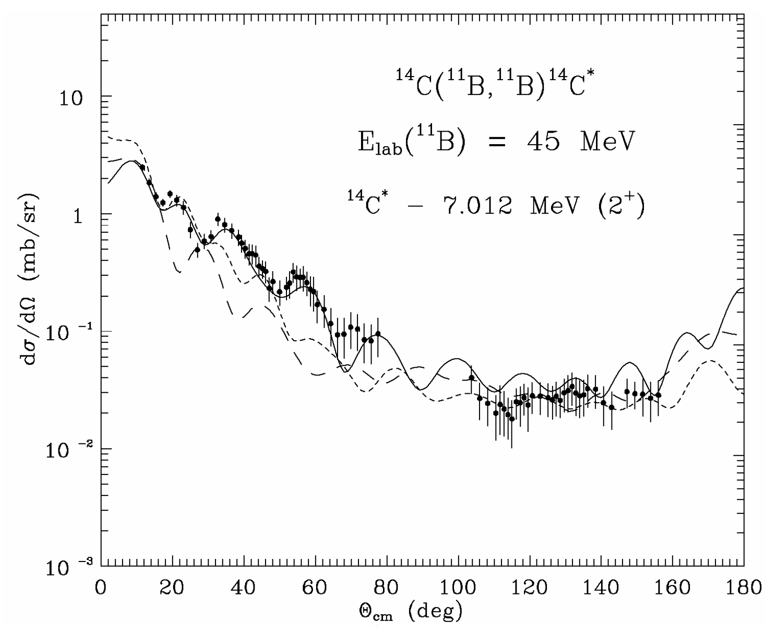

Fig.2 Angular distribution of the $^{14}C(^{11}B,^{11}B)^{14}C^*$ inelastic scattering for the transition to the 2^+ (7.012 MeV) excited state of ^{14}C. See text for the description of the curves.

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5. Status of the IGISOL device

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Investigation of a gas catcher/ion guide system as well as the physics experiments in the trans-lead region were continued in 2005. Some technical improvements of the device were also performed.

The new cell with a volume of 400 cm^3, for which the gas flow simulation were performed using FLUENT code [1], was off-line tested with an alpha-decay recoil source ^{223}Ra. The efficiency of the gas-catcher/ion guide system, measured for ^{219}Rn without mass/charge separation, has the maximum of about 20%.

Because of the conservation of laminar helium flow this gas cell was chosen for on-line experiments. Optimization of an ion extraction efficiency of the IGISOL system was performed with a 80.7 MeV ^{14}N beam on ^{209}Bi target placed inside the helium cell. The maximum extraction efficiency of about 3% was determined for the production of ^{213}Rn ($T_{1/2}$ = 25 ms) isotope. The reaction cross-section values were taken from HIVAP code.

For the physics experiments four silicon detectors were placed at the collection point of the IGISOL system. The digital electronics was tested in the α-α-t correlation and pile-up modes with the ^{223}Ra α source and the heavy-ion reaction product ^{220}Ac ($T_{1/2}$ = 26 ms), respectively [2].

A degrader of the energy of heavy-ion beam was constructed and mounted in front of the target inside of the target chamber.

An integrated vacuum measuring system based on a multichannel controller unit with full range gauges was installed in the IGISOL vacuum device.

These works were partially performed in the frame of the Warsaw University – IN2P3 (nr 04-112) and the ION CATCHER (Nr HPRI-CT-2001-50022) collaborations.

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6. Mechanism of the ^{12}C(^{11}B, ^{15}N)^{8}Be reaction and ^{8}Be + ^{15}N optical-model potential

A. A. Rudchik[1], A. T. Rudchik[1], A. Budzanowski[2], A. Szczurek[2,5], B. Czech[2], T. Czosnyka, J. Choiński, L. Głowacka[3], S. Kliczewski[2], E. I. Koshchy[4], S. Yu. Mezhevych[1,6], A. V. Mokhnach[1], O. A. Momotyuk[1], Val. M. Pirnak[1], R. Siudak[2], I. Skwirczyńska[2]

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Angular distributions of the ^{12}C(^{11}B,^{15}N)^{8}Be reaction were measured at the energy E_{lab}(^{11}B) = 49 MeV for the transitions to the ground and 2.94 MeV (2^+) excited state of ^{8}Be and to the ground and 5.270 MeV ($5/2^+$) + 5.299 MeV ($1/2^+$), 6.324 MeV ($3/2^-$), 7.155 MeV ($5/2^+$) + 7.301 MeV ($3/2^+$), 7.567 MeV ($7/2^+$) excited states of ^{15}N [1].

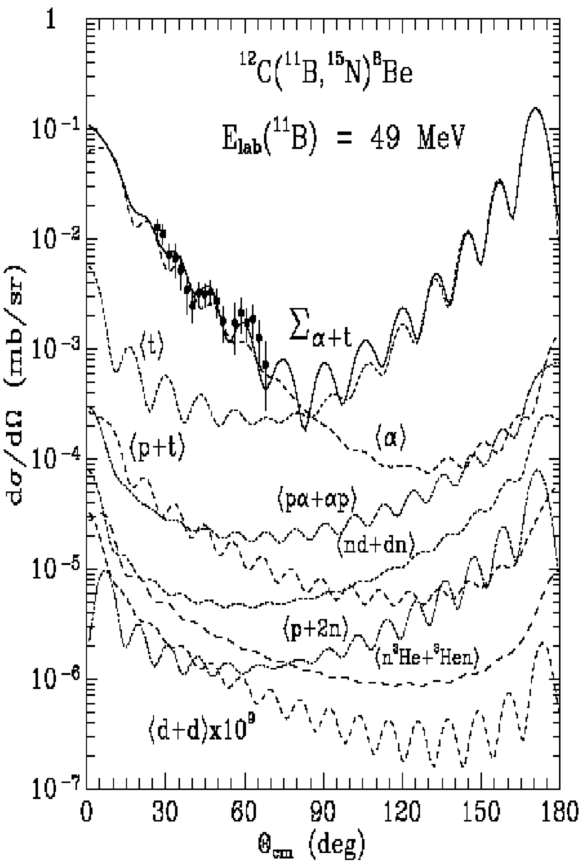

Fig. 1. Angular distribution of the ^{12}C(^{11}B, ^{15}N)^{8}Be reaction for the transitions to the ground states of ^{15}N and ^{8}Be at the energy E_{lab}(^{11}B) = 49 MeV. The curves represent the CRC cross-sections.

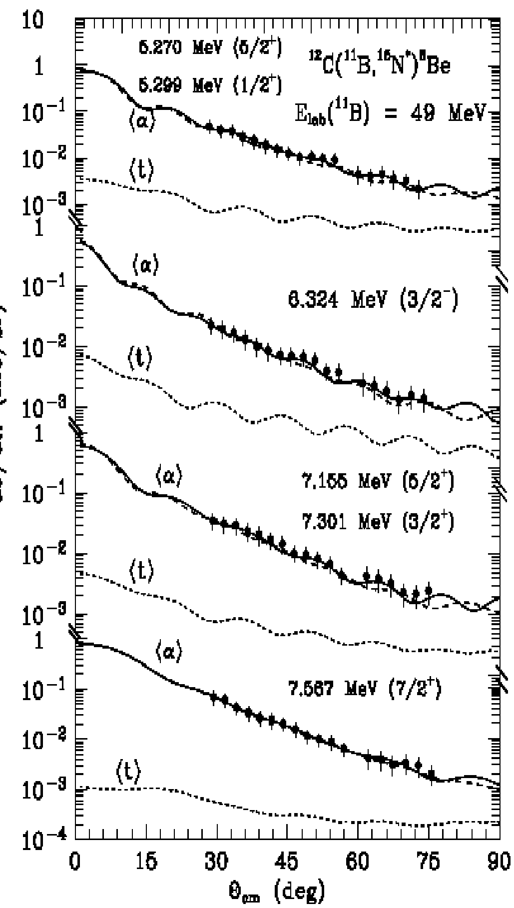

Fig. 2. The same as in Fig. 1 but for the excited states of ^{15}N

The data were analyzed by the coupled-reaction-channel (CRC) method. The elastic, inelastic scattering and one- and two-step transfers were included in the coupling scheme. The data of the $^{12}C(^{11}B,^{8}Be)^{15}N$ reaction at E_{cm} = 9:4-17.8 MeV [2] known from the literature, were also included in the analysis. The mechanism of the $^{12}C(^{11}B,^{15}N)^{8}Be$ reaction and the optical-model potential parameters for the ^{15}N + ^{8}Be channel were deduced. The energy dependence of the optical-model parameters for the ^{15}N + ^{8}Be channel was obtained.

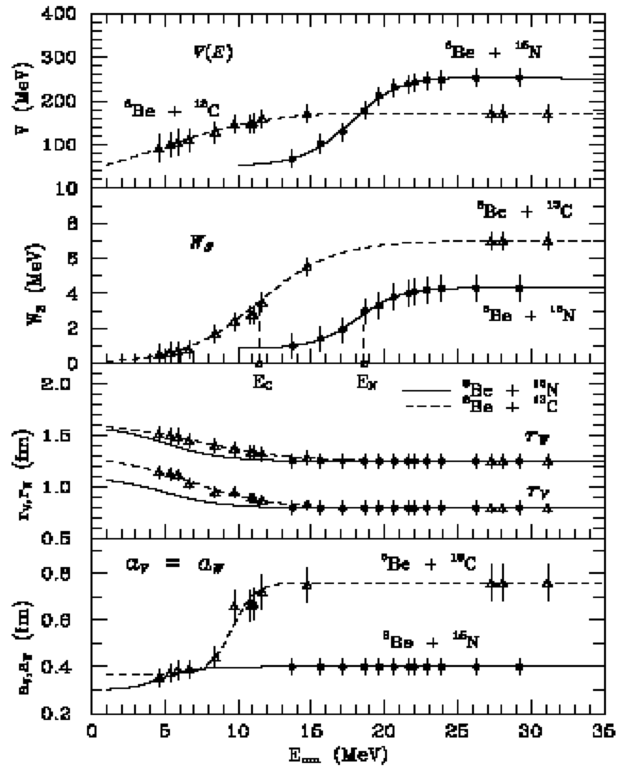

Fig. 3. Energy dependence of the OM potential parameters for the ^{8}Be + ^{13}C (open triangles and dashed curves) [3] and ^{8}Be + ^{15}N (solid circles and curves) channels.

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7. Search for shape coexistence in even-even stable molybdenum isotopes using Coulomb excitation method

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Among the stable, even-even nuclei of medium masses it happens very rarely that the first excited state has a spin and parity equal to 0^+. ^{98}Mo nucleus is one of these and was studied with Coulomb excitation method few years ago [1,2]. The measured shape parameters of the 0^+_2 excited state shown that while the overall quadrupole deformation remains (within the error bars) the same for both 0^+ states, their triaxialities differ remarkably (the ground state of ^{98}Mo is triaxial while the first excited state has a prolate shape).

A natural continuation of these studies, to understand better the nature of low-lying 0^+ states, was to perform similar experiments with neighbouring, even-even stable Mo isotopes, A=96 and 100 [3,4].

Several experiments were carried out both at Heavy Ion Laboratory, Warsaw, and at Japan Atomic Energy Research Institute in Tokai. Warsaw experiments employed the CUDAC [5] set-up and lighter, ^{20}Ne and ^{40}Ar beams. Tokai runs involved both ^{96}Mo beam excitation on a natural lead target and ^{98}Mo target experiments with heavy, ^{84}Kr and ^{136}Xe beams. All the Tokai experiments used combined GEMINI and LUNA detection systems [6].

A standard analysis of the gamma-ray spectra collected in coincidence with charged particles was performed and transition intensities were determined.

Electromagnetic matrix elements describing couplings between the sub-set of nucleus states was found by a global fit of calculated to measured (or previously known) observables (line intensities, level lifetimes, branching and mixing ratios). The fit and the error calculation was done using the GOSIA Coulomb Excitation Data Analysis Code [7].

Quadrupole deformation parameters were deduced and compared for first two (ground and excited) 0^+ states in ^{96,98,100}Mo.

The results, together with comparison with data obtained for germanium isotopes (which also have low-lying 0^+ excited states) are presented in Figure 1.

Presented systematics shows that:

- ^{96}Mo: ground state 0^+_1 is deformed while the excited state 0^+_2 is almost spherical. This behaviour is similar to the one observed in Ge isotopes and ^{96}Zr [8,9].
- ^{98}Mo: the expectation value of Q^2 is almost the same for the ground state and for the first excited state.
- ^{100}Mo: the preliminary results show similar trend as observed in case of the ^{98}Mo isotope: the expectation value of Q^2 is almost the same for both 0^+ states. Deformation of ^{100}Mo seems to be larger compared to other Mo isotopes.

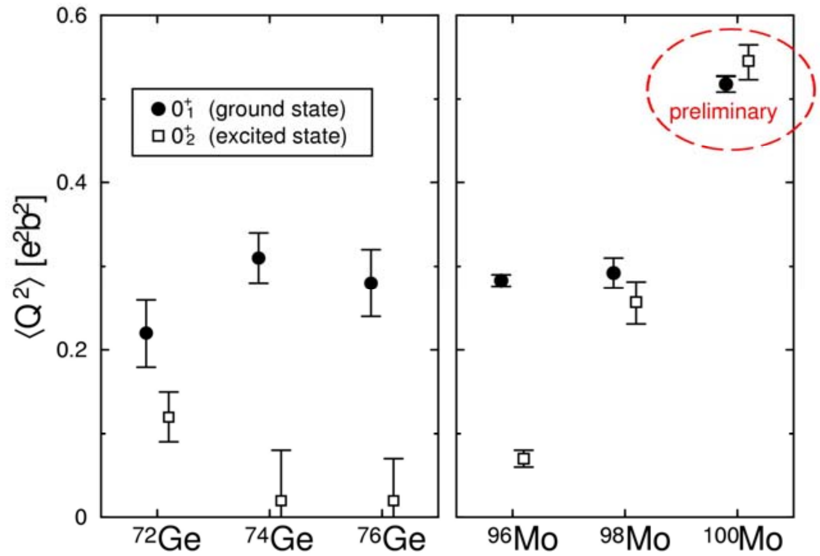

Fig. 1: Comparison of known quadrupole deformation parameters for the first two 0^+ states in selected Ge and Mo isotopes.

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8. Pulse-shape analysis of signals from monolithic silicon E–ΔE telescopes produced by the Quasi-Selective Epitaxy

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Two monolithic E–ΔE charged particle telescopes with ΔE layers of 11 and 20 μm thick, respectively, produced with the Quasi-Selective Epitaxy method were tested at the Heavy Ion Laboratory in Warsaw using pulse-shape analysis.

E–ΔE telescope consists of two high resistivity silicon layers, acting as ΔE and E detectors, separated by a low resistivity layer forming a common contact of the two detectors. The main problem to deal with is a cross-talk of signals between the two active layers of the telescope, caused by the insufficiently low resistance of separating layer. The aim of this work was the application of the pulse shape analysis to pulses from monolithic E–ΔE telescopes in order to reduce influence of unwanted cross-talks on measured energies.

Cross-talk signals in the monolithic E–ΔE telescope as a function of position were simulated using the numerical solution of the telegraphic equation describing time-dependent evolution of the cross-talk potentials in the ΔE detector RC network. The decay of cross-talk signal depends on position. The slowest decay of cross-talk potential occurs for central position of generated potential and fastest decay corresponds to position closest to detector edge.
Since the detector does not have the position sensitivity feature, correction of position-dependent cross-talk signal is not possible. Leading parts of ΔE and E pulses, where cross-talk signals were present, were rejected during off line elaboration.

The measurements were performed using a very basic electronic set-up consisting of two preamplifiers connected directly to the Tektronix 744A oscilloscope. Scope readouts were sent to an IBM-PC class computer via the GPIB interface. The oscilloscope was triggered with the E detector pulse. Both E and ΔE pulses were stored in the computer memory in event-by-event mode (Fig.1).
Pulse shape analysis technique was then applied to obtain the final two dimensional spectrum (Fig. 2). The zero level (baseline) was calculated using an average value of 10 μs pre-trigger part of the measured signal. After ca. 2 μs (20 μm detector) or 4 μs (11 μm detector) the energy was evaluated using an average value of measured samples in the 25 μs window.
Thorium source α particles and $^{12}C(^{14}N,X)$ reaction products at 80 MeV beam energy and 20° laboratory angle were used to test the telescopes. The energy resolution of the monolithic E–ΔE telescope measured using α particles was about 0.7 MeV for telescope with 20 μm thick ΔE layer and 0.4 MeV for telescope with 11 μm ΔE layer.

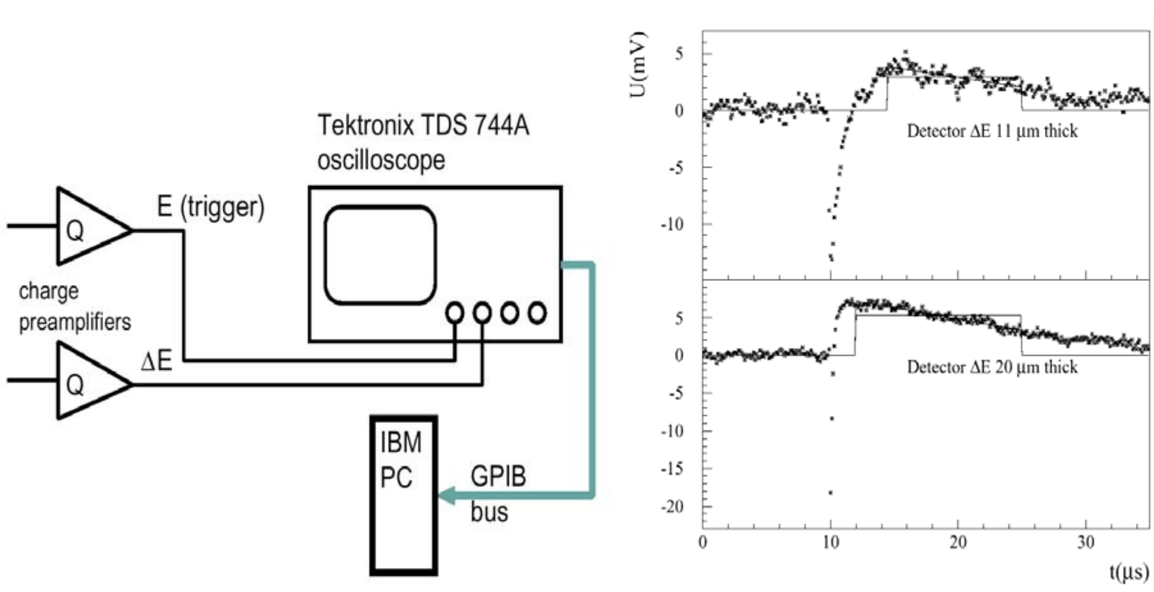

Fig. 1. Left: electronic set-up used for measurements with α-particles and heavy ions using the monolithic E–ΔE telescope Right: Pulses from ΔE detectors of monolithic telescopes irradiated by the α-particles from the thorium calibration source measured by the Tektronix 744A oscilloscope. Upper frame: ΔE detector 11 μm thick. Lower frame: ΔE detector 20 μm thick. The negative fast cross-talk signal originated from the E detector is present at the beginning of both pulses.

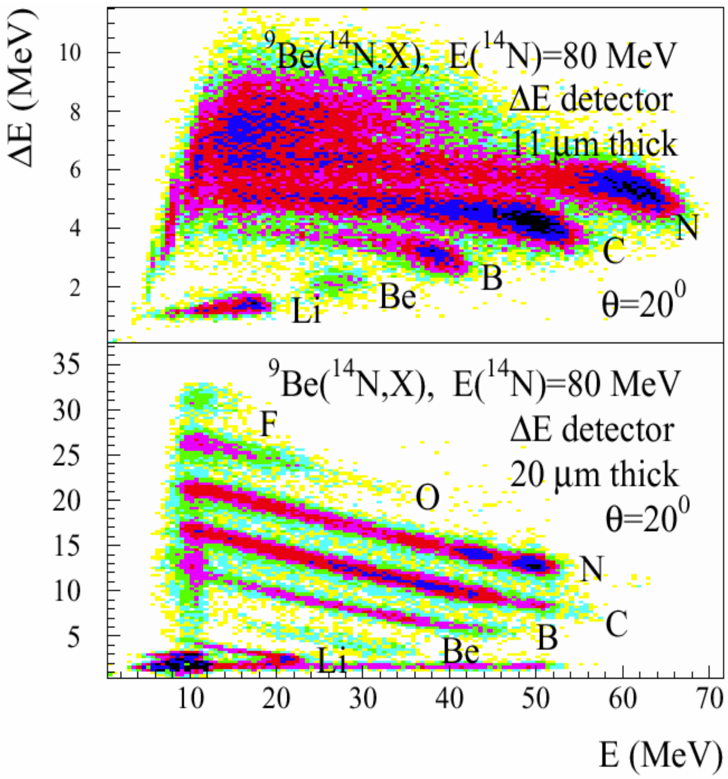

Fig. 2. ΔE-E scatter plots obtained after irradiation of the monolithic telescopes with ^{12}C(^{14}N,X) reaction products. The upper frame - results for the monolithic telescope with 11 μm thick ΔE detector, the lower frame - results for the monolithic E–ΔE telescope with 20 μm ΔE detector. In both cases the pulse shape analysis technique was applied.

Full description of this work was accepted by Nucl. Instr. and Meth. (2006)

9. In- and off-beam spectroscopy of the ^{40}Ar^{+8} + ^{120}Sn reaction

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The OSIRIS-II array consisting of 12 Compton suppressed HPGe detectors and equipped with an inner 48-elements BGO ball for sum-energy and γ-ray multiplicity measurements [1] has been employed to study the ^{40}Ar + ^{120}Sn reaction, with an attempt to study nuclear shape changes above the yrast line, as well as to search for the high spin isomers and to prepare the future playground for advanced students workshops.

In the experiments reported here a target of approx. 20 mg/cm^2 ^{120}Sn on ^{198}Au backing was bombarded with a $^{40}Ar^{+8}$ beam from the HIL K=160 cyclotron at energy of E_{lab}=233MeV. It is worth mentioning that the intensive beam of $^{40}Ar^{+8}$ ions was produced in the ECR ion source at HIL for the first time.
The investigations described in this contribution are focused on the compound system of $^{156}Er^*$ decaying to several reaction channels, where at higher angular momentum significant deformations are expected.

The OSIRIS-II BGO ball [2,3] consists of 48 crystals in 3 rings K1, K2 and K3 and 2 central detectors K4. The equatorial ring K1 consists of 12 or 10 crystals, the K2 ring has 12x2, while the K3 ring includes 2x6 elements. Each of the 48 BGO crystals provides a fast timing and slow energy signals, which are aligned in time. In this way, a signal related to the sum-energy of the γ-ray cascade can be obtained by summing the energy signals from the crystals. On the other hand, the fast timing signals from the individual BGO elements are sent to a multichannel constant fraction discriminator. The signals from the Ge detectors constitute the basic condition for master trigger. An array of BGO detectors with low energy resolution but high efficiency, positioned very close to the target was covering a solid angle of approx. 70% of 4π. The entry line for different exit channels (average excitation energy <E*> for each M or I) was deduced using the γ-ray sum-energy information from the BGO ball. Figure 1 shows the total entry line for ^{40}Ar + ^{120}Sn reaction deduced from the data at 232MeV bombarding energy. A change of the slope of the experimental entry line is observed for considered reaction.

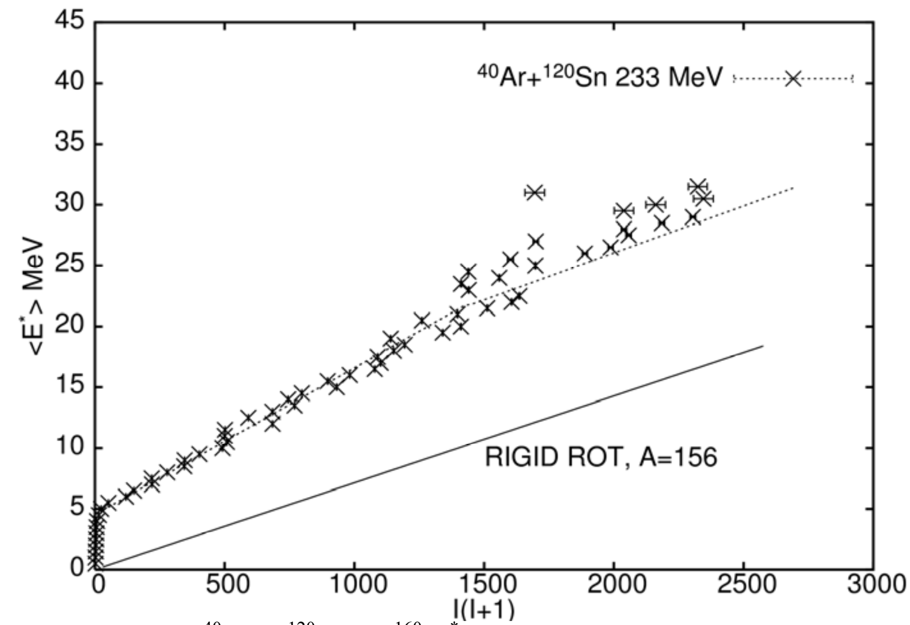

Fig 1. Total entry line for the ^{40}Ar + ^{120}Sn → $^{160}Er^*$ reaction measured at the bombarding energy of 232 MeV. The slope of the experimental entry line is changing from ~80 MeV^{-1} to ~129 MeV^{-1}. The straight line represents the calculated yrast line for a rotating rigid nucleus (A=156).

In the spin region I~10-35 a slope of about 80MeV^{-1}, and in the higher spin region I~35-50 shows a slope as high as ~129 MeV^{-1} consistent with the slope of rigid rotor ($2J_{rig}/\hbar^2$ = 140 MeV^{-1} for A=156).

Besides the topic presented above a search for the existence of isomers in this region of nuclei is also developed. The full account of the result of our "Entry line" and "Isomer search" is under preparation.

Comment:
The OSIRIS-II detector array was in the last months rearranged in order to obtain a better efficiency for γ-γ coincidences. For this reason the multiplicity filter was temporary replaced by small target chamber and detectors are in more compact geometry.

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10. The stopping power of Cs recoils moving in Sn target

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The knowledge of the slowing-down process of heavy ions moving in matter is of considerable interest in modern technology, medicine and some branches of physics. In nuclear physics the precise information on the stopping power of recoils moving in a target is indispensable when short lifetimes of nuclear states are measured by the Doppler Shift Attenuation (DSA) method [1]. The stopping powers of heavy ions can be found in Ziegler's tables [2] but some experiments (see e.g. Refs. [3, 4]) and our recent results [5] on the stopping power of La recoils moving in Sn target show substantial differences from these data.

The preliminary results of our study of the slowing-down process of Cs ions moving in Sn matter with a velocity $v \leq 0.01c$ are presented below. These results are used for determining the lifetime of excited states of ^{128}Cs nuclei as measured by the DSA method.

The slowing-down process of heavy nuclei moving with a low velocity (≈0.01c) can be described in the frame of the LSS theory [6]. According to this theory the stopping power (defined in terms of the dimensionless energy (ε) and range (ρ) parameters) is:

$$\frac{d\varepsilon}{d\rho} = f_e k \varepsilon^{1/2} + f_n \varepsilon^{1/2} / (0.67 + 2.07\varepsilon) \qquad (1)$$

where k is the Lindhard electronic stopping power coefficient and f_e, f_n are correction factors for the electronic and nuclear stoppings, respectively.

In our experiment we used the "semi-thick target" method [7]. In this method γ-rays are mostly emitted from excited recoils (in our case ^{127}Cs nuclei) moving in vacuum after they left the target. The γ-ray lineshape is governed by the velocity distribution of the escaping recoils and gives information about the stopping power.

The Cs ions have been produced in the reaction at the beam energy of 49 MeV provided by the Warsaw U-200P cyclotron. The γ-rays were measured by the OSIRIS II multidetector array consisting of 12 Compton-suppressed HPGe detectors. The semi-thick natural Sn target 1.2 mg/cm^2 thick was used. Its thickness and homogeneity were checked by the RBS method [8] on beams of protons and ^4He at the LECH VdG accelerator of the Institute for Nuclear Studies (Warsaw).

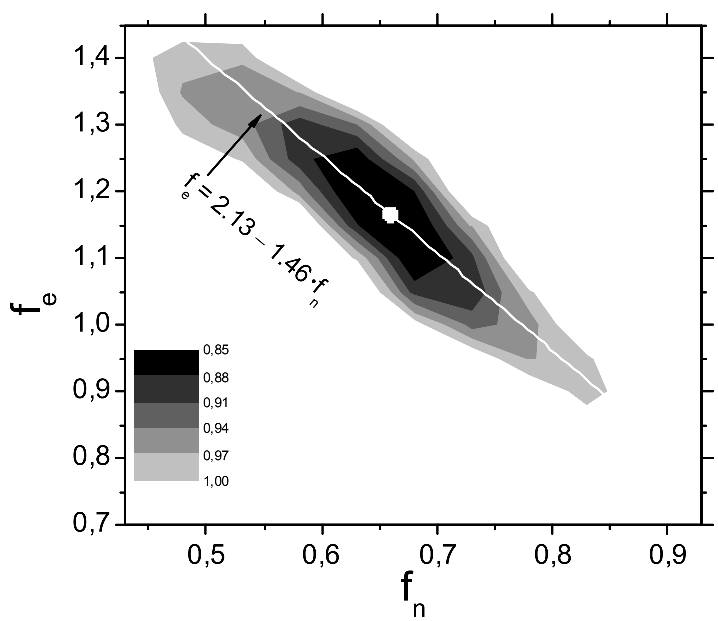

Fig.1. Quality of fit (χ^2) as a function of correction factors (f_e, f_n). The confidence area is presented in black.

The theoretical lineshapes for various values of f_e and f_n were fitted to the experimental shapes of the most intense γ-lines in ^{127}Cs (414 keV, 434 keV and 590 keV). The results are given in Fig. 1 which shows the quality of fit (value of χ^2) plotted as a function of f_e and f_n. We see from this figure that the best are the values of $f_e = 1.17 \pm 0.08$ and $f_n = 0.66 \pm 0.06$. These values differ significantly from Ziegler's predictions: $f_n = 0.83$, $f_e = 0.53$ [2].

The "valley" in the χ^2 plot is well described by the linear function (see white straight line in Fig. 1). It is worth noting that our recent experiment [9] on ^{128}Cs (produced in the thick ^{122}Sn target, analyzed by the DSA method) shows that for each f_e, f_n pair which fulfills this function and for $f_n \approx 0.5 \div 0.8$ the lifetimes are approximately the same.

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11. New particle – gamma detection set-up for Coulomb excitation experiments. Test of COULEX configuration of the future multidetector gamma set – up TROLL.

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Coulomb excitation experiment of ^{100}Mo with ^{32}S beam – a continuation of previously reported project [1,2] - was performed using a new particle – gamma detection set-up at HIL.

New coincidence set-up was prepared and tested. New set-up consists of up to 110 particle detectors placed at backward angles and 12 BGO-shielded gamma detectors. Particle detector system, presented in Fig.1, was constructed in LMU Munich and tested within the German – Polish collaboration.

Particle detectors (PiN diodes) are mounted inside a spherical chamber of 5 cm radius. The active area of a single PiN-diode is 0.5 cm × 0.5 cm. Each diode can be placed in any of 110 different positions. Scattering angle coverage extends from 110^o to 170^o (with respect to the beam direction).

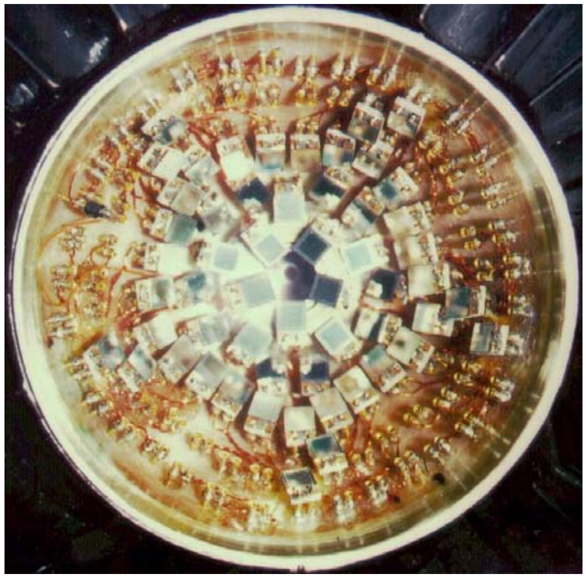

Fig 1. The particle detector chamber showing the PiN – diodes distribution (beam dump side view).

An original electronics involving purpose-built fast/slow amplifiers and analog multiplexers were replaced with three 16-fold, digitally controlled fast/slow amplifiers (CAEN model N568/LC) and Constant Fraction discriminators (CAEN model C808).

New electronics system was tested on-beam during a short run with a carbon beam. During the subsequent experiment (January 2006) with ^{32}S beam and ^{100}Mo target the number of 48 PiN - diodes were used to show that the new particle detector system and the related electronics work well in the coincidence with gamma detector array OSIRIS. It can be considered a first step towards construction a new multidetector gamma - particle detection set-up TROLL (being a proposed name). It is a new project involving 20 ÷ 30 Germanium detectors and 60 BaF_2 detectors.

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[2] Int. J. Mod. Phys. E15 (2006) 374.

12. Mean charge of fast sulphur projectiles traveling in solid

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The knowledge of ion charge states in solids and gases is very important for determination of the ion stopping power, the atomic excitation and subsequent materials modification during ion-atom interaction which are essential in different accelerator systems and therefore, the charge state of projectiles passing through matter is one of the most relevant question for studies of ion penetration in matter. The charge state of the ion changes with the depth of target penetration as a result of loss and capture processes. After some path in the target, the projectiles reach the equilibrium electron defect configuration which yields the equilibrium charge state. The parameters of K x-ray spectra, like x-ray energy and its width, are sensitive to the degree of projectile ionization of L and M shells [1,2]. Therefore the characteristic x-rays inform about the electronic configuration of highly ionized projectiles at the time of x-rays emission and simultaneously the energy of emitted x-rays lets to estimate the mean equilibrium charge of projectiles. The effect of the projectile K x-rays line shifts with respect to the corresponding diagram lines has been used for evaluation of a mean equilibrium charge $\bar{q}$ for sulphur ions passing with energies of 9.6-122 MeV through Al, Ti and Fe foils. The dependence of sulphur charge state on the target atomic number is discussed taking into account the data of the cross sections for ionization, decay and electron capture processes. During the experiment sulphur ion beams with incident energies of 9.6, 16.0, 22.4, 32.0~MeV and with initial charge states q=4+, 6+ were obtained from the tandem accelerator at the Institute of Physics of the Erlangen-Nürnberg University and with energies 65, 79, 99 and 122 MeV and with charge states q=13+, 14+ were extracted from the U-200P cyclotron at the Heavy Ion Laboratory of the Warsaw University. The x-ray line shifts measured for sulphur ions passing through C targets were linked to the mean equilibrium charge $\bar{q}$ calculated according to the empirical formula by Shima [3] and were used as reference data for estimation of $\bar{q}$ of S projectiles passing through Al, Ti and Fe targets. The estimated value of $\bar{q}$ increases with enhancement of the ion energy for each kind of target. Figure 1 presents the shape of universal curve describing the dependence of our experimental $\bar{q}$ value on target atomic number Z_t and semi-empirical predictions of Shima.

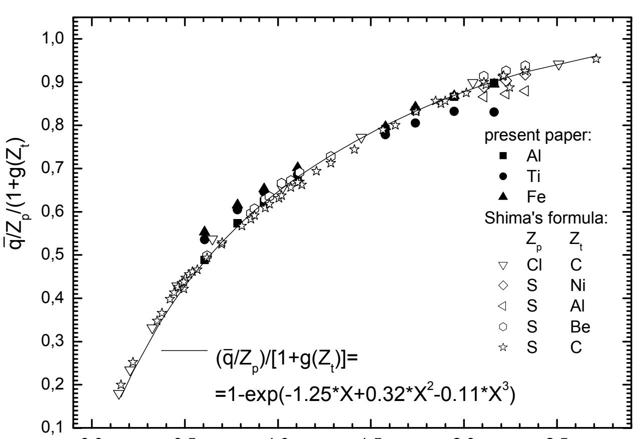

Fig.1. Experimental values of average equilibrium charge state and universal curve calculated according to the semi empirical formula by Shima [3]

As was mentioned above the values of average ion charge and its dependence on target atomic number Z_t reflects effect the competition between ionization, excitation, electron capture, electron loss and decay processes, which undergo the S projectiles inside targets. Therefore in order to explain the dependence of $\overline{q}$ on Z_t the values of the cross sections for direct K and L shell ionisation of sulphur ions by an atom of carbon, aluminium, titanium and iron (on the base of PWBA model), and the values of total electron capture cross section from K, L, M and N shells of target atoms to the sulphur projectile K, L and M shells have been calculated (using the Oppenheimer-Brinkmann-Kramers (OBK) formulation of electron exchange by Nikolaev [4] given by Lapicki and McDaniel [5]). A very good agreement between the dependence of $\overline{q}$ on Z_t and dependence of ratio of total cross section for electron capture to total cross section for ionisation $\sigma_{EC}^{tot}/\sigma_{ion}^{tot}$ on Z_t is observed for lower ion energies 9.6-32.0MeV. The increase of domination of the total EC process over the ionization process in the sulphur projectiles means the decrease of $\overline{q}$ value. The dependence of $\overline{q}$ on Z_t and $\sigma_{EC}^{tot}/\sigma_{ion}^{tot}$ on Z_t disappears with increasing ions energy. In the case of higher energies 65-122 MeV we can observe that $\sigma_{EC}^{tot}/\sigma_{ion}^{tot}<1$, which means the domination of loss processes over electron capture process in sulphur projectiles. The value of $\sigma_{EC}^{tot}/\sigma_{ion}^{tot}$ decreases exponentially with Z_t for each energy when $\overline{q}$ value decreases linearly for C, Al and Fe targets for each energy. The $\overline{q}$ value in Ti foil is lower and difference increases with energy enhancement.

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13. An irradiation facility with a horizontal beam for radiobiological studies

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A facility with a horizontal beam for radiobiological experiments with heavy ions has been designed and constructed at the Heavy Ion Laboratory in Warsaw University. The facility is optimal to investigate the radiobiological effects of charged heavy particles on a cellular or molecular level as the plateau of the Bragg curve as well as in the Bragg peak. The passive beam spread out by a thin scattering foil provides a homogeneous irradiation field over an area of at least 1x1 cm^2. For in vitro irradiation of biological samples the passive beam spreading combined with the x-y mechanical scanning of the irradiated sample was found to be an optimum solution. Using x-y step motor, the homogenous beam of ions with the energy loss range in the cells varied from 1 MeV/µm to 200 keV/µm is able to cover a 6 cm in diameter Petri dish that holds the biological samples [1]. Moreover on-line fluence monitoring based on single-particle counting is performed to determine the dose absorbed by cells.

1. Introduction

The use of heavy ion accelerators has enjoyed extensive interest for biophysical experiments over the past years. The radiobiological effects of charged heavy particles on a cellular or molecular level are of fundamental importance in the field of biomedical applications, especially in hadron therapy and space radiation biology.

The study of the influence of high linear energy transfer (LET) ions on the DNA in the cell nucleus yields a basic information to the models describing the effects of radiation of different cells, the track structure of projectiles passing in the cell and the DNA geometry [2]. The use of heavy ions in radiotherapy ("hadrontherapy") could result in effective treatment due to a very good depth dose profile ("Bragg curve") and the high relative biological effectiveness (RBE) for cell inactivation. Nowadays, there are some clinical centers and research facilities performing treatments with protons and heavy ions. Therefore the study of biological characteristics of different particles has to be known to avoid therapy-induced side effects. The knowledge of radiation-induced DNA-breaks is also the base to estimate the risk from radiation exposure during long-manned space flights. There is also increasing interest in learning the influence of ionizing particles on the apoptosis or cell membrane damage.

The main aim of the work was to set up a facility for radiobiological experiments for different ionizing particles in the region of the Bragg peak. The special attention has been concentrated on the information concerning the effectiveness of the low-energy ions, where the dosimetry of slow particles around the Bragg peak is a technical challenge. The V79 Chinese hamster cells were used for the first radiobiological experiments with carbon ions.

2. Technique

2.1 Irradiation facility

At the designing process we have made the cardinal assumption that the facility will be used for irradiation of biological samples under physiological conditions by various ions at a wide range of LET. The U-200P cyclotron of the Heavy Ion Laboratory provides heavy ions from boron up to argon with energies from 2 MeV/amu to 10 MeV/amu. At this facility almost all types of ions, which are potentially useful in hadrontherapy can be accelerated, so different radiobiological experiments covering a wide range of LET values are possible. The set-up with a horizontal beam has been constructed.

The ion beams are transported from the cyclotron area to the set-up by a horizontal beam line [3] with a conventional beam tuning components including a fast mechanical beam shutter, which can be activated by the irradiation control system. Starting from the switching magnet of the cyclotron the beam line consists of the following components:

- pneumatic operated valve,

- turbo molecular pumping system,
- scattering chamber with collimating system, target holder and detectors,
- beam tube (about 2.3 m long) with vacuum gauge
- pressure pick-up activating safety valve
- exit Havar window
- irradiation system mounted at the X-Y sliding table

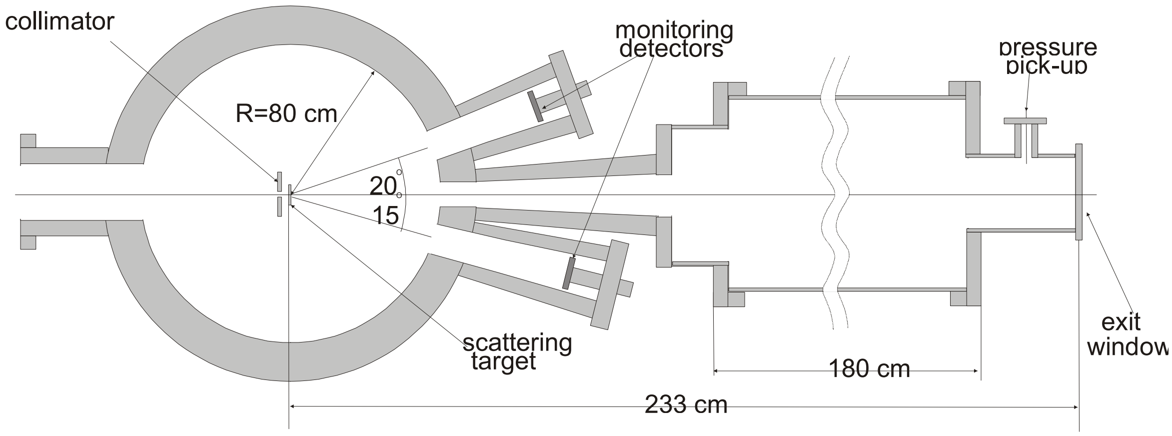

Fig. 1. The scheme of the set-up for radiobiological studies with the horizontal beam line at the U-200P cyclotron of the Heavy Ion Laboratory.

A protective failure system has been interlocked into the vacuum gauge circuit. This failure system shuts of the pneumatically opened safety-valve at the pressure of 10-4mm Hg. At a pressure greater than 10-1 mm Hg the vacuum pumps are shut down also. At the entrance into the radiobiological set-up (see figure 1) the beam is collimated by a 2 mm in diameter aperture.

To achieve a homogeneous radiation field over the area of the exit window the beam is passively spread out by scattering foil of high atomic number material with appropriate thickness. Usually, gold scattering foils in the 3-50 $mg \cdot cm^{-2}$ thickness range are used. The ion beam intensity is analyzed on-line by an integral monitoring system of two silicon detectors placed inside the scattering chamber at the angles of 15º and 20º. The irradiation ion beam parameters are also examined at separate measurements by a removable diagnosis system following the exit window.

The beam extraction in air is performed through a quadratic window with 10 mm side length sealed by a Havar foil with 2.45 $mg \cdot cm^{-2}$ thickness. The foil is cemented to stainless-steel flange using epoxy glue. The thickness of this foil prevents the break of the window due to the pressure gradient.

2.2 Beam monitoring and dosimetry

Two independent detector systems for the beam diagnosis and for the beam monitoring were used: the Si-detector measuring the particle flux at the position of the cell container and two on-line detectors monitoring the particle flux by intensity of the scattered particles.The intensity and the distribution of the scattered ions was measured outside of the exit window (at the position of the Petri dish holding the cells) by surface-barrier silicon detector fastened to a x-y-z sliding table and moving across the two dimensional array centers, distant each of other by 0.5 mm. To reduce the count rate and to obtain information about particle flux from the fine window area an Al collimator with opening diameter of 0.5 mm was placed in front of the detector. The fast electronic circuit of the charge sensitive pre-amplifier allows rates up to 10^3 particles/s without intolerable losses.

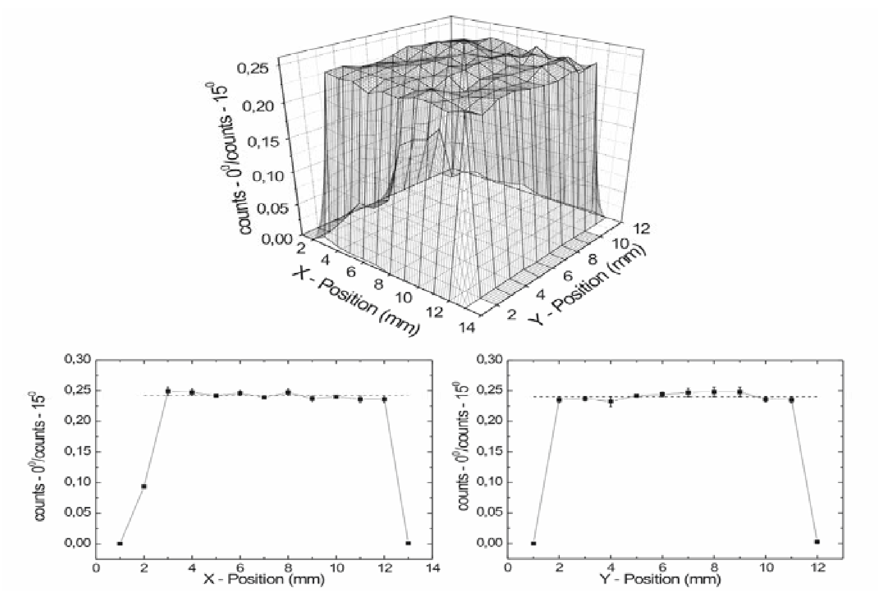

Fig. 2. Measured two dimensional plot of the ^{12}C ions intensity scattered over the 1×1 cm^{-2} exit window at the cell container position normalized to the intensity of the elastically scattered ions at the 15°silicon detector (a) and the profiles in x- (b) and y-direction (c).

The detectors mounted stationary in the scattering chamber at the angle of 15° and 20°measure on-line the intensity of the scattered ions at the scattering foil during cell irradiation. To reduce the count rate, collimators with 2 mm diameter were placed in front of each detector. The 20° detector was placed at a distance of 118 mm from the center of a scattering foil and the 15° detector at 147 mm. The typical spatial intensity distribution of the ^{12}C scattered ions over exit window, is presented in figure 2. The distribution was measured by silicon detector in air at the biological sample position and normalized to the yield of on-line scattered particles at the 15°. Combining scattering of the beam with mechanical displacement of the detector, the beam uniformity of 2.5% over area of 6×6 cm^2 was obtained.

Our irradiation facility allows to vary the available energy for radiobiological experiments in the range of ~2 MeV/amu to ~10 MeV/amu. At the energy of ~2 MeV/amu the energy loss in the biological cells is about 1 MeV·μm^{-1} and the range of ions in water ~10 μm which correspond to a typical cell diameter, while at the energy of ~10 MeV/amu the energy loss reaches the value of 200 keV·μm^{-1} and the range of ~400 micrometers.

2.3 Data readout and visualization

In radiobiological experiments with charged particles the cells are typically seeded at the Petri dishes with a typical diameter of 5-6 cm which let to minimize the errors concerning the statistics of cells and events. At our facility the biological cells should be seeded at the Petri dishes as a plastic ring with 4.8 cm diameter glued to the bottom of a thin 3 μm Mylar foil. A special construction of the top of this Petri dish allows also for cell irradiation under physiological conditions.

To obtain homogeneous irradiation of all the cells the Petri dishes were placed vertically in a specially designed sample holder mounted into the controlled x-y-z stepping motor with remote control. At this system time dependence of the beam intensity as well as the energy spectrum of the scattered beam is registered. The signals from the monitor detectors mounted in the vacuum are counted in the fast programmable scaler. When the number of registered particles reaches the preset value (characteristic for settled dose), a start signal is created and the target changes its position according planned route. During irradiation all count rates are measured with a sampling rate of 100 Hz and stored on hard disc. The data are on-line visualized at the PC's monitor by a graphical interface. The communication between the PC's and electronics takes place with CAMAC crate controller and located in control system. From these data an off-line dose-analysis can be performed [1].

When the beam is stopped, the count rate is reduced to zero. The next sample is turned into the irradiation position and the irradiation resumes with the next characteristic presume rate. From the plot it is also evident that the accelerator beam stability does not play important role in the irradiation process. The exit window and sliding table with the samples to be irradiated are controlled by a video camera.

3.Conclusions

The radiobiological facility at the Heavy Ion laboratory is operational. The facility allows to vary the available energy for radiobiological experiments in the range of ~2 MeV/amu to ~10 MeV/amu. At the energy of ~2 MeV/amu the energy loss in the biological cells is about 1 MeV·μm^{-1} and the range of ions in water ~10 μm which correspond to a typical cell diameter, while at the energy of ~10 MeV/amu the energy loss reaches value of 200 keV·μm^{-1} and range of ~400 micrometers. Lastly, some experiments were done to test the new setup and the results show that the system works in a satisfactory manner. A biological program with experiments studying the relative biological efectiveness and chromosomal aberrations will be started soon.

The work was partially supported by the Polish State Committee for Scientific Research under Grant No. 1P03B10527.

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14. Synchrotron studies of hp - ht treated silicon implanted with 42 MeV nitrogen ions

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The aim of present research is an attempt to explore physical mechanisms affecting transformations of nitrogen-implanted silicon crystals if annealed under enhanced pressure. The previously reported results concerned pressure-treated Si:N prepared by nitrogen implantation with a 2×10^{16} cm^{-2} dose of total energy up to 150 keV [1-3]. The dislocation-free silicon single crystal was grown by the Czochralski method. The (100)-oriented samples were implanted with a 5×10^{14} ions·cm^{-2} dose of N ions, with the total energy 42 MeV (corresponding to 3 MeV/nucleon) of the ion beam, from a *K=160 Cyclotron* at the Heavy Ion Laboratory of the Warsaw University. The beam current was equal to 50 enA. The implantation was performed at room temperature by a uniformly defocused beam. The calculated mean range of 42 MeV N ions in silicon is equal to 37 μm. The buried layer is 2 μm thick. Some investigation of Si implanted with high energy ions were described in [4-6].

Next, the samples were subjected to annealing under enhanced hydrostatic pressure (HP-HT treatment) in inert gas (Ar) atmosphere at up to 1000°C (see Ref. [7] for details of the method). Experimental conditions applied for studied samples are given in Table 1. The HP-HT treatment is known to affect strongly the profiles of implanted ions in silicon as well as to influence the creation of clusters/precipitates containing the implanted species, *e.g.* oxygen [8].

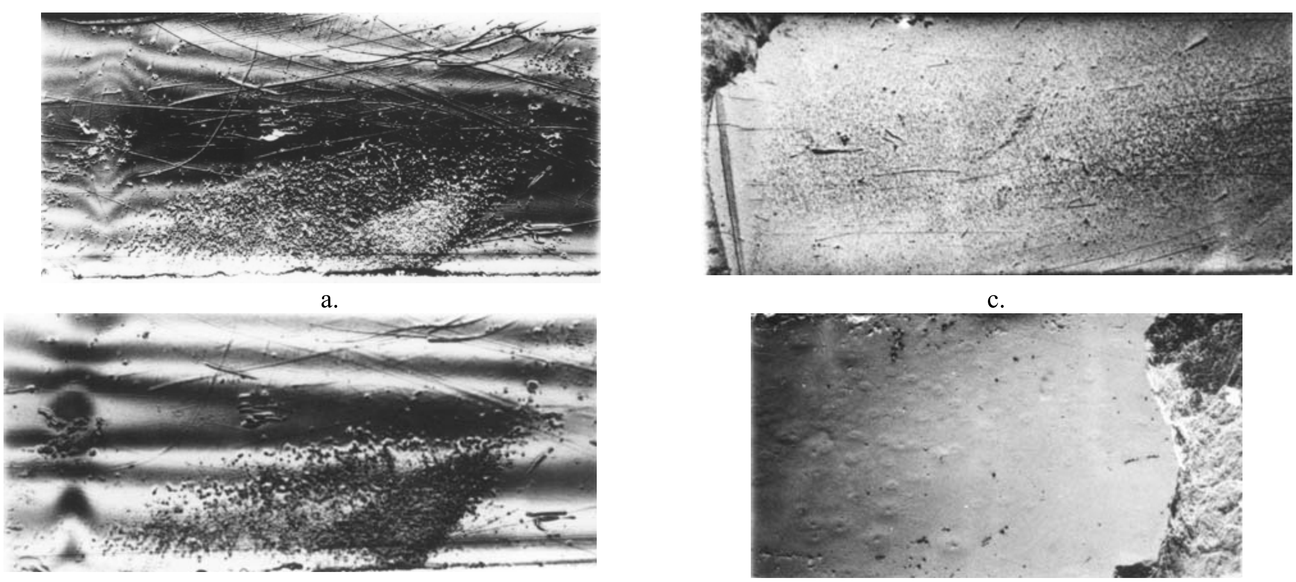
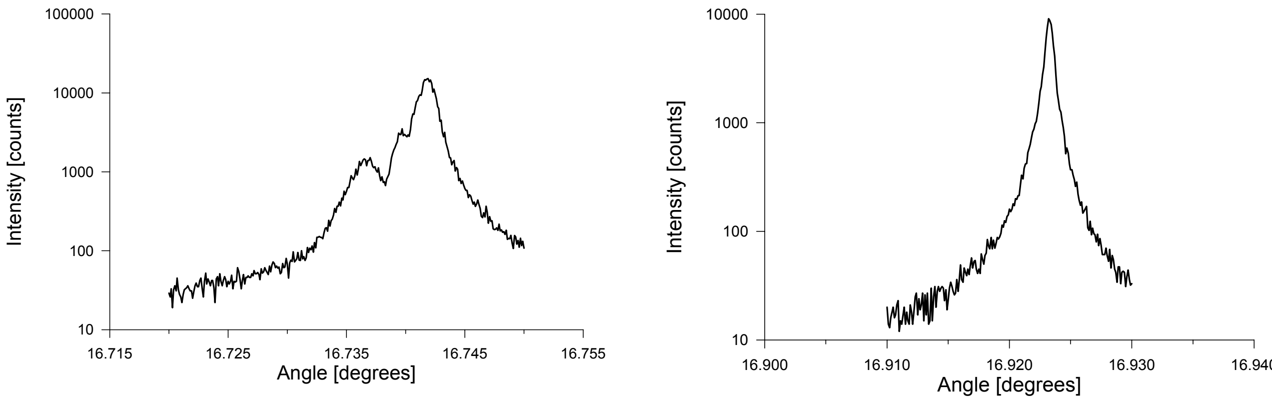


Figure 1. Monochromatic beam topographs from: (a) and (b) - sample 1 taken for different angular positions, (c) - sample 2, and (d) - sample 4.



a **b**

Figure 2. Rocking curves recorded in (511) asymmetric reflection of 0.115 nm radiation with small point probe beam $50\times100\ \mu m^2$ from samples 1 (a) and 3 (b).

The samples were investigated at the monochromatic-beam station E-2 at HASYLAB [(511) asymmetric reflection of 0.115 nm radiation] by recording local rocking curves using the beam limited to the $50\times100\ \mu m^2$ and by taking monochromatic beam topographs at various angular positions with $2\times8\ mm^2$ beam.

Table 1: Condition of HP – HT treatment.

Sample	HT [°C]	HP [kbar]	Duration [h]
1	325	11.0	0.75
2	1000	11.46	1.0
3	450	10.6	10.0
4	650	11.0	10.0

It was found that only the treatment performed during 0.75 h at 325°C (sample 1) did not remove the strain caused by ion implantation. In this case we observed the interference maxima at low angle side of the main peak (Fig. 2a), characteristic for the strain maximum located at certain depth under the surface [9, 10]. The topographs, presented in Figures 1a and 1b, taken for this sample revealed some interference fringes, forming the pattern corresponding to the irregularities of the ion dose, and changing for different angular setting. For the treatment performed at higher temperatures (samples 2, 3 and 4) we observed a single maximum only with insignificant amount of diffuse scattering (Fig. 2b). We observed some contrast at the topographs shown in Figures 1c and 1d, which may be attributed to some initial stages of the exfoliation. Almost complete exfoliation was observed in the case of the treatment performed at the temperature 650°C for 11 hours (Fig. 1d).

Paper was presented at the 6th National Symposium of Synchrotron Radiation Users, Warsaw, 8 – 9 September 2005; extended abstract was published in "Synchrotron Radiation in Natural Science. Bulletin of the Polish Synchrotron Radiation Society", Vol. ***4*** *(2005) 40-41.*

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15. Project ICARE at HIL

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ICARE is the charged particles detector system used for their identification and energy measurements. Built in the IReS (Strasbourg), during next years will be used at HIL by the physicist teams from Strasbourg, Cracow, Kiev and Warsaw.

The ICARE system consists of the 1m diameter reaction chamber with 48 E-ΔE gas and semiconductor telescopes, supplied with the electronics and data acquisitions systems (see Fig.1). The detectors can be mounted in any configuration preferred by users, using internal mounts. The self-supporting target holder allows to use up to 6 different targets. It can be remotely operated without necessity of opening the reaction chamber. The detector system layout is presented in Fig.2.

In the near future several experiments are planned to be performed using the ICARE system:

- Study of the entrance channel effects on light-charged particles emission in deep-inelastic collisions [1]

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* ICARE collaboration involves: Heavy Ion Laboratory, Warsaw University; Institute of Experimental Physics, Warsaw University, Poland; Institut de Recherches Subatomiques, Strasbourg, France; The Henryk Niewodniczański Institute of Nuclear Physics, PAN, Kraków, Poland; Institute for Nuclear Research, Kiev, Ukraine.

- Study of nucleus deformation using light-charged particles emission spectra [2]
- Experimental measurement of emission barriers using quasi-elastic scattering [3]
- Study of properties of isotopes far from stability line produced in heavy-ion reactions[4]

These experiments are, to some extent, continuation of the study performed in the past in HIL[3,4], as well as performed by HIL researchers in other European laboratories[1,2]. The project milestones:

- April 2004 - first ideas
- December 2004 - official statement from IReS and HIL
- December 2004 - program PICS dedicated for the project started
- May 2005 - ICARE set-up test performed in Strasbourg
- July 2005 - experimental vault for ICARE adapted
- November 2005 - ICARE transported to Warsaw
- December 2005 - assembly of ICARE mechanical parts in the vault (with the help of IReS team)

The first test experiment using the beam from Warsaw Cyclotron is expected in 2006.

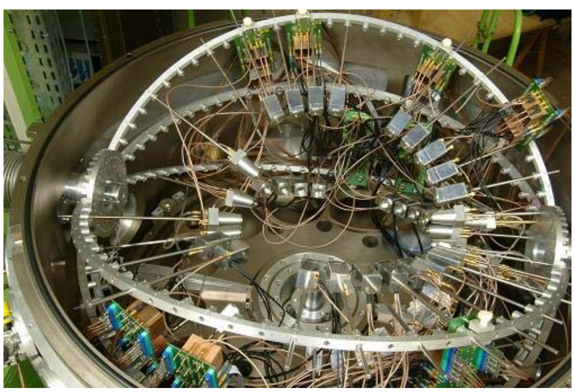

Fig.1. ICARE detectors inside the chamber

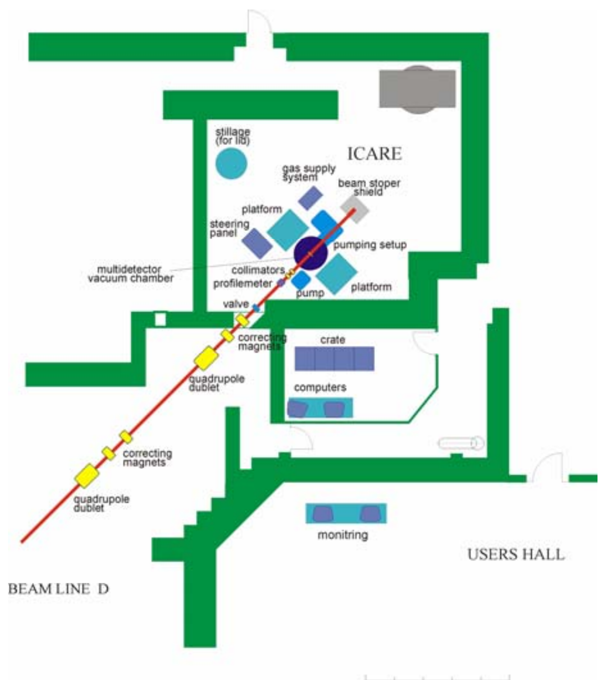

Fig.2. Experimental hall layout

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Part C:

Experiments using the outside facilities

1. Coulomb excitation of a neutron-rich ^{88}Kr beam – search for Mixed Symmetry states

*J.Iwanicki, T.Czosnyka, A.Hurst[1], J.Mierzejewski[2], D.Mücher[3], K.Wrzosek[2], M.Zielińska and ISOLDE/REX/MINIBALL collaborationT**

1) Oliver Lodge Laboratory, University of Liverpool
2) PhD student at HIL
3) Institut für Kernphysik, Universität zu Köln

The aim of the IS423 experiment is to measure properties of the predicted Mixed Symmetry [1] 2_3^+ state of ^{88}Kr at 2.216 MeV using Coulomb Excitation of the radioactive, post-accelerated krypton beam. The experiment involved ISOLDE primary target/separator/beamline, REX post-accelerator assembly and MINIBALL detection system. The first test run was unexpectedly made in November 2003 thanks to a generous gesture of IS405 experiment experiencing its own problems and offering some beamtime. Comparing various krypton isotopes excitation on a ^{28}Si target a preliminary value of reduced transition probability $B(E2{:}0^+ \rightarrow 2_1^+)$ was found. An attempt made in July 2004 failed due to technical reasons: a failure of the secondary ion source (REX-EBIS) made any radioactive beam acceleration impossible.

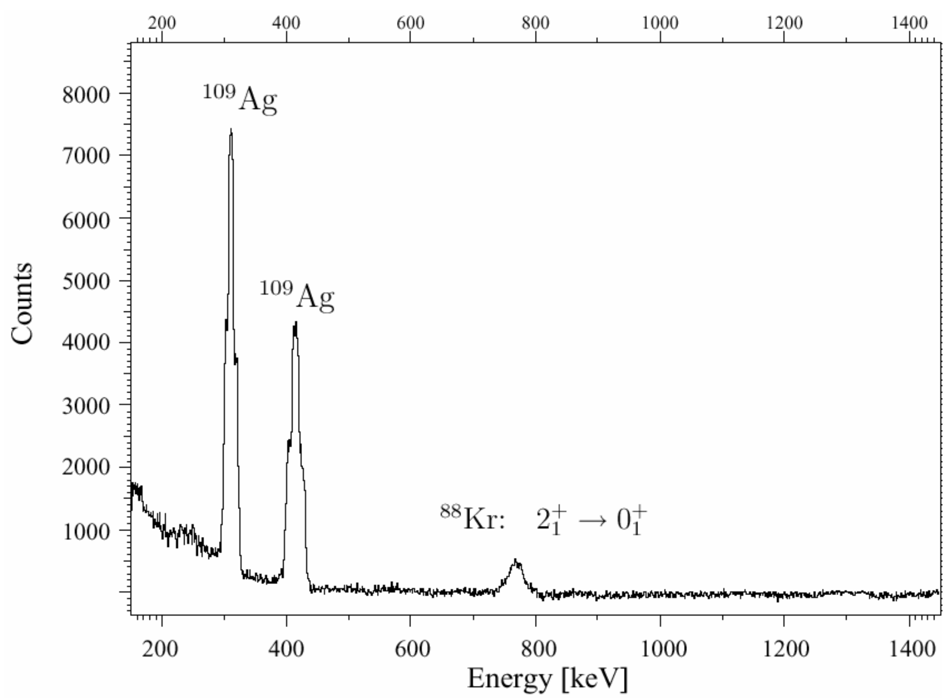

Fig. 1. Gamma-ray energy spectrum after Coulomb excitation of post-accelerated ^{88}Kr beam on ^{109}Ag target

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* Laboratories involved in the experiment and the REX-ISOLDE-MINIBALL collaboration: CERN, Geneva, Switzerland; IKS Leuven, Belgium; LMU Munich, MPI Heidelberg, TU Darmstadt, TU Munich, University of Köln, Germany; Heavy Ion Laboratory, Poland; Lund University, Sweden; University of Edinburgh, University of Liverpool, University of York, United Kingdom;

See the ISOLDE collaboration web page: isolde.cern.ch

In September 2005 another run was scheduled and all the remaining 16 shifts had been planned to be used for irradiation of 2 mg/cm^2 ^{12}C target with a 2.2 MeV/A ^{88}Kr beam. According to simulations, this beam energy, target material and thickness maximize the Mixed Symmetry state excitation cross section.

A very high (as for the secondary beam) intensity of the beam caused unexpected problems with background radiation from the activity collected in the beam dump. A high random coincidence rate, combined with very short REX beam pulse and non-optimal data acquisition solutions resulted in very high dead time and drastic efficiency decrease. After approximately two days of beamtime it became clear that the current set-up will not allow for reaching the main goal of the experiment.

It was decided to make a complementary measurement on an easy to excite ^{109}Ag target for normalization purposes (see figure). This provided data for more precise measurement of the B(E2) value. A test run with ^{92}Kr beam and the same silver target was also performed, giving promising results for possible future studies of other neutron-rich krypton isotopes.

Several modifications are foreseen to make the set-up better suited for the planned measurement. The most important is the beam dump extension and shielding to reduce the background. It is also planned to modify the REX-EBIS release curve to achieve longer beam pulses together with modifications to MINIBALL acquisition system.

After modifications are made a proposal addendum will be submitted asking for more beamtime to complete the measurement.

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2. Antiprotonic X-rays – data interpretation with new potentials

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The studies of antiprotonic atoms were reported in previous HIL Annual Reports [1]. The set of data collected in series of measurements performed at CERN (LEAR facility) was interpreted using the optical potential proposed by Batty et al. [2]. The neutron densities for a wide range of isotopes were determined [3,4]. Last year new, more sophisticated potentials of antiproton-nucleus interaction were made available [5,6]. The new analysis taking into account this latest information is in progress. In particular the detailed studies of data concerning ^{208}Pb are planned.

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3. Impact of ancillary detectors on the performance of the AGATA array

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The "Advanced GAmma Tracking Array" (AGATA)[1] will be the first γ-ray spectrometer in which germanium crystals cover almost entire solid angle, enabling detection of γ-ray radiation in a very large energy range (from few tens of keV up to more than 10 MeV) with the maximum achievable efficiency (about 50%) and a very good quality of spectra. Such device will open new perspectives for the studies of nuclear structure, by enabling observation of γ rays emitted from excited states of nuclei in most exotic regions of spin, excitation energy and isospin.

In most applications, AGATA will be used together with ancillary detectors of various kinds. Such detectors may provide information on beam particles, beam-target interaction point, charged particles and neutrons emitted in the interaction, as well as directly on the produced nuclei emitting γ rays. This information will be used to select nuclei of interest, to determine velocity of the source of the γ-ray radiation (which is necessary for the Doppler correction), and to improve information on the γ-ray emission position (which may perhaps improve the tracking quality). The ancillary detectors may greatly enhance the detection and resolving power of AGATA. On the other hand, their presence will (or may) disturb γ-ray radiation detected in the Ge crystals. The overall impact of the ancillary detectors on the Agata performance has thus to be evaluated in details, prior to any experiments in which ancillary detectors will be employed.

Various ancillary detectors have been already included in the AGATA simulation code [2]. In the Heavy Ion Laboratory the work currently concentrates on the simulation of the Recoil Filter Detector [3], and of the CUP detector [4]. The impact of other detectors, such as the Neutron Wall [5] and EUCLIDES [6] is also evaluated.

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4. Heavy-ion Coulomb excitations as a comprehensive test of microscopic quadrupole collective models

J. Srebrny[1], T. Czosnyka, Ch. Droste[1], S. G. Rohoziński[1], L. Próchniak[2], K. Zając[2], K. Pomorski[2], D. Cline[3], C. Y. Wu[3], A. Bäcklin[4], L. Hasselgren[4], R. M. Diamond[5], D. Habs[6], H. J. Körner[7], F. S. Stephens[5], C. Baktash[8], R. P. Kostecki[1]

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Heavy-ion induced Coulomb excitations make possible to excite states up to high spin and to measure both the signs and magnitudes of the practically complete set of E2 matrix elements for the low laying collective states in the stable even-even nuclei. Sets of data from the Coulomb excitation experiments having a wide range of projectile Z values and scattering angles made it possible to obtain a model independent set transitional and diagonal E2 matrix elements. Here we present results of ^{104}Ru target excitation using ^{58}Ni, ^{136}Xe and ^{208}Pb projectiles [1]. The entire data are confronted to calculations preformed in a frame of the Bohr Generalized Collective Hamiltonian. This Hamiltonian is obtained from a more general "quadrupole plus pairing" collective model trough the Born-Oppenheimer approximation which takes into account the effect of the pairing dynamics [2]. All six inertial functions and the potential were determined from a microscopic theory. Without any parameters fitted to ^{104}Ru experimental data, a very good agreement was obtained between the experimental and theoretical results for absolute energy levels as well as for the rich set (about 30) of E2 matrix elements.

In Fig.1 detailed comparison of experimental and theoretical spin, parity and energy values are shown. One can see that the effect of the pairing dynamics is essential for reproduction of the experimental energy levels. As an example of E2 matrix elements experimental and theoretical comparison in Fig.2 the E2 interband transition matrix elements of γ–transitions from bands based on 0_2^+ and 0_3^+ levels are given. In both figures the comparison with the prediction of the five following models are shown:

1. the standard microscopic quadrupole collective Bohr Hamiltonian – $QCBH_{std}$,
2. the microscopic quadrupole collective Bohr Hamiltonian with the effect of the dynamical pairing – $QCBH_{dyn}$,
3. the rigid triaxial rotor – D-F,
4. the γ-unstable β-vibrator in the version of ref. [3] – W-J ,
5. the standard quadrupole harmonic vibrations – harm. vibr.

Such comprehensive test of microscopic quadrupole collective models was not possible by any other experimental methods but heavy-ion induced Coulomb excitations.

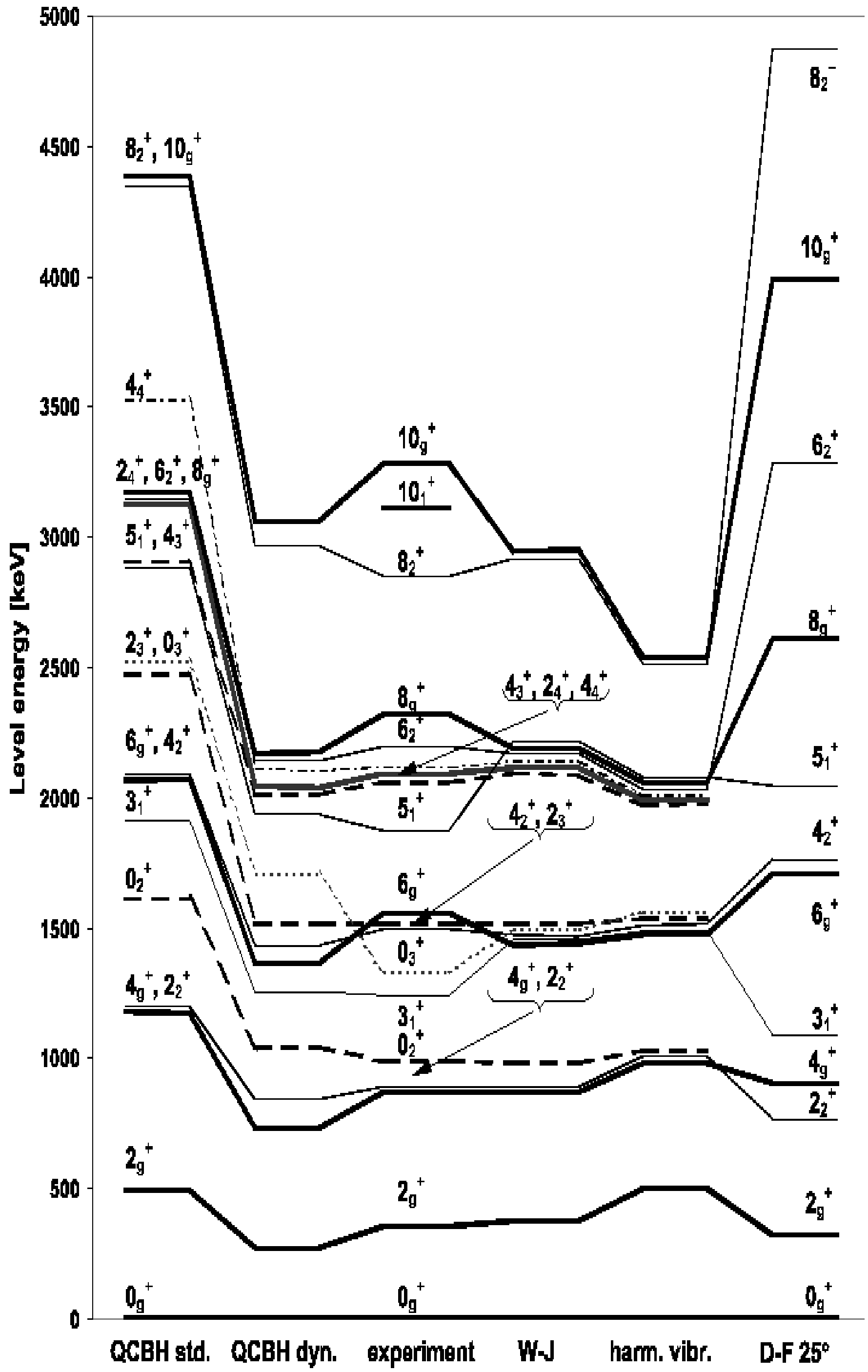

Fig. 1. Comparison of experimental and theoretical energy levels values. Ground state band levels are marked by thick continous lines, 2_2^+ band levels are marked by thin continous lines, 0_2^+ band levels are marked by thick dashed lines, 0_3^+ band levels are marked by dotted lines.

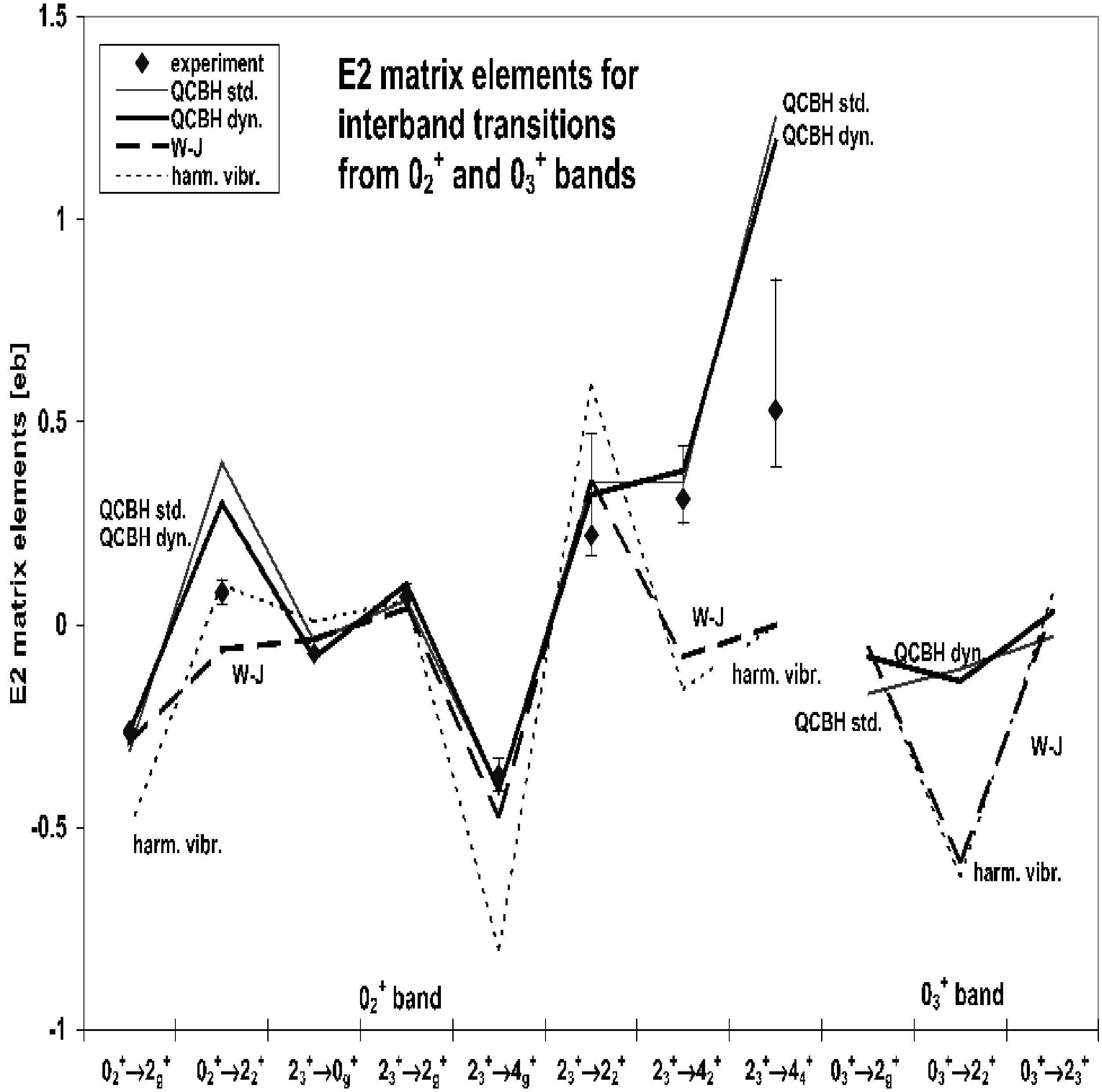

Fig. 2. E2 matrix elements for interband transitions from 0_2^+ and 0_3^+ bands.

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Part D:

General information on HIL activities

1. Educational and science popularization activities at HIL

Apart from its main committment – provididing the heavy-ion beams to the users – the Laboratory is strongly engaged in diversified educational activities, addressed to those interested from high-school students to professionalists. As in previous years the program of cyclotron guided tours (by appointment) attracted large audience. In 2005 the Laboratory hosted 22 organized groups – high school students, Physics and Biology students from Warsaw University, students from Warsaw and Gdańsk Technological Universities, participants of the Polish Physical Society Annual Meeting and winners of a nationwide Physics Contest „ Search for Talents". Dependent on the audience the program of the tours is diversified , including (when necessary) a basic introduction to nuclear physics, a lecture about the need of accelerators to probe the subatomic world, animated computer show illustrating the principles of cyclotron operation, cyclotron control room, cyclotron vault and finally experimental set-ups and a possibility to look at the running experiment, if active at the time. Altogether about 650 people visited the Laboratory in the framework of the guided-tours program in 2005. It should be stressed that the access is free of charge and is organized by HIL staff beyond normal duties.

In March 2005 the first Polish Workshop on Heavy Ion Acceleration and its Applications was organized at HIL. The Workshop was designed for third year physics students interested in nuclear physics. The participants gained experience in methods of data acquisition and analysis, in operating the cyclotron including the beam diagnostic measurements and in charged particles and gamma rays detection (more see Sec. 7).

For the ninth year HIL actively participated in the annual Warsaw Festival of Science. Two so-called Festival Lessons for high-school students (by appointment, heavily overbooked) – „Physics for Goalkeepers" (P.J. Napiorkowski, attendance about 120) and „Flight to Mars – what with?" (L. Pieńkowski, attendance also about 120) were an obvious success. Open weekend meetings with lectures by P.J. Napiorkowski, L. Pieńkowski and M. Zielińska - „Physics for Goalkeepers", „Mysteries of Your Vacuum Cleaner", „Flight to Mars – what with?", „Nuclear Energy –Yes,but how?" and „How to See an Atomic Nucleus" - attracted about 200 people vividly interested in discussing the presented matters. In parallel guided tours of the Laboratory were offered, similar to those mentioned above – more than 250 people participated. HIL also assumed some organizational effort such as distribution of invitations and service of lecture rooms for outside presenters.

For the third time HIL participated in Science Picnic organized at New Town Market Square by Radio BIS. More than 400 people of all ages, just coming from the street, were enjoying improvised „nuclear physics" games, set up in the Laboratory tent. While games were fun, the questions frequently asked were serious and the answers maybe moderated the feelings associated with the word „nuclear" among some of the public.

In the annual "Science Popularizer" contest organized by Polish Press Agency Paweł Napiorkowski was awarded for the best presentation during the "Day of Science", 18 September 2004.- „Mysteries of Your Vacuum Cleaner".

HIL staff is also engaged in routine educational activity within the Department of Physics student laboratories, as well as in supervision of MSc and PhD theses – see below. The Laboratory has organized the summer student workshops for students from Warsaw Technical University. Their activity was supervised by Laboratory staff members: Paweł Napiorkowski and Marcin Palacz.

As can be seen HIL maintains its profile as an institution strongly devoted to educational mission in addition to routine operation and research.

1.1 PhD theses of the Laboratory staff members and PhD students affiliated at HIL

MSc. Magdalena Zielińska
Struktura elektromagnetyczna jąder atomowych izotopów molibdenu badana metodą wzbudzenia kulombowskiego
Electromagnetic structure of the molybdenum isotopes atomic nuclei investigated using the Coulomb excitation method
Supervisor : dr hab.T.Czosnyka. Thesis defended on January 16 th, 2006

MSc. Marzena Wolińska-Cichocka
Struktura jąder neutronowo deficytowych z obszaru A~100 tworzonych w reakcjach z ciężkimi jonami
Structure of the neutron deficient nuclei from the A~100 region produced in heavy ion reactions
Supervisor: prof. dr hab. J.Kownacki. Expected completion time: 2006

MSc. Jan Mierzejewski
Supervisor: prof. dr hab.T..Matulewicz. Expected completion time: 2009

MSc. Katarzyna Wrzosek
Supervisor: dr hab.T.Czosnyka. Expected completion time: 2009

1.2 PhD theses completed in 2005 or in progress based on the experiments on the Warsaw Cyclotron

V.M. Kyryanchuk, Institute for Nuclear Research of Ukrainian Akademy of Sciences
Scattering and transfer reactions in collisions of ^{9}Be+^{11}B nuclei
Supervisor: prof. A.T. Rudchik. Thesis defended on January 20th , 2005

Izabela M. Fijał, The Andrzej Sołtan Institute for Nuclear Studies
Wpływ efektów jonizacji wielokrotnej i sprzężeń powłokowych na emisję promieniowania rentgenowskiego serii L wzbudzonego ciężkimi jonami
Supervisor: prof. dr hab. M. Jaskóła. Thesis defended on June 27 th, 2005

Sergei Mezhevych, The Andrzej Sołtan Institute for Nuclear Studies
Scattering of ^{11}B nuclei from carbon isotopes
Supervisor: dr hab. K. Rusek. Thesis defended on November 22th, 2005

Łukasz Świderski, Faculty of Physics Warsaw University
Badanie rozkładu barier na fuzję ^{20}Ne z izotopami Sn i Ni
Supervisor: dr hab. E. Piasecki. Thesis defended on December 5th, 2005

Olimpia Kijewska, Faculty of Physics Warsaw University
Badanie emisji lekkich cząstek naładowanych w zderzeniach ciężkich jonów o energiach 4-12 MeV/u jako źródło informacji o lekkich jądrach gorących
Supervisor: prof. dr hab. M. Kicińska-Habior. Expected completion time: 2006

Elżbieta Wójcik, Faculty of Physics Warsaw University
Badanie zmieszania izospinowego w jądrach gorących poprzez wzbudzenie Gigantycznego Rezonansu Dipolowego

Supervisor: prof. dr hab. M. Kicińska-Habior. Expected completion time: 2006

Jan Kurcewicz, Faculty of Physics Warsaw University
Poszukiwanie stanów izomerycznych powyżej ołowiu
Supervisor: dr hab. M. Pfützner. Expected completion time: 2006

Ernest Grodner, Faculty of Physics Warsaw University
Badanie czasów życia jądrowych poziomów wzbudzonych ^{132}La i ^{128}Cs jako test łamania symetrii chiralnej
Supervisor: dr hab. T. Morek. Expected completion time: 2006

Iwona Zalewska, Faculty of Physics Warsaw University
Badanie pikosekundowych czasów życia stanów wzbudzonych izotopów cezu
Supervisor: dr hab. T. Morek, Expected completion time: 2007

Joanna Czub, Faculty of Physics Świętokrzyska Academy
Biologiczne działanie promieniowania o wysokim LET
Supervisor: prof. dr hab. J. Braziewicz. Expected completion time: 2007

A.A. Rudchik, Institute for Nuclear Research of Ukrainian Akademy of Sciences
Interaction of nuclei ^{7}Li+^{11}B+^{18}O, ^{8}Be+^{15}N in ground and excited states
Supervisor: dr O.A. Ponkratenko. Expected completion time: 2007

V.O. Romanyshyn, Institute for Nuclear Research of Ukrainian Akademy of Sciences
Isotopic and isobaric effects in ^{6,7}Li+^{10}B reactions
Supervisor: prof. A.T. Rudchik. Expected completion time: 2008

1.3 MSc. theses completed in 2005 or in progress, supervised by HIL staff members

Katarzyna Wrzosek, Faculty of Physics, Warsaw University
Badanie struktury elektromagnetycznej jądra ^{100}Mo metodą wzbudzeń kulombowskich
Supervisors: dr hab. T. Czosnyka, dr J. Srebrny. Completed in 2005.

Jacek Gałkowski, Faculty of Physics, Warsaw University of Technology
Badanie struktury jąder z obszaru ^{100}Sn produkowanych w reakcjach fuzji-ewaporacji z wiązką ^{58}Ni na tarczy ^{45}Sc
Supervisor: dr M. Palacz.

1.4 MSc. theses completed in 2005 or in progress based on the experiments on the Warsaw Cyclotron

Małgorzata Gawinek, Faculty of Physics Warsaw University
Badanie procesu hamowania jąder odrzutu lantanu w reakcjach ciężkojonowych
Supervisor: dr J. Srebrny. Completed in 2005

Jan Mierzejewski, Faculty of Physics Warsaw University
Filtr krotności BGO jako narzędzie badania kwantów γ w reakcjach ciężko-jonowych
Supervisor: dr J. Srebrny. Completed in 2005

Paweł Czosnyka, Faculty of Physics Warsaw University
Badanie transferu cząstek naładowanych w quasi-elastycznym rozproszeniu $^{20}Ne + {}^{A}Sn$ w pobliżu bariery kulombowskiej
Supervisor: dr hab. E. Piasecki. Completed in 2005

Olga Steczkiewicz, Faculty of Physics Warsaw University
Badanie krótkożyciowych izotopów przy użyciu separatora typu IGISOL
Supervisor: prof. dr hab. W. Kurcewicz

Aleksandra Krasińska, Faculty of Physics Warsaw University
Emisja cząstek naładowanych w reakcji $^{20}Ne + {}^{12}C$
Supervisor: prof. dr hab. Marta Kicińska-Habior

Anna Karbowska, Faculty of Physics Warsaw University
Gigantyczny rezonans dipolowy w jądrach argonu
Supervisor: prof. dr hab. Marta Kicińska-Habior

Tomasz Adamus, Faculty of Physics Warsaw University
Optymalizacja odchylania wiązki ^{12}C dla badań radiobiologicznych
Supervisor: dr hab. Z. Szefliński

Jan Dyczewski, Faculty of Physics Warsaw University
Opracowanie metodyki uzyskania jednorodnej wiązki jonów z Cyklotronu Warszawskiego
Supervisor: dr hab. Z. Szefliński

Agnieszka Żywno, Faculty of Physics Warsaw University
Nowe technologie w budowie skanerów dla diagnostyki medycznej
Supervisor: dr hab. Z. Szefliński

Paweł Tarnowski, Faculty of Physics Warsaw University
Badanie struktury jadra ^{125}I
Supervisor: dr hab. Tomasz Morek

1.5 BSc theses based on the Warsaw Cyclotron activity

Robert Maj, Faculty of Physics Warsaw University
Opracowanie strony internetowej pomiarów czasów życia poziomów jądrowych z wykorzystaniem efektu Dopplera
Supervisors: dr J. Srebrny and dr R. Budzyński. Completed in 2005

Urszula Górak, Faculty of Physics Warsaw University
Układ eksperymentalny do badań radiobiologicznych na wiązce Cyklotronu Warszawskiego
Supervisor: dr hab. Z. Szefliński

2. Seminars

2.1. Seminars at HIL

J.Sura January 20
Układy elektromagnetyczne zwiększające prąd wiązki z cyklotronu

M.Kicińska-Habior,W.Kurcewicz,I.Zalewska March 22
Z.Szefliński, A.Wójcik, H.Parchomenko, J.Iwanicki, J.Miszczak, J.Kownacki
Prezentacja eksperymentów zgłoszonych do wykonania na wiązkach warszawskiego cyklotronu w okresie od kwietnia do czerwca/lipca 2005

J.Miszczak, A.Jakubowski, A.Pietrzak, B.Filipiak, T.Bracha,
M.Kopka, V.Khrabrov, L.Pieńkowski June 30

Stan zaawansowania prac modernizacyjnych warszawskiego cyklotronu w roku 2005

J.Toke October 11
Jądro złożone z entropią powierzchniową. Jednolity opis parowania rozszczepienia, produkcji fragmentów i multifragmentacji

J.Sura October 20
Spektrometr typu Parabola Thomsona do diagnostyki cząstek lasera ABC ENEA - Frascati, Italy

E. Wójcik, K. Rusek, T. Morek, W. Kurcewicz, Z.Szefliński, A.Wójcik, October 25
K.Wrzosek, J. Perkowski, Ł. Świderski
Prezentacja eksperymentów zgłoszonych do wykonania na wiązkach warszawskiego cyklotronu w okresie od listopada 2005 do lutego/marca 2006

2.2. External seminars given by HIL staff

A. Trzcińska February 23
Antiprotonic atoms X rays
EXA '05, Stefan Meyer Institut für subatomare Physik - Austrian Academy of Sciences, February 21-25, 2005, Wien, Austria

J. Jastrzębski February 28
Tomografia pozytonowa w Warszawie - *Positron Tomography in Poland*
Jerzy Pniewski Colloquium, Faculty of Physics, Warsaw University

J. Jastrzębski March 15
Research at Warsaw Cyclotron
North-East European Network meeting "Central Europe Nuclear Physics"
Prague, Czech Republic, 14.3.-16.3. 2005

J. Choiński March 15
Project of a PET radiopharmaceutical production center at HIL
North-East European Network meeting "Central Europe Nuclear Physics"
Prague, Czech Republic, 14.3.-16.3. 2005

A. Trzcińska March 16

Antiprotonic atoms - a tool for the investigation of the nuclear periphery
Workshop on Physics with Ultra Slow Antiproton Beams
14-16 March 2005, RIKEN, Japan

T. Czosnyka, P. Napiorkowski June 9
Analysis of Coulex data
INTAG meeting, Saclay, France, 8-9 June 2005

A. Kordyasz June 24
New Silicon Detectors, Technologies and Applications
Meeting of the Physics & Instrumentation Task of the EURISOL Design Study, 24 June 2005, Liverpool, UK

J. Kownacki July 5
Entry line and angular momentum transfer studies for A~110-130 in heavy-ion fusion evaporation reactions
NBI, University of Copenhagen

K. Wrzosek August 27
Search for shape coexistence in even-even stable molybdenum isotopes using Coulomb excitation method
12th Euroschool on Exotic Beams, Mainz, August 25th - September 2nd, 2005

K. Wrzosek September 23
Search for shape coexistence in even-even stable molybdenum isotopes using Coulomb excitation method
XII Nuclear Physics Workshop Marie and Pierre Curie, Nuclear Structure and Low Energy Reactions, September 21-25, 2005, Kazimierz Dolny, Poland

T. Czosnyka, M.Zielińska September 26
Coulex data analysis using the GOSIA code - lecture and workshop
MINIBALL Working Meeting, 26-27 September 2005, CERN, Switzerland

J. Jastrzębski September 29
Warszawski Ośrodek Tomografii Pozytonowej - ***Warsaw PET Centre***
National Conference "Physics and engineering in the present medicine and health care - the challenges to Poland as a new EU member" 29-30 September 2005, Warszawa, Poland

M. Palacz October 6
Approaching single-particle states around ^{100}Sn
SPIRAL2 Workshop: "Future prospects for high resolution gamma spectroscopy at GANIL" 4-5-6th October, 2005

J. Choiński October 6
Heavy Ion Laboratory, Warsaw University – today and in the near future
XXXIV European Cyclotron Progress Meeting (XXXIV ECPM), Oct. 6-8 2005, Belgrade, Serbia and Montenegro

A. Kordyasz October 7
Response to heavy ions of 50 μm thick ΔE strip detectors produced by PPPP process

7th International Conference on Large Scale Applications and Radiation Hardness of Semiconductor Detectors, October 5-7, 2005 - Florence, Italy

J. Choiński October 26
Heavy Ion Laboratory of the Warsaw University and Warsaw PET Centre
Cyclotron Research Infrastructures "Enlargement and Integration Workshop"
26-28 October 2005, Joint Research Centre, Ispra, Italy

M. Zielińska, K. Wrzosek November 4
Wzbudzenie kulombowskie parzysto-parzystych izotopów molibdenu – ***Coulomb excitation of even-even molybdenum nuclei***
Faculty of Physics, Warsaw University,

M.Palacz November 23
Ancillary detector impact on AGATA performance
The AGATA Week, 21-25th November 2005, IreS Strasbourg, France

M.Palacz December 16
AGATA dobrze się zapowiada, czyli przyszłość spektroskopii gamma
Faculty of Physics, Warsaw University

2.3 Poster Presentations

E. Kulczycka
ECR ion source and injection line for the Warsaw cyclotron
CERN Accelerator School "Small Accelerators", Zeegse, the Netherlands
24 May - 2 June 2005

K. Wrzosek, M. Zielińska
Search for shape coexistence in even-even stable molybdenum isotopes using Coulomb excitation method
12th Euroschool on Exotic Beams, Mainz, August 25th - September 2nd, 2005

A. Kordyasz
Response of thin, large-area dE strip detectors by the PPPP process to light & heavy ions
EURISOL Design Study – Town Meeting, 28-29 November 2005, Caen, France

2.4. Science popularization lectures during the Ninth Science Festival, September 2005

P.Napiorkowski
Tajemnice twojego odkurzacza – ***The mysteries of your vacuum cleaner***

P.Napiorkowski
Fizyka dla bramkarzy – ***Physics for goalkeepers***

L.Pieńkowski
Energetyka jądrowa? Tak, ale jak? - ***Nuclear energy? Yes, but how?***

L.Pieńkowski
Czym polecieć na Marsa? - *How to reach Mars?*

M.Zielińska
Jak zobaczyć jądro atomowe? - *How to see an atomic nucleus?*

3. ISI listed publications, other publications

3.1. Publications in journals listed by ISI

3.1.1 Publications resulting from work performed with the HIL facilities

Calibration of PM-355 nuclear detectors track, comparison of track diameter diagrams with track characteristics depth,
A.Szydłowski, B.Sartowska, A.Banaszak, J.Choiński, I.Fijał, M.Jaskóła, A.Korman, MJ.Sadowski,
RADIAT. MEAS. **40**, 401(2005)

^{7}Li+^{11}B elastic and inelastic scattering in a coupled-reaction-channels approach
A.A.Rudchik, A.T.Rudchik, G.M.Kozeratska, O.A.Ponkratenko, E.I.Koshchy, A.Budzanowski, B.Czech, S.Kliczewski, R.Siudak, I.Skwirczyńska, A.Szczurek, S.Y.Mezhevych, K.W.Kemper, J.Choiński, T.Czosnyka, L.Głowacka,
PHYS.REV.**C72**, 034608(2005)

Highly efficient charged particle veto detector CUP
M.Palacz, J.Nyberg, P.Bednarczyk, J.Dworski, M.Górska, J.Iwanicki, M.Kapusta, J.Kownacki, E.Kulczycka, K.Lagergren, M.Moszyński, L.Pieńkowski, A.Stolarz, D.Wolski, M.Ziębliński,
NUCL.INST.METH.PHYS.RES.**A 550**, 414(2005)

Response of semi-insulating 100 µm thick GaAs detector for alpha-particles, gamma-rays and X-rays
AJ.Kordyasz, SG.Strzelecka, J.Kownacki, L.Dobrzański, A.Hruban, W.Orłowski, E.Wegner, L.Reissig,
NUCL.INST.METH.PHYS.RES.**A 545**, 716(2005)

Gamma-ray spectroscopy in ^{110}Sn and ^{111}Sn
M. Wolińska-Cichocka, J.Kownacki, W.Urban, E.Ruchowska, W.A.Płóciennik, B.Bekman, C.Droste, W.Gast, R.Lieder, W.Męczyński, M.Kisieliński, A.Kordyasz, M.Kowalczyk, P.Kowina, J.Iwanicki, T.Morek, J.Perkowski, J.Srebrny, A.Stolarz, J.Styczeń,
EUR.PHYS.J.**A24**, 259(2005)

Lifetime measurements in ^{128}Cs and ^{132}La as a test of chirality
E.Grodner, I.Zalewska, T.Morek, J.Srebrny, C.Droste, M.Kowalczyk, J.Mierzejewski, M.Sałata, A.A.Pasternak, J.Kownacki, M.Kisieliński, A.Kordyasz, P.Napiorkowski, M.Wolińska, S.G.Rohoziński, R.Kaczarowski, W.Płóciennik, E.Ruchowska, A.Wasilewski, J.Perkowski,
INT.J.MOD.PHYS.**E**-NUCL.PHYS. **14**, 347(2005)

Search for shape coexistence in ^{100}Mo using Coulomb excitation
K.Wrzosek, M.Zielińska, J.Choiński, T.Czosnyka, J.Iwanicki, M.Kisieliński, M.Kowalczyk, P.Napiorkowski, L.Reissig, J.Srebrny, I.Ushakov, K.Zając,
INT.J.MOD.PHYS.**E**-NUCL.PHYS. **14**, 359(2005)

Absence of structure in the ^{20}Ne, ^{22}Ne+^{118}Sn quasi-elastic barrier distribution
E.Piasecki, Ł.Świderski, P.Czosnyka, M.Kowalczyk, K.Piasecki, M.Witecki, T.Czosnyka, J.Jastrzębski, A.Kordyasz, M.Kisieliński, T.Krogulski, M.Mutterer, S.Khlebnikov, W.H.Trzaska, K.Hagino, N.Rowley,
PHYS.LETT.**B** **615**, 55(2005)

Excitation of ^{14}C by 45 MeV ^{11}B ions
S.Y.Mezhevych, A.T.Rudchik, K.Rusek, A.Budzanowski, B.Czech, J.Choiński, L.Głowacka, S.Kliczewski, E.I.Koshchy, V.M.Kyryanchuk, A.V.Mokhnach, A.A.Rudchik, S.B.Sakuta, R.Siudak, I.Skwirczyńska, A.Szczurek,
NUCL.PHYS.**A** **753**, 13(2005)

Search for chirality in ^{128}Cs and ^{132}La
J.Srebrny, E.Grodner, T.Morek, I.Zalewska, C.Droste, J.Mierzejewski, A.A.Pasternak, J.Kownacki, J.Perkowski,
ACTA.PHYS.POL.**B** **36**, 1063(2005)

^{20}Ne+^{12}C reaction at 5 and 9 MeV/A studied at the Warsaw cyclotron
O.Kijewska, M. Kicińska-Habior, E.Wójcik, M.Kisieliński, M.Kowalczyk, J.Choiński, W.Czarnacki,
ACTA.PHYS.POL.**B** **36**, 1185(2005)

Shape coexistence in even-even Mo isotopes studied via Coulomb excitation
M.Zielińska, T.Czosnyka, K.Wrzosek, J.Choiński, Y.Hatsukawa, J.Iwanicki, M.Koizumi, H.Kusakari, M.Matsuda, T.Morikawa, P.J.Napiorkowski, A.Osa, M.Oshima, T.Shizuma, J.Srebrny, M.Sugawara, K.Zając,
ACTA.PHYS.POL.**B** **36**, 1289(2005)

Delta E strip detectors produced by PPPP process
AJ.Kordyasz, E. Nossarzewska-Orłowska, J.Wojtkowska, M.Kisieliński, E.Kulczycka, L.Reissig, J.Kownacki, A.Wojtasiewicz, J.Sarnecki, J.Iwanicki,
NUCL.INSTRUM.METH.PHYS.RES.**A** **539**, 262(2005)

Mechanism of the ^{12}C(^{11}B, ^{15}N)^{8}Be reaction and ^{8}Be+^{15}N optical-model potential
A.A.Rudchik, A.Rudchik, A.Budzanowski, A.Szczurek, B.Czech, T.Czosnyka, J.Choiński, L.Głowacka, S.Kliczewski, E.I.Koshchy, S.Y.Mezhevych, A.V.Mokhnach, O.A.Momotyuk, V.M.Pirnak, R.Siudak, I.Skwirczyńska,
EUR.PHYS.J.**A** **23**, 445(2005)

Calibration and application of Solid-State Nuclear Track Detectors in spectroscopy of heavier ions of energy in a few MeV/amu range
A.Szydłowski, A.Banaszak, I.Fijał, J.Choiński, B.Sartowska,
CZECH.J.PHYS. **54**, 228(2005)

3.1.2 Publications resulting from work performed with facilities outside HIL

Shape coexistence in Krypton isotopes studied through Coulomb excitation of radioactive Krypton ion beams
W.Korten, E.Bouchez, E.Clément, A.Chatillon, A.Görgen, Y. Le Coz, C.Theisen, J.Wilson, JM.Casandjian, G.de France, G.Sletten, T.Czosnyka, J.Iwanicki, M.Zielińska, C.Andreoiu, P.Butler, RD.Herzberg, D.Jenkins, G.Jones, F.Becker, J.Gerl, W.Catford, C.Timis,
NUCL.PHYS.**A 746**, 90C(2005)

A low energy storage ring for partly stripped radioactive ions
T.Fritioff, M.Grieser, M.Lindroos, A.Trzcińska,
NUCL.PHYS.A 746, 384C(2005)

Retardation of particle evaporation from excited nuclear systems due to thermal expansion
J.Toke, L.Pieńkowski, L.G.Sobotka, M.Houck, and W.U.Schröder
PHYS. REV. **C 72**, 031601 (2005)

Coulomb excitation of neutron-rich beams at REX-ISOLDE
H.Scheit, O.Niedermaier, V.Bildstein, H.Boie, J. Fitting, R. von Hahn, F.Kock, M.Lauer, U.K.Pal, H.Podlech, R.Repnow, D.Schwalm, C.Alvarez, F.Ames, G.Bollen, S.Emhofer, D.Habs, O.Kester, R.Lutter, K.Rudolph, M.Pasini, P.G.Thirolf, B.H.Wolf, J.Eberth, G. Gersch, H.Hess, P.Reiter, O.Thelen, N.Warr, D.Weisshaar, F.Aksouh, P.Van den Bergh, P.Van Duppen, M.Huyse, O.Ivanov, P.Mayet, J.Van de Walle, J.Aysto, P.A.Butler, J.Cederkall, P.Delahaye, H.O.U.Fynbo, L.M.Fraile, O.Forstner, S.Franchoo, U.Köster, T.Nilsson, M.Oinonen, T.Sieber, F.Wenander, M.Pantea, A.Richter, G.Schrieder, H.Simon, T.Behrens, R.Gernhauser, T.Kroll, R.Krücken, M.Munch, T.Davinson, J.Gerl, G.Huber, A.Hurst, J.Iwanicki, B.Jonson, P.Lieb, L.Liljeby, A.Schempp, A.Scherillo, P.Schmidt, G.Walter,
EUR.PHYS.J **A25**, 397(2005)

"Safe" Coulomb excitation of ^{30}Mg
O.Niedermaier, H.Scheit, V.Bildstein, H.Boie, J.Fitting, R.von Hahn, F.Kock, M.Lauer, U.K.Pal, H.Podlech, R.Repnow, D.Schwalm, C.Alvarez, F.Ames, G.Bollen, S.Emhofer, D.Habs, O.Kester, R.Lutter, K.Rudolph, M.Pasini, P.G.Thirolf, B.H.Wolf, J.Eberth, G.Gersch, H.Hess, P.Reiter, O.Thelen, N.Warr, D.Weisshaar, F.Aksouh, P.Van den Bergh, P.Van Duppen, M.Huyse, O.Ivanov, P.Mayet, J.Van de Walle, J.Aysto, P.A.Butler, J.Cederkall, P.Delahaye, H.O.U.Fynbo, L.M.Fraile, O.Forstner, S.Franchoo, U.Köster, T.Nilsson, M.Oinonen, T.Sieber, F.Wenander, M.Pantea, A.Richter, G.Schrieder, H.Simon, T.Behrens, R.Gernhauser, T.Kroll, R.Krücken, M.Munch, T.Davinson, J.Gerl, G.Huber, A.Hurst, J.Iwanicki, B.Jonson, P.Lieb, L.Liljeby, A.Schempp, A.Scherillo, P.Schmidt, G.Walter,
PHYS.REV.LETT. **94**, 172501(2005)

Difference of the root-mean-square sizes of neutron and proton distributions in nuclei: Comparison of theory with data
W.J.Świątecki, A.Trzcińska, J.Jastrzębski,
PHYS.REV.**C 71**, 047301(2005)

Maximally aligned states in the proton drip line nucleus ^{106}Sb
D.Sohler, M.Palacz, Z.Dombradi, M.Hjorth-Jensen, C.Fahlander, L.O.Norlin, J.Nyberg, T.Back, K.Lagergren, D.Rudolph, A.Algora, C.Andreoiu, G.de Angelis, A.Atac, D.Bazzacco, J.Cederkall, B.Cederwall, B.Fant, E.Farnea, A.Gadea, M.Górska, H.Grawe, N. Hashimito-Saitoh, A.Johnson, A.Kerek, W.Klamra, J.Kownacki, S.M.Lenzi, A.Likar, M.Lipoglavsek, M.Moszyński, DR.Napoli, C.Rossi-Alvarez, H.A.Roth, T.Saitoh, D.Seweryniak, O.Skeppstedt, J.Timar, M.Weisflog, M.Wolińska,
NUCL.PHYS.**A 753**, 251(2005)

Investigation of heavy N similar to Z nuclei using energetic radioactive ion beams
W.Korten, E.Clément, E.Bouchez, A.Chatillon, A.Görgen, Y.Le Coz, C.Theisen, J.M.Casandjian, G.de France, G.Sletten, T.Czosnyka, J.Iwanicki, M.Zielińska, F.Becker, J.Gerl, W.Catford, C.Timis, P.Butler, C.Andreoiu,
NUCL.PHYS.**A 752**: 255c (2005)

The neutron-rich Mg isotopes: first results from MINIBALL at REX-ISOLDE
O.Niedermaier, H.Scheit, V.Bildstein, H.Boie, J.Fitting, R.von Hahn, F.Kock, M.Lauer, U.K.Pal, H.Podlech, R.Repnow, D.Schwalm, C.Alvarez, F.Ames, G.Bollen, S.Emhofer, D.Habs, O.Kester, R.Lutter, K.Rudolph, M.Pasini, P.G.Thirolf, B.H.Wolf, J.Eberth, G.Gersch, H.Hess, P.Reiter, O.Thelen, N.Warr, D.Weisshaar, F.Aksouh, P.Van den Bergh, P.Van Duppen, M.Huyse, O.Ivanov, P.Mayet, J.Van de Walle, J.Aysto, P.A.Butler, J.Cederkall, P.Delahaye, H.O.U.Fynbo, L.M.Fraile, O.Forstner, S.Franchoo, U.Köster, T.Nilsson, M.Oinonen, T.Sieber, F.Wenander, M.Pantea, A.Richter, G.Schrieder, H.Simon, T.Behrens, R.Gernhauser, T.Kroll, R.Krücken, M.Munch, T.Davinson, J.Gerl, G.Huber, A.Hurst, J.Iwanicki, B.Jonson, P.Lieb, L.Liljeby, A.Schempp, A.Scherillo, P.Schmidt, G.Walter,
NUCL.PHYS.**A 752**, 273C(2005)

Shape coexistence in light krypton isotopes
A.Görgen, E.Clément, E.Bouchez, A.Chatillon, W.Korten, Y.Le Coz, C.Theisen, C.Andreoiu, F.Becker, B.Blank, A.Burger, P.Butler, JM.Casandjian, W.Catford, T.Czosnyka, P.Davies, S.P.Fox, G.de France, G.Georgiev, J.Gerl, H.Hubel, J.Iwanicki, D.G.Jenkins, F. Johnston-Theasby, P.Joshi, I.Matea, P.Napiorkowski, F.D.Santos, G.Sletten, C.Timis, R.Wadsworth, M.Zielińska,
ACTA.PHYS.POL.**B 36**, 1281(2005)

3.2 Other conference contributions

Antiprotonic atoms X rays
A.Trzcińska, J.Jastrzębski, P.Lubiński, B.Kłos, F.J.Hartmann, T.von Egidy, S.Wycech
Proceedings of EXA '05, Stefan Meyer Institut für subatomare Physik - Austrian Academy of Sciences, February 21-25, 2005, Wien, Austria

Antiprotonic atoms - a tool for the investigation of the nuclear periphery
A.Trzcińska, J.Jastrzębski, P.Lubiński, B.Kłos, F.J.Hartmann, T.von Egidy, S.Wycech
AIP Conference Proceedings, Vol 793, 214 (2005)
Workshop on Physics with Ultra Slow Antiproton Beams,14-16 March 2005, RIKEN, Japan

3.3. Internal reports

Projekt instalacji siłowej zasilającej pompy poziomów w pomieszczeniu 43 cyklotronu U 200
M.Kopka, V.Khrabrov, P.Krysiak, K.Łabęda, Z.Morozowicz, K.Pietrzak
Konsultacja: J.Choiński, J.Kurzyński

4. Laboratory Staff

Director: Jerzy Jastrzębski
Deputy directors: Jarosław Choiński and Tomasz Czosnyka
Financial executive: Paweł Napiorkowski
Secretary: Iwona Tomaszewska

Senior Scientists:
Tomasz Czosnyka, Jerzy Jastrzębski, Jan Kownacki, Ludwik Pieńkowski, Józef Sura

Scientific staff and engineers:
Andrzej Bednarek, Bohdan Filipiak, Wojciech Gawlikowicz, Dorota Hechner, Jędrzej Iwanicki, Andrzej Jakubowski, Viatcheslav Khrabrov, Maciej Kisieliński[a)], Andrzej Kordyasz, Michał Kowalczyk[a)], Ewa Kulczycka, Janusz Kurzyński[a)], Ireneusz Mazur, Jan Miszczak, Marcin Palacz, Mateusz Sobolewski, Anna Stolarz, Roman Tańczyk, Agnieszka Trzcińska, Jan Tys[a)], Magdalena Zielińska

Doctoral candidates:
Marzena Wolińska-Cichocka, Jan Mierzejewski [b)], Katarzyna Wrzosek[b)]

Technicians:
Mariusz Antczak, Tomasz Bracha, Marek Figat, Andrzej Górecki, Janusz Jasiński, Piotr Jasiński, Wiesław Kalisiewicz, Zdzisław Kondeja[c)], Marian Kopka, Zbigniew Kruszyński, Piotr Krysiak, Krzysztof Łabęda, Zygmunt Morozowicz, Bogusław Paprzycki, Wiesław Perkowski[a)], Andrzej Pietrzak, Krzysztof Pietrzak, Ryszard Pozorek, Irena Skrzeczanowska, Krzysztof Sosnowski

Administration and support:
Edyta Czerwonka[a)], Danuta Gałecka, Ewa Sobańska, Krystyna Szczepaniak, Hanna Szczekowska[a)], Iwona Tomaszewska, Joanna Wasilewska, Wanda Wesoły, Andrzej Wiechowski

a) *part time*
b) *PhD student at HIL from Institute of Experimental Physics, Warsaw University*
c) *Retired since 1st September, 2005*

5. Laboratory Scientific Council

1. Prof. dr hab. Andrzej Białynicki-Birula
   Wydział Matematyki, Informatyki i Mechaniki UW
   Warszawa, ul. Banacha 2
2. Prof. dr hab. Janusz Braziewicz
   Instytut Fizyki, Akademia Świętokrzyska
   Kielce, ul. Świętokrzyska 15
3. Prof. dr hab. Andrzej Budzanowski
   Instytut Fizyki Jądrowej
   Kraków, ul. Radzikowskiego 152
4. Prof. dr hab. Katarzyna Chałasińska-Macukow
   Prorektor UW
   Warszawa, ul. Krakowskie Przedmieście 26/28
5. Dr hab. Tomasz Czosnyka
   Środowiskowe Laboratorium Ciężkich Jonów UW
   Warszawa, ul. Pasteura 5A
6. Prof. dr hab. Marian Jaskóła
   Instytut Problemów Jądrowych
   Warszawa, ul. Hoża 69
7. Prof. dr hab. Marta Kicińska-Habior (Chairman)
   Wydział Fizyki UW
   Warszawa, ul. Hoża 69
8. Prof. dr hab. Jan Kownacki
   Środowiskowe Laboratorium Ciężkich Jonów UW
   Warszawa, ul. Pasteura 5A
9. Doc. dr hab. Adrian Kozanecki
   Instytut Fizyki PAN
   Warszawa, al. Lotników 32/46
10. Prof. dr hab. Reinhard Kulessa
    Uniwersytet Jagielloński, Instytut Fizyki
    Kraków, ul. Reymonta 4
11. Dr Zygmunt Łuczyński
    Instytut Technologii Materiałów Elektronicznych
    Warszawa, ul. Wólczyńska 133
12. Doc. dr hab. Krzysztof Rusek
    Instytut Problemów Jądrowych
    Warszawa, ul. Hoża 69
13. Prof. dr hab. Teresa Rząca-Urban
    Wydział Fizyki UW
    Warszawa, ul. Hoża 69
14. Dr Brunon Sikora
    Wydział Fizyki UW
    Warszawa, ul. Hoża 69
15. Prof.dr hab. Adam Sobiczewski
    Instytut Problemów Jądrowych
    Warszawa, ul. Hoża 69
16. Prof. dr hab. Jan Styczeń
    Instytut Fizyki Jądrowej
    Kraków, ul. Radzikowskiego 152
17. Prof. dr hab. Ziemowid Sujkowski
    Instytut Problemów Jądrowych
    Świerk k. Otwocka
18. Prof. dr hab. Henryk Szymczak
    Instytut Fizyki PAN
    Warszawa, Al. Lotników 32/46
19. Prof. dr hab. Andrzej Twardowski
    Wydział Fizyki UW
    Warszawa, ul. Hoża 69
20. Prof. dr hab. Wiktor Zipper
    Uniwersytet Śląski, Instytut Fizyki
    Katowice, ul. Uniwersytecka 4
21. Prof. dr hab. Jan Żylicz
    Wydział Fizyki UW
    Warszawa, ul. Hoża 69

6. Program Advisory Committee

Brunon Sikora, IFD UW (Chairman)
Reinhard Kulessa, IF UJ
Adam Maj, IFJ
Andrzej Marcinkowski, IPJ
Adam Sobiczewski, IPJ
Władysław Trzaska, University of Jyvaskyla
Andrzej Turos, IPJ and ITME
Teresa Rząca-Urban, IFD UW
Jan Żylicz, IF

The **Users Committee**, serving as a link between the cyclotron users and the Laboratory is chaired by Julian Srebrny (IFD UW).

7. Polish Workshop on Heavy Ion Acceleration and its Applications Warsaw, 7-12 March 2005.

The National Workshop on Heavy Ion Acceleration and its Applications was organized by Heavy Ion Laboratory of Warsaw University on 7-12 March 2005. It was for the first time that the Laboratory invited students form other Polish universities for one week of advanced training in nuclear physics. Participants attended introductory lectures and performed simple experiments on the heavy ion beams from the Warsaw cyclotron. They had an opportunity to get acquainted with the unique scientific equipment which is installed at HIL. During the final session students presented results of their workshop exercises.

The Workshop was planned to deliver information about the current possibilities of the infrastructure of HIL to perform research aiming the Master of Science degrees thesis.
The main topics which were presented during the meeting were:

1. heavy ion acceleration and basics of the ion optics;
2. charged particles and gamma-ray detection;
3. experimental electronics and data taking systems;
4. interdisciplinary applications of nuclear physics.

Workshop's participants during a party sponsored by Foundation „Budowa i Promocja Warszawskiego Cyklotronu U-200P"

The introductory lectures were open for general public. The Workshop program consisted of the following presentations:

1. Acceleration of heavy ions - dr hab. T.Czosnyka (7 March)
2. Detection of the nuclear radiation - dr J.Iwanicki (8 March)
3. Technique of a gamma-rays analysis. - dr M. Palacz (9 March)
4. In beam gamma spectroscopy - prof. Ch.Droste (10 March)
5. Medical applications of nuclear physics - dr hab. Z.Szefliński (11 March)

Subjects of practical exercises were:

1. Beam focusing in heavy ion acceleration.
2. Beam energy measurements based on Rutherford scattering.
3. Identification of excited states' bands in gamma-gamma coincidences.
4. Radon measurements in gas and liquid samples.

The Workshop gathered students from Adam Mickiewicz University in Poznań, Silesian University in Katowice and Warsaw University

DZIEKAN
WYDZIAŁU FIZYKI
UNIWERSYTETU IM. ADAMA MICKIEWICZA

Pan
Dr Paweł J. Napiórkowski
Środowiskowe Laboratorium Ciężkich Jonów
Uniwersytet Warszawski
ul. Pasteura 5A, 02-093 Warszawa

Wielce Szanowny Panie Doktorze,

w imieniu Studentów Wydziału Fizyki UAM oraz w imieniu Władz Wydziału chciałbym złożyć wyrazy podziękowania za znakomicie zorganizowane Ogólnopolskie Warsztaty Akceleracji Ciężkich Jonów i ich Zastosowań.
Jednoznacznie pozytywne opinie studentów o zawartości merytorycznej Warsztatów oraz o niezwykłej gościnności Państwa wskazują na potrzebę, a nawet na konieczność kontynuacji tego przedsięwzięcia w przyszłości. Możliwość zapoznania się z unikatową aparaturą badawczą Laboratorium oraz świetnie poprowadzone wykłady i ćwiczenia dały możliwość poszerzenia wiedzy naszym Studentom w zakresie niedostępnym na naszym Wydziale.

PRODZIEKAN
WYDZIAŁU FIZYKI
Prof. dr hab. Ryszard Naskręcki

Poznań, 15 marca 2005 r.

ul. Umultowska 85, 61-614 Poznań
tel: +48 61 / 829 5202
fax: +48 61 / 825 7018

8. “Science Popularizer” Award for P. J. Napiorkowski

In 2005 Paweł Napiorkowski received a prestigious nationwide award for the best presentation during the “Day of Science 2004”. This award is commonly granted by the Ministry of Science and Information Society and Polish Press Agency. During the “Day of Science 2004” P. Napiorkowski presented “The mysteries of your vacuum cleaner”, a lecture combined with demonstration of radioactivity surrounding us everywhere. For this purpose the dust from the vacuum cleaner has been checked for the contents of radioactive radon, emitted from the soil and absorbed by dust particles. Radon is “glued to dust like paper to amber”, using the lecturer's words. The presentation was received enthusiastically by the audience, proving that science can be discussed at general public level without loosing fully professional approach.

9. Laboratory Guests:

Participants of HIL experiments:

A. A. Rudchik	Institute for Nuclear Research, Kiev, Ukraine	February
A. T. Rudchik	Institute for Nuclear Research, Kiev, Ukraine	February
S. Yu. Mezhevych	Institute for Nuclear Research, Kiev, Ukraine	February
O. A. Ponkratenko	Institute for Nuclear Research, Kiev, Ukraine	February
E. I. Koshchy	Kharkiv National Univeristy, Kharkiv, Ukraine	February
B. Roussiere	Institut de Physique Nucleaire, Orsay, France	March

Short time visitors:

E. Clement	CEA Saclay, France	May
A. Hurst	University of Liverpool, UK	July, December
A. A. Pasternak	A.F. Ioffe Phys.-Tech. Inst. St. Petersbourg, Russia	July, August

10. Permanent collaborations

CERN, Geneva, Switzerland
GANIL, Caen, France
GSI Darmstadt, Germany
Hahn-Meitner Institut Berlin, Germany
Institute für Kernphysik KFA Jülich, Germany
Institute for Nuclear Research, Kiev, Ukraine
Institut de Recherches Subatomiques, Strasbourg, France
Japan Atomic Energy Agency Japan
Joint Institute for Nuclear Research, Dubna, Russia
Ludwig-Maximilians Universität, München, Germany
Laboratori Nazionali di Legnaro, Padova, Italy
Manne Siegbahn Institute, Stockholm, Sweden
Niels Bohr Institute, Denmark
Oliver Lodge Laboratory, Liverpool, United Kingdom
Technische Universität München, Germany
University of Jyväskylä, Finland
University of Liverpool, United Kingdom
University of Rochester, USA
Uppsala University, Sweden
A.F. Joffe Physical Technical Institute RAS, St. Petersburg, Russia
University of Tokyo, Japan
CEA Saclay, Gif-sur-Yvette, France
Institut de Physique Nucleaire, IN2P3-CNRS, Orsay, France

11. Appendix

Information on HIL facilities presented in the international survays

11.1 Worldwide survey by International Union of Pure and Applied Physics 2006

11.2 EC 2006 survey on Research Infrastructure

HEAVY ION LABORATORY

Warsaw University, Ochota Science Campus
Warsaw, Poland
PL 02 094 Warszawa, ul. Pasteura 5a

email: slcj@slcj.uw.edu.pl

University Unit

Governmental funds

Head (Institution and facility): Jerzy Jastrzębski, Laboratory Director

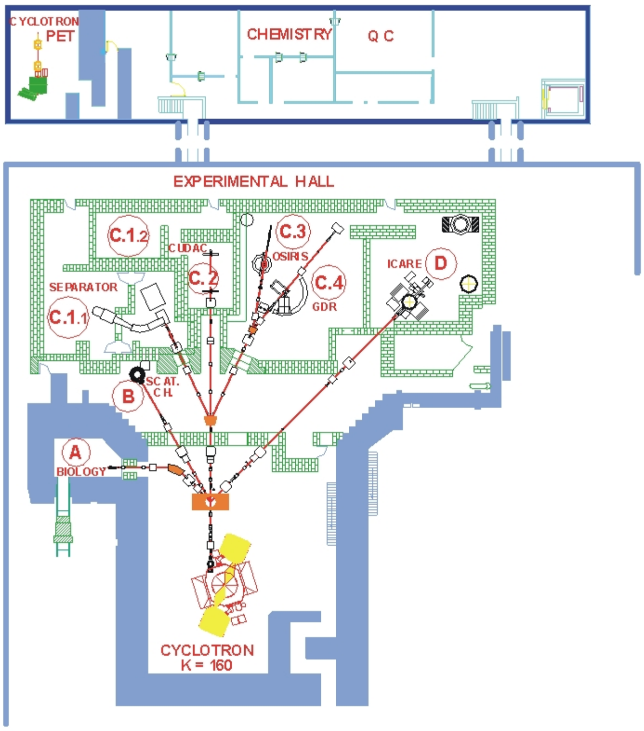
Web address: www.slcj.uw.edu.pl

In a brief abstract (5 – 10 lines) describe the scientific mission and, broadly, the main current and future research programs of the institution/facility:

The Heavy Ion Laboratory is a "User Facility" with around 100 national and foreign users per year. The isochronous K_{max}=160 cyclotron delivers around 3000 h of heavy ion beams yearly ranging from B to Ar with energies between 2 and 10 MeV/nucleon. The current research program comprises nuclear physics, atomic physics, material sciences, solid state physics, biology, particle detectors development and testing.

Actually the Heavy Ion Laboratory is in its transformation phase to become the Warsaw University accelerator centre, operating two cyclotrons. Shortly (2006/7) a second commercial proton – deuteron cyclotron (E_p = 16.5 MeV) will be installed in the Laboratory building for the production of – and research on the radiopharmaceuticals for the Positron Emission Tomography (PET). Production of long – lived radiopharmaceuticals for other medical and life – science applications is also foreseen.

Technical facilities: please provide one (for smaller facilities) or two (for larger facilities) figures and/or photos providing a technical layout of the facility and its instrumentation, and a visual overview:



Briefly characterize the facility:

a) Medium – energy (2 -10 MeV/nucleon) cyclotron with heavy ion beams;
b) Low – energy, high current proton – deuteron cyclotron.

Provide a compact (exemplary) table of facility parameters (e.g. beam species, intensities, range of energies, special properties):

Cyclotron	Ion	Energy [MeV]	Extracted current [pnA]
K= 90 - 160	$^{10}B^{+2}$	50	4
	$^{11}B^{+2}$	38 - 55	3 - 4
	$^{12}C^{+2}$	22 - 50	2 - 20
	$^{12}C^{+3}$	89.6- 112	0.8 - 12
	$^{14}N^{+2}$	28 - 50	13 - 143
	$^{14}N^{+3}$	57 - 110	80
	$^{16}O^{+2}$	32	5.7
	$^{16}O^{+3}$	46 - 80	5.7 - 138
	$^{16}O^{+4}$	90	6.5
	$^{19}F^{+3}$	38 - 66	1.3
	$^{20}Ne^{+3}$	50 - 65	11 - 35
	$^{20}Ne^{+4}$	70 - 120	11 - 35
	$^{20}Ne^{+5}$	140 - 190	24 - 40
	$^{22}Ne^{+3}$	44	10
	$^{22}Ne^{+4}$	132	8
	$^{32}S^{+5}$	64- 121.6	0.5 – 1.4
	$^{40}Ar^{+6}$	80 - 132	2.5
	$^{40}Ar^{+7}$	120 - 172	0.9 – 2.3
	$^{40}Ar^{+8}$	195	0.9 – 2
K=16.5	$^{1}H^{+1}$	16.5	> 75 μA
	$^{2}D^{+1}$	8.4	> 60 μA

If appropriate, provide a brief and compact table with the facility's major experimental instrumentation and its capabilities:

1. GDR multidetector system JANOSIK;
2. Gamma - ray, 12HPGe multidetector system OSIRIS II;
3. Two universal scattering chambers CUDAC and SYRENA;
4. Charged particle multidetector system ICARE;
5. Scandinavian type on - line mass separator IGISOL;
6. Irradiation chambers with target water cooling;
7. Low background lead shielded HPGe counters;
8. Radiochemistry and Quality Control equipment for the radiopharmaceuticals production;

For details see: www.slcj.uw.edu.pl/en/96.html

Is the facility considered to be a user facility (officially and by whom; unofficially?):

Heavy Ion Laboratory (HIL) was founded jointly by the Ministry of Education and Sciences, Polish Academy of Sciences and Polish Atomic Energy Agency. In the founding agreement the above three authorities enacted HIL to become, from the very beginning a national "User Facility".

Does the facility have a Program Advisory Committee or the equivalent, adjudicating experimental proposals?

The K=160 cyclotron beam time is allocated by the Laboratory director on the recommendation of the Program Advisory Committee. The proposals are received twice a year (www.slcj.uw.edu.pl/pac) in a written form and publicly presented. In their ranking PAC considers the scientific value of the proposal, its expected international impact, its contribution to the teaching process and the previous achievements of the proposers.

Number of actual, active users of the facility in a given year:

About 100 real users per year as indicated by the access record plus about 15 virtual users, participating in data interpretation (co-authors of publications).

Percentage of users, and percentage of facility use (these numbers may differ) that come from inside the institution (if no statistics exist , please give an estimate but indicate this as such):

About 10% of K=160 cyclotron users come from inside HIL. Less than 5% of the beam time is used by the HIL staff alone.

Percentage of users and percentage of facility use from national users:

About 80% of users come from Polish institutions.

Percentage of users and percentage of facility use from outside the country where your facility is located:

About 20% of users come from abroad.

What fraction of the international users is from outside your geographical region (i.e. Asia; Australia & New Zealand; North-America; South-America; Africa; Europe):

During last 5 years cooperation with HIL involved groups from India, Japan, USA as well as European Countries (80% of users from abroad come from Europe).

Does a formal users group exist for your facility (s) and what is the number of registered members (in general this may be quite different from the number of actual users in a given year):

The users group has an elected chair – person, who reports to the Laboratory Scientific Council. The facility users meet 3 times per year on a voluntary basis. No official record of people participating to the users group exists.

Number of a) permanent staff and b) temporary staff (including graduate students and postdoctoral researchers):

a) 46
b) 7.25

Number of theoretical staff employed at the facility: permanent; postdoctoral, students:

No theoretical staff is employed at HIL.

Number of postdoctoral researchers employed at the facility:

2

Number of graduate students resident at the facility (>80% of their time):

2

Number of non-resident graduate students with thesis work primarily done at the facility:

13

Involvement of undergraduate students in research (approximate average number at a given time):

16 per year (quoted nb. is for 2005)

Special student programs, e.g. summer programs, student labs etc. (high school, under graduates, graduate students?):

An undergraduate Student's Workshop of one week duration is organized in March each year for about 15 participants coming from Physics Faculties located outside Warsaw. Students, supervised by the Laboratory staff are performing various nuclear physics experiments, including the cyclotron operation.
During Summer up to 7 students from various Physics Faculties take part in one month duration training, participating in experiments, conducted by the Laboratory staff.

Describe any plans you might have and their status for future developments at the facility (major instrumentation; facility upgrades; expansions and new construction etc.):

Heavy Ion Laboratory is conveniently placed in the heart of the Warsaw University, Polish Academy of Sciences and Academy of Medicine Scientific Campus Ochota. Shortly the intense proton and deuteron beams from

a medical cyclotron, equipped with an external beam line will be also available. These beams will be used for the production of PET radioisotopes, subsequently transformed to radiopharmaceuticals using the commercially available chemistry and quality control modules. This 4 Million Euro project is currently financed by the Polish Ministry of Education and Sciences and International Atomic Energy Agency. The Polish Health Ministry will finance the PET scanner, to be located in the neighboring Academy of Medicine Clinical Hospital. Leading the Warsaw PET Consortium, the Laboratory foresees the development of a large interdisciplinary research program including medicine and life sciences, unique at least in this part of Europe.
For the K=160 cyclotron, a purchase of a new ECR ion source allowing a substantial increase of the accelerated ion species and masses is planned within coming two years if the funding is available.

Please provide in brief abstract form any other information you might want included in the report:

HIL is an open user facility, serving the needs of scientific community based on evaluation of the merit of proposed programs only. No restrictions, other than negative peer review, apply.

Which is the total number of physicists considered as nuclear physicists nationally?

468 physicists. This number is obtained from the NuPECC report on Resources in European Nuclear Physics (www.nupecc.org/pub/survey97/survey.ps) published in 1997. It is estimated that the actual number can be 20% lower.

How many of these are nuclear theorists?

102 nuclear theorists. Source as above.

Which is the total number of graduate students in nuclear physics nationally?

161 graduate students. Source as above.

Which is the total amount of funding available for nuclear physics nationally?

Rough estimate for nuclear physics (including salaries) – 10 M€/year.

2006 Survey on Research Infrastructures

Meta Informations

Creation date
03-04-2006

Last update date

User name
null

Case Number
842135112381209306

Invitation Ref.

Section 1: Information on respondent and responding institution

1. Mr./Mrs. Name, first name: (Example: Mrs. de Guzman, Ana / Mr. Schmitt, Johann)
Mr. Pieńkowski, Ludwik

2. Name of institution: (Example: CNRS, Lyon / Max-Planck-Institute, Stuttgart)
Warsaw University

3. Are you responding on behalf of this institution? (Please note that in order to avoid multiple entries, each institution should designate internally the person to fill in this questionnaire on behalf of the institution):	No
4. Your position in the institution:	Other (please specify)

Please specify your position in the institution
Research Infrastructure Deputy Director

5. Your email address:
pienkows@slcj.uw.edu.pl

6. Institution's host country:	PL - Poland

Section 2: Description

1. Name of Research Infrastructure: (please submit one questionnaire per Research Infrastructure)
Heavy Ion Laboratory (HIL)

2. Research Infrastructure web site:
www.slcj.uw.edu.pl

3. Country where the Research Infrastructure is located (in case of a distributed Research Infrastructure, please indicate as host country the country of the central office):	PL - Poland

4. City where the Research Infrastructure is located (please indicate the region in brackets; in case of a distributed Research Infrastructure, please indicate as host region the region of the central office):
Warsaw (Capital city of Poland)

5. Organisation/institution type of Research Infrastructure or of the Research	Governmental/public University/Higher education

Infrastructure's host institution (more than one choice possible):	

6. Main scientific and technological domain(s) served by the Research Infrastructure (more than one choice is possible):	Life Sciences Health and Medical Sciences Physics Engineering

7. Research Infrastructure type (more than one choice is possible)	Single-sited

8. Short description of Research Infrastructure (should not be more than 700 characters; only important facts for general public about the usage of the Research Infrastructure)

Heavy Ion Laboratory is in its upgrade phase to become in 2007 the Warsaw University accelerator centre operating two cyclotrons. A large K=160 isochronous cyclotron provides heavy ion beams since 1994 for research in nuclear physics, atomic physics, material sciences, solid state physics, biology and for particle detectors development and testing. Shortly (2006-7) a second commercial proton - deuteron cyclotron (Ep=16.5 MeV) will be installed in the Laboratory building for the production of- and research on the radiopharmaceuticals for the Positron Emission Tomography (PET). Production of long - lived radiopharmaceuticals for other medical and life - science applications is also foreseen.

9. Major facilities, installations, attached instruments and services provided to researchers (e.g. telescopes, reactors, vessels,wave channels, databases, communication networks, etc.; please provide list, maximum 700 characters):

1. Isochronous heavy ion cyclotron (K=160); 2. GDR multidetector system JANOSIK; 3. Gamma - ray, 12HPGe multidetector system OSIRIS II; 4. Two universal scattering chambers CUDAC and SYRENA; 5. Charged particle multidetector system ICARE; 6. Scandinavian type on - line mass separator IGISOL; 7. Irradiation chambers with target water cooling; 8. Low background lead shielded HPGe counters; 9. PETtrace proton - deuteron cyclotron (in the installation phase). Services provided: taret laboratory, mechanical and electronic workshops. For details see: www.slcj.uw.edu.pl/en/96.html

10. Years already in operation:	11-15 years

11. How many years ago was the latest major upgrade of the equipment or the whole Research Infrastructure? (by major upgrade, we mean an upgrade that costs at least 10% of the total cost of the facility

0

For comment (if desired) on the latest major upgrade (maximum 700 characters):

The current upgrade consists in the establishment within the Heavy Ion Laboratory of the PET Radiopharmaceuticals Production Department for the Warsaw Positron Emission Tomography project. This project got support from the Polish Ministry of Sciences and Informatics (presently Ministry of Education and Sciences), Ministry of Health and International Atomic Energy Agency. A Warsaw PET Consortium, organized by the Laboratory and consisting of twenty scientific and medical units, will undertake a number of interdisciplinary projects in research and diagnostics.

Operation

12. Main type(s) of structured international co-operation activities (through contract or co-operation agreement) - more than one choice is possible:	Bilateral co-operation with other research infrastructures/organisations/institutions Multilateral co-operation with other research infrastructures/organisations/institutions Participation in EC-funded projects Participation in international programmes/projects extending beyond Europe

13. List of international co-operation agreements and partnerships which exist at organisational level for this Research Infrastructure, between different organisations in different European Countries (please give up to five examples over the last five years, maximum 700 characters)

- Convention IN2P3 - Polish laboratories, operating from 1974 till now, participation in the Coordinating Board and in a number of common research projects. - HIL - JUELICH co-operation research contract related to the installation and use at HIL of OSIRIS gamma multidetector system. - HIL - IReS (Strasbourg) co-operation research project related to the installation and use at HIL of ICARE particle multidetector system (in negotiation phase). - HIL – JINR Dubna technical accelerator cooperation.

14. Please indicate any further needs and opportunities for further integration or collaboration with similar or related Research Infrastructures (maximum 500 characters) The organization by the EU of a network of the intermediate scale Research Infrastructures having a clear User Facility character (e.g. more than 70% of users not belonging to the facility permanent scientific staff and a clear international users participation) in less favored, peripheral European Countries. (Common rules of evaluation, financial support of Review Panels, PAC and users access). Objective: to increase the international role of the regional research centers.	
15. Permanent scientific/engineering staff operating the Research Infrastructure:	21-50
16. Average number of individual internal users per year (i.e. individuals who are employed, working or studying in the facility):	11-50
17. Average number of individual external users per year (i.e. individuals who are not employed, working or studying in the facility):	51-100
18. Referring to external individuals, average number of trainees/students per year	11-50
19. Referring to external users, estimated percentage of individual users from other countries than the country where the Research Infrastructure is hosted:	10-25%
20. Referring to external users, estimated percentage of individual users from industry or organisationsserving industry:	0%
21. Referring to external users, estimated percentage of individual virtual users (e.g. using a database virtually from another site or using remote access to equipment):	10-25%
22. Short description of access policy and procedures for users of this Research Infrastructure (please briefly desribe your access policy, especially indicating any arrangements for transnational access; maximum 1000 characters): The Heavy Ion Laboratory is a typical "User Facility" with around 100 national and foreign users per year. The K=160 cyclotron heavy ion beam (around 3000h yearly) is allocated for experiments of 1 to 3 weeks duration by the Laboratory director on the recommendation of the Program Advisory Committee. The proposals are received twice a year (www.slcj.uw.edu.pl/pac) in a written form and publicly presented. In their ranking PAC considers the scientific value of the proposal, its expected international impact, its contribution to the teaching process and the previous achievements of the proposers. The transnational access to HIL is facilitated by its location in the University Campus Ochota, (close to the city centre and to the international airport) and services provided: 12 guest rooms with private toilets and a common kitchen, a number of non - expensive restaurants in the near neighbourhood, close 3 and 4 stars hotels.	
23. Activities undertaken by the Research Infrastructure and service(s) provided to users (more than one choice is possible):	Upgrade of the core facility Upgrade of the attached instruments and/or associated softwares Support to users during experiments Support to preparation, installation and operation of specific instruments Support to processing of the measurements
Finance	
24. Total cumulative investment for initial construction/setting up of this Research Infrastructure (including buildings, equipment and current upgrades, but excluding operational costs; please indicate in today's	20 M€ - 50 M€

equivalent):	

For comments (if desired, maximum 500 characters):
The K=160 cyclotron and the experimental equipment is located in the three store + underground 10 000 m2 surface building including: Cyclotron vault (250 m2) Experimental hall (850 m2) Data acquisition room (160 m2) Conference room (100 m2) Seminar room (160 m2) Library (100m2) Guest rooms (housing 12 persons) (320 m2)

25. Yearly operational costs (including administrative personnel and maintenance):	1 M€ - 10 M€

For comments (if desired, maximum 500 characters):
The operational cost, about 1.2 M€, is provided by the Ministry of Education and Sciences, funneling by two different paths: via Warsaw University educational budget (~75%) and directly by the Ministry support of the research infrastructures (~25%).

26. Main sources of construction/setting up funding (more than one choice is possible):	National public funding
27. Main sources of funding for operational costs (more than one choice is possible):	National public funding

Section 3: Scientific Impact

28. Most important publications or conference proceedings (peer-reviewed), technical reports or patents highlighting the cutting-edge research carried out through this Research Infrastructure (please list up to ten examples from the last five years, maximum 700 characters):
E. Grodner, et al., Int. Jour. of Mod. Phys. E 15 (2006) 548; E. Piasecki, et al., Phys. Lett. B 615 (2005) 55; A.J. Kordyasz, et al,. Nucl. Inst. Meth. A 539 (2005) 262; M. Palacz, et al., Nucl. Inst. Meth. Phys. Res. A 550 (2005) 414; A.A. Rudchik, et al., Phys. Rev. C 72 (2005) 034608; M.Wolinska-Cichocka, et al., Eur. Phys. J. A24 (2005) 259; M. Kicinska-Habior, et al., Nucl. Phys. A731 (2004) 138; J. Iwanicki, et al., Journ. of Phys. G29, 4, 743 (2003); E. Piasecki, et al., Phys. Rev. C 65, (2002) 054611; M. Zielinska, et al., Nucl. Phys. A 712 (2002) 3;

29. Main international structured co-operation research projects (through contract or co-operation agreement) highlighting the recognition of this Research Infrastructure at international level (please give up to five examples from the last five years, maximum 700 characters):
- Participation in 4FP activities: European Spallation Source Project, EU TMR project ERB-FMRX-CT98-0244 - Participation in 5FP activities: ION CATCHER, contract HPRI-CT-2001-50022 - Participation in 6FP activities: EURONS, contract 506065, tasks: 1. JRA2 AGATA 2. JRA6 INTAG 3. N4 EWON - Participation in 6FP activities: EURISOL DS, contract 515768 RIDS, tasks: Safety and Radioprotection Physics and Instrumentation Beam Intensity Calculations

30. Please explain why you consider this Research Infrastructure as of top-level relevance for the scientific community, having a "clear European dimension" and European added value (e.g. in terms of users, research, technologies, co-operation, publications, mission statement, etc.; maximum 1000 characters):
HIL remains one of a few European Centers of the "User Facility" type providing low energy, heavy ion beams for nuclear physics and its application in other research area (see eg. NuPECC Handbook 2004, (Intern. Acc. to Nucl. Phys. Facilities in Europe), Finuphy Handbook 2004, (Interdisc. Use of Europ. Nucl. Phys. Facilities), IUPAP Handbook, in preparation. Besides the scientific program performed in Warsaw (see sec. 28) the laboratory using local infrastructure is currently involved in the preparation of future experiments in Large Facilities (see sec. 29). HIL is conveniently placed in the heart of the Warsaw scientific campus Ochota. Shortly the intense proton and deuteron beams from a medical cyclotron, equipped with an external beam line will be also available. Leading the Warsaw PET Consortium, the Laboratory foresees the development of a large interdisciplinary research program including medicine and life sciences, unique at least in this part of Europe.

31. Provided that funding is available, do you see a clear potential for long-term continuation of the operation of this Research Infrastructure at international level?	Yes