Warsaw University
Heavy Ion Laboratory

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INTRODUCTION

The Heavy Ion Laboratory of the Warsaw University is a user-type facility, providing heavy ion beams to a number of Polish and foreign research groups and, to a limited extent, for its own research programme. In 2007 the Warsaw Cyclotron delivered almost 2000 hours of beam on target. Fifteen experiments were performed following the recommendations of the Programme Advisory Committee and for these studies more than one hundred user accesses to our facility were granted.

Among papers, published in 2007 and in the beginning of 2008, one should mention the first "regular" publication resulting from work using the Warsaw IGISOL system (Phys. Rev. C76(2007)054320), dealing with the α decay of a newly found isomer in ^{216}Fr. The Łódź-Warsaw collaboration published a detailed description of their recently developed conversion electron spectrometer (NIM A585(2008)155), which is presently coupled to the gamma-ray multidetector system OSIRIS-II in order to investigate properties of long-lived isomeric states in gamma-electron coincidence measurements. Two papers from the Kiev-Kraków-Warsaw collaboration (Eur. Phys. J. A33(2007)317, Nucl. Phys. A785 (2007)293) describe the results of investigation of elastic and inelastic scattering of light heavy ions on light targets. Finally, a paper by visitors from Kielce presents the data obtained without the cyclotron using directly the beam from the ECR ion source (Vacuum 81(2007) 1348).

The section B of this Report presents on-going research projects, the results of which are often not yet published elsewhere. Let me quote a few examples of these contributions. The very active Coulomb Excitation group (based mainly at HIL) presents a new implementation of an algorithm inspired by evolutionary biology, allowing to speed up the data evaluation using the GOSIA code. After years of work with single germanium detectors, operating in coincidence with the CUDAC scattering chamber, the same group eventually migrated to the OSIRIS-II gamma-ray multidetector system, substantially increasing the event statistics in the study of Coulomb excited levels in ^{100}Mo. A team led by Nuclear Physics Division of the Warsaw University continues its research on chiral symmetry breaking in nuclei in the mass region around A=130. Their recent experimental work resulted in a large set of nuclear level lifetimes in ^{130}La measured using the Doppler Shift Attenuation Method, which are reported here for the first time. The same group proposes a phenomenological classification of the symmetry breaking phenomenon based on the transition probabilities, previously determined using the Warsaw Cyclotron beams. Their achievements were clearly recognized by the Polish scientific community – Dr. Ernest Grodner from this group was awarded in 2007 the prestigious Zdzisław Szymański Prize, as well as the Prime Minister Prize for the best PhD thesis in physics defended in 2006. A young and active team from the Department of Physics, University of Łódź, already mentioned above, reports on the conversion electron study of the 9 ms isomer in ^{132}Ce.

A substantial funding from the Ministry of Science and Higher Education in December 2006 allowed us to order a part of the new ECR ion source from the French company PANTECHNIK. The contract between the Warsaw University and the Company was signed in the beginning of 2008. Simultaneously, a document specifying further purchases to complement the already bought equipment was signed. This Memorandum of Understanding (MOU) identifies the scope of the future collaboration between HIL and PANTECHNIK, including a project of the cyclotron's new high voltage injection line. It is expected that the consecutive part of the Ministry funding for the ECR ion source will be available in 2008.

The strong involvement of the Heavy Ion Laboratory in the Warsaw PET Project was continued in 2007 and is described in section A. However, the installation of the Radiopharmaceuticals Production Centre in the Heavy Ion Laboratory building has been substantially delayed due to legal and administrative problems encountered during the last two years. After a lot of efforts, the deadline for the building adaptation and the equipment installation has been fixed for the beginning of 2009.

The idea of constructing in Poland a fourth generation High Temperature Nuclear Reactor (HTR) emerged from our Laboratory. The process of coal to liquid fuels conversion (nuclear-coal synergy) would allow the reduction of CO_2 emission. The future of this project, depending on decisions to be made at the governmental level, is still uncertain. However, its reception by at least a part of European atomic energy communities was encouraging.

The rich programme of educational and science popularisation activities, in which the Laboratory staff is engaged, was continued in 2007 and is described in Part A of this Report. We hope to substantially boost this activity using supplementary resources from the European Structural Funds under Human Capital program.

Another important and time-consuming activity was related to the HIL participation in the European Commission FP7 programmes. Last year, under call FP7-Infrastructures-2007-1 the proposal "SPIRAL2-Preparatory Phase" was accepted and is presently in the negotiation phase. Our Laboratory participates in one of the Work Packages of this proposal. Two other proposals were recently prepared by the European nuclear physics community within a similar EC call for 2008. The first one, ENSAR, as a successor of EURONS realized within the FP6 was mainly intended to finance the nuclear physics research via the European Large Scale Facilities within Networking Activities (NA), Transnational Access (TNA) and Joint Research Activities (JRA). However, the activity and persistence of smaller laboratories from Central and Eastern Europe (operating within the East-West Outreach Network in EURONS) resulted in them being accepted into ENSAR within a common JRA EWIRA (East-West Integrated Research Activity). In addition, our Laboratory participates in one of the Networks of the ENSAR project.

The second proposal, called EUCYNET, emanates from the network of small European cyclotrons operating for medical and material research applications. Within this proposal our Laboratory offers the Transnational Access to the presently operating heavy ion cyclotron as well as to the future proton machine. If it is accepted, we will also participate in three Networking Activities of this project.

The two above-mentioned proposals were submitted to the European Commission at the end of February 2008. It is expected that the Evaluation Summary Reports will be sent to proposal coordinators mid-May 2008.

Jerzy Jastrzębski

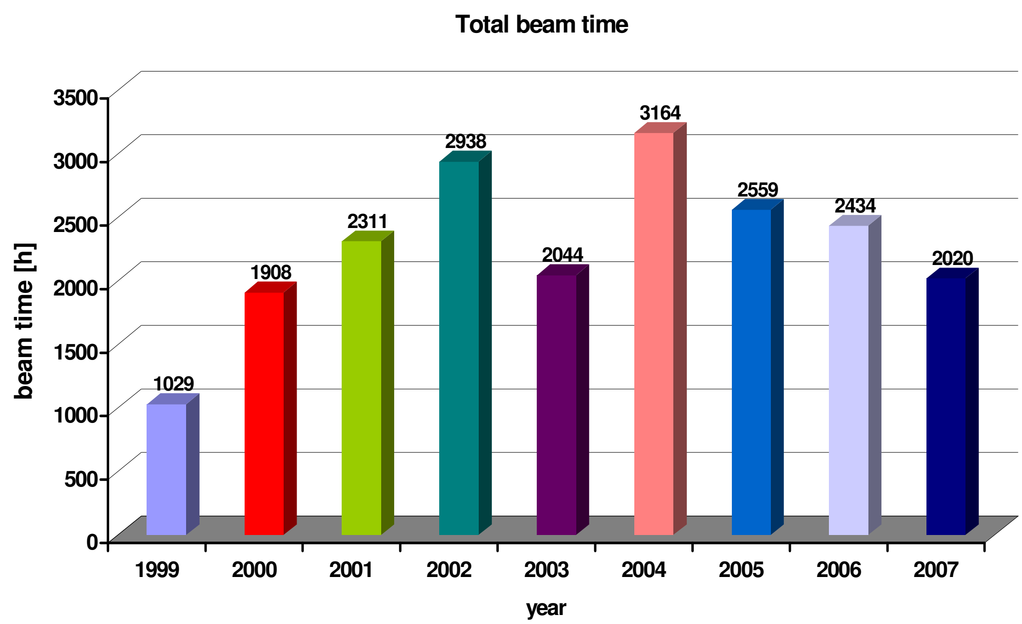
Part A:
Laboratory overview

1. Operation of the cyclotron during 2007

J. Choiński, A. Bednarek, A. Jakubowski, W. Kalisiewicz, M. Kopka, J. Kurzyński, J. Miszczak, B. Paprzycki, A. Pietrzak, R. Tańczyk, O. Steczkiewicz, J. Sura, M. Wolińska-Cichocka

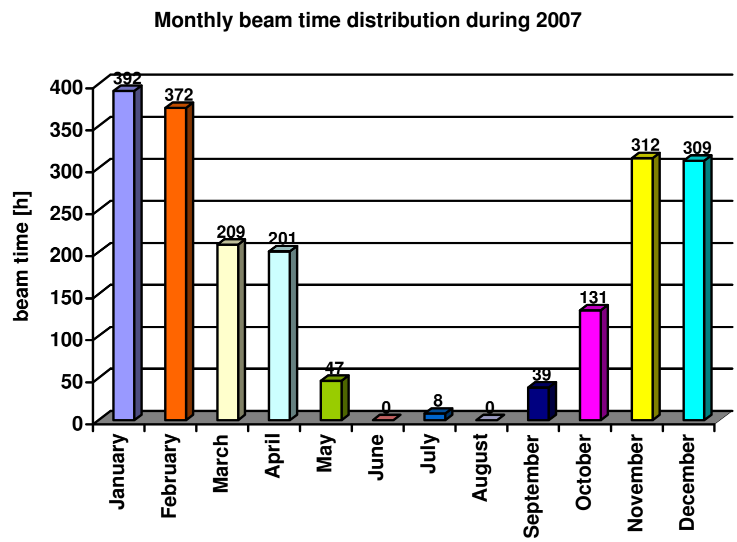
Cyclotron facility

In 2007 the cyclotron delivered a total of 2020 hours of beam-on-target. The figure below shows the usage of cyclotron beams over the last nine years.

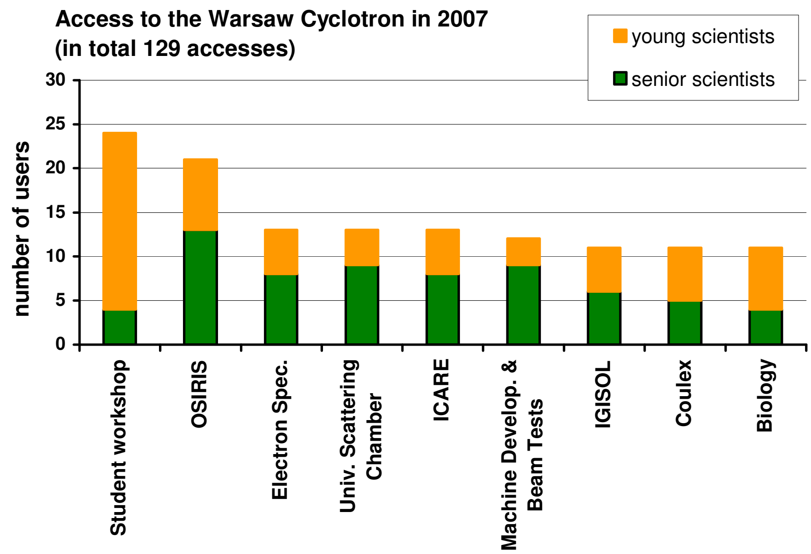


A decrease in the number of hours as compared to previous years was caused by severe technical problems, which could not be solved immediately and therefore strongly reduced the time when the accelerator was fully operational. The most important problem was related to the cyclotron water cooling system. The successive extension of the heat exchange system, performed at the beginning of 2007 by an external firm, proved insufficient again and Laboratory was forced to curtail some of the experiments scheduled for late spring and summer because of overheating problems. In September the heat exchange system was replaced completely. We have re-established the previous design of the cooling system and the proper cooling was restored, assuring again an undisturbed performance of the machine. Furthermore, the automatic control of water levels in primary and secondary cooling circuits was installed and put into operation.

Monthly distribution of the beam time during 2007 is presented in the following figure. The above-mentioned problems with water cooling system were responsible for the long break during summer months.



Participation of undergraduate and graduate students in experimental campaigns strongly reinforces the experimental teams currently working at HIL and helps them maintaining the research momentum. Involvement of young researchers is illustrated by the figure below, which shows the number of participants for each of the research projects performed in 2007 on beams of the Warsaw Cyclotron (see Table 1). Detailed description of experimental set-ups can be found at the Heavy Ion Laboratory website.



Despite the fact that basic nuclear physics research consumed most of the beam time, a fair share of it was allocated to other areas: the programme of radiobiological studies using heavy-ion beams was continued with three new measurements, and a week of beam time was assigned for the student workshop.

More detailed data concerning the development of the apparatus for research projects can be found in articles describing the on-going activities, published further in this section. The first experiment performed with the ICARE set-up on the upgraded line D is especially worth mentioning. The histogram and table with the number of hours used for various projects in 2007 are presented below.

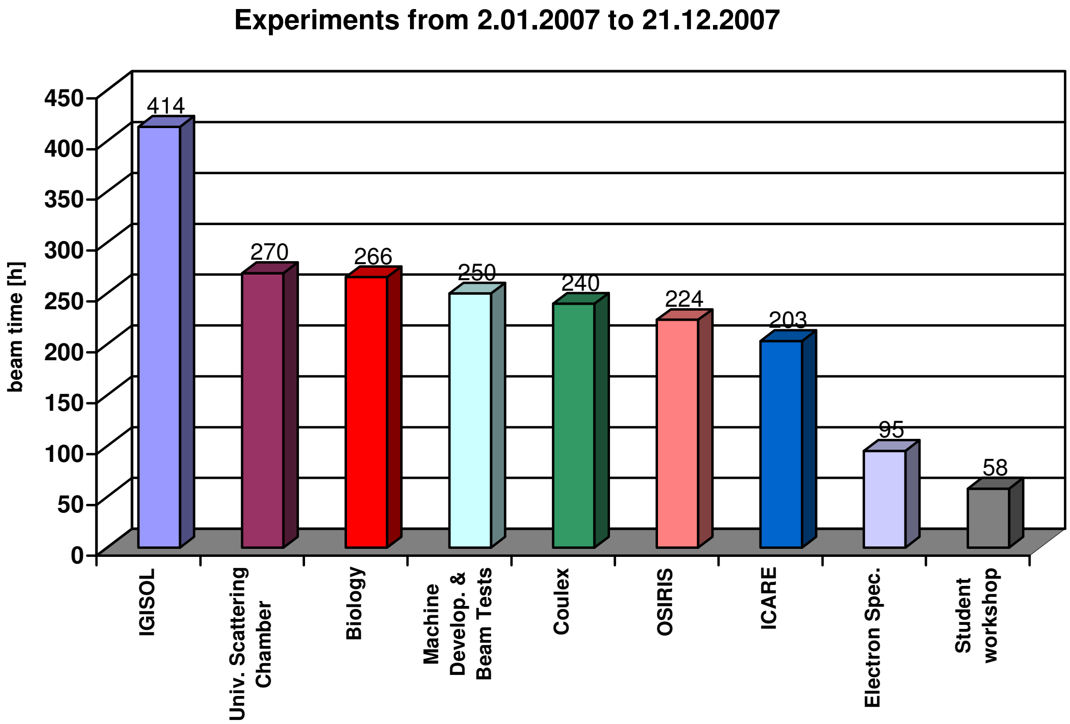


Table 1. Experiments from 02.01.2007 to 21.12.2007

Dates	Ion	Energy [MeV]	Experiment	Leading institution	Collaborating institutions
15.01 - 26.01	$^{40}Ar^{+8}$	208	OSIRIS	HIL	IEP UW, DP UŁ, INS Świerk, INP Kraków
29.01 - 02.02	$^{12}C^{+2}$	50	Biology	IEP UW, IB AŚ Kielce	HIL, IP AŚ Kielce, INS Świerk
05.02 - 16.02	$^{20}Ne^{+3}$	52 - 76	Machine dev. & test	HIL	
19.02 - 02.03	$^{18}O^{+4}$	117	Univ.Scat. Chamber	INR Kiev	INS Świerk, INP Kraków, HIL, NU Kharkiv
05.03 - 09.03	$^{16}O^{+3}$	85	IGISOL	IEP UW	HIL, INS Świerk, IPN Orsay, JYFL
13.03 - 15.03	$^{16}O^{+3}$	60	Student workshop	HIL	
16.04 - 20.04	$^{12}C^{+3}$ $^{20}Ne^{+3}$	50 118	Biology	IEP UW, IB AŚ Kielce	HIL, IP AŚ Kielce, INS Świerk
23.04 - 27.04	$^{16}O^{+3}$	79	Electron Spec.	DP UŁ	HIL, IEP UW, INS Świerk
10.05 - 23.05	$^{16}O^{+3}$		Machine dev. & test	HIL	
04.07 - 05.07			Machine dev. & test	HIL	
14.09 - 27.09	$^{20}Ne^{+3}$	52 - 76	Machine dev. & test	HIL	
02.10 - 10.10			Machine dev. & test	HIL	
18.10 - 19.10	$^{16}O^{+3}$		Machine dev. & test	HIL	
22.10 - 26.10	$^{16}O^{+4}$	96	IGISOL	IEP UW	HIL, INS Świerk, IPN Orsay
06.11 - 07.11	$^{16}O^{+3}$		Machine dev. & test	HIL	
08.11 - 09.11	$^{14}N^{+3}$	84	ICARE	HIL, IPHC Strasbourg	IEP UW, INS Świerk, INP Kraków
12.11 - 16.11	$^{18}O^{+4}$	102	IGISOL	IEP UW	HIL, INS Świerk
19.11 - 30.11	$^{14}N^{+3}$	83	ICARE	HIL, IPHC Strasbourg	NU Kharkiv, US Katowice, UB
02.12 - 14.12	$^{32}S^{+5}$	84	Coulex	HIL	FP UAM, DE&IT WUT, IP UMCS CEA Saclay, SE&T UB
17.12 - 21.12	$^{12}C^{+3}$	50	Biology	IEP UW, IB AŚ Kielce	HIL, IP AŚ Kielce, INS Świerk

Abbreviations used in Table 1:

CEA Saclay	CEA Saclay, IRFU/SPhN, Gif-sur-Yvette, France
DE&IT WUT	Dep. of Electronics and Information Technology, Warsaw University of Technology
DP UŁ	Department of Physics, University of Łódź, Łódź
HIL	Heavy Ion Laboratory, Warsaw University, Warsaw
IB AŚ Kielce	Institute of Biology, Świętokrzyska Academy, Kielce
IEP UW	Institute of Experimental Physics, Warsaw University, Warsaw
IP AŚ Kielce	Institute of Physics, Świętokrzyska Academy, Kielce
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 Sołtan Institute for Nuclear Studies, Świerk
IPHC Strasbourg	IPHC Strasbourg, France
IPN Orsay	Institute Physique Nucléaire, Orsay, France
IP UMCS	Institute of Physics, M. Curie-Skłodowska University, Lublin
JYFL	Department of Physics, University of Jyväskylä, Finland
NU Kharkiv	National University, Kharkiv, Ukraine
UB	University of Białystok
US Katowice	University of Silesia, Katowice

Plans of development

		Estimated completion time
1.	Cyclotron	
1.1	Simulations of a new injection beam line	2008
1.2	Design of a new injection beam line to connect the two external ECR ion sources to the cyclotron	2009
2	Experimental hall	
2.1	Upgrade of the beam line on line “D”	First half of 2008
2.2	Installation of a new vacuum control system	2008
3	Power supplies	
3.1	Design of a new interface for existing quadrupole power supplies	2009

<u>4</u>	<u>ECR ion source</u>	
4.1	Installation of the new buncher	First half of 2008
4.2	Execution of the contract for a new ECR ion source	2008
4.3	Factory test of the new ECR ion source	Second half of 2008

<u>5</u>	<u>RF generators</u>	
5.1	Project of a new synthesizer with DDS (Direct Digital Synthesis) for RF signals	2009
5.2	Phase and amplitude noise compensation system for the RF power amplifiers	2009
5.3	Design and installation of a new water leak detection system for the RF generators	2008

<u>6</u>	<u>Vacuum system</u>	
6.1	Installation of the diffusion pump drivers	2008

<u>7</u>	<u>PET</u>	
7.1	Design of the PET radiopharmaceutical production centre	First half of 2008
7.2	Construction works	Second half of 2008
7.3	Beginning of assembling of the PET equipment	Second half of 2008
7.4	Conclusion of the project	February 2009

2. Activity report of the ECR group

A. Górecki, B. Filipiak, A. Pietrzak, M. Sobolewski, J. Sura, R. Tańczyk

In 2007 ECR ion source worked smoothly, delivering the following ions to the cyclotron:

Ion	$^{12}C^{+3}$	$^{14}N^{+3}$	$^{16}O^{+3}$	$^{16}O^{+4}$	$^{18}O^{+4}$	$^{20}Ne^{+3}$	$^{20}Ne^{+4}$	$^{35}S^{+5}$	$^{40}Ar^{+8}$
Current on the inflector [eμA]	95	134	100	132	102	100	115	85	50

Apart from routine maintenance and cleaning of the ion source, the ECR team was involved in tests of the new buncher. The tested buncher was equipped with a cylindrical electrode of about 50 mm length, designed for ions with q/m ratio in the 0.15 – 0.18 range. For comparison, the buncher presently used at HIL has an electrode of 36 mm length, suitable for q/m ranging from 0.18 to 0.25. The ion current obtained with the new electrode was about four times larger than without the buncher (test performed with Ne^{+3} ions).

The results of the tests were used to design and construct a new buncher equipped with a double electrode: one of 36 mm length and the other one of 10 mm length, with a 4 mm long gap. The new buncher will work with ions in the q/m range from 0.15 to 0.25. The electric connections are designed in such a way that one can use both electrodes together as a single one of 50 mm length, or only one of them (36 mm), while the second one (10 mm) is connected to the mass. The new buncher will be installed and put into operation probably in May 2008.

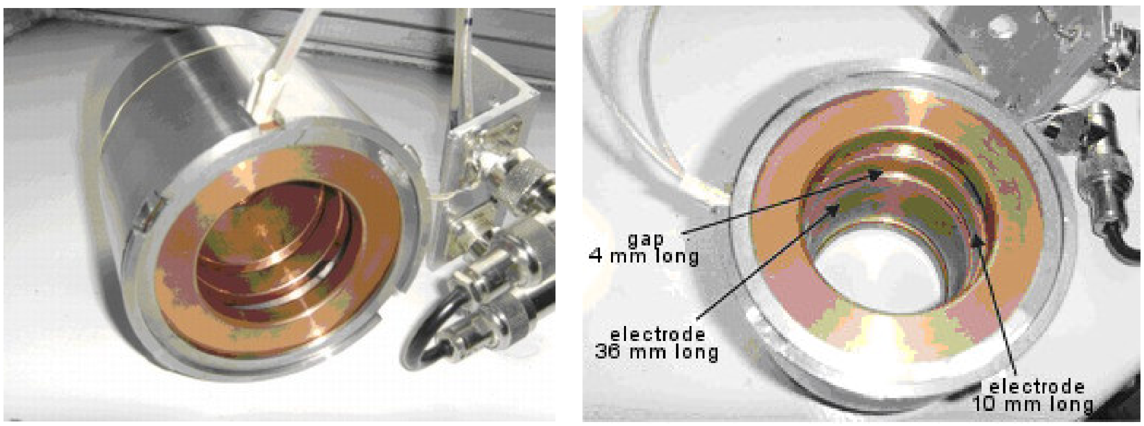


Figure 1. General view of the buncher and localization of the electrodes inside.

3. Activity report of the electrical support group

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

I. Design and implementation:

1. Installation of the controller for the water level in the cyclotron cooling system. Details of this project are given in HIL Annual Report 2006. Fig. 1 shows a sample screenshot of the monitoring program, presenting water levels in the graphical mode. Results of a water pressure measurement performed after changes in the cooling system done in September 2007 are given in Table 1.
2. Maintenance of power circuits and automatics of emergency water dump system. Redesigning of automatics and other adaptation works indispensable for installing the new pumps.
3. Design and implementation of the new elements of the power supply line for ICARE set-up. Details will be given in an internal report.
4. Installation of the second (final) controller for the power supply of the main magnet (ZM1).

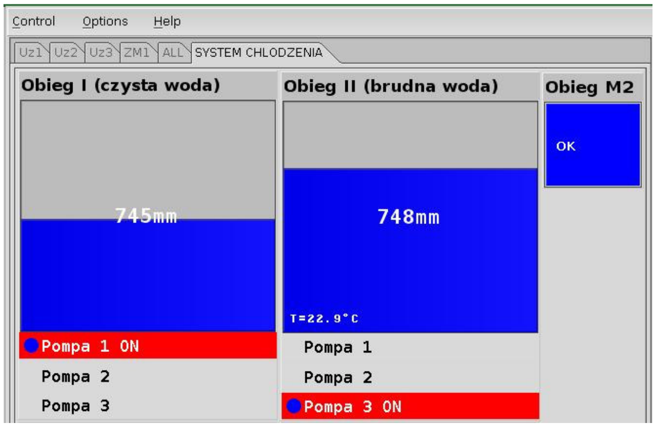


Figure 1. A screenshot of the water level monitoring program.

Table 1. Water pressure in the cooling system for circuits I („clean”) and II („dirty”) after improvements in 2007. Measurements were performed for the 60 m^3/h water stream in circuit I and for the 100 m^3/h stream in circuit II.

Circuit I			**Circuit I Filter**			**Circuit II**		
Pressure before heat exchanger	Pressure after heat exchanger	Δp	Pressure before filter	Pressure after filter	Δp	Pressure before heat exchanger	Pressure after heat exchanger	Δp
kPa	kPa	kPa	kPa	kPa	kPa	kPa	kPa	kPa
508	500	8	492	468	24	157	139	18

II. Measurements and maintenance

1. Measurements and maintenance of the street lighting and related electrical circuits in the cyclotron building area, systematic replacement of broken lighting inside the cyclotron building.
2. Monitoring of the cyclotron electrical circuits in Building A (in total about 650 routine measurements in the cable network).
3. Continuous maintenance of master and slave cable network switchboards as well as the control systems, including minor improvements of the interlocks designed to facilitate the cyclotron operation.
4. Maintenance and monitoring of electrical circuits during the cyclotron operation.
5. Implementation of a new method to measure current in the quadrupole magnet coil to prevent overheating.
6. Installation of hydrostatic water level detectors in cooling water tanks.
7. Replacement of old electrical switchboards in Building A.

4. Repair of the "A" resonator

A. Jakubowski, M. Antczak, P. Jasiński, A. Pietrzak, T. Bracha, W. Kalisiewicz, B. Paprzycki, J. Sura, J. Miszczak, A. Bednarek

Many years ago, during commissioning of the Warsaw Cyclotron, it was discovered that the unloaded Q factor of the "A" resonator is by 20-25% lower than the one of the "B" resonator. The difference in the Q value did not affect the ability of the cyclotron to accelerate ions, so no further investigation of this problem was done. The difference persisted despite numerous repairs and modifications to both resonators (the last major overhaul of the resonators took place in 2001 [1]). However, during the first half of 2007 new problems were reported regarding operation of the "A" resonator, including high VSWR, RF amplitude instabilities, sparking etc.

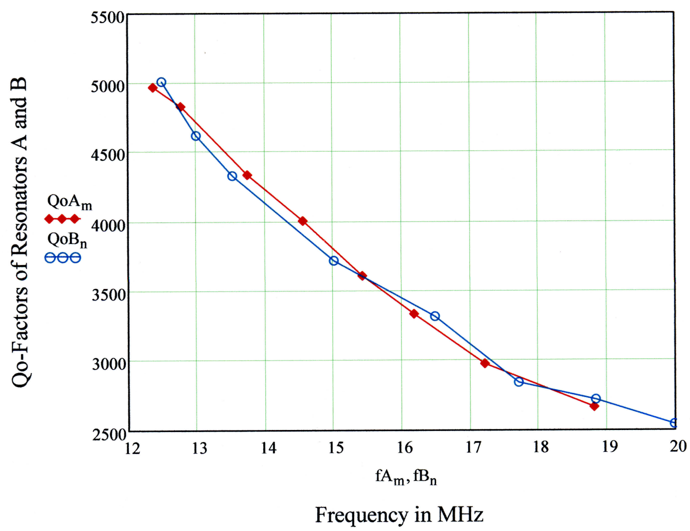


Figure 1. The Q factors of "A" and "B" resonators

It was decided to take the "A" resonator and the "A" dee completely apart for a detailed inspection and repair. After disassembly, a heavy discoloration was found in some parts of the copper liner of the resonator tuning panel, indicating that it has been submitted to an excessive temperature. In addition, a serious damage to the copper was discovered along the seams (the tuning panel consists of an aluminium frame with sheets of copper screwed on the outside). No visible damage was found in the other parts of the resonator nor in the dee. To prevent overheating of the copper liner new cooling tubes were added. Damaged areas of the copper were replaced with a new metal. The whole copper liner was copper-welded to reduce overall resistivity, in this way decreasing the heat generation due to lower ohmic losses. After re-assembly of the resonator the Q factor was measured. As shown in Fig. 1, the "A" resonator is now identical to the "B" resonator in the 12-19 MHz frequency range. One can hope for a trouble-free operation of the "A" resonator for the years to come.

References:

[1] J. Dworski *et al.*, HIL Annual Report 2001

5. Beam energy measurement

M. Wolińska-Cichocka, O. Steczkiewicz, M. Sobolewski, R. Tańczyk, J. Iwanicki, K. Pietrzak, J. Sura

Beam energy measurement systems have been developed at HIL for several years. Presently Time-of-Flight and Rutherford scattering methods are implemented for this purpose. One of the two existing TOF set-ups and the scattering set-up are installed on the beam line, which is common to all the experimental caves, while another TOF arrangement serves the C1.1 line only (IGISOL experiments).

The common TOF implementation [1,2] employs two sets of induction plates placed 6530 mm one from another. The charge pulse induced in each plate is amplified, shaped, and displayed on the oscilloscope, allowing to measure the time of flight of the ions. An example of such an oscilloscope picture is shown in Fig. 1. Note that the time of flight between the two induction plates is longer than the typical beam repetition time and thus a multiple of beam periods corresponds to the measured time of flight.

Another method is implemented in the beam scattering system [3]. The diagnostic set-up comprises a dedicated beam scattering chamber with a charged particle detector and cyclotron RF reference feed. It allows to measure the beam energy as well as its energy and time spread. A gold target (typically 100 μg/cm^2) is used. The particle detector is placed at 45° scattering angle. Such geometry ensures that only elastically scattered particles are registered. This condition is valid for any ion accelerated by the cyclotron. Energy calibration is made with an alpha source built into the device. A spectrum for $^{32}S^{+5}$ beam is presented in Fig. 2.

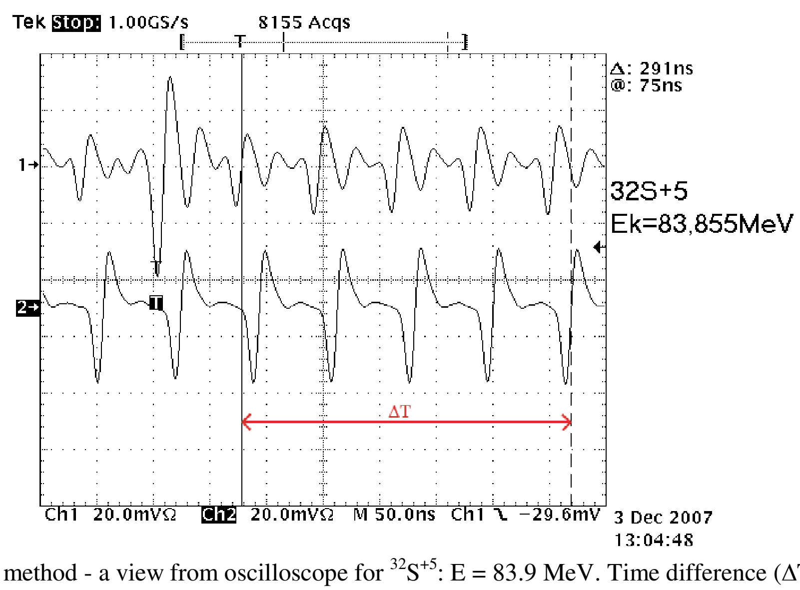


Figure 1. TOF method - a view from oscilloscope for $^{32}S^{+5}$: E = 83.9 MeV. Time difference (ΔT = 291 ns) used for energy determination is marked.

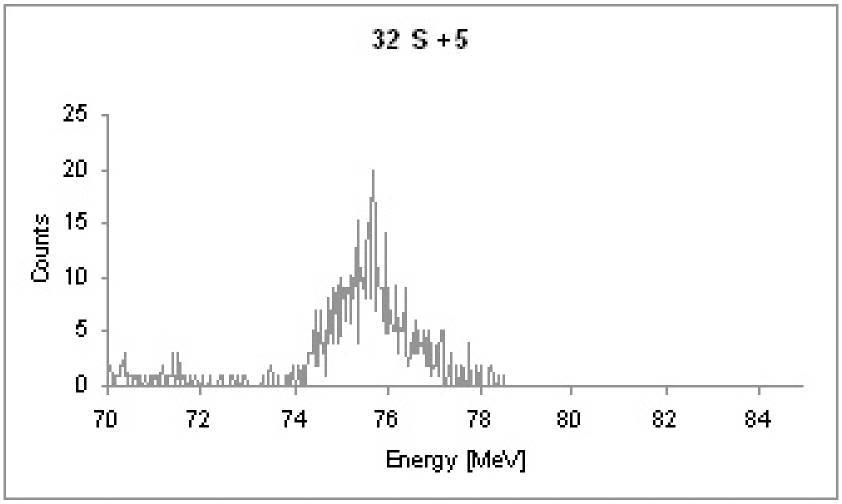


Figure 2. A sample spectrum from the beam scattering set-up ($^{32}S^{+5}$ beam). To calculate the beam energy, the energy of scattered ions measured by the detector should be divided by a factor resulting from the scattering kinematics. In this case the factor is equal to 0.91, therefore E = 75.6 MeV / 0.91 = 83.1 MeV.

The third device, installed on the C1.1 beam line, works also on the principle of time-of-flight (TOF) measurement. This apparatus is located in the experimental set-up area, so it can be used only for IGISOL experiments.

Results of beam energy measurements performed using set-ups described above agree with each other. A comparison of such measurements for recently extracted beams is presented in Table 1.

Table 1. Comparison of beam energies determined using various diagnostic set-ups available at HIL.

ion	TOF	beam scattering	TOF at IGISOL
$^{18}O^{+4}$	82.9 ± 0.8 MeV	82.3 ± 1.6 MeV	-
$^{32}S^{+5}$	83.9 ± 0.8 MeV	83.0 ± 0.8 MeV	-
$^{16}O^{+4}$	97.8 ± 1.0 MeV	-	96.6 ± 1.0 MeV

Each method has its strengths and weaknesses. The TOF technique is convenient to use and rather precise but requires high beam intensity. The beam scattering method suffers from energy calibration uncertainty, but can be used for lower beam intensities and allows to determine other beam parameters.

References:

[1] J. Miszczak *et al.*, HIL Annual Report 2001
[2] M. Sobolewski *et al.*, HIL Annual Report 2002
[3] J. Iwanicki *et al.*, HIL Annual Report 2005

6. Computer network at HIL

J. Miszczak, Z. Kruszyński, M. Sobolewski

In 2007 the layout of the computer network at HIL was modified. What was once a single network was divided into 2 subnetworks. The first subnetwork connects servers (WWW, DNS, file, other) and PC computers, which use Linux/Unix operating system. Public IP addresses are used throughout this network. The second subnetwork connects Windows PCs. This network uses private IP addresses served by a dedicated DHCP server. The IP traffic is routed between the subnets via a router with source network address Interestingly enough the partitioning of the network was done in software, not in hardware. All modern manageable switches have virtual lan (VLAN) capabilities - the 802.1Q standard. A switch can be divided into a number of smaller (virtual) switches. The beauty of the 802.1Q technology is that it allows overlapping of virtual switches i.e. one physical port can connect to different logical networks yet the networks are separate. Also in 2007 a few wireless access points (AP) were installed throughout the Laboratory. The AP are 802.10 b/g compliant and serve the following areas: entrance hall, both lecture rooms A and B, users' hall, the whole second floor of the B building and the hotel. For security reasons, access to the wireless network is protected by WPA encryption, pass-phrases, and MAC address filtering. Anyone whishing to use the network should contact the network administrators at HIL beforehand, to obtain necessary access codes.

7. New ECR ion source and injection line

O. Steczkiewicz, J. Choiński, P. Napiorkowski, L. Pieńkowski, J. Sura, R. Tańczyk, M. Wolińska-Cichocka

During the whole second half of the year procedures of tender for purchase of the new ECR ion source went on. At the end of the year a contractor was chosen and both sides reached an agreement in the matter of contract conditions. On 11 January 2008 the contract and Memorandum of Understanding between Heavy Ion Laboratory, Warsaw University and PANTECHNIK S.A. were signed. The contract execution is fixed for 12 November 2008. The scope of the order is the fabrication and factory acceptance test of the items listed below:

1. SUPERNANOGAN ECR,
2. RF amplifier 400W-14.5 GHz,
3. Chariot for the source,
4. Packing, transportation and insurance CIP HIL,
5. Standard factory test with gases (O, Ar, Xe) and one metallic ion (high temperature oven).

According to the conditions of collaboration described in the Memorandum of Understanding, a complementary order of items necessary to the correct operation and exploitation of the SUPERNANOGAN ECR will be placed with PANTECHNIK when funds allow it. HIL scientists will be instructed in the ion source technique and operations both during the construction and assembly periods. The planned collaboration includes also involvement of PANTECHNIK in the calculations and technical projects of the injection line, which are going to be prepared at HIL. Fabrication of some mechanical parts by the HIL workshop on the basis of PANTECHNIK project drawings is considered.

The ion species, which will be delivered by the new ECR ion source, together with available currents (in eμA) are listed in Table 1.

Table 1. Ion currents [eμA] available from the new ECR ion source.

Ion/charge	+1	+2	+4	+6	+8	+9	+11	+14	+20	+25	+26	+27	+30	+31	+32
H	2000														
He	2000	1000													
C	500	350	200	3											
N	1000	300	100	10											
O	1000	400	300	200											
Ne	1000	300	200	160	25										
Ar	1000	350	250	200	200	90	30	1							
Kr	1000						25	15							
Ag			250	250	200	90	30		4						
Xe	500				220				3						
Ta									4	0.8					
Au											10	6	1	0.7	0.2
Pb									10	5	3	1			

8. The Warsaw PET Project – Radiopharmaceuticals Production Centre

J. Choiński, I. Cydzik, D. Hechner, J. Jastrzębski, K. Kilian, P.J. Napiorkowski

The information on the Warsaw Consortium for PET Collaboration (WCPC), the Warsaw PET Project and its Radiopharmaceuticals Production Centre (RPC) was already presented in previous Annual Reports of HIL [1,2]. During 2007 a substantial progress in the administrative, legal and financial preparation of RPC realization in the HIL building was achieved.

In 2007 we have finalized long negotiations with International Atomic Energy Agency (IAEA), related to the building adaptation contract. The Amendment 2 to our Collaboration Agreement settling the encountered problems was signed on 5 September.

Last year our activity also resulted in a substantial increase of funds available for the RPC equipment purchase. In July the subvention for the acquirement of the Quality Control units was allocated to the Laboratory by the Ministry of Health. One month later the Warsaw University signed a contract with the Ministry of Science and Higher Education allowing us, using European funds, to buy a supplementary equipment for the production of radiopharmaceuticals used in the research programme.

Finally, on 23 October two contracts for the realization of a turnkey project were signed in the Agency offices by the Rector of the Warsaw University between

a) Warsaw University and GE Healthcare Company for the building adaptation;
b) Warsaw University, IAEA and GE Healthcare Company for the supply of the equipment (including the 16.5 MeV proton cyclotron).

After the contract signature the Contractor and its Subcontractors prepared and discussed with Laboratory representatives the layout of the RPC, including the calculation and design of the cyclotron protection walls. Recently (19-22 February 2008) the preliminary version of this layout has been reviewed and substantially modified after discussions with the Agency experts (the visit of two experts was arranged and financed by IAEA using funds for Technical Cooperation between Agency and Poland, within our PET project).

It is expected that the building adaptation design will be ready by the end of April 2008 and the construction permit will be obtained two months later. The Contractor plans to finalize the whole project during the first trimester of 2009. The regular production of the most popular radiopharmaceutical, fluorodeoxyglucose (FDG) will, however, be only possible after its registration. This may take up to one year.

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9. Nuclear-coal synergy project

L. Pieńkowski for the Nuclear-Coal Synergy consortium

The goal of the nuclear-coal synergy project is to develop and demonstrate the technologies that can efficiently use the nuclear hydrogen and oxygen to reduce CO_2 emission (clean coal technologies, CCT), and for coal to liquid fuels conversion (CTL) without CO_2 emission. Nuclear hydrogen production is a CO_2 emission free technology driven by high temperature reactors (HTR), i.e. by the nuclear process heat and/or by electricity that split water molecules. This project requires common European efforts and should be formulated as European programme concentrated in Poland.

The idea of the Polish nuclear-coal synergy project originated in the Heavy Ion Laboratory. The following parties declared their interest in joining the Consortium established on 28 June 2006:

- AGH University of Science and Technology,
- The Andrzej Sołtan Institute for Nuclear Studies,
- Central Mining Institute, Katowice,
- Częstochowa University of Technology,
- Institute of Atomic Energy,
- Institute for Chemical Processing of Coal, Zabrze,
- Institute of Nuclear Physics, Polish Academy of Sciences,
- Institute of Nuclear Chemistry and Technology,
- Silesian University of Technology at Gliwice,
- University of Silesia,
- Warsaw University,
- Warsaw University of Technology,
- Wrocław University of Technology,
- Institute of Chemical Engineering, Polish Academy of Sciences, Gliwice.

AGH University of Science and Technology is the leading institution of the project and is represented by Professor Kazimierz Jeleń, Deputy Rector of AGH. Ludwik Pieńkowski, from the Heavy Ion Laboratory and Jerzy Cetnar, from AGH are coordinators of the project.

This challenging project is included in the frame of the strategic programme of the Council for Atomic Energy Matters [1], aiming at increasing the role of nuclear research in Poland.

The vision of nuclear-coal synergy programme was presented to the European High Temperature Reactor Technology Network (HTR-TN) committee on 26 January 2007. The Network acknowledged the convergence of this initiative with the strategy it promotes for the development of HTR in Europe as a CO_2 free heat source for industrial applications.

References:

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10. Educational and science popularisation activities at HIL

A. Trzcińska, K. Wrzosek, J. Iwanicki, G. Jaworski[1], A. Kordyasz, J. Kownacki, Z. Morozowicz, P.J. Napiorkowski, M. Palacz, L. Pieńkowski, J. Srebrny, O. Steczkiewicz, M. Wolińska-Cichocka

1) also at the Faculty of Physics, Warsaw University of Technology, Warsaw, Poland

For many years the Laboratory has been strongly involved in education and science popularisation. Guided tours at HIL have become our regular activity. These "live" lessons on cyclotron and nuclear physics continue to enjoy popularity in high schools, including ones from outside Warsaw. During a guided tour visitors can see the control room and the cyclotron, get acquainted with facilities installed in the Laboratory and experiments performed here. Short lectures – basic introduction to the nuclear physics and principles of the cyclotron operation – are also offered, especially to high school students. Tours are free of charge.

In total, 37 organized groups (over 850 people) visited our Laboratory in 2007. Twenty of them were high school classes. We also hosted groups of students from various faculties of the Warsaw University, including Physics, Chemistry and Biology, as well as from the Physics Faculty of the Warsaw University of Technology and the Dominican College of Theology. Finalists of Physics Olympiad, finalists of Young Physics Talents Competition, participants of Summer School of Physics and numerous groups of physics teachers were also among our visitors in 2007.

In 2007 for the 11th time HIL participated in the annual Warsaw Festival of Science and during this event the "Researchers' Night" was organized in the Laboratory for the first time. We opened the door for general public on 28 and 29 September. During the Researchers' Night, the visitors (about 150 people in a wide spectrum of ages, ranging from school children to the elders) took part in a nuclear physics measurement performed using the OSIRIS-II set-up, aiming at observation of gamma-ray radiation emitted from excited nuclei. Our guests had an opportunity to talk to physicists, ask all kinds of individual questions and learn how the scientific work looks like. We presented our motivations of being a scientist and explained why we have chosen this career path. We discussed as well the significance of science for the future of Poland, for the economy, and for our position in the world. A short movie was recorded during this event by the internet television station LIM TV.

The following day more than 250 people visited the Laboratory. They could choose from a rich programme, including a guided tour of the cyclotron and other experimental facilities, lectures "Physics for Goalkeepers", "Radiation and health – story about PET" (by P.J. Napiorkowski), "High temperature reactors: history and perspective", "How to reach Mars" (by L. Pieńkowski). Two of these lectures were also presented during the preceding week in the form of so-called Festival Lessons for high-school classes, and attracted large attention.

The Third Polish Workshop on Heavy Ion Acceleration and its Applications was organized at HIL in March 2007. The participants gained experience in methods of data acquisition and analysis, in operating the cyclotron including the beam diagnostics measurements and in charged particle and gamma-ray detection techniques (see Sec. 11).

HIL staff members are also engaged in supervising MSc and PhD theses – see Part D.

11. Polish Workshop on Heavy Ion Acceleration and its Applications

P.J. Napiorkowski, A. Trzcińska, J. Choiński, K. Hadyńska[1], G. Jaworski[2], J. Kownacki, J. Mierzejewski[3], M. Palacz, J. Srebrny, O. Steczkiewicz, J. Sura, K. Wrzosek

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2) also at the Faculty of Physics, Warsaw University of Technology, Warsaw, Poland
3) also at the Faculty of Physics, Warsaw University, Warsaw, Poland

The workshop was organized by the Heavy Ion Laboratory for the third time on 12-17 March 2007. As in previous years, it was intended for third year physics students interested in nuclear physics. The success of earlier editions of the workshop led to the increased popularity of this event – we received over two times more applications than we were able to accept. Seventeen selected students from four Polish universities (Adam Mickiewicz University in Poznań, University of Silesia, Maria Curie-Skłodowska University in Lublin and University of Szczecin) had an opportunity to attend a series of lectures on topics related to heavy ion physics. The experimental part of the Workshop allowed the participants to get acquainted with HIL infrastructure by performing measurements using dedicated detection set-ups available in the Laboratory.

The programme of the lectures was the following:

- Ion optics (J. Sura),
- Radioprotection at HIL (R. Tańczyk),
- Technique of a gamma-ray analysis (M. Palacz),
- In-beam gamma spectroscopy (Ch. Droste),
- High Temperature Reactor in Poland (L. Pieńkowski),
- Accelerators in cancer therapy (Z. Szefliński).

Students took part in the following experimental tasks:

- Beam focusing in heavy ion acceleration,
- Beam energy measurements based on the Rutherford scattering,
- Determination of cross section in the Rutherford scattering,
- Identification of excited bands in gamma-gamma coincidences,
- Measurements of ^{137}Cs activity in mushrooms.

Student presentations concluded the workshop. Each group prepared a 20 minutes talk on their measurements and results.

Part B:
Experiments and experimental set-ups

1. New results in barrier distributions

E. Piasecki[1,4], *M. Kowalczyk*[1,2], *J. Jastrzębski*[1], *T. Krogulski*[3], *K. Piasecki*[2], *K. Rusek*[4], *Ł. Świderski*[4], *S. Khlebnikov*[5], *M. Mutterer*[6], *W.H. Trzaska*[7], *M. Sillanpää*[7], *S. Smirnov*[8], *G. Tiourin*[5], *S. Dmitriev*[9], *E. Kozulin*[9], *A. Ogloblin*[9], *N. Rowley*[10]

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7) University of Jyväskylä, Jyväskylä, Finland
8) JINR, Dubna, Russia
9) Kurchatov Institute, Moscow, Russia
10) IPHC, Strasbourg, France

One of the most important near-barrier reactions is fusion. It turns out that a connection between nuclear reaction mechanism and structure of the interacting nuclei exists and manifests itself in a strong enhancement of fusion cross sections at sub-barrier energies. This can be understood as a result of the interplay between various reaction channels: elastic and inelastic scattering, transfer reactions, break-up and fusion. It has been demonstrated experimentally in many systems that the fusion barrier between two nuclei does not have a unique value but rather a weighted distribution D_{fus} of heights, which can be determined directly from fusion excitation function measurements [1]. The best theoretical description of this phenomenon can be made in the framework of the coupled-channels method, according to which the distribution is a manifestation of the strong couplings to different reaction channels, in particular to strong collective excitations of the participating nuclei. In some cases the distribution turns out to be markedly structured and gives a fingerprint of the couplings involved [2,3].

It has been shown both theoretically and experimentally that the difficult fusion measurements can be replaced by much simpler quasi-elastic scattering measurements at backward angles, giving rise to the barrier distribution D_{qe}, and there exist many experimental data confirming the basic equivalence of these two methods [4,5]. The latter consists in determining the excitation function of quasi-elastic scattering of projectile-like nuclei at large angles. The quasi-elastic cross section is the sum of elastic, inelastic and transfer channels, with no need to individually identify the particular channels involved. The barrier distribution is obtained directly from the data as the first derivative of the ratio of the excitation function and the Rutherford cross section [6].

Our programme of measurements performed at the Warsaw Cyclotron concentrated on the ^{20}Ne projectile, since this nucleus has spectacularly large deformation parameters: $\beta_2 = 0.46$, $\beta_3 = 0.39$, $\beta_4 = 0.27$ [7-9]. According to calculations performed using the coupled-channels code CCQEL [10], this projectile, used in conjunction with a relatively inert target nucleus, should give rise to a strongly structured barrier distribution.

The results of our measurements were perplexing: the barrier distributions for ^{20}Ne + ^{112,116,118}Sn turned out to be smooth [11,12]. The natural suspicion is that the smoothing is due to couplings not taken into account in our calculations; for example, those connected with transfer channels.

On the other hand, the simultaneously performed measurements for the ^{20}Ne + ^{nat}Ni system, resulted in a clearly structured distribution [13] in a very good agreement with calculations based on the coupled-channels method.

A possible hypothesis is that the smoothing is due to the neutron transfer (pick-up) channel, which for the Ni target is expected to be much weaker than for Sn. This expectation relies on the Rehm transfer cross-section systematics [14], for which the effective Q value [15] is the main factor influencing the transfer probability. While for both cases the Q values are negative, the expected neutron transfer cross sections are smaller by a factor of ~3 for ^{58}Ni than for ^{118}Sn.

To check our hypothesis experimentally, we performed, under the same experimental conditions, measurements for the ^{20}Ne + ^{90,92}Zr systems. According to the Rehm systematics, for the ^{90}Zr target, the neutron-transfer probability should be only slightly larger than for Ni, while being considerably smaller than for the ^{118}Sn target. In the other case, for the ^{92}Zr target, the n-transfer probability should be similar to that for the ^{118}Sn target. Thus, if our hypothesis is correct, we should expect a structured barrier distribution for the ^{90}Zr target, while in the case of ^{92}Zr we expect to have its structure considerably smoothed out. On the other hand the structure of both Zr nuclei is so similar that, if one excludes the transfer channels, according to the coupled-channels calculations one should not expect any difference between the two distributions.

In agreement with our expectations, the barrier distributions for the ^{90}Zr and ^{92}Zr targets turned out to be different [16]: the former is structured, while the latter is structureless and wider. In case of the ^{90}Zr target the observed structure is similar to that calculated using the CCQEL code. The larger width and the lack of structure in case of the ^{92}Zr target is apparently due to a large transfer coupling strength, which cannot be taken into account by the calculations, at least using the present code. This points to the same reason for the disagreement between experiment and theory observed in the case of Ne + Sn system: that is, these are the transfer channels, which smooth out the expected structure.

We report here results of experiment performed at the Jyväskylä Cyclotron, in which we determined the barrier distribution for the ^{20}Ne + ^{208}Pb system using both (fusion and quasielastic) methods simultaneously. Basically, the method and experimental set-up was similar to that described in Ref. [6], however, to distinguish between fusion/fission and the backscattering quasielastic events, we identified the mass of registered ions using the TOF technique, with the start/stop generated by the semiconductor detector and cyclotron RF signals, respectively. Compilation of our results concerning the interaction of ^{20}Ne with various targets is shown in Fig. 1.

In the calculations, although it was checked that the shape of barrier distribution is determined almost entirely by the properties of ^{20}Ne, we also took into account the vibrational excitations of the targets. The coupling scheme included the states 0^+, 2^+, 4^+, 6^+ in the ^{20}Ne rotational band. The convergence of the results, with the number of states included, was checked. In addition, we took into account the strong octupole-phonon state in the projectile (E^* = 5.62 MeV, β_3 = 0.39).

As can be seen, in the case of ^{208}Pb target, the experimental barrier distributions, quasielastic and fusion, are very similar but both structureless, in a clear disagreement with the coupled channels calculations.

To check whether the Rehm systematics is sufficiently reliable, we identified the mass of ions scattered to ~150^o from the targets shown in Fig. 1.

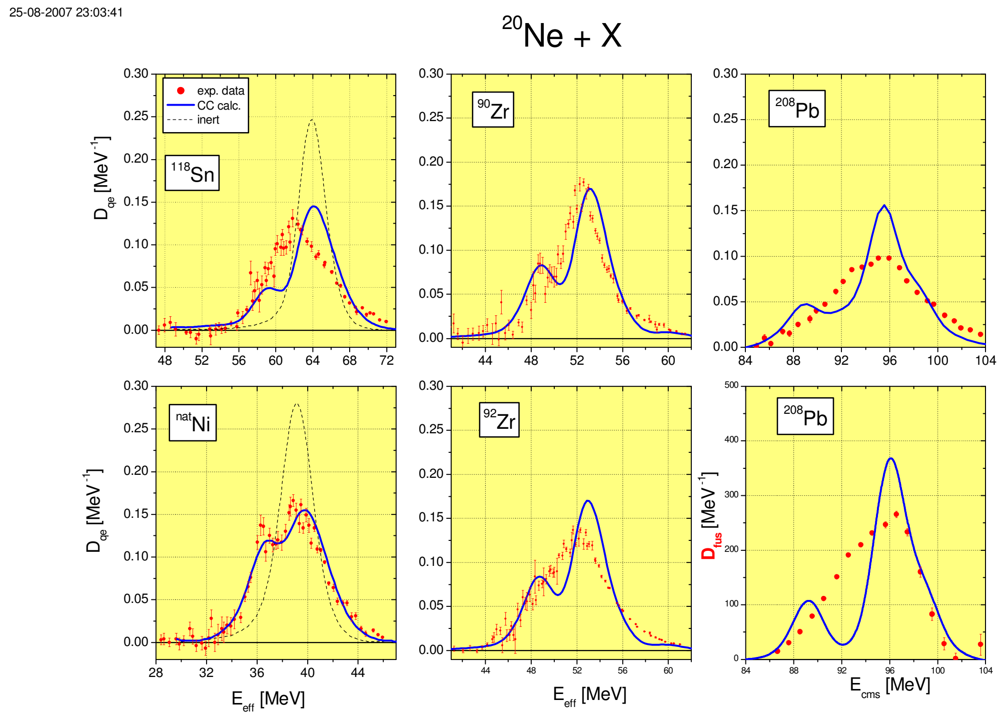

Figure 1. Barrier height distributions obtained by this collaboration for ^{20}Ne + various targets, compared with the coupled channels calculations. The dashed lines describe the results of calculations where all couplings were disregarded (nuclei treated as inert). The lower right panel shows the fusion barrier distribution D_{fus}, other panels present quasielastic barrier distributions D_{qe}.

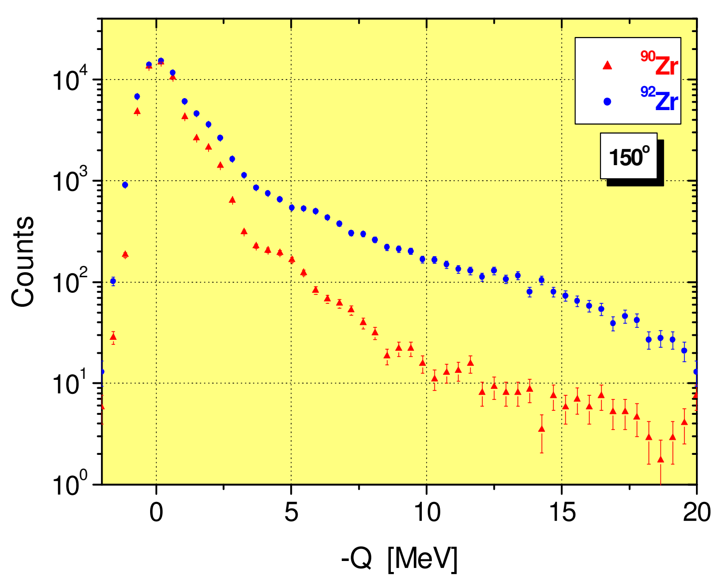

Figure 2. Excitation-energy spectra of the ^{20}Ne + ^{90,92}Zr systems generated in non-transfer backscattering to 150^{o} at near-barrier energy.

For Zr targets experimental data are in agreement with the systematics: the transfer probability for ^{92}Zr is larger by a factor of almost 2 in comparison with the ^{90}Zr (and the Ni) targets. Moreover, the inelastic excitations are clearly stronger in the former case (see Fig. 2). Whether this is related to the smoother barrier distribution in the former case – remains to be seen.

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2. ICARE @ HIL

E. Piasecki[1], M. Antczak[1], J. Devin[2], W. Gawlikowicz[1], A. Jakubowski[1], P. Jasiński[1], M .Kisieliński[1,3], M. Kowalczyk[1,4], L. Pieńkowski[1], R. Pozorek[1], E. Koshchy[5], A. Pietrzak[1], M. Rousseau[2], K. Rusek[4], I. Strojek[4] for ICARE@HIL[1] collaboration

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ICARE is a charged particle detector system used for their identification and energy measurements, built in the IReS (Strasbourg). This year first experiments employing this set-up were performed at HIL by teams from Strasbourg, Cracow, Ukraine and Warsaw. The ICARE system consists of the 1m diameter reaction chamber with up to 48 E-ΔE gas, semiconductor and scintillator telescopes, supplied by the vacuum and gas systems, electronics and data acquisition systems. The detectors can be mounted in various configurations using internal

[1] ICARE collaboration involves: Heavy Ion Laboratory, Warsaw University, Warsaw, Poland; Institute of Experimental Physics, Warsaw University, Warsaw, Poland; IPHC, Strasbourg, France; The Andrzej Sołtan Institute for Nuclear Studies, Świerk, Poland; The Henryk Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, Poland; Institute for Nuclear Research, Kiev, Ukraine

mounts. The self-supporting target holder allows to use up to 8 different targets. Some of the detectors as well as the target holder can be remotely operated without necessity of opening the reaction chamber.

During this year some elements of the system were upgraded, including collimator, target holder, detector mounting, preamplifiers, amplifiers, data acquisition. In November the French – Polish – Ukrainian team started measurements of angular distribution of products from $^{14}N + {}^{12}C$ reaction at 80 MeV in the laboratory frame. An example of charge and mass identification is shown in Fig. 1.

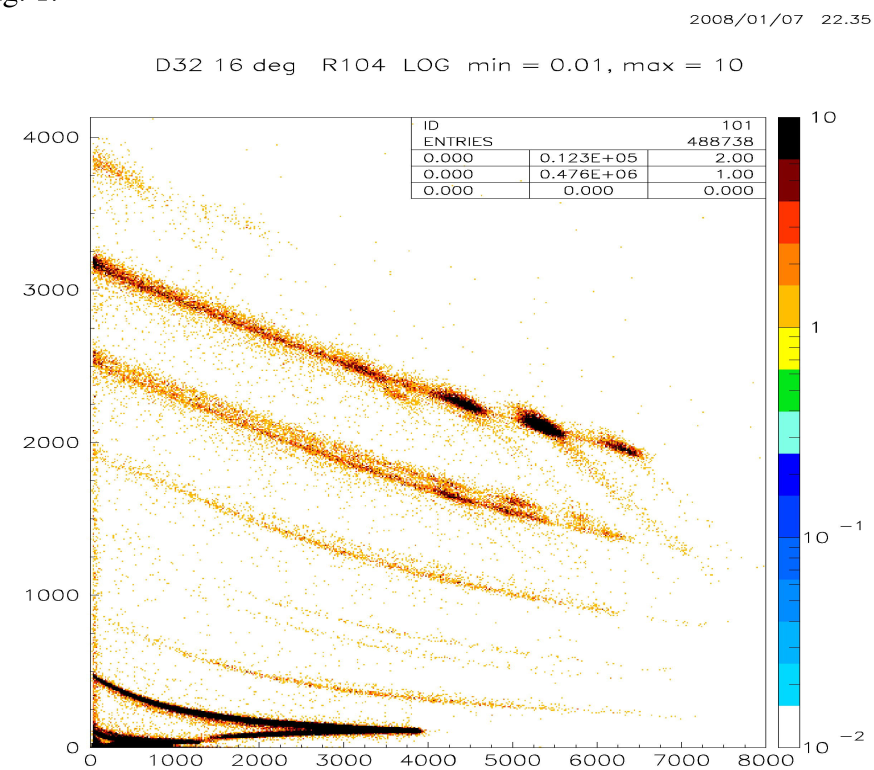

Figure1. Reaction products observed in one of the Si E-ΔE telescopes in the $^{14}N + {}^{12}C$ reaction at the LAB energy of 80 MeV.

We plan to expand soon the ICARE possibilities by adding to the system the Time-of-Flight detectors and increasing the flight base.

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

- Study of properties of isotopes far from stability line produced in heavy-ion reactions [1]
- Studies of fusion barrier height distributions using the quasi-elastic scattering method [2,3]
- Study of nuclear deformation using light-charged particles emission spectra [4]

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3. Mechanism of ^{7}Li(^{10}B, ^{9}Be)^{8}Be reaction and ^{8}Be + ^{9}Be potential

V.O. Romanyshyn[1], A.T. Rudchik[1], E.I. Koshchy[2], O.A. Ponkratenko[1], S. Kliczewski[3], K. Rusek[4], A. Budzanowski[3], K.W. Kemper[5], J. Choiński[6], B. Czech[3], L. Głowacka[7], S.Yu. Mezhevych[1], V.M. Pirnak[1], A.A. Rudchik[1], I. Skwirczyńska[3], R. Siudak[3], A. Szczurek[3]

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Angular distributions of the ^{7}Li(^{10}B, ^{9}Be)^{8}Be reaction were measured at the energy E_{lab}(^{10}B) = 51 MeV for the ground and excited states of ^{8}Be at the Warsaw Cyclotron U-200P. Silicon *ΔE-E* detectors were used for identification of reaction products. A fragment of a typical *ΔE(E)* spectrum of ^{7}Li(^{10}B, *X*) reaction products is presented in Fig. 1 (left panel), showing a good identification of the beryllium isotopes. The measured angular distributions for the ground state and 2.94 MeV (2^{+}), 11.4 MeV (4^{+}) excited states of ^{8}Be are presented in Fig. 1 (right panel). The data were analysed with the coupled-reaction-channels (CRC) method for one- and two-step transfers of nucleons and clusters. The CRC-calculations were performed with the ^{7}Li + ^{10}B-potential obtained by fitting elastic scattering data [1]. The ^{8}Be + ^{9}Be-potential was deduced by fitting the measured (^{10}B, ^{9}Be) reaction data. It was found that proton, deuteron and n + p transfers are important in this reaction. The parameters of the ^{8}Be + ^{9}Be-potential differ essentially from those of the ^{7}Li + ^{10}B-potential.

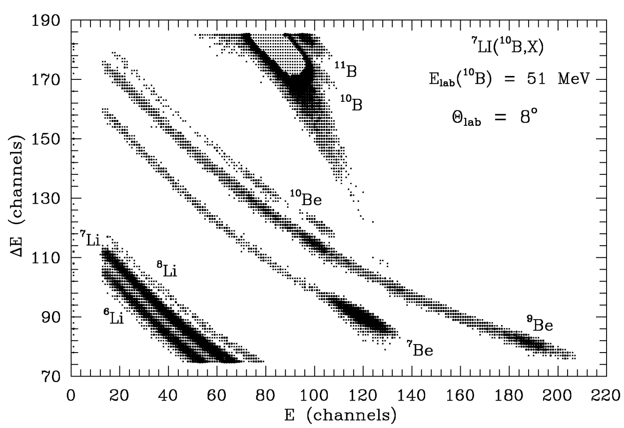
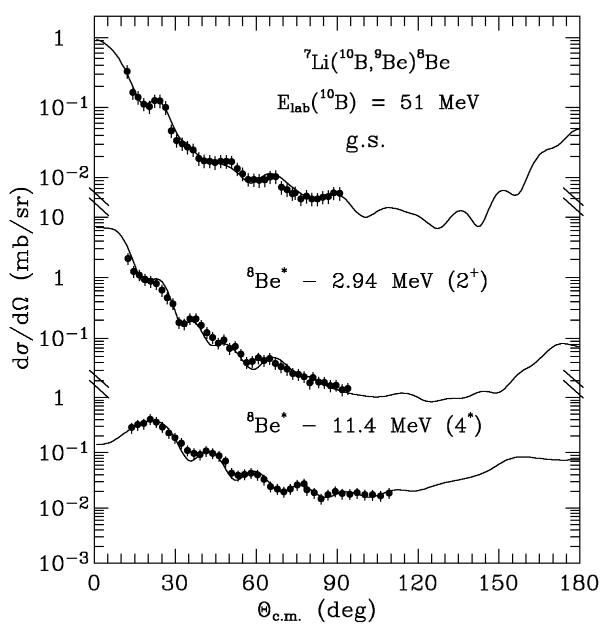


Figure 1. Left panel: Typical *ΔE(E)*-spectrum of the ^{7}Li(^{10}B, *X*) reaction products.



Right panel: Angular distributions of the ^{7}Li(^{10}B, ^{9}Be)^{8}Be reaction for the ground and excited states of ^{8}Be. The curves show the CRC-calculations for sum of all transfers.

References:

[1] A.T. Rudchik, V.O. Romanyshyn *et al.,* Eur. Phys. J. **A 33** (2007) 317

4. Elastic and inelastic scattering of ^{18}O ions on ^{12}C at 117 MeV

A.T. Rudchik[1], Yu.O. Shyrma[1], E.I. Koshchy[2], S. Kliczewski[3], B.G. Novatski[4], O.A. Ponkratenko[1], E. Piasecki[5,6], K. Rusek[5], G.P. Romanyshyna[1], Yu.M. Stepanenko[1], I. Strojek[5], S.B. Sakuta[4], A. Budzanowski[3], K. W. Kemper[7], J. Choiński[6], L. Głowacka[8], I. Skwirczyńska[3], R. Siudak[3], A. Szczurek[3]

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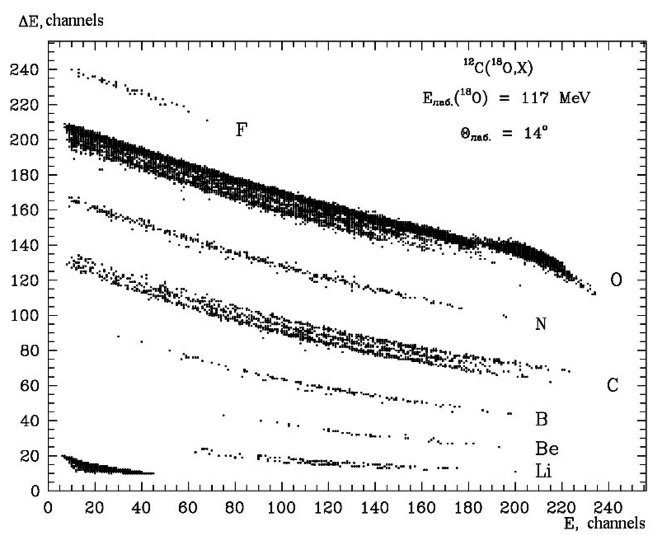
Beam of ^{18}O, accelerated at the Warsaw Cyclotron U-200P to LAB energy of 117 MeV, was used to study the angular distributions of the $^{12}C + {}^{18}O$ elastic and inelastic scattering. The reaction products were identified using silicon *ΔE-E*-telescopes. A typical *ΔE(E)*-spectrum of $^{12}C(^{18}O, X)$ reaction products is shown in Fig. 1 (left panel). The measured angular distributions of the $^{12}C + {}^{18}O$ elastic and inelastic scattering are presented in the right panel of Fig. 1. The data were interpreted within the optical model (OM) and coupled-reaction-channels (CRC) method. Both rotational and vibrational transitions were included in the CRC-calculations. The parameters of $^{12}C + {}^{18}O$ potential of the Wood-Saxon type as well as the deformation parameters of ^{12}C and ^{18}O were deduced by fitting scattering data.



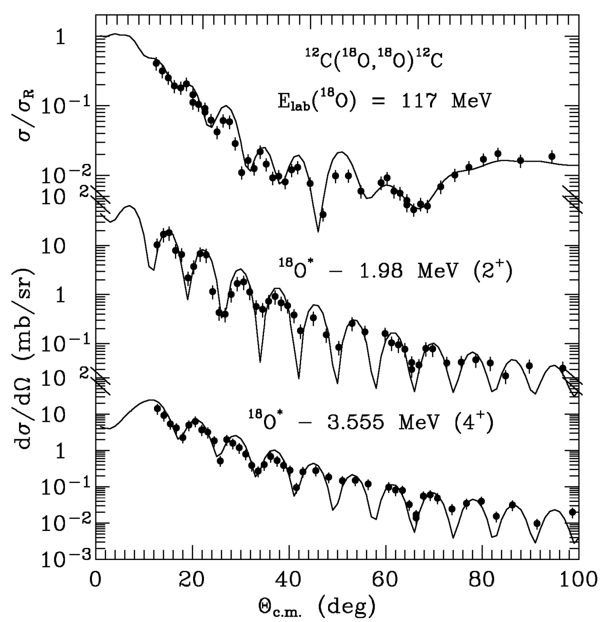


Figure 1. Left panel: Typical *ΔE(E)*-spectrum of the $^{12}C(^{18}O, X)$ reaction products at $E_{lab}(^{18}O) = 117$ MeV.
Right panel: Angular distributions of the $^{12}C + {}^{18}O$ elastic and inelastic scattering at $E_{lab}(^{18}O) = 117$ MeV. The curves represent the OM- and CRC-calculations.

5. Coulomb excitation of ^{100}Mo – towards determination of triaxiality

K. Wrzosek[1,2], K. Hadyńska[2,3], J. Iwanicki[2], M. Kisieliński[2,4], A. Kordyasz[2], M. Kowalczyk[1,2], J. Kownacki[2], S. Lalkovski[5], P. Napiorkowski[2], L. Pieńkowski[2], D. Piętak[2,6], J. Srebrny[2], A. Trzcińska[2], M. Zielińska[2,7]

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Coulomb excitation experiment of ^{100}Mo was performed in December 2007 using 85 MeV ^{32}S beam from the Warsaw Cyclotron. It is a continuation of the systematic study of low-lying 0^+ states structure in stable even-even molybdenum isotopes [1-3].

The main goal of the experiment was to extract the triaxiality parameter of the 0^+_1 and 0^+_2 states. Previously performed measurements show clearly that a very precise determination of the $0^+_2 \rightarrow 2^+_1$ (159 keV) transition intensity is essential to achieve this aim.

New γ-particle detection set-up dedicated for Coulomb excitation experiments at HIL was used. The γ rays depopulating Coulomb-excited states were detected in the OSIRIS-II array in coincidence with scattered projectiles. An array of 45 PiN-diodes was used for projectile detection. Scattering angle coverage extends from 112° to 152° with respect to the beam direction.

A very good coincidence time resolution, which was achieved also in the low γ-ray energy region (below 200 keV), makes it possible to distinguish between true and random coincidences more precisely than in previous experiments. This improvement is crucial in particular in the case of the above-mentioned 159 keV transition [4].

Two types of measurements were performed. During the first part of the experiment γ rays were detected in coincidence with back-scattered projectiles. The second part of the experiment was performed in the non-coincidence mode. Since excitation strength depends strongly on the scattering angle, the excitation patterns obtained in these two types of measurements are different and bring complementary information on matrix elements involved.

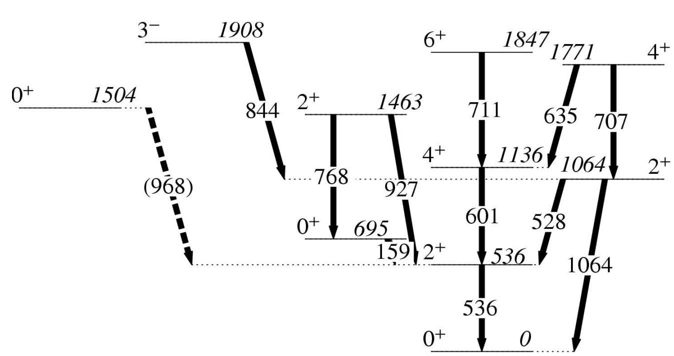

Figure 1. Low-energy part of the level scheme for ^{100}Mo isotope and γ-ray transitions observed in the Coulomb excitation experiment. Transition $0^+_3 \rightarrow 2^+_1$ (dashed line) was observed only in the single mode measurement.

The collected data are encouraging. First results show that the weak $3^- \to 2^+_2$ line is clearly observed, indicating the population of a negative-parity state 3^-. It seems that γ-ray measurement in the single mode allows to observe $0^+_3 \to 2^+_1$ transition. The 0^+_3 state seems to be populated for the first time using Coulomb excitation method. The on-going data analysis aims for determination of electromagnetic matrix elements for a wide range of transitions, as well as shape parameters of the 0^+ states in ^{100}Mo.

The authors would like to thank John Sheridan from the Portora Royal School for his help during the experiment.

References:

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[2] K. Wrzosek *et al.,* Int. J. Mod. Phys. **E15** (2006) 374
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6. Implementation of a genetic algorithm to the Coulex data analysis

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Coulomb excitation is a well-established method to determine electromagnetic properties of nuclei in ground and excited states. Since early eighties a semi-classical coupled-channel Coulomb excitation least-squares search code GOSIA [1] has been a basic tool for data analysis. The code was developed by the Rochester-Warsaw collaboration to analyse large sets of experimental data required to unambiguously determine many electromagnetic matrix elements involved in heavy-ion induced multiple Coulomb excitation.

The main advantages of GOSIA are:

- χ^2 fitting procedure (using a gradient method) to determine the best set of electromagnetic matrix elements,
- fast approximation method developed to speed up the analysis of complex experiments,
- extensive possibilities to describe various geometries of experimental set-ups.

The main difficulty in GOSIA use is a time-consuming test of alternative solutions.

Future exotic beam facilities, delivering beams of intensities higher than the ones available from state-of-the-art radioactive beam accelerators, together with a new generation of highly efficient detection systems, will challenge the present method of data analysis. With new experimental tools more information will be collected, making the analysis more complex.

A *genetic algorithm* is a heuristic multidimensional surface search technique. It is inspired by phenomena studied by evolutionary biology, such as inheritance, selection, crossover (also called recombination) and mutation. Genetic algorithms are implemented as a computer simulation, in which a population of abstract representations (called chromosomes, genotype, genome) of candidate solutions (called individuals, creatures or phenotypes) evolves towards better solutions. The advantages of genetic algorithm are such that it finds the exact or an approximate solution to the global optimum and it densely samples χ^2 surface near the extremum.

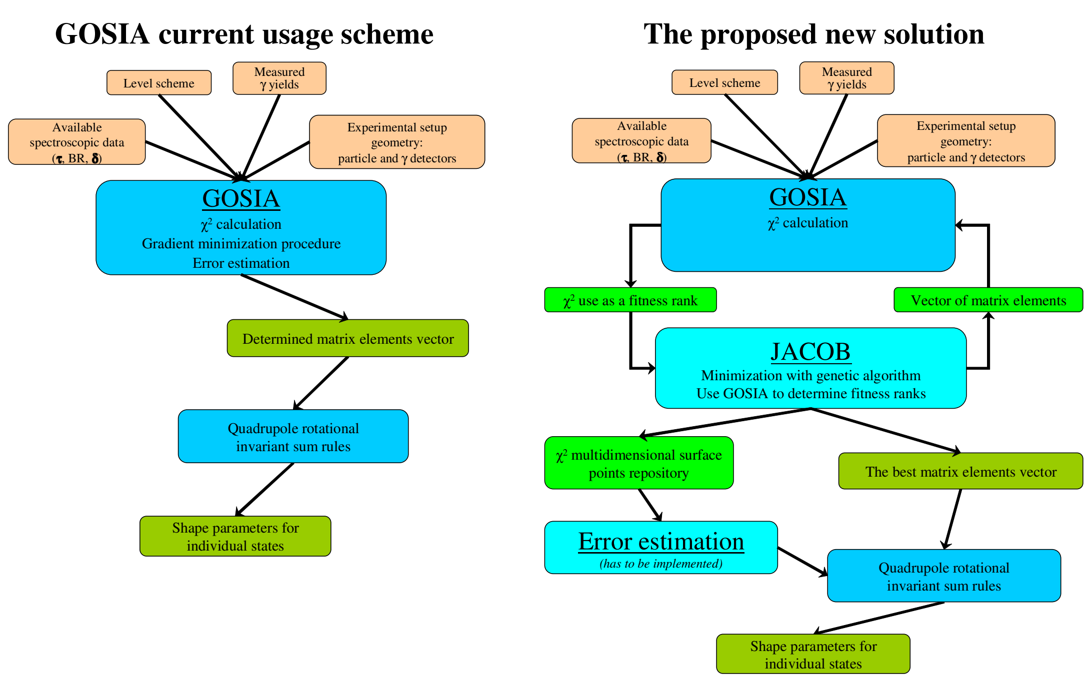
In case of Coulex data analysis each individual is a vector of matrix elements represented in binary as a string of 0s and 1s. The evolution starts from a population of randomly generated individuals and continues in subsequent generations. In each generation the fitness of every individual is evaluated. Multiple individuals (parents) are, based on their fitness, stochastically selected and modified (recombined and randomly mutated) to form a new generation. The algorithm terminates when a stop rule is reached.

The newly developed code JACOB, implementing genetic algorithm solutions to Coulomb excitation data analysis, is a .Net 2.0 application written in C++. It includes both genetic algorithm implementation, adapted to specific requirements of Coulex data analysis, and graphical user interface.

User can choose settings that characterise methods of selection, crossing-over and mutation. Three selection types have been implemented:

- a roulette with an adjustable elimination level and probability function shape,
- a tournament with an adjustable size of a tournament,
- a truncation with an adjustable truncation level.

A complex crossing-over method has been applied. User is allowed to set the number of crossover points, the probability function shape and the maximum number of ‘children’ for each creature (this is a part of incest prevention process). The mutation method is adjustable too. Mutation ratio and its evolution in time may be given.



The stop rule has to be specified. User can choose to stop evolution after:

- one generation (one step mode),
- a given number of generations,
- the average population χ^2 reaches a given level,
- the best individual χ^2 reaches a given level,
- the χ^2 convergence reaches a given limit.

GOSIA is used to compute the fitness function. It is invoked as a child process for each particular estimation.

The main advantages of the proposed solution are as follows:

- the same data input scheme as in GOSIA,
- a resistance to the local minimum problem,
- an automatic scan for alternative solutions and expected better convergence to the global minimum, particularly important for matrix elements signs determination,
- the first step towards the modern graphical user interface of the GOSIA analysis package.

The new method is also open for further development. JACOB gives an opportunity to collect points of a multidimensional χ^2 surface. The idea is to build an application for the error estimation based on the scan of the surface. A possible source of problems is the increase of numerical complexity with the number of free parameters. On the other hand, the genetic algorithm is a good candidate for parallelization. The plan is to extend the presented application, creating the code, which runs on several clustered computers connected into a network.

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7. Nuclear level lifetimes in ^{130}La

I. Sankowska[1], A.A. Pasternak[2], T. Morek[1], Ch. Droste[1], E. Grodner[1], J. Srebrny[3], M. Sałata[1], J. Kownacki[3], M. Wolińska-Cichocka[3], M. Kowalczyk[1,3], M. Kisieliński[3,4], A. Kordyasz[3], A.A. Wasilewski[4], R. Kaczorowski[4], E. Ruchowska[4], W. Płóciennik[4]

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Within the program of chirality phenomenon test of A≈130 nuclei [1], the Doppler Shift Attenuation Method was used for lifetime determination of excited states in ^{130}La. High-spin states of the ^{130}La nucleus were studied in the ^{120}Sn (^{14}N, 4n) reaction. Beam of 76 MeV ^{14}N was provided by the U-200P cyclotron at the Heavy Ion Laboratory of the Warsaw University. The γ-γ coincidence events were collected by the OSIRIS-II array consisting of ten Compton-suppressed HPGe detectors. The γ-ray spectra were analysed applying procedure presented in Ref. [2]. The resulting lifetimes in the yrast bands of ^{130}La are presented in Fig.1.

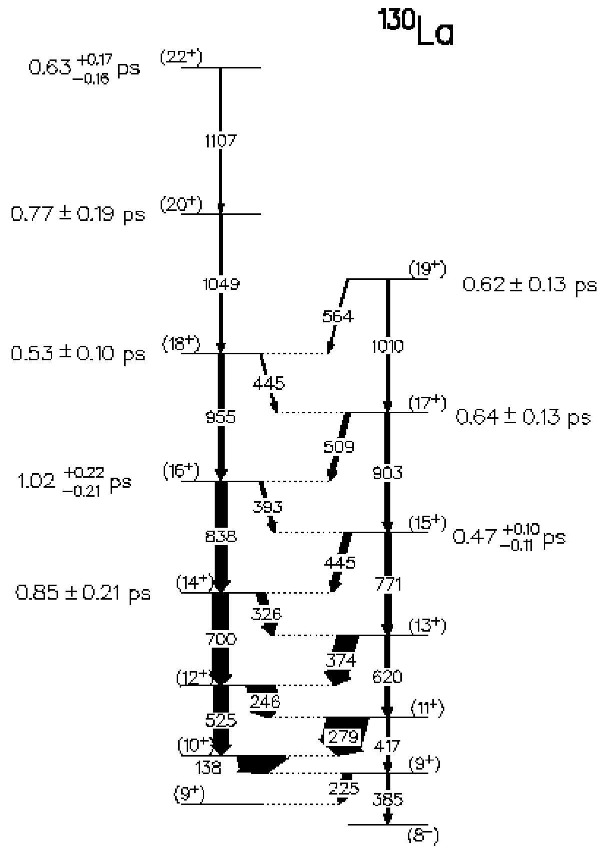

Figure 1. Partial level scheme of ^{130}La.

References:

[1] E. Grodner, J. Srebrny, A.A. Pasternak, I. Zalewska, T. Morek, Ch. Droste, J. Mierzejewski, M. Kowalczyk, J. Kownacki, M. Kisieliński, S.G. Rohoziński, T. Koike, K. Starosta, A. Kordyasz, P.J. Napiorkowski, M. Wolińska-Cichocka, E. Ruchowska, W. Płóciennik, J. Perkowski, Phys. Rev. Lett. **97**, 172501 (2006)

[2] E. Grodner, A.A. Pasternak, Ch. Droste, T. Morek, J. Srebrny, J. Kownacki, W. Płóciennik, A.A. Wasilewski, M. Kowalczyk, M. Kisieliński, R. Kaczorowski, E. Ruchowska, A. Kordyasz, M. Wolińska, Eur. Phys. J. **A 27**, 325 (2006)

8. Phenomenological classification of chiral symmetry breaking based on experimental transition probabilities in ^{132}La, ^{128}Cs and ^{126}Cs.

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Reduced gamma transition probabilities recently measured in the partner bands of ^{132}La, ^{128}Cs and ^{126}Cs give a unique opportunity for a phenomenological study of the chiral symmetry breaking phenomenon. These data allow to introduce a new experimental quantity $\epsilon(E(M)\lambda, I)$, being a function of the transition type (electric/magnetic), its multipolarity λ, and initial spin, *I*. This quantity can be helpful in classification and systematisation of a degree of chiral symmetry breaking in atomic nuclei. As reported in Ref. [1], the electromagnetic transition matrix elements between excited states of the chiral bands take the following form:

$$\langle I \| E(M)\lambda \| I_i \rangle = \frac{B_0 + \Delta B}{1+\varepsilon}$$

in one of the partner bands, and

$$\langle I \| E(M)\lambda \| I_i \rangle = \frac{B_0 - \Delta B}{1-\varepsilon}$$

in the other one. The phenomenological parameters $\Delta B = \mathrm{Re}\langle L \| E(M)\lambda \| R \rangle$ and $\varepsilon = \mathrm{Re}\langle L | R \rangle$ describe a possible electromagnetic transition between left- (L) and right-handed (R) states, and the overlap between these states, respectively. Both values should be small in case of a strong chiral symmetry breaking limit making the electromagnetic properties of both bands equal.

Having the experimental values of the reduced transition probabilities $B^{exp}(E(M)\lambda; I_i \rightarrow I)$ one can calculate matrix elements in the formulae quoted above using the following relations (see Ref. [1,2]):

$$\sqrt{(2I_i+1)B^{exp}_{yrast}(E(M)\lambda; I_i \rightarrow I)} = \frac{B_0 + \Delta B}{1+\varepsilon}$$

$$\sqrt{(2I_i+1)B^{side}_{yrast}(E(M)\lambda; I_i \rightarrow I)} = \frac{B_0 - \Delta B}{1-\varepsilon}$$

It is useful to construct the following quantity, which can be calculated by means of experimental transition probabilities:

$$\epsilon(E(M)\lambda, I_i) = \frac{\sqrt{(2I_i+1)B^{exp}_{yrast}(E(M)\lambda; I_i \rightarrow I)} - \sqrt{(2I_i+1)B^{exp}_{side}(E(M)\lambda; I_i \rightarrow I)}}{\sqrt{(2I_i+1)B^{exp}_{yrast}(E(M)\lambda; I_i \rightarrow I)} + \sqrt{(2I_i+1)B^{exp}_{side}(E(M)\lambda; I_i \rightarrow I)}}$$

As described in [2], it takes the following values for the two limiting cases:
$|\epsilon(E(M)\lambda, I_i)| \approx 0$ for the strong chiral symmetry breaking limit,
$|\epsilon(E(M)\lambda, I_i)| \approx 1$ for the chiral symmetry conserving limit.

The plot of the experimentally obtained values of $\epsilon(E(M)\lambda, I)$ as a function of spin I_i is shown in Fig. 1.

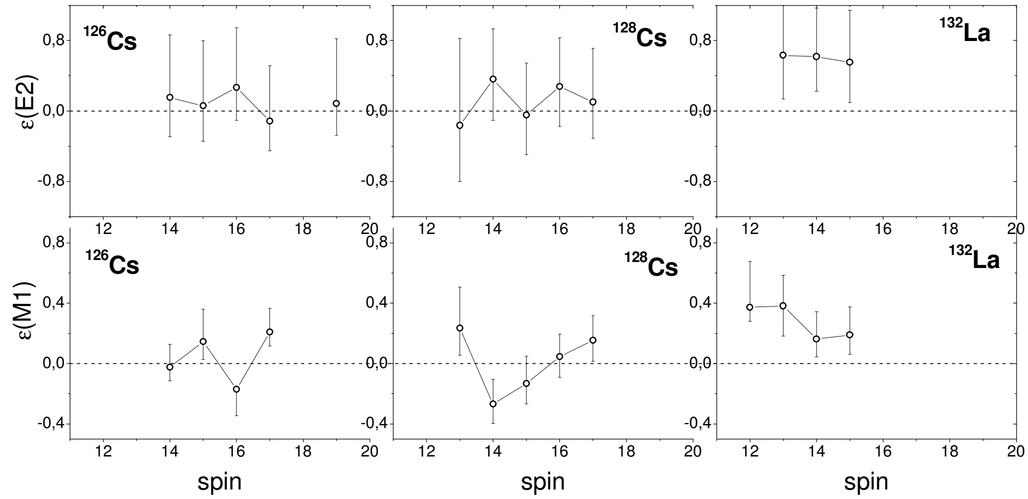

Figure 1. Experimental values of transition probabilities $\epsilon(E(M)\lambda, I)$ as a function of spin.

The $\epsilon(E2, I_i)$ values are close to zero for the ^{126}Cs and ^{128}Cs nuclei where the limit of chiral symmetry breaking is expected to be strong (M1 selection rules are observed). For ^{132}La these values are close to 0.5, confirming a weak symmetry breaking limit in this nucleus.

One can see that E2 transition probabilities can be used to calculate the experimental values of $\epsilon(E2, I_i)$ that seem to be sensitive to the degree of chiral symmetry breaking, while the M1 transition probabilities give information on the expected B(M1) staggering, which is a fingerprint of the chirality phenomenon.

References:

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9. Calibration of BaF_2 scintillators as a γ-ray spectrometer

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Barium Fluoride detectors, previously used in the multiplicity filter of the NORDBALL array, were energy-calibrated using ^{152}Eu, ^{60}Co and ^{137}Cs sources. The experimental set-up, consisting of one HPGe detector and five BaF_2 crystals, allowed us to measure γ-γ coincidences between Ge and BaF_2 as well as singles in BaF_2. ^{152}Eu and ^{60}Co sources were used to collect coincidence data, while with ^{137}Cs, which emits only a 667 keV line, a measurement in the non-coincident mode was performed.

The following gates were set on the energy value measured by the Ge detector:

Calibration source	Gate	Calibration line
^{152}Eu	344 keV	779 keV
^{152}Eu	779 keV	344 keV
^{60}Co	1173 keV	1333 keV
^{60}Co	1333 keV	1173 keV

In order to check the predictive power of GEANT4 code for our spectrometer, shapes of experimental spectra were compared to the simulation. Sample experimental spectra for one of the tested BaF_2 detectors are shown in Fig. 1, together with corresponding simulations, which in all cases reproduce well the experimental results.

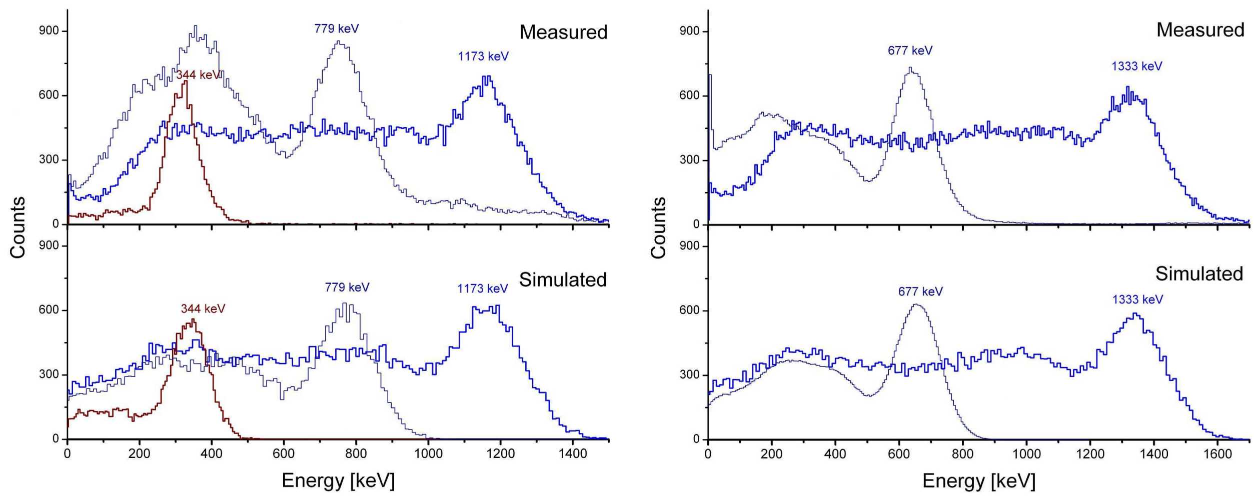

Figure 1. Measured and simulated (GEANT4) BaF_2 energy spectra.

The energy resolution measured for one of the tested crystals is presented in Fig. 2.

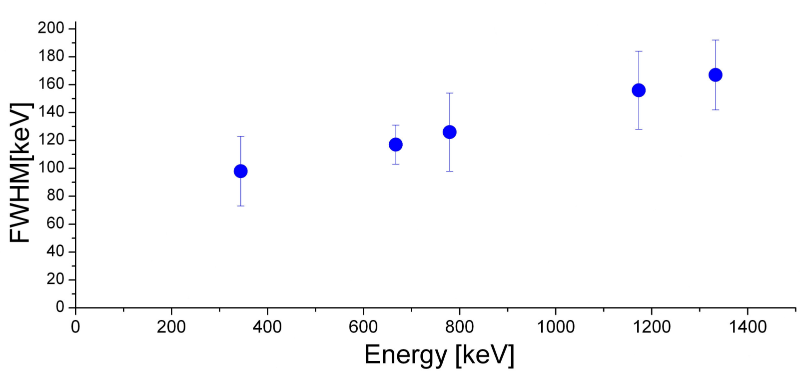

Figure 2. Energy resolution of one of the tested BaF_2 crystals, shown as a function of γ-ray energy.

Linear calibration up to 1.5 MeV was obtained for each of the tested BaF_2 crystals. To extend calibration to higher energies, five BaF_2 crystals were coupled with OSIRIS-II HPGe ACS detectors set-up for an in-beam experiment. ^{24}Al and ^{24}Na nuclei were produced in ^{12}C(^{14}N,2n)^{24}Al and ^{12}C(^{14}N,2p)^{24}Na reactions at 80 MeV bombarding energy. Lines from the β decay of both ^{24}Al (2 s) and ^{24}Na (15 h) were observed. We expect to get calibration points for 1368 keV, 2754 keV and 7069 keV γ-ray energies. To obtain an additional calibration point, the ^{244}Cm + ^{13}C monochromatic source, emitting a single 6128.9 keV γ line from an excited state of ^{16}O, was used. The data analysis is progressing. Preliminary results indicate that GEANT4 calculations are able to reproduce the experimental spectra and can be used in the future to extrapolate the energy calibration curve to γ-ray energies above 1.5 MeV.

10. Nuclear structure studies of ms, μs and ns isomers in the A = 150 mass region

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The OSIRIS-II array including 12 Compton suppressed HPGe detectors has been employed to search for high spin isomers in the region of neutron-deficient nuclei in the vicinity of N=82 neutron closed shell. The ^{40}Ar + ^{112,114,120}Sn and ^{32}S + ^{116}Sn reactions at the energy of about 5 MeV/nucleon were used, leading to nuclei placed far from the stability line. Apart from attempting to look for still unknown, or ambiguous isomeric states in the ms, μs and ns regions, the production yield of different kind of isomers was studied.

Earlier investigation [1] of the three valence particle nucleus ^{149}Dy located the ($27/2^-$) isomeric state of the $\mathrm{ph}^2_{11/2}\,\mathrm{nf}_{7/2}$ character at the excitation energy of 2661 keV. The half-life of the higher-lying isomer reported in Ref. [1] has been also determined later [2-3]. The same measurements brought conflicting results on its excitation energy (7.4–8.5 MeV) as well as different spin-parity assignments ($43/2^+$,49/2). The half-life of this state has been presently determined as a weighted average of the values obtained for the eight γ rays de-exciting the high-spin isomeric state in question. The resulting value ($T_{1/2} = 23.0 \pm 3.4$ ns) is close to the one reported in Ref. [3]. However, additional experimental data are required in order to establish a more reliable level structure above spin $39/2^+$.

In the present study the high spin states in ^{148}Dy have been most efficiently populated by the ^{112}Sn(^{40}Ar, 2p2n)^{148}Dy reaction. Apart from the ~0.5 μs 10^+ isomer, reported in Ref. [4] and presently confirmed, there is an indication for the existence of a high-spin isomer connected to the cascade of 113, 333, 763, 1170, 279, 1061, 463, 1045 and 495 keV γ rays. From the decay curves of the γ rays, the half-life $T_{1/2}$ of 5.3 ± 1.1 ns was obtained. It is worth mentioning that an identical cascade was formerly [5] ascribed to ^{143}Dy, which is rather not accessible in the reaction studied (it would require an α5n channel). A dedicated experiment to solve this ambiguity is necessary.

References:
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11. Lifetime of the (25/2$^+$) isomer in ^{121}Sb

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The beam pulse structure of the HIL cyclotron makes it possible to perform γ-γ coincidence measurements in in-beam and off-beam time intervals. This technique can be applied to search for isomeric states in the ms, µs and ns ranges. In the present work the A ≈ 120 mass region, where the existence of unknown high-spin isomers was expected, has been studied using the ^{10}B + ^{120}Sn reaction. The OSIRIS-II array consisting of 12 Compton suppressed HPGe detectors was combined for this study with the 48-elements BGO sum-energy and γ-ray multiplicity filter.

A new (25/2$^+$) isomeric state at 2721 keV in ^{121} Sb, so far only predicted from the systematics of Sb isotopes [1], has been populated via the ^{10} B + ^{120} Sn reaction and its lifetime has been deduced. Isotopic identification of the isomer was performed by examining coincidences of X-rays and γ-ray transitions, and the isomer-delayed γ rays measured in the off-beam mode.

The level scheme deduced from the present experiment is shown in Fig. 1. It agrees well with the one proposed in Ref. [1].

This new isomer decays by a 287 keV transition to the 2434 keV, (19/2$^-$) state, which then decays via previously known 292, 715 and 392 keV γ lines, visible in the off-beam delayed spectrum. In addition to this branch, denoted (I) in Fig. 1, another delayed branch (II) of similar intensity, namely the sequence of 320, 361, 346, 328 and 374 keV transitions was observed in the off-beam spectrum. In both branches one can observe a short-lived component (ascribed to the isomer described here) as well as a long-lived contribution due to the presence of some unresolved lines. The half-life observed in the branch (I) ($T_{1/2}$ = 161 ± 20 µs) is close to the one observed in the branch (II) ($T_{1/2}$ = 203 ± 50 µs), suggesting the existence of one isomeric state with the half-life of 167 ± 19 μs, calculated as a weighted average of the values obtained for the two decay branches [2].

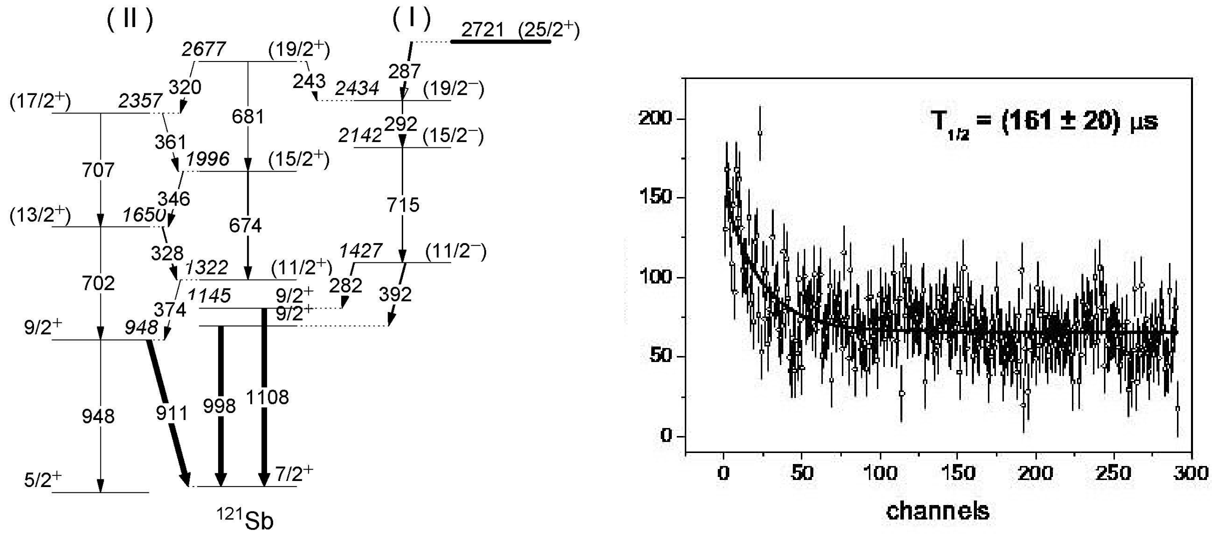

Figure 1. Left panel: Decay scheme of the 167 (19) μs isomer in ^{121}Sb observed in the present work. Two branches of the (25/2$^+$) isomer decay are marked (I) and (II). Right panel: Sum of the time spectra (1 channel=10 μs) of 287, 292, 715 and 392 keV γ rays in the branch (I)

Data collected in another measurement, which used the ^{40}Ar + ^{114}Sn reaction to study nuclei in the A ~ 150 region [3], allowed to re-investigate the neighbouring N=68 neutron-deficient ^{119}Sb nucleus. Population of ^{119}Sb in the above-mentioned reaction was interpreted as resulting from one proton transfer reaction into the target contamination, i.e. ^{118} Sn. Results obtained previously for the ^{119}Sb nucleus [1,4] were conflicting. Instead of the isomeric 25/2$^+$ state proposed in Ref. [1], an existence of the isomeric 27/2 level de-excited by an unobserved low energy transition is suggested in Ref. [4]. Our coincidence results (see Figs. 2 and 3) confirm the level scheme from Ref. [1]. The present lifetime estimation ($T_{1/2}$ = 1.45 ± 0.30 s), however, is closer to the value given in Ref. [4]. This situation is still unclear and requires an additional experiment.

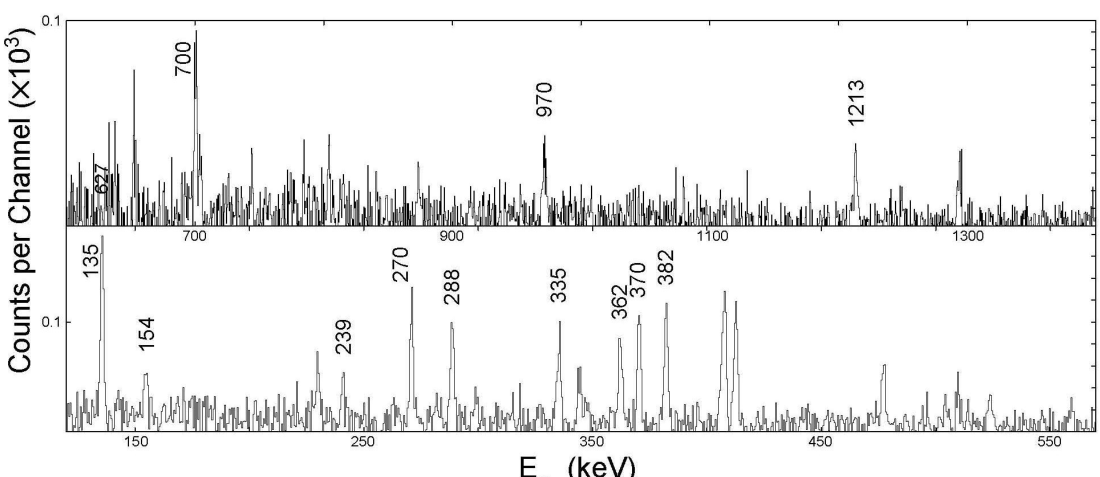

Figure 2. Coincidence spectrum gated by sum of 135, 154 and 700 keV γ rays. Only γ rays belonging to the ^{119}Sb nucleus are labelled.

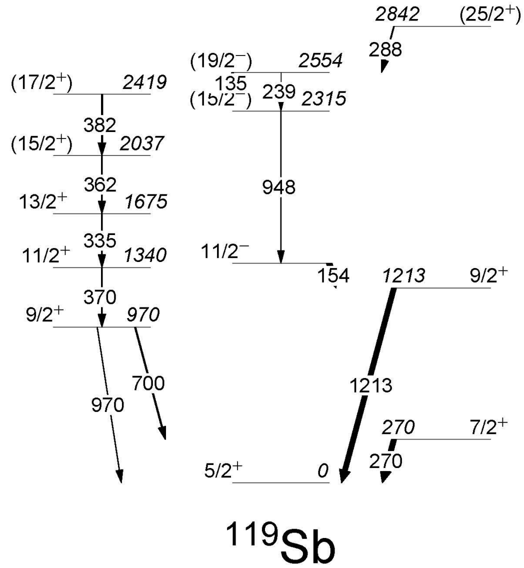

Figure 3. Decay scheme of the 1.45 (30) s isomer in ^{119}Sb obtained in the present work.

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12. Electron and gamma spectroscopy of transitions below isomeric state in ^{132}Ce

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The problem of violation of the K selection rule for electromagnetic transitions in nuclei is a subject of extensive investigations and is not yet well understood. One of its possible reasons is the Coriolis interaction, which causes substantial increasing of admixture of the wave function components with higher and higher K values. The increasing of rotational frequency and angular momentum of nuclei is responsible for this mechanism [1-3]. However, the non-axial deformation may cause the same experimental effects. Measurements of absolute values of the transition probability can clarify this mechanism. The nuclei from the mass area around A=130, exhibiting large triaxiality (γ around 20 ÷ 30), constitute an excellent testing ground to study this phenomenon.

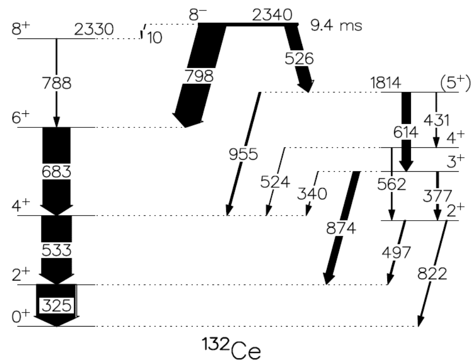

Figure 1. Low-lying excited levels of ^{132}Ce [2].

The low-energy part of the ^{132}Ce level scheme is presented in Fig. 1. The isomeric state $K^{\pi}=8^{-}$ ($T_{1/2}$ = 9.4 ms) is deexcited by two strong γ transitions. The determination of the multipolarity of the 526 keV line (tentatively assumed as E3) and mixing ratio for the 798 keV line (probably M2 with E3) will allow to obtain the absolute probabilities of these transitions. The comparison of the spectroscopic information with predictions of the Davydov-Filippov triaxial rotor model [4] should allow to get more information about the nature of K isomers in the A=130 mass region.

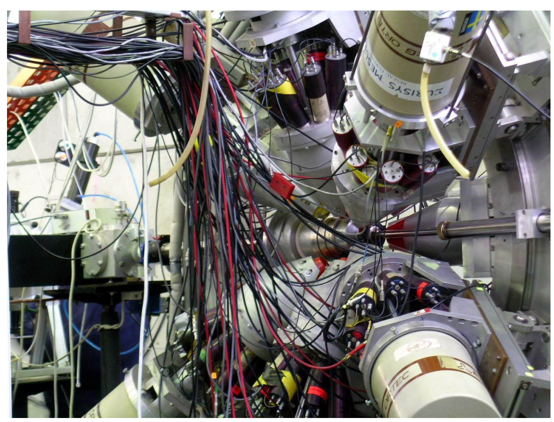

Figure 2. A photo of the experimental set-up. The internal conversion electron spectrometer (in the middle) is coupled to the OSIRIS-II array.

The gamma and internal conversion electron (ICE) spectroscopy measurement, aiming at determination of multipolarity of selected gamma transitions in ^{132}Ce, was performed in April 2007 at Heavy Ion Laboratory. Eleven HPGe detectors with anticompton shielding of the OSIRIS-II array were used together with electron spectrometer including 6 silicon detectors (Fig. 2). The ICE spectrometer was constructed at the University of Łódź and its detailed description can be found in Ref. [5]. The measurement was carried out in electron-gamma and gamma-gamma coincidence modes during 3.5 ms "off-beam" time intervals. The width of macrostructure pulses of the cyclotron beam was 5 ms.

Calculations of the $^{120}Sn(^{16}O,4n)^{132}Ce$ reaction cross section done with the EMPIRE II code [6] predict a broad maximum in the cross section with the value of about 40 mb at the energy of 74 MeV. The tin target of 3 mg/cm^2 thickness was used in the experiment. Since the energy loss in the target was about 2 MeV/(mg/cm^2) for ^{16}O ions at 80 MeV energy, the production of ^{132}Ce nuclei was possible in the whole target volume.

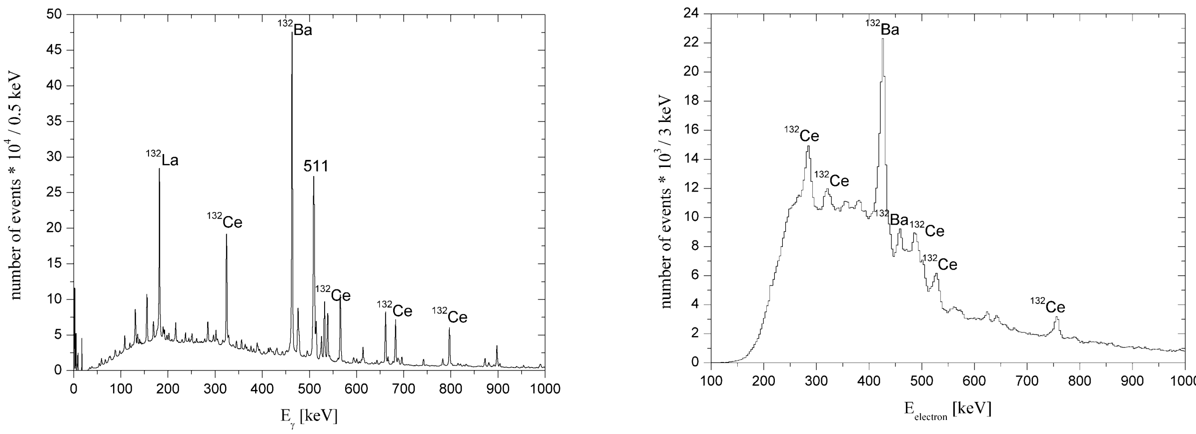

Figure 3. Left: The total gamma ray spectrum in coincidence with electrons from reaction $^{120}Sn(^{16}O,4n)^{132}Ce$. Peaks from ^{132}Ce and its daughter nuclei ^{132}La and ^{132}Ba are clearly visible. Right: The total electron spectrum in coincidence with gammas from the induced reaction. Internal conversion electron peaks from ^{132}Ce and ^{132}Ba are clearly visible.

During 50 hours of the measurement gamma and electron coincidence spectra were collected. The γ-ray and electron total spectra from the induced reaction are shown in Fig. 3. The electron spectrum gated by γ lines: 325, 533 and 683 keV is shown in the left panel of Fig 4. The multipolarity of the 798 keV transition was determined using coincidence with gamma spectrum being a sum of spectra gated by the same lines. Using the calculated value of the conversion coefficient for the K line for 798 keV (α = 0.0090 $\pm$ 0.0009), a preliminary magnitude of mixing ratio (E3 with M2) equal 45 $\pm$ 18 % was deduced. The electron spectrum for the second interesting transition is shown in the right panel of Fig. 4. The value of conversion coefficient for the K line was estimated as α = 0.0211 $\pm$ 0.0025. The value agrees with the theoretical prediction for an E3 type transition ($\alpha_{Theo.}$ = 0.0198) very well.

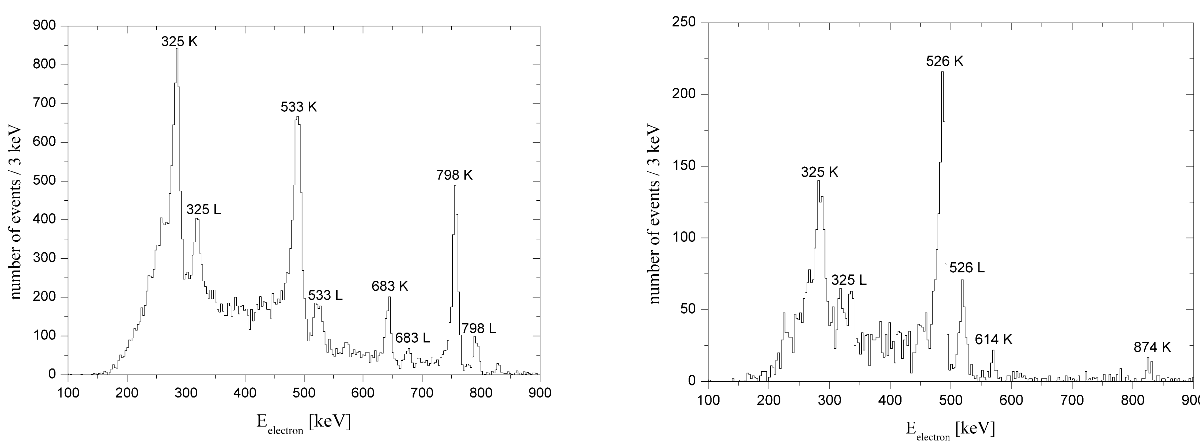

Figure 4. The electron spectra showing the K and L electron peaks descent from decay transitions of the K isomer in ^{132}Ce. Left: The sum of spectra gated by 325, 533 and 683 keV gamma lines. Right: The sum of spectra gated by 614 and 874 keV gamma lines.

The insufficient statistics, resulting in the uncertainty of the obtained B(E3; $8^- \to 6^+$) value above 40%, unfortunately does not allow to draw conclusions about the influence of the non-axial nuclear deformation on K isomers. Further measurements are planned to study the nature of K isomers close to the A=130 mass number.

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[4] A.S. Davydov, G. F. Filippov, Nucl. Phys. **8**, 237 (1958)
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[6] http://www-nds.iaea.org/empire/

13. European Array for Gamma Levels Evaluations (EAGLE) on beam of the Warsaw Cyclotron at HIL UW – status report

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In 2007 several important steps were taken, leading to the realization of the EAGLE array.

The final drawings of the supporting structure are ready (see Fig. 1). We have decided that the array would open perpendicularly to the beam axis. The construction allows for coupling of 20-30 Germanium spectrometers to the following equipment:

- InnerBall multiplicity and sum-energy filter consisting of 60 BaF_2 scintillation spectrometers;
- Conversion electron spectrometer including 6 silicon detectors cooled to -30° C;
- Coulex chamber including 100 P-i-N Si diodes;
- Cologne-Bucharest Plunger device.

The construction will start in May-June 2008 and we hope to test the first phase of the EAGLE array before the end of 2008.

HIL UW on behalf of the EAGLE collaboration applied to the European Gamma Pool for 20 Phase-I HPGe detectors (70% efficiency) with anti-Compton shields for 2009-2012, starting from the second half of 2009. The EGP Committee "has found the proposed physics case very interesting and the coupling of the requested resources with the equipment already available at HIL feasible" [1]. Since the detectors in question are allocated to other research groups until December 2009, we are requested to submit an updated proposal before July 2008.

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[1] The EAGLE collaboration involves more than 50 scientists from 9 Polish institutions as well as from CEA Saclay, Lund and Sofia Universities.

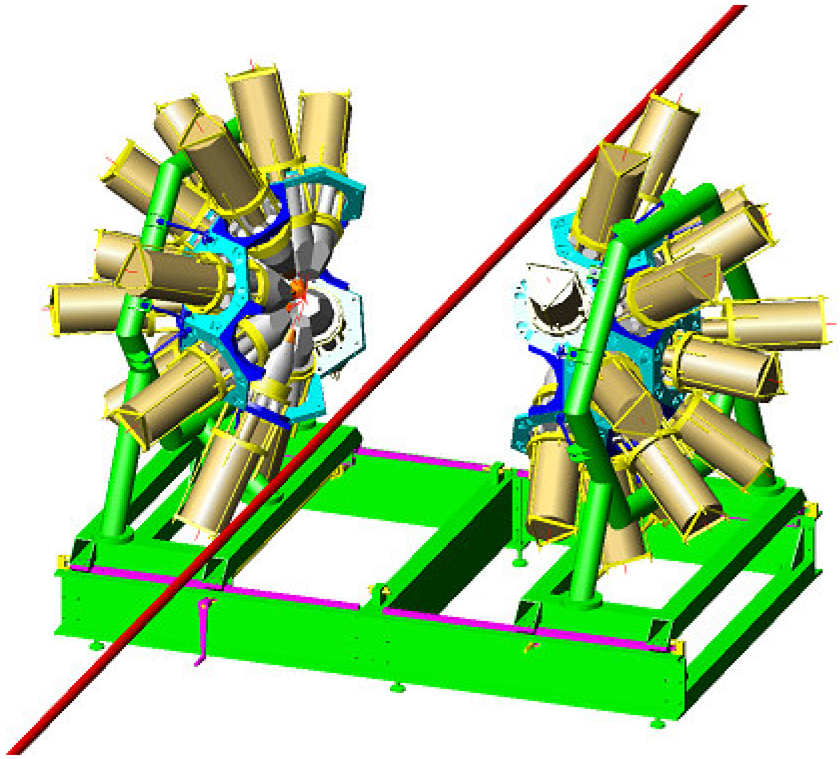

Figure 1. Final layout of the EAGLE array: configuration with 30 HPGe detectors.

References:

[1] Decision of the EGP OC concerning the proposed EAGLE campaign, available at the project website : http://www.slcj.uw.edu.pl/eagle

14. Status of the IGISOL device

A. Wojtasiewicz[1], W. Czarnacki[2], M. Karny[1], M. Kasztelan[1,3], M. Kisieliński[2,4], A. Korgul[1], J. Kurcewicz[1], W. Kurcewicz[1], J. Kurpeta[1], S. Lewandowski[1], P. Majorkiewicz[1], H. Penttilä[5], A. Płochocki[1], B. Roussière[6] and O. Steczkiewicz[4].

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In 2007 the search for isomeric states in nuclei beyond lead and investigations of gas catcher/ion guide system were performed.

We used mass-separated sources and analogue as well as digital electronics (DGF) for reinvestigating the α-decay chain from ^{220}Ac to ^{208}Bi. To our knowledge this is the first time that such a combination of experimental methods was used to study trans-lead nuclei. The new data improved the accuracy of the α-decay and mass-excess values of ^{216}Fr^{g} (1^{-}) and allowed to determine the α-decay energy and half-life of isomer $^{216}Fr^{m}$ (9^-) for the first time. The isomer ratios of 0.28(1) and 0.31(2) were determined for the (9^-) isomers of ^{212}At and ^{216}Fr, respectively [1].

It would have been a difficult task to obtain these results without using mass-separation and α-α time correlation (i.e. on the basis of measuring a mere α single spectrum). If the (9^-) state energies of parent and daughter nuclei are very similar, the α line originating from the transition between these levels could be obscured by the much stronger ground-state to ground-state α transition.

Identification of the α-decaying (9^-) isomer in ^{216}Fr provides a basis for assignment of level energies of alternating parity band. Recently, high-spin octupole yrast levels in ^{216}Rn were studied [2]. All experimental characteristics indicate that ^{216}Rn is a transitional nucleus. From this result, the lightest nucleus showing evidence of octupole collectivity at low spins is still ^{216}Fr, thereby defining the lowest mass "cornerstone" for this phenomenon in the $N \geq 129$, $Z \geq 87$ region of the nuclear chart [2].

The results obtained in this work suggest the existence of an isomeric state in ^{220}Ac. The search for an α-decaying (9^-) isomer in ^{220}Ac will be the aim of our next study.

Some technical improvements were performed on the IGISOL system. The most important one was the installation of a movable diaphragm in the focal plane of the mass separator, which allows to cut off the neighbouring masses in the mass spectrum and, consequently, to purify the α-spectra.

These works were partially performed in frame of the Warsaw University – IN2P3 (France) collaboration (N0. 04-112) and have been supported in part by the EU-RTD project ION CATCHER (HPRI-CT-2001-50022), the Polish Ministry of Science and High Education Grant No. N202 017032/0696, and the Interdisciplinary Centre for Mathematical and Computational Modelling of Warsaw University Grant No. G26-4.

The authors would like to acknowledge the staff of the Warsaw Cyclotron for cooperation during the experiments.

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[1] J. Kurcewicz, W. Czarnacki, M. Karny, M. Kasztelan, M. Kisieliński, A. Korgul, W. Kurcewicz, J. Kurpeta, S. Lewandowski, P. Majorkiewicz, H. Penttilä, A. Płochocki, B. Roussière, O. Steczkiewicz , A. Wojtasiewicz, Phys. Rev. **C76**, 054320 (2007)

[2] M.E. Debray *et al.*, Phys. Rev. **C73**, 024314 (2006)

15. Double sided strip monolithic silicon E-ΔE telescope produced by Quasi-Selective Epitaxy

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The main problem discovered during tests of the monolithic silicon E-ΔE telescopes produced by the Quasi-Selective Epitaxy was a cross-talk of signals between the two active layers of the telescope. It was shown by solving the telegraphic equation [1] that the time evolution of induced signals in the E-ΔE detector RC line depends strongly on the detector shape. The calculations were performed for rectangular detectors of various length to width ratio, at a constant area. For long and narrow detectors (high length to width ratio) the fall time of induced signals was significantly shortened (see Fig. 1) resulting in a cross-talk pulse length below the minimum required by the related electronics. These results are experimentally supported by measurements of α particles with a circular monolithic E-ΔE telescope [2,3]. When α particles were measured at the telescope edge, the induced signal (cross-talk) was decreased. For α particles measured at the centre of the telescope the amplitude of cross-talk was higher, see Fig. 2.

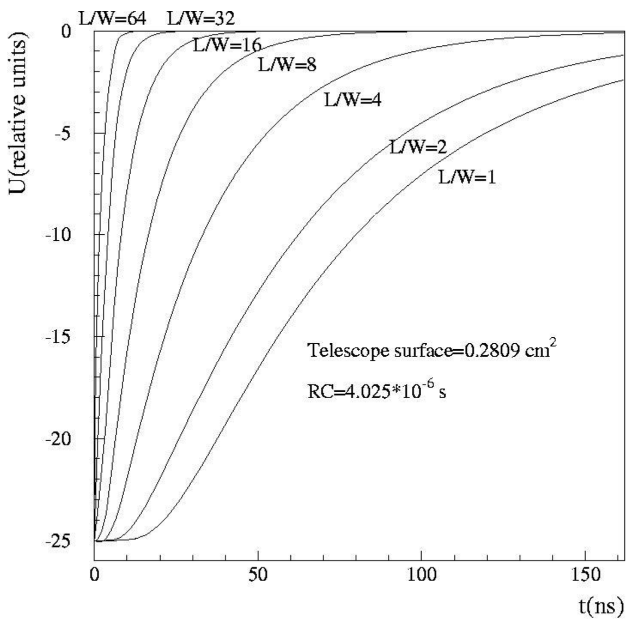

Figure 1. Average potential versus time for rectangular monolithic E - ΔE telescopes calculated using (A.8) from Ref. [3] for various rectangular telescope shapes L (length) and W (width) with constant telescope area=L*W=0.2809 cm^2 and RC=4.025*10^{-6} s, where C = 917.4 pF/cm^2 and sheet resistance R = 4387.4 Ω. The initial position of the source cross-talk potential was localized at the centre of the detector. The curves were calculated for the following values of the ratio L/W: 1, 2, 4, 8, 16, 32, and 64.

Applying these results we have designed a new type of the device based on the n^+- n – p^+- n – n^+ structures: double-sided strip monolithic silicon E-ΔE telescope, see Fig. 3. The device is similar to the traditional double sided strip detector [4], however, an introduced p^+- type buried grounded separating layer isolates the (upper) ΔE strip detector from the (bottom) E strip detector of the telescope. We plan to build such a device in the following months in collaboration with the Institute of Electronic Materials Technology and Institute of Electron Technology in Warsaw.

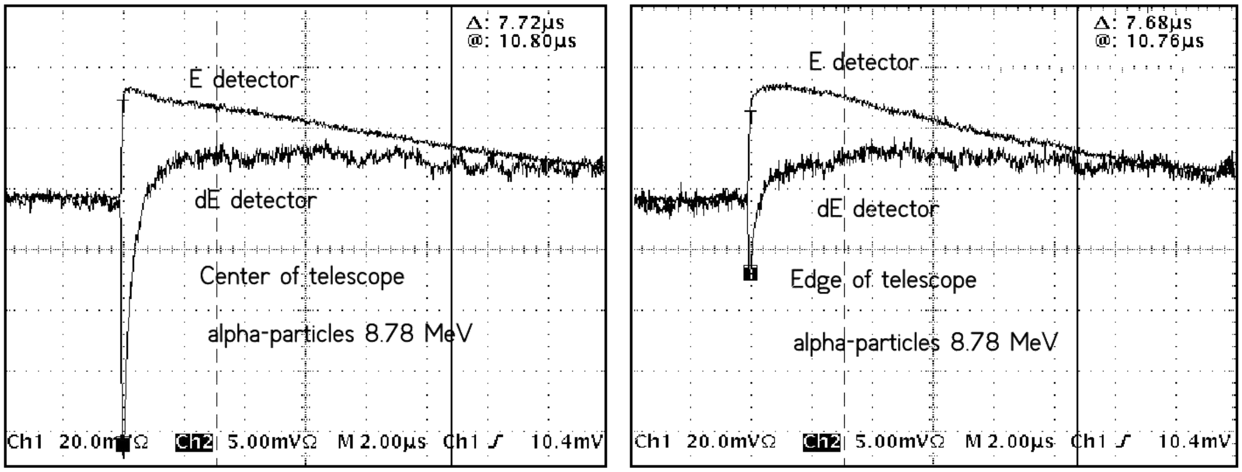

Figure 2. Oscilloscope pictures of the charge preamplifier outputs for a monolithic E - ΔE telescope with a 20 µm thick E-ΔE detector irradiated by α particles of 8.78 MeV energy. For ΔE detectors a negative cross-talk signal is observed. Left: α particles hit the centre of the telescope. Right: α particles hit the edge of the ΔE detector.

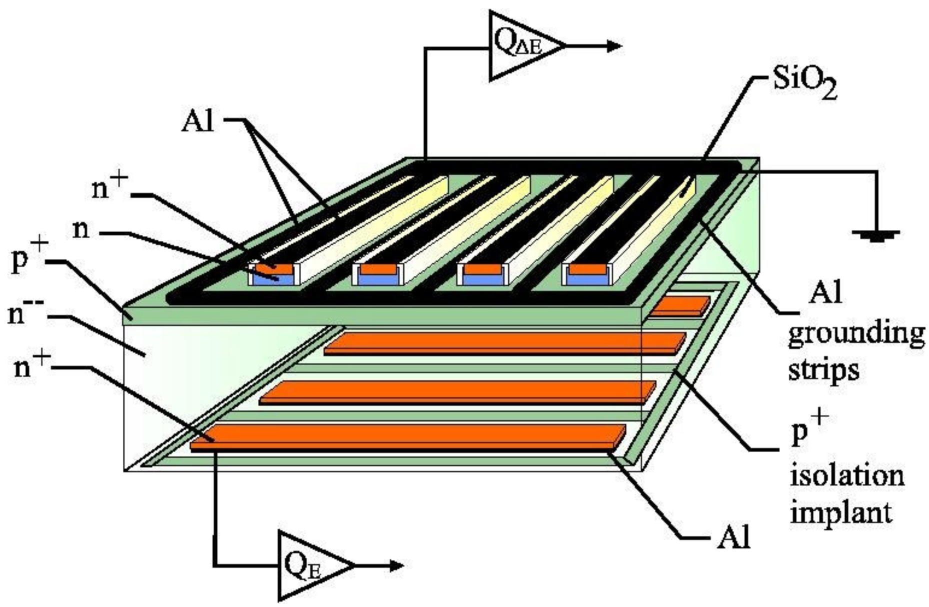

Figure 3. Design of the double-sided strip monolithic silicon E - ΔE telescope produced by Quasi-Selective Epitaxy.

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16. Reactor for homo-epitaxial growth of thick MV CVD single crystal diamonds for detector applications

A.J. Kordyasz[1], K. Sudlitz[1], E. Kulczycka[1], J. Sura[1], M.Kowalczyk[1,2], A. Bednarek[1], A. Pietrzak[1], A. Jakubowski[1], M. Figat[1], J. Jasiński[1], P. Jasiński[1], M. Antczak[1], R. Pozorek[1], K. Sosnowski[1]

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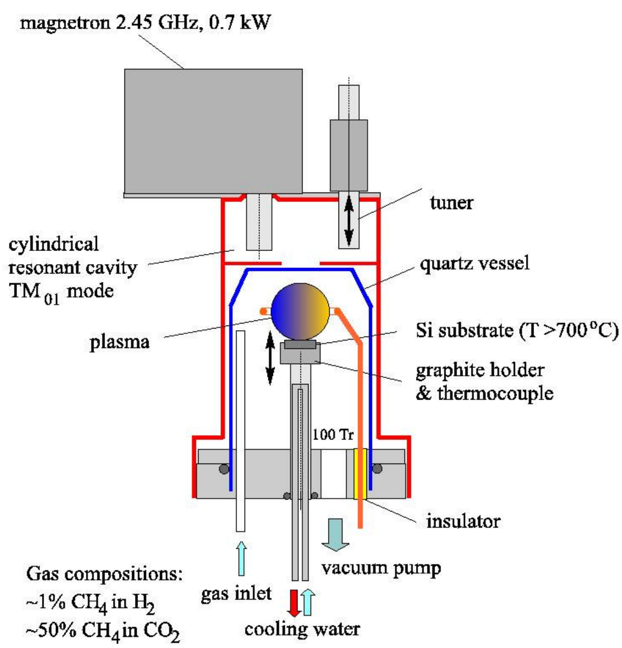
Diamond has excellent properties as a material for solid state detector applications, such as an outstanding resistance to radiation damage and short charge collection time. A reactor for Microwave Chemical Vapour Deposition was constructed in the Heavy Ion Laboratory in order to produce high quality homo-epitaxial single-crystal CVD-diamond layers for detector applications. Schematic drawing of the device is shown in Fig.1.

The reactor is presently under development. An attempt to generate plasma at the gas pressure of few Tr was successful. Further effort is needed to maximize the absorbed power. To achieve a proper deposition of diamond layers, substrate temperature above 700 °C has to be obtained at the gas pressure of 100 Tr.



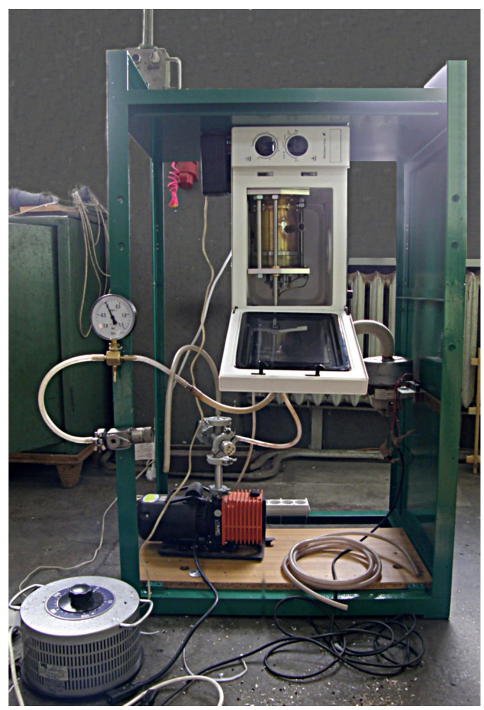


Figure 1. Design of the reactor for Microwave Chemical Vapour Deposition and photo of the device.

17. Biological Effectiveness of ^{12}C and ^{20}Ne Ions with Very High LET

J. Czub[1], *D. Banaś*[1,2], *A. Błaszczyk*[3], *J. Braziewicz*[1,2], *I. Buraczewska*[4], *J. Choiński*[5], *U. Górak*[6], *M. Jaskóła*[7], *A. Korman*[7], *A. Lankoff*[8], *H. Lisowska*[8], *A. Łukaszek*[6,9], *Z. Szefliński*[6], *A. Wójcik*[4,8]

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Knowledge of radiobiological effects of heavy ions at the cellular and molecular level is of fundamental importance in the field of radiation therapy (for example C ions) and space radiation biology (for example Ne ions). One of the issues that require deeper investigations is a determination of RBE values for a wide range of LET, for all relevant doses, for many cell types and various kinds of radiations [1].

During recent years, the biological effectiveness of heavy ions has been widely investigated with the aim to identify physical characteristics relevant to biological actions. These investigations are pertinent to the use of heavy ions in radiosurgery and radiotherapy. What has not been investigated so thoroughly is the biological effectiveness of heavy ions at low energies and very high LET values. The LET, which is equal to the stopping power of heavy particles, increases sharply at the end of the particle's path, forming a so-called Bragg peak. The shape of the Bragg peak depends on the particle type. Because overlying beams with different energies and components of primary and secondary particles are used in radiotherapy, the knowledge of RBE values of very high LET radiation need to be well characterized.

An experimental set-up designed for such investigations was constructed at the isochronic cyclotron in Heavy Ion Laboratory. A more detailed description of the set-up can be found in Ref. [2]. In the present work the partially stripped $^{12}C^{2+}$ and $^{20}Ne^{4+}$ ions were accelerated to 48.5 MeV and 105 MeV. The measured beam uniformity was better than ±2.5%.

CHO-K1 cells have been used as a suitable biological system for our studies. The cell line is characterized by genetic stability, the ability to form colonies, a relatively rapid growth rate with a cell cycle of 12-14 hours. For exposure to ions the cells were seeded in specially designed Petri dishes, which were filled with medium, sealed by a parafilm cover and placed in a vertical sample holder mounted in an x-y-z table that was connected to a special stepping motor. The irradiated sample moved under the beam according to a planned route. Movement was initiated when the number of counts detected by the 20^{o} particle detector reached the preset value. When all fields have been exposed the sample holder returned to the start position. Stored information enabled to evaluate the beam stability and intensity. The whole set-up was surveyed by a digital camera. The total time of exposure per dish was between 1-5 min. depending on the dose and beam intensity. The dose rates were changed from 0.05 Gy/min. to 1 Gy/min depending on the dose. Cell survival was estimated according to standard procedures [3]. To obtain RBE estimation cell survival data were fitted by the linear quadratic model $SF(D)=\exp(-\alpha D-\beta D^2)$ where SF is the survival at dose D. Fitting was performed by the non-linear least squares method using a Trust-Region algorithm implemented in the commercial Matlab 7.1 software.

Survival data for the CHO-K1 cell line at various energies of ^{12}C and ^{20}Ne ions as a function of the absorbed dose are shown in Fig. 1. The dose response curves are presented for the inactivation of CHO-K1 cells irradiated with ^{12}C ions with LET (evaluated at cell entrance) of 438, 576 and 832 keV/μm, and for ^{20}Ne ions irradiated with LET of 933, 1245 and 1616 keV/μm.

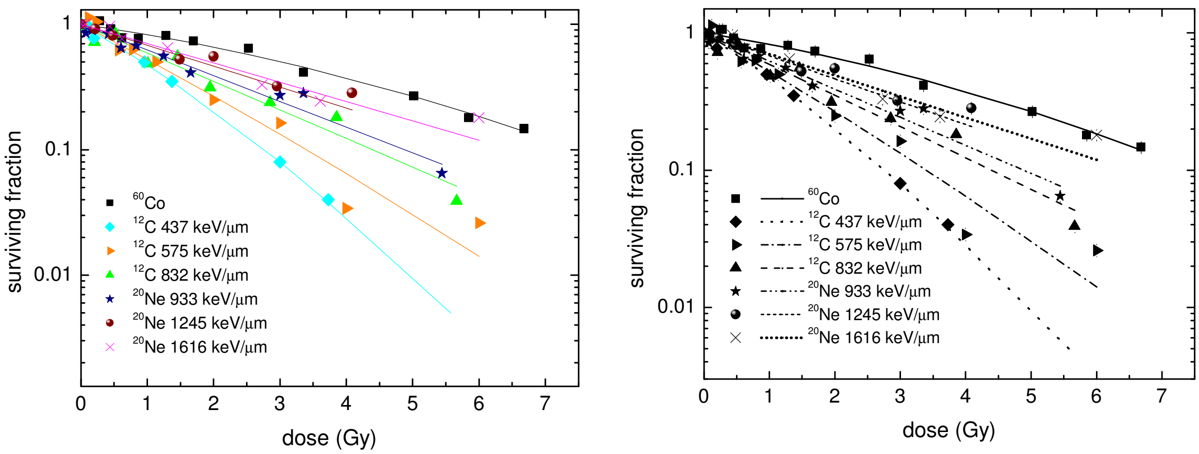

Figure 1. Survival curves of CHO-K1 cells as a function of dose for γ-rays, ^{12}C and ^{20}Ne ions.

The estimated values of α and β parameters of the linear quadratic model allow to determine the RBE_M values, obtained as the ratio of α terms for particle and ^{60}Co irradiation. The RBE_M were deduced from the initial slopes of the survival-dose curves. RBE_M corresponds to the maximum RBE assuming a monotonous decrease of the effectiveness with increasing dose [4] as shown in Fig. 3.

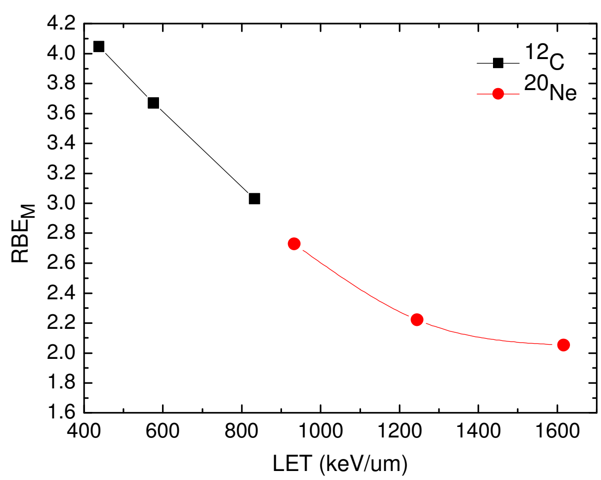

Figure 2. RBE_M of CHO-K1 cell line versus LET for ^{12}C and ^{20}Ne.

It is assumed that the increase of RBE with LET up to 100-200 keV/μm is caused by an increased spatial accumulation of DNA double-strand breaks that lead to cell death (Han *et al.*, 1998). The fall of RBE at LET above 250 keV/μm is caused by the deposition of more energy than necessary for cell deactivation. The excess energy results in an ‘overkill’ effect and, per unit of Gy, the number of hit cells is reduced, leading to an increased survival.

Interestingly, the surviving fraction was ~30%, indicating that more than a half (60-65%) of the survivors have not been hit. The presence of non-hit cells among hit ones is one of the features characteristic for the exposure to very high LET heavy ions. A wider discussion on the decrease of RBE in the high LET region, along with the evaluation of the fraction of non-hit cells, will be presented in our forthcoming paper (Czub *et al.*, in preparation).

In conclusion, our results show that the RBE of ions depends solely on the LET and not on any physical characteristics of the ions. The inactivation cross sections describing the killing efficiency of a single particle at the end of particle track come close to the size of the cell nucleus.

Acknowledgments

We are grateful to J. Dyczewski and T. Adamus for their help in setting up the radiation facility and for their technical support during the experiments. The work was partially supported by the Polish Ministry of Science and Higher Education Grant No 1P03B10527.

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Part C:
Experiments using the outside facilities

1. Re-separation modes of $^{197}Au + ^{197}Au$ system at sub-Fermi energies

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2) Heavy Ion Laboratory, Warsaw University, Warsaw, Poland
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4) INFN, Sezione di Catania and Università di Catania, Italy
5) INFN, Laboratori Nazionali del Sud, Catania, Italy

Contrary to lighter nucleus-nucleus systems, which usually fuse or undergo binary deep-inelastic scattering processes, very heavy systems cannot fuse and are expected to re-separate not only into two but sometimes also into three large fragments. In this contribution we report on our study [1] focused on ternary partitions of a super-heavy system $^{197}Au + ^{197}Au$ at the relatively low energy of 15 MeV/nucleon. We demonstrate existence and importance of a new reaction mode: a fast ternary fission mechanism and we determine the time scale of this reaction mode.

The experiment was carried out at the Laboratori Nazionali del Sud in Catania by using beams from the LNS Superconducting Cyclotron. For detection and identification of reaction products the Charged Heavy Ion Mass and Energy Resolving Array (CHIMERA), consisting of 1192 ΔE-E telescopes, was used.

In our analysis [1] we selected a class of almost completely reconstructed three-main-fragments events, in which only a small missing charge and mass can be attributed to evaporation of light particles of $Z \leq 2$ from primary excited fragments. (In the experiment all charged particles of $Z \geq 3$ were detected and included in the mass balance.)

A group of most probable ternary events in which one large fragment, either target-like fragment (TLF) or projectile-like fragment (PLF), is accompanied by two comparable fragments (resulting from break-up of PLF or TLF) was selected for detailed analysis. As in the laboratory reference frame the split of PLF is easier to observe, we focused our analysis on a subset of events, in which the TLF remains as a whole, while PLF splits onto two fragments F1 and F2. All events selected in this way were reconstructed kinematically event-by-event.

In Fig. 1 we show the angular distribution of fragments F1 and F2 projected onto the reaction plane (defined by the PLF, TLF separation axis and the beam direction), and measured in the rest frame of the decaying PLF. Highly anisotropic distribution of the PLF $\rightarrow$ F1 + F2 decay gives a strong argument that the PLF decay is a very fast, nonstatistical process. For comparison, in Fig. 2 we show results of a simulation of the in-plane distribution generated with the quantum molecular dynamics (QMD) code [2] of Łukasik which does predict the splitting of excited PLFs (or TLFs), but the time scale of this process evidently is predicted too long, resulting in the nearly isotropic angular distribution. As seen from Fig. 1, fragments F1 are peaked at $\phi = +15^o$ (with respect to the TLF, PLF separation axis, $\phi = 0^o$), which means that after separation from the TLF, the PLF rotates only by about $+15^o$ prior to splitting. From this rotation angle one can attempt to estimate the average time Δt between the scission of the PLF+TLF system and the scission of the PLF. Under certain assumptions we obtained $\Delta t \approx 40$ fm/c. During such a short time the PLF can move away from TLF only by less than 5 fm. This means that the split of the PLF takes place almost immediately after the primary separation of TLF and PLF. Therefore we propose to name this very violent, dynamical process "fast ternary fission".

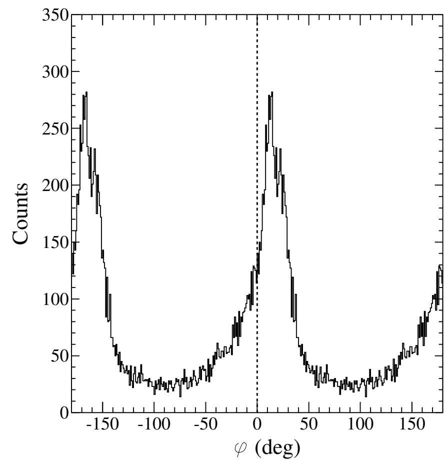

Figure 1. In-plane angular distribution of fragments F1 and F2 from the PLF→F1+F2 decay. Direction of the TLF, PLF separation axis corresponds to ϕ=0.

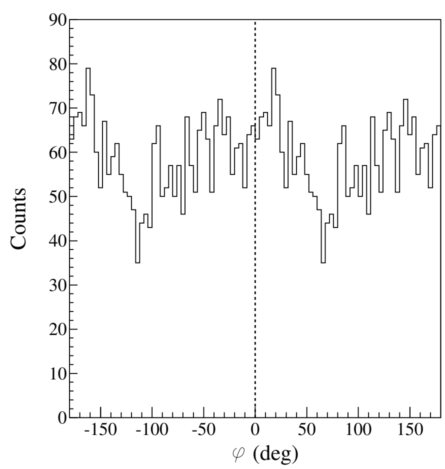

Figure 2. Same as Fig. 1, but the events are generated with the QMD model of Łukasik [2]. Theoretical events are filtered with the detection filter of the CHIMERA multidetector.

References:

[1] J. Wilczyński *et al.*, J. Mod. Phys. **E17** (2008) 41

[2] J. Łukasik, Ph.D. Thesis, Jagiellonian University, Cracow, 1993
J. Łukasik, Z. Majka, Acta Phys. Pol. **B24** (1993) 1959

2. RDDS lifetime measurement in ^{70,72}Se: no evidence for the prolate shape of the 2^+_1 state in ^{70}Se

J. Ljungvall[1], A. Görgen[1], A. Dewald[2], C. Dossat[1], W. Korten[1], B. Melon[2], R. Megenazzo[3], A. Obertelli[1], R. Orlandi[4], T. Pissulla[2], S. Siem[5], R.P Singh[4], J. Srebrny[6], Ch. Theisen[1], C.A. Ur[3], J.J. Valiente-Dobón[4], M. Zielińska[1,6]

1) IRFU/SPhN, CEA Saclay, Gif-sur-Yvette, France
2) Institut für Kernphysik, Universität zu Köln, Köln, Germany
3) INFN-Laboratori Nazionali di Legnaro, Legnaro, Italy
4) Department of Physics, University of Padova, Padova, Italy
5) Department of Physics, University of Oslo, Oslo, Norway
6) Heavy Ion Laboratory, Warsaw University, Warsaw, Poland

Lifetimes of 2^+_1, 4^+_1, 6^+_1 states in ^{70,72}Se were measured at the Laboratori Nazionali di Legnaro, Italy, using the recoil-distance Doppler shift method following the reactions ^{40}Ca(^{36}Ar,$\alpha 2p$)^{70}Se and ^{40}Ca(^{36}Ar,$4p$)^{72}Se at the beam energy of 136 MeV. Gamma rays were detected in the GASP array and the Cologne Plunger device was used to control the distance between the target (0.5 mg/cm^2 ^{40}Ca evaporated onto a 2.0 mg/cm^2 Au foil) and the stopper foil (10 mg/cm^2 Au). Data was collected for 12 distances between 8 μm and 400 μm with a trigger condition of at least two coincident γ rays. A more detailed description of the experimental procedure can be found in Ref. [1].

To obtain intensities of the stopped and Doppler-shifted components, in all cases a coincidence gate was placed on the shifted component of the transition directly feeding the state of interest, so that effects of unknown side feeding were eliminated. The lifetimes of the states were extracted from the intensities of both components as a function of the plunger distance using the differential decay-curve method [2].

Only the lifetimes of the 4^+_1 state in ^{70}Se and the 2^+_1 state in ^{72}Se agree with results of earlier measurements. The most likely reason for the disagreement of all other lifetimes with literature values are effects from unknown side feeding in the previous singles measurements. The revised lifetime of the 2^+_1 state in ^{70}Se has important consequences for the interpretation of the results obtained in a recent Coulomb excitation experiment [3]. The measured Coulex cross section, sensitive to the quadrupole moment via the reorientation effect, combined with old lifetime allowed to conclude that the shape of the 2^+_1 state in ^{70}Se is prolate. The present, much more precise value of the lifetime does not permit a precise determination of the quadrupole moment due to the relatively large error on the Coulomb excitation cross section and its relatively weak dependence on the quadrupole moment, but it clearly favours a positive value of the spectroscopic quadrupole moment.

This work was partly supported by the European Commission FP6 - Structuring the ERA - Integrated Infrastructure Initiative – Contract EURONS No. RII3-CT-2004-506065.

References:

[1] J. Ljungvall *et al.,* Phys. Rev. Lett., accepted
[2] A. Dewald *et al.*, Z. Phys. **A** 334, 163 (1989)
[3] A.M. Hurst *et al.*, Phys. Rev. Lett. **98** 072501 (2007)

3. Coulomb excitation of neutron-rich ^{44}Ar at SPIRAL

M. Zielińska[1,2], *A. Görgen*[1], *A. Bürger*[3], *W. Catford*[4], *E. Clément*[1,5], *C. Dossat*[1], *J. Iwanicki*[2], *W. Korten*[1], *J. Ljungvall*[1], *P.J. Napiorkowski*[2], *D. Piętak*[6], *G. Sletten*[7], *J. Srebrny*[2], *Ch. Theisen*[1], *K. Wrzosek*[2]

1) IRFU/SPhN, CEA Saclay, Gif-sur-Yvette, France
2) Heavy Ion Laboratory, Warsaw University, Warsaw, Poland
3) HISKP, University of Bonn, Germany
4) University of Surrey, Guildford, UK
5) CERN, Geneva, Switzerland
6) Department of Electronics and Information Technology, Warsaw University of Technology, Warsaw, Poland
7) Niels Bohr Institute, University of Copenhagen, Denmark

The weakening of the N=28 shell closure and the development of deformation and shape coexistence was addressed in a low-energy Coulomb excitation experiment using a radioactive ^{44}Ar beam from SPIRAL facility at GANIL.

The ^{44}Ar beam was Coulomb excited on ^{208}Pb and ^{109}Ag targets at beam energies of 3.7 MeV/A and 2.7 MeV/A, respectively. The average beam intensity was 2 10^5 pps at the secondary target position. The γ rays from the Coulomb-excited states were detected in the EXOGAM array, while the energies of scattered projectiles and the recoiling target nuclei were measured in an annular highly segmented silicon detector, covering scattering angles between 25° and 56° in the laboratory frame. More detailed description of the experimental set-up can be found in Ref. [1].

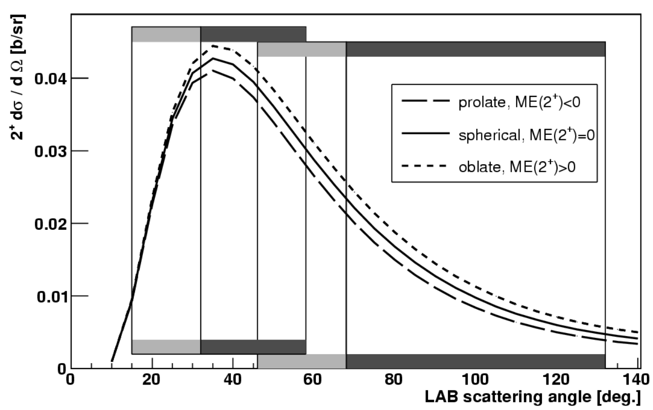

Figure 1. Differential Coulomb excitation cross section to populate the 2^+_1 state in ^{44}Ar on a ^{109}Ag target. The angular ranges used in the analysis are marked. The three curves corresponding to oblate, spherical and prolate deformation were calculated using both the B(E2; 2+→0+) and the quadrupole moment values obtained in the present analysis.

On the ^{208}Pb target, in addition to the first 2^+ state one higher-lying level at 2010 keV was populated and two γ lines from its de-excitation were observed. With the ^{109}Ag target both projectile and target nuclei were excited, which can be used to normalize the excitation probability in ^{44}Ar with the well-known transition strengths in ^{109}Ag. The statistics collected during ~50 hours of data taking with the ^{109}Ag target (~4300 counts in the $2^+ \rightarrow 0^+$ transition) allowed subdividing the data into four sub-sets corresponding to different ranges of scattering angles (two for recoil detection and another two for scattered projectile detection), as shown in Fig.1. The influence of the quadrupole moment of the 2^+ state on its excitation probability varies significantly with scattering angle, thus it was possible to obtain from one experiment information on both the transitional and diagonal matrix elements involved in the excitation process.

For the smallest scattering angles the influence of the quadrupole moment on the excitation probability of the 2^+ state is below the statistical error of 7% of the corresponding γ-ray yield, and it is a reasonable approximation to assume that in this case the observed transition strength depends only on the transitional matrix element. Therefore it was possible to determine the B(E2; $2^+ \rightarrow 0^+$) value from the excitation cross-section of the 2^+ state for the smallest angular range using the normalization to known excitation probabilities in ^{109}Ag. The resulting value of the transitional matrix element was used then to determine the quadrupole moment of the 2^+ state from the remaining data sets. Further constraints come from the Z dependence of the Coulomb excitation cross section when comparing the data from the ^{109}Ag and ^{208}Pb targets.

The value of B(E2; $2^+ \rightarrow 0^+$) equal 380(+40,-60) e^2fm^4 obtained in the present analysis is in agreement with the result of an earlier intermediate-energy Coulex measurement [2]. The quadrupole moment of the first 2^+ state, -8(3) $e$fm^2, proves prolate shape of the ^{44}Ar nucleus and indicates the onset of deformation already two protons and two neutrons away from the doubly-magic ^{48}Ca. The present Coulomb excitation experiment was the first one to measure the quadrupole moment of a radioactive nucleus without need for constraints from complementary lifetime measurements.

This work was partly supported by the European Commission FP6 - Structuring the ERA - Integrated Infrastructure Initiative – Contract EURONS No. RII3-CT-2004-506065.

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[2] H. Scheit *et al.*, Phys. Rev. Lett. **77** (1996) 3967

4. Simulations of fusion-evaporation reactions with AGATA and ancillary detectors

G. Jaworski[1,2], M. Palacz[2], G. de France[3], W. Męczyński[4], J. Mierzejewski[2,5], B. Nyako[6]

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5) Faculty of Physics, Warsaw University, Warsaw, Poland
6) ATOMKI, Debrecen, Hungary

The first sub-system of Advanced Gamma Tracking Array (AGATA) [1,2], the so-called Demonstrator, consisting of 5 to 6 triple cluster Germanium detectors (out of 60 for the complete AGATA), will come to the operation in the end of 2008 at the Laboratori Nazionali di Legnaro in Padova in Italy. The primary aim of the Demonstrator will be to test the innovatory technical solutions of the new array and to prove the feasibility of the γ-ray tracking concept [1-3]. An ambitious experimental campaign will follow, which will profit from the relatively large γ-ray photopeak detection efficiency of the Demonstrator (3-8%), concentrated in a small fraction of the solid angle, and from its uniquely large angular resolution of the γ-ray detection (of the order of 1 degree).

Ancillary detectors will play a crucial role in experiments with AGATA and are necessary to fully exploit its technical advantages − they will, for example, enable selection of certain classes of events and make it possible to distinguish events of interest from the background. An important role of some of the ancillary detectors is also to provide information on the velocity vector of the nucleus emitting γ rays. Such information is necessary for a precise Doppler correction of the detected γ-ray energies, together with the information on the direction of the γ ray, provided by AGATA itself.

In the last year Annual Report of HIL [4] we communicated on the GEANT4 computer model of the Recoil Filter Detector [5]. RFD detects recoiling nuclei of fusion-evaporation reactions and provides information on their velocity, as well as selects fusion-evaporation events from the background of other processes, like fusion-fission and Coulomb excitation events. Simulated performance of RFD in connection with AGATA was now evaluated in detail [6]. Response of the 3Π AGATA + RFD system in the $^{30}Si(^{18}O,p2n)^{45}Sc$ and $^{175}Lu(^{28}Si,4n)^{199}At$ experiments was analysed. The capability of improving the quality of AGATA γ-ray spectra using data from RFD was demonstrated.

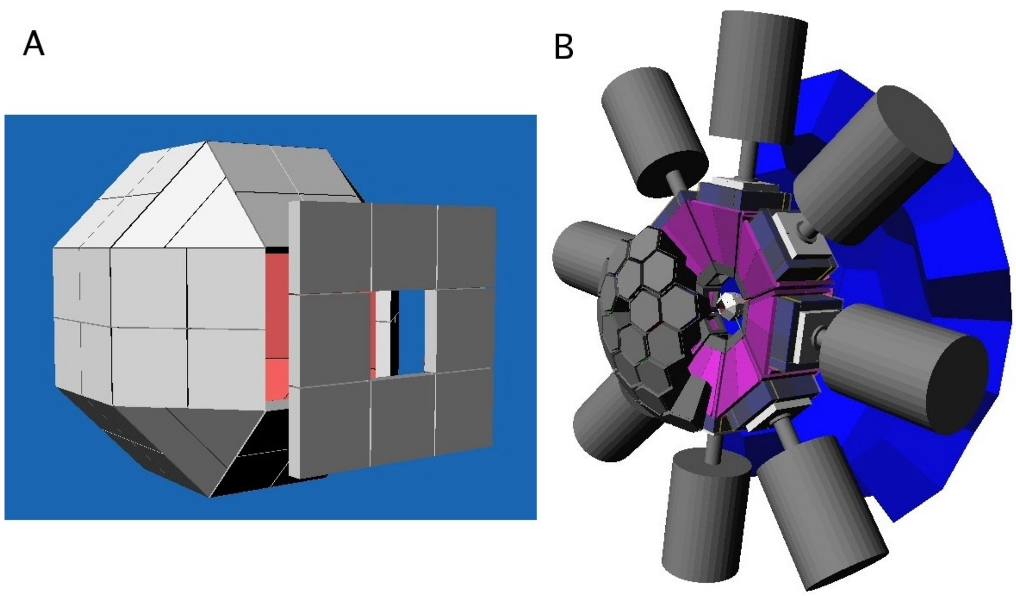

Figure 1. GEANT4 models of detectors: DIAMANT charged particle detector **(a)** and the AGATA Demonstrator combined with EXOGAM, Neutron Wall and DIAMANT **(b)**.

The geometry of the DIAMANT [7] charged particle detector was implemented in the framework of GEANT4 and the AGATA Simulation Code (ASC) [8]. The GEANT4 computer model of DIAMANT is presented in Fig. 1a. Analysis of the performance of DIAMANT is in progress and it will be evaluated in the configuration comprising AGATA and EXOGAM [9] γ-ray detectors together with DIAMANT and Neutron Wall [10,11] (see Fig. 1b). The possibility to combine several different devices in one Monte Carlo simulation is an important future of ASC. This will be also used in evaluating results of the experiments performed so far using EXOGAM with DIAMANT and the Neutron Wall, as well as in planning future experiments with the same set-up.

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5. Antiprotonic atoms: neutron densities and optical potentials

A. Trzcińska[1], *J. Jastrzębski*[1], *B. Kłos*[2], *S. Wycech*[3], *J.F. Hartmann*[4], *T. von Egidy*[4]

1) Heavy Ion Laboratory, Warsaw University, Warsaw, Poland
2) Physics Department, Silesian University, Katowice, Poland
3) Physik-Department, Technische Universität München, Germany
4) The Andrzej Sołtan Institute for Nuclear Studies, Warsaw, Poland

The PS209 experiment at CERN/LEAR was devoted to measurements of level widths and shifts in antiprotonic atoms. A rich set of data for a wide range of mass numbers (A=16-238) was collected. The main objective of the experimental program was to obtain information on the neutron distribution at the nuclear periphery and to provide data useful for deducing the antiproton-nucleus optical potential parameters.

The neutron densities for several isotopes were determined using optical potential deduced in 1995 by A. Batty *et al*. Data on the isotopes studied recently, ^{208}Pb and ^{209}Bi [1], were interpreted using this old optical potential and two new ones [2,3]. The neutron density distributions and differences of neutron and proton rms radii were determined. For each isotope the results obtained using three available potentials were coherent within experimental errors. The finally adopted values are the following: Δr_{np}= 0.16+/-$(0.02)_{stat}$ +/-$(0.4)_{syst}$ fm for ^{208}Pb and 0.14+/-$(0.04)_{stat}$+/-$(0.04)_{syst}$ fm for ^{209}Bi.

The obtained results for ^{208}Pb were used to investigate the relationship between the nucleon density at large radii and the value of the rms radius in the framework of Skyrme Hartree-Fock and relativistic mean field models [4].

The whole set of the PS209 measurement results and the atomic data from the antiprotonic hydrogen, deuterium and helium atoms were used to fit parameters of a new optical potential with two basic complex strength parameters [2]. These parameters are related to average *S* and *P* wave-scattering parameters in the sub-threshold energy region.

References:
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[4] B. Alex Brown, G. Shen, G.C. Hillhouse, J. Meng, A. Trzcińska, Phys. Rev. **C 76** (2007) 034305

6. The EURISOL-Task 11 database

W.Gawlikowicz[1], *L.Pieńkowski*[1], *A.Kelić*[2], *S.Lukić*[2], *K.-H.Schmidt*[2]

1) Heavy Ion Laboratory, Warsaw University, Warsaw, Poland
2) GSI Darmstadt, Germany

The final goal of the Task 11 is the prediction of available exotic-beam intensities at the EURISOL facility. One of the important tools for that end is a database of available experimental and calculated cross-sections for nuclide production in reactions relevant for EURISOL.

Figure 1. EURISOL-Task 11 participants.

Presently the database contains data on relevant experimental and calculated cross-sections [1], as well as a very rough estimate of ISOL efficiencies, based on ISOLDE SC yield database [2], as analysed in Ref. [3].

The database is currently running at the HIL server :
http://www.slcj.uw.edu.pl/~wojtek/eurisol_database_HIL.php

and at GSI:
http://www-win.gsi.de/eurisol%2Dt11/database.htm

Production cross-sections

Most of the experimental cross-sections included in this database have been measured in inverse kinematics at the GSI FRagment Separator (FRS) [4].

For many target materials important for EURISOL, experimental cross-section data do not exist. In those cases, a reliable prediction can nevertheless be made using ABRABLA nuclear reaction code developed at GSI.

In the near future the database should be supported with more experimental data, including all calibrated experiments made at FRS, and all theoretical calculations made using ABRABLA code.

In the figures below one can see the reaction database page (Fig.2) with a chosen reaction (^{238}U+p at E=1000 AMeV) and cross-sections (production cross-sections). By simply 'clicking' at different fields of the database results section, one can download the information about the chosen cross-sections (Fig.3) or download the reaction cross sections picture in the N-Z plane (Fig.4)

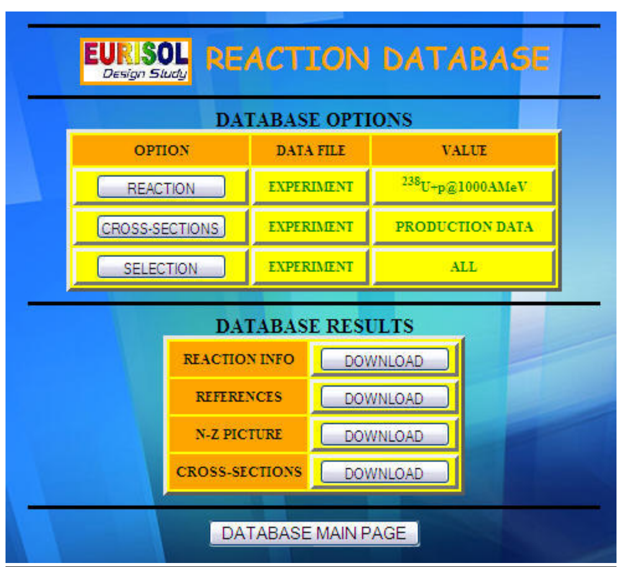
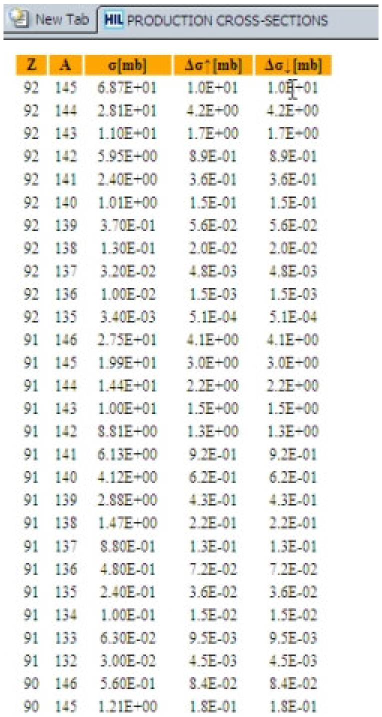


Figure 2. The reaction database main page.



New Tab HIL PRODUCTION CROSS-SECTIONS

Z	A	σ[mb]	Δσ↑[mb]	Δσ↓[mb]
92	145	6.87E+01	1.0E+01	1.0E+01
92	144	2.81E+01	4.2E+00	4.2E+00
92	143	1.10E+01	1.7E+00	1.7E+00
92	142	5.95E+00	8.9E-01	8.9E-01
92	141	2.40E+00	3.6E-01	3.6E-01
92	140	1.01E+00	1.5E-01	1.5E-01
92	139	3.70E-01	5.6E-02	5.6E-02
92	138	1.30E-01	2.0E-02	2.0E-02
92	137	3.20E-02	4.8E-03	4.8E-03
92	136	1.00E-02	1.5E-03	1.5E-03
92	135	3.40E-03	5.1E-04	5.1E-04
91	146	2.75E+01	4.1E+00	4.1E+00
91	145	1.99E+01	3.0E+00	3.0E+00
91	144	1.44E+01	2.2E+00	2.2E+00
91	143	1.00E+01	1.5E+00	1.5E+00
91	142	8.81E+00	1.3E+00	1.3E+00
91	141	6.13E+00	9.2E-01	9.2E-01
91	140	4.12E+00	6.2E-01	6.2E-01
91	139	2.88E+00	4.3E-01	4.3E-01
91	138	1.47E+00	2.2E-01	2.2E-01
91	137	8.80E-01	1.3E-01	1.3E-01
91	136	4.80E-01	7.2E-02	7.2E-02
91	135	2.40E-01	3.6E-02	3.6E-02
91	134	1.00E-01	1.5E-02	1.5E-02
91	133	6.30E-02	9.5E-03	9.5E-03
91	132	3.00E-02	4.5E-03	4.5E-03
90	146	5.60E-01	8.4E-02	8.4E-02
90	145	1.21E+00	1.8E-01	1.8E-01

Figure 3. Cross-sections.

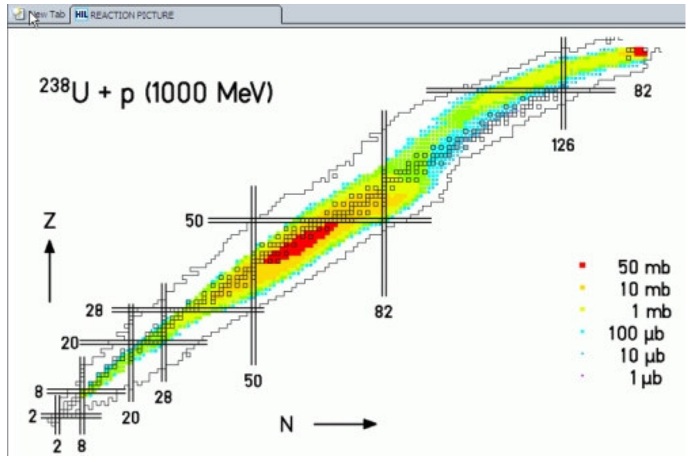


Figure 4. Cross-sections in the N-Z plane (reaction picture).

ISOL efficiencies

This part of the database is intended to provide measured and predicted ISOL efficiencies for the elements and target materials relevant to EURISOL. At the present stage, only data derived from Ref. [3] are available. The predictions are based on the parameterisation of extraction efficiencies in function of nuclide half-lives, as proposed in Ref. [3]. The values of the parameters used in the database have been obtained by analysis of the yield data measured at CERN-ISOLDE with 600 MeV protons [2].

One should note that these data do not reflect the performance of modern state-of-the-art ISOL targets, or of those that will be available at EURISOL. They are rather intended to serve as a starting guideline, which allows an overview of documented ISOL efficiencies across the table of nuclides and different Target-and-Ion-Source (TIS) systems. It is our aim to update the values of efficiency parameters based on a thorough analysis of more recent yield data, and eventually, a projection to the future technologies that will be available at EURISOL.

The efficiency database is similar in use to the reaction database. One can choose an element for which efficiency data exist, and then download information about efficiencies measured in reactions with different targets. Fig.5 shows an example of ISOL efficiencies for the Na element measured with UC_x and Ti foil targets.

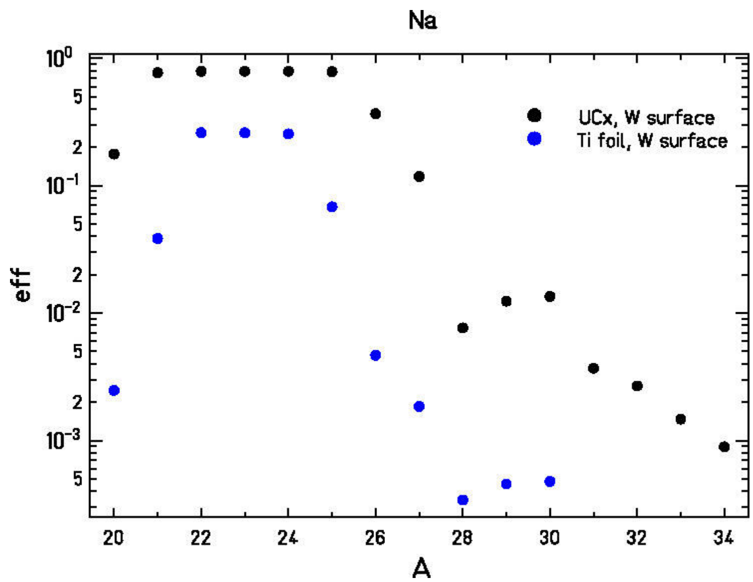


Figure 5. Efficiencies for UC_x and Ti foil targets for the Na element.

This work was supported by the European Community under the FP6 "Research Infrastructure Action - Structuring the European Research Area" EURISOL DS Project; Contract No. 515768 RIDS.

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[3] S. Lukić *et al.*, NIM **A565** (2006) 784, arXiv nucl-ex/0601031
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Part D:
General information on HIL activities

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

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

Katarzyna Wrzosek
Supervisor: dr hab. L. Pieńkowski. Expected completion time: 2009

Grzegorz Jaworski, Faculty of Physics, Warsaw University of Technology
Supervisor: prof. dr hab. J. Kownacki. Expected completion time: 2011

1.2 PhD theses based on the experiments on the Warsaw Cyclotron completed in 2007 or in progress

Elżbieta Wójcik, Faculty of Physics, Warsaw University 26 March
Badanie zmieszania izospinowego w jądrach gorących poprzez wzbudzenie Gigantycznego Rezonansu Dipolowego
Isospin mixing in hot nuclei studied by excitation of the Giant Dipole Resonance
Supervisor: prof. dr hab. M. Kicińska-Habior.

Andrii A. Rudchik, Institute for Nuclear Research, Ukrainian Academy 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: 2008

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

Iwona Sankowska, Faculty of Physics, Warsaw University
Badanie pikosekundowych czasów życia stanów wzbudzonych izotopów cezu
Study of picosecond lifetimes of excited states in Cs isotopes
Supervisor: dr hab. T. Morek. Expected completion time: 2008

Joanna Czub, Faculty of Physics, Świętokrzyska Academy
Biologiczne działanie promieniowania o wysokim LET
Biological effects of radiation with high LET value
Supervisor: prof. dr hab. J. Braziewicz. Expected completion time: 2008

Adam Król, University of Łódź
Spektrometr elektronów konwersji wewnętrznej do badań na wiązce jonów cyklotronu Środowiskowego Laboratorium Ciężkich Jonów UW
Internal conversion electron spectrometer for on-beam studies at the HIL cyclotron
Supervisor: prof. nadzw. UŁ dr hab. J. Andrzejewski. Expected completion time: 2008

Izabela Strojek, The Andrzej Sołtan Institute for Nuclear Studies, Świerk/Otwock
Supervisor: doc. dr hab. K. Rusek. Expected completion time: 2010

Kamil Sobczak, University of Łódź
Supervisor: prof. J. Andrzejewski. Expected completion time: 2010

1.3 MSc theses supervised by HIL staff members completed in 2007 or in progress

Grzegorz Jaworski, Faculty of Physics, Warsaw University of Technology — 21 November
Analiza wpływu detektora jąder odrzutu na funkcjonowanie układu AGATA
Analysis of the impact of the Recoil Filter Detector on the AGATA performance
Supervisor: dr M. Palacz

Daniel Piętak, Department of Electronics and Information Technology, Warsaw University of Technology
Implementacja algorytmu genetycznego do analizy danych z pomiarów wzbudzeń kulombowskich
Implementation of a genetic algorithm to the Coulomb excitation data analysis
Supervisors: dr A. Pająk, dr P. Napiorkowski. Expected completion time: 2008.

Katarzyna Hadyńska, Department of Physics, Adam Mickiewicz University, Poznań
Supervisors: prof. dr hab. W. Nawrocik, dr P. Napiorkowski. Expected completion time: 2008

Łukasz Czernik, Faculty of Physics, Warsaw University of Technology
Kalibracje spektrometru scyntylacyjnego promieniowania γ z wykorzystaniem krótkożyciowych produktów reakcji jądrowych
Calibration of the scintillator γ-ray spectrometer using short-lived nuclear reaction products
Supervisor: dr J. Srebrny. Expected completion time: 2008

Miron Sadziak, Faculty of Physics, Warsaw University
Kalibracja detektora scyntylacyjnego BaF_2 oraz stosowane metody numeryczne
Calibration of the BaF_2 scintillator and applied numerical solutions
Supervisors: dr E. Grodner, dr J. Srebrny. Expected completion time: 2008

1.4 Other MSc theses based on the experiments on the Warsaw Cyclotron completed in 2007 or in progress

Anna Karbowska, Faculty of Physics, Warsaw University — 12 January
Gigantyczny rezonans dipolowy w jądrach argonu
Giant Dipole Resonance in argon nuclei
Supervisor: prof. dr hab. M. Kicińska-Habior.

Tomasz Adamus, Faculty of Physics, Warsaw University — 2 March
Optymalizacja odchylania wiązki ^{12}C dla badań radiobiologicznych
Optimising of the ^{12}C beam deflection for radiobiological studies
Supervisor: dr hab. Z. Szefliński.

Agnieszka Żywno, Faculty of Physics, Warsaw University
Nowe technologie w budowie skanerów dla diagnostyki medycznej
New technologies for construction of medical diagnostics scanners
Supervisor: dr hab. Z. Szefliński. Expected completion time: 2008.

Jan Dyczewski, Faculty of Physics, Warsaw University
Opracowanie metodyki uzyskania jednorodnej wiązki jonów z Cyklotronu Warszawskiego
A method to obtain homogeneous beams from the Warsaw Cyclotron
Supervisor: dr hab. Z. Szefliński. Expected completion time: 2008.

Alicja Staudt, Department of Physics, University of Silesia
Supervisors: prof. dr hab. W. Zipper, dr hab. E. Piasecki. Expected completion time: 2009.

Anna Piórkowska, Department of Physics, University of Silesia
Supervisors: prof. dr hab. W. Zipper, dr hab. E. Piasecki. Expected completion time: 2009.

2. Seminars

2.1. Seminars at HIL

L. Pieńkowski — 22 March
Wysokotemperaturowy reaktor jądrowy dla realizacji synergii węglowo-atomowej w Polsce
High temperature reactor for the nuclear-coal synergy in Poland

J. Jastrzębski — 29 March
Sprawozdanie z działalności Laboratorium
Report from the HIL director

Z. Szefliński — 24 May
ENLIGHT – przyszłość hadronowej terapii nowotworów w Europie
ENLIGHT – the future of European hadronotherapy

L. Calabretta — 20 June
SCENT - a Superconducting Cyclotron for Hadronotherapy

L. Calabretta — 21 June
Hadronotherapy Center: Hospital factory or multidisciplinary research center?

C. Bieth — 10 July
Recent and future progress in the PANTECHNIK ECR family

M. Wolińska-Cichocka — 27 September
Testy termiczne i ciśnieniowe układu chłodzenia cyklotronu
Thermal and pressure tests of the cyclotron cooling system

2.2. External seminars given by HIL staff

M. Palacz 18 January
Impact of ancillary detectors on AGATA performance
5^{th} AGATA Week, Orsay, France

M. Zielińska 13 February
Coulomb excitation of neutron-rich ^{44}Ar at SPIRAL
ISOLDE Workshop 2006/2007, CERN, Geneva, Switzerland

J. Kownacki 28 March
Poszukiwanie izomerów w obszarze mili- i mikrosekundowym w eksperymentach na wiązce jonów z cyklotronu U-200 w Warszawie
Search for ms and μs isomers in on-beam experiments at the Warsaw U-200 Cyclotron
Seminar of the Nuclear Spectroscopy Division,
Faculty of Physics, Warsaw University, Warsaw, Poland

A. Trzcińska 13 April
Rozkłady gęstości neutronów w jądrze ^{208}Pb wyznaczone w badaniach atomów antyprotonowych
Neutron density distributions in ^{208}Pb from antiprotonic atom studies
Seminar of the Nuclear Physics Division,
Faculty of Physics, Warsaw University, Warsaw, Poland

M. Palacz 24 April
Overview of the EXOGAM - NWall campaign
EXOGAM Workshop 2007 "Exogam at GANIL, Today and Tomorrow"
GANIL, Caen, France

M. Zielińska 24 April
Coulex of ^{44}Ar
EXOGAM Workshop 2007 "Exogam at GANIL, Today and Tomorrow"
GANIL, Caen, France

L. Pieńkowski 25 April
Reaktory wysokotemperaturowe dla realizacji synergii węglowo-atomowej w Polsce
High temperature reactor for the nuclear-coal synergy in Poland
Workshop "Energetyczne dylematy Polski",
Polish Academy of Sciences, Warsaw, Poland

L. Pieńkowski 9 May
Wysokotemperaturowy reaktor jądrowy dla realizacji synergii węglowo-atomowej w Polsce
High temperature reactor for the nuclear-coal synergy in Poland
Seminar of the Institute of Physics,
Polish Academy of Sciences, Warsaw, Poland

J. Choiński 11 May
Heavy Ion Laboratory – today and tomorrow
EWON Town Meeting, Prague, Czech Republic

P.J. Napiorkowski 11 May
GOSIA as a tool for Coulex on exotic beams
EWON Town Meeting, Prague, Czech Republic

M. Palacz 11 May
Investigations of nuclei in the vicinity of ^{100}Sn with EUROBALL and EXOGAM
EWON Town Meeting, Prague, Czech Republic

A. Trzcińska 11 May
Antiprotonic atoms
EWON Town Meeting, Prague, Czech Republic

J. Srebrny 11 May
Presentation of the multidetector gamma spectrometer array at Heavy Ion Laboratory, Warsaw University
Workshop for the European Gamma-ray Spectroscopy Network, Padova, Italy

P.J. Napiorkowski 24 May
Coulex analysis code – GOSIA: current status of development
INTAG Workshop, GSI Darmstadt, Germany

L. Pieńkowski 7 June
Réacteur à haut température pour la réalisation de la synergie charbon-nucléaire
High temperature reactor for the nuclear-coal synergy
Paris, France

J. Srebrny 4 September
The nuclear microscope for ground and excited states
XXX Mazurian Lakes Conference on Physics, Piaski, Poland

K. Wrzosek 4 September
Shape coexistence in even-even stable molybdenum isotopes using Coulomb excitation method
XXX Mazurian Lakes Conference on Physics, Piaski, Poland

M. Zielińska 4 September
Shape coexistence in exotic nuclei studied by low-energy Coulomb excitation
XXX Mazurian Lakes Conference on Physics, Piaski, Poland

E. Piasecki 6 September
Heavy Ion Laboratory of Warsaw University
EWON Workshop, Crete, Greece

E. Piasecki 10 September
Some questions and answers in barrier distributions
Frontiers in Nuclear Structure, Astrophysics and Reactions (FINUSTAR), Crete, Greece

A. Kordyasz 4 October
Improvement of silicon detector technology for FAZIA Digital Pulse Shape Analysis
FAZIA-days, Napoli, Italy

M. Palacz 4 October
Report on experiments performed so far at GANIL
NWall at GANIL and New Neutron Detectors for SPIRAL2, HIL, Warsaw

K. Wrzosek 10 October
Badanie struktury niskoleżących stanów 0^+ w izotopach Mo - wzbudzenia kulombowskie na Warszawskim Cyklotronie
Structure of the low-lying 0^+ states in Mo isotopes – Coulomb excitation at the Warsaw Cyclotron
Seminar of the Nuclear Spectroscopy Division, Faculty of Physics, Warsaw University, Warsaw, Poland

J. Srebrny 29 October
Quest for the chiral symmetry breaking in the atomic nucleus
Australian National University, Canberra, Australia

M. Palacz 12 November
Introduction to simulations of ancillary detectors
6^{th} AGATA Week, LNL INFN, Legnaro, Italy

G. Jaworski 12 November
Simulations of fusion-evaporation reactions with AGATA and ancillary devices
6^{th} AGATA Week, LNL INFN, Legnaro, Italy

J. Choiński 21 November
WARSAW PET CENTRE – possibilities for the production of metallic PET radionuclides
Workshop „Radionuclides and their carriers for medical and industrial applications", Institute of Nuclear Chemistry and Technology, Warsaw, Poland

P.J. Napiorkowski 26 November
Normal Coulex with PARIS
PARIS Collaboration Meeting – SPIRAL2 Week, Caen, France

J. Choiński 4 December
Applied research at HIL UW and Warsaw PET Centre and observations concerning I3 proposals
Cyclotron Research Workshop "JRC Enlargement and Integration Programme", Joint Research Centre, Ispra, Italy

M. Zielińska 19 December
Coulomb excitation of neutron-rich ^{44}Ar at SPIRAL
ISOLDE Workshop 2007/2008, CERN, Geneva, Switzerland

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

A.J. Kordyasz, M. Kowalczyk, E. Nossarzewska-Orłowska, M. Kisieliński, E. Kulczycka, J. Sarnecki, J. Iwanicki,
"*Response to light particles and heavy ions of thin, large area ΔE strip detectors produced by the PPPP process*",
Nucl. Inst. and Meth. **A570** (2008) 336.

M. Drabik, K. Dworecki, R. Tańczyk, S. Wąsik, J. Żuk,
"Surface modification of PET membrane by ion implantation",
Vacuum **81** (2007) 1348.

E. Wójcik, M. Kicińska-Habior, O. Kijewska, M. Kowalczyk, M. Kisieliński, J. Choiński,
"Giant dipole radiation and isospin mixing in hot nuclei with A=32-60",
Acta Phys. Pol. **B38** (2007) 1469.

E. Grodner, S.G. Rohoziński, J .Srebrny,
"Simple picture of the nuclear system diverging from the strong chiral symmetry breaking limit",
Acta Phys. Pol. **B38** (2007) 1411.

E. Piasecki, Ł. Świderski, K. Rusek, M. Kisieliński, J. Jastrzębski, A. Kordyasz, M. Kowalczyk, M. Mutterer, T. Krogulski, K. Piasecki, P. Russotto, A.M. Stefanini, N. Rowley,
"Structure of barrier distributions: probing the role of neutron transfer channels",
Int. J. of Mod. Phys. **E16** (2007) 502.

A.A. Rudchik, A.T. Rudchik, S. Kliczewski, E.I. Koshchy, O.A. Ponkratenko, K.W. Kemper, K. Rusek, A. Budzanowski, J. Choiński, B. Czech, T. Czosnyka, V.D. Chesnokova, L. Głowacka, E. Kozik, V.M. Kyryanchuk, S.Y. Mezhevych, A.V. Mokhnach, O.A. Momotyuk, I. Skwirczyńska, R. Siudak, A. Szczurek,
"Elastic and inelastic scattering of ^{7}Li+^{18}O versus ^{7}Li+^{16}O",
Nucl. Phys. **A785** (2007) 293.

A.T. Rudchik, V.O. Romanyshyn, E.I. Koshchy, A. Budzanowski, K.W. Kemper, K. Rusek, V.D. Chesnokova, J. Choiński, B. Czech, L. Głowacka, S. Kliczewski, V.M. Kyryanchuk, E.I. Koshchy, S.Y. Mezhevych, A.V. Mokhnach, O.A. Momotyuk, O.A. Ponkratenko, R. Siudak, I. Skwirczyńska, A. Szczurek,
"Isotopic effects in the ^{7}Li+^{10}B,^{11}B elastic and inelastic scattering",
Eur. Phys. J. **A33** (2007) 317.

J. Kurcewicz, W. Czarnacki, M. Karny, M. Kasztelan, M. Kisieliński, A. Korgul, W. Kurcewicz, J. Kurpeta, S. Lewandowski, P. Majorkiewicz, H. Penttil, A. Płochocki, B. Roussiere, O. Steczkiewicz, A. Wojtasiewicz,
"Identification of an α-decaying (9^-) isomer in ^{216}Fr",
Phys. Rev. **C76** (2007) 054320.

J. Andrzejewski, A. Król, J. Perkowski, K. Sobczak, R. Wojtkiewicz, M. Kisieliński, M. Kowalczyk, J. Kownacki, A. Korman,
"Electron spectrometer for „in-beam" spectroscopy",
Nucl. Inst. and Meth. **A585** (2008) 155.

K. Wrzosek, M. Zielińska, T. Czosnyka, J. Choiński, K. Hadyńska, J. Iwanicki, M. Kisieliński, M. Kowalczyk, J. Kownacki, P. Napiorkowski, D. Piętak, J. Srebrny, K. Zając,
"New γ -particle detection set-up for Coulomb excitation experiments – towards determination of triaxiality of ^{100}Mo",
Acta Phys. Pol. **B39** (2008) 513.

J. Kownacki, M. Kisieliński, M. Kowalczyk, Ch. Droste, T. Morek, E. Ruchowska, J. Srebrny, M. Wolińska-Cichocka, M. Palacz, A. Korman, J. Andrzejewski, A. Król, J. Perkowski, R. Lieder, J. Mierzejewski, I. Sankowska,
"Observation of a new ($25/2^+$) isomer in ^{121}Sb",
Acta Phys. Pol. **B39** (2008) 489.

A. Król, J. Andrzejewski, J. Perkowski, K. Sobczak, R. Wojtkiewicz, M. Kisieliński, M. Kowalczyk, J. Kownacki, A. Korman,
"The internal conversion electron and gamma spectroscopy in the ^{14}N + ^{197}Au reaction measurements",
Acta Phys. Pol. **B39** (2008) 495.

E. Grodner,
"Quest for the chiral symmetry breaking in atomic nuclei",
Acta Phys. Pol. **B39** (2008) 531.

3.1.2 Publications resulting from work performed with facilities outside HIL

A.M. Hurst, P.A. Butler, D.G. Jenkins, P. Delahaye, F. Wenander, F. Ames, C.J. Barton, A. Bürger, J. Cederkäll, E. Clément, T. Czosnyka, T. Davinson, G. de Angelis, J. Eberth, A. Ekström, S. Franchoo, G. Georgiev, A. Görgen, R. Herzberg, M. Huyse, O. Ivanov, J. Iwanicki, G.D. Jones, P. Kent, U. Köster, R. Krücken, A.C. Larsen, M. Munch, M. Nespolo, M. Pantea, E.S. Paul, M. Petri, H. Scheit, T. Sieber, S. Siem, J.F. Smith, A. Steer, I. Stefanescu, N. Syed, J. Van de Walle, P. Van Duppen, R. Wadsworth, N. Warr, D. Weisshaar, M. Zielińska,
"Measurement of the sign of the spectroscopic quadrupole moment for the 2^+_1 state in ^{70}Se: no evidence for oblate shape",
Phys. Rev. Lett. **98** (2007) 072501.

E. Clément, A. Görgen, W. Korten, E. Bouchez, A. Chatillon, J.-P. Delaroche, M. Girod, H. Goutte, A. Hurstel, Y. LeCoz, A. Obertelli, S. Peru, Ch. Theisen, J.N. Wilson, M. Zielińska, C. Andreoiu, F. Becker, P.A. Butler, J.M. Casandjian, W.N. Catford, T. Czosnyka, G. de France, J. Gerl, R.-D. Herzberg, J. Iwanicki, D.G. Jenkins, G.D. Jones, P.J. Napiorkowski, G. Sletten, C. Timis,
"Shape coexistence in neutron-deficient krypton isotopes",
Phys. Rev. **C 75** (2007) 054313.

A. Görgen, E. Clément, W. Korten, E. Bouchez, A. Chatillon, A. Hürstel, Y. LeCoz, C. Theisen, J.N. Wilson, M. Zielińska, C. Andreoiu, F. Becker, P. Butler, J.M. Casandjian, W.N. Catford, T. Czosnyka, G. de France, J. Gerl, R.D. Herzberg, J. Iwanicki, D.G. Jenkins, G.D. Jones, P.J. Napiorkowski, G. Sletten, C. Timis,
"Shape coexistence in ^{74}Kr and ^{76}Kr",
Eur. Phys. J.-Spec. Top., **150** (2007)117.

J. Van de Walle, F. Aksouh, F. Ames, F. Azaiez, T. Behrens, V. Bildstein, J. Cederkäll, E. Clément, T.E. Cocolios, T. Davinson, P. Delahaye, J. Eberth, A. Ekström, D.V. Fedorov, V.N. Fedosseev, L.M. Fraile, S. Franchoo, R. Gernhauser, G. Georgiev, D. Habs, K. Heyde, G. Huber, M. Huyse, F. Ibrahim, O. Ivanov, J. Iwanicki, J. Jolie, O. Kester, U. Köster, T. Kröll, R. Krücken, M. Lauer, A.F. Lisetskiy, R. Lutter, B.A. Marsh, P. Mayet, O. Niedermaier, T. Nilsson, M. Pantea, O. Perru, R. Raabe, P. Reiter, M. Sawicka, H. Scheit, G. Schrieder, D. Schwalm, M.D. Seliverstov, T. Sieber, G. Sletten, N. Smirnova, M. Stanoiu, I. Stefanescu, J.-C. Thomas, J.J. Valiente-Dobon, P. Van Duppen, D. Verney, D. Voulot, N. Warr, D. Weisshaar, F. Wenander, B.H. Wolf, M. Zielińska,
"Coulomb excitation of neutron-rich Zn isotopes:
First observation of the 2^+_1 state in ^{80}Zn",
Phys. Rev. Lett. **99** (2007) 142501.

D.L. Smith, H. Mach, H. Penttila, H. Bradley, J. Aystö, V.-V. Elomaa, T. Eronen, D.G. Ghita, J. Hakala, M. Hauth, A. Jokinen, P. Karvonen, T. Kessler, W. Kurcewicz, H. Lehmann, I.D. Moore, J. Nyberg, S. Rahaman, J. Rissanen, J. Ronkainen, P. Ronkanen, A. Saastamoinen, T. Sonoda, O. Steczkiewicz, C. Weber,
"Lifetime measurements of the negative-parity 7^- and 8^- states in ^{122}Cd",
Phys. Rev. **C77** (2008) 014309.

M. Papa, F. Amorini, A. Anzalone, L. Auditore, V. Baran, I. Berceanu, J. Blicharska, J. Brzychczyk, A. Bonasera, B. Borderie, R. Bougault, G. Cardella, S. Cavallaro, M.B. Chatterjee, A. Chbihi, M. Colonna, R. Dayras, E. De Filippo, M. Di Toro, J. Frankland, E. Galichet, W. Gawlikowicz, E. Geraci, G. Giuliani, F. Giustolisi, A. Grzeszczuk, P. Guazzoni, D. Guinet, M. Iacono-Manno, S. Kowalski, E. La Guidara, G. Lanzalone, G. Lanzano, C. Maiolino, Z. Majka, N. Le Neindre, A. Pagano, M. Petrovici, E. Piasecki, S. Pirrone, R. Płaneta, G. Politi, A. Pop, F. Porto, F. Rizzo, E. Rosato, S. Russo, P. Russotto, M. Sassi, K. Schmidt, K. Siwek-Wilczyńska, I. Skwira, A. Sochocka, Ł. Świderski, A. Trifiro, M. Trimarchi, G. Vannini, G. Verde, M. Vigilante, J.P. Wieleczko, J. Wilczyński, L. Zetta, W. Zipper,
"Dynamical multi-breakup processes in the ^{124}Sn+^{64}Ni system at 35 MeV/nucleon",
Phys. Rev. **C75** (2007) 054616.

J. Cederkäll, A. Ekström, C. Fahlander, A.M. Hurst, M. Hjorth-Jensen, F. Ames, A. Banu, P.A. Butler, T. Davinson, U. Datta-Pramanik, J. Eberth, S. Franchoo, G. Georgiev, M. Górska, D. Habs, M. Huyse, O. Ivanov, J. Iwanicki, O. Kester, U. Köster, B.A. Marsh, O. Niedermaier, T. Nilsson, P. Reiter, H. Scheit, D. Schwalm, T. Sieber, G. Sletten, I. Stefanescu, J. Van de Walle, P. Van Duppen, N. Warr, D. Weisshaar, F. Wenander,
"SubBarrier Coulomb Excitation of ^{110}Sn and Its Implications for the ^{100}Sn Shell Closure",
Phys. Rev. Lett. **98** (2007) 172501.

I. Stefanescu, G. Georgiev, F. Ames, J. Aysto, D.L. Balabanski, G. Bollen, P.A. Butler, J. Cederkall, N. Champault, T. Davinson, A. De Maesschalck, P. Delahaye, J. Eberth, D. Fedorov, V.N. Fedosseev, L.M. Fraile, S. Franchoo, K. Gladnishki, D. Habs, K. Heyde, M. Huyse, O. Ivanov, J. Iwanicki, J. Jolie, B. Jonson, Th. Kroll, R. Krucken, O. Kester, U. Koster, A. Lagoyannis, L. Liljeby, G. Lo Bianco, B.A. Marsh, O. Niedermaier, T. Nilsson, M. Oinonen, G. Pascovici, P. Reiter, A. Saltarelli, H. Scheit, D. Schwalm, T. Sieber, N. Smirnova, J. Van De Walle, P. Van Duppen, S. Zemlyanoi, N. Warr, D. Weisshaar, F. Wenander,
"Coulomb Excitation of ^{68,70}Cu: First Use of Postaccelerated Isomeric Beams",
Phys. Rev. Lett. **98** (2007) 122701.

D. Mücher, J. Iwanicki, A. Blazhev, P. Van Duppen, C. Fransen, J. Jolie, A. Linnemann, J. Mierzejewski, I. Stefanescu, J. Van de Walle, N. Warr, K. Wrzosek for the MINIBALL collaboration,
"Coulomb excitation of ^{88}Kr and ^{92}Kr in inverse kinematics",
Prog. Part. Nucl. Phys. **59** (2007)36.

B. Kłos, A. Trzcińska, J. Jastrzębski, T. Czosnyka, M. Kisieliński, P. Lubiński, P. Napiorkowski, L. Pieńkowski, F.J. Hartmann, B. Ketzer, P. Ring, R. Schmidt, T. von Egidy, R. Smolańczuk, S. Wycech, K. Gulda, W. Kurcewicz, E. Widmann, B.A. Brown,
"Neutron density distributions from antiprotonic ^{208}Pb and ^{209}Bi atoms",
Phys. Rev. **C76** (2007) 014311.

S. Wycech, F.J. Hartmann, J. Jastrzębski, B. Kłos, A. Trzcińska, T. von Egidy,
"Nuclear surface studies with antiprotonic atom x rays",
Phys. Rev. **C76** (2007) 034316.

B. Alex Brown, G. Shen, G.C. Hillhouse, J. Meng, A. Trzcińska,
"Neutron skin deduced from antiprotonic atom data",
Phys. Rev. **C76** (2007) 034305.

K. Andgren, E. Ganioglu, B. Cederwall, R. Wyss, S. Bhattacharyya, J.R. Brown, G. de Angelis, G. de France, Z. Dombradi, J. Gal, B. Hadinia, A. Johnson, F. Johnston-Theasby, A. Jungclaus, A. Khaplanov, J. Kownacki, K. Lagergren, G. La Rana, J. Molnar, R. Moro, B.S.N. Singh, J. Nyberg, M. Sandzelius, J.-N. Scheurer, G. Sletten, D. Sohler, J. Timar, M. Trotta, J.J. Valiente-Dobon, E. Vardaci, R. Wadsworth, S. Williams,
"Low-spin collective behavior in the transitional nuclei ^{86}Mo, ^{88}Mo",
Phys. Rev. **C76** (2007) 014307.

A.B. Hayes, D. Cline, C.Y. Wu, H. Ai, H. Amro, C. Beausang, R.F. Casten, J. Gerl, A.A. Hecht, A. Heinz, H. Hua, R. Hughes, R.V.F. Janssens, C.J. Lister, A.O. Macchiavelli, D.A. Meyer, E.F. Moore, P. Napiorkowski, R.C. Pardo, C. Schlegel, D. Seweryniak, M.W. Simon, J. Srebrny, R. Teng, K. Vetter, H.J. Wollersheim,
"Spin dependence of K mixing, strong configuration mixing, and electromagnetic properties of ^{178}Hf",
Phys. Rev. **C75** (2007) 034308.

M. Zielińska, A. Görgen, A. Bürger, W. Catford, E. Clément, C. Dossat, J. Iwanicki, W. Korten, J. Ljungvall, P.J. Napiorkowski, D. Piętak, G. Sletten, J. Srebrny, Ch. Theisen, K. Wrzosek,
"Coulomb excitation of neutron-rich ^{44}Ar at SPIRAL",
Acta Phys. Pol. **B39** (2007) 519.

I. Skwira-Chalot, K. Siwek-Wilczyńska, J. Wilczyński, F. Amorini, A. Anzalone, L. Auditore, V. Baran, J. Błocki, J. Brzychczyk, G. Cardella, S. Cavallaro, M.B. Chatterjee, M. Colonna, E. De Filippo, M. Di Toro, W. Gawlikowicz, A. Grzeszczuk, P. Guazzoni, S. Kowalski, E. La Guidara, G. Lanzano, G. Lanzalone, C. Maiolino, Z. Majka, N.G. Nicolis, A. Pagano, M. Papa, E. Piasecki, S. Pirrone, R. Płaneta, G. Politi, F. Porto, F. Rizzo, P. Russotto, K. Schmidt, A. Sochocka, Ł. Świderski, A. Trifiro, M. Trimarchi, J.P. Wieleczko, L. Zetta, W. Zipper,
"Dynamics of "binary" ^{197}Au+^{197}Au collisions as a test of energy dissipation mechanism",
Acta Phys. Pol. **B38** (2007) 1509.

I. Skwira-Chalot, K. Siwek-Wilczyńska, J. Wilczyński, F. Amorini, A. Anzalone, L. Auditore, V. Baran, J. Brzychczyk, G. Cardella, S. Cavallaro, M.B. Chatterjee, M. Colonna, E. De Filippo, M. Di Toro, W. Gawlikowicz, A. Grzeszczuk, P. Guazzoni, S. Kowalski, E. La Guidara, G. Lanzano, G. Lanzalone, C. Maiolino, Z. Majka, N.G. Nicolis, A. Pagano, M. Papa, E. Piasecki, S. Pirrone, R. Płaneta, G. Politi, F. Porto, F. Rizzo, P. Russotto, K. Schmidt, A. Sochocka, Ł. Świderski, A. Trifiro, M. Trimarchi, J.P. Wieleczko, L. Zetta, W. Zipper,
"Ternary reactions in ^{197}Au+^{197}Au collisions revisited",
Int. J. of Mod. Phys. **E16** (2007) 511.

R. Płaneta, F. Amorini, A. Anzalone, L. Auditore, V. Baran, A. Benisz, I. Berceanu, A. Bonasera, B. Borderie, J. Borgensztajn, R. Bougault, M. Bruno, J. Brzychczyk, G. Cardella, S. Cavallaro, M.B. Chatterjee, A. Chbihi, M. Colonna, M. D'Agostino, R. Dayras, E. De Filippo, M. Di Toro, J. Frankland, E. Galichet, W. Gawlikowicz, E. Geraci, G. Giuliani, F. Giustolisi, A. Grzeszczuk, P. Guazzoni, D. Guinet, S. Kowalski, M. Krauze, E. La Guidara, G. Lanzano, G. Lanzalone, N. Le Neindre, J. Łukasik, C. Maiolino, Z. Majka, N.G. Nicolis, A. Pagano, M. Papa, M. Petrovici, E. Piasecki, S. Pirrone, G. Politi, A. Pop, F. Porto, M.F. Rivet, E. Rosato, F. Rizzo, P. Russotto, K. Schmidt, K. Siwek-Wilczyńska, I. Skwira-Chalot, A. Sochocka, L. Świderski, A. Trifiro, M. Trimarchi, G. Vannini, M. Vigilanti, J.P. Wieleczko, J. Wilczyński, L. Zetta, W. Zipper,
"Centrality dependence of isospin effect signatures in ^{124}Sn+^{64}Ni and ^{112}Sn+^{58}Ni reactions",
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3.2 Other conference contributions

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Jan Żylicz (Faculty of Physics, Warsaw University)

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

The international Programme Advisory Committee of the Heavy Ion Laboratory meets usually twice a year, in spring and in autumn. Deadline for submitting proposals is two weeks before a PAC meeting. In 2007, PAC meetings took place on 20 March and 9 October. Ten research projects have been approved and 280 cyclotron shifts allocated in total.

7. Events at HIL

7.1 Meeting of the East-West Outreach Network of EURONS

A meeting on the future collaboration of the East-West Network was held at HIL on 26-27 January 2007. Representatives of the major nuclear physics institutes from the central and eastern part of the European Union discussed the idea to form a distributed Large Scale Facility.

The following institutions were represented:

ATOMKI, Debrecen, Hungary:	*Attila Krasznahorkay*
HIL UW, Warsaw, Poland:	*Jerzy Jastrzębski, Jarosław Choiński, Paweł Napiorkowski*
IFJ PAN, Cracow, Poland:	*Rafał Broda, Adam Maj, Jan Styczeń*
NCSR Demokritos, Athens, Greece:	*Sotirios Harissopulos*
NIPNE, Bucharest, Romania:	*Gheorghe Cata-Danil*
NPI, Řež, Czech Republic:	*Vaclav Kroha, Jan Stursa*
RBI, Zagreb, Croatia:	*Milko Jaksic, Neven Soic*
University of Sofia, Bulgaria:	*Dimiter Balabanski*
EURONS Coordinator:	*Alex Mueller*

The idea of the distributed Large Scale Facility was considered as a good platform for further collaboration of nuclear physicists from our region. The total scientific potential of the infrastructures presented during the meeting was recognized as comparable to a single European Large Scale Facility. In addition to the proposed valuable research programme, training of students and nuclear physics industrial applications would be of special interest for potential dLSF users. The pan-European interest to use the existing nuclear physics infrastructure in EWON countries can help attracting the National Funding Agencies to invest in significant development of the facilities. It was concluded to apply for the Trans-National Access in the future call for I3 proposals.

7.2 NWall at GANIL and New Neutron Detectors for SPIRAL 2 meeting

A meeting on experiments with the Neutron Wall detector system at GANIL and on the project of new neutron detectors for SPIRAL2 was held at HIL on 4-5 October 2007.

The Neutron Wall [1] is an aggregate of 50 liquid scintillator neutron detectors, primarily used to select rare fusion-evaporation residua (associated with the emission of neutrons from the compound nucleus) in in-beam gamma-ray spectroscopy studies of proton-rich nuclei. The Neutron Wall, previously used with EUROBALL, was installed at GANIL in 2005 and two experimental campaigns were run in 2005 and 2006. During the first day of the Warsaw meeting the performance of the Neutron Wall in the experiments performed so far at GANIL was discussed, and plans of future experiments were evaluated. During the second day of the meeting, work concentrated on the feasibility study of constructing new neutron detectors for SPIRAL2, which is one of the tasks within the SPIRAL2 Preparatory Phase program (FP7-INFRASTRUCRURES-2007-1).

Further information on the meeting can be found at its WWW page:
http://www.slcj.uw.edu.pl/neutrons

[1] Ö. Skeppstedt *et al.*, NIM A421(1999)531-541
J. Ljungvall *et al.*, NIM A528 (2004) 741-762
http://nsg.tsl.uu.se/nwall/

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