Warsaw University
Heavy Ion Laboratory

ANNUAL REPORT
2006

WARSAW, March 2007

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Contents

D. General information on HIL activities

In memory of Tomek Czosnyka

It is with deep sorrow that we learned of the passing away of Tomek Czosnyka on October 19th, 2006.

We will always remember him as an excellent physicist, wonderful tutor and great boss. In the opinion of all people, even those who knew him for a short time, he was an exceptionally amiable person, dedicated to his work and mission. Tomek was the one who was making things moving. Usually, it was him who was giving ideas to follow. He was always ready to help other people, frequently encouraging them in their work. That was especially appreciated among students and young scientists for whom Tomek was as well a "guru" as a best friend.

Among many Tomek achievements the Warsaw Cyclotron has a special place. Its success would not have been possible without his theoretical work and great effort put in everyday operation. There is no experimental team which wouldn't get successful results without Tomek important impact on our U-200P cyclotron operation.

His great impact on the field of nuclear structure was best described by one of the world leading nuclear spectroscopists Doug Cline: "Tomek was a truly brilliant scientist, who made pioneering advances in the field of Coulomb excitation. His Ph.D. thesis developed sophisticated techniques that solved a problem that many in the field claimed was impossible to solve when we started in 1979. This important development now forms the foundation of modern Multiple Coulomb excitation leading to exciting new advances in nuclear structure.Coulomb excitation studies by international collaborations, much of which has included Tomek, has made significant advances in understanding the shapes and structure of nuclear states. His work will continue to play a major role in the nuclear physics research at the new radioactive beam facilities now in operation or under construction."

His deeds will not be forgotten and we will benefit from his legacy long after his death.

Tomek's friends

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 limited extent, for its own research programme. In 2006 the Warsaw cyclotron has operated during about 2500 hours of beam on target. 18 experiments, all recommended by the Program Advisory Committee, have been performed by more than one hundred facility users. Their scientific achievements are presented in this Report.

This year the publication harvest was slightly smaller as compared to previous years. However, the first Phys. Rev. Letters paper, based completely on the HIL data, should be noticed.

The important part of the Laboratory team effort was devoted to educational and science popularization activities, described in details in the following pages of this report. Here, I would like to especially mention the Workshop on Heavy Ion Acceleration and its Application, devoted to physics students of Universities outside Warsaw. The 2006 Workshop was organized for the second time. We do hope, that this workshop will contribute to establishing in Poland more formal recognition for inter-university students and tutors exchange. This, as we hope, will benefit in the Ministry funding of this programme in the future.

In 2006 the Laboratory equipment was further developed. The ICARE particle multidetector system was installed on the beam line D and was tested using ^{16}O beam. Work is in progress on improving its characteristics (signal processing and acquisition) and on expanding possible applications by adding the Time-of-Flight components.

The project of a new gamma-ray spectrometer with up to 30 Ge detectors was prepared, discussed and preliminary accepted for realization, when necessary funds are available. In the mean time a new particle detector chamber was tested in coincidence with the OSIRIS II set-up, demonstrating a substantially higher efficiency and lower background in the Coulomb excited gamma-ray spectra.

An irradiation facility for radiobiological studies described in details in the last year Annual Report was also presented in a recent publication.

Finally, after many years of unsuccessful applications, 50% of funds necessary for the acquisition of a new ECR ion source were allocated by the Ministry of Science and Higher Education at the end of 2006. At present commercial offers are evaluated.

Besides running of the U-200P cyclotron, educational activity, development of new experimental tools, and participation in experiments using local and European facilities, the Laboratory team is strongly involved in many new projects.

Basing on funds allocated by the Ministry of Scientific Research and Information Technology, International Atomic Energy Agency, and the Ministry of Health, the project of the installation in the Laboratory building of a second p/d cyclotron for the production of PET radiopharmaceuticals is in progress. The short history and current situation of this project is presented in the following pages of this report.

The Laboratory is also involved in the Polish Hadron-Therapy Consortium, contributing to the preparation of the project of the National Hadron-Therapy Center in Warsaw. European Structural Funds allocated to Poland for 2007-2013 open a possibility to acquire funds for realization of such an initiative.

Basing on the same source of funding, plus the resources of 7FP, the Laboratory launched the idea of the preparatory program for constructing in Poland a demonstration facility for High Temperature Nuclear Reactor in synergy with coal. The Consortium of Polish Universities and industrial partners was organized. The project was accepted by Polish Government and placed in the first place of the list of Large Projects in the "Innovative Economy Programme". It will be discussed with European Commission. More information on this project can be found on the Laboratory web pages.

Jerzy Jastrzębski

Part A:
Laboratory overview

1. Operation of the cyclotron during 2006

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

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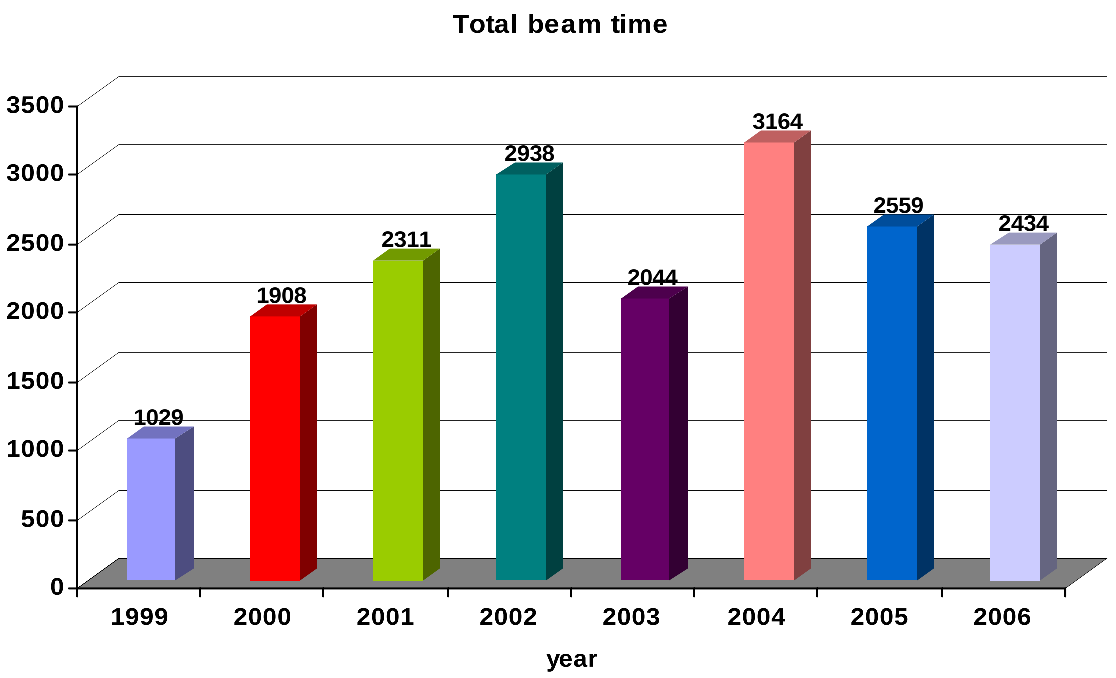
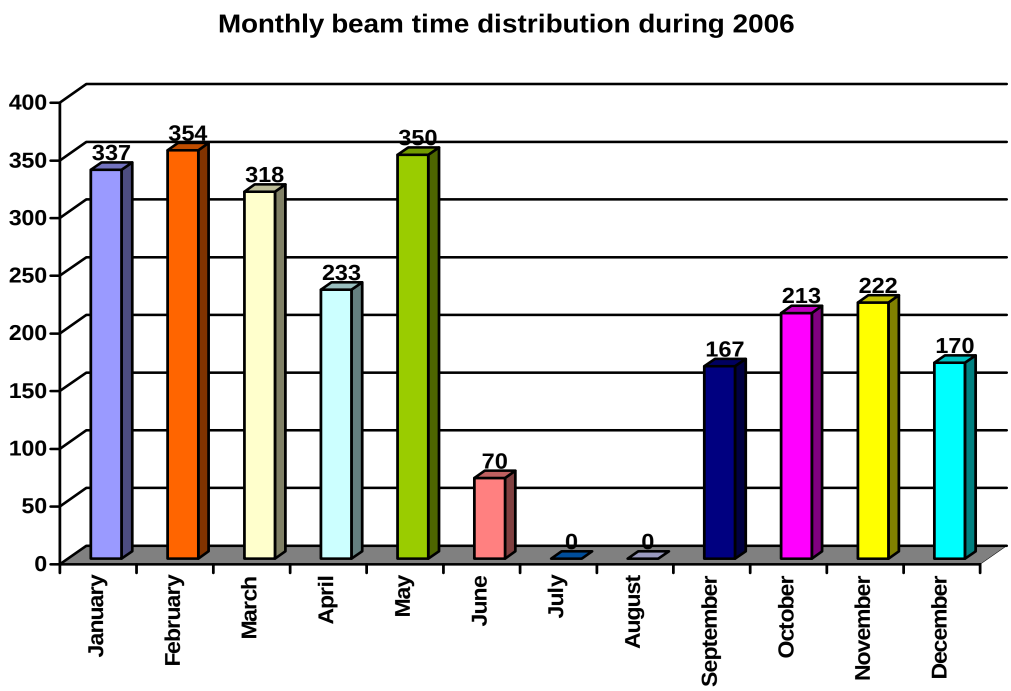
Cyclotron facility

In 2006 the cyclotron delivered a total of 2434 hours of beam-on-target. This number includes beam time used for machine testing and development. The figure below shows usage of cyclotron beams over the last eight years.



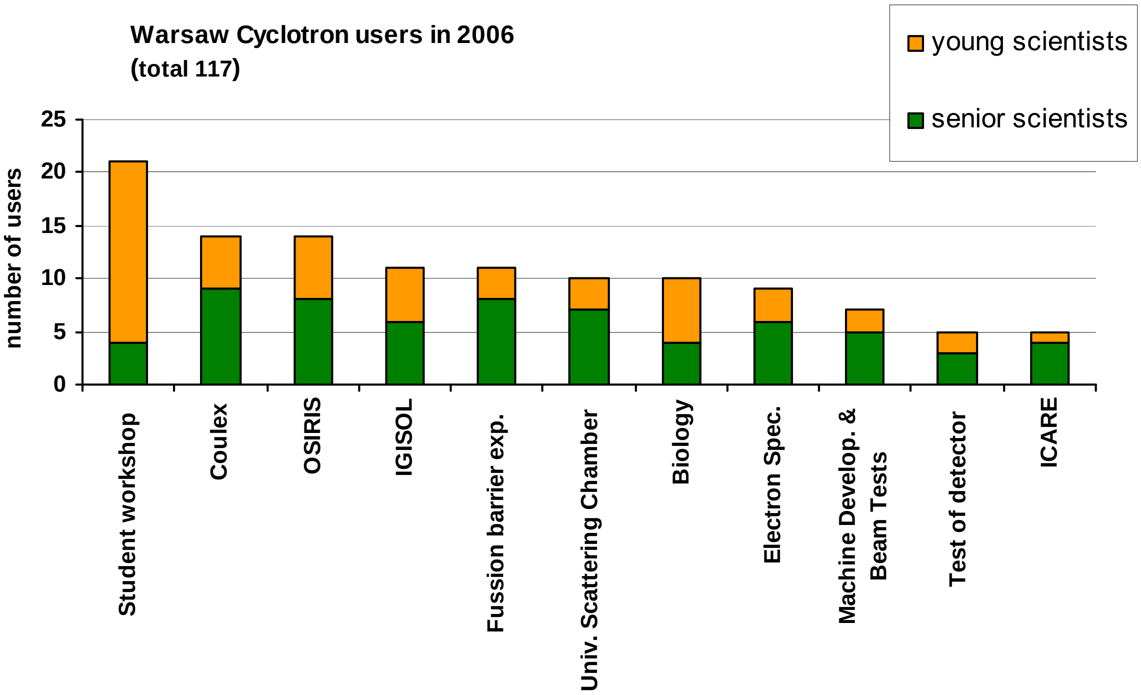
A slight decrease in the number of hours, as compared to previous years, was due to technical problems which plagued the normal operations of the accelerator, and because of the remaining severe financial shortages, could not be solved immediately. These problems were mainly connected to the vacuum system and also, to some extend, to problems with the water cooling system which occurs to be inefficient. As an effect of both problems, the Laboratory was forced (as in 2005) to curtail some of the experiments scheduled during hot spring-summer-autumn season because of overheating of the water-cooled accelerator systems and vacuum leaks. This can be seen in the figure "*Monthly beam time distribution during 2006*" attached to this part. The Laboratory continues negotiation with the firm responsible for the cooling system refurbishment. The modernization is planned in 2007. In June 2006 water pulverizes in cooling towers were exchanged. Another serious issue was maintaining the vacuum in the cyclotron chamber. The cyclotron cryo-pumps motioned in the last Laboratory Status Report were exchanged on May, 17. Additionally, during 2006 we had to change the main vacuum cyclotron chamber O-ring seal, and an O-ring seal between the vacuum cyclotron chamber and the upper pole piece of the magnet. Also, a problem appeared concerning the diffusion pump connected to the switching magnet M2. The water leak between cooling blanket and interior of the pump was located. The reason of this damage was that the pumping stand is almost 30 years old. We have replaced the broken pump with a new one. A new cryogenic pump from CTI-cryogenics replaced a broken one from Edwards in injection line just below the cyclotron magnet. The crucial and successful development of the machine was focused on the installation and start-up of the new system for automatic tuning of RF resonators and the installation and start-up of the modernized phase stability control system. One can find more information later in this Report. The mechanical installment of ICARE experimental set-up was finally done on the beam line "D" which was also equipped with additional steering magnets. The adjustments to the electronic and detectors systems allowed to take advantage of a heavy ion beam inside this scattering chamber.

The usage of cyclotron beams during 2006 is shown at the figure below. The numbers represent beam-on-target time, development of new beams, and development of machine.



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

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



Below, one can find a list of experiments performed in 2006 showing the number of used hours. Description of the beam lines can be found in the HIL web page.

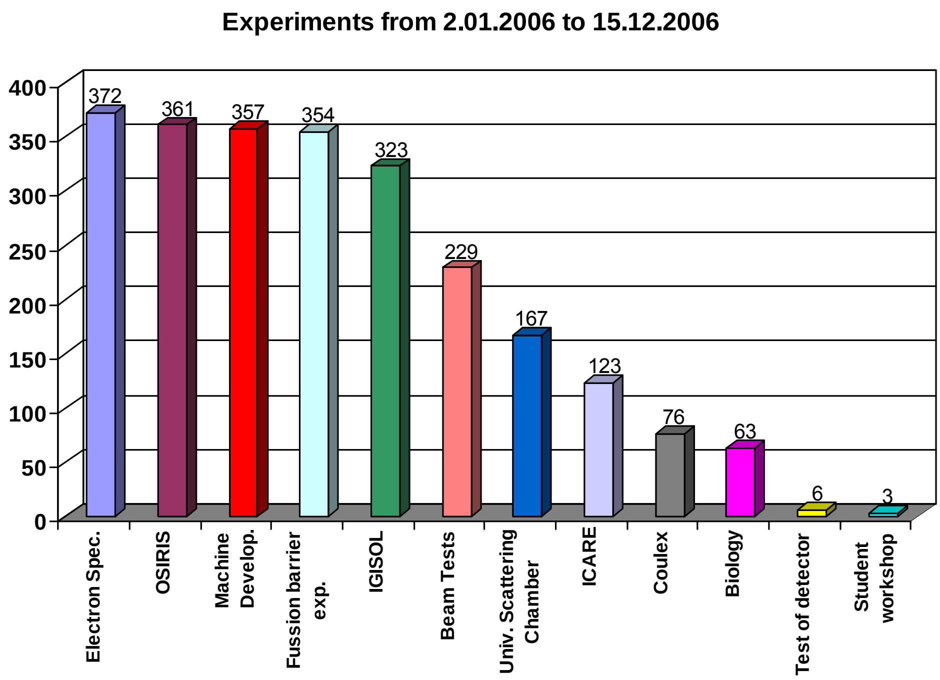


Table 1. Experiments from 1.01.2006 to 31.12.2006

Dates	Experiment	Ion	Energy [Mev]	Leading institution	Collaborating institutions
2.01 -6.01	Coulex	$^{32}S^{+5}$	83.2	HIL	IEP UW, IPT St. Petersburg, IP UMCS
9.01 - 13.01	IGISOL	$^{14}N^{+3}$	79	IEP UW	HIL, IPN Orsay, JYFL
16.01 – 20.01	Electron spec.	$^{14}N^{+3}$	84	DP UŁ	HIL, INS Świerk
23.01 – 3.02	Univ. Scattering chamber	$^{18}O^{+4}$	90	INR Kiev	INS Świerk, INP Kraków, HIL, NU Kharkiv
13.02 – 3.03	Fusion barrier exp.	$^{20}Ne^{+3}$	52-76	IEP UW	HIL, INS Świerk, LNL, IreS Strasburg
6.03 – 10.03	Student workshop	$^{40}Ar^{+8}$	86	HIL	
13.03 – 14.03	OSIRIS	$^{10}B^{+2}$	50	IEP UW	HIL, IPT St. Petersburg, INS Świerk
15.03 – 17.03	Biology	$^{12}C^{+3}$	108	IEP UW IB AŚ Kielce	HIL, IP AŚ Kielce, INS Świerk
17.03 – 17.03	Test of detector	$^{12}C^{+3}$	108	IEP UW	
20.03 – 24.03	IGISOL	$^{14}N^{+3}$	79	IEP UW	HIL, JYFL, IPN Orsay
27.03 – 7.04	OSIRIS	$^{10}N^{+2}$	50	IEP UW	HIL, IPT St. Petersburg, INS Świerk
10.04 – 12.04	OSIRIS	$^{10}N^{+2}$	50	IEP UW	HIL, IPT St. Petersburg, INS Świerk
24.04 – 29.04	OSIRIS	$^{40}Ar^{+8}$	86	HIL	IEP UW, INS Świerk, DP UŁ, INP Kraków, IfK Juelich
15.05 – 26.05	Electron spec.	$^{14}N^{+3}$	84	DP UŁ	HIL, INS Świerk
29.05 – 2.06	IGISOL	$^{14}N^{+3}$	79	IEP UW	HIL, JYFL, IPN Orsay
25.09 – 27.09	Biology	$^{12}C^{+3}$	108	IEP UW IB AŚ Kielce	HIL, IP AŚ Kielce, INS Świerk
27.09 – 29.09	Machine development	$^{12}C^{+3}$	108	HIL	
3.10 – 6.10	ICARE	$^{16}O^{+3}$	58.7	HIL IreS Strasburg	INS Świerk, IEP UW
25.10 – 27.10	Machine development	$^{16}O^{+3}$	58.7	INS Świerk	IEP UW, HIL
9.11 – 12.11	Machine development	$^{20}Ne^{+3}$	52-76	HIL	
13.11 – 17.11	IGISOL	$^{14}N^{+3}$	79	IEP UW	HIL, JYFL, IPN Orsay
11.12 – 15.12	OSIRIS	$^{14}N^{+3}$	82	DP UŁ	HIL, INS Świerk

Abbreviations used in the table above:

IB AŚ Kielce	Institute of Biology, Świętokrzyska Academy, Kielce
IP AŚ Kielce	Institute of Physics, Świętokrzyska Academy, Kielce
IEP UW	Institute of Experimental Physics, Warsaw University, Warsaw
INP Kraków	The Henryk Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, Kraków
INR Kiev	Inst. For Nuclear Res., Ukrainian Nat. Ac. Of Science, Kiev, Ukraine
INS Świerk	The Andrzej Soltan Institute for Nuclear Studies, Świerk
IPN Orsay	Institut de Physique Nucléaire, Orsay, France

IPT St. Petersburg	Ioffe Physical-Technical Institute RAN, St. Petersburg, Russia
JYFL	Department of Physics, University of Jyvaskyla, Finland
IP UMCS	Institute of Physics, M. Curie Skłodowska University, Lublin
NU Kharkiv	National University, Kharkiv, Ukraine
HIL	Heavy Ion Laboratory, Warsaw University, Warsaw
DP UŁ	Department of Physics, University of Łódź, Łódź
LNL	LNL, Legnaro, Italy
IreS Strasburg	IreS, Strasburg, France
IfK Juelich	Institut fur Kerphysik, Forschungszentrum Juelich, Germany

Plans of development

		Estimated completion time
1.	Cyclotron	
1.1	Cooling system upgrade	
1.1.1	Modernization of heat exchangers	January 2007
1.1.2	Installation and putting into operation the automatic control of water levels in primary and secondary circuits	First half of 2007
1.2	New experimental set-up ICARE	
1.2.1	Beam profile probes on line D	2-nd quarter of 2007
1.2.2	First experiments with ICARE	3-th quarter of 2007
1.3	Power supplies	
1.3.1	Final design and installation of a new main magnet power supply driver	February 2007
1.3.2	Design of a new quadrupole lenses power supply	First half of 2007
1.3.3	Design of a new driver for existing quadrupoles	Second half of 2007
1.4	ECR ion source	
1.4.1	Lunching a tender for a new ECR ion source	First half of 2007
1.4.2	Execution of the tender	Second half of 2007
1.4.3	Computerized remote control system	2008
1.5	Vacuum system	
1.5.1	Installation and start-up of the diffusion pump drivers	2007

2. Activity report of the ECR group

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

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1. In 2006 the following ion beams were produced using ECR ion source:

Ion	S^{+5}	N^{+3}	$_{18}O^{+4}$	Ne^{+3}	Ne^{+4}	Ar^{+8}	Ar^{+6}	$_{10}B^{+2}$	C^{+3}	Ne^{+5}	O^{+3}
Ion current on the inflector [eµA]	67	135	80	91	101	46	49	7	93	92	80

2. The ion source was periodically surveyed and cleaned.
3. The power supply of the correction coil has been exchanged.
4. The vacuum cryogenic pump (a new model) has been placed on a top of injection line.
5. The parallel connection to the inflector of a high voltage resistor of power supply has been improved.

3. Activity report of the electrical support group

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

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Design projects and implementation:

I. The design of the steering modules

A. In 2006 the controller for main cyclotron magnet, ZM1, was finally mounted. It was a continuation of the project from 2005. In this year, the software for computer control was completed, allowing automatic steering of the ZM1 module. Full description of this unit can be found in the manual: “**Projekt, wykonanie i uruchomienie sterownika do zasilacza magnesu głównego ZM1 Cyklotronu U-200P”.**

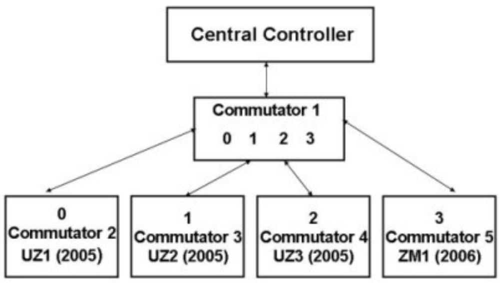

Fig.1 Structure of ZM1 controller communication network

B. Project corrections and mounting of cooling system water level controller (cabling and automatics replacement). New software was added. The project was carried out according to assumptions from 2005. Fig.2 presents the project highlights (version from 2005).

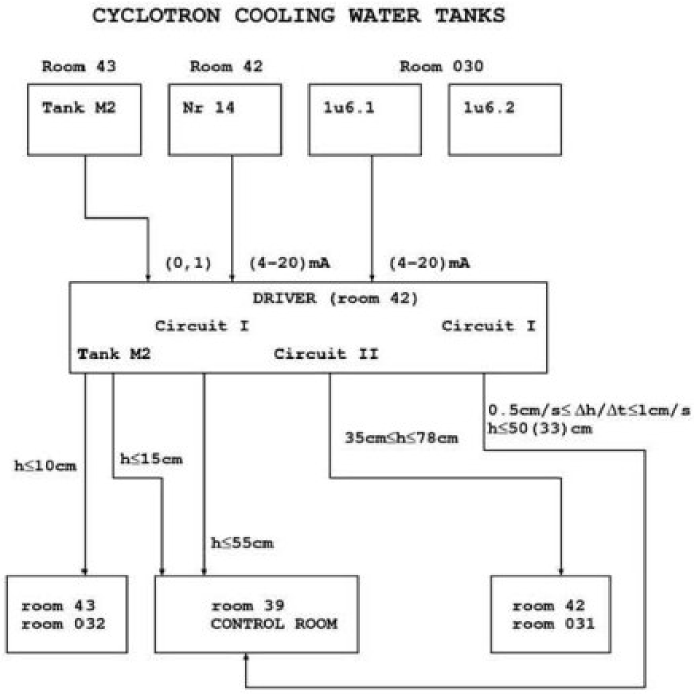

Fig.2**.** Block scheme of the cooling circuit (2005 design).

C. Design and mounting of power supply line for the ICARE project, including new lines for quadruple and correction magnets power supplies.

II. Measurements and maintenance

A. Measurements and maintenance of the street lighting in the cyclotron building area;
B. Control, measurements and monitoring of cyclotron electrical circuits (cable network);
C. Continuous maintenance of master and slave cable network switchboards and automation and steering systems, including the small projects concerning interlocks and steering to facilitate cyclotron operations.
D. Maintance and monitoring of electrical circuits during cyclotron operation.

4. Power supplies for the ICARE beamline

J.Miszczak, Z.Kruszynski, M.Sobolewski, T.Bracha, K.Sosnowski

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Before experimental setup ICARE was assembled at HIL [1], a major upgrade of the ion optics on the beam line connecting the cyclotron to the ICARE setup was performed. In all, 5 new steering and 3 new dipole magnets were added to the existing setup of 3 steering and 2 double dipole magnets.

The electronics workshop at HIL designed and built power supplies for the new magnets. Each steering magnet required 2 variable DC power supplies rated at 8A/25V. Since all ICARE beam line magnets are closely spaced on one beam line, it was decided to combine all required power electronics within one 19" rack enclosure, along with a computerized control unit. Ten DC supplies for the steering magnets share a common 3 phase step-down transformer /rectifier/ filter capable of 100A at 25V DC. The transformer was built by an outside contractor. The rectifier and the filter were salvaged from an old trim coil power supply. The chassis was built by the mechanic workshop at HIL. The chassis additionally houses three 30A/30V power supplies for the dipole magnets which were adapted from surplus power supplies from decommissioned accelerator in Julich, Germany.

All 13 power supplies are controlled by a local PC computer which is equipped with the necessary assortment of D/A, A/D, and binary input/output interface cards. The computer is connected to the HIL control network, so the supplies can be remotely controlled by the cyclotron operator.

References

[1] L.Pieńkowski et al, HIL Annual Report 2005, p.43

5. Microprocessor controller for U-200P cyclotron automatic resonator tuning

A.Bednarek, J.Miszczak, J.Sura

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For an efficient operation of heavy-ion cyclotron the highest possible accelerating voltage is required. A resonator is used to couple accelerating electrode (dee) with a transmission line from high-frequency generator.

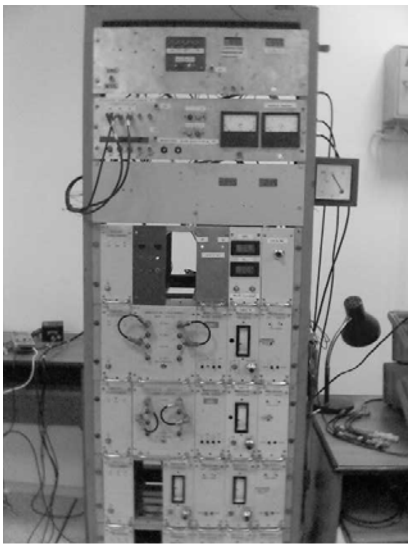

Fig.1 Old high-frequency tuning control unit

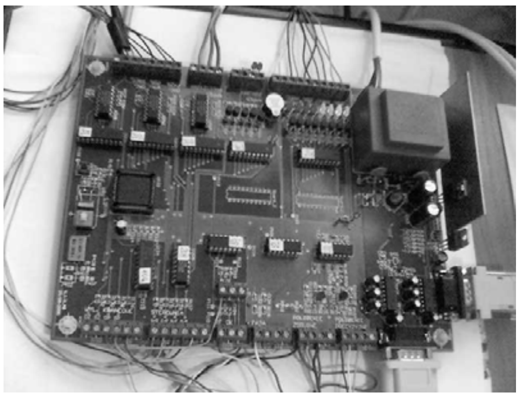

Fig.2 New microprocessor controller

The design of the resonator and high-frequency power transmission line requires their impedances to be matched to equal value of 50 Ohm (no reflected wave condition). This aim is achieved by moving the panel and the trimming loop into the resonator. The resonator works as an transformer coupling the real impedance of the transmission line with the complex impedance of the dee. The resonator has to work in resonance with high-frequency signal from generator. Only in the latter case the impedance "seen" by the transmission line has the real value, without imaginary component.

The existed high-frequency tuning control unit (Fig.1) became obsolete in such way that a new control was needed. It was decided to build a new microprocessor controller. The design of a new unit has started in June 2005. First tests were performed in February 2006. Finally, two controllers for resonators "A" and "B", respectively, were fully operational in October 2006.

The microprocessor controllers were build using 8-bit microcontroller Z8F-Encore from ZILOG corporation (see Fig.2). The hardware project was developed in Protel, and the software for microcontroller was written in C language. The software performs all the functions performed by previous analog circuitry and some new diagnostic and communication functions as well. There are two modes of operation. In the manual mode the operator can tune the resonator up or down in the frequency domain, watching reflected wave on an oscilloscope. A stepping motors are used to tune panel or trimming loop respectively. In the automatic mode controller automatically runs the stepping motors in direction to reduce resonator detuning. Detuning of the resonator is computed from phase measurement between RF generator signal and a signal from coupler in resonator cavity. Detailed construction description and operation modes are contained in document "Instrukcja_Dokumentacja ARCZ.pdf ".Up to now the controllers are working without any accident.

6. Universal control system "Ania" of a diffusion pump stand

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The beam lines at HIL are equipped with diffusion pump stands which are almost 30 years old. Each stand consists of one diffusion pump, one mechanical pump, and few vacuum gauges. Gauges allow measuring rough and high vacuum level. They are the same in all units. The whole set is governed by dedicated autonomic control system. Most of the mechanical failures are easily repairable. However, the control units had old-fashioned electronic components. For this reason, a new control unit, universal for all vacuum sets, was developed.

The control unit "Ania" consists of three functional parts: administrative bloc based on programmable PLC controller type LOGO 5, vacuum analog comparators bloc, and power supply bloc. The LOGO 5 controller, depends on the signals coming from peripherals,. i.e., front control panel, cooling medium circuit, vacuum valves positions, vacuum levels in different sections, temperature of the diffusion pump, and the mechanical pump. The bloc diagram of the universal control unit is presented bellow in Fig.1.

The system can operate in automatic and manual modes. To secure against malfunctions, the system is equipped with expanded interlock circuits. In the automatic mode the cyclotron operator activity is reduced to pushing the button "START". The control unit "Ania" is taking into account present status of the vacuum stand and the beam line, driving the whole process according to the saved procedure. In normal operation the ultimate vacuum in the beam line is achieved. The present status is displayed in the front panel of the control unit. In case of problems during operation the system can itself recognize them and undertake adequate activity to secure the cyclotron vacuum system against breakdown. If any activity of the operator is required, the control unit has to be switch to the manual mode. Using push buttons, localized on the front panel of the unit, and following the status displaying all important parameters, one can fully control the vacuum stand. In this mode interlock circuits are active.

The vacuum analog comparators bloc allowed to obtain better stability, as compared to original one. The use of programmable vacuum thresholds gates makes the system more reliable.

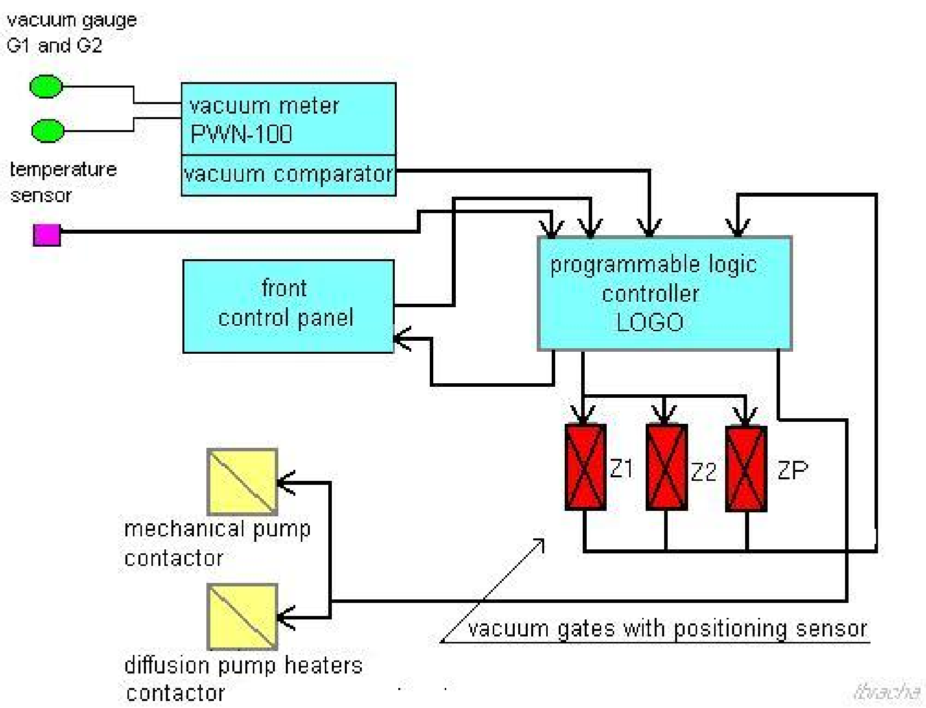

Figure 1 The bloc diagram of the universal control unit “Ania”

A prototype of the control unit “Ania” has been released and tested in the middle of 2005. After minor developments, related mainly to hardware, the final version was installed in February 2006, replacing control unit of the SP 6000 stand. The control unit “Ania” was operating smoothly since the time of installation.

Part B:
Experiments and experimental set-ups

1. The ^{14}N + ^{197}Au reaction studied by the gamma and the internal conversion electron spectroscopy

J. Andrzejewski[1], A. Król[1], J. Perkowski[1], K. Sobczak[1], M. Kisieliński[2], M. Kowalczyk[2], J. Kownacki[2], and A. Korman[3]

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The schematic view of the internal conversion electron spectrometer designed and constructed at the University of Łodź is presented in Fig. 1. This spectrometer has a radial symmetry and relatively small dimensions: (390 x 190 mm).

The main features of the new electron spectrometer are as follows:

- energy selection of electrons, elimination of positrons, α and proton particles,
- backward arrangement of the detectors in relation to the target (minimalization of the amount of delta electrons reaching the detectors),
- decrease of gamma and X- ray background by absorbers: Cu (inner heat sink covering detectors at collimator side) and Pb (between target and detectors),
- effective two-step cooling by using Peltier modules,
- stabilisation of temperature (outer radiator cooled by water),
- five silicon detectors (with active area of 300 mm^2 for each one).

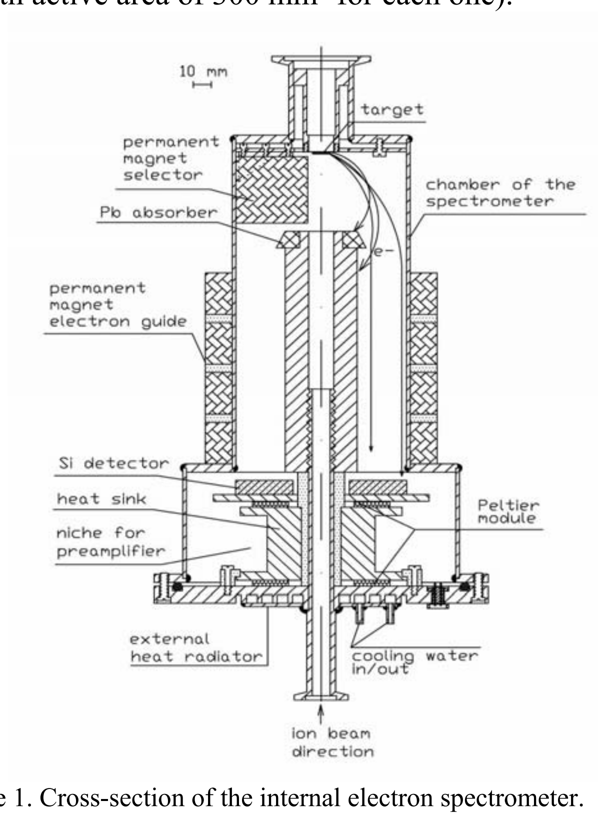

Figure 1. Cross-section of the internal electron spectrometer.

The internal conversion electron spectroscopy is complementary to the γ-ray spectroscopy. Both methods provide powerful tools for nuclear structure studies. The construction of the spectrometer allows simultaneous application of these methods. For this purpose the spectrometer was used together with the OSIRIS-II multi-detectors HPGe array placed at the Heavy Ion Laboratory. As a test of possibilities, determination of the multipolarity and type of transitions between the excites states in ^{206}Rn was chosen. This isotope was produced in the ^{14}N + ^{197}Au reaction. During the experiment, the spectra of the gamma transitions in ^{206}Rn nucleus, and ^{202}Pb and ^{206}Po daughter nuclei were collected together with the corresponding internal conversion electron "in beam" and "off beam" spectra of K- and L-lines.

Fig.2 presents an example of γ – ray spectra observed during beam, as well as, in-between beam pulses.

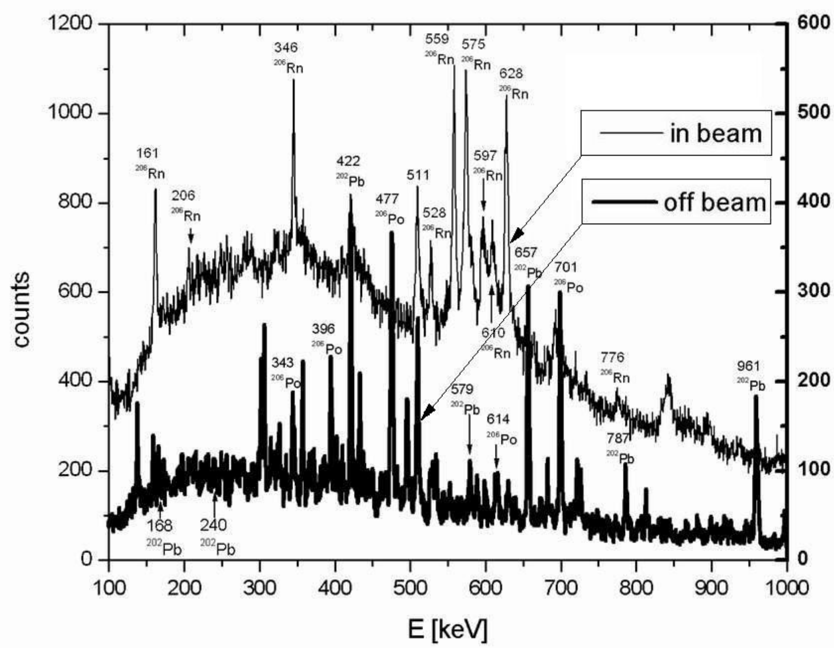

Figure 2. The gamma-ray spectra measured during the experiments. The peaks from the ^{206}Rn and daughter nuclei are labelled.

The gamma lines from ^{206}Rn at energies: 161, 206, 346, 528, 559, 575, 597, 628 keV dominate the „in beam" spectrum. The lines observed in the "off beam" spectrum correspond to photons emitted by daughter nuclei of the ^{206}Rn isotope. Namely, gamma lines 343, 396, 447, 614, 701 keV can be attributed to the ^{206}Po nucleus and lines 168, 240, 422, 579, 657, 787, 961 keV to the ^{202}Pb nucleus.

The spectrum of the internal conversion electrons from the ^{206}Rn measured "in beam" is presented in the Figure 3. The peaks for K and L electrons corresponding to gamma lines: 346 (L), 528 (K), 559 (K), 575 (K), (L), 628 (K), (L) from the ^{206}Rn nucleus dominate the total "in beam" spectrum.

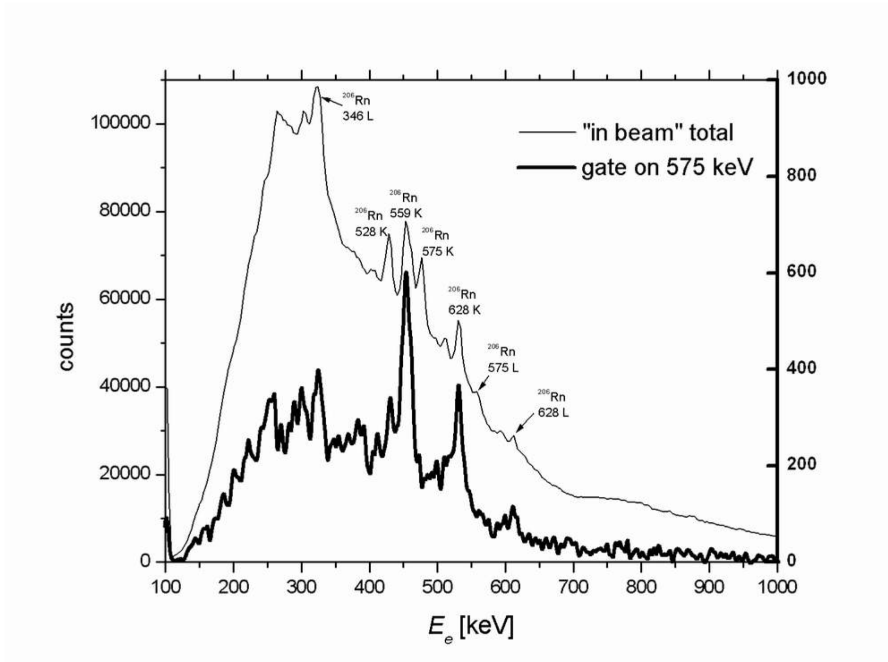

Figure 3. Spectrum of internal conversion electrons measured "in beam" (thin line), and spectrum of internal conversion electrons in coincidence with gamma ray at the energy 575 keV from the ^{206}Rn (thick line).

Using the collected spectra, and taking into account efficiency of both spectrometers, the total conversion coefficients of the individual transitions in the ^{206}Rn nucleus were calculated. The evaluation made using the HSICC code [1], allowed to determine multipolarity of a few nuclear transition – see Table 1.

Table 1

$E\gamma$ [keV]	E_{eK} [keV]	$\alpha_{K\ exp.}$	λ	E_{eL} [keV]	$\alpha_{L\ exp.}$	λ
346	248	$(8,5 \pm 1,7) \cdot 10^{-3}$	**E1**	330	$(6.3 \pm 1,2) \cdot 10^{-3}$	**E1**
559	461	$(2,1 \pm 0,4) \cdot 10^{-2}$	**E2**	543	$(5,6 \pm 1,2) \cdot 10^{-3}$	**E2**
575	477	$(1,9 \pm 0,4) \cdot 10^{-2}$	**E2**	559	$(5,5 \pm 1,1) \cdot 10^{-3}$	**E2**
597	499	$(1,9 \pm 0,4) \cdot 10^{-3}$	**E1**	581	$(1,13 \pm 0,27) \cdot 10^{-3}$	**E1**
629	531	$(4,4 \pm 0,9) \cdot 10^{-3}$	**E1**	613	$(6,5 \pm 1,5) \cdot 10^{-4}$	**E1**
684	586	$(2,5 \pm 0,7) \cdot 10^{-3}$	**E1**	668	-	-
891	793	$(2,6 \pm 0,6) \cdot 10^{-3}$	**E1**	875	$(7 \pm 2) \cdot 10^{-4}$	**E1**

For energies 346, 559 and 575 keV, the obtained results are consistent with earlier data. On the other hand, for energies 551, 684 and 891 keV this result is a first attempt of multipolarity determination. For 597 and 629 keV transitions, a comparison with the theoretical values of the conversion coefficient, allowed to conclude, that we deal with the E1 transition. However, the data that have been published so far, based on gamma-gamma coincidence measurements and on systematics of nuclear levels in this mass numbers region, point to a quadruple transitions [2,3,4]. The few peaks at energy between 200 and 300 keV can be seen in the spectra of electrons gated by gamma lines from the ^{206}Rn. These peaks don't correspond to any gamma lines collected in databases for this nuclide. In connection to this, there is suspicion that the observed electron conversion lines are descended from unknown so far transitions in the ^{206}Rn, or also, what is less probable, they correspond to E0 transitions.

In order to verify our predictions and to extend knowledge about the excited levels in the ^{206}Rn, the next experiment was carried out in the Heavy Ion Laboratory in December 2006. In this measurement only set-up of the HPGe detectors of the OSRIS II was used to register γ-γ coincidences. The ^{206}Rn was produced in the same reaction as previously: $^{14}N + ^{197}Au \rightarrow ^{211}Rn^{*}$. The data collected in this experiment are under analysis.

It was shown, that connection of the electron spectrometer with the OSIRIS-II detectors array is a useful experimental set-up to characterise excites levels of the nuclei.

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2. In- and off-beam spectroscopy investigation of nuclei in the A=150 and 130 regions

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The OSIRIS-II array consisting of 12 Compton suppressed HPGe detectors has been employed to study the $^{40}Ar^{+8} + ^{112,114,120}Sn$ reactions, with an attempt to search for the isomers in μsec-msec, as well as, in nsec regions.

In the experiments reported here targets of 20 mg/cm^2 ^{120}Sn on a ^{197}Au backing, 8 mg/cm^2 of ^{112}Sn and 6 mg/cm^2 of ^{114}Sn were bombarded with a beam of 40Ar^{+8} at energy E_{lab}=206 MeV. These investigation are focused on the ^{156}Er*, ^{154}Er* and ^{152}Er* compound systems decaying to several reaction channels with strong preference of charged particles emission. Half-life information was obtained by examining background subtracted time spectra obtained from γ-time matrices. These measurements involved registering of the relative time of γ-ray events with respect to the beam pulses. Half-lifes were extracted by fitting an exponential function. This technique is suitable for spectra without a prompt lifetime component, i.e. related to isomers which belong to μsec and msec regions, observed in the off-beam period of the cyclotron work. In our case we had two different beam pulse configurations: a) 2 ms onbeam/ 4 ms off-beam and in another run 4 ms on-beam/ 8 ms off-beam. After setting the gates in the off-beam period (e.g. the 30 channels at the beginning of beam-off period and 30 channels at the end) on the γ-γ-t matrices one gets quick information about the existence of long living isomers.

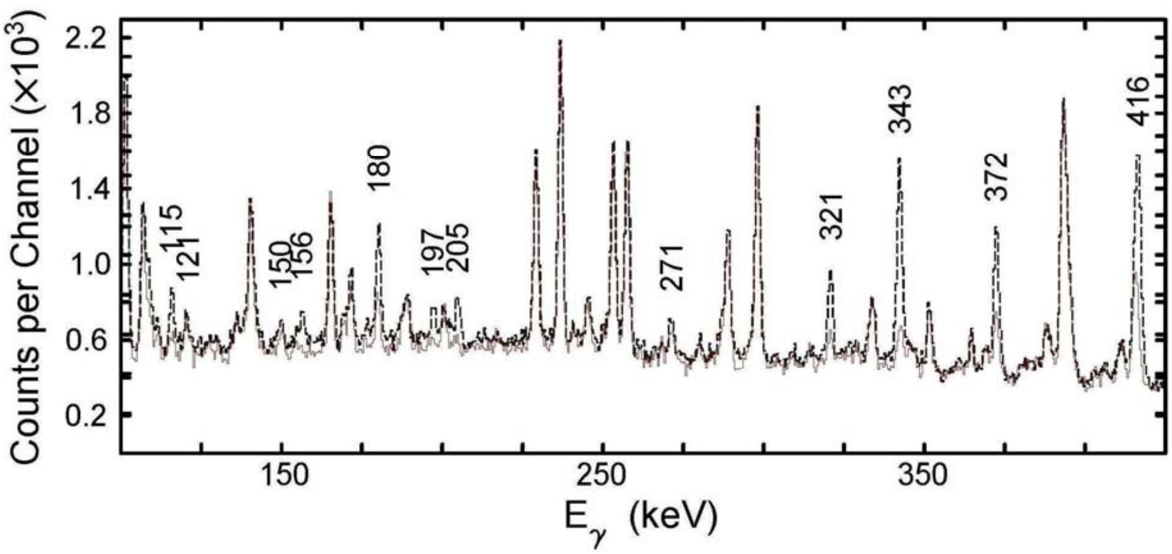

Fig.1 A quick test of the existence of isomers in the μsec and msec regions. Two spectra are presented: a) broken line shows a γ-ray spectrum gated by the 30 channels (0,3 ms) at the beginning (40 μsec after the end of beam-on pulse) the off-beam period, and b) continuous line presents such spectrum when gated by the 30 channels (0.3 ms) at the end (2.84 ms after the end of the beam-on pulse) of beam-off cycle. The γ-rays of energy 416, 342, 205 and 156 keV belong to 1.3 ms (10+) isomer in ^{146}Tb, while lines 372, 321, 180 keV are ascribed to ^{148}Ho, 0.9 ms (10+) [1]. Lines observed at energy of 115 and 156 keV show an indication for a newly observed isomer most probably belonging to odd-odd ^{146}Eu nucleus.

An example of such spectra is shown in Fig.1, for the reaction $^{40}Ar^{+8}+^{112}Sn$. Here, the well known [1] isomers in ^{146}Tb and ^{148}Ho are observed. Besides those known cases, few other γ-rays indicate a significant delay in the μsecond region and are now under consideration.

Another region of our interest from the point of view of isomer search was based on the reaction $^{10}B^{+2} + ^{120}Sn \rightarrow ^{130}Cs^*$. It shows also the possible existence of unknown isomers.

The analysis of the data in both mass regions is in progress, showing that the beam structure of U-200P cyclotron can be efficiently used for a search of isomers in the wide region of delays.

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3. Fusion Barrier Distributions

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Nuclear reactions at sub-barrier energies play extremely important role in Nature, being responsible for the very existence of the stars, their evolution and many aspects of the origin of elements. One of the most important class of sub-barrier reactions is fusion. It turns out that connection between nuclear reaction mechanism and structure of the interacting nuclei exists and manifests itself in strong enhancement of fusion cross-sections at sub-barrier energies. It can be understood as the result of couplings between various reaction channels: elastic and inelastic scattering, transfer reactions, break-up and fusion. Experiments point to the presence of the barriers of various heights in the same projectile– target system, giving rise to the barrier height distributions.

It was demonstrated that the barrier distributions could be extracted from the sum of the cross-sections of all quasielastic reactions (elastic and inelastic scattering and the transfer reactions) using the cyclotron beams [1]. Since 5 years we are using this method for studying interaction of ^{20,22}Ne with various targets (^{nat}Ni, ^{112,116,118}Sn). The ^{20}Ne nucleus was chosen for these studies because of its remarkable properties: its β_2 and β_4 ground state deformations are enormous, namely 0.46 and 0.27. Due to this, calculations performed by means of the coupled channels method predict in the ^{20}Ne + Sn case the strongly structured barrier distribution. However, the experimental distribution turned out [2,3] to be completely smooth, of the Gaussian-like shape (Fig.1, upper left panel). Suspicions, that smoothing of the barrier distribution was caused by the strong α particle transfer and break-up channels (due to the strongly clustered ^{20}Ne nucleus) were falsified [4] by replacing the projectile by ^{22}Ne. This replacement resulted in considerable (by the factor of 6) decreasing of the α transfer probability without, however, significant changing of the barrier distribution (the lower left panel of the Fig.1). On the other hand, using the same experimental method, the clear structure was observed for the ^{20}Ne projectile, when the Sn target was replaced by the ^{nat}Ni one (right panels) [5].

It seems that the reason of structure smoothing, observed in the case of Ne + Sn, is due to the strong neutron transfer channels. This would point to the limits of the present version of the Coupled Channels method, consisting in assuming that only the collective channels have to be taken explicitly into account in the calculations. Usually the other reaction channels, being considered as the "weak" ones, are treated by including them into the imaginary Optical Model Potential.

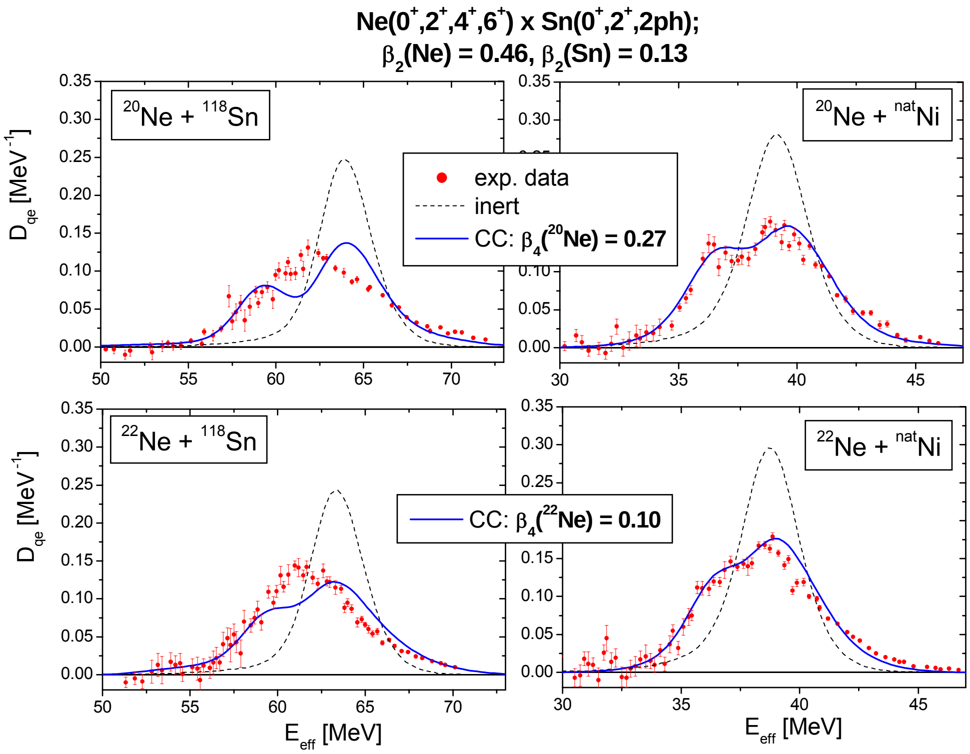

Fig. 1. Comparison of calculated and experimental quasi-elastic barrier distributions. The dashed curves were calculated without taking into account any couplings. The solid lines show calculated results assuming the coupling parameters taken from the literature.

To check our hypothesis on the importance of the neutron-transfer channels, we performed, under the same experimental conditions, measurements for the ^{20}Ne + ^{90,92}Zr systems. According to the systematics of Rehm et al. [6], the precision of which should be, however, checked experimentally, 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 (and the Rehm systematics) is correct, we should expect a structured barrier distribution for the ^{90}Zr target, while in the case of ^{92}Zr we expect the distribution having 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.

The method and experimental set-up was similar to that described in Ref. [1]. That is, we measured quasi-elastic large-angle scattering excitation functions using thirty 10x10 mm PIN diodes placed at 130^{o}, 140^{o} and 150^{o} in the laboratory system and two “Rutherford” semiconductor detectors (of 6 mm diameter) placed at 35^{o} with respect to the beam.

The ^{20}Ne beam, with an intensity of a few pnA from the Warsaw Cyclotron, bombarded 100 μg/cm^2 targets of ^{90,92}Zr (enriched to 98%) on 20 μg/cm^2 C backings. As energy degraders we used nickel foils. Together with measurements performed at different angles, these enabled us to obtain an excitation function with very small energy intervals (see Fig.2).

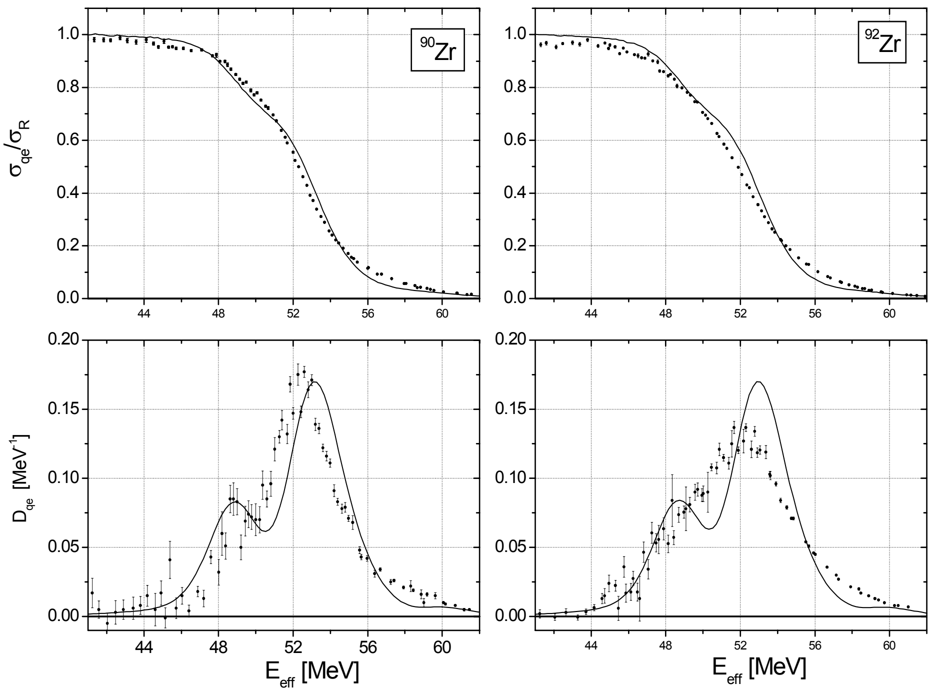

Fig. 2 Experimental excitation functions and barrier distributions for $^{20}Ne + ^{90,92}Zr$ compared with theoretical distributions. The ^{20}Ne deformation parameters were taken as for Fig. 1. All calculated distributions are folded with experimental resolution.

The energy resolution was continuously monitored during the experiment using the energy spectra measured in the forward detectors, and turned out not to exceed 1.15 MeV [FWHM], being very similar for both Zr targets. Apart from the contributions coming from straggling in the degrader and the targets (about 30% of this value), the main contribution to the width comes from the characteristics of the beam. Other effects, for example detector geometry, had very little influence on the energy resolution. In addition to checking the resolution, the stability of the gain and the offset of the electronics and detectors were continuously monitored using a precise pulse generator and an α-particle source.

In the Coupled Channels calculations, although it was checked that the shape of D_{qe} is determined almost entirely by the properties of ^{20}Ne, we also took into account the vibrational excitations of the target. 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, $\beta_3 = 0.39$ [7]). The same deformation parameters of ^{20}Ne as in our Ne + Sn, Ni studies were assumed. For the β_2 deformation parameter of Zr we took the value 0.1027 [7].

It can be seen that in agreement with our expectations, the barrier distributions for $^{20}Ne + ^{90,92}Zr$ differ: the former seems to be structured, while the latter is structureless. The latter is also wider: dispersions (r.m.s.) are correspondingly equal to: 3.034 ± 0.045 and 3.271 ± 0.026. In the case of the ^{90}Zr target the observed structure seems to be similar to that calculated using the CCQEL code [8], while the larger width and the lack of structure in the case of ^{92}Zr target is apparently due to a large transfer coupling strength, which cannot be taken into account by the calculations. This suggests the same reason of disagreement between experiment and theory, observed also in the case of Ne + Sn system: the transfer channels, which smooth out the expected structure. It seems that we come here to the limits of existing coupled-channels programs which only account explicitly for strong collective inelastic excitations, while other reaction channels are considered as "weak", and assumed to contribute only to the imaginary part of the optical-model potential.

At the moment our speculations concerning the reasons of absence of structure are rather tentative and await further experimental and theoretical investigation.

We are grateful to the Warsaw Cyclotron staff for the excellent beam they provided. We thank also the target production staff of the LNL and in particular to Mr. Massimo Loriggiola. This work was funded in part by Grant No N202 152 31/2796 and supported by the cooperation agreement (03-110) between the IN2P3 (France) and the Polish Laboratories.

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4. Status of the IGISOL device

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In 2006 the investigations of gas catcher/ion guide system, as well as, the physics experiments on nuclei beyond lead were continued. The main technical improvement was installation of an additional polarized electrode in extraction region of the ion guide [1] (called the NEC electrode). The aim was to neutralize the space charges in this region. Besides, it eliminates the perturbing oscillations of the ion beam and considerably increases the ion extraction efficiency. This efficiency (for stopping, guiding and extracting) had achieved 6% for the production of ^{213}Rn ($T_{1/2}$=25 ms) isotope in the on-line experiment performed with a ^{14}N (5.6-5.9 MeV/u) beam on a ^{209}Bi target placed inside the helium cell of the Warsaw IGISOL system. The efficiency remained essentially the same up to 40 particle nA ^{14}N primary beam intensity.

The two-dimensional ion beam grid scanner placed in front of the collection point of the mass separator was improved to obtain higher sensitivity. Now, with the sensitivity of 1 pA/mV, it is possible to perform more precisely the mass calibration during on-line experiments using as the mass markers the very low intensity ion beams of stable isotopes coming from trace impurities in the helium cell and target chamber.

For the physics experiments the search for isomeric state in ^{216}Fr was continued [2]. The ^{220}Ac activity ($T_{1/2}$=26 ms) was produced in the heavy-ion reaction ^{14}N+^{209}Bi, with target placed inside the helium gas cell of the IGISOL system [1]. The ^{14}N beam of energy 5.5 MeV/u and an average intensity of 30 particle·nA was used. The reaction products after stopping in a gas cell were extracted and separated by the mass separator according to the mass number A. The previously tested gas cell was used [3]. A set of silicon alpha detectors was placed at the collection point of the mass separator. The digital electronics DGF [4] was used in the α-α-t correlations and pile-up modes with the ^{223}Ra alpha source and the heavy-ion reaction product ^{220}Ac, respectively.

For the mass A = 220 focused at the collection point, α-particles originating from the decay of ^{212}At and ^{212m}At were observed. Population of both, ground (1^-) and isomeric (9^-) states of ^{212}At, in the presence of suppression of γ-deexcitation channel, indicates a possible existence of 9^- isomeric state in ^{216}Fr.

These works were partially performed in the frame of the Warsaw University – IN2P3 (nr 04-112) collaboration.

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5. ^{7}LI + ^{10}B ELASTIC AND INELASTIC SCATTERING

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Angular distributions of the ^{7}Li + ^{10}B elastic and inelastic scattering were measured at the energy $E_{lab}(^{10}B)$ = 51 MeV (21 MeV c.m.) at the Warsaw University cyclotron U-200P. The *ΔE-E*-telescopes with silicon detectors were used in the experiment. Figure 1 shows a typical *ΔE(E)*-spectrum of the ^{7}Li(^{10}B, X) reaction products. The measured angular distributions of the ^{7}Li + ^{10}B elastic and inelastic scattering are shown in Figs. 2 – 4.

The data were analyzed within the optical model (OM) and coupled-reaction-channels method (CRC). The Woods-Saxon potential with volume absorption was used in the calculations. The potential parameters were fitted to the ^{7}Li + ^{10}B data for both, entrance and exit channels. In Figs. 2 – 4, the curves <A_i> (i = 2 – 15) represent the calculated cross sections for these parameters. The OM- and CRC-calculations with energy dependent parameters of ^{7}Li + ^{11}B scattering potential [1] are shown by curves <B_i>. The transitions to the excited states of ^{7}Li and ^{10}B were calculated within the rotational and vibratory models. The most important one- and two-step transfers were also included in the calculations.

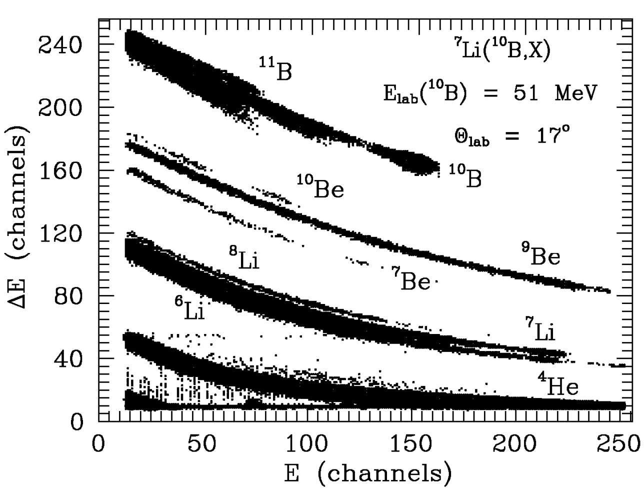

Fig. 1. Typical ΔE(E)-spectrum from the ^{7}Li(^{10}B, X) reactions at energy $E_{lab}(^{10}B)$ = 51 MeV for the angle θ_{lab} = 17^{O}.

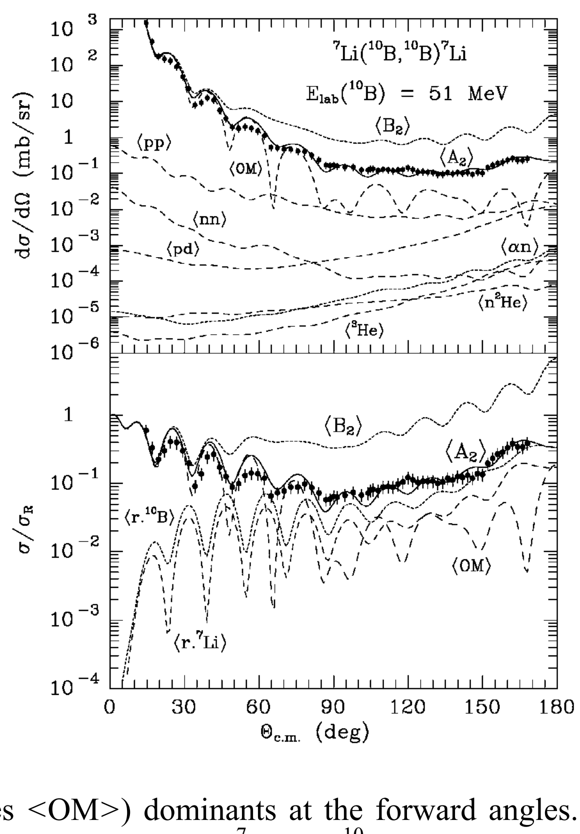

Fig. 2. Angular distributions of the ^{7}Li(^{10}B, ^{10}B) elastic scattering at the energy $E_{lab}(^{10}B)$ = 51 MeV.

It was found that potential scattering (curves <OM>) dominants at the forward angles. The large angle scattering are mainly caused by the reorientations of ^{7}Li and ^{10}B nuclei (curves <r.^{7}Li> and <r.^{10}B>, respectively). The transfer contributions (see curves <pp>, <nn> and so on in Fig. 2) are small as compared to the calculated cross-section of the elastic scattering channel.

The parameters of $^{7}Li + {}^{11}B$ scattering potential fail in the description of the $^{7}Li + {}^{10}B$ reaction scattering data (*scattering isotopic effect*).

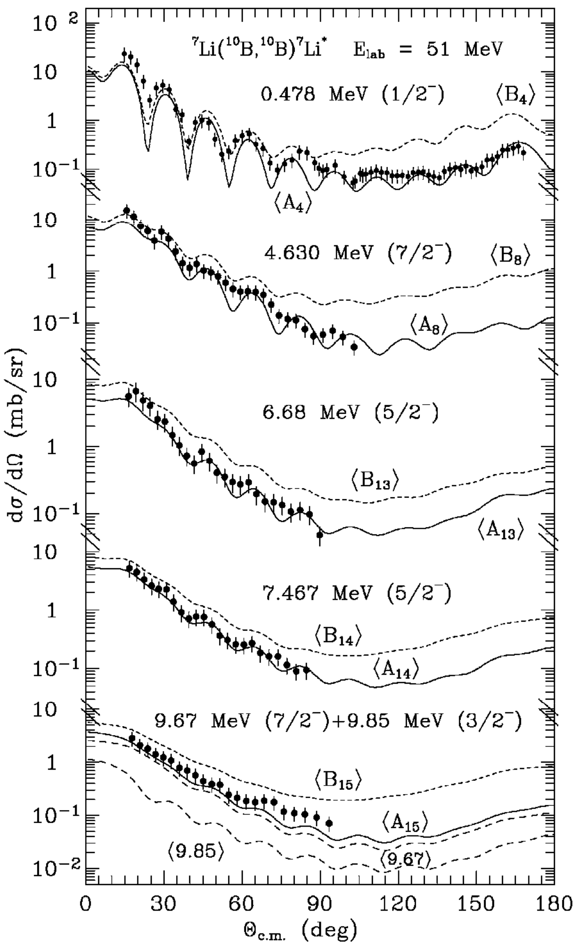

Fig. 3. Angular distributions of the $^{7}Li(^{10}B, {}^{10}B)$ inelastic scattering at the energy $E_{lab}(^{10}B)$ = 51 MeV for the transition to the excited states of ^{7}Li.

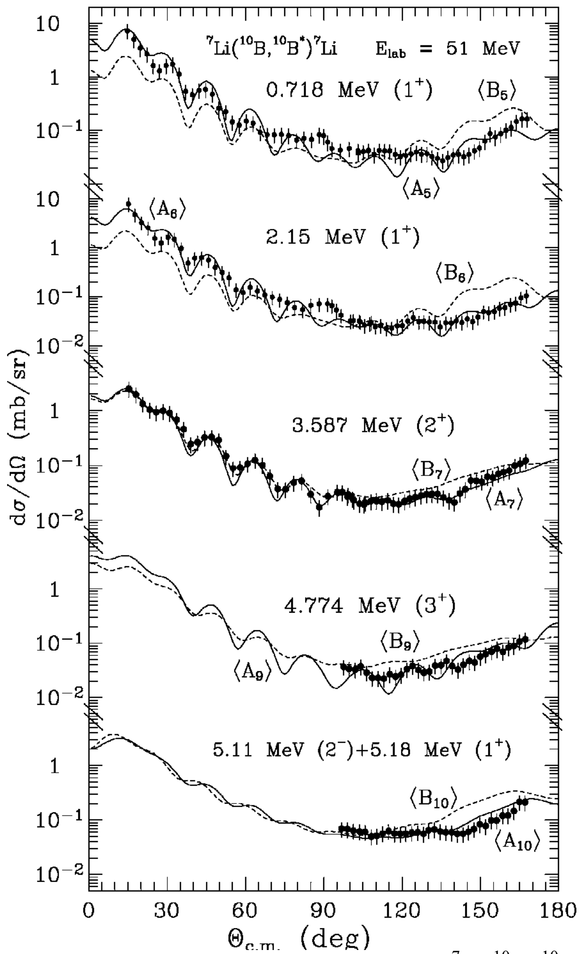

Fig. 4. Angular distributions of the $^{7}Li(^{10}B, {}^{10}B)$ inelastic scattering at the energy $E_{lab}(^{10}B)$ = 51 MeV for the transition to the excited states of ^{10}B.

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6. Elastic and inelastic scattering of ^{7}Li + ^{18}O versus ^{7}Li + ^{16}O

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Angular distributions of the ^{7}Li + ^{18}O elastic and inelastic scattering were measured at the energy $E_{\rm lab}(^{18}$O) = 114 MeV (32 MeV c.m.) in inverse kinematics using ^{18}O-beam of the Warsaw University U-200P cyclotron. This technique allowed both, small and large angle data, to be collected simultaneously. The reaction products were detected by a ΔE-E Si telescope that was composed of a 67 μm ΔE-and 1 mm E-detectors. Standard CAMAC electronics were used with the data acquisition system SMAN. Fig. 1 shows typical $\Delta E(E)$-spectra for reaction products with Z = 3 - 8 identified. Figs. 2–4 show measured angular distributions of the elastic and inelastic scattering of the ^{7}Li + ^{18}O reaction at $E_{\rm lab}(^{18}$O) = 114 MeV for transitions to the 0.478 MeV (1/2^{-}), 4.63 MeV (7/2^{-}) + 4.456 MeV (1^{-}) (^{18}O), 6.68 MeV (5/2^{-}), 7.467 MeV (5/2^{-}) excited states of ^{7}Li, and for 1.982 MeV (2^{+}), 3.555 MeV (4^{+}) + 3.635 MeV (0^{+}), 3.92 MeV (2^{+}), 5.098 MeV (3^{-}), 5.26 MeV (2^{+}) excited states of ^{18}O.

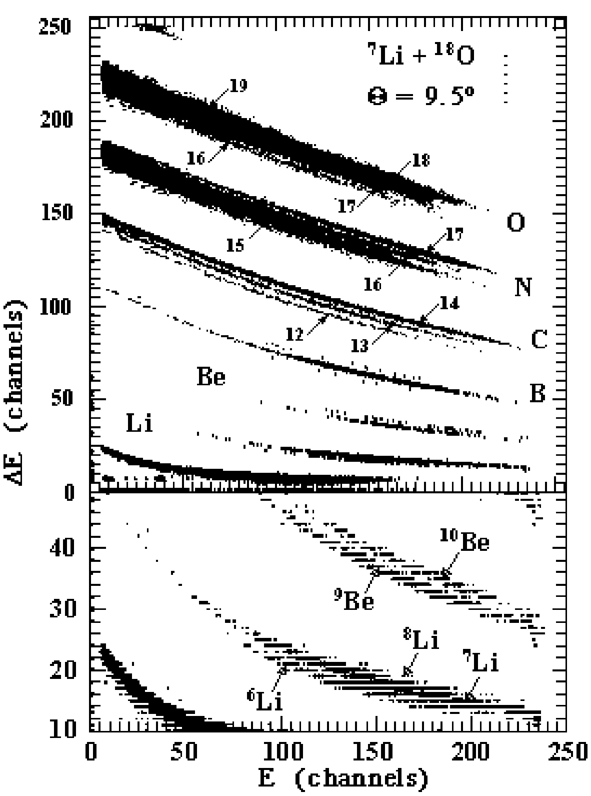

Fig. 1. Typical $\Delta E(E)$-spectra from the ^{7}Li(^{18}O, X) reactions at energy $E_{\rm lab}(^{18}$O) = 114 MeV.

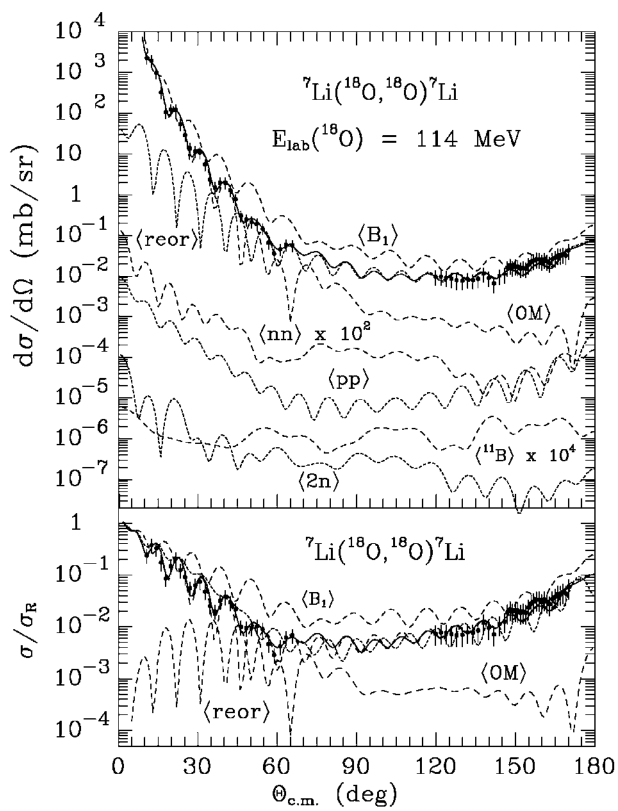

Fig. 2. The angular distributions of ^{7}Li + ^{18}O elastic scattering at energy $E_{\rm lab}(^{18}$O) = 114 MeV.

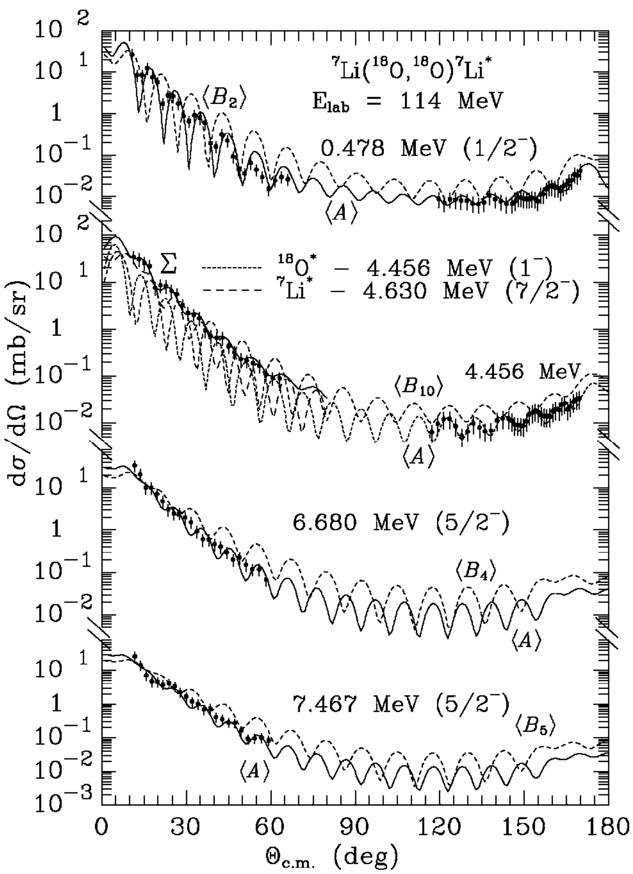

Fig. 3. The angular distributions of ^{7}Li + ^{18}O inelastic scattering at energy $E_{\rm lab}$(^{18}O) = 114 MeV for the transitions to the excited states of ^{7}Li and the 4.456-MeV state of ^{18}O. The curves <*A*> and <B_i > (*i* = 2, 4, 5, 10) show the CRC calculations for collective excitations using *A* and B_i potential parameters, respectively.

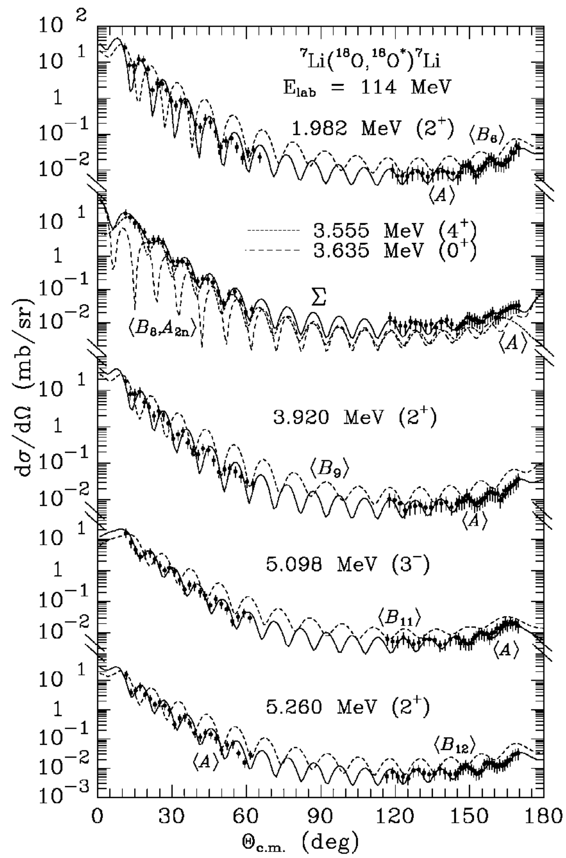

Fig. 4. The same as in Fig. 3 but for the excited states of ^{18}O. Curve Σ shows the incoherent sum of 3.555-MeV rotational model transition and 3.635-MeV 2n-cluster excitation of ^{18}O (curve <*B*8,*A*2*n* >).

The data were analyzed within the optical model (OM) and coupled-reaction-channels method (CRC) in order to determine the potential parameters of ^{7}Li + ^{18}O scattering. The reaction channels dominating the scattering were also determined. The present data shows that the ^{7}Li + ^{18}O system has a much stronger absorption as compared to previously measured ^{7}Li + ^{16}O data. The derived optical model parameters (set A, curves <A> in Figs. 2-4) clearly differ from the same of the ^{7}Li + ^{16}O system (sets B_i, curves < B_i>).

The ^{18}O inelastic scattering deformation parameters were obtained.

In Figs. 2-4, the curves show the OM and CRC angular distributions of the potential scattering (curves <OM>), reorientation of ^{7}Li (curves <reor>) and transfers (other curves). The solid and dashed <*B*1 >curves represent the coherent sum of these processes, calculated with the potential parameters *A* and $B_{\rm i}$), respectively.

7. Giant Dipole Radiation and Isospin Mixing in Hot Nuclei with A=32-60

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Statistical decay of the Giant Dipole Resonance (GDR) built on highly excited states populated in heavy-ion fusion reactions may be used as a tool to study the isospin mixing in hot self-conjugate nuclei [1-4]. The experimental method [1,2] of extracting the isospin mixing probability α^2, which describes the amount of the admixture of states with isospin T' into the excited state with isospin T [5], is based on the measurements of the high-energy γ-rays yields from the statistical decay of the GDR built in neighboring $N = Z$ and $N \neq Z$ compound nuclei at similar excitation energy. The GDR yield from the decay of the self-conjugate compound nuclei, when populated by $T = 0$ reaction channel, depends strongly on the isospin mixing due to the isovector character of the GDR. The GDR yield for $N \neq Z$ compound nuclei does not. The isospin mixing probability α^2 in $N = Z$ nuclei is extracted by comparing these yields with the statistical model calculations.

In order to investigate the dependence of the isospin mixing probability on the atomic number of highly excited self-conjugate nuclei we have studied statistical GDR decay of ^{32}S, ^{36}Ar, ^{44}Ti, and ^{60}Zn compound nuclei formed at similar excitation energies (temperatures) by $T = 0$ reaction channels: ^{20}Ne+^{12}C, ^{12}C+^{24}Mg, ^{20}Ne+^{24}Mg and ^{36}Ar+^{24}Mg. The neighboring compound nuclei with $N \neq Z$: ^{31}P, ^{37}Ar, ^{45}Ti, and ^{61}Zn at close excitation energy (temperature) were populated by reactions: ^{19}F + ^{12}C, ^{12}C + ^{25}Mg, ^{20}Ne + ^{25}Mg and ^{36}Ar + ^{25}Mg. All experiments were performed with the use of beams from the Warsaw Cyclotron and self-supporting isotopic enriched targets. Gamma rays from the decay of the compound nuclei studied were measured with the multidetector JANOSIK set-up [6]. Measured high-energy γ-ray spectra were fitted with CASCADE statistical model.

The results presented in this section were newly obtained by a consistent analysis of the entire set of experimental data from all reactions mentioned above. The high-energy γ-ray yields from the decay of $N \neq Z$ compound nuclei were fitted with the statistical model in order to extract the GDR parameters. In the first step it was assumed that these yields do not depend on the isospin mixing, so the calculations were done with no mixing. Taking into account that the GDR parameters should be very similar for nuclei close in mass and having the same excitation energy and spin, the extracted parameters were applied in the CASCADE calculation for neighboring $N = Z$ nuclei. Such calculations were performed for different values of the isospin mixing, treated as the only one free parameter when comparing by the χ^2 test the calculated spectrum with the experimental data. In order to increase the sensitivity to the isospin mixing we have also analysed the ratios of γ-ray cross-sections, for the reactions forming $N = Z$ and $N \neq Z$ nuclei, for the measured and calculated yields. The best value of isospin mixing probability $\alpha^2_<$, corresponding to the minimum value of χ^2 was found for each $N = Z$ nucleus studied. The extracted value of isospin mixing probability $\alpha^2_<$ was then used in the new fitting procedure for the $N \neq Z$ neighboring nucleus in order to obtain a new set of GDR parameters suitable for both neighboring nuclei.

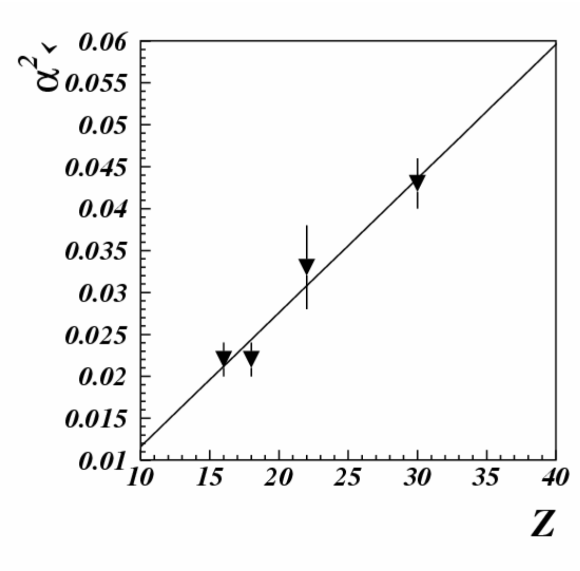

Fig. 1 Isospin mixing probability $\alpha^2_<$ dependence on atomic number.

Consistent analysis of the measured γ-ray spectra for all reactions studied proves that the isospin mixing probability at high excitation in nuclei at similar energy increases with increasing atomic number *Z*. In our experiments it was confirmed in the range of Z=16-30 (Fig.1). The best values of the GDR parameters for the nuclei studied were also extracted.

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

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8. Coulomb excitation of ^{100}Mo as a test of the new particle-gamma detection set-up

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Low-lying 0^+ states, close in energy to the first 2^+ state, have been observed in the even-even molybdenum isotopes, indicating shape coexistence in these nuclei. The recent Coulomb excitation measurements [1,2] of ^{96,98}Mo provided large sets of both transitional and diagonal electromagnetic matrix elements, supporting the shape coexistence scenario.

As a natural continuation of this study, a series of Coulomb excitation measurements using the ^{100}Mo target has been performed on beams of the Warsaw Cyclotron. The recent experiment, performed in January 2006, was the first one to use the new dedicated particle-gamma detection set-up.

A 2.7 MeV/A ^{32}S beam from the U-200P cyclotron was used for Coulomb excitation of a ^{100}Mo target of 20 mg/cm^2 thickness. Deexcitation gamma-rays were measured by the OSIRIS-II germanium detector array (comprising 12 BGO-shielded HPGe detectors) in coincidence with backscattered projectiles. The scattered projectiles were detected by 48 PiN-diodes placed inside a small spherical chamber of 5 cm radius, which can in the future accommodate up to 110 PiN-diodes.

It was demonstrated that the new particle detection system was successfully integrated into the OSIRIS-II set-up, allowing for a coincident particle-gamma measurement. The experiment has benefited from higher overall efficiency and improved peak-to-Compton ratio of the OSIRIS-II array. The figure below shows the comparison of the ^{100}Mo spectrum collected by a single germanium detector of OSIRIS compared to similar spectrum measured by a HPGe detector used previously with CUDAC set-up. Beam intensities, Coulomb excitation cross-sections and data-taking times were comparable in both cases.

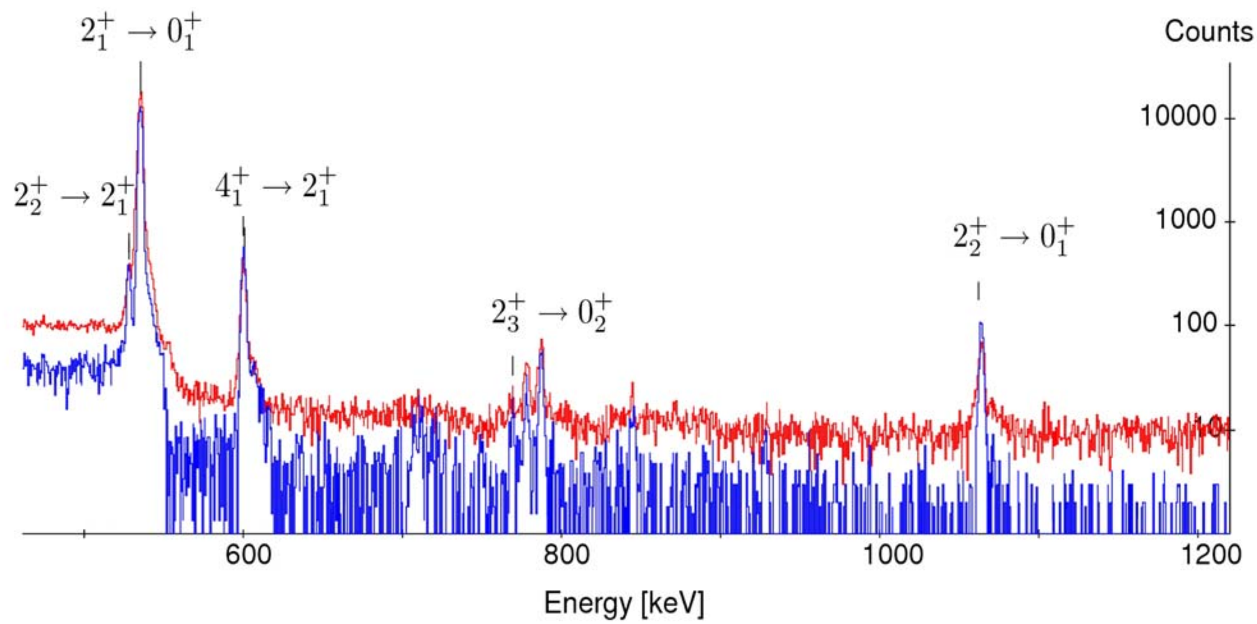

Figure 1. *Red:* Gamma-ray spectrum in coincidence with ^{20}Ne projectiles scattered on a ^{100}Mo target collected by a single HPGe detector in coincidence with the CUDAC particle detection set-up.
Blue: Gamma-ray spectrum in coincidence with ^{32}S ions backscattered on a ^{100}Mo target collected by a single BGO-shielded HPGe detector of the OSIRIS II set-up. The level of background is much lower.

In the present experiment three lowest 2^+ states, two 4^+ states and one low-lying 0^+ state were populated, as shown on the presented spectrum. However, the performance of the set-up for the low-energy gamma rays (below 200 keV) was not fully satisfying and required further effort. The results of the recent on-beam test (January 2006) are encouraging.

The precise measurement of the 159 keV ($0^+_2 \rightarrow 2^+_1$) gamma yield is crucial to determine the static quadrupole moment of the first 2^+ state. This transition intensity could not be extracted with satisfying accuracy from the data collected previously and its measurement remains the main goal of the subsequent experiment, scheduled for May 2007.

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9. ^{128}Cs as the best example revealing the chiral symmetry breaking phenomenon

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The results of the lifetime measurements of the excited states in ^{132}La and ^{128}Cs show that these nuclei, in spite of the similar level schemes, have essentially different electromagnetic properties. The reduced transition probabilities for ^{132}La are not consistent with the symmetry requirements imposed by chirality attained in the intrinsic system. The properties of the $\pi h_{11/2} \otimes (\nu h_{11/2})^{-1}$ bands in ^{128}Cs exhibit the main features expected for chiral partner bands from nuclear models. It is the first case of such a good agreement of comprehensive experimental data with the chiral interpretation. The present study shows clearly that investigation of chirality would be impossible without lifetime measurements[1].

The high spin states of the ^{128}Cs and ^{132}La nuclei were populated in the ^{122}Sn(^{10}B,4n)^{128}Cs and ^{122}Sn(^{14}N,4n)^{132}La reactions at a beam energy of 55 MeV and 70 MeV, respectively. The beam was provided by the Warsaw U-200P cyclotron. The target thickness was 40 mg/cm^2 and 10 mg/cm^2 for the ^{128}Cs and ^{132}La reactions, respectively. The thick targets played both roles: that of the target and that of the stopper. About 108 γ-γ coincidences were collected by the OSIRIS II multidetector array consisting of 10 Compton-suppressed HPGe detectors. The lifetimes of the excited levels were determined by the Doppler Shift Attenuation method with the use of the procedure and computer code developed by A. A. Pasternak [2].

The reduced B(E2) and B(M1) transition probabilities resulting from our experiment are presented in Fig. 1. One can see a large difference between the electromagnetic properties of ^{132}La and of ^{128}Cs. The B(E2) values in the side band of ^{132}La are about 20 times lower than the corresponding ones in the yrast band, and there is smooth spin dependence on these values. In the case of M1 transitions the B(M1) values in the side band are 2-5 times lower than those in the yrast band. In contrast to ^{132}La data, the B(E2) and also B(M1) values are similar in the side and the yrast bands of ^{128}Cs. The spin dependence of reduced M1 transition probabilities inside bands show characteristic staggering. The staggering of the B(M1) values is observed also for the side→yrast transitions in ^{128}Cs, while in case of ^{132}La no clear pattern of this quantity is observed.

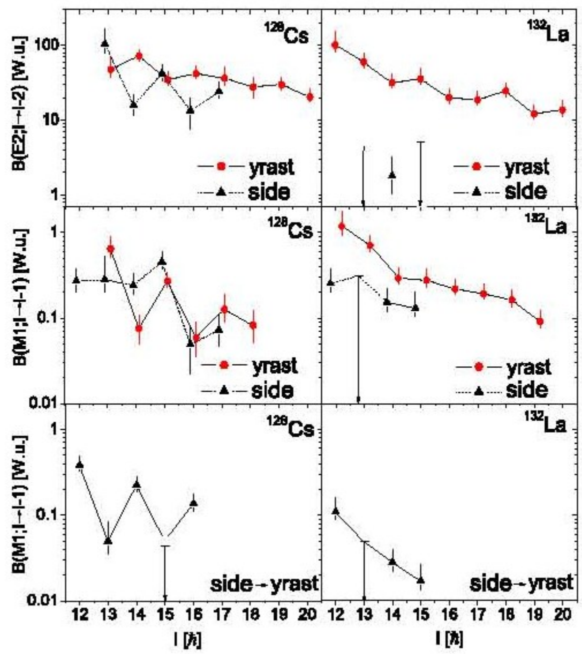

Fig.1 (Color online) B(E2) and B(M1) reduced transition probabilities of ^{128}Cs (left part) and ^{132}La (right part). Top and middle: B(E2) and B(M1) values for inband transitions of ^{128}Cs and ^{132}La. Bottom: B(M1) values for interband side→yrast transitions.

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10. Nuclear level lifetimes in ^{126}Cs as a test of chirality

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The manifestation of chirality in atomic nuclei is still a subject of intense discussion. Our last measurements [1] have indicated that the electromagnetic properties, i.e. energy and spin of levels belonging to the partner bands, show that ^{128}Cs is the best known example revealing the chiral symmetry breaking phenomenon. This was the reason why we have undertaken the same kind of measurement for neighboring nucleus ^{126}Cs.

The excited states of the ^{126}Cs nucleus were populated in the ^{120}Sn (^{10}B, 4*n*) reaction at 55 MeV. The ^{120}Sn target was 43 mg/cm^2 thick. The beam was provided by the U-200P cyclotron at the Heavy Ion Laboratory of the Warsaw University. The γ-γ coincident events were collected by the OSIRIS II array, consisting of twelve Compton-suppressed HPGe detectors. The Doppler Shift Attenuation Method was used for lifetime determination [2]. The spectra were analysed applying the COMPA, GAMMA and SHAPE codes [3]. The preliminary results of lifetimes in the partner bands of ^{126}Cs are presented in Fig.1. The transitions probabilities $B(E2)$ and $B(M1)$ obtained in this experiment are very similar to those observed in the chiral bands of ^{128}Cs [1].

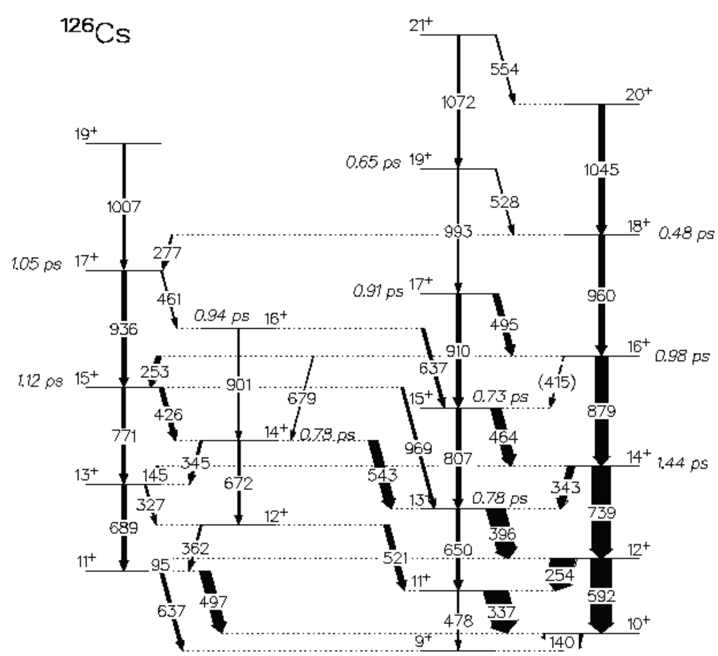

Fig. 1. Partial level scheme of ^{126}Cs. Lifetimes of the levels are given in italics.

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11.New multidetector gamma-ray spectrometer on beam of Warsaw Cyclotron

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We have designed a project of detector array to be located on beam of Warsaw Cyclotron. In principle it was going to be Ge detectors array able to cooperate with wide spectra of ancillary detectors. We present possible applications for our detector system in experimental nuclear physics. Four setup configurations were identified and adjusted to different types of experiments.

1. Standard gamma spectroscopy configuration

This configuration was designed in order to fit in maximal number of anti-Compton shielded Germanium detectors to address needs of following experiments:

- picosecond lifetime measurements by DSAM,
- Coulomb excitation measurements,
- investigation of isomeric states in miliseconds region.

- traditional on-line gamma spectroscopy,
- spectroscopy of internal conversion electrons.

There would be space for maximum 30 Ge detectors. Detectors would cover solid angle Ω_{Ge}=8.2%of 4π. Anti-Compton shields should be equipped with collimators. Adjustments of distance between collimated ACSGe spectrometer and centre of sphere is possible:

- R_{int}=6cm for the biggest close-up (Ω_{Ge}=8.2%),
- R_{int}=16cm for the maximum distance (Ω_{Ge}=4.4%).

At the moment we have 17 Ge detectors (ε_{int} from 20 to 40% at 1332.5 MeV) and 20 anti-compton shields. The Ge detectors would cooperate with charged particles detectors that we have in our disposal:

- 5 cm radius scattering chamber consisting of 100 PiN Si detectors (red in the fig. 1a).
- internal conversion electrons spectrometer (yellow in the fig. 1b).

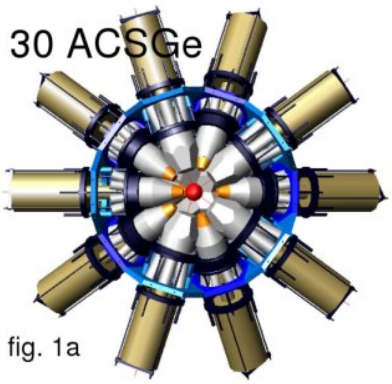


fig. 1a

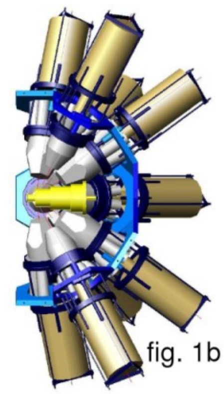


fig. 1b

2. Multiplicity and energy sum configuration

This configuration is designed to study distributions of multiplicity and energy sum of gamma cascades and interpret them to get information on nuclear structure, reaction mechanism or so called *side-feeding* mechanism. This kind of research requires highly efficient and granular multiplicity filter able to cooperate with Germanium detectors.

There would be space for 20 Ge detectors and multiplicity filter (black in fig. 2) consisting of 60 BaF_2 crystals (10 cm thick), surrounding 5 cm radius target chamber (Ω_{Ge}=6.7%, Ω_{BaF2} ≈80%). This configuration is identical to NORDBALL System.

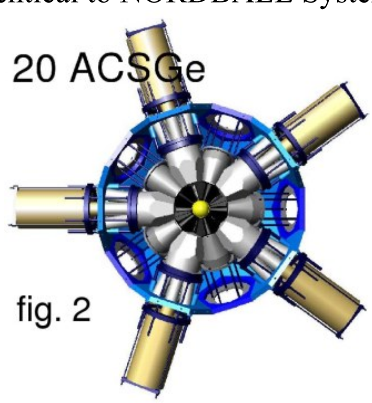
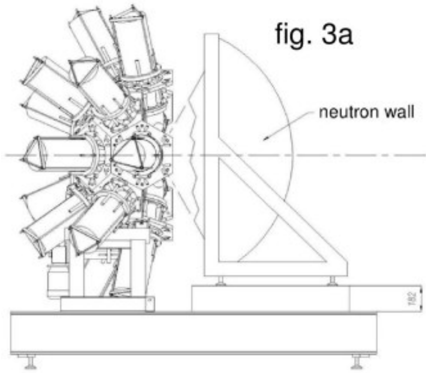
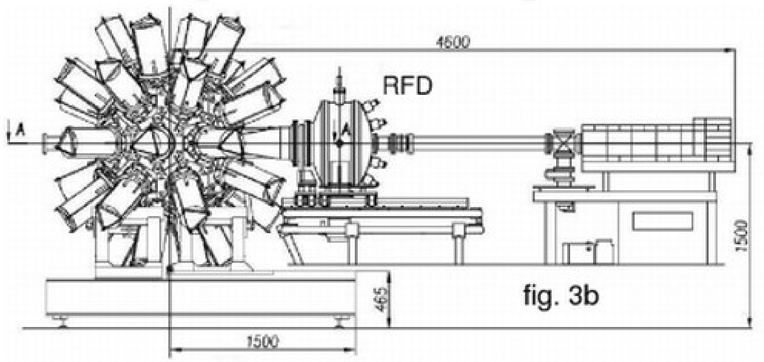


fig. 2

3. RFD and Neutron wall configuration

This configuration allows the setup to cooperate with other multidetector systems. Two multidetector systems are being considered: Neutron wall currently at GANIL (see in fig. 3a) and Cracow Recoil Filter Detector (RFD) chamber (see in fig. 3b).

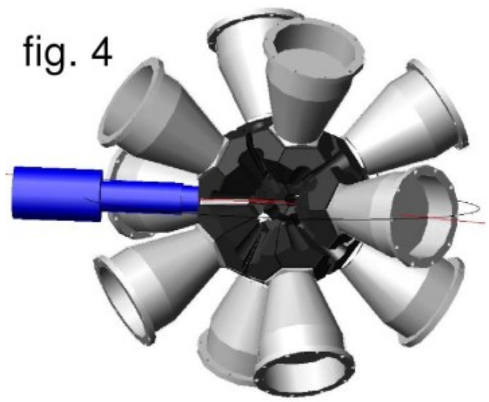




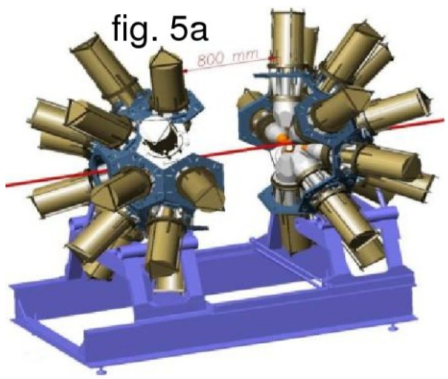
4. Giant Resonances configuration

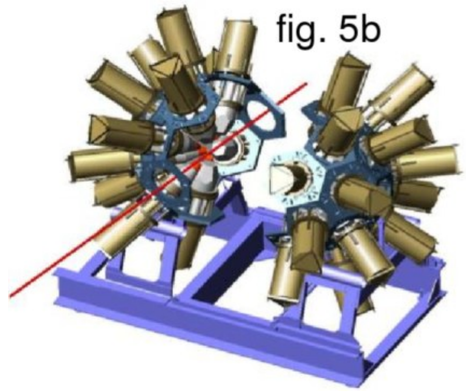
This configuration was designed to study Giant Resonances. This kind of research requires high energy gamma ray detector (Φ30cmX29cm NaI(Tl) currently at JANOSIK system) able to cooperate with highly efficient and granular multiplicity filter and telescopes (E,dE). Our NaI(Tl) scintillator appeared to be too big to place it close enough. So we decided to create concept of another ball, that would be situated nearby.

BaF_2 multiplicity filter (see in fig. 4) surrounds 6.5 cm radius scattering chamber consisting of 12 telescopes (E,dE). To allow gammas reach NaI(Tl) detector (too huge to show in fig. 4) through no absorber, one element (5 cristals) of multiplicity filter has to be taken from the ball (see in fig. 4). To improve multiplicity filter efficiency, 12 BaF_2 (Φ2inX2in) detectors (blue in fig. 4) would be added. Finally we would have multiplicity filter consisting of 57 BaF_2 crystals. Filter would cover $\Omega_{BaF2} \approx 40\%$ of 4π.



We consider two different ways of opening. Configurations shown before concern situation, when array is drawn aside in the beam direction (see in fig. 5a). It is also possible to draw aside perpendicularly to the beam pipe (see in fig. 5b), but then Ge detectors change position and efficiency decreases (Ω_{Ge} =8.2% to Ω_{Ge} =6.8%$ however, access to target chamber seems to be easier. Decision has not been made yet and we would be grateful for advises and opinions about advantages and disadvantages of both solutions.





At the moment cyclotron at Warsaw University Heavy Ion Laboratory provides following ion beams: ^{10}B, ^{11}B, ^{12}C, ^{14}N, ^{16}O, ^{19}F, ^{20}Ne, ^{22}Ne, ^{32}S, ^{40}Ar at energies up to 10 AMeV. Our dream is to get new ion source to broaden our offer up to ^{120}Xe.

In June 2007 we would like to start preparation of technical documentation, parts machining and assembly of supporting structure. It depends on funds that we applied for to Ministry of Science and Higher Education. Preparation of technical documentation, parts machining and assembly should last less than one year. If our grant proposal for building supporting structure is accepted, funding should be available in autumn 2007. First measurements would be possible using HPGe detectors and DAQ system from OSIRIS System. Simultaneously, we want to apply for grant for new electronics. As natural born optimists we believe that we will obtain this grant too, but not sooner than in June 2008. We believe that in mid 2009 fully operational array would be ready.

12. Project ICARE at HIL

E.Piasecki[1], M.Antczak[1], J.Devine[2], W.Gawlikowicz[1], A.Jakubowski[1], P.Jasiński[1], M.Kisieliński[1], M.Kowalczyk[1], E.Kulczycka[1], L.Pieńkowski[1], A. Pietrzak[1], V.Rauch, J.Rehberger, and M.Rosseau for ICARE@HIL[1] collaboration

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2) IPHC, Strasbourg, France

ICARE is the charged particles detector system used for their identification and energy measurements. Built in the IReS (Strasbourg) is presently under preparation to the first experiment at HIL by the physicist teams from Strasbourg, Cracow, Kiev and Warsaw. The ICARE system consists of the 1m diameter reaction chamber with up to 48 E-ΔE gas and semiconductor telescopes, supplied with the electronics and data acquisitions systems (see Fig.1).

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[1] *ICARE collaboration involves: Heavy Ion Laboratory, Warsaw University; Institute of Experimental Physics, Warsaw University, Poland; IPHC, Strasbourg, France; The Andrzej Soltan Instytut Problemow Jadrowych, Swierk, Poland, The Henryk Niewodniczański Institute of Nuclear Physics, PAN, Kraków, Poland; Institute for Nuclear Research, Kiev, Ukraine.*

Fig.1 External view of the ICARE reaction chamber with vacuum and gas system.

The detectors can be mounted in any configuration preferred by users, using internal mounts. The self-supporting target holder allows to use up to 6 different targets. It can be remotely operated without necessity of opening the reaction chamber. The detector system layout is presented in Fig.2.

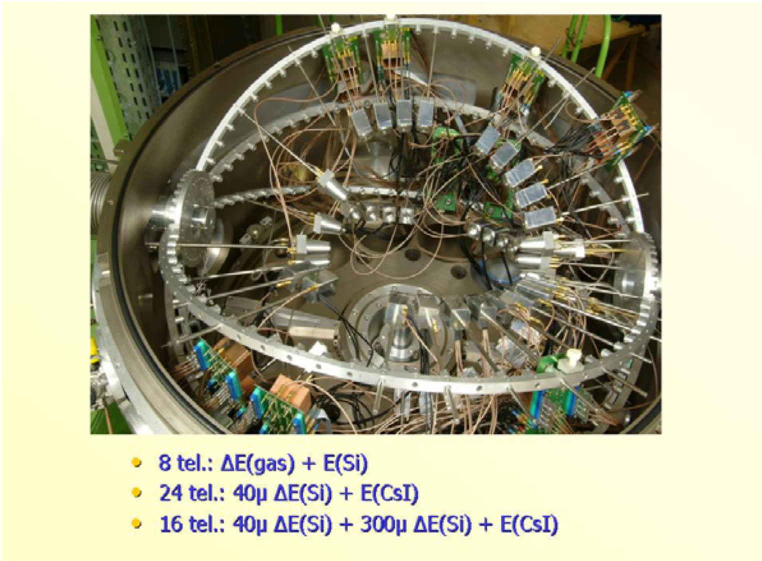

Fig. 2. Telescopes mounted inside the ICARE reaction chamber

An example of particle identification obtained in one of the telescopes during the recent in-beam test is shown in Fig. 3.

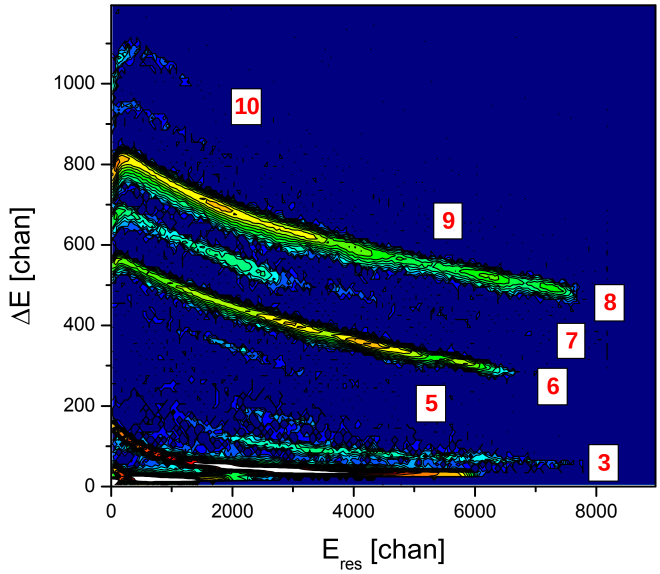

Fig.3 Reaction products observed in the $^{16}O + ^{12}C$ at 6 MeV/u in one of the telescopes.

Presently we are working on improving some ICARE characteristics and we plan to expand its possibilities by adding to the system the Time-of-Flight possibilities.

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]
• Study of nucleus deformation using light-charged particles emission spectra [3]

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13. Organosilane as a binding site for instant fluorination of peptides for PET radiopharmaceuticals

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Positron labelled biomolecules such as peptides and proteins have the ability to quantitatively detect many kinds of disease processes in human body. As an example one can use the octreotide (analogues for imaging somatostatin). It can be used as positive tumours receptor in combination with the imaging technique, Positron Emission Tomography.

The half life of ^{18}F (109.7 min) demands a quick and simple biomolecule labelling process. However, the present procedures for incorporating ^{18}F into peptides or proteins are complex and time-consuming. The aim of this study was to develop a faster strategy for labelling peptides and proteins with F-18.. The solution could use silicon derivatives as fluoride-selective binding sites. In this approach a precursor for the labelled ^{18}F organosilane can be incorporated into the protein as a fluoride - specific binding site.

In this study the labelling of the *tert*-butyldiphenylmethoxysilane with ^{18}F was carried out. In a quick and easy synthesis we obtained radioactive *tert*-butyldiphenylsiliconflouride for instant labelling of protein and peptides. Acidic conditions were needed to prevent hydrolysis of the compound.

The ^{18}F supplied from the cyclotron in an aqueous solution was extracted from water by QMA cartridge with a solution of Kryptofix in acetonitrile. The chemical purity of samples was checked by HPLC and TLC methods. The amount of product synthesised was followed over time, at room temperature and with heating. The labelling efficacy was the best after 20 minutes reaction time at room temperature and heating significantly helped to increase the reaction yield. The amount of hydrolysed product was small and did not change during the reaction.

In summary, the short synthesis time and high stability of radioactive *tert*-butyldiphenylsiliconfluoride determines its usefulness for *in vivo* diagnostic studies, when conjugated to the proteins or peptides.

The above project was carried out in St. Thomas' Hospital, The Clinical PET Centre in London during the "Radiopharmaceutics and PET Radiochemistry" course.

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

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

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15. The Warsaw PET Center

J.Jastrzębski, J. Choiński, P.J.Napiorkowski

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

After four years of efforts, in 2004 the Warsaw PET project obtained the financial support from the Ministry of Sciences and Informatization, which allocated 10 MPLN (about 2.4 MEUR) for the equipment of the Radiopharmaceuticals Production Department of the Warsaw PET Centre. At the end of the same year the Board of Governors of the International Atomic Energy

Agency accepted our project of Technical Cooperation with the Agency and allocated almost 0.9 MUS$ for this project. The same year, Ministry of Health reiterated its written engagement to supply in 2006 the Warsaw PET Centre with a PET CT scanner.

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

Unfortunately, the unexpected difficulties in the formulation of the contract terms delayed its signature by more than one year!

At present, we do hope, that all negotiations will be terminated before the end of April 2007. About 16 months later, the Warsaw PET Radiopharmaceutics Production Center should deliver the first doses of the radiopharmaceuticals, produced with the new cyclotron.

Part C:
Experiments using the outside facilities

1. Shape coexistence in radioactive ^{74,76}Kr studied by Coulomb excitation

E. Clément[1], A. Görgen[1], W. Korten[1], C. Andreoiu[2], E. Bouchez[1], F. Becker[3], P. Butler[2], J.M. Casandjian[4], W. Catford[5], A. Chatillon[1], T.Czosnyka[6], G. de France[4], J. Gerl[3], R.D. Herzberg[2], A. Hürstel[1], J. Iwanicki[6], D. Jenkins[2], G. Jones[2], Y. Le Coz[1], P. Napiorkowski[6], G. Sletten[7], C. Theisen[1], J.N. Wilson[1], M. Zielińska[6]

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2) University of Liverpool, UK;
3) GSI Darmstadt, Germany,
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6) Heavy-Ion Laboratory, Warsaw University, Warsaw, Poland
7) NBI Copenhagen, Danemark

The neutron-deficient krypton isotopes near the *N*=*Z* line are considered to be among the best examples of nuclear shape coexistence. States of prolate and oblate shape are thought to coexist within a narrow energy range of only a few hundred keV. This competition can be understood from the existence of large shell gaps in the single-particle spectrum at proton and neutron numbers 34, 36, and 38, both, for prolate and oblate deformation. Experimental indication for shape coexistence in the light krypton isotopes comes from the observation of low-lying excited 0^+ states. Based on their excitation energy, the electric monopole strength of their decay to the ground state, and the distortion of the otherwise regular rotational bands at low spin, a scenario has been proposed in which the ground states of the heavier isotopes ^{76,78}Kr have a prolate shape, prolate and oblate configurations strongly mix in ^{74}Kr, and the oblate configuration dominates the ground state of ^{72}Kr [1]. The Coulomb excitation experiments of radioactive isotopes ^{76}Kr and ^{74}Kr aimed at testing this scenario by measuring both transitional and static electromagnetic moments in these nuclei.

The radioactive ^{76}Kr and ^{74}Kr beams were produced by the SPIRAL facility at GANIL by fragmentation of a ^{78}Kr beam on ^{12}C primary target and post-accelerated in the CIME cyclotron to 4.4 A MeV for ^{76}Kr and 4.7 A MeV for ^{74}Kr. The beams were Coulomb excited on a ^{208}Pb target of 1 mg/cm^2 thickness. Scattered Kr projectiles and recoiling target nuclei were measured in a highly segmented annular Si detector mounted at forward angles. De-excitation γ-rays were detected with the EXOGAM spectrometer comprising 7 and 11 Ge clover detectors, respectively. In both isotopes the ground-state bands were populated up to the 8^+ state, and several non-yrast states were observed.

The Coulomb excitation analysis was performed using the least squares code GOSIA [2]. Both transitional and diagonal electromagnetic matrix elements were determined in a χ^2 minimization optimally reproducing the observed yields, as well as, previously known spectroscopic data (lifetimes, branching ratios, mixing ratios). During the preliminary analysis discrepancies with earlier lifetime measurements were found. A new lifetime measurement was performed. It confirmed the Coulomb excitation data [3]. The precise transition probabilities obtained in this complementary experiment enhanced significantly the sensitivity of the GOSIA fit to the diagonal matrix elements.

Positive values are found for the static quadrupole moments of the states in the ground-state band for both ^{74}Kr and ^{76}Kr, while the quadrupole moments of the second 2^+ state are negative. It should be stressed that the experiments exploited, for the first time, the reorientation effect with a radioactive beam. Furthermore, about 15 transitional matrix elements between low-lying states were determined for each isotope. The comparison of the experimentally determined matrix elements with configuration mixing calculations using the generator coordinate method shows an overall agreement, pointing out the importance of the triaxial degree of freedom in the theoretical description of light krypton isotopes [4].

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2. Recoil Filter Detector simulation for AGATA

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The European "Advanced GAmma Tracking Array" (AGATA) [1] project enters the Demonstrator phase, in which 15 to 18 HPGe detectors grouped in triple clusters will be employed to demonstrate the feasibility of the γ-ray tracking. Commissioning of the Demonstrator will take place in 2008 at the Laboratori Nazionali di Legnaro, Italy, and it will be followed by an experimental campaign. It is expected that the Demonstrator will provide γ-ray spectra of significantly better quality (P/T and FWHM) then any existing γ-ray detectors. The ancillary detectors used together with the Demonstrator should enhance the detection and resolving power of the array. On the other hand, their presence will disturb γ-ray radiation detected in the Ge crystals. The use of the Recoil Filter Detector (RFD, Fig.1) [2] as an ancillary detector in the Demonstrator phase is considered, thus reliable Monte Carlo simulation of the Demonstrator with RFD setup is necessary.

AGATA is expected to provide exact information on the position of the first interaction of each γ-ray in Ge crystals and this makes possible precise Doppler correction. In conventional detectors, the quality of the Doppler correction is limited by the uncertainty of the γ-ray detection angle, determined by the opening angle of the detector (or detector segment). In order to exploit fully this feature of AGATA, the velocity vector of the γ-ray source must be known. Such information can be provided by RFD.

Geant4 procedures defining the geometry of RFD were incorporated in the Geant4 [3] AGATA simulation code [4]. Eighteen Mylar foils which are the sensitive parts of RFD, as well as mechanical parts, like the target chamber, conical RFD chamber and beam tube were included. Work on the RFD simulation is in progress and it currently concentrates on providing realistic physics input (fusion-evaporation events) and on analyzing transport of residual nuclei in the target material. Results of the calculations will be verified by comparing them with the experimental data.

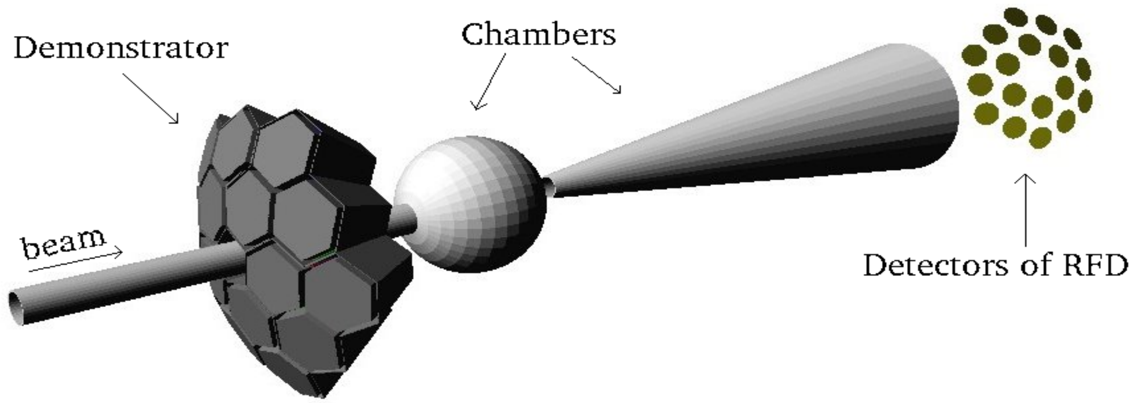

Fig. 1: AGATA Demostrator with RFD

This work was supported by the Polish Ministry of Science and High Education grant No. 1P03B03126.

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3. Neutron density distributions from antiprotonic ^{208}Pb and ^{209}Bi atoms

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The last year activity of the PS209 collaboration was devoted to the detailed studies of ^{208}Pb and ^{209}Bi antiprotonic atoms. Measured antiprotonic level widhts and shifts due to the strong interaction were interpreted using three available optical potentials [1,2,3]. Assuming two parameter Fermi distributions (2pF) describing the proton and neutron densities the neutron rms radii were deduced for both nuclei. The difference of neutron and proton rms radii Δr_{np} equal to 0.16+/-$(0.02)_{stat}$ +/-$(0.04)_{syst}$ fm for ^{208}Pb and 0.14+/-$(0.04)_{stat}$+/-$(0.04)_{syst}$ fm for ^{09}Bi were determined. The Δr_{np} values and the deduced shapes of the neutron distributions were compared with mean field model calculations (HF calculations with SkP and SkX Skyrme forces and realivistic meanfield model calculations with DD-ME2 force). The article describing these results will be submitted to Physical Review C at the beginning of 2007.

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

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

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5) CERN, Geneva, Switzerland,
6) Warsaw University of Technology, Poland,
7) NBI Copenhagen, Danemark; 7) PhD student at HIL

A low-energy Coulomb excitation experiment on neutron-rich ^{44}Ar has been performed at the SPIRAL facility of GANIL. The primary question addressed by the experiment was the possible weakening of the N=28 shell closure in neutron-rich nuclei and, closely connected to that, the development of deformation and shape coexistence in this region of the nuclear chart.

A beam of ^{44}Ar was produced by fragmentation of a primary ^{48}Ca beam at 60 A MeV on the carbon production target of SPIRAL. The ^{44}Ar fragments were re-accelerated in the CIME cyclotron to 2.7 and 3.7 MeV/nucleon and Coulomb excited on ^{109}Ag and ^{208}Pb targets, respectively. The scattered projectiles and recoiling target nuclei were detected in a highly segmented double-sided silicon detector and the gamma rays were detected with the EXOGAM germanium detector array.

Apart from the first excited 2^+ state, at least one higher-lying level was populated. The level of statistics is sufficient to determine the gamma-ray yields for several ranges of scattering angles and for the two different target materials. Although the analysis is still in progress, it is anticipated that the collected data will allow extracting the transition probabilities between the observed states, as well as the static quadrupole moment of the first 2^+ state. It is anticipated to continue in this experimental program with the Coulomb excitation of ^{46}Ar.

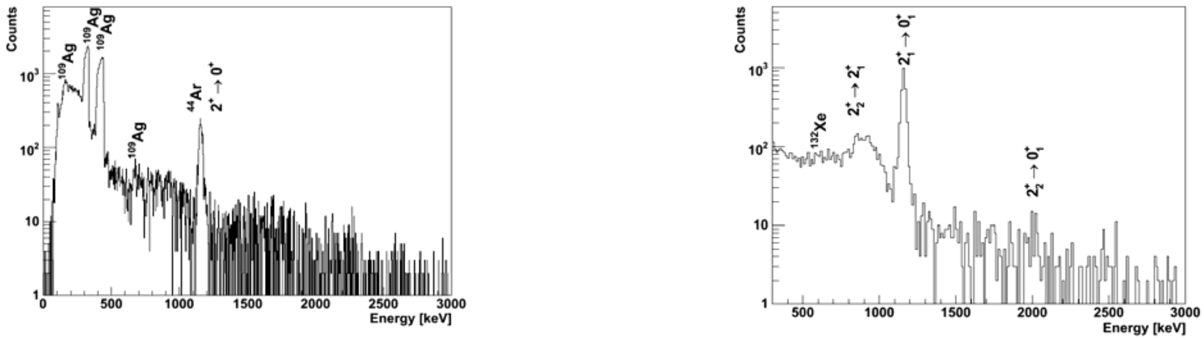

Figure 1. *Left:* Gamma-ray spectrum in coincidence with ^{44}Ar projectiles scattered on a ^{109}Ag target, corresponding to scattering angles of 35°< θ_{cm} < 72°. The $2^+ \rightarrow 0^+$ transition is observed together with several transitions in ^{109}Ag, which can be used for normalization. *Right:* Gamma-ray spectrum in coincidence with recoiling ^{208}Pb target nuclei, corresponding to scattering angles of 67°< θ_{cm} < 130°.

This work has been supported by the European Community FP6 - Structuring the ERA - Integrated Infrastructure Initiative - contract EURONS RII3-CT-2004-506065

5. Dynamical and Statistical Fragment Production in ^{136}Xe+^{209}Bi Reactions at E/A = 28, 40, and 62 MeV[1]

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The heavy-ion reaction scenario at low bombarding energies (below 10 MeV/nucleon) is quite well understood[1]. In this scenario the projectile and target either fuse forming a single compound nucleus, or undergo a relatively "gentle" dissipative collision. In the latter case, which is of interest in the present study, two excited remnants of the projectile and target emerge from the collision site. Subsequently, the excited compound nucleus or the projectile- (PLF) and target- (TLF) like fragments deexcite, primarily via emission of neutrons and light charged particles (LCP). With increasing bombarding energy one begins to observe the emission of intermediate-mass fragments (IMFs)[2].

In the intermediate bombarding energy range of E/A= 10-100 MeV[3] a new effective source of fragments becomes discernible in the yield distribution that moves with a velocity intermediate between the velocities of PLF and TLF[3]. This intermediate-velocity source (IVS) can be conceptually associated with the overlap region of PLF and TLF.

The present study concentrates on correlations between neutron and charged particle production in the ^{136}Xe+^{209}Bi reaction studied at three bombarding energies of E/A=28, 40, and 62 MeV. At every bombarding energy, the experimental setup included two 4π detector systems :

(i) the Washington University charged-particle detector array -Dwarf Ball/Wall[4],

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[1] Talk given at the 11th International Conference on Reaction Mechanisms, Varenna 2006.

(ii) the University of Rochester neutron calorimeter RedBall for 28 MeV/nucleon study,and the SuperBall neutron multiplicity meter [5] for 40 and 62 MeV/nucleon studies.

The experimental data are compared with model calculations in which the collision stage is modeled by the classical transport code CLAT [6], and the subsequent deexcitation of the primary products modeled by the equilibrium-statistical deexcitation code GEMINI[7]. The code CLAT is based on the stochastic nucleon exchange model NEM[8].

The main features of particle emission is well represented by a joint distribution of neutron and light-charged particles (LCP) multiplicities, presented in Fig.1. The characteristic pattern observed in Fig.1 is consistent with an emission scenario implemented in CLAT/GEMINI model calculations, where neutrons and light charged particles are emitted dominantly from equilibrated PLFs and TLFs produced in the course of dissipative collisions. Under this scenario, the segment of the yield ridge running from the origin of the plot parallel to the ordinate axis represents peripheral collisions, where the excitation energy is too low to allow noticeable LCP evaporation. Then, with decreasing impact parameter and, accordingly, with increasing excitation energy, LCP emission sets in and begins competing successfully with neutron evaporation. As a result, the yield ridge parts with the ordinate axis and continues at an angle with respect to it.

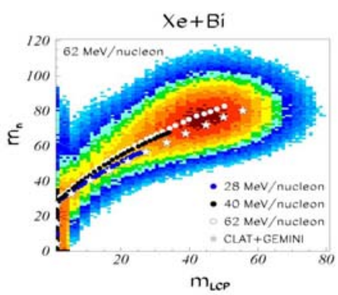

Fig.1. Logarithmic contour plot of joint multiplicity distribution of neutrons m_n and light-charged particles m_{LCP} for $^{136}Xe+^{209}Bi$ reactions at E/A=62 MeV.

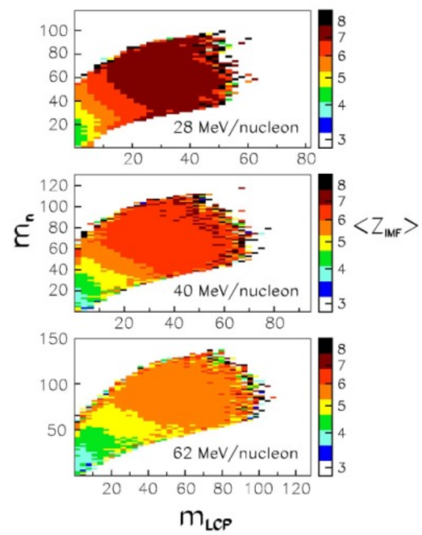

Fig.2 Logarithmic contour plot of average atomic number of IMFs, $<Z_{IMF}>$, s a function of associated neutron and LCP multiplicities.

At higher excitation energies, the emission of intermediate-mass fragments (IMF) sets in, with the IMF multiplicity increasing with increasing excitation energy, as can be seen in Fig.2. One can notice that the average atomic number of IMFs, $<Z_{IMF}>$, increases prominently and systematically with increasing excitation energy, as measured by neutron and LCP multiplicities. More importantly, however, this average size depends also on the bombarding energy, inconsistent with a thermal emission scenario. However, the observed trend is qualitatively consistent with a scaling of the IMF size with the size of the interface zone formed transiently between projectile and target during the interaction phase. This is so, because at a fixed bombarding energy the size of the interface zone increases with decreasing impact parameter and, hence, with increasing excitation energy, accounting for trends seen in the three individual panels in Fig.2. On the other hand, as a result of window friction increasing with increasing bombarding energy, the size of the interface zone required to generate a definite excitation energy decreases with increasing bombarding energy. Therefore, the correlation pattern shifts toward higher neutron and LCP multiplicities with increasing bombarding energy.

A common technique of identifying sources of particles emitted in low- and intermediate-energy heavy-ion reactions involves measurement of particle velocities and the subsequent construction of Galilei-invariant distributions of these velocities in a coordinate system of the velocity components parallel and perpendicular to the beam axis.

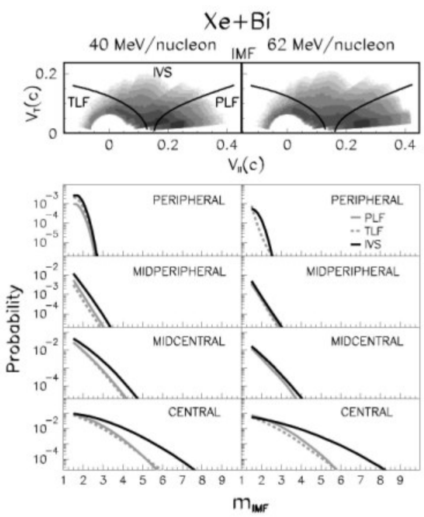

Fig.3 Multiplicity distributions of IMFs (bottom panels) associated with different decay sources as determined by the source selection criteria depicted by solid lines in the associated Galilei-invariant velocity distributions of the top panels, and “gated" by different bins in the associated total excitation energy.

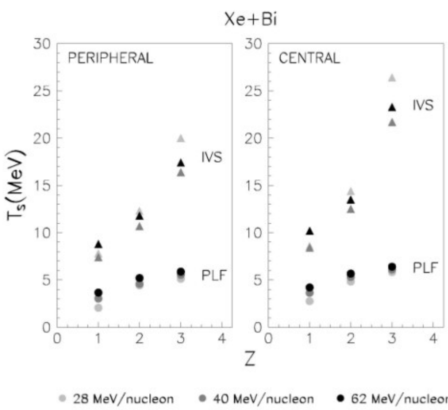

Fig.4 Effective temperature parameters for PLF (circles) and IVS (triangles) sources, as determined from energy spectra of protons, α-particles, and lithium fragments, for peripheral and central collisions.

Attempts to quantify the relative importance of emission sources and to determine their characteristics are illustrated in Fig.3. These attempts rely on first establishing operational boundaries of domains associated with the three sources, as shown in the top row of panels of Fig.3 and then on sorting the products according to the domains they fall on. Even though such procedure is relatively coarse, it is sufficient to demonstrate different properties of the three components.

Fig.3 illustrates the impact parameter dependence of the multiplicity distributions of IMFs from the PLF, TLF, and IVS sources. As seen in this figure, the average IMF multiplicity increases with decreasing impact parameter for all emission sources.The observed distributions associated with PLF and TLF sources are almost identical. In contrast, the multiplicity distributions associated with the IVS source are broader. However, the majority of the observed IMFs appears to come from a statistical process even for the most central collisions.

As seen in Fig.3, for events with high IMF multiplicities for central collisions, a large fraction of the observed IMFs are originating from IVS. An increased rate of IMF production may be a simple reflection of an increase in the volume of the overlap region. Assuming that the IVS source represents the nuclear matter in the overlap region [3], one would expect increased fragment emission from this region for central collisions.

Like LCPs, IMFs emitted from the three sources also differ with respect to their energy spectra in the respective source rest frames. The energy spectra can be quantified in terms of inverse logarithmic slope parameters or effective source temperatures, T_s. The results of such evaluations for $^{136}Xe+^{209}Bi$ reactions at three bombarding energies are presented in Fig.4 for both, LCPs and lithium IMFs. Results for peripheral collisions are shown in the left panels and those for the central collisions in the right panels. As seen in this figure, the spectra associated with the IVS are significantly harder than those associated with evaporation from PLF and follow trends known from preequilibrium nucleon emission.

Together, the results on emission patterns imply the existence of two competing mechanisms for IMF emission - a statistical emission from accelerated PLFs and TLFs, on the one hand, and a nonstatistical emission from an effective IVS, on the other hand.

This work was supported by the U.S. D.O.E. grant No. DE-FG02-88ER40414.

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[8] J.Randrup, Nucl. Phys. **A307** (1978) 319; **A327** (1979) 490; **A383** (1982) 468.

6. Fragmentation of very neutron-rich projectiles around ^{132}Sn

J. Benlliure[a], H. Alvarez[a], B. Blank[b], E. Cesarejos[a], D. Cortina[a], D. Dragosavac[e], M. Gascon[a], W. Gawlikowicz[c], J. Giovinazzo[b], A. Heinz[d], K. Helariutta[a], A. Kelic[d], S. Lukic[d], F. Montes[d], D. Perez[a], L. Pieńkowski[c], M.V. Ricciardi[d], K.-H. Schmidt[d], M. Staniou[d], K. Subotic[e], K. Suemerrer[d], J. Taieb[b], A. Trzcińska[c], M. Veselsky[f]

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(b) CENBG, Le Haut-Vigneau, BP 120 F-33185 Gradignan Cedex, France
(c) Warsaw University, Hoza 69, PL-00-681, Warsaw, Poland
(d) GSI, Planckstrasse 1, 64291, Darmstadt, Germany
(e) VINCA-Institute, POB 522 11001 Belgrade, Serbia
(f) Institute of Physics, Slovak Academy of Sciences, Dubravska cesta 9, SK-84511 Bratislava, Slovakia

This experiment aims to isotopically identify and determine the production cross sections of residual nuclei in the fragmentation of very neutron-rich nuclei around ^{132}Sn produced in the fission of ^{238}U primary projectiles. These measurements will provide valuable information about a possible two-step reaction scheme (fission-fragmentation) to optimise the production of extremely neutron-rich nuclei in future radiaoactive bema facilities (EURISOL,FAIR). At the same time, the interaction cross section, projectile proton- and neutron-pickup cross sections and proton removal cross sections of these medium mass neutron-rich isotopes will be measured. These observables will allow to investigate basic ground state properties of those extremely nuclei, like density distributions and/or binding energies.

The experiments are performed at the SIS synchrotron accelerator at GSI which delivers the ^{238}U beam with an energy of 1 A GeV. The beam impinge into a Pb target and the ^{132}Sn produced by fission is isotopically identify by using the first part of a magnetic spectrometer Fragment Separator (FRS)- see Fig.1. The ^{132}Sn produced impinges on a second reaction target of berylium for the identification of the fragments on the second part of the spectrometer.

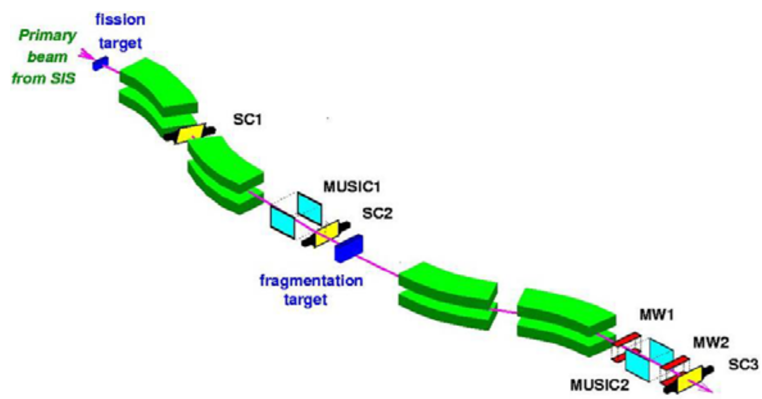

Fig.1 Experimental set-up including Fragment Separator (FRS) magnets

In order to optimize the production yield of fission residues and the isotopic separation, a compromise was found between the energy of the primary ^{238}U projectiles and the lead target thickness, corresponding to 950 A MeV and 1500 mg/cm^2. Having a primary beam current of $10^8 s^{-1}$, the rate of tin isotopes at the intermediate image plane of the FRS was varying between 10^3 and 10^4 s^{-1} along the isotopic chain between ^{124}Sn and ^{132}Sn.

In the present experiment, a fast scanning of proton- and neutron-pickup and proton-removal cross sections along long isotopic chains of fission residues was made. Five different magnetic settings of the FRS centered between ^{124}Sn and ^{132}Sn were used for that purpose.

For the correct assignment of the atomic and mass number of the produced residues a parasitic ^{136}Xe beam to calibrate the FRS was used just before the main beam time.

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.

Part D:
General information on HIL activities

1. Educational and science popularization activities at HIL

The Laboratory is not only a facility providing heavy-ion beams - many educational activities are as well undertaken by the Laboratory staff. Guided tours at HIL are more and more popular and attract audience from all over the country. Thirty-seven organized groups (~850 people) visited our Laboratory in 2006. Most of them were high school classes. We also hosted groups of students from Physics, Chemistry and Biology Faculties of Warsaw University, winners of Physics Olympiad and groups of physics teachers. During the tours 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.

The Polish Workshop on Heavy Ion Acceleration and its Applications was organized at HIL in March 2006, for the second time. The Workshop was meant for third year physics students interested in nuclear physics. The first Workshop in 2005 was very well received by students and in 2006 we got much more applications than we were able to accept. Selected participants gained experience in methods of data acquisition and analysis, in operating the cyclotron including the beam diagnostic measurements and in charged particle and gamma rays detection techniques (see Sec. 7).

Since 1996 HIL participates in the annual Warsaw Festival of Science. More than 300 people of all ages visited the Laboratory on 23rd September 2006. In addition to seeing the Laboratory facilities, the visitors could attend lectures on „Physics for Goalkeepers" and „Mysteries of Your Vacuum Cleaner" (by P.J. Napiorkowski), „How to reach Mars", and „Nuclear Energy –Yes, but how?" (by L. Pieńkowski). Two of these lectures were also presented during the preceding festival week in the form of so-called Festival Lessons, for high-school student groups, and attracted large attention.

For the fourth time HIL participated in Science Picnic organized at the New Town Market Square by Radio BIS. This year, the project of High Temperature Reactor was presented to general public participating in the Picnic. Many questions concerning nuclear energy, nuclear physics, etc., were asked and discussed.

HIL staff is also engaged in the routine educational activity of the Department of Physics student laboratories, as well as is supervising MSc and PhD theses – see Sec. 1.1-1.5.

In July the two-week training program for the students was organized. Four groups of students were involved in our scientific activities. They did tasks under our supervision. (see Sec.7).

1.1 DSc theses of the Laboratory staff members

Dr. Andrzej Kordyasz January 31
Budowa unikalnych detektorów krzemowych i ich zastosowanie w fizyce i środowisku naturalnym

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

MSc Magdalena Zielińska January 16
Struktura elektromagnetyczna jąder atomowych izotopu molibdenu badana metodą wzbudzenia kulombowskiego
Supervisor : dr hab. Tomasz Czosnyka

MSc Marzena Wolińska-Cichocka June 19
Struktura jąder neutronowo-deficytowych z obszaru A~100 tworzonych w reakcjach z ciężkimi jonami
Supervisor : prof. dr hab. Jan Kownacki

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

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

1.3 PhD theses completed in 2006 or in progress based on the experiments on the Warsaw Cyclotron

Ernest Grodner, Faculty of Physics Warsaw University December 4
Badanie czasów życia jądrowych poziomów wzbudzonych ^{132}La i ^{128}Cs jako test łamania symetrii chiralnej
Supervisor: dr hab. T. Morek.

Elżbieta Wójcik, Faculty of Physics Warsaw University
Badanie zmieszania izospinowego w jądrach gorących poprzez wzbudzenie Gigantycznego Rezonansu Dipolowego
Supervisor: prof. dr hab. M. Kicińska-Habior. Expected completion time: 2007

Jan Kurcewicz, Faculty of Physics Warsaw University
Poszukiwanie stanów izomerycznych powyżej ołowiu
Supervisor: dr hab. M. Pfützner. Expected completion time: 2007

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

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

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

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

1.4 MSc theses completed in 2006 or in progress, supervised by HIL staff members

Jacek Gałkowski, Faculty of Physics, Warsaw University of Technology September 21
Badanie struktury jąder z obszaru ^{100}Sn produkowanych w reakcjach fuzji-ewaporacji z wiązką ^{58}Ni na tarczy ^{45}Sc
Supervisor: dr M. Palacz.

1.5 MSc theses completed in 2006 or in progress based on the experiments on the Warsaw Cyclotron

Olga Steczkiewicz, Faculty of Physics Warsaw University
Badanie krótkożyciowych izotopów przy użyciu separatora typu IGISOL
Supervisor: prof. dr hab. W. Kurcewicz June 21

Aleksandra Krasińska, Faculty of Physics Warsaw University
Emisja cząstek naładowanych w reakcji ^{20}Ne + ^{12}C
Supervisor: prof. dr hab. Marta Kicińska-Habior. Expected completion time: 2007.

Anna Karbowska, Faculty of Physics Warsaw University
Gigantyczny rezonans dipolowy w jądrach argonu
Supervisor: prof. dr hab. Marta Kicińska-Habior. Expected completion time: 2007.

Tomasz Adamus, Faculty of Physics Warsaw University
Optymalizacja odchylania wiązki ^{12}C dla badań radiobiologicznych
Supervisor: dr hab. Z. Szefliński. Expected completion time: 2007.

Jan Dyczewski, Faculty of Physics Warsaw University
Opracowanie metodyki uzyskania jednorodnej wiązki jonów z Cyklotronu Warszawskiego
Supervisor: dr hab. Z. Szefliński. Expected completion time: 2007.

Agnieszka Żywno, Faculty of Physics Warsaw University
Nowe technologie w budowie skanerów dla diagnostyki medycznej
Supervisor: dr hab. Z. Szefliński. Expected completion time: 2008.

Paweł Tarnowski, Faculty of Physics Warsaw University
Badanie struktury jadra ^{125}I
Supervisor: dr hab. Tomasz Morek. Expected completion time: 2007.

1.6 BSc theses based on the Warsaw Cyclotron activity

Urszula Górak, September 20

Uklad eksperymentalny do badan radiobiologicznych na wiązce Cyklotronu Warszawskiego- hardware i interfejs.
Supervisor: dr hab. Z.Szefliński

2. Seminars

2.1. Seminars at HIL

J.Jastrzębski March 28
Spotkanie Komitetu Eksperymentów (PAC)

Z.Szefliński March 30
Akceleratory dla terapii nowotworowej – współczesne rozwiązania

S.Braccini April 20
The CYCLINAC : An Innovative Accelerator Complex for Diagnostics and Handrontherapy

O.Lebeda May 11
Production of medically interesting radionuclides on cyclotron U-120M in Nuclear Physics Institute in Řež, Czech Republic

J.Jastrzębski June 1
Sprawozdanie z działalności Laboratorium w okresie 1.01.2005-23.05.2006

J.Choiński, J.Jastrzębski, Ludwik Pieńkowski November 8
Posiedzenie Komitetu Eksperymentów

D.Hechner November 16
Radiofarmaceutyki i radiochemia PET – sprawozdanie z pobytu w King's College of London

2.2. External seminars given by HIL staff

L.Pieńkowski January 26
Energetyka jądrowa w Polsce ? Tak, ale jak?
Politechnika Warszawska, Warszawa, Poland

J.Srebrny March 17
Obecne i przyszłe badania na wiązce warszawskiego cyklotronu-spojrzenie osobiste
IFD, Warszawa, Poland

K.Wrzosek May 31
Search for shape coexistance in even-even stable molybdenum isotopes using Coulomb excitation method
IFD, Warszawa, Poland

W.Gawlikowicz June 14

Dynamical and Statistical Fragment Production in Heavy-ion in ^{136}Xe+^{209}Bi Reactions at E/A = 28, 40, and 62 MeV
11th International Conference on Reaction Mechanisms,Varenna, Italy

L.Pieńkowski November 6
Energetyka jądrowa w Polsce – synergia jądrowo-węglowa
IFD, Warszawa, Poland

E.Piasecki November 20
Rozkłady wysokości barier : czy zagadka rozwiązana?
IFD, Warszawa, Poland

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

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
"***^{128}Cs as the best example revealing the chiral symmetry breaking phenomenon***"
Phys. Rev. Lett. **97** (2006) 172501.

E. Grodner, A.A. Pasternak, Ch. Droste, T. Morek, J. Srebrny, J. Kownacki, W. Płóciennik, A. Wasilewski, M. Kowalczyk, M. Kisieliński, R. Kaczarowski, E. Ruchowska, A.Kordyasz and M.Wolińska
"***Lifetimes and side-feeding population of the yrast band levels in ^{131}La***",
Eur. Phys. J. **A27** (2006) 325-340 .

A.J.Kordyasz, J.Iwanicki, M. Kowalczyk, E.Kulczycka, E.Nossarzewska-Orłowska, D.Lipiński and A.Brzozowski,
"***Pulse-shape analysis of signals from monolithic silicon E-DE telescopes produced by the quasi-selective epitaxy***",
Nucl. Inst. and Meth. **A568** (2006) 778-783 .

A.J.Kordyasz, M. Kowalczyk, E.Nossarzewska-Orłowska, M. Kisieliński, E.Kulczycka, J.Sarnecki and J.Iwanicki,
"***Response to light particles and heavy ions of thin, large area DE strip detectors produced by the PPPP process***",
Nucl. Inst. and Meth. **A570** (2006) 336-342 .

K.Wrzosek, M.Zielińska, J.Choiński, T.Czosnyka, Y.Hatsukawa, J.Iwanicki, J.Katakura, M.Kisieliński, M.Koizumi, M.Kowalczyk, H.Kusakari, M.Matsuda, T.Morikawa, P.Napiorkowski, A.Osa, M.Oshima, L.Reissig, T.Shizuma, J.Srebrny, M.Sugawara, Y.Toh, Y.Utsuno, K.Zając,
***"Search for shape coexistence in even-even stable molybdenum isotopes using coulomb excitation method"*;**

Int. J. Mod. Phys. E-Nucl. Phys; **E15** 374(2006).

E.Grodner, J.Srebrny, I.Zalewska, T.Morek, C.Droste, M.Kowalczyk, J.Mierzejewski, A.A.Pasternak, J.Kownacki, M.Kisielinski,
"Support for the chiral interpretation of partner bands in Cs-128 - The electromagnetic properties",
Int. J. Mod. Phys. E-Nucl. Phys; **E15** 648(2006).

E.Wójcik, M.Kicinska-Habior, O.Kijewska, M.Kowalczyk, M.Kisielinski, J.Choiński,
"Giant dipole radiation and isospin mixing in hot light nuclei",
Acta Phys. Pol., **B37**, 207(2006).

E. Grodner, S.G. Rohoziński, J. Srebrny,
"Simple picture of the nuclear system diverging from the strong chiral symmetry breaking limit",
Acta Physica Polonica, in publication

J.Choiński,
"Tomografia Pozytonowa w Warszawie"
Postępy Techniki Jądrowej Vol. **49** Z.4, 4-2006.

J. Czub, D. Banaś, J. Braziewicz, J. Choiński, M. Jaskóła, A. Korman, Z. Szefliński, A. Wójcik
"An irradiation facility with a horizontal beam for radiobiological studies"
Radiation Protection Dosimetry (2006), doi:10.1093/rpd/ncl518.

3.1.2 Publications resulting from work performed with facilities outside HIL

C.M.Herbach, D.Hilscher, U.Jahnke, V.G.Tishchenko, J.Galin, A.Letourneau, A.Peghaire, D.Filges, F.Goldenbaum, L.Pieńkowski, W.U.Schroeder, J.Toke,
"Systematic investigation of 1.2-GeV proton-induced spallation reactions on targets between Al and U",
Nucl. Inst. Meth. Phys .Res. **A 562**, 729(2006).

G.Georgiev, I.Stefanescu, D.L.Balabanski, P.Butler, J.Cederkall, T.Davinson, P.Delahaye, V.N.Fedosseev, L.M.Fraile, S.Franchoo, K.Gladnishki, K.Heyde, M.Huyse, O.Ivanov, J.Iwanicki, Th.Kroll, U.Koster, A.Lagoyannis, G.Lo Bianco, A.De Maesschalck, A.Saltarelli, T.Sieber, N.Smirnov, P.Van Duppen, N.Warr, F.Wenander, J.van de Walle, and the REX-ISOLDE and MINIBALL Collaborations,
"First use of post-accelerated isomeric beams for Coulomb excitations studies of odd-odd nuclei around N=40",
Int.J.Mod.Phys. **E15**, 1505 (2006).

A.Stolarz, J.Van Gestel
"Polyimide foils as backing supports for optical filters",
Nucl. Inst. Meth. Phys. Res. **A 561**, 115(2006).

F.Becker, A.Petrovici, J.Iwanicki, N.Amzal, W.Korten, K.Hauschild, A.Hurstel, C.Theisen, P.A.Butler, R.A.Cunningham, T.Czosnyka, G. de France, J.Gerl, P.Greenlees, K.Helariutta, R.D.Herzberg, P.Jones, R.Julin, S.Juutinen, H.Kankaanpa, M.Muikku, P.Nieminen, O.Radu,

P.Rahkila, C.Schlegel,
"Coulomb excitation of Kr-78",
Nucl .Phys. **A770**, 107(2006).

J.Srebrny, T.Czosnyka, C.Droste, S.G.Rohozinski, L.Prochniak, K.Zając, K.Pomorski, D.Cline, C.Y.Wu, A.Backlin, L.Hasselgren, R.M.Diamond, D.Habs, H.J.Korner, F.S.Stephens, C.Baktash, R.P.Kostecki,
"Experimental and theoretical investigations of quadrupole collective degrees of freedom in Ru-104",
Nucl. Phys. **A766**, 25(2006).

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"Charged-particle evaporation and pre-equilibrium emission in 1.2 GeV proton-induced spallation reactions",
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A.B.Hayes, D.Cline, C.Y.Wu, J.Ai, H.Amro, C.Beausang, R.F.Casten, J.Gerl, A.A.Hecht, A.Heinz, R.Hughes, R.V.F.Janssens, C.J.Lister, A.O.Macchiavelli, D.A.Meyer, E.F.Moore, P.Napiorkowski, R.C.Pardo, Ch.Schlegel, D.Seweryniak, M.W.Simon, J.Srebrny, R.Teng, K.Vetter, H.J.Wollersheim ,
"Breakdown of K Selection in ^{178}Hf" ,
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A.Gadea, S.M.Lenzi, S.Lunardi, N.Marginean, A.P.Zuker, G.deAngelis, M.Axiotis, T.Martinez, D.R.Napoli, E.Farnea, R.Menegazzo, P.Pavan, C.A.Ur,D.Bazzacco, R.Venturelli, P.Kleinheinz, P.Bednarczyk, D.Curien, O.Dorvaux,J.Nyberg, H.Grawe, M.Gorska, M.Palacz, K.Lagergren, L.Milechina, J.Ekman,D.Rudolph, C.Andreoiu, M.A.Bentley, W.Gelletly, B.Rubio, A.Algora, E.Nacher,L.Caballero, M.Trotta, M.Moszynski
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3.2 Other conference contributions

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3.3. Internal reports

Projekt, wykonanie i uruchomienie sterownika do zasilacza magnesu głównego ZM1 Cyklotronu U-200P
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Reinhard Kulessa, IF UJ
Bogdan Fornal, IFJ Kraków
Andrzej Marcinkowski, IPJ
Adam Sobiczewski, IPJ
Władysław Trzaska, University of Jyvaskyla
Andrzej Turos, IPJ and ITME
Teresa Rząca-Urban, IFD UW
Jan Żylicz, IFD UW

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

7. Students Workshop and Summer Training

A. Polish Workshop on Heavy Ion Acceleration and its Applications

The Polish Workshop on Heavy Ion Acceleration and its Applications was organized by Heavy Ion Laboratory for the second time. It was held on 6-11 March 2006. 16 students from 4 polish Universities and from Sołtan Institute for Nuclear Studies participated in the event. During the Workshop students could attend a series of lectures on topic related to heavy ion physics and participated in practical task. The experimental part of the Workshop allowed students to performed measurements using facilities installed and working at HIL and get acquainted with this infrastructure.

The program of the lectures was as follows:
1. Ion optics – dr J. Sura
2. Detection of the nuclear radiation – dr. J. Srebrny
3. Nuclear energy in Poland. Plans for future – dr hab. L. Pieńkowski
4. Technique of a gamma-rays analysis – dr M. Palacz
5. In beam gamma spectroscopy – prof. Ch. Droste
6. Physics in cancer fight – dr hab. Z. Szefliński

Experimental tasks for students:
- Beam focusing in heavy ion acceleration.
- Beam energy measurements based on the Rutherford scattering.
- Identification of excited states bands in gamma-gamma coincidences.
- Measurements of ^{137}Cs activity in mushrooms.

The Workshop finished with student presentations. Each group prepared 20 minutes talk on its measurements and results.

B. Summer Training for Students

The workshop was very well received by students and many of them were interested in continuation of the collaboration. It was main motivation to organize 2 week Summer Practice. 16 students (from 3 Universities) applied . They were involved in regular scientific activity of experimental groups at HIL and supposed to do task single-handedly. The following task were offered to students:
Run new scintillator detectors (BaF2) and their calibration (energetic and efficiency).
Test of heavy ion detectors (PIN diodes) installed in the "Munich" chamber.
Preparation of the web page devoted to the code GOSIA and coulex excitations.
Calibration of the HPGe detector with the point source for large samples measurements.

Workshop participants

8. Laboratory Guests:

Participants of HIL experiments from outside-Warsaw laboratories:

J.Andrzejewski	Łódź	May
D.Banaś	Kielce	September
A.Błaszczyk	Toruń	May
B.Czech	Kraków	January
J.Czub	Kielce	March
M.Kasztelan	Łódź	May
S.Kliczewski	Kraków	January
E.J.Koszui	Ukraine	January
T.Krogulski	Białystok	February
A.Król	Łódź	March
M.Mutterer	Germany	February
J.Perkowski	Łódź	May
W.M.Pimak	Ukraine	January
O.Ponkratenko	Ukraine	January
B.Roussiere	France	June
A.A.Rudczyk	Ukraine	January

P.Russotto	Italy	February
S.B.Sakuta	Russia	January
R.Siudak	Kraków	January
I.Skwierczyńska	Kraków	January
K.Sobczak	Łódź	May
W.H.Trzaska	Finland	February
Ch.Wabwitz	France	June
R.Wojtkiewicz	Łódź	May
A.Wójcik	Kielce	May

Short time visitors:

A. A. Pasternak	A.F. Ioffe Phys.-Tech. Inst. St. Petersbourg, Russia	April, June, September
D.Muecher	IKP Koeln	August
V.Rauch	IHPC Strasbourg	June, October
M.Rousseau	IHPC Strasbourg	June, October
J.Devin	IHPC Strasbourg	June, October
J.Rehberger	IHPC Strasbourg	June
W.Trzaska	JYFL Jyvaskyla	September

9. Permanent collaborations

CERN, Geneva, Switzerland
GANIL, Caen, France
GSI Darmstadt, Germany
Hahn-Meitner Institut Berlin, Germany
Institute für Kernphysik KFA Jülich, Germany
Institute for Nuclear Research, Kiev, Ukraine
Institut de Recherches Subatomiques, Strasbourg, France
Japan Atomic Energy Agency, Japan
Joint Institute for Nuclear Research, Dubna, Russia
Ludwig-Maximilians Universität, München, Germany
Laboratori Nazionali di Legnaro, Padova, Italy
Manne Siegbahn Institute, Stockholm, Sweden
Niels Bohr Institute, Denmark
Oliver Lodge Laboratory, Liverpool, United Kingdom
Technische Universität München, Germany
University of Jyväskylä, Finland
University of Liverpool, United Kingdom
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