WARSAW UNIVERSITY
HEAVY ION LABORATORY

ANNUAL REPORT
2004

Warsaw University
Heavy Ion Laboratory

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WARSAW, May 2005

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Contents

Introduction

A. Laboratory overview

B. Experiments and experimental set-ups

C. Experiments using the outside facilities

D. General information on HIL activities

INTRODUCTION

The Heavy Ion Laboratory of the Warsaw University is the „User type” facility, providing heavy ion beams to a number of Polish and foreign research groups and to limited extent for its own research programme. In 2004 the Warsaw cyclotron operated for more than 3000 hours of beam on target. 22 experiments were performed by about 100 facility users, with a large participation of young researchers. Their scientific achievements in 2004 are presented in this Report. For the first time we welcome in these pages the information from the very active team from Kielce and Warsaw, which after publishing excellent papers in atomic physics started the experiments using biological samples. The interdisciplinary use of our facility is well promoted by this group.

The machine operated without major breaks, behaving “normally” during the whole year. Some technical upgrades presented in this Report were, as already during previous two years, achieved only due to the effort of the cyclotron team without any substantial purchases. For a few consecutive years the financial support from the Ministry of Sciences and Informatization decreases what not only prohibits any developments, but jeopardize the very existence of our Heavy Ion Facility.

The very difficult financial situation of our Heavy Ion Facility is in opposition to the success of our second activity – 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 MUSD 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. At present the choice of the equipment to be purchased is discussed with IAEA experts and appropriate tender(s) will be launched soon. At the same time the projects for the building adaptation to host the new cyclotron and radiochemistry units are prepared. We expect the first radiopharmaceutical (FDG) production line to be operational at the end of 2006, beginning of 2007 (for more information, see Laboratory web pages).

At the end of this Introduction let me come back to the activity of the heavy ion machine and its relation to the educational mission of our University. The recent assessment of this activity shows that 9 PhD, 8 Master of Sciences and 2 Bachelor of Sciences theses are presently conducted using our facility whereas two PhD were already defended in 2004. Their titles are listed on following pages of this Report. These numbers together with information on various other educational activities of our staff addressed to the students or general public shows that Heavy Ion Laboratory fulfills well its role not only of a scientific but also of an educational centre.

Jerzy Jastrzębski

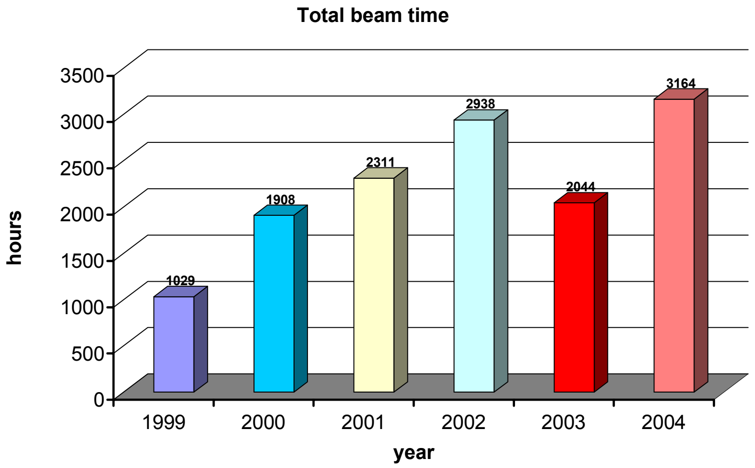
Part A:
Laboratory overview

1. Operation of the cyclotron and associated apparatus during 2004

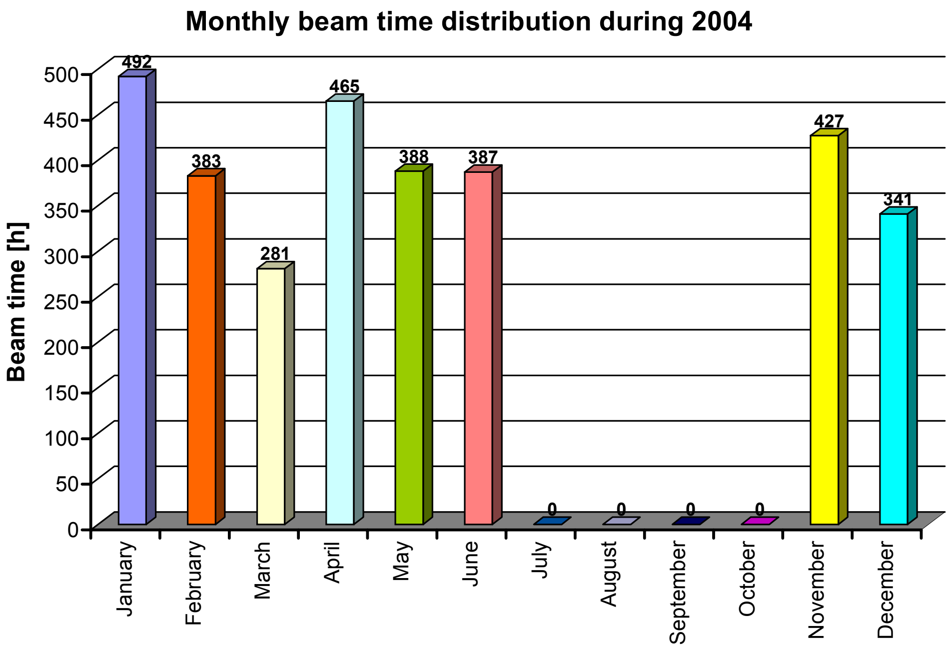
J.Choiński, T.Czosnyka, J.Jastrzębski, W.Kalisiewicz, J.Kownacki, E.Kulczycka, J.Kurzyński, J.Miszczak, B.Paprzycki, J.Sura

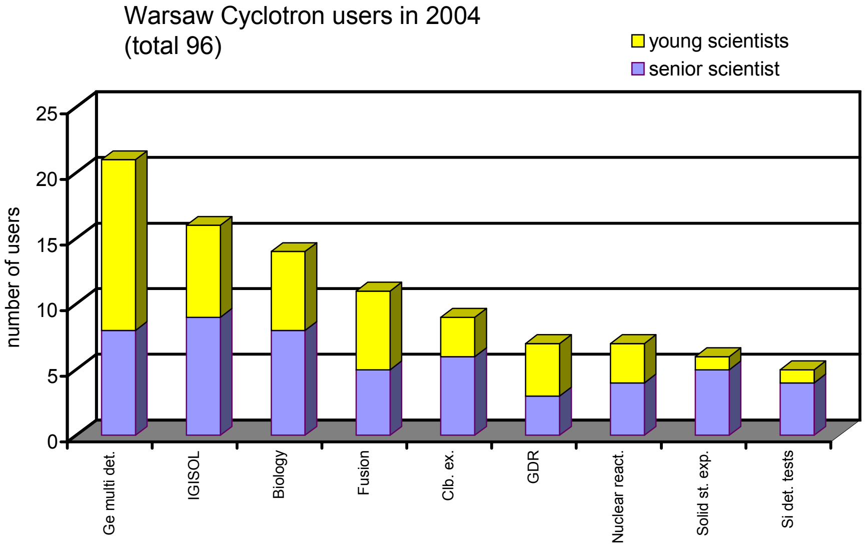
Cyclotron facility

In 2004 the cyclotron delivered the beams-on-target for 3164 hours. The beam time available to the users in past years is illustrated in the figure below.



Monthly distribution of the beam time during 2004 is presented in the following figure. July, August and September was the vacation period, during which delayed leaves of the accelerator crew have been partly used.





The number of users of the Warsaw cyclotron facility is presented in the above figure. The beams available did not change from these reported in HIL Annual Report 2003. Previously installed time-of-flight system was upgraded and continuously used. Three induction coils permanently mounted on the first section of the beamline assure continuous monitoring of the beam energy with high precision (of the order of few hundreds keV). Remote computer-controlled system of reading beam current from the diagnostic boxes is working reliably. The implementation of the system allows to control the beam transmission from the exit of the cyclotron to the target without necessity of hardware modifications.

Experiments performed on the cyclotron

Examples of experiments employing heavy ions beams from the cyclotron include:
1) Investigation of the high spin states of nuclei with the multidetector OSIRIS II system. The experimental set-up consists of 12 anticompton shielded HPGe detectors equipped with charged particle 4π multiplicity filter Si-Ball, 50 elements BGO γ-rays multiplicity filter and 4 sector HPGe polarimeter.
2) Coulomb Excitation (COULEX) studies. A permanent set-up for such investigations, consisting of an array of PIN-diodes (CUDAC - Coulomb Universal Detector Array Chamber) in connection with the computer data analysis package GOSIA, maintained by the Laboratory, attracts the scientists from many institutions. The same set-up is used for the investigation of fusion barriers via detection of scattered projectiles.
3) Investigation of the reaction products by means of the on-line mass separator with ion-guide system IGISOL. The system uses the Scandinavian-type mass separator.
4) Reaction studies of the light nuclei using universal large scattering chamber equipped with the charged particles detectors (gas filled ionization counter as well as semiconductor detectors).
5) Giant Dipole Resonance studies using experimental set-up JANOSIK developed for the detection of high-energy photons emitted in heavy-ion collisions. The set-up consists of a large NaI(Tl) detector (25cm · 29cm) surrounded by shields: passive lead shield, active anticoincidence plastic shield and LiH shield to absorb neutrons, and a multiplicity filter of 32 small scintillator detectors (BaF_2 and NaI(Tl)). During the GDR experiments 9.7 MeV/amu neon beam was used for the extended period, showing the operational possibilities of the accelerator in the 10 MeV/amu range.
6) Applications of heavy ion beams in solid state physics (internal or extracted beams).

7) Investigation of the ion-atom collision processes by X-ray spectroscopy using the Si(Li) detector. The scientific interest is concentrated on:

a) studies of the X-ray emission from swift heavy projectiles slowing down in thin target foils,

b) studies of the multiple ionization effect through the measurement of the L- and M shells X-ray production cross section, X-ray shift and line broadening induced by heavy ions in selected heavy elements.

More details concerning the development of the apparatus for research projects can be found in the articles describing the ongoing activities presented in this Report. The histogram and table of the beam time for different projects in 2004 is presented below. Requirements for the beams now exceed the available time, so the selection, based on suggestions of the independent Program Advisory Committee, is often necessary.

Experiments from 1.01.2004 to 31.12.2004, total beam time 3164 hours

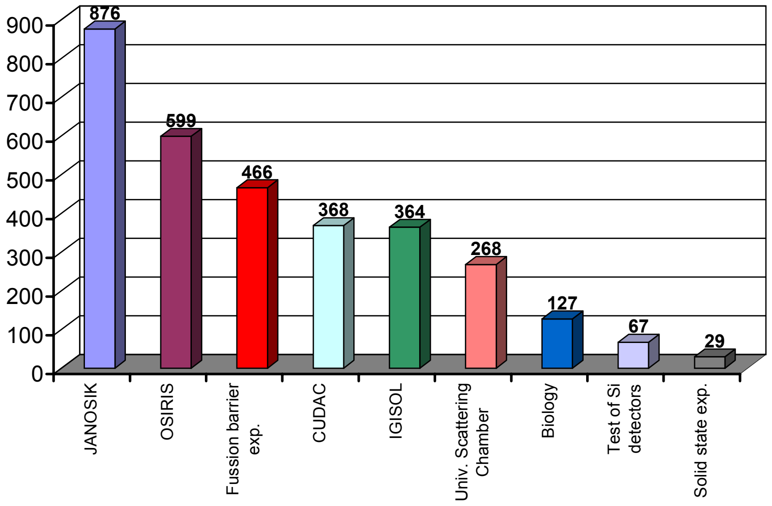


Table 1. Experiments form 1.01.2004 to 31.12.2004

Dates	Beam line	Ion	<u>Energy</u> [Mev]	Leading institution	Collaborating institutions
5.01 - 16.01	C4 JANOSIK	$^{20}Ne^{+5}$ $^{11}B^{+2}$	190 49	IFD UW	Heavy Ion Laboratory (HIL)
19.01 - 23.01	C1 IGISOL	$^{14}N^{+3}$	72	IFD UW	
26.01 – 6.02	B Univ. Scat. Chamber	$^{11}B^{+2}$	51,6	AN UKRAINY	IPJ, IFJ Kraków, HIL
9.02 – 12.02	C2 CUDAC Fusion	$^{22}Ne^{+3}$	44	IFD UW	HIL, IFD Białystok, IReS Strasbourg, Kyoto University, University of Jyväskylä, GSI
23.02 – 5.03	C2 CUDAC Fusion	$^{22}Ne^{+4}$	Up to: 132	IFD UW	HIL, IFD Białystok, IReS Strasburg, Kyoto University, University of Jyväskylä, GSI
8.03 – 12.03	C1 IGISOL	$^{14}N^{+3}$	72	IFD UW	
29.03 – 2.04	C2 CUDAC Fusion	$^{22}Ne^{+3,4}$	Up to: 132	IFD UW	HIL, IFD Białystok, IReS Strasburg, Kyoto University, University of Jyväskylä, GSI

Dates	Beam line	Ion	Energy [Mev]	Leading institution	Collaborating institutions
5.04 – 9.04	C3 OSIRIS	$^{14}N^{+3}$	72	IFD UW	HIL, IPJ, IPT St. Petersburg
13.04 – 15.04	D Solid state exp.	$^{12}C^{+3}$	108	IF WSP	IFD UW, HIL, IPJ
15.04 – 16.04	C2 CUDAC Coulex	$^{40}Ar^{+6}$	100	HIL	IFD UW
19.04 – 30.04	C2 CUDAC Coulex	$^{40}Ar^{+6}$	100	HIL	IFD UW, OLL Liverpool
19.05 – 28.05	C4 JANOSIK	$^{20}Ne^{+5}$, $^{11}B^{+2}$	190, 49	IFD UW	HIL
31.05 – 2.06	C2 CUDAC Test of Si detec.	$^{14}N^{+3}$	49	HIL	IFD UW
3.06 – 4.06	D Biology	$^{12}C^{+3}$	108	IFD UW	IB AŚ Kielce , IF AŚ Kielce, HIL, IPJ
14.06 – 25.06	C3 OSIRIS	$^{12}C^{+3}$	108	IFD UW	HIL, IPJ
28.06 – 2.07	C1 IGISOL	$^{14}N^{+3}$	89,6	IFD UW	HIL, IPJ, IPN Orsay, University of Jyväskylä, INR Kijów
18.10 – 3.11	C4 JANOSIK	$^{12}C^{+2}$ $^{11}B^{+2}$	50,5 49	IFD UW	HIL, IPJ
4.11 – 5.11	C1 IGISOL	$^{14}N^{+3}$	72	IFD UW	HIL, IPJ, IPN Orsay, University of Jyväskylä, INR Kijów
15.11 – 19.11	C2 CUDAC Coulex	$^{20}Ne^{+3}$	50	HIL	IFD UW, OLL Liverpool
1.12 – 3.12	D Biology	$^{12}C^{+3}$	108	IFD UW	IB AŚ Kielce , IF AŚ Kielce, HIL, IPJ
7.12 – 17.12	C3 OSIRIS	$^{16}O^{+4}$	77	HIL	IFD UW
20.12 – 24.12	C1 IGISOL	$^{14}N^{+3}$	91	IFD UW	HIL, IPJ, IPN Orsay, University of Jyväskylä, INR Kijów

Abbreviation used in the table above

AŚ Kielce	Instytut Fizyki Akademii Świętokrzyskiej, Kielce
GSI	GSI, Darmstadt
IB AŚ Kielce	Instytut Biologii Akademii Świętokrzyskiej, Kielce
IF AŚ Kielce	Instytut Fizyki Akademii Świętokrzyskiej, Kielce
IF PAN	Instytut Fizyki Polskiej Akademii Nauk
IFD Białystok	Instytut Fizyki Doświadczalnej, Uniwersytet w Białymstoku
IFD UW	Instytut Fizyki Doświadczalnej, Uniwersytet Warszawski
IFJ Kraków	Instytut Fizyki Jądrowej, Kraków
IF WSP	Instytut Fizyki Wyższej Szkoły Pedagogicznej, Kielce
IKFJ Juelich	Institut fur Kernphysik, Juelich, Niemcy
INR Kijów	Inst. For Nuclear Res., Ukrainian Nat. Ac. Of Science, Kijów, Ukraina
IPJ Świerk	Instytut Problemów Jądrowych, Świerk
IPN Lyon	Institute Physique Nucleaire, Lyon, Francja
IPN Orsay	Institute Physique Nucleaire, Orsay, Francja
IPT St. Petersburg	Joffe Physical-Technical Institute RAN, St. Petersburg, Rosja
IReS Strasbourg	Institute des Recherches Subatomiques, Strasbourg, Francja
ITE Warszawa	Instytut Technologii Elektronowej, Warszawa
ITME Warszawa	Instytut Technologii Materiałów Elektronicznych, Warszawa
JAERI Tokio	Japan Atomic Energy Research Institute, Tokai, Japonia
KSU Charków	Kharkiev State University, Charków, Ukraina

Plans of Development

Depending on the financial condition of the Laboratory during the next few years the following major upgrades of the machine and its infrastructure are foreseen:

	Estimated completion time
1. Cyclotron	
1.1. Cyclotron upgrade	
1.1.1. Improvement of radiation protection system	2005
1.1.2. Precise beam energy definition using RBS method	2005
1.1.3. Saw-pulse buncher to replace existing sine-wave device	2005
2. ECR ion source	
2.1. Upgrade of the source	
2.1.1. Computerized remote control system	2005

To summarize, the operation of the cyclotron in 2004 was definitely successful as manifested by the results obtained. It should be also stressed that some key staff members were heavily engaged in preparing the project of Warsaw PET Center and this time-consuming activity did not disrupt the normal operation of the accelerator.

2. Activity report of the ECR group

B. Filipiak, A. Górecki

In 2004 the following ion beams were produced using ECR ion source and provided to the cyclotron as shown in the table below.

Table 1. Ion currents on the cyclotron inflector:

Jon	${}_{10}\mathrm{B}^{+2}$	${}_{11}\mathrm{B}^{+2}$	${}_{12}\mathrm{C}^{+2}$	${}_{12}\mathrm{C}^{+3}$	${}_{14}\mathrm{N}^{+3}$	${}_{16}\mathrm{O}^{+3}$	${}_{20}\mathrm{Ne}^{+3}$	${}_{20}\mathrm{Ne}^{+4}$	${}_{22}\mathrm{Ne}^{+4}$	${}_{36}\mathrm{Ar}^{+6}$
Jon current [eµA]	10	26	94	95	105	80	92	95	96	73

- The ion source was periodically maintained and cleaned.
- The vacuum rotary pump has been changed to improve pumping efficiency.
- The malfunctioning switch of the r.f. generator has been replaced.
- The power supply for magnetic coil of the ion trap has been repaired with help of HIL electrical support group.

3. Solid-state driven sawtooth buncher

M.Sobolewski, J.Miszczak, Z.Kruszyński

The Warsaw cyclotron operates with a sinusoidal buncher [1]. The typical increase in beam current intensity due to buncher operation is 2 - 2.5 times. To further increase available beam current an effort was made to change the design of the buncher to a sawtooth one. The accelerating electrode was redesigned, and a new driver stage was employed, as shown on Fig.1. This is a variation of a classic design used in TV deflection circuits, however the switching transistor is pushed to its limits due to high operating frequency (up to 19 MHz). Very clean sawtooth voltage was obtained on the accelerating electrode, but voltage swing is limited to 180Vpp@12MHz and 140Vpp@ 17MHz as can be seen on Fig.2. The results of preliminary tests confirm calculations, that the voltage is too low for the sawtooth buncher to perform much better than the existing sinusoidal one, but also show that ion optics in the transport line between the ion source and the cyclotron should be improved. The work on the sawtooth buncher and the ion optics will be continued in 2005.

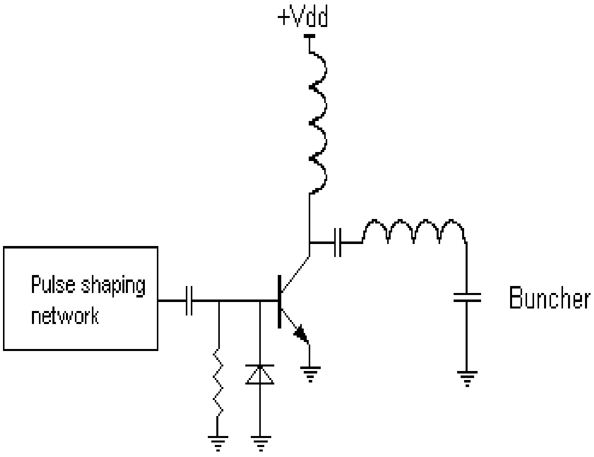


Fig. 1.

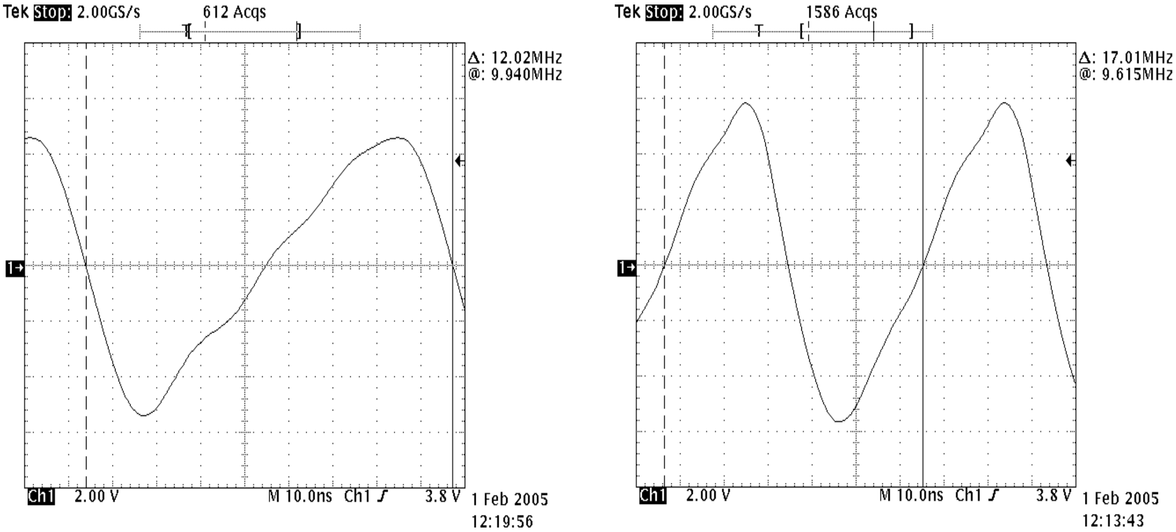


Fig. 2

References

[1] *Designing and commissioning of the prototype buncher*, J.Sura et al, HIL Annual Report, 2001.

4. Activity of the electrical support group

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

1. Main design projects during 2004:

- Steering system of the UZ-series power supplies has been redesigned. This work has been started in 2003, but not completed. Introduced modifications involved technical schemes, logical schemes and relevant circuitry. The project started in 2003 has been extended to implement the steering modules of all current supplies: UZ1, UZ2 (17kW) and UZ3 (60kW), designated to serve the bending magnets. All changes were introduced following the tests performed in 2003.
- QNX-compatible software for the power supply steering was developed. The prototype of the steering module was manufactured, tested and improved to design the final version, according to the timetable accepted in 2003. The system is being used since September 2004. Until the end of 2004 there were no critical remarks concerning the operation of computer-controlled UZ-series power supplies.
- The design, manufacturing and putting in operation modernized switchboards for the cyclotron cooling system was completed. An original idea of the system was preserved.
- Electrical circuitry for the stationary air compressor serving the mechanical workshop has been designed, mounted and put into operation
- 300A switchboard for dipoles D1-1 and D1-2 installed at the beginning of the beamline was designed, manufactured and put into operation

2. Measurements and conservation

- Measurements and conservation of the street lightning in the cyclotron building area
- Consultation and following adaptation of the power supplies circuitry for the IGISOL separator
- Measurements and control of cyclotron electrical circuits (cable network)
- Current maintenance of master and slave switchboards connected to HIL cable network, automation and steering systems, including the small projects concerning the blockades and steering to facilitate cyclotron operation

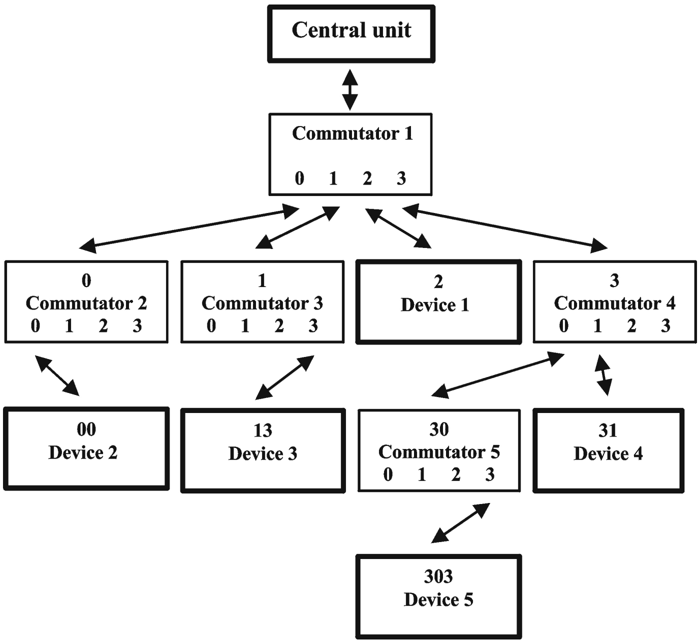


Fig.1. Structure of the computer control communication

3. Cyclotron operation service

- Much work has been devoted to the design and production of the model of the steering module for bending magnets power supplies. The design is based on on the programmable PIC16F628 circuit with 12-bit ADC/DAC converters and the module allowing to communicate with a PC-class computer.
- Communication protocol steering computer-power supply adheres to the common standard in use in the cyclotron with RS 232 interface.
- The adopted solution will allow in the future to enlarge the capability of the system implementing the cheap modules of digital electronics.
- Control software was written for the QNX environment and graphics interface Photon.
- The system allows to control few power supplies via a single RS 232 port, making use of the steering blocks of virtual serial ports.
- After testing of the model the accuracy of setting and reading out of the current in UZ-series power supplies turned out to be in the order of 10^{-3}.
- Finally, the computerized steering system (see Fig.1) of UZ-series power supplies became fully operational by the end of 2004.

5. Control system for the Warsaw Cyclotron

J.Miszczak, J.Choiński

The control system for the Warsaw cyclotron is relatively simple, with measurement/set-point counts in the low hundreds. It is a direct descendant of a system built about 12 years ago. The old system, like many control system of that era, was built around PC hardware and used the MS-DOS operating system [2]. Computers were not networked, instead a remote console approach was used to access them from the control room. Control software was written in C. When Microsoft discontinued support for MS-DOS and the next generation of Microsoft operating systems was clearly not suitable for control purposes, it was time for a change. To preserve the investment in the PC hardware the QNX was chosen as the next OS platform.

Overview of the QNX OS

QNX is a real time, very robust and reliable, commercial version of UNIX for PC compatible computers aimed at control applications. It does not use AT&T UNIX code. The OS version used at the Heavy Ion Laboratory is 4.25. A newer version (5.0) has been available for some time now, but the changes offer more support for open standards than OS improvements. A detailed description of the QNX OS can be found on manufacturer website [1], but some of its features are worth mentioning here. QNX uses a micro-kernel architecture, what in practice translates into low memory and mass storage footprint, and low requirements for CPU processing power. A Pentium 100-200MHz machine with 32 MB of RAM will comfortably run most common control algorithms in real time. For use as graphic console those numbers should be doubled. A hard disk drive (or solid state media like Compact Flash) with storage capacity of 60MB is required for a fully functional text mode base system. Development package (window managers, graphic libraries, etc.) require an additional 120MB. One can now easily buy PC systems with multi-gigabyte disk storage and gigahertz processor clocks, so QNX low system requirements seem irrelevant, but this brute force approach comes at the price of excessive power consumption, bulky heatsinks, and forced air cooling. Besides support for TCP/IP there is the QNX proprietary networking protocol (Qnet). The networked computers have their resources transparently available to one another by simply prefixing directory path names with 'node number'. Another proprietary addition to UNIX standard suite of programs and utilities is the Photon window manager. It is fast and efficient and is used instead of the X window manager.

Out of the box QNX is just the OS with core libraries and utilities, C and C++ compilers, window managers, and simple GUI application builder. Third party sophisticated application builders exist, but their high price nullify the advantage of low cost of PC hardware.

Hardware

The control system at Heavy Ion Laboratory uses a mixture of PC computers in different form factors, PLCs (Programmable Logic Controllers), and embedded processors. The latter were developed and built in house, in cases when no adequate commercial hardware existed for devices which initially lacked support for computerized remote control, like some high current power supplies. Moreover we were concerned about ground loop currents flowing in and out off high precision circuits (14 to 16 bit accuracy). Since it is easier to opto-isolate a few RS-232 lines then D/A and A/D converters, we chose to process the signals locally. The controllers also offload PC computers and significantly reduce the amount of cabling.

PLC are used in 'mission critical' systems like the radiological safety interlock system. PLC are also used for very simple automation tasks that require no precision analog set-points/measurements like vacuum power up sequencing. Siemens S7 series PLC were chosen because of good local support, but other manufacturers (Omron, GE) offer almost the same products feature for feature.

In the early '90s a desktop PC was not recognized as an automation platform, so very few add-on I/O cards for that purpose existed on the market. The only exception were multi-port RS-232 cards intended for connecting dumb serial terminals to a PC running a multi-user OS like (long forgotten) Xenix. So RS-232 was and is used at the Warsaw cyclotron instead of the more robust and faster RS-485.

Since enough hardware expertise was on hand, several I/O ISA boards were developed and built in-house, ranging from simple non-isolated binary input and output boards, to A/D and D/A converters, to sophisticated, one of a kind PWM/modulator circuits for RF control. It was a good choice, as the ISA bus architecture turned out to be a very stable subsystem in the ever changing PC environment. Only 2-3 years ago it was dropped completely off new computer motherboards in favour of all PCI designs. There are many PCI I/O cards on the market now, but most manufacturers of those cards seem slow to adopt the newest (rev.3.0) PCI standard of 3.3 volts only bus signalling, or keyed 3.3V and 5V cards (rev. 2.3). One has to write QNX drivers for I/O cards, since QNX drivers are usually not included. So we try to keep the number of types of I/O boards low.

The architecture of the control system for the Warsaw cyclotron differs from the typical system [3]. There is no field bus, instead PC computers equipped with I/O cards are located next to controlled devices. The PCs are connected via Ethernet. The Ethernet network can be the field bus – it has all the properties of an industrial strength interconnection. Even in the most common twisted pair form (copper) is sports 250V dielectric isolation, has speeds an order of magnitude higher than other technologies (LON, CAN, Profibus [3]), and has well standardized higher level protocols. With the advent of microprocessors or microprocessor modules with Ethernet hardware on-board, and prepackaged WWW servers or software TCP/IP stacks [4], it is easy to connect any device to the Ethernet without the use of a PC type computer.

Software

As it was mentioned earlier QNX out of the box lacks a database engine, scripting languages, etc. Since QNX is 'UNIX compatible' it is not all that difficult to port GPL (General Public Licence) software to QNX. Some GPL packages are even available for download pre-compiled for QNX, while others can be installed using the standard 'make' utility. Some software, like graphic utilities and libraries, can not be ported due to differences in windowing environments. When ported, however, several individual software packages have to be maintained (patches, version upgrades) on computers running 24/7 most of the time. To avoid this troublesome and time consuming scenario a decision was made to maintain control computers with as little add-on software installed as possible. All cyclotron data is available to cyclotron users, accelerator physicists etc, via a dedicated gateway. The control system software for the Warsaw cyclotron falls into 3 main categories :

- ***local/low level control***
- ***main (operator) console***
- ***gateway to laboratory LAN***

Low level control

Low level software uses multiple programs for ease of maintenance and code reuse. There are four processes running on each computer: startup, network, control, and application that exchange data via shared memory. The startup process registers the application process name with the main console, and assures proper start and termination of other processes. The network process is responsible for reliable exchange of application data with the main console. The repetition rate for this process is 20Hz. The control process interfaces with the hardware using device drivers, checking for alarms, updating set-points, measuring read-back values etc. The repetition rate for this process is 100Hz. The application process is responsible for displaying data on the local console (text mode only), and passing data between network and control processes. Set-points are either sent over the network from the main console, or are entered locally via the keyboard. Control can be switched from remote to local (and vice versa) by just one keystroke. Software is designed in such a way that remote settings take precedence over local ones – when set-points are altered locally, and then control is switched back to the main console, set-points from the main console are automatically put into effect. The repetition rate for the application process is 10Hz.

Main console

The main console queries all registered low level processes in a loop and displays cyclotron data in a simple graphical manner. The Photon windowing environment makes displaying all the required information easy thanks to nine virtual desktops on one display monitor. Set-points can be entered manually or retrieved from a crude database. All control data is also copied every 2 seconds to a small RAM disk.

Gateway

One QNX based PC was set aside to act as a gateway between the control network and the laboratory LAN. It has two network interface cards – one for each network. There is no routing of protocols between the nets, instead an Apache WWW server with the aid of Perl scripts reads values from the RAM disk at the main console. Only WWW protocol is enabled on the public NIC interface. It is felt that such a setup provides additional level of security to the control network. Applications and services that use cyclotron data are decoupled from the control network, and can be platform and OS independent.

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[3] D.Anicis, T.Blumer, I.Jirousek, H.Lutz, A.Mezger, “Requirements and Solutions for Accelerator Control Systems”, Cyclotrons and Their Applications, East Lansing, 2001, p.364

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6. Unix computers at HIL

M.Palacz, A.Trzcińska, M. Zielińska[1]

1) PhD student at HIL

The Unix network at HIL consists of more than 15 PC computers with the Linux operating system, and one Digital Unix machine. The Unix computers are used by about 30 users, including the HIL personnel, as well as physicists and students from other institutions involved in experiments at HIL. Almost 800 GB of disk space is available for user files and experimental data analysis. The maintenance of this system involves daily handling of user accounts and meeting various users' needs, installation and upgrades of software packages, performing backups, monitoring the security of the system and ensuring uninterrupted accessibility of the network services, such as e-mail, WWW and DNS.

The Unix computers also provide a platform for the WWW service of the Polish Nuclear Physics Network, which is used to disseminate information among its 150 registered members - the majority of the nuclear physics community in Poland.

In June 2004 a major upgrade of the Laboratory WWW pages available at **http://www.slcj.uw.edu.pl** was completed. Now a consistent set of bilingual WWW pages provides information on all aspects of Laboratory activity, and is accessible in a new, attractive graphical framework. The WWW pages are also continuously updated.

A new system of automatic disk backups was recently introduced, which replaced the old practice of manual backups on DLT tapes, which in practice used to be performed a few times a year in irregular intervals. A complete backup of user files is now performed once a month, and incremental backups are made daily. The data are stored on hard disks of a dedicated computer. At any time it should be possible to recover user files, which were present on disks for at least a day within the period of the last two months. The new backup system proved reliable during a major disk failure in November 2004, when all user files on a terminally damaged 60 GB disk were successfully recovered.

7. Q-factor and shunt impedance of the Cracow cyclotron. Experimental results

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The operating cyclotron AIC-144 at the Niewodniczański Institute of Nuclear Physics in Cracow was subject of many improvements in the Radio Frequency system, especially at the upper frequency limit, i.e. around 26 MHz (its operating range is 10-26 MHz). The aim of this work was to check the Q-factor and the shunt impedance of its resonator and, using the measured values, to refine the parameters of the matching network between the power stage of the amplifier Γ-94A and the resonator.

The Network Analyzer (NA) Hewlett Packard HP 8712S was chosen as the measurement instrument. The experimental procedure followed the requirements of the Slater perturbation method and consisted of two steps:

1. The NA was set to measure the S_{11} element of the scattering matrix. The resonator was matched to see at Port 1 the real impedance Z_0=50 Ohm at a given frequency. To reach

the matching point, the sliding short was moved and the coupling loop turned till the Standing Wave Ratio (SWR) took the value close to unity (in the range 1-1.1).

2. At the matching point the NA was set to measure the S_{21} element of the scattering matrix. At this point the critically coupled (loaded) Q-factor was read.

Both steps were repeated **without** and **with** the perturbing disc. The disc of diameter equal to 24.5 mm and 5 mm thick was being put between the Dee and the Liner close to the center of the accelerating gap.

Some of the smoothed out results are shown in the Table below. Q_0-the uncoupled Q-factor, R_{shunt}-the shunt impedance of the resonator, Power corresponds to the amplitude voltage on the Dee of 50 kV. The discontinuity at 16 MHz is due to the essential change in geometry of the resonator by insertion of the three sliding shorts.

A detailed description is given in a Report being in preparation.

freq.	**Qo**	**R_{shunt}**	**Power**
MHz	**-**	**KOhm**	**kWatt**
10	2836	33.545	37.263
12	2334	27.409	45.605
14	1976	23.026	54.285
16	1708	19.739	63.325
Discontinuity			
16	3607	27.065	46.185
18	3269	25.780	48.487
20	2999	24.752	50.501
22	2778	23.911	52.277
24	2594	23.210	53.856
26	2438	22.617	55.268

Part B:

Experiments
and experimental set-ups

1. Coulomb Excitation experiment of ^{100}Mo

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Coulomb excitation experiment of ^{100}Mo is a natural continuation of the systematic study of ^{96}Mo [1] and ^{98}Mo [2, 3] nuclei having low lying 0^+ excited states, with energy very close to the first 2^+ state.

A set of two experiments with ^{40}Ar and ^{20}Ne beams and ^{100}Mo target was performed using CUDAC set-up at HIL in Warsaw. The collected spectrum with marked transitions is shown in figures 1 and 2.

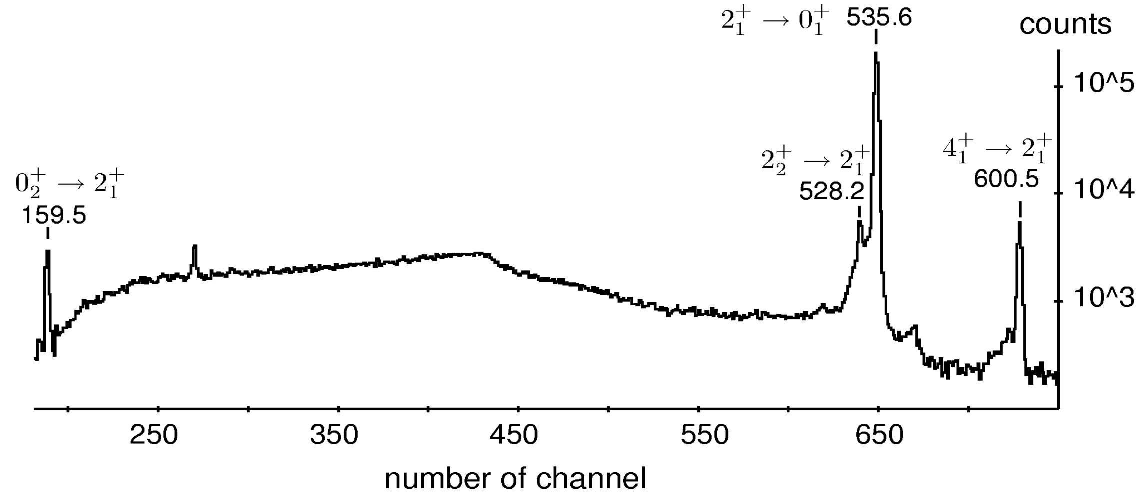

Fig 1. Low-energy part of the γ – ray spectrum observed in the ^{40}Ar + ^{100}Mo experiment

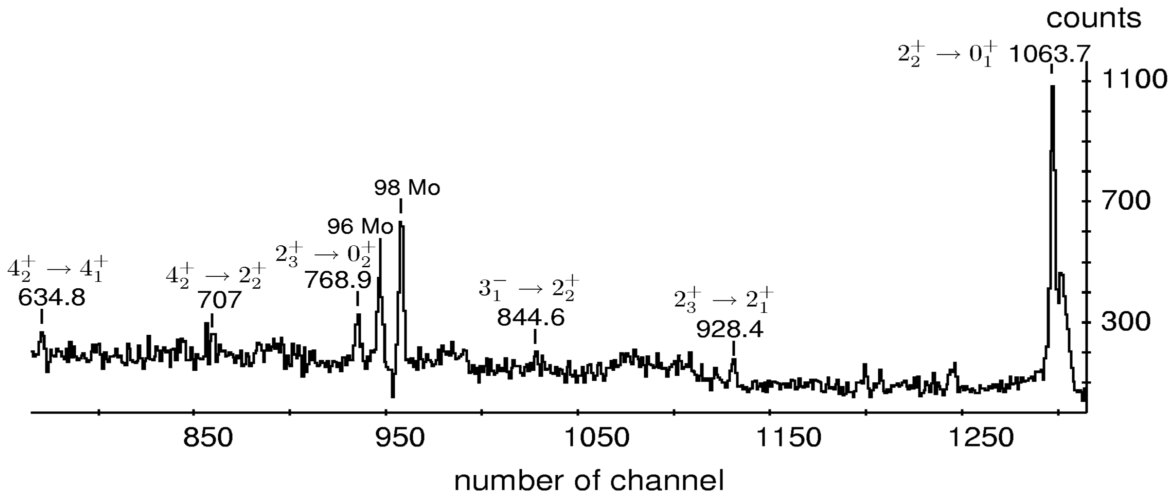

Fig 2. High-energy part of the γ – ray spectrum observed in the ^{40}Ar + ^{100}Mo experiment

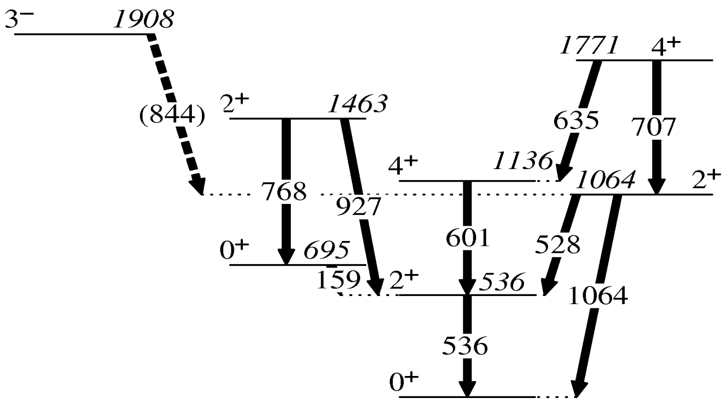

Fig 3. Low-lying excited states of the ^{100}Mo nucleus.

The level scheme, showing the transitions observed in the experiment, is presented in Fig.3. The energy of the 0^+_2 state is very close to the one of the first excited state 2^+_1, while the theoretical collective calculations [4] predict much higher energy for the 0^+_2 state. A weak $3^- \rightarrow 2^+_2$ line was observed, indicating the population of a negative-parity state 3^-. One should note that no negative-parity states were populated during previous experiments with neighbouring isotopes of molibdenum: ^{96}Mo and ^{98}Mo.

The presented excited level scheme of ^{100}Mo is much more extended as compared to the one observed in Coulomb excitation of ^{96}Mo and ^{98}Mo. The collected data is being now analyzed. We expect to obtain shape parameters of the ^{100}Mo nucleus in both 0^+ states as soon as the complete set of matrix elements of the electromagnetic transitions is determined. The analysis of the collected experimental data on ^{100}Mo should help to understand the nature of the first excited state in ^{98}Mo. The description of the preliminary results is published in the International Journal of Modern Physics E.

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2. Shape coexistence in ^{96}Mo studied via Coulomb excitation

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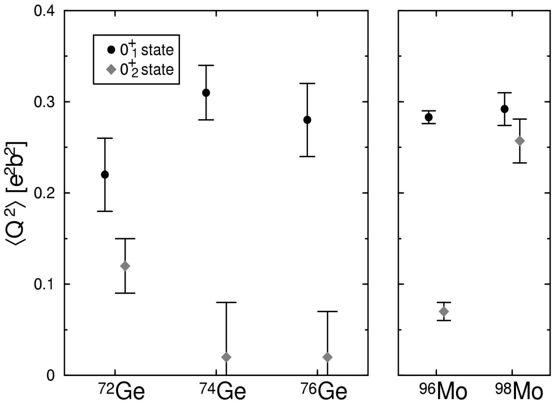
Isotopes of molybdenum with neutron number close to 50 have spherical shape and single-particle structure. As the number of neutrons increases, collective modes of excitation become visible. In the $^{96\text{-}100}$Mo isotopes both single-particle and collective excitations compete, resulting in the unusual features of these nuclei. ^{98}Mo is one of four stable even-even nuclei heavier than calcium, having the first excited state of spin and parity 0^+. The nature of such low-lying 0^+ states in Mo isotopes is still unknown. Previous experiments [1] proved that the ground state of ^{98}Mo is triaxial, while the first excited state is prolate. As a continuation of this study, experiments of Coulomb excitation of ^{96}Mo were performed. Two experiments were done at Heavy Ion Laboratory with ^{20}Ne and ^{40}Ar beams and a ^{96}Mo target, the third one at Japan Atomic Energy Research Institute (JAERI, Tokai) with a ^{96}Mo beam and a ^{nat}Pb target. Over 20 reduced matrix elements connecting the 8 low-lying levels of ^{96}Mo have been detemined using the GOSIA code [2]. The quadrupole sum rules approach was used to determine the shape parameters of the ground state and of the first excited 0^+ state. Fig. 1 shows the quadrupole deformation parameter $<Q^2>$ calculated for both states in ^{96,98}Mo, compared to available data from selected Ge isotopes. For ^{96}Mo the ground state is deformed, and the first excited 0^+ is almost spherical, which is similar to the case of Ge isotopes. For ^{98}Mo its overall deformation is similar for both 0^+ states.

Fig. 1. Mean values of the deformation parameter $<Q^2>$ found for the two first 0^+ states in ^{96,98}Mo and ^{72,74,76}Ge.



Most of the properties of low-lying states of ^{96}Mo and ^{100}Mo can be reproduced quite well within the collective model based on the microscopic collective Bohr Hamiltonian modified in order to include the coupling of quadrupole degrees of freedom and collective pairing vibrations [3], but the interpretation of the excited 0^+ states seems to be more complicated. The point is, that ^{96}Mo, ^{100}Mo are deremined by the same shell model structure as the ^{98}Mo [4] with valence neutrons on the $g_{9/2}$ subshell while two valence protons occupy the $g_{7/2}$ one. It could be expected that the "deuteron-like" proton-neutron pairs with the orbital momentum L=0, spin S =1 and the isospin T=0 could be easily formed also in A=96 and A=100 Mo isotopes. In fact, the same boson scheme [5] describing the collective 0^+ and 1^+ excitations of an even nucleus in terms of the system of interacting isoscalar L=0, S=1, T=0 bosons (corresponding to the "deuteron-like" nucleon pairs) and isovector L=0, S=0, T=1 bosons (representing pairs of identical particles) was as succesfully applied to A=96 and A=100 isobars [6] as to A=98 nuclei [4]. Up to now only the energies of the 0^+ and 1^+ excitations were reproduced within the mentioned boson scheme but the agreement obtained in the complete absence of quadrupole degrees of freedom shows that the proton-neutron pairing interaction can modify the behaviour of a nucleus through the process of creating "deuteron-like" or α clusters.

This work was partly supported by the Polish State Committee for Scientific Research (KBN Grants No. 2 P03B 007 25).

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3. Giant Dipole Radiation and Isospin Mixing in ^{36}Ar Nuclei

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It is well known that the isospin mixing in self-conjugate nuclei may be studied through the statistical decay of the Giant Dipole Resonance (GDR) built on excited states formed in heavy-ion fusion reactions [1,2]. Nevertheless, the degree of isospin mixing at high excitation has been determined only for few nuclei.

In this contribution, we present studies concerning the isospin mixing in the ^{36}Ar compound nuclei at the excitation energy of 49.1 MeV. It is a continuation of our previous work for ^{32}S compound nuclei [3]. The self-conjugate nuclei of ^{36}Ar, were formed in the entrance channel with the isospin T=0. The ^{12}C beam of 51 MeV from the Warsaw Cyclotron at the Heavy Ion Laboratory of Warsaw University and the self-supporting targets of ^{24}Mg (isotopic 99.94%) were used. Gamma rays from the decay of the compound nuclei studied were measured with the multidetector JANOSIK set-up [4]. JANOSIK consists of a 25.4cm×29cm cylindrical NaI (Tl) crystal surrounded by an active plastic anticoincidence shield and passive ^{6}LiH and Pb shields. The gain of the NaI spectrometer was monitored during the experiment by a LED pulser. The neutron discrimination achieved by the time-of-flight technique with the time resolution of 4.5 ns allowed for very good separation of the events caused by γ-rays produced in the target from these caused by neutrons. Light charged particles have been detected with a Si-ball with twelve triple Si telescopes placed in the vacuum chamber around the target at the angles from 39° to 135°.

Measured high-energy γ-ray spectrum from the decay of ^{36}Ar is presented in Fig. 1. Gamma-ray cross sections were calculated within the statistical model by using modified version of the code CASCADE which included the effect of isospin. Statistical model calculations were performed independently for several values of an isospin mixing spreading width $\Gamma_{>}^{\downarrow}$, assuming that $\Gamma_{>}^{\downarrow}$ is the same in neighboring nuclei at a given excitation energy. The parameters of the GDR strength function were treated as variables in the least-square fitting of the calculated spectrum to the experimental data. The best fits were obtained with a double Lorentzian GDR strength function, with the following GDR parameters: the strength S_{GDR}, the energy E_{GDR} and width Γ_{GDR} for each GDR component. For $\Gamma_{>}^{\downarrow}$ below 70 keV no reasonable fit could be obtained. The measured spectrum is well reproduced (Fig. 1) for the GDR parameters: $S_1= 0.4$, $S_2= 0.6$, $E_1= 16.8$ MeV, $E_2= 22.00$ MeV, $\Gamma_1= 9.4 \pm 0.2$ MeV, $\Gamma_2= 5.6 \pm 0.4$ MeV and the isospin mixing probability $\alpha_{<}^{2} = 0.07 \pm 0.03$. Extracted value of isospin mixing $\alpha_{<}^{2}$ corresponds to the isospin mixing spreading width $\Gamma_{>}^{\downarrow}= 90$ keV$\pm$ 40 keV.

To verify if the analysis of the high-energy γ-ray spectrum from the decay of ^{36}Ar nuclei was correct, we extracted the GDR parameters by the same procedure for another nucleus, ^{39}K, close in mass and formed at similar excitation energy in the ^{12}C + ^{27}Al reaction [5], but with isospin $T \neq 0$. The γ-ray yield in nuclei with $N \neq Z$ does not depend much on isospin mixing. It would allow to determine the GDR parameters in those nuclei in a way less dependent on the isospin mixing. Gamma-ray cross sections were calculated for the ^{39}K compound nuclei at two values of isospin mixing probability $\alpha_{<}^{2} = 0$ and 0.07. The fitted GDR parameters are almost the same for two values of $\alpha_{<}^{2}$, thus proving the weak dependence of the GDR parameters on isospin mixing in $N \neq Z$ nuclei.

In order to increase the sensitivity to the isospin mixing we have analyzed the ratios of γ-ray cross-sections for the reactions forming ^{36}Ar (N=Z) and ^{39}K (N≠Z) nuclei for the measured and calculated yields. Calculations for several values of isospin mixing parameters: $\alpha_{<}^{2} = 0$ (no mixing), $\alpha_{<}^{2} = 0.07$ and $\alpha_{<}^{2} = 0.5$ (full mixing) are shown in Fig. 1. As it can be seen, the best reproduction of the ratio of the experimental data is obtained at $\alpha_{<}^{2} = 0.07$.

At the end of the year we have also measured the $^{12}C + {}^{25}Mg$ reaction populating neighboring ^{37}Ar compound nuclei at similar excitation energy, but with isospin $T \neq 0$. It will allow us to determine the GDR parameters in nuclei very close in mass to ^{36}Ar but in a way less dependent on the isospin mixing than for ^{36}Ar itself. Thus, we would extract the amount of isospin mixing in the $T=0$ ^{36}Ar compound nuclei by comparison of the measured and calculated ratios of γ-ray cross-sections (above $E_\gamma = 15$ MeV) for reactions in which $T=0$ and $T \neq 0$ neighboring compound nuclei were formed at similar excitation energies with presumably the same GDR parameters.

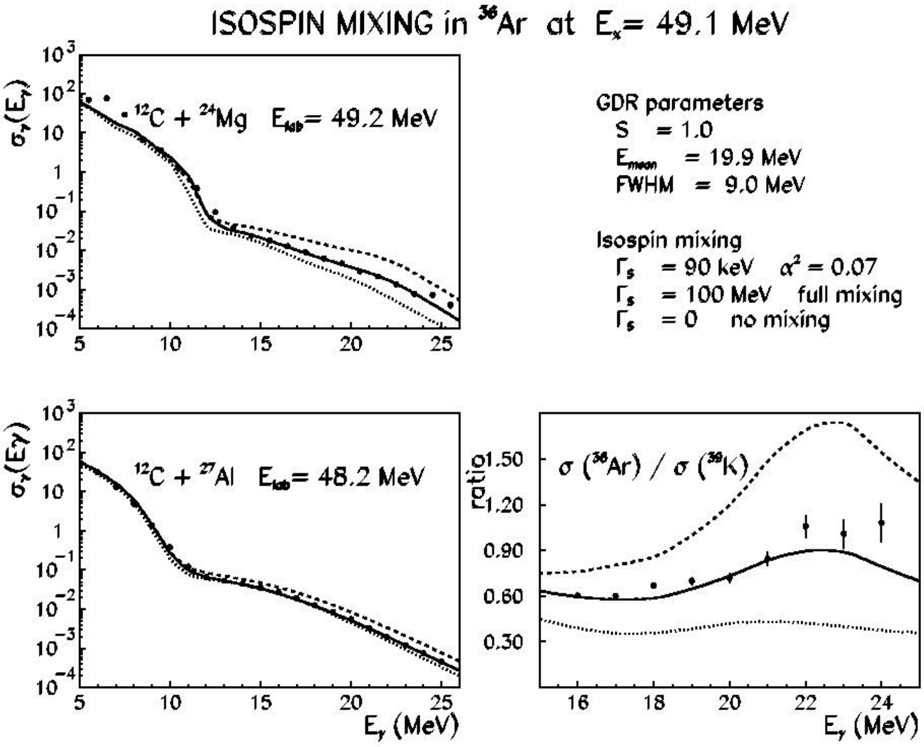

Fig. 1. Spectra of γ-rays emitted during the decay of ^{36}Ar (upper-left) and ^{39}K (bottom-left) and the ratios of these spectra (bottom-right). The curves - CASCADE fit with different isospin mixing spreading width: $\Gamma_>^{\downarrow}=0$ - no mixing (lowest curve), $\Gamma_>^{\downarrow}= 90$ keV (middle curve) and $\Gamma_>^{\downarrow}= 100$ MeV- full mixing (upper curve).

This work was partly supported by the Polish State Committee for Scientific Research (KBN Grants No. 2 P03B 030 22).

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4. ^{20}Ne+^{12}C reaction at 5 and 9 MeV/A studied at the Warsaw Cyclotron

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Measurements for ^{20}Ne+^{12}C reaction at 5.2 and 9.2 MeV/A projectile energy have been recently performed in order to examine reaction mechanism and to extract the parameters of Giant Dipole Resonance (GDR) excited in compound nucleus formed.

For light-ion induced reactions at low projectile energies up to about 5-6 MeV/A the only mechanism of a compound nucleus creation is the complete fusion reaction (CF) and the γ-quanta as well as light-charged particle emission is due to purely statistical decay of the compound nucleus (CN). An experiment for ^{20}Ne+^{12}C reaction at 5.2 MeV/A has been performed to confirm the statistical character of γ-quanta and particle emission from the thermalized source.

At projectile energies above 6 MeV/A, besides complete fusion reaction, also the incomplete fusion reaction (ICF) mechanism occurs and other processes of the bremsstrahlung radiation (BR) and preequilibrium nucleon emission (PREEQ) become significant. The study of the ^{20}Ne+^{12}C reaction performed at 9.2 MeV/A was intended to examine the mechanism of compound nucleus creation (CF, ICF) and additional emission processes (PREEQ, BR). The goal of the present studies was to indicate the importance of all the processes present in the reaction mechanism for the extraction of GDR parameters, especially the width.

Present experiments have been undertaken by using the ^{20}Ne cyclotron beams of 5.2 MeV/A and 9.2 MeV/A energies at the Heavy-Ion Laboratory of Warsaw University. Self-supporting target foils of 2-3 mg/cm^2 of carbon were used. Emitted γ-ray spectra have been collected with NaI(Tl) spectrometer consisting of one NaI(Tl) detector and surrounding shields which suppress the background. The neutron-gamma discrimination achieved by the standard time-of-flight technique with the time resolution of 4.5 ns was good enough to allow for the separation of the events caused by neutron from these caused by γ-quanta. The NaI(Tl) detector was calibrated by using ^{244}Cm/^{13}C source and the 15.1 MeV line from ^{11}B+D resonant reaction.

Light particles were measured with the new Si-ball consisting of 12 triple telescopes placed in a metal sphere at angles in the range of 45 $^{\circ}$ -135 $^{\circ}$ with respect to the beam axis, which allowed for the angular distribution measurement. Each telescope consisted of three silicon detectors: 2 surface barrier detectors of thickness of 10μm and 130μm, and one lithium-drifted detector Si(Li) with thickness of 10mm. They were calibrated using ^{241}Am alpha source.

The measurements for the γ-quanta and light-charged particles at lower beam energy were inclusive ones. Spectra for γ-quanta, protons (undistinguished from deuterons) and alpha particles have been collected. Spectra for charged particles are presented in Fig.1. The data are compared to the theoretical calculations performed with CASCADE code which included the effect of isospin, and used the Reisdorf level density description, and a spin-dependent moment of inertia in agreement with the rotating liquid drop model, defining yrast line. Gamma-ray spectrum is well described by the statistical model calculations assuming the purely statistical emission from a formed compound nucleus of ^{32}S of initial excitation energy of 58.3 MeV. GDR parameters are found to be respectively: E_{GDR} = 17.4 MeV, Γ_{GDR} = 13.3 MeV, S_{GDR} = 0.9 [1]. However proton and alpha-particle spectra are not well reproduced by reported calculations, especially at forward angles. Particle data collected at each angle were normalized to the number of events collected by monitor placed at 39° with respect to the beam axis and then the spectra were normalized to the theoretical CASCADE calculations. The calculations have been performed in nucleus-nucleus center-of-mass system and then transformed to the laboratory system via Lorentz transformation using LORENT code. Proton spectra have been calculated together with the deuteron spectra and summed (for each angle independently), since the experimental ones have been the sum of protons and deuterons as well (see Fig.1). The theoretical spectra for alpha particles together with the ^{3}He-particle have also been taken into account (Fig.1). The differences between the esperimental data and theoretical calculations may be caused by non-statistical effects presence or by not well adjusted parameters assumed in the calculations.

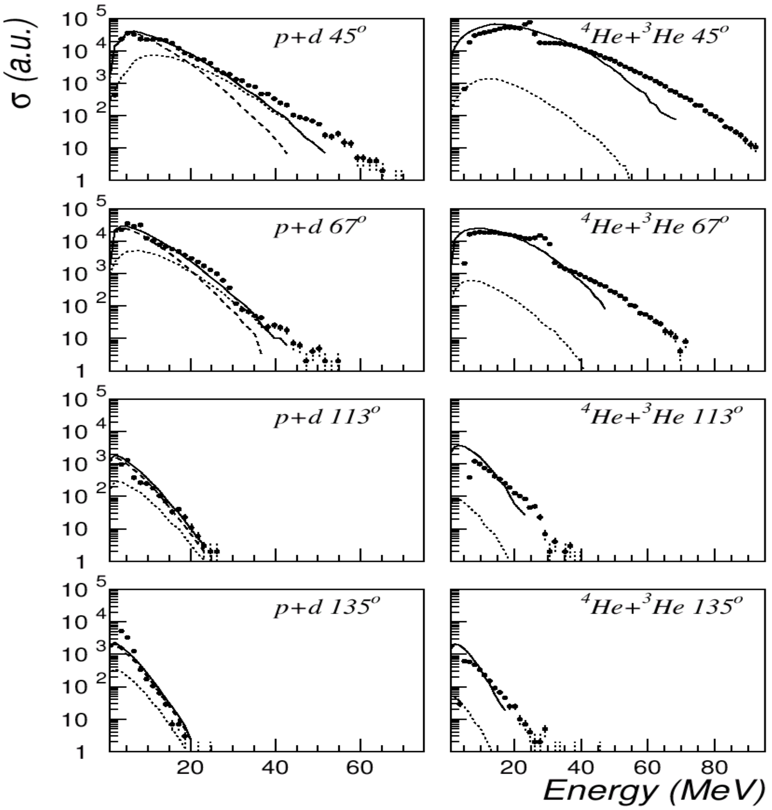

Fig. 1. Proton and alpha particle spectra measured in ^{20}Ne+^{12}C reaction at 5.2 MeV/A. Spectra are compared to the statistical calculations performed with CASCADE code. Straight line - summed spectra for particles: *p+d* and $^{3}He+^{4}He$, dashed line – spectra for *p* and ^{4}He, dotted line - spectra for *d* and ^{3}He, respectively.

For the higher beam energy particles were measured in coincidence with high energy γ-quanta. Inclusive high-energy γ-ray spectrum for this reaction has been collected in an earlier experiment [1] and exclusive one in the present experiment. The CASIBRFIT code was used to fit the inclusive spectra assuming the influence of preequillibrium emission and incomplete fusion reaction mechanism and the bremmstrahlung radiation presence.

The γ-ray spectrum was reproduced by these calculations when the decay of the average compound nucleus of ^{30}P at excitation energy of 54.8 MeV was assumed, while in the case of pure complete fusion the ^{32}S would have been formed at 87.8 MeV of excitation energy [1]. It indicates the importance of preequilibrium emission and incomplete fusion reaction mechanism assumption. The particle spectra for protons and alpha particles analyzed in coincidence with γ-quanta of energies $E_{\gamma} > 7$ MeV collected at 90^{o} are still under analysis now.

This work was partly supported by the Polish State Committee for Scientific Research (KBN Grants No. 2 P03B 030 22)

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5. L-subshell ionisation of Ta, Os, and U atoms by S ions with energy of 0.3 – 3.7 MeV/amu

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The present work is a continuation of our previous investigations of the L shell ionisation induced by heavy ions with $Z_1 \geq 6$ in selected heavy elements ($Z_2 > 70$). We study L subshell ionisation of Ta, Os, and U atoms by S^{q+} ions in the energy range 9.6 – 120 MeV. The investigations cover the range of atomic number ratios $0.174 < Z_1/Z_2 < 0.219$ and the reduced velocities $0.11 < v_1/v_2 < 0.46$, where v_1 and v_2 denote the projectiles and target L-shell electron velocities.

Sulphur ions of incident energies 9.6 – 41.6 MeV and charge states 4+, 6+, 7+ were obtained from EN tandem accelerator at the Erlangen-Nürnberg University and of energies 64, 79, 99, and 120 MeV and charge states 13+, and 14+ from the U-200P cyclotron at the Heavy Ion Laboratory (HIL) of Warsaw University. The targets were irradiated with typical beam currents of 1-10 nA in Erlangen tandem accelerator and about 1-2 nA in Warsaw Cyclotron. The same apparatus i.e. target chamber, x-ray Si(Li) detector, acquisition system, surface barrier Si detector, have been used in these two experiments. Also the geometry of measurement was the same.

The L-x-rays excited in thin Ta, Os, and U targets (10-40 $\mu g/cm^2$ evaporated on thin carbon backings) were measured by a Si(Li) detector placed at 90° to the beam direction outside the target chamber. The x-ray spectrometer energy resolution was measured to be about 200 eV at 6.4 keV. The counting rate under the full x-ray spectrum was always less than 1000 counts per second, and the instrumental dead time was between 1 and 3%. The L-x-ray production cross section was normalised to the elastically scattered projectiles measured by Si detector kept at angles of 150° and 20°.

In order to study the L-subshell ionisation cross sections, the x-ray production cross sections for $L_{\alpha1,2}(L_3\text{-}M_{4,5})$, $L_{\gamma1}(L_2\text{-}N_4)$, $L_{\gamma2}(L_1\text{-}N_2)$ and $L_{\gamma3}(L_1\text{-}N_3)$ x-ray transitions were obtained.

The measured L x-ray spectra were analyzed using the recently proposed method [1-3] accounting for the multiple-ionization effects, such as x-ray line shifting and broadening which enable one to obtain the ionization probabilities for outer shells. The ionization cross sections of L_1, L_2, and L_3 subshells have been obtained from the measured x-ray production cross sections for resolved $L_{\alpha1,2}$, $L_{\gamma1}$, and $L_{\gamma2,3}$ transitions using the L shell fluorescence and Coster–Kronig yields being substantially modified by the multiple ionization in the M and N shells. In particular, the effects of closing the strong L_1–$L_3M_{4,5}$ Coster–Kronig transitions in multiple-ionized atoms were evidenced and taken into consideration [4].

The experimental ionisation cross section values for the L_1, L_2, and L_3 subshells have been compared with the predictions of the SemiClassical Approximation within the United-Atom limit (SCA–UA) [5] and the ECUSAR (projectile Energy loss, Coulomb deflection from straight–line, United or Separated Atom binding energy, Relativistically increased mass effect) [6,7] theories for direct ionisation and for the electron capture (EC) process. The ECUSAR approximations is a modified version of the well known ECPSSR theory [6].

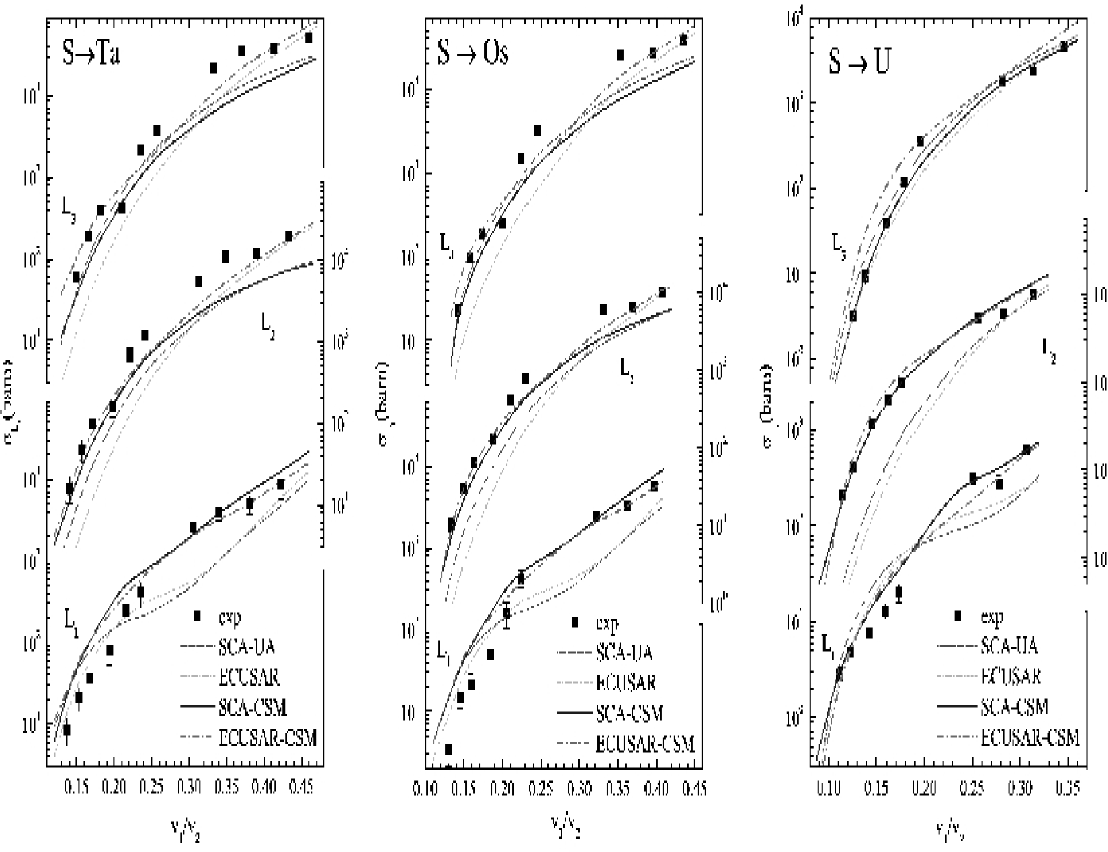

Fig. 1. The measured ionisation cross sections for L_1, L_2, and L_3 subshells of Ta, Os and U atoms bombarded by S-ions plotted versus relative projectile to L–shell electron velocity v_1/v_2, compared to the predictions of the SCA–UA, and the ECUSAR theories, as well as their modifications accounting for the coupling effects, namely, the SCA–CSM and ECUSAR–CSM calculations.

In order to account for the L-subshell coupling effects, the "coupled–subshells model" CSM of Sarkadi et al. [8] was used. Both approaches, when modified for coupling effect, are in better agreement with the data as it is presented on the Fig. 1. The predictions of the SCA–CSM calculations reproduce the experimental L subshell ionisation cross sections quite well, particularly when it is further modified to include the saturation of the binding effect [9]. Owing to the ECUSAR approximation we have found that the electron capture process practically does not play any important role in L-subshells cross section values.

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6. “Dynamic” background of γ–rays created by ^{16}O ion beam

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In γ–ray spectrometry with charged-particle beams (in-beam experiments) there usually are several sources of background radiation. The most common of them can be listed [1] as follows:

(i) “Static” laboratory background (i.e., when no beam is present).
(ii) “Dynamic” laboratory background, due to the beam hitting slits, collimators, beam dump, etc., and scattering of beam by the target onto chamber and beam-line walls, target frame etc.
(iii) Radiation caused by neutrons in the γ–ray detector itself.
(iv) Radiations from radioactive species produced in the detector surroundings and elsewhere in the laboratory during the experiment.
(v) γ–rays produced in (n,n’) reactions by neutrons from (projectile,xn) type of reaction in the target.

One of the most important sources of background is due to item (ii) caused by beam hitting of the detector surroundings especially aluminum target frame or chambers. We report here the case of the ^{16}O ion beam bombarding ^{27}Al which can efficiently contaminate the reaction of interest (e.g. experiments with ^{16}O beam on ^{98}Mo or ^{107,109}Ag targets). However, the high energy γ–rays can also serve as the energy calibration points. In the contaminant reaction considered here the ^{34}S and ^{38}Ar nuclides are intensively produced due to beam hitting Al target frame and chamber parts:

$$\begin{array}{ll} & \rightarrow {}^{38}\mathrm{Ar} + \alpha p \\ {}^{16}\mathrm{O} + {}^{27}\mathrm{Al} \rightarrow {}^{43}\mathrm{Sc}\ (\mathrm{CB}) & \\ & \rightarrow {}^{34}\mathrm{S} + 2\alpha p \end{array}$$

Examples of coincidence spectra illustrating the main features of observed as a contamination lines are shown in Fig.1. It is true that typically the majority of the observed γ–rays can be identified on the basis of coincidence measurements (cf. coincidence finder [2]) and known level schemes [3]. Nevertheless, there often are weak lines, which either are not in coincidence with other lines or are mixed with the γ lines presently studied. Therefore, the problem of identifying such lines occurs repeatedly and that is the reason of showing the present contribution. It is interesting that strongest **experimentally** observed in the reaction ^{27}Al(^{16}O,xnypγ) channels are **αp and 2αp**, while **calculated** [4] cross sections favor rather **pnα and pn2α** decays.

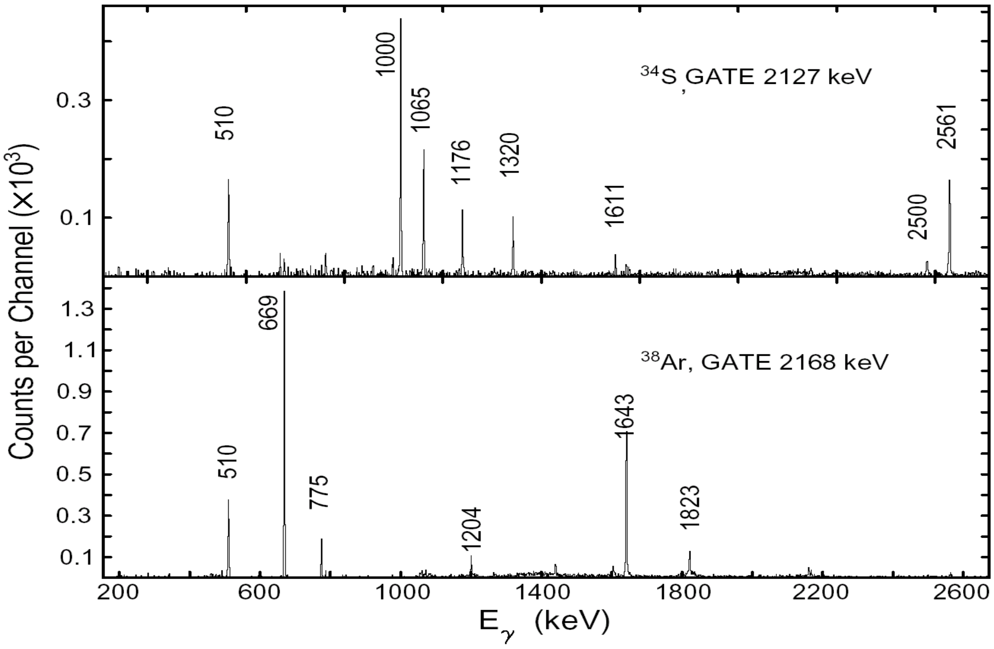

Fig. 1. Examples of coincidence spectra obtained due to the ^{27}Al + ^{16}O reaction at a bombarding energy of 80 MeV. The upper panel shows the gate on 2127 keV γ–ray in ^{34}S nucleus (2αp reaction channel). The lower panel shows the gate on 2168 keV γ–ray in ^{38}Ar nucleus (αp reaction channel).

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7. Entry line and angular-momentum transfer studies for A ~ 110 in heavy-ion fusion-evaporation reactions

J.Kownacki, M.Kowalczyk[1], J.Mierzejewski[1], M.Wolińska-Cichocka[2], A.A.Pasternak[3], J.Perkowski[4], M.Kisieliński[5], E.Ruchowska[5], R.Lieder[6], M.Palacz, W.Męczyński[7], J.Styczeń[7], Ch.Droste[1], E.Grodner[1], T.Morek[1], J.Srebrny[1], J.Iwanicki, A.Król[4]

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The OSIRIS-II array consisting of 12 Compton suppressed HPGe detectors equipped with an inner BGO ball (48-elements, each connected to separate ADC) for sum-energy and γ–ray multiplicity measurements has been employed to study the ^{16}O + ^{98}Mo reaction. Average γ–ray multiplicities were measured in coincidence with discrete γ–rays from the residual nuclei. The fusion–evaporation reactions lead to the population of "entry states", i.e. the states characterized by the excitation energy E^* and spin I, in which the residual nuclei are left after particle evaporation.

It is the aim of this study to investigate the shape changes of the nucleus above the yrast line, i.e. to study a general trends in the decays preceding the yrast region of discrete transitions. The investigations are focused on the compound systems around A=110, where significant deformations are expected at higher angular momentum, i.e. in a region where several shape–coexisting deformed (intruder bands) and spherical structures are predicted by theory [1–3] and observed in experiment, e.g. [4–6]. The data are used to construct the entry line with the excitation energy at each point given by:

$$E_x = < M_\gamma >_\Sigma * < E_\gamma >_\Sigma \tag{1}$$

while the measured multiplicity can be related to the average spin, $< I >$, in the entrance channel by the following commonly used expression (see e.g. [3,4]):

$$< I > \approx (\Delta L) * (< M > - s) + I_0 \tag{2}$$

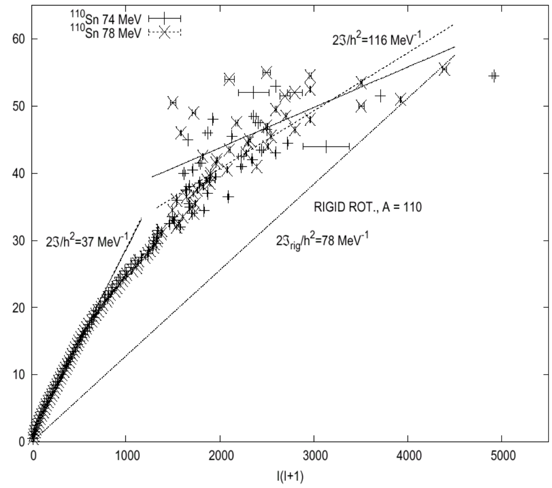

Fig. 1. The entry line from the reaction $^{16}O + ^{98}Mo \rightarrow ^{114}Sn^*$ measured at the bombarding energies of 74 and 78 MeV, respectively. The curves are corrected for measured k (fold) – to M – (multiplicity) transformation and detector-to-detector scattering

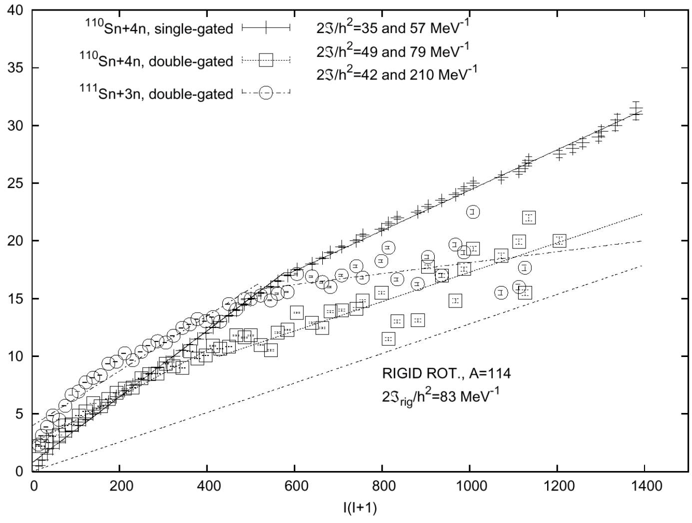

Fig. 2. Entry lines for 4n and 3n channels from the $^{16}O + ^{98}Mo \rightarrow ^{114}Sn^*$ reaction measured at 78 MeV. The channel selection was done by setting the gates on two (or one in upper curve with crosses) most intensive γ–rays in each level scheme.

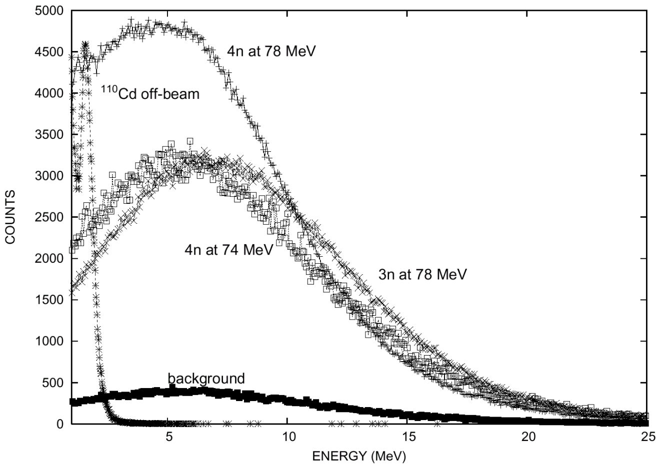

Fig. 3. Total energy projections for xnyp reaction channels as measured at 74 and 78 bombarding energy.

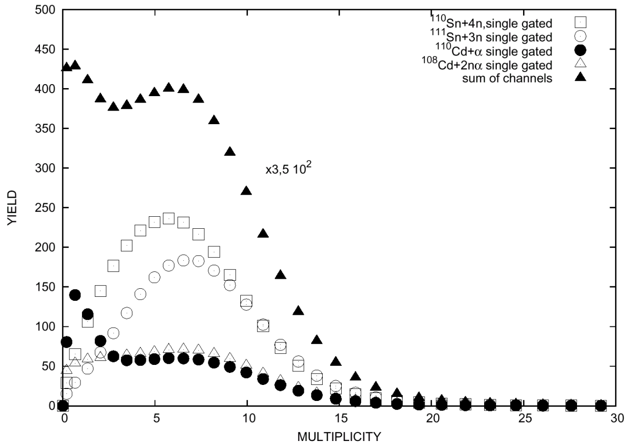

Fig. 4. Multiplicity projections for xnyp reaction channels.

where I_0 is the spin of the final state (ground-state spin) of the γ–ray cascade, and ΔL stands for the average angular momentum removed by one yrast transition. For example, from the analysis of ^{110}Sn data [7] an average ΔL changes slightly with the number of considered states from 2.0 (two levels included) to 1.4 ($\approx$ 40 levels included). The angular momentum dissipation in the γ–ray cascades characterized by $< M >$ is assumed to be produced by s statistical transitions and $< M > - s$ stretched quadrupole transitions.

The present experiment reveals the information on strongly populated residual nuclei, i.e. ^{110}Sn, ^{111}Sn,^{111}In, ^{110}In, ^{110}Cd and ^{108}Cd in the reaction studied, which are due to 4n, 3n, p2n, p3n, α and 2nα channels, respectively.

The analysis of data is in progress showing that the entry region studies can provide information on details of the decay pattern from selected high spin regions. Attached figures give the examples of entry line constructed for two bombarding energies and different reaction channels in the reaction studied and the projection of total energy and multiplicity distributions. Interesting results are observed in Fig.2, where the experimental points (when double-gated) are consistent with the slope of rigid rotor (78 MeV^{-1}) in the spin region I = 20-35.

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8. Lifetimes in supposed chiral bands of ^{128}Cs – comparison with ^{132}La

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The aim of our experiments presented below are the lifetime measurements in nuclei from the A=130 region where chiral phenomena are expected [1-3]. Till now the information about lifetime of levels belonging to chiral bands is very scarce. For the first time such measurements have been performed recently by our group for ^{132}La [4]. The significant differences between values of the B(E2) reduced transition probabilities in the yrast band built on the $\pi h_{11/2}\otimes\nu h_{11/2}^{-1}$ configuration and transition probabilities in the side band have been found. This result is in disagreement with theoretical predictions [5]. For this reason our lifetime studies have been extended to neighbouring nuclei. This report presents results of lifetime measurements of the ^{128}Cs levels being candidates for chiral bands built on the $\pi h_{11/2}\otimes\nu h_{11/2}^{-1}$ [1-3].

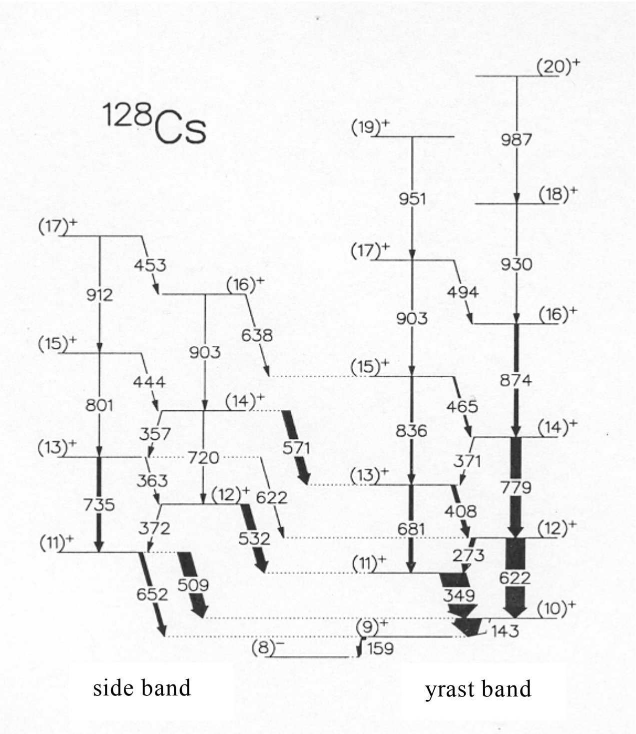

Fig.1. Partial level scheme of ^{128}Cs [2]. Only the yrast and partner bands built on the $\pi h_{11/2}\otimes\nu h_{11/2}^{-1}$ configuration are shown.

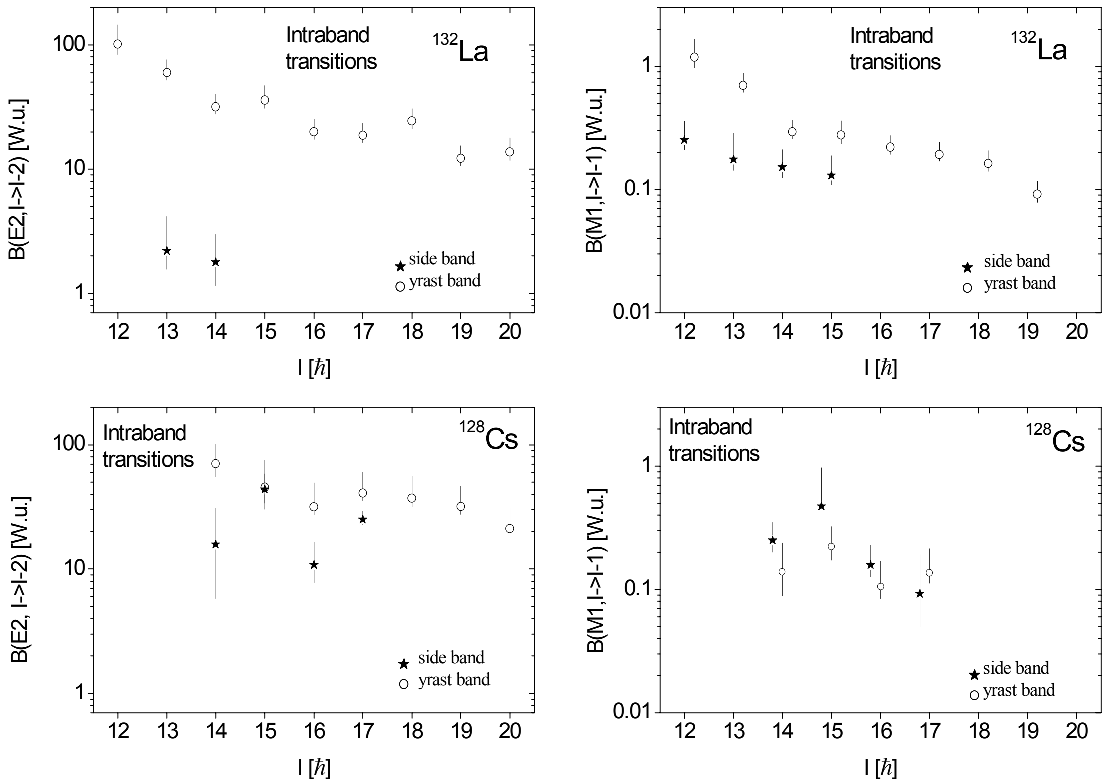

Fig. 2. Reduced transition probabilities in the side and yrast bands versus spin. Top-left: B(E2) values in ^{132}La. Top-right: B(M1) values in ^{132}La. Bottom-left and bottom-right: B(E2) and B(M1) values for ^{128}Cs, respectively.

The relevant part of the level scheme of ^{128}Cs is shown in Fig. 1. The energy splitting between members of the yrast and side bands built on this configuration in ^{128}Cs is about $100 \div 150$ keV, about two times smaller than in the analogous bands in ^{132}La. From this point of view these bands in the ^{128}Cs nucleus seem to be better candidates for chiral bands than similar pair of bands in ^{132}La.

Lifetimes of the high spin states in ^{128}Cs have been investigated via the ^{122}Sn(^{10}B,4n)^{128}Cs reaction using the Doppler Shift Attenuation method. 55 MeV ^{10}B beam was provided by the Warsaw U-200P cyclotron. The measurements were performed using the OSIRIS II multidetector array consisting of 10 Compton-suppressed HPGe detectors. Lifetimes of the excited levels were determined from the γ-line shape of deexciting transitions using procedure and computer program developed by A. Pasternak [6,7].

Lifetimes of thirteen levels in the supposed chiral partner bands in ^{132}La have been already determined in our previous studies [4,8]. In the present experiment the lifetimes of seven levels in bands built on the $\pi h_{11/2} \otimes \nu h_{11/2}^{-1}$ configuration in the ^{128}Cs nucleus have been found. The deduced values of the B(E2) and B(M1) reduced transition probabilities in both nuclei are presented in Fig. 2.

The preliminary results for ^{128}Cs show that the B(E2) values for the side band are about three times smaller than those in the yrast band. This observation is in striking contrast with results obtained for ^{132}La nucleus where much larger differences (about $20 \div 30$ times) between the B(E2) values in the side and yrast bands were found. It is worth noting that the values of B(M1) for the intraband transitions in both bands in the ^{128}Cs and ^{132}La nuclei are not so dramatically different (Fig. 2).

A comparison of the electromagnetic properties and energy splittings between the side and yrast bands built on the $\pi h_{11/2}\otimes\nu h_{11/2}^{-1}$ configuration in ^{128}Cs and ^{132}La suggests that ^{128}Cs is a better candidate for the presence of chiral bands than ^{132}La. The ^{132}La presents a challenge for further investigations, since the question whether we really observe the chiral bands in this nucleus remains open.

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9. Status and development of the OSIRIS-II project destined for "in-beam" experiments

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Apparatus

Presently, the OSIRIS-II array consists of 12 HPGe detectors equipped with 12 anticompton BGO shields (ACS), and the γ-ray multiplicity filter built of 48 elements BGO detectors in 4π geometry. Besides the above mentioned and used in the last several experiments array, the 4 sector HPGe polarimeter and the 28 elements SiBall are available. The HPGe detectors with ACS are located in a solid mechanical wheel arrangement, which can be rotated and situated in the perpendicular or parallel plane relative to the beam axis. At present the 6 HPGe's are

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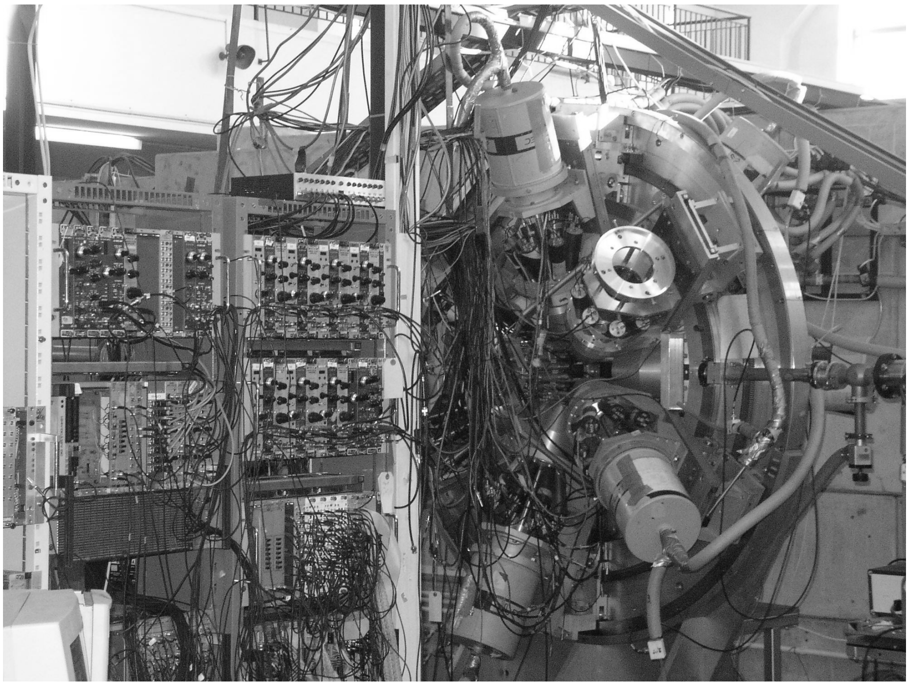
positioned on one side of parallel plane through the beam axis, while the other 6 HPGE's+ACS are placed at the opposite side of the wheel at different angles with respect to the beam axis (see photo). The 3 new Philips 16 ADC's were connected to each of 48 BGO elements, which constitute the 4π multiplicity filter being a part of the OSIRIS-II detector array. The updated electronics block scheme of the OSIRIS-II array is included below (Fig.1).



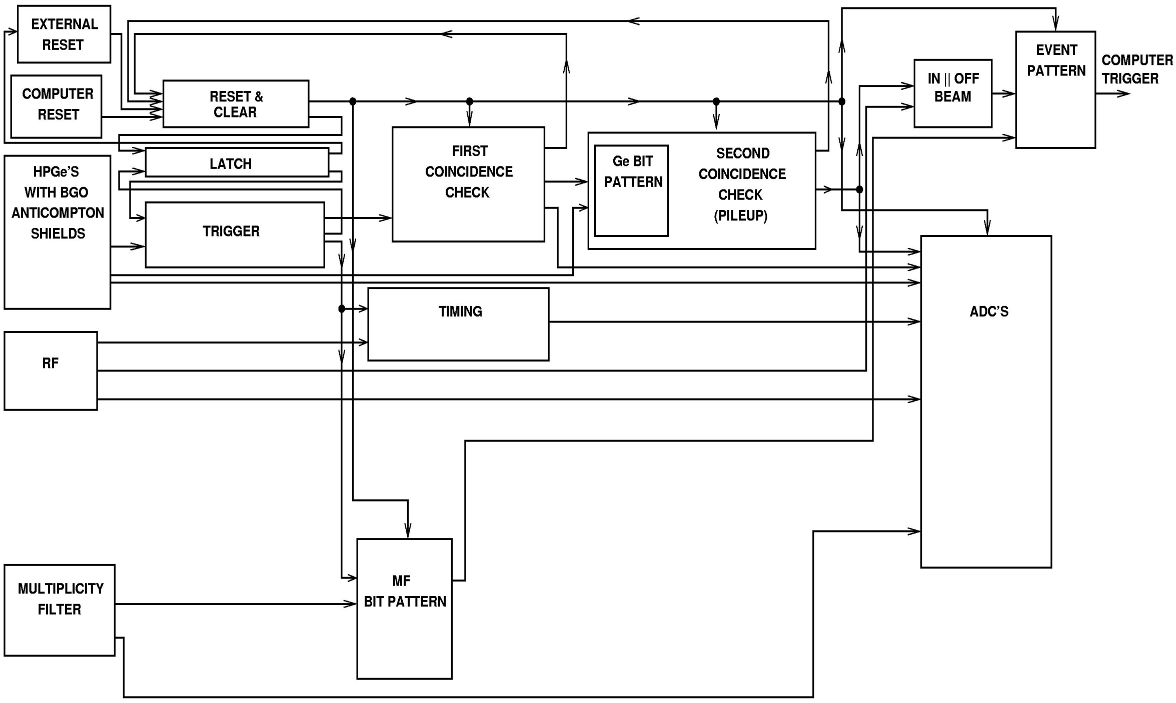


Fig. 1. The updated electronics block scheme of the OSIRIS-II array

The OSIRIS-II project started in 1997 at HIL on the base of cooperation agreement between the KFA, Jülich (8 HPGe detectors and 6 AC shields) and HIL of the Warsaw

University. Two AC shields, a property of Institute of Nuclear Physics, Kraków are also installed in the OSIRIS-II array. It is worth to note that two detectors were bought thanks to the State Committee for Scientific Research grants (2865/IA/115/98 and 3256/IA/115/99) obtained for the extension of the equipment. In 2004 additional 4 HPGe detectors and 2 AC shields belonging to NORDBALL collaboration were delivered from Jyväskylä University. Also in 2004 three HPGe detectors were donated from KFA, Jülich from old OSIRIS-I detector pool. Future plan (and dream) is to extend our HPGe detectors array ("POLNOSIR") to the dimension of at least NORDBALL array and we are making effort to realize this.

Annealing of the HPGe detectors.

During last year 7 HPGe detectors were renovated, i.e. heated and pumped off to improve the energy resolution and repair aging detectors for vacuum leaks. The membrane rotary pump belonging to the annealing stand was replaced by new one after 6500 hours of permanent work.

Experiments

One of the main topics of our experimental work concerns the life time measurements of the excited states. There is a need to get a rich experimental data concerning different properties of the states being a possible members of chiral bands. Especially there is a lack of information on the $\gamma\gamma$-rays selection rules and excited states life-times in order to get a proper wave functions of the states in question.

Another field of interest contains a study of the fusion-evaporation reactions which lead to the population of "entry states", i.e. the states characterized by the excitation energy E_x and spin I, in which the residual nuclei are left after particle evaporation. It is the aim of this studies to investigate the shape changes of the nucleus above the yrast line, i.e. to study a general trends in the decays preceding the yrast region of discrete transitions. For high precision lifetime determination a few experiments aimed to measure stopping power of recoils moving in the target medium was performed. The experimental determination of the dE/dx value is very important, since the electronic stopping power for recoils moving with velocity below 0.01c may differ by about 50% from the values given on the widely used Ziegler's tables. During year 2004, a total of 650 hours of beam time were dedicated to in-beam spectroscopy carried out in collaboration between the groups listed above.

Between 1st January and 31st December 2004 four experiments were carried out in the OSIRIS-II campaigns:

1) Measurements of stopping power of La recoils moving in the Sn target medium (two runs).
2) Lifetime measurements of the excited states in 128Cs nucleus.
3) Entry line and angular-momentum transfer studies for A~110 in heavy-ion fusion evaporation reactions.
4) Test experiment to study the excited states properties in octupole deformed actinide nuclei.

These experiments involved 31 collaborators from 6 institutions.

10. Investigation of thin ΔE strip detector produced by PPPP process at Warsaw Cyclotron

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A new chamber for investigation of detector parameters has been manufactured at HIL mechanical workshop. The chamber is equipped with 6 target holders, changeable under vacuum, and 2 holders for detectors. A detector can be shifted (under vacuum) with respect to the target in range of 150 mm that allows to change the laboratory angle from 10° to 45°.

Using the chamber the first measurement with medium heavy ions of thin, passivated transmission ΔE strip detector produced by PPPP process [1,2], has been performed. An E-ΔE telescope, consisting of 52μm thick ΔE strip detector (operating at low bias potential of about 5 V) and an independent 400μm E detector, was tested using medium heavy ions. Ions of Li, Be, B were produced in the ^{14}N(^{9}Be, X) reaction with 80MeV energy at the laboratory angle of 20°. Test measurement was performed using the electronic set-up consisting of preamplifiers followed by active filter amplifiers. Only one strip of the ΔE detector was collimated with a Ø=6mm Al collimator. Test shows good separation between medium heavy ions (Fig. 1).

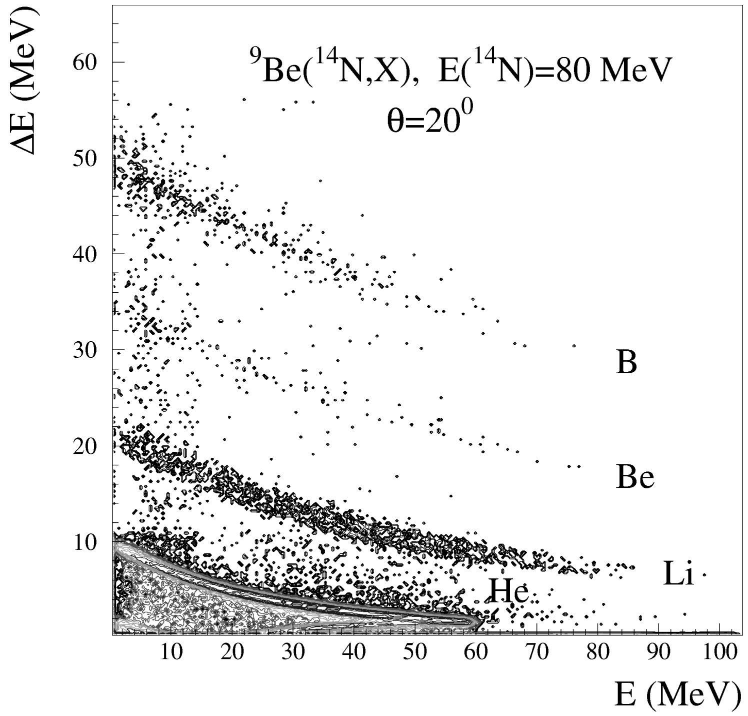

Fig. 1. E-ΔE contour plot obtained after irradiation with α particles and medium heavy ions Li, Be, B of the E-ΔE telescope with 52μm thick ΔE detector followed by 400μm thick E detector.

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11. Status of the IGISOL device

A. Wojtasiewicz[1], W.Czarnacki[2], S.Essabaa[3], M.Gierlik[1,2], Z.Janas[1], M.Kasztelan[1], M.Kisieliński[2], A.Korgul[1], J.Kurcewicz[1], W.Kurcewicz[1], J.Kurpeta[1], S.Lewandowski[1], H.Penttilä[4], A.Płochocki[1], E.Roeckl[1], B.Roussière[3], S.Sidor[1]

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2) *The Andrzej Sołtan Institute for Nuclear Studies, Otwock-Świerk, Poland*
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4) *Department of Physics, University of Jyväskylä, Finland*

The new gas cell (helium chamber for the IGISOL device) was constructed with special care for conservation of laminar helium flow. The properties of gas-catcher/ion guide system, connected to a mass separator, were investigated by using the alpha-decay recoil products obtained from a ^{223}Ra source [1]. For the new gas cell volume of 400cm^3 an extraction time of about 5.5ms was deduced for ^{215}Po ions with charge state 1^+.

After test experiments a series of improvements have been introduced. A new beam diagnostics system for the measurements of beam current and energy, ion masses and evacuation time from the gas cell was implemented. Previous systems did not allow to reach the high accuracies required in the experiments. At the exit hole of the gas cell a new oil-free pump was mounted. Test results clearly show that only under very clean condition a sufficiently high transmission efficiency through the gas cell can be obtained.

The gas flow simulation were performed using FLUENT code to obtain the best design of gas cell including gas inlet-exit hole configuration. After all improvements in off-line experiments the efficiency of the system was compared with the simulation results of FLUENT code [2].

In the on-line experiment the heavy-ion reaction ^{14}N (6.2MeV/u) + ^{209}Bi was studied with target placed inside the helium cell. Extraction efficiency of about 2% was determined for the production of ^{214}Ra isotope [3].

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

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[3] M. Gierlik, 3rd Joint Coll. Meeting HITRAP-NIPNET-ION CATCHER, Kraków, June 2-6, 2004

12. Fusion barrier distributions in ^{20,22}Ne + ^{nat}Ni

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

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Barriers height distributions for ^{20,22}Ne on ^{nat}Ni have been measured using quasi-elastic scattering at backward angles. The results have been compared to coupled-channels calculations performed with the CCQUEL code. A fair agreement with data has been obtained if the values of a hexadecapole deformation parameters of ^{20}Ne and ^{22}Ne are reduced by a factor of 2 with respect to their previously quoted values.

The experiment was performed at the Warsaw Heavy Ion Laboratory Cyclotron. The detectors were arranged in the same manner as described in our previous paper [1], namely the back-scattering was registered at 130°, 140° and 150°, while the Rutherford scattering at 35°. The ^{nat}Ni target of 100μg/cm^2 was bombarded by ^{20}Ne and ^{22}Ne beams at energy range from 1.9 to

3.3MeV/u. The intensity varied from 1 to 50pnA (depending on energy). A set of Ni and Ag degraders and the fact that the quasi-elastically scattered particles were registered at three angles simultaneously resulted in energy intervals not exceeding 0.5MeV (see Fig. 1a).

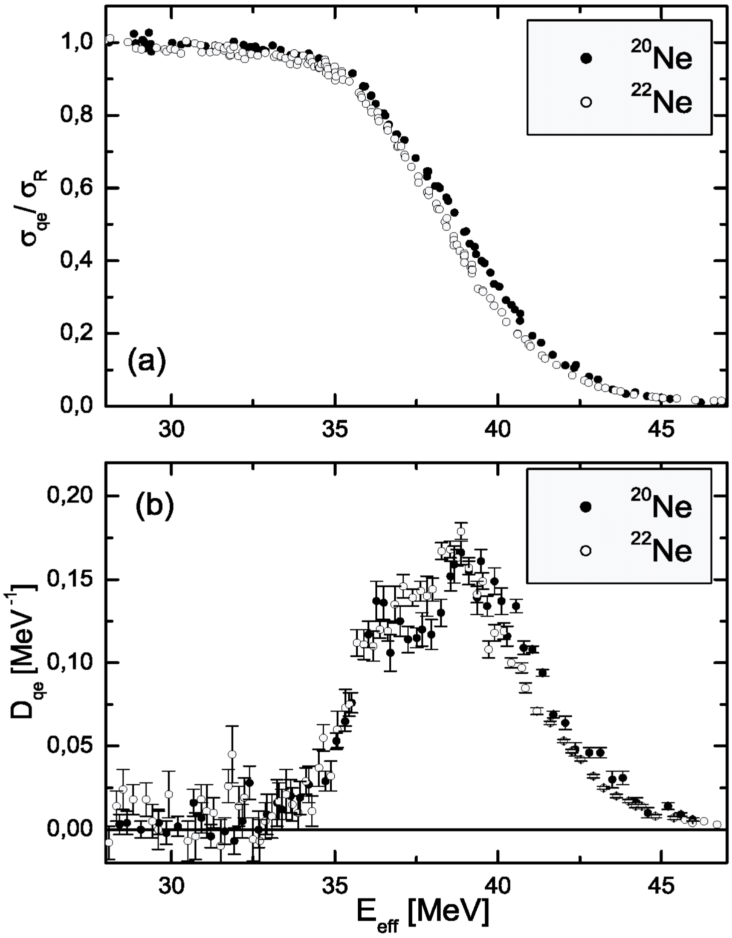

Fig. 1. Excitation functions (a) and barrier distributions (b) for ^{20,22}Ne on ^{nat}Ni. The error bars on panel (a) are within the points size.

The barrier distributions were obtained from quasi-elastic scattering excitation functions by a numerical differentiation. The results are shown on Fig. 1b. The distribution for ^{20}Ne + ^{nat}Ni (full circles) shows a significant structure, while for ^{22}Ne + ^{nat}Ni (open circles) the shape is only weakly asymmetric. This may be attributed to the different values of hexadecapole deformation parameters of ^{20}Ne and ^{22}Ne. The experimental distributions were compared to coupled channels calculations (discussed in details in ref. [2]), performed using the CCQUEL code [3].

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

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13. The beam of Warsaw Cyclotron for radiobiological studies

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2) *Nuclear Physics Division, Institute of Experimental Physics, Warsaw University*
3) *The Andrzej Soltan Institute for Nuclear Studies, Otwock - Świerk, Poland*
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In recent years the application of beams from heavy ion accelerators for biophysical experiments has been gaining increasing importance [1]. The understanding of radiobiological effects of charged heavy particles are of fundamental importance both for radiation protection and radiotherapy, where the number of patients treated with heavy ions is increasing [2]. The physical environment of the sample is the major problem in biological studies of living cells under irradiation by the uniform beam of heavy ions. The temperature and humidity of the sample can influence the survival of the biological sample. In order to ensure a high humidity of the cell environment the vertical beam facility are usually used to irradiate the sample [3]. The vertical beam allows keeping the sample in the medium or in the solution placed in petri dishes in horizontal position.

However, thin sample (< 400μm) should be kept in vertical position during irradiation without influence on the humidity of the environment of the cells. In the experiment carried out at the Warsaw Cyclotron the 120MeV ^{12}C ions were extracted to the atmosphere from the vacuum tube through an exit window made from the Havar foil 2.5mg/cm^2 thick. The exit window of a size of 14 × 14 mm was used. The Au scattering foil of thickness 20mg/cm^2 was used to produce a beam directed to exit the window placed at 15^0 and to the monitor at 20^0 (Fig. 1). The spatial distribution of the beam intensity at the exit window is not uniform, and determined by the Rutherford scattering. The cell containers fastened to an X-Y sliding table (Fig. 2) was moved along the X and Y axes in order to ensure a uniform dose distribution at the irradiated target (see Fig. 1).

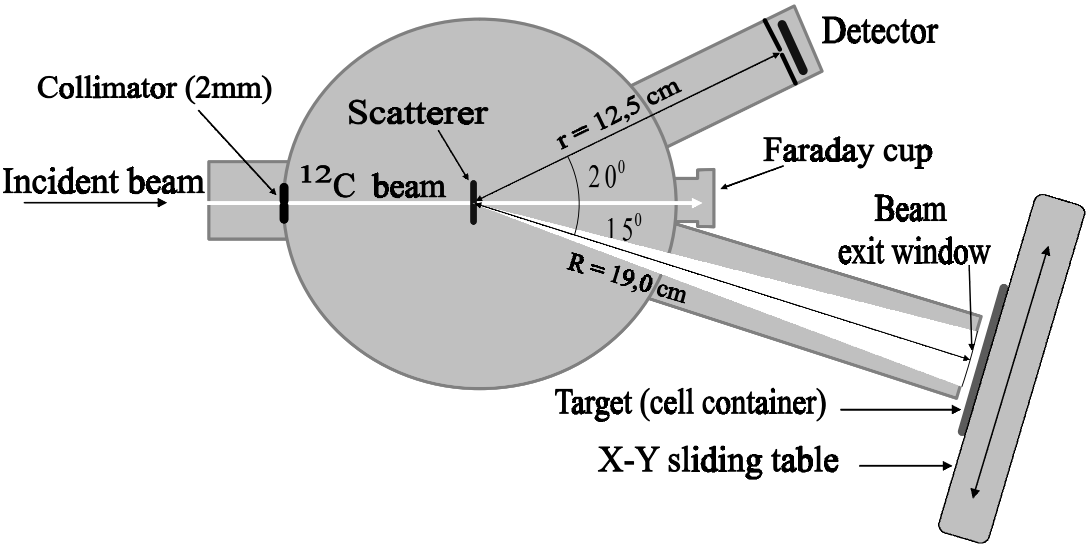

Fig. 1. Sketch of the set up for cell irradiation at Warsaw cyclotron

The intensity of the beam scattered at the gold foil was measured by a barrier silicon detector placed at 20^0. To reduce the count rate, a collimator with 2mm diameter was placed in front of the detector monitoring beam intensity. The detector was placed at a distance of 125mm from the center of the scattering chamber, where the scattering foil was mounted. Appropriate calculation of Rutherford scattering ratios $\frac{d\sigma_R}{d\Omega}(\theta) \Big/ \frac{d\sigma_R}{d\Omega}(\theta = 20^0)$ allowed us to determine the intensity of the scattered beam and the spatial distribution at the target position.

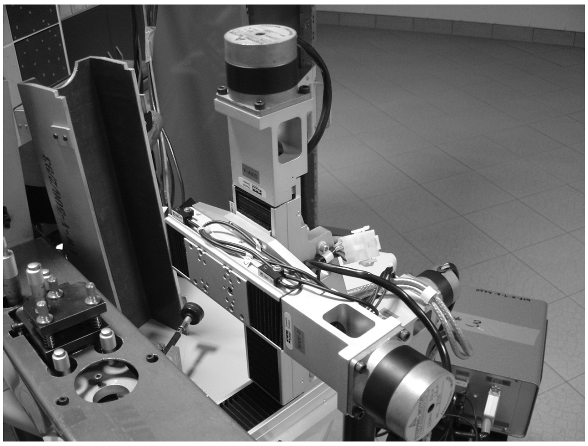

Fig. 2. The X-Y sliding table

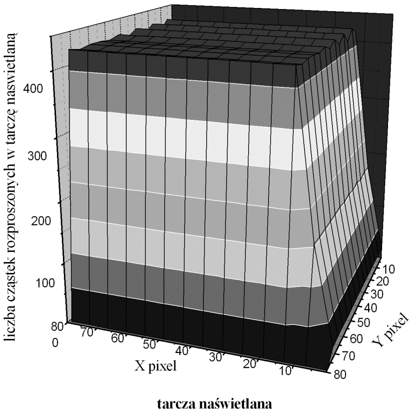

Fig.3 Two-dimensional plot of the dose field at the irradiated target.

Before irradiation with the beam of the Warsaw Cyclotron, the radiation field at the position of the target was simulated. A two-dimensional intensity distribution was calculated assuming X-Y scanning of the target field with the beam transmitted through the exit window. A combination of the Rutherford scattering and the displacement of the beam on the target area ensured that the homogeneity of the beam was better than 5% across the target area (see Fig. 3).

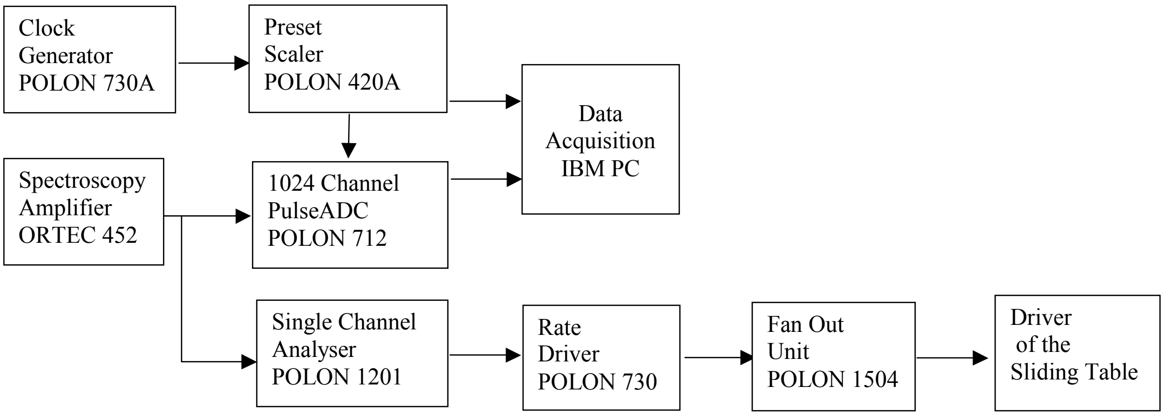

Fig. 4. The scheme of the control system of the irradiation

Data acquisition system is registering time dependence of the beam intensity as well as the energy spectrum of the scattered beam. A selected number of counted particles initiates the programmed shift of the sliding table with the sample.

In order to perform uniform irradiation of biological samples, which are spread over 6 to 8cm in diameter, the moving sample was scanned by the beam passively smeared by the scattering foil. The required flux of the particles 10^7/s of ^{12}C at incident energy 100MeV corresponds to the dose rate 10 Gy/min. The scanning in the horizontal and vertical direction was performed to obtain a homogeneity of the beam in the order of <5%. The dose determination based on the counting of ions scattered at 20^0 leads to the determination of number of particles reaching the sample. To verify the dose a set of thermoluminescence detectors, as well as an X-ray film were irradiated. The results of irradiation of the X-ray film irradiated with doses 0.25Gy, 0.5Gy, and 1.0Gy respectively are shown in Fig. 5.

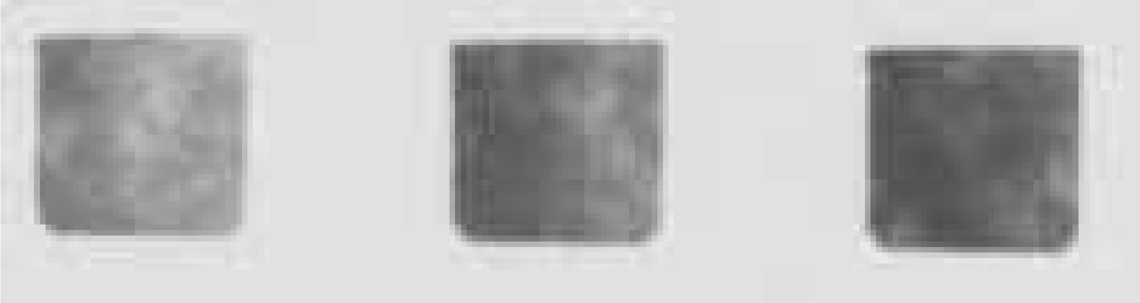

Fig. 5. The result of irradiation of the X-ray film irradiated with doses 4.7 Gy (left), 9.5 Gy (center) and 18.9 Gy (right).

V79 Chinese hamster fibroblasts were grown on thin foils for 24 hours, transported to the Heavy Ion Laboratory on ice and irradiated for different time periods in order to determine the optimal doses and exposure times that yield enough mitotic cells for scoring of chromosomal aberrations. Following irradiation the cells were transported on ice back to the laboratory where they were incubated at 37°C for 16 hours. Colcemid was added for the last 3 hours in order to block cells in mitosis. Cells were harvested as described elsewhere and aberrations were scored under a light microscope [4]. An example of a cell with chromosomal aberrations is shown in figure 6. A good yield of mitotic cells was observed after exposure times of 10-15 minutes and doses of 0.5-1 Gy. These exposure conditions will be used in future experiments.

Fig. 6. An example of a mitotic cell with chromosomal aberrations.

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14. Samples selection for direct Z measurements of heavy elements using synchrotron radiation

J.Tys

The researches of Super Heavy Elements (SHE) in nature were based on the measurement of natural radioactivity using, mainly, the tracks detectors [1]. These measurements did not give the Z number directly. Often, known natural radioactivity masked small unknown effect and the results were not conclusive. R.V. Gentry [2] claimed the discovery of SHE in the inclusion of "giant halo" but C.J.Sparks Jr. and S.Raman [3] did not proved this result using the synchrotron radiation for excitation the samples. If SHE exist in nature they are extremely dispersed in known minerals or can form small inclusions in them.

Big progress has been done in the synchrotron radiation technique. Now the beam of high energy and high intensity is available in many laboratories.

Use of X-ray gives the Z number directly by exact characteristic lines energy measurements. Since all isotopes give the same line, the measured effect is enhanced. A sample preparation is not necessary, a form and a mass of a sample can be very different. Scanning with the beam permits to analyze even small grain in the non-homogenous sample. High beam intensity results in higher sensitivity.

The samples must be preliminary selected from different natural minerals and rocks so they do not have peaks in the region of interest for SHE. Many K-X ray of known elements have the energies very close to the L-X ray of SHE. This selection is done in Heavy Ion Laboratory of Warsaw University, using Si detector for X-ray detection and 200 mC 241Am source for excitation. The promising samples were made available for the research by geological museums, since the method used is non-destructive.

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Part C:

Experiments using the outside facilities

1. Coulomb Excitation at REX-ISOLDE

J.Iwanicki for the HIL – REX-ISOLDE collaboration[1]

Members of the Coulex group were involved in Coulomb Excitation experiments performed with unstable beams delivered by REX-ISOLDE facility in CERN. All the experiments were performed within the REX-ISOLDE-MINIBALL collaboration, involving secondary beams produced by the ISOLDE set-up, post-accelerated by the REX linear accelerator system and detected by the combination of MINIBALL segmented germanium detectors array, double sided silicon strip detector (CD) and ancillary detectors. Some of experiments also involved the RILIS laser ion source assembly.

Sections below describe experiments we were involved in, together with preliminary results. Two similar experiments, with ^{88}Kr and ^{70}Se beams, are scheduled to be run in 2005 campaign.

Structure of neutron – rich Zn isotopes

The aim of the project is to study properties of nuclei with close-to-magic number of neutrons. Unstable beams of neutron-rich even-even Zn isotopes were Coulomb excited on heavy targets (Sn and Pd isotopes). Resulting gamma energy spectra measured in coincidence with scattered charged particles are shown below. Average beam intensities of unstable ions were 4.2E6 pps (^{74}Zn), 1.3E6 pps (^{76}Zn), 3.2E4 pps (^{78}Zn).

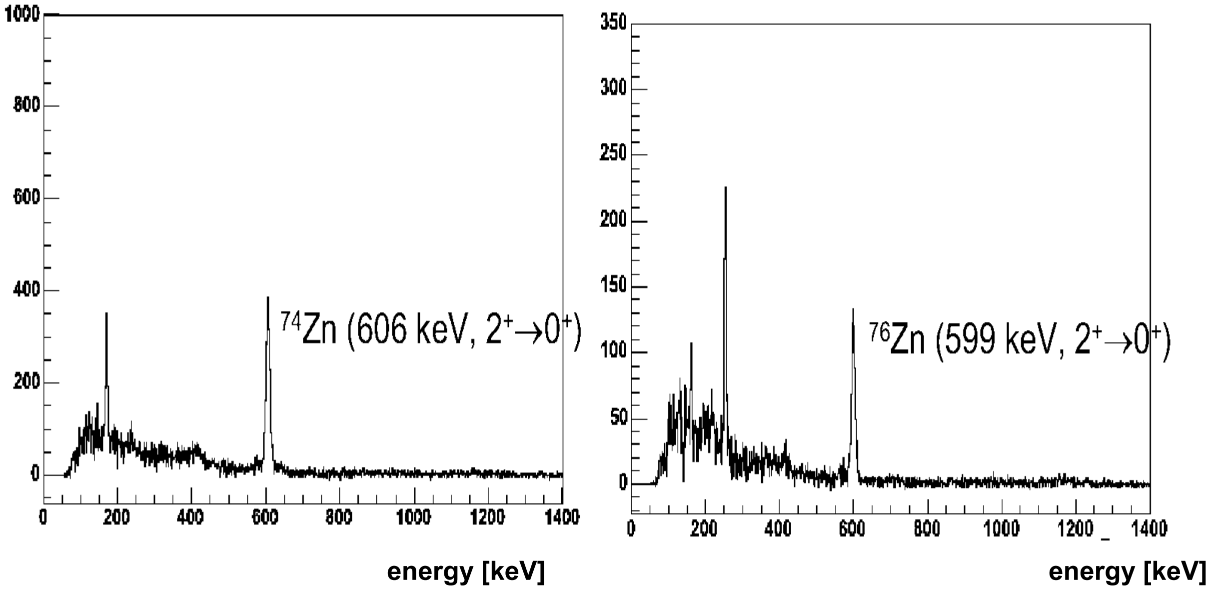

Fig. 1. Doppler-corrected Coulomb Excitation spectra measured with ^{74}Zn beam (12.5 h measurement time) and ^{76}Zn (14.5 h measurement time)

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[1] Part of the REX-ISOLDE collaboration involved in experiments described comprises a number of laboratories: CERN, Geneva, Switzerland; IKS Leuven, Belgium; LMU Munich, MPI Heidelberg, TU Darmstadt, TU Munich, University of Köln, Germany; Heavy Ion Laboratory, Poland; Lund University, Sweden; University of Edinburgh, University of Liverpool, University of York, UK; See the ISOLDE collaboration web page: isolde.cern.ch

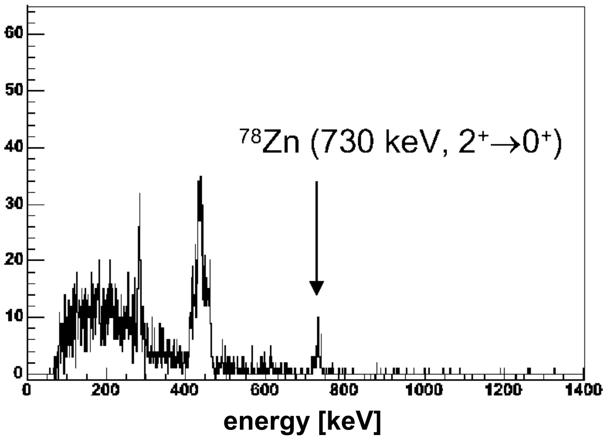

Fig. 2. Doppler-corrected Coulomb Excitation spectra measured with ^{78}Zn beam (23.5 h measurement time)

Coulomb Excitation of A~140 nuclei

Grodzins' rule describes the behavior of $E(2^+{}_1)\times B(E2{:}0^+\rightarrow 2^+{}_1)$ in even-even nuclei. In order to test an enhanced version of the rule, working for wider set of nuclei, a series of experiments is planned to measure B(E2) values of lowest transitions in even-even nuclei away from the stability path.

One of first steps was to measure these values for neutron-rich cadmium isotopes. Beam intensity was around 1-3E4 pps, depending on the case. Reasonable statistics were collected for ^{122}Cd and ^{126}Cd, feasibility for such experiment was demonstrated in the ^{126}Cd case.

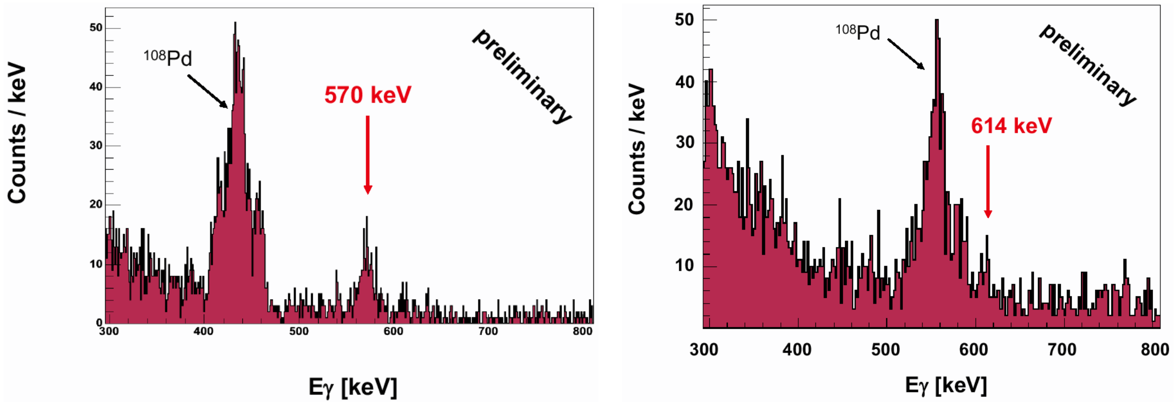

Fig. 3. Coulex spectra for ^{122}Cd and ^{124}Cd measurements

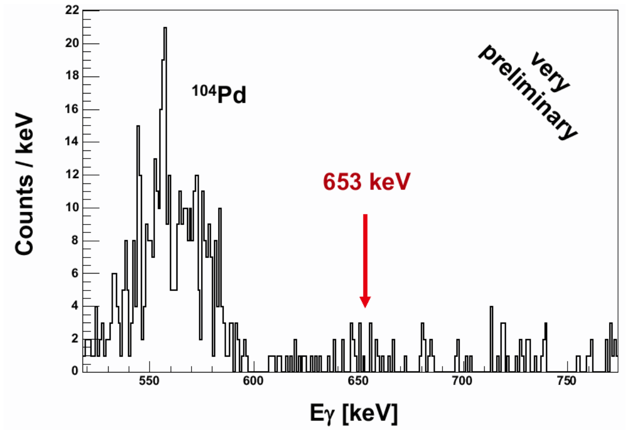

Fig. 4. Coulex spectrum measured for ^{126}Cd

2. The differences of the rms radii of neutron and proton distributions: comparison of experimental data with Droplet Model theory

W.Świątecki[1], *A.Trzcińska, J.Jastrzębski,*

1) Lawrence Berkeley National Laboratory, Berkeley, California 94720

Within the PS209 experiment the nuclear matter at nucleus periphery was studied using antiprotons as a probe. Deduced density distributions allowed also to determine the differences between the rms radii of neutrons and protons, Δr_{np} , in wide range of isotopes: from ^{40}Ca to ^{238}U. Neutron density distributions were determined at relatively large radii and were then converted to rms radii by the use of a two-parameter Fermi function [1,2]. A comparison of the antiprotonic results with the prediction of macroscopic Droplet Model [3,4] was done (see Fig. 1). One can see that there is quite fair agreement between the Droplet Model theory and the set of experimental data. The detailed discussion of this comparison is presented in Ref. [5].

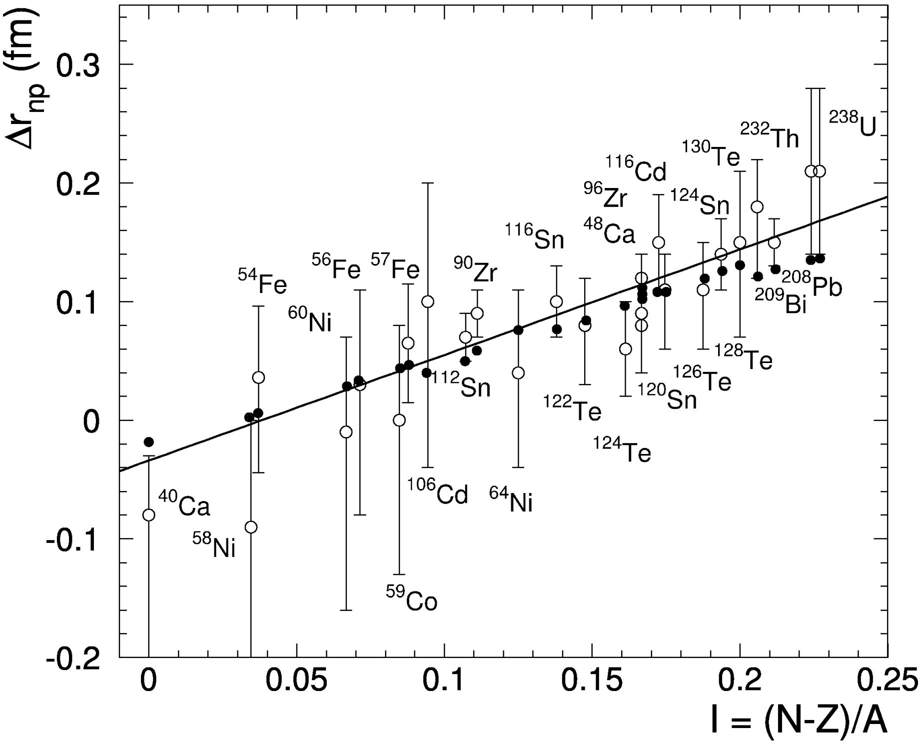

Fig.1. Difference Δr_{np} between the rms radii of the neutron and proton distributions deduced from the antiprotonic atom X-ray data as a function of I=(N-Z)/A (open points with indicated statistical errors, Ref. [2]). Full points show the droplet model predictions for the same isotopes as measured in the experiment. The line is a fit to the experimental data:
$\Delta r_{np} = (-0.03 +/- 0.020) + (0.90+/-0.15)I$ fm

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3. Study of neutron deficient nuclei in the vicinity of ^{100}Sn

M.Palacz, J.Nyberg[1], G.de Angelis[2], P.Bednarczyk[3], A.Blazhev[4], Z.Dombradi[5], O.Dorvaux[3], J.Ekman[6], M.Górska[4], H.Grawe[4], J.Iwanicki, J.Kownacki, J.Ljungvall[1], M.Moszyński[7], L.Pieńkowski, D.Rudolph[6], D.Sohler[5], D.Wolski[7], M.Ziębliński[8]

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Nuclei in the vicinity of ^{100}Sn are in focus of numerous experimental and theoretical studies. In particular, during the last 2 decades most advanced setups of germanium detectors have been employed in-beam in experiments aiming at extending the knowledge of nuclear excited states as close as possible towards the double-magic N=Z=50 shell closure. In this contribution we report on the progress of data analysis from one of the largest experiments of this kind, which was performed with the EUROBALL [1] detector array connected to the Neutron Wall [2,3] and the CUP [4] detector. The experiment aimed at the observation of excited states in ^{100}In and have already been described in our contribution to the HIL Annual Report 2003 [5]. Search for the γ-ray radiation emitted from excited states of ^{100}In is in progress.

Several other exotic nuclei in the vicinity of ^{100}Sn have also been populated in this experiment and they are presently analyzed. In particular, selection of events with two neutrons identified in the Neutron Wall and no charged particle detected in the CUP detector lead to γ-ray spectra with a significant contribution of the ^{97}Ag nucleus, which was produced by the emission of 1 α-particle and 2 neutrons from the compound nucleus ^{103}In. In most of the events produced in the reaction used, at least two protons are emitted from the compound nucleus, and this explains why requiring that no charge particles were detected, selects events in which only one α-particle was emitted. The efficiency of the CUP charged particle detector for the detection of protons and α-particles is about 80 and 63%, respectively.

The ^{97}Ag nucleus was previously studied in-beam [6] and 4 excited states of this nucleus were identified, with the maximum excitation energy of 2343 keV. This nucleus has only 3 proton-holes outside the double magic core and as such, provides valuable information on single-particle energies and interactions of protons on the $g_{9/2}$ and $p_{1/2}$ orbitals below N=Z=50. In case core excitation are observed, it can also provide an insight into the properties of the magic Shell Model gap.

The present data allows for a significant extension of the existing level scheme, up to the excitation energy of about 7 MeV, and indeed high energy γ-rays (2–3 MeV) are observed, feeding the previously known states, which can be associated with the deexcitation of the core excitations. The data analysis is in progress, as well as the theoretical interpretation of the identified states. The results will soon be published.

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Part D:

General information on HIL activities

1. Educational activities at HIL

The personnel of HIL, apart from the main duty - providing the heavy ion beams to the users - is also engaged in various educational activities. Four PhD theses were supervised by the Laboratory faculty. Two doctoral programs were completed in 2004. Jarosław Choiński was awarded the degree by of the Andrzej Sołtan Institute for Nuclear Studies. Paweł Napiorkowski defended the thesis at the Physics Faculty Warsaw University. His continuous science popularization efforts were awarded in 2004 by a nomination for the Science Popularizer Contest, organized by Polish Press Agency. Five persons from the HIL staff are involved in regular teaching at Student Laboratories of the Physics Faculty on a full time basis. This includes Electronics Laboratory and Basic Physics Laboratory on the first and second level. The HIL organizes in-house seminars to present the status of the cyclotron, the performed and planned experiments and to popularize the heavy ion physics and its applications.

For the eighth year HIL took part in the organization of annual Warsaw Festival of Science. This involvement included the organization of the distribution of the invitations and guided tours of the facility. Within the program of this Festival Magdalena Zielińska gave a series of lectures on nuclear physics at the layman's level. Ludwik Pieńkowski gave a lecture on nuclear energy and nuclear waste transmutation technology. Paweł Napiorkowski and Jędrzej Iwanicki demonstrated the methods of detecting natural radioactivity. One of the highlights of Laboratory's educational activities was the participation in the Eighth Science Picnic organized by Radio BIS at the New Town Market in Warsaw. Presented demonstrations showing the basics of nuclear physics attracted hundreds of people of all ages. Large audience was also present during the University Open Doors Day at the Cyclotron. The laboratory hosted a number of high-school and physics teachers tours, altogether amounting in 2004 to about 30 groups, i.e. more than 700 persons.

The Laboratory has organized the summer student workshops for the group of four students from Warsaw Technical University. Their activity was supervised by Laboratory staff members: Jarosław Choiński, Paweł Napiorkowski and Marcin Palacz. The students gained experience in methods of data acquisition and analysis, in operating the cyclotron including the beam diagnostic measurements and in charged particles and gamma rays detection.

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

a) MSc. Jarosław Choiński
Struktura elektromagnetyczna i dynamika wiązek Warszawskiego Cyklotronu U-200P
Supervisor: dr hab.T.Czosnyka. Thesis defended on April 20th, 2004 r

b) MSc. Paweł Napiorkowski
Elektromagnetyczne własności stabilnych izotopów hafnu
Supervisor: dr hab.T.Czosnyka. Thesis defended on June 14th, 2004 r

c) MSc. Magdalena Zielińska
Struktura elektromagnetyczna jąder atomowych izotopów molibdenu badana metodą wzbudzenia kulombowskiego
Supervisor: dr hab.T.Czosnyka. Expected completion time: 2005

d) MSc. Marzena Wolińska-Cichocka
Struktura jąder neutronowo deficytowych z obszaru A~100 tworzonych w reakcjach z ciężkimi jonami
Supervisor: prof. dr hab. J.Kownacki. Expected completion time: 2005

1.2 PhD theses in preparation based on the experiments on the Warsaw Cyclotron

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

b) MSc. Ernest Grodner, Faculty of Physics Warsaw University
Badanie pikosekundowych czasów życia stanów wzbudzonych izotopów lantanu
Supervisor: dr hab. Tomasz Morek. Expected completion time: 2006

c) MSc. Olimpia Kijewska, Faculty of Physics Warsaw University
Badanie emisji lekkich cząstek naładowanych w zderzeniach ciężkich jonów o energiach 4-12 MeV/u jako źródło informacji o lekkich jądrach gorących
Supervisor: prof. dr hab. Marta Kicińska-Habior. Expected completion time: 2005

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

e) MSc. Łukasz Świderski, Faculty of Physics Warsaw University
Badanie rozkładu barier na fuzję ^{20}Ne z izotopami Sn i Ni
Supervisor: dr hab. Ernest Piasecki. Expected completion time: 2005

f) MSc. Elżbieta Wójcik, Faculty of Physics Warsaw University
Badanie zmieszania izospinowego w jądrach gorących poprzez wzbudzenie Gigantycznego Rezonansu Dipolowego
Supervisor: prof. dr hab. Marta Kicińska-Habior. Expected completion time: 2006

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

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

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

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

c) Małgorzata Gawinek, Faculty of Physics Warsaw University
Badanie procesu hamowania jąder odrzutu lantanu w reakcjach ciężkojonowych
Supervisor: dr Julian Srebrny

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

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

f) Jan Mierzejewski, Faculty of Physics Warsaw University
Filtr krotności BGO jako narzędzie badania kwantów γ w reakcjach ciężko-jonowych
Supervisor: dr Julian Srebrny

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

h) Katarzyna Wrzosek, Faculty of Physics Warsaw University
Badanie struktury elektromagnetycznej jądra ^{100}Mo metodą wzbudzeń kulombowskich
Supervisors: dr hab. Tomasz Czosnyka and dr Julian Srebrny

1.4 BSc theses based on the Warsaw Cyclotron activity

a) Robert Maj, Faculty of Physics Warsaw University
Opracowanie strony internetowej pomiarów czasów życia poziomów jądrowych z wykorzystaniem efektu Dopplera
Supervisors: dr Julian Srebrny and dr Robert Budzyński

b) Przemysław Sieczko, Faculty of Physics Warsaw University
Rola tomografii pozytonowej w diagnostyce medycznej i badaniach naukowych- strona internetowa ośrodka PET
Supervisor: dr hab. Zygmunt Szefliński

2. Seminars

2.1. Seminars at HIL

T.Czosnyka February 19
Podstawy fizyki cyklotronu

R.Tańczyk February 26
Zagadnienia ochrony radiologicznej w ŚLCJ

The joint seminar organized by HIL, Division of Nuclear Spectroscopy UW and Nuclear Physics Division UW February 27
D. Goutte
Evolution of the GANIL facility in the European context: SPIRAL 2 Project
Marek Lewitowicz
Physics with SPIRAL and SPIRAL 2

R.Tańczyk March 4
Zagadnienia ochrony radiologicznej w ŚLCJ, cz.II

N.E.Hertel March 11
Development of a Boron Neutron Capture Enhanced Fast Neutron Therapy Beam

S.J.Heselius April 15
The Turku PET Center: Past, Present and Future

H.Vera-Ruiz April 15
Concepts and Strategies in setting up cyclotron/PET programme

2.2. External seminars given by HIL staff

A.Trzcińska February 17
Neutron density distributions deduced from antiprotonic atoms
ISOLDE, CERN, Geneve, Switzerland

M.Palacz March 5
Badania jąder z obszaru ^{100}Sn z wykorzystaniem układu EUROBALL
IFD, Warszawa, Poland

M.Zielińska March 24
Wzbudzenia kulombowskie jako metoda badania koegzystencji kształtu w jądrach atomowych
IFD, Warszawa, Poland

A.Kordyasz April 23
Monolityczne, krzemowe teleskopy typu E-ΔE wykonane metodą kwaziselektywnej epitaksji
IFD, Warszawa, Poland

L.Pieńkowski June 25
Thermal Expansion-Induced Retardation of Evaporation from Highly Excited Nuclear Systems
University of Catania, Department of Physics and Astronomy
Catania, Italy

J.Jastrzębski July 26
Neutron Density Distributions Deduced from Antiprotonic Atoms
Conference on “Nuclei at the Limits”, Argonne National Laboratory, Argonne ,Illinois, USA, July 26-30, 2004

M.Zielińska September 3
Shape coexistence in even-even Mo isotopes studied via Coulomb excitation
XXXIX Zakopane School of Physics – International Symposium
“Atomic nuclei at extreme values of temperature, spin and isospin”

Zakopane, Poland, August 31- September 5, 2004

T.Czosnyka September 14
INTAG, Instrumentation for Tagging
North-East European Network Meeting
IFJ PAN, Kraków, Poland, September 14-15, 2004

J.Jastrzębski September 14
Information on the Polish Nuclear Physics Network
North-East European Network meeting
IFJ PAN, Kraków, Poland, September 14-15, 2004

A.Trzcińska September 14
Antiprotons in FLAIR and NUSTAR-future Darmstadt research programme
North-East European Network meeting
IFJ PAN, Kraków, Poland, September 14-15, 2004

M.Zielińska September 14
Information on the PNPN Web page
North-East European Network meeting
IFJ PAN, Kraków, Poland, September 14-15, 2004

L.Pieńkowski September 15
EURISOL – european project of radioactive beams
North-East European Network meeting
IFJ PAN, Kraków, Poland, September 14-15, 2004

A.Trzcińska September 20
X-ray measurements of heavy antiprotonic atoms
FLAIR meeting
GSI Darmstadt, Germany, September 20-21, 2004

T.Czosnyka September 23
Physics with the Warsaw heavy ion cyclotron
11th Nuclear Physics Workshop “Marie and Pierre Curie”
on Physics of Exotic Nuclei
Kazimierz Dolny, Poland, September 23-26, 2004

J.Jastrzębski, M.Zielińska October 8
Sieć Polskiej Fizyki Jądrowej
IFD, Warszawa, Poland

J.Miszczak October 20
Control System for the Warsaw Cyclotron
XVII Conference on Cyclotrons and their Applications
Tokyo, Japan. October 18-22, 2004

J.Iwanicki November 5
Wzbudzenie kulombowskie wiązek radioaktywnych
IFD, Warszawa, Poland

J.Choiński December 3
Oddział produkcji radiofarmaceutyków w ŚLCJ UW
„Tomografia pozytonowa w Polsce”
Warszawa, Poland, December 3, 2004

J.Jastrzębski December 3
Warszawskie Konsorcjum Współpracy PET
„Tomografia pozytonowa w Polsce”
Warszawa, Poland, December 3, 2004

P.Napiorkowski December 3
PET w Europie, USA i Japonii
„Tomografia pozytonowa w Polsce”
Warszawa, Poland, December 3, 2004

J.Iwanicki December 13
Coulomb Excitation of ^{88}Kr beam at REX-ISOLDE
ISOLDE Workshop and Users Meeting 2004
CERN, Geneve, Switzerland, December 13-15, 2004

2.3. Science popularization lectures during the Eighth Science Festival, September 2004

M.Zielińska
Jak zobaczyć jądro atomowe?

J.Iwanicki
Jak zobaczyć niewidzialne, czyli o pomiarach promieniowania jonizującego

P.Napiorkowski
Tajemnice twojego odkurzacza

L.Pieńkowski
Reaktor hybrydowy – energetyka jądrowa w zgodzie ze środowiskiem

3. ISL listed publications, other publications

3.1. Publications in journals listed by ISI

Calibration and application of Solid-State Nuclear Track Detectors in spectroscopy of heavier ions of energy in a few MeV/amu range
A.Szydłowski; A.Banaszak; I.Fijał; J.Choiński; B.Sartowska
Czech. J. Phys. **54**, 228 (2004)

Shape coexistence in Krypton isotopes studied through Coulomb excitation of radioactive Krypton ion beams
W.Korten; E.Bouchez; E.Clement; A.Chatillon; A.Gorgen; Y.Le Coz; C.Theisen; J.Wilson;

J.M.Casandjian; G.de France; G.Sletten; T.Czosnyka; J.Iwanicki; M.Zielińska; C.Andreoiu; P.Butler; R.D.Herzberge; D.Jenkins, G.Jones; F.Becker; J.Gerl; W.Catford; C.Timis
Nucl. Phys. **A746**, 90c (2004)

A low energy storage ring for partly stripped radioactive ions
T.Fritioff; M.Grieser; M.Lindroos; A.Trzcińska
Nucl. Phys. **A746**, 384c (2004)

Investigation of a gas catcher/ion guide system at the Warsaw cyclotron
A.Wojtasiewicz; G.Canchel; A.Emsallem; M.Gierlik; Z.Janas; M.Kisieliński; W.Kurcewicz; J.Kurpeta; H.Lefort; S.Lewandowski; H.Penttila; A.Płochocki; E.Roeckl; B.Roussiere; S.Sidor; A.Syntfeld
Nucl. Phys. **A746**, 663c (2004)

Response to heavy ions and fission fragments of the monolithic silicon E-Delta E telescopes produced by the Quasi-Selective Epitaxy
A.J.Kordyasz; E.Nossarzewska-Orłowska; E.Piasecki; D.Lipiński; A.Brzozowski; J.Kownacki; M.Kowalczyk; L.Świderski; A.Syntfeld; L.Reissig; A.Pietrzak; A.Jakubowski; R.Pozorek; R.Gąsiorowski
Nucl. Instrum. Meth. Phys. Res. **A530**, 87 (2004)

The LSO/APD array as a possible detector for in-beam PET in hadron therapy
M.Kapusta; P.Crespo; D.Wolski; K.Heidel; L.Heinrich; J.Hutsch; J.Pawelke; M.Sobiella; A.Trzcińska; M.Moszyński; W.Enghardt
IEEE Trans. Nucl. Sci. **51**, 1389 (2004)

Monolithic silicon E-Delta E telescope produced by the quasi-selective epitaxy
A.J.Kordyasz; E.Nossarzewska-Orłowska; E.Piasecki; D.Lipiński; A.Brzozowski; J.Kownacki; M.Kowalczyk; L.Świderski; A.Syntfeld; L.Reissig; A.Pietrzak; A.Jakubowski; R.Pozorek; R.Gąsiorowski
Nucl. Instrum. Meth. Phys. Res. **A528**, 721 (2004)

Monte Carlo simulations of the neutron wall detector system
J.Ljungvall; M.Palacz; J.Nyberg
Nucl. Instrum. Meth. Phys. Res. **A528**, 741 (2004)

Dynamics of formation of K-hole fractions of sulfur projectiles inside a carbon foil
J.Braziewicz; U.Majewska; K.Słabkowska; M.Polasik; I.Fijał; M.Jaskóła; A.Korman; W.Czarnacki; S.Chojnacki; W.Kretschmer
Phys. Rev. A **69**, 062705 (2004)

Observation of a core-excited E4 isomer in ^{98}Cd
A.Blazhev; M.Górska; H.Grawe; J.Nyberg; M.Palacz; E.Caurier; O.Dorvaux; A.Gadea; F.Nowacki; C.Andreoiu; G.de Angelis; D.Balabański; C.Beck; B.Cederwall; D.Curien; J.Doring; J.Ekman; C.Fahlander; K.Lagergren; J.Ljungvall; M.Moszyński; L.O.Norlin; C.Plettner; D.Rudolph; D.Sohler; K.M.Spohr; O.Thelen; M.Weiszflog; M.Wisell; M.Wolińska; W.Wolski
Phys. Rev. C **69**, 064304 (2004)

Strong interaction and E2 effect in even-A antiprotonic Te atoms
B.Kłos; S.Wycech; A.Trzcińska; J.Jastrzębski; T.Czosnyka; M.Kisieliński; P.Lubiński; P.Napiorkowski; L.Pieńkowski; F.J.Hartmann; B.Ketzer; R.Schmidt; T.von Egidy; J.Cugnon;

K.Gulda; W.Kurcewicz; E.Widmann
Phys. Rev. C **69**, 044311 (2004)

Measurement of the E1/E3 phase in ^{226}Ra
N.Amzal; P.A.Butler; D.Hawcroft; N.J.Hammond; E.D.Herzberg; G.D.Jones; C.Scholey; O.Stezowski; T.Czosnyka; J.Iwanicki; P.J.Napiorkowski; R.Julin; H.Mach; J.Cerderkall; L.M.Fraile; HOU.Fynbo
Nucl. Phys. **A734**, 465 (2004)

Survey of E1 transitions in the mass A similar to 60 region
O.Izotova; D.Rudolph; J.Ekman; C.Fahlander; A.Algora; C.Andreoiu; R.Cardona; C.Chandler; G.de Angelis; E.Farnea; A.Gadea; J.G.Narro; J.Nyberg; M.Palacz; Z.Podolyak; T.Steinhardt; O.Thelen
Phys. Rev. C **69**, 037303 (2004)

Coulomb excitation of ^{150}Nd
M.Zielińska
Int. J. Mod. Phys. E-Nucl. Phys. **13**, 71 (2004)

DSAM lifetime measurements in the yrast band of ^{131}La and the chiral bands in ^{132}La
E.Grodner; J.Srebrny; C.Droste; T.Morek; A.Pasternak; J.Kownacki
Int. J. Mod. Phys. E-Nucl. Phys. **13**, 243 (2004)

How many fusion barriers?
L.Świderski; P.Czosnyka; M.Kowalczyk; E.Piasecki; K.Piasecki; M.Witecki; J.Jastrzębski; A.Kordyasz; M.Kisieliński; T.Krogulski; N.Rowley; C.Marchetta; A.Pagano; M.Mutterer; W.H.Trzaska; K.Hagino
Int. J. Mod. Phys. E-Nucl. Phys. **13**, 315 (2004)

Neutron density distributions from antiprotonic atoms compared with hadron scattering data
J.Jastrzębski; A.Trzcińska; P.Lubiński; B.Kłos; F.J.Hartmann; T.von Egidy; S.Wycech
Int. J. Mod. Phys. E-Nucl. Phys. **13**, 343 (2004)

Simultaneous determination of ^{224}Ra and ^{226}Ra isotopes by measuring of emanated ^{220}Rn and ^{222}Rn using a 4-inch silicon epitaxial detector
A.J.Kordyasz; B.Bartos; A.Bilewicz
Chem. Anal. **49**, 29 (2004)

Giant dipole radiation and isospin purity in highly excited ^{32}S nuclei
M.Kicińska-Habior; E.Wójcik; O.Kijewska; M.Kisieliński; M.Kowalczyk; J.Choiński
Nucl. Phys. **A731**, 138 (2004)

Band-terminating states in ^{101}Ag
D.Sohler; J.Timar; Z.Dombradi; J.Cederkall; J.Huijnen; M.Lipoglavsek; M.Palacz; A.Atac; C.Fahlander; H.Grawe; A.Johnson; A.Kerek; W.Klamra; J.Kownacki; A.Likar; L.O.Norlin; J.Nyberg; J.Persson; D.Seweryniak; G.de Angelis; P.Bednarczyk; D.Foltescu; D.Jerrestam; S.Juutinen; E.Makela; M.de Poli; H.A.Roth; T.Shizuma; O.Skeppstedt; G.Sletten; S.Tormanen; M.Weiszflog
Nucl. Phys. **A733**, 37 (2004)

Information on the nuclear periphery deduced from the properties of heavy antiprotonic atoms
A.Trzcińska; J.Jastrzębski; P.Lubiński; F.J.Hartmann; R.Schmidt; T.von Egidy; B.Kłos
Nucl. Instrum. Meth. Phys. Res. **B214**, 157 (2004)

Multiple Coulomb excitation experiment of ^{68}Zn
M.Koizumi, A.Seki; Y.Toh; A.Osa; Y.Utsuno; A.Kimura; M.Oshima; T.Hayakawa; Y.Hatsukawa; J.Katakura; M.Matsuda; T.Shizuma; T.Czosnyka; M.Sugawara; T.Morikawa; H.Kusakari
Nucl. Phys. **A730**, 46 (2004)

Structural changes induced by implantation with 3 MeV/amu nitrogen ions in GaAs single crystals
D.Żymierska; K.Godwod; J.Auleytner; J.Adamczewska; J.Choiński; K.Regiński
J. Alloys Compounds **362**, 248 (2004)

Internal reports

Sterowanie komputerowe zasilaczami UZ (wraz z dokumentacją ideową Elektromagnetyczną zasilaczy)
S.Dawidowicz, V.Khrabrov, J.Kurzyński, M.Kopka, K.Łabęda,Z.Morozowicz, P.Krysiak, K.Pietrzak
Konsultacja : J.Choiński, T.Czosnyka

4. Laboratory staff

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

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

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

Doctoral candidates:
Magdalena Zielińska[b], Marzena Wolińska-Cichocka

Technicians:
Mariusz Antczak, Tomasz Bracha, Marek Figat, Ryszard Gąsiorowski, Andrzej Górecki, Stanisław Dawidowicz, Janusz Jasiński, Piotr Jasiński, Wiesław Kalisiewicz, Zdzisław Kondeja[a], Marian Kopka, Zbigniew Kruszyński, Piotr Krysiak, Krzysztof Łabęda, Zygmunt Mrozowicz, Bogusław Paprzycki, Wiesław Perkowski[a], Andrzej Pietrzak, Krzysztof Pietrzak, Ryszard Pozorek, Irena Skrzeczanowska, Sławomira Wąsowska

Administration and support:
Danuta Gałecka, Ewa Sobańska, Krystyna Szczepaniak, Hanna Szczekowska[a], Joanna Wasilewska, Wanda Wesoły, Andrzej Wiechowski, Maria Wodzińska

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[a] *part time*

[b] *PhD student at HIL from Institute of Experimental Physics, Warsaw University*

5. Laboratory Scientific Council

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

6. Program Advisory Committee

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

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

7. Permanent collaborations

CERN, Geneva, Switzerland
GANIL, Caen, France
Hahn-Meitner Institut Berlin, Germany
Institute für Kernphysik KFA Jülich, Germany
Institute for Nuclear Research, Kiev, Ukraine
Japan Atomic Energy Research Institute, Japan
Joint Institute for Nuclear Research, Dubna, Russia
Ludwig-Maximilians Universität, München, Germany
Manne Siegbahn Institute, Stockholm, Sweden
Niels Bohr Institute, Denmark
Oliver Lodge Laboratory, Liverpool, United Kingdom
Technische Universität München, Germany
University of Jyväskylä, Finland
University of Liverpool, United Kingdom
University of Rochester, USA
Uppsala University, Sweden
Institute of Experimental Physics, Warsaw University, Poland
The Andrzej Soltan Institute for Nuclear Studies, Świerk, Poland
Institute of Nuclear Physics, Bronowice, Kraków, Poland
Department of Physics, University of Łódź, Poland
Institute of Experimental Physics, University of Białystok, Poland
Institute of Physics, Świętokrzyska Academy, Kielce, Poland
Institute of Electronic Materials Technology, Warsaw, Poland

RAPORT ROCZNY 2004

ŚRODOWISKOWE LABORATORIUM CIĘŻKICH JONÓW
UNIWERSYTET WARSZAWSKI

WARSZAWA, MAJ 2005