WARSAW UNIVERSITY
HEAVY ION LABORATORY

ANNUAL REPORT
2003

Warsaw University
Heavy Ion Laboratory

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WARSAW, April 2004

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INTRODUCTION

The year 2003 was a consecutive period of a regular activity of the Heavy Ion Laboratory. The cyclotron was delivering the heavy ion beams ranging from ^{11}B to ^{40}Ar to ten different experiments during more than 2000 hours.

A few teams were able to finalize their previous years data collection by papers published in high-ranked journals. Other teams published in the proceedings of the international conferences their invited talks or oral contributions. Thirteen publications in ISI listed journals appeared last year basing on the data obtained using the Warsaw machine. A similar number was published by the Laboratory staff using external facilities.

The modest technical upgrades presented in this Report were achieved almost with no cost above the salaries. The 15% decrease of the previous years running subvention from the Ministry of Science and Informatics accompanied by a consecutive refusal to fund the new ECR ion source makes the status of the Laboratory as the nuclear physics center in a very precarious position.

The situation looks much more promising with the new project: the creation of an interdisciplinary Laboratory – the Warsaw Positron Emission Tomography Centre, launched by the Heavy Ion Laboratory and the Nuclear Medicine Department at the Clinical Hospital of the Warsaw Academy of Medicine in 2001. In 2003 the Warsaw Consortium for PET Collaboration (WCPC) was created and presently it takes an active role in the project preparation. The WCPC will dispose of a single radiopharmaceuticals production unit located at HIL and equipped with a commercial proton/deuteron cyclotron, chemical units and 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 radiopharmaceutical production place. The participation in the WCPC of numerous University and 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.

In 2003 a proposal was submitted to the Technical Co-operation Programme of the International Atomic Energy Agency (IAEA) for a partial support of the Warsaw PET Centre equipment purchase and activity. This proposal got a strong support and written promises of the local financial contribution from the Ministry of Sciences and Informatics and Ministry of Health.

It is hoped that the Warsaw PET Centre will begin its diagnostic, research and educational activity in 2006. Starting from this time the Laboratory with its well trained team will operate two cyclotrons, one for research, the another one for radioisotope production.

Jerzy Jastrzębski

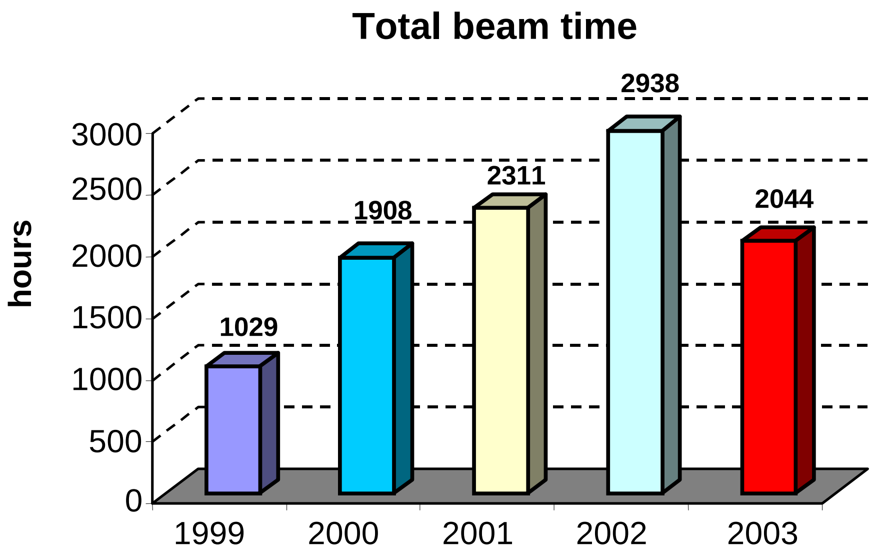
Part A:
Laboratory overview

1. Operation of the cyclotron and associated apparatus during 2003

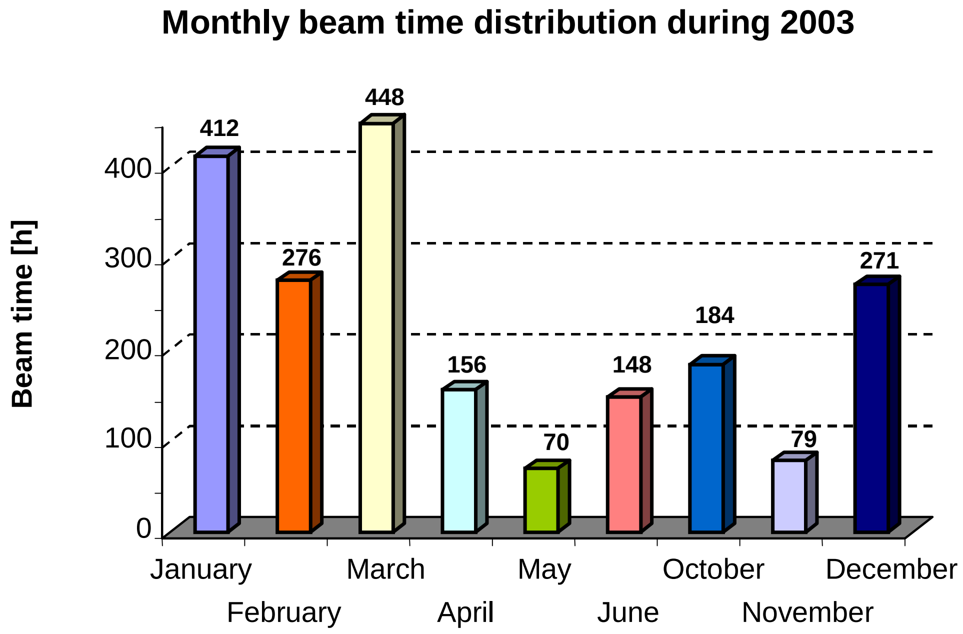
J. Choiński, *T. Czosnyka*, *J. Jastrzębski*, *W.Kalisiewicz*, *J. Kownacki*, *E. Kulczycka*,
J. Kurzyński, *J. Miszczak*, *B. Paprzycki*, *J. Sura*

Cyclotron facility

In 2003 the cyclotron delivered the beams-on-target for 2044 hours. The beam time available to the users is illustrated in the figure below.



Monthly distribution of the beam time during 2003 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 beams currently available (ions, energies and currents) are shown below.

Available ions beams and their intensities.

Ion	Energy [MeV]	Extracted current [pnA]	Charge after extraction	Extraction radius [cm]
$^{11}B^{+2}$	38 - 55	3 – 4	5	71 - 85
$^{12}C^{+2}$	22 - 48	2 - 20	5, 6	56 - 83
$^{14}N^{+2}$	28 - 42	13 - 22	6	69 - 84
$^{14}N^{+3}$	70 - 84	100 - 143	7	72 - 79
$^{16}O^{+2}$	32	5.7	7	79
$^{16}O^{+3}$	46 - 80	5.7 - 137.5	7, 8	63 - 83
$^{19}F^{+3}$	38 - 66	1.25	8	62 - 82
$^{20}Ne^{+4}$	70 - 120	11 - 35	9, 10	65 - 85
$^{20}Ne^{+5}$	194	40	10	73
$^{32}S^{+5}$	64 – 121.6	0.5 – 1.4	13, 14	62 - 85
$^{40}Ar^{+7}$	120 - 172	0.9 – 2.3	16 - 18	69 - 82

Precise measurements of the beam energies were made possible by the installation of the time-of-flight system. 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). This system, announced already in 2002 Report, is now working reliably under full control of the operators. Remote computer-controlled system of reading beam current from the diagnostic boxes has been installed. 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.

Ion Beam Lines and Experiments

A schematic view of the experimental hall is reminded in the figure below. Lines C1, C2, C3 and C4 are used by permanent experimental set-ups while lines B and D accommodate the needs of the users having their own dedicated chambers.

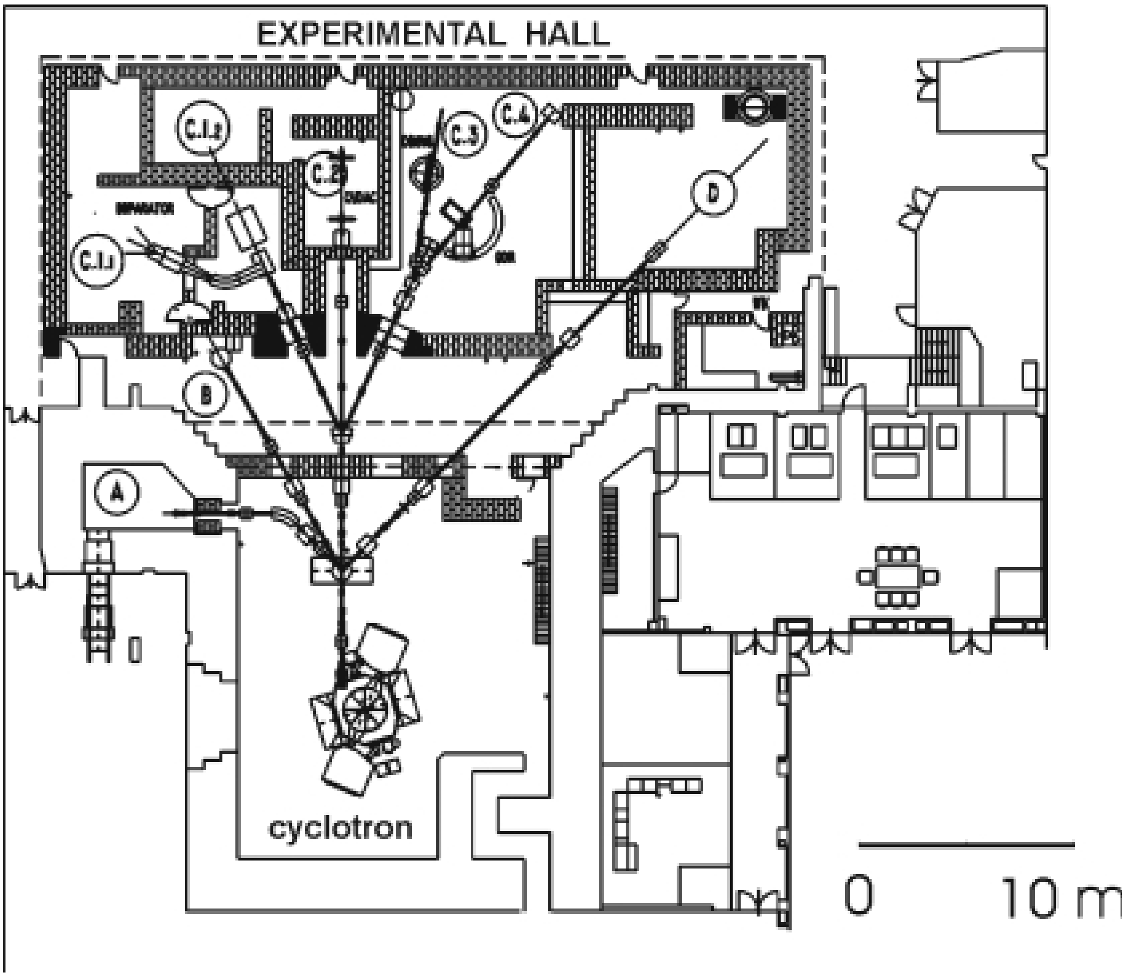
Examples of experiments employing heavy ions beams from the cyclotron include:

1) Investigation of the high spin states of nuclei with the multidetector OSIRIS II system. The experimental set-up consists of 10 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 (line C3).
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 (line C2). 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 built in Institute for Nuclear Studies, Świerk (line C1). First preliminary results have been already obtained.
4) Reaction studies of the light nuclei using universal large scattering chamber at the line B 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)) (line C4). 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.

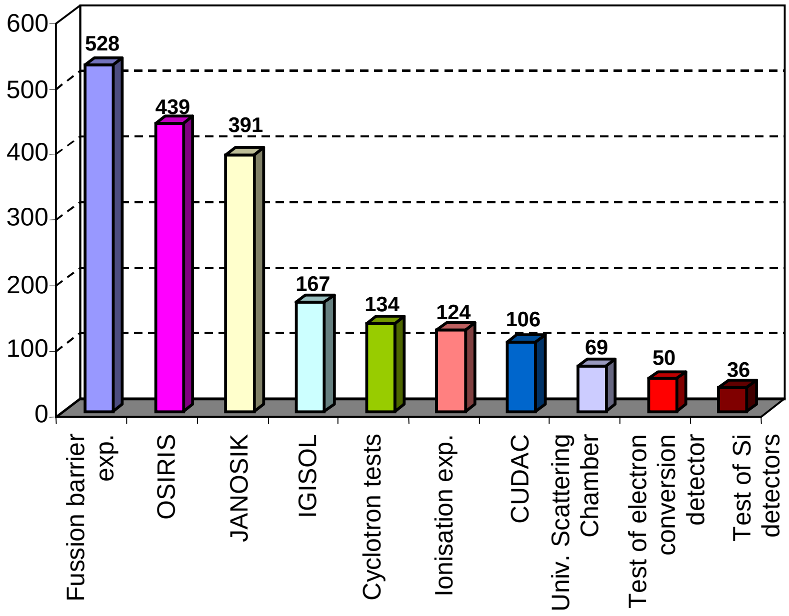
6) Applications of heavy ion beams in solid state physics (internal or extracted beams).

7) Investigation of the ion-atom collision processes by X-ray spectroscopy using the Si(Li) detector (lines B or D). 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.



Schematic view of the experimental area.

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 of the beam time for different projects in 2003 is presented below. It is to be stressed that the scientific output generated by the cyclotron experiments is on a high level with 13 publications, as seen in the list in this Report. Requirements for the beams now exceed the available time, so the selection, made by independent Experimental Committee, is necessary.


Experiments from 1.01.2003 to 31.12.2003, total beam time 2 044 hours

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	2004
1.1.2.	Precise beam energy definition using RBS method	2004
1.1.3.	Final version of the computerized remote control system	2004
1.1.4.	Saw-pulse buncher to replace existing sine-wave device	2004
2.	ECR ion source	
2.1.	Upgrade of the source	
2.1.1.	Computerized remote control system	2004
2.2.	Second ECR ion source	funding - dependent
3.	Injection line for the second ECR ion source	funding - dependent

To summarize, the operation of the cyclotron in 2003 was definitely successful, despite a few major breakdowns due to vacuum leakage on one of main rubber cyclotron chamber O-rings.

2. Activity report of the ECR group

B. Filipiak, A. Górecki, E. Kulczycka

1. In 2003 the following ion beams were produced using ECR ion source and provided to the cyclotron (ion currents on the cyclotron inflector):

Ion	He^{+1}	$^{10}B^{+2}$	B^{+2}	N^{+3}	N^{+4}	O^{+3}	O^{+4}	$^{18}O^{+4}$	Ne^{+3}	Ne^{+4}	Ne^{+5}	S^{+5}	S^{+6}	Ar^{+7}
Ion current (eμA)	185	7,5	26	113	130	99	76	45	108	114	61	47	100	43

The beam stability was very high (intensity fluctuation in order of a few %). Two new beams were obtained: $^{10}B^{+2}$ and $^{18}O^{+4}$.

2. The ion source was periodically surveyed and cleaned.

3. The vacuum rotary and turbomolecular pumps have been changed because of wear. Set in motion of the regenerated (by Edwards) cryogenic pump was unsuccessful.

4. The vacuum meter with protection against a break-down due to the worsening of the vacuum, has been installed.

5. The power supply for red-heat current of the r.f. generator has been changed because of lack of the current stabilization.

6. The power supply for magnetic coil of the ion trap has been broken. The power supply was repaired by HIL electricians group.

7. The damaged interface for compact vacuum gauges has been repaired.

8. The gas supply installation has been modified and completed.

3. The Time-of-Flight beam energy control

M. Sobolewski, J. Sura, J. Miszczak

The TOF setup installed in the beam lines of the HIL cyclotron consists of five pickups and permits to measure the velocity of accelerated particles and consequently the energy with an accuracy better than 0.5%. This system is being routinely used [1] to enhance the accuracy of determination of the particles energy resulting from the settings in the cyclotron extraction system.

The actual system is shown in Figure 1. Pickups 1 and 2 are installed in the common line for all beams. The probe number 3 is in the beam line C2 and the pickups 4 and 5 in the line D.

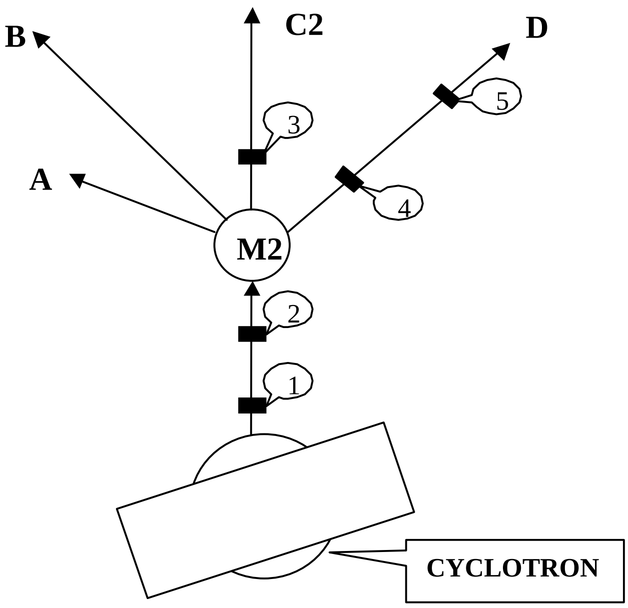


Fig. 1. Schematic of the main beam lines with the five TOF pickups, not in scale. Probes 1 and 2 are installed in the common beam line, between the extraction system of the CYCLOTRON and the first switching magnet M2. The base 1-2 is equal to 2.738 meters. Probe 3 in the line C2 is being used with the probe 2, and the base 2-3 is equal to 6.530 meters. The base between pickups 4 and 5 in the beam line D is longer (equal to 10.260 m) what results in enhanced accuracy.

The schematic design of the pickups is shown in Figure 2.

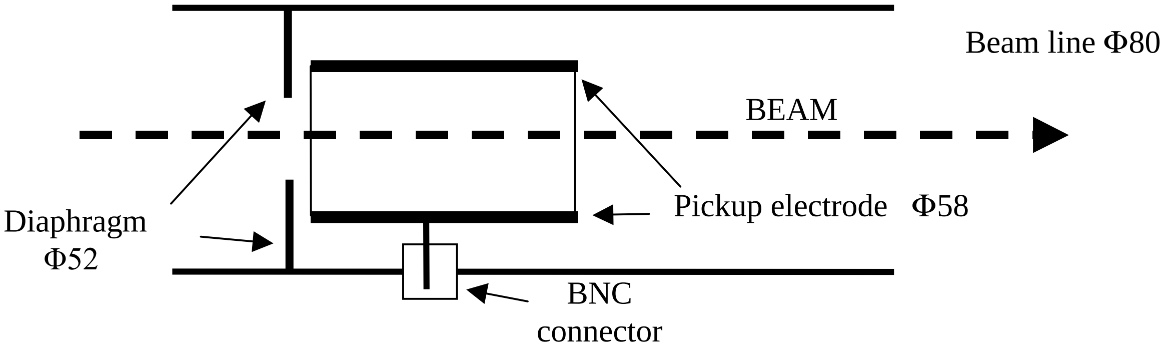


Fig. 2. Schematic design of a probe. The pickup electrode is made of a copper cylinder with inner diameter of 58mm and length of 30mm (the length of the probe 1 is reduced to only 15mm). The electrode is preceded by a diaphragm of 52mm. The signal induced in the electrode is fed to an amplifier through a BNC connector. The electrode and the diaphragm mounted on a holder are inserted in the tube of the beam line with inner diameter of 80mm. The capacitance of the electrode is 25pF.

The principle of the design was taken from the work [2] for the electrostatic case fulfilling the condition: the length of the probe is much smaller than the length of the beam bunch. The HIL cyclotron operates practically in the RF frequency range from 12.5 MHz to 19 MHz. The phase acceptance of the cyclotron is estimated to be around 50° of an RF cycle. The energy varies from 2 MeV/amu to 10 MeV/amu. The relative velocity ranges between β=0.0927 and β=0.206 and consequently, the length of beam bunches varies between 11ns and 7.3ns [in time] and between 203mm and 685mm [in length]. This means, that the length of the pickup electrode is much shorter than the length of all beam bunches.

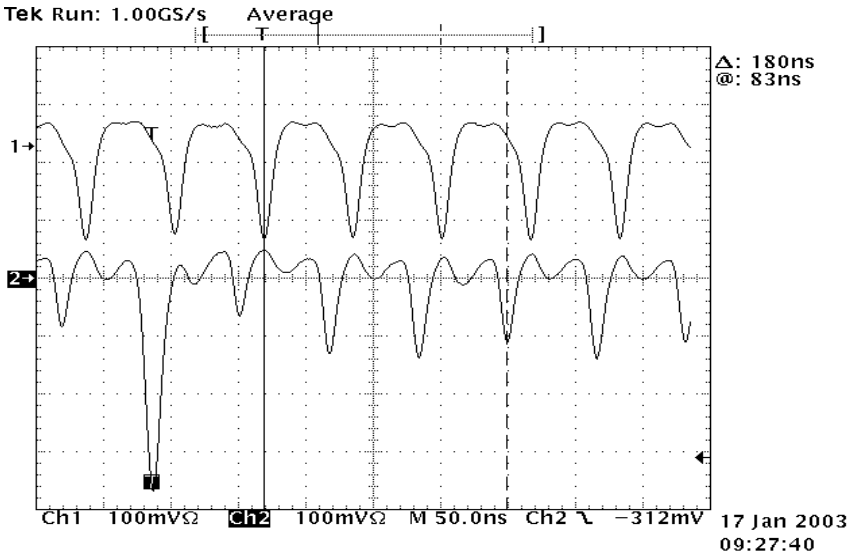


Fig. 3. Reading of time-of-flight picked up between peaks of probes 2-3. The second channel is perturbed by RF noise due to low beam intensity.

The signal induced in the probe is amplified by 100dB and fed by cables of equal length to the Tektronix TDS 640A digital oscilloscope (with time resolution of 50ps) in the control room. The time-of-flight may be measured between signal peaks in both channels like described in papers [3,4]. An example is shown in Fig. 3. The reading of the second channel shows some perturbation due to RF noise. In this case the intensity of the beam at the point 3 was too low. The loss of intensity between the two probes was due to a mismatching of ion-optical elements. It was found experimentally, that the average beam intensity should surpass the value of 50enA to give a proper signal to noise ratio. Besides the noise there is another source of error, which is the human, manually positioning markers on top of the peaks of pulses. To minimize this error we introduced differentiating circuits at the input of the oscilloscope. This way we point the markers on the "zeroes" of the pulses, which are well defined. A reading picked up with these circuits is shown in Fig. 4.

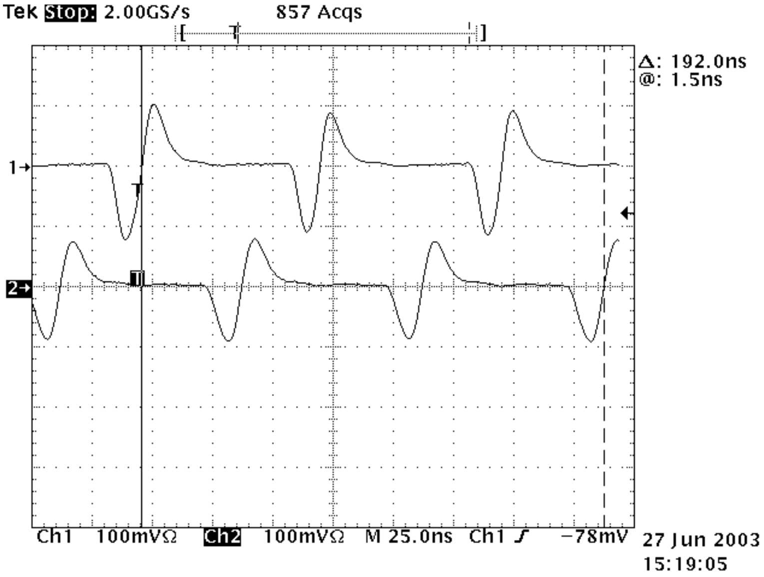


Fig. 4. Differential reading. The measurement is taken between probes 2 (trace 1) and 3 (trace 2).

Results of some physical experiments could be used for calibration of the TOF. While some energy readings from experiments were in very good agreement with the TOF (0.1% relative difference) others were not, with relative differences up to 5%. It was decided to build semi-permanent elastic scattering station to get TOF calibration.

Roughly the same can be said about energy spread. The TOF estimate of energy spread was taken from the enlargement of the bell-like pulse while passing two pickups. This enlargement can be read between the maximum of its derivative-the negative and positive maximum. This effect is shown in Figures 5 and 6.

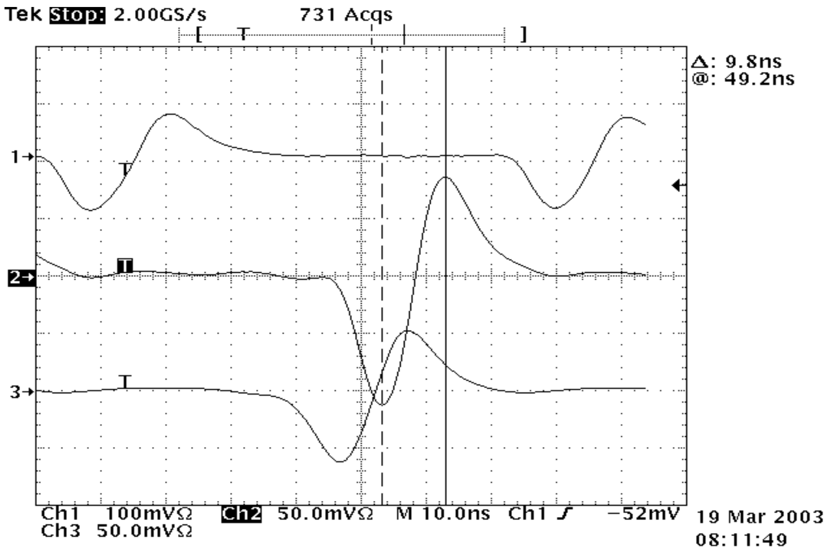


Fig. 5. The width of the bunch pulse at the pickup 2 is 9.8 ns.

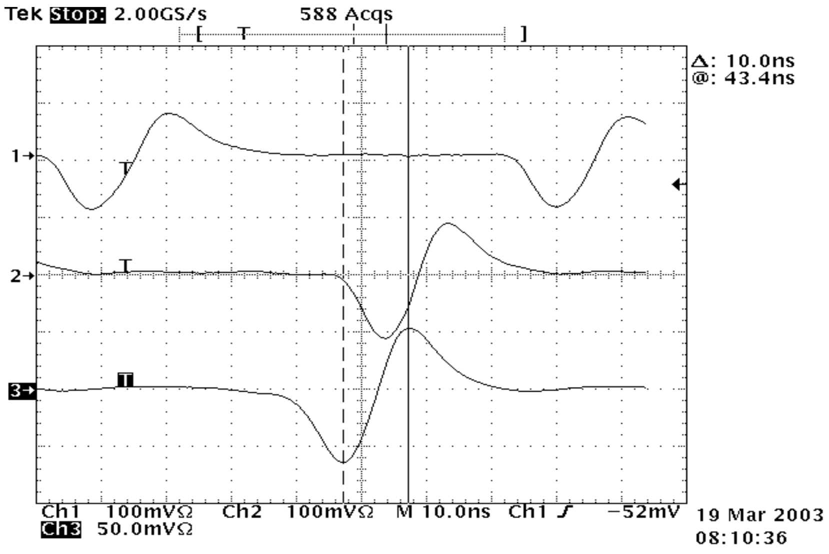


Fig. 6. The bunch width at the pickup 3 is 10 ns.

The formulas used by the cyclotron’s operators to obtain energy values and energy spread from oscilloscope readouts follow.
The full energy-E is determined by the velocity-v, which follows from the known distance between probes-s and the time difference-Δt. The relative velocity β (relative to the velocity of light-c) appears in the final formula.

$$v = \frac{s}{\Delta t} \qquad \beta = \frac{v}{c}$$

$$E = A \cdot E_0 \cdot \left(\frac{1}{\sqrt{1-\beta^2}} - 1 \right)$$

Where A denotes the atomic mass number and E_0=931,5 is the atomic mass unit in MeV.

The energy spread δE/E is determined by the difference of the length of a bunch while it travels between the two pickups

$$\delta t = \delta t2 - \delta t1$$

$$\frac{\delta E}{E} \approx 2 \cdot \frac{\delta t}{\Delta t}$$

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4. Activity of the electrical support group

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

Designs and implementation

Design and project of the Printed Circuit Board (PCB) for the controller to be used with 60kW current supplies serving the switching magnets has been done. Programming of the controller compatible with QNX environment, montage, adjustment, stabilization and circuit calibration were performed. Tests showed that some improvements of the system should be introduced. This task is already completed.

Special attention is paid to the development of the computer-controlled power supplies of the UZ-series. The project assumes the use of PIC microprocessors with 12-bit ADC/DAC converters a RS232 communication switching module serving sequent ional 8-bit control packages from a PC-class computer. Implemented communication protocols are fully compatible with those already used. The solutions implemented will allow, should the need arise, to extend the control systems with easy to implement and also inexpensive JuPiC programators compatible with Microchip processors.

Front-end PC-computers, controlling the power supplies, are powered by QNX system coupled to Photon graphic interface, licensed for non-commercial use. The solution adopted allows to simultaneously control few of the power supplies using a single PC computer via RS232 port using a concept of virtual serial ports.

The measurements with the existing prototype proved the possibility of obtaining the accuracy of current setting, as well as readout of the current, with accuracy 10^{-3} of the nominal setting. Final implementation of the system is expected during 2004.

Routine technical activities

a) Control and maintenance of electrical network - switches, connections, relays and lighting
b) Calibration and maintenance of all power supplies
c) Modifications of electrical circuits to improve their performance

Cyclotron operation

Members of the group, along with their routine work, serve as the cyclotron operators taking shifts during the beam time. Moreover, they are on call in case of any problems concerning the electrical network.

5. Control system of the Warsaw Cyclotron

J.Miszczak, M.Sobolewski, T.Bracha, B.Daniel

In 2003 one notable feature was added to the control system. Now it is possible to have a look at the real time data at the cyclotron's operator main console using web browser anytime, anywhere. For interested parties the address is http://ctrl1.slcj.uw.edu.pl. The data is available in read only mode in two forms: as a table, with all the data on one page - great for printout and documentation; and several pages of the same information intermixed with graphics representing various parts of the cyclotron. To accomplish this some modifications were necessary to the main control program and a few CGI scripts had to be written in PERL to provide dedicated WWW server with the data. Another significant software project was the replacement of radiation monitoring program NetView. The NetView program was bought from Eberline Instruments GmbH (together with radiation monitoring probes). The program is quite sophisticated allowing measurements to be recorded, displayed and processed. However the program operates only under DOS/Windows 3.1 and newer versions are expensive (over 4000 Euro). It was decided to write custom program, with similar functionality, under QNX operating system to get better integration of the radiation measurements with the cyclotron control system. The new program now records and displays the data in text mode, graphics GUI will be added by the end of 1Q of 2004. The beam intensity measuring/display system underwent some modifications. The system suffered from high failure rate, attributed mainly to long cable runs. The cables connect microprocessor based measuring/control stations scattered throughout the experimental hall to the control room. The longest cable is about 40 m. The measurements are transmitted using

RS232 signaling. After upgrading RS232 hardware the transmission problems mostly disappeared.

A new 18 channel video mux (for the above beam measuring system) has been built to replace the old one, which was in good working condition, however integrated circuits necessary for its repairs are no longer available.

6. Computers and Computer Networks

J. Miszczak, *Z. Kruszyński*

About 30 PC computers in the Laboratory use DOS and various versions of Microsoft Windows as an operating system. The rest uses QNX, Linux, and Digital Unix. The Windows computers use Novell Netware server for file sharing, network printing, and e-mail. The network runs 24 hours a day, 7 days a week since second half of the 1992 year. The Novell software is long obsolete (version 3.11) which means no new patches and fixes for the OS, and no drivers for a new hardware. The actual configuration of the server hasn't changed since 1995 (except for hard disc drives) so the server was running out of steam. Fortunately we got slightly newer version of the Netware (4.11-Intranetware) for free from another department of the Warsaw University, so it was decided to replace both server hardware and Novell software at the same time. Such a change is time consuming and prone to errors, but fortunately it was not the case and after one weekend in December of 2003 the changeover was complete. Another big improvement in Laboratory's networking capabilities was installation of two new Ethernet switches - one in the B part of the building, and another in the experimental (users) room. The new 3COM 4400SE switches have 1000 Mb/s ports so the backbone now runs at gigabit speeds, and all user's ports are 10/100 Mb/s. The new switches replace a collection of older 10Mb/s switches, one Fast Ethernet only switch, and 10Mb/s hubs.

7. Unix computers at HIL

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

About 15 PC computers running the Linux operating system and 1 Digital Unix machine comprise at present the cluster of Unix machines at HIL. These computers share a system of common accounts with about 30 active users and the user disk space of about 270~GB. Three network printers are available, and the unix computers provide e-mail, WWW and DNS (name server) services.

In 2003, system upgrades of all the Linux computers were gradually performed. At present all the machines run Mandrake 9.2 Linux distribution, with the latest security and bug fixes applied. Note that it is imperative to keep the installed system software up to date, as knowledge of any potential security holes in the old versions of the programs is often widely spread in the Internet, and this can be easily exploited to obtain unauthorised access to the system.

Several important software packages were updated and in some cases modified. This includes latest versions of the RadWare package commonly used in the gamma-ray spectroscopy data analysis, ROOT data analysis framework, TSCAN tape sorting package, GEANT4 Monte-

Carlo simulation software, and the TeX typesetting system. The newly installed OpenOffice software facilitates handling of various files typical for Microsoft Windows. This development, longed for by Unix users, considerably reduces the need of the troublesome switching to another operating system, if MS Windows files have to be processed. In addition, numerous graphical packages were added or upgraded.

For the purpose of the analysis of data from large scale experiments, a system of especially allocated disks was installed. More than 200 GB of disk space is now available, as one volume, for storing list mode data. Sorting such data with the speed of up to 40 MB/s is possible. This is a significant improvement in comparison to sorting data from tapes (up to 5 MB/s in case of DLT).

New software packages were required for the development of the WWW page of HIL. A processor of the PHP scripting language was installed and activated, as well as the PostgreSQL data base system. A modified, bi-lingual version of the HIL WWW page will soon be available.

Backups of user files have been so far manually performed by the system administrator, using DLT tapes. Difficulties are obvious with keeping the pace of such manual backups regular, especially that one DLT drive was used both for the backups and data analysis. Also, the volume of files which must be backed up increases, exhausting the capacity of a single DLT cartridge (about 70 GB), which makes the backup procedure even more difficult. Thus, the present backup techniques were considered unreliable and unsufficient. A new system of automatic (daily) backups using hard disks is currently in preparation.

Part B:

Experiments
and experimental set-ups

1. The ^{13}C +^{11}B elastic and inelastic scattering and isotopic effects in the ^{12,13}C + ^{11}B scattering

S.Yu. Mezhevych[1,2], *K. Rusek*[1], *A.T. Rudchik*[2], *A. Budzanowski*[3], *V.K. Chernievsky*[2], *B. Czech*[3], *J. Choiński*, *L. Głowacka*[4], *S. Kliczewski*[3], *E.I. Koshchy*[5], *V.M. Kyryanchuk*[2], *A.V. Mokhnach*[2], *A.A. Rudchik*[2], *S.B. Sakuta*[6], *R. Siudak*[3], *I. Skwirczyńska*[3], *A. Szczurek*[3,7], *L. Zemło*

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7) *University of Rzeszów, Rzeszów, Poland*

Angular distributions of the ^{13}C + ^{11}B elastic and inelastic scattering were measured for the first time at $E_{\rm lab}(^{11}\rm B)$ = 45 MeV for the transitions to the ground state and 2.125 MeV ($1/2^-$), 4.445 MeV ($5/2^-$), 5.02 MeV ($3/2^-$), 6.743 MeV ($7/2^-$), 7.286 MeV ($5/2^+$), 7.976 MeV ($3/2^+$), 8.56 MeV ($3/2^-$) excited states of ^{11}B and 3.088 MeV ($1/2^+$), 3.684 MeV ($3/2^-$), 7.490 MeV ($7/2^+$) + 7.547 MeV ($5/2^-$) + 7.680 MeV ($3/2^+$), 8.2 MeV ($3/2^+$) of ^{13}C.

The data were analyzed using the optical model (OM) and coupled-reaction-channels method. The elastic, inelastic scattering and transfers were included in the coupling scheme.

The isotopic effects in the elastic and inelastic scattering of ^{13}C + ^{11}B (full points and solid curves in Fig. 1) and ^{12}C + ^{11}B (open points and point curves) are observed [1,2]. In both cases the anomalous large angle scattering (ALAS) cannot be described by the optical model (curve <OM>). It was found that the ^{12}C + ^{11}B ALAS is caused by the ^{11}B reorientation and proton transfer (curve <p>), but in the ^{13}C + ^{11}B elastic scattering only the ^{11}B reorientation dominates at large angles. The deuteron-transfer and two-step processes (curve <np+pn>) are negligible in the ^{13}C + ^{11}B elastic and inelastic scattering.

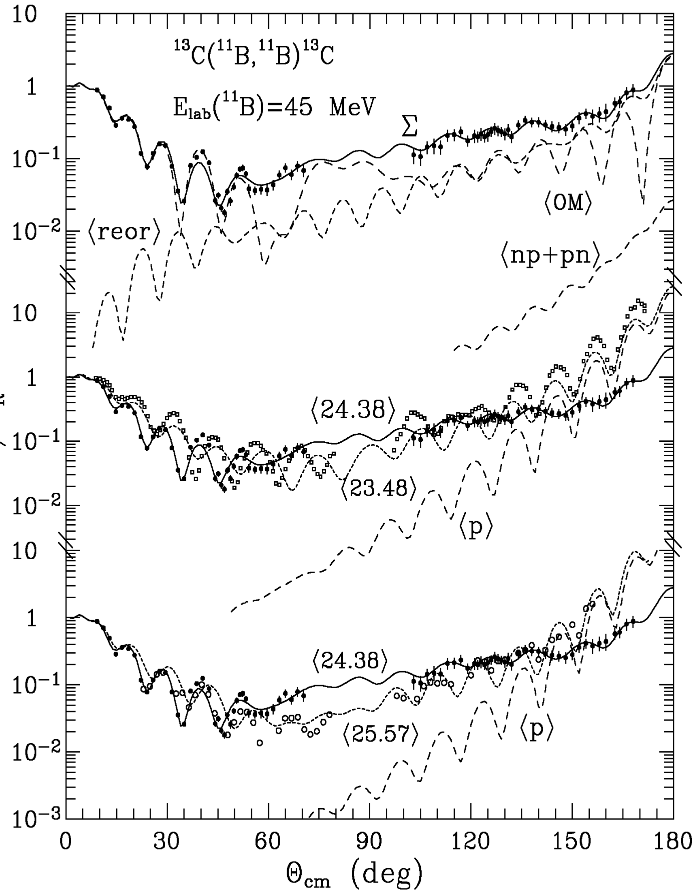

Fig. 1. Angular distributions of the ^{13}C + ^{11}B and ^{12}C + ^{11}B elastic scattering.

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2. One-nucleon transfer reaction ^{9}Be(^{11}B, ^{10}B)^{10}Be and optical potential for the ^{10}B + ^{10}Be interaction

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Angular distributions of the ^{9}Be(^{11}B, ^{10}B)^{10}Be reaction were measured at E_{lab}(^{11}B) = 45 MeV for the transitions to the ground state and 1.74 MeV (0^+), 2.154 MeV (1^+), 3.587 MeV (2^+) excited states of ^{10}B and 3.368 MeV (2^+) excited state of ^{10}Be.

The data were analyzed using the coupled-reaction-channels method. One- and two-step transfers were studied.

The optical model (OM) parameters for the entrance reaction channel were obtained in Ref. [1] from the analysis of the ^{9}Be + ^{11}B elastic scattering data. The OM parameters for the ^{10}Be + ^{10}B channel were fitted to the reaction data.

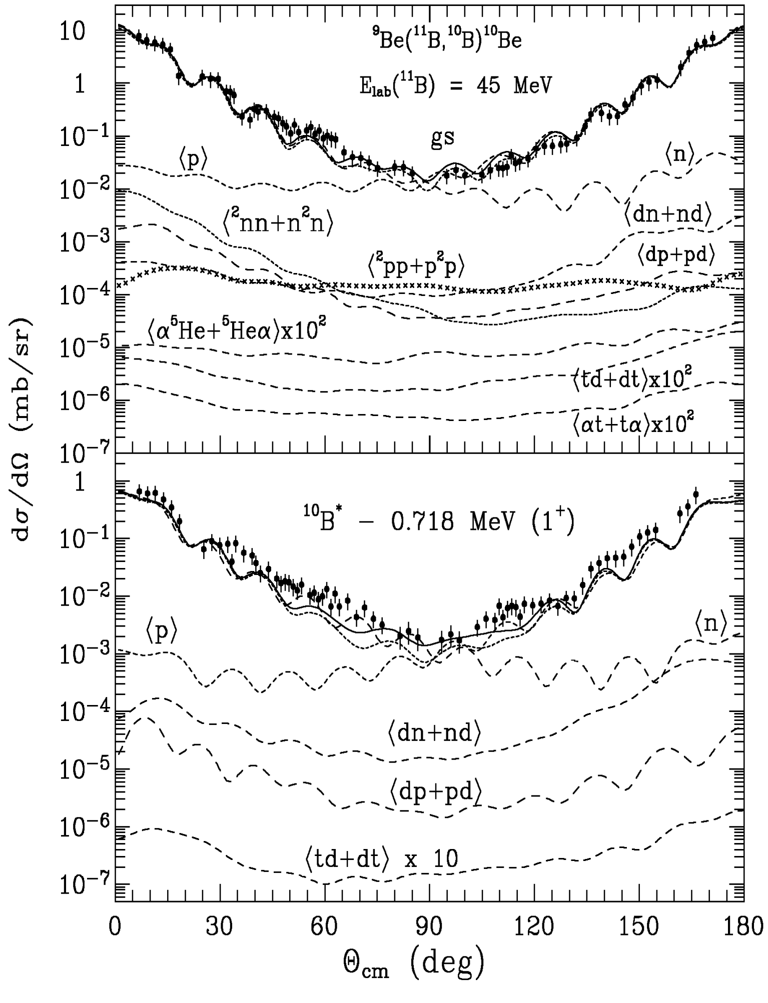

Fig. 1. Angular distributions of the ^{9}Be(^{11}B, ^{10}B)^{10}Be reaction at the energy E_{lab}(^{11}B) = 45 MeV.

It was found that in the ^{9}Be(^{11}B, ^{10}B)^{10}Be reaction the neutron-transfer (curve <n> in Fig. 1) and proton-transfer (curve <p>) dominate at forward and backward angles, respectively. The two-step transfers (curves <dn+nd> and others) are negligible in this reaction.

The ^{10}Be + ^{10}B OM parameters deduced were compared with the ^{9}Be + ^{11}B and ^{9}Be + ^{10}B OM parameters obtained from the analysis of the ^{9}Be + ^{10}B elastic scattering data at energies E_{cm} = 8.42 - 47.37 MeV [2,3]. The energy dependence of the ^{9}Be + ^{10}B and ^{10}Be + ^{10}B OM potential parameters was deduced.

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3. Fusion barrier distributions in ^{20}Ne + ^{112,116,118}Sn

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Fusion barrier distributions for the ^{20}Ne + ^{112,116,118}Sn systems have been extracted from quasi-elastic scattering cross sections measured at the Warsaw HIL Cyclotron. Results are compared to coupled-channels calculations performed with the CCFULL code. The overall widths of the distributions are reproduced on taking account of the low-lying collective states of the target and projectile but some puzzling discrepancies in their shapes remain to be explained.

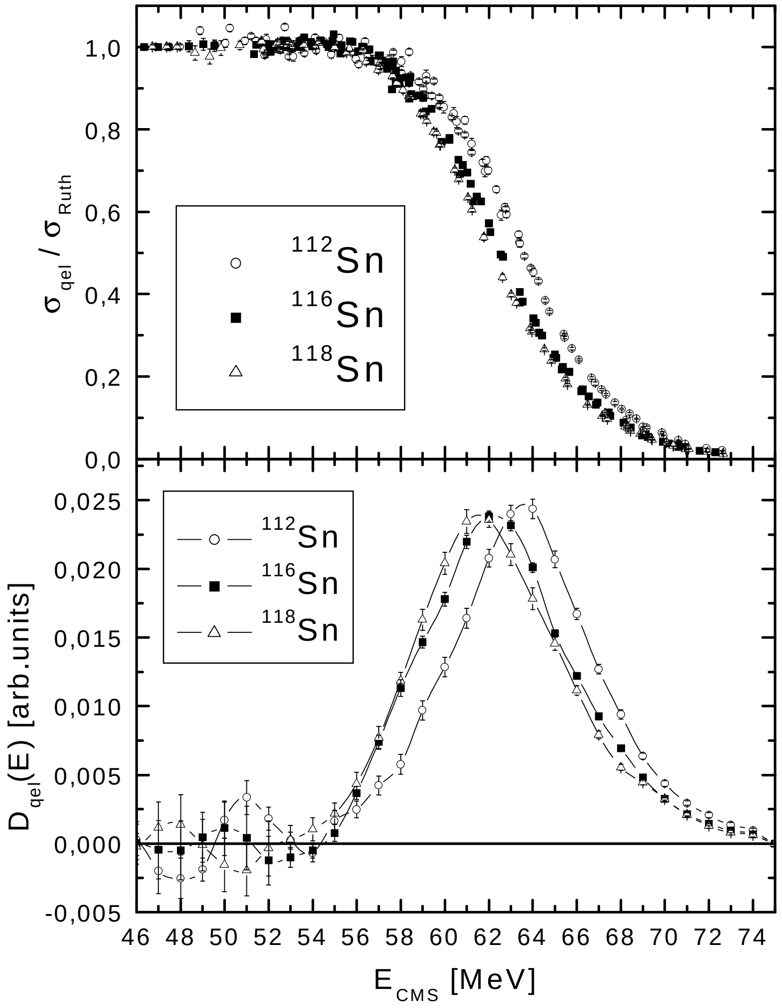

Fig. 1. Excitation functions and barrier distributions in the ^{20}Ne + ^{112,116,118}Sn systems studied.

We have used the quasi-elastic back-scattering method to extract fusion barrier distributions for the ^{20}Ne + ^{112,116,118}Sn systems. The measurements were performed using beam from the Warsaw HIL Cyclotron. The ^{20}Ne beam was delivered onto tin targets of about 180μg/cm^2 thickness. The beam energy ranged between 64 MeV and 88 MeV and the use of Ni and Ag degraders allowed us to achieve an overall beam-energy step of around 2 MeV. The angular arrangement of our detectors yields a final step in the effective energy of about 0.5 MeV.

The targets were placed inside the CUDAC scattering chamber. We used 30 PIN-diodes of area 10x10 mm placed at backward angles 130°, 140° and 150° to register quasi-elastically scattered ions and two silicon detectors at 35° to monitor Rutherford scattering and to measure the beam energy.

Additionally 4 silicon E-ΔE telescopes were put at 120° and 160° to measure the transfer of light charged particles. Details of the experimental setup and data analysis are given in ref. [1].

The measured excitation functions for quasi-elastic scattering normalized to Rutherford scattering are shown in the upper plot of Fig. 1. The relative shift in the functions is due to the different reaction radii for the different Sn isotopes. The lower plot presents fusion barrier distributions for the three systems measured. Discrepancies at energies of about 50 MeV are within statistical errors but the difference in shapes in the energy range 56-58 MeV imply that we observe isotopic effects. Moreover, in comparison to ^{116}Sn (solid squares), the distribution for ^{112}Sn (open circles) is shifted 1.2 MeV towards higher energy. The shift is two times larger than expected using nuclear radii taken from compilations [2].

The experimental distribution for ^{20}Ne + ^{116}Sn have been compared with calculations performed using the coupled-channels code CCFULL [3]. The analysis and conclusions are given in ref. [4].

The authors wish to thank A. Stolarz and S. Khlebnikov for preparing our 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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4. Low-background housing for environmental measurements

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A low-background housing for environmental measurements has been designed and constructed for Biology Department. The housing is devoted to a vertical detector, for measurements with two standards of containers (see Fig.1, "sample I", "sample II"). The detector is shielded by 6 cm of ultra low activity lead (<3 Bq/kg) and 1 mm of copper. There is a possibility to add a cadmium layer between lead and copper, to cut-off X-rays from lead in case of very precise measurements [1,2].

The housing consists of 10 lead rings, of weight of about 17 kg each, and is easy to montage. A cover of the sample chamber is mounted on the axial bearings. This allows an easy access to the chamber. Apart from a small interstice under the cover, the housing is air-tight.

Certified, high-radiopurity lead, in form of ingots (of 40 kg each), has been supplied by Polish company Plombum Fl. All elements of the housing have been cast and machined at HIL workshop.

Measurements performed with the 15% relative efficiency germanium detector at Biology Department proved that the background in the housing is low: 1,8 cps in the energy range of 0 to 1900 keV. The set-up suits very well for environmental samples analysis, especially for ^{137}Cs and ^{40}K, even without additional cadmium layer.

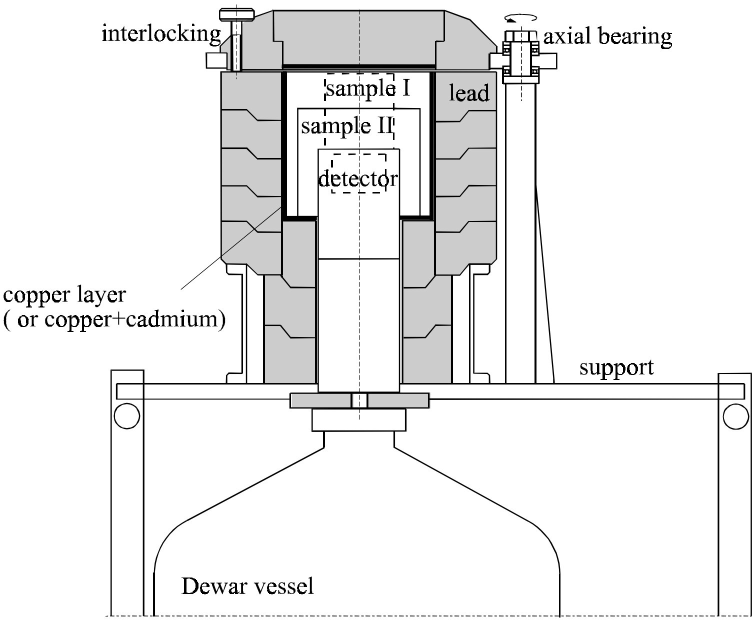

Fig. 1. The low-background housing for environmental measurements.

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5. Dynamics of formation of K–hole fractions of sulphur projectiles inside a carbon foil

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In collisions of heavy ions with target atoms the strong Coulomb field of one of the “partners” of collision can cause simultaneous ejection of several electrons of the second one. This process results in a reduction of the nuclear charge screening and increases the binding energy of remaining electrons [1]. Consequently, the energies of x-rays emitted from such multiply ionized atoms are shifted, with respect to the corresponding x-ray energies of singly ionized atoms and their energies reflect the actual configuration of electrons during the x-ray emission. Finally, as a result of the multiple ionization, instead of a single-hole x-ray transition called the diagram line, the structure of x-ray satellites appears.

The main goal of the present work is to study the dynamics of formation of K-shell vacancy fractions of sulphur projectiles passing through a carbon foil. Therefore, using the so called three component model [2], we have performed an interpretation of target thickness dependence of measured x-ray production cross-sections, for the first time separately for each recorded line ($K\alpha^{s}_{1,2}$, $K\alpha^{h}_{1,2}$, $K\beta^{s}_{1,3}$, $K\beta^{h}_{1,3}$, Ky^{s}, and Ky^{h}). This model evaluates the values of K-shell vacancy production and filling cross sections.

Sulphur ion beams with incident energies of 65, 79, 99 and 122 MeV and with incident charges of 13^{+} and 14^{+} was obtained from the U–200P cyclotron at the Heavy Ion Laboratory of Warsaw University. The experimental set-up applied in this work was the same as that described earlier [3]. Two collimators are used to define 2 mm in diameter beam spot on the target. Self-supporting carbon foils with effective thickness of 15 – 210 μg cm^{-2} were positioned in target holder at the center of vacuum chamber at an angle of 25° to the direction of the beam. The geometry of experimental arrangement used in this work means that the detector should register x-rays emitted by projectile inside the target as well as from distance up to 1.2 cm behind the target, so during such experiments x-rays with lifetimes up to 10^{-12} s were registered.

The carbon targets were prepared by vacuum evaporation and their thickness was determined by the energy loss of 5.48 MeV α-particles from ^{241}Am source. Independent measurements of target thickness enabled absolute normalization of the x-rays intensity on the incident number of projectiles obtained from elastically scattered sulphur ions detected in a silicon surface-barrier detector located inside the chamber at 12.5° to the beam direction.

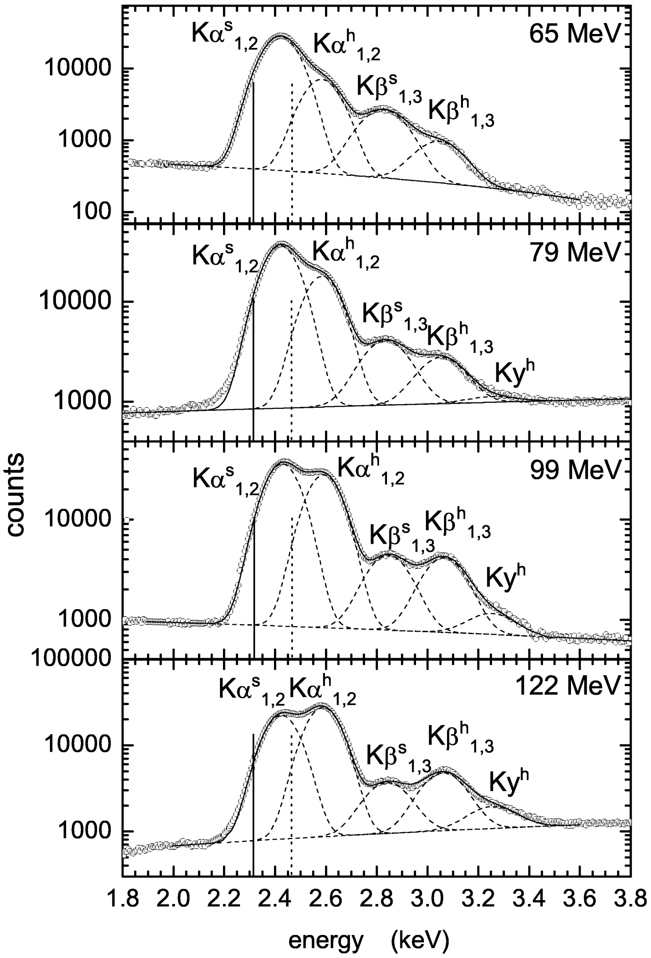

Fig.1 The K x-ray spectra emitted by sulphur projectiles with 65, 79, 99 and 122 MeV energy moving through a carbon foil with thickness ~150 μg cm^{-2}. Dashed vertical lines show positions of $K\alpha_{1,2}$ and $K\beta_{1,3}$ diagram lines while dotted lines show resolved individual transitions.

The K x-rays emitted from the moving projectiles were measured in the beam incident side of the target at 90° to the beam direction by a Si(Li) detector placed outside the target chamber. Projectile x-rays passed in their way to the detector through 10 μm metallised Mylar chamber window, 25 μm thick beryllium detector window and 5 mm air gap between both windows. Since the registered K x-rays of the sulphur projectile were attenuated due to transmission through these various absorbers the used x-ray spectrometer was carefully calibrated to obtain its detection efficiency. The calibration was performed in x-ray energy range 1.5 – 120 keV using standard calibrating sources of ^{57}Co, ^{133}Ba, ^{152}Eu, ^{241}Am and by PIXE measurements of x-rays from thin targets ($Z_t = 13 – 42$) according to the recipe of Pajek et al. [4]. For the essential at the present work low energy region (2 – 5 keV) the detector efficiency was determined with uncertainty less than 4%. The energetic calibration of the spectrometer (a second sensitive parameter at the present study) was checked several times during experimental runs by measurements of the x-rays emitted from radioactive sources and it was determined with an uncertainty of 2 – 3 eV depending on the experimental run.

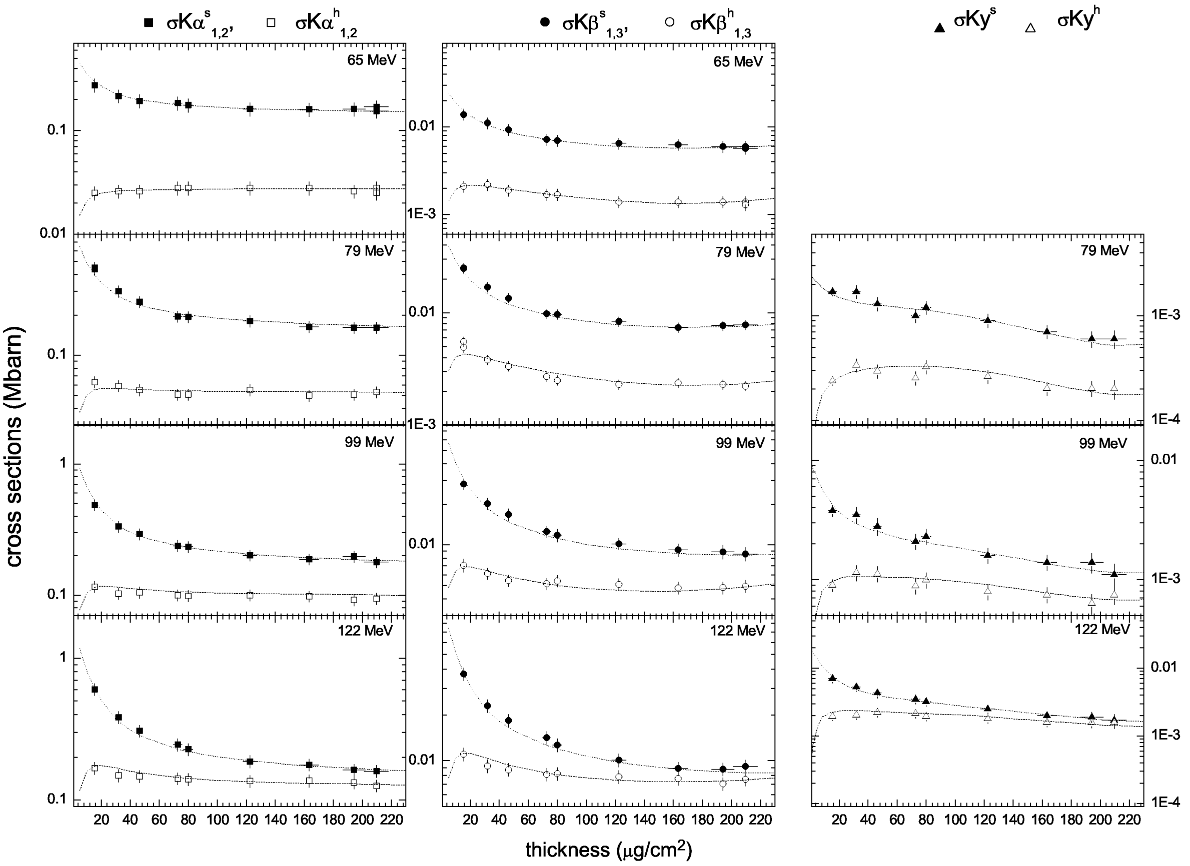

Fig.2 Dependence of $\sigma_{K\alpha}{}^{s}{}_{1,2}$ (solid squares), $\sigma_{K\alpha}{}^{h}{}_{1,2}$ (open squares), $\sigma_{K\beta}{}^{s}{}_{1,3}$ (solid circles), $\sigma_{K\beta}{}^{h}{}_{1,3}$ (open circles), $\sigma_{Ky}{}^{s}{}_{1,2}$ (solid triangles) and $\sigma_{Ky}{}^{h}$ (open triangles) x-ray production cross sections on the target thickness for the sulphur projectiles with energy 65, 79, 99, and 122 MeV. The smooth curves are the result of least–squares fits. Target thickness uncertainties are marked only for satellite data.

The x-ray spectra recorded by Si(Li) detector for sulphur ions with energies of 65, 79, 99 and 122 MeV passing through a carbon target are presented in Fig.1. The origins of all recorded peaks are described in detail in our previous paper [3]. The K$\alpha^{s}_{1,2}$, K$\beta^{s}_{1,3}$ satellite and K$\alpha^{h}_{1,2}$, K$\beta^{h}_{1,3}$ hypersatellite peaks are the results of the overlapped contributions corresponding to transitions of the following types: $1s^{-1}\rightarrow 2p^{-1}$, $1s^{-1}\rightarrow 3p^{-1}$, and $1s^{-2}\rightarrow 1s^{-1}2p^{-1}$, $1s^{-2}\rightarrow 1s^{-1}3p^{-1}$, respectively, from highly ionized sulphur projectiles. For sulphur ions with incident energies of 79 – 122 MeV additional highest-energy peak in the measured x-ray spectra labelled as Ky^h (see Fig.1) has been detected. This peak corresponds to the hypersatellite transitions from the 4p and 5p subshells ($2s^r4p^1\rightarrow 1s^12s^r$ and $2s^{r5}p^1\rightarrow 1s^12s^r$; r = 0, 1, 2) and proves that the corresponding satellite transitions (Ky^s) also take place. The lack of separate Ky^s satellite peak in the observed spectra indicates [3] that the contribution of this type of transition must overlap with any other peak. The $K\gamma^s$ line intensity has been calculated from $K\beta^h_{1,3}$ one according to the procedure described by Majewska et al. [3].

The satellite and hypersatellite x-ray production cross sections (marked as $\sigma_{K\alpha}{}^s{}_{1,2}$, $\sigma_{K\beta}{}^s{}_{1,3}$, $\sigma_{K\gamma}{}^s$, $\sigma_{K\alpha}{}^h{}_{1,2}$, $\sigma_{K\beta}{}^h{}_{1,3}$, and $\sigma_{K\gamma}{}^h{}_{1,2}$) have been calculated as a result of normalization of measured x-ray lines intensities on the number of projectiles and effective target thickness. The cross sections dependence on target thickness for all projectile energies is presented in Fig. 2. Such a behavior is determined by the dynamics of creation and disappearance of K-vacancy fractions of sulphur ions passing through a carbon target. The x-ray production cross section, being a result of x-ray emission by projectile inside and outside the target, was expressed by a function of: the ion equilibrium fraction, the formation and loss K-shell vacancy cross sections σ_{ij} [5], the radiation probability per unit path length, the satellite/hypersatellite fluorescence yield of the multiply ionized atom, and the fraction of ions able to emit studied x-rays.

Extensive description of the obtained results about the dynamics formation of K-hole of sulphur projectiles inside a carbon foil are presented in our paper recently accepted for publication in Physical Review A [6].

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6. Coulomb Excitation experiment with a ^{96}Mo target

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As a continuation of the project of shape coexistence studies in molybdenum isotopes (results on ^{98}Mo already published [1]) an experiment with ^{20}Ne and ^{40}Ar beams and ^{96}Mo target was performed using CUDAC set-up. Complementary data were collected in JAERI, Japan using the ^{96}Mo beam and ^{nat}Pb target. Whole set of data is now being analyzed in order to extract electric and magnetic multipole matrix elements. As in case of ^{98}Mo we expect to evaluate shape parameters in a model-independent way. This will extend the knowledge of the shape evolution in the medium-mass nuclei.

This work is partially supported by Polish State Committee for Scientific Research (KBN grant No. 2 P03B 007 25).

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7. Nuclear level lifetimes for supposed chiral bands in ^{132}La

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

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Recent theoretical and experimental works have attracted attention to the problem of chirality in atomic nuclei with odd numbers of protons and neutrons. In these nuclei the total nuclear spin is built from the valence proton and valence neutron momenta and angular momentum of the even-even core. These three vectors can be mutually perpendicular and coupled in two manners forming system (left- and right-handed) with opposite chirality in the intrinsic frame of the nucleus. In the laboratory it manifests itself as a presence of two rotational bands, nearby degenerated, with the same parities. The study of the chiral partner bands is in its early stage.

Chiral symmetry breaking in ^{132}La was studied via lifetime measurements using the DSA method at the Heavy Ion Laboratory of the Warsaw University. The ^{132}La nuclei were produced in the ^{122}Sn(^{14}N,4n)^{132}La reaction at a beam energy of 70MeV. γ-γ coincidences were collected by the OSIRIS II multidetector array, which consists of 10 ACS Ge detectors placed at angles 25°, 38°, 63°, 90°, 117°, 142° and 155° in respect to the beam direction. Lifetimes of excited states were extracted from the Doppler modified peaks using codes COMPA, GAMMA and SHAPE developed by A. Pasternak [1]. Up to 30 reduced transition probabilities B(M1) and B(E2) were determined. Fig. 1 presents level scheme obtained in the experiment. Bands 1 and 2 were already known [2]. These bands have been interpreted as a chiral partner bands. Band 3 is observed for the first time.

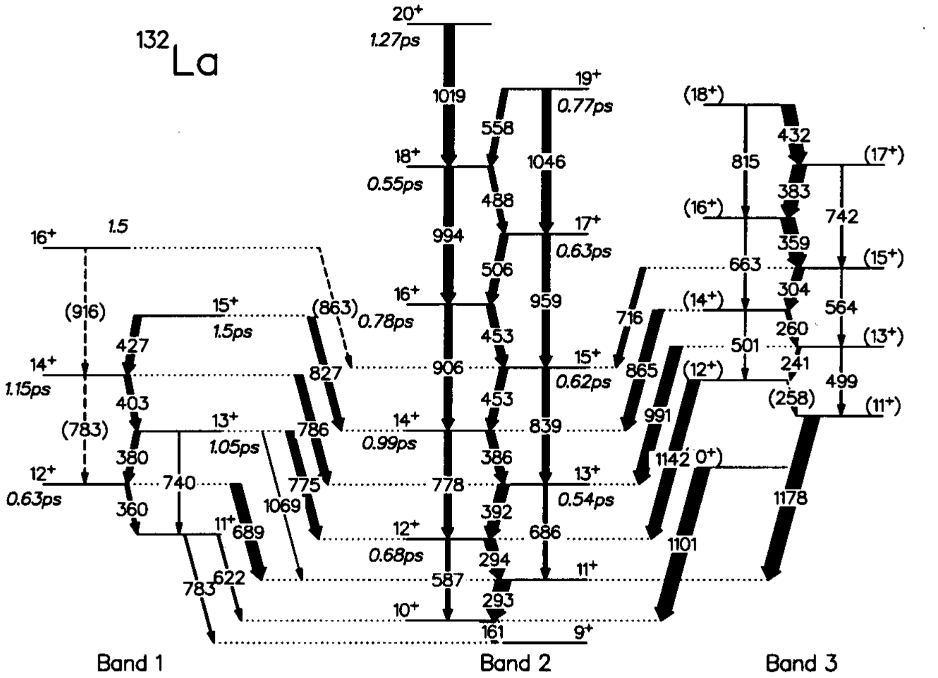

Fig. 1. Experimental level scheme. Width of the arrows denote branching ratios. Lifetimes are also given.

The experiment did not allow to determine spins of levels in band 3. These spins shown in Fig. 1 are taken directly form the CPHC (Core Particle Hole Coupling) calculation [2],[3]. Lifetimes of excited states are also shown in Fig. 1. They are between 0.5 ps and 1.5 ps what correspond to the sensitivity range of the DSA method. As example, the Doppler modified peak of E_γ=959 keV is presented in Fig. 2.

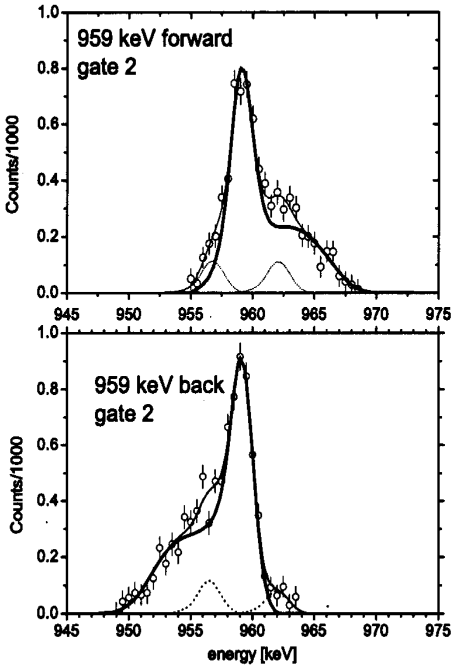

Fig. 2. Example of the fit to the Doppler modified peak. Upper panel-spectrum obtained from the detectors places forward to the beam direction; lower panel-spectrum from backward detectors. Dotted lines-contamination peaks. Bold solid line-fit to the peak of interest. Solid line-fit to the sum of all peaks.

Comparison of Fig. 1 with Fig. 3 shows that theoretical level scheme (level energies and spins) is in satisfactory agreement with the experimental results.

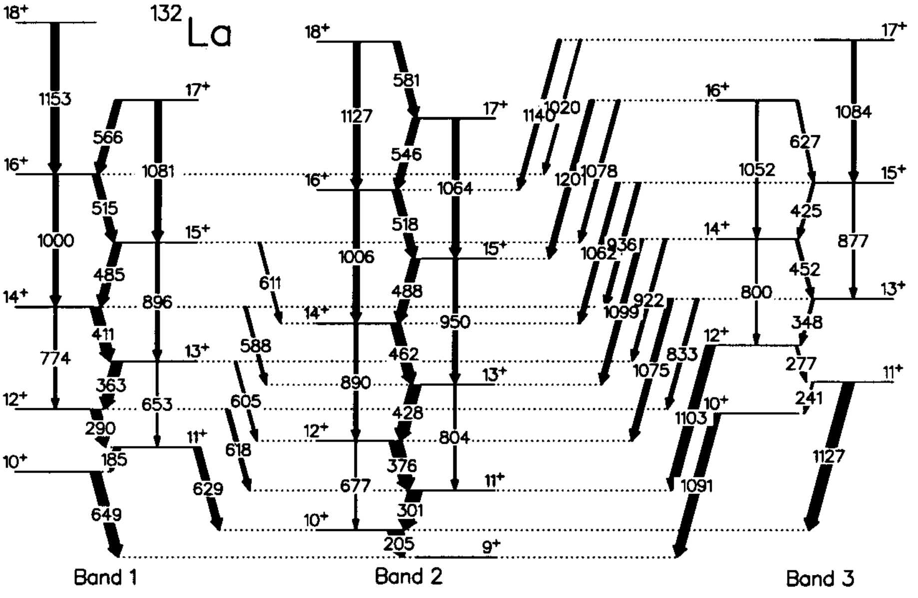

Fig. 3. Theoretical level scheme calculated in frame of the CPHC model.

The intraband reduced transition probabilities (for band 1 and 2) and interband transition probabilities (from band 2 to band 1) are presented in Figs. 4 and 5 respectively. Dramatic disagreement between the theory and the experiment is seen in band 1where the B(E2) values are about 20 times smaller than the calculated ones. Such small collectivity of band 1 can not be explained in the framework of CPHC model. Data analysis concerning band 3 is in progress.

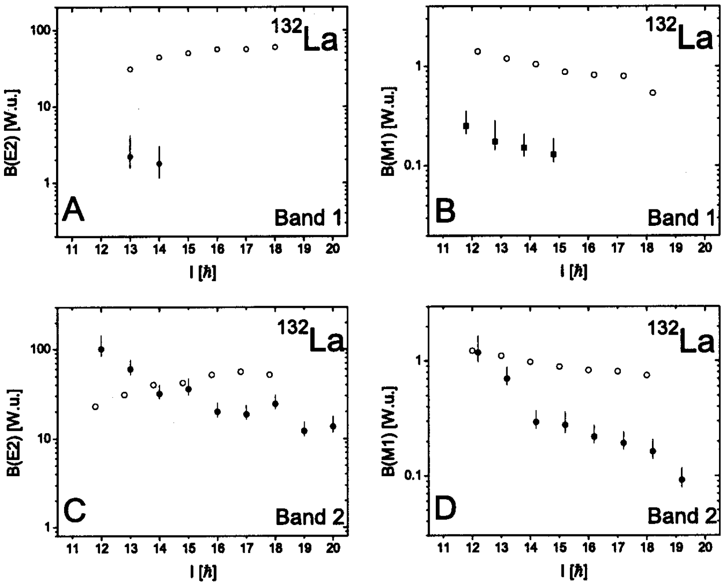

Fig. 4. Intraband reduced transition probabilities in bands 1 and 2. Open points-transition probabilities calculated by the CPHC model. Full points-experimentally measured values.

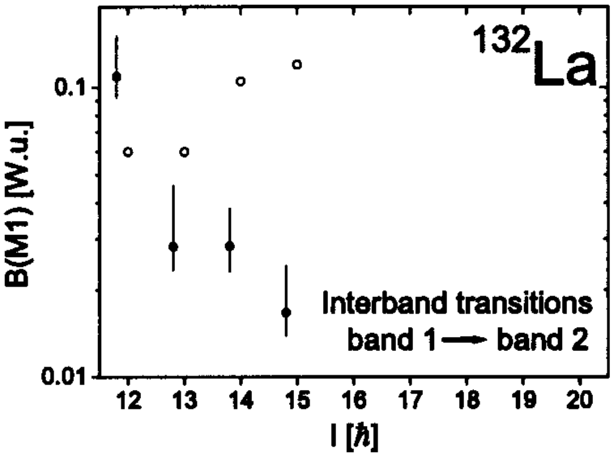

Fig. 5. Interband reduced transition probabilities for the transitions from band 2 to band 1. Open points-transition probabilities calculated by the CPHC model. Full points-experimentally measured values.

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8. Isospin mixing in ^{32}S nuclei

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In the Giant Dipole Resonance (GDR) studies of N=Z compound nuclei formed in heavy-ion fusion reactions the isospin mixing may be determined from comparison of the measured high-energy γ-ray spectrum with statistical model calculations [1, 2]. In order to extract the degree of isospin mixing in the ^{32}S compound nuclei, the γ-ray spectra from the statistical decay of the GDR built on excited states in ^{32}S and ^{31}P compound nuclei have been measured, analyzed and compared with statistical model calculations.

The ^{32}S and ^{31}P compound nuclei were formed with similar excitation energies of 58.3 MeV and 55.1 MeV by reactions ^{20}Ne + ^{12}C (with isospin T = 0) and ^{19}F + ^{12}C (with isospin T ≠ 0). These two reactions have been measured by using the cyclotron beams at the Heavy-Ion Laboratory of Warsaw University: 5.2 MeV/u ^{20}Ne and 4.4 MeV/u ^{19}F. The energy spectra of the emitted high-energy γ-rays and light charged particles have been measured with the multidetector JANOSIK set-up [3].

As a first step of the analysis, appropriate values of the statistical model parameters have been chosen, which reproduced well the γ-ray spectrum for N≠Z, ^{31}P compound nuclei. In such nuclei the E1 decays to all final states are allowed, and the γ-ray yield does not depend much on the isospin mixing. Statistical model calculations have been performed using a modified version of the computer code CASCADE [4] including the effect of isospin. The experimental values of fusion cross-section [5, 6], the Reisdorf level density description [7, 8], and the spin-dependent moment of inertia in agreement with the rotating liquid drop model were also used. The γ-ray yield from the T≠0 ^{31}P compound nuclei has been fitted by CASCADE calculations with a single Lorentzian GDR strength function and the GDR parameters treated as free parameters, with the assumption of no isospin mixing. The measured spectrum is well reproduced for the GDR parameters: S=0.90 ± .04, E=17.4 ± .06, Γ=13.3 ± 0.3 MeV (Fig. 1, left bottom).

Next, it was assumed that the GDR built in compound nuclei with similar mass and excitation energy, such as ^{32}S and ^{31}P, should have very close GDR parameter values. The GDR parameters extracted for ^{31}P in statistical model calculations have been then used for $^{20}\mathrm{Ne} + {}^{12}\mathrm{C} \rightarrow {}^{32}\mathrm{S}$ reaction, and the degree of the isospin mixing in ^{32}S was extracted from comparison of the measured γ-ray spectrum above E_γ =15 MeV with the statistical model calculations.

Our experiment was analyzed in terms of Coulomb spreading width $\Gamma_>\!\downarrow$. The $\Gamma_>\!\downarrow$ determines the mixing of the $T_>$ states into $T_<$ states at each excitation energy. The Coulomb spreading width $\Gamma_<\!\downarrow$ in mixing of the $T_<$ states with the $T_>$ states may be calculated as [9]:

$$\Gamma_<\!\downarrow = \rho(T_>) / \rho(T_<) \bullet \Gamma_>\!\downarrow,$$

where $\rho(T_>)$ and $\rho(T_<)$ are the level densities for $T_>$ and $T_<$ states. The isospin mixing coefficient $\alpha_<^{\ 2}$, i.e. the fraction of states with T = $T_<$ that mix to states with $T_>$ is given by [9] as:

$$\alpha_<^{\ 2} = (\Gamma_<\!\downarrow / \Gamma_<) / (1 + \Gamma_<\!\downarrow / \Gamma_< + \Gamma_>\!\downarrow / \Gamma_>).$$

The statistical model reproduces well the measured ^{32}S spectrum for $\Gamma_>\!\downarrow$ < 60 keV, i.e. $\alpha_<^{\ 2} < 0.024$, when assuming that the isospin mixing occurs only in the initial compound nucleus. This assumption should be regarded as giving upper limits on isospin mixing degree. On the basis of sum rules and experimental suggestions it is expected that the Coulomb spreading width should not change much with the excitation energy and the mass of the nucleus [9]. Thus probably the same $\Gamma_>\!\downarrow$ should be used for ^{32}S and ^{31}P, as well as for the daughter nuclei at a given excitation energy. This results in $\Gamma_>\downarrow$ = 20 ± 25 keV, and $\alpha_<^{\ 2}$ = 0.013 ± 0.015 (Fig. 1, left top).

In order to increase the sensitivity to the isospin mixing the ratios of γ-ray cross-sections for the reactions forming ^{32}S and ^{31}P nuclei, for the measured and calculated yields were analyzed. In this way, small errors in the statistical model calculations canceled and the dependence on the GDR parameters was removed. Thus $\Gamma_>\downarrow$ and $\alpha_<^{\ 2}$ in the T=0 ^{32}S compound nuclei were extracted by comparing the measured and calculated ratios of γ-ray cross-sections (above E_γ =15 MeV) for reactions in which T=0 and T ≠ 0 neighboring compound nuclei were formed at similar excitation energies (Fig. 1, right bottom). Our results are consistent with small isospin mixing, $\Gamma_>\downarrow$= = 20 ± 25 keV, and $\alpha_<^{\ 2}$ = 0.013 ± 0.015, at 58.3 MeV excitation energy, in agreement with [2, 9].

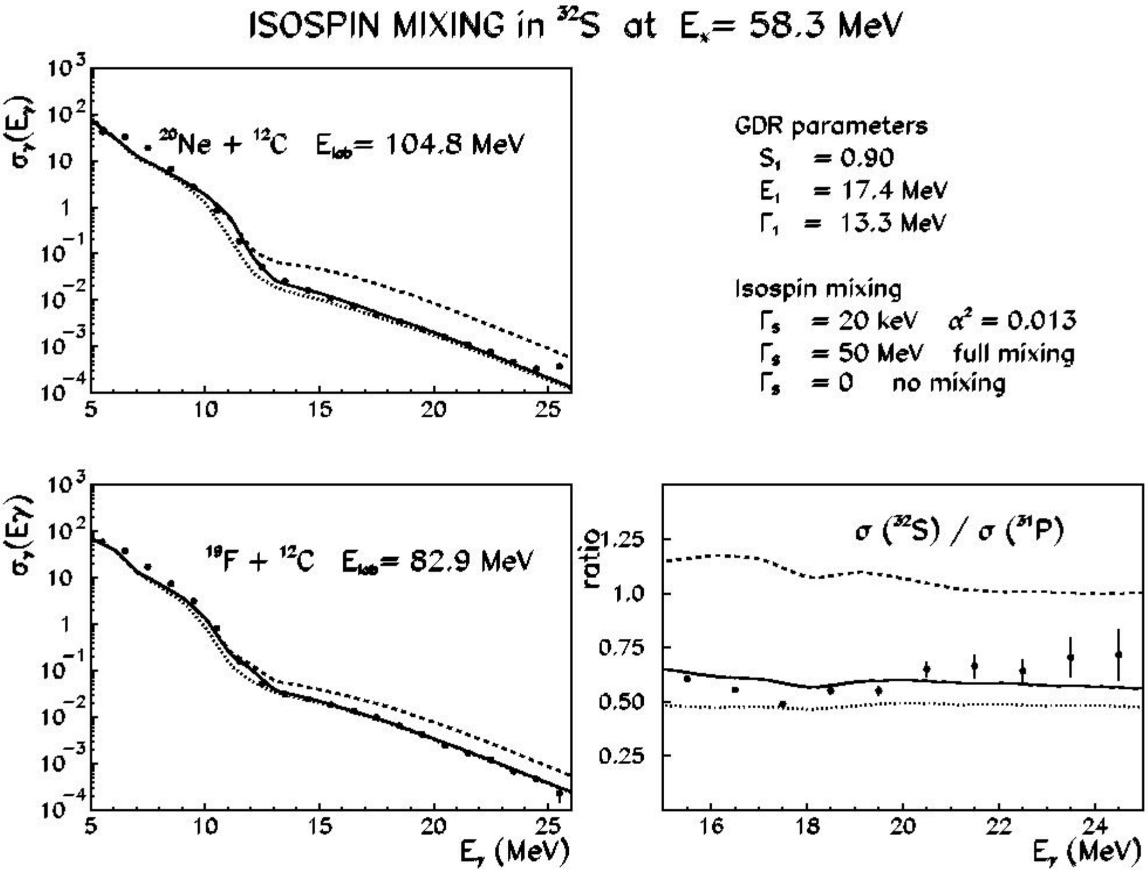

Fig. 1. Measured γ-ray spectra from the decay of ^{32}S at E_x =58.3 MeV and ^{31}P at E_x =55.1 MeV, and the ratios of these spectra. The curves are CASCADE calculations for $\Gamma_>\downarrow$ =0 (lowest), 20 keV, and completely mixed isospin.

We plan to use the presented method to deduce the isospin mixing at low excitation in another light and medium nuclei. Data for ^{12}C + ^{24}Mg → ^{36}Ar have been already measured.

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9. Entry region and angular momentum transfer studies for nuclei with A~110-130 produced in heavy-ion fusion-evaporation reactions

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The OSIRIS array consisting of 10 Compton suppressed HPGe detectors and equipped with an inner BGO ball for sum-energy and multiplicity measurements has been employed to study the entry region for nuclei with A~110-130. The ^{16}O+^{98}Mo, ^{16}O+^{107,109}Ag and ^{14}N+^{118,120,122}Sn fusion-evaporation reactions have been used in measurements. Sum-energies and γ-ray multiplicities have been measured with the BGO ball in coincidence with discrete γ-rays from the residual nuclei, registered in the HPGe detectors. To calibrate the BGO ball the response function measurements have been performed using sources emitting cascade of two γ-rays with approximately equal energies and intensities.

The obtained γ-ray sum-energy and multiplicity data were used to deduce the entry line (dependence of average excitation energy $< E^* >$ on multiplicity M or spin I) for different exit channels. For the entry line construction up to ~100 windows has been set on the sum-energy spectrum in order to achieve reasonable precision of the excitation energy definition. For each window the average value of multiplicity <M> has been determined from the corresponding multiplicity distribution while the average excitation energy $< E^* >$ has been calculated with the formula $< E^* > = < E ><M>$, where $< E >$ corresponds to the center of each window set on the sum-energy spectrum. A change of slope (bending) of the experimental entry line is observed for all studied reactions. The analysis of the γ-ray sum-energy and multiplicity data is in progress.

10. Structure of the intruder bands in light Sn nuclei

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The ^{98}Mo(^{16}O,xn) reaction have been used [1,2] to study the level structure of the semi-magic ^{110}Sn, ^{111}Sn and ^{112}Sn nuclei and the neighbouring isotopes using the OSIRIS-II array equipped with 10 HPGe detectors with anticompton shields and with 48 elements BGO multiplicity filter. In this work, the properties of excited states in ^{110}Sn, ^{111}Sn and ^{112}Sn have been studied with a special interest put on investigation of the intruder bands.

An intruder state is a state with an intrinsic structure significantly different from that of the other states in the same excitation region. In the odd nuclei intruder single particle states come in most cases from the next higher shell and have parity opposite to the neighbouring states. In the even nuclei the intruder states are associated with excitation of one or two particles into the next shell. They thus have 1p-1h (one-particle one-hole) or 2p-2h configurations with opposite or the same parities with respect to the normal states, respectively. The particle-hole states may induce deformation in an excitation region which is predominantly characterized by the spherical symmetry. The excitation energy of the intruder states decreases with increasing number of the valence nucleons and approaches minimum in the middle of the shell. The shape coexistence in this nuclear region is thus expected to occur predominantly in proton semi-magic nuclei with the half-filled neutron shell.

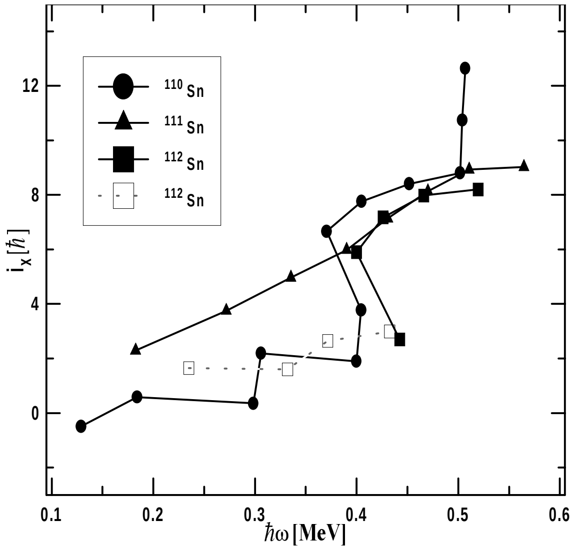

Fig. 1. Alignments for intruder bands in the ^{110}Sn, ^{111}Sn, and ^{112}Sn nuclei. A reference configuration with parameters $J_0=15\hbar^2$/MeV and $J_1=25\hbar^4$MeV^{-3} has been subtracted.

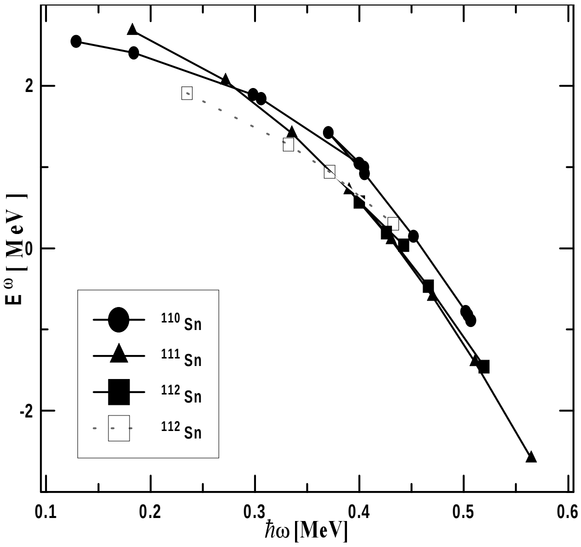

Fig. 2. Experimental Routhians for intruder bands in ^{110}Sn, ^{111}Sn, and ^{112}Sn. The crossing frequency in ^{110}Sn and ^{112}Sn is observed around 0.37 MeV, while in ^{111}Sn the first $\nu h_{11/2}$ alignment is shifted due to the occupation of $\nu h_{11/2}$ orbital.

Gamma-spectroscopy investigations of the semi-magic Sn nuclei established shape coexistence in the even-mass $^{114\text{-}118}$Sn isotopes [3]. Experimental branching ratios $B(E2)_{intr}/B(E2)_{inter}$ for intruder band in ^{110}Sn [1,4] show that in high spin region intraband E2 transitions are very strong compared to reduced interband transitions of the same multipolarity while in low spin region intensities of these transitions are comparable. This indicates that the low spin states of the intruder band are mixed (perturbed) contrary to the high spin region with pure spherical configurations. Therefore the intruder band is not so well developed at low excitation energies as it is at the higher spins. A simple level mixing calculations account for the values of B(E2) ratios of the intraband-to-interband transitions. In the alignment plot this mixing would manifest itself as an irregularity at low rotational frequencies.

The alignment (Fig. 1) and Routhian (Fig. 2) plots for ^{110}Sn and ^{112}Sn look similar in many aspects. The band crossing in the intruder band in ^{110}Sn and in higher of two bands in ^{112}Sn occurs roughly at $\hbar\omega \sim 0.37$ MeV while the increase in alignment is about $6.5\hbar$ in both cases. In this mass region the first band crossing has usually been attributed to the $h_{11/2}$ neutrons [5,6].

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11. ^{20}Ne+^{12}C reaction at 9.5 MeV/u studied with JANOSIK set-up

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Present work reports on continuation of our project devoted to the Giant Dipole Resonance (GDR) studies in light nuclei with $A \approx 32$. In order to populate a compound nucleus at excitation energy higher than 58 MeV studied earlier [1, 2], the ^{20}Ne+^{12}C reaction was analyzed at projectile energy 9.5 MeV/u, the highest possible beam energy from the Warsaw Cyclotron.

In heavy-ion collisions at projectile energies above 6 MeV/u, besides complete fusion also other processes such as incomplete fusion, preequilibrium nucleon emission, and bremsstrahlung γ-ray emission occur. Giant Dipole Resonance may be built in a compound nucleus formed in complete fusion and then decay, but it may also follow incomplete fusion or preequilibrium nucleon emission. Mass, charge and excitation energy of the average compound nucleus which decays by high-energy γ-ray are expected to be lower than in case of complete fusion. In order to investigate the mechanism of the reaction there were plans to measure high-energy γ-rays and light charged particles with the multidetector JANOSIK set-up [3].

In the first experiment, energy spectra of emitted γ-rays have been measured at three angles of 60°, 90°and 120°, with respect to the beam axis. The absolute gain calibration has been determined in a separate measurement by bombarding the ^{2}D target with 50 MeV ^{11}B beam degraded to 19 MeV in a gold foil. Inclusive proton and alpha particle energy spectra have been also measured with two triple Si telescopes (with thickness 10 μm, 130 μm, 10 mm) placed in the vacuum chamber around the target at 50°, 90° and 100°, with respect to the beam axis.

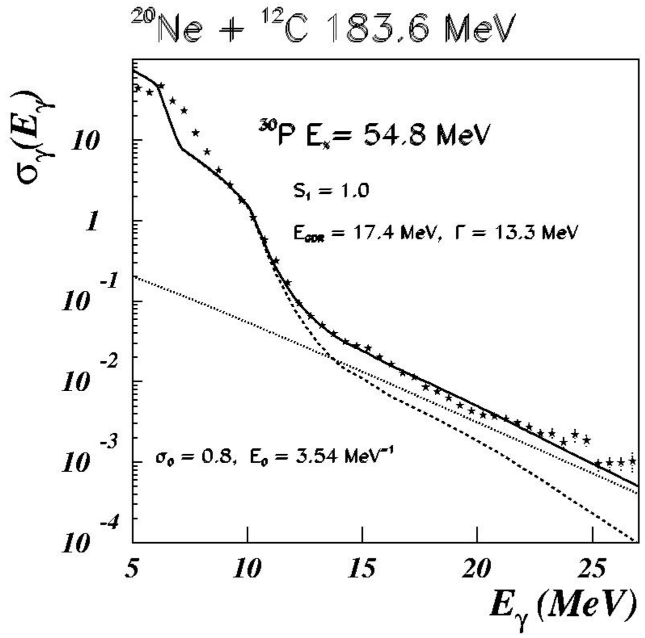

Fig. 1. Measured γ-ray spectrum for ^{20}Ne+^{12}C reaction at 9.5 MeV/u; the curves - CASIBRFIT [4] fits with incomplete fusion and bremsstrahlung included

The measured high-energy γ-ray spectrum is shown in Fig. 1. It is compared with the results of calculations including statistical GDR decay and a non-statistical bremsstrahlung component, both folded with the response function of the NaI spectrometer. The γ-ray spectrum has been calculated using CASIBRFIT code [4], a modified version of the computer code CASCADE [5], including a bremsstrahlung emission. It should be possible to disentangle statistical γ-ray emission and bremsstrahlung emission by simultaneous analysis of the total measured cross-section and angular distribution of high-energy γ-rays [4]. However, the statistics collected in this preliminary experiment was too small to reliably extract angular distribution coefficient $a_1(E_\gamma)$ at high γ-ray energies. Thus in the analysis of the presented data bremsstrahlung parameters have been estimated from the systematics.

The statistical component was calculated with the Reisdorf [6,7] level density description, the effect of isospin and a spin-dependent moment of inertia in agreement with the rotating liquid drop model. Statistical calculations were done assuming the decay of the average compound nucleus produced by complete and incomplete fusion processes at effective excitation energy which was estimated by using a semi-empirical formula proposed by M. Kelly et al. [8].

The initial excitation energy of the compound nucleus produced in the reaction studied in case of complete fusion would be 87.8 MeV. Excitation energy losses according to [8] were set to ΔE_X = 33 MeV. It should be mentioned that the shape of the low-energy part of the γ-ray spectrum is reproduced only when incomplete fusion is included in the calculations and the ΔE_X is not much lower than 30 MeV. The high-energy part of the spectrum is then well reproduced with reasonable GDR parameters and bremsstrahlung parameters.

The measured proton and alpha particle spectra are shown in Fig. 2. They are compared with the statistical model calculations done under the same assumption as for the γ-rays with the CASCADE code and Lorentz transformed from the compound nucleus center-of-mass to the laboratory frame. Inclusive energy spectra of protons show an excess of yield at forward angle and high particle energy comparing to the statistical CASCADE code calculations with incomplete fusion included. In alpha particle spectra an excess is not so evident.

To conclude about light particle emission in the reaction studied a similar experiment is planned, in which particle spectra, inclusive and in coincidence with high-energy γ-rays, will be measured with the Si-ball consisting of twelve triple telescopes in the angular range of 39°-140°. An improved acquisition system and new preamplifiers for Si detectors will be used.

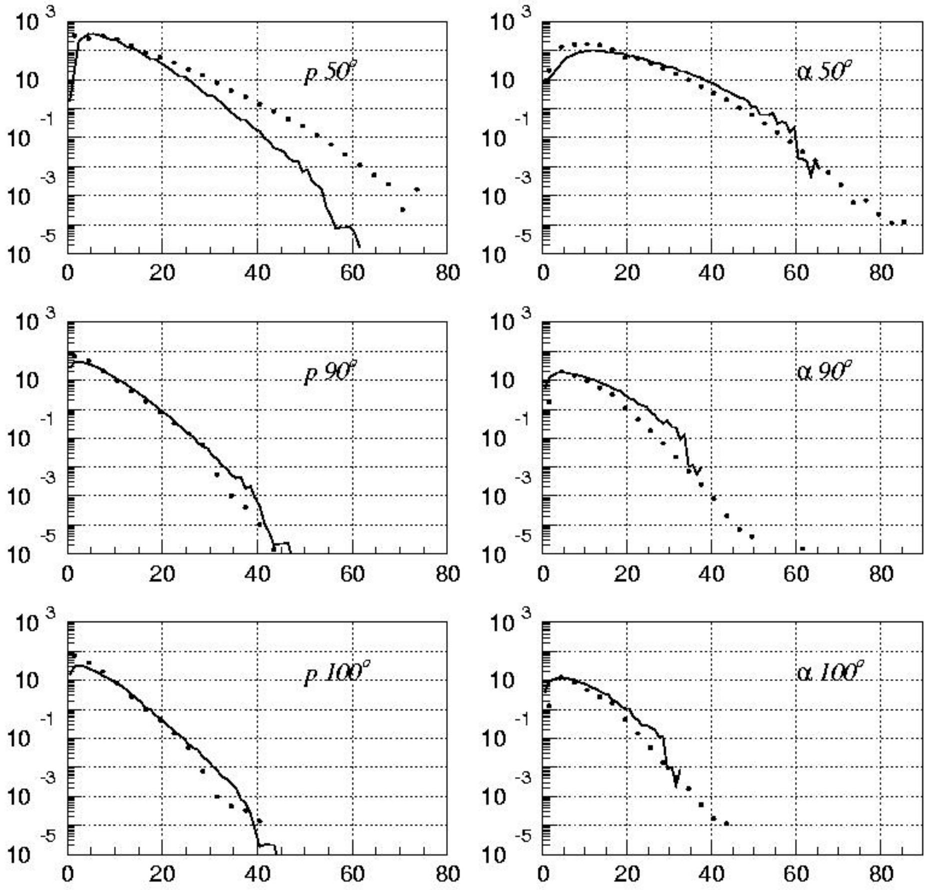

Fig. 2. Measured inclusive proton and α-particle spectra (laboratory frame) for ^{20}Ne+^{12}C reaction at 9.5 MeV/u. The curves - statistical model calculations with incomplete fusion included.

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

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12. Status of the IGISOL device

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After first test experiments [1] a series of improvements was introduced last year at the IGISOL device. The most important of them was a new helium supply and control system and additional vacuum pumps .

The new helium supply and control system consists of high quality stainless steel Swagelok elements and control units for helium flow. Application of this design had considerably decreased the impurities in the helium passing through the helium cell.

Two additional pumps, a primary pump and a turbo one installed at the extraction region of the IGISOL had improved the vacuum about one order of magnitude in the region between the helium cell and the extraction electrode of the mass separator.

These improvements had caused increasing of the efficiency of the gas cell and extraction system about 8 times in comparison with the previous conditions.

In these conditions we continued investigation of a gas catcher/ion guide system. The gas cell (helium chamber) of 120 cm^3 volume [2] was filled with high-purity (99,9999%) helium. The α spectra of the recoil nucleus ^{219}Rn ($T_{½}$=3,96 s) and its dauther ^{215}Po ($T_{½}$=1,78 ms) were measured by two silicon detectors placed in front of and behind the IGISOL magnet. Extraction efficiences for ^{219}Rn and ^{215}Po ions were measured as function of helium pressure in the cell and distance of the ^{223}Ra source from the cell exit hole. In order to investigate the so called "plasma effect" the 3,5 MeV/u ^{14}N beam was passed through the cell for some measurements.

The efficiency of the gas catcher/ion system measured for ^{219}Rn was between 25% and 55% depending on the position of the α source and without mass separation. After mass separation the maximum yield is 10%, decreasing with ^{14}N beam by a factor of ~9 for both $^{219}Rn^{1+}$ and $^{215}Po^{1+}$ ions. The estimated extraction time of 2,4 ms is obtained for $^{215}Po^{1+}$.

In the later measurements the α source (^{223}Ra) was removed and the heavy-ion reaction ^{14}N (5,8 MeV/u) + ^{209}Bi was studied. The short-lived products ^{213}Rn ($T_{½}$=25 ms), ^{214}Ra ($T_{½}$=2,5 s) and ^{215}Ra ($T_{½}$=1,6 ms) were identified. The observation of the very short-lived isotope ^{215}Ra seems to confirm the promissing results concerning the high extraction efficiency, the short extraction time and limited influence of the plasma effect [3].

These works were partially performed in the frame of the Warsaw University – IN2P3 (Nr 97-87 and 99-96) and the ION CATCHER (Nr HPRI-CT-2001-50022) collaborations.

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13. Structural changes induced by heavy ions in semiconductors

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Collaboration of:

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5) *Heavy Ion Laboratory Warsaw University, Warsaw, Poland*

The aim of the research was to determine by means of X-ray diffraction methods the structural changes induced by heavy ions in semiconductors, silicon single crystals and GaAs single crystals. It was shown that the implantation at medium dose of 3 MeV/amu nitrogen ions into GaAs single crystals did not cause damage in the ion shot-through layer and that at the depth corresponding to the ion mean range a distorted buried layer was created [1]. This layer is only a small fraction of the whole volume of the sample studied and consists of small precipitates of an additional phase, different from the GaAs single crystal matrix. Owing to the diffractometric method proposed by us recently, it was shown that this very thin layer consists of randomly oriented small precipitates of other polycrystalline phase, probably hexagonal GaN [2]. The high-resolution transmission electron microscopy observations are in progress.

An influence of a dose was studied by means of X-ray topography. Quartz single crystals irradiated with different doses of 2 MeV/amu Ar ions and InP single crystals implanted with different doses of 2.5 MeV/amu S ions were investigated. First results were presented as posters [3] and [4], respectively.

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14. Silicon passivated thin ΔE strip detectors produced using the PPPP process

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Particle identification method using the E-ΔE method is very popular in nuclear physics studies. For light charged particles and heavy ions the ΔE part of the telescope has to be thin and uniform which is difficult to attain using the standard production methods. Thin epitaxial transmission detectors obtained by the substrate anodic dissolution [1,2,3] of the thin n-n^+ structures are known for many years [4,5,6,7]. The 10 μm thick epitaxial transmission ΔE passivated silicon detectors have been produced in the two step process [8,9]. The first step is an application of planar process developed by Kemmer [10] to the epitaxial side of the n-n^+ structure. The second step is an electrochemical thinning by the anodic dissolution of the detector substrate [8,9] followed by the Al metallization of the back detector contact. The essential problem is the protection of the detector oxide layers against the very agressive HF vapour accompanying the anodic dissolution process which can destroy the SiO_2 layer.

Using above technology an attempt was made to obtain a thin (<100 μm), large area, passivated, epitaxial strip silicon detector. Unfortunately we have observed increased speed of the anodic dissolution in the regions where the boron implantation was present. This problem becomes severe for strip detectors where some parts of the device are oxidated and are free from boron implantation and Al metallisation. The speed of anodic dissolution remain constant for all regions of the wafer before the boron implantation step of the Kemmer technology [10] to the n-n^+ structure has been applied.

Due to these reasons we have elaborated a new technological process named Planar Process Partially Performed on the Thin Silicon Membrane (PPPP process). The substrate have been electrochemically removed before the boron implantation step was performed. After electrochemical thinning of the n-n^+ structure have been finished, the next planar technological steps were followed on the thin epitaxial silicon membrane supported by the wafer edges forming a ring made of the 300 μm thick substrate which was not removed.

Our device for the anodic dissolution protects the oxide layers present on the epitaxial layer against the HF vapour etching, see Fig. 1. The cylindrical graphite cathode in the form of nozzle directs the HF electrolyte jet, controlled by an external pomp, to the substrate. The cathode can be moved in the horizontal plane. Electrolyte is pumped in a closed circuit assembly. The n-n^+ epitaxial sample is attached by slowly rotating holder connected to the positive potential necessary for the anodic dissolution of the n^+ substrate. The upper side of the holder contain holes for the air penetration to the upper oxidated surface of the sample. The clean air is pumped through in order to protect the oxide of the epitaxial layer against HF acid vapour emitted from the 5% aqueous HF solution used during the anodic dissolution process. The HF acid vapour is blowing off the upper side region without any chemical contact with the oxidated surface.

The anodic dissolution process of 3-inch wafer takes about 20 hours.

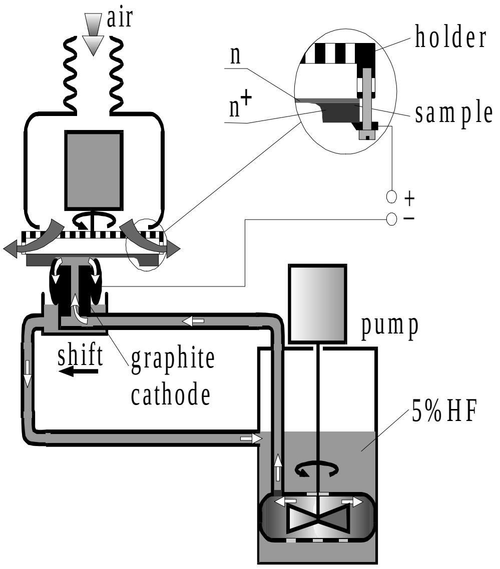

Fig.1. Electrolyte jet technique device used for thinning by anodic dissolution of the large-area n-n^+.

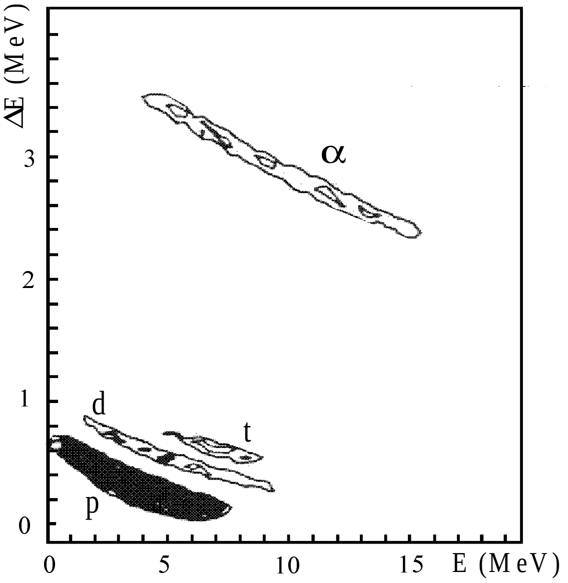

Fig.2. E-ΔE contour plot obtained after irradiation with light charged particles p, d, t, α of the E-ΔE telescope with 52 μm thick ΔE detector followed by 400 μm thick E detector. The hydrogen isotopes (p, d, t) and α - particles have been distinguished by the telescope.

Test measurements were performed using the electronic set-up consisting of preamplifiers followed by active filter amplifiers. Only one strip of the ΔE detector followed by a 400 μm thick E detector were collimated with a φ=3 mm thick Al collimator. Response of the self-biased, transmission strip detector with 52 μm thick ΔE detector to the light charged particles was investigated using the reaction p(^{9}Be,X) with the proton energy of 22 MeV at the laboratory angle θ=90˚. The results are shown in the Fig. 2.

The developed new technology (PPPP process) gives the possibility to produce large-area, passivated, thin, transmission ΔE strip silicon detectors. Detector tests produced by PPPP process show good separation between light charged particles, however, performed tests were limited to the self-biased non-fully depleted detector. A new tests with heavy ions and transmission detectors working with external bias potential are in preparation.

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Part C:

Experiments using the outside facilities

1. Coulomb Excitation experiment with a radioactive ^{88}Kr beam from REX-ISOLDE

J.Iwanicki, T.Czosnyka, M.Zielińska and the REX-ISOLDE MINIBALL collaboration

The INTC-P-172 proposal, envisaging Coulomb Excitation experiment with the ^{88}Kr beam, was accepted by the CERN Research Board on 13/11/2003, after positive recommendation from the Isolde - Neutron Time of Flight Committee. A total number of 24 shifts out of 32 requested were granted and the number IS423 was ascribed to the project.

The experiment is planned to involve ISOLDE primary target assembly and magnetic separator to supply the high intensity radioactive ^{88}Kr beam to the REX post-accelerator. After acceleration to 2.2 MeV/A (first run on a light target) and 3.1 MeV/A (another run on a heavy target) it is planned to observe Coulomb excitation of the beam using particle-gamma coincidence events in the CD detector (scattered beam detection) and MINIBALL array (gamma energy measurement).

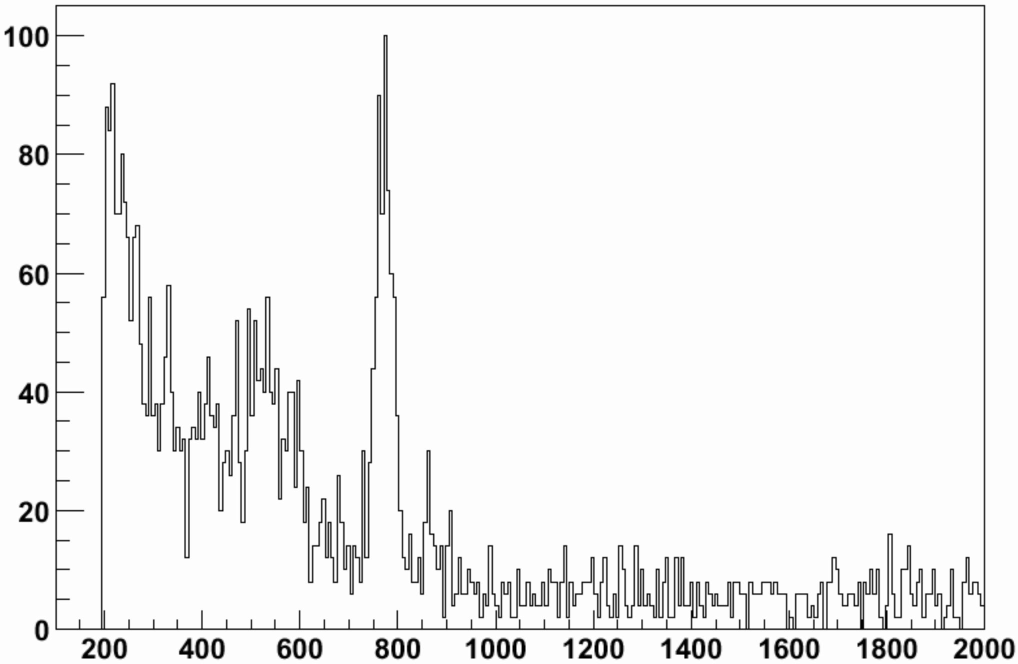

Fig. 1. Deexcitation gamma-ray energy [keV]

The same set-up was used by the IS405 experiment - Coulomb excitation of the radioactive 2.2 MeV/A ^{70}Se beam, scheduled for the period 1-8/11/2003. Due to technical problems with obtaining the pure ^{70}Se beam it was decided to give four shifts of the beam time to the other group and prepare another target on the GPS separator of ISOLDE facility (uranium carbide target with a cooled transfer line) which could deliver clean and high intensity ^{88}Kr beam. This allowed to perform the first on-beam test for the IS423 experiment.

The ^{88}Kr beam was intense enough to observe the first excited state deexcitation γ-rays. However, due to non-optimal experimental conditions (this mostly means the target, which was optimized for ^{70}Se, not the ^{88}Kr case) the expected number of counts in the interesting γ line, deexciting the supposed Mixed Symmetry state, is estimated to be 1-2, far below any experimental sensitivity limit. Figure 1 shows the collected γ energy spectrum with the first excited state line at 776 keV clearly visible.

Since it is planned to use another target for the low energy part of the experiment, the collected data cannot be combined with future measurement of the Mixed Symmetry state.

However, the used time gave us valuable experience concerning set-up efficiency measurements, background estimation and checking the assumptions about ^{88}Kr Coulomb excitation cross section.

2. The E2 resonance effect in antiprotonic Te atoms and evidence of the level width saturation

B. Kłos[1]*, S. Wycech*[2]*, A. Trzcińska, J. Jastrzębski, T. Czosnyka, M. Kisieliński, P. Lubiński*[3]*,*
P. Napiorkowski, L. Pieńkowski, F. J. Hartmann[4]*, B. Ketzer*[4]*,R. Schmidt*[4]*, T. von Egidy*[4]*,*
J. Cugnon[5]*, K. Gulda*[6]*, W. Kurcewicz*[6]*, E. Widmann*[7]

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3) *CAMK, Warsaw, Poland*
4) *Physik-Department, Technische Universitat Munchen, D-85747 Garching, Germany*
5) *Institut de Physique, Universite de Liege au Sart Tilman, B4000 Liege 1, Belgium*
6) *Institute of Experimental Physics, Warsaw University, PL-00-681, Warsaw, Poland*
7) *CERN, CH-1211 Geneva 23, Switzerland*

The PS209 experiment investigating medium and heavy antiprotonic atoms was performed at CERN in 1995 and 1996. A part of the experimental results of these measurements have been published [1-6], other data await for publication. In 2003 the analysis of the x-ray cascade from antiprotonic atoms of even-A Te isotopes: ^{122}Te, ^{124}Te, ^{126}Te, ^{128}Te, ^{130}Te was completed. Width and shift due to the strong interaction were deduced for *(n,l)=(8,7)* and *(n,l)=(7,6)* levels. The E2 nuclear resonance effect was observed in all investigated nuclei. In ^{130}Te the E2 resonance, predicted in [7], allowed to determine level widths and shifts of the LS-split deeply bound *(n,l)=(6,5)* state, otherwise unobservable.

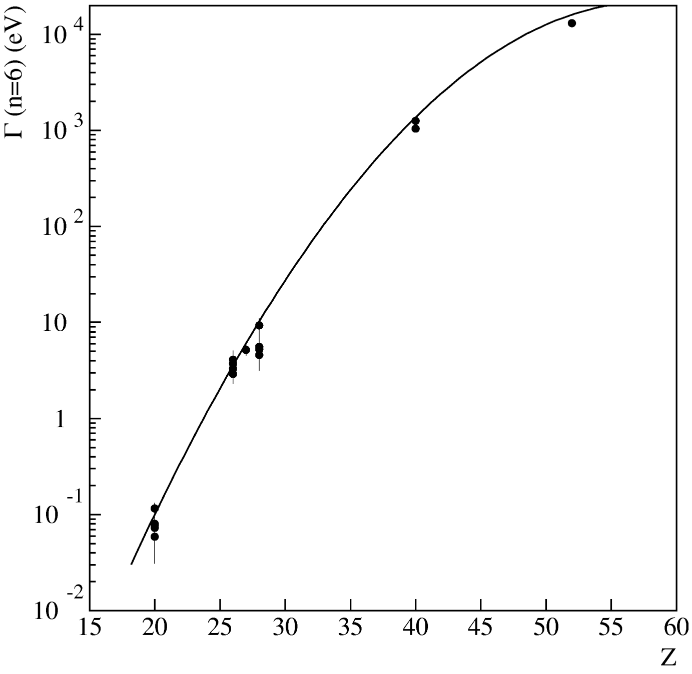

Fig. 1. The widths of the circular n=6 level [2], including the deeply bound level in ^{130}Te as a function of the atomic number *Z*. The line interpolates the widths calculated with the optical potential proposed in [8].

In Fig. 1 the systematics of the $n=6$ level widths is shown and compared with the optical model calculations. A clear saturation effect is observed for the widths with increasing Z value. The saturation effect is even better demonstrated in Fig. 2 where the level width was multiplied by B^{2l+3} (B - Bohr radius) removing the trivial consequence of atomic wave function normalization. This figure indicates the initial increase, saturation and ultimate damping of the absorption that follows the increasing penetration of antiproton into the nuclear interior. Such a behavior typical for strongly absorptive interaction was already observed in very light nuclei. The ^{130}Te is the case with the largest atomic-nucleus overlap observed so far.

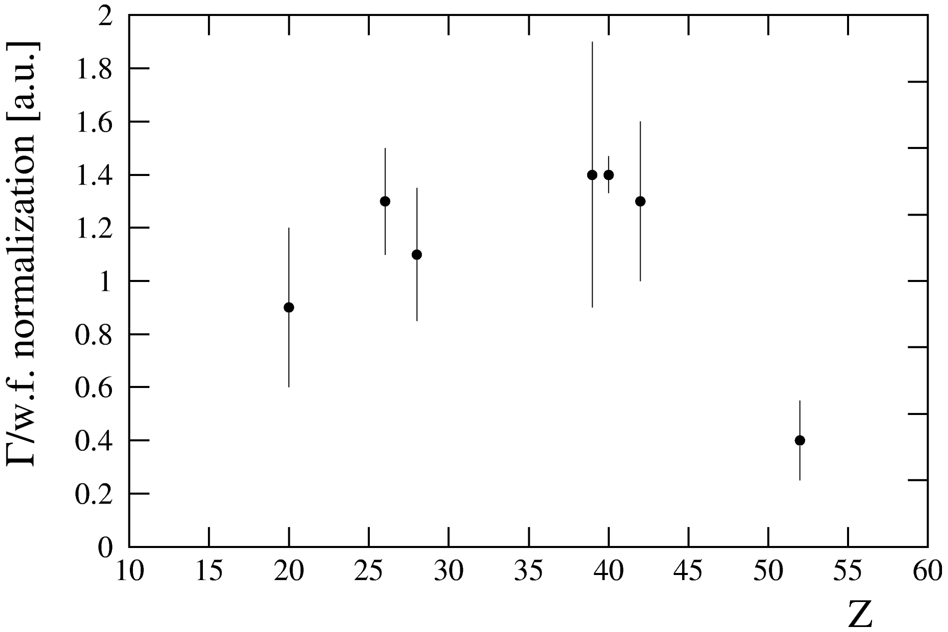

Fig. 2. The experimental widths of the circular $n=6$ level (averaged over isotopes of a given element) scaled by the normalization factor of the atomic wave function (arbitrary units) plotted vs the atomic number Z.

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

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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2) *Laboratori Nazionali di Legnaro, Padova, Italy*
3) *Institut de Recherches Subatomic, Strasbourg, France*
4) *Gesellschaft fur Schwerionenforschung, Darmstadt, Germany*

5) *Institute for Nuclear Research, Debrecen, Hungary*
6) *Department of Physics, Lund University, Lund, Sweden*
7) *Sołtan Institute for Nuclear Studies, Świerk, Poland*
8) *Niewodniczański Institute of Nuclear Physics, Kraków, Poland*

Approaching ^{100}Sn as close as possible in in-beam γ-ray spectroscopy studies is a long-standing challenge. A large scale experiment aiming at observation of excited states in the ^{100}In nucleus has recently been performed in Strasbourg, France. Excited states in ^{100}In, if identified, would provide direct verification of the proton-neutron interaction in the region of ^{100}Sn.

A DC beam of ^{58}Ni ions with an energy of 205 MeV, and an average intensity of 5 pnA, was used to bombard a 10 mg/cm^2 thick ^{45}Sc target. In this reaction, ^{100}In can be produced via the emission of 3 neutrons from the compound nucleus ^{103}In. The estimated cross section for such a process is very low: 1 μb, or $3*10^{-6}$ relative to the total fusion-evaporation cross section. The EUROBALL [1] array of Ge γ-ray detectors was employed in the experiment, and the Neutron Wall [2] together with the newly constructed charged particle veto detector CUP[3] were used for the selection of events in the 3n reaction channel. During 14 days of effective beam time, about $2*10^9$ events were collected with a trigger requirement of detecting 1 γ-ray in Ge detectors and at least 1 or 2 (for different parts of the data set) hardware preselected neutrons. Such a trigger condition significantly enhanced the reaction channels leading to the most neutron deficient residua.

Data from the experiment were scanned in intervals corresponding to maximum 2 hours of beam time each, and all the experimental parameters were checked and corrected for instrumental drifts or instabilities. Where applicable, the parameters were also calibrated. A new "presorted" data set was created and placed on hard disks, resulting in about 200 GB of easily accessible list mode data, which are further used for the creation of γ-ray spectra, gated by the optimum condition on the Neutron Wall and CUP parameters.

It was determined from the data, that the efficiency of the CUP detector is about 80 and 65 %, for the detection of protons and α particles, respectively, with a negligible probability to obtain a false charged particle signal. The efficiency to detect a single neutron in the Neutron Wall is equal about 30 %.

A large effort was devoted to optimize conditions to detect and identify 3 neutrons [4] in Neutron Wall. The difficulty of this task is mainly due to the fact that a single neutron often scatters in more than one neutron detector, giving rise to the apparent increase of the number of detected neutrons, which hinders the selection of events with more than 1 neutron emitted. The spectrum presented in Fig. 1 illustrates the achieved quality of the discrimination. We conclude that clean selection of 3n events is possible, but this can only be done at the cost of a very significant reduction of the collected 3n statistics. Only about 10% of events with 3 neutrons apparently detected could be accepted by the Neutron Wall conditions leading to spectrum in Fig. 1. Note that a combined gate on the Neutron Wall parameters and the CUP detector was needed to obtain this spectrum. The dominating lines belong to the ^{99}Cd nucleus, which is produced by the emission of 1 proton and 3 neutrons from the compound nucleus ^{103}In. The CUP veto condition enhances lines from the p3n evaporation channel relatively to 2p2n and 3p1n evaporation channels, which would otherwise form the major contamination in the clean 3n gated spectrum. About 20% of the ^{99}Cd intensity is left in spite of the CUP veto, whereas the channels with two and three protons emitted are suppressed by a factor of about 25 and 125, respectively.

Further data analysis, in particular search for γ-ray radiation emitted by the ^{100}In nucleus, is in progress.

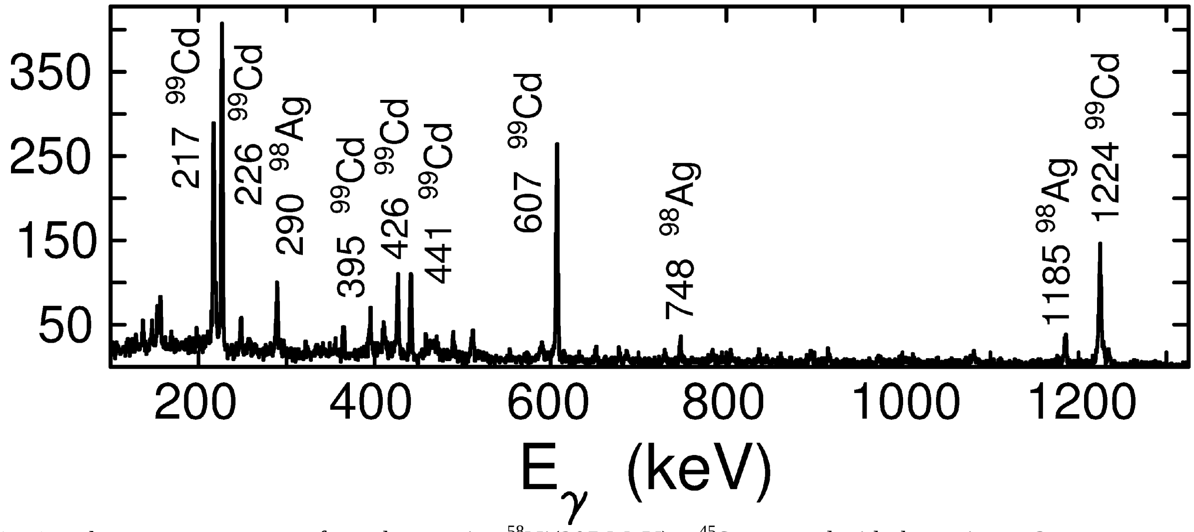

Fig. 1 In beam γ-ray spectrum from the reaction ^{58}Ni(205 MeV) + ^{45}Sc, created with the optimum 3n discrimination conditions and with the CUP detector veto.

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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. One DSc thesis was completed in 2003 (Ludwik Pieńkowski), the title awarded by the Physics Faculty of the Warsaw University. Four 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 seventh 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 Zielisńka gave a series of lectures on nuclear physics at the layman's level and Paweł Napiorkowski demonstrated the methods of detecting natural radioactivities. One of the highlights of Laboratory's educational activities was the participation in the Seventh 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 2003 to about 40 groups, i.e. more than 1000 persons.

1.1. DSc Theses

Dr Ludwik Pienkowski
Badanie własności gorących jąder tworzonych w reakcjach z energetycznymi cząstkami lekkimi
(Investigation of the properties of the hot nuclei produced in the reactions with energetic light ions)

2. Seminars

2.1. Seminars at HIL

M.Palacz May 8
CUP- scyntylacyjny detector cząstek naładowanych i jego zastosowanie w eksperymencie z EUROBALL-em

M.Wolińska-Cichocka October 16
Badanie „in-beam” izotopów ^{110}Sn i ^{111}Sn z wykorzystaniem spektrometru OSIRIS II

J.Perkowski –Uniwersytet Łódzki October 23
Pomiary elektronów konwersji wewnętrznej na wiązce ciężkich jonów

M.Zielińska November 13
Wzbudzenia kulombowskie radioaktywnych izotopów kryptonu

J.Jastrzębski November 27
SPIRAL2, EURISOL, współpraca GANIL

2.2. External seminars given by HIL staff

A.Trzcińska March 6
Information on the nuclear periphery deduced from the properties of heavy antiprotonic atoms
LEAP'03 (Low Energy Antiproton Physics), March 3-7, 2003, Yokohama, Japan

J.Kownacki April 16
Advanced Gamma Tracking Array (AGATA)
IFD, Hoża 69

L.Pieńkowski April 25
Reakcja spallacji w grubej tarczy jako źródło neutronów – projekt ESS
IFD, Hoża 69

A.Stolarz June 6
Targets for nuclear physics: what are they, how to prepare them?
European Commission, IRMM, Geel Belgium

A.Trzcińska June 10
Neutron Density Distribution Deduced from Antiprotonic Atoms
10th INTERNATIONAL CONFERENCE ON NUCLEAR REACTION MECHANISMS
Varenna, Italy, 9-10 June, 2003

M.Zielińska August 15
Coulomb Excitation of radioactive Kr isotopes
Workshop on Coulomb excitation of high-quality FP beams
JAERI, Tokai, Japan, August 15, 2003

T.Czosnyka August 15
Approach to ultra Relativistic COULEX
Workshop on Coulomb excitation of high quality FP beams
JAERI, Tokai, Japan, August 15, 2003

A.Trzcińska September 18
Antiprotonic X-rays from medium and heavy elements
Meeting of the "Users group for low-energy antiproton physics at GSI", GSI, Darmstadt, Germany, September, 2003

M.Zielińska September 25
Coulomb excitation of ^{150}Nd
10th Nuclear Physics Workshop Marie and Pierre Curie
Kazimierz Dolny, September 24-28, 2003

J.Jastrzębski September27
Neutron density distribution deduced from antiprotonic atoms
10th Nuclear Physics Workshop Marie and Pierre Curie

Kazimierz Dolny, September 24-28, 2003

M.Wolińska-Cichocka October 22
Spektroskopia jąder produkowanych w reakcji ^{16}O + ^{98}Mo
IFD, Hoża 69

A.Trzcińska November 18
Rozkłady gęstości neutronów uzyskane na postawie badań atomów antyprotonowych
IFJ PAN, Kraków,

3. ISL listed publications, conference contributions, other publications

3.1. Publications in journals listed by ISI

Multiple Coulomb excitation experiment of ^{66}Zn
M. Koizumi, A. Seki , Y. Toh, M. Oshima, A. Osa, A. Kimura, Y. Hatsukawa, T. Shizuma, T. Hayakawa, M. Matsuda, J. Katakura, T. Czosnyka, M.Sugawara, T. Morikawa, H.Kusakari
Eur. Phys. J. A18, 1 (2003)

One-nucleon transfer reaction ^{9}Be (^{11}B, ^{10}B) ^{10}Be and optical potential for the ^{10}B+^{10}Be interaction
V.M. Kyryanchuk, A.T. Rudchik, A. Budzanowski, V.K. Chernievsky, T. Czosnyka, B.Czech, L. Głowacka, S. Kliczewski, E.I. Koshchy, S.Y. Mezhevych, A.V. Mokhnach, K.Rusek, S.B. Sakuta, R. Siudak,I. Skwirczyńska, A.Szczurek, L.Zemło
Nucl. Phys. A726,3-4, 231 (2003)

Multiple ionization and coupling effects in L-subshell ionization of heavy atoms by oxygen ions
M. Pajek, D. Banas, J. Semaniak, J. Braziewicz, U. Majewska, S.Chojnacki, T. Czyżewski, I. Fijał, M. Jaskóła, A. Glombik, W. Kretschmer, D. Trautmann, G. Łapicki, T. Mukoyama
Phys. Rev. A68, 2 (2003)

Coulomb excitation and structure of the rotational bands in ^{231}Pa
M. Wurkner, J. de Boer, A.I. Levon, M .Loewe, J. Kvasil, J.Srebrny, P.J.Napiorkowski, J. Iwanicki, T. Czosnyka
Nucl. Phys. A725, 3 (2003)

A combination of two 4 pi detectors for neutrons and charged particles. Part I. The Berlin neutron ball - a neutron multiplicity meter and a reaction detector
U. Jahnke, C.M. Herbach, D. Hilscher, V. Tishchenko, J. Galin, A. Letourneau, B. Lott, A. Peghaire, F. Goldenbaum, L. Pieńkowski
Nucl. Instrum. Meth. Phys. Res. A508,3, 295 (2003)

A combination of two 4 pi-detectors for neutrons and charged particles. Part II. The Berlin silicon ball BSiB for light- and heavy-ion detection
C.M. Herbach, D. Hilscher, U. Jahnke, V. Tishchenko, W. Bohne, J. Galin, A. Letourneau, B.

Lott, A. Peghaire, F. Goldenbaum, L. Pieńkowski
Nucl. Instrum. Meth. Phys. Res. A508, 3, 315 (2003)

The ^{13}C+^{11}B elastic and inelastic scattering and isotopic effects in the ^{12,13}C+^{11}B scattering
S.Y. Mezhevych, K. Rusek, A.T. Rudchik, A. Budzanowski, V.K. Chernievsky, B. Czech, J. Choiński, L. Głowacka, S. Kliczewski, E.I. Koshchy, V. Kyryanchuk, A. Mokhnach, A.T. Rudchik, S.B. Sakuta, R. Siudak, I. Skwirczyńska, A. Szczurek, L.Zemło
Nucl. Phys. A724, 1-2, 29 (2003)

Projectile Coulomb excitation of ^{78}Se
T. Hayakawa, Y. Toh, M. Oshima, A. Osa, M. Koizumi, Y. Hatsukawa, Y. Utsuno, J.Katakura, M. Matsuda, T. Morikawa, M. Sugawara, T.Czosnyka
Phys. Rev. C67, 6, (2003)

Highly excited states of sulphur projectiles inside a carbon target
U. Majewska, J. Braziewicz, M. Polasik, K. Słabkowska, I. Fijał, M. Jaskóła, A. Korman, S.Chojnacki, W. Kretschmer
Nucl. Instrum. Meth. Phys.Res. B205, 799 (2003)

Nucleon density in the nuclear periphery determined with antiprotonic x rays: Cadmium and tin isotopes
R. Schmidt, A.Trzcińska, T.Czosnyka, T. von Egidy, K. Gulda, F.J. Hartmann, J.Jastrzębski, B. B. Ketzer, M. Kisieliński, B. Kłos, W. Kurcewicz, P. Lubiński, P. Napiorkowski, L.Pieńkowski, R. Smolarczuk, E. Widmann, S. Wycech
Phys. Rev. C67, 4, (2003)

Electromagnetic properties of ^{165}Ho inferred from Coulomb excitation
J. Iwanicki, M. Zielińska, T. Czosnyka, J. Choiński, P. Napiorkowski, M. Loewe, M. Würkner, J. Srebrny
Journal Phys. G29, 4, 743 (2003)

Multiple Coulomb excitation interpretation of the ^{70}Ge beam and the interpretation of the 0_2^+ as a deformed intruder
M. Sugawara, Y.Toh, T.Czosnyka, M. Oshima, T. Hayakawa, H. Kusakari, Y. Hatsukawa , J. Katakura, N. Shinohara, M. Matsuda, T. Morikawa, A. Seki, F. Sakata
Eur. Phys. J. A16, 3, 409 (2003)

Maximally aligned states in ^{99}Ag
D. Sohler, Z. Dombradi, J. Blomqvist, 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, J. Timar, S. Tormanen, M. Weiszflog
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Monolithic silicon E-ΔE telescope produced by the Quasi-Selective Epitaxy
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