WARSAW K=160 HEAVY ION CYCLOTRON - STATUS REPORT

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Abstract

Warsaw University isochronous heavy ion cyclotron, commissioned in 1994, is at present an unique machine of this type throughout Central Europe. Currently it operates with a PIG ion source, delivering beams below 5 MeV/amu, as requested by the low-energy heavy ion physical programs accepted for the first two years of operation. Obtaining low-energy beams from K=160 machine requires the development of non-standard ways of beam extraction, as will be discussed in detail. With the installation of ECR ion source, planned for 1997, the cyclotron operation will gradually move towards higher energies and the machine will reach its full capability providing over-the-barrier beams up to xenon.

1 INTRODUCTION

The Heavy Ion Laboratory (HIL) has been founded by the Ministry of Education, National Atomic Energy Agency and the Polish Academy of Sciences. The Laboratory is intended to be as a national facility for heavy ion basic research and applications with its 2-m diameter variable energy, isochronous cyclotron. The Cyclotron Facility is being erected in the very center of University Ochota Campus surrounded by natural sciences departments and research centres: Biology, Biophysics, Chemistry, Radiochemistry, Geology, Geophysics, Nuclear Spectroscopy and Mathematics. Presently the Laboratory is financed mainly by the State Committee for Scientific Research and Ministry of Education. HIL is serving as:

- Heavy Ion Research Centre
- Advanced professional training facility for undergraduate and graduate students
- Link with advanced technology - oriented institutions in Poland
- Undergraduate level didactic centre

The permanent HIL staff consists of about 60 employees, mainly highly qualified engineers and technicians, plus a small group of in-house physicists. The number of people connected with the Laboratory is, however, much larger, including the research groups from throughout the country presently building their experimental set-ups. Experimental projects currently under way are supported by three large research grants from the State Committee for Scientific Research and Volkswagen Foundation.

2 THE CYCLOTRON

Technical characteristics of the Warsaw Cyclotron are presented in Table 1.

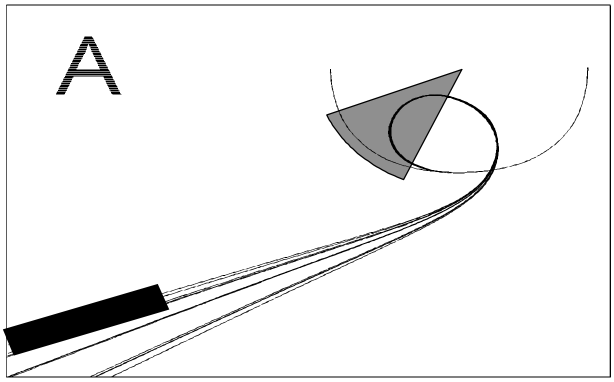
Table 1

Magnetic Structure	
K range	120 ÷ 160
Total mass of the main magnet	240 tons
Diameter of the magnet	200 cm
Excitation current range	600 ÷ 1200 A
Sectors	4 pairs
Sector gap in the center	41 mm
Sector gap at the extraction radius	26 mm
Valley gap	150 mm
Mean magnetic field in the hill at 1200 A	2.7 Tesla
Mean magnetic field in the valley at 1200 A	1.7 Tesla
Trim coils, water cooled	10 pairs
Accelerating Structure	
Number of dees	2
Angular range of dees	45 deg
Frequency range	12 ÷ 22 MHz
Amplitude	75 kV
RF power	2 x 120 kW
RF mode	cw/pulsed
Harmonics	1 through 6
Ion Source Penning Type	
Mode	pulsed
Pulse length	0.3 ÷ 2 ms
Repetition rate	10 to 100 Hz
Extraction of the Beam	
Stripper material, carbon foil	~50 mg/cm^2
Radial range	60 to 90 cm
Beam energy range	45% to maximum
Vacuum System	
Cyclotron vacuum chamber volume	~13000 litres
Static vacuum	~3 x 10^{-6} Torr
Pumping speed	4 x 6000 l/s

Since three years the cyclotron is operational. The first internal beam $^{20}Ne^{2+}$ was obtained in November 1993 and the first external beam $^{14}N^{2+}$ was extracted using the stripping method in April 1994. Plans for 1994 till now called for acceleration and extraction of the beams of gaseous elements of low energies. It allowed to avoid possible radioactive contamination of the structure prior to final debugging of the whole system and satisfy big demand of the beams of the energy range 5 MeV/amu and lower.

3 BEAM EXTRACTION

Significant effort has been done to improve extracting low energy beams from the cyclotron. The stripper for the U-200P cyclotron has been primarily designed to extract the ions recharged by a factor 2 to 2.5 from the radii in the range of 80 ÷ 90 cm. In such cases a simple one-turn extraction is feasible. An apparent need for the beams of energies lower than those resulting from accelerating ions up to the maximum radius forced us to test the possibility of extracting the ions from the orbits of radii much closer to the cyclotron centre than the original stripper design assumed. Deeper insertion of the stripper foil into the cyclotron chamber causes that the radius of curvature after stripping is to small to bring out the ions in a single turn. The same happens when recharging ratio exceeds 2.5, which is a common situation when accelerating low energy ions with small charge-to-mass ratio. To fulfil the users needs we had to investigate the possibility of multiturn extraction, a situation in which stripped ions travel outwards along the hill-valley edge making more than one turn in the process. Perhaps the most spectacular result was obtained by extracting 0.6 MeV/amu $^{20}Ne^{2+}$ beam, recharged to the 8^+ state, from 58 cm orbit. Two- and three-turn extraction modes were tested on a number of beams.



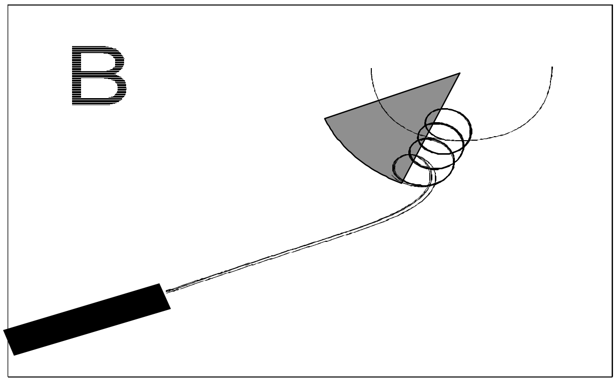


Fig. 1. Extraction by stripping. Upper drawing (A) shows the usual one-turn extraction from the orbit close to the edge of the magnet. Shaded area represents the hill of magnetic field. Different trajectories after stripping correspond to different positions of the stripping foil sliding along the orbit within 2 deg range. Lower part of the figure (B) presents the computer simulation of four-turn extraction of 0.6 MeV/amu ^{20}Ne beam (58 cm extraction orbit), successfully verified in April '94. The position of the beamline is marked in the lower left corners. [Ref 1.]

4 ECR ION SOURCE AND AXIAL INJECTION LINE

A major upgrade of the accelerator is the forthcoming installation of the ECR ion source and the axial injection line. Two types of ECR sources have been developed at HIL. First one is an experimental cusp model with the magnetic bottle formed by electromagnets. The second is a classical 10 GHz source based on SmCo permanent magnet arrangement. The use of the external ECR instead of internal PIG ion source will dramatically increase both the scope and quality of delivered beams. The injection line has been designed to minimize its overall length and the number of beam optics elements. Only axially symmetric elements - solenoids and Glaser lenses - are used. The double focusing magnet will play the role of the bending and analyzing element. The system will provide transmission of the beam with the emittance of 300 mm mrad for mass-to-charge ratios ranging from 8 to 2. Designed arrangement is easy to shield from stray magnetic field present in the vicinity of the cyclotron (50 ÷ 800 Gs). For the first experiments with axial injection line a mirror type inflector is proposed. The installation of the ECRIS and axial injection line is planned for 1997 and then the machine will reach its full capability.

5 EXPERIMENTS

First experiments performed with the Warsaw cyclotron included basic research in nuclear physics, atomic physics and pilot application runs. Nuclear physics studies concentrated mainly on Coulomb Excitation (Warsaw University, LMU Munich), Giant Dipole Resonance (Warsaw University, Niewodniczanski Institute of Nuclear Physics, Cracow and Soltan Institute of Nuclear Studies, Swierk), studies of reaction products using He-jet apparatus and lifetime measurements with a plunger (Warsaw University). Atomic physics experiments, performed by the groups from Soltan Institute of Nuclear Studies and Warsaw University, included the measurements of K- and L-shell ionization cross-sections. With respect to the applications pilot irradiations of nuclear filters (Institute of Nuclear Chemistry and Technology), electronic materials (Institute of Physics of the Polish Academy of Sciences) and test radioisotope production runs were made.

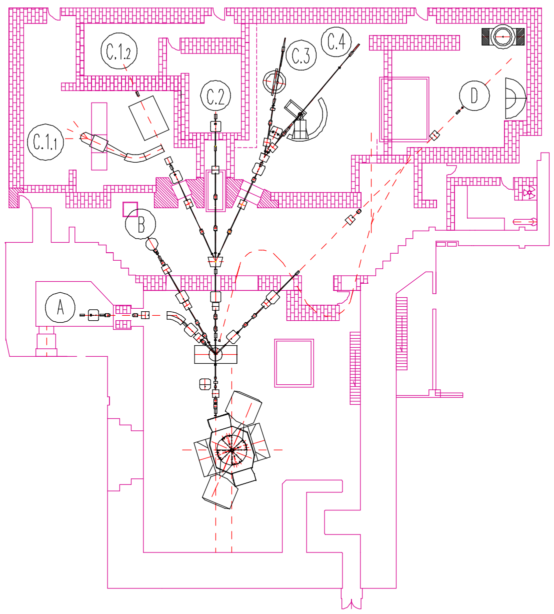


Fig.2 Plan view of the facility
The caves are intended for:
A - radioisotope production (planned)
B - universal scattering chamber
C1 - ion guide on line separator/ helium jet
C2 - Coulomb excitation and subbarrier nucleon transfer experiments with particle detector arrays
C3 - multidetector gamma-ray spectroscopy set-up OSIRIS (part of original OSIRIS system, moved from Juelich)
C4 - Giant Dipole Resonance

Since the Warsaw heavy ion facility is still *in statu nascendi* the experimental programme is open for discussions both within and outside Poland. New proposals are welcome and, at present stage, can still be accomodated.

6 INFRASTRUCTURE AND SUPPORTING SERVICES

To accomodate the needs of the users Heavy Ion Laboratory maintains a number of services necessary to prepare and run the experiments. Electronics group not only takes care of existing electronics pool, but also designs and manufactures unique modules. Detector group is able to build custom semiconductor particle detectors to fit specific scattering chambers. HIL has its own target laboratory and mechanical workshop.

Multiparametric data acquisition system is based on PC class computers and CAMAC standard. It is interfaced through the ETHERNET link to off-line computers and to ouside world.

As a part of the University HIL is strongly engaged in didactic activity. Physics students use the beams to run measurements within the Advanced Student Laboratory. A number of MSc theses was, or is being, prepared partly based on the material collected with the cyclotron. Five PhD theses are supervised by HIL scientists. Some limitations of this activity is due to the fact that the Laboratory building is still not finished. The construction should be completed by the beginning of 1998. In its final shape the building will house a large lecture hall, computing centre, library and few small seminar rooms. At this point the educational role of Heavy Ion Laboratory will sharply increase.

7 REFERENCES

1. T. Czosnyka, Nucl. Phys. News, Vol.4, No3, 1994