# PROJECT OF THE DC-60 CYCLOTRON WITH SMOOTHLY ION ENERGY VARIATION FOR RESEARCH CENTER AT L.N.GUMILEV EUROASIA STATE UNIVERSITY IN ASTANA (KAZAKHSTAN)

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*Abstract*

The paper presents a cyclotron designed for applied researches using an ECR ion source and accelerated ions from Carbon to Xenon. The energy of the extracted beams can be varied from 0.9 up to 1.66 MeV/nucl in the case of the 4$^{th}$ harmonic mode and from 0.4 up to 0.8 MeV/nucl in the case of the 6$^{th}$ harmonic mode. The cyclotron has four 50° sectors with two 40° dees in the opposite valleys. An electrostatic deflector performs the beam extraction. The paper gives an overview of the current status of the cyclotron design.

## INTRODUCTION

The suggested project involves working out and creation of the compact accelerator of heavy ions. It will allow one realizing wide program of basic and applied researches such as: basic research in the solid states physics, radiation damage studies, modification of metal surfaces, ion-implantation nanotechnology, production, and utilization of nuclear track membranes.

The accelerating complex consists of the cyclotron DC-60, ECR (Electron Cyclotron Resonance) ion source and the axial injection system, one channel for ion transportation from the ECR-source to a physical target, three channels for accelerated beam transportation. All beam channels are equipped with experimental and technological set-ups. The main cyclotron parameters are shown in Table 1.

Table 1: Main cyclotron parameters

| | |
|---|---|
| Type of ions | Li ÷ Xe |
| Range of accelerated ions (A/Z) | 6 ÷ 12 |
| Accelerated ion energy | 0,35 ÷ 1.6 MeV/nucl |
| Discreet change of the ion energy | Changing the ion charge |
| Smooth variation of the ion energy | 30% (± 15%) Variation of the magnetic field |

## ION SOURCE

The ECR ion source is one of principal parts of the accelerator. It can serve as an injector of the cyclotron providing heavy ions for several high-energy experimental channels [1]. On the other hand, it can also work as autonomous set-up, delivering ion beams directly to the low energy experimental channels.

The operating frequency of the microwaves in the ECR ion source is 14 GHz. The discharge chamber of the source is insulated up to 25 kV. The ion extraction is accomplished by two elements containing a plasma electrode and movable puller.

## CHANNEL OF AXIAL INJECTION

For transportation of a beam from the ECR ion source to the cyclotron centre an axial injection system of the beam will be used. It consists of focusing elements, analysing magnet, diagnostic elements, buncher, vacuum pumps, and electrostatic inflector (see Figure 1).

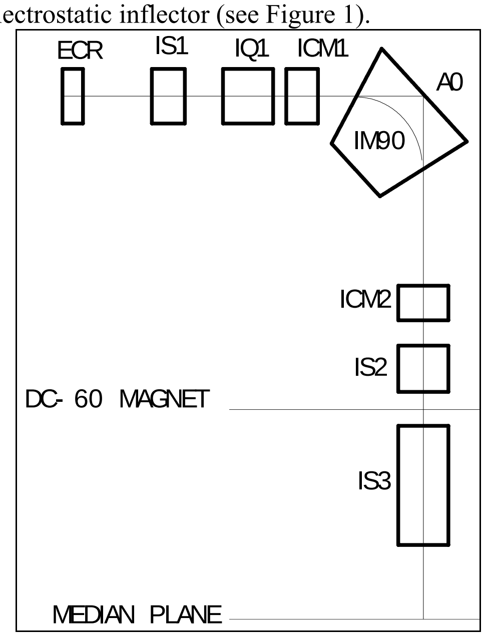


Figure 1: Scheme of axial injection channel. IS1, IS2, IS3 - focusing solenoids. IM90 - analyzing magnet. IQ – quadrupole lens, ICM1, ICM2 correcting magnets.

The axial injection system of the beam will be equipped with an additional channel, which will make it possible to carry out research using ion beams with the injection energy. It is possible to vary the ion energy by changing the ion charge and injection voltage.

## CHANNEL FOR APPLIED RESEARCH

Scheme of the channel for applied research is shown in Figure 2. The point A0 is the intersection point of the vertical and horizontal axes of the axial injection channel (see Figure 1). This channel allows one the ion transportation from the ECR-source to the target in rather wide range of the ions (from A/Z = 2 up to A/Z = 20). The ion energy is equal to 25 keV/charge. Two electrostatic scanners (vertical and horizontal) will be installed before the beam target.

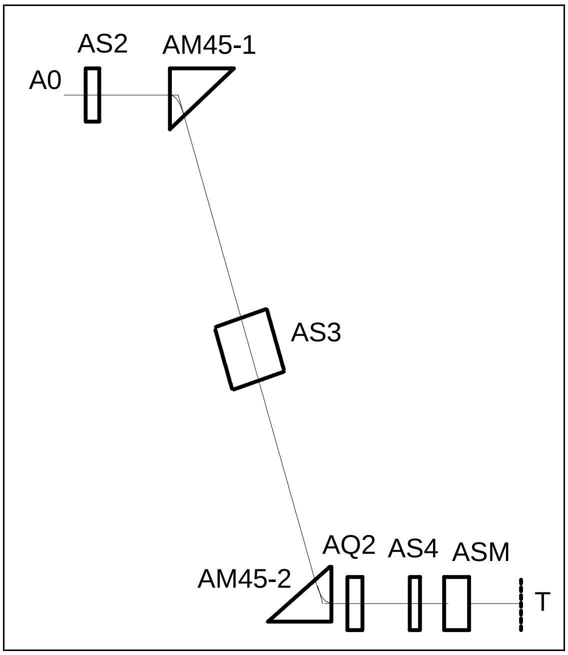


Figure 2: Scheme of the channel for applied research. AS2 ÷ AS4 - focusing solenoids, AM45-1, AM45-2 - $45^0$ bending magnets, AQ2 - quadrupole and T is a beam target.

## CYCLOTRON MAGNET

The cyclotron magnet has 162 cm pole diameter. The length of the magnet is approximately 4 m, the width 1.68 m, the height 2.3 m, and the weight about 100 tons. The magnet power consumption is equal to 67 kW.

Azimutal variation of the magnetic field is performed by four sectors. The isochronous magnetic field will be carried out mainly by means of iron shims. Five pairs of circular trimming coils will be used for smooth variation of the beam energy. Two pairs of azimutal coils are intended for the beam correction at extraction region.

## CENTRAL REGION

The ion injection from the axial channel into the acceleration region will be carried out by means of two electrostatic spiral inflectors. The inflectors having $R_{mag}$ = 2.9 mm and 3.5 mm, respectively, the most optimally meet the requirements of maximum dee voltage $U_{dee} \leq 50$ kV. The injection voltage verifies from 10 to 20 kV.

For both operation modes one geometry of the central region will be used. The chosen inflector parameters give initial start radiuses. They are equal to 54 mm and 66 mm respectively.

## BEAM EXTRACTION

One uses a combination of an electrostatic deflector (ESD) and magnetic channel (MC) for the ion extraction from the cyclotron DC-60 (see Figure 3).

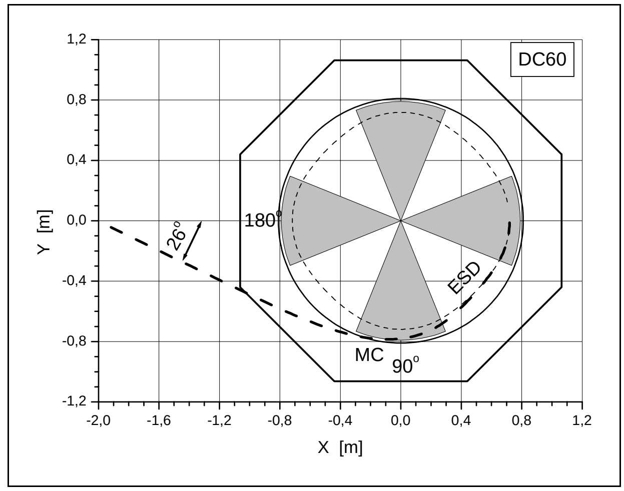


Figure 3: The scheme of the beam extraction.

The deflector is placed in the cyclotron valley and has the azimuth length $\Delta\Theta \approx 34°$. The magnetic channel provide the radial focusing with gradient $G \approx 35 \div 40$ T/m (working aperture is $25 \times 10$ $mm^2$).

The radial beam dimension at the deflector input is within the limits of 6 ÷ 16 mm. The axial one does not depend practically on the mode of operation and is equal to ~12 mm.

## TRANSPORTATION CHANNELS FOR EXTRACTED BEAMS

The transportation system of the extracted ions is shown in Figure 4. It consists of three channels. Channel is intended for irradiation of polymer films by different heavy ions. In this channel the extracted beam focusing is realized by two quadrupoles. In order to irradiate large area target of $(300 \times 600)$ $mm^2$ by heavy ion beam with uniform density ($\pm$ 5%) two magnetic scanners creating horizontal and vertical beam motion will be used.

The bending magnet realizes the beam turning at an angle of $\pm 30^o$ for beam transportation in #2 and #3 channels The bending magnet has the bending radius $\rho$ = 150 cm and maximum induction of the magnetic field B = 1.6 T. The beam focusing is performed by quadrupols lenses with the effective length $L_{eff}$ = 30 cm and maximum gradient $G_{max}$ = 6 T/m.

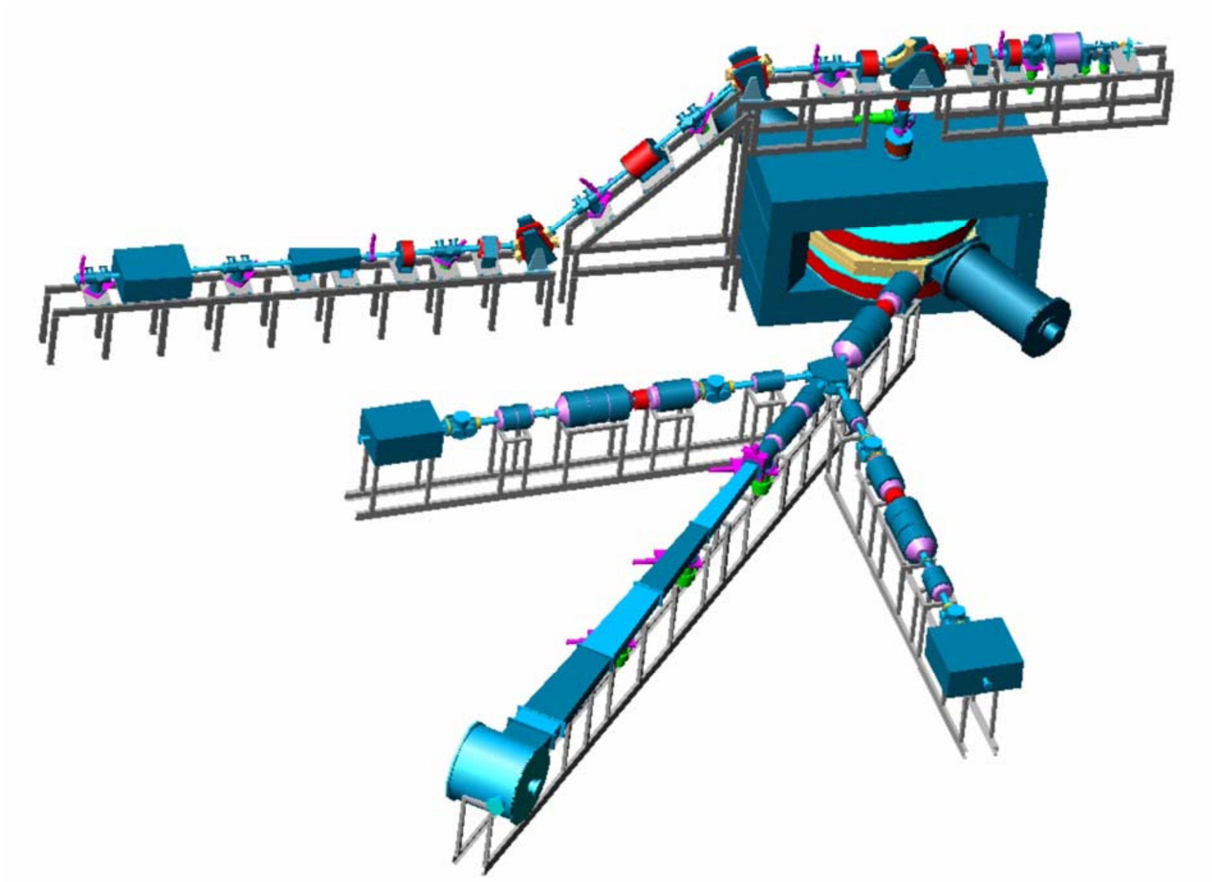

Figure 4: The layout of the DC-60 cyclotron with transported channels.

The channels #2 and #3 are intended for nuclear physics experiments. One demands that the beam diameter on the target material should be equal to 10 mm in the channel #2. In the channel #3 the magnetic scanners are placed after the second doublet. They scan the ion beam on the target having the area 50 × 50 $mm^2$. At that one demands that the ion beam having the diameter ~20 mm was formed on the target.

## PROJECT STATUS

- The construction of the cyclotron was started in 2003.
- The fabrication of the main cyclotron systems is planned to be finished in the middle of 2005.
- Assembling, installation and testing of the cyclotron at Astana will start in the middle of 2006.
- We expect to begin the first beam tests at the end of 2006.

## REFERENCES


[1] B.N. Gikal et al., JINR Communications, P9-03-121, Dubna, 2003.

[2] B.N. Gikal et al., JINR Communications, P9-02-240, Dubna, 2002.