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DESIGN AND SIMULATION OF THE EXTRACTION SYSTEM OF DC140 CYCLOTRON

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EXTRACTION SYSTEM OF DC140

JINR 114 Flerovium FLNR Dubna

Abstract
Flerov Laboratory of Nuclear Reaction of Joint Institute for Nuclear Research carries out the works under creating of FLNR JINR Irradiation Facility based on the cyclotron DC140. The facility is intended for SEE testing of microchip, for production of track membranes and for solving of applied physics problems. The DC140 cyclotron is intended for acceleration of heavy ions with mass-to-charge ratio A/Z within interval from 5 to 5.5 up to two fixed energies 2.124 and 4.8 MeV per unit mass. The intensity of the accelerated ions will be about 1 pmcA for light ions (A<86) and about 0.1 pmcA for heavier ions (A>132). The system based on three main elements - electrostatic deflector, focusing magnetic channel, Permanent Magnet Quadrupole lens is used in the DC140 cyclotron for extraction of the accelerated beam. The design and simulation of the beam extraction system from the DC140 cyclotron are present-ed in this report.

EXTRACTION SYSTEM OF DC140

INTRODUCTION

The DC140 is a sector cyclotron is intended for acceleration of heavy ions with variation of the magnetic field level at range Bo=1.415÷1.546 T. The main parameters of DC140 cyclotron are given in Table 1.

The DC140 will be a reconstruction of the DC72 cyclotron [2,3].

Table 1: DC140 cyclotron main parameters

Pole (extraction) radius, m	1.3 (1.18)	
Number of sectors	4	
RF frequency, MHz	8.632	
Harmonic number	2	3
Energy, MeV/u	4.8	2.124
A/Z range	5.0÷5.5	7.57÷8.25
RF voltage, kV	60	
Number of Dees	2	
Ion extraction method	Electrostatic deflector	
Deflector voltage, kV	73.5	

EXTRACTION SYSTEM OF DC140

INTRODUCTION

For beams extraction from the cyclotron is used the electrostatic deflector. The extraction system of the DC140 cyclotron consist a next elements (see Fig. 1):

1. Electrostatic deflector (ESD);
2. Focusing magnetic channel (MC);
3. Permanent Magnet Quadrupole lens (PMQ).

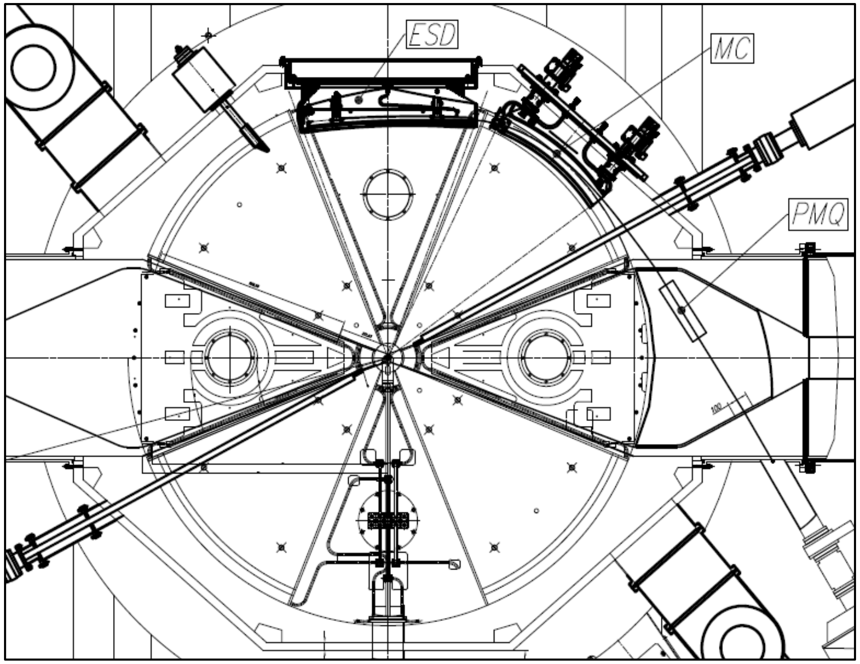

Figure 1: Layout of the elements of extraction system

EXTRACTION SYSTEM OF DC140

OPTIMIZATION OF THE CURVATURE RADIUS OF THE ELECTROSTATIC DEFLECTOR

Azimuthal position of the electrostatic deflector - 70÷110 ° (40 °).

The main parameters of the electrostatic deflector are given in Table 2.

Table 2: Parameters of the electrostatic deflector

Azimuthal position [deg]	70÷110
Max. Voltage [kV]	73.5
Thickness of the “septum” plate [mm]	0.3÷1.0
Gap between plates [mm]	9
Displace of the deflector edges [mm]	± 10

EXTRACTION SYSTEM OF DC140

OPTIMIZATION OF THE CURVATURE RADIUS OF THE ELECTROSTATIC DEFLECTOR

The task of the optimization comes down to minimizing the sum of differences of radius of curvature of the deflector R_d centered at a point (x0;y0) and distances from this point to the point of the extraction orbit as shown in Eq.1.

$$\frac{1}{n}\sum_{i=1}^{n}(R_d - R_i)^2 = \min \qquad (1)$$

R_d – radius of curvature of deflector, cm;

$R_i = \sqrt{(r_i \cdot \cos(\varphi_i) - X_0)^2 + (r_i \cdot \sin(\varphi_i) - Y_0)^2}$ – the minimal distance from the centre of curvature of the deflector (X0; Y0) to the *i* point of extraction orbit of ion beam (Table 3);

φ_i – the angle of *i* point of extraction orbit of ion beam,°.

Table 3: Coordinates for the centre of curvature and radius of curvature

Ion	$^{40}Ar^{8+}$	$^{209}Bi^{38+}$	$^{197}Au^{26+}$	$^{132}Xe^{16+}$
W, MeV	4.8	4.8	2.124	2.124
$B\rho$, T×m	1.58	1.74	1.59	1.73
X_0, cm	20.87	19.01	20.6	19.16
Y_0, cm	-200.26	-176.31	-198.67	-177.33
R_d, cm	309.28	285.68	307.68	286.71
d_{max}, cm	0.011	0.011	0.01	0.008

EXTRACTION SYSTEM OF DC140

OPTIMIZATION OF THE CURVATURE RADIUS OF THE ELECTROSTATIC DEFLECTOR

The y-axis of the local coordinate system (x,y) is turned up to 3.71 ° angle (for all the considered ions) from Y-axis of the global one (X,Y) with origin in the centre of the cyclotron (see Fig. 2). Figure 3 shows the extraction orbits of beams and the medium position of septum of electrostatic deflector. On the basis of the calculation of the optimization, the deflector radius is R= 2947 mm, L= 775 mm.

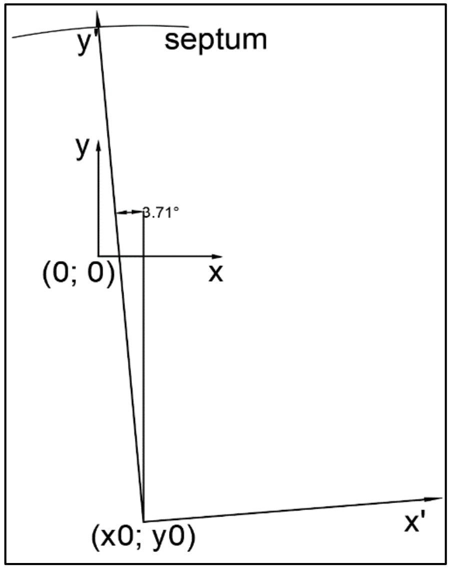

Figure 2: The septum of deflector in the local coordinate system

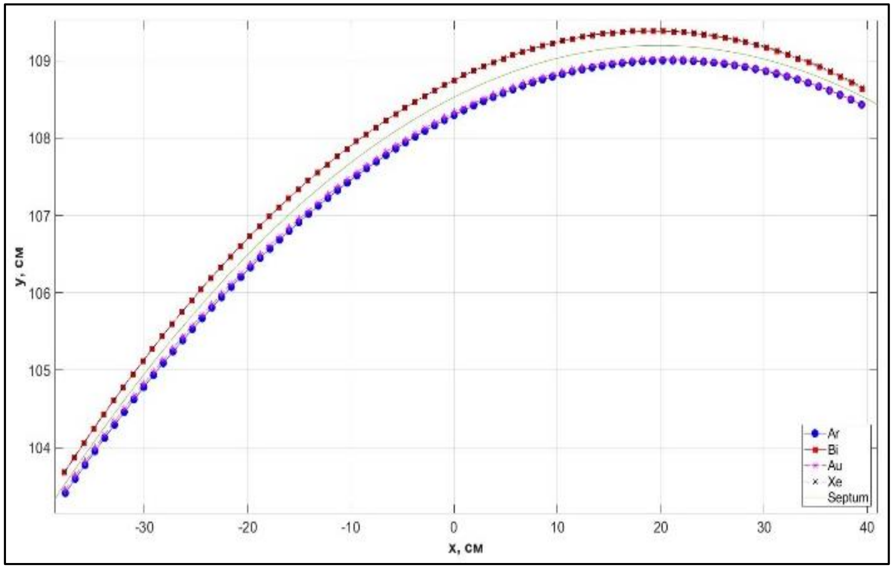

Figure 3: The graph of extraction orbits of ion beams and medium position of septum of electrostatic deflector

EXTRACTION SYSTEM OF DC140

NUMERICAL SIMULATION OF THE BEAM EXTRACTION

For numerical simulation the test ion in accordance with working diagram are used. The parameters of there ion are given in Table 4.

Table 4: Parameters of the test ions

Ion	$^{209}Bi^{38+}$
A/Z	5.5
Bo, T	1.5458
B(R), T	1.5540
E (R)	4.80
Fion MHz	4.316
har	2
Rmag, cm	3
Uinj, kV	18.86

EXTRACTION SYSTEM OF DC140

NUMERICAL SIMULATION OF THE BEAM EXTRACTION

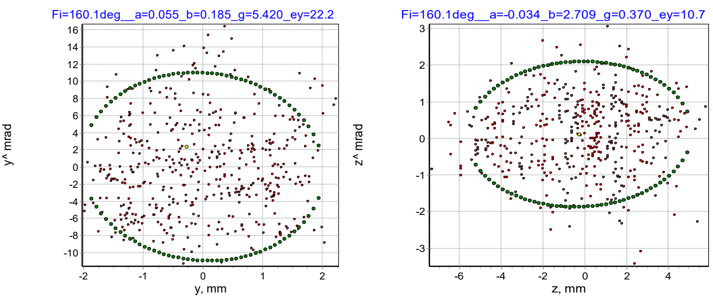

Figure 4. The horizontal and vertical beam emittances at the deflector entrance (A/Z=5.5, Bo=1.55 T)

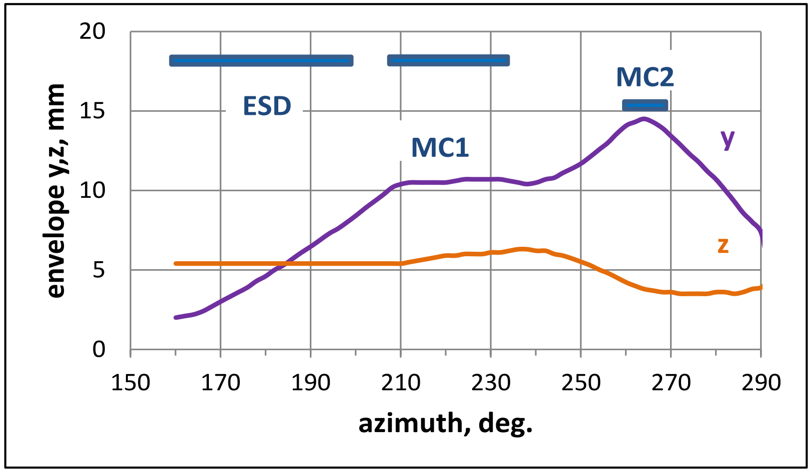

Figure 5. The horizontal and vertical beam envelopes

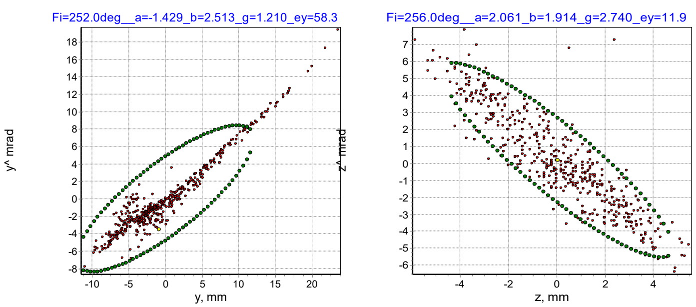

Figure 6. The horizontal and vertical beam emittances at the PMQ entrance (A/Z=5.5, Bo=1.55 T)

EXTRACTION SYSTEM OF DC140

FOCUSING MAGNETIC CHANNEL

The main parameters of the magnetic channel are given in Table 5. The magnetic channel is shown in Figure 7.

PERMANENT MAGNET QUADRUPOLE LENS

The main parameters of the permanent magnet quadrupole lens are given in Table 6.

Table 6: Parameters of PMQ

Aperture [mm] horizontal	64
vertical	25
Effective length [cm]	29.9
Focusing gradient of the magnetic field [T/m]	8.1

Table 5: Parameters of magnetic channel

Azimuthal position [deg]	36÷64
Aperture [mm] horizontal	32
vertical	20
Displace of the edges [mm]	± 15
Focusing gradient of the magnetic field [T/m]	13.5

Figure 7: Computer model of the magnetic channel MC [2]

EXTRACTION SYSTEM OF DC140

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