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THE EXTRACTION SYSTEM OF DC140 CYCLOTRON

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Abstract

The main activities of Flerov Laboratory of Nuclear Reactions, following its name - are related to fundamental science, but, in parallel, plenty of efforts are paid for practical applications. For the moment continues the works under creating irradiation facility based on the cyclotron DC140 which will be dedicated machine for applied researches in FLNR. The beam transport system will have three experimental beam lines for testing of electronic components (avionics and space electronics) for radiation hardness, for ion-implantation nanotechnology and for radiation materials science. The DC140 cyclotron is intended for acceleration of heavy ions with mass-to-charge ratio A/Z within interval from 5 to 8.25 up to two fixed energies 2.124 and 4.8 MeV per unit mass. The intensity of the accelerated ions will be about 1 pμA for light ions (A<86) and about 0.1 pμA for heavier ions (A>132). The following elements are used to extract the beam from the cyclotron: electrostatic deflector, focusing magnetic channel, Permanent Magnet Quadrupole lens and steering magnet. The design of the beam extraction system of DC140 cyclotron are presented in this report.

INTRODUCTION

The DC140 is a sector cyclotron is intended for acceleration of heavy ions [1]. It will be a reconstruction of the DC72 cyclotron [2, 3]. In DC72 beam was extracted by stripping method. In DC140 the extraction will be carried out using an electrostatic deflector.

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).

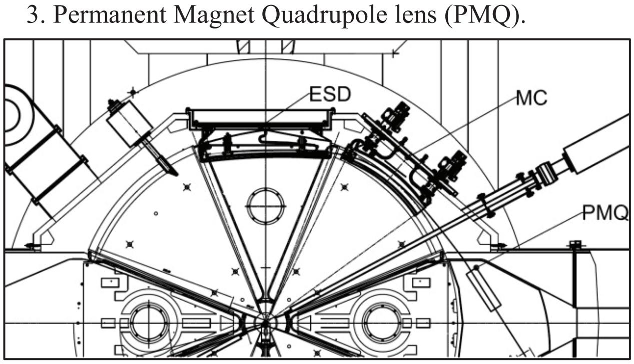

Figure 1: Layout of the elements of extraction system.

The main parameters of DC140 cyclotron are given in Table 1.

Table 1: DC140 Cyclotron Main Parameters

Parameter	Value	
Magnetic field [T]	1.415÷1.546	
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	

NUMERICAL SIMULATION OF THE BEAM EXTRACTION

For numerical simulation the test ion in accordance with working diagram are used [see Fig. 2, 3, 4, 5]. The parameters of this ion are given in Table 2.

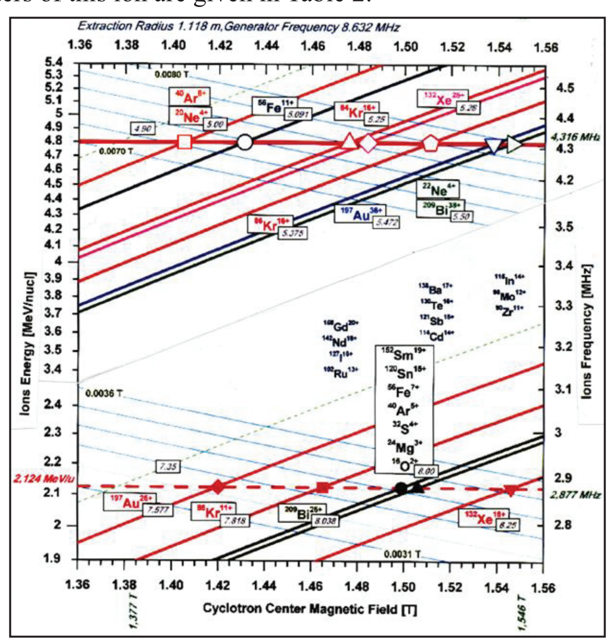

Figure 2: Working diagram of DC140 cyclotron.

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Table 2: Parameters of the Test Ions

Ion	$^{209}Bi^{38+}$
A/Z	5.5
B_o [T]	1.5458
B(R) [T]	1.5540
E(R)	4.80
F_{ion} [MHz]	4.316
Harmonic	2
R_{mag} [cm]	3
U_{inj} [kV]	18.86

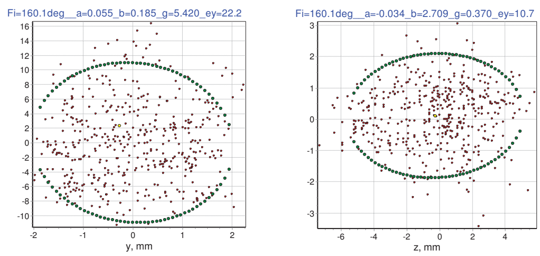

Figure 3: The horizontal and vertical beam emittances at the deflector entrance (A/Z=5.5, Bo=1.55 T).

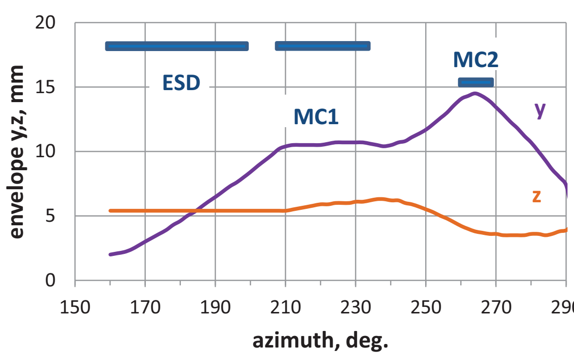

Figure 4: The horizontal and vertical beam envelopes.

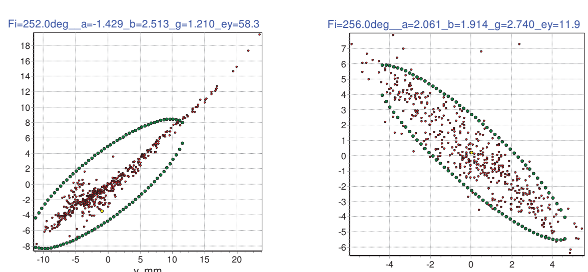

Figure 5: The horizontal and vertical beam emittances at the PMQ entrance (A/Z=5.5, Bo=1.55 T).

ELECTROSTATIC DEFLECTOR

The electrostatic deflector (ESD) consists of two parallel plates (septum plate and potential plate), between which an electric field is created and deflecting the beam from the cyclotron chamber.

The azimuthal position of electrostatic deflector is 40º (70º - 110º). Due to the low power of the accelerated ion beams, it was decided that the potential electrode will not have an active cooling system.

The main parameters of the electrostatic deflector are given in Table 3.

Table 3: Parameters of the Electrostatic Deflector

Parameter	Value
Azimuthal position [deg]	70÷110
Max. Voltage [kV]	73.5
Length of the “potencial” plate [mm]	780
Length of the “septum” plate [mm]	775
Thickness of the “septum” plate [mm]	0.3÷1.0
Material of the “potencial” plate [mm]	Al
Material of the “septum” plate [mm]	W
Gap between plates [mm]	9
Displace of the deflector edges [mm]	± 10

During the design, three modifications of the deflector were considered: with constant gap $g = 9$ mm, with a linearly increasing gap ($g_1/g_n = 6/9$) and with a linearly decreasing electrostatic field ($g_1/g_n = 6/9$).

Modeling of the electrostatic deflector in detail in [4].

The electrostatic deflector with constant gap between electrodes provides the lowest beam losses ($\eta = 21.25$ %) at the septum compared to the other modifications (see Fig. 6).

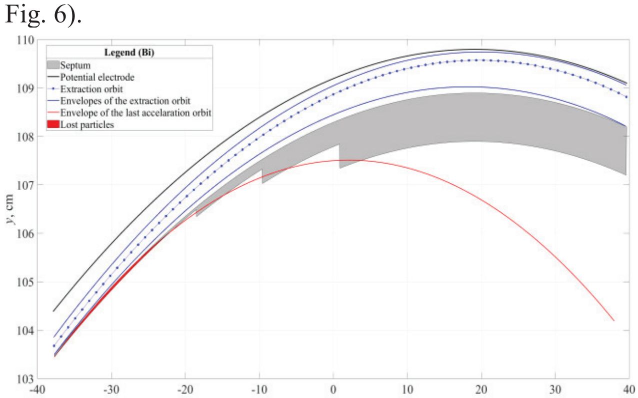

Figure 6: Graph of losses of ion beam $^{209}Bi^{38+}$ in an electrostatic deflector with a constant gap.

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FOCUSING MAGNETIC CHANNEL

The focusing magnetic channel (MC) is intended for focusing in the horizontal direction of the heavy ion beam extracted from the cyclotron (see Fig. 7). The MC consists of 4 parts with different cross-sections. Azimuth extent of each section 8.3° (see Fig. 8).

The main parameters of the magnetic channel are given in Table 4.

Table 4: Parameters of Magnetic Channel

Parameter	Value
Azimuthal position [deg]	36÷64
Horizontal aperture [mm]	32
Vertical aperture [mm]	20
Displace of the edges [mm]	± 15
Focusing gradient of the magnetic field [T/m]	13.5

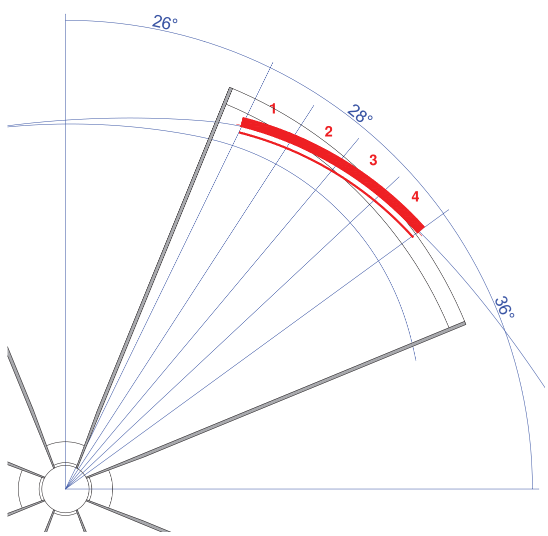

Figure 7: Layout of the magnetic channel in the cyclotron extraction system.

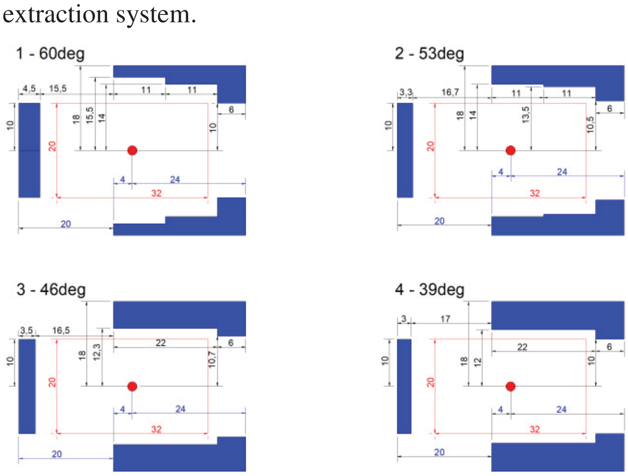

Figure 8: Cross section of four parts of magnetic channel.

PERMANENT MAGNET QUADRUPOLE LENS

The cross-section of the permanent magnet quadrupole lens consisting of 26 permanent magnets is shown in Fig. 9. The main parameters of the permanent magnet quadrupole lens are given in Table 5.

Simulation and design of the PMQ is presented in the work [5].

Table 5: Parameters of PMQ

Parameter	Value
Horizontal aperture [mm]	64
Vertical aperture [mm]	25
Effective length [cm]	29.9
Focusing gradient of the magnetic field [T/m]	8.1

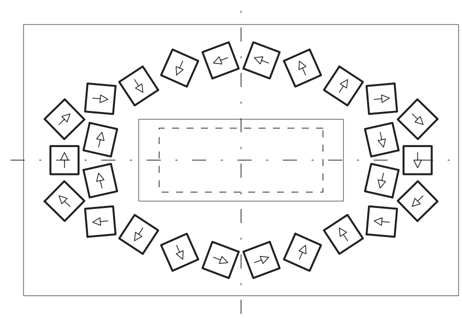

Figure 9: Cross section of PMQ consisting of 26 permanent magnets.

The working area takes into account the horizontal spread of orbits ± 4 mm.

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