BEAM LINES FOR PHYSICAL EXPERIMENTS OF DC-350 CYCLOTRON

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Abstract

The beam lines for physical experiments of DC-350 cyclotron are presented. The bending magnet with variable magnetic field up to 1.5 T gives possibility to transport ion beam to five experimental installations. The beam focusing in the beam lines is provided by set of quadrupole lenses. The beam diagnostics consists of the Faraday caps, luminophors, aperture diaphragms, wire scanners and slit collimators.

INTRODUCTION

DC-350 cyclotron designed for the Institute of Nuclear Physics of the Republic of Kazakhstan at the Flerov Laboratory of Nuclear Reaction (JINR, Dubna) is intended for carrying out fundamental and applied investigations with ions from C to Xe (mass-to-charge ratio A/Z being within interval 5÷10) produced by the ECR-source. The energy of the ions extracted from the cyclotron may vary from 3 up to 12 MeV/nucl. The main parameters of the DC-350 cyclotron are given in [1].

Utilization efficiency of the accelerator is determined in many respects by quality of the transportation system for the extracted ions. Widely branched system of channels allows one to carry out numerous investigations. This work is devoted to the design of the channels for transportation of the extracted heavy ions from the cyclotron to a target.

Lay-out of the channels for heavy ion transportation is shown in Figure.

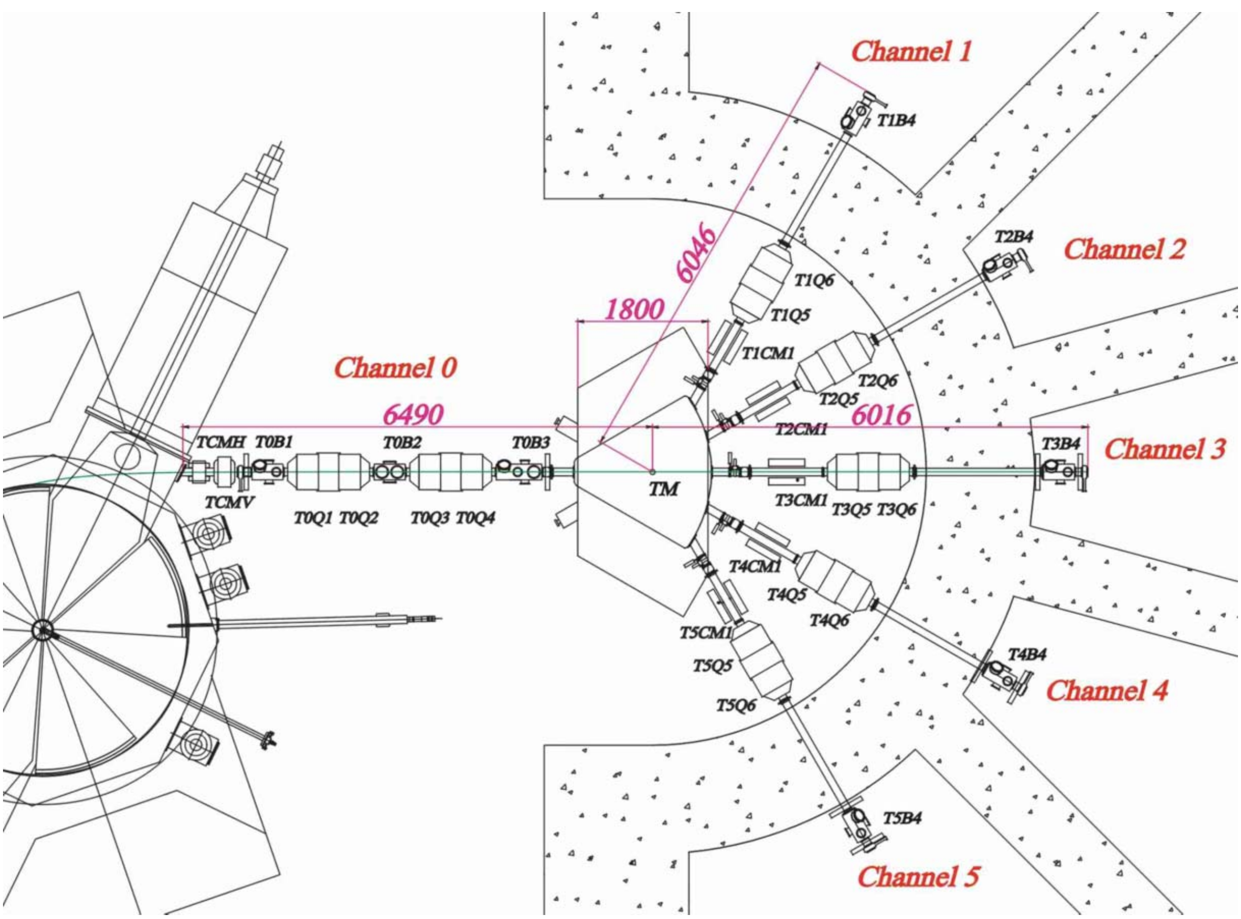

Figure 1: Lay-out of the channels for heavy ion transportation

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DESCRIPTION OF CHANNELS

The particularity of the channel system is using one bending magnet to move ion beams to five experimental channels, similar to the channel scheme at RCNP of Osaka University [2]. Every physical setup will be separated from others by concrete walls, the scheme allows beam users to prepare experimental equipment in parallel with beam experiments on a neighbor channels. After the bending magnet a special water-cooled beam stopper will be installed into every channel to prevent wrong beam transportation into the channels that are prepared to work. Also, the total channel length will be less than one of wide spread channels with more than one bending magnets, and the total channel cost will be low correspondingly.

Common part of all channels from the center of the **TCMH** extraction magnet to the **TM** bending magnet input is named as channel 0. The beam tracing to the **TM** input is carried out by means of two quadrupole doublets **T0Q1** – **T0Q4**. The scheme of **TM** bending magnet is shown in Figure.

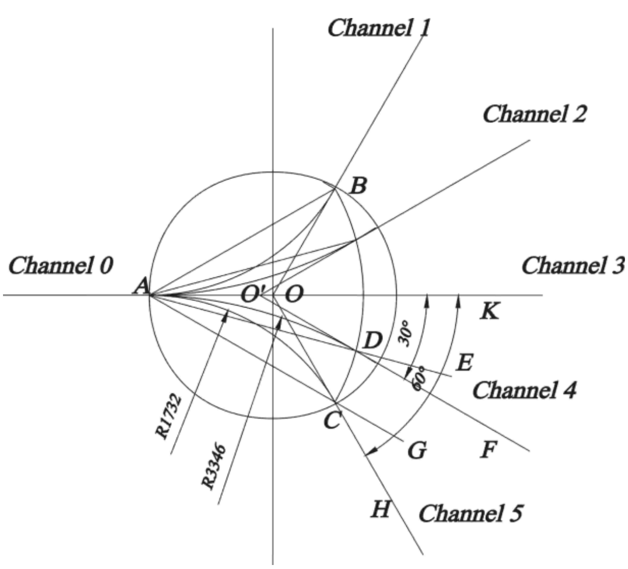

Figure 2: Scheme of **TM** bending magnet

It has the magnetic field induction not less than 1.53 T. **TM** magnet provides the ion beam turning at angles $\pm 60^0$ (in channels 1 and 5) and also at angles $\pm 30^0$ (in channels 2 and 4). When **TM** is switched off the beam is traced along the channel 3. One more quadrupole doublet that focuses the ion beam on a target is placed in every channel behind TM.

The edge angle at **TM** input is ε_{in} = 0 for all five channels. The performed calculations showed that the positive edge angles at **TM** output ε_{out} can bring to decrease of the demanded gradient in quadrupoles on ~17%. Therefore the calculations were performed with using the bending magnet **TM** which scheme is shown in Fig. 2 (ABC outline).

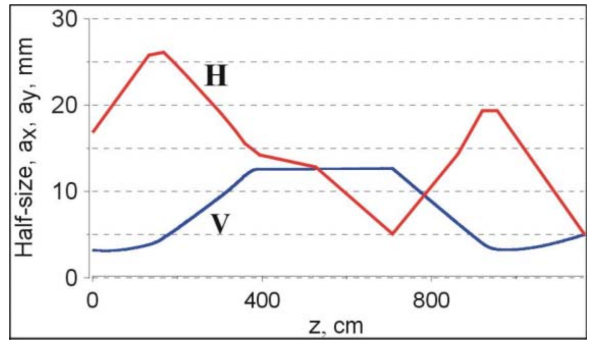

Figure 3: Beam envelopes in the channel N1

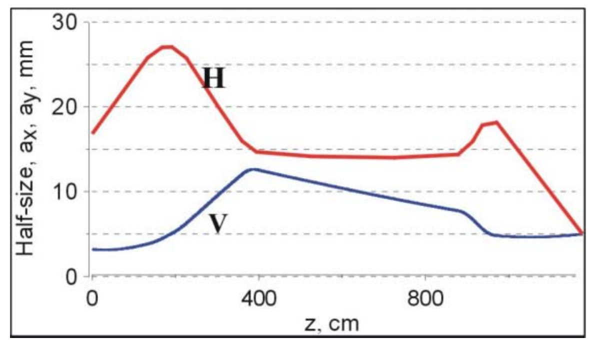

Figure 4: Beam envelopes in the channel N3

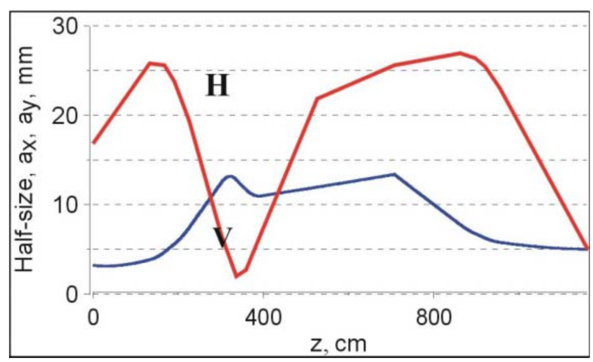

Figure 5: Beam envelopes in the channel N5

CALCULATION RESULTS

Calculations of the extracted ion beam tracing were carried out for the beam parameters given in Table 1. They correspond to 7 points on the working diagram of the cyclotron. The following designations are used in the Table: W is the ion beam kinetic energy, $\alpha_x, \beta_x, \alpha_y, \beta_y$ are Twiss parameters, $\varepsilon_{x,y}$ are the RMS values of horizontal and vertical emittances, D_x and D_x' are the values of the dispersion function and its derivative. It was

Table 1: Parameters of the extracted heavy ion beams

A/Z	W $\frac{MeV}{nucl}$	α_x	β_x $\frac{cm}{rad}$	α_y	β_y $\frac{cm}{rad}$	ε_x π •mm mrad	ε_y π •mm mrad	D_x cm	$D_x^{'}$
4.8	9.8	-16.9	3674	0.936	1444	0.853	1.146	286.7	1.078
5.33	10.4	-1.907	623.1	0.397	153.1	0.943	1.007	462.5	1.781
5.33	12.05	-3.324	1200	0.008	117.5	0.761	1.003	492.5	1.886
6.86	6.35	-2.065	738.9	0.353	130.4	1.702	1.137	471.5	1.803
8	3.5	-22.3	4975	1.16	1509	1.333	1.731	315.2	1.21
9.6	3.22	-1.901	515.7	0.558	250.7	2.13	1.516	450.4	1.727
9.6	3.73	-2.501	863.5	0.209	157.8	1.659	1.698	485.0	1.858

also supposed that relative spread of ion momentums . P/P was equal to ±0.16% and the ion beam current was equal to 3 ∝A. The values of the vertical dispersion function D_y and its derivative $D_y^{'}$ were considered equal to zero.

In fulfilled calculations one took in account the influence of the initial ion longitudinal momentum spread . P/P [3]. For that one calculated the behavior of the dispersion function D_x along the beam trajectory and took in account contribution of the initial ion momentum spread on the behavior of the horizontal beam dimension.

Quadrupole gradients in the channels were chosen so that the beam diameter on the target to be equal to 10 mm and the dispersion function D_x to be close to zero.

In the channels 1 and 2 the ion beam is deflected in the direction opposite to the beam circulation in the cyclotron.

As an example of calculation results, the dependences of the horizontal (**H**) and vertical (**V**) ion beam half dimensions versus the channel length for the channels 1,3 and 5 are shown in Figure 3 , Figure and Fig for A/Z = 9.6 and W = 3.73 MeV/nucl.

For the channel 3 the **TM** output edge angle is equal to $\varepsilon_{out} = 0^0$. For channels 1 and 5 the calculated path in **TM** is equal to 175.2 cm and $\varepsilon_{out} = 30^0$. For channels 2 and 4 the path in **TM** is equal to 181.4 cm and $\varepsilon_{out} = 15^0$.

BEAM POSITION CORRECTION

The system of beam position correction in the channels will consist of the horizontal and vertical steering magnets (**TCMH**, **TCMV**) at the cyclotron exit and five two-plane dipole steering magnets (**T**x**CM**y) situated after **TM**.

BEAM DIAGNOSTICS

The beam diagnostics will be situated in 8 diagnostic boxes (**T**x**B**y). The Faraday caps will be used to measure the ion currents. The moveable luminophors with TV-cameras and rotating wire scanners will be used to measure the beam profile and intensity distribution in the beam cross section. Stationary installed aperture diaphragms will be situated before the **TM** and at the end of every channel to adjust the axial transportation of the ion beams. The slit collimators will be used to change the beam intensity and transverse distribution.

VACUUM SYSTEM

The channel will be pumped by turbopumps with the pumping speed of 150 l/s installed at the diagnostic boxes and two turbopumps with the pumping speed of 500 l/s installed at the **TM** vacuum chamber. The estimated average pressure in the channels is about $1 \cdot 10^{-6}$ Torr, the vacuum beam losses will be not more than 5 %.

CONCLUSION

Calculations of transportation of the heavy ion beams extracted from DC-350 cyclotron showed that the chosen structure of 5 channels allows one to trace these beam without losses.

At that the beam diameters on the targets in all variants of the beams and channels are not more than 10 mm.

Maximum demanded gradient value in all quadrupoles is equal to 6.8 T/m.

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