AXIAL INJECTION BEAM LINE OF A COMPACT CYCLOTRON*

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Abstract

Axial injection beam line of the compact cyclotron is presented. It is intended for transportation of the C5+ ion beam obtained in the permanent magnet ion source. The beam line is only 3.486 m from the ion source to the entrance of spiral inflector, it consists of two glasser lens, one double 90-degree bend magnet, one quadrupole and two solenoid lens. The sinusoidal buncher, Faraday cap and chopper are used respectively for increasing seizing efficiency, beam diagnostics and choice of beam utilizing time. The bend magnet and a slit collimator are used for choice of C^{5+} ion beam.

INTRODUCTION

A new compact cyclotron is designed at the Institute of Modern Physics, it is intended for acceleration of C^{5+} ions and energy 7 MeV/u at the extraction radius. The cyclotron will be used as the injector of a compact synchrotron. The overall equipment will be built for the medical application. The main parameters of the cyclotron are contained in Table 1.

Table 1 The cyclotron main parameters

Extraction radius /m	0.75
Magnetic field /T	1.168
Number of sectors	4
RF frequency /MHz	31.02
Harmonic number	4
Extraction energy /MeV/u	7.0
Z/A	0.4167(C^{5+})
RF voltage /kV	70
Number of Dees	2
Ion extraction method	Electrostatic deflector and bend

Axial injection beam line of the cyclotron is designed for transportation of the C^{5+} ion beam obtained in the permanent magnet ion source. A big vacuum box is installed in the vertical part of the beam line. A sinusoidal buncher, a Faraday cap, a slit collimator and a chopper are located in the big vacuum box. The sinusoidal bunchers are used for increasing of the injection efficiency from about 11% to 47%, it is about 1.3 m from the median plane of the cyclotron. The Faraday cap is used for the beam diagnostics and monitoring. The chopper is used for choice of the beam utilizing time, its running period is decided by the synchrotron.

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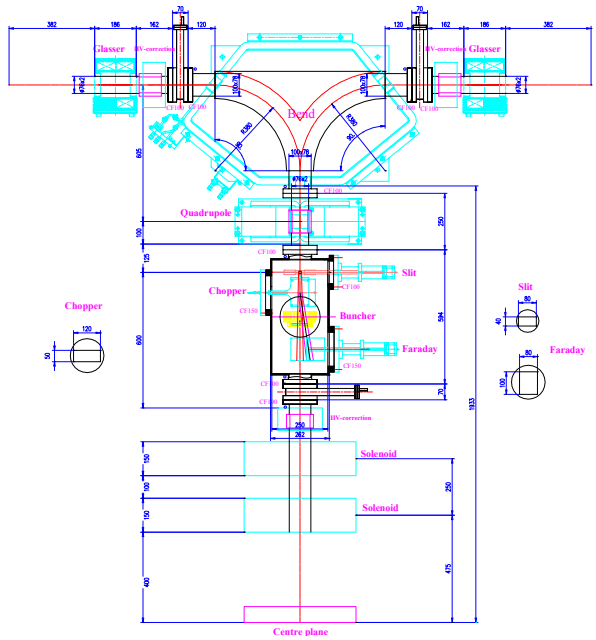

Fig.1 Beam line layout

BEAM LINE DESIGN

The C^{5+} ion beams are obtained in the permanent magnet ion source. The some parameters of beam are contained in the Table 2.

Table 2 Beam parameters

Beam intensity /eμA	200
Emittance /πmm*mrad	150
Energy /keV	100

The beam line is situated above the cyclotron magnet. It consists of the permanent magnet ion source, the double 90-degree analyzing bending magnet (DM90) and two focusing glasser lens that will be placed at the horizontal part of the beam line. A quadrupole and a buncher will be placed at the vertical part of the beam line, two focusing solenoids will be installed above the plug. The spiral inflector will transfer ion beams to the median plane of the cyclotron.

The beam line is designed with trace-3D program. The initial C^{5+} beam parameters used in the simulation are contained in Table 2. The computed C^{5+} beam envelopes along the beam line from the ion source to the entrance of the inflector are shown in Fig.2. The multi-ion simulation with 2σ gauss distribution is made for the axial injection beam line, the simulation result shows that the ion beam pass through the injection line without loss. The ion beam distributions at ion source exit and inflector entrance are shown in Fig.3.

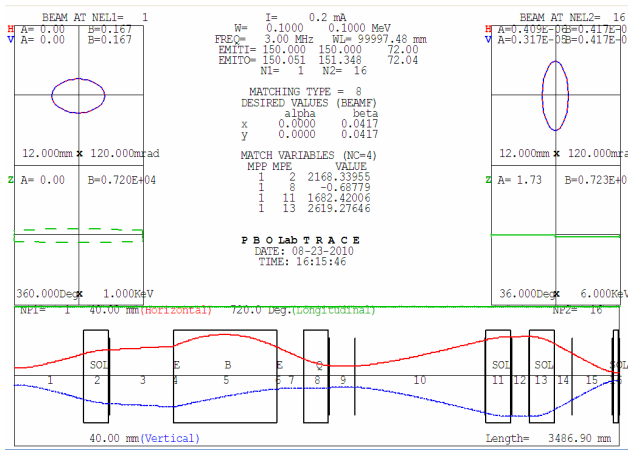

Fig.2 beam envelopes along beam line

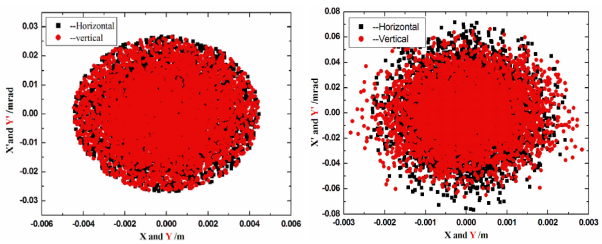

Fig.3 Ion distributions at source exit and inflector entrance

BUNCHING SYSTEM

The sinusoidal buncher is located in a big vacuum box at 130 cm from median plane of the cyclotron above the first solenoid. The longitudinal seizing efficiency of the compact cyclotron was calculated with space charge effect considered. Beam seizing efficiency, buncher voltage amplitudes and corresponding current is shown in Fig.4.

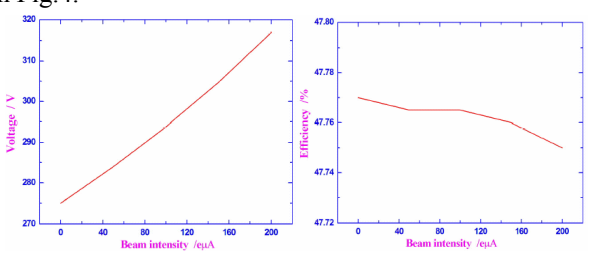

Fig.4 Beam seizing efficiency and buncher voltage amplitudes

BEAM POSITION CORRECTION

The system of the center of beam correction will consist of two two-plane dipole steering magnets, situated before and after DM90. This system gives us possibility to eliminate displacement and angle of the beam center that will appear due to cyclotron magnet fringing field.

BEAM DIAGNOSTICS

The Faraday cap is used for the beam diagnostics and ion analysis spectrum identification after the DM90. The electrostatic chopper will be used for fast interruption and modulation the beam current. All the elements will be situated in the big vacuum box below the analyzing magnet.

VACUUM SYSTEM

The horizontal part of the beam line will be pumped by two turbopumps installed at the ion source exit with the pumping speed of 700 l/s.

The vertical part will be pumped by a turbopump installed at the big vacuum box with the pumping speed of 1000 l/s.

The vacuum volume will be divided into four sections by three gate valves that will be installed before DM90 and after the big vacuum box.

The estimated average pressure in the beam line is about 10^{-7}mbar.

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