AXIAL INJECTION CHANNEL OF THE DC-350 CYCLOTRON

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Abstract

Axial injection channel of the DC-350 cyclotron is presented. It is intended for transportation of the high intensity ion beam from Li to Bi obtained in the superconducting ECR-ion source (SECRIS). The sharp shortening of the distance between SECRIS and the analyzing bending magnet allow removing the focusing elements between the SECRIS and the analyzing magnet. This reduces the negative effect of the space charge on the ion beam emittance. The beam focusing in the beam line after the analyzing bending magnet is provided by solenoidal lenses. The linear and sinusoidal bunchers installed in the vertical part of the channel are used for increasing of the accelerating efficiency. The beam diagnostics consists of the Faraday caps and the wire scanner. The slit collimator, pepper pot and chopper will be used for variation of the beam parameters.

INTRODUCTION

DC-350 is the new cyclotron for the Institute of Nuclear Physics of the Republic of Kazakhstan designed at the Flerov Laboratory of Nuclear Reaction of the Joint Institute for Nuclear Research. It is intended for acceleration of ions with mass-to-charge ratio A/Z within interval 4.8 ÷ 9.6 and energy 3÷12 MeV/u at the extraction radius. These ion beams will be used in the nuclear and applied physics experiments, in particular for synthesis of exotic nuclei. The main parameters of the DC-350 cyclotron are contained in Table 1.

Table 1. DC-350 main parameters

Pole (extraction) radius, m	2 (1.76)
Magnetic field, T	1.24÷1.5
Number of sectors	4
RF frequency, MHz	6.45÷13.0
Harmonic number	3
Energy range, MeV/u	3 ÷ 12
A/Z range	4.8 ÷ 9.6
RF voltage, kV	80
Number of Dees	2
Ion extraction method	Electrostatic deflector

Axial injection channel of the DC-350 cyclotron gives possibility for transportation of the high intensity ion beam from Li to Bi obtained in the superconducting ECR-ion source (**SECR**). The beam focusing in the beam line after the analyzing bending magnet is provided by solenoidal lenses. The linear and sinusoidal bunchers installed in the vertical part of the channel are used for increasing of the accelerating efficiency. The beam diagnostics consists of the Faraday caps and the scanner. The slit collimator and pepper pot will be used for variation of the beam current.

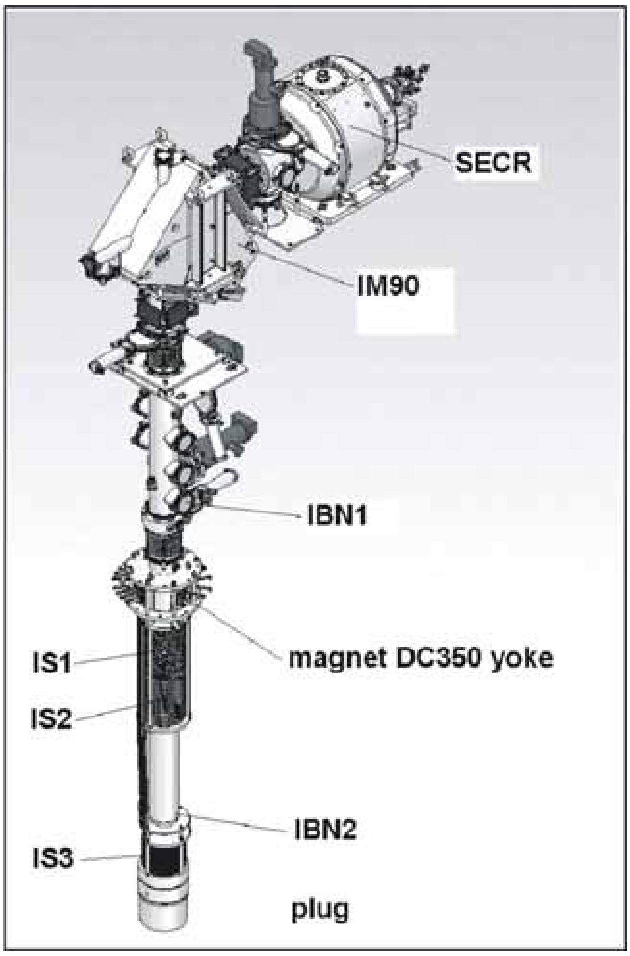

Figure 1: Beam line layout

Table 2. Beam parameters

Ions	Energy, keV/u	Current, pμA
$^{7}Li^{1+}$	3.8	400
$^{48}Ca^{6+}$	3.1	30
$^{132}Xe^{22+}$	4.2	1.5
$^{208}Bi^{40+}$	4.8	0.15

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ION BEAM PARAMETERS

The ion beams from Li to Bi are obtained in the superconducting ECR ion source [1]. The parameters some of the beam are contained in the Table 2.

BEAM LINE LAYOUT

The beam line is shown in Fig.1. The beam line is situated above the cyclotron magnet. It consists of the **SECR** and the analyzing magnet **IM90** that will be placed at the horizontal part of the channel. The focusing solenoids **IS1**, **IS2** and bunchers **IBN1**, **IBN2** will be installed at the vertical part of the channel at aperture of 153 mm. The focusing solenoids **IS3** at aperture of 100 mm will be installed above the plug. The spiral inflector **I** will transfer ion beams to the median plane of the cyclotron.

BEAM SEPARATION

To separate ions that extracted from **SECR** the analyzing magnet **IM90** at aperture of 120 mm will be used. The **IM90** vacuum chamber aperture will be 110 mm. Two iron screens will be installed before an after the magnet to cut its own fringing field.

Table 3: ^{48}Ca beam initial parameters

Injected beam	$^{48}Ca^{6+}$
Mass, A	48
Charge, Z	2÷8
Injected current, μA	0÷190
Ca beam current, μA	0÷700
He beam current, μA	200
$^{48}Ca^{6+}$ kinetic energy, keV/u	3.1375
Diametr, mm	8
Emittance, π mm×mrad	142

BEAM FOCUSING

The sharp shortening of the distance between **SECR** and the analyzing bending magnet allow removing the focusing elements between the **SECR** and the analyzing magnet. This reduces the negative effect of the space charge on the ion beam emittance [2].The beam focusing is provided by analyzing magnet fringing field and focusing solenoids IS1, IS3. Solenoid IS2 serves as a corrector.

As one of test ions the $^{48}Ca^{6+}$ ion was taken for the beam line calculations as a possible projectile for future experiments on exotic nuclei synthesis. The variant of computed focusing system for $^{48}Ca^{6+}$ ion beam is given below. The initial ^{48}Ca beam parameters used in the simulation are contained in Table 3. The charge state distributions for ion beam (Fig.2) and its self fields were taken into account in this simulation. The computed $^{48}Ca^{6+}$ beam envelopes along the beam line are shown in Fig.3 at the ion current of 190 μA. The beam envelopes near inflector and beam emittances along the channel are given in Fig.4, 5 correspondingly.

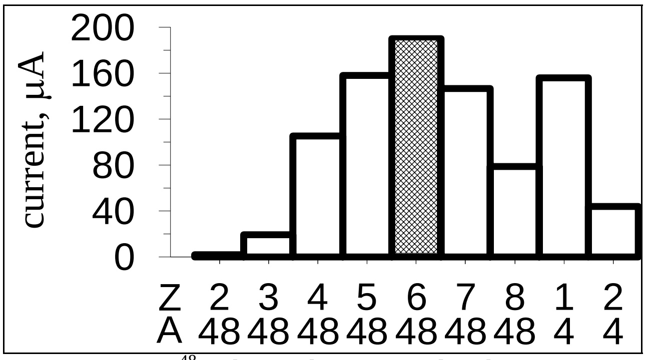

Figure 2: ^{48}Ca beam charge state distribution

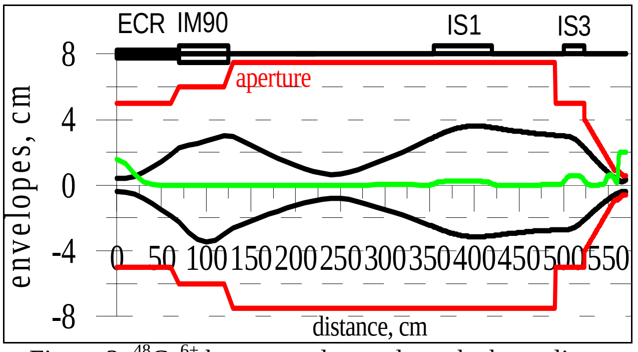

Figure 3: $^{48}Ca^{6+}$ beam envelopes along the beam line. Beam current 190 μA

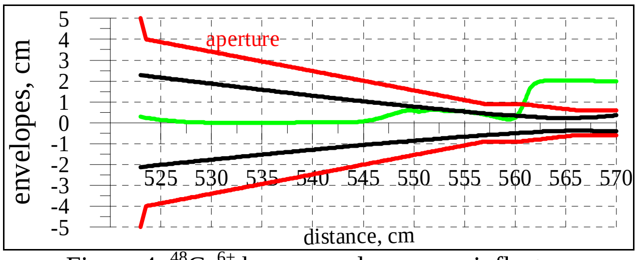

Figure 4: $^{48}Ca^{6+}$ beam envelopes near inflector

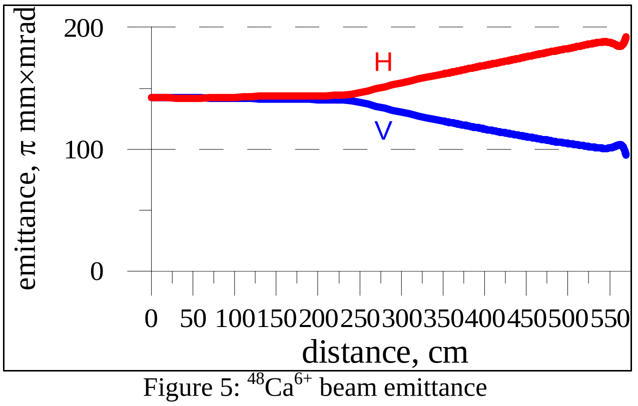

Figure 5: $^{48}Ca^{6+}$ beam emittance

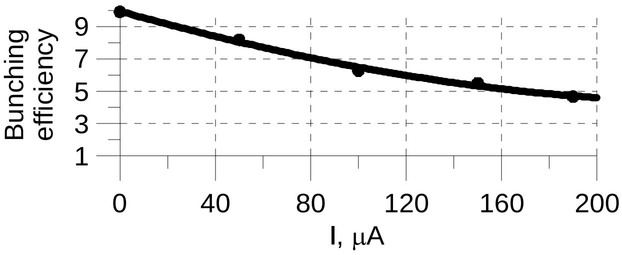

Figure 6: Bunching efficiency *versus* beam current

BUNCHING SYSTEM

The bunching system consists of linear IBN1 [3] and sinusoidal IBN2 [4] bunchers. The linear buncher is placed at 275 cm in the diagnostic box and sinusoidal – at 80 cm from median plane of the cyclotron above the IS3 solenoid. Every buncher will be created as an assembly of two wire grids. The RF voltage will be applied to both grids in antiphases. The simulation of the bunching system of the DC350 cyclotron axial injection beam-line was fulfilled by using created 3D version of MCIB04 code [5, 6].

The dependence of the bunching efficiency [5] on the $^{48}Ca^{6+}$ beam current at the exit of the system is shown in Fig.6. The corresponding voltage amplitudes at linear (U0LIN) and sinusoidal (U0SIN) bunchers are given in Fig.7.

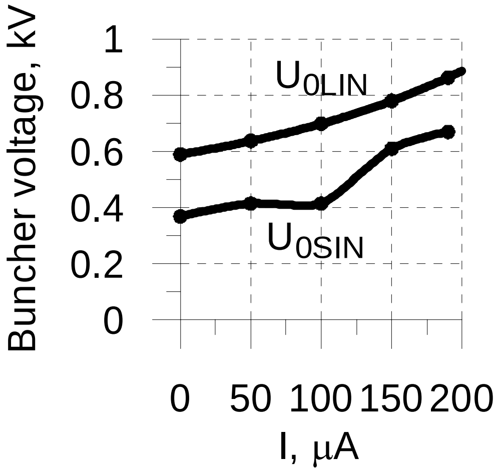

Figure 7: Bunchers voltage for various beam currents

BEAM POSITION CORRECTION

The system of the center of beam correction will consist of two two-plane dipole steering magnets, situated before and after **IM90**. 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 beam diagnostics consists of a Faraday cap and a wire scanner. The Faraday cap will be used to analyse the ion spectrum after the **IM90**. The scanner will be used for beam profile monitoring and emittance measurements. A slit collimator and a pepper pot at the current degrading ratio of 10 will be used as additional devices to vary the beam parameters at diagnostics. The electrostatic chopper will be used for fast interruption and modulation the beam current at edge duration about 1μs.

All the elements will be situated in the diagnostics box below the analyzing magnet.

VACUUM SYSTEM

The horizontal part of the channel will be pumped by three turbopumps with the pumping speed of 150 l/s, that will be situated before and after **SECR** and on the **IM90** vacuum chamber. Also a cryopump with the pumping speed of 800 l/s will be installed at the **SECR** exit.

The vertical part will be pumped by a turbopump with the pumping speed of 500 l/s, and a cryopump with the pumping speed of 800 l/s that will be situated on the diagnostics box.

The vacuum volume will be divided into three sections by two gate valves that will be installed below **IM90** and after the diagnostics box.

The estimated average pressure in the channel is $1{\cdot}10^{-7}$ Torr, the vacuum beam losses will be not more than 10%.

The vacuum monitoring will be provided by using combination of Pirani and Penning gauges.

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