AXIAL INJECTION CHANNEL OF THE DC-72 CYCLOTRON

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Abstract

Axial injection channel of the DC-72 cyclotron consists of two horizontal part placed at the opposite side of the vertical analysing magnet and common vertical part from the magnet to median plane of the cyclotron. The first part is intended for transportation of H^-, $^2H^{1+}$ and $^4He^{1+}$ ions obtained from the multi-cusp ion sources. The second part is used for transportation of the heavy ions from Li to Xe obtained from the ECR-ion source. The focusing in the beam line is produced by solenoidal and quadrupole lenses. The sinusoidal buncher installed in the vertical part of the channel is used for increasing of the accelerating efficiency. The beam diagnostics placed in the special boxes consists of the Faraday caps and the scanners. The scanners are used for beam profile monitoring and emittance measurements. The first experiments at H^-, $^2H^{1+}$ and $^4He^{1+}$ part of the channel were performed.

GENERAL LAYOUT OF THE CHANNEL

The scheme of DC-72 axial injection channel is shown in Fig.1. The vertical channel height is 5.2 m. The magnetic focusing elements were made by NIIEFA, St.Peterburg, Russia. The vacuum elements were made by Vacuum-Prague, Prague, Czech Republic.

ION SOURCES

The heavy ions from He to Xe are obtained from 14 GHz electron cyclotron resonance ion source (IECR) [1]. The H^- and the $^2H^{1+}$ ions are obtained from two identical "multi-cusp" ion sources produced by Université catholique de Louvain, Centre de Recherches du Cyclotron.

BEAM FOCUSING

The focusing of the H^- and the $^2H^{1+}$ ions beam is produced by magnets IM60 and IM90 fringe fields and solenoidal lenses IS2,3,4. The set of quadrupoles IQH,2,3 are used for the formation of the axial symmetric beam between quad Q3 and the middle plane of the cyclotron. The solenoidal lenses IS2,3,4 are used for matching of the optical functions with the acceptance of the cyclotron inflector. The computed trajectories of the particles of the $^2H^{1+}$ ions beam with kinetic energy 16.83 keV and current 500 μA are shown in Fig.2.

The focusing of the heavy ion beams is produced by magnet IM90 fringe fields and solenoidal lenses IS1,2,3,4. Solenoidal lens IS1 decreases the beam divergence just after IECR ion source. As in the H^- and $^2H^{1+}$ part of the channel the set of quadrupole lenses Q1,2,3 forms the axial symmetric beam just after Q3 quad. The solenoidal lenses IS2,3,4 are used for matching of the optical functions with the acceptance of the cyclotron inflector. The computed trajectories of the particles of the argon beam with kinetic energy Z×13.5 keV (Z is ion charge) and current 160 μA are shown in Fig.3.

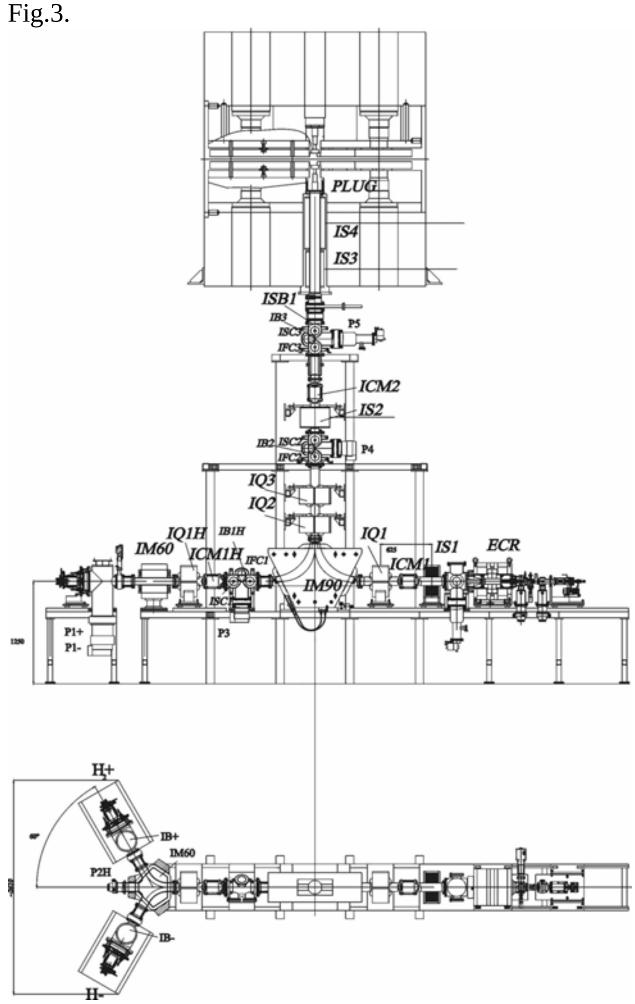

Figure 1: The scheme of the axial injection channel.

Where IECR – electron cyclotron resonance ion source; H^-, H2+ – multi-cusp ion sources; IM60 – 60^0 horizontal magnet; IM90 – 90^0 vertical magnet; IQ1H, IQ1,2,3 – quadrupoles; IS1,2,3,4 – solenoidal lenses; IB1H,IB1,2,3 – diagnostic boxes; ISC1,2,3 – scanners; ISB1 – sinusoidal buncher; IFC1H, IFC2,3 – Faraday caps.

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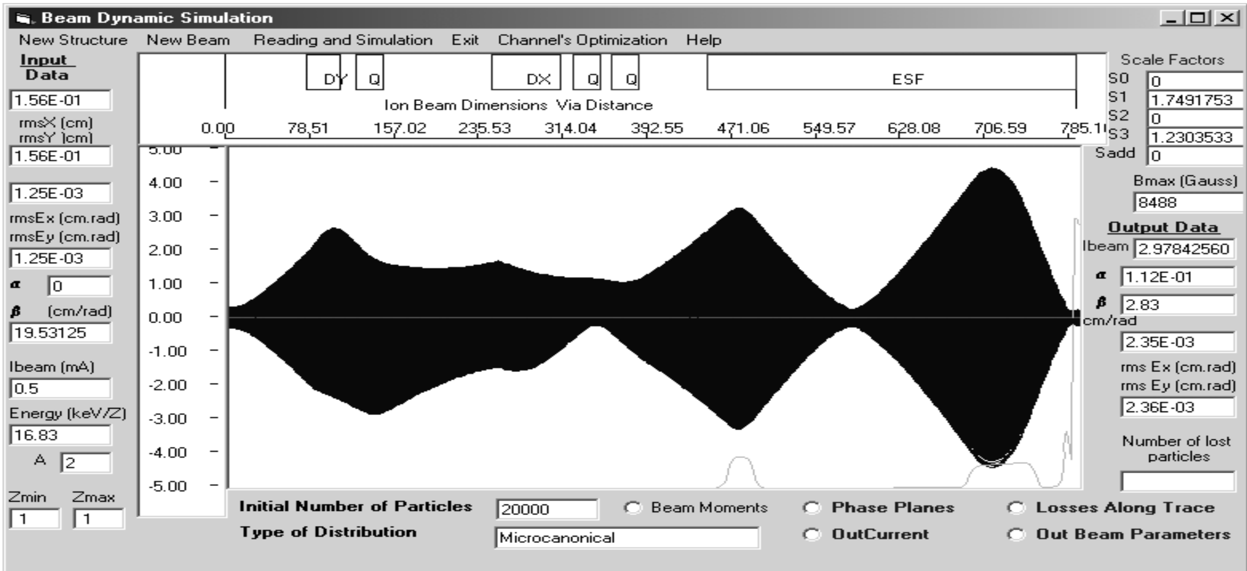

Figure 2: $^{2}H^{1+}$ ion trajectories. Beam current 500 μA.

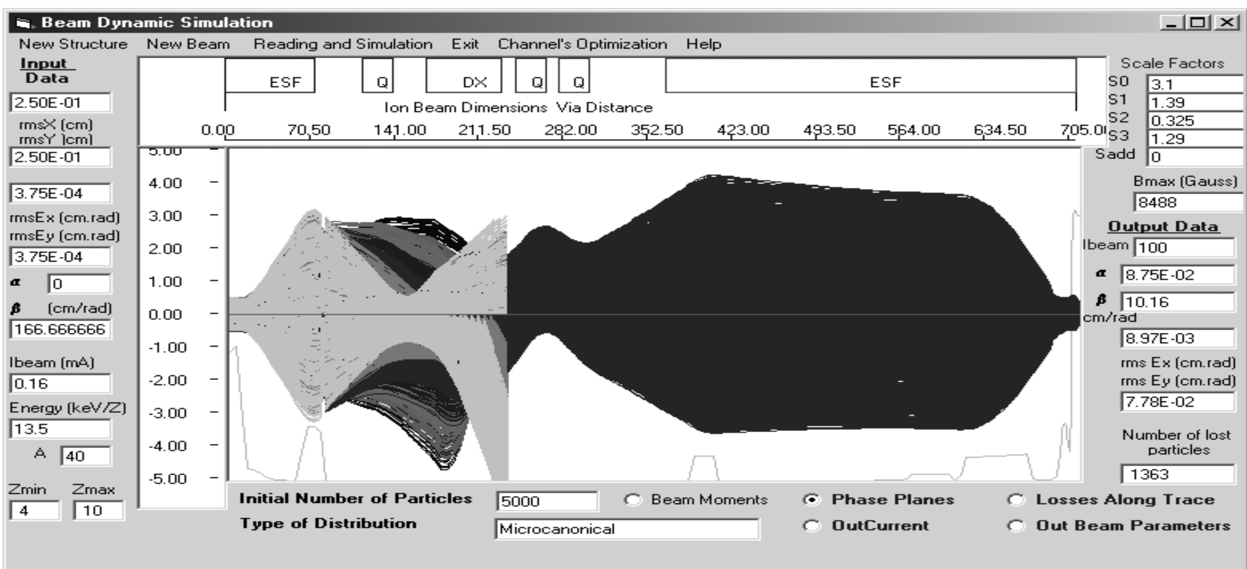

Figure 3: Argon ion trajectories. Beam current 160 μA.

SINUSOIDAL BUNCHER

The sinusoidal buncher ISB1 installed in the vertical part of the channel at 190 cm from the median plane of the cyclotron is used for increasing of the accelerating efficiency. The simulation has shown that longitudinal beam density will be increased at about 5 times.

VACUUM SYSTEM

The vacuum system of the injection channel consists of 4 sections. The extraction boxes of two multicusp ion sources are pumped by turbopumps with the pumping speed of 1400 l/s. The horizontal part of the channel is pumped by two turbopumps with the pumping speed of 500 l/s, and the vertical part of the channel is pumped by two cryopumps with the pumping speed of 800 l/s. In static mode the pressure in the extraction boxes is about 10^{-7} Torr, about $6\cdot10^{-8}$ Torr in the chamber of IM60 magnet, and about $3\cdot10^{-8}$ Torr in the diagnostic box IB3. During the operation with the $^{2}H^{1+}$ and $^{4}He^{1+}$ ion beams the pressure in the extraction box consists of about $2\cdot10^{-6}$ Torr, and about $2\cdot10^{-5}$ Torr in operation with H^{-} ion beam. The vacuum monitoring is provided by using combination of Pirani and Penning gauges.

SYSTEM OF DIAGNOSTIC

The beam diagnostics placed in the special boxes IB1H, IB1, IB2, IB3 consists of the Faraday caps IFC1H, IFC2, IFC3 and the wire scanners ISC1, ISC2, ISC3. The scanners are used for beam profile monitoring and emittance measurements [2]. The diagnostics elements were made by the Laboratory for Technical Development in Physics of Bulgarian Academy of Science, Sofia, Bulgaria.

SYSTEM OF CORRECTION

The system of the center of beam correction consists of two-plane dipole steering magnet ICM1H, ICM1, and ICM2. This system gives possibility to eliminate the displacement and angle of the beam center just after the steering magnet ICM2.

FIRST EXPERIMENTS

All elements of the channel have been manufactured and tested. During the first experiments the beams of H^-, $^{2}H^{1+}$and $^{4}He^{1+}$ ions have been transported up to IFC3 Faraday cup. The current of the beam measured by IFC1H, IFC2 and IFC3 Faraday cap are contained in Table1.

Table 1: Measured beam current

beam	kinetic energy keV	current μA IFC1H	current μA IFC2	current μA IFC3
H^-	16.83	356	301	321
$^{2}H^{1+}$	16.83	643	530	552
$^{4}He^{1+}$	15.39	587	286	500

The maximal currents of the H^- and $^{2}H^{1+}$ beam measured at IFC1H Faraday cap have been equal to about 750 μA. The $^{4}He^{1+}$ beam has been produced in the same source as $^{2}H^{1+}$ ions. The currents at IFC2 are less than currents at IFC3 Faraday cap because of the beam dimensions at IFC2 are greater than diameter of the cup (60 mm). The maximum current of the $^{4}He^{1+}$ beam measured at IFC1H Faraday cap have been equal to about 700 μA.

The measurements of the H^- beam emittance by gradient method have been performed [3]. The measured values of the rms emittances have been equal to 19±2 π mm·mrad in horizontal and vertical planes respectively.

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