

MODERNIZATION OF THE U-400 AXIAL INJECTION SYSTEM

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Abstract

The modernization of the U-400 cyclotron axial injection system is described.

INTRODUCTION

The project of U400 modernization intends decreasing the magnetic field level at the cyclotron center from $1.93 \pm 2.1T$ to $0.8 \pm 1.8T$. This requires changing the construction of the axial injection

The beginning modernization of the U400 axial injection that has been undertaken in 2002 included sharp shortening the injection channel horizontal part. As the result, the distance from the electron cyclotron resonance ion source to the vertical analyzing magnet became equal to 730 mm. These changes allow us to increase the $^{48}\text{Ca}^{+18}$ ion intensity at the U400 output from 0.9 to 1.4 μA .

In the future, we are planning to search possibility increasing the injection voltage from the range of 13 ± 20 kV to 40 ± 50 kV and supersede the focusing solenoids by the quadrupole lenses. These changes can give us possibility of increasing the U400R accelerating efficiency in 1.5 \pm 2 times, it is particularly important for ^{48}Ca ions.

GENERAL LAYOUT OF THE CHANNEL

The scheme of U400R axial injection channel is shown in Fig. 1.

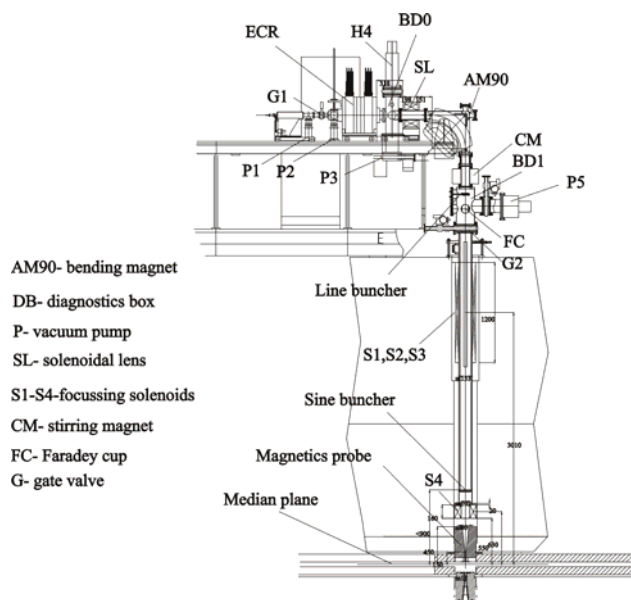


Fig. 1: The U400R axial injection

APERTURE INCREASING

Further modernization intends decreasing ion losses by means of increasing the SL solenoid inner diameter from 68 to 100 mm and the AM90 bending magnet horizontal aperture from 70 to 94 mm. The inner surface of the AM90 vacuum camera that made from stainless steel will be covered by titanium foil in the area of active ion bombarding. These changes allow us to decrease the sputtering yield of the AM90 camera. The effect of AM90 camera sputtering was observed in existing version of axial injection. Today, the estimated mass of stainless steel sputtered by ^{48}Ca ions per year is more than 20 g.

BEAM FOCUSING

In according to calculation results, decreasing the U400 magnetic field demands to install two S1, S2, S3 solenoids in the top part of the channel and one extra S4 solenoid in the bottom part (Fig. 2) to provide ion focusing at the inflector input. The S1, S2, S3 solenoids will have total magnetic field of 0.2 T at the total effective length of 812 mm. The S4 will have the magnetic field up to 0.45 T at the effective length of 134 mm. The distribution of the longitudinal magnetic field in the vertical part of the channel is shown in Fig. 3.

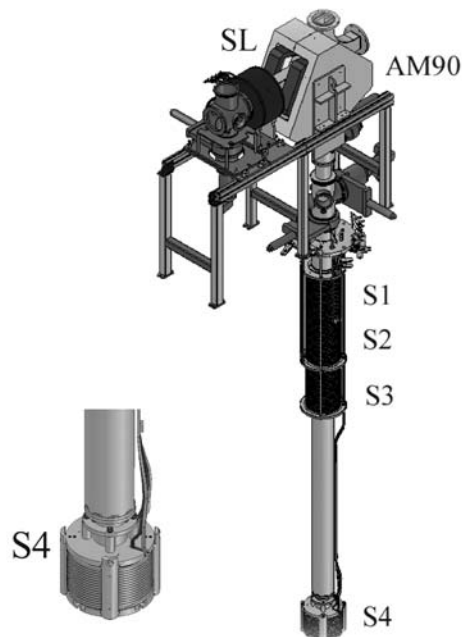


Fig. 2: The design of the U400R axial injection

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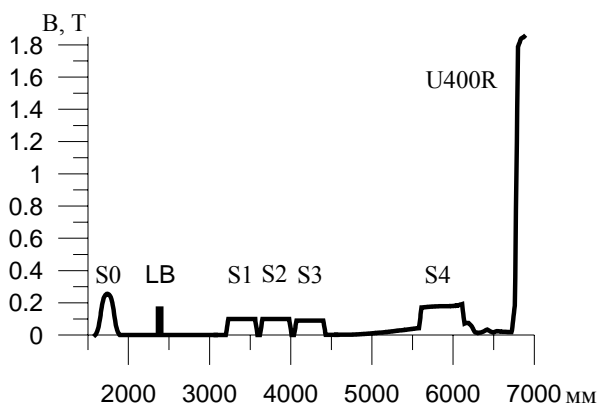


Fig. 3: Longitudinal magnetic field

The ion trajectories calculated with taking into account beam space-charge effects are shown in Fig. 4.

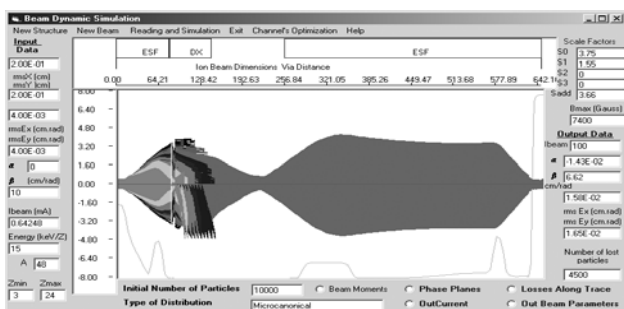


Fig. 4: $^{48}\text{Ca}^{5+}$ ions trajectories in the channel

These changes allow transporting the $^{48}\text{Ca}^{5+}$ ion beam with current up to 100 μA and kinetic energy 75 keV with efficiency to be equal to 100%. The helium beam current in the simulation was equal to 200 μA .

ADVANTAGES OF INJECTION VOLTAGE INCREASING

The possibility increasing the injection voltage from the range of 13÷20 kV to 40÷50 kV have been considered. Such increasing admits to dispose the solenoidal lens SL (Fig. 6) from the channel and therefore to eliminate the nonlinear distortion of the beam emittance caused by self-fields [1]. The quadrupole lenses supersede the focusing solenoids. The scheme of the beam focusing is shown in Fig. 6.

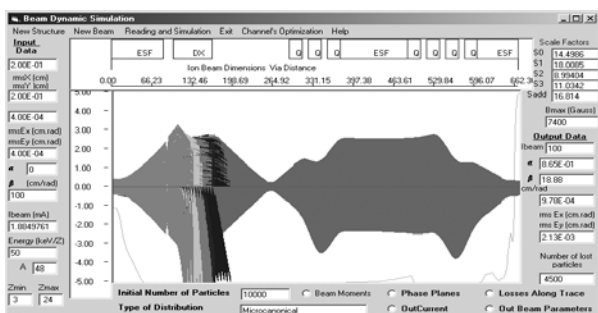


Fig. 5: $^{48}\text{Ca}^{5+}$ ions trajectories in the channel

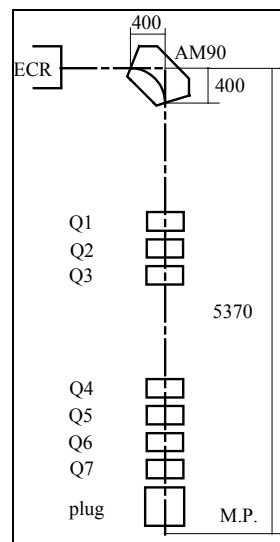


Fig. 6: Scheme of the quadrupole focusing
Q1 ÷ Q7 – quadrupole lenses

The calculated particle trajectories in this channel are shown in Fig. 5.

In the simulation the transportation of the $^{48}\text{Ca}^{5+}$ ion beam with kinetic energy 250 keV was considered. The current of the $^{48}\text{Ca}^{5+}$ beam was equal to 200 μA (calcium beam current – 880 μA). The current of the helium beam (helium is plasma supported gas in the ECR-ion source) was equal to 1mA. The efficiency of transportation was equal to 100% in this simulation.

These changes can give us possibility of increasing the U400R accelerating efficiency in 1.5÷2 times, it is particularly important for ^{48}Ca ions.

REFERENCES

[1] N.Yu. Kazarinov. Non-linear distortion of multi-component heavy ion beam emittance caused by space charge fields. In: Proceedings of the 14th International Conference on Ion Sources, Dubna, Russia, 2003, Review of Scientific Instruments, 75, 1665, (2004).