THE PROJECT OF THE HV AXIAL INJECTION FOR THE DC-280 CYCLOTRON AT THE FLNR JINR

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Abstract

The project of the high-voltage (HV) axial injection for the DC-280 cyclotron which is being created at the FLNR JINR is presented. The injection system will consists of a Permanent Magnet ECR ion source and a Superconducting ECR ion source, beam analyzing magnets, focusing solenoids, beam choppers, a polyharmonic buncher, 75 kV DC accelerating tubes, a commutating electrostatic deflector and a spiral inflector. One part of the injection system is situated on the HV platform, another part is on the grounded yoke of the DC-280 magnet. The injection system will allow one to inject efficiently ions of elements from Helium to Uranium with the atomic mass to charge ratio in the range of 4÷7.5 providing acceleration of ion currents with intensity more than 10 pμA.

INTRODUCTION

At present time the project of Super Heavy Element Factory is being realized at the FLNR JINR [1]. The project implies design and creation of the DC-280 cyclotron (Figure 1) which has to provide intensities of ion beams with middle atomic masses (A~50) up to 10 pμA. The DC-280 will be equipped with high voltage injection system. The injection system has to provide ion transportation from the ECR-ion source to the cyclotron centre and capture into acceleration not less than 50% of ions with the atomic mass to charge ratio of A/Z=4÷7.5. Our experience in modernization of U-400 cyclotron [2] and creation of the DC-110 cyclotron [3] demonstrates that at ion energies of E_{inj}=15÷20 keV/Z (energy per single ion charge) the injection efficiency essentially depends on the ion beam current. At the ion beam currents of 80÷150 eμA the efficiency of capture into acceleration reaches 30÷35%, but for the ion currents less than 10 eμA increasing of the efficiency to 50÷60 % has been observed. The reason of it may be lowering influence of the ion beam space charge and decreasing the beam emittance, especially at low level of the microwave power in the ECR source. To improve the injection efficiency we will increase the injection energy up to E_{inj}=100 keV/Z, since the emittance and the space charge effects have to be decreased. The similar problem has been decided at Ganil, France by means of using the high voltage platform (HVP) equipped with the ECR-4 ion source [4]. Besides, we would like to create the injection with low electrical power consumption. In the last decade some of HVP in the world were equipped with the ECR with low power consumption, for example 300 kV HVP with the superconducting PK-ISIS ECR at “Pantechnik”, (France) [**5**], 320 kV HVP with the permanent magnet ECR at IMP, Lanzhou, China [**6**].

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LAYOUT OF THE AXIAL INJECTION

The high-voltage axial injection of the DC-280 will consist of two HVP. Every HVP will be equipped with an ECR ion source, a focusing solenoid, Einzel lenses and a magnet for ion separation and analyzing. The high voltage accelerating tube will be installed At the edge of the HVP to increase the ion energy up to 100 keV/Z. Both HVP will be placed on standoff insulators above the DC-280 magnet. The insulators will be fastened to the grounded metal platform which leans on the DC-280 magnet yoke (Figure 1).

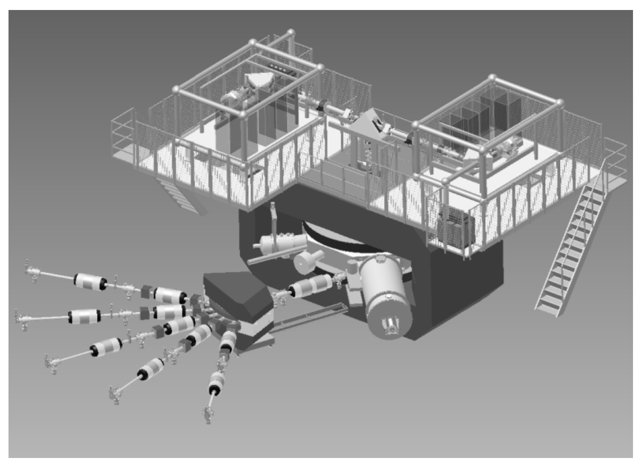

Figure 1: Layout of the DC-280 assembling.

HIGH VOLTAGE PLATFORM

We plan to limit the HVP power consumption to 50 kW to minimize maintenance charges and sizes of isolating transformers. The maximal HV on the HVP will be 75 kV. Every platform will have peripheral tube railings for equalization of the electrical potentials. Water cooling of the magnetic elements will be provided through water tube coils (head, drain) having the maximal total current leakage of 1 mA. When the HV is switched off the service personal can walk around the HVP for maintenance. The scheme allows us to work with every ECR source independently.

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ECR ION SOURCES

To satisfy the HVP power consumption requirements, the electrical power of every ECR ion source has to be less than 10 kW. At that, the first ECR ion source has to produce high intensities (15÷20 pμA) of ions with medium masses (for example, $^{48}Ca^{7+,8+}$), the second one has to produce the high charged heavy ions, such as $^{238}U^{39+,40+}$. Therefore we will create two types of ECR ion sources: the DECRIS-PM source with permanent magnets [7] and the DECRIS-SC superconducting one [8].

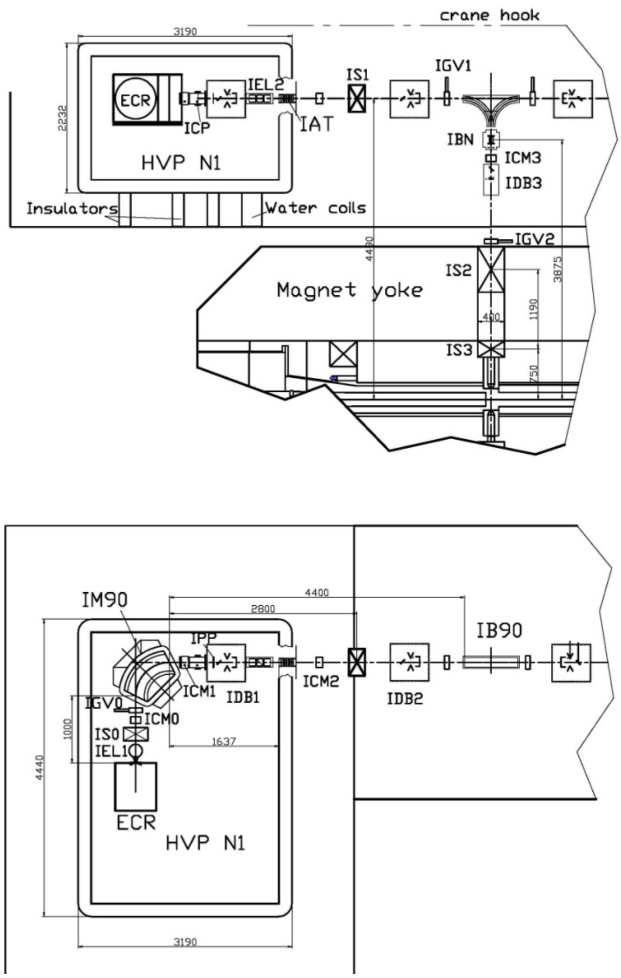

Figure 2: The scheme of the axial injection channel, front view and view from above.

Where: ECR- DECRIS-PM or DECRIS-SC are the ion sources; IM90 is the analysing magnet; IB90 is the bender; IEL1, IEL2 are the Einzel lenses; IS0,IS1,IS2,IS3 are the focusing solenoids; IAT is the accelerating tube; ICM0÷ICM3 are the steering magnets; IPP is the pepper-pot; ICP is the beam chopper; IDB1÷IDB3 are the diagnostic boxes; IBN is the polyharmonic buncher; IGV0, IGV1, IGV2 are the vacuum gate valves.

BEAM TRANSPORT AND FOCUSING

The scheme of the axial injection channel is shown in Figure **2** (only the HVP N1). The ion beam will be extracted from ECR with the energy of 25 keV/Z. After extraction the ion beam will be focused by the IEL1 Einzel lens and by the IS0 solenoid to the IM90 analysing magnet input. The ion charge spectrum will be analyzed by means of magnetic field variation in the IM90 and by the IS0 with measuring the ion current by Faraday cup (FC) in the IDB1 diagnostic box. After analyzing and separation the ion beam will be focused by IEL2 Einzel lens at the input of the IAT acceleration tube (NEC 2JA000260). The ion energy can reach 100 keV/Z after acceleration. Increasing the ion energy allows us to decrease of the ion beam emittance and space charge influence [**9**]. After the IAT the ion beam is matched with the acceptance of the IB90 electrostatic deflector (bender) with help of the IS1 solenoid. The IB90 bends the ion beam in the vertical direction to the cyclotron center. After the IB90, the ion beam longitudinal density will be modulated by the IBN polyharmonic buncher. Two solenoids (IS2, IS3) will match the ion beam emittance with the acceptance of the spiral inflector, which will turn the beam to the cyclotron median plane.

In our numerical calculations we supposed that compensation of the full space charge (by slow electrons accumulated in a beam) is absent in the channel parts with electrostatic elements, such as: the Einzel lenses, the IB90, the IAT, and also after the IBN. The calculation was carried out for $^{48}Ca^{8+}$ ion beam with the injection energy of 80 keV/Z (Fig. 3). The results show that this acceleration allows us to decrease the ion beam emittance in about 1.5 times. (Fig. 4) The calculated efficiency of the ion transport from the ECR to the DC-280 median plane is equal to 100%.

Of cause, the real transport efficiency will depend on many reasons: real value of the space charge compensation in the low energy part (it can be less than 60% so far as it depends on the beam parameters and vacuum conditions [10]), quality of the IM90, the IB90 and the inflector. To improve quality of the elements the special calculations have been carried out, including 3-D calculation [11], [12].

POLYHARMONIC BUNCHER

To increase the accelerating efficiency the polyharmonic buncher IBN will be installed in the vertical part of the channel at the distance of 388 cm from the cyclotron median plane. A prototype of the buncher could be the multiple cavity buncher [13]. The buncher consists of drift tube having the diameter of 5 cm at the length of $\beta\lambda/2$=7.8 cm and harmonic grids. The RF voltage is applied to the tube with the frequency equal to the cyclotron accelerating one (first harmonic, f=7.32÷10.38 MHz). Two thin tungsten grids are installed at the edges of the drift tube. Harmonic grids (for the second and the third harmonics) are situated before and after the drift tube. Two grounded grids are installed in the gaps to exclude interference between the tube and the harmonic grids,. All the grids have spacing of 0.8 cm. The numerical simulation has shown that longitudinal beam density will be increased in 8÷10 times.

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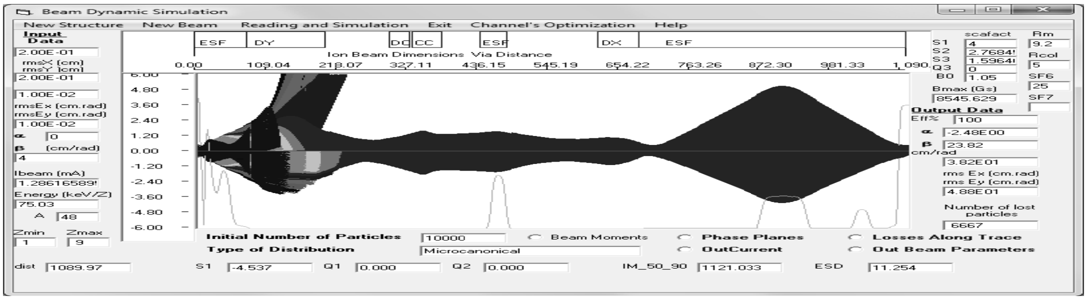

Figure 3: $^{48}Ca^{8+}$ ion trajectories along the injection line.

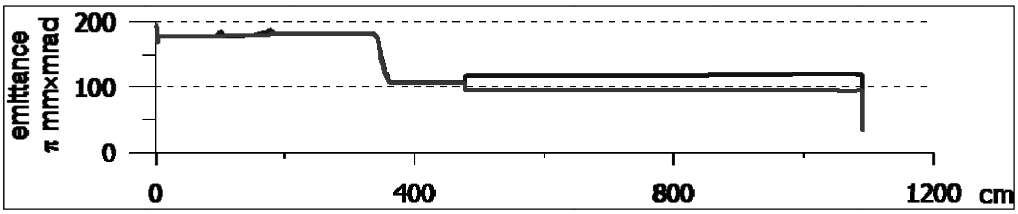

Figure 4: Behaviour of the emittance of $^{48}Ca^{8+}$ ion beam along the injection line. The ion beam emittance has been decreased in about 1.5 times after acceleration to 80 keV/Z. The IAT was situated at 370 cm from the ECR.

DIAGNOSTIC SYSTEM

The beam diagnostics placed in the special boxes IDB1÷IDB3 will consist of the FC, slit collimators and luminophors with TV cameras for beam intensity and profile monitoring. Decreasing the beam intensity in about 10 times can be made by means of the beam modulation by the ICP beam chopper, or using the IPP pepper-pot. It is necessary to measure parameters of high intensity beam in the DC-280 extraction channels.

VACUUM SYSTEM

The system is zoned on HVP and GP parts. Four turbopumps (total pumping speed of G_Σ=2720 l/s) will be installed at HVP and four turbopumps (G_Σ=1880 l/s) will be installed at GP. The expected average vacuum will be about (4÷6)·10^{-8} mbar to provide the ion losses of 2÷4% for $^{48}Ca^{7+,12+}$ and of 10÷15% for $^{238}U^{40+}$.

CONCLUSION

The project of the HV axial injection for the DC-280 cyclotron has been created at the FLNR JINR. The injection has to provide the DC-280 with the ion beam intensities more than 10 pμA for A/Z=4÷7.5.

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