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The ion beam extraction system upgrade of the GTS ECR ion source at GANIL

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Abstract. The GTS ion source, operated at 14.5 GHz, provides multiply charge heavy ion beams for the ARIBE facility at GANIL. The facility variety is limited by the efficiency of the extraction especially in the few keV domain. In order to improve the ion source, the extraction system was upgraded numerically. The shape of the plasma and the puller electrodes was changed. It causes the increase of the electric field near the plasma meniscus and allows to increase the maximum available ion beam current while decreasing the optimal extraction voltage.

The new extractor was designed and compared with the existing one using IBSimu. The required beam parameters were taken from the experimental data. The possibility of the increase in the extracted beam current was investigated. Also, the opportunity of effective low energy beam formation (at a few kV or sub-kV extraction voltage) was studied. The high current and low energy ion beam production will provide new possibilities for ARIBE facility users.

Extraction system upgrade task

There are two cases:

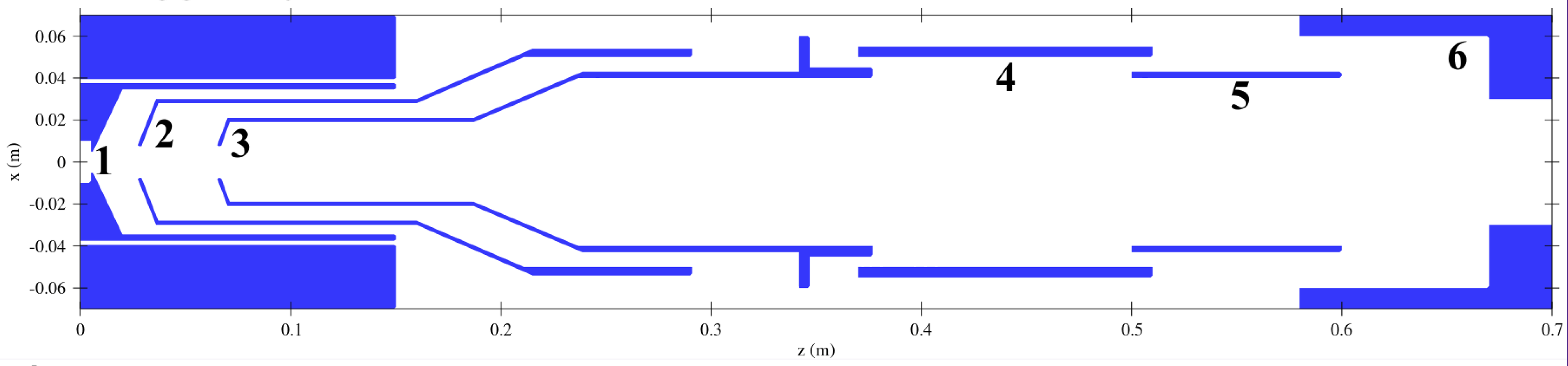
1) **solar wind ions**
   Requirements: The beam with typical velocity of 400 km/s. Ion species: H^+, He^{2+}, C^{5+}, O^{6+}, Fe^{10+}.
   Applications: Simulating the interaction of solar wind ions with astrophysical samples.
2) **slow highly charged ions**
   Requirements: The beam kinetic energy must be smaller than ionization potential. Very low extraction voltage (about 300V) is needed.
   Applications: Nanopatterning of surface and the fundamental study of collision regime where ionization potential is higher than kinetic energy.

The new extraction system has to create a low energy beam with high transmission through the extractor.

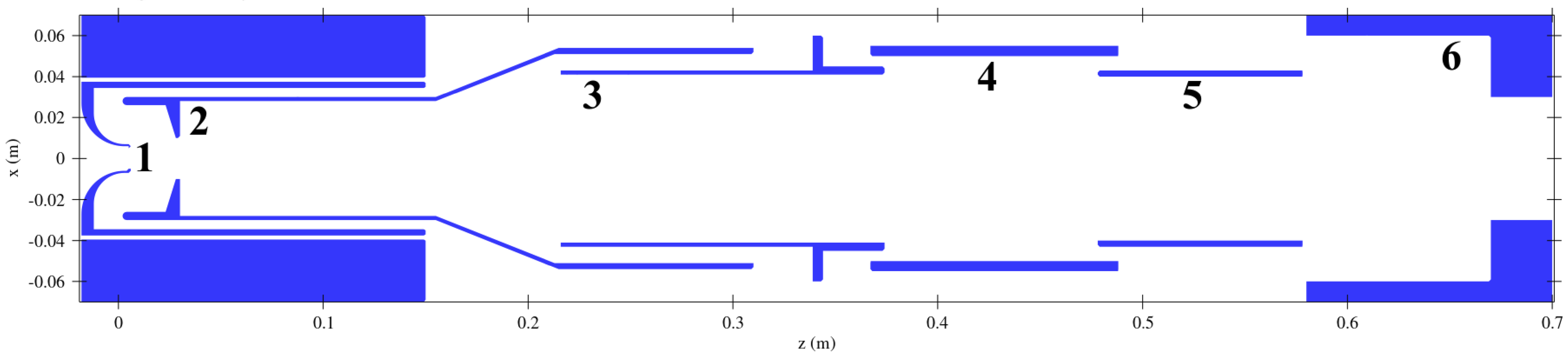
Ion beam calculations are made using IBSimu code: http://ibsimu.sourceforge.net/.

Extraction system geometry

The existing geometry:

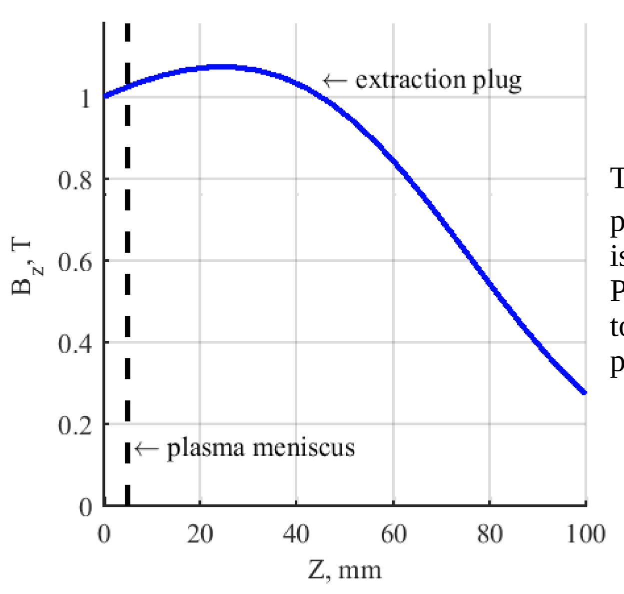


The new geometry:



Legend: **1** – plasma electrode; **2** – puller; **3**, **5**, **6** – grounded electrodes; **4** – focusing einzel lens electrode.

Magnetic field profile

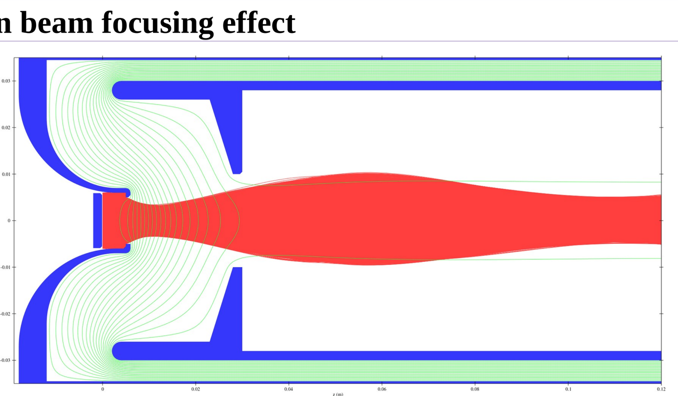


The magnetic field (B_z) profile at Z-axis (X=Y=0) is shown on the figure. Point Z=5mm corresponds to the plasma aperture position.

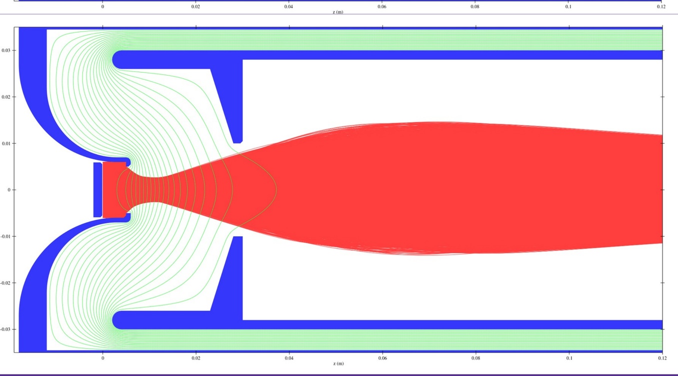
This magnetic field profile is created by the magnetic trap. The extraction plug serves as a magnetic lens. It leads to better ion beam formation at low energies. An ion species filtering also exists.

Ion beam focusing effect

He^{2+} beam, V_{extr} = 3kV:



He^{2+} beam, V_{extr} = 7kV:

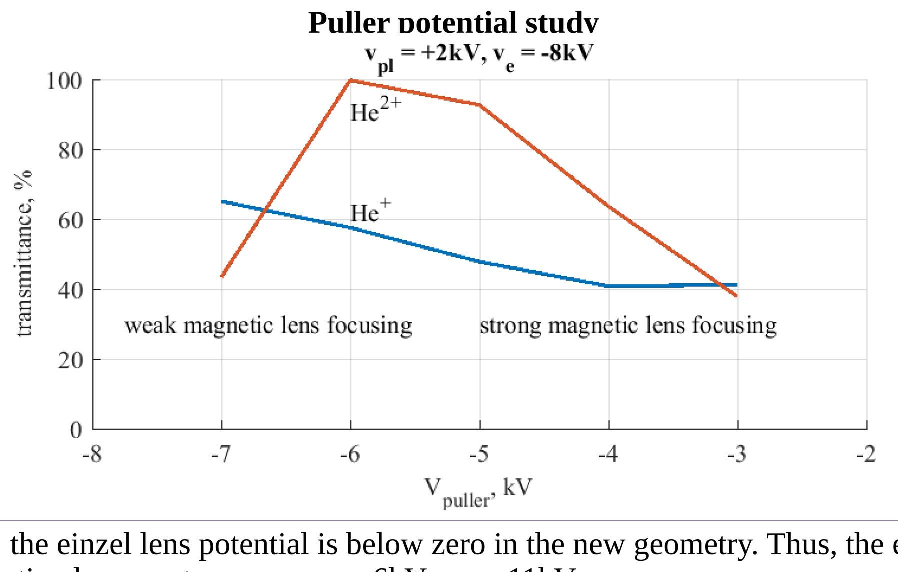


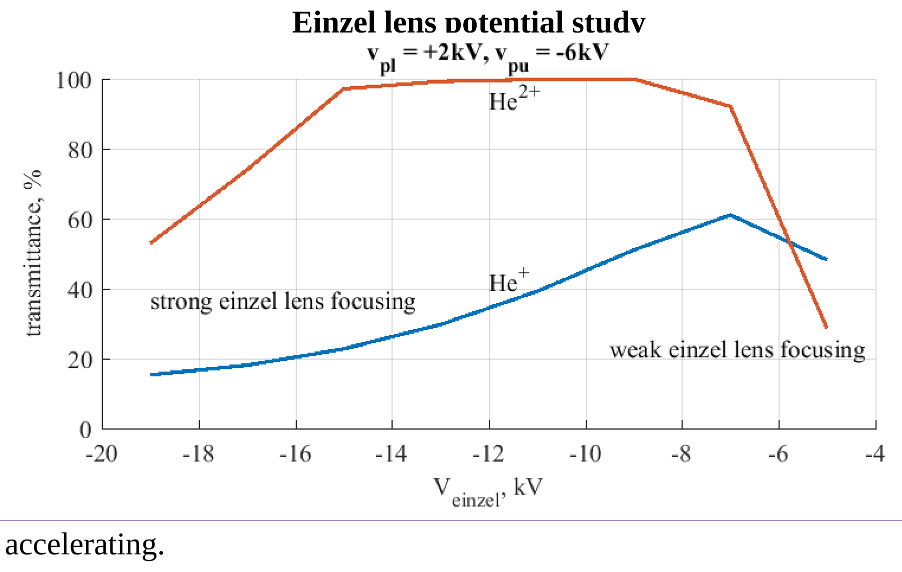
The new extraction system study

Case: He^{2+} beam, output energy: 2 qkeV.

Plasma electrode potential: $\mathbf{v_{pl}}$ = +2kV. Puller potential ($\mathbf{v_{pu}}$) and einzel potential ($\mathbf{v_e}$) are varied. There is no space charge compensation.

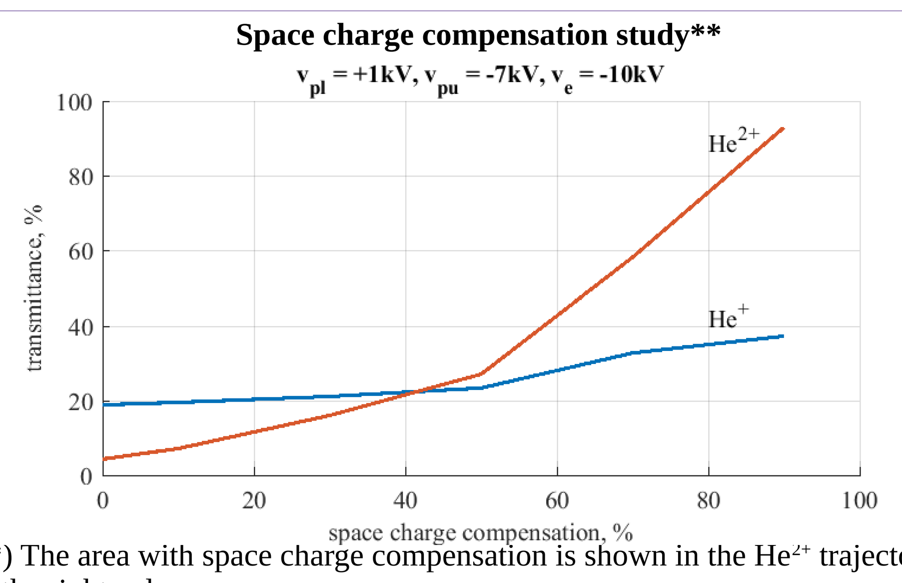
The extraction system **transmittance** ($T = I_{output} / I_{input}$) is the key parameter in this study.

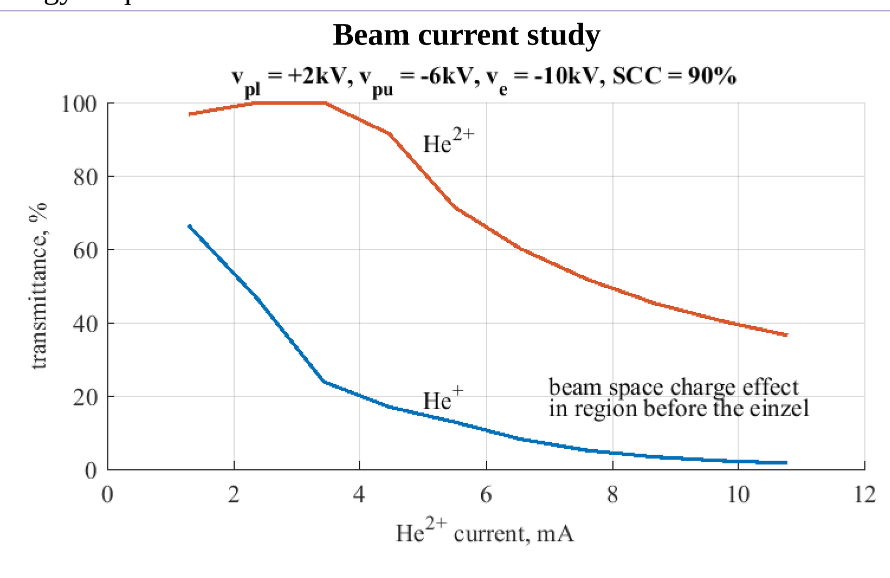




Note: the einzel lens potential is below zero in the new geometry. Thus, the einzel lens is accelerating.
The optimal parameters are: $\mathbf{v_{pu}}$ = -6kV, $\mathbf{v_e}$ = -11kV.

Case: He^{2+} beam, output energy: 1 qkeV.



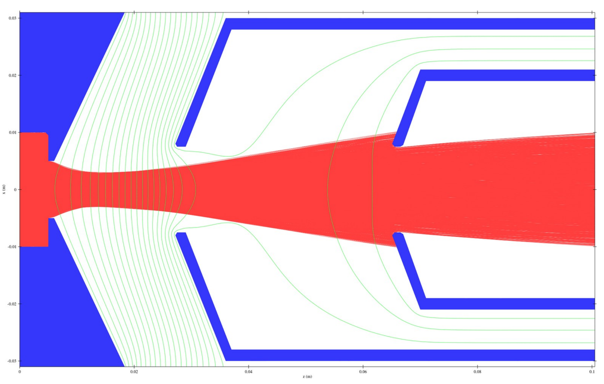


**) The area with space charge compensation is shown in the He^{2+} trajectory plot at the right column.

Comparison of the extractors

Case: Helium beam

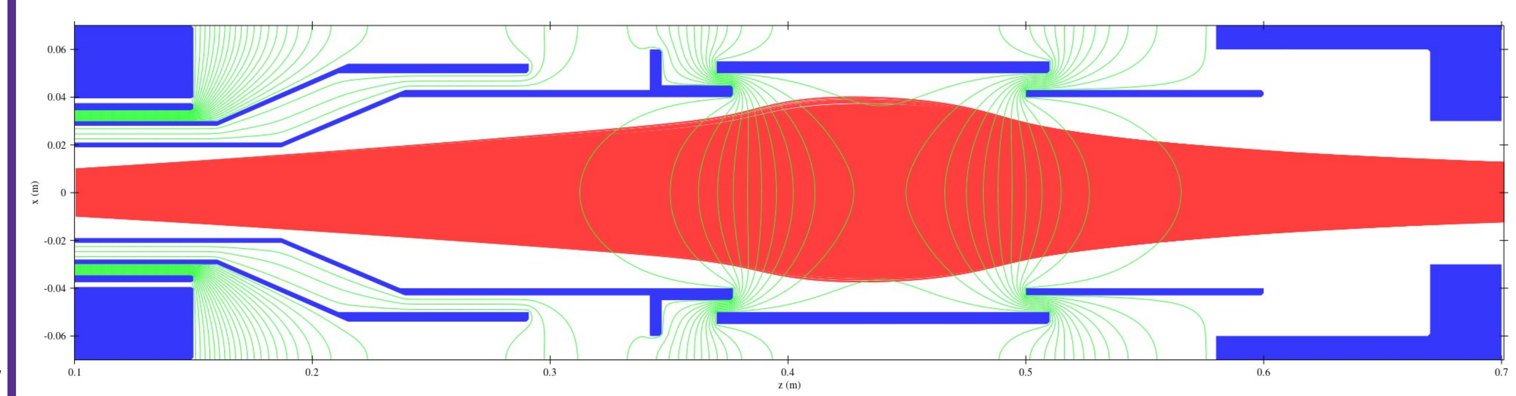
The existing extractor parameters: ($\mathbf{v_{pl}}$ = +15kV, $\mathbf{v_{pu}}$ = -3kV, $\mathbf{v_e}$ = +10.5kV, **SCC** = 0%).



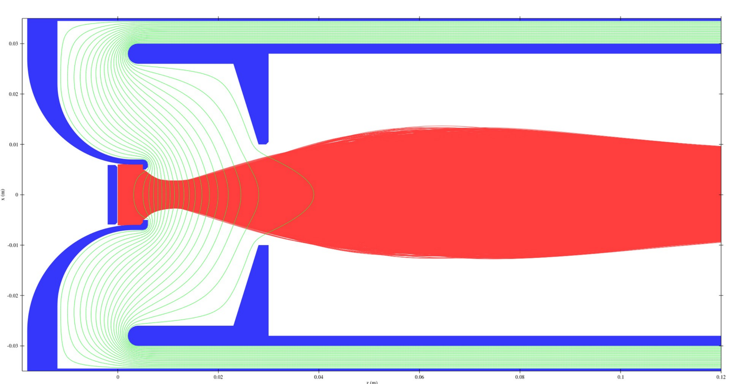
The top figure: He^{2+} beam trajectories near the extractor.

The bottom figure: He^{2+} beam propagation through the einzel lens.

Note: for the existing geometry there are the beam losses inside the extractor. The beam hits the electrode #3.



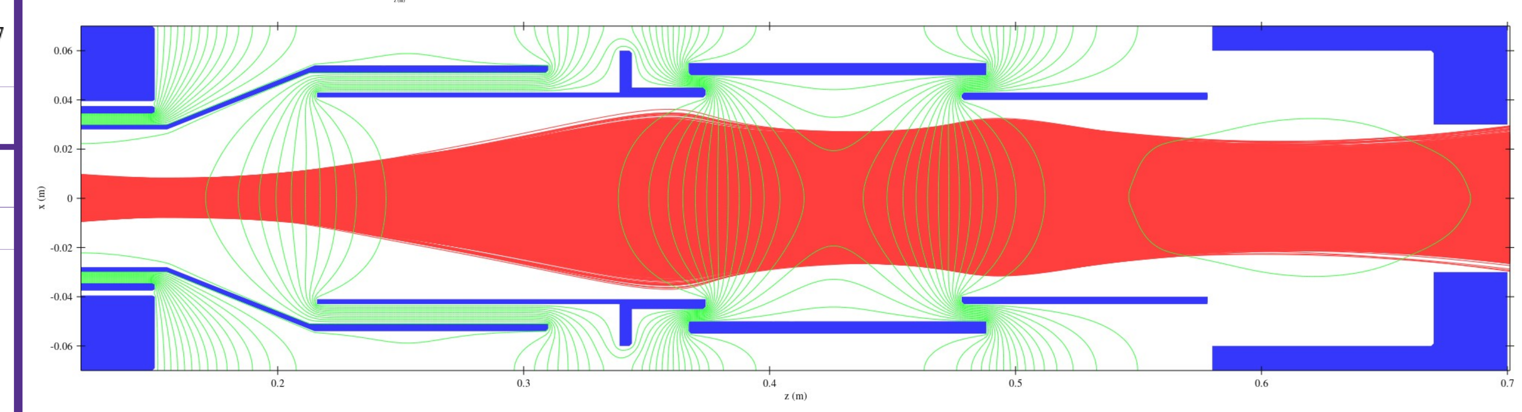
The new extractor parameters: ($\mathbf{v_{pl}}$ = +2kV, $\mathbf{v_{pu}}$ = -6kV, $\mathbf{v_e}$ = -11kV, **SCC** = 0%).



The top figure: He^{2+} beam trajectories near the extractor.

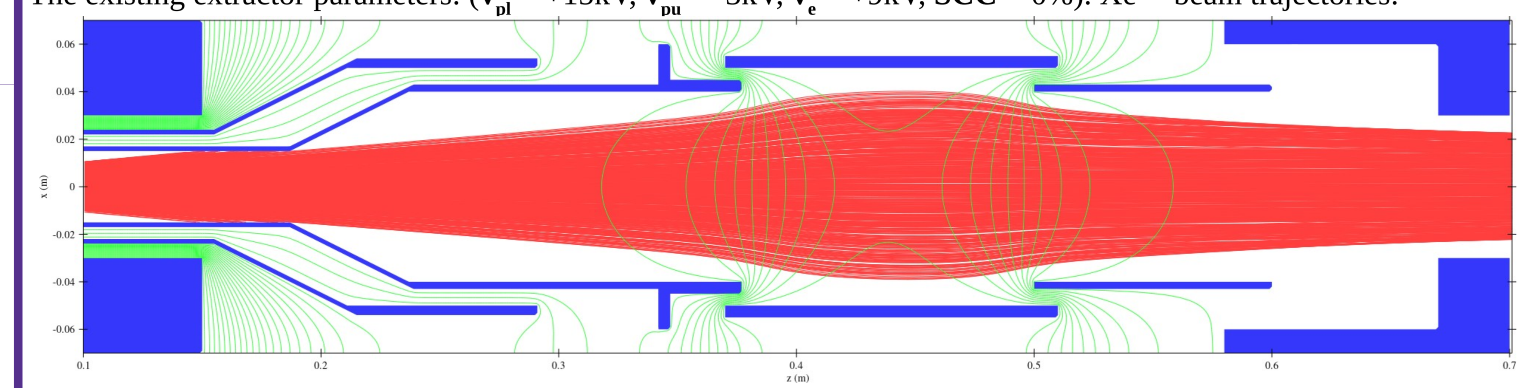
The bottom figure: He^{2+} beam propagation through the einzel lens.

Note: there are no He^{2+} beam losses in the extractor.

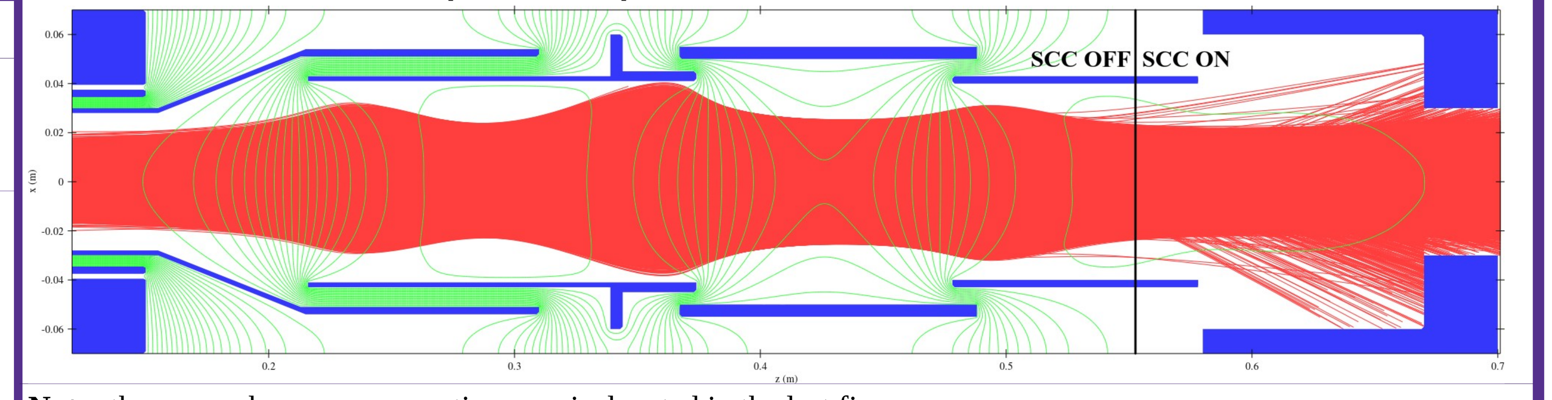


Case: Xenon beam

The existing extractor parameters: ($\mathbf{v_{pl}}$ = +15kV, $\mathbf{v_{pu}}$ = -3kV, $\mathbf{v_e}$ = +9kV, **SCC** = 0%). Xe^{32+} beam trajectories:



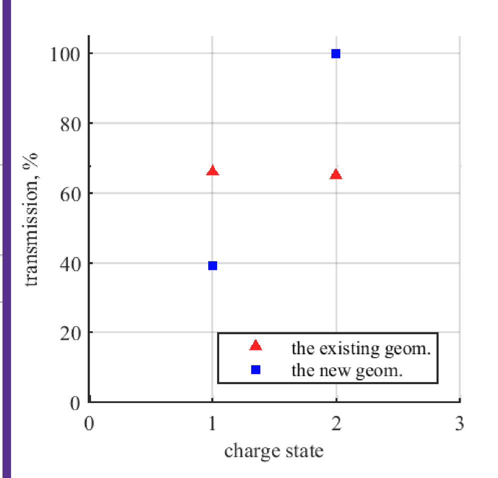
The new extractor parameters: ($\mathbf{v_{pl}}$ = +0.5kV, $\mathbf{v_{pu}}$ = -6kV, $\mathbf{v_e}$ = -4kV, **SCC** = 90% **(!)**). Xe^{32+} beam trajectories:



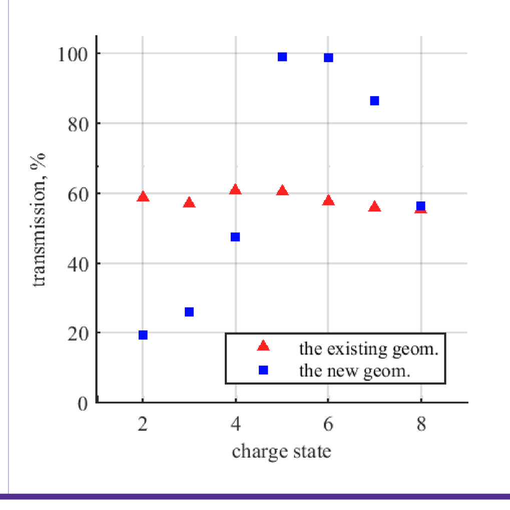
Note: the space charge compensation area is denoted in the last figure.

Comparison of the extractor's transmission

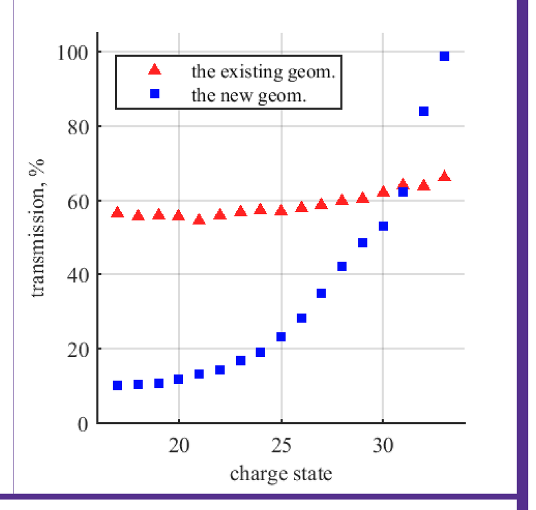
Helium case



Oxygen case



Xenon case



Conclusion

The new extraction system allows an effective low energy ion beam formation. The 100% ion beam transmission through the extractor is achieved for a certain charge state.
There is also an ion beam filtering which is implemented using magnetic lens (the extraction plug of the magnetic trap).
High space charge compensation is a vitally necessity for a sub-qkeV ion beams.

The further step is an experimental verification of these results.

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