Conceptual Design of A Next-Generation Cryogenic Stopping Cell for the Low-Energy Branch of the Super-FRS*

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The conceptual design of a next-generation cryogenic stopping cell (CSC) for the Low-Energy Branch (LEB) [1] of the Super-FRS has been developed. It builds on advanced stopping cell techniques implemented in the first version of the cryogenic stopping cell for the LEB [2, 3], which has recently been commissioned as part of the FRS Ion Catcher [4]. These include in particular (i) a cryogenic operation to ensure a high purity of the stopping gas and (ii) high density operation enabled using an RF carpet with a small electrode structure size.

The new CSC is shown schematically in Fig. 1. It consists of two main vacuum chambers, an outer chamber that provides the insulation vacuum for the inner chamber, which is held at cryogenic temperature ($\sim$ 70 K). The inner chamber is divided into a high-density stopping region and a low-density extraction region and is pumped differentially. The ion beam enters the stopping region horizontally through two windows and is stopped in the buffer gas. Using electric DC fields the ions are transported in the vertical direction to a wall of RF carpets, which focuses the ions onto the intermediate extractions nozzels. There the ions are swept into the low-pressure extraction region by the gas flow, where they are transported to the main exit nozzle from the stopping cell.

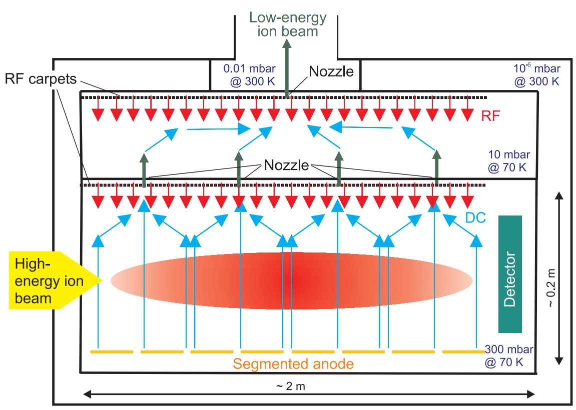

Figure 1: Schematic figure of the next-generation cryogneic stopping cell for the LEB of the Super-FRS.

Compared to conventional stopping cells, the new design features several important advantages: (i) Due to the vertical extraction the extraction path is shortened considerably. (ii) Higher DC field strengths can be applied in the direction of extraction, extending the rate capability of the CSC. (iii) Compared to stopping cells with an RF body the ratio of RF carpet area to stopping volume is reduced significantly, thus minimizing power disspipation, which is crucial for cryo-operation. (iv) The design scales favorably with an increased length of the stopping volume; the length can be increased without increasing extraction times or decreasing ion extraction efficiencies or rate capability. (v) A segmented anode opposite to the RF carpet wall collects the electrons created during the stopping; the electron current indicates the stopping distribution of the ions. (vi) A detector can be mounted on the inner side of the CSC opposite to the entrance windows. Alternatively, two windows can be implemented, through which ions with a longer range leave the cell. These ions can be identified in a detector positioned behind the CSC. (vii) The ion beam does not hit the RF carpet and desorption of atoms and molecules from the RF carpet is avoided. (viii) The dual-density design enables very efficient pumping of the CSC.

In the stopping region, a dual-layer RF carpet with rectangular geometry and electrode lines that overlapp at right angles is used. It has a structure size with up to 6 electrodes / mm. A maximum helium buffer gas pressure of 300 mbar at 70 K will be achieved. The stopping volume has a width of 25 cm, a height of 10 cm and a length of 2 m. The corresponding maximum areal density amounts to 40 mg/cm^2, an increase by a factor of 8 from the areal density of the present CSC. The extraction region is kept at a pressure of 10 mbar at 70 K. Due to the lower pressure, an RF carpet with a larger structure size can be used in this region and fast ion transport is achieved.

In combination with the momentum compression provided by the energy buncher of the Super-FRS [1], stopping efficiencies close to unity are expected for all but light nuclei. Ion survival and extraction effciencies of better than 50% are expected. The extraction time of the ions will be about 5 ms, shorted by a factor of 5 compared to the present CSC. The novel CSC will thus remove the performance bottleneck of present stopping cells and give access to very exotic and short-lived nuclei available at the Super-FRS.

References

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