Performance of the Prototype Cryogenic Stopping Cell for the Low-Energy Branch of the Super-FRS*

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At the Low-Energy Branch [1] of the Super-FRS at FAIR, projectile and fission fragments will be produced at relativistic energies, separated in-flight, range-bunched, and then slowed down and thermalized in a cryogenic stopping cell (CSC) [2] filled with helium gas, extracted and delivered to precision experiments at MATS and LaSpec.
The key goal is to operate the stopping cell at high stopping and extraction efficiencies, requiring a high density and an ultra pure stopping gas. To get access to rare and short-lived exotic nuclei, short extraction times (< 50 ms) are needed. To achieve these goals the prototype of the LEB stopping cell has been designed as a cryogenic stopping cell, using DC and RF electric fields for the extraction of the ions. The CSC is filled with He at 50 to 100 mbar and 70 to 100 K, resulting in an areal density of up to 5 mg/cm^2. The cryogenic operation increases the buffer gas density for the same pressures and drastically enhances the cleanliness of the stopping gas, via the freeze out of contaminants.
The CSC has been commissioned online as part of the FRS Ion Catcher [3] using heavy Uranium fragments produced at 1000 MeV/u during two experiments. The spatial isotopic separation in flight and the momentum compression were performed by the FRS. A total efficiency of up to $15\,\%$ and a combined ion survival and extraction efficiency of about $50\,\%$ have been achieved [4]. ^{223}Th, ^{221}Ac, ^{220}Fr, ^{213}Fr, ^{211}Fr, ^{219}Rn, ^{218}Rn, ^{213}Rn, ^{211}Rn, ^{211}Po, ^{210}Pb and ^{207}Tl ions have been successfully thermalized, extracted and identified at the FRS Ion Catcher using different detection methods (Si-detector, MR-TOF-MS). No element dependent ion survival and extraction efficiencies have been seen, showing the universality of the CSC. Using an electric field of 22.2 V/cm along the body of the CSC, a mean extraction time of 24 ms for ^{221}Ac ions has been measured, agreeing well with simulations and theory.
Figure 1 shows a broadband spectrum of the ions extracted from the CSC taken by a multiple reflection time-of-flight mass spectrometer (MR-TOF-MS) [5] connected to the CSC. All prominent ions measured result from a ^{218}Rn beam or the ^{223}Ra source installed inside the CSC. The ions are extracted without addition of adducts, demonstrating the excellent cleanliness of the CSC.

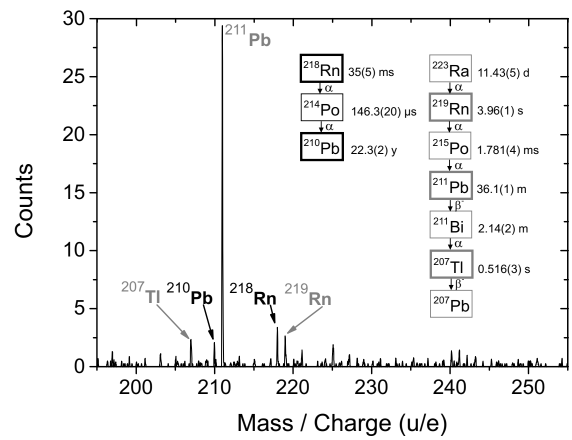

Figure 1: Broadband mass spectrum of a ^{218}Rn beam and a ^{223}Ra source extracted from the CSC. No major contaminants or adducts are formed in the CSC.

For further investigation of the behavior of the CSC, two new ion sources have been implemented. First, a movable ^{223}Ra source, which allows studies of the focussing DC electric fields and the behavior of the RF carpet. Second, a laser ion source with a movable target wheel, allowing the production of reference and calibration ions of different elements and therefore measurments of mass dependencies. Using short laser pulses (~ 10 ns) for the production of the reference ions, the extraction time of the CSC can be measured and monitored during operation.
The intensity limitations of the CSC will be investigated in an upcomming experiment at GSI, and the final version of the LEB stopping cell will be designed.

References

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