Production and characterization of highly charged alkali ions from the TITAN Electron Beam Ion Trap

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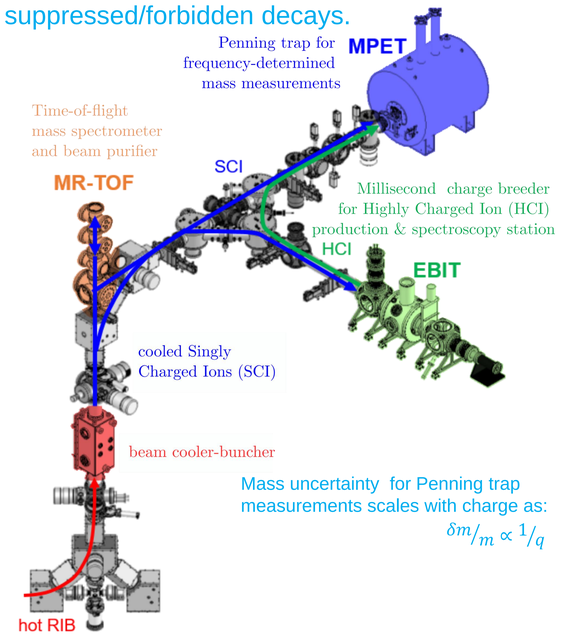
Motivation

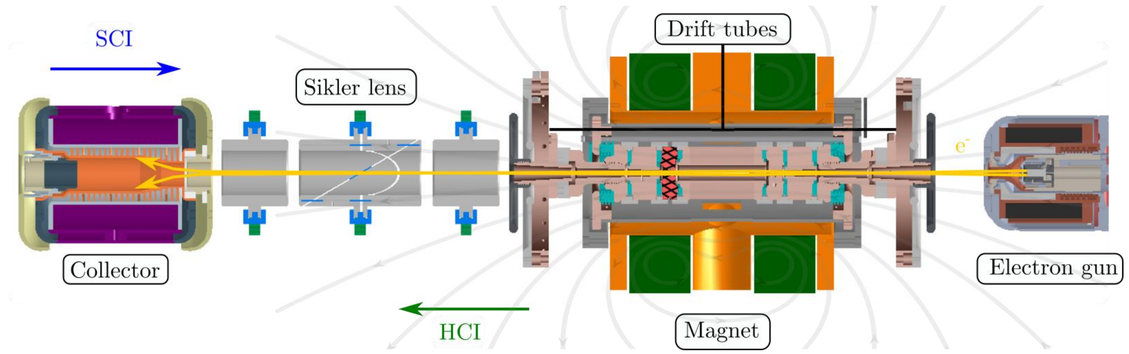
Highly Charged Ions (HCIs) enable increased precision for ion-trap-based mass measurements of **short-lived radioactive ions**. The TRIUMF's Ion Trap for Atomic and Nuclear science (**TITAN**) facility receives radioactive, singly charged ions (**SCIs**) from the ISAC facility before charge breeding them to HCIs. Specifically, the TITAN Electron Beam Ion Trap (**EBIT**) generates the higher charge states that are sent to the Measurement PEnning Trap (**MPET**) to measure the mass of the ion of interest. Recently re-established operations of the EBIT enabled in-depth characterization of the electron beam and the charge breeding dynamics, paving the way for high precision mass measurements and suppressed/forbidden decays.



Mass uncertainty for Penning trap measurements scales with charge as: $\delta m/m \propto 1/q$

TITAN focuses on high-precision, high-accuracy mass spectrometry as well as atomic and nuclear spectroscopy with ion traps.

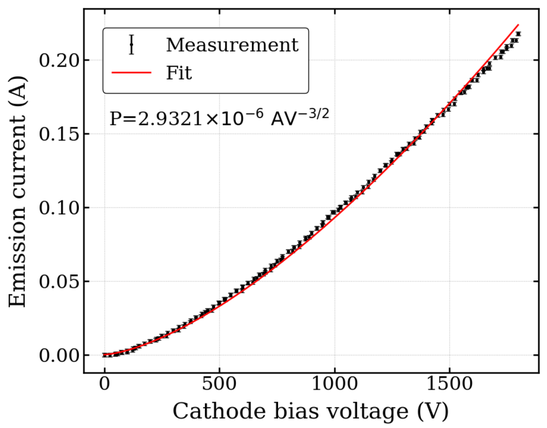
EBIT



The EBIT consists of an electron gun, a set of electrostatics drift tubes, a semi-Helmholtz coil, and an electron collector. HCIs are created by successive electron impact ionization from the SCI injected into the drift tube region (red, cross-hatch). EBIT design for 5A, 60 kV, and 6T.

Electron gun characterization

The perveance of the cathode has been measured by varying the accelerator voltage of the gun while maintaining the anode and focus electrode at 0 V. The EBIT has been capable of reaching **500 mA at 7.1 keV** energy and is in preparation for beamtime in the early fall. The results here, however, are those taken electron currents <140 mA at 3.5 keV.

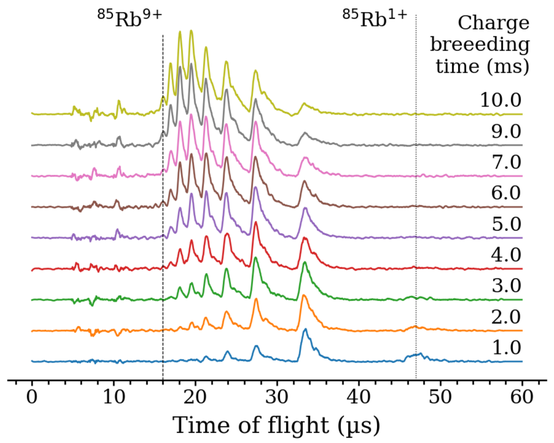


The TITAN EBIT perveance is about 2.9e-6 A V^(-3/2) or 2.9 µPerv. Above 1500 V there is a small deviation from the space-charge limited emission indicating an underheated cathode.

Charge breeding at fixed current

$^{85}Rb^{1+}$ was charge bred with a 100 mA electron beam at different breeding times and the charge distribution shifts to higher charge states with a longer breeding time.

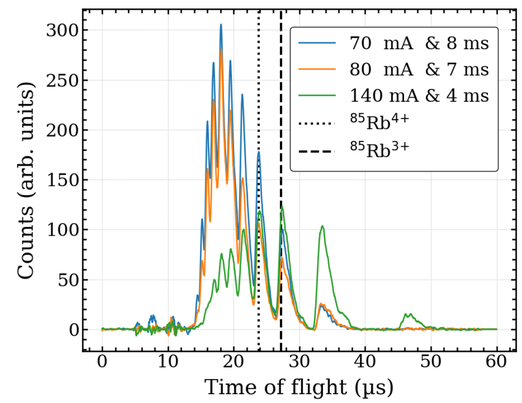
During the measurements, transport losses were noted on a 45º bender, and future measurements will take place on a straight trajectory.



HCI spectrum for the same electron current (100 mA). By increasing the breeding time, higher charge states are populated. In this case, $^{85}Rb^{9+}$ is achieved as of 5 ms.

Charge breeding at varying currents and time

The product *Jt* dictates the charge distribution, and similar values should provide similar results. Here, a comparison is made with *It*: the electron current and breeding time. The result found is that higher currents did not compensate for shorter breeding times. This could be due to transport losses, bad overlapping of ions and electrons, or different electron beam radii affecting the true *Jt* comparison. Spectroscopical investigations are ongoing to determine the electron beam radius.



HCI spectrum for the same It (560 mA ms). Only some peaks overlap for lower charge states (3+ & 4+).

- ✓ $^{85}Rb^{1+}$ successfully charged bred at different electron currents and breeding times.
- ✓ Characterization ongoing for the newly record established of 500 mA at 7.1 keV.
- Several upgrades of and at the EBIT ongoing :
  - ❑ A new electron gun (Cardona, ICIS 2022) is being manufactured for installation 2024.
  - ❑ A 7-detector germanium detector array has been recently installed to probe highly suppressed/forbidden nuclear decays.
  - ❑ An Extreme UltraViolet spectrometer will permit absolute nuclear charge radii determinations for BSM investigations.