The TITAN EBIT

First Charge Breeding of Radioactive Isotopes

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TRIUMF

TITAN ISAC-TRIUMF

Mass measurements & why use HCI's?

- The mass of a nucleus is a fundamental property, which reveals information on the binding energy of its constituents, and combined all acting forces.
- A mass, *m*, is measured with Penning trap mass spectrometers from the cyclotron frequency of trapped ions (*q*: ion charge, *B*: magnetic field strength):

$$\nu_c = \frac{1}{2\pi}\frac{q}{m}B$$

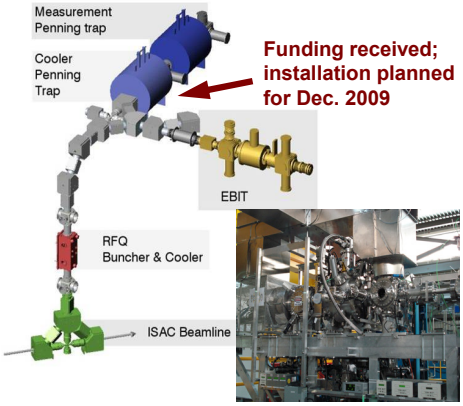
- The precision is proportional to the ion charge state:

$$\frac{m}{\Delta m} \propto \frac{T_{RF}\, qB\sqrt{N}}{m}$$

- For a fixed observation time T_{RF}, and number of detected ions *N*, **highly charged ions (HCI's) "boost" the precision of mass measurements.**

TITAN: High-precision mass measurements

The **TITAN** (**T**RIUMF's **I**on **T**rap for **A**tomic and **N**uclear science) facility consists of 3 *(later 4)* ion traps: a radio-frequency quadrupole (**RFQ**) cooler, an Electron Beam Ion Trap (**EBIT**) and a **Penning trap**.



Funding received; installation planned for Dec. 2009

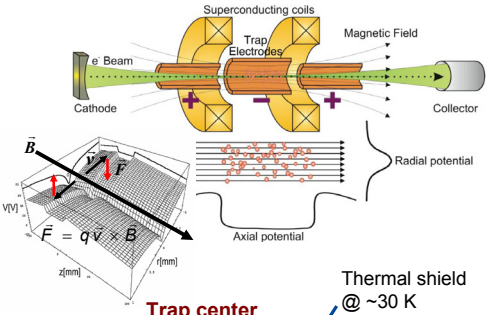
Mass measurements at TITAN with the time-of-flight ion cyclotron resonance method (**TOF-ICR**) can reach a precision of $\Delta m/m < 10^{-8}$, $T_{1/2} \sim 10$ ms, for short-lived radioactive isotopes **(see Li-11 & He-8 Ref's.)**.

TITAN EBIT

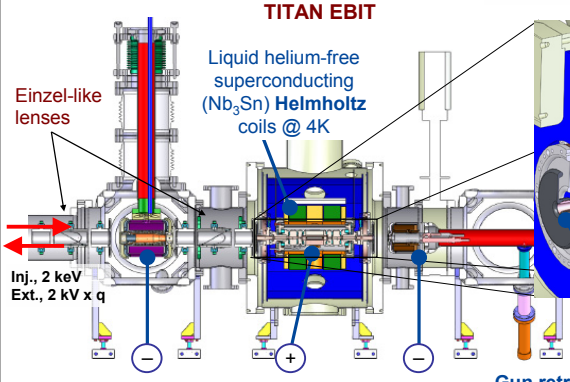
The TITAN EBIT is a charge state breeder to boost the precision of mass measurements.

- An EBIT produces and traps HCI's with an electron beam compressed to high densities by a strong magnetic field generated by Helmholtz coils.
- HCI's are trapped axially by electrostatic potentials applied to drift tubes and radially by the electron beam space charge potential and magnetic field.
- The advantage of an EBIT over other charge breeders is the possibility of reaching well-defined high charge states and rapid breeding needed for short-lived isotopes.

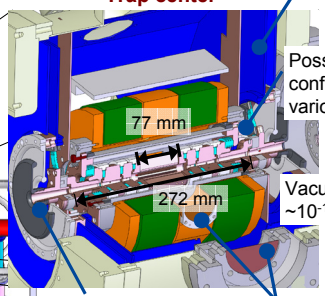
Working principle of an EBIT



TITAN EBIT



Trap center



Thermal shield @ ~30 K

Possibility of trap configurations of various lengths

Vacuum pressure ~10^{-11} Torr

Be windows for X-ray spectroscopy with HPGe detectors

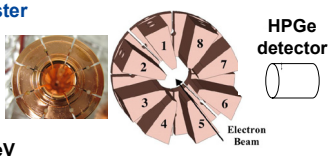
Gun retractable for detector assemblies; T. Brunner's poster

Design values		Demonstrated values
Present max. e-beam energy	~70 keV	~25 keV @ ~200 mA
Present max. e-beam current	500 mA	~400 mA @ ~7 keV
Planned cathode upgrades	1 & 5 A	
Max. magnetic flux density	6 T	
Theoretical beam radius	~40 μm	
Electron beam current density	10^4 - 10^5 A/cm²	

Theoretical breeding times @ 400 mA, 25 keV

He-like Ar^{16+}	~2 ms
Bare Ar^{18+}	~30 ms

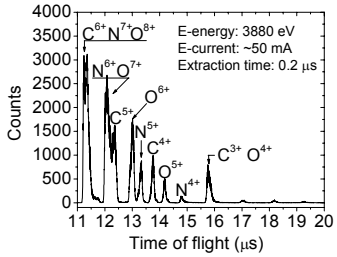
TITAN-EBIT Special feature



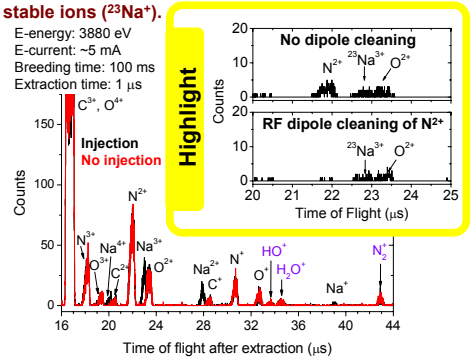
The central drift tube is segmented into 8 segments for RF cleaning of contaminants in the EBIT.

Recent progress & preliminary results

FIRST time-of-flight spectrum of *residual gas* ions extracted from the EBIT.

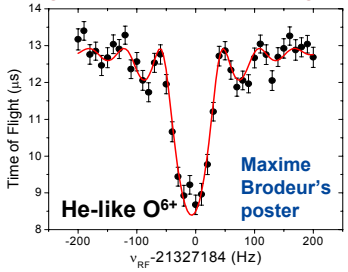


FIRST time-of-flight spectra of charge-bred injected stable ions ($^{23}Na^+$).



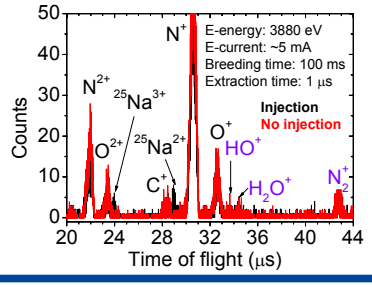
FIRST TOF-ICR resonance of a highly charged ion in the TITAN Penning trap.

Milestone

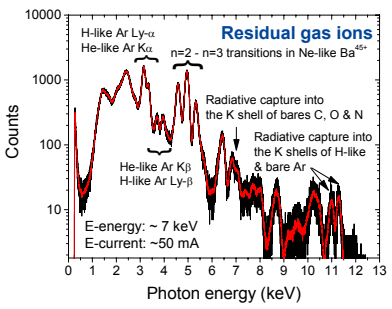


FIRST charge breeding of an injected short-lived radio-active isotope (^{25}Na). ^{25}Na half-life~59.1 s

Milestone



An EBIT allows visual access to HCI's for in-trap diagnostics by X-ray spectroscopy.



Outlook & References

- Breeding of injected ions to higher charge states.
- Installation of a time-resolved DAQ system for charge breeding time measurements by X-ray and TOF spectroscopy.
- Energy spread and transverse emittance studies of beams extracted from the EBIT.
- **Mass measurements of ^{70}Kr & ^{70}Br (June), and superallowed ^{38m}K (Sept.) & ^{74}Rb (Oct.) with highly charged ions.**

He-8: V. Ryjkov, et al., PRL 101, 012501(2008)
Li-11: M. Smith, et al., PRL 101, 202501(2008)