EBIT – Status and Future Plans

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TITAN Collaboration Meeting, May 2010

Outline

- Motivation of EBIT
- EBIT and Charge Breeding
- Results
- Plans and Outlook

Motivation

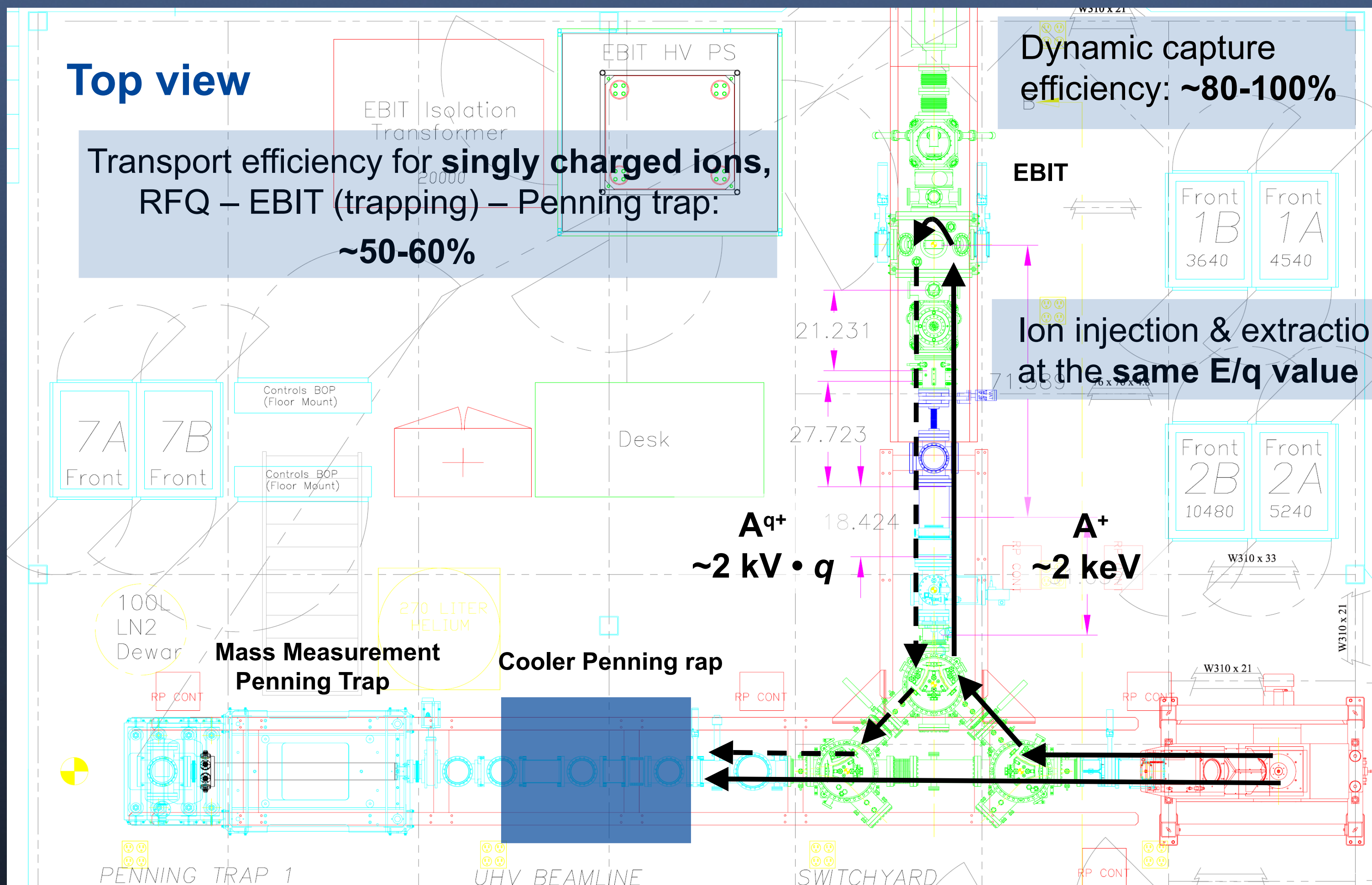
- Resolution in Penning trap mass measurement:

$$\frac{m}{\delta m} = \frac{q B T_{RF} \sqrt{N}}{m}$$

- Only practical way to increase resolution is to increase ion's charge state
- Since isotopes are short lived charge breeding needs to be fast and efficient

TITAN

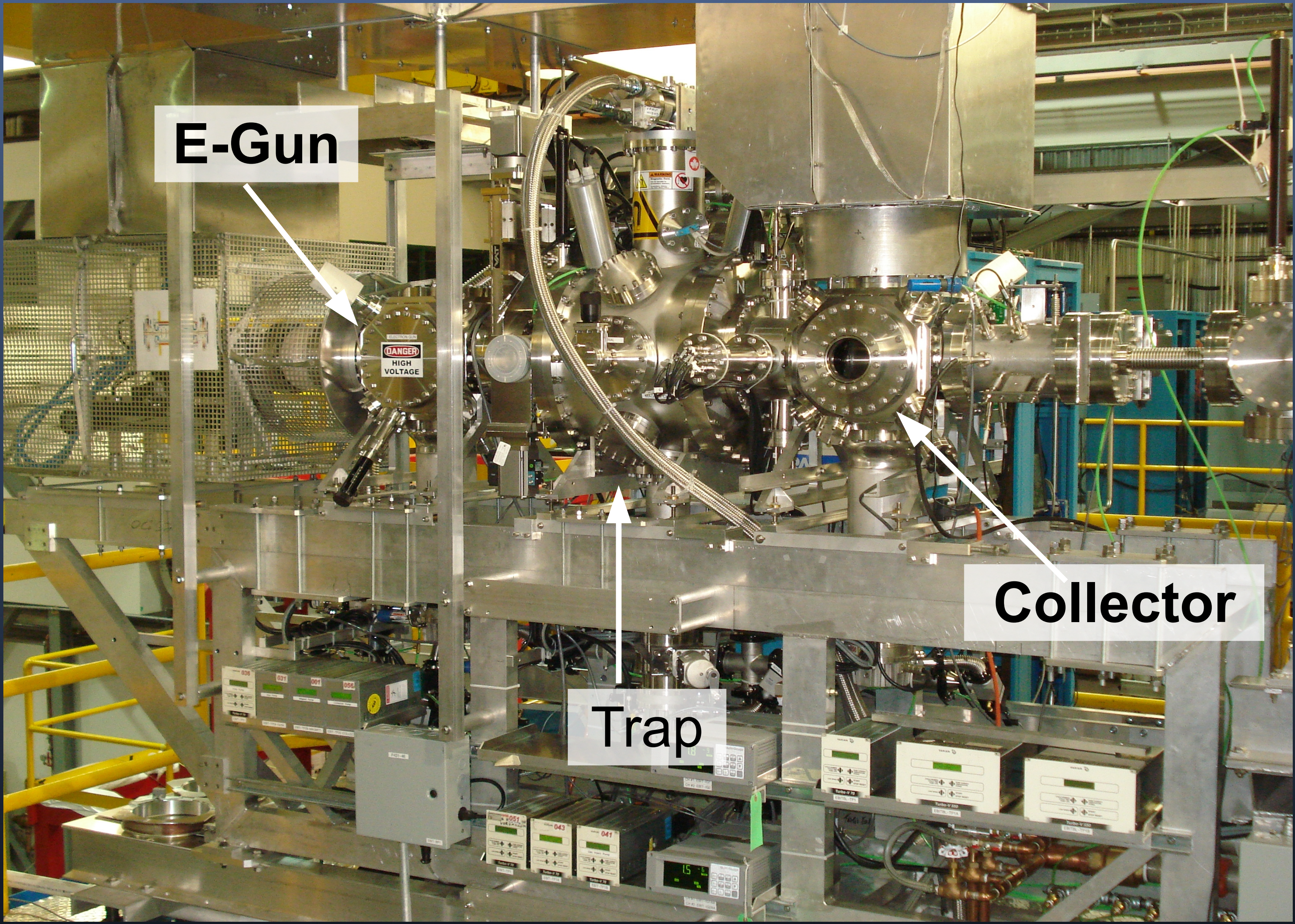
Bunched ion beams from the RFQ can be sent to the Penning trap or the EBIT.



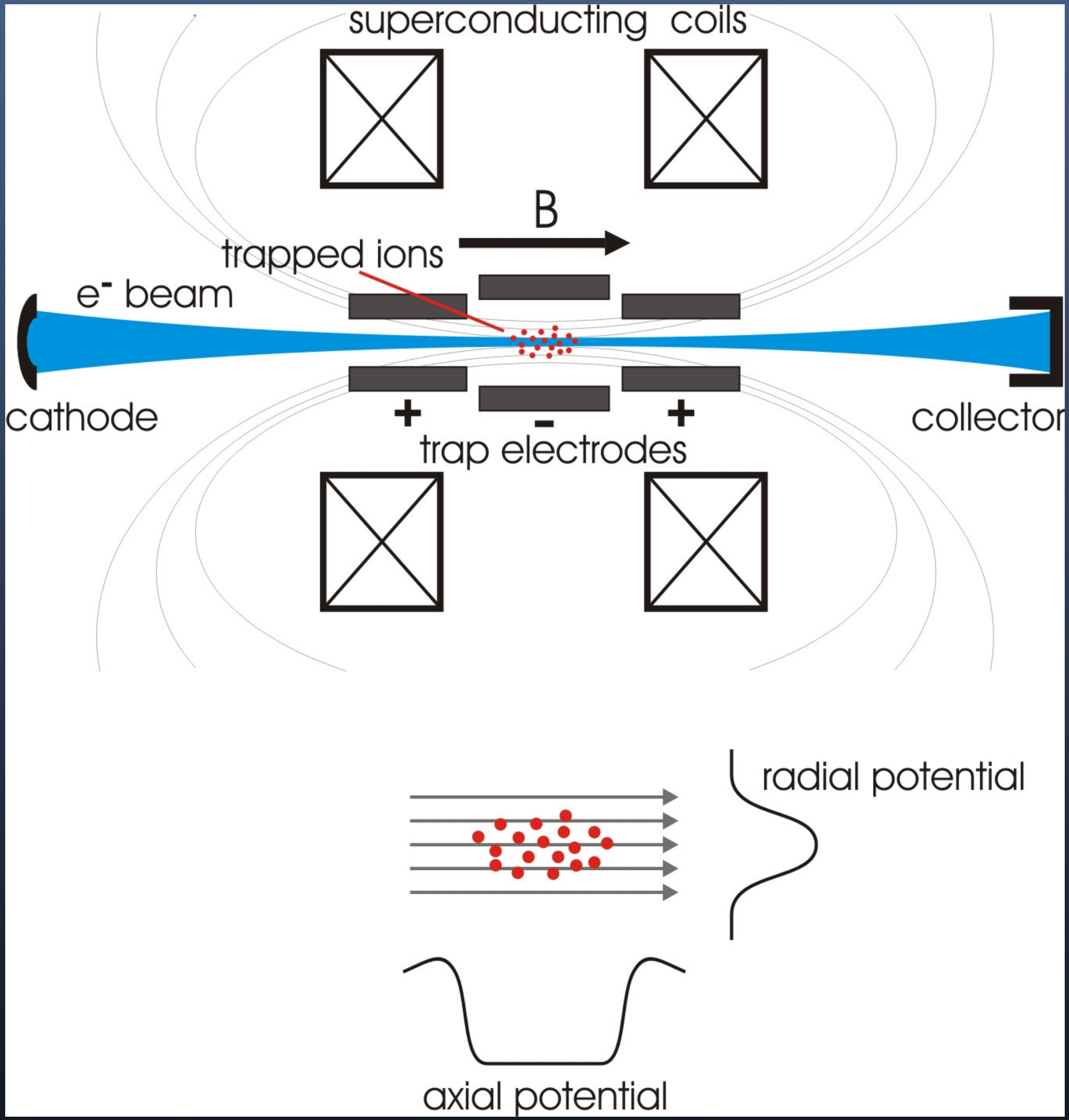
No analyzing magnet:

- All the ion optics elements are **electrostatic.**
- Different **m/q ratios resolved by time of flight (m/ m~50).**

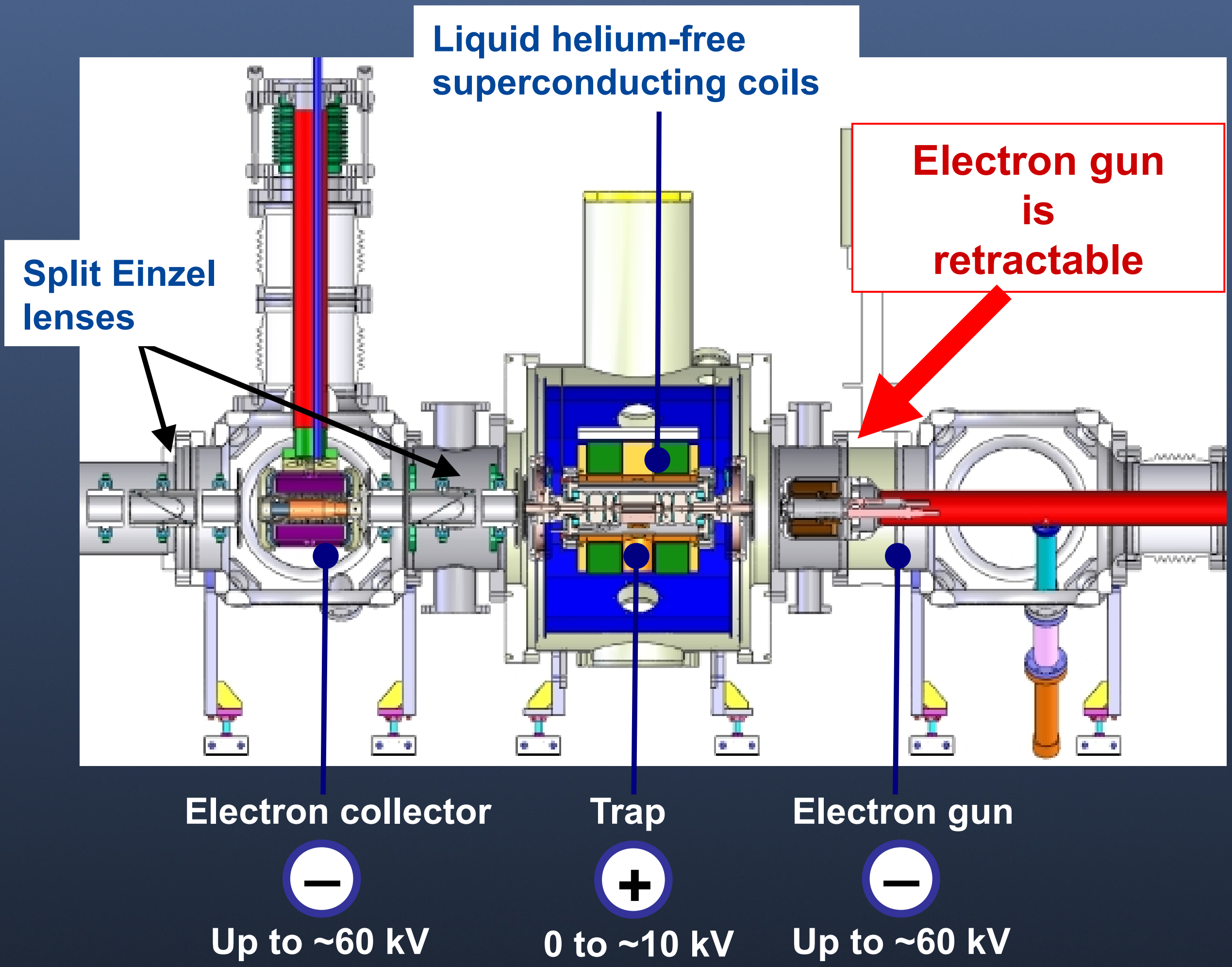
TITAN EBIT



Charge Breeding in a EBIT



TITAN EBIT



The gun & collector must be biased at high voltages to reach high electron beam energies.

Design specifications

E-beam energy	~70 keV [25]
E-beam current (Ba disp. cath.)	500 mA [400]
Magnetic field strength	6 T
Cathode upgrades	1 A & 5 A
(Herrmann) beam diameter (FWHM)	~40 µm
Electron beam current density	10^{4-5} A/cm^2

Number of trapped ions: 10^6-10^8

Electron number density: ~5x10^{22} e/cm^2/s

Beam energy spread: ~50 eV

Highest charge state: ~ He-like U^{90+}

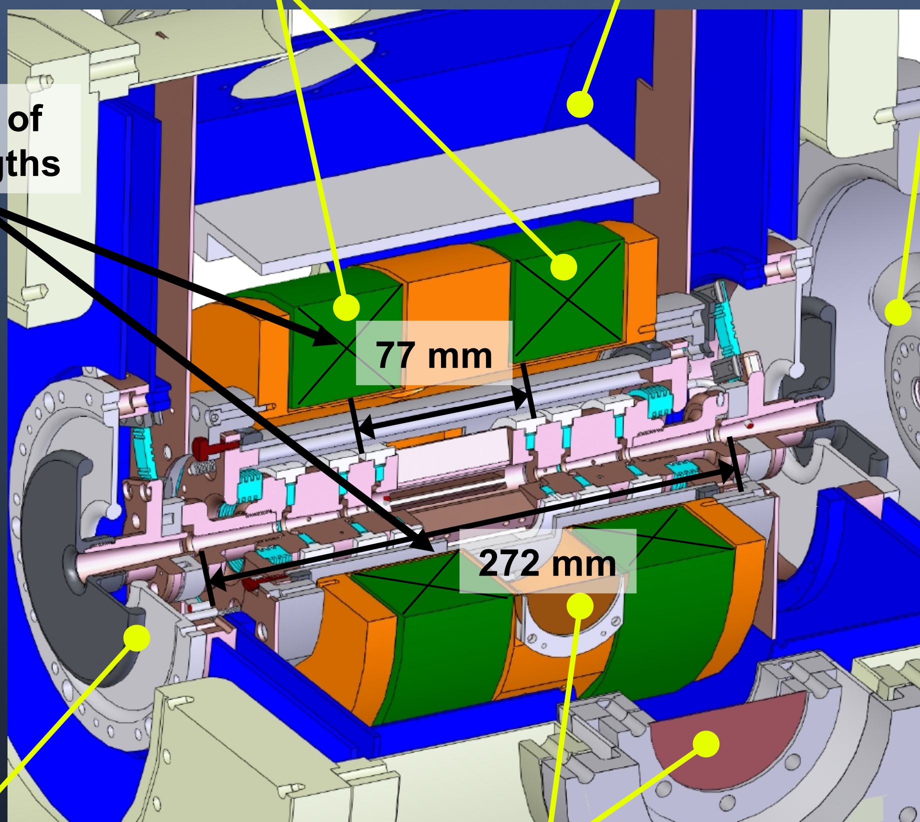
The Trap

Superconducting coils (Nb_3Sn) @ ~4 K

Thermal shield @ ~30 K

Electron gun

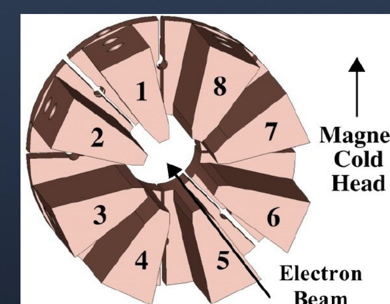
Trap config. of various lengths



9 cylindrical drift tubes

Be windows
7 access viewports for spectroscopy

TITAN-EBIT special feature



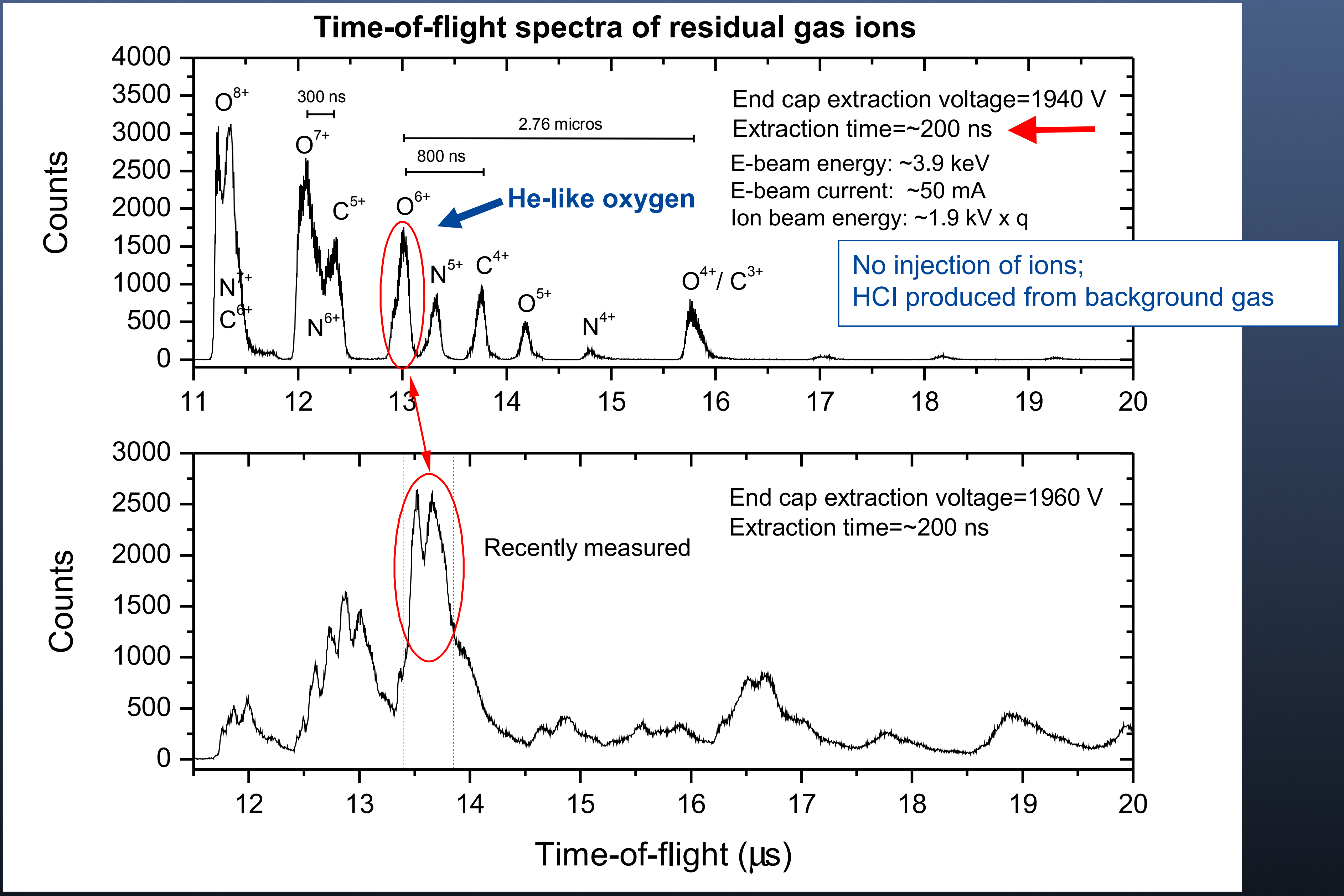
8-fold segmented central drift tube:

- Clean ion contaminants with RF field.
- Study the trap content by **I**on **C**yclotron **R**esonance.

Status

Charge Breeding & Extraction

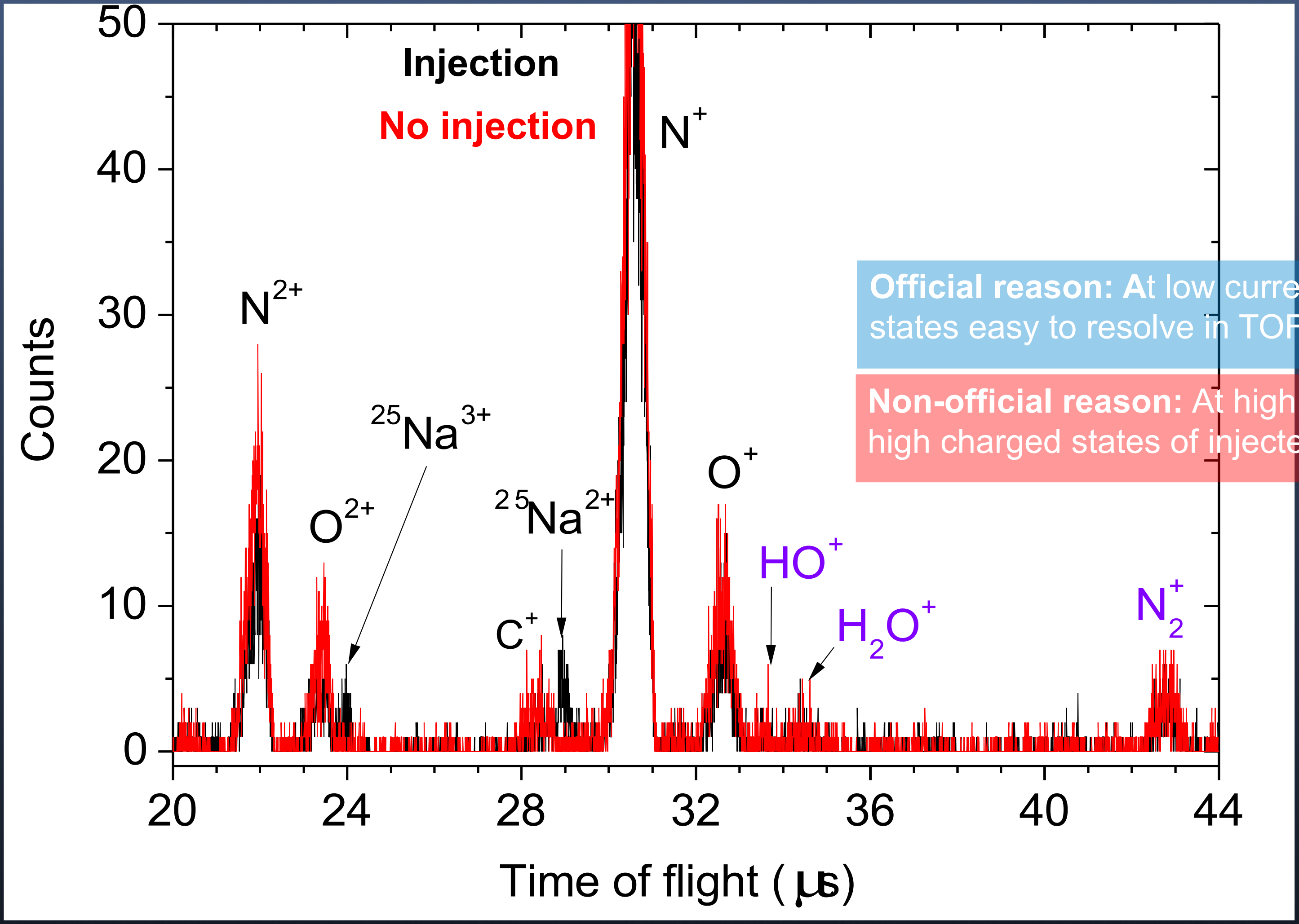
Since Nov. 2008, we can extract HCI's from the EBIT…



“Charge-Breeding” Test of a Radioactive Isotope

In April 2009, injected & charge bred our **first** radioactive ion (^{25}Na)

^{25}Na half-life= 59.1 s



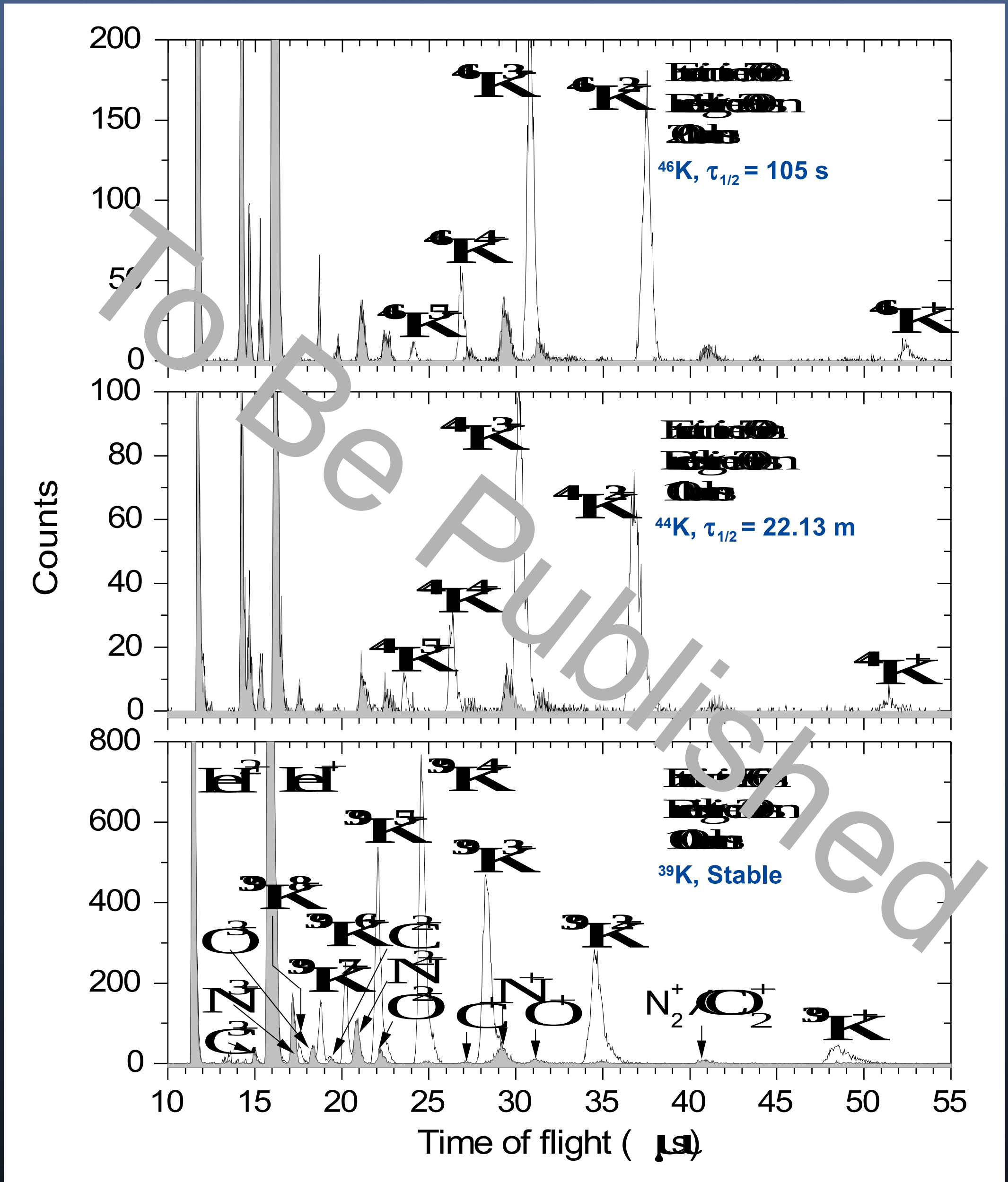
E-beam energy: ~3.9 keV
E-beam current: ~5 mA
Ion beam energy: ~1.9 kV_{ext} x q
Trapping potential: ~150 V
Extraction time: 1 s

Official reason: At low currents, we produce low charge states easy to resolve in TOF spectra.

Non-official reason: At high currents, we do not see high charged states of injected ions ?????

Charge Breeding of a Radioactive Isotope

A few months later, in September 2009, injected & charge bred K isotopes…



Injection of K+

No injection *(residual gas)*

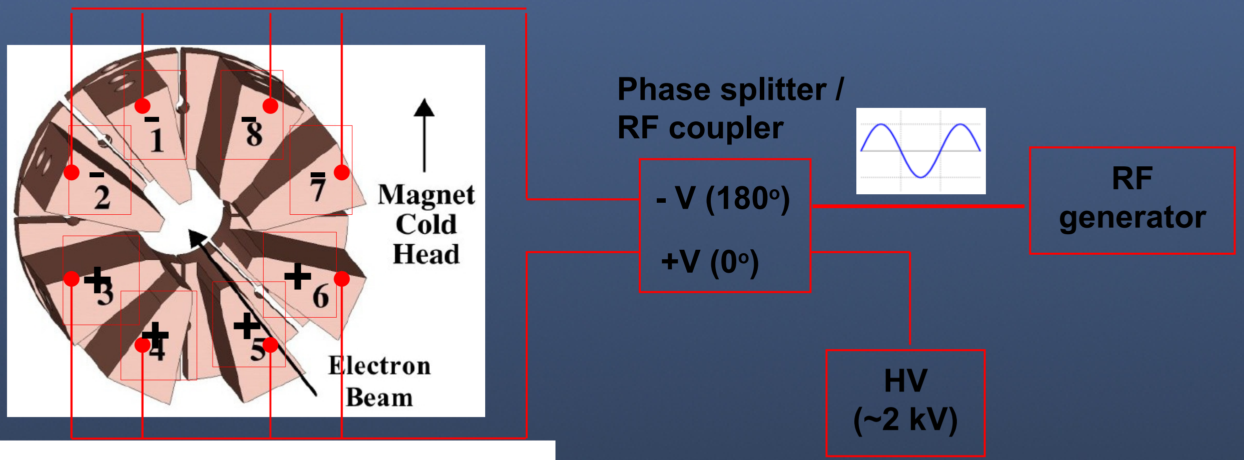
E-beam energy: ~3.9 keV
E-beam current: ~1 mA, *<u>Cathode warmed up</u>*
Ion beam energy: ~1.9 kV_{ext} x q
Trapping potential: ~150 V

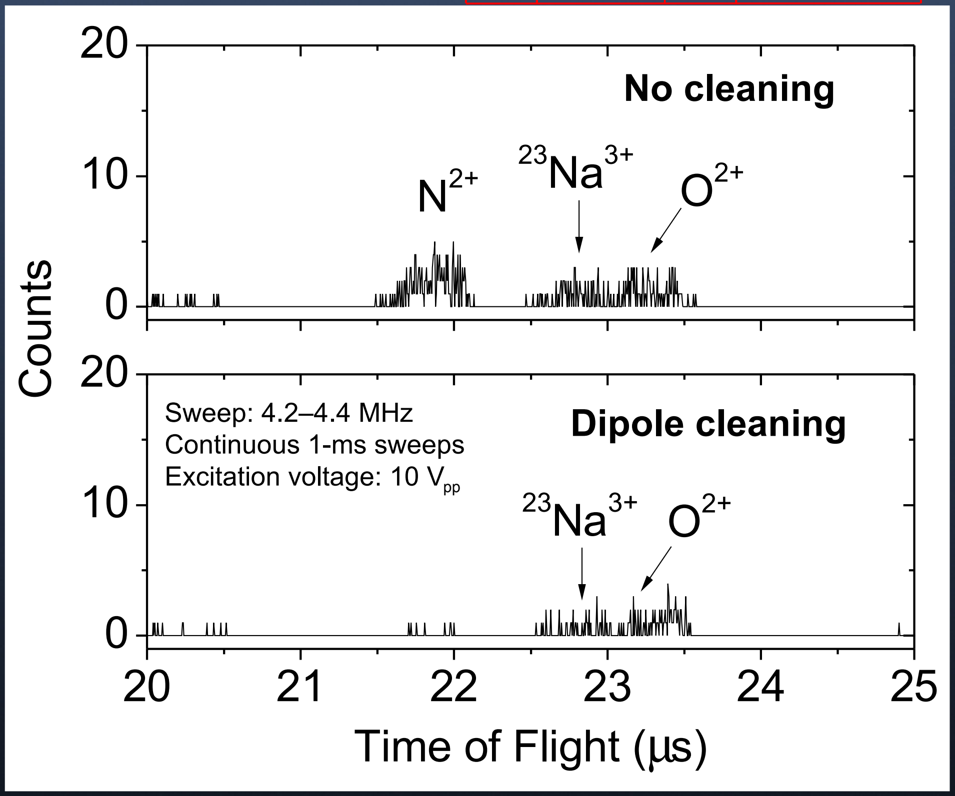
Pulsed extraction efficiency is **<5%**
→ Penning trap capture ion bunches of 1-2 s:

RF Dipole Cleaning

8-fold segmented central drift tube allows for multipole RF excitation in the EBIT

Dipole cleaning: Increase the reduced cyclotron amplitude until ions crash onto the trap's wall





An RF dipole excitation sweep around the cyclotron frequency of N^{2+} removes this ionic species from trap.

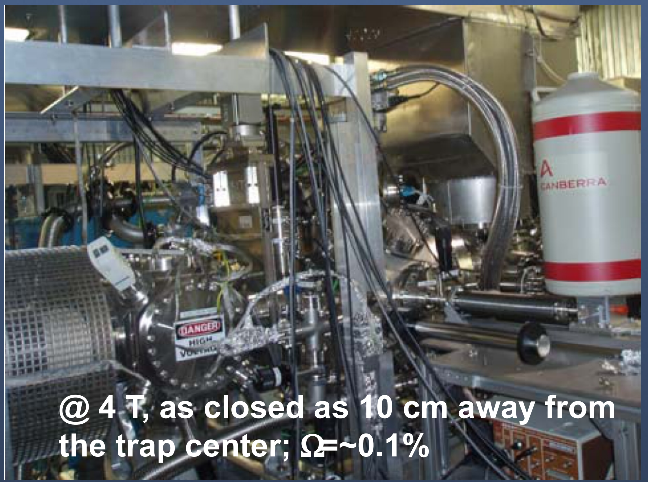
Across the long trapping region the magnetic field is inhomogeneous

→ **Mass resolving power ~50**.

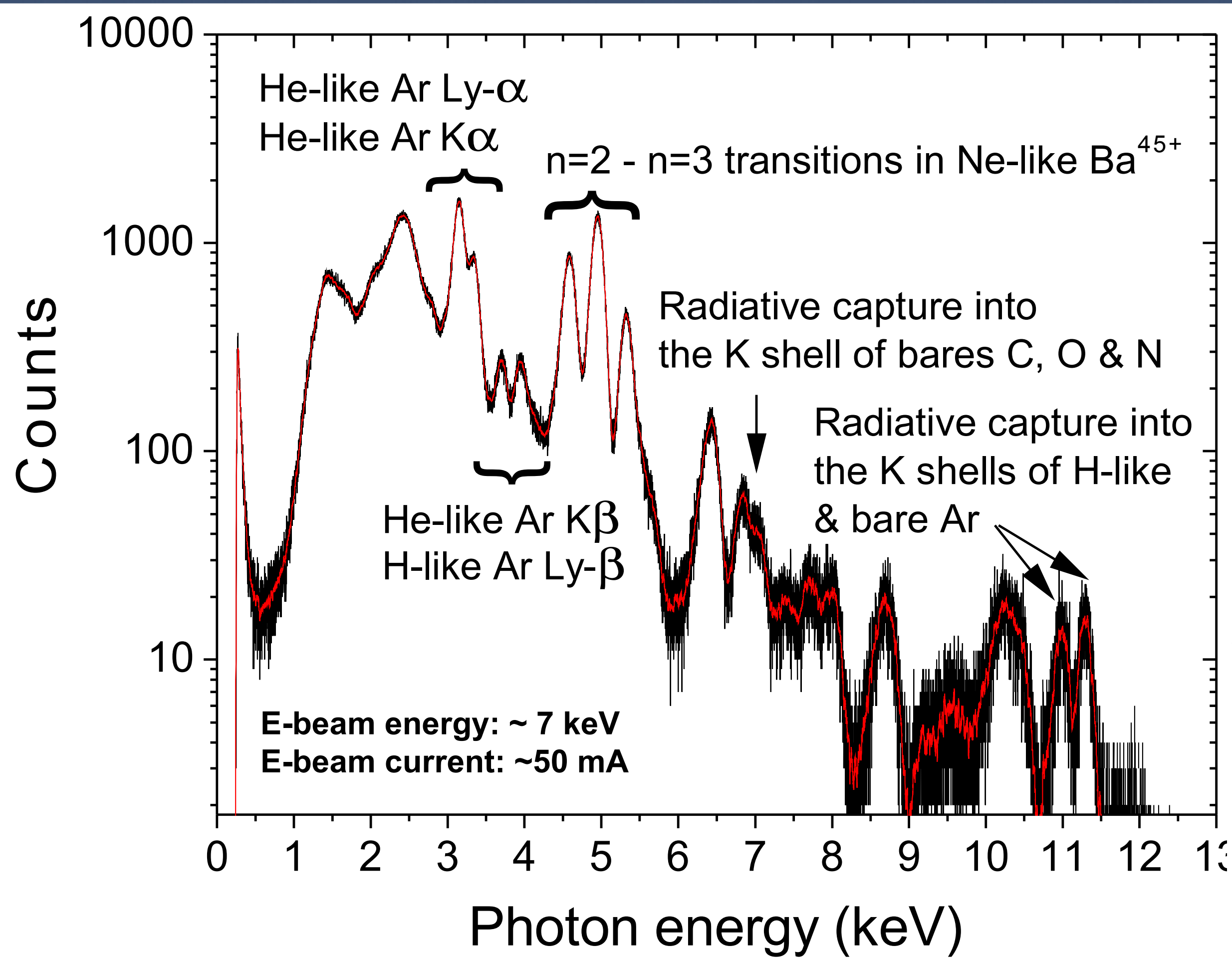
Effect of RF dipole cleaning in X-ray Spectra

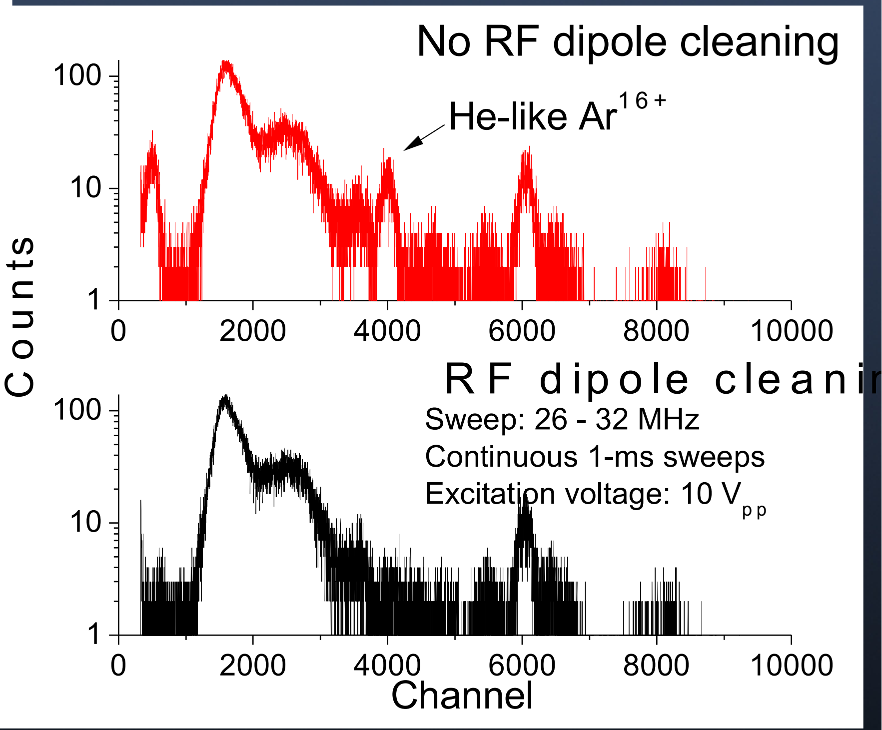
The geometry of the coils (*Helmholtz*) allows visible access to trapped ions for spectroscopy.

LEGe X-ray detector



X-ray spectrum of residual-gas ions

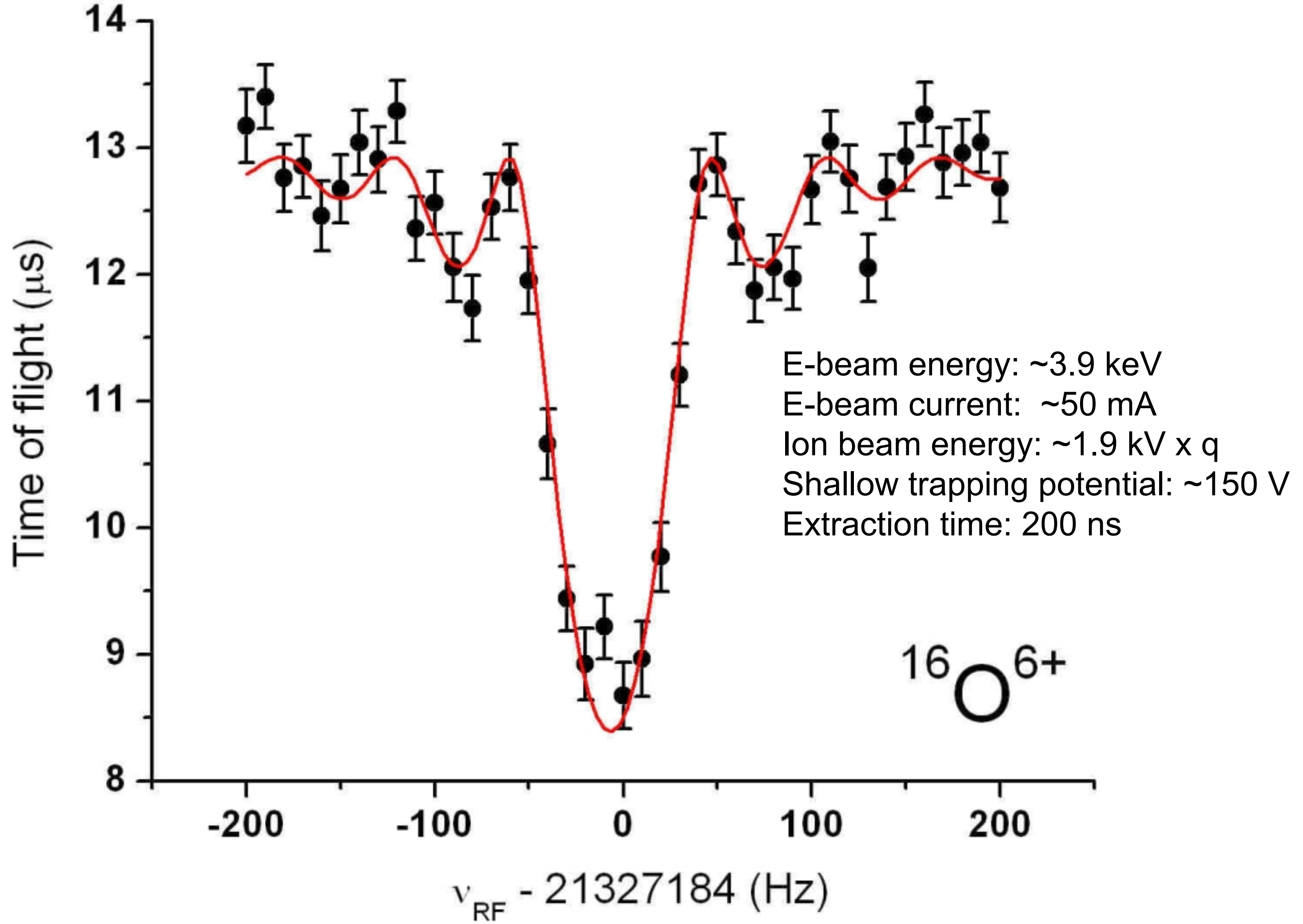




Mass Measurements

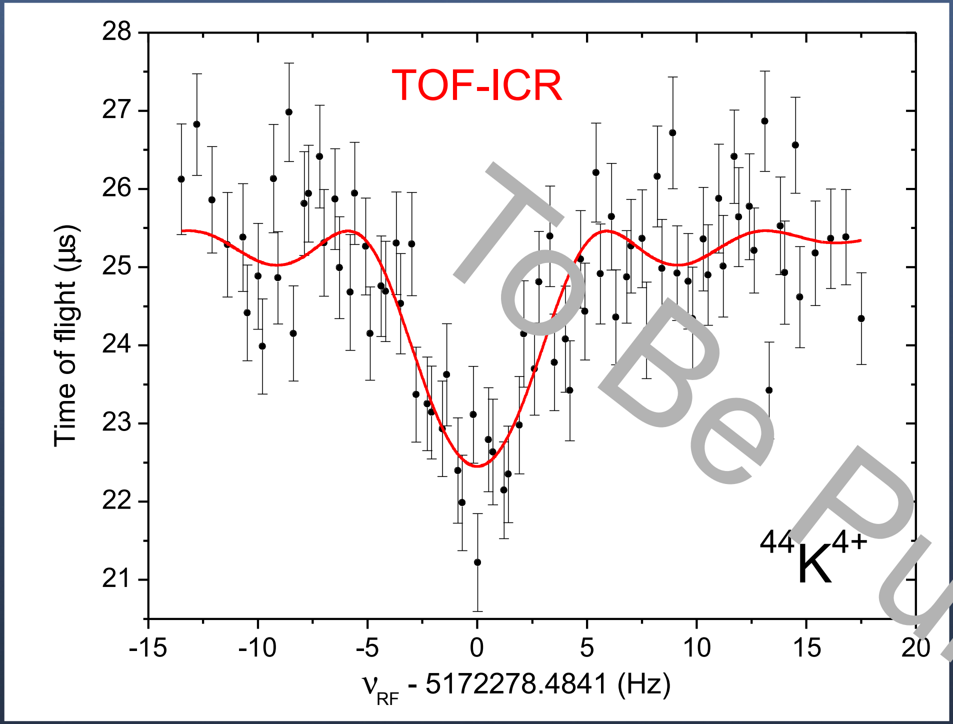
We can send highly charged ions to the Penning trap…

First *TOF ion-cyclotron resonance obtained with* He-like O^{6+}



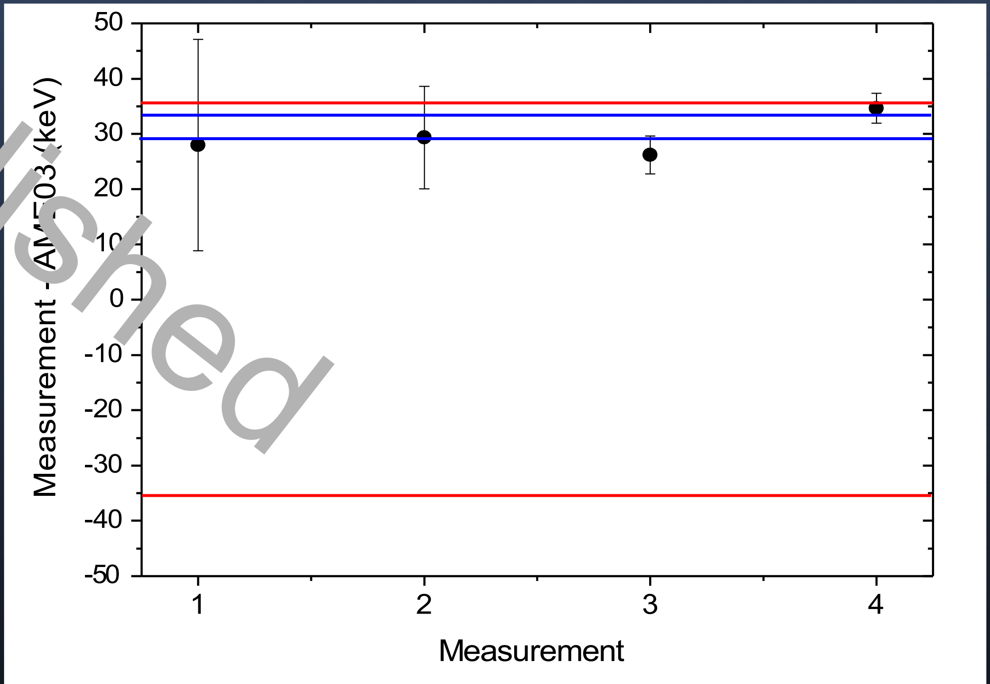
Mass Measurements

In October 2009, first mass measurement with a multiply charged radioactive ion



E-beam energy: ~3.9 keV
E-beam current: ~1 mA, *Cathode warmed up*
Ion beam energy: ~1.9 kV_{ext} x q
Trapping potential: ~150 V
Extraction time: 200 ns
Breeding time: 200 ms
RF excitation time: 147 ms
(limited by the high charge-exchange rate in the Penning trap)

Mass-excess measurements of ^{44}K

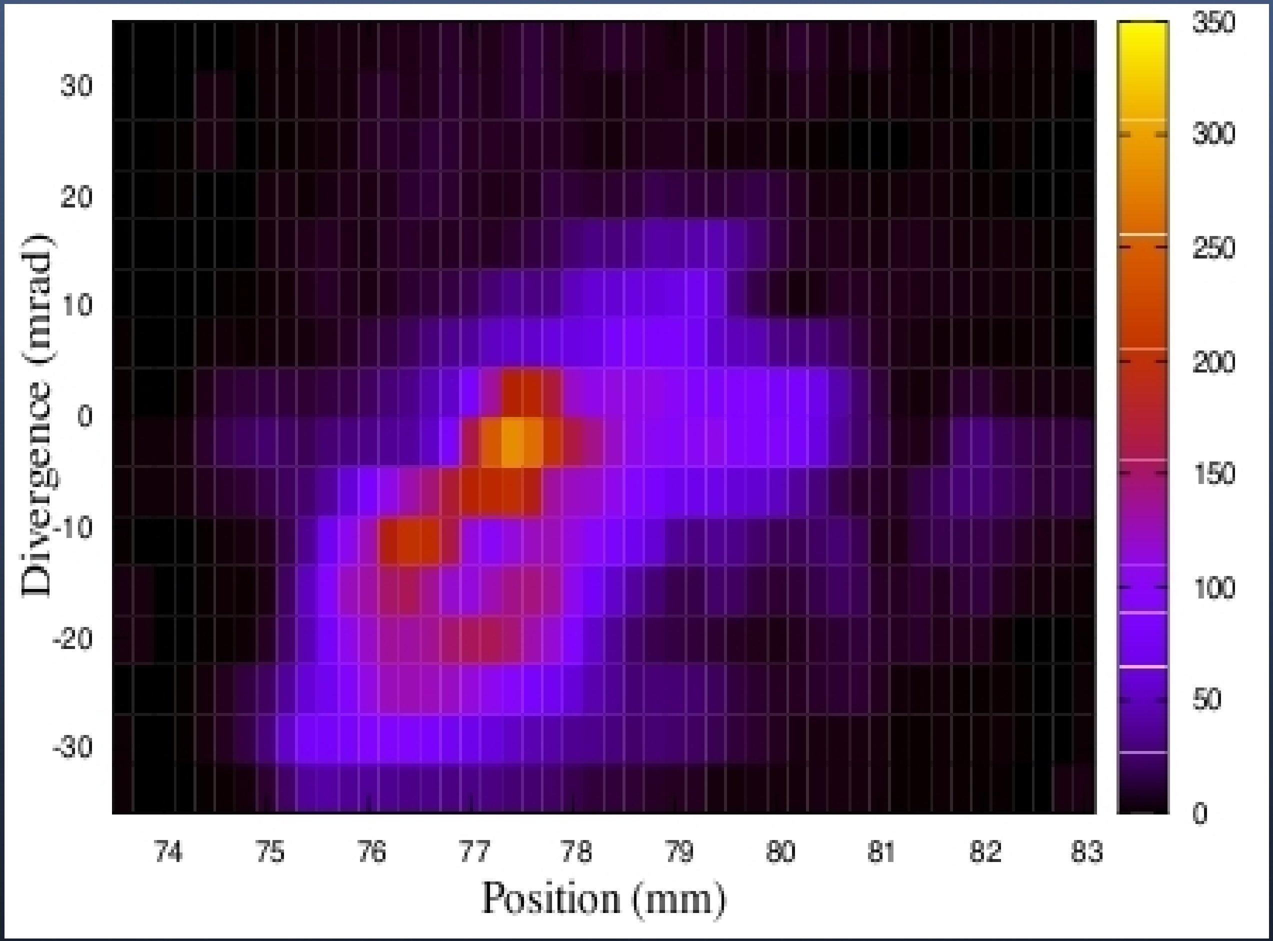


^{44}K mass excess
TITAN: -35778(2) keV
AME03: -35810(40) keV
ISOLTRAP: -35781.29(0.47) keV

Good agreement with AME03 and ISOLTRAP values…

Plans

Emittance



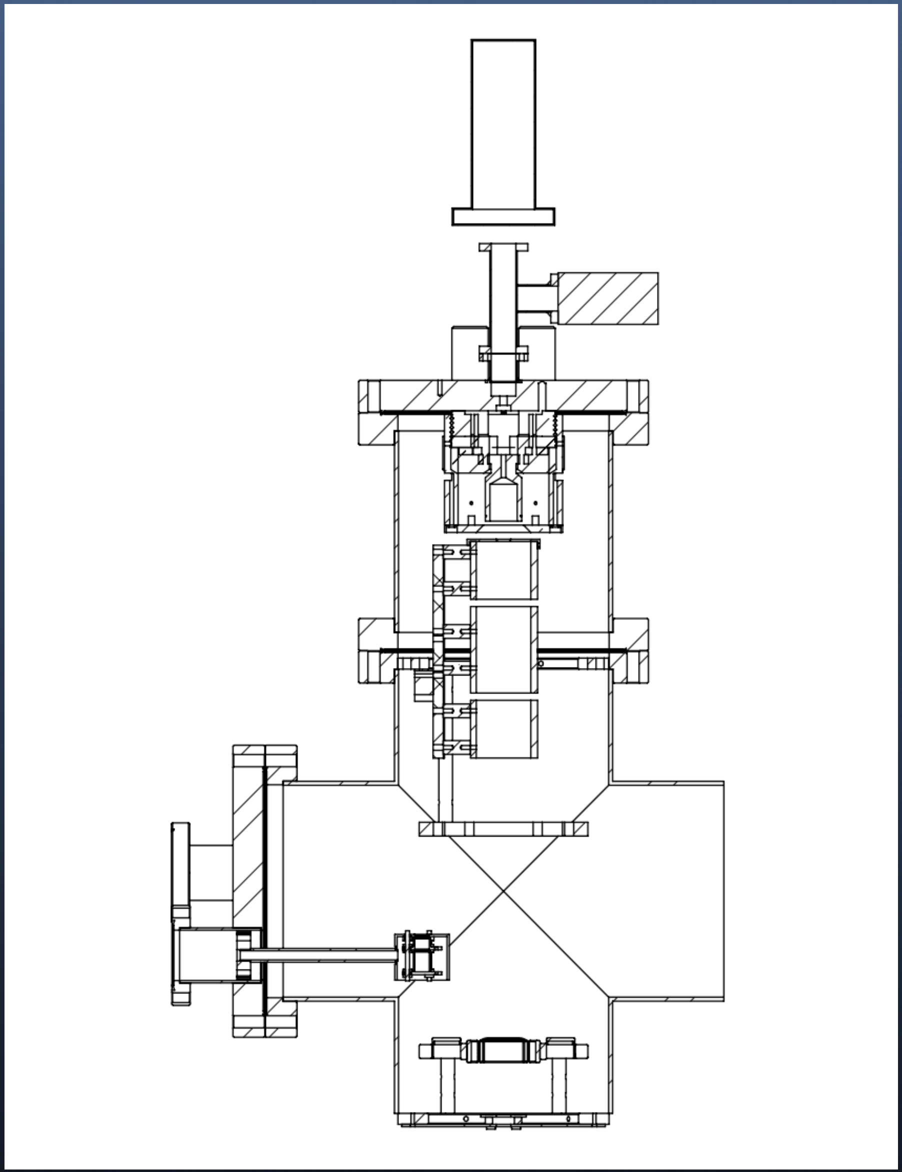
$\varepsilon_{39\%}$ = 15.7 πmm-mrad

Acceptance of most optical elements is <100πmm-mrad.

We're clipping the beam!

Need to improve

Plasma Ion Source



Ion source for systematic studies of charge breeding

Allows independent operation of EBIT from rest of TITAN

Changing design to allow for MCP detector and Wien filter for detailed trap analysis.

Other Plans

- Refinement of the current gas injection system
- Upgrades to the high voltage system
- Improvement of the interlock system
- Upgrades to the DAQ system to optimize charge breeding
- Systematic studies and detailed simulations of injection and extraction to improve transport efficiency to MPET
- Aim for HC measurement of ^{74}Kr in July