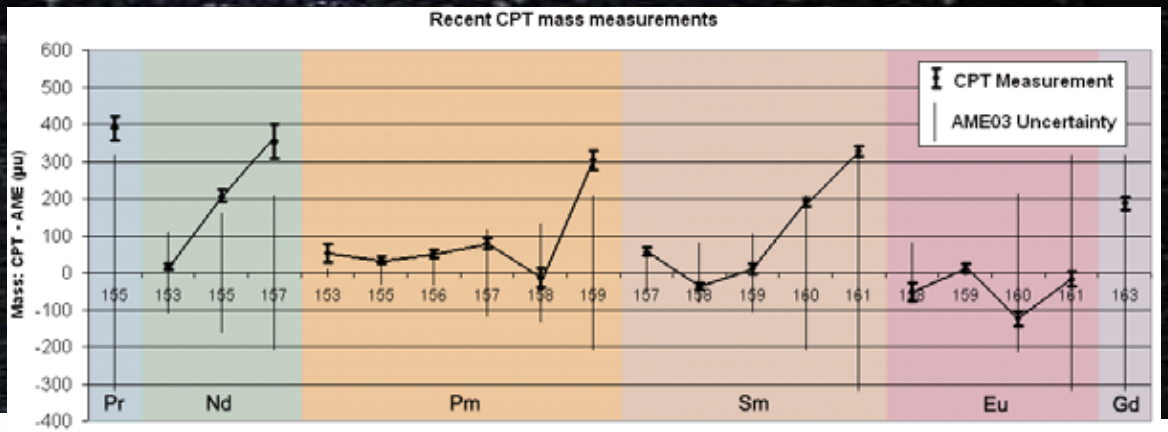
First measurements with the Canadian Penning Trap at CARIBU

Jason Clark

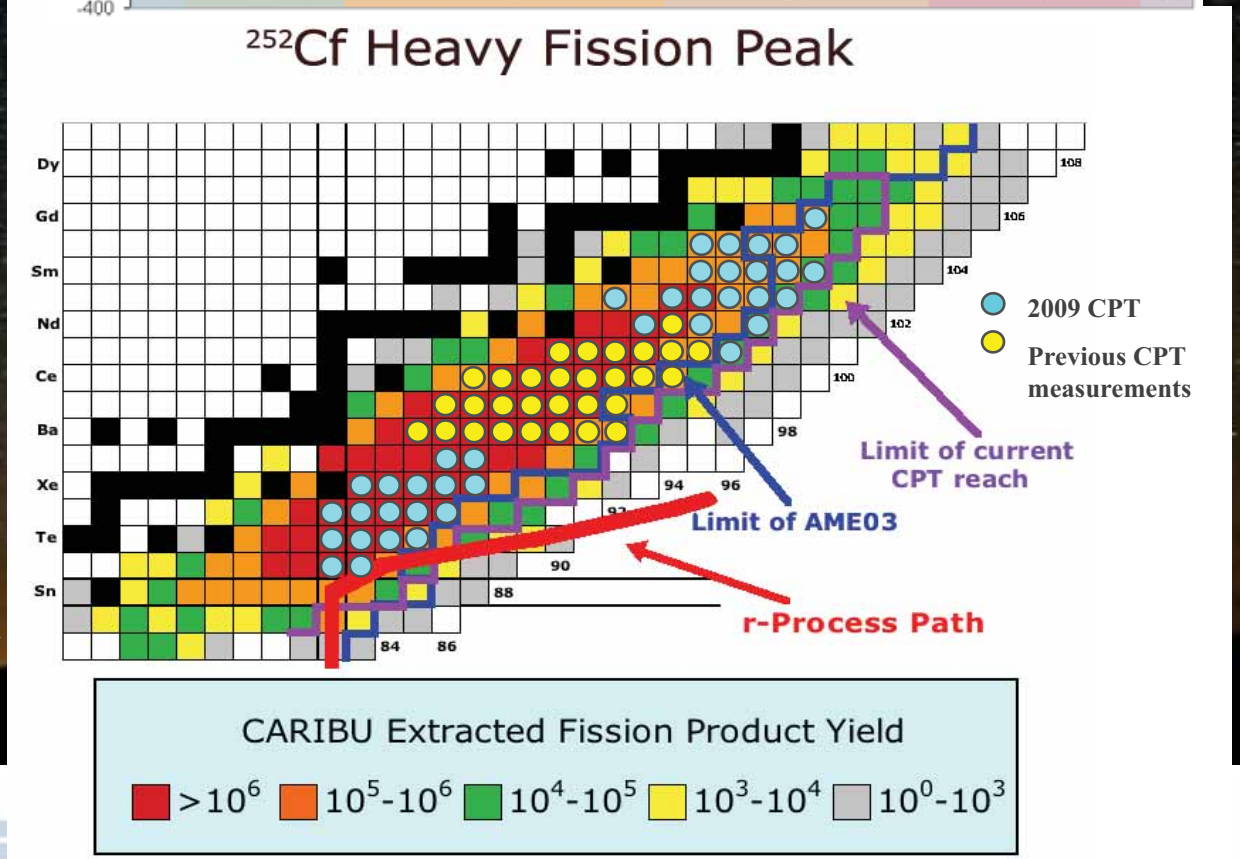
AFC Workshop

April 14, 2011

Measurements of neutron-rich nuclides from 'weak' ^{252}Cf



- CPT had measured ~ 70 neutron-rich nuclides using prototype gas catcher delivery system over past few years in 'old' location
- Trends showing nuclei less bound with neutron excess
  - Changes location of dripline, astrophysical *r*-process path
- Goal: Measure ~ 100 neutron-rich masses with CARIBU which have never been previously measured



Overview of CARIBU

1 Ci ^{252}Cf source

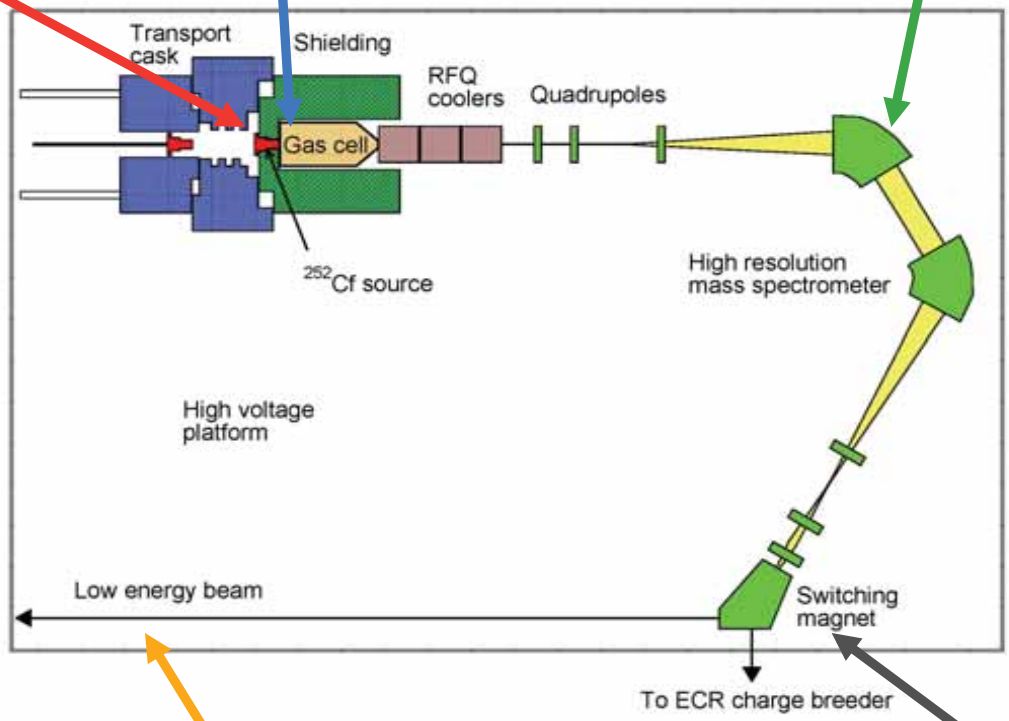
Gas catcher

(collect fission fragments)

Isobar separator

(select specific fragment)

'Stopped' beam experimental area

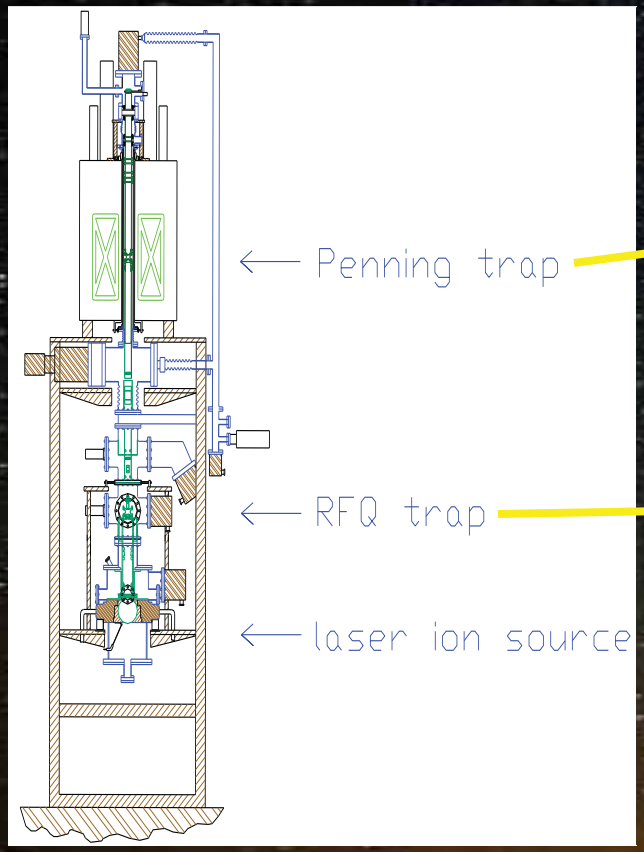


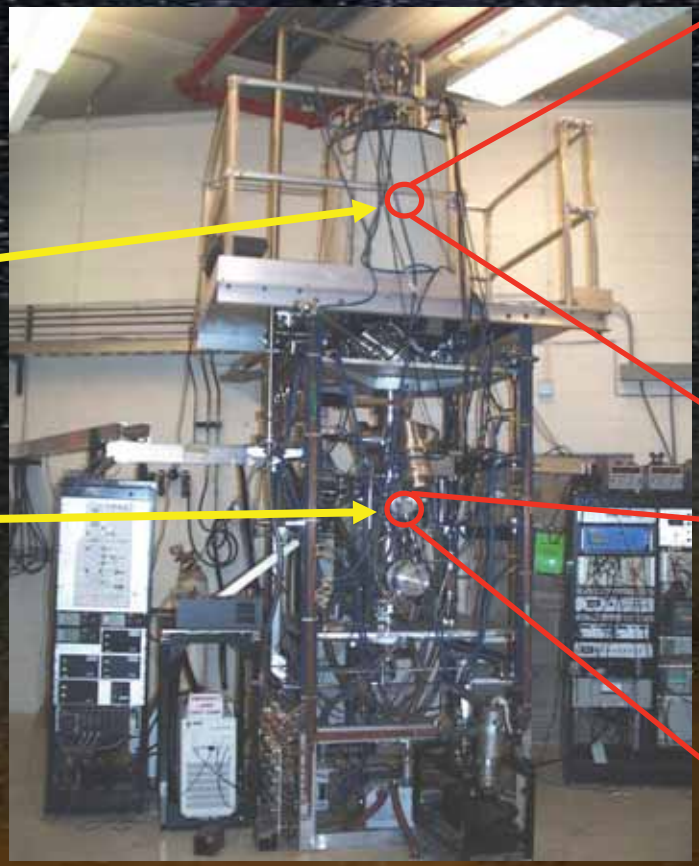
Delivery of beam

- to 'stopped' area through low-energy beamline

Switchyard

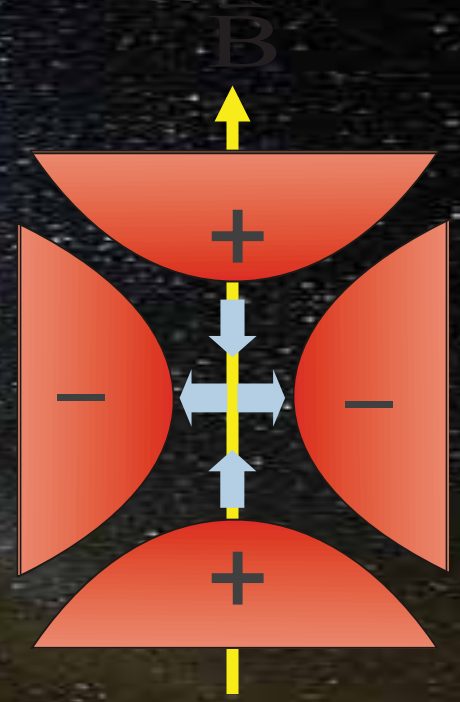
The early days of the CPT at ATLAS





Penning trap mass spectroscopy

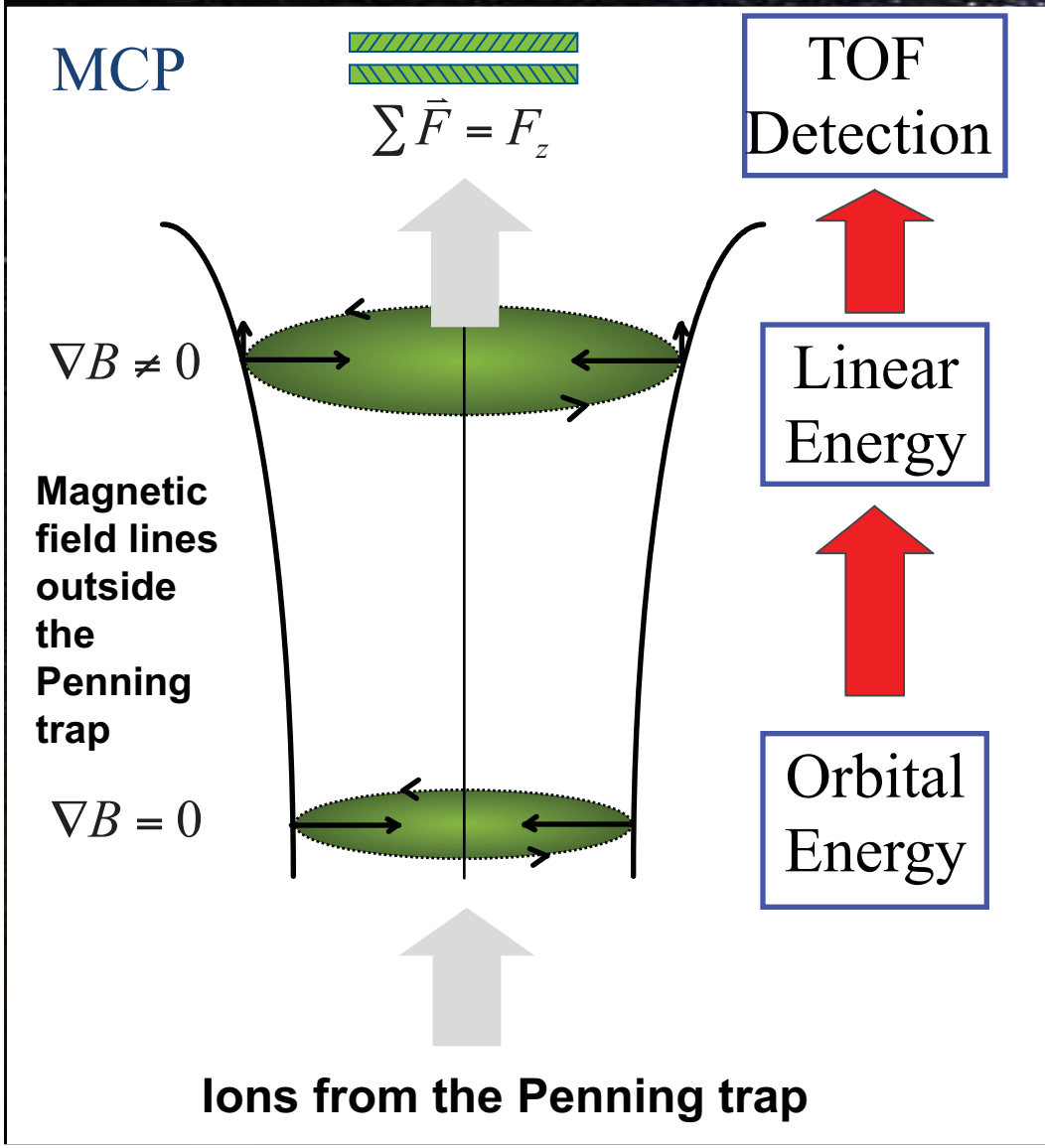
$$\omega_c = \frac{qB}{m}$$



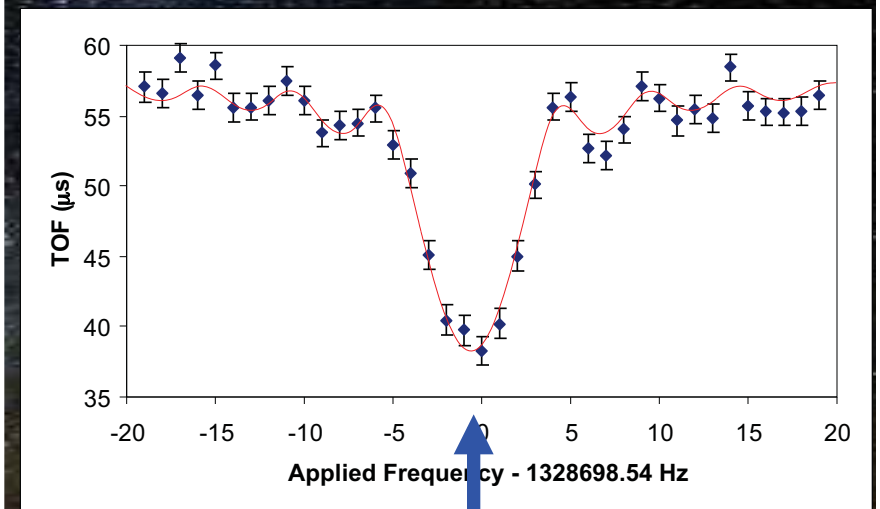
A homogeneous magnetic field provides radial confinement and an axially harmonic electric potential provides axial confinement.

Since ω_c depends upon the magnetic field strength and the mass of the ion, and not on the electric fields, accurate and precise mass measurements can be made.

Determining the cyclotron frequency

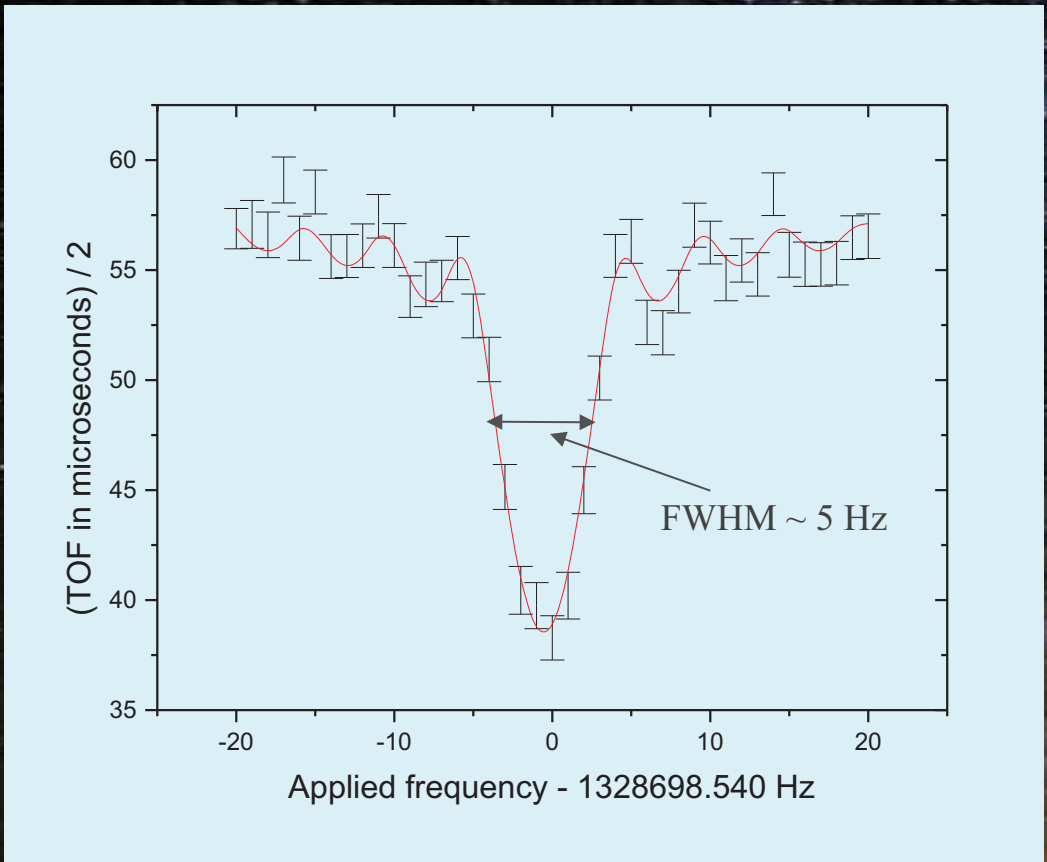


Sample TOF spectrum



$$\omega_c = \frac{q_c B_c}{m_c}$$

Sample time-of-flight (TOF) spectrum



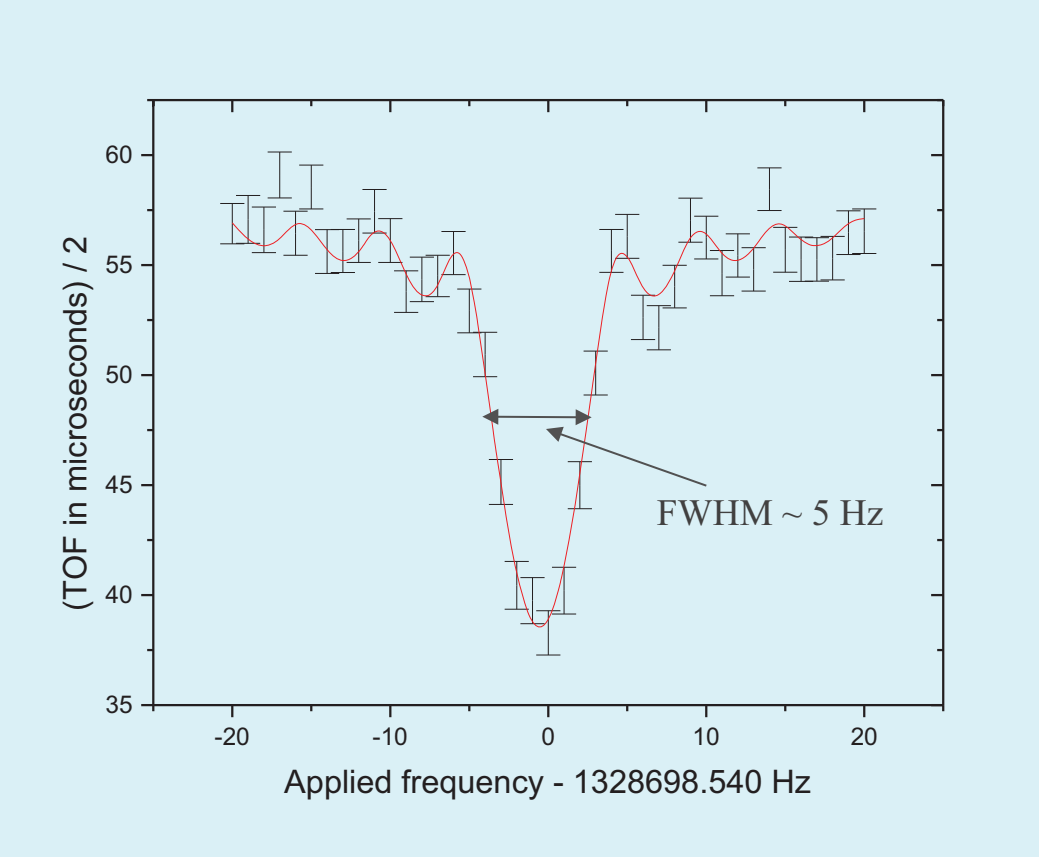
$$\omega_c = \frac{q_c B_c}{m_c}$$

Unknown: $$\omega_? = \frac{q_? B_c}{m_?}$$

$$\frac{Unknown}{Calibration} \Rightarrow m_? = \frac{q_?}{q_c}\frac{\omega_c}{\omega_?} m_c$$

Well-known mass is a requirement for accurate measurements.

Penning trap characteristics



$$\text{Resolution} = \frac{\Delta\omega_{FWHM}}{\omega}$$

~ 10^{-6} or 120 keV/c^2 (for A~133, T_{RF} = 1 s)

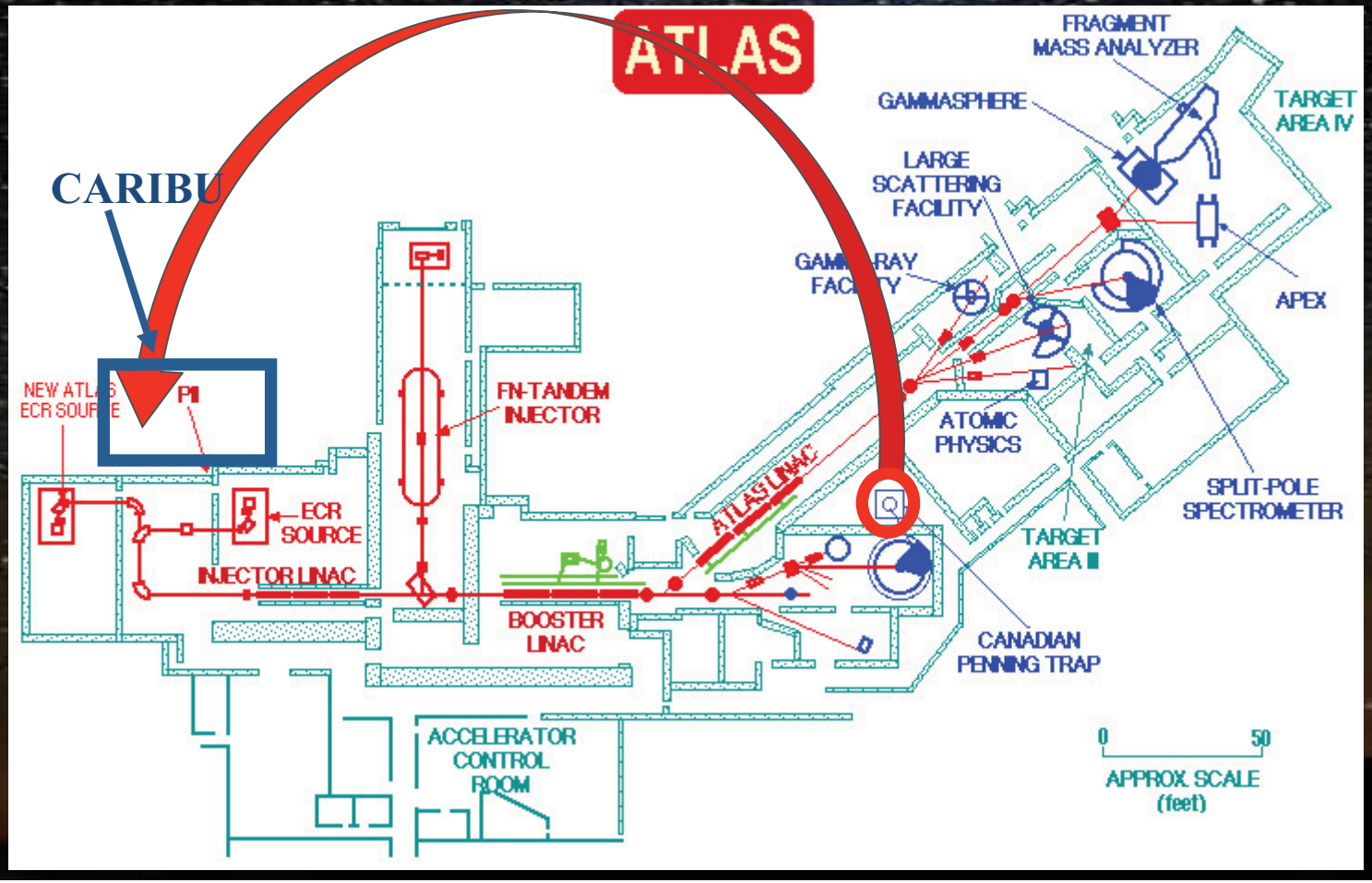
$$\Delta\omega_{FWHM} \sim \frac{0.9}{T_{RF}}$$

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

~ 10^{-8} or 1.2 keV/c^2 (for A~133, T_{RF} = 1 s, N ~ 7500 ions)

Timeline of CPT Move From Triangle Room to CARIBU

- 2009-07-15: Break vacuum, begin disassembly
- 2009-07-28: (rapidly) de-energize magnet



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- **2010-06: Assemble CPT tower, including modified linear RFQ trap**

- Trap is positioned just below Penning trap
- Does final cooling and staging of ions for injection into the Penning trap
- Added LN_2 channels to trap frame – cools the He buffer gas
- Cooler ions reduce both statistical and systematic uncertainties
- Denser gas allows operation at lower He flow rates

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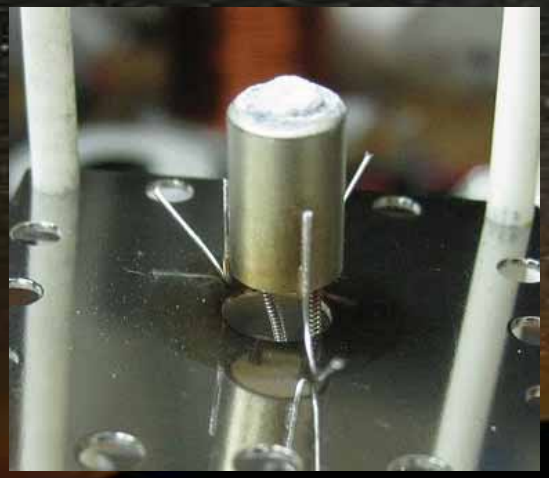
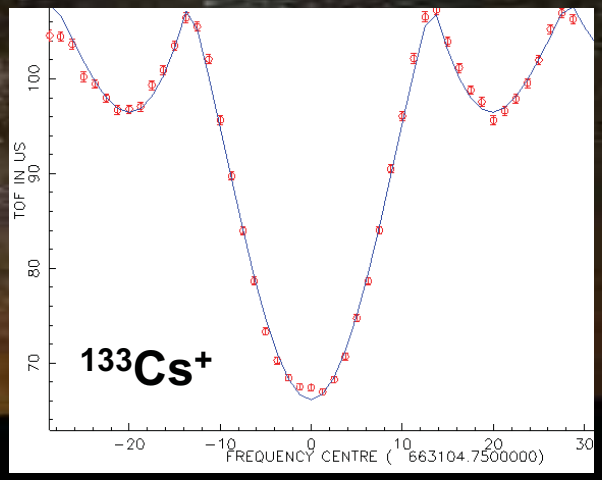
- 2010-07-31: Pump down CPT tower
- 2010-08-26: Begin ion transport from SIS
- 2010-12-1: First cyclotron resonance (stable ions)





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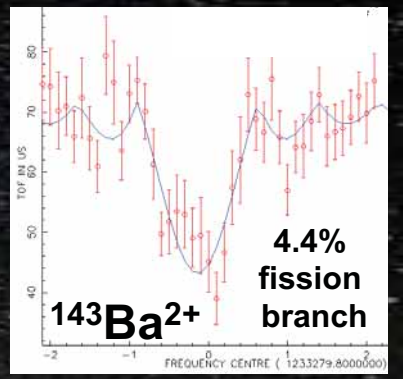
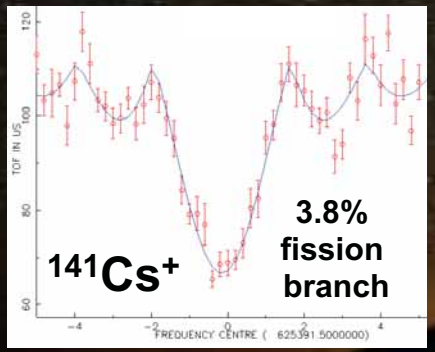
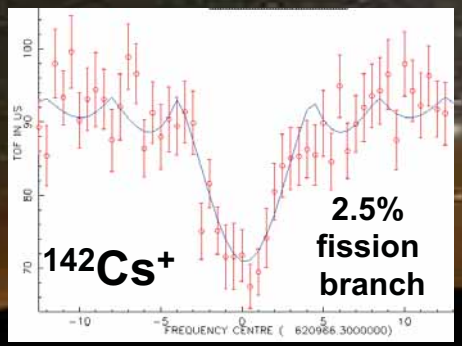
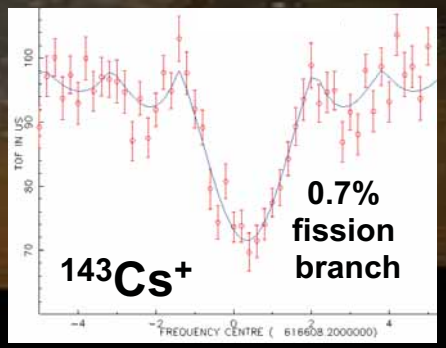
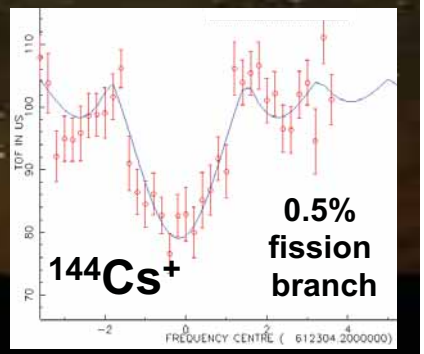
- 2011-03-11: First use of elevator and transport of CARIBU ions toward CPT
- 2011-03-21: First cyclotron resonance of radioactive ions from CARIBU











Next steps

- Improve transport efficiency to CPT
  - Currently ~ 20% from buncher to CPT
- Perform checks of systematic effects
  - Check how the number of simultaneous trapped ions affects measurements
    - not normally an issue -- just keep ion number low anyways
  - Determine effect of contaminant ions
    - effect is more significant, but kept under control with low numbers of mostly pure ions
  - Get handle on frequency-dependent shift with additional calibrations
    - not normally an issue -- use hydrocarbons as reference masses
- Measure, measure, measure
  - current detected yield of 1000 ^{141}Cs/s => should get 25 ^{132}Sn/s, 0.16 ^{135}Sn/s

CPT Effort

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