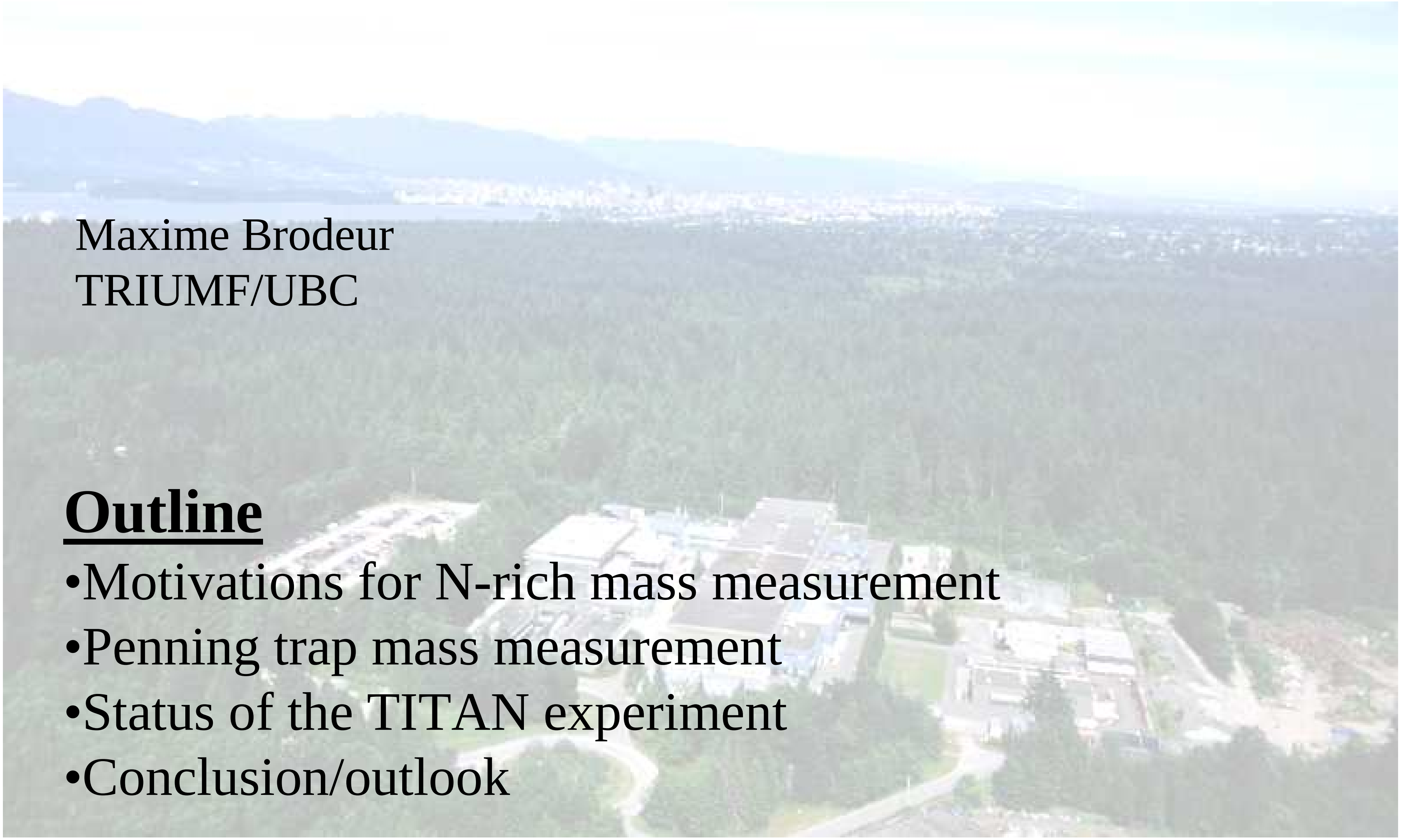
Mass Measurement of Neutron Rich Isotopes at the TITAN Experiment

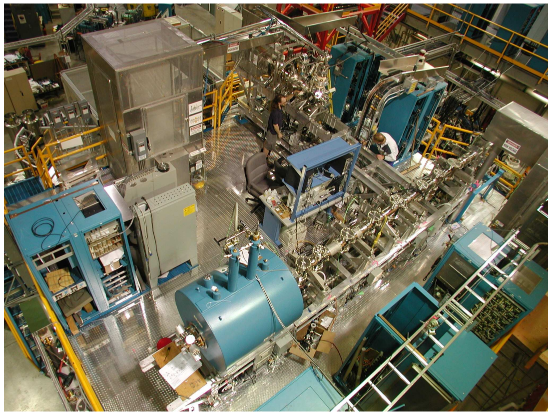


Maxime Brodeur
TRIUMF/UBC

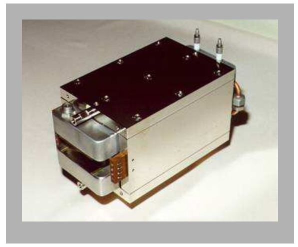
Outline

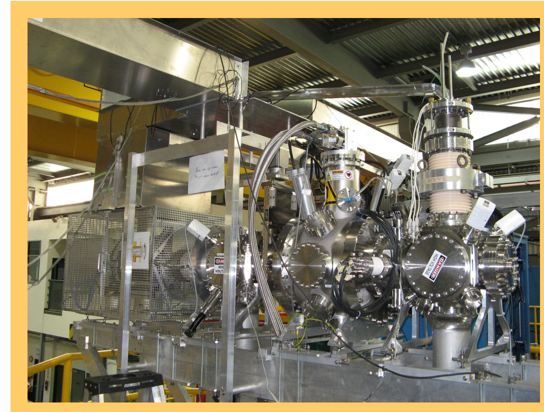
- Motivations for N-rich mass measurement
- Penning trap mass measurement
- Status of the TITAN experiment
- Conclusion/outlook

TITAN: TRIUMF Ion Trap for Atomic and Nuclear science

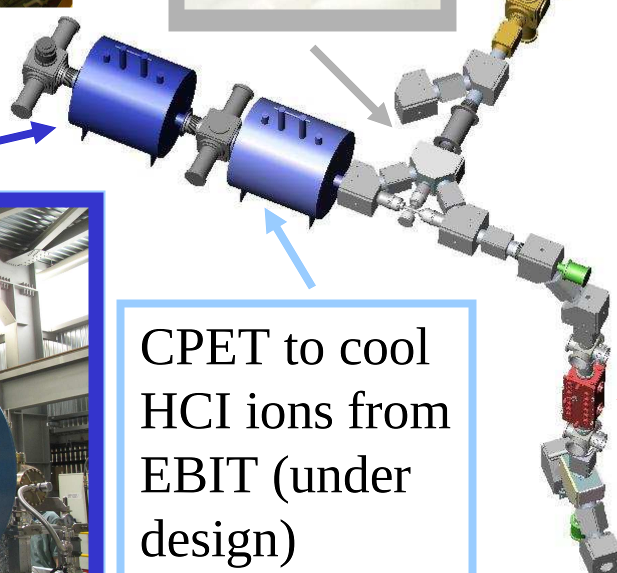


Wien filter:
m/q selection



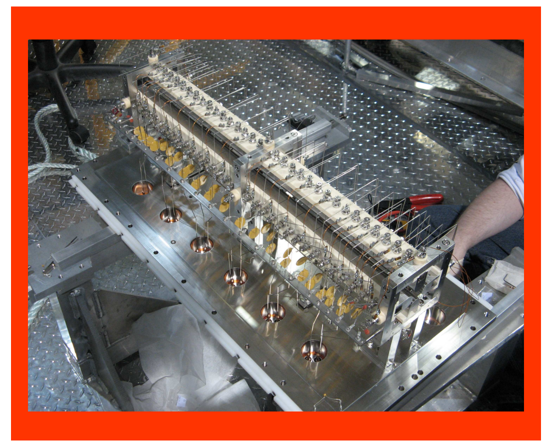


Electron-Beam Ion Trap (EBIT)
charge breeding of ion bunches



CPET to cool HCI ions from EBIT (under design)

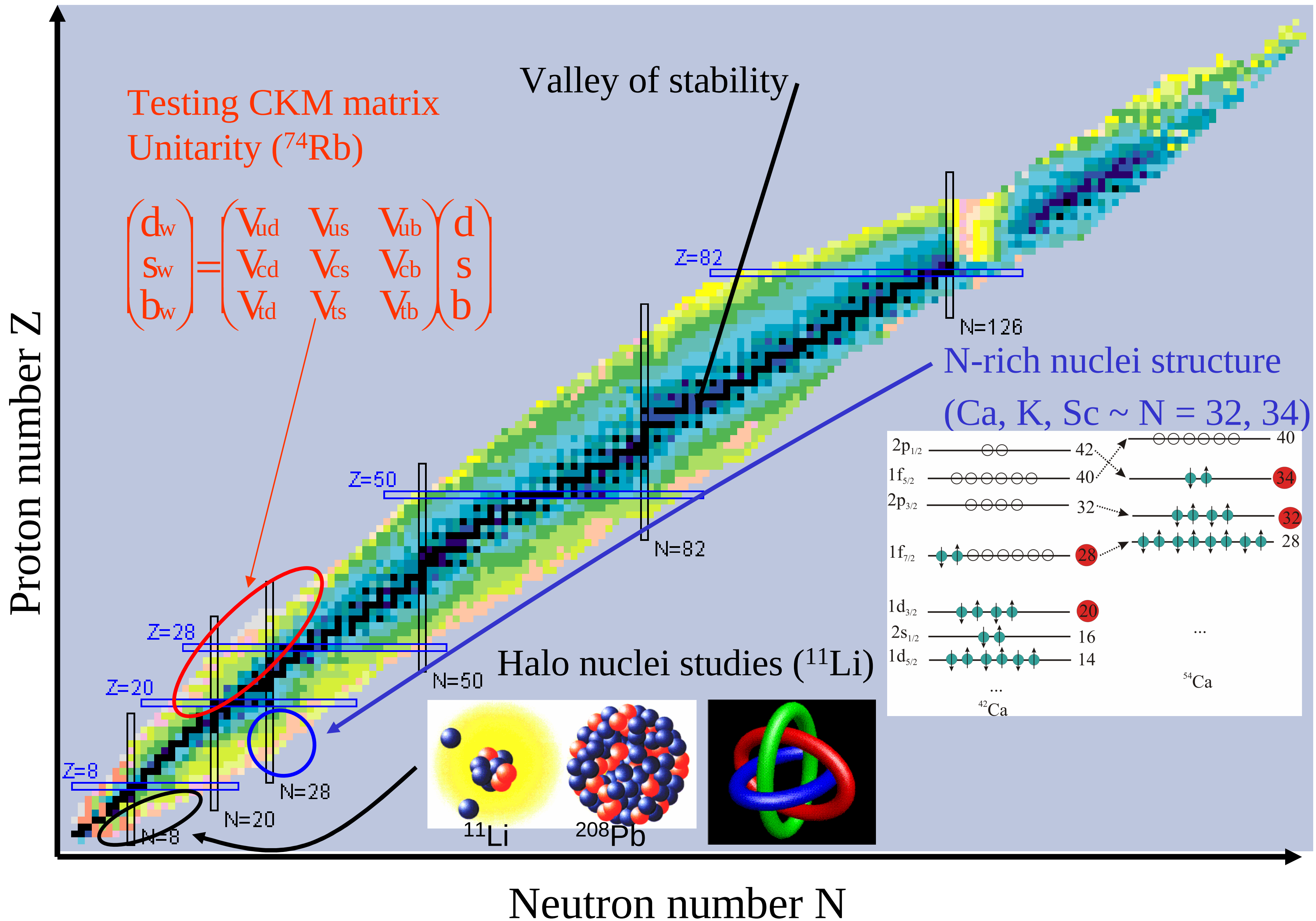
ISAC beam



TITAN MPET performs the high precision mass measurement.

Radio-Frequency Quadrupole (RFQ) cools and bunch the ISAC beam

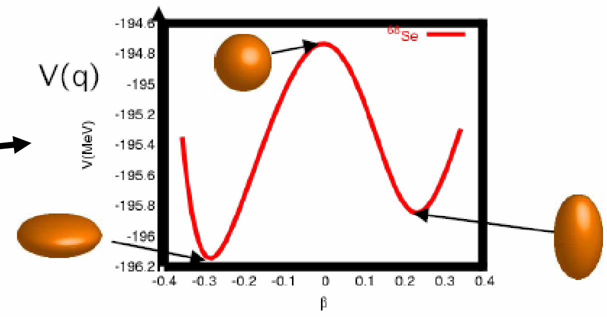
Motivation for Mass Measurement



Change of Neutron Rich Nuclear Structure

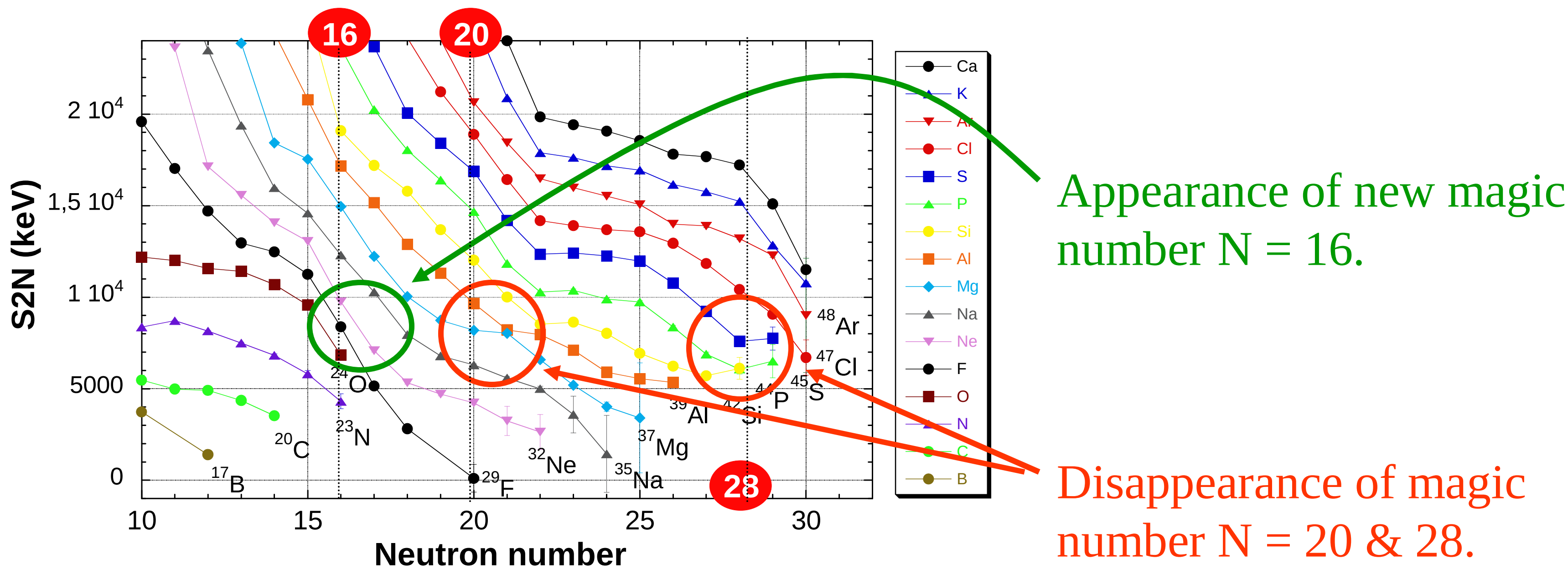
Structure Changes:

- Deformation
- Shape coexistence
- Variation of spin-orbit strength



Structure change are seen through two-neutron separation energy:

$S_{2n} = M(A\text{-}2, Z) - M(A,Z) + 2M_n$ (allows to avoid pairing effects)



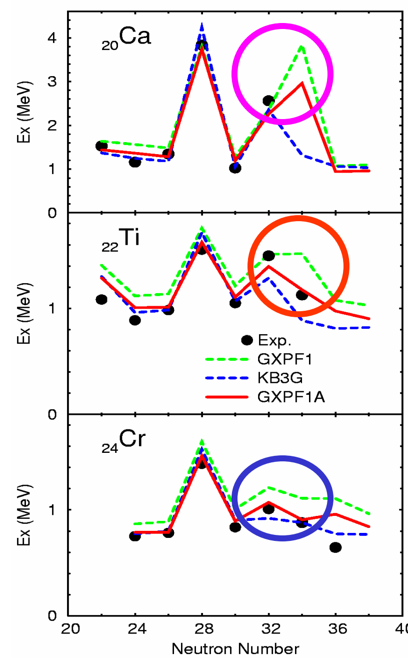
H. Savajols et al., Eur. Phys. J A 25, s01, 23 (2005)

Mass Measurement around N = 32 and N = 34

Motivations:

➡ A model predicts a new magic number at N = 34 for Ca. Honma et al., Phys. Rev. C 65, 1301R (2002)

➡ Experimental evidence of sub-shell at N = 32 in:
- Ti through measurement of the 2+ excited state energy. B. Fornal et al., Phys. Rev. C, 70, 064304 (2004)
- Cr through Penning trap mass measurement. C. Guénaut et al., J. Phys. G: Nucl. Part. Phys., 31, S1765 (2005)

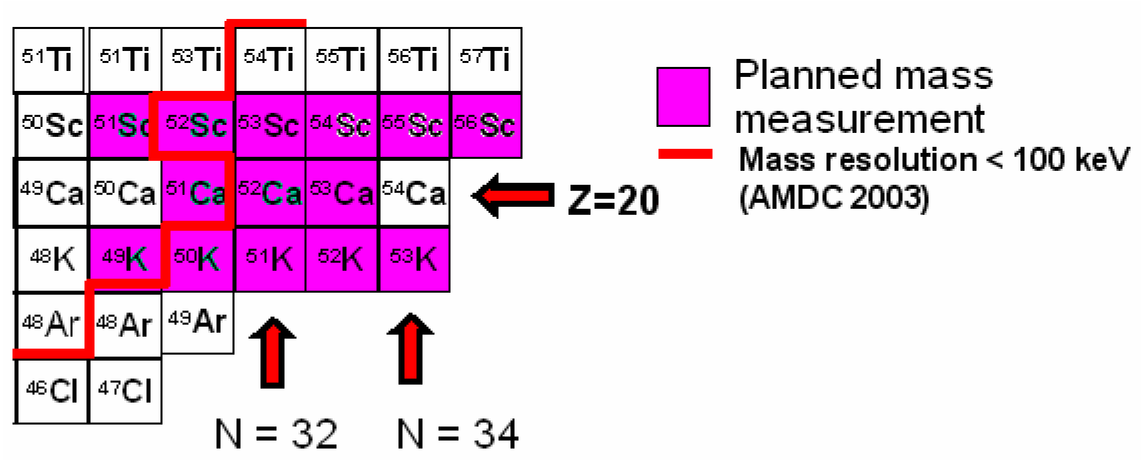


Needs verification through mass measurement considering:
- Sufficient precision: $\delta m/m \sim 10^{-6}$
- Short measurement time ($T_{1/2}$ = 90 ms for ^{53}Ca)

} TITAN Penning trap allows $\delta m/m < 10^{-8}$ for $T_{1/2}$ = 50 ms.

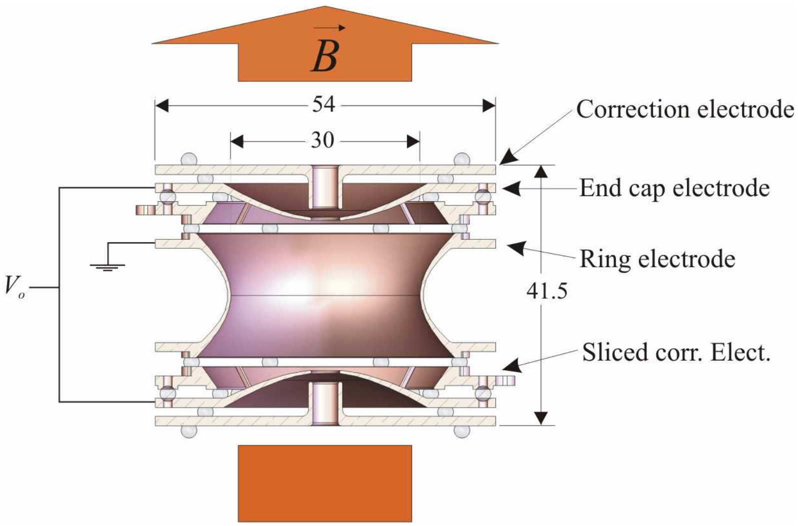
- Yield of at least 100 ions/s

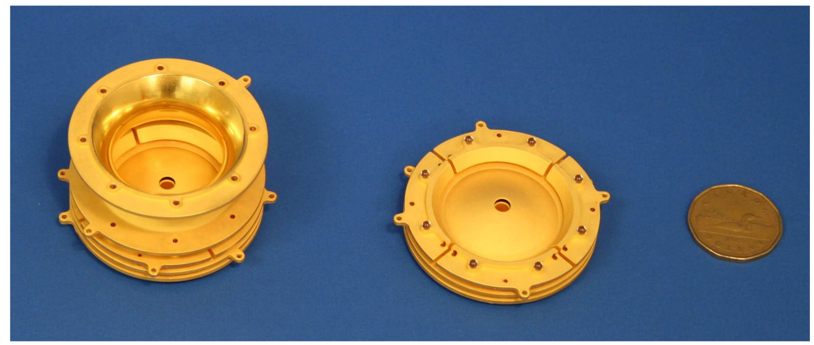
↳ Can be delivered by the Isotope Separator and Accelerator (ISAC) facility.



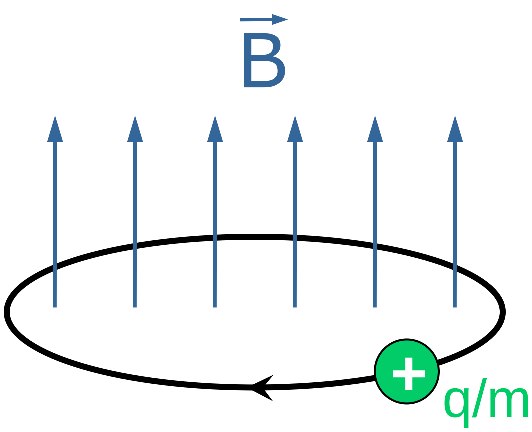
TITAN’s Mass Measurement Penning Trap

Penning trap structure





Mass determination



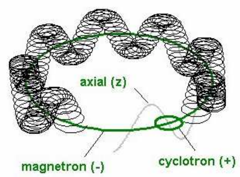
Cyclotron frequency: $\nu_c = \frac{1}{2\pi} \cdot \frac{q}{m} \cdot B$

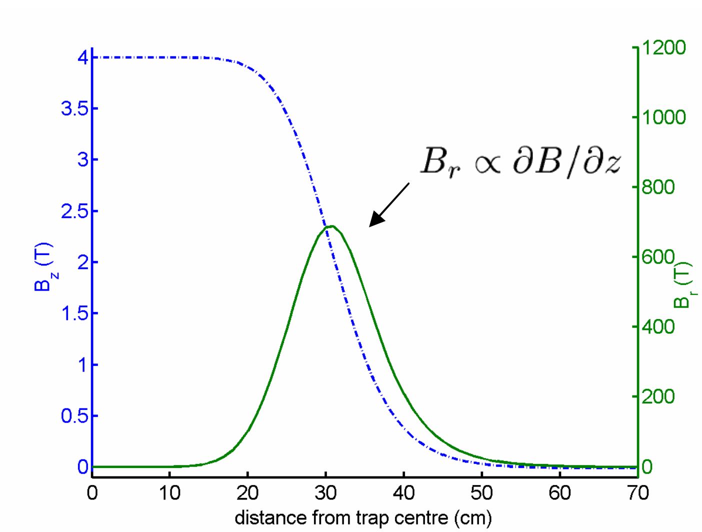
Resolution: $\frac{m}{\delta m} \approx \frac{T_{rf}\, q B \sqrt{N}}{m}$

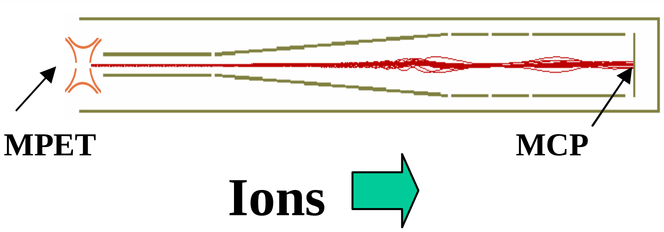
Time-Of-Flight (TOF) technique

In the process the ions are:

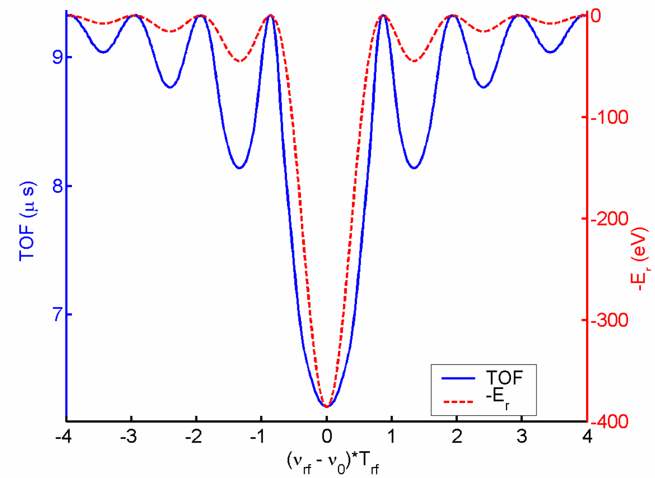
- submitted to an rf-excitation ω_{rf} of duration T_{rf}, then released
- accelerated by the magnetic field gradient: $\vec{F} = -\frac{E_r(\omega_{rf})}{B}\frac{\partial B(z)}{\partial z}\hat{z}$
- detect by an MCP where TOF is recorded







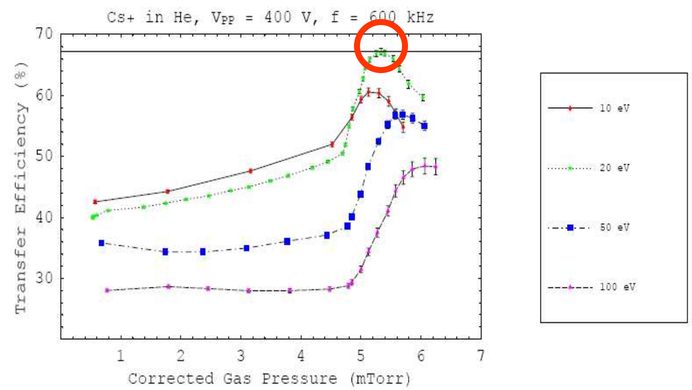
Large E_r = shorter TOF



The mass is found by a scan of ω_{rf} around the resonance: $\omega_{rf} = \omega_c = \frac{qB}{m}$

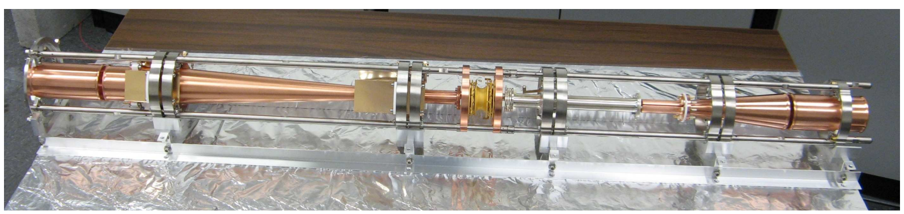
Status of the TITAN experiment

•RFQ has been tested with stable Li, Xe and Cs beams.
•69% transfer efficiency was obtained.
•rms emittance < 4 mm mrad at 4 keV.



•The EBIT has been fully commissioned in the ISAC experimental hall. *For more details about the EBIT see C. Champagne poster*.

•Penning trap and its optics are installed and aligned, ready for commissioning.



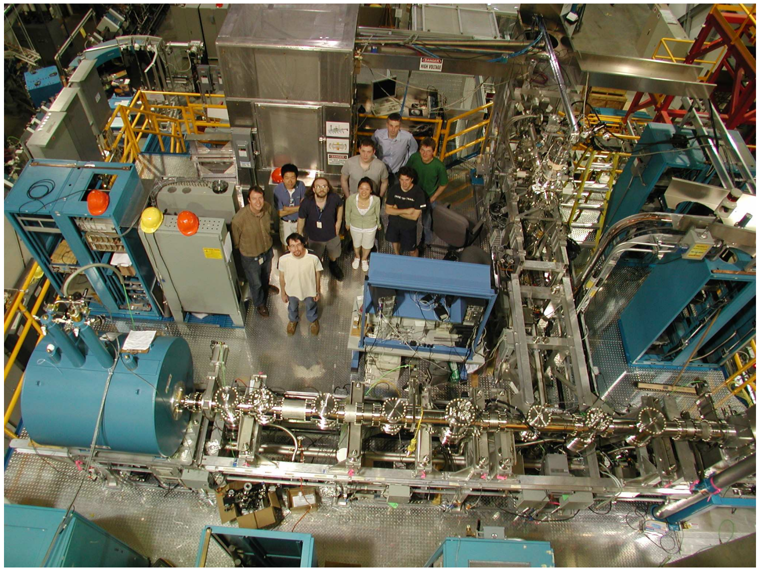
<u>Planned mass measurements</u>:

1. Halo nuclei study → ^{11}Li, August 2007
2. CKM unitarity test → ^{74}Rb, Winter 2007
3. Nuclear structure → Ca, K, Sc ~ N = 32, Spring 2008

Collaboration / Acknowledgement

<u>Special thanks to</u>:

The TITAN group at TRIUMF:



Jens Dilling, Thomas Brunner, Alexei Bylinskii, Christian Champagne, Paul Delheij, Melvin Good, Alain Lapierre, Cecilia Leung, Ryan Ringle, Vladimir Ryjkov, Mathew Smith

and the rest of the TITAN collaboration:

U. of Manitoba

McGill U.

Muenster U.,

Max Plank Inst. of Heidelberg

GANIL

U. of Calgary

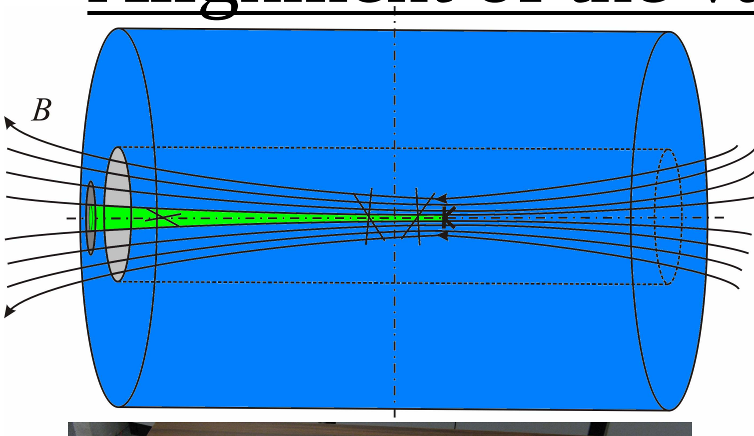
U. of Windsor

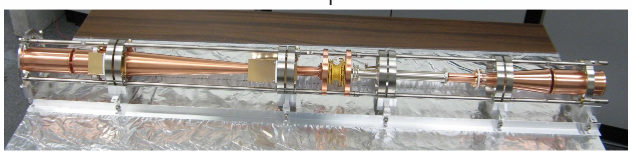
Colorado School of Mines

TRIUMF

UBC

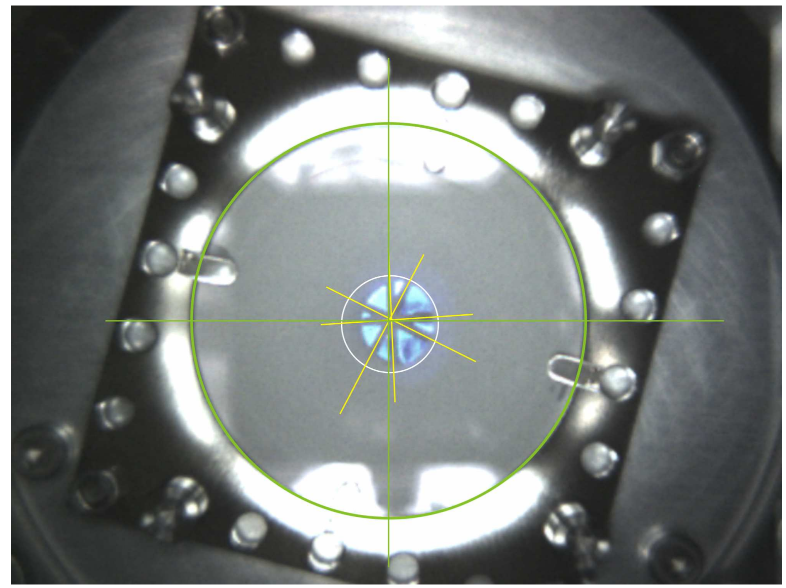
Alignment of the vacuum chamber





In the strong field region:

- 1 mm wide electron beam
- Two 0.1 mm thick “crossed-hair” mask
- e-gun and masks attached on electrode structure



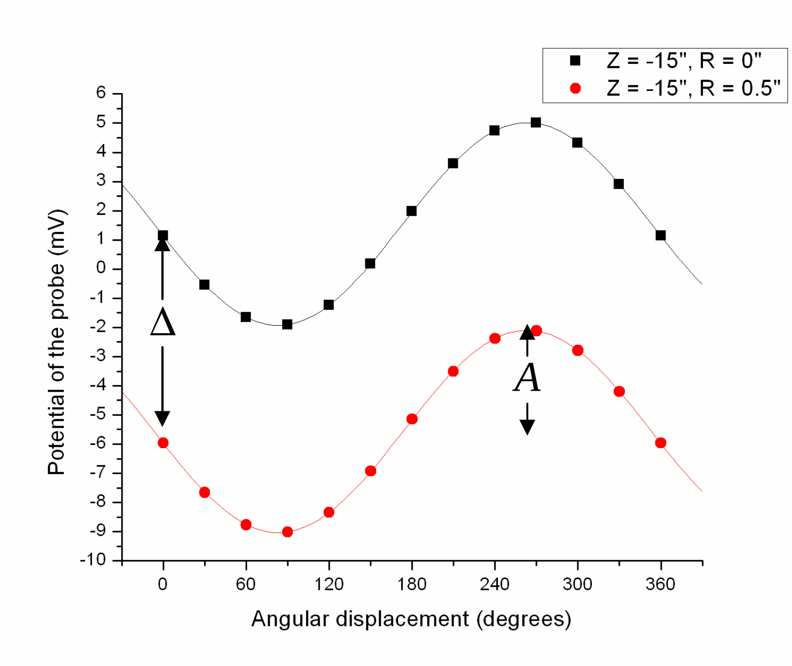
At the phosphor screen:

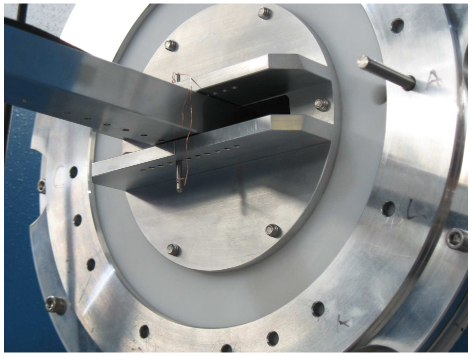
- 1 cm wide electron beam
- Crosses appear 1 mm thick
- Magnification: 10 fold

	Accuracy needed	Alignment accur.
Radial position of the chamber with the field.	±0.1 mm	±0.03 mm
Angular position of the chamber with the field.	±1 mrad	±0.2 mrad

Determination of the magnetic field centerline

Determined by turning a radial Hall probe at different radial position *R* from the bore centre.





	Hall probe (inches)	e-gun (inches)
Vertical shift (down)	0.245(5)	0.242(3)
Horizontal shift (east)	0.025(5)	0.030(3)

The displacement *D* is given by: $D \cong A \bullet R / \Delta$

The centreline is offset by ~ ¼”.
Compensated by offsetting the beam line.