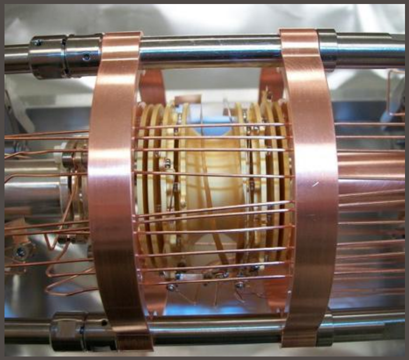
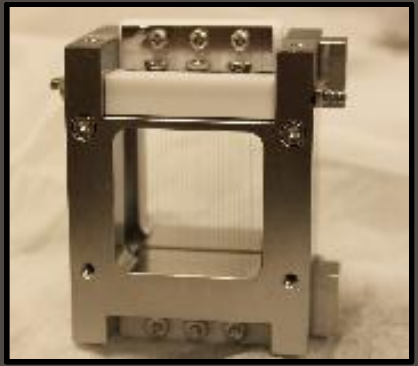
TRIUMF

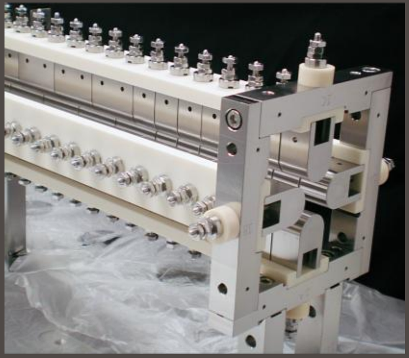
Canada's national laboratory for particle and nuclear physics
Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules

Penning Trap Mass Spectrometry with TITAN

Precision Mass Measurement of Short-lived Nuclei to Explore the Island of Inversion





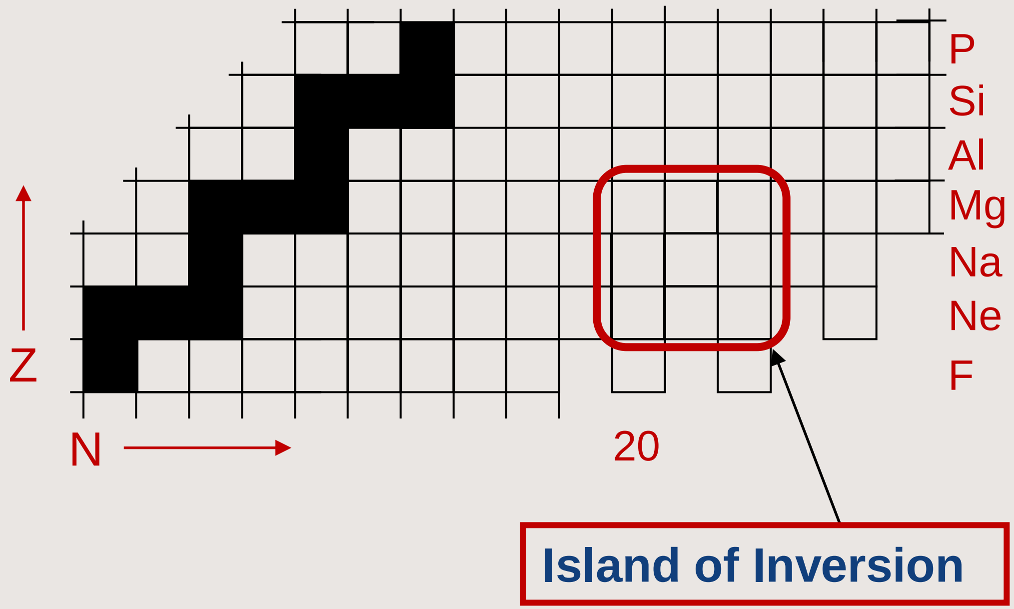


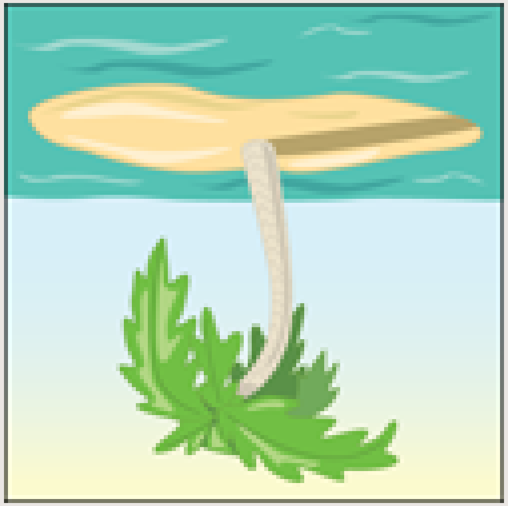
Ankur Chaudhuri

for the TITAN collaboration

WNPPC-2012, Mont Tremblant, February 26, 2012

Island of inversion





Credit: Carin Cain

C. Thibault et al., Phys. Rev. C12 (1975) 644

The first observation of irregularities in the binding energies of neutron-rich $A \approx 32$ nuclei and the suggestion that this might be due to deformation

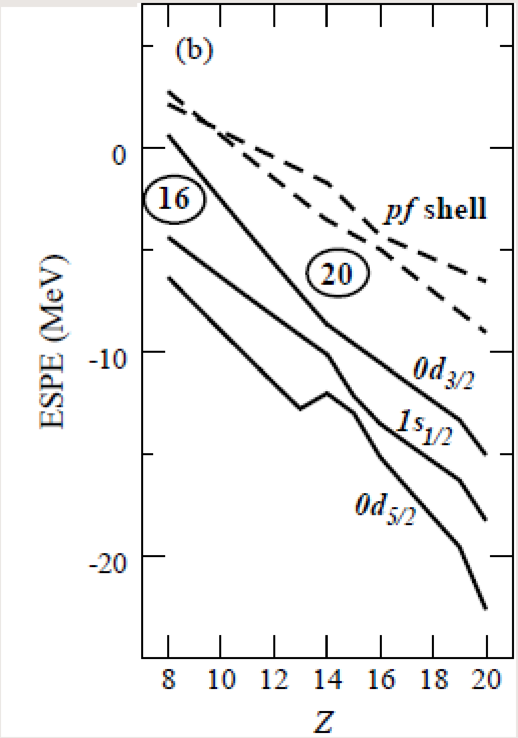
Island of inversion

The breakdown of the N = 20 magic structure

E.K. Warburton, J. A. Becker
and B. A. Brown, PRC**41**(1990)1147

- Nuclear deformation and the resultant inversion of the standard *sd*-shell configuration and *pf*-shell intruder configuration.

- The reduced N = 20 shell gap allows *pf*-shell intruder configurations, in the form of multiparticle, multihole (np-nh) cross shell excitations.

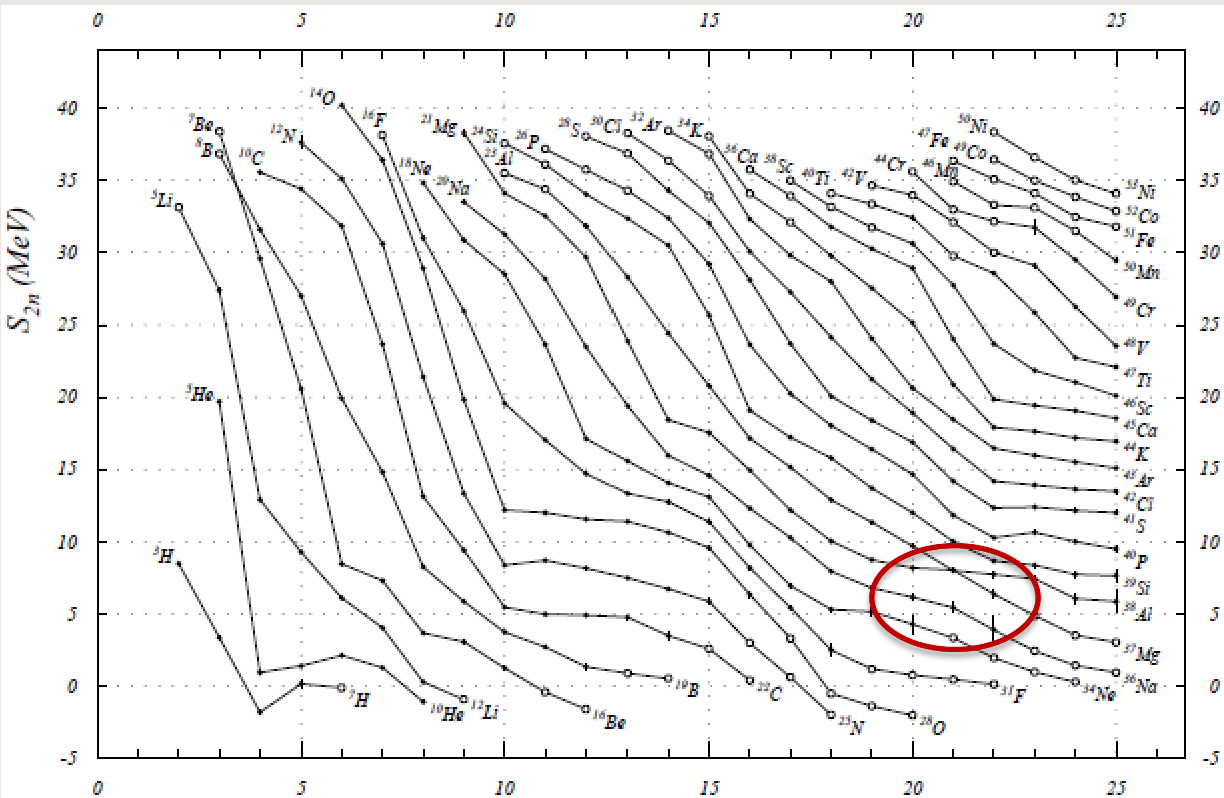


T. Osuka et al., European Physics Journal A 15 (2002) 151

Island of inversion

View on the island of inversion through S_{2n}:

Vanishing of a shell closure at N=20

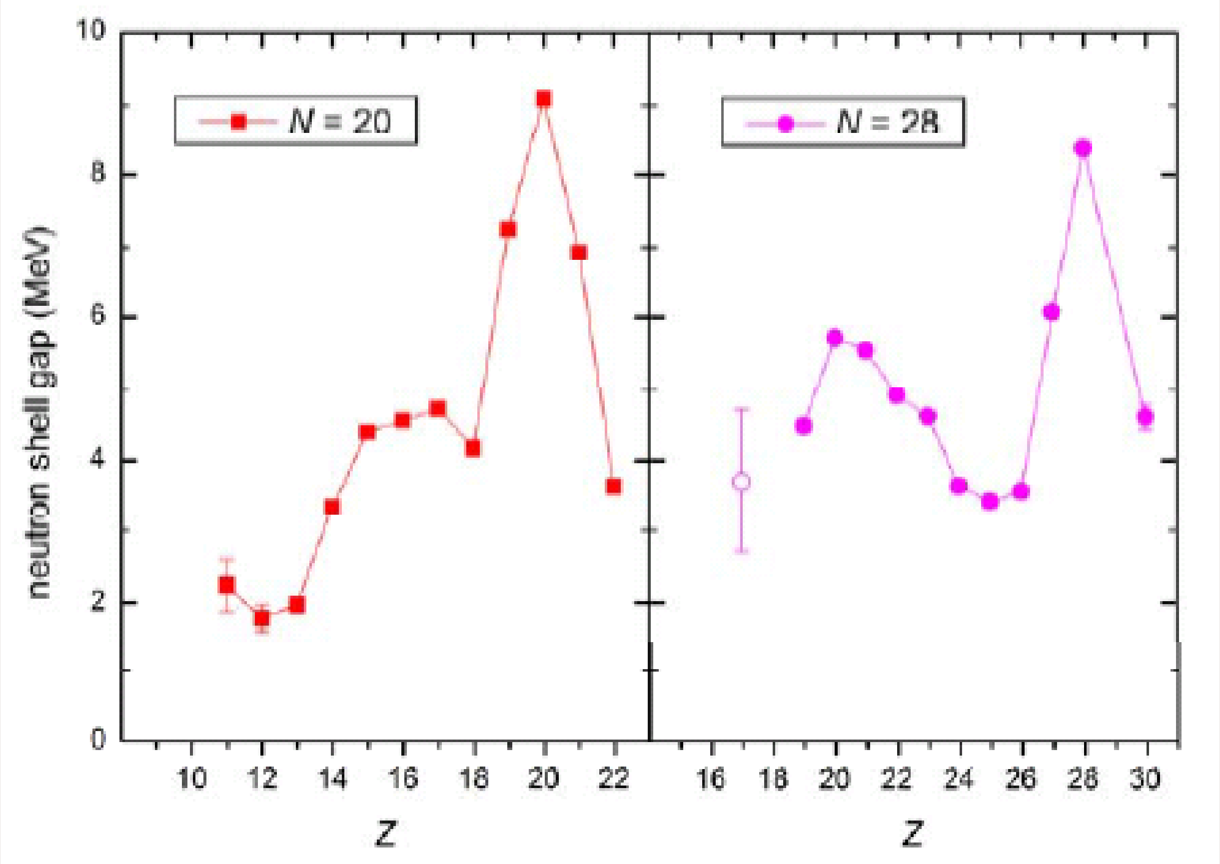


S_{2n}=BE(Z,N)-BE(Z,N-2)
=-M(Z,N)+M(Z,N-2)+2m_n

G. Audi et al., Nucl. Phys. A 729 (2003) 337

Island of inversion

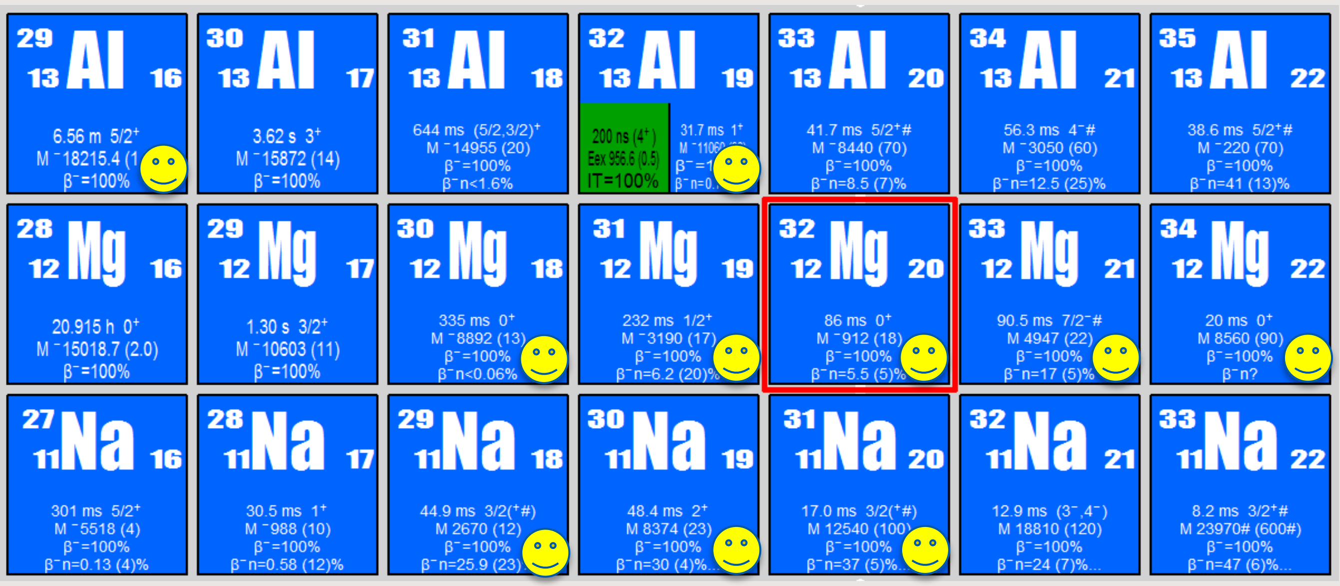
The shell gap illustrates the magic number disappearance for N=20



Neutron shell gap= $S_{2n}(Z,N)-S_{2n}(Z,N+2)$

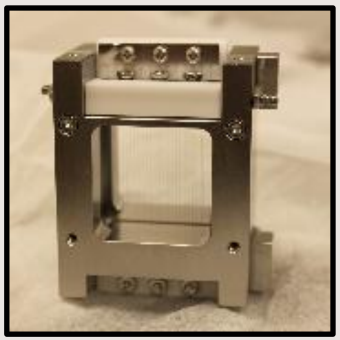
Figure courtesy:
TRIUMF EEC proposal S1240

TITAN measurement

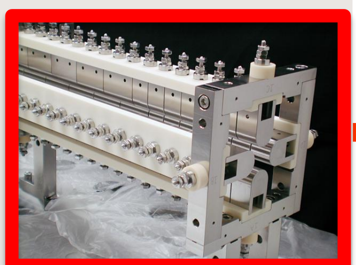


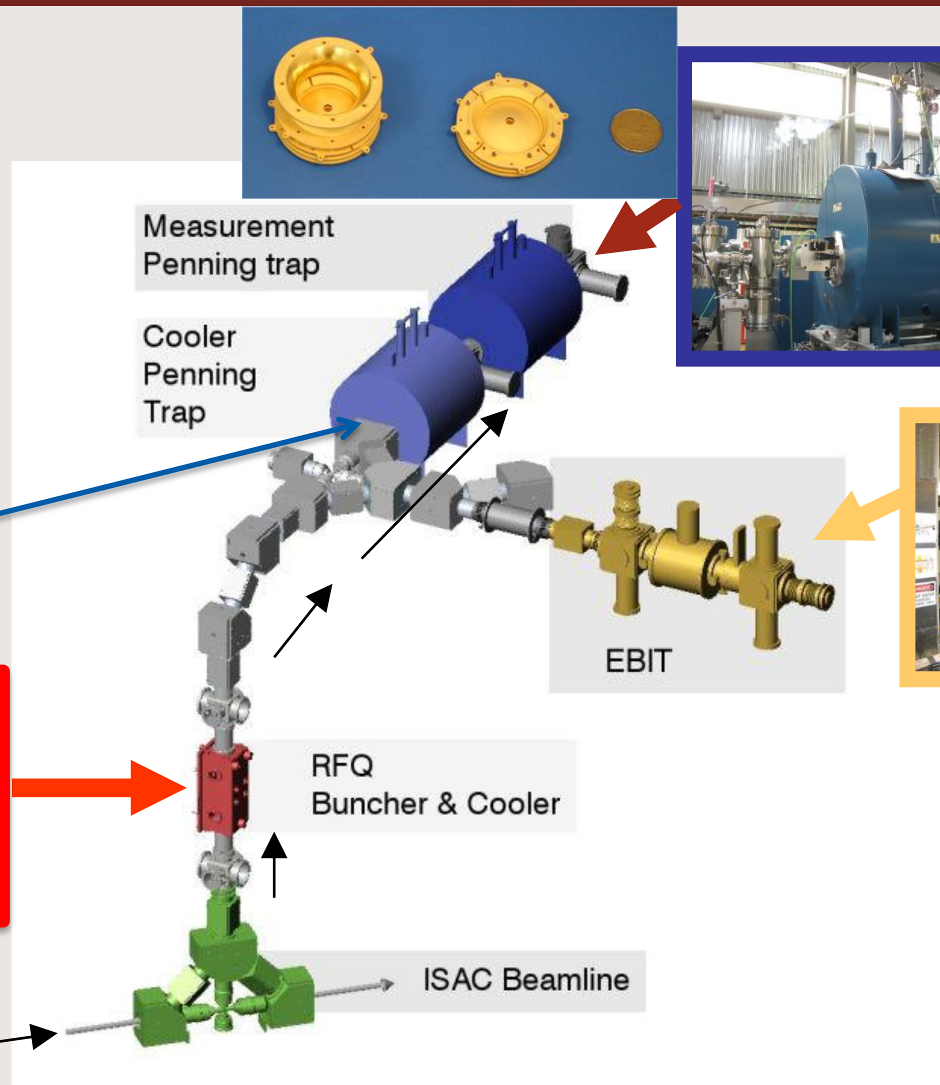
Isotopes	$T_{1/2}$
^{30}Mg	335 ms
^{31}Mg	232 ms
^{32}Mg	86 ms
^{33}Mg	90.5 ms
^{34}Mg	20 ms
^{29}Na	44.9 ms
^{30}Na	48.4 ms
^{31}Na	17 ms
^{29}Al	6.56 min
^{32}Al	31.7 ms

TITAN set-up



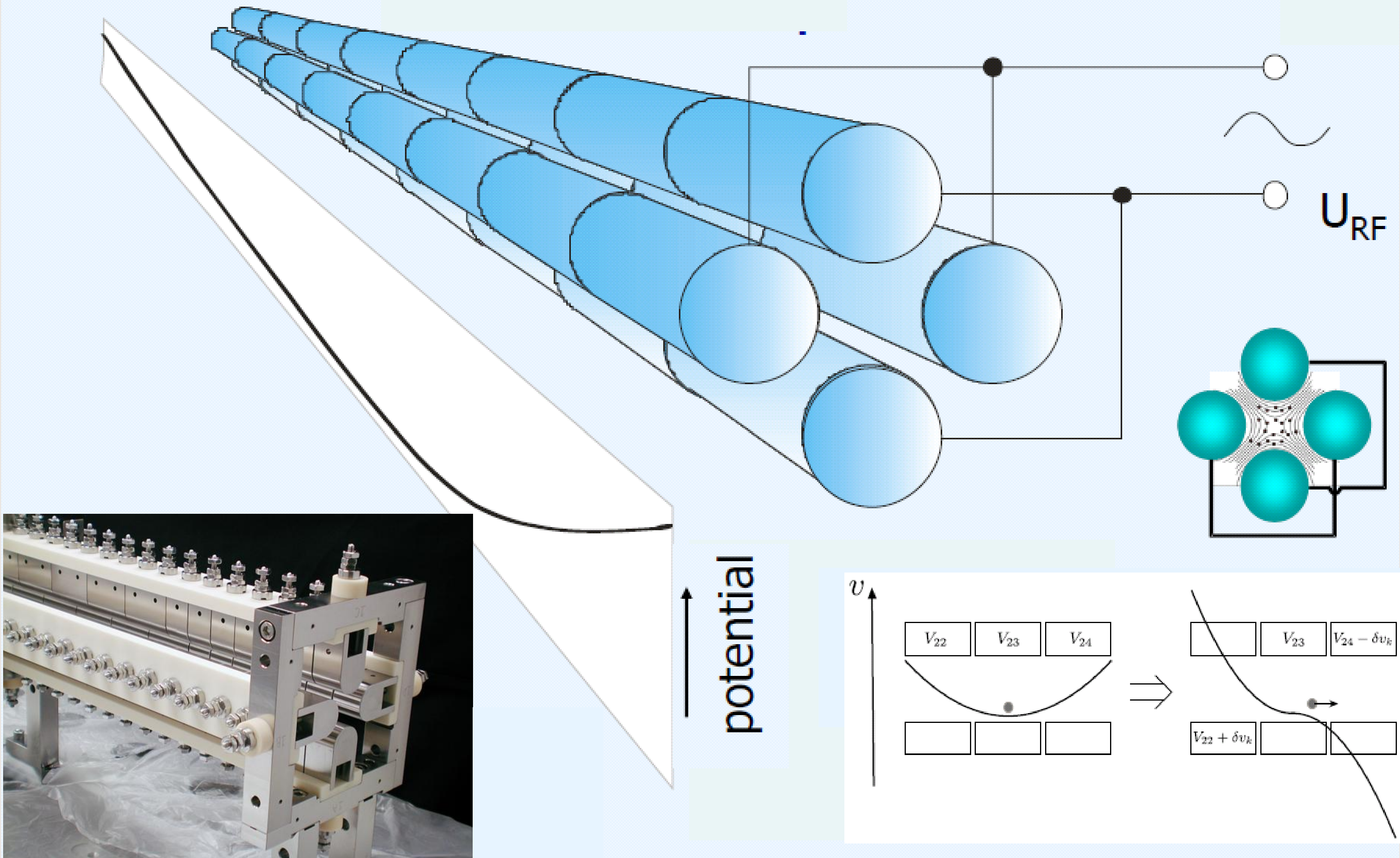
Bradbury–Nielsen Gate



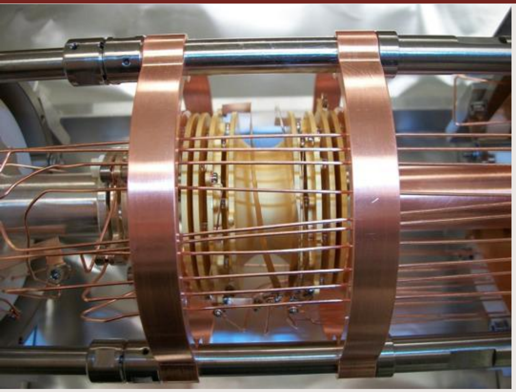


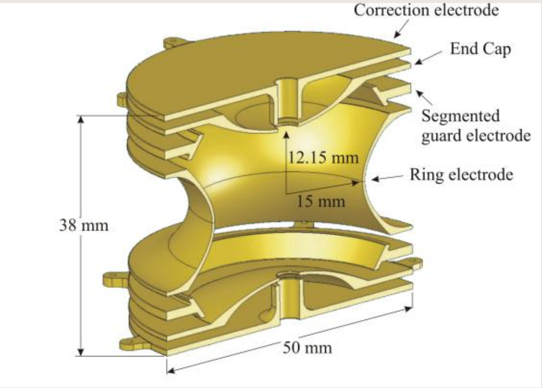
Radio-active ion

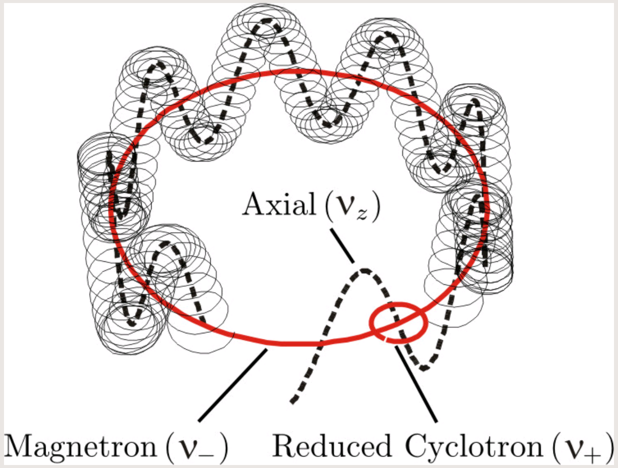
RFQ Buncher & Cooler



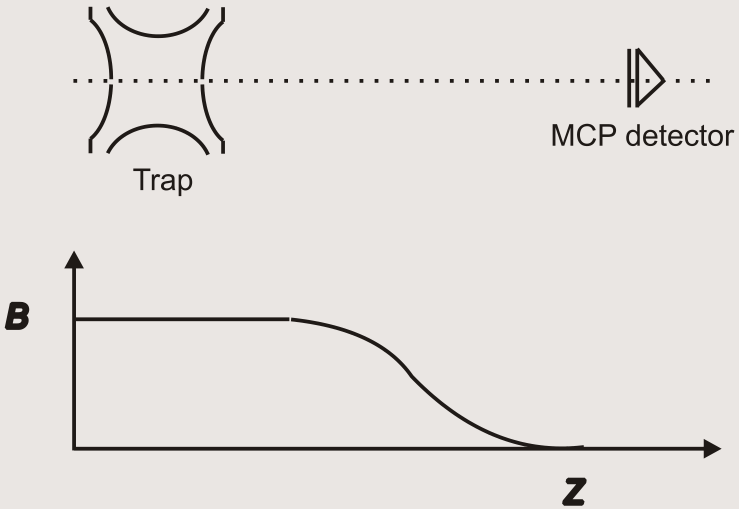
Penning trap mass spectrometry

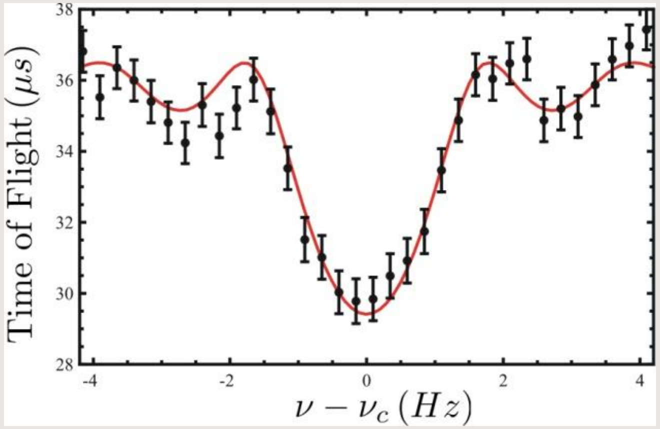






$$\nu_c = \nu_+ + \nu_- = \frac{1}{2\pi}\frac{q}{m}B$$





Penning trap mass spectrometry

Determine mass via cyclotron frequency measurement

$$\nu_C = \frac{1}{2\pi}\frac{qB}{m_{ion}}$$

Magnetic field calibration

$$\nu_{c,ref} = \frac{1}{2\pi}\frac{q_{ref}B}{m_{ion,ref}}$$

$$\frac{m_{ion}}{m_{ion,ref}} = \left(\frac{\nu_{c,ref}}{\nu_c}\right)\left(\frac{q}{q_{ref}}\right)$$

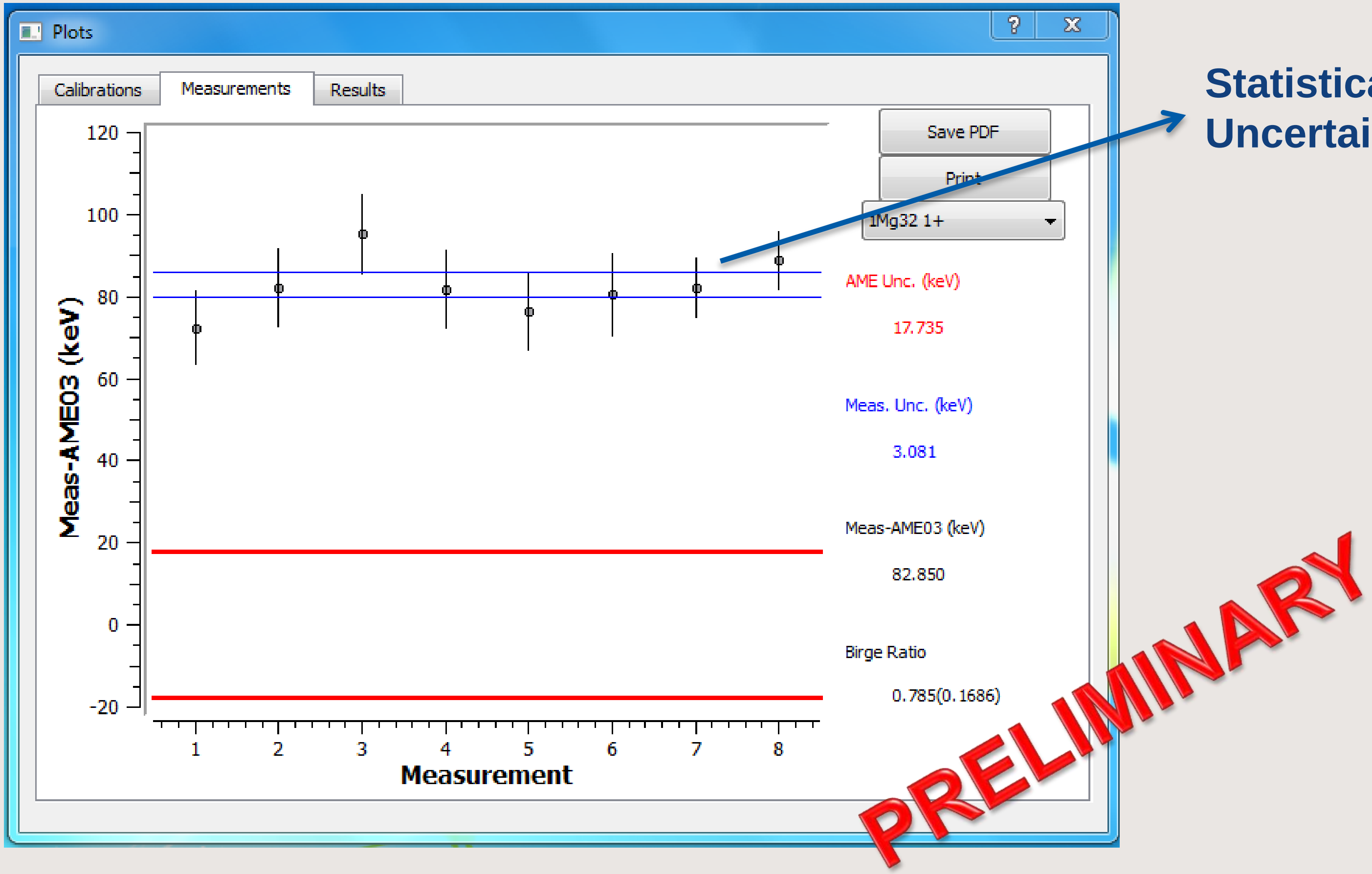
$\Rightarrow$ **atomic mass**

$$m = r\left(m_{ref} - m_e\right) + m_e$$

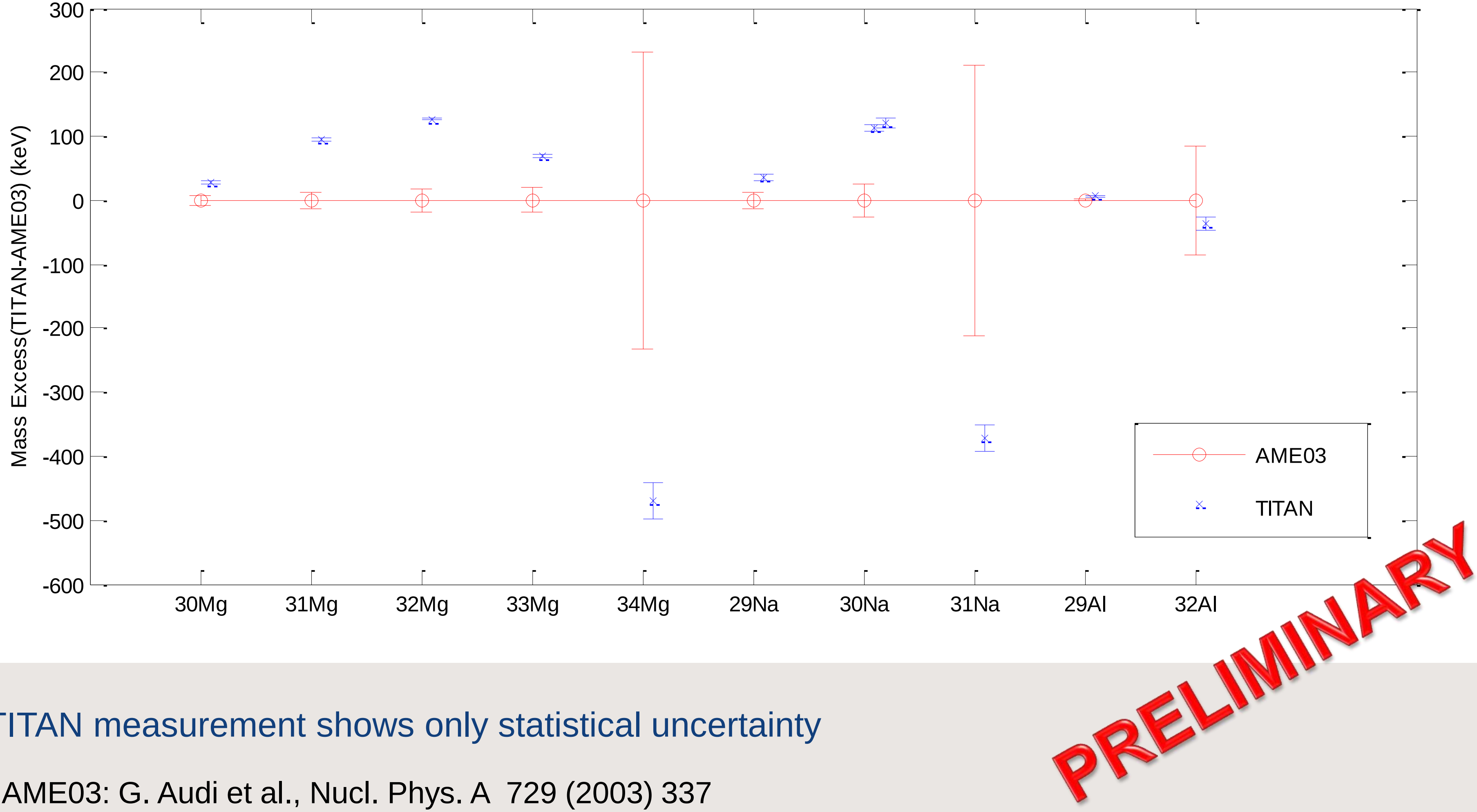
$$r = \frac{\nu_{c,ref}}{\nu_c}$$

Mass measurement

- Example : ^{32}Mg
- Reference ion: $^{16}O_2$
- Measurement cycle : 10Hz



Preliminary results

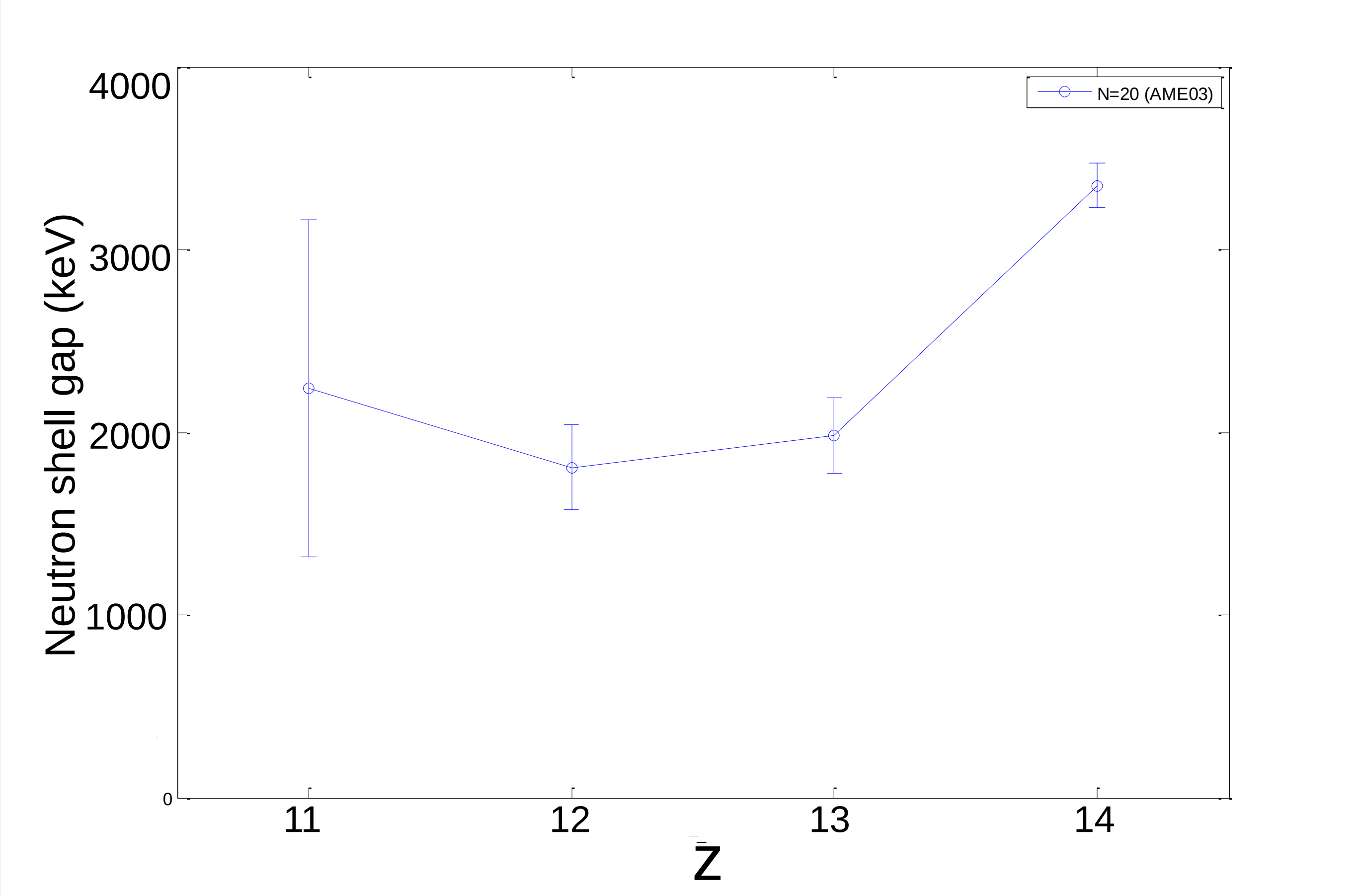


* TITAN measurement shows only statistical uncertainty

AME03: G. Audi et al., Nucl. Phys. A 729 (2003) 337

Neutron shell gap

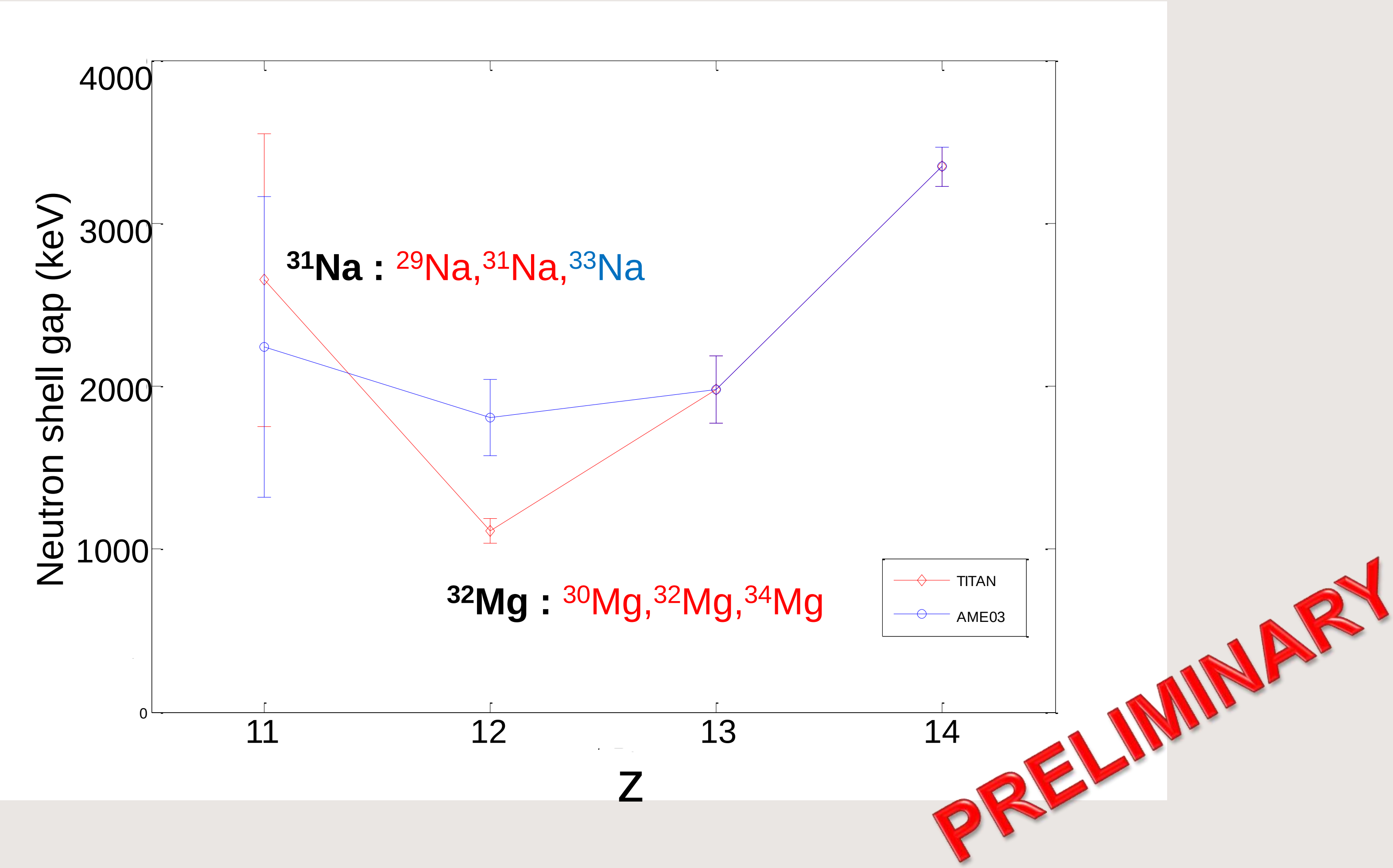
Neutron shell gap $\Delta = S_{2n}(Z,N) - S_{2n}(Z,N+2)$ for N=20



AME2003: G. Audi et al., Nucl. Phys. A 729 (2003) 337

Neutron shell gap

Neutron shell gap $\Delta = S_{2n}(Z,N) - S_{2n}(Z,N+2)$ for N=20



Summary

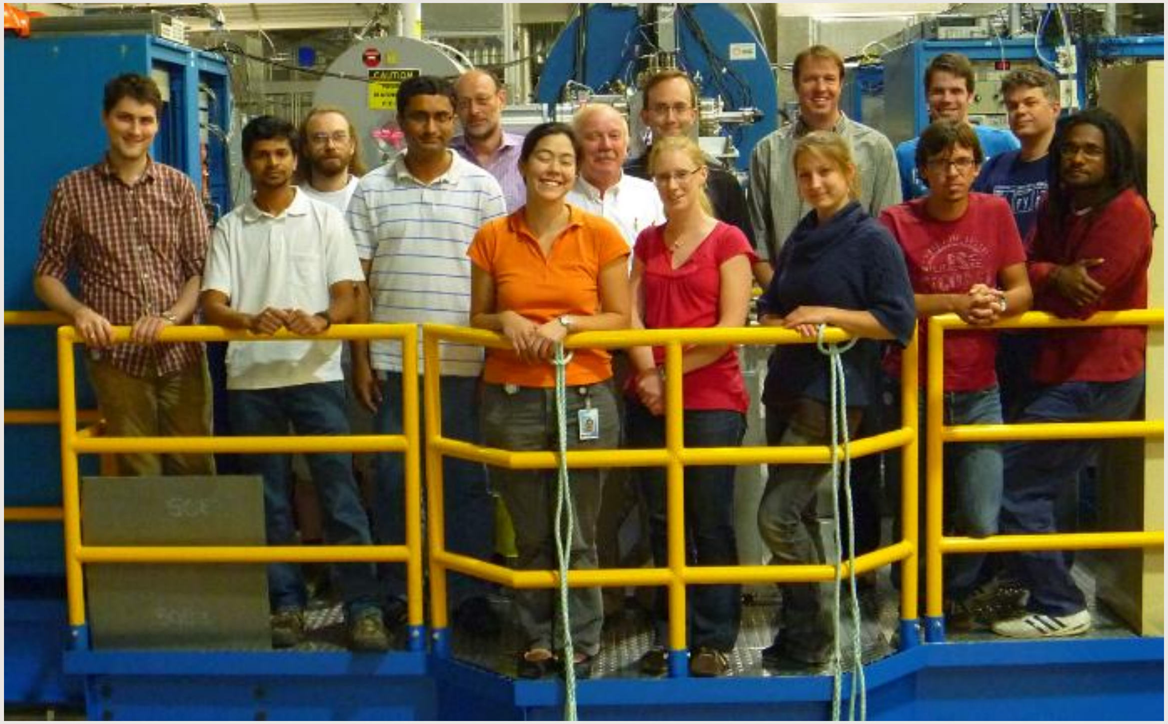
- **Masses of ten short-lived nuclei in the region of island of inversion were measured using TITAN facility. Those are $^{29-31}$Na, $^{30-34}$Mg and ^{29,32}Al.**

- **TITAN is the only Penning trap facility capable of carrying out such high-precision mass measurements due to the very short half-lives involved.**

- **New mass values from TITAN deviate by 2-7 sigma from the literature values. Uncertainty of TITAN measurement ~ 10-30 keV depending on the half-life of the isotope.**

- **Preliminary analysis confirms the disappearance of magic number at N=20 around Z=12.**

TITAN Collaboration



Jens Dilling, Corina Andreoiu, Paul Delheij, Gerald Gwinner, Dieter Frekers, Melvin Good, David Lunney, Mathew Pearson, Ankur Chaudhuri, Alexander Grossheim , Ania Kwiatkowski, Ernesto Mané, Martin Simon, Brad Schultz, Thomas Brunner, Usman Chowdhury, Stephan Ettenauer, Aaron Gallant, Annika Lennarz, Tegan D Macdonald, Vanessa Simon

Thank you!
Merci

TRIUMF: Alberta | British Columbia | Calgary Carleton | Guelph | Manitoba | McMaster Montréal | Northern British Columbia | Queen's Regina | Saint Mary's | Simon Fraser | Toronto Victoria | Winnipeg | York