S1191 & S1374. High precision mass measurements of Al and Mg isotopes.

ISAC Science Forum

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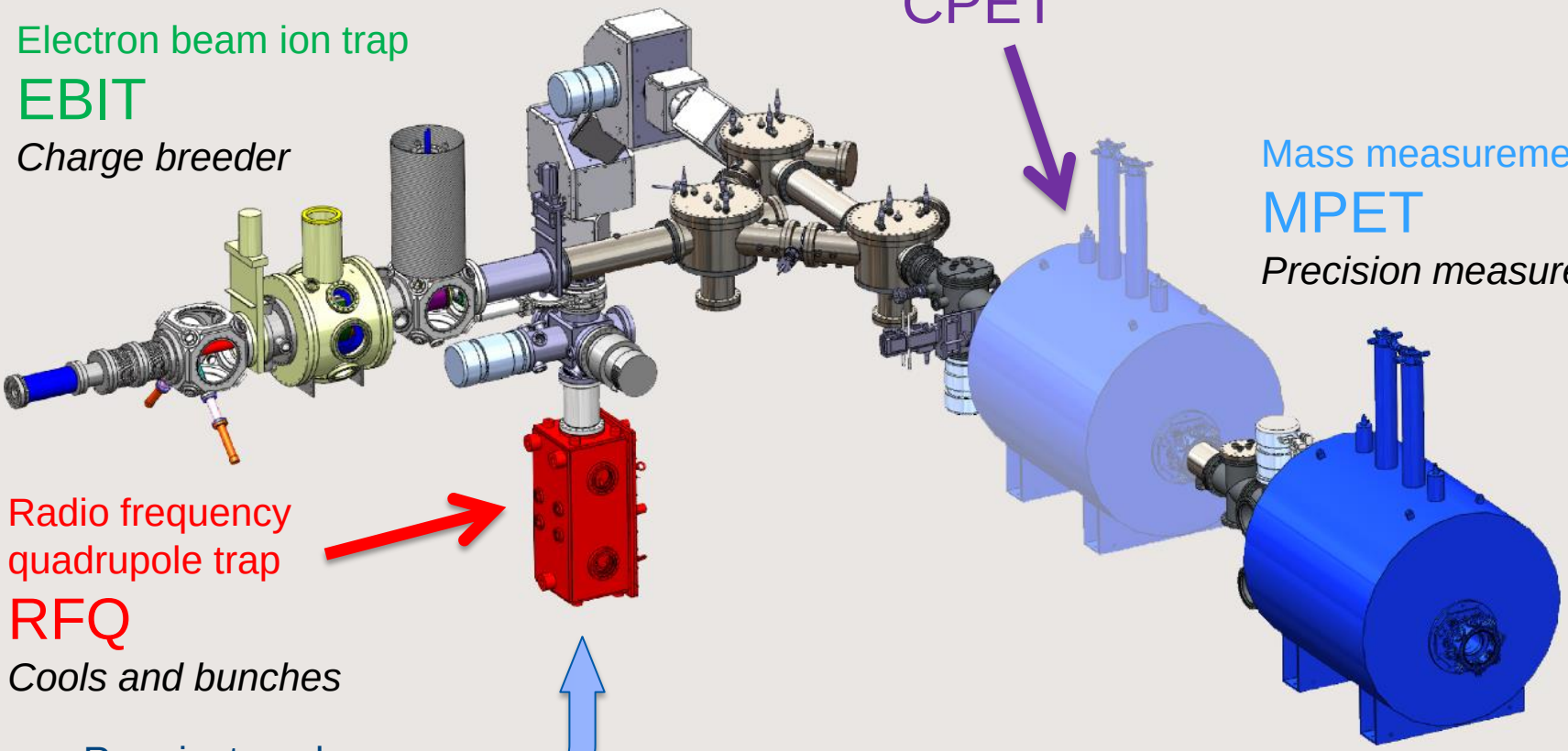
Motivation

- Isobaric multiplet mass equation (IMME) is a powerful predictive tool for masses
- Charge independence of nuclear force leads to quadratic behavior of binding energy with respect to isospin projection $T_z = (N - Z)/2$
- Large deviations from the expected quadratic behavior require addition of higher-order terms
- ^{20}Mg and ^{21}Mg are ideal test cases as their respective multiplets contain only particle-bound nuclei
- Reactions in classical novae involving ^{24}Al influence amounts of key astronomical elements, e.g. ^{22}Na

TITAN



Future location of cooler Penning trap
CPET

Electron beam ion trap
EBIT
Charge breeder

Mass measurement trap
MPET
Precision measurement

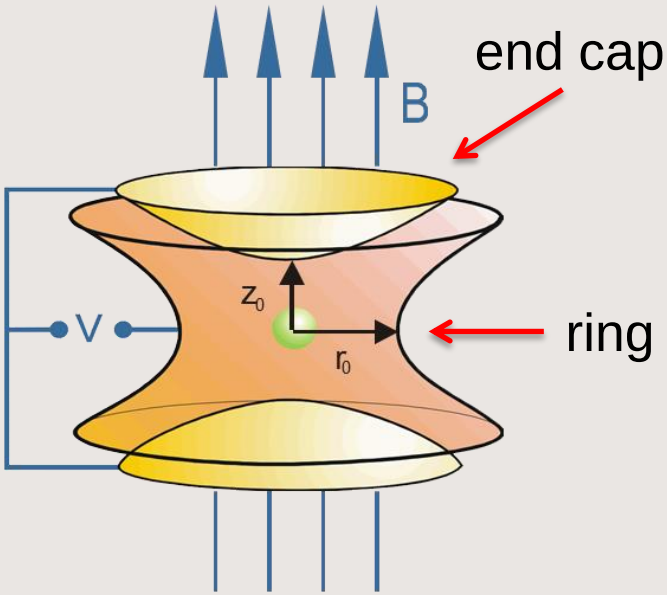
Radio frequency quadrupole trap
RFQ
Cools and bunches

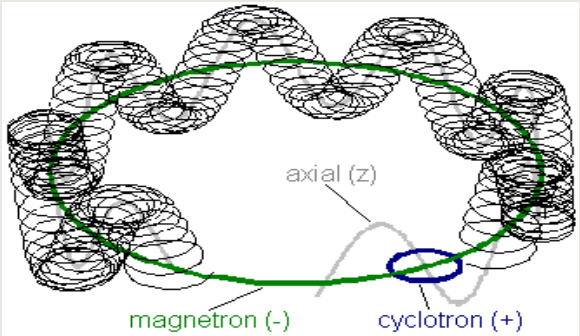
Rare isotope beam
ISAC

TITAN ion source
TIS

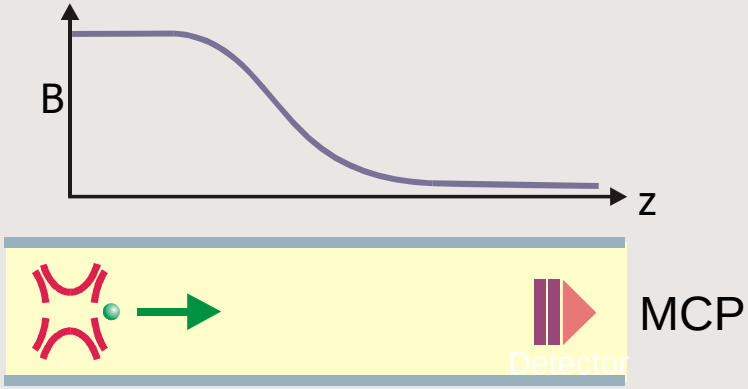
Al & Mg

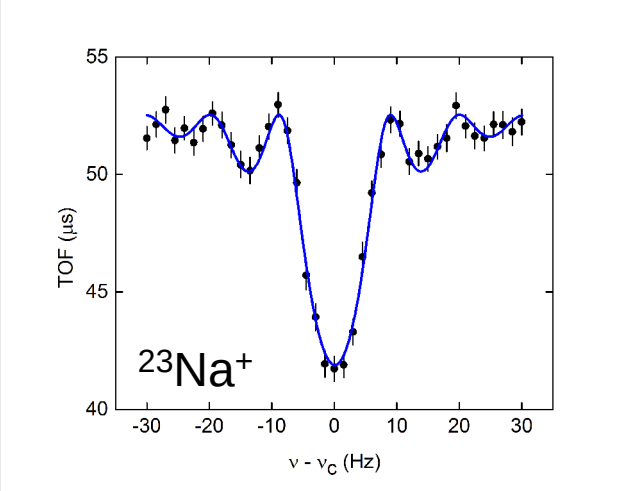
Penning Traps and TOF-ICR





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



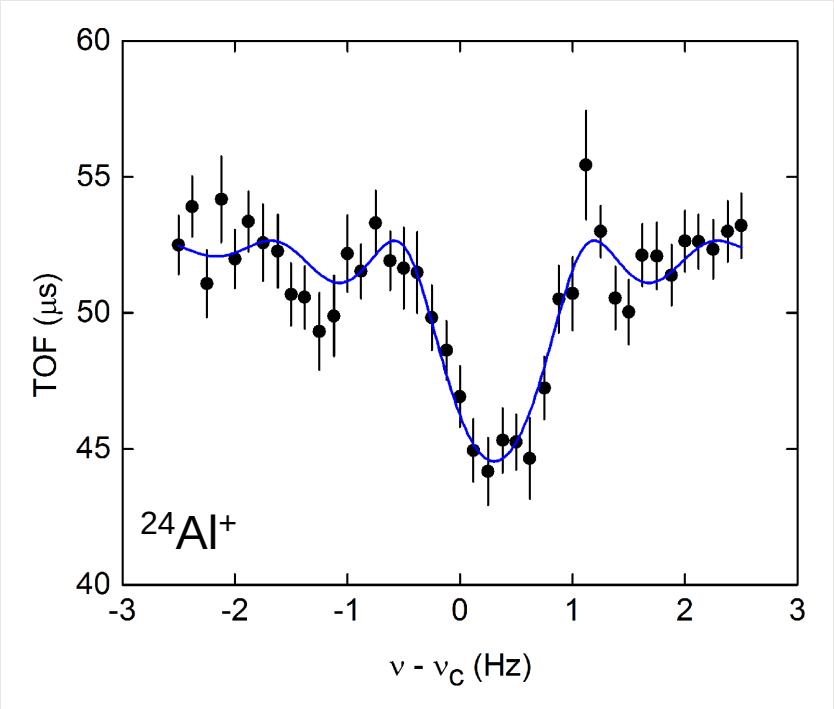


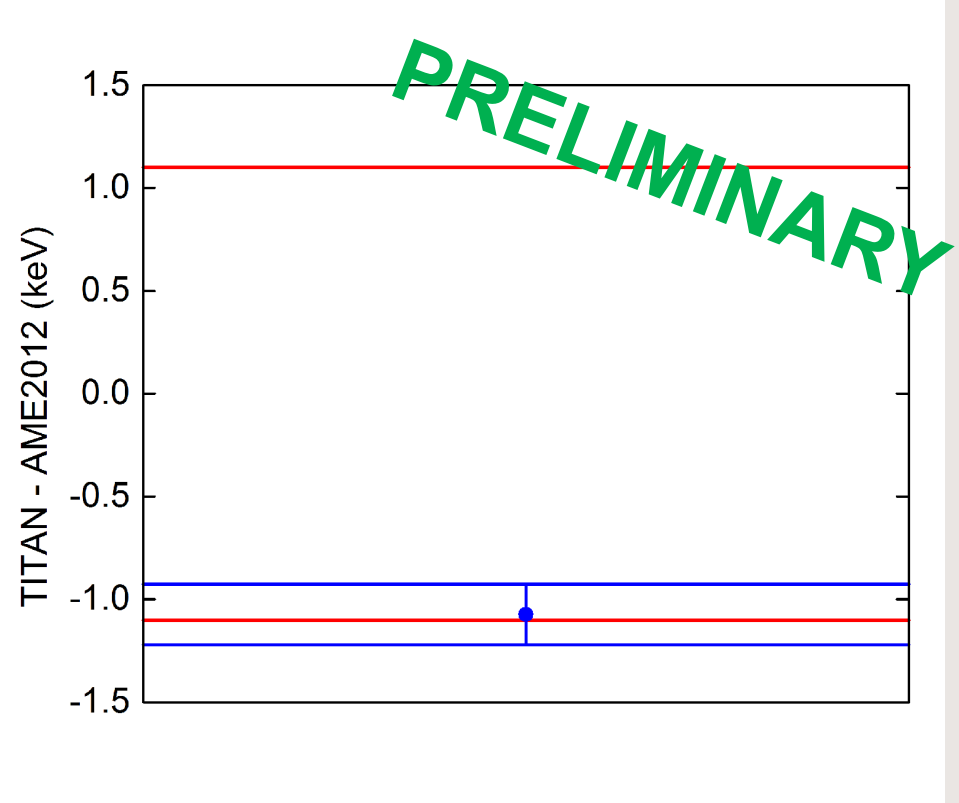
Measured Isotopes

- Seven isotopes measured over the course of 6 days

Isotope	Half-Life
^{24}Al	2.1 sec
^{20}Mg	90 msec
^{21}Mg	122 msec
^{23}Mg	11.3 sec
^{27}Mg	9.5 min
^{28}Mg	20.9 hr
^{29}Mg	1.3 sec

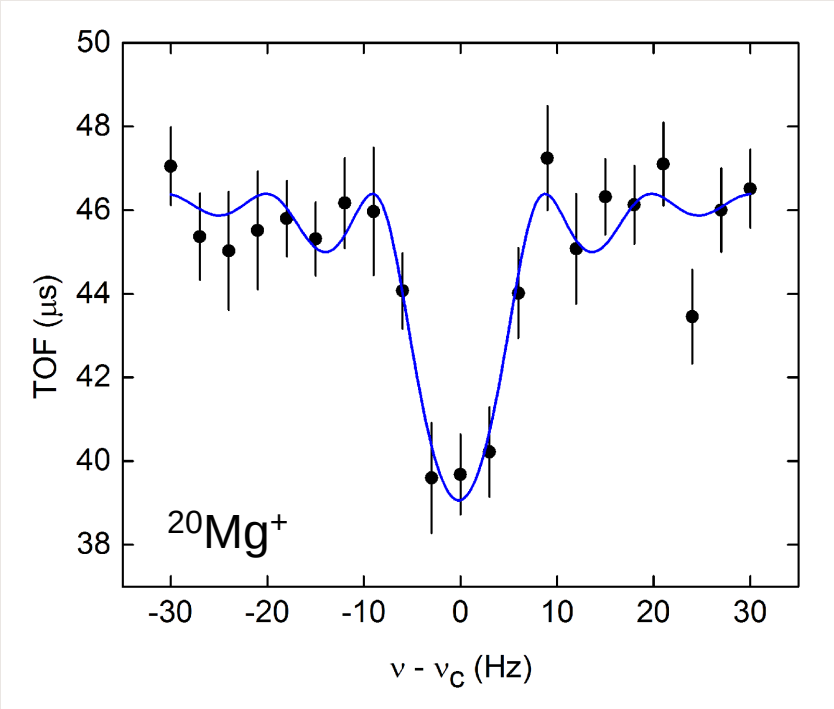
Results: ^{24}Al

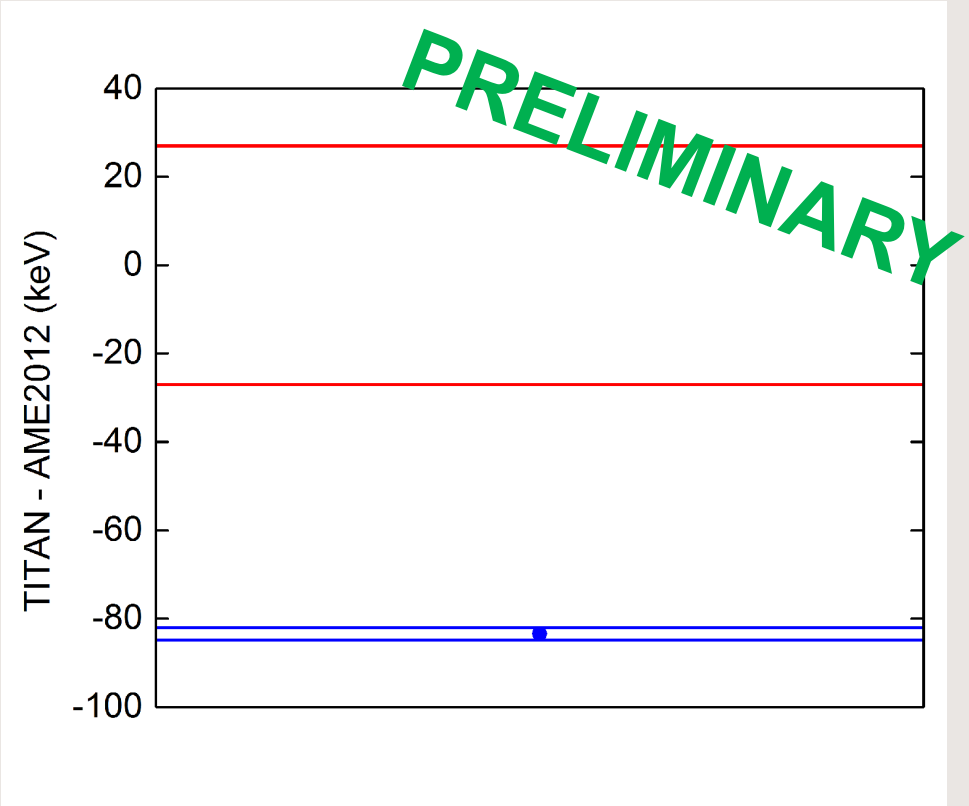




- About 100 pps ^{24}Al, 500 pps background
- Estimate contaminate ratio Al – Na – Mg ~ 35% - 51% - 14%
- Almost factor of 40 gain in ^{24}Al counts with lasers on

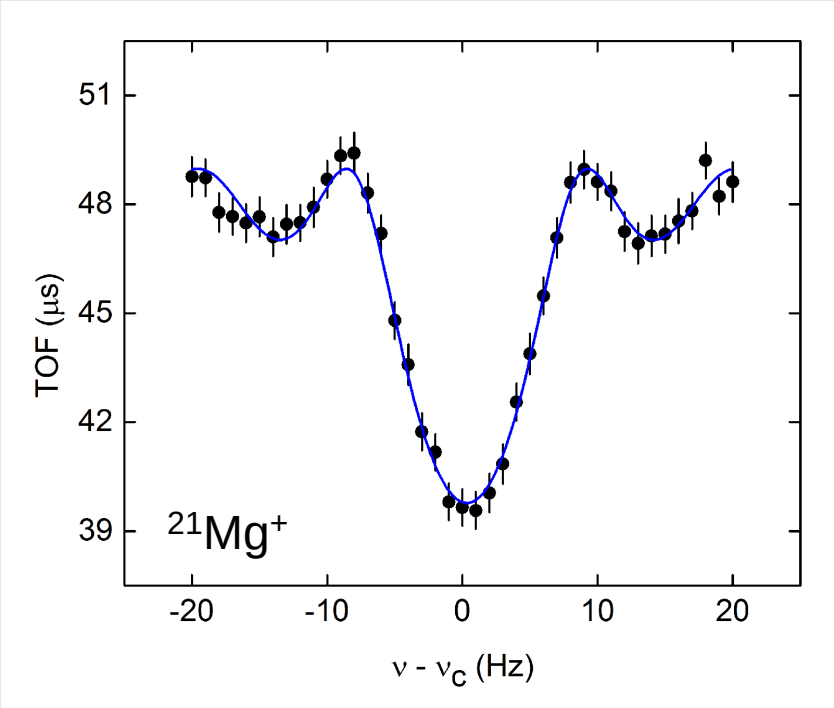
Results: ^{20}Mg

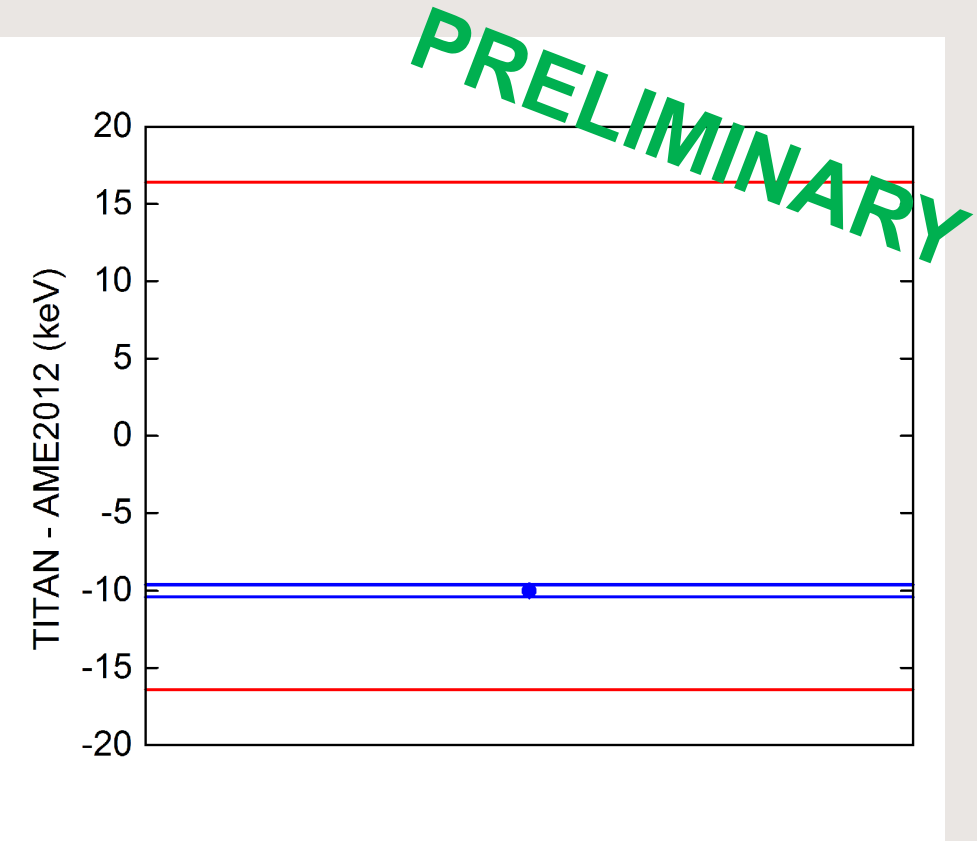




- About 120 pps on channeltron in front of RFQ
- No detectable contamination

Results: ^{21}Mg





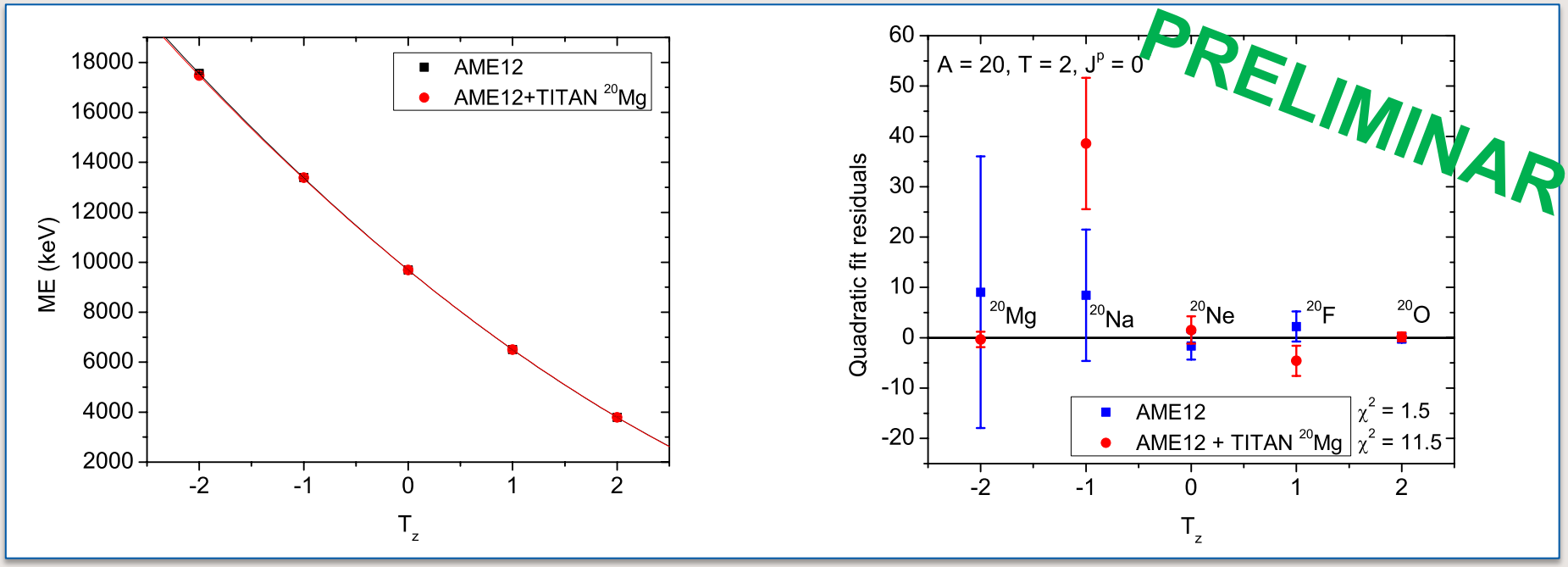
- Yields: 1500 pps ^{21}Mg, 4500 pps total
- Estimate only < 1% contaminant level

IMME

- The strong interaction is essentially charge-independent
- Nuclei about the $N = Z$ line share a series of isobaric analogue states (same spin J, parity p, isospin T)
- Binding energy (or mass excess Δ) differs due to Coulomb interaction
- Parabolic dependence of Δ on isospin projection T_z leads to IMME:

$$\Delta(A, T, T_z) = a(A, T) + b(A, T)T_z + c(A, T)T_z^2$$

The A = 20 Quintet

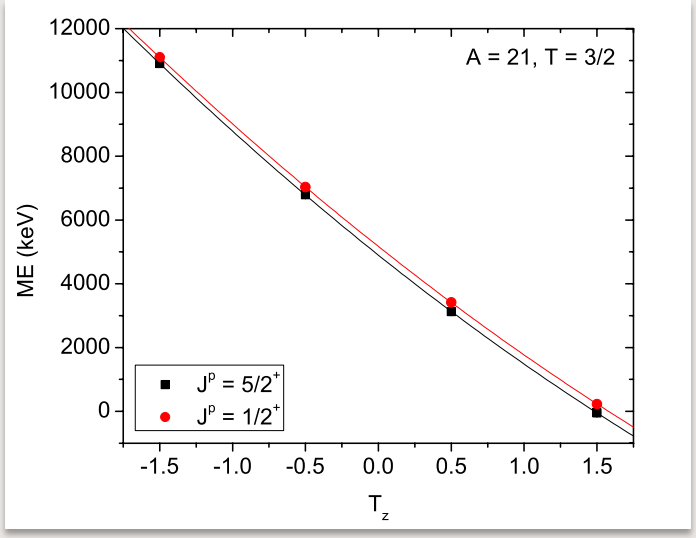


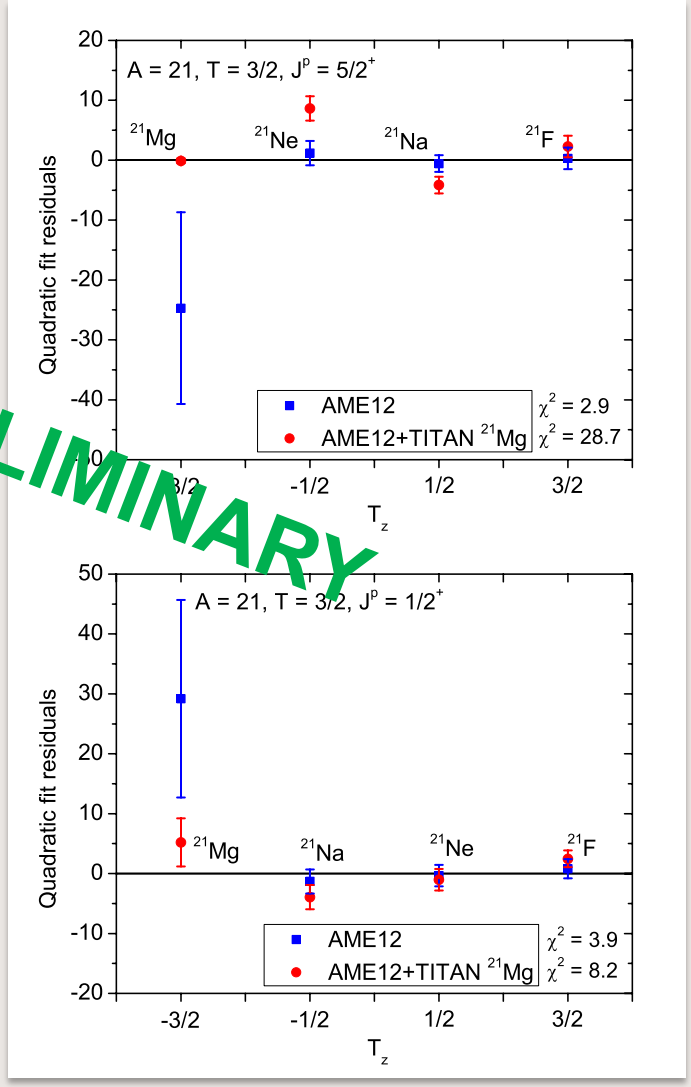
- New ^{20}Mg mass from TITAN results in larger χ^2 for the quadratic fit
- May require cubic (d) or quartic (e) terms

d (keV)	e (keV)	χ^2
-	-	11.5
2.9(11)	-	5.2
-	1.2(12)	10.5
7.2(22)	-5.3(23)	-

Courtesy of Maxime Brodeur

The A = 21 Quartets



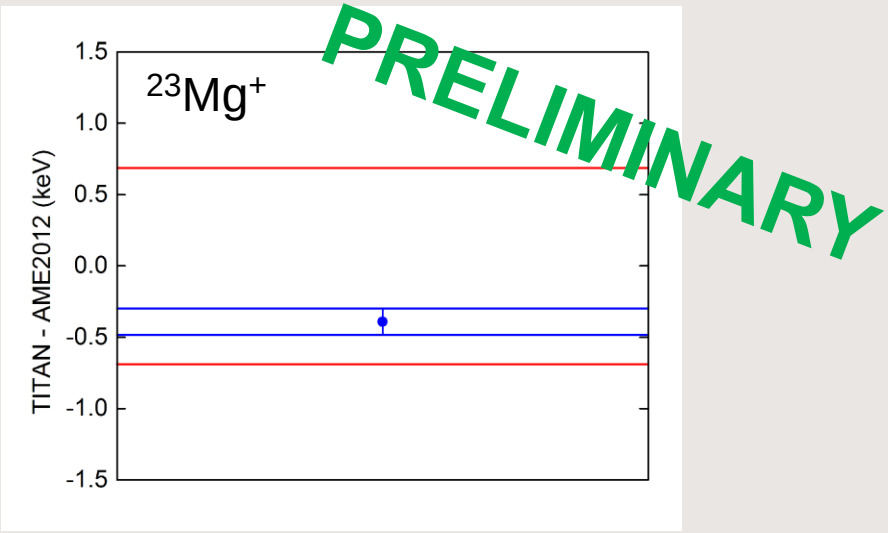


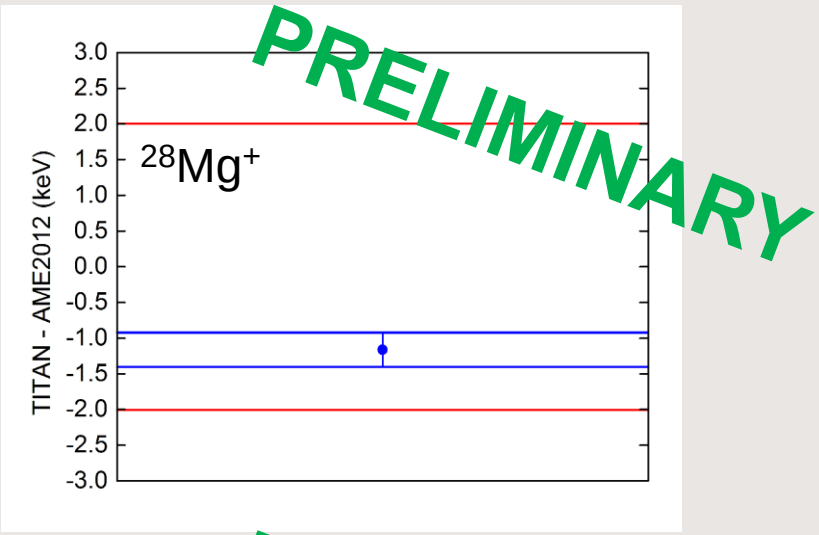
PRELIMINARY

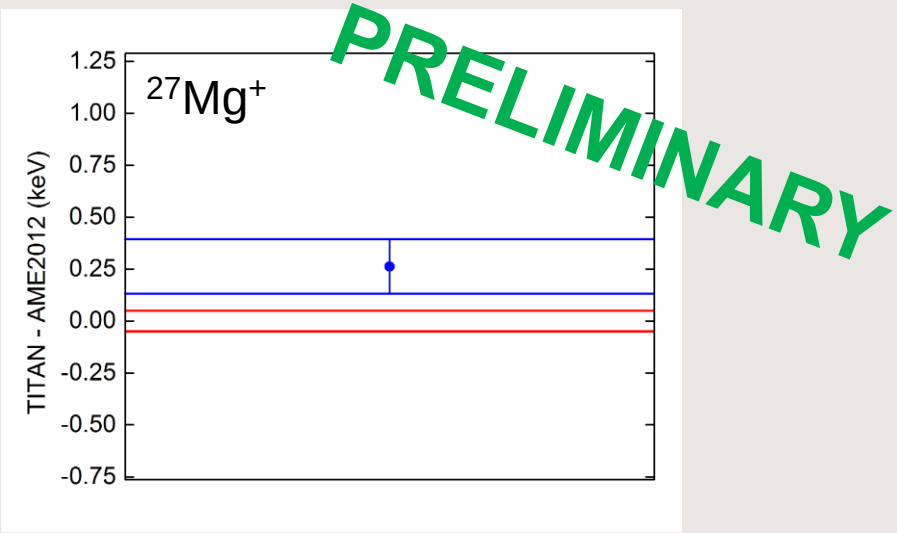
- Increased χ^2 for both quartets
- Large non-zero cubic term may be required, or excited state energy may be wrong

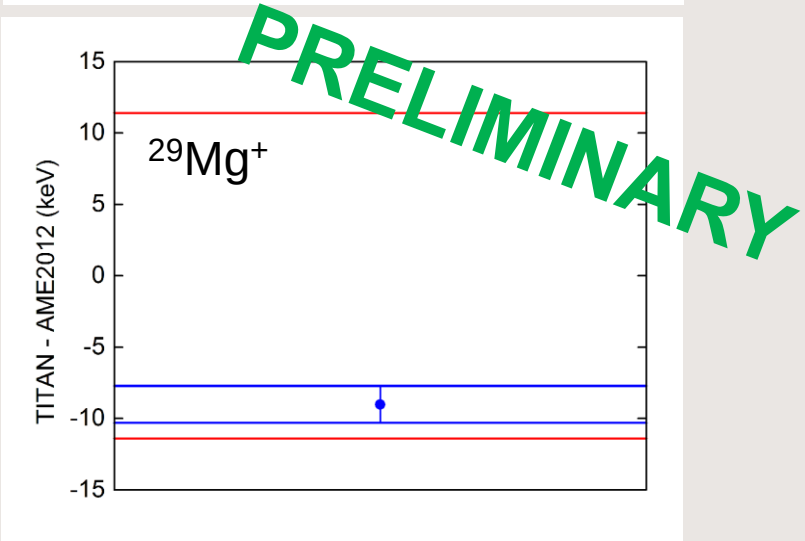
Jp	Old d (keV)	New d (keV)
5/2+	5.0(30)	6.8(13)
1/2+	-6.0(31)	-4.2(15)

Results: ^{23}Mg, ^{27}Mg, ^{28}Mg, ^{29}Mg









Thank you!
Merci

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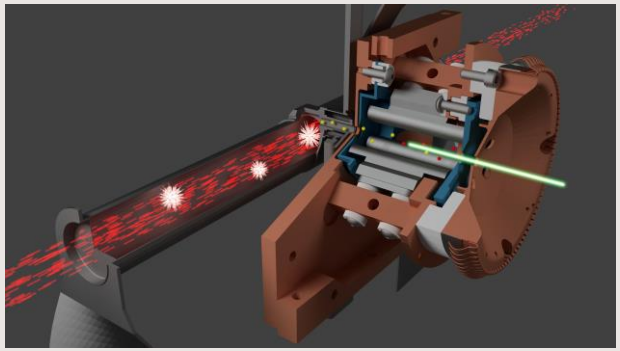

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