TITAN SEPT. ’09 BEAM TIME

Exp. S1112: Mass determination of N-rich K and Ca

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Outline

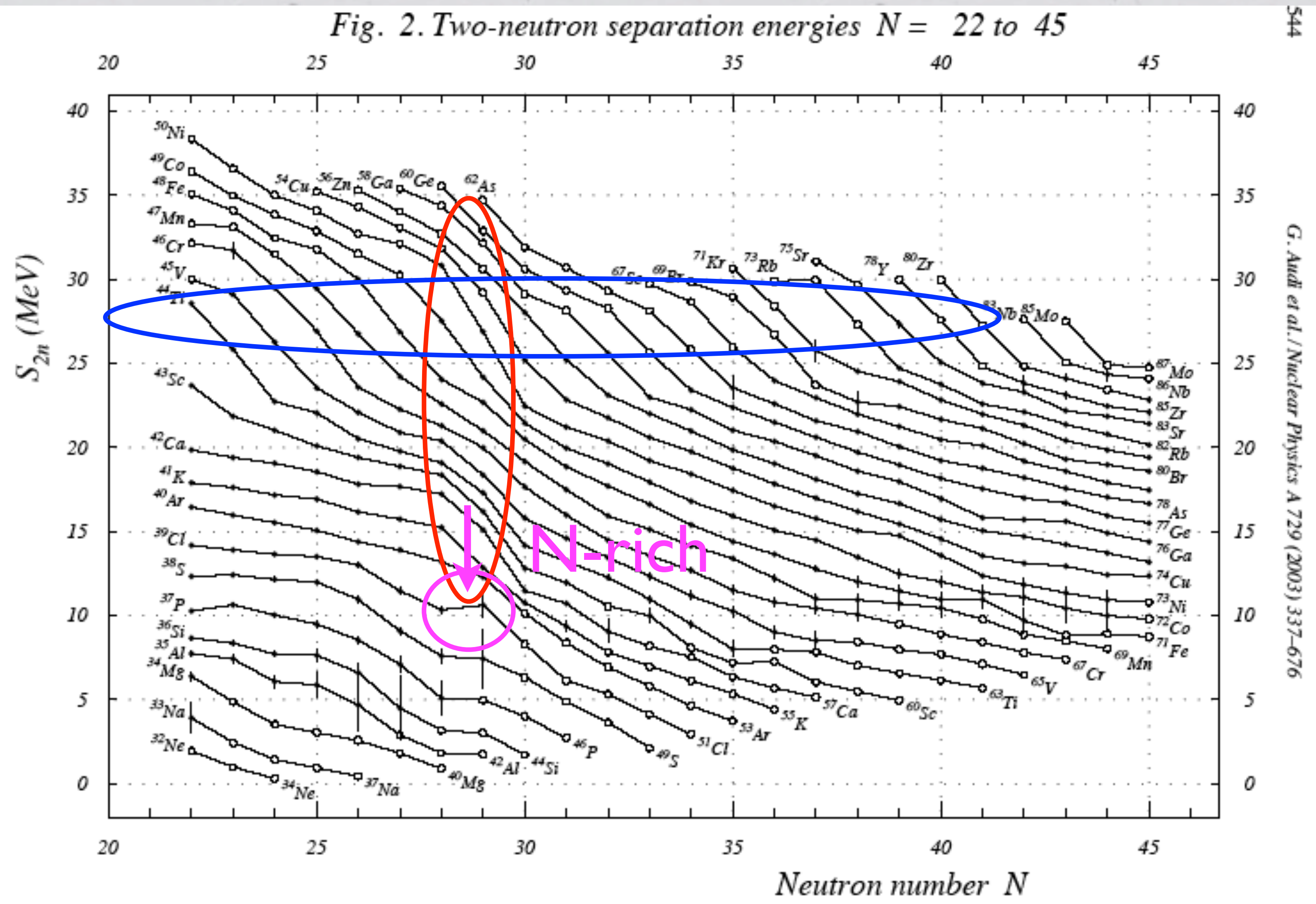
- Masses as a probe for nuclear structure changes
- Motivation to measure the mass of N-rich K and Ca
- Beam time summary
- Results
- Outlook

Mass measurement as a tool to probe nuclear structure changes

The two-neutron separation energy: $S_{2N}(Z,N) = B(Z,N)-B(Z,N-2)$

$S_{2N}(Z,N) = M(Z,N-2) + 2*M_N - M(Z,N)$: small pairing term effect

$B(Z,N) = a_v*A - a_{sf}*A^{2/3} - a_c*Z*(Z-1)*A^{-1/3} - a_{sym}*(N-Z)^2/A + \text{pairing}$



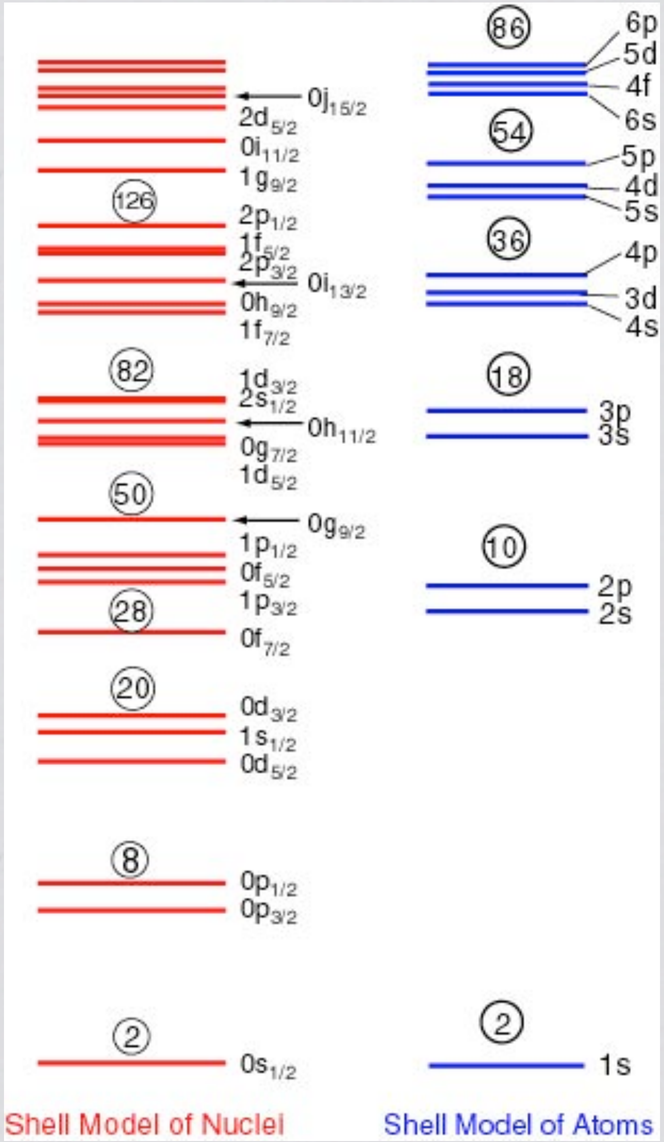
- From LDM, B ↘ with N
- ↘ in S_{2N} from a_{sym} term

non-LDM effects:

- ↘ in B after magic #
- Shell quenching

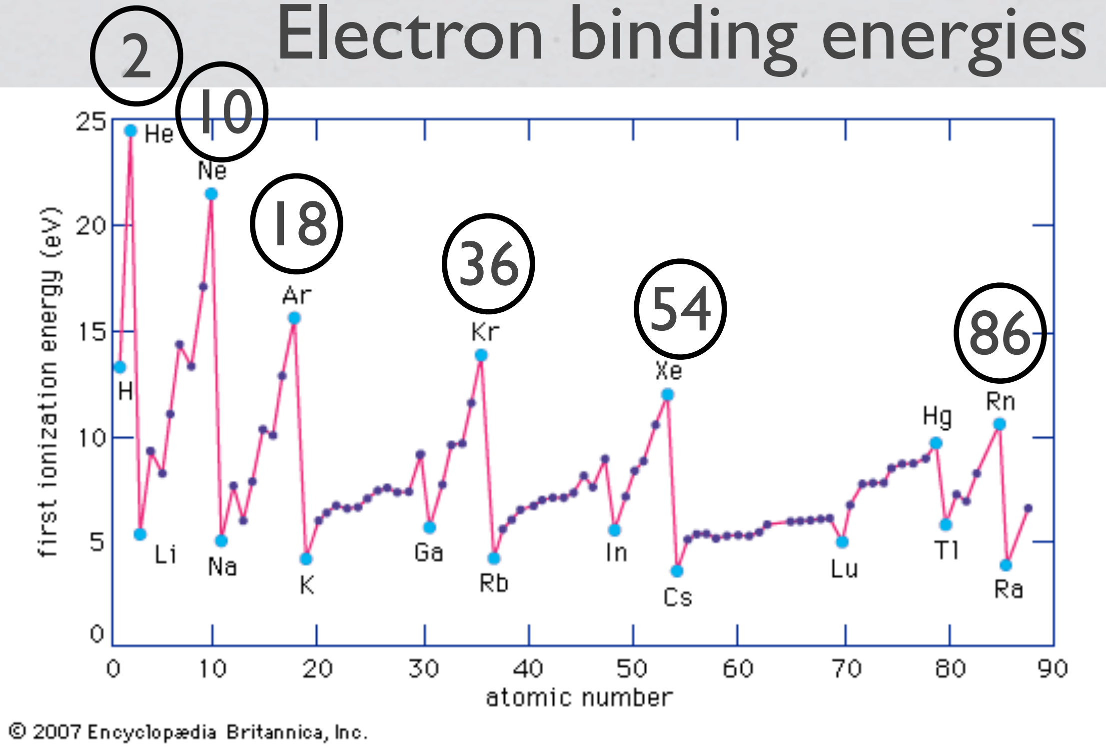
Binding energies (masses) are a sensitive to nuclear structure changes

Nuclear shell model



Shell Model of Nuclei Shell Model of Atoms

Electron binding energies



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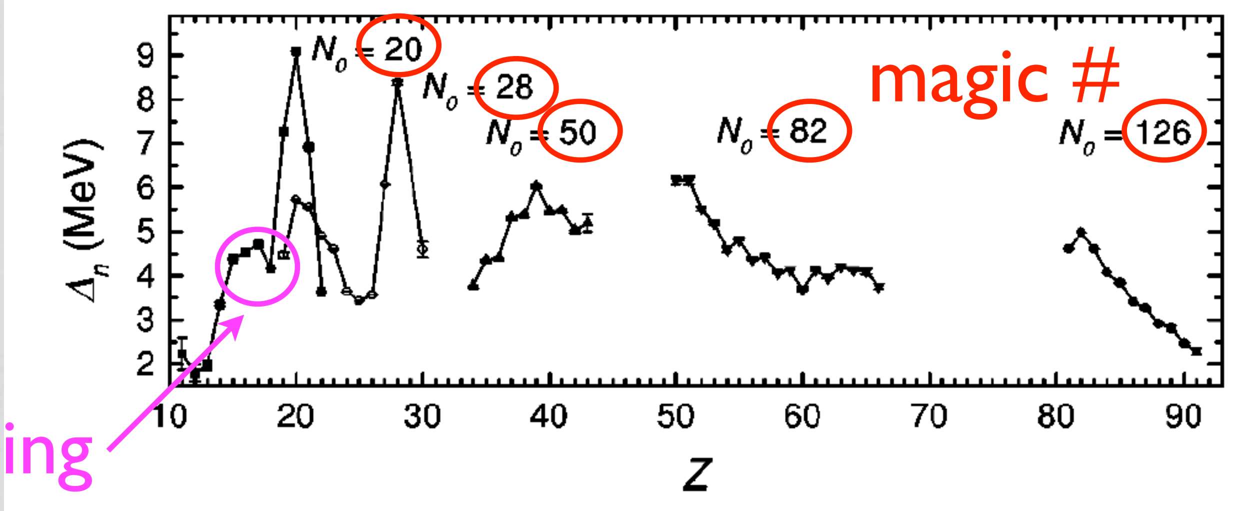
Neutron shell gap

$$\Delta_N(Z,N) = S_{2N}(Z,N) - S_{2N}(Z,N+2)$$



quenching of N = 20

(from D.Lunney, Rev. Mod. Phys. **75**, 1021 (2003))

Similarities:

- Different shell gap size
- Closed shell before

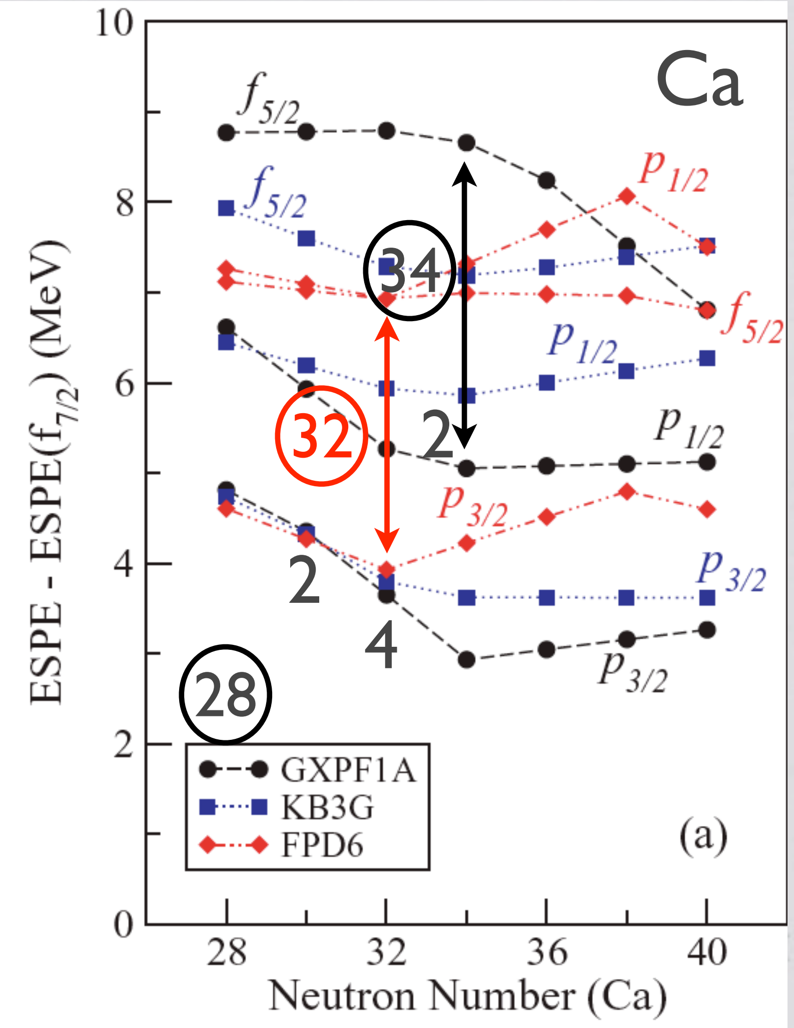
large gap: larger binding

Difference:

n-p interaction; level spacing changes

Motivations for Precision mass measurement of N-rich K and Ca isotopes

For N-rich, change in shell structure induce a change in the magic number



(Effective Single Particle Energy)

(from S.Zhu, PRC **80**, 024318 (2009))

Different nuclear model predicts different new magic numbers for Ca

FPD6: N = 32 (Analytic 2-body pot.; selected energy levels)

GXPF1A: N = 34 (G-matrix pot.; full fp shell; cross-shell exc.)

KB3G: no new (Kuo-Brown G-matrix pot.; full fp shell)

Goal: put tighter constrain on nucl. models through mass measurements

Could requires 3-body forces to explain findings (above models 2-body).

Other new magic numbers were found, such as ^{24}O

Planned measurements for the S1112 experiment

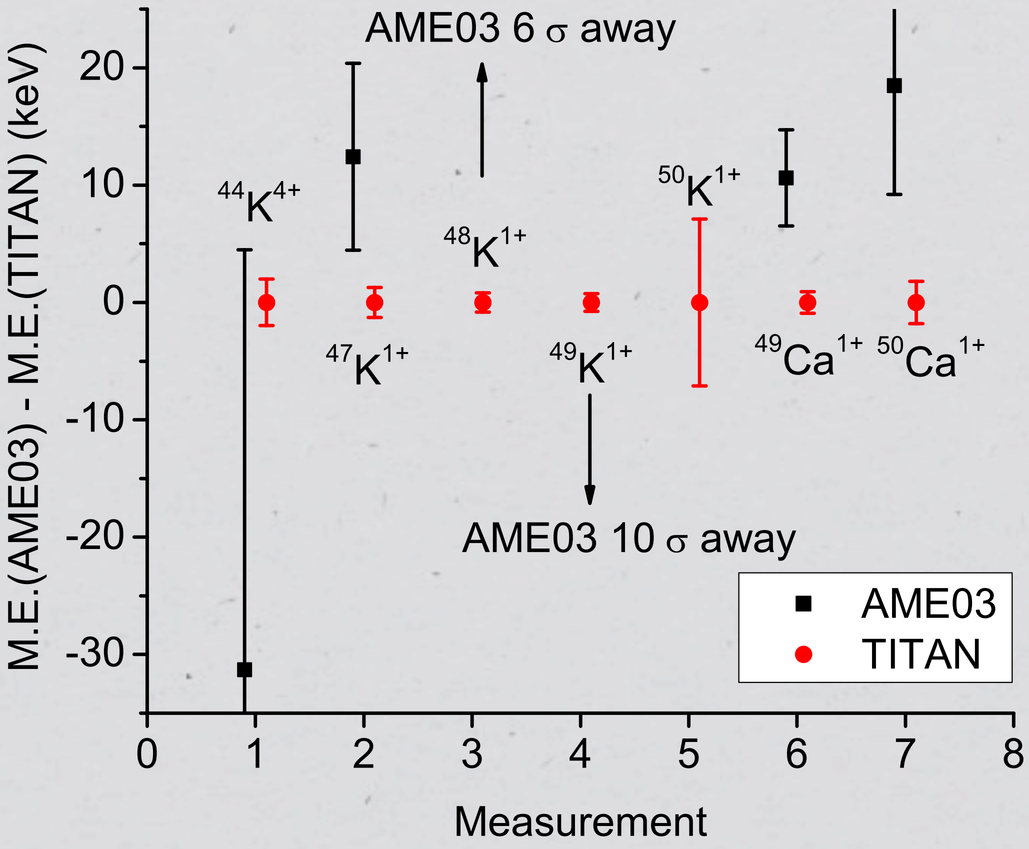
Measurements in the proposal:

Isotope	*Half-live*	*Present Δm*	*TITAN Δm*	*(Expected) Yield*	*Ion source*	***Yields meas. (70 μA)***
^{49}K	1.26 s	70 keV	$< 1.10^{-8}$	$2\bullet10^{5}$	Surface	11 000/s
^{50}K	472 ms	280 keV	$< 1.10^{-8}$	$1\bullet10^{4}$	Surface	560/s
^{51}K	365 ms	unknown	$< 1.10^{-8}$	$2\bullet10^{3}$	Surface	29/s
^{52}K	105 ms	unknown	$< 1.10^{-8}$	$1\bullet10^{3}$	Surface	
^{53}K	30 ms	unknown	1.10^{-8}	$5\bullet10^{2}$	Surface	
^{51}Ca	10 s	90 keV	$< 5.10^{-9}$	$9\bullet10^{4}$	TRILIS	
^{52}Ca	4.6 s	700 keV	$< 5.10^{-9}$	$8\bullet10^{3}$	TRILIS	
^{53}Ca	90 ms	unknown	5.10^{-9}	$7\bullet10^{2}$	TRILIS	
^{51}Sc	12.4 s	20 keV	$< 5.10^{-9}$	$1\bullet10^{5}$	Surface	
^{52}Sc	8.6 s	190 keV	$< 5.10^{-9}$	$8\bullet10^{3}$	Surface	
^{53}Sc	> 3 s	unknown	5.10^{-9}	$1\bullet10^{3}$	Surface	

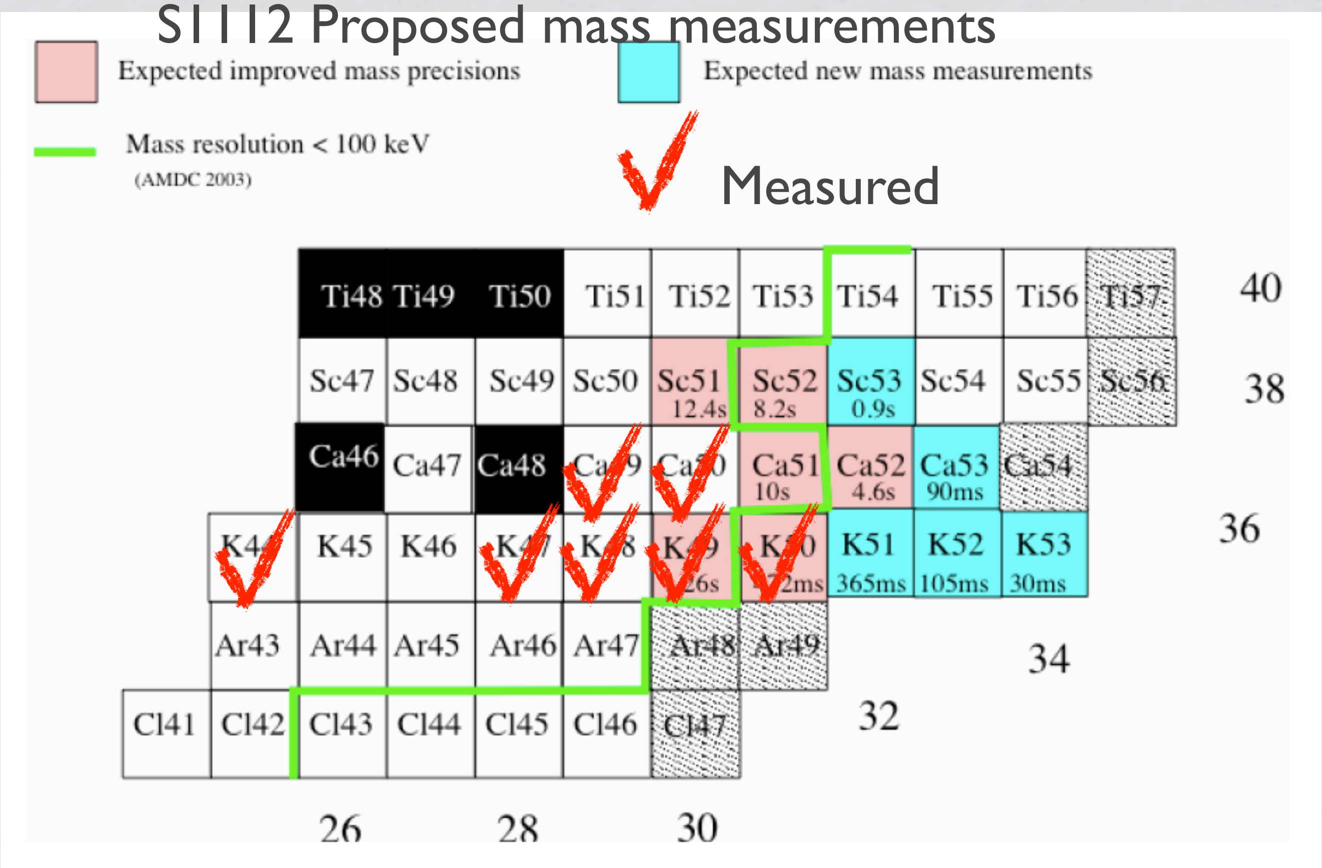
- The desired level of precision could be reached without the use of HCI and to minimize losses during EBIT operation, most measurements were done with singly charged ions.
- ^{51}K brought into the system, but because of the low yield and high level of unknown contamination, would have required more time to identify and then remove the contamination before measuring in the Penning trap.

Beam time summary

- $^{44}\text{K}^{4+}$: First on-line mass measurement using charged bred ions from the EBIT
- $^{47\text{-}50}\text{K}^{1+}$ and $^{49,50}\text{Ca}^{1+}$: masses improved by factor of up to 100
- $^{48}\text{K}^{1+}$ and $^{49}\text{K}^{1+}$: deviations of 6 and 10 σ from AME03
- Found lots of ^{50}Cr in the ^{50}K and ^{50}Ca beam. (dipole cleaning)
- Reduced the isobaric contam. by touching the mass sep. (0.12 G enough)

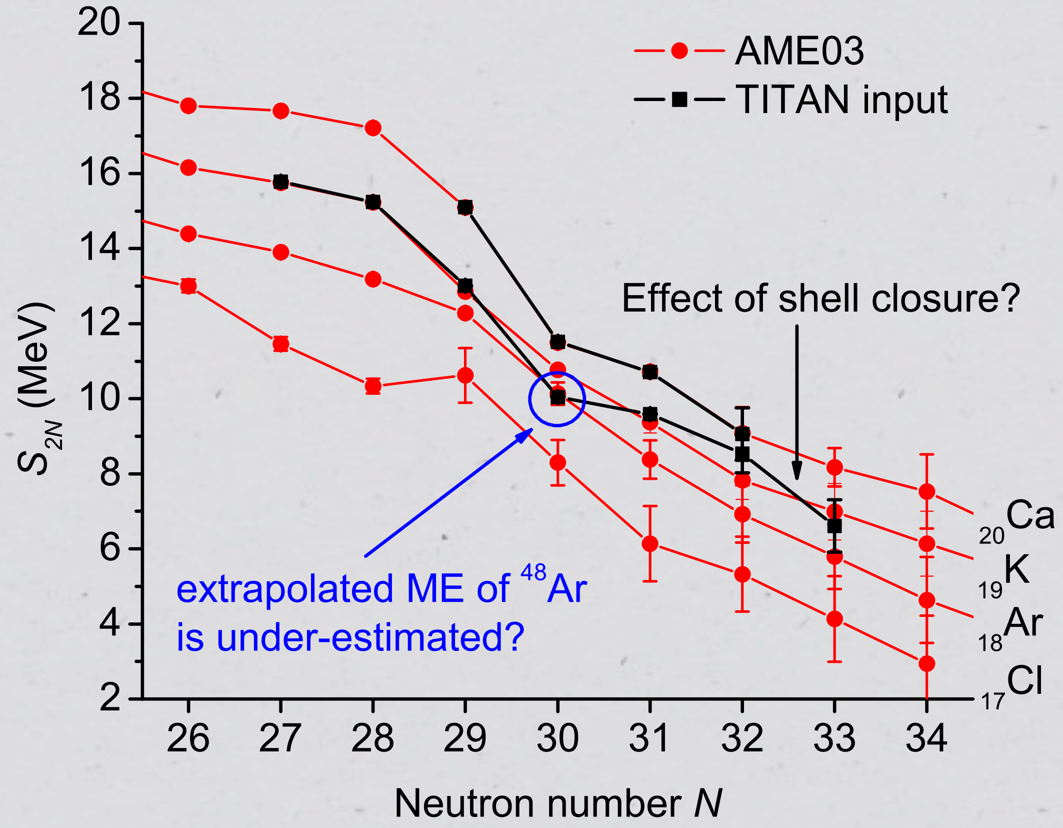


S1112 Proposed mass measurements



Results interpretation

Recall: $S_{2N}(Z,N) = M(Z,N-2) + 2*M_N - M(Z,N)$



Hint of shell closure at N = 32 for K?

Mass measurement of ^{51}K and ^{52}K would clarify the situation & would start to put constraint on N = 34

$S_{2N}(^{49}K) \sim S_{2N}(^{48}Ar)$: extrapolated value for ^{48}Ar under-estimated?

Mass measurement of ^{46}Ar and ^{48}Ar are needed

As the N-rich mass land scape get refined, more measurements are needed!

Together with measurement on ^{51}Ca and ^{52}Ca, it will refine S_{2N} values and start to constrain the various models

Summary & Outlook

- Finer probing of the mass surface along the isotopic chain (improved up to factor 100, deviation up to 10 sigma found)
- Need to pursue these measurements towards more N-rich K and along the Ca and Ar chains
- ^{48}K is along the r-process path just as ^{48}Ar which present an anomaly in its S_{2N} value.
- Could make use of the UO testing in Dec. to measure the mass of N-rich Ar.

FIN

EBIT efficiency

- Calculated efficiency:
  - Total % ion extracted: 2%
  - Transfer efficiency: 50%
  - Distribution in q: 20%
  - Total calc. EBIT to MCP0: 0.2%
- Observed efficiency:
  - ISAC to MCP0 (1+): 0.2%
  - 44K counts on FC3: 2x10^8/s
  - 44K4+ counts on MCP0: 330/s
  - Efficiency EBIT to MCP0: 0.1%
- What we learned from this beam time:

  Only 50% of the losses after charge breeding are not accounted for

  In order to have well-defined extracted bunches, the EBIT is open for a very short time compared to the time it will take to fully empty the trap (2%). This is were most of the losses happen.