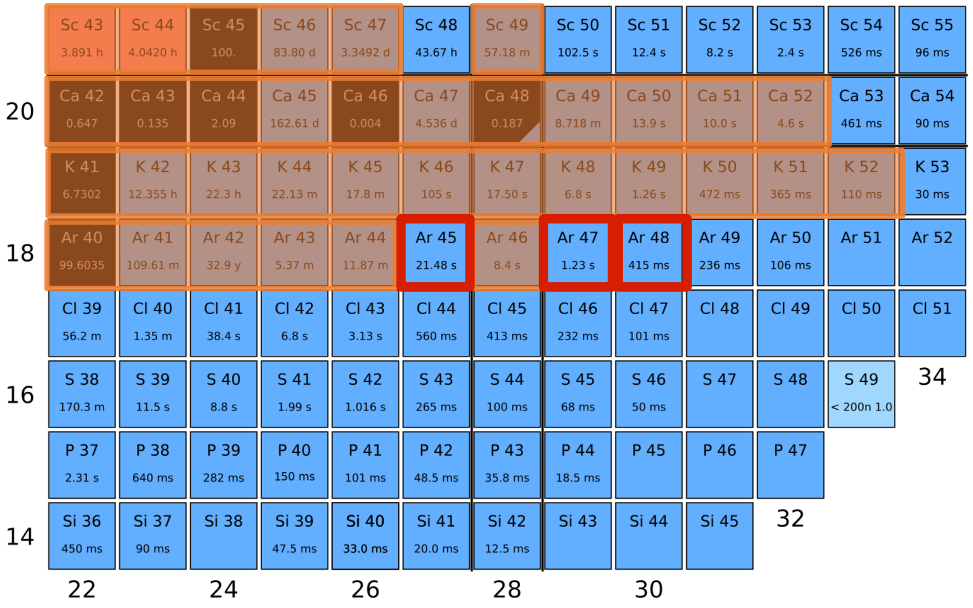
Study of the $N = 28$ shell closure in the argon isotopes

Abigail McGlone, Holly Perrett, Jessica Warbinek

and the CRIS collaboration

INTC Meeting 76, May 22, 2024

Introduction



This proposal   Published laser spectroscopy

Persistence of N=28 shell closure below ^{48}Ca

- Complete disappearance in ^{42}Si
- Signatures of shape coexistence in ^{44}S
- Study onset of collectivity

A. Gade et al., Phys. Rev. Lett. 102, 182502 (2009).
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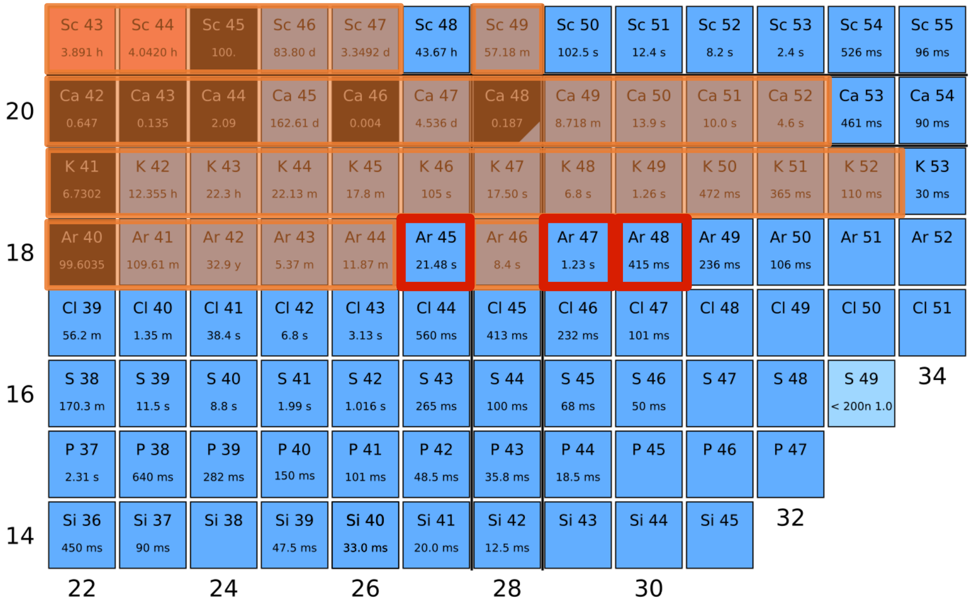

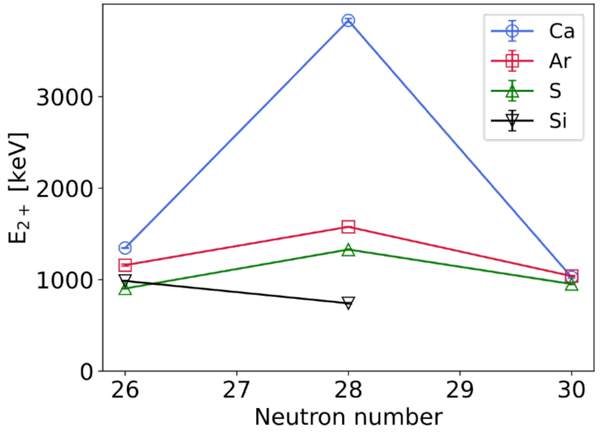

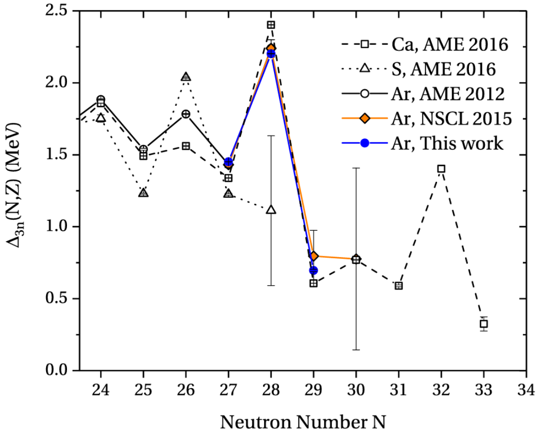

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Indications for closed shell in Ar

- High lying E(2+) excitation energy at N=28
- Mass measurements confirmed large shell gap
- Lifetime measurements suggest erosion of shell gap from Ar on

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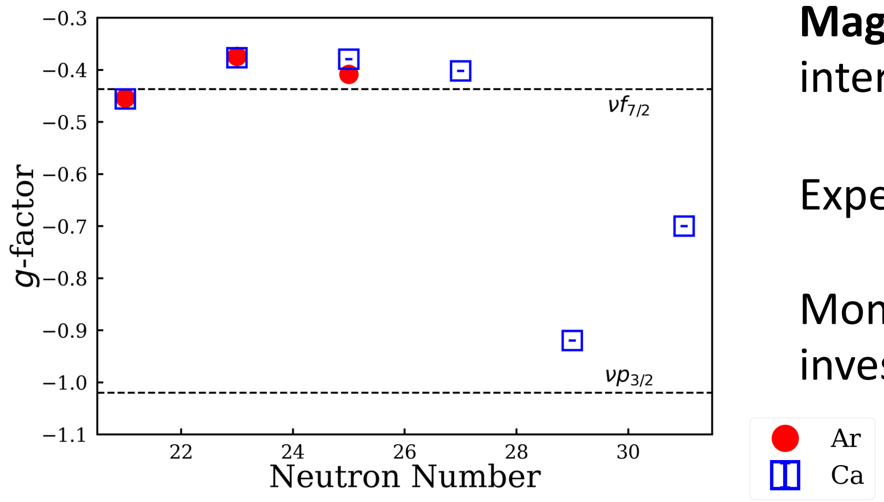
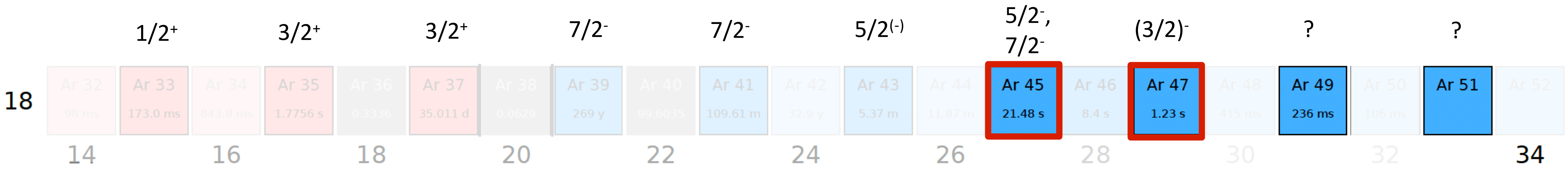
Nuclear moments and spins of odd-Ar nuclei



Magnetic moments of odd-A nuclei are a sensitive probe to study the interplay between the single particle structure and many-body correlations.

Experimental **g-factors** up to ^{45}Ar follow the same trend as the Ca g-factors

Moments of ^{45,47}Ar will be sensitive to the presence of mixed configurations – investigate strength of the *N*=28 shell gap in Ar.



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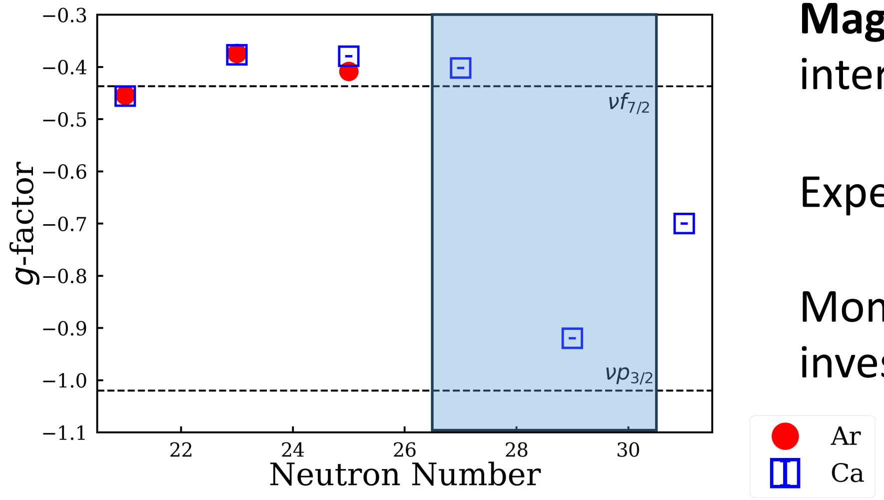

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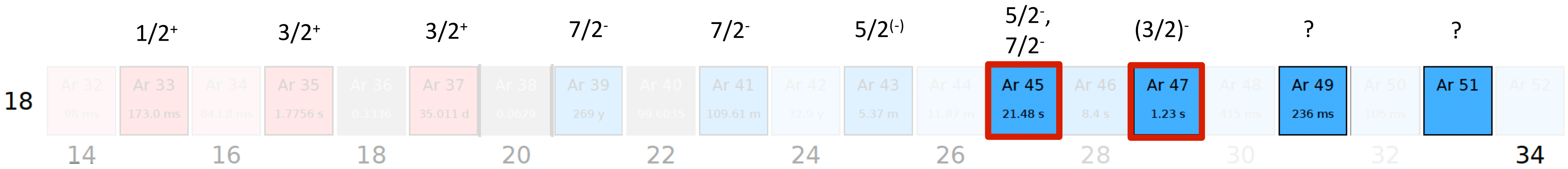

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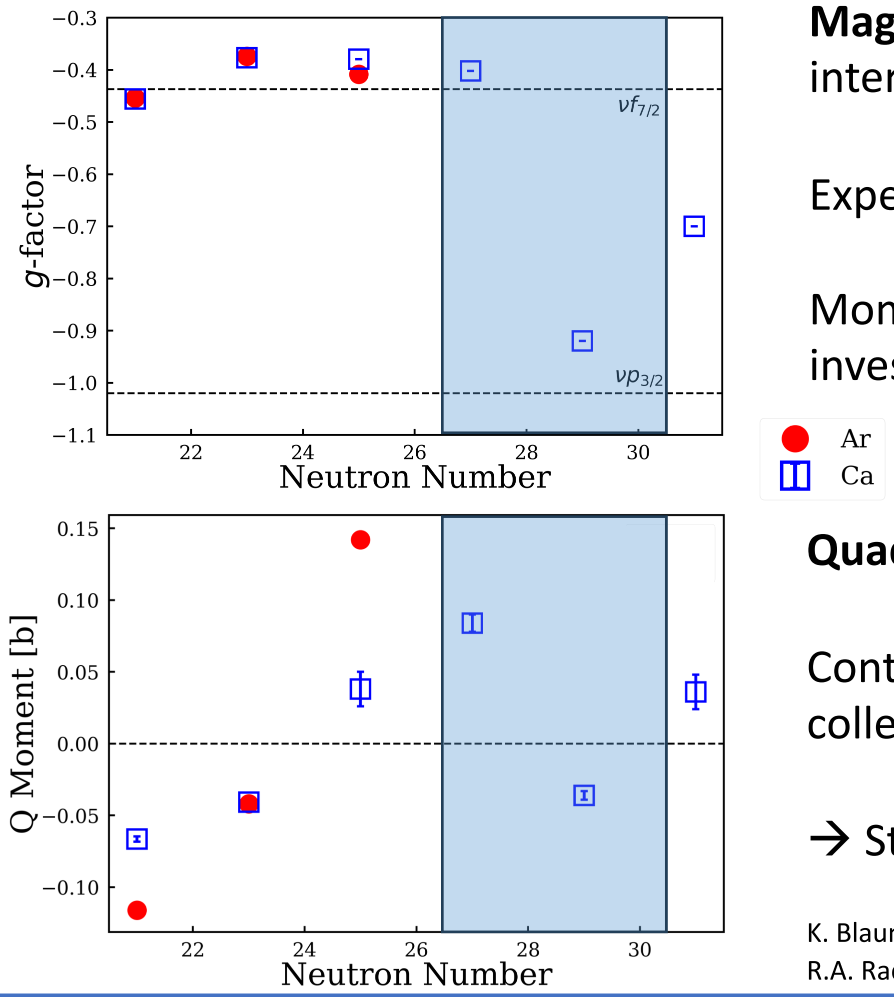

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Quadrupole moments of Ar follow trend Ca chain

Continuing measurements beyond shell closure to investigate signs of collectivity arising

→ Studying the Ar ground states to have full picture for excited state studies

K. Blaum et al., Nucl. Phys. A 799, 30–45 (2008).
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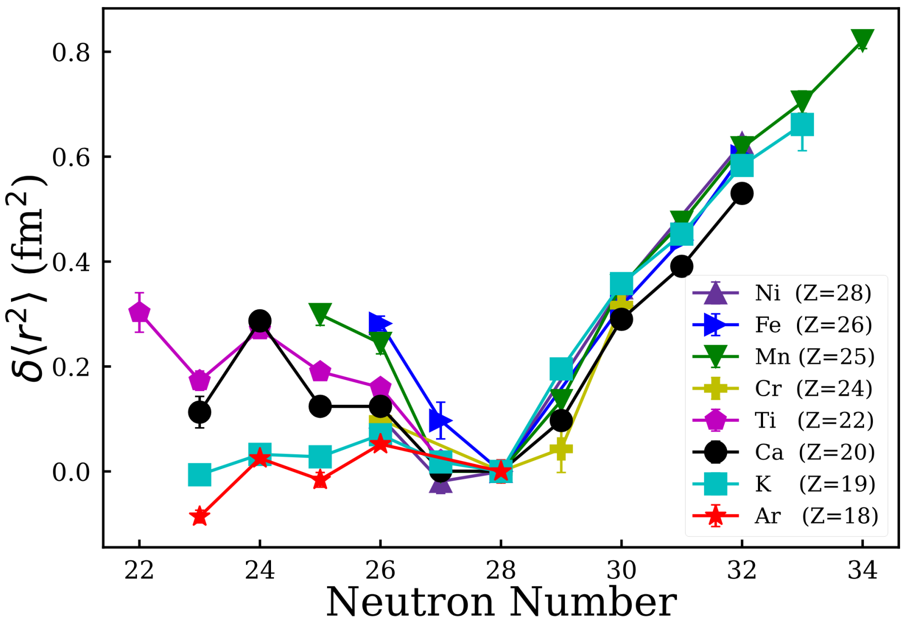
Charge radii of neutron-rich Ar



Kink in charge radii trends as probe for shell closure

- Observed at *N*=28 consistently observed for *Z*=19-28

→ Data missing for Ar *Z*=18

Outlook: further measurements towards *N*=32

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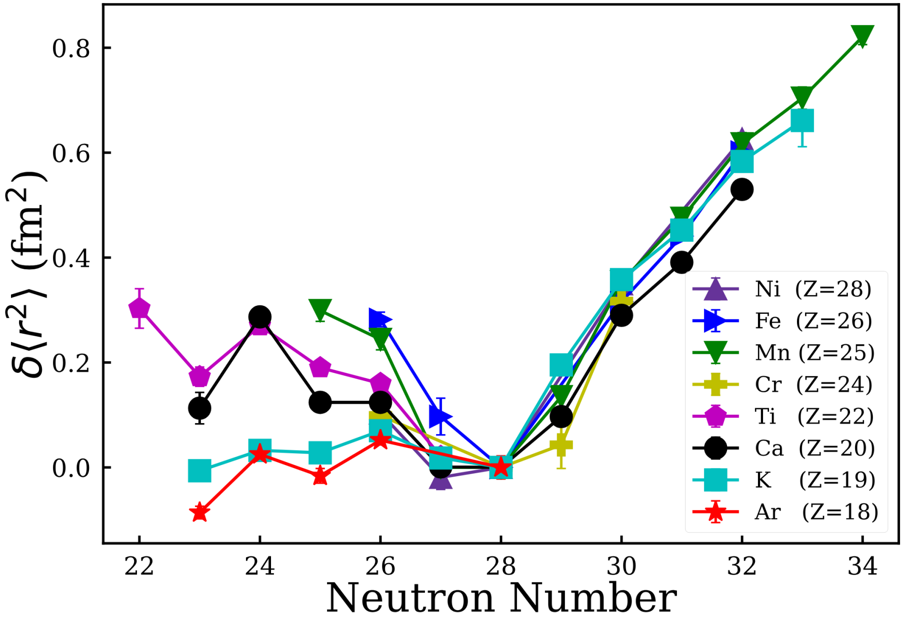

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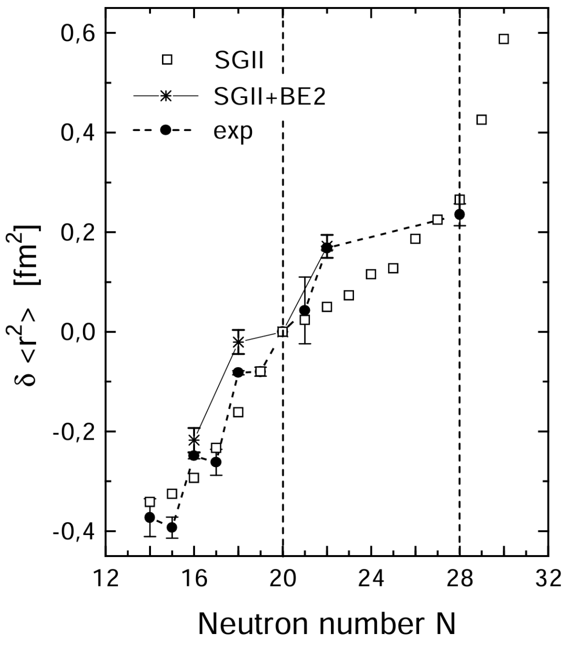

Early spherical Skyrme (SGII) Hartree-Fock calculations predict kink in charge radii

→ Experimental confirmation needed, triggering new theoretic efforts

A. Klein et al., Nucl. Phys. A 607 , 1-22 (1996).

K. Blaum et al., Nucl. Phys. A 799, 30–45 (2008).
I. Angeli, K.P. Marinova. J. Phys. G, 42, 055108 (2015).
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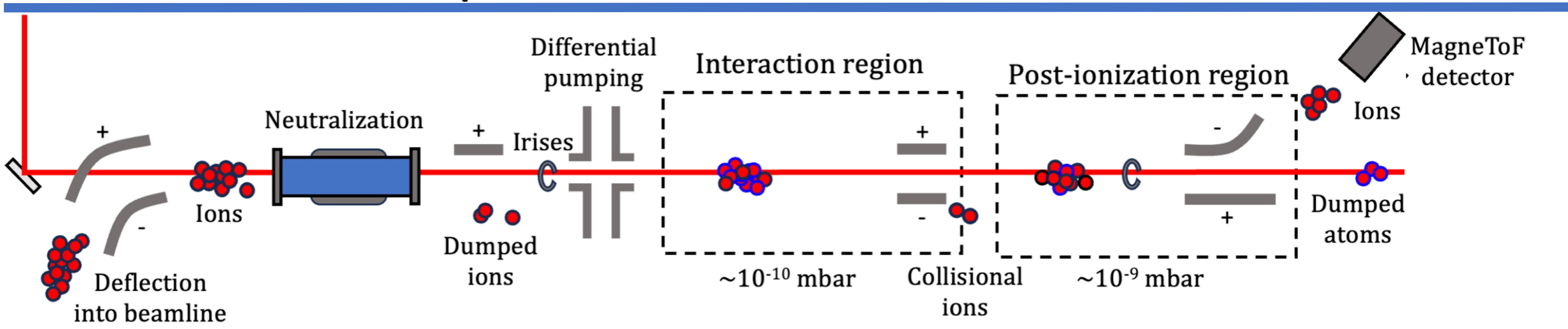
CRIS technique



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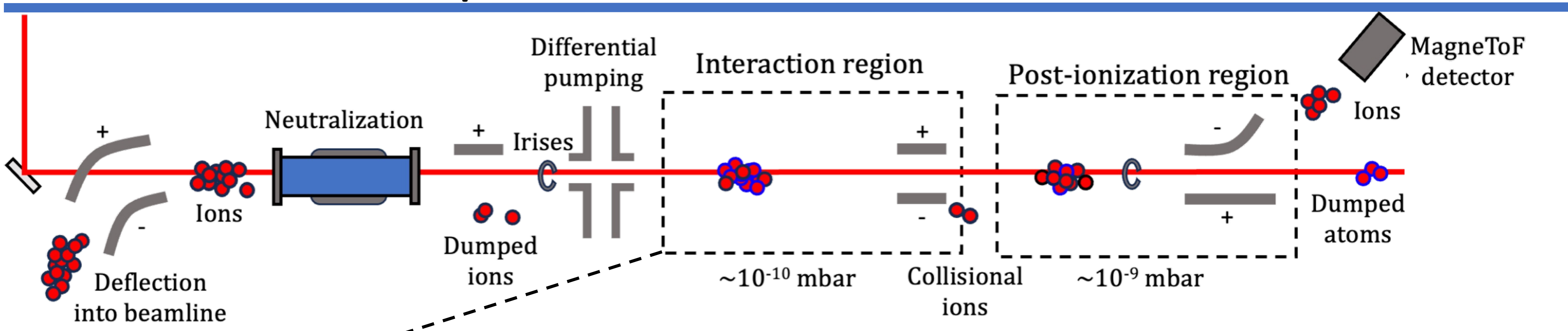
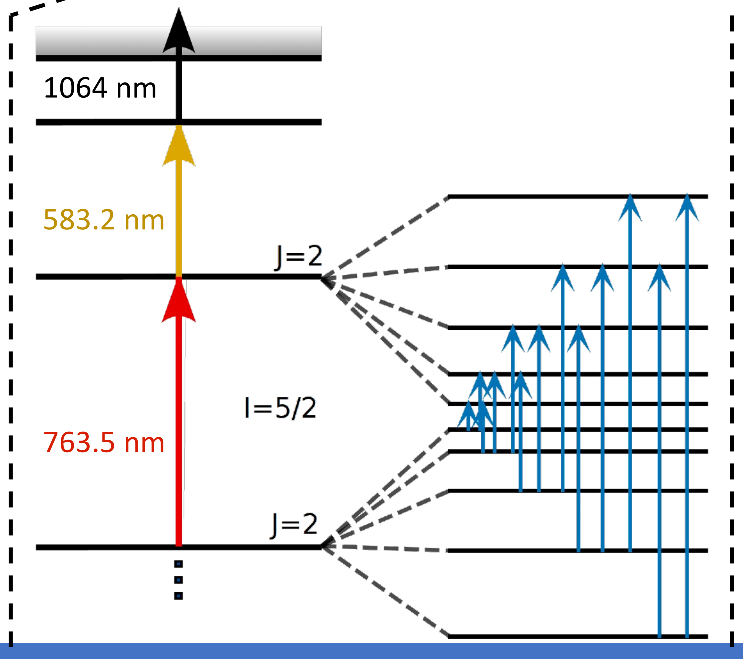


Laser scheme to be used

Three-step scheme:

- High selectivity
- Minimized background

All lasers existing at CRIS



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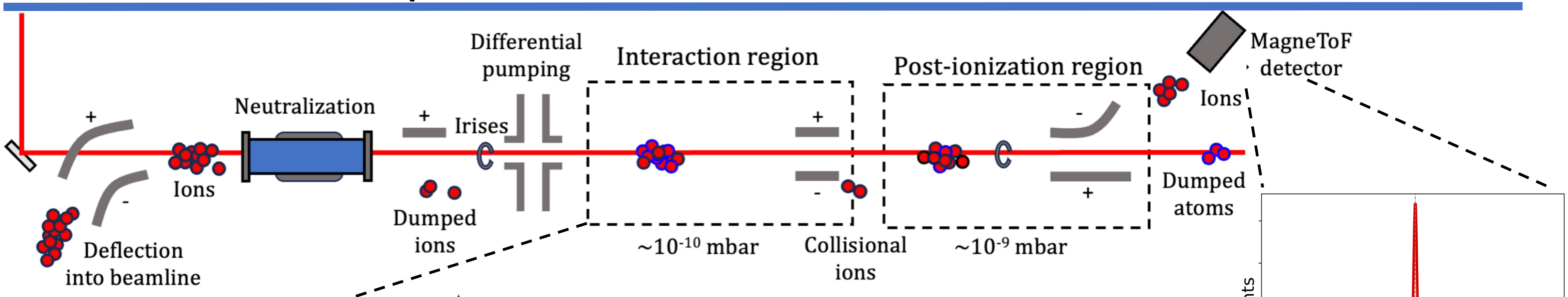

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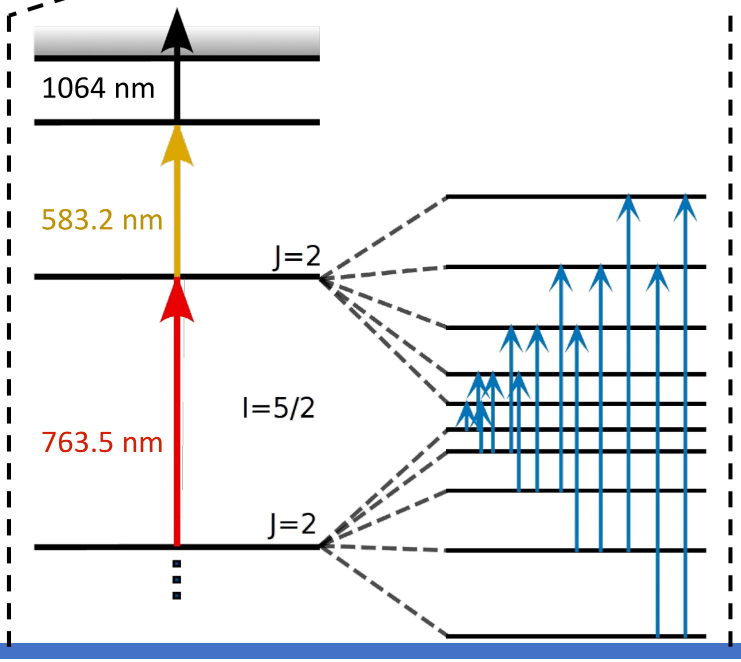

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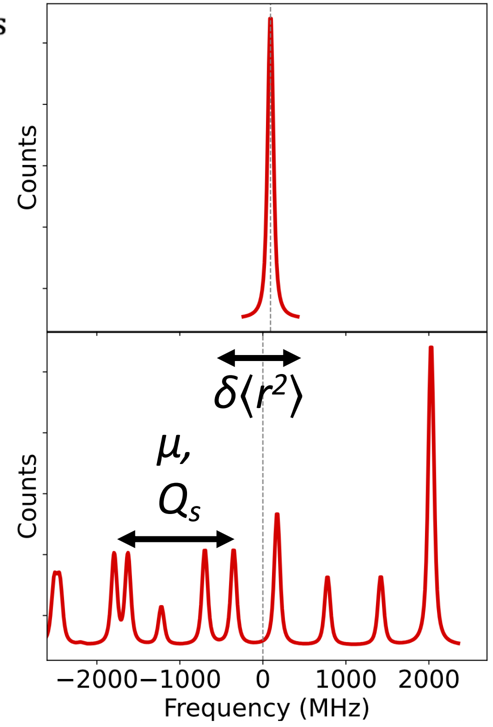
High resolution necessary to resolve HFS and isotope shift

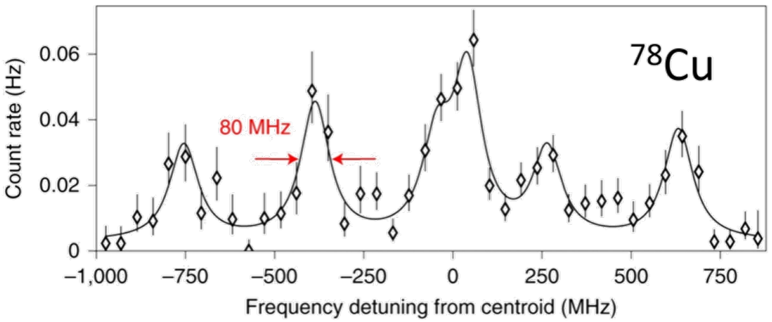


Shift request

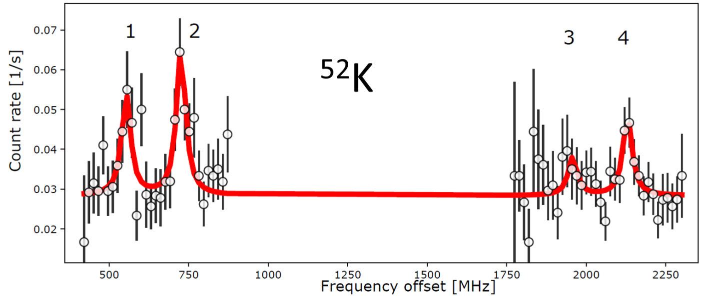
- UCx target + FEBIAD plasma ion source
- Yields (extrapolated) sufficient for CRIS
- Contamination known (ISOLTRAP)

Measurements feasible down to ^{48}Ar

	Half live	Yields (/µC)	Shifts	New results
$^{38\text{-}44}$Ar	> 8s	10^6-10^7*	3	-
^{46}Ar	8.4 s	1.11×10^5*	2	-
^{45}Ar	21.48(15) s	3.49×10^5*	2	$I, \mu, Q_s, \delta\langle r^2\rangle$
^{47}Ar	1.23(3) s	7.72×10^3*	6	$I, \mu, Q_s, \delta\langle r^2\rangle$
^{48}Ar	415(15) ms	1.58×10^3*	5	$\delta\langle r^2\rangle$
Stable		CRIS setup	3 (no protons)	



20 ions/s



360 ions/s

R.P. de Groote et al., Nature Phys. 16, 620–624 (2020).
A. Koszorus et al., Nature Phys. 17 439–443 (2021).

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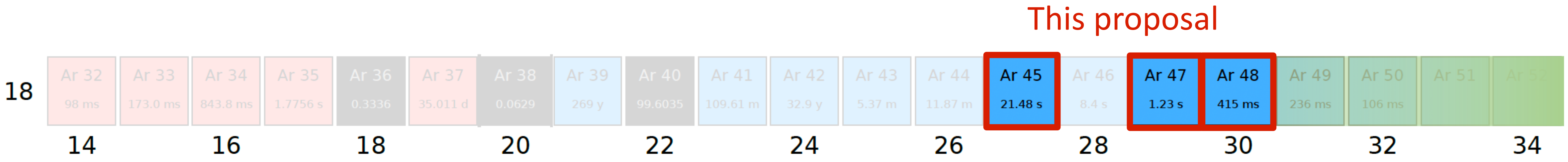
- Stable beamtuning for **CRIS setup**: 3 shifts
- **Reference measurements** throughout experiment, calibration of voltage drifts and systematic effects: 5 shifts
- **Laser spectroscopy** of ^{45}Ar: 2 shifts, **Laser spectroscopy** of ^{47,48}Ar: 11 shifts
- Shifts requested account for expected contamination and reduction of yields by using a narrow beamgate

TAC comments: The TAC does not foresee any serious issues with this proposal.

Conclusion

We propose to study neutron rich argon isotopes crossing the *N*=28 shell closure to study its evolution between double magic ^{48}Ca and the onset of collectivity in ^{44}S

- Assess the charge radii crossing the shell gap to look for an evolving kink signature
- Determine spins which are only tentatively assigned
- Investigate g-factor and nuclear moments to investigate impact of shell closure in Ar



18+3 shifts using UCx target + FEBIAD Plasma ion source

Perform collinear resonance ionization laser spectroscopy using CRIS

Acknowledgments

MANCHESTER 1824
The University of Manchester

KU LEUVEN

Massachusetts Institute of Technology

北京大學 PEKING UNIVERSITY

CERN

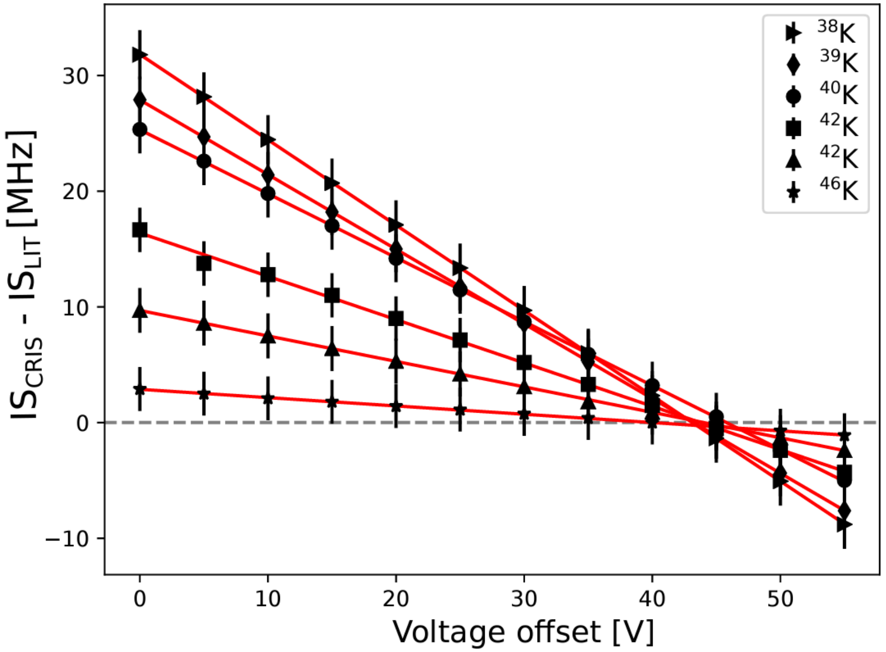
sck cen

iPHC Institut Pluridisciplinaire Hubert CURIEN STRASBOURG

A.C. McGlone[1], H.A. Perrett[1], J. Warbinek[2], O. Ahmad[3], S.W. Bai[4], J. Berbalk[3], T.E. Cocolios[3], R.P. de Groote[3], C.M. Fajardo-Zambrano[3], K.T. Flanagan[1], R.F. Garcia Ruiz[5], Á. Koszorús[3,6], L. Lalanne[7], P. Lassegues[3], Y.C. Liu[4], Y.S. Liu[4], K.M. Lynch[1], G. Neyens[3], F. Pastrana[5], J.R. Reilly[2], B. van den Borne[3], R. Van Duyse[3], J. Wessolek[2,1], S.G. Wilkins[5], X.F. Yang[3].

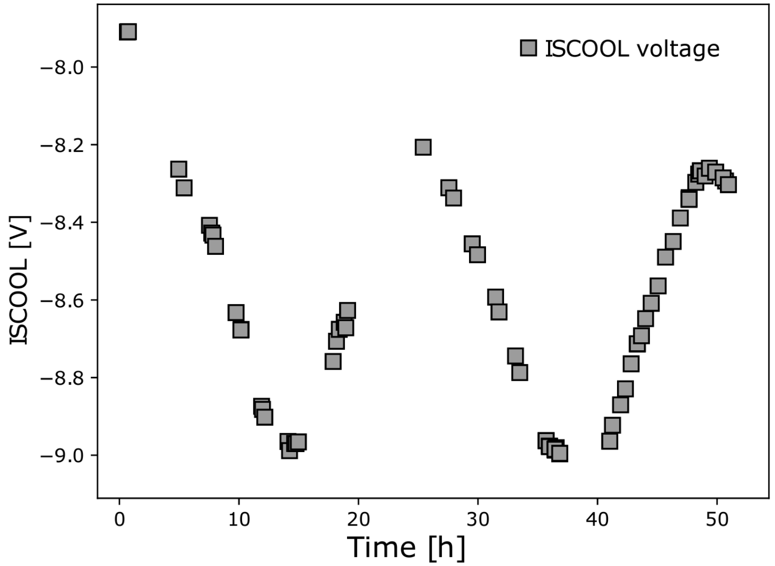
[1]Department of Physics and Astronomy, The University of Manchester, United Kingdom
[2]Experimental Physics Department, CERN, Switzerland
[3]KU Leuven, Instituut voor Kern- en Stralingsfysica, Belgium
[4]School of Physics and State Key Laboratory of Nuclear Physics and Technology, Peking University, China
[5]Department of Physics, Massachusetts Institute of Technology, USA
[6]Belgian Nuclear Research Centre (SCK CEN), Belgium
[7]IPHC, Université de Strasbourg, France

Systematic drifts



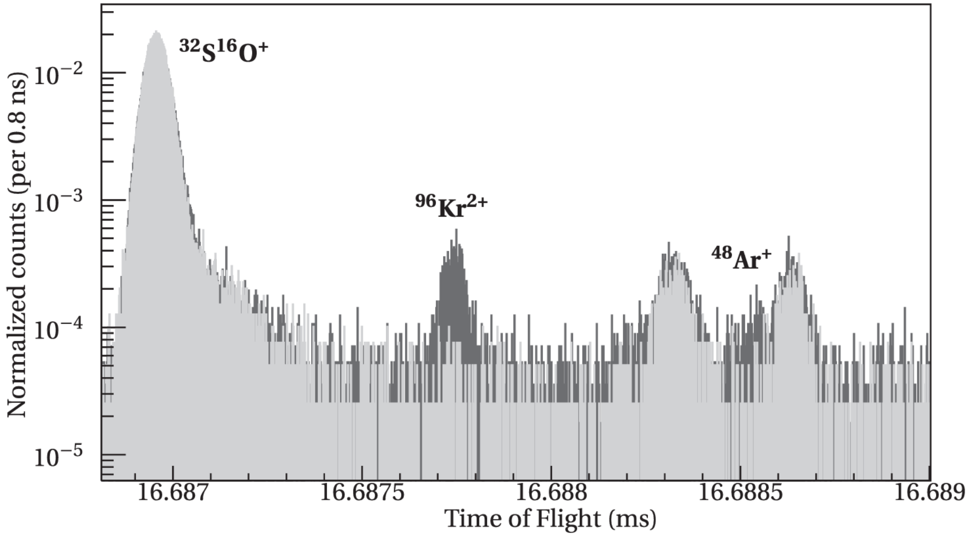
Voltage calibration necessary over long range of isotopes

Instabilities observed in ISCOOL voltage readout



Agota Koszorus, Dissertation, KU Leuven (2019).

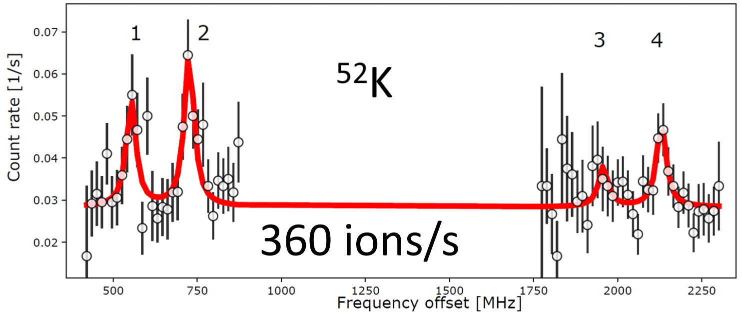
Yields and contaminations



M. Mougeot *et al*. Phys. Rev. C 102, 014301 (2020).

ISOLTRAP measurements on ^{48}Ar

- Expect similar level of contamination
- Mostly $^{32}S^{16}O^+$, $^{96}Kr^+$
- Narrow beam gate required to reduce contamination
- Shifts estimated from worst case of expected background in CRIS



A. Koszorus et al., Nature Phys. 17 439–443 (2021).

Contributions for shift estimate:

- Reduction of yield due to narrow beam gate
- CRIS efficiency
- Population of metastable state, hyperfine structure
- Time needed for multiple scans (strongly dependent on signal-to-background ratio)