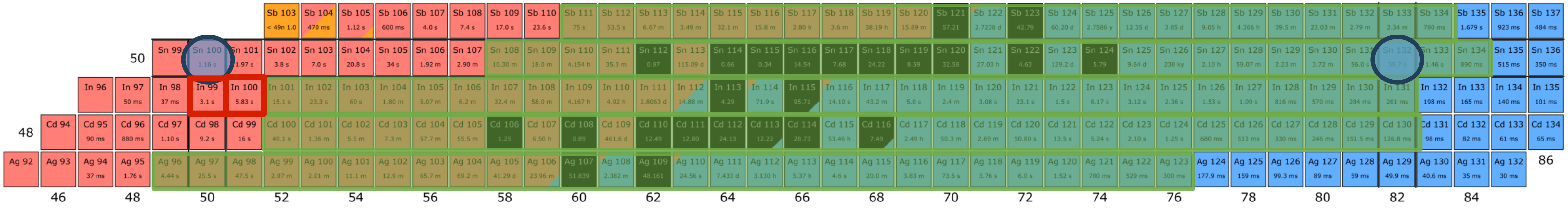
Collinear resonance ionization of neutron-deficient indium: closing up on $N = 50$

Jessica Warbinek on behalf of the CRIS collaboration

INTC Meeting 77, November 12, 2024

Introduction



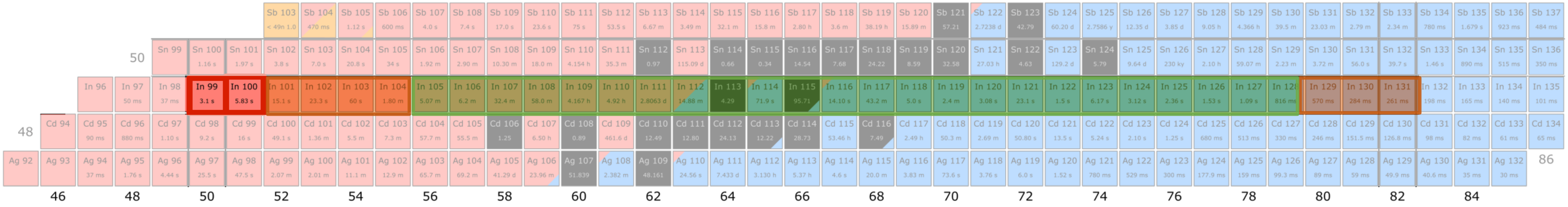
This proposal

(Un-)published laser spectroscopy

Studying the shell structure around doubly magic ^{100}Sn

- Testing the shell model under extreme conditions
- Robustness of N=50 near Z=50, towards dripline
- Proton-neutron interactions near shell closure
- Role of electro-weak currents

Previous indium runs at CRIS



This proposal | (Un-)published laser spectroscopy | Recent CRIS results

Studying the shell structure around doubly magic ^{100}Sn

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Studying In isotopes at CRIS, with one p-hole to ^{100}Sn

- Studying nuclear structure evolution approaching N=50 and N=82
- Correlations of single proton hole with n / n-holes

We propose: closing up on N=50 in the indium chain

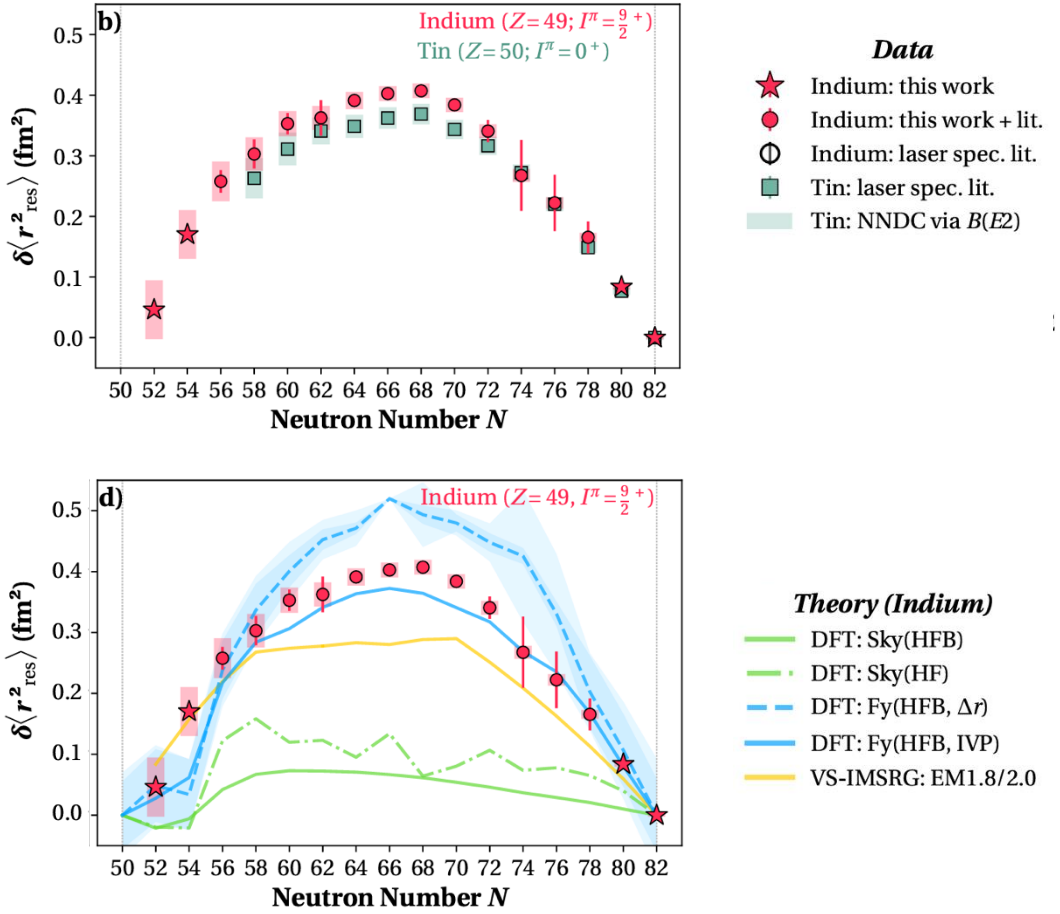
^{99,100}**In**: pin-point the evolution of nuclear structure, sensitive to the presence of mixed configurations, benchmarking nuclear theory, investigating magicity of N=50

Charge radii of neutron-deficient In

Changes in mean square charge radii:
A sensitive probe to study the evolution of nuclear size and deformation

- Kink in charge radii: probe for shell closure
- Odd-even staggering: many body correlations & local effects

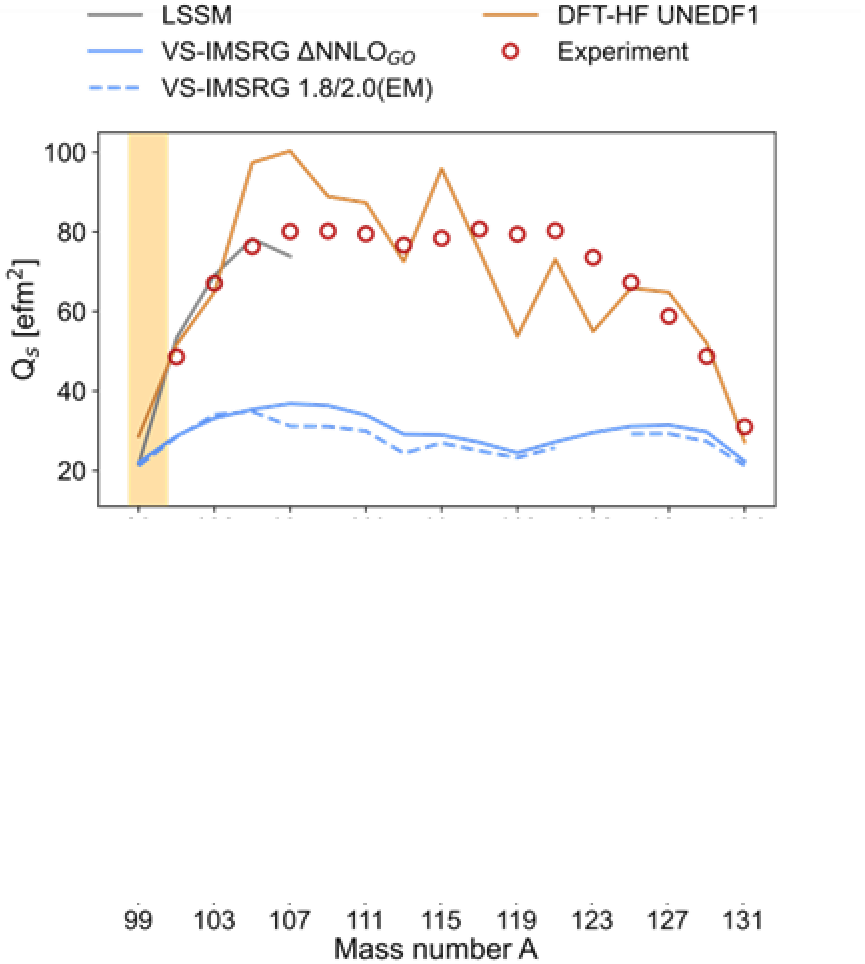
- Benchmarking nuclear theory models:
  Predictions for indium by DFT and ab-initio frameworks available, discrepancies observed towards N=50



M. Reponen et al., Nat. Commun. 12, 4596 (2021).
J. Karthein et al., Nat. Phys. (2024).
J. Karthein et al., arXiv preprint 2310.15093 (2023).

Nuclear moments and spins of In nuclei

Electric quadrupole moments:
Reflects the evolution of collectivity towards mid-shell
Probe arising collectivity beyond shell closure
Reflects arising deformation



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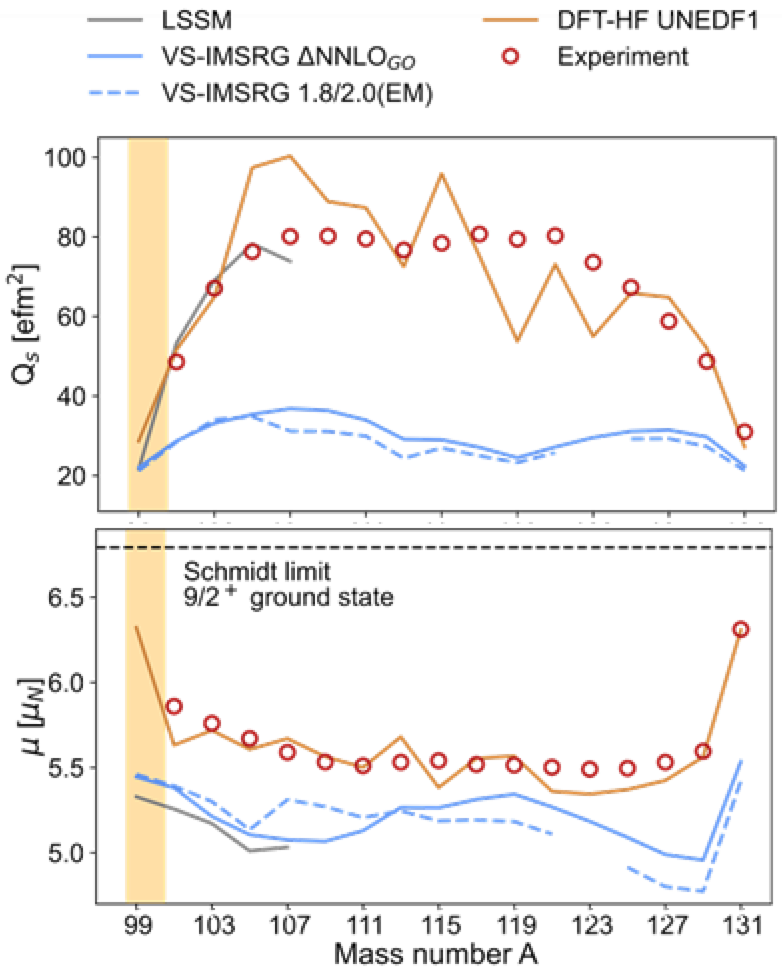
Magnetic dipole moments:
A sensitive probe to study the interplay between the single particle structure and many-body correlations.
Reflect the strength of a shell closure
Ordering of shell model levels and leading configuration for odd-odd nuclei



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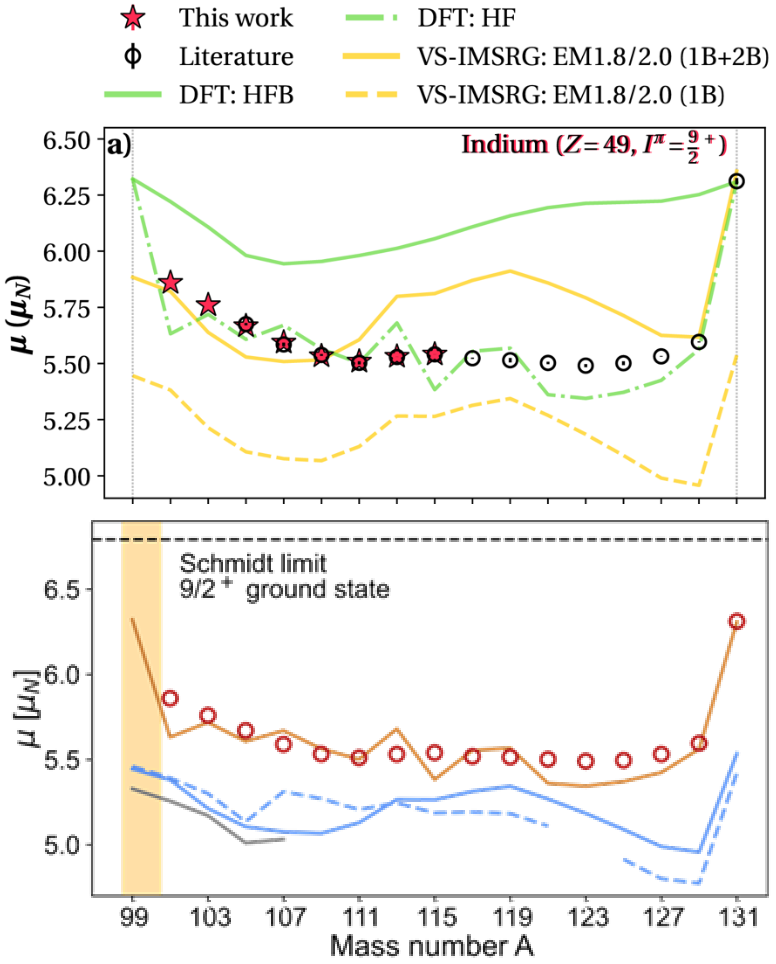

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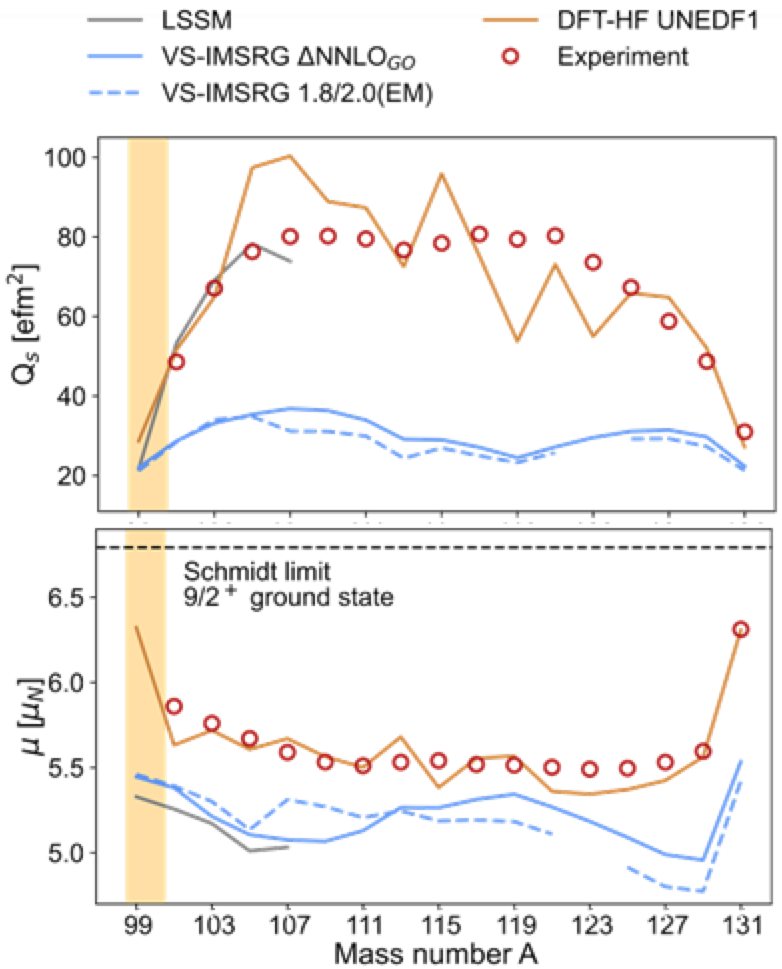
			?	(6^+)	$9/2^+$	(6^+)	$9/2^+$	6^+	$9/2^+$	7^+	$9/2^+$	7^+	$9/2^+$	7^+	9/2
In 96	In 97	In 98	In 99	In 100	In 101	In 102	In 103	In 104	In 105	In 106	In 107	In 108	In 109	In 110	In 111
	50 ms	37 ms	3.1 s	5.83 s	15.1 s	23.3 s	60 s	1.80 m	5.07 m	6.2 m	32.4 m	58.0 m	4.167 h	4.92 h	2.8063 d
	48		50		52		54		56		58		60		62



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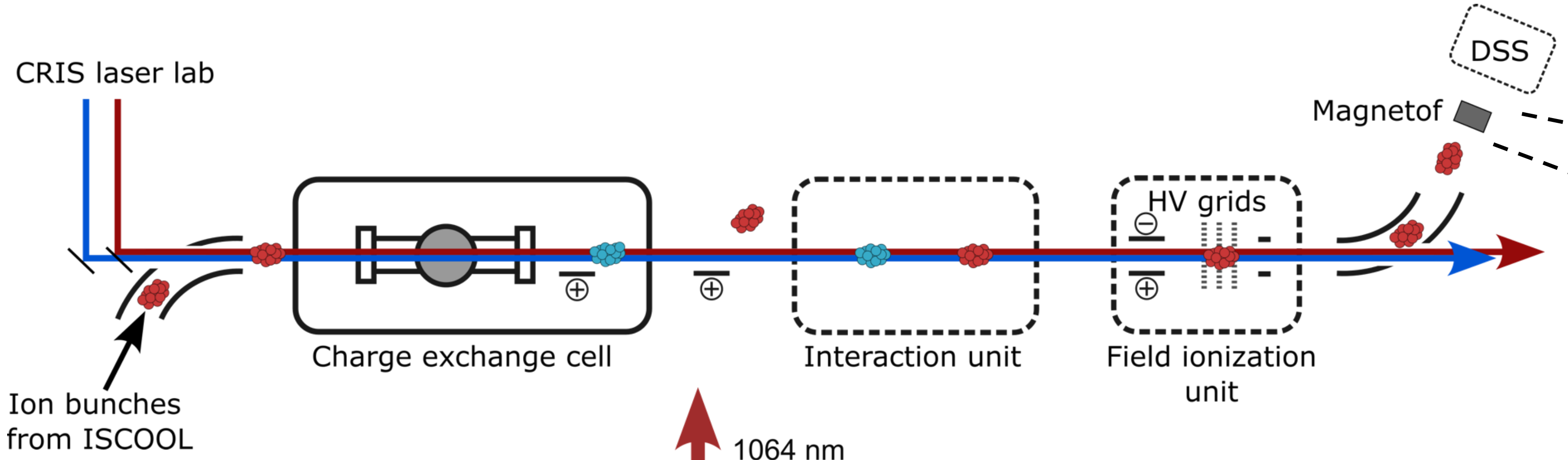
CRIS technique

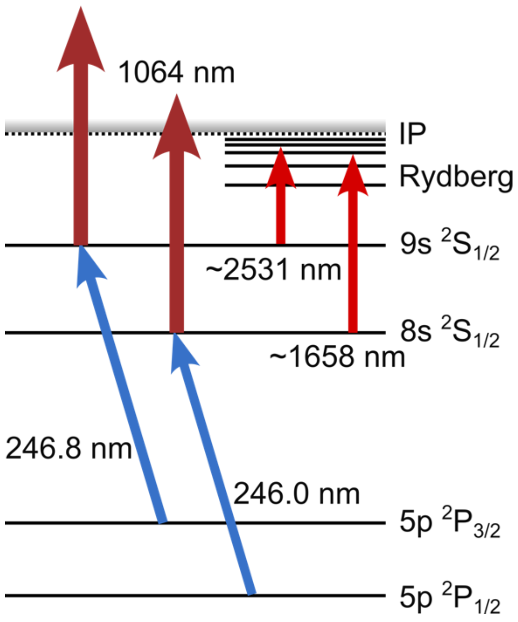


Laser scheme to be used

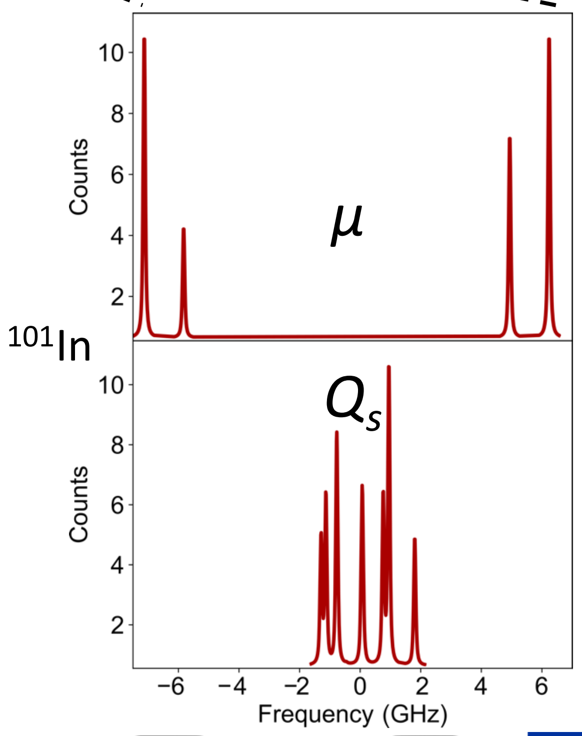
Two-step RIS schemes:

- High selectivity
- Minimized background

All lasers existing at CRIS



High resolution necessary (tens of MHz) to resolve HFS and isotope shift



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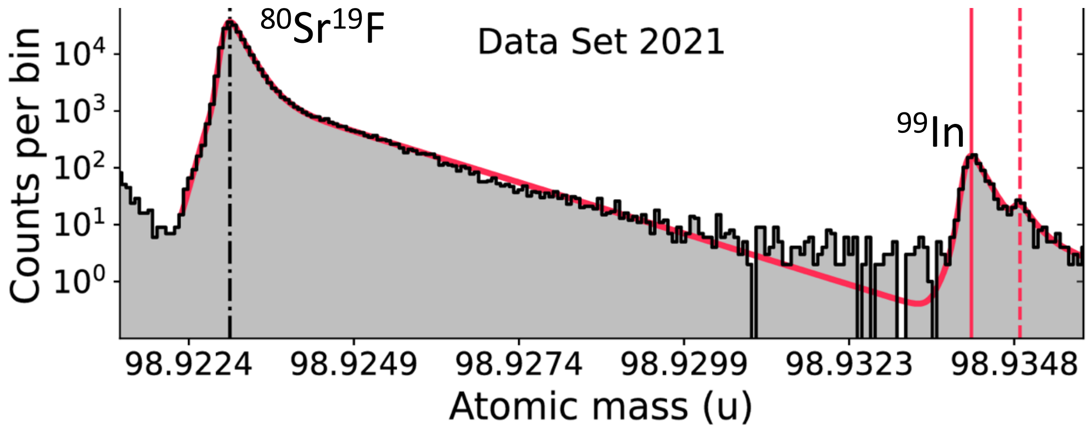
Challenge: low yields and large contamination



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- In 2 days of measurements: no decrease in yield for ^{99}In
- Main contamination $^{81,80}SrF$ yields known from ISOLTRAP

→ CRIS technique selective, previously handled 3 orders of magnitude and more higher contamination

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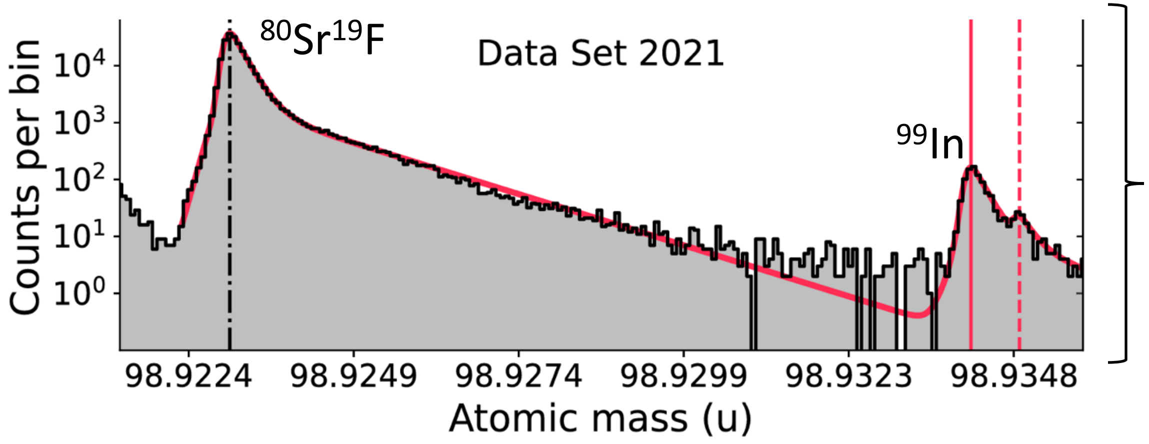

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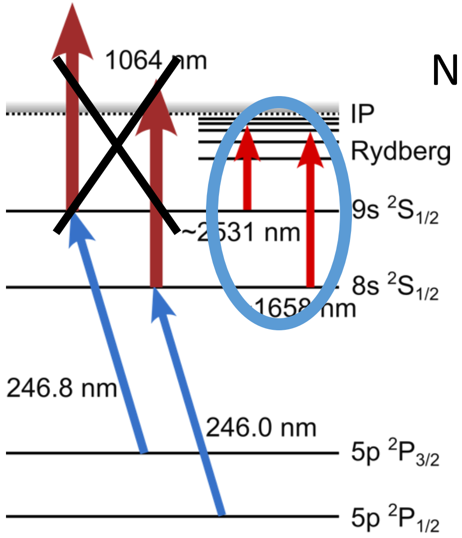
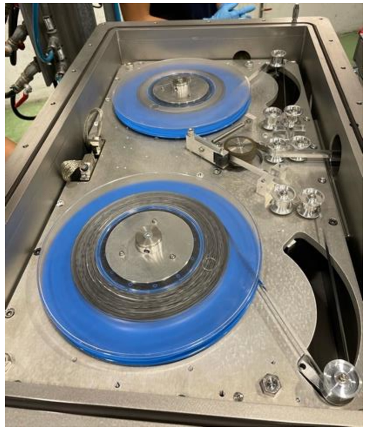
New CRIS developments offer further background reduction by 2 orders of magnitude



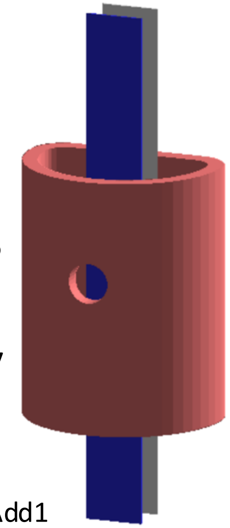
New FIU successfully commissioned

No laser related background from high power non-resonant step

A. Vernon et al., Sci. Rep. 10, 12306 (2020).
C. Schulz et al., J. Phys. B 24, 4831, (1991).



Upgraded CRIS DSS for increased sensitivity



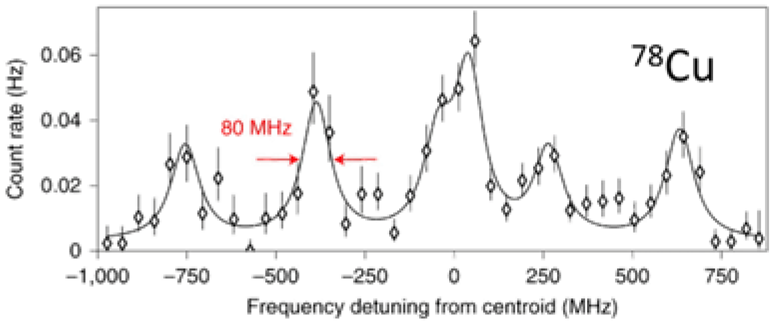
T.E. Cocolios, IS682 – Add1

Shift request

- LaC_x target + RILIS
- Yields for $^{99,100}In$ measured by ISOLTRAP
- Contamination known and yields measured (ISOLTRAP)

	Half live	Yields (/2µC)	Shifts	New results
$^{112\text{-}122}In$	> 1s	$> 10^4$	3	Reference
^{100}In	5.65(6) s	3×10^2	3	$I, \mu, Q_s, \delta\langle r^2\rangle$
^{99}In	3.1(2) s	5×10^0	15	$I, \mu, Q_s, \delta\langle r^2\rangle$
Stable		CRIS setup	3 (no protons)	

Combination of FIU and decay-based detection available: enables options for background free experiment



20 ions/s

- Measurement done in 1 shift, single ion counting
- Similar complex HFS
- Similar charge exchange cross section and laser transition strength
- Shifts requested account for low yields and estimated from previous CRIS run with low yields

L. Nies et al., Phys. Rev. Lett. 131, 022502 (2023).
A. Vernon et al., Spectrochim. Act. B 153, 61-83 (2019).
R.P. de Groote et al., Nature Phys. 16, 620–624 (2020).
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Combination of FIU and decay-based detection available: enables options for background free experiment

- Stable beamtuning for **CRIS setup**: 3 shifts
- **Reference measurements** throughout experiment, calibration of voltage drifts and systematic effects: 3 shifts
- **Laser spectroscopy** of ^{100}In: 3 shifts, **Laser spectroscopy** of ^{99}In: 15 shifts

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

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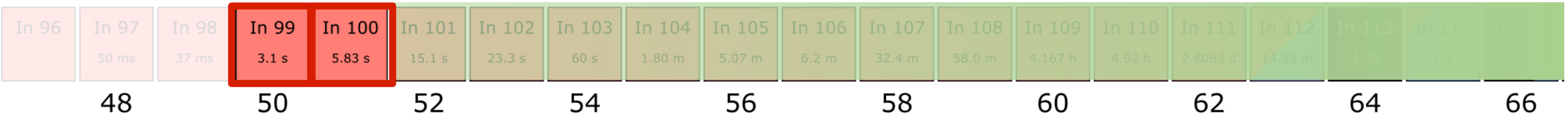
Conclusion

We propose to study neutron deficient indium isotopes closing up on the *N*=50 shell closure to investigate the structural evolution in the direct vicinity of in ^{100}Sn

- Assess the charge radii towards the shell gap for the onset of collectivity
- Determine spins which are only tentatively assigned
- Investigate g-factor and nuclear moments to investigate impact of the N=50 shell closure in In

This proposal



21+3 shifts using LaC_x target + RILIS ion source

Perform collinear resonance ionization laser spectroscopy using CRIS

Acknowledgments

J. Warbinek[1], O. Ahmad[2], J. Berbalk[2,3], A. Belley[4], T.E. Cocolios[2], R.P. de Groote[2], C.M. Fajardo-Zambrano[2], K.T. Flanagan[5], R.F. Garcia Ruiz[4], J. Karthein[6], A. Koszorus[2,7], L. Lalanne[8], P. Lassegues[2], Y. Liu[9], K.M. Lynch[5], D. McElroy[5], A.C. McGlone[5], J. Munoz[4], G. Neyens[2], L. Nies[1], F. Pastrana[4], A. Raggio[10], J.R. Reilly[3], B. van den Borne[2], R. Van Duyse[2], J. Wessolek[3,5], S.G. Wilkins[4], X.F. Yang[9].

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[2]Instituut voor Kern- en Stralingsfysica, KU Leuven, B-3001 Leuven, Belgium
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[4]Department of Physics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA
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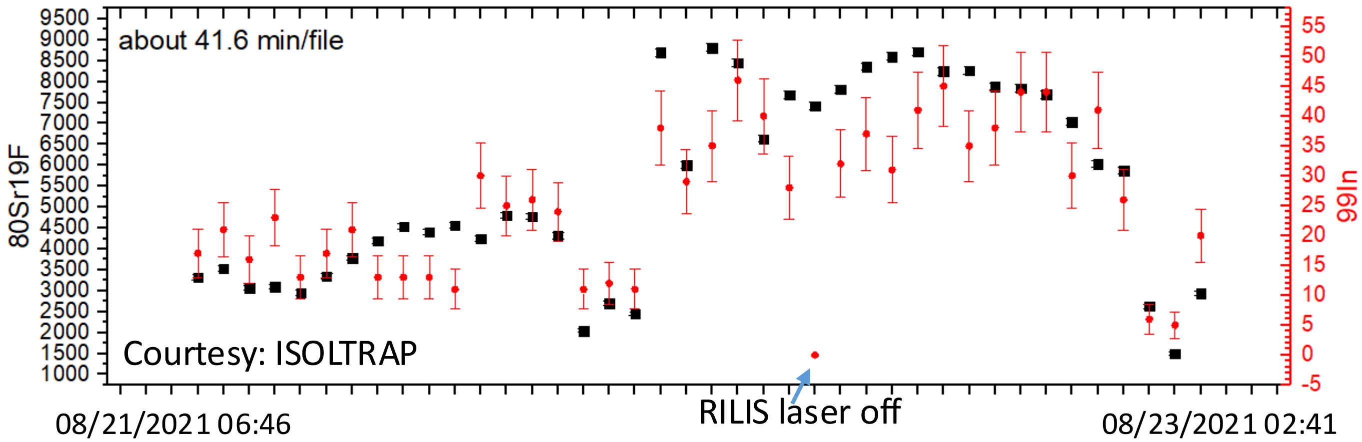
[10]Department of Physics, University of Jyvaskyla, 40500 Jyvaskyla, Finland

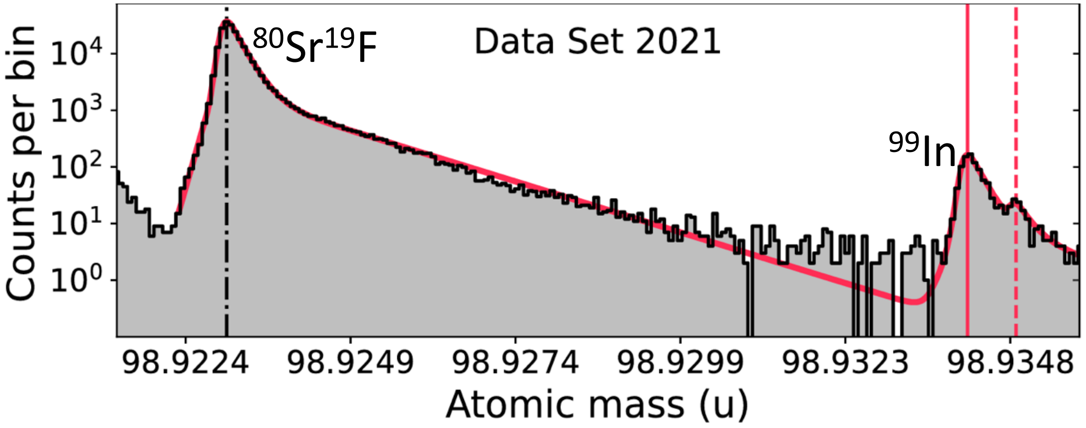
Challenge: low yields and large contamination



In 2 days of measurements: no decrease in yield observed
Conservative target heating ensured longevity

ISOLTRAP efficiency 0.3% to CA0 rate:

Corresponds to average of 4 cps in CA0
No drop observed in SrF or In



L. Nies et al., Phys. Rev. Lett. 131, 022502 (2023).

Accidental Mo contamination in target container: increased background on mass 100 hindered ^{100}In in 2018

(Resonant) background for ^{100}In from laser scheme on SrF observed

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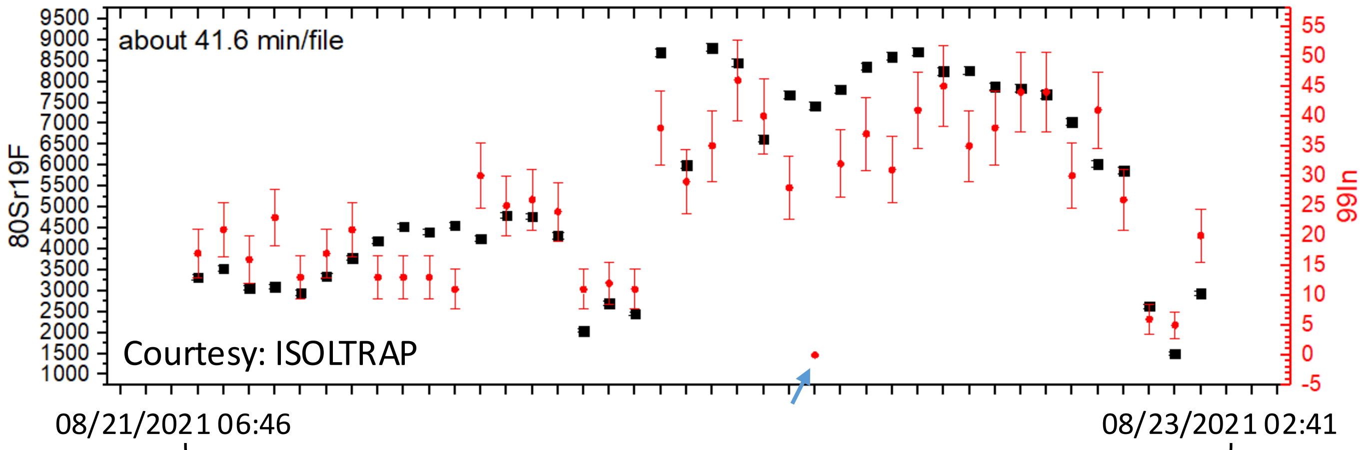

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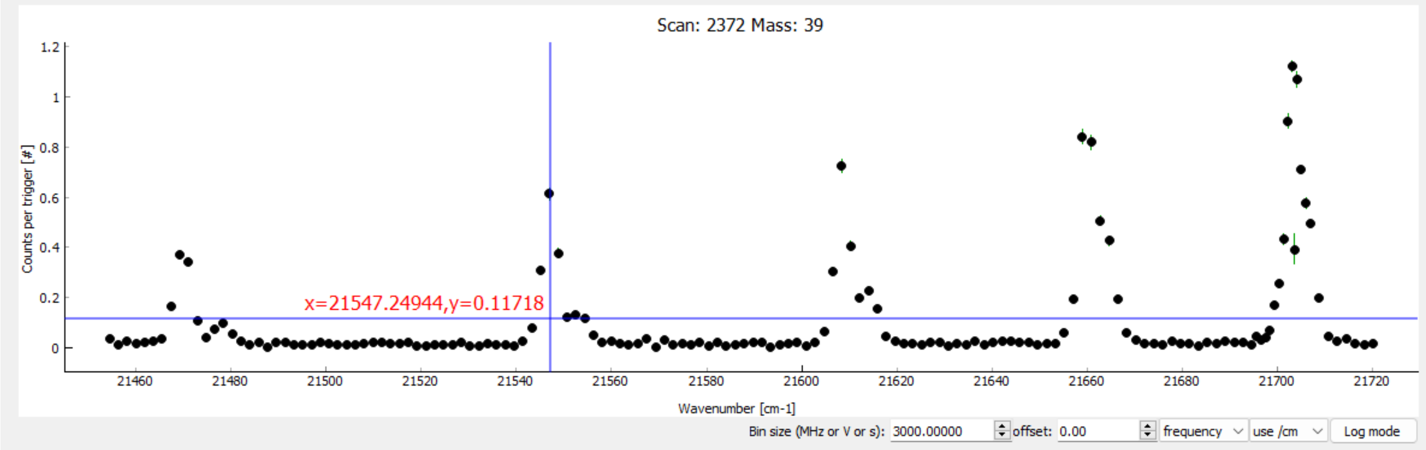
TAC comments:

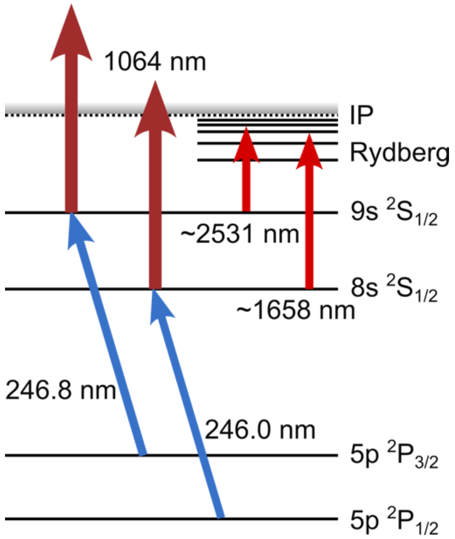
- Contamination mainly from SrF (as in case of IS661) -> should be removed by tape station on experiment side
  -> Recommend proton trigger to handle SrF – In is likely faster ✔ setup prepared on CRIS side
- For such exotic cases RILIS would certainly be operated with both 1st steps
  from gs and first thermal ✔ increase yield by ~20%

Field ionization unit + Decay station



Field ionization unit successfully implemented in CRIS

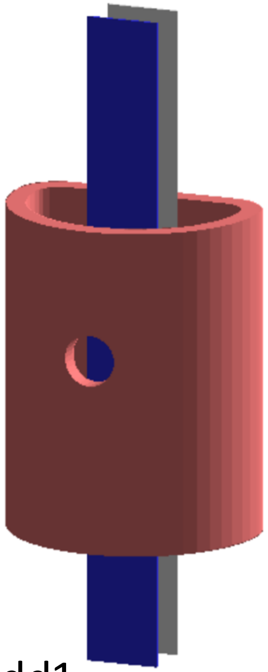
Principle shown with stable K beam from ISOLDE



Laser background from 1064 observed from molecular species during ^{101}In experiment

FIU via Rydberg state makes high power laser obsolete

Upgraded CRIS decay station available with new plastic scintillators: enhanced sensitivity



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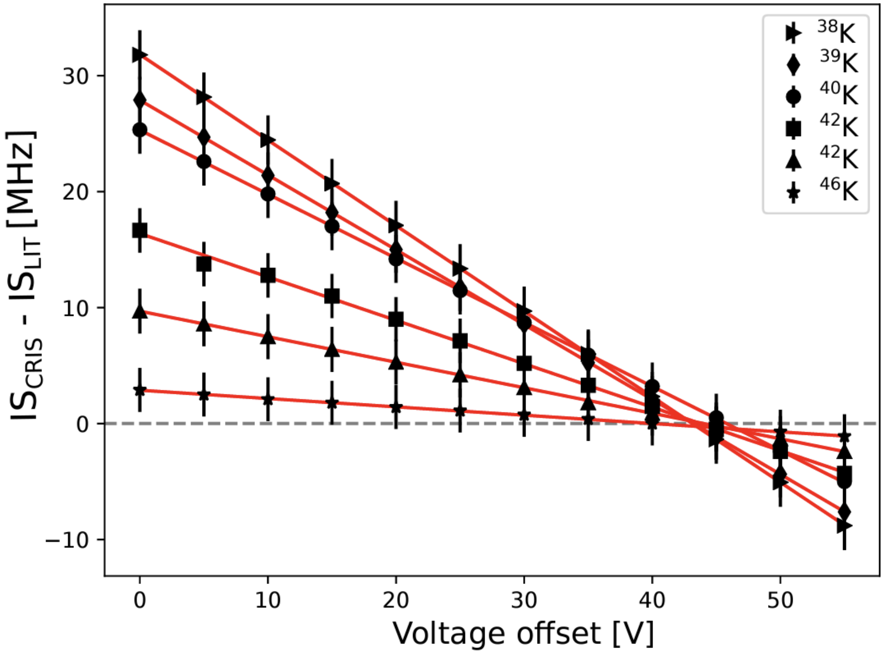
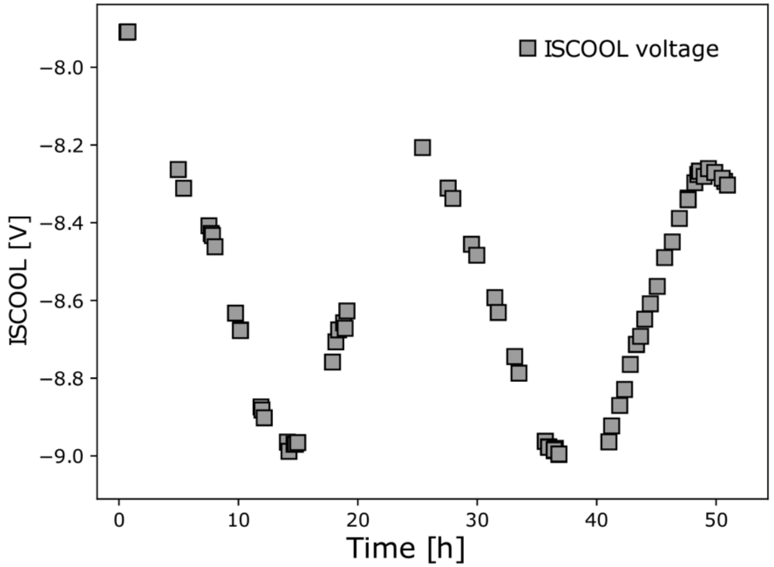
Systematic drifts



Voltage calibration necessary over long range of isotopes

Instabilities observed in ISCOOL voltage readout



Agota Koszorus, Dissertation, KU Leuven (2019).