Status report for the COLLAPS collaboration

M.L. Bissell[1], H. Heylen[2], L. Vázquez-Rodríguez[3] and Z.Y. Xu[4,5] for the IS529 and IS635 collaborations.

[1] School of Physics and Astronomy, The University of Manchester, Manchester, M13 9PL, UK
[2] Experimental Physics Department, CERN, Geneva, Switzerland
[3]Max-Plank-Institut f˙ur Kernphysik, D-69117 Heidelberg, Germany
[4]KU Leuven, Instituut voor Kern-en Stralingsfysica, B-3001 Leuven, Belgium
[5]Department of Physics and Astronomy University of Tennessee, Knoxville, Tennessee, USA

LS1 to LS2 Summary

Table 1: Main COLLAPS results and publications obtained between long shutdown 1 and 2.

Experiment	Isotopes	Status	Results, publications and PhD theses
IS508	$^{51,53-64}$Mn	Fully completed	- First application of optical pumping in ISCOOL at ISOLDE [2] - Onset of collectivity towards $N = 40$ studied via the magnetic moments [3, 4] quadrupole moments [2] and mean-square charge radii [5] - Firm spin assignments of low-spin and high-spin isomers in ^{58,60,62,64}Mn [4] - Part of PhD thesis of C. Babcock [6] and H. Heylen [7]
IS519	$^{63-79}$Zn	Fully completed	- Observation of unexpectedly large difference in charge radius between the ground state and isomer in $^{79}Zn_{49}$ [8] - Structural evolution studied from magnetic and quadrupole moments [9, 10] - Cross-shell proton excitations investigated via Zn charge radii [11] - Part of Phd thesis of C. Wraith [12] and L. Xie [13]
IS529	$^{50,52-54}$Ca	See section 3.1	- Development of a sensitive setup to study very exotic calcium isotopes [14] - Part of Phd thesis of R.F. Garcia Ruiz [15]
IS568	$^{58-68,70}$Ni	Articles in preparation	- First measurement of charge radii of radioactive Ni isotopes, new moments for 2 isotopes [16, 17] - Study of the ^{68}Ni charge radius in relation to its dipole polarizability [18] - Part of PhD thesis of L. Xie [13] and S. Kaufmann [19]
IS573	$^{108-134}$Sn	Articles in preparation	- Established and explained the kink in the charge radii at $N = 82$ in Sn [20] - Simple but surprising linear and quadratic mass-dependent trends of quadrupole moments and isomer shifts [21] - Study of the doubly-magic-plus-one-neutron nucleus ^{133}Sn [22] - Part of PhD thesis of C. Gorges [23] and L. Vázquez-Rodríguez [24]
IS617	$^{26-32}$Al	Articles in preparation	- First measurement of charge radii of radioactive Al isotopes, new moments for 2 isotopes [25] - Follow-up proposal to study ^{26g,m}Al accepted at IGISOL PAC
IS623	$^{68-74}$Ge	Data analysis ongoing	- Will be part of thesis of A. Kanellakopoulos
IS635	$^{112-134}$Sb	Data analysis ongoing, see section 3.2,	- Will be part of thesis of S. Lechner
IS649	$^{44-50}$Sc	Data analysis ongoing	- Will be part of thesis of S. Bai
⋆	$^{197-209}$Bi	Articles in preparation	- The relevance of the ^{208}Bi magnetic moment for testing bound-state strong-field QED [26] - The hyperfine anomaly in Bi-isotopes [27]

⋆ Note that the Bi-data are the by-product of a collaboration to understand unexpected observations of the IS608 in-source laser spectroscopy experiment.

IS529: Spins, Moments and Charge Radii beyond ^{48}Ca

- INTC approved bunched-beam collinear spectroscopy for $^{49\text{-}52}$Ca.

RAPID COMMUNICATIONS

PHYSICAL REVIEW C 91, 041304(R) (2015)

Ground-state electromagnetic moments of calcium isotopes

R. F. Garcia Ruiz,[1,*] M. L. Bissell,[1] K. Blaum,[2] N. Frömmgen,[3] M. Hammen,[3] J. D. Holt,[4,5,6] M. Kowalska,[7] K. Kreim,[2] J. Menéndez,[4,5,8] R. Neugart,[2,3] G. Neyens,[1] W. Nörtershäuser,[4] F. Nowacki,[9] J. Papuga,[1] A. Poves,[10] A. Schwenk,[4,5] J. Simonis,[4,5] and D. T. Yordanov[2]

ARTICLES

PUBLISHED ONLINE: 8 FEBRUARY 2016 | DOI: 10.1038/NPHYS3645

nature physics

Unexpectedly large charge radii of neutron-rich calcium isotopes

R. F. Garcia Ruiz[1*], M. L. Bissell[1,2], K. Blaum[3], A. Ekström[4,5], N. Frömmgen[6], G. Hagen[4], M. Hammen[6], K. Hebeler[7,8], J. D. Holt[9], G. R. Jansen[4,5], M. Kowalska[10], K. Kreim[3], W. Nazarewicz[4,11,12], R. Neugart[3,6], G. Neyens[1], W. Nörtershäuser[6,7], T. Papenbrock[4,5], J. Papuga[1], A. Schwenk[3,7,8], J. Simonis[7,8], K. A. Wendt[4,5] and D. T. Yordanov[3,13]

- First addendum approved the application of the ROC technique to ^{53,54}Ca.

OPEN ACCESS
IOP Publishing

Made open access 7 August 2017
Journal of Physics G: Nuclear and Particle Physics

J. Phys. G: Nucl. Part. Phys. 44 (2017) 044003 (19pp)

https://doi.org/10.1088/1361-6471/aa5a24

Development of a sensitive setup for laser spectroscopy studies of very exotic calcium isotopes

R F Garcia Ruiz[1,2,8], C Gorges[3,8], M Bissell[2], K Blaum[4], W Gins[1], H Heylen[1], K Koenig[3], S Kaufmann[3], M Kowalska[5], J Krämer[3], P Lievens[6], S Malbrunot-Ettenauer[5], R Neugart[4], G Neyens[1], W Nörtershäuser[3], D T Yordanov[7] and X F Yang[1]

However

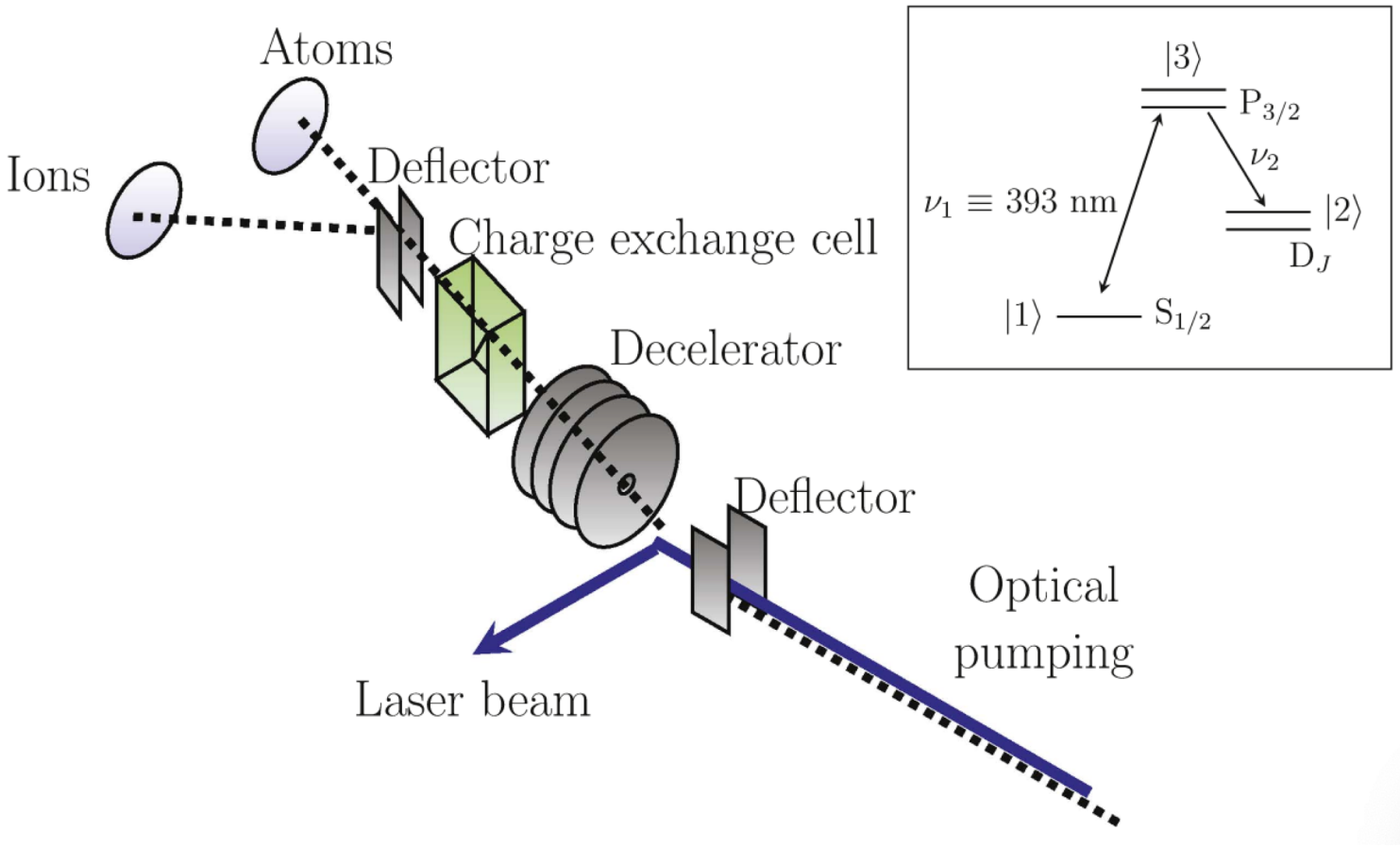
Yield of ^{54}Ca was <1/100 of that previously observed by ISOLTRAP. ✣

- Technical developments required.
- ROC beamline incompatible with BBCLS.
- Postpone development until LS2.

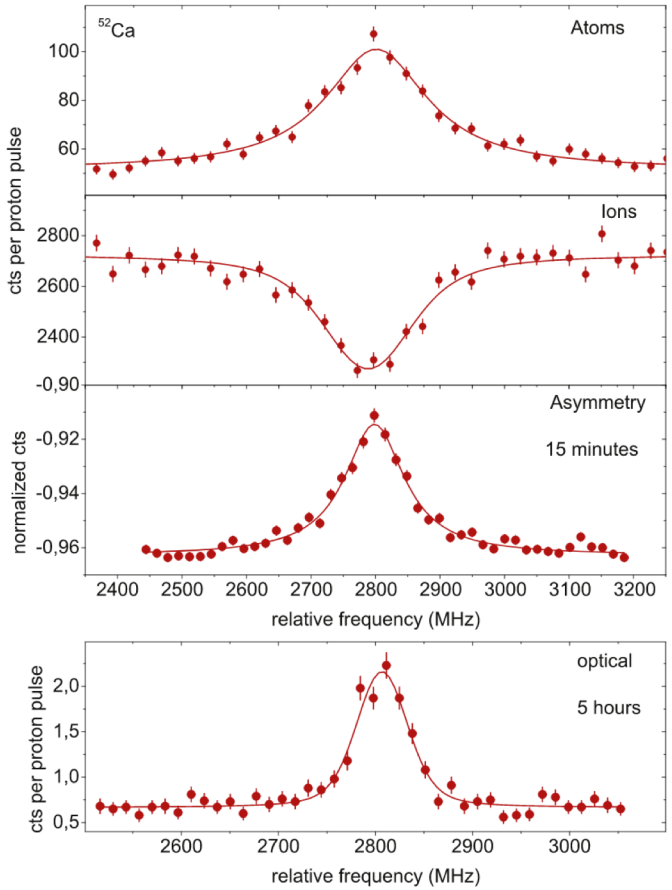
✣ F. Wienholtz et al., *Nature* **volume 498**, pages 346–349 (20 June 2013)

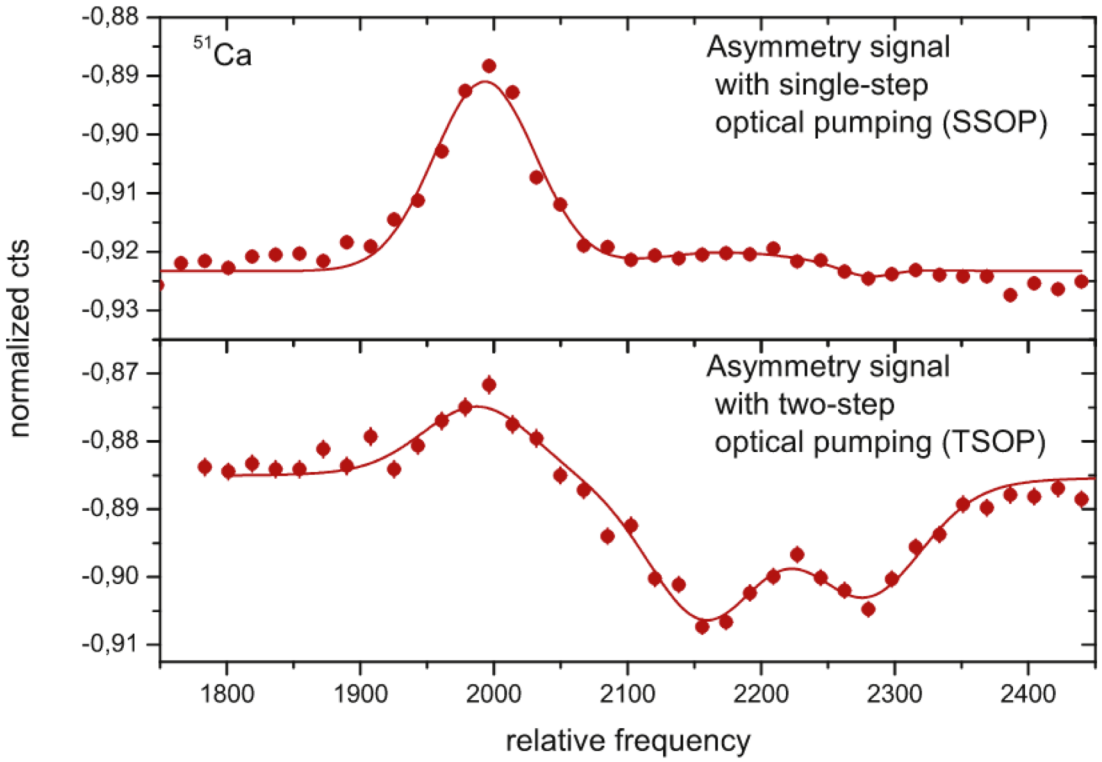
IS529: What is ROC ?

(Radioactive detection of Optically pumped ions after state selective Charge exchange)



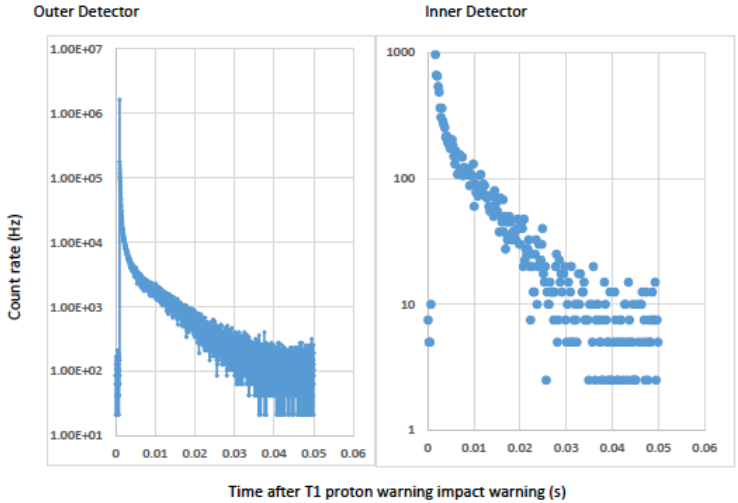
IS529: What has been achieved?

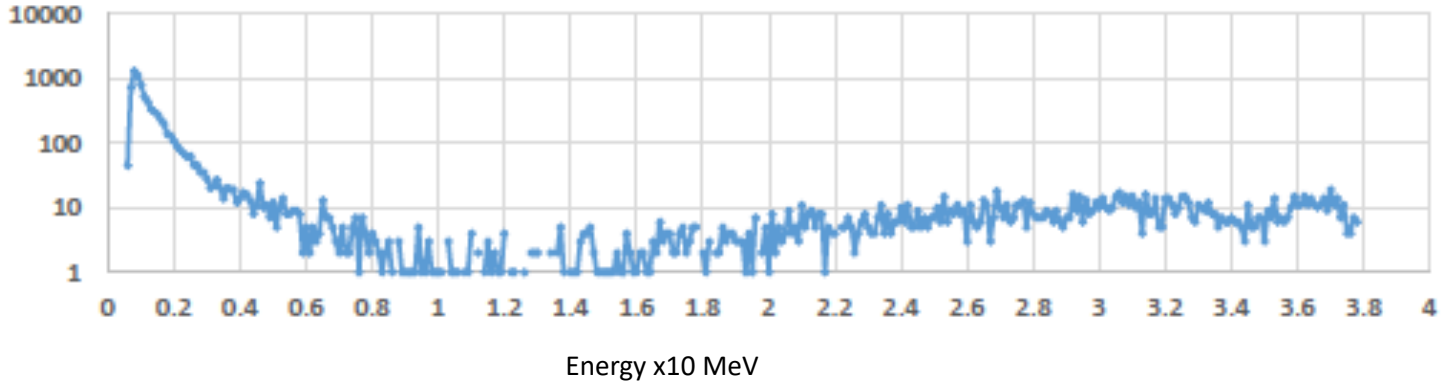




IS529: Sensitivity improvements

- 1) Fully characterise timing and energy spectra of background in the ISOLDE hall.
    - Full study undertaken : Background in detectors can be reduced to below 0.1/pp

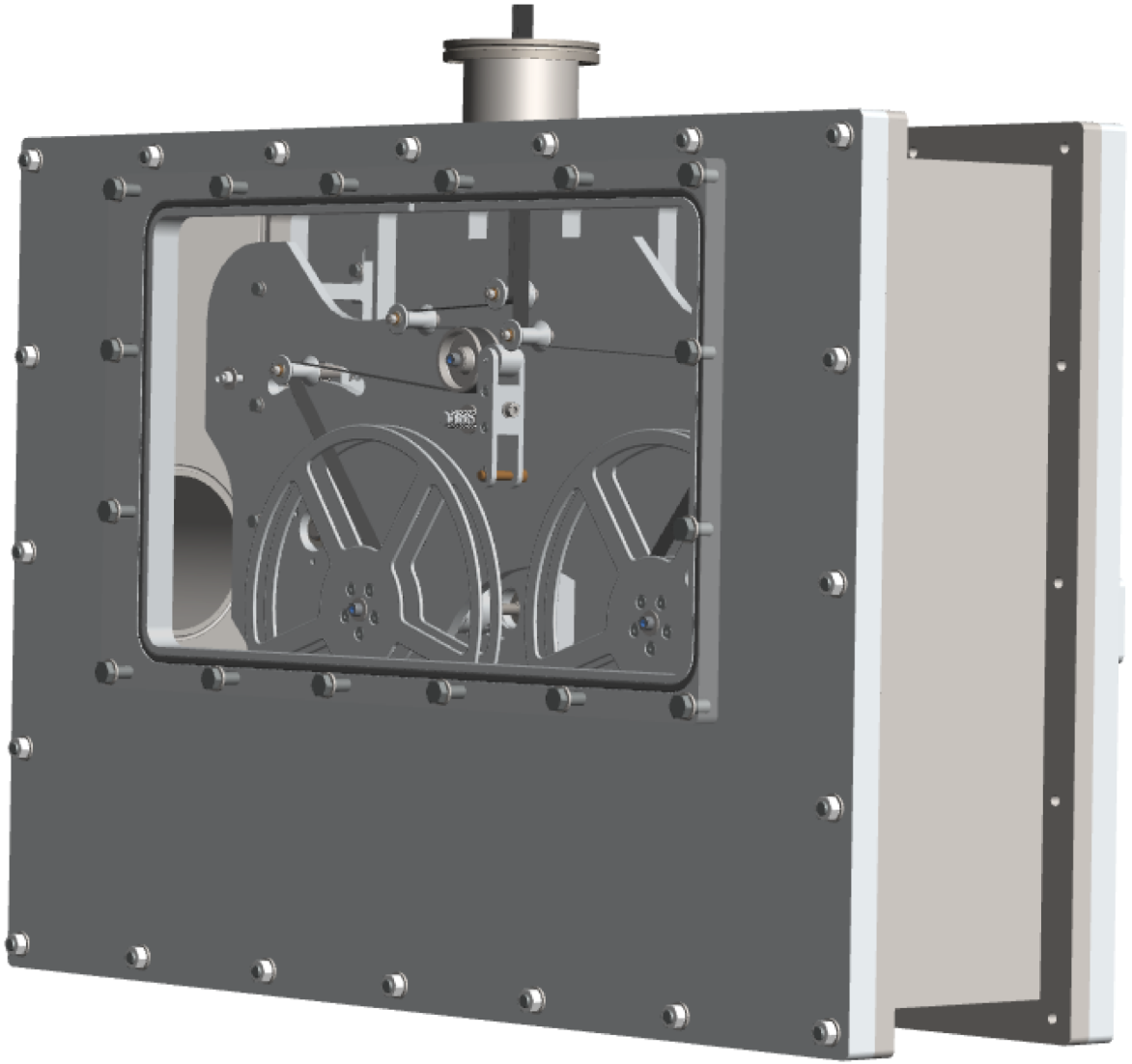


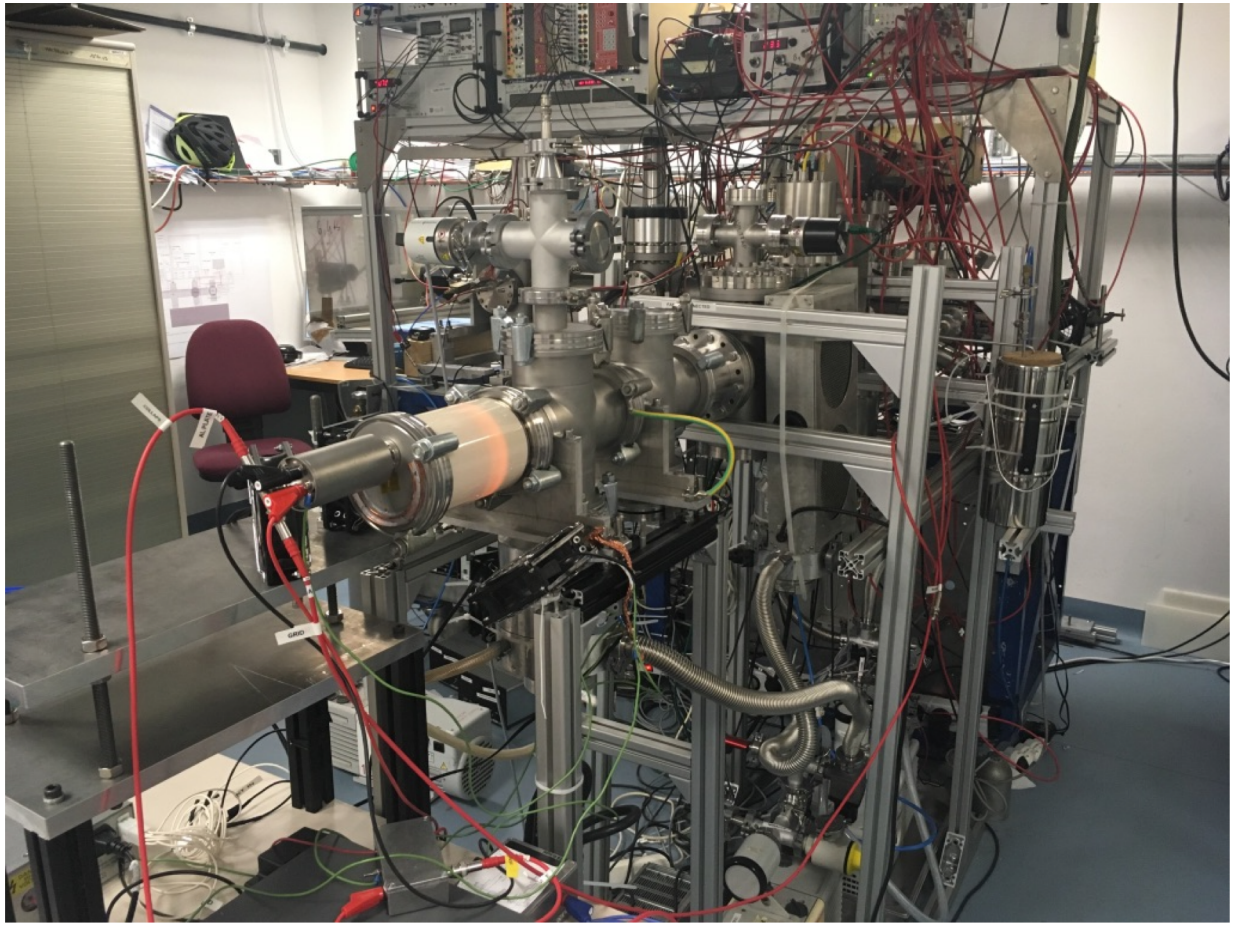


- 2) Fast reliable tape systems to move away activity with every proton pulse.
    - Longer tape
    - Faster cycle time
    - Improved reliability

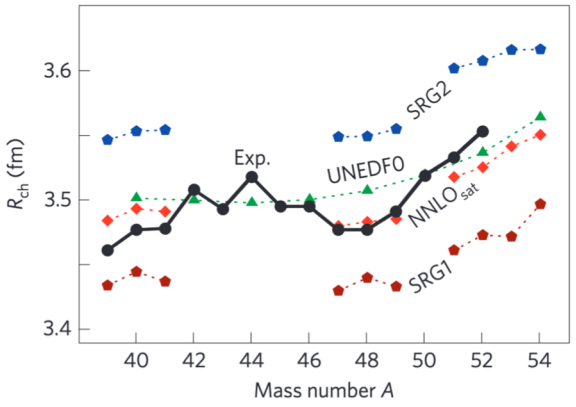
- 3) Improve transmission to the atom beta detection station.
    - Construct offline Ca ion source.
    - Characterise transmission and validate simulations.

IS529: Technical developments

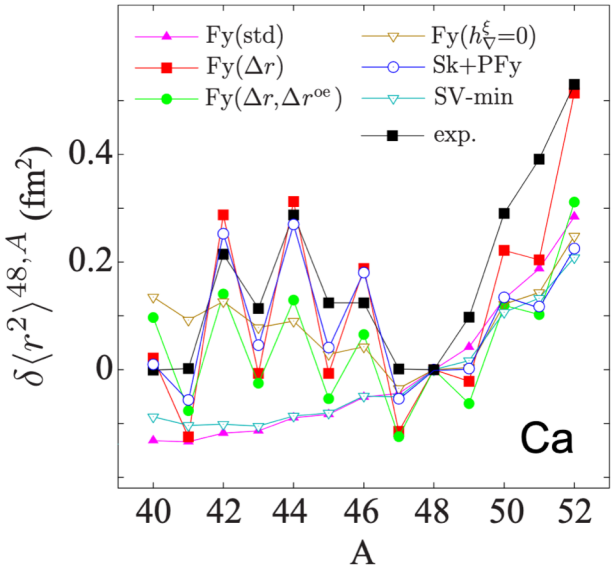




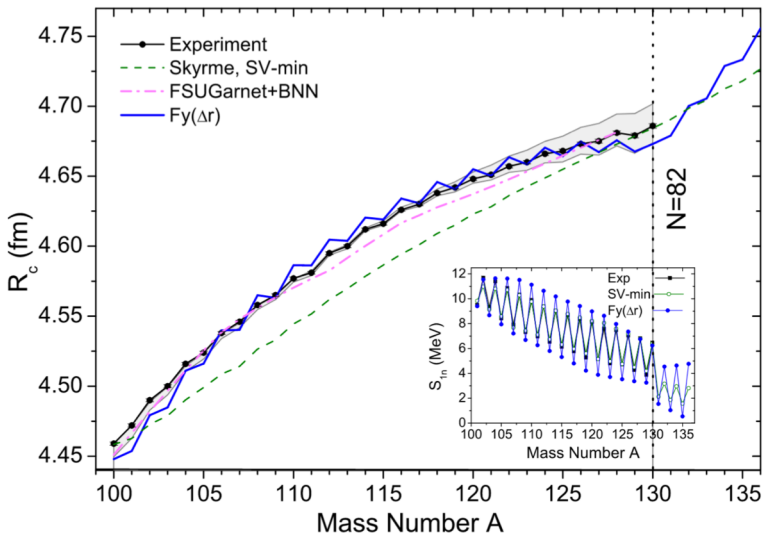
IS529: Ongoing Physics relevance



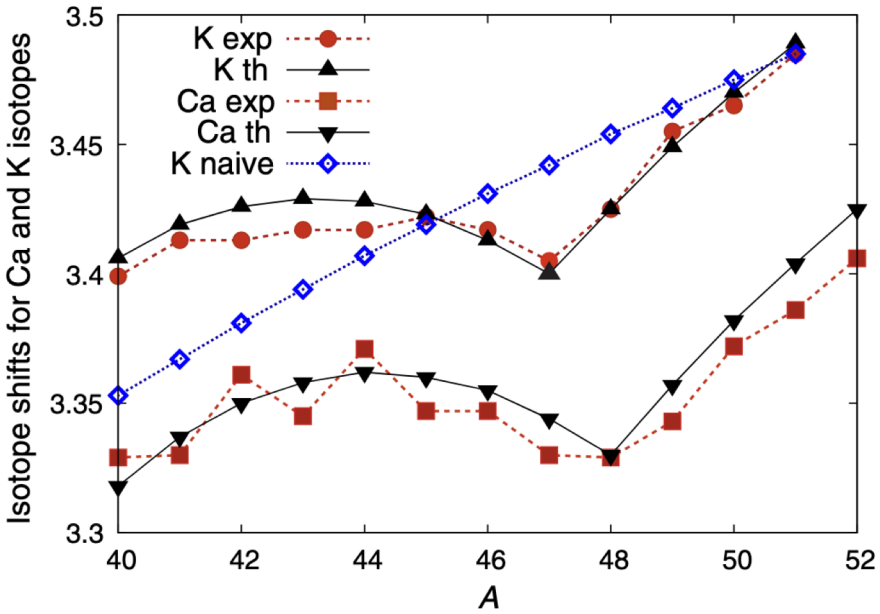
R.F. Garcia Ruiz et al., Nature Physics **12**, 594 (2016)



P.-G. Reinhard, W. Nazarewicz, Phys. Rev. C **95**, 064328 (2017)



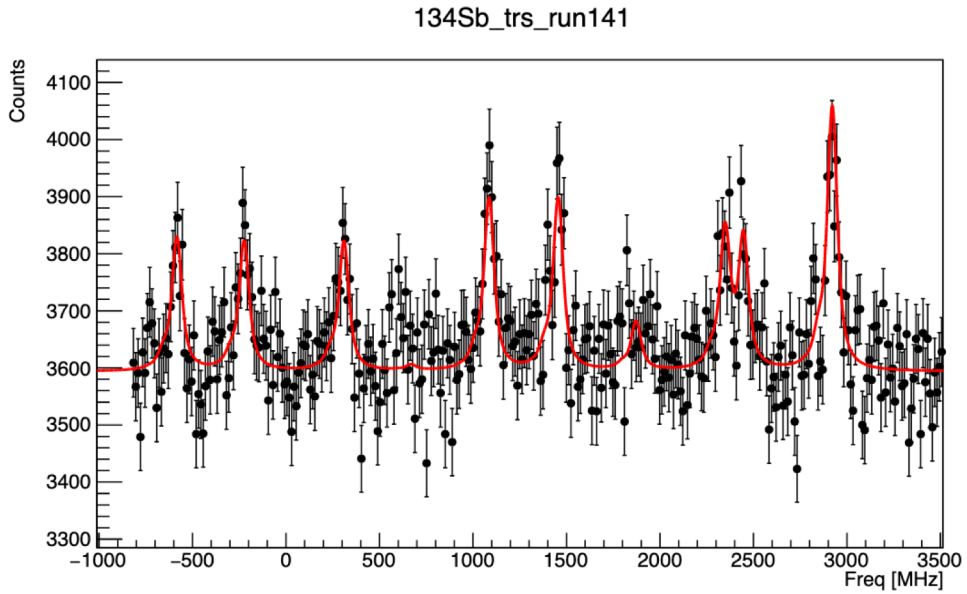
M. Hammen *et al.*, Phys. Rev. Lett. **121**, 102501 (2018)



J. Bonnard, S. M. Lenzi, A. P. Zuker, Phys. Rev. Lett. **116**, 212501 (2016)

IS635: Nuclear quadrupole moments and charge radii of the $_{51}$Sb isotopes via collinear laser spectroscopy

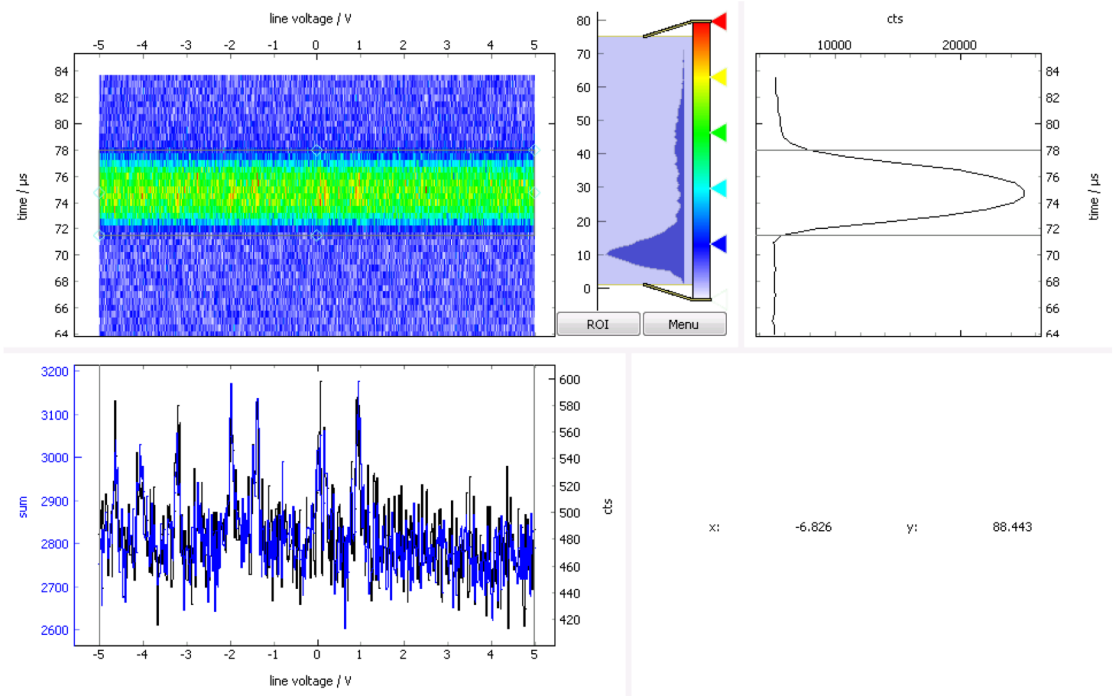
- INTC approved measurements of $^{112\text{-}135}$Sb.
  - In our first run $^{112\text{-}134}$Sb measured (including 22 ground states and 11 isomers.)



  - 6 shifts remaining for the measurement of ^{135}Sb.

IS635: Feasibility considerations

- With the same conditions as the previous run ^{135}Sb would not be possible within 6 shifts.
- ^{135}Cs atoms are exited in the K charge exchange cell -> Strong beam correlated background.



	track	scaler	v_min [V]	v_max [V]	t_min [µs]	t_max [µs]	show
1	track0	0	-5.0	5.0	71.0	77.5	☐
2	track0	1	-5.0	5.0	71.5	78.0	☑
3	track0	2	-5.0	5.0	71.0	77.5	☐
4	track0	3	-5.0	5.0	71.5	78.0	☐

<u>Cs charge exchange</u>

From simulation (Adam Vernon), replacing K with Cs should significantly reduce the background and also improve signal (x1.5).

<u>Filters</u>

85% of photons emitted are >267 nm. UG5 filter could be used to cut all laser related background, but with a 28% loss in signal.

<u>Limit of feasibility within 6 shifts.</u>

TAC Comments and Conclusions

Status report for the COLLAPS collaboration					
Status report #	**Proposal #**	**IS #**	**Setup**	**Shifts**	**Isotopes**
INTC-SR-090	INTC-P-313; INTC-P-313-ADD-1	IS529	COLLAPS	17	53,54Ca
	INTC-P-484; INTC-CLL-028	IS635	COLLAPS	6	135Sb
Beam intensity/purity, targets-ion sources	**IS529:** The ability to deal with current levels of 53,54Ca have been solved on the COLLAPS side. **IS635:** 135Sb yield measured 2018: 2.7E5 /uC 135 contamination -> Cs Needs some development time Break up of SbS in charge exchange cell ? SbS tests will be carried out at the offline separator and as part of the ALTO campaign in 2019. VADLIS could be an option to remove Cs. RILIS is ok for both.				
General implantation and setup					
REX, HIE-ISOLDE					
General Comments					
Safety	Complete additional risk assessment required (specification of HV platform to be given; electrical inspection necessary before operating - more info required for high temperatures – etc.). For COLLAPS set-up, Safety Clearance granted (EDMS 1806800).				
TAC recommendation	**The TAC does not see any serious issues for Ca if the ROC setup is performing. For Sb the Cs suppression will require development; molecular breakup could be a possibility? VADLIS could also be considered. Safety aspects for ROC are required.**				

- ROC developments on track for successful measurement of ^{53,54}Ca.
- ^{135}Sb theoretically possible, although further investigation required.

Thanks to