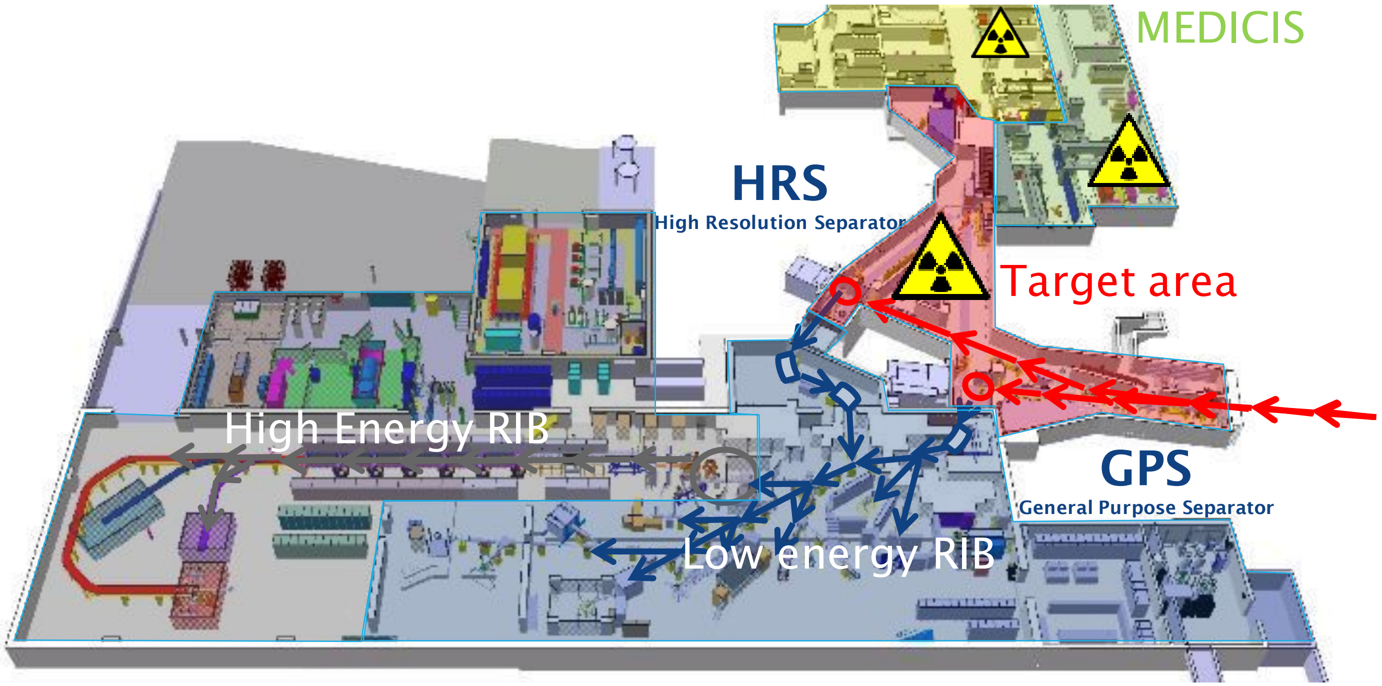
CRIS at ISOLDE : Recent results and future projects

Louis Lalanne
on behalf of the CRIS collaboration

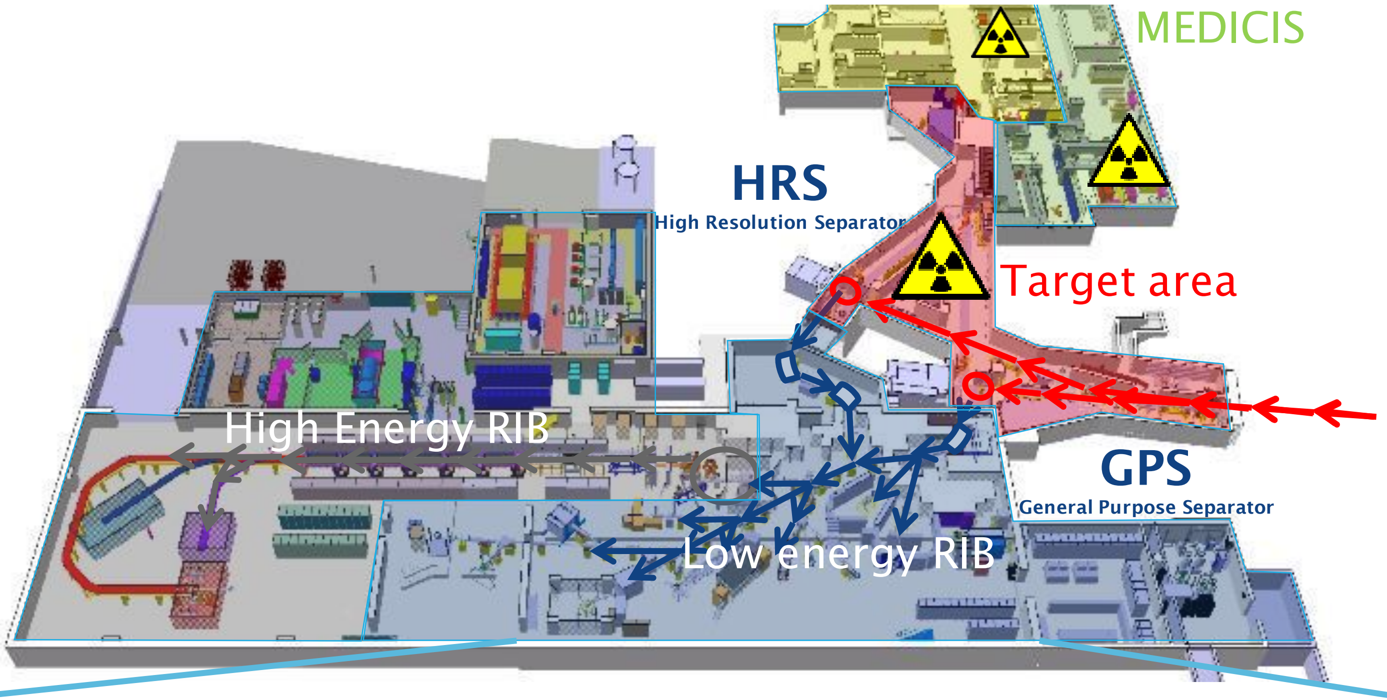
ISOL France

21/03/2023

CRIS @ ISOLDE


MEDICIS
HRS
High Resolution Separator
Target area
High Energy RIB
GPS
General Purpose Separator
Low energy RIB

CRIS @ ISOLDE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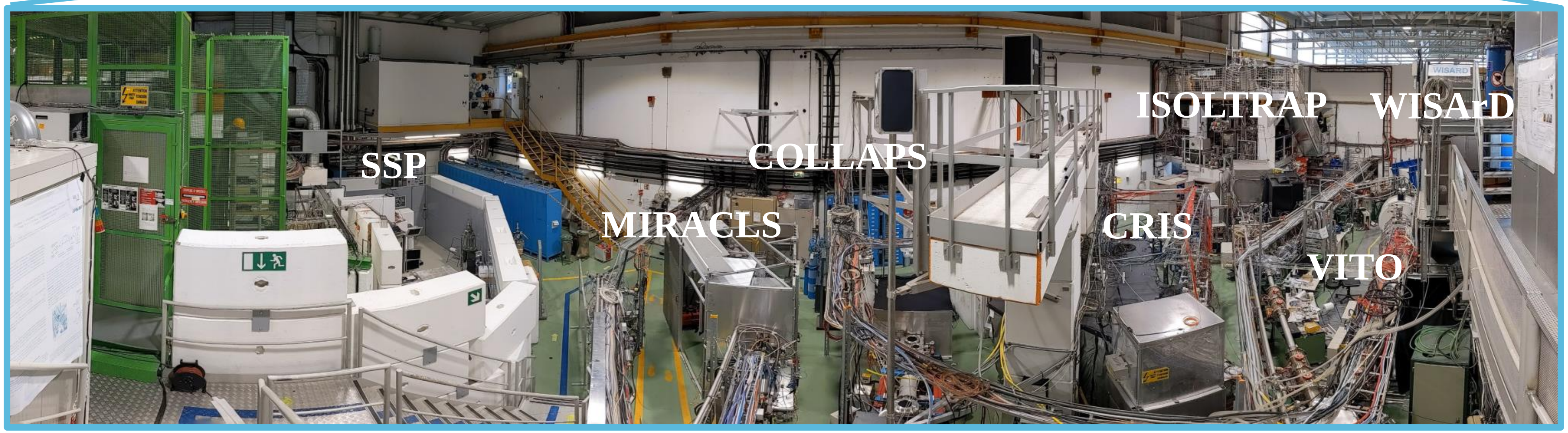
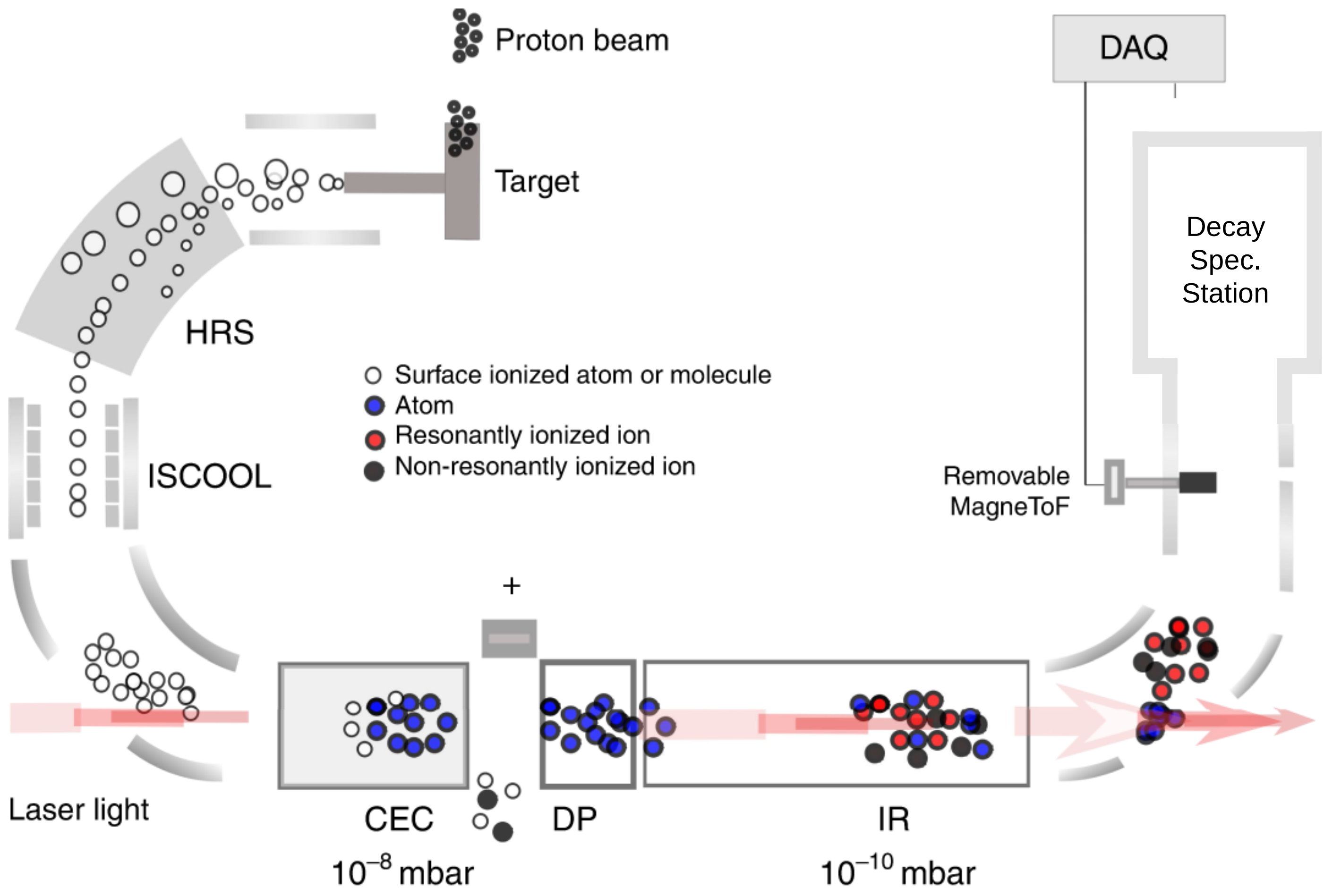
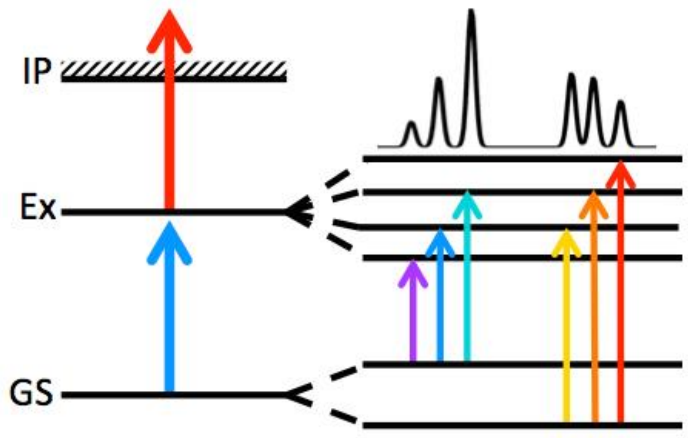

ISOLTRAP
WISArD
SSP
COLLAPS
MIRACLS
CRIS
VITO

CRIS @ ISOLDE

CRIS : Collinear Resonance Ionization Spectroscopy





Measuring the HFS allows access to:

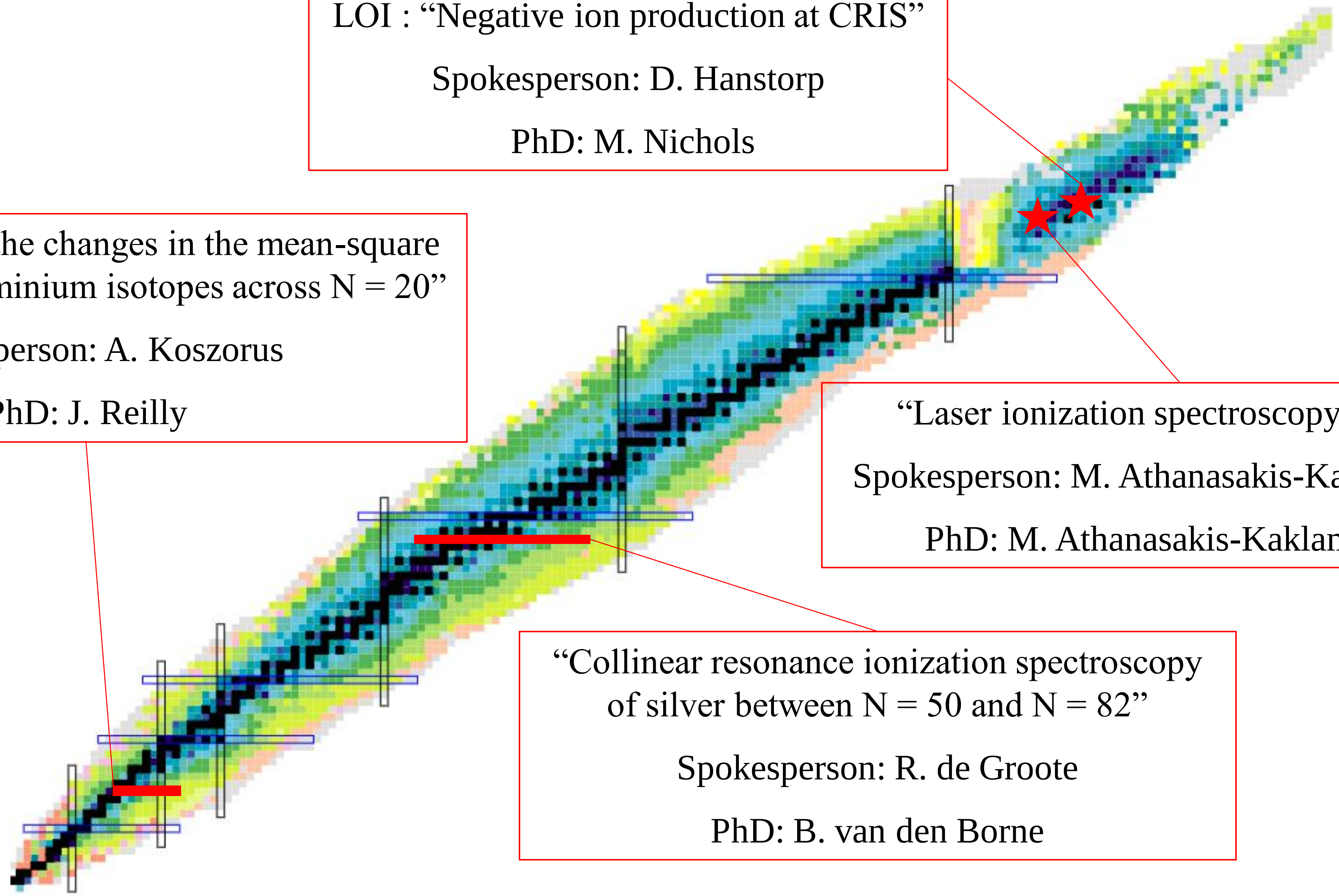
- Nuclear spin
- Dipole magnetic moment
- Electrical quadrupole moment
- Mean-squared charge radii

✓ High sensitivity : few 10 ions/s

✓ High resolution : ~ 100 MHz

✓ High versality : Nuclear structure, atomic structure, molecular spec., negative ions

2022 experimental campaign



LOI : “Negative ion production at CRIS”

Spokesperson: D. Hanstorp

PhD: M. Nichols

“Measurement of the changes in the mean-square charge radii of aluminium isotopes across N = 20”

Spokesperson: A. Koszorus

PhD: J. Reilly

“Laser ionization spectroscopy of AcF”

Spokesperson: M. Athanasakis-Kaklamanakis

PhD: M. Athanasakis-Kaklamanakis

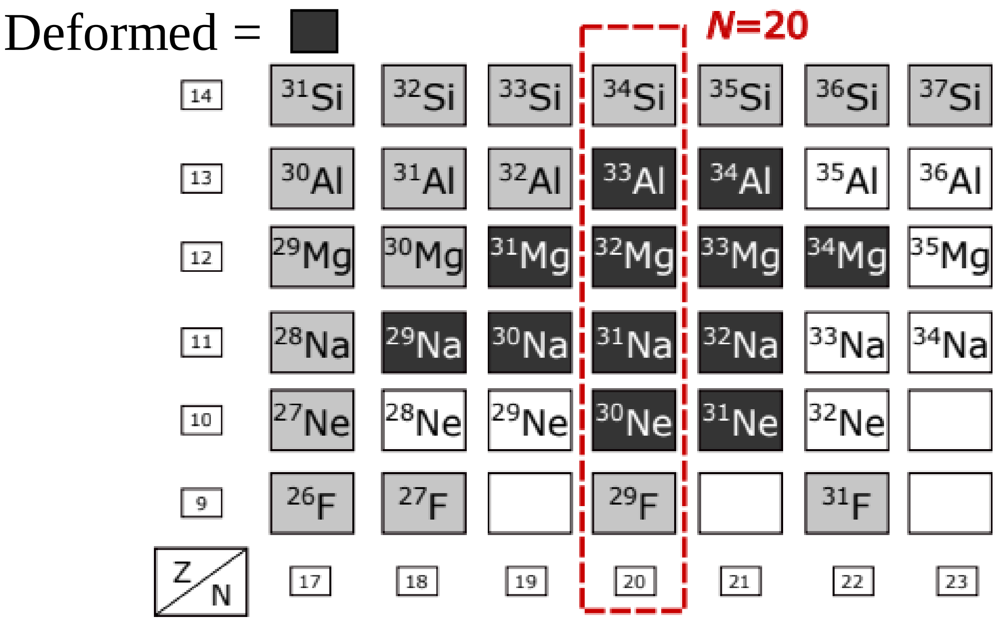
“Collinear resonance ionization spectroscopy of silver between N = 50 and N = 82”

Spokesperson: R. de Groote

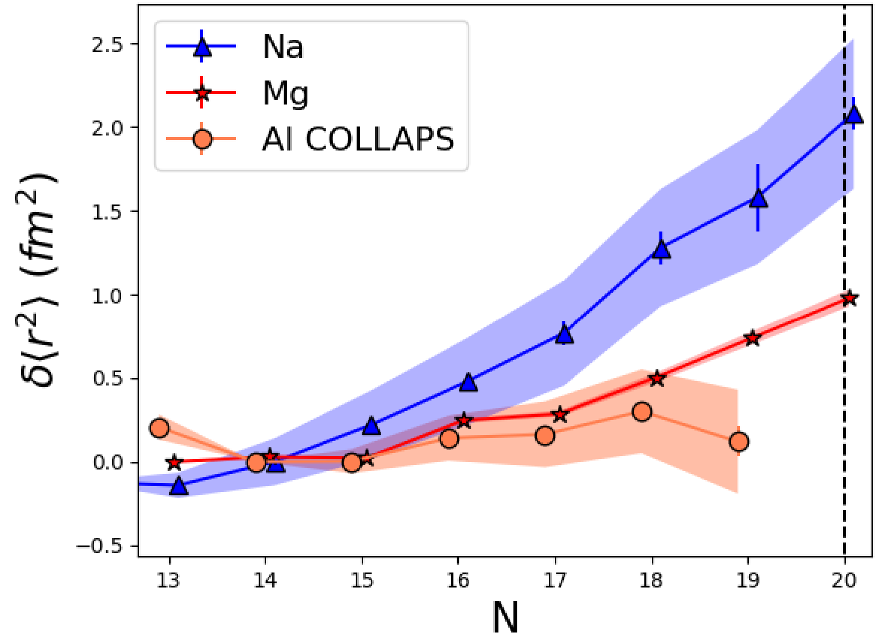
PhD: B. van den Borne

2022 experimental campaign: Al

- N=20 Island of Inversion: Strongly mixed and deformed ground state configuration
- This level of deformation is evidenced in the charge radii
- ^{33}Al located between strongly deformed ^{32}Mg and spherical ^{34}Si - Transition into the Island of inversion?



- Large increase in charge radii towards the $N = 20$ shell closure is observed for **Na** and **Mg**
- Previous measurements of Al radii display an unexpected decrease in $\boldsymbol{\delta\langle r^2\rangle}$ between ^{31}**Al** and ^{32}**Al**

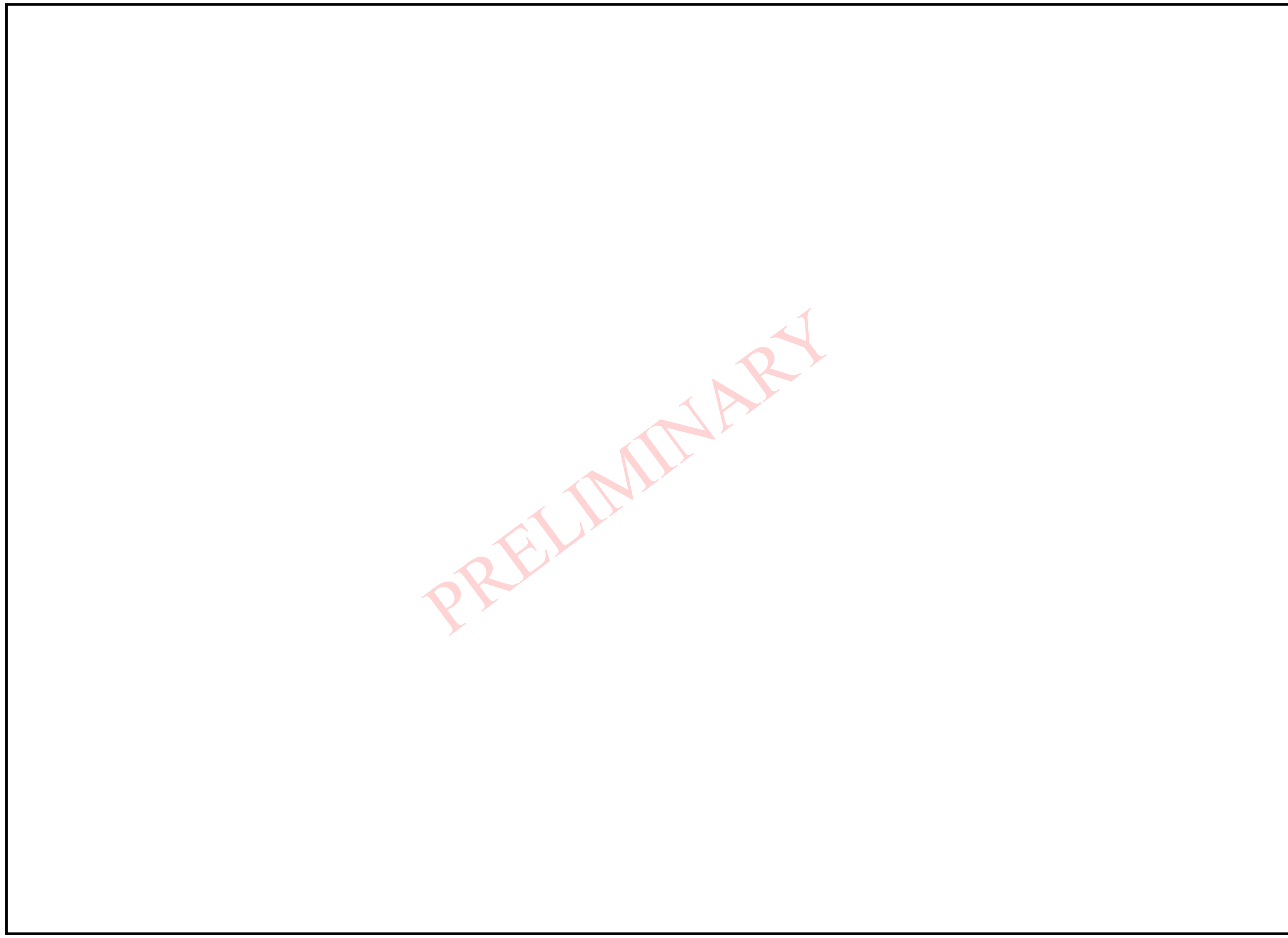


2022 experimental campaign: Al

- First measurement of charge radii across N=20 in the vicinity of the IoI
- $^{27\text{-}31}$Al in agreement with previous measurements
- $^{32\text{-}34}$Al upwards trend towards and crossing $N = 20$

More statistic is needed to reduce uncertainties and to clarify the increase in charge radii

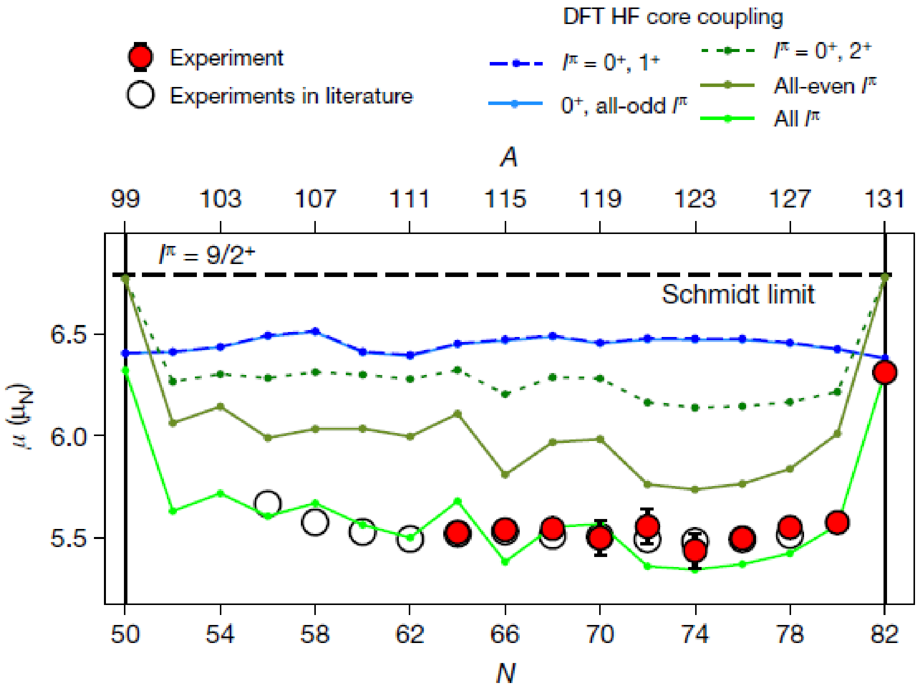
→ second Al run to come in 2023

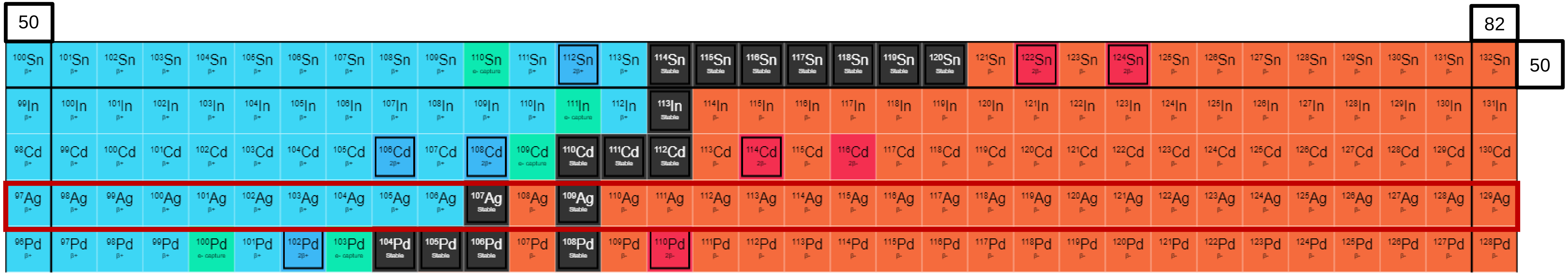


Analysis and plots from Jordan Reilly

2022 experimental campaign: Ag

- Isotopic chain spans N = 50 and N = 82
- Many isomers with unclear structure
- Investigate validity of single particle behaviour
  - Single particle behaviour challenged in indium[1]
  - What is the effect of the two extra proton holes?



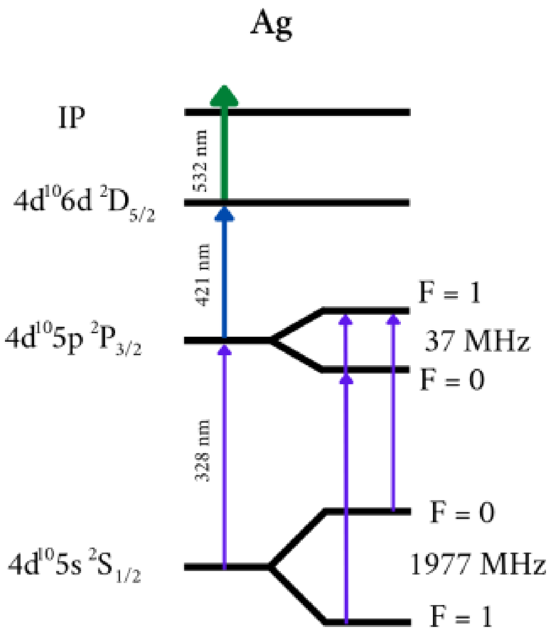


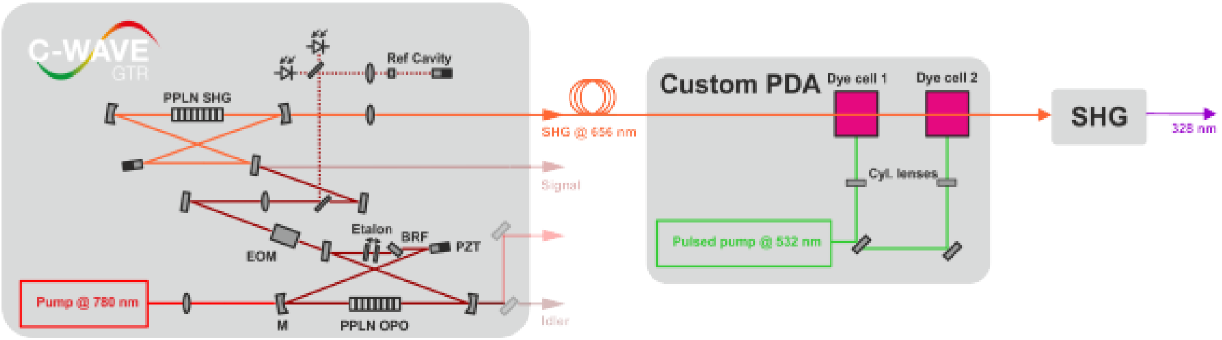
[1] Vernon A.R., Garcia Ruiz R.F., Miyagi T., *et al.* *Nature* **607**, 260–265 (2022).

2022 experimental campaign: Ag

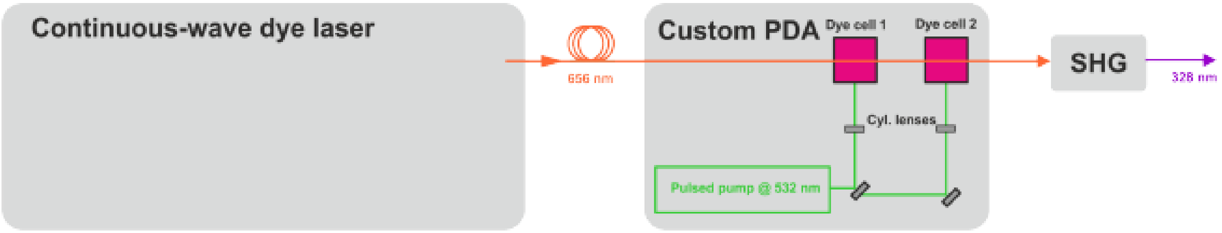
Laser development for the production of narrow band 328 nm UV light:

- OPO seeded Pulsed Dye Amplifier
- Dye Matisse seeded Pulsed Dye Amplifier
- Sum frequency of Matisse seeded Ti:Sa injection locked and single mode 532 nm

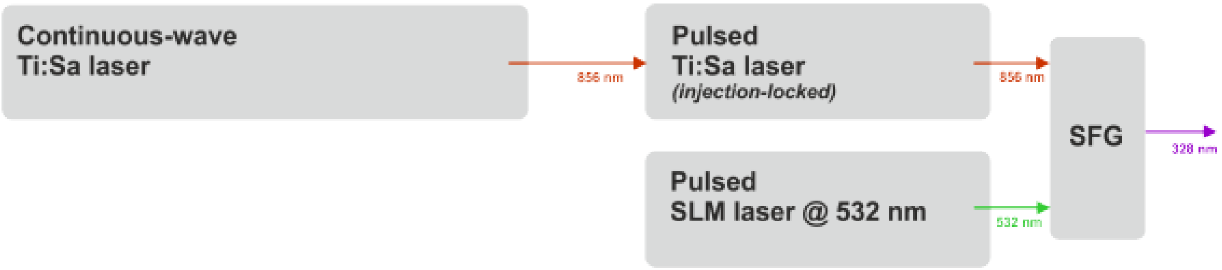




(a) OPO seeded PDA: OPO PDA setup.



(b) Dye seeded PDA: dye PDA setup.



(c) Sum frequency generation (SFG): SFG setup.

M. Urquiza-Gonzalez, …, L. Lalanne *et al.*, Proc. SPIE 12399, Solid State Lasers XXXII, 123990M (2023)

2022 experimental campaign: Ag

Odd-even high-spin states:

- Very constant trend, except close to N = 50
- Comparison to indium data

→The additional proton holes have no effect on the magnetic moment

Odd-even low-spin states:

- Slight downwards trend that flattens out
- In g-factors are very different than in Ag

→Two proton holes induce different configuration mixing

Analysis and plots from Bram van der Borne

2022 experimental campaign: AcF

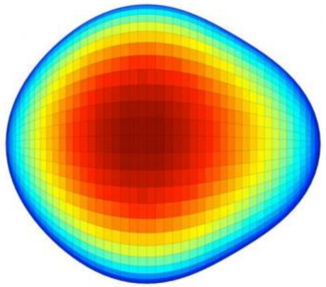
- Nonzero permanent electric dipole moments (EDM's) implies the existence of the T,P-violating interactions

- Schiff moment $\vec{S}$: permanent electric field localized inside the nucleus that can produce EDM

$$\vec{S} \approx 1 \times 10^{-4} \frac{J}{J+1} \beta_2 \beta_3^2 Z A^{\frac{2}{3}} \frac{[keV]}{E^+ - E^-} \quad [e\eta fm^3]$$

[(1)] Flambaum & Dzuba, Phys. Rev. A **101** (2020)

- Large Z & A, and $\beta_3 \neq 0$
  → Strongly enhanced $\vec{S}$ [(2)]



- ^{227}Ac: predicted as largest S across nuclear chart [(1)]

- Energetically close levels of opposite parity in molecules
  → Strong enhancement of the T,P-violating effects [(2)]

CRIS can contribute to future Schiff moment searches by measuring the low-lying electronic and vibrational structure of ^{227}AcF to benchmark quantum chemistry calculations

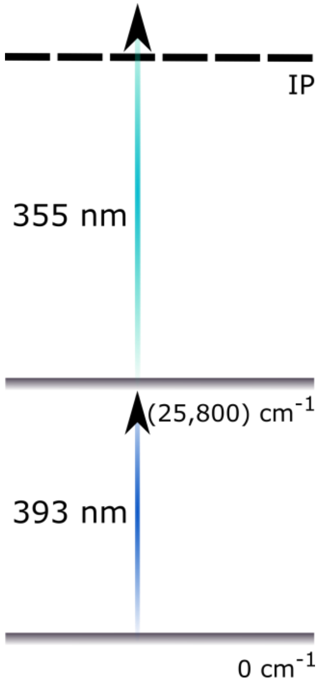
^{227}AcF predicted as one of the most promising system for the first measurement of a non-zero EDM [(1,2)]

[(2)] L. V. Skripnikov, N. S. Mosyagin, A. V. Titov, V. V. Flambaum, Physical Chemistry Chemical Physics 22(33), 18374 (2020).

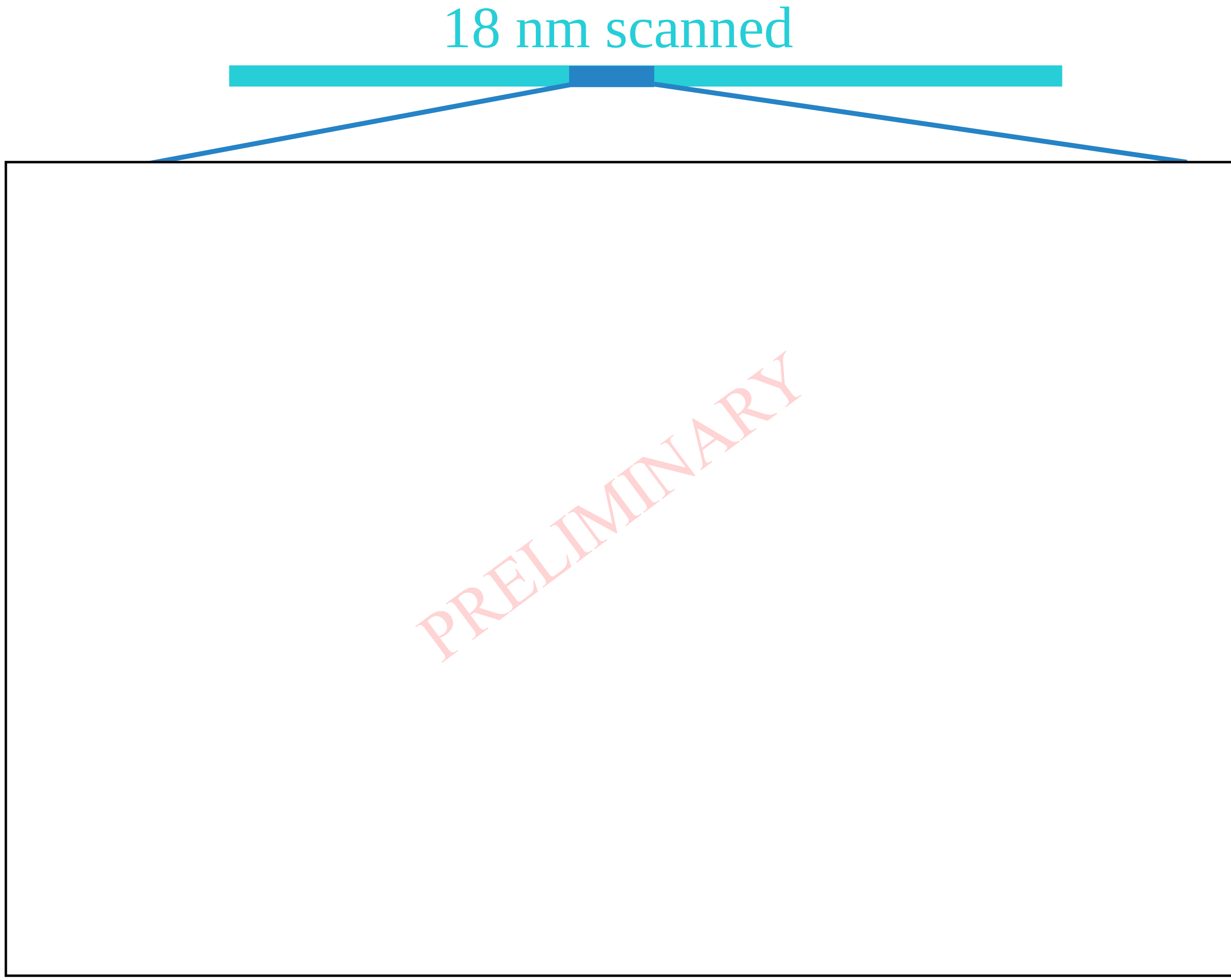
2022 experimental campaign: AcF

- First laser resonance ever observed in AcF
- 3 step resonance observed

  → higher-lying state discovery is under analysis



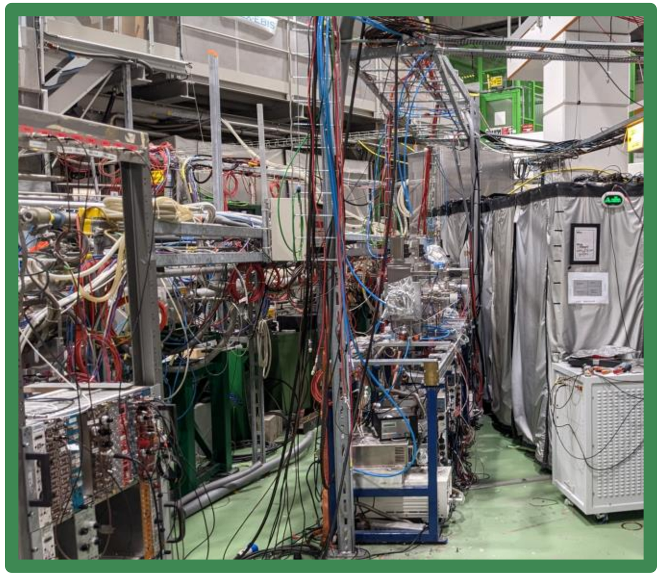
→ First step of an experimental program dedicated to AcF



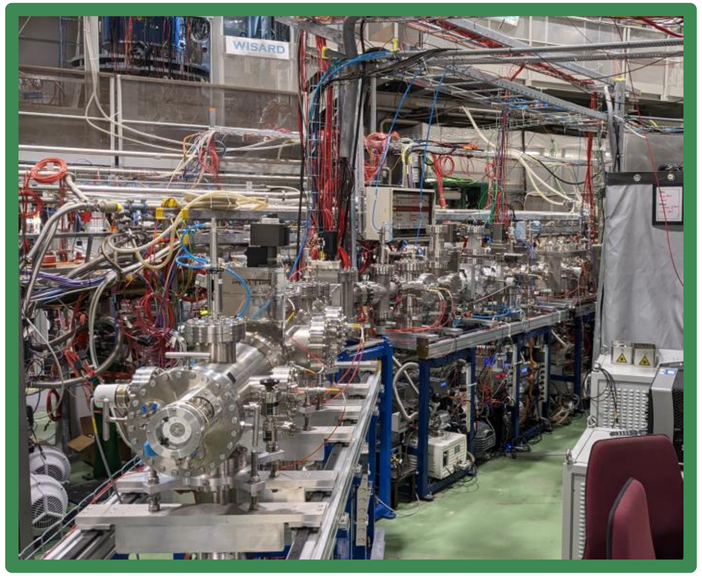
Analysis and plots from Michail Athanasakis-Kaklamanakis

2023 CRIS upgrades

January 2023



March 2023



New end of the beam line:

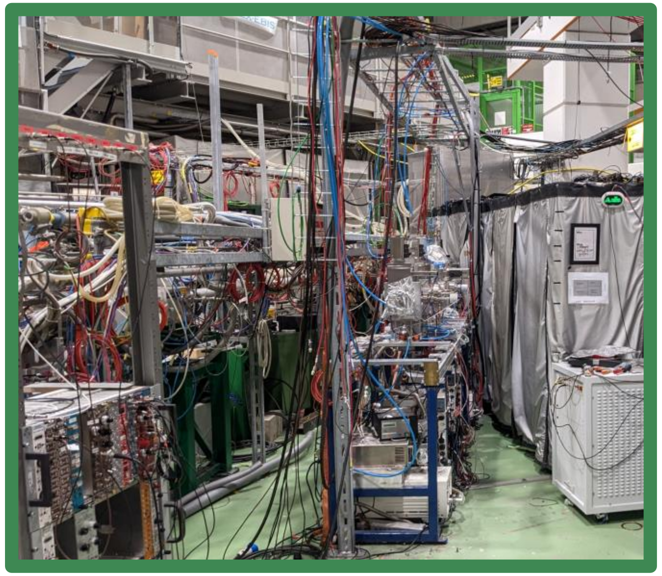
- New field ionization unit
- New bender
- New beam optics toward the DSS

→ Allows Rydberg ionization scheme

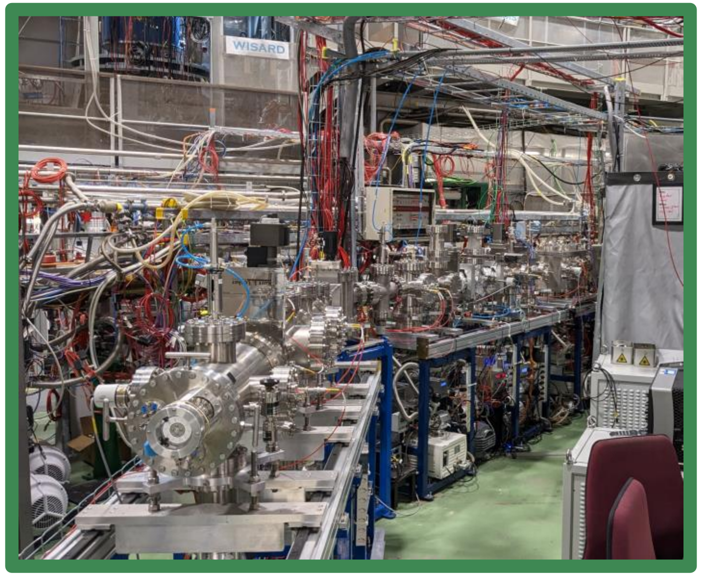
→ Improved beam transport efficiency

2023 CRIS upgrades

January 2023



March 2023



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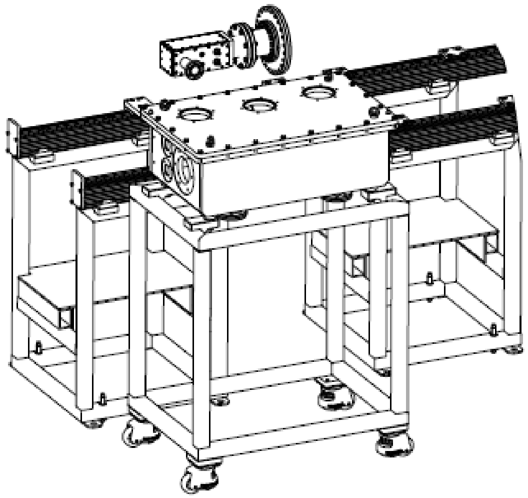
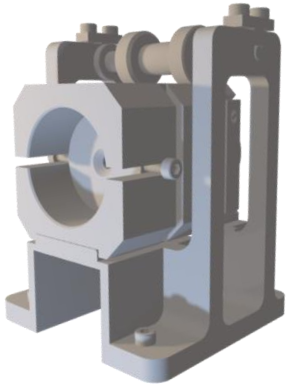




New Decay Spectroscopy Station:

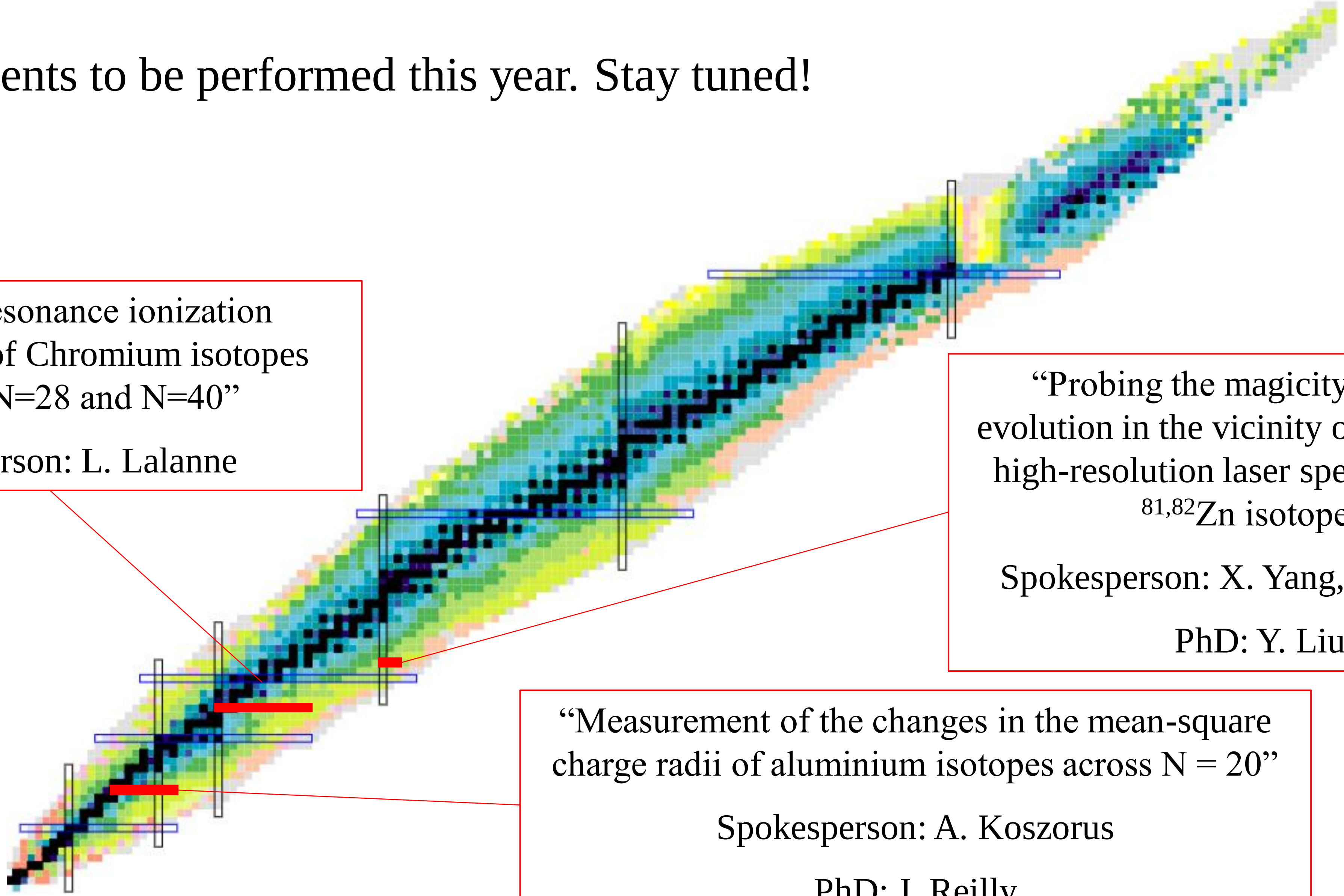
- Tape station
- Alpha/proton decay mode (Si sandwich)
- Beta decay mode (plastic + Ge)

→ Improved sensitvity (decay tagging)

→ Allows decay spec. with isomeric purified beam

2023 experimental campaign

→ 3 experiments to be performed this year. Stay tuned!



"Colinear resonance ionization spectroscopy of Chromium isotopes between N=28 and N=40"

Spokesperson: L. Lalanne

"Probing the magicity and shell evolution in the vicinity of N = 50 with high-resolution laser spectroscopy of ^{81,82}Zn isotopes"

Spokesperson: X. Yang, T. Cocolios

PhD: Y. Liu

"Measurement of the changes in the mean-square charge radii of aluminium isotopes across N = 20"

Spokesperson: A. Koszorus

PhD: J. Reilly

THANK YOU FOR YOUR ATTENTION