LASAGN : new collinear laser spectroscopy setup at DESIR

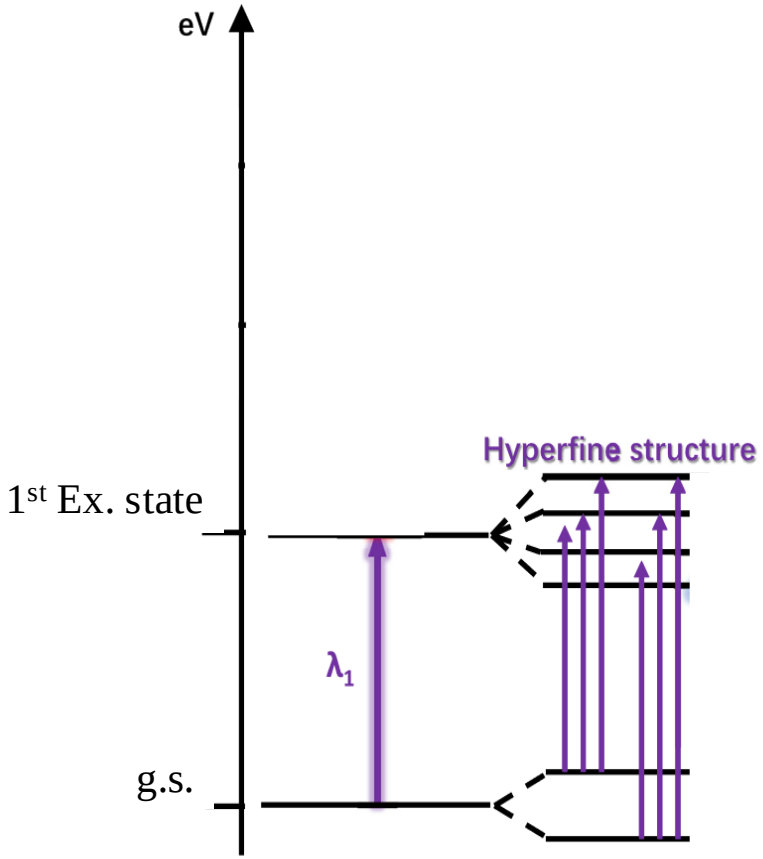
Louis Lalanne

IPHC

GANIL Community Meeting

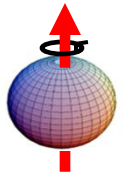
16/10/2024

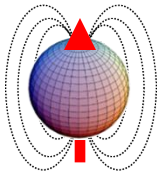
HFS : HyperFine Structure

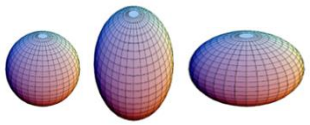


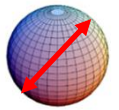
Measuring the HFS allows access to:

- Nuclear spin I
- Dipole magnetic moment μ
  - → Single particle configuration
- Electrical quadrupole moment Q_s
  - → Nuclear shapes
- Mean-squared charge radii
  - → Magicity, collectivity, correlations









X.F. Yang et al., PPNP 129 105005 (2023)

Hyperfine splitting:

$$E(F) = kA + k'B \qquad A = \frac{\mu\, Be(0)}{I.J} \qquad B = e\, Qs\, V(0)$$

Isotope shift : HFS shift between an isotope A and A'

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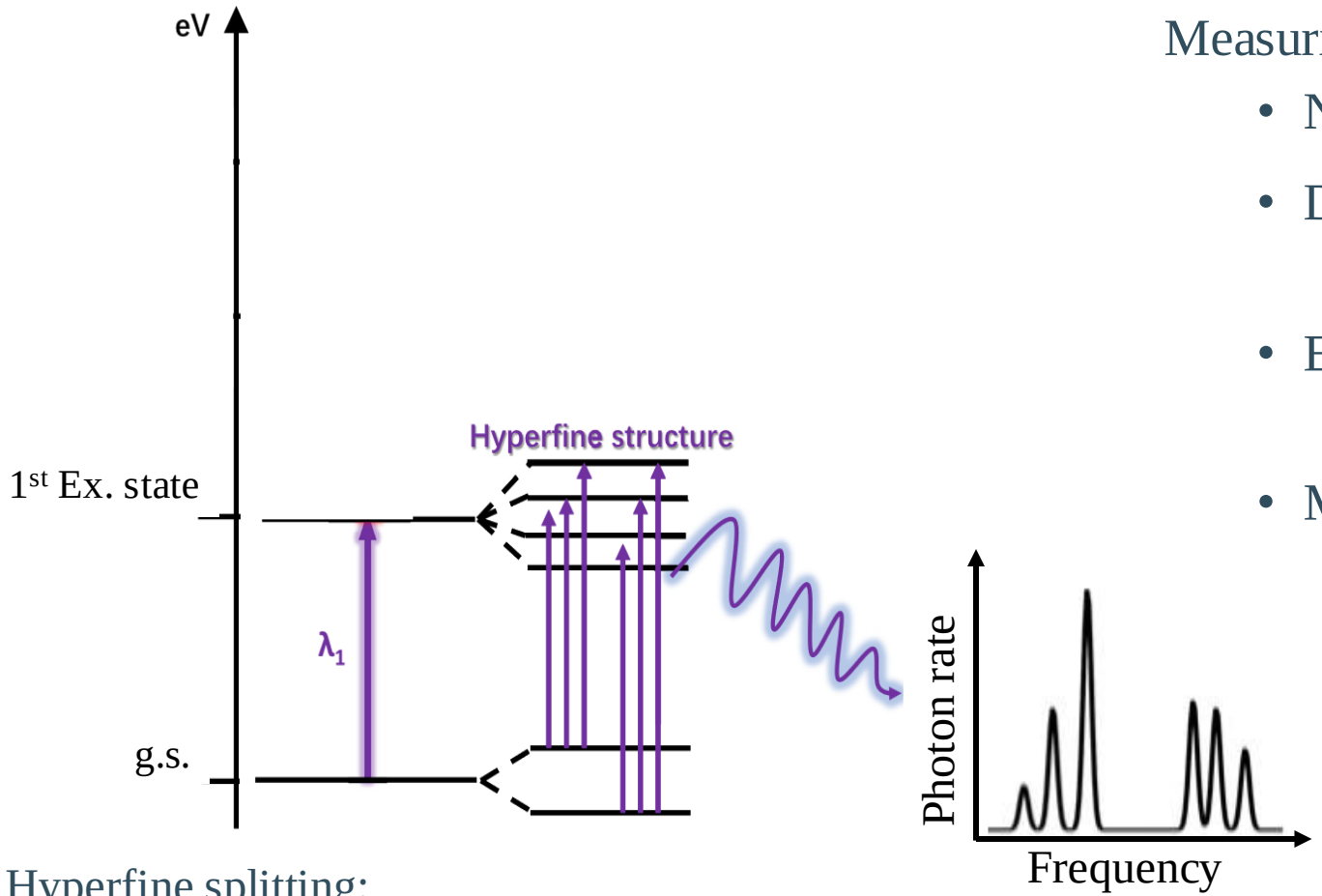
Colinear Laser Spectroscopy



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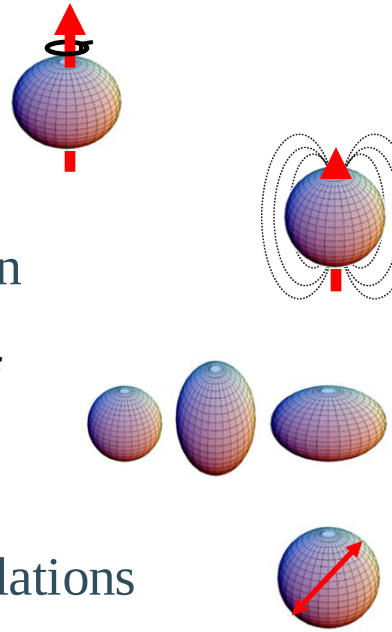

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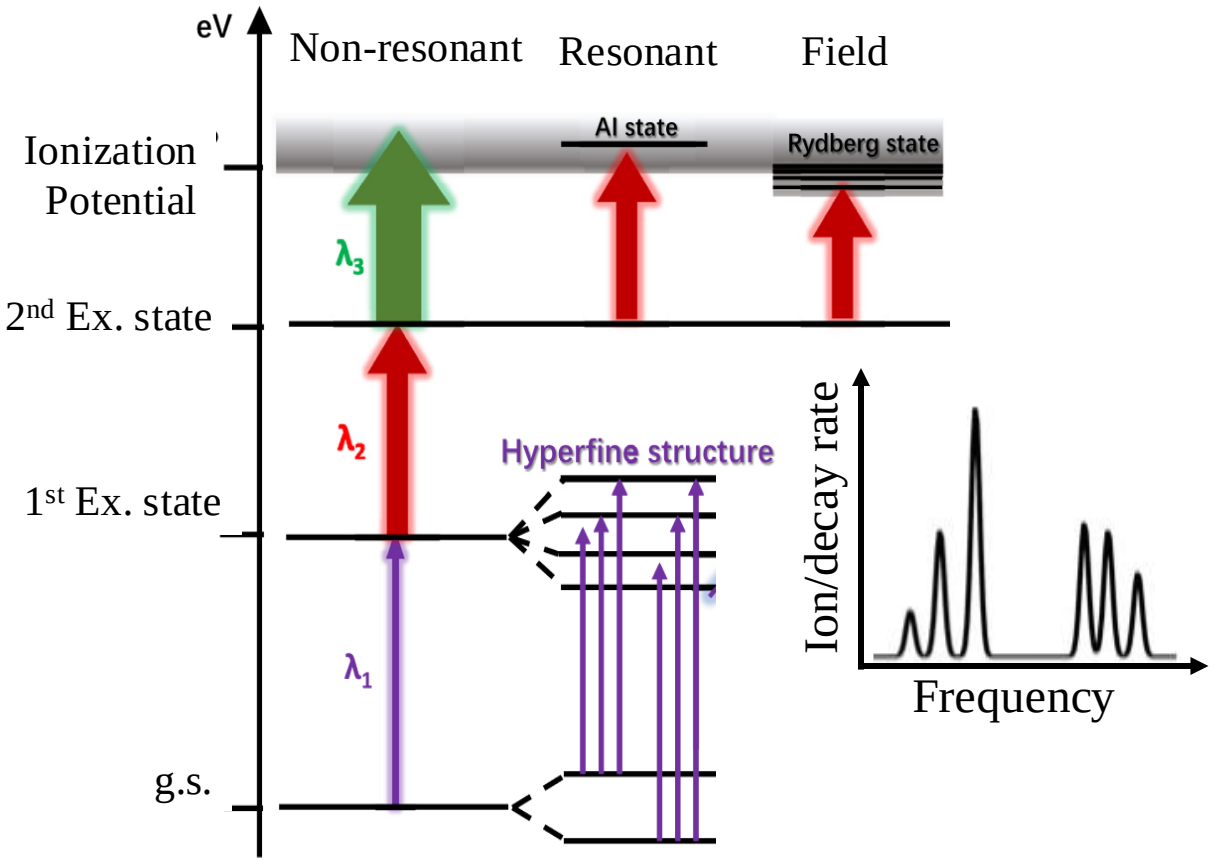
Resonance Ionization Spectroscopy



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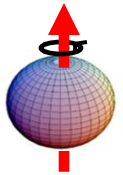

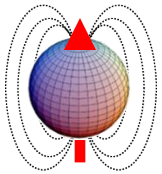

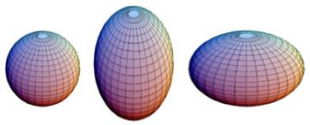

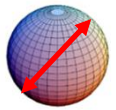

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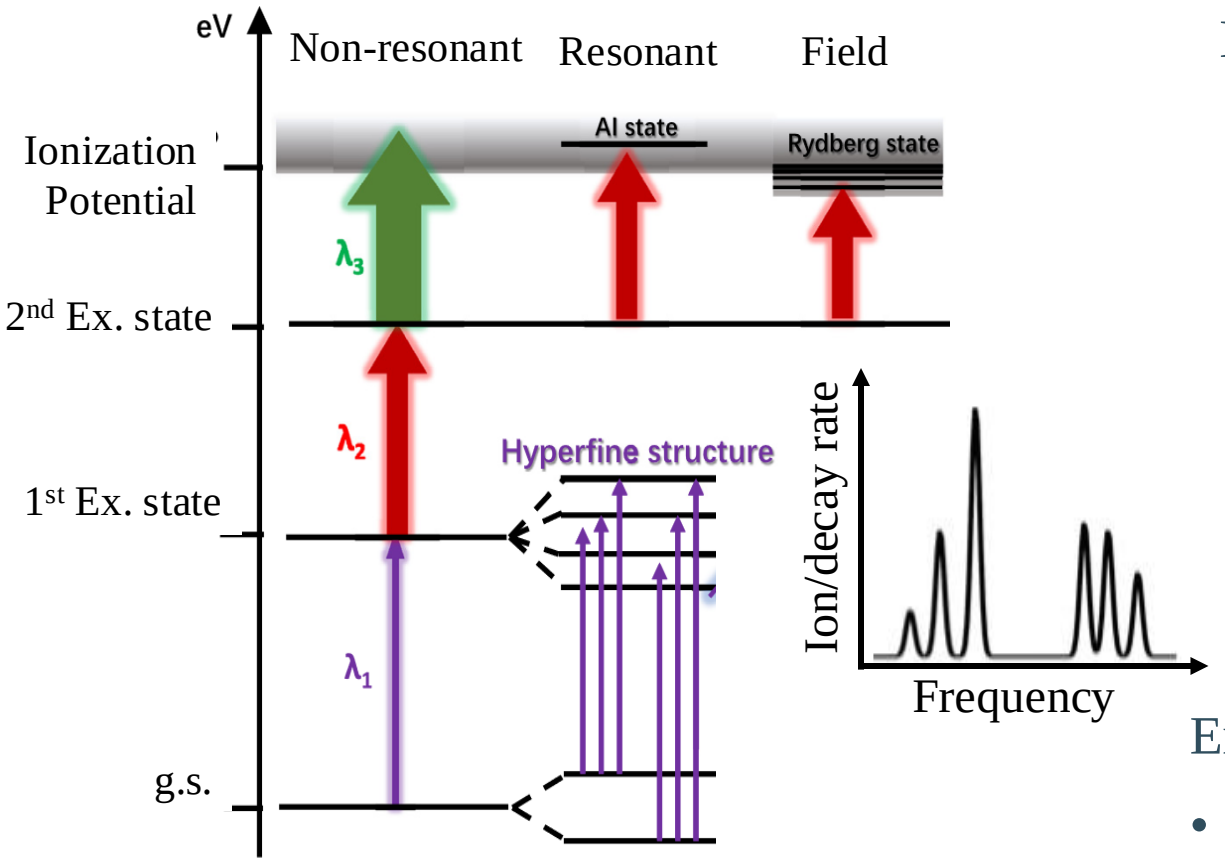

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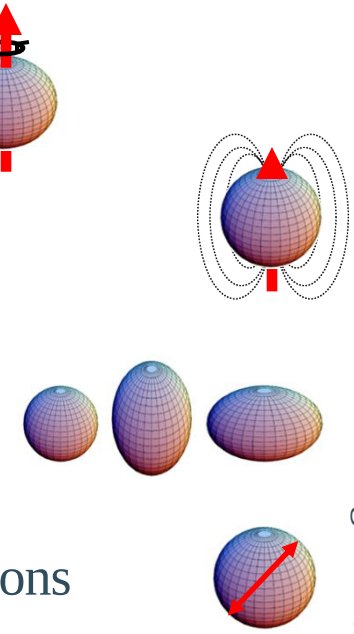
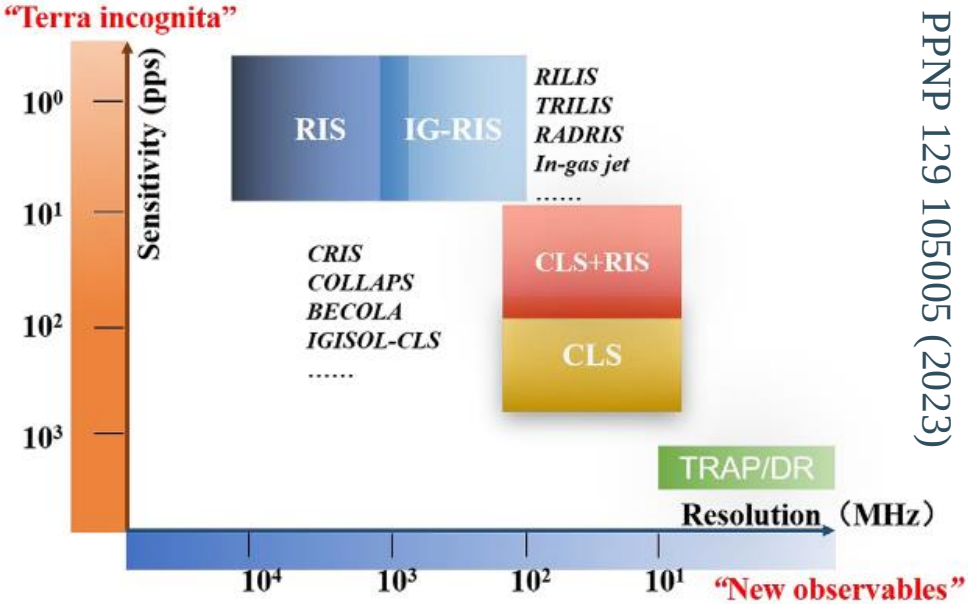


X.F. Yang et al., PPNP 129 105005 (2023)

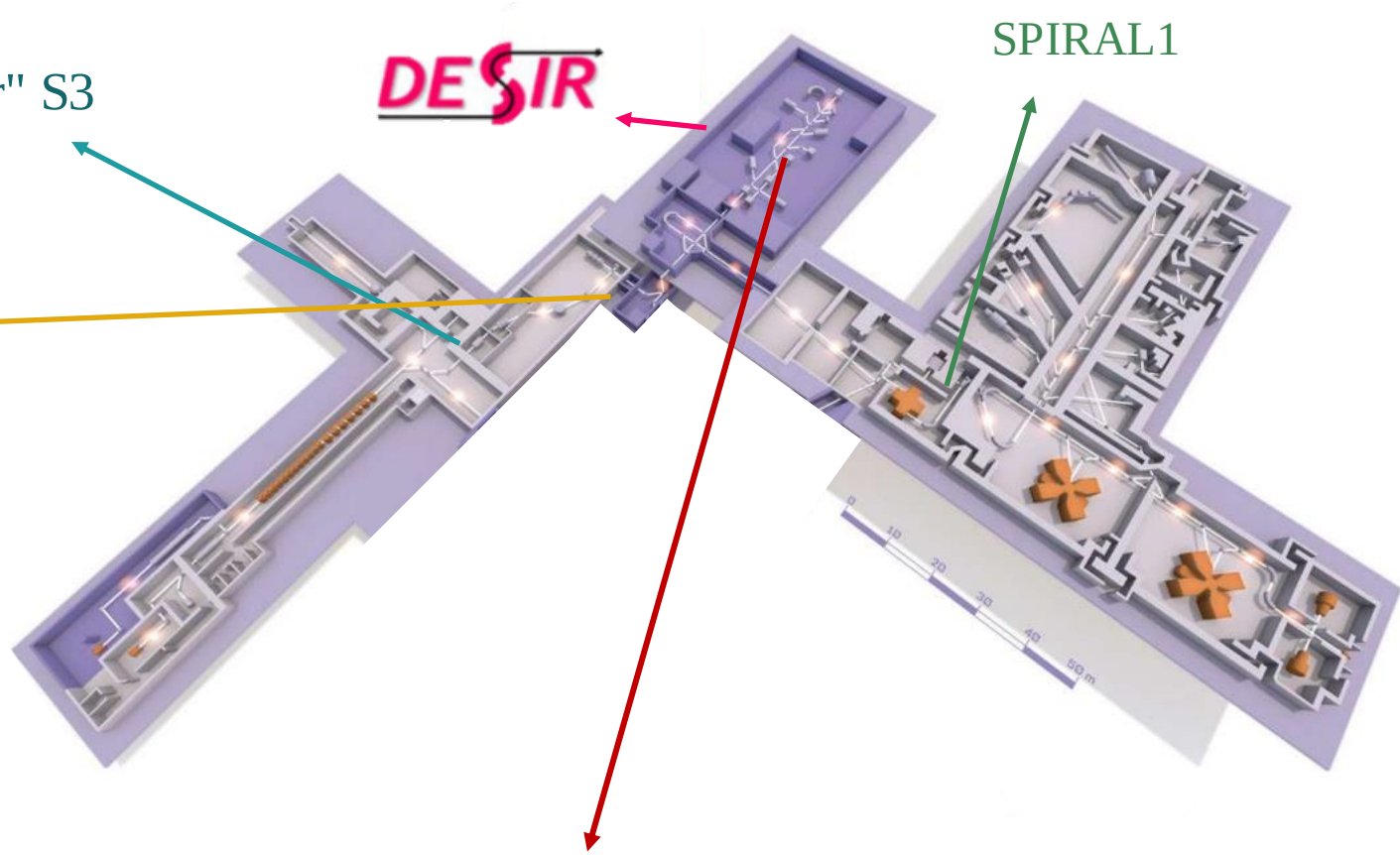
Environments:

- In-source
- In-gas-cell
- In-gas-jet
- Atomic beam
- In trap



LASAGN @ DESIR

SPIRAL2 and the "Super Separator Spectrometer" S3



S3 Low Energy Branch (S3-LEB):
In gas-jet RIS

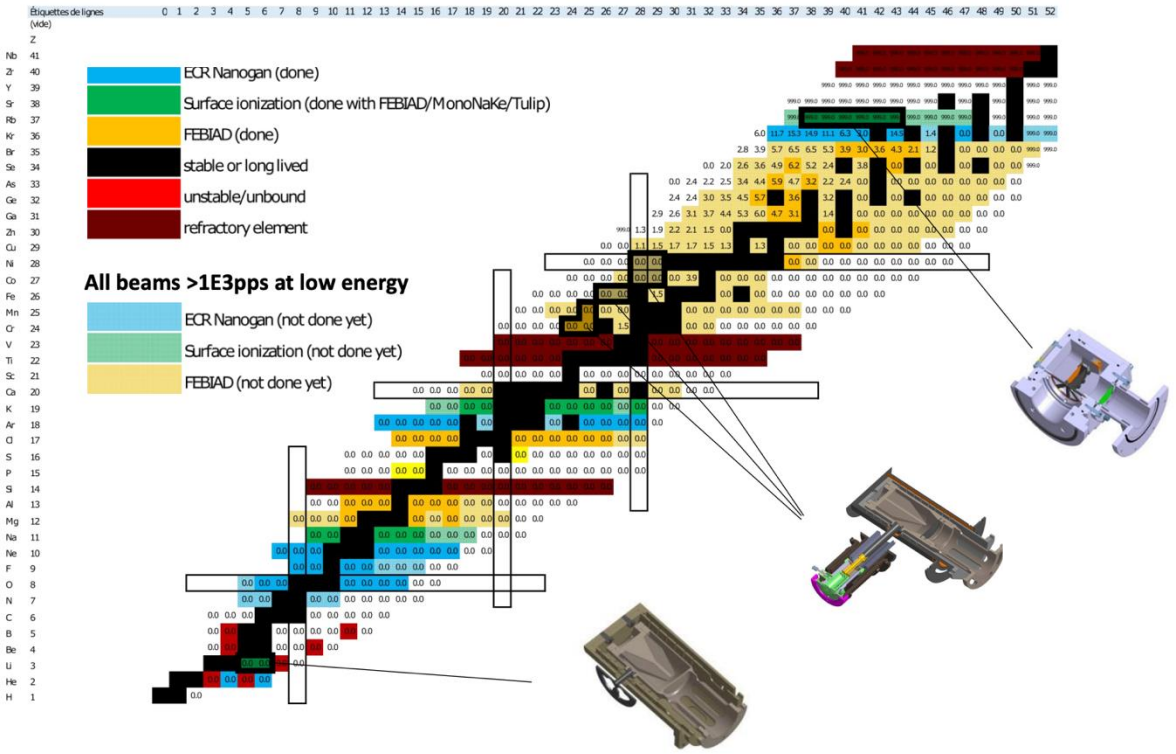
- Medium-resolution and very high sensitivity
- Located at S3 focal plane
- Laser ion source for DESIR

→ Big benefits from a high resolution high sensitivity laser spectroscopy setup in DESIR

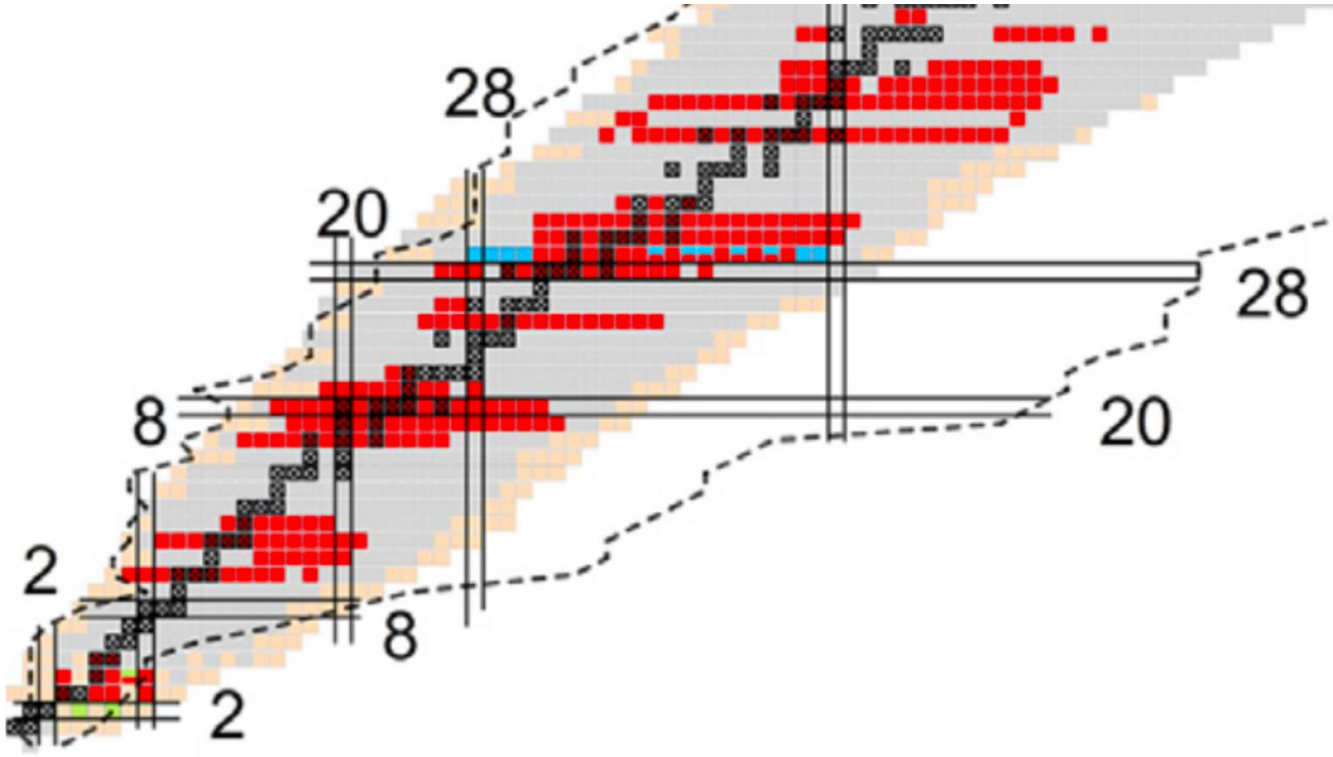
LASAGN @ DESIR :

- ✓ Versatile, high resolution, precision and sensitivity laser spec.
- ✓ Unique nuclear structure studies opportunities
- ✓ Highly complementary to S^3-LEB
- ✓ Excellent synergy with Bestiol and Detrap
- ✓ Open to future development

SPIRAL1 opportunities



From Pierre Chauveau's talk

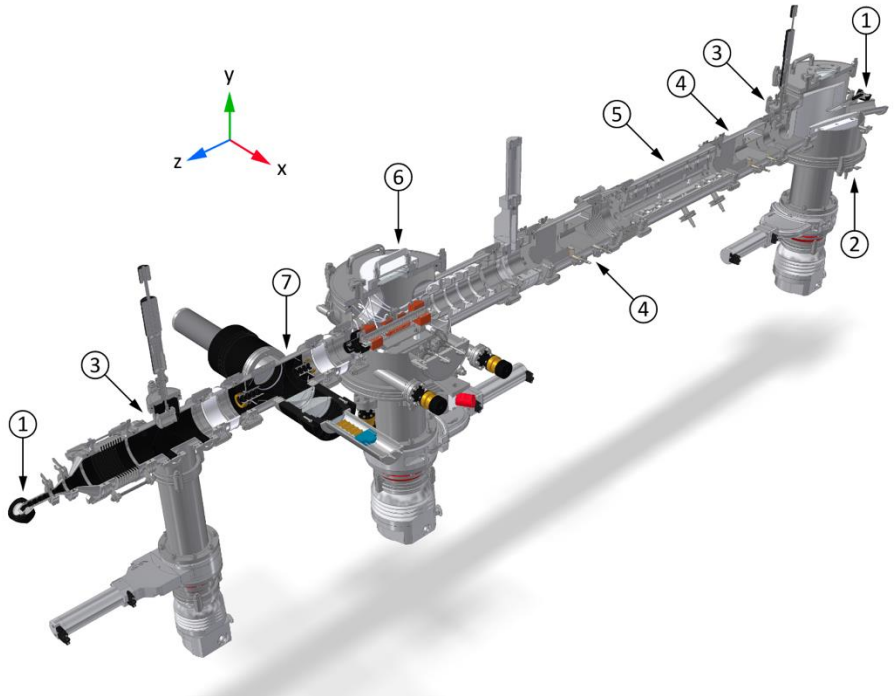


X.F. yang et al., PPNP 129 105005 (2023)

→ Intense light RIB from Spiral1 + a new versatile laser spec setup @ DESIR

Unique opportunities for the study of nuclear g.s. structure of exotic light isotopes N, O, F, P, Na, Cl…

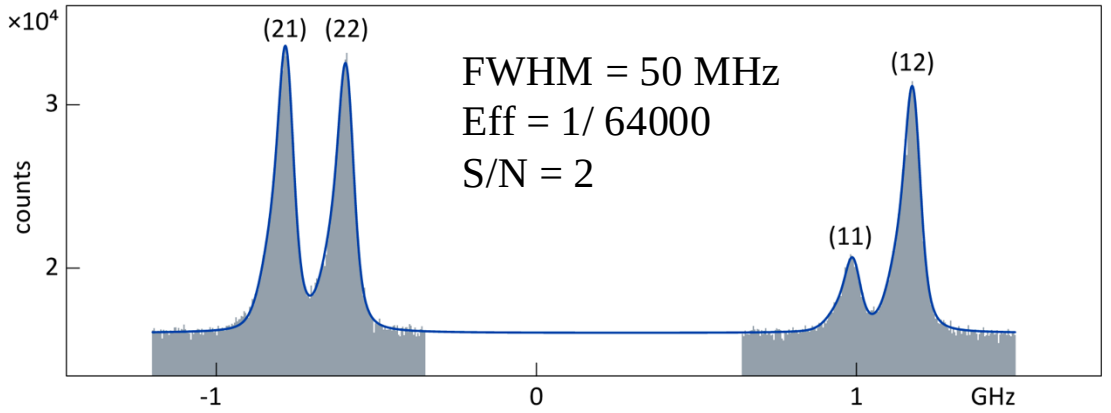
LINO at ALTO



D.T. Yordanov *et al* 2020 *JINST* **15** P06004

The LINO beam line (Laser Induced Nuclear Orientation)

- Collinear Laser Spectroscopy with fluorecence detection (COLLAPS-type)
- Commissioned at ALTO facility (Orsay) w/o cooler buncher



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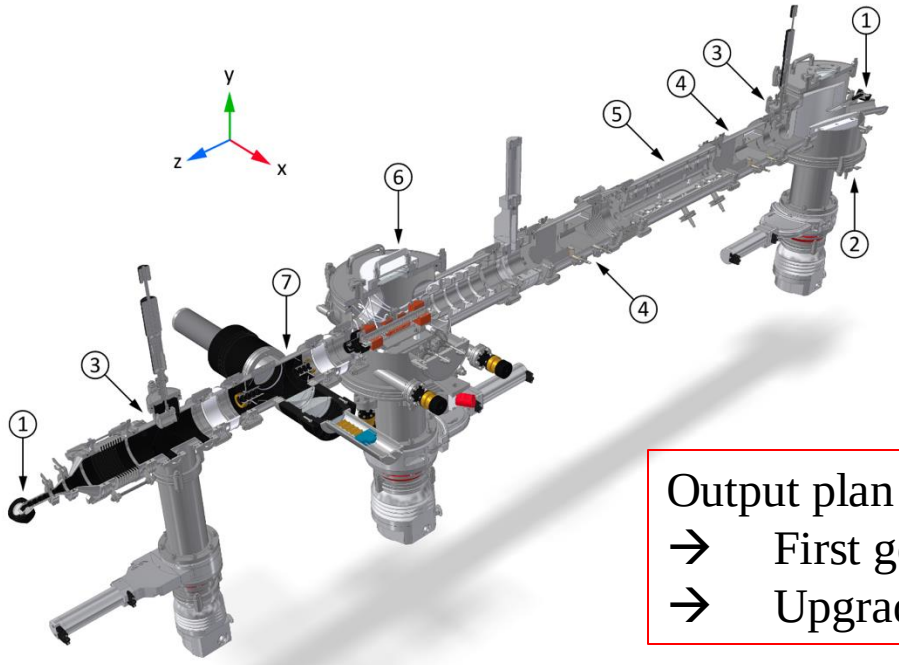

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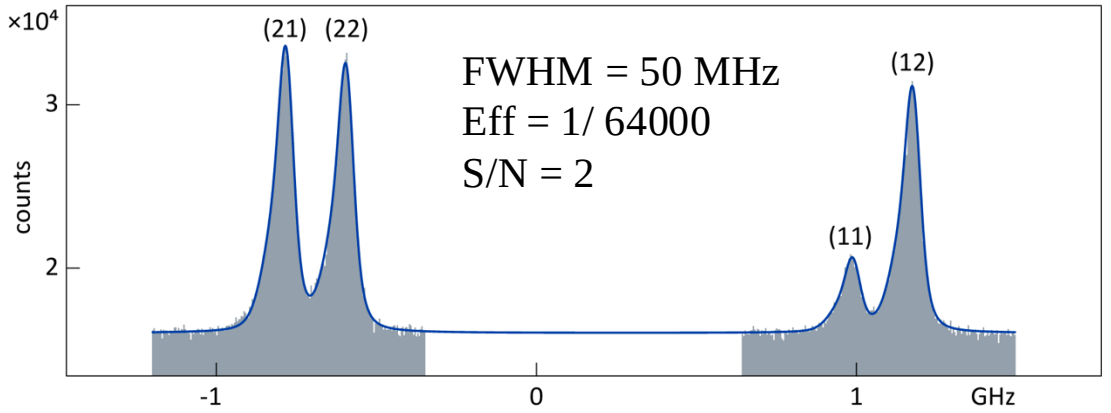
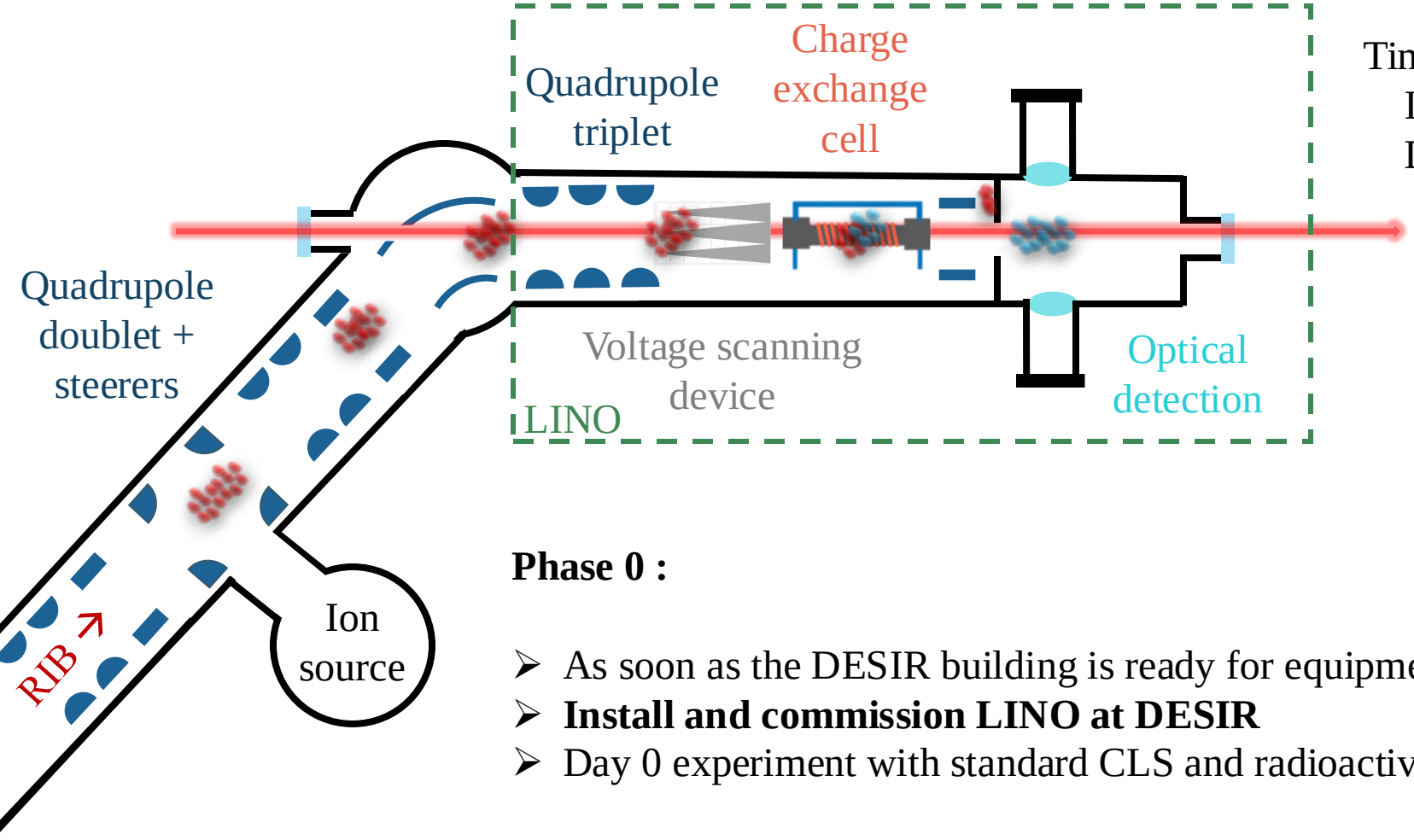


Output plan from DESIR WS, ISOL-France meeting and LUMIERE WS (2024):

→ First goal : install and commission LINO at DESIR as standard CLS

→ Upgrade LINO toward a CRIS-like setup

LASAGN Phase 0



Timeline :

Installation, comissioning : end 2025 - 2027

Day 1 experiment : end 2027 / begining 2028

✓ CLS with fluorescence detection

✓ High res : < 50MHz

X Sensitivity limit: > 10^4pps

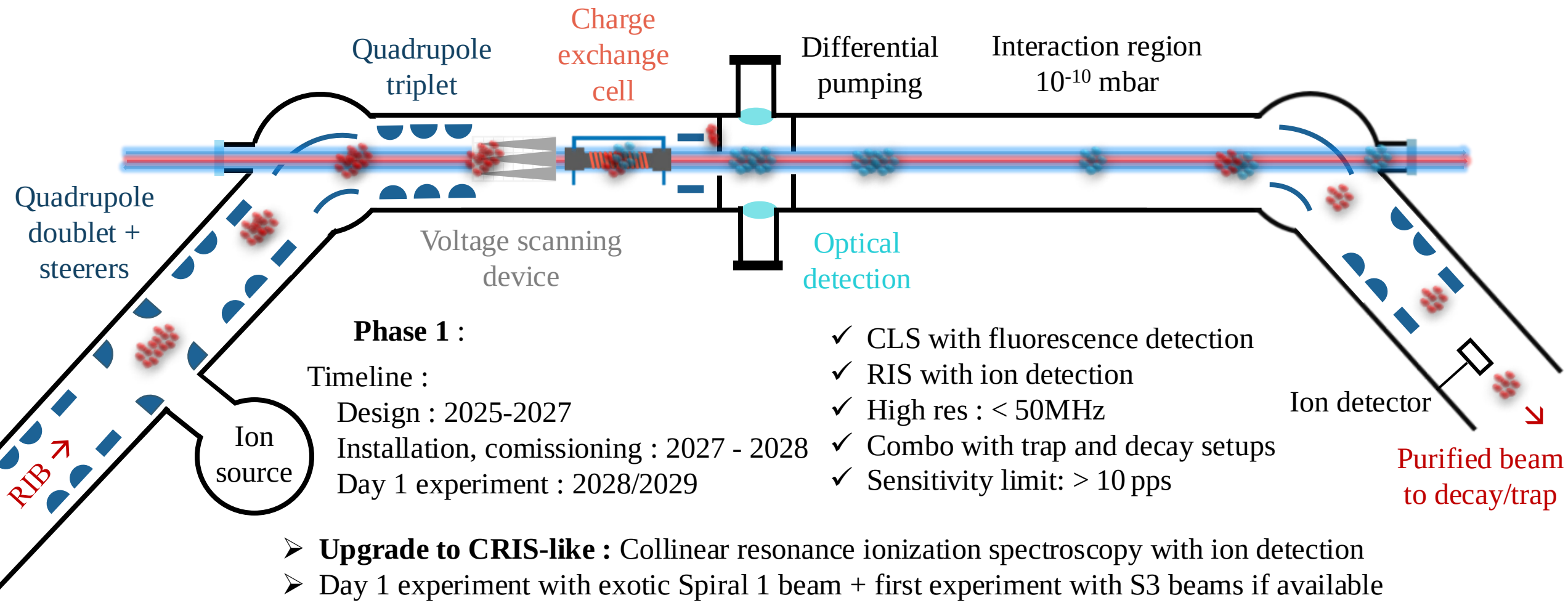
Phase 0 :

- As soon as the DESIR building is ready for equipment installation
- **Install and commission LINO at DESIR**
- Day 0 experiment with standard CLS and radioactive Spiral1 beam

Needs:

- Narrow band CW laser (Ti:Sa Matisse from Syrah) (532 CW pump laser already available)
- New control and DAQ system
- An offline ion source to test everything offline before to get the first stable beam from spiral1

LASAGN Phase 1



Phase 1 :

Timeline :

Design : 2025-2027

Installation, comissioning : 2027 - 2028

Day 1 experiment : 2028/2029

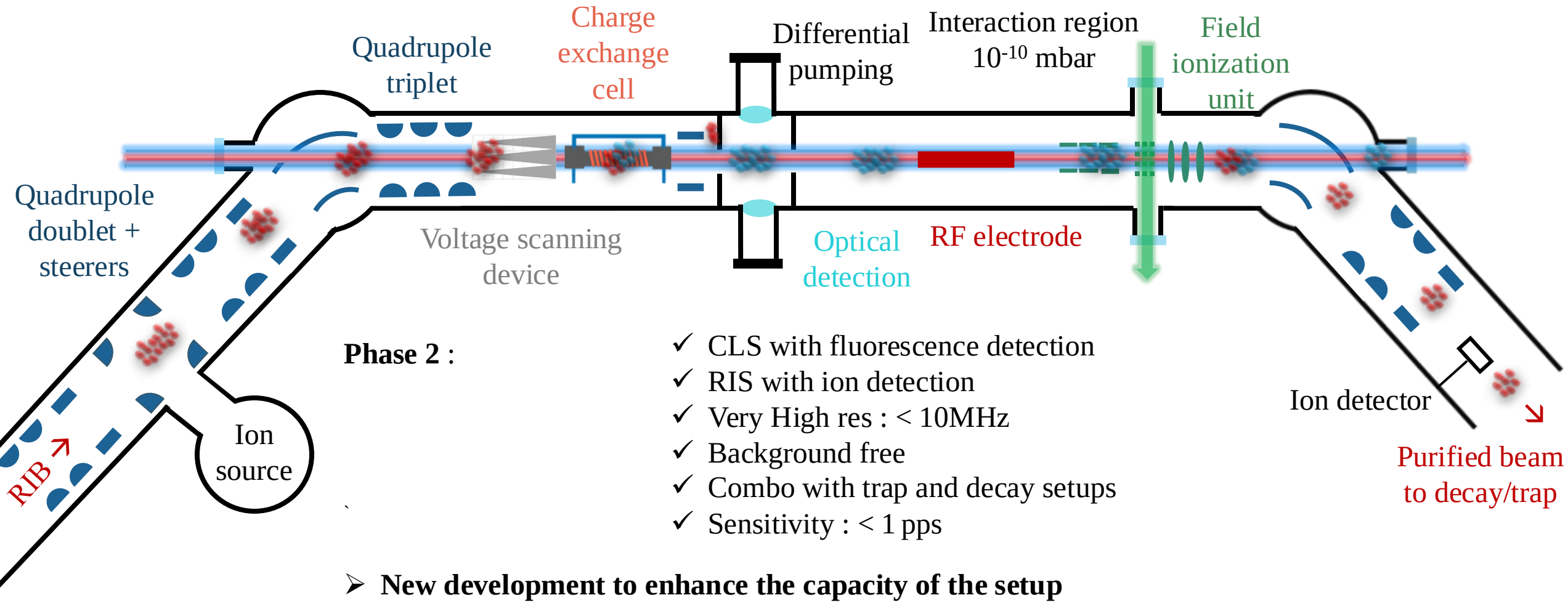
- ✓ CLS with fluorescence detection
- ✓ RIS with ion detection
- ✓ High res : < 50MHz
- ✓ Combo with trap and decay setups
- ✓ Sensitivity limit: > 10 pps

- ➢ **Upgrade to CRIS-like :** Collinear resonance ionization spectroscopy with ion detection
- ➢ Day 1 experiment with exotic Spiral 1 beam + first experiment with S3 beams if available

Needs:

- UHV interaction region
- End of beam line (bender, beam optics, ion detector)
- Pulsed BB TiSa, injection locked, 1064+532+355 high power pulsed laser and pulsed 532 pump lasers

LASAGN Phase 2



Phase 2 :

- ✓ CLS with fluorescence detection
- ✓ RIS with ion detection
- ✓ Very High res : < 10MHz
- ✓ Background free
- ✓ Combo with trap and decay setups
- ✓ Sensitivity : < 1 pps

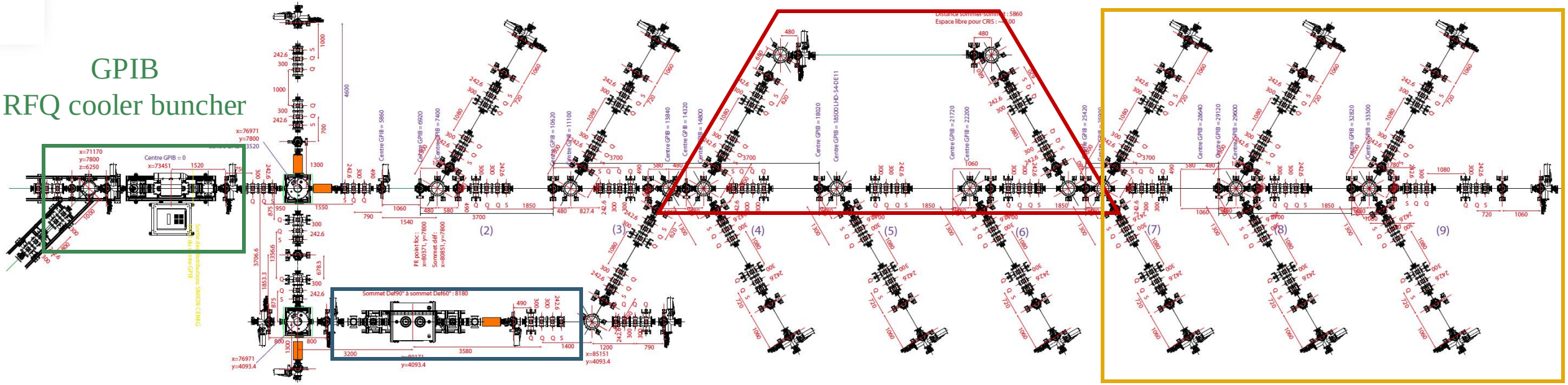
➢ **New development to enhance the capacity of the setup**

- Collinear-Anticolinear fluorescence and RIS → <1MHz precision on IS
- Perpendicular illumination using ultra narrow bunches → background free spec.
- Double laser-RF spectroscopy → resolution < 10 MHz

LASAGN at DESIR

LASAGN

GPIB
RFQ cooler buncher



PIPERADE
double penning trap
for beam purification

Trap and decay setups
- trap/decay assisted laser spectroscopy
- Laser purification for trap or decay exp.

LASAGN : Versatile high-res high-sensibilty laser spec. setup
- ✓ Benefits from the many beam preparation and purification devices of DESIR
- ✓ Allow to re-inject RIS beams to the central beam line → synergy with trap and decay setups
- ✓ Can take beam from S3 and Spiral1

LASAGN at DESIR

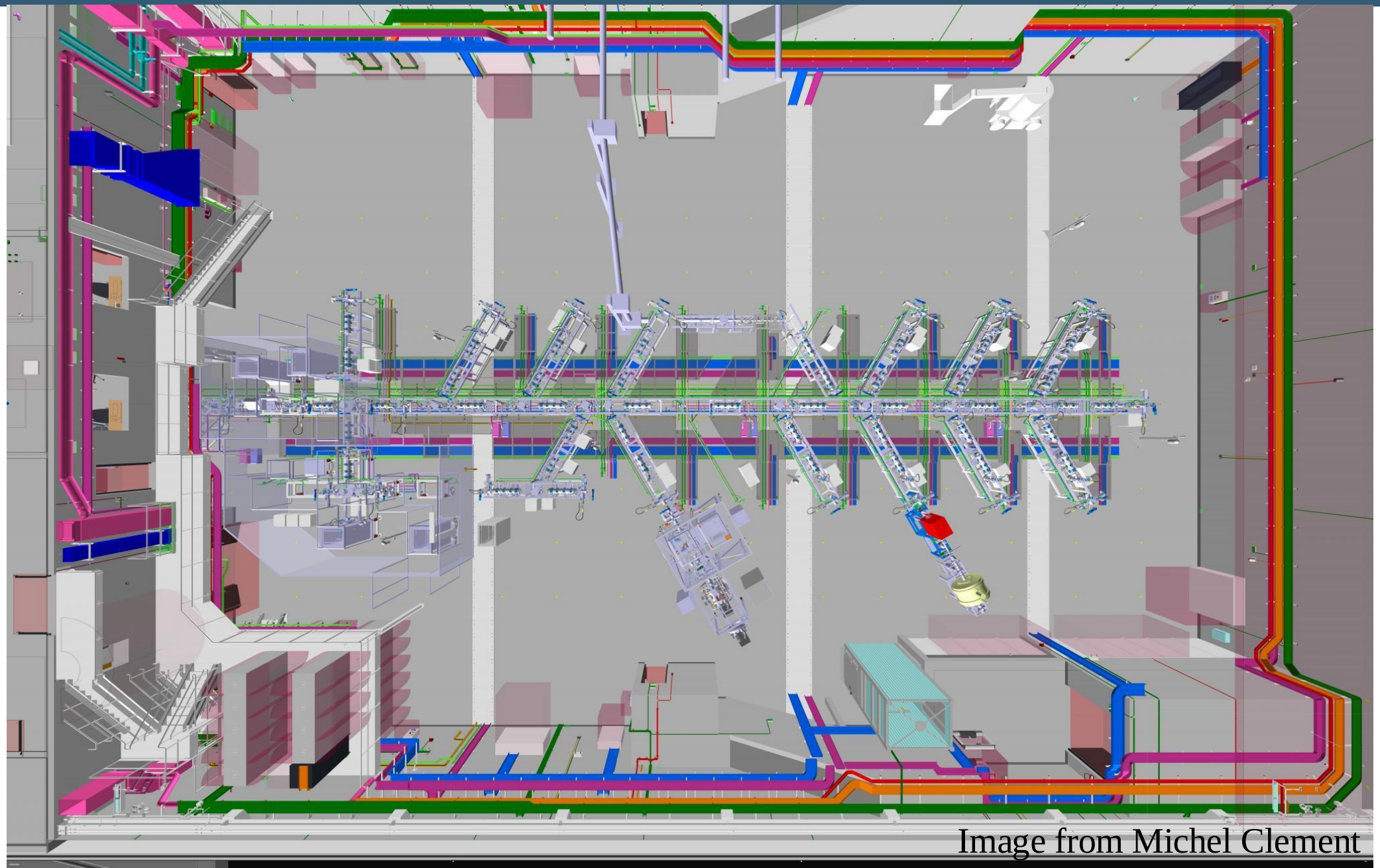
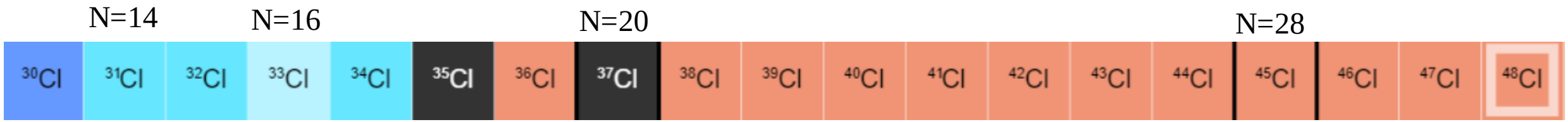


Image from Michel Clement

Day 1 Exp. : CLS and CRIS of Chlorine



Statues of knowledge:

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- Only moments of $^{32\text{-}38,44}$Cl known
- No charge radii measured

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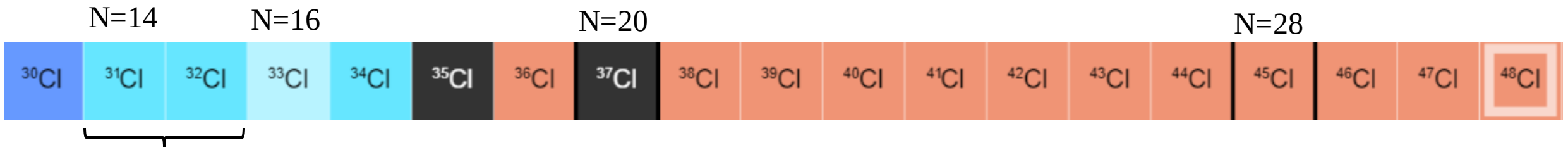

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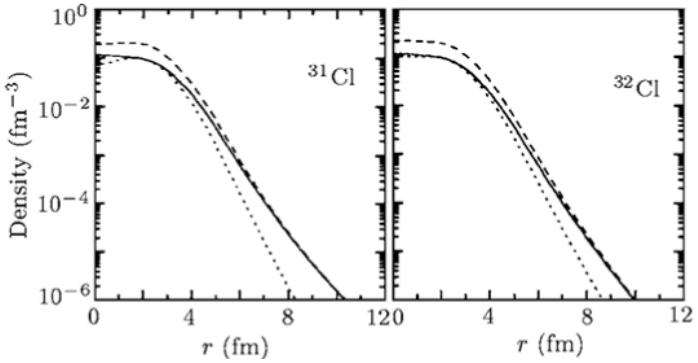
→ Increase in charge radii? Influence of continuum?



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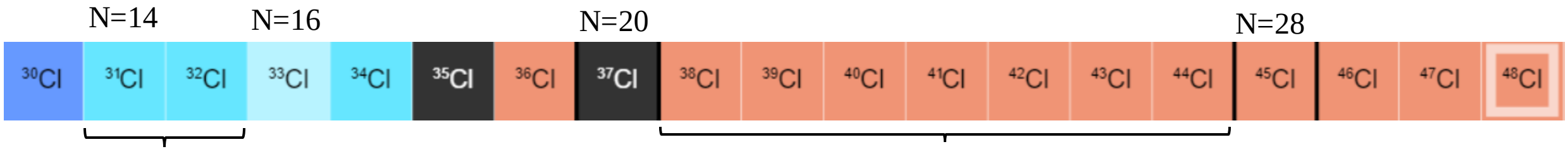

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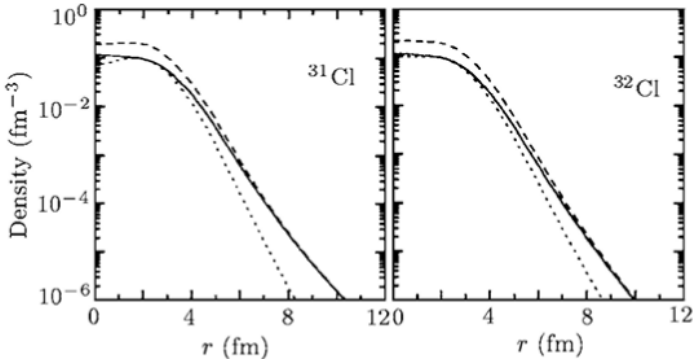

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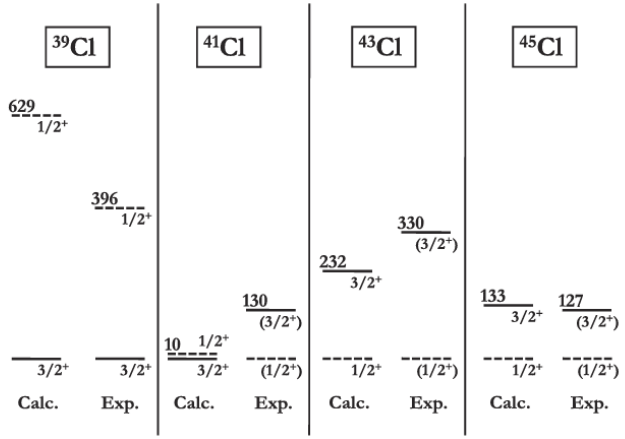

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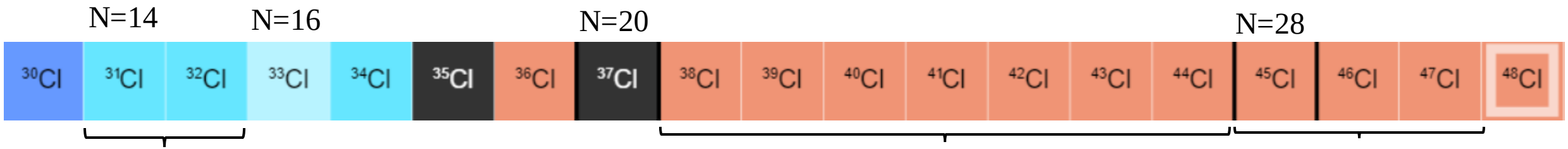

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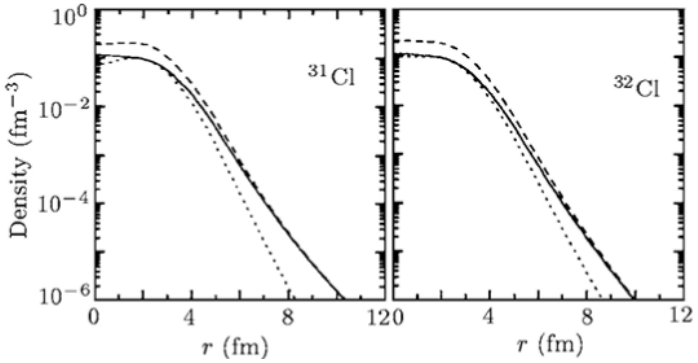

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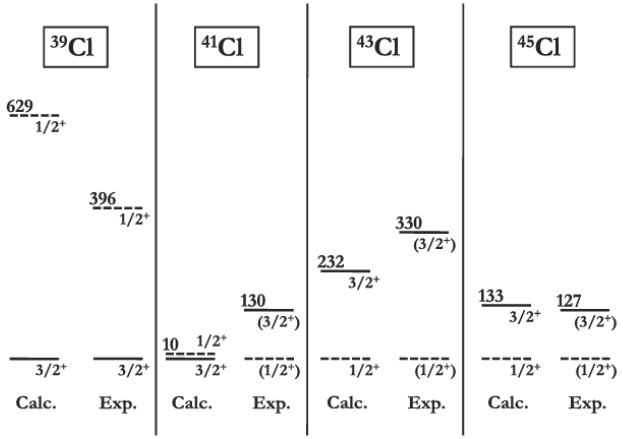

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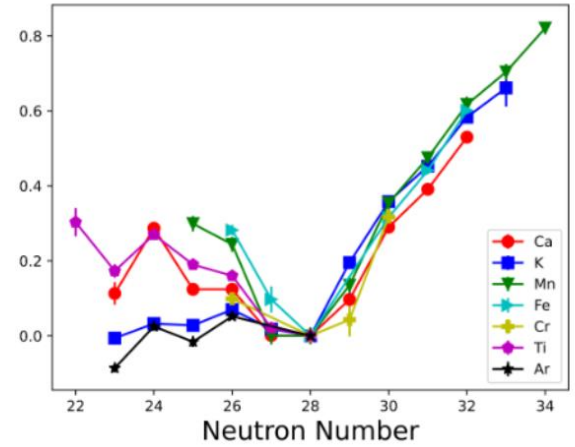
^{45}Cl transition into the N=28 IoI
→ Radii kink at N=28?
→ *s.p.* config and purity from moments



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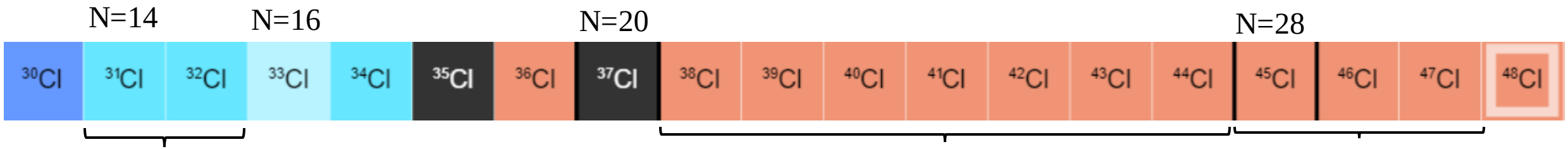

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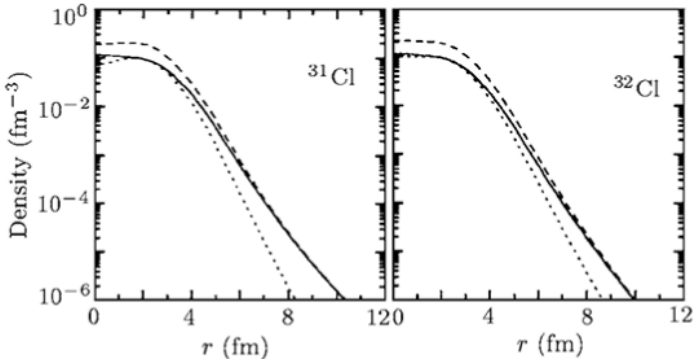

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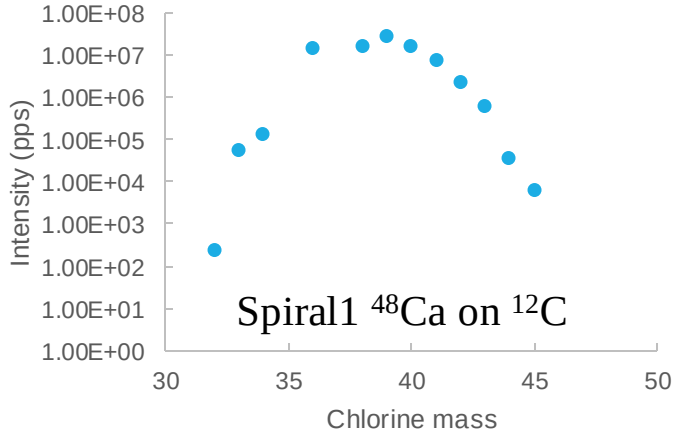
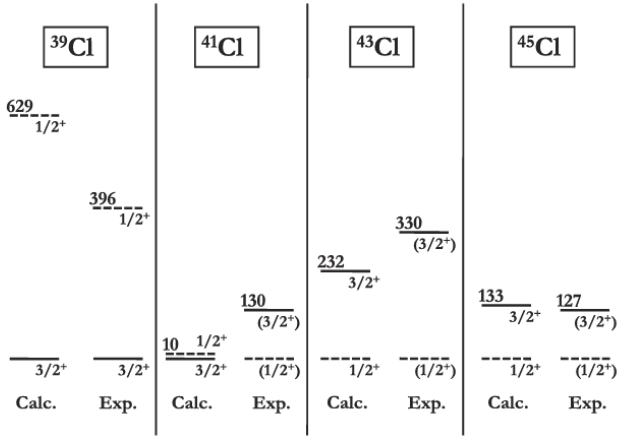
F. Sammarruca, Front. Phys. 6:90 (2018)





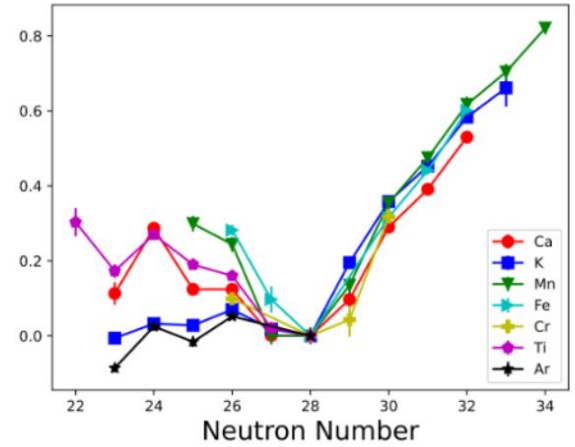
- Cl Z=17 is very sensitive to the π $s_{1/2}$ $d_{3/2}$ degeneracy
- Odd $s_{1/2}$ proton in ^{44}Cl - M. De Rydt et al., PRC 81 (2010)
- Inversion of $3/2^+$ and $1/2^+$ g.s. at A=41?

S. Szilner et al., PRC 87, 054322 (2013)

Feasibility:

- Good population of high-lying state in CEC
- Suitable known transitions
- RIS scheme to be develloped
- Spiral1 yields:
  - $^{33\text{-}44}$Cl in reach for CLS
  - $^{31\text{-}47}$Cl in reach for CRIS

^{45}Cl transition into the N=28 IoI
→ Radii kink at N=28?
→ *s.p.* config and purity from moments



Statues of knowledge:

- g.s. spin A>40 not firmly assign
- Only moments of $^{32\text{-}38,44}$Cl known
- No charge radii measured

Conclusion

LASAGN @ DESIR

- ✓ Versatile laser spectroscopy beam line of high resolution, precision and sensitivity
- ✓ Exploits well established methods routinely used in ISOLDE and IGISOL
- ✓ Open for future development (collinear / anti-collinear RIS, perpendicular illumination, RF…)
- ✓ Unique opportunities for the study of light exotic isotopes, benefiting from existing Spiral1 beams
- ✓ Highly complementary to S^3-LEB
- ✓ Excellent synergy with Bestiol (decay spec.) and Detrap (mass spec.)

Timeline : Phase 0 (standard CLS) completed in 2027, Phase 1 (CRIS) completed in 2029

Collaboration : IPHC, KU Leuven, IJCLab, LPC


THANK YOU FOR
YOUR
ATTENTION