In-Gas Laser Ionization and Spectroscopy of Ac: A quest for the atomic and nuclear structure of very heavy elements

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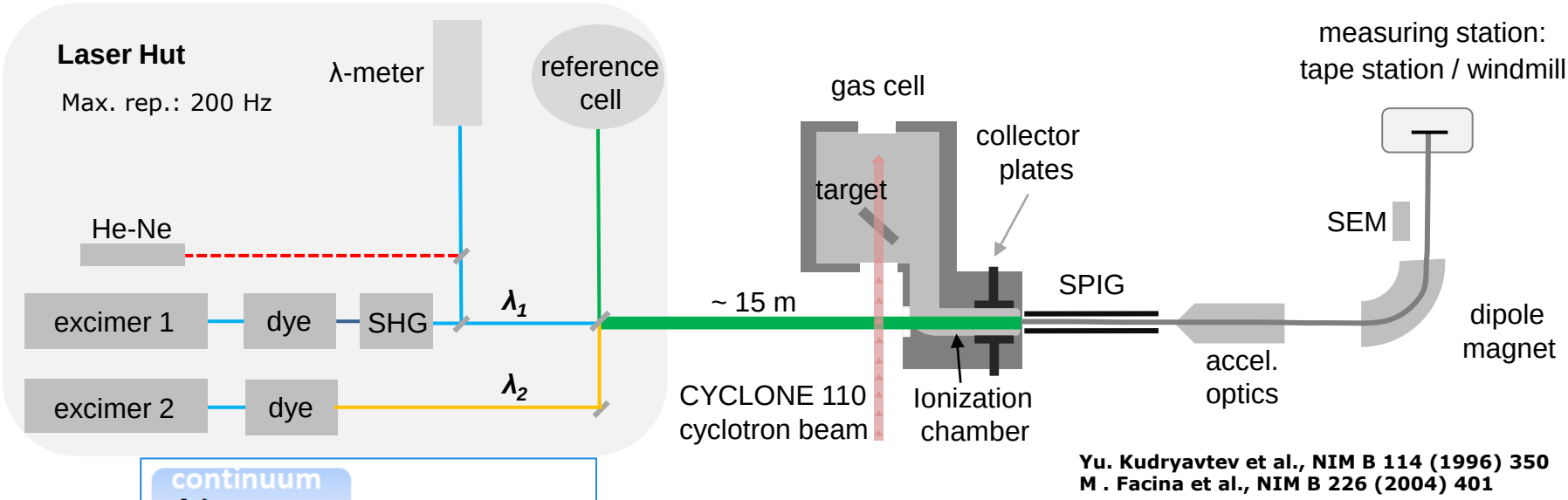
Outline

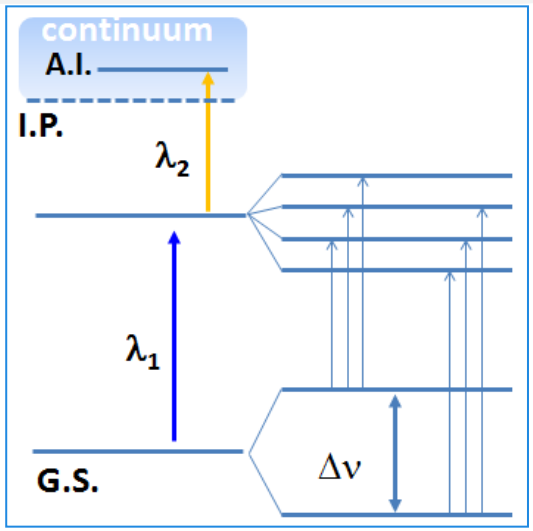
- The IGLIS technique
- First Results on Ac isotopes at the LISOL facility
- Final R&D phase at the HELIOS laboratory
- Outlook

Resonance Ionization Spectroscopy

- Leuven Isotope Separator On-Line (LISOL) facility :
  In-Gas Laser Ionization and Spectroscopy of RIB's



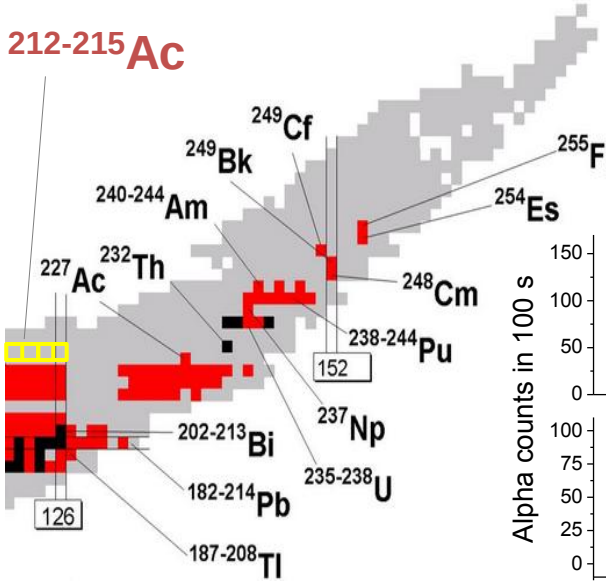
Yu. Kudryavtev et al., NIM B 114 (1996) 350
M . Facina et al., NIM B 226 (2004) 401



In-gas-cell laser spectroscopy of neutron deficient Cu, Ag and Ac isotopes

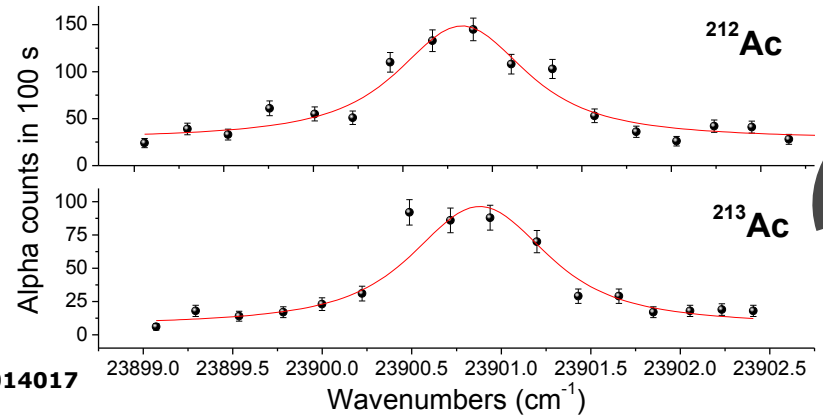
T. E. Cocolios et al., PRL 103 (2009) 102501
T. E. Cocolios et al., PRC 81 (2010) 014314
R. F. et al., PLB 728 (2014) 191

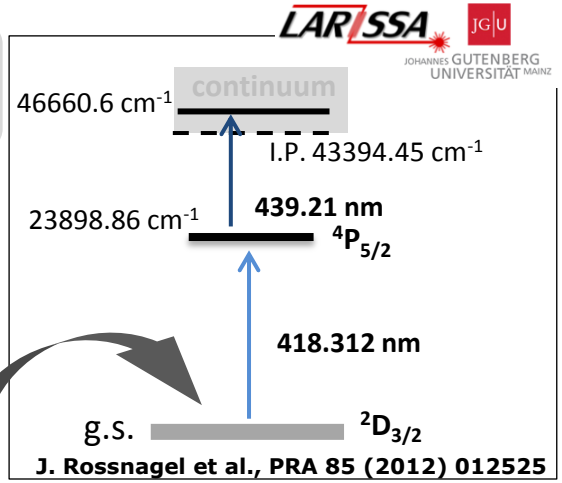
Production & First Spectroscopy of Ac



K. Blaum et al., Phys. Scr. T152 (2013) 014017

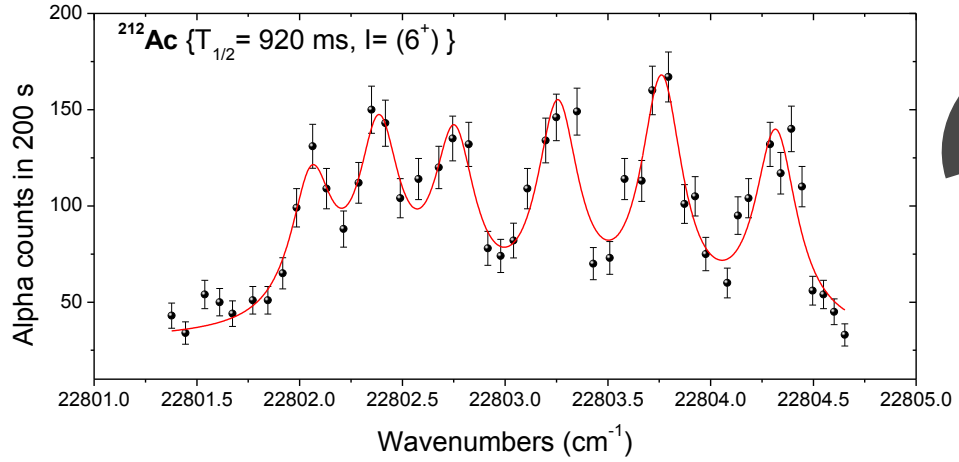
^{197}Au(^{20}Ne-145 MeV,4-5n)^{212,213}Ac
^{197}Au(^{22}Ne-143 MeV,4-5n)^{214,215}Ac

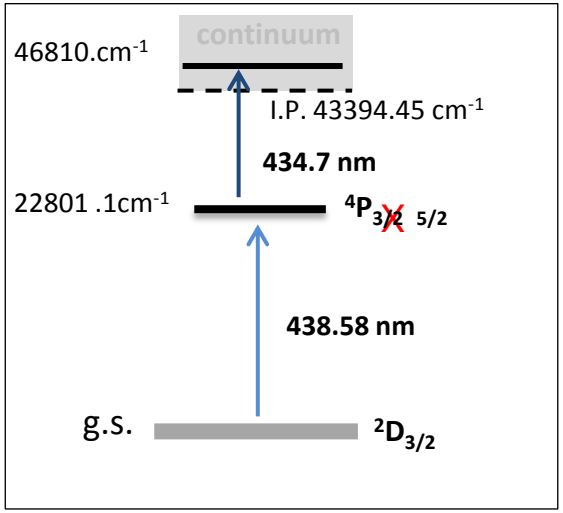




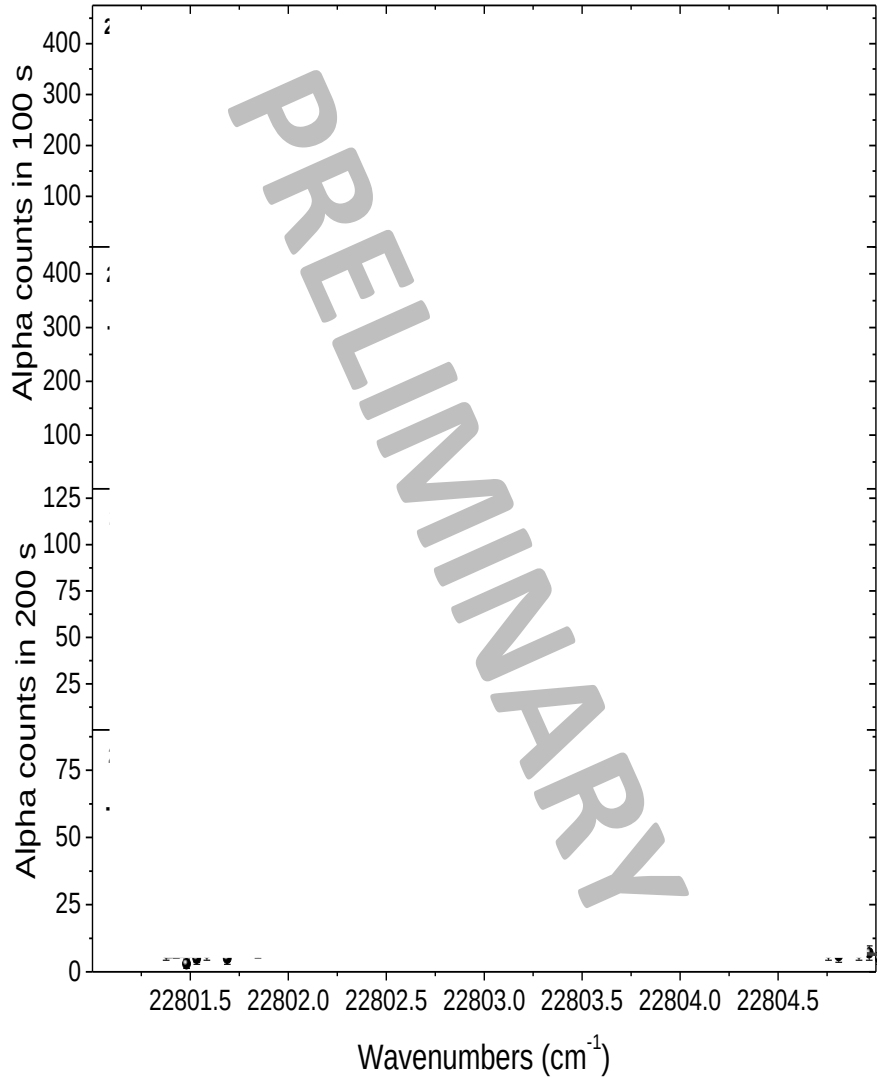
J. Rossnagel et al., PRA 85 (2012) 012525

$\varepsilon_{total} \sim 1$ %

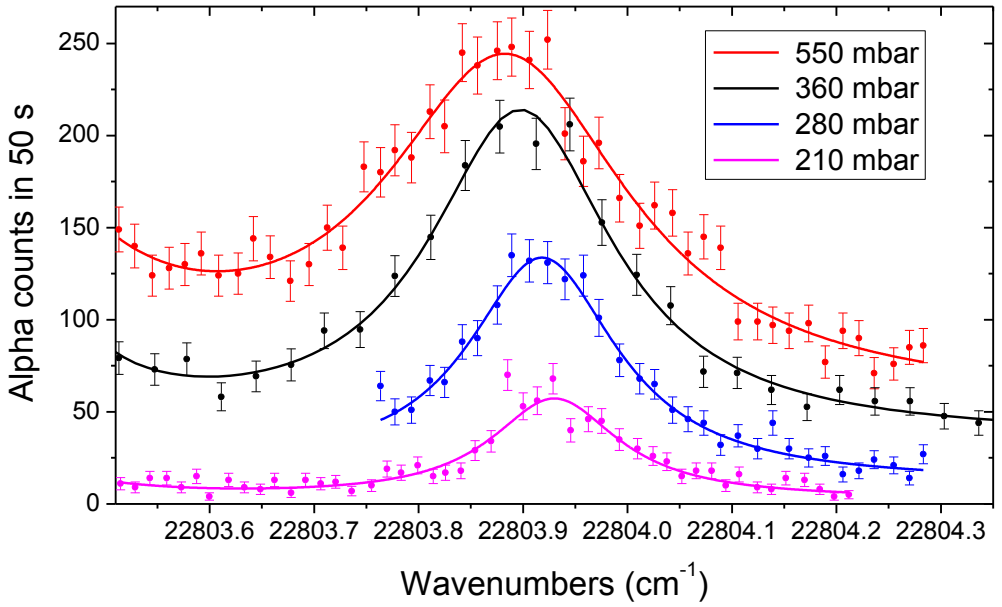


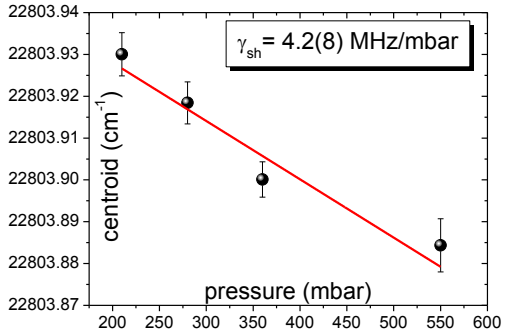


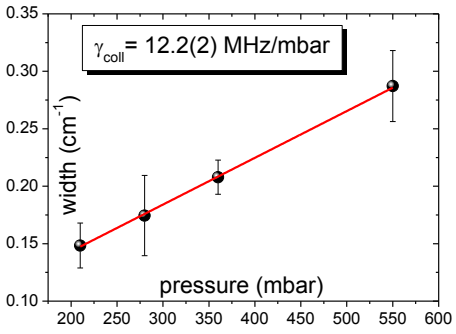
HFS of $^{212-215}$Ac - 438 nm transition -



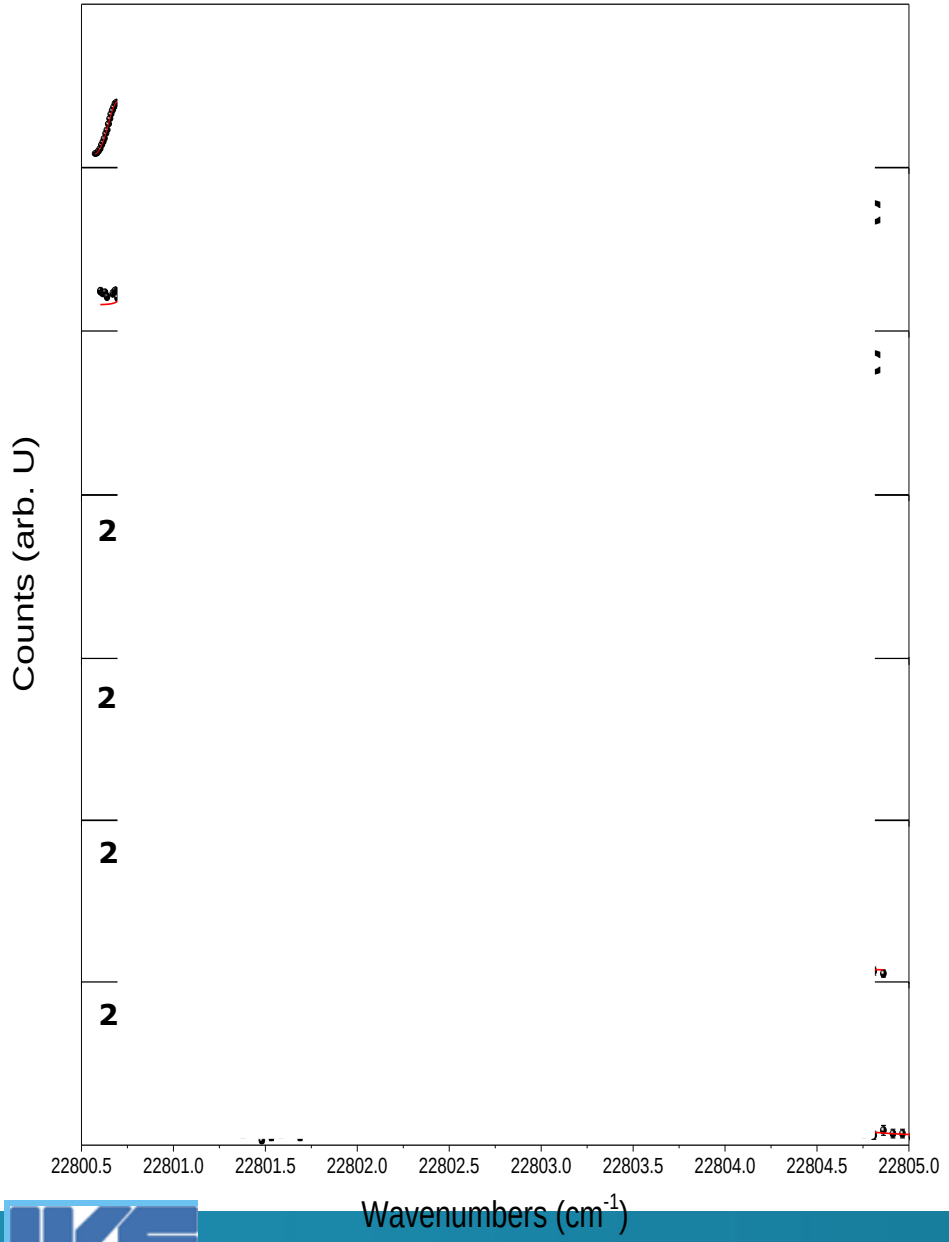
Pressure shift and broadening







HFS of $^{212\text{-}215,225\text{-}227}$Ac



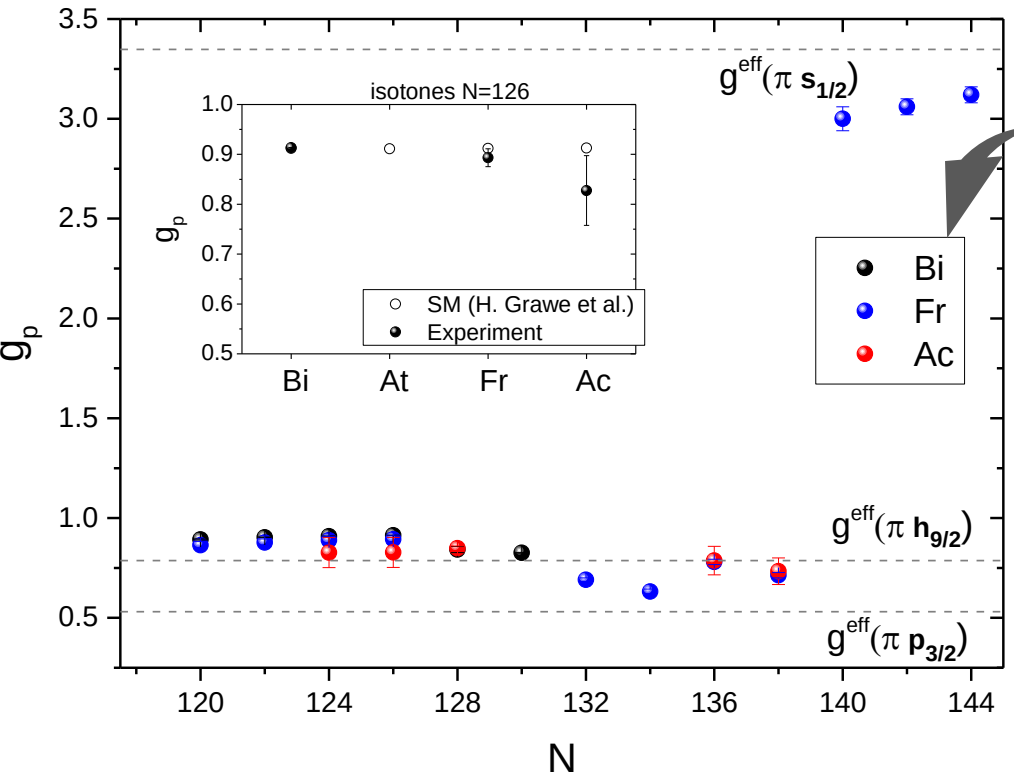
- Complementary set of data from TRIUMF of neutron rich actinium isotopes
  (PhD thesis: **Andrea Teigelhoefer**)

  Hot cavity (Doppler broadening)

- Isotope shifts (nuclear mean-square charge radii), magnetic moments, and spins!?

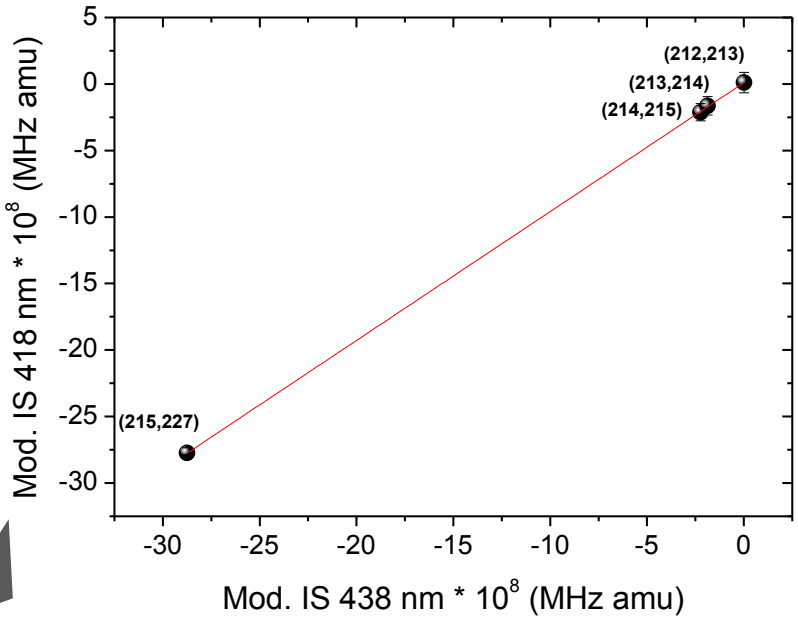
→ information on underlaying nuclear structure of actinium isotopes

μ Odd-A Nuclei and Isotope Shifts



PhD Thesis Camilo Granados

- Proton g-factors of ^{213,215}Ac consistent with observed trend for spin 9/2
- Spin 3/2 for ^{225}Ac only possibility according to observed hfs



In order to determine mean charge radii:

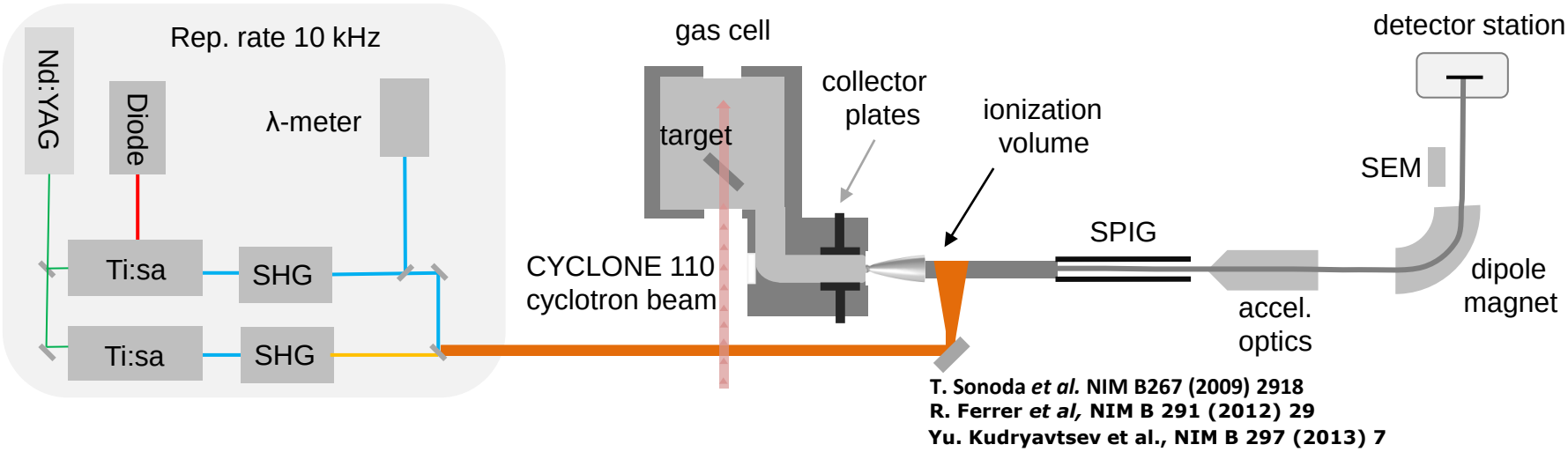
- Calculate electronic factor and specific mass shift
- Use King plot to test calculations

$$\mu * \delta\vartheta_{418} = \frac{F_{418}}{F_{438}} \mu * \delta\vartheta_{438} + M_{418} - \frac{F_{418}}{F_{438}} M_{438}$$

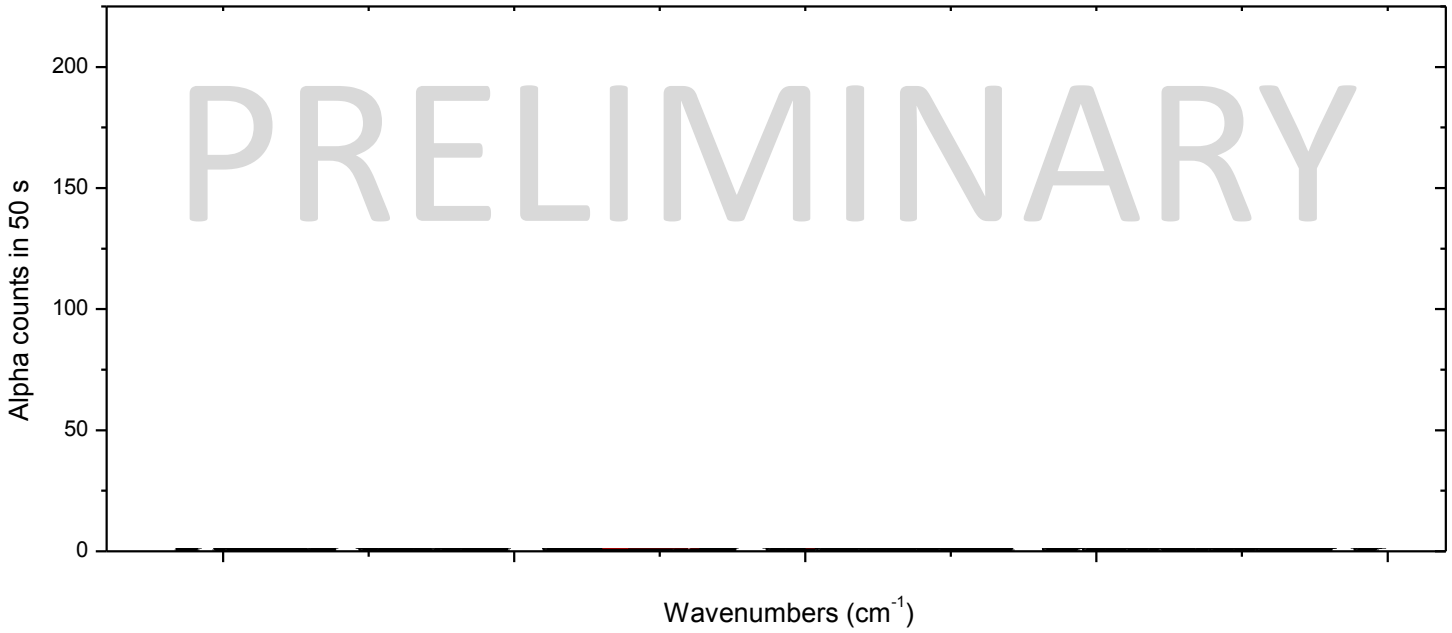
C. Ekströmet al., Phys. Scr. 34 (1986) 624
H. T. Duong et al., Europhys. Lett. 3 (1987) 175
I. Budinčević et al., Phys. Rev. C 90, 014317

A. Coc et al., Phys. Lett. B 163 (1985) 66
D.J. Decman et al., NPA 436 (1985) 311
M. Fred et al., Phys. Rev. 111 (1958) 1747
M. R. Pearson et al., J. Phys. G 26 (2000) 1829,
T. Bastug et al., Z. Phys. D 37 (1996) 281
J. Kilgallon et al., Phys. Lett. B 405 (1997) 31

In-Gas-Jet Spectroscopy of ^{214,215}Ac



T. Sonoda *et al.* NIM B267 (2009) 2918
R. Ferrer *et al,* NIM B 291 (2012) 29
Yu. Kudryavtsev et al., NIM B 297 (2013) 7

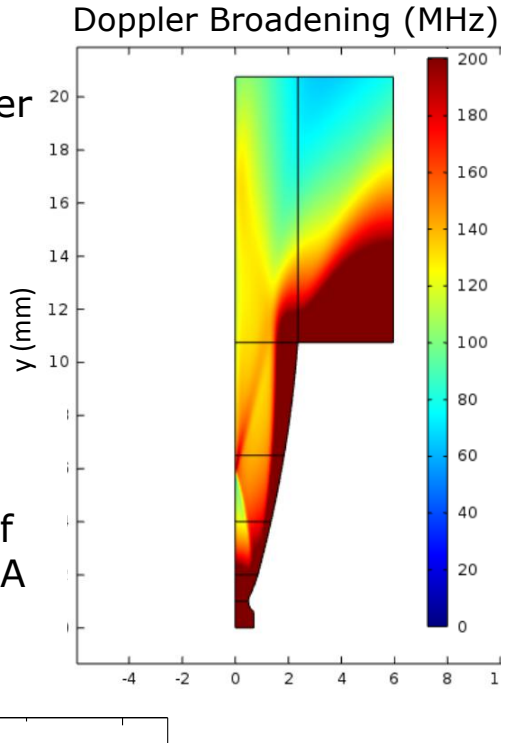


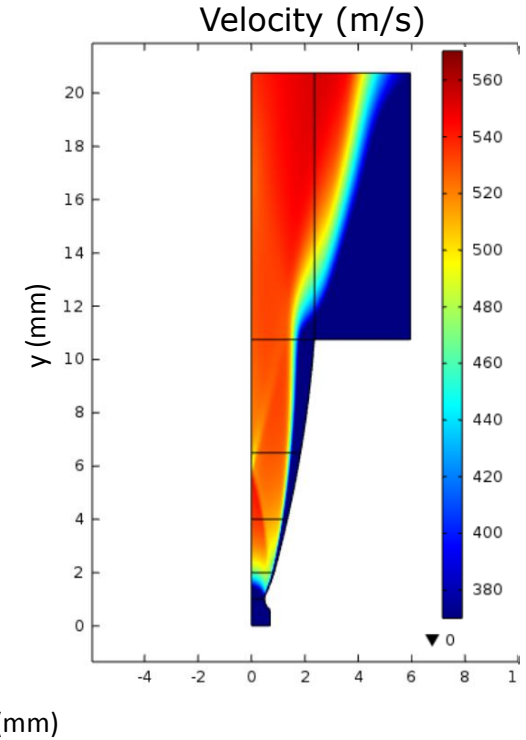
Figures of merit:

- ✓ Resolution ~ 5e-7 (FWHM= 400 MHz)
- ✓ Selectivity ~ 200
- ✓ Efficiency ~ 0.5%

In-Gas-Jet Spectroscopy of ^{214,215}Ac

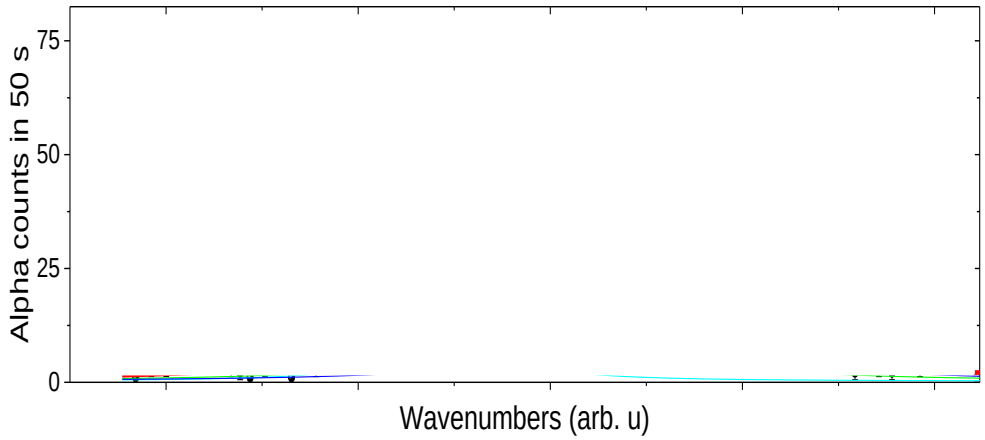
- Observed spectral widths → jet T and jet divergence, and laser power
- Reduction energy up to 80 nJ → singlet FWHM~300 MHz, mainly Gaussian contribution





<u>In-jet spectroscopy results in:</u>

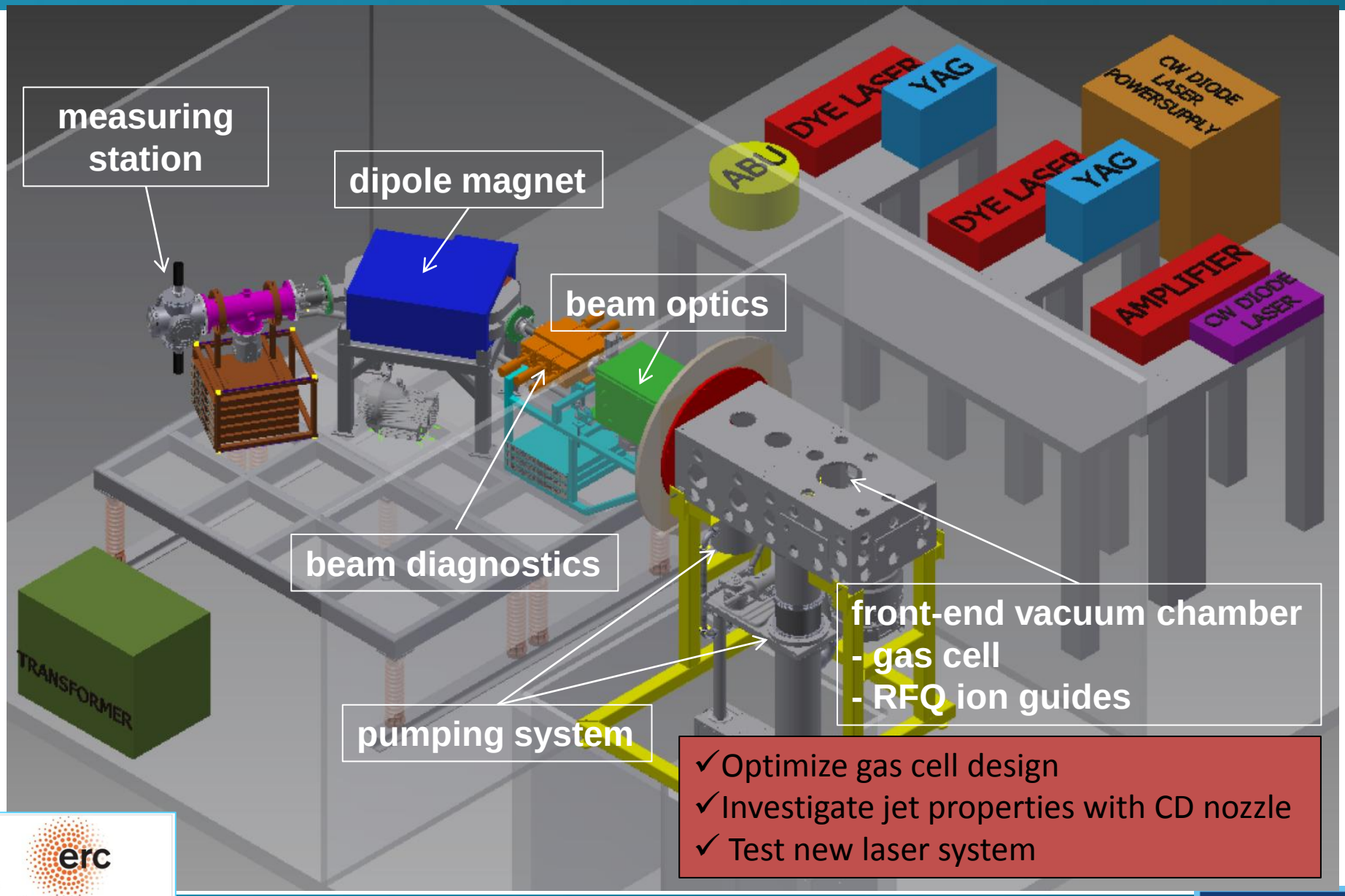
- 25-fold improvement in uncertainties of istope shifts and magnetic hf constant A
- access to quadrupole moments as well



- ➢ Improve temporal overlap to increase efficiency → 1/10 to 10/10
- ➢ Design of a better nozzle and characterization of gas jets →

Jet visualization by PLIF

HELIOS @ KU Leuven



- ✓Optimize gas cell design
- ✓Investigate jet properties with CD nozzle
- ✓ Test new laser system

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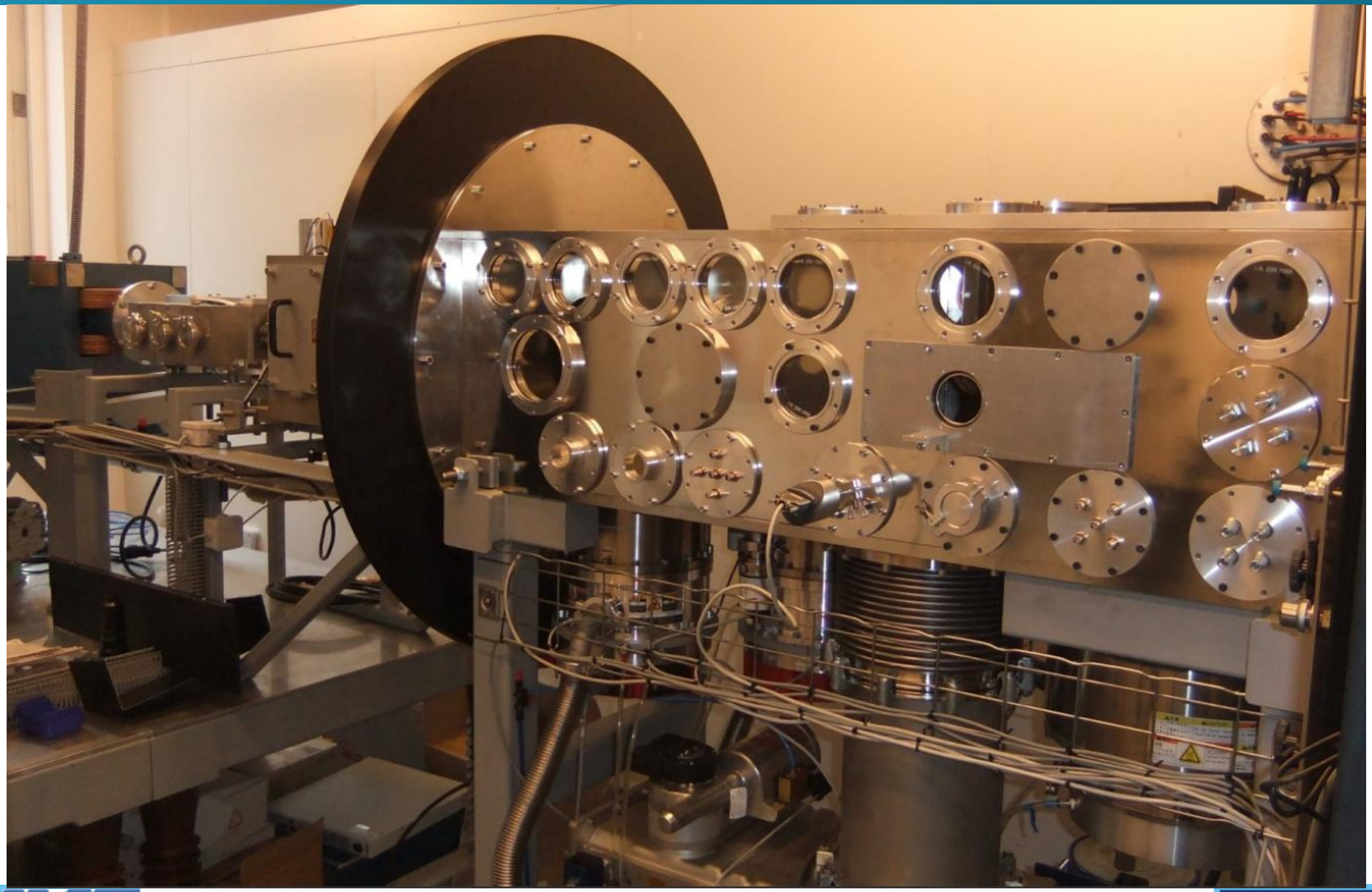
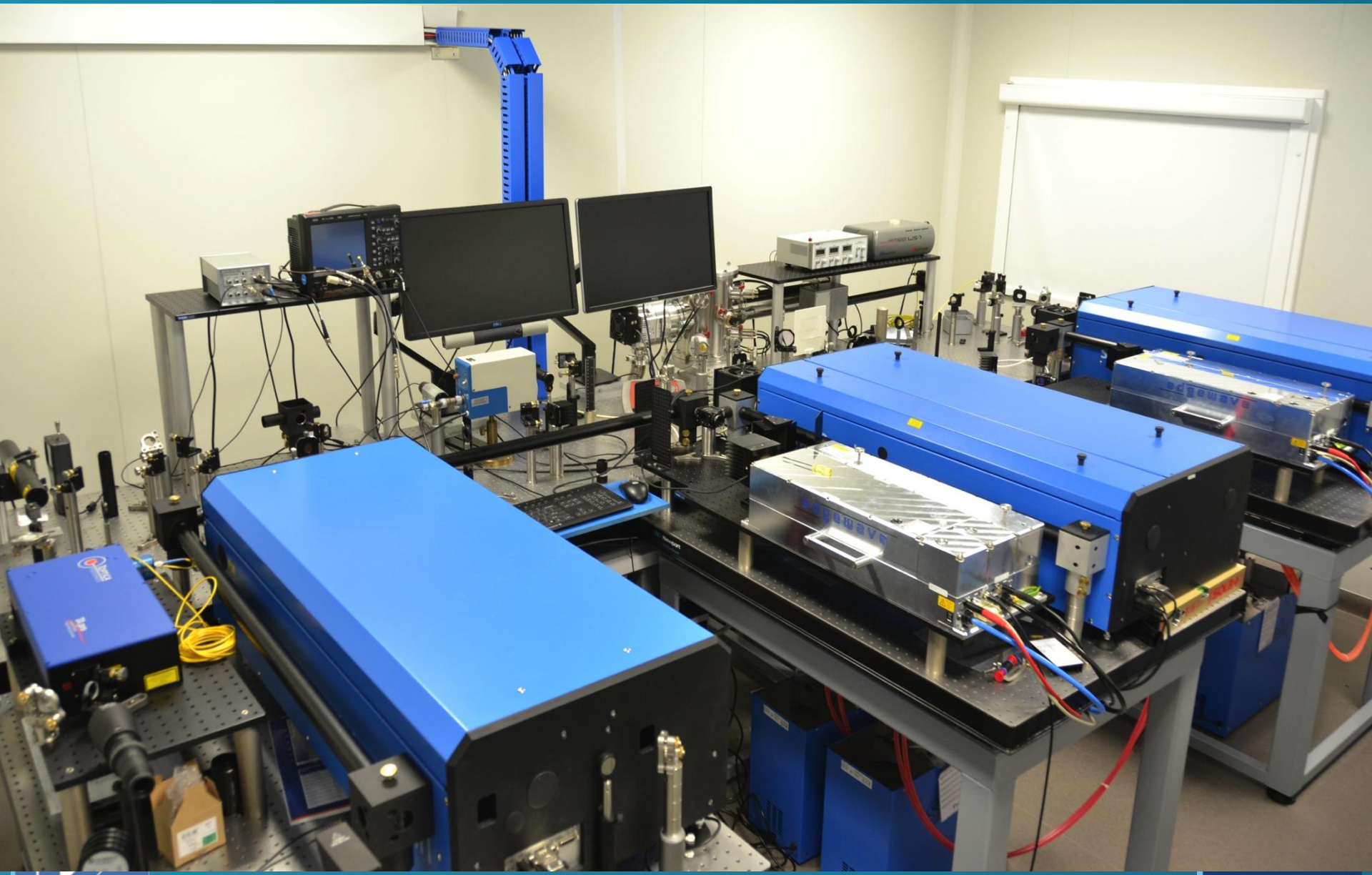
HELIOS –Jet Room–



HELIOS –Laser Room–

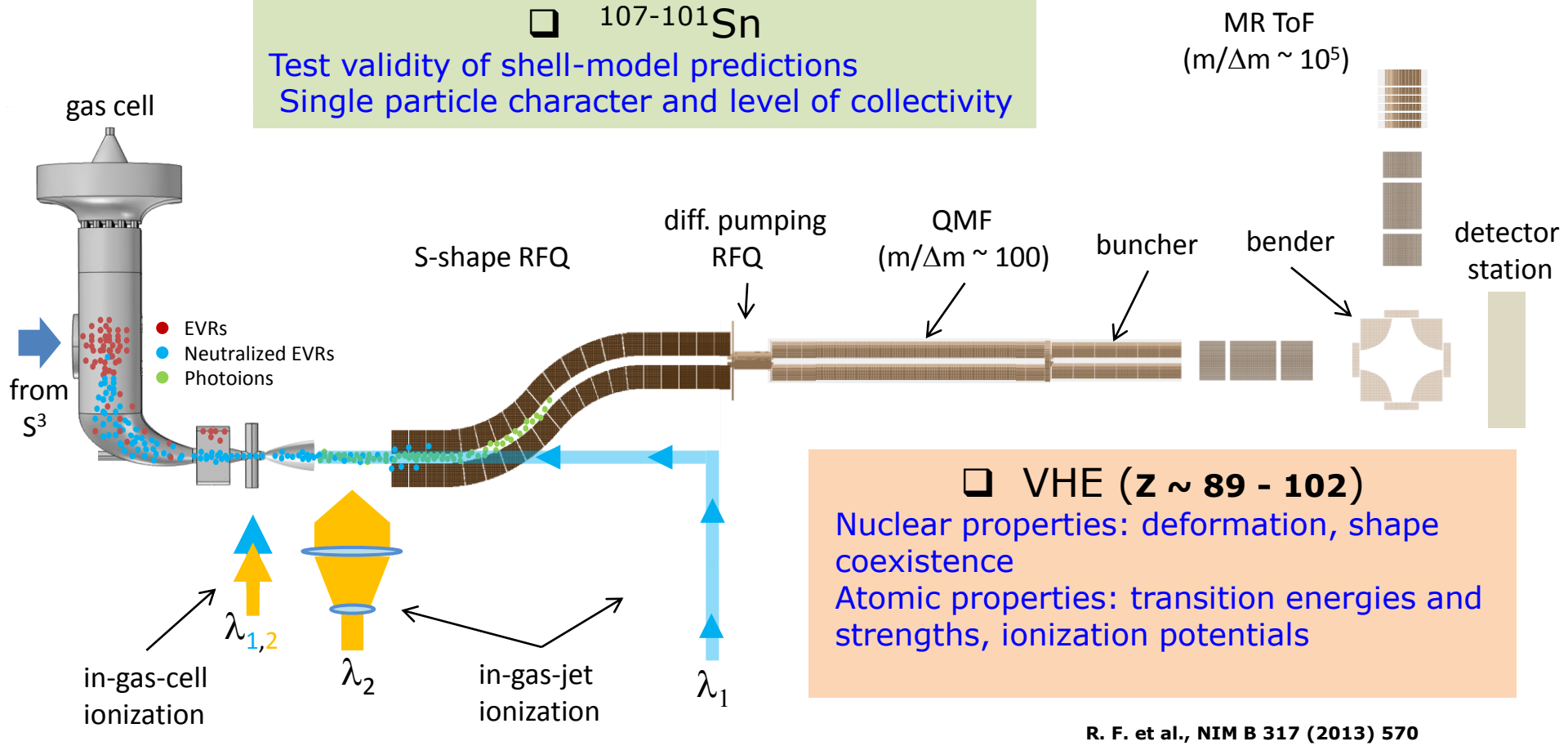


REGLIS³ @ SPIRAL2

❑ ^{94}Ag
High-spin isomerism (J=21⁺)
β,β-delayed p, 1p-, and 2-p!? emission

❑ ^{80}Zr
Shape coexistence and single-particle behavior

❑ $^{107-101}$Sn
Test validity of shell-model predictions
Single particle character and level of collectivity



❑ VHE (**Z ~ 89 - 102**)
Nuclear properties: deformation, shape coexistence
Atomic properties: transition energies and strengths, ionization potentials

R. F. et al., NIM B 317 (2013) 570

Acknowledgments

LISOL team

P. Creemers, L.P. Gaffney, L. Ghys, C. Granados, M. Huyse, Yu. Kudryavtsev, Y. Martínez, E. Mogilevskiy, S. Raeder, S. Sels, P. Van den Bergh, P. Van Duppen, A. Zadvornaya

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