S^3LEB progress report

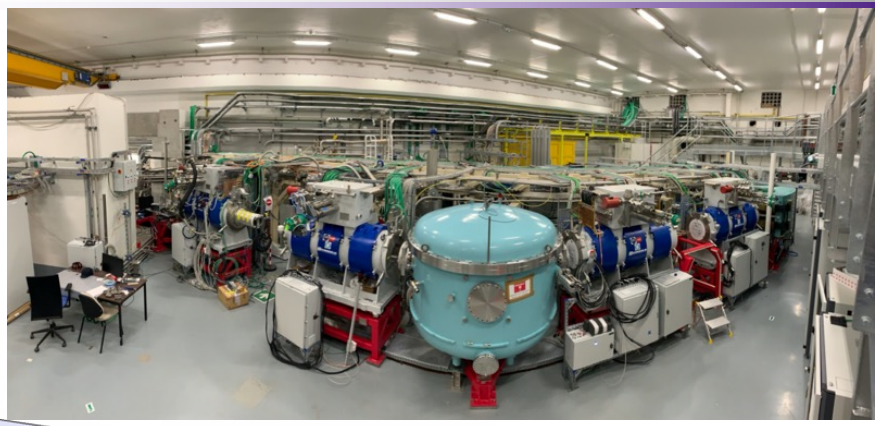
Nathalie Lecesne

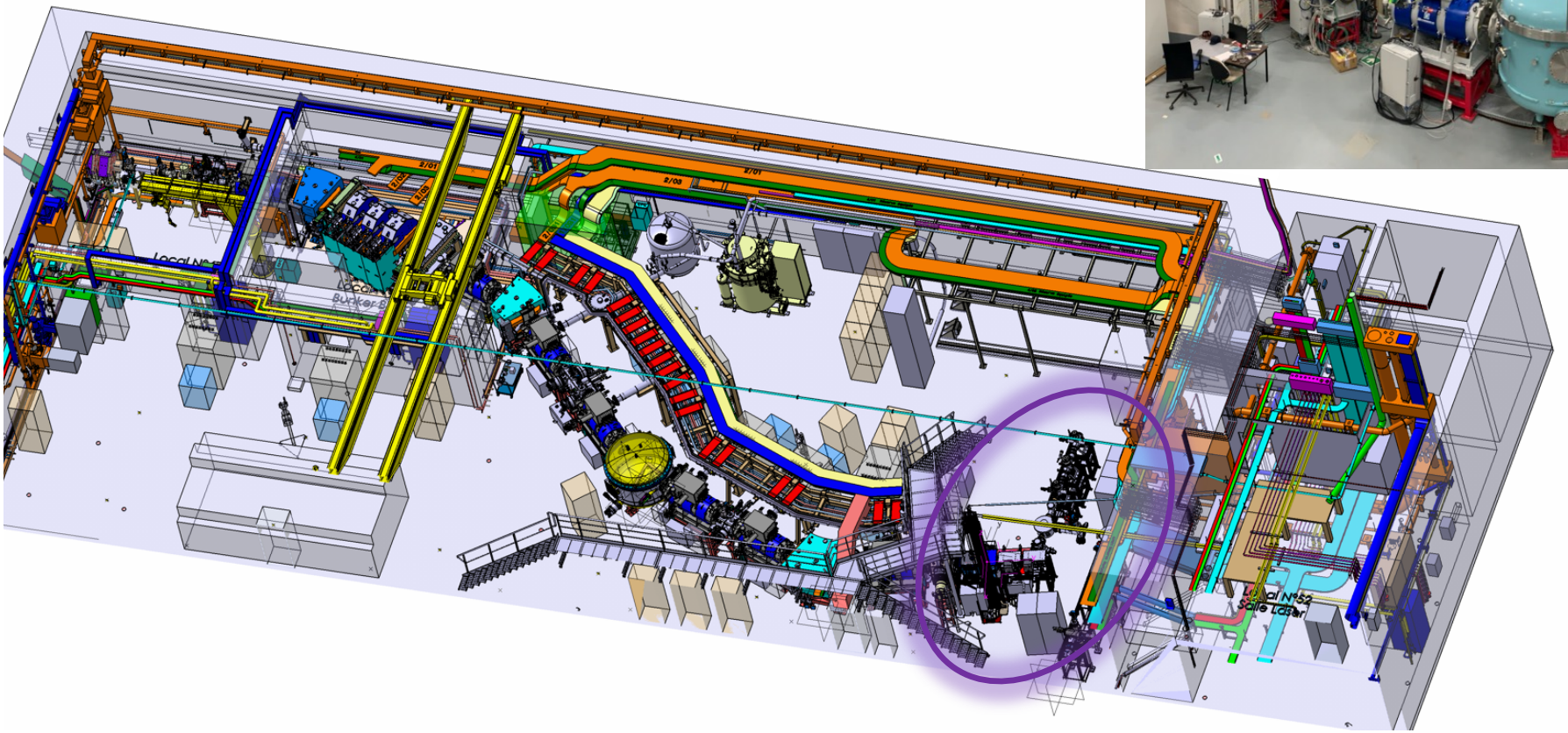
GANIL

S^3-LEB collaboration

S^3 – Super Separator Spectrometer

- Wide range (H to U) of primary beams at high intensity ($10 \mu Ap$)
- High primary beam rejection and high acceptance spectrometer
- High power beams technology (targets & beam dumps)
- Supra conducting magnet technology



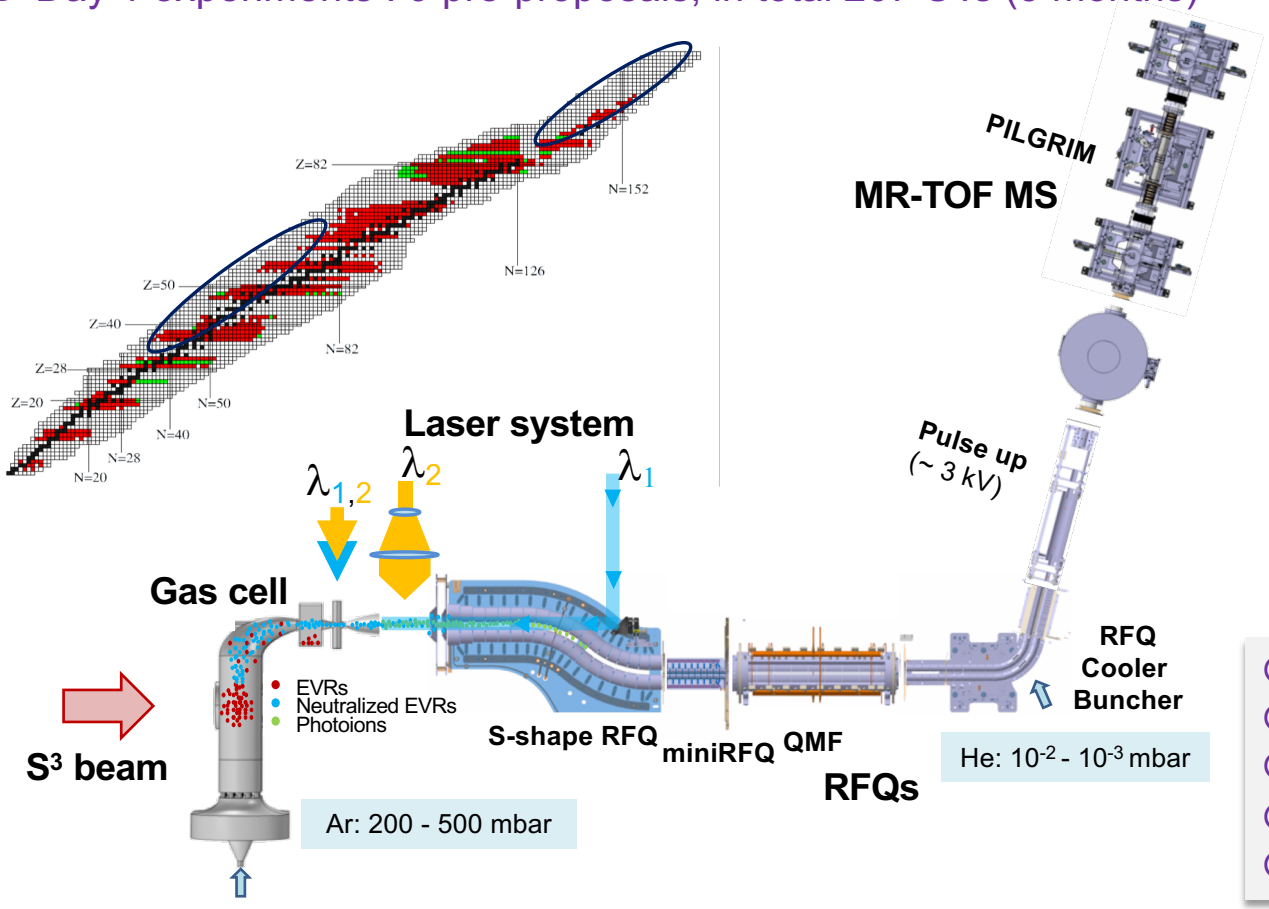


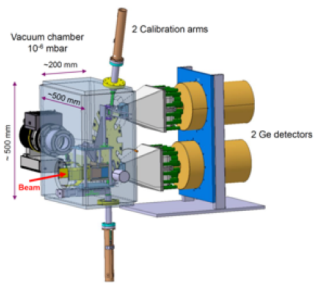
S^3 EQUIPEX:

- 22M€
- 400 ETP (12 years)

S³ LEB - S³ Low Energy Branch

◎ Day 1 experiments : 9 pre-proposals, in total 267 UTs (3 months)

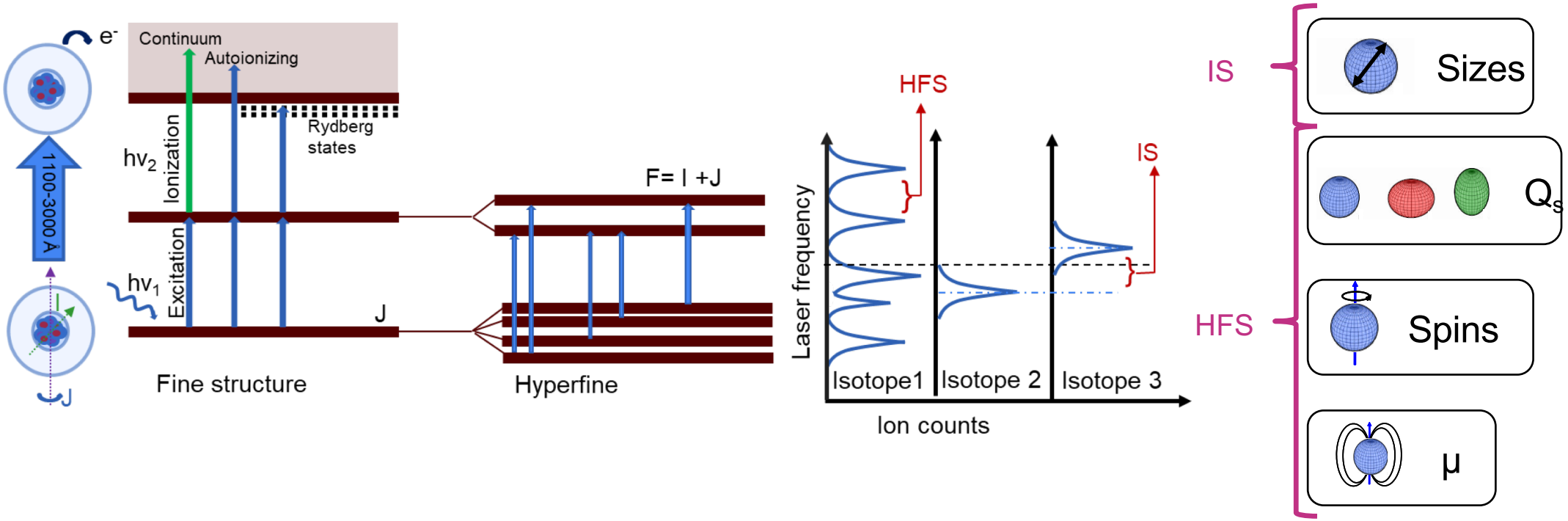




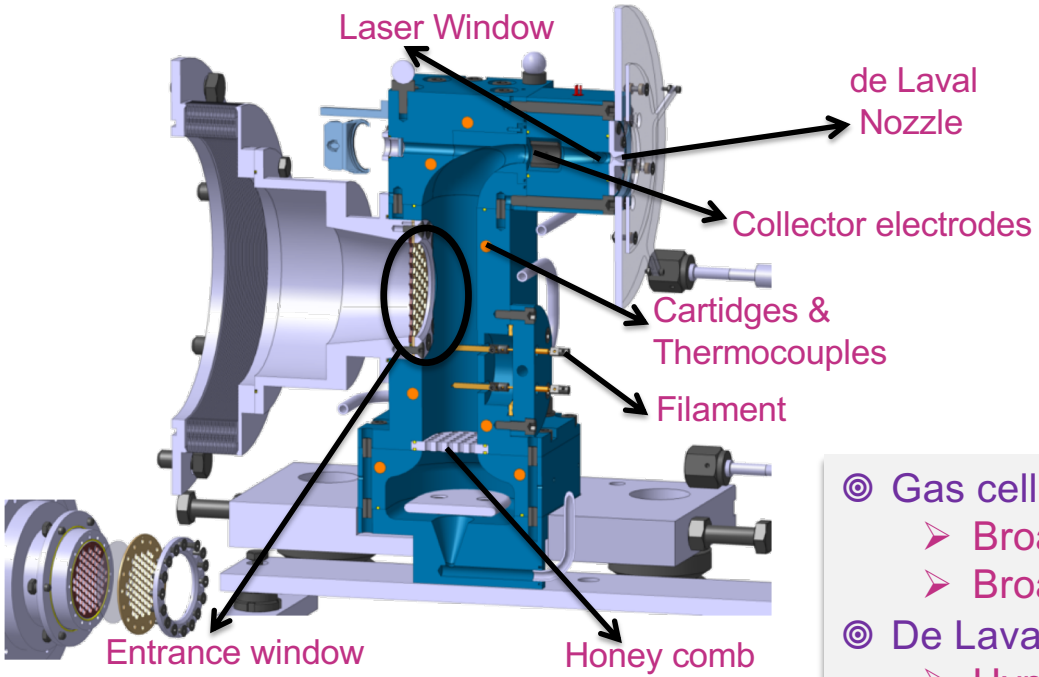
◎ Pure (isomers) RIBs @ low energy
◎ Refractory elements (gas cell)
◎ High resolution laser spectroscopy (gas jet)
◎ Mass spectrometry (PILGRIM)
◎ Decay spectroscopy (SEASON)

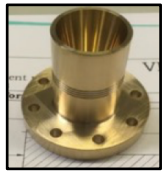
S³ LEB Selectivity

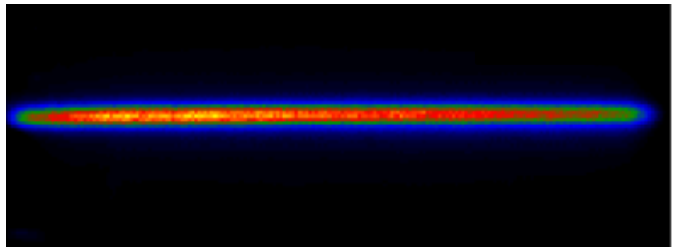
◎ Resonant Laser Ionisation Spectroscopy : Z Selectivity



In Gas Cell / Jet Spectroscopy

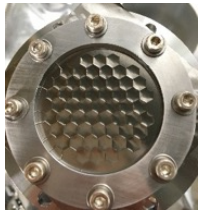






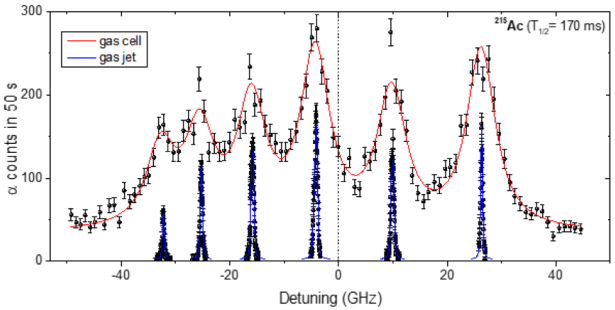
Fluorescence spectrum of gas jet

[1] A.Zadvornaya et al. Phy.Rev X 8.041008(2018) doi:10.1103/PhysRevX.8.041008



Ti or Mylar foils
5 – 1.5 µm

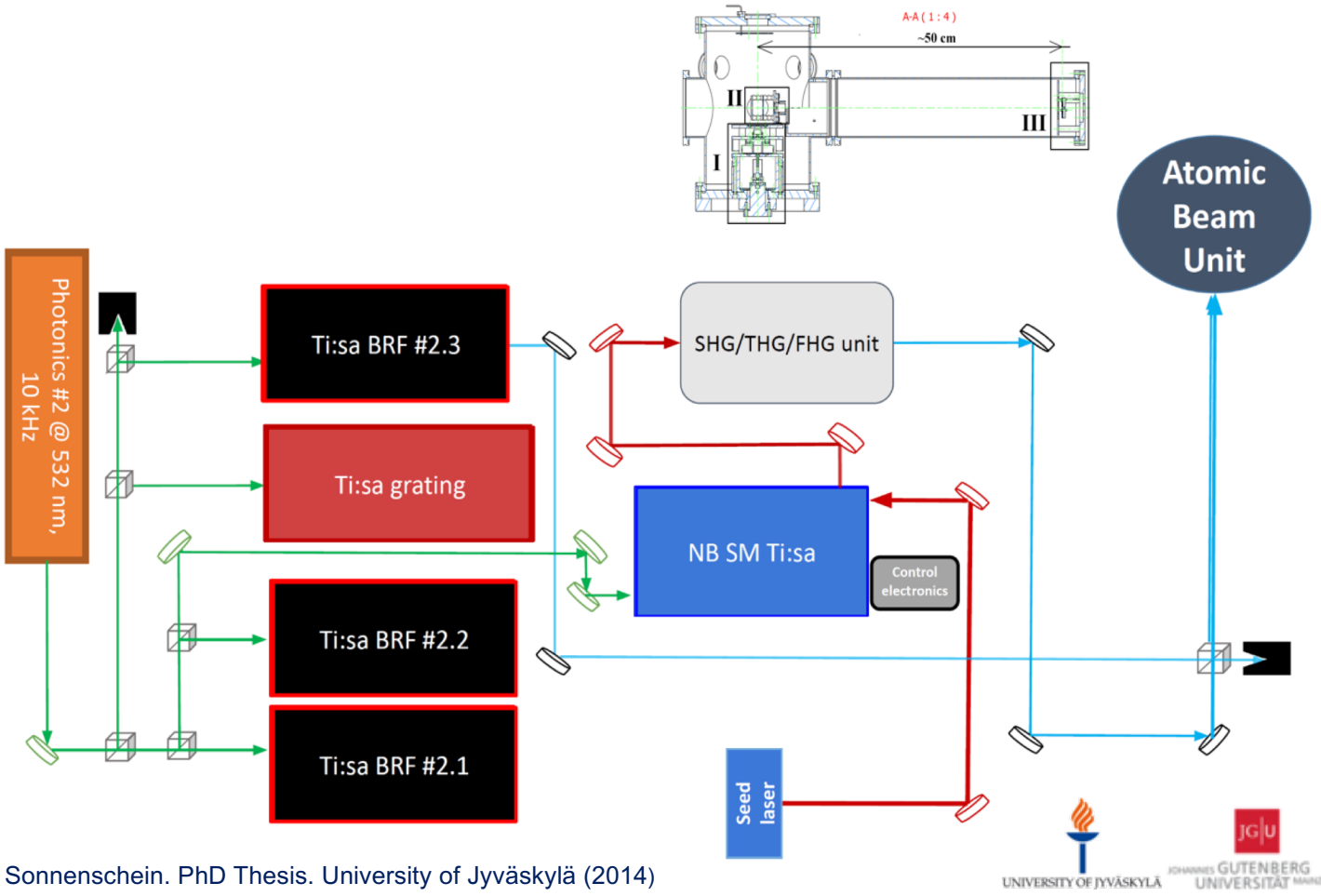
- Gas cell
  - Broadening effects
  - Broad band laser (GHz)
- De Laval Nozzle
  - Hypersonic gas jet
    ρ ↓ T ↓
  - Narrow band laser (MHz)



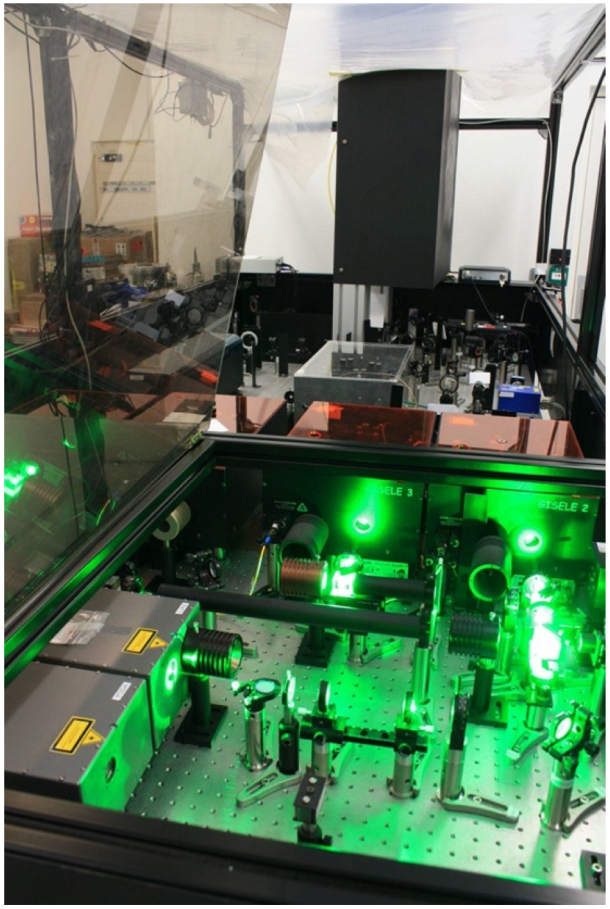
[2] R.Ferrer et al. Nature Communications.8.14520 .doi: 10.1038/ncomms14520

GISELE TiSa Laser system @ GANIL

◎ Narrow-bandwidth / Single-mode TiSa laser system ($\Delta\lambda$ < 50 MHz)



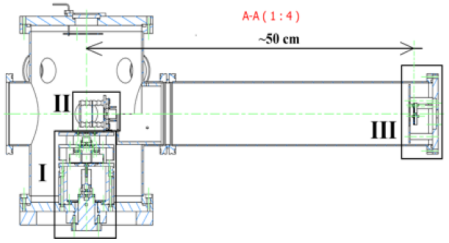
V. Sonnenschein. PhD Thesis. University of Jyväskylä (2014)

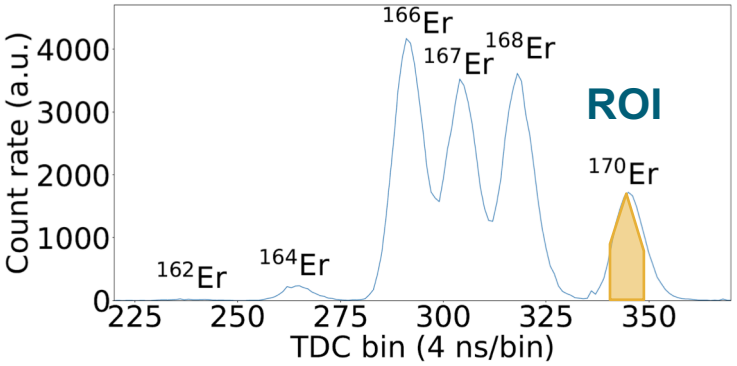


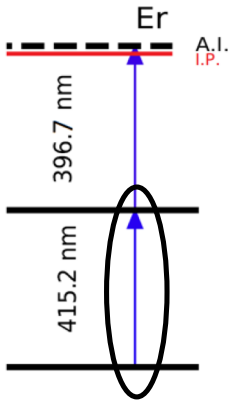
PhD: J. Romans

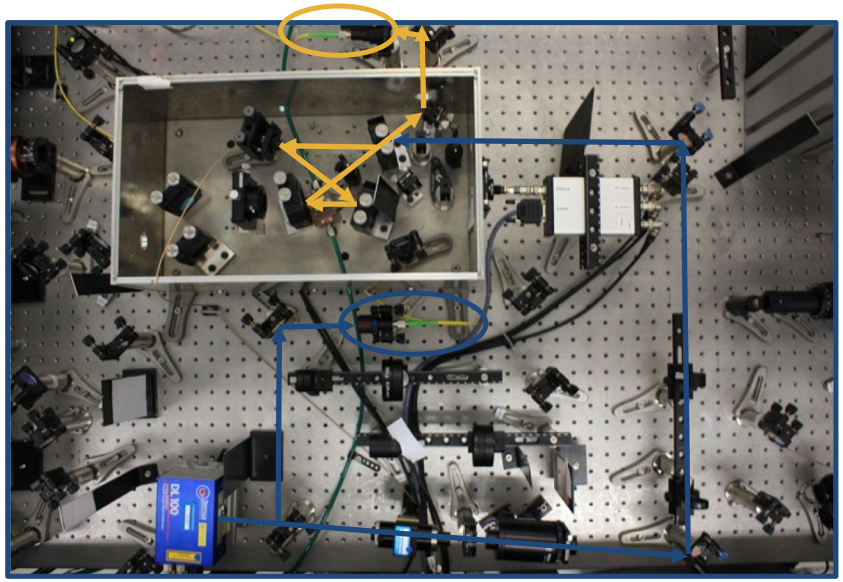
GISELE TiSa Laser system @ GANIL

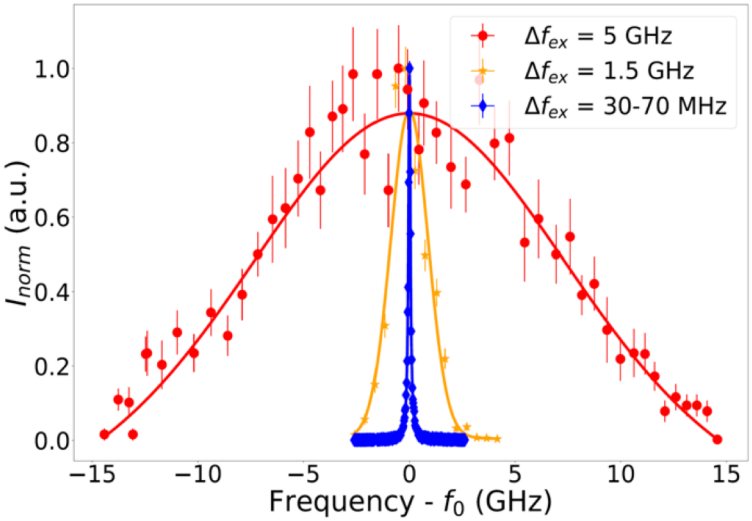
◎ Narrow-bandwidth / Single-mode TiSa laser system (**$\Delta\lambda$ < 50 MHz**)











V. Sonnenschein. PhD Thesis. University of Jyväskylä (2014)

PhD: J. Romans

First laser spectroscopy results @ GISELE

- $^{162,164,166,167,168-170}$Er I RIS

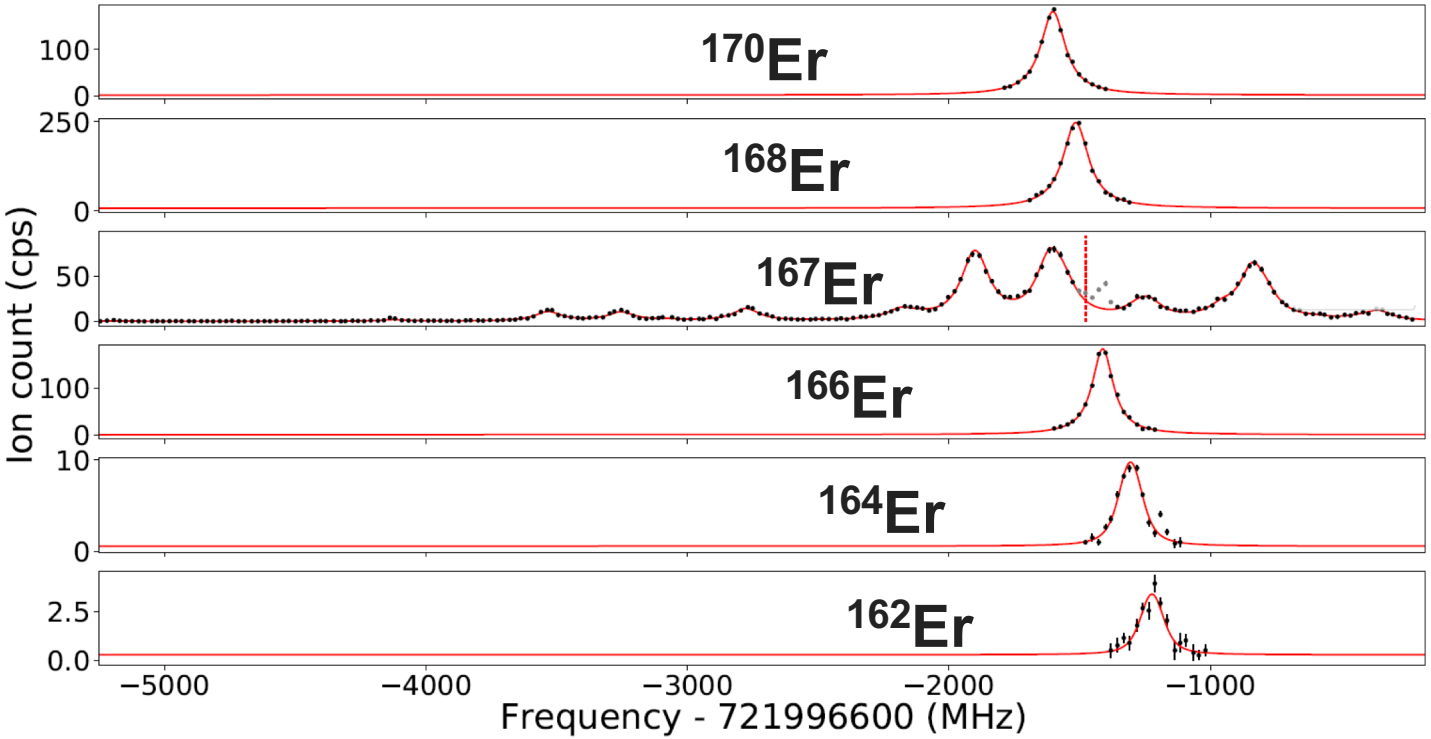
$$\delta\nu_{\mathrm{IS}}^{AA'} = \delta\nu_{\mathrm{MS}}^{AA'} + \delta\nu_{\mathrm{FS}}^{AA'}$$

$$\delta\nu_{\mathrm{FS}} = F\delta\langle r^2\rangle$$

$$\Delta E_{HFS} = \frac{A}{2}C + \frac{B}{2}\frac{3C(C+1) - 2I(I+1)2J(J+1)}{2I(I-1)2J(J-1)}$$

$$A = \frac{\mu_I B_e(0)}{IJ}$$

$$B = eQ_s\langle\frac{\partial^2 V}{\partial z^2}\rangle$$



J. Romans et al. To be submitted (2022)

$\Delta f_{\mathrm{WA}}^{170,A*}$ (MHz)

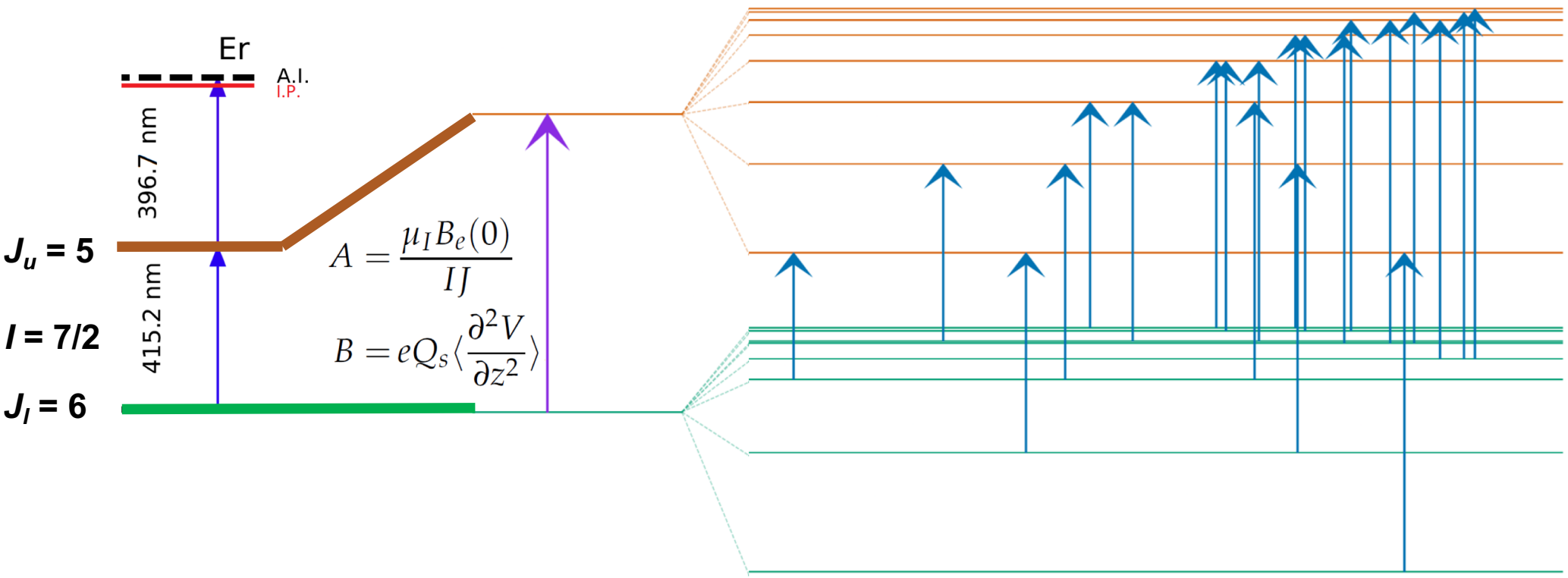
$4f^{12}6s^2\ {}^3H_6 \rightarrow 4f^{12}({}^3H_5)6s6p$

A	I^π	This work
168	0^+	97 (5) [30]
167	$7/2^+$	127 (5) [30]
166	0^+	197 (5) [30]
164	0^+	298 (3) [30]
162	0^+	388 (9) [30]

PhD: J. Romans

First laser spectroscopy results @ GISELE

- Odd-even ^{167}Er HFS

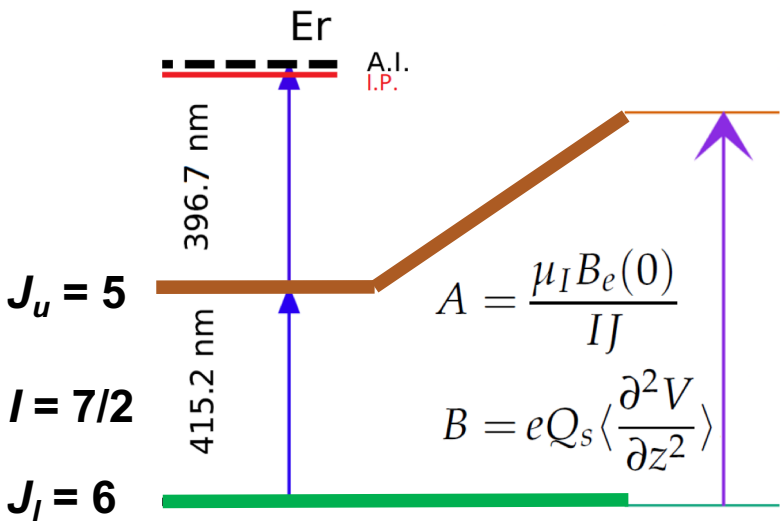


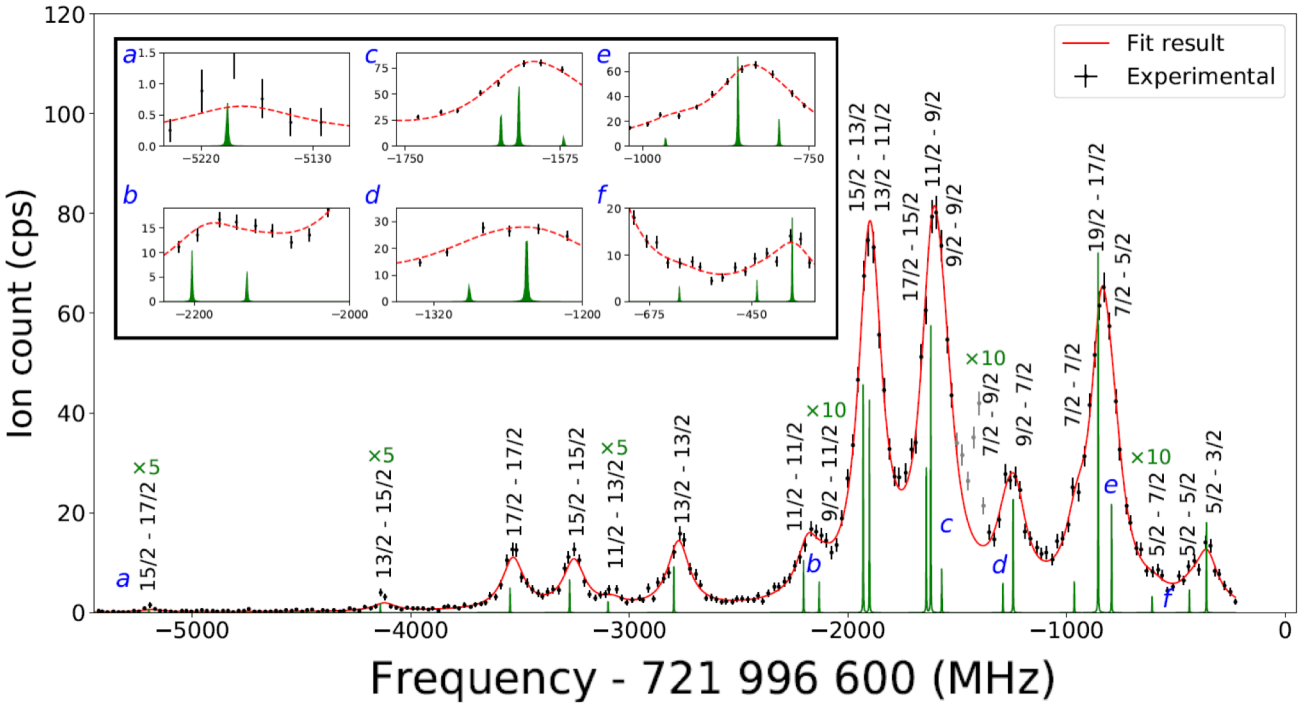
J. Romans et al. To be submitted (2022)

PhD: J. Romans

First laser spectroscopy results @ GISELE

- Odd-even ^{167}Er HFS





- + IS in Sn in known transition
- + IS in Sn in new transition

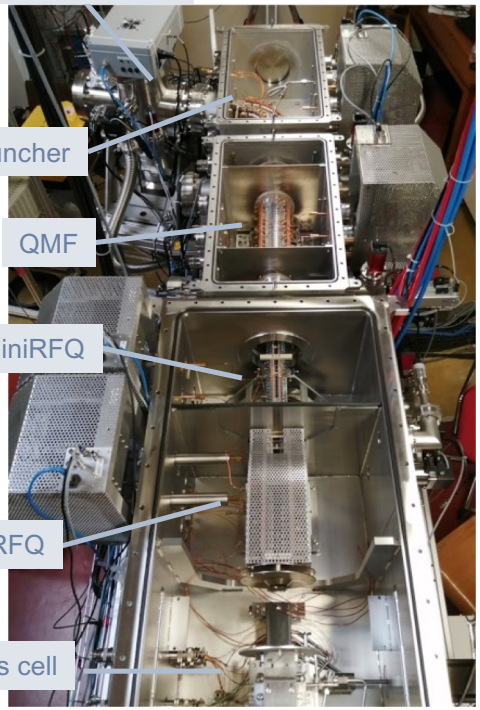
J. Romans et al. To be submitted (2022)

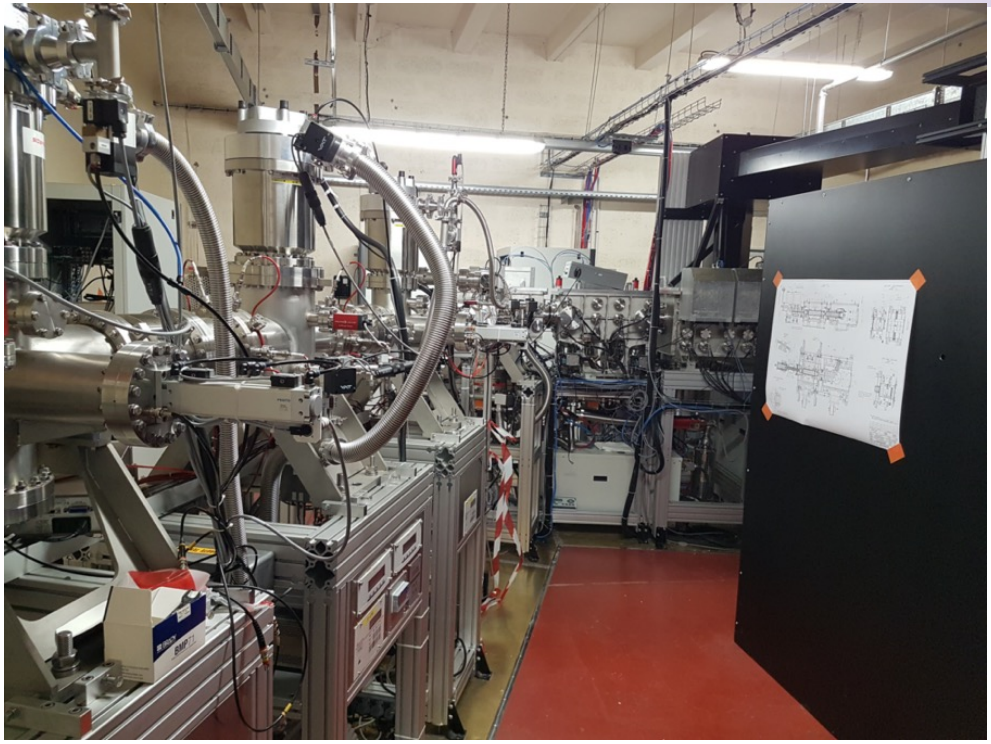
^{167}Er HFS coefficients

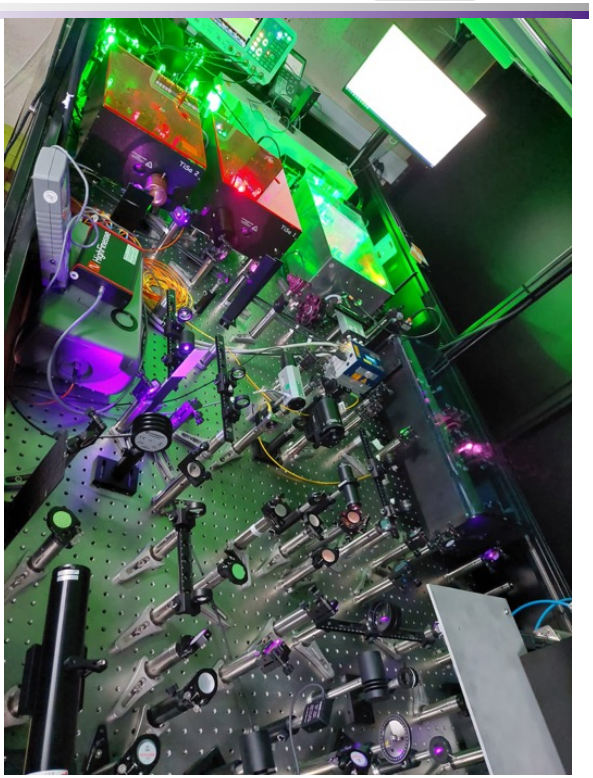
$4f^{12}6s^2\ {}^3H_6$			$4f^{12}({}^3H_5)6s6p$		
Ref.	A (MHz)	B (MHz)	Ref.	A (MHz)	B (MHz)
This work	-120.85 (99)	-4567 (29)	This work	-147.1 (13)	-1875 (24)
[28]	-120.487 (1)	-4552.984 (10)	[29]	-146.6 (0.3)	-1874 (16)
[30]	-120.8 (0.3)	-4546 (11)			
[31]	-120.42	-4554			

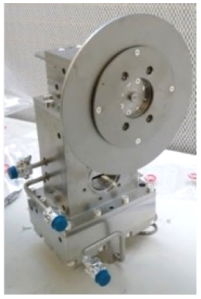
PhD: J. Romans

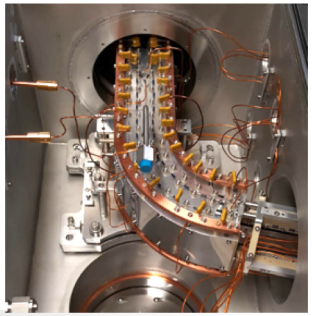
S^{3}LEB commissioning @ LPC

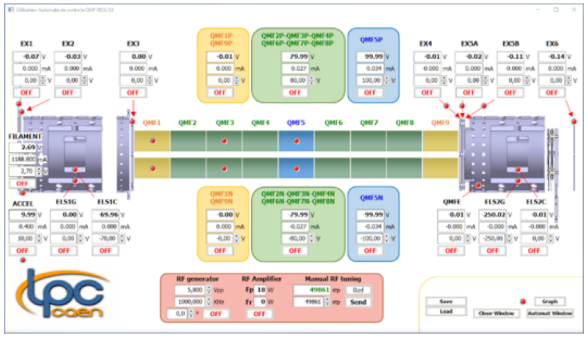


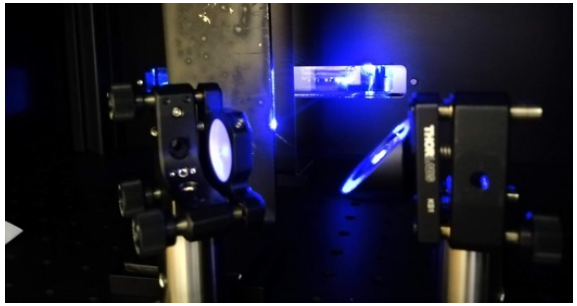




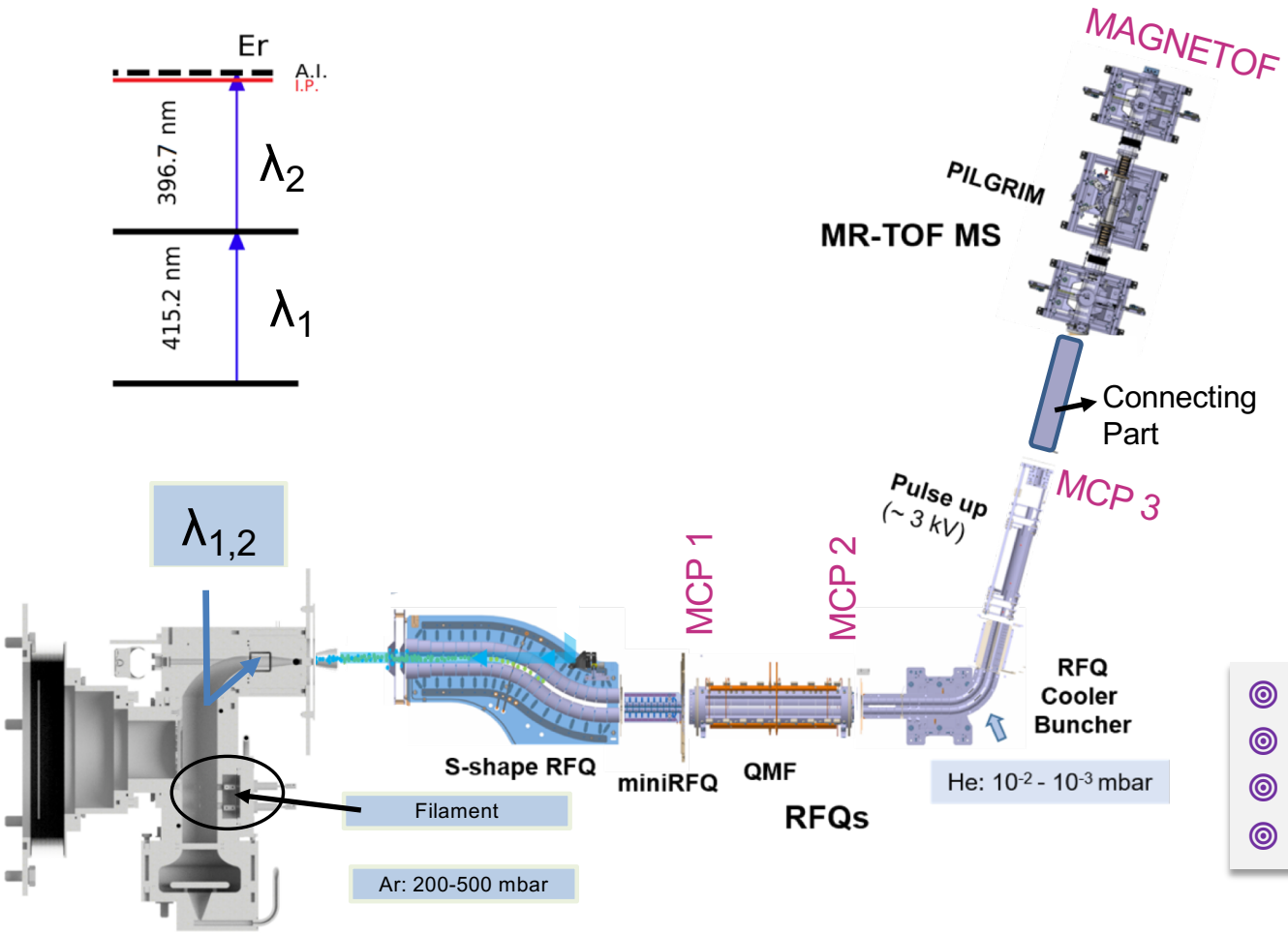




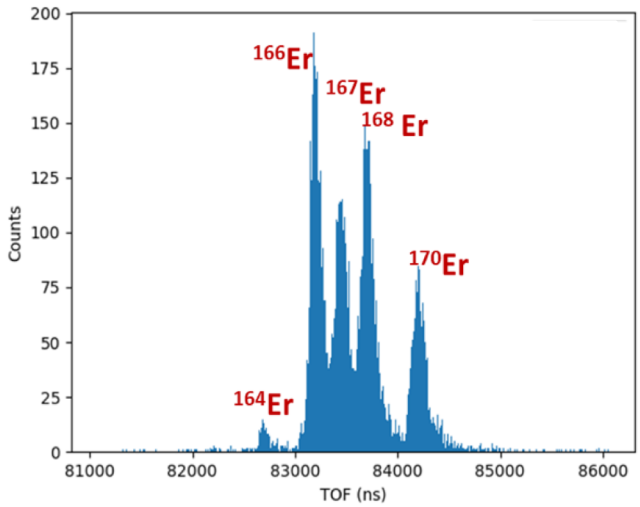




S³LEB commissioning @ LPC



TOF Spectrum after PILGRIM

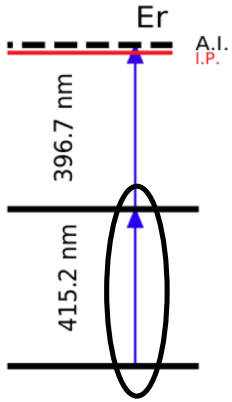


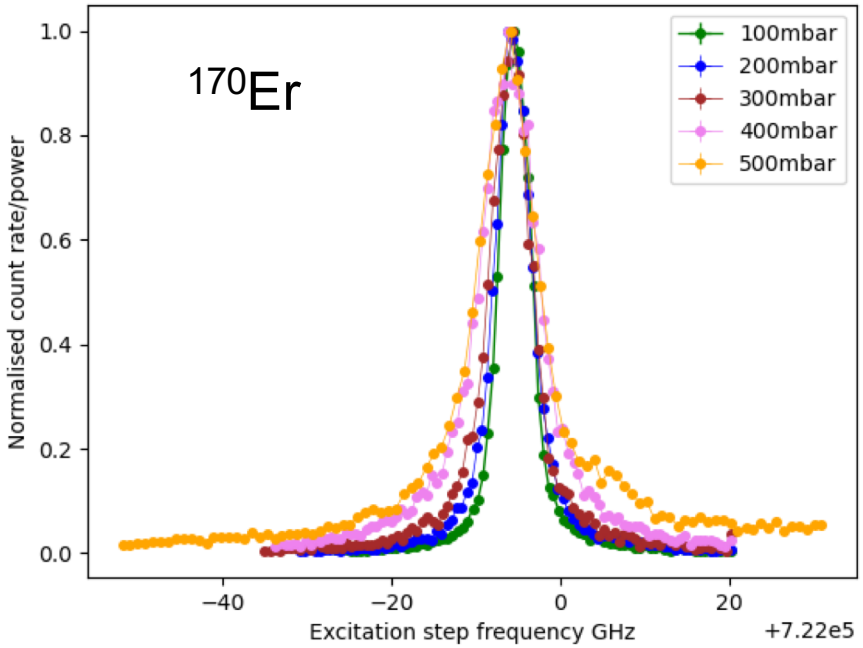
- S-RFQ + miniRFQ: ε ≈ 95(5)%
- QMF: ε ≈ 95(5)% (moderate filtering)
- Buncher: ε_{cont} ≈ 60(5)% ; ε_{bunch} ≈ 20(5)%
- MCP3-PILGRIM: ε > 50 %

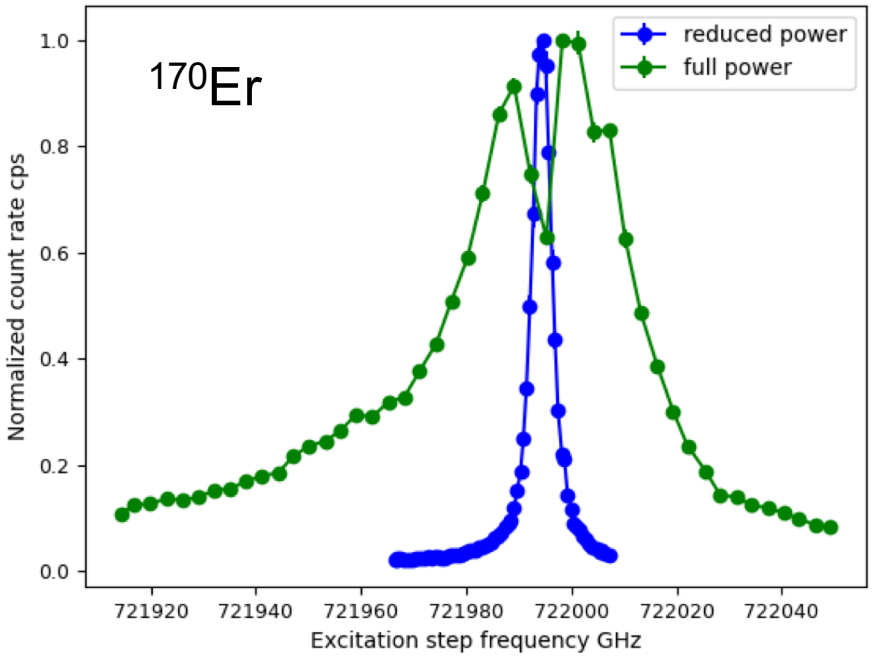
PhD: A. Ajayakumar

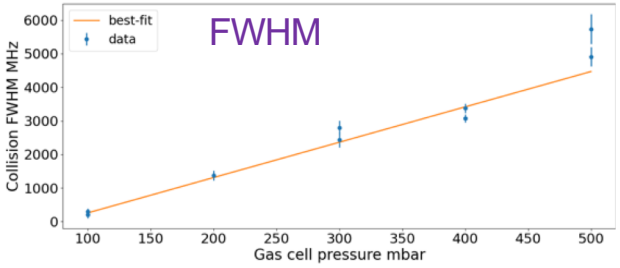
S³LEB commissioning @ LPC

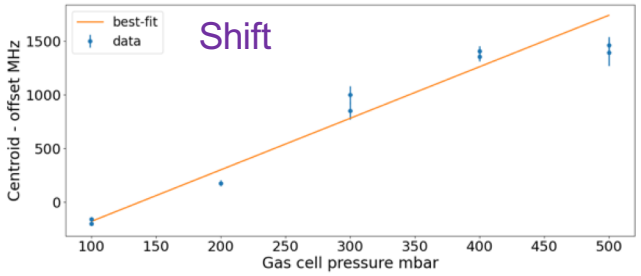
- In-gas cell spectral broadening: Broadening as a function of gas cell pressure and laser power









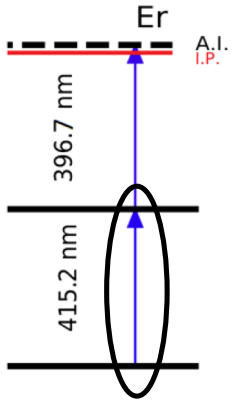


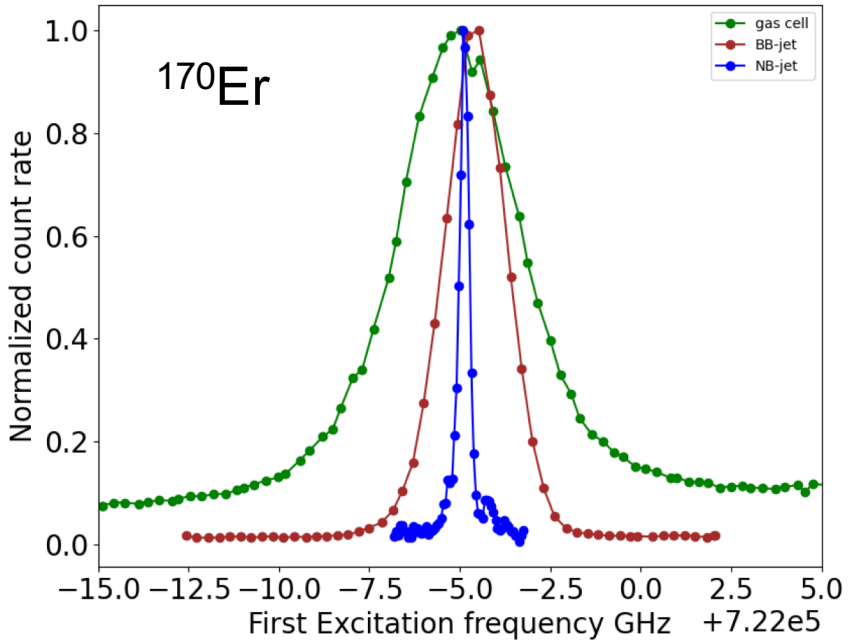
- Broadening coefficient = 8(2) MHz/mbar
- Shift coefficient = 5(1) MHz/mbar

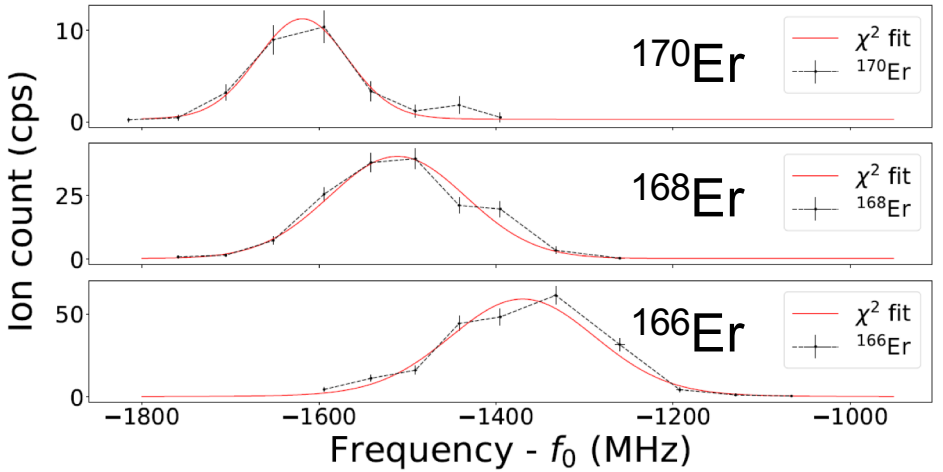
PhD: A. Ajayakumar

S³LEB commissioning @ LPC

- In-gas jet spectroscopy and first measured Isotope Shifts in Er







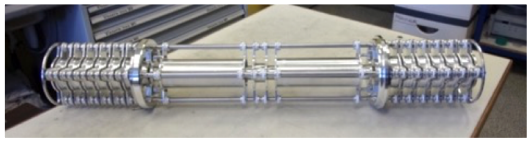
- Excitation step with Narrow Band Laser < 100 MHz
  - Spectral Linewidth (FWHM): 316(5) MHz
- Ionization step: Broad Band Laser ~ 1.8 GHz
  - Spectral Linewidth (FWHM): 2(1) GHz

$\Delta f^{170,A^*}$ (MHz) $4f^{12}\,6s^2\,{}^3H_6 \rightarrow 4f^{12}\,6s\,({}^3H_5)\,6p$	In-Gas jet with BB laser RIS PRELIMINARY	In-Gas jet with NB laser RIS PRELIMINARY	Vacuum (J.Romans et al. article in preparation)
$\Delta f^{170,166}$	181(30)	231(14)	197(5)
$\Delta f^{170,168}$	80(34)	99(7)	97(5)

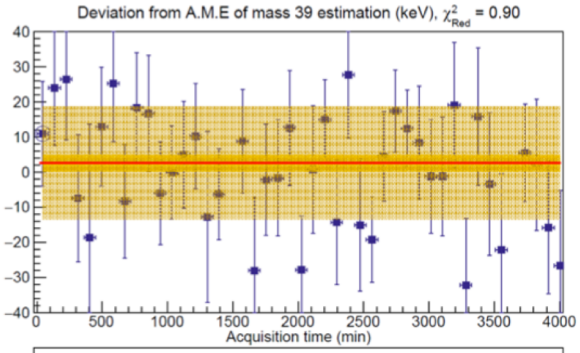
PhD: A. Ajayakumar

PILGRIM MR-ToF-MS

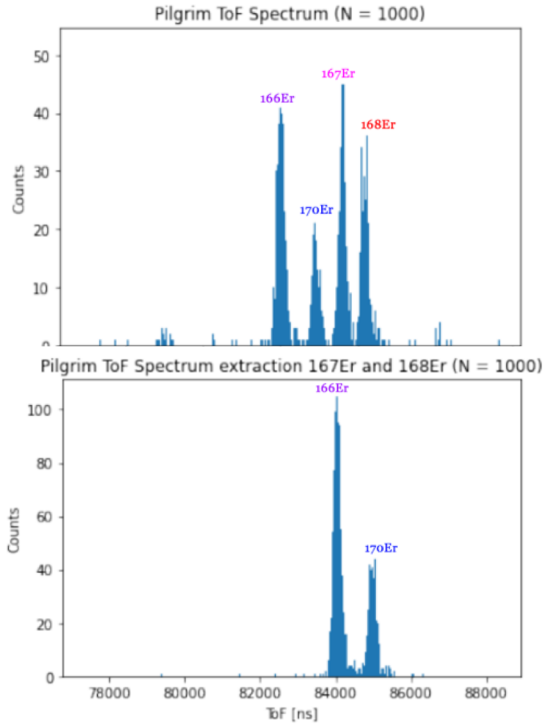
PILGRIM (Piège à Ions Linéaire du Ganil pour la Résolution des Isobares et la mesure de Masse)



- ^{39}K using ^{23}Na and ^{85}Rb as references



σ_m=2.4 keV, σ_m/m=6.7 10^{-8}



PhD: P. Chauveau , B-M. Retailleau

Collaboration :
GANIL, U. Greifswald & LPC Caen

- Tests with ^{23}Na, ^{39,41}K, ^{85,87}Rb, ^{133}Cs
- Mass resolution R=Δt/(2t) ~ 130 000
- Time of Flight fluctuations corrected by mass of reference => δm/m~10^{-7}
- Mass precision ~ 12keV

- Tests with ^{162,164,166,167,168,170}Er
- Mass resolution R=Δt/(2t) ~ 75 000
- δm/m~10^{-7}
- Efficient suppression of contaminants

Master: Y. Balasmeh

Conclusion and outlook

Conclusion

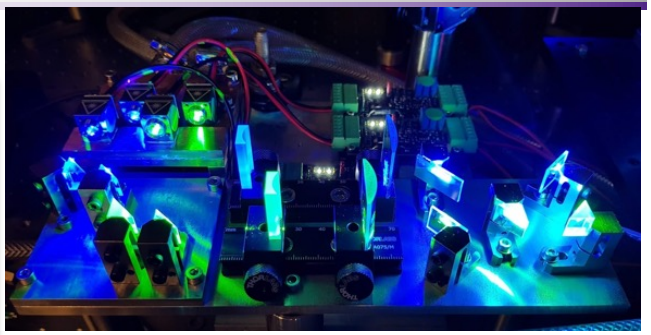
- TiSa laser system ready for High Resolution Laser Spectroscopy
- First in-jet laser spectroscopy of Er @ S^3LEB
- Characterization of the gas cell, gas jet, PILGRIM @ S^3LEB ongoing
- S^3LEB MoU signed (GANIL, IN2P3, DRF, KUL, JGU, JYU)

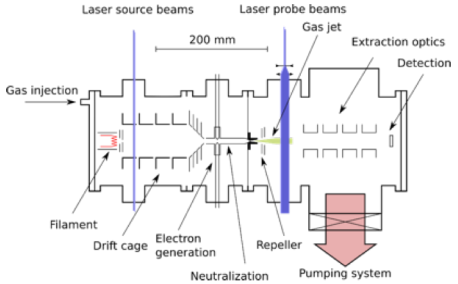
Outlook

- Laser spectroscopy of Pd (PhD A. Ortiz)
- New CW cavity for continuous wavelength scanning (PhD A. Ajayakumar)
- New Frequency mixing cavity development for extended wavelength range
- Fast gas cell development: ANR FRIENDS3 (IJCLab) (PhD W. Dong)
- Test of Day 1 experiment elements of interest (Sn, In, Ag, Zr, U…)

Installation @ S^3 timeline

- S^3 Laser room end of 2022
- Installation of S^3LEB @ S^3 end 2023





Thanks to S^3 LEB TEAM

GANIL:

Anjali Ajayakumar; **Alexandre Brizard**; Lucia Caceres; Pierre Delahaye; Sarina Geldhof; Nathalie Lecesne; Renan Leroy; Franck Lutton; **Alejandro Ortiz-Cortes**; Benoit Osmond; Julien Piot; **Blaise-Maël Retailleau**; Hervé Savajols

LPC:

Frédéric Boumard; Jean-François Cam; Philippe Desrues; Xavier Fléchard; Julien Lory ; Yvan Merrer ; Christophe Vandamme

IJC Lab:

Wenling Dong; Patricia Duchesne; Serge Franchoo; Vladimir Manea; Olivier Pochon

KU Leuven:

Arno Claessens; Rafael Ferrer; Ruben de Groote; **Sandro Kraemer** ; **Jekabs Romans**; Simon Sels; Paul Van Denbergh; Piet Van Duppen;

JGU:

Sebastian Raeder; **Matou Stemmler**; Klaus Wendt

JYU:

Iain David Moore; Michael Reponen; Juha Uusitalo

IRFU:

Martial Authier; Olivier Cloue; Antoine Drouard; **Emmanuel Rey-Herme**; Marine Vandebrouck

PhD students