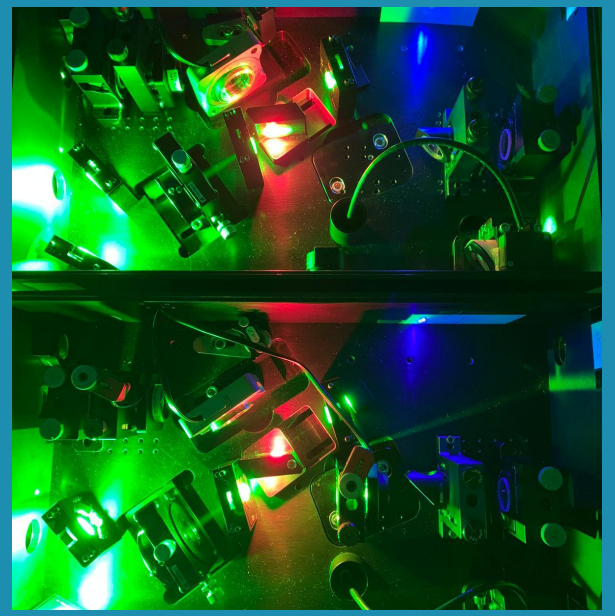
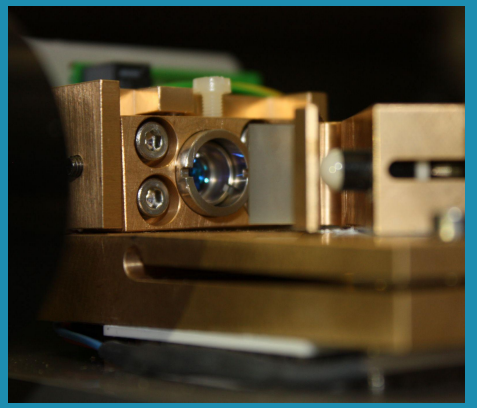
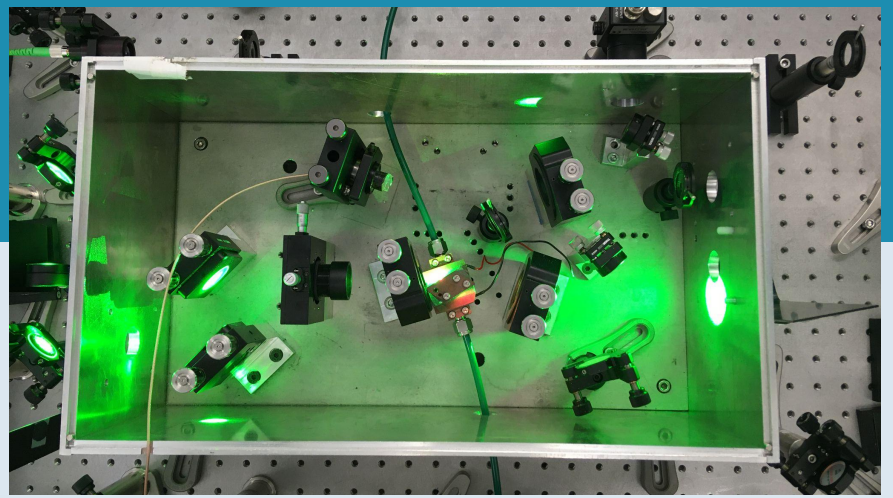
Development of Ti:Sa based laser ion sources for the S^3-Low Energy Branch (S^3-LEB) at SPIRAL2-GANIL







Jekabs Romans

27.09.2021

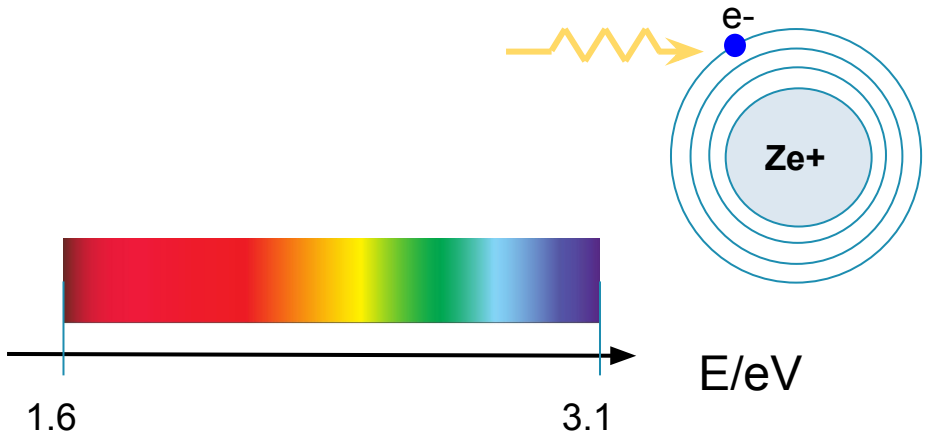
Faculty of Science, IKS, Nuclear and Radiation Physics

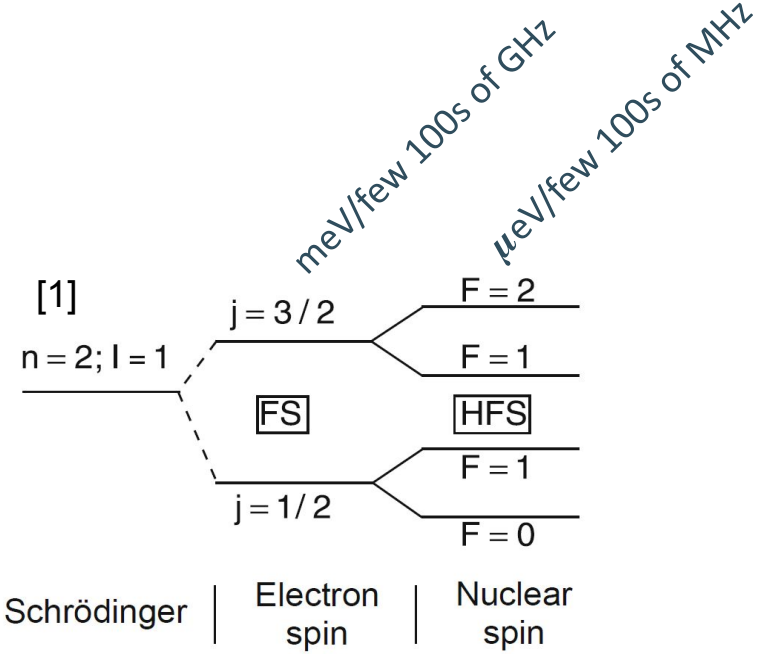
Outline

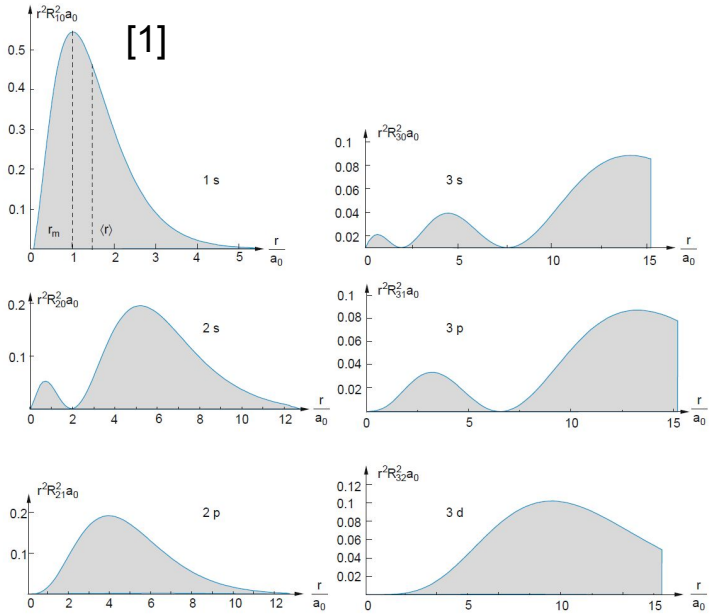
- Motivation
- GISELE laser laboratory progress/development
  - Er I RIS (commissioning experiment and first scientific result)
    - Broadband - mid-range bandwidth RIS ($\Delta\lambda$>=5 GHz & 1.5 GHz)
    - Narrow bandwidth RIS (30<$\Delta\lambda$<100 MHz)
- Outlook
  - First laser spectroscopy at LPC using S^3-LEB

Motivation

- Nuclear-model independent property information
  - Probing of an atom (valence electron/-s)
    - Fine structure (*j = l x s* coupling)
      - $\delta\langle r^2\rangle$ -> size
    - Hyperfine structure (*f = j x I* coupling)
      - *μ, Q* -> state admixture & shape info
      - *s*, $p_{1/2}$ states
    - Ionization potential ~ 7 eV
      - 2-3 lasers needed for RIS to ionize the atom



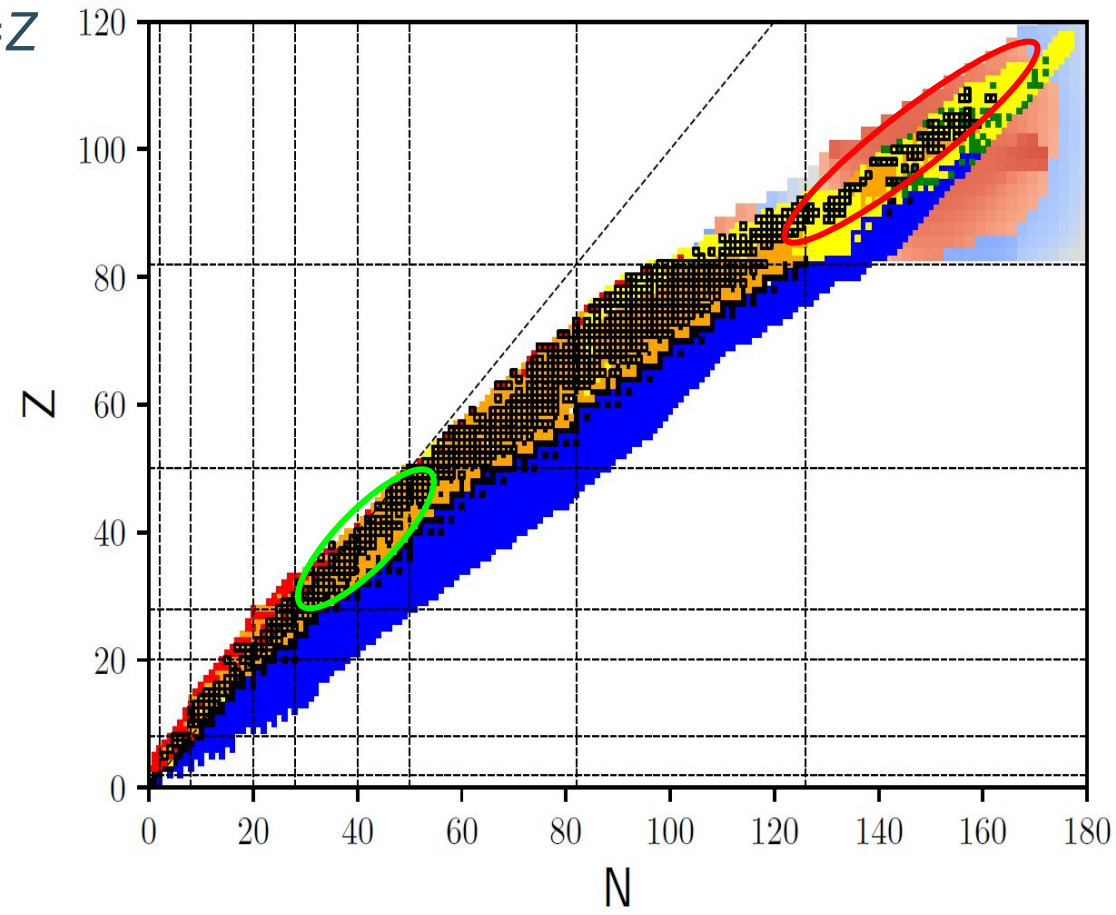




[1] W. Demtröder. Atoms, Molecules and Photons. An Introduction to Atomic-, Molecular- and Quantum Physics. Second Edition. Germany: Springer, 2010.

Motivation

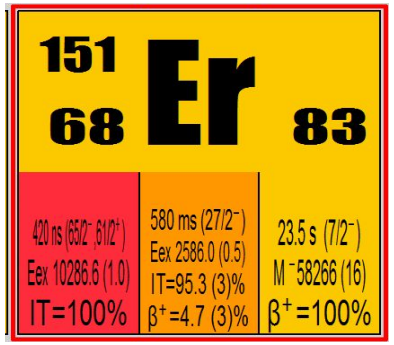
- S^3 day 1 experiments [2]
  - Region of ^{100}Sn: double shell closure and N=Z
  - Very & super-heavy nuclei



[2] GANIL. URL: https://www.ganil-spiral2.eu/scientists/ganil-spiral-2-facilities/experimental-areas/s3/

Motivation

- Commissioning with Er and first physics case ^{151g,m}Er
  - long isotope half-lifetimes w.r.t. setup extraction time
  - high nuclear spin states



A	Expected entering rate/pps
TOTAL	2,11E+6
^{152}Er	1,12E+03
^{151}Er	3,99E+04

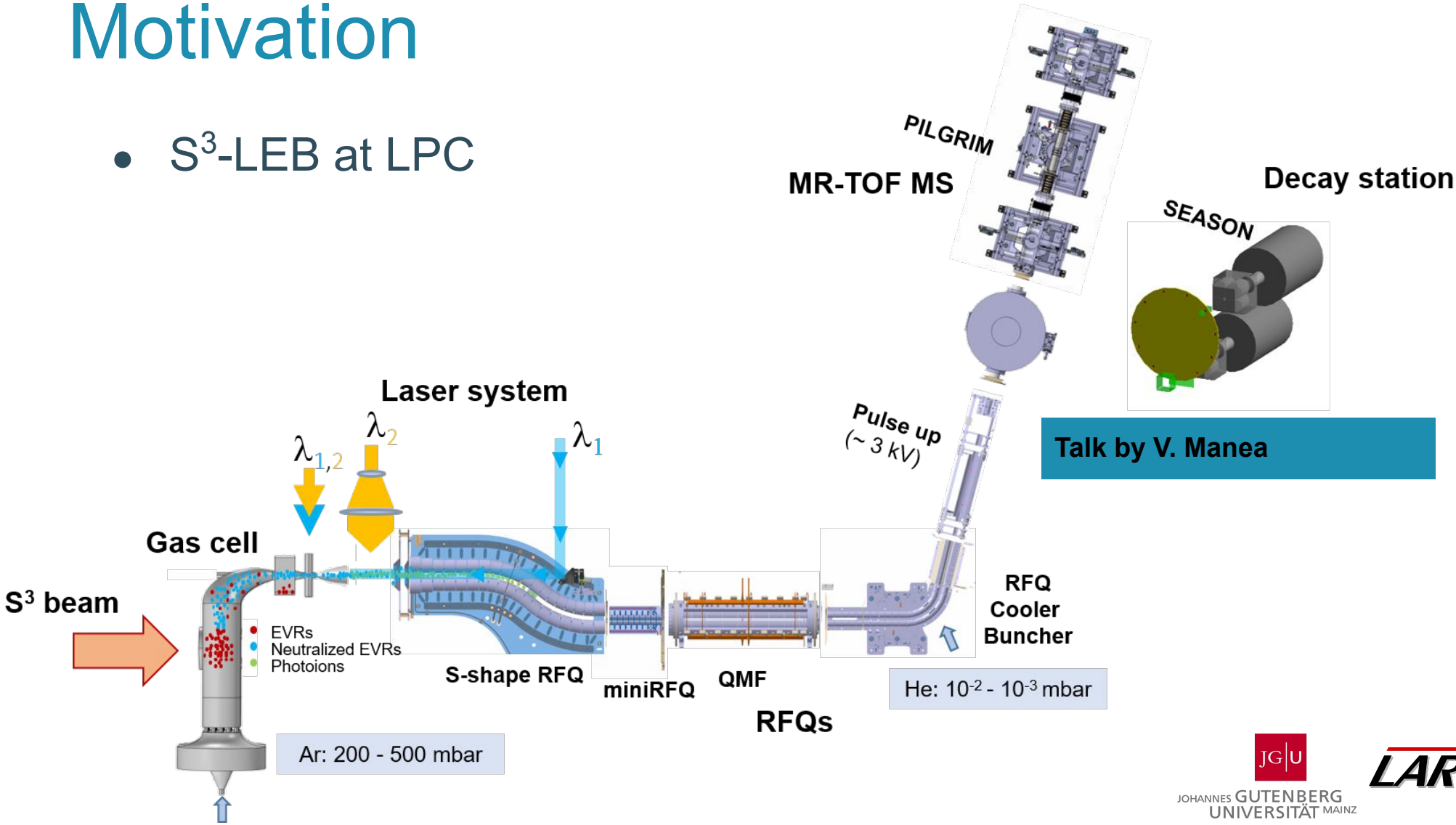
HFS measurements of ^{151}Er during the S^3 commissioning run of ^{152}Er [3]

[3] H. Savajols. Expected Day-one experiment productions (2019)

Motivation

- S^3-LEB at LPC

[4,5]



KU LEUVEN (Gas cell, laser system)

GANIL spiral2 laboratoire commun CEA/DRF CNRS/IN2P3 (MR-TOF-MS, infrastructure, safety, RFQs and detectors)

lpc caen laboratoire de physique corpusculaire (RFQs)

IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis (Gas cell)

cea (Decay station)

JG|U JOHANNES GUTENBERG UNIVERSITÄT MAINZ

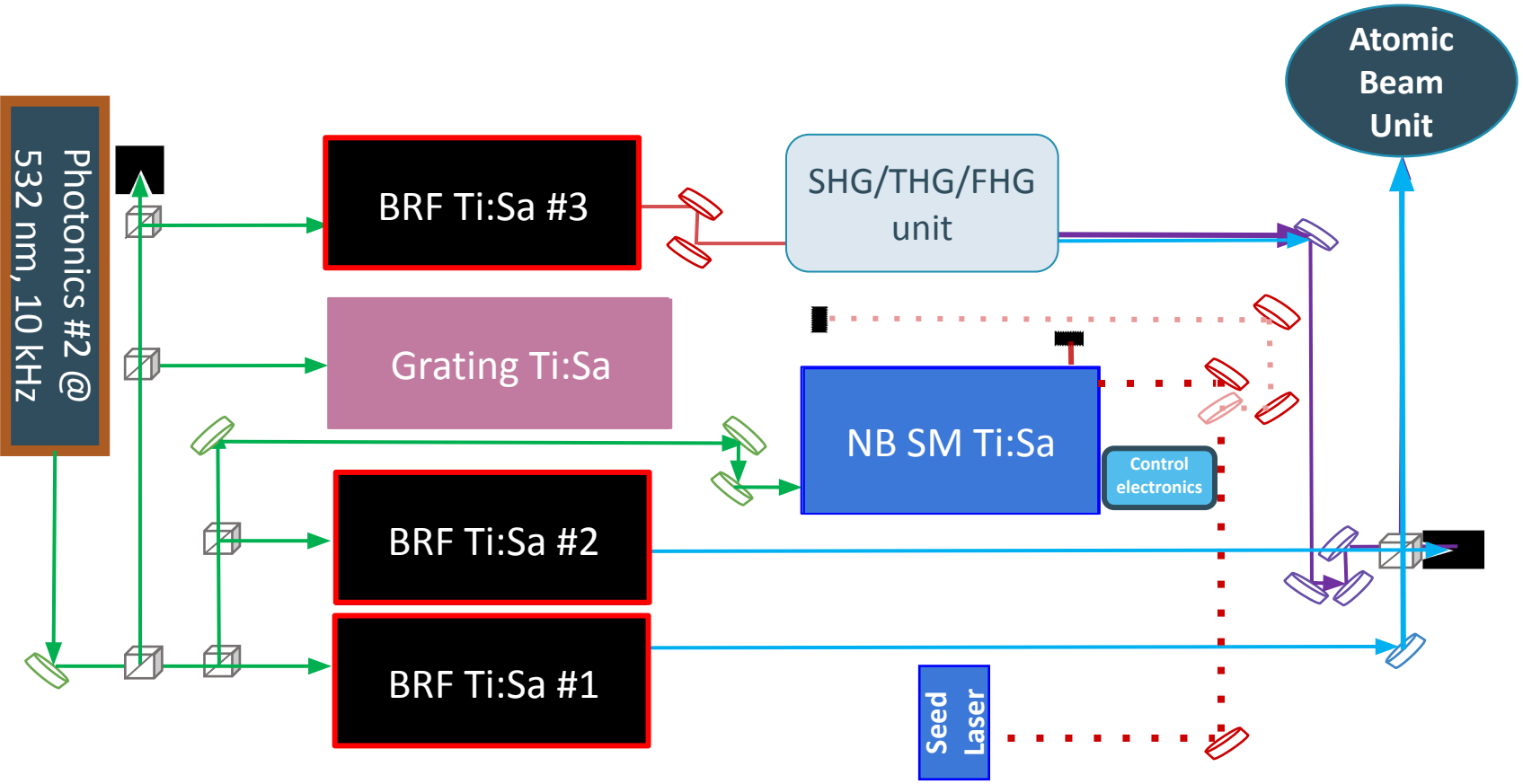
LARISSA

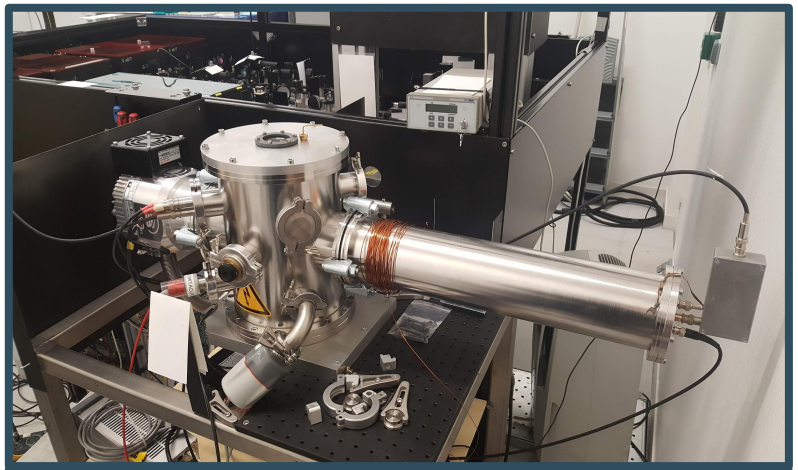
JYVÄSKYLÄN YLIOPISTO UNIVERSITY OF JYVÄSKYLÄ

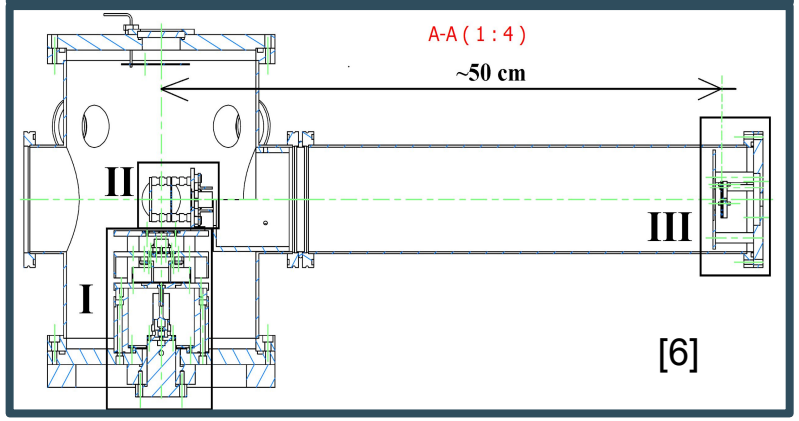
(Narrow band-width laser, pre-studies at MARA)

[4] R. Ferrer et al. Nucl. Instrum. Meth. Phys. Res. B **317** (Dec. 2013), pp. 570-581. doi: 10.1016/J.NIMB.2013.07.028.
[5] N. Lecesne. S^3 Workshop talk (June 2018)

GISELE laser laboratory

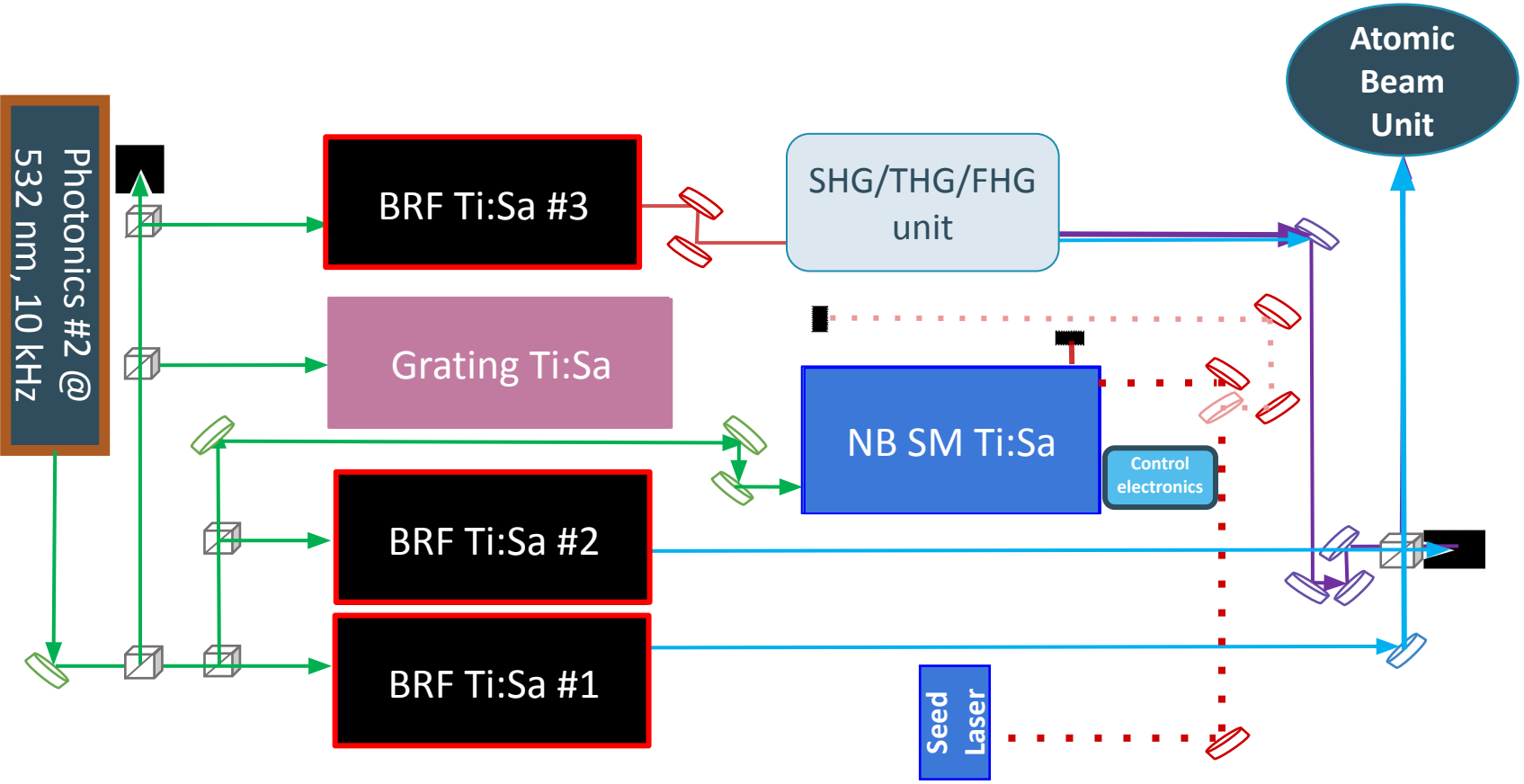


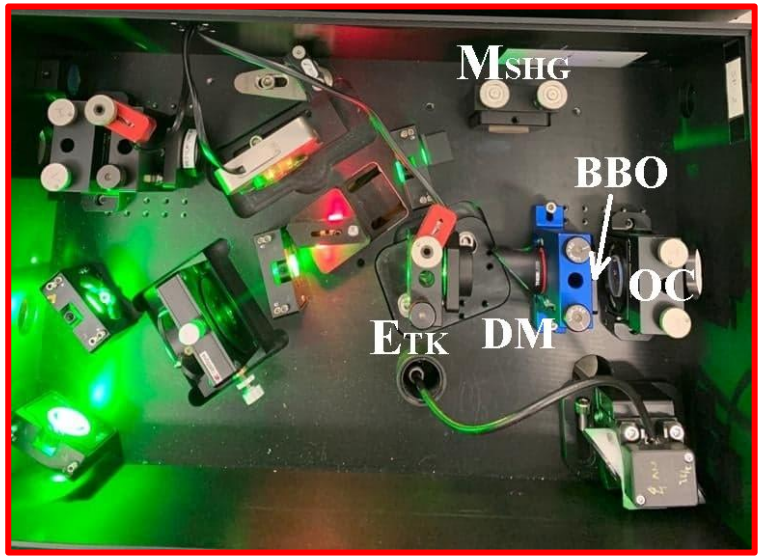


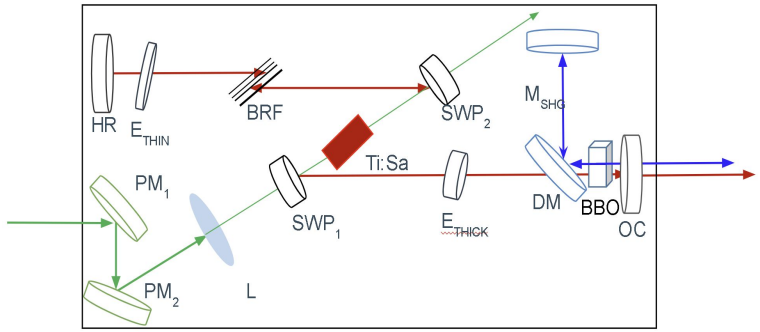


[6] G. Vinck. Masters thesis. KU Leuven (2014)

GISELE laser laboratory

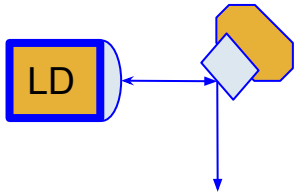


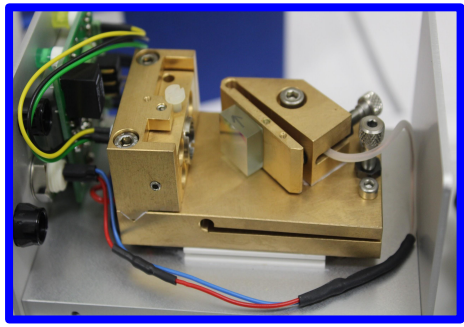


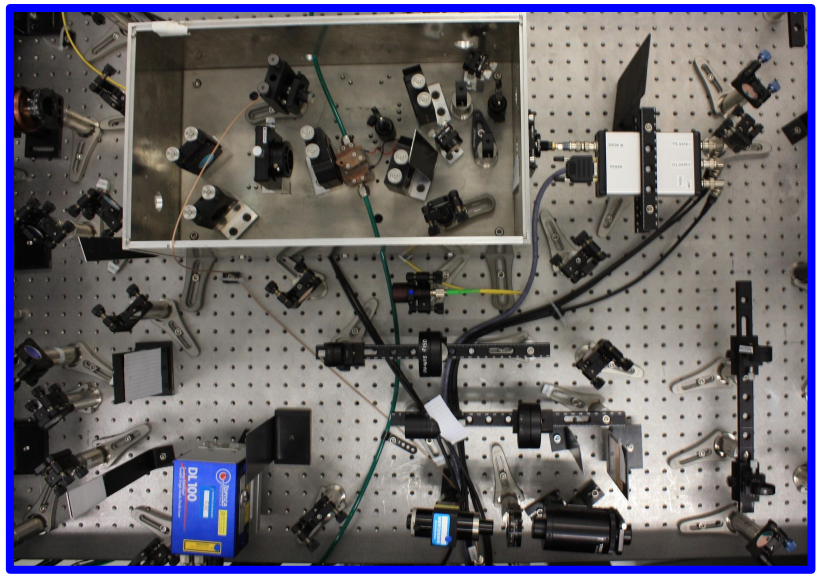


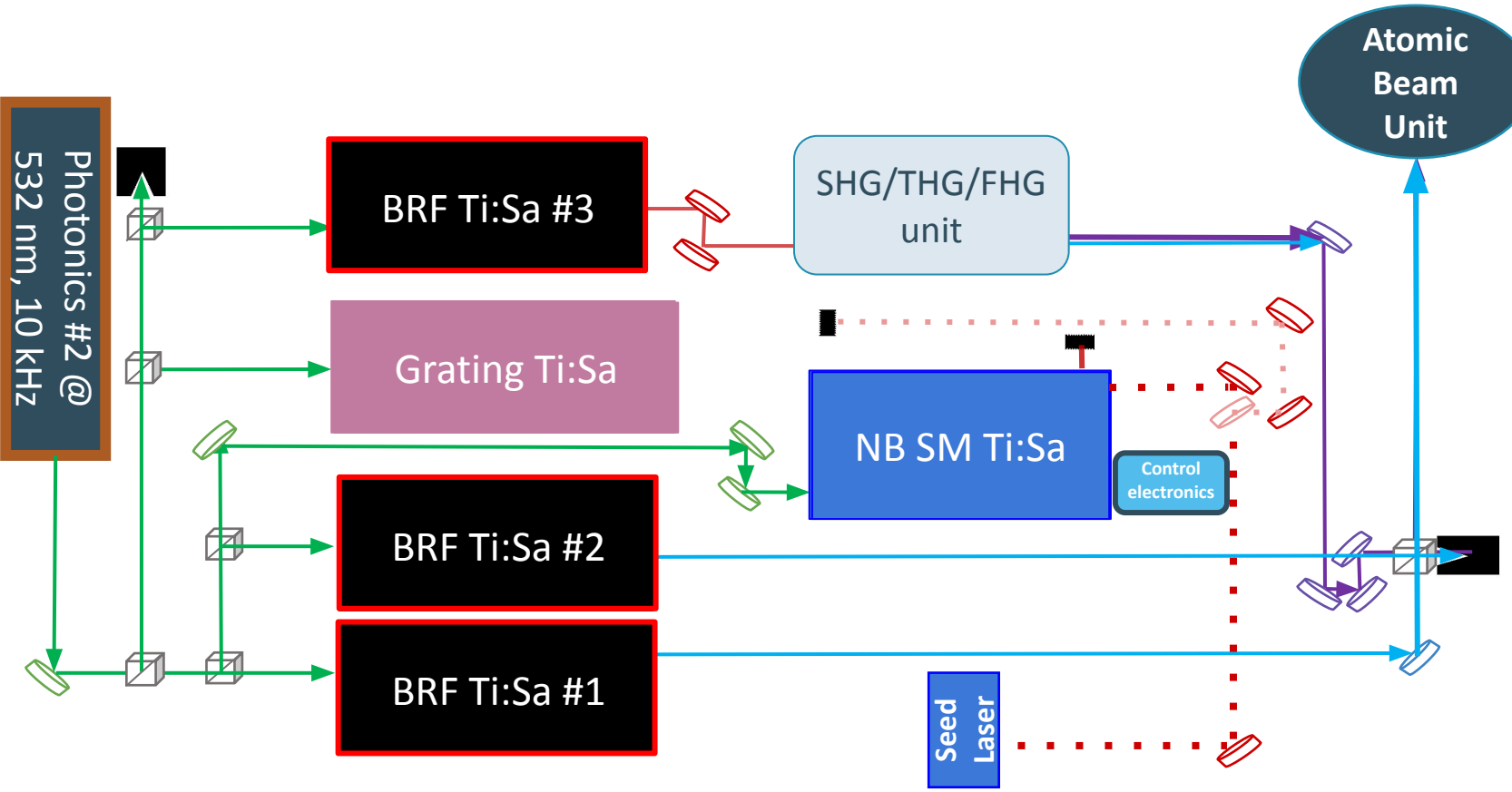
- Z-type Titanium:Sapphire laser
  - Standart resolution $\Delta\lambda$ of 5 GHz. With adaptations, can achieve $\Delta\lambda$ of 1.5 GHz
  - Intra-cavity second harmonic generation

GISELE laser laboratory









- Narrow-bandwidth Ti:Sa system [7]
  - Master-slave system
  - Single mode seed laser ($\Delta\lambda$<100 MHz)
  - Slave cavity has improved stability
  - Active cavity length adjustement

[7] V. Sonnenschein. PhD Thesis. University of Jyväskylä (2014)

GISELE development

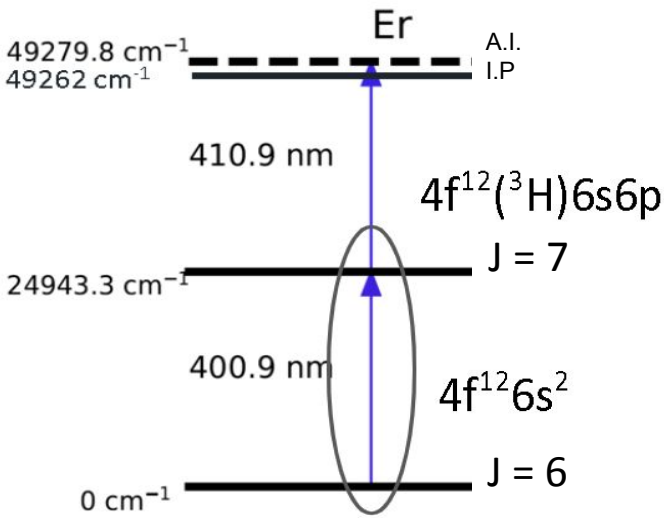
- Resonance Ionization Spectroscopy (RIS)
  - 1 laser per excitation step
  - Ground state transition is scanned
  - Scan procedure
    - Preparation time: ≤1 week if the RIS scheme is known and laser setup does not need mirror change
    - Necessary time depends on count rate and scan step size
    - Best temporal resolution: 4 ns

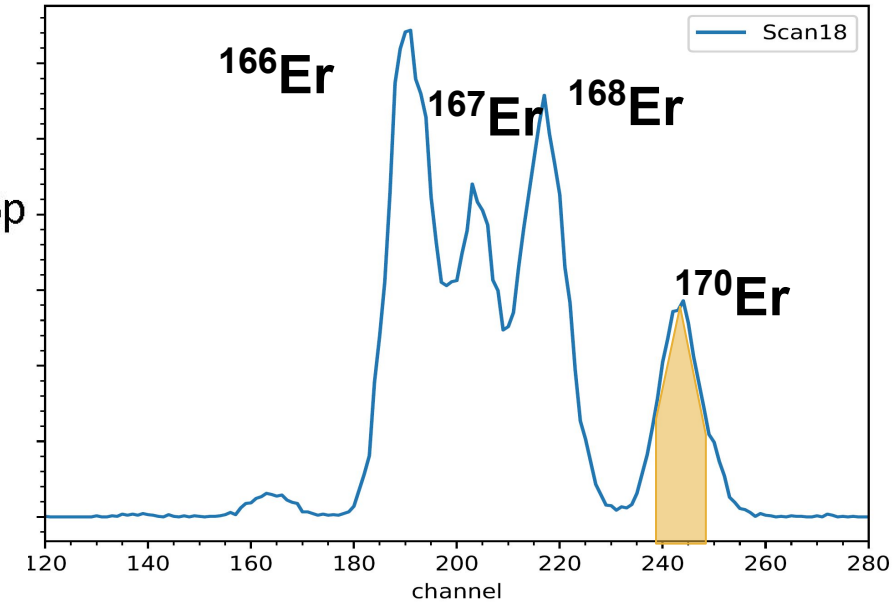
I/cps	Scan step size $\Delta\nu$/cm^{-1}	Scan time Δt/min
100	0.004	60-120
	0.0002	180-240
1000	0.004	5-10
	0.0002	20-40

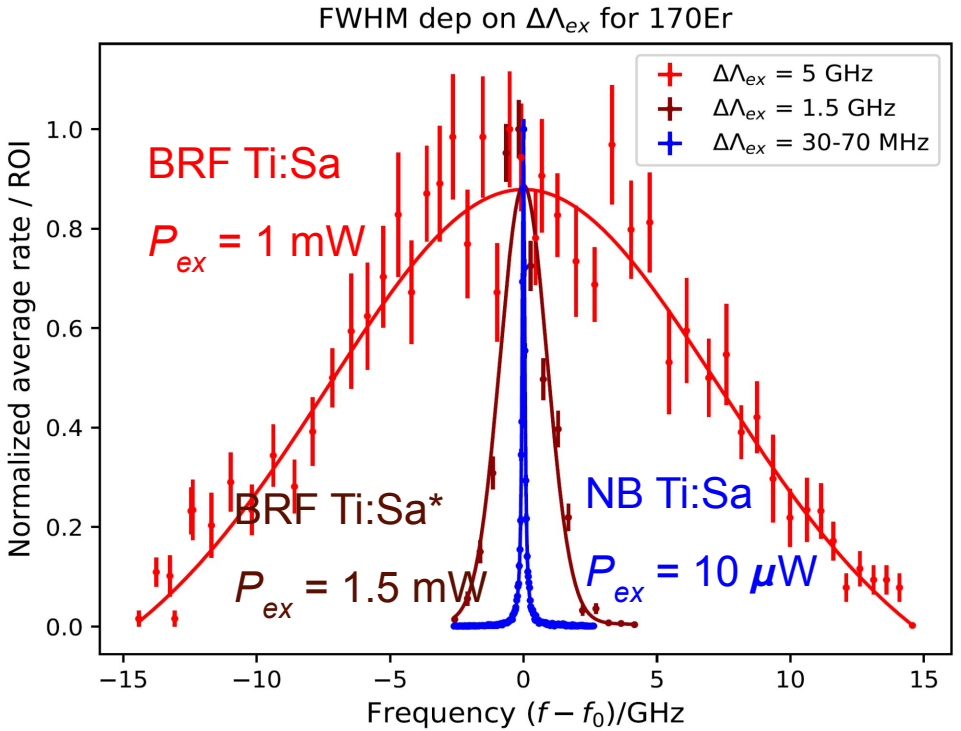
GISELE Results

- Day-one experimental case: Er I RIS (FWHM improvement)
  - Minimization on P_{ex} and $\Delta\lambda$
  - Linewidth and lineshape change
  - Hyperfine structure resolving capabilities

[8]



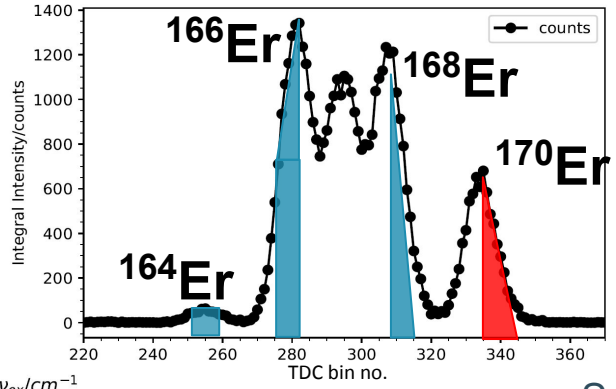




[8] D. Studer. Masters thesis. Johannes Gutenber-Universitaet Mainz (2015)

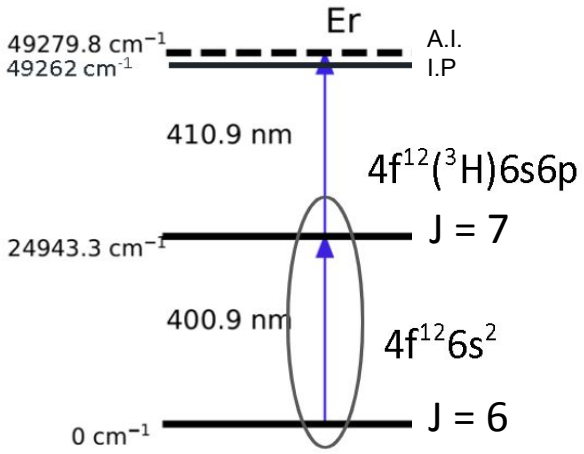
GISELE Results

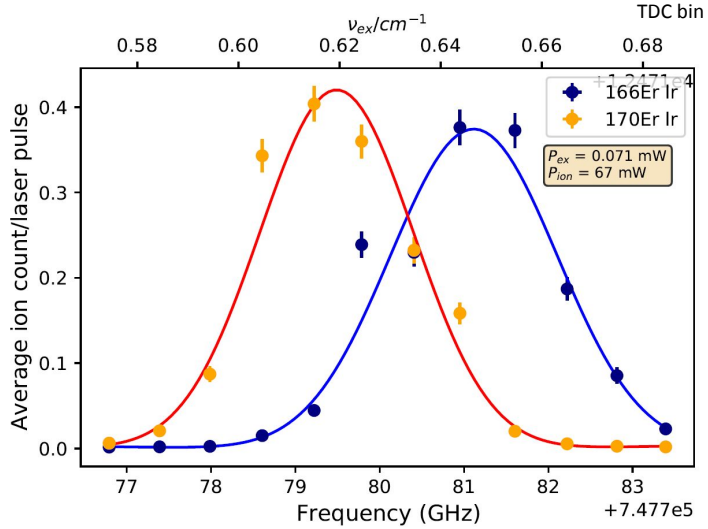
- Day-one experimental case: Er I RIS (even-even IS)



[8]

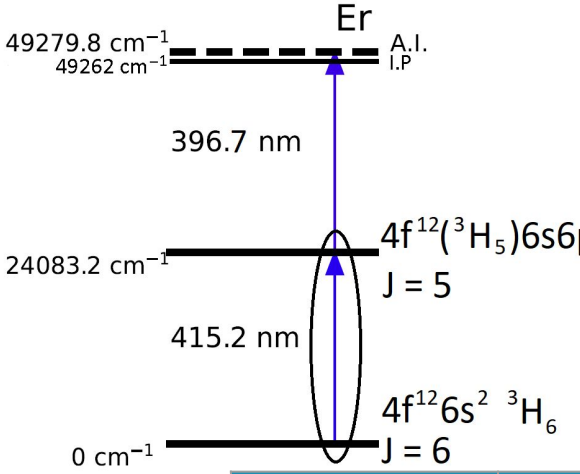
Scheme a

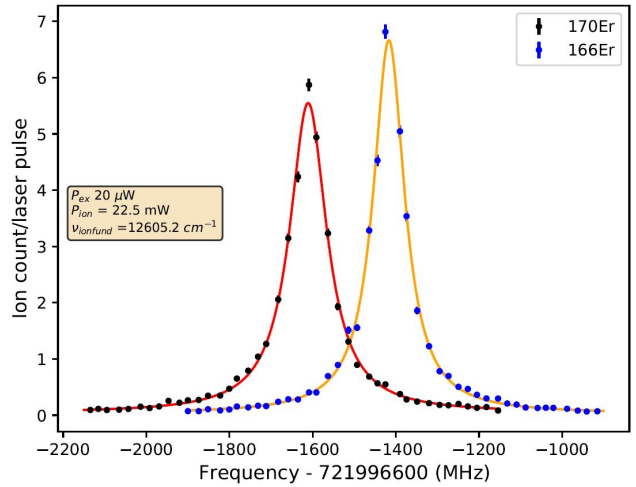




Scheme b

[8]





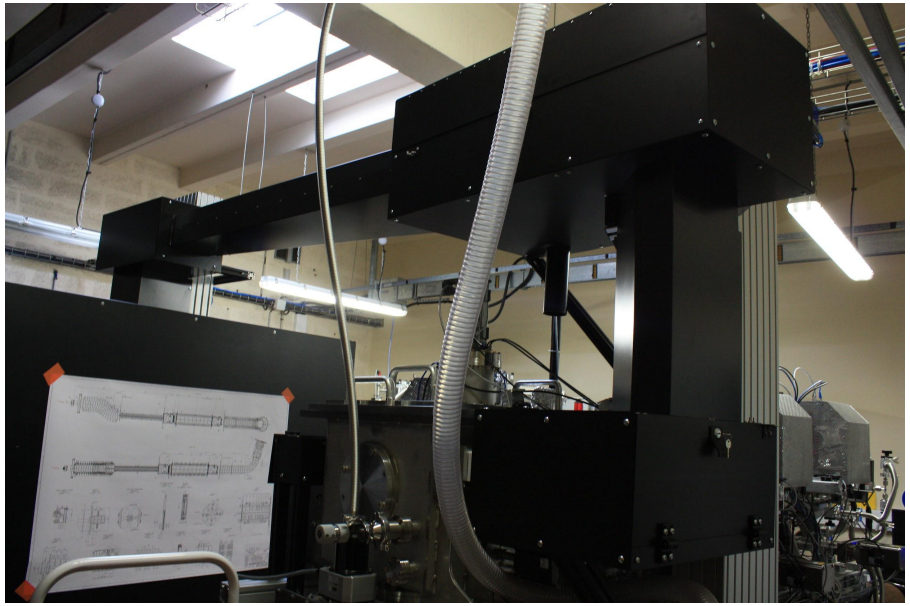
	Our results* (multi-Gaus fit)	Lit. [9]
$\Delta\nu(^{166\text{-}170}\text{Er})$/GHz	1.764+/-0.079 (0.03)	1.681±0.014
$\Delta\nu(^{168\text{-}170}\text{Er})$/GHz	0.865+/-0.031 (0.03)	0.84±0.014

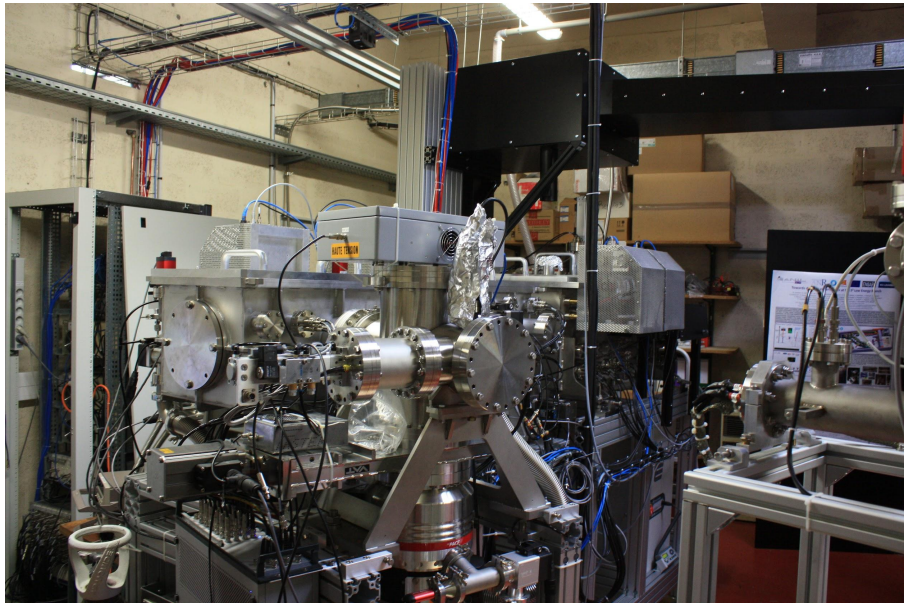
	Our results	Lit. [10]	Lit. [11]
$\Delta\nu(^{164\text{-}170}\text{Er})$/MHz	297.556+/-0.974 (30)	-	-
$\Delta\nu(^{166\text{-}170}\text{Er})$/MHz	194.261+/-1.671 (30)	180	0
$\Delta\nu(^{168\text{-}170}\text{Er})$/MHz	89.388+/-1.208 (30)	-	-

[9] Albert Frisch et al. Phys. Rev. A **88**.3 (Sept. 2013), p. 032508. doi:10.1103/PhysRevA.88.032508
[10] J. Cajko and R. Textoris. Czech. J. Phys. **B17** (1967), p. 917.
[11] B.K. Ankush and M.N. Deo. J. Quant. Spectrosc. Radiat. Transf. **155** (2015), pp. 96–119. doi: https://doi.org/10.1016/j.jqsrt.2015.01.007

Outlook

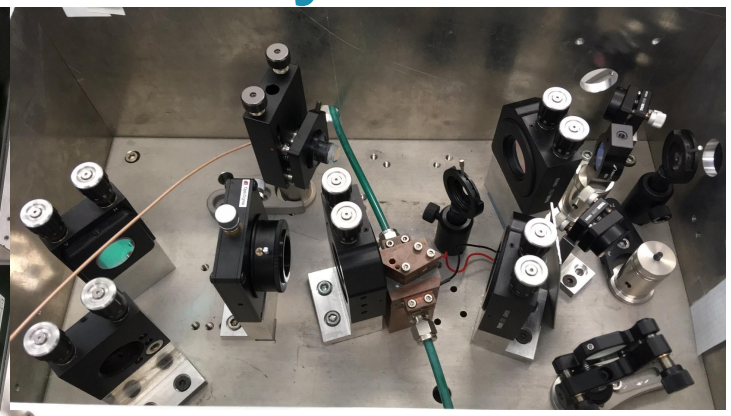
- Move with lasers to S^3-LEB (LPC Caen)
- First ions in gas cell
- 2^{nd} NB Ti:Sa cavity for S^3-LEB
- Continuous wave seed laser for wide scanning ranges (A. Ajayakumar, based on V. Sonnenschein's design [12])
- Day1 isotopes: laser scheme developments and optimisations (Sn, Pd, ...)





[12] V. Sonnenschein et al. Nucl. Instrum. Meth. Phys. Res. B. **463** (2020), pp. 512-514. doi: 10.1016/j.nimb.2019.03.017

Thank you for you attention!



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JGU:

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JYU:

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IRFU:

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Emmanuel Rey-Herme; Marine Vandebrouck

and the RESIST network in ENSAR2