Developments for the S3 Low Energy Branch at the GISELE laser laboratory

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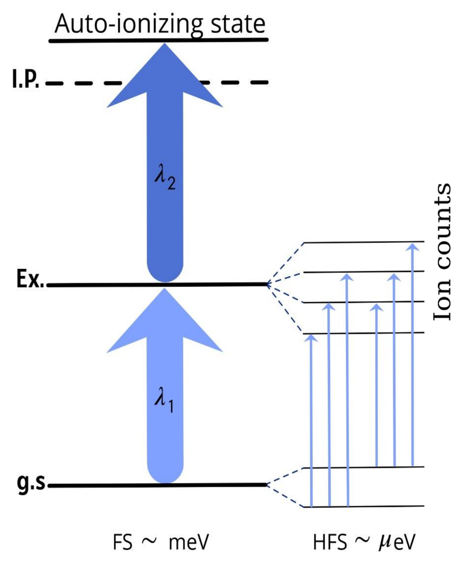
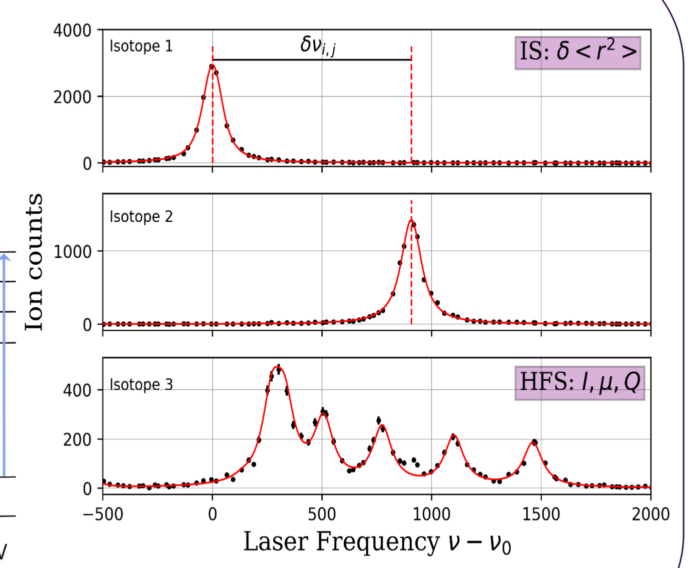
The Low-Energy-Branch (LEB) joined to The Super Spectrometer Separator (S3) facility at GANIL-SPIRAL2 will enable high-resolution in-gas-jet laser spectroscopy of radioactive nuclei produced with extremely low cross sections [2-3]. The online commissioning plan for S3 (and thus S3-LEB) has been established, and the first fusion-evaporation reaction used will give the opportunity to obtain nuclear and atomic information of neutron-deficient isotopes around erbium, towards the $N = 82$ shell closure.

Resonance Ionization Spectroscopy (RIS)

To perform high resolution spectroscopy the laser setup must fulfiled the following requirements

- ✓ Pulse energy and repetition rate ~ 10 kHz
- ✓ Tunable
- ✓ Geometrical and temporal overlap
- ✓ Suitable linewidth
  - Broadband $\delta\nu$ ~ few GHz
  - Narrowband $\delta\nu$ ~ tens MHz



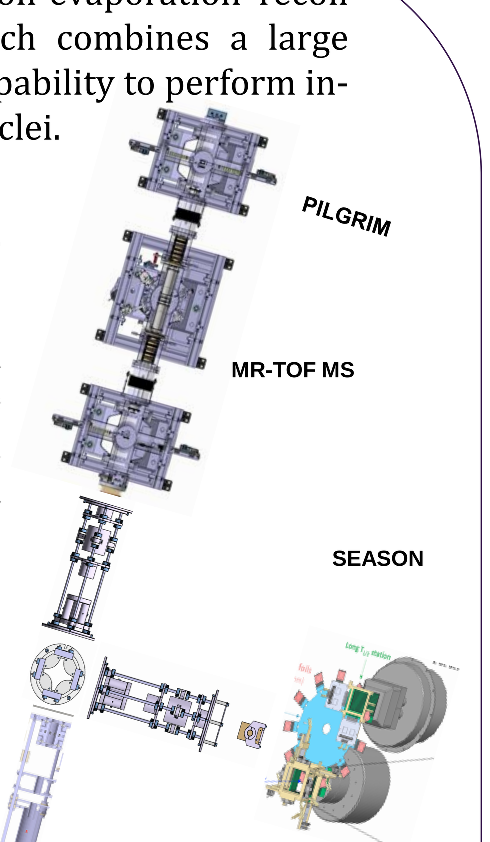


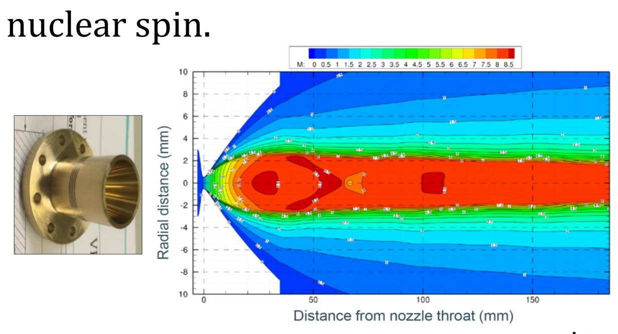
S³-LEB

The Super Separator Spectrometer (S3) is a fusion-evaporation recoil separator at the SPIRAL2 facility of GANIL, which combines a large transmission with a very high selectivity and the capability to perform in-flight mass-number determination of short-lived nuclei.

The Low-Energy-Branch (LEB) joined to The Super Spectrometer Separator (*S*3) will enable a variety of low-energy measurement techniques: Laser spectroscopy, decay spectroscopy and mass spectrometry.

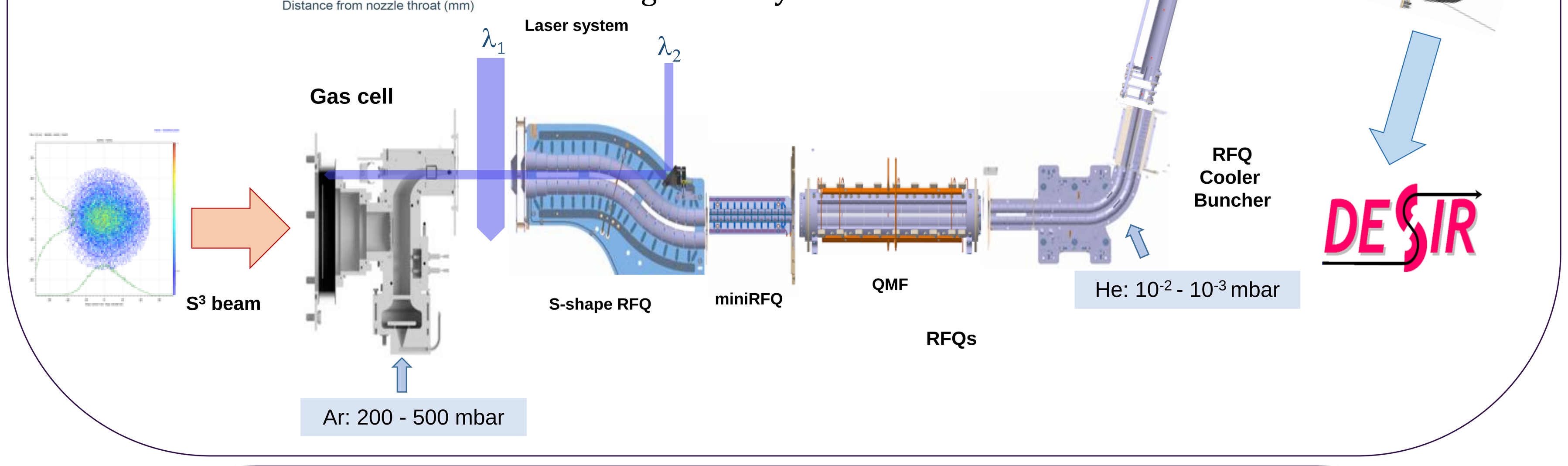
The main highlight of S³-LEB is the high sensitivity and high resolution spectral measurements of atomic transitions in gas-jet environment aimed to provide fundamental and nuclear model-independent data on the structure of ground and isomeric nuclear states, as charge radii, electromagnetic moments and nuclear spin.





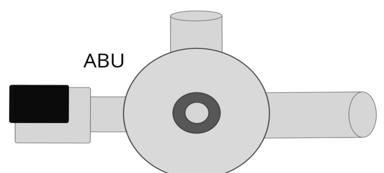
Gas-Jet environment

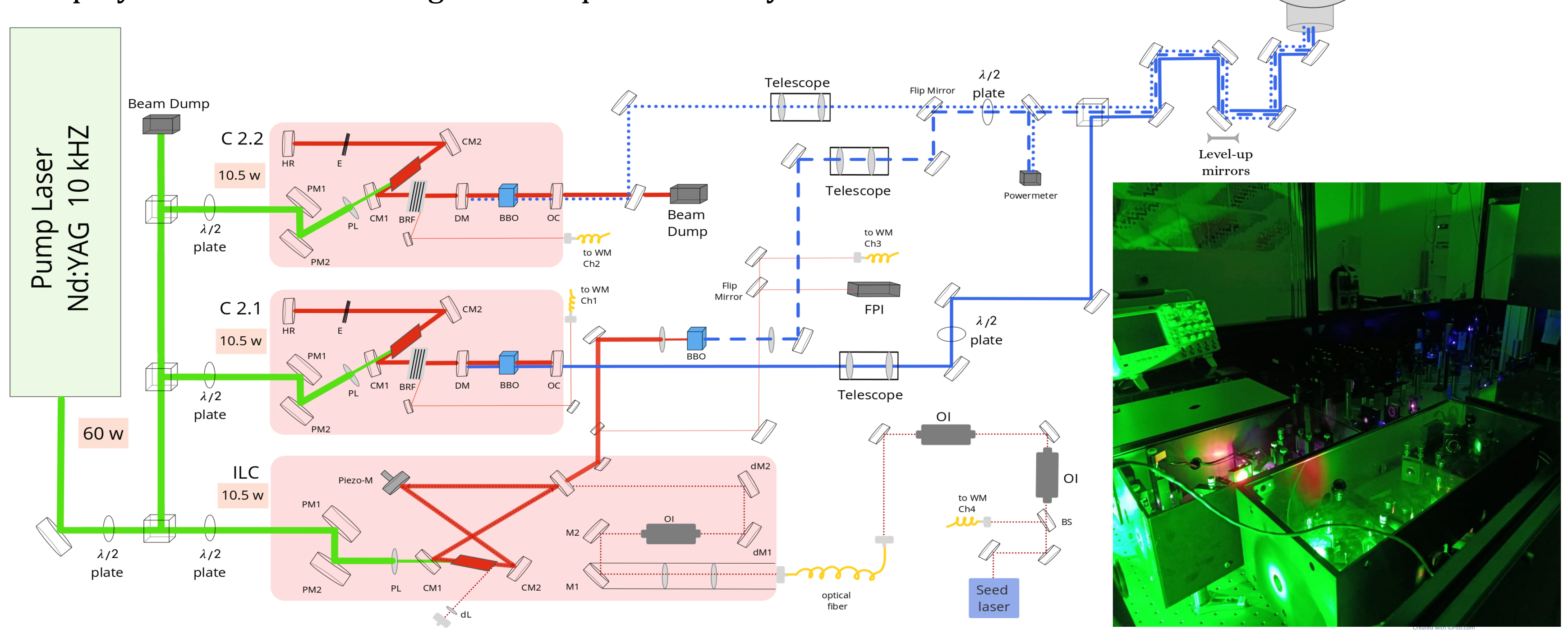
- ➢ Low temperature.
- ➢ Low density.
- ➢ Homogeneous flow and low divergence.
- ➢ High velocity.



GISELE

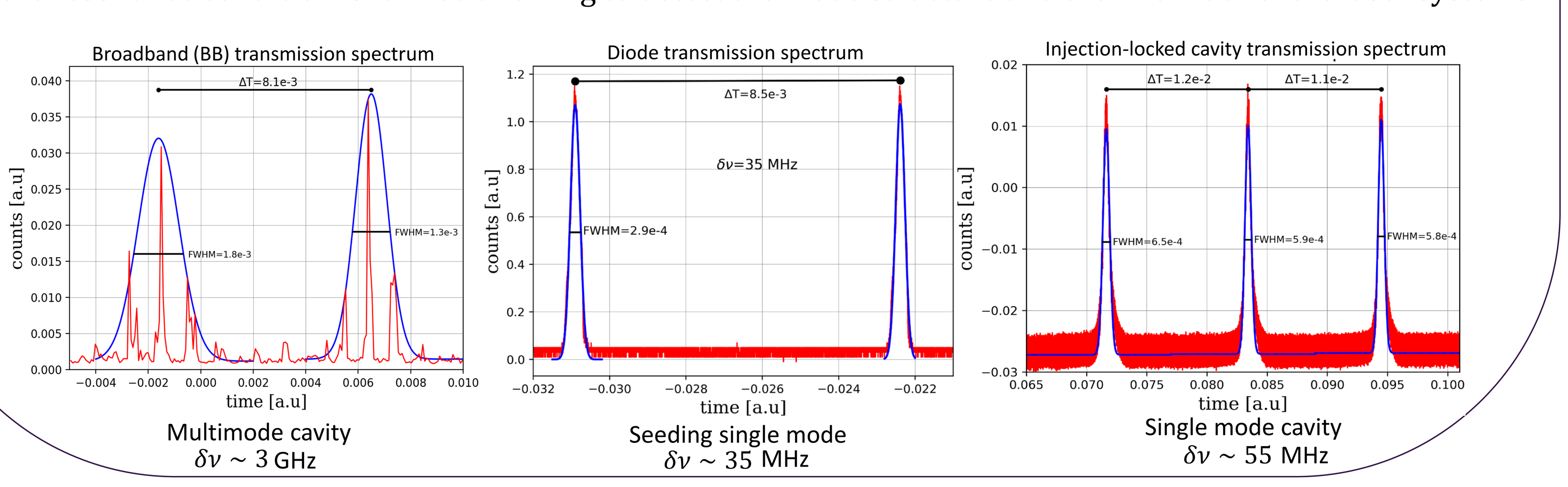
Composed by two broadband (BB) cavities and one narrowband (NB) cavity also referred as Injection-Locked cavity (IL), all of them pumped by a Nd:YAG solid state laser working at its second harmonic of 532 nm and with a repetition rate of 10 kHz GISELE laboratory is meant to be an offline setup intended to test and develop candidate RIS schemes planned for S3LEB's experiments and also employed for commissioning of the required laser systems.





Laser cavity characterization

Composed by two mirrors, one of them movable, a Fabry-Perot interferometer (FPI) is a device that transmits light only when the resonance condition is fulfiled allowing to detect the mode structure and the linewidth of the laser systems.



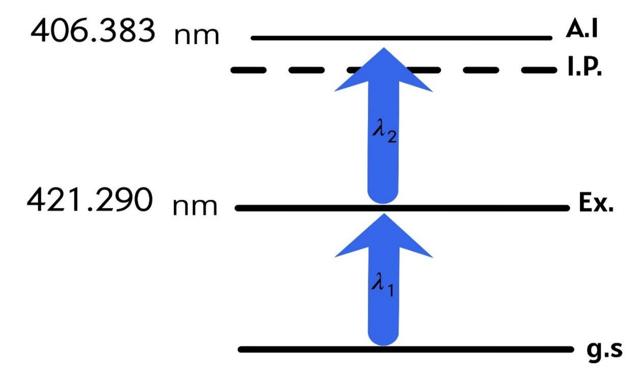
Multimode cavity $\delta\nu$ ~ 3 GHz

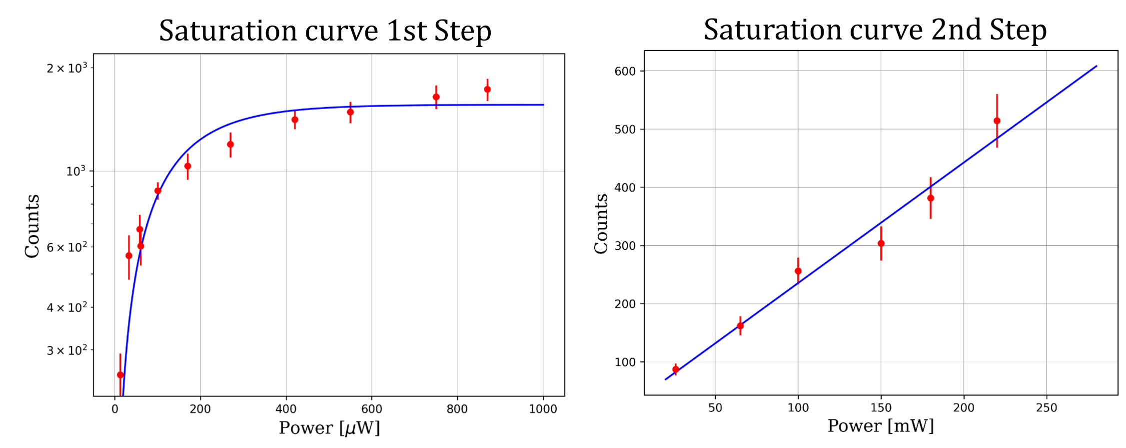
Seeding single mode $\delta\nu$ ~ 35 MHz

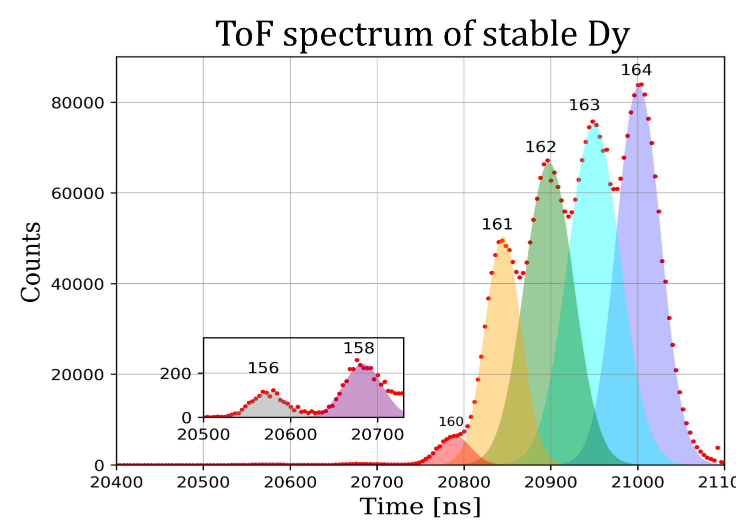
Single mode cavity $\delta\nu$ ~ 55 MHz

Dy

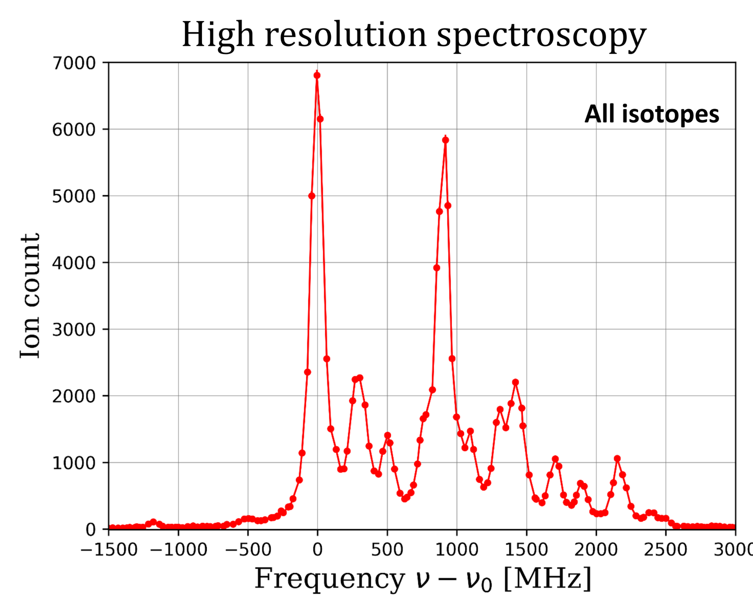
As part of the preparation for the first online experiments, offline tests of the full Ti:sapphire laser system and required laser spectroscopic schemes are carried out at the GISELE laser laboratory on elements of interest such as dysprosium and erbium [4].

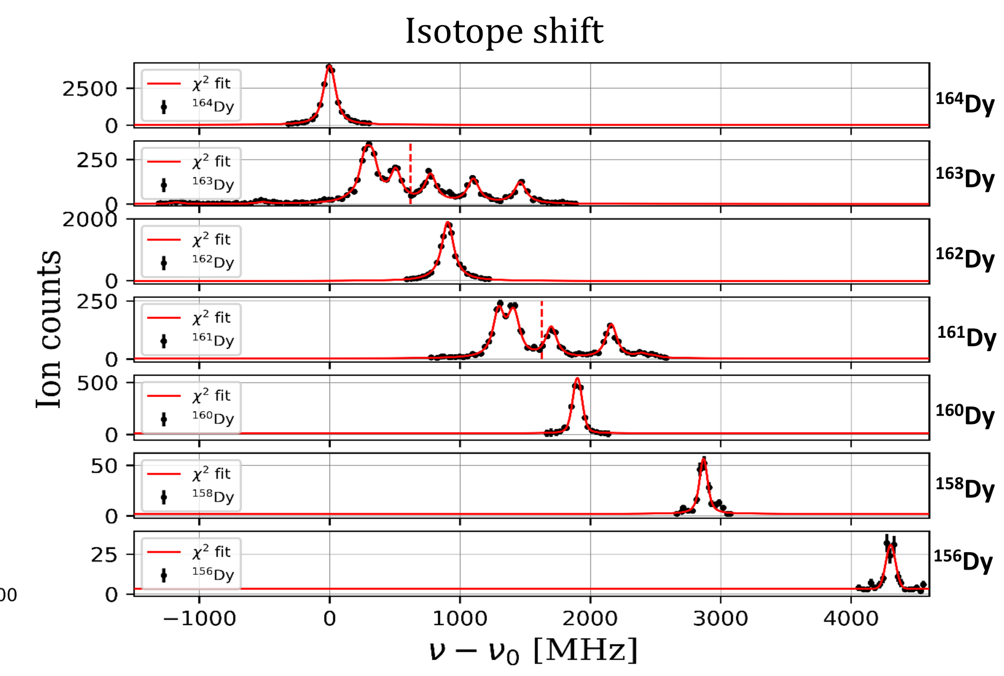






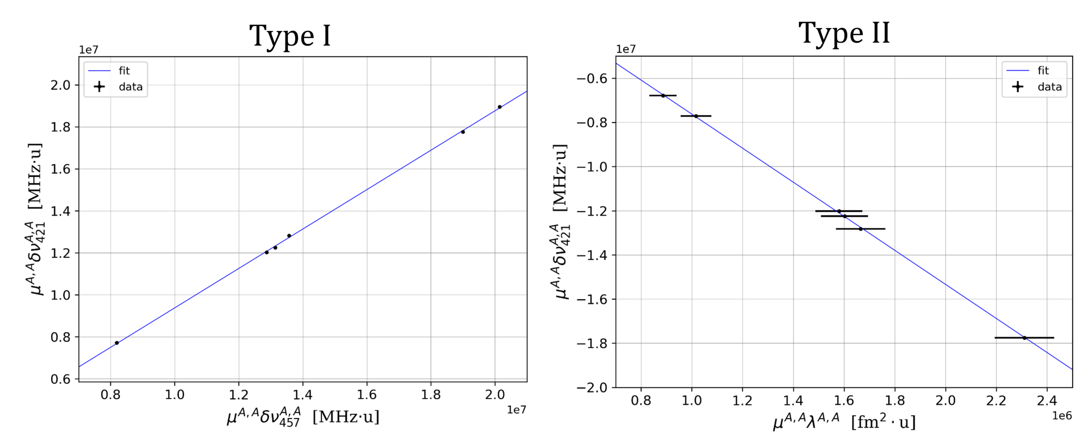
- Using the two broadband cavities as first and second step, all the stable isotopes in the sample are ionized at the same time intended to **optimize** the electrodes that will provide the best time of flight resolution of the device.
- The ToF spectrum serves to **discriminate** from the complete spectrum the counts belonging to each isotope. Afterward, Isotope shift (IS) and hyperfine parameters might be extracted fitting each spectrum using SATLAS library [5].



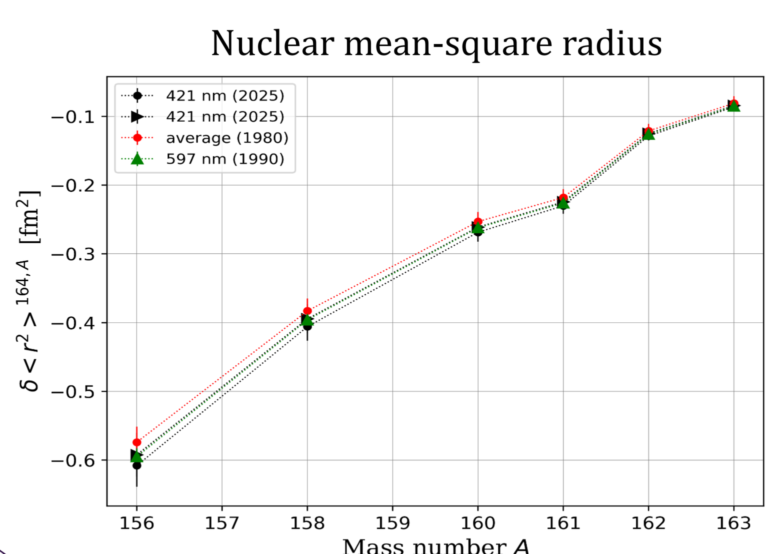


The **King plot** is a combined anaysis strategy that pursuits the use of optical, muonic atom and electron scattering data to determine the RMS-radii the atomic factors as precisely as possible with no atomic theory input needed, leading to nuclear model-independent measures.

IS of a line i is plotted versus IS of another line j allowing the estimation of the atomic factors of the transition i from the knowledge of these factors for the transition j.



IS of a selected line is plotted versus λ values for the same isotope pairs. The λ values are evaluated in a combined analysis of muonic atom and elastic electron scattering data.



$$\delta\nu^{A,A'} = F(Z)\lambda^{A,A'} + \frac{m^A - m^{A'}}{m^A m^{A'}} M$$

- From the combined analysis the field and mass factor are deduced, allowing the calculation of the mean-square radius along the isotopic chain for stable dysprosium. The same procedure will be followed for the neutron-deficient isotopes in S³-LEB facility.

Conclusions

- ➢ After a complete restructuring of the GISELE laboratory, the current experiments on stable dysprosium represent a benchmark of the laser systems which are going to be implemented in the new laser laboratory for the online campaigns at S3-LEB.
- ➢ Future experiments on stable Gd are going to be conducted as part of the program and the GISELE laser system will serve for offline test benches as FRIENDS3 [6] and LRC [7].

References

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