First in-gas jet laser spectroscopy with S³-LEB

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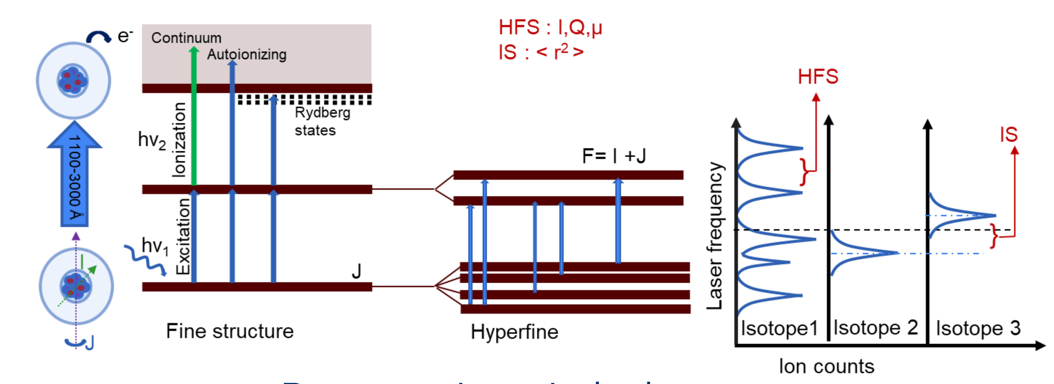
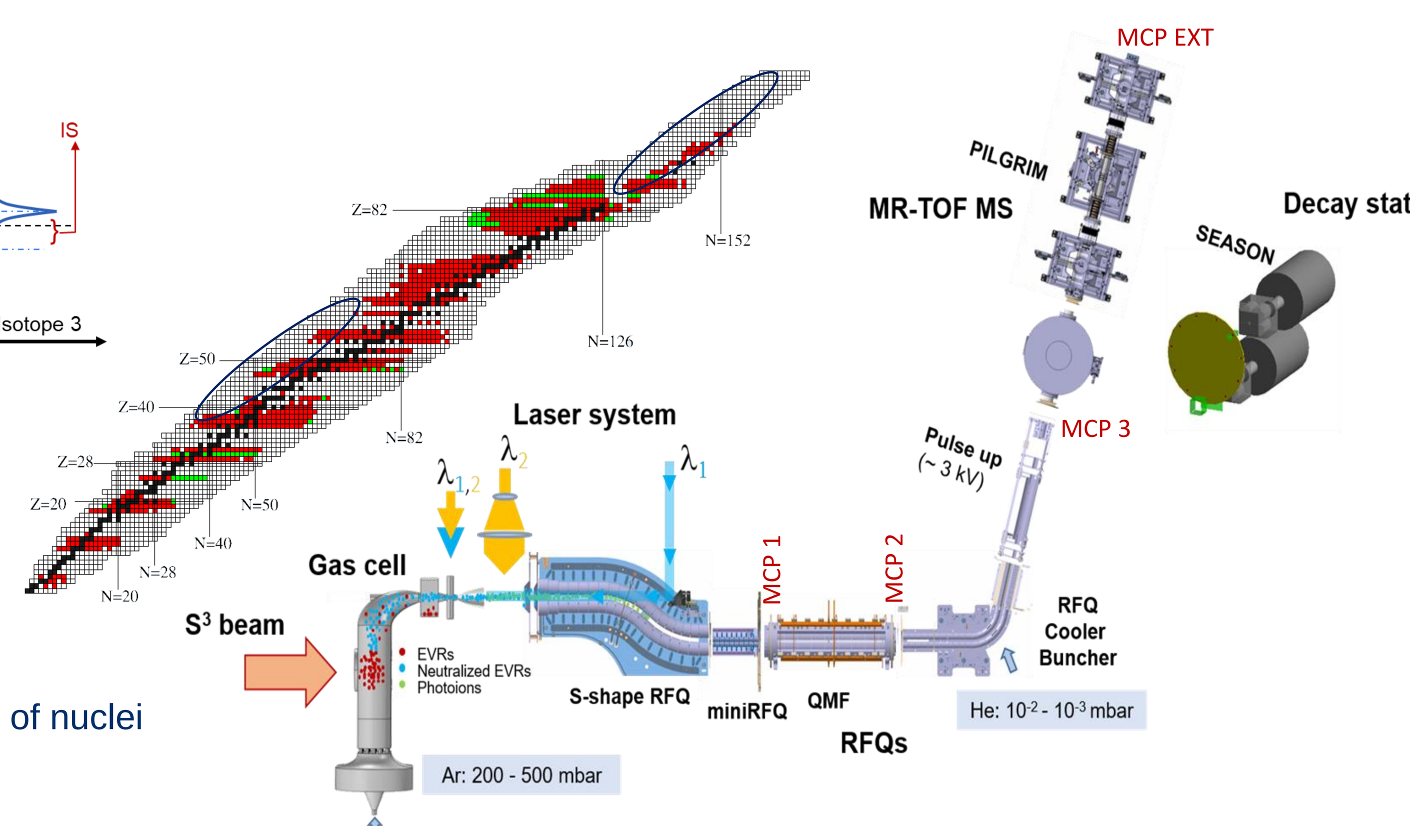
Introduction

The Super Separator Spectrometer-Low Energy Branch (S³-LEB) is a low energy radioactive ion beam installation dedicated to the study of exotic nuclei, which is currently under commissioning as a part of the GANIL-SPIRAL2 facility[1][2] . High intensity primary beams (He to U), delivered by the superconducting LINAC of SPIRAL2, will allow increased production rates of nuclei by fusion evaporation reactions and thus will facilitate the exploration of the neutron-deficient and heavy-mass extremes of the nuclear chart.



Resonance Laser Ionization



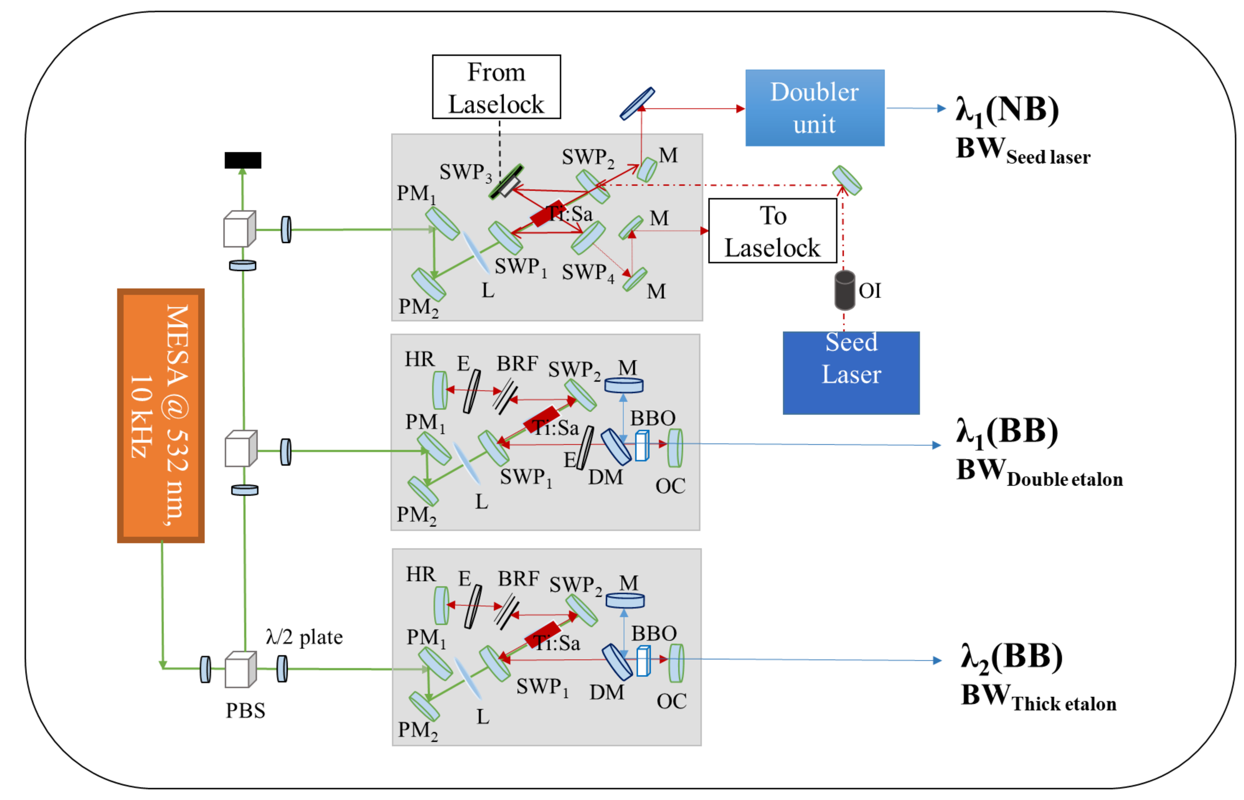
S³-LEB will allow to perform
- High resolution laser spectroscopy
- Mass spectrometry (PILGRIM)
- Decay spectroscopy (SEASON)

Resonance laser ionization allows
- Measurement of ground state/isomeric state properties of nuclei and give insight on the nuclear structure
- Produce high purity radioactive ion beams

Laser ion source

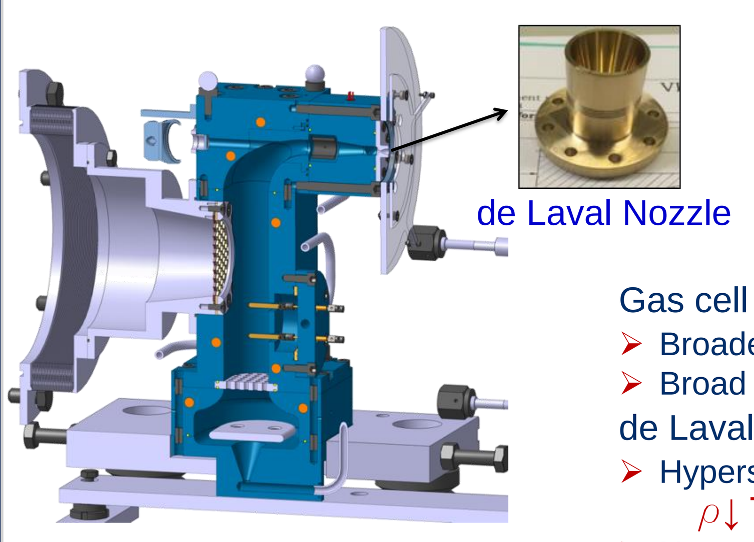
Requirements :
- Pulsed high repetition laser sources
- Laser line width to match the atomic transition line width
- Ti:sa/ dye laser used complementarily

Ti:sa lasers were commissioned and set up for in-gas laser spectroscopy.



In-gas cell/gas jet laser spectroscopy

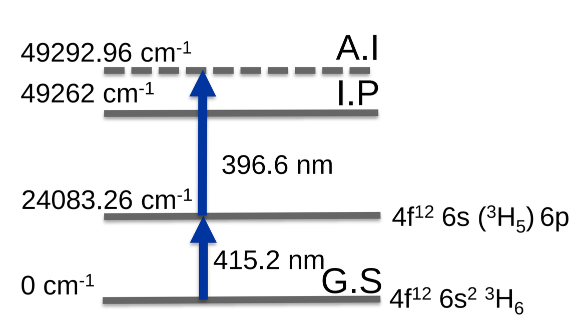
Offline commissioning of S³-LEB[3] is in progress with recently coupling the gas cell set up to the ion guides. Erbium is the chosen commissioning element and hence the laser spectroscopy tests have been performed with stable isotopes of ^{162,164,166,167,168,170}Er. In-gas cell/jet ionization has been performed and characterized.



De Laval Nozzle creates a jet of atoms with narrow velocity distribution and low density thereby reducing temperature and collision rate.

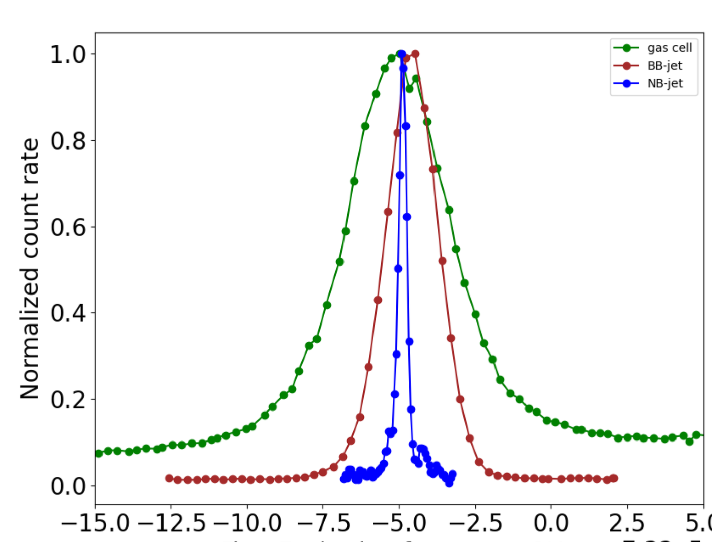
Gas cell
- Broadening effects
- Broad band lasers (GHz)

de Laval Nozzle
- Hypersonic gas jet
  $\rho\downarrow T\downarrow$
- Narrowband laser (MHz)



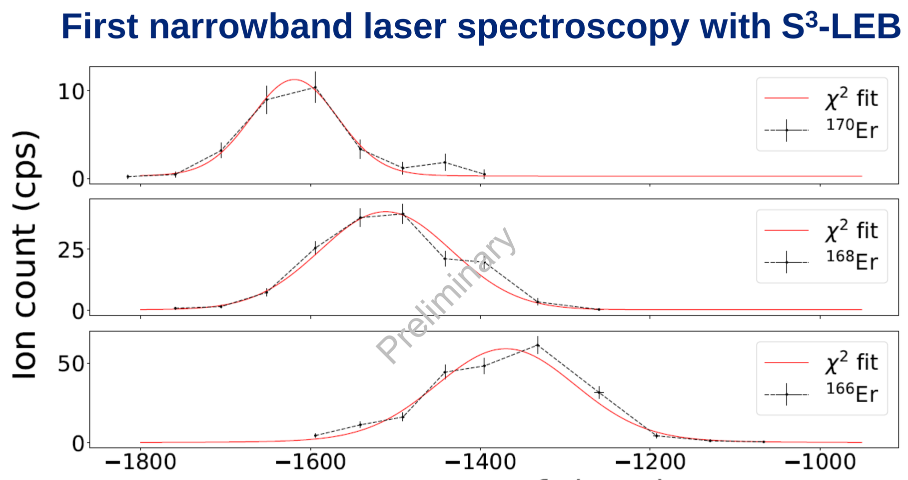
Er RIS Scheme[4]

The in-gas cell/jet spectroscopy was performed with a broadband laser of 1.8 GHz and a narrowband injection locked laser of < 100 MHz fundamental line width giving a spectral linewidth of $\Delta\nu_{FWHM}$ = 2(1) GHz and 316(5) MHz respectively.



In-gas cell/jet laser ions were transported to the PILGRIM multi-reflection time of flight (ToF) spectrometer for ToF of the different isotopes of Er. This way, isotope shift measurements were performed and compared with results obtained in vacuum.

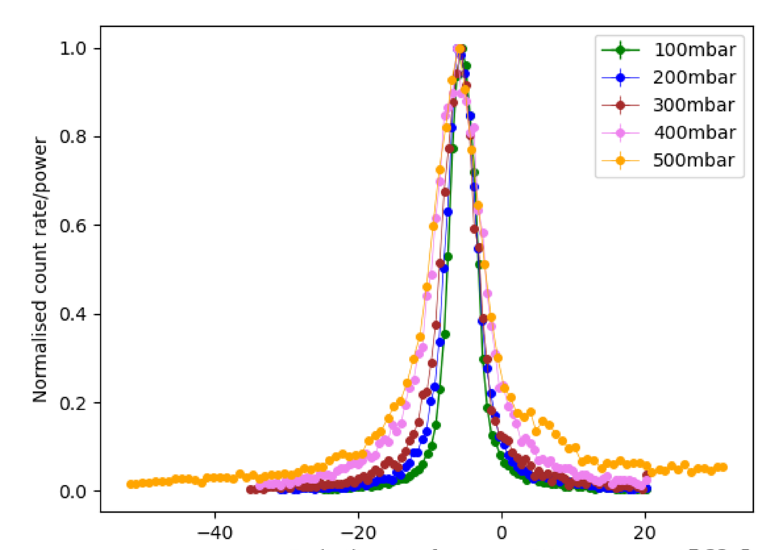
First narrowband laser spectroscopy with S³-LEB



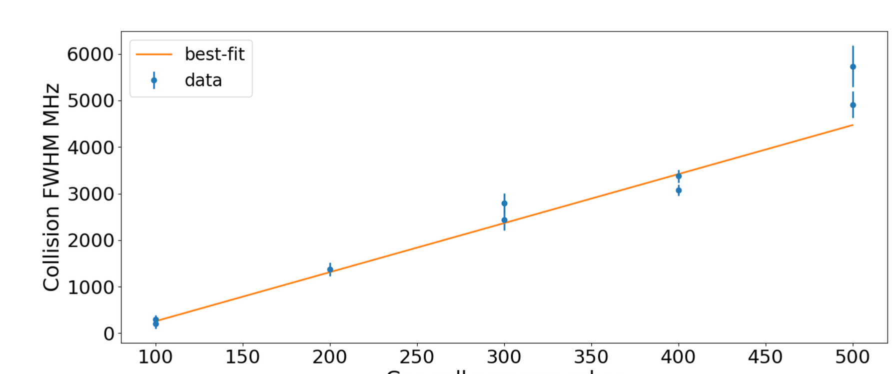
$\Delta f^{170,A^*}$ (MHz) $4f^{12}6s^2\,^3H_6 \rightarrow 4f^{12}6s\,(^3H_5)\,6p$	In-Gas jet with BB laser RIS Preliminary	In-Gas jet with NB laser RIS Preliminary	Vacuum (J.Romans et al. article in preparation)
$\Delta f^{170,166}$	181(30)	231(14)	197(5)
$\Delta f^{170,168}$	80(34)	99(7)	97(5)

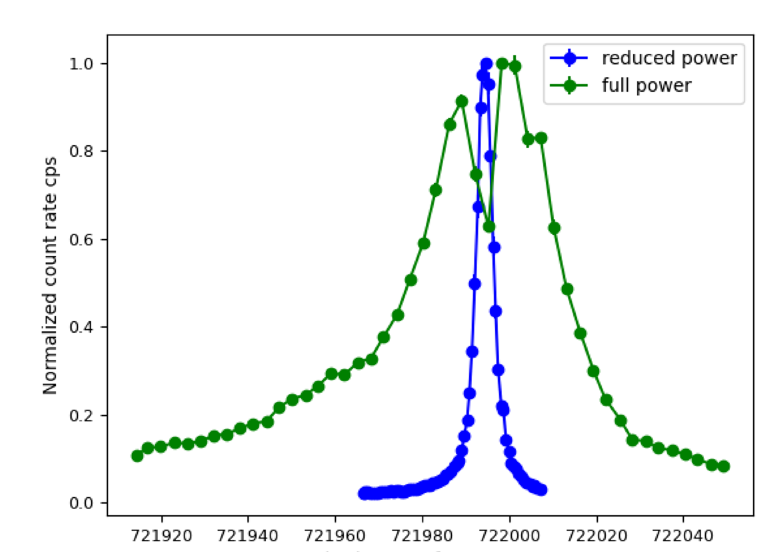
In-gas cell spectral broadening

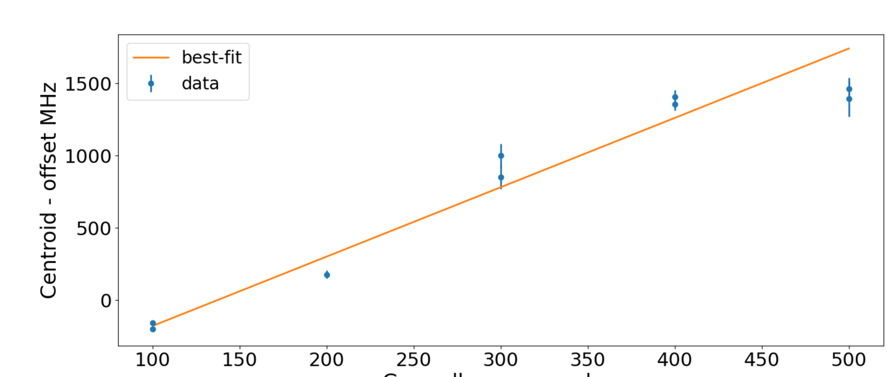
The buffer gas in the gas cell causes collisional broadening of the spectrum. The broadening can be several GHz wide which prohibits precise measurements of atomic isotope shift and hyperfine constants. The gas might also hamper the ionization efficiency even for strong transition schemes by collisional de-excitation of states. Hence the broadening effects in the gas cell for the first step transition in the Er RIS scheme have been studied and quantified.



Broadening as a function of gas cell pressure[5]







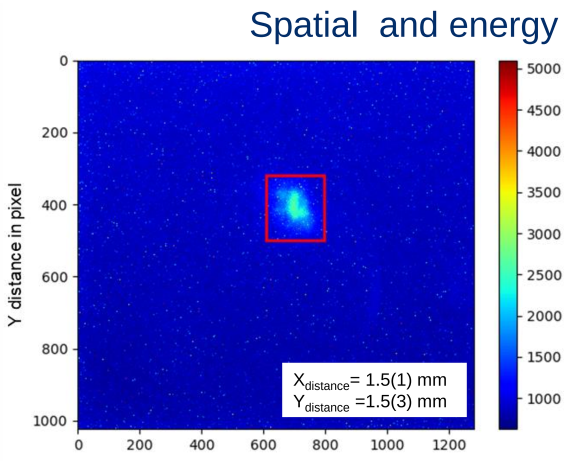
The broadening coefficient (T_{coll}) and the shift coefficient (T_{sh}) are calculated to be 8(2) MHz/mbar and 5(1) MHz/mbar.

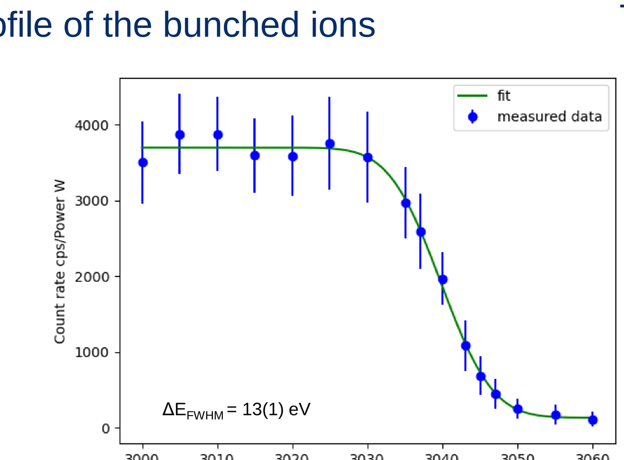
Apart from the collisional broadening, power broadening effects combined with collisional de-excitations are also observed as dips in the resonances.

Ion transport and bunching optimization

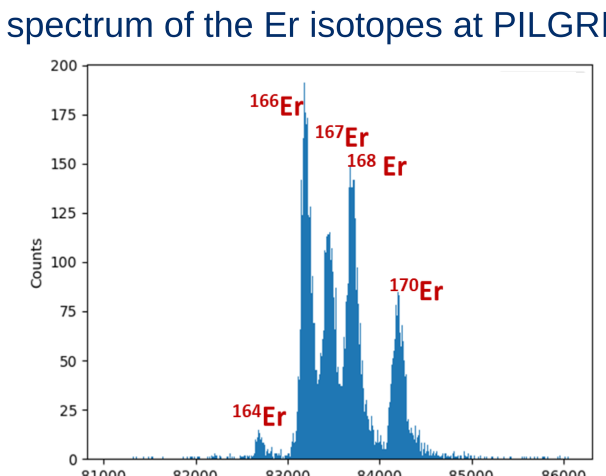
- The laser ionized beam is mass separated by a quadrupole mass filter and then sent to a cooler buncher before injecting it into the PILGRIM mass spectrometer.
- The relative transmission efficiency of the laser ionized beam until the mass spectrometer (PILGRIM) was improved.
- The emittance of the bunches were characterized and optimized for improving the PILGRIM efficiency.

Spatial and energy profile of the bunched ions





ToF spectrum of the Er isotopes at PILGRIM



- Laser ion bunches were injected into PILGRIM for its performance tests. Efficient suppression of contaminants was achieved. Performed mass measurement with PILGRIM gave:
  - Resolving power, R~ 75000
  - Mass accuracy in the order of 10^{-7}

Cycling between ^{162,164}Er as test ions and ^{166,170}Er as reference ions					
Isotopic mass	m (keV)	σ_m (keV)	m-AME(keV)	$\sigma_m/m*10^7$	Cleaned isotopes
^{162}Er	150835144	44	-57	2.9	^{166}Er, ^{167}Er, ^{181}Ta
^{164}Er	152698574	24	-7	1.6	^{166}Er, ^{170}Er, ^{168}Er^{16}O

Conclusions

Offline commissioning of S³-LEB is currently in progress with the following milestones achieved:
- In-gas cell Laser ionization and spectroscopy performed
  - Broadening effects in the gas cell studied
- In-gas jet ionization with broadband and narrowband laser performed
  - Ionization in-gas cell/gas jet characterterized
- Transmission efficiency of the laser ions until PILGRIM has been improved
- First narrowband laser spectroscopy performed
  - Upgrade of narrowband Ti:sa laser system is in progress by replacing the diode seed laser with CW diode pumped Ti:sa laser system[6]

References

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