In-Gas Laser Ionization and Spectroscopy (IGLIS) studies of actinides

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Laser Spectroscopy on Actinides

Challenges Laser technique:

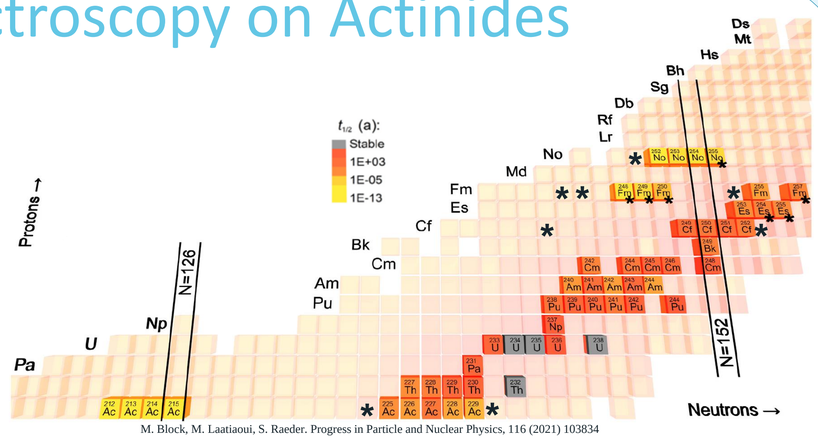
- Laser spectroscopy on products of fusion evaporation reactions at ~ MeV energy (excluding long-lived actinides)
- Low production rates

In-Gas-Cell Laser Ionization and Spectroscopy
→ RADRIS & In-Gas Cell methods

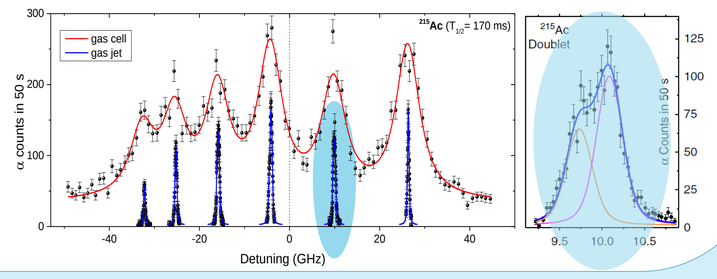
Spectral resolution provides access to Isotope shift ($\delta\langle r^2\rangle$), partial hyperfine splitting (μ)

In-Cell vs In-Jet Spectroscopy

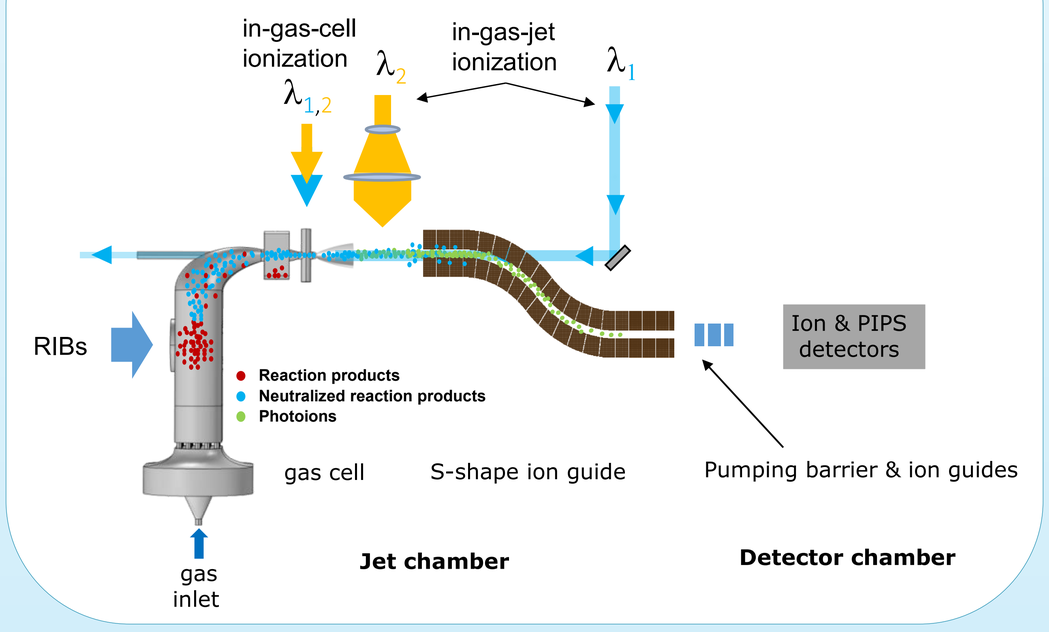
➢ Reduced Doppler and collisional broadening effects gives access to complete hyperfine splitting: magnetic & quadrupole moments, and nuclear spins



M. Block, M. Laatiaoui, S. Raeder. Progress in Particle and Nuclear Physics, 116 (2021) 103834



Generic Layout IGLIS setup

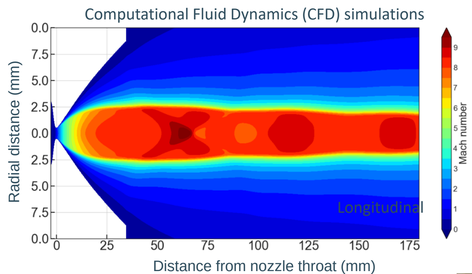


Gas Jet Formation : Nozzle characterization for best performance

Contour calculations at Von Karman Institute (VKI) (M=8.5)

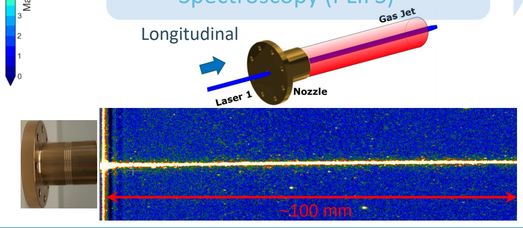
- Viscous corrections included

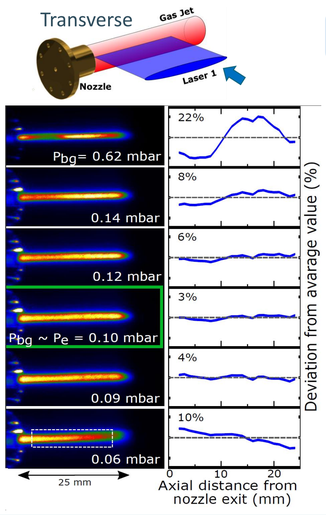
Computational Fluid Dynamics (CFD) simulations



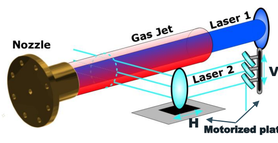
Precision machining

Planar Laser-Induced Fluorescence Spectroscopy (PLIFS)

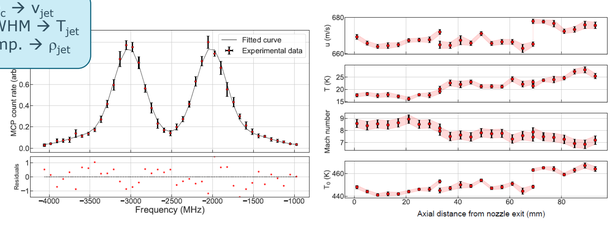




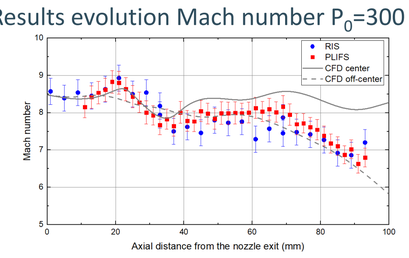
Flow mapping by Resonance Ionization Spectroscopy



$\Delta\nu_c \rightarrow v_{jet}$
FWHM → T_{jet}
Amp. → ρ_{jet}



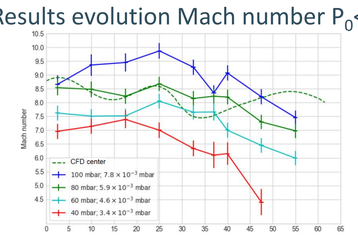
Results evolution Mach number P_0=300 mbar



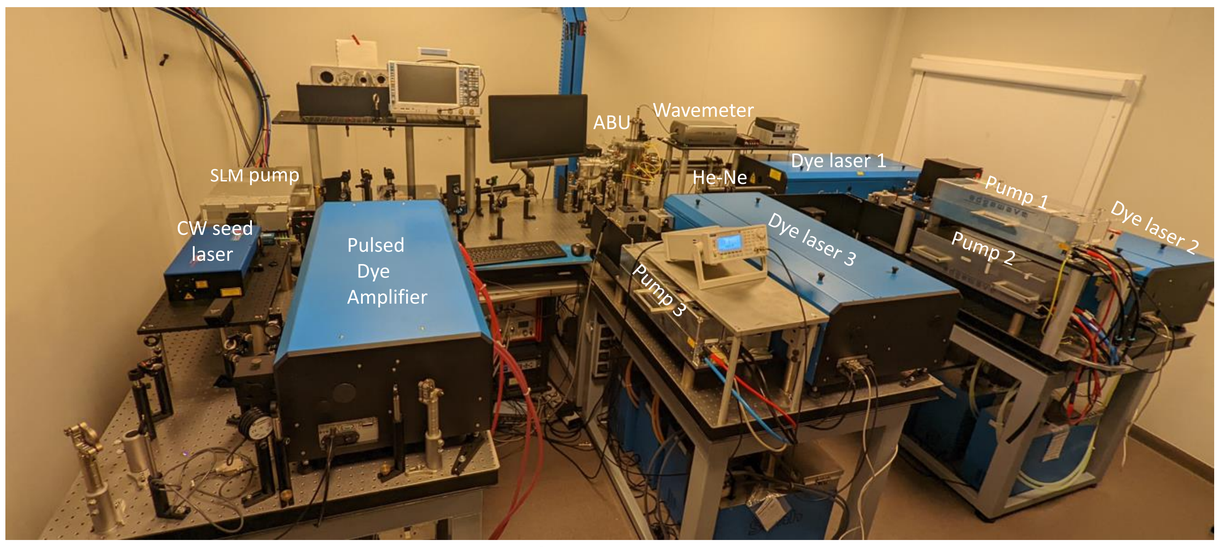
➢ Good agreement between RIS and PLIFS methods (validation RIS flow mapping method)

➢ Good agreement exp. data with CFD results ~70 mm **(M_{avg}= 8.2, T= 17 K)**

Results evolution Mach number P_0<100 mbar



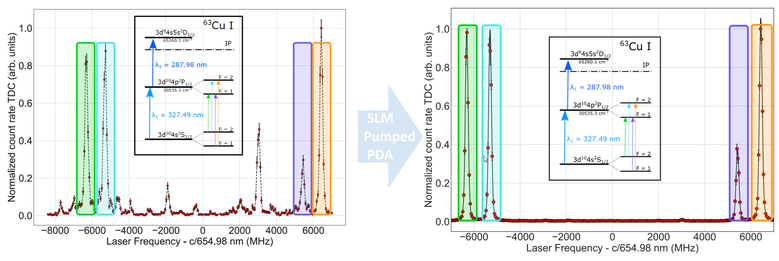
Laser Laboratory :Nd:YAG pumped dye laser system



IGLIS Laser Laboratory at KU Leuven

- Pulsed dye amplifier pumped by Single Longitudinal Mode (SLM) pump laser (60 W @ 15 kHz and 532 nm)

→ single-mode (Fourier limited) spectroscopy with S/N >200



Power Output 532 nm , 15 kHz

Dye		150 W	
Rhodamine 6G	(570 nm)	45 W	(30 %)
DCM	(630 nm)	37.5 W	(25 %)
Styryl 8	(745 nm)	18.8 W	(12.5 %)

➢ High power pump laser (165 W @ 15 kHz and 532 nm)
(75 W @ 15 kHz and 355 nm)

➢ 2 x High repetition rate dye lasers

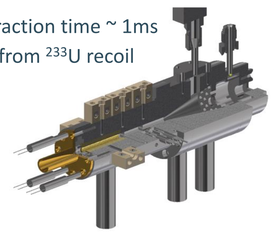
✓ 3-step ionization scheme Th+
✓ Ionization via continuum of No isotopes

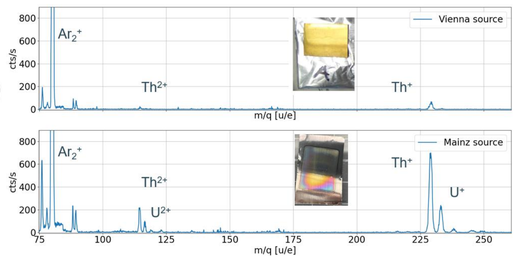
Power Output 355 nm , 15 kHz

Dye		70 W	
Coumarin 307	(500 nm)	10.5 W	(15 %)
Coumarin 2	(450 nm)	10.5 W	(15 %)
Exalite 389/398	(393 nm)	10.5 W	(15 %)

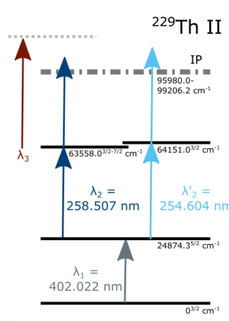
Towards IGLIS on $^{229m}Th^+$

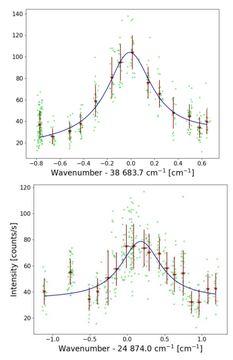
- Fast gas cell: extraction time ~ 1ms
- ^{229m}Th produced from ^{233}U recoil sources (BR 2%)





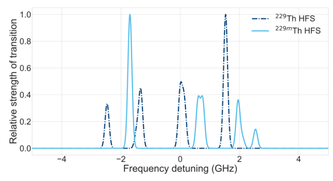
Search for autoionizing states in $^{232}Th^+$





The goal is to perform IGLIS on $^{229}Th^+$ and check existence of $^{229m}Th^+$

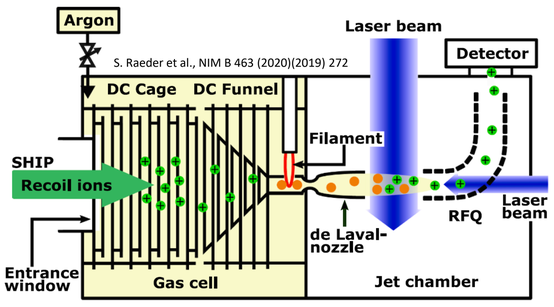
Expected HFS (FWHM ~ 160 MHz)



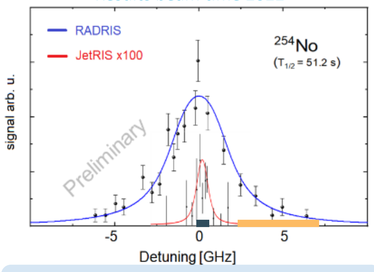
TETRIS @ GSI:

In-gas-jet laser spectroscopy on ^{253,254m}No

Combination of high-efficiency RADRIS with high resolution in-jet methods

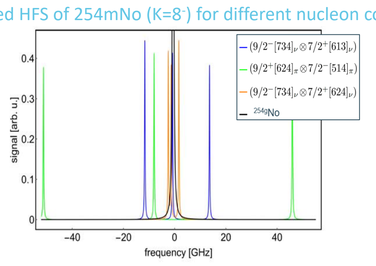


Results beam time 2022

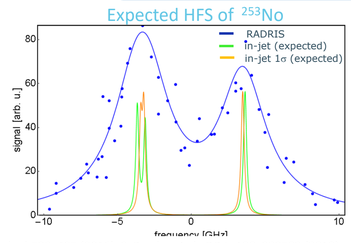


Proof of principle: First narrowband of ^{254g}No (7-fold improved resolution)

Expected HFS of 254mNo (K=8⁻) for different nucleon configurations



Expected HFS of ^{253}No



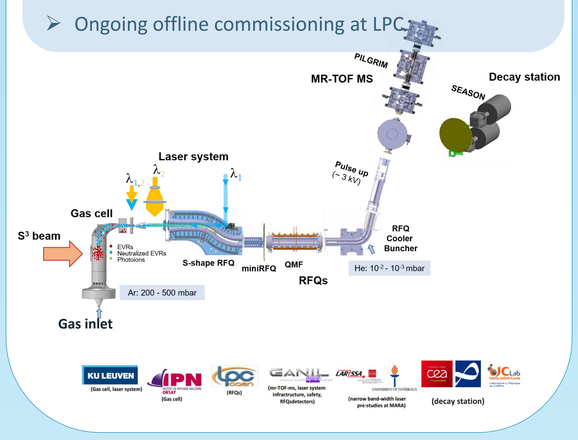
M. Laatiaoui et al., Nature (London) 538, 495 (2016), S. Raeder et al., P.R.L. 120, 232503 (2018)

S³ Low Energy Branch @ SPIRAL2 (GANIL)

➢ Laser spectroscopy on actinides from S³ thermalized in the gas cell and ionized in the gas jet

➢ Mass measurements and decay spectroscopy with dedicated setups

➢ Ongoing offline commissioning at LPC



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