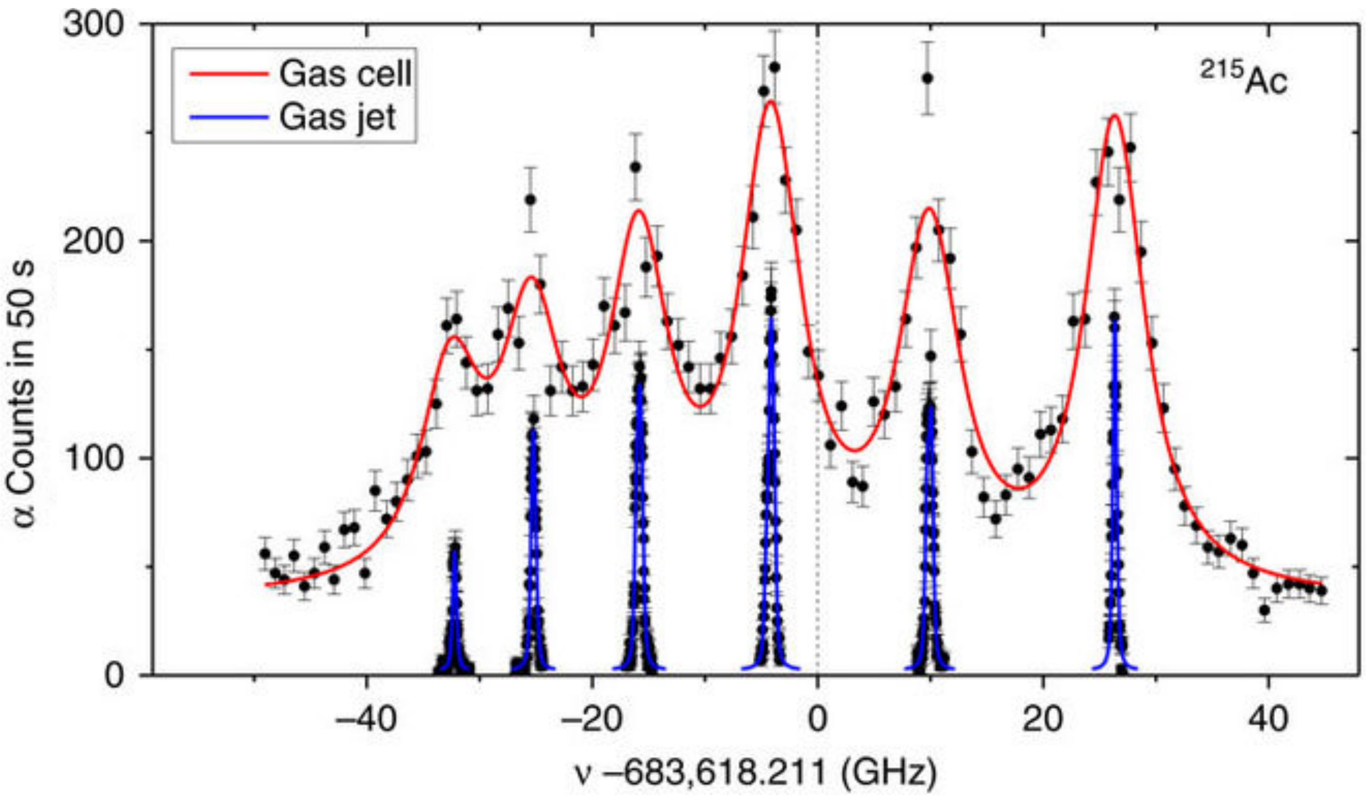
The in-Gas Laser Ionisation and Spectroscopy technique

Camilo Granados

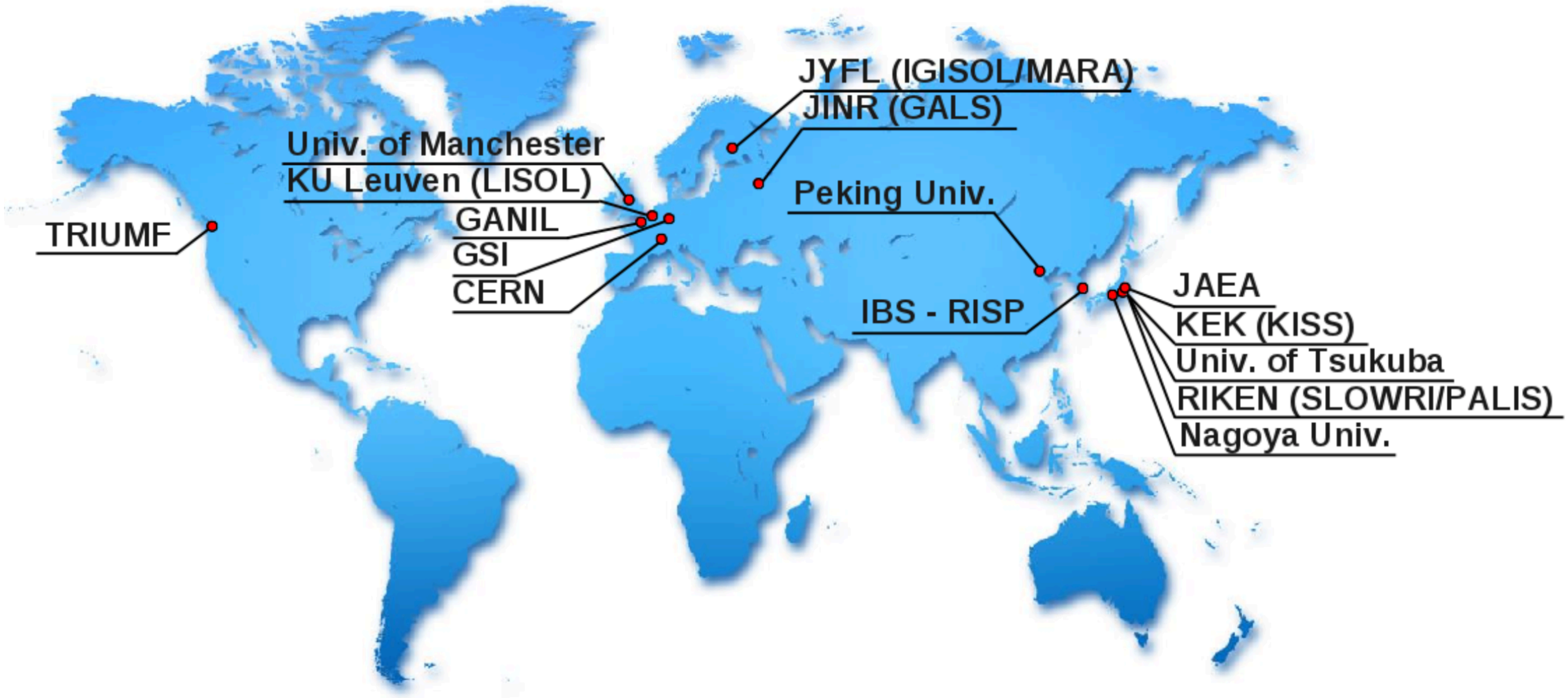
HELIOS project



Towards the study of the heavy elements nuclear structure

https://fys.kuleuven.be/iks/ns/home
http://research.kek.jp/group/wnsc/iglis-net/

In-gas laser ionisation and spectroscopy (IGLIS) net



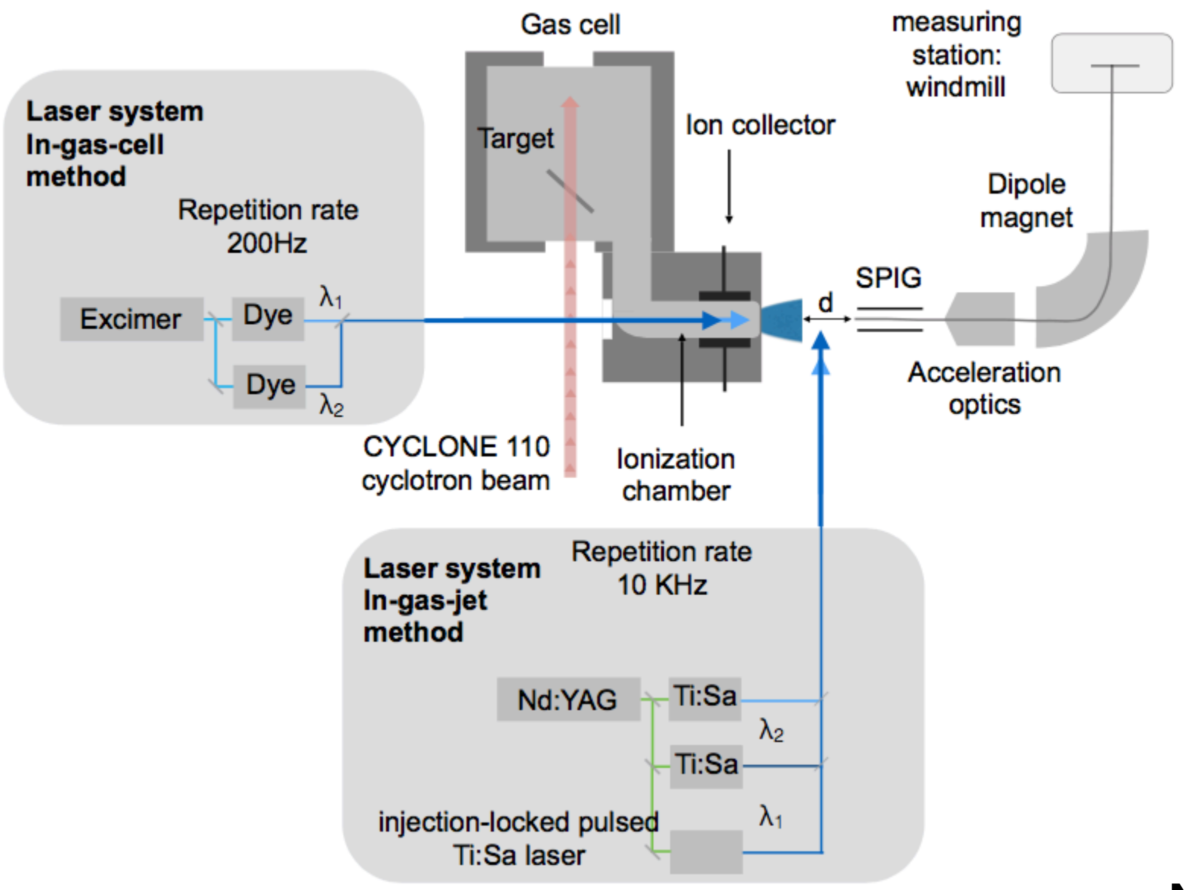
http://research.kek.jp/group/wnsc/iglis-net/

Outline

- The experimental technique
  - In-gas-cell vs in-gas-jet
  - Production, efficiency and selectivity
- Results
- Challenges for the future

The in-gas technique

Proposed at JYFL, developed and used at KU Leuven.



Nuclear reaction

↓

Stoping and neutralisation

↓

Flow to the exit hole of the gas cell

Production mode	**Spectroscopy mode**
↓	↓
In-gas-cell	**In-gas-jet**
↓	↓
Production of RIBs **inside** the gas cell	Production of RIBs **outside** the gas cell

→ Mass separation ←

↓

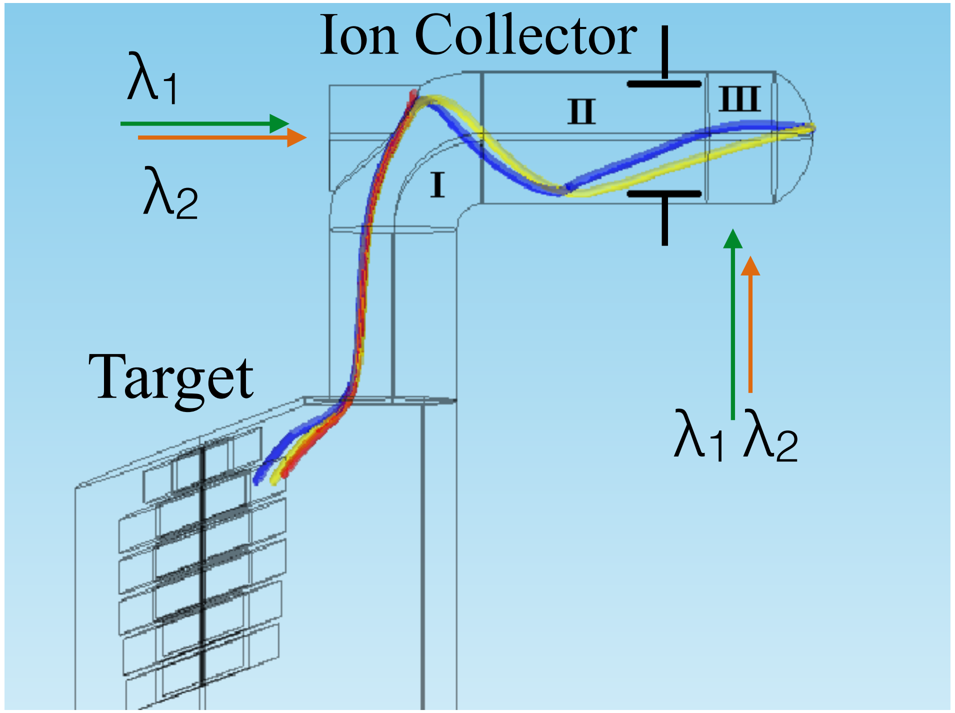
Detection

↓

No totally true

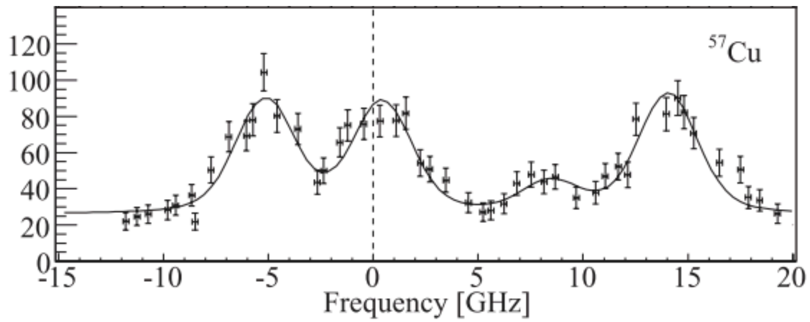
The in-Gas Laser Ionisation and Spectroscopy (IGLIS) of actinium isotopes around the N =126 closed shell. Accepted for PRC journal publication

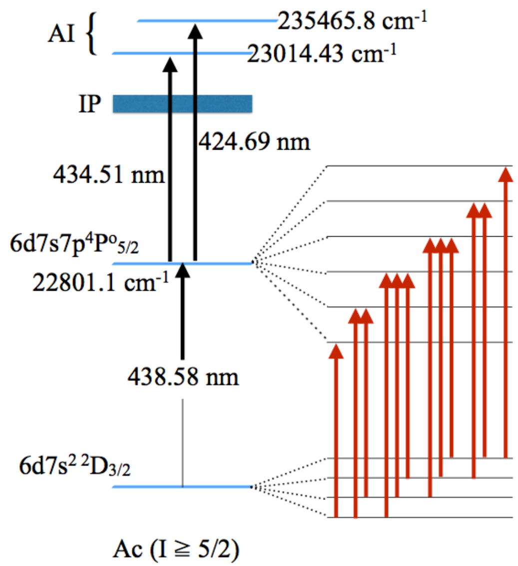
In-gas-cell method

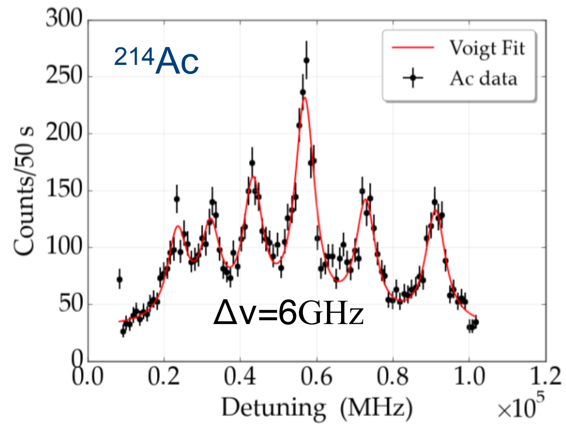


Advantages	Points to improve
Efficiency Chemical universality	Resolution Extraction time

HFS dominated by collision broadening



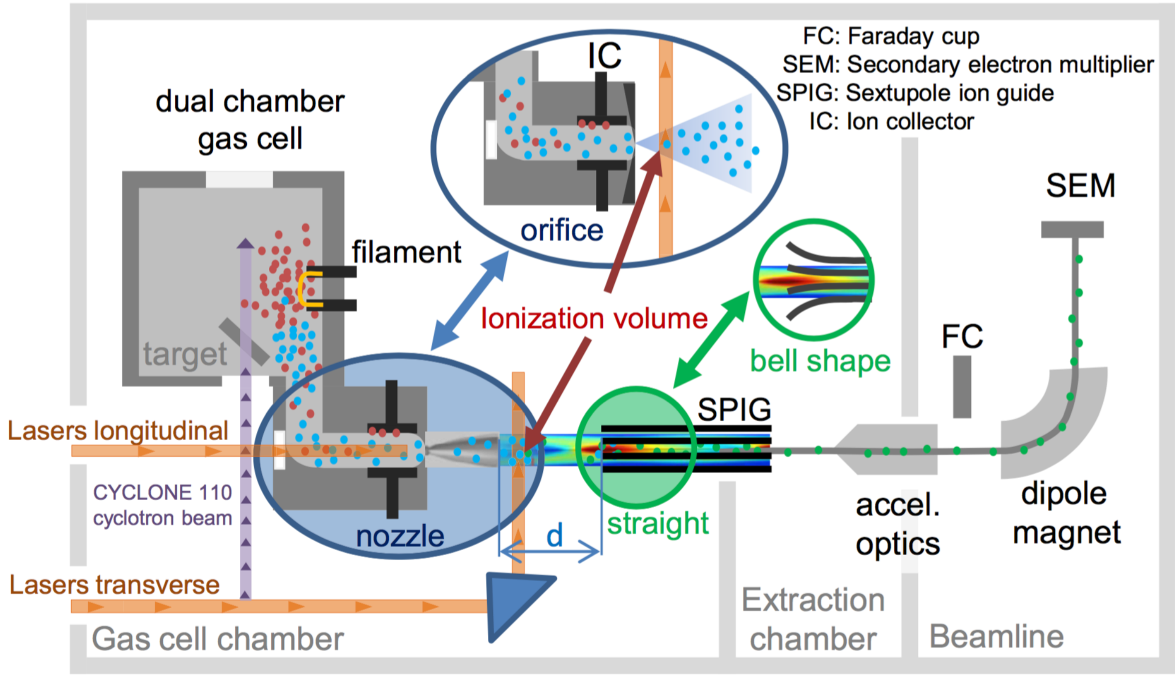


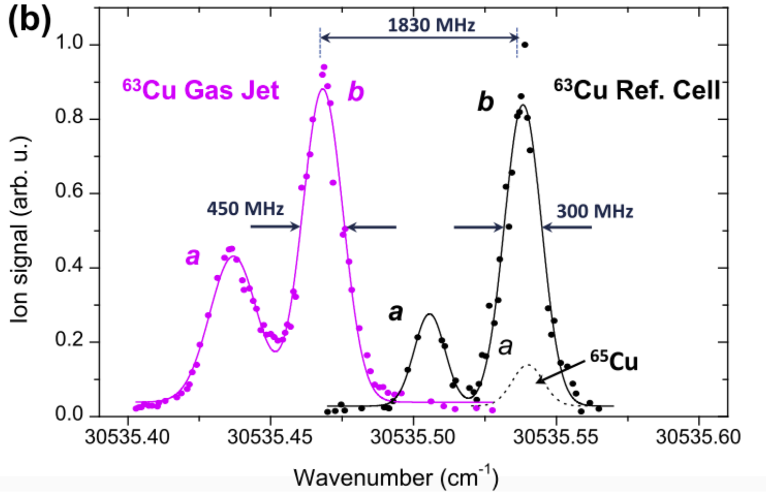


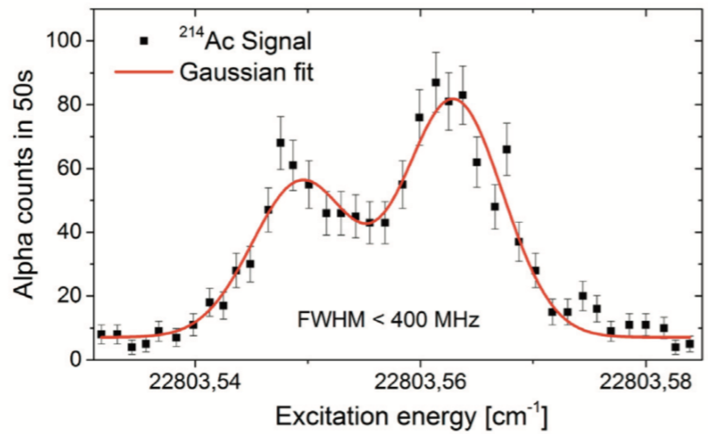
The in-Gas Laser Ionisation and Spectroscopy (IGLIS) of actinium isotopes around the N =126 closed shell. Accepted for PRC journal publication

PRL 103, 102501 (2009)

In-gas-jet method





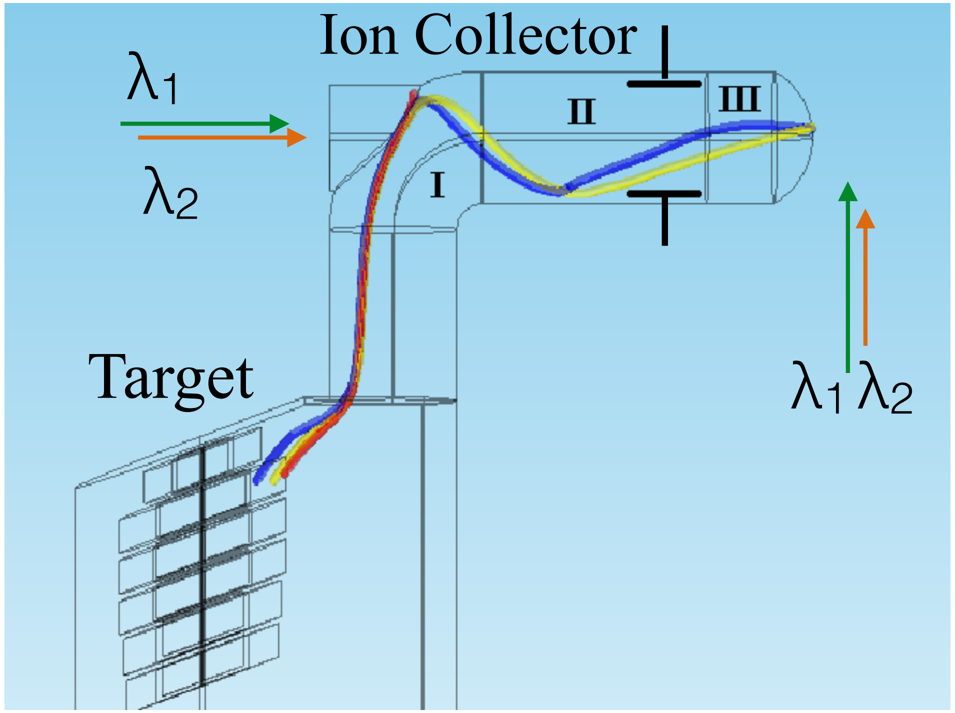


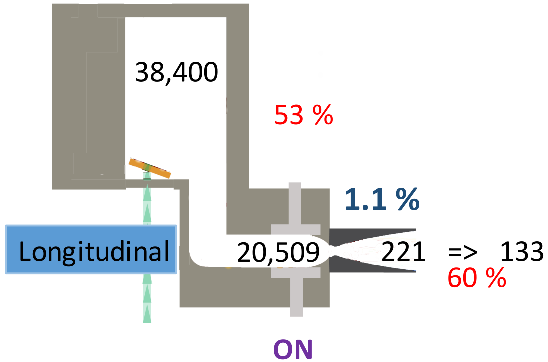
Full characterisation of the technique performed under offline conditions

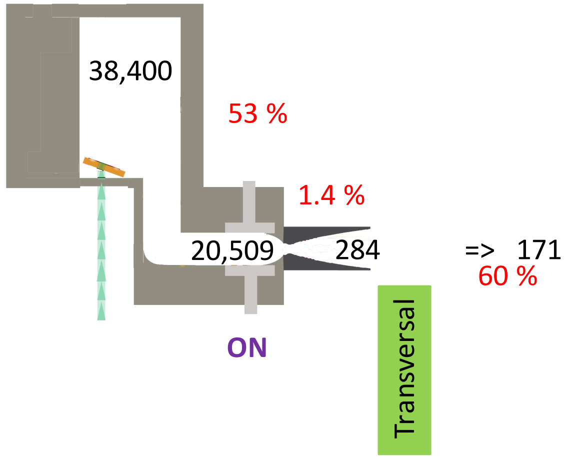
The in-Gas Laser Ionisation and Spectroscopy (IGLIS) of actinium isotopes around the N =126 closed shell. Accepted for PRC journal publication
PRL 103, 102501 (2009)
NIM B 376 (2016) 382–387

In-gas-cell vs in-gas-jet

$^{197}Au(^{20}Ne, 4\text{-}5n)^{212,213}Ac$ and $^{197}Au(^{22}Ne, 4\text{-}5n)^{214,215}Ac$.







	Gas cell	Gas jet (this work)*	Gas jet (projected)†
Ionization volume			
Pressure (mbar)	350 (15)	0.7–1	~0.05
Temperature (K)	350 (25)	25–30	~9
Jet divergence (deg.)	—	10–11	<1
Linewidth (FWHM)			
Total (MHz)	5,800 (300)	394 (18)	~100
Lorentz‡ (MHz)	4,000 (400)	42 (6)	<10
Gauss§ (MHz)	1,400 (100)	280 (30)	~100
Selectivity‖	8.3 (17)	121 (27)	>3,000
Efficiency¶ (%)	0.42 (13)	0.40 (13)	>10

PhD thesis Camilo Granados

in-gas-cell vs in-gas-jet

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- Pressure → Better pumping system
- Temperature → Higher Mach numbers
- Jet divergence → Better pressure ratio
- Lorentz → Further reduction of density
- Gauss → Reduced jet divergence
- Selectivity → Better background to signal ratio

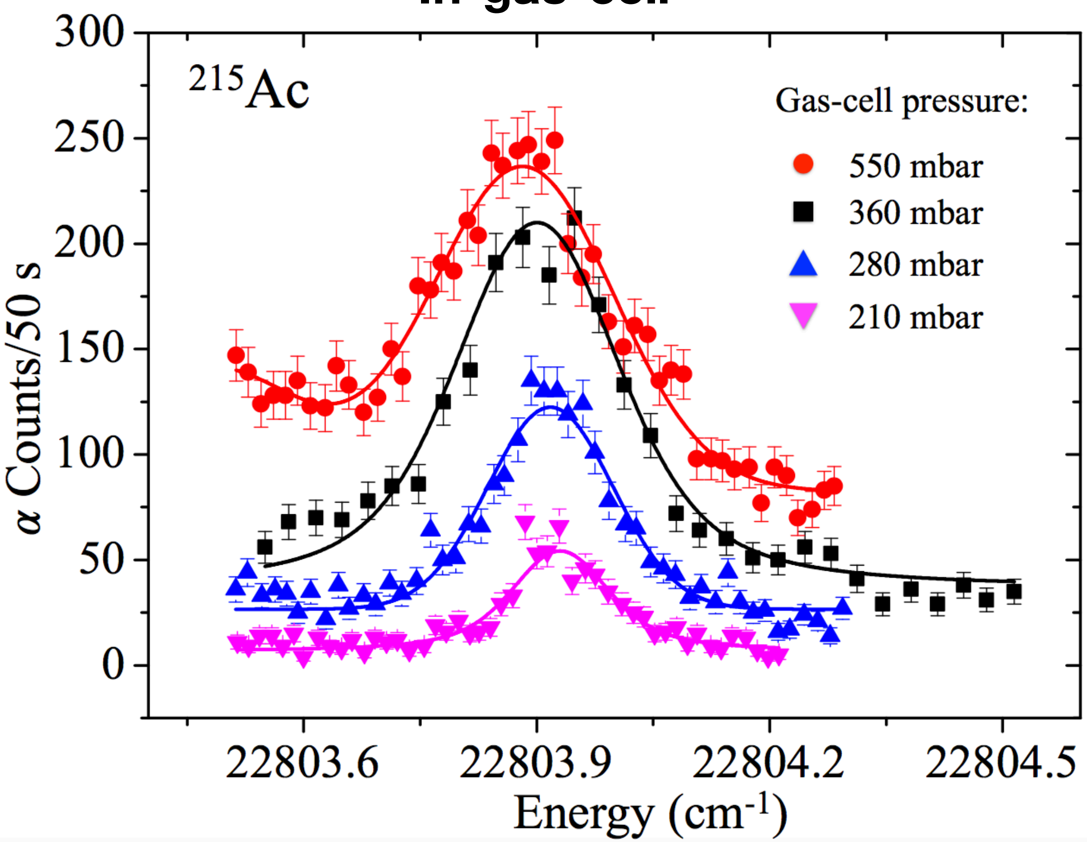
Duty cycle = 14 times

Increased power for production mode = 1.9 times

Results

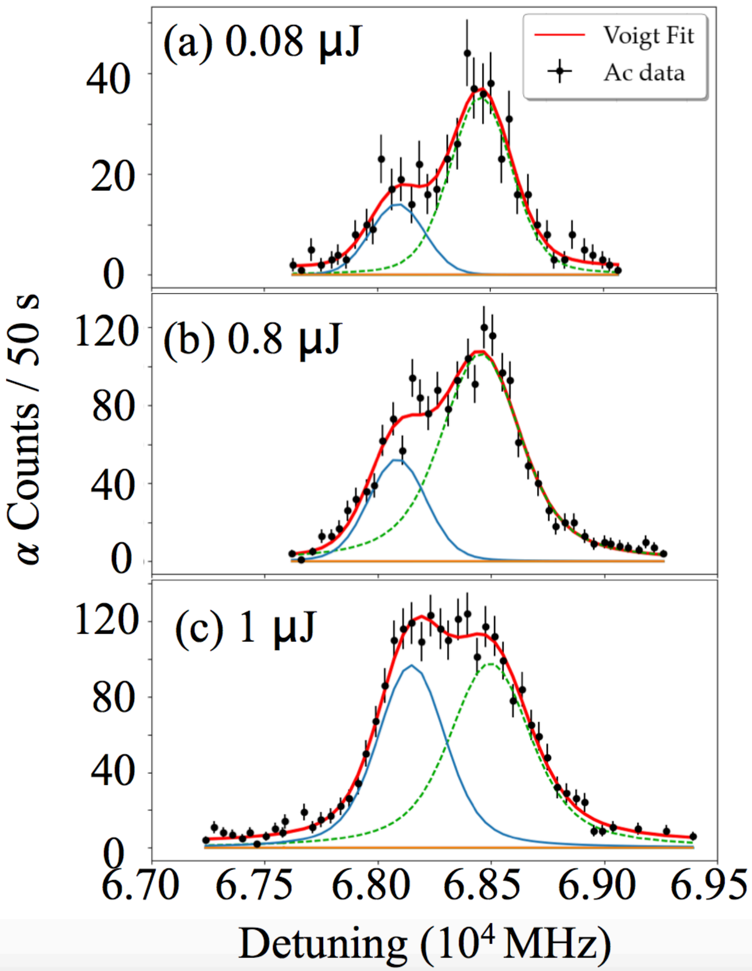
Some atomic measurements

In-gas-cell



Pressure broadening and pressure shift

In-gas-jet



Racah Coefficients
Different saturation

Mean square charge radii

Conclusions and outlook

1) In-gas-jet method v.s. the in-gas-cell method

High resolution in combination with high efficiency still missing… Control of the full jet is necessary.

2) Indication of nuclear spin for the more neutron deficient isotopes

$I(^{215}Ac)=9/2$
$I(^{214}Ac)=5$
$I(^{213}Ac)=(9/2)$
$I(^{212}Ac)=(7)$

3) μ, Q, $\delta\nu$, $\delta\langle r^2\rangle$

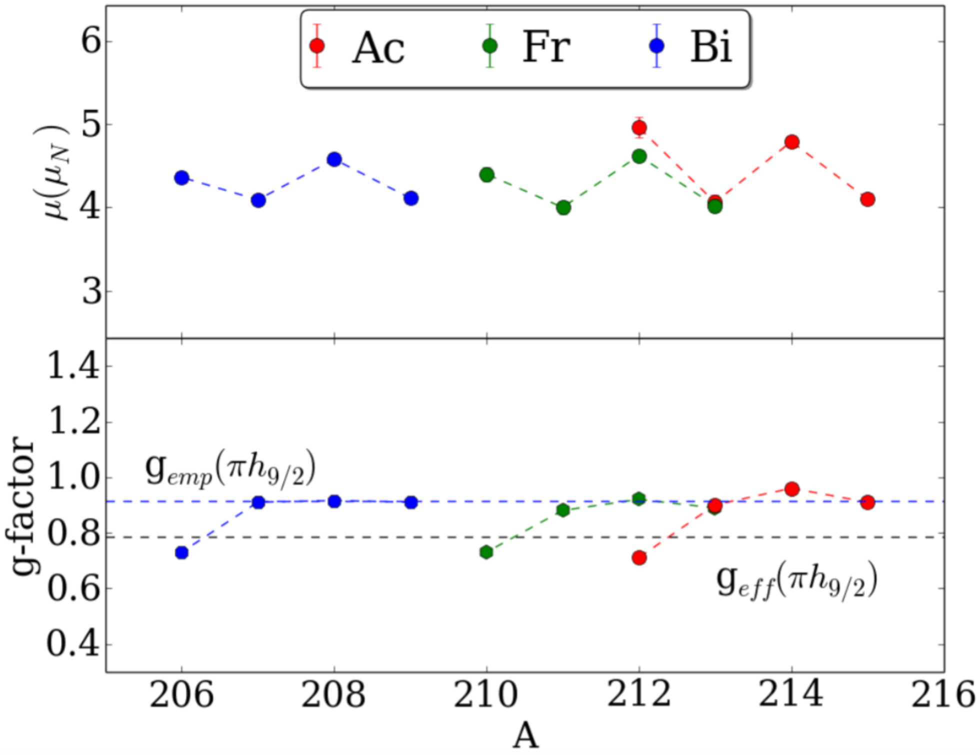
What did we pursuit?

1) HELIOS project

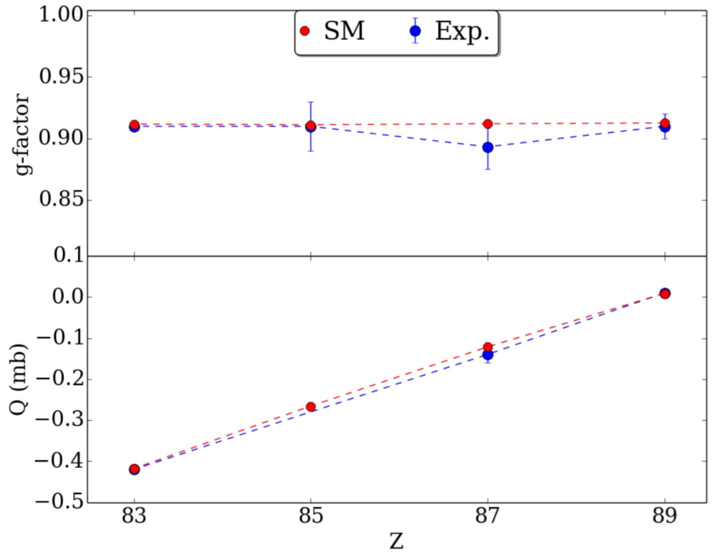
Thank you

Nuclear moments

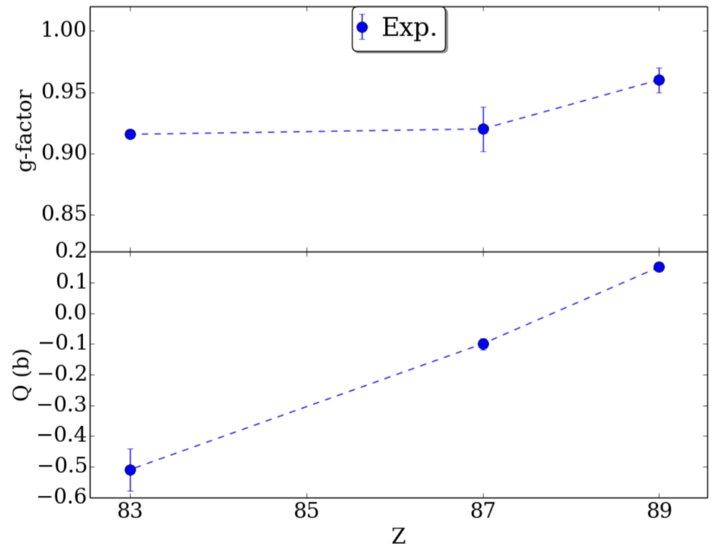
$$g = g_{ref} \frac{(A \times J)}{(A \times J)_{ref}}.$$



The Additivity rule indicates
I=7 and I=5 for ^{212,214}Ac

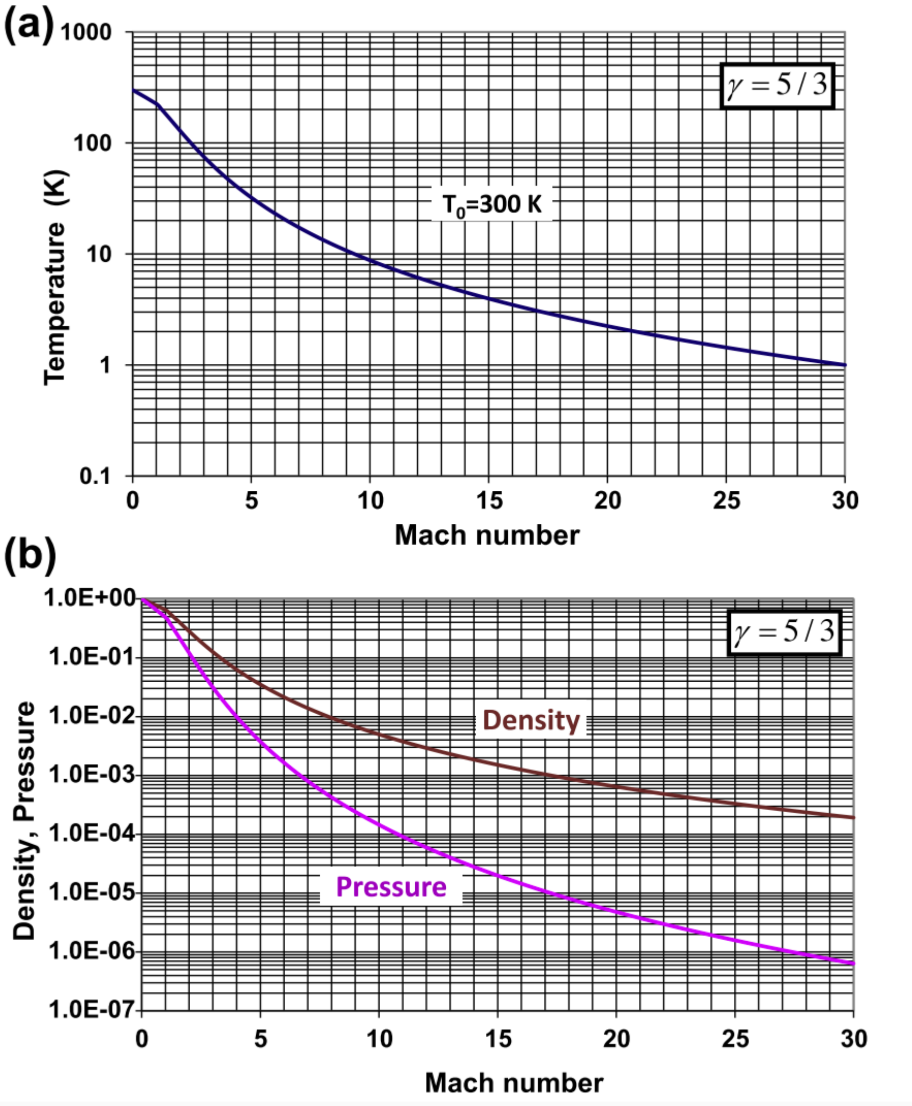


N=126

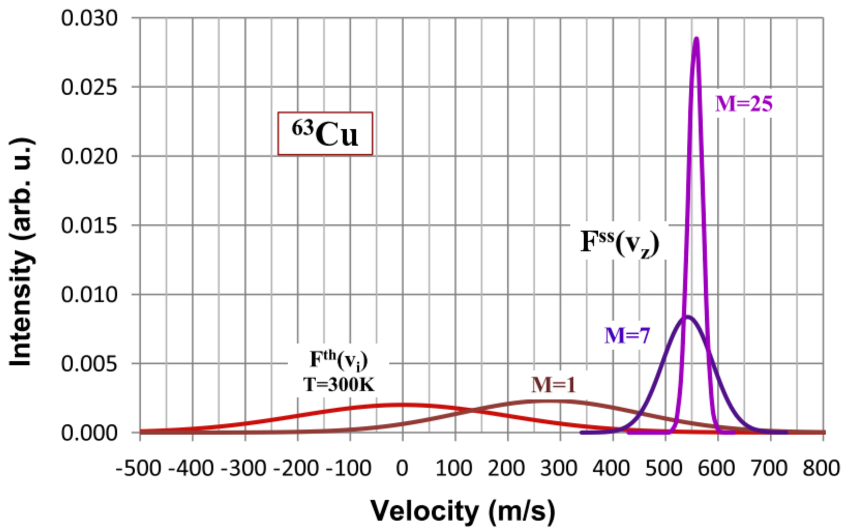


N=125

Broadening



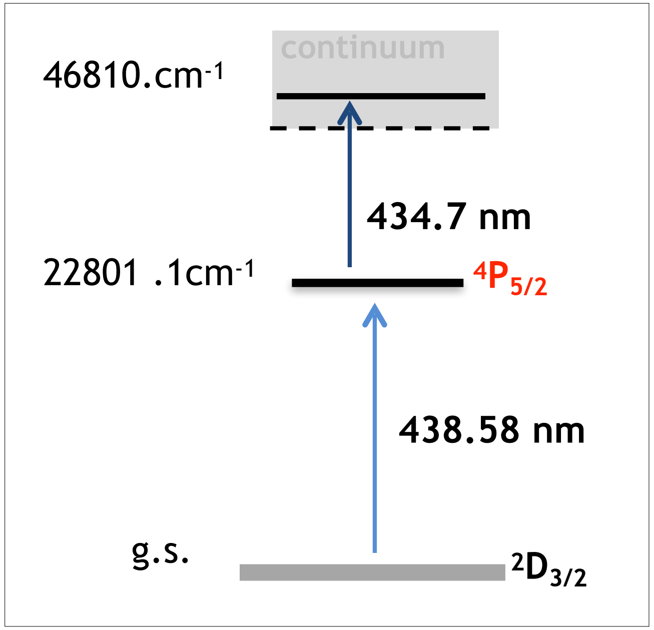
$$\frac{T}{T_0} = [1 + \left(\frac{\gamma - 1}{2}\right) M^2]^{-1}$$
$$\frac{\rho}{\rho_0} = [1 + \left(\frac{\gamma - 1}{2}\right) M^2]^{-\frac{1}{\gamma-1}}$$
$$\frac{P}{P_0} = [1 + \left(\frac{\gamma - 1}{2}\right) M^2]^{-\frac{\gamma}{\gamma-1}}.$$



In-gas laser ionisation and spectroscopy

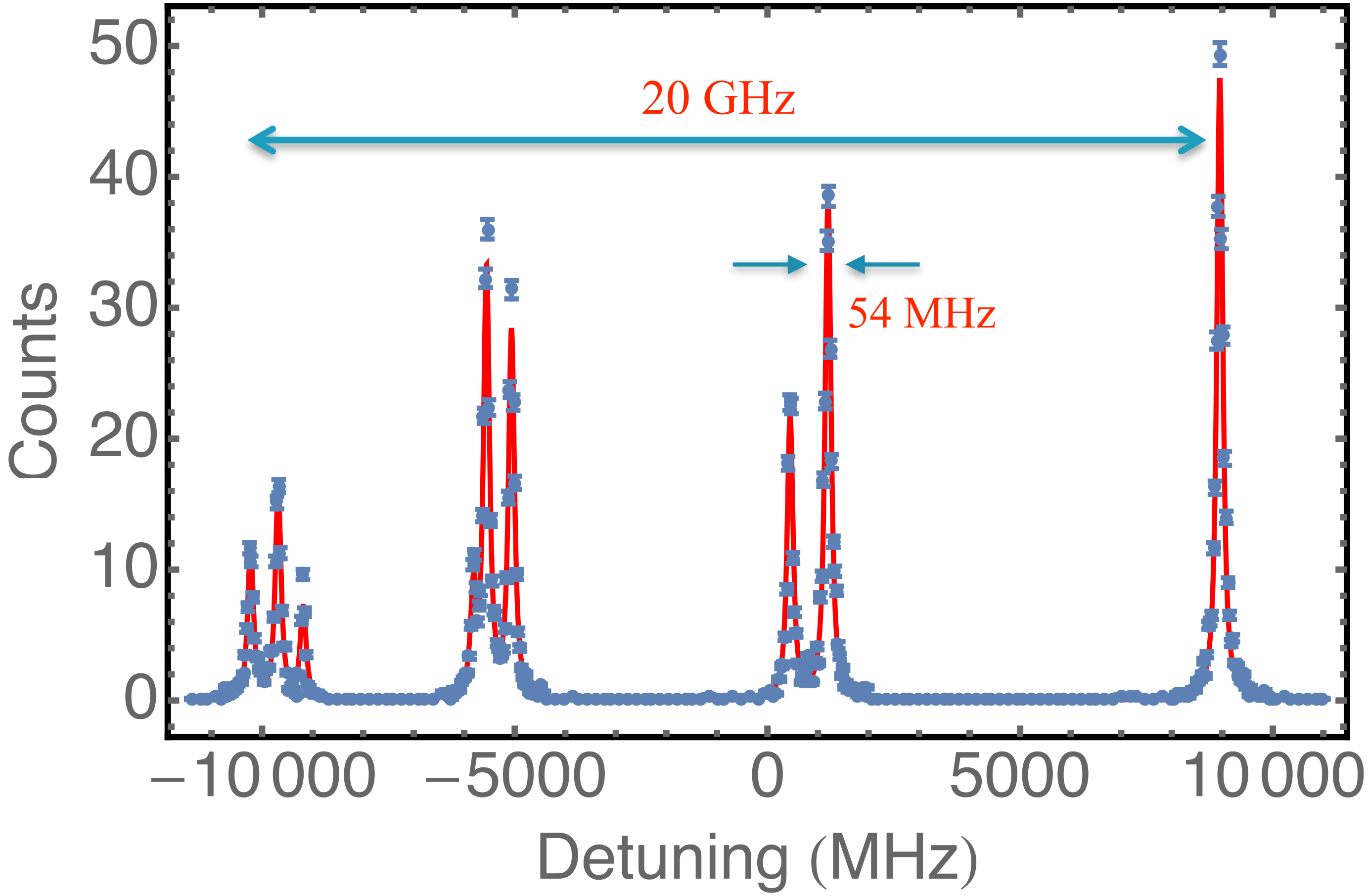
- Alternative experimental technique for the production of radioactive ion beams to the combinational hot cavity approach will be presented. The in-gas technique, that can be divided in in-gas-jet and in-gas-cell methods, presents many advantages when compare with other techniques. Resent experiments using both techniques performed at the Leuven Isotope Separator On-Line (LISOL) will be discuss and results on nuclear ground state observables will be presented.

LISOL: previous work

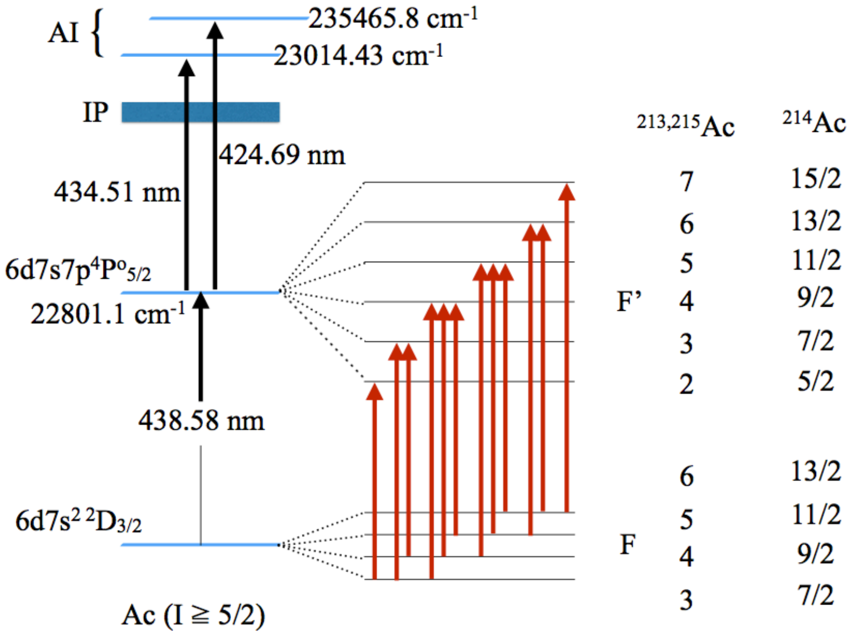


- -Large hyperfine splitting
- -Well characterized atomic structure.
- -Bigger hyperfine splitting for larger spin in neutron deficient actinium isotopes

Off-line 227Ac

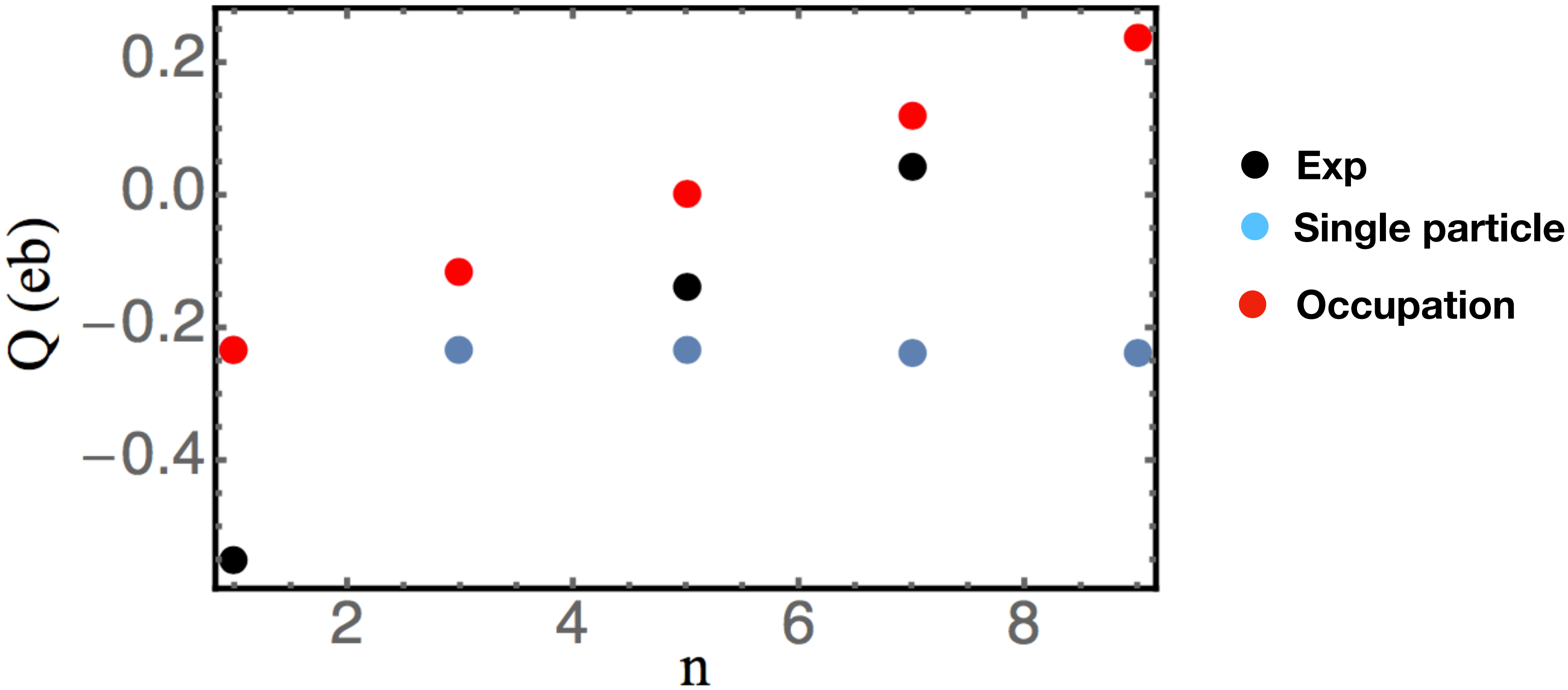


J. Rossnagel et al., PRA 85 (2012) 012525
Lieve Rens Master Thesis, KU Leuven

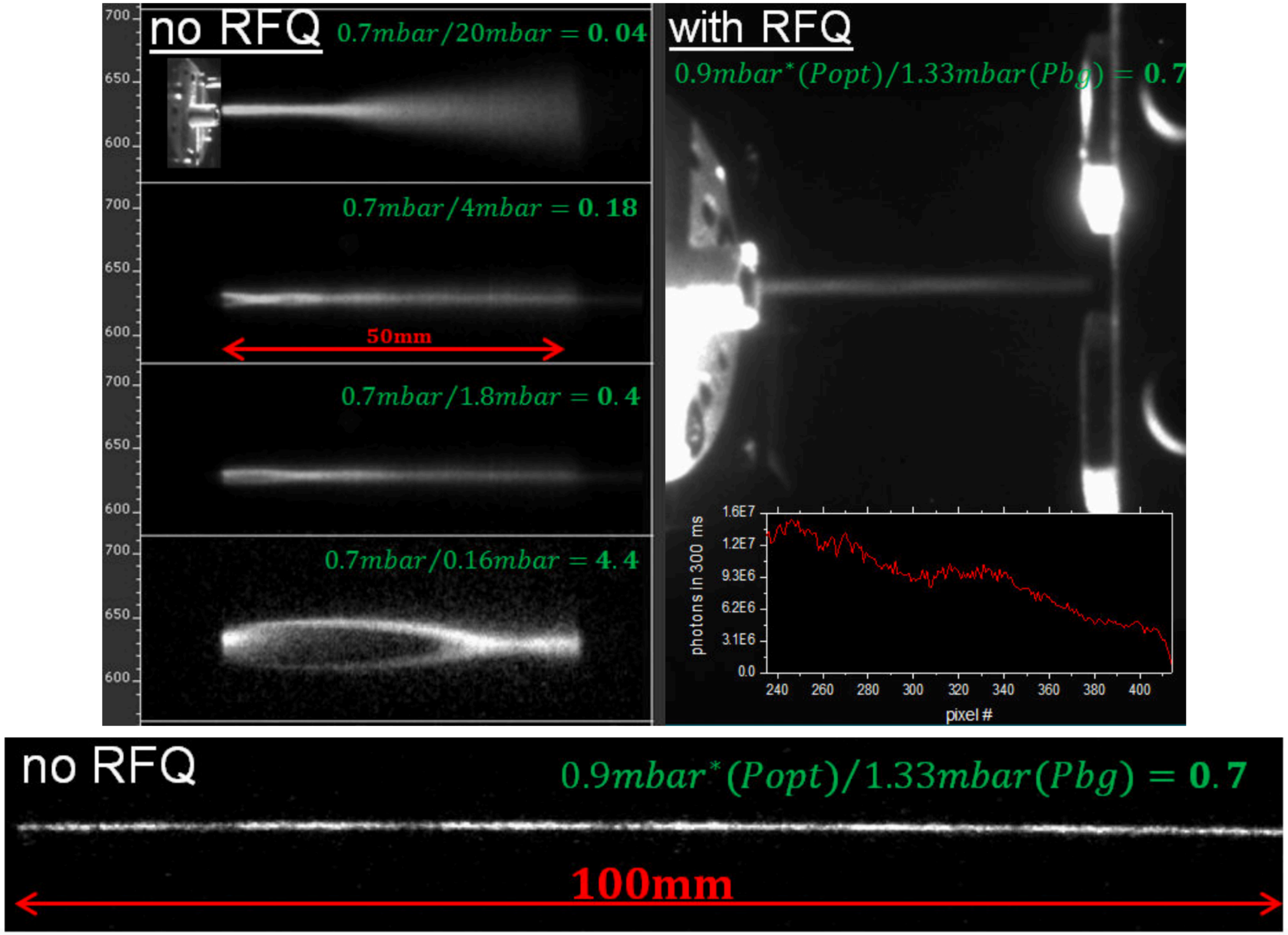


AI
235465.8 cm-1
23014.43 cm-1
IP
424.69 nm
434.51 nm
6d7s7p4Po5/2
22801.1 cm-1
438.58 nm
6d7s2 2D3/2
Ac (I ≧ 5/2)
213,215Ac
214Ac
7 15/2
6 13/2
5 11/2
F' 4 9/2
3 7/2
2 5/2
6 13/2
5 11/2
F 4 9/2
3 7/2

Quadrupole moments



The jet



$* \; P0 = 360mbar, Mach = 5.5 \rightarrow Pj\_opt \approx 0.9mbar$