

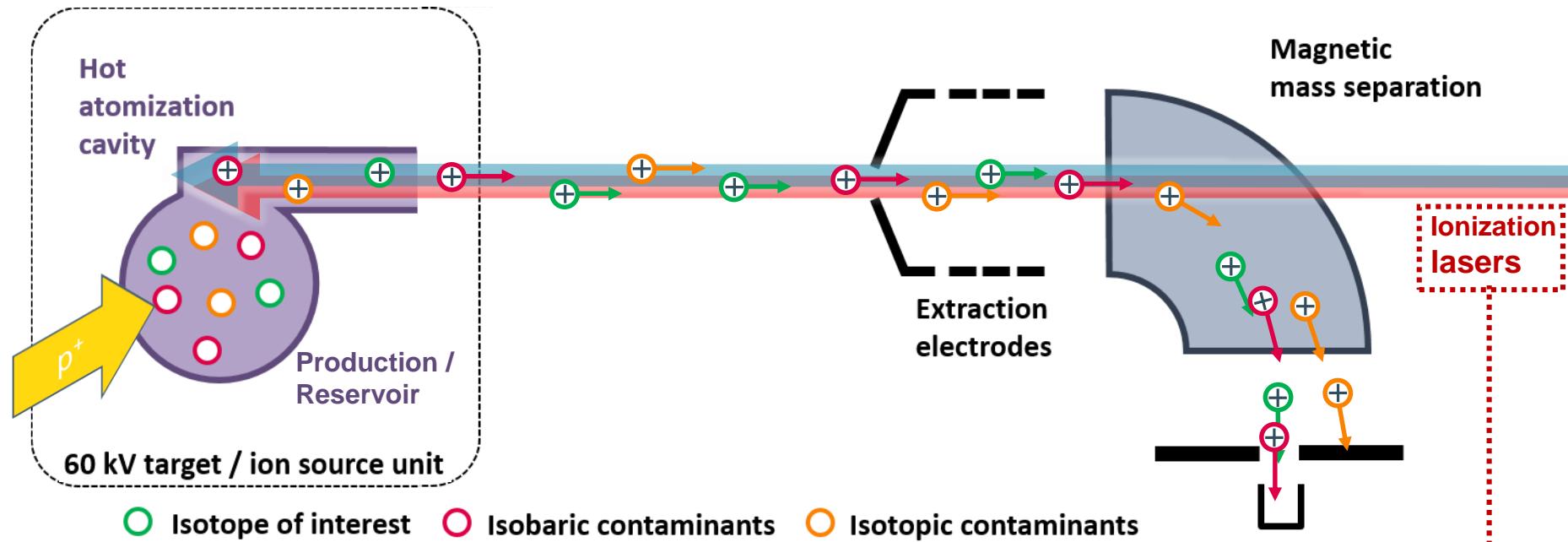
# ISOLDE's high purity ion source LIST

## Prospects for Run 3

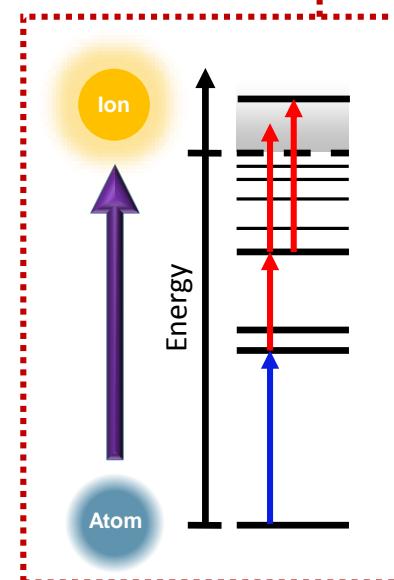
R. Heinke<sup>1</sup>, M. Bissell<sup>2</sup>, K. Chrysalidis<sup>3</sup>, T. E. Cocolios<sup>1</sup>, V. Fedosseev<sup>3</sup>,  
J. Johnson<sup>1</sup>, B. Marsh<sup>3</sup>, S. Raeder<sup>4</sup>, B. Reich<sup>3,5</sup>, S. Rothe<sup>3</sup>, F. Weber<sup>5</sup>, K. Wendt<sup>5</sup>

<sup>1</sup>KU Leuven – <sup>2</sup>University of Manchester – <sup>3</sup>CERN – <sup>4</sup>Helmholtz Institute Mainz – <sup>5</sup>Johannes Gutenberg University Mainz

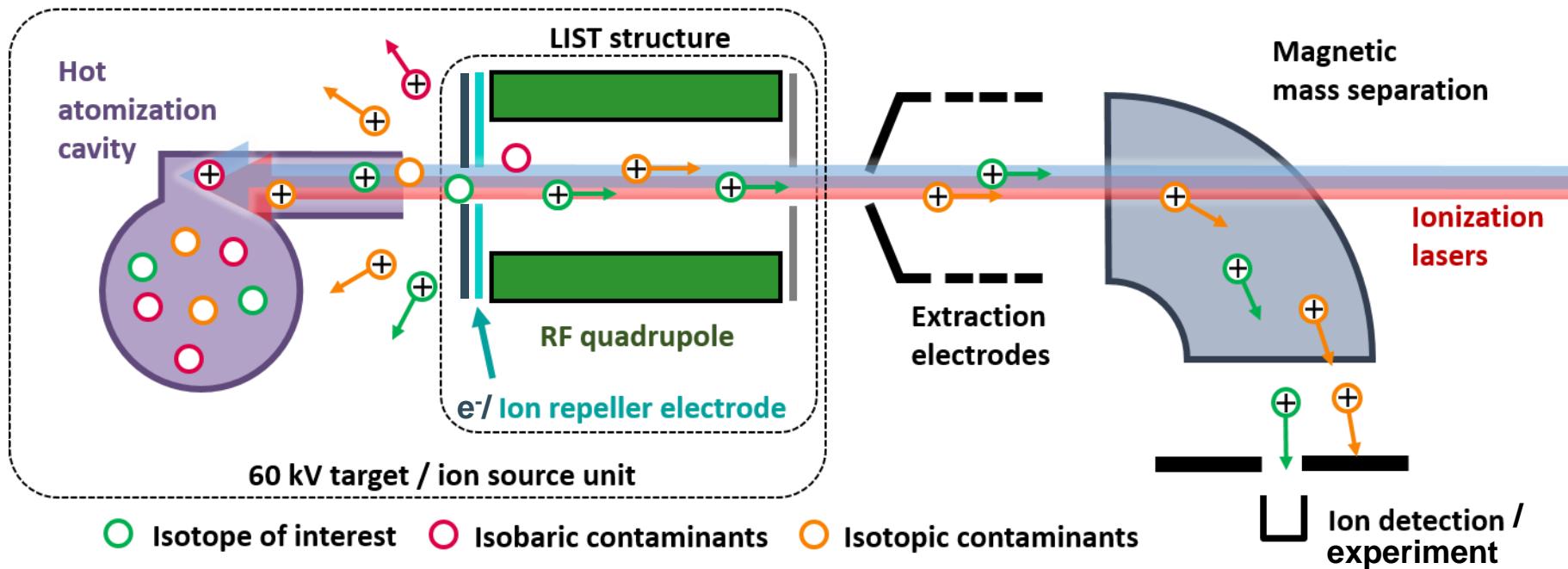
# RILIS at ISOLDE



- Effusion of reaction products provided as **hot atomic vapor** ( $> 2000^\circ\text{C}$ )
- Highly efficient laser ionization of **element of choice**  
*as function of laser wavelength → in-source spectroscopy (<< 1pps)*
- Extraction and mass separation as **ion beam**
- **Beam purity influenced by competing ionization mechanisms**

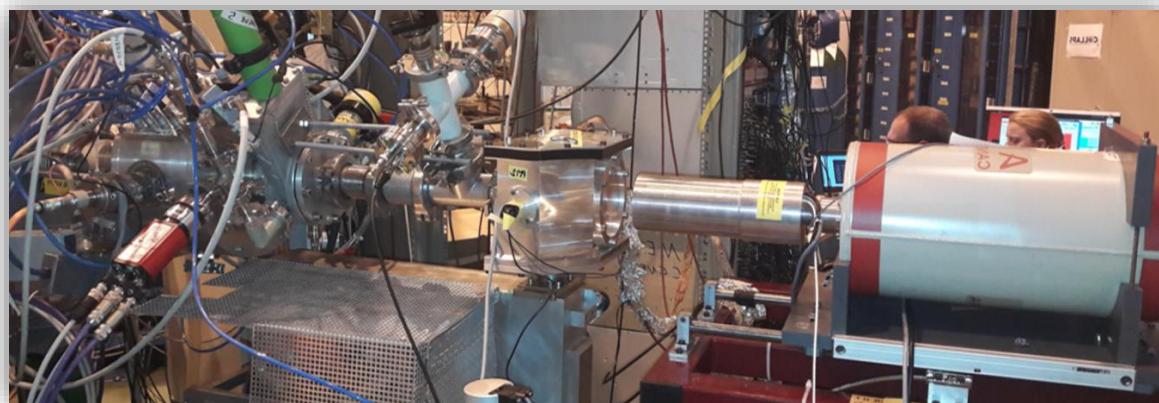
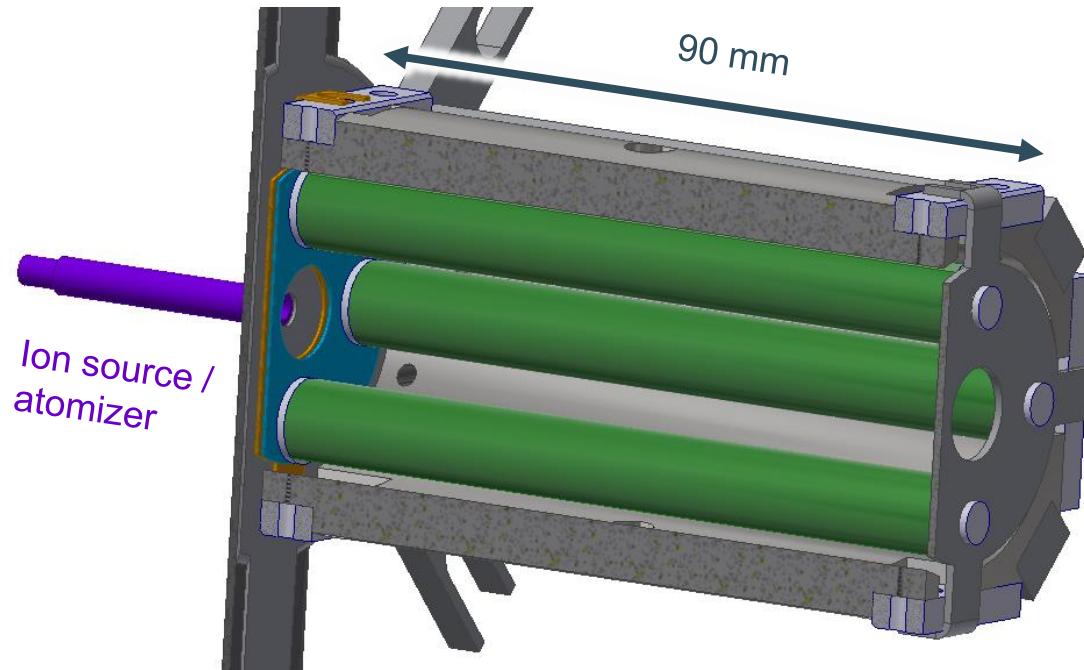


# The Laser Ion Source and Trap LIST



- **Spatial separation:** hot cavity ↔ laser ionization volume
- **Suppression** of surface ionized species
- **Pure laser ionization** inside RF quadrupole structure

# LIST 2018: „Na-free“ magnesium



## ISOLDE Experiment IS 614 / Proposal P459

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

### Proposal to the ISOLDE and Neutron Time-of-Flight Committee

#### Measurement of the super-allowed branching ratio of $^{22}\text{Mg}$

B. Blank, M. Aouadi, P. Ascher, M. Gerbaux, J. Giovinazzo, T. Goigoux, S. Grévy,  
T. Kurtukian Nieto, C. Magron  
CEN Bordeaux-Gradignan, France

A. de Roubin

MPIK Heidelberg, Germany and CEN Bordeaux-Gradignan, France  
P. Delahaye, G.F. Grinyer, J. Grinyer, A. Laffoley, J.-C. Thomas  
GANIL Caen, France

M.R. Dunlop, R. Dunlop, P.E. Garrett, C.E. Svensson  
University of Guelph, Canada

G.C. Ball

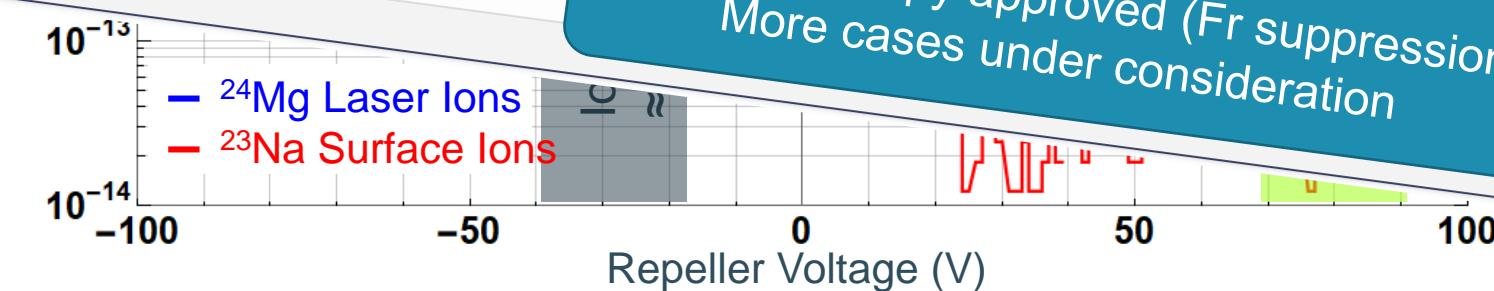
TRIUMF, Vancouver, Canada  
P. Finlay  
K.U. Leuven, Belgium

Silicon 14	Si 22 29 ms	Si 23 42.3 ms	Si 24 140 ms	Si 25 220 ms	Si 26 2.234 s
Aluminium 13	Al 21 35 ns	Al 22 59 ms	Al 23 470 ms	Al 24 131.3 ms	Al 25 7.183 s
Magnesium 12	Mg 20 90 ms	Mg 21 122 ms	Mg 22 3.857 s	Mg 23 11.17 s	Mg 24 78.99
Sodium 11	Na 19 40 ns	Na 20 447.9 ms	Na 21 2.49 s	Na 22 2.60 y	Na 23 100
Neon 10	Ne 18 1.672 s	Ne 19 17.22 s	Ne 20 90.48	Ne 21 0.27	Ne 22 9.5

# LIST performance



/BB/

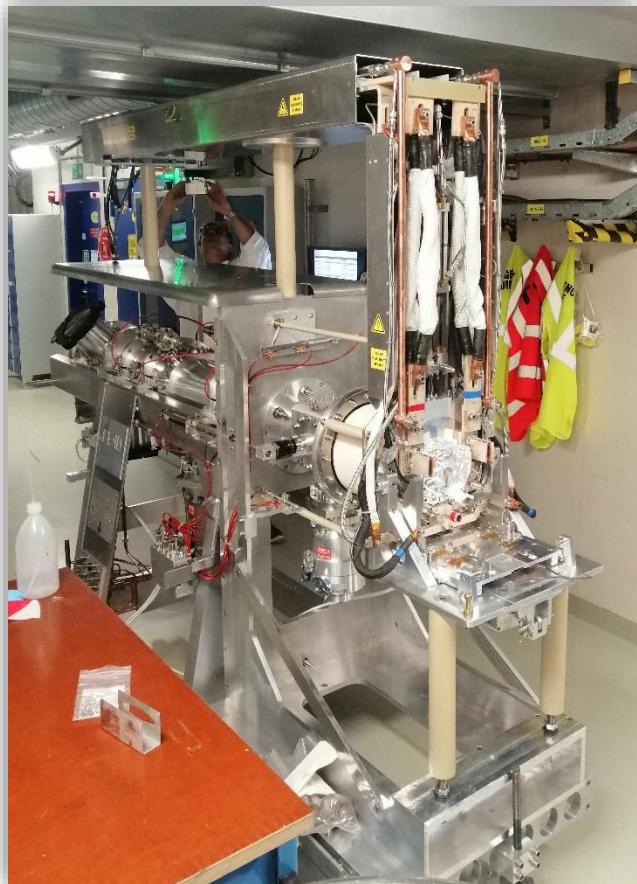


## Radioisotopes ( $\beta$ counting)

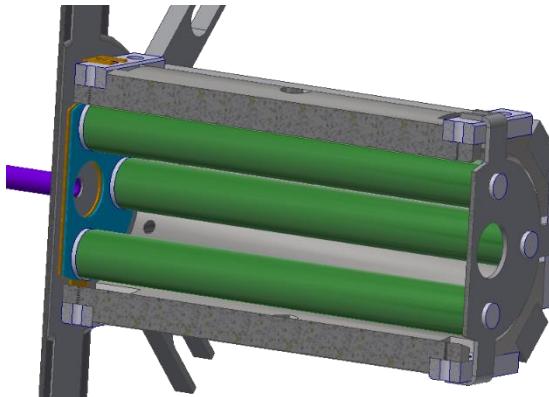
	Before run	After run (4 days)
Loss Factor ( $^{22}\text{Mg}$ , $T_{1/2} = 3.9\text{s}$ )	28	26
Suppression Factor ( $^{21}\text{Na}$ , $T_{1/2} = 22.5\text{s}$ )	$1.0 \cdot 10^6$	$1.6 \cdot 10^6$

# Infrastructure upgrade in LS2

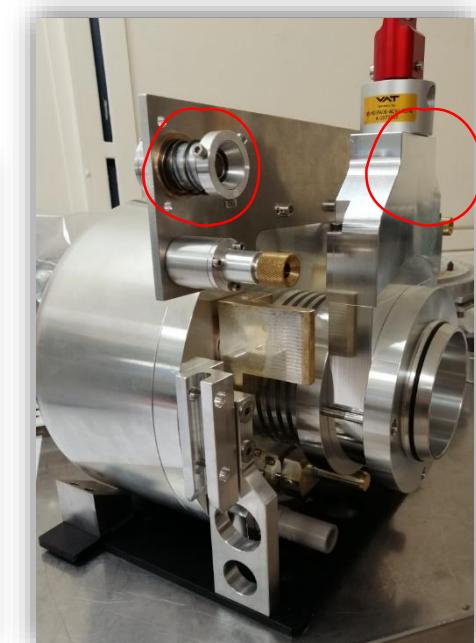
Both GPS and HRS frontends will be compatible with LIST



New GPS frontend



RF coupling connectors



New RF and gas line connections on target side

# LIST RF supply



Previous LIST  
target unit

Transformer circuit at the target unit

- Phase splitting and voltage amplification
- Radiation-hard design
- Final tuning to be done before coupling
- No direct monitoring
- Complex manufacturing for every unit
- Non-routine robot handling and storage
- Additional radioactive waste

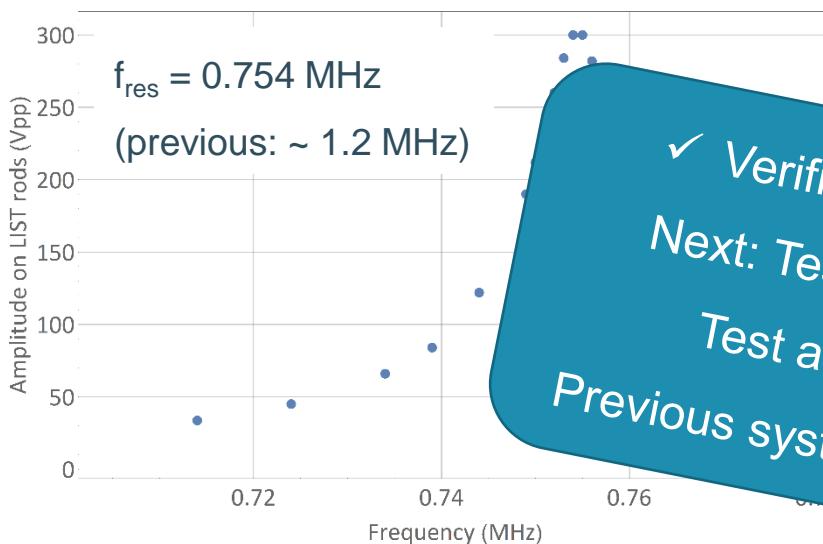
→ Two independent RF supply lines  
open up interesting alternatives!

# RF supply refinement

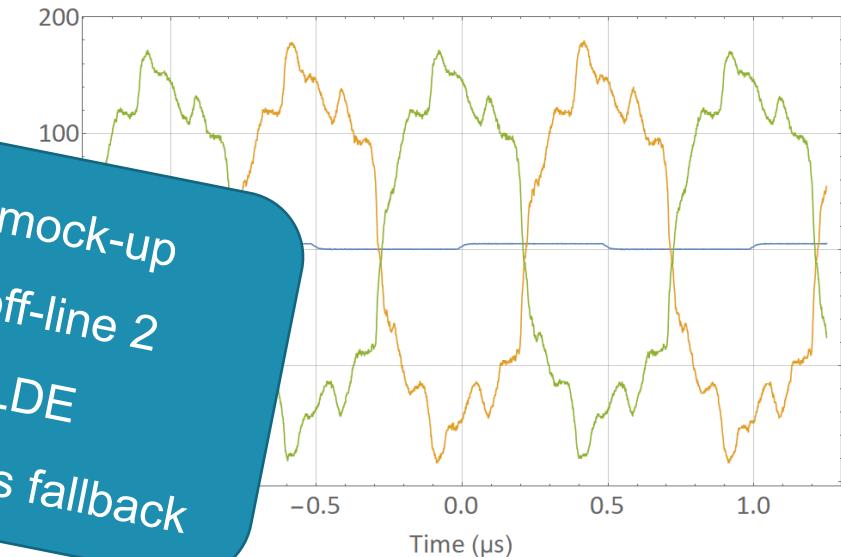
Mock-up setup for testing: >15m coax cable in between voltage generation and LIST

Requirement: **up to 200 Vpp amplitude** on quadrupole rods

Option 1: Transformed sine wave



Option 2: Fast switching of +/- DC supply



✓ Verified in mock-up  
Next: Test at off-line 2  
Test at ISOLDE  
Previous system as fallback

- “Old” electronics and transformer box in HV cage
- Refinement via simulations

- Setup like TRIUMF’s IG-LIS
- Possible with anode power supplies
- Frequency adjustable

Both options:

- Direct monitoring / tuning options
- Possibility for DC offset

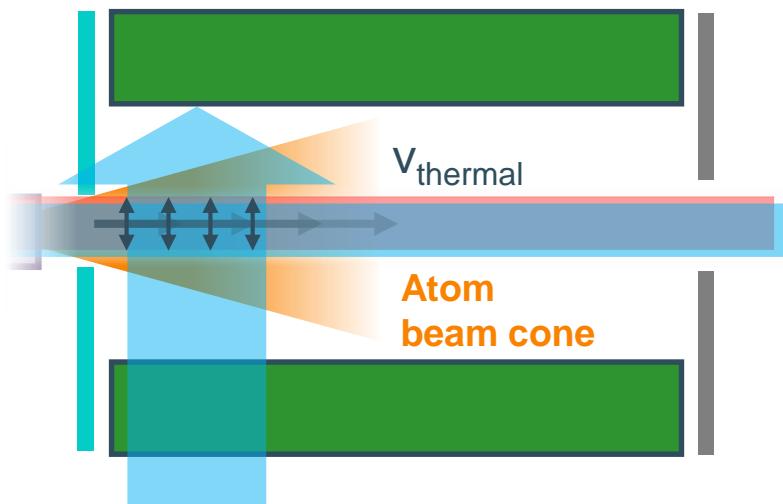
# ISOLDE's high purity ion source LIST

## High-resolution laser spectroscopy upgrade

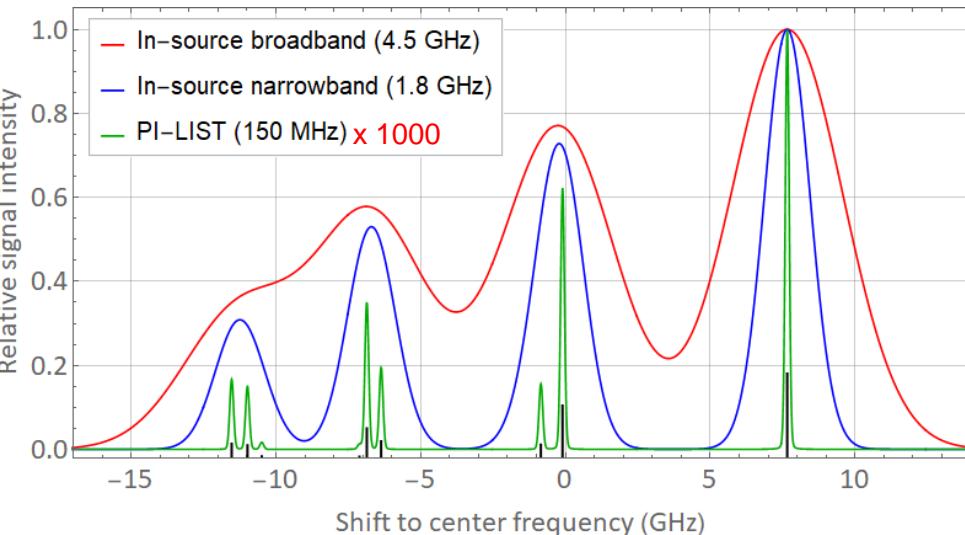
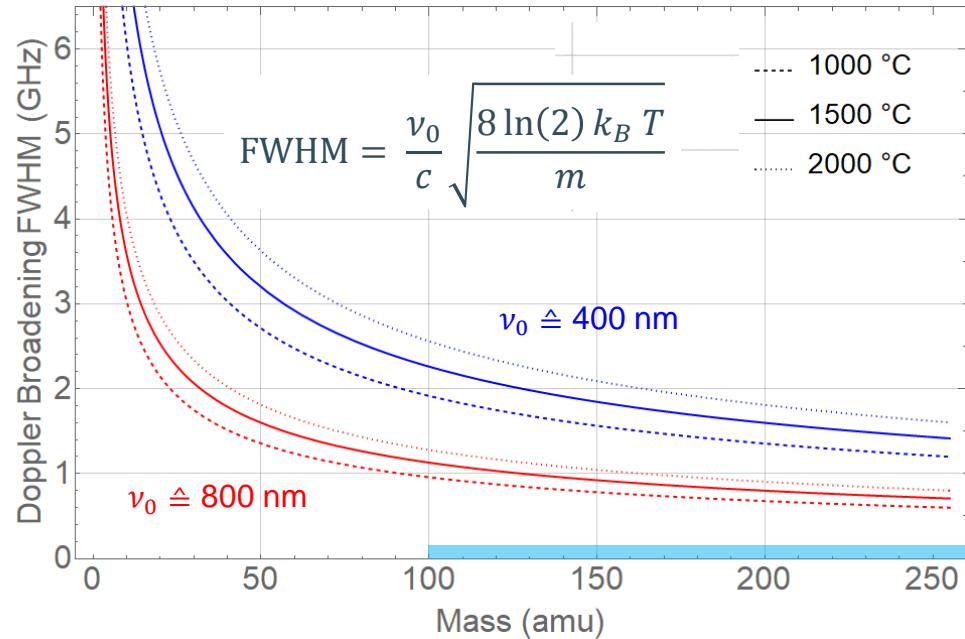
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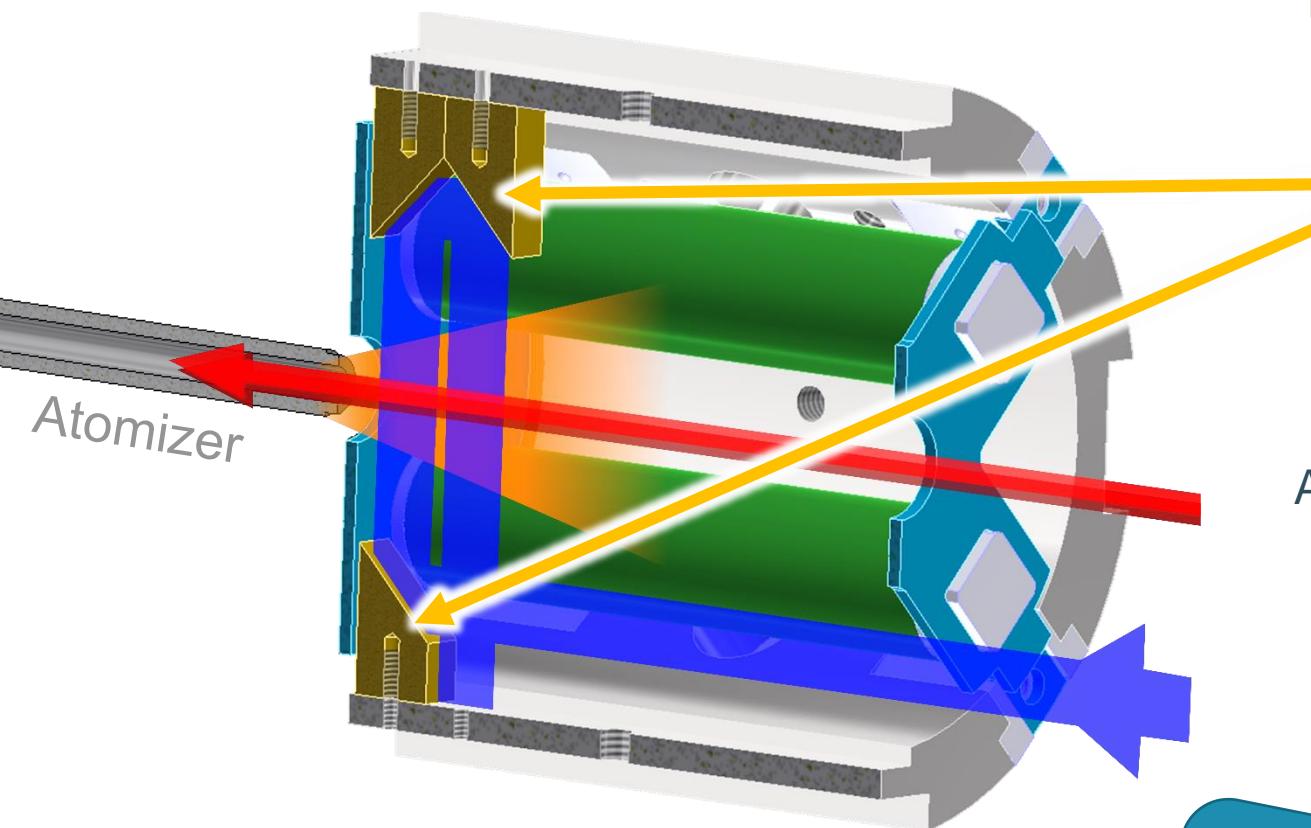
# Enhanced laser resolution: Cross-beam geometry



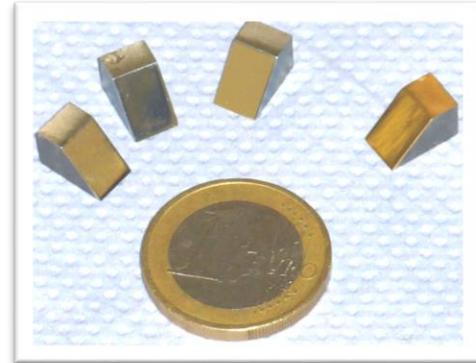
Narrow bandwidth spectroscopy laser available via CRIS-RILIS link



# The perpendicularly illuminated PI-LIST



Robust metallic mirrors



Adapted extraction electrode

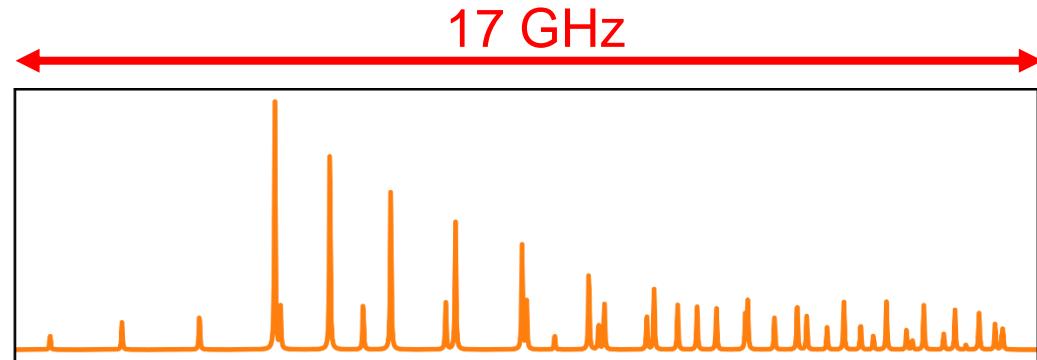


✓ Machined  
Next: Extensive “real life”  
comparison with current  
version at off-line 2

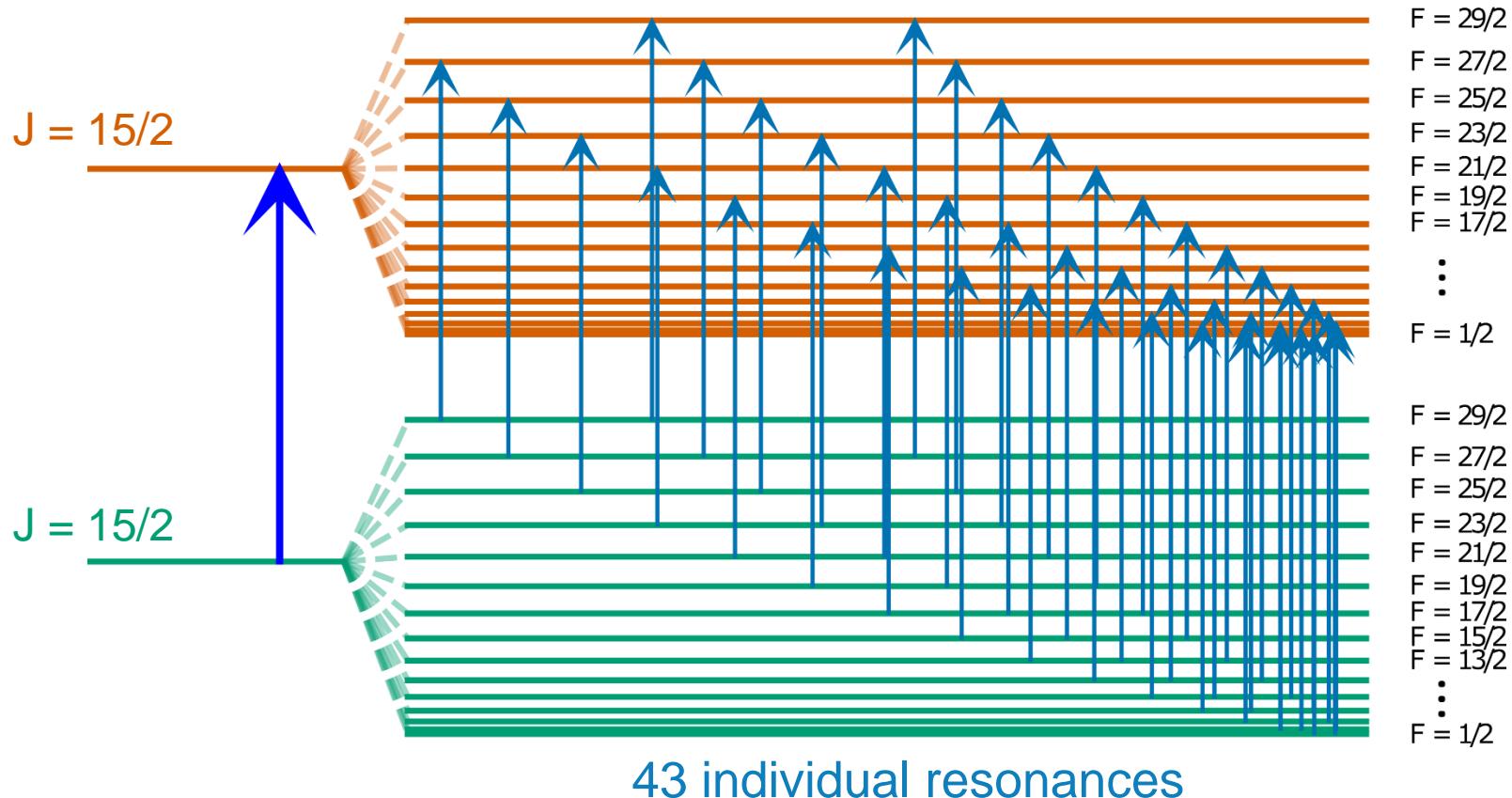
- Transversal reflection by **metallic mirror** surfaces
- **Off-axis guiding** of laser through ion beam line

# Holmium: A case for high resolution

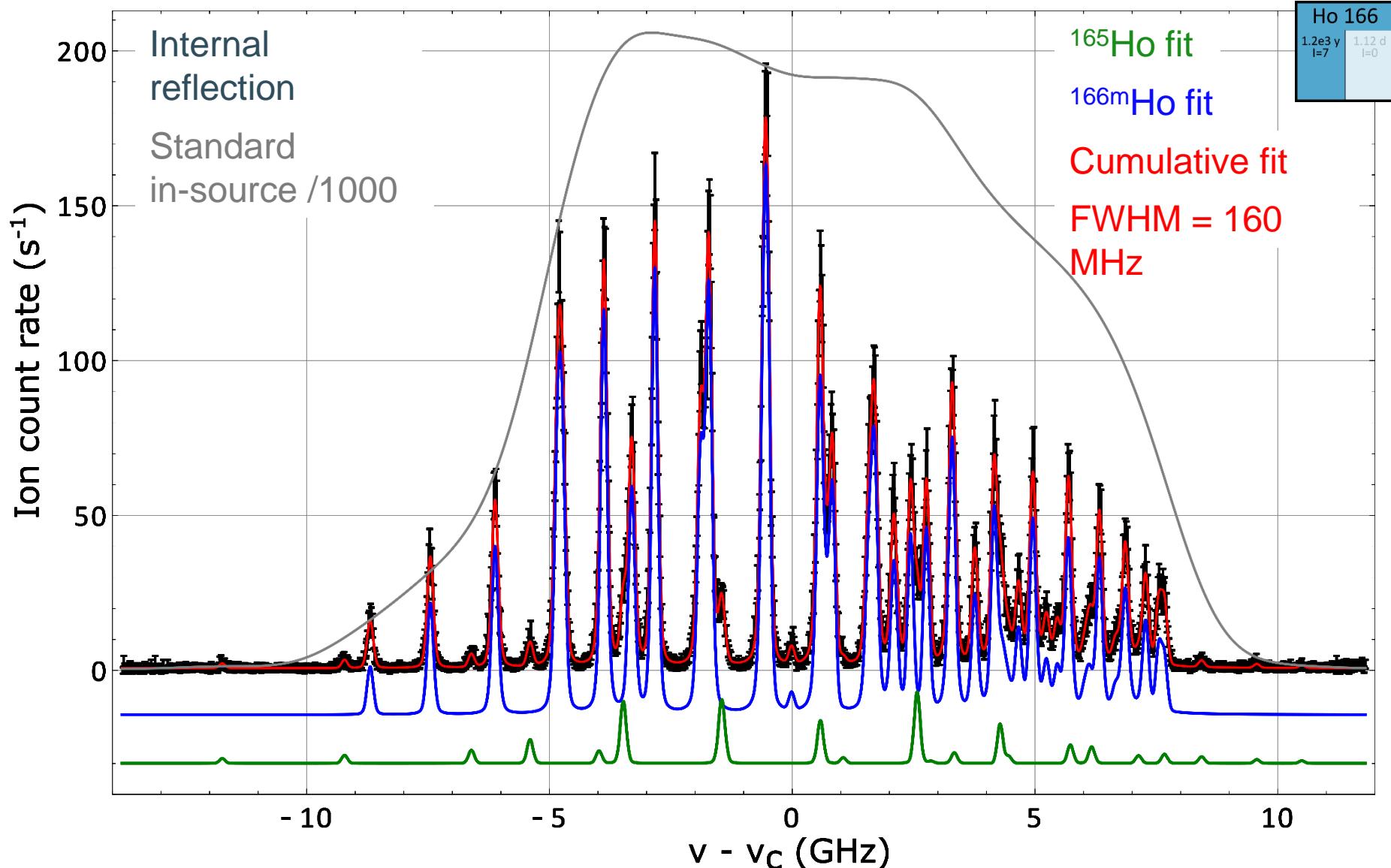
PI-LIST  
introduced at



Ho 166	
1.2e3 y I=7	1.12 d I=0



# PI-LIST in action: Holmium hyperfine structure

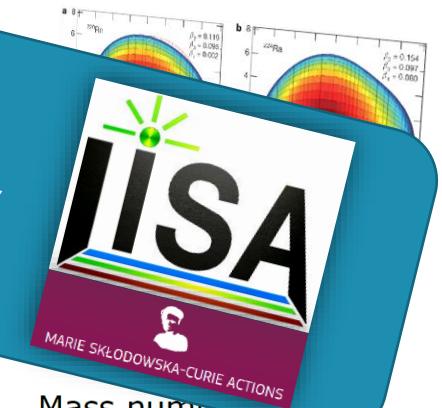


„Bonus“: Direct extraction of isotope shift  $\Delta v_{IS}$  → Isomer selection capability

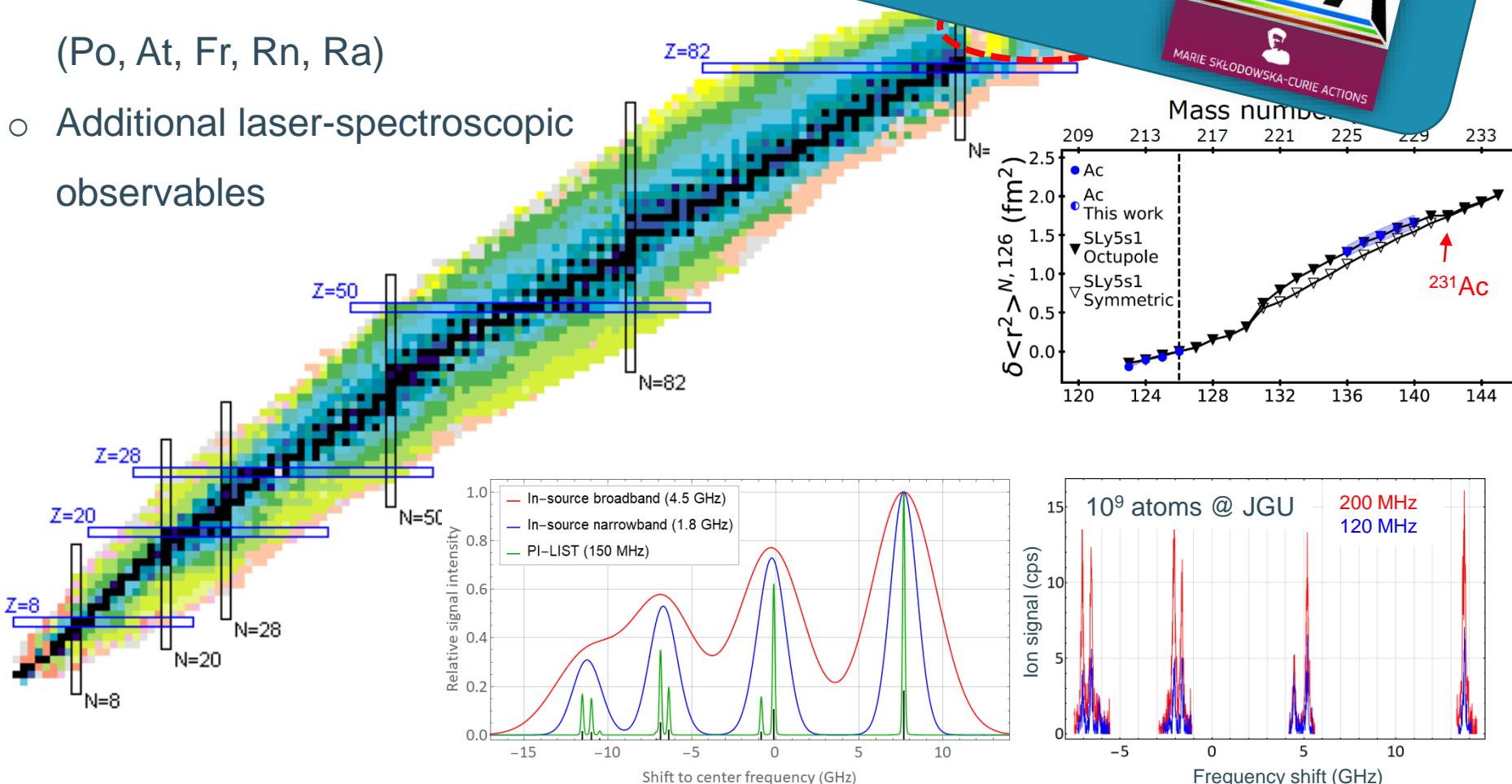
# Nuclear shape investigations in actinium (P-556)

- Pear shaped intrinsic nuclear configurations
- Inverted odd-even staggering of charge radius as characteristic?  
(Po, At, Fr, Rn, Ra)
- Additional laser-spectroscopic observables

Laser Ionization  
and Spectroscopy  
of Actinides



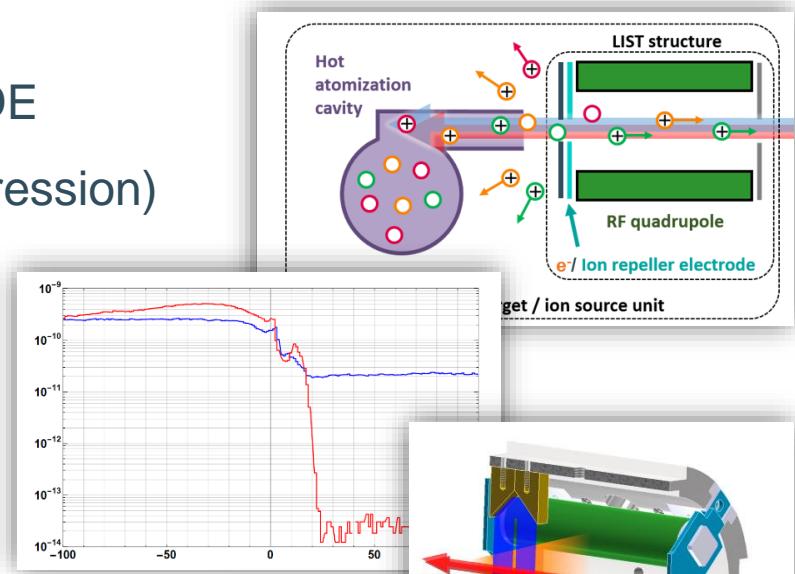
Verstraelen et al., Phys. Rev. C 100, 044321 (2019)



# Summary

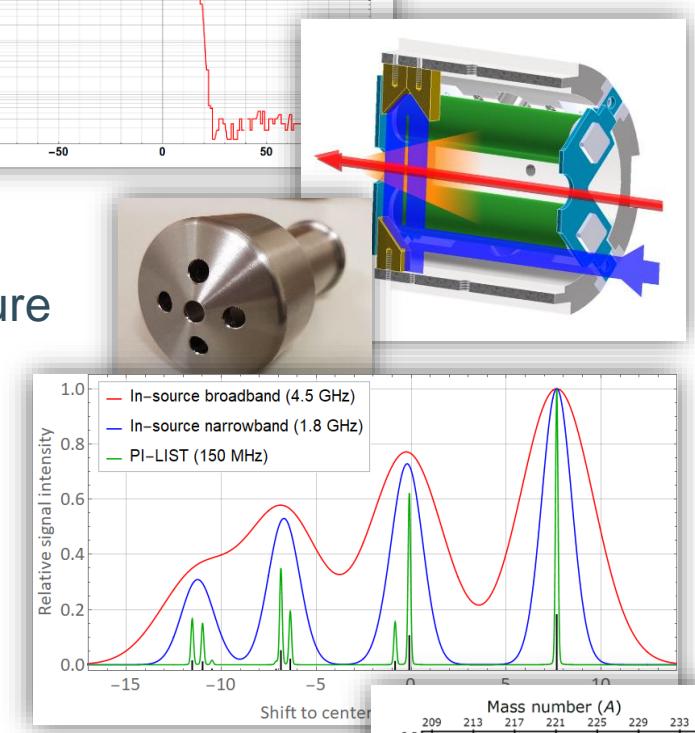
## The Laser Ion Source and Trap LIST @ ISOLDE

- Purified ion beams ( $\sim 10^6$  contaminant suppression)  
@ moderate intensity decrease ( $\sim 1/25$ )
- Both GPS and HRS supporting LIST
- Refined RF supply infrastructure



## The high-resolution upgrade PI-LIST

- Perpendicular laser irradiation inside LIST structure
- Implementation at ISOLDE ongoing
- High resolution laser spectroscopy on actinium
- Isomer-selective ionization (depending on HFS)  
@ significant intensity decrease ( $\sim 1/1000$ )



LIST to be on-line again in 2021!

Thanks for *LIS*Tening ...



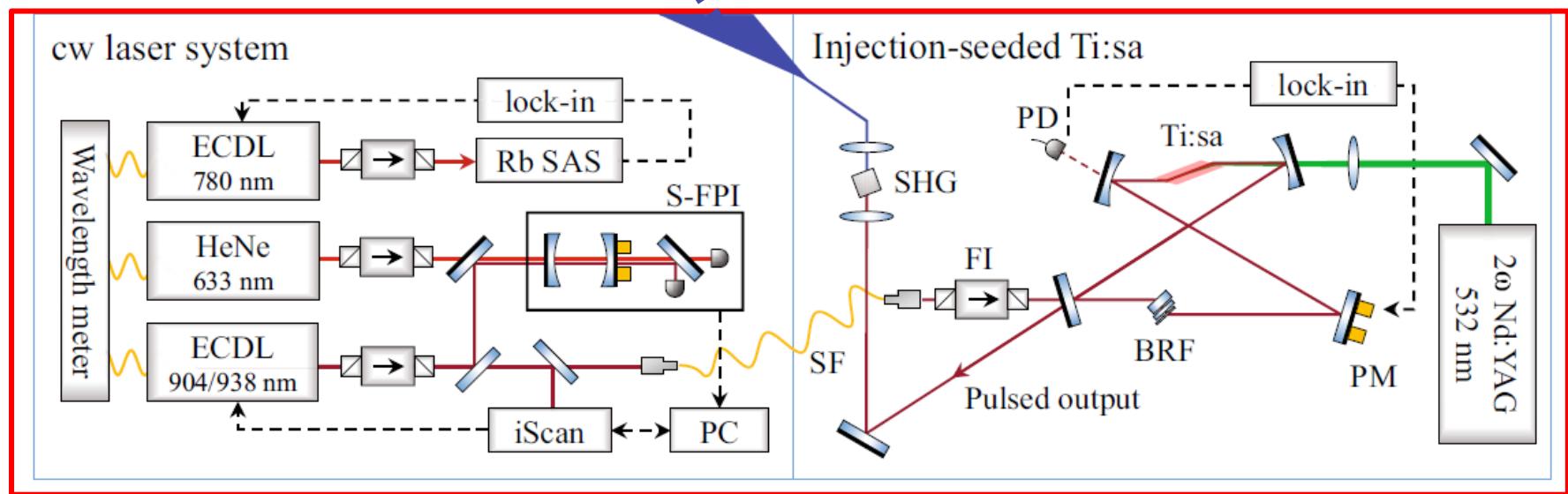
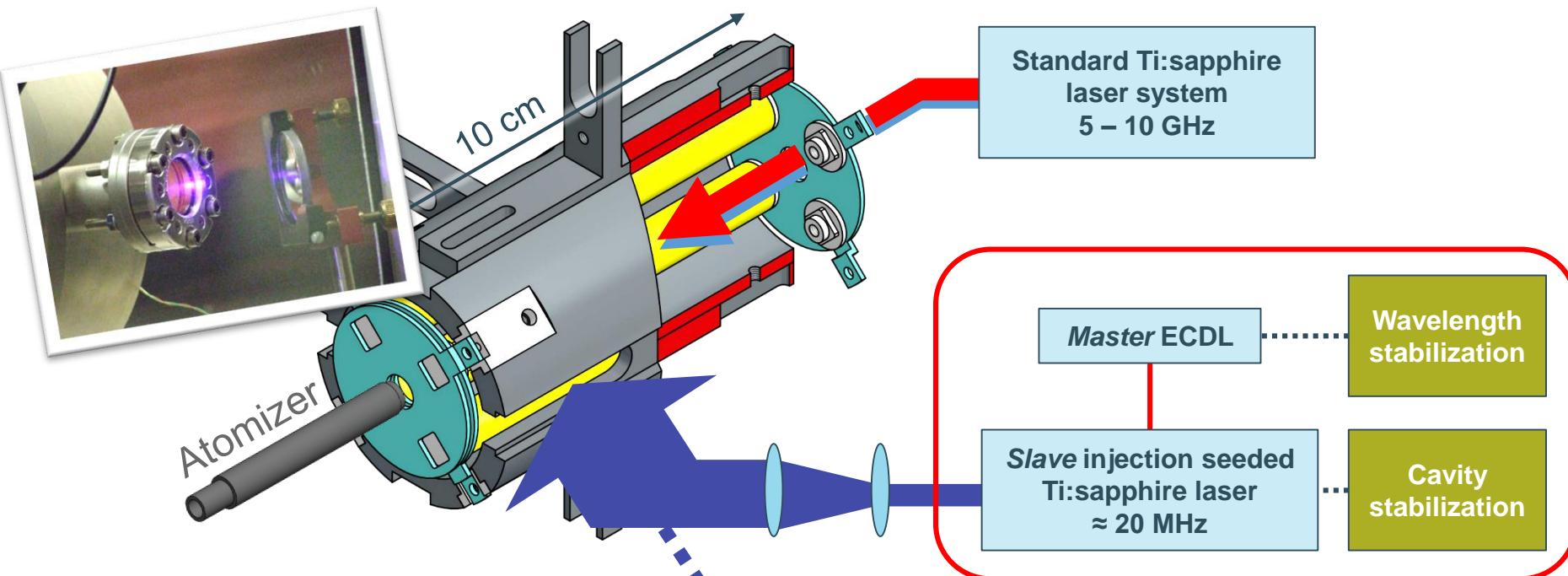
JOHANNES GUTENBERG  
UNIVERSITÄT MAINZ

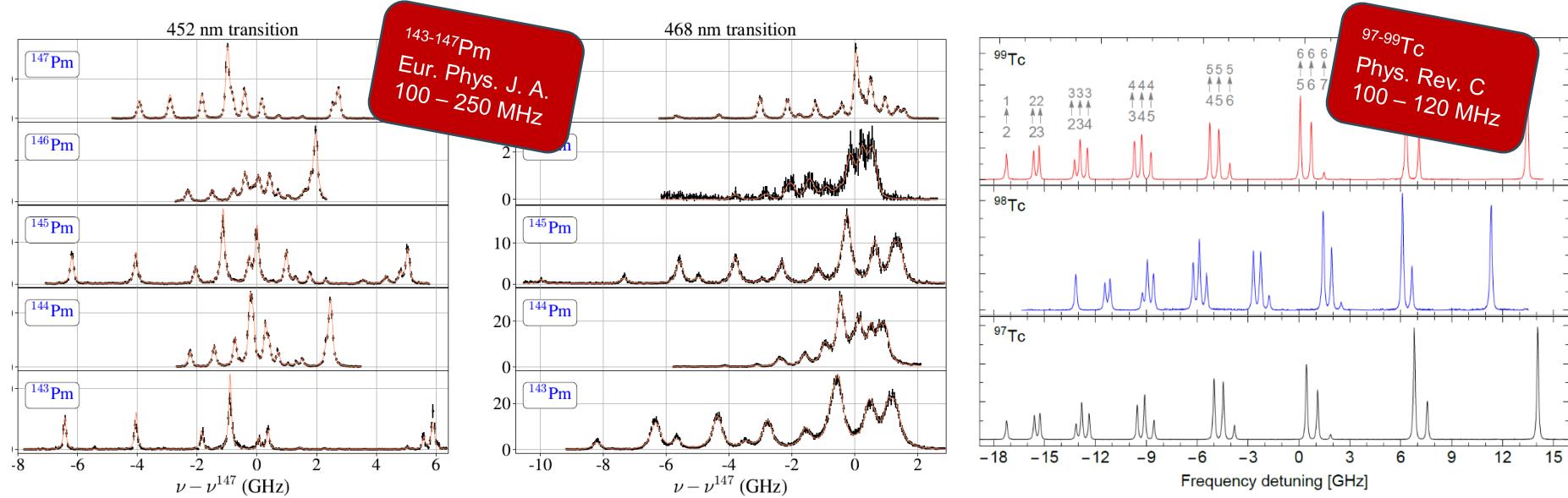


... and thanks to the collaborators!

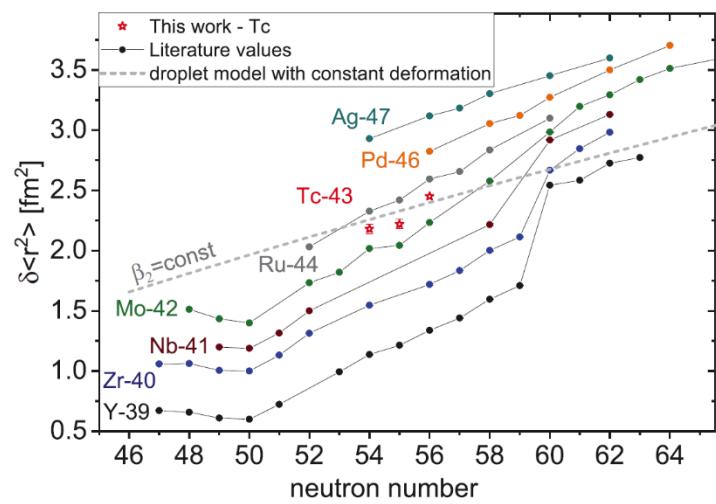
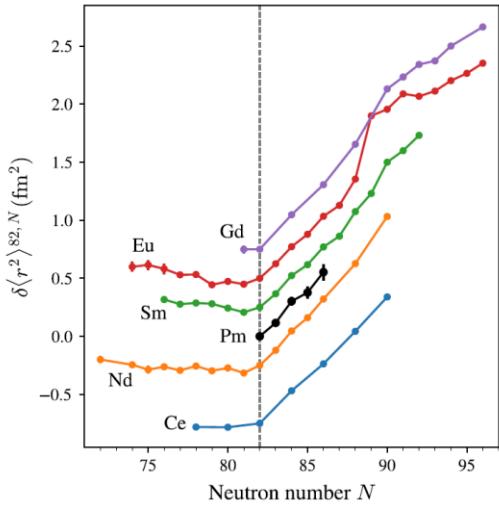
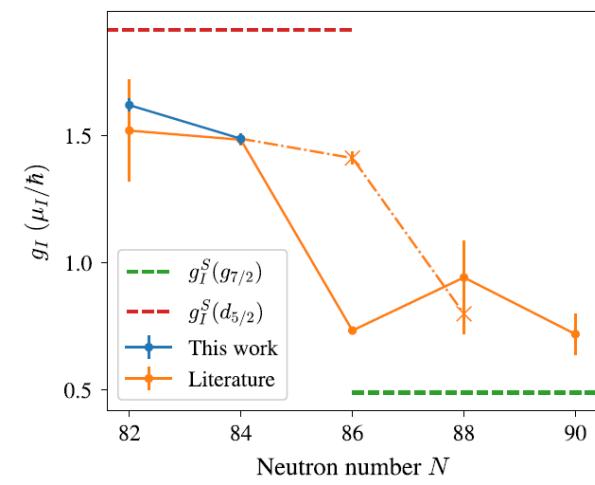


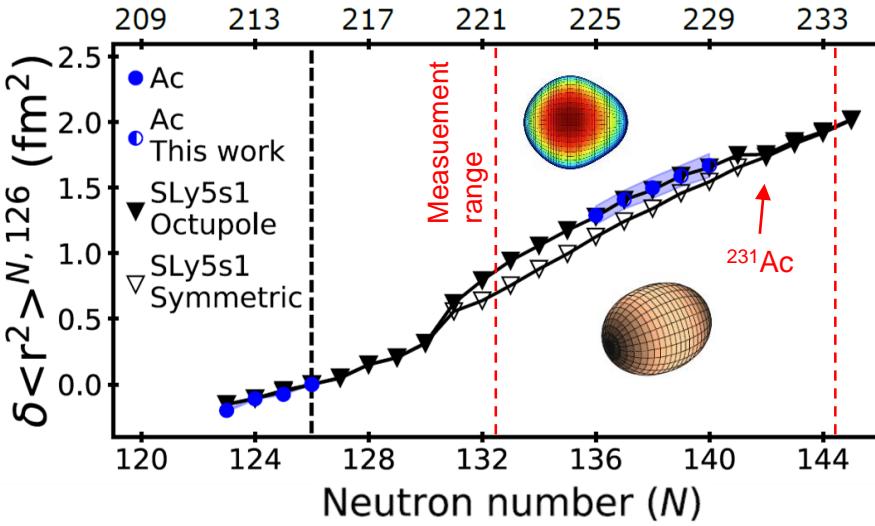
Loss factors	Operation mode	Estimated efficiency (%)
RILIS → LIST ~ 30	Standard RILIS	20
	LIST ion guide mode	10
	LIST suppression mode	0.2
LIST → PI-LIST ~ 4	External PI mode (BB)	0.1
	Internal PI mode (BB)	0.1 .. 0.02
PI-LIST opt. ~ 10	External PI mode(NB)	0.001 .. 0.02
<b>~ 1,000 → Overall efficiency</b>		<b><math>10^{-4} .. 10^{-5}</math></b>





Extraction of  $I$ ,  $\mu$ ,  $Q_s$ ,  $\delta\langle r^2 \rangle$



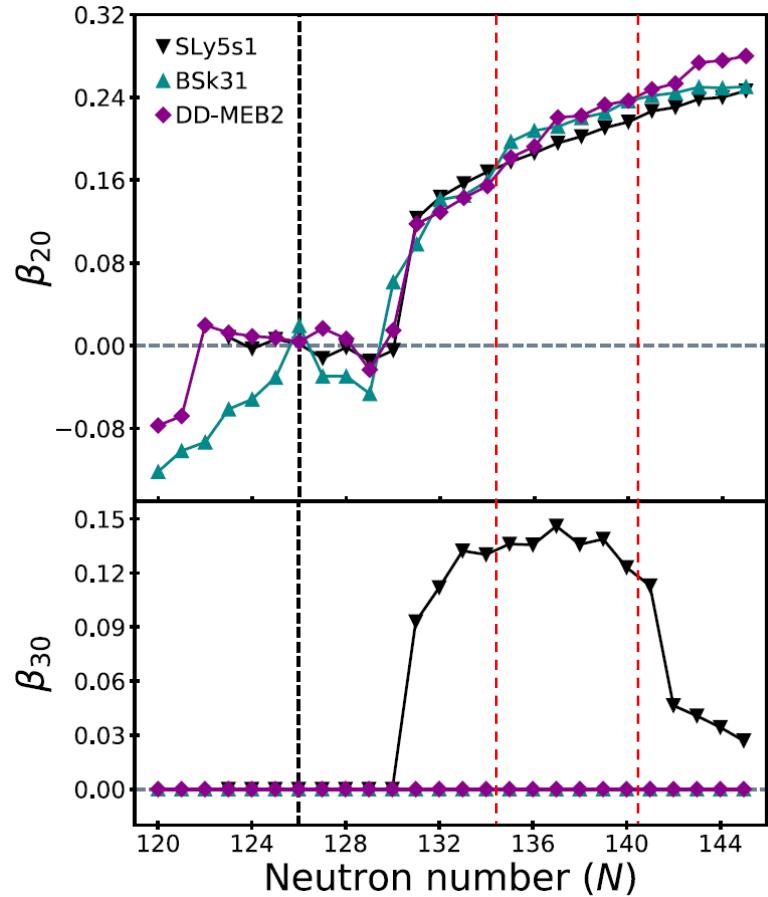


### Mean square charge radii

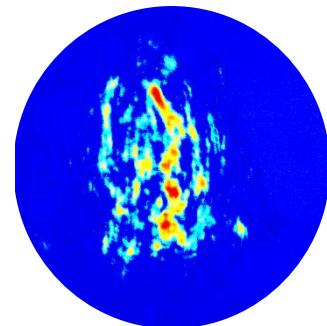
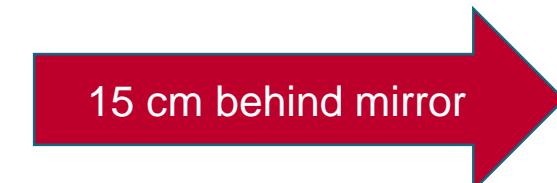
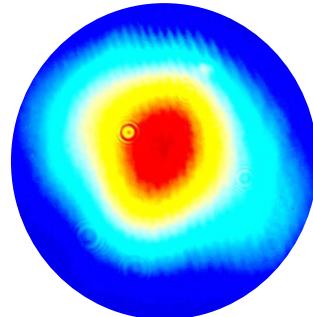
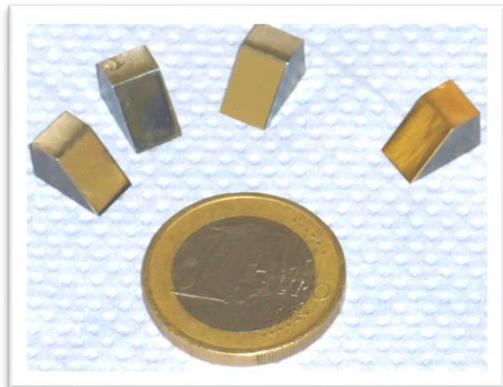
- Incorporation of reflection-asymmetry
- Evaluation of odd-even staggering
- High-res. measurements of  $\delta \langle r^2 \rangle$

### Higher order deformation parameters

- A priori charge radii potentially arising from different multipole contributions
- Non-symmetry restricted calculations agrees with Th data
- Disentanglement by determinations of  $Q_s$



$6 \times 6 \text{ mm}^2$  polished steel, produced at institute workshop



- Shape distortion - no influence on opening angle

Long term reflectivity performance:

$R = 60 - 65 \%$

3 weeks

$R = 50 - 60 \%$   
(last: 20 %)

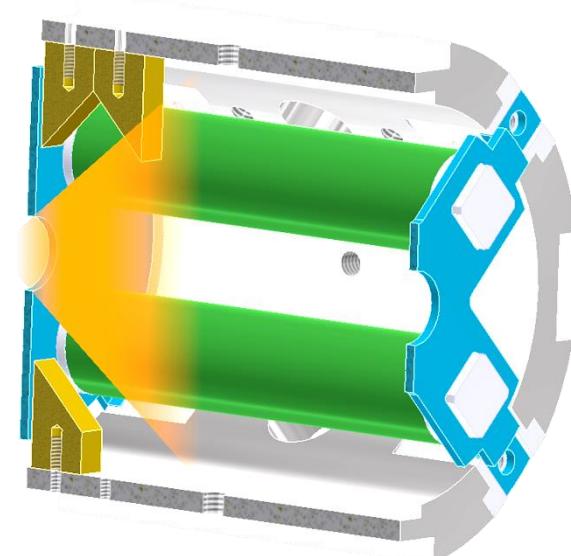


- **Silver coating by pulsed laser deposition:**

$R = 80 - 85 \%$

6 weeks

$R = 75 - 85 \%$



## Use of existing laser infrastructure - easy mode switching by mirror adjustment

- Full conservation of „classical“ operation modes

