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MARA Low-Energy Branch: A new facility for the study of exotic proton-rich nuclei

2021 ECR Forum

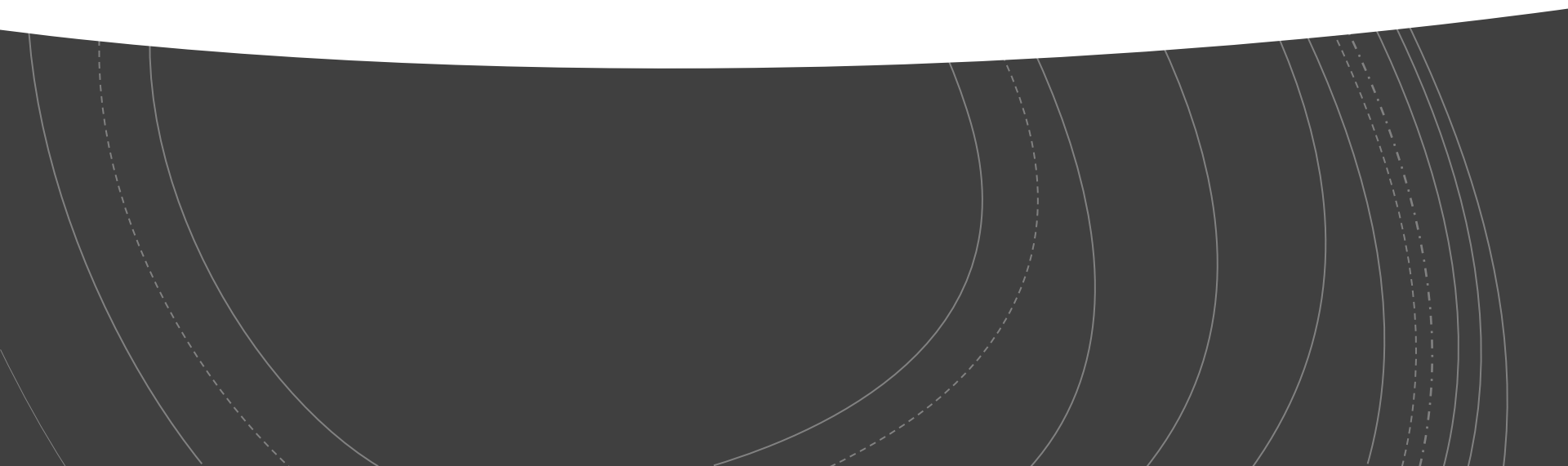
Philippos Papadakis

UKRI-STFC

Outline

- My career path
- Scientific motivation and concept
- Facility layout and individual parts
- Project outlook

My career path



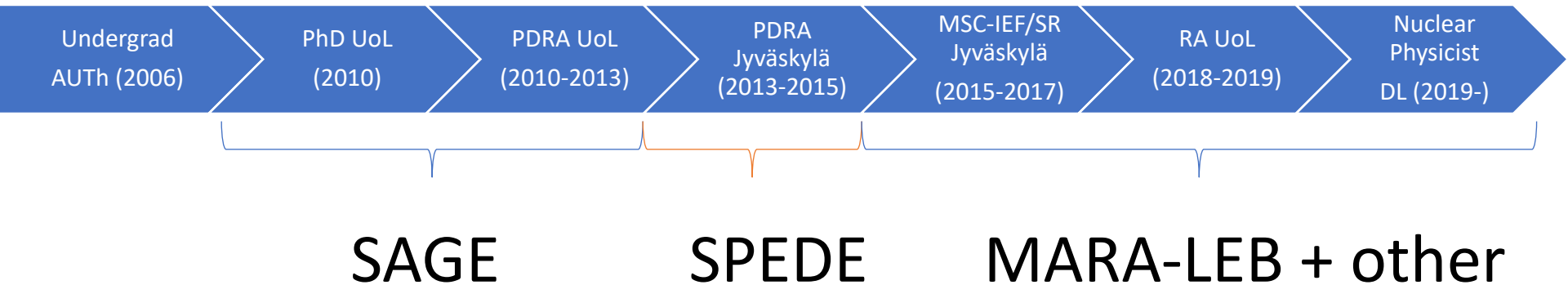
My career path



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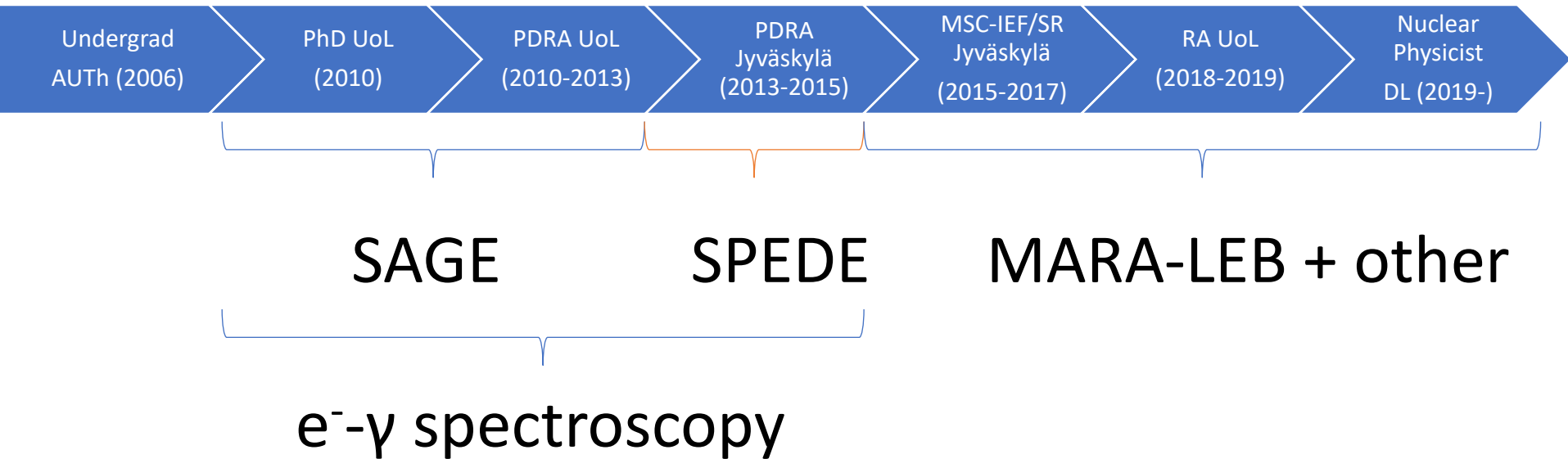
My career path



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My career path



A few words of advice

- Mobility

A few words of advice

- Mobility
- Variety

A few words of advice

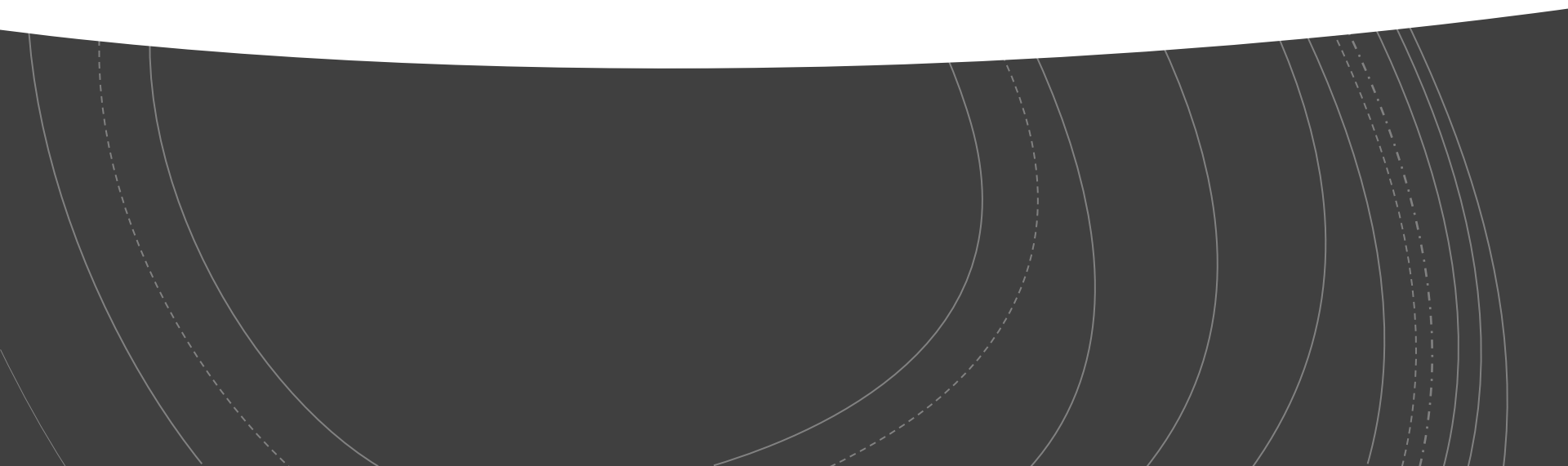
- Mobility
- Variety
- Diversify outside research



A few words of advice

- Mobility
- Variety
- Diversify outside research
- Just give it a go

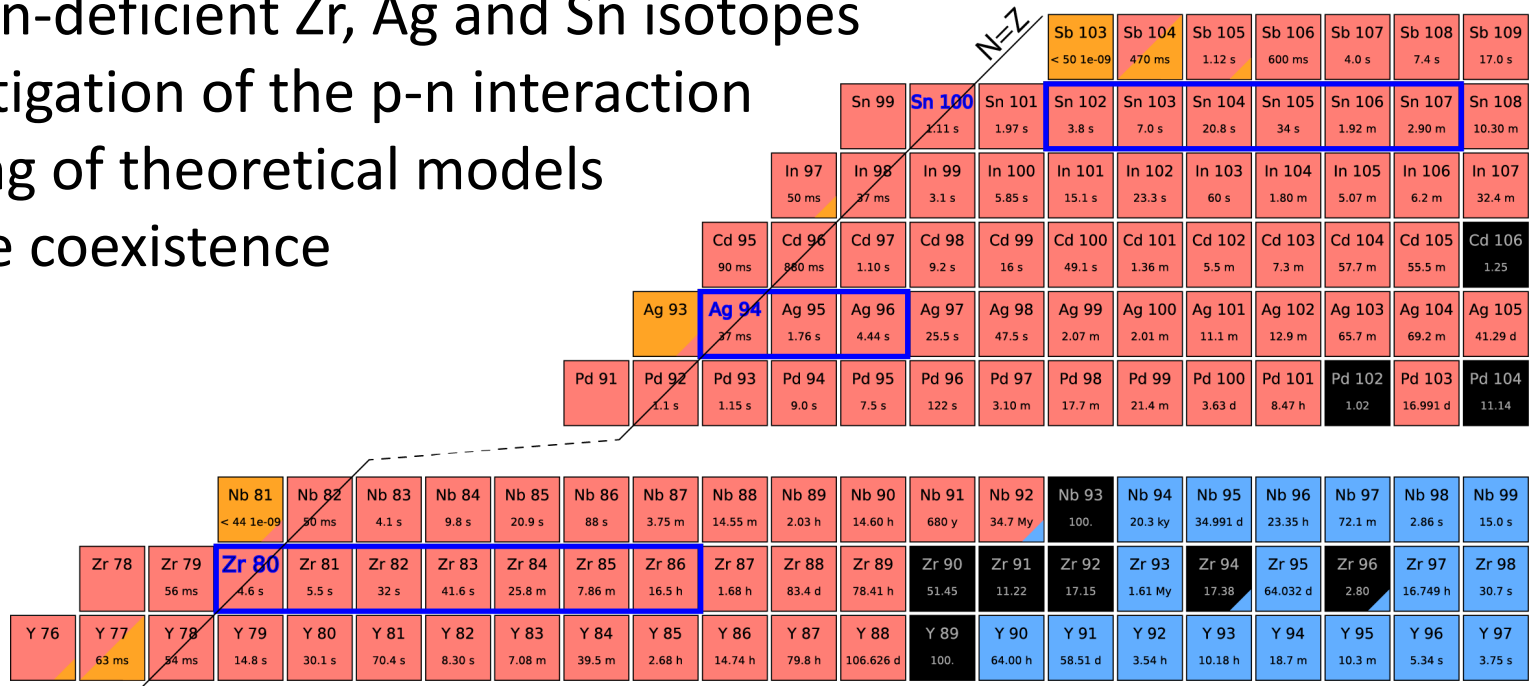
Scientific motivation and concept



Scientific motivation – Laser ionization and spectroscopy

Neutron-deficient Zr, Ag and Sn isotopes

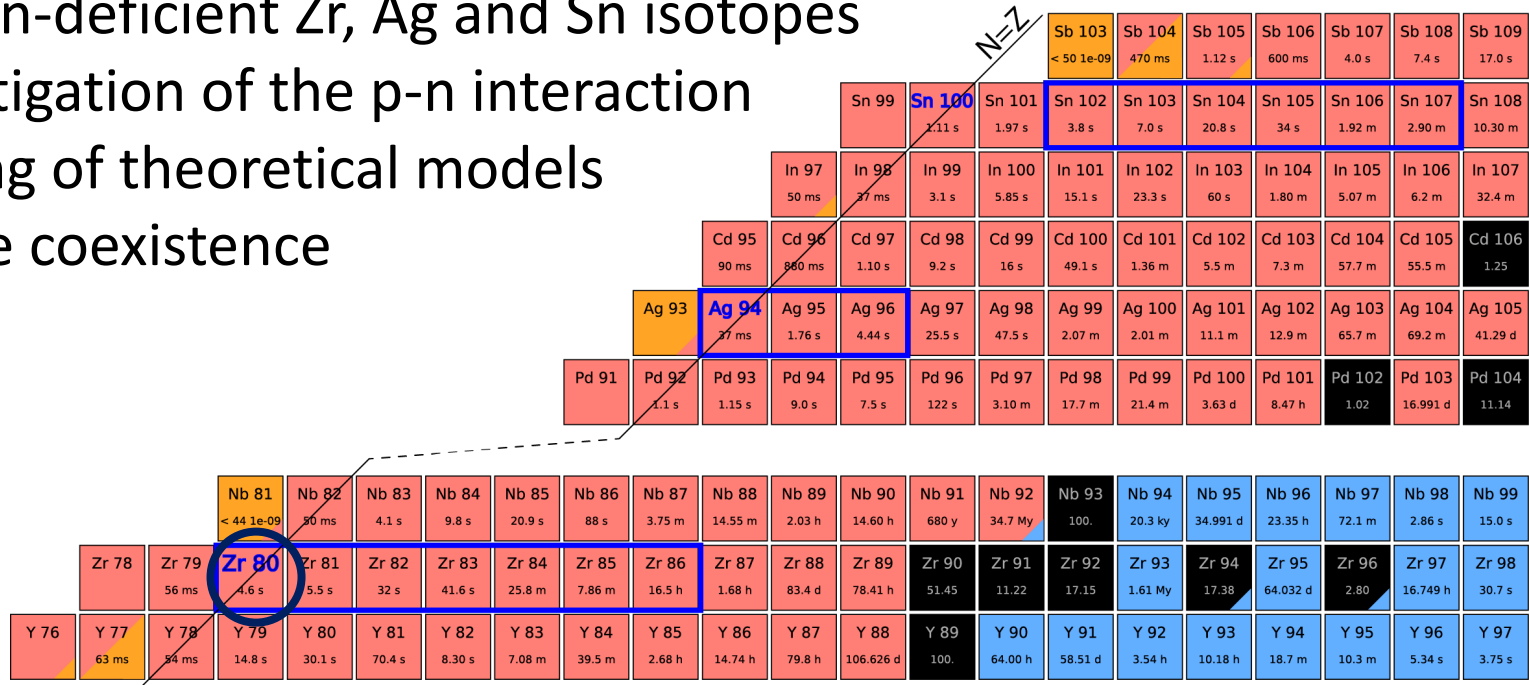
- Investigation of the p-n interaction
- Testing of theoretical models
- Shape coexistence



Scientific motivation – Laser ionization and spectroscopy

Neutron-deficient Zr, Ag and Sn isotopes

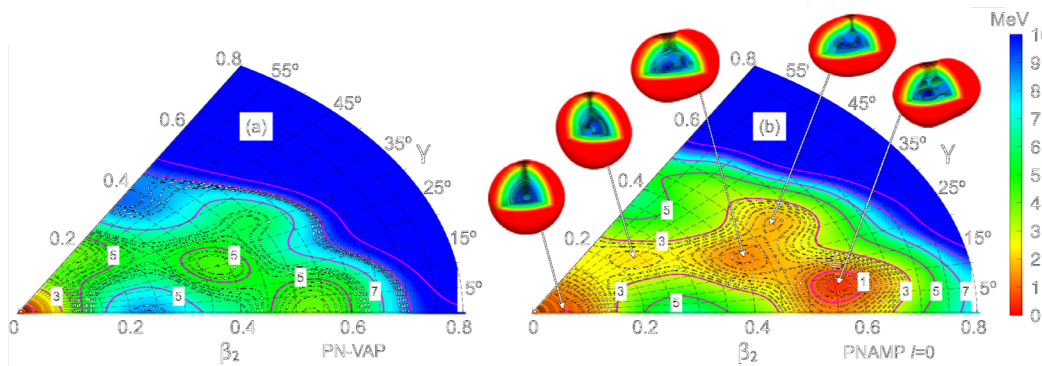
- Investigation of the p-n interaction
- Testing of theoretical models
- Shape coexistence



Scientific motivation – Laser ionization and spectroscopy

Example: ^{80}Zr

- Highly deformed
- Theoretical predictions indicate coexistence of 5 shapes
- Waiting point of astrophysical rp-process



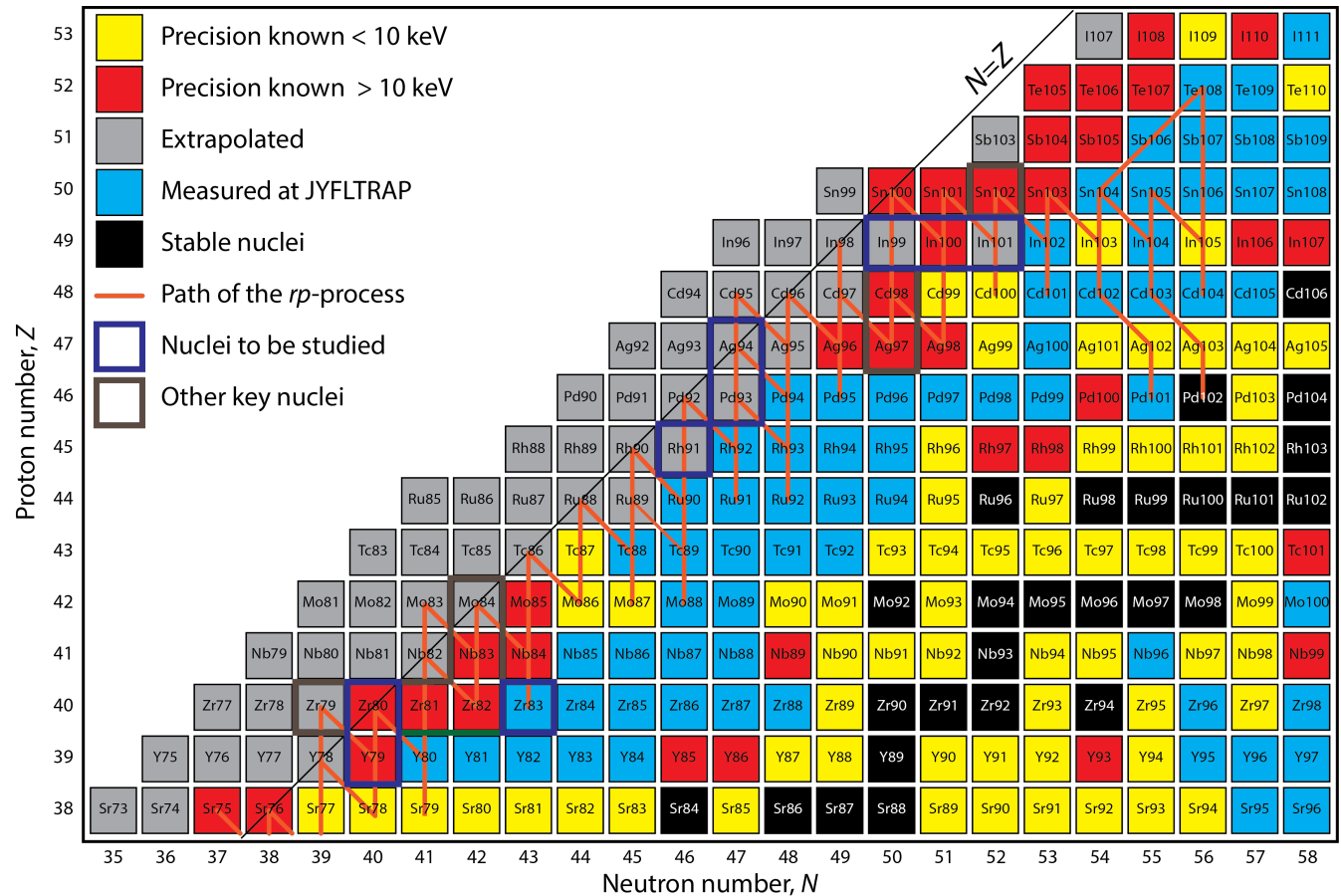
PN-VAP: Particle number
symmetry restored
PNAMP: Rotational
symmetry also restored

T. Rodriguez and J. Luis Egido, Phys. Lett. B **705**, 255 (2011)

Scientific motivation – Mass measurements

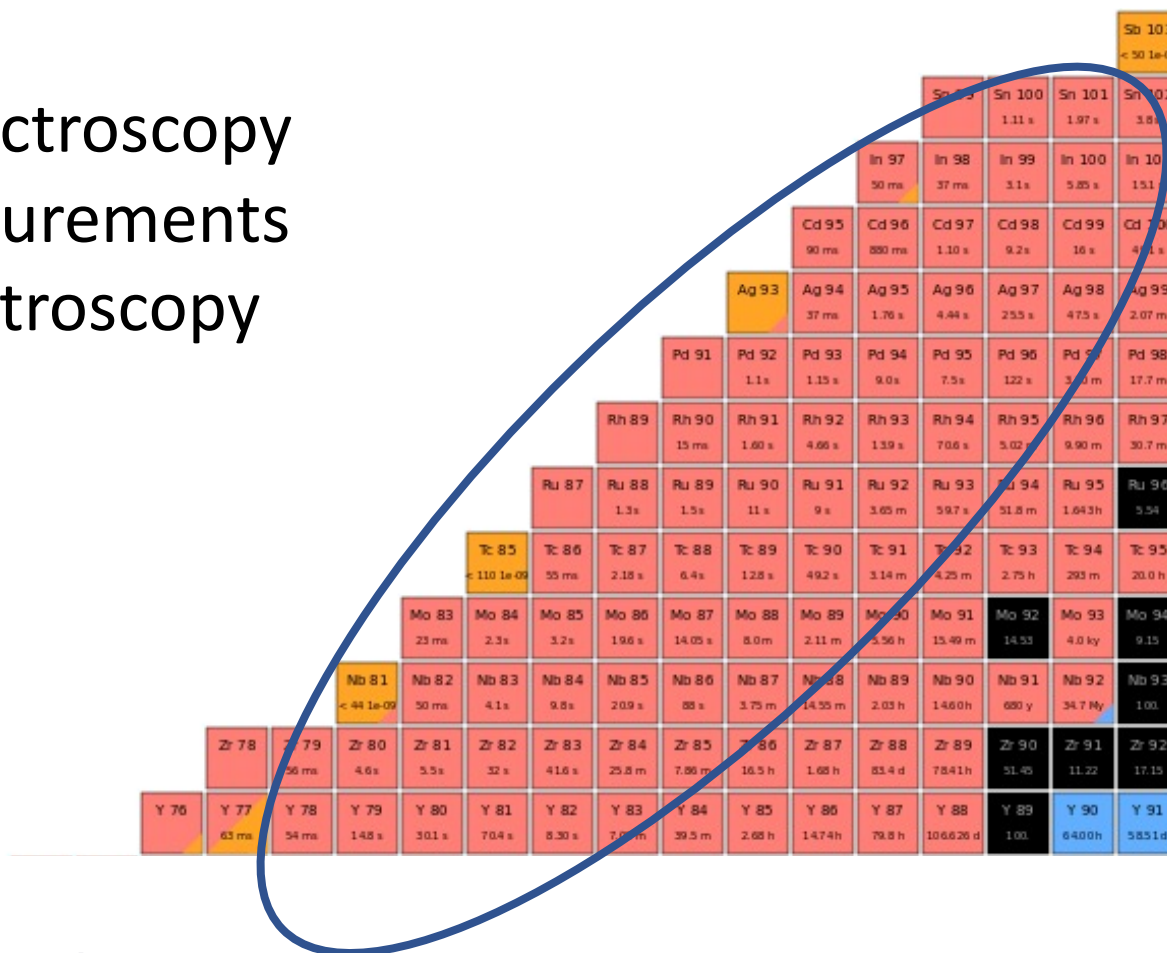
Nuclei close to the
proton drip line with
 $79 < A < 108$:

- Key nuclei for the *rp*-process
- ^{80}Zr waiting point nucleus
- ^{94}Ag : 2p decay of $J^\pi=(21^+)$ isomer?



Scientific motivation

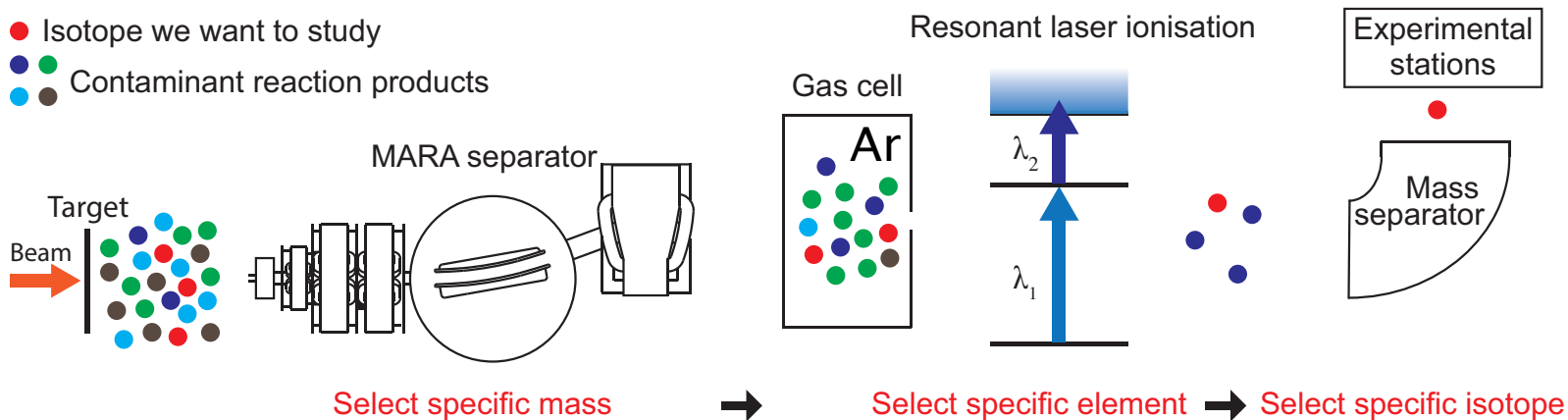
- Optical spectroscopy
- Mass measurements
- Decay spectroscopy



MARA-LEB concept

1

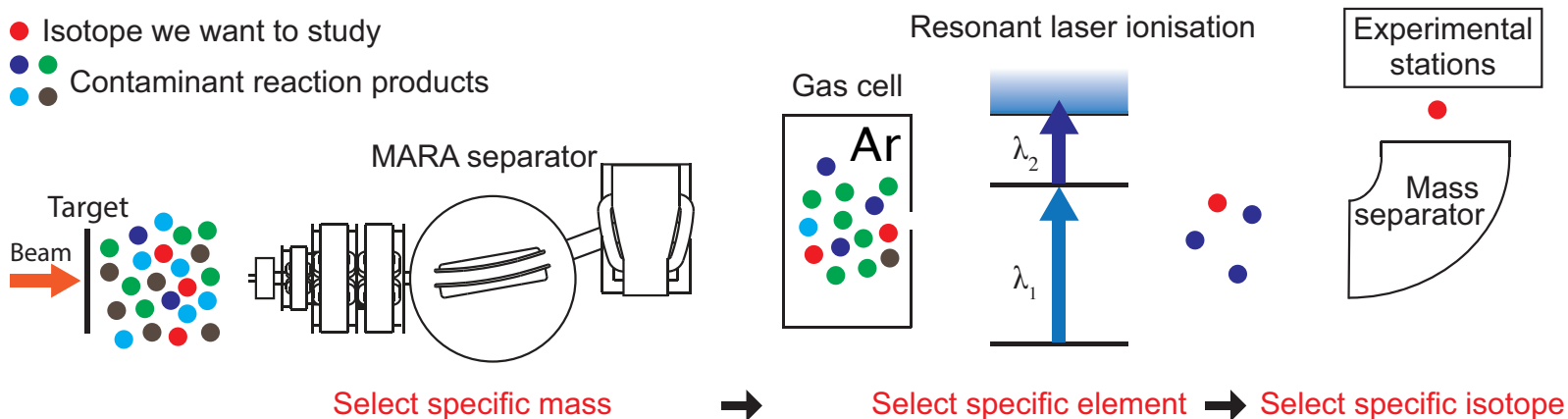
- Isotope we want to study
- Contaminant reaction products



MARA-LEB concept

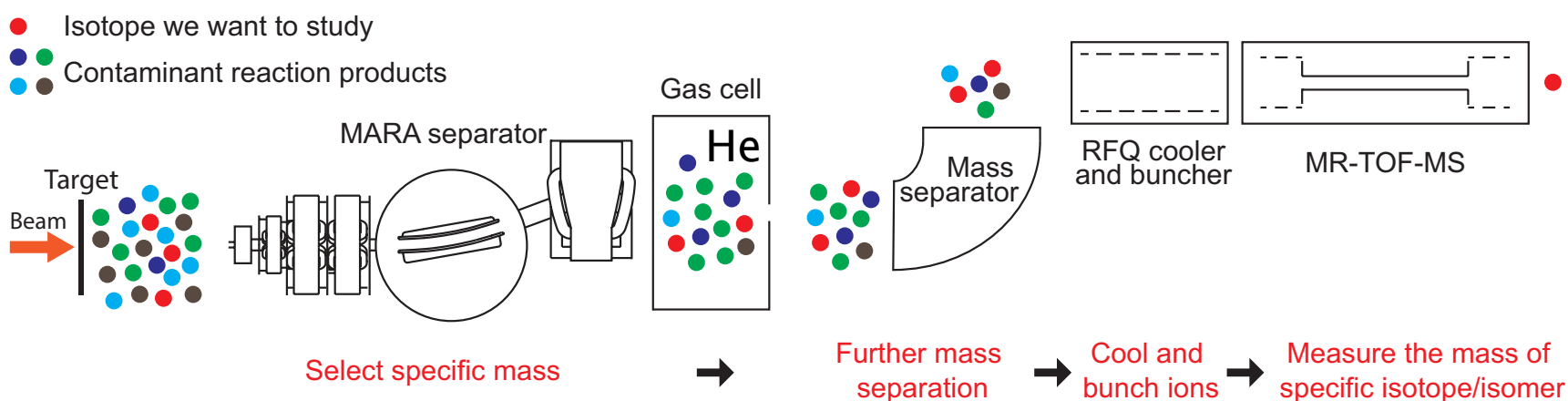
1

- Isotope we want to study
- Contaminant reaction products

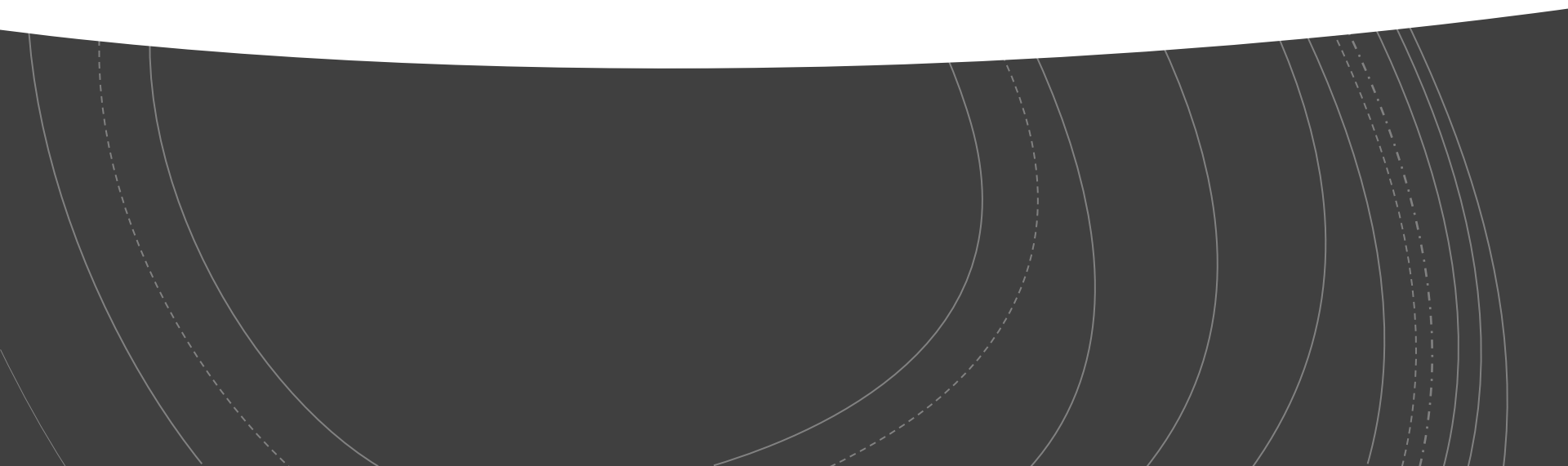


2

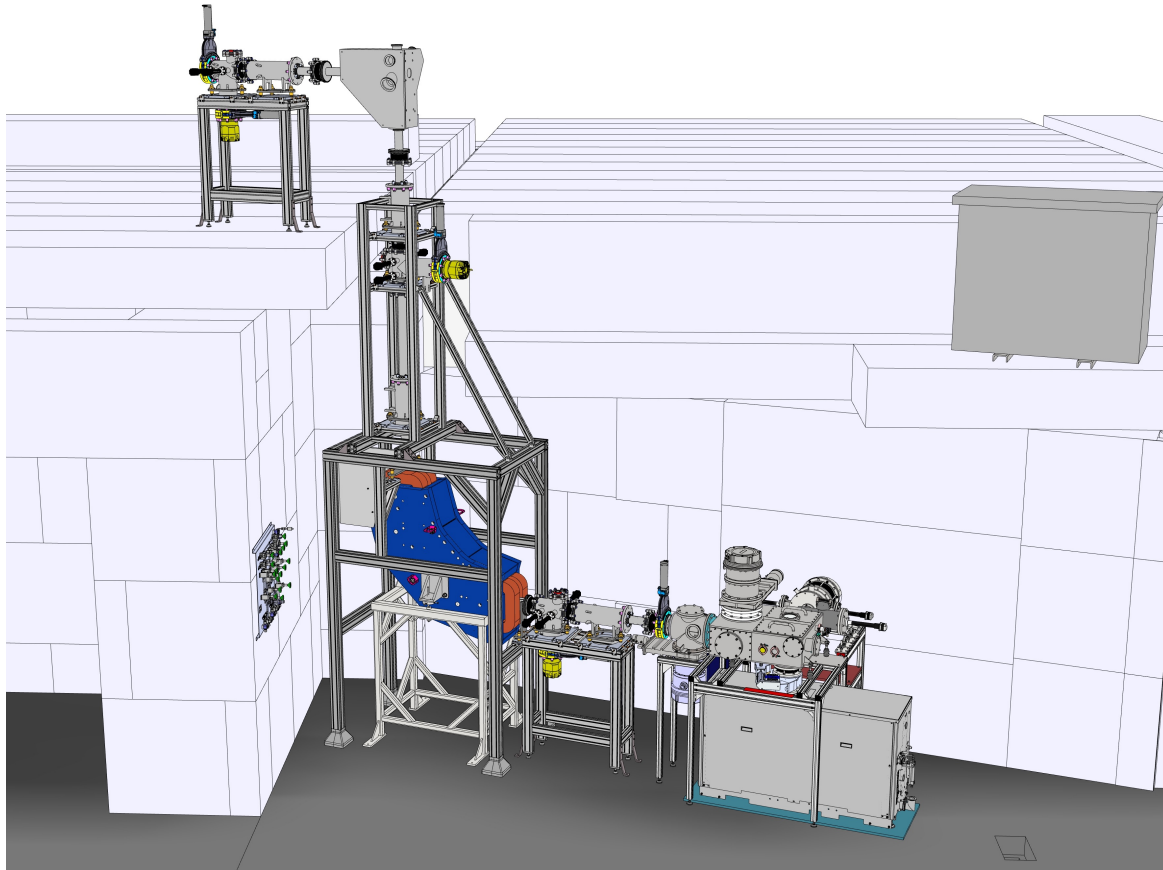
- Isotope we want to study
- Contaminant reaction products



Facility layout and individual parts



Facility layout



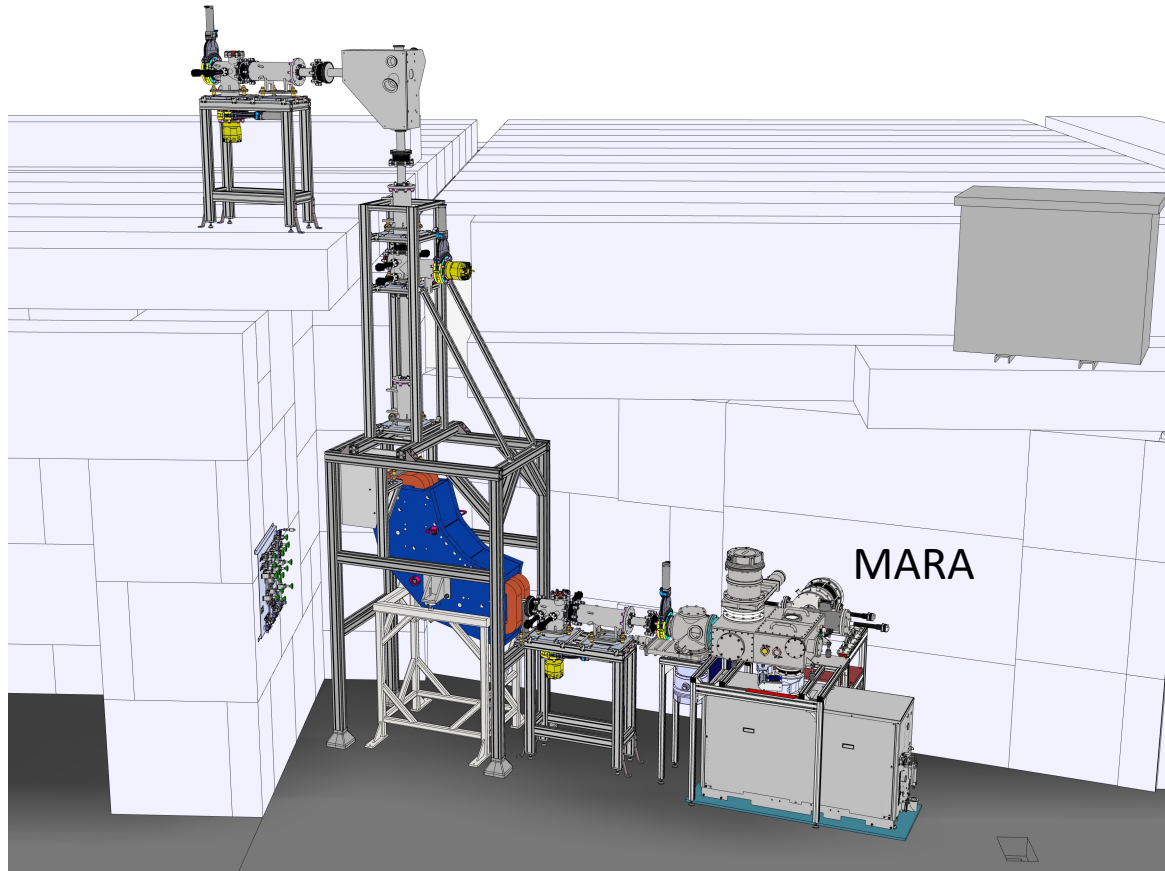
Courtesy of J. Tuunanen



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Facility layout



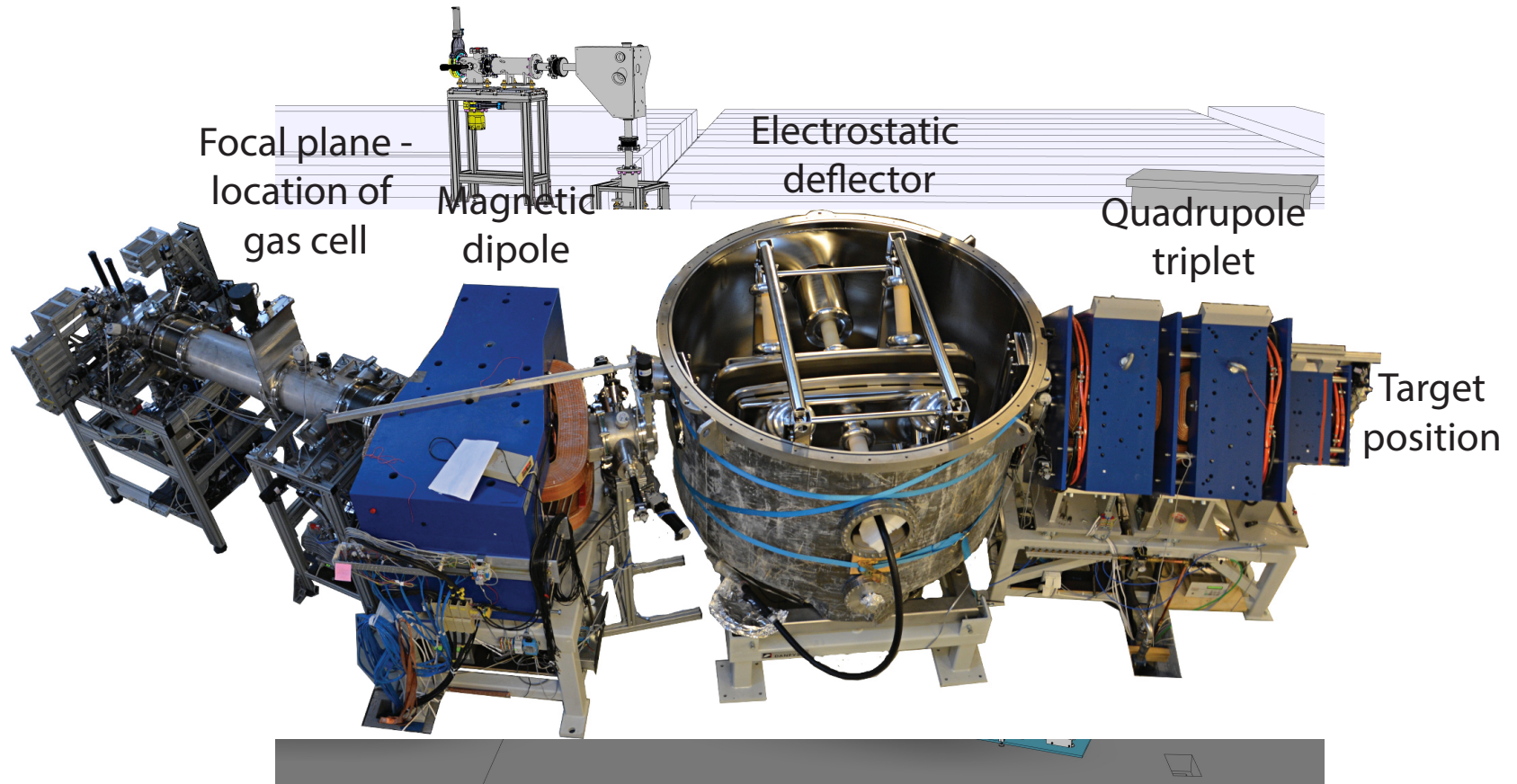
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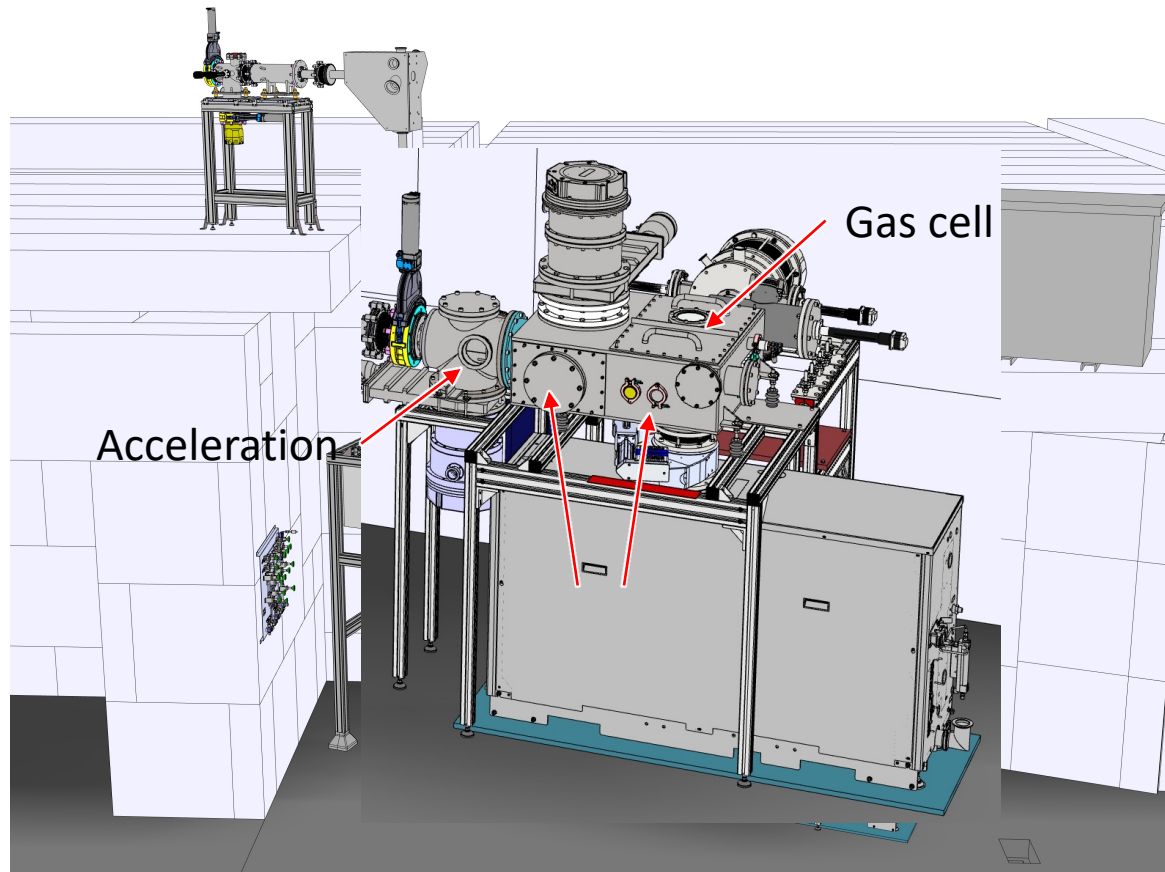


Facility layout



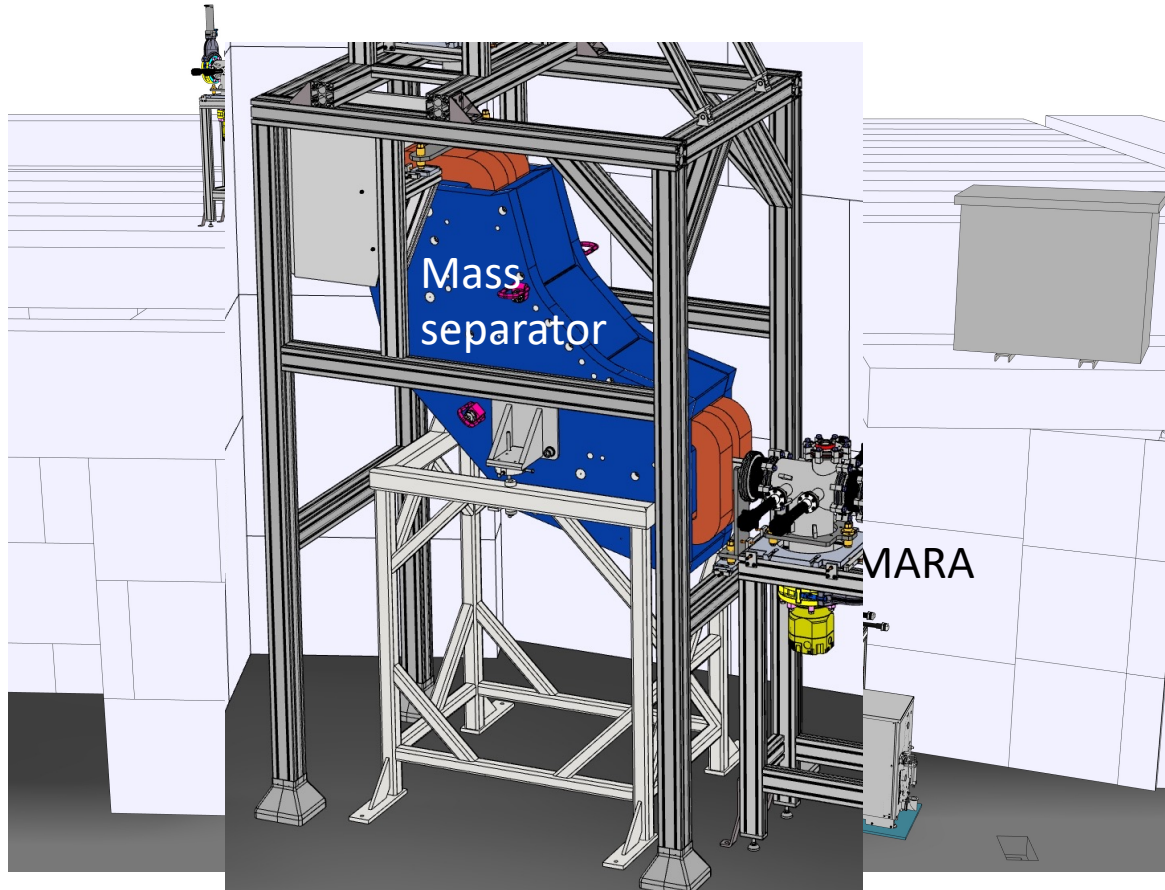
Courtesy of J. Tuunanen

Facility layout



Courtesy of J. Tuunanen

Facility layout



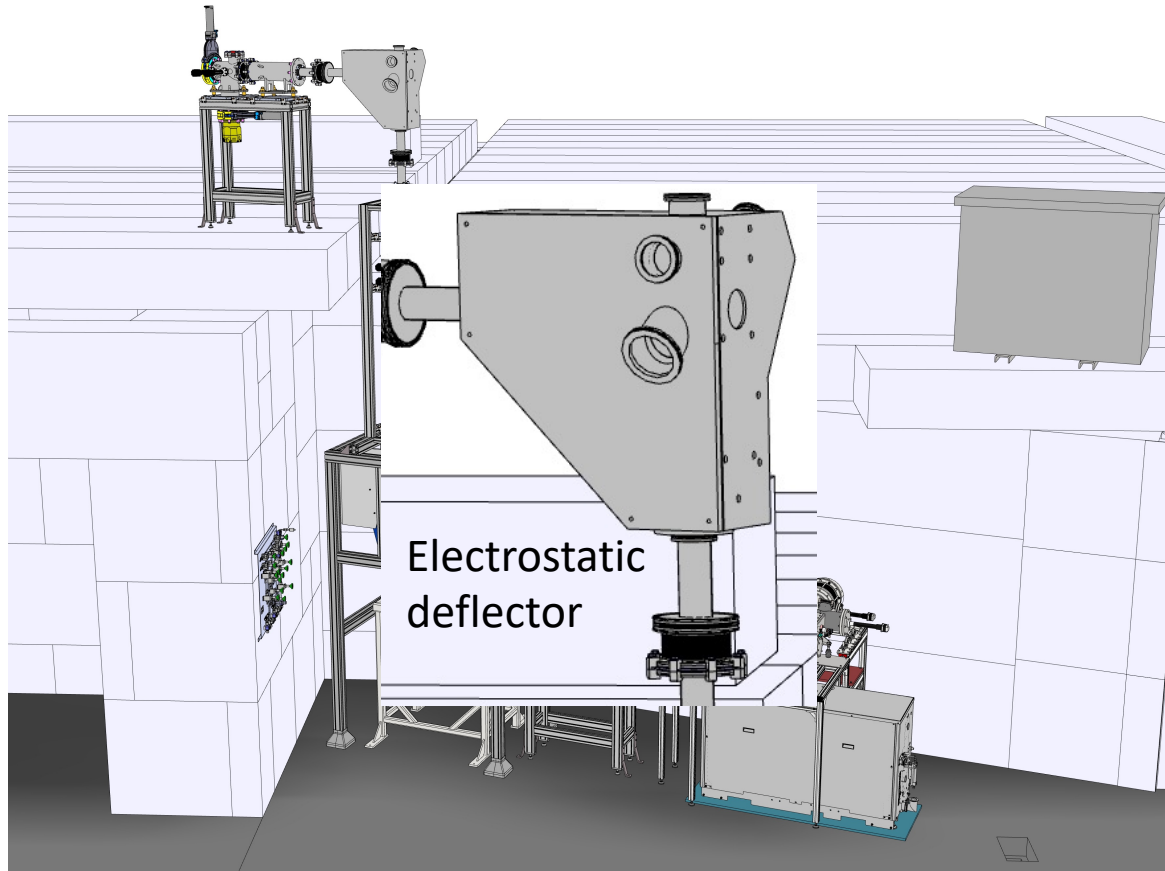
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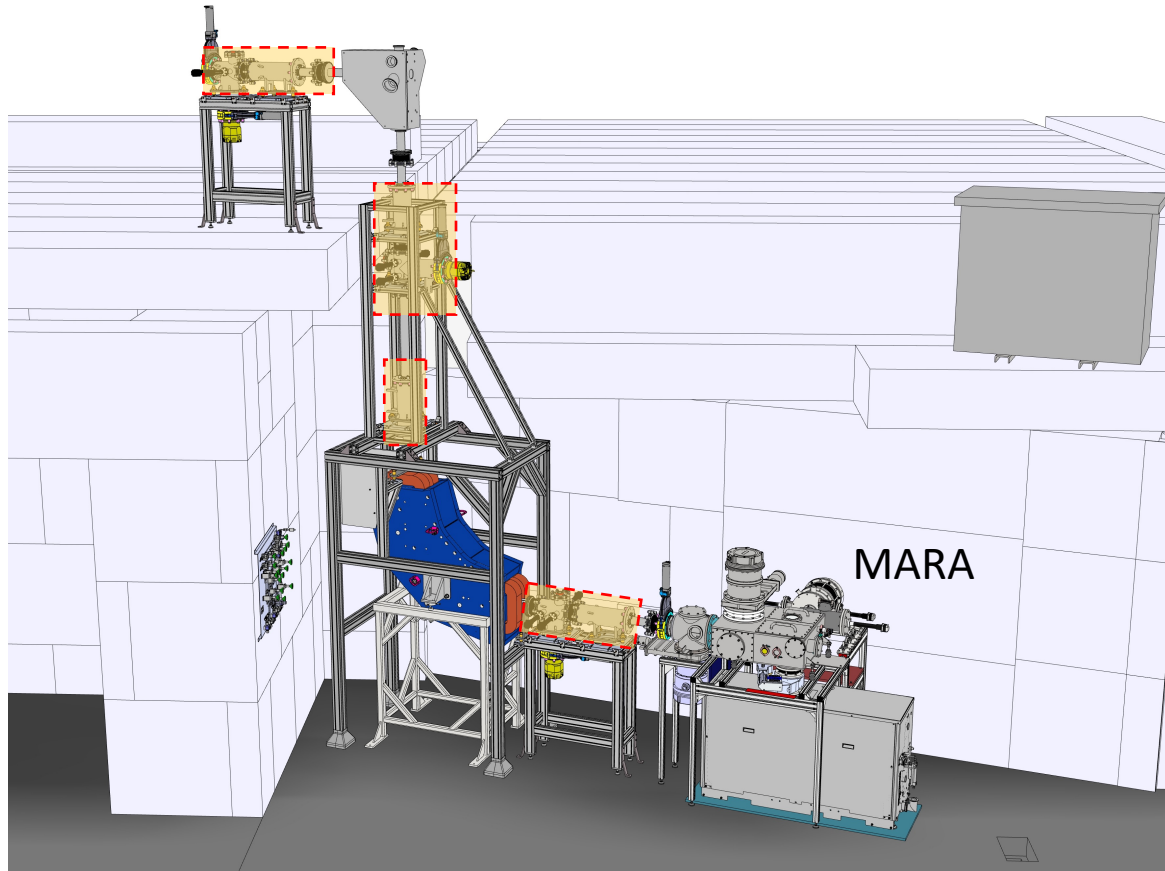


Facility layout



Courtesy of J. Tuunanen

Facility layout



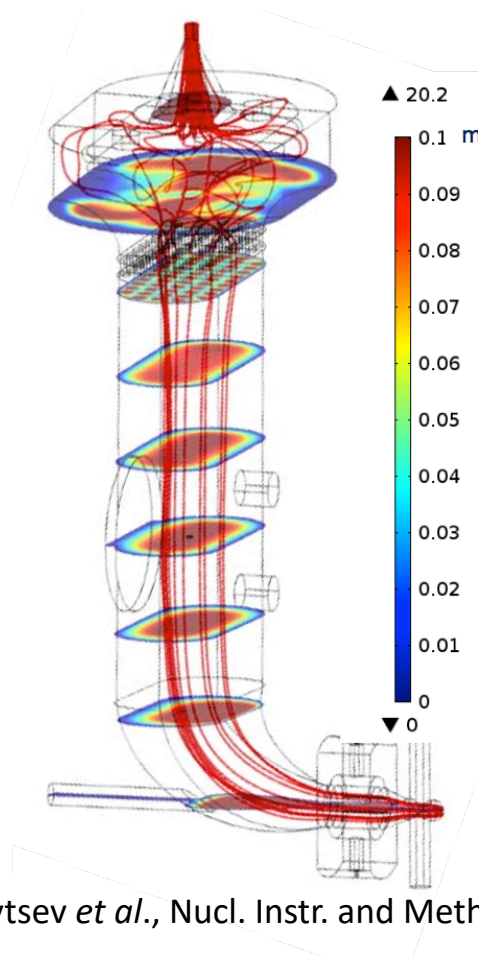
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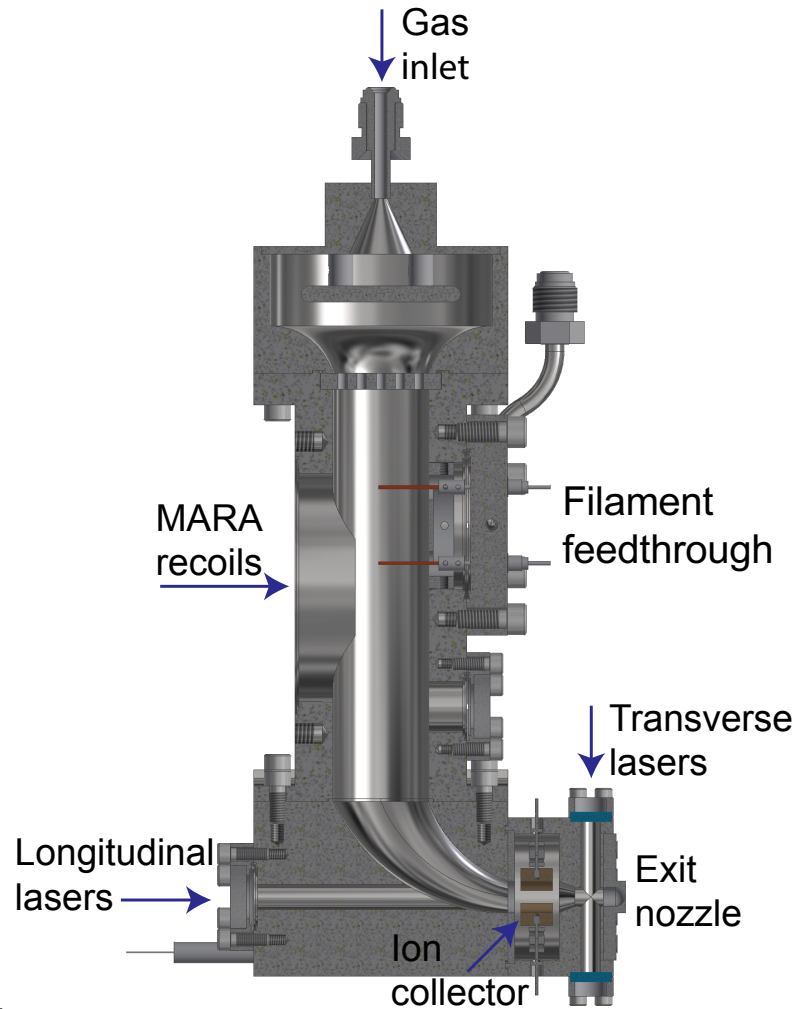
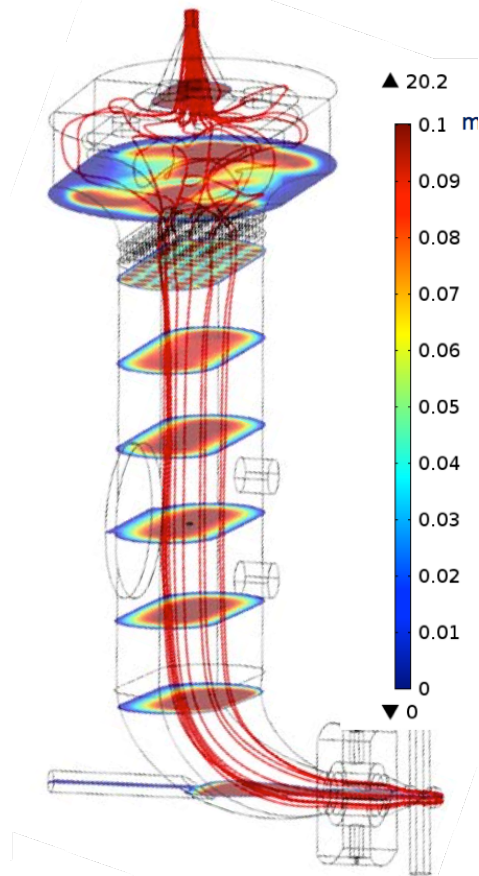


Gas cell



Yu. Kudryavtsev *et al.*, Nucl. Instr. and Meth. B **376**, 345 (2016)

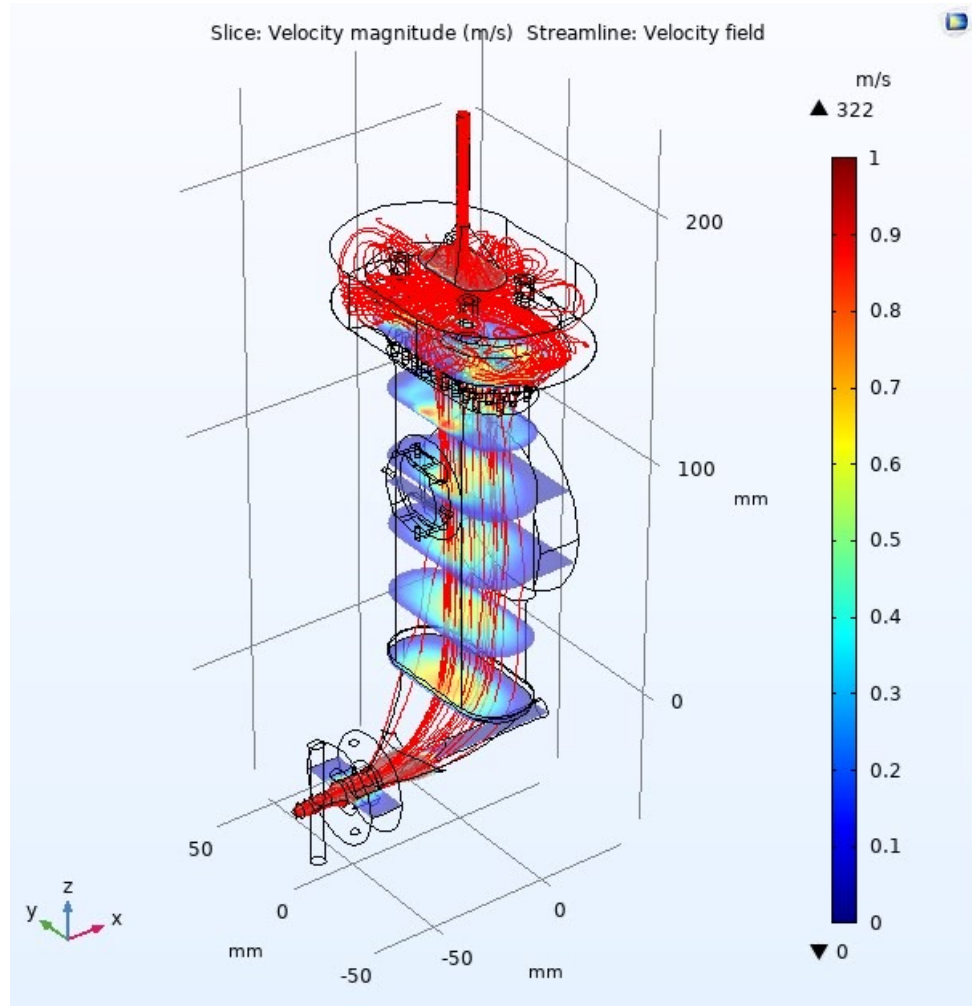
Gas cell



Yu. Kudryavtsev *et al.*, Nucl. Instr. and Meth. B **376**, 345 (2016)

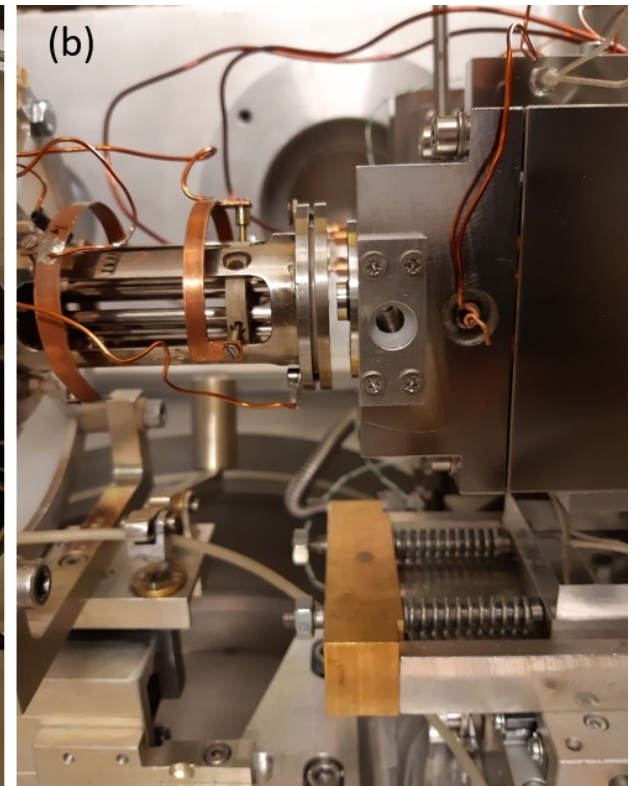
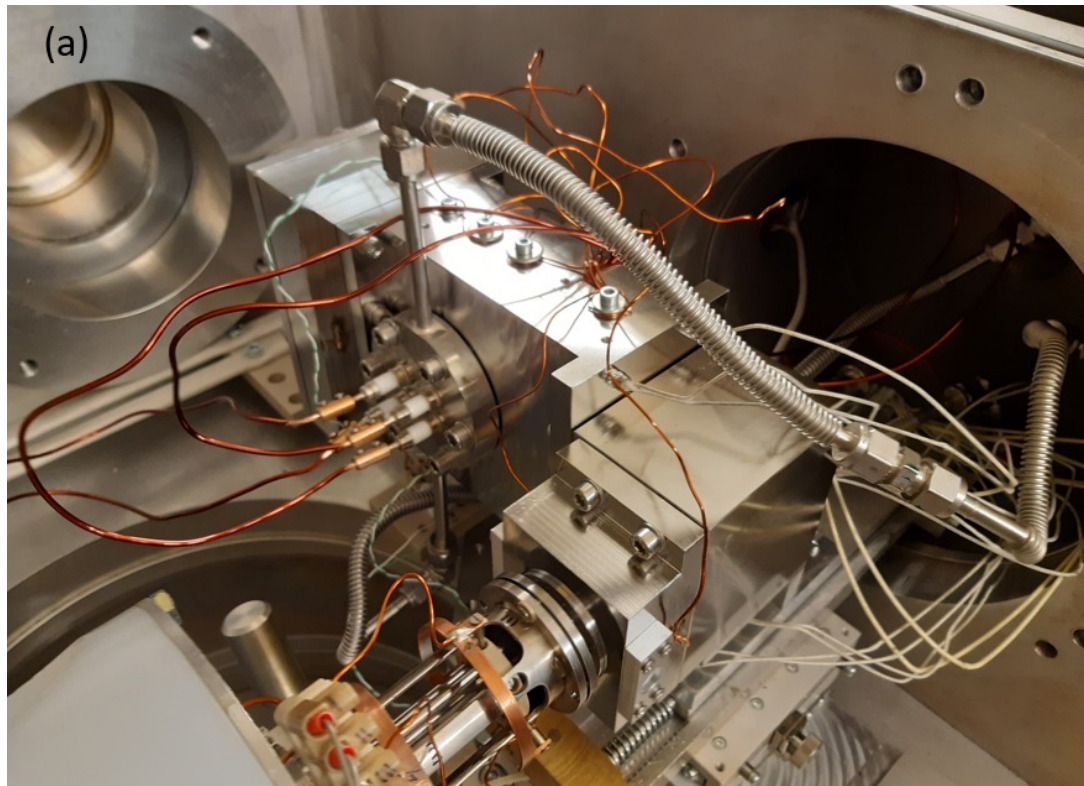
Gas cell simulations

- Numerical calculations using COMSOL
 - Interpret test results
 - Design connection to MARA
- Helium buffer gas



A. Zadvornaya, *article in preparation*

Gas cell testing



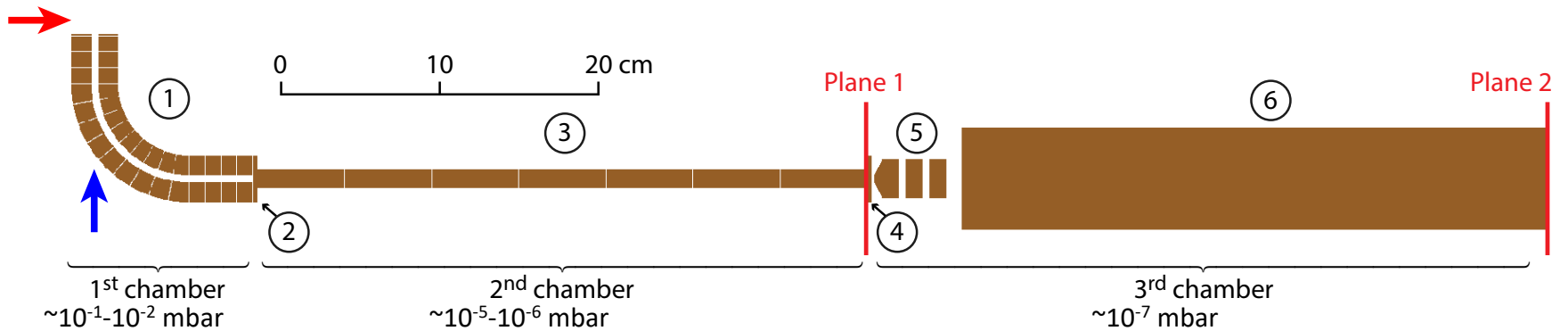
A. Zadvornaya, *article in preparation*



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Ion guides



①

90°-bent RFQ

⑤

acceleration electrodes

② ④

pumping apertures

⑥

ground electrode

③

straight segmented RFQ

→ →

laser beams

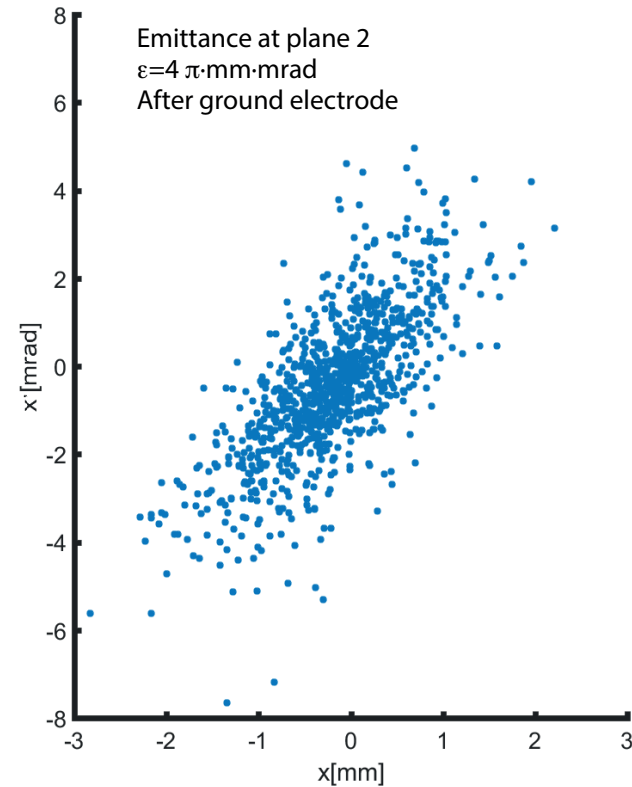
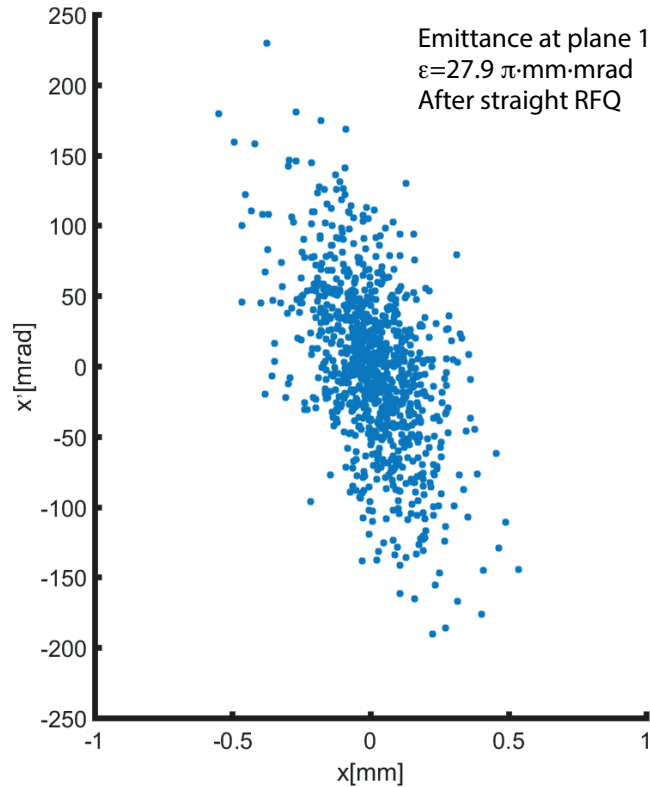
Courtesy of J. Liimatainen



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Ion guides – SIMION simulations



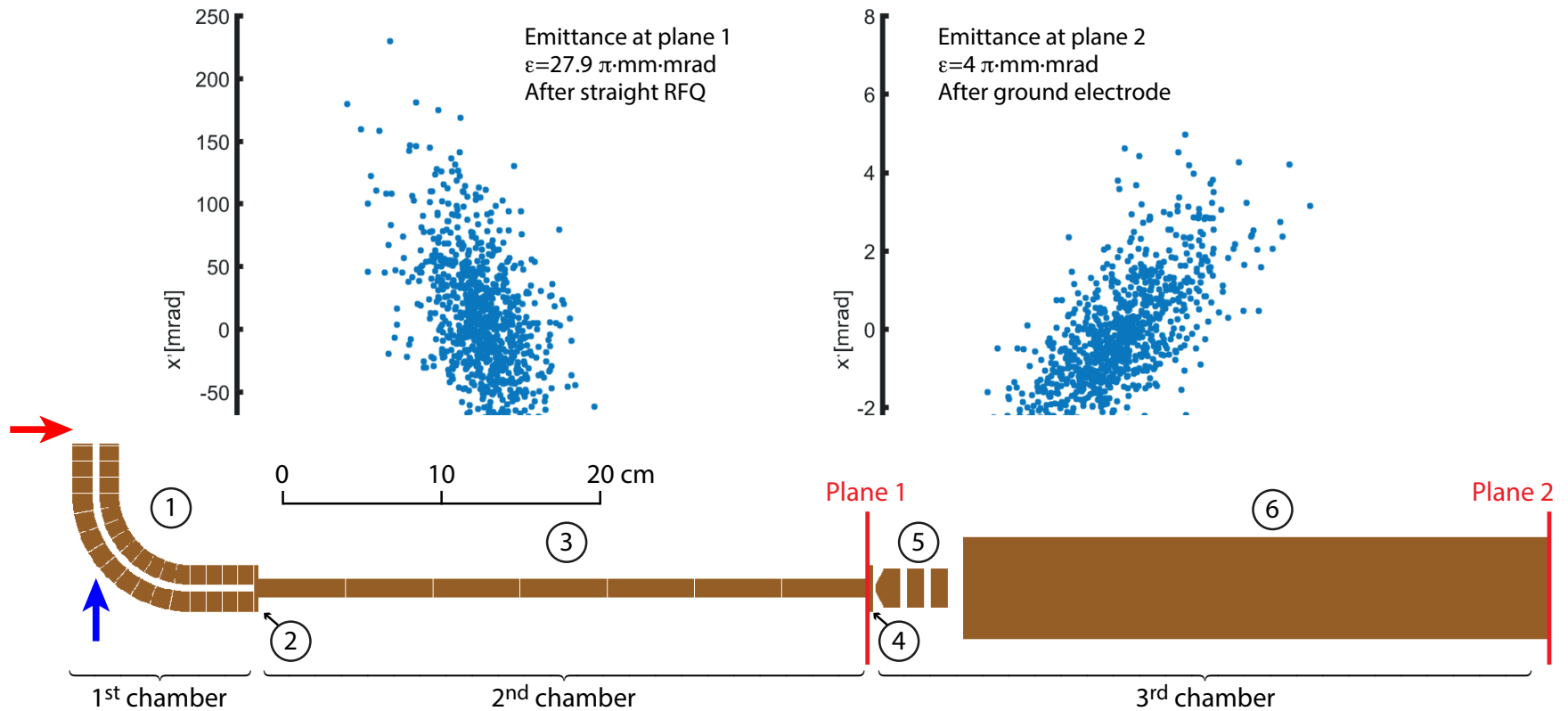
Simulated emittance for 1000 $^{94}\text{Ag}^+$ ions.

Helium at 500 mbar pressure, 0.5 mm exit hole, free expanding jet.

Transmission efficiency 97%.

P. Papadakis *et al.*, Nucl. Instr. and Meth. B **463**, 286 (2020)

Ion guides – SIMION simulations



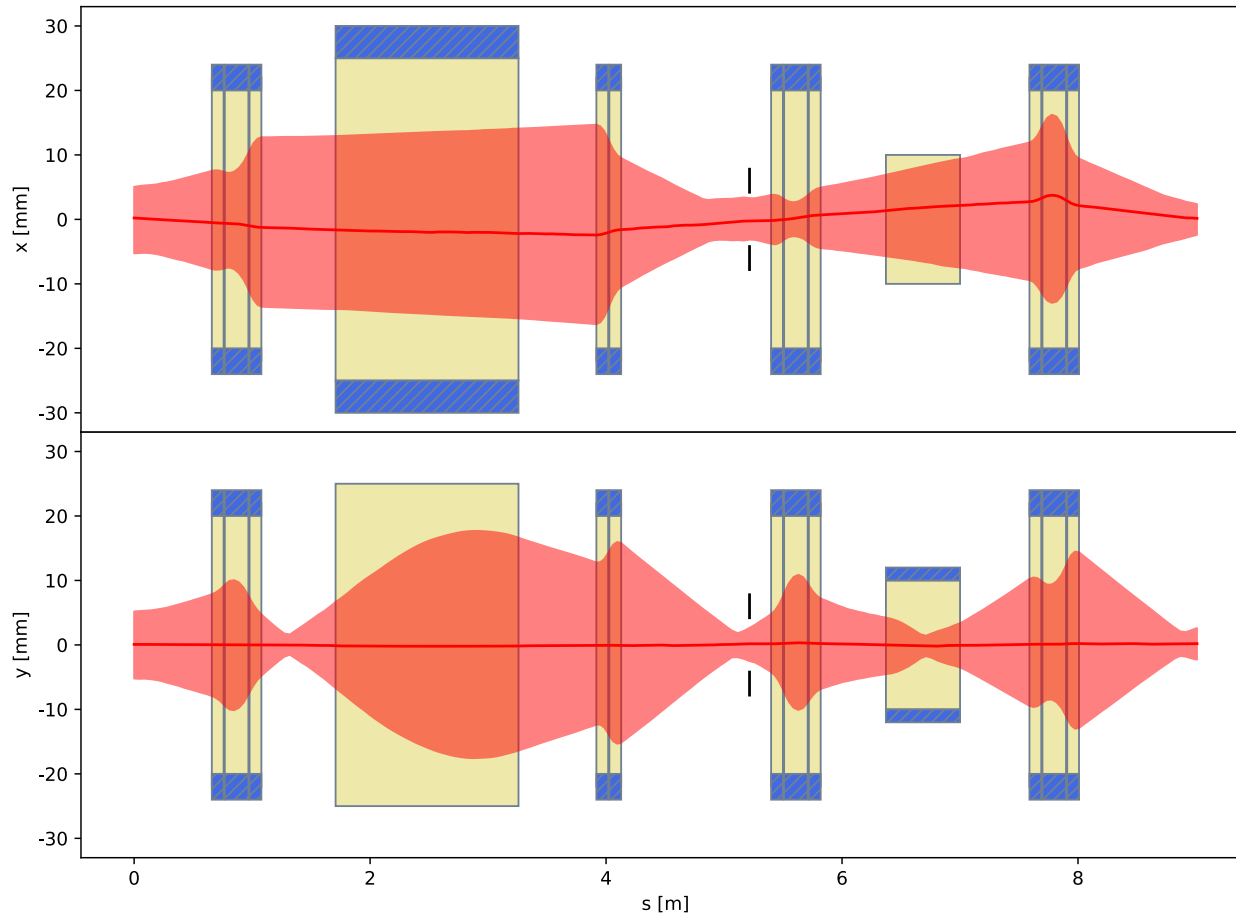
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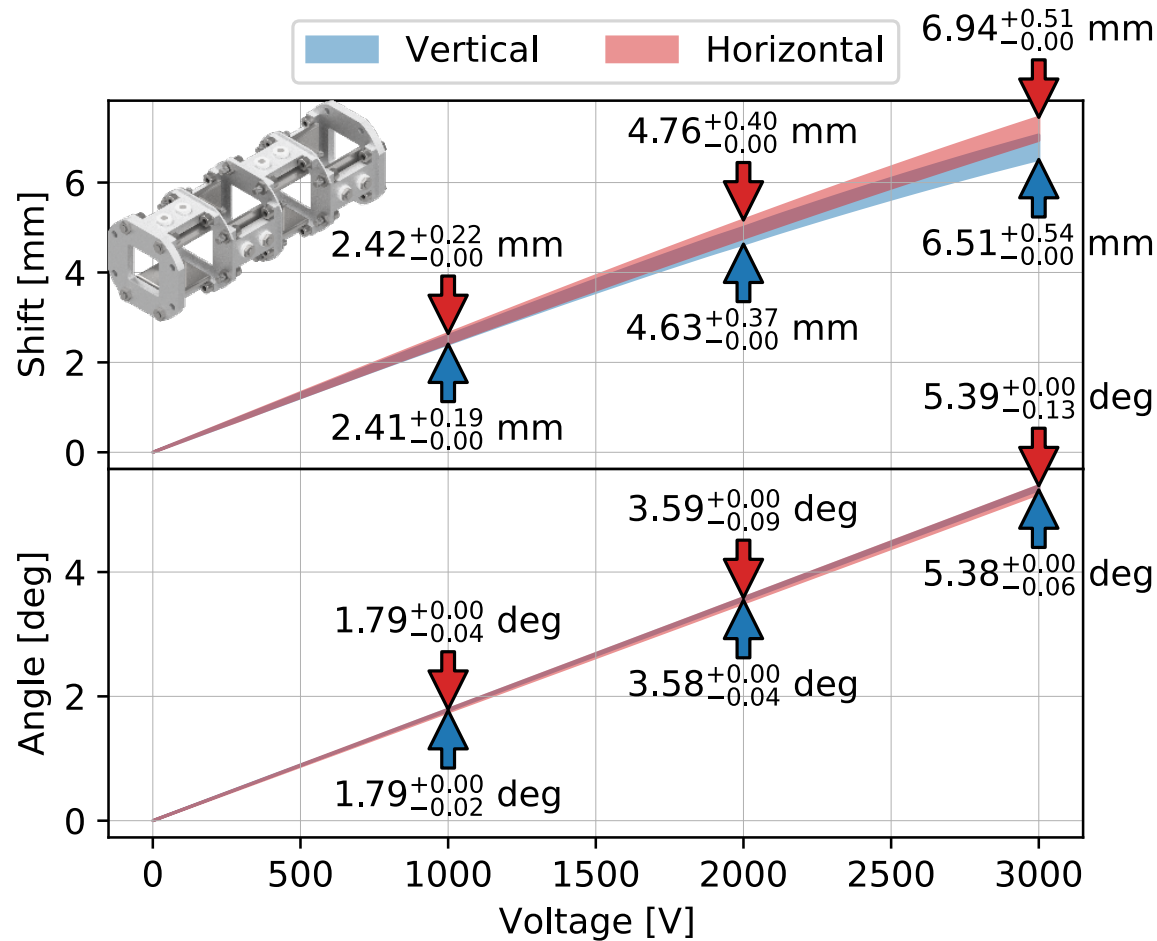
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P. Papadakis *et al.*, Nucl. Instr. and Meth. B **463**, 286 (2020)

Transfer line – piol simulations



XY beam alignment



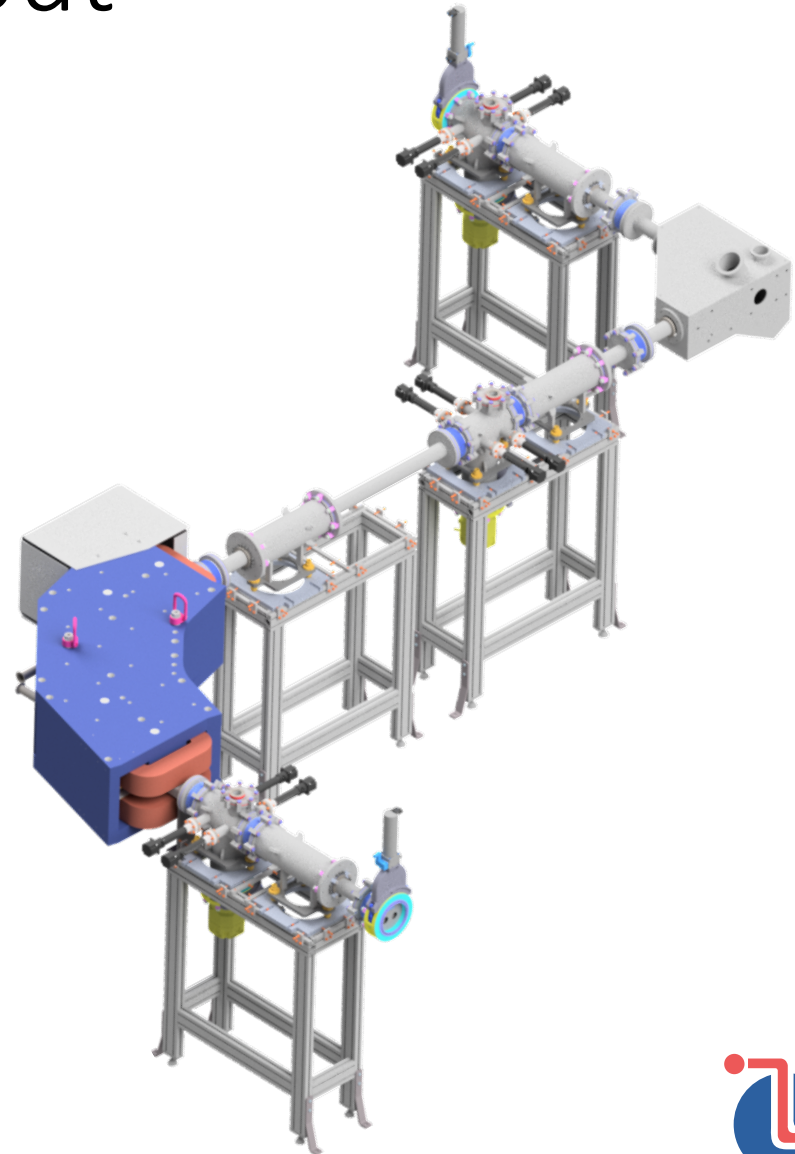
Laser system



- 3 Ti:Sapphire laser cavities built in collaboration with the University of Mainz
- Lasers built and tested
- In use in a so-called dual-etalon setup employed in the study of neutron deficient Ag isotopes

Initial testing layout

- Horizontal arrangement
- RITU roof
- Test all components before moving to final layout



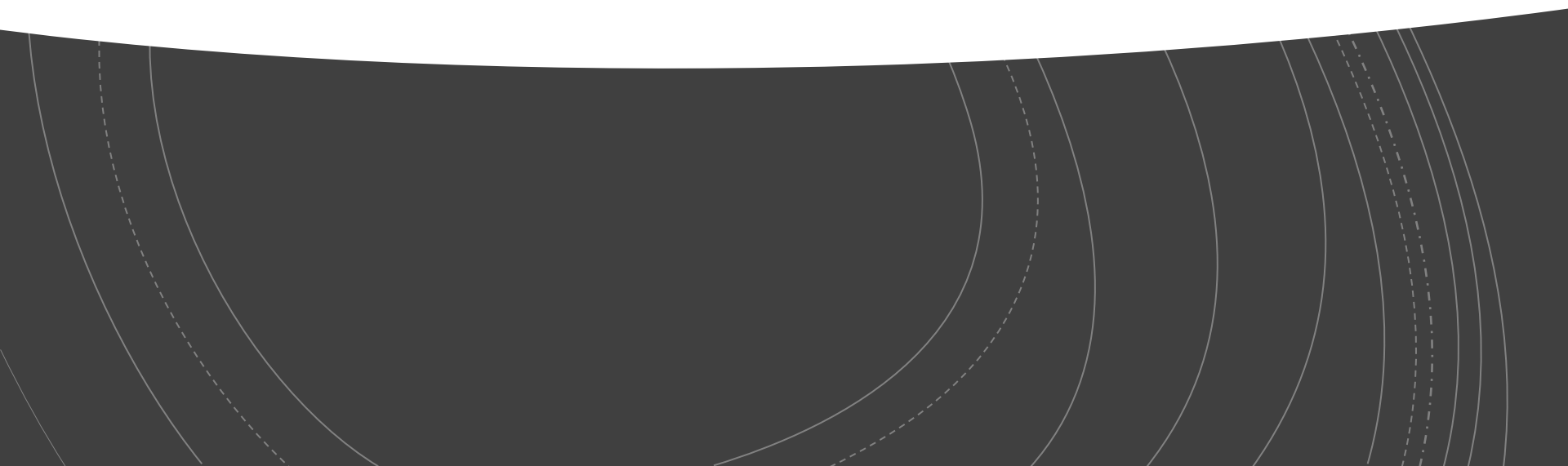
Courtesy of R. Smith and M. Cordwell



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Project outlook



Project outlook

- ✓ Gas cell: Designed, built and tested
 - α -recoil source and bronze filament tests
 - Gas flow verification finalised
- ✓ Lasers: Ti:Sapphire lasers built and tested
 - Procured 2nd hand pump lasers
- ✓ Transfer line: Design finalised
- ✓ Vacuum system: All pumps have been purchased and tested
- ✓ Gas purification system: Delivered to JYFL
- ✓ Dipole magnet: Delivered to JYFL
- ✓ Electrostatic deflector: Exists in JYFL
- ✓ High-voltage supplies: Delivered to JYFL
- ✓ Transformer to isolate the components on high voltage from ground: Delivered to JYFL
- ✓ Control system for pumps and high-voltage supplies: Partially designed

Project outlook

- Gas cell, ion guide chambers:
 - Construction ongoing
- Ion guides:
 - Mechanical design and construction ongoing
- Decay station: Funding requested
- MR-TOF-MS/RFQ cooler buncher:
 - Design based on a similar devices for IGISOL-4
 - Funding not secured



P. Papadakis, R. Smith, M. Cordwell



T. Eronen, **W. Gins**, **J. Liimatainen**, I. Moore, J. Partanen[†], I. Pohjalainen, M. Reponen, S. Rinta-Antila, J. Sarén, J. Tuunanen, J. Uusitalo, **S. Zadvornaya**



J. Romero

Funding

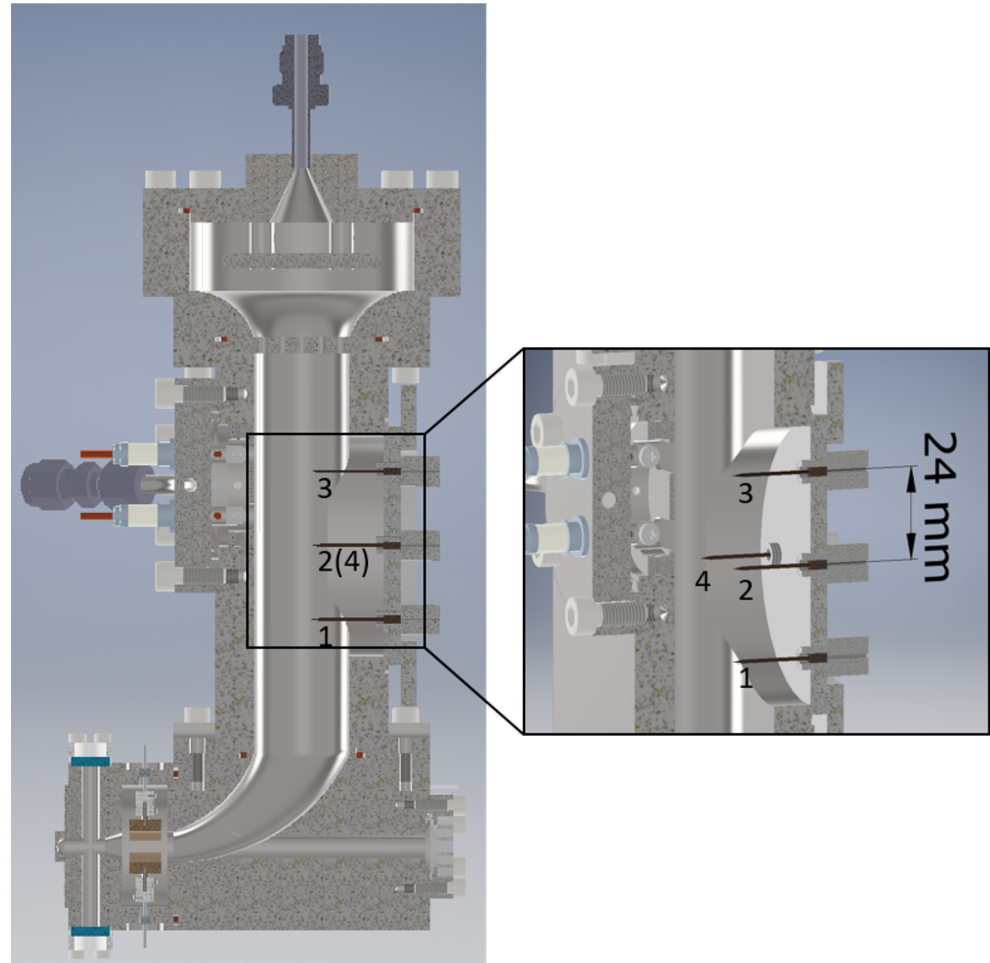


In collaboration with



Gas cell testing

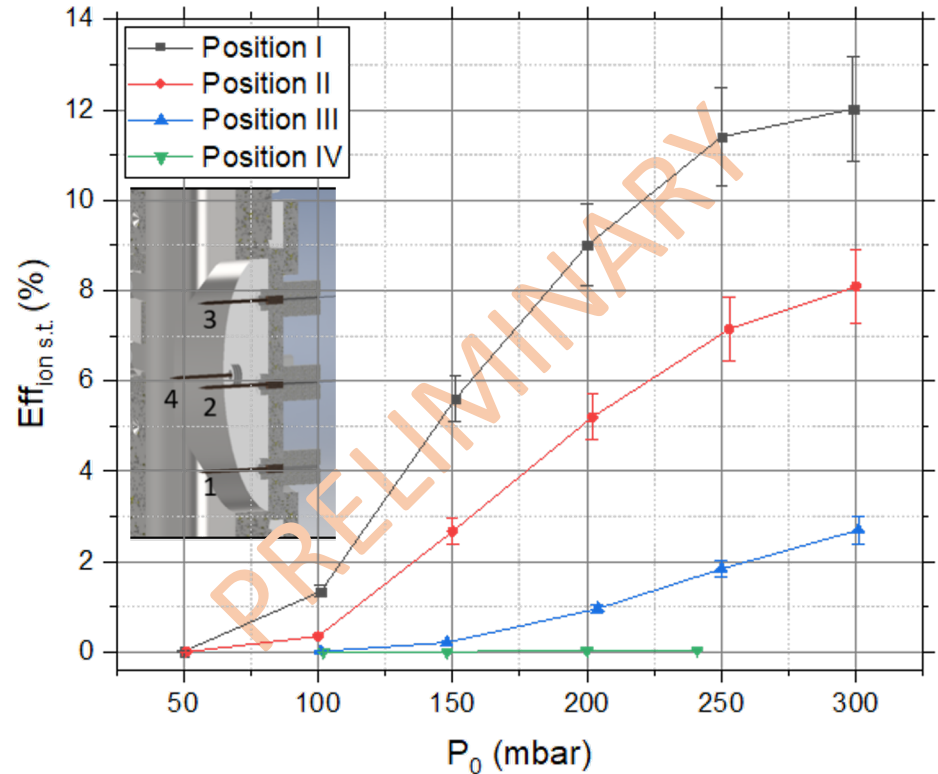
- Used ^{223}Ra α -recoil source on a needle
- Known activity
- Needle placed in four different positions
- Measured ^{219}Rn α spectra with a Si detector at different gas cell pressures



A. Zadvornaya, *article in preparation*

Gas cell testing

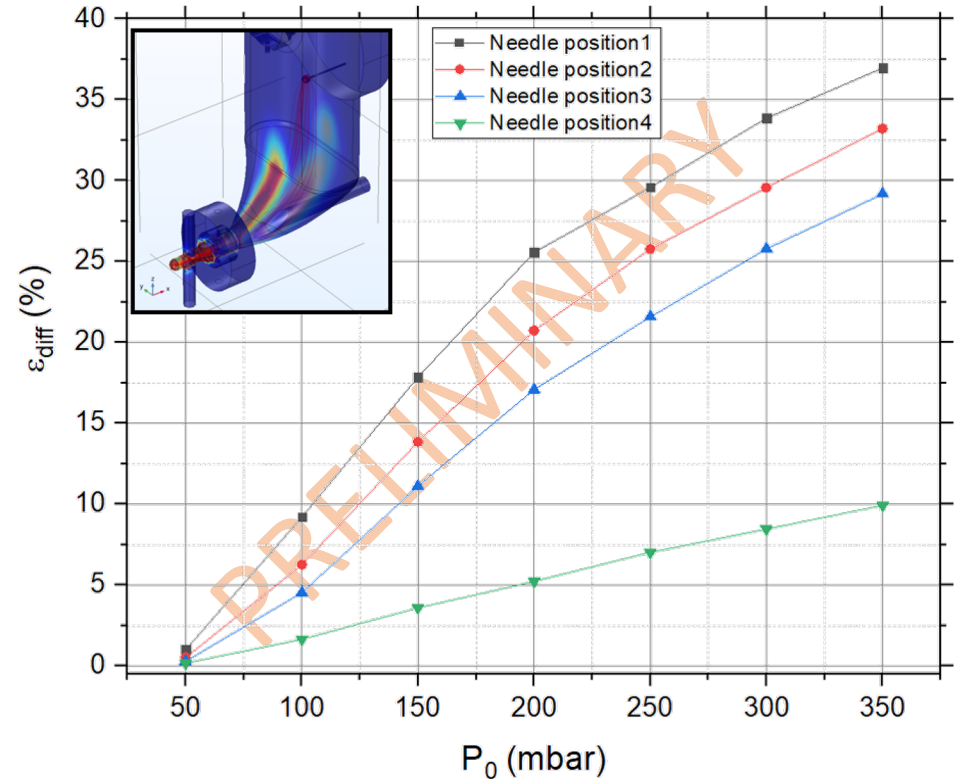
- Highest efficiency for position 1 (closest to the exit hole) ~12% @300mbar
- Very low efficiency for position 4 (closest to the gas cell wall)



A. Zadvornaya, *article in preparation*

Gas cell testing

- Numerical calculations using COMSOL
- Only diffusion to gas cell walls considered
- Differences under investigation



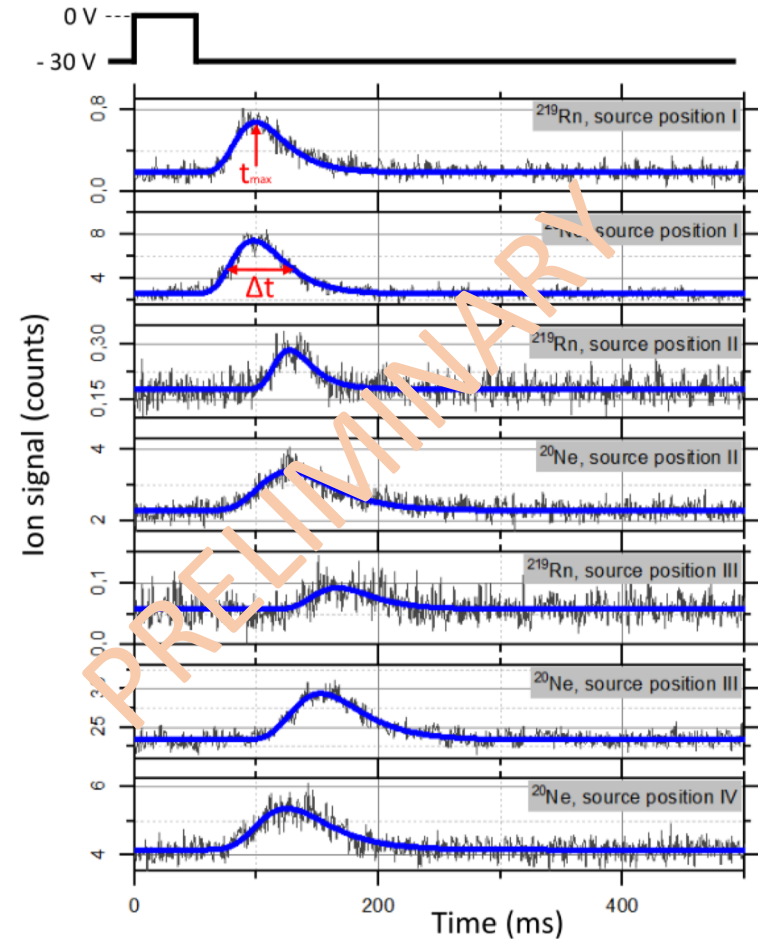
A. Zadvornaya, *article in preparation*



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Gas cell testing

- Applied pulsed voltage on needle
- -30V, 50ms step
- Extracted evacuation time for different needle positions
- Helium 200mbar
 - Evacuation time ~100-150ms
 - Peak width ~60ms
- Argon 100mbar
 - Evacuation time ~270ms
 - Peak width ~150ms



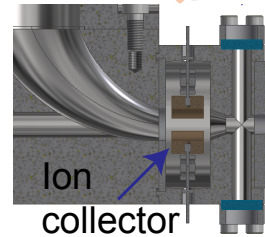
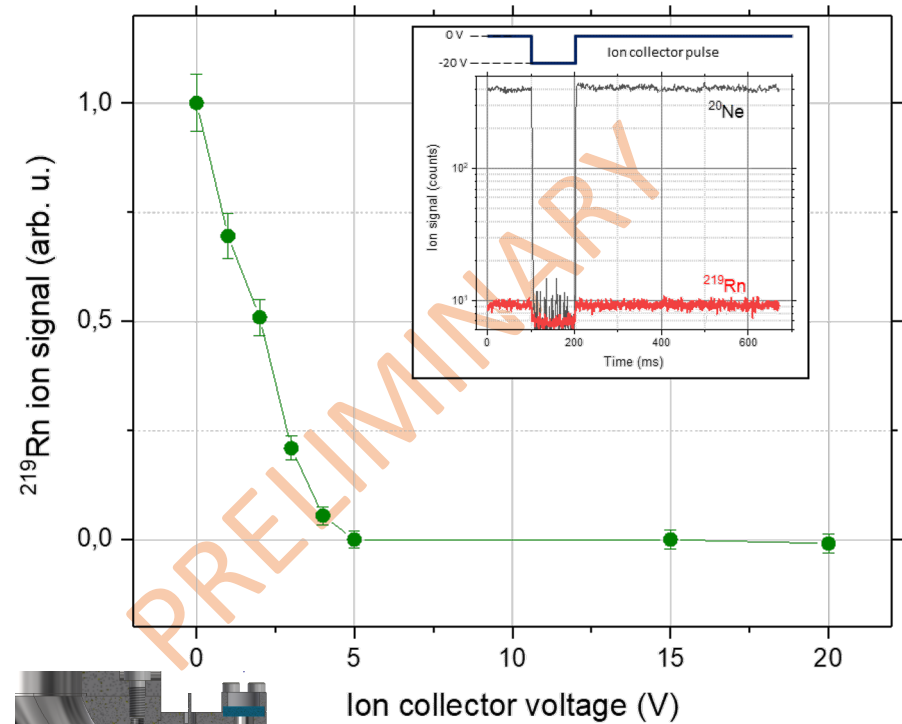
A. Zadvornaya, *article in preparation*



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Gas cell testing

- Ion collectors at the exit of the cell to suppress background
- Tested using helium gas at 166mbar pressure.
- 5V on one ion collector enough to fully suppress ions produced by the needle-source.



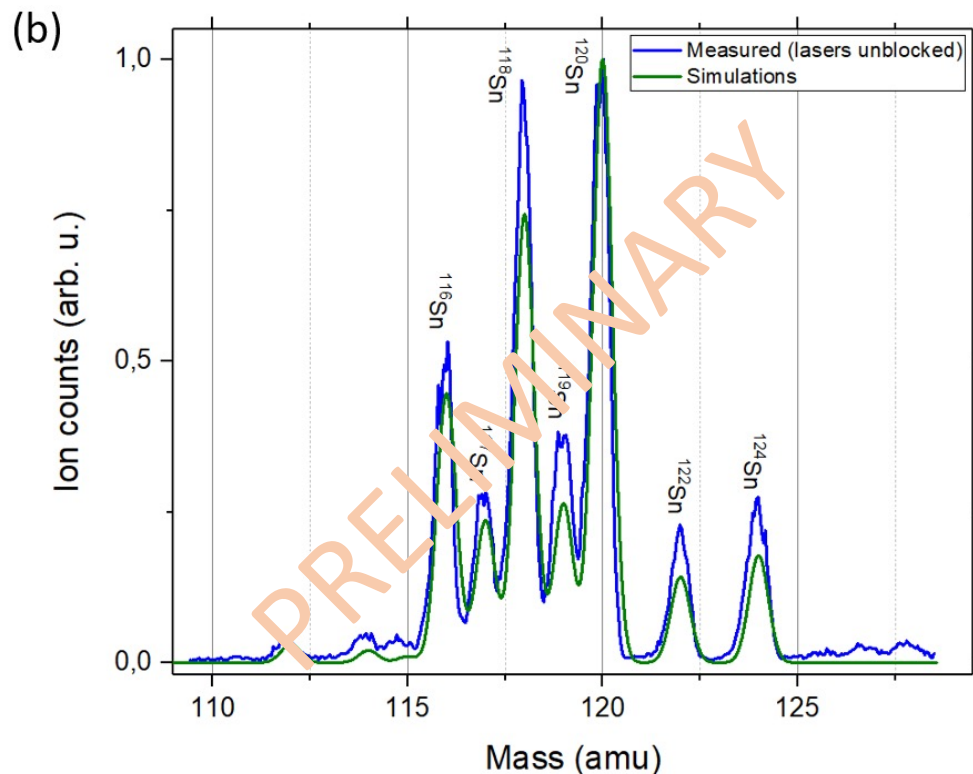
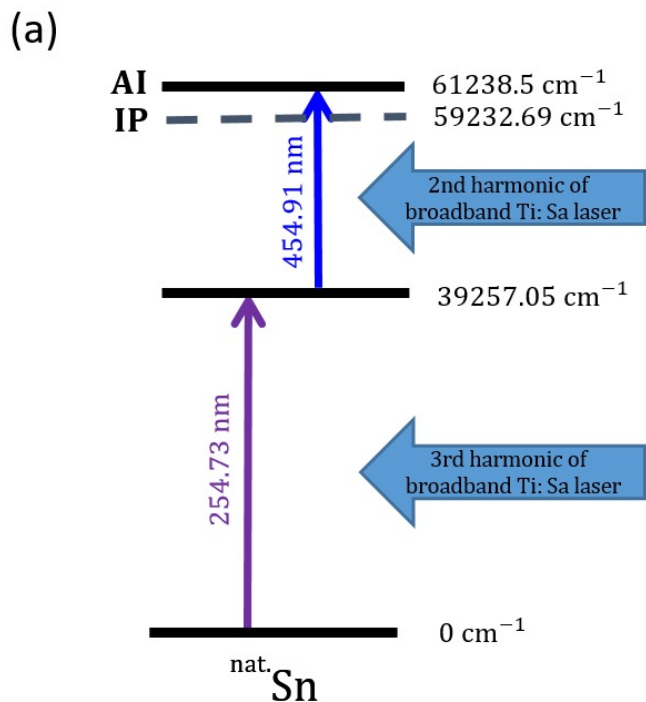
A. Zadvornaya, *article in preparation*



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Gas cell testing

- Two-step laser ionization of tin isotopes produced from heated filaments inside the cell



A. Zadvornaya, *article in preparation*