The MARA Low-Energy Branch

INPC 2019

Philippos Papadakis

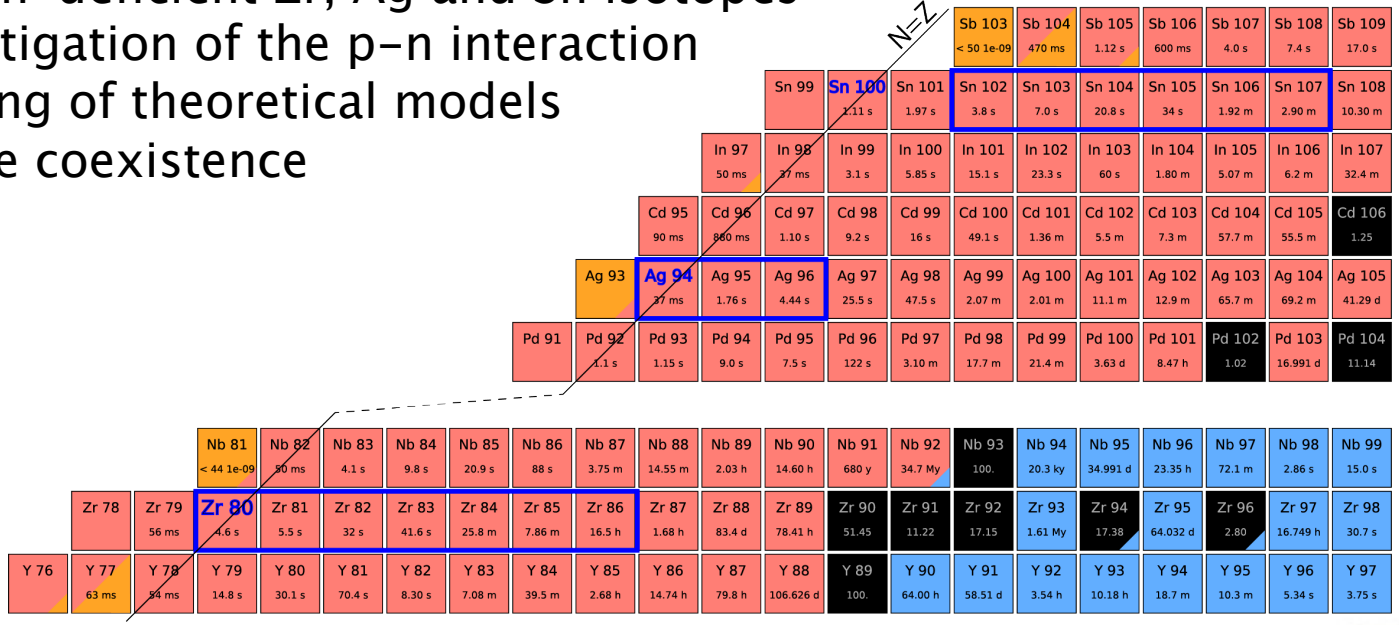
Outline

- Motivation
- MARA-LEB concept
- Facility layout
- Individual parts
- Project outlook

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



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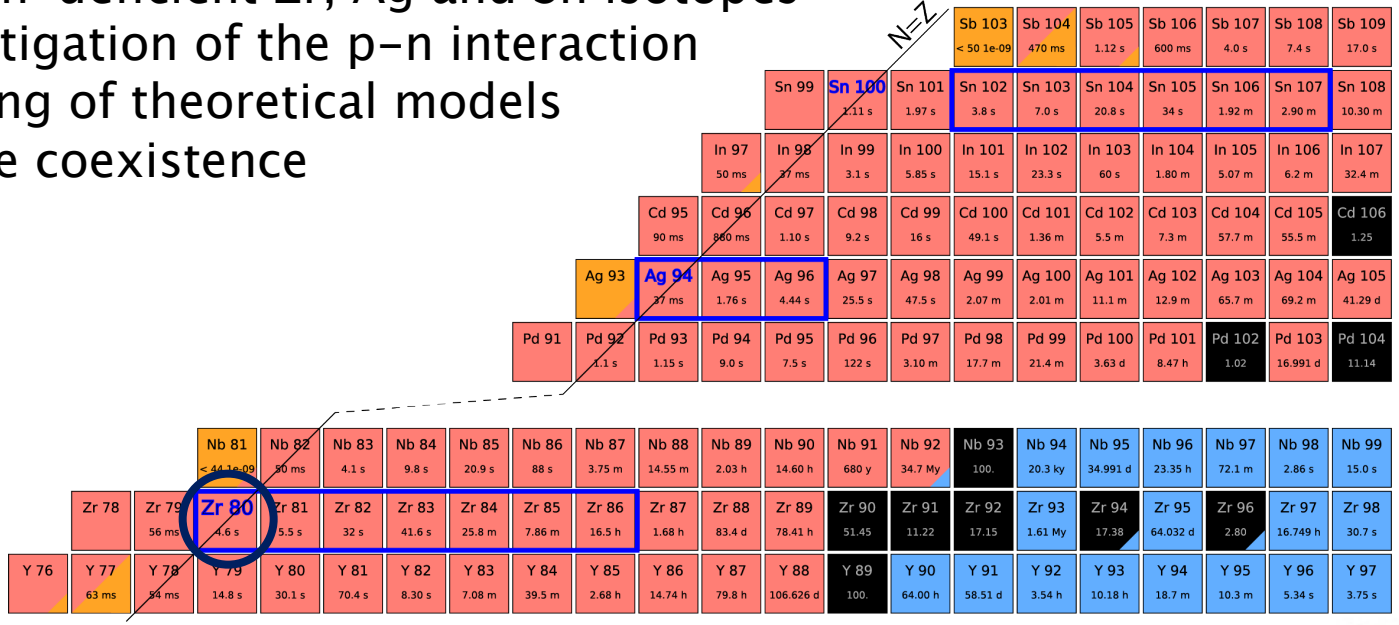

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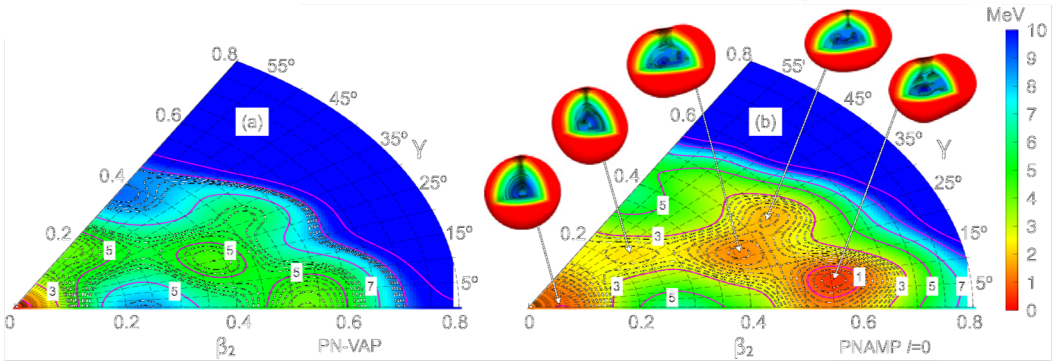
Scientific motivation – Laser ionization and spectroscopy

Example: ^{80}Zr
- Highly deformed
- Theoretical predictions indicate coexistence of 5 shapes
- Waiting point of astrophysical rp-process



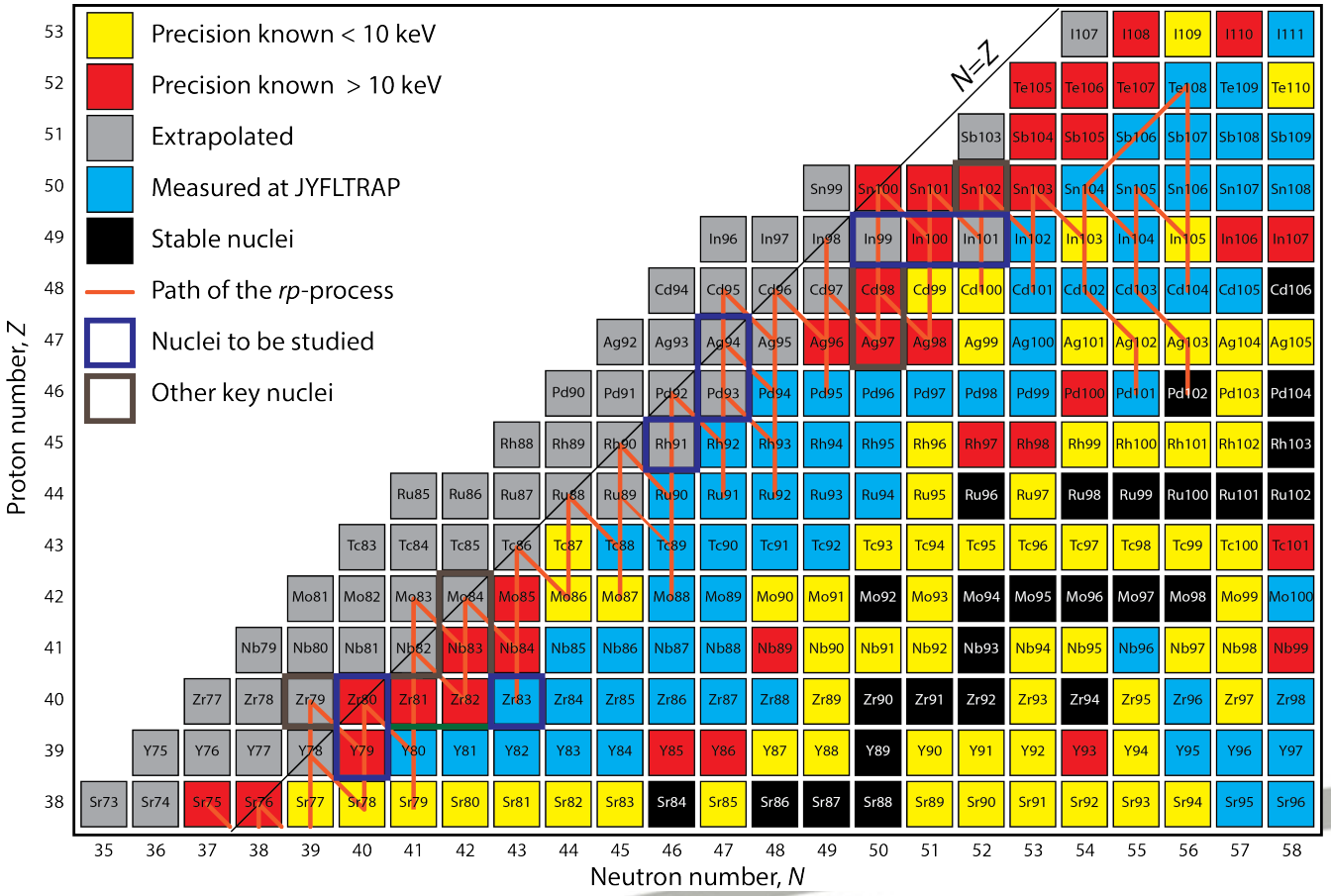
PN-VAP: Particle number symmetry restored
PNAMP: Rotational symmetry also restored

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?



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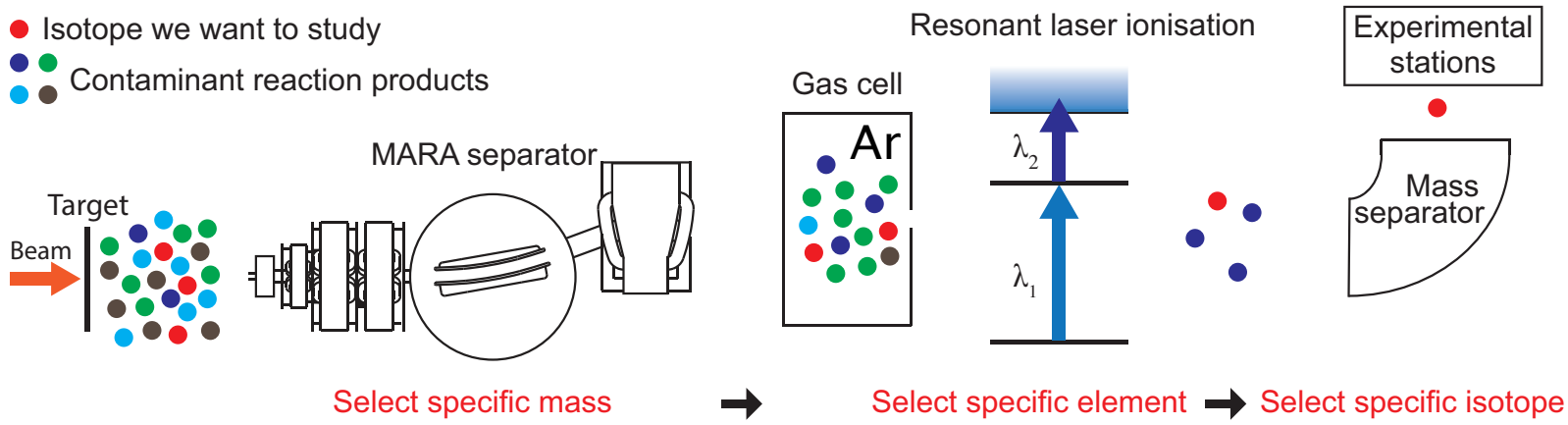
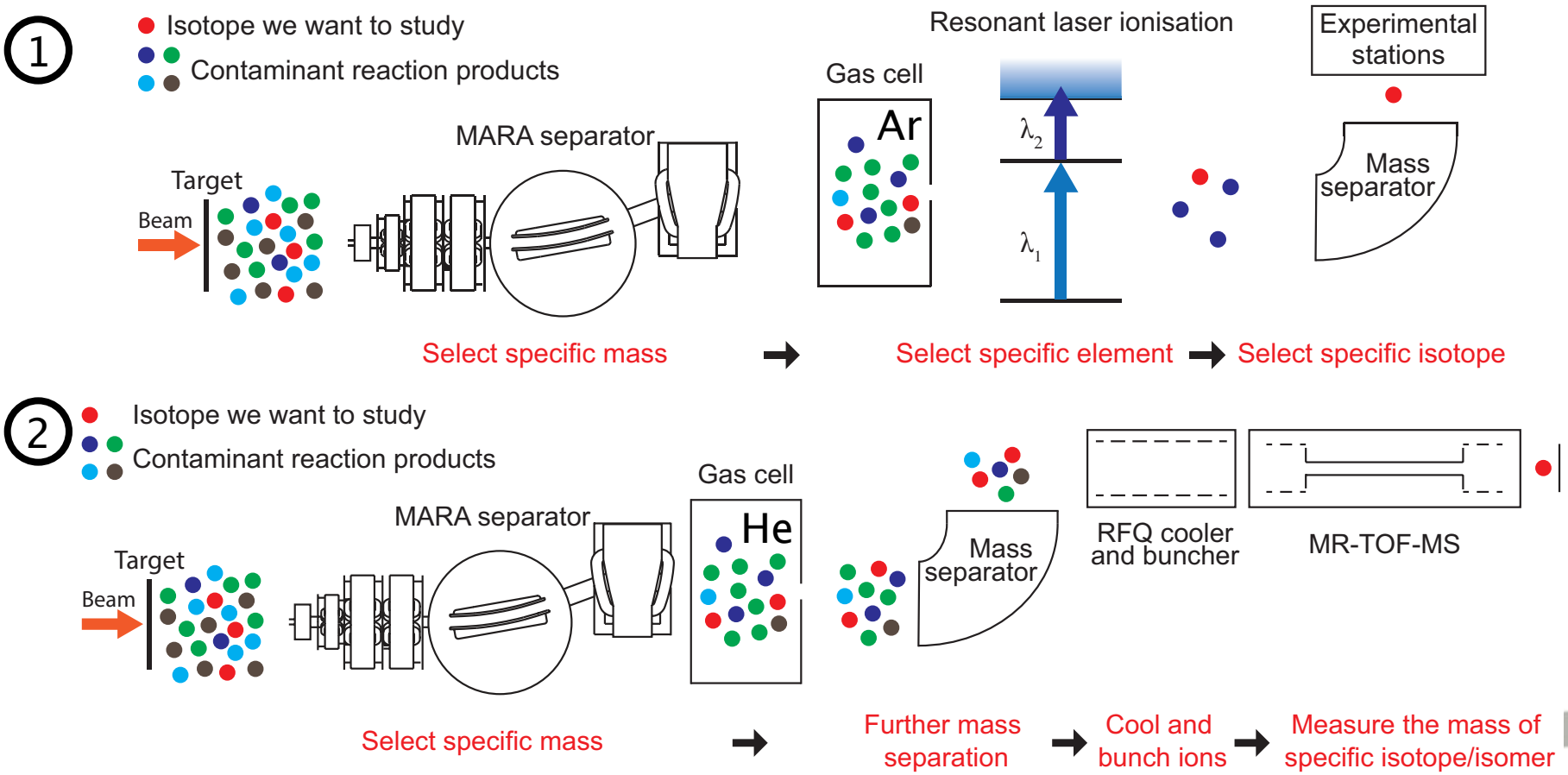
MARA-LEB concept

①



MARA-LEB concept



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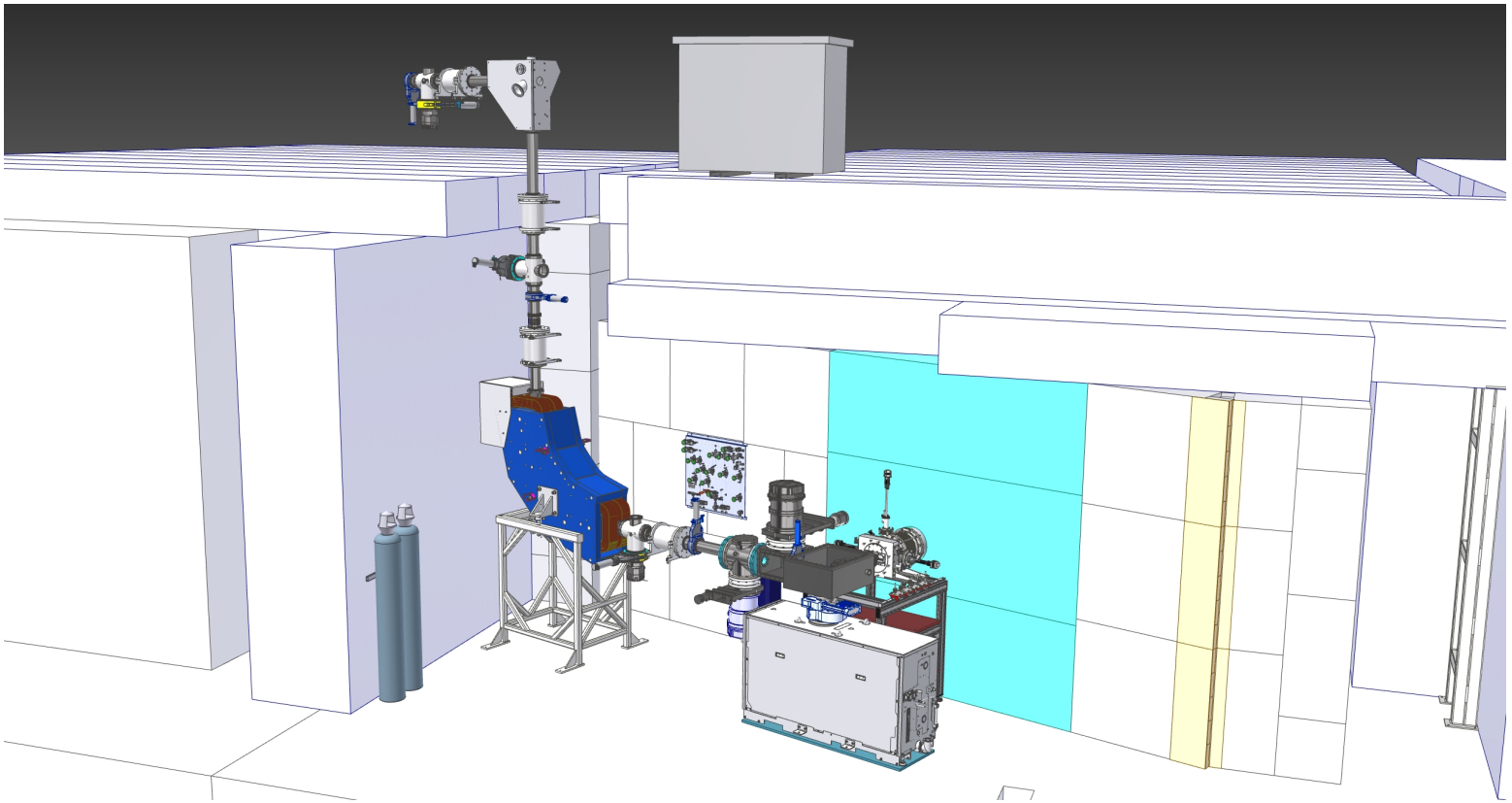
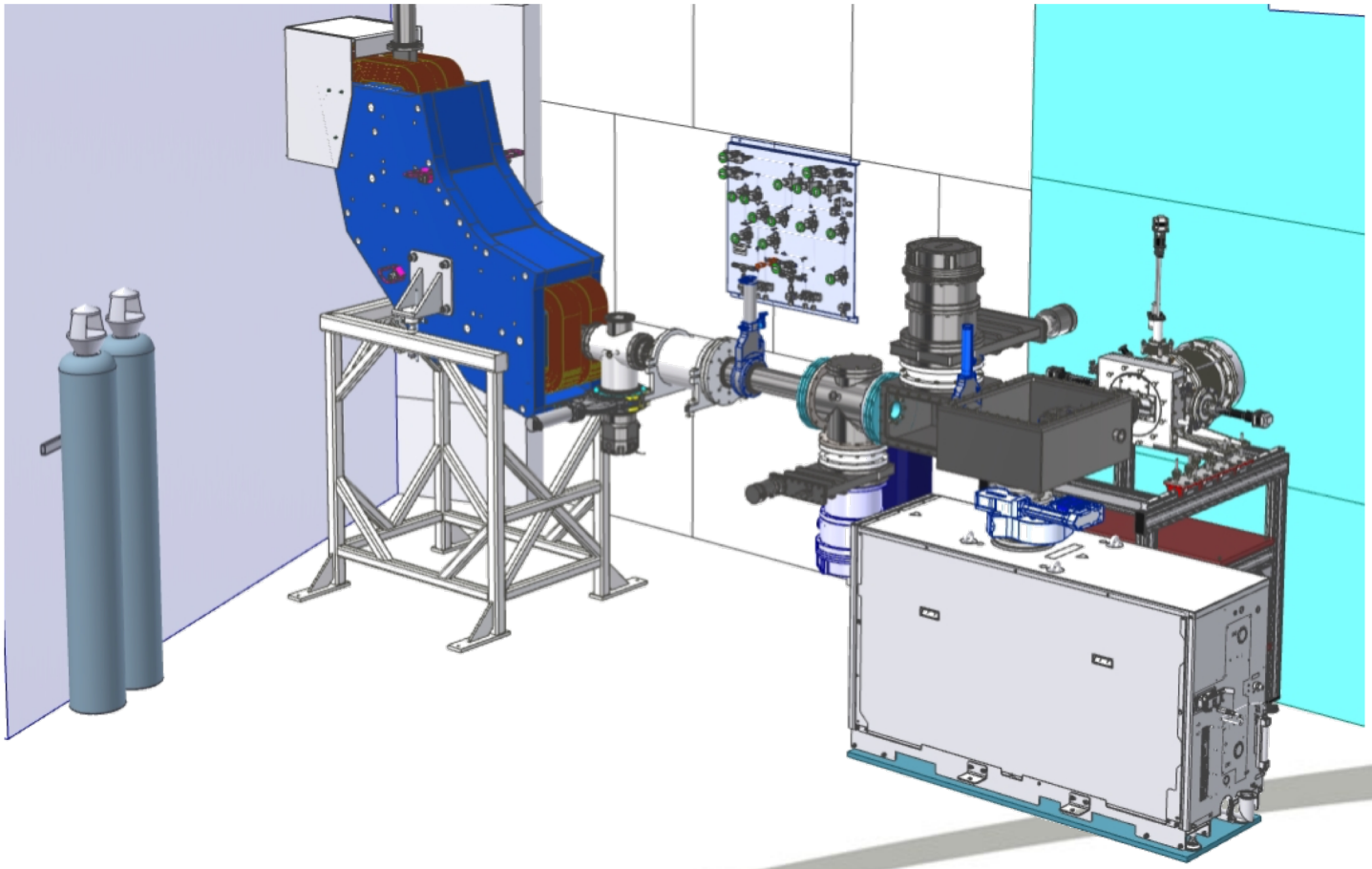
Facility layout



Courtesy of Juha Tuunanen

Facility layout



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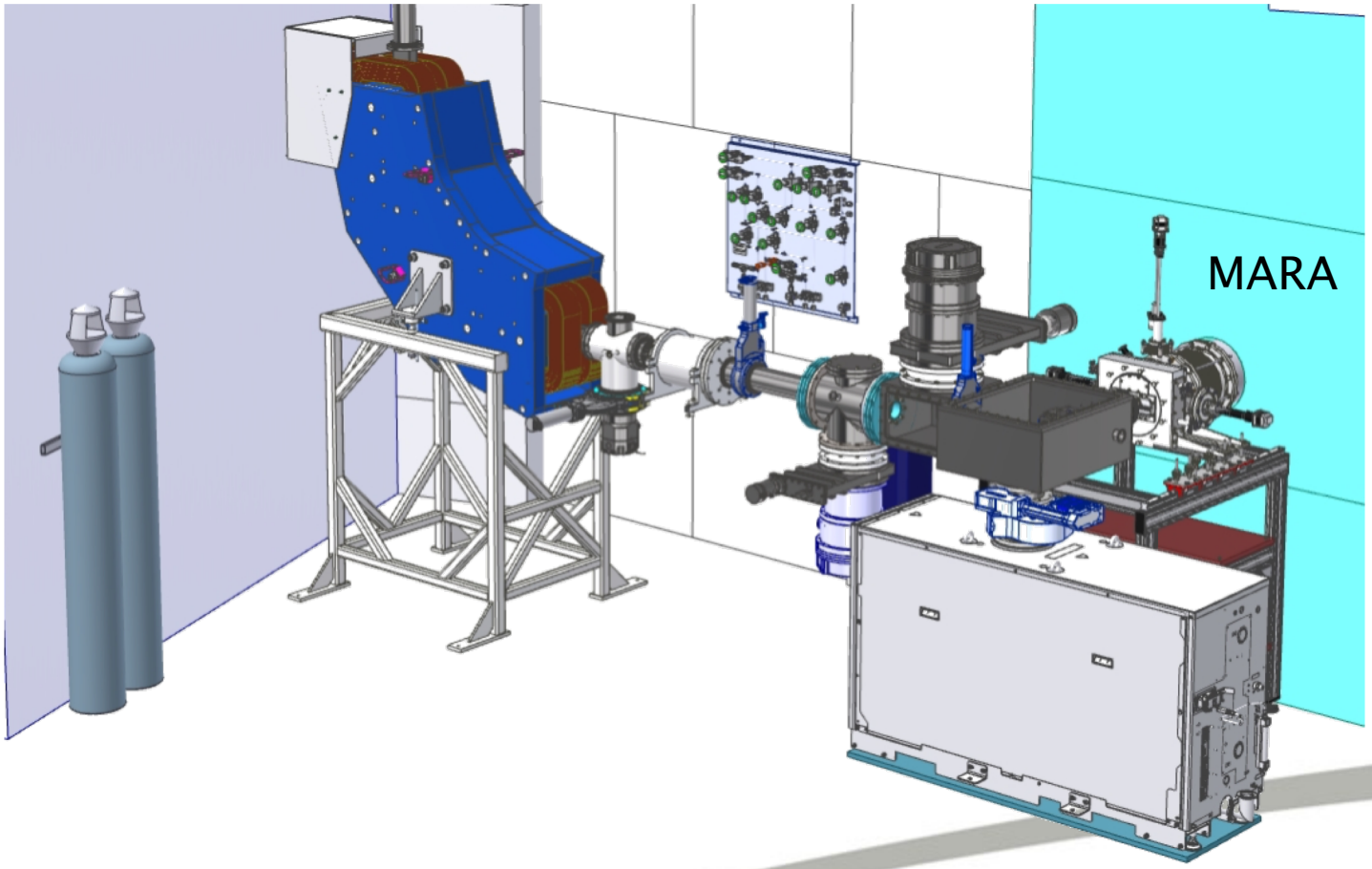

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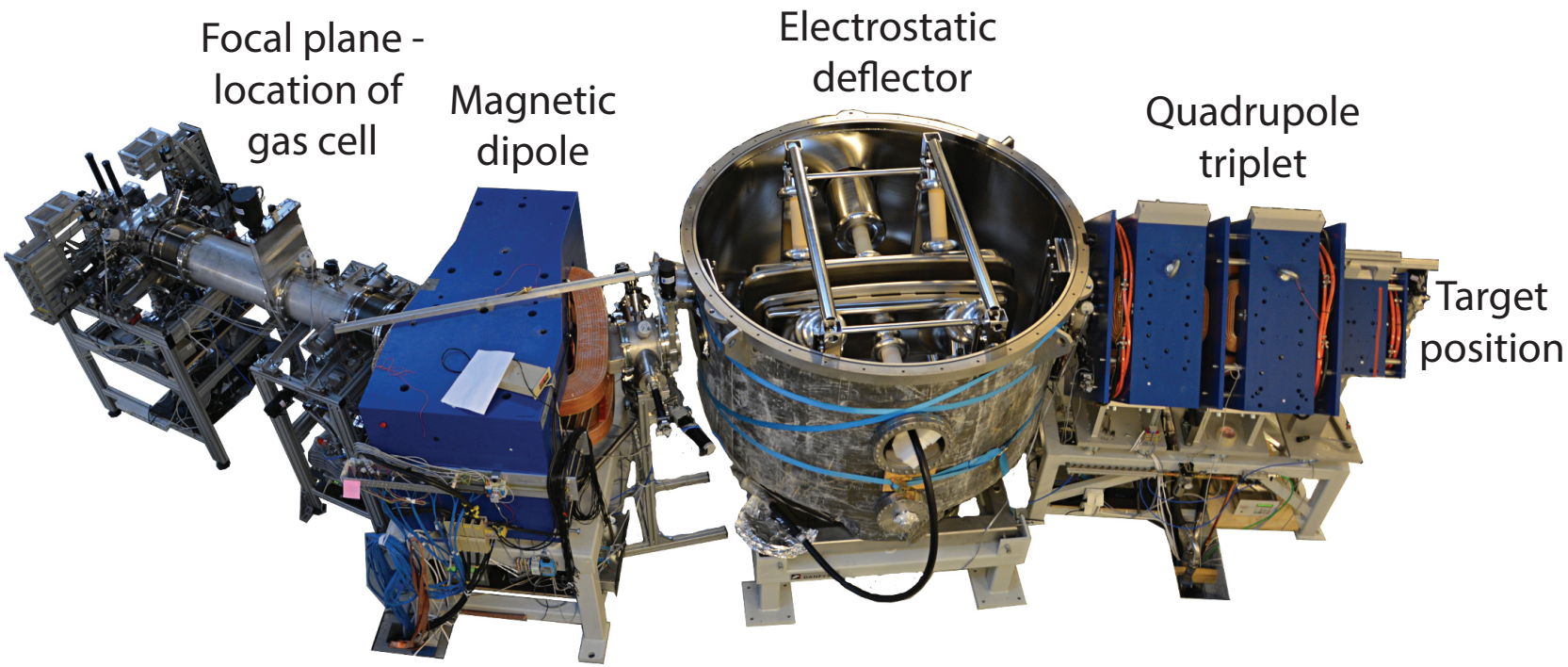
The MARA separator

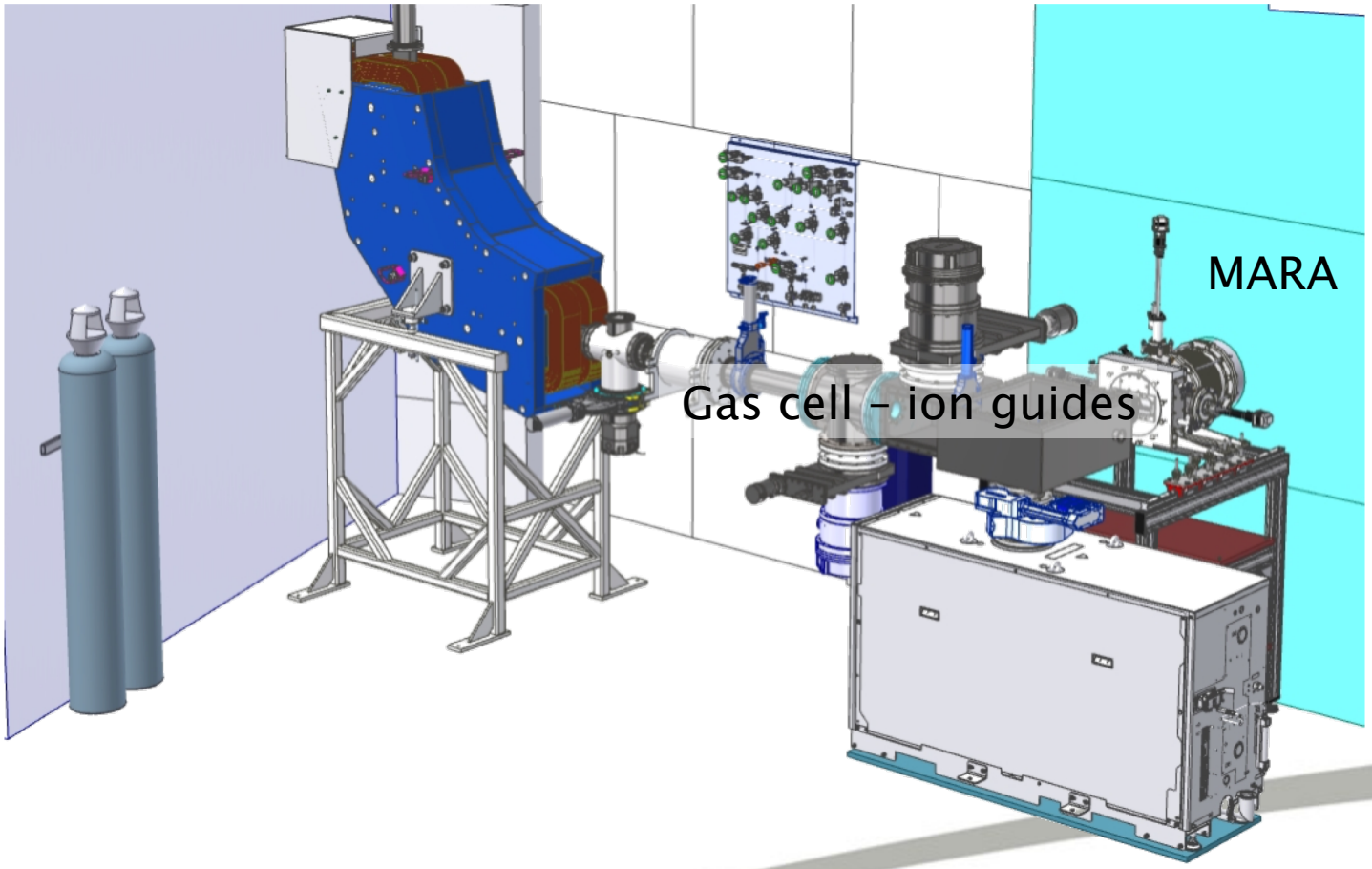


J. Sarén *et al.*, Nucl. Instr. and Meth. B **266**, 4196 (2008)
J. Sarén, PhD Thesis, University of Jyväskylä (2011)
J. Uusitalo *et al.* , Acta Phys. Pol. B **50**, 319 (2019)

The MARA separator

- 5 new isotopes from first experimental campaign
- ~230d of planned experiments
- JUROGAM 3 (talk J. Pakarinen) in-beam Ge detector array
- SAGE in-beam Ge (γ) and Si (e^-) detectors
- JYTube in-beam particle detector array
- Focal plane detector array (MWPC, DSSD, punch-through, Si box array and Ge
- Fully digital DAQ

Facility layout



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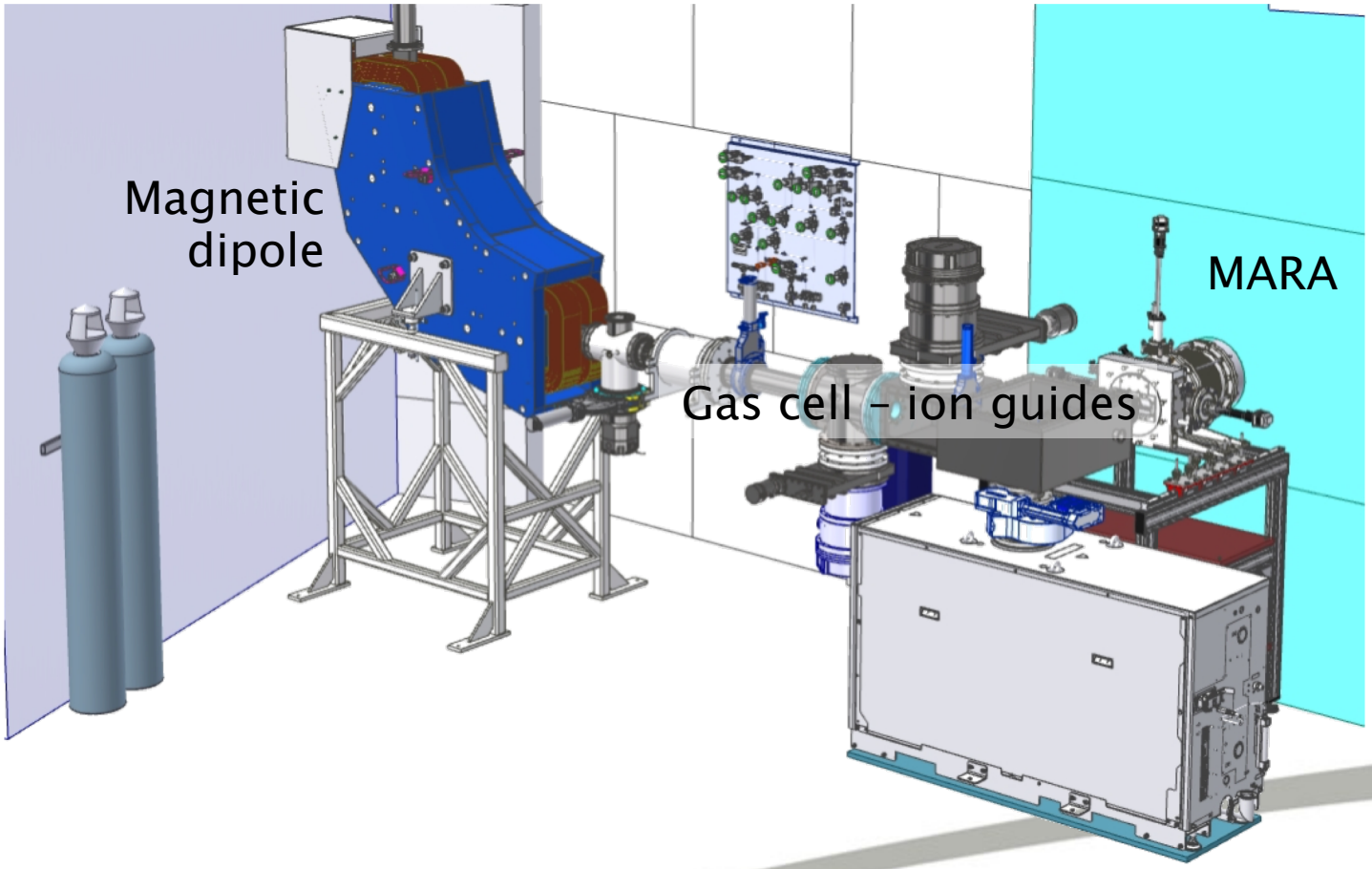
Facility layout



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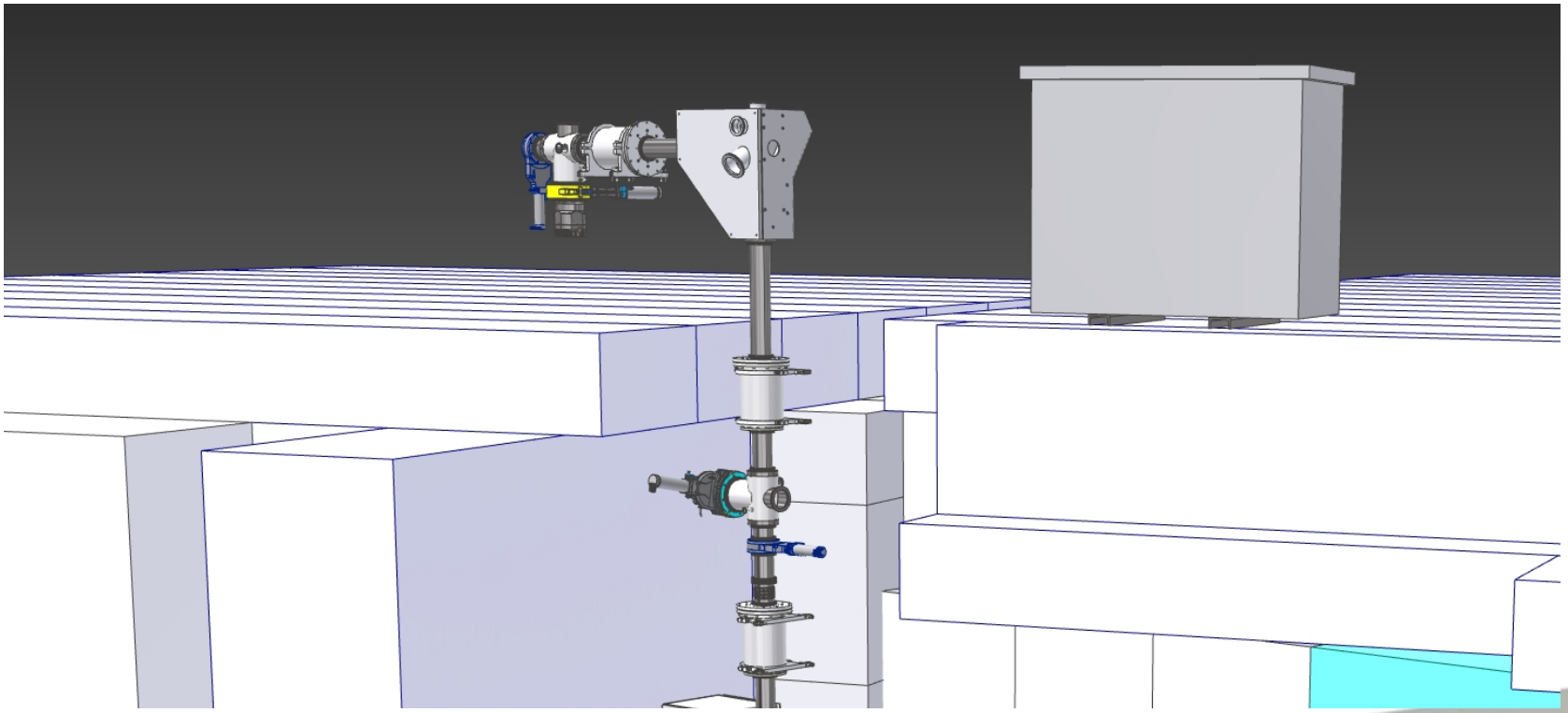

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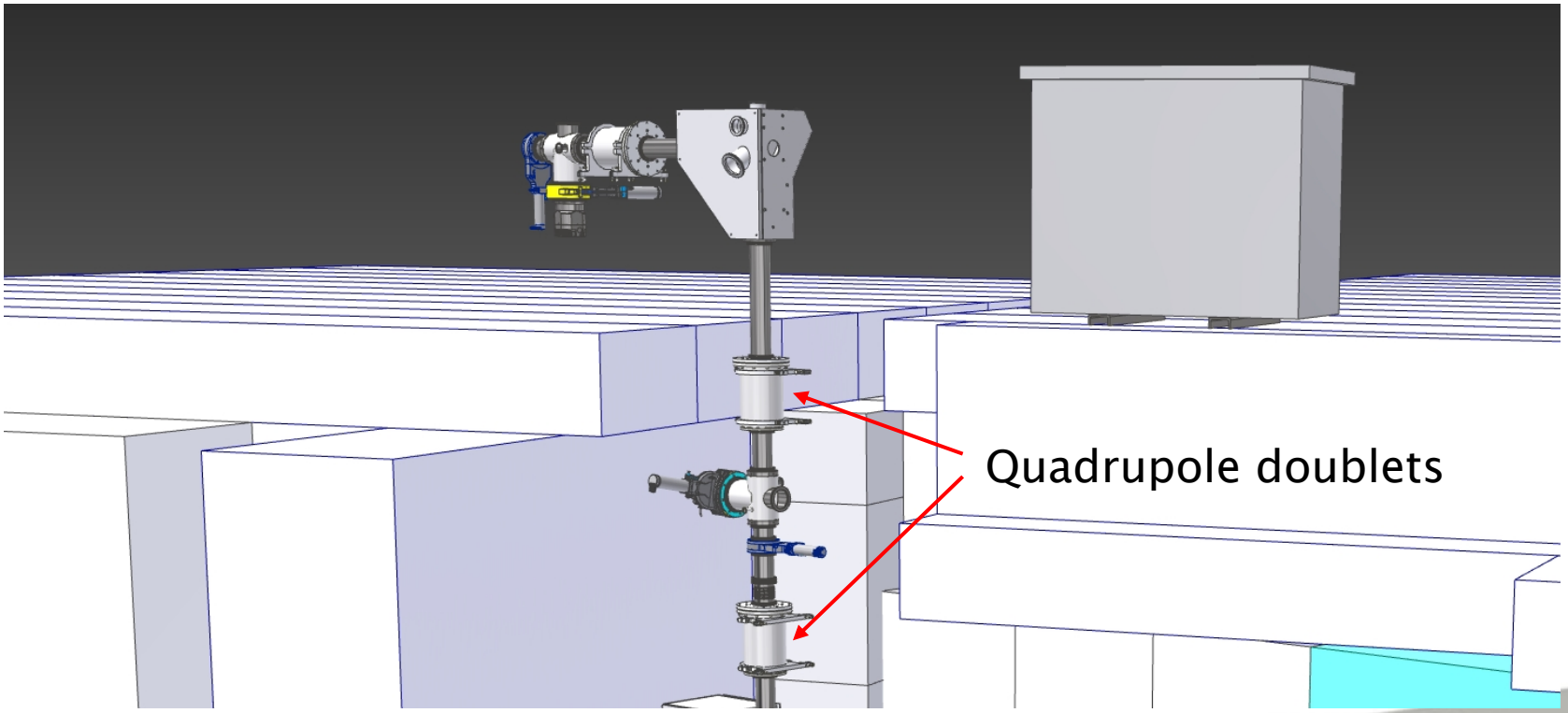

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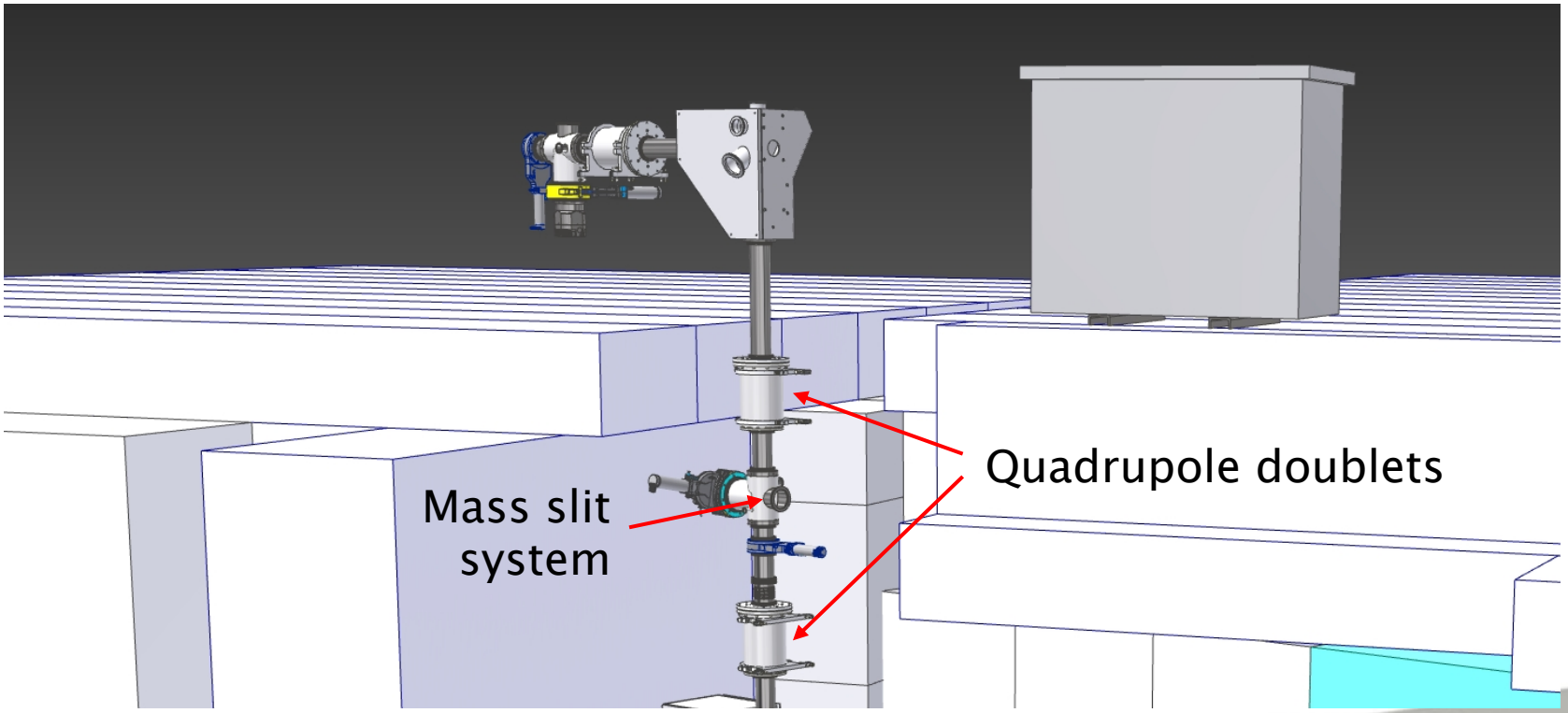

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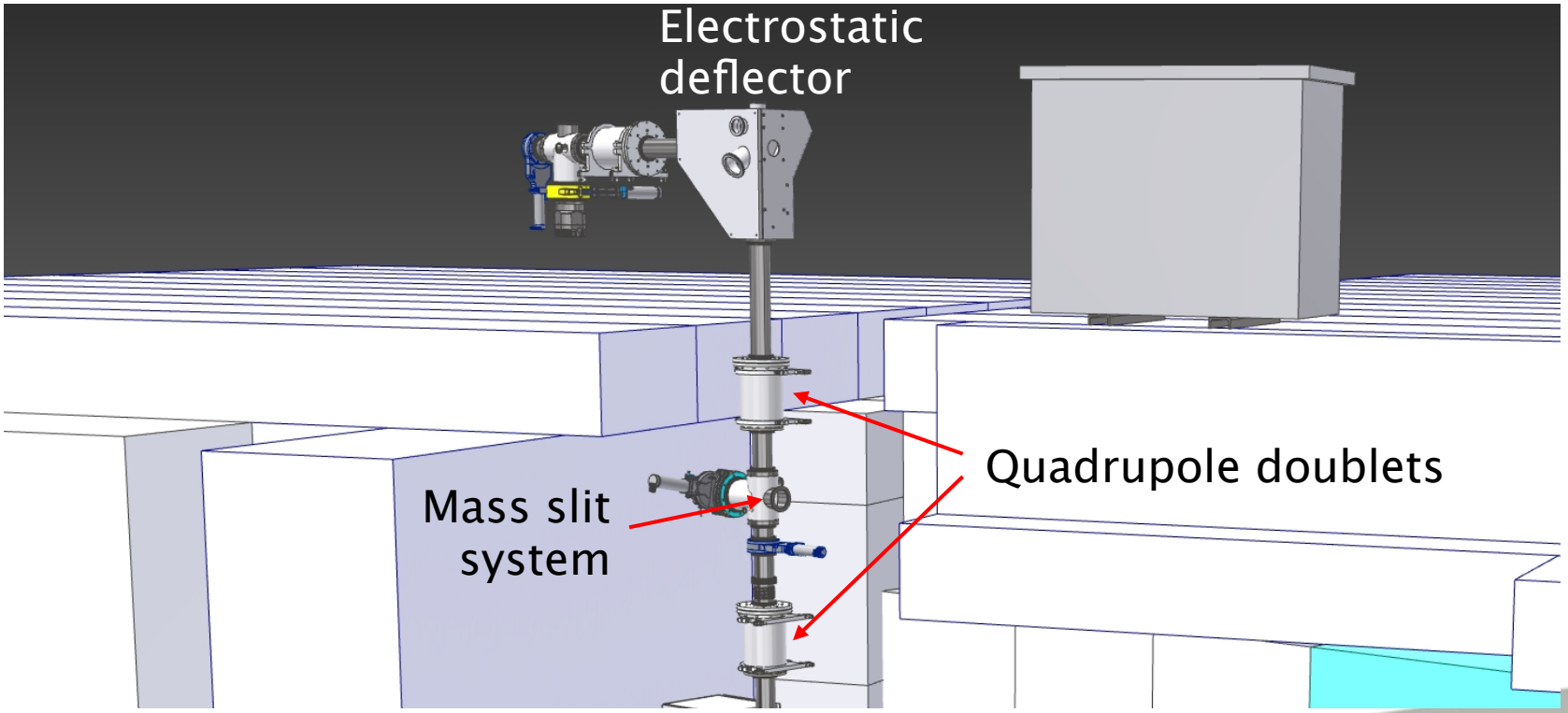

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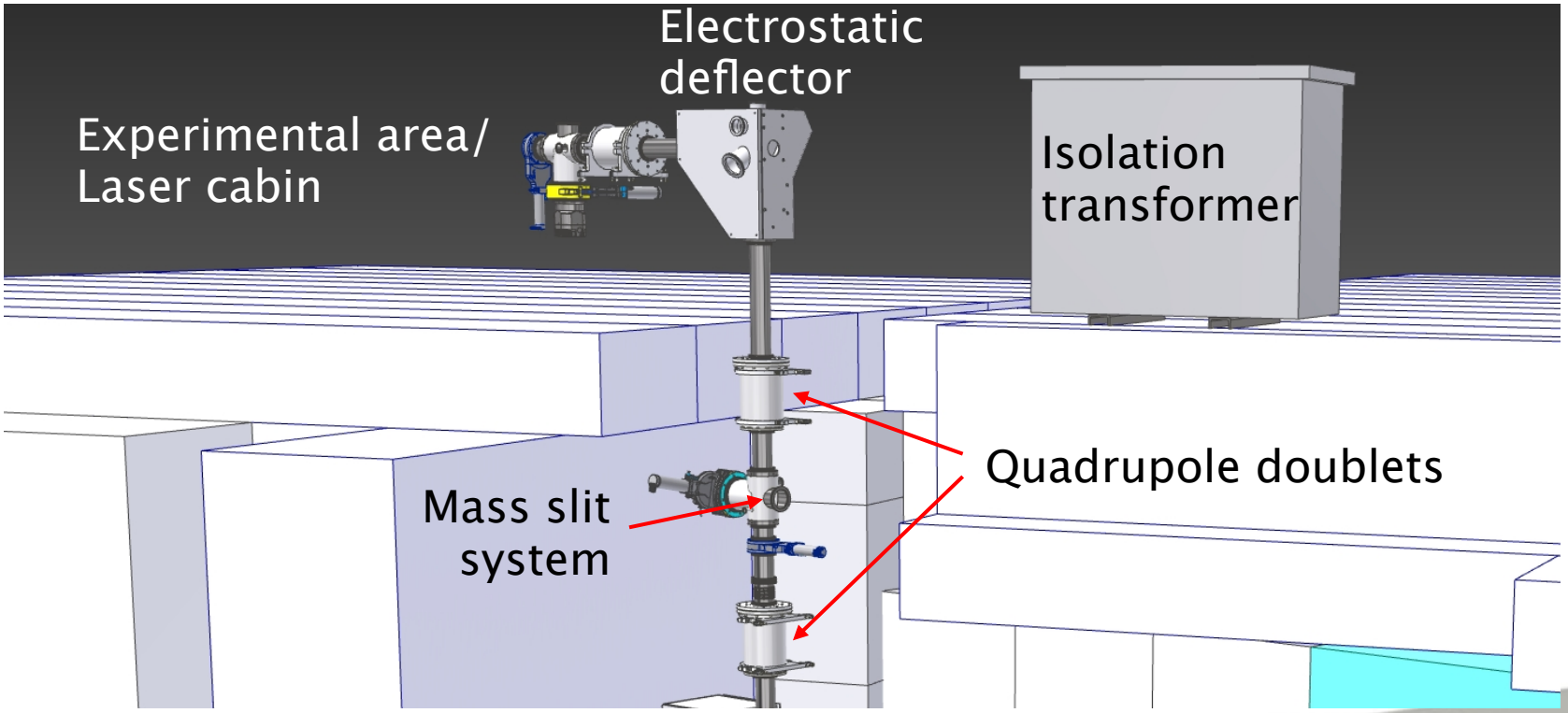
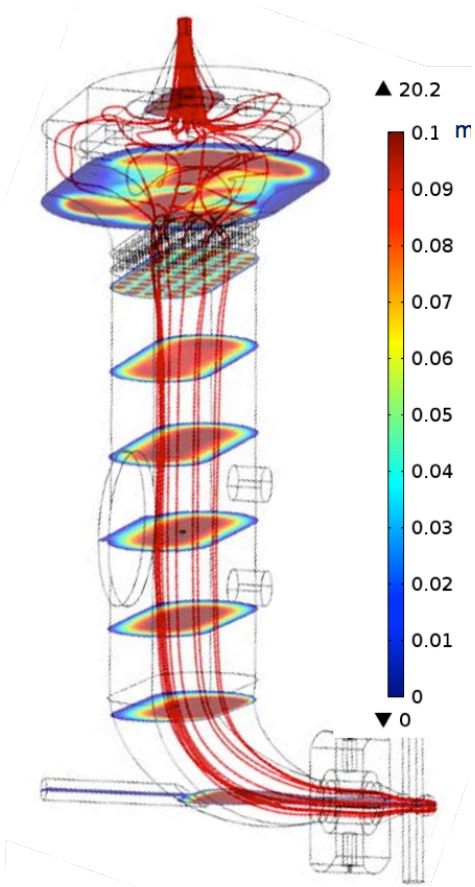


Gas cell



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

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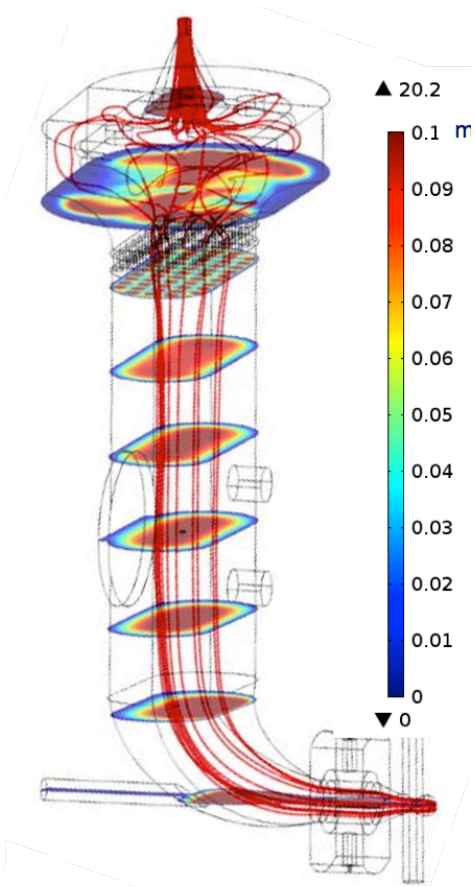
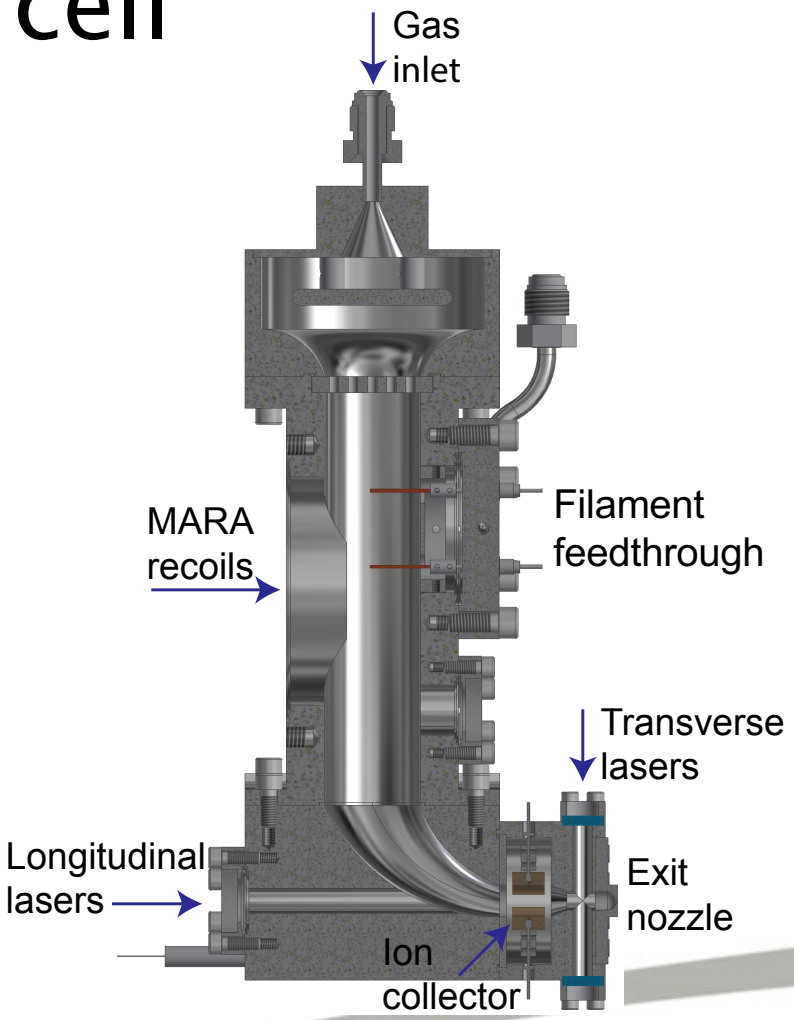
Gas cell





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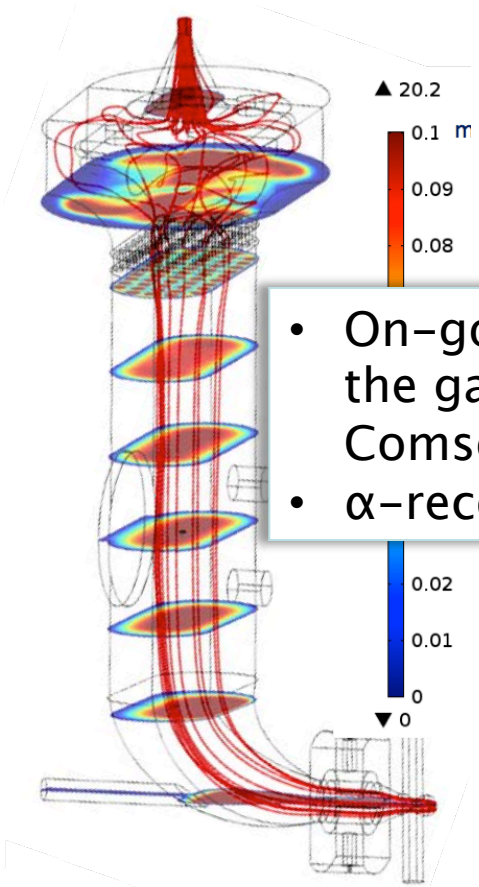
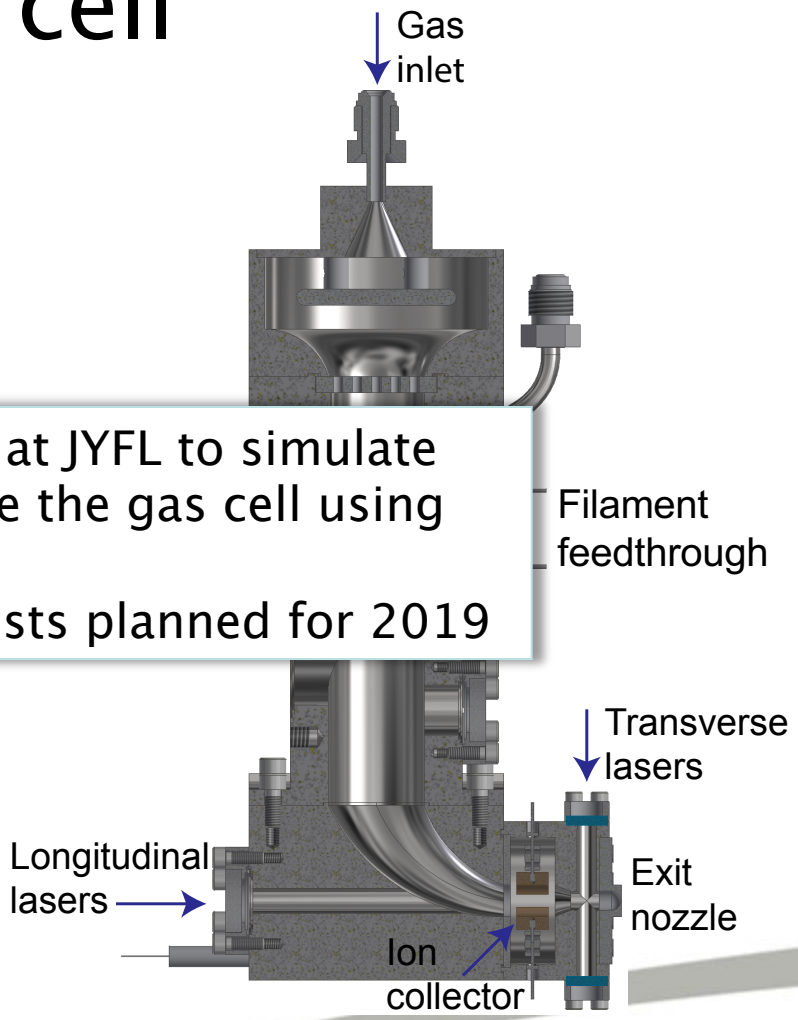


- On-going project at JYFL to simulate the gas flow inside the gas cell using Comsol
- α-recoil source tests planned for 2019



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

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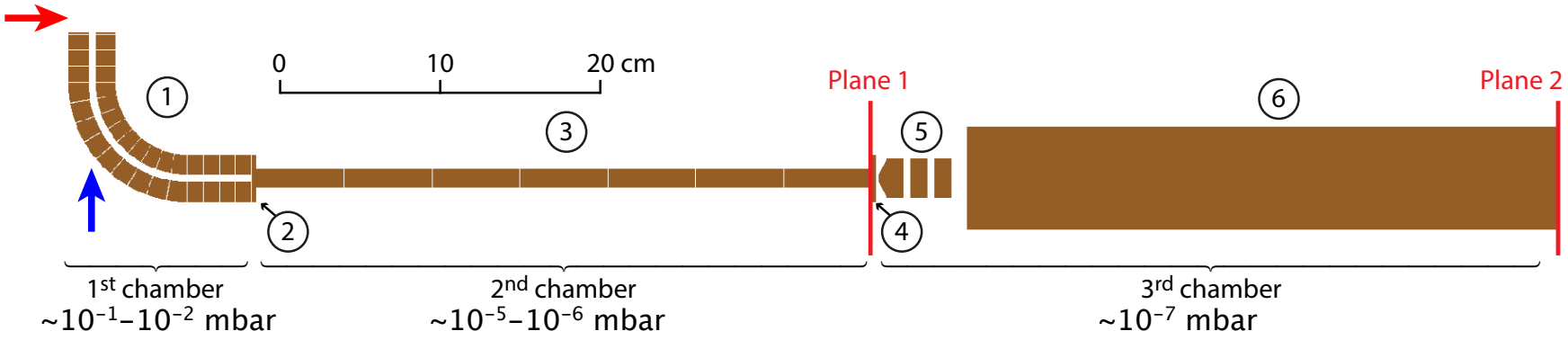
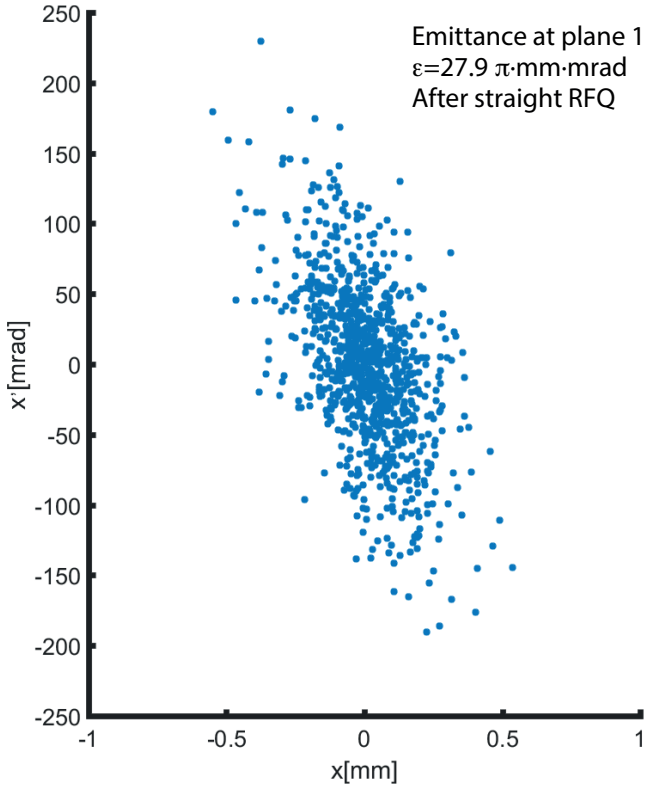
Ion guides

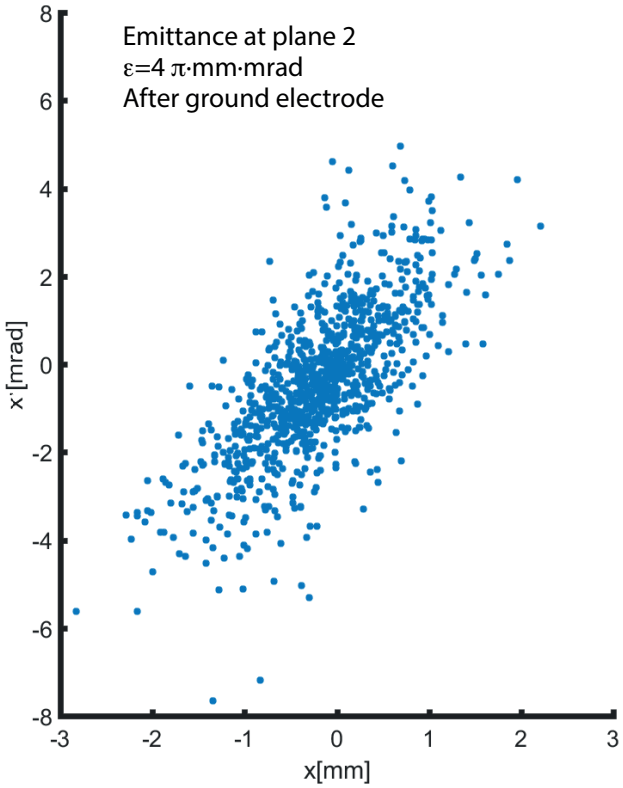


①	90°-bent RFQ
② ④	pumping apertures
③	straight segmented RFQ
⑤	acceleration electrodes
⑥	ground electrode
⇉	laser beams

Courtesy of Jarkko Liimatainen

Ion guides – SIMION simulations





P. Papadakis *et al.*, Nucl. Instr. and Meth. B *article in press*

Simulated emittance for 1000 $^{94}Ag^{+}$ ions.
Helium at 500 mbar pressure, 0.5 mm exit hole, free expanding jet.
Transmission efficiency 97%.

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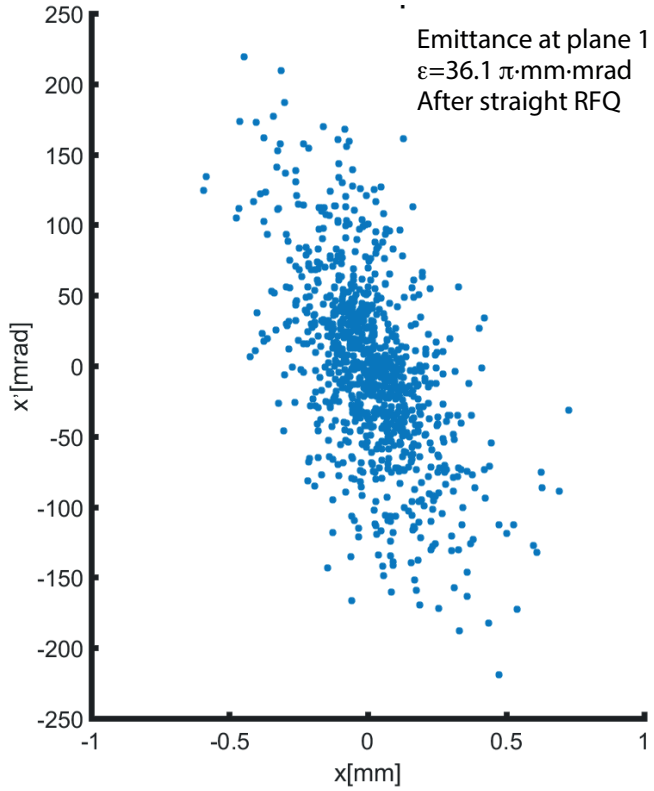

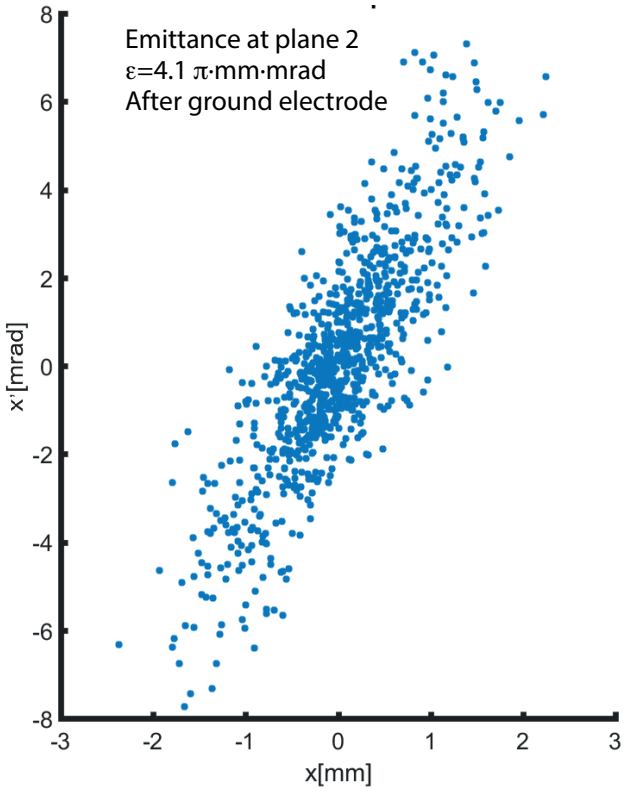

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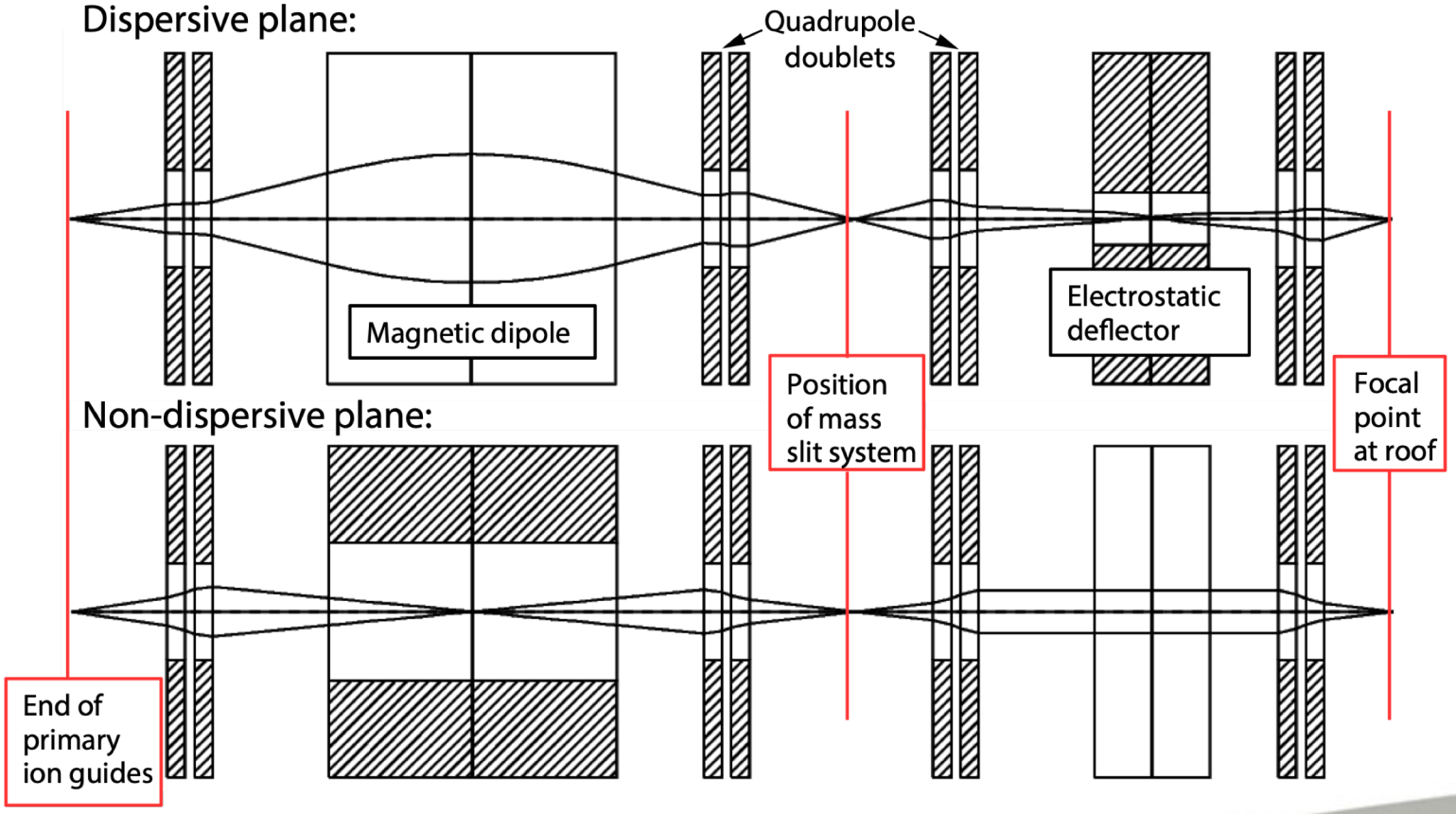
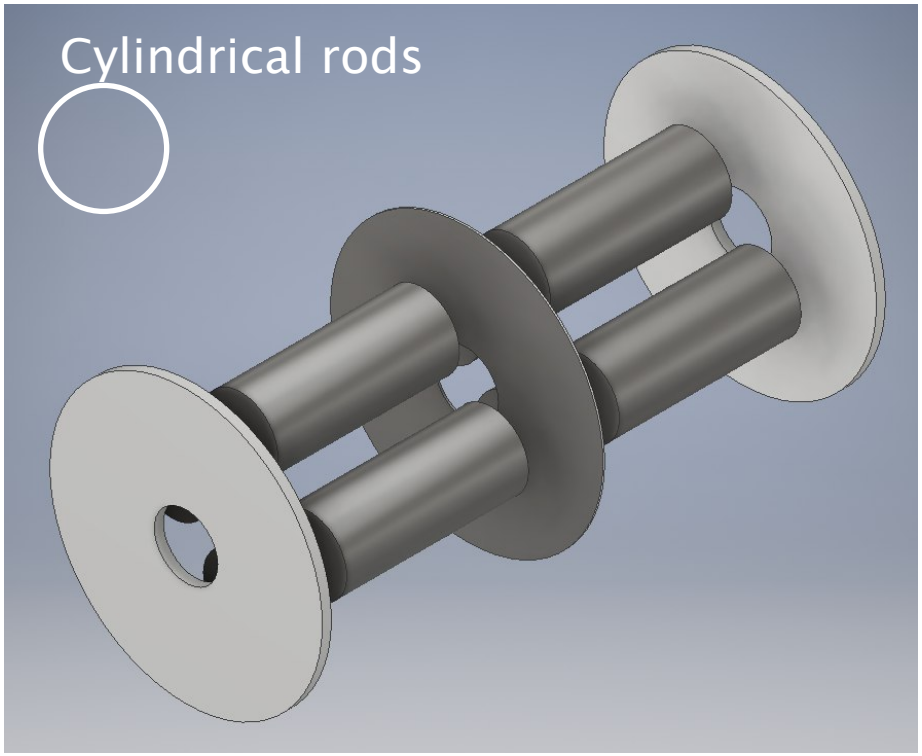
Transfer line – GICOSY simulations

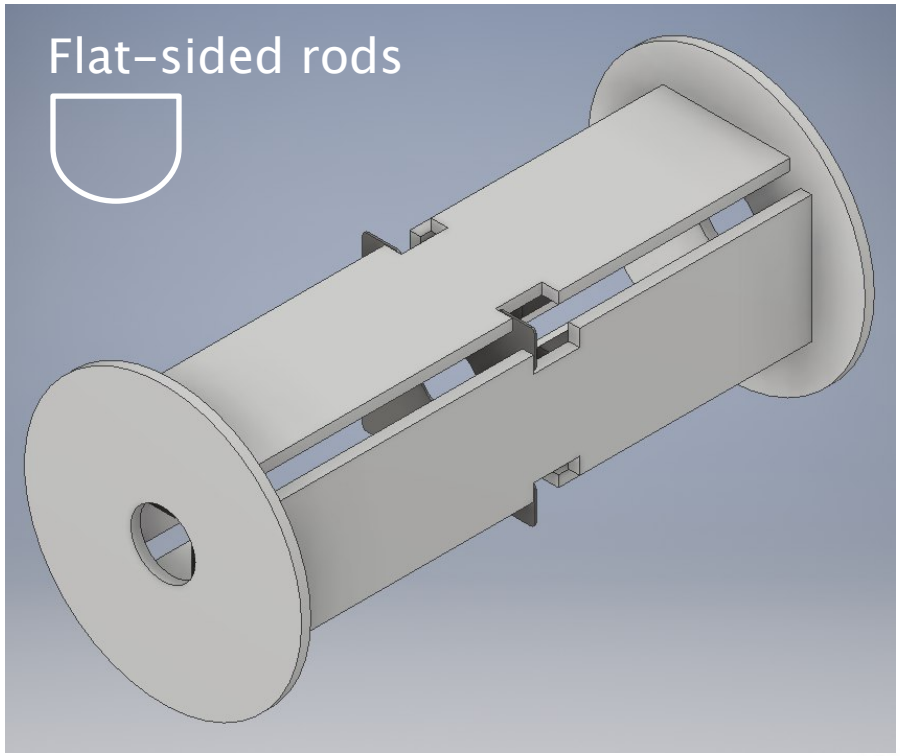


P. Papadakis *et al.*, Nucl. Instr. and Meth. B *article in press*

Courtesy of Jan Sarén

Quadrupole doublets

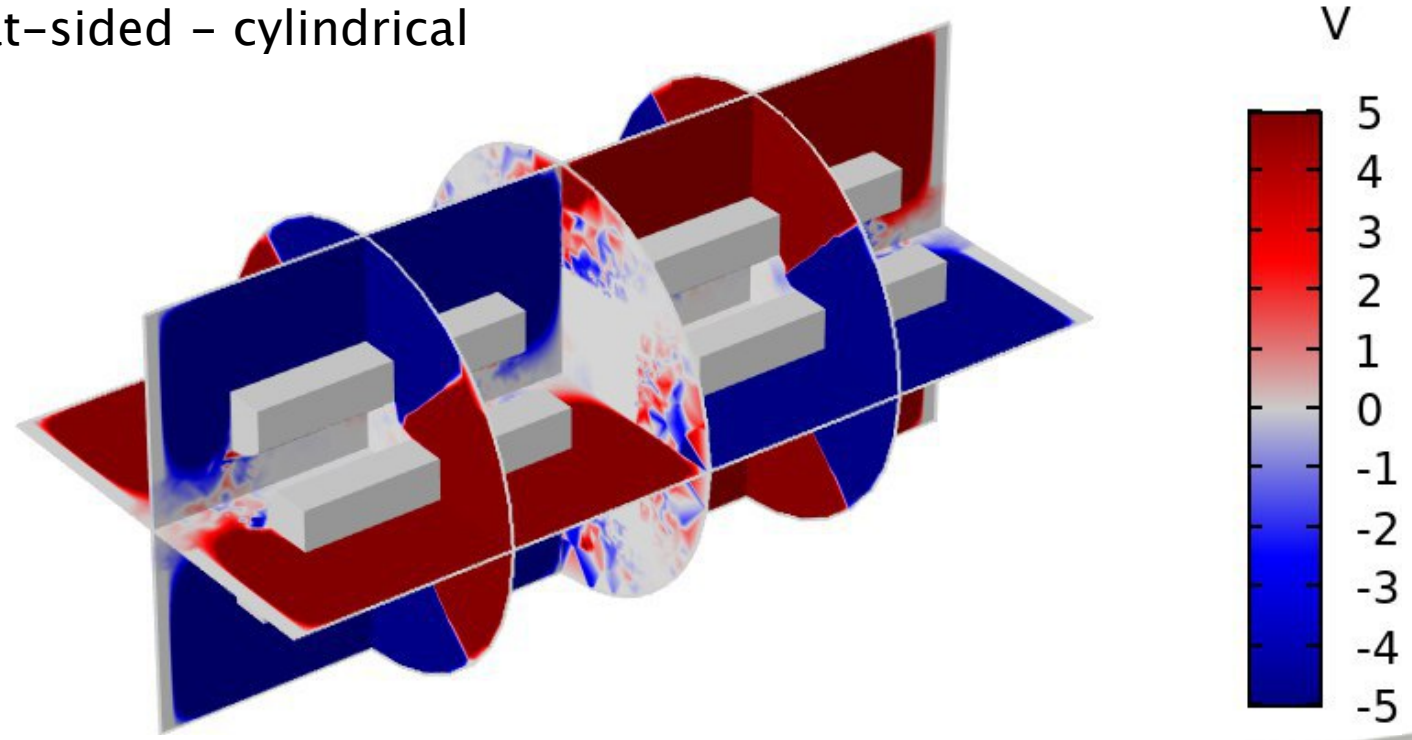




Courtesy of Wouter Gins

Quadrupole doublets – COMSOL simulations

Voltage difference map
Flat-sided – cylindrical



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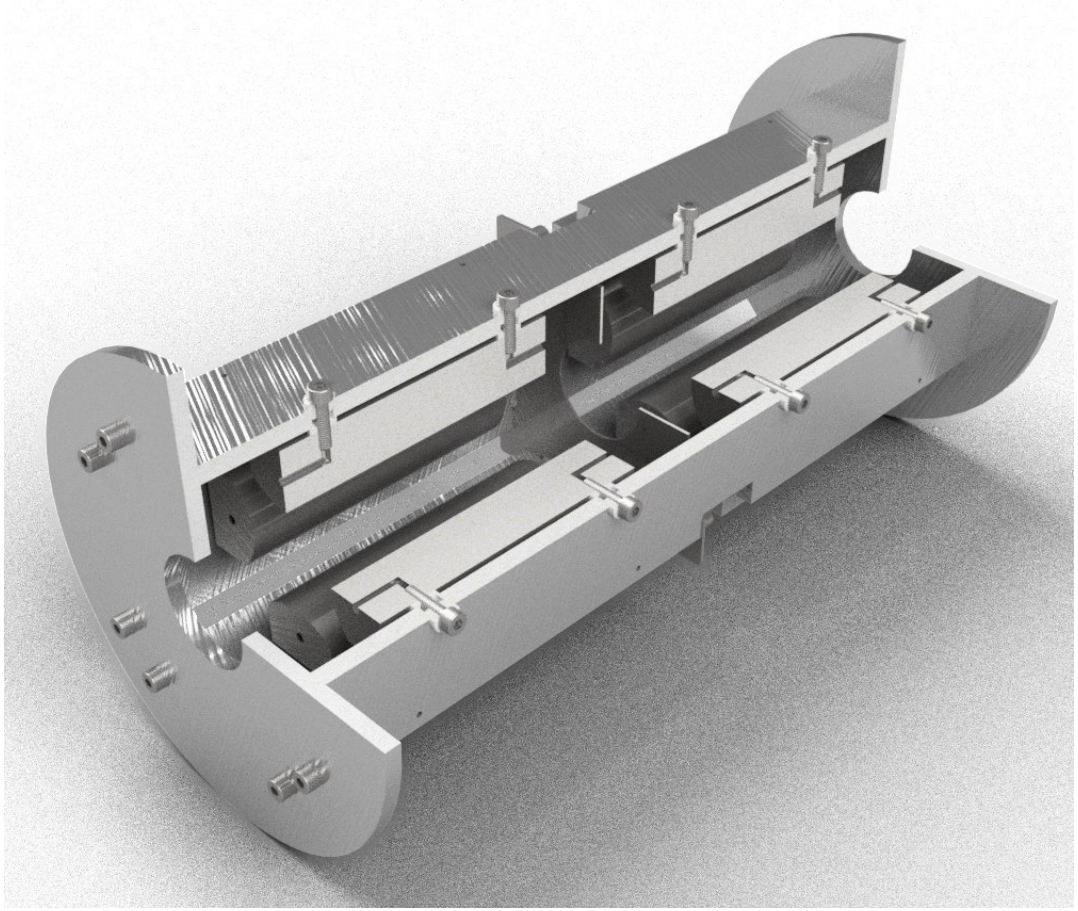
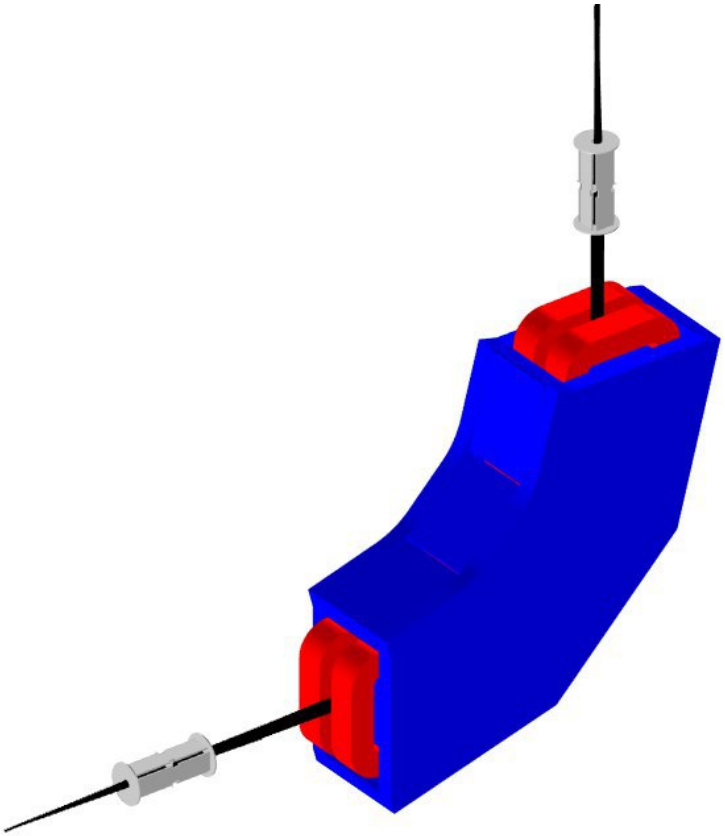
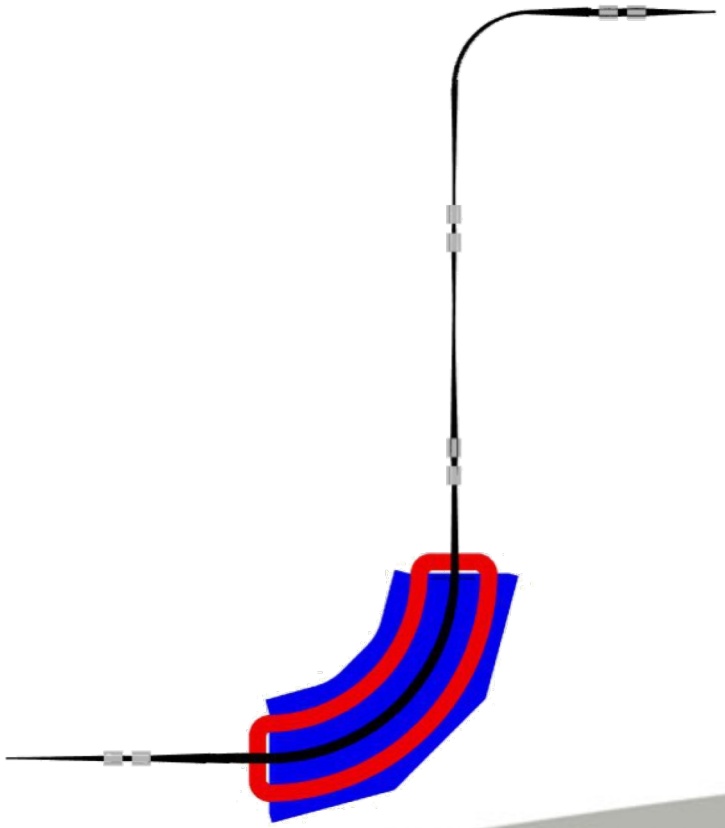
Quadrupole doublets



Courtesy of Wouter Gins

Combined simulation – COMSOL





Courtesy of Wouter Gins

Laser system

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

Laser system

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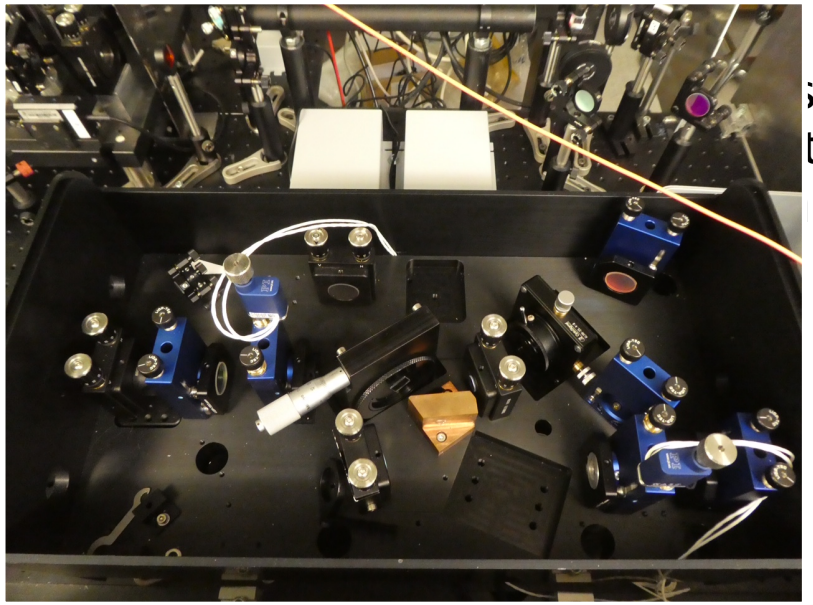

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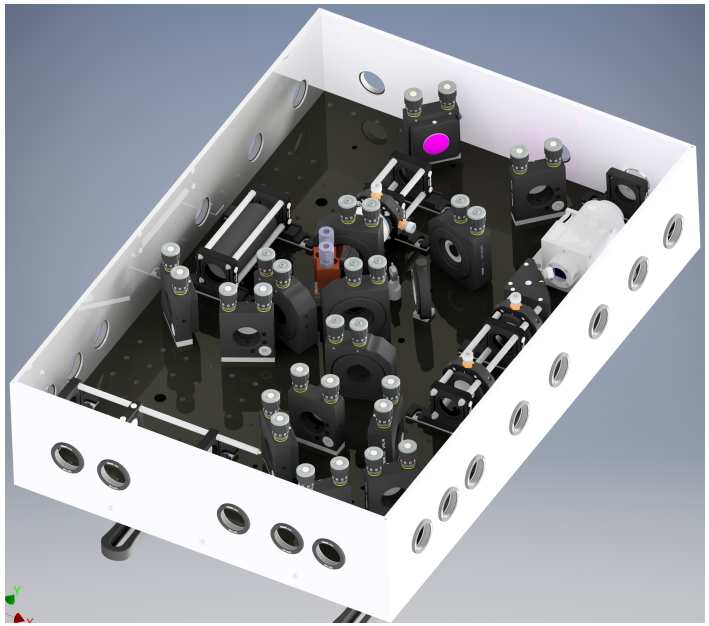
Laser system



New injection-locked cavity has been built in Jyväskylä to provide narrow-band radiation for high-resolution studies

V. Sonnenschein *et al., Laser Phys.* **27**, 085701 (2017)
M. Reponen *et al.*, Nucl. Instrum. Meth. **908**, 236 (2018)

Project outlook

- ✓ Gas cell: Designed and built.
  - α-recoil source tests planned in 2019
  - Gas flow verification ongoing
- ✓ Lasers: Ti:Sapphire lasers built and tested
  - FIRI funding request for pump lasers submitted
- ✓ 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: Designed, components purchased

Project outlook

- Ion guides: Simulations being verified
  - Mechanical design and construction in 2019
- Transfer line: Design will be finalised in 2019
- Vacuum chambers/support structures: Design ongoing
- Decay station: Funding to be requested
- MR-TOF-MS/RFQ cooler buncher: Design based on a similar devices for IGISOL-4

✓ Approved proposal to investigate the feasibility of studying $^{94-96}$Ag with MARA-LEB

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UNIVERSITY OF JYVÄSKYLÄ

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

Funding

ACADEMY OF FINLAND

MARIE CURIE ACTIONS

SEVENTH FRAMEWORK PROGRAMME

In collaboration with

KU LEUVEN

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

UNIVERSITY OF LIVERPOOL

Jari Partanen

Skilled physicist,
electronics engineer extraordinaire,
core member of the MARA team,
but above all a wonderful human being.

21 February 1988 – 19 June 2019