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New Experimental Prospects for the MARA-LEB Facility

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14th International Conference on Stopping and Manipulation of Ions and Related Topics

Contents

Photo: Arthur Jaries

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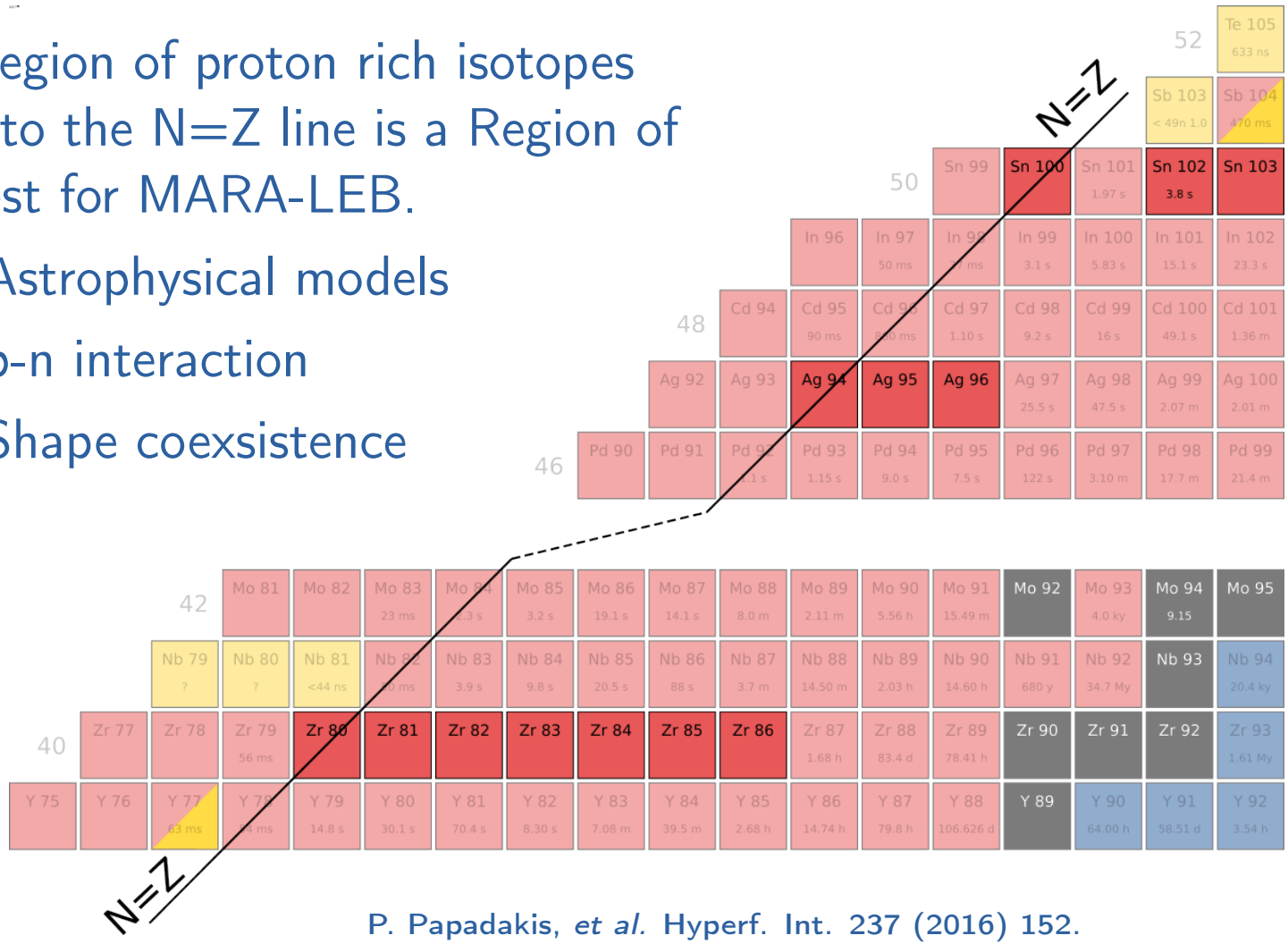
The Facility

Motivation

The region of proton rich isotopes close to the N=Z line is a Region of Interest for MARA-LEB.

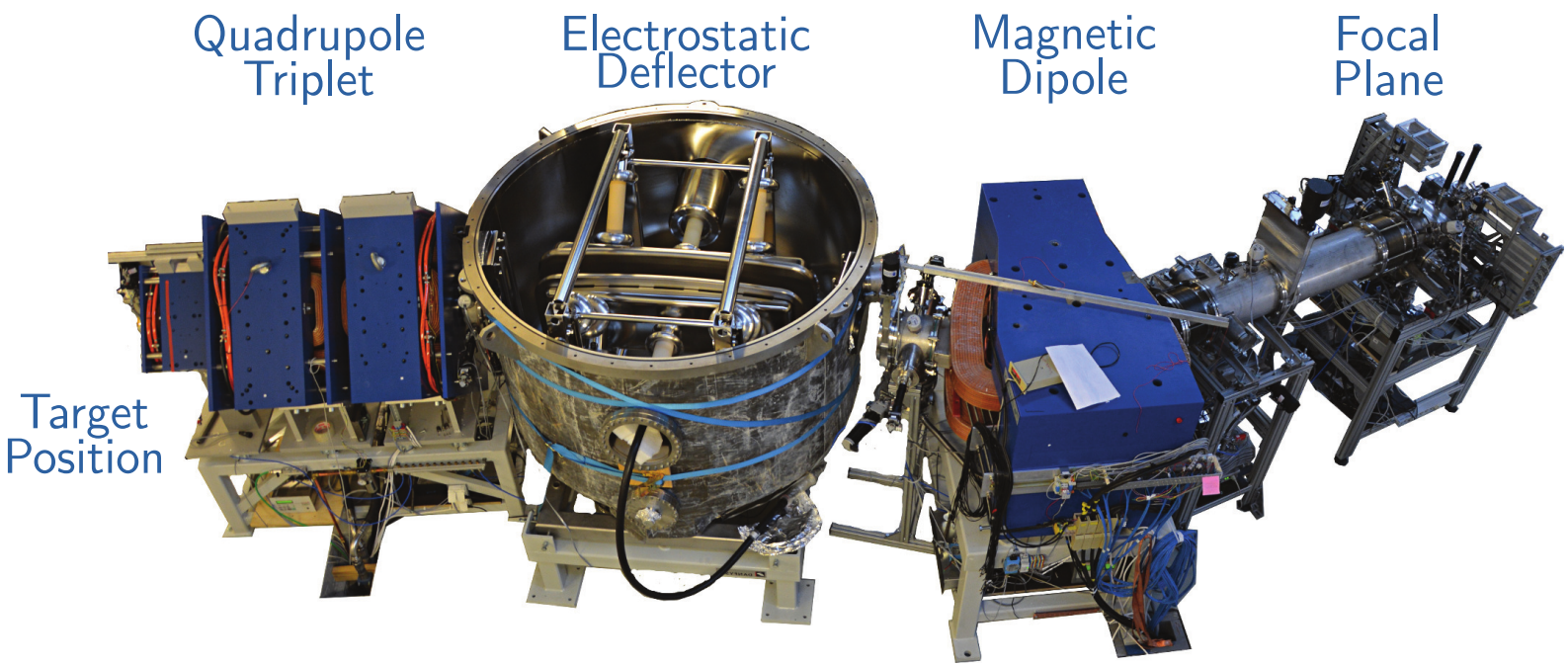
- Astrophysical models
- p-n interaction
- Shape coexsistence



P. Papadakis, *et al.* Hyperf. Int. 237 (2016) 152.

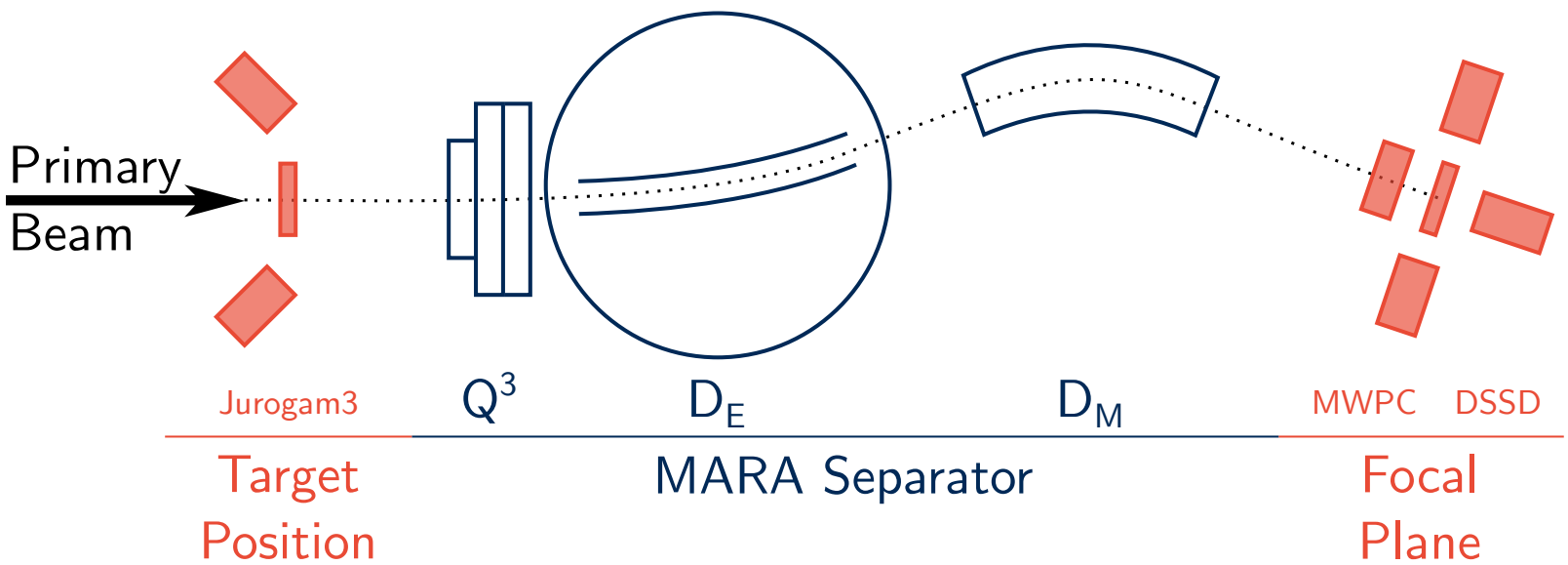
MARA

The Mass Analysing Recoil Apparatus (MARA) is a $Q^3D_ED_M$ separator with a mass resolution of 250, mainly used for symmetric fusion-evaporation reactions.



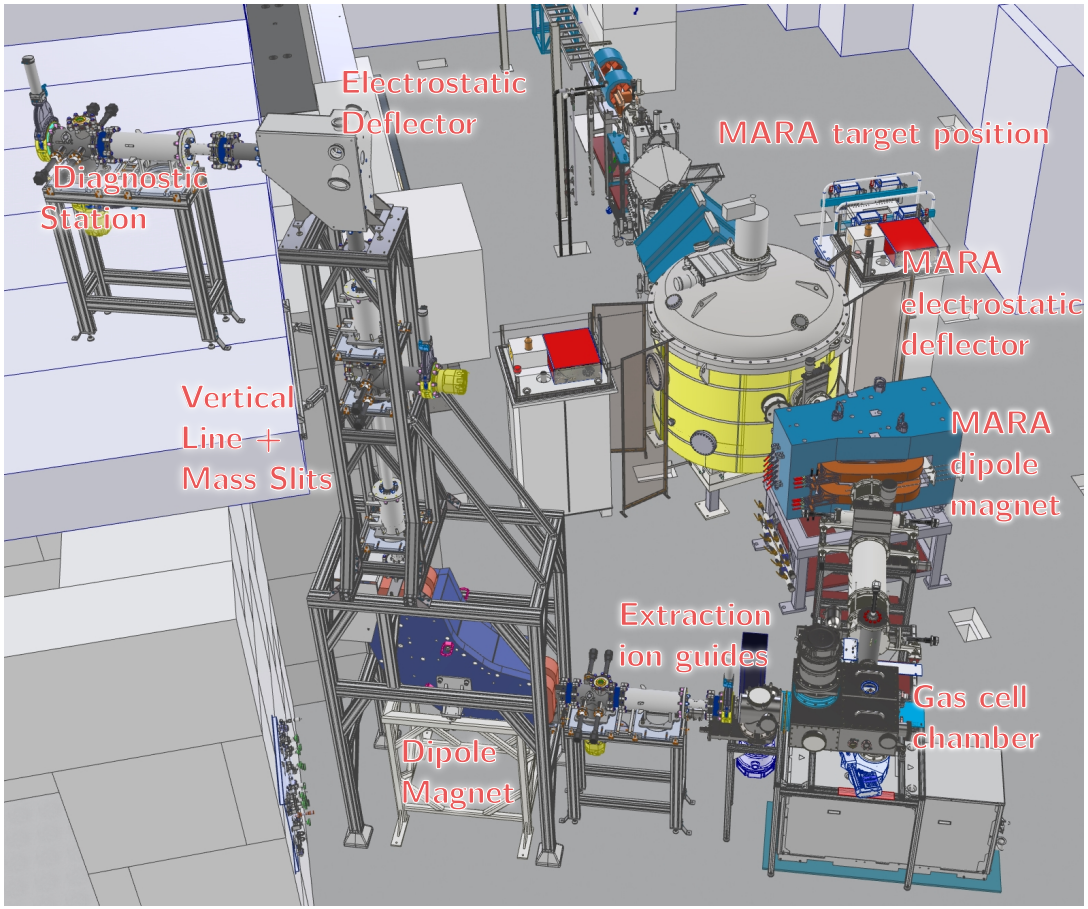
J. Uusitalo, *et al.* Acta Phys. Polonica B 50 (2019) 319.

MARA


Primary
Beam
Jurogam3
Q^3
D_E
D_M
MWPC
DSSD
Target
Position
MARA Separator
Focal
Plane

MARA-LEB

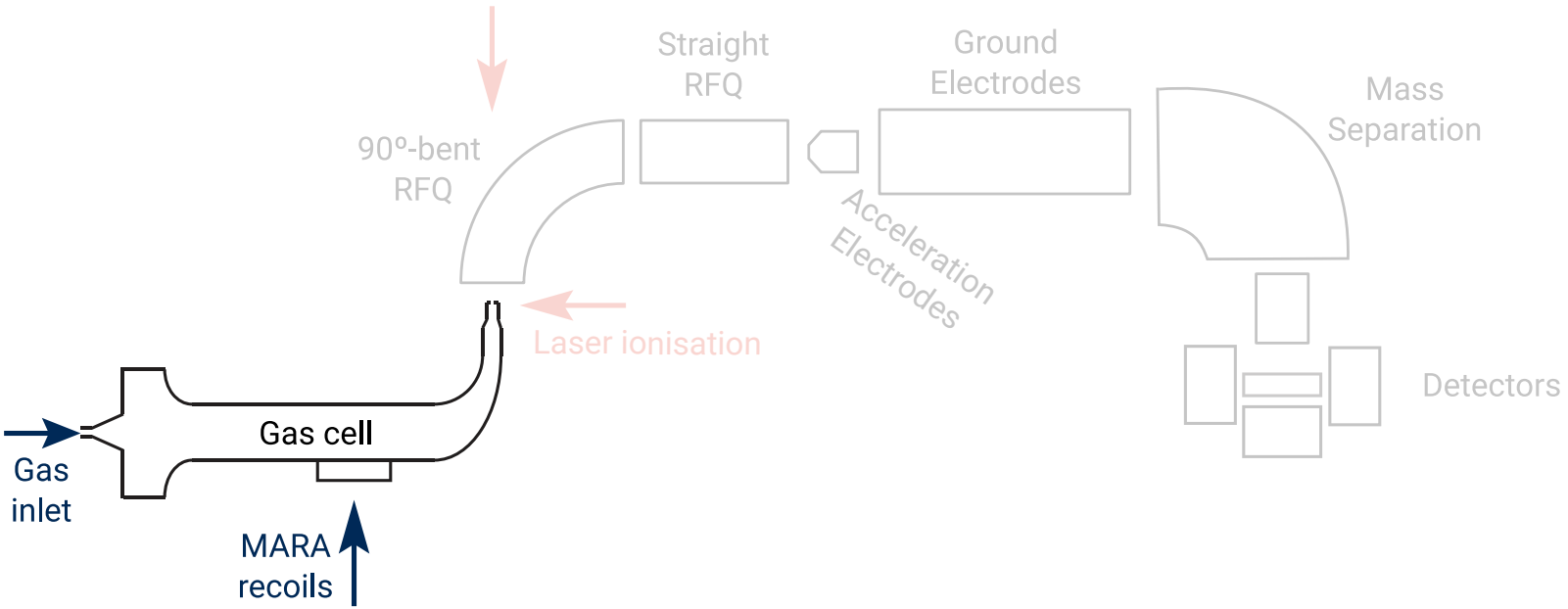
The MARA Low Energy Branch (MARA-LEB) will combine several separation techniques to purify beams of exotic ions produced at MARA.



It is currently under initial construction and testing at the Accelerator Laboratory in Jyväskylä, Finland.

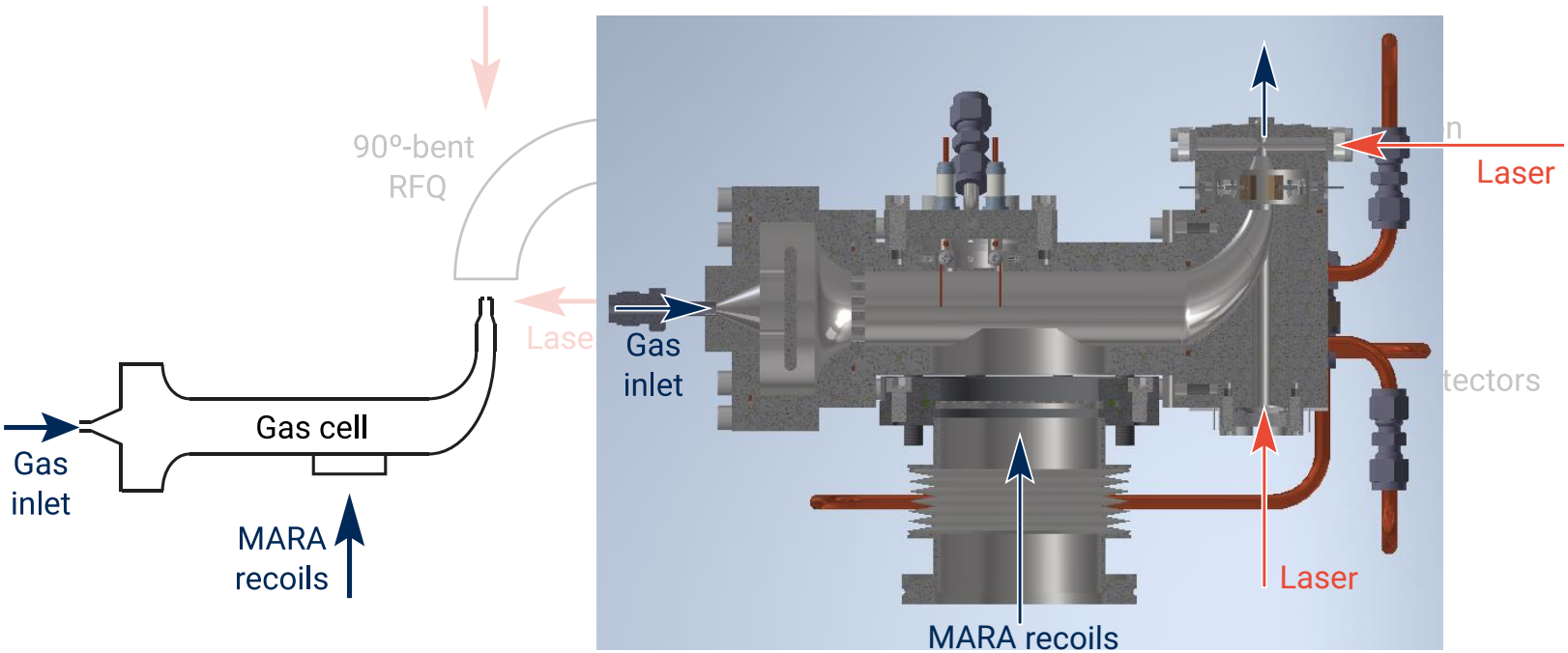
MARA-LEB

Recoils produced at MARA are stopped and neutralised in a small-volume buffer gas cell. Typical buffer gases are helium and argon.



MARA-LEB

Neutralised recoils can be re-ionised via in-gas-cell laser ionisation. The gas is flushed out of the gas cell through a 1.65 mm-diameter nozzle.

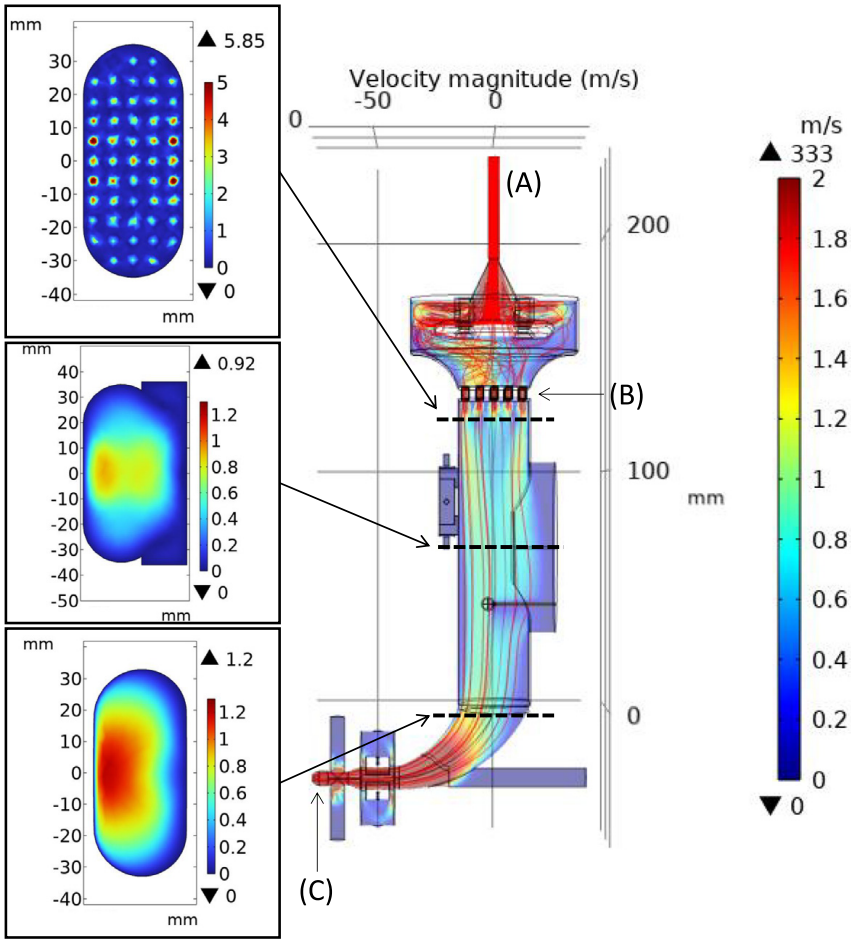


A. Zadvornaya, J. Romero, *et al.* Nucl. Instrum. Meth. B 539 (2023) 33.

MARA-LEB

The gas cell design is informed by Comsol simulations to optimise the laminarity of the gas flow.

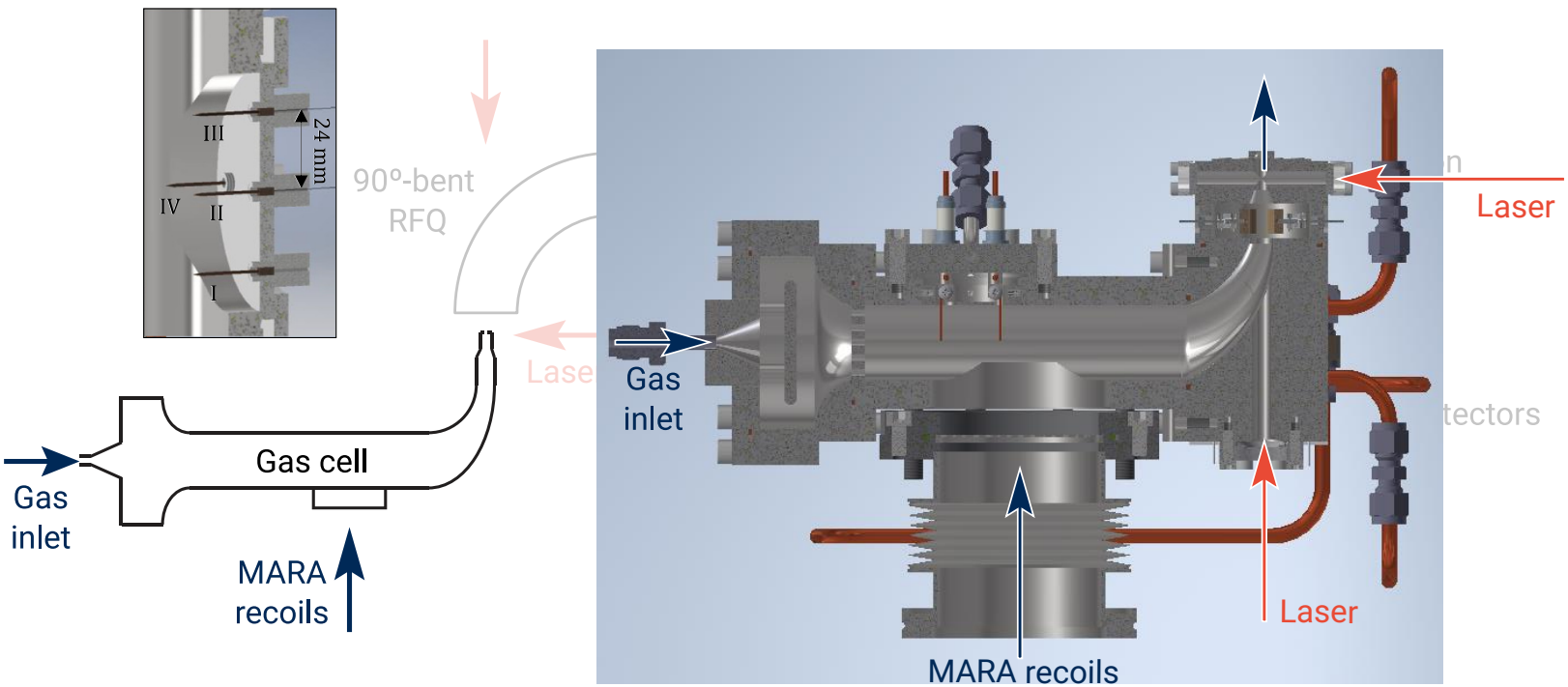
A honeycomb structure is present before the stopping volume to straighten the gas flow.



A. Zadvornaya, J. Romero, *et al.* Nucl. Instrum. Meth. B 539 (2023) 33.

MARA-LEB

The gas cell has been tested offline at IGISOL, obtaining ion survival and transport efficiencies of up to 12% for an ^{223}Ra needle source.



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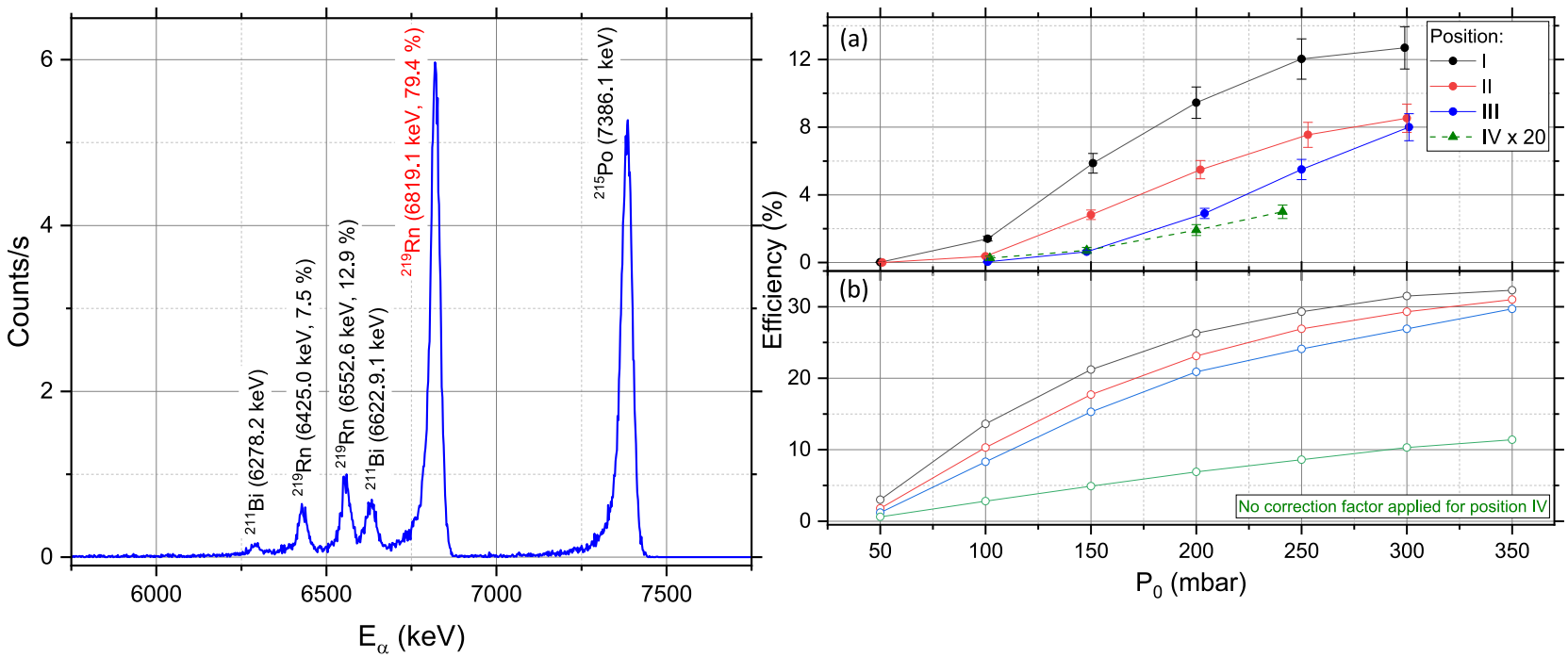
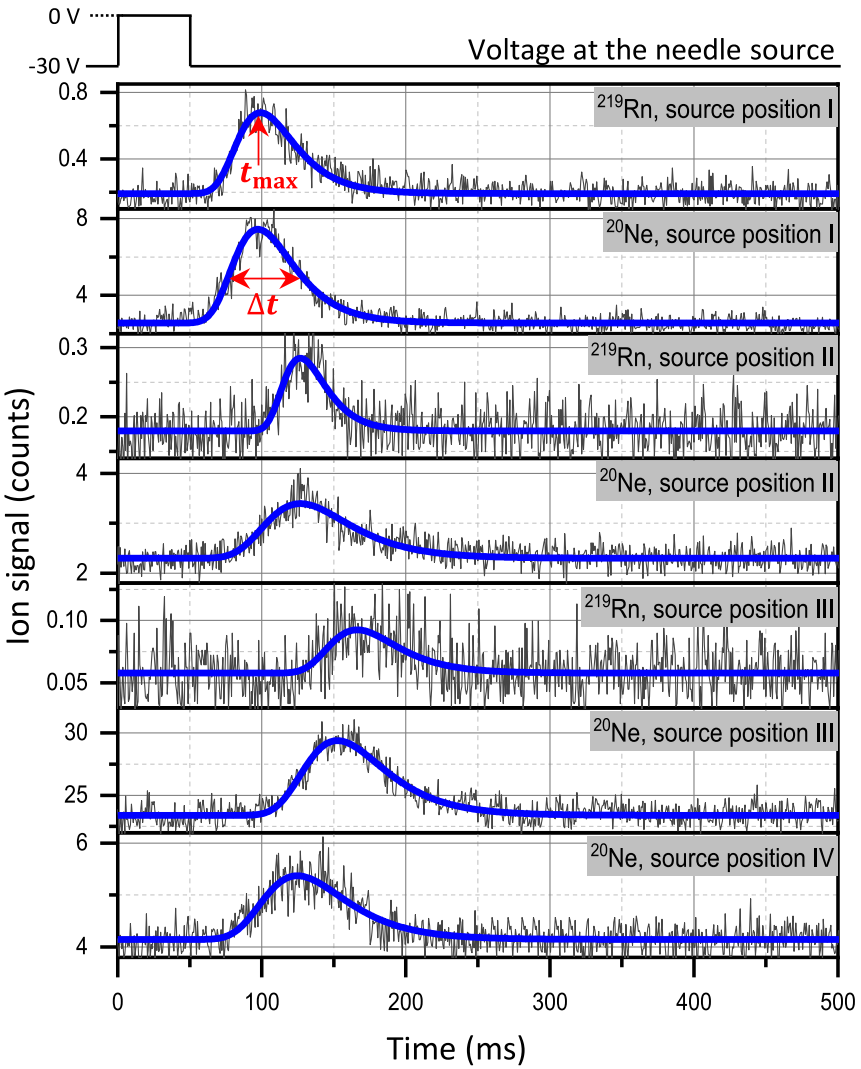


A. Zadvornaya, J. Romero, *et al.* Nucl. Instrum. Meth. B 539 (2023) 33.

MARA-LEB

By applying a pulsing voltage to the needle source, extraction time profiles can be obtained for ^{219}Rn and gas impurities.

- $t_{He} \approx 125\,ms$
- $t_{Ar} \approx 370\,ms$
- The extraction time ratio: $t_{Ar}/t_{He} = 2.94(2)$ is close to the estimate: $\sqrt{A_{Ar}/A_{He}} = 3.16$.



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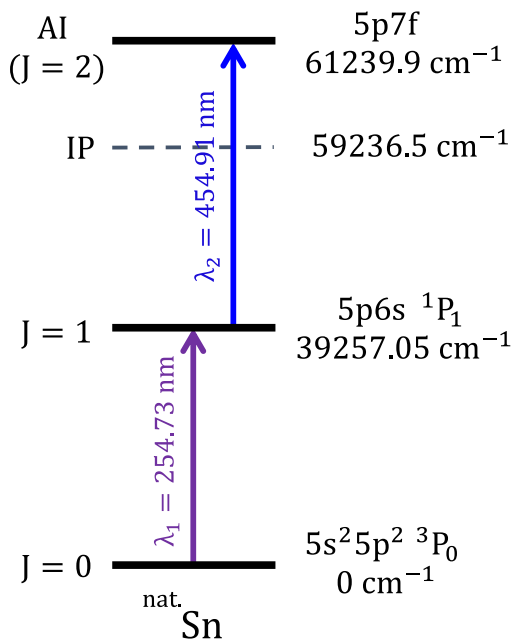
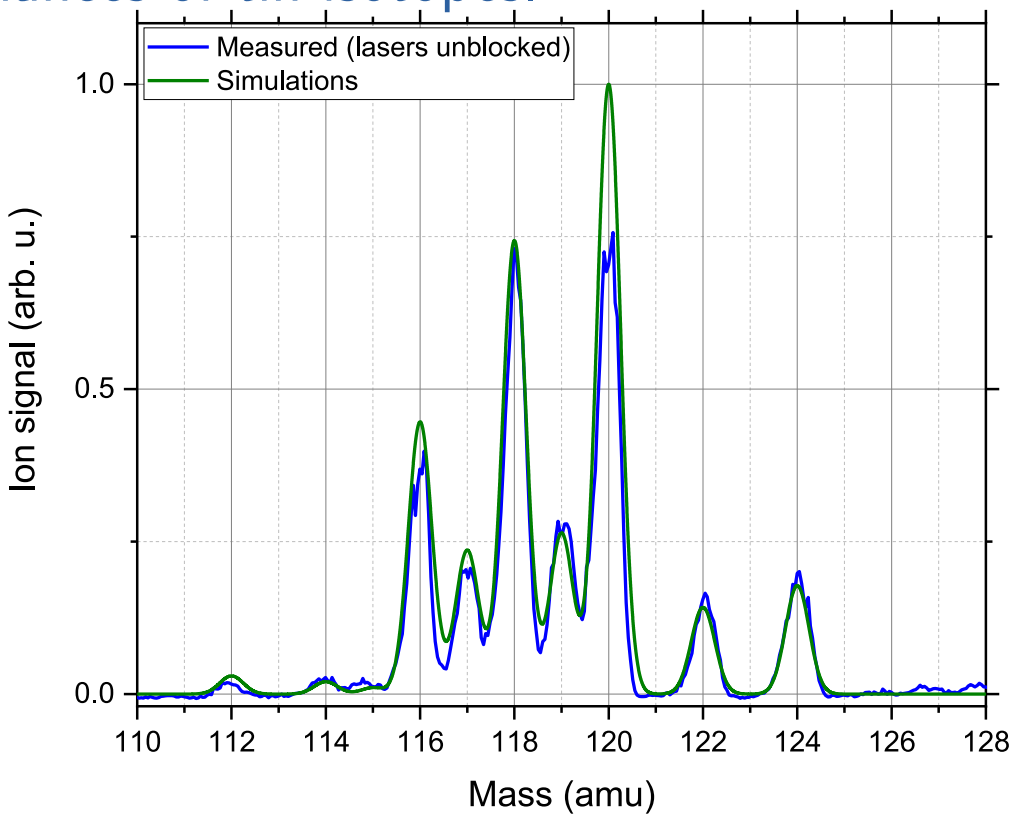
MARA-LEB

Two-step in-gas-cell laser ionisation of natural tin was tested at IGISOL, with good agreement between the experimental data and the nautral abundances of tin isotopes.

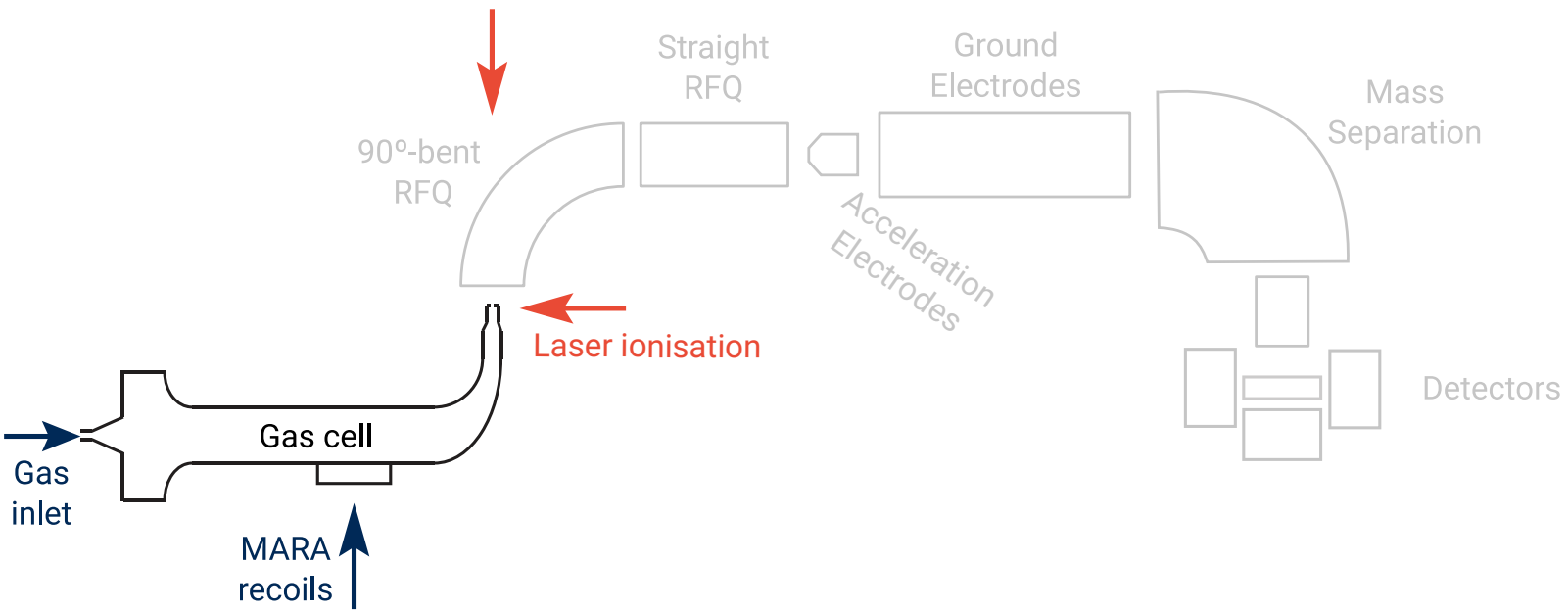




A. Zadvornaya, J. Romero, *et al.* Nucl. Instrum. Meth. B 539 (2023) 33.

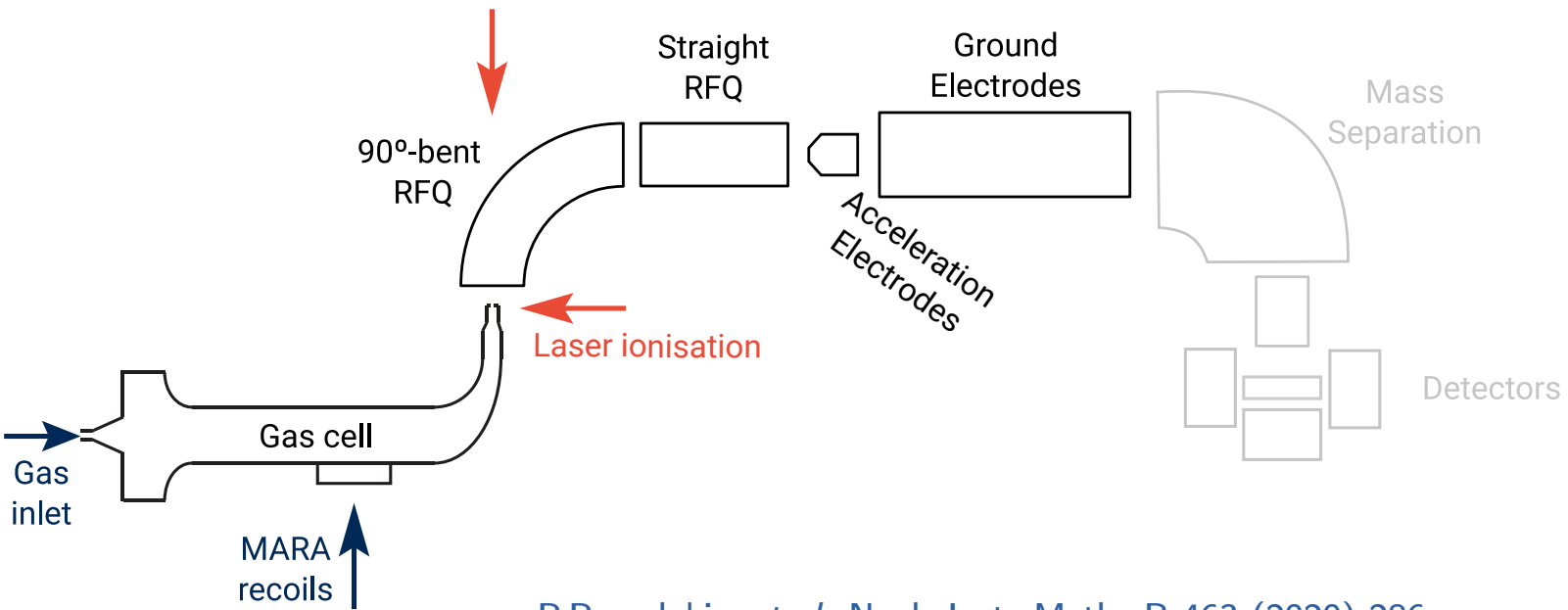
MARA-LEB

The nozzle produces a supersonic jet, so in-gas-jet laser ionisation and spectroscopy can also be performed.



MARA-LEB

Ions are transported and accelerated to 30 kV via the use of Radio-Frequency Quadrupole ion guides and other forms of ion optics.



P.Papadakis, *et al.* Nucl. Inst. Meth. B 463 (2020) 286.
J. Liimatainen, Masters thesis.
J. Romero, PhD thesis.

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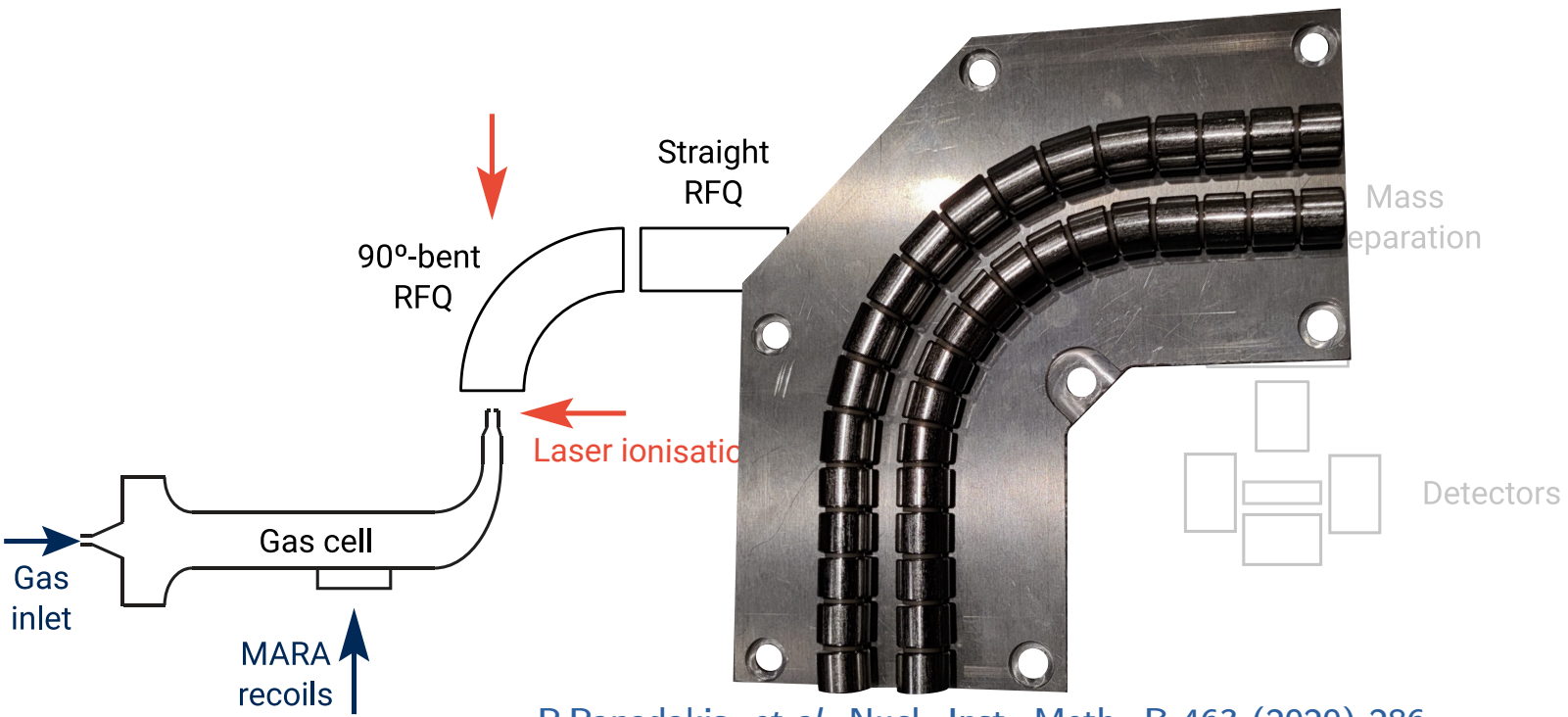

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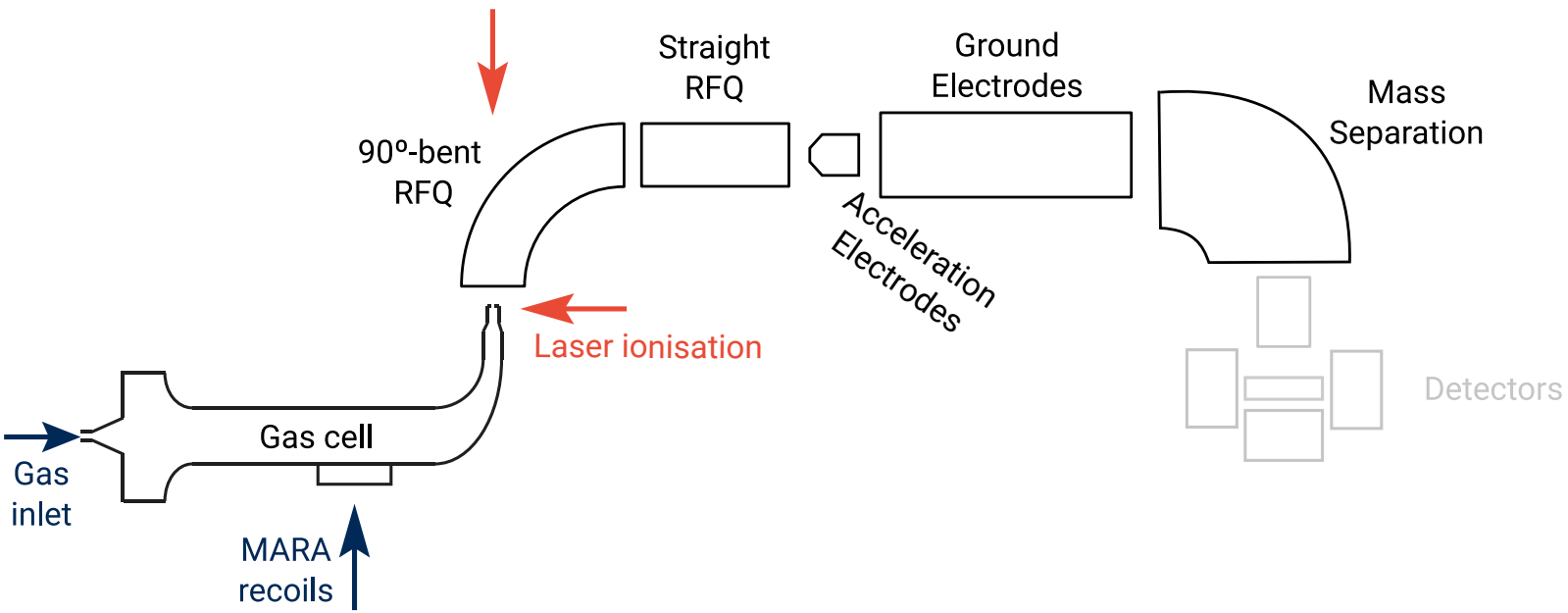
MARA-LEB

Selected ions are further mass separated by a dipole magnet and an electrostatic deflector.



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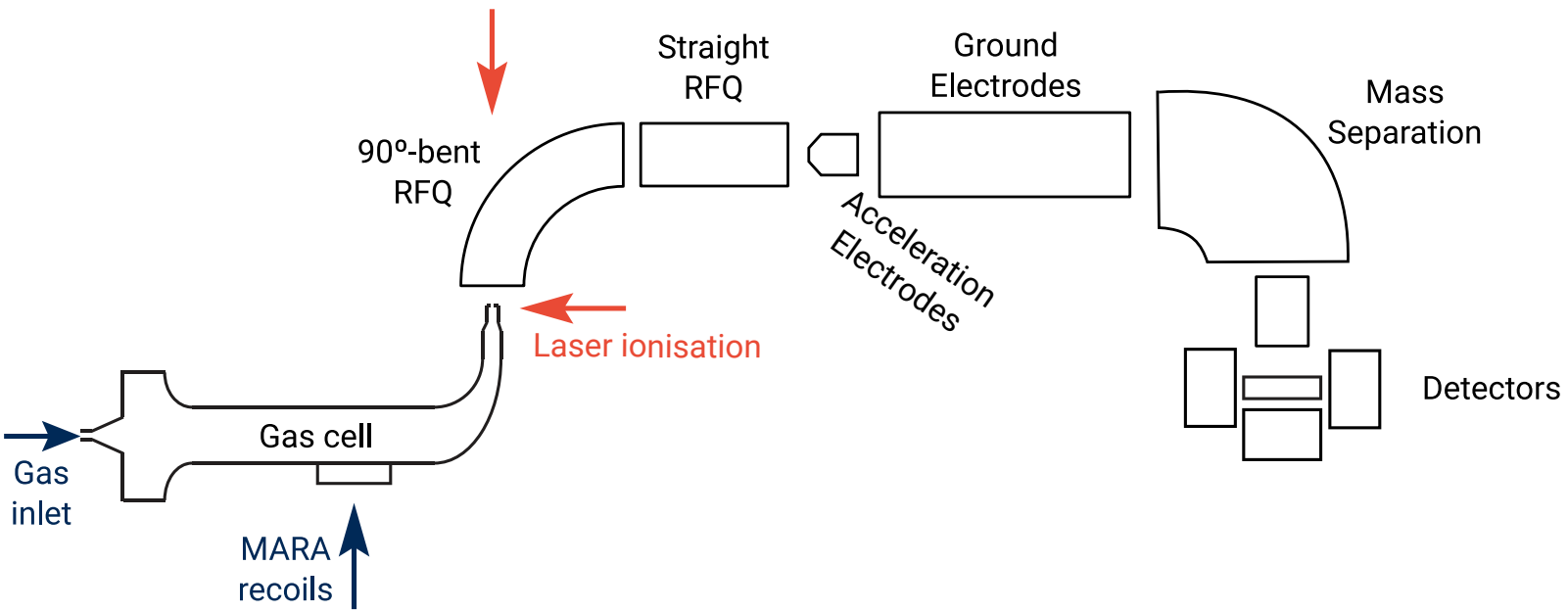
MARA-LEB

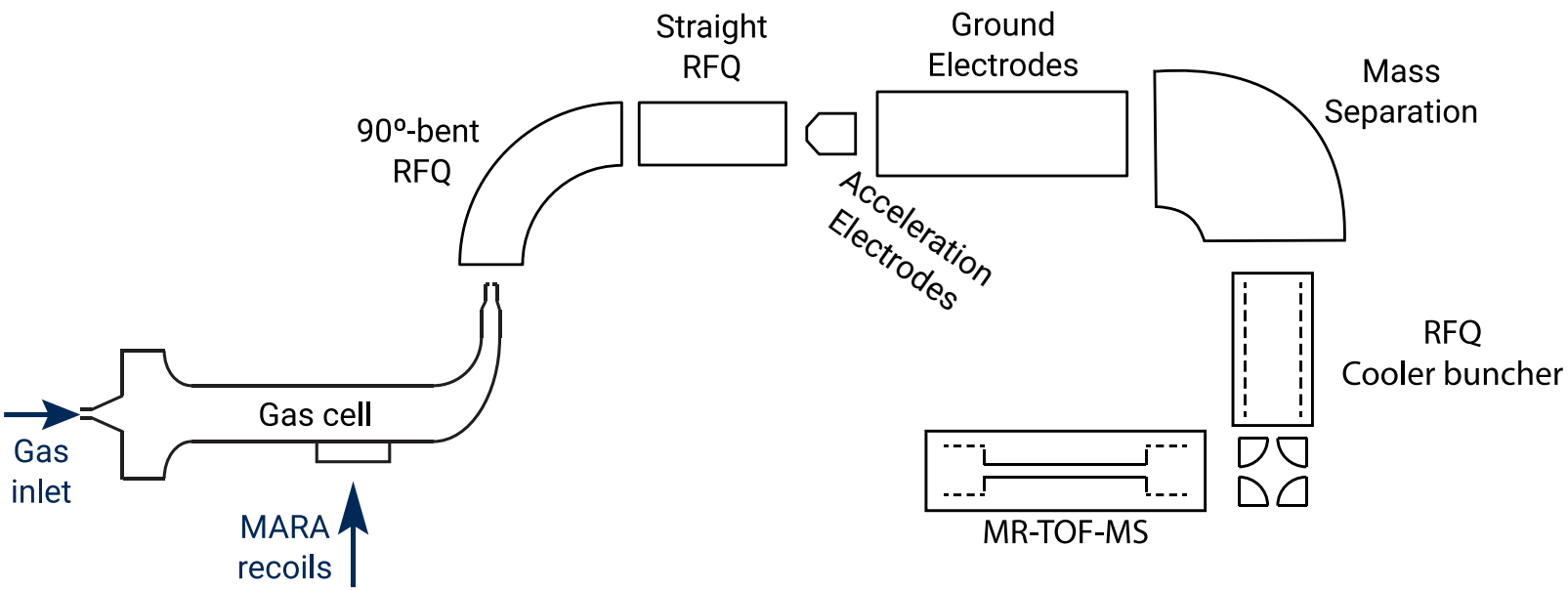
Finally, the purified recoil beam arrives at a detector station that is variable to adapt to individual experiment requirements.



Funding request sumbmitted to FIRI for a detector station (K. Auranen).

MARA-LEB

A mass measurement setup is also planned for future phases, with a cooler-buncher and an MR-TOF-MS.



Design will be based on the IGISOL MR-TOF (V. Virtanen)
Funding request sumbmitted to Academy of Finland.

2

Actinides at MARA

Actinide Region

Experiment JM20 was carried out in the Accelerator Laboratory of the University of Jyväskylä in November 2021.

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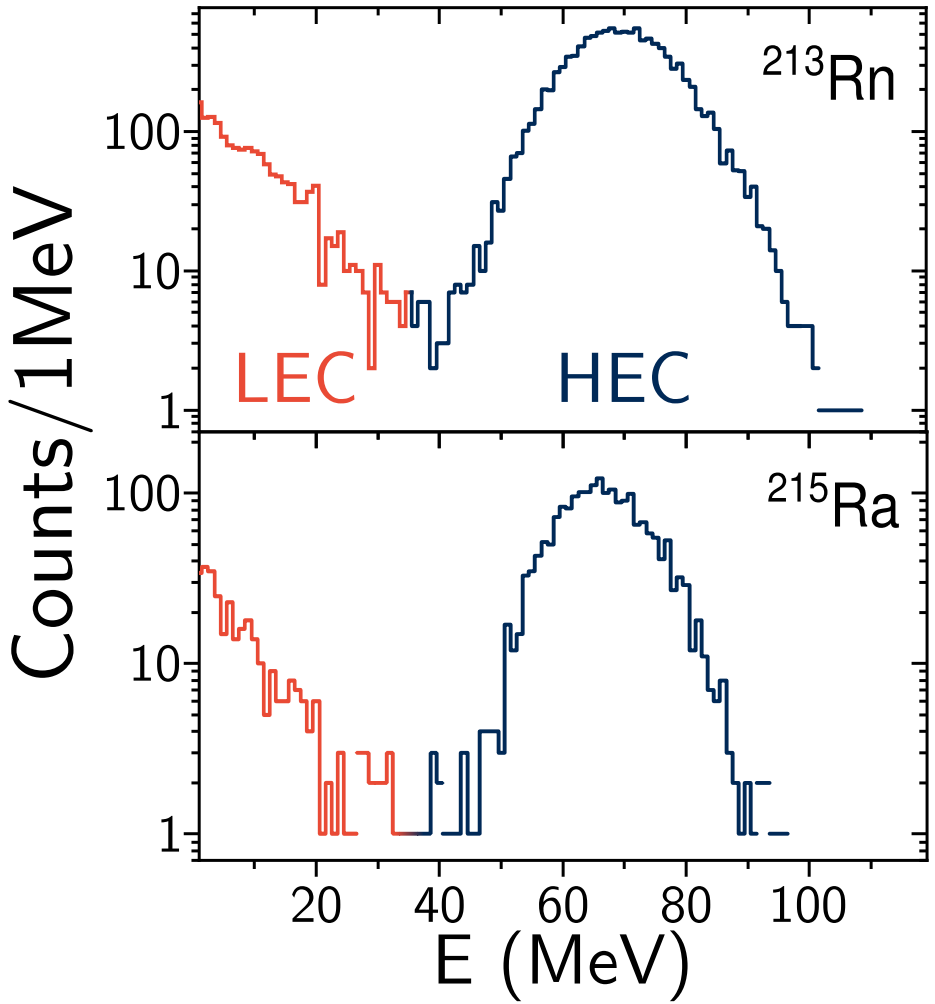

Fig 1: *Energy distribution of the non-fusion products of $^{50}Ti+^{249}Cf$ at TASCA.*

Actinide Region

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QF may be an alternate production method for actinides, which can be used to perform experiments in MARA-LEB.

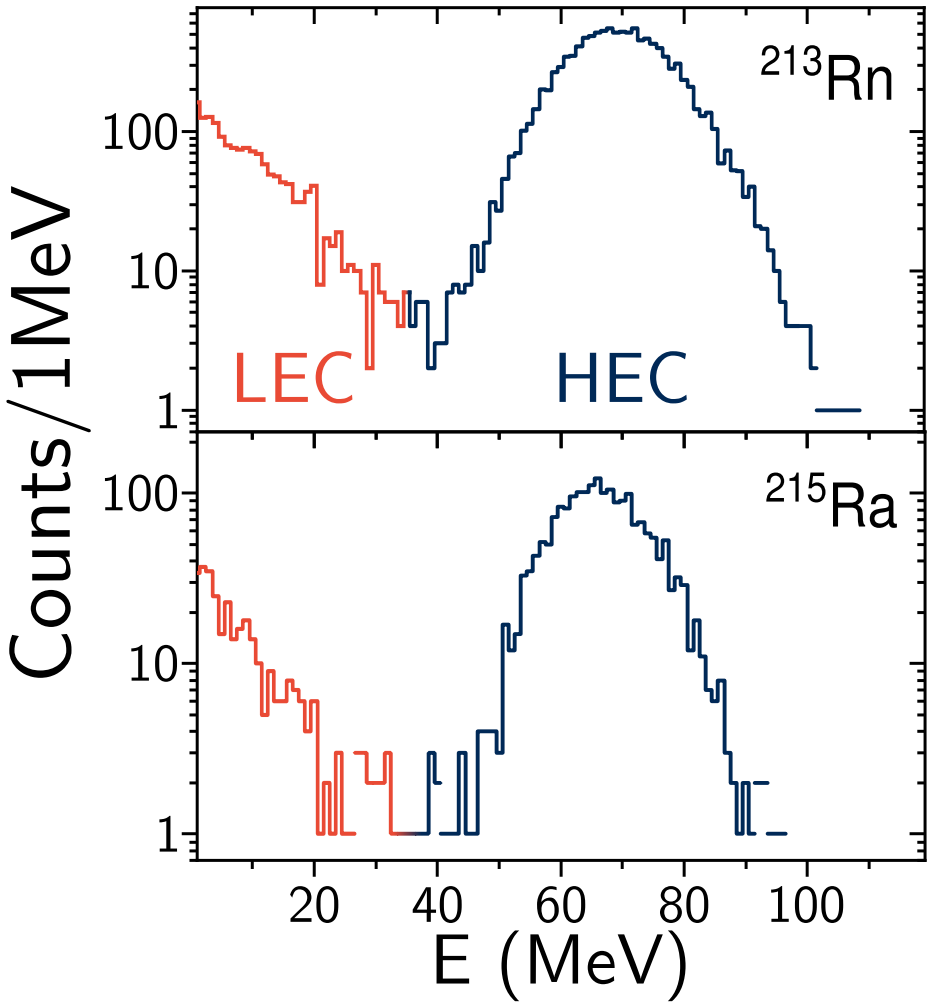
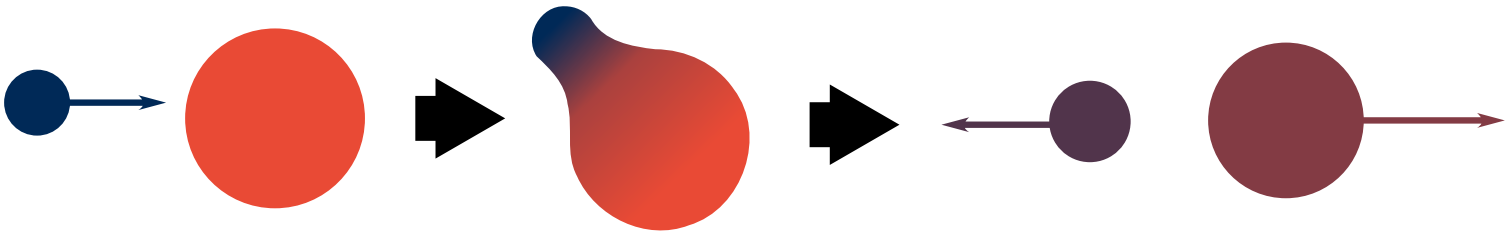


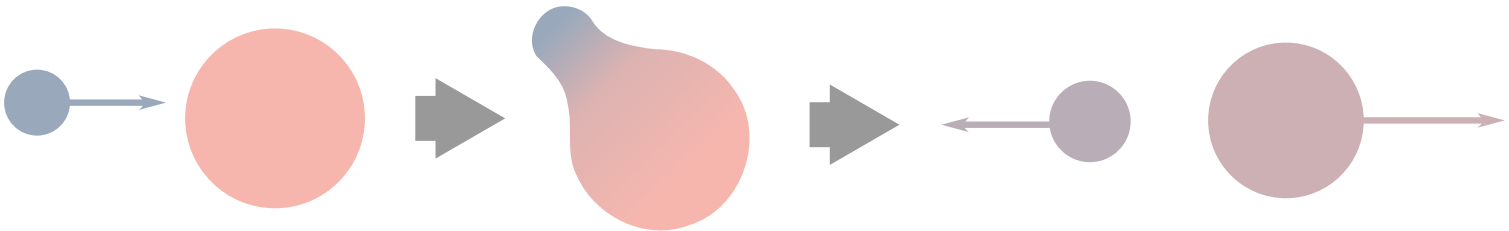
Fig 1: *Energy distribution of the non-fusion products of $^{50}Ti+^{249}Cf$ at TASCA.*

Quasi-Fission

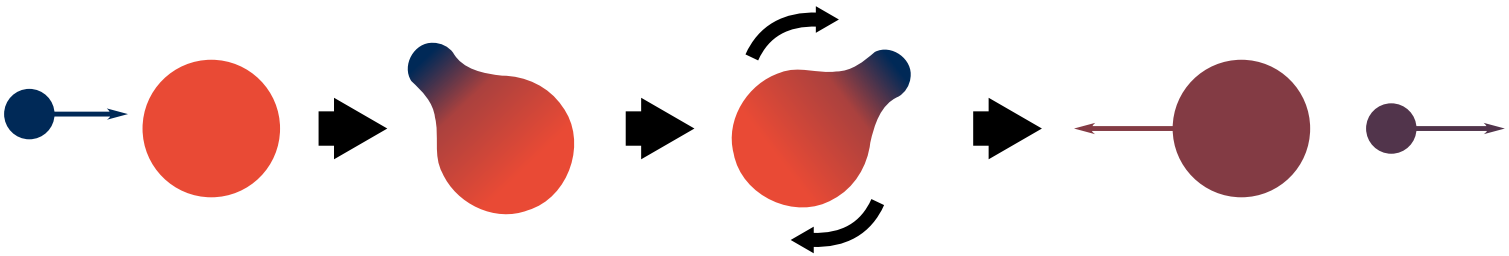


The high energy component is analogous to a usual fusion-fission reaction, where an inelastic collision occurs.

Quasi-Fission



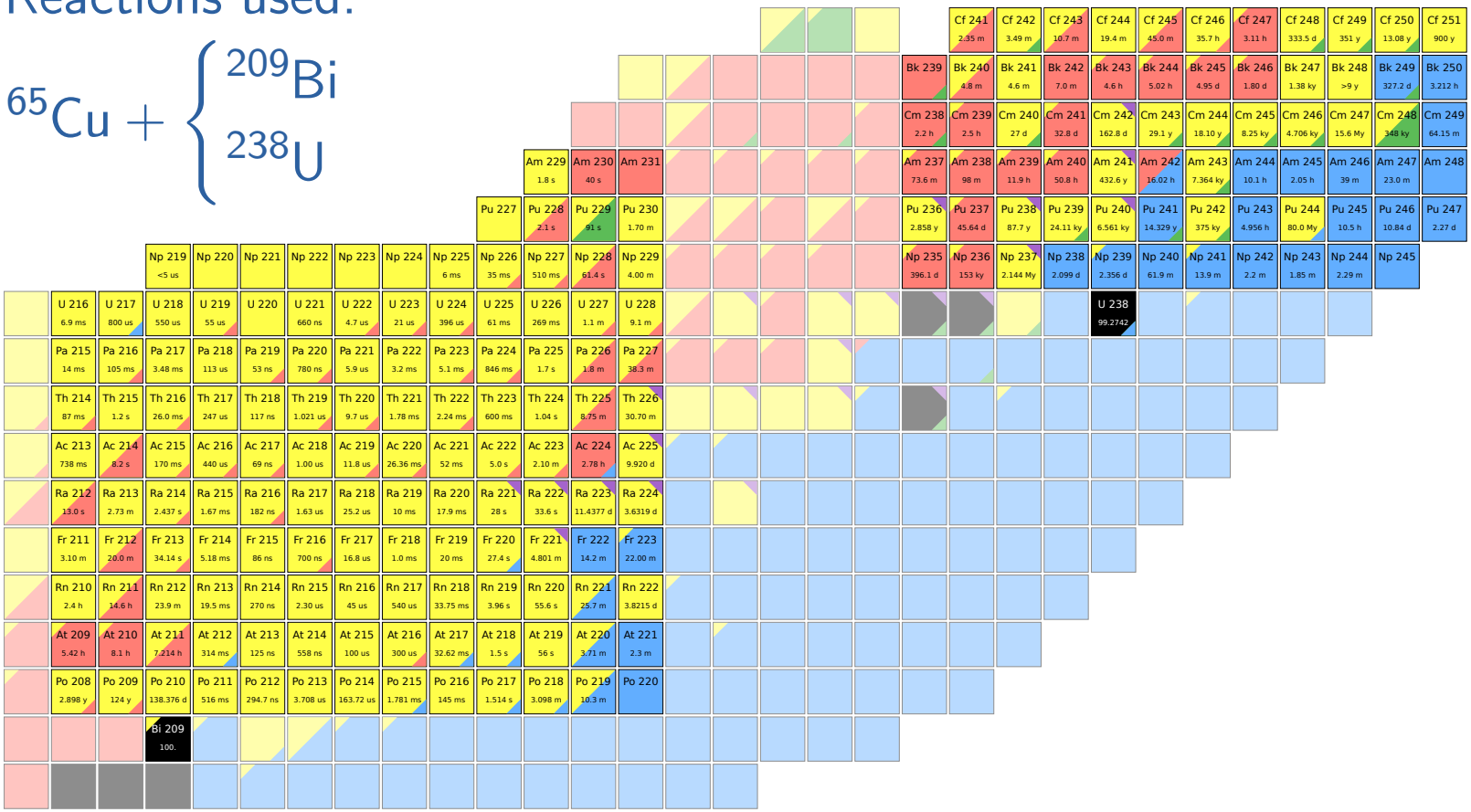
The low energy component can be interpreted as the rotation of the compound in the centre-of-mass frame before fission.



Experiment JM20

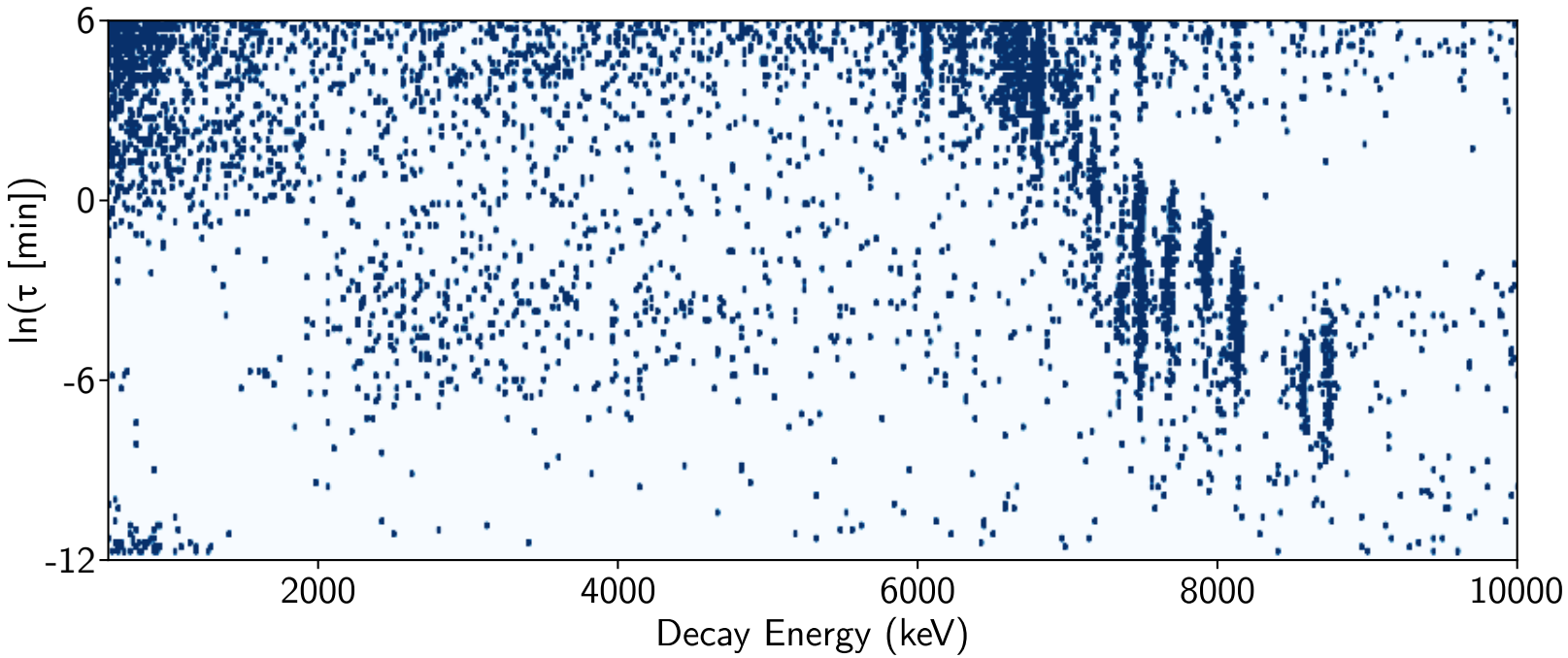
Reactions used:

$$^{65}\mathrm{Cu} + \begin{cases} ^{209}\mathrm{Bi} \\ ^{238}\mathrm{U} \end{cases}$$



Analysis

Alpha decays are identified by their energy and timing.



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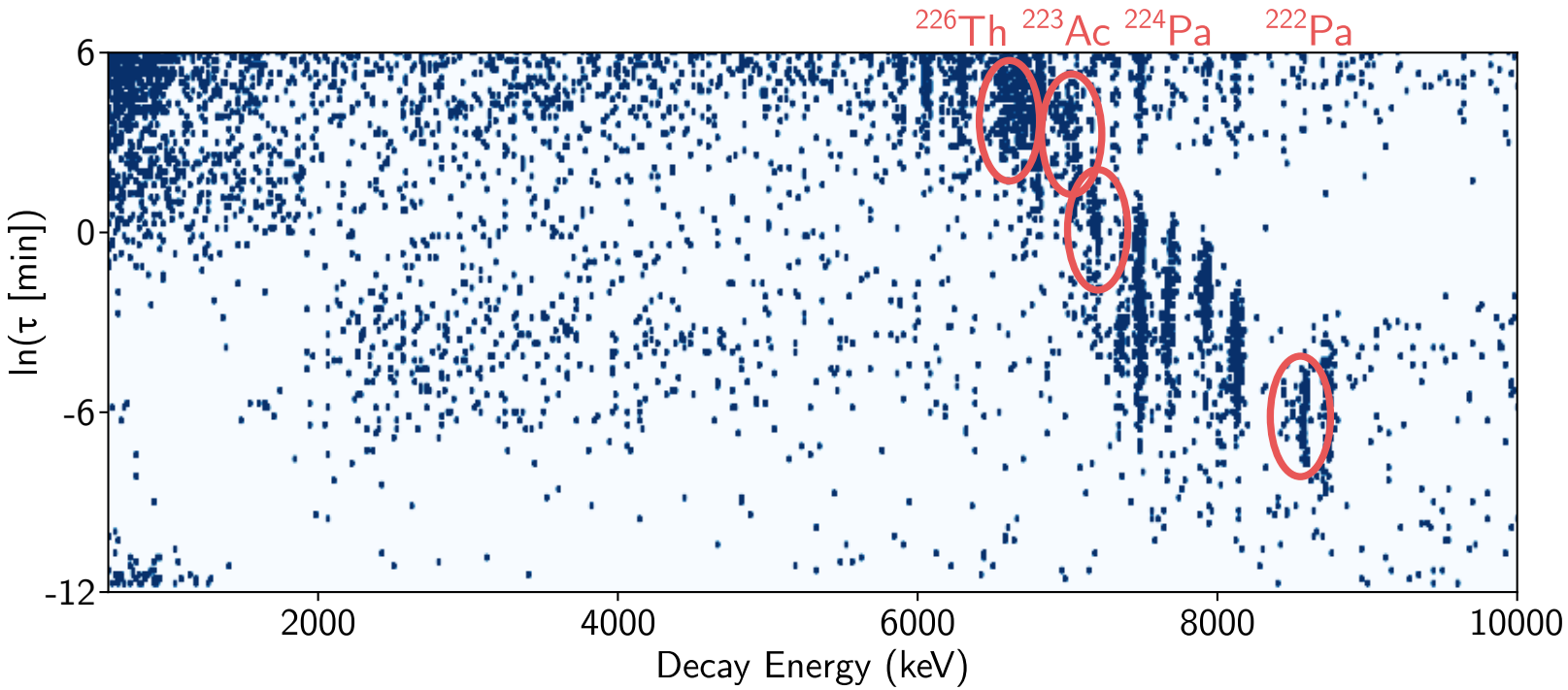
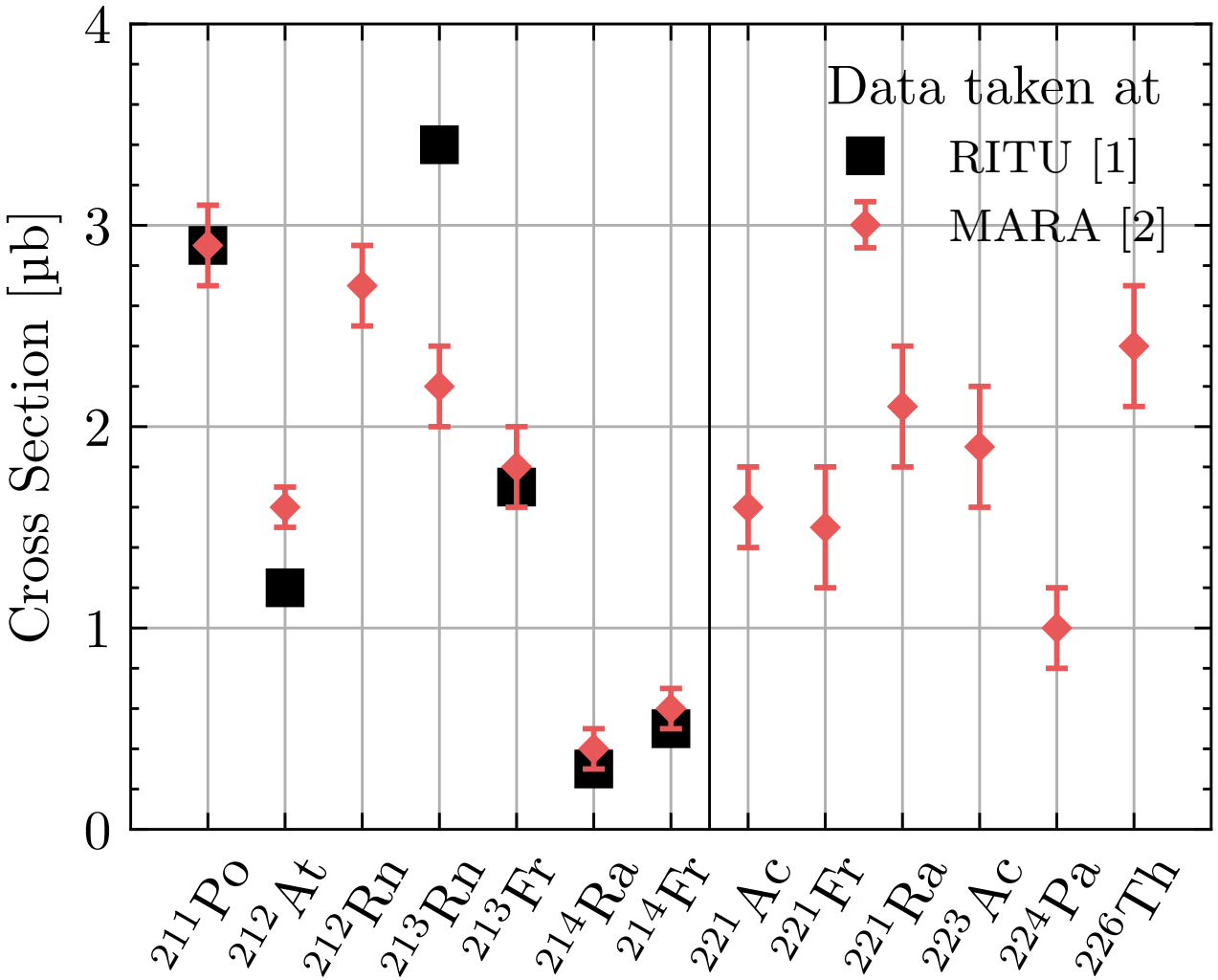


Results



[1] U. Jakobsson, Master's Thesis (2006), University of Jyväskylä

[2] J. Romero, *et al.*, Acta Phys. Pol. B Proc. Suppl. 16 (2023) 4-A12.

3

Outlook

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Experimental Prospects

- Actinides produced, opening up a new region of interest for MARA-LEB.
- Cross-sections are compatible with laser spectroscopy.

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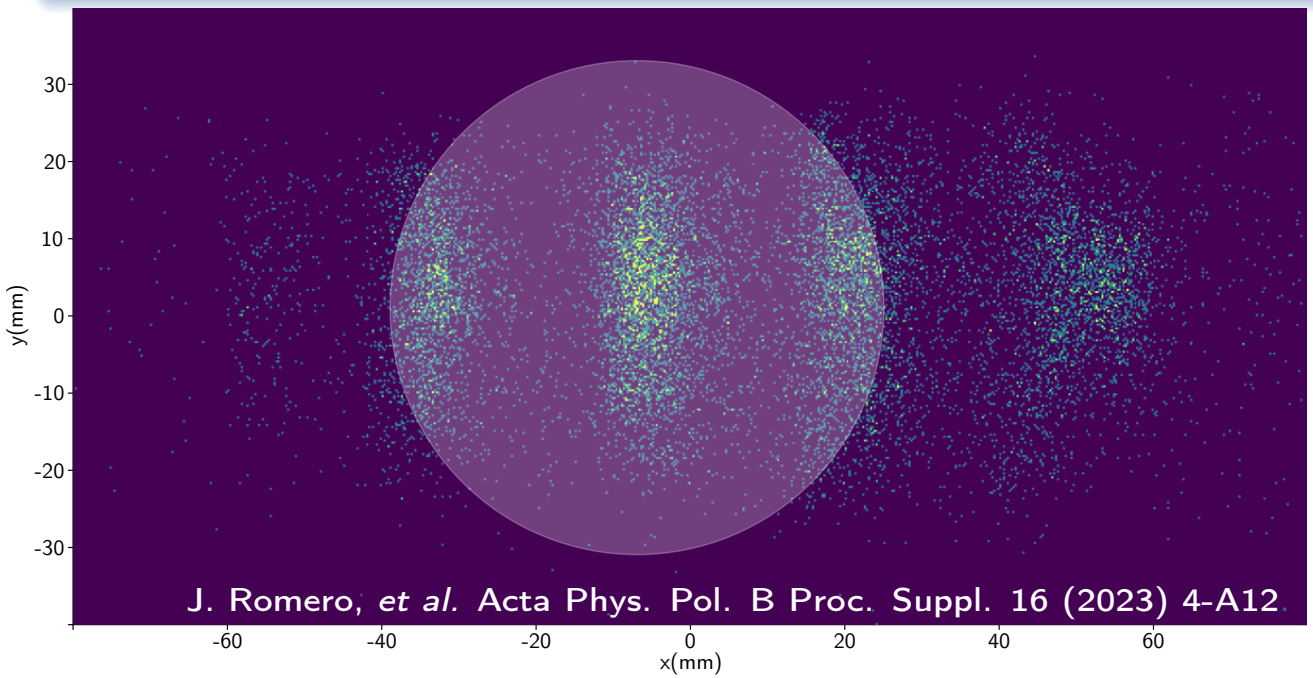

Outlook

Experimental Prospects

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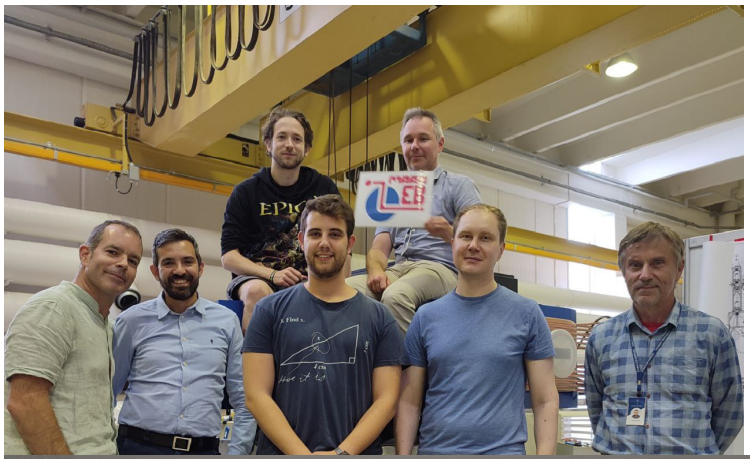
Long-Term Prospects

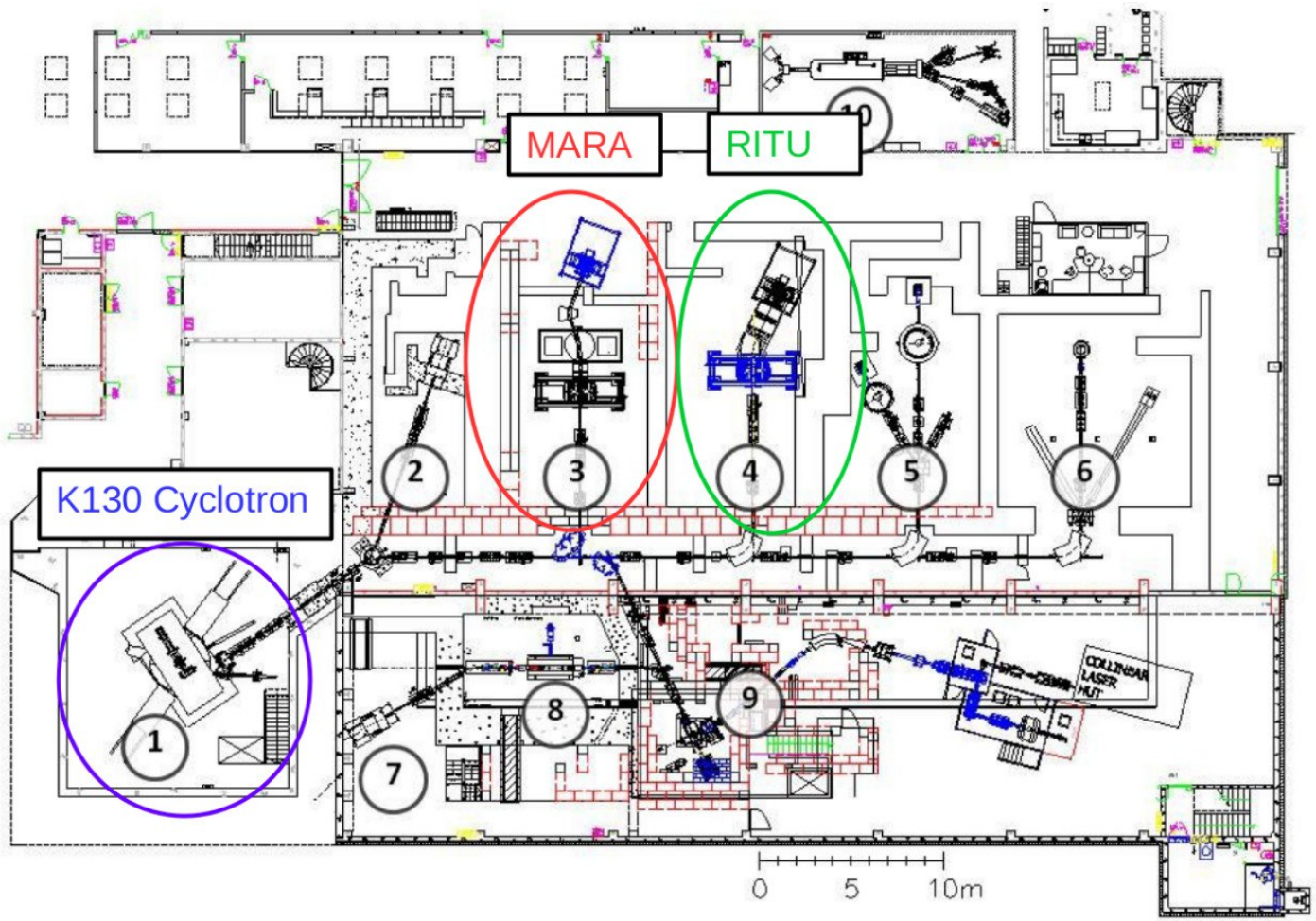
- Recent application for infrastructure funding.
- New regions of interest have been proposed by collaborators.
  - Close colaboration with S^3-LEB at Ganil (See N. Lecesne's talk tomorrow)
- RITU-LEB for the study of Super-Heavies.

Thank you! Kiitos! Danke!



Thanks to the MARA-LEB group in particular and to the Nuclear Spectroscopy group as a whole!

Backup


MARA
RITU
K130 Cyclotron
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COLLINEAR LASER HUT
0
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10m