

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

ĉ	acti	on	•			ALV.	Sb 103 < 50 1e-09	Sb 104 470 ms	Sb 105 1.12 s	Sb 106 600 ms	Sb 107 4.0 s	Sb 108 7.4 s	Sb 109 17.0 s
S Sn 99 Sn 120							Sn 102 3.8 s	Sn 103 7.0 s	Sn 104 20.8 s	Sn 105 ^{34 s}	Sn 106 1.92 m	Sn 107 2.90 m	Sn 108 10.30 m
			In 97 50 ms	In 98 37 ms	In 99 3.1 s	In 100 5.85 s	In 101 15.1 s	In 102 23.3 s	In 103 ^{60 s}	In 104 1.80 m	In 105 5.07 m	In 106 6.2 m	In 107 32.4 m
		Cd 95 90 ms	Cd 96 860 ms	Cd 97 1.10 s	Cd 98 9.2 s	Cd 99 16 s	Cd 100 49.1 s	Cd 101 1.36 m	Cd 102 5.5 m	Cd 103 7.3 m	Cd 104 57.7 m	Cd 105 55.5 m	Cd 106 1.25
	Ag 93	Ag 94 37 ms	Ag 95 1.76 s	Ag 96 4.44 s	Ag 97 25.5 s	Ag 98 47.5 s	Ag 99 2.07 m	Ag 100 2.01 m	Ag 101 11.1 m	Ag 102 12.9 m	Ag 103 65.7 m	Ag 104 69.2 m	Ag 105 41.29 d
91	Pd 92	Pd 93 1.15 s	Pd 94 9.0 s	Pd 95 7.5 s	Pd 96 122 s	Pd 97 3.10 m	Pd 98 17.7 m	Pd 99 21.4 m	Pd 100 3.63 d	Pd 101 8.47 h	Pd 102	Pd 103 16.991 d	Pd 104 11.14

			Nb 81	Nb 82	Nb 83	Nb 84	Nb 85	Nb 86	Nb 87	Nb 88	Nb 89	Nb 90	Nb 91	Nb 92	Nb 93	Nb 94	Nb 95	Nb 96	Nb 97	Nb 98	Nb 99
			< 44 1e-09	50 ms	4.1 s	9.8 s	20.9 s	88 s	3.75 m	14.55 m	2.03 h	14.60 h	680 y	34.7 My	100.	20.3 ky	34.991 d	23.35 h	72.1 m	2.86 s	15.0 s
	Zr 78	Zr 79	Zr 80	Zr 81	Zr 82	Zr 83	Zr 84	Zr 85	Zr 86	Zr 87	Zr 88	Zr 89	Zr 90	Zr 91	Zr 92	Zr 93	Zr 94	Zr 95	Zr 96	Zr 97	Zr 98
		56 ms	4.6 s	5.5 s	32 s	41.6 s	25.8 m	7.86 m	16.5 h	1.68 h	83.4 d	78.41 h	51.45	11.22	17.15	1.61 My	17.38	64.032 d	2.80	16.749 h	30.7 s
Y 76	Y 77	Y 78	Y 79	Y 80	Y 81	Y 82	Y 83	Y 84	Y 85	Y 86	Y 87	Y 88	Y 89	Y 90	Y 91	Y 92	Y 93	Y 94	Y 95	Y 96	Y 97
	63 ms	54 ms	14.8 s	30.1 s	70.4 s	8.30 s	7.08 m	39.5 m	2.68 h	14.74 h	79.8 h	106.626 d	100.	64.00 h	58.51 d	3.54 h	10.18 h	18.7 m	10.3 m	5.34 s	3.75 s



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			Sn 99	Sn 100 7.11 s	Sn 101 1.97 s	Sn 102 3.8 s	Sn 103 7.0 s	Sn 104 20.8 s	Sn 105 ^{34 s}	Sn 106 1.92 m	Sn 107 2.90 m	Sn 108 10.30 m
		In 97 50 ms	In 98 27 ms	In 99 3.1 s	In 100 5.85 s	In 101 15.1 s	In 102 23.3 s	In 103 ^{60 s}	In 104 1.80 m	In 105 5.07 m	In 106 6.2 m	In 107 32.4 m
	Cd 95 90 ms	Cd 96 860 ms	Cd 97 1.10 s	Cd 98 9.2 s	Cd 99 16 s	Cd 100 49.1 s	Cd 101 1.36 m	Cd 102 5.5 m	Cd 103 7.3 m	Cd 104 57.7 m	Cd 105 55.5 m	Cd 106 1.25
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Pd 92 1.1 s	Pd 93 1.15 s	Pd 94 9.0 s	Pd 95 7.5 s	Pd 96 122 s	Pd 97 3.10 m	Pd 98 17.7 m	Pd 99 21.4 m	Pd 100 3.63 d	Pd 101 8.47 h	Pd 102	Pd 103 16.991 d	Pd 104 11.14
	Ag 93 Pd 92	90 ms Ag 93 Ag 94 27 ms Pd 92 Pd 93	In 97 50 ms Cd 95 90 ms Cd 96 860 ms Ag 93 Ag 94 77 ms Ag 95 1.76 s Pd 92 Pd 93 Pd 94	Sn 99 In 97 50 ms 20 95 Cd 95 90 ms 90 ms 20 95 20 95 20 95 20 95 20 95 20 95 20 95 20 95 20 95 20 95 20 95 20 95 20 95 20 92 Pd 93 Pd 94 Pd 93 Pd 94	Current Sn 99 Sn 120 y11s In 97 In 98 In 99 50 ms 27 ms 3.1s Cd 95 Cd 96 Cd 97 Cd 98 90 ms 260 ms 1.10s 9.2s Ag 93 Ag 94 Ag 95 Ag 96 Ag 97 37 ms 1.76s 4.44s 25.5s Pd 92 Pd 93 Pd 94 Pd 95 Pd 96	Sn 99 Sn 100 211s Sn 101 197s In 97 50ms In 98 37ms In 99 3.1s In 100 5.85s Cd 95 90ms Cd 96 260ms Cd 97 1.0s Cd 98 9.2s Cd 99 16s Ag 93 77ms Ag 94 77ms Ag 95 1.76s Ag 96 4.44s Ag 97 25.5s Ag 98 47.5s Pd 92 Pd 93 Pd 94 Pd 95 Pd 96 Pd 97	CCUION Sn 99 Sn 1800 Sn 102 1.975 3.85 In 97 In 97 In 98 In 99 In 100 In 101 1.51.5 Cd 95 Cd 96 Cd 97 Cd 98 Cd 99 Cd 100 91.5 90 ms 960 ms 1.105 92.5 165 49.15 Ag 93 Ag 94 Ag 95 Ag 96 Ag 97 Ag 98 Ag 99 20.7 m Pd 92 Pd 93 Pd 94 Pd 95 Pd 96 Pd 97 Pd 98	CLION Sn 99 Sn 190 Sn 101 Sn 102 Sn 103 Sn 99 Sn 190 Sn 101 Sn 102 Sn 103 Sn 103	CLIPON Solution <	CLIFON Sn 99 Sn 100 X11s Sn 102 Sn 99 Sn 102 X11s Sn 102 Sn 99 Sn 102 X1s Sn 102 Sn 99 Sn 102 X1s Sn 102 Sn 99 Sn 102 ZNS Sn 103 ZNS Sn 102 ZNS Sn 103 ZNS Sn 104 ZNS Sn 104	CCUION Sn 99 Sn 100 X11s Sn 101 Sn 102 X11s Sn 102 Sn 103 Sn 103 Sn 102 Sn 5 Sn 103 Zn 5 Sn 104 Zn 5 Sn 105 Zn 5 Sn 106 Zn 7 Sn 106 Zn 7	CLIPON Subset Subset<

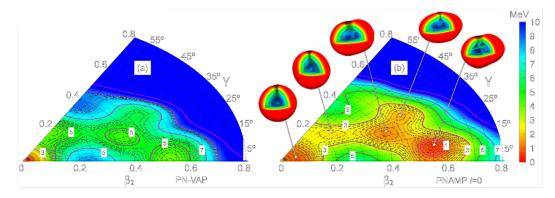
			Nb 81	Nb 82	Nb 83	Nb 84	Nb 85	Nb 86	Nb 87	Nb 88	Nb 89	Nb 90	Nb 91	Nb 92	Nb 93	Nb 94	Nb 95	Nb 96	Nb 97	Nb 98	Nb 99
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Y 76	Y 77	Y 78	179	Y 80	Y 81	Y 82	Y 83	Y 84	Y 85	Y 86	Y 87	Y 88	Y 89	Y 90	Y 91	Y 92	Y 93	Y 94	Y 95	Y 96	Y 97
	63 ms	\$ 4 ms	14.8 s	30.1 s	70.4 s	8.30 s	7.08 m	39.5 m	2.68 h	14.74 h	79.8 h	106.626 d	100.	64.00 h	58.51 d	3.54 h	10.18 h	18.7 m	10.3 m	5.34 s	3.75 s



Scientific motivation – Laser ionization and spectroscopy

Example: 80Zr

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

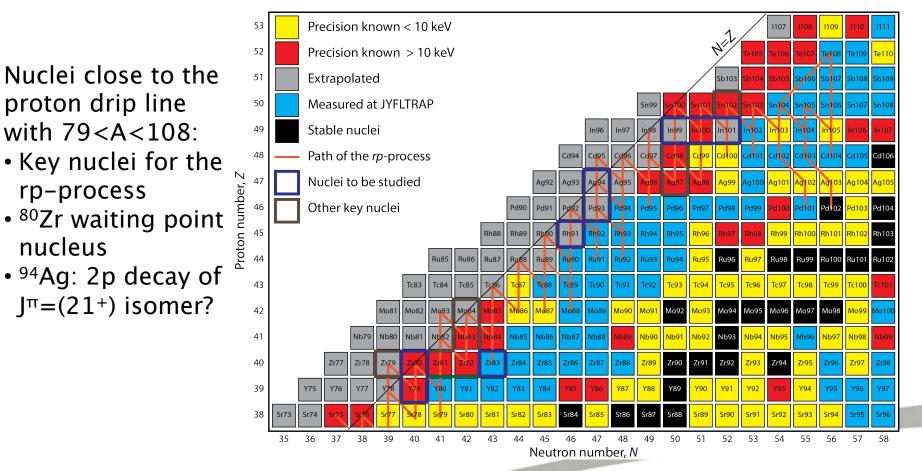


PN-VAP: Particle number symmetry restored PNAMP: Rotational symmetry also restored

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

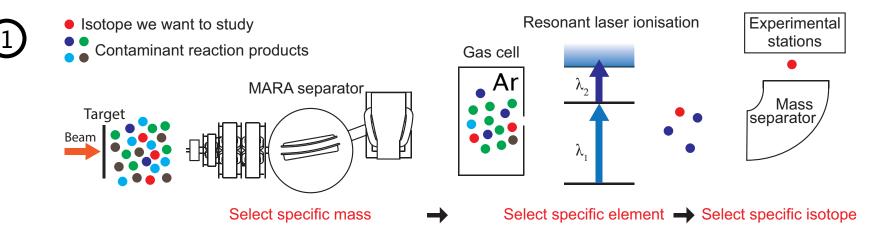


Scientific motivation -Mass measurements



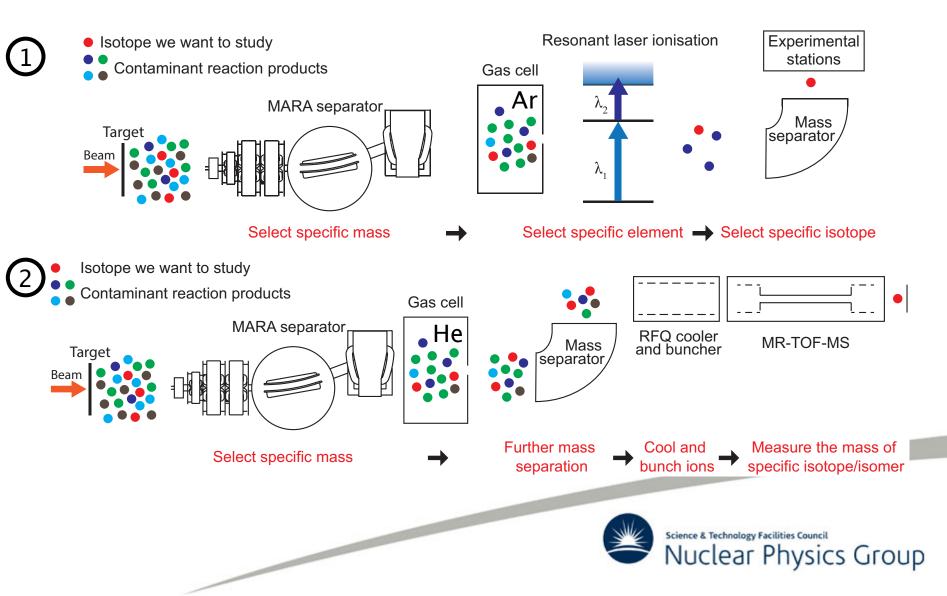


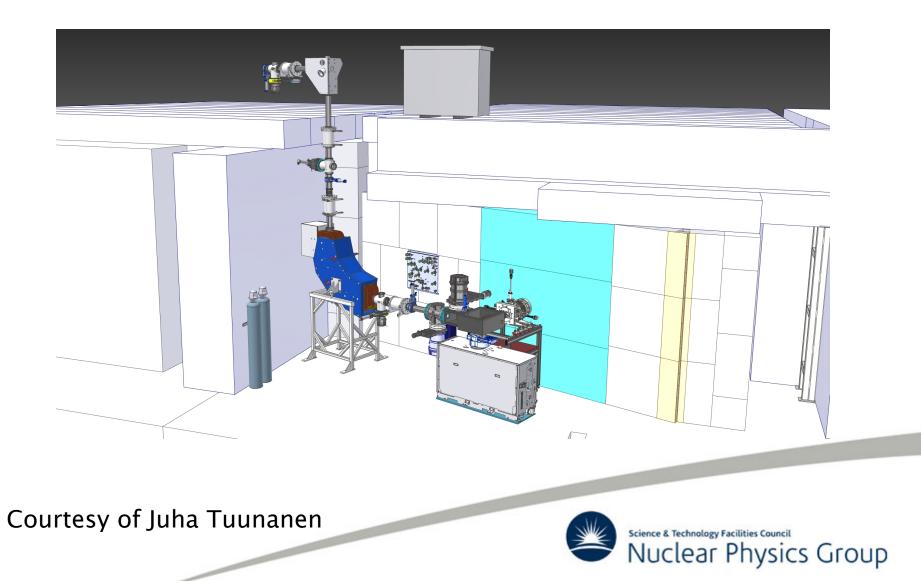
MARA-LEB concept

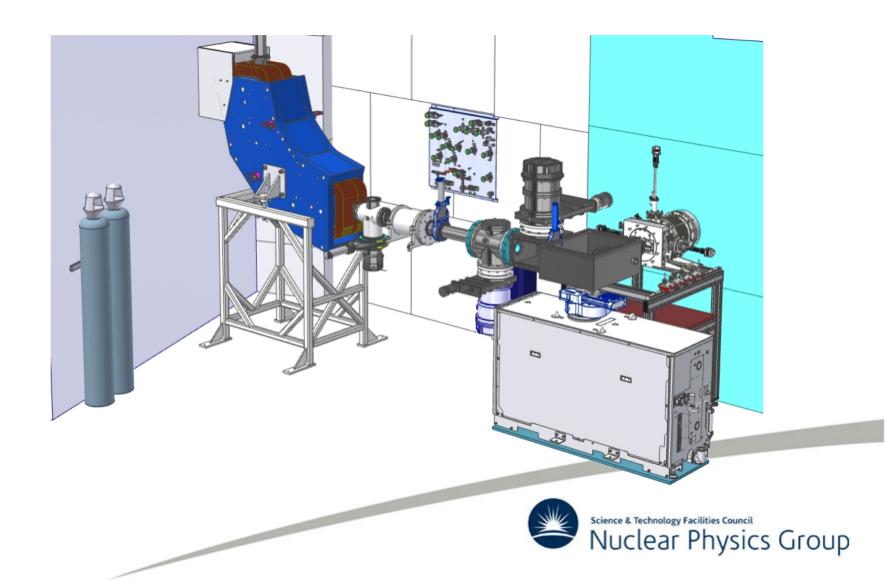


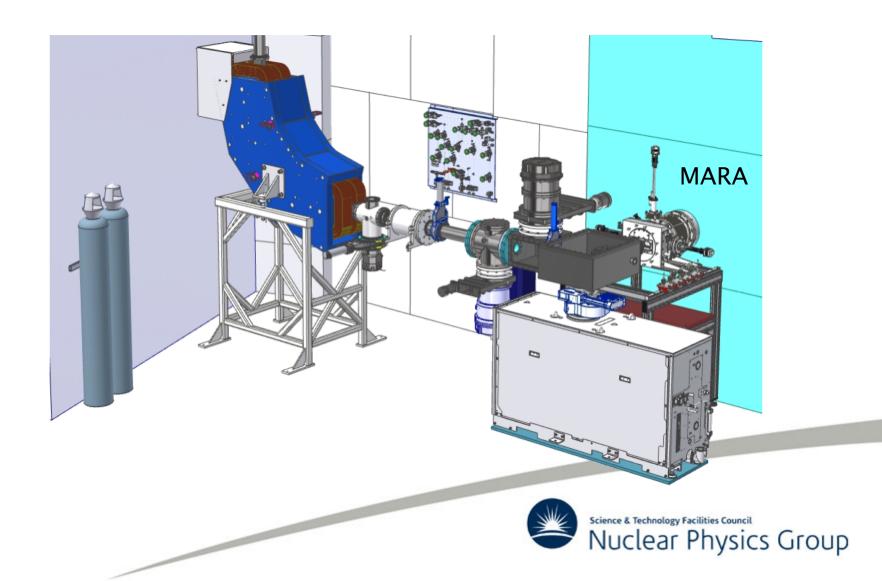


MARA-LEB concept

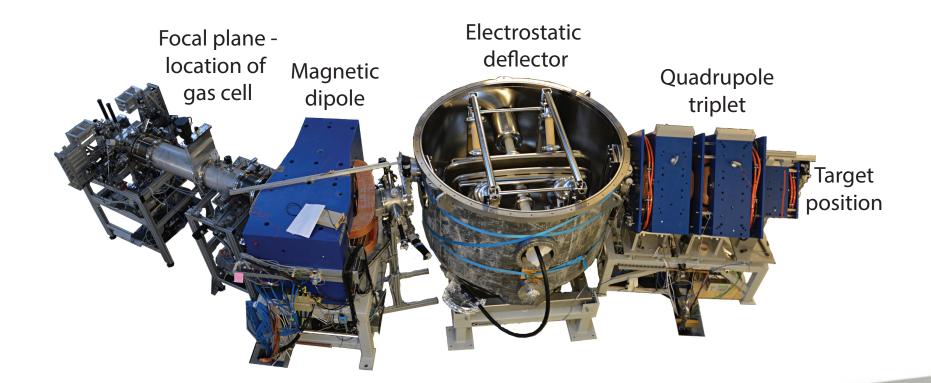








The MARA separator



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)

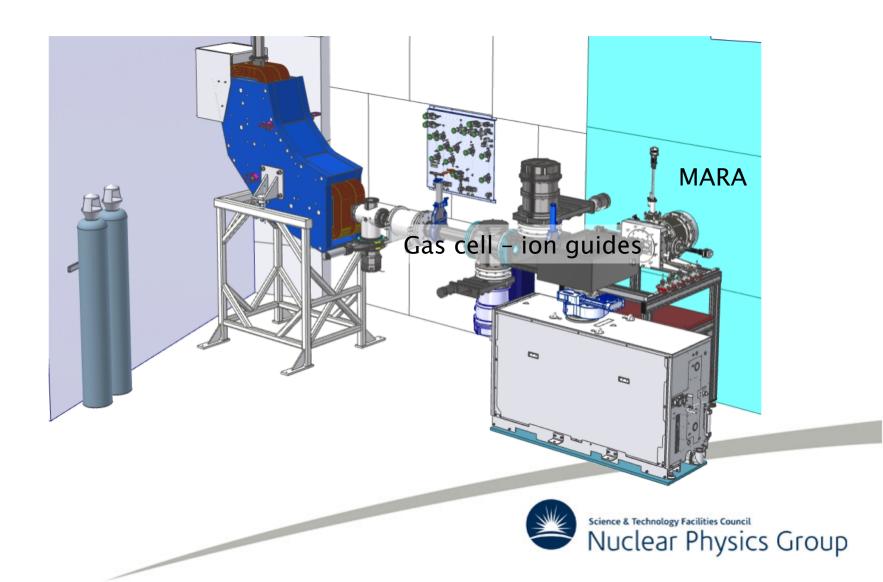


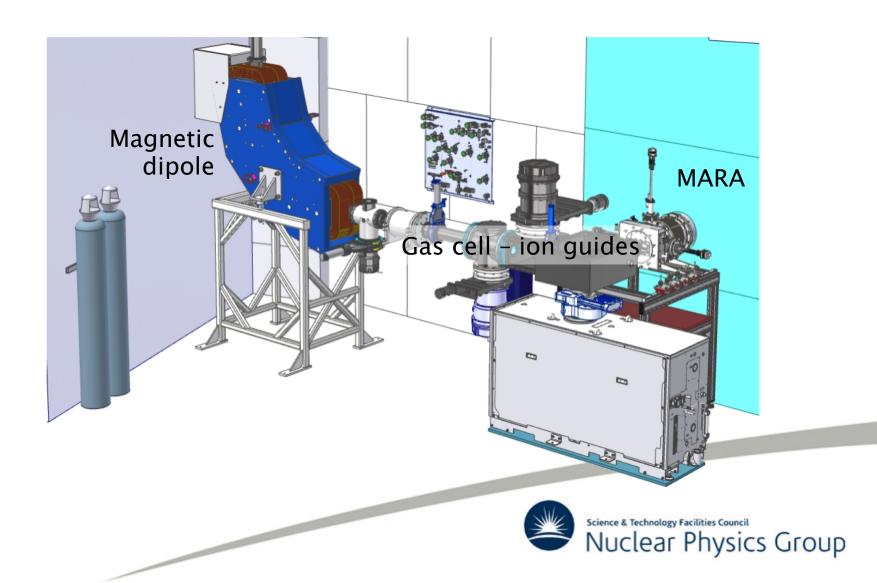
The MARA separator

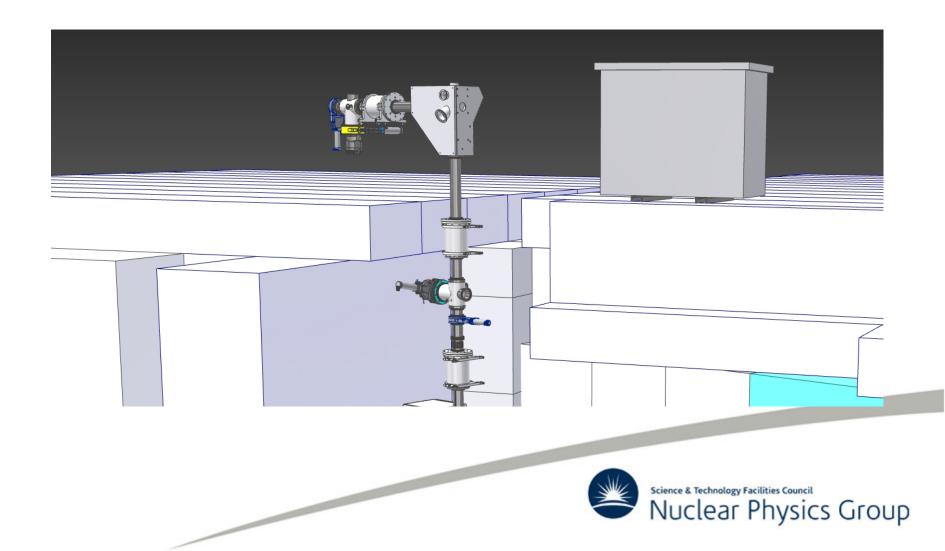
- 5 new isotopes from first experimental campaign
- ~230d of planned experiments
- JUROGAM 3 (talk J. Pakarinen) in-beam Ge detector array
- SAGE in-beam Ge (γ) and Si (e⁻) detectors
- JYTube in-beam particle detector array
- Focal plane detector array (MWPC, DSSD, punchthrough, Si box array and Ge
-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

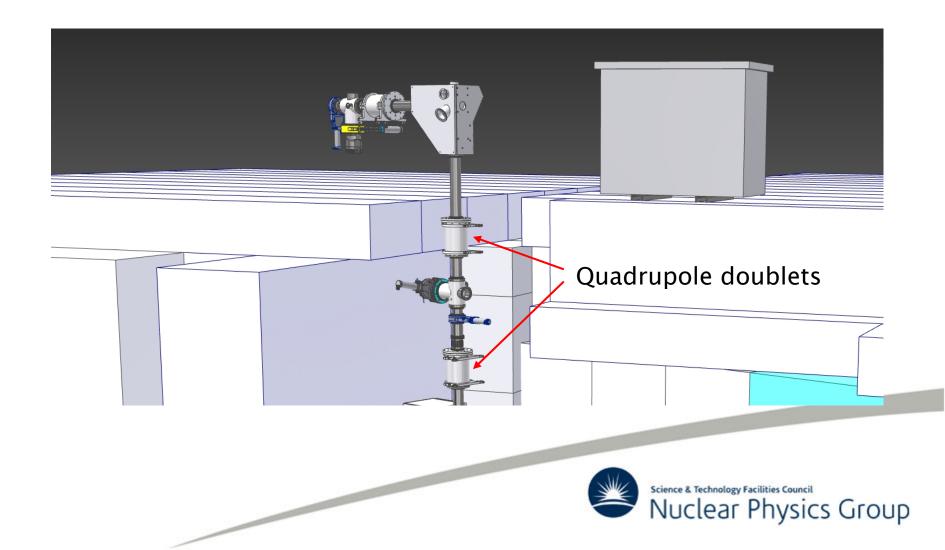


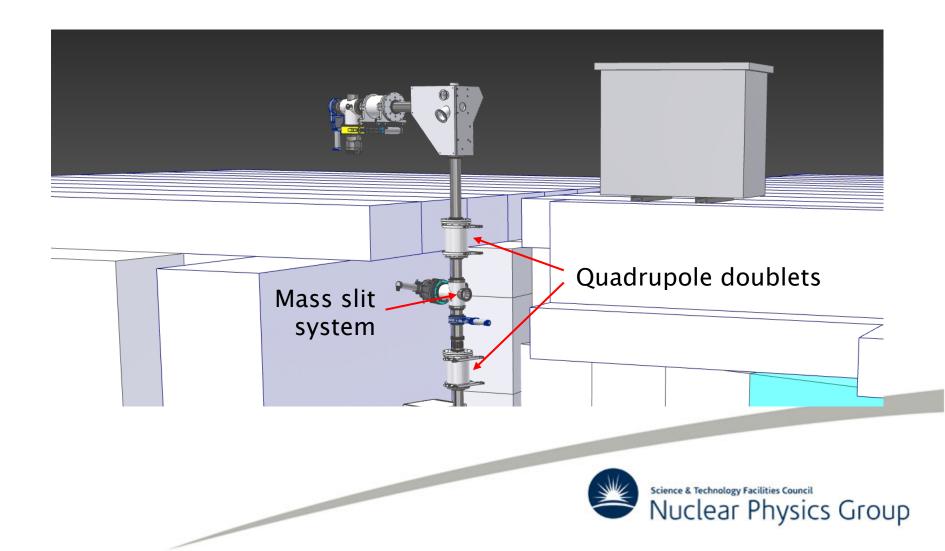
clear Physics Group

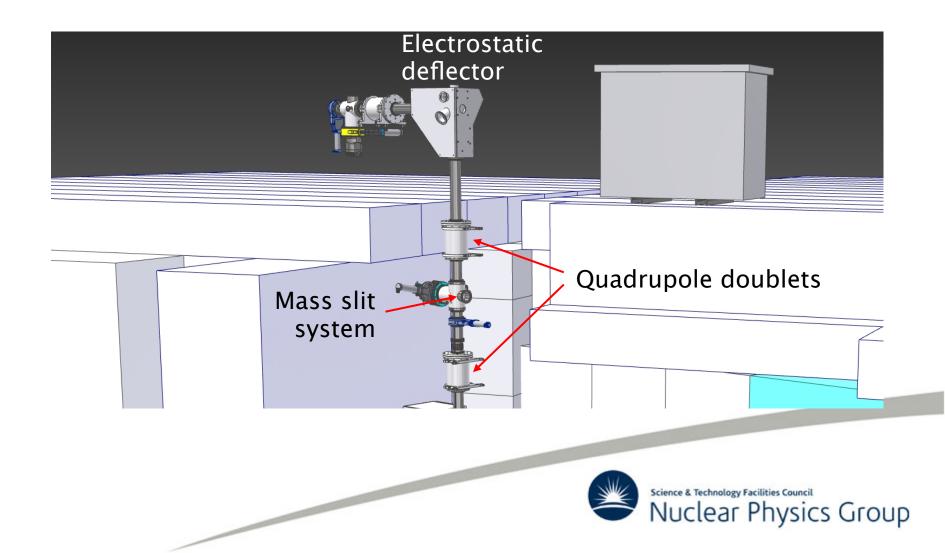


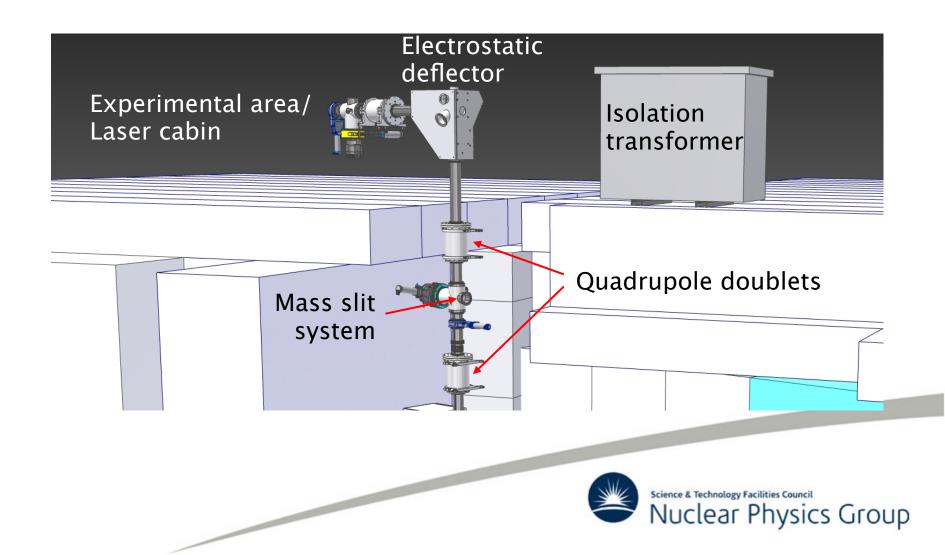




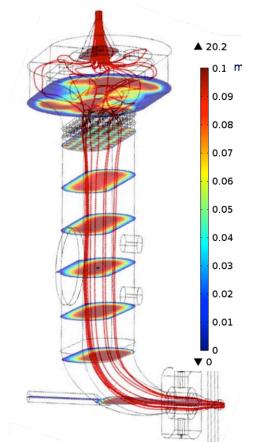








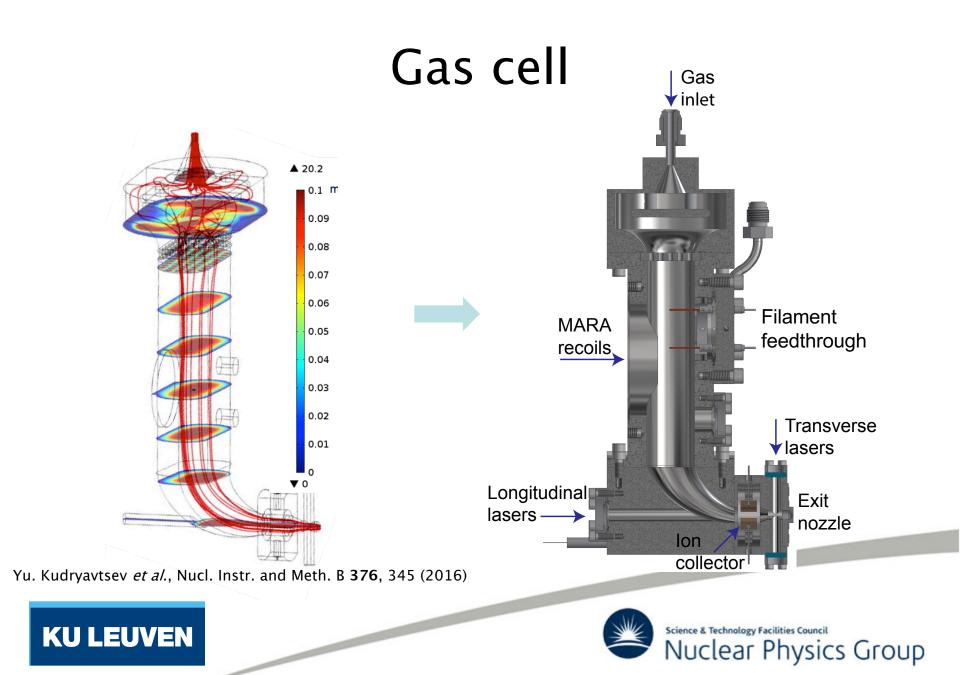
Gas cell

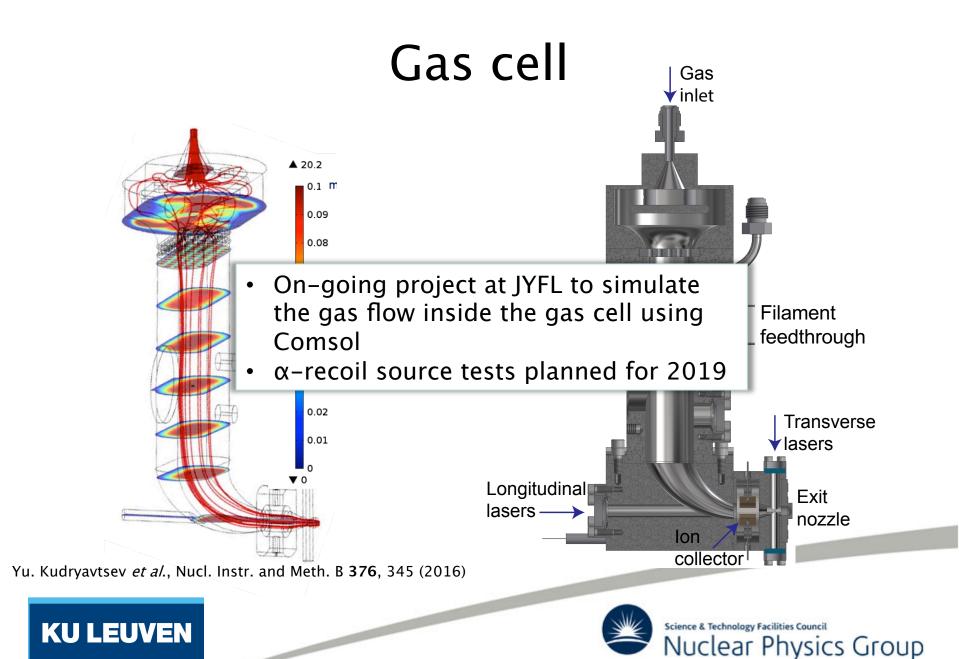


Yu. Kudryavtsev et al., Nucl. Instr. and Meth. B 376, 345 (2016)

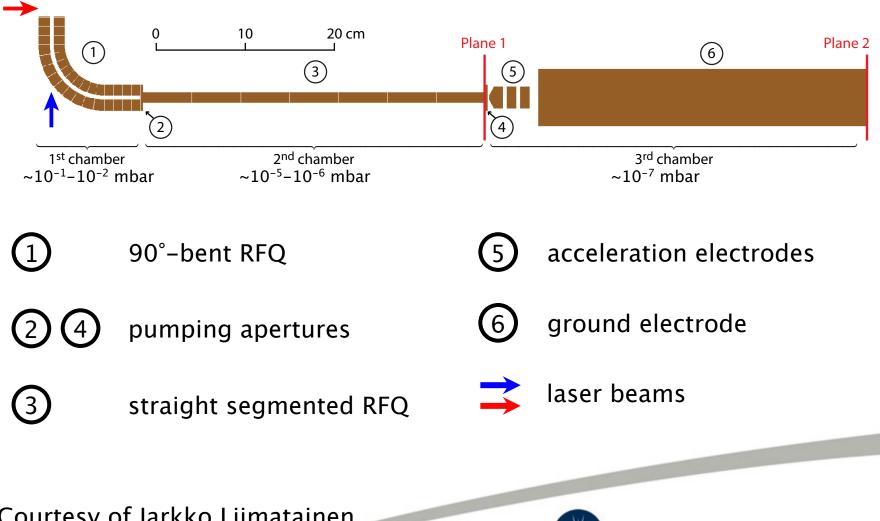
KU LEUVEN







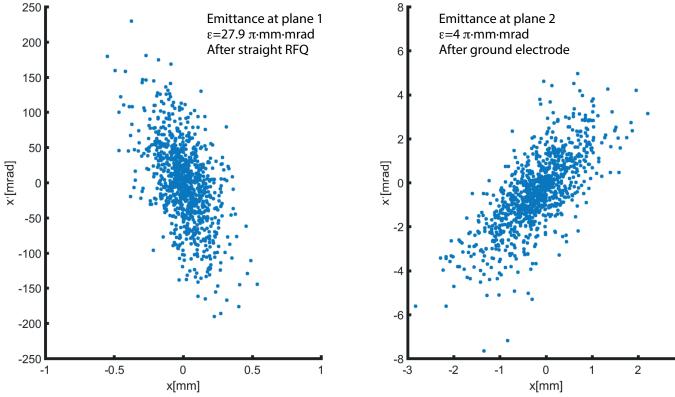
lon guides



Courtesy of Jarkko Liimatainen



Ion guides - SIMION simulations

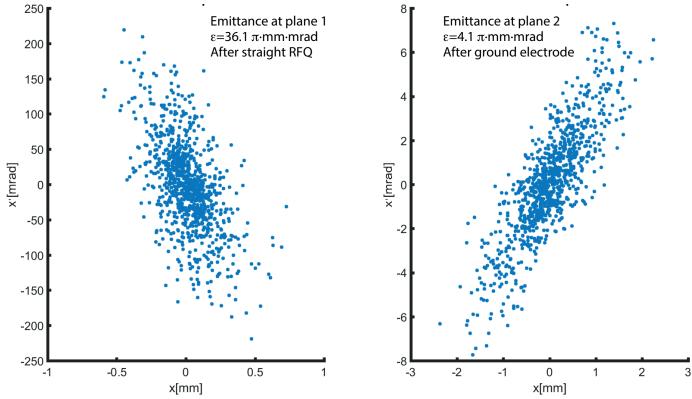


P. Papadakis et al., Nucl. Instr. and Meth. B article in press

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



Ion guides - SIMION simulations



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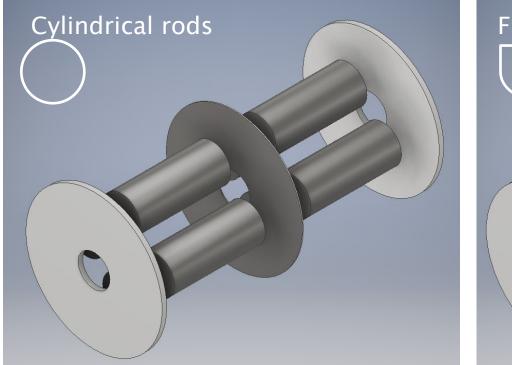
Transfer line – GICOSY simulations Dispersive plane: Quadrupole doublets Electrostatic deflector Magnetic dipole 88 88 Focal Position Non-dispersive plane: of mass point at roof slit system 00 88 End of primary ion guides

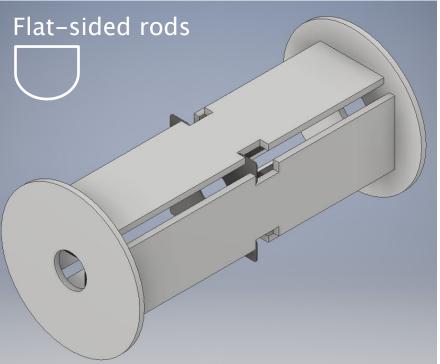
P. Papadakis et al., Nucl. Instr. and Meth. B article in press

Courtesy of Jan Sarén



Quadrupole doublets

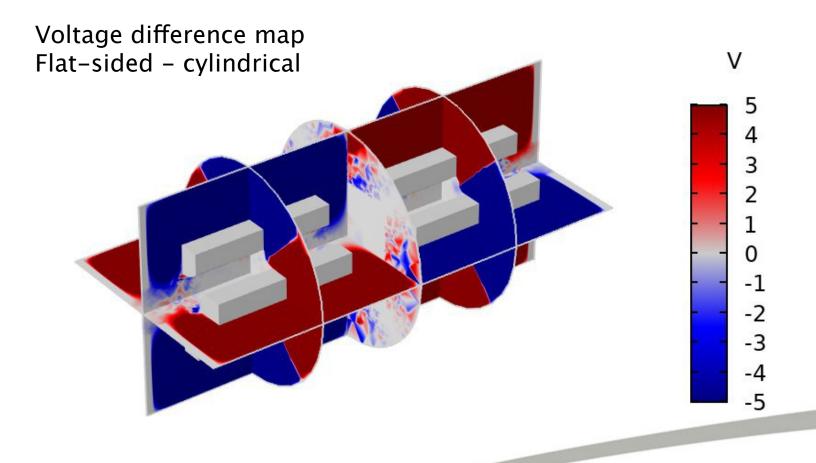




Courtesy of Wouter Gins



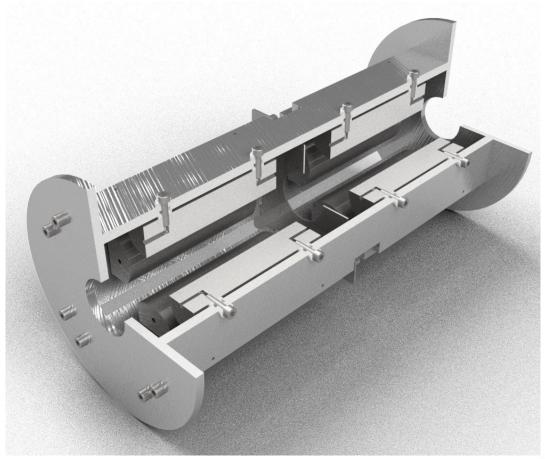
Quadrupole doublets - COMSOL simulations



Courtesy of Wouter Gins



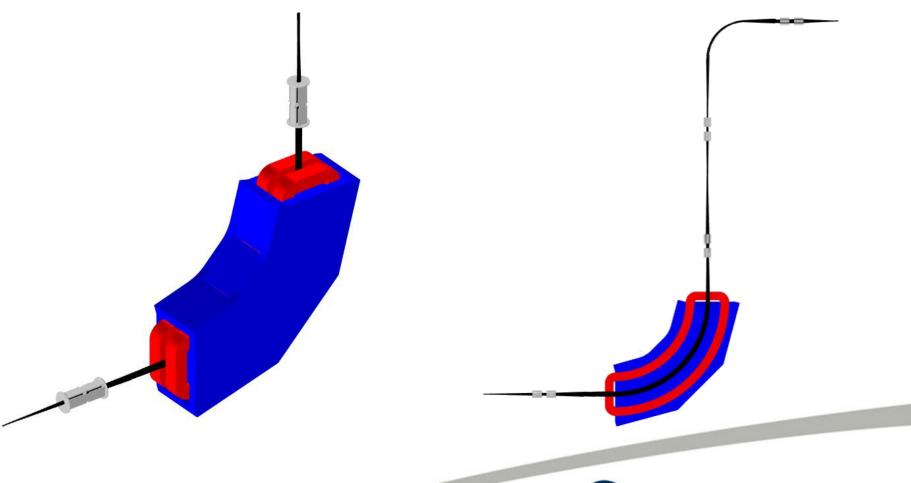
Quadrupole doublets



Courtesy of Wouter Gins



Combined simulation - COMSOL



Courtesy of Wouter Gins



Laser system

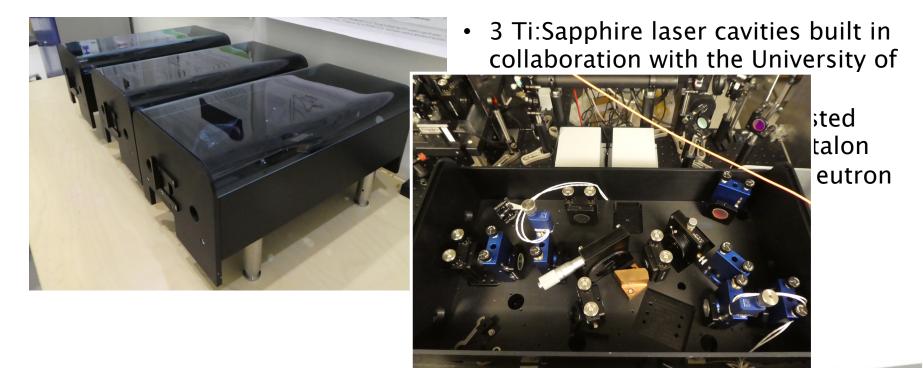


- 3 Ti:Sapphire laser cavities built in collaboration with the University of Mainz
- 1 laser cavity thoroughly tested
- In use in a so-called dual-etalon setup employed in the study of neutron deficient Ag isotopes





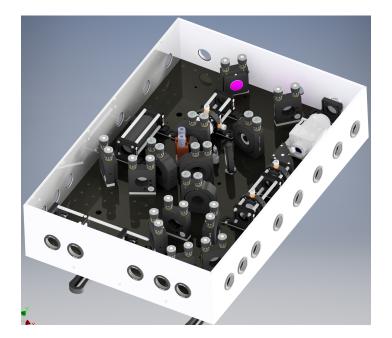
Laser system







Laser system



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

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



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 ⁹⁴⁻⁹⁶Ag with MARA-LEB





Science & Technology Facilities Council Nuclear Physics Group



Science & Technology Facilities Council

P. Papadakis



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J. Tuunanen, J. Uusitalo, S. Zadvornaya

Funding



In collaboration with





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

