INTC-P-565

MIRACLS at ISOLDE:
The Charge Radii of Exotic Magnesium Isotopes

Markus Vilén

Stephan Malbrunot-Ettenauer

collaboration

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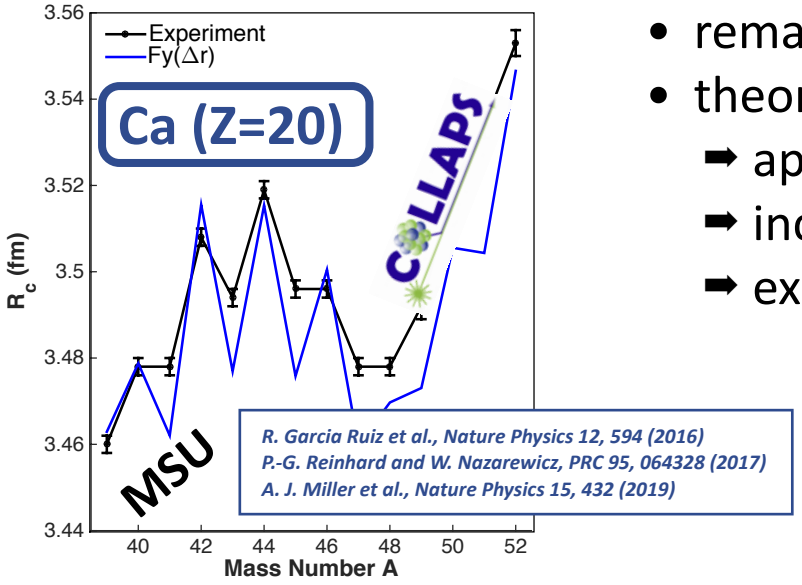
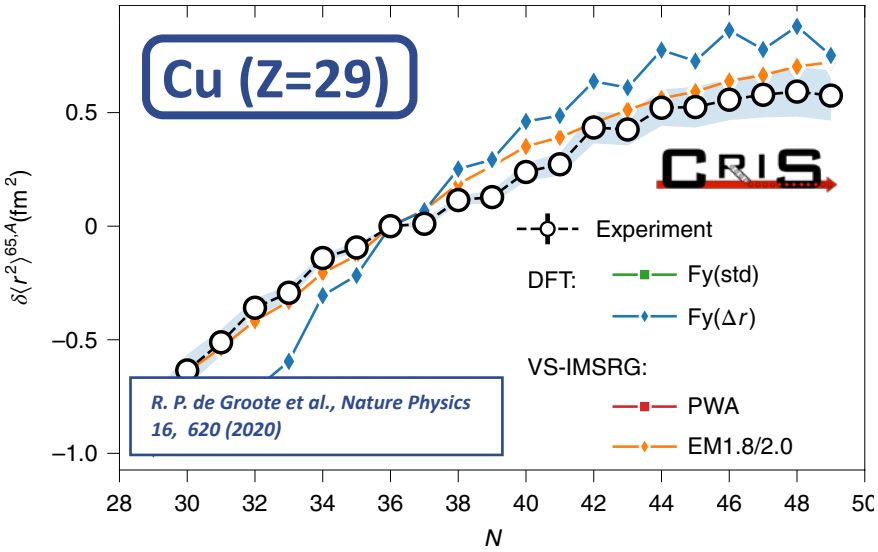
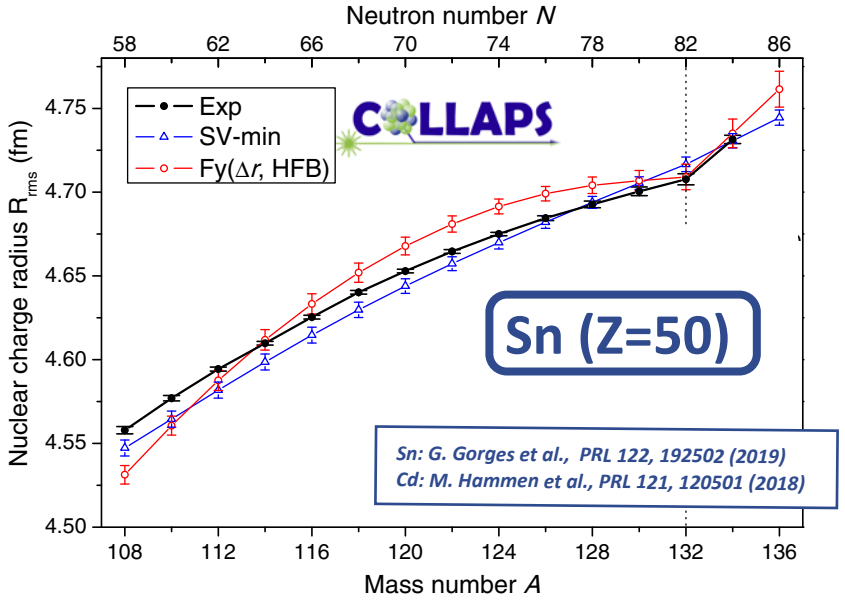
[5] *University of Innsbruck, A-6020, Innrain 23, Austria*

Towards a ‘universal’ description of charge radii



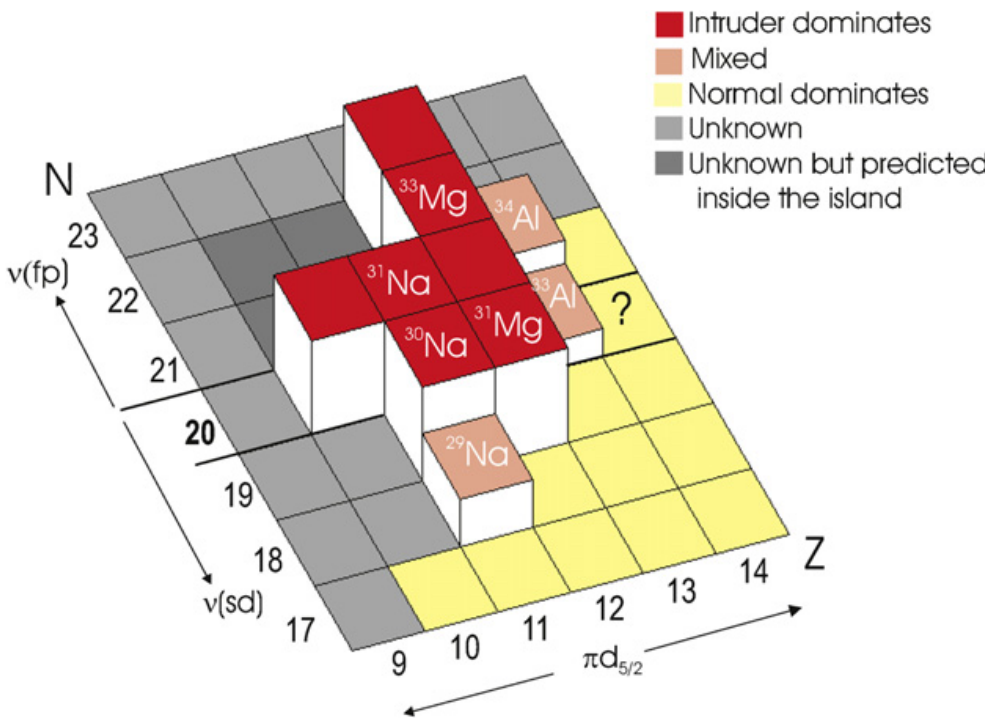
- remarkable progress in theory and experiment
- theoretical models:
  - ➡ applicable over wider mass range
  - ➡ including DFT and ab-initio methods
  - ➡ excellent agreement to experiment
    - ‘kink’ at shell closures
    - odd-even staggering



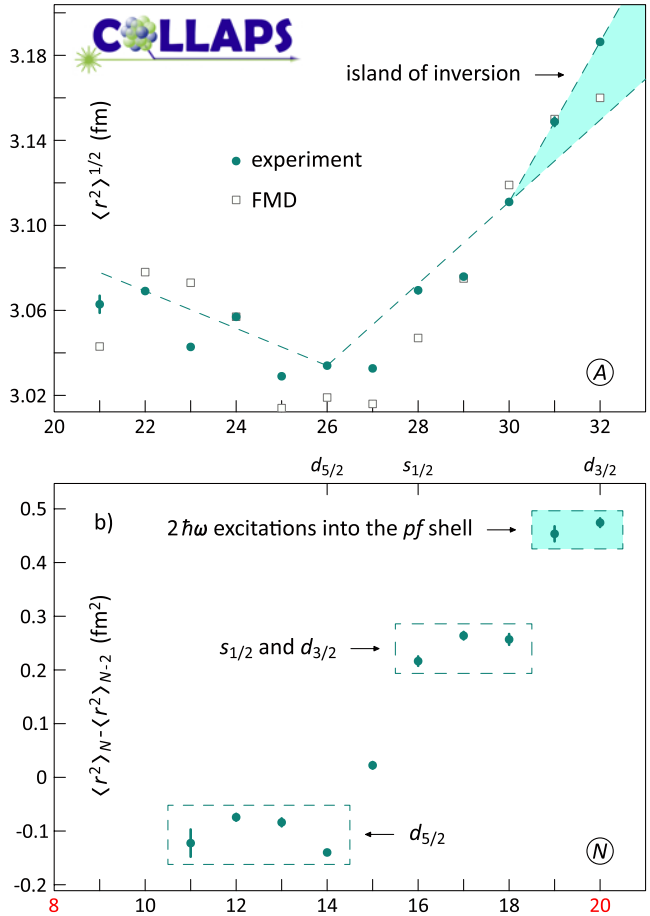


charge radii & the island of inversion

predictive power of theory away from semi-magic nuclei?



Mg isotopic chain



D. T. Yordanov et al., PRL 108, 042504 (2012)

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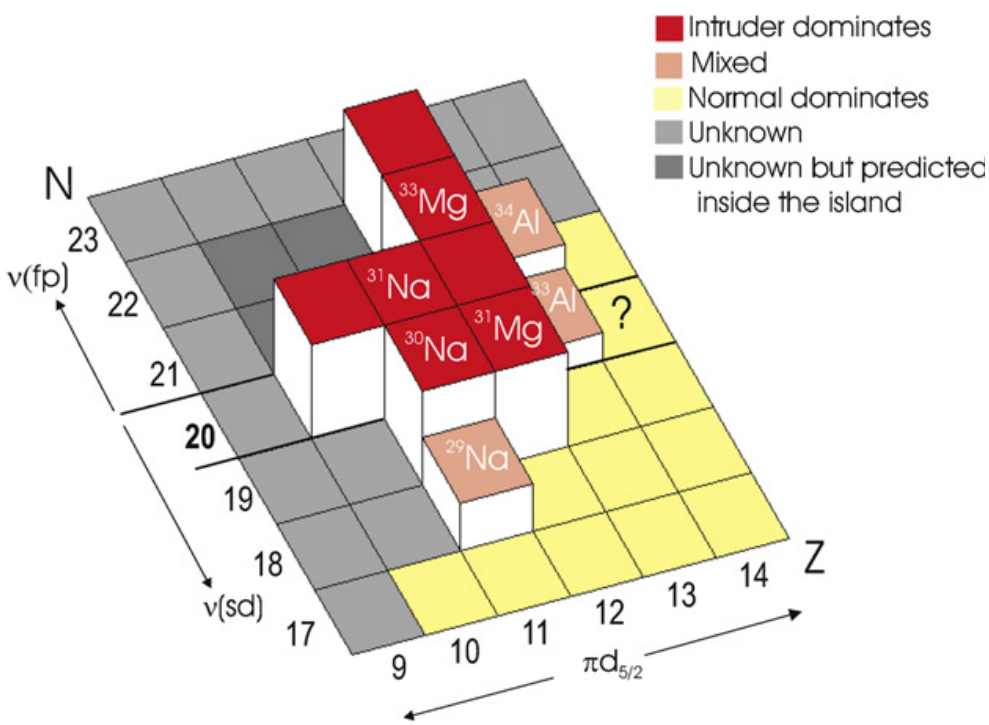

expectations?

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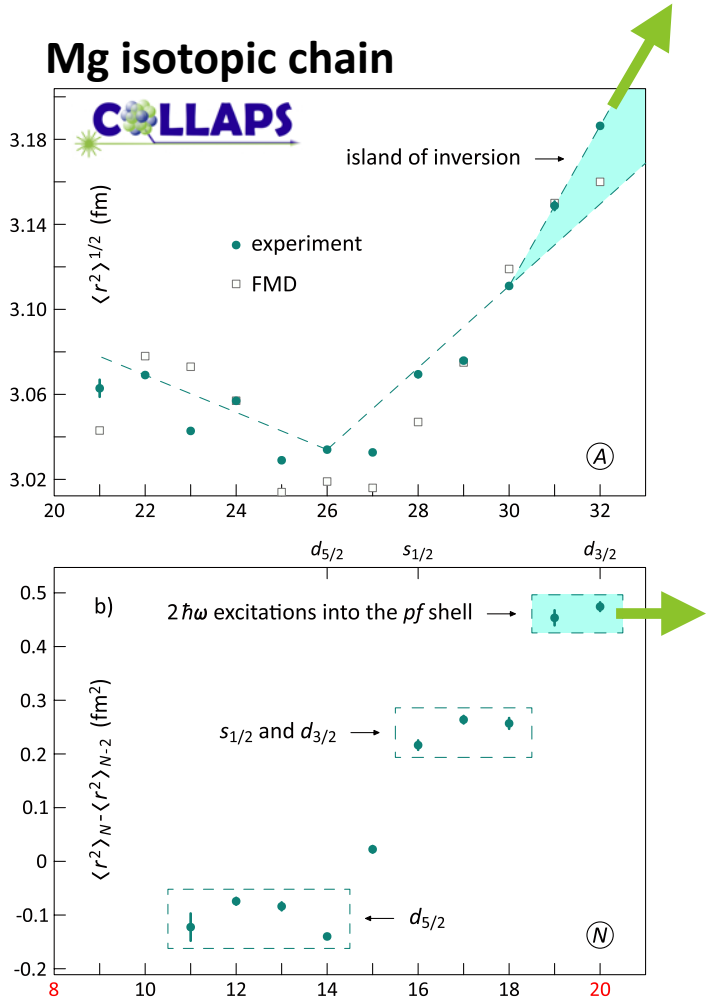

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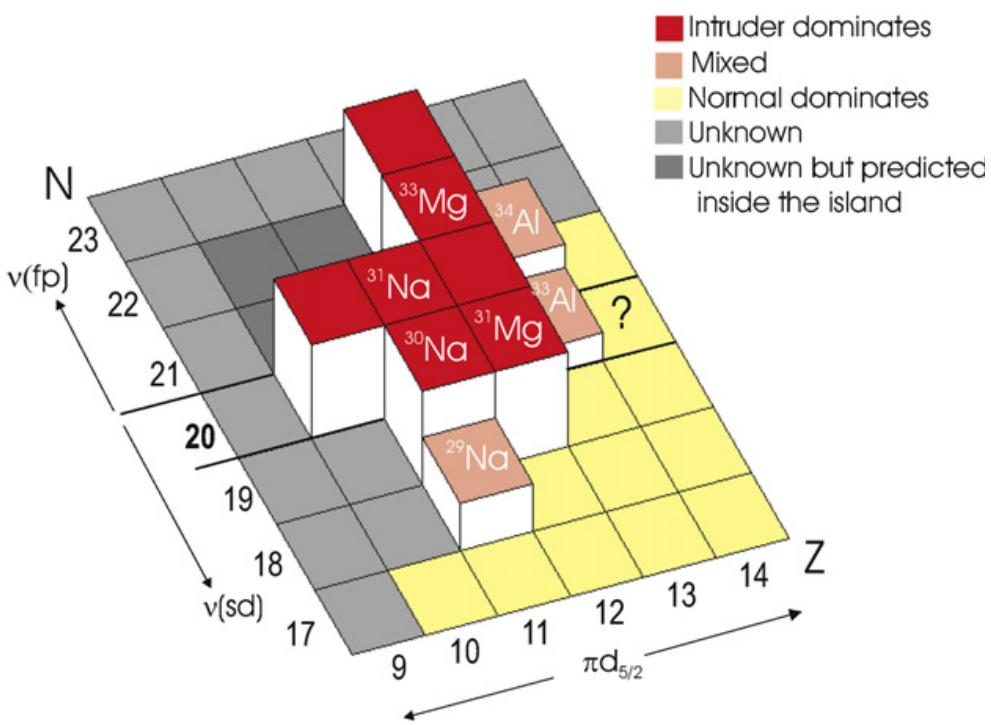

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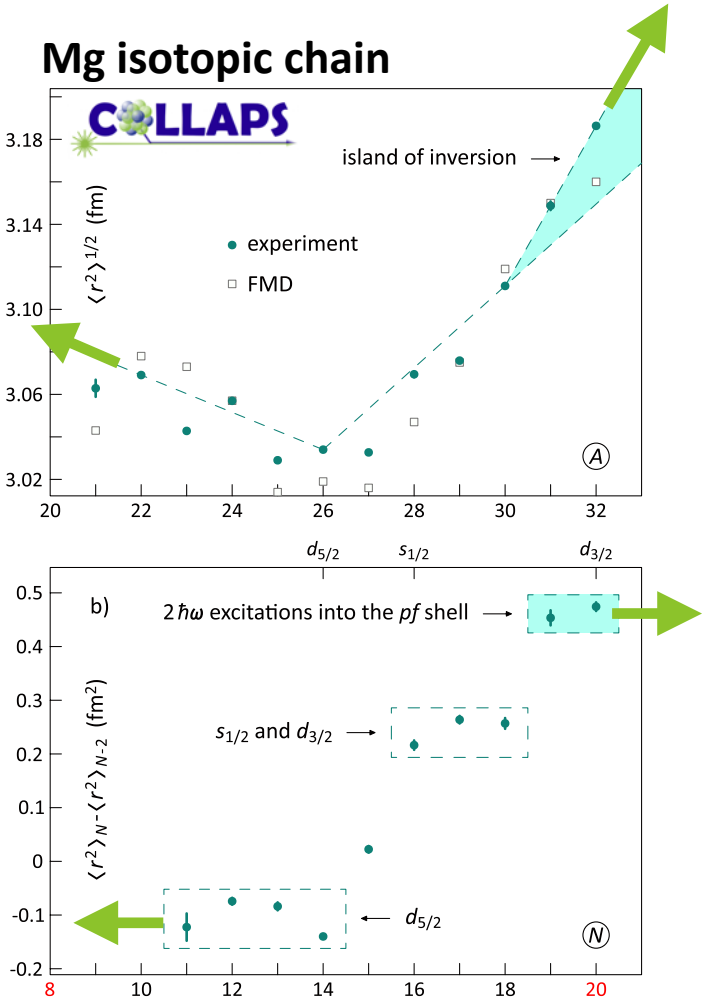

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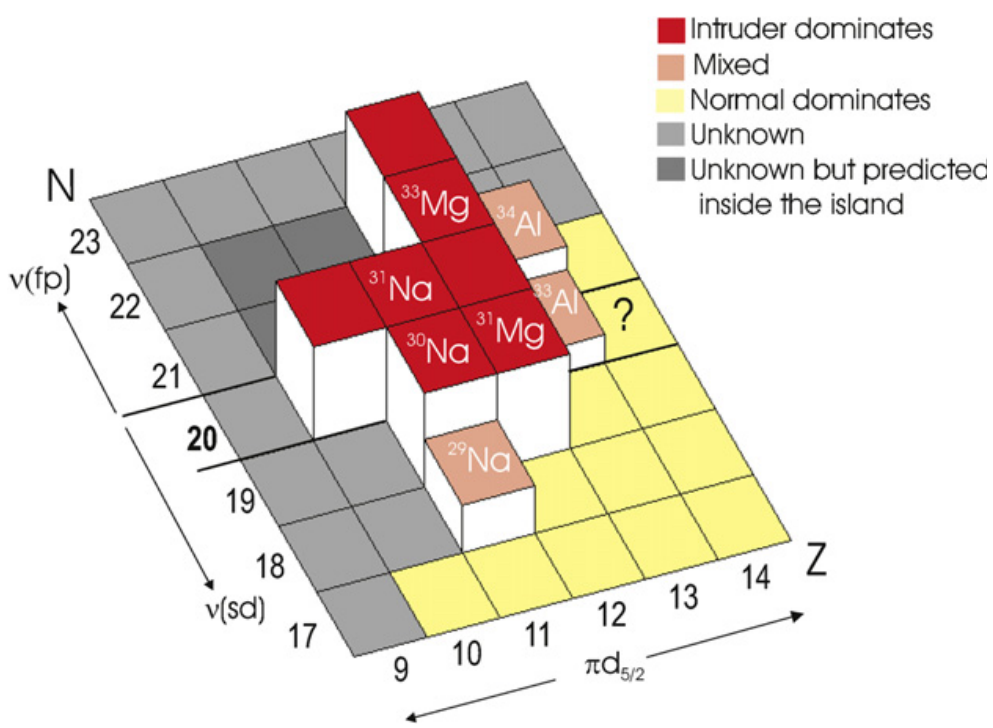

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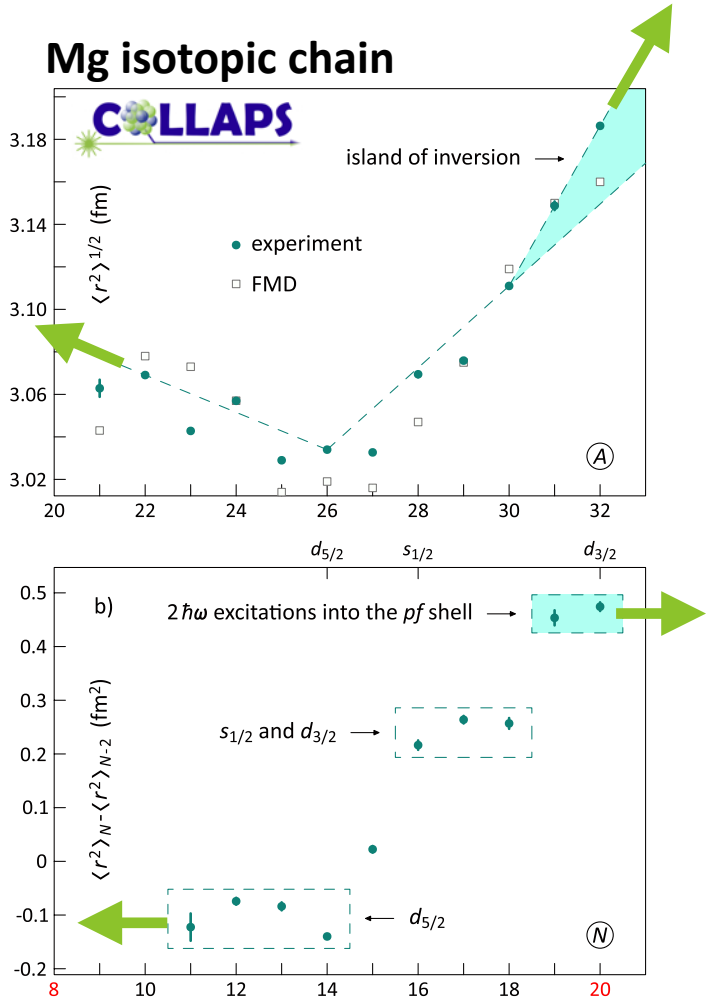

expectations?

validate trends in more 'exotic' Mg isotopes!

D. T. Yordanov et al., PRL 108, 042504 (2012)

Mg charge radii in ab-initio methods

new developments in

- **VS-IM-SRG:** mixed-parity valence spaces

T. Miyagi et al., arXiv:2004.12969 (2020)
J. Holt, private communication (2020)

- **couple cluster (CC) theory:** beyond closed (sub-)shell nuclei & neighbours

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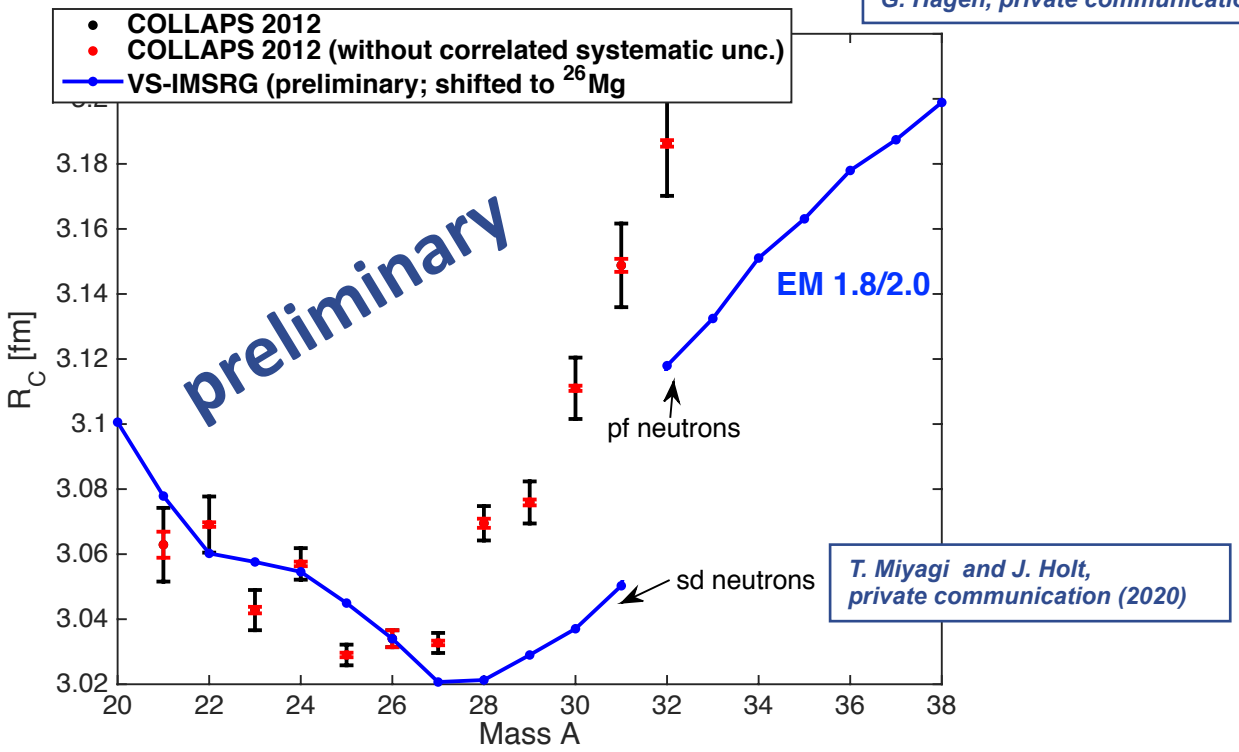

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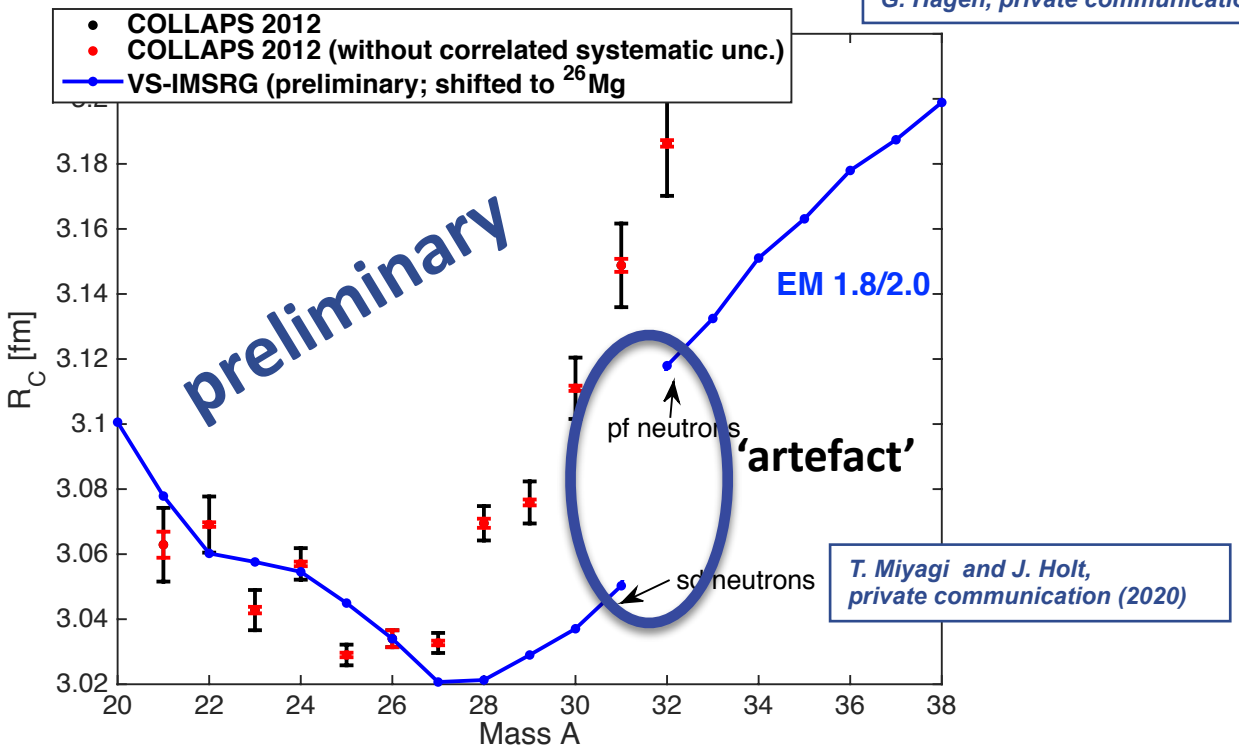

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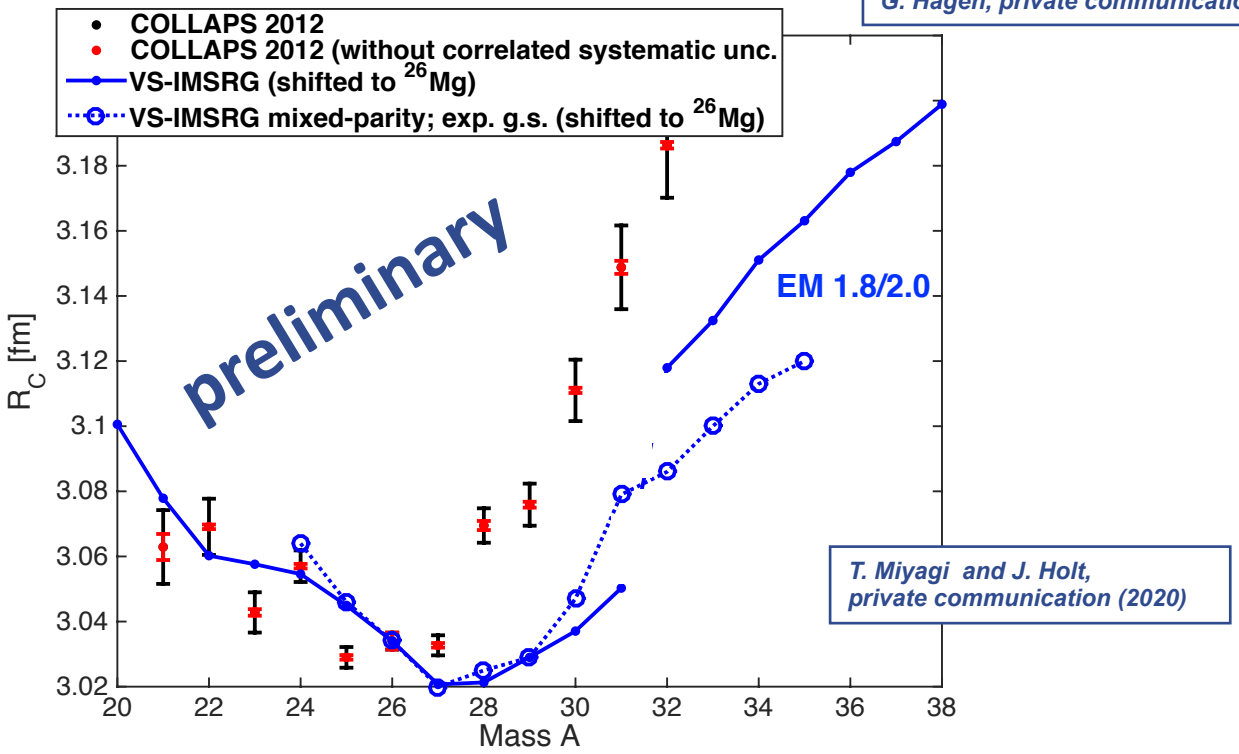

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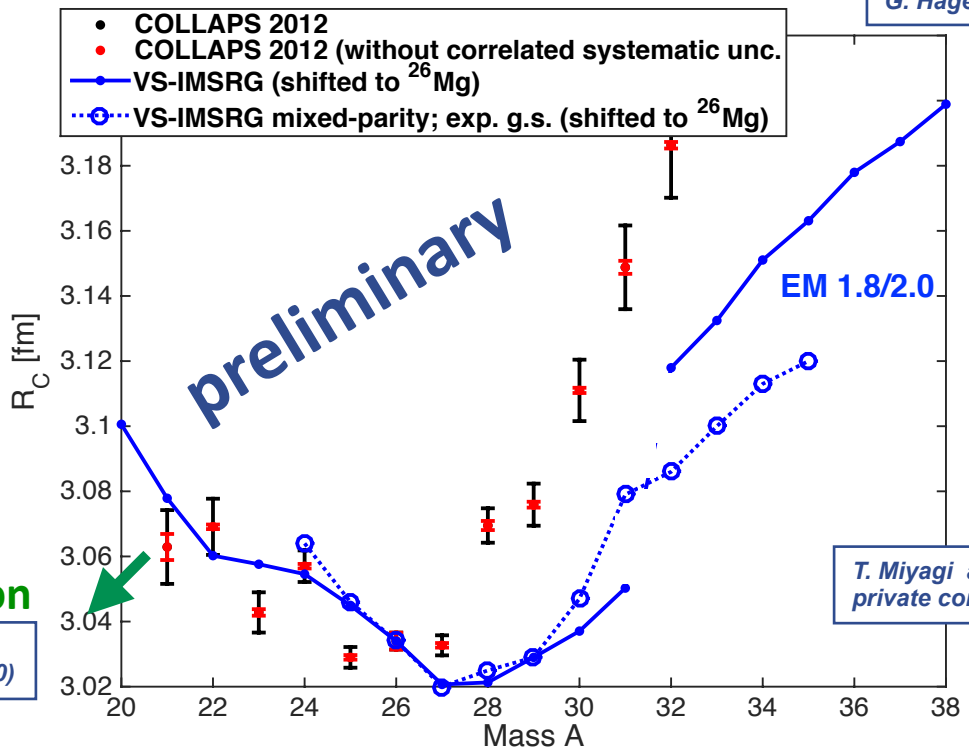

- **CC prediction**

G. Hagen, private communication (2020)

T. Miyagi and J. Holt, private communication (2020)

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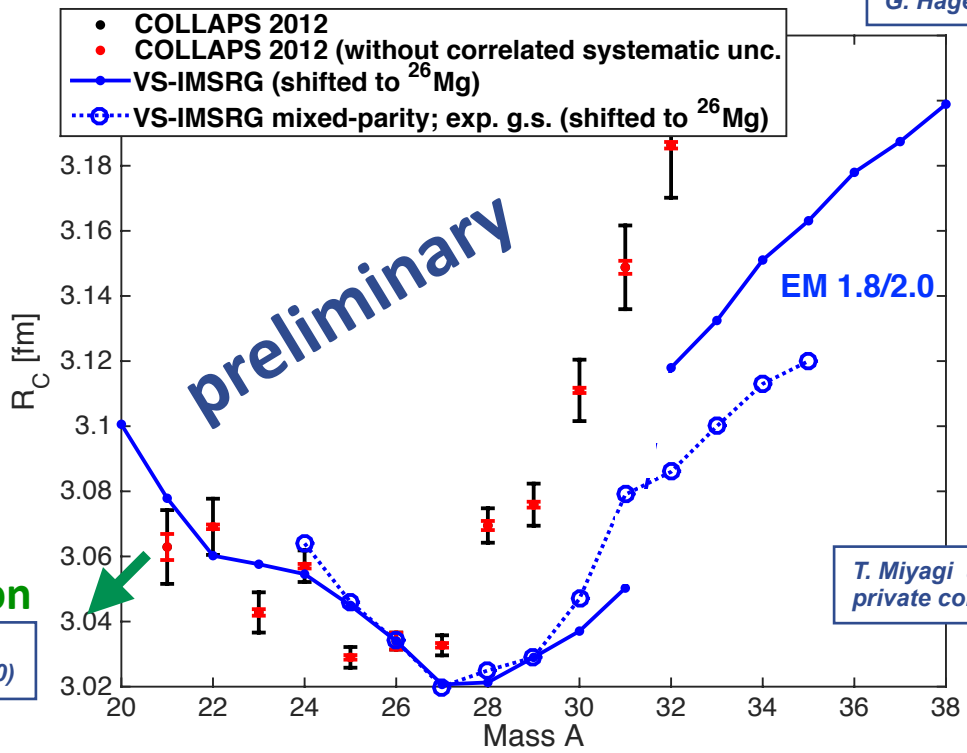


- **CC prediction**

G. Hagen, private communication (2020)

T. Miyagi and J. Holt, private communication (2020)

- **new experimental data to benchmark new nuclear models**
- **requires a new, more sensitive experimental technique**

the Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy

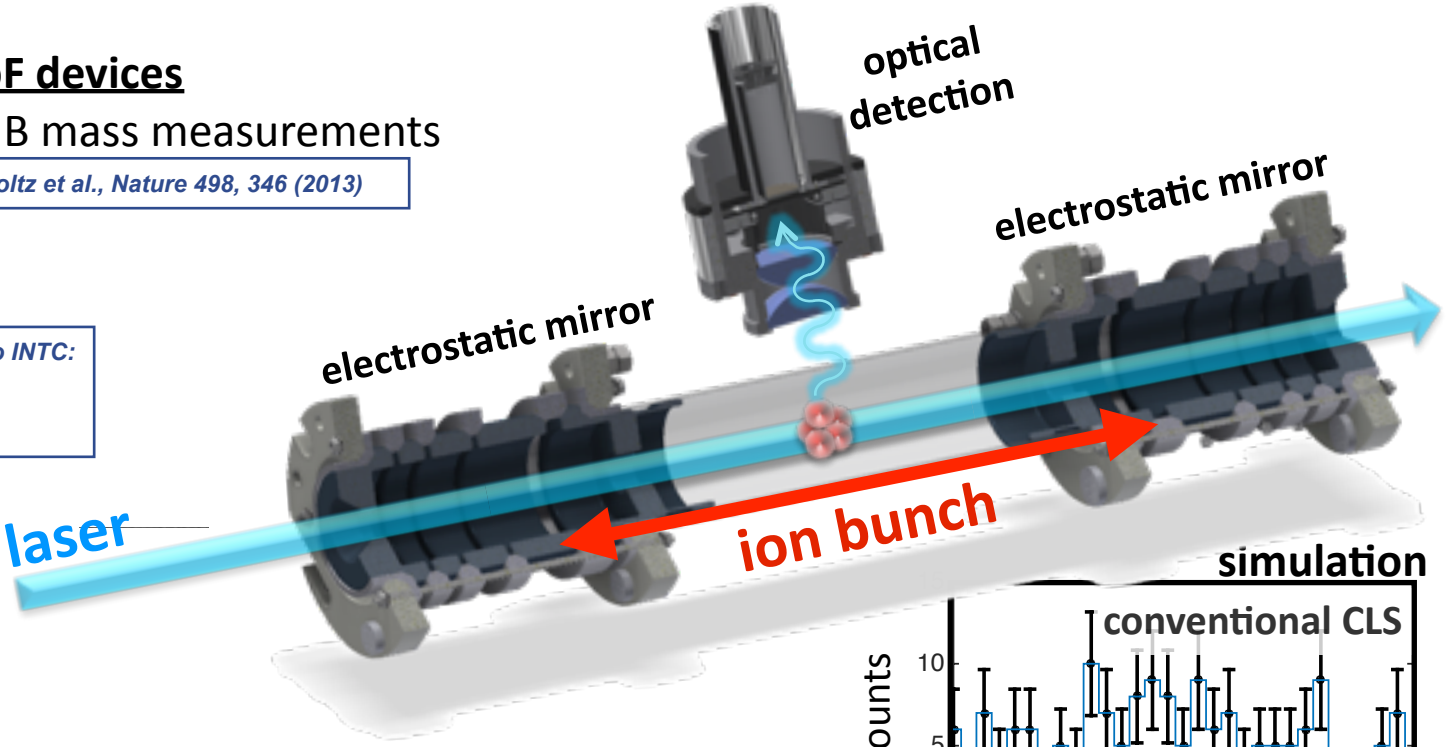
trap ⇒ long observation time ⇒ higher sensitivity ⇒ more exotic nuclides accessible

→ **MR-ToF devices**

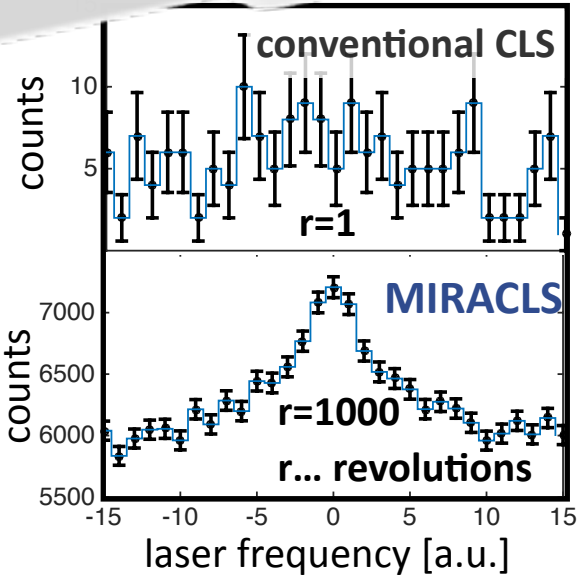
first RIB mass measurements

F. Wienholtz et al., Nature 498, 346 (2013)

previous reports to INTC:
INTC-I-197
INTC-I-215
INTC-M-019



simulation



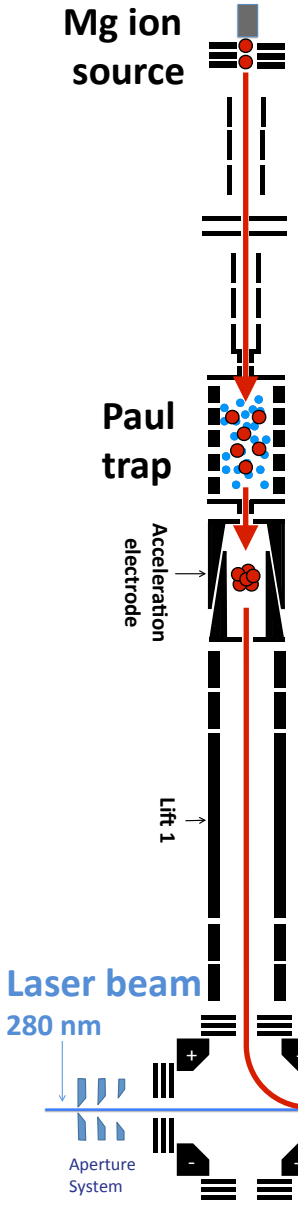
novel approach for collinear laser spectroscopy:

- ion trap ⇒ long observation time
- 30 keV beam ⇒ high resolution

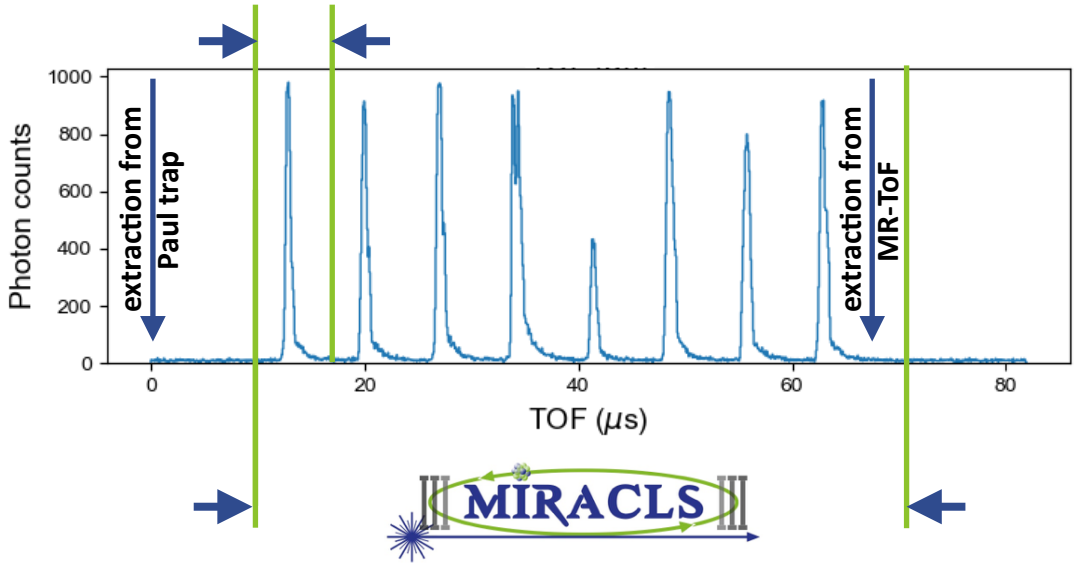
proof-of-principle experiment

- modified existing MR-ToF (low beam energy)

F. Maier et al., Hyperfine Interact. 240, 54 (2019)
S. Lechner et al., Hyperfine Interact 240, 95 (2019)
S. Sels et al., Nucl. Instr. Meth. B 463, 310 (2020)
V. Lagaki et al., Acta Phys. Pol. B 51, 571 (2020)
V. Lagaki et al., in preparation

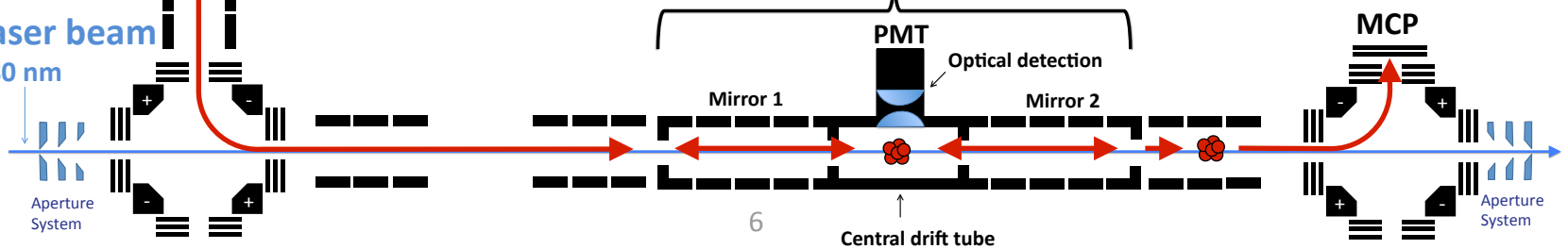


conventional CLS

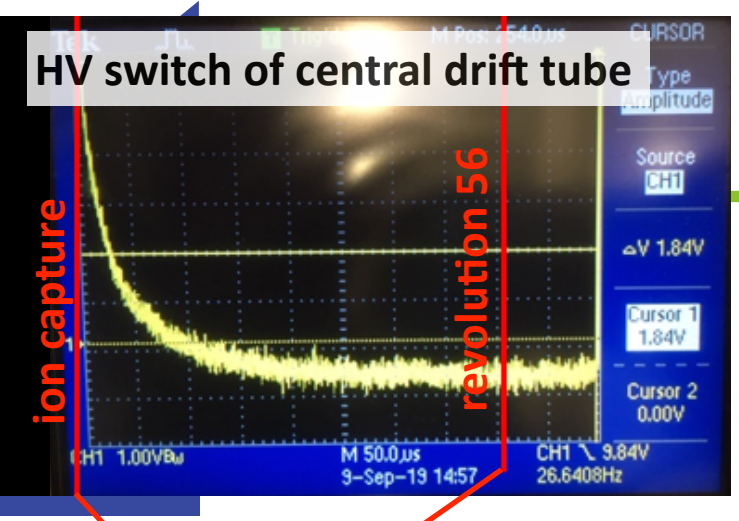


MIRACLS

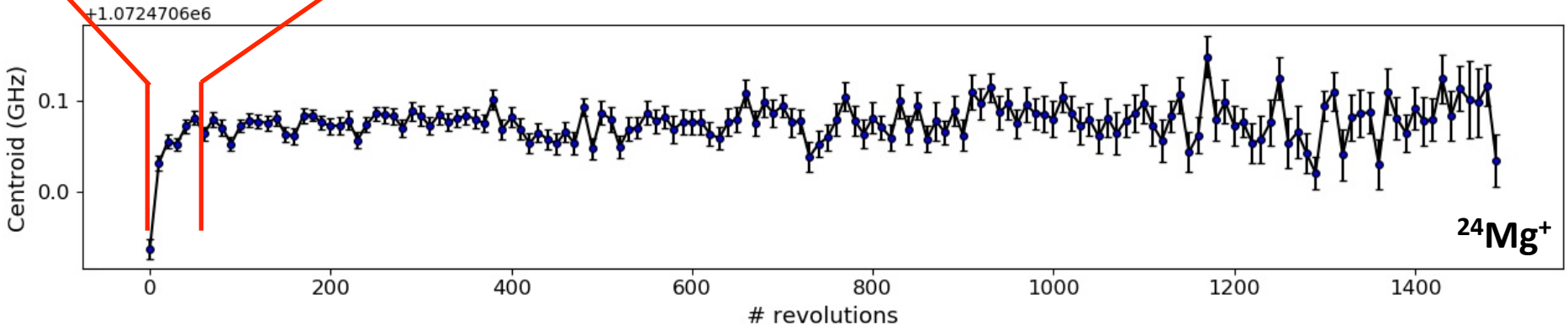
MR-ToF



CLS performance



- excellent centroid stability after revolution ≈60
- initial drift due to HV switch



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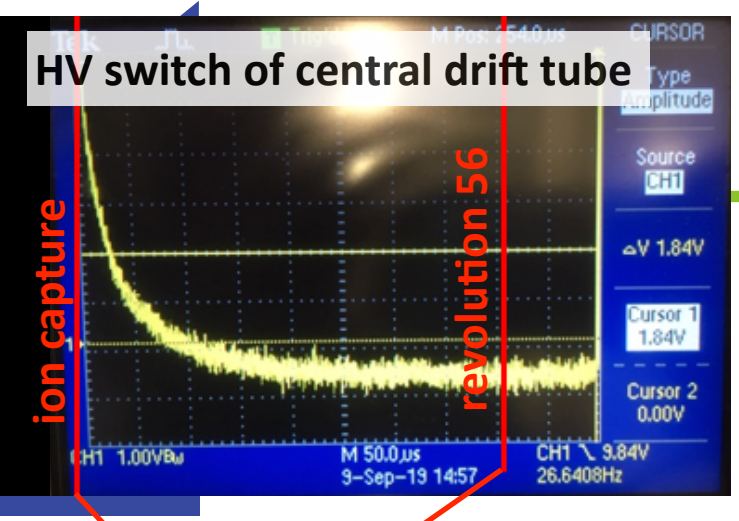

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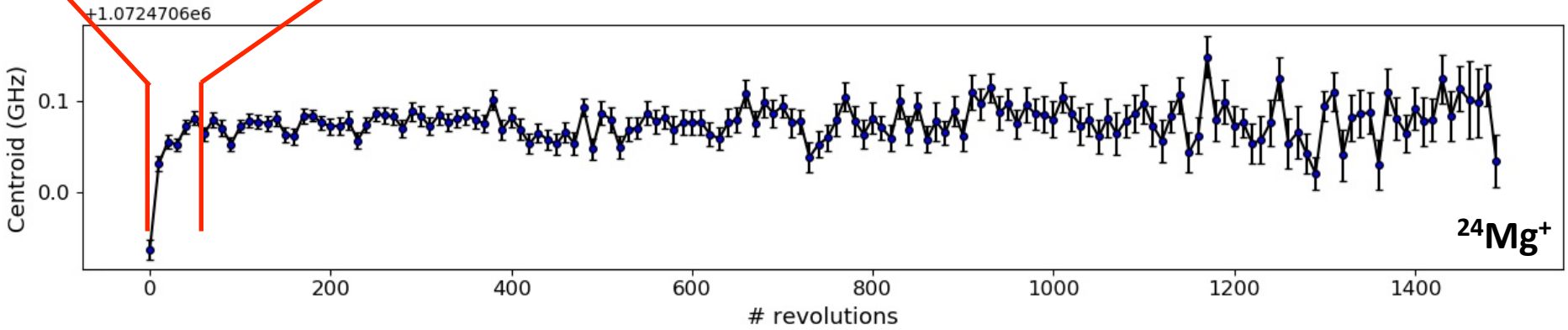
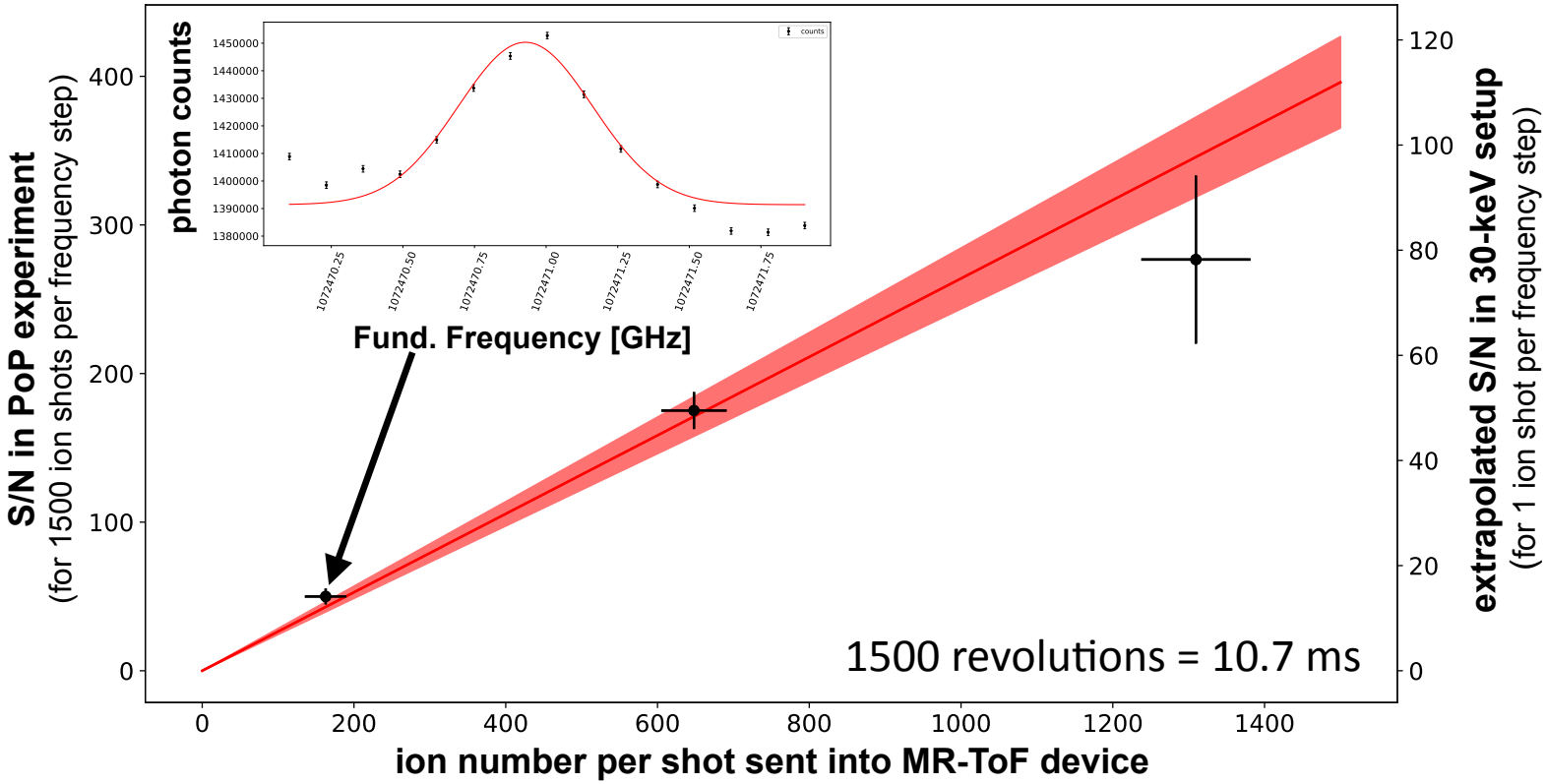


Achieved milestones

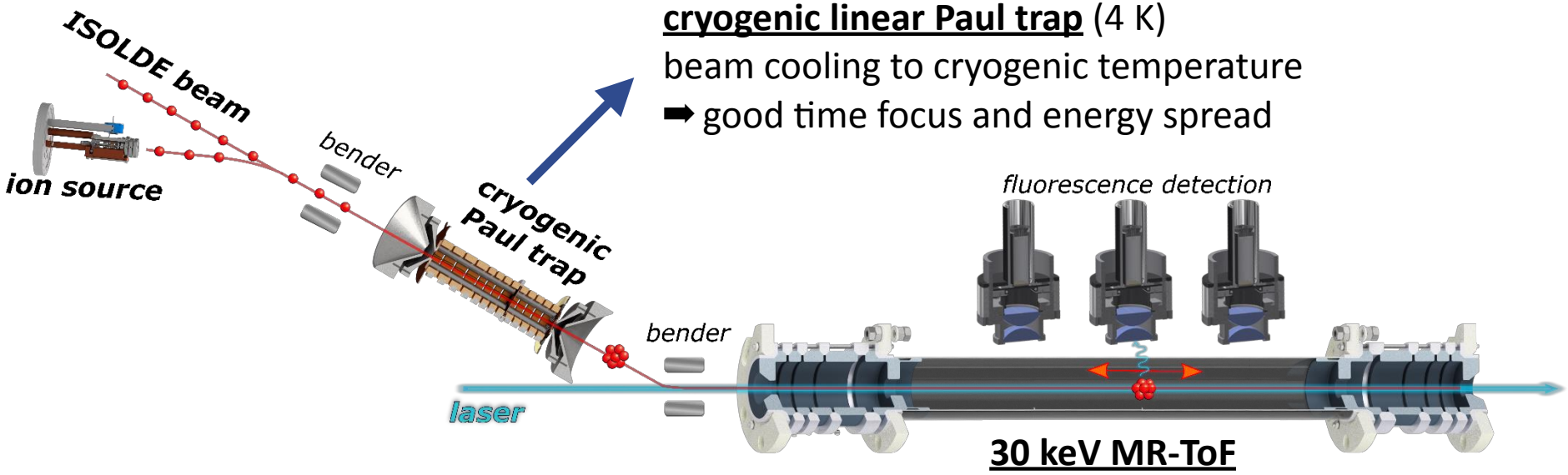
- CLS over 5000 revolutions
- 'quasi-simultaneous' anti/ collinear laser spectroscopy
- optical re-pumping in $^{40}Ca^{+}$

MIRACLS sensitivity in $^{24}Mg^{+}$



online measurements with *O*(10) ions/sec possible

MIRACLS 30-keV setup



cryogenic linear Paul trap (4 K)

beam cooling to cryogenic temperature

➡ good time focus and energy spread

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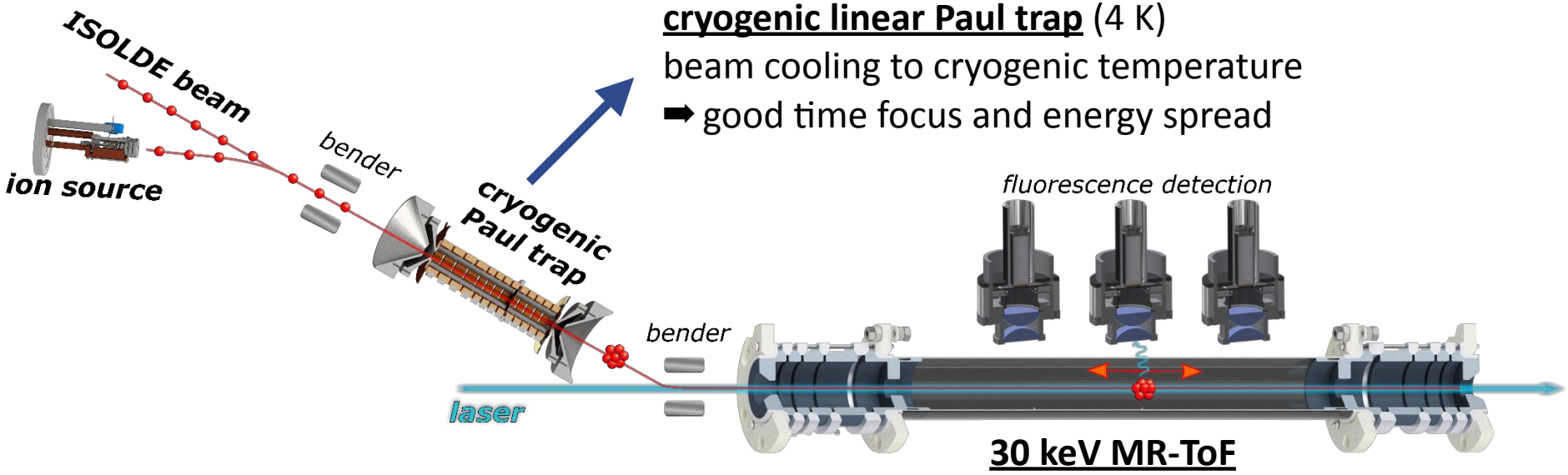

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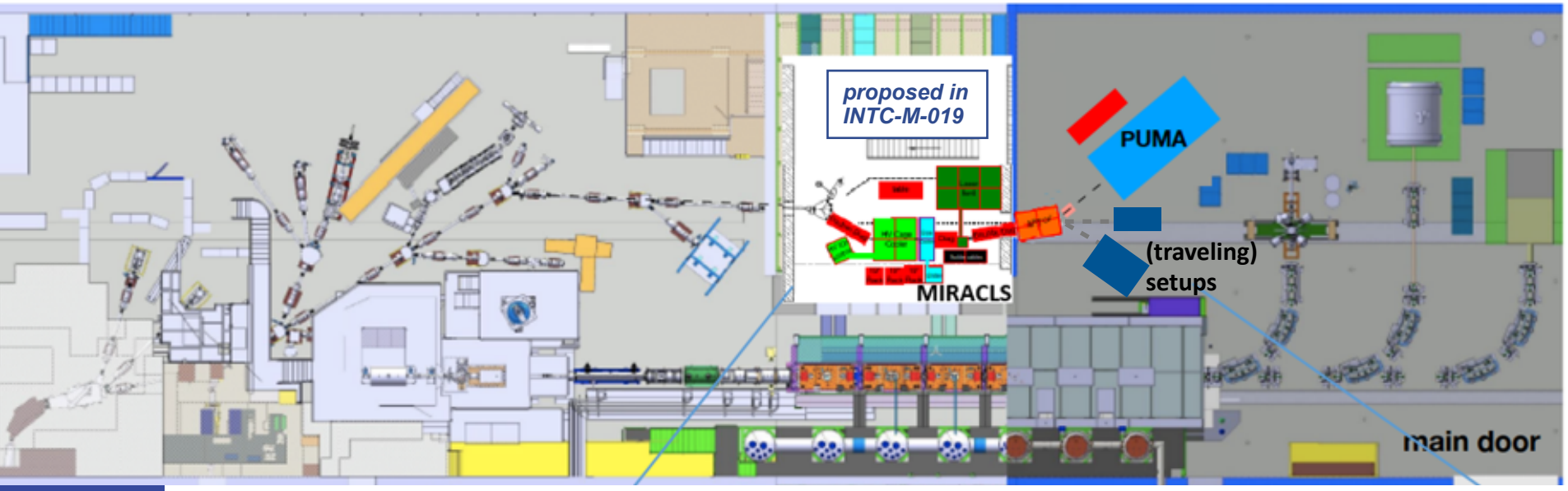

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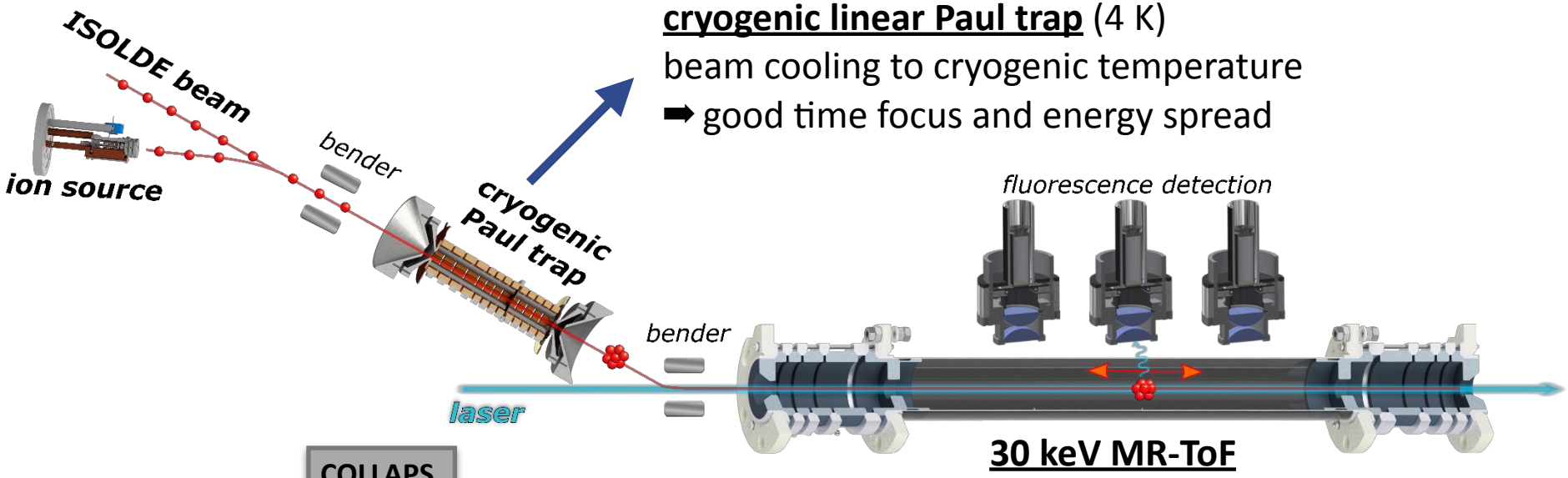

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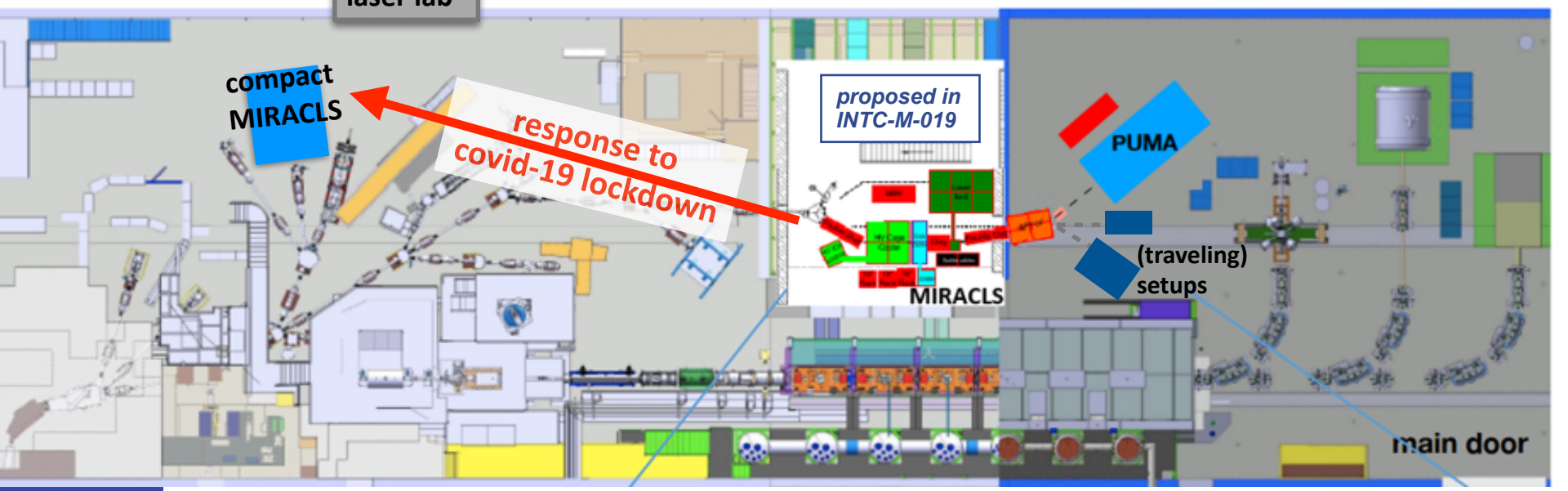
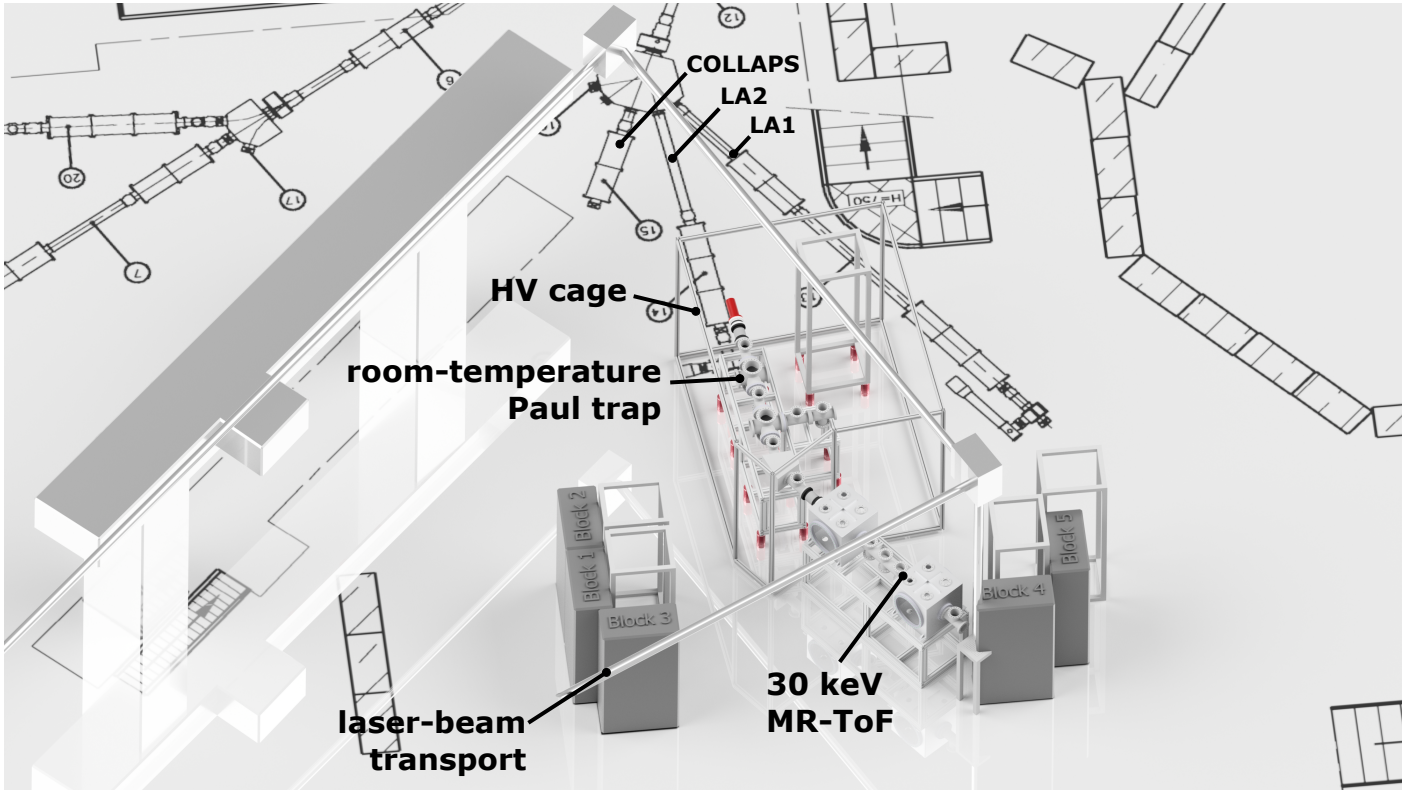


compact MIRACLS at LA2



- ➡ setup with reduced complexity (and capabilities)
- ➡ commissioning of 30-keV MR-ToF device
- ➡ addresses ERC science goals within funding period
- ➡ requires infrastructure at LA2 (see proposal & ISCC discussion)

Beamtime estimate

- sensitivity extrapolated from proof-of-principle experiment

Nuclide	$T_{1/2}$ [ms]	Target	ion source	Yield [ions/µC]	Contaminaton & Yield [ions/µC]	m/Δm	Requested Shifts	Comments
^{34}Mg	20	UC_x	RILIS	140	^{34}Al: 15 (surface)	2'800	2	} contamination
^{33}Mg	89	UC_x	RILIS	3'000	^{33}Al: <490 (RILIS)	2'300	3	} rate acceptable
^{21}Mg	122	SiC	RILIS	15'000			-	
^{20}Mg	91	SiC	RILIS	≈500	^{20}Na: 1.1E6	1'750	-	Estimate
		SiC	LIST	≈17	^{20}Na: ≈1		5	Estimate
Systematics							2+1	
Setup							2+2	with stable Mg

Total: 17 8-h shifts split in 2 runs

IMPORTANT: offline beam during LS2!!!

- establish ion transfer from ISOLDE to MIRACLS
- 3x 4 days

Summary

- novel developments in nuclear theory
  - ➡ excellent agreement to recent experiments for charge radii R_c
  - ➡ ”towards universal description of R_c”
  - ➡ ab-initio theory: new developments for mid-shell nuclei
    - island of inversion around ^{32}Mg now in reach (especially R_c)
- exotic Mg require new experimental technique

- successful proof-of-principle experiment
  - ➡ sensitivity estimate: ^{20,33,34}Mg accessible
- compact MIRACLS@LA2
  - ➡ response to COVID-19 lockdown
  - ➡ addresses ERC science goals within funding period
- request 17 shifts (split in to runs)

common effort on the forefronts of nuclear theory and experiment

MIRACLS

collaboration:

CERN

UNIVERSITÄT GREIFSWALD
Wissen lockt. Seit 1456

TECHNISCHE UNIVERSITÄT DARMSTADT

team members:

P. Fischer, **V. Lagaki, S. Lechner, F. Maier, P. Plattner**,
H. Heylen, M. Rosenbusch, **S. Sels**, F. Wienholtz, **M. Vilen**,
R. Wolf, G. Neyens, W. Nörtershäuser, L. Schweikhard,
S. Malbrunot- Ettenauer (Spokesperson)

MIRACLS Alumni:
F. Hummer (2019), **L. M. Bartels** (2018),
F. Maier (2018), **L. Fischer** (2017)
F. Stabel (2017), **S. Sailer** (2017)

CERN based people:
PhD students
MSc students
BSc students
Fellows

funding:

erc European Research Council

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https://miracls.web.cern.ch

ISOLDE