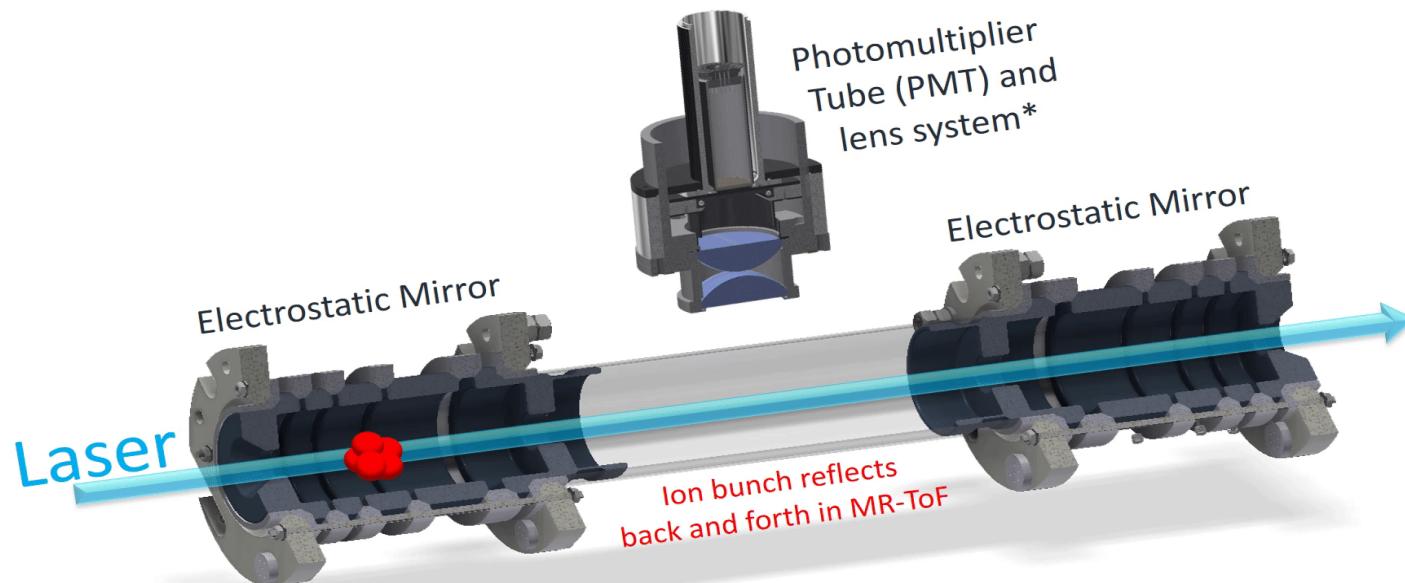


MIRACLS: From Proof of Principle Towards First Online Operation

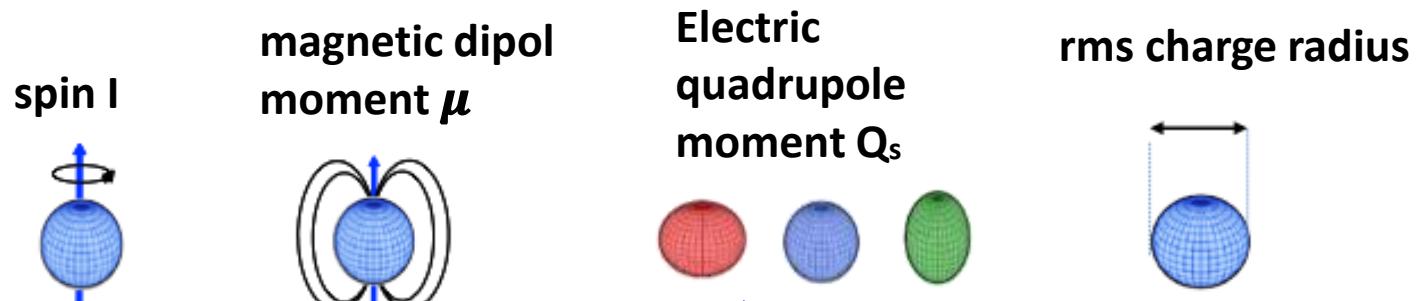
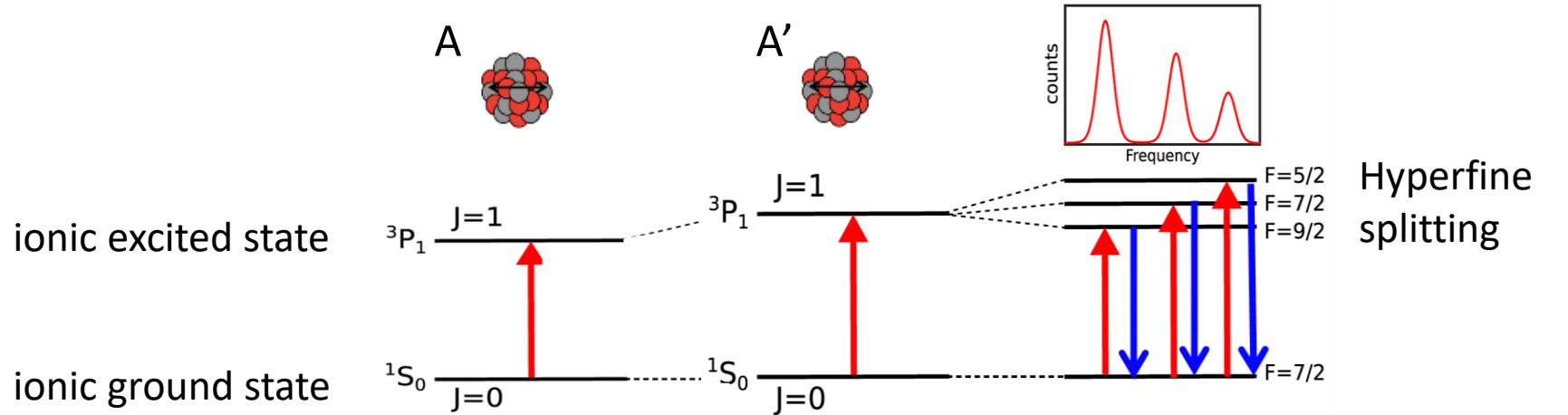


* Not to scale



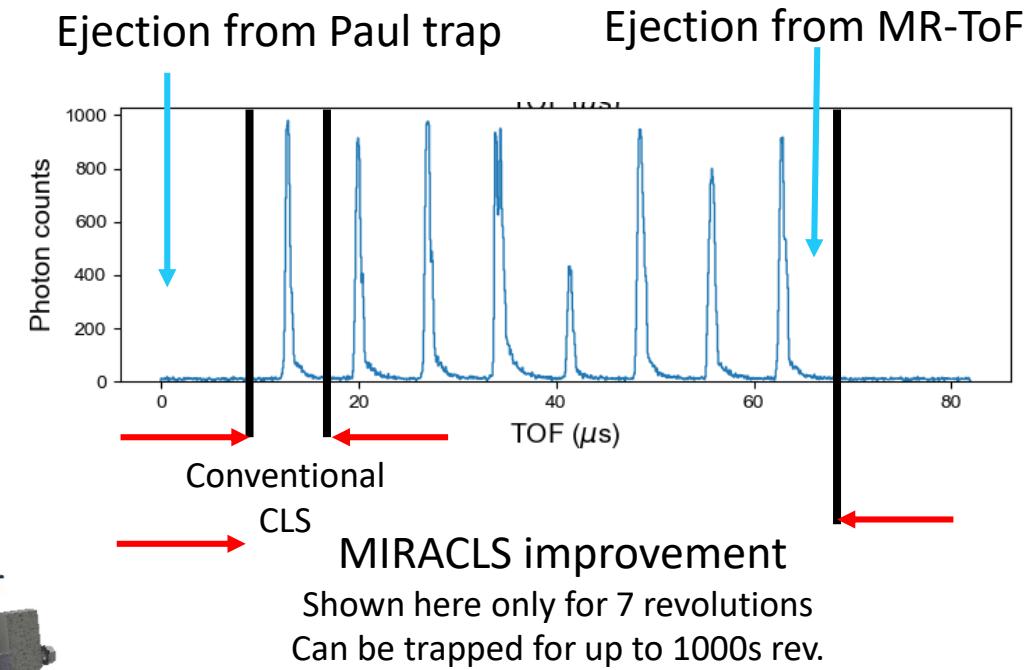
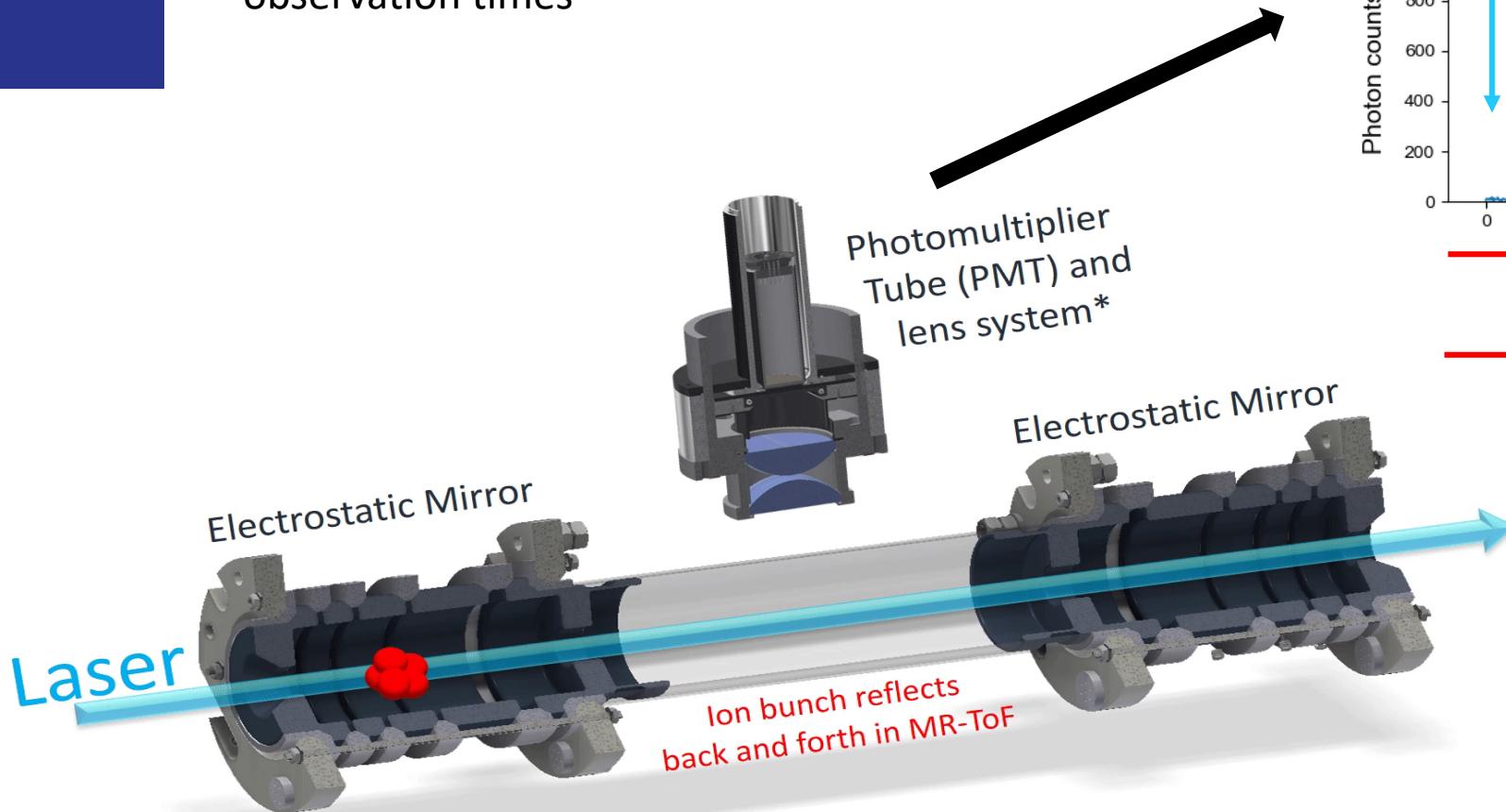
Laser Spectroscopy

Resonant excitation of (hyper)fine transitions in an atom or ion:

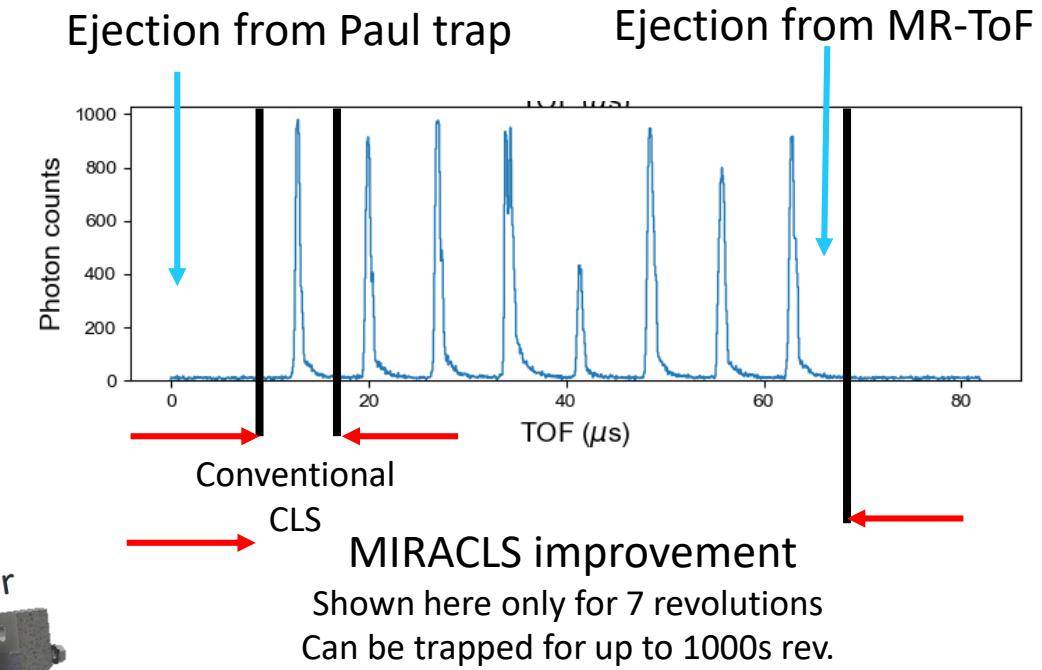
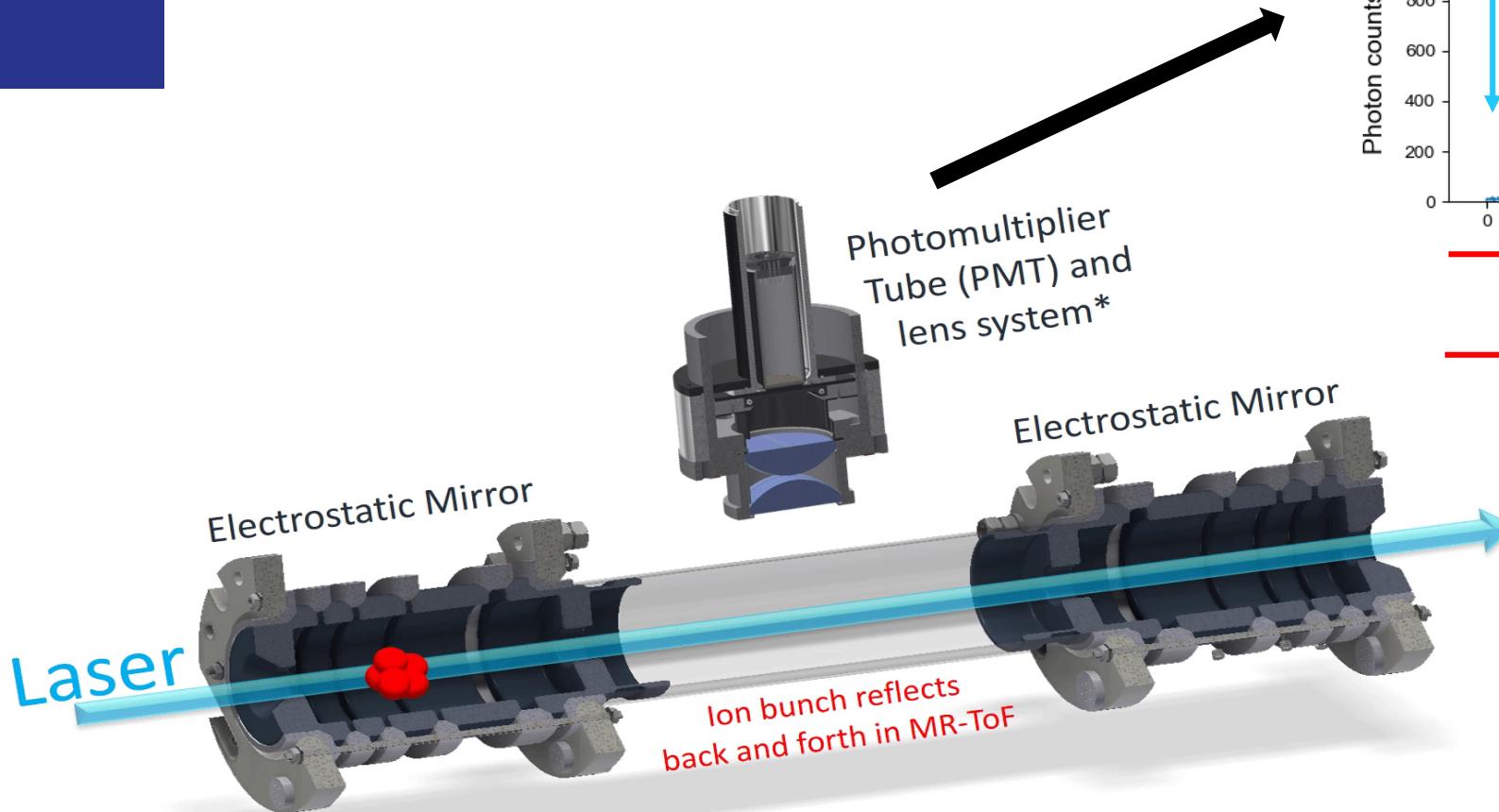


- study nuclear structure phenomena
- benchmark for modern nuclear theory

- Collinear Laser Spectroscopy known for high resolution
- Conventional fluorescence based CLS is limited to short observation times



* Not to scale

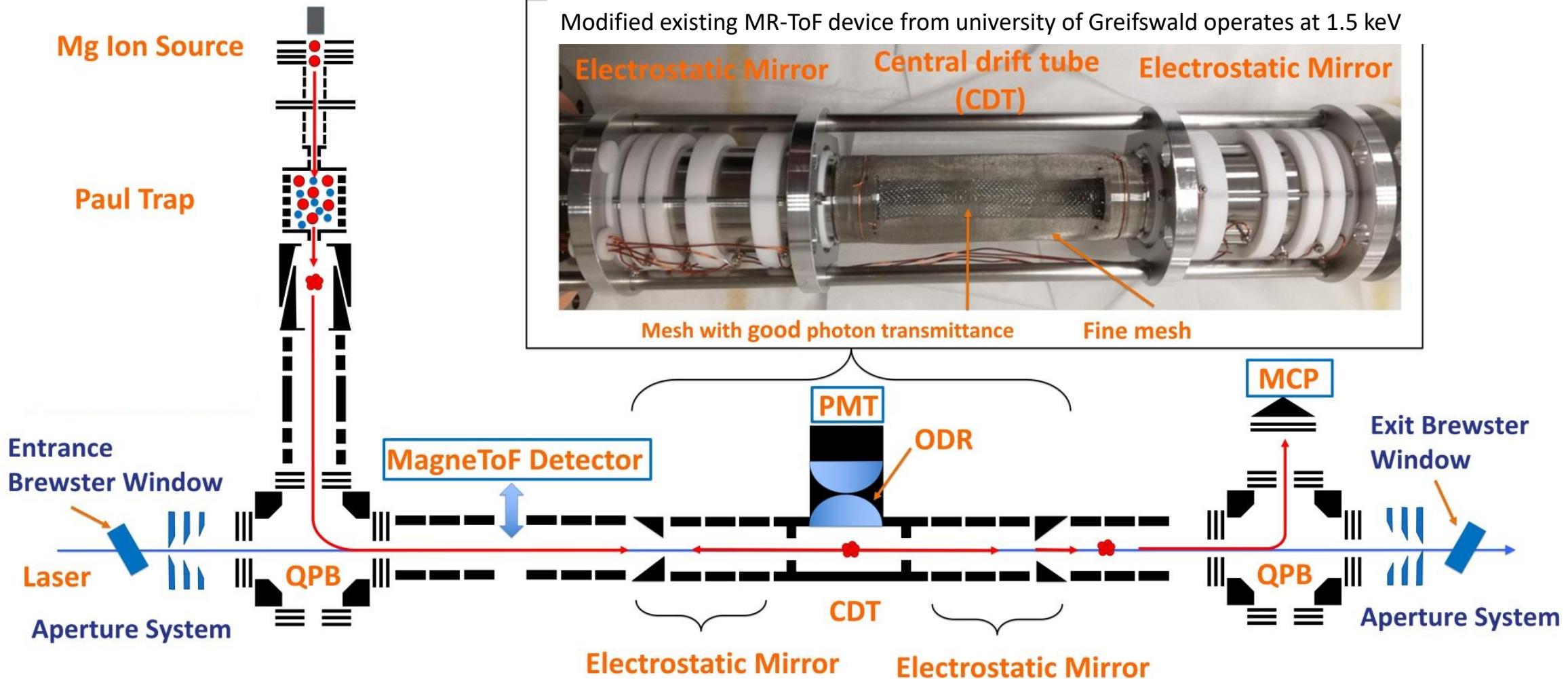


Increased observation time
 → gain in sensitivity by a factor of 40-700
 → More exotic nuclides accessible

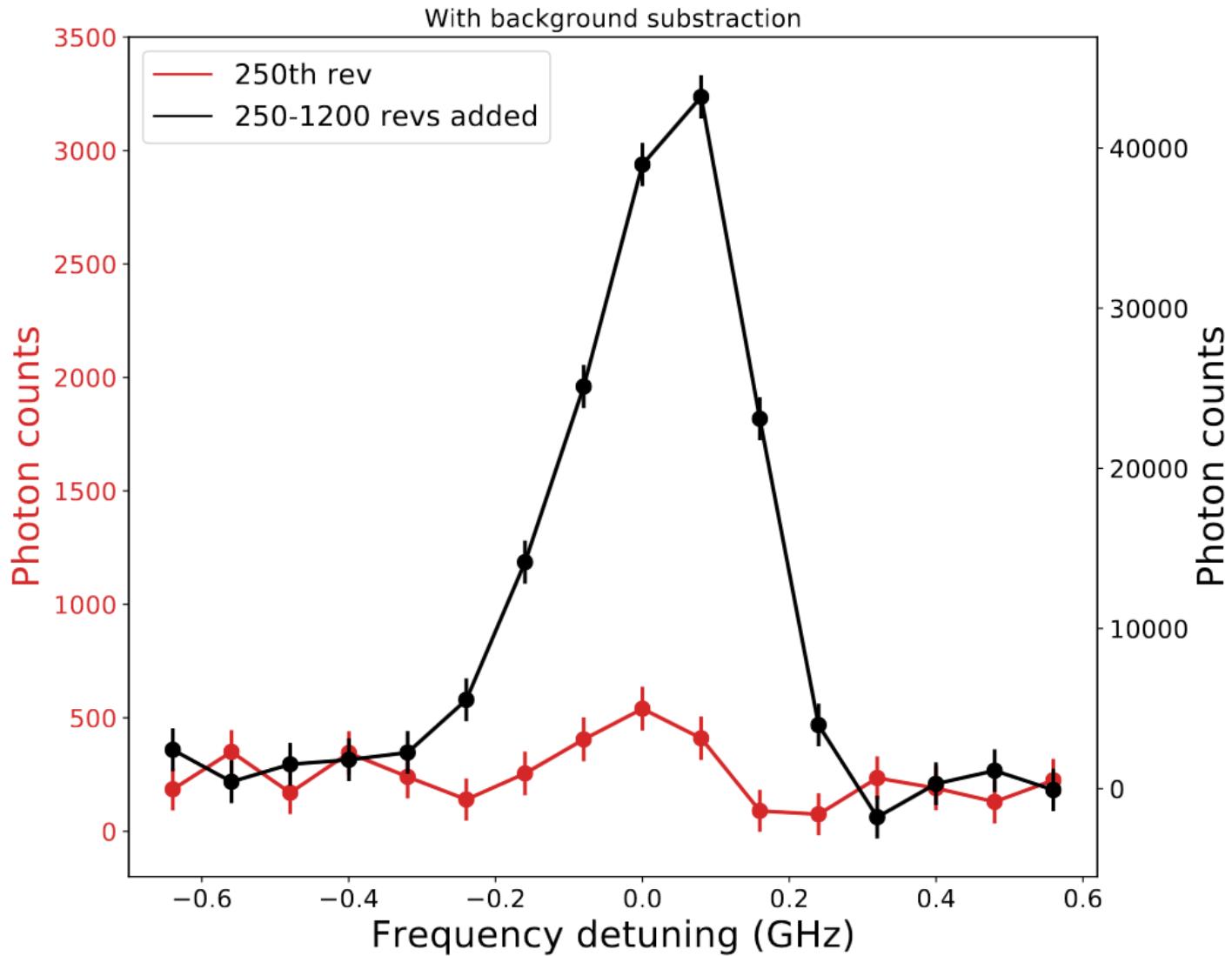
* Not to scale

maintain high resolution
 → 30-keV MR-ToF device

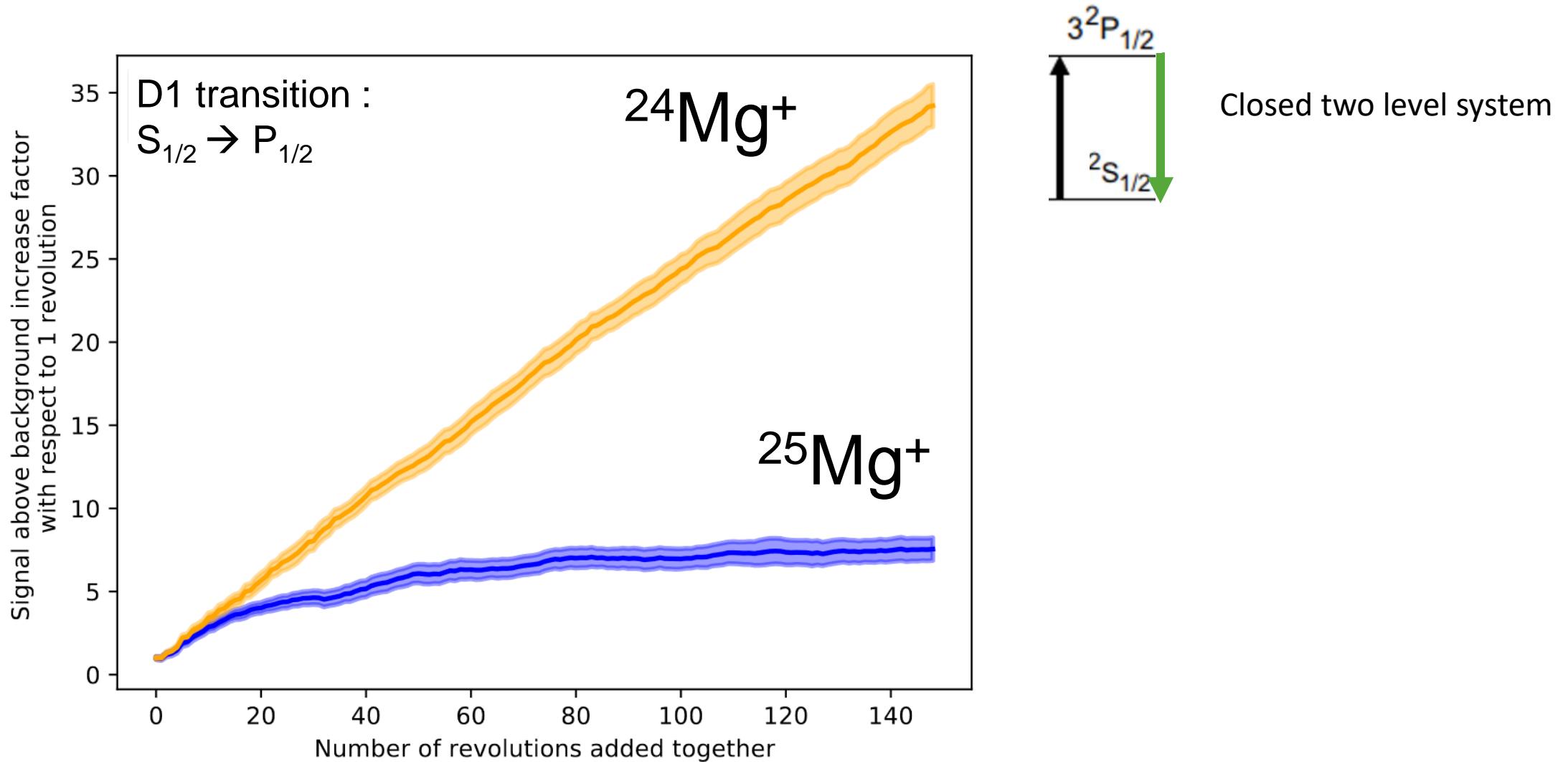
Proof-of-Principle Experiment



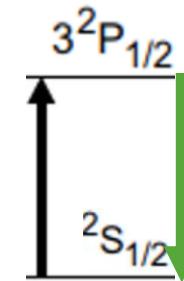
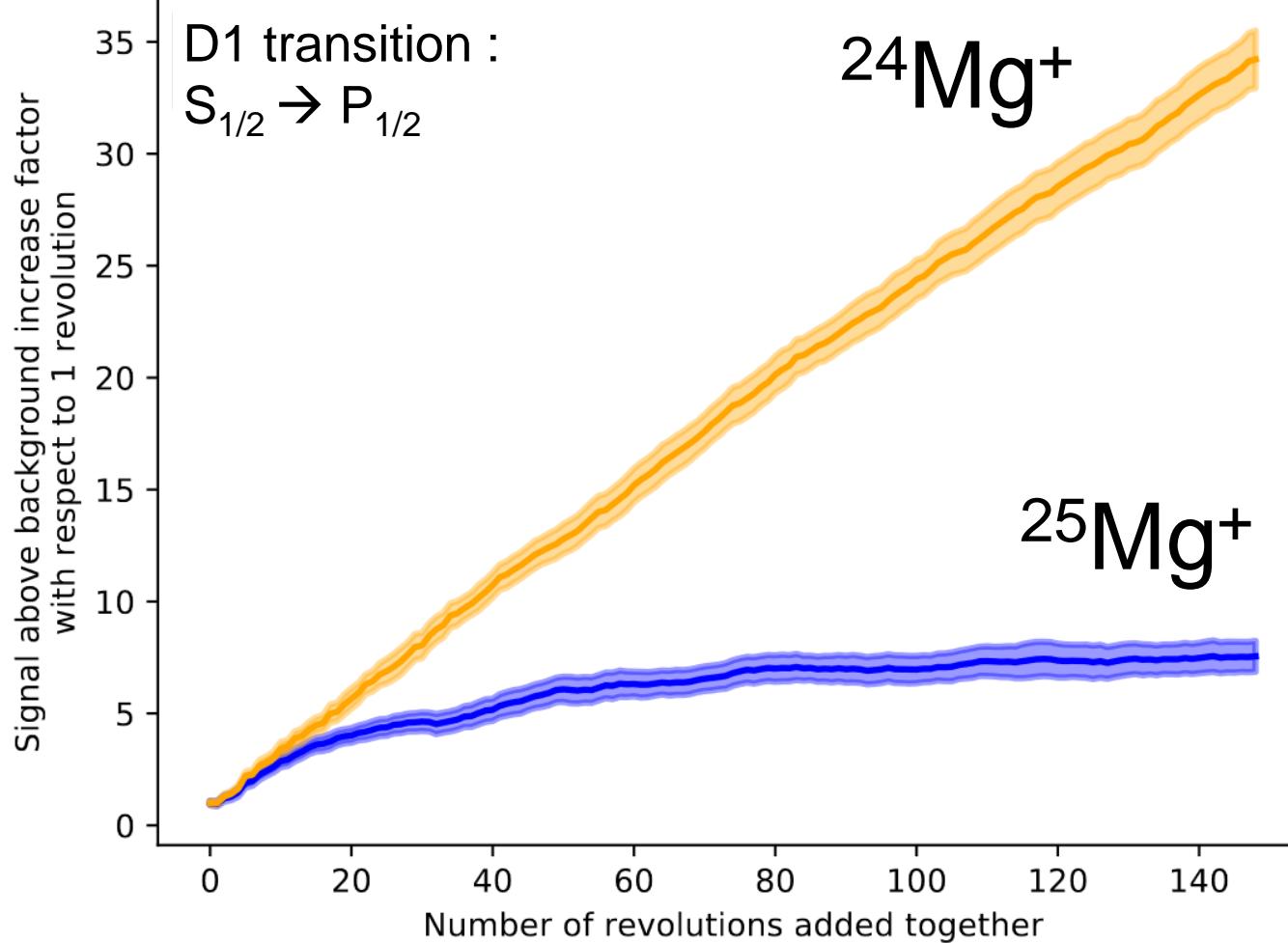
Improvement in Signal for $^{26}\text{Mg}^+$



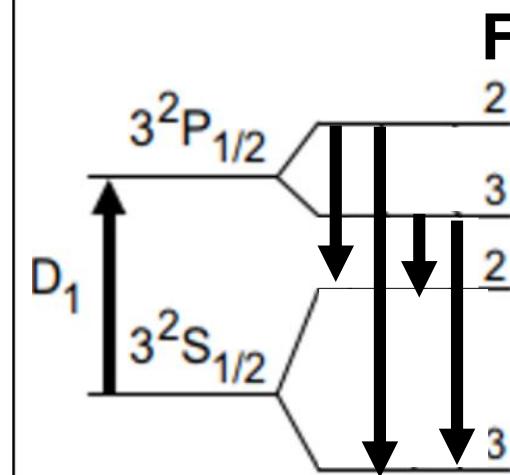
Improvement in Signal



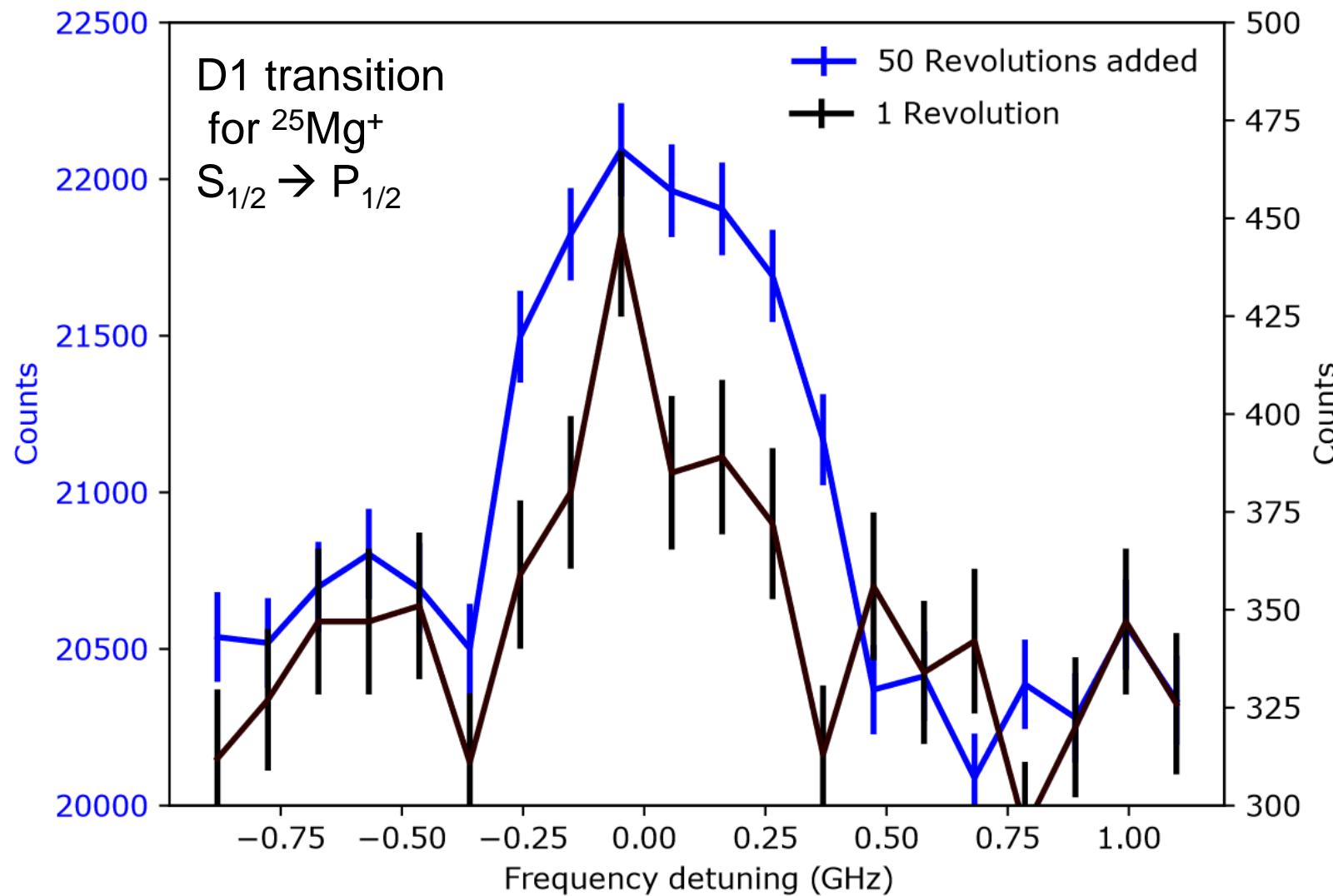
Improvement in Signal



Closed two level system



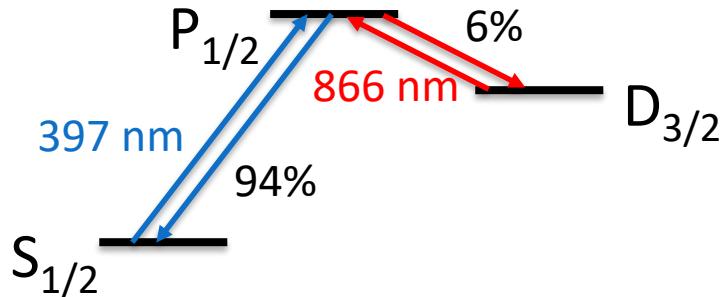
Improvement in Signal for $^{25}\text{Mg}^+$



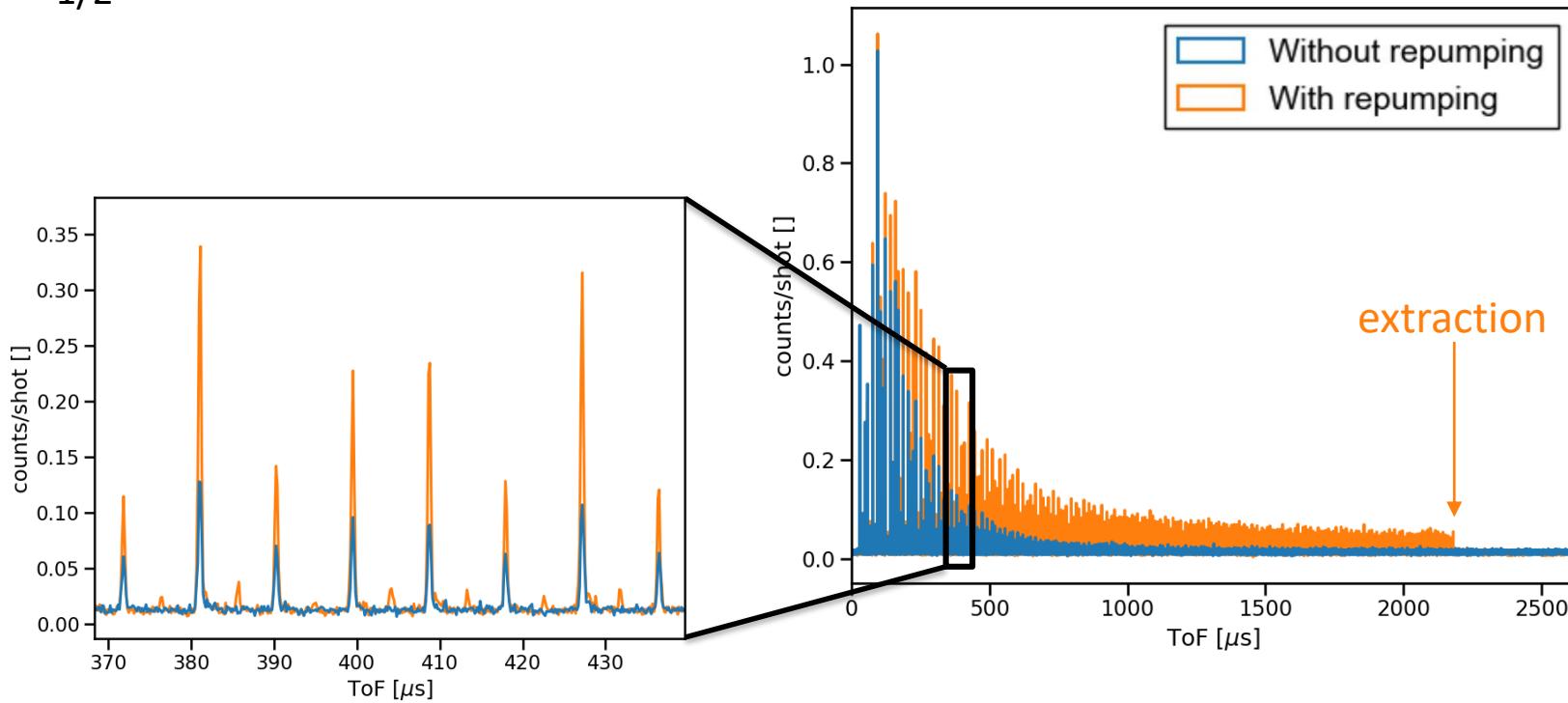
Even without repumping of the dark states there is an improvement in signal visible.

Explore repumping schemes in the future.

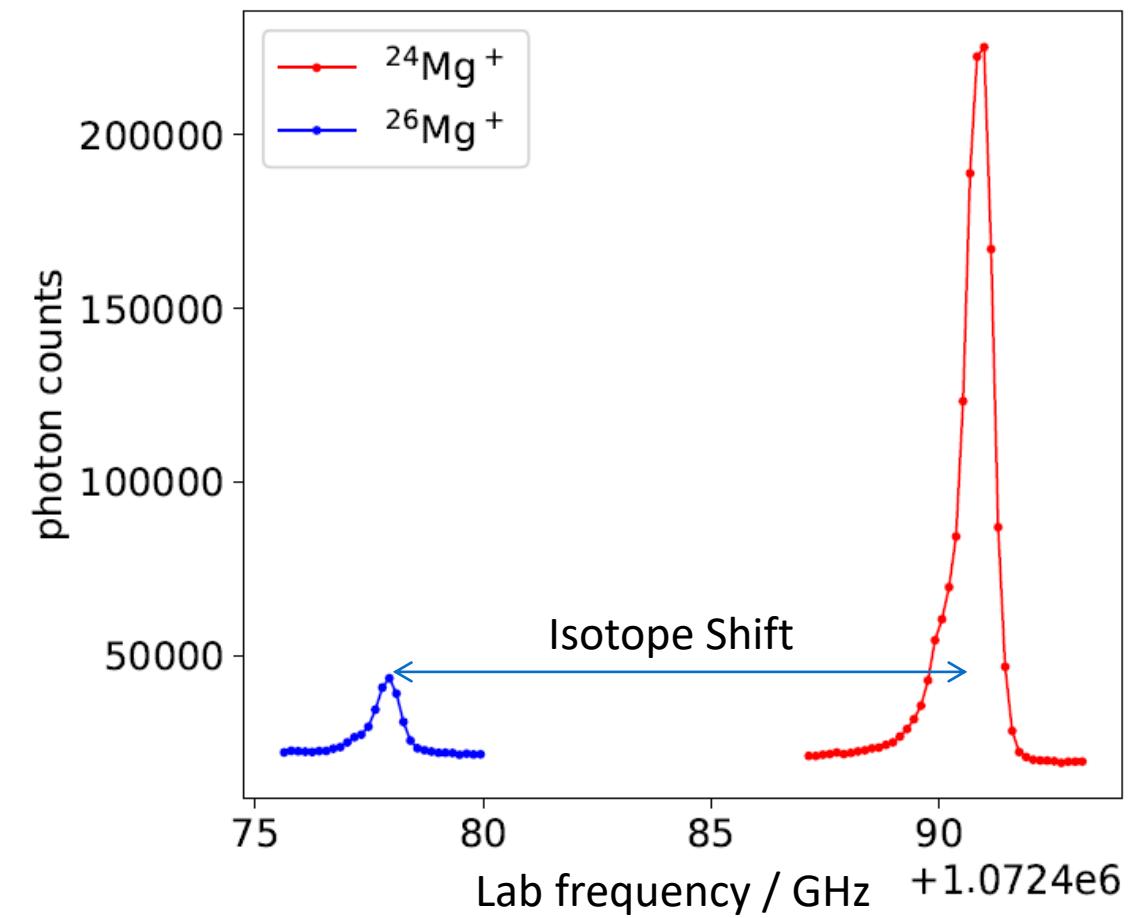
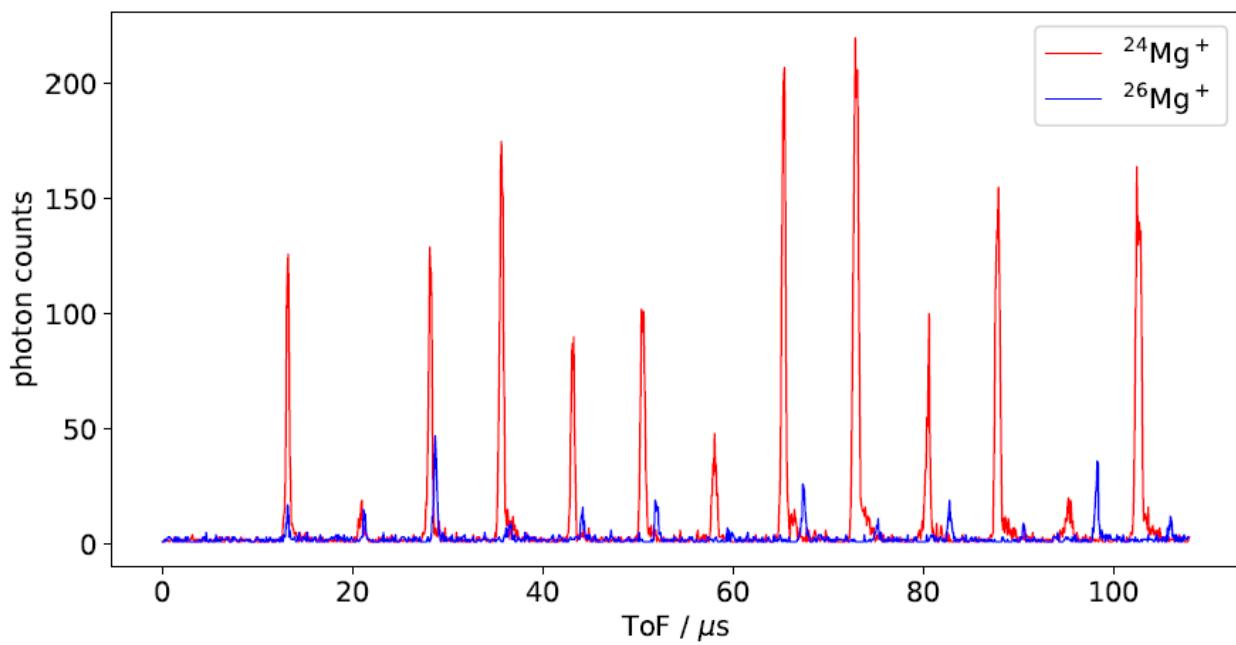
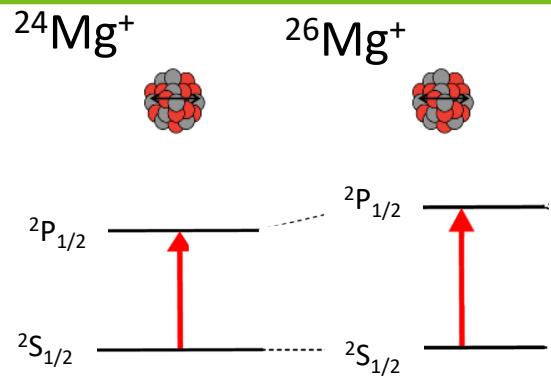
$^{40}\text{Ca}^+$: Repumping of dark state



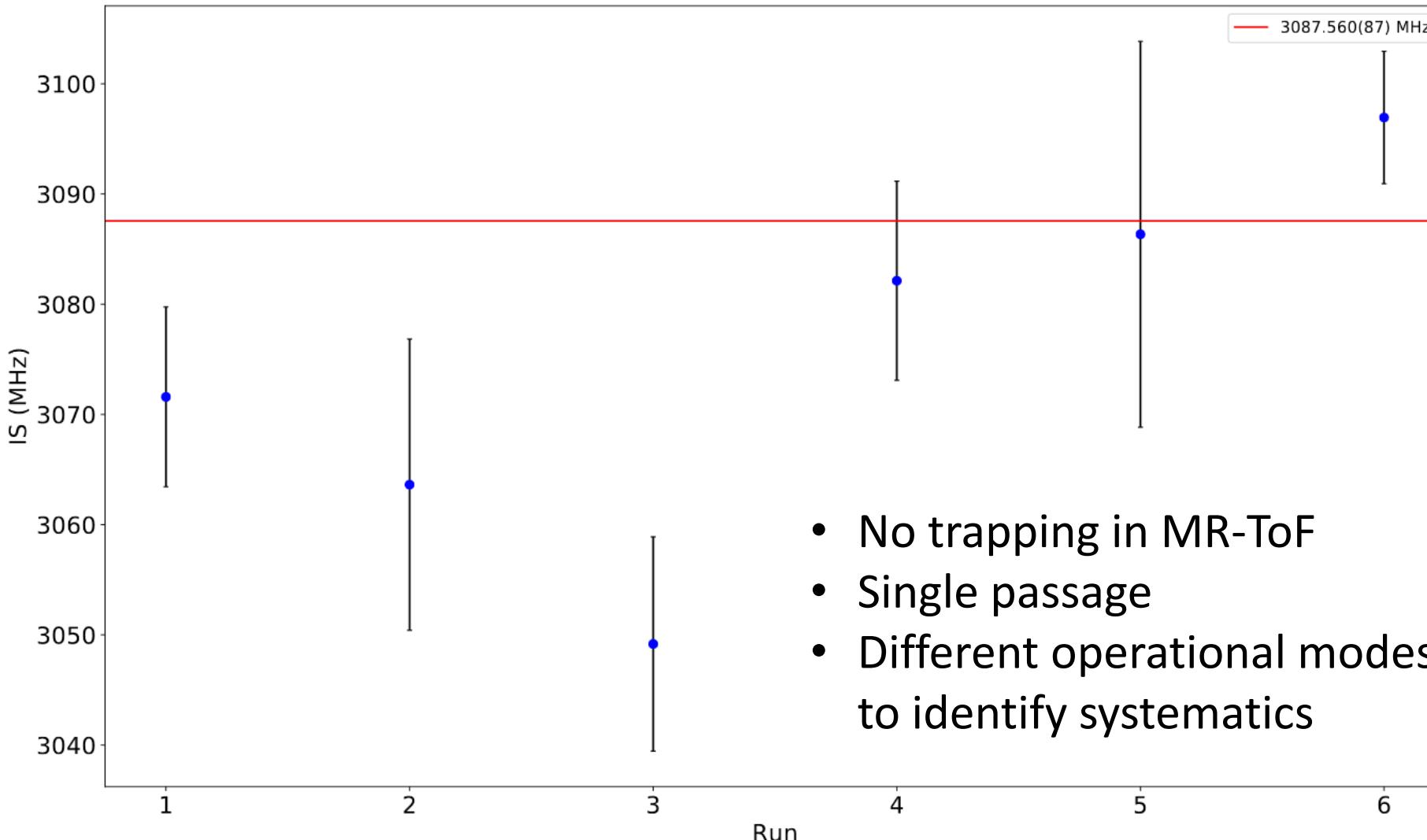
- Problem: using only 397nm transition → pumping into dark state
- Re-pumping with 866nm laser necessary



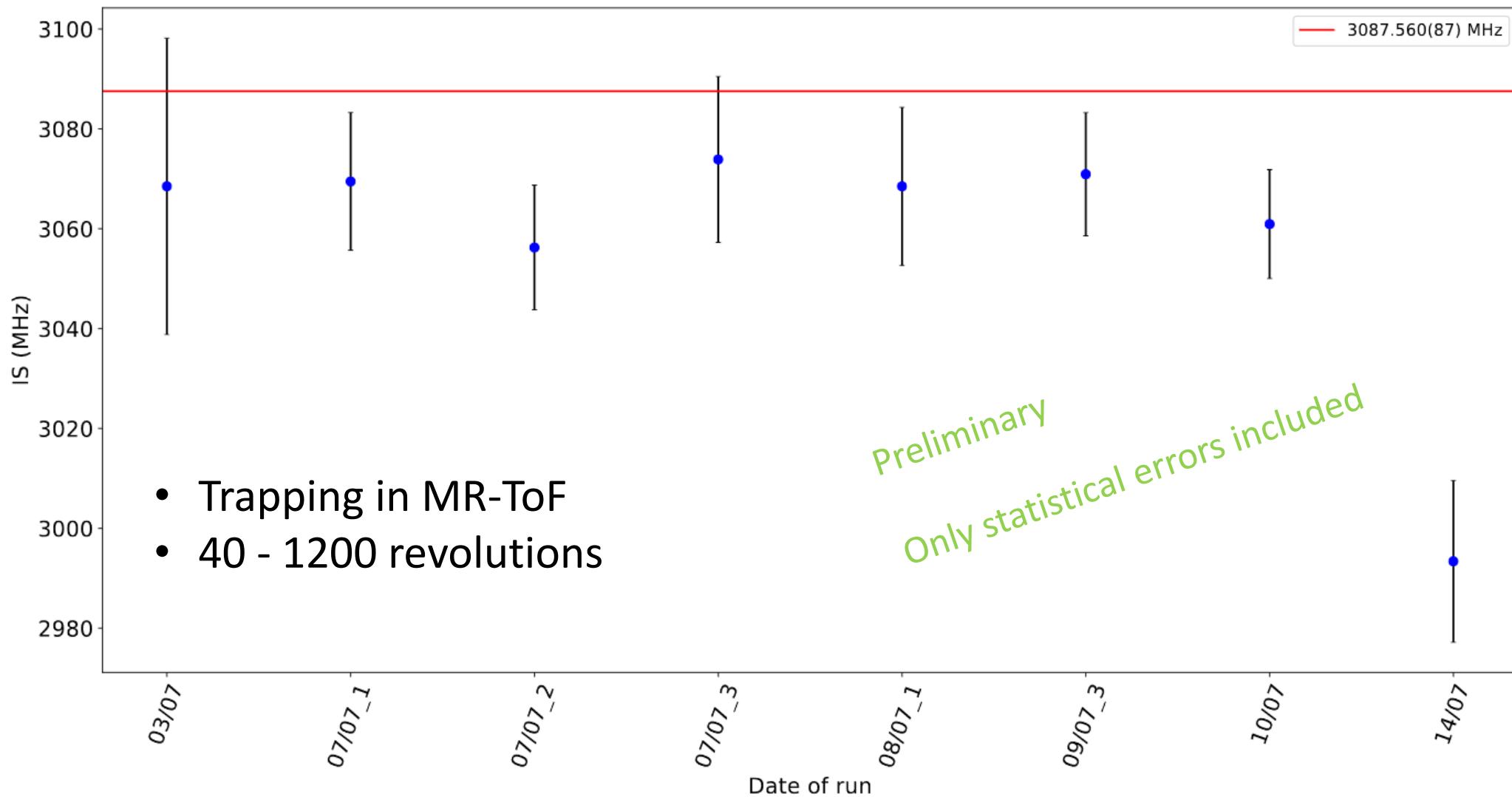
Isotope Shift



Accuracy Check for Conventional CLS

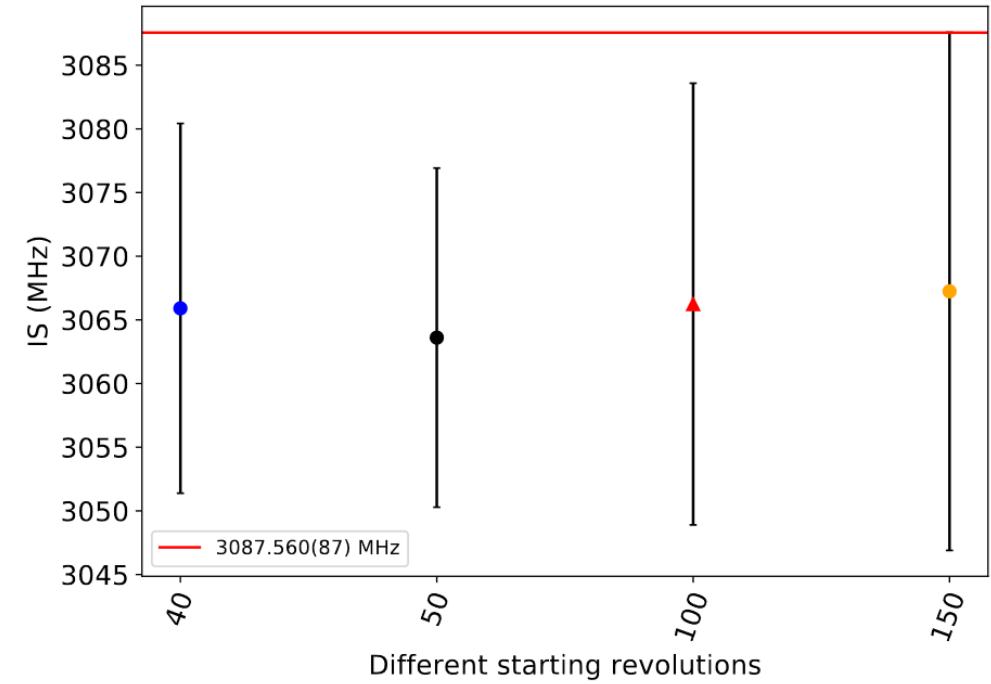
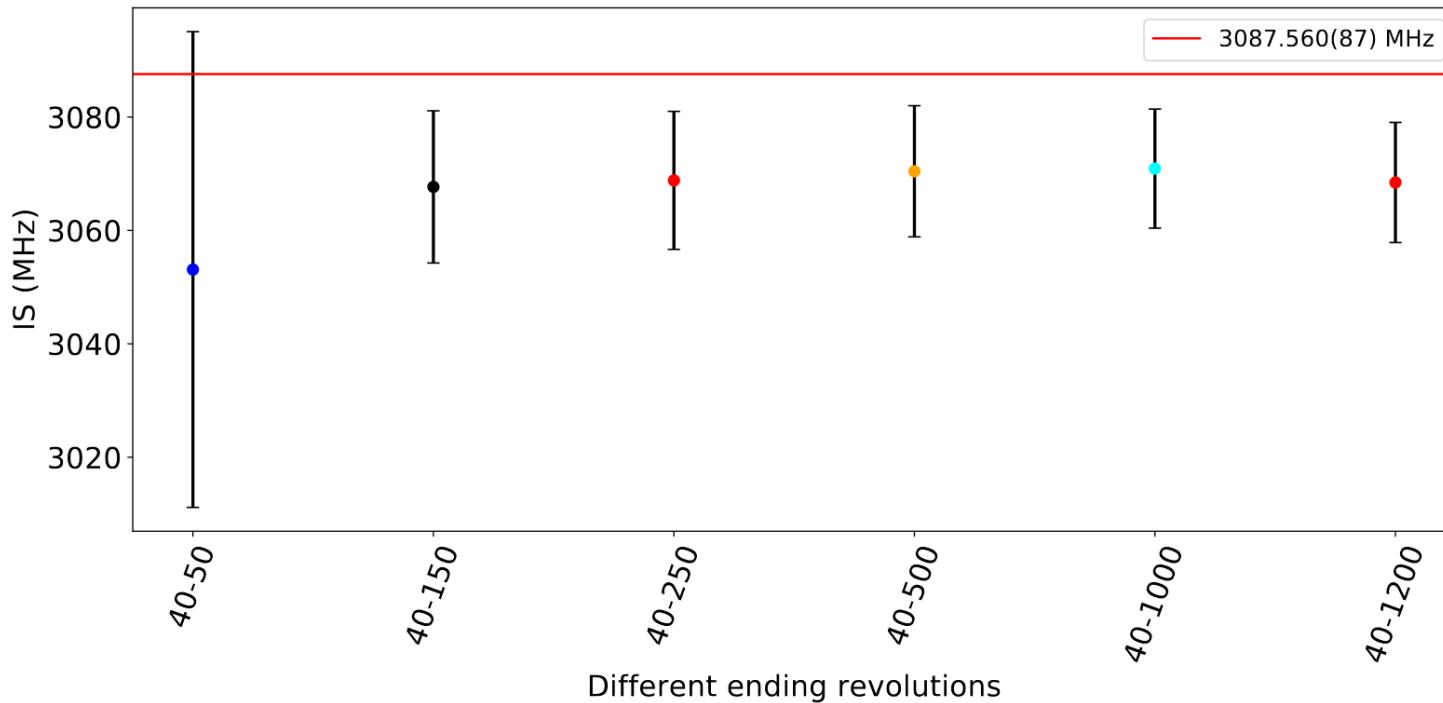


Accuracy Check for MIRACLS' Mode



Accuracy Check for MIRACLS' Mode

- Paul trap settings
- Timings of HV switching
- Space charge effects
- Frequency dependent background
- Influence of revolution numbers taken into account:



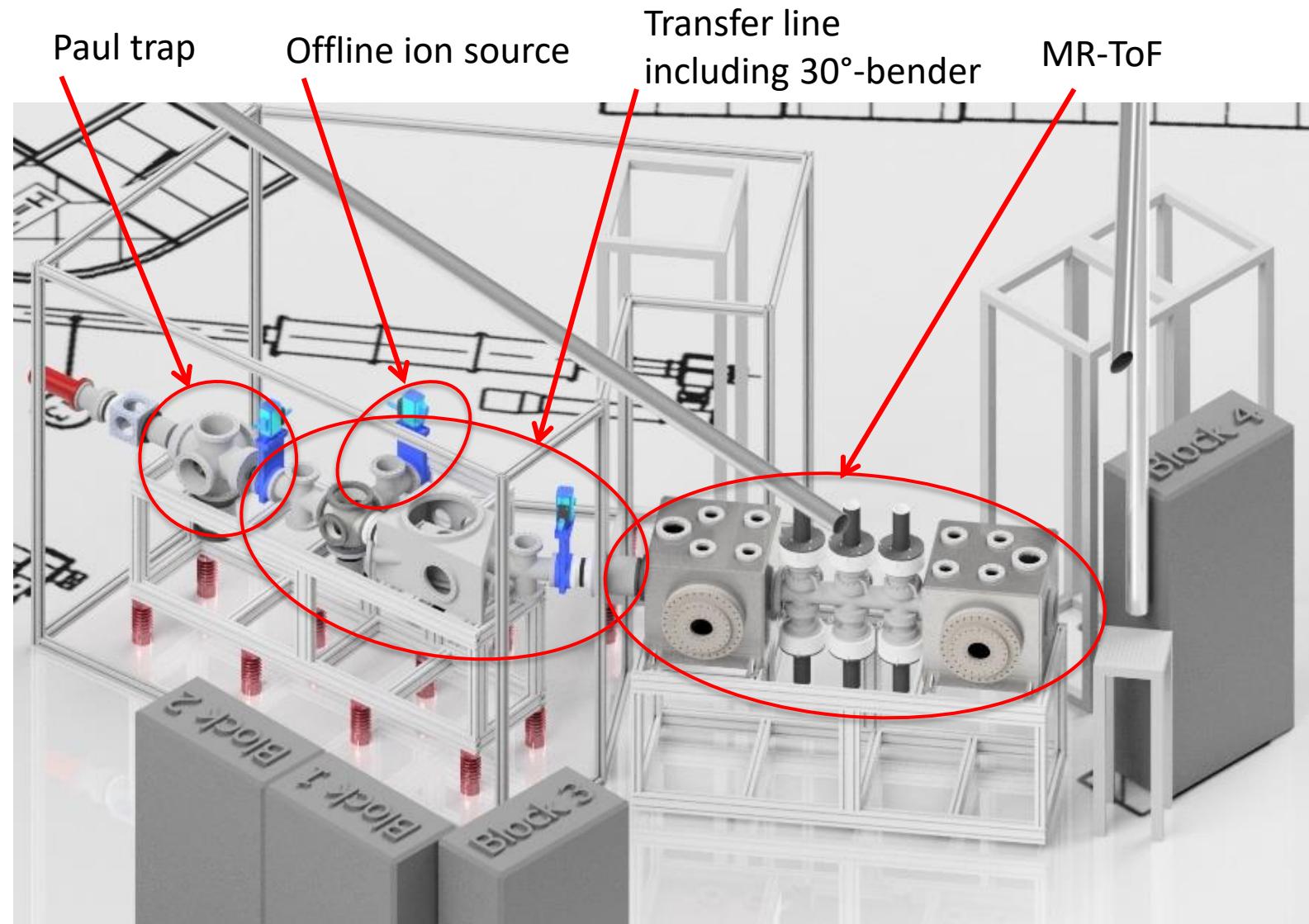
From PoP Towards First Online Operation

MIRACLS @ LA2:

- ... unprecedented 30-keV MR-ToF device
- ... minimize the Doppler broadening
- ... higher vacuum
- ... reduced stray light
- ... designed for CLS

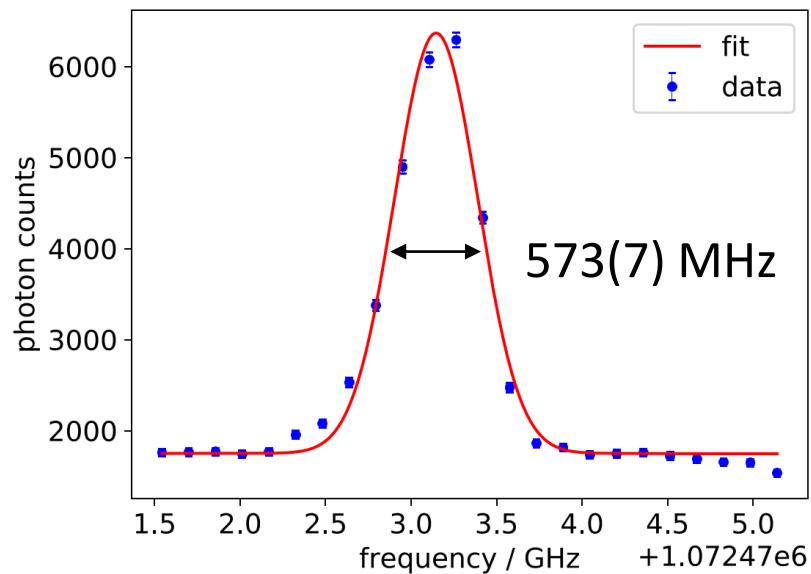
Coating in Vantablack to
reduce stray light
→ poster P. Plattner

HV stability
→ poster K. Kanitz



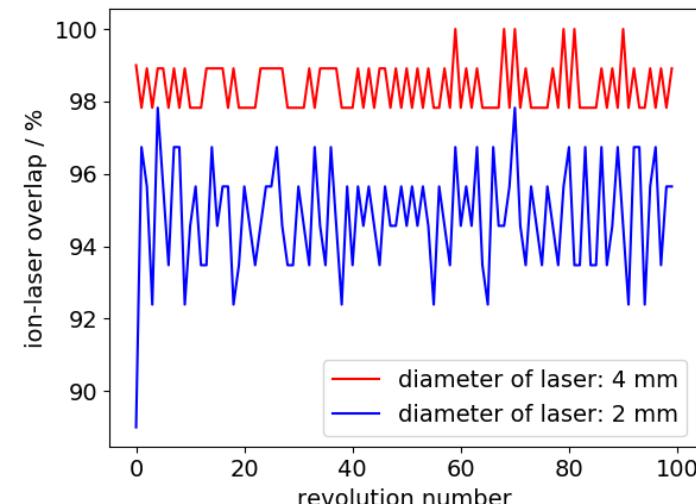
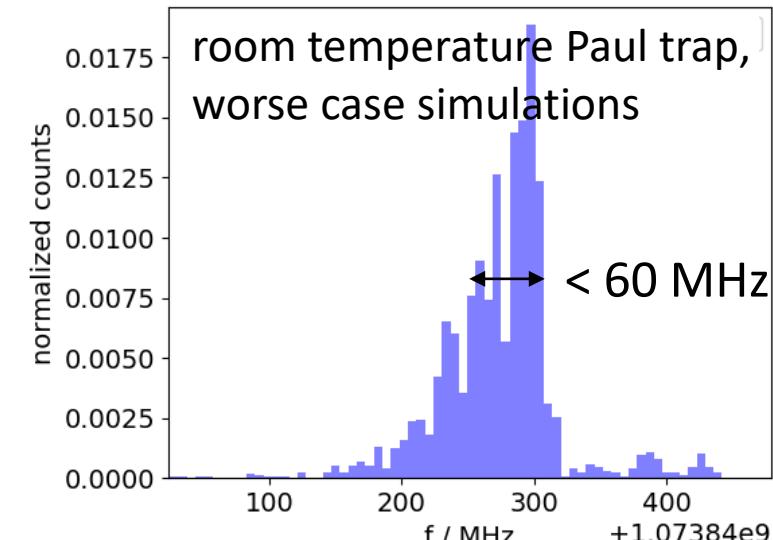
From PoP Towards First Online Operation

PoP experiment: 1.5-keV MR-ToF device



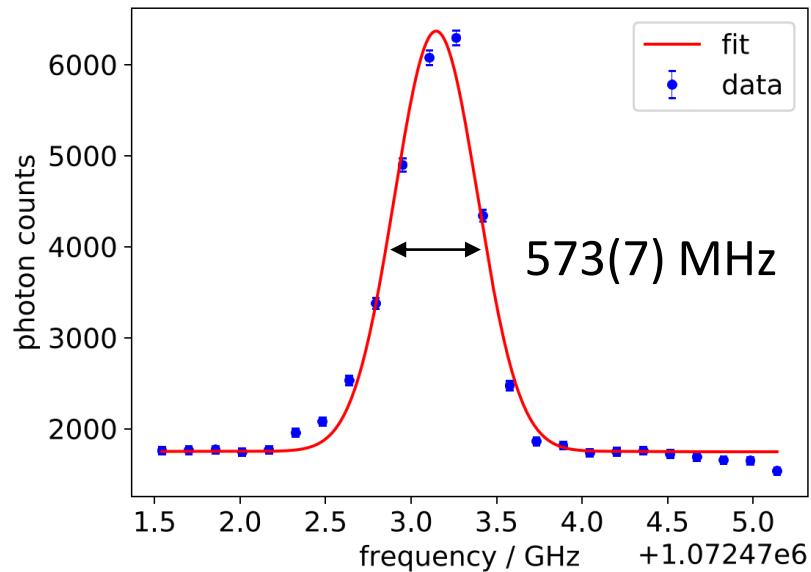
1.5 keV to 30 keV

Online Operation: 30-keV MR-ToF device



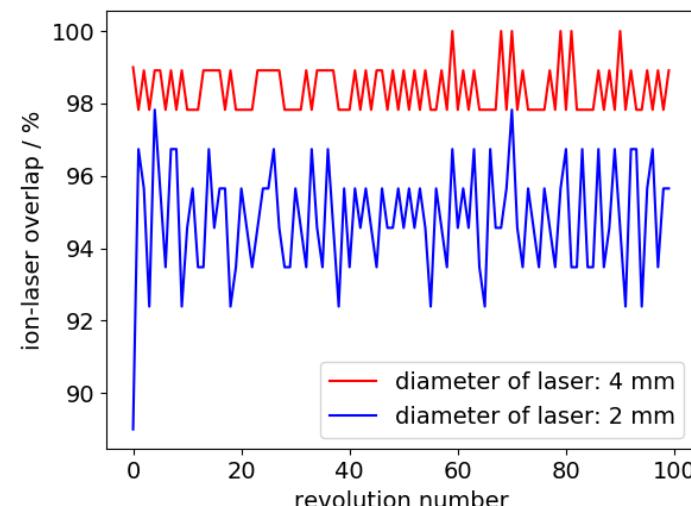
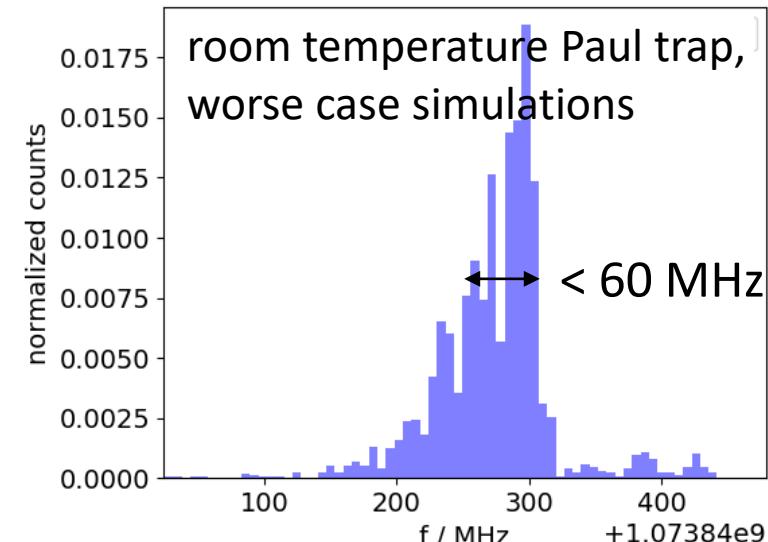
From PoP Towards First Online Operation

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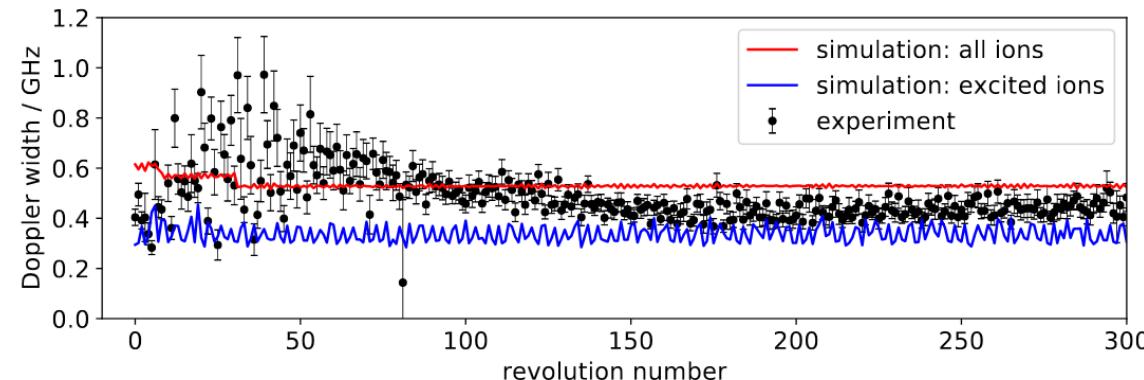
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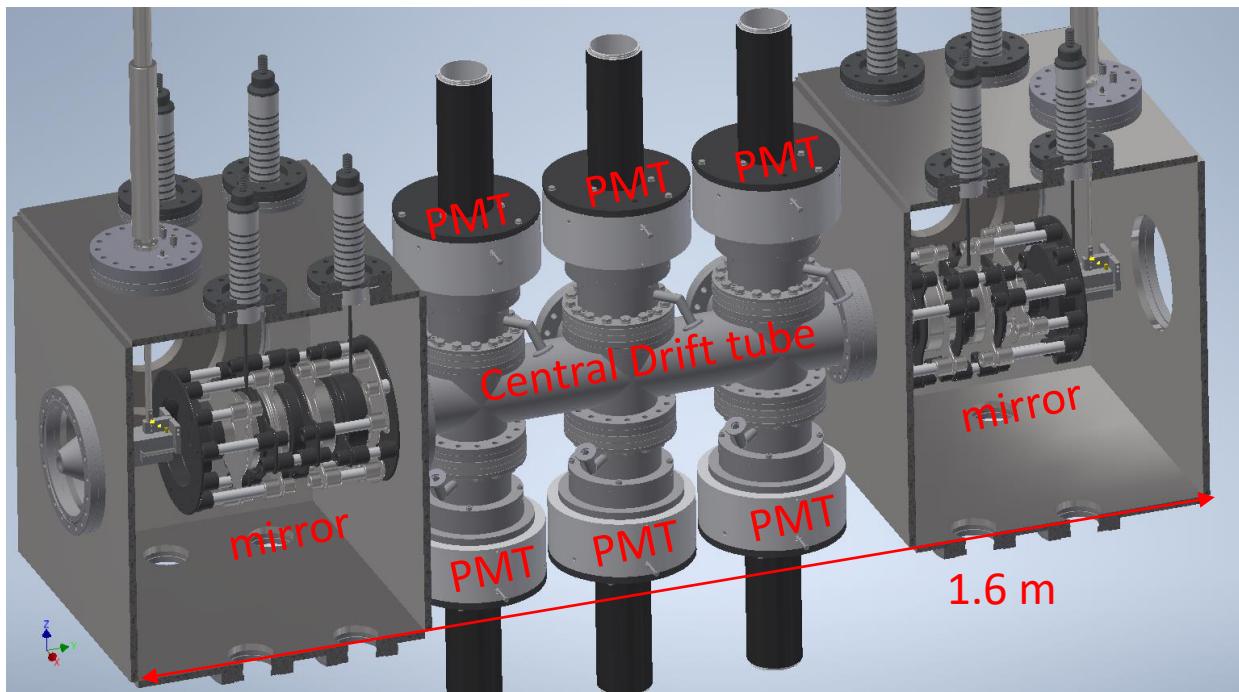
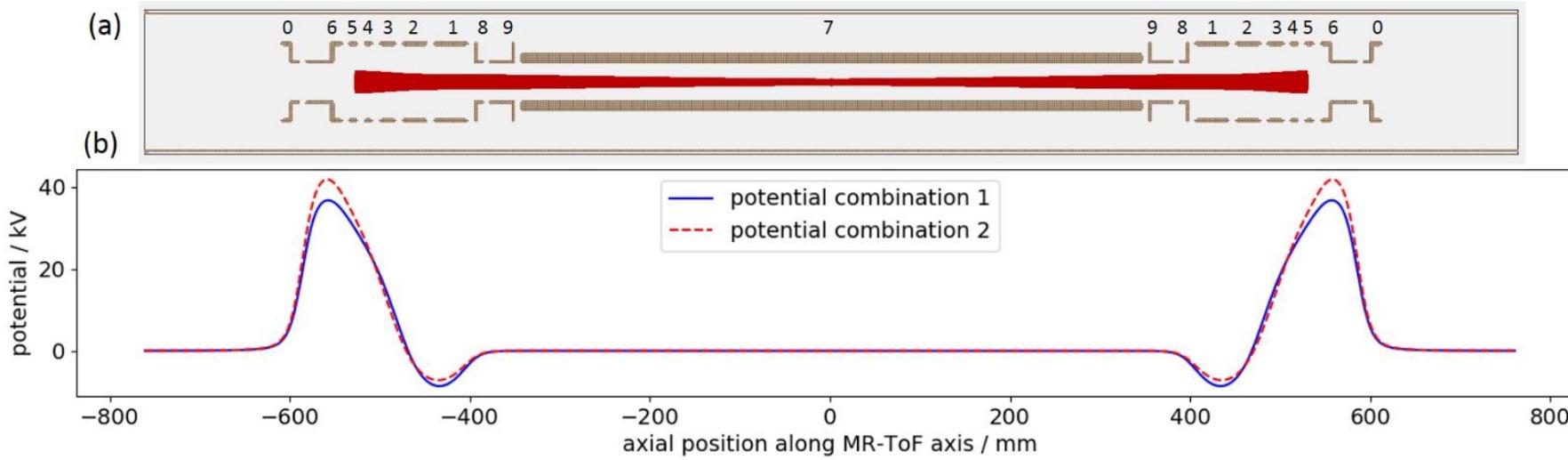


Simulation approach benchmarked against PoP experiment:

F. Maier et al., Hyperfine Interact. 240, 54 (2019)



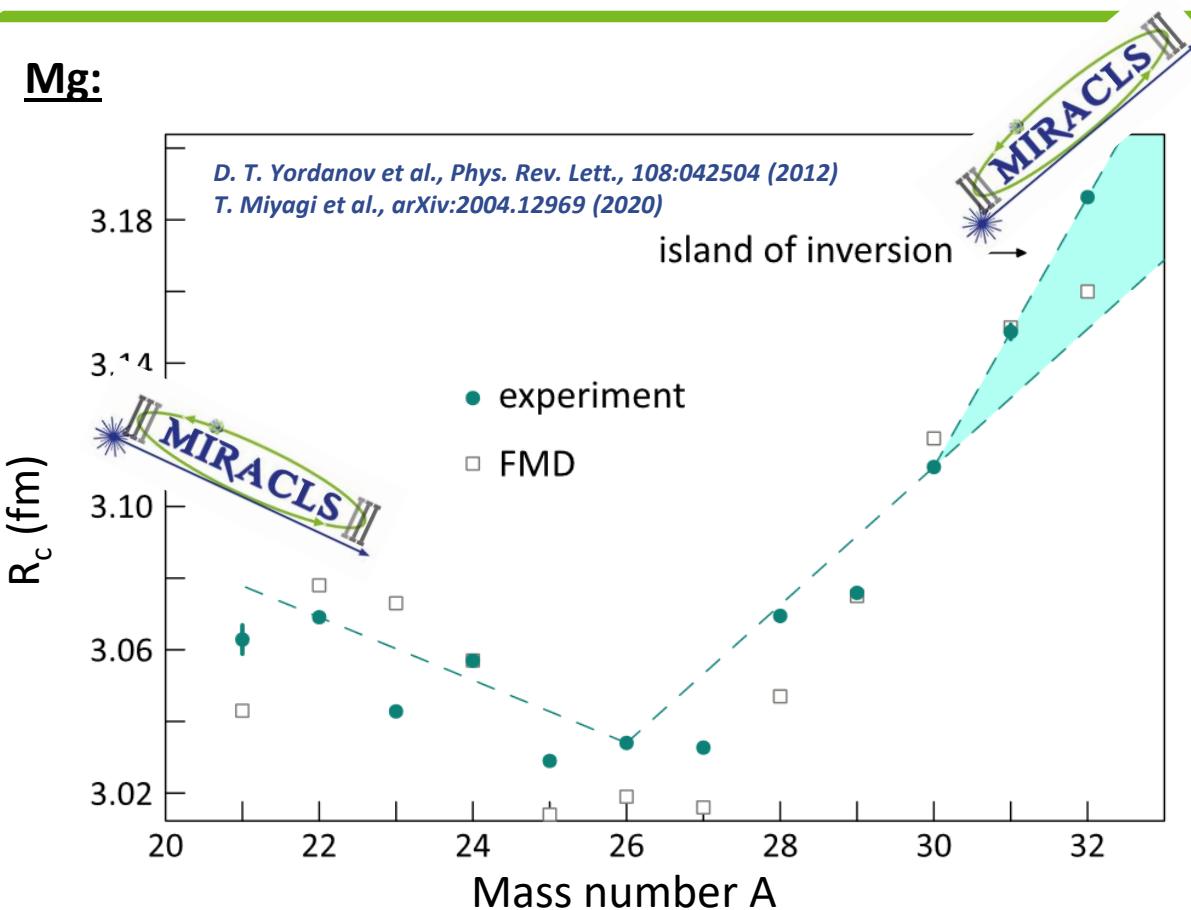
30-keV MR-ToF device for CLS



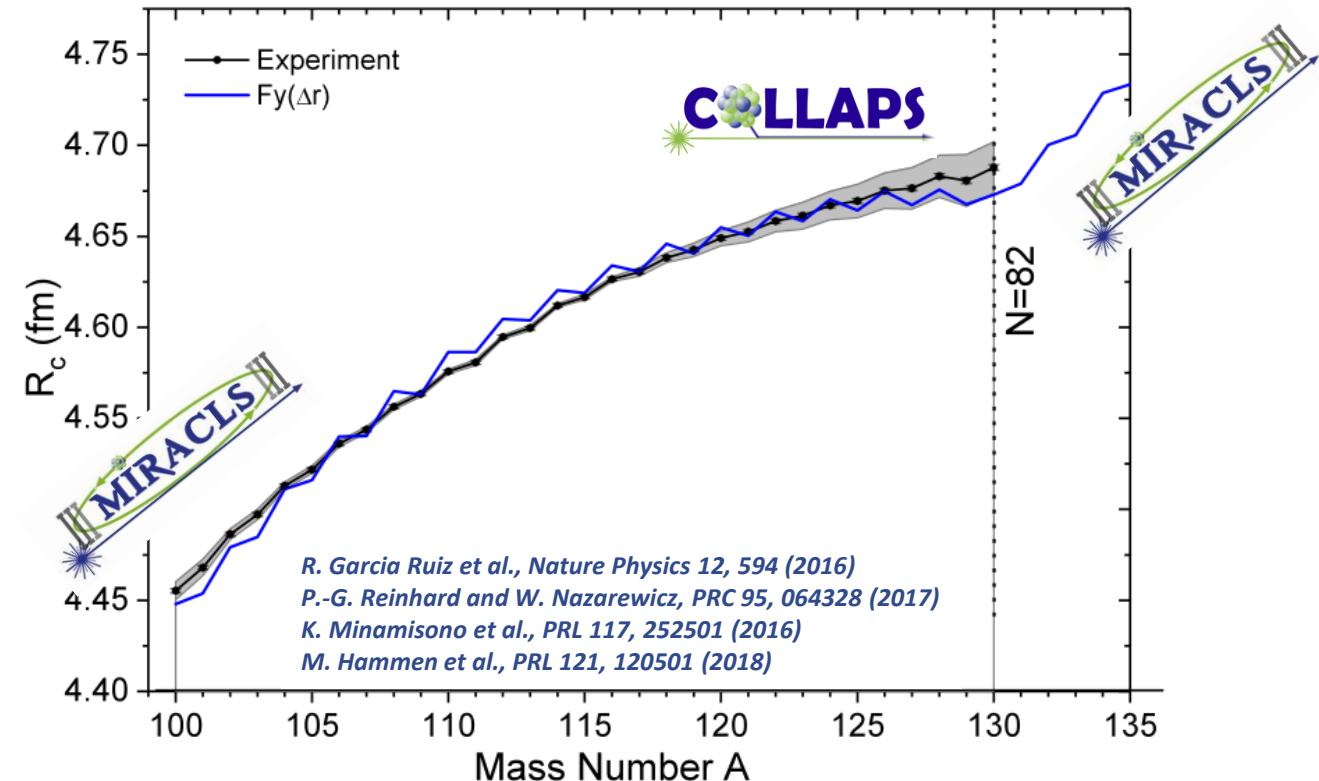
- simulation and design phase almost finished
- Ready to build

Towards a ‘universal’ description of charge radii

Mg:



Cd:

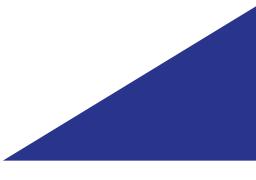


ab initio methods: T. Miyagi et al., arXiv:2004.12969 (2020)

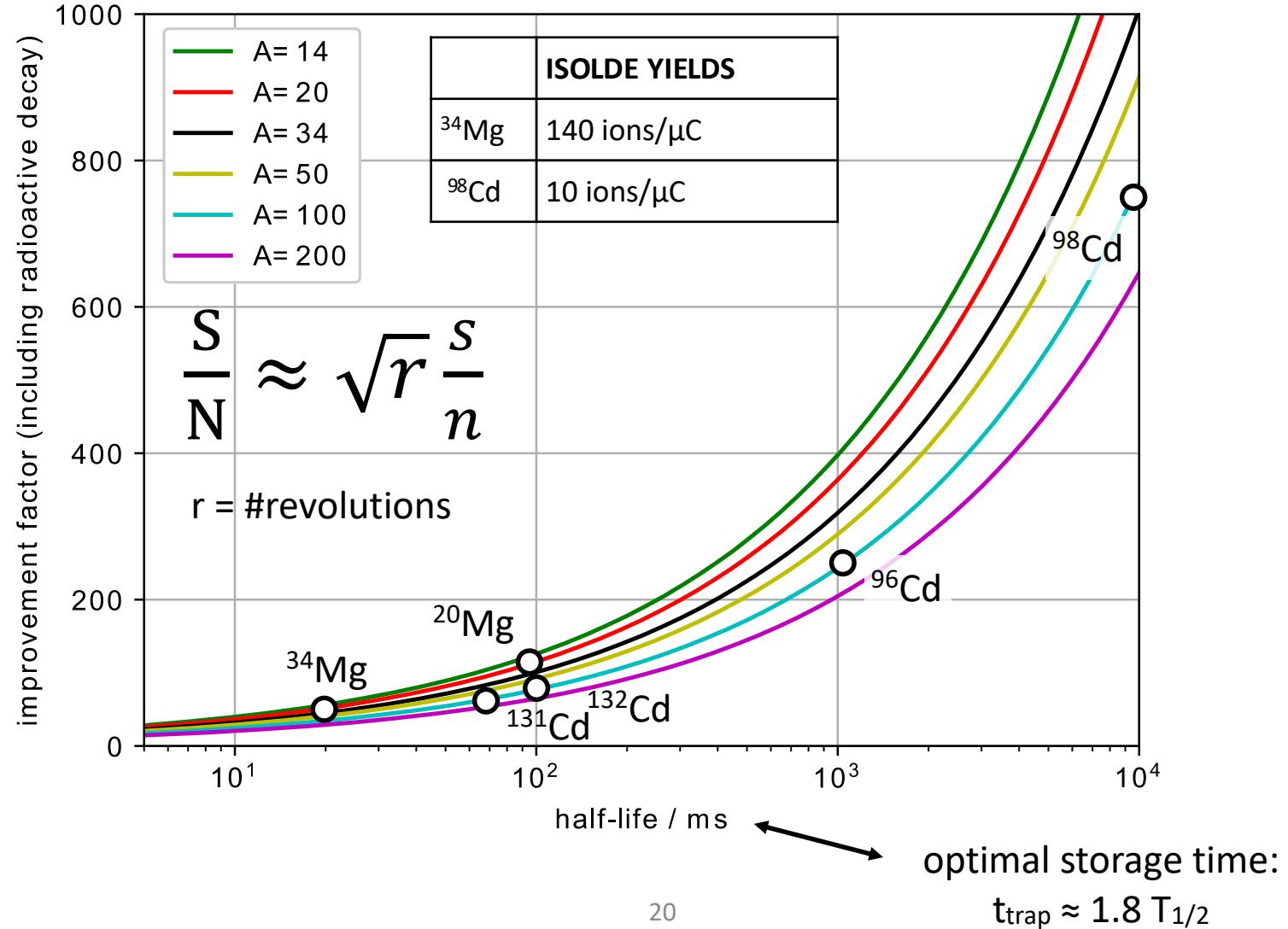
- currently in the process of calculating charge radii along the entire Mg isotopic chain
- Successful in the description of nuclear properties

Fayans energy density functional

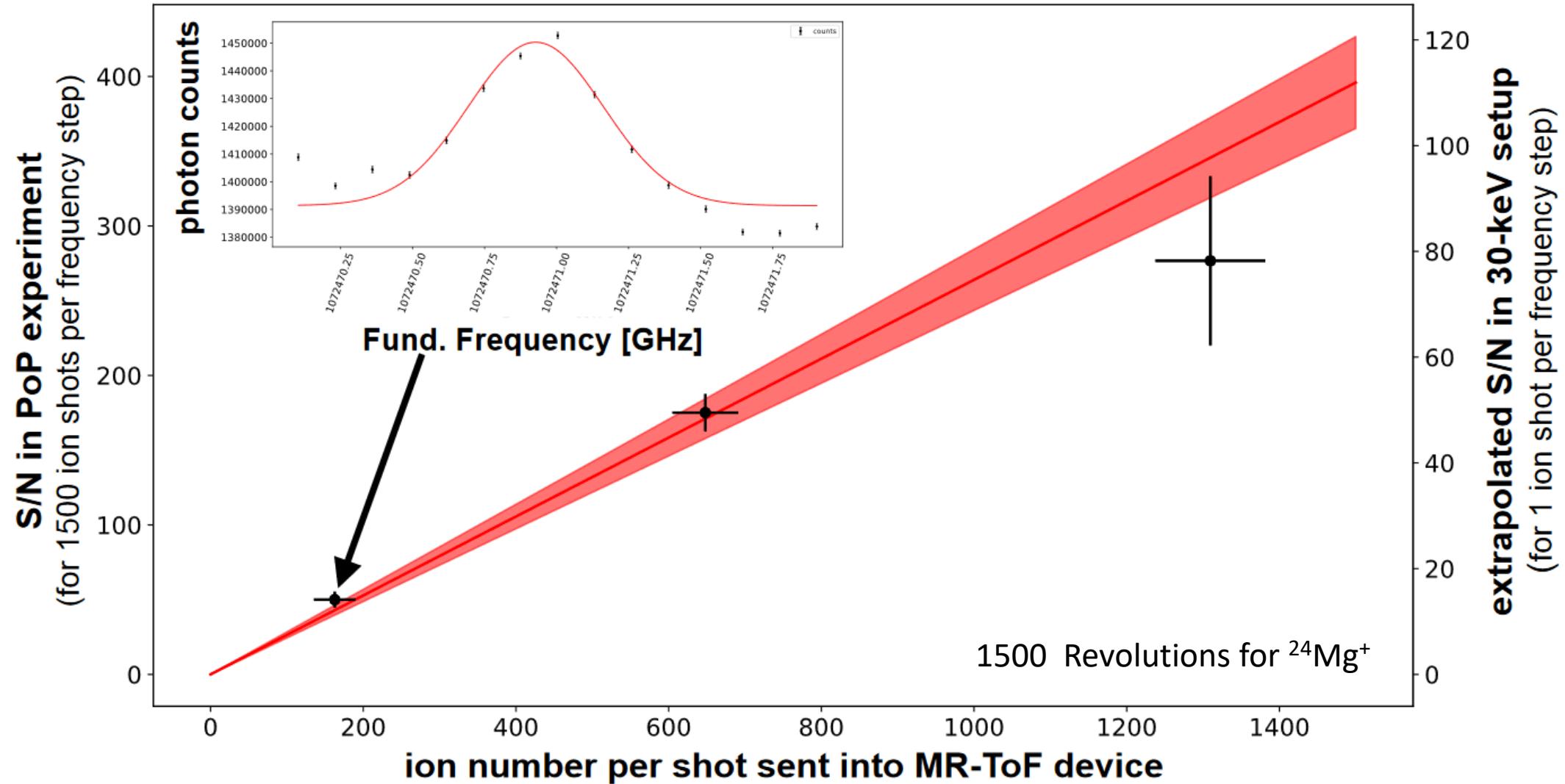
- Reproduces Cd charge radii very well
- Very successful along Ca isotopic chain



Expected Improvement Factors

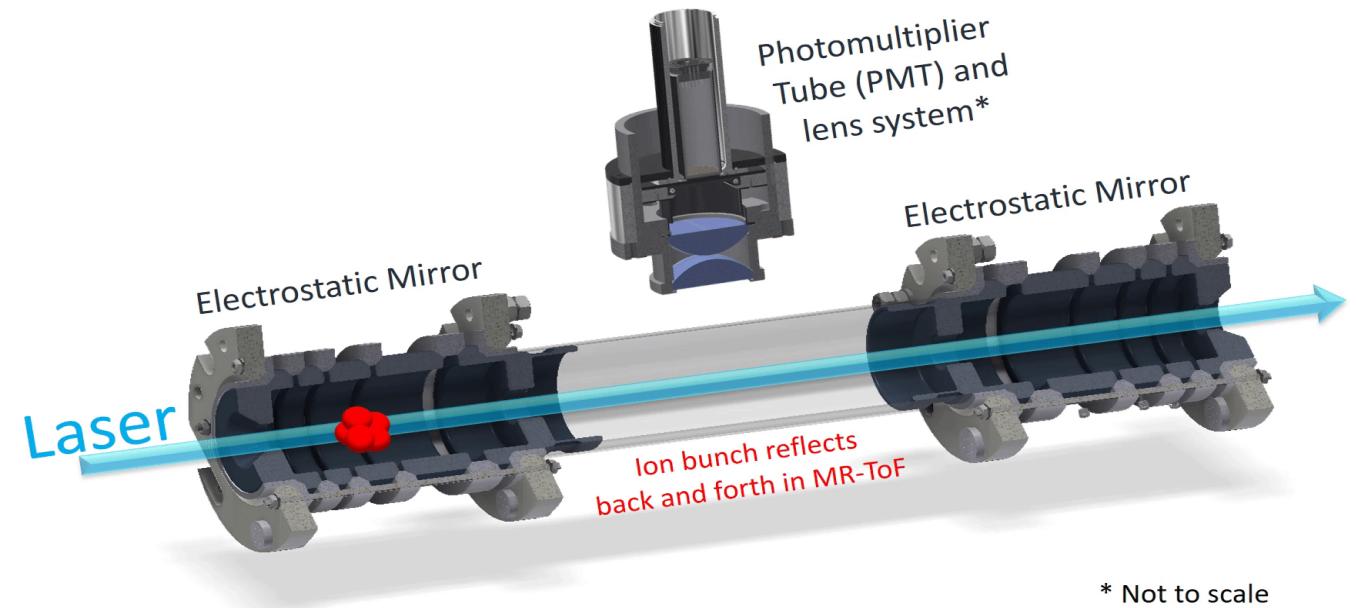


Expected sensitivity



Conclusions

- ... higher sensitivity for collinear laser spectroscopy
- ... rare isotopes more efficiently used by trapping them in a MR-TOF
- ... novel tool to access exotic nuclides with CLS with improvements in sensitivity by a factor of 40-700



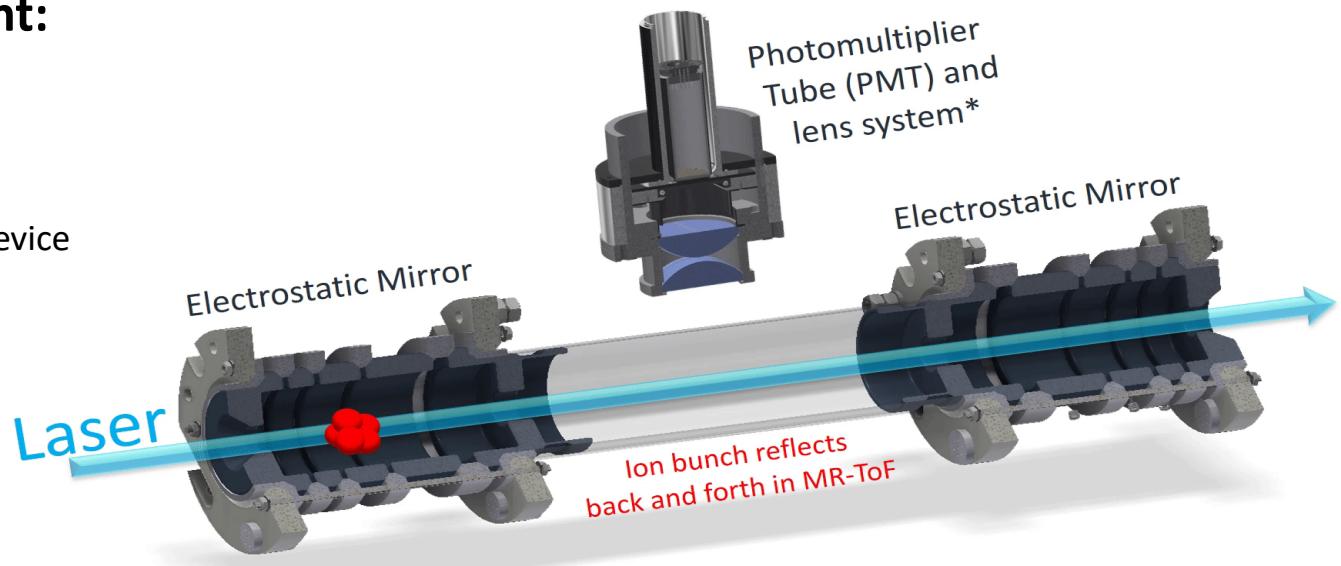
- F. Maier et al., Hyperfine Interact. 240, 54 (2019)
S. Lechner et al., Hyperfine Interact. 240, 95 (2019)
S. Sels et al., Nucl. Instr. Meth. Phys. Res. B 463, 310 (2020)
V. Lagaki et al., Acta Physica Polonica Series B 51, 571 (2020)

Conclusions

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MIRACLS' proof-of-principle experiment:

- ... Existing 1.5-keV MR-ToF device modified for CLS
- ... successfully implemented
- ... demonstrates potential of the novel technique
- ... validates simulations for future 30-keV MR-ToF device



* Not to scale

- F. Maier et al., Hyperfine Interact. 240, 54 (2019)
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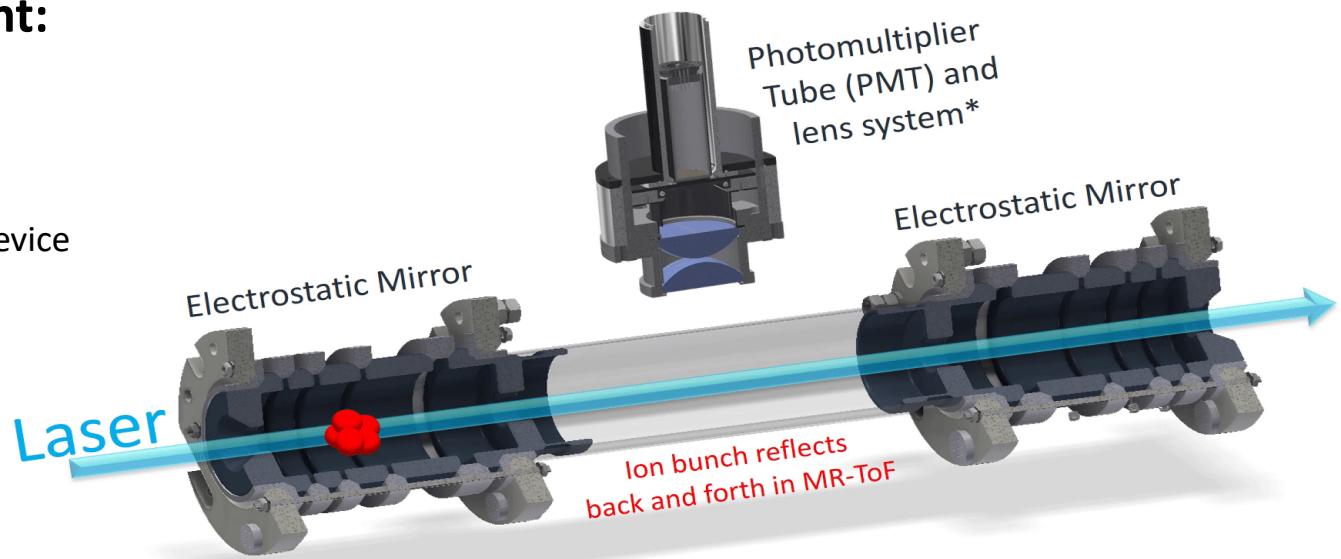
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MIRACLS @ LA2:

- ... unprecedented 30-keV MR-ToF device
- ... minimize the Doppler broadening
- ... higher vacuum
- ... reduced stray light
- ... simulation and design phase almost finished
- ... $^{20,33,34}\text{Mg}$ and $^{98,99,131,132}\text{Cd}$ isotopes as first science cases



- 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. Phys. Res. B 463, 310 (2020)
V. Lagaki et al., Acta Physica Polonica Series B 51, 571 (2020)

Thanks!

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⁶ Institut für Kernphysik, TU Darmstadt, D-64289 Darmstadt, Germany



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