The Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy

Peter Plattner

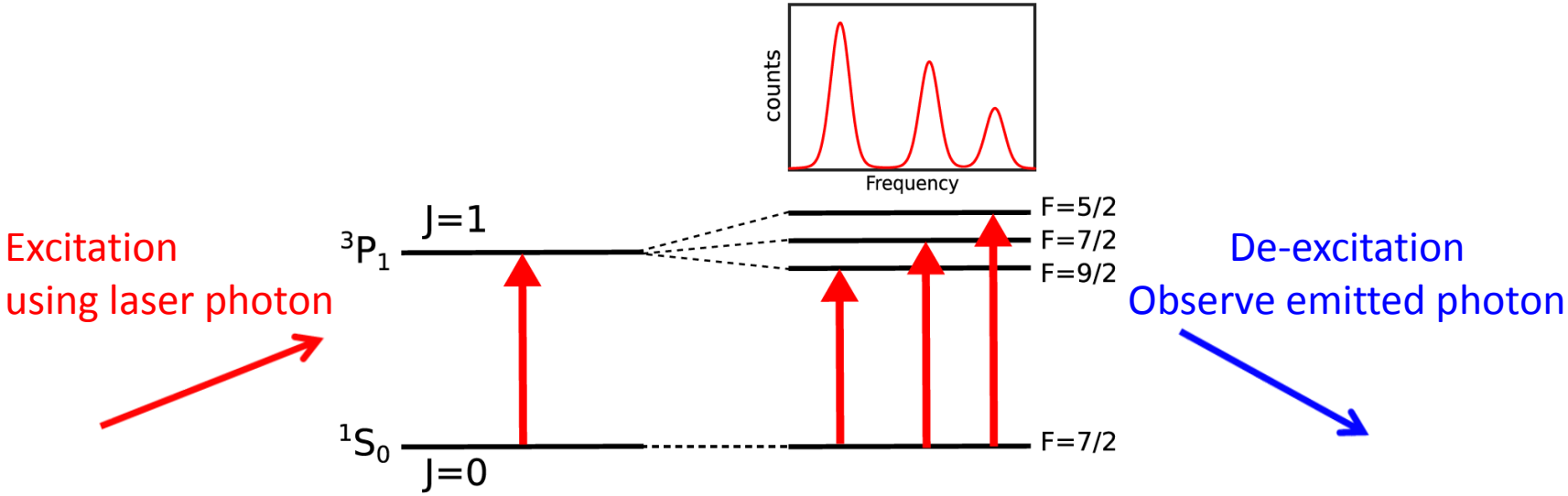
ISOLDE Workshop and Users Meeting

5.12.2019

Outline

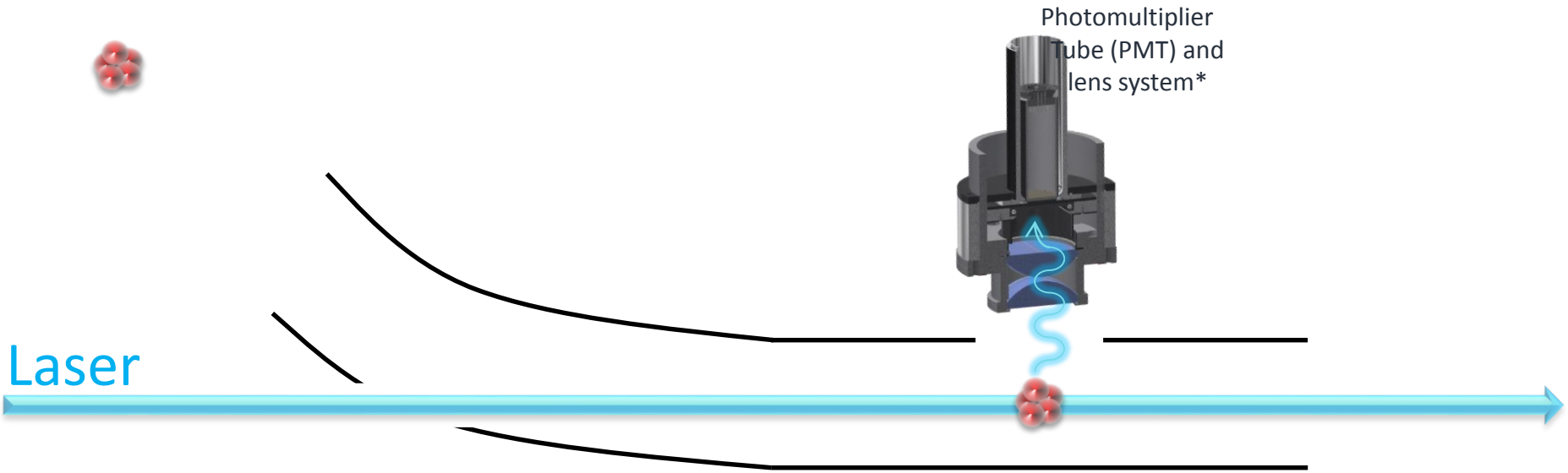
- Overview of laser spectroscopy
- MIRACLS concept
- Recent results with $^{24}Mg^{+}$ and $^{40}Ca^{+}$ ions
- Outlook at 30 keV MR-ToF

Laser Spectroscopy



- Hyperfine transitions in atoms or ions yield information about
  - Nuclear spin
  - Magnetic dipole and electric quadrupole moments of nuclei
  - Isotope shifts and nuclear charge radii

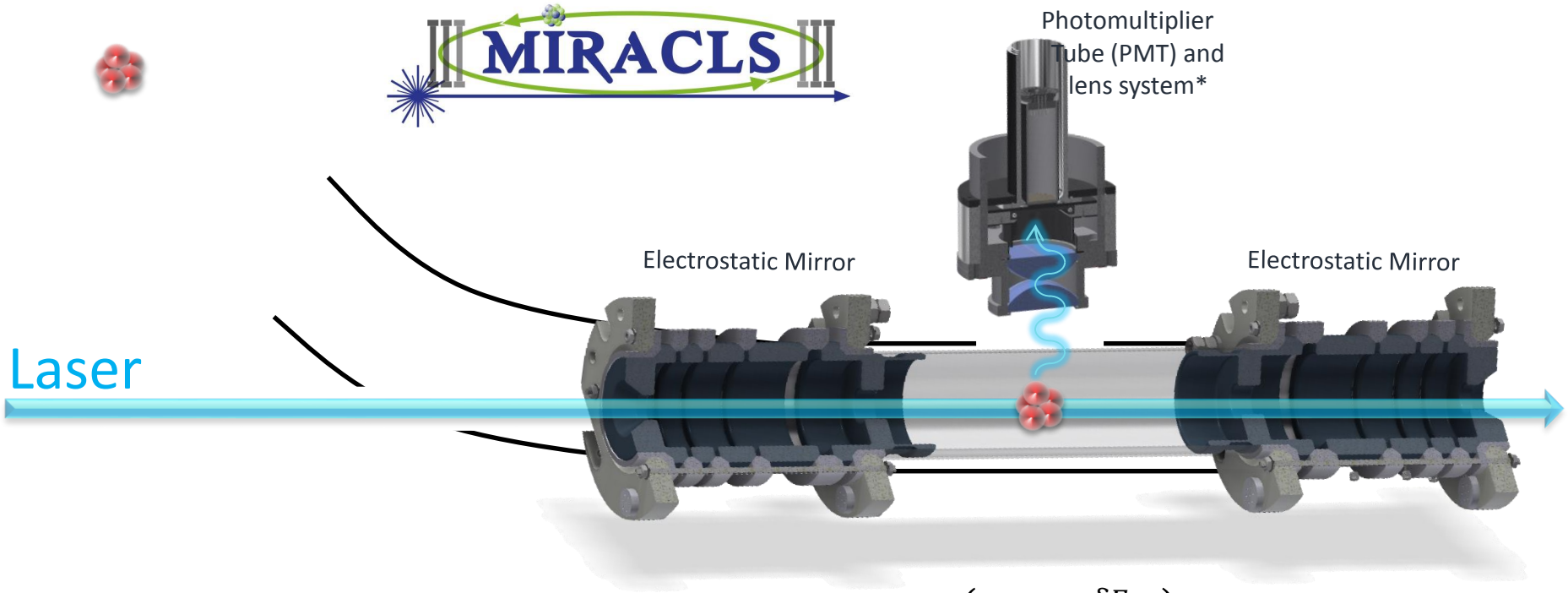
Collinear Laser Spectroscopy (CLS)



- High ion energies to reduce Doppler spread $\left(\delta f \propto \frac{\delta E_{kin}}{\sqrt{E_{kin}}}\right)$
- $T_{1/2}$ of radionuclides at ISOL facilities: ms to s
- Effectively used: below few µs
- Limit of detection for isotopes with low production yield

* Not to scale

Multi Reflection Apparatus for Collinear Laser Spectroscopy



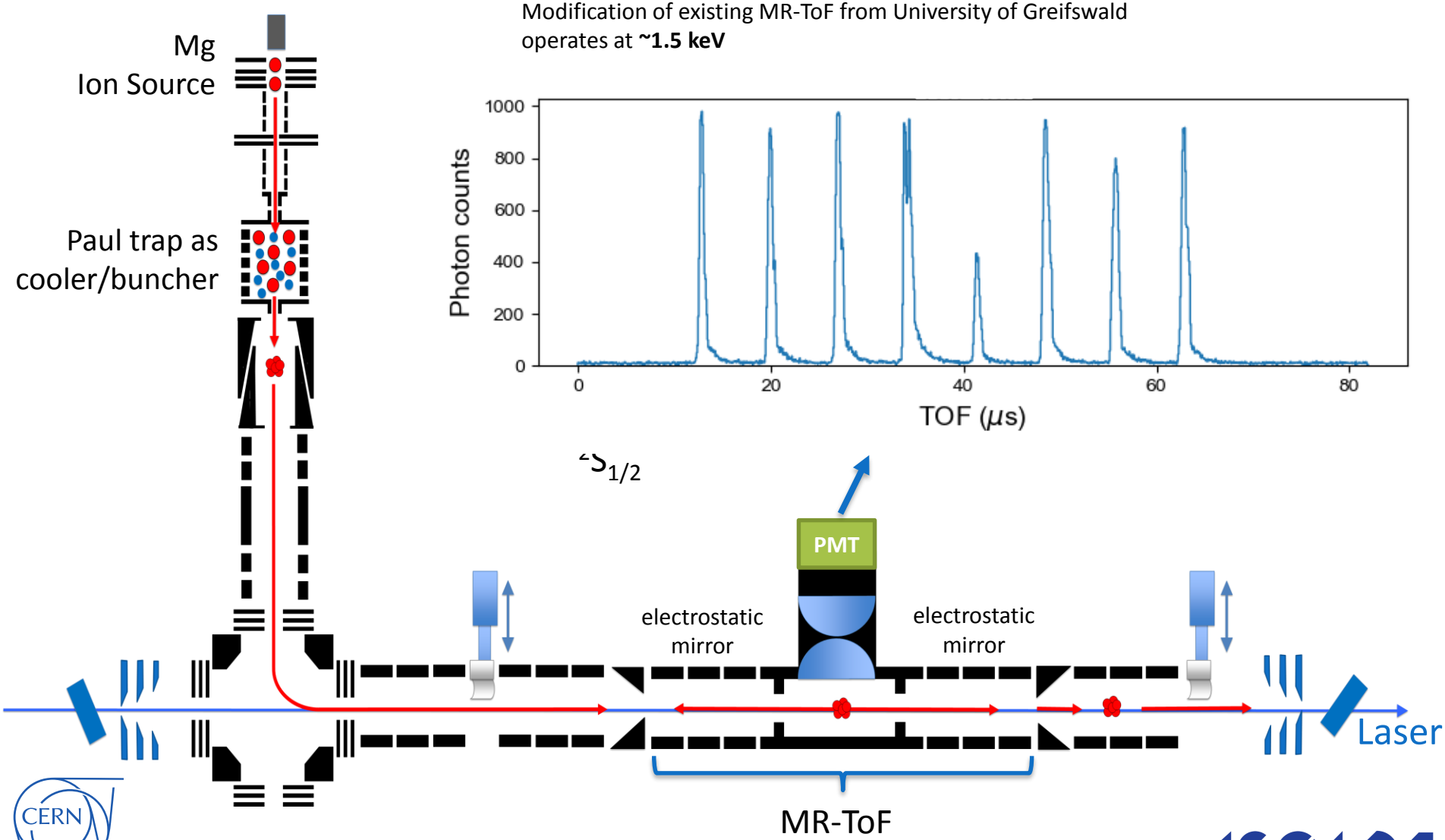
- High ion energies to reduce Doppler spread $\left(\delta f \propto \frac{\delta E_{kin}}{\sqrt{E_{kin}}}\right)$
- $T_{1/2}$ of radionuclides at ISOL facilities: ms to s
- Effectively used: below few µs
- Limit of detection for isotopes with low production yield
- Trap and store ions

$$\frac{Signal}{Noise} \approx \sqrt{\#revolution}$$

* Not to scale

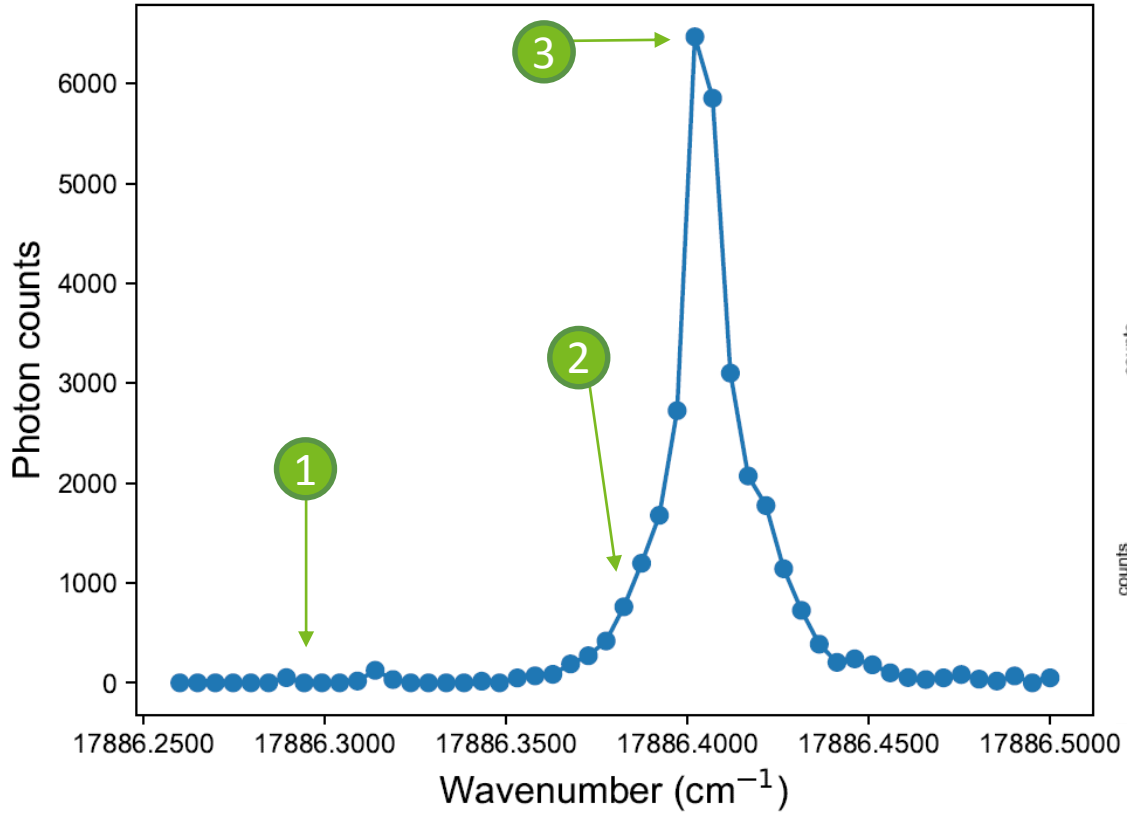
Proof-of-Principle Experiment

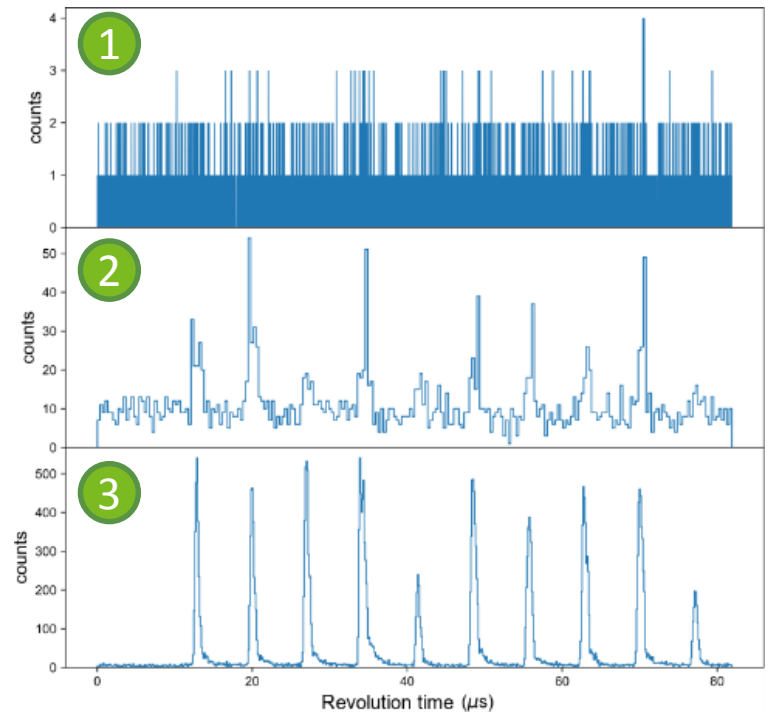
Modification of existing MR-ToF from University of Greifswald operates at **~1.5 keV**



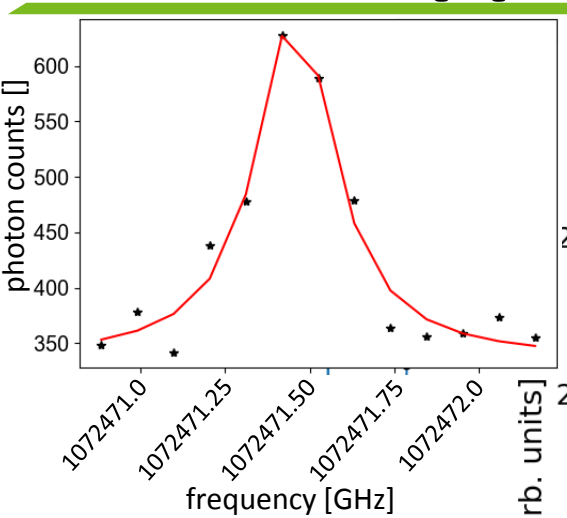
S. Sels et al., Nucl. Instrum. Methods Phys. Res. Section B 2019, 0168-583X

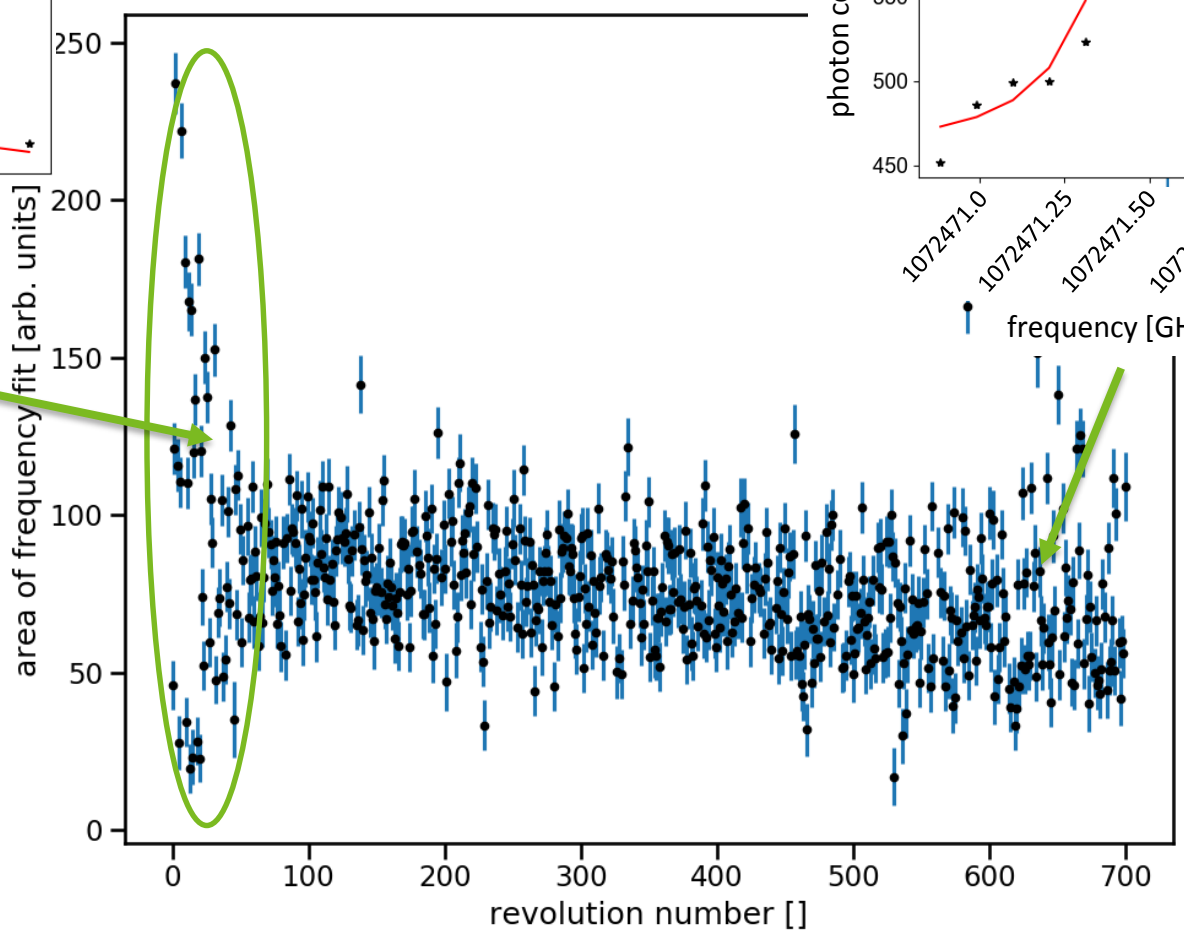
Hyperfine Spectrum

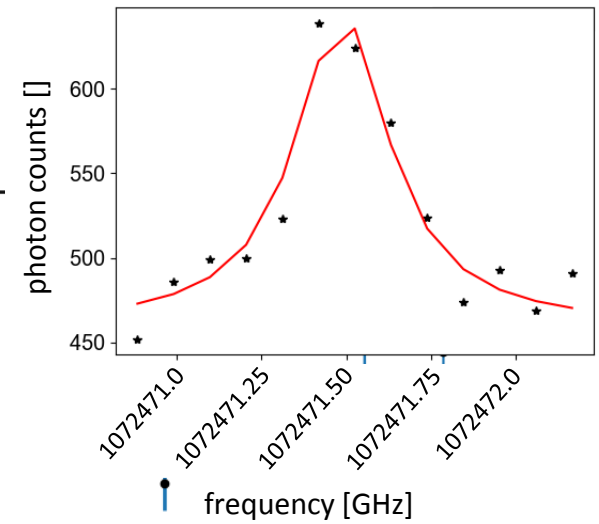




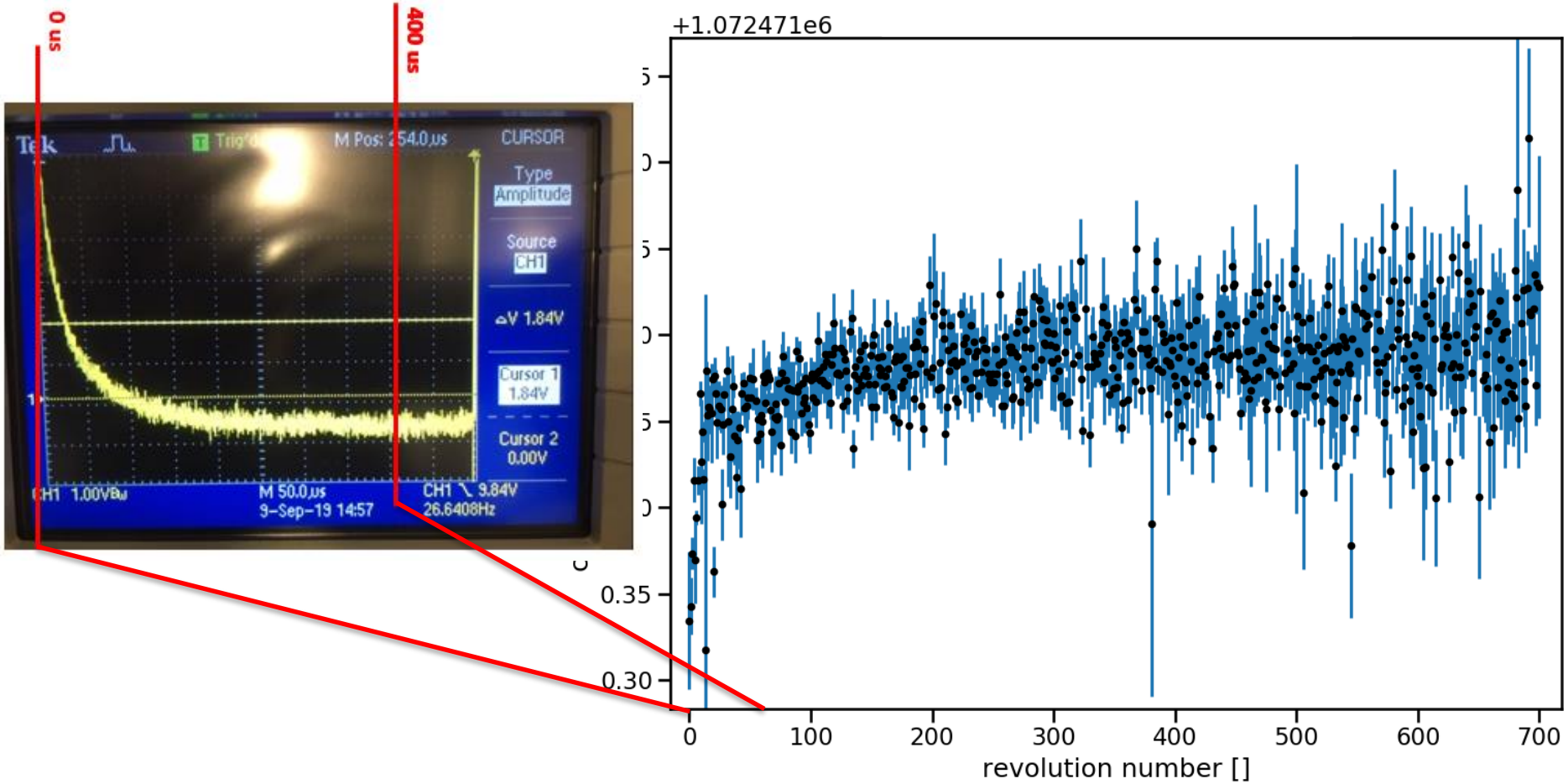
Trapping $^{24}Mg^{+}$ for 700 revolutions







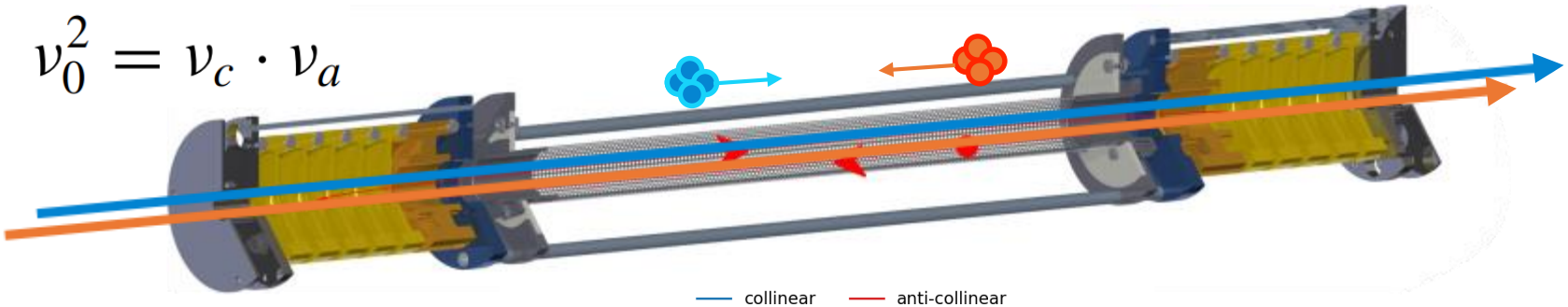
Trapping $^{24}Mg^{+}$ for 700 revolutions

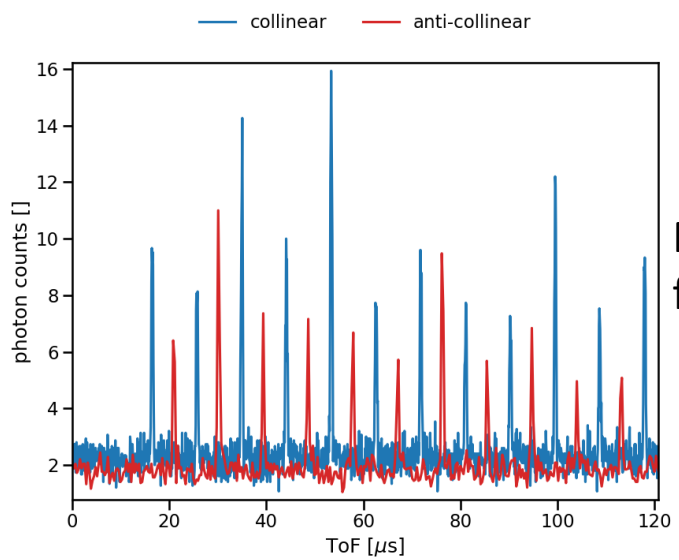


Simultaneous Collinear/Anti-collinear Laser spectroscopy

- Allows determination of absolute transition frequencies
- Removes knowledge of beam energy as a leading source of uncertainty
- Uses radioactive beam even more effectively

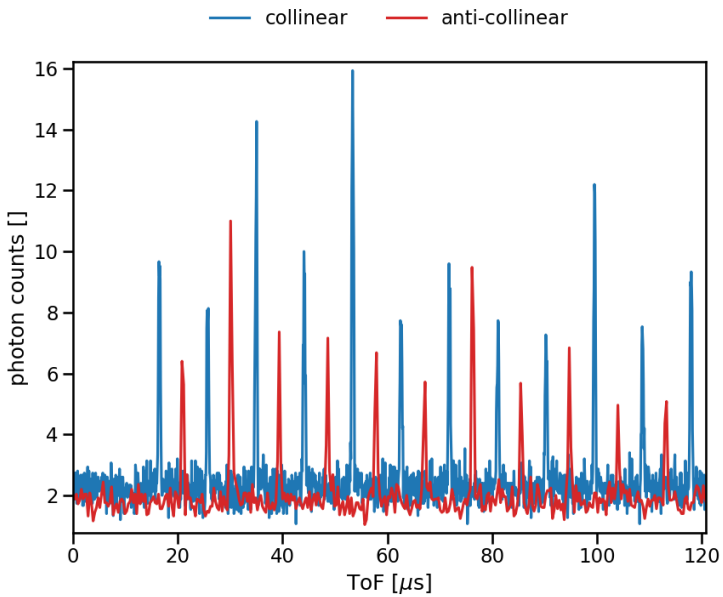
$$\nu_0^2 = \nu_c \cdot \nu_a$$

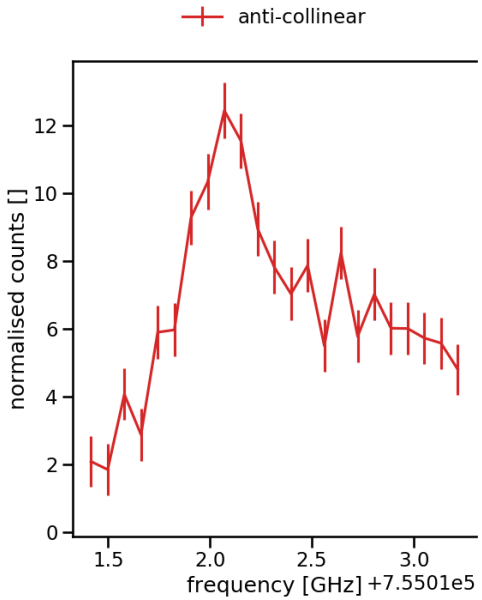


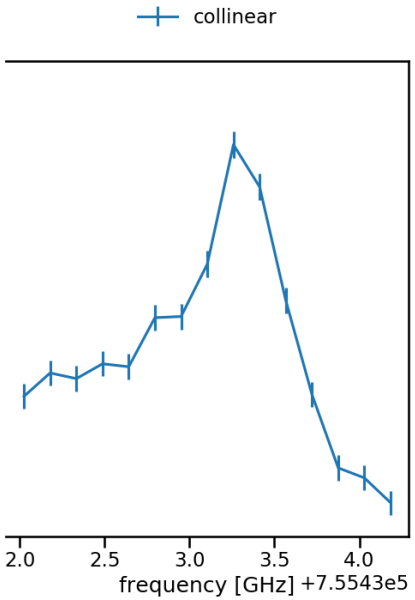


Measurement for $^{40}Ca^{+}$

Collinear/Anti-collinear of $^{40}Ca^{+}$

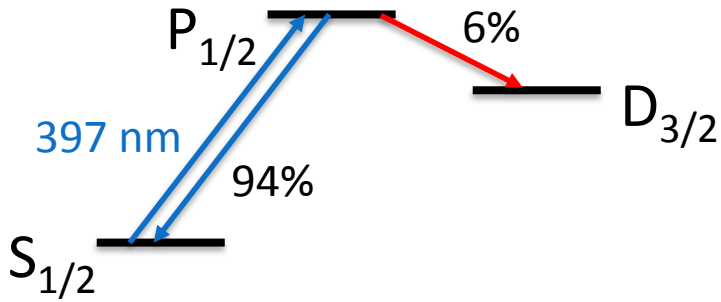




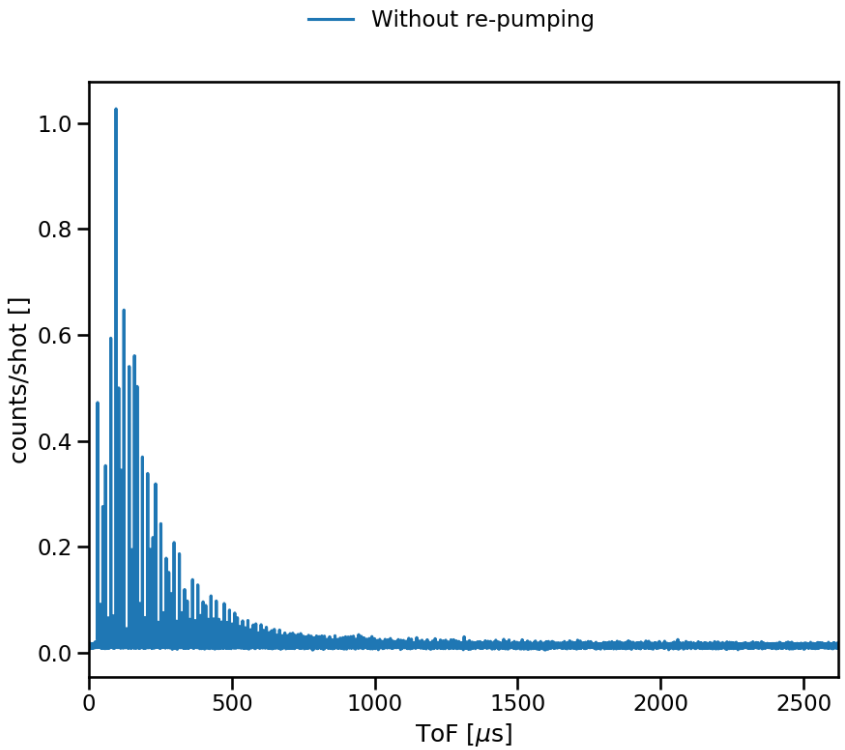


Note: performed in two separate measurements

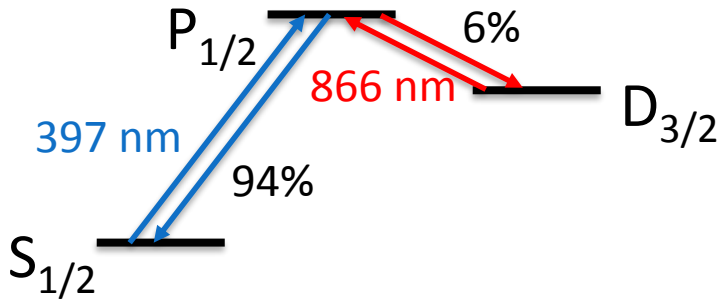
Optical re-pumping of $^{40}Ca^{+}$

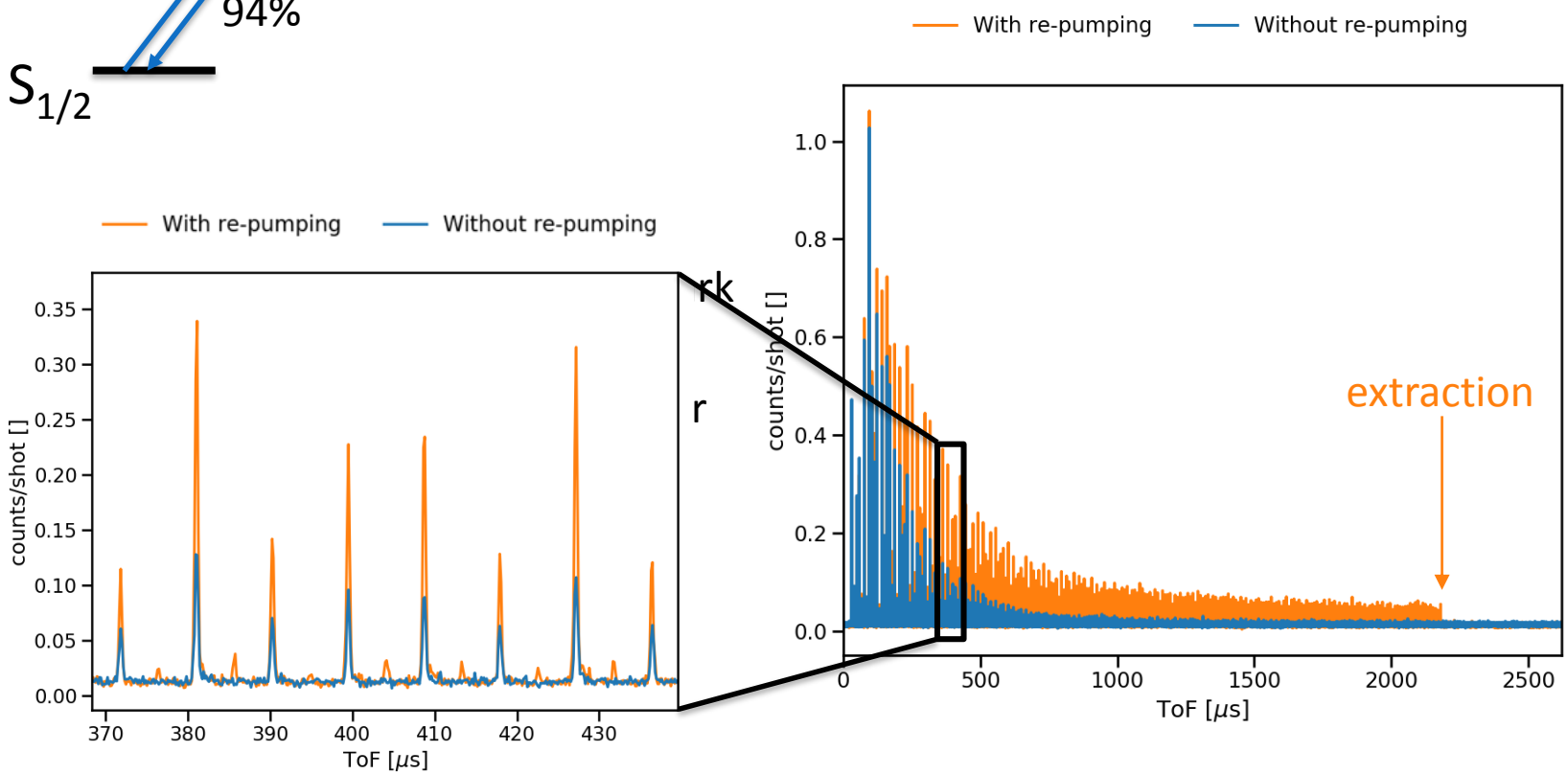


- Problem: using only 397nm transition → pumping into dark state

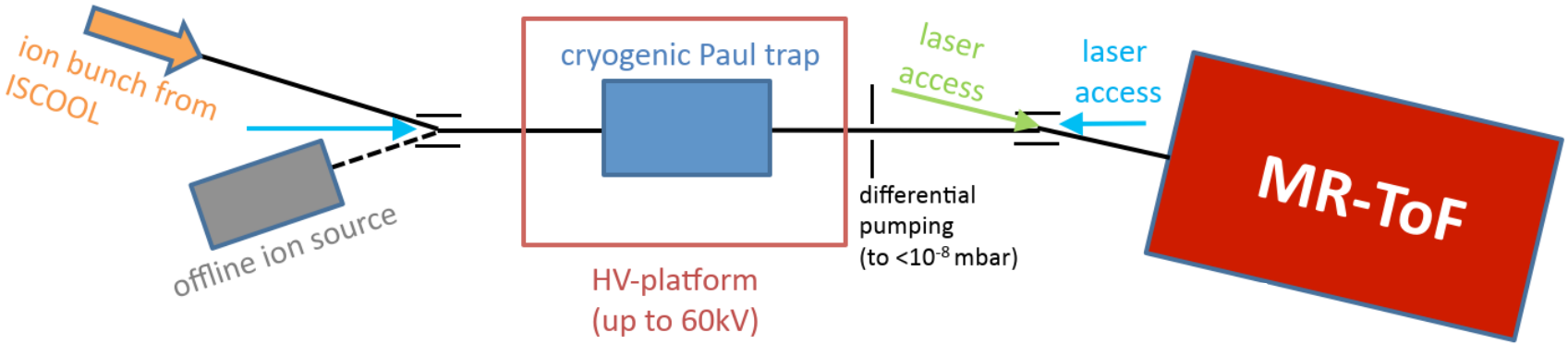


Optical re-pumping of $^{40}Ca^{+}$

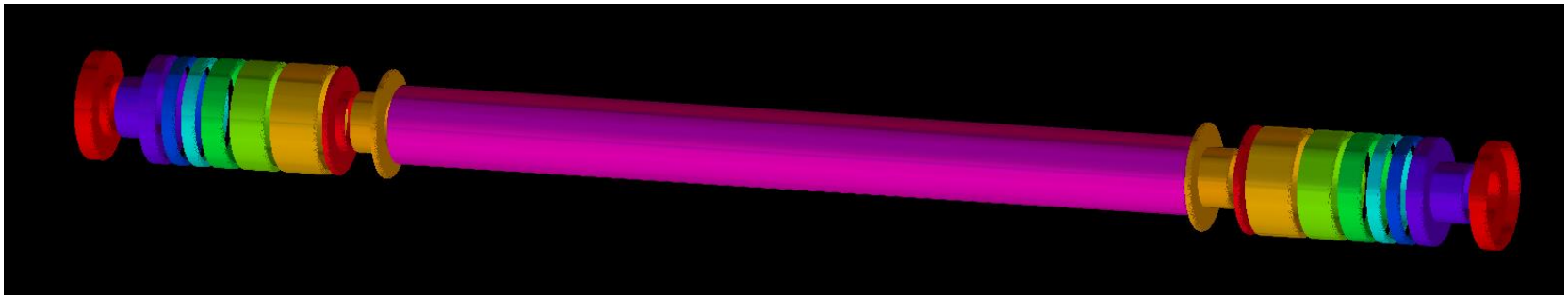




Outlook: 30 keV MR-ToF



- Suitable design and potentials of mirror electrodes have been identified in simulations
- Current focus:
  - Simulation of injection optics + beam transport to MR-ToF
  - High voltage tests of mirror electrodes and power supplies
- Construction drawings and manufacturing will be started soon



Maier, F.M., et al. Hyperfine Interactions 2019, 240: 54

Summary

- Photon signal decay very low over 700 revolutions (with constant centroid after first 100 revolutions)
- Showed the capability to perform collinear/anti-collinear laser spectroscopy
- Demonstrated re-pumping from a dark state with a second laser
- In parallel:
  - Stray-light suppression with UV-absorbent coatings
  - Work with negative ions & GANDALPH
  - Using proof-of-principle to investigate space charge effects (→ beam purification for ISOLDE)

S. Lechner et al., Hyperfine Interactions 2019, 240:95

Thank you for your attention!

P. Fischer, F. Hummer, C. Kanitz, V. Lagaki, S. Lechner, F. Maier, P. Plattner, H. Heylen, M. Rosenbusch, S. Sels, F. Wienholtz, M. Vilen, W. Nörtershäuser, L. Schweikhard, S. Malbrunot-Ettenauer

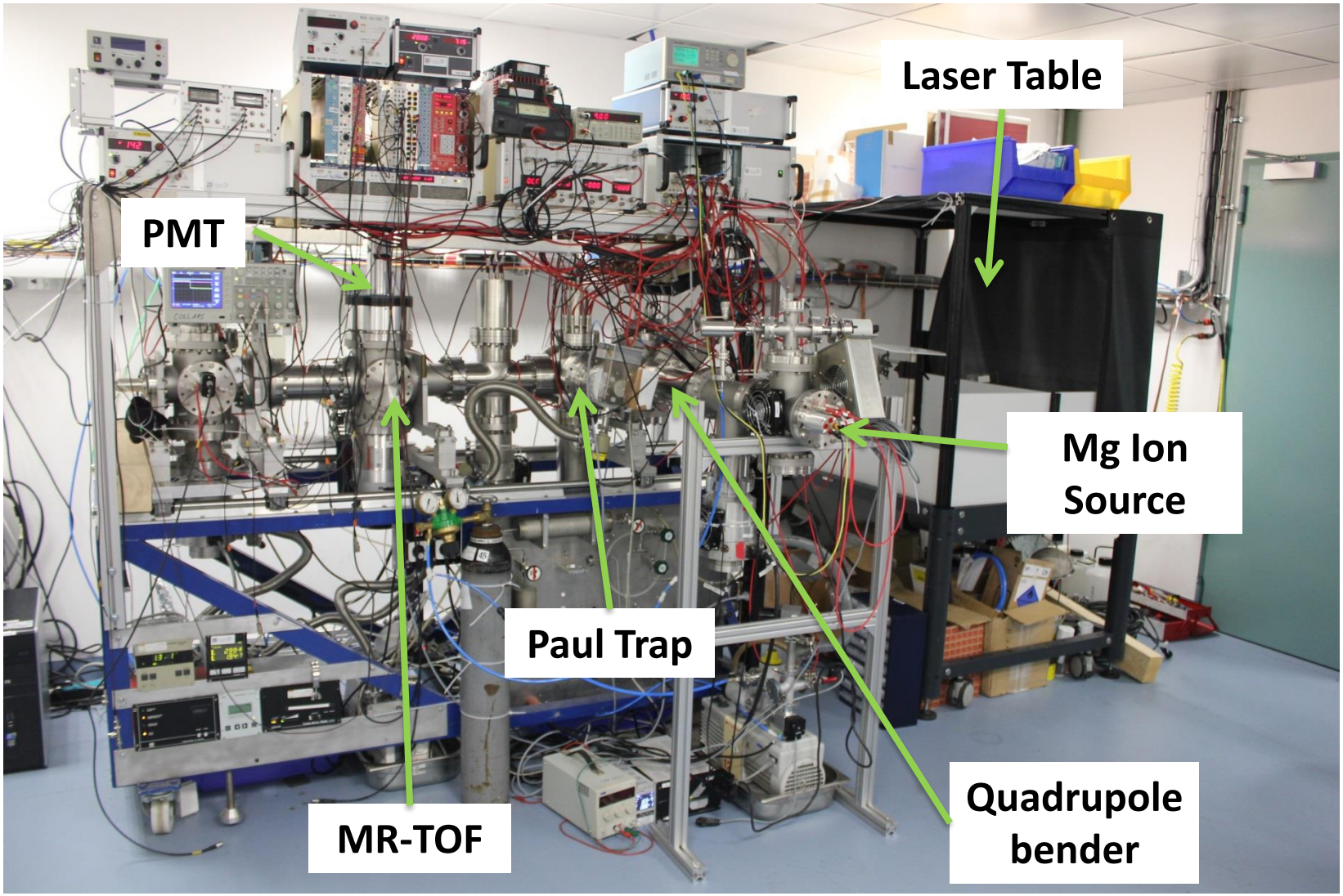
Many thanks for advice, help & support:

M. Bissell, R. Garcia, M. Kowalska, R. Neugart, L. Vazquez Rodriguez, R. Sanchez, COLLAPS team, CRIS, ... G. Neyens, M. Garcia Borge, K. Blaum, Anita Ivanova, … ISOLDE, CERN Directorate & EP Department, CERN Budget for Knowledge Transfer to Medical Applications

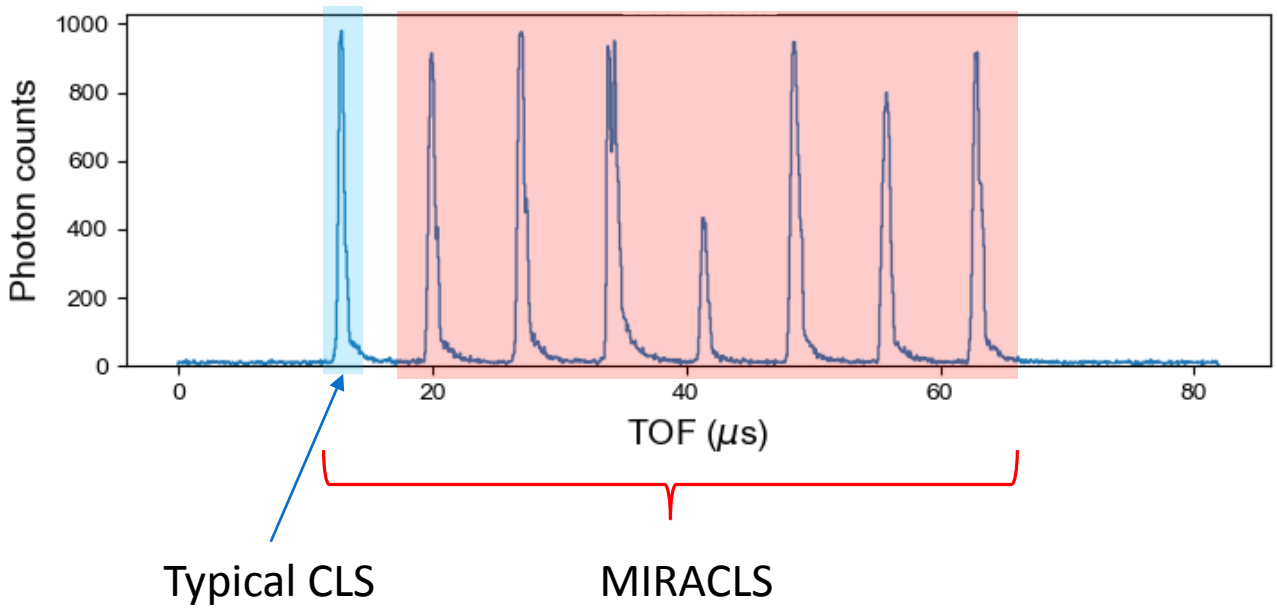
Visit: cern.ch/miracls

Backup slides

Proof of Principle (2)



Improvement Compared to Conventional CLS



- 7 revolutions in MR ToF shown
- Trapping possible for up to 1000 revolutions

Trapping for 700 Revolutions