



Laser photodetachment in an MR-ToF device: Towards the isotope shift measurements in short-lived radionuclides

David Leimbach

For the GANDALPH and MIRACLS collaboration



Negative ions

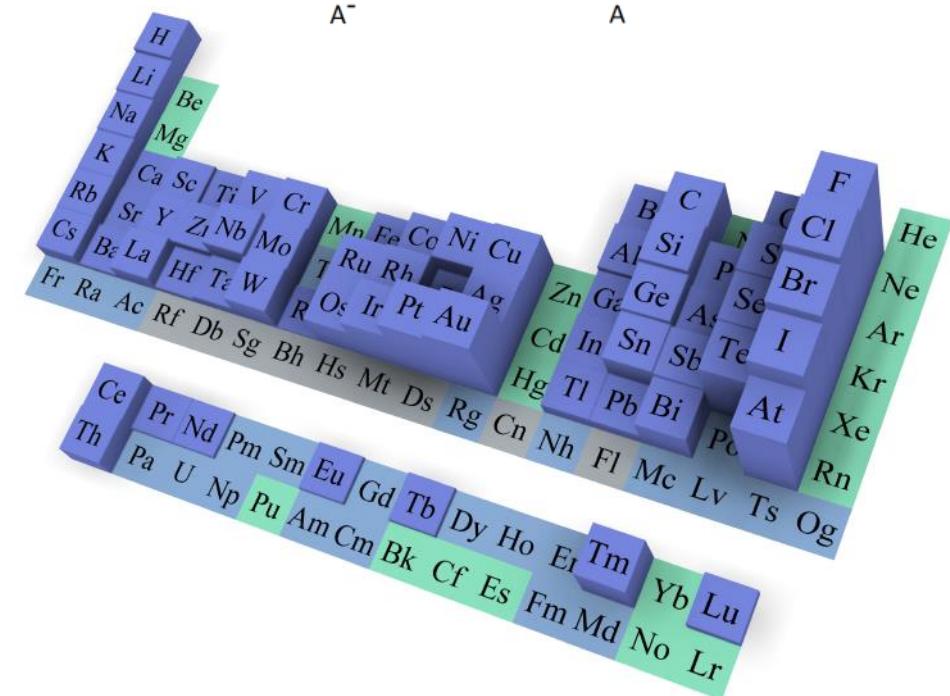
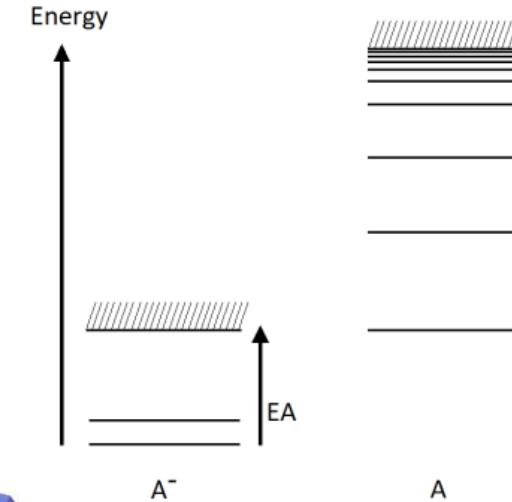
- **Electron affinity (EA)** is the binding energy of the additional electron in a negative ion (in the order of ~1eV)
- Typically no bound excited states

Motivation

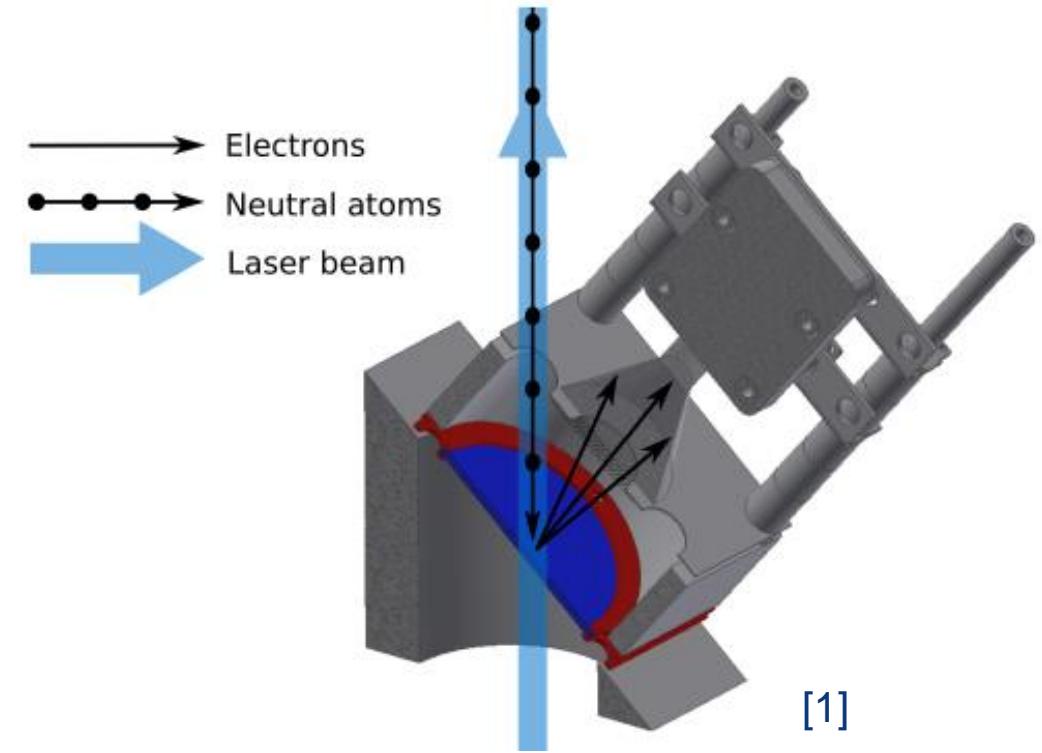
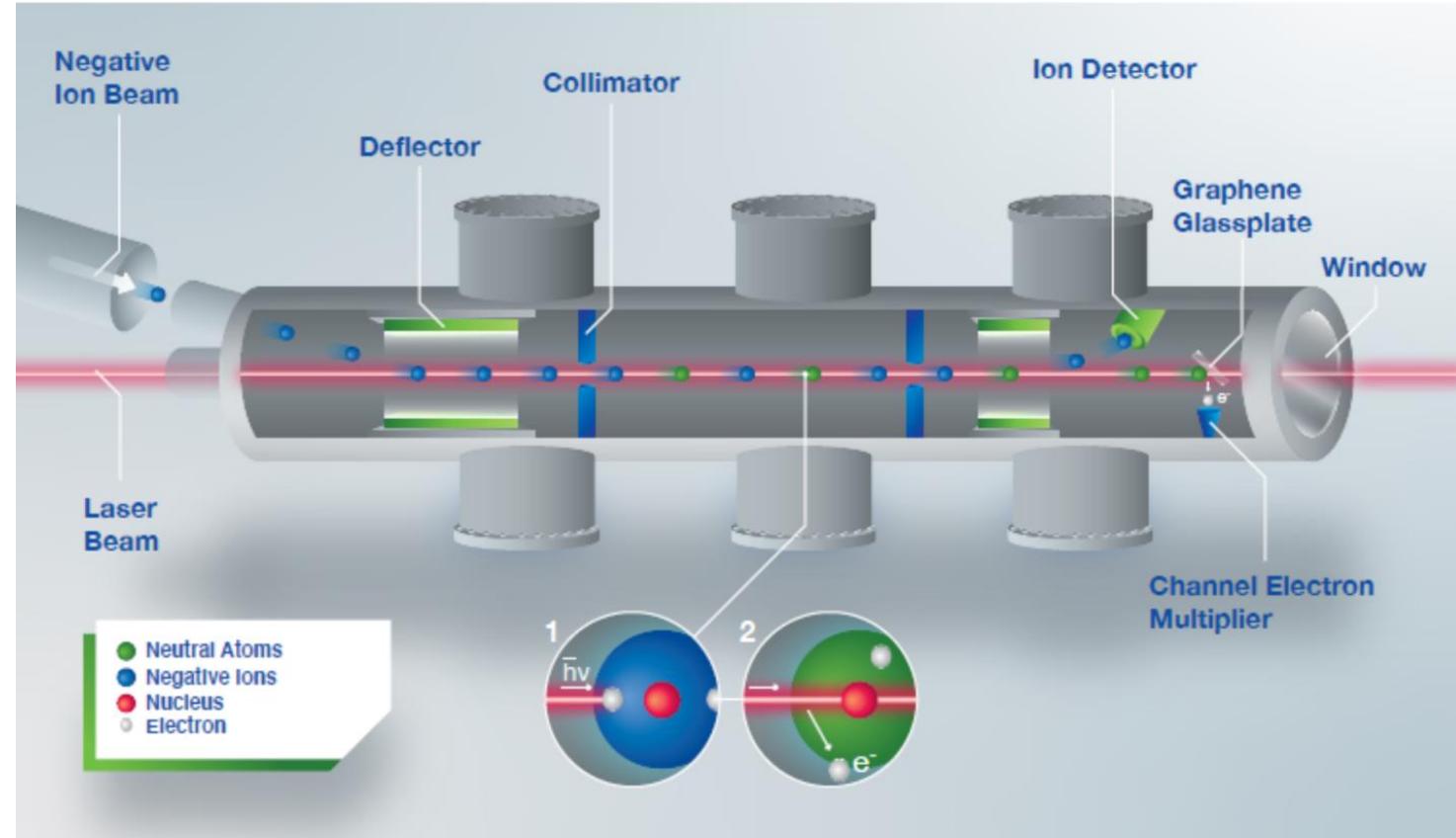
- Excellent model for validation of atomic theory beyond the single particle model
- High beam purity and selectivity possible

Applications

- AMS, e.g. carbon dating with suppression of isobars
- Injection and stripping of H^- for proton beams (e.g. LINAC 4)
- Sympathetic cooling of antimatter

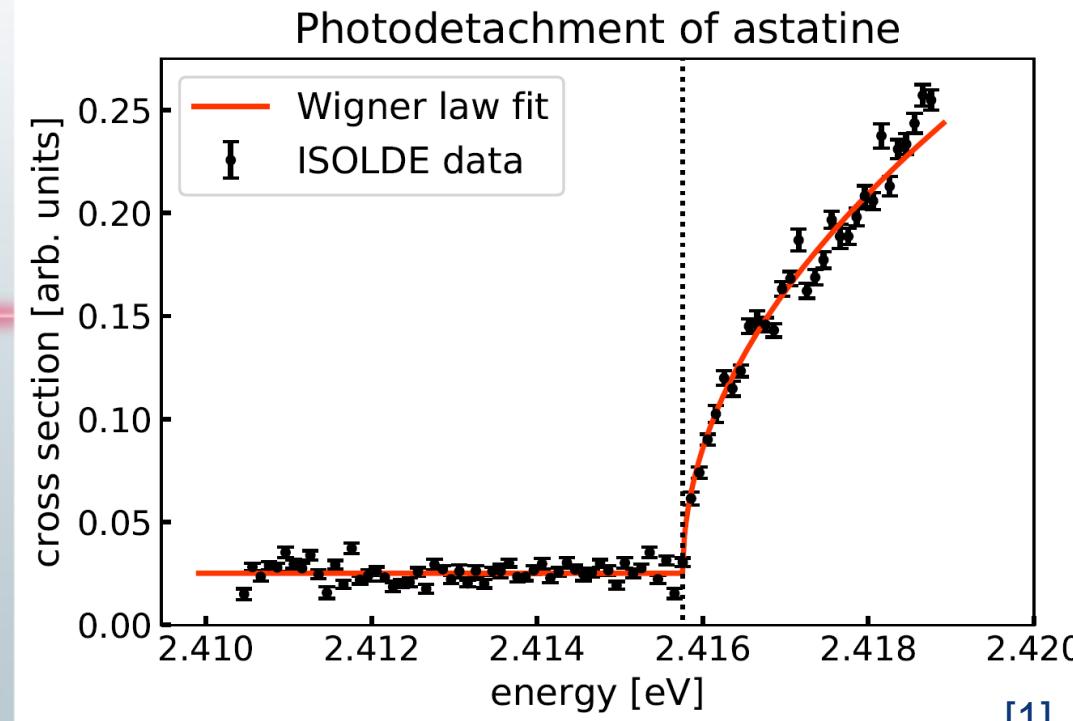
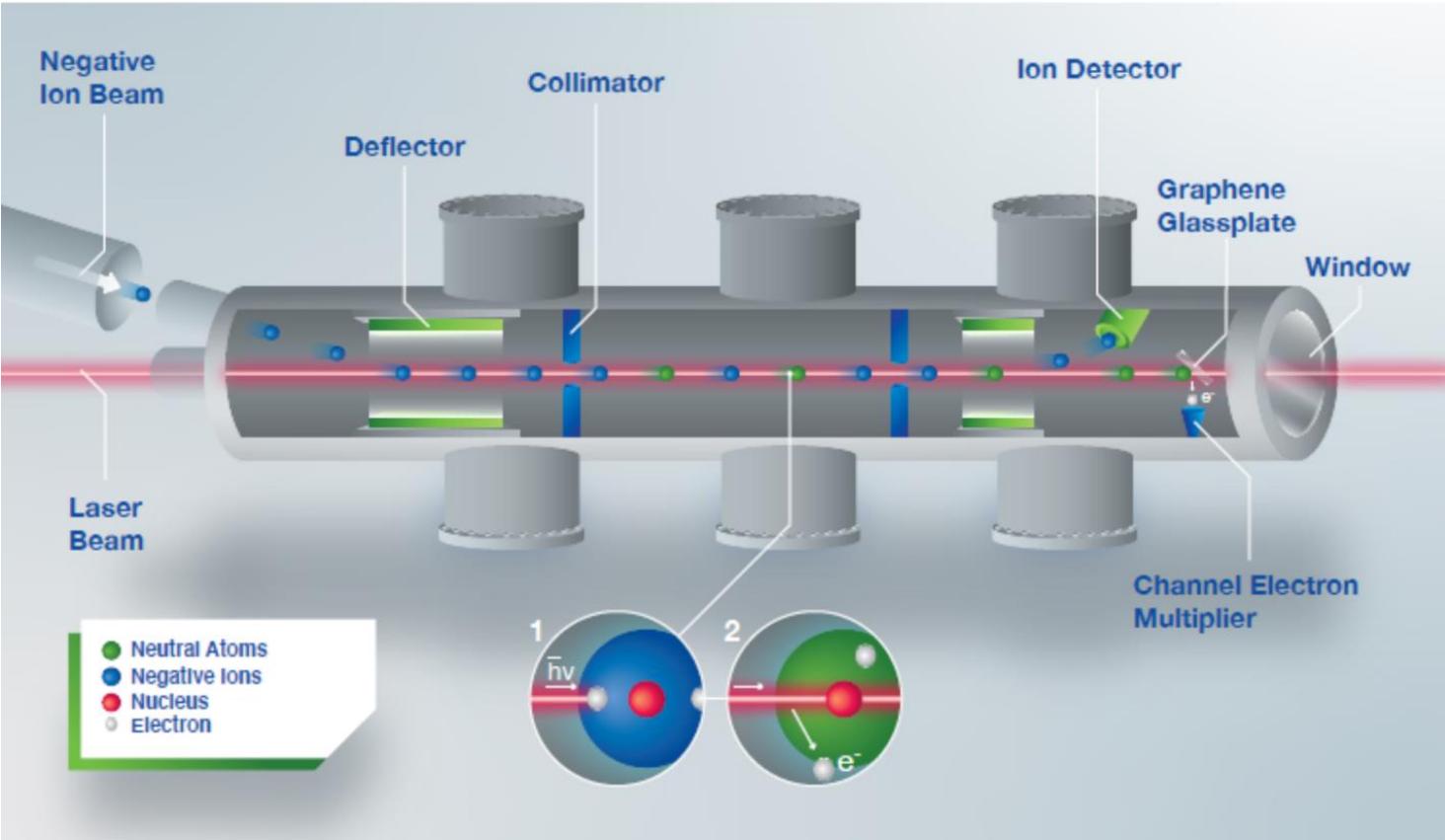


Laser photodetachment



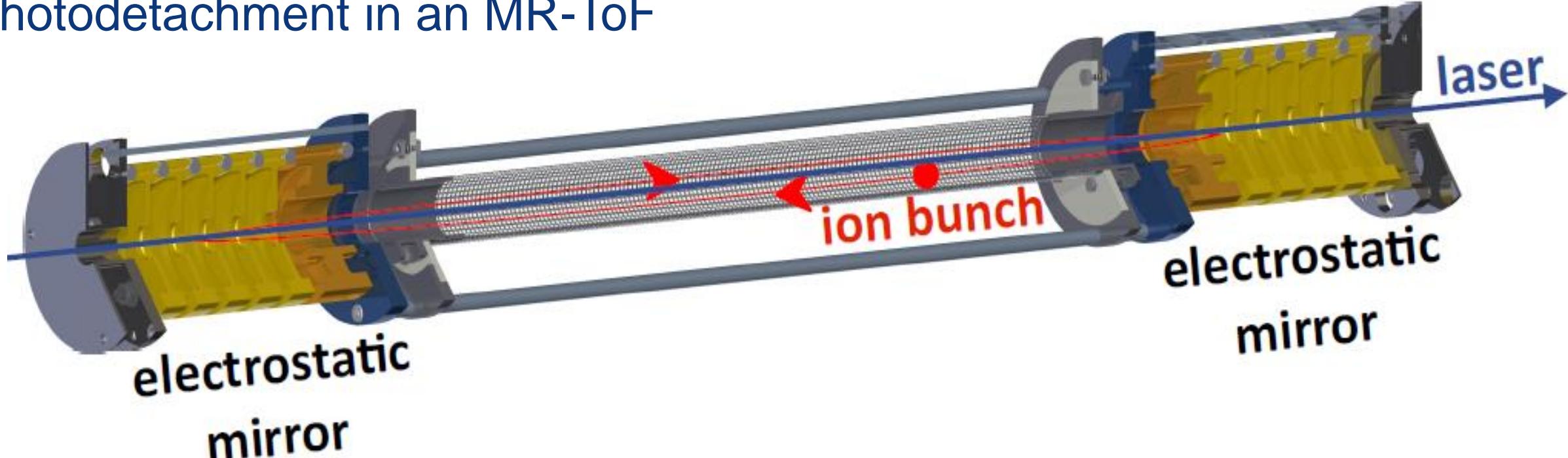
- Frequency tune-able laser overlapped with negative ion beam
- Wigner threshold law: $\sigma(E) = (E_\gamma - E_{th})^{l+\frac{1}{2}}$

Laser photodetachment



- Frequency tune-able laser overlapped with negative ion beam
- Wigner threshold law: $\sigma(E) = (E_\gamma - E_{th})^{l+\frac{1}{2}}$

Photodetachment in an MR-ToF



- **MR-ToF:**
 - Bunched ions are reflected between mirror electrodes
 - Re-use of the ions possible for spectroscopy, therefore increased efficiency
- **Goal:**
 - Proof of principle of photodetachment threshold spectroscopy in an MR-ToF device
 - Step towards EA measurements of sparsely produced radioelements
 - Improved resolution by using cw lasers and by compensating laser power with laser-ion interaction time

Measurement of shifts in the electron affinities of chlorine isotopes

Isotope shift:

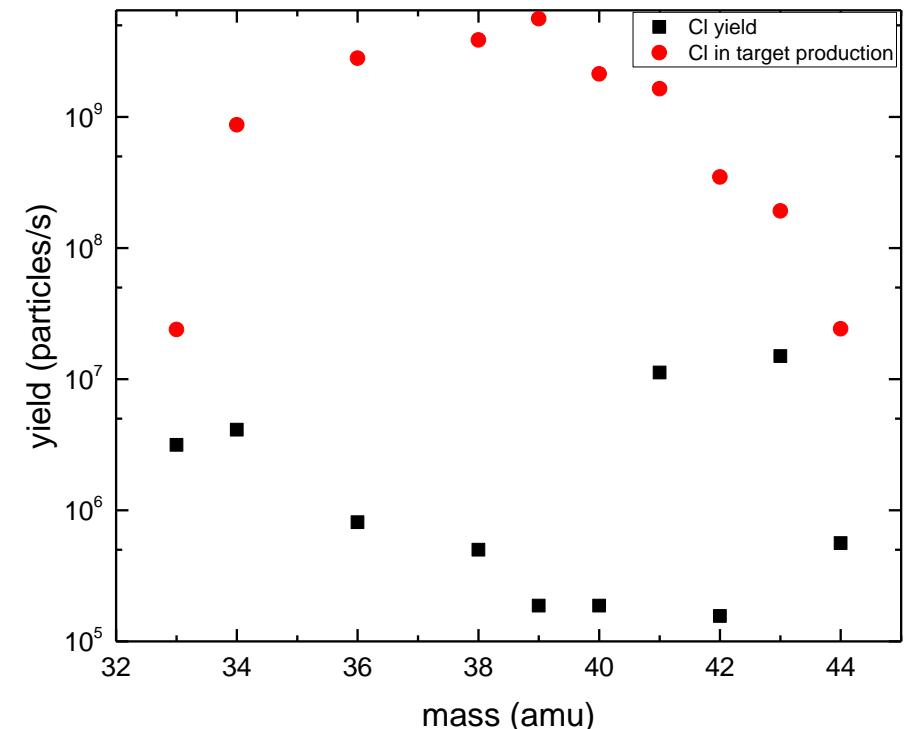
$$\delta\nu_{AA'} = (K_{\text{NMS}} + K_{\text{SMS}})\left(\frac{1}{A} - \frac{1}{A'}\right) + F\delta\langle r^2 \rangle^{AA'}$$

- SMS depends highly on electron correlation effects
- Relevance for nuclear charge radii determination

Chlorine:

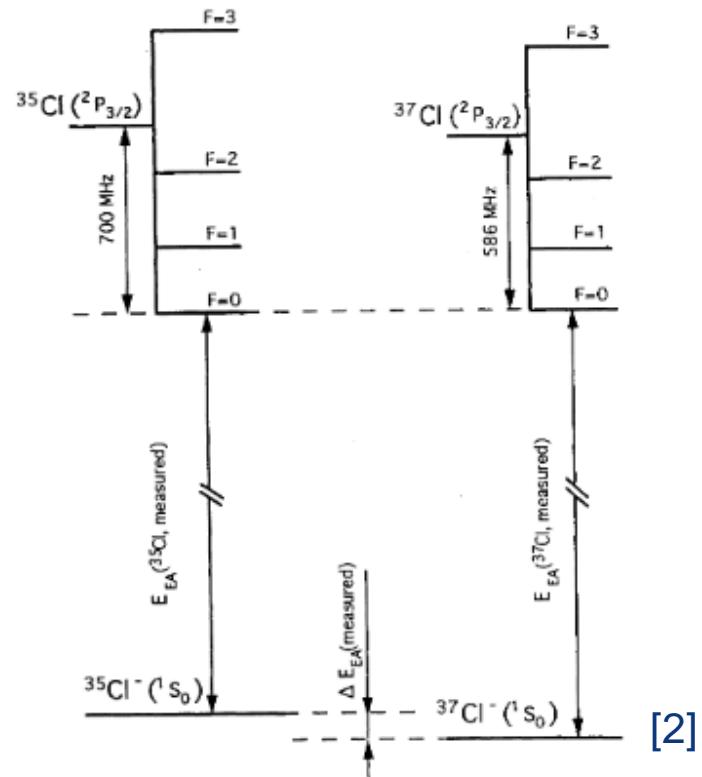
- Light element => mass shift dominant
- Calculations go beyond current experimental precision
- Attempt of measurement was made at At run 2018
 - Issues with laser setup
 - Yields dropping

Dag Hanstorp¹, Jakob Welander¹, David Leimbach¹, Annie Ringvall-Moberg^{1,2}, Michel Godefroid³, Per Jönsson⁴, Jörgen Ekman⁴, Tomas Brage⁵, Klaus Wendt⁶, Reinhard Heinke⁶, Oliver Forstner⁷, Yuan Liu⁸, Ronald Garcia Ruiz⁹, Shane Wilkins⁹, Adam Vernon⁹, Cory Binersley⁹, Kieran Flanagan⁹, Gerda Neyens¹⁰, Agi Koszorus¹⁰, Kara Lynch², Sebastian Rothe², Tim Giles², Katerina Chrysalidis^{2,6}, Pierre Larmonier², Valentin Fedosseev² and Bruce Marsh².



IS643: Isotope shift of the EA of Cl

- **Offline experiment:**
 - Cl efficiently produced with LaB_6 surface ionizer (MK4)
 - High precision measurement of $^{35,37}\text{Cl}$
- **Milestones:**
 - Establish negative ion source at MIRACLS
 - Trapping of negative ion bunches in MR-ToF
 - 1st photodetachment signal
 - High precision measurement of ^{35}Cl and ^{37}Cl

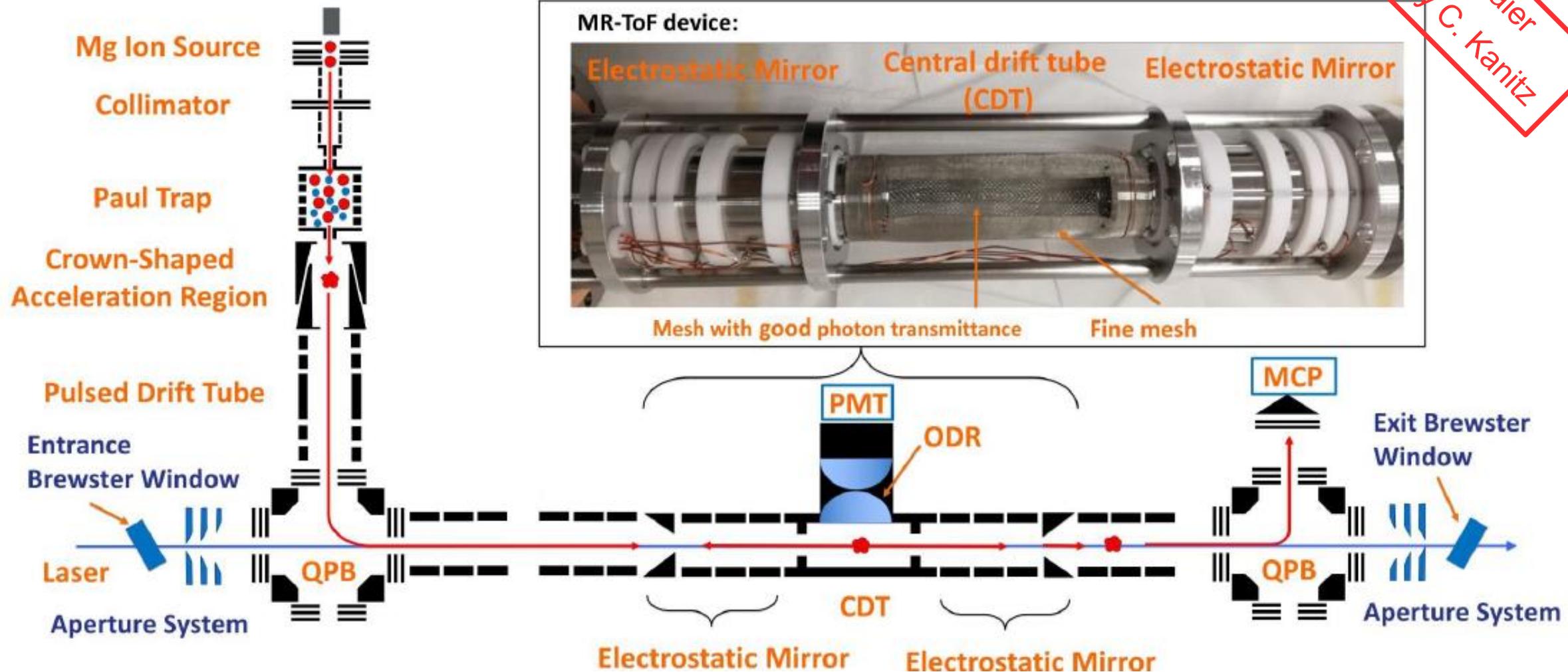


	SMS	MS	FS	RIS	IS
HF	-1.348	-0.607	-0.003(22)	-1.351(22)	-0.610(22)
val. FC-MCHF	-0.674	+0.067	-0.002(20)	-0.676(20)	+0.065(20)
val. MCHE	-0.495	+0.246	-0.003(21)	-0.497(21)	+0.244(21)
final results	-0.535(51)	+0.206(51)	-0.003(22)	-0.538(72)	+0.203(72)
Berzinsh <i>et al</i> [27]					
Exp.				-0.51(14)	+0.22(14)
DF	-1.3	-0.6	+0.014(14)	-1.3	-0.6
MB low corr.	+0.50	+1.24	+0.014(14)	+0.51(2)	+1.26(2)

[1]

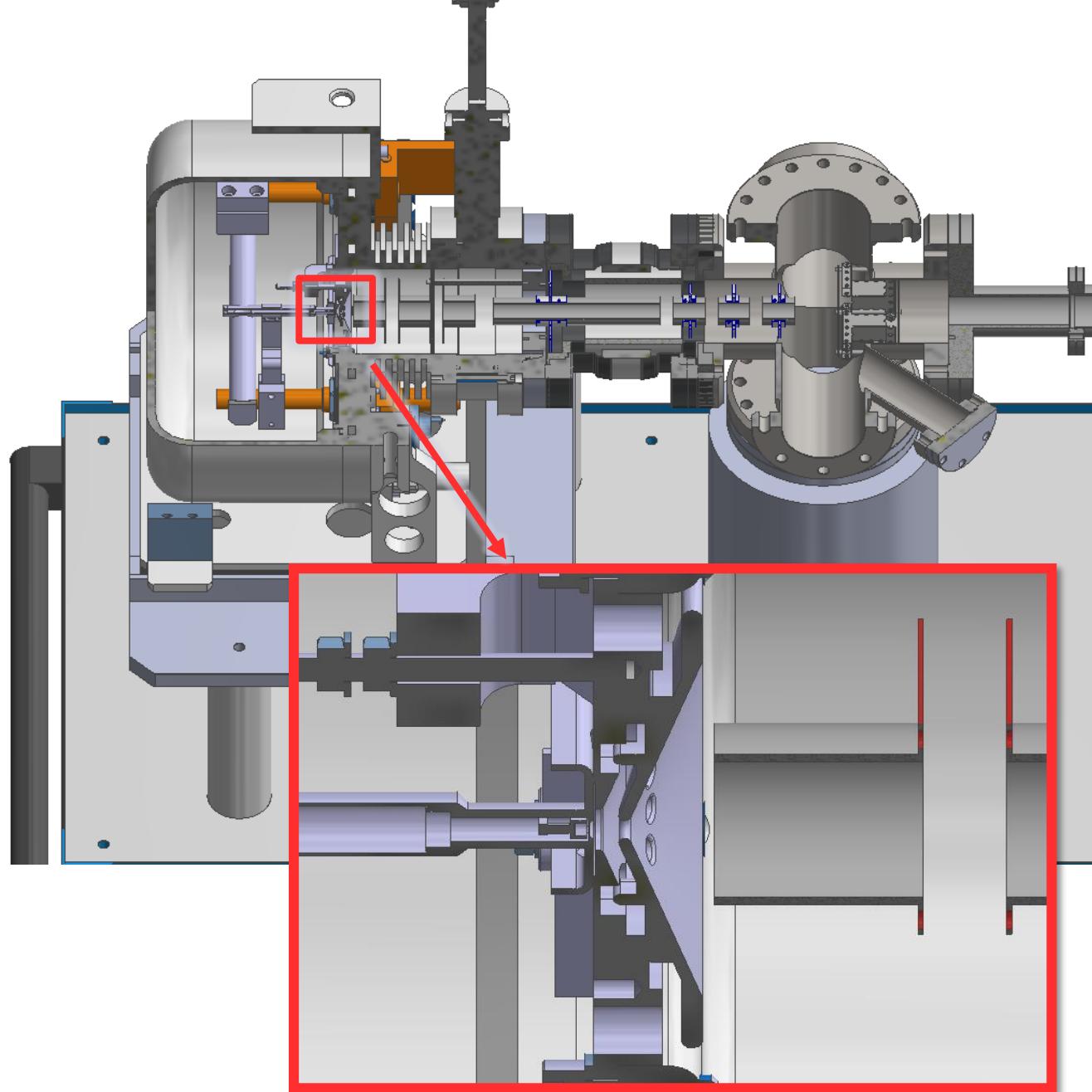
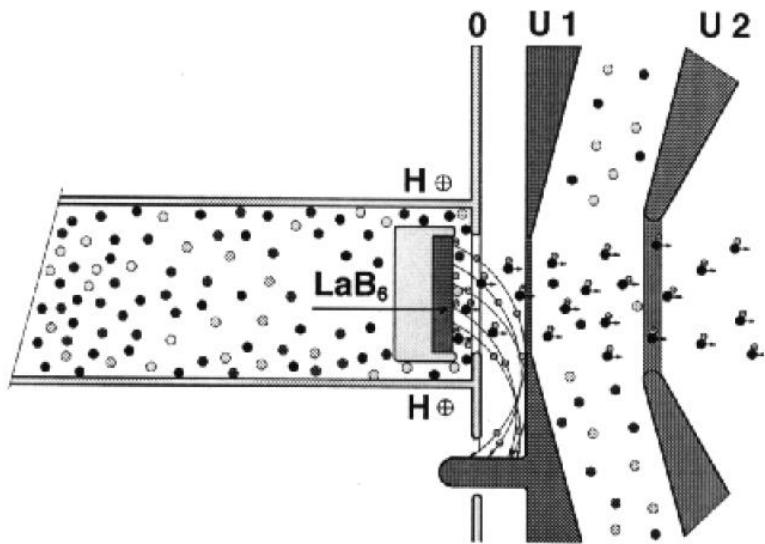
MIRACLS Proof of Principle setup

Talk by F. Maier
Poster by C. Kanitz

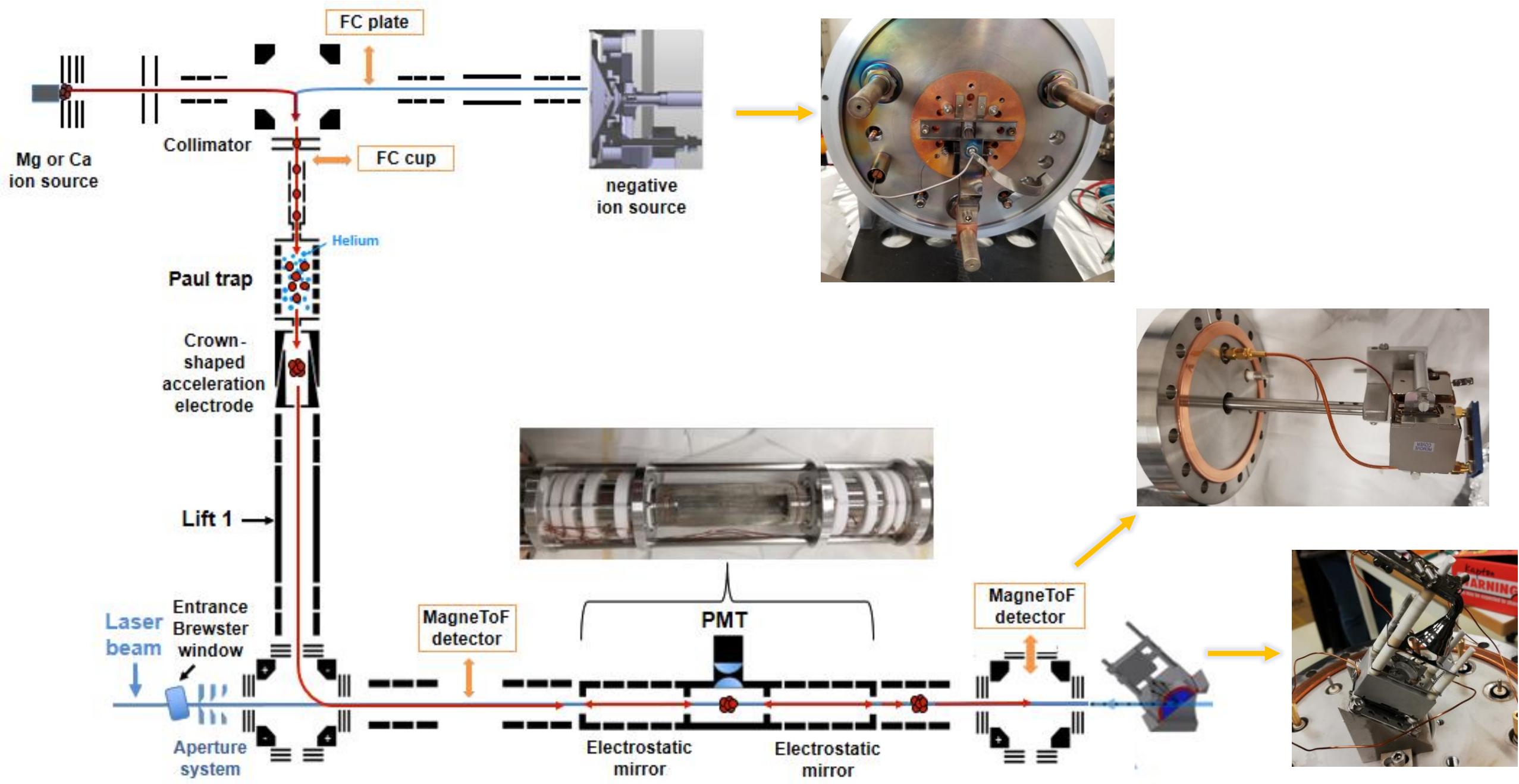


Negative ion source for MIRACLS

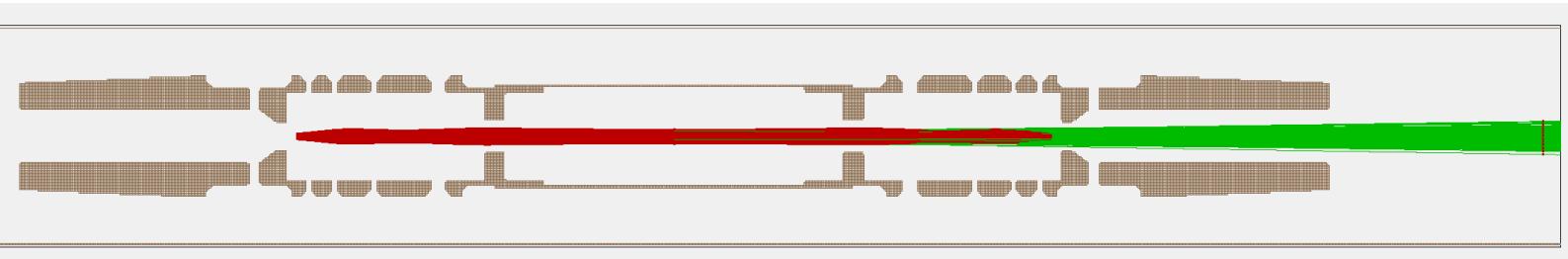
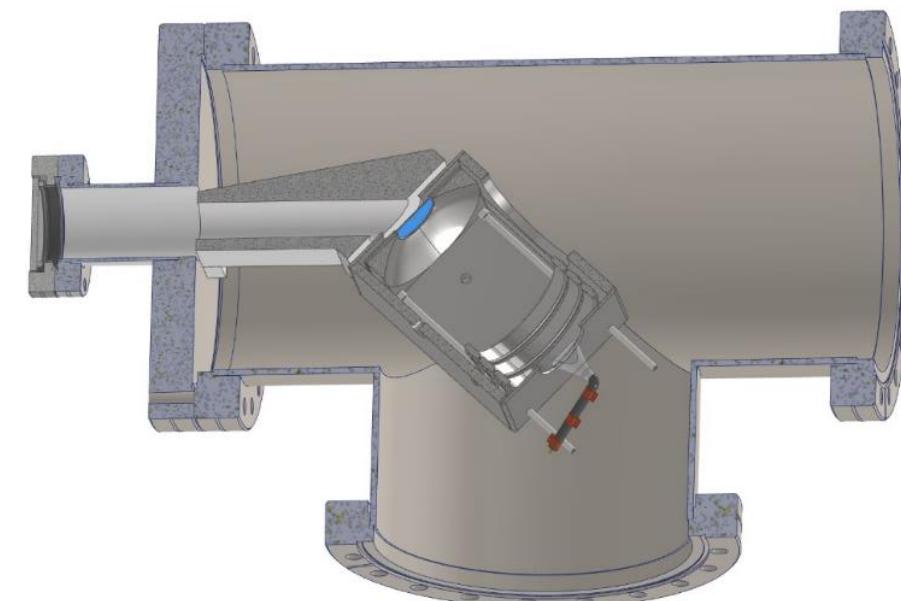
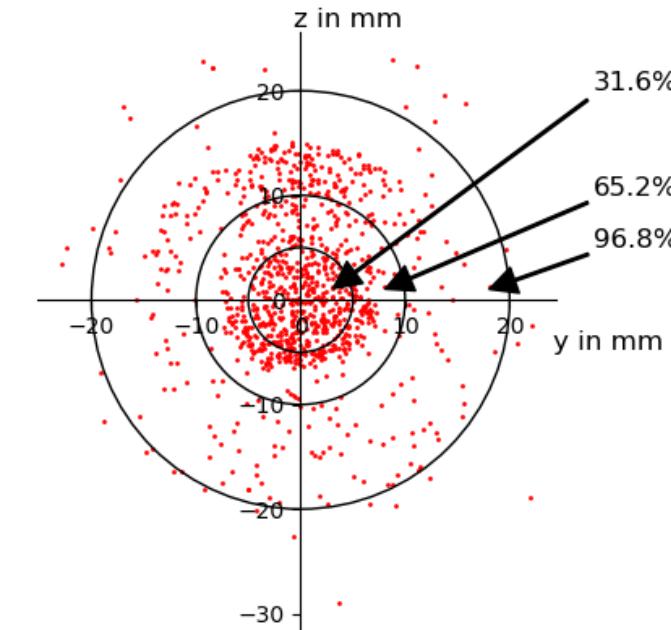
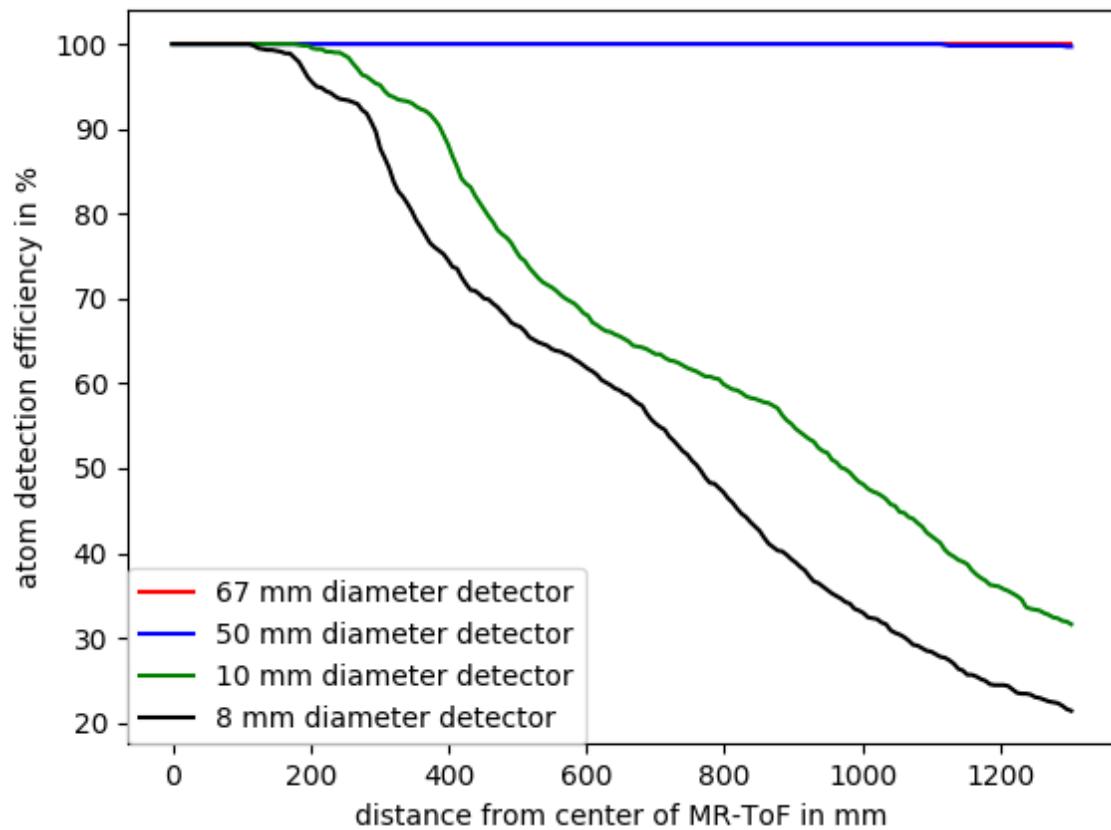
- Isolde target connected to moveable beamline
- MK4 surface ion source for negative ion production
- 0.50 keV beam energy
- Beamline compatible with other ISOLDE targets



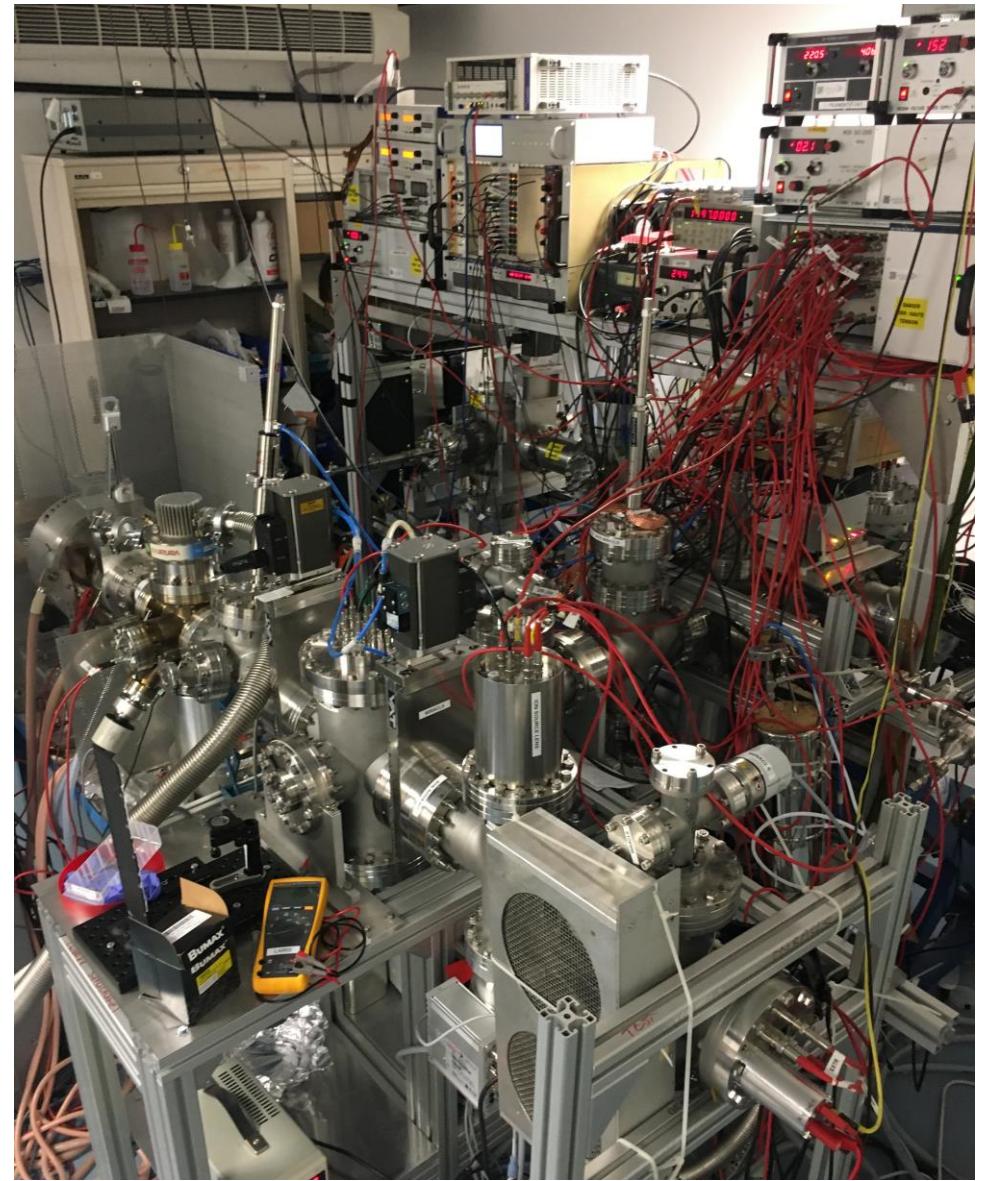
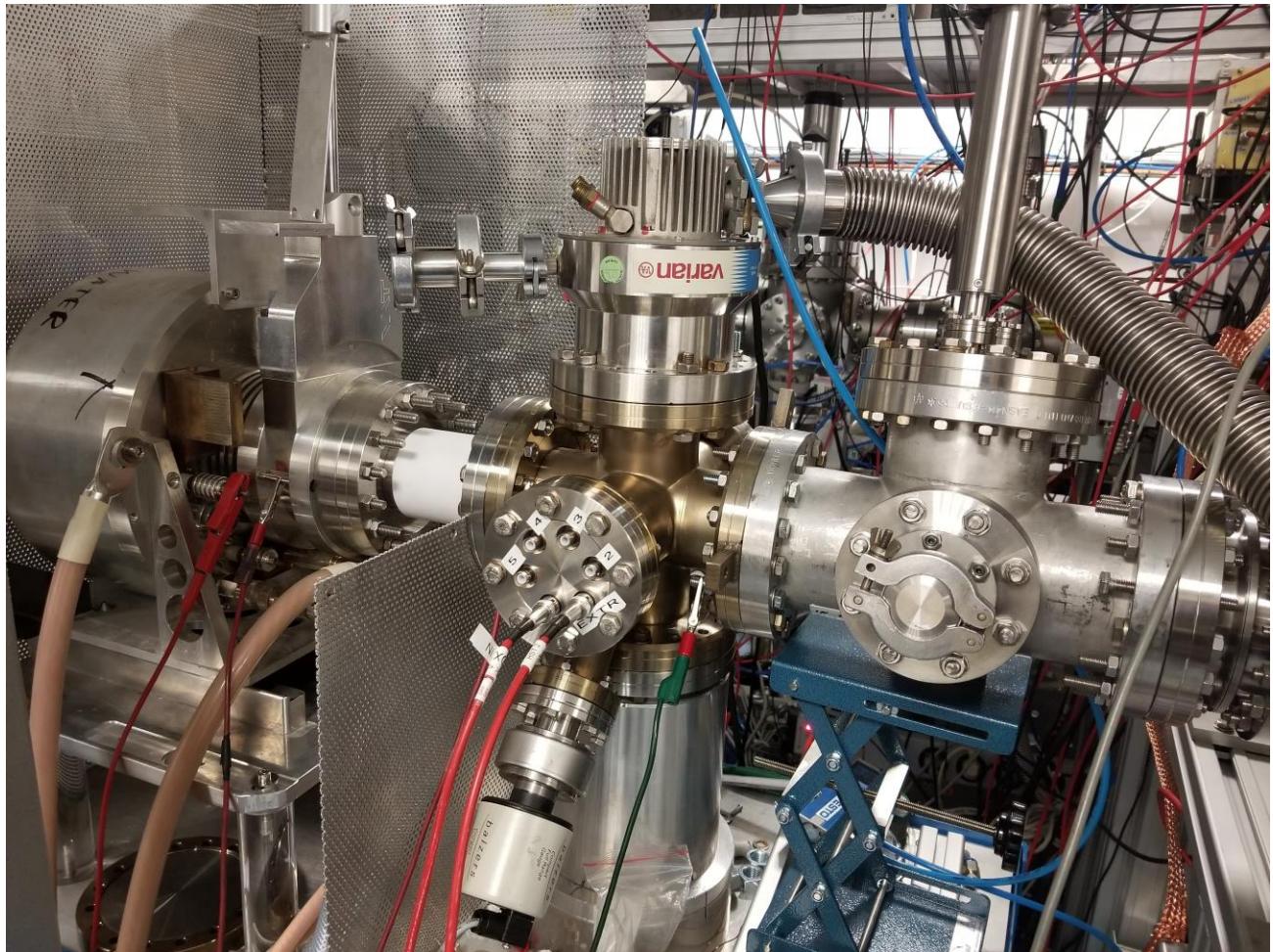
David Leimbach



Neutral particle detector upgrade

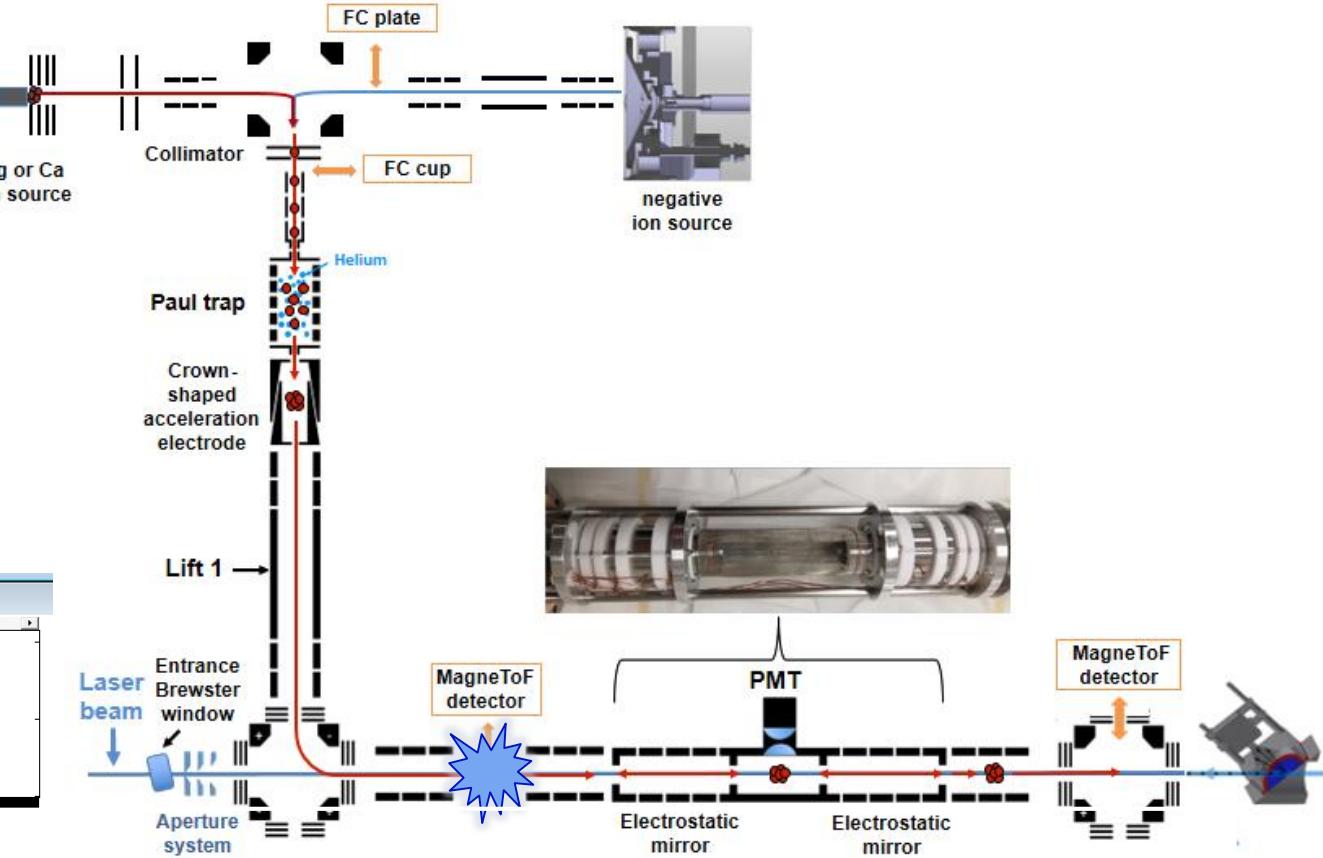
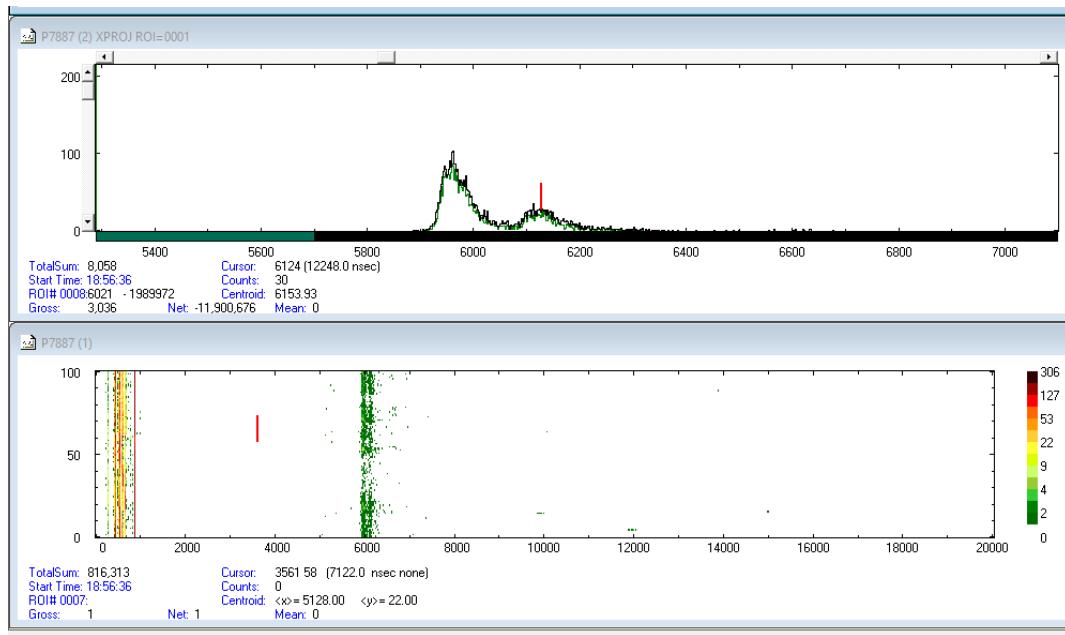


The setup



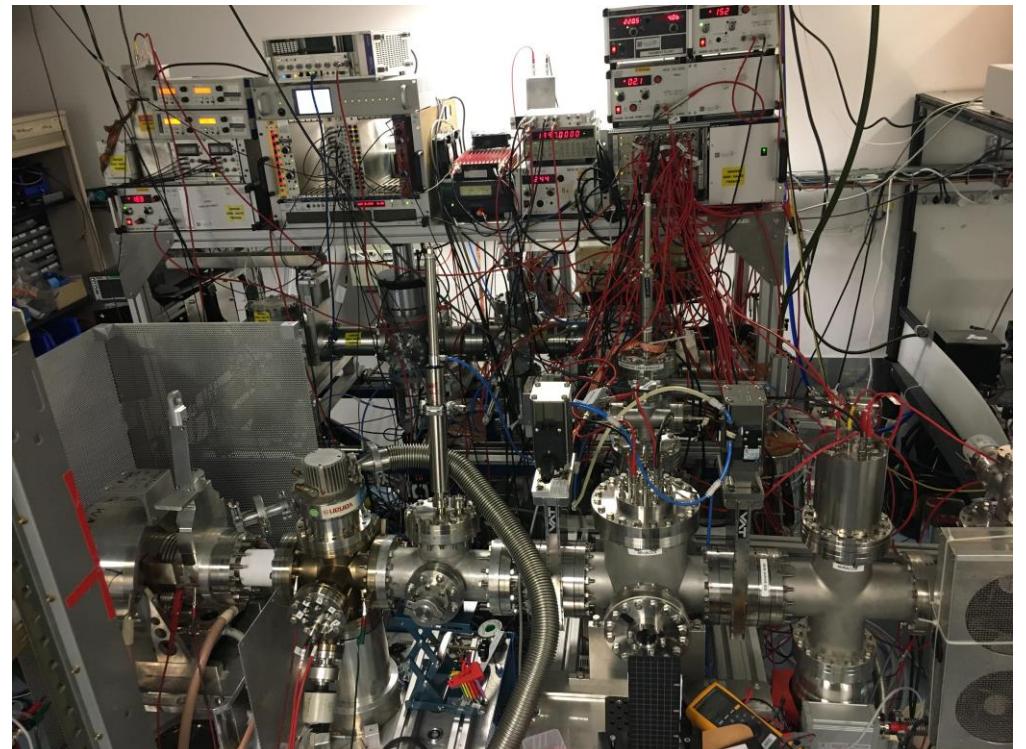
Current status

- Beam line commissioning complete
 - Successful transmission of K⁺ ions through setup
 - Cl⁻ transmitted through paul trap
- Neutral detector to be installed



Conclusion

- Successfully commissioned a negative ion source and beam-line on the MIRACLS PoP setup
- Work towards the isotope shift of stable Cl isotopes ongoing
 - Proof of principle of photodetachment spectroscopy in an MR-ToF
 - Offline measurement of ^{36}Cl planned
- Online measurements of Cl isotope shift in 2022



Acknowledgement

Y. Nel Vila Garcia

M. Au

F. Maier

C. Kanitz

V. Lagaki

S. Malbrunot-Ettenauer

S. Rothe

A. Suarez

J. Warbinek

D. Hanstorp

M. Nichols

M. Reponen

P. Fischer

S. Lechner

P. Plattner

S. Sels

F. Wienholtz

M. Vilen

W. Nörtershäuser

L. Schweikhard

D. Lu

A. Ringvall-Moberg

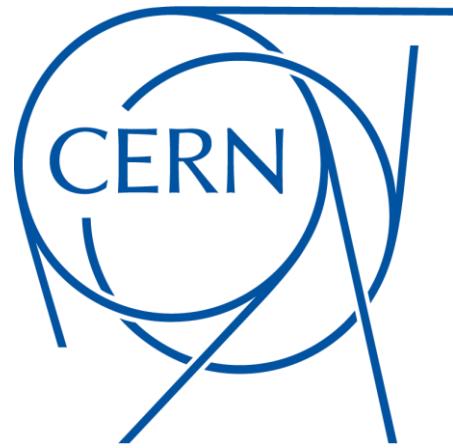
K. Wendt

J. Sundberg

...



Thank you for your attention!



ENGINEERING
DEPARTMENT