HILITE – A well-defined ion target for laser experiments

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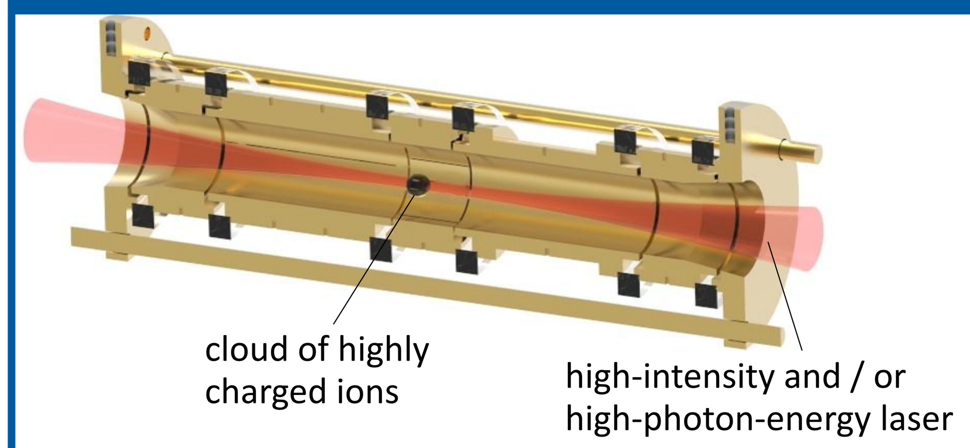
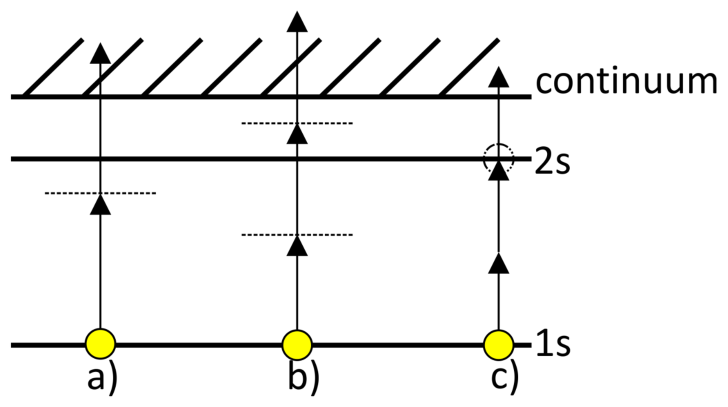
Detailed investigations of laser-ion interactions require well-defined ion targets and detection techniques for high-sensitivity measurements of reaction educts and products. To this end, we have designed and built the HILITE (High-Intensity Laser-Ion Trap Experiment) Penning trap [2] as a versatile tool to prepare well-defined clouds of highly charged ions. It comprises ion-cloud formation techniques as well as destructive and non-destructive measurement techniques to deduce the number of stored ions for all charge states individually and simultaneously.
We have recently performed first commissioning experiments of ion deceleration and dynamic ion capture with highly-charged-ion bunches from an EBIT. We have characterised our single-pass non-destructive charge counter in detail. We are able to determine the ion velocity as well as the number of particles directly from the ion traces acquired. Our current storage time inside our trap is better than one second.

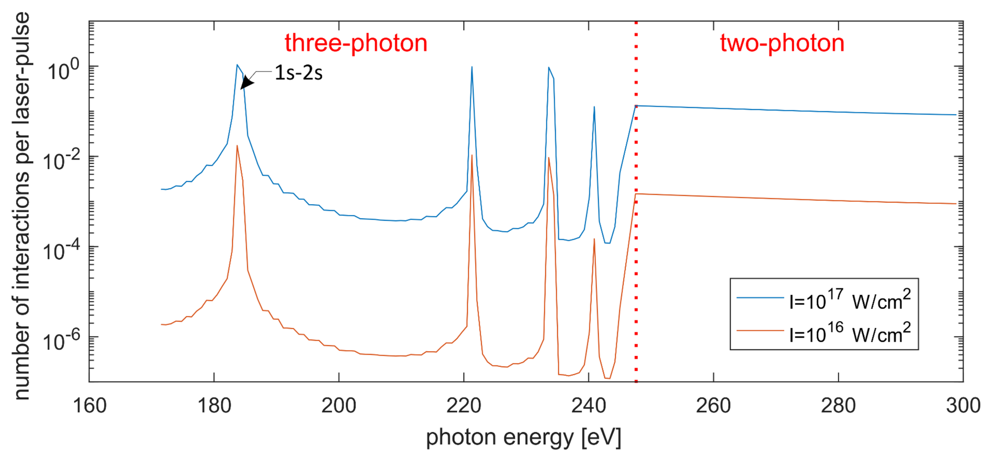
Laser Experiments with Highly Charged Ions



- Mechanically compensated Penning trap
- Open-endcap configuration allows full access from outside
- Conical capture electrodes with an aperture of up to f/5 to improve laser acceptance

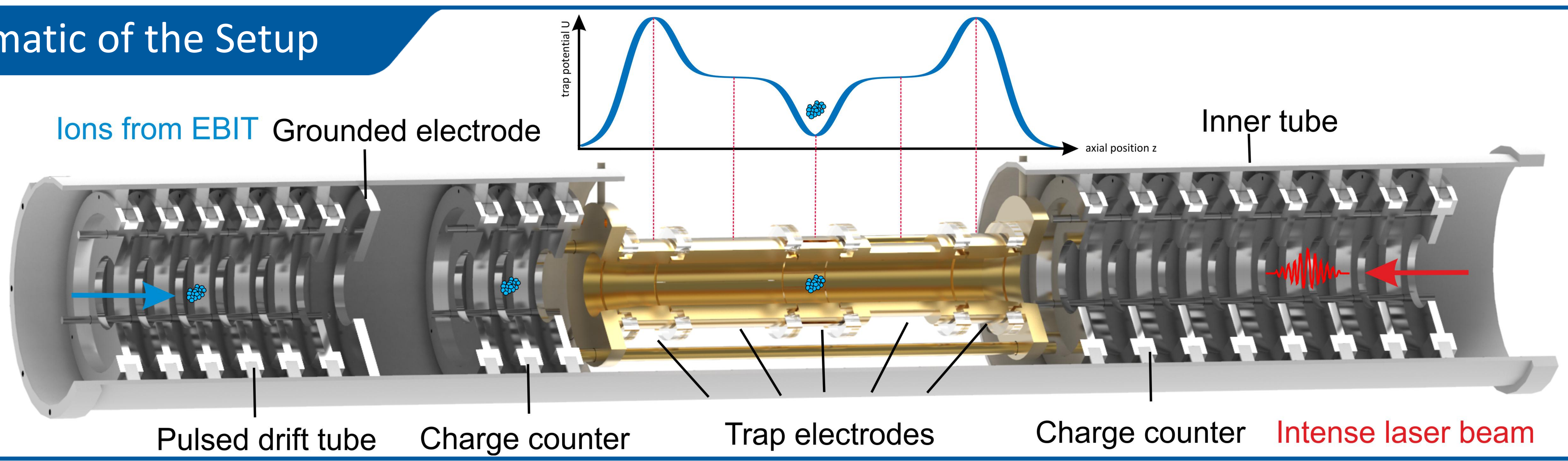


- Two-photon non-sequential ionisation (a)
- Three-photon non-sequential ionisation (b)
- Two-photon 1s-2s excitation with subsequent ionisation (c)

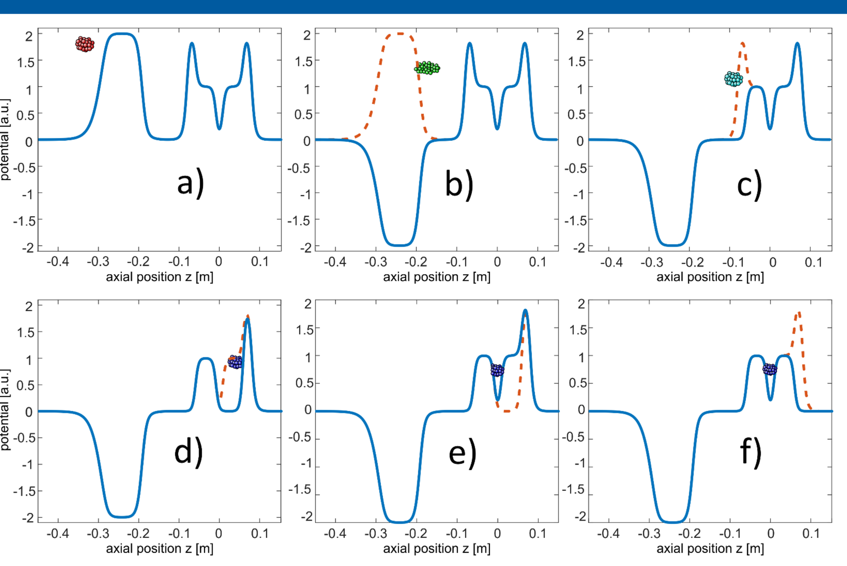


- Expected ion yield for hydrogen-like carbon (C^{5+}) in the high photon-energy regime
- Calculation base on theoretical predictions for the transition rate [1]

Schematic of the Setup



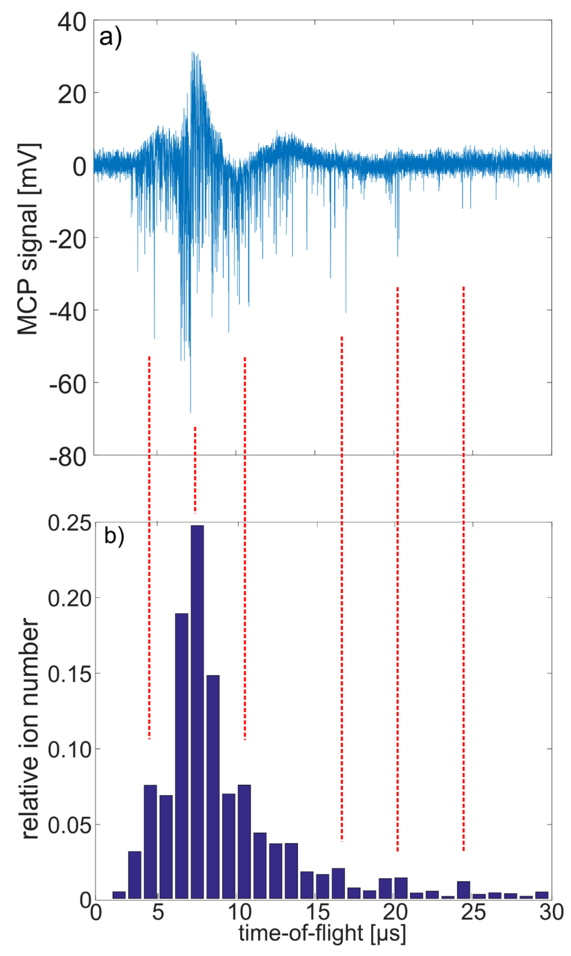
Dynamic Ion Capture and Storage



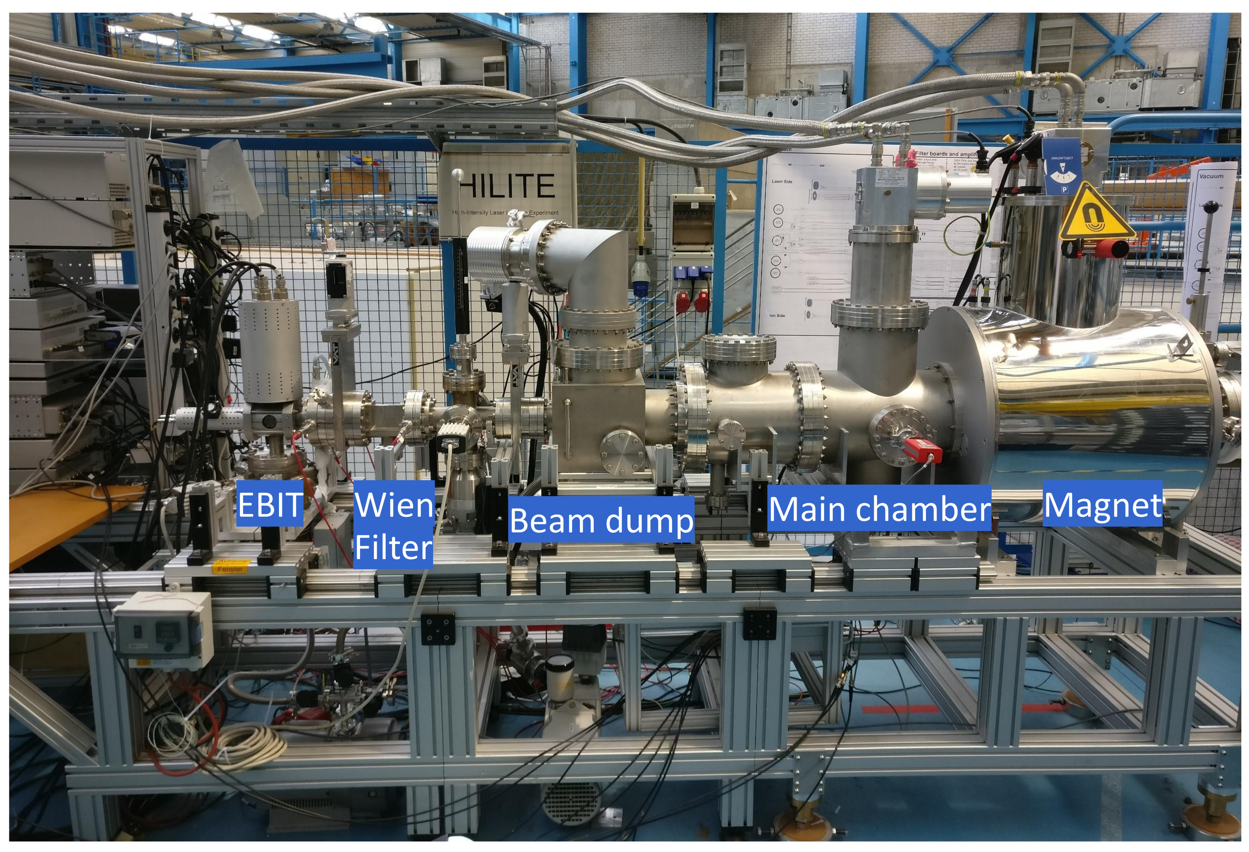
- First deceleration with PDT (b)
- Re-bunching with first capture electrode (c)
- Second deceleration with second endcap electrode (d)
- Reflection of ion bunch by second capture electrode with subsequent trapping by switching second endcap electrode on (e)

- MCP signal of released ions after a storage time of around 250 ms (a)
- The MCP detector is located approx. 40 cm from the trap centre

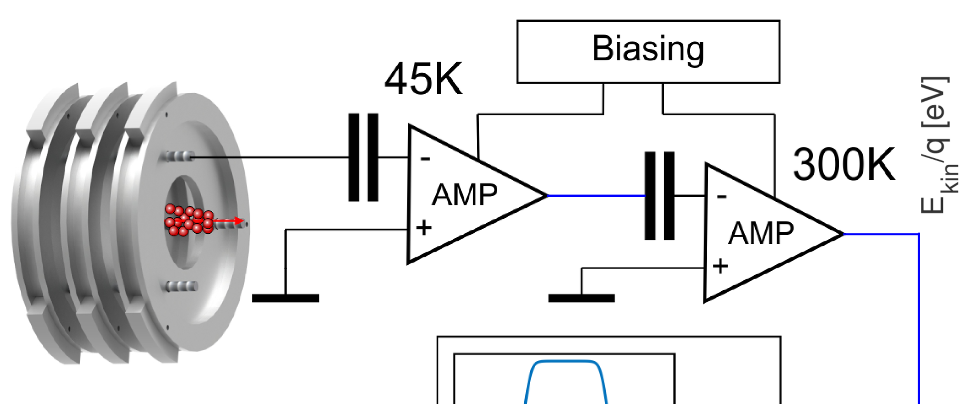
- ToF distribution of the relative ion number after analysis of the ‚pure' MCP signal (b)
- The tof-distribution corresponds to an energy distibution of the stored ions



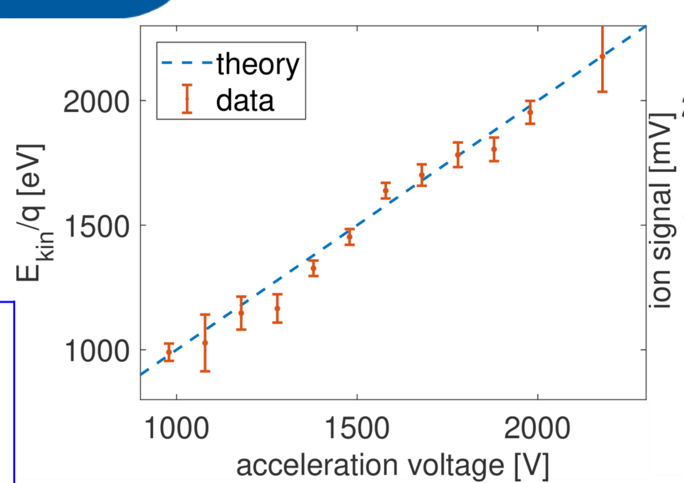
Experimental Setup



Single-Pass Charge-Counter



- Two-stage amplification of induced image charge
- Direct determination of ion number and ion energy from ion trace [3,4]

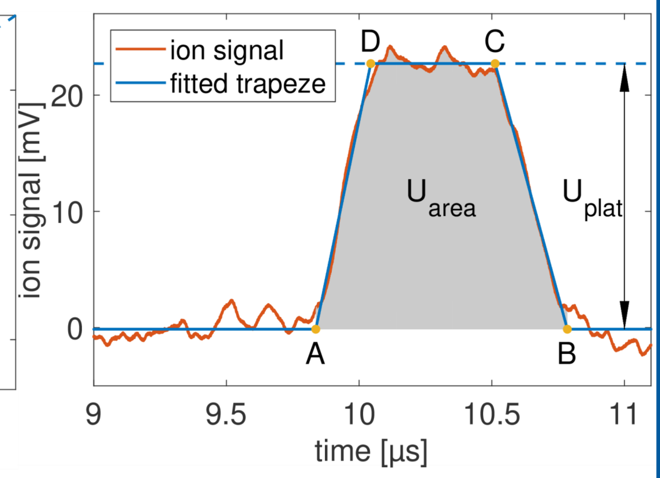


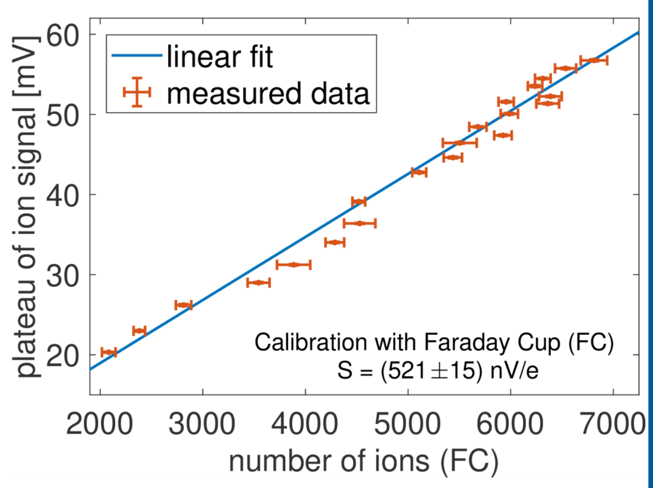
$$E_{kin} = \frac{1}{2} m\, L^2 \cdot \frac{U_{plat}^2}{U_{area}^2}$$

- L (= 0.1716 m) is the integral of the geometry function for the given electrode geometry

$$N_{ion} = \frac{U_{plat}}{S \cdot q \cdot e}$$

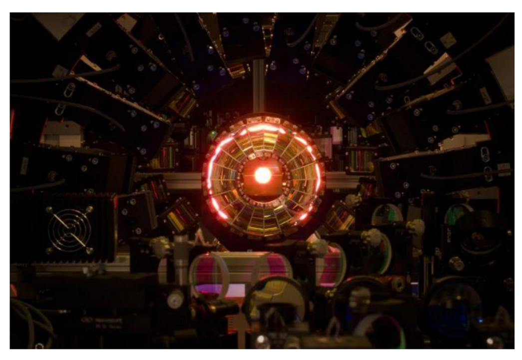
- S needs calibration for absolute ion number (N_{ion}) measurement





Future Plans

- Move the complete setup to Jena (HI Jena) – new building
- Access to ‚in-house' laser system in the high-intensity regime e.g



POLARIS

- 1.2 eV photon energy
- $10^{20} - 10^{21}$ W/cm² intensity regime
- 150 fs pulse duration

JETI

- 1.55 eV photon energy
- $10^{20} - 10^{21}$ W/cm² intensity regime
- 20 fs pulse duration

Upcoming Steps

- Detect stored ions inside the trap
- Apply active ion cooling and resistive cooling
- Find capture parameters for all charge states and proposed beam time targets
- Prepare setup for transport to laser facilities
- Laser beam times foreseen this year

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References
[1] J. Hofbrucker, A. Volotka (HI Jena) ; private communication
[2] Vogel et al. NIMB: Beam Interactions with Materials and Atoms **285**, 65 (2012)
[3] Schmidt et al. Rev. Sci. Inst. **86,** 113302 (2015)
[4] Publication in preparation

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