Universität Hamburg
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Bundesministerium
für Bildung
und Forschung

RECORD ACCUMULATION OF COLD ANTIPROTONS

TOWARDS A BEAM OF ANTIHYDROGEN AND NEW PHYSICS PERSPECTIVES

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ANTIMATTER EXPERIMENT: GRAVITY, INTERFEROMETRY, SPECTROSCOPY

$$Ps^* + \bar{p} \rightarrow \bar{H}^* + e^-$$

"charge exchange reaction"

Positronium
→ bound state of
electron + positron
→ laser-excited to
Rydberg state ($\sigma_{\bar{H}} \sim n_{Ps}^4$)

Antiproton
→ available from Antiproton Decelerator (**AD**) at CERN
→ trapped & cooled

Antihydrogen
→ antiatom consisting of
antiproton + positron
→ **gravity** measurement to compare to regular H

Phys. Rev. Lett. **132**, 083402 (2024)

Commun.Phys. 4 (2021) 1, 19

AEgIS

PHYSICAL REVIEW LETTERS 132, 083402 (2024)

Editors' Suggestion | Featured in Physics

Positronium Laser Cooling via the 1^3S-2^3P Transition with a Broadband Laser Pulse

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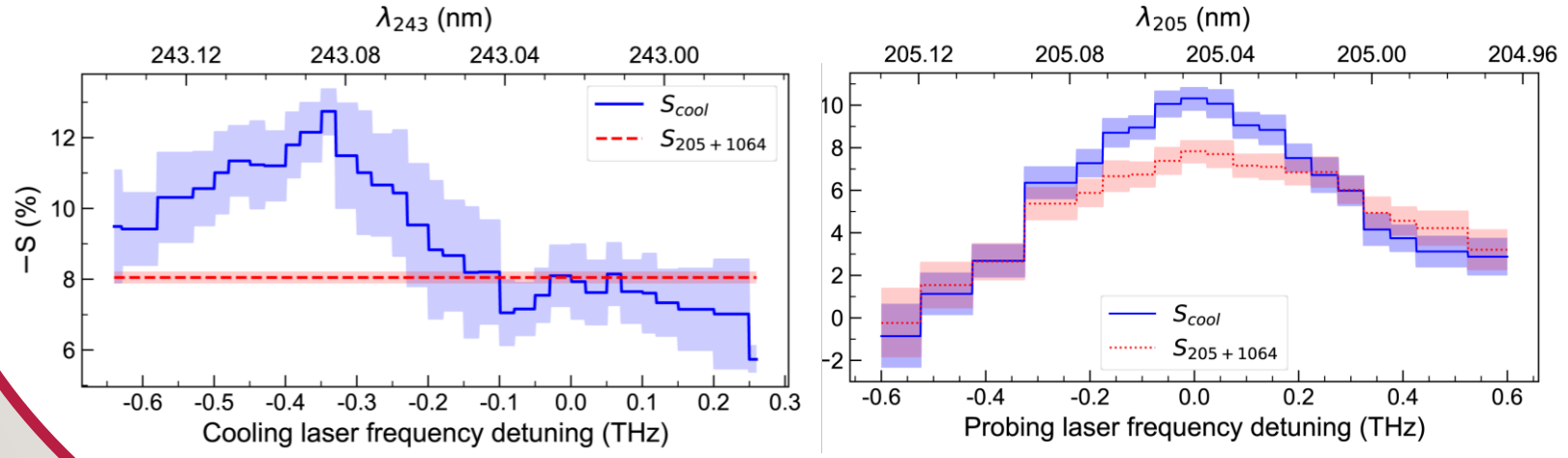
(AEgIS Collaboration)



Positronium

→ bound state of **electron + positron**

→ laser-excited to **Rydberg state ($\sigma_{\bar{H}} \sim n_{Ps}^4$)**

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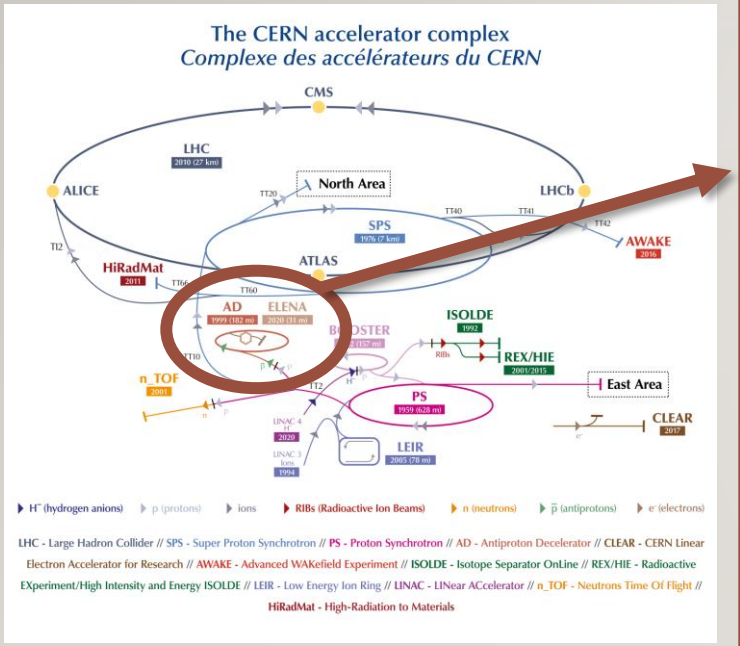
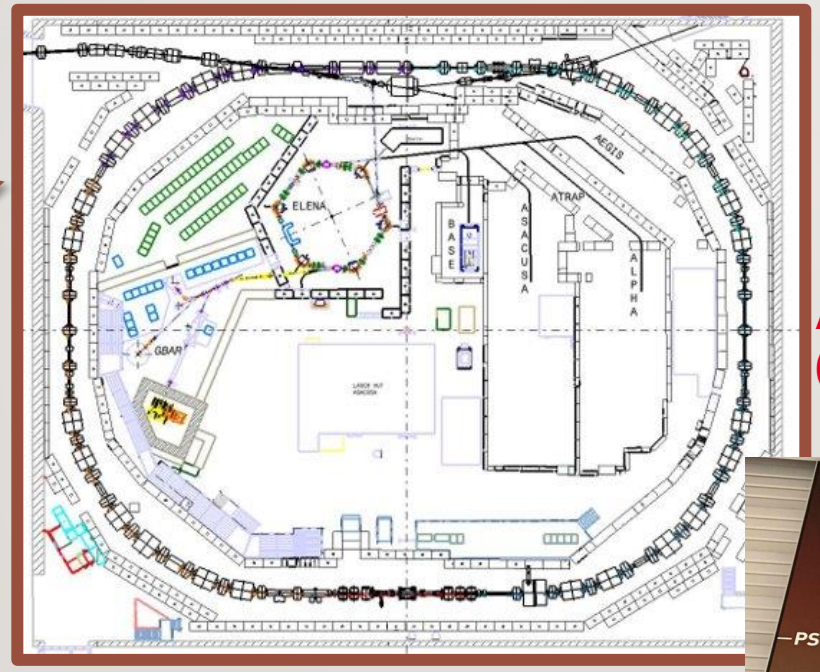
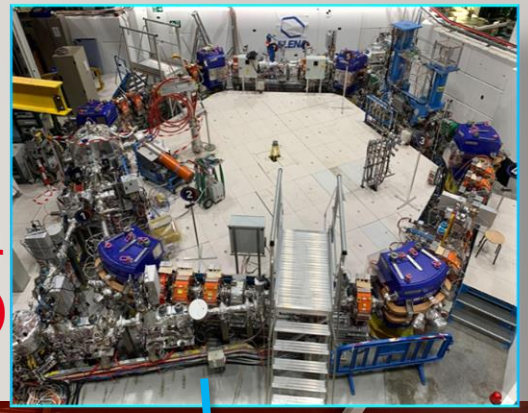
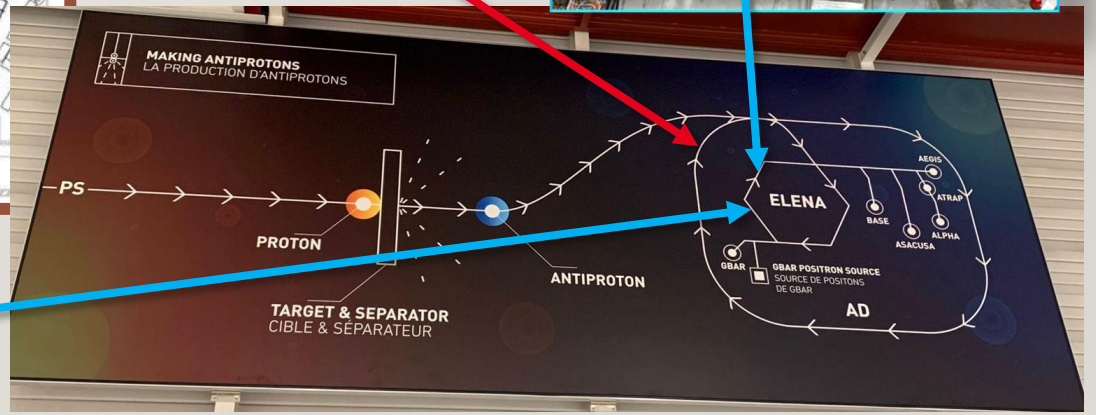
CERN'S ANTIPROTON DECELERATOR





Antiproton Decelerator (circumference: 188 m)





Extra Low ENergy Antiproton decelerator (circumference: 30 m)

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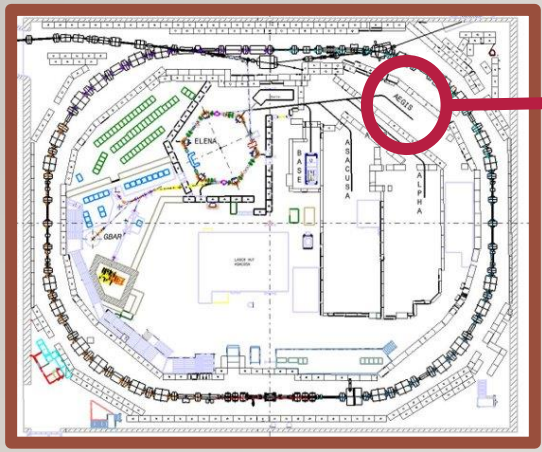
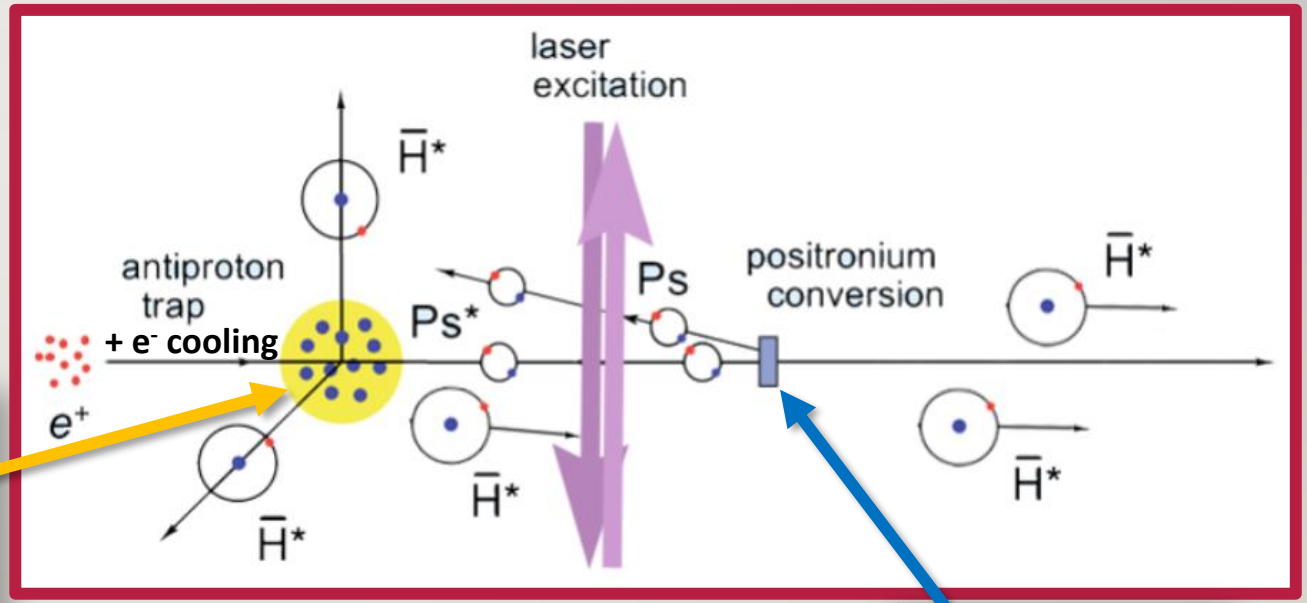
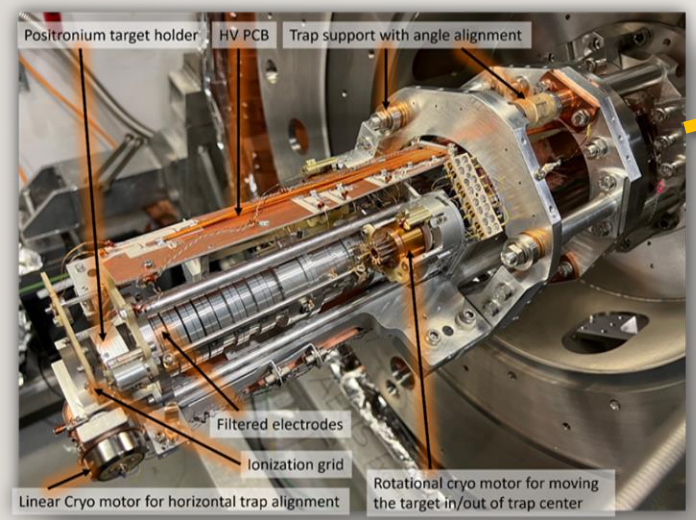
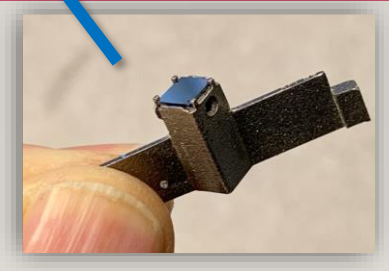
$$Ps^* + \bar{p} \rightarrow \bar{H}^* + e^-$$





Penning-Malmberg trap





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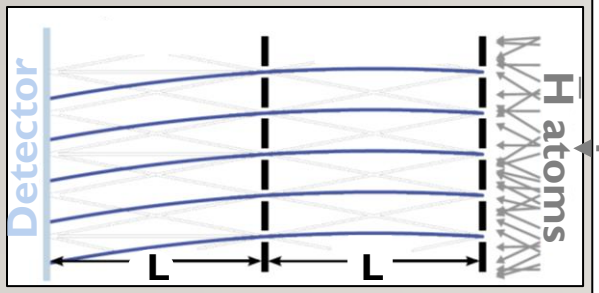
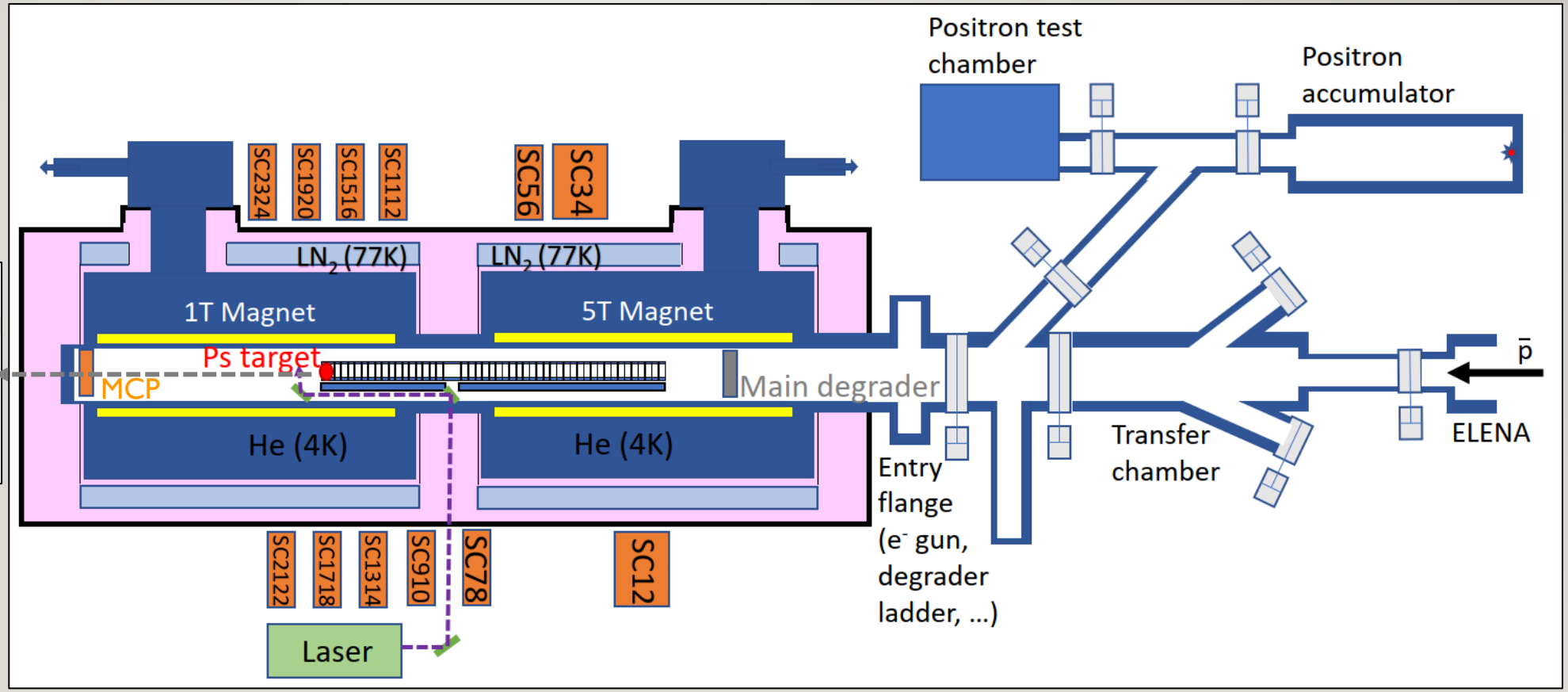
Gravity measurement with deflectometer



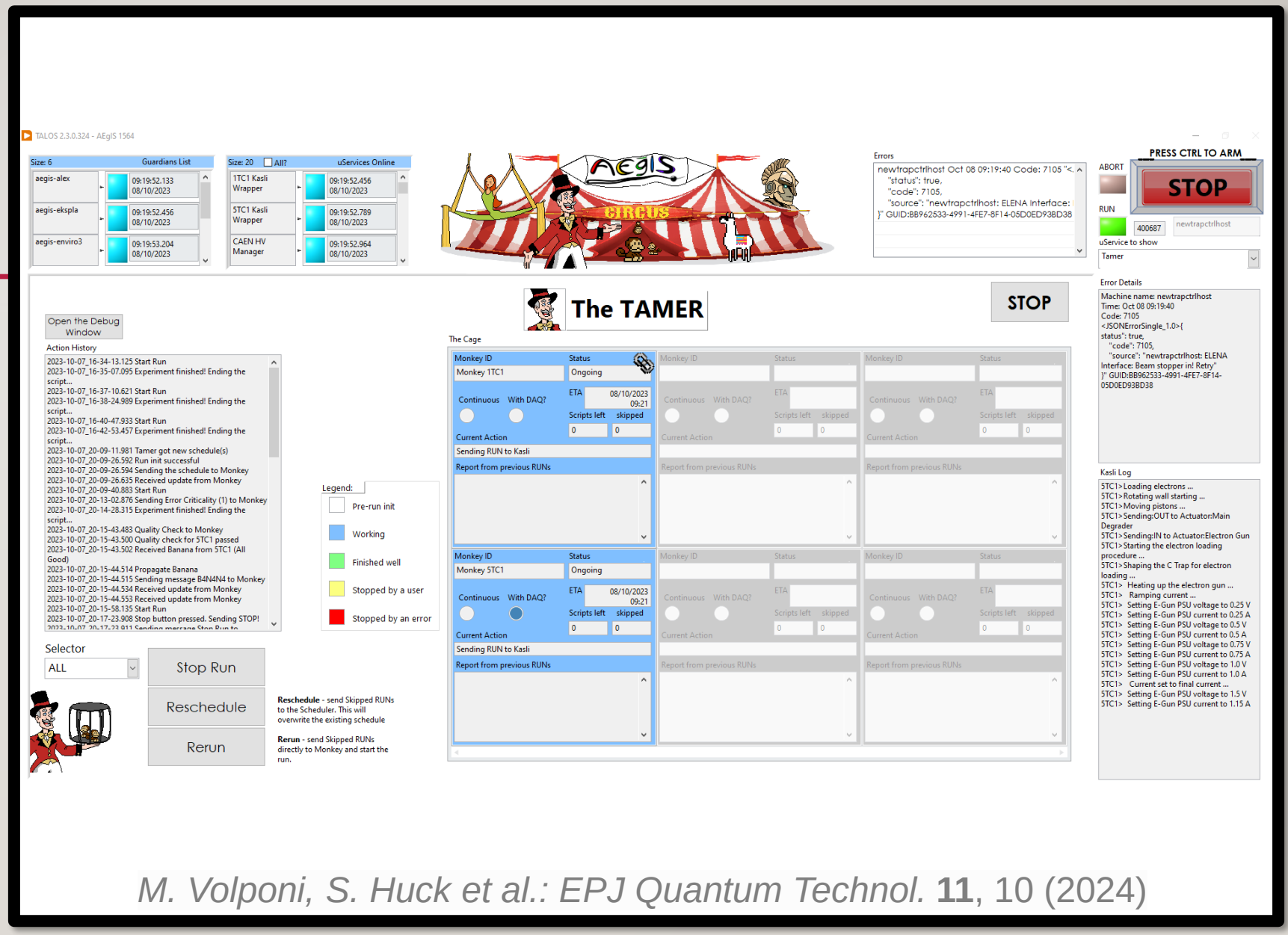
$\Delta y = -1/2 g \Delta t^2$



CIRCUS

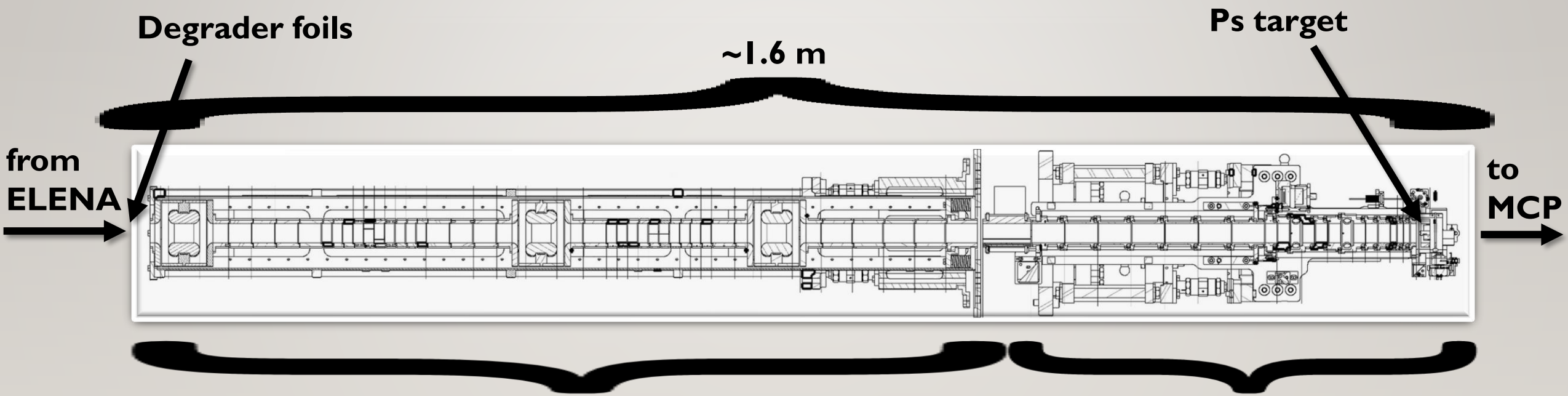
COMPUTER INTERFACE FOR RELIABLY CONTROLLING, IN AN UNSUPERVISED MANNER, SCIENTIFIC EXPERIMENTS

- **<u>Trap electrode control</u>: Sinara hardware & ARTIQ software**
- **<u>Automation</u>: TALOS framework**



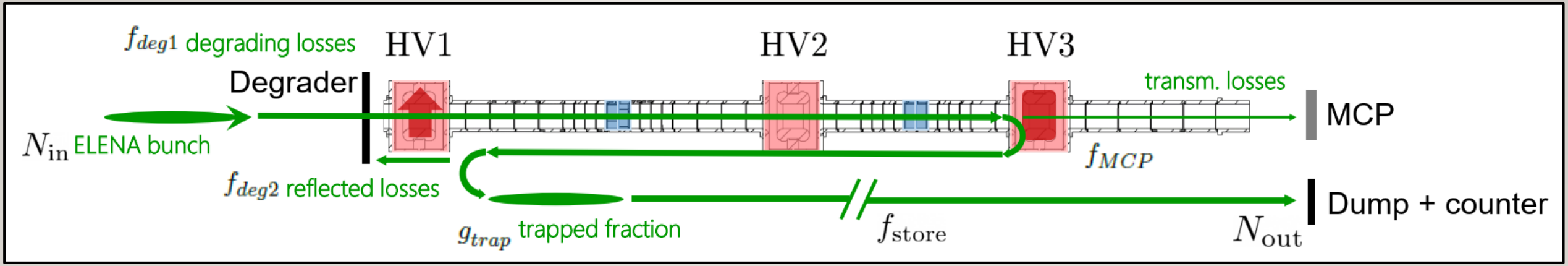
M. Volponi, S. Huck et al.: EPJ Quantum Technol. **11**, 10 (2024)

PENNING TRAP SYSTEM

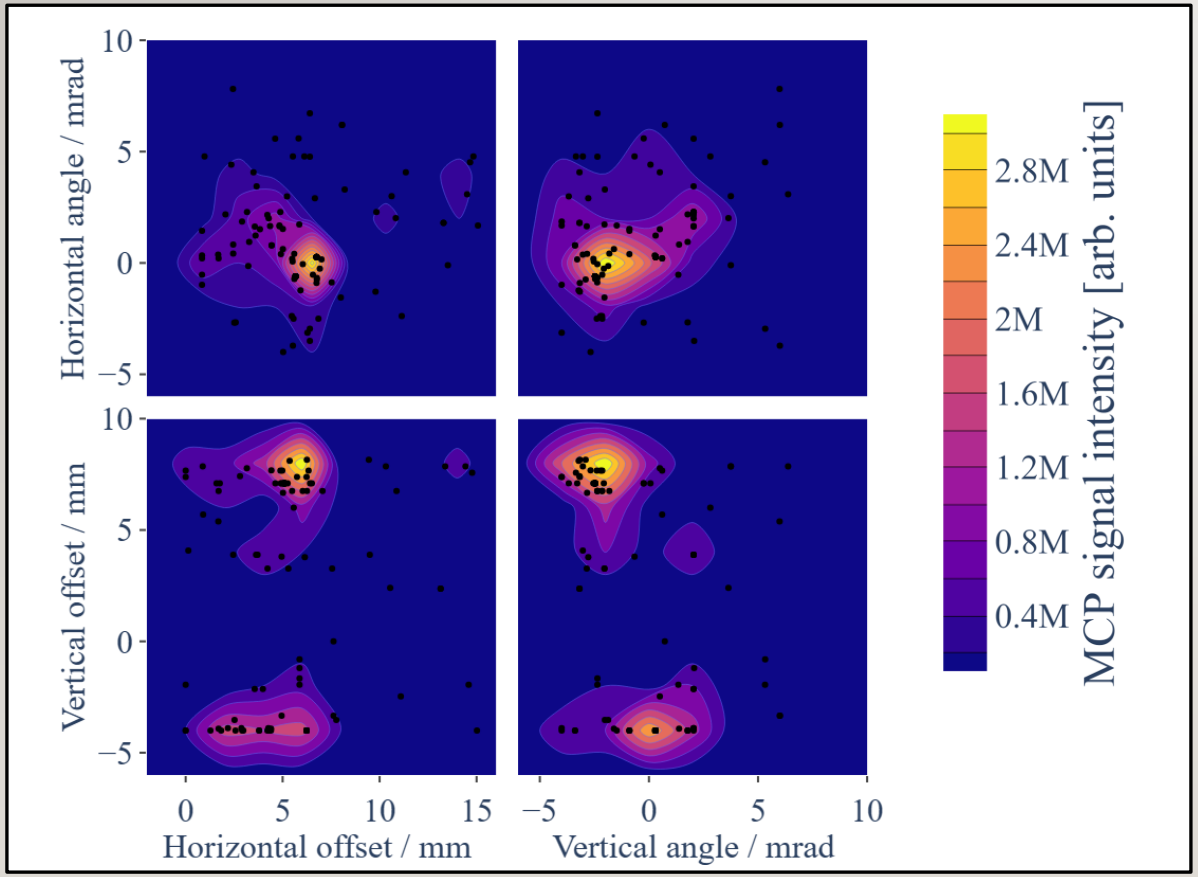


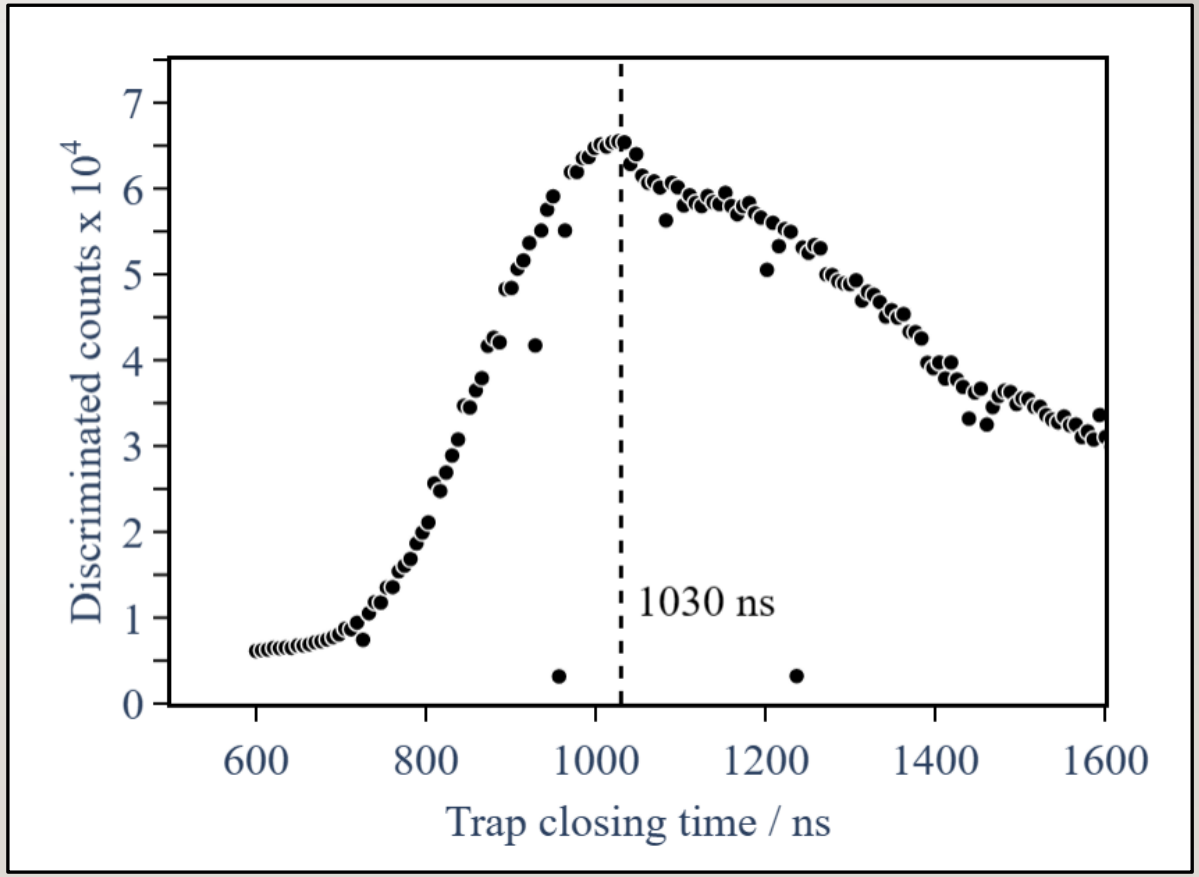
CAPTURING & TRAPPING ANTIPROTONS

5T Trap



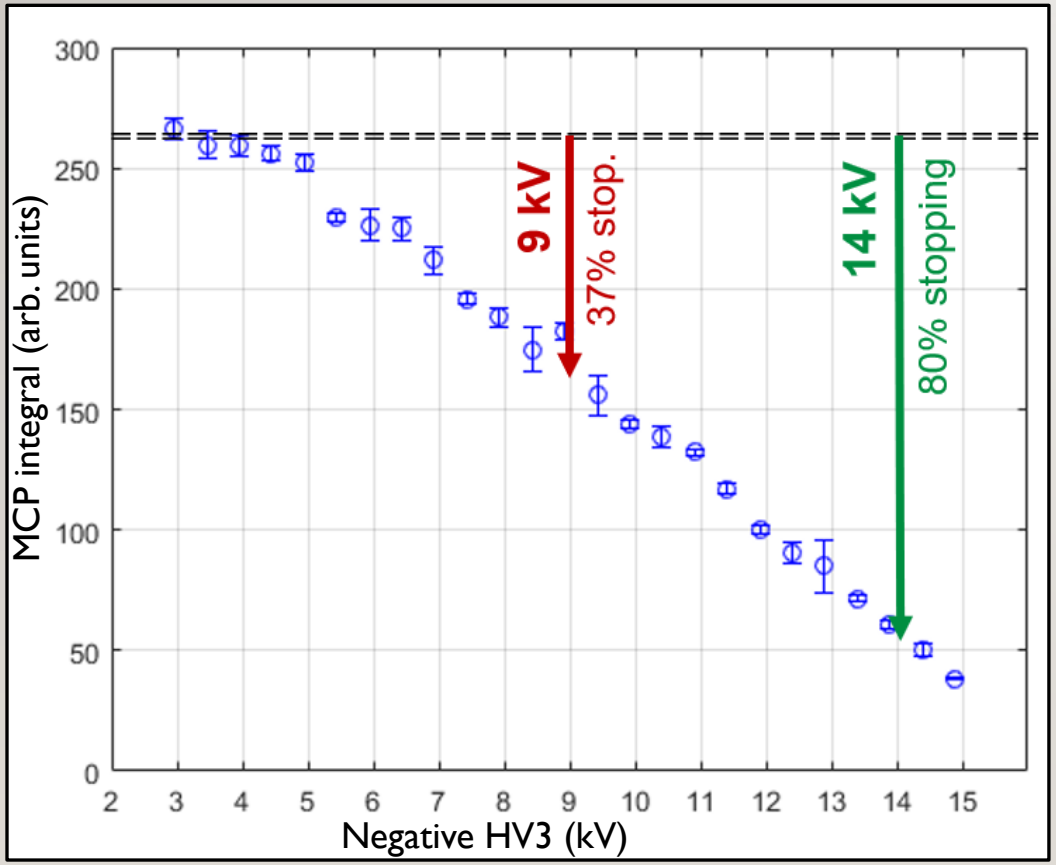
ANTIPROTON CAPTURE PARAMETER OPTIMIZATION

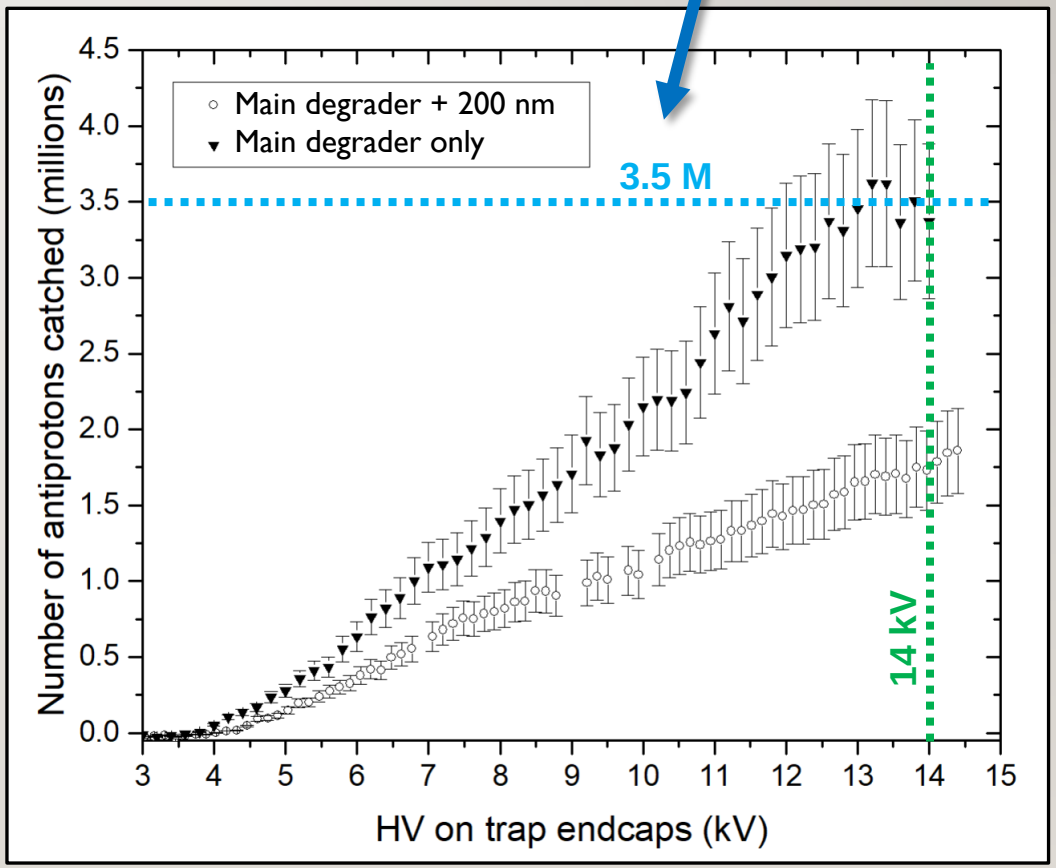




EFFICIENT ANTIPROTON CAPTURE

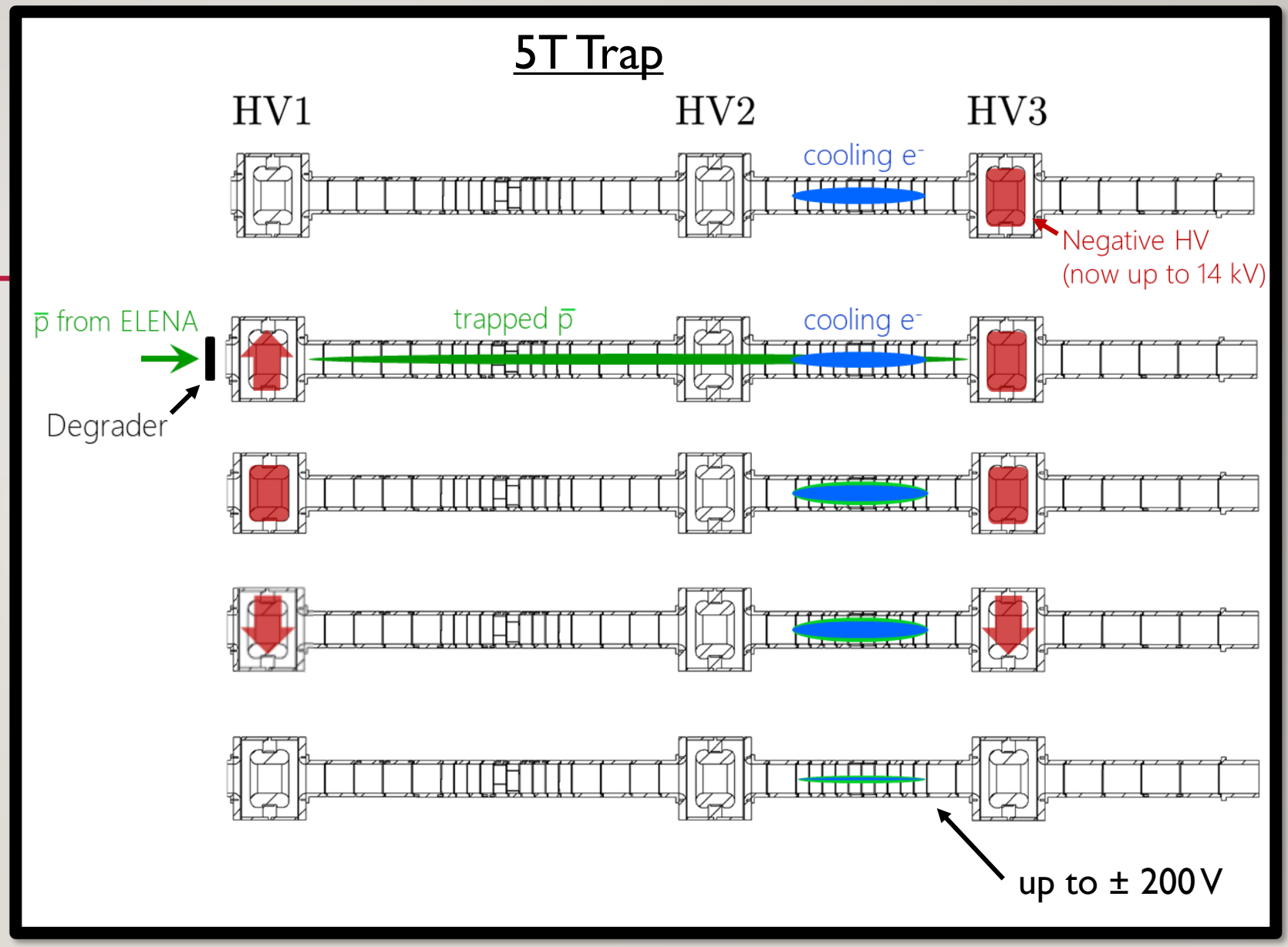
Routine capture efficiencies of the order of 70%





COLD ANTIPROTON TRAPPING

1. Preparation of electron plasma
2. Antiproton energy degradation & capture
3. Antiproton sympathetic cooling with electrons
4. Dumping of the hot fraction
5. Rotating Wall compression, more cooling



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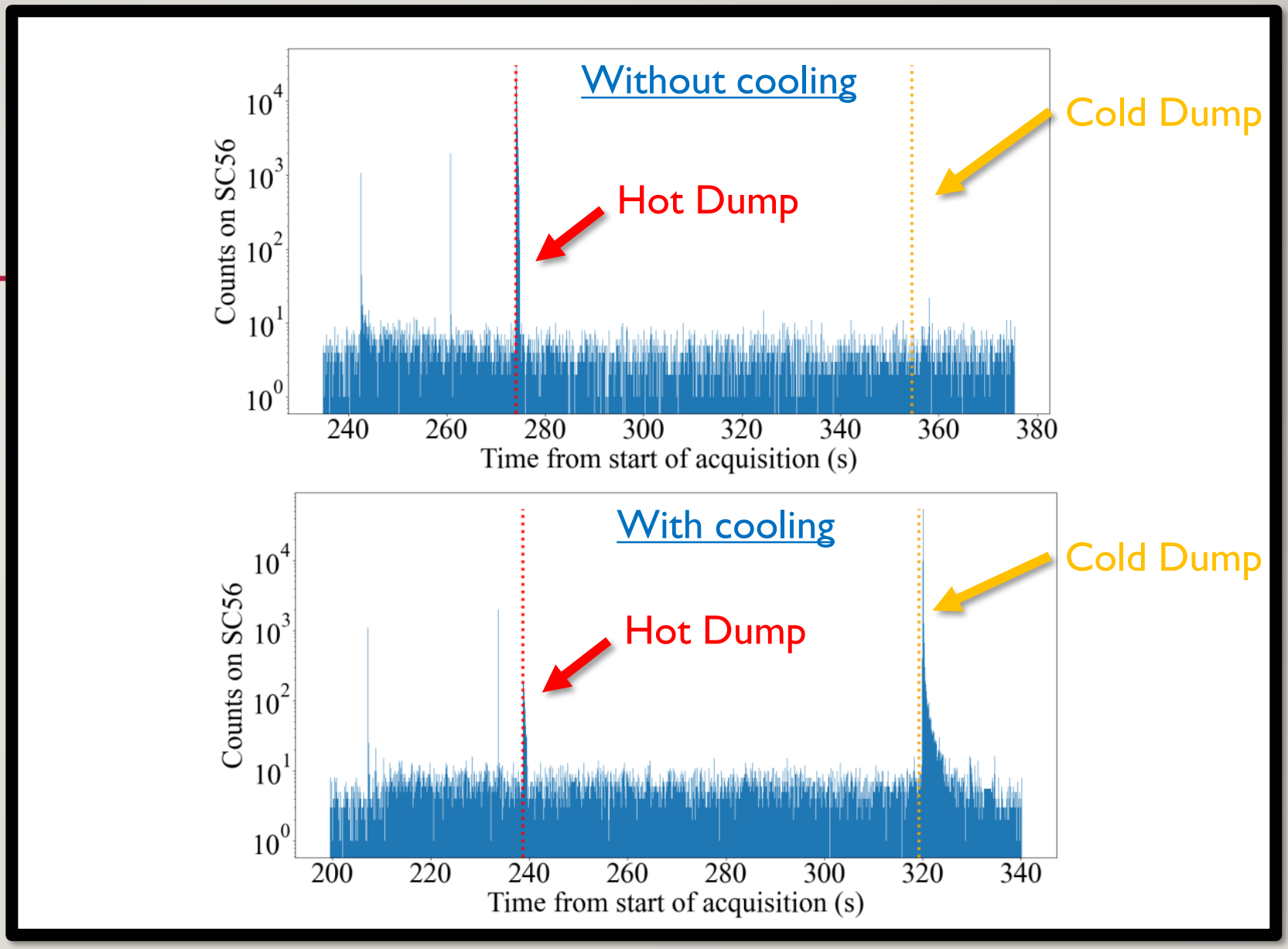

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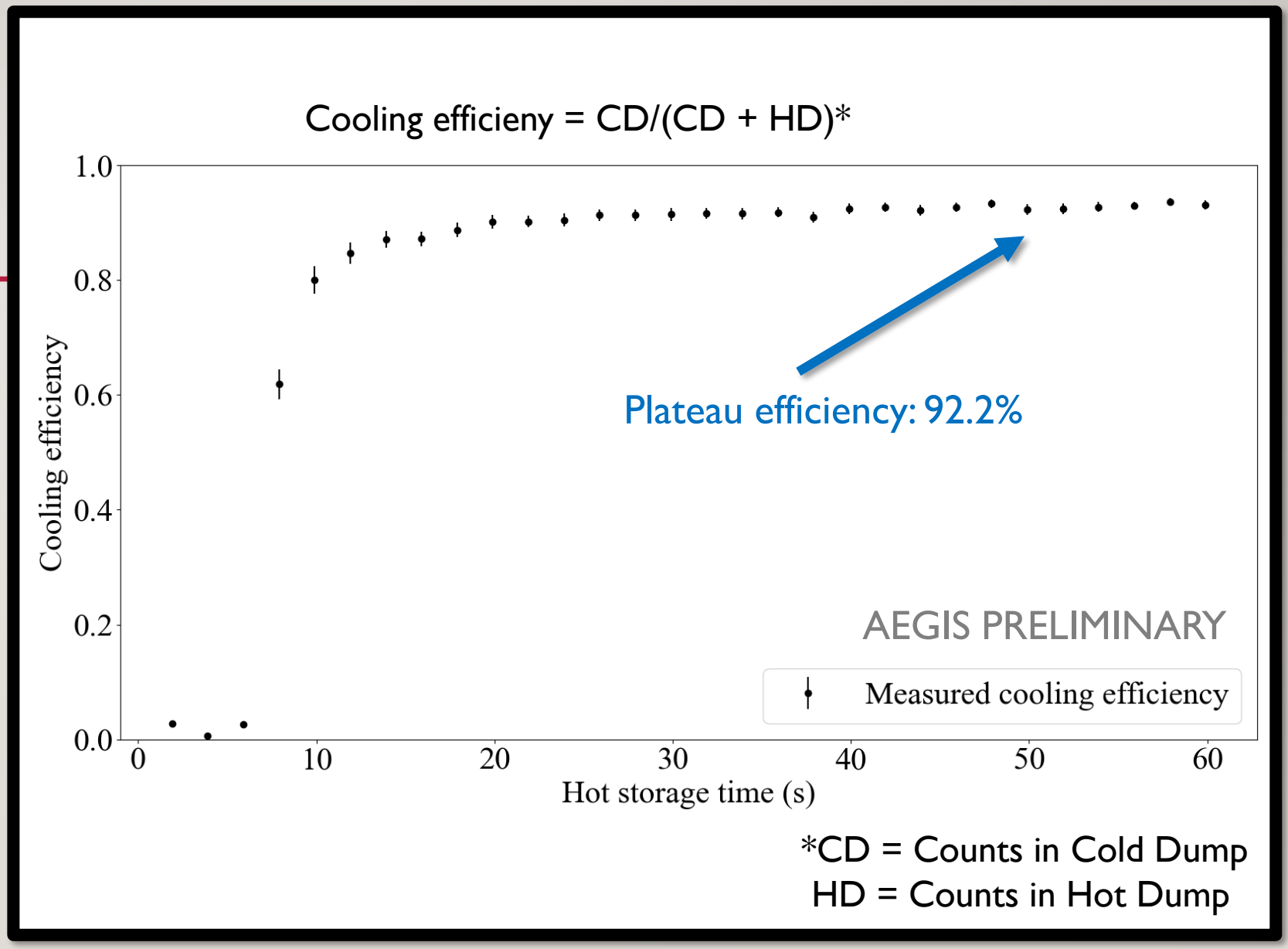

*CD = Counts in Cold Dump
HD = Counts in Hot Dump

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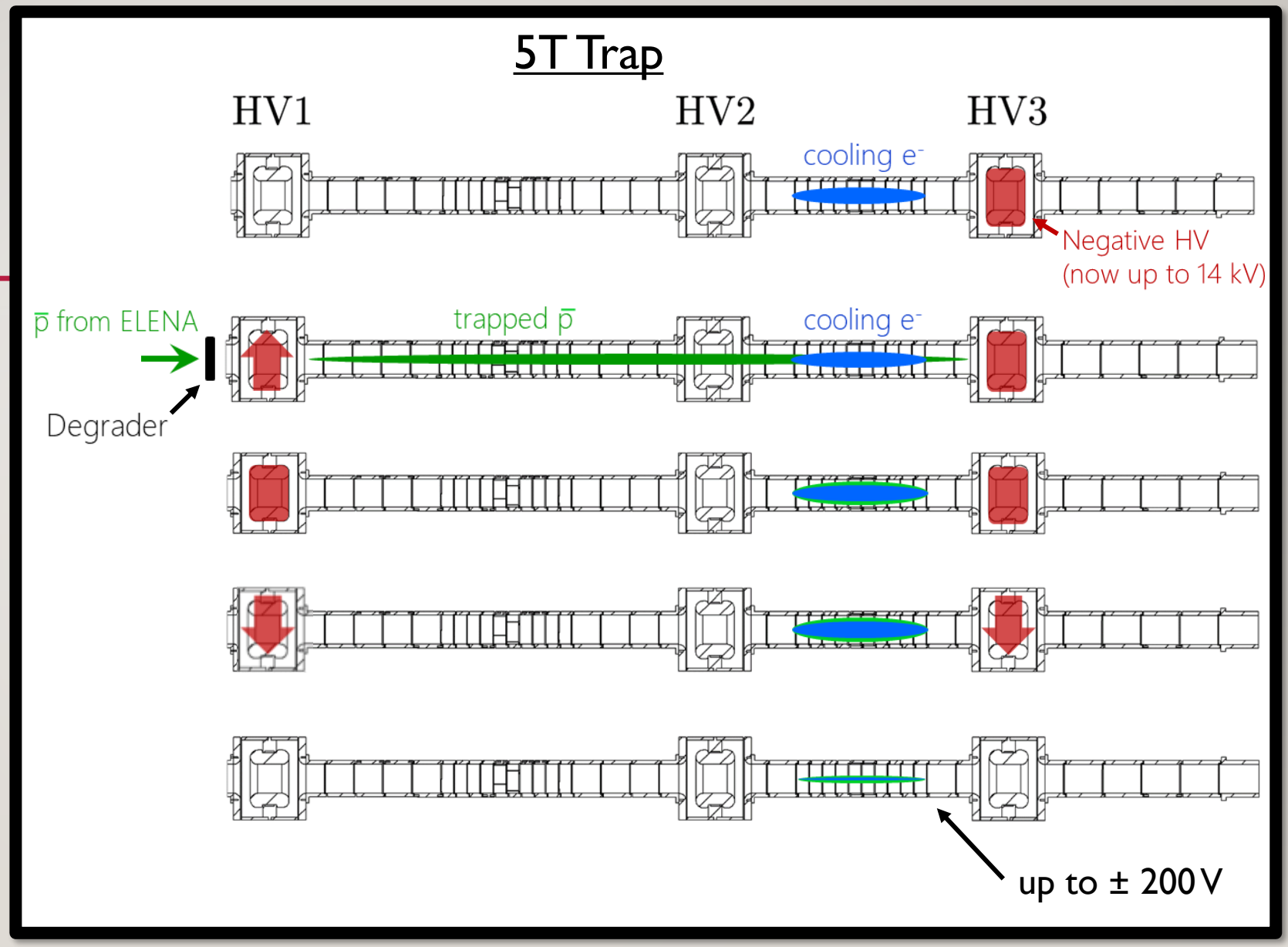

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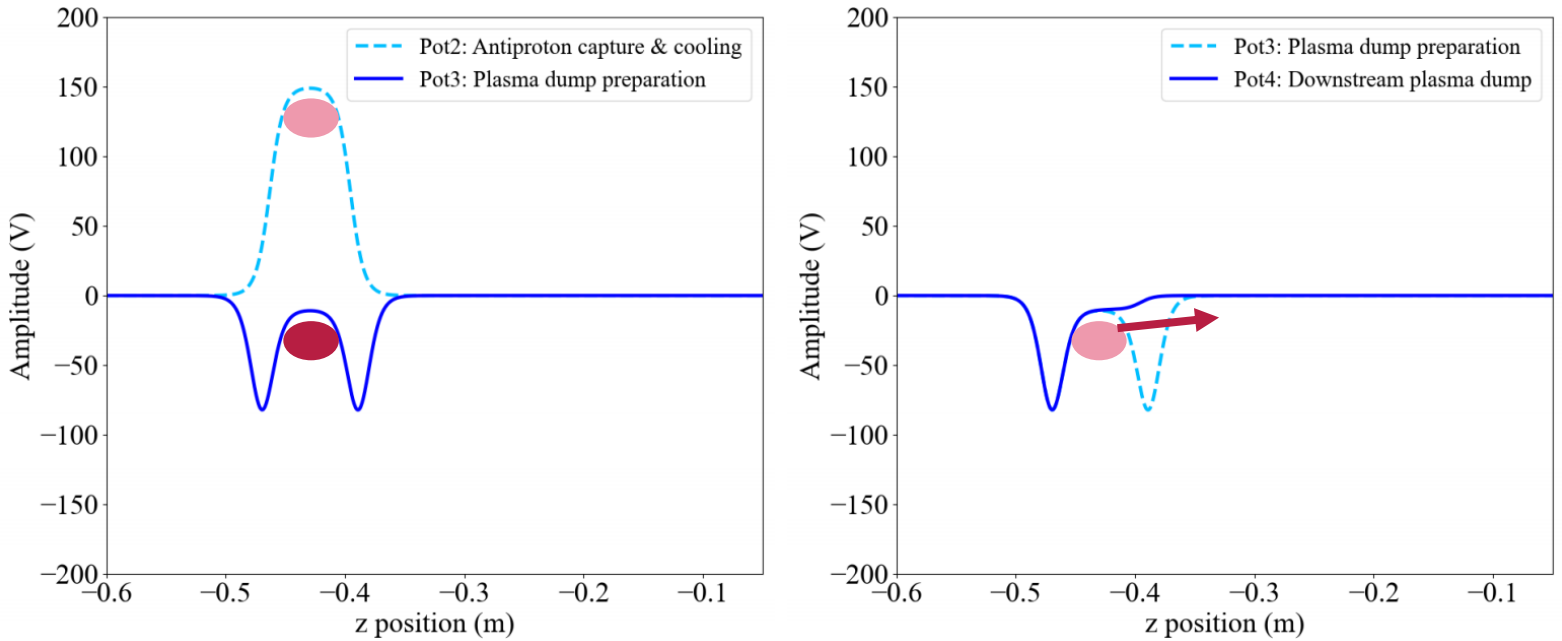
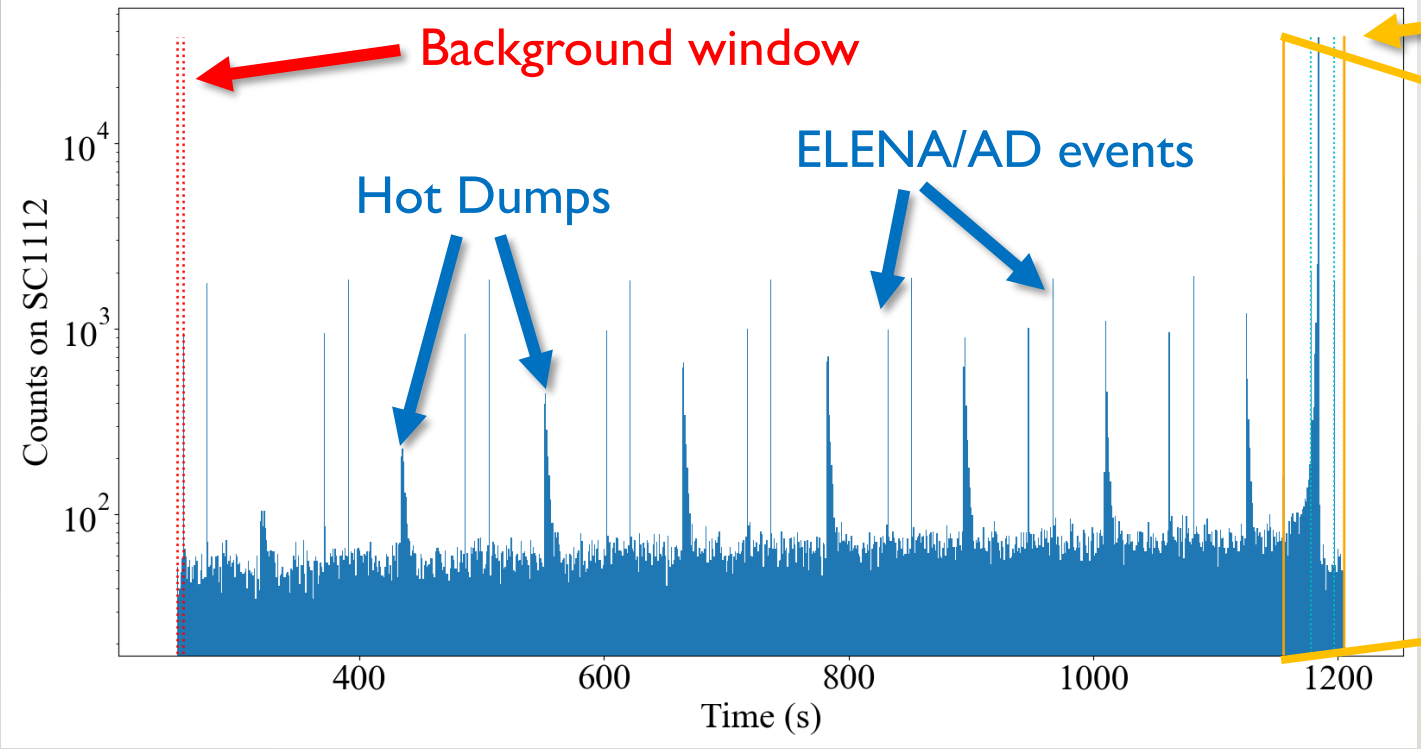
→ Repetition of the steps for accumulation of cold antiprotons; then **Cold Dump**

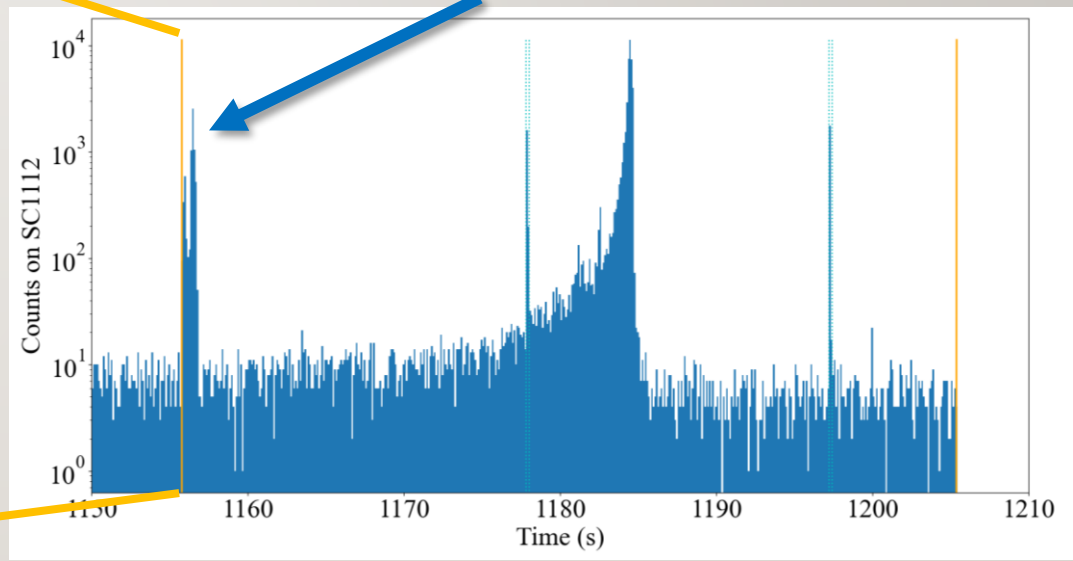
5T Trap



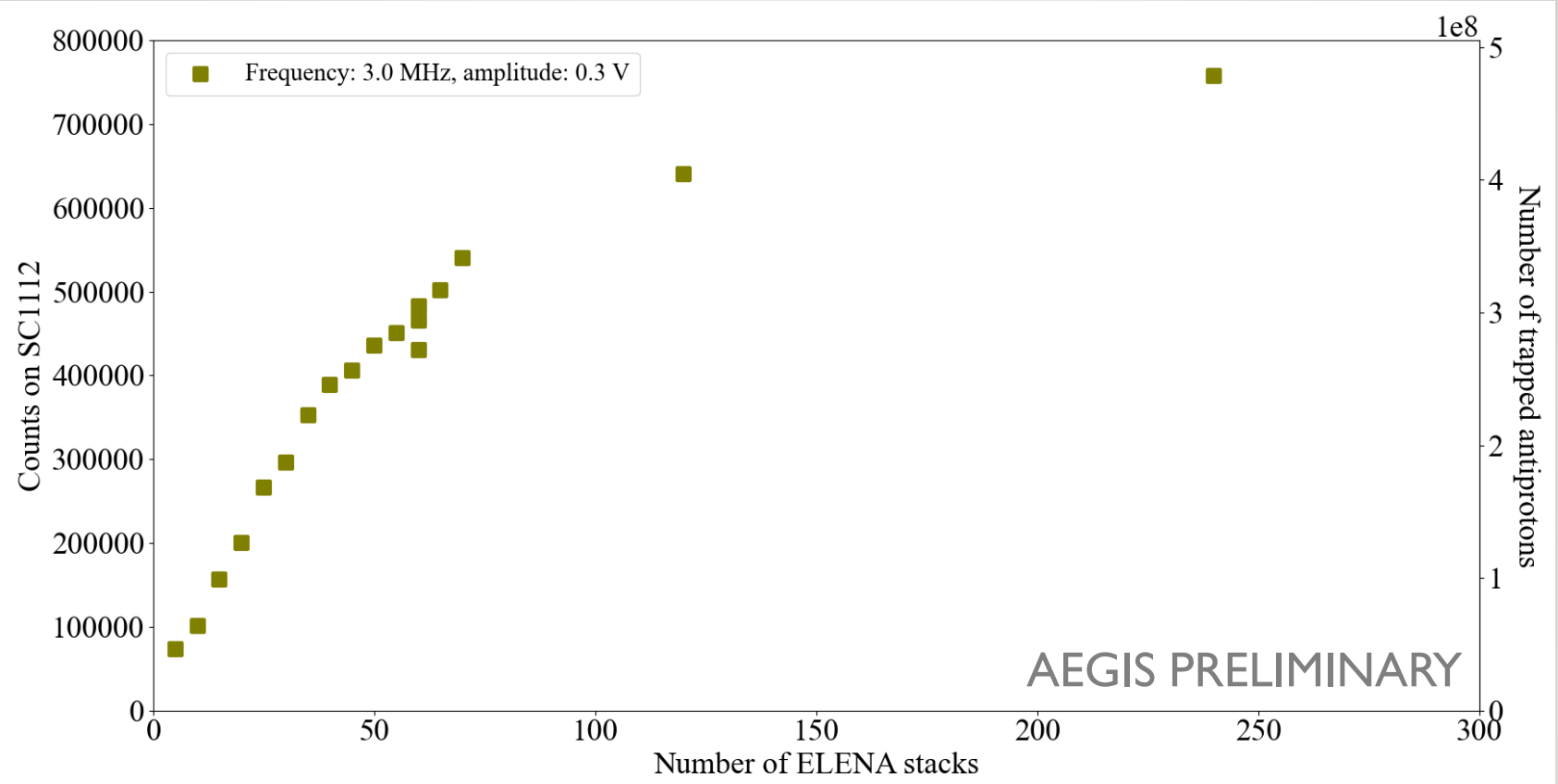
antiproton capture – hot storage – Hot Dump – cold storage and compression – antiproton capture – ... – Cold Dump

SIGNAL ANALYSIS EXAMPLE: STACKING OF 8 ELENA SHOTS

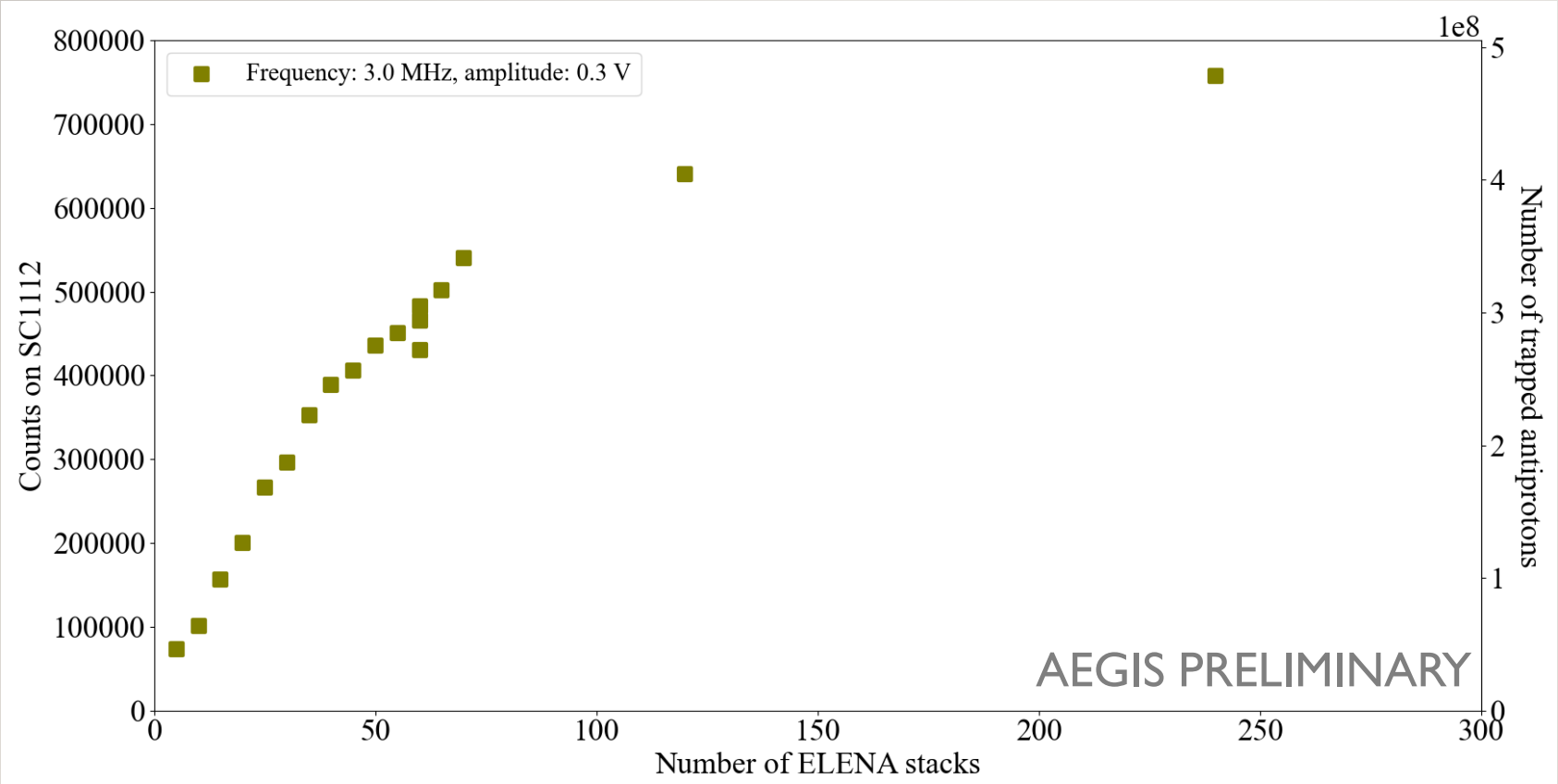




RECORD ACCUMULATION OF COLD ANTIPROTONS

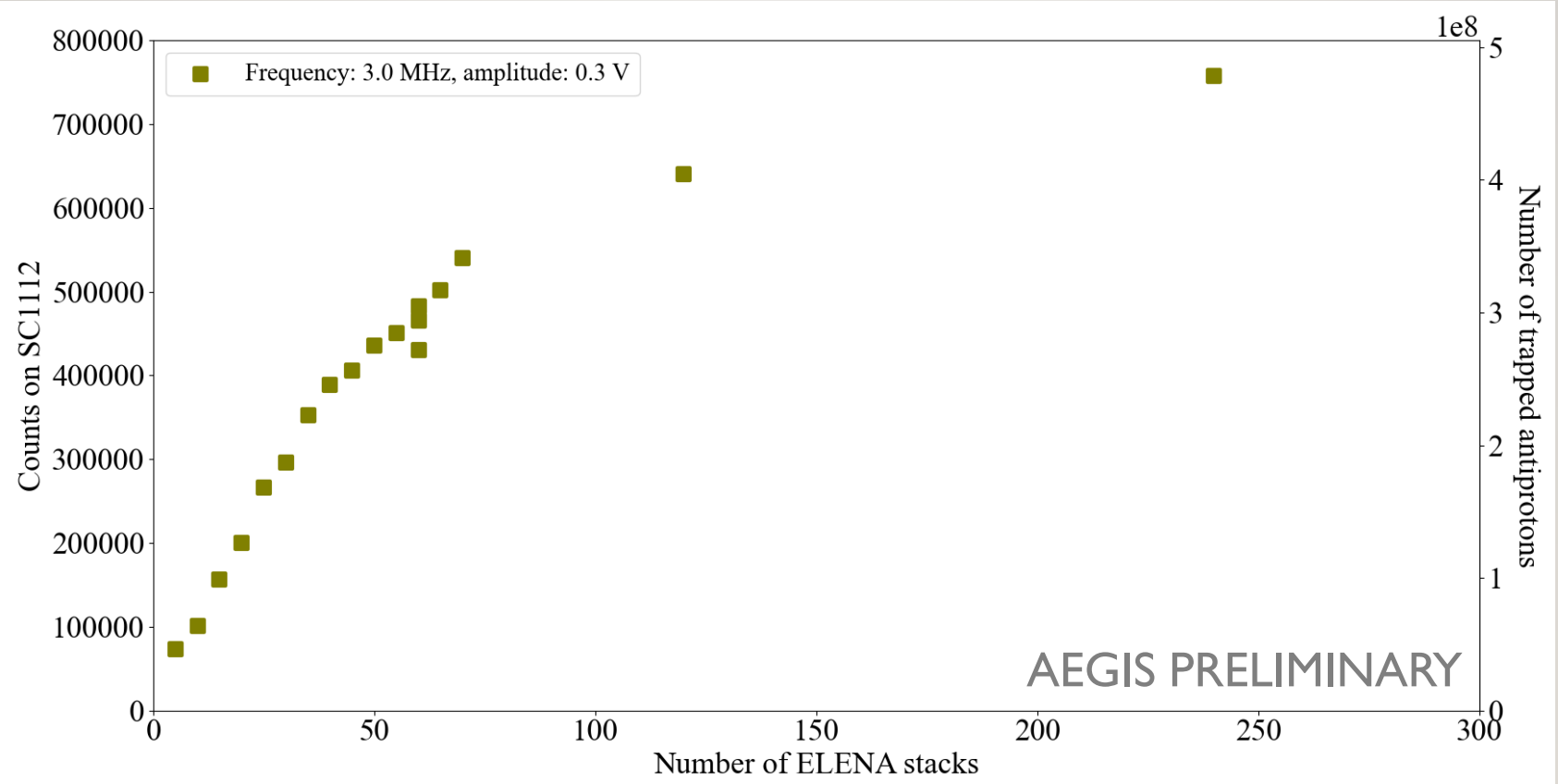


RECORD ACCUMULATION OF COLD ANTIPROTONS



- Boosted number of produced antihydrogen atoms ($N_{\bar{H}} \sim N_{\bar{p}}$)
- Formation & study of antiprotonic atoms
- Antiproton spectroscopy
- BSM & Dark Matter searches
- …

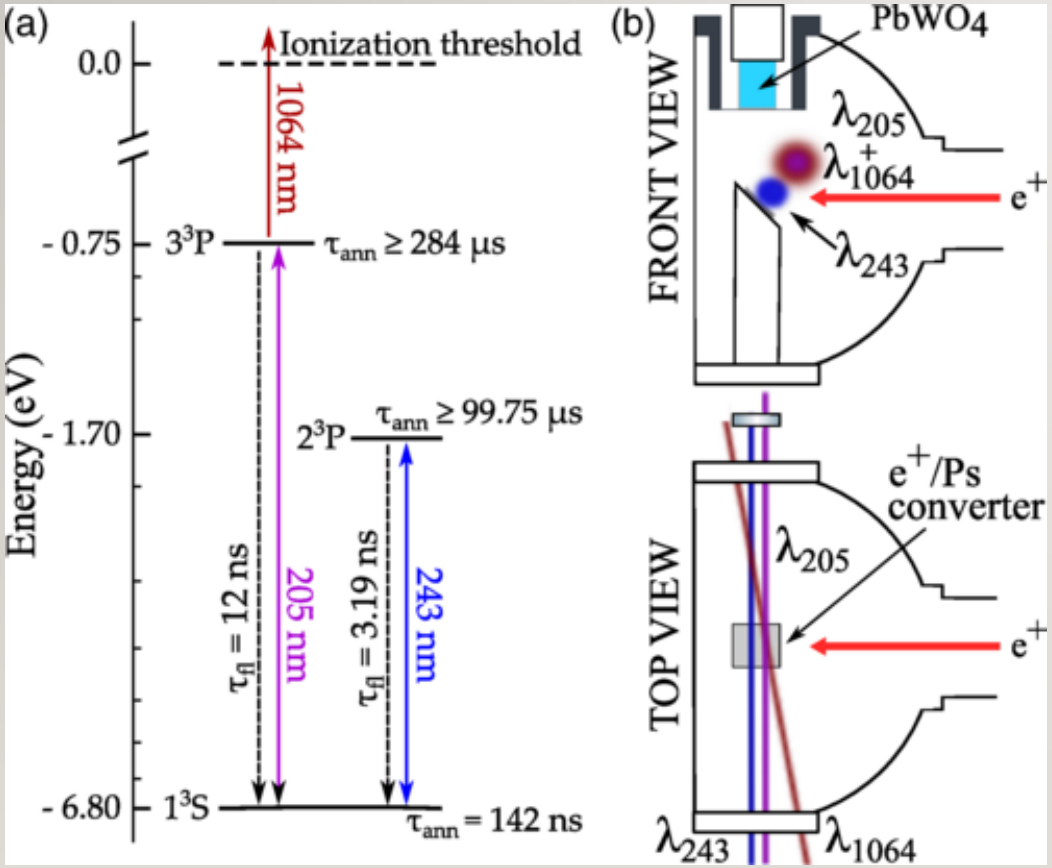
RECORD ACCUMULATION OF COLD ANTIPROTONS

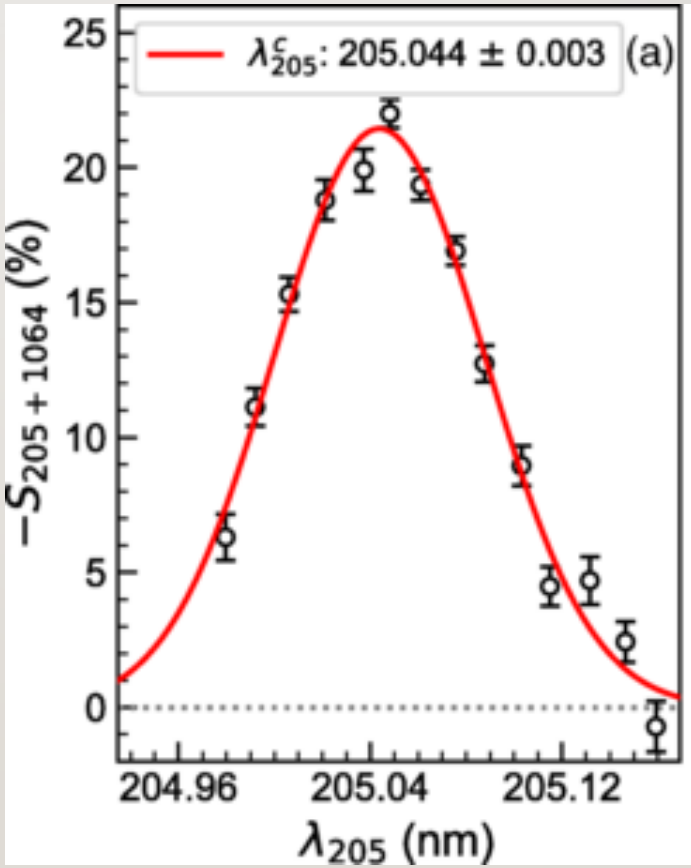


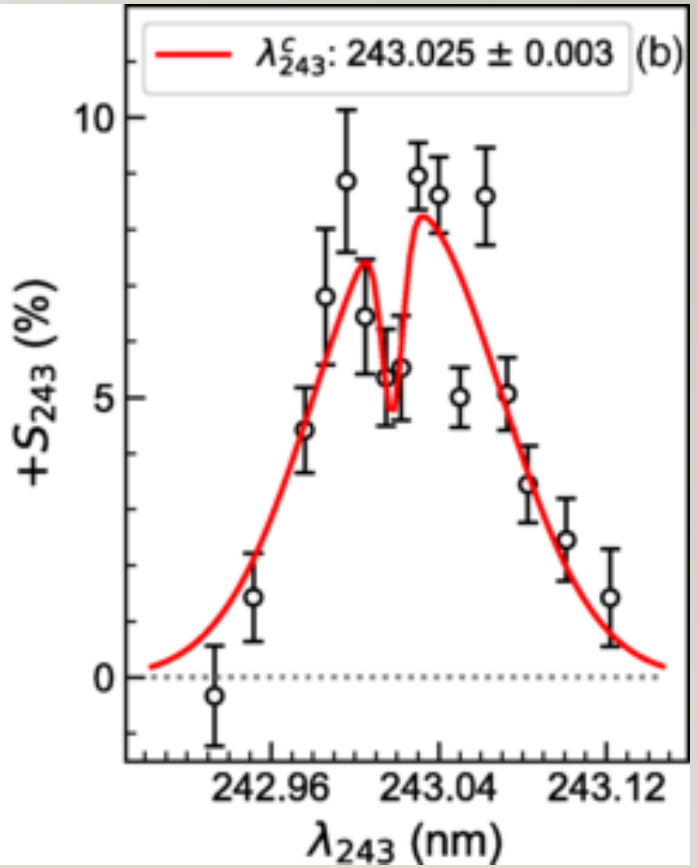
THANK YOU FOR YOUR ATTENTION!

BACKUP

PS LASER COOLING







SEXAQUARK

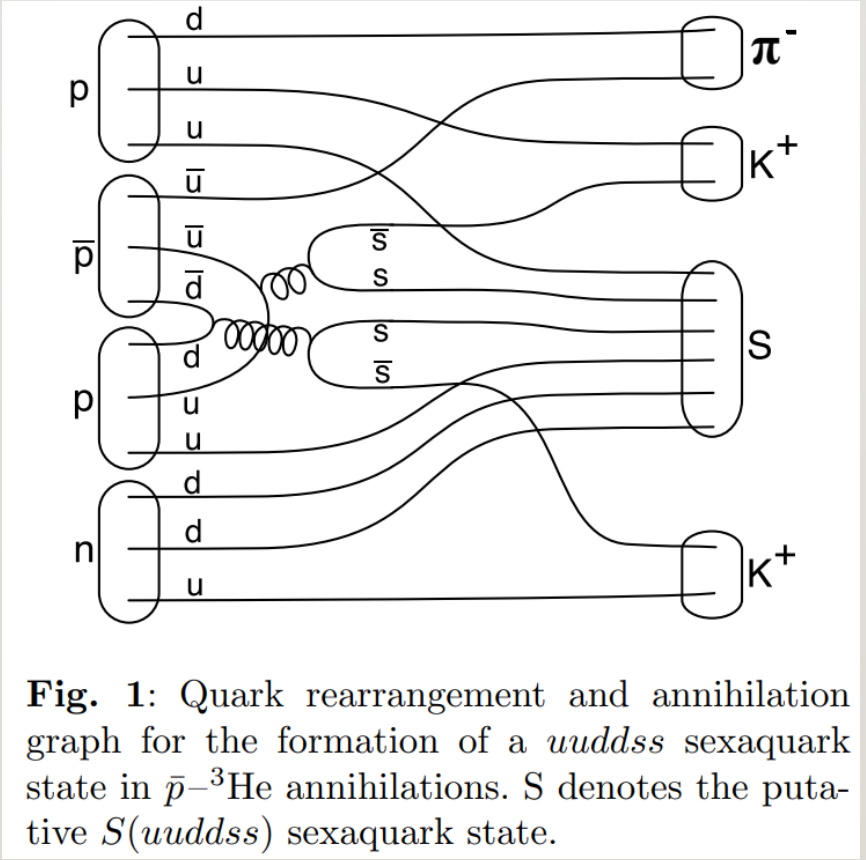
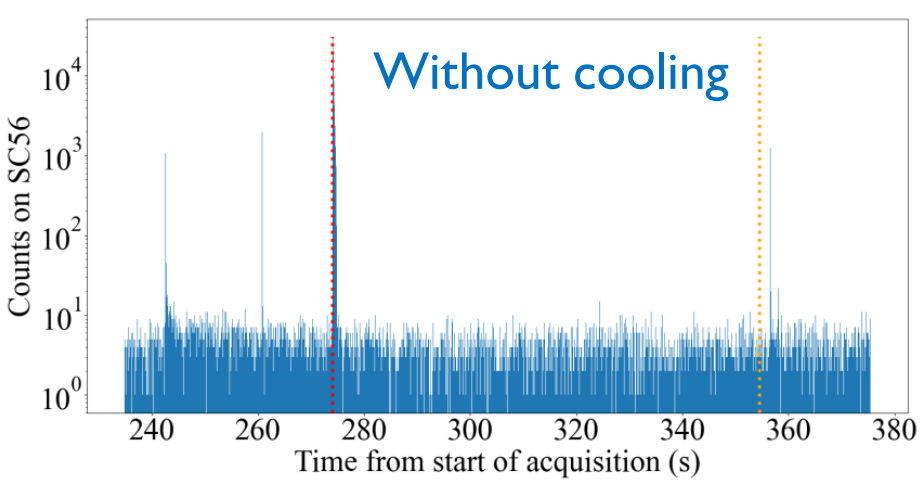
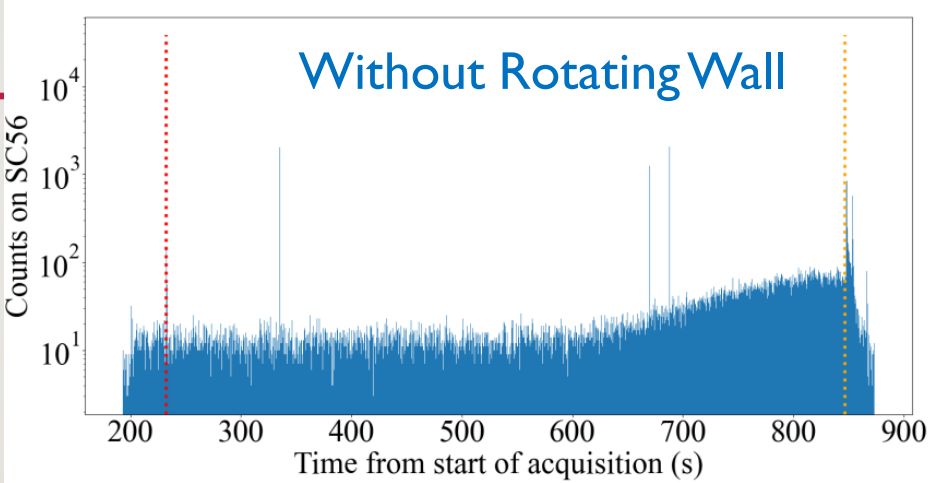


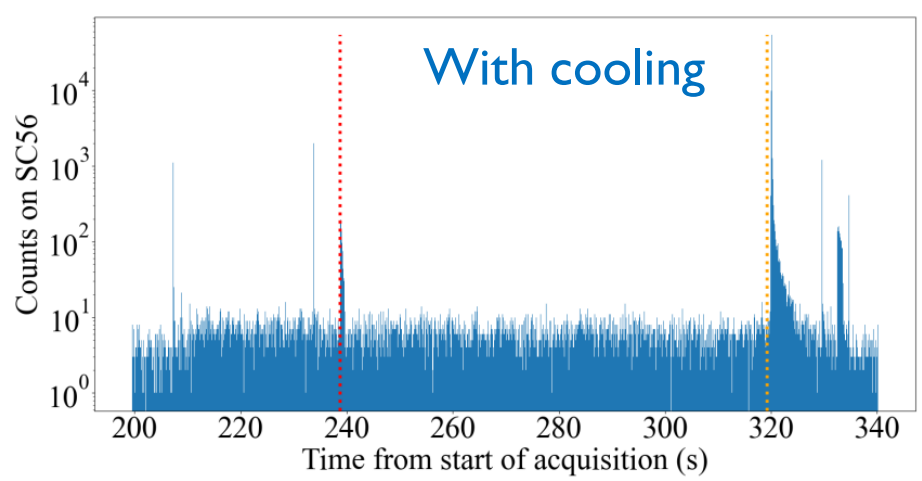
Fig. 1: Quark rearrangement and annihilation graph for the formation of a *uuddss* sexaquark state in $\bar{p}$–^{3}He annihilations. S denotes the putative $S(uuddss)$ sexaquark state.

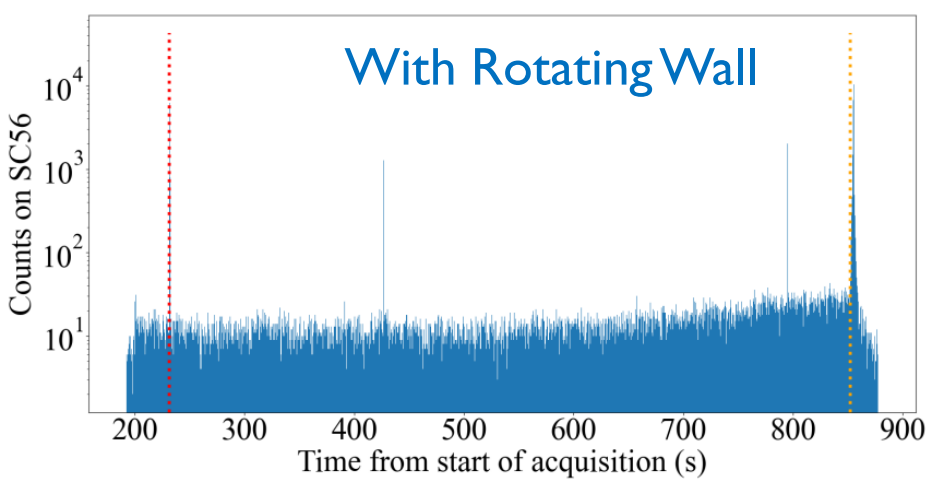
Doser, M., Farrar, G. & Kornakov, G. *Eur. Phys. J. C* **83**, 1149 (2023)

ELECTRON COOLING & RW









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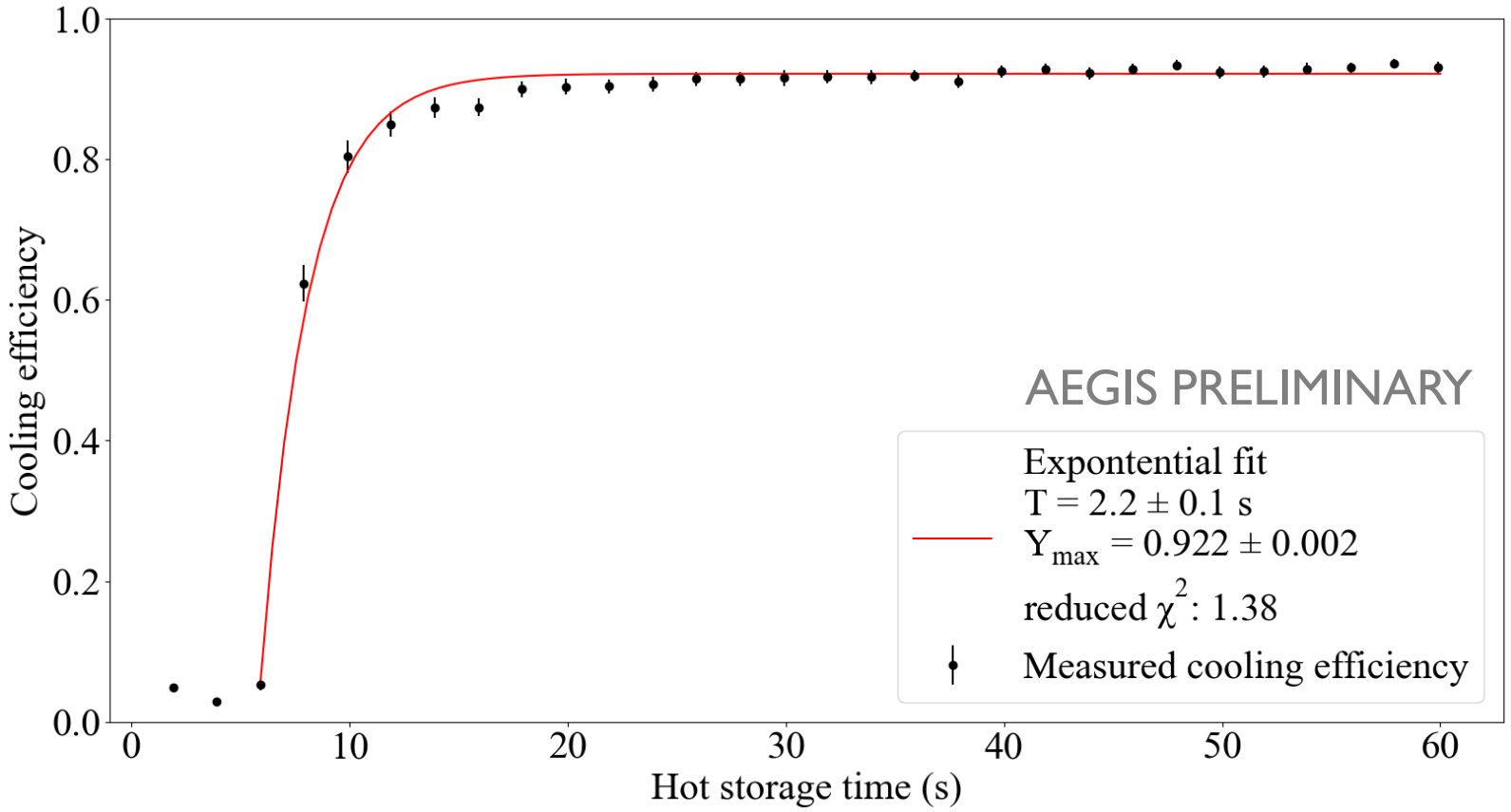
5T Trap

Cooling efficieny = CD/(CD + HD)*



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