Activity A4: low energy nuclear physics

NorCC workshop 27.09.2023 in Bergen

Norwegian AEgIS group in the last 2 years

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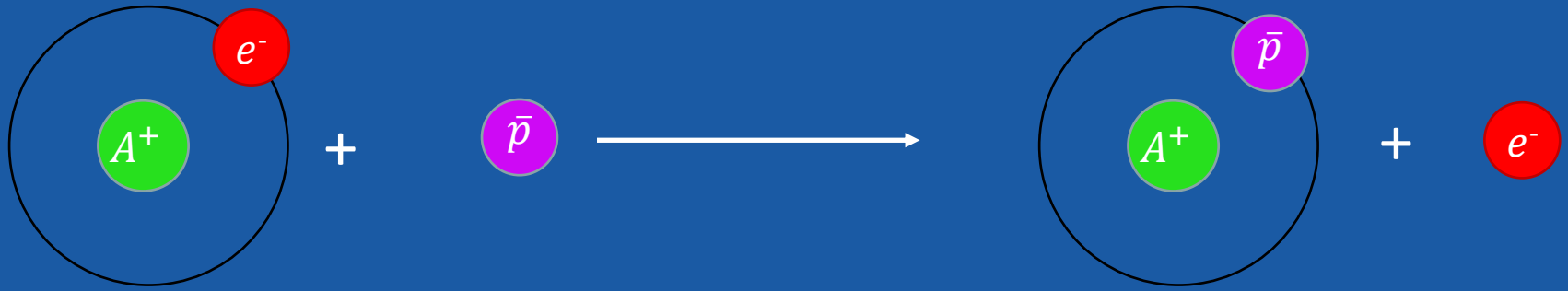
	H. Sandaker	F. Gustafsson

Highly Charged Ions
(in trap)

Antiproton

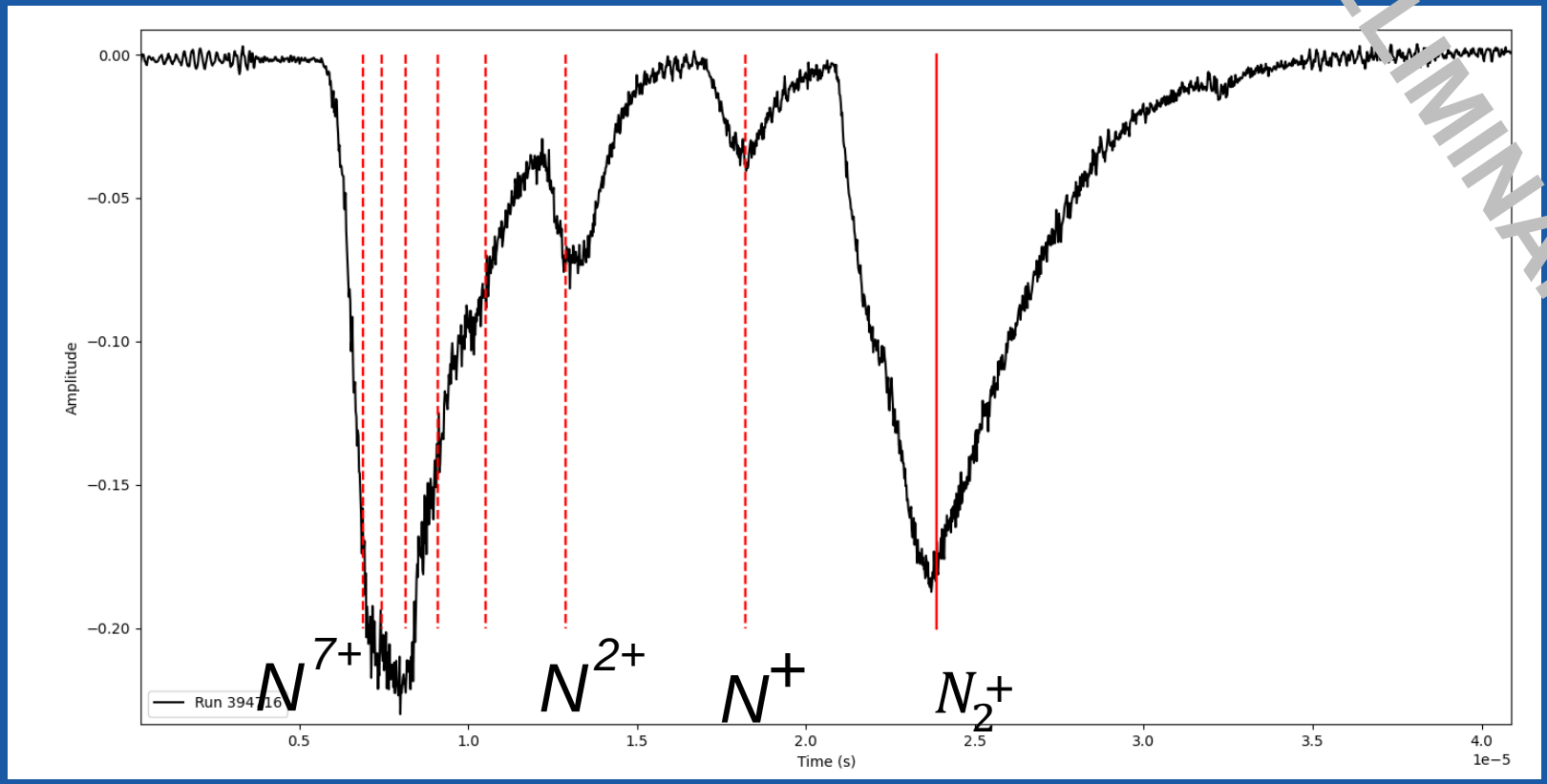
Antiprotonic atom



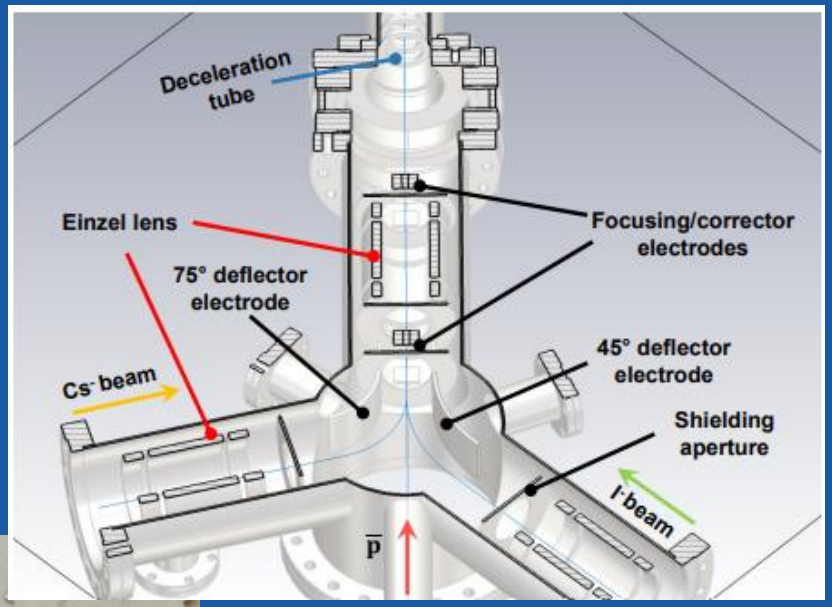
Nuclear iosotopes
(fully stripped, in trap)

HCI formation?

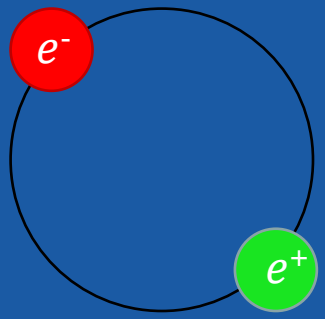
PRELIMINARY



Negative ions in, antiprotons out



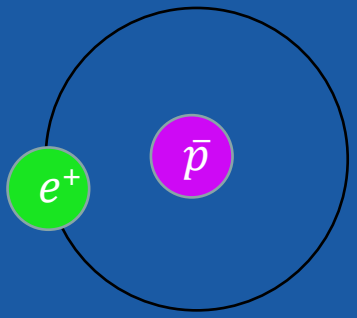
Positronium (Ps)



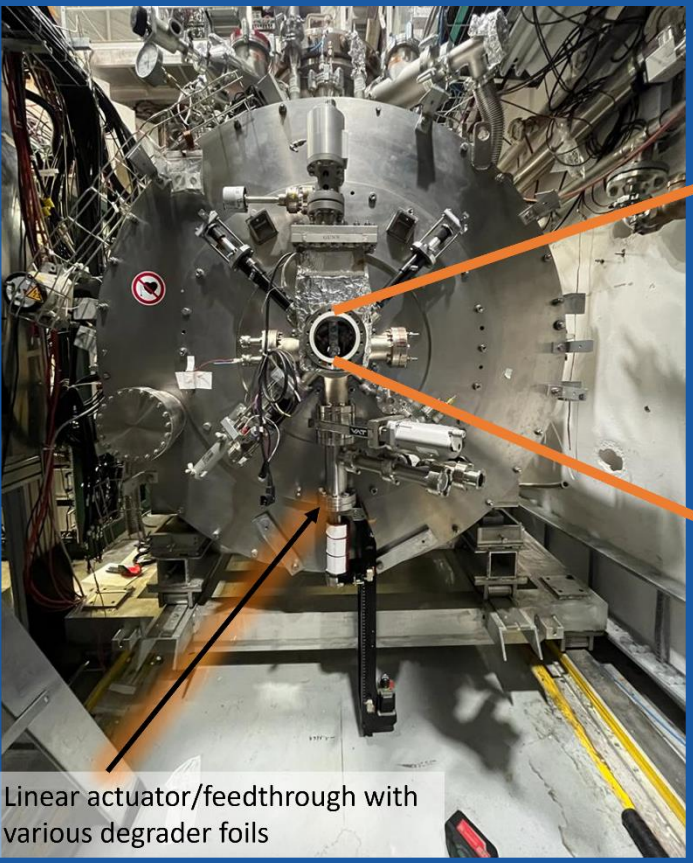
142 ns lifetime

Antiproton

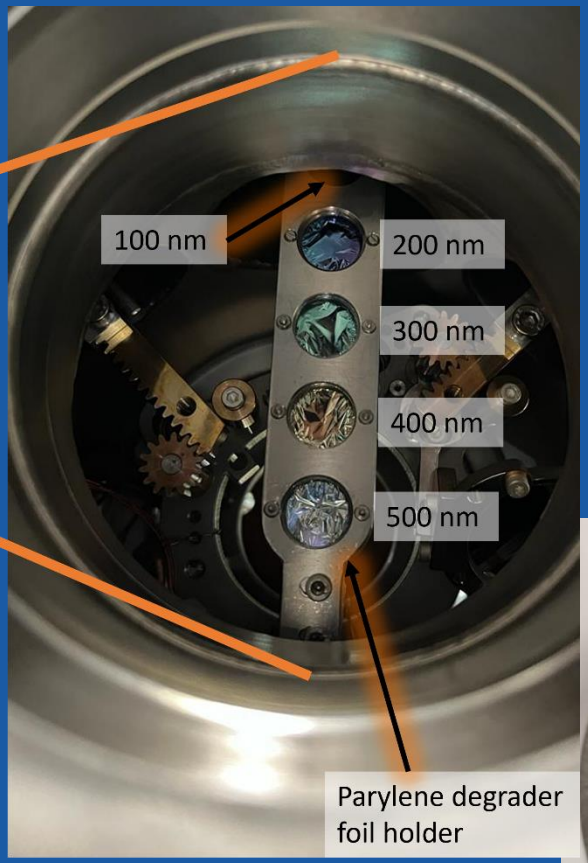
Antihydrogen



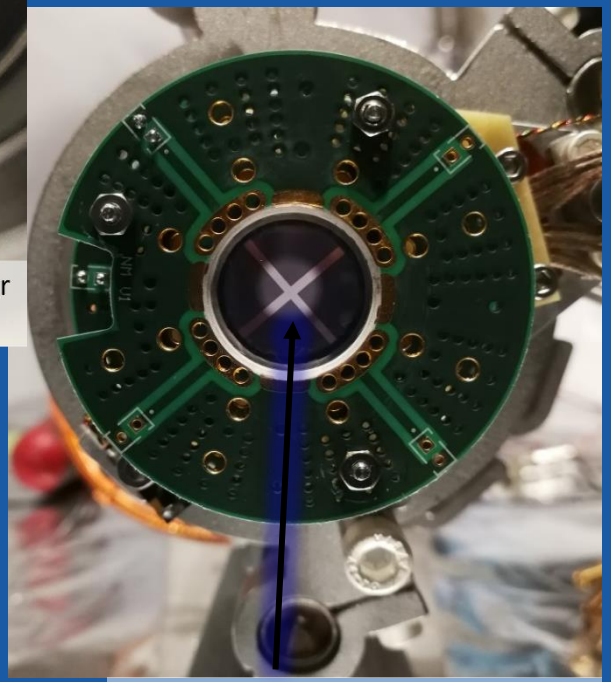
Credits Olivia Adams (CERN, 2023)



Linear actuator/feedthrough with various degrader foils

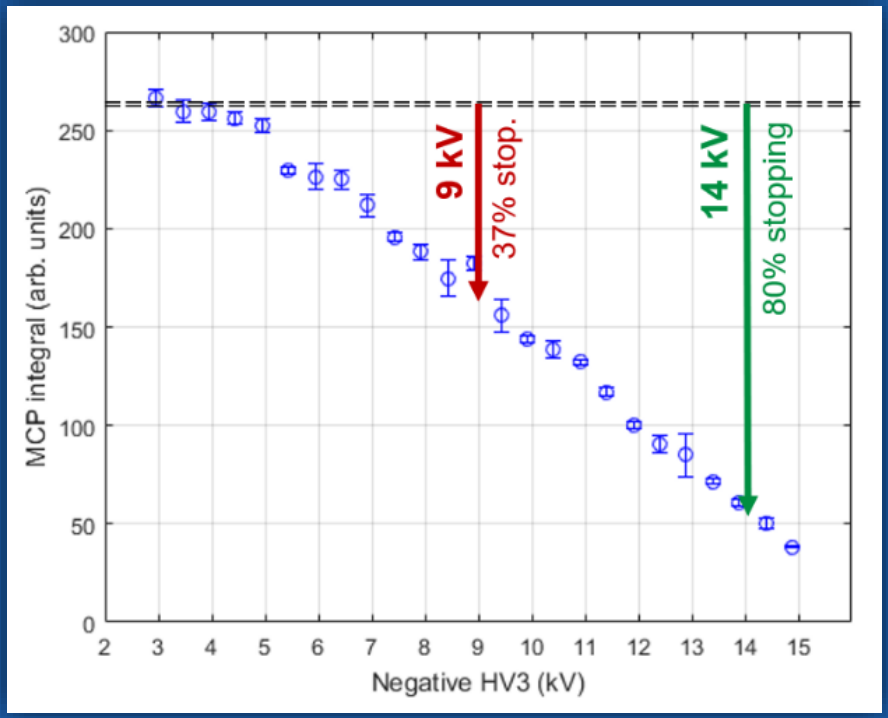


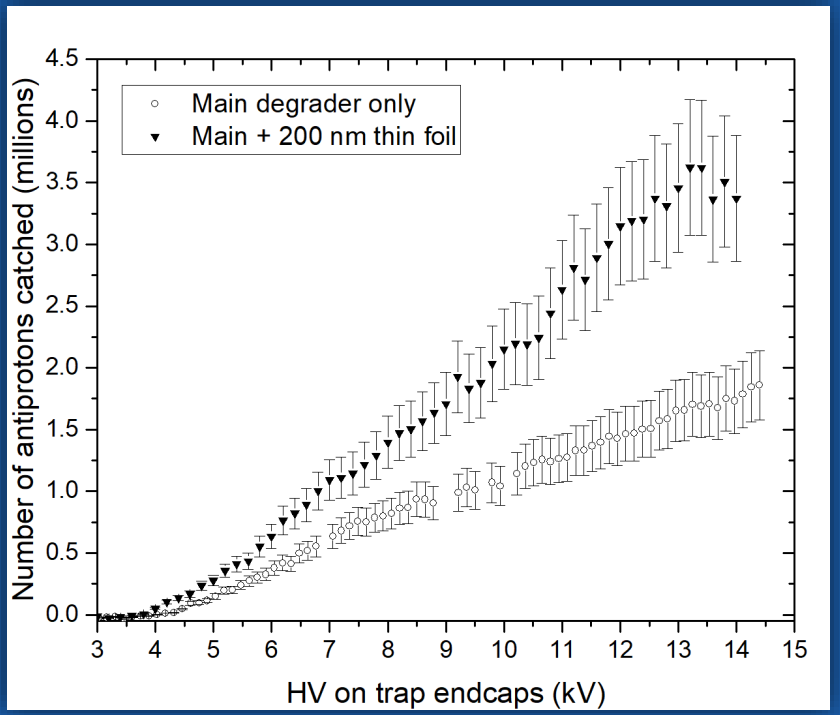
Parylene degrader foil holder

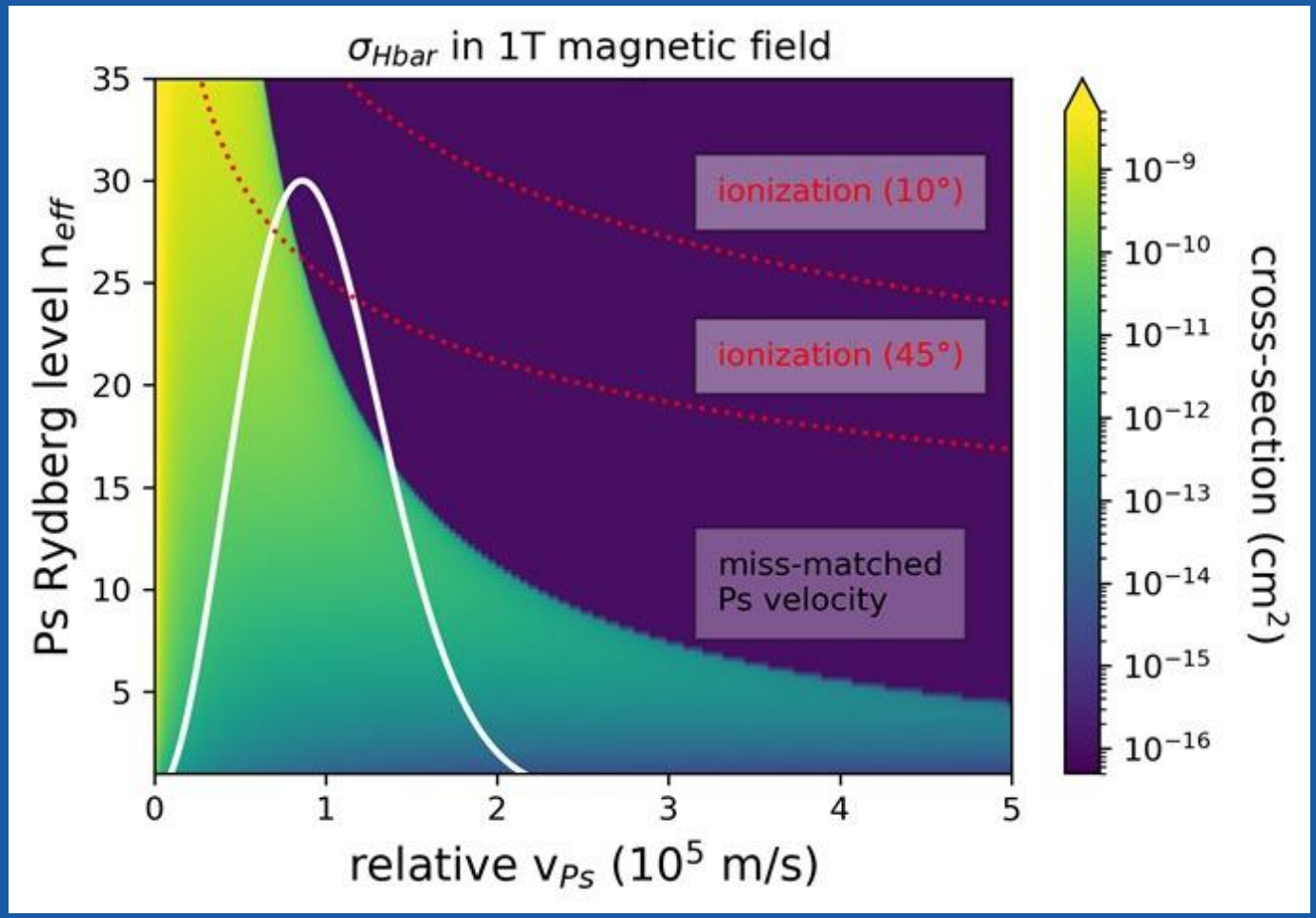


Main degrader foil (1.4 um mylar) + beam position monitor

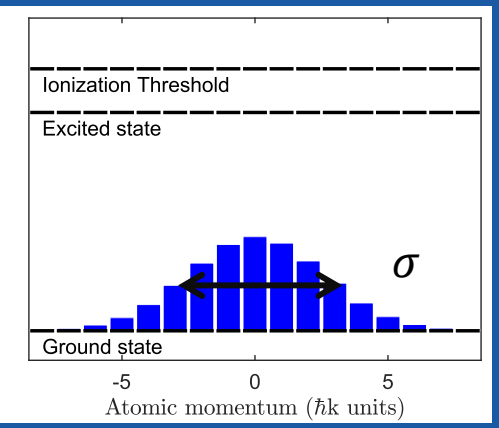
Record Pbar trapping number
(working towards 10^8 recyclable $\bar{p}$ trap)






σ_{Hbar} in 1T magnetic field
Ps Rydberg level n_{eff}
relative v_{Ps} (10^5 m/s)
ionization (10°)
ionization (45°)
miss-matched
Ps velocity
cross-section (cm^2)
35
30
25
20
15
10
5
0
1
2
3
4
5
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}

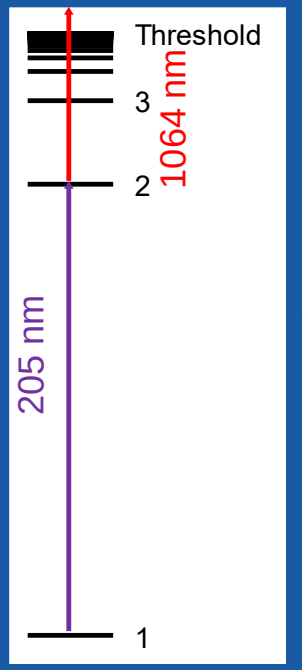
SSPALS Doppler velocimetry

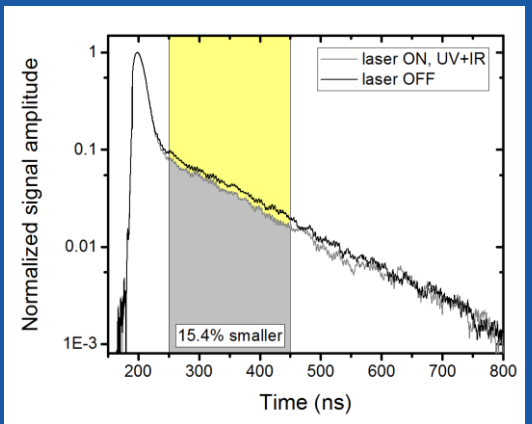


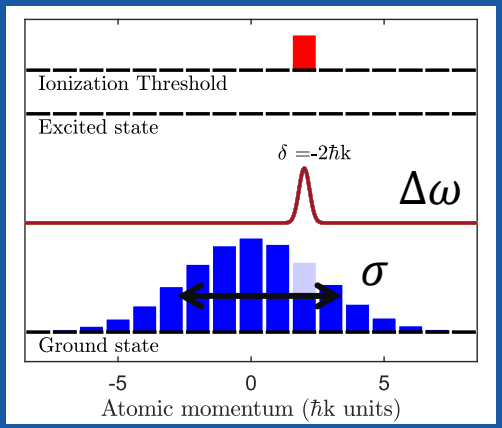
$$S(\omega) = e^{-(\omega-\omega_0-\delta)^2/(2\Delta\omega^2)}$$

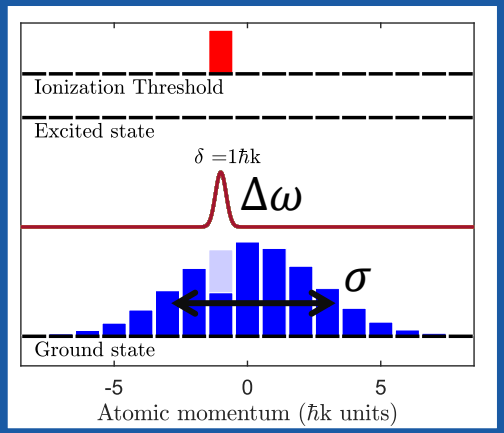
$$\Delta\omega \ll \sigma$$

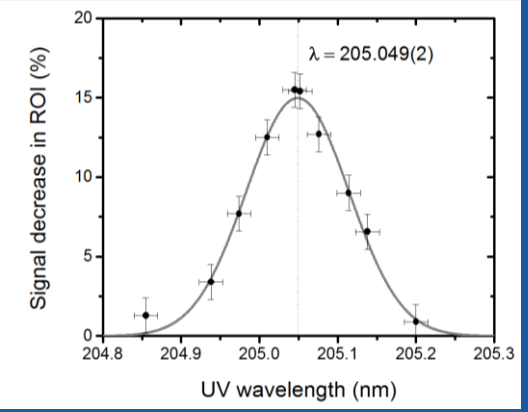
$$\delta = -\frac{v}{c}\omega_0$$









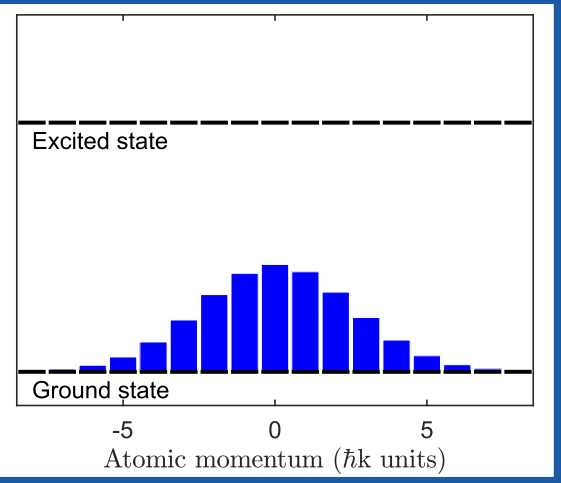


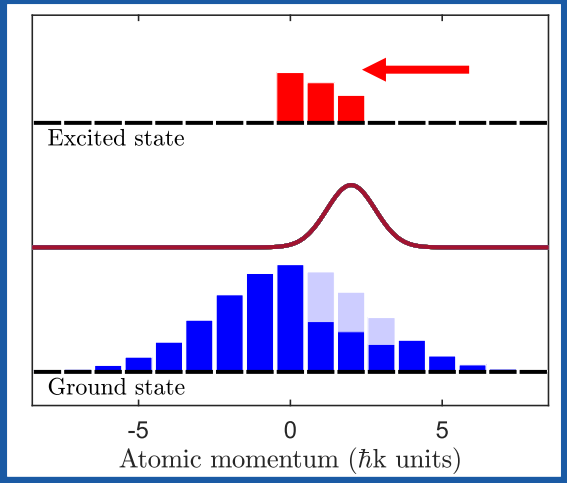
Aghion S. et al (AEgIS collaboration), *Physical Review A 94 (2016) 012507*

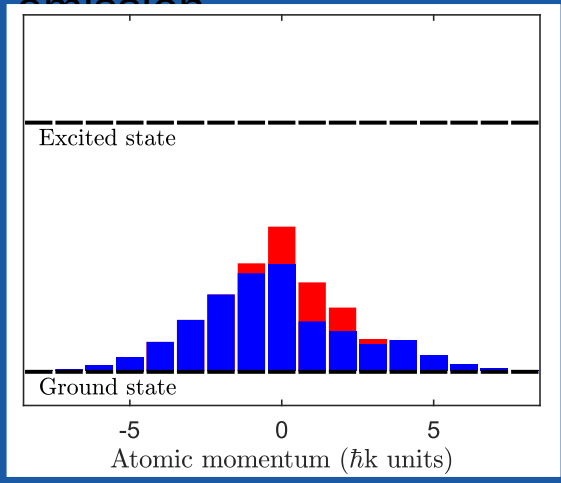
Doppler laser cooling

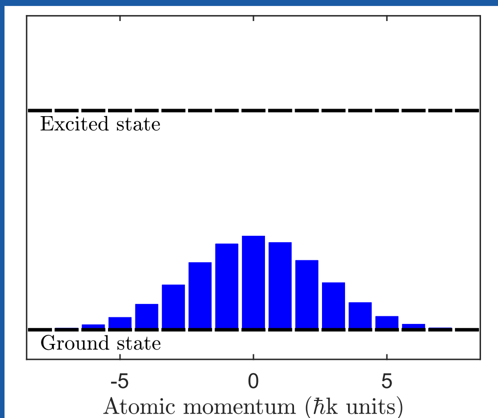
Absorption

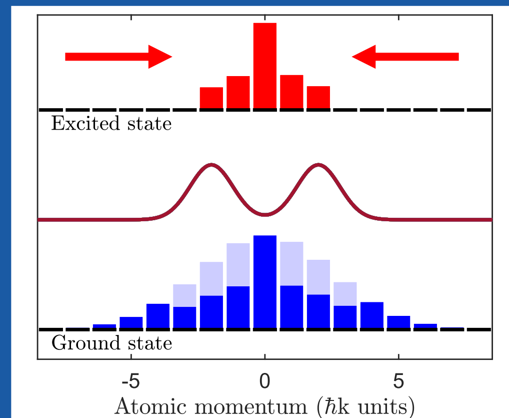
Spontaneous emission

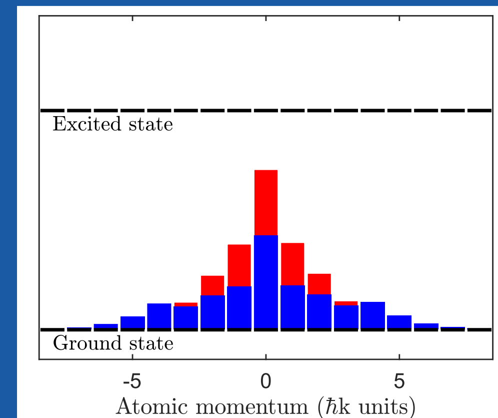


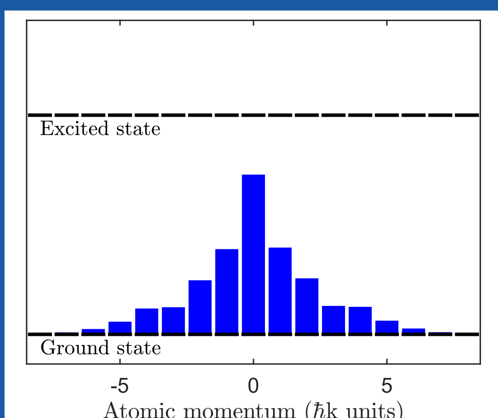


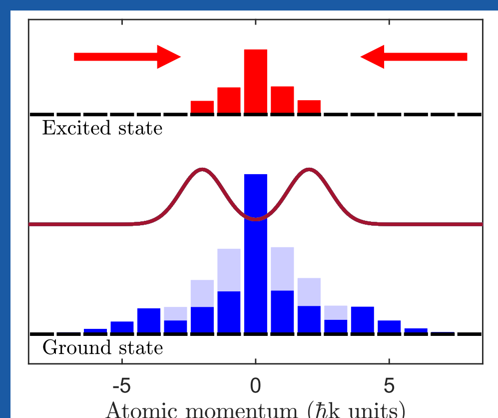


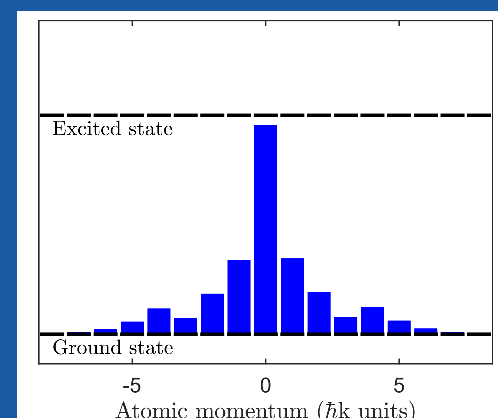

Excited state
Ground state
-5
0
5
Atomic momentum (ħk units)

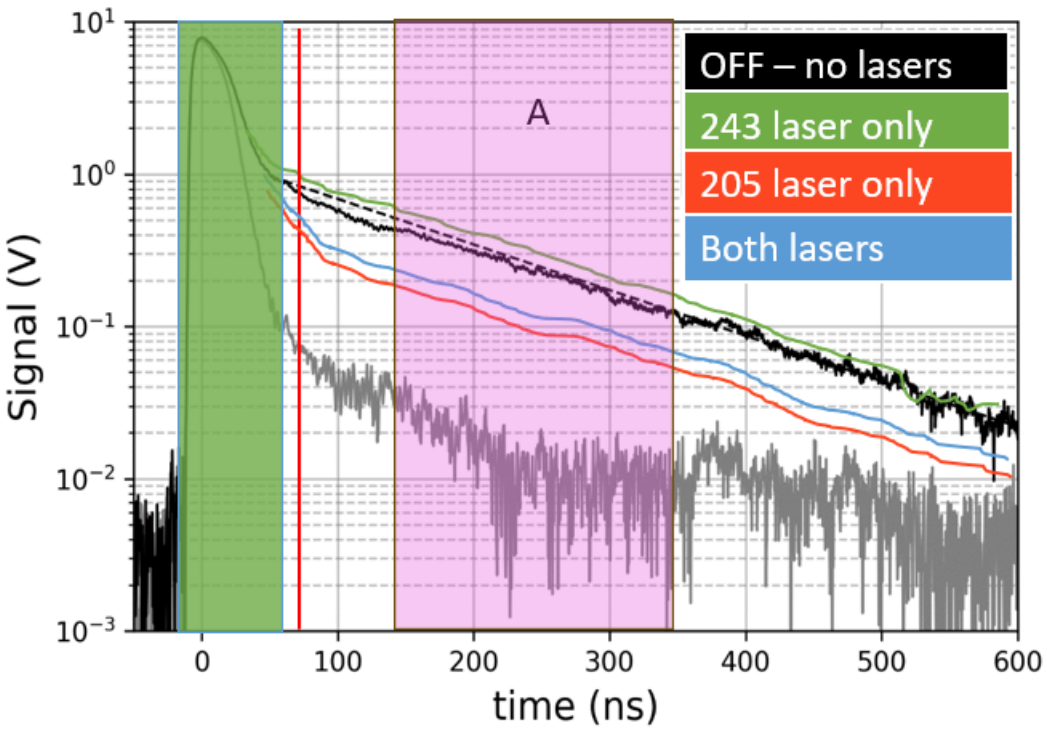

Excited state
Ground state
-5
0
5
Atomic momentum (ħk units)


Excited state
Ground state
-5
0
5
Atomic momentum (ħk units)


Excited state
Ground state
-5
0
5
Atomic momentum (ħk units)


Excited state
Ground state
-5
0
5
Atomic momentum (ħk units)


Excited state
Ground state
-5
0
5
Atomic momentum (ħk units)



No cooling: $S\% = \frac{A_{205} - A_0}{A_0} < 0$

Lifetime extension: $S\% = \frac{A_{243} - A_0}{A_0} > 0$

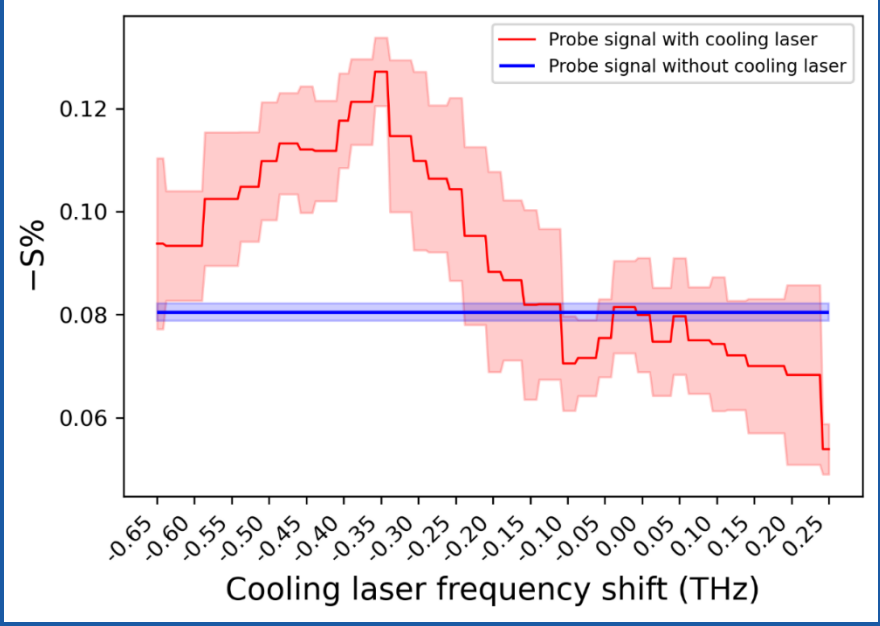
Both lasers: $S\% = \frac{A_{205+243} - A_0}{A_0} < 0$

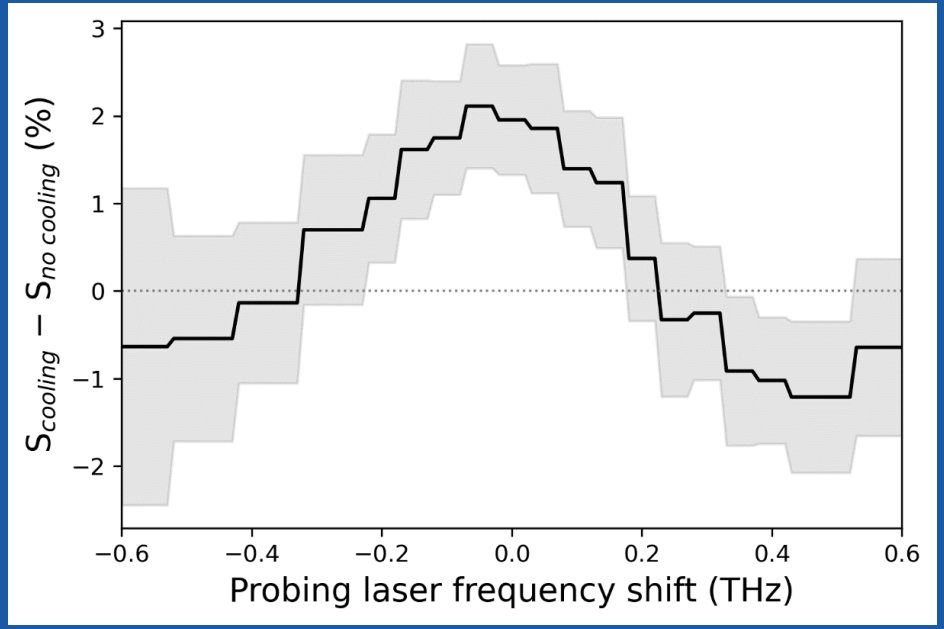
$$S\% = \frac{A_{205+243} - A_0}{A_0} - \frac{A_{243} - A_0}{A_0}$$

Cooling: $S\% = \frac{A_{205+243} - A_{243}}{A_0} < 0$

$$S\% = \frac{A_{205+243} - A_{243}}{A_0}$$

$$\Delta S\% = \frac{A_{205+243} - A_{243}}{A_0} - \frac{A_{205} - A_0}{A_0}$$





To go beyond see J. Malamant master thesis on Ultrafast Laser Cooling

Precision spectroscopy of positronium: Testing bound-state QED theory and the search for physics beyond the Standard Model

G.S. Adkins [a], D.B. Cassidy [b], J. Pérez-Ríos [c,*]

particles. However, there is still much to be done on this front. For instance, there is a 4.2σ discrepancy between the experimentally measured energy difference and the QED prediction for the $2\,^3S \rightarrow 2\,^3P_0$ interval. This observation cannot be explained by the existence of a new scalar or axion-like particle, but there are other interesting possibilities, such as the Chameleon model, in which a new scalar interacts with SM leptons with a strength depending on the environment's density [540]. Another model is the Arkani-Hamed, Dimopoulos, Dvali model [478], in which it is assumed that gravity operates in a higher-dimensional space. In contrast, the rest of the fundamental forces exist only in a four-dimensional

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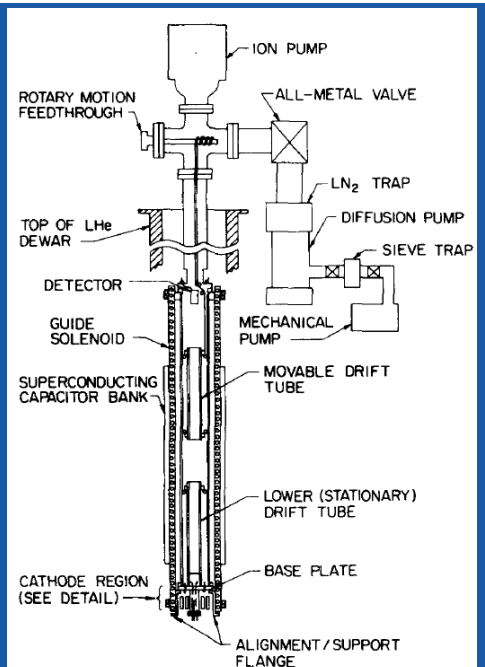
EXPERIMENTAL COMPARISON OF THE GRAVITATIONAL FORCE ON FREELY FALLING ELECTRONS AND METALLIC ELECTRONS*

F. C. Witteborn and W. M. Fairbank
Physics Department, Stanford University, Stanford, California
(Received 2 October 1967)

A free-fall technique has been used to measure the net vertical component of force on electrons in a vacuum enclosed by a copper tube. This force was shown to be less than $0.09mg$, where m is the inertial mass of the electron and g is 980 cm/sec^2. This supports the contention that gravity induces an electric field outside a metal surface, of magnitude and direction such that the gravitational force on electrons is cancelled.



$\bar{H}$ falls in the same direction as H
in the Earth gravitational field

(Nature, ALPHA collaboration 27.09.2023)

Article

Observation of the effect of gravity on the motion of antimatter

https://doi.org/10.1038/s41586-023-06527-1

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