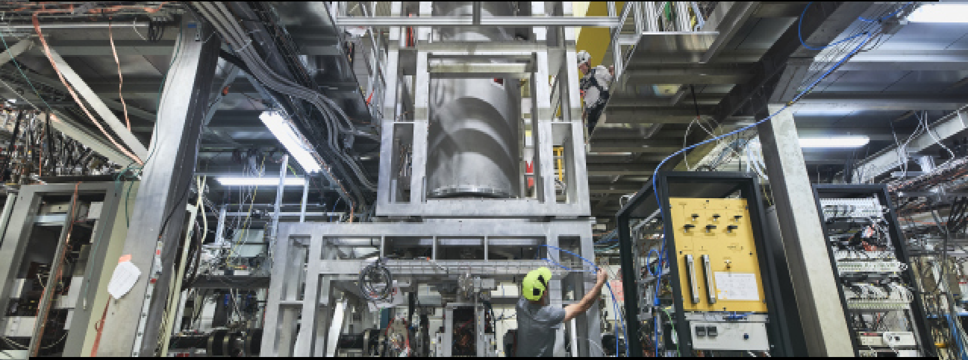
Precision Antihydrogen Annihilation Reconstructions Using the ALPHA-g Detector



UNIVERSITY OF CALGARY

Pooja Woosaree

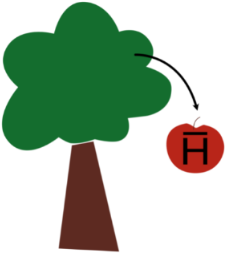
CAP 2022

June 8, 2022

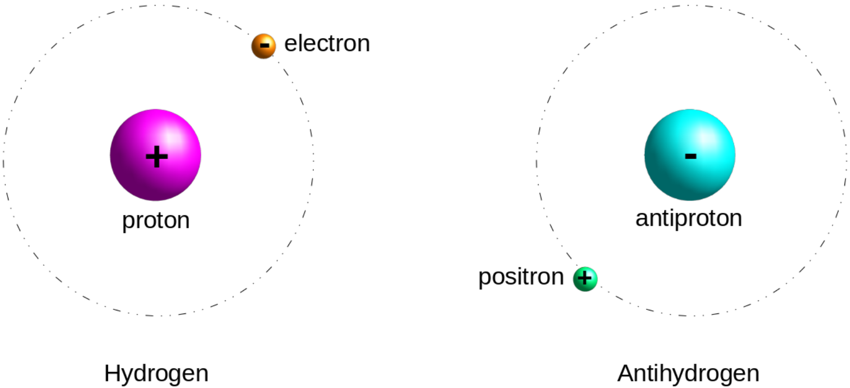
ALPHA

Outline

- Weak Equivalence Principle
- ALPHA
  - How is antihydrogen produced
  - How is antihydrogen trapped
- The ALPHA-g Apparatus
  - How is antihydrogen released
  - The radial Time Projection Chamber
  - Laser Calibration



Antihydrogen



- Antimatter counterpart of hydrogen
- Neutral atom
- Useful to test for Charge-Parity-Time (CPT) symmetry

The effects of gravity on antihydrogen

Einstein's Weak Equivalence Principle
The acceleration due to gravity that a body experiences is independent of its structure or composition

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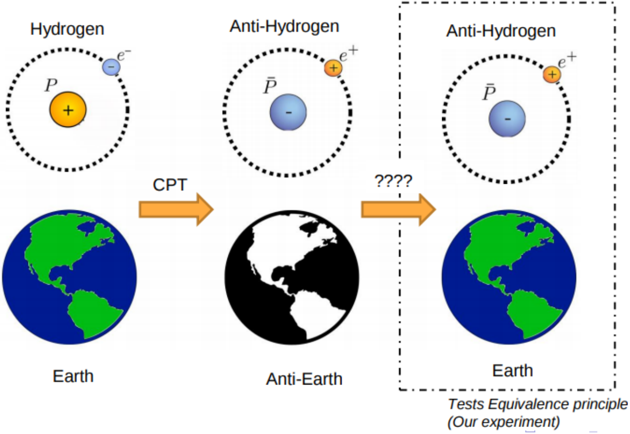


Antiproton Decelerator

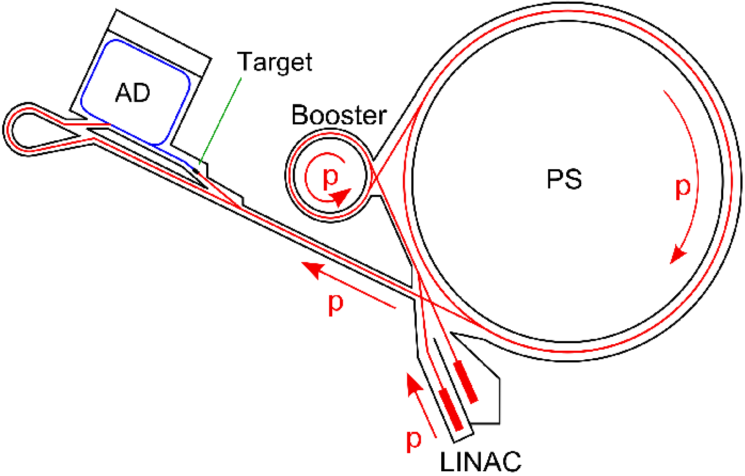
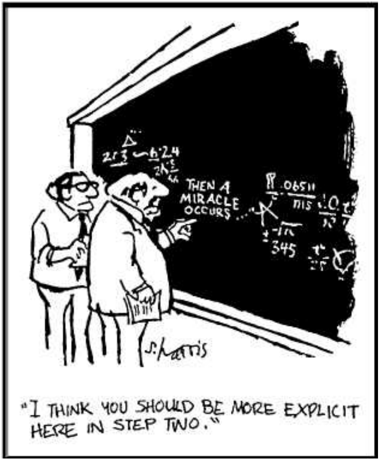


Image: Wikimedia Commons

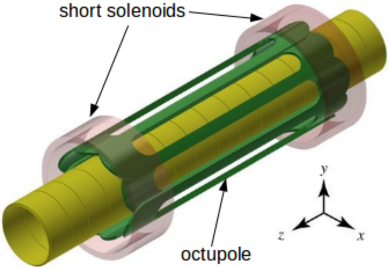
How to make antihydrogen

How to make antihydrogen



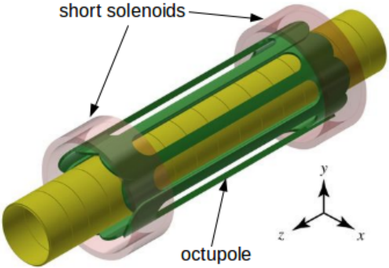
The Magnetic Minimum Trap

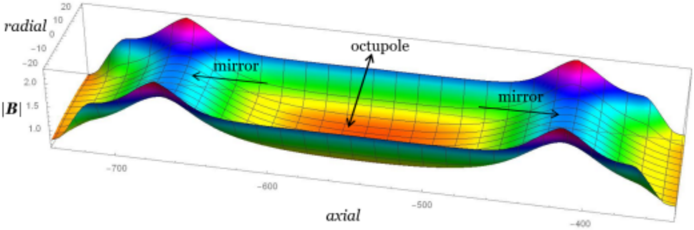
- Short solenoids provide axial confinement
- Octupole provides radial confinement



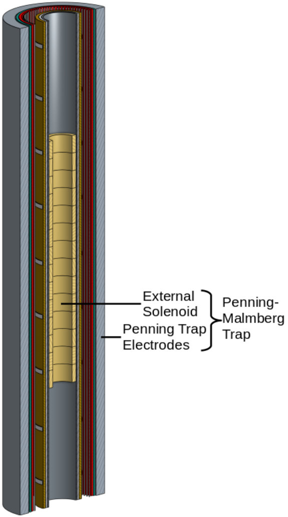
The Magnetic Minimum Trap

- Trap Depth: 0.8T
- Temperature: 0.5K for ground state antihydrogen





The ALPHA-g detector



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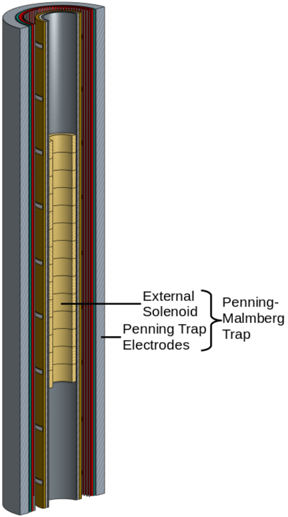
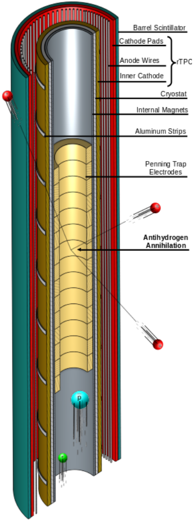
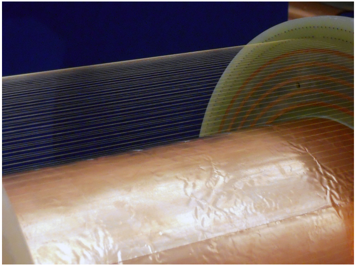




The radial Time Projection Chamber (rTPC)

- Gas detector surrounding the trap
- Detects the charged products of antihydrogen annihilations



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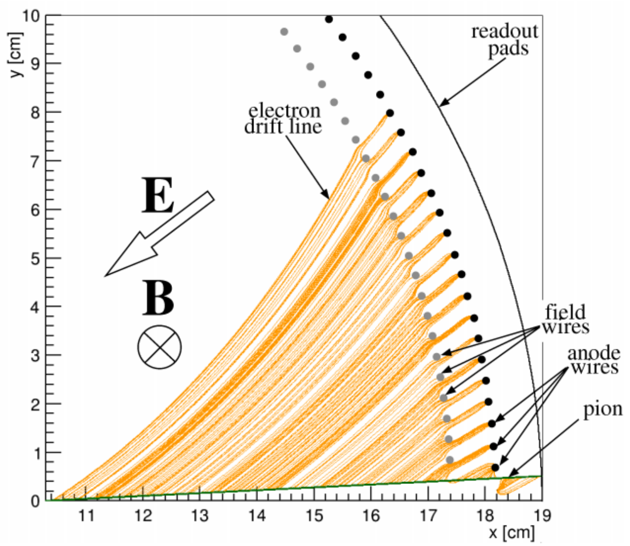
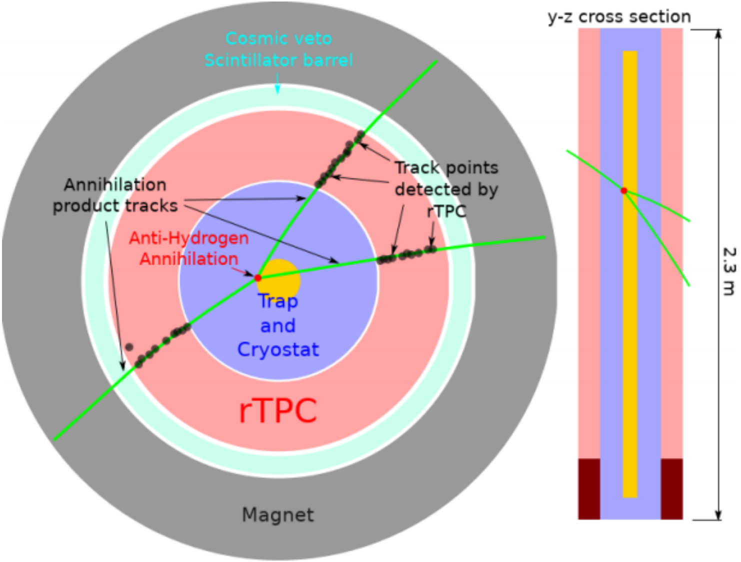


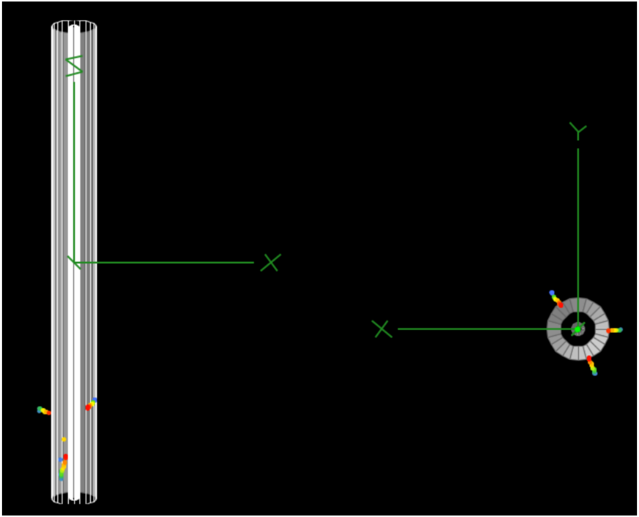
(Image by Andrea Capra)

ALPHA-g Antihydrogen Detection



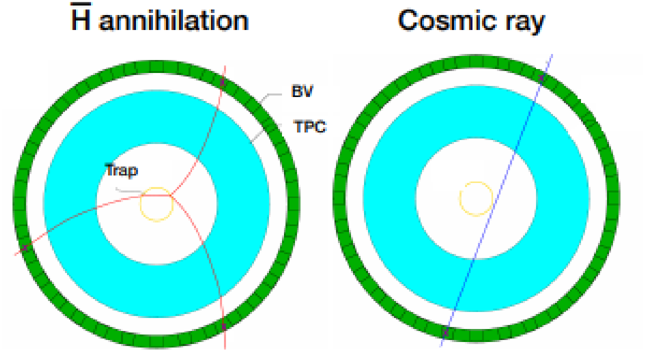
ALPHA-g Antihydrogen Detection

What we might expect to see in the event reconstruction



Cosmic Ray Backgrounds

- Cosmic rays are the largest source of background
- Discriminate between cosmic rays and antihydrogen annihilations



Laser Calibration

Purpose

To understand the detector response in tracking particles in a non-uniform magnetic field

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Key observables: **Drift time** and **Lorentz angle**

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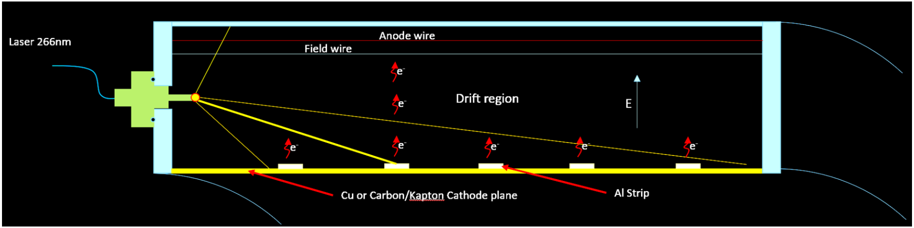
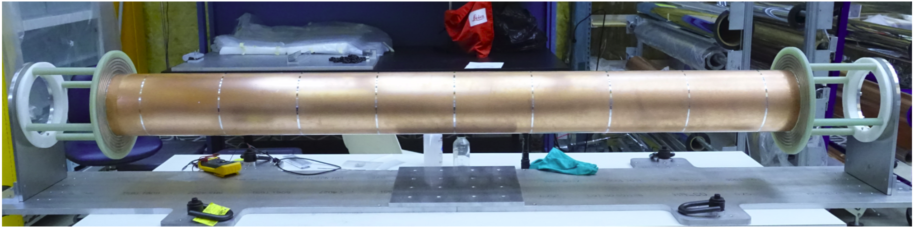
Factors that affect electron drift:

- pressure
- temperature
- gas mixture
- magnetic field

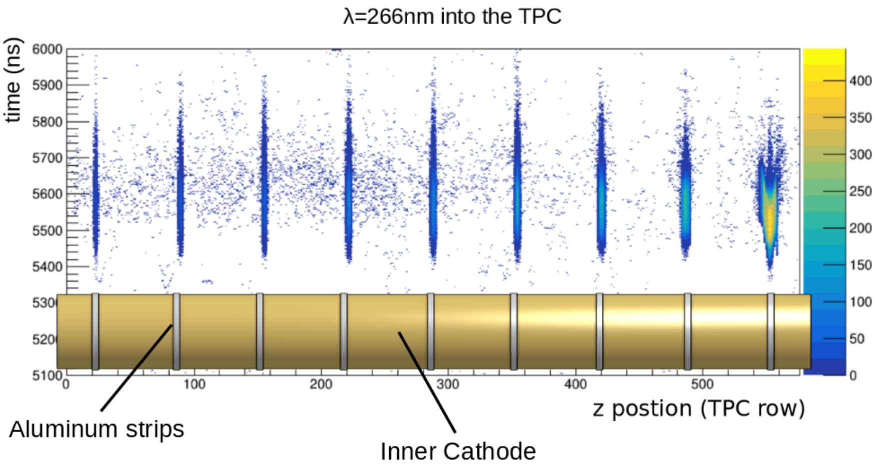
Laser Calibration

Technique

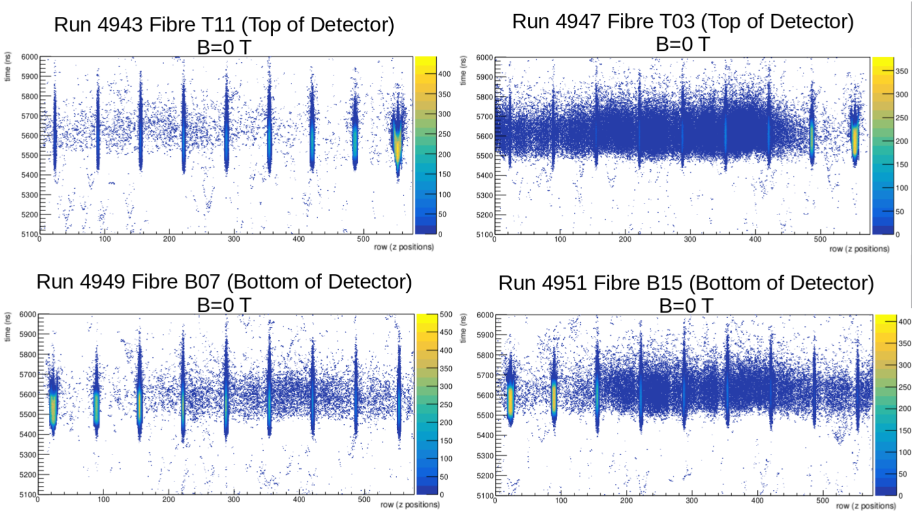




Laser Calibration



Laser Calibration Results



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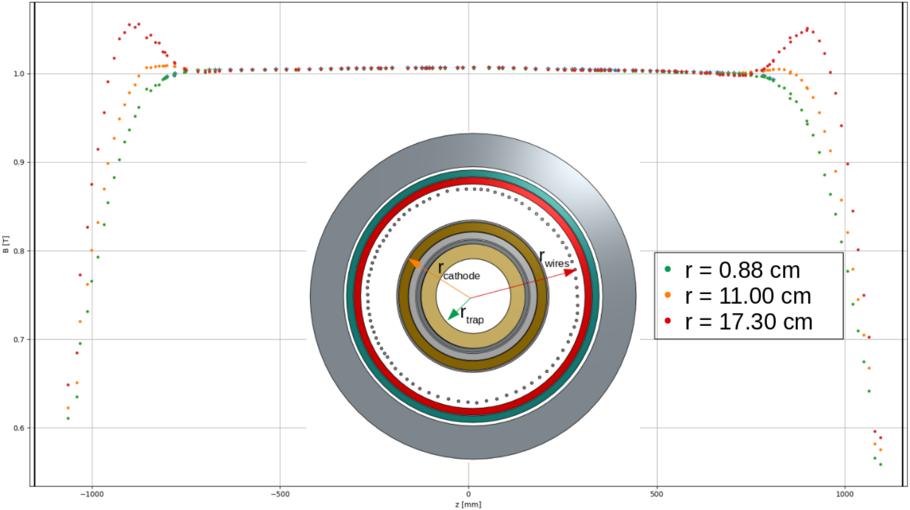
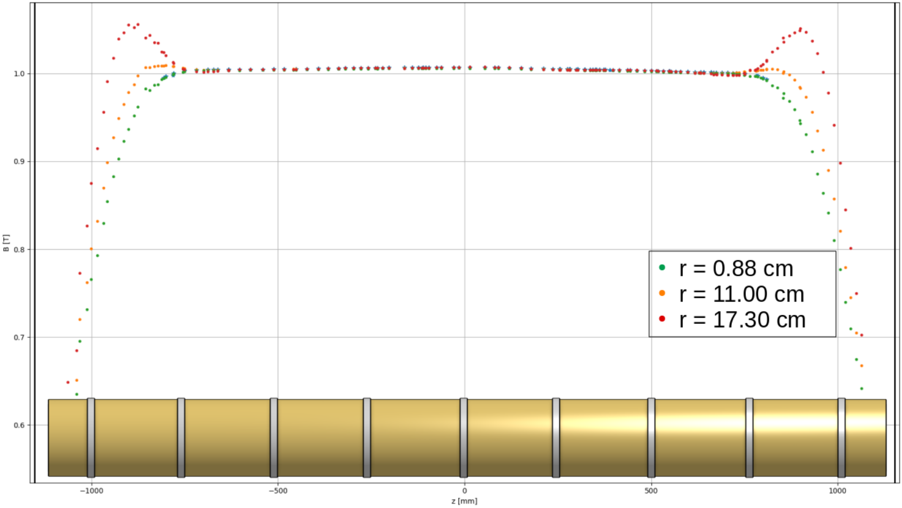


Original plot by Andrea Capra

Laser Calibration Results



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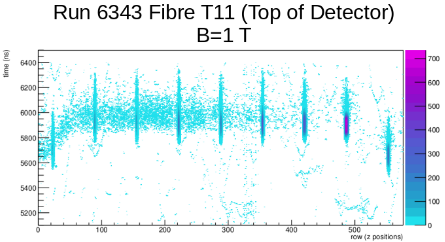
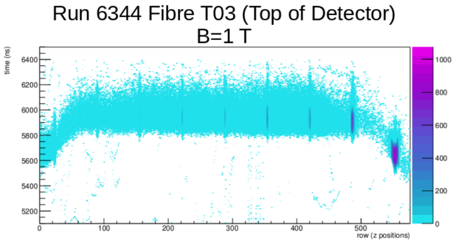
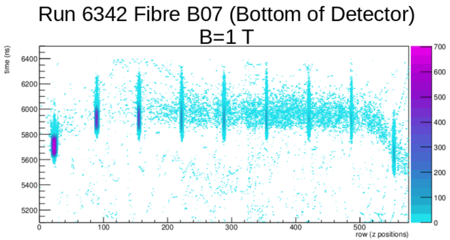
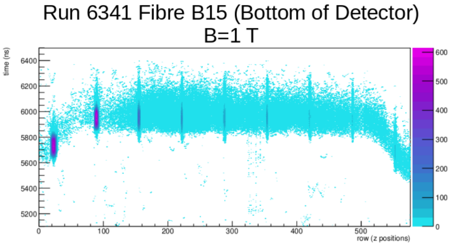


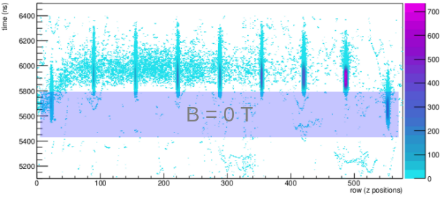




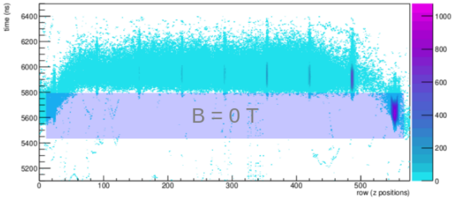


Laser Calibration Results

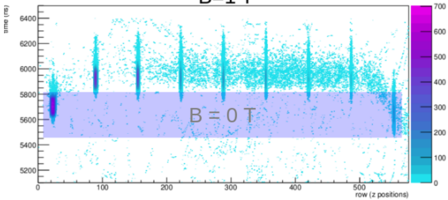
Run 6343 Fibre T11 (Top of Detector)
B=1 T



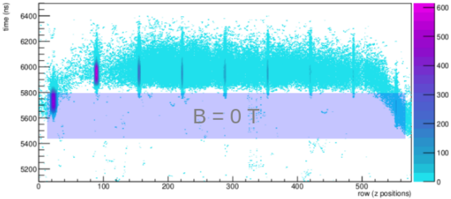
Run 6344 Fibre T03 (Top of Detector)
B=1 T



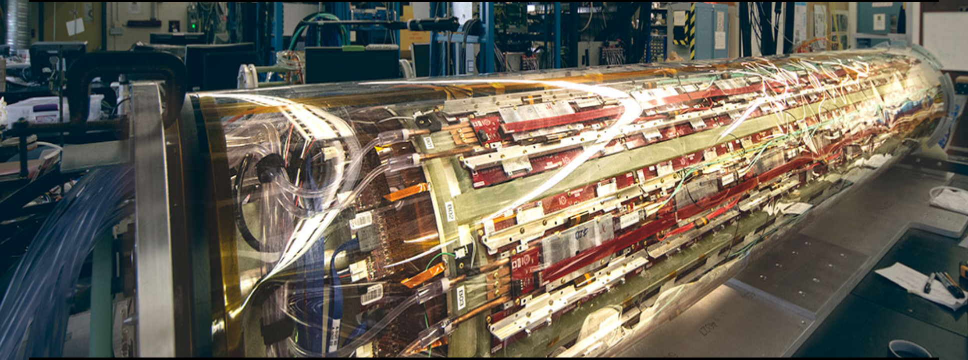
Run 6342 Fibre B07 (Bottom of Detector)
B=1 T



Run 6341 Fibre B15 (Bottom of Detector)
B=1 T



Conclusion



- ALPHA-g is being commissioned to track antihydrogen annihilations in free fall
- Laser calibration is crucial to determining key drift information in the rTPC
- First results expected over the coming year

The ALPHA Collaboration

Thank you for listening!

Backup Slides

How to distinguish antiproton vs antihydrogen annihilations?

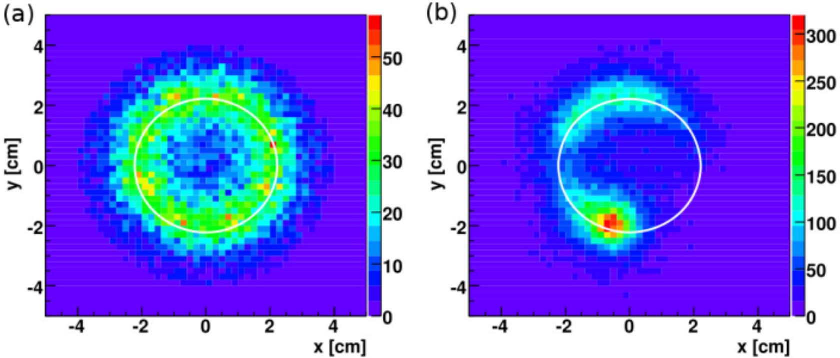
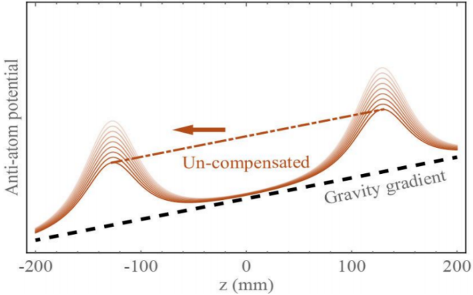
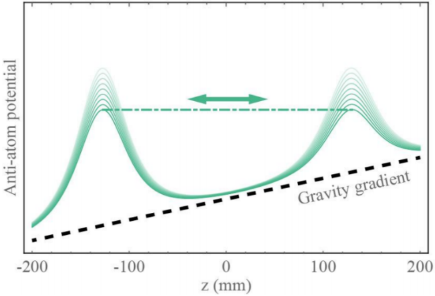


Figure: (a) antihydrogen (b) antiprotons (Image by Tim Friesen)

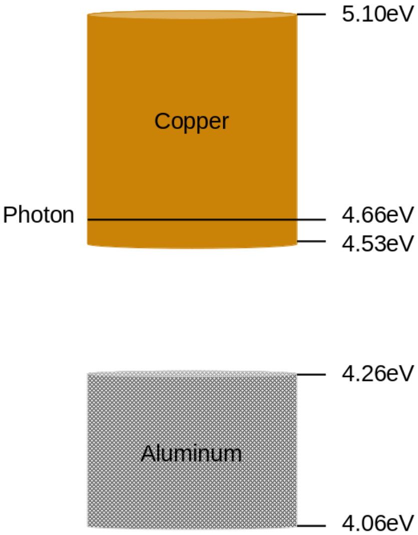
Balance Magnetic and Gravity Trapping

- Equal currents means loss of antihydrogen
- Larger current in bottom solenoid means an equal possibility of antihydrogen falling up or down



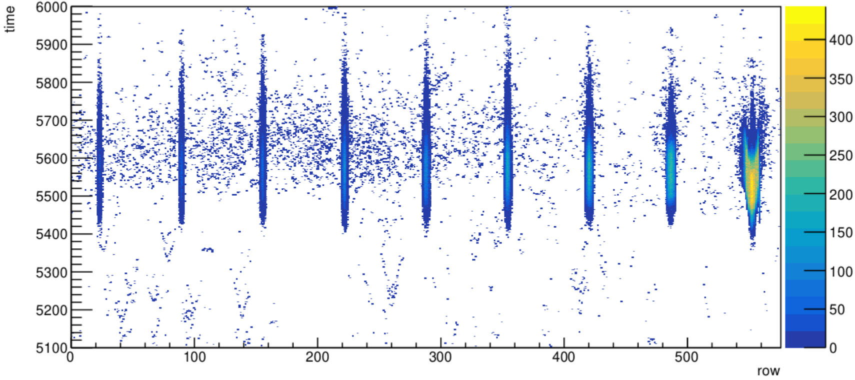


Work Functions



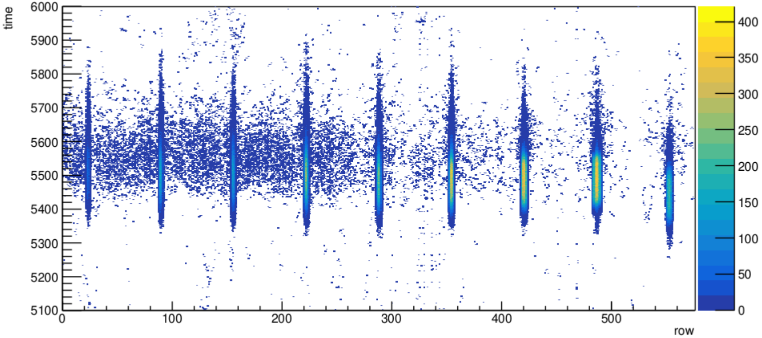
Laser Runs

Run 4943: Horizontal, T11, B=0



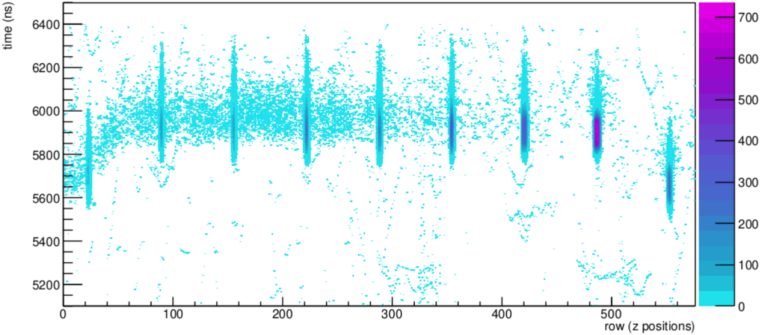
Laser Runs

Run 6457: Vertical, T11, B=0



Laser Runs

Run 6343: Vertical, T11, B=1



Laser Specifications

Laser type	Nd:YAG*
Laser pulsed beam	50 Hz
Wavelength	266nm
Pulse Energy	2.6 mJ
Near field beam diameter	1.7 mm
Al strip width	6 mm

*neodymium-doped yttrium aluminium garnet

Lorentz Force and Drift Time

Lorentz force $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$

where the drift velocity can be defined as $\vec{v}_d = \mu_e \vec{E}$. The electron mobility, μ_e is dependent on the gas.

The radial coordinate can be defined as $r = |\vec{v}_d| t_d$ where t_d is the drift time.

Lorentz angle

The angle between drift velocity and magnetic field, α

$\tan\alpha = \omega\tau$
where $\omega = \frac{e|\vec{B}|}{m}$ is the electron Larmor frequency and $\tau = \frac{m}{k}$.

m is the electron mass, and k is the frictional force proportional to $\vec{v}_d$