

Precision Measurements on Antihydrogen using the ALPHA-g Apparatus



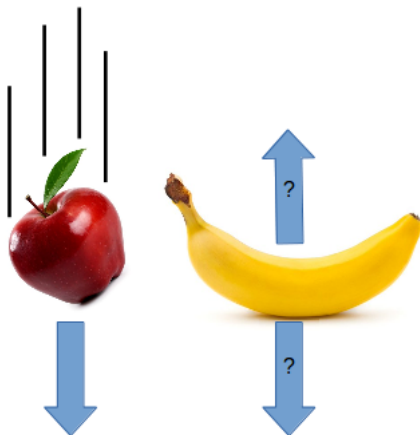
UNIVERSITY OF
CALGARY


Pooja Woosaree
WNPPC 2020
February 15, 2020



Outline

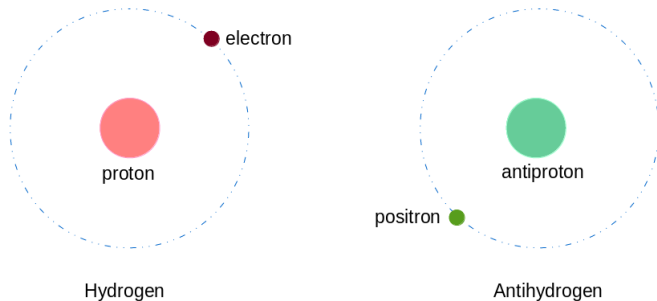
- The baryon asymmetry problem
 - Antihydrogen
 - WEP
- The ALPHA-g Apparatus
 - How is antihydrogen produced
 - How is antihydrogen trapped
 - How is antihydrogen released
 - rTPC
 - Magnetic effects
 - Barrel scintillators
- My research
- Future progress





Why is there more matter than antimatter?

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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- Is this true for antimatter?
- In theory, WEP should hold true for antimatter. But how can we know for sure?

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

- Is this true for antimatter?
- In theory, WEP should hold true for antimatter. But how can we know for sure?
- Test by performing a direct, free fall experiment using antihydrogen

The ALPHA Collaboration



SIMON FRASER UNIVERSITY
THINKING OF THE WORLD



Stockholm
University



Swansea University
Prifysgol Abertawe



Antihydrogen
Laser
PHysics
Apparatus

A L P A

Antihydrogen
Laser
Physics
Apparatus

- antihydrogen spectroscopy

A L P H A

Antihydrogen
Laser
Physics
Apparatus

- antihydrogen spectroscopy
- fine structure

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A L P A

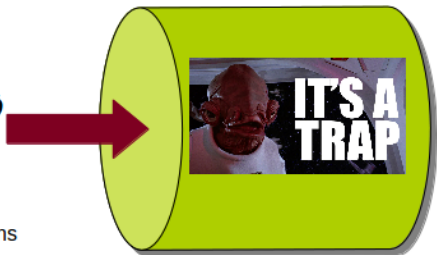
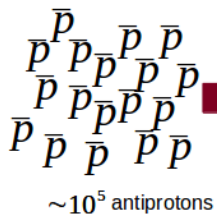
Antihydrogen
Laser
Physics
Apparatus

- antihydrogen spectroscopy
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- gravity

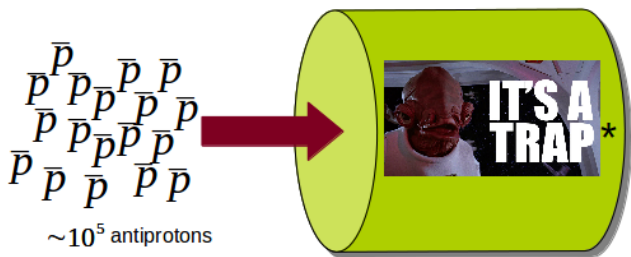
How to make antihydrogen



How to make antihydrogen

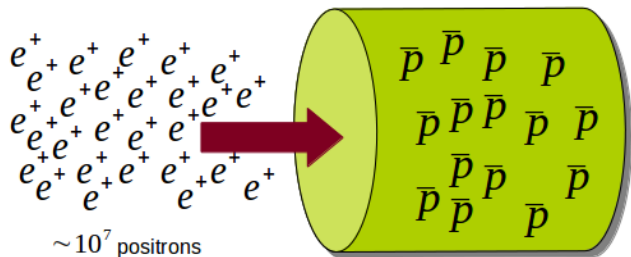


How to make antihydrogen

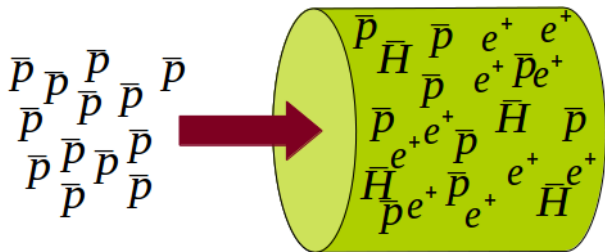


* A Penning-Malmberg Trap!

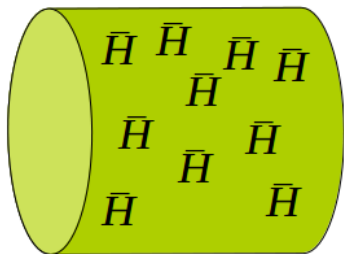
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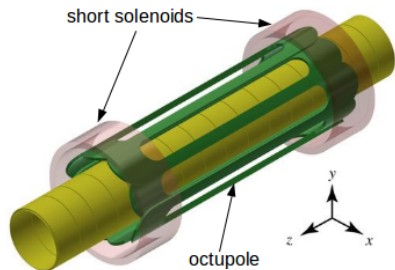
The Magnetic Minimum Trap

- positrons and antiprotons are mixed in a Penning-Malmberg trap



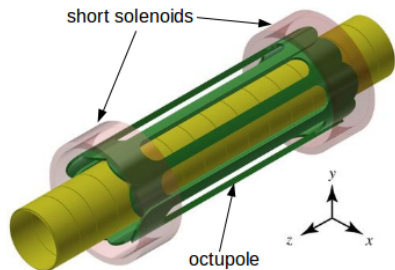
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- Antihydrogen is neutral, so how can it be trapped?



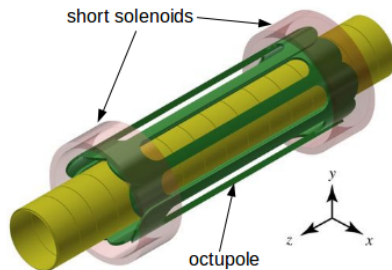
The Magnetic Minimum Trap

- positrons and antiprotons are mixed in a Penning-Malmberg trap
- Antihydrogen is neutral, so how can it be trapped?
- Use a magnetic minimum trap



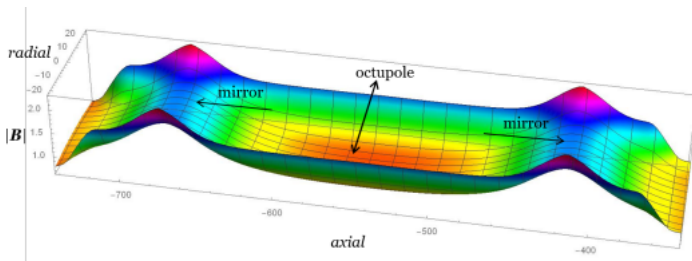
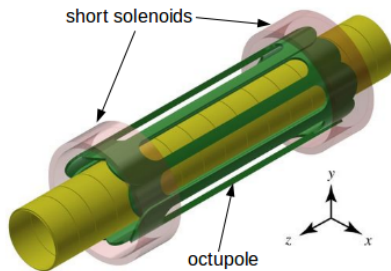
The Magnetic Minimum Trap

- Short solenoids provide axial confinement
- Octupole provides radial confinement



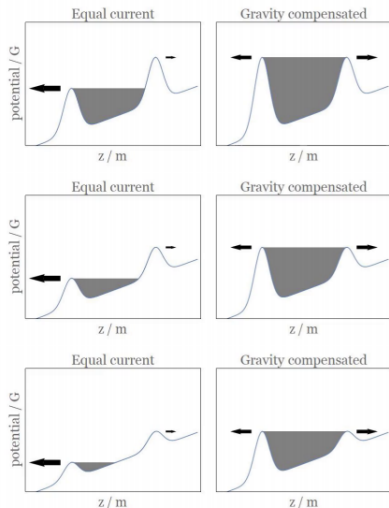
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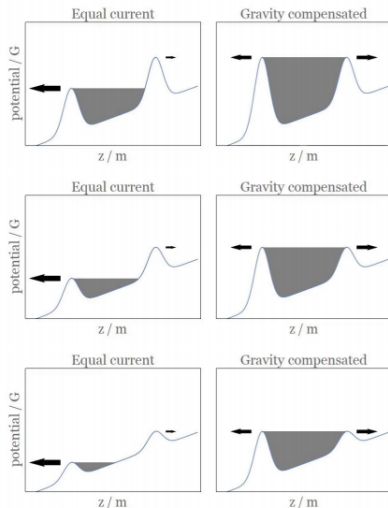
Balance Magnetic and Gravity Trapping

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

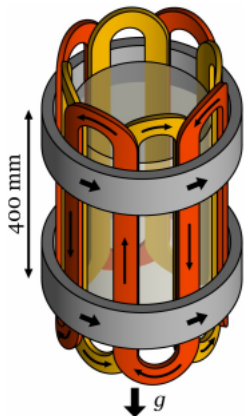


Balance Magnetic and Gravity Trapping

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- **See Nathan Evetts' talk at 12:00PM today**

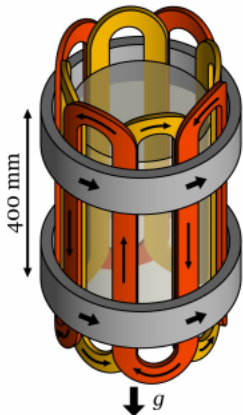


The ALPHA-g Apparatus



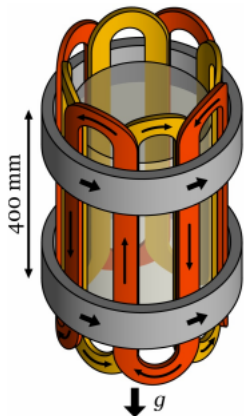
- Set up a vertical trap

The ALPHA-g Apparatus



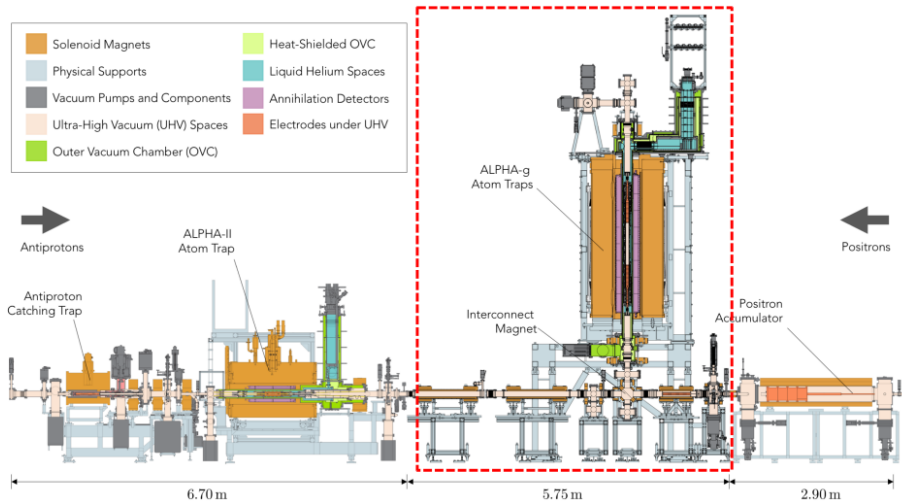
- Set up a vertical trap
- Release antihydrogen

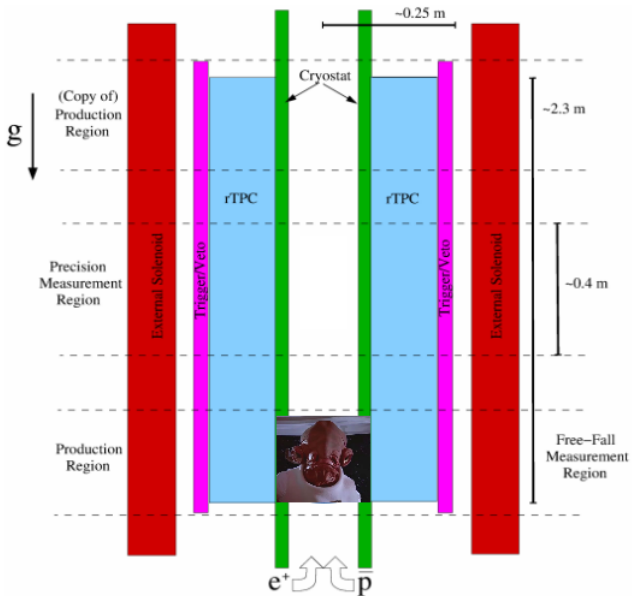
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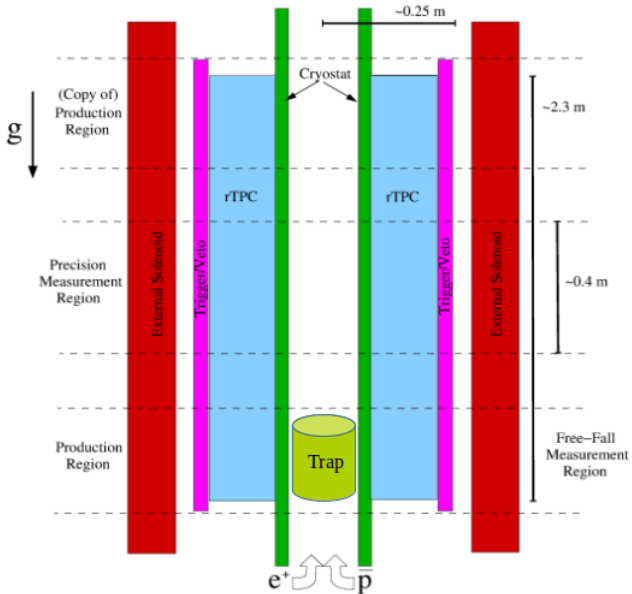
- Set up a vertical trap
- Release antihydrogen
- Observe antihydrogen annihilations

The ALPHA-g Apparatus

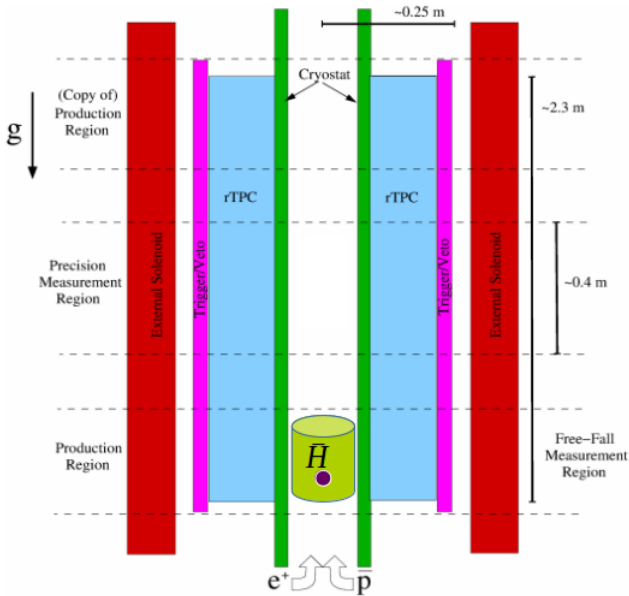




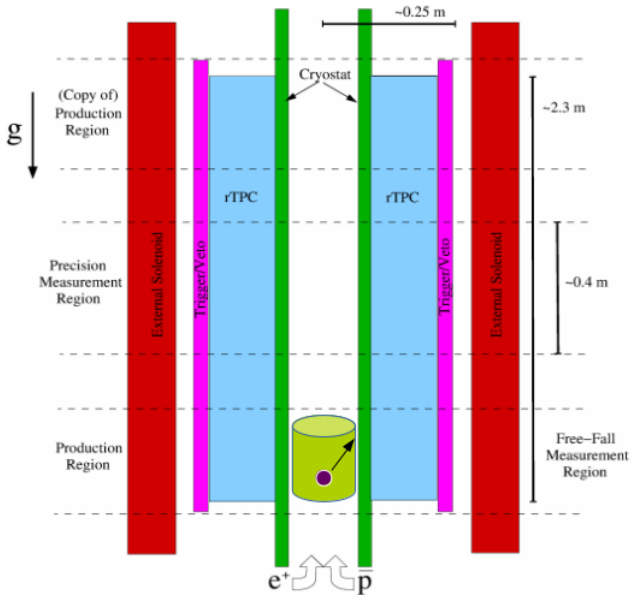
Adapted from images by A. Capra



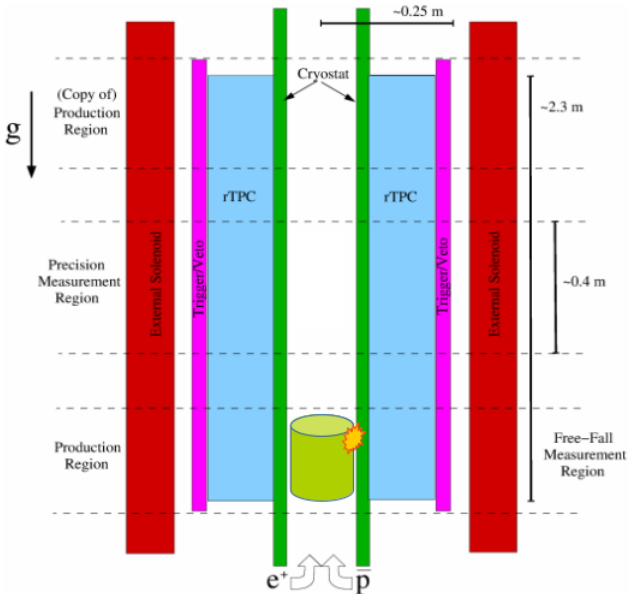
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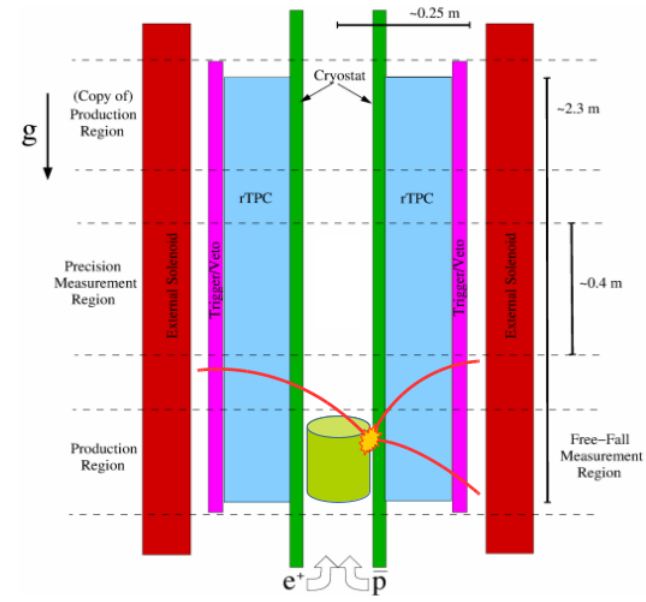
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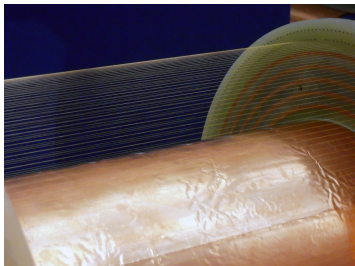
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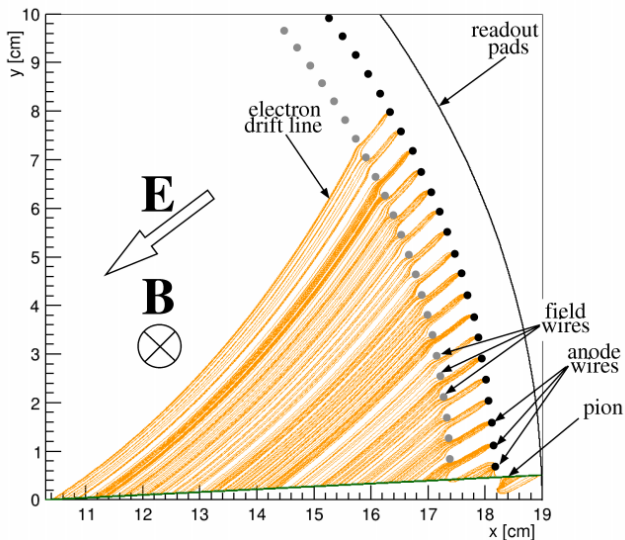
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The radial Time Projection Chamber (rTPC)

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



The radial Time Projection Chamber (rTPC)

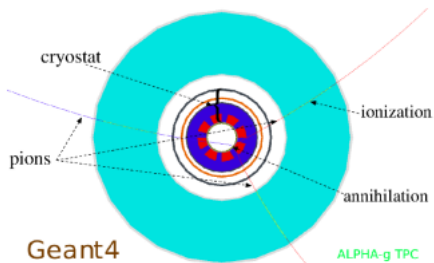


[A. Capra, et. al. (2016)]

Cosmic Ray Backgrounds

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

See Gareth Smith's talk at 11:45AM today



& Garfield++

- GEANT4 simulates antihydrogen annihilations
- Garfield++ simulates gas ionizations

My research:

- Debug software
- Determine detector resolution

Future of ALPHA-g

- Continue commissioning the apparatus
- Prepare for data taking in 2021
- Aim to determine direction of antimatter gravity
- Future goal to measure gravity to 1% precision

Conclusion

- Tests for WEP have never been done on neutral antimatter
- ALPHA-g is being commissioned to track antihydrogen annihilations in free fall
- First results expected by late 2021