Precision Antihydrogen Annihilation Reconstructions using the ALPHA-g Apparatus

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Antihydrogen

Antihydrogen, the antimatter equivalent of hydrogen, is the simplest anti-atom as it only requires a positron (e^+) and an antiproton (p).

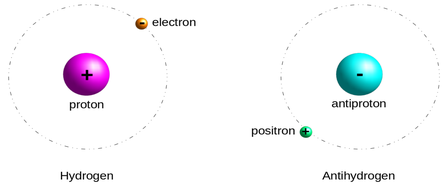

Figure 1. Hydrogen and Antihydrogen atoms.

Given the neutral charge of antihydrogen, it can be used as a sensitive probe of gravity in a free-fall experiment. This will test the theory known as the Weak Equivalence Principle (WEP), where the acceleration due to gravity that a body experiences is independent of its structure or composition.

ALPHA-g

Using a Penning trap to capture antiprotons from the Antiproton Decelerator (AD) at CERN, the ALPHA (Antihydrogen Laser PHysics Apparatus) collaboration has developed techniques to trap and cool positrons and antiprotons and mix them to form antihydrogen.

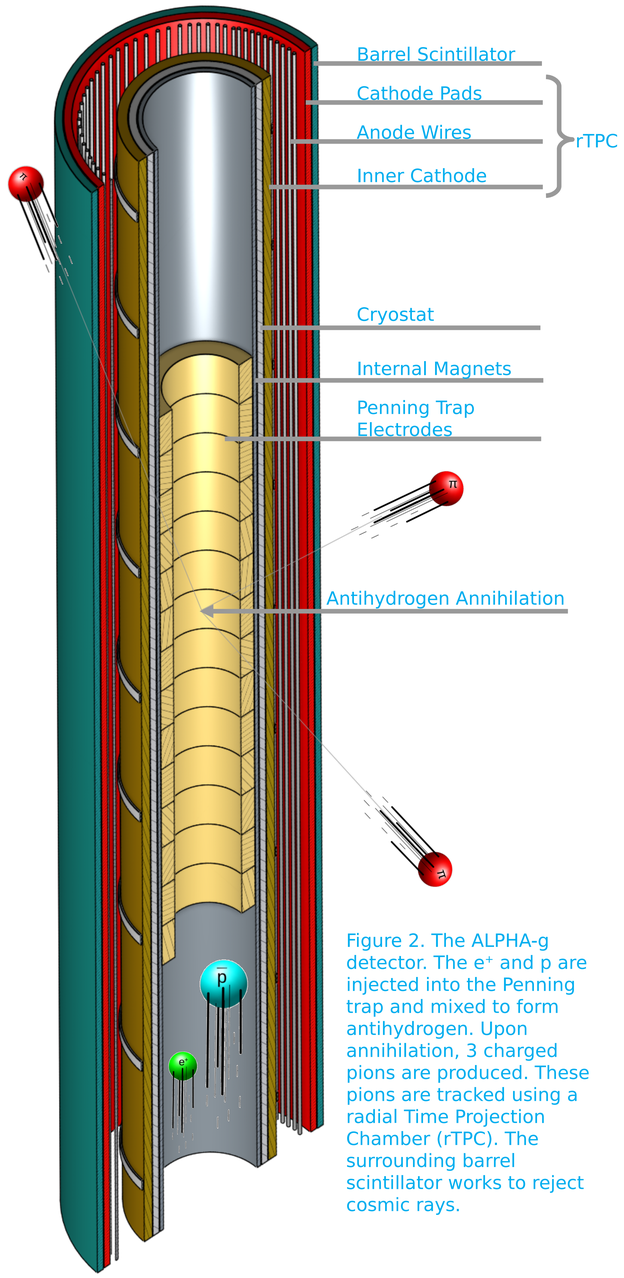

Figure 2. The ALPHA-g detector. The e^+ and p are injected into the Penning trap and mixed to form antihydrogen. Upon annihilation, 3 charged pions are produced. These pions are tracked using a radial Time Projection Chamber (rTPC). The surrounding barrel scintillator works to reject cosmic rays.

ALPHA-g is a vertical apparatus, and comprises a Penning trap to confine charged particles using an external solenoid, a cryostat, a gas detector, a barrel scintillator, and superconducting magnets that form the magnetic minimum atom trap.

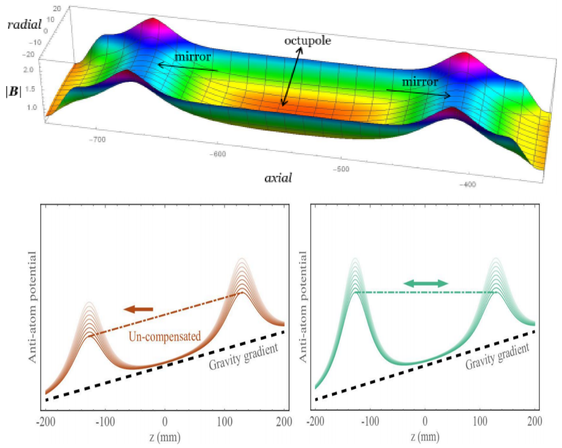

Figure 3. Antihydrogen is held in a magnetic field due to its magnetic moment. A compensated release of the axial confiment is required to account for gravity. This is done in a effort to eliminate a bias for the antihydrogen to fall down due to Earth's gravity. Images made by Chukman So.

The magnetic minimum trap is composed of an octupole that radially confines the antihydrogen and two short solenoids on either end of the trap that provide axial confinement. The current in the short solenoids are decreased and the axial confinement of the antihydrogen atoms will be slowly removed, resulting in the escape of antihydrogen from the trap.

Laser Calibration

The Lorentz angle (the angle by which electrons traveling through the rTPC are deflected by the magnetic field), and drift times can be found through laser calibration. Such data can then be implemented in the data analysis for the annihilation of antihydrogen to determine the z information of the annihilation.

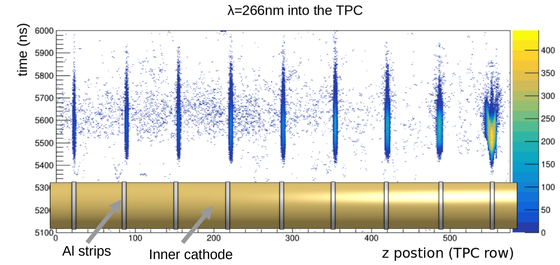

Figure 4. At the bottom of the plot is a superimposed image of the inner cathode of the rTPC and the aluminium strips secured to it (not to scale). UV light shone inside the rTPC can be seen interacting with all 9 aluminium strips. The y-axis denotes the time at which the electrons produced by the light hitting the aluminium strips arrived at the anode wires. The x-axis denotes the z-positions within the rTPC. The events in the plot produced by light hitting the aluminium strips appear to align with the aluminium strips.

Conclusion

Precise reconstruction of the antihydrogen annihilations will result in precision measurements for the gravitational mass of antihydrogen. Tests of the gravitational mass of antihydrogen are key measurements towards understanding the symmetries between matter and antimatter.

Discovery, accelerated