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Gravity experiments with magnetically confined antihydrogen in ALPHAg.

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The hydrogen atom has been studied extensively throughout history and provides the most precisely measured systems in physics. Antihydrogen has a significantly shorter history of study but the same potential for precision physics measurements. Comparisons between hydrogen and antihydrogen then offer the possibility to test fundamental symmetries such as charge, parity, and time reversal (CPT) symmetry at high precision.

The antihydrogen laser physics apparatus (ALPHA) at CERN produces and traps antihydrogen atoms in a magnetic minimum and studies its atomic spectrum. The latest venture for the ALPHA collaboration has been a new experiment, ALPHAg, aiming to observe the motion of antimatter in Earth's gravitational field for the first time. As CPT makes no assertion about the motion of antimatter in Earth's gravitational field this is a test of the equivalence principle.

Antihydrogen atoms are confined in a vertical magnetic minimum trap, the trapping potential is then different between the top and bottom of the trap by -mgΔh, where m is the antihydrogen mass, g is the gravitational acceleration and h is the height. When the vertical confining field is then removed during a slow magnetic release, antihydrogen escape in a direction favouring the gravitational acceleration. The difference in trapping potential is equivalent to a magnetic field difference of approximately 4×10^{-4} T. It follows then that by intentionally adding a magnetic bias to the trap, one can find a bias that balances the effect of gravity. As the magnetic field is changed from 1.7 T to 1 T over 20 seconds during the release, it is necessary to control and measure the magnetic fields at each end of the magnetic trap to a higher precision than the gravitational potential difference.

I will discuss the systematic studies of these magnetic fields using electron plasmas in a Penning-Malmberg trap [1] and the magnetic release experiment results that enabled the first determination of the gravitational acceleration of antihydrogen, $a_{\bar{g}}$ = (0,75 ± 0,13 (stat. + syst.) ± 0,16 (simulation))g where g = 9.81 $\mathrm{m/s^2}$ [2].

[1] Electron cyclotron resonance (ECR) magnetometry with a plasma reservoir, E. D. Hunter ; A. Christensen ; J. Fajans ; T. Friesen ; E. Kur ; J. S. Wurtele Phys. Plasmas 27, 032106 (2020)

[2] Observation of the effect of gravity on the motion of antimatter, The ALPHA collaboration, Nature volume 621, pages716–722 (2023)

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