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Detecting Anti-Hydrogen in the ALPHA-g Antimatter-Gravity Experiment

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Performing measurements on anti-matter atoms is an alluring proposition for studying the symmetries between matter and anti-matter; however, it presents a number of technical challenges. The ALPHA group has met these challenges and successfully trapped large numbers of anti-hydrogen atoms, opening the door for many such measurements. The new ALPHA-g experiment has the ability to measure the gravitational force exerted by the Earth on these anti-hydrogen atoms, by counterbalancing this force with precisely controlled magnetic fields. By relaxing only the confinement along the gravitational axis, the anti-atoms are released into two "up"and "down"regions separated by tens of centimetres. Here they annihilate, and the ratio of counts in the two regions describes the overall –magnetic plus gravitational –bias.

Charged pions resulting from these annihilations are tracked in a time projection chamber; these tracks are fit and extrapolated back to a common annihilation vertex. Our ability to reconstruct the position of these annihilation vertices into the correct region was previously one of the limiting factors of the experiment. Here I present the steps taken to improve our position resolution beyond that necessary for the experiment.

Furthermore, due to the low number of anti-atoms produced and slow experiment timescale, cosmic rays produce a sizeable background in our time projection chamber. To mitigate this, a second plastic scintillator-based detector system was implemented, called the "barrel veto". This was used to discriminate against the cosmic ray background based on event topology in the first data-taking run in 2022. It has the additional possibility of using time-of-flight to further identify background events. Here I present the usage of the barrel veto to reject the cosmic ray background, and demonstrate the overall effectiveness of the ALPHA-g detector system.

Keyword-1

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Keyword-2

Anti-hydrogen

Keyword-3

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