Contribution ID: **55** Type: **Contributed Oral**

Towards a High Precision Measurement of the Hyperfine Structure of Antihydrogen

Friday, 14 February 2025 11:15 (15 minutes)

The imbalance of matter and antimatter in the universe challenges our understanding of physics. While the Standard Model predicts that matter and antimatter should exist in equal proportions, observations show a matter-dominated universe. To address this, the ALPHA Collaboration conducts precision spectroscopy experiments on antihydrogen, the antimatter counterpart to the hydrogen atom. Investigating differences between matter and antimatter could reveal violations of the Standard Model and suggest new physics. The ground state hyperfine splitting of antihydrogen is an area of particular interest in these measurements. ALPHA has measured the hyperfine splitting to four parts in ten thousand (compared to seven parts in ten trillion in hydrogen) by inducing resonant positron spin flip transitions, whose energy depends linearly on magnetic field. The precision of this measurement is limited by fluctuations and non-uniformity in the magnetic fields used to trap antihydrogen. This research aims to develop a novel experimental method for high-precision measurements of the hyperfine structure of antihydrogen by performing the first-ever measurements of antiproton spin flip transitions. These transitions depend quadratically on the magnetic field, with a broad maximum resonance frequency at 655 MHz. A new microwave injection system is required since the current antihydrogen trap does not support the propagation of microwaves at 655 MHz. This system features a half-wavelength stripline resonator antenna incorporated into the antihydrogen trap to inject microwaves into the antihydrogen confinement area. Efforts are currently underway to produce the first iterations of this system, with initial measurements following soon after. Comparing these results to those expected from hydrogen will provide valuable insights into the differences between matter and antimatter, potentially revealing new physics and improving our understanding of nature.

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Session Classification: Morning 2 - Particle Physics

Track Classification: Physics Beyond the Standard Model