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The magnetic moment of the antiproton

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A scheme is proposed with which it may be possible to utilize extremely cold antiprotons in a Penning trap to measure the magnetic moment of an antiproton.

Antiprotons cooled to 4 K and confined for months in a Penning trap ($B = 6$ T) are now available [1–4]. If these are used to make antihydrogen, the antiproton magnetic moment may be determined from precise spectroscopic measurements of the antihydrogen energy levels. However, familiar techniques used with trapped electrons [5] cannot be used to measure the antiproton's magnetic moment directly. Such techniques rely on the particle residing mostly in the lowest cyclotron level, requiring temperatures of 4 mK rather than the much more readily achievable 4 K used for electrons and positrons.

We suggest instead to drive the spin flip and the anomaly transition of antiprotons simultaneously with both a magnetic dipole field ($\nu_s = 250$ MHz) and a magnetic quadrupole field ($\nu_a = 160$ MHz), thereby exciting the cyclotron motion ($\nu_c = 90$ MHz) in two steps via the reserved spin state. Relevant energy levels are given in fig. 1. Scanning ν_s and ν_a, with $\nu_s - \nu_a = \nu_c$ fixed, allows resonant detection of the cyclotron energy via a potential induced across a tuned circuit. In a cylindrical and compensated open end cap trap [6], with size $\rho_0 = 1.5$ mm, coils for the anomaly transition placed at the compensation electrodes would produce a field gradient $b_1 = 12$ G/cm and coils for the spin flip transition would be located at the ring electrode. Our calculations show the radius of the cyclotron orbit of the antiprotons is then increased by 90 nm/min, which should allow detection in 10 min.

This resonant technique could allow improving the present 0.3% accuracy in the measured antiproton magnetic moment [7] by many orders of magnitude and add a second precise CPT test with baryons to the antiproton to proton mass comparison [4].

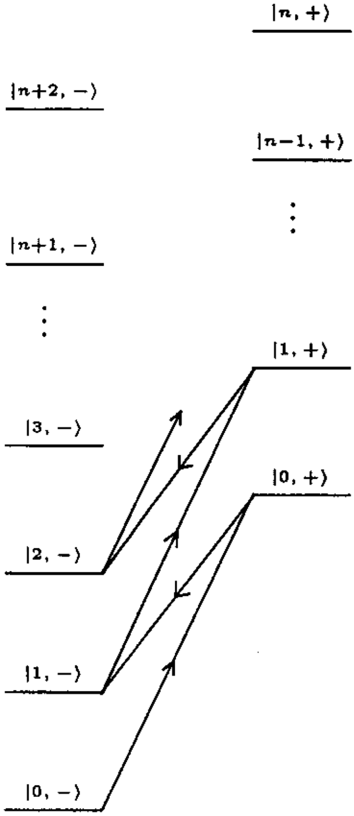

Fig. 1. Energy levels and transition frequencies for detecting the magnetic moment of the antiproton.

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