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Single Spin Flips of a Single Isolated Proton

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The CPT symmetry is a fundamental cornerstone of the Standard Model. It predicts the exact equality between the properties of particles and their antimatter counterparts. Thus, precise experimental comparisons of matter/antimatter properties provide stringent tests of the CPT symmetry. The goal of our experiment is a precise CPT test with baryons. We aim at a direct measurement of the magnetic moment of a single isolated proton in a Penning trap at a relative precision of at least 10-9. All experimental methods can directly be applied to the antiproton.
In a Penning trap the magnetic moment μp can be determined by the measurement of the Larmor frequency νL and the cyclotron frequency νc of the proton. The frequency ratio νL/νc=μp/μN yields μp in units of the nuclear magneton μN. νc can readily be determined via image current detection of the three eigenfrequencies of the trapped proton. The Larmor frequency νL is obtained by application of the continuous Stern-Gerlach effect. In this scheme an inhomogeneous magnetic field is superimposed to the trap, which couples the spin magnetic moment of the proton to its axial motion. A spin flip causes an axial frequency shift of about 170 mHz out of 740 kHz. By measuring the spin flip rate as a function of an applied drive frequency, νL is obtained. Based on a statistical detection of spin flips in the inhomogeneous magnetic field [1] we measured the magnetic moment of the proton with a precision of 8.9 ppm [2]. Another group achieved 2.5 ppm in the case of the proton [3] and 4.4 ppm in the case of the antiproton [4] using a similar setup.
However, the precision of these results is limited by the superimposed inhomogeneity of the magnetic field, which significantly broadens the Larmor resonance line. The precision can be improved by orders of magnitude by using the double-Penning trap technique. In this method the frequency measurements of νc and νL, and the spin state analysis by means of the magnetic inhomogeneity are spatially separated to two traps, a precision trap and an analysis trap, respectively. In the PT the magnetic field is about a factor of 100000 more homogeneous than in the AT. This reduces the line with of the Larmor resonance drastically. The double-Penning trap technique requires that single spin flips can be resolved, which was so far not possible with nuclear spins. However, with a significantly improved apparatus we recently achieved this challenging goal by using Bayesian statistics [5]. This enabled the first demonstration of the double trap technique with a single proton [6], which is a major step towards a high precision measurement of the proton/antiproton magnetic moment at the ppb level.
In the talk an overview on the experimental status is presented and an outlook towards the first high precision measurement of the proton magnetic moment by means of the double trap technique is given.

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