Contribution ID: **33** Type: **not specified**

First Direct High Precision Measurement of the Magnetic Moment of the Proton and Status of the BASE Experiment

Wednesday, 17 September 2014 09:30 (30 minutes)

One of the fundamental properties of the proton and the antiproton is the spin magnetic moment μ_{p,p}. So far, the most precise value of the proton magnetic moment was based on spectroscopy of a hydrogen maser in a magnetic field [1]. Theoretical corrections at the level of 17.7 ppm were required to extract μp with a fractional precision of about 10ppb. Using a Penning trap with a superimposed magnetic inhomogeneity, the magnetic moment of the antiproton was measured with a fractional precision of 4.4ppm [2]. In our Penning trap experiments we aim at direct measurements of both values with fractional precisions at the ppb level, or better. The comparison of both values will provide a stringent test of CPT-invariance with baryons.
Our measurements are based on the determination of a frequency ratio μ_p/μ_N = ν_L/ν_c, where μ_N is the nuclear magneton, and ν_L and ν_c the Larmor- and the cyclotron frequency, respectively. The cyclotron frequency is measured by image current detection, while the Larmor frequency is obtained by performing quantum jump spectroscopy in a magnetic inhomogeneity. This method has already been applied with great success in measurements of the electron/positron magnetic moments, however the (anti)proton magnetic moment is about 660 times smaller than that of the electron/position system which constitutes a significant challenge. To resolve proton spin quantum transitions a magnetic bottle of 300.000 T/m^2 is required [3]. This strong inhomogeneity limits experimental precision to the ppm level. Thus, we apply the so-called double Penning trap technique which separates the spin state analysis and the precision frequency measurement to two traps, an analysis trap and a precision trap, where the magnetic field is homogeneous. Recently we demonstrated this technique for the first time with a single proton [4] and based on this success we measured the proton magnetic moment for the first time directly[5]. Our first direct high-precision measurement of the proton magnetic moment is more than 760 times more precise than any direct measurement performed so far. The value is consistent with the currently accepted CODATA value, but 2.5 times more precise. To apply this method to the antiproton, we are currently constructing the BASE experiment at the antiproton decelerator of CERN. In the talk I will present our recent magnetic moment measurement and report on the status of both experiments.

References

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