The Magnetic Moments of the Proton and the Antiproton

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One of the fundamental properties of the proton/antiproton is the spin magnetic moment $\mu_p/\mu_{\bar{p}}$. In case of the proton the most precise value of μ_p was based on spectroscopy of atomic hydrogen conducted in 1972. Significant theoretical bound-state corrections had to be applied to indirectly determine μ_p with a relative precision of 9 ppb [1]. Very recently, we improved this value by a factor of 2.5 by directly measuring μ_p using a single proton in a Penning trap [2]. In case of the antiproton $\mu_{\bar{p}}$ is known with a relative precision at the ppm level [3]. By applying our methods to $\mu_{\bar{p}}$, we aim at a thousandfold improvement in precision of its value. To this end, we were setting up the BASE (Baryon Antibaryon Symmetry Experiment) experiment at the antiproton decelerator of CERN [4], to eventually provide a stringent test of CPT-invariance with baryons.

In a Penning trap the measurement of $\mu_p/\mu_{\bar{p}}$ is based on the determination of two frequencies of a single proton/antiproton, the Larmor and the cyclotron frequency. Based on a statistical detection of spin transitions we measured the Larmor frequency of a single proton for the first time [5], which resulted in a direct determination of μ_p with a fractional precision at the ppm level [6]. The precision was improved significantly by using a double Penning-trap technique. This required the detection of single spin flips, which was achieved with an improved apparatus and by using Bayesian data analysis [7]. Our developments ultimately culminated in the most precise and first direct high-precision measurement of μ_p with a fractional accuracy of 3.3 ppb.

For BASE a significantly improved setup using a state-of-the-art trapping system has been developed. We successfully commissioned our four-Penning trap system with antiprotons provided by the antiproton decelerator of CERN. Within our first experiments we were able to demonstrate cyclotron frequency measurements with fractional precisions at the level of 70 ppt. The achieved precision will enable us to perform the aimed antiproton magnetic moment measurement. Moreover, an improvement in precision of the proton-to-antiproton charge-to-mass ratio is in reach. A detailed status update will be presented.

References

[1] S. G. Karshenboim, V. G. Ivanov Phys. Lett. B **566**, 27 (2003)
[2] A. Mooser *et al.* Nature **509**, 59 (2014)
[3] J. DiSciacca *et al.* Phys. Ref. Lett. **110**, 130801 (2013)
[4] C. Smorra *et al.* Hyperfine Interact. **228**, 31 (2014)
[5] S. Ulmer *et al.* Phys. Ref. Lett. **106**, 253001 (2011)
[6] C. C. Rodegheri *et al.* New J. Phys. **14**, 063011 (2012)
[7] A. Mooser *et al.* Phys. Ref. Lett. **110**, 140405 (2013)