

The magnetic moments of the proton and the antiproton

A. Mooser

¹RIKEN, Ulmer Initiative Research Unit, Japan

One of the fundamental properties of the proton/antiproton is the spin magnetic moment $\mu_{p,\bar{p}}$. In case of the proton the most precise value of μ_p was based on spectroscopy of atomic hydrogen conducted 42 years ago. 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 with 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 the antiproton, we aim at a thousandfold improved measurement of $\mu_{\bar{p}}$. To this end, we are setting up the BASE 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 $\mu_{p,\bar{p}}$ is based on the determination of the 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 measurement of μ_p .

For BASE a significantly improved setup using a state of the art trapping system has been developed. After a construction phase of about 1.5 years, 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 at the 100ppt level, which is precise enough to perform the aimed antiproton magnetic moment measurement. A detailed status update will be presented.

References

- [1] S. G. Karshenboim and V. G. Ivanov, Phys. Lett. B 566, 27 (2003).
- [2] A. Mooser et al., Nature 509, 59 (2014).
- [3] J. DiSciaccia et al., Phys. Rev. Lett. 110, 130801 (2013).
- [4] C. Smorra *et al.* Hyperfine Interact. DOI: 10.1007/s10751-014-1018-7 (2014).
- [5] S. Ulmer et al., Phys. Rev. Lett. 106, 253001 (2011).
- [6] C. C. Rodegheri et al., New J. Phys. 14, 063011 (2012).
- [7] A. Mooser et al., Phys. Rev. Lett. 110, 140405 (2013).