Towards Sympathetic Cooling of a Single (Anti)Proton in a Penning Trap for a High-Precision Measurement of the Particle's Magnetic Moment

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Precise comparisons of the fundamental properties of protons and antiprotons, such as magnetic moments and charge-to-mass ratios, provide stringent tests of CPT invariance, and thus, matter-antimatter symmetry. Using advanced Penning-trap methods, we have recently determined the magnetic moments of the proton and the antiproton with a relative precision of 0.3 p.p.b. and 1.5 p.p.b., respectively [1, 2].

Both experiments rely on sub-thermal cooling of the particle's modified cyclotron mode using feedback-cooled tuned circuits. This time-consuming process is ultimately required to identify single spin quantum transitions with high detection fidelity, which is a major prerequisite to apply the multi-trap methods that are essential for p.p.b. measurements.

Methods of laser cooling achieved unprecedented quantum control of trapped ions. However, they are not directly applicable to our experiments because the proton and antiproton lack the electronic structure required for laser cooling.

In order to advance our techniques and to drastically reduce the measurement time, we are currently implementing methods to sympathetically cool protons and antiprotons by coupling them to laser-cooled beryllium ions, using a common endcap method [3].

To this end, our collaboration has developed a new apparatus featuring a common endcap double Penning trap. Based on our calculations we expect that this new apparatus will enable us to prepare single protons and antiprotons with energies close to the Doppler limit of laser cooling within tens of seconds, which will ultimately reduce our particle preparation times by a factor of at least 50 [4].

In this poster we present the experiment and the status of our ongoing efforts to deterministically prepare single protons and antiprotons at mK-temperatures.

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[1] Schneider, G. *et al.*, Science **358**, 1081 (2017)
[2] Smorra, C. *et al.*, Nature **550**, 371 (2017)
[3] Heinzen, D. J. & Wineland, D. J., Phys. Rev. A **42**, 2977 (1990)
[4] Bohman M. *et al.*, J. Mod. Opt. (2017)