Sympathetic Cooling of Single Protons (and Antiprotons)

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Within the BASE collaboration, we perform most precise tests of the CPT symmetry in the baryon sector by measurements of the fundamental properties of protons and antiprotons. Our recent 300 ppt measurement of the proton magnetic moment at the proton g-factor experiment in Mainz is predominantly limited by statistics [1]. The reason is that the current use of sub-thermal cooling of a single proton by a resistive method is extremely time-consuming and leads to cycle times of hours.

To overcome this limitation, sympathetic cooling by laser-cooled Be+ ions in a separate Penning trap, connected by a common-end-cap, is being developed [2,3]: The method not only promises to produce single protons and antiprotons with mK temperatures within tens of seconds but also ensures separation of the cooled ion and the refrigerator ions.

We present the current setup of the proton g-factor experiment and report on the status and recent upgrades, such as in-trap detection of fluorescence photons using SiPMs at 4 K, located 12 mm from the laser-cooled Be+ ion cloud. We further present first experiments on sympathetic cooling of a single proton to temperatures of a few K. In these experiments, coupling of laser-cooled Be+ ions and a single proton is achieved with the help of a common LC resonator. This enhances the coupling strength compared to the common-end-cap coupling, but also leads to additional heating effects.

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[3] Bohman, M. et al., J. Mod. Opt. **65**, 568 (2017)