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Sympathetic cooling of a single proton in a Penning trap by laser-cooled beryllium ions

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The BASE collaboration performs high-precision Penning trap measurements of the g-factors and charge-to-mass ratios of the proton and antiproton to test CPT in the baryonic sector [1]. Currently, the g-factor measurement of the proton is limited by the statistical uncertainty. This uncertainty stems from finite particle temperatures, which were so far restricted to about 1K by the technique of resistive cooling [2]. However, cooling a single (anti-)proton to even lower temperatures is challenging as it has no electronic structure for laser-cooling. Moreover, sympathetic cooling methods typically rely on co-trapping another laser-cooled species, which is often detrimental to the precision measurement. As a consequence, proposals to cool arbitrary charged particles by coupling them to a laser-cooled species via image currents have been made [3]. The coupling can either be mediated by a common superconducting resonator, which is normally used for particle detection, or a common trap electrode.

Recently our group has published the first proof-of-principle measurement on sympathetically cooling a single proton from 17.0(2.4)K to 2.6(2.5)K [4]. The proton was coupled to laser-cooled beryllium ions via a common resonator. In order to optimize the experimental parameters and study different cooling schemes, simulation code has been developed. A comparison between simulation and existing experimental data yields good agreement. Furthermore, we find that temperatures in the 10mK-regime with cooling time constants of about 10s are feasible with dedicated cooling schemes. On the experimental side, at the time of this abstract a setup is being commissioned with which we anticipate to resolve the expected mK temperatures.

This talk will give an overview of the BASE-Mainz experiment as well as the most recent experimental results towards cooling a single proton in a Penning trap. A special focus will be placed on the simulation work towards improved cooling schemes.

[1] C. Smorra et al., The European Physical Journal Special Topics, 224, 16, 2015.
[2] G. Schneider et al., Science, 358, 6366, 2017.
[3] D. Heinzen, D. J. Wineland, PRA, 42, 5, 1990.
[4] M. Bohman et al., Nature, 596, 514–518, 2021.

Author: WILL, Christian (Max-Planck-Institute for Nuclear Physics (DE))

Co-authors: BOHMAN, Matthew Anders (Max-Planck-Gesellschaft (DE)); DRISCOLL, Thomas (The University of Texas at Austin (US)); WIESINGER, Markus (Max-Planck-Gesellschaft (DE)); ABBASS, Fatma (Johannes Gutenberg-Universität Mainz (DE)); BORCHERT, Matthias Joachim (Leibniz Universitaet Hannover (DE)); DEVLIN, Jack (CERN (CH)); ERLEWEIN, Stefan (Max-Planck-Gesellschaft (DE)); FLECK, Markus (University of Tokyo (JP)); JAGER, Julia Ines (Max-Planck-Gesellschaft (DE)); LATACZ, Barbara Maria (RIKEN (JP)); MICKE, Peter (CERN (CH)); MOOSER, Andreas (Max-Planck-Gesellschaft (DE)); POPPER, Daniel (Johannes Gutenberg-Universität Mainz (DE)); WURSTEN, Elise (RIKEN (JP)); BLAUM, Klaus (Max-Planck-Gesellschaft (DE)); MATSUDA, Yasuyuki (University of Tokyo (JP)); OSPELKAUS, Christian (Leibniz Universitaet Hannover (DE)); QUINT, Wolfgang Peter (GSI - Helmholtzzentrum fur Schwerionenforschung GmbH (DE)); Prof. WALZ, Jochen (Johannes Gutenberg-Universität Mainz (DE)); SMORRA, Christian (Johannes Gutenberg-Universität Mainz (DE)); ULMER, Stefan (RIKEN (JP))

Presenter: WILL, Christian (Max-Planck-Institute for Nuclear Physics (DE))

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