Sympathetic Cooling of a Single Trapped Proton

Markus Wiesinger[a]
on behalf of the BASE collaboration

[a] *Max-Planck-Institut für Kernphysik, Heidelberg, Germany*

Precise tests of the CPT symmetry in the baryon sector are performed by high-precision measurements of the fundamental properties of protons and antiprotons [1, 2, 3]. The most precise measurement of the proton magnetic moment, performed at the proton g-factor experiment in Mainz, is currently at 300 ppt, 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 $^9Be^+$ ions stored in a separate Penning trap and connected by a common-end-cap, is being developed [4, 5]. 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 initial experiments on sympathetic cooling of a single proton to a temperature of 2.6(2.5) K [6]. In these experiments, coupling of laser-cooled $^9Be^+$ ions and a single proton is achieved with the help of a common LC resonator (figure 1). This enhances the coupling strength compared to the common-end-cap coupling significantly, but also leads to additional heating effects.

We further discuss recently installed upgrades of the proton g-factor experiment such as a dedicated cyclotron temperature measurement trap with higher temperature resolution and report on the status of ongoing measurements.

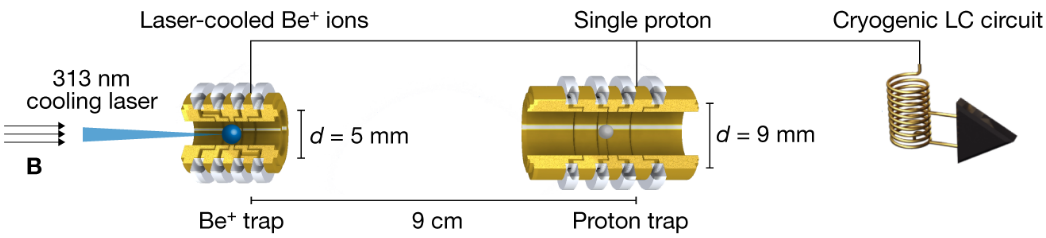

Figure 1: A single trapped proton coupled to laser-cooled beryllium ions via a superconducting resonator.

[1] Schneider, G. *et al.*, Science **358**, 1081 (2017)
[2] Smorra, C. *et al.*, Nature **550**, 371 (2017)
[3] Borchert, M. J. *et al.*, Nature **601**, 53 (2022)
[4] Heinzen, D. J. & Wineland, D. J., Phys. Rev. A **42**, 2977 (1990)
[5] Bohman, M. *et al.*, J. Mod. Opt. **65**, 568 (2017)
[6] Bohman, M. *et al.*, Nature **596**, 514 (2021)

BASE collaboration:

Markus Wiesinger[a], Fatma Abbass[b], Matthew Bohman[a,c], Ron Moller[b], Daniel Popper[b], Friedemann Rohland[b], Christian Will[a], Matthias Borchert[c,d,e], Jack Devlin[c,f], Stefan Erlewein[a,c], Markus Fleck[c,g], Julia Jäger[a,c,f], Barbara Latacz[a,c], Peter Micke[c,f], Gilbertas Umbrazunas[c,h], Frederik Völksen[c,i], Elise Wursten[b,c], Klaus Blaum[a], Yasuyuki Matsuda[g], Andreas Mooser[a], Christian Ospelkaus[d,e], Wolfgang Quint[i], Christian Smorra[b], Anna Soter[h], Jochen Walz[b,j], Yasunori Yamazaki[c], and Stefan Ulmer[c]

[a] *Max-Planck-Institut für Kernphysik, Heidelberg, Germany*
[b] *Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany*
[c] *RIKEN, Ulmer Fundamental Symmetries Laboratory, Wako, Japan*
[d] *Institut für Quantenoptik, Leibniz Universität, Hannover, Germany*
[e] *Physikalisch-Technische Bundesanstalt, Braunschweig, Germany*
[f] *CERN, Meyrin, Switzerland*
[g] *Graduate School of Arts and Sciences, University of Tokyo, Tokyo, Japan*
[h] *Eidgenössisch Technische Hochschule Zürich, Zürich, Switzerland*
[i] *GSI-Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany*
[j] *Helmholtz-Institut Mainz, Johannes Gutenberg-Universität, Mainz, Germany*