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Precision measurements on protons and antiprotons in the BASE collaboration

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Precision measurements of conjugate particles and antiparticles test CPT invariance, a fundamental symmetry in the Standard Model of particle physics. Penning traps can precisely measure the charge-to-mass ratios and magnetic moments of charged particles. The BASE collaboration is performing such measurements on single trapped protons and antiprotons, and reported recently a charge-to-mass ratio comparison of the proton and antiproton with 16 parts per trillion (ppt) relative uncertainty [1]. The magnetic moments of the proton and antiproton were measured with 300 ppt in the BASE-Mainz apparatus [2] and with 1600 ppt in the BASE-CERN experiment [3], respectively. Presently, precise control of magnetic field gradients in the measurement trap and highly optimized resistive cyclotron cooling in a dedicated cooling trap enable improved magnetic moment measurements in the BASE-CERN experiment. Further, we have developed a sympathetic cooling method by image-current coupling between two traps to cool single protons and antiprotons for precision measurements [4], and developments regarding ground-state cooling and quantum logic methods for protons and antiprotons are ongoing in BASE Hannover [5]. As next step, we aim to implement transportable antiproton traps to relocate antiproton precision measurements into laboratories with calm magnetic field conditions to circumvent limitations by magnetic field fluctuations imposed by the operations in the antiproton decelerator hall. We are presently setting up the BASE-STEP trap system in a transportable superconducting magnet to demonstrate the relocation of an antiproton reservoir [6].
I will present an overview of the physics goals, methods, and recent developments in the BASE collaboration.
[1] M. J. Borchert et al., Nature 601, 53 (2022).
[2] G. Schneider et al., Science 358, 1081 (2017).
[3] C. Smorra et al., Nature 550, 371 (2017).
[4] M. A. Bohman et al., Nature 596, 514 (2021).
[5] J. M. Cornejo et al., Physical Review Research 5, 033226 (2023).
[6] C. Smorra et al., Rev. Sci. Instr. 94, 113201 (2023).

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