SYAM 1: Atomic Anti-Matter Physics I

Time: Thursday 11:00–13:00 Location: P 1

Invited Talk SYAM 1.1 Thu 11:00 P 1

Buffer gas cooling of antiprotonic helium to T=1.5-1.7 K, and the antiproton to electron mass ratio — •Masaki Hori — Max-Planck Institute for Quantum Optics, Garching, Germany

The antiproton-to-electron mass ratio can be precisely determined from the single-photon transition frequencies of antiprotonic helium. We measured 13 such frequencies with laser spectroscopy to a fractional precision of 2.5 to 16 ppb. About two billion antiprotonic helium atoms were cooled to temperatures between 1.5 and 1.7 kelvin by using buffer-gas cooling in cryogenic low-pressure helium gas; the narrow thermal distribution led to the observation of sharp spectral lines of small thermal Doppler width. The deviation between the experimental frequencies and the results of three-body quantum electrodynamics calculations was reduced by a factor of 1.4 to 10 compared with previous single-photon experiments. From this, Embedded Image was determined as 1836.1526734(15), which agrees with a recent proton-to-electron experimental value within 0.8 ppb.

Invited Talk SYAM 1.2 Thu 11:30 P 1

The BASE Experiment: High-precision comparisons of the fundamental properties of protons and antiprotons — •C. Smorra[1,2], M. Besirli[1], K. Blaum[3], M. Bohman[3], M. J. Borchert[1,4], J. Harrington[1,3], T. Higuchi[1,5], H. Nagahama[1,5], Y. Matsuda[5], A. Mooser[1], C. Ospelkaus[4,6], W. Quint[7], S. Sellner[1], G. Schneider[1,8], N. Schoen[8], T. Tanaka[1], J. Walz[8,9], Y. Yamazaki[10], and S. Ulmer[1] — [1]RIKEN, Ulmer IRU, Wako, Japan — [2]CERN, Geneva, Switzerland — [3]Max-Planck-Institut für Kernphysik, Heidelberg — [4]Institut für Quantenoptik, Universität Hannover — [5]Graduate School for Arts and Sciences, University of Tokyo — [6]Physikalisch Technische Bundesanstalt, Braunschweig — [7]GSI Helmholtzzentrum fuer Schwerionenforschung, Darmstadt — [8]Institut für Physik, Universität Mainz — [9]Helmholtz-Institut Mainz — [10]RIKEN, Atomic Physics Laboratory, Wako, Japan

One of the puzzles of modern physics is the striking imbalance of matter and antimatter observed in our universe. The Standard Model of particle physics and cosmology struggle to find a satisfying explanation for the lack of antimatter in our universe. This fact inspires to test the most fundamental discrete symmetry of the Standard Model, the CPT symmetry, by comparing the fundamental properties of protons and antiprotons at low energy and with highest precision. I will present the results obtained by the BASE collaboration: a high-precision measurement of the antiproton charge-to-mass ratio with 69 ppt relative uncertainty, and results obtained on the way to a direct high-precision measurement of the antiproton magnetic moment.

Invited Talk SYAM 1.3 Thu 12:00 P 1

Antihydrogen physics at the ALPHA experiment — •Niels Madsen — Swansea University, Swansea, UK

The ALPHA experiment studies trapped antihydrogen. Antihydrogen is synthesised and trapped by merging cold samples of positrons and antiprotons inside an energised magnetic minimum neutral atom trap. A recent upgrade to the ALPHA apparatus - called ALPHA-2 - allows us to not only illuminate the trapped atoms with microwaves but also with laser-light. This setup allows for a number of exciting fundamental tests by measuring the internal quantum states of the trapped antihydrogen.

I will report on recent progress in trapping and synthesis of antihydrogen as well as progress towards precision measurements of the internal states of antihydrogen in both the microwave (hyperfine) and the laser regimes (1S-2S). In particular the 1S-2S transition holds great promise for precision comparisons of matter and antimatter as its frequency is known to about 15 decimal places in hydrogen.

SYAM 1.4 Thu 12:30 P 1

Sympathetic Laser Cooling of Coupled Ions in a Penning Trap — •Matthew Bohman[1,2], Andreas Mooser[2], Natalie Schön[3], Georg Schneider[2,3], James Harrington[1,2], Takashi Higuchi[2,4], Hiroki Nagahama[2,4], Stefan Sellner[2], Christian Smorra[2,5], Toya Tanaka[2,4], Klaus Blaum[1], Yasuyuki Matsuda[4], Wolfgang Quint[6], Jochen Walz[3,7], Yasunori Yamazaki[8], and Stefan Ulmer[2] — [1]MPIK Heidelberg, Germany — [2]RIKEN, Ulmer IRU, Japan — [3]University of Mainz, Germany — [4]University of Tokyo, Japan — [5]CERN, Switzerland — [6]GSI Darmstadt — [7]HIM Mainz, Germany — [8]RIKEN, APL, Japan

Many atomic systems cannot practically be directly addressed by an electric dipole cooling transition, however, temperatures on the mK scale or below are often necessary for precision experiments. As a result, ions with a readily accessible transition can be directly cooled and thermally cool the system of interest. To this end, we have designed an experiment with two Penning traps coupled together with a common endcap. Beryllium ions in one trap can be Doppler cooled on one of the 2s-2p lines at approximately 313 nm and a proton, coupled through image currents in the common endcap, should be able to reach temperatures near the Doppler limit. Ultimately, this technique will allow additional precision measurements of the proton, including a stringent test of CPT symmetry through a measurement of the g-factor of the proton and anti-proton.

SYAM 1.5 Thu 12:45 P 1

The Proton g-Factor Experiment at Mainz — •Georg Schneider[1,2], Matthew Bohman[3], Andreas Mooser[2], Natalie Schön[1], James Harrington[3], Takashi Higuchi[2,4], Hiroki Nagahama[2,4], Stefan Sellner[2], Christian Smorra[2,5], Toya Tanaka[2,4], Klaus Blaum[3], Yasuyuki Matsuda[4], Wolfgang Quint[6], Jochen Walz[1,7], Yasunori Yamazaki[8], and Stefan Ulmer[2] — [1]University of Mainz, Germany — [2]RIKEN, Ulmer IRU, Japan — [3]MPIK Heidelberg, Germany — [4]University of Tokyo, Japan — [5]CERN, Switzerland — [6]GSI Darmstadt, Germany — [7]HIM Mainz, Germany — [8]RIKEN, APL, Japan

In 2014 we measured the *g*-factor of a single proton in a Penning trap with a relative precision of 3.3 parts per billion. Now we aim to improve the precision even further to a level of 10^{-10} or better.

The measurement technique makes use of two spatially separated traps, the homogeneous precision trap (PT) to perform high-precision frequency measurements and the analysis trap (AT) with a superimposed magnetic inhomogeneity to detect the spin-state. One of the previous limitations was a residual magnetic field inhomogeneity in the PT caused by the AT. To reduce this systematic effect the distance between the two traps was increased. Furthermore, a self-shielding coil and new detectors were installed. Ultimately, the implementation of these improved techniques at our antiproton experiment BASE at CERN will provide one of the most sensitive tests of the fundamental CPT symmetry in the baryon sector.