Symposium Atomic Anti-Matter Physics (SYAM)

jointly organized by
the Atomic Physics Division (A),
the Quantum Optics and Photonics Division (Q),
the Molecular Physics Division (MO),
the Mass Spectrometry Division (MS),
the Hadronic and Nuclear Physics Division (HK), and
the Particle Physics Division (T)

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Overview of Invited Talks and Sessions

(Lecture room P 1)

Invited Talks

SYAM 1.1	Thu	11:00–11:30	P 1	**Buffer gas cooling of antiprotonic helium to T=1.5-1.7 K, and the antiproton to electron mass ratio** — •Masaki Hori
SYAM 1.2	Thu	11:30–12:00	P 1	**The BASE Experiment: High-precision comparisons of the fundamental properties of protons and antiprotons** — •C. Smorra, M. Besirli, K. Blaum, M. Bohman, M. J. Borchert, J. Harrington, T. Higuchi, H. Nagahama, Y. Matsuda, A. Mooser, C. Ospelkaus, W. Quint, S. Sellner, G. Schneider, N. Schoen, T. Tanaka, J. Walz, Y. Yamazaki, S. Ulmer
SYAM 1.3	Thu	12:00–12:30	P 1	**Antihydrogen physics at the ALPHA experiment** — •Niels Madsen
SYAM 2.1	Thu	14:30–15:00	P 1	**Muon g-2** — •Klaus Jungmann
SYAM 2.2	Thu	15:00–15:30	P 1	**Antihydrogen physics at ASACUSA and AEGIS** — •Chloé Malbrunot
SYAM 2.3	Thu	15:30–16:00	P 1	**An experiment to measure the anti-hydrogen Lamb shift** — •Paolo Crivelli

Sessions

SYAM 1.1–1.5	Thu	11:00–13:00	P 1	**Atomic Anti-Matter Physics I**
SYAM 2.1–2.5	Thu	14:30–16:30	P 1	**Atomic Anti-Matter Physics II**

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.

SYAM 2: Atomic Anti-Matter Physics II

Time: Thursday 14:30–16:30 Location: P 1

Invited Talk SYAM 2.1 Thu 14:30 P 1
Muon g-2 — •Klaus Jungmann — Van Swinderen Institute, University of Groningen, The Netherlands

The magnetic anomaly of the muon has been measured to o.54ppm at the Brookhaven National Laboratory, USA. The theoretical value of this quantity has been calculated using several approaches which have converged at a value which differs from the experimental result by about 3.5 standard deviations. In order to clarify whether a significant difference (>5 standard deviations) exists an improved experiment is underway at the Fermi National Laboratory, USA. It uses in all essential parts the same approach and technological concepts, in particular the very same storage ring of 7m radius in which muons at magic momentum are stored in 1.45 Tesla magnetic field. At J-PARC, Japan, a second experiment is underway. It uses different rather technology in many essential parts, in particular higher magnetic field and a much smaller radius magnet. The perspectives for both experiments will be discussed together with the possible implications of a measurement at higher accuracy.

Invited Talk SYAM 2.2 Thu 15:00 P 1

Antihydrogen physics at ASACUSA and AEGIS — •Chloé Malbrunot — CERN, Geneva, Switzerland

A growing number of collaborations are performing experiments at the CERN Antiproton Decelerator (AD), the only available facility providing slow antiprotons suitable for precision measurements with anti-atoms. The majority of these experiments are forming antihydrogen atoms with the main goal of probing their atomic transitions which have been measured in hydrogen to a remarkable precision. The precise comparison between the hydrogen and antihydrogen transitions has indeed the potential to provide one of the most sensitive tests of CPT symmetry. More recently, experiments have begun to employ antihydrogen atoms to test the validity of the Weak Equivalent Principle on antimatter by measuring the fall of these anti-atoms in the Earth's gravitational field. The ASACUSA-CUSP and AEGIS collaborations are both aiming at forming a cold beam of antihydrogen atoms in order to measure their ground-state hyperfine splitting (ASACUSA) and free fall in the Earth gravitational field (AEGIS) in an electromagnetic field-free region. After shortly describing the experimental setups adopted by those collaborations and discussing their respective sensitivities, I will highlight the latest developments and the upcoming experimental challenges towards CPT and gravity tests with antihydrogen atoms.

Invited Talk SYAM 2.3 Thu 15:30 P 1

An experiment to measure the anti-hydrogen Lamb shift — •Paolo Crivelli — ETH Zurich, Institute for Particle Physics, 8093 Zurich, Switzerland

The upcoming operation of the Extra Low ENergy Antiprotons (ELENA) ring at CERN, the upgrade of the anti-proton decelerator (AD), and the installation in the AD hall of an intense slow positron beam with an expected flux of 10^8 e^+/s will open the possibility for new experiments with anti-hydrogen ($\bar{H}$). In this talk we will present an experiment to measure the Lamb shift of $\bar{H}$ at the 100 ppm level. This will provide a test of CPT and the first determination of the anti-proton charge radius at the level of 10%.

SYAM 2.4 Thu 16:00 P 1

Monitoring o-Ps formation by means of the scintillating fibre detector at AEgIS (CERN) — •Benjamin Rienäcker — Physics Department, CERN, 1211 Geneva 23, Switzerland

The AEgIS experiment at CERN aims to directly measure Earth's gravitational force on antihydrogen with a precision of 1%. To achieve this, antihydrogen will be produced by charge exchange reaction between cold antiprotons and Rydberg-positronium. As an intermediate step, ground-state ortho-positronium is produced by implanting a bunch of several 10^7 positrons into a nanochanneled Si-target. Here, a novel method to use the Fast Annihilation Cryogenic Tracking (FACT) scintillating fibre detector to monitor the formation of ortho-positronium atoms inside the 1T magnet of the AEgIS experiment is described. A single scintillating fibre was coupled to a PMT and irradiated by flashes of about 6×10^6 gamma rays (511 keV) produced by 10 ns FWHT positron bursts. Results have been used to demonstrate the possibility to time-tag the decay of ortho-positronium in vacuum by using the FACT detector as a digital calorimeter.

SYAM 2.5 Thu 16:15 P 1

Permanent Electric Dipole Moment Search in 129Xe — •Olivier Grasdijk[1], Fabian Allmendinger[2], Peter Blümler[3], Werner Heil[3], Klaus Jungmann[1], Sergei Karpuk[3], Hans-Joachim Krause[4], Andreas Offenhäusser[4], Maricel Repetto[3], Ulrich Schmidt[2], Yury Sobolev[3], Lorenz Willmann[1], and Stefan Zimmer[3] — [1]VSI, University of Groningen — [2]Universität Mainz — [3]Universität Heidelberg — [4]Forschungszentrum Jülich

A permanent electric dipole moment (EDM) implies breakdown of P (parity) and T (time reversal) symmetries. Provided CPT holds, this implies CP violation. Observation of an EDM at achievable experimental sensitivity would provide unambiguous evidence for physics beyond the Standard Model and limits towards matter-antimatter asymmetry. Our experiment uses differential spin precession of 3He and 129Xe, cooccupying the same volume, to measure the EDM of xenon. We have reached in a first test already sensitivity in the range 10-28 ecm. I will present the current status of the experiment and challenges like long term (weeks) tight control over magnetic and electric fields.