Q 72: Precision Spectroscopy of Atoms and Ions IV (with A)

Time: Friday 11:00–13:00 Location: C/kHS

Q 72.1 Fri 11:00 C/kHS

The BASE catching trap: A reservoir for antiprotons — •Christian Smorra for the BASE-Collaboration — CERN, CH-1211 Geneva 23, Switzerland

The Baryon-Antibaryon Symmetry Experiment BASE has commissioned a four-Penning trap system for the high-precision measurement of the antiproton magnetic moment at the Antiproton Decelerator (AD) of CERN. To inject, capture and cool antiprotons of 5.3 MeV kinetic energy from the AD to below 100 meV, a catching trap forms the interface between the decelerator and the precision trap system. It features a mesh degrader system of variable thickness with broad energy acceptance, high-voltage electrodes to apply catching pulses, and a five-pole Penning trap with a high-quality image current detection system for measurements of the motional frequencies and resistive cooling.

An extraction scheme for single particles from an antiproton cloud has been developed, which allows to separate and merge fractions of the antiproton cloud without particle loss. Using this scheme BASE will be able to perform precision experiments with antiprotons even in long accelerator shutdown periods.

Results of the commissioning of the catching trap and the BASE apparatus with protons and antiprotons will be presented.

Q 72.2 Fri 11:15 C/kHS

BASE: Topics in Data Analysis — •Kurt Franke for the BASE-Collaboration — Max-Planck-Institut für Kernphysik, Heidelberg, Germany — Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

BASE (Baryon-Antibaryon Symmetry Experiment) is a new experiment at CERN with the purpose of making high-precision comparison measurements of the properties of protons and antiprotons. As such, BASE functions as a sensitive test of CPT invariance in the baryon sector. This talk will cover several important data analysis aspects relevant to BASE and similar Penning-trap experiments. A single trapped particle in thermal equilibrium with a detection system creates a narrow notch or “dip” in the thermal noise of the detector at the eigenfrequency of the particle. First, these so-called “dip” measurement will be analyzed, and an expression for the expected accuracy and optimal FFT-window function for this measurement technique will be given. Next, a Bayesian recursive algorithm for calculating probabilities for spin states will be presented. Finally, the parameter selection algorithm for analyzing Larmor resonances will be presented. These analysis techniques have been applied in the most precise measurement of the proton’s magnetic moment [Nature **509**, 596–599 (2014)].

Q 72.3 Fri 11:30 C/kHS

Identification of optical transitions in Ir^{17+} ions with high sensitivity to a variation of the fine-structure constant — •Alexander Windberger[1], Oscar O. Versolato[2,3], Hendrik Bekker[1], Natalia S. Oreshkina[1], Julian C. Berengut[4], Anastasia Borschevsky[5], Victor Bock[1], Zoltán Harman[1], Sebastian Kaul[1], Ulyana I. Safronova[6], Victor V. Flambaum[4], Christoph H. Keitel[1], Piet O. Schmidt[2,7], Joachim Ullrich[1,2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik — [2]Physikalisch-Technische Bundesanstalt — [3]Advanced Research for Nanolithography — [4]University of New South Wales — [5]GSI Helmholtzzentrum für Schwerionenforschung, — [6]University of Nevada — [7]Leibniz Universität Hannover

The unique electronic structure of the Nd-like Ir^{17+} ion allows for optical transitions of interest for metrology and the investigation of a possible variation of the fine-structure constant α. We performed spectroscopy in the optical range on Ir^{17+} ions produced and trapped in an electron beam ion trap (EBIT). Complex electron correlations in Ir^{17+} impede accurate theoretical predictions making a direct identification of transitions impossible. In a different approach, we investigated the characteristic energy scaling of fine-structure transitions with the atomic number Z. In the obtained spectra of the isoelectronic Nd-like W^{14+}, Re^{15+}, Os^{16+}, and Pt^{18+}, we identified 45 transitions contributing to these energy scalings. To confirm this method, the established transitions in Ir^{17+} were independently identified via their Zeeman-structures in the magnetic field of the EBIT.

Q 72.4 Fri 11:45 C/kHS

Current status of the Proton Radius Puzzle — •Julian J. Krauth and the CREMA Collaboration — Max-Planck-Institute of Quantum Optics, Garching

This talk gives an overview on the current status of the Proton Radius Puzzle.

In 2009 the CREMA Collaboration provided a measurement of the rms charge radius of the proton via the 2S-2P Lamb shift in muonic hydrogen. It is particularly remarcable that the proton radius is found to be 4% smaller than indicated by previous experiments using electronic hydrogen or electron scattering. The radius measured by the CREMA Collaboration has a 7σ discrepancy with respect to the 2010 CODATA value which is composed by the mentioned previous experiments. The so-called Proton Radius Puzzle has caused a huge debate in the scientific community but remains unsolved up to this date. In order to shed light on the puzzle we recently performed 2S-2P Lamb shift measurements with muonic helium.

Q 72.5 Fri 12:00 C/kHS

The Experimental Apparatus of the Muonic Helium Lamb Shift Measurement — •Beatrice Franke and the CREMA Collaboration — Max-Planck-Institute of Quantum Optics, Garching

Muonic atoms have an increased sensitivity on finite size effects of the nucleus due to the approximately 200-fold mass of the muon compared to the electron. The Lamb shift experiment of the CREMA collaboration in muonic hydrogen [1] and deuterium allowed to determine the proton radius and other nuclear properties with an improved precision compared to previously conducted measurements. As a successor experiment, the determination of the Lamb shift in the muonic helium ions mu3He+ and mu4He+ [2] will be a contribution to solving the proton radius puzzle [3] as well as the discrepancy in electronic isotope-shift measurements. In this talk, an overview of the components of the experimental apparatus is given: Details on the muon beam line, the laser scheme and the different detector systems as well as other specifics necessary to perform this high sensitivity measurement.

[1] R. Pohl et al. (CREMA coll.), Nature 466, 213 (2010)

[2] A. Antognini et al. (CREMA coll.), Can. J. Phys. 89, 47-57 (2011)

[3] R. Pohl et al., Annu. Rev. Nucl. Part. Sci. 63, 175-204 (2013)

Q 72.6 Fri 12:15 C/kHS

Towards solving the proton radius puzzle: Results from the Muonic Helium Lamb Shift experiment — •Marc Diepold and the CREMA Collaboration — Max-Planck-Institute of Quantum Optics, Garching

The recently completed muonic helium Lamb shift experiment located at Paul-Scherrer-Institute (Switzerland) measured different $2S \to 2P$ Lamb-shift transition frequencies in the μ^4He^+ and μ^3He^+ exotic ions by means of laser spectroscopy.

In these hydrogen-like systems all of the atom’s electrons are replaced by a single muon upon creation when negative muons are stopped in ordinary matter. The muon’s Bohr radius is 200 times smaller than the corresponding electronic Bohr radius in ordinary H-like ions due to the 200 times larger mass of the muon. This results in a large increase in sensitivity to the finite charge and magnetic radius of the nucleus.

Preliminary results are presented that will use this to determine the nuclear rms charge radii of the smallest helium isotopes ten times more accurately in the future, serving as important input parameters in both nuclear models and atomic theory.

Furthermore these findings shed new light on the so-called Proton Radius Puzzle that was created by the 7 sigma discrepancy between measurements of the proton rms charge radius in muonic hydrogen and normal hydrogen spectroscopy or electron scattering experiments.

Q 72.7 Fri 12:30 C/kHS

First measurements of Metallic Magnetic Calorimeters for High-Resolution X-ray Spectroscopy at GSI — •D. Hengstler[1], M. Keller[1], C. Schötz[1], M. Krantz[1], J. Geist[1], T. Gassner[2,3], K.H. Blumenhagen[2,3], R. Märtin[2,3], G. Weber[2,3], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], Th. Stöhlker[2,3,4], and C. Enss[1] — [1]KIP, Heidelberg University — [2]Helmholtz-Institute Jena — [3]GSI Darmstadt — [4]IOQ, Jena University

Metallic magnetic calorimeters are particle detectors that provide a high energy resolution over a large energy range as well as an excellent linearity. They convert the energy of a single incoming photon into a temperature rise, leading to a change of magnetization in a paramagnetic Au:Er temperature sensor that is inductively read out by a SQUID magnetometer. Three different detector arrays, optimized for x-rays with energies up to 20, 30 and 200 keV respectively are presently developed as well as a compton polarimeter. With a detector optimized for 200 keV photons we performed two successful measurements at the Experimental Storage Ring at GSI. The detector was operated at $T = 20$mK and was attached to the tip of a 400 mm long and 80 mm wide cold finger of a cryogen free ^{3}He/^{4}He-dilution refrigerator. During the two beamtimes we achieved an energy resolution below 60 eV for photon energies up to 60 keV and investigated projectile beams of Au^{76+} and Xe^{54+} colliding with a Xe gas target, respectively. We were able to identify the Lyman series of Xe^{53+} up to Ly-η as well as spectral lines from He-like Xe and show that metallic magnetic Calorimeters will be a promising tool for future precision experiments at FAIR.

Q 72.8 Fri 12:45 C/kHS

Comparative study of the nuclear-polarization corrections in highly charged ions — •Andrey Volotka and Günter Plunien — Institut für Theoretische Physik, TU Dresden

A systematic investigation of the nuclear-polarization effects in one- and few-electron heavy ions is presented. The nuclear-polarization corrections in the zeroth and first orders in 1/Z have been evaluated to the binding energies, the hyperfine splitting, and the bound-electron g factor. The effect of the nuclear polarization has been investigated for the specific differences constructed in a way to cancel the nuclear size corrections. In all cases considered, it has been demonstarted, that the nuclear-polarization contributions can be substantially canceled simultaneously with the rigid nuclear corrections [1]. Therefore, the rigorous investigations of the specific differences provide a unique opportunity to test the strong-field QED with a much higher accuracy than expected before.

[1] A. V. Volotka and G. Plunien, Phys. Rev. Lett. 113, 023002 (2014).