A 36: Highly Charged Ions and their Applications II

Time: Friday 11:00–13:00 Location: HS 1010

Invited Talk A 36.1 Fri 11:00 HS 1010

Stringent Test of QED predictions using Highly Charged Tin — •Jonathan Morgner, Bingsheng Tu, Charlotte M. König, Tim Sailer, Fabian Heisse, Bastian Sikora, Chunhai Lyu, Vladimir Yerokhin, Zoltán Harman, José R. Crespo López-Urrutia, Christoph H. Keitel, Sven Sturm, and Klaus Blaum — Max-Planck-Institut für Kernphysik, Heidelberg

Quantum electrodynamics (QED) is one of the pillars of the Standard Model. Its success in describing the fundamental interactions of charged particles, including non-classical effects such as self-energy and vacuum polarisation, is demonstrated in weak fields by the precise measurement of the electron magnetic moment (or $g-2$) [1]. Testing this in strong fields is of similar importance, as it allows exploring the boundaries of validity of the theory.

Here we present our recent measurement of the bound-electron magnetic moment of hydrogen-like tin [2]. The highly charged ions are produced in an electron beam ion trap and ejected into the Alphatrap apparatus, where we store a few single ions for months to perform high-precision Penning-trap spectroscopy on them. A comparison with the *ab initio* theory prediction shows agreement, and is therefore a precise test of the underlying theory at the highest Z so far. We additionally present measurements and first results of the lithium-like and the boron-like tin system [3].

[1] X. Fan, *et al.*, PRL **130**, 071801 (2023),
[2] J. Morgner, *et al.*, Nature **622**, 53*57 (2023),
[3] J. Morgner, *et al.*, in preparation.

A 36.2 Fri 11:30 HS 1010

Sympathetic cooling of ions using electron cyclotron radiation at the ELCOTRAP experiment — •Jost Herkenhoff, Sergey Eliseev, Sven Sturm, and Klaus Blaum — Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

The evolution of precision in recent Penning-trap experiments is driving the need for ever-improving cooling techniques. In this talk, the prospect of a new sympathetic cooling technique using an electron-plasma coupled to a single ion is presented.

The cyclotron mode of electrons in a strong magnetic field and cryogenic environment decays to very low quantum numbers by emission of cyclotron radiation, causing this mode to end up predominantly in its ground state. Driving the motional sideband allows the axial motion to thermalize with the cyclotron motion to its ground state, which can then be coupled to a single ion stored in a spatially separated Penning trap using a common-resonator, allowing sympathetic cooling of all motional degrees of the ion. The extremely low expected temperatures in the millikelvin range open up an exciting new frontier of measurements in Penning traps.

The first implementation of this technique is currently being developed at the dedicated ELCOTRAP experiment at the Max-Planck Institute for Nuclear Physics, whose current status and prospects will be presented in this talk.

A 36.3 Fri 11:45 HS 1010

Metastable state detection with Penning-trap mass spectrometry — •Kathrin Kromer[1], Menno Door[1], Pavel Filianin[1], Zoltán Harman[1], Jost Herkenhoff[1], Paul Indelicato[2], Christoph H. Keitel[1], Daniel Lange[1], Chunhai Lyu[1], Yuri N. Novikov[1], Christoph Schweiger[1], Sergey Eliseev[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, — [2]Laboratoire Kastler Brossel, Sorbonne Université, CNRS, Paris, France

The construction of clocks in the XUV has recently become possible due to the extension of the frequency comb method to this frequency range. In combination with the vast landscape of transitions in highly charged ions (HCIs) a next generation of ultra precise clocks has come within reach. However, the search for suitable clock transitions, e.g. involving long-lived metastable electronic states, usually relies heavily on complicated atomic structure calculations.

With the Penning-trap mass spectrometer Pentatrap, we can discover long-lived metastable states and measure their energies without actively driving the transition and therefore being independent of theoretical predictions. With this method we have measured a metastable state energy in Pb as a mass difference of just 31.2(0.8) eV on top of the mass of the lead nuclei of ≈194 GeV, making it one of the most precise mass determination to date with a relative uncertainty of 4×10^{-12} [K. Kromer *et al.*, Phys. Rev. Lett., in print (2023)]. It is thereby possible to benchmark atomic structure calculations in open-shell HCI.

A 36.4 Fri 12:00 HS 1010

Developments of microwave filters for the LSym experiment — •Fabian Raab, Maria Pasinetti, Lukas Holtmann, Daniel Rubin, Andreas Thoma, Sangeetha Sasidharan, and Sven Sturm — MPIK Heidelberg

LSym is a new cryogenic Penning trap experiment that intends to test the symmetry of matter and antimatter in the lepton sector. In particular, the experiment will test for differences in mass, charge and g-factor of the positron and electron to achieve the most precise test for a hypothetical CPT violation so far.

In the experiment the positron has to be cooled to its ground state of motion. Therefore, the trap assembly is cooled to about 300 mK, where the trap cavity is largely depleted from black-body photons around the cyclotron frequency of 140 GHz. However, for the sideband cooling and the spin-manipulation we need drives very close to the cyclotron frequency, which can cause adverse heating far above the ground state if not accounted for.

This can be counteracted by implementing a microwave filter structure, which allows the two drives to enter the trap almost unhindered, while blocking almost all of the power close to the cyclotron frequency. Challenges that arise from the close proximity of the drive modes to the cyclotron mode and some ideas to overcome them will be presented here.

A 36.5 Fri 12:15 HS 1010

Positron source in the LSym experiment — •Maria Pasinetti, Fabian Raab, Lukas Holtmann, Daniel Rubin, Andreas Thoma, Sangeetha Sasidharan, and Sven Sturm — Max-Planck-Institut für Kernphysik

The goal of LSym is to conduct a stringent CPT test by comparing the properties of matter and antimatter with unprecedented sensitivity by simultaneously comparing the spin precession frequencies of a single positron and an electron in a millikelvin-cooled Penning trap. One of the challenges in this project is to trap one or a few positrons from a rather weak (about 1MBq) radioactive ^{22}Na source. Furthermore, an efficient detection method for the positrons needs to be designed and implemented. As the positrons follow a β^+ decay spectrum, they have to be moderated before entering the trap, a process with low efficiency requiring careful execution. The trapped positron is then cooled to the ground-state of motion in the center of the trap. This presentation illustrates the principles and techniques that will be used for the positron source at LSym.

A 36.6 Fri 12:30 HS 1010

Hyper-EBIT: The development of a source for very highly charged ions — •Athulya Kulangara Thottungal George, Matthew Bohman, Fabian Heisse, Charlotte Maria König, Jonathan Morgner, Kunal Singh, José Ramon Crespo López-Urrutia, Sven Sturm, and Klaus Blaum — Max-Planck-Institut für Kernphysik, Heidelberg

Precision tests of quantum electrodynamics (QED) in strong fields can be performed using highly charged ions (HCI). Here, only a few or even a single one of the innermost electrons are left, experiencing the strong fields originating from the nucleus. The Alphatrap experiment is a cryogenic Penning trap experiment which is dedicated to perform strong-field QED tests by measuring the bound electron magnetic moment (or g factor).

Recently, we have measured the bound electron g factor of hydrogen-like tin with Alphatrap to sub parts-per-billion precision. Our ultimate goal is to further advance such tests into the strongest fields by performing similar measurements on the heaviest HCI such as $^{208}Pb^{81+}$. For the production of $^{208}Pb^{81+}$ an electron beam ion trap called "Hyper-EBIT" is being constructed at the Max-Planck-Institut für Kernphysik with planned beam energies of 300 keV and up to 500 mA of beam currents. This contribution presents the recent developments of Hyper-EBIT.

A 36.7 Fri 12:45 HS 1010

King Plots: Constraining New Physics using Isotope Shift Spectroscopy — •Agnese Mariotti[1], Erik Benkler[2], Julian Berengut[8], Shuying Chen[2], Jose R. Crespo Lopez-Urrutia[3], Melina Filzinger[2], Elina Fuchs[1,2,4], Nils Huntemann[2], Steven A. King[2], Fiona Kirk[2], Nils H. Rehbehn[3], Jan Richter[2], Matteo Robbiati[4,6,7], Micheal K. Rosner[3], Piet O. Schmidt[2,5], Lucas J. Spiess[2], Andrey Surzyhkov[2], Anna Viatkina[2], Malte Wehrheim[2], Alexander Wilzewski[2], Diana A. Craik[9], Jeremy Flannery[9], Jonathan Home[9], Luca Huber[9], Roland Matt[9], Menno Door[3], Klaus Blaum[3], and Martin R. Steinel[2] — [1]LUH-ITP — [2]PTB — [3]MPI — [4]CERN — [5]LUH-IQ — [6]TIF Lab — [7]TII — [8]UNSW — [9]ETH/TBD

With 95% of the universe's content still unexplained by modern physics, the motivations for new physics searches are becoming more and more evident. The approach used in our work exploits the high precision of low-energy experiments to identify deviations from the theoretical predictions of the Standard Model. We utilize a combination of isotope shift measurements and King plots, which allows to minimize the required theoretical input and is sensitive to a new interaction that couples electrons and neutrons. A wise combination of experimental data enables us to set strong constraints on such coupling. Here, we show how we improve the previous bounds by building King plots with the recent measurement of isotope shift in Ca14+, carried out at PTB. Additionally, we present two ways of utilizing the available data: a geometrical approach and a fitting method.