A 4: Highly Charged Ions and their Applications I

Time: Monday 11:45–13:00 Location: N 25

A 4.1 Mon 11:45 N 25

Charge Exchange Mechanisms in Slow Highly Charged Ions Colliding with Gas Targets — •Anju Shaji Nair, Stefan Facsko, and René Heller — Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstrasse 400, Dresden 01328, Germany

The dynamic charge exchange processes occurring during the interaction of slow, highly charged ions (HCI) with a material surface are the key mechanisms guiding the inelastic processes and material response [1,2]. To isolate and understand these fundamental mechanisms, a clean two-body system is required. For this purpose, gas targets are used, as they provide an intrinsically clean environment that enables the examination of individual collision events and provide insights into the underlying electron transfer dynamics.

In this work, the interaction mechanism of slow Xenon ions having charge states 5+ to 30+ with He and N2 targets is investigated. The experimentally determined single-electron capture cross-sections show a decreasing trend with increasing projectile charge state, indicating a shift in the dominant charge exchange pathways from predominantly single-electron capture to contributions from multiple electron transfer processes.

References:

[1] Niggas, A., Werl, M., Aumayr, F., & Wilhelm, R. A. (2024) J. Phys. B: At. Mol. Opt. Phys. 57(7) 072001

[2] Wilhelm, R. A. (2022) Surf. Sci. Rep. 77(4) 100577

A 4.2 Mon 12:00 N 25

Nuclear Excitation by Electron Capture - Towards a Direct and Unambiguous Detection — •Esther B. Menz for the NEEC-at-GSI-Collaboration — University of Cologne — GSI, Darmstadt

Nuclear excitation by electron capture (NEEC) is a fundamental process that provides a direct interaction between the nucleus and the atomic shell. It is the time-inverse of the well-understood process of internal conversion (IC): an electron is resonantly captured into an atomic bound state and the nucleus is simultaneously excited by the energy made available by the capture. The process is thought to be relevant for plasma and astrophysics and might have useful applications such as producing desirable nuclear isomeric states. Despite significant efforts, no uncontroversial experimental observation of NEEC has yet been reported. A claimed observation by Chiara et al. [1] deviated from theoretical predictions by nine orders of magnitude [2] and could not be independently confirmed in an experiment by Guo et al. [3]. Motivated by successful measurements of dielectronic recombination processes in ion storage rings, we plan to search for NEEC at the ESR storage ring of GSI. Using the ESR electron cooler as a free-electron target provides the distinct advantage of avoiding effects introduced by the solid target in the aforementioned single-pass experiment.

We will present the current status of experiment preparation along with estimations of the expected count and background rates.

[1] C. J. Chiara et al., Nature 554, 216 (2018)

[2] Y. Wu et al., Phys. Rev. Lett. 122, 212501 (2019)

[3] S. Guo et al., Phys. Rev. Lett. 128, 242502 (2022)

A 4.3 Mon 12:15 N 25

Update on the Lsym experimental setup — •Fabian Raab, Maria Pasinetti, Paul Holzenkamp, Sarah Placek, Leonie Marzel, Andreas Thoma, Sangeetha Sasidharan, and Sven Sturm — MPIK, Heidelberg, Germany

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 for leptons so far. In the experiment we detect the particles motional frequencies via image current detectors. To further cool the trapped positron to its ground state of motion, 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. In this presentation our recent steps towards setting up our detection system as well as an update on the microwave setup, that will be used to counteract heating above the groundstate, will be illustrated.

A 4.4 Mon 12:30 N 25

Positron trapping and current trap design at LSym — •Maria Pasinetti, Fabian Raab, Paul Holzenkamp, Andreas Thoma, Sangeetha Sasidharan, Leonie Marzel, Sarah Placek, and Sven Sturm — MPIK, Heidelberg, Germany

LSym is a new cryogenic Penning trap experiment under development at the Max-Planck-Institut für Kernphysik in Heidelberg. Its goal is a stringent CPT test by comparing matter*antimatter properties through a high-precision measurement of the electron and positron spin precession frequencies. To this end, a single positron and a He+ ion, a proxy for the electron are trapped simultaneously, enabling a decoherence-free comparison. A positron capture technique was successfully tested in December 2024. Positrons from a weak ^{22}Na β^+ source are moderated and converted into positronium in a high Rydberg state, which is then ionized inside the Penning trap, allowing the positron to be retained. The key observable is the difference in the two Larmor frequencies, determined by the charge-to-mass ratios and g-factors of the particles. These frequencies are measured with a dual Ramsey sequence, where we determine the spin projection of each particle non-destructively via the continuous Stern-Gerlach effect in a magnetic bottle. At LSym, spin-state detection occurs in the "AnalysisTrap", a five-electrode Penning trap with a ferromagnetic ring electrode that generates the required gradient. The presentation outlines the positron source concept and the current status of the AnalysisTrap fabrication and assembly.

A 4.5 Mon 12:45 N 25

Hadronic Vacuum Polarization: From functional QCD to Atomic Physics — •Eugen Dizer[1], Zoltán Harman[2], Franz R. Sattler[3], and Jonas Wessely[4] — [1]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg, Germany — [2]Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany — [3]Fakultät für Physik, Universität Bielefeld, 33615 Bielefeld, Germany — [4]Institut für Theoretische Physik, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

Hadronic vacuum polarization (HVP) remains a major source of uncertainty in precision tests of the Standard Model, particularly in the muon anomalous magnetic moment a_μ. The persistent discrepancy between data-driven evaluations and lattice QCD, together with recent updates to $g-2$, motivates a deeper investigation of HVP across independent methods. We study the hadronic polarization function $\Pi_{\mathrm{had}}(q^2)$ using functional QCD techniques, and compare with state-of-the-art data-driven determinations and lattice calculations.

We propose highly charged ions and muonic atoms as sensitive and experimentally accessible systems for probing HVP at low momentum transfer. Their clean QED structure and tunable energy scales make them an ideal platform for testing effective hadronic contributions. Using an updated effective Uehling potential, we evaluate HVP effects in these systems and assess their potential to clarify the present data–lattice tension.