A 32: Precision spectroscopy of atoms and ions IV (joint session A/Q)

Time: Friday 10:30–12:00 Location: A-H2

Invited Talk A 32.1 Fri 10:30 A-H2

High-resolution DR spectroscopy with slow cooled Be-like Pb^{78+} ions in the CRYRING@ESR storage ring — •Sebastian Fuchs[1,2], Carsten Brandau[1,3], Esther Menz[3,4,5], Michael Lestinsky[3], Alexander Borovik Jr[1], Yanning Zhang[6], Zoran Andelkovic[3], Frank Herfurth[2], Christophor Kozhuharov[3], Claude Krantz[3], Uwe Spillmann[3], Markus Steck[3], Gleb Vorobyev[3], Regina Hess[3], Volker Hannen[7], Dariusz Banaś[8], Michael Fogle[9], Stephan Fritzsche[4,5], Eva Lindroth[10], Xinwen Ma[11], Alfred Müller[1], Reinhold Schuch[10], Andrey Surzhykov[12,13], Martino Trassinelli[14], Thomas Stöhlker[3,4,5], Zoltán Harman[15], and Stefan Schippers[1,2] — [1]JLU Gießen — [2]HFHF Campus Gießen — [3]GSI — [4]HI Jena — [5]FSU Jena — [6]Xi'an Jiaotong University — [7]WWU Münster — [8]JKU Kielce — [9]Auburn University — [10]Stockholm University — [11]IMPCAS Lanzhou — [12]TU Braunschweig — [13]PTB — [14]UPMC Paris — [15]MPIK

Dielectronic recombination (DR) collision spectroscopy is a very successful tool for studying the properties of ions. Due to its versatility and the high experimental precision, DR spectroscopy plays an important role in the physics program of the SPARC collaboration. CRYRING@ESR is particularly attractive for DR studies, since its electron cooler provides an ultra-cold electron beam promising highest experimental resolving power. Here, we report on the first DR experiment with highly charged ions in the heavy-ion storage ring CRYRING@ESR of the international FAIR facility in Darmstadt. The recent results are well in accord with our expectations and the theory.

A 32.2 Fri 11:00 A-H2

Theory of the $^{3}He^{+}$ magnetic moments and hyperfine splitting — •Bastian Sikora, Zoltán Harman, Natalia S. Oreshkina, Igor Valuev, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

In an external magnetic field, the ground state of the $^{3}He^{+}$ ion is split into four sublevels due to hyperfine and Zeeman effect. The bound electron's g-factor, the ground-state hyperfine splitting as well as the shielded magnetic moment of the nucleus can be determined by measurements of transition frequencies between these sublevels [1,2].

We present the theoretical calculation of the nuclear shielding constant, the ground-state hyperfine splitting and the bound-electron g-factor. The nuclear shielding constant is required to extract the magnetic moment of the bare nucleus with unprecedented precision, enabling new applications in magnetometry. Furthermore, one can extract the nuclear Zemach radius from the experimental hyperfine splitting value. The theoretical uncertainty of the bound-electron g-factor is dominated by the uncertainty of the fine-structure constant, allowing in principle an independent determination of α in future.

[1] A. Mooser et al., J. Phys.: Conf. Ser. 1138:012004 (2018)
[2] A. Schneider et al., submitted (2021)

A 32.3 Fri 11:15 A-H2

Path integral formalism of Dirac propagators for atomic physics — •Sreya Banerjee and Zoltán Harman — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The very basic building blocks of perturbative calculations in atomic structure and collision theory are Green's functions. We extend this study of Green's functions, in the nonperturbative regime, using Feynman's path integral approach. As a first step, we derive the free Dirac propagator followed by the derivation of the Dirac-Coulomb Green's function (DCGF) in spherical coordinates, using this formalism.

For the free relativistic Dirac particle, the effective Hamiltonian for the iterated Dirac equation is constructed. The corresponding Green's function is expanded into partial waves in spherical coordinates. The radial part of this Green's function is then converted into a path integral, through reparametrisation of the paths by local time rescaling, followed by a one-to-one mapping of the radial variable with the local time parameter. This yields a closed form of the Green's function. Following the same procedure, the DCGF is diagonalised in Biedenharn's basis into a radial path integral, the effective action of which is similar to that of the non-relativistic hydrogen atom. We convert the radial path integral from Coulomb type to that of an isotropic harmonic oscillator through coordinate transformation along with local time rescaling. As such, an explicit path integral representation of the DCGF is obtained, along with the energy spectrum of the bound states.

A 32.4 Fri 11:30 A-H2

Progress of the Laser Resonance Chromatography project — •EunKang Kim[1,2], Elisabeth Rickert[1,2,3], Elisa Romero Romer[1,2,3], Harry Ramanantoanina[1,2], Michael Block[1,2,3], Mustapha Laatiaoui[1,2], and Philipp Sikora[1] — [1]Department Chemie, Johannes Gutenberg-Universität, Fritz-Strassmann Weg 2, 55128 Mainz, Germany — [2]Helmholtz-Institut Mainz, Staudingerweg 18, 55128 Mainz, Germany — [3]GSI, Planckstraße 1, 64291 Darmstadt, Germany

Optical spectroscopy of superheavy elements is experimentally challenging as their production yields are low, half-lives are very short, and their atomic structure is barely known. Conventional spectroscopy techniques such as fluorescence spectroscopy are no longer suitable since they lack the sensitivity required in the superheavy element research. A new technique called Laser Resonance Chromatography (LRC) could provide sufficient sensitivity to study super-heavy ions and overcome difficulties associated with other methods. In this contribution, I will explain the LRC technique and the progress that we made towards LRC experiments. This work is supported by the European Research Council (ERC) (Grant Agreement No. 819957).

A 32.5 Fri 11:45 A-H2

CREMA-Measuring the Ground State Hyperfine splitting of Muonic Hydrogen — •Siddharth Rajamohanan[1], Ahmed Ouf[1], and Randolf Pohl[2] — [1]QUANTUM, Institut für Physik & Exzellenzcluster PRISMA,Johannes Gutenberg Universität Mainz, 55099 Mainz, Germany — [2]Institut für Physik, QUANTUM und Exzellenzcluster PRISMA+, Johannes Gutenberg-Universität Mainz,55099 Mainz, Germany

Precision measurements on atoms and ions are a powerful tool for testing bound-state QED theory and the Standard Model [1]. Experiments done in the last decade by the CREMA collaboration on muonic Hydrogen and Helium have given a more accurate understanding of the lightest nuclei charge radius [2,3]. Our present experiment aims at a measurement of ground state Hyperfine Splitting in muonic hydrogen up to a relative accuracy of 1 ppm using pulsed laser spectroscopy. This allows us to determine the Zemach radius, which encodes the magnetic properties of the proton. A unique laser system, multi-pass cavity, and scintillation detection system are necessary for the experiment. We report the current status of our experiment and the recent developments.

[1] M. S. Safronova, D. Budker, D. DeMille, Derek F. Jackson Kimball, A. Derevianko, and Charles W. Clark, Rev. Mod. Phys. 90, 025008 (2018) [2] R. Pohl et al., Nature 466, 213 (2010) [3] A. Antognini, et al., Science, Vol. 339, 2013, pp. 417-420