A 30: Highly Charged Ions and their Applications II

Time: Friday 14:30–16:30 Location: F107

Invited Talk A 30.1 Fri 14:30 F107

Investigation of Molecular Ions as Sensitive Probes for Fundamental Physics — •Carsten Zuelch, Konstantin Gaul, and Robert Berger — Fachbereich Chemie, Philipps-Universität Marburg, Hans-Meerwein-Straße 4, 35032 Marburg, Germany

Small polar molecules provide large enhancements of $\mathcal{P}, \mathcal{T}$-odd effects due to large internal fields, which are further increased by using heavy elements as metal center. Molecular ions would give additional benefits: From an experimental point of view, ions have the advantage that they can be guided by electric fields, sympathetically cooled and trapped for long times, possibly opening a path for subsequent direct laser cooling. Further, with increasing charge the electronic spectra become typically compressed, which is favourable for the search of a spatio-temporal variation of fundamental constants. But with the compressed level structure arise different challenges like the need for an analysis of congested rovibronic spectra. At present, comparatively little is known about the detailed electronic structure of small molecular ions containing short-lived nuclei, since only recently advances in precision spectroscopy made the study of such systems possible. Therefore, an extensive theoretical investigation on different systems is needed to find suitable molecular ions for future fundamental physics research, faciliated by current developments in theory. Our estimations for symmetry-violating properties and laser-coolability are based on calculations on the level of two-component complex generalized Hartree-Fock (cGHF) and Kohn Sham (cGKS), with properties being subsequently obtained with our toolbox approach.

A 30.2 Fri 15:00 F107

High-resolution spectroscopy on core-excited lithium-like ions in the soft x-ray regime — •Moto Togawa[1,2], Steffen Kühn[1], Chintan Shah[3], Rene Steinbrügge[1], Sonja Bernitt[4], Thomas Baumann[2], Michael Meyer[2], Thomas Pfeifer[1], Maurice Leutenegger[3], and José R. Crespo López-Urrutia[1] — [1]Max-Planck Institut für Kernphysik — [2]European XFEL — [3]Nasa Goddard Space Flight Center — [4]GSI Helmholtzzentrum für Schwerionenforschung

Two core-excited soft x-ray transitions, q and r of lithium-like oxygen, fluorine and neon were measured, and calibrated using several transitions of helium-like ions. After identification and removal of a systematic error by means of photoelectron spectroscopy, we achieved a relative accuracy of 1.5 parts-per-million, higher than that of current theory. This allows for a preliminary assessment of predictions including quantum electrodynamics and mass-shift corrections.

A 30.3 Fri 15:15 F107

Laser Spectroscopy of the Hyperfine Structure in ^{208}Bi^{82+} at the Experimental Storage Ring (ESR) @ GSI — •Max Horst for the LIBELLE/E128-Collaboration — Institut für Kernphysik, TU Darmstadt, Darmstadt — Helmholtz Akademie Hessen für FAIR HFHF, TU Darmstadt, Darmstadt

We present results of a laser spectroscopy experiment at the Experimental Storage Ring (ESR) at the GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt. During a beamtime in May 2022, we were able to measure the hyperfine splitting of hydrogen-like ^{208}Bi^{82+}. The ions of the radioactive isotope were produced in-flight before injection into the ESR and a few 10^5 ions were stored at $\beta = v/c = 0.72$. This is the first time that an artificially produced isotope is successfully targeted by laser spectroscopy in a storage ring.

To excite the hyperfine transition ($\lambda_0 = 221\,\mathrm{nm}$) the ion beam was superimposed with a counterpropagating beam of a pulsed dye laser at $\lambda_{\mathrm{lab}} = 548\,\mathrm{nm}$. Fluorescence detection was realized spatially separated from the laser interaction with a new detection region to obtain the required low background.

In combination with a measurement on lithium-like ^{208}Bi^{80+}, which is in preparation, the result will provide the so-called specific difference [1] between the two hyperfine splittings, which will constitute the most stringent test of QED in strong magnetic fields.

Funding by BMBF under contract 05P21RDFA1 is acknowledged.

[1]: V. M. Shabaev, et al., Phys. Rev. Lett. 86, 3959 (2001).

A 30.4 Fri 15:30 F107

Precision x-ray spectroscopy of U90+ using novel microcalorimeter detectors — •G. Weber[1,2], Ph. Pfäfflein[1,3], F. Kröger[1,3], B. Zhu[1,3], M. O. Herdrich[1,3], S. Bernitt[1,2], Ch. Hahn[1,2], M. Lestinsky[2], U. Spillmann[2], A. Kalinin[2], B. Löher[2], T. Over[1,3], D. Hengstler[4], A. Fleischmann[4], S. Allgeier[4], P. Kuntz[4], E. B. Menz[1,2,3], M. Friedrich[4], Chr. Enss[4], and Th. Stöhlker[1,2,3] — [1]Helmholtz-Institut Jena — [2]GSI, Darmstadt — [3]IOQ, FSU Jena — [4]KIP, Universität Heidelberg

He-like ions are the simplest atomic multibody systems and the study of L -> K transitions along the isoelectronic sequence provides a unique testing ground for the interplay of the effects of correlation, relativity and quantum electrodynamics. However, for high-Z ions with nuclear charge Z > 54, where K transition energies reach up to 100 keV, there are currently no data available to challenge state-of-the-art theory.

We report on the study of Kα radiation in He-like uranium at the electron cooler of CRYRING@ESR at GSI, using novel microcalorimeters dedicated to high-precision x-ray spectroscopy. A spectral resolution of better than 100 eV FWHM was achieved over a wide range of x-ray energies from a few keV up to more than 100 keV, enabling for the first time to resolve the individual components of the Kα peaks in a heavy He-like system.

This work was conducted in the framework of the SPARC collaboration, exp. E138 of FAIR Phase-0 supported by GSI. We also acknowledge the support provided by ErUM FSP T05 "Aufbau von APPA bei FAIR" (BMBF n°05P19SJFAA and n°05P19VHFA1).

A 30.5 Fri 15:45 F107

An optical clock based on highly charged ions and its application for new physics searches — •Alexander Wilzewski[1], Lukas J. Spiess[1], Steven A. King[1], Malte Wehrheim[1], Shuying Chen[1], Michael K. Rosner[2], Andrey Surzhykov[1,4], Erik Benkler[1], Nils Huntemann[1], José R. Crespo Lopez-Urrutia[2], and Piet O. Schmidt[1,3] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Max-Planck-Instituts für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [4]Technische Universität Braunschweig, Universitätsplatz 2, 38106 Braunschweig, Germany

In our experiment, we extract highly charged ions (HCIs) from an electron-beam ion trap (EBIT) and transfer them to a linear Paul trap where they are recaptured and sympathetically cooled by laser-cooled Be$^+$ ions. Recently, we fully evaluated the systematic uncertainty of an optical clock based on Ar^{13+}. By comparison with the octupole transition in Yb$^+$ we determined the isotope shift of the optical transitions between ^{36}Ar^{13+} and ^{40}Ar^{13+} with sub-Hz accuracy [1]. Ca^{14+} offers five stable isotopes and a suitable optical transition [2] for a King plot analysis to search for a hypothetical fifth force when combined with isotope shifts of the clock transition in Ca$^+$. We present results on a laser ablation source for our EBIT, the Ca^{14+} clock laser system, and first isotope shift measurements. [1] S. A. King, L. J. Spiess *et al.*, Nature **611** (2022), [2] N. Rehbehn *et al.*, Phys. Rev. A **103** (2021)*et al.*, Phys. Rev. Research 2, (2020)

A 30.6 Fri 16:00 F107

Bound-Electron *g* Factor Measurement of Hydrogenlike Tin — •Jonathan Morgner, Charlotte M. König, Tim Sailer, Fabian Heisse, Bingsheng Tu, Vladimir A. Yerokhin, Bastian Sikora, Zoltán Harman, José R. Crespo López-Urrutia, Christoph H. Keitel, and Sven Sturm — Max-Planck Institut für Kernphysik, Heidelberg

Highly charged ions are a great platform to test fundamental physics in strong electric fields. The field strength experienced by a single electron bound to a high-Z nucleus reaches strengths exceeding 10^{15} V/cm. Perturbed by the strong field, the g factor of a bound electron is a sensitive tool that can be both calculated and measured to high accuracy. In the recent past, g-factor measurements of low-Z ions reached precisions below 5×10^{-11}. Following this route, the Alphatrap Penning-trap setup is dedicated to precisely measure bound-electron g factors of the heaviest highly charged ions.

In this contribution, our recent measurement of the bound-electron g factor in hydrogenlike tin will be presented. Comparison with the theoretical calculations allows a stringent test of bound-state QED in

strong electric fields.

Additionallly we present the mass measurement of hydrogenlike tin-118, allowing to improve the literature mass by roughly a factor ten. Furthermore, developments for the Hyper-EBIT experiment are presented. This will eventually allow Alphatrap to inject even heavier highly charged ions in our Penning-trap apparatus.

A 30.7 Fri 16:15 F107

Parity violation in highly charged ions — •Jan Richter[1], Anna V. Maiorova[7], Anna V. Viatkina[1,2,3], Dmitry Budker[2,3,4], and Andrey Surzhykov[1,5,6] — [1]Physikalisch-Technische Bundesanstalt Braunschweig — [2]Helmholtz Institute Mainz — [3]Johannes Gutenberg University Mainz — [4]Department of Physics University of California — [5]Technische Universität Braunschweig — [6]Laboratory for Emerging Nanometrology Braunschweig — [7]Helmholtz Institute Jena

Atomic parity-violation phenomena arising due to the weak interaction of atomic electrons with nuclei have been in the focus of experimental and theoretical research for several decades [1,2].
In this study, the focus lies on the influence of the mixing of opposite-parity ionic levels on the excitation rates in highly charged ions. This mixture arises due to an external electric field and the weak interaction between electrons and the nucleus. In order to reinvestigate this "Stark-plus-weak-interaction" mixing, detailed calculations are performed in hydrogen- and lithium-like ions. In particular, we focus on the difference between the excitation rates obtained for right- and left-circularly polarized incident light. This difference arises due to the parity violating mixing of ionic levels.

[1] I. B. Khriplovich, Parity Nonconservation in Atomic Phenomena, Taylor Francis, Amsterdam 1991.

[2] M.-A. Bouchiat, C. Bouchiat, Rep. Prog. Phys. 1997, 60, 1351