SYHC 2: Intersection of the Electron-Shell and Nuclear Degrees of Freedom

Time: Monday 17:00–19:00 Location: E415

Invited Talk SYHC 2.1 Mon 17:00 E415

Observation of metastable electronic states in highly charged ions by 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 vast landscape of transitions in highly charged ions including transitions in the optical and the extreme ultraviolet (XUV) regime offer up the opportunity for next generation clock research. Thanks to the rapid advances in the development of frequency combs, the XUV spectral range has become accessible for spectroscopy. 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 mass spectrometer Pentatrap, we have found a new way to measure metastable state energies without actively driving the transition and therefore being independent of theoretical predictions. We use the metastable states populated during the ion production inside an electron beam ion trap (EBIT) and measure their mass difference to the ground state in a Penning-trap mass spectrometer. With this method we have detected a metastable state in lead and measured its energy as a mass difference of just 30.X(0.6) eV on top of the mass of the lead nuclei of ≈194 GeV, making it the most precise mass determination to date with a relative uncertainty of 3×10^{-12}.

Invited Talk SYHC 2.2 Mon 17:30 E415

Towards extreme-ultraviolet optical clocks — •José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik

Frequency metrology with optical clocks has become a key tool for novel fundamental physics studies using atomic systems. Its outstanding resolution, reproducibility and accuracy makes it in principle capable of sensing effects of all Standard Model interactions on the frequency of electronic transitions, such as, e. g., a variation of the fine-structure constant. Disentangling the different sources of the underlying modifications of the electronic wave function is thereby crucial. For this, it is necessary to change the neutron number as well as the overlap of the electronic wave function with that of the nucleus in a well-defined way, as in the generalized King-plot method [1]. Isoelectronic and isonuclear sequences of highly charged ions (HCI) offer a plethora of possibilities in this regard [2], since they possess many different types of exceptionally long-lived metastable states up to x-ray energies. The development of an optical clock based on HCI [3] show the promise from an extension of frequency metrology beyond the optical range. For this purpose, we are preparing an experiment combining an extreme-ultraviolet frequency comb based on high-harmonic-generation [4] with a superconducting radio-frequency trap [5].

[1] Berengut, J. C., et al., Rev. Res. 2, 043444 (2020)
[2] Kozlov, M. G., et al., Rev. Mod. Phys. 90, 045005 (2018)
[3] King, S.A., et al., Nature 611, 43 (2022)
[4] Nauta, J., et al., Opt. Express 29, 2624 (2021)
[5] Stark J., et al., Rev. Sci. Instrum. 92, 083203 (2021)

Invited Talk SYHC 2.3 Mon 18:00 E415

Coupling atomic and nuclear degrees of freedom in highly charged ions — •Adriana Pálffy — Institut für Theoretische Physik und Astrophysik, Universität Würzburg

Nuclear transitions of low energy can couple efficiently to the atomic shell in a variety of processes such as internal conversion, its inverse process nuclear excitation by electron capture or electronic bridge. The talk will illustrate two such examples involving highly charged ions.

First, the talk will follow theoretical developments on employing electronic bridge processes for the driving the nuclear clock transition in ^{229}Th [1]. This nucleus possesses the lowest known nuclear transition energy and promises a novel and unprecedently precise nuclear clock. The nuclear excited level is a metastable state with energy of 8.19(12) eV, allowing driving with vacuum-ultraviolet lasers. Second, we will discuss recent results for nuclear excitation by electron capture employing electron vortex beams whose wave function has been especially designed and reshaped on demand [2]. On the example of ^{93m}Mo, we show theoretically that the use of tailored electron vortex beams increases the depletion by 4 orders of magnitude compared to the spontaneous nuclear decay of the isomer.

[1] P. V. Bilous *et al.*, Phys. Rev. Lett. 124, 192502 (2020).
[2] Y. Wu *et al.*, Phys. Rev. Lett. 126, 162501 (2022).

Invited Talk SYHC 2.4 Mon 18:30 E415

Laser Spectroscopy at the Storage Rings of GSI/FAIR — •Wilfried Nörtershäuser — TU Darmstadt, Institut für Kernphysik, Schlossgartenstr. 9, 64289 Darmstadt — Helmholtz-Forschungsakademie Hessen für FAIR (HFHF), Campus Darmstadt, Schlossgartenstr. 9, 64289 Darmstadt

The availability of highly charged ions and the large Doppler shifts of relativistic beams make laser spectroscopy at storage rings an attractive tool to test strong-field QED as well as electron-electron correlations in few-body calculations. Laser light can also be used to address and analyze internal and external degrees of motion of the stored ions. An overview on recent results and activities in these fields at the GSI/FAIR storage rings ESR and CRYRING@ESR will be presented.