A 27: Precision Spectroscopy of Atoms and Ions III (joint session A/Q)

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

A 27.1 Thu 11:00 HS 1010

Resolved sideband spectroscopy of cold mixed ioncystals of Ca^+ and Th^+ — •Azer Trimeche[1], Can Leichtweiss[1], Jonas Stricker[2,3], Valerii Andriushkov[1,2], Dmitry Budker[1], Christoph E. Düllmann[2,3,4], and Ferdinand Schmidt-Kaler[1] — [1]QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany — [2]Helmholtz-Institut Mainz, Germany — [3]Department Chemie - Standort TRIGA, Johannes Gutenberg-Universität Mainz, Germany — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

Thorium isotopes became of high interest in the search for new physics, and fundamental physics tests, because of their unique nuclear and atomic properties. The **T**rapping **A**nd **C**ooling of **T**horium **I**ons in **Ca**lcium crystals (TACTICa) project develops ion trapping and spectroscopic techniques for a precise determination of the nuclear moments, hyperfine intervals, and isotope shifts with different Th isotopes. For the production, we use two different sources: a recoil ion source [1] and a laser ablation source [2]. $^{232}Th^+$ ions are trapped in a $^{40}Ca^+$ crystal [2], and cooled down sympathetically by polarization gradient cooling [3]. We implement resolved sideband spectroscopy of mixed Ca-Th ion crystals as a starting point for resolved sideband ground state cooling of crystals with extreme charge-to-mass ratio difference and quantum logic spectroscopy of Th ions.

[1] R. Haas et al., Hyperfine interactions 241 (2020) 25.
[2] K. Groot-Berning et al., *PRA* 99 (2019) 023420.
[3] W. Li et al., *NJP* 24(4) (2022) 043028.

A 27.2 Thu 11:15 HS 1010

High-resolution spectroscopy of fermium-255 at the RISIKO mass separator — •Mitzi Urquiza-González for the Fermium-Collaboration — Division HÜBNER Photonics, Hübner GmbH & Co KG, 34123 Kassel, Germany

Laser spectroscopy measurements can provide information about fundamental properties of both atomic and nuclear structure. Such measurements are of particular importance for the heaviest actinides and superheavy elements, where data is sparse. During the last measurement campaign at the RISIKO mass separator facility in the Institute of Physics in the Johannes Gutenberg University Mainz (JGU), nine successive samples, consisting of 108 to 109 atoms, were used to study the atomic and nuclear structure of ^{255}Fm (Z=100).

This presentation will focus on the hyperfine structure (HFS) of ^{255}Fm for two different excited levels, from which the hyperfine coupling constants have been determined.

A 27.3 Thu 11:30 HS 1010

Hyperfine Spectroscopy of Single Molecular Hydrogen Ions in a Penning Trap at Alphatrap — •C. M. König[1], M. Bohman[1], V. Hahn[1], F. Heisse[1], I. V. Kortunov[2], A. Kulangara Thottungal George[1], J. Morgner[1], F. Raab[1], T. Sailer[1], K. Singh[1], B. Tu[1,3], V. Vogt[2], K. Blaum[1], S. Schiller[2], and S. Sturm[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [2]Institut für Experimentalphysik, Univ. Düsseldorf, 40225 — [3]Institute of Modern Physics, Fudan University, Shanghai 200433

Molecular hydrogen ions (MHI) are a simple system allowing the comparison of high-precision measurements to state-of-the-art QED theory, testing the validity of the latter. At Alphatrap [1], we can isolate and confine a single MHI for months and perform high-precision spectroscopy using non-destructive quantum state detection.
I will present the results of hyperfine structure measurements on a single HD^+ ion. From these, the bound g factor of the constituent particles, as well as coefficients of the hyperfine Hamiltonian can be extracted. The latter are important for a better understanding of rovibrational spectroscopy performed on this ion, from which fundamental constants, such as m_p/m_e are determined to highest precision [2].
We are currently upgrading our trap for single-ion rovibrational laser spectroscopy of MHI. The development of these techniques is one of the required steps towards spectroscopy of an antimatter $\overline{H}_2^-$ ion [3].

[1] S. Sturm *et al.*, Eur. Phys. J. Spec. Top. **227**, 1425*1491 (2019)
[2] I. V. Kortunov, *et al.*, Nature Physics vol **17**, 569*573 (2021)
[3] E. Myers, Phys. Rev. A **98**, 010101(R) (2018)

A 27.4 Thu 11:45 HS 1010

MMC Array to Study X-ray Transitions in Muonic Atoms — •Daniel Unger, Andreas Abeln, Thomas Elias Cocolios, Ofir Eizenberg, Christian Enss, Andreas Fleischmann, Loredana Gastaldo, Cesar Godinho, Michael Heines, Daniel Hengstler, Paul Indelicato, Daniel Kreuzberger, Klaus Kirch, Andreas Knecht, Jorge Machado, Ben Ohayon, Nancy Paul, Randolf Pohl, Katharina von Schoeler, Stergiani Marina Vogiatzi, and Frederik Wauters — for the QUARTET Collaboration

The QUARTET collaboration aims to improve the accuracy of absolute nuclear charge radii of light nuclei from Li to Ne. A proof-of-principle measurement with lithium, beryllium and boron has recently been performed at the Paul Scherrer Institute. Conventional solid-state detectors do not provide sufficient accuracy in the relevant energy range. We use a low temperature Metallic Magnetic Calorimeter (MMC) array for high-precision X-ray spectroscopy of low-lying states in muonic atoms. MMCs are characterized by a high resolving power of several thousand and a high quantum efficiency in the energy range of interest. We present the experimental setup and the performance of the detector used. We discuss the first preliminary spectra and systematic effects in this first measurement. The obtained data in combination with the achieved energy resolution and calibration should allow a more precise characterization of the muonic X-ray lines. With the knowledge gained, a significant improvement in the determination of nuclear charge radii is expected.

A 27.5 Thu 12:00 HS 1010

Advancing RAdiation Detected Resonance Ionization towards more exotic nuclei — •Kenneth van Beek for the Radris Collaboration — TU Darmstadt

Experimental data on atomic and nuclear properties for exotic nuclei in the heavy actinide region ($Z \geq 100$) remains scarce up to date. The RAdiation Detected Resonance Ionization Spectroscopy (RADRIS) apparatus, located at GSI, Darmstadt, Germany, is employed to determine such quantities — such as energy levels, ionization potentials, moments, mean-square charge radii, and isotope shifts. Past measurements at RADRIS encompassed the study of $^{245,246,248-250,254}$Fm and $^{251-255}$No. In the current design of the setup the detection of laser ions via their α-decay for nuclei with half-lives in the order of several hours to tens of hours becomes impractical. This presentation will show already obtained results by RADRIS and how future improvements will increase the methods reach towards longer-lived nuclei. This will allow accessing, e.g., ^{246}Cf (35.7 h) and ^{252}Fm (25.39 h). The latter is of special interest, as it lies directly at the $N = 152$ shell gap in the fermium isotopic sequence, thus closing the gap between already studied isotopes on the neutron-rich and on the neutron-poor side.

A 27.6 Thu 12:15 HS 1010

Electron Optical Systems for High-Resolution Electron Time-of-Flight Spectrometer — •Niclas Wieland[1], Lars Funke[2], Lasse Wülfing[2], Arne Held[2], Sara Savio[2], Markus Ilchen[1], and Wolfram Helml[2] — [1]Universität Hamburg, Insitut für Experimentalphysik — [2]Technische Universität Dortmund, Fakultät Physik

Angular streaking allows resolving the sub-femtosecond temporal structure of SASE free-electron laser pulses. A circularly polarized infrared laser imprints a phase-dependent momentum shift onto the photoelectron spectra of a gas target. Angle-resolving time-of-flight spectrometers can be used to resolve these. The latter devices typically consist of electron optics, a drift section, and a detector. Parameters such as energy resolution and energy-dependent transmission for the whole system can be determined by simulation. In this talk, we present the finalized simulation-supported spectrometer design used inside our new chamber for the SpeAR_XFEL project. Furthermore, we will introduce the possibility of adaptive electron optics in our spectrometer using the popular open-source computing platform FEniCSx to further increase the achievable resolution and transmission by applying optimizer-determined voltage sets to our optics. Gaining insight into electron trajectories using precise simulations appears to be an efficient way to improve the overall performance of such experiments-We present our progress in terms of electrode design and applied voltages for a 0-3 keV electron energy spectrum to further develop spectrometer research in this field.

A 27.7 Thu 12:30 HS 1010

Calorimetric wire detector for monitoring atomic hydrogen beam — Christian Matthé, •Alec Lindman, and Sebastian Böser for the Project 8-Collaboration — Johannes Gutenberg Universität, Mainz

The Project 8 collaboration aims to determine the absolute neutrino mass with a sensitivity of 40 meV by measuring the tritium decay spectrum around the endpoint energy. For this level of precision it is necessary to use atomic tritium, since molecular tritium sensitivity is limited by the molecular final state distribution to about 100 meV.

A flux of $\approx 10^{19}$atoms/s from the source will be required to inject a beam with $\approx 10^{15}$atoms/s into the detection volume after cooling and state selection inefficiencies. For monitoring this beam, we have built a detector that uses a wire with a micrometer-scale diameter intersecting the beam on which a small fraction of the beam's hydrogen atoms recombine into molecules. The energy released heats the wire and produces a measurable change in its resistance. Such a detector is suitable for both development work and for minimally disruptive online monitoring in the final experiment. In this talk results will be presented on measurements of the atomic hydrogen fraction as well as the shape of the produced beam.

A 27.8 Thu 12:45 HS 1010

Comparison of Sr lattice clocks from Japan, UK, and Germany — •Tim Lücke[1], Clock Teams[1,2,3,4,8], and Link Teams[1,2,5,6,7] — [1]PTB, Braunschweig, Deutschland — [2]NPL, London, UK — [3]RIKEN, Tokyo, Japan — [4]University of Tokyo, Tokyo, Japan — [5]LNE-SYRTE, Paris, France — [6]LPL, Paris, France — [7]RENATER, Paris, France — [8]University of Birmingham, Birmingham, UK

We present a measurement campaign investigating the agreement of state-of-the-art optical clocks from Japan and Europe. Two transportable Sr lattice clocks from RIKEN in Japan [1] and PTB in Germany were compared with the stationary Sr clocks at NPL in London [2] and PTB in Braunschweig. In addition to local comparisons an interferometric fiber [3] link was used to compare the clocks remotely. The data will also be analyzed with respect to chronometric leveling as a geodetic application.

[1] M. Takamoto *et al.*, Nat. Photonics **14**, 411-415 (2020).
[2] R. Hobson *et al.*, Metrologia **57** 065026 (2020).
[3] M. Schioppo *et al.*, Nat. Commun. **13**, 212 (2022).