A 20: Precision spectroscopy of atoms and ions (joint session A/Q)

Time: Wednesday 16:30–18:30 Location: P

A 20.1 Wed 16:30 P

Precise solution of the two-center Dirac equation using a finite-element-technique — •Ossama Kullie[1], Stephan Schiller[2], and Vladimir I. Korobov[3] — [1]Theoretical Physics, Institute of Physics, University of Kassel — [2]Institut für Experimentalphysik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany — [3]Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna 141980, Russia

In the field of spectroscopy of the molecular hydrogen ions H_2^+, HD^+ etc., precise experimental transition frequencies are compared with ab initio predictions [3]. The solution of the two-center Dirac problem, one electron in the field of two fixed nuclei at distance R, is therefore of interest. Here, $R \simeq 2$ Bohr. The numerical solution of the problem utilizes the finite-element method (FEM) [1,2]. Our technique allows determining the relativistic contribution to various rovibrational transition frequencies with spectroscopic accuracy. Our results are compared with perturbation theory based on the nonrelativistic one-body variational solution. The deviations found are smaller than the theory uncertainty stemming from uncalculated quantum-electrodynamic effects, and are therefore not resolvable experimentally. [1] O. Kullie et al, Chemical Physics Letters 383 (2004) 215-221. [2] O. Kullie, S. Schiller and V. I. Koborov, in preparation. [3] S. Alighanbari et al, Nature 581, 152 -158 (2020).

A 20.2 Wed 16:30 P

Towards high precision quantum logic spectroscopy of single molecular ions — •Maximilian Jasin Zawierucha[1], Till Rehmert[1], Fabian Wolf[1], and Piet O. Schmidt[1,2] — [1]Physikalisch- Technische Bundesanstalt, Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany

High precision spectroscopy of trapped molecular ions constitutes a promising tool for the study of fundamental physics. Possible applications include the search for a variation of fundamental constants and measurement of the electric dipole moment of the electron. Compared to atoms, molecules offer a rich level structure, permanent dipole moment and large internal electric fields which make them exceptionally well suited for those applications. However, the additional rotational and vibrational degrees of freedom result in a dense level structure and absence of closed cycling transitions. Therefore, standard techniques for cooling, optical pumping and state detection cannot be applied. This challenge can be overcome by quantum logic spectroscopy. In addition to the molecular ion, a well-controllable atomic ion is co-trapped, coupling strongly to the molecule via the Coulomb interaction. The shared motional state can be used as a bus to transfer information about the internal state of the molecular ion to the atomic ion, where it can be read out using fluorescence detection. Here, we present the status of our experiment, aiming at high precision quantum logic spectroscopy of molecular oxygen ions.

A 20.3 Wed 16:30 P

Precision x-ray spectroscopy of transitions in He-like uranium at the CRYRING@ESR electron cooler — •Felix Martin Kröger[1,2,3], Steffen Allgeier[4], Andreas Fleischmann[4], Marvin Friedrich[4], Alexandre Gumberidze[3], Marc Oliver Herdrich[1,2,3], Daniel Hengstler[4], Patricia Kuntz[4], Michael Lestinsky[3], Bastian Löher[3], Esther Babette Menz[1,2,3], Philip Pfäfflein[1,2,3], Uwe Spillmann[3], Günter Weber[1,3], Christian Enss[4], and Thomas Stöhlker[1,2,3] — [1]HI Jena, Fröbelstieg 3, Jena, Germany — [2]IOQ, FSU Jena, Max-Wien-Platz 1, Jena, Germany — [3]GSI, Planckstraße 1, Darmstadt, Germany — [4]KIP, RKU Heidelberg, Im Neuenheimer Feld 227, Heidelberg, Germany

We present the first application of metallic magnetic calorimeter detectors for high resolution x-ray spectroscopy at the electron cooler of CRYRING@ESR, the low energy storage ring of GSI-Darmstadt. Within the experiment, x-ray emission associated with radiative recombination cooler electrons and stored U^{91+} ions was studied. For this purpose, two maXs detectors were positioned under observation angles of 0° and 180° with respect to the ion beam axis. This report will focus on preliminary results of the data analysis, namely the first observation of the splitting of the $K_{\alpha 2}$ line into its fine-structure for a high-Z He-like system.

This research has been conducted in the framework of the SPARC collaboration, experiment E138 of FAIR Phase-0 supported by GSI. We acknowledge substantial support by ErUM-FSP APPA (BMBF n° 05P19SJFAA).

A 20.4 Wed 16:30 P

Towards the setup of a calcium beam clock — •Lara Becker and Simon Stellmer — Physikalisches Institut der Universität Bonn, Nussallee 12, Bonn, Germany

Since the invention of atomic clocks the precision of time-keeping has been significantly enhanced and the clock stabilities reach even higher levels for systems based on optical transitions.

We would like to build a robust and compact optical clock which relies on a Ramsey-Bordé interferometer of a thermal beam of calcium and is envisaged attaining instabilities in the order of 10^{-16}. The goal is to implement the beam clock as an experiment to the students' laboratory course to allow physics master students access to this field of recent research.

We refer to the work at NIST [1] for the main setup and we report on the current status of our project.

[1] Judith Olson et al. "Ramsey-Bordé Matter-Wave Interferometry for Laser Frequency Stabilization at 10^{-16} Frequency Instability and Below". In: Physical Review Letters 123, 073202 (2019)

A 20.5 Wed 16:30 P

Towards 1S-2S Spectroscopy in Atomic Tritium — •Hendrik Schürg, Merten Heppener, Jan Haack, Gregor Schwendler, and Randolf Pohl — Johannes Gutenberg-Universität Mainz, QUANTUM, Institut für Physik & Exzellenzcluster PRISMA+, Mainz, Germany

The study of the hydrogen-deuterium isotope shift for the 1S-2S transition successfully demonstrated access to a high-precision result for the root-mean-square charge radius of the deuteron [1, 2]. We are currently setting up an experiment to perform a complementing measurement of the hydrogen-tritium 1S-2S isotope shift on magnetically trapped cold tritium atoms – allowing for a 400-fold improvement of uncertainty for the triton charge radius [3]. For an intermediate result, we plan to perform 1S-2S spectroscopy on hot tritium atoms inside a discharge. The excitation can be monitored using the optogalvanic signal induced by a change of conductivity in the hot gas. The available high-precision result for the 1S-2S transition frequency in atomic hydrogen [4] will be used to determine systematic effects in our apparatus. We will present details about our laser system and preliminary measurements with atomic hydrogen.

[1] C. G. Parthey et al. Phys. Rev. Lett. 104, 233001 (2010)
[2] U. D. Jentschura et al. Phys. Rev. A 83, 042505 (2011)
[3] S. Schmidt et al. J. Phys.: Conf. Ser. 1138, 012010 (2018)
[4] C. G. Parthey et al. Phys. Rev. Lett. 107, 203001 (2011)

A 20.6 Wed 16:30 P

Towards Magnetic Trapping of Atomic Hydrogen — •Merten Heppener, Gregor Schwendler, Jan Haack, Hendrik Schürg, and Randolf Pohl — Johannes Gutenberg-Universität Mainz, QUANTUM, Institut für Physik & Exzellenzcluster PRISMA+, Mainz, Germany

We are currently setting up an experiment to determine the root mean square triton charge radius via two-photon 1S-2S laser spectroscopy at 243 nm on magnetically trapped tritium atoms [1]. For preparation of trapping, an atomic hydrogen source including a microwave dissociation was set up, followed by a cryogenic nozzle and a magnetic quadrupole guide for velocity selection. In the future, it is planned to load the slow hydrogen atoms into a magnetic minimum trap using a cold lithium buffer gas, for which we will present the planned trap configuration. Parallel, a spectroscopy laser system at 243 nm is being developed. The available laser power for exciting the 1S-2S two-photon transition is increased in a stabilized enhancement cavity. The population of the hydrogen 2S state can be monitored by detecting quenched Lyman-α photons using micro-channel plate-based system. In the next stage, we will test our laser system on an atomic hydrogen sample.

[1] S. Schmidt et al. J. Phys. Conf. Ser. 1138, 012010 (2018)

A 20.7 Wed 16:30 P

Enhancing Atom-photon Interaction with Integrated Nano-photonic Resonators — •Xiaoyu Cheng[1], Benyamin Shnirman[1,4], Artur Skljarow[1], Hadiseh Alaeian[2], Wei Fu[3], Sunny Yang[3], Hong Tang[3], Markus Greul[4], Mathias Kaschel[4], Tilman Pfau[1], and Robert Loew[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology (IQST), Universität Stuttgart, Germany — [2]School of Electrical and Computer Engineering, Purdue University, Indiana, USA — [3]Department of Electrical Engineering, Yale University, Connecticut, USA — [4]Institut für Mikroelektronik Stuttgart (IMS-Chips), Stuttgart, Germany

We study hybrid devices consisting of thermal atomic vapours and Nano-photonic waveguides for manipulating the interaction of atoms with single photons. This allows applications of collective and cooperative effects in the field of quantum technologies. One goal here is to reach the strong coupling regime for a single atom interacting with the mode of photonic crystal cavity (PhC). Our first resonator design is a suspended photonic crystal cavity, which allows us to tightly confine the mode into the interaction region. We have fabricated these devices with a novel high selectivity under-etching technique. A second line of research is to make use of the Rydberg blockade effects to generate single photons. We work with high Q (Q>400000) resonators coupled with bus waveguides. This allows high intensities to excite the weak dipole transitions to Rydberg states. In addition, we plan to taper the waveguides to enhance the range of the evanescent field such that we will be less vulnerable to transit time effects and surface interactions.

A 20.8 Wed 16:30 P

Rydberg systems under a reaction microscope — •Max Althön, Markus Exner, Philipp Geppert, and Herwig Ott — TU Kaiserslautern

With our MOTRIMS-type reaction microscope we observed collisions between Rydberg atoms and ground state atoms. In these inelastic collisions, the Rydberg electron can change to a lower-lying state. The resulting energy is imparted onto the Rydberg core and the ground state atom as kinetic energy. We measured the final state distribution after these state-changing collisions and observed a wide range of possible final Rydberg states. State-changing collisions are a major decay channel of Rydberg atoms in a dense environment and are of importance for Rydberg molecules. Rydberg molecules are bound by the scattering interaction between the Rydberg electron and a ground state atom. In this context, we aim to directly photoassociate Trilobite molecules, which can be addressed efficiently due to 3-photon excitation. We also show how another type of Rydberg molecule can be used to create a Heavy-Rydberg system, which consists of an ion and anion bound in a high vibrational state.

Our sample consists of ^{87}Rb atoms in a crossed optical dipole trap. Using a 3-photon excitation scheme, atoms are excited to atomic or molecular Rydberg states and photoionized by a short laser pulse from a CO_2 laser after a variable evolution time. Following small homogeneous electric fields, the produced ions are subsequently detected by a time and position sensitive micro channel plate detector. This allows momentum resolved measurements of few-body Rydberg dynamics.

A 20.9 Wed 16:30 P

Most Precise g-Factor Comparison at Alphatrap — •Tim Sailer[1], Vincent Debierre[1], Zoltán Harman[1], Fabian Heisse[1], Charlotte König[1], Jonathan Morgner[1], Bingsheng Tu[4], Andrey Volotka[2,3], Christoph H. Keitel[1], Klaus Blaum[1], and Sven Sturm[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Helmholtz-Institut Jena, Jena — [3]Department of Physics and Engineering, ITMO University, St. Petersburg, Russia — [4]Institute of Modern Physics, Fudan University, Shanghai, China

The Alphatrap experiment is a cryogenic Penning-trap setup, designed to measure the g factor of the bound electron of heavy highly-charged ions (HCI) to provide tests of fundamental physics in strong fields. Recently, a novel measurement technique based on the coupling of ions as an ion crystal has been developed and applied to measure the most precise g-factor difference to date. By coupling two neon ions, $^{20}Ne^{9+}$ and $^{22}Ne^{9+}$, in a magnetron crystal, a coherent measurement of the Larmor frequency difference of the respective bound electrons becomes possible. The strong suppression of magnetic field fluctuations due to the close proximity of the ions results in a common behaviour of the electron spin states. This allows a determination of the isotopic shift of the g factor to an unprecedented precision of 5.6×10^{-13} relative to the absolute g factors, and, in combination with theory, resolves and confirms the QED contribution to the nuclear recoil for the first time. Alternatively, the result can be applied to improve upon the precision of the charge radius difference of the isotopes or to apply constraints on a potential fifth force in the Higgs portal mechanism.

A 20.10 Wed 16:30 P

A cold atomic lithium beam via a 2D MOT — •Hendrik-Lukas Schumacher, Marcel Willig, Gregor Schwendler, and Randolf Pohl — Johannes Gutenberg-Universität Mainz Institut für Physik, QUANTUM und Exzellenzcluster PRISMA+

We plan to build a source for a very high flux of cold atomic Li for spectroscopy [1], and for using trapped cold Li as a buffer gas to enable trapping of atomic hydrogen, deuterium and tritium. Laser spectroscopy of atomic ^{6,7}Li has been used to determine the (squared) rms charge radius difference of the stable Li nuclei [2]. One important systematic effect in this experiment, as well as in most other precision spectroscopy measurements, is the distortion and apparent shift of resonance line by quantum interference of close-lying states [3]. Li with its unresolved hyperfine structure is an excellent testbed for precision studies of quantum interference [4].

In another line of research, we plan to trap large amounts of cold Li and use it as a cold buffer gas to enable trapping and laser spectroscopy of atomic hydrogen from a cryogenic beam [2].

[1] T.G. Tiecke, S.D. Gensemer, A. Ludewig, J.T.M. Walraven, Phys. Rev. A 80, 013409 (2009), arXiv
[2] S. Schmidt et al., J. Phys. Conf. Ser. accepted (2018), arXiv
[3] M. Horbatsch, E.A. Hessels, Phys.Rev. A 84, 032508 (2011)
[4] R. C. Brown et al., Phys.Rev. A 87, 032504 (2013)

A 20.11 Wed 16:30 P

Probing physics beyond the standard model using ultracold mercury — •Thorsten Groh, Quentin Lavigne, Felix Affeld, and Simon Stellmer — Physikalisches Institut, Universität Bonn, 53115 Bonn, Germany

Searches for physics beyond the standard model (SM) range from high-energy collision experiments to low-energy table-top experiments. Cosmological phenomena suggest the existence of yet undiscovered particles, described as dark matter.

Recently, it was proposed to employ high precision spectroscopy of atomic isotope shifts [Delaunay, PRD 96, 093001 (2017); Berengut, PRL 120, 091801 (2018)] to search for a new force carrier that directly couples quarks and leptons. Signatures of such new particles would emerge as nonlinearities in King plots of scaled isotope shifts on different electronic transitions.

Mercury is one of the heaviest laser-coolable elements and possesses five naturally occurring bosonic isotopes, all of which have been laser-cooled in a magneto-optical trap. We report on optimizing these trap parameters and we present our latest results of precision isotope spectroscopy in ultracold mercury on various optical transitions. Our King plot analysis of the nonlinearities indicates deviations from SM predictions.

A 20.12 Wed 16:30 P

Two-loop self-energy corrections to the bound-electron g-factor: M-term — •Bastian Sikora[1], Vladimir A. Yerokhin[2], Christoph H. Keitel[1], and Zoltán Harman[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Center for Advanced Studies, Peter the Great St. Petersburg Polytechnic University, 195251 St. Petersburg, Russia

The theoretical uncertainty of the bound-electron g-factor in heavy hydrogenlike ions is dominated by uncalculated two-loop Feynman diagrams. Due to the presence of ultraviolet divergences, diagrams with two self-energy loops need to be split into the loop-after-loop (LAL) contribution and the so-called F-, M- and P-terms which require different numerical techniques. In our previous work, we have obtained full results for LAL and the F-term [1].

In this work, we present our results for the M-term contribution. This corresponds to the ultraviolet finite part of nested and overlapping loop diagrams in which the Coulomb interaction in intermediate states is taken into account exactly.

Our results are highly relevant for ongoing and future experiments with high-Z ions as well as for an independent determination of the fine-structure constant α from the bound-electron g-factor [2].

[1] B. Sikora, V. A. Yerokhin, N. S. Oreshkina, et al., Phys. Rev. Research 2, 012002(R) (2020).

[2] S. Sturm, I. Arapoglou, A. Egl, et al., EPJ ST 227, 1425 (2019)

A 20.13 Wed 16:30 P

Status of the ALPHATRAP *g*-factor experiment — •FABIAN HEISSE[1], CHARLOTTE KÖNIG[1], JONATHAN MORGNER[1], TIM SAILER[1], BINGSHENG TU[1,2], SVEN STURM[1], and KLAUS BLAUM[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Fudan University, China

Quantum electrodynamics (QED) is considered to be the most successful quantum field theory in the Standard Model. Its most precise test is conducted via the comparison of QED calculations with the measurement of the free electron g-factor. However, this test is restricted to low electrical field strengths. Consequently, it is of utmost importance to perform similar tests at high field strengths.

The ALPHATRAP experiment is a dedicated cryogenic Penning-trap setup to measure the g-factor of bound electrons in highly charged ions up to hydrogen-like uranium [1]. There, an electric field strength on the order of 10^{16} V/cm acts on the electron, allowing to test bound state QED with highest precision.

Our latest measurements of the g-factor for different charge states of a single tin ion are presented. Furthermore, an outlook on upcoming studies and prospects will be given.

[1] S. Sturm *et al.*, Eur. Phys. J. Spec. Top. **227**, 14251491 (2019)

A 20.14 Wed 16:30 P

Pound method of stabilizing the trap frequencies of an ion trap — •MARTIN FISCHER[1], ATISH ROY[1], SEBASTIAN LUFF[1,2], MARKUS SONDERMANN[1,2], and GERD LEUCHS[1,2,3,4] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Friedrich-Alexander University Erlangen- Nürnberg (FAU), Department of Physics, Erlangen, Germany — [3]Department of Physics, University of Ottawa, Canada — [4]Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod, Russia

We report on the stabilization of the secular motion frequencies of an ion trapped in the potential of a Paul-trap by analyzing the phase of the reflected trapping filed. This is done by mixing the field reflected from the LC-circuit[1] made up by the helical resonator and the trap with the RF-drive frequency. By adjusting the relative phase of the two signals it is possible to determine how far the driving field is detuned from the resonance of the LC-circuit. Feeding this signal back to the RF-drive one can lock it to the resonance of the trap. In this way the power coupled into the trap system remains almost constant while the small relative variations of the drive field hardly change the magnitude of the trap frequencies. The stability of the method is measured by directly monitoring the trap frequencies visible in the detected fluorescence light when it is filtered by imaging it onto a knife edge.

[1] R. V. Pound, Review of Scientific Instruments **17**, 490-505 (1946)

A 20.15 Wed 16:30 P

maXs100: A 64-pixel Metallic Magnetic Calorimeter Array for the Spectroscopy of Highly-Charged Heavy Ions — •S. ALLGEIER[1], A. ABELN[1], M. FRIEDRICH[1], A. GUMBERIDZE[2], M.-O. HERDRICH[2,3,4], D. HENGSTLER[1], F. M. KRÖGER[2,3,4], P. KUNTZ[1], A. FLEISCHMANN[1], M. LESTINSKY[2], E. B. MENZ[2,3,4], PH. PFÄFFLEIN[2,3,4], U. SPILLMANN[2], B. ZHU[4], G. WEBER[2,3,4], TH. STÖHLKER[2,3,4], and CH. ENSS[1] — [1]KIP, Heidelberg University — [2]GSI, Darmstadt — [3]IOQ, Jena University — [4]HI Jena

Metallic magnetic calorimeters (MMCs) are energy-dispersive X-ray detectors which provide an excellent energy resolution over a large dynamic range combined with a very good linearity. They are operated at mK temperatures and convert the energy of each incident photon into a temperature rise which is monitored by a paramagnetic sensor.

We present the MMC array maXs-100, which was used to investigate electron transitions in $\mathbf{U^{90+}}$ at CRYRING@FAIR. The detector features 8x8 pixels with a detection area of 1 cm^2 and a stopping power of 40 % for 100 keV X-rays. We discuss details of the two detector systems used during the beam time, including the cryogenic setup and magnetic shielding. An absolute energy calibration with eV-precision at 100 keV as well as an energy resolution of 40 eV (FWHM) at 60 keV were demonstrated, allowing for high-precision X-ray spectroscopy.

This research has been conducted in the framework of the SPARC collaboration, experiment E138 of FAIR Phase-0 supported by GSI. We acknowledge substantial support by ErUM-FSP APPA (BMBF no 05P19VHFA1).

A 20.16 Wed 16:30 P

Laser photodetachment threshold spectroscopy at FLSR: the experiment preparation — •VADIM GADELSHIN[1], OLIVER FORSTNER[2,3,4], LOTHAR SCHMIDT[5], KURT STIEBING[5], DOMINIK STUDER[1], and KLAUS WENDT[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz — [2]Friedrich Schiller-Universität Jena — [3]Helmholtz-Institut Jena — [4]GSI Helmholtzzentrum Darmstadt — [5]Institut für Kernphysik, Goethe-Universität Frankfurt

The Frankfurt Low-energy Storage Ring (FLSR) is a room-temperature electrostatic storage ring, which can reduce the internal energy of stored ions almost to the ambient temperature, being suitable for laser photodetachment threshold (LPT) spectroscopy to determine the electron affinity of negatively charged ions. The latter play a key role in accelerator mass spectrometry (AMS): lasers can selectively neutralize undesired isobars, providing a purified beam of an isotope of interest. To extend the range of available for AMS nuclides, it is necessary to identify neutralization schemes for unwanted ions.

With this intention, a compact laser lab was constructed with an optical path, guiding laser beams into FLSR. The laser setup is based on a tunable Ti:Sapphire laser and a pulsed Nd:YAG laser, serving as a pump laser for Ti:Sapphire crystal and as a high-energy laser beam at 532 nm. The RF plasma ion source with a Rb charge exchange cell was installed to produce beams of negatively charged ions.

The results of the experiment preparation and of first tests will be presented. The proof-of-principle of the setup is carried out for O- and OH- ions. An overview of planned LPT studies will be given.

A 20.17 Wed 16:30 P

A variable out-coupling optical parametric oscillator for the laser system of the ground hyperfine splitting in muonic hydrogen experiment. — •AHMED OUF ON BEHALF OF THE CREMA COLLABORATION[1], SIDDARTH RAJAMOHANAN[1], LUKAS GOERNER[1], and RANDOLF POHL[2] — [1]Johannes Gutenberg-Universität Mainz, QUANTUM, Institut für Physik — [2]Johannes Gutenberg-Universität Mainz, QUANTUM, Institut für Physik & Exzellenzcluster PRISMA +, Mainz, Germany

We are working on a measurement of the ground-state hyperfine splitting in the exotic muonic hydrogen atom, i.e. a proton orbited by a negative muon. From this measurement, we will be able to determine the parameters of the magnetization distribution inside the proton. The experiment requires a unique pulsed laser system delivering 5mJ pulses at a wavelength of 6.8 μm. The laser has to be triggered on detected muons which enter the apparatus at stochastic times with an average rate of about $\frac{1000}{s}$. Because of the short $2\mu s$ lifetime of the muon, the laser has to produce pulses within about $1\mu s$ after a random trigger. We use a novel Yb:YAG thin-disk laser with a line width less than 10 MHz at 1030nm, whose light output will be shifted in frequency by several OPO/OPA stages in 2 parallel branches at 3.15 μm and 2.1μm, before a DFG yields the intense pulses at 6.8 μm. To enable easy optimization of the OPOs conversion we have developed an OPO cavity with variable finesse, based on polarization optics. We will present this cavity, an optimized specific PDH locking scheme, and first experimental results.

A 20.18 Wed 16:30 P

The muonic hydrogen ground state hyperfine splitting experiment — •AHMED OUF ON BEHALF OF THE CREMA COLLABORATION[1], SIDDARTH RAJAMOHANAN[1], LUKAS GOERNER[1], and RANDOLF POHL[2] — [1]Johannes Gutenberg-Universität Mainz, QUANTUM, Institut für Physik, Mainz, Germany — [2]Johannes Gutenberg-Universität Mainz, QUANTUM, Institut für Physik & Exzellenzcluster PRISMA +, Mainz, Germany

The ground state hyperfine splitting (1S-HFS) in ordinary hydrogen (the famous 21 cm line) has been measured with 12 digits accuracy almost 50 years ago [1], but its comparison with QED calculations is limited to 6 digits by the uncertainty of the Zemach radius determined from elastic electron-proton scattering. The Zemach radius encodes the magnetic properties of the proton and it is the main nuclear structure that contributes to the hyperfine splitting (HFS) in hydrogen together with the proton polarizability. The ongoing experiment of the CREMA Collaboration at PSI aims at the first measurement of the 1S-HFS in muonic hydrogen (μp). The measurement aims at determining the proton structure effects referred to as the two-photon exchange with an accuracy of 1×10^{-4}, which is a hundredfold improved determination of (Zemach radius and the proton polarizability). Eventually, then this will improve the QED test using the 21 cm line by a factor of 100. We will present the current status of the experimental effort including the unique detection system and the novel laser development.

A 20.19 Wed 16:30 P

Study of Highly Charged Ions for the Tests of Bound-State QED — •Manasa Chambath[1], Khwaish Anjum[1,2], Patrick Baus[3], Gerhard Birkl[3], Kanika Kanika[1,4], Jeffrey Klimes[1,4,5], Wolfgang Quint[1], and Manuel Vogel[1] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [2]Delhi Technological University, Delhi, India — [3]Institute for Applied Physics, TU Darmstadt, Germany — [4]Heidelberg Graduate School for Fundamental Physics, Heidelberg, Germany — [5]Max Planck Institute for Nuclear Physics, Heidelberg, Germany

The high-precision measurement of the Zeeman splitting of fine- and hyper-fine structure levels can be performed using spectroscopy techniques. The Penning trap ARTEMIS at the HITRAP facility at GSI utilises the method of laser-microwave double-resonance spectroscopy to measure the magnetic moment and to test bound-state QED calculations by g-factor measurements of heavy, highly charged ions like Ar13+ and Bi82+. Non-destructive electronic detection is used to analyse and resistively cool the stored ions. Different ion species in the trap are resolved according to their charge-to-mass ratio by fixing the detection frequency and ramping over a range of trapping potentials. By selectively exciting the axial motion, Ar13+ ions are isolated from the ion cloud for the g-factor measurements. Studies are also done to determine the phase transition of dense ion clouds due to the discontinuous behaviour of spectral features during cooling.

A 20.20 Wed 16:30 P

Detector for Atomic Hydrogen — •Benedikt Tscharn, Hendrik-Lukas Schumacher, Gregor Schwendler, Jan Haack, and Randolf Pohl — Johannes Gutenberg-Universität Mainz, Institut für Physik, QUANTUM & Excellenzcluster PRISMA+, Mainz, Germany

Laser spectroscopy is the most precise way to experimentally determine the RMS charge radius of light nuclei.[1] Performing it on muonic hydrogen has raised the proton radius puzzle, a 5.6σ difference to previous electron scattering experiments.[2] Measuring the isotope shift of the 1S-2S transition in atomic tritium will yield the radius of triton, the mirror nucleus to the helion, by two orders of magnitude improved precision.[1] Together with muonic hydrogen, deuterium and helium, this will allow for precise tests of nuclear theory.
The T-REX experiment aims to perform laser spectroscopy on cooled and trapped atomic tritium. The atomic tritium flux to the MOT where the measurement takes place has to be monitored with a non-destructive detector for optimisation. Since tritium is radioactive, hydrogen is used during build-up.
We have developed such a detector measuring the resistance change of a $5\mu m$ diameter tungsten wire due to recombination energy. It is sensitive to a hydrogen flux of 10^{17} atoms per second and can distinguish molecular and atomic hydrogen beams.

[1] S. Schmidt et al., J. Phys. Conf. Ser. (2018), arXiv 1808.07240
[2] R. Pohl et al., Nature 466.723, 213-216 (2010)

A 20.21 Wed 16:30 P

Recoil correction to the energy level of heavy muonic atoms — •Romain Chazotte[1,2] and Natalia Oreshkina[2] — [1]Unversität Heidelberg — [2]Max-Plank-Institut

In this work, the relativistic recoil correction to the energies of heavy muonic atoms has been considered, based on the formalism suggested by Borie and Rinker.

Muonic atoms are atoms, which have a bound muon instead of an electron. The lifetime of a muon is long enough so it can be considered stable on the atomic scale. Additionally, an atom with a single bound muon can be considered as a hydrogenlike system. As muons are about 200 times heavier than electrons, they orbit around the nucleus 200 times closer. This leads to a larger contribution of all kinds of nuclear effects to the energy.

We calculated the recoil effect for the shell, sphere and Fermi nuclear models. The model and nuclear parameters dependence has been studied. The results have been compared with previous studies. They also can be used for the high-precision theoretical predictions of the spectra of heavy muonic atoms, and in the further comparison with experimental data, aiming at the extraction of the nuclear properties and parameters. In the future, a more rigorous quantum electrodynamics formalism can be applied for enhancing the accuracy of the relativistic recoil effect.