# A 28: Precision Spectroscopy V - highly charged ions (joint session A/Q)

Time: Wednesday 14:00–15:45 Location: K 1.016

A 28.1 Wed 14:00 K 1.016

**Ion sources and beamline of the ALPHATRAP *g*-factor experiment** — •Tim Sailer[1,2], Ioanna Arapoglou[1,2], José R. Crespo López-Urrutia[1], Alexander Egl[1,2], Martin Höcker[1], Sandro Kraemer[1,2], Andreas Weigel[1,2], Robert Wolf[1,3], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik — [2]Fakultät für Physik und Astronomie, Universität Heidelberg — [3]ARC Centre of Excellence for Engineered Quantum Systems, School of Physics, The University of Sydney, NSW Australia

The Penning-trap experiment ALPHATRAP, located at the Max-Planck-Institut für Kernphysik in Heidelberg, aims to measure the $g$ factor of bound electrons in highly charged ions (HCI) up to hydrogen-like $^{208}Pb^{81+}$. In the electrical field of the nucleus with a strength of the order of $10^{16}$ V/cm bound-state quantum electrodynamics can be tested with highest precision in extreme conditions. To enable measurements beyond the current thermal limits, laser-cooling will be implemented. To this end, a Laser Ion Source (LIS) based on a Nd:YAG laser is used to produce $^{9}Be^{+}$ ions, which will subsequently be laser cooled inside the trap using a 313nm laser system. HCI, which cannot be directly addressed by the laser, will be sympathetically cooled by the beryllium ions. The LIS is attached to the existing beamline, which allows an external production and injection of the $^{9}Be^{+}$ ions. Additionally, a table-top electron beam ion source has been used successfully to produce and inject ions up to $^{40}Ar^{13+}$ into the trap. Finally, the HD-EBIT will be connected to the experiment in the near future to enable the transfer and subsequent measurement of heavy HCI.

A 28.2 Wed 14:15 K 1.016

**SIM-X: Silicon Microcalorimeters for X-ray Spectroscopy at Storage Rings - Status and Perspectives** — •Pascal Andree Scholz[1], Victor Andrianov[2], Artur Echler[3,4], Peter Egelhof[3,4], Oleg Kiselev[3], Saskia Kraft-Bermuth[1], and Damian Müll[1] — [1]Justus Liebig University Giessen, Germany — [2]Lomonosov Moscow State University, Russia — [3]GSI Helmholtz Center, Germany — [4]Johannes Gutenberg University Mainz, Germany

High-precision X-ray spectroscopy of highly-charged heavy ions provides a sensitive test of quantum electrodynamics in very strong Coulomb fields. However, one limitation of the current accuracy of such experiments is the energy resolution of available X-ray detectors. Due to their excellent energy resolution for X-ray energies around 100 keV, silicon microcalorimeters, based on silicon thermistors and tin absorbers, have already demonstrated their potential in previous experiments at the Experimental Storage Ring (ESR) of the GSI Helmholtz Center for Heavy Ion Research. Based on these experiments, a larger detector array with three times the active detector area in a cryogen-free cryostat equipped with a pulse tube cooler is currently in preparation. After a successful test experiment in june 2016 at the ESR with SIM-X, efforts in optimization and characterization concerning the thermal design and performance were made in order to improve the overall energy resolution and performance. In this presentation, we will present the current status of developments and perspectives in particular with respect to the next FAIR Phase 0 experiments.

A 28.3 Wed 14:30 K 1.016

**Commissioning of the ALPHATRAP double Penning-trap system** — •Ioanna Arapoglou[1,2], Alexander Egl[1,2], Martin Höcker[1], Sandro Kraemer[1,2], Tim Sailer[1,2], Andreas Weigel[1,2], Robert Wolf[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max Planck Institute for Nuclear Physics, Heidelberg — [2]Faculty of Physics and Astronomy, University of Heidelberg

The ALPHATRAP experiment is a state-of-the-art Penning-trap setup aiming for high-precision g-factor measurements on heavy highly charged ions (HCI), such as hydrogen-like $^{208}Pb^{81+}$. That way the most stringent test of bound-state quantum electrodynamics (BS-QED) can be carried out. The storage and manipulation of the ions is achieved using a double Penning-trap system in which the electron's $g$-factor is deduced from measuring the magnetic moment of the bound electron. The setup includes several ion creation possibilities for offline ion production, additional to the online injection of heavy HCI from the Heidelberg Electron Beam Ion Trap. The latter will deliver the ions of interest via an ion beam-line to the cryogenic double Penning-trap system, which is currently at the commissioning stage. Presently, proof-of-principle measurements are taking place in preparation for the first $g$-factor measurement. Among other things, necessary requirements for such a measurement will be the optimisation of the trapping potential, effective ion cooling, adiabatic ion transport as well as accurate knowledge of field inhomogeneities within the trapping region. These results and the current status of the experiment will be discussed.

A 28.4 Wed 14:45 K 1.016

**Progress of the MEDeGUN commissioning and extension of the TwinEBIS test bench** — •Hannes Pahl[1,2], Martin Breitenfeldt[1], Alexander Pikin[1,3], Johanna Pitters[1], and Fredrik Wenander[1] — [1]CERN, 1211 Geneva 23, Switzerland — [2]Universität Heidelberg, 69120 Heidelberg, Germany — [3]Brookhaven National Laboratory, Upton 11973, USA

We report on recent results related to the commissioning of a Brillouin-type electron gun (MEDeGUN) at TwinEBIS, a test bench for the development of Electron Beam Ion Sources (EBIS) at CERN. MEDeGUN is developed for both nuclear research and medical applications. It combines a strong electrostatic compression of the electron beam inside the magnetically shielded gun with the conventional magnetic compression into the ionisation region, providing high current-density electron beams for rapid charge breeding. During the commissioning, a 10 keV electron beam of more than 1 A was successfully injected into a 2 T solenoid field with negligible losses.

In order to measure the charge breeding efficiency, an upgrade of the existing setup is required. Hence, the TwinEBIS setup will be extended with a low-energy ion beam line that allows for external ion injection and extraction. A number of diagnostic devices for the extracted ion bunches will be installed, and a gas feed will be added to enable neutral gas injection directly into the EBIS ionisation region. Here, we present the design of the beam line and modifications to MEDeGUN intended to be implemented for the next commissioning run.

A 28.5 Wed 15:00 K 1.016

**Electronic transitions in highly charged ions as X-ray wavelength standards** — •Sven Bernitt[1,2], Steffen Kühn[2], René Steinbrügge[3], Hans-Christian Wille[3], Thomas Stöhlker[1,4], and José R. Crespo López-Urrutia[2] — [1]IOQ, Friedrich-Schiller-Universität, Jena, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [3]Deutsches Elektronen-Synchrotron, Hamburg, Germany — [4]Helmholtz-Institut Jena, Germany

The newest generations of synchrotron and free-electron laser light sources combined with high resolution monochromators offer high X-ray photon fluxes over narrow bandwidths. This allows for a wide range of new applications, among others in material science, biophysics, laboratory astrophysics, and fundamental atomic physics. However, currently most experiments have to rely on crystallographic standards or absorption edges measured in macroscopic samples for the calibration of X-ray wavelengths, which limits the achievable accuracies. Electronic transitions in few-electron highly charged ions can serve as reliable high-precision alternative X-ray wavelength standards. We have developed PolarX-EBIT, a compact electron beam ion trap with a novel off-axis electron gun. It allows to measure resonantly excited fluorescence of highly charged ions interacting with X-rays without blocking the photon beam, therefore allowing wavelength calibration simultaneous with arbitrary downstream experiments. We present the new trap as well as the results of an experiment where it was used to provide an accurate calibration of the photoabsorption of various gases relevant for the interpretation of astropysical X-ray spectra.

A 28.6 Wed 15:15 K 1.016

**Recent laser cooling and laser spectroscopy experiments at the ESR** — •Danyal Winters[1], Oliver Boine-Frankenheim[1,2], Axel Buss[3], Christian Egelkamp[3], Lewin Eidam[2], Volker Hannen[3], Zhongkui Huang[4], Daniel Kiefer[2], Sebastian Klammes[1,2], Thomas Kühl[1,5], Markus Löser[6,7], Xinwen Ma[4], Peter Spiller[1], Wilfried Nörtershäuser[2], Rodolfo Sanchez Alarcon[1], Ulrich Schramm[6,7], Mathias Siebold[6], Markus Steck[1], Thomas Stöhlker[1,5,8], Johannes Ullmann[3], Thomas Walther[2], Hanbing Wang[4], Weiqiang Wen[4], Christian Weinheimer[3], Daniel Winzen[3], and Michael Bussmann[6] — [1]GSI

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One of the most promising techniques for ion beam cooling at relativistic energies, is laser cooling. The fluorescence emitted after laser excitation can be used for both optical beam diagnostics and precision spectroscopy. We present results on experiments with $^{12}C^{3+}$ beams (122 MeV/u) stored in the experimental storage ring (ESR) in Darmstadt, Germany. The cooling transition in the ions was excited using a pulsed laser system with a high repetition rate, and a wide-scanning cw laser system. A novel XUV detector system, installed inside the vacuum of the ESR, was used to detect the fluorescence from the ions. We will present the experimental setup and preliminary data, and give an outlook on future experiments at FAIR in Germany and HIAF in China.

A 28.7 Wed 15:30 K 1.016

**Commissioning of a detection system for forward emitted XUV photons at the ESR** — M. Bussmann[1], A. Buss[2], C. Egelkamp[2], L. Eidam[3], V. Hannen[2], Z. Huang[4], D. Kiefer[5], S. Klammes[5], Th. Kühl[6,7,8], M. Loeser[1], X. Ma[4], W. Nörtershäuser[9], H.-W. Ortjohann[2], R. Sánchez[6,9], M. Siebold[1], Th. Stöhlker[6,7,10], J. Ullmann[7,9,10], J. Vollbrecht[2], Th. Walther[5], H. Wang[4], Ch. Weinheimer[2], D. Winters[6], and •D. Winzen[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Institut für Kernphysik, WWU Münster — [3]Institut für Theorie Elektromagnetischer Felder, TU Darmstadt — [4]Institute of Modern Physics, CAS Lanzhou — [5]Institut für Angewandte Physik, TU Darmstadt — [6]GSI, Darmstadt — [7]Helmholtz-Institut Jena — [8]Institut für Physik, Uni Mainz — [9]Institut für Kernphysik, TU Darmstadt — [10]Institut für Optik und Quantenelektronik, Uni Jena

The Institut für Kernphysik in Münster developed an XUV-photon detection system for laser spectroscopy measurements at the ESR. In a test beam time for laser cooling with $^{12}C^{3+}$-ions at $\beta \approx 0.47$, the $^2S_{1/2} - {}^2P_{1/2}$ and the $^2S_{1/2} - {}^2P_{3/2}$ transitions were investigated to commission the system. The detector features a movable cathode plate which is brought into the vicinity of the beam to collect forward emitted Doppler shifted photons ($\lambda_{\text{lab}} \approx 93$ nm). The photons produce mostly low energetic (<3 eV) secondary electrons which are electromagnetically guided onto an MCP detector. Preliminary results of the beam time will be presented. This work is supported by BMBF under contract number 05P15PMFAA.