A 37: Electron scattering and recombination

Time: Thursday 10:30–12:30 Location: BEBEL E42

Invited Talk A 37.1 Thu 10:30 BEBEL E42

Electron-impact ionization of highly-charged heavy ions relevant for plasma applications — •Alexander Borovik — Institut für Atom- und Molekülphysik, Universität Giessen

Accurate data on atomic processes are of crucial importance for the correct description and understanding of ionized-matter environments. The need for the huge amount of data on electron-impact ionization cross sections and plasma rate coefficients required for plasma modeling can only be met by theoretical calculations. However, for many-electron systems like heavy ions, an extremely complicated pattern of atomic processes makes the task to correctly predict the cross-sections and plasma-rate-coefficients challenging. An experimental approach, on the other hand, can give accurate data but only with a limited coverage of the required data amount and also has inherent limitations. We present a detailed study of electron-impact ionization cross-sections for highly-charged heavy ions involving both the measured results obtained from crossed-beam experiments and theoretical data calculated with the configuration-averaged distorted wave method. The combination of theory and experiment allows us to infer accurate plasma rate coefficients for plasma physics applications.

A 37.2 Thu 11:00 BEBEL E42

First systematic measurement of the photon emission anisotropy following resonant recombination into highly charged ions — •Chintan Shah[1], Pedro Amaro[1], René Steinbrügge[2], Sven Bernitt[2], Zoltan Harman[2,3], Stephan Fritzsche[4,5], Andrey Surzhykov[4,5], José Ramón Crespo López-Urrutia[2], and Stanislav Tashenov[1] — [1]Physikalisches Institut, Heidelberg, Germany — [2]Max-Planck-Institut für Kernphysik Heidelberg, Germany — [3]ExtreMe Matter Institute, Darmstadt, Germany — [4]Helmholtz-Institut, Jena, Germany — [5]GSI, Darmstadt, Germany

We report the first systematic measurement of the photon angular distribution in the inter-shell dielectronic and higher-order resonant electron recombination into highly charged ions. Iron and krypton ions in the He-like through O-like charge states were produced in an electron beam ion trap, and the electron beam energy was scanned over the K-shell dielectronic and higher-order recombination resonances. Improving on earlier work [1, 2], the photons emitted in the decay of the resonance states were simultaneously recorded by two germanium detectors which were mounted both along and perpendicular to the electron beam propagation direction. The measured photon emission asymmetries indicate the alignment of the total angular momentum of each resonance state with respect to the beam axis. The results can be used to benchmark atomic calculations, and can be applied for polarization diagnostics of hot astrophysical and laboratory fusion plasmas. [1] C. Beilmann et al., Phys. Rev. Lett. 107, 143201(2011) [2] C.Beilmann et al., Phys. Rev. A 88, 062706(2013)

A 37.3 Thu 11:15 BEBEL E42

Polarization of bremsstrahlung photons in coincidence (e, e', γ) **studies** — •Robert A. Müller[1,2], Vladimir A. Yerokhin[3], and Andrey Surzhykov[1] — [1]Helmholtz-Institut Jena — [2]Universität Jena — [3]St. Petersburg State Polytechnical University

In atomic bremsstrahlung the scattering of an electron by an atomic field is accompanied by the emission of a photon. The polarization of this photon has been studied in detail both in theory and experiment during the last years [1,2]. In most of these studies, however, the scattered electron remained unobserved. Owing to recent experimental advances, a new generation of studies becomes feasible in which the photon polarization is detected in coincidence with the electron scattering angle. First steps towards these coincidence experiments have been done for low- and medium-Z targets [3]. Moreover experiments are planned for the high-Z domain. Therefore we present in this contribution the theoretical study of the polarization of bremsstrahlung photons observed together with the scattered electrons. We applied the density matrix approach and pertubation theory to perform calculations for electrons with an energy of 100keV up to 500keV scattered by gold targets. The electron scattering angle shows a strong influence on the polarization properties of the photon, especially in comparison to the case when the scattered electron is not observed.

[1] R. Märtin et al., Phys. Rev. Lett. **108**, 264801 (2012)
[2] V. A. Yerokhin and A. Surzhykov, Phys. Rev. A **82**, 062702 (2010)
[3] W. Nakel, Radiat. Phys. Chem. **75**, 1164 (2006)

A 37.4 Thu 11:30 BEBEL E42

Giant Effect of the Spin-Orbit Interaction in Coulomb Scattering — •Oleksiy Kovtun[1], Stanislav Tashenov[1], Valery Tioukine[2], Andrey Surzhykov[1,3,4], and Vladimir Yerokhin[1,4,5] — [1]Physikalisches Institut der Universität Heidelberg, Germany — [2]Institut für Kernphysik Johannes Gutenberg-Universität Mainz, Germany — [3]Helmholtz-Institut Jena, Germany — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — [5]Center for Advanced Studies, St. Petersburg State Polytechnical University, Russia

Coulomb scattering of an electron in the field of the nucleus is influenced by the spin-orbit interaction. Due to the orbital momentum precession the electron trajectory is not confined to a single scattering plane as evidenced by the recent bremsstrahlung experiments. In that the angle of bremsstrahlung linear polarization is correlated with the spin direction of the incoming electron [S. Tashenov PRL 107, 173201 (2011), R. Maertin PRL 108, 264801 (2012)]. In the recent experiment we found this effect to be dramatically enhanced at relativistic energies. The scattering plane was turning by as much as several tenth of degrees. The results are in agreement with the full-order relativistic calculations. For this experiment we applied the novel techniques of the pulse shape analysis of the germanium detector signals and gamma-ray Compton imaging. The principles of the Compton imaging were invented in 1973 and our experiment marked their first application in a laboratory physics experiment.

A 37.5 Thu 11:45 BEBEL E42

Pair production and annihilation via nuclear resonances in atoms and ions — •Nikolay A. Belov and Zoltan Harman — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Processes connected with pair production and annihilation in atoms and ions are theoretically investigated. These include nuclear excitation by resonance positron annihilation (NERPA) and nuclear-resonant e^-e^+ pair creation in heavy ion collisions. Possible experimental schemes are put forward for the observation of these reactions. NERPA is an alternative channel of positron-matter interaction, with potential relevance in cosmic ray studies, medical positron emission tomography research, in experimental investigations of nuclear chain reactions, and in star evolution simulations. It also constitutes a novel means for the energy-selective excitation of nuclei. In heavy ion collisions, the Coulomb-excited nucleus may decay by a creation of a free-free or bound-free e^-e^+ pair. Thus, it is an additional, resonant channel of pair creation in nucleus-nucleus collisions, an experimental investigation of which is projected at the FAIR facility.

A 37.6 Thu 12:00 BEBEL E42

Spin-dependent Kapitza-Dirac diffraction in a two-color laser field — •Matthias Maximilian Dellweg and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

The Kapitza-Dirac effect [1] is the diffraction of an electron beam on the periodic potential generated by a standing light wave. An experimental verification of the effect, as originally proposed, was accomplished only recently [2]. Spin effects due to 3-photon interaction have been predicted for X-ray photons [3].

We study a generalization of the Kapitza-Dirac effect to the case of a bifrequent light field, which allows 3-photon interactions to occur even in the nonrelativistic regime. To this end, we solve the Pauli equation numerically for the relevant momentum eigenstates, and compare the results with fourth order perturbation theory.

[1] P. L. Kapitza, P. A. M. Dirac, Proc. Cambridge Philos. Soc. **29**, 297-300 (1933)
[2] D. L. Freimund, K. Aflatooni, H. Batelaan, Nature **413**, 142-143 (2001)
[3] S. Ahrens, H. Bauke, C. H. Keitel, C. Müller, Phys. Rev. Lett. **109**, 043601 (2012)

A 37.7 Thu 12:15 BEBEL E42

Interaction of relativistic electron vortex beams with few-cycle laser pulses — •Armen Hayrapetyan[1,2], Oliver Matula[1,3], Andrea Aiello[2,4], Andrey Surzhykov[5], and Stephan Fritzsche[5,6] — [1]Universität Heidelberg, 69120 Heidelberg, Germany — [2]Max-Planck-Institut für die Physik des Lichts, 91058 Erlangen, Germany — [3]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — [4]Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [5]Helmholtz-Institut Jena, 07743 Jena, Germany — [6]Universität Jena, 07743 Jena, Germany

We have studied the interaction of relativistic electron vortex beams (EVBs) with laser light. Exact analytical solutions for this problem are obtained by employing the Dirac-Volkov wave-functions to describe the (monoenergetic) distribution of the electrons in vortex beams with well-defined orbital angular momentum (OAM). Our new solutions explicitly show that the OAM components of the laser field couple to the total angular momentum of the electrons. When the field is switched off, it is shown that the laser-driven EVB coincides with the field-free EVB as reported by Bliokh et al. [Phys. Rev. Lett. 107, 174802 (2011)]. Moreover, we calculate the probability density for finding an electron in the beam profile and demonstrate that the center of the beam is shifted with respect to the center of the field-free EVB. This shift is unavoidably accompanied with an azimuthal dependence of the electronic probability density distribution and can be an important observable that manifests itself in the interaction of the twisted electrons with laser pulses.