A 16: Collisions, Scattering and Correlation Phenomena I

Time: Wednesday 14:30–16:30 Location: HS PC

Invited Talk A 16.1 Wed 14:30 HS PC

Entanglement in the motional degree of freedom created in ultracold collisions — •Yimeng Wang and Christiane Koch — Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

Despite cold collisions being one of the most important tools of demonstrating quantum features and manipulating the particles, entanglement generated during the cold collision processes has been comprehensively studied only for the internal structures. The relative motion between the particles, which is crucial to the resonance phenomena and reactive processes, has been rarely discussed in entanglement literature because of its high dimensionality and complexity. In this project, we quantify the motional entanglement between two particles generated in ultracold collisions by computing the inter-particle purity. We reexam the formal scattering theories by using the Gaussian wave packets as pre-collision states, and then demonstrate the time evolutions of the scattered wave packets and the time-dependent inter-particle purity. We compare the degree of entanglement generated under different initial conditions, then study the influences from resonance states, and finally discuss the efficiency of different entanglement witnesses.

A 16.2 Wed 15:00 HS PC

Recoil-Ion and Electron Momentum Spectroscopy of Anion Neutral Interactions at a Cryogenic Ion Storage Ring — •Michael Schulz, Felix Herrmann, Weiyu Zhang, David Chicharro, Alexander Dorn, Manfred Grieser, Florian Grussie, Holger Kreckel, Oldrich Novotny, Florian Trost, Andreas Wolf, Thomas Pfeifer, Claus Dieter Schröter, and Robert Moshammer — Max-Planck-Institut für Kernphysik Heidelberg

We have measured momentum analyzed recoil ions and ejected electrons in triple coincidence with projectiles neutralized in collisions of slow anions with atoms. The experiment was performed at the Heidelberg cryogenic storage ring. From the data we extracted multiple differential cross sections for electron loss from the projectile (detachment) and for detachment accompanied by single and double target ionization (DI and DDI). Surprisingly large DI (and DDI) to detachment cross section ratios were found. Furthermore, in the differential momentum distributions of electrons ejected in DI we only observe signatures of a correlated mechanism while uncorrelated channels appear to be insignificant. This is also surprising because the projectile energy is well below the threshold for the correlated mechanism and DI is kinematically possible only because of the initial momentum distribution of the electrons in their initial bound states.

A 16.3 Wed 15:15 HS PC

Towards Light Scattering Experiments in Dense Dipolar Gases — •Rhuthwik Sriranga, Marvin Proske, Ishan Varma, Chung-Ming Hung, Dimitra Cristea, and Patrick Windpassinger — Johannes-Gutenberg Universität Mainz

In ultracold atomic ensembles where interatomic spacing is smaller than the wavelength of scattered light, direct matter-matter coupling through electric and magnetic interactions significantly influence system dynamics, challenging the approximation of atoms as independent emitters. We study the role of magnetic dipole-dipole interactions (DDI) in the cooperative behavior of dense atomic ensembles using dysprosium, which has the highest ground-state magnetic moment (10 Bohr magnetons). Our light-scattering experiments probe these effects in thermal and degenerate dense dipolar media.

This presentation details progress in generating ultradense cold dysprosium clouds, including optical transport of atoms into a home-built science cell enabling precise cloud manipulation. The cell's compact design allows tight dipole trapping with a high numerical aperture objective made in-house. We also discuss the impact of optical dipole trap polarization on atomic lifetime and outline future experiments to uncover collective effects, advancing the study of cooperative quantum phenomena.

A 16.4 Wed 15:30 HS PC

Electron-Impact Ionization of La^{1+} with a new Scan-System — •B. Michel Döhring[1,2], Alexander Borovik Jr.[1], Kurt Huber[1], and Stefan Schippers[1,2] — [1]Justus-Liebig-Universität Gießen — [2]Helmholtz Forschungsakademie Hessen für Fair, GSI Helmholtzzentrum für Schwerionenforschung, Campus Gießen

Recently, we commissioned a new scanning system for the measurement of electron-impact ionization cross sections in a crossed-beams geometry. Here, we present experimental results for single, double and triple electron-impact ionization of La^{1+} ions, with impact energies starting from the ionization threshold and ranging up to 2000 eV. As compared to previous single-ionization measurements [1], we have extended the energy range by a factor of two. The results are geared towards providing atomic data for kilonova modelling and may be another good opportunity to apply our hybrid method for the calculation of electron-impact ionization cross sections [2] in future works.

[1] A. Müller et al., Phys. Rev. A **40**, 3584 (1989)
[2] F. Jin et al., Eur. Phys. J. D **78**, 68 (2024)

A 16.5 Wed 15:45 HS PC

A Novel Compton Telescope for Polarimetry in the MeV Range — •Tobias Over[1,2,3], Thomas Krings[4], Wilko Middents[1,2,3], Uwe Spillmann[1], Günter Weber[1,2], and Thomas Stöhlker[1,2,3] — [1]Helmholtz Institute Jena, Jena, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [3]Friedrich Schiller University Jena, Jena, Germany — [4]Forschungs Zentrum Jülich, Jülich, Germany

For photon energies from several tens of keV up to a few MeV, Compton polarimetry is an indispensable tool to gain insight into subtle details of fundamental radiative processes in atomic physics. Within the SPARC collaboration [1] several segmented semiconductor detectors have been developed that are well suited for application as efficient Compton polarimeters. For photon emission processes in the hard x-ray regime these kind of detectors enable revealing photon polarization effects in great detail [2]. In our presentation, a novel Compton telescope detector that will enable us to extend to photon energies up to the MeV range will be presented. In particular, we will discuss new experimental possibilities in the higher energy range.

[1] Th. Stöhlker et al. Nucl. Instrum. Methods Phys. Res. B 365 (2015) 680.
[2] K.H. Blumenhagen et al. New J. Phys. 18 (2016) 119601.

A 16.6 Wed 16:00 HS PC

Polarization effects in the Compton scattering from atomically bound electrons — •Wilko Middents[1,2,3], Günter Weber[1,2], Tobias Over[1,2,3], Alexander Gumberidze[2], Philip Pfäfflein[1,2,3], Uwe Spillmann[2], and Thomas Stöhlker[1,2,3] — [1]Helmholtz Institute Jena, Jena, Germany — [2]GSI, Darmstadt, Germany — [3]Friedrich Schiller University Jena, Jena, Germany

Precise studies of the linear polarization for Compton scattered photons open the unique opportunity for a detailed test of the impulse approximation for energetic photon matter interaction. Compton scattering is the inelastic scattering of a photon from an electron, in which the scattered photon carries a lower energy than the incident photon. The energy of the scattered photon depends on the scattering angle. For scattering from bound electrons, the resulting Compton scattering peak is broadened due to the momentum distribution of the electrons leading to a Doppler shift of the incident and scattered photons. Additionally, we expect the electron momentum distribution to influence the scattered photon polarization such, that the linear polarization will vary across the Compton peak.

We performed an experiment at the synchrotron facility PETRA III at DESY in Hamburg, in which we scattered the highly polarized hard x ray beam from a gold target. We analyzed the scattered radiation under several scattering angles with a special interest to the linear polarization of the scattered radiation. We will show the result of the analysis of the Compton scattered radiation and compare it to a simulation developed in the framework of the impulse approximation.

A 16.7 Wed 16:15 HS PC

Three-charged-particle systems in the framework of coupled coordinate-space few-body equations — •Renat Sultanov — The University of Texas Permian Basin, Odessa, Texas, USA

We study three-charged-particle low-energy elastic collision and particle-exchange reaction with special attention to the systems with

Coulomb and an additional nuclear interaction employing a close-coupling expansion scheme to a set of coupled two-component few-body equations [1]. First we apply our formulation to compute low-energy elastic scattering phase shifts for the $d+(t\mu^-)_{1s}$ collision, which is of significant interest for the muon-catalyzed-fusion D-T cycle. Next, we study the particle-exchange reaction $d+(pX^-) \to p+(dX^-)$ with the long lived elementary heavy lepton stau X^- which can play a critical role in the understanding of the Big-Bang nucleosynthesis and the nature of dark matter.

We also study the total cross sections and rates for two particle-exchange reactions involving antiprotons ($\bar{p}$), deuteron (d) and triton (t), e.g., $\bar{p}+(d\mu)_{1s} \to (\bar{p}d)_{1s}+\mu^-$ and $\bar{p}+(t\mu)_{1s} \to (\bar{p}t)_{1s}+\mu^-$, where μ^- is a muon. The effect of the final state short-range strong $(\bar{p}d)$ and $(\bar{p}t)$ nuclear interaction is significant in these reactions, which increases the reaction rates by a factor of ≈ 3. Additionally (if time permits), a 3-body $\bar{p}+Mu$ collision will be discussed, where Mu is a muonium atom [2].

1. R. A. Sultanov and S. K. Adhikari, Phys. Rev. C 107, 064003 (2023).

2. R. A. Sultanov and D. Guster, J. Phys. B 46, 215204 (2013).