A 1: Collision Experiments

Time: Monday 14:30–16:30 Location: HS 20

Invited Talk A 1.1 Mon 14:30 HS 20

Tunable entanglement resource in elastic electron-exchange collisions out of chaotic spin systems — •Bernd Lohmann[1], Karl Blum[1], and Burkhard Langer[2] — [1]Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Straße 9, 48149 Münster, Germany — [2]Physikalische Chemie, Freie Universität Berlin, Takustraße 3, 14195 Berlin, Germany

Elastic collisions between initially unpolarized electrons and hydrogen-like atoms are discussed aiming to analyze the entanglement properties of the correlated final spin system. Explicit spin-dependent interactions are neglected and electron exchange only is taken into account. It is shown that the final spin system is completely characterized by a single spin correlation parameter depending on scattering angle and energy. Its numerical value identifies the final spins of the collision partners to be either in the separable, entangled, or Bell correlated regions.

The symmetry of the scattering process allows for the construction of explicit examples applying methods of classical communication and local operations for illustrating the concepts of nonlocality versus separability.

It is shown that strong correlations can be produced violating Bell*s inequalities significantly. Furthermore, the degree of entanglement can be continuously varied simply by changing either the scattering angle and/or energy. This allows for the generation of tunable spin pairs with any desired degree of entanglement. We suggest to use such nonlocally entangled spin pairs as a resource for further experiments, for example in quantum information processes.

A 1.2 Mon 15:00 HS 20

Commissioning of a high-power electron gun for electron-ion crossed-beams experiments — •Benjamin Ebinger[1], Alexander Borovik Jr.[1], B. Michel Döhring[1], Tobias Molkentin[1], Alfred Müller[2], and Stefan Schippers[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen

In an electron-ion crossed-beams experiment, the experimental sensitivity is mainly determined by the densities of both beams in the interaction region. Aiming at the extension of the available range of accessible electron energies and densities, a new high-power electron gun has been developed and built. It delivers a ribbon-shaped beam with high currents at all energies variable between 10 and 3500 eV [1,2]. The expected high electron currents and good beam transmission have already been shown.

Here, we report on the current status of commissioning of this electron gun. The electron gun is integrated into the experimental electron-ion crossed-beams setup in Giessen. Employing the *animated crossed-beams* technique [3], first cross sections for electron-impact ionization of xenon and helium ions were measured. The measurement of more cross sections is intended for the near future. Further investigations concerning, e.g., space-charge effects in the high-density electron beam are currently performed.

[1] Shi et al., Nucl. Instr. Meth. Phys. Res. B 205 (2003) 201-206
[2] Borovik et al., J. Phys.: Conf. Ser. 488 (2014) 142007
[3] Müller et al., J. Phys. B. 18 (1985) 2993-3009

A 1.3 Mon 15:15 HS 20

A new electron beam ion source as charge breeder for rare isotope beams — •Michael A. Blessenohl[1], Stepan Dobrodey[1], Zachary Hockenbery[2], Renate Hubele[1], Thomas Baumann[3], Jens Dilling[4], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]McGill, Montreal, Canada — [3]European XFEL, Hamburg — [4]TRIUMF, Vancouver, Canada

The 500 MeV cyclotron at TRIUMF bombards heavy-element targets with protons to generate rare isotopes for nuclear physics studies at the post-accelerators ISAC (Isotope Separator and Accelerator) I and II. The new Advanced Rare IsotopE Laboratory (ARIEL) will use a new electron beam ion source (EBIS) for charge breeding of those isotopes. At high charge states, the charge to mass ratio $^{A}/_{Q}$ can stay low, as required by ISAC I and II. For rare isotopes with half-lives down to 65 milliseconds and low abundances of down to 10^6 per bunch, the whole process of injection, charge breeding and extraction has to be as efficient as possible. At bunch repetition rates of 100 Hz fast high-voltage control and switching are needed, with a goal charge breeding efficiency of at least 20 %. We present the design including finite-element and Monte-Carlo simulations results, as well as concepts for both on-line diagnostics and control system.

A 1.4 Mon 15:30 HS 20

Towards ion-atom scattering in the ultracold regime — •Thomas Schmid[1], Christian Veit[1], Nicolas Zuber[1], Thomas Dieterle[1], Robert Löw[1], Tilman Pfau[1], Michal Tarana[2], and Michal Tomza[3] — [1]5th Physical Insitute & Center for Integrated Quantum Science and Technology, University of Suttgart, Stuttgart, Germany — [2]J. Heyrovský Institute of Physical Chemistry of the ASCR, Prague, Czech Republic — [3]Centre of New Technologies, University of Warsaw, Warsaw, Poland

We propose an experiment to extend the investigation of ion-atom collisions from the so far studied cold, but still essentially classical regime covered by hybrid ion-atom-trap experiments [1] to the ultracold, quantum regime. Reaching the quantum scattering regime is made possible, first, by the use of an ion-atom system (in our case $^{87}Rb^{+}$-^{6}Li) with a small reduced mass, and second, by employing a specific type of heteronuclear F-state Rb*-Li Rydberg molecules to initialize the scattering event. We present calculations on this type of heteronuclear Rydberg molecules together with quantum mechanical simulations showing how the initial wave function evolves in the presence of the ion-atom scattering potential. Finally, we outline how quantum scattering features could be extracted experimentally from the scattered wave function.

[1] A. Härter, and J. Hecker Denschlag; *Contemp. Phys.* **55**, 33 (2014).

A 1.5 Mon 15:45 HS 20

Towards Ultracold Li – Ba^{+} Interactions — •Markus Debatin, Pascal Weckesser, Fabian Thielemann, Yannick Minet, Julian Schmidt, Alexander Lambrecht, Leon Karpa, and Tobias Schaetz — Physikalisches Institut, Universität Freiburg, Germany

Research on the interplay of atoms and ions allows to observe a large variety of interesting physics phenomena [1]. Optical trapping of ions [2] allows to overcome heating effects caused by technical and intrinsic micromotion, which is ubiquitous in Paul traps [3].

We are currently setting a novel experiment targeting ultracold interactions between Ba^{+} ions and Li atoms. We give details on our strategy to combine an Ion trap with homogenous mangetic fields required for tuning Li interac- tions and good optical access necessary for optical trapping of Ba + Ions and imaging of both species.

[1] A. Haerter et al., Contemp. Phys., 55, 1, pp. 33-45 (2014).
[2] T. Huber et al., Nat. Comm. 5,5587 (2014).
[3] M.Cetina et al., Phys.Rev.Lett. 109,253201 (2012).

A 1.6 Mon 16:00 HS 20

Setup for studying Li-Yb+ mixtures in the quantum regime — •Henning Fürst[1], Jannis Joger[1], Norman Ewald[1], Thomas Feldker[1], Thomas Secker[2], and René Gerritsma[1] — [1]Institute of Physics, University of Amsterdam, Netherlands — [2]Institute for Coherence and Quantum Technology, TU Eindhoven, Netherlands

Mixtures of trapped atoms and ions form exciting new systems enabling the study of quantum chemistry, ultracold collisions and polaronic physics. Possible applications include sympathetic cooling of ions, ion-assisted detection of atoms and quantum simulation. In the ultracold regime the quantum dynamics of mixtures of fermionic atoms and ions and of fermion-phonon coupling may be studied [1]. We present our setup for realising a hybrid system of trapped Li atoms and Yb+ ions, where the large mass-ratio between ion and atom will allow us to reach the ultracold regime [2]. We discuss overlapping of magnetically trapped atoms with an ion crystal confined in the Paul trap and show first experimental results of atom-ion interactions and prospects for reaching the quantum regime.

[1] U. Bissbort et al., Phys. Rev. Lett. 111, 080501 (2013).
[2] M. Cetina et al., Phys. Rev. Lett. 109, 253201 (2012).

A 1.7 Mon 16:15 HS 20

Effective two-channel model for cold reactive collisions —

•Christian Cop and Reinhold Walser — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt

In a previous work experimental data [1] of cold collisions of metastable neon atoms (Ne*) has been analyzed theoretically in terms of a coupled two-channel model with realistic interaction potentials [2]. This model gave good agreement between theory and experiment.

Here we present an effective two-channel square well potential which contains all the features present in the coupled two-channel model of [2]. For the coupled square-well potential, the S matrix is analyzed analytically in the complex k plane. Based on a single pole expansion of the S matrix we derive analytic expressions for the two-body loss rates of the coupled square-well potential. These analytic expressions show good agreement of scattering rates in the coupled square-well model and the model with realistic interaction potentials. Thus, threshold collisions rates can be well approximated by a single pole expansion of an effective two-channel potential theory.

[1] J. Schuetz et al., *Heteronuclear collisions between laser-cooled metastable neon atoms*, Phys. Rev. A, **86**, 022713 (2012).

[2] C. Cop et al., *Penning ionization and elastic scattering in cold collisions of metastable neon atoms*, to be published.