SYLB 1: Loosely-Bound States – From the Coldest to the Hottest Environments

Time: Monday 10:45–12:45 Location: ZHG104

Invited Talk SYLB 1.1 Mon 10:45 ZHG104
Fermion Pairing and Correlation at Ultralow Temperatures — •Philipp Preiss — Max Planck Institute of Quantum Optics, Garching, Germany — Physics Institute, Heidelberg University, Heidelberg, Germany

Strongly correlated Fermi systems pose challenges across a wide range of energy scales, from quark-gluon plasmas in high-energy physics to correlated insulators in condensed matter physics.

At the lowest energies - in the microkelvin or picoelectronvolt regime - correlated fermion problems emerge in ultracold atomic gases. Reaching such ultralow temperatures presents experimental challenges but also opens opportunities: the physics unfolds at micrometer length scales and kilohertz time scales. This allows spatial resolution down to the interparticle spacing and real-time observation of dynamics.

In this talk, I will describe the toolset we have developed to microscopically study correlation and pairing effects in small two-dimensional systems of ultracold fermions. Using optical traps and fluorescence imaging, we deterministically prepare single quantum states, tune interactions, and capture particle-resolved momentum correlations in single snapshots of the wavefunction. I will show how this technique reveals Cooper-like pairs in samples containing only a few atoms and how rapid rotation induces correlations akin to Laughlin states. These results showcase the microscopic tunability of fermion pairing effects in synthetic quantum matter.

Invited Talk SYLB 1.2 Mon 11:25 ZHG104
The structure of loosely-bound nuclear states: when the tail wags the dog — •Hans-Werner Hammer — Technische Universität Darmstadt, Department of Physics, Institut für Kernphysik, 64289 Darmstadt, Germany

Loosely-bound quantum states with very different interactions at short distances can show universal behavior at large distances. These states are in the extreme quantum regime, as their constituents spend most of the time outside of the range of their interaction and the tail of the wave function determines many of their properties. They can have the peculiar property that removing one particle from a multi-body bound state can cause the whole bound state to fall apart. Such systems can be found over a large range of scales ranging from nuclear and particle physics to ultracold atoms. The talk will give an overview of current research questions and future challenges with a particular focus on nuclear systems.

Invited Talk SYLB 1.3 Mon 12:05 ZHG104
Fragile Matter in Extreme Conditions: insights from the LHC — •Francesca Bellini — Dept. of Physics and Astronomy, University of Bologna and INFN, Bologna, Italy

The formation of light nuclei and hypernuclei in high-energy collisions provides a valuable probe of nuclear structure and the strong interaction in few-body quantum systems. These nuclei, though relatively well bound in nuclear terms - the deuteron has a binding energy of 2.2 MeV are remarkably fragile when produced in extreme environments. At the CERN Large Hadron Collider, temperatures exceed 100 MeV (over a trillion Kelvin), vastly surpassing nuclear binding energies and raising fundamental questions about how loosely bound states can form and survive.

Over the past decade, the LHC has delivered a wealth of high-precision data on light nuclei and their antimatter counterparts, from deuterons to alpha particles to hypertritons. These notable results define the current experimental frontier and offer an unprecedented opportunity to confront theoretical models of nuclear formation.

Key findings are discussed in the context of recent theoretical developments, in particular focusing on the statistical hadronization and coalescence models, two quantum-mechanical frameworks that describe the production of light nuclei and hypernuclei. Comparisons between data and model predictions enable us to probe the quantum structure of matter under extreme conditions and to explore how few-body nuclear systems emerge from the underlying principles of quantum chromodynamics.