HK 24: Heavy-Ion Collisions and QCD Phases IV

Time: Wednesday 13:45–15:45 Location: PHIL A 401

Group Report HK 24.1 Wed 13:45 PHIL A 401

Diquark Properties from First Principles and Their Impact on Color Superconducting Matter — Hosein Gholami[1], •Ugo Mire[2], Fabian Rennecke[2,3], Bernd-Jochen Schaefer[2,3], and Shi Yin[2] — [1]Technische Universität Darmstadt, Fachbereich Physik, Institut für Kernphysik, Theoriezentrum, Darmstadt, Germany — [2]Institut für Theoretische Physik, Justus-Liebig-Universität Gießen, Gießen, Germany — [3]Helmholtz Forschungsakademie Hessen für FAIR (HFHF), GSI Helmholtzzentrum für Schwerionenforschung, Campus Gießen, Gießen, Germany

Recent neutron star observations demand increasingly precise equations of state at extreme densities where exotic phases of matter may appear. An intriguing candidate is color superconductivity, in which quarks pair into diquarks that condense, making a first-principles understanding of diquark dynamics essential for interpreting astrophysical data. In this talk I will present results for the vacuum properties of the scalar diquark in a self-consistent and first-principle approach to QCD. Using the functional renormalization group, I will show how the high energy quark and gluon degrees of freedom can be smoothly integrated resulting in a low-energy description in terms of mesons and diquarks. I will show that our approach predict a scalar diquark bound state, consistent with the quark-diquark picture of the nucleon. Finally, I will demonstrate how these results can constrain low-energy models of color superconductivity, yielding new insights into the equation of state of cold and dense quark matter.

HK 24.2 Wed 14:15 PHIL A 401

Renormalization-Group Invariant Parity-Doublet Model for Nuclear and Neutron-Star Matter — •Mattia Recchi[1], Lorenz von Smekal[1,2], and Jochen Wambach[3] — [1]Institut für Theoretische Physik, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [2]Helmholtz Forschungsakademie Hessen für FAIR (HFHF), GSI Helmholtzzentrum für Schwerionenforschung, Campus Giessen — [3]Technische Universität Darmstadt, 64289, Darmstadt, Germany

The Parity-Doublet Model (PDM) is a chirally invariant effective theory for nuclear matter that incorporates a chirally invariant mass through opposite-parity partners. We develop a multiplicatively renormalizable mean-field approach to include baryonic vacuum contributions in the grand-canonical potential in a manifestly renormalization-group invariant form. We study the chiral dynamics and equation of state of the model, focusing on the restoration of spontaneously broken chiral symmetry at baryon densities and temperatures relevant for neutron-star astrophysics and heavy-ion collisions. We find that baryonic vacuum fluctuations have a crucial impact on the evolution of the chiral condensate and are essential for a realistic description of neutron-star structure.

HK 24.3 Wed 14:30 PHIL A 401

Neutron Star Properties with Skyrme Potentials from Relativistic Heavy-Ion Physics — •Eleonora Foerster, Sarah Pitz, Selina Kunkel, Ishfaq Rather, and Jürgen Schaffner-Bielich — Goethe Universität, Frankfurt am Main, Germany

The study of ultra-dense matter created in relativistic heavy-ion collisions provides important constraints on the nuclear equation of state (EoS), which is a key input for modeling neutron stars. In this contribution, we explore the mutual interplay between EoS constraints extracted from heavy-ion flow measurements and observational mass-radius constraints of neutron stars. Using a Skyrme-based EoS constrained by heavy-ion data, mass-radius relations for symmetric nuclear matter and pure neutron matter are calculated and compared to current neutron-star observations. The focus is on investigating how specific properties of the nuclear interaction, in particular the nuclear incompressibility K, influence neutron-star observables such as the maximum mass and radius. Variations of K lead to noticeable changes in the predicted maximum mass, demonstrating the connection between neutron star observables and contraints on the EoS by heavy-ion physics.

HK 24.4 Wed 14:45 PHIL A 401

Global Lambda Polarization in Au+Au collisions at 0.8 AGeV measured with HADES — •Florian Alef for the HADES-Collaboration — TU Darmstadt, Darmstadt, Germany

In heavy-ion collisions, large angular momenta are generated which might translate to a spin polarization of the produced particles. Extracting the spin orientation of an outgoing proton from a weakly decaying Λ hyperon with respect to the reaction plane could probe a global polarization and be a hint for high vorticities in the early stages of the collision. Measurements of the Λ polarization by HADES and STAR collaboration both indicate a strong enhancement towards lower beam energies, reaching $\langle P_\Lambda \rangle(\%) = 4.4 \pm 0.3\,(\text{stat.}) \pm 0.4\,(\text{sys.})$ in Ag+Ag collisions at $\sqrt{s}_{\text{NN}} = 2.55\,\text{GeV}$, which corresponds to the free NN Λ production threshold.
This contribution will report on the status of the Λ polarization in Au+Au collisions at $\sqrt{s}_{\text{NN}} = 2.25\,\text{GeV}$ measured with HADES, which is the first Λ polarization measurement below the production threshold.

HK 24.5 Wed 15:00 PHIL A 401

Strangeness fluctuations in the HADES experiment* — •Athira Sreejith for the HADES-Collaboration — Bergische Universität Wuppertal, Wuppertal, Deutschland

Fluctuations of conserved charges such as baryon number, electric charge, and strangeness are effective probes of the QCD phase diagram. Their higher-order cumulants are particularly sensitive to critical phenomena and remain an important focus of current heavy-ion research.

In this work, an exploratory study of strangeness fluctuations in Ag+Ag collisions at $\sqrt{s_{NN}}$= 2.55 GeV, measured with the High Acceptance Di-Electron Spectrometer (HADES), a fixed-target experiment at GSI, Germany, is presented. Operating in the 1*2A GeV regime, HADES accesses QCD medium at high net-baryon density and low temperature, providing complementary coverage to higher-energy programs. The very low strange-hadron yields at these energies, especially for kaons, necessitate robust particle identification. Therefore, a fuzzy-logic-based probabilistic technique is employed to reconstruct strange-hadron multiplicity moments.

This contribution focuses on the feasibility study of strangeness fluctuations at HADES, including the identification and reconstruction performance for strange particles, and the resulting cumulants of their multiplicity distributions.

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HK 24.6 Wed 15:15 PHIL A 401

Proton and light nuclei yields and E-by-E fluctuations measured at HADES — •Marvin Nabroth — Goethe-University Frankfurt

Low energy heavy-ion collisions in the 1 AGeV regime, as studied by the HADES experiment at SIS18/GSI, allow to probe QCD matter under highest net-baryon densities and moderate temperatures.
In this contribution we present refined efficiency corrected transverse and longitudinal yield spectra of protons, deuterons, tritons, He3 reconstructed from Ag+Ag collisions at $\sqrt{s_{NN}} = 2.55$ GeV and $\sqrt{s_{NN}} = 2.42$ GeV measured at HADES in 2019. We discuss the spectral shape properties and the coalescence behavior as a function of centrality, as well as the beam-energy dependence. These results contribute to a better understanding of the formation of light nuclear clusters, and help constrain the freeze-out conditions via thermal-model fits. Furthermore, we present an update of the analysis of higher order moments of the e-by-e fluctuations of the proton yields in different rapidity windows. Such fluctuation observables are essential for exploring signs of criticality expected from the conjectured first-order phase transition or critical end point.
This work has been supported by BMBF (05P21RFFC2, 05H24RF5), GSI and HGS-Hire.

HK 24.7 Wed 15:30 PHIL A 401

Lambda reconstruction at SIS18: a mCBM campaign — •Abhishek Anil Deshmukh for the CBM-Collaboration — Bergische Universität Wuppertal, Wuppertal, Deutschland

The production of strange hadrons, such as the Λ particle, serves as a standard candle for probing the properties of dense nuclear matter created in heavy-ion collisions at SIS18 energies at GSI, Darmstadt. The mini-CBM (mCBM) experiment, a prototype for the upcoming CBM experiment, allows for these measurements. Its narrow acceptance, combined with the lack of magnetic field present a unique challenge, rendering the reconstruction of multi-particle decay topologies particularly difficult.

This contribution presents the reconstruction of Λ particles via their dominant charged hadronic decay channel $\Lambda \rightarrow p + \pi^-$ (63.9%). The method has been successfully developed, tested, and optimized on Monte Carlo simulations, where its performance and selection criteria have been thoroughly characterized.

The mCBM collaboration conducted beamtime campaigns in 2024 and 2025, collecting a total of six datasets with various beam and energy combinations. This contribution will present the status of applying the validated analysis technique to experimental data from the Ni+Ni collisions at 1.93A GeV. A first look at the Λ signal will be provided, and the preliminary performance of the reconstruction algorithm on real data will be discussed in comparison to the simulation.

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