HK 15: Heavy-Ion Collisions and QCD Phases II

Time: Tuesday 16:15–18:45 Location: PHIL C 601

HK 15.1 Tue 16:15 PHIL C 601

Flow phenomena at high nuclear densities with HADES — •Behruz Kardan for the HADES-Collaboration — Goethe-Universität, Frankfurt am Main

Heavy-ion collisions in the few-GeV energy range create strongly interacting matter at extreme baryon densities, comparable to those in neutron star mergers. Precise measurements of the dense-matter *Equation-of-State* in this regime are therefore essential for the understanding of neutron stars.

We present new results from HADES (*High-Acceptance Dielectron Spectrometer*) located at the SIS18, GSI Darmstadt, the only current setup capable of measuring rare and penetrating probes at the high-μ_B frontier of the QCD phase diagram.

High-statistics measurements of collective flow for protons and light nuclei are reported in Au+Au and Ag+Ag collisions at $\sqrt{s_{\rm NN}}$ = 2.42 and 2.55 GeV, along with recent Au+Au data at $\sqrt{s_{\rm NN}}$ = 1.98, 2.07, 2.16, and 2.24 GeV, extending the excitation function to lower beam energies ($200-800$ AMeV).

Beyond directed and elliptic flow, flow coefficients v_n up to 6$^{\rm th}$ order are measured for the first time in this energy range, enabling a 3D characterization of angular particle emission in momentum space. Furthermore, the event-by-event flow fluctuations can be explored via correlations between the different flow coefficients, providing even stronger constraints on the *Equation-of-State*, and will also be presented.

This work was supported by the Helmholtz Forschungsakademie HFHF and GSI F&E.

HK 15.2 Tue 16:30 PHIL C 601

Low-mass, low-momentum virtual photon measurement with HADES — •Iuliana-Carina Udrea for the HADES-Collaboration — TU Darmstadt/GSI GmbH

Collisions of heavy nuclei at relativistic energies create a hot and dense medium, offering a unique environment to explore its microscopic properties using electromagnetic probes.

Dileptons are particularly advantageous for this purpose, as they do not interact strongly with the surrounding matter, allowing them to carry undisturbed information about the QCD matter produced during the reaction.

In particular, low-invariant-mass and low-momentum dileptons are highly sensitive to the transport properties of the system, providing a means to identify signatures of novel phases, such as precursor phenomena of color superconductivity, in dense QCD matter.

In this contribution, we outline the key steps towards investigating soft dileptons. For this purpose data from Ag+Ag collisions at 1.23A GeV with a nominal magnetic field strength are compared with a reduced magnetic field (5% of $B_{\rm max}$), the latter increasing the acceptance for low-momentum leptons. Additionally, we will present the new data collected in 2025 for Au+Au collisions at 0.8A GeV with a lower magnetic field strength, allowing us to study the low-mass and low-momentum dileptons in more detail.

This work is supported by: GSI F&E and HGS-HIRe.

HK 15.3 Tue 16:45 PHIL C 601

Characterising the hot and dense fireball with virtual photons at HADES — •Niklas Schild for the HADES-Collaboration — TU Darmstadt, Darmstadt, Germany

The High-Acceptance Di-Electron Spectrometer (HADES) at GSI, Darmstadt, investigates heavy-ion and elementary collisions at beam energies of a few GeV, providing valuable insights into QCD matter at high densities and moderate temperatures. One key aspect of HADES is the study of these collisions via rare electromagnetic probes, which offer unique access to the evolution of the system due to their penetrating nature.

In this contribution, we present recent measurements of dielectron production from Ag+Ag collisions at $\sqrt{s_{NN}}$ = 2.55 GeV and $\sqrt{s_{NN}}$ = 2.42 GeV. Expanding on previous results, we aim to study dielectron spectra in a multi-differential manner, considering observables such as invariant mass, centrality, rapidity, and transverse momentum. This not only provides detailed information about the properties of the hot and dense medium created in the collisions, but also allows for a more refined and differential comparison with theoretical models. This will be crucial for advancing our understanding of the thermal radiation emitted by the medium and, as such, can help to further constrain and improve existing descriptions.

This work has been supported by BMFTR and HGS-HIRe.

HK 15.4 Tue 17:00 PHIL C 601

Dielectron analysis in p+p collisions at 1.58 GeV beam energy with HADES — •Karina Scharmann for the HADES-Collaboration — Justus-Liebig-Universität Gießen

In this contribution we present preliminary results on the dielectron production in p+p interactions at 1.58 GeV beam energy measured with the **H**igh **A**cceptance **DiE**lectron **S**pectrometer (HADES). The HADES RICH detector has been upgraded with a new photon detection camera which strongly enhances the electron efficiency and conversion pair rejection. With this upgrade, a signal-to-background ratio above 1 is achieved over the entire dielectron spectrum. 0.5 billion collisions have been analyzed showing a contribution of π^0 and η Dalitz decays in a signal up to an invariant mass of 600 MeV/c^2. Furthermore, by analyzing elastic $p+p$ collisions, a normalization procedure for differential cross sections has been established. Additionally, collisions with the empty target (target mounting) provide a p+Mylar spectrum and allow the extraction of a p+n reference spectrum.

The p+p and p+n dielectron spectra can serve as a baseline for the understanding and interpretation of Ag+Ag collisions which have been measured in HADES at the same energy. A precise understanding of the dielectron production in elementary reactions is needed to disentangle the various contributions to the measured dielectron yield in Ag+Ag collisions.

HK 15.5 Tue 17:15 PHIL C 601

Dissecting the moat regime at low energies — •Shi Yin and Fabian Rennecke — Justus Liebig University Giessen, Heinrich-Buff-Ring 16 D-35392 Giessen

Dense QCD matter can feature a moat regime, where the static energy of mesons is minimal at nonzero momentum. Valuable insights into this regime can be gained using low-energy models. This, however, requires a careful assessment of model artifacts. We therefore study the effects of renormalization and in-medium modifications of quark-meson interaction on the moat regime. To capture the main effects, we use a two-flavor quark-meson model at finite temperature and baryon density in the random phase approximation. We put forward a convenient renormalization scheme to account for the nontrivial momentum dependence of meson self-energies and discuss the role of renormalization conditions for renormalization group consistent results on the moat regime. In addition, we demonstrate and that its extent in the phase diagram critically depends on the interaction of quarks and mesons.

HK 15.6 Tue 17:30 PHIL C 601

Hydrodynamic attractors in periodically driven weakly and strongly coupled systems — •Simon Schneider[1], Sören Schlichting[2], Aleksas Mazeliauskas[3], Louis Onwuka[4], Martin Vrdoljak[5], and Toshali Mitra[6] — [1]Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — [2]Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — [3]Institut für Theoretische Physik, Universät Heidelberg, D-69120 Heidelberg, Germany — [4]Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — [5]Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — [6]Institut für Theoretische Physik, Universät Heidelberg, D-69120 Heidelberg, Germany

We study equilibration and hydrodynamic response in systems undergoing periodic expansion and contraction in one spatial direction. We use strongly coupled holographic, weakly coupled kinetic and hydrodynamic frameworks to study the shear response to periodic drive for different amplitudes and frequencies. Unlike the monotic Bjorken expansion, the system does not approach equilibrium or even Navier-Stokes behavior. For small drive amplitudes and frequencies, the late time cyclic attractor is universal across systems and is described by MIS theory. For large drive amplitudes, the non-linear heating induces the drift in the system properties and the attractor behaviour.

HK 15.7 Tue 17:45 PHIL C 601

Numerical simulations of stochastic fluids via the Metropo-

lis algorithm — •Mattis Harhoff[1], Sören Schlichting[1], and Lorenz von Smekal[2,3] — [1]Fakultät für Physik, Universität Bielefeld, Universitätsstr. 25, Bielefeld, 33615, Germany — [2]Institut für Theoretische Physik, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392, Gießen, Germany — [3]Helmholtz Forschungsakademie Hessen für FAIR (HFHF), Campus Gießen, 35392, Gießen, Germany

Stochastic hydrodynamics provides a dynamical framework for the evolution of fluctuations in heavy-ion collisions, but poses significant challenges in numerical simulations. We present an algorithm for the simulation of non-relativistic stochastic hydrodynamics in two spatial dimensions in a box, both in the cases of compressible and incompressible fluids. We use the robust Metropolis algorithm, handling fluctuations and dissipation at once by systematically replacing dissipative terms in the hydrodynamic equations by random forces. The algorithm can easily be modified for numerical simulations of other hydrodynamic theories. We present test cases as well as numerical calculations of the renormalization of shear viscosity, and give an outlook to critical dynamics and relativistic theories.

HK 15.8 Tue 18:00 PHIL C 601

Event Generator Comparison for Centrality Studies in Heavy-Ion Collisions at FAIR Energies — •Beatriz Artur — IKF, Goethe-Universität Frankfurt

The initial geometry of a relativistic heavy-ion collision greatly influences important observables of the strongly interacting matter, such as collective flow or event-by-event fluctuations of conserved quantities. Experimentally, it cannot be measured directly, so other observables have to be used as a proxy. The multiplicity of produced charged particles at mid-rapidity or the energy deposition of the forward-going spectator particles can be used, for instance. In this work, we compare different event generators, such as PHQMD, DCM-QGSM-SMM and SMASH+afterburner for centrality studies. We look specifically into the fragment production in the forward direction, since all models employ different methods for cluster production. Implications on an optimized strategy for centrality determination and consequent definition of the reaction volume will be discussed.

HK 15.9 Tue 18:15 PHIL C 601

Monte-Carlo sampling of nucleon positions in the nuclear shell model for heavy-ion collisions — •Lisa Kröger[1], Oscar Garcia-Montero[2], and Sören Schlichting[1] — [1]Bielefeld University — [2]University of Santiago de Compostela

Recently, it has been shown that investigating the structure of atomic nuclei is essential for correct description of fluctuations imprinted into the initial stage of a heavy-ion collision event. In fact, the examination of the N-body density distributions has shown to be crucial for better understanding deeply inelastic scattering (DIS) and nucleus-nucleus collisions [1]. Motivated by the recent interest to represent quantitatively the structure properties of the incoming nuclei, we present a new sampling algorithm which takes on account quantum correlations of the nuclear many-body wave function. Using the nuclear shell model (NSM) as a proof of concept model, a Markov Chain Monte Carlo method algorithm was implemented in order to generate nucleon positions, according to the full N-nucleon probability distribution. We benchmark it by comparing our numerical results to the analytic one- and two-body densities. By using this algorithm, quantum correlations in the nucleus are then imprinted into the positions. Additionally, the usage of the NSM permits the extension of this algorithm to large systems, such as Au and Pb, which are still prohibitively expensive for full *ab-initio* computations. We explore the impact of these new sources of fluctuation on the creation of long-range correlations by exploring initial state observables sensitive to the N-body densities, such as the initial eccentricities, extracted from the novel McDIPPER model [2].

HK 15.10 Tue 18:30 PHIL C 601

Dependence of resonance parameters on the pion momentum spectra — •Tim Weinreich — Physikalisches Institut, Universität Heidelberg

Ultrarelativistic heavy-ion collisions, which are studied at the Large Hadron Collider and Relativistic Heavy Ion Collider, are believed to create a deconfined state of matter called the Quark-Gluon-Plasma. It has been demonstrated that this state can be adequately described by relativistic viscous hydrodynamics. However, some of the measured observables or features observed in experimental data remain to be fully understood.

For instance, the pion spectrum at low transverse momentum indicates a discrepancy between experimental data and hydrodynamic models. One potential explanation for this phenomenon is the insufficient treatment of resonances that contribute to the total particle spectra. In fact, heavy-ion collision models typically neglect or omit uncertainties in all resonance parameters, e.g., resonance masses, decay widths, and branching ratios.

This talk presents a systematic study investigating the dependence of resonance parameter uncertainties on the pion production. This study is conducted using the FastReso [1] framework to calculate the irreducible spectral components for resonance decays.

This work is funded via the DFG ISOQUANT Collaborative Research Center (SFB 1225).

[1] Mazeliauskas, A. *et al.* Eur. Phys. J. C 79, 284 (2019)