HK 3: Heavy-Ion Collisions and QCD Phases II

Time: Monday 14:00–15:30 Location: HK-H2

Group Report HK 3.1 Mon 14:00 HK-H2

Kinetics of the chiral phase transition in a quark-meson σ model — •Hendrik van Hees, Carsten Greiner, and Alex Meistrenko — Institut für Theoretische Physik, Goethe-Universität Frankfurt, Max-von-Laue-Str. 1, D-60438 Frankfurt am Main

A challenging goal in relativistic heavy-ion physics is the investigation of the phase diagram of strongly interacting matter and the determination of its phase structure, governed by the approximate chiral symmetry of the light-quark sector of QCD. In this study [1] we investigate a linear quark-meson σ model in and out of equilibrium employing Schwinger-Keldysh real-time techniques to derive a set of coupled Boltzmann-Uehling-Uhlenbeck (BUU) equations for the σ-mean field (the order parameter of the phase transition) and the quark- and meson phase-space distribution function from a Φ-derivable approximation. We numerically solve the equations to evaluate the grand-canonical baryon-number fluctuations for an expanding fireball. The evolution results in a temporary buildup of higher-order fluctuations of the net-baryon number like the curtosis at low momenta when the system is evolving close to the critical point or the first-order phase-transition line due to slowly evolving σ-mean field. This is partially counterballanced by the further dissipative evolution due to collisions of the quarks, mesons, and the mean field, leading to a considerable weakening of the final fluctuations, depending on the expansion rate of the fireball.

[1] Annals of Physics **431**, 168555 (2021)

HK 3.2 Mon 14:30 HK-H2

Non-hydrodynamic modes from linear response in effective kinetic theory — •Stephan Ochsenfeld, Xiaojian Du, and Sören Schlichting — Bielefeld University, Bielefeld, Germany

Viscous hydrodynamics serves as a successful mesoscopic description of the quark-gluon plasma (QGP) produced in relativistic heavy-ion collisions (HICs). In order to investigate, how such an effective description emerge from the underlying microscopic dynamics we calculate the linear response of energy and flow perturbations in the sound and shear channels from a first-principle calculation in kinetic theory. By using multiple collision integrals we investigate the similarities and differences of the excitations in different microscopic theories and compare them to first and second order hydrodynamics. Surprisingly, we find that even for large gradients the Greens functions in QCD Kinetic theory are well described by one hydrodynamic and one non-hydrodynamic mode. We extract the dispersion relations of hydrodynamic and non-hyrodynamic modes and speculate how these results can be used to improve hydrodynamic descriptions of hot QCD matter.

HK 3.3 Mon 14:45 HK-H2

J/Ψ formation within microscopic Langevin simulations — •Naomi Oei, Nadja Krenz, Juan Torres-Rincon, Hendrik van Hees, and Carsten Greiner — Institute for Theoretical Physics, Frankfurt am Main, Germany

We present a microscopic model to describe dissociation and recombination processes of charmonia in the quark-gluon plasma. For this we simulate the time evolution of a system with several charm-anticharm-quark pairs, in which the heavy quarks are able to interact over a Coulomb like potential. The motion of the heavy quarks and the interaction with the medium are based on a Fokker-Planck equation, which can be realized with Langevin simulations. In this approach we use a momentum-dependent drag force and include random momentum kicks due to collisions with the medium particles. Therefore, through interactions of the heavy quarks with the medium, recombination and dissociation processes are possible. We describe the evolution of the medium as a boost-invariant transversally expanding fireball. We demonstrate that the system reaches the expected thermal distribution in the equilibrium limit and bound-state properties were tested in box simulations. The initial momentum distribution of the pairs is generated using the PYTHIA event-generator and results of the model are studied at RHIC and at LHC energy. We analyze results for different numbers of charm-anticharm-pairs for two initial conditions: The charm- and anticharm-quarks are either placed randomly inside the system or are initially created as a bound state. We show first results of the elliptic flow of charm-quarks and of bound states.

HK 3.4 Mon 15:00 HK-H2

Dynamical broadening of vector-meson spectral functions — •Renan Hirayama[1,2], Jan Staudenmaier[2], and Hannah Elfner[1,2] — [1]Helmholtz Forschungsakademie Hessen für FAIR (HFHF), GSI Helmholtzzentrum für Schwerionenforschung, Frankfurt am Main, Germany — [2]Frankfurt Institute for Advanced Studies (FIAS), Frankfurt am Main, Germany

We reconstruct effective spectral functions of the ρ-meson in different scenarios via lifetime analysis using the hadronic transport SMASH. The theoretical interest in the behavior of in-medium spectral functions lies in the expected restoration of chiral symmetry at high energy densities, which may be accessed experimentally by studying dilepton mass spectra in heavy-ion collisions. Within SMASH, a direct assessment of particle lifetimes and the mass distributions is possible. Our reconstruction of the spectral function consists in using the total width – considering both decays and collisions – as input for a Breit-Wigner ansatz. The broadening of the spectral function in a thermal system is shown to be consistent with model calculations, and the dependence of total width on local hadron density is provided. This broadening develops dynamically, since SMASH relies only on vacuum properties of resonances as an input. On the other hand, we present the effective ρ-meson spectral function for the dynamical evolution of heavy-ion collisions, finding a clear correlation of broadening to system size. The results shown in this work are of interest to distinguish dynamical broadening from additional genuine medium-modified spectral functions.

HK 3.5 Mon 15:15 HK-H2

Diffusion coefficients for hot hadron gases in the quark flavor representation — •Jakob Lohr, Jan Fotakis, and Carsten Greiner — University of Frankfurt

Heavy ion collisions play a big role in exploring the properties of hot and dense nuclear matter. In these the baryon number B, the electric charge Q, and the strangeness S of the produced matter are conserved. Their transport could especially be relevant in the description of the evolution of highly compressed baryonic matter, where strong gradients in baryon number are expected.

In general, the diffusion currents generated by gradients in the charge densities are coupled to each other, the coupling of which is characterized by the so-called diffusion coefficient matrix. In most works concerning diffusion coefficients or conductivites, the constituents of matter are usually characterized through the above mentioned conserved charges (BQS). However, in the case of strongly-interacting matter the particles can as well be characterized by their quark content and the corresponding conserved quark flavors.

In this talk, we will give a systematic discussion of the diffusion coefficient matrix of various hadronic systems in the so-called quark flavor representation using linear response theory in relativistic kinetic theory.