# HK 44: Heavy Ion Collisions and QCD Phases 5

Time: Wednesday 14:30–16:30 Location: T/HS1

**Group Report** HK 44.1 Wed 14:30 T/HS1

**Dynamical Locking of the Chiral and the Deconfinement Phase Transition in QCD at Finite Chemical Potentials** — •Paul Springer[1], Jens Braun[2], Marc Leonhardt[2], and Stefan Rechenberger[2] — [1]Physik Department, Technische Universität München, 85747 Garching — [2]Institut für Kernphysik, Theoriezentrum, Technische Universität Darmstadt, 64289 Darmstadt

Studies of the QCD phase diagram at finite temperature and quark chemical potential are currently one of the most discussed topics in theoretical physics and are of great importance to better our understanding of heavy-ion collision experiments. However, the relation of confining and chiral dynamics is not yet completely understood. At vanishing chemical potential, results from lattice QCD indicate that the chiral and the deconfinement phase transition lie close to each other. In this talk, we analyze the fixed-point structure of four-fermion interactions in two-flavor QCD and show that there indeed appears to be a mechanism which dynamically locks the chiral phase transition to the deconfinement phase transition, both at vanishing and at finite quark chemical potential. As a direct consequence, this observation suggests that the chiral phase transition and the deconfinement phase transition temperatures lie close to each other.

This work is supported in part by BMBF

HK 44.2 Wed 15:00 T/HS1

**The Chiral Phase Transition in the Presence of Vector Mesons from the Functional Renormalization Group Approach.** — •Jürgen Eser, Mara Grahl, and Dirk Rischke — Institut für Theoretische Physik, Goethe-Universität, Max-von-Laue-Str. 1, 60438 Frankfurt am Main

The characteristics of the transition in quantum chromodynamics (QCD) from familiar hadronic matter to the quark-gluon plasma (QGP) are subject to an ongoing debate. This transition is associated with the spontaneous restoration of chiral symmetry. Experimental setups such as CBM at GSI aim to produce the QGP state via heavy-ion collisions. Here, dropping in-medium masses of (axial-)vector mesons are promising candidates for indicating the restoration of chiral symmetry. Furthermore, (axial-)vector mesons play an important role in QCD phenomenology due to vector meson dominance. It is therefore crucial to include those degrees of freedom in a theoretical analysis. Nonperturbative methods, such as the functional renormalization group (FRG), provide new insights into the QCD transition as they do not rely on weak couplings and avoid essential drawbacks of the lattice approach.

We shed light on the two-flavor chiral phase transition in the presence of (axial-)vector mesons by applying the FRG formalism to an effective model for QCD. The order of the phase transition within this extended linear sigma model is determined. Moreover, we investigate the mass degeneracy of chiral partners occuring at the phase boundary.

HK 44.3 Wed 15:15 T/HS1

**Inhomogene chiral gebrochene Phasen in ladungsneutraler stark-wechselwirkender Materie** — •Daniel Nowakowski, Michael Buballa und Jochen Wambach — Institut für Kernphysik, Technische Universität Darmstadt

Im Rahmen eines Zwei-Flavor-Nambu–Jona-Lasinio Modells untersuchen wir das Phasendiagramm stark-wechselwirkender Materie. Kürzlich wurde für ein solches Modell für den Fall entarteter Quark-Flavors gezeigt, dass neben den bekannten homogenen Phasen auch inhomogene Phasen auftreten können, in denen der chirale Ordnungsparameter räumlich variiert. In diesem Vortrag diskutieren wir den Einfluss einer zusätzlichen Isospin-Asymmetrie zwischen den Quarks und die Auswirkungen der Forderung nach elektrischer Ladungsneutralität auf die inhomogenen chiral gebrochenen Phasen. Dabei konzentrieren wir uns zunächst auf eindimensionale räumliche Modulationen des Ordnungsparameters und finden für realistische Parameter, dass inhomogene Phasen auch in elektrisch neutraler Materie auftreten. Beschränkt man die Modulation der beiden Quark-Flavors auf eine gemeinsame Periode, dann sind diese inhomogenen chiral gebrochenen Phasen weniger favorisiert. Lässt man jedoch unterschiedliche Perioden zu, so finden wir, dass die inhomogenen Phasen gegenüber dem zusätzlichen Paarungsstress stabilisiert werden können. Als Anwendung präsentieren wir die Masse-Radius Beziehung eines Quark-Sterns.

HK 44.4 Wed 15:30 T/HS1

**The QCD phase diagram from imaginary chemical potential** — •Christopher Pinke and Owe Philipsen — Institut für Theoretische Physik, Goethe Universität Frankfurt am Main

The phase diagram of QCD is subject to ongoing investigations. First principle calculations are possible by means of Lattice QCD (LQCD) simulations. At non-zero values of the chemical potential, these are hampered by the sign-problem, which renders the currently available simulation algorithms ill-defined.

An up-to-now unresolved issue is the nature of the chiral transition in the limit of two massless flavours of quarks. This transition is either first or second order. It is important to clarify this issue in order to constrain the physical phase diagram of QCD, in particular regarding the possible existence of a critical end point in QCD at non-zero chemical potential.

At purely imaginary values of the chemical potential, QCD has very interesting symmetries. More specifically, the Roberge-Weiss or extended center symmetry limits the physically relevant region to be within specific values. In addition, the Roberge-Weiss transition, happening at these specific values, then allows for constraints on the physical phase diagram.

We explore this region by means of two flavour LQCD simulations and present results regarding the two flavour chiral limit.

Supported by the Hessian LOEWE initiative through the Helmholtz International Center for FAIR (HIC for FAIR).

HK 44.5 Wed 15:45 T/HS1

**Studying properties of the QCD phase diagram with Dyson-Schwinger equations** — Christian S. Fischer, Gernot Eichmann, Christian H. Lang, and •Christian A. Welzbacher — Institut für Theoretische Physik, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany

The Dyson-Schwinger equations (DSEs) as one kind of functional methods provides us with a toolbox to investigate the structure of the QCD phase diagram. By solving the carefully truncated coupled set of equations, the quark and gluon propagators at finite temperature and light-quark chemical potential are obtained. Those quantities give insights about the chiral and deconfinement phase transitions and have interesting analytic properties. We present results for $N_f$=2+1 flavors and discuss the location of a potential critical endpoint as well as the possible influence of baryonic degrees of freedom on its position.

HK 44.6 Wed 16:00 T/HS1

**Thermalization of hadrons through Hagedorn states** — •Maxim Beitel, Kai Gallmeister, and Carsten Greiner — Institut für Theoretische Physik Johann Wolfgang Goethe-Universität Max-von-Laue-Str. 1 60438 Frankfurt am Main, Germany

One of the most intriguing questions in high energy collisions is how hadrons produced in a non-equilibrium system achieve thermal equilibrations on such short time scales. To simulate the dynamic multiplicity evolution of hadron multiplicities we use the hadronic transport model "UrQMD" as microscopic model for high-energetic heavy ion collisions. Currently the equilibration times in this model are too long because detailed balance is not realized for all collisions which may occur. In our approach to get rid of this drawback we deploy Hagedorn-States proposed by the "Statistical Bootstrap Model". Creation of these states in binary collisions and their decay into two particles only will lower the thermalization times in UrQMD. Supported by HGS-HIRe.

HK 44.7 Wed 16:15 T/HS1

**Lattice QCD based equation of state at finite baryon density** — •Pasi Huovinen[1,2], Peter Petreczky[3], and Christian Schmidt[4] — [1]Institut für Theoretische Physik, Goethe-Universität, Frankfurt am Main, Germany — [2]Frankfurt Institute for Advanced Studies, Frankfurt am Main, Germany — [3]Brookhaven National Laboratory, USA — [4]Fakultät für Physik, Universität Bielefeld, Bielefeld, Germany

The effects of non-zero baryon density are expected to become important in hydrodynamic modeling of heavy-ion collisions below the highest energy at RHIC. Recent calculations in effective models and in QCD using Dyson Schwinger equation suggest that the transition

in QCD remains a crossover up to baryon chemical potentials of about 800MeV. If so, the equation of state relevant for hydrodynamic models can be calculated on the lattice using Taylor expansion. However, except for the coefficients of the lowest order, there are large cutoff effects in present lattice calculations for non-zero chemical potentials.

To extend our previous parametrization of the equation of state to finite baryon density, we employ the continuum extrapolated lattice QCD data on Taylor expansion coefficients in order two, and complement them with coefficients in order four and six evaluated using p4 action. To avoid large cutoff efects these coefficients are smoothly matched to those of hadron resonance gas at low temperature. We also show how the hydrodynamical evolution is affected by this equation of state in the energy range relevant for SPS and the RHIC energy scan.

This work is funded by BMBF under contract no. 06FY9092.