The role of fluctuations in the phase diagram of two color QCD*

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The investigation of the phase diagram of Quantum Chromodynamics (QCD) at finite temperature and density is an area of very active experimental and theoretical research [1] due to the existence of a variety of symmetry broken phases, the transitions between them and the presence of strong interactions. A straightforward application of lattice methods is inhibited by the property that for nonzero chemical potential the path integral measure of the QCD Lagrangian is complexAn instructive way to approach the full problem and to shed light on particular aspects is the investigation of deformations of QCD [2]. Generally, this can be achieved by changing e.g. mass parameters, symmetries or the field content. In this work, we will choose the latter two possibilities and study a theory similar to real QCD, however with two colors, $N_c = 2$, and two quark flavors $N_f = 2$. An appealing feature within this two-color two-flavor version of QCD is that, apart from the chirally broken mesonic phase of quark-antiquark pairs, it allows for the formation and (Bose-Einstein-) condensation of colorless diquarks, i.e. a bosonic baryon state. This results in a rich phase diagram with two dynamically competing order parameters.

In this work we employ a functional renormalization group (FRG) approach to an effective quark-meson-diquark model to study the phase diagram of two-color QCD. The FRG method is a suitable tool for the systematic study of (strongly) interacting field theories allowing for the formulation and computation of non-perturbative approximation schemes.The present work systematically extends the truncation scheme in Ref. [3] by taking into account the scale dependence of the wave function renormalizations as well as the renormalization of the Yukawa coupling between the quarks and the order parameter fields. Additional quantitative effects can be accessed systematically by extensions of the truncation scheme within the FRG. Here, we can monitor the quantitative corrections that are induced by the additional scale dependent quantities, namely the wave function renormalizations as well as the Yukawa interaction and study their impact on the phase diagram. Due to an alternative expansion scheme for the effective potential we gain direct access to the phenomenon of precondensation, a regime in the phase diagram where order occurs at intermediate scales but no order is found when all fluctuations are integrated out. In this way, we establish a refined picture of the FRG phase diagram for QC_2D, which is shown in Fig.1.

* Work supported by Helmholtz Alliance HA216/EMMI and by ERC-AdG-290623.

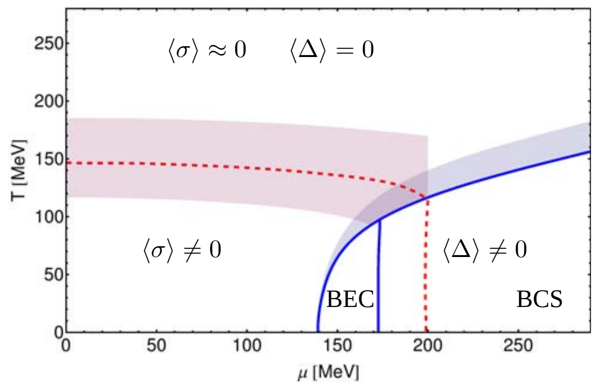

Figure 1: The phase daigram of QC_2D. μ is the baryon chemical potential in this plot.

The condensates are determined by the minimum of an order parameter potential, which is truncated to a one dimensional Taylor expansion up to six-point interaction terms. In addition, we have added a linear term in the chiral condensate σ, which causes chiral symmetry always to be broken, this is rooted in the fact that quarks have a small but finite current mass. At small temperatures and chemical potentials chiral symmetry is broken and quarks have a constituent mass of about 300 MeV. With increasing temperature the system undergoes a smooth crossover where chiral symmetry is nearly restored. The line and the shaded area in the left part of the figure mark the crossover and its width. At higher μ the system undergoes a second order phase transition at the onset of the diquark condensate Δ. At first the system is in BEC like state while at the limit of high chemical potentials the system spproaches a BCS like state. The line where the quark mass drops below the chemical potential indicates the region of the BEC-BSC crossover. The shaded area in the right part indicates the precondensation phase.

For the future this result is to be compared to lattice simulations, in order to evaluate our methods and truncation schemes.

References

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