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Exploring Hot Quark Matter in Strong Magnetic Fields

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Considering LQCD results for the quark condensates we determine the thermomagnetic dependence of NJL model coupling and then study the thermodynamical properties of hot magnetized quark matter.

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1. Introduction

Both high energy collision experiments and astrophysical objects, like compact stars, indicate presence of strong magnetic fields in hadronic matter under extreme conditions of temperature and density. This has motivated many studies of nuclear and quark matter in presence of magnetic fields with a variety of effective models.

Recent lattice QCD (LQCD) results [1] for the chiral condensates under strong magnetic fields have provided a sound basis for constraining effective models and their parametrizations. In this work we employ the magnetic field independent regularization scheme (MFIR) [2–5].

2. Building a Thermomagnetic Coupling

We want to construct a coupling $G(eB,T)$ [6] so that the NJL model gives the same results for the quark condensates as LQCD simulations at vanishing baryon densities. For selected values of the magnetic field strength and temperatures around the chiral transition, we fit the NJL coupling to the corresponding LQCD result. Once we have the values of $G(eB,T)$ we perform a second fit with an ansatz of the form

$$G_{\mathrm{NJL}}(eB,T) = \alpha \left[1 - \frac{1}{1+\exp\left[\beta(\tau - T)\right]}\right] + \gamma\,, \tag{1}$$

where the parameters $\alpha(eB)$, $\tau(eB)$, $\gamma(eB)$ and $\beta(eB)$ depend solely on the magnetic field strength and are listed in Table 1.

Table 1. Parameters for the running coupling constant according to the ansatz given by Eq.(1) at selected values of eB.

eB (GeV^2)	α (GeV^{-2})	τ (MeV)	γ (GeV^{-2})	β (MeV^{-1})
0.0	0.900	168.0	3.731	0.400
0.2	1.225	167.9	3.262	0.341
0.4	1.769	169.2	2.294	0.230
0.6	0.741	155.6	2.864	0.144
0.8	1.289	157.8	1.804	0.115

3. Numerical Results

We now compare the properties of magnetized quark matter obtained from the NJL model with both G and $G(eB,T)$. For the values of the magnetic field strength given in Table 1, we solve the NJL gap equation for temperatures up to about 300 MeV. The effective mass is then used in the computation of other thermodynamic quantities. In Fig. 1 we show the condensates average and the pseudo critical temperature calculated using G (left panels) and $G(eB,T)$ (right panels).

The difference is substantial in both cases. The entropy density and the sound velocity are displayed in Fig. 2 for fixed coupling (left) and running coupling (right).

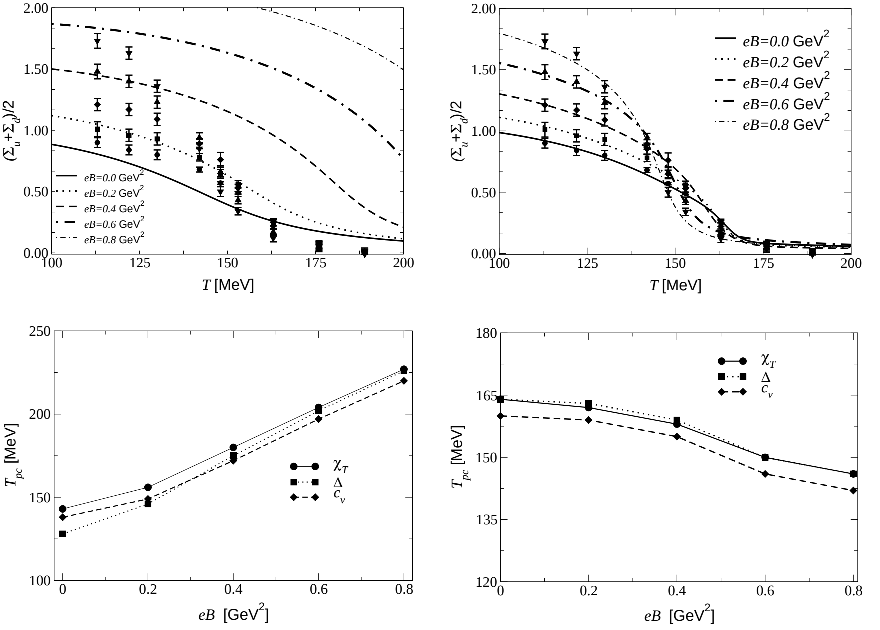

Fig. 1. Chiral condensates (top) and pseudo critical temperature (bottom) for fixed coupling G (left) and running coupling $G(eB, T)$ (right).

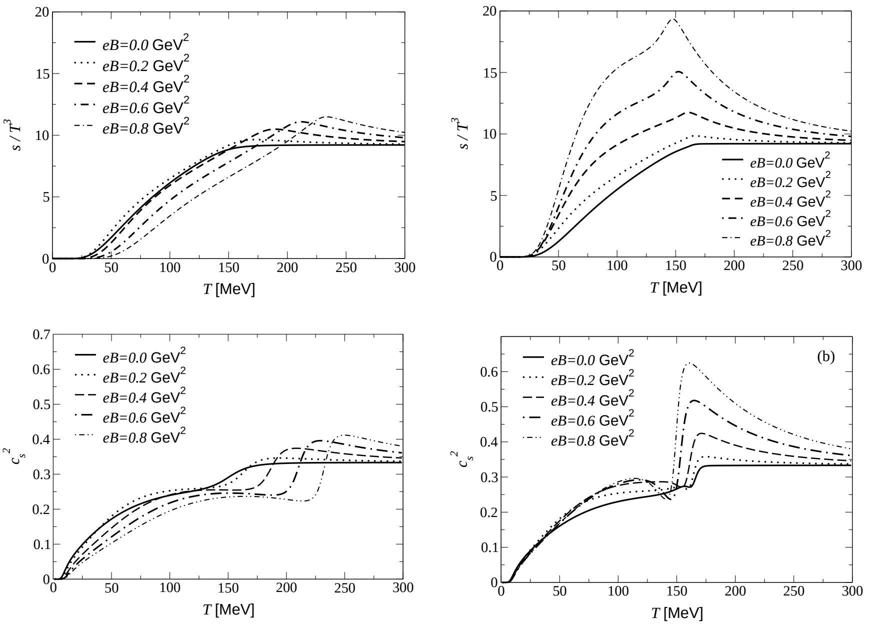

Fig. 2. Entropy density (top) and sound velocity (bottom) for fixed coupling G (left) and running coupling $G(eB, T)$ (right).

In this case we observe a major difference in the phase transition region which is a consequence of a sharper transition provided by the running coupling $G(eB, T)$.

4. Final Remarks

We have built a thermomagnetic coupling for the NJL model by constraining the chiral condensates to LQCD results. We have then analyzed how the thermodynamical properties of quark matter are affected by such a running coupling. For more details, please see Farias et al. [7].

Acknowledgments

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