Dilepton production from magnetized quark matter

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Study of deconfined state of strongly interacting quarks and gluons in local thermal equilibrium, commonly known as the quark-gluon plasma (QGP), is one of the major objective of heavy ion collision (HIC) experiments RHIC and LHC. This hot and dense matter is created in the HIC is very short lived (∼few fm/c) and cannot be observed directly. So to investigate microscopic as well as bulk properties of QGP,one has to rely on indirect probes and observables [1]. One such primary theoretical tool is the study of the in medium electromagnetic spectral function using the vector-vector current correlator which, in turn, is connected to the dilepton production rate (DPR) from the hot and dense medium. Moreover, recent studies [2] suggest that, in a non-central or asymmetric HIC experiment, very strong magnetic fields of the order $\sim 10^{18}$ Gauss or larger might have been generated. Thus, the modifications of the DPR in the presence of a uniform background magnetic field has gained a lot of research interest.

It is well-known that, the imaginary part of the electromagnetic vector current correlator containing the thermo-magnetically modified quark propagators is the most important component in the calculation of DPR which determines the thresholds as well as the intensity of emission of dileptons. Now, as the system cools down owing to the chiral symmetry restoration of the quark mass acquires large values (∼ of few hundred MeV) due to the build up of the quark condensate. Simultaneously the colour deconfined matter converts to hadronic matter through a crossover or phase transition at smaller values of temperature. The theoretical analysis of these phenomena using first principle calculations is severely hindered due to the non-perturbative nature of QCD at low energies. As an alternative, one can use the effective theories which possess some of the essential features of QCD and is mathematically tractable.

In this work, we have attempted to calculate the DPR from hot and dense quark matter in the presence of an arbitrary external magnetic field considering the finite values of the AMM of the quarks. We have used the 3-flavor PNJL model with a gauge invariant regularization scheme namely the Pauli-Villiars scheme. We have applied the real time formalism of finite temperature field theory and the Schwinger proper time formalism to evaluate the electromagnetic spectral function of the vector current correlator (which is proportional to the DPR) at finite temperature (T), chemical potential (μ), external magnetic field (B) and AMM (κ) of the quarks where the constituent quark mass $M = M(T, \mu, B, \kappa)$ will go as an input. We the compare the whole study with 2-flavor PNJL model to observe the effects of strangeness. Formalism, analytic structure and other details about model parameters can be found in [3].

In Fig. 1 we have shown the temperature dependence of the constituent quark masses. The constituent mass of low lying quarks (up and down) starts from a high value at low T, remains almost constant in the smaller values of T, falls off sharply in a small range of tem-

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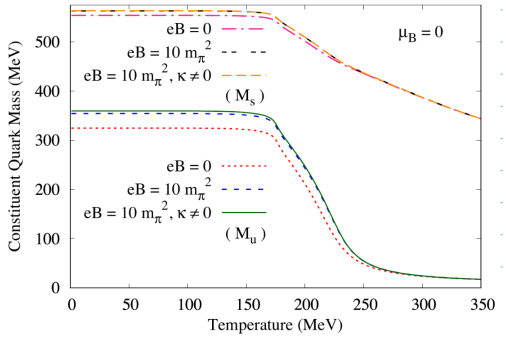

FIG. 1: Constituent quark mass in PNJL model.

perature and finally become nearly equal to the bare masses of the quarks at high T values representing the restoration of the chiral symmetry. However, for the strange quark even at $T = 350$ MeV, the s quark mass is still higher than its current mass. The constituent quark mass increases at $T \to 0$ limit and the transitions to the symmetry restored phase take place at the larger values of temperature. This phenomenon is known as magnetic catalysis. The inclusion of finite values of the AMM of the quarks do not lead to significant change in values of the constituent mass of quarks.

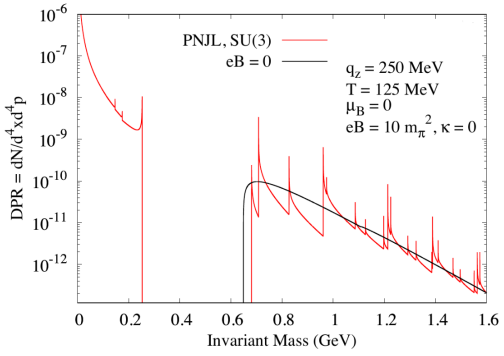

FIG. 2: Dilepton production rate using 3-flavour PNJL model. The DPR at $eB = 0$ is also shown for comparison.

Next, in Fig. 2, we present the numerical results for DPR from a hot and dense magnetized medium. At $eB = 0$, one can observe that, the threshold for dilepton production

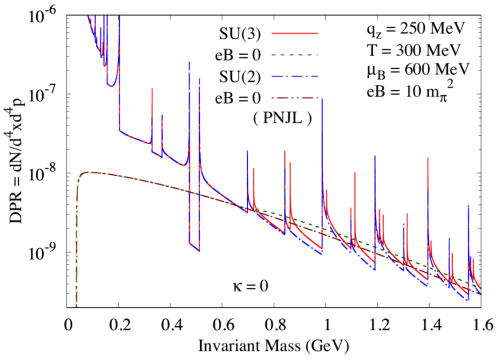

FIG. 3: Comparison of Dilepton production rate from 2 and 3-flavor PNJL models.

starts below 0.7 GeV which can be understood from Fig. 1 as at $T = 125$ MeV, where the constituent quark mass is around ≈ 0.32 GeV. However, when the magnetic field is turned on, DPR receives contributions from both Landau cut as well as unitary-I, a purely magnetic field dependent effect. For finite background field, the spike-like structures can be observed over whole range of allowed invariant mass for dilepton production. This can be explained in terms of 'threshold singularities' which occurs at each Landau level. A more detailed discussion on this can be found in [3].

As the temperature of quark matter produced in HIC is expected to be of the order of $\sim 300 - 400$ MeV, we have evaluated DPR for both 2 and 3-flavour system at high values of T and μ_B. It can be seen that, DPR from 3-flavour model is slightly enhanced due to contributions from strange quarks for both eB zero and nonzero case at higher values of invariant mass.

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