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Heavy quark potential at finite magnetic field

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Introduction

QGP at sufficiently high temperature behaves like a weakly interacting gas of quarks and gluons, which can also be studied perturbatively by using hard thermal loop (HTL) resummation [1, 2] techniques, apart from the first principle lattice QCD estimations. According to recent lattice quantum chromodynamic (LQCD) calculation [3, 4], non-zero QCD vaccum at finite temperature and magnetic field can face both magnetic catalysis (MC) and inverse magnetic catalysis (IMC).

The main goal of the present work though is to incorporate the IMC effect in the heavy quark potential through the effective quark masses. These two components are mainly introduced within the standard formalism of heavy quark potential [5, 6], which is the sum of both Coulomb and string terms [7].

Debye mass in presence of magnetic field

Debye screening mass can be directly evaluated from the temporal component of the gluon self energy tensor ($\Pi_{00}(\omega, \mathbf{k})$) by employing the static limit ($k = 0, \omega \to 0$) through a perturbative order by order evaluation. On the other hand one can also determine the Debye screening mass through the semi-classical transport theory [6, 8, 9]. Now the Debye screening mass m_D for a magnetized QGP medium becomes,

$$m_D^2 = g_s^2 T^2 \frac{N_c}{3} + \frac{g_s^2 |q_f eB|}{\pi^2 T} \times \int_0^\infty dk_z \sum_{l=0}^{\infty} (2 - \delta_{l0}) f_q^l (1 - f_q^l). \quad (1)$$

where $g_s^2 \equiv 4\pi\alpha_s$ is the strong coupling constant, $C_{q/g}$ are the Casimir constants for quarks and gluons. The quark distribution function gets modified in presence of external anisotropic magnetic field to:

$$f_q^l = \frac{1}{\exp(\beta E_f^l) + 1}, \quad (2)$$

where the Landau quantized dispersion relation reads as $E_f^l = \sqrt{k_z^2 + m_f^2 + 2l|q_f eB|}$, with $l = 0, 1, 2, ..$ being the number of Landau levels and $q_f = +\frac{2}{3}, -\frac{1}{3}$ being the fractional charge of the u and d quarks respectively. To consider the effect of IMC near transition temperature at finite eB we can also build a connection between the medium dependent quark

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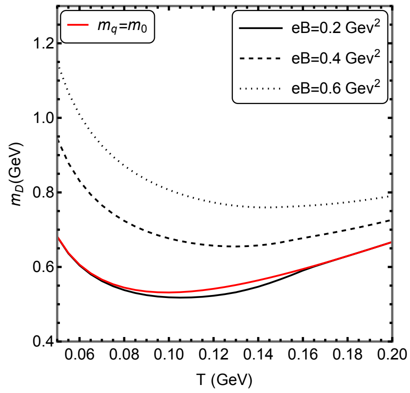

FIG. 1: Variation of the Debye mass (m_D) with temperature for different values of magnetic fields $eB = 0.2$ (black solid line), 0.4 (dash line), 0.6 (dotted line) GeV^2

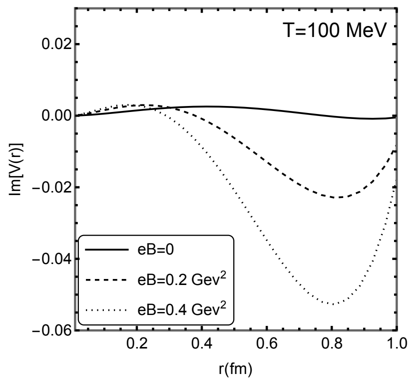

FIG. 2: Variation of the imaginary part of potential with separation distance r between $Q\bar{Q}$ for various values of magnetic field $T = 100$ MeV.

mass $M_f(T, eB)$ and LQCD predicted condensates $\langle q\bar{q}\rangle_f(T, eB)$ as $M_f(T, eB) = M_f(T = 0, eB = 0) \times \langle q\bar{q}\rangle_f(T, eB) + m_f$ $\approx M_f(T = 0, eB = 0) \times \langle q\bar{q}\rangle_f(T, eB)$. In the calculation effective masses of quarks are considered.

Results

In the result section we will start with the Debye mass which carries the MC and IMC profiles through the medium dependent constituent quark mass. In the Fig. 1, we have plotted the variation of the Debye mass with T for different values of magnetic fields, i.e. $eB = 0.2$ (black solid line), 0.4 (dashed line), 0.6 (dotted line) GeV^2. Whereas, the Fig. 2 shows the variation of the imaginary part of the potential with the separation distance (r) for different values of magnetic field ($eB = 0, 0.2$ GeV^2 and 0.4 GeV^2) at $T = 100$ MeV. As we can see from the figure that magnitude of the imaginary part of the potential increases with the increase in magnetic field and hence it provides more contribution to the thermal width obtained from the imaginary part of the potential. This study incorporated two important ingredients: inverse magnetic catalysis information and all Landau level summations within the Debye mass.

Acknowledgments

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