Open charmed pseudoscalar mesons in magnetized nuclear matter

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Introduction

The impact of strong magnetic field (eB$\sim$ $2-15\ m^2{}_\pi$) on the medium attributes of D meson is a topic of great interest in heavy ion collision (HIC) physics [1]. In 1986, Matsui and Satz suggested that J/ψ suppression can be considered as a signature of quark gluon plasma [2]. In-medium variation of D meson is also related to above suppression as the main source of J/ψ in medium is higher charmonia and if the mass of D meson decreases by interaction of medium, the higher charm states will prefer to decay to D meson instead of decaying to ground state J/ψ [3]. In the present article, we have used a joint approach of QCD sum rules and chiral SU(3) model to calculate the magnetic effect on effective masses of pseudoscalar $D(D^+, D^0)$ meson [1, 3]. The result of this work may be helpful to understand the QCD phase diagram in high density and moderate temperature region in the outcomes of experimental facilities like Compressed Baryonic Matter (CBM) and PANDA at FAIR.

Formalism

The in-medium scattering length of pseudoscalar D (D^+, D^0) meson, using QCD sum rules can be written as [4]

$$a_D = \frac{a m_c^2}{f_D^2 m_D^4(-8\pi(m_N + m_D))}, \quad (1)$$

where, a is a medium dependent unknown parameter and f_D is a decay constant of D meson. Also, m_c, m_N and m_D denotes the masses of charm quark, nucleon and D meson respectively.

The magnetic field induced mass-shift of D meson in the QCD sum rules is given as [1]

$$\Delta m_D^* = 2\pi \frac{m_N + m_D}{m_N m_D} \rho_N a_D \, . \quad (2)$$

In above, ρ_N denotes nucleon density.

The unknown parameter a is solved from the two coupled equations of pseudoscalar current [1, 4]. These mesonic current equations have dependency on nucleonic expectation of quark and gluon condensates and in present methodology these condensates are calculated from the scalar fields (σ, ζ, δ and χ) of chiral SU(3) model under the different conditions of nuclear matter [1].

Using Eq.(2), the effective mass of the uncharged D^0 meson will be

$$m_{D^0}^* = m_{D^0} + \Delta m_{D^0}^*, \quad (3)$$

where, m_D^0 is the vacuum mass of D^0 meson.

Moreover, due to charge particle interaction with magnetic field ,*i.e.*, Landau quantization, D^+ meson will have addition positive shift and is given as

$$m_{D^+}^{**} = \sqrt{{m_{D^+}^*}^2 + |eB|}, \quad (4)$$

where, $m_{D^+}^*$ is the effective mass analogous to Eq.(3).

Numerical Results and Discussions

In the present work, we have calculated the in-medium mass of pseudoscalar D meson under the effect of the magnetic field by considering the effect of medium's density, temperature and asymmetry. In these calculations, we have used the value of vacuum mass of D^+ and D^0 mesons as 1869 and 1864 MeV, respectively. Moreover, the vacuum value of decay constant is taken as 210 MeV. In table I, we listed the values of in-medium masses of D^+ and D^0 meson at finite magnetic field and also

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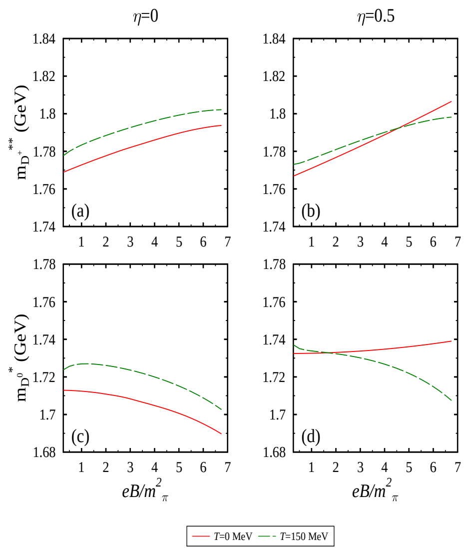

FIG. 1: (Color online) The magnetic field induced in-medium mass of pseudoscalar D^+ and D^0 meson plotted as a function of eB/m_π^2 in hot asymmetric nuclear matter at nucleonic density, ρ_N=4ρ_0.

compared it with the zero magnetic field case. In fig.(1), variation of in-medium mass versus magnetic field is shown at finite medium attributes. We can see from above two panels, the mass of charged D^+ meson increase with the increase in magnetic field (the mass shift is negative) in both symmetric and asymmetric nuclear matter. This is due to the generation of additional Landau levels (see Eq.(4)). The asymmetry effects here are compensated by the magnetic field interaction. On the other hand, the mass of uncharged D^0 meson decreases as a function of magnetic field in symmetric matter whereas for pure neutron matter it reduce for high temperature but increase for low temperature.

This is due to fact that the mass of D meson is calculated from QCD sum rules, in which the unknown parameter a has medium dependence through quark and gluon condensates. These condensates are calculated from the variation of scalar fields having dependencies on scalar density of nucleons and in the asymmetric matter, the scalar density of neutron and protons modifies differently [1]. We have compared our work with the zero magnetic field case [3] and found appreciable effects of magnetic field on the mass of pseudoscalar D meson.

	$Mass$(MeV)	T=0 MeV		T=150 MeV	
		η=0	η=0.5	η=0	η=0.5
D^+	m_D^{**}	1786	1789	1796	1790
	m_D	1759	1757	1774	1769
D^0	m_D^*	1696	1719	1734	1726
	m_D	1701	1723	1721	1742

TABLE I: In the above table, at $4\rho_0$ we tabulate the effect of magnetic field on the in-medium mass of D^+ and D^0 mesons. Here, $m_D^{**,*}$ represents mass of respective D meson at eB=6m_π^2 and m_D denotes the mass of respective D meson without magnetic effect [3].

Conclusion

The negative mass shift in mass of D^+ and D^0 is calculated in the presence of strong magnetic field. It is observed that due to Landau quantization the mass of charged and uncharged D meson varies differently with magnetic field. This medium dependent mass can be used to investigate the magnetic field induced decay width of higher charmonia in non-central asymmetric HICs.

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