Magnetic field induced decay constant of vector D^* meson in hot asymmetric nuclear matter

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Introduction

In-medium study of the open charm mesons plays a crucial role in an unambiguous understanding of the various signatures of production of the quark gluon plasma produced in heavy ion collision experiments [1]. In particular the in-medium modification of the vector D^* meson can have significant impact on the production of J/ψ state through the shift in the in-medium decay width of the higher charmonium states. In addition, the leptonic decay width of D^* meson will change through the shift in decay constant of the D^* meson. In our previous work we calculated the shift in the mass and decay constant of the vector D^* meson in the asymmetric nuclear medium at zero magnetic field [2]. However, in the present work we extended our work and calculate the shift in the value of the decay constant of D^* meson in the finite magnetic field of the medium. For this, we use the chiral SU(3) model to calculate the magnetic field induced quark and gluon condensates and use these as input in the QCD sum rule approach to calculate the magnetic field induced decay constant. The results of the present investigation may be useful to understand the possible outcomes of the future experiments CBM and PANDA under the FAIR facility.

Formalism

Using QCD sum rules, the in-medium mass shift of vector $D^*(D^{*+}, D^{*0})$ meson can be written as [2, 3]

$$\Delta m_{D^*} = 2\pi \frac{(m_N+m_{D^*})a\rho_N}{m_N m_{D^*} f_{D^*}^2 m_{D^*}^2 (-8\pi(m_N+m_{D^*}))} ,(1)$$

where, f_{D^*} is a decay constant of D^* meson. Also, m_N, ρ_N and m_{D^*} denote the mass of nucleon, nucleon density and mass of D^* meson, respectively. The magnetic field induced shift in decay constant of D^* meson in the QCD sum rules is given as [2]

$$\Delta f_{D^*} = \frac{1}{2f_{D^*} m_{D^*}^2} \left(\frac{b\rho_N}{2m_N} - 2f_{D^*}^2 m_{D^*} \Delta m_{D^*} \right) (2)$$

The medium dependent unknown parameters a and b in Eq.(1) and (2) are solved from the two coupled equations of vector meson current [2, 3]. The medium effects such as density, magnetic field, temperature and isospin asymmetry are introduced in these mesonic current via nucleon expectation value of light quark and gluon condensates. In the present formalism, these condensates are derived in terms of the scalar fields (σ, ζ, δ and χ) of chiral SU(3) model [4]. The chiral light quark condensates in this model is given as [2]

$$\langle \bar{q}q \rangle_{\rho_N} = \frac{1}{m_q} \left(\frac{\chi}{\chi_0} \right)^2 \left[\frac{1}{2} m_\pi^2 f_\pi (\sigma \pm \delta) \right] \quad (3)$$

In above, q represents u or d quark. Also, m_π and f_π denote the mass and decay constant of π meson. Moreover, the + sign represent up quark condensate while − sign represents down quark condensate.

Numerical Results and Discussions

In this article, we show the in-medium shift in decay constant of vector D^* meson under

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	Δf(MeV)	T=0 MeV		T=150 MeV	
		η=0	η=0.5	η=0	η=0.5
D^{*+}	$\Delta f^*_{D^{*+}}$	-41	-39	-38	-40
	$\Delta f_{D^{*+}}$	-23	-23	-19	-21
D^{*0}	$\Delta f^*_{D^{*0}}$	-64	-50	-58	-56
	$\Delta f_{D^{*0}}$	-36	-26	-33	-29

TABLE I: In the above table, at $4\rho_0$ we tabulate the effect of magnetic field on the shift in decay constant D^{*+} and D^{*0} mesons. Here, $\Delta f^*_{D^*}$ represents decay constant of respective D^* meson at eB=$5m^2_\pi$ and f_{D^*} denotes the decay constant of respective D^* meson without magnetic effect [2].

finite magnetic field. In this work, we used the value of vacuum mass of D^{+*} and D^{0*} mesons as 2010 and 2006 MeV, respectively. In addition, the vacuum value of decay constant f_{D^*} is taken as 270 MeV. In table I, we have listed the in-medium values of shift in decay constant of D^{*+} and D^{*0} meson at finite magnetic field, asymmetry, density and temperature. We also compared our present results with the zero magnetic field case [2]. In fig.(1), we show the dependence of decay constant on magnetic field at finite medium properties. From panels (a) and (c), we can see that in symmetric matter, the magnitude of $\Delta f^*_{D^*}$ increases with the increase in magnetic field. At $4\rho_0$, the increase in magnitude of $\Delta f^*_{D^{*0}}$ is more as for charged D^{*+} meson. From table I, we observed the appreciable effect of magnetic field on $\Delta f^*_{D^*}$ as compared to B=0 case.

Moreover, in asymmetric matter, $\Delta f^*_{D^*}$ follows the same trend with respect to density, and magnetic field for high temperature but opposite for low temperature. This crossover behaviour is due to the imbalance between scalar density of neutron and proton in the presence of finite magnetic field [4].

Conclusion

We observed significant effect of magnetic field and temperature (especially in high asymmetric matter) on the decay constant of vector D^* meson. These observations will help further to calculate in-medium mass of D^* meson and hence decay width of the higher D mesons and charmonium states to lower states [2].

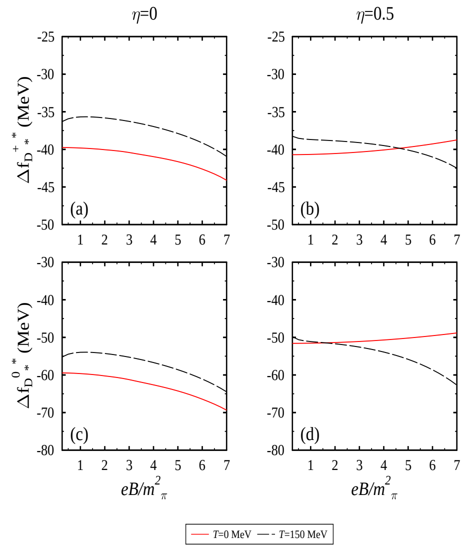

FIG. 1: (Color online) The magnetic field induced in-medium shift in decay constant of vector D^{*+} and D^{*0} meson plotted as a function of eB/m^2_π in hot asymmetric nuclear matter at nucleonic density, ρ_N=$4\rho_0$.

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