Open charm mesons in strong magnetic fields

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Introduction

Heavy flavour mesons consist of one or more quark (antiquark) belonging to the heavy flavors (charm or bottom). The estimation of strong magnetic fields produced in the peripheral ultra relativistic heavy ion collision experiments at LHC, CERN has initiated a lot of research activities in the study of the hadrons in the presence of magnetic fields. There is a profuse production of the open heavy flavour mesons and the quarkonium in the early phase of these collisions. They serve as essential probes into these collisions. D and D^* mesons are the open heavy flavour mesons comprising of a charm quark (antiquark) and a light (u,d) antiquark (quark). In the presence of a magnetic field, the mixing of the pseudoscalar (D) mesons and the vector (D^*) mesons has been shown to lead to dominant contributions to the masses of these mesons. Besides this, the charged $D^{*\pm}$ and the $D^{\pm}$ mesons have Landau level contributions to them as well.

D and D^* mesons in magnetic field

We investigate the effects of a uniform magnetic field on the masses of the open charm (D, D^*) mesons. The modifications in the masses of these mesons arise from the mixing of the pseudoscalar (D) and the vector (D^*) mesons in the presence of an external magnetic field, with additional contributions from the Landau energy levels for the charged open charm mesons. The mixing of the (D) and (D^*) mesons in the presence of a magnetic field is taken into account through the interaction Lagrangian

$$\mathcal{L}_{PV\gamma} = \frac{g_{PV}}{m_{av}} e\tilde{F_{\mu\nu}}(\partial^\mu P)V^\nu \quad (1)$$

where $m_{av} = \frac{m_P+m_v}{2}$, m_P and m_V are the masses of the pseudoscalar (D) and vector (D^*) mesons respectively. The coupling parameter g_{PV} is fitted from the observed radiative decay $\Gamma(V \rightarrow P\gamma)$. The modified masses due to the mixing of the pseudoscalar and the vector meson masses is given by,

$$m^2_{V,P} = (M^2_+ + \frac{c^2_{PV}}{m^2_{av}} + \sqrt{M^4_- + \frac{2c^2_{PV}}{m^2_{av}} + \frac{c^4_{PV}}{m^4_{av}}}) \quad (2)$$

$M^2_+ = m^2_P + m^2_V, M^2_- = m^2_P - m^2_V$ and $c_{PV} = g_{PV}eB$. m_P and m_V are the masses of pseudoscalar and vector meson masses respectively [1].

In the presence of an external magnetic field, the masses of the charged D and D^* mesons have contributions from the Landau levels. Their masses are taken to be arising from the lowest Landau level as [2]

$$m^{eff}_{D^{*\pm}} = \sqrt{m^2_{D^{*\pm}} - eB} \quad m^{eff}_{D^{\pm}} = \sqrt{m^2_{D^{\pm}} + eB} \quad (3)$$

The mixing parameter for the charged $D-D^*$ mesons, determined from the observed decay width $D^* \rightarrow D\gamma$ is magnetic field dependent because of the lowest Landau level contributions to their vacuum masses.The masses of the charged mesons are modified due to PV mixing in addition to the lowest Landau level contributions.

The decay width of $D^* \rightarrow D\pi$ in the presence of magnetic field is investigated using the effective hadronic Lagrangian.

$$\mathcal{L} = gD^{*\mu}[\bar{D}(\partial_\mu\pi) - (\partial_\mu\bar{\pi})D + \bar{\pi}(\partial_\mu D) - (\partial_\mu\bar{D})\pi] \quad (4)$$

The imaginary part of the $D-\pi$ loop is computed from which the expression for the decay width is obtained, and the real part of $D-\pi$ loop gives modification to the mass of the D^* meson.The decay width is compared with the one obtained from the $^3P_0$ model [3]. In the

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$^3P_0$ model, a light quark-antiquark pair is created in the $^3P_0$ state, and this light quark (antiquark) combines with the heavy charm antiquark (light quark (u or d)) of the decaying D^* state at rest, resulting in the production of the open charm D meson and a light flavor meson, the π meson. The decay width is calculated using the phenomenological Lagrangian as well as the $^3P_0$ model in magnetized matter.

References

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