

# D mesons in matter and the in-medium properties of charmonium

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The D-meson mass in matter is expected to decrease as a consequence of the partial restoration of chiral symmetry. At nuclear matter density model calculations [1, 2] predict a downward shift of about 50 MeV. This is contrary to heavy quarkonia, such as  $J/\psi$  and  $\psi(3686)$ , which are expected to experience only a relatively small mass shift in medium. This implies that, with increasing density, the  $D\bar{D}$  threshold will cross the energy of some of the excited charmonium states [1, 3]. Thus, the reduction of the  $D\bar{D}$  threshold in matter may be reflected in the dilepton spectrum of  $\bar{p}A$  or  $AA$  reactions as an increased width of the peaks corresponding to the  $\psi(3686)$  state. Furthermore, since more than 40% of the  $J/\psi$  produced in heavy ion collision emanate from the  $\psi(3686)$  and  $\chi$  states, such crossings will induce a stepwise suppression of  $J/\psi$  signal due to the successive melting of excited charmonium states at finite density and temperature.

In this work [4], we point out that the level crossing between the charmonium and the  $D\bar{D}$  threshold does not result in an immediate dissolving of the charmonium states, as found in naive calculations, where the participating mesons are effectively treated as point particles. When the internal structure is taken into account, the effective coupling to the  $D\bar{D}$  final state depends strongly on the Q-value. In other words, the overlap of the  $D$  mesons with the wavefunction of the initial heavy quarks of the charmonium depends strongly on the relative momentum of the  $D$  mesons in the final state.

We compute the decay of the charmonium states into  $D\bar{D}$  mesons using the 3P0 model [5, 6]. In fig. 2 we show the dependence of the partial widths for the decay into the  $D\bar{D}$  channel on the D meson mass in medium. Due to the nodes in the radial and orbital wave functions of the  $J^{PC} = 1^{--}$  states ( $\psi(3686)$  and  $\psi(3770)$ ), the partial decay widths first increase and then decrease as the mass of the D meson is reduced. The corresponding results for the  $\chi_{c0}(3417)$  and  $\chi_{c2}(3556)$  mesons are also shown.

In fig. 3, we illustrate the important role of the internal structure of the mesons by comparing the in-medium width of the  $\psi(3770)$  with the naive estimate, where the mesons are treated as point particles. In such a picture, the width is enhanced due to the increase in phase space, while the coupling constant is kept fixed. Clearly, the width of the  $\psi(3770)$  in matter is strongly overestimated in the naive calculation, where the internal meson structure is ignored. Consequently, the expectation that the  $\psi$  states would melt instantly as the  $D\bar{D}$  channel opens up is not well founded.

In matter the total width of charmonium states is further enhanced by reactions with the surrounding particles, like e.g.  $\psi + N \rightarrow \Lambda_c + \bar{D}$ . We find that these contributions to the width are small and thus that the total width of the charmonium resonances in nuclear matter is dominated by the decay into the  $D\bar{D}$  channel.

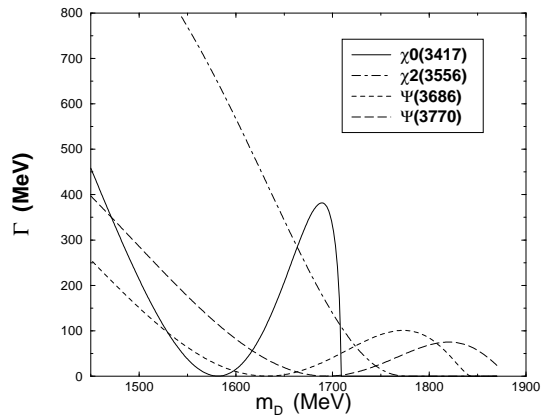


Figure 1: Partial decay width of charmonium decaying into  $D\bar{D}$ , as a function of the D meson mass.

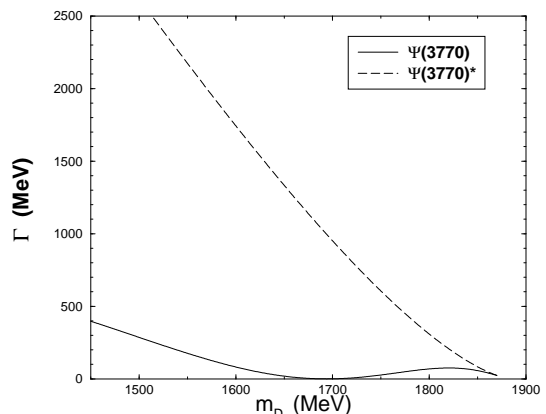


Figure 2: The solid line is the partial decay width  $\Gamma(\psi(3770) \rightarrow D + \bar{D})$  from 3P0 model. The dashed line is assuming a constant coupling normalized to give the same leading behaviour at the threshold point.

We conclude that measurements of the in-medium properties of charmonium states can provide valuable information on the characteristics of QCD in dense and hot matter.

## References

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