Short range $\pi J/\psi - D\bar{D}^*$ interaction†

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Exotic hadrons such as XYZ states reported in the heavy flavor sector have been one of the interesting topics in hadron and nuclear physics.[1] Especially, for the exotic mesons near the thresholds, those states could be realized as a hadronic molecule, which is a loosely bound or resonant state of multi-mesons.

$Z_c(3900)$ is an exotic state that has been reported by BESIII,[2] Belle,[3] and other facilities.[4,5] This state has a nonzero electric charge that cannot be possessed by the standard $c\bar{c}$ state. There have been various studies of $Z_c(3900)$, where multiquark states and hadronic molecules have been discussed (see Ref. 1)). On the other hand, the non bound state explanation has also been studied. Recent Lattice QCD simulation by HALQCD[6] indicates that $Z_c(3900)$ is a virtual state induced by the strong $\pi J/\psi - D\bar{D}^*$ potential.

For the exotic state near the threshold, heavy hadron interaction is important to understand the structure. We study the short range $\pi J/\psi - D\bar{D}^*$ interaction described by (i) the meson exchange model, and (ii) quark exchange model, and compare the results obtained by these models.

In the meson exchange model, the $D^{(*)}$ meson exchange is introduced, which is given as the Born term of the $t-$channel scattering amplitude. The amplitude is obtained by the effective Lagrangians with respect to the heavy quark and chiral symmetries,[7,8] which are given by

$$\mathcal{L}_{\pi HH} = -\frac{g_\pi}{2f_\pi}\mathrm{Tr}\left[H_1\gamma_\mu\gamma_5\partial^\mu\hat{\pi}\bar{H}_1\right], \quad (1)$$

$$\mathcal{L}_{\psi HH} = g'\mathrm{Tr}\left[\mathcal{J}\bar{H}_2\overleftrightarrow{\partial}_\mu\gamma^\mu\bar{H}_1\right] + \mathrm{H.c.}, \quad (2)$$

where $g_\pi = 0.59$, $g' = 4/\sqrt{m_\psi m_D^2}$, and the pion decay constant $f_\pi = 93$ MeV.

In the quark exchange model, the $\pi J/\psi - D\bar{D}^*$ interaction is described by the constituent quark model Hamiltonian[9,10]

$$H^q_{ij} = K_q + \left(-\frac{3}{4}br + \frac{\alpha_s}{r} - C\right)\vec{F}_i\cdot\vec{F}_j - \frac{8\pi\alpha_h}{3m_im_j}\left(\frac{\sigma^3}{\pi^{3/2}}e^{-\sigma^2 r_{ij}^2}\right)\vec{S}_i\cdot\vec{S}_j\vec{F}_i\cdot\vec{F}_j. \quad (3)$$

In Fig. 1, the cross sections of the $\pi J/\psi - D\bar{D}^*$ transition obtained using the two models are compared. The cross section obtained using quark exchange is dominated by the spin-spin term, which is contributed by the light quark dynamics instead of the charm quark dynamics. In comparison with that of quark exchange, the cross section obtained by meson exchange is very small. A large difference is obtained between the two models, and it would be useful to understand the short range interaction in the $\pi J/\psi - D\bar{D}^*$ channel.

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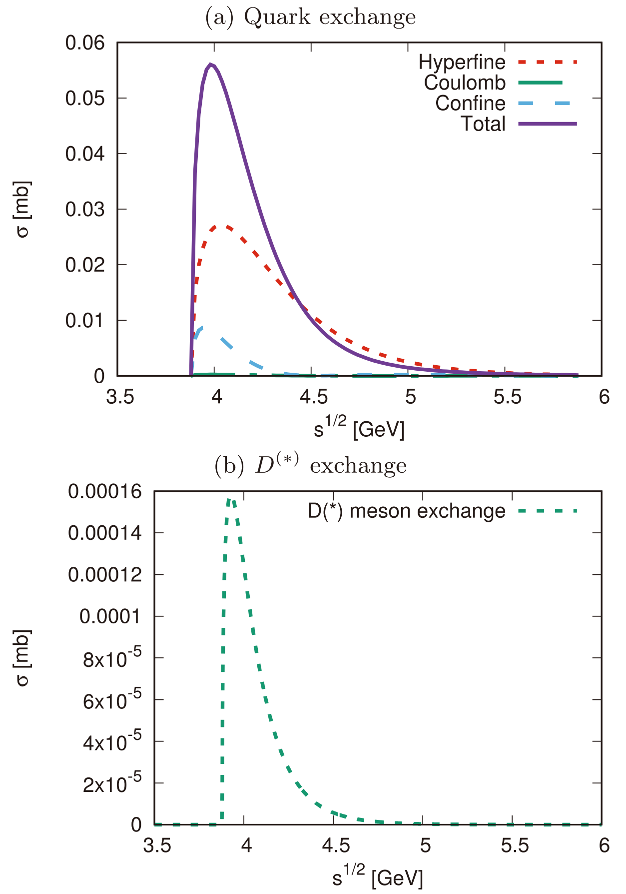

Fig. 1. $\pi J/\psi - D\bar{D}^*$ cross sections obtained by (a) quark exchange model, and (b) $D^{(*)}$ exchange model.

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