The isospin mixing in the X(3872) decay spectrum

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The large isospin symmetry breaking found in the $X(3872)$ decay is investigated by looking into the transfer strength from the $c\bar{c}$ quarkonium to the two-meson states: $c\bar{c} \to D^0\overline{D}^{*0}$, D^+D^{*-}, $J/\psi\omega$, and $J/\psi\rho$. The widths of the ρ and ω mesons are also taken into account. It is found that very narrow $J/\psi\rho$ and $J/\psi\omega$ peaks appear just on the $D^0\overline{D}^{*0}$ threshold; the strength of the $J/\psi\rho$ peak becomes comparable to that of the $J/\psi\omega$ peak. The large width of the ρ meson enhances the isospin one component considerably, which makes the ratio $X \to J/\psi\rho$ to $X \to J/\psi\omega$ close to one, the experimental value.

X(3872) The $X(3872)$ peak has been found first by Belle as a $J/\psi\pi\pi K$ observation from the B decay, and then confirmed by various experiments [1,2]. The mass of $X(3872)$ is found to be 3871.68±0.17 MeV, which is almost on the $D^0\overline{D}^{*0}$ threshold, 3871.84 MeV [1]. The width of $X(3872)$ is less than 1.2 MeV [1], which is very narrow for such a highly excited resonance. One of the peculiar features of the $X(3872)$ is that it decays both to the $J/\psi\rho$ and to the $J/\psi\omega$ states. According to the experiments [3], the decay branching ratio of $X(3872)$ to two pions is comparable to that of three pions; there is a very large isospin mixing:

$$\frac{Br(X \to \pi^+\pi^-\pi^0 J/\psi)}{Br(X \to \pi^+\pi^- J/\psi)} = \begin{cases} 1.0 \pm 0.4 \pm 0.3 & \text{(Belle)} \\ 0.8 \pm 0.3 & (\textit{BABAR})\ . \end{cases} \tag{1}$$

Transfer strength One of the weak decay processes of the B meson contains the $\bar{b} \to \bar{c}c\bar{s}$ vertex, which produces a $c\bar{c}$ quarkonium state as well as the K meson. We consider that the $X(3872)$ is produced mainly from the $(2P)$ component of this $c\bar{c}$ state [4]. In this work, we investigate the transfer strength from this $c\bar{c}$ state to the final two-meson states, $D^0\overline{D}^{*0}$, D^+D^{*-}, $J/\psi\rho$, and $J/\psi\omega$, considering that it corresponds to the observed spectra. We assume the weak transition, the formation factors of K or the $c\bar{c}$ state are a smooth function of the energy in the concerning energy region, and omit them from our calculation.

The transfer strength from the $c\bar{c}$ state to the two-meson channel f of the relative momentum k_f, the reduced mass μ_f, and the energy dependent width Γ_V, can be written as

$$\frac{\mathrm{d}W(c\bar{c} \to f)}{\mathrm{d}E} = \frac{2}{\pi}\mu_f \int \frac{k^2 \mathrm{d}k\ \mu_f \Gamma_V}{\left(k_f^2 - k^2\right)^2 + \left(\mu_f \Gamma_V\right)^2} \left| \langle f; k | (1 + V_M \tilde{G}^{(M)}) V_{MQ} \tilde{G}_Q | c\bar{c} \rangle \right|^2 , \tag{2}$$

where E is the energy of $D^0\overline{D}^{*0}$ when the center of mass of the two mesons is at rest, $\tilde{G}_Q$ is the $c\bar{c}$ diagonal part of the full propagator with the width of the vector mesons, and $\tilde{G}^{(M)}$ is the 'full' propagator within the two-meson space. V_M is the potential among the two-meson states, and V_{MQ} is transition potential between the two-meson and the $c\bar{c}$ state.

Model features We solve the system employing a model which includes only the hadronic degrees of freedom because it enables us to treat the meson mass in the kinetic term correctly and to take the vector meson widths into account. The strength of the coupling between $D\overline{D}^*$ and $J/\psi V$ channels as well as the energy of the $c\bar{c}$ state, however, are taken from the quark model results. We assume a separable potential for V_M, and its strength is determined so that the wave function of the zero-energy bound state gives the same size for the matrix element as that of the quark potential. The interaction between D and $\overline{D}^*$ mesons are taken to be consistent with the observed $Z_b(10610)$ and $Z_b(10650)$ masses; the interaction is assumed to be a central attraction and its size is the same as the one which gives a zero-energy bound state in the $B^{(*)}\overline{B}^*$ channel [4]. The coupling between the $c\bar{c}$ quarkonium to $D\overline{D}^*$ is taken empirically so that the model gives a almost zero-energy resonance $X(3872)$ as observed. The isospin symmetry breaking in the present model originates from the difference in the meson masses and in the vector meson widths.

Results and conclusion In figure 1 we show the transfer strength from the $c\bar{c}$ quarkonium to the final two-meson states: $D^0\overline{D}^{*0}$, $J/\psi\rho$ and $J/\psi\omega$. Since the D^+D^{*-} threshold is 3879.9 MeV, the final D^+D^{*-} state does not appear in the figure though the channel itself is included in the interaction. The final $J/\psi\omega$ state, whose threshold is 3879.6 MeV, however, appears around the $D^0\overline{D}^{*0}$threshold because of the ω meson decay width. We have found following two notable features: (A) each of the $J/\psi\rho$ and $J/\psi\omega$ makes a very thin peak at the $D^0\overline{D}^{*0}$ threshold, and (B) the peaks are comparable to each other in size, though the $J/\psi\omega$ component is larger than the $J/\psi\rho$. The former implies that the observed peak found in the pion spectrum may not directly correspond to the mass of the $X(3872)$. As for the latter, the factor $\mu\Gamma_V/\{(k_f^2-k^2)^2+(\mu\Gamma_V)^2\}$ in eq. (2) is by about five times larger for the ρ meson than that of the ω meson at around $k \sim k_f$, where the factor has the largest value. The ρ meson width enhances the isospin one component in the $X(3872)$ decay considerably. We found that both of the features persist provided that the $D^0\overline{D}^{*0}$ has a peak close to the threshold.

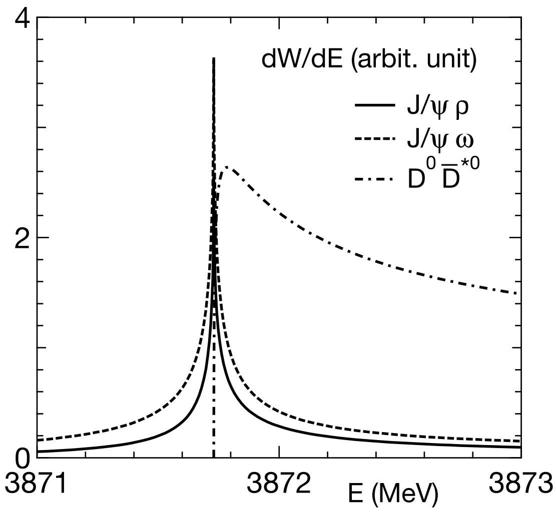

Figure 1: The transfer strength from the $c\bar{c}$ quarkonium to the final two-meson states.

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