Radiative Decays of the $X(3872)$ in the Charmonium-Molecule Hybrid Picture

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The ratio of the branching fractions of the $X(3872)$ radiative decays, $R_\gamma = \mathrm{Br}(X(3872) \to \psi(2S)\gamma)/\mathrm{Br}(X(3872) \to J/\psi\gamma)$, was reported first by BABAR that $R_\gamma = 3.4 \pm 1.4$ (3.5σ) [3]. Belle reported that $R_\gamma < 2.1$ (90% CL) [2], and LHCb found that $R_\gamma = 2.46 \pm 0.64(\mathrm{stat}) \pm 0.29(\mathrm{sys})$ (4.4σ) [3]. The data from these three experiments seem not to be inconsistent, though BABAR and LHCb prefer a larger value whereas Belle prefers a smaller one. It is important to investigate the above ratio in order to understand the nature of the $X(3872)$, the most well-investigated exotic meson.

In this work, we study the radiative decays of the $X(3872)$ ($J^{PC} = 1^{++}$) in the charmonium-molecule hybrid model. In this picture, the quark degrees of freedom are integrated out; their effects appear only in the single hadron properties and in the hadron interactions. This picture enables us to deal with hadron resonance states as well as bound states without losing characteristic features of a quark model. We assume that the $X(3872)$ consists of $D^0\overline{D}^{*0}$, D^+D^{*-}, $J/\psi\omega$, $J/\psi\rho$ and the $c\bar{c}(2\mathrm{P})$ components. It is found that the $X(3872)$ can be a shallowly bound state or a S-wave virtual state [4]. This model can explain many of the observed $X(3872)$ features. It explains that both of the $c\bar{c} \to J/\psi\rho$ and $c\bar{c} \to J/\psi\omega$ mass spectra have a very narrow peak below or on the $D^0\overline{D}^{*0}$ threshold while the peak of $D^0\overline{D}^{*0}$ spectrum has the width of a few MeV, and that the strength of the $J/\psi\pi^2$ peak is comparable to that of the $J/\psi\pi^3$ peak [5].

We assume that the radiative decay of the $X(3872)$ occurs from the $c\bar{c}(2\mathrm{P})$ component via the $E1$ transition and from the ω and ρ mesons in the $J/\psi\omega$ and $J/\psi\rho$ components via the vector-meson-dominance mechanism. We neglect the decay from the $D\overline{D}^*$ channel; which is considered to be small because this channel consists of the two color-octet $q\overline{q}$ mesons rather than D and $\overline{D}^*$ mesons at the short distance [6].

The obtained widths are $\Gamma(X(3872) \to J/\psi\gamma) = 3.8$-$13.2$ keV and $\Gamma(X(3872) \to \psi(2S)\gamma) = 2.6$ keV. The ambiguity of the former width is due to the unknown relative phase of the two decay mechanisms we consider. The ratio of these two is 0.20-0.68, which is rather small comparing especially to *BABAR* and LHCb results.

Our result may change when we introduce other components such as $\chi_{c1}(1P)$ into the system. It should also be interesting to know how the situation changes if one takes into account the light vector meson width. We are currently investigating these effects.

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