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The nature of the $X(3915)/X(3930)$ resonances from a coupled-channels approach

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The measured properties of the $X(3915)$ and $X(3930)$ make difficult their theoretical description. These charmonium resonances, firstly detected by the Belle and BaBar Collaborations in $\gamma\gamma$ fusion process, were measured in different final channels: the $X(3915)$ was discovered in the $\omega J/\psi$ [1, 2] invariant mass distribution whereas the $X(3930)$ was seen in the $D\bar{D}$ one [3, 4]. Both Collaborations rapidly agreed that the $X(3930)$ has most likely $J^{PC} = 2^{++}$ quantum numbers based on the angular distribution of the initial $\gamma\gamma$ particles. Therefore, this state was identified as the $\chi_{c2}(2P)$ state in the Particle Data Group (PDG), despite the fact that most quark models predict masses above the experimental one.

The assignment for the $X(3915)$ is being more controversial. Both $J^{PC} = 0^{++}$ and 2^{++} quantum numbers are allowed, although BaBar data clearly prefers the 0^{++} assignment. Following the predictions of different quark models [5, 6], finding good agreement with experiment on the state's mass and width, the $X(3915)$ was assigned to the $\chi_{c0}(2P)$ in the PDG. However, the $\chi_{c0}(2P)$ assignment was challenged by Olsen [7], who pointed out that the decay patterns of the $X(3915)$ do not fit with those expected for the $\chi_{c0}(2P)$ state. Moreover, new theoretical and experimental studies reanalyzed the available data and concluded that a $J^P = 2^+$ assignment is preferred if some assumptions taken by BaBar Collaboration in their original work were abandoned. Consequently, PDG relabeled the state back to $X(3915)$.

Additionally, a new charmonium-like state dubbed $X(3860)$ with a mass 3862^{+26+40}_{-32-13} MeV and width $201^{+154+88}_{-67-82}$ MeV has been recently reported by the Belle Collaboration [8]. The existence of this state agrees with the suggestion of Ref. [9], where the authors identify the broad bump below the narrow peak of the $\chi_{c2}(2P)$ with the real $\chi_{c0}(2P)$. Also, its mass coincides with the predictions of dynamical coupled-channel models for the $\chi_{c0}(2P)$.

In view of the assignment puzzle of the $X(3915)$ and $X(3930)$ resonances, and to explore the possible non-$q\bar{q}$ components of these resonances, in this work we perform a coupled-channels calculation in the framework of the constituent quark model (CQM) proposed in Ref. [10, 11], following the formalism in Ref. [12]. Our results favors the hypothesis that the $X(3915)$ and the $X(3930)$ resonances are the same $J^{PC} = 2^{++}$ state with a large molecular component, whereas the $J^{PC} = 0^{++}$ state appears with a mass $M = 3890$ MeV/c^2, lowered by nearby threshold effects.

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