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The non-perturbative unquenched quark model

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Since the discovery of the $X(3872)$ in 2003 [1] it became evident that the naive quark model would not be enough to describe all the baryon spectrum. This state has properties that can not be explained in such a quark model, as its decay into $J/\Psi\pi\pi$ through a ρ meson, which is an isospin violating decay. However this property can be easily explained in a picture in which the state in understood as a DD^* bound state, due to the isospin violation in the D and D^* masses and the close position of the state to the $D_0 D_0^*$ threshold. In previous studies [2] we described the X(3872) as a DD^* molecule coupled to the $2P$ $c\bar{c}$ state, which in our framework is essential to bind the system. The coupling of two and four quark states was performed microscopically using the $^3P_0$ model [3]. Although it was shown that the contribution to the mass of the coupling to the $1P$ and $3P$ states is small, some decay properties could have a sizable contribution, like the radiative decays. Including many different states makes the problem too involved and so the contribution of all the tower of bound quark-antiquark states remains as an open question.

For this reason we have developed a new framework in which the contribution of all the states can be obtained. To do so, the main idea is not to expand the quark-antiquark wave function in a linear combination of bare quark-antiquark states, but leave the radial wave function as an unknown of the problem solving for it. We have applied it to the study of the $X(3872)$ and check that when the $^3P_0$ coupling is small the results are the same as the perturbative calculation and for the physical value of the coupling some deviations are obtained. We have studied the probability of bare states in the physical one and the most important is the $2P$ as expected. Different decay properties will be presented.

[1] S.K. Choi *et al.* (Belle Collaboration), Phys. Rev. Lett. **91**, 262001 (2003).

[2] P.G. Ortega, J. Segovia, D.R. Entem and F. Fernandez, Phys. Rev. D **81**, 054023 (2010).

[3] J. Segovia, D.R. Entem and F. Fernandez, Phys. Lett. B **715**, 322 (2012).

Summary

In recent years states in the quarkonium spectrum not expected in the naive quark model have appeared and created a lot of interest. In the theoretical side the study of the effect of meson-meson thresholds in the spectrum have been performed in different approximations. In a quark model framework, and in the spirit of the Cornell model, when a meson-meson threshold is included, the coupling to all the quark-antiquark states have to be considered. In practice only the closest states are included perturbatively. In this contribution we will present a framework in which we couple quark-antiquark states with meson-meson states non-perturbatively, taking into account effectively the coupling to all quark-antiquark states. The method will be applied to the study of the $X(3872)$ and a comparison with the perturbative calculation will be performed.

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