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Heavy Quark Spin Symmetry and the partners of the $X(3872)$

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The discovery of the $X(3872)$ by the Belle collaboration [1] and its confirmation by BaBar and CDF has provided the best candidate to an exotic structure in the meson sector. Because of its proximity to the D^*D threshold a description of this state in terms of a $c\bar{c}$ state coupled to a D^*D molecular structure seems to be natural.

For the heavy quark sector, the spin-dependent interactions are of the order $1/m_Q$ and vanish in the heavy quark limit $m_Q \to \infty$. Then the dynamics involving heavy quarks are independent of their spin leading to heavy quark spin symmetry (HQSS). This symmetry has been often used to constrain effective hadronic models. Recently the LHCb Collaboration has determined unambiguously the $X(3872)$ quantum numbers to be $J^{PC} = 1^{++}$. Based on this result HQSS suggest the existence of $X(3872)$ partners either in the $c\bar{c}$ sector with $J^{PC} = 2^{++}$ or in the $b\bar{b}$ sector with $J^{PC} = 1^{++}$ or 2^{++}.

An extensive experimental search has been done by LHCb for the $J^{PC} = 1^{++}$ bottom partner of the $X(3872)$, the so-called X_b through its decay to different channels, but no evidence of an X_b signal has been observed.

In this work we perform a calculation of the possible partners of the $X(3872)$ using a constituent quark model which has been successful in describing the hadronic phenomenology [2]. In this framework the $X(3872)$ resonance is understood as a mixture of a P-wave charmonium $\chi_{c1}(2P)$ and a S-wave DD^* molecule. The $D - D^*$ residual interaction, driven basically by one pion exchange, is not enough attractive to form a DD^* bound state but the coupling with the $c\bar{c}$ state, slightly above the DD^* threshold produces the attraction necessary to bind the system. This is not the case of the $J^{PC} = 2^{++}$ D^*D^* molecule where the absence of a $c\bar{c}$ state nearby avoid the formation of a bound states.

In the bottom sector the situation is different. In this case, as the bottom quark mass is larger than the charm quark mass, the interaction in the BB^* and the B^*B^* systems is enough attractive to produce loosely bound states. However in the BB^*
$J^{PC} = 1^{++}$ case a $b\bar{b}$ state exists just below threshold. The coupling with this states produces repulsion and the BB^* bound state disappears. In the B^*B^* system any nearby $b\bar{b}$ state does exit and the $J^{PC} = 2^{++}$ remains as a bound state with a mass of 10650 MeV.$/c^2$

Therefore, although HQSS predicts more bound states the coupled channels dynamics breaks the symmetry and only the B^*B^*
$J^{PC} = 2^{++}$ state survives.

Similar effects are analyzed in the heavy baryon sector.

\vspace{12pt}

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