Four-quark spectroscopy within the hyperspherical formalism

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The understanding of few-body systems relies in our capability to design methods for finding an exact or approximate solution of the $N-$body problem. In two-, three-, and four-body problems it is possible to obtain mathematically correct and computationally tractable equations such as the Lippmann-Schwinger, Faddeev and Yakubovsky equations describing exactly, for any assumed interaction between the particles, the motion of few-body systems [1]. However, the exact solution requires sophisticated techniques whose difficulty increases when increasing the number of particles.

The solution of any few-particle system may be found in a simple and unified approach as an expansion of a trial wave function in terms of hyperspherical harmonic (HH) functions. The main difficulty of this method is to construct HH functions of proper symmetry for a system of identical particles. This is a difficult problem that may be overcome by means of the HH formalism based on the symmetrization of the $N-$body wave function with respect to the symmetric group using the Barnea and Novoselsky algorithm [2]. This method, applied in nuclear physics for $N \leq 7$, has only been applied to quark physics for $N = 3$. Therefore, its generalization would be ideally suited for the study of the properties of multiquark systems. During the last few years there has been a renewed interest on the possible existence of multiquark states, specially $qq\bar{q}\bar{q}$ and $qqqq\bar{q}$, and the possible role played by these configurations in the hadron spectra [3]. It is our aim in this contribution to make a general study of four-quark systems of identicalflavor in an exact way. For this purpose we have generalized the HH method [4], widely used in traditional nuclear physics, to study four-quark systems.

This formalism has been applied to $L = 0$ four-charm quark states within the constituent quark model of Ref. [5]. Our results suggest the possible existence of three four-quark bound states with quantum numbers 0^{+-}, 2^{+-} and 2^{++} and masses of the order of 6515, 6648, and 6216MeV. The two states with exotic quantum numbers, clearly below their corresponding two-meson threshold, should present narrow widths and, if produced, may be easily detected. We have also analyzed the variation of our results with the constituent quark mass. In the light-quark case only the 0^{+-} and 2^{++} quantum numbers remain bound, being the 0^{+-} the lowest one with an energy close to 1800 MeV. The four-quark state with quantum numbers 1^{-+} lies around 2900 MeV, far from the experimental states $\pi_1(1400)$ and $\pi_1(1600)$. A possible description of the $X(1600)$ as a four-quark has also been justified.

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