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Masses of dibaryonic $\Xi_c^*\Xi_c^*$ states

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We investigate the possible pair of charmed spin 1/2 and spin 3/2 baryons within the variational scheme. Incorporating the Yukawa-like and one-boson-exchange, we obtain the binding energy and mass spectrum of Ξ_c dibaryon for different spin states. Our results show the possible molecular state with a quantum number (I, J^P)=$(1, 0^+), (0, 1^+), (1, 0^+)$, and $(0, 3^+)$. The obtained results of Ξ_c-Ξ_c and Ξ_c^* -Ξ_c^* dibaryons are in accordance with theoretical predictions.

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1. Introduction

Certain multiquark states are hard to understand in terms of the standard quark model. The theoretical article proposes a number of potential exotic states including molecules, glueballs, hybrids, tetraquarks, pentaquarks, and hexaquarks [1–11]. Numerous exotic states, including XYZ, P_c, $Z(3900)^+$, and the double charm T_{cc}^{++} state, have been observed experimentally within the past years [12, 13].

It makes sense to think of the unusual states that are close to the threshold of two heavy hadrons as potential molecule states. We call the loosely bound state consisting of two color-singlet hadrons as hadronic molecular state. The simplest nuclei with baryon number 2, dibaryons, allow for the transparent study of baryon-baryon interactions. Nonetheless, the deuteron is the only known stable dibaryon, and recent reports suggest that one more unstable light dibaryon $d^*(2380)$ has been observed [14]. At present, there are no newly discovered heavy six quark states in current scenario. It is therefore natural to investigate the presence of hadrons with six valence quark configurations within Quantum Chromodynamics (QCD), with the hope that QCD-predicted states of this kind can help guide their future searches at high energy laboratories. There have been lot of theoretical studies that try to explain the existence of dibaryons within the frame work of lattice QCD [15, 16], "one boson" exchange (OBE) potential [17], potential models [18, 19], and dispersion relation technique [20].

We investigate the possible Ξ_c-Ξ_c and Ξ_c^*-Ξ_c^* dibaryonic molcules in the open charm sector in the present study. The addition of heavy quarks can produce configurations that are stable to decay into two baryons in the dibaryon sector. We have approximated the dibaryon as an S-wave OBE plus screen "Yukawa-like" potential. We predict the masses of molecule in its relativistics S-wave state.

2. Methodology

The variational scheme is used for the calculation of mass spectra for the dihadronic systems by using the hydrogen-like trial wave function. To determine the S-wave spectra, we use the OBE plus screen Yukwa-like potential. The Hamiltonian of dihadronic molecule is given by [3, 4]

$$H = \sqrt{P^2 + m_{h_1}^2} + \sqrt{P^2 + m_{h_2}^2} + V_{hh} \tag{1}$$

where m_{h_1} and m_{h_2} are the masses of constituents, P is the relative momentum of two hadrons, and V_{hh} is the inter-hadronic interaction potential. To incorporate the relativistic effect, we included corrections to the potential and expand the kinetic energy term of Hamiltonian up to O(P^6). The binomial expansion of the kinetic energy term is given by [3],

$$K.E. = \frac{P^2}{2}\left(\frac{1}{m_{h_1}} + \frac{1}{m_{h_2}}\right) - \frac{P^2}{8}\left(\frac{1}{m_{h_1}^3} + \frac{1}{m_{h_2}^3}\right) + \frac{P^2}{16}\left(\frac{1}{m_{h_1}^5} + \frac{1}{m_{h_2}^5}\right) + O(P^6) \tag{2}$$

The interaction potential is given by,

$$V_{hh} = V_{\mathrm{OBE}} + V_Y \tag{3}$$

Table 1: The threshold mass, reduced mass and k_{mol} of dibaryonic systems are given.

System	Threshold mass (in GeV)	Reduced mass (in GeV)	k_{mol}
$\Xi_c\ \Xi_c$	4.941	1.235	0.242
$\Xi_c^*\ \Xi_c^*$	5.291	1.322	0.237

where $V_Y(r_{db})$ is the screen Yukawa-like potential and V_{OBE} is S-wave OBE potential. The screen Yukawa-like potential is expressed as

$$V_Y = -\frac{k_{mol}}{r_{db}} e^{\frac{-c^2 r_{db}^2}{2}} \tag{4}$$

where, c is a screen fitting parameter of the potential and k_{mol} is the residual running coupling constant. The net S-wave OBE potential with finite size effect can be expressed as [21]

$$V_{OBE} = V_{ps} + V_s + V_v \tag{5}$$

3. Results and discussions

In this work, we attempt to systematically inspect the most promising single-flavored dibaryon bound states, $\Xi_c\ \Xi_c$ with the J^P values of $\frac{1}{2}^+$ and $\frac{3}{2}^+$. The different I(J^P) combinations, $0(0^+), 1(1^+), 1(3^+), 1(0^+), 0(1^+), 0(3^+)$, are considered for the ground state calculations. Among them, the channels, $0(0^+)$, $1(1^+)$ and $1(3^+)$ are forbidden in our calculations. The similar calculations can be performed for $\Xi_s\ \Xi_s$, $\Xi_s^*\ \Xi_s^*$, $\Xi_b\ \Xi_b$, $\Xi_b^*\ \Xi_b^*$ dibaryonic combinations.

For $\Xi_c\ \Xi_c$ dibaryon, the mass for $1(0^+)$ channel is 4.940 GeV and for $0(1^+)$ channel is 4.936 GeV. For $\Xi_c^*\ \Xi_c^*$ dibaryon, the mass for $1(0^+)$ channel is 5.291 GeV and for $0(1^+)$ channel, it is 5.281 GeV. In Ref. [17], the authors predicted the $\Xi_c\ \Xi_c$ bound with binding energy between 2.5 and 36.5 MeV. Our result for the $\Xi_c\ \Xi_c$ bound state is in agreement with it. The masses are predicted as 4.873 and 5.219 GeV for the systems $\Xi_c\ \Xi_c$ and $\Xi_c^*\ \Xi_c^*$. In ref. [22], they are clearly in agreement with our results.

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