Revisited: the spectra of doubly heavy Ξ_{cc} baryon

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Introduction

Doubly heavy baryons are very interesting hadrons that consist of two heavy and one light quark. To examine the coupling between these quarks are also challenging. The Ξ baryon family with six members are: Ξ_{cc}^{+} ,Ξ_{bb}^{-}, Ξ_{bc}^{+}, Ξ_{cc}^{++}, Ξ_{bb}^{0} and Ξ_{bc}^{0} [1]. In which, first three baryons are combined with down quark and other three are combined with up quark. The SELEX Collaboration reported the first detection of Ξ_{cc}^{+} state in the charge decay mode $\Xi_{cc}^{+} \to \Lambda_c^{+} K^{-}\pi^{+}$[2]. The LHCb Collaboration reported the mass of Ξ_{cc}^{++} state in the charge decay mode $\Xi_{cc}^{++} \to \Lambda_c^{+} K^{-}\pi^{+}\pi^{-}$ [3]. The measured mass for this state was 3519 $\pm$ MeV/c^2 and 3621.40 $\pm$ 72(stat.) $\pm$ 0.27 (syst.) $\pm$ 14(Λ_c^{+}) MeV/c^2. The production and the possibility of observation of Ξ_{bc} baryons at the LHC is disscussed in ref. [4]. The other family Ω with three baryons don't have any experimental evidence yet [5].

Many theoretical approaches have devoted properties of doubly heavy Ξ baryons so far. Like QCD sum rule [6], Regge Phenomology [7], Lattice QCD [8] , Hamiltonian model [9], relativized quark model [10], etc. We have also studied the properties using Hypercentral Constituent Quark Model. But, if we compare the difference of two doubly charmed Ξ bayons, its nearly $\approx$ 100 MeV; which is not reasonable. Thus, we find to revisit the spectra. Althogh, they are no experimental evidence of doubly beauty and charm-beauty baryons yet.

Our scheme accounts to an average two-body potential for the three quark system over the hyper angle using the relative Jacobi coordinates ($\vec{\rho}$ and $\vec{\lambda}$) [12]. The Hamiltonian of the baryonic system in the hCQM is expressed as [13]

$$H = \frac{P_x^2}{2m} + V(x). \qquad (1)$$

where, The quark masses m_c and m_u are 1.275 and 0.338 GeV. The model is formed by a linear confining interaction with a spin, flavor and orbital angular momentum dependent hyperfine interaction. The potential is in form of,

$$V(x) = V^0(x)+\left(\frac{1}{m_\rho} + \frac{1}{m_\lambda}\right) V^{(1)}(x)+V_{SD}(x). \qquad (2)$$

This interaction potential consists of a central term $V^0(x)$, spin dependant part $V_SD(x)$ and first order correction $V^1(x)$ is also added [14].

In this paper, we revised the ground state, first radial excited state and first orbital excited state of Ξ_{cc}^{++} baryon. The results are tabulated in Table 1. The ground state is matched with the LHCb data. The first radial excited state 2S is calculated for $J^P = \frac{1}{2}^{+}$ and $\frac{3}{2}^{+}$. They show 13 and 48 MeV difference with ref. [9]. The first orbital excited state 1P is calculated for $J^P = \frac{1}{2}^{-}$. The result shows only 46 MeV difference with ref. [9]. Thus, the new spectra are very much reliable with the new experimental findings.

TABLE I: Mass Spectra

State	J^P	Mass	[9]	[11]
1S	$\frac{1}{2}^{+}$	3.621	3.685	3.676
2S	$\frac{1}{2}^{+}$	4.092	4.079	4.029
2S	$\frac{3}{2}^{+}$	4.162	4.114	4.042
1P	$\frac{1}{2}^{-}$	4.027	3.947	4.073

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We will extent our study for higher excited states as well. It would be very intersting to determine the difference of two baryons and also with considering their isospin splittings. In Ref. [15], the negative parity Ξ_{cc} baryons are calculated using a unitarized coupled channel approach based on chiral effective Lagrangians up to NLO. They give the difference of the negative parity states of Ξ_{cc}^{+} and Ξ_{cc}^{++} baryons and also disscussed the Ω baryons. They also stated that the negative parity P state should be lie below 4.2 GeV which is fullfiled in our results.

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