

## Decay properties of $\Xi_{cc}^{++}$ baryon

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### Introduction

The doubly heavy baryons are among the best tools to understand the quantum chromodynamics and heavy quark effective theory. Using weak decays of doubly heavy baryons, one can determine the elements of CKM matrix that help to understand quark mixing angle. The first doubly heavy baryon  $\Xi_{cc}^+$  was discovered by SLEX collaboration [1, 2] and recently LHCb have discovered the doubly charmed  $\Xi_{cc}^{++}$  in the  $\Lambda_c^+ K^- \pi^+ \pi^-$  mass spectrum at  $\sqrt{s} = 13$  TeV [3]. There are many theoretical approaches in literature to compute the mass spectra and decay properties. The models based on lattice QCD [7], QCD sum rules [8] relativistic quark model (RQM) [9], hypercentral constituent quark model [10] and many more.

In this article we compute the mass of doubly heavy  $\Xi_{cc}^{++}$  in the extended version of relativistic harmonic confinement model (ERHM). The spin dependent part of the confined one gluon exchange interaction is employed to compute the mass of excited state. Using the potential parameters and spin flavor wave-functions, we compute the transition magnetic moments between  $3/2^+ \rightarrow 1/2^+$  states. We also compare our findings with the available experimental data and other theoret-

ical predictions.

### Formulation

We employ the extended relativistic harmonic confinement model (ERHM) to compute the masses of  $\Xi_{cc}^{++}$  baryon. In ERHM, the quarks are confined through in the Lorentz scalar with vector harmonic oscillator potential of the form[4, 5].

$$V_{conf} = \frac{1}{2}(1 + \gamma_0)A^2 r^2 \quad (1)$$

We employ the nonrelativistic reduction of Dirac equation to compute the bound state masses of the doubly heavy baryons for the potential Eq. (1). In above equation  $A$  is the confinement mean field parameter and  $\gamma_0$  is the Dirac matrix. Using the wave function, we incorporate the Coulomb potential with color dielectric coefficient perturbatively. The Coulomb potential is given by

$$V_{coul} = \frac{k\alpha_s}{\omega r} \quad (2)$$

Here, in this equation  $\omega$  is the state dependent color dielectric coefficient and  $\alpha_s$  is the strong running coupling constant. We also include the spin dependent part of confined one gluon exchange potential perturbatively to compute the mass of excited state. We assume here that the light quark interacts with both the heavy quarks separately (three body description) and not with a heavy diquark as proposed by other theoretical approach [6] as that causes increase in the baryon mass as a consequence. The mass of baryonic system in the

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TABLE I: Masses of  $\Xi_{cc}^{++}$  baryon in MeV

State	Present	[9]	[10]	[7]
$\Xi_{cc}^{++}$	3620.75	3620	3511	3610 (23) (22)
$\Xi_{cc}^{*++}$	3752.28	3727	3687	3692 (28) (21)

\* indicates  $J^P = \frac{3}{2}^+$  state

different  $n^{2S+1}L_J$  state can be written as

$$M_N^J = \sum_{i=1}^3 \epsilon_N(q_i)_{conf} + \sum_{i<j=1}^3 \epsilon(q_i, q_j)_{coul} + \sum_{i<j=1}^3 \epsilon_N^J(q_i, q_j)_{S.D.} \quad (3)$$

The potential parameters are: Coulomb interaction strength  $k = 0.37$ , the mean field parameter  $A = 2166 \text{ MeV}^{3/2}$  and quark masses  $m_c = 1315 \text{ MeV}$  and  $m_u = 240 \text{ MeV}$ . The computed masses of  $\Xi_{cc}^{++}$  is tabulated in Tab. I

### Transition Magnetic Moment

The radiative transition magnetic moment in terms of nuclear magneton ( $\mu_N$ ) is computed using

$$\mu_{B^* \rightarrow B\gamma} = \langle B | \hat{\mu}_{B^*z} | B^* \rangle \quad (4)$$

where  $B$  and  $B'$  represents the constituent quarks of parent and daughter baryon respectively. We obtain the following result

$$\mu_{\Xi_{cc}^{*++} \rightarrow \Xi_{cc}^{++}} = 1.564 \mu_N$$

Our results are in good agreement with the other theoretical approaches such as  $\chi$ CQM [11] and the model based on effective mass scheme [12].

### Conclusion

We have computed the masses of doubly heavy baryons employing the extended version of relativistic harmonic confinement model and the results are tabulated in Tab I in comparison with results from LQCD [7], relativistic quark model [9] and hypercentral quark

model [10]. Our results are in good agreement with LQCD and RQM. We have also computed the weak transition magnetic moment and it is in compliance with the other theoretical predictions. We notice that the three body description of the double heavy baryons provide better mass spectra without addition of correction terms. The study on computation of weak decay properties and lifetimes of differently charged states of doubly heavy baryons are underway.

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