Masses and radiative decay of Ω_{cc}^{+} baryon

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Introduction

The fact that the energy scales of doubly heavy baryons are much larger in comparison to strong interaction scale Λ_{QCD}, makes study of their spectroscopy an important tool for testing quantum chromodynamics [1, 2]. We employ extended relativistic harmonic model for computing the masses of Ω_{cc}^{+} baryon. Though this state is yet to be observed experimentally, many theoretical models have computed their mass spectra and decay modes. We compute masses and radiative decay widths using the model parameters along with spin-flavor wave functions and compare the results with the available theoretical predictions.

Methodology

For computation of bound state masses of baryon, we use the relativistic harmonic confinement model in which the quarks are confined through the Lorentz scalar plus vector potential of the form

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

Where A is the confinement strength mean field parameter and γ_0 is the Dirac matrix. The non relativistic reduction of the Dirac equation is performed for the potential Eq. (1) and the energy eigen values (ϵ_{conf}) are obtained. We perturbatively add the Columb potential along with state dependent colour dielectric coefficient (ω_n) given by [3]

$$V_{coul} = \frac{k\alpha_s(\mu)}{\omega_n r} \tag{2}$$

Where $\alpha_s(\mu)$ is the strong runing coupling constant. The mass of baryon in the different $n^{2S+1}L_J$ state acording to different J^{PC} can be written as [3]

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

where the last term corresponds to the expectation value of spin dependent part of confined one gluon exchange potential.

The potential parameters used in computation of octet and decuplet masses of Ω_{cc}^{+} are as follows: $k = 0.37$, confinement mean field parameter $A = 2166$ MeV$^{3/2}$, quark masses: $m_c = 1315$ MeV and $m_s = 470$ MeV.

TABLE I: Masses of Ω_{cc}^{+} baryon in MeV

State	Present	[4]	[5]	[6]	[7]	[8]
Ω_{cc}^{+}	3769.91	3770	3747	3713	3738	3650
Ω_{cc}^{*+}	3835.3	3824	3819	3785	3822	3810

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

Radiative decays

The radiative decay width can be expressed in terms of transition magnetic moment (in nuclear magneton μ_N) as [9]

$$\Gamma_{B^*\to B\gamma} = \frac{\omega^3}{4\pi}\frac{2}{2J+1}\frac{e^2}{m_p^2}\mu^2_{B^*\to B\gamma} \tag{4}$$

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TABLE II: Radiative transition magnetic moment in μ_N and radiative decay width in keV

	Present	[10]	[11]	[4]	[12]	[13]
$\mu_{\Omega_{cc}^{*+}\to\Omega_{cc}^{+}\gamma}$	-0.877	1.54	0.789	–	–	-0.89
$\Gamma_{\Omega_{cc}^{*+}\to\Omega_{cc}^{+}\gamma}$	0.89	9.45	0.949	8.61	6.93	–

where, m_p is the mass of proton, μ is the transition magnetic moment that can be written in terms of magnetic moment of constituent quark of final and initial state of baryons as $\mu_{B^*\to B\gamma} = \langle B|\hat{\mu}_{B^*z}|B^*\rangle$.

Result and discussion

We employed the extended relativistic harmonic model (ERHM) for computing the masses of doubly heavy Ω_{cc}^{+} baryon and our results are tabulated in Table I. Since no experimental results are available for these state we compare our results with theoretical predictions such as relativistic quark model [4], hypercentral model [8] as well with lattice QCD [5–7]. Our results deviate by less than 2 % from those obtained using lattice QCD as well as relativistic quark model.

Next we compute the radiative transition width of Ω_{cc}^{+} baryons. The decay rate is expressed in terms of transition magnetic moment. Considering the masses of confined quarks as the effective mass, the magnetic moments are obtained using the spin flavor structure of constituent quarks. The computed results are tabulated in Table II and compared with the other theoretical predictions. Our results for transition magnetic moments are matching well with modified Bag model [11] and chiral constituent quark model [13]. We also compare our result for radiative decay width with modified Bag model [11], chiral constituent quark model [13] along with recent papers on chiral quark model [10] and relativistic quark model [4]. We observe that our results match very well with modified Bag model.

Conclusion

Employing extended relativistic harmonic confinement model, we compute the mass of doubly heavy Ω_{cc}^{+} baryon which are matching well with lattice QCD results. The computed radiative transition magneic moment and decay width are lower than the recent theoretical predictions. However, due to the fact that the results from lattice calculations and experimental results are still awaited, the present results might be of interest as they are in tune with chiral constituent quark model and modified Bag model. Further study on the radiative decay properties of doubly heavy baryons is underway.

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