Excited mass spectra of Σ_c^+ Baryon

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Introduction

Baryons are strongly interacting fermions made up of three quarks[1–3]. Recently, many of single charm baryons are discovered by different colliders like CLEO, Belle, BABAR, etc[4]. Among different phenomenological Quark models, we practise on Hypercentral Constituent Quark Model(hCQM) with coulomb plus power potential. The methodology of single charmed Baryon Σ_c^+ is derived in the paper[5, 6]. Our predictions for charmed baryon masses are matched with other theoretical prediction as well as known experimental data. The obtained results are used for constructing the heavy baryon Regge trajectories in the (n_r, M^2).

The Hypercentral Model

Baryon as a bound state of three constituent quarks are describe in terms of Jacobi Coordinates($\vec{\rho}$ and $\vec{\lambda}$) as,

$$\vec{\rho} = \frac{1}{\sqrt{2}}(\vec{r_1} - \vec{r_2}) \ \& \ \vec{\lambda} = \frac{1}{\sqrt{6}}(\vec{r_1} + \vec{r_2} - 2\vec{r_3}) \quad (1)$$

For Σ_c^+ (udc) system, the constituent quark mass used in our calculations are m_1= 0.338, m_2=.350, m_3=1.275 (in GeV). The Hamiltonian of three body baryonic system with different constituent quark masses for the hCQM is[5, 6],

$$H = \frac{P_\rho^2}{2m_\rho} + \frac{P_\lambda^2}{2m_\lambda} + V(\rho, \lambda) = \frac{P_x^2}{2m} + V(x) \quad (2)$$

Where, $m = \frac{2m_\rho m_\lambda}{m_\rho + m_\lambda}$, is reduced mass. The hyperradial Schrödinger Eqn. corresponds to the Hamiltonian reduces to,

$$\left[\frac{-1}{2m}\frac{d^2}{dx^2} + \frac{\frac{15}{4} + \gamma(\gamma+4)}{2mx^2} + V(x)\right]\phi_\gamma(x) = E\phi_\gamma(x) \quad (3)$$

TABLE I: Masses of radial excited states of Σ_c^+

(ν)	A	B	Others	A	B	Others
	$1^2S_{\frac{1}{2}}$			$1^4S_{\frac{3}{2}}$		
0.5	2.444	2.453	2.453[1]	2.504	2.501	2.518[1]
0.7	2.444	2.452	2.443[2]	2.501	2.501	2.519[2]
0.9	2.444	2.452	2.453[9]	2.501	2.501	2.520[9]
1.0	2.444	2.452	2.452[10]	2.506	2.501	2.538[10]
2.0	2.444	2.452		2.509	2.501	
	$2^2S_{\frac{1}{2}}$			$2^4S_{\frac{3}{2}}$		
0.5	2.871	2.887		2.916	2.921	
0.7	2.912	2.925	2.901[2]	2.950	2.960	2.936[2]
0.9	2.942	2.961		2.984	2.996	
1.0	2.960	2.978		3.000	3.012	
2.0	3.094	3.123		3.140	3.160	
	$3^2S_{\frac{1}{2}}$			$3^4S_{\frac{3}{2}}$		
0.5	3.179	3.199		3.206	3.220	
0.7	3.270	3.293	3.271[2]	3.293	3.314	3.293[2]
0.9	3.351	3.381		3.378	3.403	
1.0	3.393	3.424		3.419	3.445	
2.0	3.746	3.801		3.777	3.826	
	$4^2S_{\frac{1}{2}}$			$4^4S_{\frac{3}{2}}$		
0.5	3.464	3.490		3.483	3.503	
0.7	3.612	3.645	3.581[2]	3.628	3.658	3.598[2]
0.9	3.751	3.793		3.770	3.808	
1.0	3.822	3.866		3.839	3.880	
2.0	4.443	4.526		4.465	4.543	
	$5^2S_{\frac{1}{2}}$			$5^4S_{\frac{3}{2}}$		
0.5	3.735	3.766		3.748	3.775	
0.7	3.944	3.986	3.861[2]	3.956	3.995	3.873[2]
0.9	4.146	4.200		4.160	4.210	
1.0	4.249	4.306		4.261	4.316	
2.0	5.176	5.291		5.193	5.304	

$A \rightarrow$without first Order correction
$B \rightarrow$with first Order correction

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where ϕ_γ(x) is the hypercentral wave function and γ is the grand angular quantum number. For the present study we consider the hypercentral potential V(x) as the color coulomb plus power potential with relativistic correction,

$$V(x) = V^0(x) + \left(\frac{1}{m_\rho} + \frac{1}{m_\lambda}\right) V^{(1)}(x) + V_{spin} \quad (4)$$

The relativistic correlation[7] and the spin-dependent part of the three-body interaction potential of is taken as[5, 6, 8],

$$V^{(0)}(x) = \frac{\tau}{x} + \beta x^\nu \ \ \& \ \ V^{(1)}(x) = -C_F C_A \frac{\alpha_s^2}{4x^2}$$

$$V_{spin}(x) = -\frac{1}{4} A\alpha_s \frac{e^{-x/x_0}}{xx_0^2} \sum_{i>j} \frac{\vec{\sigma_i}\vec{\sigma_j}}{6m_i m_j} \vec{\lambda_i}\vec{\lambda_j}$$

Here, $\tau = -\frac{2}{3}\alpha_s$ related to strong coupling constant; $\frac{2}{3}$ is the color factor for baryon, β corresponds to the string tension of the confinement. $C_F = \frac{2}{3}$ and C_A =3 are the Casimir charges of the fundamental and adjoint representation. The baryon spin average mass in this hypercentral model is given by $M_B = \sum_{i=1} m_i + BE + \langle V_{SD}(x)\rangle$. We take $A = A_0/(\omega + \gamma + \frac{3}{2})^2$, where A_0 is arbitary constant. We fix potential parameter β and hyperfine parameter τ for each choices of potential index(ν) from 0.5 to 2.0 using ground state experimental masses of $J^P = \frac{1}{2}^+$ and $J^P = \frac{3}{2}^+$ for single charmed flavor Σ_c^+ baryon.

Results and Discussions

We have calculated the excited state masses of the Σ_c^+ baryon in Hypercentral model(hCQM). We have used the first order correction to the potential and calculated results are shown in Table(1) without(A) and with(B) first order correction. With correction results are slightly higher than that of without correction. We have plotted the graph of Mass $\to \nu$(potential index) and M^2 $\to$ n(like Regge trajectory, see fig(1)). The details of the results will be presented in conference.

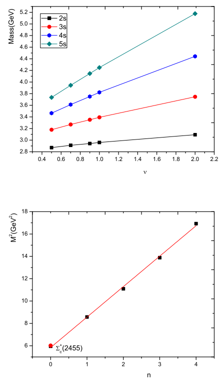

FIG. 1: Variation of mass with potential index ($M \to \nu$) and quantum number ($M^2 \to n$) for Σ_c^+

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References

[1] K.A. Olive et. al., Chi. Phys.C **38** , 090001 (2014) .

[2] D. Ebert, R. N. Faustov and V. O. Galkin, Phys. Rev. D **84** 014025 (2011).

[3] M.M. Giannini et al., arXiv:1506.05952v1 [nucl-th] (2015).

[4] A. J. Bevan et al. [BaBar and Belle Collaborations], Eur. Phys. J. C **74**, 3026 (2014).

[5] B. Patel, A. K. Rai and P. C. Vinodkumar, Pramana J. Phys. **70**, 797-804 (2008);B. Patel, A. K. Rai and P. C. Vinodkumar, J.Phys.G **35**, 065001 (2008).

[6] Kaushal Thakkar et al., Pramana J. Phys. **77**, 1053-1067 (2011);Kaushal Thakkar et al., Chinese Physics C **36**,385-389 (2011); Kaushal Thakkar et al.,AIP Conf. Proc. **1536**, 1097 (2013)

[7] Y. Koma, M. Koma, H. Wittig, Phys. Rev. Lett. **97**, 122003 (2006).

[8] N. Devlani et al., Eur. Phys. J. A **50**, 154 (2014).

[9] R. Roncaglia, D. B. Lichtenberg, and E. Predazzi, Phys. Rev. D **52**, 1722 (1995).

[10] N. Mathur et al., Phys. Rev. D **66**, 014502 (2002).