Radial excited states of Σ_c^{++} in a hypercentral quark model

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Introduction

One of the main goals of recent experiments in hadron physics is the determination of the excited baryon spectrum and the identification of possible new symmetries in the spectrum. Many of the narrow hadron resonances observed recently by the experimental facilities at Belle, BaBar, CLEO, CDF, SELEX, ALICE, BES-III *etc.,* [1–3] brought up considerable interest in QCD spectroscopy. Though many of the recently discovered hadronic states belongs to mesonic family there exist states in the heavy flavour baryonic sector as well. So our interest here is to study the radially excited states of charm baryons using hypercentral quark model and assign the quantum number (J^P) to the newly observed baryon state. In this article, we compute the radial excited states of Σ_c^{++} baryon.

Methodology

The Hamiltonian of baryonic systems in hypercentral model can be written as [4]

$$H = \frac{P_\rho^2}{2\,m_\rho} + \frac{P_\lambda^2}{2\,m_\lambda} + V(\rho,\lambda) = \frac{P_x^2}{2\,m} + V(x) \quad (1)$$

where m is the reduced mass of the system and expressed as $m = \frac{2m_\rho m_\lambda}{m_\rho + m_\lambda}$. For the present study, we consider the hyper central potential $V(x)$ as [4, 5]

$$V(x) = -\frac{2}{3}\frac{\alpha_s}{x} + \beta x^\nu \quad (2)$$

Here, α_s is strong running coupling constant and β is confining term. The hyper radial *Schrödinger* equation corresponds to the Hamiltonian given by Eqn.(1) can be written as

$$\left[\frac{d^2}{dx^2} + \frac{5}{x}\frac{d}{dx} - \frac{\gamma(\gamma+4)}{x^2}\right]\phi_\gamma(x) = -2m[E - V(x)]\,\phi_\gamma(x) \quad (3)$$

where γ is the grand angular quantum number. For the reduced radial wave function $\chi(x) = x^{\frac{5}{2}}\phi_\gamma(x)$, Eqn. (3) reduces to

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

The hypercentral S-wave states correspond to $\gamma = 0$. The *Schrödinger* equation (4) can be solved numerically using the mathematica program. The spin dependent part of the three body interaction is incorporated perturbatively and is given by

$$V_{spin}(x) = -\frac{A}{4}\alpha_s \frac{e^{\frac{-x}{x_0}}}{xx_0^2}\sum_{i<j}\frac{\vec{\sigma_i}\cdot\vec{\sigma_j}}{6m_i m_j}\vec{\lambda_i}\cdot\vec{\lambda_j} \quad (5)$$

Here, the parameter A and the regularization parameter x_0 are considered as the hyperfine parameter of the model.

The baryon masses are then obtained as

$$M_B = \sum_i m_i + \langle H\rangle \quad (6)$$

We fix potential parameter β and hyperfine parameter A for each choice of ν using ground state experimental mass of $J^P = \frac{1}{2}^+$ and

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TABLE I: Mass of radially excited states for single charm baryon Σ_c^{++} with different choices of ν.

Baryon State	Potential Index	Mass of Radially Excited states			
		$J^P = \frac{1}{2}^+$		$J^P = \frac{3}{2}^+$	
		Present	others [6, 7]	Present	others [7]
1S	0.5	2454	2454	2518	2518
	1.0	2454		2518	
	2.0	2454		2518	
2S	0.5	2839.46	2939.3	2978.10	2936
	1.0	2932.25	2901	3065.60	
	2.0	3072.15		3210.44	
3S	0.5	3129.61	3271	3296.64	3293
	1.0	3353.04		3518.01	
	2.0	3712.28		3896.33	
4S	0.5	3409.67	3581	3594.37	3598
	1.0	3780.59		3967.27	
	2.0	4409.27		4628.71	
5S	0.5	3680.98	3861	3877.32	3873
	1.0	4212.16		4414.52	
	2.0	5152.33		5399.84	

$J^P = \frac{3}{2}^+$ baryon. The regularization parameter x_0 is 1 $GeV^{-1}$and quark mass parameters are m_u=338 MeV, m_d=350 MeV, m_c=1275 MeV. For orbitally excited states, potential parameter β is found to vary as $\beta = \beta_0\sqrt{n+\gamma+\frac{3}{2}}$ where β_0 correspond to the ground state ($n = 0$, $\gamma = 0$) potential strength.

Results and Discussion

We have obtained the radial excited states 2S, 3S, 4S, and 5S for Σ_c^{++} in the frame work of hypercentral quark model with hypercentral coulomb plus power law potential . The calculated masses of radially excited states are listed in Table 1. Our results follow the Regge trajectory as shown in the FIG. 1. The present result for 2S (2932) state at potential index ν=1 having $J^P = \frac{1}{2}^+$ is found to be in agreement with the experimentally known $\Sigma_c(2932)$ state. We look forward to see future experimental support for other predicted states.

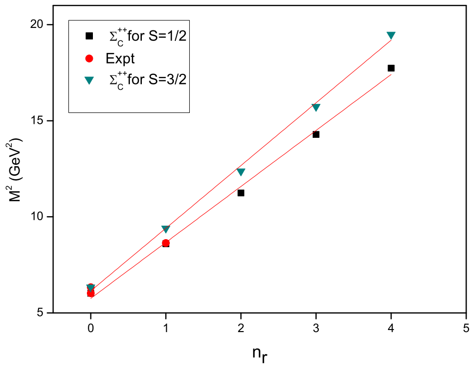

FIG. 1: Regge trajectory of radially excited Σ_c^{++} for potential index ν=1

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