S-wave masses and magnetic moment of singly heavy beauty baryon Ξ_b^-.

Rameshri V. Patel[1*] and Manan Shah[1†]
[1]*Department of Physical Sciences, P. D. Patel Institute of Applied Sciences, Charotar, University of Science and Technology, CHARUSAT, Changa - 388421, Gujarat, INDIA.*

Introduction

Recently, the $\Xi_b(6100)^-$ state was confirmed in the $\Xi_b^-\pi^+\pi^-$ decay mode at LHCb [1]. Spin parity(J^P) of which was predicted to be $(3/2)^-$ [2] that may fall into the masses of the P-wave of Ξ_b^-. These observations may provide some insight into the potential models that can produce the experimental masses for the singly heavy baryons like Ξ_b. We have used the independent quark model in the relativistic framework [3–7] to explore the ground state and radial excitation of Ξ_b^-. The magnetic moment is also calculated for the its identification.

Methodology

In this study we have considered independent confinement of quarks within the baryon using the potential of the form $\frac{1}{2}(1+\gamma_0)(\lambda r^{0.1}+V_0)$ in relativistic Dirac formalism. The spin-average mass of a baryon can be written as

$$M_{SA}^{Qqq} = E_b^D + E_d^D + E_s^D - E_{CM}, \qquad (1)$$

Here, E_b^D, E_d^D, and E_s^D denote the Dirac energies of the b, d, and s quarks respectively, which are determined by solving the Dirac equation for this system

$$[\gamma^0 E_q - \vec{\gamma}\vec{P} - m_q - V(r)]\psi_q(\vec{r}) = 0 \qquad (2)$$

Here, E_{CM} represents the parametric center-of-mass correction. The potential parameters are fitted by equating the theoretical spin-averaged mass obtained using 1 with the spin-averaged mass calculated using the experimental masses of the respective spin state (M_{nJ}) using the Eqn 3 as given below,

$$M_{SA} = \frac{\sum_J (2J+1)M_{nJ}}{\sum_J (2J+1)}. \qquad (3)$$

With the fitted parameters, we can calculate the spin-averaged masses of the excited S wave states. We account for the spin degeneracy by incorporating the spin-spin interaction along with the spin-averaged mass M_{SA} 1. This is done by considering the total spin of the quark system as, $\vec{J_{3q}} = \vec{J_1} + \vec{J_2} + \vec{J_3}$.

$$\left\langle V_{q_1q_2q_3}^{jj}(r)\right\rangle = \sum_{i=1,i<k}^{i,k=3} \frac{\sigma\left\langle j_i.j_k JM|\hat{j_i}\cdot\hat{j_k}|j_i.j_k JM\right\rangle}{(E_{q_i}+m_{q_i})(E_{q_k}+m_{q_k})}, \qquad (4)$$

which describes the interaction as sum of the interaction of individual pair of quarks and σ is $j-j$ coupling constant for Ξ_b^- baryon.

Magnetic Moment

In addition to the mass calculation, the magnetic moment of the baryon plays significant role in determining the internal structure of baryon. Magnetic moment which arises from the intrinsic spins and orbital motion of constituent quarks can be computed by the following equation

$$\mu_B = \sum_q < \phi_{sf}|\vec{\mu}_{qz}|\phi_{sf} >, \qquad (5)$$

where

$$\mu_q = \frac{e_q}{2M_q^{eff}}\sigma_q. \qquad (6)$$

*Electronic address: rameshri.patel1712@gmail.com
†Electronic address: mnshah09@gmail.com

Here, e_q and σ_q represent the charge and the spin of the quark, and $|\phi_{sf}>$ is spin-flavor wave function. Within the baryon the constituent quark possess additional inertia due to binding interaction among the bound quarks which is accounted through the effective mass M_q^{eff}, we define $M_q^{eff} = E_q(1 + \frac{<H>+E_{cm}}{\Sigma_q E_q})$.

TABLE I: S State mass of Ξ_b^- (In GeV).

State	V_{jj}	Mass	[2]	[8]	[9]	[10]
$1^2S_{\frac{1}{2}}$	-0.099	5.804	5.797	5.797	5.861	5.795
$1^4S_{\frac{3}{2}}$	0.059	5.962	5.956	5.955	5.932	5.942
$2^2S_{\frac{1}{2}}$	-0.077	6.149	-	6.189	-	6.189
$2^4S_{\frac{3}{2}}$	0.046	6.272	-	6.298	-	6.298
$3^2S_{\frac{1}{2}}$	-0.067	6.347	-	6.558	-	6.527
$3^4S_{\frac{3}{2}}$	0.040	6.454	-	6.623	-	6.595
$4^2S_{\frac{1}{2}}$	-0.061	6.487	-	6.907	-	6.853
$4^4S_{\frac{3}{2}}$	0.037	6.585	-	6.933	-	6.899
$5^2S_{\frac{1}{2}}$	-0.057	6.596	-	7.239	-	7.172
$5^4S_{\frac{3}{2}}$	0.034	6.688	-	7.230	-	7.206

TABLE II: Magnetic moment of Ξ_b^- (In GeV).

State	Expression	our	[11]	[12]
$\frac{1}{2}^+$	$\frac{2}{3}\mu_d+\frac{2}{3}\mu_s$-$\frac{1}{3}\mu_b$	-0.607	-0.963	-0.887
$\frac{3}{2}^+$	$\mu_d + \mu_s + \mu_b$	-1.015	-1.499	-1.048

Discussion

The calculated ground state masses fall very close to the experimental masses [2], which confirm the accuracy of the potential model adopted for the study. The present result also agree with other theoretical predictions [8–10] as shown in II. We predict the masses up to the 5^{th} radially excited state, and the masses predicted lies in the range $5.8 - 6.7\ GeV$. The orbital excitation of Ξ_b^- can also be calculated, for the comprehensive study of this baryon our predicted magnetic moment of $\Xi_b^-(\frac{1}{2}\&\frac{3}{2})$ states are in accordance with other model predictions [11, 12].

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