Ground State Masses of Singly Heavy Flavour Baryons in the Relativistic Framework

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Introduction

The measurement and calculation of baryonic ground and excited states are an important area of activity for worldwide experimental facilities such as CLEO, Belle, BABAR and LHCb as well as for lattice QCD calculations. Recently, five excited states of Ω_c were confirmed by LHCb and four were confirmed by Belle [1]. The investigation of properties of hadrons containing heavy quarks is of great interest in understanding the dynamics of QCD at the hadronic scale. We have calculated the ground state masses of singly heavy (spin-1/2 and spin-3/2) baryons by incorporating spin-spin interaction to get hyperfine splitting. The purpose of this study is to estimate ground state masses of heavy Baryons using Relativistic Dirac formalism. The mass spectra of the heavy Baryon is obtained from the relativistic independent quark model using a Martin-like potential for the quark confinement. The predicted ground state masses are in good agreement with the other theoretical predictions.

Theoretical Formalism

To study the heavy Baryons we have used Martin-like potential for quark confinement in relativistic approach. The form of the model potential is expressed as,

$$V(r) = \frac{1}{2}(1+\gamma_0)(\lambda\, r^{0.1} + V_0)$$

The wave function $\psi_q(\vec{r})$ satisfies the Dirac equation given by [2],

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

To obtain the binding energy of the quark (+ve energy) and the anti-quark (-ve energy) we have solved the Dirac equation. The solution of Dirac equation can be written in two component form as [2] but here for baryons we require only the positive energy solution as given by [2];

$$\psi_{nlj}(r) = \begin{pmatrix}\psi_A \\ \psi_B\end{pmatrix}$$

Where

$$\psi_A{}^{(+)}(\vec{r}) = N_{nlj}\begin{pmatrix}\frac{i\,g(r)}{r} \\ \frac{(\sigma.\hat{r})f(r)}{r}\end{pmatrix}\mathcal{Y}_{ljm}(\hat{r})$$

And N_{nlj} is the overall normalization constant.

The dimensionless energy Eigen value is given by [2],

$$\varepsilon = (E_{q_i} - m_{q_i} - V_0)\,(m_{q_i} + E_{q_i})^{1/21}\left(\frac{2}{\lambda}\right)^{\frac{20}{21}}$$

The singly heavy flavour baryon ($q_i q_j q_k$) masses,

$$M_{baryon} = \sum_{q_i=1}^{3}(E_{q_i} + m_{q_i}) - E_{CM}$$

Here, i *and* $1 \in \{b, c\}$ and j, k *and* $2,3 \in \{u, d, s\}$

The j–j coupling term is expressed as;

$$< V_{baryon}^{j_p j_q} > = \sigma \sum_{\substack{p\neq q \\ p,q=1}}^{3} \frac{< j_p j_q\, J\, M|\ \hat{j_p}\hat{j_q}|j_p j_q\, J\, M >}{(E_1+m_1)(E_2+m_2)(E_3+m_3)}$$

Here, σ is the j–j coupling constant.

And $< j_p j_q\, J\, M|\ \hat{j_p}\hat{j_q}|j_p j_q\, J\, M >$ Contains the square of the Clebsch–Gordan coefficient.

Table 1**:** The Ground state masses (MeV) of the singly heavy baryons with potential index 0.1 are shown in table.1

Baryon	Quark content	Spin=1/2 Our	Other[4]	Exp.[5]	Spin=3/2 Our	Other[4]	Exp. [5]	Hyperfine splitting
Σ_c^0	ddc	2488	2471	2453.7 ± 0.14	2508	2516	2518.4±0.2	20
Ω_c^0	css	2589	2696	2695.2±1.7	2784	2757	2765.9 ± 2.0	195
Ξ_c^+	cus	2419	2514	$2467.9\pm^{+0.28}_{-0.40}$	2436	2706	2645.9±0.5	17
Ξ_c^0	cds	2418	2494	$2470.8\pm^{+0.28}_{-0.40}$	2630	2680	2645.9± 0.5	212
Λ_c^+	cud	2477	2461	2283.4±0.14	2562	2526	-	85
Σ^+_b	buu	5815	5801	5811.3±1.9	5828	5834	5832.1±1.9	13
Σ_b^-	bdd	5740	5821	5815.5 ± 1.8	5829	5844	5835.1±1.9	89
Ω_b^-	bss	6001	6005	6046.4± 1.9	6023	6065	-	22
Ξ_b^-	bds	5897	5887	5794.5± 1.4	5959	5943	5955.3±0.13	62

Result and Discussion

Ground state masses of the singly heavy baryons have been computed in a relativistic framework using Martin like potential. The results obtained are listed in Table 1. Our computed ground state masses are in good agreement with the reported PDG [5] values of known states and it is also in accordance with available theoretical predictions.

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