

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],

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

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

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

And N_{nlj} is the overall normalization constant.

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

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

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

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

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;

$$\begin{aligned} & \langle V_{\text{baryon}}^{j_p j_q} \rangle \\ &= \sigma \sum_{\substack{p \neq q \\ p, q=1}}^3 \frac{\langle j_p j_q J M | \hat{J}_p \hat{J}_q | j_p j_q J M \rangle}{(E_1 + m_1)(E_2 + m_2)(E_3 + m_3)} \end{aligned}$$

Here, σ is the j - j coupling constant.

And $\langle j_p j_q J M | \hat{J}_p \hat{J}_q | j_p j_q J M \rangle$ 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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