Semi-leptonic and pionic decays of Doubly Strange baryons

N R Soni* and J N Pandya
Applied Physics Department, Faculty of Technology and Engineering, The M S University of Baroda, Vadodara, Gujarat, INDIA.

Introduction

The doubly strange b-baryon Ω_b^- was reported by $D0$ [1] and CDF [2] Collaboration through the channel $\Omega_b^- \to J/\psi\Omega^-$ at $\sqrt{1.96}$ TeV. Doubly strange c-baryon Ω_c^0 was observed by $E687$ [3] significantly in the channel of $\Omega_c^0 \to \Sigma^+ K^- K^- \pi^+$ and later was confirmed by other groups [4]. We employ the extended harmonic confinement model in order to understand semi leptonic and pionic decay modes of these states to compute their masses and decay widths.

Methodology

The mass of baryon in the N energy eigenstate and J spin state can be computed as[5]

$$M_N^J = \sum_{i=1}^{3} \epsilon_N(q_i)_{conf} + \sum_{i<j=1}^{3} \epsilon(q_i, q_j)_{coul} + \sum_{i<j=1}^{3} \epsilon_N^J(q_i, q_j)_{S.D.} \quad (1)$$

where the first term is the confinement part, second term is due to the Coulomb interaction between the constituent quarks and the third term corresponds to the spin-dependent interactions.
The confinement energy of the baryonic system is given by [6],

$$\epsilon(q)_{conf} = \sqrt{(2N+3)\Omega_N(q) + M_q^2 - \frac{3M_q}{\sum_{i=1}^{3} M_{q_i}}}$$

where the size parameter, $\Omega_N(q)$ of RHM radial wave function is energy dependent and is given by

$$\Omega_N(q) = A\sqrt{E_N + M_q} \quad (2)$$

M_q is the constituent quark mass. The Coulomb of eq. 1 can be computed as

$$\epsilon(q_1, q_2)_{coul} = \left\langle NS \left| \frac{k\alpha_s^{eff}}{r} \right| NS \right\rangle \quad (3)$$

where α_s^{eff} is the strong running coupling coefficient. The spin-spin interaction is computed using the spin hyperfine interaction of the residual confined one gluon exchange potential [5–9]

$$V_{\sigma_i \cdot \sigma_j} = \frac{\alpha_s(\mu) N_i^2 N_j^2}{4} \frac{\lambda_i \lambda_j}{[E_i + m_i][E_j + m_j]} \times \left[4\pi\delta^3(r) - C^4 r^2 D_1(r)\right] \left(-\frac{2}{3}\sigma_i \sigma_j\right)$$

where $N_{i/j}$ is the normalization constant, C is the confinement strength of the gluon, r is the inter-quark distance, $\lambda_i \lambda_j$ is the spin factor, $D_1(r)$ is the confined gluon propagator and can be fitted to $\sim \frac{k_1}{r} exp(-C^2 r^2/2)$ [7, 8].

$$\epsilon_N^J(q_i, q_j)_{S.D.} = \langle NS | V_{SD} | NS \rangle \quad (4)$$

Here we have used m_b = 4829 MeV, m_c = 1479 MeV and m_s = 410 MeV. The potential parameters k, k_1 and C are fine tuned to obtain the experimental mass of Ω^-. The parameters used in this computation are k = 0.006, k_1 = 21.36 and C = 100 MeV.

Decay of Doubly strange baryons

In this section we compute the decay of Ω_c^0 and Ω_B^- baryon. The general definition for the semi-electronic decay width is given by [10]

*Electronic address: nakulphy@gmail.com

$$\frac{d\Gamma}{dw} = \frac{G_f^2 M^5}{192\pi^3}|V_{CKM}|^2\sqrt{w^2-1}P(w) \quad (5)$$

where $P(w)$ contains the hadronic and leptonic tensor. After evaluating the integration over $w = 1$ in the hadronic form factors one will get the following relation for the decay width for electronic $(1/2)^+ \to (1/2)^+$ transition [10]

$$\Gamma_{\Omega^{0/-}_{c/b} \to \Xi^{+/0}_{c/b} e^- \bar{\nu}} = \frac{G_f^2|V_{CKM}|^2}{15\pi^3}(M-m)^5 \quad (6)$$

where G_f is the Fermi coupling constant. The pionic decay width using the transition amplitude is computed using [10]

$$\Gamma_{\Omega_b^- \to \Xi_b^0 \pi^-} = \frac{(\Delta M)^{\frac{3}{2}}}{192\pi M^7}|A((ss)_1 \to (us)_0\pi^-)|^2$$

here $\Delta M = [M^2-(m-m_\pi)^2][M^2-(m+m_\pi)^2]$ and the weak di-quark decay amplitude can be approximated with $|a_{weak}| \sim (1...2)\times 10^{-6}$ as [10]

$$A((ss)_1 \to (us)_0\pi^-) \sim 2MV_{us}V_{ud}^* a_{weak}$$

Where V_{us} and V_{ud} are the CKM matrices. We compute the semi-leptonic and pionic decay widths of Ω_c^0 and Ω_b^- without any additional parameters and the results are given in the table II.

Conclusion

The ground state masses of Ω_c^0 and Ω_b^- are computed using the methodology explained in the first section and compared with the experimental data. We also compute the semi-leptonic and pionic decay widths of Ω_c^0 and Ω_b^-. It is observed from table II that our results are well within the range as proposed by [10].

Acknowledgments

This work is supported by the University Grants Commission of India under Major Research Project F.No.42-775/2013(SR)

TABLE I: ground state masses in MeV

State	quark content	present	[11]
Ω_c^0	css	2694.63	2695.2 ± 1.7
Ω_b^-	bss	6049.58	6048.8 ± 3.2

TABLE II: baryonic decay widths in GeV

mode of decay	present	[10]
$\Omega_c^0 \to \Xi_c^+ e^- \bar{\nu}$	9.05×10^{-18}	2.6×10^{-18}
$\Omega_c^0 \to \Xi_c'^+ e^- \bar{\nu}$	3.65×10^{-19}	3.63×10^{-19}
$\Omega_b^0 \to \Xi_b^0 e^- \bar{\nu}$	16.17×10^{-18}	4.05×10^{-18}
$\Omega_b^- \to \Xi_b^0 \pi^-$	0.93×10^{-18}	$(0.7...2.6) \times 10^{-18}$
$\Omega_b^- \to \Xi_b^- \pi^0$	0.91×10^{-18}	$(0.3...1.3) \times 10^{-18}$

References

[1] V. M. Abazov et al. (D0 Collaboration)Phys. Rev. Lett. **101**, 232002 (2008)

[2] T. AALTONEN et al. (CDF Collaboration) Phys. Rev. D **80**, 072003 (2009)

[3] P. L. Frabetti et al. (E687 Collaboration), Phys. Lett. B **338**, 106 (1994)

[4] D. Cronin-Hennessy et al. (CLEO Collaboration), Phys. Rev. Lett. **86**, 3730 (2001), B. Aubert et al. (BaBar Collaboration), Phys. Rev. Lett. **97**, 232001 (2006) , C. Amsler et al., Phys. Lett. B **667**, 1 (2008)

[5] P C Vinodkumar, J N Pandya, V M Bannur and S B Khadkikar, Euro. J. Phys. A **4**, 83 (1999)

[6] S B Khadkikar and S K Gupta, Phys. Lett. B **124**, 523 (1983)

[7] S B Khadkikar and K B Vijayakumar, Phys. Lett. B **254**, 320 (1991)

[8] S B Khadkikar and K B Vijayakumar, Pramana J. Phys. **36**, 557 (1991), P C Vinodkumar, K B Vijayakumar and S B Khadkikar, Pramana J. Phys. **39**, 47 (1992)

[9] K B Vijayakumar and S B Khadkikar, Nucl. Phys. A **556**, 396 (1993)

[10] Sven Fallera and Thomas Mannela arXiv:1503.06088v2 [hep-ph]

[11] K.A. Olive et al. (Particle Data Group), Chin. Phys. C, **38**, 090001 (2014)