Strong decay of singly heavy baryon in the relativistic quark model

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Introduction

On account to the rich mass spectrum and relatively narrow widths of the excited states, the charmed baryon system offers an excellent ground for testing the ideas and predictions of heavy quark symmetry. Here, we study the strong decays of singly heavy (charmed and bottom) baryons from Dirac relativistic formalism.

Theoretical Methodology

The quarks within the baryon is assumed to be subjected to a mean field corresponds to the form of linear potential. The form of the mean field potential is thus expressed as [1]

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

Here, λ is the strength of the linear part of the potential and V_0 is a constant negative potential depth. The wave functions $\psi(\vec{r})$ satisfies the Dirac equation given by,

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

To get the binding energy of the quarks, we have solved the two component Dirac equation [1–4]. As we are interested to have the energy of the quarks (positive energy), the positive energy solution only is expressed as,

$$\psi_A^{(+)}(\vec{r}) = N_{nlj}\begin{pmatrix} \frac{ig(r)}{r} \\ \frac{(\sigma.\hat{r})f(r)}{r} \end{pmatrix}\mathcal{Y}_{ljm}(\hat{r}) \quad (3)$$

with the energy eigen value as [1],

$$\epsilon = (E_q - m_q - V_0)(m_q + E_q)^{\frac{1}{3}}\lambda^{\frac{-2}{3}} \quad (4)$$

are considered here.

The mass of particular three quark system $(q_1q_2q_3)$ can be written as

$$M_{q_1q_2q_3} = (E_{q_1}+m_{q_1})+(E_{q_2}+m_{q_2})+(E_{q_3}+m_{q_3})-E_{123}^{cm} \quad (5)$$

where $(E_{q_i}+m_{q_i})$ corresponds to the confined energy of respected quarks constituting the baryon. E_{123}^{cm} is the center of mass correction.

Strong decay of singly heavy flavour baryons

From unique importance of many decay processes in hadron spectroscopy, strong decays are expected to dominate the branching ratio. The decay mode is through one- and two- pion transition which was experimentally detected for charmed baryon. The strong interaction decay width can be estimated as [9, 12],

$$\Gamma\{(\Sigma_Q^*/\Lambda_Q^*/\Xi_Q^*) \rightarrow (\Sigma_Q/\Lambda_Q/\Xi_Q),\pi\} = \frac{g_A^2}{2\pi f_\pi^2}\frac{M_{(\Sigma_Q/\Lambda_Q/\Xi_Q)}}{M_{(\Sigma_Q^*/\Lambda_Q^*/\Xi_Q^*)}} \times |\vec{P}_\pi|^3$$

where g_A is axial vector coupling constant, f_π is the decay constant of π meson, and P_π is the pion momentum. The pion momentum $|P_\pi|^2$ in the rest frame of the decaying particles can be obtained by

$$|P_\pi|^2 = \frac{(M^2 + m_\pi^2 + m^2)}{4M^2} - m_\pi^2 \quad (6)$$

Here, M, m_π and m are mass of decaying baryon, mass of pion and mass of outgoing baryon respectively.

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TABLE I: Strong one pion decay rates for Singly charmed baryons (in MeV)

Decay Mode	Γ	[5]	[6]	[7]	[8]
$\sum_c^{++} \to \Lambda_c^+ \pi^+$	6.41	2.34	2.41 $\pm$ 0.07	2.5	1.64
$\sum_c^{+} \to \Lambda_c^+ \pi^0$	6.41	2.59	2.79 $\pm$ 0.08	3.2	1.70
$\sum_c^{0} \to \Lambda_c^+ \pi^-$	6.41	2.21	2.37 $\pm$ 0.07	2.4	1.57
$\sum_c^{*++} \to \Lambda_c^+ \pi^+$	33.71	21.34	17.52 $\pm$ 0.75	-	12.84
$\sum_c^{*+} \to \Lambda_c^+ \pi^0$	33.71	12.83	15.31 $\pm$ 0.74	25	-
$\sum_c^{*0} \to \Lambda_c^+ \pi^-$	33.71	20.97	16.90 $\pm$ 0.97	-	12.40
$\Xi_c^{*0}/\Xi_c^{*+} \to \Xi_c^0/\Xi_c^+ \pi^0$	7.41	-	-	-	-

TABLE II: Strong one pion decay rates for Singly bottom baryons (in MeV)

Decay Mode	Γ	[9]	[10]	[11]	[12]
$\sum_b^* \to \Lambda_b \pi$	6.17	12.44	6.73 - 13.40	8.00	4.63
$\sum_b \to \Lambda_b \pi$	13.37	22.85	10.00 - 17.54	15.00	8.74
$\sum_b^* \to \sum_b \pi$	4.56	-	-	-	0.055
$\Xi_b^{*0}/\Xi_b^{*-} \to \Xi_b^0/\Xi_b^- \pi^0$	7.41	-	-	-	0.14/0.28

Results and Conclusion

The strong decay mode is important to extract the information about the internal structure of hadrons and low energy dynamics of heavy baryons. The strong decays are calculated for singly charmed and bottom baryons and compared with other calculated results. Our calculated decay widths of charmed baryon is higher than the other model predictions. Two decay widths of bottom baryon are comparable with other model predictions, but other two decay widths are over estimated to other predictions. The few experimental results (PDG) [13] of strong decay widths of baryon are available, but our predicted decay widths of charmed baryons are higher than the experimental results.

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