Semi-electronic decays of singly heavy baryons

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Introduction

Singly heavy baryons are made up of two light quark and one heavy quark. Many excited states of these baryons are discovered by expeimental facilities like LHC and Belle recently and new more precise data are expected in near future [1]. The ground, radial and orbital excited states are also predicted by many theoretical approaches [2–6].

Weak decays of heavy hadrons play a crucial role to understand the heavy quark physics. In these decays the heavy quark(c or b) acts as a spectator and the light quark inside heavy hadron decays in weak interaction [7–9]. The transition can be s $\to$ u or d $\to$ u depending on the available phase space. These kind of small phase space transition could be possible in weak decays of baryons and mesons, such as, semi-electronic, semi-muonic and non leptonic decays. In this paper, we discuss, semi-electronic weak decays of heavy baryons; Ω_c, Ξ_c, Ξ_b and Ω_b using our spectral parameters [6].

Methodology

To calculate weak decay rates of heavy baryons it is necessary to determine the form factors. For that, we need to look at the transition in light-quark system in the colour background created by the (static) heavy quark. This picture allows us to obtain information on the form factors.

The differential decay rates for the semi-electronic decays are given by [8],

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

where $P(w)$ contains the hadronic and leptonic tensor. Assuming that the form factors are slowly varying functions of the kinematic variables, we may replace all form factors by their values at variable w=1. After evaluating the integration over w=1 in the hadronic form factors we study the weak decays given below. For the final state with "Λ" baryon,

$$\Gamma^{\frac{1}{2}^+ \to \frac{1}{2}^+}_{0^+\to 0^+} = \frac{G_F^2|V_{CKM}|^2}{60\pi^3}(M-m)^5 \quad (2)$$

For the final state with "Σ" baryon,

$$\Gamma^{\frac{1}{2}^+ \to \frac{3}{2}^+}_{0^+\to 1^+} = \frac{G_F^2|V_{CKM}|^2}{30\pi^3}(M-m)^5|A(1)|^2 \quad (3)$$

For the final state with "Ξ" baryon,

$$\Gamma^{\frac{1}{2}^+ \to \frac{1}{2}^+}_{1^+\to 1^+} = \frac{G_F^2|V_{CKM}|^2}{15\pi^3}(M-m)^5 \quad (4)$$

where G_F is the Fermi Coupling constant and the value of $G_F = 1.16 \times 10^{-5}\text{GeV}^{-2}$, V_{CKM} is the Cabibo-Kobayashi-Maskawa matrix and we have taken the value of V_{CKM}=0.225. Values are taken from PDG[1] and $|A(1)|^2$=1. The superscript of Γ indicates spin parity transition ($J^P \to J'^{P'}$) of baryon , while the subscripts of Γ indicate spin parity transition ($s^l \to s'^{l'}$) of light degrees of freedom. We have determined the masses of the singly heavy baryons using Hypercentral Constituent quark model(hCQM) with coloumb plus liner potential [6]. These masses are used for $J^P = \frac{1}{2}^+, \frac{3}{2}^+$.

The obtained results for the different channels are tabulated in Table 1. In second column of table 1, we list initial and final total angular momentum (J) and parity (P) and in third column we give initial and final total spin s_l of the light degree of freedom. Where, $\triangle m$ = M - m, is a the mass difference between initial and final state of baryons.

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TABLE I: Semi-electronic decays in $s \to u$ transition for charm and bottom baryons are listed.

	Mode	$J^P \to J'^{P'}$	$s^l \to s'^{l'}$	$\triangle m$ (GeV)	Decay Rates (GeV)	[8] (GeV)
Charm sector	$\Xi_c^0 \to \Lambda_c^+ e^- \bar{\nu}$	$\frac{1}{2}^+ \to \frac{1}{2}^+$	$0 \to 0$	0.184	7.839×10^{-19}	7.91×10^{-19}
	$\Xi_c^0 \to \Sigma_c^+ e^- \bar{\nu}$	$\frac{1}{2}^+ \to \frac{1}{2}^+$	$0 \to 0$	0.018	7.023×10^{-24}	6.97×10^{-24}
	$\Xi_c^+ \to \Sigma_c^{*++} e^- \bar{\nu}$	$\frac{1}{2}^+ \to \frac{3}{2}^+$	$0 \to 1$	0.013	2.760×10^{-24}	3.74×10^{-24}
	$\Omega_c^0 \to \Xi_c^+ e^- \bar{\nu}$	$\frac{1}{2}^+ \to \frac{1}{2}^+$	$1 \to 0$	0.228	2.290×10^{-18}	2.26×10^{-18}
	$\Omega_c^0 \to \Xi_c^{*+} e^- \bar{\nu}$	$\frac{1}{2}^+ \to \frac{3}{2}^+$	$1 \to 1$	0.071	2.436×10^{-28}	1.49×10^{-29}
Bottom sector	$\Xi_b^- \to \Lambda_b^0 e^- \bar{\nu}$	$\frac{1}{2}^+ \to \frac{1}{2}^+$	$0 \to 0$	0.174	5.928×10^{-19}	6.16×10^{-19}
	$\Omega_b^- \to \Xi_b^0 e^- \bar{\nu}$	$\frac{1}{2}^+ \to \frac{1}{2}^+$	$1 \to 0$	0.255	4.007×10^{-18}	4.05×10^{-18}
	$\Omega_b^- \to \Xi_b^{*0} e^- \bar{\nu}$	$\frac{1}{2}^+ \to \frac{3}{2}^+$	$1 \to 1$	0.101	1.675×10^{-26}	3.27×10^{-28}

Conclusion

The strange baryon with heavy flavor charm/bottom quark undergo weak transitions. The quark transitions for the singly charmed baryon (Ξ_c^0, Ξ_c^+ and Ω_c^0) and singly bottom baryons (Ξ_b^- and Ω_b^-) are tabluated in Table 1. The obtained results are in good accordance with Ref. [8]. Similarly we can obtain the weak decays for doubly heavy baryons [10]. We will calculate the muonic and pionic weak decays of strange baryons in our future study.

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