Strong Decay of Singly Heavy Bottom-strange Baryons

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Introduction

In the last two decades, progress has been achieved towards understanding the fundamental nature of the hadrons that consist of single bottom quarks. The mass spectra and characteristics of heavy baryons have been the subject of a significant amount of research, both experimental and theoretical. There have been several bottom baryon decay channels observed at experimental facilities in worldwide [1–5], and a significant quantity of information on heavy baryons has been collected. And Partcle Data Group (PDG) also established the singly bottom states [6].

One bottom quark (b), one strange quark (s), and one of the two light quarks (u or d) are make up the singly-heavy bottom-strange baryons. The heavy hadron chiral perturbation theory (HHChPT) is used to investigate the strong decays of these baryons, this structure provides an essential basis for assessing the Heavy Quark Symmetry (HQS) of the bottom quark (heavy quark) and the chiral symmetry of the light quarks [7, 8]. The masses used to investigate decay properties are calculated by Hypercentral Constituent Quark Model (hCQM). The hCQM is a non-relatrivistic perturbative approach, which simplifies the three body problem to one body problem. The detailed information of hCQM can be found in Refs. [9–12]. The masses can be also obtained by using other theoretical models such as flux tube model [13], Regge phenomenology [14] etc. .

When the baryonic states decays into any hadronic state is called strong decay, which obeys all conservation laws. In this work, some of strong decay channels are investigated to acquire information about the behavior of heavy quark in presence of light quarks and the changing of quantum number hierarchy. The strong decay width calculation has been done by our group for singly charm baryons [15, 16]. The same scheme has been carried out further for singly bottom baryons [17, 18].

Method

The strong decay transition are classified in three types: P-wave, S-wave and D-wave transition; P-wave transition is transition between s-wave baryons, S-wave transition is transition between s-wave to p-wave($J^P = \frac{1}{2}$) baryons and D-wave transition is transition between p-wave($J^P = \frac{3}{2}, \frac{5}{2}$) to s-wave baryons. The decay widths for P-wave, S-wave and D-wave transitions have been enumerated in this work using the Lagrangian given in Ref. [7].

The expression of the decay width for P-wave transitions $\Xi_b^0(1^2S_{\frac{3}{2}}) \rightarrow \Xi_b^0\pi$, $\Xi_b^-(1^2S_{\frac{3}{2}}) \rightarrow \Xi_b^-\pi$ and $\Xi_b^{'-}(1^2S_{\frac{3}{2}}) \rightarrow \Xi_b^-\pi$ respectively is [19],

$$\Gamma = \frac{a_1^2}{8\pi f_\pi^2}\frac{M_{\Xi_b^{0,-}}}{M_{\Xi_b^{0,-,'-}}(1^2S_{\frac{3}{2}})}p_\pi^3 \qquad (1)$$

And the expressions of the decay width for P-wave transitions $\Xi_b^0(1^2S_{\frac{3}{2}}) \rightarrow \Xi_b^-\pi$, $\Xi_b^-(1^2S_{\frac{3}{2}}) \rightarrow \Xi_b^0\pi$ and $\Xi_b^{'-}(1^2S_{\frac{3}{2}}) \rightarrow \Xi_b^0\pi$ respectively is [19],

$$\Gamma = \frac{a_1^2}{4\pi f_\pi^2}\frac{M_{\Xi_b^{-,0}}}{M_{\Xi_b^{0,-,'-}}(1^2S_{\frac{3}{2}})}p_\pi^3 \qquad (2)$$

where, strong coupling constant $a_1 = 0.565$ [19], the pion decay constant $f_\pi = 132$ MeV. Masses of initial and final baryon state have been taken as listed in our article [18].
p_π^3 represents the P-wave transition momentum [8] (for two body decay $x \rightarrow y + \pi/K$)

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which can be expressed as,

$$p_{\pi/K} = \frac{1}{2m_x}\sqrt{[m_x^2 - (m_y + m_\pi/m_K)^2]} \sqrt{[m_x^2 - (m_y - m_\pi/m_K)^2]} \quad (3)$$

TABLE I: Strong decay width of doubly heavy bottom-strange baryons (in MeV).

Decay channel	Decay width	[21]	[22]
$\Xi_b^{*0} \to \Xi_b^0 + \pi^0$	0.339	0.20	1.3
$\Xi_b^{*0} \to \Xi_b^- + \pi^+$	0.398		
$\Xi_b^{*-} \to \Xi_b^- + \pi^0$	0.265	0.40	1.3
$\Xi_b^{*-} \to \Xi_b^0 + \pi^-$	0.839		
$\Xi_b^0(1P) \to \Xi_b^{*0} + \pi^0$	1.783		
$\Xi_b^0(1P) \to \Xi_b^{*-} + \pi^+$	3.399		
$\Omega_b^-(1P) \to \Xi_b^0 + \bar{K}^-$	445.1		
$\Xi_b^-(1P) \to \Xi_b^- + \pi^0$	1.517		
$\Omega_b^-(1P) \to \Xi_b^0 + \bar{K}^-$	0.489		

The expressions for other decay channels are given in Ref. [18]. Decay width for some decay channels of Ξ_b and Ω_b baryons are listed in Table I.

Conclusion

In the absence of any experimental result, we have compared our results with the results presented in Refs. [21] and [22]. The strong decay width of several channels (P-wave, S-wave, and D-wave of singly heavy bottom-strange baryons) is evaluated in the Heavy Hadron Chiral Perturbaation Theory (HHChPT). The results shown in the table do not all correspond to one another in a way. More efforts has to be put into studying the decay properties of these baryons since those qualities are extremely important for the internal structure of baryonsin both the fronts, experimental as well as theoretical.

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