Bottom baryon decays to pseudoscalar meson and pentaquark

Hai-Yang Cheng[1] and Chun-Khiang Chua[2]

[1]*Institute of Physics, Academia Sinica, Taipei, Taiwan 115, Republic of China*
[2]*Department of Physics and Center for High Energy Physics, Chung Yuan Christian University, Chung-Li, Taiwan 320, Republic of China*

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Based on SU(3) flavor symmetry, we decompose the decay amplitudes of bottom baryon decays to a pseudoscalar meson and an octet (a decuplet) pentaquark in terms of three (two) invariant amplitudes T_1 and $T_{2,3}$ ($\tilde{T}_1$ and $\tilde{T}_2$) corresponding to external W-emission and internal W-emission diagrams, respectively. For antitriplet bottom baryons Λ_b^0, Ξ_b^0, and Ξ_b^-, their decays to a decuplet pentaquark proceed only through the internal W-emission diagram. Assuming the dominance from the external W-emission amplitudes, we present an estimate of the decay rates relative to $\Lambda_b^0 \to P_p^+ K^-$, where P_p^+ is the hidden-charm pentaquark with the same light-quark content as the proton. Hence, our numerical results will provide a very useful guideline to the experimental search for pentaquarks in bottom baryon decays. For example, $\Xi_b^0 \to P_{\Sigma^+} K^-$, $\Xi_b^- \to P_{\Sigma^-} \bar{K}^0$, $\Omega_b^- \to P_{\Xi^-} \bar{K}^0$, and $\Omega_b^- \to P_{\Xi^0} K^-$ may have rates comparable to that of $\Lambda_b^0 \to P_p^+ K^-$ and these modes should be given the higher priority in the experimental searches for pentaquarks.

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I. INTRODUCTION

The LHCb Collaboration has recently announced two hidden-charm pentaquark-like resonances $P_c(4380)^+$ and $P_c(4450)^{+1}$ in the $J/\psi p$ invariant mass spectrum through the $\Lambda_b^0 \to J/\psi p K^-$ decay [1]. The measured masses and widths are

$$\begin{aligned} &M = 4380 \pm 8 \pm 29 \text{ MeV}, \qquad \Gamma = 205 \pm 18 \pm 86 \text{ MeV}, \\ &\quad \text{for } P_c(4380)^+, \\ &M = 4449.8 \pm 1.7 \pm 2.5 \text{ MeV}, \quad \Gamma = 39 \pm 5 \pm 19 \text{ MeV}, \\ &\quad \text{for } P_c(4450)^+. \end{aligned} \tag{1}$$

The best-fit solution has spin-parity J^P values of $(3/2^-, 5/2^+)$, though acceptable solutions are also found for additional cases with opposite parity, either $(3/2^+, 5/2^-)$ or $(5/2^+, 3/2^-)$. LHCb has also reported the branching fractions of $\Lambda_b^0 \to P_c^+(\to J/\psi p)K^-$ to be [2]

$$\begin{aligned} &\mathcal{B}(\Lambda_b^0 \to P_c^+ K^-)\mathcal{B}(P_c^+ \to J/\psi p) \\ &\quad = \begin{cases} (2.56 \pm 0.22 \pm 1.28^{+0.46}_{-0.36}) \times 10^{-5} & \text{for } P_c(4380)^+, \\ (1.25 \pm 0.15 \pm 0.33^{+0.22}_{-0.18}) \times 10^{-5} & \text{for } P_c(4450)^+. \end{cases} \end{aligned} \tag{2}$$

The valence-quark content of the pentaquark-like resonance is $\bar{c}cuud$. If this new resonance is indeed a genuine pentaquark state, it is natural to ask what is its nature (such as spin-parity quantum numbers, mass, and the internal structure) and what are the dynamical properties (such as strong and weak decays). Many models have been proposed recently to explain the hidden-charm pentaquarks, including (i) a cluster structure for quarks inside the pentaquark (for example, two colored diquarks bound with an antiquark [3–5], a model originally proposed by Jaffe and Wilczek [6], or one diquark and one triquark [7] as originally advocated by Karliner and Lipkin [8]), (ii) the charmed meson-charmed baryon molecular state [for example, $P_c(4380)^+$ and $P_c(4450)^+$ being $\bar{D}\Sigma_c^*$ and $\bar{D}^*\Sigma_c$ molecular states, respectively [9–13]],[2] (iii) a composite $\chi_{c1}p$ state for $P_c(4450)^+$ [14], (iv) composite $J/\psi N(1440)$ and $J/\psi N(1550)$ states for $P_c(4380)$ and $P_c(4450)$ [15], respectively, (v) soliton states for pentaquarks [16], and (vi) threshold enhancement or kinematic effect [4,17–20].

If the pentaquark resonances discovered by the LHCb Collaboration in $\Lambda_b^0 \to J\psi p K^-$ are genuine states, it will be quite important to search for them in other bottom baryon decays, in inclusive production at the LHC and e^+e^- factories, and in photoproduction off a proton target [15,21,22]. Since the LHC can produce a huge number of bottom baryons in addition to Λ_b's, it can provide a rich source for the pentaquark production in bottom baryon decays. Under SU(3) symmetry the pentaquark state can be

[1]Starting in the next section and thereafter we will use $P_\mathcal{B}$ to denote the hidden-charm pentaquark with the same light-quark content as the octet or decuplet baryon $\mathcal{B}$. Hence, P_c^+ with the $\bar{c}cuud$ quark content will be denoted by P_p^+ in our notation.

[2]Because of their opposite parities, $P_c(4380)$ and $P_c(4450)$ cannot be both the S-wave states of $\bar{D}\Sigma_c^*$ and $\bar{D}^*\Sigma_c$, respectively. The assignment is opposite that in Ref. [10] where $P_c(4380)$ was identified with $\bar{D}^*\Sigma_c$ and $P_c(4450)$ with the admixture of $\bar{D}\Sigma_c^*$ and $\bar{D}^*\Lambda_c$.

in the octet or decuplet representation. Under a plausible assumption on the relative importance of decay amplitudes, we give an estimate on the decay rates relative to $\Lambda_b^0 \to P_c^+ K^-$. Hence, our numerical results will provide a very useful guideline to the experimental search for pentaquarks in bottom baryon decays.

This work is organized as follows. In Sec. II we set up the formulism. Under SU(3) flavor symmetry, the bottom baryon decays to a pseudoscalar meson and an octet or a decuplet pentaquark can be expressed in terms of three invariant amplitudes which correspond to two different types of W-emission diagrams. Assuming the dominance of one of the W-emission amplitudes, we proceed to show in Sec. III the numerical estimates for the decay rates relative to $\Lambda_b^0 \to P_c^+ K^-$. Section IV gives our conclusions.

II. FORMALISM

The flavor structure of the weak Hamiltonian governing a weak $\Delta S = -1$ decay at tree level is expressed as

$$\mathcal{O}_T \sim (\bar{c}b)(\bar{s}c) = H^i(\bar{c}b)(\bar{q}_i c), \qquad H^i = \delta_{i3}, \quad (3)$$

where $\bar{q}_{1,2,3} = \bar{u}, \bar{d}, \bar{s}$, respectively, and H^i is a spurion field. The above expression is also applicable to the $\Delta S = 0$ case with the s-quark field replaced by the d-quark one, and with the spurion field defined as $H^i = \delta_{i2}$.

The new charmonium-like pentaquarks were observed by LHCb as $J/\psi + p$ resonances produced in Λ_b^0 decays. Since a proton transforms as an octet under SU(3), the pentaquarks should also belong to octet multiplets. For octet pseudoscalar and pentaquark multiplets, we write

$$\Pi = \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \frac{\eta_8}{\sqrt{6}} & \pi^+ & K^+ \\ \pi^- & -\frac{\pi^0}{\sqrt{2}} + \frac{\eta_8}{\sqrt{6}} & K^0 \\ K^- & \bar{K}^0 & -\sqrt{\frac{2}{3}}\eta_8 \end{pmatrix},$$

$$\mathcal{P} = \begin{pmatrix} \frac{P_{\Sigma^0}}{\sqrt{2}} + \frac{P_\Lambda}{\sqrt{6}} & P_{\Sigma^+} & P_p \\ P_{\Sigma^-} & -\frac{P_{\Sigma^0}}{\sqrt{2}} + \frac{P_\Lambda}{\sqrt{6}} & P_n \\ P_{\Xi^-} & P_{\Xi^0} & -\sqrt{\frac{2}{3}}P_\Lambda \end{pmatrix}, \quad (4)$$

where we have denoted P_p as the hidden-charm pentaquark with the same light-quark content as the proton and likewise for other pentaquark fields. Note that $\mathcal{P}_k^j$ has the flavor structure $\bar{c}c(q^j q^a q^b \epsilon_{abk} - \frac{1}{3}\delta_k^j \epsilon^{abl} q^l q^a q^b)$. To match the flavor of $q_i\bar{q}^j$ and $\bar{c}cq_jq_kq_l$ final states in bottom baryon decays as depicted in Fig. 1(a), for example, we use[3]

$$q_i\bar{q}^j \to \Pi_i^j, \qquad \bar{c}cq_jq_kq_l \to \epsilon_{jka}\bar{\mathcal{P}}_l^a, \qquad \epsilon_{jal}\bar{\mathcal{P}}_k^a, \qquad \epsilon_{akl}\bar{\mathcal{P}}_j^a \quad (5)$$

as the corresponding rules in obtaining $H_{\rm eff}$.[4] Note that the right-hand side of the above equation contains all possible permutations of j, k, l. In fact, not all terms are independent as there is an identity, $\epsilon_{ika}\bar{\mathcal{P}}_l^a + \epsilon_{ial}\bar{\mathcal{P}}_k^a + \epsilon_{akl}\bar{\mathcal{P}}_i^a = 0$. Therefore, for the $\bar{c}cq_kq_jq_l$ configuration we only need two independent terms. We will choose two of them for our convenience.

We now come to the initial state. The low-lying bottom baryons can be classified into an antitriplet $\mathcal{B}_a$ and a sextet $\mathcal{B}^{kl}$ under SU(3):

$$\mathcal{B}_a = (\Lambda_b^0, \Xi_b^0, \Xi_b^-), \qquad \mathcal{B}^{kl} = \begin{pmatrix} \Sigma_b^+ & \frac{\Sigma_b^0}{\sqrt{2}} & \frac{\Xi_b'^0}{\sqrt{2}} \\ \frac{\Sigma_b^0}{\sqrt{2}} & \Sigma_b^- & \frac{\Xi_b'^-}{\sqrt{2}} \\ \frac{\Xi_b'^0}{\sqrt{2}} & \frac{\Xi_b'^-}{\sqrt{2}} & \Omega_b^- \end{pmatrix}. \quad (6)$$

While all the bottom baryons in the $\bar{\mathbf{3}}$ representation decay weakly, only Ω_b^- in the $\mathbf{6}$ representation decays weakly. We can project bq^kq^l in Fig. 1 to an antitriplet state or a sextet state according to the following rule:

$$bq^kq^l \to \epsilon^{kla}\mathcal{B}_a, \qquad \mathcal{B}^{kl}. \quad (7)$$

We can now write down the effective Hamiltonian in terms of hadronic degrees of freedom. Using the above corresponding rules, we obtain[5]

$$\begin{aligned} H_{\rm eff} = {}& \epsilon^{kla}\mathcal{B}_a H^i \Pi_i^j (\epsilon_{jkb}\bar{\mathcal{P}}_l^b T_{1'} + \epsilon_{jbl}\bar{\mathcal{P}}_k^b T_{1''}) \\ &+ \epsilon^{kla}\mathcal{B}_a H^i \Pi_l^j (\epsilon_{ikb}\bar{\mathcal{P}}_j^b T_2 + \epsilon_{bkj}\bar{\mathcal{P}}_i^b T_3) \\ &+ \mathcal{B}^{kl} H^i \Pi_i^j (\epsilon_{jka}\bar{\mathcal{P}}_l^a t_{1'} + \epsilon_{jal}\bar{\mathcal{P}}_k^a t_{1''}) \\ &+ \mathcal{B}^{kl} H^i \Pi_l^j (\epsilon_{ika}\bar{\mathcal{P}}_j^a t_2 + \epsilon_{akj}\bar{\mathcal{P}}_i^a t_3), \end{aligned} \quad (8)$$

where $T_{1',1''}(t_{1',1''})$ terms correspond to the external W emission of Fig. 1(a), and $T_{2,3}(t_{2,3})$ to the internal W emission of Fig. 1(b). By interchanging k and l indices in the second and fourth terms and replacing $T_{2,3}(t_{2,3})$ by $T_{4,5}(t_{4,5})$, we obtain the contributions from Fig. 1(c). However, the additional $T_{4,5}(t_{4,5})$ terms are identical to the $T_{2,3}(t_{2,3})$ ones up to a sign and can be absorbed in $T_{2,3}(t_{2,3})$. With the help of the spurion field H^i, this effective Hamiltonian has the same SU(3) property as the

[3]The procedure is similar to the one used in Refs. [23,24].

[4]We use a subscript and a superscript according to the field convention. For example, we assign a superscript (subscript) to the initial (final) quark state q^k (q_k).

[5]To incorporate the SU(3)-singlet state η_1, we will make use of U(3) symmetry by adding $\delta_i^j\eta_1/\sqrt{3}$ to the Π_i^j matrix elements.

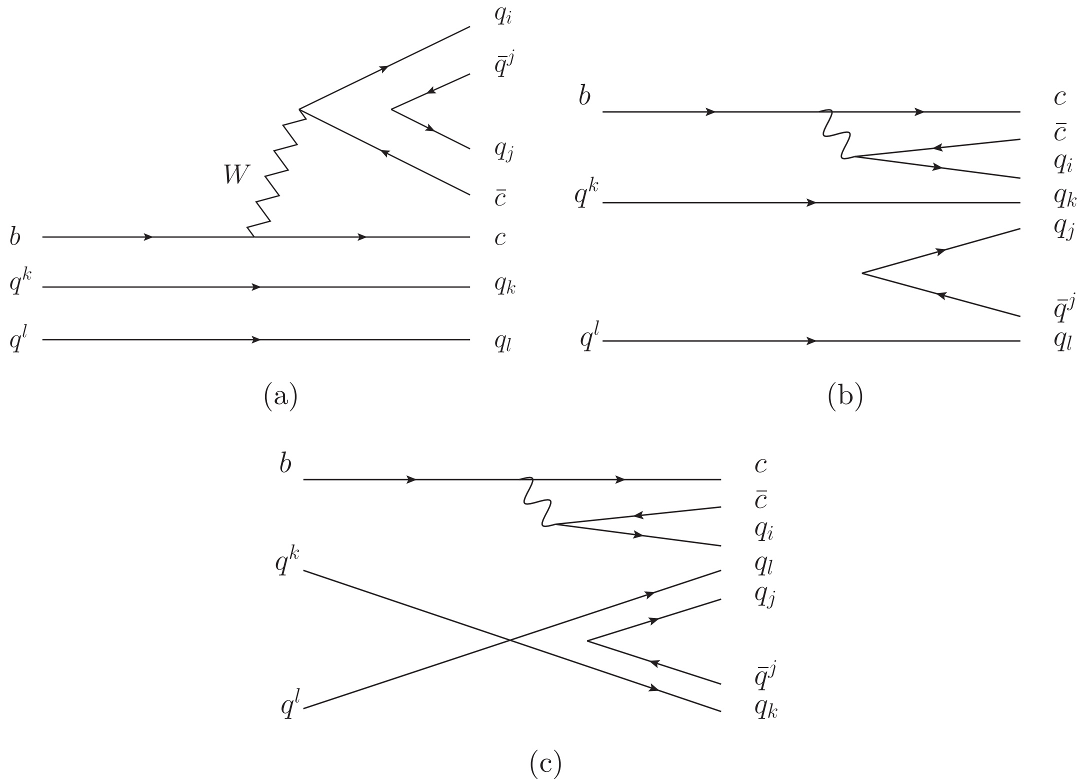

FIG. 1. External W-emission (a) and internal W-emission diagrams (b) and (c) for the bottom baryon decays to a pseudoscalar meson and a pentaquark. Note that the amplitude of (c) is the same as that of (b) up to a sign, since the former corresponds to switching k and l in the initial diquark state of the latter, which is antisymmetric (symmetric) under the interchange of two light quarks of the antitriplet (sextet) bottom baryon.

one in terms of quark fields. Defining $T_1 \equiv -T_{1'} - T_{1''}$ and $t_1 \equiv t_{1'} - t_{1''}$, we can recast the above Hamiltonian as

$$\begin{aligned} H_{\rm eff} = {}& \mathcal{B}_a H^i \Pi_i^j \bar{\mathcal{P}}_j^a (T_1 - T_2) + \mathcal{B}_a H^a \Pi_i^j \bar{\mathcal{P}}_j^i T_2 \\ &+ \mathcal{B}_a H^i \Pi_j^j \bar{\mathcal{P}}_i^a T_3 - \mathcal{B}_a H^i \Pi_l^a \bar{\mathcal{P}}_i^l T_3 \\ &+ \mathcal{B}^{kl} H^i \Pi_i^j \epsilon_{jka} \bar{\mathcal{P}}_l^a t_1 + \mathcal{B}^{kl} H^i \Pi_l^j \epsilon_{ika} \bar{\mathcal{P}}_j^a t_2 \\ &+ \mathcal{B}^{kl} H^i \Pi_l^j \epsilon_{akj} \bar{\mathcal{P}}_i^a t_3. \end{aligned} \tag{9}$$

We may further consider the decuplet pentaquark field $\mathcal{P}^{ijk}$ with $\mathcal{P}^{111} = P_{\Delta^{++}}$, $\mathcal{P}^{112} = P_{\Delta^+}/\sqrt{3}$, $\mathcal{P}^{122} = P_{\Delta^0}/\sqrt{3}$, $\mathcal{P}^{222} = P_{\Delta^-}$, $\mathcal{P}^{113} = P_{\Sigma^{*+}}/\sqrt{3}$, $\mathcal{P}^{123} = P_{\Sigma^{*0}}/\sqrt{6}$, $\mathcal{P}^{223} = P_{\Sigma^{*-}}/\sqrt{3}$, $\mathcal{P}^{133} = P_{\Xi^{*0}}/\sqrt{3}$, $\mathcal{P}^{233} = P_{\Xi^{*-}}/\sqrt{3}$, and $\mathcal{P}^{333} = P_{\Omega^-}$. The corresponding rule is

$$\bar{c} c q_j q_k q_l \to \bar{\mathcal{P}}_{jkl}, \tag{10}$$

and, consequently, the related weak Hamiltonian is

$$\begin{aligned} H_{\rm eff} = {}& \epsilon^{kla} \mathcal{B}_a H^i \Pi_l^j \bar{\mathcal{P}}_{ijk} \tilde{T}_2 + \mathcal{B}^{kl} H^i \Pi_i^j \bar{\mathcal{P}}_{jkl} \tilde{t}_1 \\ &+ \mathcal{B}^{kl} H^i \Pi_l^j \bar{\mathcal{P}}_{ijk} \tilde{t}_2, \end{aligned} \tag{11}$$

where $\tilde{t}_1$ and $\tilde{T}_2(\tilde{t}_2)$ correspond to Figs. 1(a) and 1(b) [including Fig. 1(c)], respectively. It should be stressed that an antitriplet bottom baryon can decay to a decuplet pentaquark only through Fig. 1(b) [with Fig. 1(c) as well], since the light-quark flavor is antisymmetric in the initial state, while it is symmetric in the final state. As a result, there is no contribution from Fig. 1(a).

Decay amplitudes of bottom baryon decays to a pseudoscalar meson and a pentaquark in the antitriplet and sextet are listed in Tables I–II and Tables III–IV, respectively, for $\Delta S = -1(0)$ transitions. The SU(3) octet and singlet states η_8 and η_1, respectively, are related to the physical η and η' states via

$$\begin{pmatrix} \eta_8 \\ \eta_1 \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} \eta \\ \eta' \end{pmatrix}. \tag{12}$$

The most recent experimental determination of the $\eta - \eta'$ mixing angle is $\theta = -(14.3 \pm 0.6)^\circ$ from KLOE [25], which is indeed close to the original theoretical and phenomenological estimates of -12.5° and $(-15.4 \pm 1.0)^\circ$, respectively, made by Feldmann, Kroll, and Stech [26]. It is interesting to notice that the decay amplitudes of $\Lambda_b^0 \to P_\Lambda \pi^0$, $P_{\Sigma^0}\eta$, and $P_{\Sigma^0}\eta'$ vanish in the SU(3) limit (see Table I). Many relations can be read off from Tables I–IV; for example,

TABLE I. The decay amplitudes of bottom baryon decays to a pseudoscalar and an octet pentaquark. T_i and t_i $(i = 1, 2, 3)$ are $\Delta S = -1$ transition amplitudes for antitriplet and sextet bottom baryons, respectively.

Process	Amplitude	Process	Amplitude
$\Lambda_b^0 \to P_p K^-$	T_1	$\Lambda_b^0 \to P_n \bar{K}^0$	T_1
$\Lambda_b^0 \to P_\Lambda \eta$	$\frac{1}{3}[(2T_1 + T_2 - 2T_3)\cos\theta$ $+(2T_1 + T_2 - 2T_3)\sin\theta]$	$\Lambda_b^0 \to P_\Lambda \eta'$	$\frac{1}{3}[-\sqrt{2}(T_1 - T_2 + 2T_3)\cos\theta$ $+\sqrt{2}(T_1 - T_2 + 2T_3)\sin\theta]$
$\Lambda_b^0 \to P_{\Sigma^+} \pi^-$	T_2	$\Lambda_b^0 \to P_{\Sigma^-} \pi^+$	T_2
$\Lambda_b^0 \to P_{\Xi^0} K^0$	$T_2 - T_3$	$\Lambda_b^0 \to P_{\Xi^-} K^+$	$T_2 - T_3$
$\Lambda_b^0 \to P_{\Sigma^0} \pi^0$	T_2	$\Lambda_b^0 \to P_\Lambda \pi^0$	0
$\Lambda_b^0 \to P_{\Sigma^0} \eta$	0	$\Lambda_b^0 \to P_{\Sigma^0} \eta'$	0
$\Xi_b^0 \to P_{\Sigma^+} K^-$	$T_1 - T_2$	$\Xi_b^0 \to P_{\Sigma^0} \bar{K}^0$	$\frac{1}{\sqrt{2}}(-T_1 + T_2)$
$\Xi_b^0 \to P_{\Xi^0} \eta$	$-\frac{1}{\sqrt{6}}(2T_1 - 2T_2 + T_3)\cos\theta$ $-\frac{1}{\sqrt{6}}(2T_1 - 2T_2 + T_3)\sin\theta$	$\Xi_b^0 \to P_{\Xi^0} \eta'$	$\frac{1}{\sqrt{3}}(T_1 - T_2 + 2T_3)\cos\theta$ $-\frac{1}{\sqrt{3}}(T_1 - T_2 + 2T_3)\sin\theta$
$\Xi_b^0 \to P_{\Xi^-} \pi^+$	$-T_3$	$\Xi_b^0 \to P_{\Xi^0} \pi^0$	$\frac{1}{\sqrt{2}} T_3$
$\Xi_b^0 \to P_\Lambda \bar{K}^0$	$\frac{1}{\sqrt{6}}(T_1 - T_2 + 2T_3)$		
$\Xi_b^- \to P_{\Sigma^-} \bar{K}^0$	$T_1 - T_2$	$\Xi_b^- \to P_{\Sigma^0} K^-$	$\frac{1}{\sqrt{2}}(T_1 - T_2)$
$\Xi_b^- \to P_{\Xi^-} \pi^0$	$-\frac{1}{\sqrt{2}} T_3$	$\Xi_b^- \to P_{\Xi^0} \pi^-$	$-T_3$
$\Xi_b^- \to P_{\Xi^-} \eta$	$-\frac{1}{\sqrt{6}}(2T_1 - 2T_2 + T_3)\cos\theta$ $-\frac{1}{\sqrt{3}}(T_1 - T_2 + 2T_3)\sin\theta$	$\Xi_b^- \to P_{\Xi^-} \eta'$	$\frac{1}{\sqrt{3}}(T_1 - T_2 + 2T_3)\cos\theta$ $-\frac{1}{\sqrt{6}}(2T_1 - 2T_2 + T_3)\sin\theta$
$\Xi_b^- \to P_\Lambda K^-$	$\frac{1}{\sqrt{6}}(T_1 - T_2 + 2T_3)$		
$\Omega_b^- \to P_{\Xi^-} \bar{K}^0$	$t_1 - t_3$	$\Omega_b^- \to P_{\Xi^0} K^-$	$-t_1 + t_3$

TABLE II. The decay amplitudes of bottom baryon decays to a pseudoscalar and an octet pentaquark. T'_i and t'_i $(i = 1, 2, 3)$ are $\Delta S = 0$ transition amplitudes for antitriplet and sextet bottom baryons, respectively.

Process	Amplitude	Process	Amplitude
$\Lambda_b^0 \to P_p \pi^-$	$T'_1 - T'_2$	$\Lambda_b^0 \to P_n \pi^0$	$-\frac{1}{\sqrt{2}}(T'_1 - T'_2)$
$\Lambda_b^0 \to P_{\Sigma^0} K^0$	$\frac{1}{\sqrt{2}} T'_3$	$\Lambda_b^0 \to P_{\Sigma^-} K^+$	$-T'_3$
$\Lambda_b^0 \to P_n \eta$	$(\frac{\cos\theta}{\sqrt{6}} - \frac{\sin\theta}{\sqrt{3}})(T'_1 - T'_2 + 2T'_3)$	$\Lambda_b^0 \to P_n \eta'$	$(\frac{\cos\theta}{\sqrt{3}} + \frac{\sin\theta}{\sqrt{6}})(T'_1 - T'_2 + 2T'_3)$
$\Lambda_b^0 \to P_\Lambda K^0$	$-\frac{1}{\sqrt{6}}(2T'_1 - 2T'_2 + T'_3)$		
$\Xi_b^0 \to P_{\Sigma^+} \pi^-$	T'_1	$\Xi_b^0 \to P_{\Sigma^0} \pi^0$	$\frac{1}{2}(T'_1 + T'_2 - T'_3)$
$\Xi_b^0 \to P_{\Xi^0} K^0$	$T_1{}'$	$\Xi_b^0 \to P_{\Xi^-} K^+$	T'_2
$\Xi_b^0 \to P_\Lambda \eta$	$\frac{1}{6}\cos\theta(T'_1 + 5T'_2 - T'_3)$ $-\frac{1}{3\sqrt{2}}\sin\theta(T'_1 - T'_2 + 2T'_3)$	$\Xi_b^0 \to P_\Lambda \eta'$	$\frac{1}{3\sqrt{2}}\cos\theta(T'_1 - T'_2 + 2T'_3)$ $+\frac{1}{6}\sin\theta(T'_1 + 5T'_2 - T'_3)$
$\Xi_b^0 \to P_{\Sigma^0} \eta$	$\frac{1}{2\sqrt{3}}\cos\theta(-T'_1 + T'_2 + T'_3)$ $+\frac{1}{\sqrt{6}}\sin\theta(T'_1 - T'_2 + 2T'_3)$	$\Xi_b^0 \to P_{\Sigma^0} \eta'$	$-\frac{1}{\sqrt{6}}\cos\theta(T'_1 - T'_2 + 2T'_3)\frac{1}{2\sqrt{3}}\sin\theta(-T'_1 + T'_2 + T'_3)$
$\Xi_b^0 \to P_p K^-$	T'_2	$\Xi_b^0 \to P_n \bar{K}^0$	$T'_2 - T'_3$
$\Xi_b^0 \to P_{\Sigma^-} \pi^+$	$T'_2 - T'_3$	$\Xi_b^0 \to P_\Lambda \pi^0$	$\frac{1}{2\sqrt{3}}(-T'_1 + T'_2 + T'_3)$
$\Xi_b^- \to P_{\Xi^-} K^0$	$T'_1 - T'_2$	$\Xi_b^- \to P_n K^-$	$-T'_3$
$\Xi_b^- \to P_{\Sigma^-} \eta$	$\frac{1}{\sqrt{6}}\cos\theta(T'_1 - T'_2 - T'_3)$ $-\frac{1}{\sqrt{3}}\sin\theta(T'_1 - T'_2 + 2T'_3)$	$\Xi_b^- \to P_{\Sigma^-} \eta'$	$\frac{1}{\sqrt{3}}\cos\theta(T'_1 - T'_2 + 2T'_3)$ $+\frac{1}{\sqrt{6}}\sin\theta(T'_1 - T'_2 - T'_3)$
$\Xi_b^- \to P_{\Sigma^-} \pi^0$	$-\frac{1}{\sqrt{2}}(T'_1 - T'_2 + T'_3)$	$\Xi_b^- \to P_{\Sigma^0} \pi^-$	$\frac{1}{\sqrt{2}}(T'_1 - T'_2 + T'_3)$
$\Xi_b^- \to P_\Lambda \pi^-$	$\frac{1}{\sqrt{6}}(T'_1 - T'_2 - T'_3)$		
$\Omega_b^- \to P_{\Xi^-} \pi^0$	$-\frac{1}{\sqrt{2}} t'_1$	$\Omega_b^- \to P_{\Xi^0} \pi^-$	$-t'_1$
$\Omega_b^- \to P_{\Xi^-} \eta$	$\frac{1}{\sqrt{6}}\cos\theta(t'_1 - 2t'_2) - \frac{1}{\sqrt{3}}\sin\theta(t'_1 + t'_2)$	$\Omega_b^- \to P_{\Xi^-} \eta'$	$\frac{1}{\sqrt{3}}\cos\theta(t'_1 + t'_2) + \frac{1}{\sqrt{6}}\sin\theta(t'_1 - 2t'_2)$
$\Omega_b^- \to P_{\Sigma^-} \bar{K}^0$	$t'_2 - t'_3$	$\Omega_b^- \to P_{\Sigma^0} K^-$	$\frac{1}{\sqrt{2}}(t'_2 - t'_3)$
$\Omega_b^- \to P_\Lambda K^-$	$\frac{1}{\sqrt{6}}(t'_2 + t'_3)$		

TABLE III. The decay amplitudes of bottom baryon decays to a pseudoscalar and a decuplet pentaquark. $\tilde{T}_2$ and $\tilde{t}_i$ $(i=1,2)$ are $\Delta S=-1$ transition amplitudes for antitriplet and sextet bottom baryons, respectively.

Process	Amplitude	Process	Amplitude
$\Lambda_b^0\to P_{\Xi^{*0}}K^0$	$\frac{1}{\sqrt{3}}\tilde{T}_2$	$\Lambda_b^0\to P_{\Xi^{*-}}K^+$	$-\frac{1}{\sqrt{3}}\tilde{T}_2$
$\Lambda_b^0\to P_{\Sigma^{*0}}\pi^0$	$-\frac{1}{\sqrt{3}}\tilde{T}_2$	$\Lambda_b^0\to P_{\Sigma^{*+}}\pi^-$	$\frac{1}{\sqrt{3}}\tilde{T}_2$
$\Lambda_b^0\to P_{\Sigma^{*-}}\pi^+$	$-\frac{1}{\sqrt{3}}\tilde{T}_2$		
$\Xi_b^0\to P_{\Sigma^{*0}}\bar{K}^0$	$\frac{1}{\sqrt{6}}\tilde{T}_2$	$\Xi_b^0\to P_{\Sigma^{*+}}K^-$	$-\frac{1}{\sqrt{3}}\tilde{T}_2$
$\Xi_b^0\to P_{\Xi^{*0}}\eta$	$\frac{1}{\sqrt{2}}\cos\theta\tilde{T}_2$	$\Xi_b^0\to P_{\Xi^{*0}}\eta'$	$\frac{1}{\sqrt{2}}\sin\theta\tilde{T}_2$
$\Xi_b^0\to P_{\Xi^{*0}}\pi^0$	$\frac{1}{\sqrt{6}}\tilde{T}_2$	$\Xi_b^0\to P_{\Xi^{*-}}\pi^+$	$\frac{1}{\sqrt{3}}\tilde{T}_2$
$\Xi_b^0\to P_{\Omega^-}K^+$	$\tilde{T}_2$		
$\Xi_b^-\to P_{\Sigma^{*-}}\bar{K}^0$	$\frac{1}{\sqrt{3}}\tilde{T}_2$	$\Xi_b^-\to P_{\Sigma^{*0}}K^-$	$\frac{1}{\sqrt{6}}\tilde{T}_2$
$\Xi_b^-\to P_{\Xi^{*-}}\eta$	$-\frac{1}{\sqrt{2}}\cos\theta\tilde{T}_2$	$\Xi_b^-\to P_{\Xi^-}\eta'$	$-\frac{1}{\sqrt{2}}\sin\theta\tilde{T}_2$
$\Xi_b^-\to P_{\Xi*-}\pi^0$	$\frac{1}{\sqrt{6}}\tilde{T}_2$	$\Xi_b^-\to P_{\Xi^{*0}}\pi^-$	$-\frac{1}{\sqrt{3}}\tilde{T}_2$
$\Xi_b^-\to P_{\Omega^-}K^0$	$-\tilde{T}_2$		
$\Omega_b^-\to P_{\Xi^{*-}}\bar{K}^0$	$\frac{1}{\sqrt{3}}(\tilde{t}_1+\tilde{t}_2)$	$\Omega_b^-\to P_{\Xi^{*0}}K^-$	$\frac{1}{\sqrt{3}}(\tilde{t}_1+\tilde{t}_2)$
$\Omega_b^-\to P_{\Omega^-}\eta$	$-\frac{1}{\sqrt{3}}(\sqrt{2}\cos\theta+\sin\theta)(\tilde{t}_1+\tilde{t}_2)$	$\Omega_b^-\to P_{\Omega^-}\eta'$	$\frac{1}{\sqrt{3}}(\cos\theta-\sqrt{2}\sin\theta)(\tilde{t}_1+\tilde{t}_2)$

$$
\begin{aligned}
&A(\Lambda_b^0\to P_{\Sigma^0}\pi^0)=A(\Lambda_b^0\to P_{\Sigma^+}\pi^-)=A(\Lambda_b^0\to P_{\Sigma^-}\pi^+),\\
&A(\Xi_b^0\to P_{\Sigma^+}K^-)-\sqrt{2}A(\Xi_b^0\to P_{\Sigma^0}\bar{K}^0)=A(\Xi_b^-\to P_{\Sigma^-}\bar{K}^0)=\sqrt{2}A(\Xi_b^-\to P_{\Sigma^0}K^-),\\
&A(\Xi_b^0\to P_{\Xi^-}\pi^+)=-\sqrt{2}A(\Xi_b^0\to P_{\Xi^0}\pi^0)=\sqrt{2}A(\Xi_b^-\to P_{\Xi^-}\pi^0)=A(\Xi_b^-\to P_{\Xi^0}\pi^-),\\
&A(\Xi_b^0\to P_{\Sigma^+}\pi^-)=A(\Xi_b^0\to P_{\Xi^0}K^0),\qquad A(\Xi_b^0\to P_{\Xi^-}K^+)=A(\Xi_b^0\to P_pK^-),\\
&\sqrt{2}A(\Xi_b^0\to P_{\Sigma^0}\eta)=-A(\Xi_b^-\to P_{\Sigma^-}\eta),\qquad \sqrt{2}A(\Xi_b^0\to P_{\Sigma^0}\eta')=-A(\Xi_b^-\to P_{\Sigma^-}\eta').
\end{aligned}
\tag{13}
$$

TABLE IV. The decay amplitudes of bottom baryon decays to a pseudoscalar and a decuplet pentaquark. $\tilde{T}'_2$ and $\tilde{t}'_i$ $(i=1,2)$ are $\Delta S=0$ transition amplitudes for antitriplet and sextet bottom baryons, respectively.

Process	Amplitude	Process	Amplitude
$\Lambda_b^0\to P_{\Sigma^{*0}}K^0$	$\frac{1}{\sqrt{6}}\tilde{T}'_2$	$\Lambda_b^0\to P_{\Sigma^{*-}}K^+$	$-\frac{1}{\sqrt{3}}\tilde{T}'_2$
$\Lambda_b^0\to P_{\Delta^0}\pi^0$	$-\sqrt{\frac{2}{3}}\tilde{T}'_2$	$\Lambda_b^0\to P_{\Delta^-}\pi^+$	$-\tilde{T}'_2$
$\Lambda_b^0\to P_{\Delta^+}\pi^-$	$\frac{1}{\sqrt{3}}\tilde{T}'_2$		
$\Xi_b^0\to P_{\Sigma^{*0}}\pi^0$	$\frac{1}{2\sqrt{3}}\tilde{T}'_2$	$\Xi_b^0\to P_{\Sigma^{*-}}\pi^+$	$\frac{1}{\sqrt{3}}\tilde{T}'_2$
$\Xi_b^0\to P_{\Sigma^{*0}}\eta$	$\frac{1}{2}\cos\theta\tilde{T}'_2$	$\Xi_b^0\to P_{\Sigma^{*0}}\eta'$	$\frac{1}{2}\sin\theta\tilde{T}'_2$
$\Xi_b^0\to P_{\Delta^0}\bar{K}^0$	$-\frac{1}{\sqrt{3}}\tilde{T}'_2$	$\Xi_b^0\to P_{\Delta^+}K^-$	$-\frac{1}{\sqrt{3}}\tilde{T}'_2$
$\Xi_b^0\to P_{\Xi^{*-}}\bar{K}^+$	$\frac{1}{\sqrt{3}}\tilde{T}'_2$		
$\Xi_b^-\to P_{\Delta^-}\bar{K}^0$	$\tilde{T}'_2$	$\Xi_b^-\to P_{\Delta^0}K^-$	$\frac{1}{\sqrt{3}}\tilde{T}'_2$
$\Xi_b^-\to P_{\Sigma^-}\eta$	$-\frac{1}{\sqrt{2}}\cos\theta\tilde{T}'_2$	$\Xi_b^-\to P_{\Sigma^-}\eta'$	$-\frac{1}{\sqrt{2}}\sin\theta\tilde{T}'_2$
$\Xi_b^-\to P_{\Sigma^{*-}}\pi^0$	$\frac{1}{\sqrt{6}}\tilde{T}'_2$	$\Xi_b^-\to P_{\Sigma^{*0}}\pi^-$	$-\frac{1}{\sqrt{6}}\tilde{T}'_2$
$\Xi_b^-\to P_{\Xi^{*-}}K^0$	$-\frac{1}{\sqrt{3}}\tilde{T}'_2$		
$\Omega_b^-\to P_{\Xi^{*-}}\eta$	$\frac{1}{3\sqrt{2}}\cos\theta(\tilde{t}'_1-2\tilde{t}'_2)-\frac{1}{3}\sin\theta(\tilde{t}'_1+\tilde{t}'_2)$	$\Omega_b^-\to P_{\Xi^{*-}}\eta'$	$\frac{1}{3}\cos\theta(\tilde{t}'_1+\tilde{t}'_2)+\frac{1}{3\sqrt{2}}\sin\theta(\tilde{t}'_1-2\tilde{t}'_2)$
$\Omega_b^-\to P_{\Xi^{*-}}\pi^0$	$-\frac{1}{\sqrt{6}}\tilde{t}'_1$	$\Omega_b^-\to P_{\Xi^{*0}}\pi^-$	$\frac{1}{\sqrt{3}}\tilde{t}'_1$
$\Omega_b^-\to P_{\Sigma^0}K^-$	$\frac{1}{\sqrt{6}}\tilde{t}'_2$	$\Omega_b^-\to P_{\Sigma^{*-}}\bar{K}^0$	$\frac{1}{\sqrt{3}}\tilde{t}'_2$
$\Omega_b^-\to P_{\Omega^-}K^0$	$\tilde{t}'_1$		

TABLE V. Estimate of the decay rate ratios of $\Gamma(\mathcal{B}_b \to P_{\mathcal{B}}^{3/2(5/2)} M)/\Gamma(\Lambda_b^0 \to P_p^{3/2(5/2)} K^-)$ for $\Delta S = -1$ (top) and $\Delta S = 0$ (bottom) transitions based on the assumption that the external W-emission diagram [Fig. 1(a)] gives dominant contributions. Note that we have applied Eq. (16) for the $\Delta S = 0$ case.

Process	$\Gamma/\Gamma(\Lambda_b^0 \to P_p^{3/2(5/2)} K^-)$	Process	$\Gamma/\Gamma(\Lambda_b^0 \to P_p^{3/2(5/2)} K^-)$
$\Lambda_b^0 \to P_p K^-$	1(1)	$\Lambda_b^0 \to P_n K^0$	0.992(0.985)
$\Lambda_b^0 \to P_\Lambda \eta'$	$0.027(4 \times 10^{-4})$	$\Lambda_b^0 \to P_\Lambda \eta$	0.145(0.084)
$\Xi_b^0 \to P_{\Sigma^+} K^-$	0.819(0.692)	$\Xi_b^0 \to P_\Lambda \bar{K}^0$	0.166(0.165)
$\Xi_b^0 \to P_\Lambda \eta$	0.200(0.108)	$\Xi_b^0 \to P_\Lambda \eta'$	$0.027(2 \times 10^{-5})$
$\Xi_b^- \to P_{\Xi^-} \eta'$	$0.025(3 \times 10^{-6})$	$\Xi_b^- \to P_{\Xi^-} \eta$	0.196(0.104)
$\Xi_b^- \to P_{\Sigma^-} \bar{K}^0$	0.800(0.662)	$\Xi_b^- \to P_{\Sigma^0} K^-$	0.168(0.168)
$\Xi_b^- \to P_\Lambda K^-$	0.408(0.343)	$\Omega_b^- \to P_{\Xi^-} \bar{K}^0$	$1.15\lvert \frac{t_1}{T_1} \rvert^2 (1.28 \lvert \frac{t_1}{T_1} \rvert^2)$
$\Omega_b^- \to P_{\Xi^0} K^-$	$1.17\lvert \frac{t_1}{T_1} \rvert^2 (1.33 \lvert \frac{t_1}{T_1} \rvert^2)$	$\Omega_b^- \to P_{\Xi^{*-}} \bar{K}^0$	$0.209\lvert \frac{\tilde{t}_1}{T_1} \rvert^2 (0.139 \lvert \frac{\tilde{t}_1}{T_1} \rvert^2)$
$\Omega_b^- \to P_{\Xi^{*0}} K^-$	$0.212\lvert \frac{\tilde{t}_1}{T_1} \rvert^2 (0.144 \lvert \frac{\tilde{t}_1}{T_1} \rvert^2)$	$\Omega_b^- \to P_{\Omega^-} \eta$	$0.132\lvert \frac{\tilde{t}_1}{T_1} \rvert^2 (0.048 \lvert \frac{\tilde{t}_1}{T_1} \rvert^2)$
$\Lambda_b^0 \to P_\Lambda K^0$	0.021(0.013)	$\Lambda_b^0 \to P_n \pi^0$	0.034(0.042)
$\Lambda_b^0 \to P_n \eta$	0.015(0.014)	$\Lambda_b^0 \to P_n \eta'$	0.004(0.001)
$\Lambda_b^0 \to P_p \pi^-$	0.068(0.084)	$\Xi_b^0 \to P_{\Xi^0} K^0$	0.029(0.017)
$\Xi_b^0 \to P_\Lambda \pi^0$	0.006(0.007)	$\Xi_b^0 \to P_\Lambda \eta$	0.003(0.002)
$\Xi_b^0 \to P_\Lambda \eta'$	$6 \times 10^{-4} (2 \times 10^{-4})$	$\Xi_b^0 \to P_{\Sigma^+} \pi^-$	0.058(0.063)
$\Xi_b^0 \to P_{\Sigma^0} \pi^0$	0.014(0.016)	$\Xi_b^- \to P_{\Sigma^0} \pi^-$	0.029(0.031)
$\Xi_b^- \to P_{\Xi^-} K^0$	0.029(0.017)	$\Xi_b^- \to P_{\Sigma^-} \pi^0$	0.028(0.031)
$\Xi_b^- \to P_{\Sigma^-} \eta$	0.012(0.009)	$\Xi_b^- \to P_{\Sigma^-} \eta'$	$0.002(3 \times 10^{-4})$
$\Xi_b^- \to P_\Lambda \pi^-$	0.011(0.014)	$\Omega_b^- \to P_{\Xi^0} \pi^-$	$0.078\lvert \frac{t_1}{T_1} \rvert^2 (0.107 \lvert \frac{t_1}{T_1} \rvert^2)$
$\Omega_b^- \to P_{\Xi^-} \eta$	$0.017\lvert \frac{t_1}{T_1} \rvert^2 (0.018 \lvert \frac{t_1}{T_1} \rvert^2)$	$\Omega_b^- \to P_{\Xi^-} \eta'$	$0.005\lvert \frac{t_1}{T_1} \rvert^2 (0.002 \lvert \frac{t_1}{T_1} \rvert^2)$
$\Omega_b^- \to P_{\Xi^-} \pi^0$	$0.038\lvert \frac{t_1}{T_1} \rvert^2 (0.052 \lvert \frac{t_1'}{T_1} \rvert^2)$	$\Omega_b^- \to P_{\Omega^-} K^0$	$0.020\lvert \frac{\tilde{t}_1}{T_1} \rvert^2 (0.008 \lvert \frac{\tilde{t}_1}{T_1} \rvert^2)$
$\Omega_b^- \to P_{\Xi^{*-}} \pi^0$	$0.008\lvert \frac{\tilde{t}_1}{T_1} \rvert^2 (0.007 \lvert \frac{\tilde{t}_1}{T_1} \rvert^2)$	$\Omega_b^- \to P_{\Xi^{*0}} \pi^-$	$0.016\lvert \frac{\tilde{t}_1}{T_1} \rvert^2 (0.015 \lvert \frac{\tilde{t}_1}{T_1} \rvert^2)$
$\Omega_b^- \to P_{\Xi^{*-}} \eta$	$0.003\lvert \frac{\tilde{t}_1}{T_1} \rvert^2 (0.002 \lvert \frac{\tilde{t}_1}{T_1} \rvert^2)$	$\Omega_b^- \to P_{\Xi^{*-}} \eta'$	$3 \times 10^{-4}\lvert \frac{\tilde{t}_1}{T_1} \rvert^2 (7 \times 10^{-6} \lvert \frac{\tilde{t}_1}{T_1} \rvert^2)$

There are in total 19 decay channels for the antitriplet bottom baryon decays to a pseudoscalar and a decuplet pentaquark as listed in Tables III and IV. Their decay amplitudes are governed by $\tilde{T}_2$ and $\tilde{T}_2'$ for $\Delta S = -1$ and ΔS transitions, respectively. Consequently, the decays of $(\Lambda_b^0, \Xi_b^0, \Xi_b^-) \to P_{\mathbf{10}} + M$ are all related to each other. The amplitudes of $\Omega_b^- \to P_{\mathbf{10}} + M$ are proportional to $\tilde{t}_1 + \tilde{t}_2$ and $\tilde{t}_{1,2}'$, respectively, for $\Delta S = -1$ and $\Delta S = 0$ transitions. Hence, Ω_b^- is allowed to decay to a decuplet pentaquark through the external W-emission diagram.

Based on SU(3) flavor symmetry, weak decays of bottom baryons to a light pseudoscalar and an octet or decuplet pentaquark were also studied in Ref. [27]. Several U-spin relations which relate $\Delta S = -1$ and $\Delta S = 0$ amplitudes were derived there. In the work of Ref. [27], $(\Lambda_b^0, \Xi_b^0, \Xi_b^-) \to P_{\mathbf{8}} + M$ decays were expressed in terms of eight unknown invariant amplitudes, while in our work they are expressed in terms of three invariant amplitudes T_1 and $T_{2,3}$ corresponding to the external W-emission and internal W-emission diagrams, respectively. Therefore, the physical pictures of invariant amplitudes are more transparent in our study. Nevertheless, as far as the relations between various modes are concerned—such as Eq. (13) in this work and Eqs. (19), (22), and (23) in Ref. [27]—we are in agreement with each other.

III. DISCUSSIONS

In the absence of a dynamical model we are not able to estimate the absolute rate of the bottom baryon decays to a light pseudoscalar and a pentaquark. Nevertheless, under a plausible assumption on the relative importance of the external and internal W-emission diagrams, we can make a crude estimate on $\Gamma(\mathcal{B}_b \to P_{\mathcal{B}} M)$ relative to $\Gamma(\Lambda_b^0 \to P_p^+ K^-)$.

The decay $\Lambda_b \to P_p K^-$ observed by LHCb receives contributions only from the external W-emission diagram [Fig. 1(a)]. Indeed, this contribution should be the dominant one in bottom baryon decays to a pseudoscalar and a pentaquark, since in internal W-emission diagrams [Figs. 1(b) and 1(c)], the three quarks $(c\bar{c}q_i)$ produced directly from the b-quark decay are too energetic to form a pentaquark. As a consequence, it is likely that the internal W-emission diagram is suppressed relative to the external W-emission one. Under this hypothesis, we are going to show in Table V the estimation of rate ratios by assuming the dominant contributions from Fig. 1(a) and neglecting other contributions. It is true that all modes in Tables I–IV should be searched, but the estimates on rates of some modes will also be useful at this moment. The contributions of the neglected subleading terms can be studied later when more modes are discovered and detected.

In a two-body decay system, the decay rate and the center-of-mass momentum have the simple relation

$$\Gamma \propto |p_{\rm cm}||A|^2 \propto |p_{\rm cm}|^{2L+1}, \tag{14}$$

where L is the orbital angular momentum quantum number of the two final-state particles. From the conservation of the angular momentum in the two-body decay, we have $1/2 = |S - L|$ or, equivalently, $L = S \pm 1/2$, where S is the spin of the pentaquark. For $S = 3/2$, L can only be 1 or 2, while for $S = 5/2$, we have $L = 2$, 3. Since the best-fit solution to the LHCb data yields $J^P = (3/2^-, 5/2^+)$ for $P_p(4380)^+$ and $P_p(4450)^+$, respectively, we see that parity in the decay $\Lambda_b^0 \to P_p(4380)^+ K^-$ is violated (conserved) for $L = 1(2)$. Likewise, parity in the decay $\Lambda_b^0 \to P_p(4450)^+ K^-$ is violated (conserved) for $L = 2(3)$. Since parity is not conserved in weak interactions, we therefore assign $L = 1(2)$ to the $S = 3/2(5/2)$ case.

As for the pentaquark masses, we shall assume the same SU(3)-breaking effects in the pentaquark sector and the low-lying baryon sector:

$$m_{P_{\mathcal{B}'}} \simeq m_{P_{\mathcal{B}}} + m_{\mathcal{B}'} - m_{\mathcal{B}}. \tag{15}$$

Moreover, we will assume that there are two different types of octet pentaquark multiplets with $J^P = 3/2^-$ and $J^P = 5/2^+$. The measured masses of $P_p(4380)^+$ and $P_p(4450)^+$ given in Eq. (1) will be used as a benchmark to fix the mass of the other pentaquark $P_{\mathcal{B}}$ through Eq. (15). The decay amplitudes of $\Delta S = -1$, 0 processes are related to each other through the relation

$$\left|\frac{T'}{T}\right|^2 = \left|\frac{t'}{t}\right|^2 = \left|\frac{\tilde{t}'}{\tilde{t}}\right|^2 = \left|\frac{V_{cd}^*}{V_{cs}^*}\right|^2 \simeq 0.053, \tag{16}$$

where V_{ij} are Cabibbo-Kobayashi-Maskawa matrix elements. With the amplitudes given in Tables I–IV we are ready to estimate the rate ratios of some bottom baryon decays to a pseudoscalar and a pentaquark, namely, $\Gamma(\mathcal{B}_b \to P_{\mathcal{B}}^{3/2(5/2)} M)/\Gamma(\Lambda_b^0 \to P_p^{3/2(5/2)} K^-)$. The results are shown in Table V. We see that the $\Lambda_b \to P_p K^-$ rate has the largest rate among the pentaquark multiplet. It also has a very good detectability. This may explain why it is the first mode observed by LHCb. Some modes have rates of similar order as the $\Lambda_b \to P_p K^-$ one, for example, $\Xi_b^0 \to P_{\Sigma^+} K^-$ and $\Xi_b^- \to P_{\Sigma^-} \bar{K}^0$, or $\Omega_b^- \to P_{\Xi^-} \bar{K}^0$ and $\Omega_b^- \to P_{\Xi^0} K^-$. These modes should be given the higher priority in experimental searches for pentaquarks. Note that the $\Delta S = 0$ modes are Cabibbo suppressed [see Eq. (16)]. The recent work in Ref. [28] suggested that the intrinsic charm content of the Λ_b baryon may lead to a dominant mechanism for the pentaquark production in the decay $\Lambda_b^0 \to P_p^+ K^-$. If this mechanism dominates, one will have the prediction [28]

$$\frac{\mathcal{B}(\Lambda_b^0 \to P_p^+ \pi^-)}{\mathcal{B}(\Lambda_b^0 \to P_p^+ K^-)} = 0.8 \pm 0.1, \tag{17}$$

to be compared with the value of $0.07 \sim 0.08$ in our model (see Table V). Therefore, a measurement of $\Lambda_b^0 \to P_p^+ \pi^-$ will be very useful to discriminate among different models.

In order to extract the branching fraction of $\Lambda_b^0 \to P_p^+ K^-$ from the measured branching fraction product (2), we need to know the decay rate of $P_p^+ \to J/\psi p$. The study of the strong decays of pentaquarks is a difficult and yet important task. For $P_p(4500)^+$, it can decay into $\chi_{c1} p$, $\Sigma_c^{(*)+} \bar{D}^0$, $\Lambda_c^+ \bar{D}^{(*)0}$, $J/\psi p, \eta_c p, \cdots$, etc. The recent work in Ref. [14] suggests that $\Gamma(P_p(4500)^+)$ is dominated by the $\chi_{c1} p$ channel in spite of its severe phase-space suppression and that $\mathcal{B}(P_p(4500)^+ \to J\psi p)$ is of order 14% or 24% depending on the solution for the coupling to $\chi_{c1} p$ and $J/\psi p$. In Ref. [29] we studied the strong decays of light and heavy pentaquarks using the light-front quark model. Along the same line, we plan to investigate the hidden-charm pentaquark strong decays in a forthcoming work.

IV. CONCLUSIONS

Assuming SU(3) flavor symmetry, we have decomposed the decay amplitudes of bottom baryon decays to a pseudoscalar meson and an octet (a decuplet) pentaquark in terms of three (two) invariant amplitudes T_1 and $T_{2,3}$ ($\tilde{T}_1$ and $\tilde{T}_2$) corresponding to external W-emission and internal W-emission diagrams, respectively. For antitriplet bottom baryons Λ_b^0, Ξ_b^0, and Ξ_b^-, their decays to a decuplet pentaquark proceed only through the internal W-emission diagram (i.e., $\tilde{T}_1$ vanishes). On the contrary, the Ω_b^- decays to the pentaquark (octet or decuplet) can proceed through the external W-emission process. Assuming the dominance from the external W-emission amplitudes, we presented an estimate of the decay rates relative to $\Lambda_b^0 \to P_p^+ K^-$. Hence our numerical results will provide a very useful guideline to the experimental search for pentaquarks in bottom baryon decays. For example, $\Xi_b^0 \to P_{\Sigma^+} K^-$, $\Xi_b^- \to P_{\Sigma^-} \bar{K}^0$, $\Omega_b^- \to P_{\Xi^-} \bar{K}^0$, and $\Omega_b^- \to P_{\Xi^0} K^-$ may have rates comparable to that of $\Lambda_b^0 \to P_p^+ K^-$ and these modes should be given the higher priority in the experimental searches for pentaquarks.

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