

Predictions for CP violation in antitriplet beauty baryon to charmonium decays

Jin Sun¹, Zhi-Peng Xing^{2,*} and Xiao-Gang He³

¹*Particle Theory and Cosmology Group, Center for Theoretical Physics of the Universe, Institute for Basic Science (IBS), Daejeon 34126, Korea*

²*Department of Physics and Institute of Theoretical Physics, Nanjing Normal University, Nanjing, Jiangsu 210023, China*

³*State Key Laboratory of Dark Matter Physics, Tsung-Dao Lee Institute and School of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 201210, China*



(Received 23 January 2026; accepted 11 May 2026; published 18 June 2026)

Motivated by the recent 3.9σ evidence for CP violation from the LHCb collaboration in decays of an antitriplet beauty baryon to a charmonium, an octet baryon, and a pseudoscalar meson, we perform, for the first time, a systematic analysis of this class of decays within the framework of flavor $SU(3)$ symmetry. Several predictions for branching ratios and CP violating relations that can be tested in future experiments are found, in particular $\Delta A_{CP} = A_{CP}(\Lambda_b^0 \rightarrow p\pi^- J/\psi) - A_{CP}(\Lambda_b^0 \rightarrow pK^- J/\psi) = A_{CP}(\Lambda_b^0 \rightarrow n\pi^0 J/\psi) - A_{CP}(\Lambda_b^0 \rightarrow (nK_S, nK_L)J/\psi)$. Our results provide guidance to test the availability of $SU(3)$ symmetry and search for possible CP violation effects in this class of decays.

DOI: 10.1103/ndrh-qxlq

I. INTRODUCTION

Charge-parity (CP) violation is a cornerstone of modern particle physics, which is a crucial ingredients for generating the observed matter-antimatter asymmetry in the Universe [1]. Within the Standard Model (SM), CP violation is incorporated via the Cabibbo-Kobayashi-Maskawa (CKM) mechanism, which describes quark mixing across three generations. Consequently, the study of CP violation serves to both probe the origins of matter-antimatter asymmetry and stringently test the SM. Great efforts have been made to search for evidences of CP violation in different decays [2,3].

Recently, the LHCb collaboration reported evidence of CP violation in beauty-baryon decays to charmonium final states [4]. A combination with a previous LHCb analysis [5] yields the difference in CP asymmetries between $\Lambda_b^0 \rightarrow p\pi^- J/\psi$ and $\Lambda_b^0 \rightarrow pK^- J/\psi$,

$$\begin{aligned} \Delta A_{CP} &= A_{CP}^{\text{dir}}(\Lambda_b \rightarrow p\pi^- J/\psi) - A_{CP}^{\text{dir}}(\Lambda_b \rightarrow pK^- J/\psi) \\ &= (4.31 \pm 1.06 \pm 0.28)\%, \end{aligned} \quad (1)$$

*Contact author: zpxing@nnu.edu.cn

Published by the American Physical Society under the terms of the [Creative Commons Attribution 4.0 International license](#). Further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation, and DOI. Funded by SCOAP³.

where the first uncertainty is statistical and the second is systematic. The combined result corresponds to a significance level of 3.9σ .

Although experimental evidence of CP violation exists in these beauty-baryon decays to charmonium final states, the theoretical analysis on these processes is extremely lacking. Inspired by these results, we carry out a first theoretical study based on the flavor $SU(3)$ symmetry of the SM. This study provides new predictions to guide future experimental searches for new CP -violating phenomena and to test the SM.

CP violation arises from the interference between tree-level and penguin-level amplitudes. Predicting CP violation requires estimating the relative strong phase between these amplitudes, which is very difficult to obtain from first-principles calculations. Various approaches have been developed to provide necessary information based on symmetry principles [6–9]. In the current stage, flavor $SU(3)$ symmetry analysis represents a powerful tool for predicting CP violation [10–22], particularly in the absence of extensive data, as it can readily yield testable predictions to guide experimental searches. However, previous studies primarily focused on the channels without charmonium, where the presence of additional $SU(3)$ representations (15 and 6) complicates the amplitude decomposition. The new LHCb results on the charmonium channels make such a dedicated analysis both timely and well motivated. To the best of our knowledge, a systematic $SU(3)$ flavor analysis of beauty-baryon decays into charmonium final states has not been carried out previously.

In this work we focus on the $SU(3)$ flavor analysis of the processes observed by LHCb [4], which involve one of the beauty-baryon antitriplets $B_{b\bar{3}}$, the Λ_b^0 , into a light octet baryon T_8 , a pseudoscalar meson M , and a charmonium J/ψ , $B_{\bar{3}} \rightarrow T_8 M + J/\psi$, a class of decays that has not been extensively studied. By analyzing in a systematic way this class of decays, we find several predictions for branching ratios and CP violating relations that can be tested in future experiments, in particular $\Delta A_{CP} = A_{CP}(\Lambda_b^0 \rightarrow p\pi^- J/\psi) - A_{CP}(\Lambda_b^0 \rightarrow pK^- J/\psi) = A_{CP}(\Lambda_b^0 \rightarrow n\pi^0 J/\psi) - A_{CP}(\Lambda_b^0 \rightarrow nK_S, nK_L) J/\psi$. Our results provide guidance to test the availability of flavor $SU(3)$ symmetry and search for possible CP violation effects in this class of decays.

II. THE DECAY AMPLITUDES OF $SU(3)$ FLAVOR SYMMETRY

The leading effective Hamiltonian in the SM that governs the weak transition of $B_{b\bar{3}} \rightarrow T_8 MJ/\psi$ is given by

$$\mathcal{H}_{\text{eff}} = \frac{G_F}{\sqrt{2}} \left(\sum_{i=1,2} C_i \lambda_q^c O_i - \sum_{j=3} C_j \lambda_q^t O_j \right) + \text{H.c.}, \quad (2)$$

with the superscript $q = d(s)$ for $\Delta S = 0(1)$ decay modes. Here we adopt the notations $\lambda_q^c = V_{cb} V_{cq}^*$ and $\lambda_q^t = V_{tb} V_{tq}^*$. The current-current operators $O_{1,2}$ and QCD penguin operators O_{3-6} are expressed by

$$\begin{aligned} O_1 &= (\bar{c}_\alpha b_\beta)_{V-A} (\bar{c}_\beta q_\alpha)_{V-A}, \\ O_2 &= (\bar{c}_\alpha b_\alpha)_{V-A} (\bar{c}_\beta q_\beta)_{V-A}, \\ O_{3,5} &= \sum_{q'=u,d,s} (\bar{q}_\alpha b_\alpha)_{V-A} (\bar{q}'_\beta q'_\beta)_{V\mp A}, \\ O_{4,6} &= \sum_{q'=u,d,s} (\bar{q}_\alpha b_\beta)_{V-A} (\bar{q}'_\beta q'_\alpha)_{V\mp A}, \end{aligned} \quad (3)$$

where $V(A)$ denotes vector (axial-vector) coupling. Here we ignore the electroweak penguin operators, which are suppressed relative to the QCD penguin operators [23].

Under $SU(3)$ symmetry, the effective Hamiltonian $\mathcal{H}_{\text{eff}}$ transforms under the fundamental representation. Its non-zero matrix elements between states can be written as

$$H_3^T = (0, \lambda_d^c, \lambda_s^c), \quad H_3^P = (0, \lambda_d^t, \lambda_s^t), \quad (4)$$

where the indices T and P denote the contributions from tree-level and penguin diagrams, respectively. In contrast to the $SU(3)$ analysis of the effective Hamiltonian for B meson decays into a pair of octet pseudoscalar where there are **15**, **$\bar{6}$** , and **3** [24], in our current case the structure involving only 3 leads to a particularly simple $SU(3)$ analysis.

Before presenting the decay amplitudes for a systematic analysis, we first define the group theory representations of the involved particles in the following. We have

$$\begin{aligned} B_{b\bar{3}} &= \begin{pmatrix} 0 & \Lambda_b^0 & \Xi_b^0 \\ -\Lambda_b^0 & 0 & \Xi_b^- \\ -\Xi_b^0 & -\Xi_b^- & 0 \end{pmatrix}, \\ M_8 &= \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \frac{\eta_8}{\sqrt{6}} & \pi^+ & K^+ \\ \pi^- & -\frac{\pi^0}{\sqrt{2}} + \frac{\eta_8}{\sqrt{6}} & K^0 \\ K^- & \bar{K}^0 & -2\frac{\eta_8}{\sqrt{6}} \end{pmatrix}, \\ T_8 &= \begin{pmatrix} \frac{\Sigma^0}{\sqrt{2}} + \frac{\Lambda^0}{\sqrt{6}} & \Sigma^+ & p \\ \Sigma^- & -\frac{\Sigma^0}{\sqrt{2}} + \frac{\Lambda^0}{\sqrt{6}} & n \\ \Xi^- & \Xi^0 & -\frac{2\Lambda^0}{\sqrt{6}} \end{pmatrix}. \end{aligned} \quad (5)$$

Additionally, a singlet η_1 is also considered to obtain the physical η and η' , which are usually expressed as $\eta = \cos\theta\eta_8 - \sin\theta\eta_1$, $\eta' = \sin\theta\eta_8 + \cos\theta\eta_1$. The mixing angle θ is $(-14.1 \pm 2.8)^\circ$ [3,25].

A single-index representation for $B_{b\bar{3}}$ can be obtained with the antisymmetric tensor, $(B_3)_i = \epsilon_{ijk} B_{b\bar{3}}^{ij}$,

$$(B_3)_i = (\Xi_b^-, -\Xi_b^0, \Lambda_b^0). \quad (6)$$

Furthermore, the charmonium state J/ψ is an $SU(3)$ singlet.

The total decay amplitudes receive contributions from both tree-level ($\mathcal{T}$) and penguin ($\mathcal{P}$) operators. The total amplitude can thus be expressed as

$$\mathcal{M} = \lambda_q^c \mathcal{M}_T + \lambda_q^t \mathcal{M}_P, \quad q = (d, s), \quad (7)$$

where we use the identity $\lambda^u + \lambda^c + \lambda^t = 0$. The $SU(3)$ invariant decay amplitudes $\mathcal{M}_{T,P}$ can be obtained by contracting the corresponding index as

$$\begin{aligned} \mathcal{M}_{T,P} &= a_{T,P} (B_3)_i (H_3^{T,P})^i (\bar{T}_8)_k^j (M_8)_j^k J/\psi \\ &\quad + b_{T,P} (B_3)_i (H_3^{T,P})^j (\bar{T}_8)_k^i (M_8)_j^k J/\psi \\ &\quad + c_{T,P} (B_3)_i (H_3^{T,P})^j (\bar{T}_8)_j^k (M_8)_k^i J/\psi \\ &\quad + d_{T,P} (B_3)_i (H_3^{T,P})^j (\bar{T}_8)_j^i \eta_1 J/\psi. \end{aligned} \quad (8)$$

One should bear in mind that $SU(3)$ symmetry is expected to be broken due to different masses of the three light quark masses, $m_{u,d,s}$. Following Ref. [20], we identify the $s\bar{s}$ condensate effect as the dominant breaking source, which induces the following terms into the amplitudes

$$\begin{aligned}
& a_{T,P}^v(B_3)_i(H_3^{T,P})^i(\overline{T}_8)_k^j(M_8)_j^l \hat{m}_l^k J/\psi \\
& + b_{T,P}^v(B_3)_i(H_3^{T,P})^j(\overline{T}_8)_k^i(M_8)_j^l \hat{m}_l^k J/\psi \\
& + c_{T,P}^v(B_3)_i(H_3^{T,P})^j(M_8)_k^l[(\overline{T}_8)_j^k \hat{m}_l^i - (\overline{T}_8)_j^i \hat{m}_l^k] J/\psi,
\end{aligned}$$

where $\hat{m} = \text{diag}(0, 0, 1)$. They are obtained by inserting the $\langle \bar{s}s \rangle$ contribution in the topological diagram and then recasting the result into the present irreducible representation amplitude basis. We will adopt these terms as the representative description of possible $SU(3)$ breaking effects in the following analysis. Due to the lack of available data for these channels, we assume the breaking size of $\mathcal{O}(20\%)$, $|f^v/f| \sim 20\%$ for $f = a, b, c$.

Note that the coefficients $d_{T,P}$ are only associated with decays with η_1 in the final states. The relevant amplitudes are given in Table I. There are only four invariant $SU(3)$ decay amplitudes and three dominant $SU(3)$ breaking terms for each of the tree and penguin amplitudes, where each amplitude, in principle, has the structures of the bibaryon operators, $\bar{B}\Gamma_i B_b$, with $\Gamma_i = (1, \gamma_5, \gamma^\mu, \gamma^\mu \gamma_5, \sigma^{\mu\nu})$. However, for our discussion within the $SU(3)$ symmetry, the detailed structure is not important if only branching ratios are concerned. This makes the analysis simple, while still yielding a lot of testable predictions.

III. $SU(3)$ BRANCHING RATIO RELATIONS AND CP VIOLATION

We begin by discussing the relations among different decay branching ratios. Several decay branching ratios have already been measured, as listed below [3,26]

$$\begin{aligned}
\mathcal{B}(\Lambda_b \rightarrow J/\psi p \pi^-) &= (2.6_{-0.4}^{+0.5}) \times 10^{-5}, \\
\mathcal{B}(\Lambda_b \rightarrow J/\psi p K^-) &= (3.2_{-0.5}^{+0.6}) \times 10^{-4}, \\
\mathcal{B}(\Lambda_b \rightarrow J/\psi \Xi^- K^+) &= (3.93 \pm 1.41) \times 10^{-6}, \\
\mathcal{B}(\Xi_b^0 \rightarrow J/\psi \Xi^- \pi^+) &= (6.42 \pm 2.98) \times 10^{-5}. \quad (9)
\end{aligned}$$

The masses and lifetimes for the antitriplet beauty baryons $B_{b\bar{3}}$ are [3]

$$\begin{aligned}
m_{\Lambda_b^0} &= 5.62 \text{ GeV}, \quad m_{\Xi_b^-} = 5.797 \text{ GeV}, \quad m_{\Xi_b^0} = 5.792 \text{ GeV} \\
\tau_{\Lambda_b} &= 1.468 \times 10^{-12} \text{ s}, \quad \tau_{\Xi_b^-} = 1.570 \times 10^{-12} \text{ s}, \\
\tau_{\Xi_b^0} &= 1.477 \times 10^{-12} \text{ s}. \quad (10)
\end{aligned}$$

For the aforementioned decay processes with measured branching ratios, we can obtain several amplitude relations for $\Delta S = 0$ processes, such as

$$\begin{aligned}
\mathcal{M}(\Lambda_b^0 \rightarrow p \pi^- J/\psi) &= -\sqrt{2} \mathcal{M}(\Lambda_b^0 \rightarrow n \pi^0 J/\psi) \\
&\approx \mathcal{M}(\Xi_b^- \rightarrow \Xi^- K^0 J/\psi)|_{b^v \rightarrow 0}, \quad (11)
\end{aligned}$$

where the second equality holds only in the exact $SU(3)$ symmetry limit ($b^v \sim 0$). Analogous relations can be obtained for $\Delta S = 1$ processes as

$$\begin{aligned}
\mathcal{M}(\Lambda_b^0 \rightarrow p K^- J/\psi) &= \mathcal{M}(\Lambda_b^0 \rightarrow n \bar{K}^0 J/\psi), \\
\mathcal{M}(\Lambda_b^0 \rightarrow \Xi^- K^+ J/\psi) &= \mathcal{M}(\Lambda_b^0 \rightarrow \Xi^0 K^0 J/\psi), \\
\mathcal{M}(\Xi_b^0 \rightarrow \Xi^- \pi^+ J/\psi) &= -\sqrt{2} \mathcal{M}(\Xi_b^0 \rightarrow \Xi^0 \pi^0 J/\psi) \\
&= -\mathcal{M}(\Xi_b^- \rightarrow \Xi^0 \pi^- J/\psi) = -\sqrt{2} \mathcal{M}(\Xi_b^- \rightarrow \Xi^- \pi^0 J/\psi). \quad (12)
\end{aligned}$$

Note that both $\Xi_b^0 \rightarrow \Xi^- \pi^+ J/\psi$ and $\Lambda_b^0 \rightarrow \Xi^0 K^0 J/\psi$ receive the dominant breaking contributions. Nevertheless, the amplitude relation between them still holds after including leading $SU(3)$ breaking effects. We then obtain the following predictions for the decay branching ratios numerically

$$\begin{aligned}
\mathcal{B}(\Xi_b^- \rightarrow \Xi^- K^0 J/\psi)|_{b^v \rightarrow 0} &\approx (2.70_{-0.41}^{+0.52}) \times 10^{-5}, \\
\mathcal{B}(\Lambda_b^0 \rightarrow n \pi^0 J/\psi) &= (1.3_{-0.2}^{+0.25}) \times 10^{-5}, \\
\mathcal{B}(\Lambda_b^0 \rightarrow n \bar{K}^0 J/\psi) &= (3.2_{-0.5}^{+0.6}) \times 10^{-4}, \\
\mathcal{B}(\Lambda_b^0 \rightarrow \Xi^0 K^0 J/\psi) &= (3.93 \pm 1.41) \times 10^{-6}, \\
\mathcal{B}(\Xi_b^- \rightarrow \Xi^0 \pi^- J/\psi) &= (6.82 \pm 3.16) \times 10^{-5}, \\
\mathcal{B}(\Xi_b^0 \rightarrow \Xi^0 \pi^0 J/\psi) &= (3.21 \pm 1.49) \times 10^{-5}, \\
\mathcal{B}(\Xi_b^- \rightarrow \Xi^- \pi^0 J/\psi) &= (3.41 \pm 1.58) \times 10^{-5}. \quad (13)
\end{aligned}$$

Note that the prediction for $\Xi_b^- \rightarrow \Xi^- K^0 J/\psi$ holds only in the limit of $b^v \rightarrow 0$ and receives corrections from leading breaking effects. Assuming the breaking size $|b^v/b| \sim 20\%$, the central value of $\text{Br}(\Xi_b^- \rightarrow \Xi^- K^0 J/\psi)$ can vary within $(1.7, 3.9) \times 10^{-5}$, depending the sign of b^v/b . By contrast, the other channels are insensitive to the dominant $SU(3)$ breaking considered here and thus provide cleaner tests of the symmetry relations. Therefore, if future measurements of the corresponding branching ratios show significant deviation from our predictions, this would point to possible new physics. In the numerical calculations, we have used the actual measured particle masses. This accounts for phase space differences, which cause the branching ratios to deviate slightly from the symmetric relations.

There are also other relations from $SU(3)$ symmetry among the decay amplitudes that can be obtained. We have

$$\Delta S = 0:$$

$$\mathcal{M}(\Lambda_b^0 \rightarrow \Sigma^- K^+ J/\psi) = -\sqrt{2}\mathcal{M}(\Lambda_b^0 \rightarrow \Sigma^0 K^0 J/\psi)$$

$$\stackrel{c^v \rightarrow 0}{\approx} \mathcal{M}(\Xi_b^- \rightarrow n K^- J/\psi),$$

$$\mathcal{M}(\Xi_b^0 \rightarrow p K^- J/\psi) \approx \mathcal{M}(\Xi_b^0 \rightarrow \Xi^- K^+ J/\psi)|_{a^v \rightarrow 0},$$

$$\mathcal{M}(\Xi_b^0 \rightarrow \Xi^0 K^0 J/\psi)|_{b^v \rightarrow -a^v} \approx \mathcal{M}(\Xi_b^0 \rightarrow \Sigma^+ \pi^- J/\psi),$$

$$\mathcal{M}(\Xi_b^0 \rightarrow \Sigma^- \pi^+ J/\psi) = \mathcal{M}(\Xi_b^0 \rightarrow n \bar{K}^0 J/\psi),$$

$$\mathcal{M}(\Xi_b^0 \rightarrow \Lambda^0 \pi^0 J/\psi) = \mathcal{M}(\Xi_b^- \rightarrow \Lambda^0 \pi^- J/\psi)/\sqrt{2},$$

$$\mathcal{M}(\Xi_b^0 \rightarrow \Sigma^0 \eta^{(\prime)} J/\psi) = \mathcal{M}(\Xi_b^- \rightarrow \Sigma^- \eta^{(\prime)} J/\psi)/\sqrt{2}.$$

$$\Delta S = 1:$$

$$\mathcal{M}(\Lambda_b^0 \rightarrow \Sigma^+ \pi^- J/\psi) = \mathcal{M}(\Lambda_b^0 \rightarrow \Sigma^- \pi^+ J/\psi)$$

$$= \mathcal{M}(\Lambda_b^0 \rightarrow \Sigma^0 \pi^0 J/\psi),$$

$$-\mathcal{M}(\Xi_b^0 \rightarrow \Sigma^+ K^- J/\psi) = \sqrt{2}\mathcal{M}(\Xi_b^0 \rightarrow \Sigma^0 \bar{K}^0 J/\psi)$$

$$= \mathcal{M}(\Xi_b^- \rightarrow \Sigma^- \bar{K}^0 J/\psi) = \sqrt{2}\mathcal{M}(\Xi_b^- \rightarrow \Sigma^0 K^- J/\psi),$$

$$\mathcal{M}(\Xi_b^0 \rightarrow \Lambda^0 \bar{K}^0 J/\psi) = -\mathcal{M}(\Xi_b^- \rightarrow \Lambda^0 K^- J/\psi),$$

$$\mathcal{M}(\Xi_b^- \rightarrow \Xi^- \eta^{(\prime)} J/\psi) = -\mathcal{M}(\Xi_b^0 \rightarrow \Xi^- \eta^{(\prime)} J/\psi).$$

(14)

Note that for $\Delta S = 0$, we use approximations for the first three equations, meaning they are valid only in the limit of $c^v \rightarrow 0$, $a^v \rightarrow 0$, and $b^v \rightarrow -a^v$, respectively. Although none of the branching ratios mentioned above have been measured to date, these relations can be tested with the substantial amount of data expected in the future.

In addition to the amplitude relations discussed above, numerous relations also exist for CP violation across various decay modes due to the U-spin symmetry, which is a subgroup of $SU(3)$ symmetry. For the direct CP asymmetry A_{CP}^{dir} , we have

$$A_{CP}^{\text{dir}} = \frac{\int |\mathcal{M}(B_b \rightarrow BMM)|^2 - \int |\bar{\mathcal{M}}(\bar{B}_b \rightarrow \bar{B} \bar{M} \bar{M})|^2}{\int |\mathcal{M}(B_b \rightarrow BMM)|^2 + \int |\bar{\mathcal{M}}(\bar{B}_b \rightarrow \bar{B} \bar{M} \bar{M})|^2}, \quad (15)$$

where the symbol $\int$ indicates the phase space integration.

Since the total amplitudes are the combination of tree-level and penguin in Eq. (7), the amplitude for the CP -conjugate process is

$$\bar{\mathcal{M}} = (\lambda_q^c)^* \mathcal{M}_T + (\lambda_q^t)^* \mathcal{M}_P, \quad q = d, s. \quad (16)$$

Here $q = (d, s)$ correspond to $\Delta S = 0$ and $\Delta S = 1$ processes, respectively. The squared amplitude is

$$\begin{aligned} |\mathcal{M}(B_b \rightarrow BMM)|^2 &= |\lambda_q^c|^2 |\mathcal{M}_T|^2 + |\lambda_q^t|^2 |\mathcal{M}_P|^2 \\ &\quad + 2\text{Re}(\lambda_q^c \mathcal{M}_T \times (\lambda_q^t)^* \mathcal{M}_P^*), \\ |\bar{\mathcal{M}}(\bar{B}_b \rightarrow \bar{B} \bar{M} \bar{M})|^2 &= |(\lambda_q^c)^*|^2 |\mathcal{M}_T|^2 + |(\lambda_q^t)^*|^2 |\mathcal{M}_P|^2 \\ &\quad + 2\text{Re}((\lambda_q^c)^* \mathcal{M}_T \times (\lambda_q^t) \mathcal{M}_P^*). \end{aligned} \quad (17)$$

Therefore, the direct CP violation can be obtained as

$$A_{CP}^{\text{dir}} = \frac{-4\text{Im}(\lambda_q^c (\lambda_q^t)^*) \int \text{Im}(\mathcal{M}_T \mathcal{M}_P^*)}{\int |\mathcal{M}(B_b \rightarrow BMM)|^2 + \int |\bar{\mathcal{M}}(\bar{B}_b \rightarrow \bar{B} \bar{M} \bar{M})|^2}, \quad (18)$$

where $\lambda_q^c \lambda_q^{t*} = V_{cb} V_{cq}^* V_{tb}^* V_{tq}$ with $q = (d, s)$. Following the CKM matrix unitarity relation $\text{Im}(V_{cb} V_{cs}^* V_{tb}^* V_{ts}) = -\text{Im}(V_{cb} V_{cd}^* V_{tb}^* V_{td})$, we can directly determine the CP asymmetry of the corresponding U-spin processes. Taking the $\Lambda_b \rightarrow p \pi^- J/\psi$ as an example, we have

$$\begin{aligned} &-(|\mathcal{M}(\Lambda_b \rightarrow p \pi^- J/\psi)|^2 - |\bar{\mathcal{M}}(\bar{\Lambda}_b \rightarrow \bar{p} \pi^+ \bar{J}/\psi)|^2) \\ &= |\mathcal{M}(\Xi_b^0 \rightarrow \Sigma^+ K^- J/\psi)|^2 - |\bar{\mathcal{M}}(\bar{\Xi}_b^0 \rightarrow \Sigma^- K^+ \bar{J}/\psi)|^2. \end{aligned} \quad (19)$$

Then the A_{CP}^{dir} ratio of these channels is

$$\begin{aligned} R(A_{CP}^{\text{dir}}) &= \frac{A_{CP}^{\text{dir}}(\Lambda_b \rightarrow p \pi^- J/\psi)}{A_{CP}^{\text{dir}}(\Xi_b^0 \rightarrow \Sigma^+ K^- J/\psi)} \\ &= -\frac{\int |\mathcal{M}(\Xi_b^0 \rightarrow \Sigma^+ K^- J/\psi)|^2 + \int |\bar{\mathcal{M}}(\bar{\Xi}_b^0 \rightarrow \Sigma^- K^+ \bar{J}/\psi)|^2}{\int |\mathcal{M}(\Lambda_b \rightarrow p \pi^- J/\psi)|^2 + \int |\bar{\mathcal{M}}(\bar{\Lambda}_b \rightarrow \bar{p} \pi^+ \bar{J}/\psi)|^2} \\ &= -\frac{\mathcal{B}(\Xi_b^0 \rightarrow \Sigma^+ K^- J/\psi) \cdot \tau(\Lambda_b)}{\mathcal{B}(\Lambda_b \rightarrow p \pi^- J/\psi) \cdot \tau(\Xi_b^0)}, \end{aligned} \quad (20)$$

where we have used $(\int |\mathcal{M}(\Lambda_b \rightarrow p \pi^- J/\psi)|^2 + \int |\bar{\mathcal{M}}(\bar{\Lambda}_b \rightarrow \bar{p} \pi^+ \bar{J}/\psi)|^2)/2 \sim \mathcal{B}(\Lambda_b \rightarrow p \pi^- J/\psi)$.

Therefore we obtain the following CP violation relation

$$\begin{aligned} \frac{A_{CP}^{\text{dir}}(\Lambda_b \rightarrow p \pi^- J/\psi)}{A_{CP}^{\text{dir}}(\Xi_b^0 \rightarrow \Sigma^+ K^- J/\psi)} &= -\mathcal{R}\left(\frac{\Xi_b^0 \rightarrow \Sigma^+ K^- J/\psi}{\Lambda_b \rightarrow p \pi^- J/\psi}\right), \\ \frac{A_{CP}^{\text{dir}}(\Lambda_b^0 \rightarrow p K^- J/\psi)}{A_{CP}^{\text{dir}}(\Xi_b^0 \rightarrow \Sigma^+ \pi^- J/\psi)} &= -\mathcal{R}\left(\frac{\Xi_b^0 \rightarrow \Sigma^+ \pi^- J/\psi}{\Lambda_b^0 \rightarrow p K^- J/\psi}\right), \end{aligned} \quad (21)$$

where a ratio is defined for convenience,

$$\mathcal{R}\left(\frac{B_b \rightarrow BMM}{B'_b \rightarrow B'M'M'}\right) = \frac{\mathcal{B}(B_b \rightarrow BMM) \cdot \tau(B'_b)}{\mathcal{B}(B'_b \rightarrow B'M'M') \cdot \tau(B_b)}. \quad (22)$$

Since LHCb has measured the difference in CP asymmetries between the two aforementioned processes, as given in Eq. (1), we have

$$\begin{aligned} \Delta A_{CP} = & \mathcal{R}\left(\frac{\Xi_b^0 \rightarrow \Sigma^+ \pi^- J/\psi}{\Lambda_b^0 \rightarrow p K^- J/\psi}\right) A_{CP}^{\text{dir}}(\Xi_b^0 \rightarrow \Sigma^+ \pi^- J/\psi) \\ & - \mathcal{R}\left(\frac{\Xi_b^0 \rightarrow \Sigma^+ K^- J/\psi}{\Lambda_b^0 \rightarrow p \pi^- J/\psi}\right) A_{CP}^{\text{dir}}(\Xi_b^0 \rightarrow \Sigma^+ K^- J/\psi). \end{aligned} \quad (23)$$

Following the same strategy outlined in Eq. (20), we derive the following U-spin-based CP -violation relations for bottom-baryon decays as

$$\begin{aligned} \frac{A_{CP}^{\text{dir}}(\Lambda_b^0 \rightarrow \Sigma^+ \pi^- J/\psi)}{A_{CP}^{\text{dir}}(\Xi_b^0 \rightarrow p K^- J/\psi)} &= -\mathcal{R}\left(\frac{\Xi_b^0 \rightarrow p K^- J/\psi}{\Lambda_b^0 \rightarrow \Sigma^+ \pi^- J/\psi}\right), \\ \frac{A_{CP}^{\text{dir}}(\Lambda_b^0 \rightarrow n \pi^0 J/\psi)}{A_{CP}^{\text{dir}}(\Lambda_b^0 \rightarrow \Sigma^0 \bar{K}^0 J/\psi)} &= -\mathcal{R}\left(\frac{\Xi_b^0 \rightarrow \Sigma^0 \bar{K}^0 J/\psi}{\Lambda_b^0 \rightarrow n \pi^0 J/\psi}\right), \\ \frac{A_{CP}^{\text{dir}}(\Lambda_b^0 \rightarrow n \bar{K}^0 J/\psi)}{A_{CP}^{\text{dir}}(\Xi_b^0 \rightarrow n K^0 J/\psi)} &= -\mathcal{R}\left(\frac{\Xi_b^0 \rightarrow n K^0 J/\psi}{\Lambda_b^0 \rightarrow n \bar{K}^0 J/\psi}\right), \\ \frac{A_{CP}^{\text{dir}}(\Lambda_b^0 \rightarrow \Sigma^- \pi^+ J/\psi)}{A_{CP}^{\text{dir}}(\Xi_b^0 \rightarrow \Xi^- K^+ J/\psi)} &\stackrel{a^v \rightarrow 0}{\approx} -\mathcal{R}\left(\frac{\Xi_b^0 \rightarrow \Xi^- K^+ J/\psi}{\Lambda_b^0 \rightarrow \Sigma^- \pi^+ J/\psi}\right), \\ \frac{A_{CP}^{\text{dir}}(\Lambda_b^0 \rightarrow \Xi^- K^+ J/\psi)}{A_{CP}^{\text{dir}}(\Xi_b^0 \rightarrow \Sigma^- \pi^+ J/\psi)} &\stackrel{c^v \rightarrow -a^v}{\approx} -\mathcal{R}\left(\frac{\Xi_b^0 \rightarrow \Sigma^- \pi^+ J/\psi}{\Lambda_b^0 \rightarrow \Xi^- K^+ J/\psi}\right), \\ \frac{A_{CP}^{\text{dir}}(\Lambda_b^0 \rightarrow \Xi^0 K^0 J/\psi)}{A_{CP}^{\text{dir}}(\Xi_b^0 \rightarrow n \bar{K}^0 J/\psi)} &\stackrel{c^v \rightarrow -a^v}{\approx} -\mathcal{R}\left(\frac{\Xi_b^0 \rightarrow n \bar{K}^0 J/\psi}{\Lambda_b^0 \rightarrow \Xi^0 K^0 J/\psi}\right), \\ \frac{A_{CP}^{\text{dir}}(\Lambda_b^0 \rightarrow \Sigma^- K^+ J/\psi)}{A_{CP}^{\text{dir}}(\Xi_b^0 \rightarrow \Xi^- \pi^+ J/\psi)} &\stackrel{c^v \rightarrow 0}{\approx} -\mathcal{R}\left(\frac{\Xi_b^0 \rightarrow \Xi^- \pi^+ J/\psi}{\Lambda_b^0 \rightarrow \Sigma^- K^+ J/\psi}\right). \end{aligned} \quad (24)$$

Note that the last four lines receive the corrections from SU(3) breaking effects, meaning that they hold only in the corresponding limit $a^v \rightarrow 0$, $a^v + c^v \rightarrow 0$, and $c^v \rightarrow 0$, respectively. With the continuous accumulation of new experimental data, the observation of new processes is anticipated in the future. Once future experiments measure the branching ratio of one or several of the above processes, we can predict the corresponding other processes. Moreover, the relevant CP violation can also further predicted. Furthermore, if future measurements on the channels insensitive to dominant SU(3) breaking, such as the first three lines, reveal a significant deviation, this would point to possible new physics.

Additionally, SU(3) symmetry also provides new information about CP asymmetry differences from the known ΔA_{CP} in Eq. (1) for other decays. We give an example below.

Using the relations

$$\begin{aligned} K_1 &= \frac{1}{\sqrt{2}}(K^0 - \bar{K}^0), \quad K_2 = \frac{1}{\sqrt{2}}(K^0 + \bar{K}^0), \\ K_S^0 &= \frac{1}{\sqrt{1+|\epsilon|^2}}(K_1 + \epsilon K_2), \\ K_L^0 &= \frac{1}{\sqrt{1+|\epsilon|^2}}(K_2 + \epsilon K_1), \end{aligned} \quad (25)$$

and results in Table I, we obtain

$$\begin{aligned} \Delta A_{CP} &= A_{CP}(\Lambda_b^0 \rightarrow p \pi^- J/\psi) - A_{CP}(\Lambda_b^0 \rightarrow p K^- J/\psi) \\ &= A_{CP}(\Lambda_b^0 \rightarrow n \pi^0 J/\psi) - A_{CP}(\Lambda_b^0 \rightarrow n K_{S,L} J/\psi) \\ &\approx A_{CP}(\Xi_b^- \rightarrow \Xi^- K_{S,L} J/\psi)|_{b^v \rightarrow 0} \\ &\quad - A_{CP}(\Lambda_b^0 \rightarrow n K_{S,L} J/\psi). \end{aligned} \quad (26)$$

Due to the definition of A_{CP} in Eq. (15), the factor related to ϵ cancels in the amplitude ratio, making the above relation insensitive to ϵ . Note that the last equation only holds in the limit $b^v \rightarrow 0$. However, the channel with a neutron is insensitive to dominant SU(3) breaking terms, which can serve as a discriminator between large SU(3) breaking and new physics. Although measuring the neutron channel is currently challenging, it can become feasible with improvements in data analysis methods and larger future datasets. Therefore, the most promising near-term targets are the channels with fully charged final states, whereas channels involving a neutron or other neutral particles represent longer-term targets.

For processes not yet measured, differences in CP asymmetries can be predicted using specific combinations of the amplitude relations in Eq. (14). Some representative examples are

$$\begin{aligned} & A_{CP}(\Lambda_b^0 \rightarrow \Sigma^- K^+ J/\psi) - A_{CP}(\Lambda_b^0 \rightarrow \Sigma^- \pi^+ J/\psi) \\ &= A_{CP}(\Lambda_b^0 \rightarrow \Sigma^0 K^0 J/\psi) - A_{CP}(\Lambda_b^0 \rightarrow \Sigma^0 \pi^0 J/\psi), \\ & A_{CP}(\Xi_b^0 \rightarrow \Lambda^0 \pi^0 J/\psi) - A_{CP}(\Xi_b^0 \rightarrow \Lambda K_{S,L} J/\psi)|_{2b^v \rightarrow c^v} \\ &\approx A_{CP}(\Xi_b^- \rightarrow \Lambda^0 \pi^- J/\psi) - A_{CP}(\Xi_b^- \rightarrow \Lambda K^- J/\psi). \end{aligned} \quad (27)$$

Note that the first equation remains valid even with dominant SU(3) breaking effects, while the second equation holds only in the limit $2b^v \rightarrow c^v$. Since these intriguing difference of CP asymmetry relations can remove some systematic errors compared with individual CP asymmetry measurements, such relations warrant further experimental investigation. Notably, current experiments are already measuring key observables in Eq. (1) and the corresponding branching ratios. A particularly compelling candidate to test our prediction is $A_{CP}(\Lambda_b^0 \rightarrow n \pi^0 J/\psi) - A_{CP}(\Lambda_b^0 \rightarrow (n K_S, n K_L) J/\psi)$, which benefits from having identical

TABLE I. $SU(3)$ amplitudes in Eq. (8) for different physical processes. Here $\lambda_q^c = V_{cb}V_{cq}^*$ and $\lambda_q^t = V_{tb}V_{tq}^*$.

Channel	$\Delta S = 0$ amplitudes	$SU(3)$ breaking	Channel	$\Delta S = 1$ amplitudes	$SU(3)$ breaking
$\Lambda_b^0 \rightarrow p\pi^- J/\Psi$	$b_T\lambda_d^c + b_P\lambda_d^t$		$\Xi_b^0 \rightarrow \Sigma^+ K^- J/\Psi$	$-(b_T\lambda_s^c + b_P\lambda_s^t)$	
$\Xi_b^- \rightarrow \Xi^- K^0 J/\Psi$	$b_T\lambda_d^c + b_P\lambda_d^t$	$b_T^v\lambda_d^c + b_P^v\lambda_d^t$	$\Xi_b^- \rightarrow \Sigma^- \bar{K}^0 J/\Psi$	$b_T\lambda_s^c + b_P\lambda_s^t$	
$\Lambda_b^0 \rightarrow n\pi^0 J/\Psi$	$-\frac{b_T\lambda_d^c + b_P\lambda_d^t}{\sqrt{2}}$		$\Xi_b^0 \rightarrow \Sigma^0 \bar{K}^0 J/\Psi$	$\frac{(b_T\lambda_s^c + b_P\lambda_s^t)}{\sqrt{2}}$	
			$\Xi_b^- \rightarrow \Sigma^0 K^- J/\Psi$	$\frac{b_T\lambda_s^c + b_P\lambda_s^t}{\sqrt{2}}$	
$\Xi_b^0 \rightarrow \Sigma^+ \pi^- J/\Psi$	$-(a_T + b_T)\lambda_d^c$		$\Lambda_b^0 \rightarrow pK^- J/\Psi$	$(a_T + b_T)\lambda_s^c$	
	$-(a_P + b_P)\lambda_d^t$			$+(a_P + b_P)\lambda_s^t$	
$\Xi_b^0 \rightarrow \Xi^0 K^0 J/\Psi$	$-(a_T + b_T)\lambda_d^c$	$-(a_T^v + b_T^v)\lambda_d^c$	$\Lambda_b^0 \rightarrow n\bar{K}^0 J/\Psi$	$(a_T + b_T)\lambda_s^c$	
	$-(a_P + b_P)\lambda_d^t$	$-(a_P^v + b_P^v)\lambda_d^t$		$+(a_P + b_P)\lambda_s^t$	
$\Xi_b^0 \rightarrow \Sigma^- \pi^+ J/\Psi$	$-(a_T + c_T)\lambda_d^c$		$\Lambda_b^0 \rightarrow \Xi^- K^+ J/\Psi$	$(a_T + c_T)\lambda_s^c$	$(a_T^v + c_T^v)\lambda_s^c$
	$-(a_P + c_P)\lambda_d^t$			$+(a_P + c_P)\lambda_s^t$	$+(a_P^v + c_P^v)\lambda_s^t$
$\Xi_b^0 \rightarrow n\bar{K}^0 J/\Psi$	$-(a_T + c_T)\lambda_d^c$		$\Lambda_b^0 \rightarrow \Xi^0 K^0 J/\Psi$	$(a_T + c_T)\lambda_s^c$	$(a_T^v + c_T^v)\lambda_s^c$
	$-(a_P + c_P)\lambda_d^t$			$+(a_P + c_P)\lambda_s^t$	$+(a_P^v + c_P^v)\lambda_s^t$
$\Xi_b^0 \rightarrow pK^- J/\Psi$	$-(a_T\lambda_d^c + a_P\lambda_d^t)$		$\Lambda_b^0 \rightarrow \Sigma^+ \pi^- J/\Psi$	$a_T\lambda_s^c + a_P\lambda_s^t$	
$\Xi_b^0 \rightarrow \Xi^- K^+ J/\Psi$	$-(a_T\lambda_d^c + a_P\lambda_d^t)$	$-(a_T^v\lambda_d^c + a_P^v\lambda_d^t)$	$\Lambda_b^0 \rightarrow \Sigma^- \pi^+ J/\Psi$	$a_T\lambda_s^c + a_P\lambda_s^t$	
			$\Lambda_b^0 \rightarrow \Sigma^0 \pi^0 J/\Psi$	$a_T\lambda_s^c + a_P\lambda_s^t$	
$\Lambda_b^0 \rightarrow \Sigma^- K^+ J/\Psi$	$c_T\lambda_d^c + c_P\lambda_d^t$	$c_T^v\lambda_d^c + c_P^v\lambda_d^t$	$\Xi_b^0 \rightarrow \Xi^- \pi^+ J/\Psi$	$-(c_T\lambda_s^c + c_P\lambda_s^t)$	
$\Xi_b^- \rightarrow n\bar{K}^- J/\Psi$	$c_T\lambda_d^c + c_P\lambda_d^t$		$\Xi_b^- \rightarrow \Xi^0 \pi^- J/\Psi$	$c_T\lambda_s^c + c_P\lambda_s^t$	
$\Lambda_b^0 \rightarrow \Sigma^0 K^0 J/\Psi$	$-\frac{c_T\lambda_d^c + c_P\lambda_d^t}{\sqrt{2}}$	$-\frac{c_T^v\lambda_d^c + c_P^v\lambda_d^t}{\sqrt{2}}$	$\Xi_b^0 \rightarrow \Xi^0 \pi^0 J/\Psi$	$\frac{c_T\lambda_s^c + c_P\lambda_s^t}{\sqrt{2}}$	
$\Xi_b^- \rightarrow \Sigma^- \pi^0 J/\Psi$	$\frac{(c_T - b_T)\lambda_d^c + (c_P - b_P)\lambda_d^t}{\sqrt{2}}$		$\Xi_b^- \rightarrow \Xi^- \pi^0 J/\Psi$	$\frac{c_T\lambda_s^c + c_P\lambda_s^t}{\sqrt{2}}$	
$\Lambda_b^0 \rightarrow \Lambda^0 K^0 J/\Psi$	$\frac{(c_T - 2b_T)\lambda_d^c + (c_P - 2b_P)\lambda_d^t}{\sqrt{6}}$	$-\frac{(2b_T^v - c_T^v)\lambda_d^c}{\sqrt{6}}$	$\Xi_b^0 \rightarrow \Lambda^0 \bar{K}^0 J/\Psi$	$-\frac{(b_T - 2c_T)\lambda_s^c + (b_P - 2c_P)\lambda_s^t}{\sqrt{6}}$	
		$-\frac{(2b_P^v - c_P^v)\lambda_d^t}{\sqrt{6}}$			
$\Xi_b^- \rightarrow \Lambda^0 \pi^- J/\Psi$	$\frac{(b_T + c_T)\lambda_d^c + (b_P + c_P)\lambda_d^t}{\sqrt{6}}$		$\Xi_b^- \rightarrow \Lambda^0 K^- J/\Psi$	$\frac{(b_T - 2c_T)\lambda_s^c + (b_P - 2c_P)\lambda_s^t}{\sqrt{6}}$	
$\Xi_b^0 \rightarrow \Lambda^0 \pi^0 J/\Psi$	$\frac{(b_T + c_T)\lambda_d^c + (b_P + c_P)\lambda_d^t}{2\sqrt{3}}$				
$\Xi_b^- \rightarrow \Sigma^0 \pi^- J/\Psi$	$\frac{(b_T - c_T)\lambda_d^c + (b_P - c_P)\lambda_d^t}{\sqrt{2}}$				
$\Xi_b^0 \rightarrow \Sigma^0 \pi^0 J/\Psi$	$-\frac{1}{2}\lambda_d^c(2a_T + b_T + c_T)$				
	$-\frac{1}{2}\lambda_d^t(2a_P + b_P + c_P)$				
$\Xi_b^0 \rightarrow \Sigma^0 \eta J/\Psi$	$\frac{[\sqrt{3}c_\theta(b_T + c_T) - 3\sqrt{2}s_\theta d_T]\lambda_d^c}{6}$	$\frac{(c_T^v)c_\theta\lambda_d^c}{\sqrt{3}}$			
	$+\frac{[\sqrt{3}c_\theta(b_P + c_P) - 3\sqrt{2}s_\theta d_P]\lambda_d^t}{6}$	$+\frac{(c_P^v)c_\theta\lambda_d^t}{\sqrt{3}}$			
$\Xi_b^- \rightarrow \Sigma^- \eta J/\Psi$	$\frac{[\sqrt{6}c_\theta(b_T + c_T) - 6s_\theta d_T]\lambda_d^c}{6}$	$\sqrt{\frac{2}{3}}c_T^v c_\theta \lambda_d^c$	$\Xi_b^- \rightarrow \Xi^- \eta J/\Psi$	$-\frac{[\sqrt{6}c_\theta(2b_T - c_T) + 6s_\theta(d_T)]\lambda_s^c}{6}$	$-\sqrt{\frac{2}{3}}(b_T^v - c_T^v)c_\theta\lambda_s^c$
	$+\frac{[\sqrt{6}c_\theta(b_P + c_P) - 6s_\theta d_P]\lambda_d^t}{6}$	$+\sqrt{\frac{2}{3}}c_P^v c_\theta \lambda_d^t$		$-\frac{[\sqrt{6}c_\theta(2b_P - c_P) + 6s_\theta(d_P)]\lambda_s^t}{6}$	$-\sqrt{\frac{2}{3}}(b_P^v - c_P^v)c_\theta\lambda_s^t$
$\Lambda_b^0 \rightarrow n\eta J/\Psi$	$+\frac{[\sqrt{6}c_\theta(b_T - 2c_T) - 6s_\theta(d_T)]\lambda_d^c}{6}$		$\Xi_b^0 \rightarrow \Xi^0 \eta J/\Psi$	$\frac{[\sqrt{6}c_\theta(2b_T - c_T) + 6s_\theta(d_T)]\lambda_s^c}{6}$	$\sqrt{\frac{2}{3}}(b_T^v - c_T^v)c_\theta\lambda_s^c$
	$+\frac{[\sqrt{6}c_\theta(b_P - 2c_P) - 6s_\theta(d_P)]\lambda_d^t}{6}$			$+\frac{[\sqrt{6}c_\theta(2b_P - c_P) + 6s_\theta(d_P)]\lambda_s^t}{6}$	$+\sqrt{\frac{2}{3}}(b_P^v - c_P^v)c_\theta\lambda_s^t$
$\Xi_b^0 \rightarrow \Lambda^0 \eta J/\Psi$	$-\frac{[c_\theta(6a_T + b_T + c_T)]\lambda_d^c}{6}$	$-\frac{(2a_T^v + c_T^v)}{3}c_\theta\lambda_d^c$	$\Lambda_b^0 \rightarrow \Lambda^0 \eta J/\Psi$	$\frac{[c_\theta(3a_T + 2b_T + 2c_T)]\lambda_s^c}{3}$	$\frac{2}{3}(a_T^v + b_T^v)c_\theta\lambda_s^c$
	$-\frac{[c_\theta(6a_P + b_P + c_P)]\lambda_d^t}{6}$	$-\frac{(2a_P^v + c_P^v)}{3}c_\theta\lambda_d^t$		$+\frac{[c_\theta(3a_P + 2b_P + 2c_P)]\lambda_s^t}{3}$	$+\frac{2}{3}(a_P^v + b_P^v)c_\theta\lambda_s^t$
	$+\frac{s_\theta(d_T\lambda_d^c + d_P\lambda_d^t)}{\sqrt{6}}$			$+\frac{\sqrt{6}s_\theta(d_T\lambda_s^c + d_P\lambda_s^t)}{3}$	
$\Xi_b^0 \rightarrow \Sigma^0 \eta' J/\Psi$	$\frac{[\sqrt{3}s_\theta(b_T + c_T) + 3\sqrt{2}c_\theta d_T]\lambda_d^c}{6}$	$\frac{(c_T^v)}{\sqrt{3}}s_\theta\lambda_d^c$			
	$+\frac{[\sqrt{3}s_\theta(b_P + c_P) + 3\sqrt{2}c_\theta d_P]\lambda_d^t}{6}$	$+\frac{(c_P^v)}{\sqrt{3}}s_\theta\lambda_d^t$			
$\Xi_b^- \rightarrow \Sigma^- \eta' J/\Psi$	$\frac{[6c_\theta d_T + \sqrt{6}s_\theta(b_T + c_T)]\lambda_d^c}{6}$	$\sqrt{\frac{2}{3}}c_T^v s_\theta\lambda_d^c$	$\Xi_b^- \rightarrow \Xi^- \eta' J/\Psi$	$-\frac{[-6c_\theta(d_T) + \sqrt{6}s_\theta(2b_T - c_T)]\lambda_s^c}{6}$	$-\sqrt{\frac{2}{3}}(b_T^v - c_T^v)s_\theta\lambda_s^c$
	$+\frac{[6c_\theta d_T + \sqrt{6}s_\theta(b_P + c_P)]\lambda_d^t}{6}$	$+\sqrt{\frac{2}{3}}c_P^v s_\theta\lambda_d^t$		$-\frac{[-6c_\theta(d_P) + \sqrt{6}s_\theta(2b_P - c_P)]\lambda_s^t}{6}$	$-\sqrt{\frac{2}{3}}(b_P^v - c_P^v)s_\theta\lambda_s^t$

(Table continued)

TABLE I. (*Continued*)

Channel	$\Delta S = 0$ amplitudes	SU(3) breaking	Channel	$\Delta S = 1$ amplitudes	SU(3) breaking
$\Lambda_b^0 \rightarrow n\eta' J/\Psi$	$\frac{[\sqrt{6}s_\theta(b_T - 2c_T) + 6c_\theta(d_T)]\lambda_d^c}{6}$ + $\frac{[\sqrt{6}s_\theta(b_P - 2c_P) + 6c_\theta(d_P)]\lambda_d^t}{6}$		$\Xi_b^0 \rightarrow \Xi^0 \eta' J/\Psi$	$\frac{[\sqrt{6}s_\theta(2b_T - c_T) - 6c_\theta(d_T)]\lambda_s^c}{6}$ + $\frac{[\sqrt{6}s_\theta(2b_P - c_P) - 6c_\theta(d_P)]\lambda_s^t}{6}$	$\sqrt{\frac{2}{3}}(b_T^v - c_T^v)s_\theta\lambda_s^c$ + $\sqrt{\frac{2}{3}}(b_P^v - c_P^v)s_\theta\lambda_s^t$
$\Xi_b^0 \rightarrow \Lambda^0 \eta' J/\Psi$	$-\frac{[s_\theta(6a_T + b_T + c_T)]\lambda_d^c}{6}$ $-\frac{[s_\theta(6a_P + b_P + c_P)]\lambda_d^t}{6}$ $-\frac{c_\theta(d_T\lambda_d^c + d_P\lambda_d^t)}{\sqrt{6}}$	$-\frac{(2a_T^v + c_T^v)}{3}s_\theta\lambda_d^c$ $-\frac{(2a_P^v + c_P^v)}{3}s_\theta\lambda_d^t$	$\Lambda_b^0 \rightarrow \Lambda^0 \eta' J/\Psi$	$\frac{[s_\theta(3a_T + 2b_T + 2c_T)]\lambda_s^c}{3}$ + $\frac{[s_\theta(3a_P + 2b_P + 2c_P)]\lambda_s^t}{3}$ $-\frac{\sqrt{6}c_\theta(d_T\lambda_s^c + d_P\lambda_s^t)}{3}$	$\frac{2}{3}(a_T^v + b_T^v)s_\theta\lambda_s^c$ + $\frac{2}{3}(a_P^v + b_P^v)s_\theta\lambda_s^t$

baryons in the initial and final states, and is insensitive to dominant SU(3) breaking effects.

IV. CONCLUSION

In this work, we perform, for the first time, a systematic analysis of the decays of antitriplet beauty baryons, $\mathbf{B}_{b3} \rightarrow T_8 M J/\psi$, within the framework of flavor SU(3) symmetry. The SU(3) singlet feature of the charmonium state J/ψ significantly simplifies the dynamics. Specifically, there exist only four independent SU(3)-invariant amplitudes for both the tree and penguin operators, along with three dominant breaking terms induced by strange-quark condensate $\langle \bar{s}s \rangle$. We categorize the decay processes into $\Delta S = 0$ and $|\Delta S| = 1$ channels, where S denotes strangeness. By decomposing the relevant decay amplitudes, we derive a set of symmetry relations among them, which lead to testable predictions for the corresponding branching ratios. Furthermore, we establish numerous relations for CP -violating observables across different decay modes, as detailed in Eqs. (21), (24), and (26). These results provide a clear guidance for testing flavor SU(3) symmetry in the SM and searching for new sources of CP violation in the three-body charmonium decays of beauty baryons. Our analysis reveals that this LHCb signal in Eq. (1) is not an isolated observation but belongs to a broader pattern. Along with the relation in Eq. (23) between

$\Xi_b^0 \rightarrow \Sigma^+ \pi^- J/\psi$ and $\Xi_b^0 \rightarrow \Sigma^+ K^- J/\psi$, one particularly interesting and testable prediction is the difference in direct CP asymmetries, $\Delta A_{CP} = A_{CP}(\Lambda_b^0 \rightarrow p\pi^- J/\psi) - A_{CP}(\Lambda_b^0 \rightarrow pK^- J/\psi) = A_{CP}(\Lambda_b^0 \rightarrow n\pi^0 J/\psi) - A_{CP}(\Lambda_b^0 \rightarrow (nK_S, nK_L) J/\psi)$. These channels are insensitive to large SU(3) breaking effects, which can serve as a discriminator between SU(3) breaking and possible new physics. We strongly encourage our experimental colleagues to carry out related searches.

ACKNOWLEDGMENTS

We thank Professor Jibo He for useful discussions on the search for the neutron channel in the experiment. The work of J. S. is supported by IBS under the Project No. IBS-R018-D1. The work of Z.-P. X. is supported by NSFC under Grant No. 12405113. X.-G. H. was supported by the Fundamental Research Funds for the Central Universities, by the National Natural Science Foundation of the People's Republic of China (No. 12090064, No. 12375088, and No. W2441004).

DATA AVAILABILITY

There are no publicly available research data or software supporting this manuscript. Requests for further information or data should be sent to the authors.

- [1] A. D. Sakharov, *Pis'ma Zh. Eksp. Teor. Fiz.* **5**, 32 (1967).
- [2] J. H. Christenson, J. W. Cronin, V. L. Fitch, and R. Turlay, *Phys. Rev. Lett.* **13**, 138 (1964).
- [3] S. Navas *et al.* (Particle Data Group), *Phys. Rev. D* **110**, 030001 (2024).
- [4] R. Aaij *et al.* (LHCb Collaboration), *Sci. Bull.* **71**, 547 (2026).
- [5] R. Aaij *et al.* (LHCb Collaboration), *J. High Energy Phys.* **07** (2014) 103.
- [6] Z. P. Xing, X. G. He, F. Huang, and C. Yang, *Phys. Rev. D* **108**, 053004 (2023).

- [7] H. Zhong, F. Xu, and H. Y. Cheng, *Phys. Rev. D* **109**, 114027 (2024).
- [8] Z. P. Xing, Y. J. Shi, J. Sun, and Y. Xing, *Eur. Phys. J. C* **84**, 1014 (2024).
- [9] D. Wang and W. C. Fu, *Chin. Phys. C* **49**, 113104 (2025).
- [10] Y. Grossman and S. Schacht, *Phys. Rev. D* **99**, 033005 (2019).
- [11] S. Roy, R. Sinha, and N. G. Deshpande, *Phys. Rev. D* **101**, 036018 (2020).
- [12] S. Roy, R. Sinha, and N. G. Deshpande, *Phys. Rev. D* **102**, 053007 (2020).

- [13] B. Bhattacharya, S. Kumbhakar, D. London, and N. Payot, *Phys. Rev. D* **107**, L011505 (2023).
- [14] S. Schacht, *J. High Energy Phys.* 03 (2023) 205.
- [15] R. Bause, H. Gisbert, G. Hiller, T. Höhne, D. F. Litim, and T. Steudtner, *Phys. Rev. D* **108**, 035005 (2023).
- [16] W. Wang, Z. P. Xing, and Z. X. Zhao, *Phys. Rev. D* **111**, 053006 (2025).
- [17] J. Sun, Z. P. Xing, and R. Zhu, *Eur. Phys. J. C* **85**, 262 (2025).
- [18] X. G. He and C. W. Liu, *Sci. Bull.* **70**, 2598 (2025).
- [19] S. Iguro, U. Nierste, E. Overduin, and M. Schüßler, *Phys. Rev. D* **111**, 035023 (2025).
- [20] C. Yang, X. G. He, and C. W. Liu, *J. High Energy Phys.* 09 (2025) 193.
- [21] Q. Chen, X. Wu, Z. P. Xing, and R. Zhu, *Phys. Rev. D* **112**, 3 (2025).
- [22] X. G. He, C. W. Liu, and J. Tandean, *Phys. Rev. D* **112**, L111302 (2025).
- [23] G. Buchalla, A. J. Buras, and M. E. Lautenbacher, *Rev. Mod. Phys.* **68**, 1125 (1996).
- [24] X. G. He and W. Wang, *Chin. Phys. C* **42**, 103108 (2018).
- [25] N. H. Christ, C. Dawson, T. Izubuchi, C. Jung, Q. Liu, R. D. Mawhinney, C. T. Sachrajda, A. Soni, and R. Zhou, *Phys. Rev. Lett.* **105**, 241601 (2010).
- [26] R. Aaij *et al.* (LHCb Collaboration), *Eur. Phys. J. C* **85**, 812 (2025).