K_S^0-K_L^0 Asymmetries in Weak Decays of Charmed Baryons

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Abstract

The K_S-K_L (SL) asymmetry occurs in the two-body charmed baryon decay with neutral kaon contained in their final states. In this work, based on the topological diagram approach and separated contributions calculated in naive factorization and the pole model, we provide explicit predictions on SL asymmetries for all the singly charmed baryon two-body decays. In particular, for the first time, we predict a sizable SL asymmetry for Ω_c decays in its unique decay channel $\Omega_c \to \Xi^0 K_{S,L}$. Among the four groups of decays in antitriplet charmed baryons, the R values for $\Xi_c^+ \to \Sigma^+ K_{S,L}$ and $\Xi_c^0 \to \Sigma^0 K_{S,L}$ are around -0.5, which are promising to be measured. However, the other two groups $\Lambda_c^+ \to pK_{S,L}$ and $\Xi_c^0 \to \Lambda^0 K_{S,L}$ are relatively small. Our predictions are partially consistent with theoretical results provided by two other groups, and an examination by future experiments is highly anticipated.

Keywords: charmed baryon, weak decay, K_S-K_L asymmetry
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1. INTRODUCTION

In recent years, progress has been made in the experimental study of charm baryons. First, both Belle [2] and BESIII [3] have measured the absolute branching fraction of the decay $\Lambda_c^+ \to pK^-\pi^+$, leading to a new average of $(6.28 \pm 0.32)\%$ for this benchmark mode quoted by the Particle Data Group (PDG) [1]. Later, measurements involving Λ_c^+, including absolute branching fractions for $\Lambda_c^+ \to \Xi^0 K^+$ [4], $\Lambda_c^+ \to K_S^0 X$ [5], and $\Lambda_c^+ \to pK_S^0\eta$ [6], as well as decay asymmetries in $\Lambda_c \to pK_S, \Lambda\pi^+, \Sigma^+\pi^0, \Sigma^0\pi^+$ [7], have been carried out by BESIII. For Ξ_c^0 and Ξ_c^+, the other two singly charmed baryons in the antitriplet, new developments have also been made by Belle. Using a data set comprising $(772 \pm 11) \times 10^6$ $B\bar{B}$ pairs collected at $\Upsilon(4S)$ resonance, Belle was able to measure the branching ratios of charged and neutral Ξ_c decays[8, 9], as well as the decay asymmetries in Ξ_c^0 decays [10, 11]. In particular, the measurement of $\Lambda_c^+ \to p\pi^0, p\eta$ performed in BESIII [12] and Belle [13] indicated that singly Cabibbo-suppressed (SCS) decays have already been accessed. Though no two-body decays for doubly Cabibbo-suppressed (DCS) processes have been measured yet, it is anticipated regarding the recent published white paper [14] on its future prospect by BESIII.

The K_S-K_L asymmetry (SL asymmetry) is induced by the interference between Cabibbo-favored (CF) and DCS amplitudes in the decays of charmed hadrons. By measuring this asymmetry, DCS processes can be extracted complementary to the direct measurement. For the D meson system, the asymmetries have been studied extensively in theory [15, 16, 17, 18, 19, 20, 21], and some experimental progress has also been made by CLEO [22]. However, the SL asymmetries have been paid less attention in charmed baryon sector for a long time. Recently, some theoretical efforts have been made in the fitting approach with consideration of SU(3) flavor symmetry [23, 24]. However, a completed calculation in a dynamical approach for the asymmetries, relying on both types of processes, is still expected.

A full calculation of charmed baryon decays should contain contributions from both factorizable and nonfactorizable components. It is known that nonfactorizable contributions from W-exchange or inner W-emission diagrams play an essential role and they cannot be neglected, in contrast with the negligible effects in heavy meson decays. Our estimation of nonfactorizable contribution has been based on the pole model. In the pole model, important low-lying $1/2^+$ and $1/2^-$ states are usually considered under the pole approximation. In the decay with a pseudoscalar in the final state, $\mathcal{B}_c \to \mathcal{B} + P$, the nonfactorizable S- and P-wave amplitudes are dominated by $1/2^-$ low-lying baryon resonances and $1/2^+$ ground state baryons, respectively. The S-wave amplitude can be further reduced to current algebra in the soft-pseudoscalar limit. That is, the evaluation of the S-wave amplitude does not require the information of the troublesome negative-parity baryon resonances which are not well understood in the quark model. The methodology was developed and applied in the earlier work [25]. Recently, based on the pole model in conjunction with the current algebra technique, we have systematically studied weak decays of antitriplet charmed baryons [26, 27, 28], the only weak decaying baryon in sextet Ω_c [29], and doubly charmed baryons [30]. In the current work, we will combine these previous studies and give explicit predictions for K_S-K_L asymmetries of all the related singly charmed baryons.

This paper is organized as follows. In Section 2, a brief review for calculating CF and DCS decays of charmed baryon, including both factorizable and nonfactorizable components, is given first. We also provide the formalism for SL asymmetry. Numerical results and discussion are presented in Section 3. Finally, concluding remarks are made in Section 4.

2. FORMALISM

In this section, we will firstly review our calculation of two-body weak decays of charmed baryons. The desired K_S-K_L asymmetry in the charmed baryon sector is described subsequently.

2.1. Weak Decays of Charmed Baryons

For the decay of an initial charmed baryon $\mathcal{B}_c$ into a final baryon $\mathcal{B}_f$ and a pseudoscalar meson P, the amplitude is generically parametrized as

$$M(\mathcal{B}_i \to \mathcal{B}_f P) = i\bar{u}_f(A - B\gamma_5)u_i, \tag{1}$$

where A and B stand for S- and P-wave amplitude, respectively. Both the two amplitudes contribute to the decay width, giving

$$\Gamma = \frac{p_c}{8\pi}\left[\frac{(m_i+m_f)^2-m_P^2}{m_i^2}|A|^2+\frac{(m_i-m_f)^2-m_P^2}{m_i^2}|B|^2\right], \tag{2}$$

where κ is defined as

$$\kappa = p_c/\left(E_f+m_f\right) = \sqrt{\left(E_f-m_f\right)/\left(E_f+m_f\right)} \tag{3}$$

and p_c is the three-momentum in the rest frame of the parent particle. Apparently, for the magnitude of decay width, S-wave amplitude gives a larger contribution than the P-wave one. Both the S- and P-wave amplitudes generally receive factorizable and nonfactorizable contributions, giving

$$A = A^{\rm fac}+A^{\rm nf},\quad B = B^{\rm fac}+B^{\rm nf}. \tag{4}$$

The nonfactorizable amplitudes, denoted as $A^{\rm nf}$ and $B^{\rm nf}$, play an essential role in the decays of charmed baryon and hence cannot be ignored.

To identify specifically factorizable and nonfactorizable components, we make use of topological diagrams as treated in previous works process by process [26, 27, 28, 29, 30]. We adopt naive factorization to evaluate the factorizable contribution. Taking DCS decays as an example, the effective Hamiltonian is given as

$$\begin{aligned}\mathcal{H}_{\rm eff} &= \frac{G_F}{\sqrt{2}}V_{cd}V_{us}^*(c_1O_1+c_2O_2)+H.c.,\\ O_1 &= (\bar{u}s)(\bar{d}c),\quad O_2=(\bar{u}c)(\bar{d}s),\end{aligned} \tag{5}$$

where the abbreviated notation in four-quark operators is defined as $(\bar{q}_1q_2)\equiv\bar{q}_1\gamma_\mu(1-\gamma_5)q_2$. The Wilson coefficients to the leading order are given as $c_1=1.346$ and $c_2=-0.636$ at $\mu=1.25\,\text{GeV}$ and $\Lambda^{(4)}_{\overline{\rm MS}}=325\,\text{MeV}$. Considering the mixing of operators, it is more convenient to introduce effective Wilson coefficients $a_1=c_1+\frac{c_2}{N_c}$ and $a_2=c_2+\frac{c_1}{N_c}$, where N_c is the number of colors. Now, under naive factorization, the amplitude can factorized as

$$\begin{aligned}M &= \langle P\mathcal{B}\,|\mathcal{H}_{\rm eff}|\,\mathcal{B}_c\rangle\\ &= \begin{cases}\frac{G_F}{\sqrt{2}}V_{cd}V_{us}^*a_1\langle P|(\bar{u}s)|0\rangle\langle\mathcal{B}|(\bar{d}c)|\mathcal{B}_c\rangle, & P=K^+,\\ \frac{G_F}{\sqrt{2}}V_{cd}V_{us}^*a_2\langle P|(\bar{s}d)|0\rangle\langle\mathcal{B}|(\bar{u}c)|\mathcal{B}_c\rangle, & P=K^0,\end{cases}\end{aligned} \tag{6}$$

where a_1 corresponds to charged kaon while a_2 characterizes the amplitude with neutral kaon final state. In terms of the decay constants and form factors

$$\langle K(q)\,|\bar{s}\gamma_\mu\,(1-\gamma_5)\,d|\,0\rangle = if_Kq_\mu, \tag{7}$$

$$\begin{aligned}&\langle\mathcal{B}\,(p_2)\,|\bar{c}\gamma_\mu\,(1-\gamma_5)\,u|\,\mathcal{B}_c\,(p_1)\rangle\\ &=\bar{u}_2\left[f_1\left(q^2\right)\gamma_\mu-f_2\left(q^2\right)i\sigma_{\mu\nu}\frac{q^\nu}{M}+f_3\left(q^2\right)\frac{q_\mu}{M}\right.\\ &\qquad\left.-\left(g_1\left(q^2\right)\gamma_\mu-g_2\left(q^2\right)i\sigma_{\mu\nu}\frac{q^\nu}{M}+g_3\left(q^2\right)\frac{q_\mu}{M}\right)\gamma_5\right]u_1,\end{aligned} \tag{8}$$

with the momentum transfer $q=p_1-p_2$, we obtain the amplitude

$$\begin{aligned}&M\left(\mathcal{B}_c\to\mathcal{B}P\right)\\ &=i\frac{G_F}{\sqrt{2}}a_{1,2}V_{us}^*V_{cd}f_P\bar{u}_2\left(p_2\right)\\ &\quad\times\left[(m_1-m_2)\,f_1\left(q^2\right)+(m_1+m_2)\,g_1\left(q^2\right)\gamma_5\right]u_1\left(p_1\right).\end{aligned} \tag{9}$$

Finally, the factorizable contributions to A and B terms read

$$\begin{aligned}A^{\rm fac} &= \frac{G_F}{\sqrt{2}}a_{1,2}V_{us}^*V_{cd}f_P\left(m_{\mathcal{B}_c}-m_{\mathcal{B}}\right)f_1\left(q^2\right),\\ B^{\rm fac} &= -\frac{G_F}{\sqrt{2}}a_{1,2}V_{us}^*V_{cd}f_P\left(m_{\mathcal{B}_c}+m_{\mathcal{B}}\right)g_1\left(q^2\right).\end{aligned} \tag{10}$$

The calculation of nonfactorizable amplitudes is carried out in the pole model. The general formula for S- and P-wave amplitudes can be extracted from their complete amplitude:

$$\begin{aligned}A^{\rm pole} &= -\sum_{\mathcal{B}_n^*(1/2^-)}\left[\frac{g_{\mathcal{B}_f\mathcal{B}_n^*M}b_{n^*i}}{m_i-m_{n^*}}+\frac{b_{fn^*}g_{\mathcal{B}_n^*\mathcal{B}_iM}}{m_f-m_{n^*}}\right],\\ B^{\rm pole} &= \sum_{\mathcal{B}_n}\left[\frac{g_{\mathcal{B}_f\mathcal{B}_nM}a_{ni}}{m_i-m_n}+\frac{a_{fn}g_{\mathcal{B}_n\mathcal{B}_iM}}{m_f-m_n}\right],\end{aligned} \tag{11}$$

with the baryonic matrix elements a_{ij} and b_{ij} defined as

$$\begin{aligned}\langle\mathcal{B}_n|H|\mathcal{B}_i\rangle &= \bar{u}_n\left(a_{ni}+b_{ni}\gamma_5\right)u_i,\\ \left\langle\mathcal{B}_i^*\left(1/2^-\right)|H|\mathcal{B}_j\right\rangle &= \bar{u}_{i*}b_{i^*j}u_j,\end{aligned} \tag{12}$$

and the strong coupling among the pseudoscalar meson and two baryons g_{ijn}.

To estimate the S-wave amplitudes in the pole model is a difficult and nontrivial task as it involves the matrix elements and strong coupling constants of $1/2^-$ baryon resonances which is less known. Nevertheless, provided a soft emitted pseudoscalar meson,[1] the intermediate excited baryons can be summed up, leading to a commutator term

$$A^{\rm com} = \frac{\sqrt{2}}{f_{P^a}}\left\langle\mathcal{B}_f\left|\left[Q^a,H_{\rm eff}^{\rm PC}\right]\right|\mathcal{B}_i\right\rangle, \tag{13}$$

with the conserving charges $Q^a=\int d^3x\bar{q}\gamma^0\frac{\lambda^a}{2}q$, $Q_5^a=\int d^3x\bar{q}\gamma^0\gamma_5\frac{\lambda^a}{2}q$. Likewise, the P-wave amplitude is reduced in the soft meson limit to

$$B^{\rm ca} = \frac{\sqrt{2}}{f_{P^a}}\sum_{\mathcal{B}_n}\left[g^{A(P)}_{\mathcal{B}_f\mathcal{B}_n}\frac{m_f+m_n}{m_i-m_n}a_{ni}+a_{fn}\frac{m_i+m_n}{m_f-m_n}g^{A(P)}_{\mathcal{B}_n\mathcal{B}_i}\right], \tag{14}$$

with the application of the generalized Goldberger-Treiman relation, $g_{\mathcal{B}'\mathcal{B}P^a}=\frac{\sqrt{2}}{f_{P^a}}(m_{\mathcal{B}}+m_{\mathcal{B}'})g^A_{\mathcal{B}'\mathcal{B}}$. Subsequent calculations will be based on equations (13) and (14) in the pole model under the soft meson approximation.

[1] The current algebra is empirically working well though the produced pseudoscalars in charmed baryon decays are not strictly soft. One possible reason is that the on-shell corrections to the current-algebra result happen to be small compared to the current-algebra amplitude. More explanations can be found in [31].

2.2. K_S-K_L asymmetry

The K_S-K_L (SL) asymmetry, induced by the interference between CF and DCS processes, occurs in the decays containing a neutral kaon in the final states. Similar to the definition in D meson system (see [17] as an example), the asymmetry in charmed baryon sector can be defined as [21]

$$R\left(\mathcal{B}_c \to \mathcal{B}K^0_{S,L}\right) \equiv \frac{\Gamma\left(\mathcal{B}_c \to \mathcal{B}K^0_S\right) - \Gamma\left(\mathcal{B}_c \to \mathcal{B}K^0_L\right)}{\Gamma\left(\mathcal{B}_c \to \mathcal{B}K^0_S\right) + \Gamma\left(\mathcal{B}_c \to \mathcal{B}K^0_L\right)}. \quad (15)$$

For convenience, $K_{S,L}$ can be rotated into the CP eigentates $K^0, \overline{K}^0$ via the relation

$$K_S = \frac{1}{\sqrt{2}}\left(\frac{1+\epsilon}{\sqrt{1+|\epsilon|^2}}K^0 + \frac{-1+\epsilon}{\sqrt{1+|\epsilon|^2}}\overline{K}^0\right) \approx \frac{1}{\sqrt{2}}\left(K^0 - \overline{K}^0\right),$$
$$K_L = \frac{1}{\sqrt{2}}\left(\frac{1+\epsilon}{\sqrt{1+|\epsilon|^2}}K^0 + \frac{1-\epsilon}{\sqrt{1+|\epsilon|^2}}\overline{K}^0\right) \approx \frac{1}{\sqrt{2}}\left(K^0 + \overline{K}^0\right), \quad (16)$$

where the smallness of ϵ ($|\epsilon| = (2.228 \pm 0.011) \times 10^{-3}$ [1]) has been used. By using equation (16), a further simplification leads to

$$R\left(\mathcal{B}_c \to \mathcal{B}\right) = -\frac{2r}{1+r^2}, \quad r \equiv \sqrt{\frac{\Gamma\left(\mathcal{B}_c \to \mathcal{B}K^0\right)}{\Gamma\left(\mathcal{B}_c \to \mathcal{B}\overline{K}^0\right)}}. \quad (17)$$

Here, the definition of r differs from the corresponding one in SL asymmetry in D meson [17] and previously given for charmed baryon [21]. In the latter one, r contains not only the ratio of sizes but also the strong phase difference between the two amplitudes. The reason is that our calculation is carried out in the framework of the topological diagram approach, in which all the strong interactions and hence strong phases, have been absorbed into types of topological diagrams in principle. The further estimation of particular topological diagram contributions relies on the model calculation. Nevertheless, the evaluation of SL asymmetry in an independent way is still meaningful.

TABLE 1: Numerical values of form factors for various nonleptonic weak decays of singly charmed baryon $\mathcal{B}_c \to \mathcal{B}_f P$ in relevant decay energy scale.

Modes	$f_1(m_P^2)$	$g_1(m_P^2)$	Modes	$f_1(m_P^2)$	$g_1(m_P^2)$	Modes	$f_1(m_P^2)$	$g_1(m_P^2)$	Modes	$f_1(m_P^2)$	$g_1(m_P^2)$
$\Lambda_c^+ \to p\bar{K}^0$	−0.37	−0.49	$\Xi_c^+ \to \Sigma^+\bar{K}^0$	−0.49	−0.57	$\Xi_c^0 \to \Lambda\bar{K}^0$	0.17	0.21	$\Omega_c^0 \to \Xi^0\bar{K}^0$	0.32	−0.14
$\Lambda_c^+ \to \Lambda\pi^+$	0.42	0.51	$\Xi_c^+ \to \Xi^0\pi^+$	−0.58	−0.67	$\Xi_c^0 \to \Sigma^0\bar{K}^0$	0.34	0.40	$\Omega_c^0 \to \Xi^-\pi^+$	0.25	−0.12
$\Lambda_c^+ \to p\pi^0$	−0.33	−0.45	$\Xi_c^+ \to \Sigma^0\pi^+$	0.28	0.35	$\Xi_c^0 \to \Xi^-\pi^+$	−0.58	−0.67	$\Omega_c^0 \to \Xi^0\pi^0$	0.25	−0.12
$\Lambda_c^+ \to p\eta$	−0.38	−0.50	$\Xi_c^+ \to \Lambda\pi^+$	−0.13	−0.18	$\Xi_c^0 \to \Lambda\eta$	0.15	0.20	$\Omega_c^0 \to \Xi^0K^0$	0.28	−0.13
$\Lambda_c^+ \to n\pi^+$	−0.33	−0.45	$\Xi_c^+ \to \Sigma^+\pi^0$	−0.39	−0.49	$\Xi_c^0 \to \Sigma^0\eta$	0.32	0.38	$\Omega_c^0 \to \Xi^-K^+$	0.28	−0.13
$\Lambda_c^+ \to \Lambda K^+$	0.47	0.55	$\Xi_c^+ \to \Sigma^+\eta$	−0.45	−0.54	$\Xi_c^0 \to \Lambda\pi^0$	0.13	0.18			
$\Lambda_c^+ \to pK^0$	−0.37	−0.49	$\Xi_c^+ \to \Xi^0K^+$	−0.64	−0.72	$\Xi_c^0 \to \Sigma^0\pi^0$	0.27	0.35			
$\Lambda_c^+ \to nK^+$	−0.37	−0.49	$\Xi_c^+ \to \Sigma^0K^+$	0.31	0.38	$\Xi_c^0 \to \Sigma^-\pi^+$	0.39	0.50			
			$\Xi_c^+ \to \Lambda K^+$	−0.15	−0.20	$\Xi_c^0 \to \Xi^-K^+$	−0.64	−0.72			
			$\Xi_c^+ \to \Sigma^+K^0$	−0.43	−0.53	$\Xi_c^0 \to \Sigma^-K^+$	0.44	0.54			
						$\Xi_c^0 \to \Sigma^0K^0$	0.31	0.38			
						$\Xi_c^0 \to \Lambda^0K^0$	0.15	0.20			

TABLE 2: Numerical values of strong couplings in the pole model treatment of singly charmed baryon nonleptonic weak decays, taking $\bar{K}^0$ in the final state as an example.

	p	n	Σ^-	Ξ^-	Ξ^0	Σ^+	Λ^0	Σ^0	Λ_c^+	Ξ_c^0	$\Xi_c^{\prime 0}$	Ξ_c^+	Σ_c^+	Σ_c^0	Ω_c^0
p	-	-	-	-	4.45	-	-	-	-	-	-	-	-	-	-
n	-	-	-	-	-	-	−15.80	−3.15	-	-	-	-	-	-	-
Σ^-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ξ^-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ξ^0	4.45	-	-	-	-	-	6.23	−18.55	-	-	-	-	-	-	0
Σ^+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Λ^0	-	−15.80	-	-	6.23	-	-	-	-	-	-	-	-	-	-
Σ^0	-	−3.15	-	-	−18.55	-	-	-	-	-	-	-	-	-	-
Λ_c^+	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-
Ξ_c^0	-	-	-	-	-	-	-	-	-	-	-	-	-	25.23	−26.47
$\Xi_c^{\prime 0}$	-	-	-	-	-	-	-	-	0	-	-	-	-	-	31.21
Ξ_c^+	-	-	-	-	-	-	-	-	-	-	-	-	17.83	-	-
Σ_c^+	-	-	-	-	-	-	-	-	-	-	-	17.83	-	-	-
Σ_c^0	-	-	-	-	-	-	-	-	-	25.23	-	-	-	-	
Ω_c^0	-	-	-	-	0	-	-	-	-	−26.47	31.21	-	-	-	-

3. NUMERICAL RESULTS

Based on the MIT bag model, we calculated all the involved three types of nonperturbative parameters [27, 28, 29], which play a critical role in the estimation of weak decays in the pole model approach and summarize here explicitly in this section.

In Table 1, numerical values of all the form factors of the singly charmed baryon weak decays in their decay energy scale are given. By calculating axial-vector form factors and applying Goldberg-Treiman relation, one can obtain strong couplings. As an example, we show baryon couplings with $\bar{K}^0$ in Table 2. The weak transition amplitudes depend on both operators and initial as well as final states. Intuitively, here, we present some of the weak transition amplitudes for CF processes

$$\begin{aligned} a_{\Sigma^+\Lambda_c^+} &= -1.08\times 10^{-2}, \quad a_{\Sigma^0\Sigma_c^0} = 1.85\times 10^{-2}, \\ a_{\Xi^0\Xi_c^0} &= -1.06\times 10^{-2}, \quad a_{\Sigma^+\Sigma_c^+} = -1.85\times 10^{-2}, \\ a_{\Xi^0\Xi_c'} &= -1.86\times 10^{-2}, \quad a_{\Lambda\Sigma_c^0} = -1.08\times 10^{-2}, \end{aligned} \tag{18}$$

multiplied by a common factor $7.75\times 10^{-6}\,\mathrm{GeV}^{-2}$ (from $\frac{G_F}{2\sqrt{2}}V_{cs}V_{ud}^{*}c_-$). With these prepared numerics as input, the SL asymmetries can be obtained straightforwardly.

There are in total 10 CF and DCS two-body decay modes related to SL asymmetry in all the singly charmed baryons. We collect explicit contributions for factorizable and nonfactorizable components of these modes as well as their branching fractions from previous works [26, 27, 28, 29], including antitriplet charmed baryons and the only sextet Ω_c^0. The corresponding SL asymmetries can be evaluated straightforwardly, listed in the last column of Table 3.

TABLE 3: Amplitudes, branching fractions, and R values for weak decays of singly charmed baryons $\mathcal{B}_c \to \mathcal{B}_f P$, in which the units for amplitudes and branching fractions are $10^{-2}G_F\mathrm{GeV}^2$ and 10^{-4}, respectively.

Modes	$A^{\rm fac}$	$A^{\rm com}$	$A^{\rm tot}$	$B^{\rm fac}$	$B^{\rm ca}$	$B^{\rm tot}$	$\mathcal{B}_{\rm theo}$	R
$\Lambda_c^+ \to p\bar{K}^0$	3.45	4.48	7.93	−6.98	−2.06	−9.04	211	−0.03
$\Lambda_c^+ \to pK^0$	−0.13	0.24	0.11	0.40	−0.51	−0.11	0.04	
$\Xi_c^+ \to \Sigma^+\bar{K}^0$	2.98	−4.48	−1.50	−9.95	12.28	2.32	20	−0.48
$\Xi_c^+ \to \Sigma^+K^0$	−0.14	−0.24	−0.39	0.50	0.08	0.58	1.28	
$\Xi_c^0 \to \Lambda^0\bar{K}^0$	−1.11	−5.41	−6.52	3.66	6.87	10.52	13.3	−0.08
$\Xi_c^0 \to \Lambda^0K^0$	0.05	−0.30	−0.25	−0.18	0.64	0.46	0.20	
$\Xi_c^0 \to \Sigma^0\bar{K}^0$	−2.11	3.12	1.02	7.05	−9.39	−2.33	2	−0.45
$\Xi_c^0 \to \Sigma^0K^0$	0.10	0.17	0.27	−0.35	−0.06	−0.41	0.22	
$\Omega_c^0 \to \Xi^0\bar{K}^0$	−2.15	10.92	8.78	−2.64	10.12	7.48	378	−0.27
$\Omega_c^0 \to \Xi^0K^0$	0.10	−1.34	−1.24	0.13	−0.49	−0.36	7.04	

We find that SL values can be as large as one-half in the two types of modes $\Xi_c^+ \to \Sigma^+K_{S,L}$ and $\Xi_c^0 \to \Sigma^0K_{S,L}$, while in the two modes $\Lambda_c^+ \to pK_{S,L}$ and $\Xi_c^0 \to \Lambda^0$ their values are relatively small, less than 10%. The smallness of R for the above two modes is understandable. According to equation (17), in the small r case, the total value is proportional to r for the identical denominator. Regarding the inverse second column in Table 3, Λ_c^+ decays indeed with the smallest prediction for r. As for the Ω_c^0 decays (the unique modes), the R value could reach around 30% and hence is promising to be measured.

The R values we have calculated here slightly differ from the ones in [23, 24]. Only the size of amplitude ratio (or decay width ratio) r is contained in this work, while a combination of both size and strong phase is incorporated in the latter ones. In principle, strong phases can be extracted by comparing results in the two different approaches.

At the current state, we make a comparison among different groups. In [23], the decay $\Xi_c^+ \to \Sigma^+K_{S,L}$ is predicted to be with largest R value, and the R values for $\Lambda_c^+ \to pK_{S,L}$ [2] and $\Xi_c^+ \to \Lambda K_{S,L}$ are the smallest while $\Xi_c^0 \to \Sigma^0K_{S,L}$ is in between. However, in [24], the pattern for the two channels with large R values changes from [23] while the two smallest channels keep unchanged. Though the detailed values for the four channels in antitriplet charmed baryon decays are different, our prediction for the sequence of R values is consistent with [23].

[2]For the theoretical prediction for branching ratio of $\Lambda_c^+ \to pK_S$, there is a 30% deviation from experimental measurement ($\mathcal{B}(\Lambda_c^+ \to pK_S)_{\rm exp} = (1.59 \pm 0.08)\times 10^{-2}$). Hence, naively for R value, it could also deviate for around 30% in this mode. One possible reason could be that the correction term for the current algebra result is not small in this mode.

Moreover, for the first time, we provide a sizable prediction $R = -0.27$ for Ω_c^0 decays, which is unique in all the two-body Ω_c^0 decays. This could be checked by future experiments when more data is accumulated.

4. CONCLUDING REMARKS

The K_S-K_L (SL) asymmetry is an important observable in D meson decays. Some attentions on the study of charmed baryon decays have been paid recently. In this work, based on previous studies in two-body charmed baryon decays, we provide explicit predictions on SL asymmetries for all the singly charmed baryon two-body decays. Among the five groups of decays, the R values for $\Xi_c^+ \to \Sigma^+K_{S,L}$ and $\Xi_c^0 \to \Sigma^0K_{S,L}$ are around -0.5 while $\Omega_c^0 \to \Xi^0K_{S,L}$ is around -0.3, which are promising to be measured. However, the other two groups $\Lambda_c^+ \to pK_{S,L}$ and $\Xi_c^0 \to \Lambda^0K_{S,L}$ are less than 10% and hence are challenging for a measurement. Our prediction on R value pattern for antitriplet charmed baryons is consistent with a previous theoretical study in [23] and partially consistent with the prediction in [24]. For the R value of Ω_c^0, it is calculated for the first time and is worthy of being examined by future experiments.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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