

Charmed Baryon Decays in View of SU(3) Flavor Symmetry

Huiling Zhong

Collaborated with Fanrong Xu, Qiaoyi Wen, Yu Gu

Jinan University

HFCPV 2022, Dec. 10, 2022

arXiv:2210.12728

CONTENTS

- ▲ 1 Introduction
- ▲ 2 Formalism
- ▲ 3 Numerical Results
- ▲ 4 Summary

Introduction

1. Experimental Progress in 2022

- **Belle**

$$\mathcal{B}(\Lambda_c^+ \rightarrow p\eta') = (4.73 \pm 0.82 \pm 0.47 \pm 0.24) \times 10^{-4},$$

JHEP 03 (2022) 090

$$\mathcal{B}(\Lambda_c^+ \rightarrow \Lambda^0 K^+) = (6.57 \pm 0.17 \pm 0.11 \pm 0.35) \times 10^{-4},$$
$$\mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^0 K^+) = (3.58 \pm 0.19 \pm 0.06 \pm 0.19) \times 10^{-4},$$

$$\alpha(\Lambda_c^+ \rightarrow \Lambda^0 K^+) = -0.585 \pm 0.049 \pm 0.018,$$
$$\alpha(\Lambda_c^+ \rightarrow \Sigma^0 K^+) = -0.55 \pm 0.18 \pm 0.09,$$

arXiv:2208.08695[hep-ex]

$$\mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^+ \eta) = (3.14 \pm 0.35 \pm 0.11 \pm 0.25) \times 10^{-3},$$
$$\mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^+ \eta') = (4.16 \pm 0.75 \pm 0.21 \pm 0.33) \times 10^{-3},$$
$$\alpha(\Lambda_c^+ \rightarrow \Sigma^+ \eta) = -0.99 \pm 0.03 \pm 0.05,$$
$$\alpha(\Lambda_c^+ \rightarrow \Sigma^+ \eta') = -0.46 \pm 0.06 \pm 0.03.$$

arXiv:2208.10825[hep-ex]

- **BESIII**

$$\mathcal{B}(\Lambda_c^+ \rightarrow n\pi^+) = (6.6 \pm 1.2 \pm 0.4) \times 10^{-4},$$

Phys. Rev. Lett. 128 (2022) 142001

$$\mathcal{B}(\Lambda_c^+ \rightarrow p\eta') = (5.62_{-2.04}^{+2.46} \pm 0.26) \times 10^{-4},$$

Phys. Rev. D 106 (2022) 072002

$$\mathcal{B}(\Lambda_c^+ \rightarrow \Lambda^0 K^+) = (6.21 \pm 0.44 \pm 0.26 \pm 0.34) \times 10^{-4},$$

arXiv:2208.04001[hep-ex]

$$\mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^+ K_S^0) = (4.8 \pm 1.4 \pm 0.2 \pm 0.3) \times 10^{-4},$$
$$\mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^0 K^+) = (4.7 \pm 0.9 \pm 0.1 \pm 0.3) \times 10^{-4}.$$

arXiv:2207.10906[hep-ex]

Introduction

2. Theoretical Progress

- Pole model + current algebra + MIT bag model

- Rescattering *J.-J. Han, H.-Y. Jiang, W. Liu, Z.J. Xiao, F.-S. Yu
arXiv:2101.12019[hep-ph]*

- NR quark model *R. Zhu, X. Liu, H. Huang, C.-F. Qiao,
Phys.Lett. B797(2019),134869*

- QCD sum rule *T.M.Aliev, S.Bilmis, M.Savci,
Phys. Rev. D 104, 054030 (2021)*

- ...

- Fit

- SU(3) flavor symmetry

- Diagrammatical approach

*J. Zou, F. Xu, G. Meng, H.-Y. Cheng,
Phys. Rev. D 101 (2020) 014011;
G. Meng, S. M.-Y. Wong, Fanrong Xu,
JHEP 11 (2020) 126*

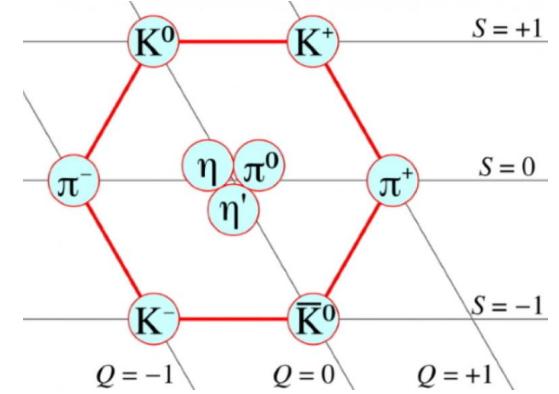
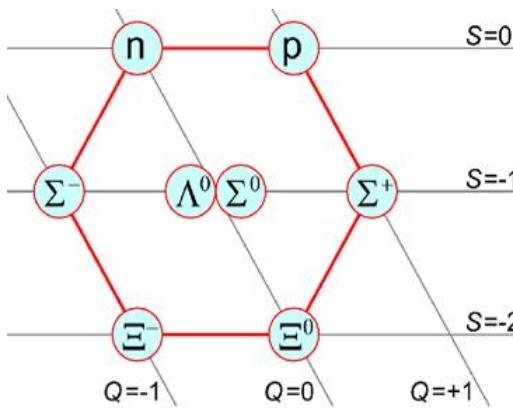
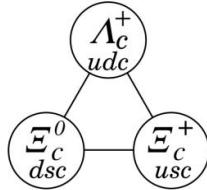
*C.Q. Geng, Chia-Wei Liu, Tien-Hsueh Tsai, Phys. Lett. B 794 (2019) 19;
F. Huang, Z.-P. Xing, X.-G. He, JHEP 03 (2022) 143*

Formalism

1. Flavour symmetry

	mass charge spin	mass charge spin
QUARKS	$\approx 2.2 \text{ MeV}/c^2$ $2/3$ $1/2$ u up	$\approx 1.28 \text{ GeV}/c^2$ $2/3$ $1/2$ c charm
	$\approx 4.7 \text{ MeV}/c^2$ $-1/3$ $1/2$ d down	$\approx 96 \text{ MeV}/c^2$ $-1/3$ $1/2$ s strange

$$m_u = m_d = m_s$$



$$\mathbf{B}_c = (\Xi_c^0, -\Xi_c^+, \Lambda_c^+),$$

$$\mathbf{B}_n = \begin{pmatrix} \frac{1}{\sqrt{6}}\Lambda^0 + \frac{1}{\sqrt{2}}\Sigma^0 & \Sigma^+ & p \\ \Sigma^- & \frac{1}{\sqrt{6}}\Lambda^0 - \frac{1}{\sqrt{2}}\Sigma^0 & n \\ \Xi^- & \Xi^0 & -\sqrt{\frac{2}{3}}\Lambda^0 \end{pmatrix},$$

$$M = \begin{pmatrix} \frac{1}{\sqrt{2}}(\pi^0 + c_\phi\eta + s_\phi\eta') & \pi^+ & K^+ \\ \pi^- & \frac{1}{\sqrt{2}}(-\pi^0 + c_\phi\eta + s_\phi\eta') & K^0 \\ K^- & \bar{K}^0 & -s_\phi\eta + c_\phi\eta' \end{pmatrix},$$

Formalism

1. Flavour symmetry

$$\mathcal{H}_{\text{eff}} = \frac{G_F}{\sqrt{2}} V_{q_1 c}^* V_{u q_2} (c_+ \mathcal{O}_+ + c_- \mathcal{O}_-) + h.c.$$

$$\mathcal{O}_+ = \frac{1}{2} (\mathcal{O}_1 + \mathcal{O}_2), \quad \mathcal{O}_- = \frac{1}{2} (\mathcal{O}_1 - \mathcal{O}_2)$$

$$\bar{3} \times \bar{3} \times 3 = \bar{3} + \bar{3} + \boxed{6} + \boxed{\bar{15}}$$

$$H(\bar{15})_k^{ij} = \left(\begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \quad \begin{pmatrix} 0 & s_c & 1 \\ s_c & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix}, \quad \begin{pmatrix} 0 & -s_c^2 & -s_c \\ -s_c^2 & 0 & 0 \\ -s_c & 0 & 0 \end{pmatrix} \right),$$

$$H(6)_{ij} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 2 & -2s_c \\ 0 & -2s_c & 2s_c^2 \end{pmatrix},$$

$$\mathcal{M} = \langle M \mathbf{B}_n | \mathcal{H}_{\text{eff}} | \mathbf{B}_c \rangle = i \bar{u}_f (A - B \gamma_5) u_i$$

$$\begin{aligned} A_0 = & a_0 H(6)_{ij} (\mathbf{B}'_c)^{ik} (\mathbf{B}_n)_k^j (M)_\ell^\ell + a_1 H(6)_{ij} (\mathbf{B}'_c)^{ik} (\mathbf{B}_n)_k^\ell (M)_\ell^j + a_2 H(6)_{ij} (\mathbf{B}'_c)^{ik} (M)_k^\ell (\mathbf{B}_n)_\ell^j \\ & + a_3 H(6)_{ij} (\mathbf{B}_n)_k^i (M)_\ell^j (\mathbf{B}'_c)^{kl} + \underline{a'_0 (\mathbf{B}_n)_j^i (M)_\ell^\ell H(\bar{15})_i^{jk} (\mathbf{B}_c)_k} + a_4 H(\bar{15})_k^{\ell i} (\mathbf{B}_c)_j (M)_i^j (\mathbf{B}_n)_\ell^k \\ & + \underline{a_5 (\mathbf{B}_n)_j^i (M)_i^\ell H(\bar{15})_\ell^{jk} (\mathbf{B}_c)_k} + a_6 (\mathbf{B}_n)_i^j (M)_\ell^m H(\bar{15})_m^{\ell i} (\mathbf{B}_c)_j + \underline{a_7 (\mathbf{B}_n)_i^\ell (M)_j^i H(\bar{15})_\ell^{jk} (\mathbf{B}_c)_k} \end{aligned}$$

$$B_0 = A_0 \Big|_{a_i \rightarrow b_i},$$

C.Q. Geng, Chia-Wei Liu, Tien-Hsueh Tsai, Phys. Lett. B 794 (2019) 19

Formalism

2. Breaking effect

mass	$\approx 2.2 \text{ MeV}/c^2$
charge	$\frac{2}{3}$
spin	$\frac{1}{2}$
U	
up	
mass	$\approx 1.28 \text{ GeV}/c^2$
charge	$\frac{2}{3}$
spin	$\frac{1}{2}$
C	
charm	
mass	$\approx 4.7 \text{ MeV}/c^2$
charge	$-\frac{1}{3}$
spin	$\frac{1}{2}$
d	
down	
mass	$\approx 96 \text{ MeV}/c^2$
charge	$-\frac{1}{3}$
spin	$\frac{1}{2}$
S	
strange	

$$H(\bar{3}) = (s_c, 0, 0)$$

*Martin J. Savage, Phys. Lett. B 257 (1991) 414;
C. Q. Geng, Y. K. Hsiao, Chia-Wei Liu, Tien-Hsueh Tsai,
Eur. Phys. J. C 78 (2018) 593*

$$\begin{aligned} A' &= u_1(\mathbf{B}_c)_i H(\bar{3})^i (\mathbf{B}_n)_k^j (M)_j^k + u_2(\mathbf{B}_c)_i H(\bar{3})^j (\mathbf{B}_n)_k^i (M)_j^k \\ &\quad + u_3(\mathbf{B}_c)_i H(\bar{3})^j (\mathbf{B}_n)_j^k (M)_k^i \end{aligned}$$

$$B' = A' \Big|_{u_i \rightarrow v_i}$$

The total *S*- and *P*-wave amplitudes are $A = A_0 + A'$, $B = B_0 + B'$

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

$$\alpha = \frac{2\kappa \text{Re}(A^* B)}{|A|^2 + \kappa^2 |B|^2}$$

Formalism

3. Amplitudes

Channel	$s_c^{-1}A$	Channel	$s_c^{-1}A$
$\Lambda_c^+ \rightarrow \Lambda^0 K^+$	$\frac{\sqrt{6}}{6}(2a_1 - 4a_2 + 2a_3 + 3a_4 - a_5 + 2a_6 + 2a_7 - 2u_2 + u_3)$	$\Xi_c^+ \rightarrow \Xi^0 K^+$	$2a_2 + 2a_3 + a_6 - a_7 - u_2$
$\Lambda_c^+ \rightarrow p\pi^0$	$\frac{\sqrt{2}}{2}(2a_2 + 2a_3 - a_6 - a_7 + u_2)$	$\Xi_c^0 \rightarrow \Lambda^0 \pi^0$	$\frac{\sqrt{3}}{6}(-2a_1 - 2a_2 + 4a_3 + 3a_4 - a_5 - a_6 - a_7 + u_2 + u_3)$
$\Lambda_c^+ \rightarrow p\eta$	$\frac{\sqrt{2}}{2}c_\phi(4a_0 + 2a_2 - 2a_3 - 2a'_0 + a_6 - a_7 + u_2) + s_\phi(-2a_0 - 2a_1 + a'_0 + a_4 + a_5 + a_6 - u_3)$	$\Xi_c^0 \rightarrow \Lambda^0 \eta$	$\frac{\sqrt{3}}{6}c_\phi(12a_0 + 2a_1 + 2a_2 - 4a_3 + 6a'_0 + 3a_4 + a_5 + a_6 + a_7 + 2u_1 + u_2 + u_3) + \frac{\sqrt{6}}{6}s_\phi(-6a_0 - 4a_1 - 4a_2 + 2a_3 - 3a'_0 - 2a_5 + a_6 - 2a_7 + 2u_1)$
$\Lambda_c^+ \rightarrow p\eta'$	$\frac{\sqrt{2}}{2}s_\phi(4a_0 + 2a_2 - 2a_3 - 2a'_0 + a_6 - a_7 + u_2) - c_\phi(-2a_0 - 2a_1 + a'_0 + a_4 + a_5 + a_6 - u_3)$	$\Xi_c^0 \rightarrow \Lambda^0 \eta'$	$\frac{\sqrt{3}}{6}s_\phi(12a_0 + 2a_1 + 2a_2 - 4a_3 + 6a'_0 + 3a_4 + a_5 + a_6 + a_7 + 2u_1 + u_2 + u_3) - \frac{\sqrt{6}}{6}c_\phi(-6a_0 - 4a_1 - 4a_2 + 2a_3 - 3a'_0 - 2a_5 + a_6 - 2a_7 + 2u_1)$
$\Lambda_c^+ \rightarrow n\pi^+$	$2a_2 + 2a_3 + a_6 - a_7 + u_2$	$\Xi_c^0 \rightarrow pK^-$	$-2a_2 - a_4 - a_7 + u_1 + u_3$
$\Lambda_c^+ \rightarrow \Sigma^0 K^+$	$\frac{\sqrt{2}}{2}(2a_1 - 2a_3 - a_4 - a_5 + u_3)$	$\Xi_c^0 \rightarrow n\bar{K}^0$	$2a_1 - 2a_2 - 2a_3 + a_5 - a_7 + u_1$
$\Lambda_c^+ \rightarrow \Sigma^+ K^0$	$2a_1 - 2a_3 + a_4 - a_5 + u_3$	$\Xi_c^0 \rightarrow \Sigma^0 \pi^0$	$\frac{1}{2}(2a_1 + 2a_2 - a_4 + a_5 - a_6 + a_7 + 2u_1 + u_2 + u_3)$
$\Xi_c^+ \rightarrow \Lambda^0 \pi^+$	$\frac{\sqrt{6}}{6}(2a_1 + 2a_2 - 4a_3 - 3a_4 - a_5 - a_6 - a_7 - u_2 - u_3)$	$\Xi_c^0 \rightarrow \Sigma^0 \eta$	$\frac{1}{2}c_\phi(-4a_0 - 2a_1 - 2a_2 - 2a'_0 - a_4 - a_5 + a_6 - a_7 + u_2 + u_3) + \frac{\sqrt{2}}{2}s_\phi(2a_0 - 2a_3 + a'_0 + a_6)$
$\Xi_c^+ \rightarrow p\bar{K}^0$	$2a_1 - 2a_3 + a_4 - a_5 - u_3$	$\Xi_c^0 \rightarrow \Sigma^0 \eta'$	$\frac{1}{2}s_\phi(-4a_0 - 2a_1 - 2a_2 - 2a'_0 - a_4 - a_5 + a_6 - a_7 + u_2 + u_3) - \frac{\sqrt{2}}{2}c_\phi(2a_0 - 2a_3 + a'_0 + a_6)$
$\Xi_c^+ \rightarrow \Sigma^0 \pi^+$	$\frac{\sqrt{2}}{2}(2a_1 - 2a_2 + a_4 - a_5 + a_6 + a_7 + u_2 - u_3)$	$\Xi_c^0 \rightarrow \Xi^0 K^0$	$-2a_1 + 2a_2 + a_5 - a_7 + u_1 + u_1$
$\Xi_c^+ \rightarrow \Sigma^+ \pi^0$	$\frac{\sqrt{2}}{2}(-2a_1 + 2a_2 + a_4 + a_5 + a_6 - a_7 - u_2 + u_3)$	$\Xi_c^0 \rightarrow \Sigma^+ \pi^-$	$2a_2 + a_4 + a_7 + u_1 + u_3$
$\Xi_c^+ \rightarrow \Sigma^+ \eta$	$\frac{\sqrt{2}}{2}c_\phi(4a_0 + 2a_1 + 2a_2 - 2a'_0 - a_4 - a_5 - a_6 - a_7 - u_2 - u_3) + s_\phi(-2a_0 + 2a_3 + a'_0 - a_6)$	$\Xi_c^0 \rightarrow \Sigma^- \pi^+$	$2a_1 + a_5 + a_6 + u_1 + u_2$
$\Xi_c^+ \rightarrow \Sigma^+ \eta'$	$\frac{\sqrt{2}}{2}s_\phi(4a_0 + 2a_1 + 2a_2 - 2a'_0 - a_4 - a_5 - a_6 - a_7 - u_2 - u_3) - c_\phi(-2a_0 + 2a_3 + a'_0 - a_6)$	$\Xi_c^0 \rightarrow \Xi^- K^+$	$-2a_1 - a_5 - a_6 + u_1 + u_2$

Channel	A	Channel	A
$\Lambda_c^+ \rightarrow \Lambda^0 \pi^+$	$\frac{\sqrt{6}}{6}(-2a_1 - 2a_2 - 2a_3 + a_5 - 2a_6 + a_7)$	$\Xi_c^+ \rightarrow \Xi^0 \pi^+$	$-2a_3 - a_4 - a_6$
$\Lambda_c^+ \rightarrow p\bar{K}^0$	$-2a_1 + a_5 + a_6$	$\Xi_c^0 \rightarrow \Lambda^0 \bar{K}^0$	$\frac{\sqrt{6}}{6}(-4a_1 + 2a_2 + 2a_3 - 2a_5 + a_6 + a_7)$
$\Lambda_c^+ \rightarrow \Sigma^0 \pi^+$	$\frac{\sqrt{2}}{2}(-2a_1 + 2a_2 + 2a_3 + a_5 - a_7)$	$\Xi_c^0 \rightarrow \Sigma^0 \bar{K}^0$	$\frac{\sqrt{2}}{2}(-2a_2 - 2a_3 + a_6 - a_7)$
$\Lambda_c^+ \rightarrow \Sigma^+ \pi^0$	$\frac{\sqrt{2}}{2}(2a_1 - 2a_2 - 2a_3 - a_5 + a_7)$	$\Xi_c^0 \rightarrow \Sigma^+ K^-$	$2a_2 + a_4 + a_7$
$\Lambda_c^+ \rightarrow \Sigma^+ \eta$	$\frac{\sqrt{2}}{6}c_\phi(-12a_0 - 6a_1 - 6a_2 + 6a_3 + 6a'_0 + 3a_5 + 3a_7) + s_\phi(2a_0 - a'_0 - a_4)$	$\Xi_c^0 \rightarrow \Xi^0 \pi^0$	$\frac{\sqrt{2}}{2}(-2a_1 + 2a_3 + a_4 - a_5)$
$\Lambda_c^+ \rightarrow \Sigma^+ \eta'$	$\frac{\sqrt{2}}{6}s_\phi(-12a_0 - 6a_1 - 6a_2 + 6a_3 + 6a'_0 + 3a_5 + 3a_7) - c_\phi(2a_0 - a'_0 - a_4)$	$\Xi_c^0 \rightarrow \Xi^0 \eta$	$\frac{\sqrt{2}}{6}c_\phi(12a_0 + 6a_1 - 6a_3 + 6a'_0 + 3a_4 + 3a_5) + \frac{1}{3}s_\phi(-6a_0 - 6a_2 - 3a'_0 - 3a_7)$
$\Lambda_c^+ \rightarrow \Xi^0 K^+$	$-2a_2 + a_4 + a_7$	$\Xi_c^0 \rightarrow \Xi^0 \eta'$	$\frac{\sqrt{2}}{6}s_\phi(12a_0 + 6a_1 - 6a_3 + 6a'_0 + 3a_4 + 3a_5) - \frac{1}{3}c_\phi(-6a_0 - 6a_2 - 3a'_0 - 3a_7)$
$\Xi_c^+ \rightarrow \Sigma^+ \bar{K}^0$	$2a_3 - a_4 - a_6$	$\Xi_c^0 \rightarrow \Xi^- \pi^+$	$2a_1 + a_5 + a_6$

Channel	$s_c^{-2}A$	Channel	$s_c^{-2}A$
$\Lambda_c^+ \rightarrow pK^0$	$2a_3 - a_4 - a_6$	$\Xi_c^+ \rightarrow \Sigma^+ K^0$	$-2a_1 + a_5 + a_6$
$\Lambda_c^+ \rightarrow nK^+$	$-2a_3 - a_4 - a_6$	$\Xi_c^0 \rightarrow \Lambda^0 K^0$	$\frac{\sqrt{6}}{6}(-2a_1 + 4a_2 + 4a_3 - a_5 - a_6 + 2a_7)$
$\Xi_c^+ \rightarrow \Lambda^0 K^+$	$\frac{\sqrt{6}}{6}(-2a_1 + 4a_2 + 4a_3 + a_5 + a_6 - 2a_7)$	$\Xi_c^0 \rightarrow p\pi^-$	$-2a_2 - a_4 - a_7$
$\Xi_c^+ \rightarrow p\pi^0$	$\frac{\sqrt{2}}{2}(-2a_2 - a_4 + a_7)$	$\Xi_c^0 \rightarrow n\pi^0$	$\frac{\sqrt{2}}{2}(2a_2 - a_4 + a_7)$
$\Xi_c^+ \rightarrow p\eta$	$\frac{\sqrt{2}}{2}c_\phi(-4a_0 - 2a_2 + 2a'_0 + a_4 + a_7) + s_\phi(2a_0 + 2a_1 - 2a_3 - a'_0 - a_5)$	$\Xi_c^0 \rightarrow n\eta$	$\frac{\sqrt{2}}{2}c_\phi(-4a_0 - 2a_2 - 2a'_0 - a_4 - a_7) + s_\phi(2a_0 + 2a_1 - 2a_3 + a'_0 + a_5)$
$\Xi_c^+ \rightarrow p\eta'$	$\frac{\sqrt{2}}{2}s_\phi(-4a_0 - 2a_2 + 2a'_0 + a_4 + a_7) - c_\phi(2a_0 + 2a_1 - 2a_3 - a'_0 - a_5)$	$\Xi_c^0 \rightarrow n\eta'$	$\frac{\sqrt{2}}{2}s_\phi(-4a_0 - 2a_2 - 2a'_0 - a_4 - a_7) - c_\phi(2a_0 + 2a_1 - 2a_3 + a'_0 + a_5)$
$\Xi_c^+ \rightarrow n\pi^+$	$-2a_2 + a_4 + a_7$	$\Xi_c^0 \rightarrow \Sigma^0 K^0$	$\frac{\sqrt{2}}{2}(2a_1 + a_5 - a_6)$
$\Xi_c^+ \rightarrow \Sigma^0 K^+$	$\frac{\sqrt{2}}{2}(-2a_1 + a_5 - a_6)$	$\Xi_c^0 \rightarrow \Sigma^- K^+$	$-2a_1 - a_5 - a_6$

Formalism

3. Amplitudes

$SU(3)$ symmetry is respected or broken:

$$\begin{aligned} A(\Lambda_c^+ \rightarrow \Sigma^0 \pi^+) &= -A(\Lambda_c^+ \rightarrow \Sigma^+ \pi^0) \\ A(\Lambda_c^+ \rightarrow n K^+) &= \sin^2 \theta A(\Xi_c^+ \rightarrow \Xi^0 \pi^+) \\ A(\Xi_c^+ \rightarrow n \pi^+) &= \sin^2 \theta A(\Lambda_c^+ \rightarrow \Xi^0 K^+) \\ A(\Xi_c^+ \rightarrow \Sigma^+ K^0) &= \sin^2 \theta A(\Lambda_c^+ \rightarrow p \bar{K}^0) \\ A(\Lambda_c^+ \rightarrow p K^0) &= \sin^2 \theta A(\Xi_c^+ \rightarrow \Sigma^+ \bar{K}^0) \\ A(\Xi_c^0 \rightarrow \Sigma^- K^+) &= -\sin^2 \theta A(\Xi_c^0 \rightarrow \Xi^- \pi^+) \\ A(\Xi_c^0 \rightarrow p \pi^-) &= -\sin^2 \theta A(\Xi_c^0 \rightarrow \Sigma^+ K^-). \end{aligned}$$

$SU(3)$ symmetry is strictly respected:

$$\begin{aligned} A(\Lambda_c^+ \rightarrow \Sigma^+ K^0) &= A(\Xi_c^+ \rightarrow p \bar{K}^0) \\ A(\Lambda_c^+ \rightarrow n \pi^+) &= A(\Xi_c^+ \rightarrow \Xi^0 K^+) \\ A(\Xi_c^0 \rightarrow n \bar{K}^0) &= -A(\Xi_c^0 \rightarrow \Xi^0 K^0) \\ A(\Xi_c^0 \rightarrow p \pi^-) &= \sin \theta A(\Xi_c^0 \rightarrow p K^-) = -\sin \theta A(\Xi_c^0 \rightarrow \Sigma^+ \pi^-) = -\sin^2 \theta A(\Xi_c^0 \rightarrow \Sigma^+ K^-) \\ A(\Xi_c^0 \rightarrow \Sigma^- K^+) &= \sin \theta A(\Xi_c^0 \rightarrow \Xi^- K^+) = -\sin \theta A(\Xi_c^0 \rightarrow \Sigma^- \pi^+) = -\sin^2 \theta A(\Xi_c^0 \rightarrow \Xi^- \pi^+) \end{aligned}$$

Formalism

4. Fitting scheme

$$\chi^2 = \sum_i \frac{(\mathcal{B}_i^{\text{th}} - \mathcal{B}_i^{\text{exp}})^2}{\delta_{1i}^2} + \sum_i \frac{(\mathcal{R}_i^{\text{th}} - \mathcal{R}_i^{\text{exp}})^2}{\delta_{2i}^2} + \sum_i \frac{(\alpha_i^{\text{th}} - \alpha_i^{\text{exp}})^2}{\sigma_i^2}$$
$$\boxed{\chi^2_{\text{min}}/\text{d.o.f.}} = 1$$

- **Branching fractions (20):**

$$\Lambda_c^+ \rightarrow \Lambda\pi^+, pK_S, \Sigma^0\pi^+, \Sigma^+\pi^0, \Sigma^+\eta, \Sigma^+\eta', \Xi^0K^+, p\eta, p\eta', p\pi^0, \Lambda K^+, \Sigma^0K^+, n\pi^+, \Sigma^+K_S,$$

$$\Xi_c^0 \rightarrow \Xi^-\pi^+, \Xi^-K^+, \Lambda K_S, \Sigma^0K_S, \Sigma^+K^-,$$

$$\Xi_c^+ \rightarrow \Xi^0\pi^+$$

- **Decay asymmetries (9):**

$$\Lambda_c \rightarrow \Lambda^0\pi^+, \Sigma^0\pi^+, \Sigma^+\pi^0, pK_S, \Sigma^+\eta, \Sigma^+\eta', \Lambda^0K^+, \Sigma^0K^+,$$

$$\Xi_c^0 \rightarrow \Xi^-\pi^+$$

- **Ratios of branching fractions (10):**

$$\Lambda_c \rightarrow \Sigma^+\eta/\Sigma^+\pi^0, \Sigma^+\eta'/\Sigma^+\pi^0, \Sigma^+\eta'/\Sigma^+\eta, \Lambda^0K^+/\Lambda^0\pi^+, \Sigma^0K^+/\Sigma^0\pi^+, \Sigma^0\pi^+/\Lambda^0\pi^+,$$

$$\Xi_c^0 \rightarrow \Lambda^0K_S/\Xi^-\pi^+, \Sigma^0K_S/\Xi^-\pi^+, \Sigma^+K^-/\Xi^-\pi^+, \Xi^-K^+/\Xi^-\pi^+$$

Numerical Results

1. Different scenarios

	Fit-I	Fit-I'	Fit-II	Fit-II'	Fit-III	Fit-III'
$(\chi^2_{\min}/\text{d.o.f.})$	1.16	2.60	1.98	2.20	1.27	2.15)

- Fit-I : $\mathcal{Br} + \alpha + R$
- Fit-II : $\mathcal{Br} + \alpha$
- Fit-III : $\mathcal{Br} + \alpha$ but $\alpha(\Lambda_c^+ \rightarrow p K_S), \mathcal{Br}(\Xi_c^0 \rightarrow \Xi^- \pi^+), \mathcal{Br}(\Xi_c^+ \rightarrow \Xi^0 \pi^+)$

Numerical Results

2. Best fit points

SU(3) respected (Fit-III')				SU(3) breaking (Fit-III)			
Coefficient	Value	Coefficient	Value	Coefficient	Value	Coefficient	Value
a_0	-0.10 ± 1.00	b_0	-0.50 ± 2.70	a_0	-1.20 ± 1.00	b_0	-0.70 ± 3.30
a_1	$-3.75^{+0.20}_{-0.17}$	b_1	$3.50^{+1.00}_{-0.90}$	a_1	$-3.50^{+0.21}_{-0.13}$	b_1	$8.60^{+1.30}_{-0.90}$
a_2	$1.10^{+0.17}_{-0.16}$	b_2	$4.04^{+0.33}_{-0.47}$	a_2	$1.45^{+0.16}_{-0.25}$	b_2	$4.00^{+0.90}_{-1.60}$
a_3	$-1.66^{+0.12}_{-0.10}$	b_3	$0.80^{+1.00}_{-0.90}$	a_3	$-1.98^{+0.15}_{-0.13}$	b_3	$-0.80^{+1.20}_{-0.70}$
a'_0	1.60 ± 2.00	b'_0	2.00 ± 5.00	a'_0	0.10 ± 2.00	b'_0	2.00 ± 7.00
a_4	$0.04^{+0.18}_{-0.21}$	b_4	$-1.20^{+0.60}_{-0.70}$	a_4	$0.23^{+0.29}_{-0.28}$	b_4	-3.40 ± 0.90
a_5	$1.36^{+0.45}_{-0.37}$	b_5	$-9.10^{+0.60}_{-0.70}$	a_5	$2.14^{+0.26}_{-0.23}$	b_5	$3.00^{+1.70}_{-2.20}$
a_6	$1.26^{+0.16}_{-0.22}$	b_6	$8.00^{+1.60}_{-1.70}$	a_6	$1.56^{+0.14}_{-0.20}$	b_6	$10.10^{+1.50}_{-2.30}$
a_7	$-1.04^{+0.33}_{-0.29}$	b_7	$0.60^{+0.90}_{-1.10}$	a_7	$-0.59^{+0.33}_{-0.42}$	b_7	$-0.90^{+1.90}_{-3.20}$
				u_1	0.00 ± 110	v_1	13.00^{+47}_{-36}
				u_2	$1.20^{+0.80}_{-0.70}$	v_2	$-3.00^{+1.70}_{-2.00}$
				u_3	2.80 ± 0.70	v_3	$4.80^{+1.40}_{-1.60}$

$$R = \begin{pmatrix} 1 & -0.00 & -0.02 & 0.03 & 0.99 & -0.02 & 0.00 & 0.00 & 0.00 & -0.00 & 0.00 & 0.01 & 0.00 & 0.00 & 0.01 & -0.01 & -0.01 & -0.00 & 0.00 \\ -0.00 & 1 & 0.09 & 0.09 & 0.00 & -0.01 & 0.89 & -0.13 & 0.11 & 0.00 & -0.25 & 0.02 & 0.09 & -0.00 & -0.09 & -0.67 & -0.05 & 0.07 \\ -0.02 & 0.09 & 1 & -0.42 & 0.02 & 0.28 & 0.08 & 0.04 & 0.78 & 0.01 & 0.09 & -0.50 & 0.12 & -0.01 & -0.05 & -0.05 & -0.14 & -0.40 \\ 0.03 & 0.09 & -0.42 & 1 & -0.03 & -0.39 & -0.05 & -0.39 & -0.10 & -0.00 & 0.22 & 0.17 & 0.24 & 0.00 & -0.01 & 0.09 & -0.26 & 0.27 \\ 0.99 & 0.00 & 0.02 & -0.03 & 1 & 0.02 & -0.00 & -0.00 & -0.00 & 0.00 & -0.00 & -0.01 & 0.00 & -0.00 & -0.01 & 0.00 & 0.00 & -0.00 \\ -0.02 & -0.01 & 0.28 & -0.39 & 0.02 & 1 & -0.11 & -0.37 & -0.19 & 0.01 & 0.17 & -0.20 & 0.09 & -0.01 & 0.12 & 0.03 & -0.13 & -0.25 \\ 0.00 & 0.89 & 0.08 & -0.05 & -0.00 & -0.11 & 1 & 0.21 & 0.17 & 0.00 & -0.48 & 0.00 & -0.11 & -0.00 & -0.12 & -0.74 & 0.22 & 0.08 \\ 0.00 & -0.13 & 0.04 & -0.39 & -0.00 & -0.37 & 0.21 & 1 & 0.27 & 0.00 & -0.54 & -0.11 & -0.47 & -0.00 & 0.01 & -0.01 & 0.48 & -0.02 \\ 0.00 & 0.11 & 0.78 & -0.10 & -0.00 & -0.19 & 0.17 & 0.27 & 1 & -0.00 & -0.02 & -0.41 & 0.10 & 0.00 & -0.13 & -0.13 & -0.04 & -0.29 \\ -0.00 & 0.00 & 0.01 & -0.00 & 0.00 & 0.01 & 0.00 & 0.00 & -0.00 & 1 & -0.01 & -0.02 & 0.01 & 0.99 & -0.01 & 0.01 & 0.00 & 0.01 \\ 0.00 & -0.25 & 0.09 & 0.22 & -0.00 & 0.17 & -0.48 & -0.54 & -0.02 & -0.01 & 1 & 0.00 & 0.78 & 0.01 & 0.03 & 0.38 & -0.89 & -0.07 \\ 0.00 & 0.02 & -0.50 & 0.17 & -0.01 & -0.20 & 0.00 & -0.11 & -0.41 & -0.02 & 0.00 & 1 & -0.10 & 0.02 & -0.10 & -0.07 & 0.05 & 0.63 \\ 0.00 & 0.09 & 0.12 & 0.24 & 0.00 & 0.09 & -0.11 & -0.47 & 0.10 & 0.01 & 0.78 & -0.10 & 1 & -0.01 & -0.32 & -0.02 & -0.83 & 0.22 \\ 0.00 & -0.00 & -0.01 & 0.00 & -0.001 & -0.01 & -0.00 & -0.00 & 0.00 & 0.99 & 0.01 & 0.02 & -0.01 & 1 & 0.01 & -0.01 & -0.00 & -0.01 \\ 0.01 & -0.09 & -0.05 & -0.01 & -0.01 & 0.12 & -0.12 & 0.01 & -0.13 & -0.01 & 0.03 & -0.10 & -0.32 & 0.01 & 1 & 0.15 & -0.06 & -0.55 \\ -0.00 & -0.67 & -0.05 & 0.09 & 0.00 & 0.03 & -0.74 & -0.01 & -0.13 & 0.01 & 0.38 & -0.07 & -0.02 & -0.01 & 0.15 & 1 & -0.14 & -0.01 \\ -0.00 & -0.05 & -0.14 & -0.26 & 0.00 & -0.13 & 0.22 & 0.48 & -0.04 & 0.00 & -0.89 & 0.05 & -0.83 & -0.00 & -0.06 & -0.14 & 1 & 0.06 \\ 0.00 & 0.07 & -0.40 & 0.27 & -0.00 & -0.25 & 0.08 & -0.02 & -0.29 & 0.01 & -0.07 & 0.63 & 0.22 & -0.01 & -0.55 & -0.01 & 0.06 & 1 \end{pmatrix}$$

Numerical Results

3. Predictions and comparison

channel	Fit-III	Fit-III'	GLT [17]	HXH [18]	ZWHY [19]	ZXMC [13, 32]	Exp. values
$10^2 \mathcal{B}(\Lambda_c^+ \rightarrow \Lambda^0 \pi^+)$	$1.30^{+0.12}_{-0.14}$	$1.27^{+0.08}_{-0.09}$	1.30 ± 0.07	1.307 ± 0.069	1.32 ± 0.34	1.30	1.30 ± 0.07
$10^2 \mathcal{B}(\Lambda_c^+ \rightarrow p K_S)$	1.65 ± 0.11	1.59 ± 0.10	1.57 ± 0.08	1.587 ± 0.077	1.57 ± 0.05	1.06	1.59 ± 0.08
$10^2 \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^0 \pi^+)$	1.27 ± 0.09	1.30 ± 0.06	1.27 ± 0.06	1.272 ± 0.056	1.26 ± 0.32	2.24	1.29 ± 0.07
$10^2 \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^+ \pi^0)$	1.27 ± 0.09	1.30 ± 0.06	1.27 ± 0.06	1.283 ± 0.057	1.23 ± 0.17	2.24	1.25 ± 0.10
$10^2 \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^+ \eta)$	$0.30^{+0.06}_{-0.07}$	0.31 ± 0.05	0.32 ± 0.13	0.45 ± 0.19	0.47 ± 0.22	0.74	0.44 ± 0.20
							0.314 ± 0.044 [7]
$10^2 \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^+ \eta')$	0.39 ± 0.08	0.24 ± 0.05	1.44 ± 0.56	1.5 ± 0.60	0.93 ± 0.28	-	1.50 ± 0.60
							0.416 ± 0.085 [7]
$10^2 \mathcal{B}(\Lambda_c^+ \rightarrow \Xi^0 K^+)$	$0.50^{+0.06}_{-0.09}$	0.38 ± 0.03	0.56 ± 0.09	0.548 ± 0.068	0.59 ± 0.17	0.73	0.55 ± 0.07
$10^3 \mathcal{B}(\Lambda_c^+ \rightarrow p \eta)$	1.27 ± 0.11	$1.36^{+0.11}_{-0.12}$	1.15 ± 0.27	1.27 ± 0.24	1.14 ± 0.35	1.28	1.42 ± 0.12
$10^4 \mathcal{B}(\Lambda_c^+ \rightarrow p \eta')$	$4.65^{+0.79}_{-0.77}$	$5.93^{+0.73}_{-0.71}$	24.5 ± 14.6	27 ± 38	7.1 ± 1.4	-	4.73 ± 0.97 [5]
							$5.62^{+2.46}_{-2.04} \pm 0.26$ [2]
$10^4 \mathcal{B}(\Lambda_c^+ \rightarrow \Lambda^0 K^+)$	$6.54^{+0.42}_{-0.49}$	$6.62^{+0.23}_{-0.22}$	6.5 ± 1.0	6.4 ± 1.0	5.9 ± 1.7	10.7	6.21 ± 0.61 [3]
							6.57 ± 0.40 [6]
$10^4 \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^0 K^+)$	$3.71^{+0.39}_{-0.36}$	$3.56^{+0.68}_{-0.69}$	5.4 ± 0.7	5.04 ± 0.56	5.5 ± 1.6	7.2	4.7 ± 0.95 [4]
							3.58 ± 0.28 [6]
$10^4 \mathcal{B}(\Lambda_c^+ \rightarrow n \pi^+)$	$6.47^{+1.33}_{-1.55}$	$8.15^{+0.69}_{-0.67}$	8.5 ± 2.0	3.5 ± 1.1	7.7 ± 2.0	-	6.6 ± 1.26 [1]
$10^4 \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^+ K_S)$	$1.99^{+0.49}_{-0.46}$	$3.11^{+0.35}_{-0.34}$	5.45 ± 0.75	1.03 ± 0.42	9.55 ± 2.4	7.2	4.8 ± 1.4 [4]
$10^4 \mathcal{B}(\Lambda_c^+ \rightarrow p \pi^0)$	$0.51^{+0.59}_{-0.61}$	0.16 ± 0.09	1.2 ± 1.2	44.5 ± 8.5	$0.8^{+0.9}_{-0.8}$	1.26	< 0.80 [30]
$10^2 \mathcal{B}(\Xi_c^0 \rightarrow \Xi^- \pi^+)$	$2.43^{+0.60}_{-0.64}$	$0.70^{+0.25}_{-0.22}$	2.21 ± 0.14	1.21 ± 0.21	1.93 ± 0.28	6.47	1.43 ± 0.32
$10^3 \mathcal{B}(\Xi_c^0 \rightarrow \Xi^- K^+)$	$0.60^{+1.03}_{-0.67}$	$0.31^{+0.11}_{-0.09}$	0.98 ± 0.06	0.47 ± 0.083	0.56 ± 0.08	3.90	0.38 ± 0.12
$10^3 \mathcal{B}(\Xi_c^0 \rightarrow \Lambda^0 K_S)$	$3.34^{+0.97}_{-0.98}$	$3.79^{+0.66}_{-0.61}$	5.25 ± 0.3	3.34 ± 0.65	4.16 ± 2.51	6.65	3.34 ± 0.67
$10^3 \mathcal{B}(\Xi_c^0 \rightarrow \Sigma^0 K_S)$	$0.74^{+0.25}_{-0.30}$	$0.73^{+0.25}_{-0.25}$	0.4 ± 0.4	0.69 ± 0.24	3.96 ± 0.25	0.2	0.69 ± 0.24
$10^3 \mathcal{B}(\Xi_c^0 \rightarrow \Sigma^+ K^-)$	$1.86^{+0.45}_{-0.71}$	$1.74^{+0.41}_{-0.51}$	5.9 ± 1.1	2.21 ± 0.68	22.0 ± 5.7	4.6	1.8 ± 0.4
$10^2 \mathcal{B}(\Xi_c^+ \rightarrow \Xi^0 \pi^+)$	$0.55^{+0.19}_{-0.20}$	0.81 ± 0.11	0.38 ± 0.20	0.54 ± 0.18	0.93 ± 0.36	1.72	1.6 ± 0.8

Numerical Results

3. Predictions and comparison

channel	Fit-III	Fit-III'	GLT [17]	HGX [18]	ZWHY [19]	ZXMC [13, 32]	Exp. values
$\alpha(\Lambda_c^+ \rightarrow \Lambda^0 \pi^+)$	-0.75 ± 0.01	-0.75 ± 0.01	-0.87 ± 0.10	-0.841 ± 0.083	-	-0.93	-0.84 ± 0.09
							-0.755 ± 0.006 [6]
$\alpha(\Lambda_c^+ \rightarrow p K_S)$	-0.29 ± 0.24	-0.57 ± 0.21	$-0.90^{+0.22}_{-0.10}$	0.19 ± 0.41	-	-0.75	0.18 ± 0.45
$\alpha(\Lambda_c^+ \rightarrow \Sigma^0 \pi^+)$	-0.47 ± 0.03	-0.47 ± 0.03	-0.35 ± 0.27	-0.605 ± 0.088	-	-0.76	-0.73 ± 0.18
							-0.463 ± 0.018 [6]
$\alpha(\Lambda_c^+ \rightarrow \Sigma^+ \pi^0)$	-0.47 ± 0.03	-0.47 ± 0.03	-0.35 ± 0.27	-0.603 ± 0.088	-	-0.76	-0.55 ± 0.11
							-0.48 ± 0.03 [7]
$\alpha(\Xi_c^0 \rightarrow \Xi^- \pi^+)$	$-0.64^{+0.11}_{-0.09}$	-0.64 ± 0.07	$-0.98^{+0.07}_{-0.02}$	-0.56 ± 0.32	-	-0.95	-0.64 ± 0.05
$\alpha(\Lambda_c^+ \rightarrow \Sigma^+ \eta)$	-0.95 ± 0.06	-0.96 ± 0.05	-0.40 ± 0.47	0.3 ± 3.8	-	-0.95	-0.99 ± 0.06 [7]
$\alpha(\Lambda_c^+ \rightarrow \Sigma^+ \eta')$	-0.47 ± 0.05	-0.43 ± 0.07	$1.00^{+0.00}_{-0.17}$	0.8 ± 1.9	-	-	-0.46 ± 0.07 [7]
$\alpha(\Lambda_c^+ \rightarrow \Lambda^0 K^+)$	-0.57 ± 0.06	-0.55 ± 0.06	0.32 ± 0.32	-0.24 ± 0.15	-	-0.96	-0.585 ± 0.052 [6]
$\alpha(\Lambda_c^+ \rightarrow \Sigma^0 K^+)$	-0.67 ± 0.05	$-0.97^{+0.02}_{-0.01}$	$-1.00^{+0.06}_{-0.00}$	-0.953 ± 0.040	-	-0.73	-0.55 ± 0.201 [6]

- The prediction of $\alpha(\Lambda_c^+ \rightarrow p K_S)$ is **negative**, pole model calculation is **negative**, while BESIII gave **positive** sign.

Summary

- Fit at current stage:
 - Providing complementary information to model calculations and experiments;
 - Providing predictions for unmeasured modes;
 - Checking SU(3) symmetry in charmed baryon decays.
- Current data prefers SU(3) flavor symmetry breaking in charmed baryon weak decays.
- Among the branching fractions of all the 16 CF channels, there are still 4 of them unmeasured. It is highly anticipated to be measured in the upcoming years for the four modes $\Xi_c^+ \rightarrow \Sigma^+ K_S$, $\Xi_c^0 \rightarrow \Xi^0 \pi^0$, $\Xi^0 \eta$, $\Xi^0 \eta'$.
- Future measurements of $\alpha(\Lambda_c^+ \rightarrow p K_S)$ from both BESIII and other experiments are expected to make a further clarification.



Thank you!