2019理论与实验联合研讨会：粲物理

Weak Decays of Anti-triplet Charmed Baryon

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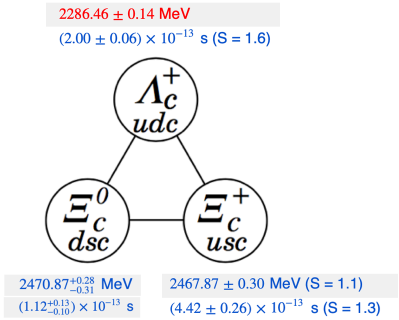
Outline

- Introduction
- Theoretical working frame
- Numerical results
- Discussion
  - Two examples
  - Comparison
- Summary

Introduction

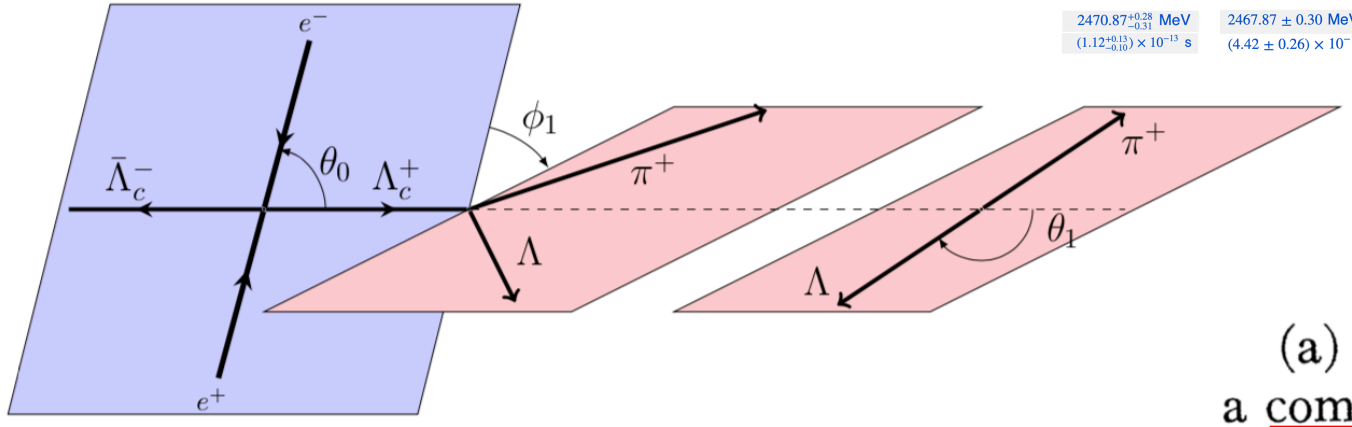
新瓶



旧酒

Branching fraction

Polarization

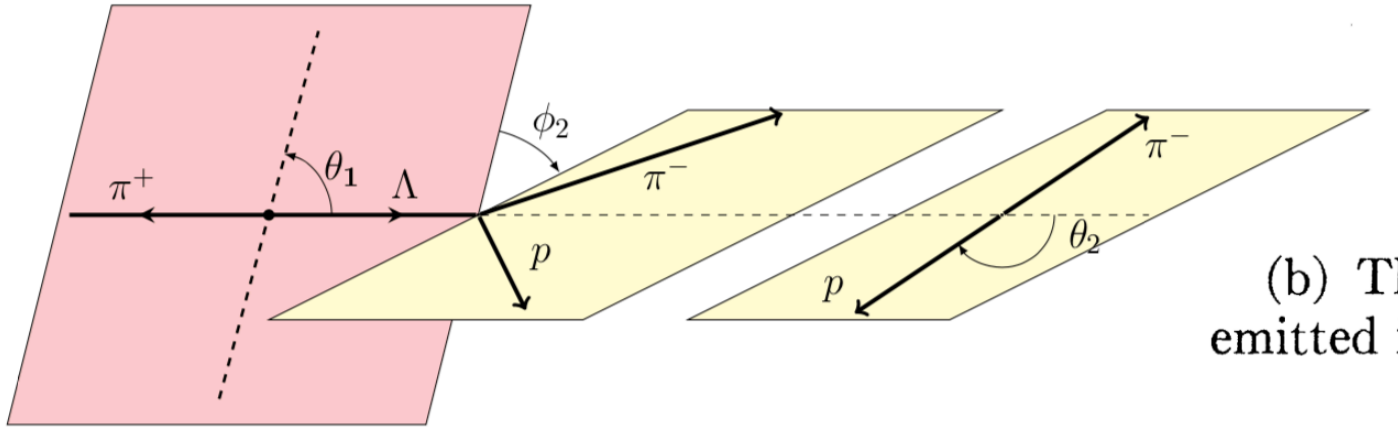


CM frame Λ_c^+ rest frame

(a) The angular distribution of the decay pion from a completely polarized hyperon at rest.

It has been pointed out before[1] that the distribution is proportional to

$$[1+\alpha\cos\chi]d\Omega, \qquad (1)$$



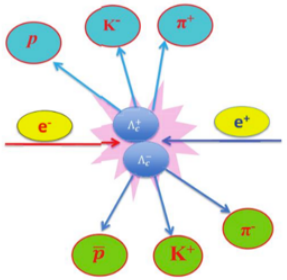
Λ_c^+ rest frame Λ rest frame

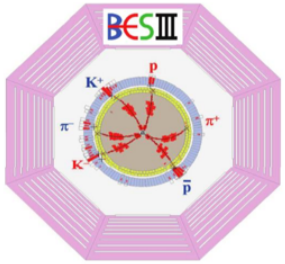
(b) The longitudinal polarization of the nucleon emitted in the decay of unpolarized hyperons at rest.

Lee-Yang, 1957

Λ_c^+ @BESIII

4.6 GeV, 567/pb





- $\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$
  - ARGUS + CLEO : $(5.0 \pm 1.3)\%$ PDG 2014
  - Belle: $(6.84 \pm 0.24^{+0.21}_{-0.27})\%$

    Belle, PRL 113 (2014), 042002
  - BESIII: $(5.84 \pm 0.27 \pm 0.23)\%$

    BESIII, PRL 116 (2016), 052001

PDG 2016: $(6.35 \pm 0.33)\%$

- 12 modes measured by BESIII

Mode	This work (%)	PDG (%)
pK_S^0	$1.52 \pm 0.08 \pm 0.03$	1.15 ± 0.30
$pK^-\pi^+$	$5.84 \pm 0.27 \pm 0.23$	5.0 ± 1.3
$pK_S^0\pi^0$	$1.87 \pm 0.13 \pm 0.05$	1.65 ± 0.50
$pK_S^0\pi^+\pi^-$	$1.53 \pm 0.11 \pm 0.09$	1.30 ± 0.35
$pK^-\pi^+\pi^0$	$4.53 \pm 0.23 \pm 0.30$	3.4 ± 1.0
$\Lambda\pi^+$	$1.24 \pm 0.07 \pm 0.03$	1.07 ± 0.28
$\Lambda\pi^+\pi^0$	$7.01 \pm 0.37 \pm 0.19$	3.6 ± 1.3
$\Lambda\pi^+\pi^-\pi^+$	$3.81 \pm 0.24 \pm 0.18$	2.6 ± 0.7
$\Sigma^0\pi^+$	$1.27 \pm 0.08 \pm 0.03$	1.05 ± 0.28
$\Sigma^+\pi^0$	$1.18 \pm 0.10 \pm 0.03$	1.00 ± 0.34
$\Sigma^+\pi^+\pi^-$	$4.25 \pm 0.24 \pm 0.20$	3.6 ± 1.0
$\Sigma^+\omega$	$1.56 \pm 0.20 \pm 0.07$	2.7 ± 1.0

PDG values for Λ_c^+ decay BFs before 2016 version become obsolete

Λ_c^+ @BESIII 4.6 GeV, 567/pb

- Singly-Cabibbo-suppressed decay has been measured

$$\mathcal{B}(\Lambda_c^+ \to p\eta) = (1.24 \pm 0.28(\text{stat.}) \pm 0.10(\text{syst.})) \times 10^{-3}$$
$$\mathcal{B}(\Lambda_c^+ \to p\pi^0) < 2.7 \times 10^{-4}$$

BESIII, PRD 95 (2017), 111102

- Neutral mode can be measured

$$\mathcal{B}(\Lambda_c^+ \to nK_S^0\pi^+) = (1.82 \pm 0.23(\text{stat}) \pm 0.11(\text{syst}))\%$$

BESIII, PRL 118 (2016), 112001

- More decay asymmetries can be measured

$$\alpha_{\Lambda\pi^+} \sim 10\%, \quad \alpha_{\Sigma^0\pi^+} \sim (19-66)\%$$

D. Wang, R.-G. Ping, L. Li, X.-R. Lyu, Y.-H. Zheng , Chin. Phys. C 41 (2017) 023106

$$\alpha_{\Lambda\pi^+} = -0.80 \pm 0.11 \pm 0.02$$
$$\alpha_{\Sigma^+\pi^0} = -0.57 \pm 0.10 \pm 0.07$$
$$\alpha_{\Sigma^0\pi^+} = -0.73 \pm 0.17 \pm 0.07$$

BESIII, 1905.04707

Λ_c^+ @BESIII 4.6 GeV, 567/pb

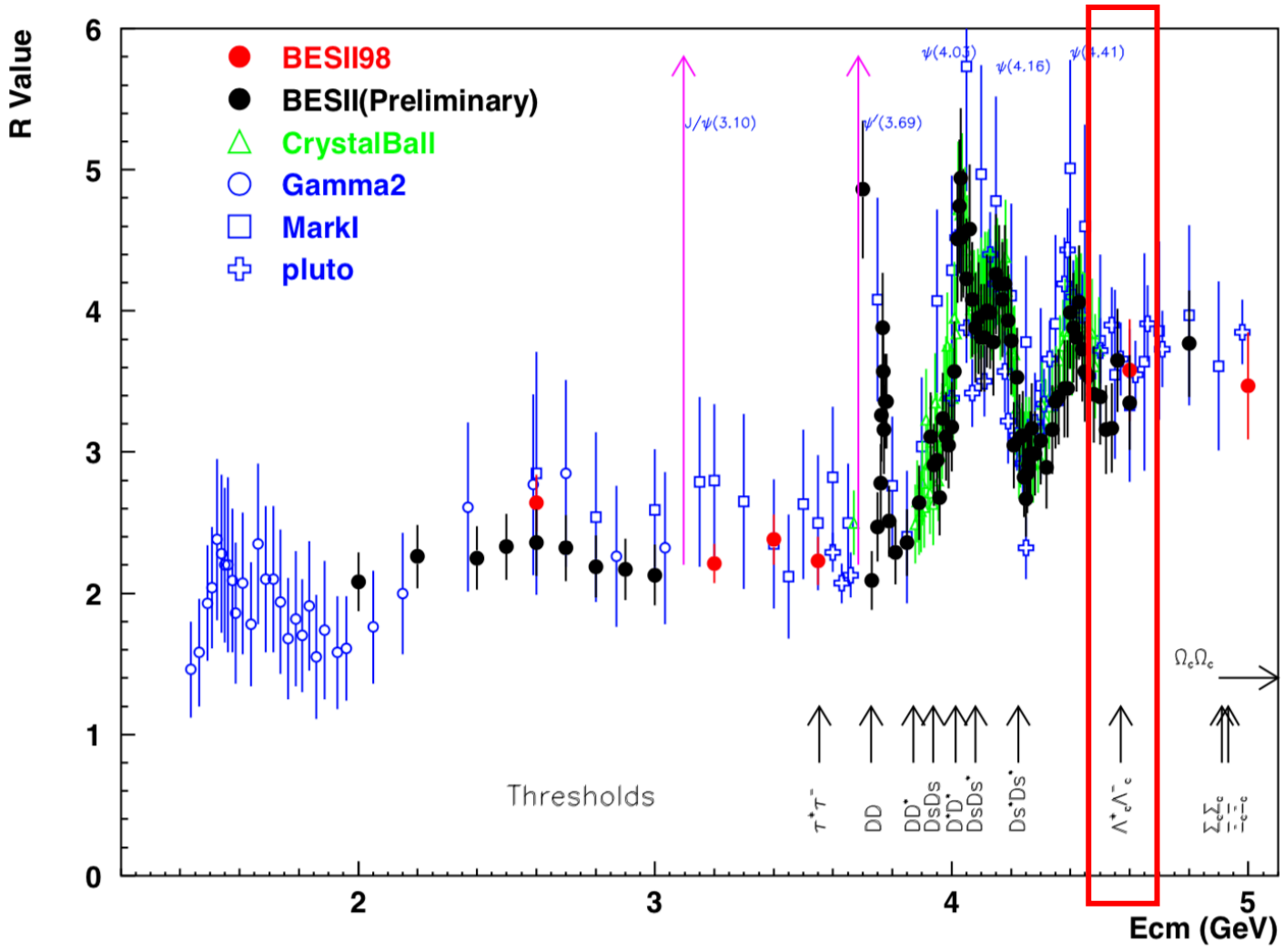
- More precise measurement of Cabibbo-favored process

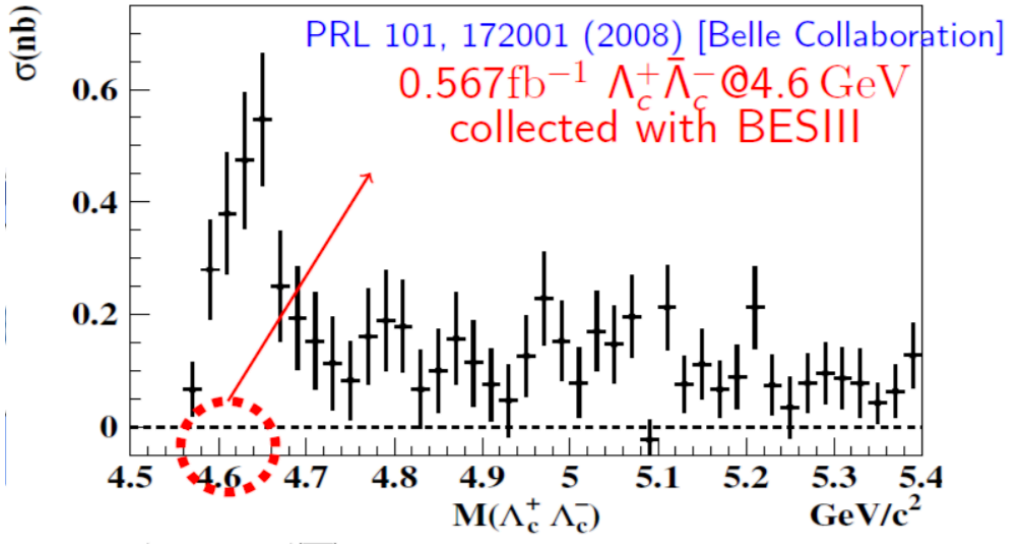
$$\mathcal{B}(\Lambda_c^+ \to \Xi^0 K^+) = (5.90 \pm 0.86 \pm 0.39) \times 10^{-3}$$ BESIII, PLB 783 (2018), 200-206

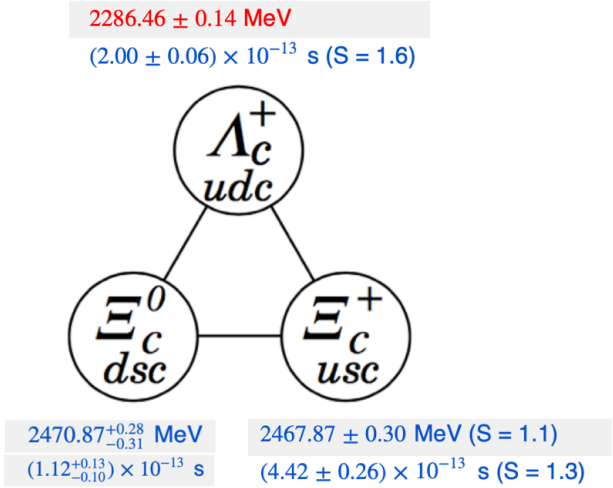
$$\mathcal{B}(\Lambda_c^+ \to \Sigma^+ \eta) = (0.41 \pm 0.19 \pm 0.05)\% \ (< 0.68\%)$$

$$\mathcal{B}(\Lambda_c^+ \to \Sigma^+ \eta') = (1.34 \pm 0.53 \pm 0.21)\% \ (< 1.9\%)$$ BESIII, 1811.08028

The future of Λ_c^+







- Beam energy
  - Ebeam = 2.3→2.35 GeV in 2019
  - Ebeam = 2.35→2.45 GeV in 2020-21

"Physics at BES-III", Int. J. Mod. Phys. A24 (2009)S1-794

Ξ_c@Belle

$(772\pm11)\times10^6$ $B\bar{B}$pair

Talk by 沈成平

- First measurement of $\Xi_c^0 \to \Xi^-\pi^+$

$$\mathcal{B}(B^- \to \bar{\Lambda}_c^- \Xi_c^0) = [9.51 \pm 2.10(\text{stat.}) \pm 0.88(\text{syst.})] \times 10^{-4}$$

$$\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+) = [1.80 \pm 0.50(\text{stat.}) \pm 0.14(\text{syst.})]\%$$

Belle, PRL 122 (2019) 082001

- The branching fraction of $\Xi_c^+ \to \Xi^0\pi^+$

$$\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+) = [1.16 \pm 0.42(\text{stat.}) \pm 0.15(\text{syst.})] \times 10^{-3}$$

$$\mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+) = (2.86 \pm 1.21 \pm 0.38) \times 10^{-2}$$

Belle, 1904.12093

$$\Gamma(\Xi_c^+ \to \Xi^0\pi^+)/\Gamma(\Xi_c^+ \to \Xi^-\pi^+\pi^+) = (0.55 \pm 0.13 \pm 0.09)$$

CLEO, PLB373(1996)261

$$\mathcal{B}(\Xi_c^+ \to \Xi^0\pi^+) = (1.57 \pm 0.83)\%$$

Lifetimes @ LHCb

$$\tau_{\Lambda_c^+} = 203.5 \pm 1.0 \pm 1.3 \pm 1.4 \text{ fs},$$

$$\tau_{\Xi_c^+} = 456.8 \pm 3.5 \pm 2.9 \pm 3.1 \text{ fs},$$

$$\boxed{\tau_{\Xi_c^0} = 154.5 \pm 1.7 \pm 1.6 \pm 1.0 \text{ fs},}$$

Talk by 杨振伟

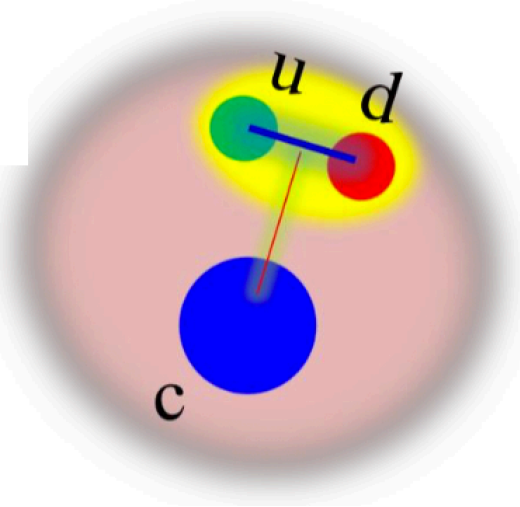
3.3 σ larger than PDG

LHCb, 1906.08350

Theory issues of charmed baryon

- Meaning of weak decays of charmed baryon
  - Examination of weak interaction
  - Exploration of strong interaction

- Difficulty in charmed baryon study
  - not heavy enough to apply HQET
  - not light enough to apply ChPT
  - **Model estimation** cannot be avoided



BF of Cabbibo-favored decays in 1990s

Decay	RQM Körner, Krämer [8]	Pole Xu, Kamal [9]	Pole Cheng, Tseng [10] CA	Pole Cheng, Tseng [10] Pole	RQM Ivanov et al [11]	Pole Żenczykowski [12]	C.A. Sharma, Verma [13]	Expt. [7]
$\Lambda_c^+ \to \Lambda\pi^+$	input	1.62	1.46	0.88	0.79	0.52	1.12	1.30 ± 0.07
$\Lambda_c^+ \to p\bar{K}^0$	input	1.20	3.64	1.26	2.06	1.71	1.64	3.16 ± 0.16
$\Lambda_c^+ \to \Sigma^0\pi^+$	0.32	0.34	1.76	0.72	0.88	0.39	1.34	1.29 ± 0.07
$\Lambda_c^+ \to \Sigma^+\pi^0$	0.32	0.34	1.76	0.72	0.88	0.39	1.34	1.24 ± 0.10
$\Lambda_c^+ \to \Sigma^+\eta$	0.16				0.11	0.90	0.57	0.70 ± 0.23
$\Lambda_c^+ \to \Sigma^+\eta'$	1.28				0.12	0.11	0.10	
$\Lambda_c^+ \to \Xi^0 K^+$	0.26	0.10			0.31	0.34	0.13	0.50 ± 0.12

- Non-factorizable contributions play an essential role
  - $\Lambda_c^+ \to \Xi^0 K^+$: only proceed through W-exchange
  - $\Lambda_c^+ \to \Sigma^+\pi^0, \Sigma^+\eta, \Sigma^+\eta'$: proceed through W-exchange or internal W-emission
- Except current algebra, predictions are generally below experiment

BF of Cabbibo-favored decays in 1990s

Decay	Körner, Krämer [16] (RQM)	Xu, Kamal [18] (Pole)	Cheng, Tseng [19] CA (Pole)	Cheng, Tseng [19] Pole (Pole)	Ivanov et al [17] (RQM)	Żenczykowski [20] (Pole)	Sharma, Verma [21] (C.A.)	Expt. [6]
$\Xi_c^+ \to \Sigma^+ \bar{K}^0$	6.45	0.44	0.04	0.84	3.08	1.56	0.04	
$\Xi_c^+ \to \Xi^0 \pi^+$	3.54	3.36	0.84	3.93	4.40	1.59	0.53	1.57 ± 0.83
$\Xi_c^0 \to \Lambda \bar{K}^0$	0.12	0.37	1.0	0.27	0.42	0.35	0.54	
$\Xi_c^0 \to \Sigma^0 \bar{K}^0$	1.18	0.10	0.02	0.13	0.20	0.11	0.07	
$\Xi_c^0 \to \Sigma^+ K^-$	0.12	0.12			0.27	0.36	0.12	
$\Xi_c^0 \to \Xi^0 \pi^0$	0.03	0.56	1.25	0.28	0.04	0.69	0.87	
$\Xi_c^0 \to \Xi^- \pi^+$	1.04	1.74	0.83	1.25	1.22	0.61	2.46	1.80 ± 0.52
$\Xi_c^0 \to \Xi^0 \eta$	0.24				0.28	0.69	0.09	
$\Xi_c^0 \to \Xi^0 \eta'$	0.85				0.31	0.01	0.14	

new

new

- No channel contains pure factorizable contributions
- Nonfactorizable contributions play an essential role
  - $\Xi_c^0 \to \Sigma^+ K^-, \Xi_c^0 \to \Xi^0 \pi^0, \Xi_c^0 \to \Xi^0 \eta$: only contain nonfactorizable contribution
  - Others contain both two parts of contributions

Decay asymmetry α of Cabbibo-favored decays in 1990s

	Decay	Körner, Krämer [8] (RQM)	Xu, Kamal [9] (Pole)	Cheng, Tseng [10] CA (Pole)	Cheng, Tseng [10] Pole (Pole)	Ivanov et al [11] (RQM)	Żenczykowski [12] (Pole)	Sharma, Verma [13] (C.A.)	Expt. [7]	BESIII
✓	$\Lambda_c^+ \to \Lambda\pi^+$	-0.70	-0.67	-0.99	-0.95	-0.95	-0.99	-0.99	-0.91 ± 0.15	$-0.80 \pm 0.11 \pm 0.02$
	$\Lambda_c^+ \to p\bar{K}^0$	-1.0	0.51	-0.90	-0.49	-0.97	-0.66	-0.99		
	$\Lambda_c^+ \to \Sigma^0\pi^+$	0.70	0.92	-0.49	0.78	0.43	0.39	-0.31		$-0.73 \pm 0.17 \pm 0.07$
	$\Lambda_c^+ \to \Sigma^+\pi^0$	0.70	0.92	-0.49	0.78	0.43	0.39	-0.31	-0.45 ± 0.32	$-0.57 \pm 0.10 \pm 0.07$
	$\Lambda_c^+ \to \Sigma^+\eta$	0.33				0.55	0	-0.91		
	$\Lambda_c^+ \to \Sigma^+\eta'$	-0.45				-0.05	-0.91	0.78		
	$\Lambda_c^+ \to \Xi^0 K^+$	0	0			0	0	0		

- $\Lambda_c^+ \to \Sigma^+\pi^0$
  - CLEO ('95) measured α = -0.45±0.31±0.06
  - Pole model & RQM predict positive α
  - Current algebra leads to negative α
  - The sign of α has been confirmed by BESIII

- $\Lambda_c^+ \to \Xi^0 K^+$
  - theory: small s-wave $\Rightarrow$ $\alpha = 0$
    - Can be improved
  - Experiment ?

BESIII, PLB 783 (2018), 200-206

Decay asymmetry α of Cabbibo-favored decays in 1990s

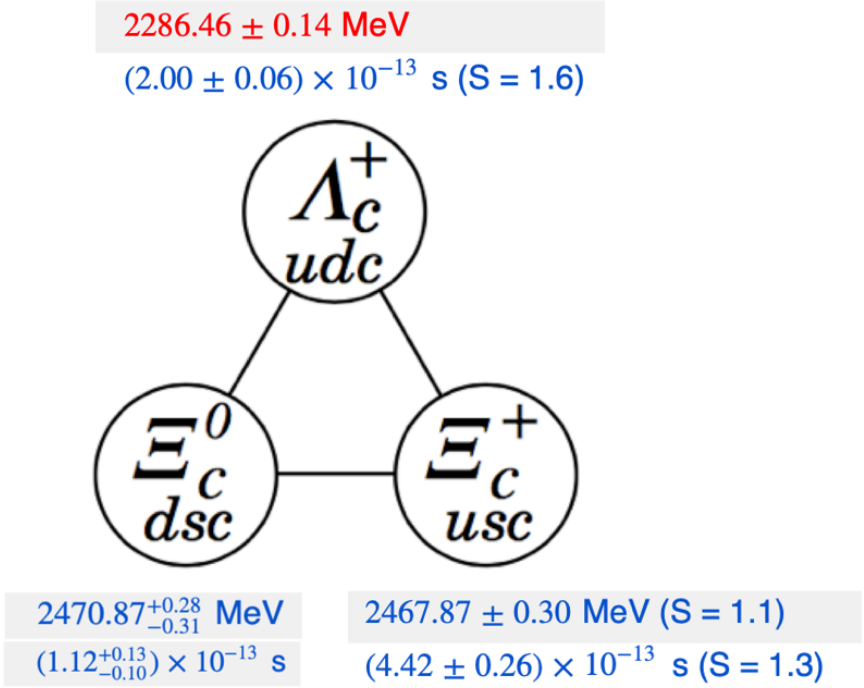
Decay	Körner, Krämer [16] (RQM)	Xu, Kamal [18] (Pole)	Cheng, Tseng [19] CA (Pole)	Cheng, Tseng [19] Pole (Pole)	Ivanov et al [17] (RQM)	Żenczykowski [20] (Pole)	Sharma, Verma [21] (C.A.)	Expt. [6]
$\Xi_c^+ \to \Sigma^+ \bar{K}^0$	-1.0	0.24	0.43	-0.09	-0.99	1.0	0.54	
$\Xi_c^+ \to \Xi^0 \pi^+$	-0.78	-0.81	-0.77	-0.77	-0.97	1.0	-0.27	
$\Xi_c^0 \to \Lambda \bar{K}^0$	-0.76	1.00	-0.88	-0.73	-0.75	-0.29	-0.79	
$\Xi_c^0 \to \Sigma^0 \bar{K}^0$	-0.96	-0.99	0.85	-0.59	-0.55	-0.50	0.48	
$\Xi_c^0 \to \Sigma^+ K^-$	0	0			0	0	0	
$\Xi_c^0 \to \Xi^0 \pi^0$	0.92	0.92	-0.78	-0.54	0.94	0.21	-0.80	
✓ $\Xi_c^0 \to \Xi^- \pi^+$	-0.38	-0.38	-0.47	-0.99	-0.84	-0.79	-0.97	-0.6 ± 0.4
$\Xi_c^0 \to \Xi^0 \eta$	-0.92				-1.0	0.21	-0.37	
$\Xi_c^0 \to \Xi^0 \eta'$	-0.38				-0.32	-0.04	0.56	

- $\Xi_c^+ \to \Xi^- \pi^+$:
  - CLEO ('96) measured α = -0.6±0.4
  - All model estimations predict correct sign of α

- Could Belle/Belle II provide α measurement ?

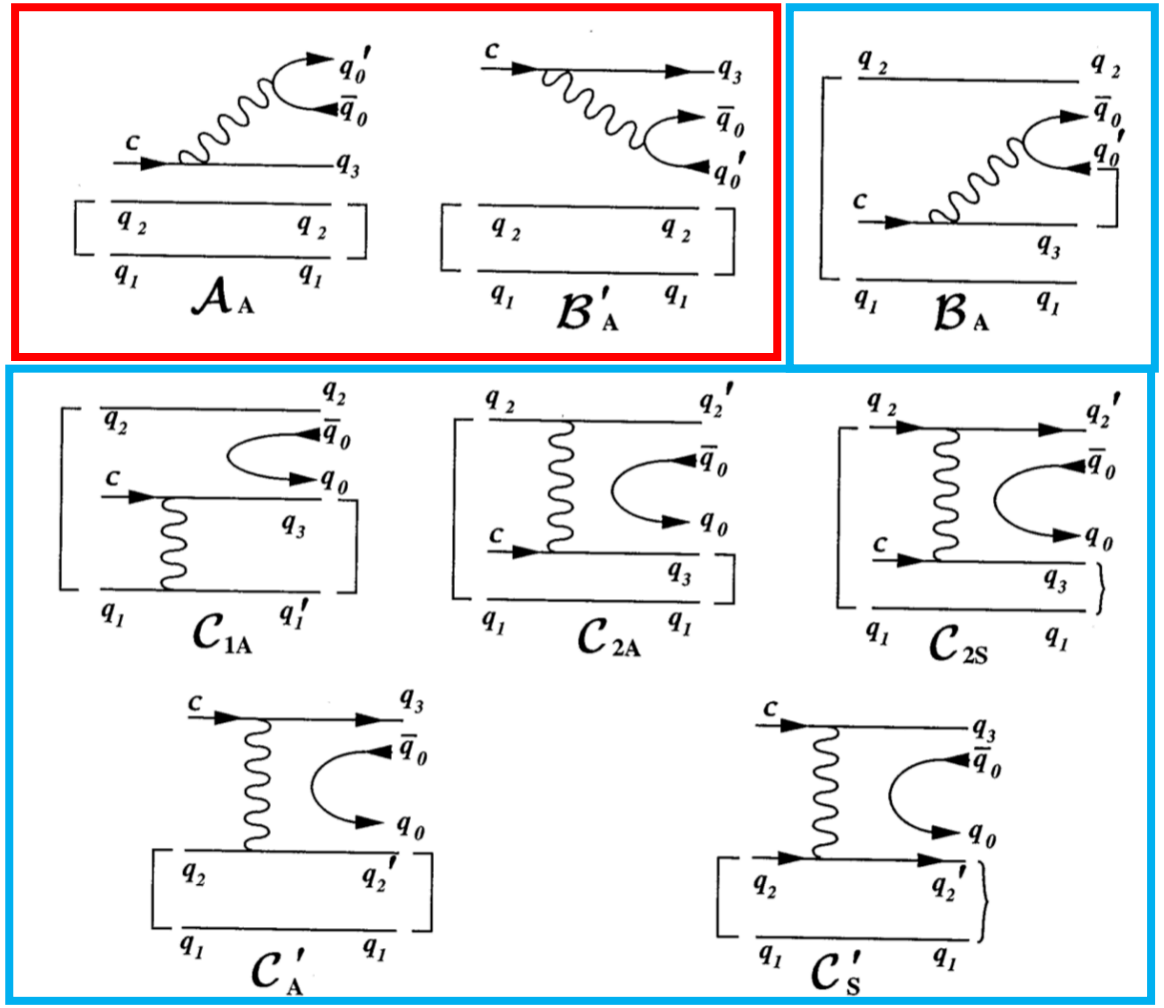
Our strategy

- Non-factorizable contribution is incorporated
- Methodology: Pole model + current algebra



Theoretical framework

Topological diagram approach



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

$$A = A^{\rm fac} + A^{\rm nf}$$

$$B = B^{\rm fac} + B^{\rm nf}$$

L.-L. Chau, H.-Y. Cheng and B. Tseng, Phys. Rev. D 54(1996)2132

Factorizable part: naïve factorization

$$A^{\text{fac.}} = \frac{G_F}{\sqrt{2}} a_{1,2} V_{ud}^* V_{cs} f_P (m_{\mathcal{B}_c} - m_{\mathcal{B}}) f_1(q^2)$$

$$B^{\text{fac.}} = -\frac{G_F}{\sqrt{2}} a_{1,2} V_{ud}^* V_{cs} f_P (m_{\mathcal{B}_c} + m_{\mathcal{B}}) g_1(q^2)$$

- The choice of $a_{1,2}$ depends on the meson in final states
- Effective N_c included in $a_{1,2}$ is determined by experiment

$$a_2 = c_2 + \frac{c_1}{N_c}$$

$$\mathcal{B}(\Lambda_c^+ \to p\phi) = (1.04 \pm 0.21) \times 10^{-3}$$

$$\Rightarrow \quad N_c^{\text{eff}} \approx 7$$

BESIII, Phys. Rev. Lett. 117, 232002 (2016).

Factorizable part: form factor

- <u>FF sign issue</u>
- MIT bag model estimation

Static limit

$$f_1^{B_f B_i}(q^2_{\max}) = \langle B_f \uparrow | b^\dagger_{q_1} b_{q_2} | B_i \uparrow \rangle \int d^3\boldsymbol{r} (u_{q_1} u_{q_2} + v_{q_1} v_{q_2})$$

$$g_1^{B_f B_i}(q^2_{\max}) = \langle B_f \uparrow | b^\dagger_{q_1} b_{q_2} \sigma_z | B_i \uparrow \rangle \int d^3\boldsymbol{r} (u_{q_1} u_{q_2} - \frac{1}{3} v_{q_1} v_{q_2})$$

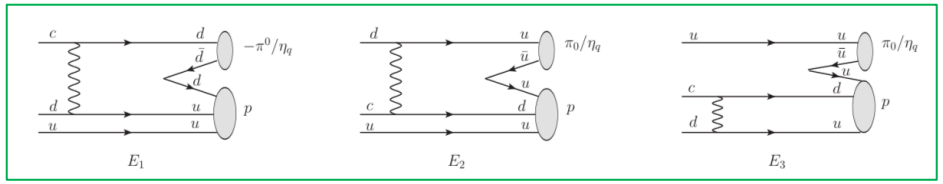
Run

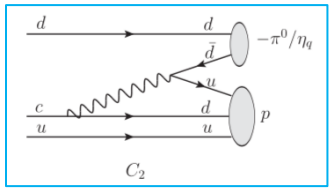
$$f_i(q^2) = \frac{f_i(0)}{(1 - q^2/m_V^2)^2}, \qquad g_i(q^2) = \frac{g_i(0)}{(1 - q^2/m_A^2)^2}$$

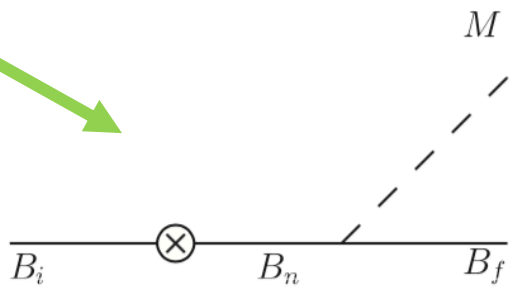
- More efforts on FF required

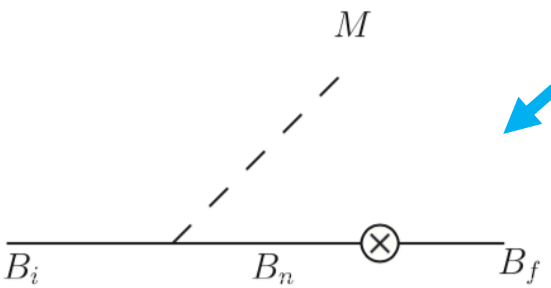
modes	$(c\bar{q})$	$f_1(q^2_{\max})$	$f_1(m_P^2)/f_1(q^2_{\max})$	$g_1(q^2_{\max})$	$g_1(m_P^2)/g_1(q^2_{\max})$
$\Xi_c^+ \to \Sigma^+ \overline{K}^0$	$(c\bar{s})$	$-\frac{\sqrt{6}}{2} Y_1$	0.44907	$-\frac{\sqrt{6}}{2} Y_2$	0.60286
$\Xi_c^+ \to \Xi^0 \pi^+$	$(c\bar{s})$	$-\frac{\sqrt{6}}{2} Y_1^s$	0.49628	$-\frac{\sqrt{6}}{2} Y_2^s$	0.63416
$\Xi_c^0 \to \Lambda \overline{K}^0$	$(c\bar{s})$	$\frac{1}{2} Y_1$	0.38700	$\frac{1}{2} Y_2$	0.55337
$\Xi_c^0 \to \Sigma^0 \overline{K}^0$	$(c\bar{s})$	$\frac{\sqrt{3}}{2} Y_1$	0.44929	$\frac{\sqrt{3}}{2} Y_2$	0.60304
$\Xi_c^0 \to \Xi^- \pi^+$	$(c\bar{s})$	$-\frac{\sqrt{6}}{2} Y_1^s$	0.49911	$-\frac{\sqrt{6}}{2} Y_2^s$	0.63636
$\Xi_c^+ \to \Sigma^0 \pi^+$	$(c\bar{d})$	$\frac{\sqrt{3}}{2} Y_1$	0.36045	$\frac{\sqrt{3}}{2} Y_2$	0.52523
$\Xi_c^+ \to \Lambda \pi^+$	$(c\bar{d})$	$-\frac{1}{2} Y_1$	0.30260	$-\frac{1}{2} Y_2$	0.47622
$\Xi_c^+ \to \Sigma^+ \pi^0$	$(c\bar{d})$	$-\frac{\sqrt{6}}{2} Y_1$	0.35774	$-\frac{\sqrt{6}}{2} Y_2$	0.52294
$\Xi_c^+ \to \Sigma^+ \eta_8$	$(c\bar{d})$	$-\frac{\sqrt{6}}{2} Y_1$	0.41371	$-\frac{\sqrt{6}}{2} Y_2$	0.57735
$\Xi_c^+ \to \Xi^0 K^+$	$(c\bar{s})$	$-\frac{\sqrt{6}}{2} Y_1^s$	0.55058	$-\frac{\sqrt{6}}{2} Y_2^s$	0.68080
$\Xi_c^0 \to \Lambda \eta_8$	$(c\bar{s})$, $(c\bar{d})$	$\frac{1}{2} Y_1$	0.39685, 0.34715	$\frac{1}{2} Y_2$	0.56286, 0.52343
$\Xi_c^0 \to \Sigma^0 \eta_8$	$(c\bar{s})$, $(c\bar{d})$	$\frac{\sqrt{3}}{2} Y_1$	0.46073, 0.41395	$\frac{\sqrt{3}}{2} Y_2$	0.61338, 0.57754
$\Xi_c^0 \to \Lambda \pi^0$	$(c\bar{d})$	$\frac{1}{2} Y_1$	0.30019	$\frac{1}{2} Y_2$	0.47410
$\Xi_c^0 \to \Sigma^0 \pi^0$	$(c\bar{d})$	$\frac{\sqrt{3}}{2} Y_1$	0.35795	$\frac{\sqrt{3}}{2} Y_2$	0.52311
$\Xi_c^0 \to \Sigma^- \pi^+$	$(c\bar{d})$	$\frac{\sqrt{6}}{2} Y_1$	0.36183	$\frac{\sqrt{6}}{2} Y_2$	0.52638
$\Xi_c^0 \to \Xi^- K^+$	$(c\bar{s})$	$-\frac{\sqrt{6}}{2} Y_1^s$	0.55371	$-\frac{\sqrt{6}}{2} Y_2^s$	0.68316

Non-factorizable part: pole model









S-wave: ½⁻:

$$A^{\rm pole} = -\sum_{B_n^*(1/2^-)} \left[\frac{g_{B_f B_n^* P} b_{n^* i}}{m_i - m_{n^*}} + \frac{b_{f n^*} g_{B_n^* B_i P}}{m_f - m_{n^*}} \right]$$

P-wave: ½⁺:

$$B^{\rm pole} = \sum_{B_n} \left[\frac{g_{B_f B_n P} a_{ni}}{m_i - m_n} + \frac{a_{fn} g_{B_n B_i P}}{m_f - m_n} \right].$$

$$\langle \mathcal{B}_i | H_{\rm eff} | \mathcal{B}_j \rangle = \bar{u}_i (a_{ij} - b_{ij}\gamma_5) u_j, \qquad \langle \mathcal{B}_i^*(1/2^-) | H_{\rm eff}^{\rm PV} | \mathcal{B}_j \rangle = i b_{i^* j} \bar{u}_i u_j.$$

Non-factorizable part: current algebra

- Advantage: avoid ½⁻

$$A^{\rm com} = -\frac{\sqrt{2}}{f_{P^a}}\langle B_f|[Q_5^a, H_{\rm eff}^{PV}]|B_i\rangle = \frac{\sqrt{2}}{f_{P^a}}\langle B_f|[Q^a, H_{\rm eff}^{PC}]|B_i\rangle$$

$$B^{\rm pole} = \frac{\sqrt{2}}{f_{P^a}}\sum_{B_n}\left[g^A_{B_f B_n}\frac{m_f+m_n}{m_i-m_n}a_{ni} + a_{fn}\frac{m_i+m_n}{m_f-m_n}g^A_{B_n B_i}\right]$$

- S-wave: commutator

$$A^{\rm com}(B_i \to B_f K^\pm) = \frac{1}{f_K}\langle B_f|[V_\mp, H_{\rm eff}^{PC}]|B_i\rangle$$

$$V_+\Lambda = -\frac{\sqrt{6}}{2}p$$
$$V_+\Sigma^0 = -\frac{\sqrt{2}}{2}p$$
$$V_+\Xi^- = -\frac{\sqrt{2}}{2}\Sigma^0 - \frac{\sqrt{6}}{2}\Lambda$$

- P-wave: generalized Goldberg-Treiman relation

$$g_{\mathcal{B}'\mathcal{B}P^a} = \frac{\sqrt{2}}{f_{P^a}}(m_{\mathcal{B}'} + m_{\mathcal{B}})g^A_{\mathcal{B}'\mathcal{B}},$$

Baryon matrix elements & axial form factors

- MIT bag model estimation

$$a_{B'B} \equiv \langle B'|\mathcal{H}_{\rm eff}^{\rm PC}|B\rangle = \frac{G_F}{2\sqrt{2}} \sum_{q=d,s} V_{cq}V_{uq}^* c_- \langle B'|O_-^q|B\rangle$$

$$O_\pm^q = O_1^q \pm O_2^q = (\bar{q}c)(\bar{u}q) \pm (\bar{q}q)(\bar{u}c)$$

$$c_- = c_1 - c_2$$

$$g_{\mathcal{B}'\mathcal{B}}^{A(P)} = \langle \mathcal{B}' \uparrow | b_{q_1}^\dagger b_{q_2} \sigma_z | \mathcal{B} \uparrow \rangle \int d^3\boldsymbol{r} \left(u_{q_1} u_{q_2} - \frac{1}{3} v_{q_1} v_{q_2} \right)$$

Jinqi's Mathematica package

Results for anti-triplet decays

Λ_c^+ decays: CF

J. Zou, FX, G. Meng and H.-Y. Cheng, 1910.13626

Channel	$A^{\rm fac}$	$A^{\rm com}$	$A^{\rm tot}$	$B^{\rm fac}$	$B^{\rm ca}$	$B^{\rm tot}$	$\mathcal{B}_{\rm theo}$	$\mathcal{B}_{\rm exp}$ [7]	$\alpha_{\rm theo}$	$\alpha_{\rm exp}$
$\Lambda_c^+ \to p\overline{K}^0$	3.45	4.48	7.93	−6.98	−2.06	−9.04	2.11×10^{-2}	$(3.18\pm0.16)10^{-2}$	−0.75	0.18 ± 0.45
$\Lambda_c^+ \to \Lambda\pi^+$	5.34	0	5.34	−14.11	3.60	−10.51	1.30×10^{-2}	$(1.30\pm0.07)10^{-2}$	−0.93	-0.84 ± 0.09
$\Lambda_c^+ \to \Sigma^0\pi^+$	0	7.68	7.68	0	−11.38	−11.38	2.24×10^{-2}	$(1.29\pm0.07)10^{-2}$	−0.76	-0.73 ± 0.18
$\Lambda_c^+ \to \Sigma^+\pi^0$	0	−7.68	−7.68	0	11.34	11.34	2.24×10^{-2}	$(1.25\pm0.10)10^{-2}$	−0.76	-0.55 ± 0.11
$\Lambda_c^+ \to \Xi^0K^+$	0	−4.48	−4.48	0	−12.10	−12.10	0.73×10^{-2}	$(0.55\pm0.07)10^{-2}$	0.90	0.77 ± 0.78
$\Lambda_c^+ \to \Sigma^+\eta$	0	3.10	3.10	0	−15.54	−15.54	0.74×10^{-2}	$(0.53\pm0.15)10^{-2}$	−0.95	

H.-Y. Cheng and B. Tseng, Phys. Rev. D 48 (1993) 4188

Reaction	$A^{\rm fac}$	$A^{\rm com}$	$A^{\rm tot}$	$B^{\rm fac}$	$B^{\rm pole}$	$B^{\rm tot}$	α	Γ	$(\mathrm{Br})_{\rm theory}$
$\Lambda_c^+ \to p\overline{K}^0$	−5.73	−4.44	−10.17	14.33	2.10	16.43	−0.90	1.82	3.46
$\Lambda_c^+ \to \Lambda\pi^+$	−5.40	0	−5.40	18.09	−4.14	13.95	−0.99	0.73	1.39
$\Lambda_c^+ \to \Sigma^0\pi^+$	0	−7.66	−7.66	0	6.42	6.42	−0.49	0.88	1.67
$\Lambda_c^+ \to \Sigma^+\pi^0$	0	7.66	7.66	0	−6.42	−6.42	−0.49	0.88	1.67
$\Lambda_c^+ \to \Xi^0K^+$	0	−0.06	−0.06	0	−2.98	−2.98			

Λ_c^+ decays: SCS

J. Zou, FX, G. Meng and H.-Y. Cheng, 1910.13626

Channel	$A^{\rm fac}$	$A^{\rm com}$	$A^{\rm tot}$	$B^{\rm fac}$	$B^{\rm ca}$	$B^{\rm tot}$	$\mathcal{B}_{\rm theo}$	$\mathcal{B}_{\rm exp}$ [7]	$\alpha_{\rm theo}$	$\alpha_{\rm exp}$
$\Lambda_c^+ \to p\pi^0$	0.41	−0.81	−0.40	−0.87	2.07	1.21	1.26×10^{-4}	$<2.7\times10^{-4}$	−0.97	
$\Lambda_c^+ \to p\eta$	−0.96	−1.11	−2.08	1.93	−0.34	1.59	1.28×10^{-3}	$(1.24\pm0.29)10^{-3}$	−0.55	
$\Lambda_c^+ \to n\pi^+$	1.64	−1.15	0.50	−3.45	2.93	−0.52	0.91×10^{-4}	–	−0.73	
$\Lambda_c^+ \to \Lambda K^+$	1.66	−0.08	1.58	−4.43	0.55	−3.70	1.07×10^{-3}	$(6.1\pm1.2)10^{-4}$	−0.96	
$\Lambda_c^+ \to \Sigma^0 K^+$	0	1.49	1.49	0	−2.29	−2.29	7.23×10^{-4}	$(5.2\pm0.8)10^{-4}$	−0.73	
$\Lambda_c^+ \to \Sigma^+ K^0$	0	2.10	2.10	0	−3.24	−3.24	1.44×10^{-3}	–	−0.73	

H.-Y. Cheng, X.-W. Kang and FX, Phys. Rev. D 97 (2018) 074028

Channel	$A^{\rm fac}$	$A^{\rm com}$	$A^{\rm tot}$	$B^{\rm fac}$	$B^{\rm ca}$	$B^{\rm tot}$	$\mathcal{B}_{\rm theo}$	$\mathcal{B}_{\rm expt}$	$\alpha_{\rm theo}$
$\Lambda_c^+ \to p\pi^0$	−0.41	0.81	0.40	0.87	−1.57	−0.70	0.75×10^{-4}	$<2.7\times10^{-4}$	−0.95
$\Lambda_c^+ \to p\eta$	0.96	1.11	2.08	−1.93	−1.24	−3.17	1.28×10^{-3}	$(1.24\pm0.29)10^{-3}$	−0.56
$\Lambda_c^+ \to n\pi^+$	−1.64	1.15	−0.50	3.45	−1.57	1.88	2.66×10^{-4}		−0.90
$\Lambda_c^+ \to \Lambda K^+$	−1.66	0.09	−1.57	4.43	−0.54	3.70	1.06×10^{-3}	$(6.1\pm1.2)10^{-4}$	−0.96
$\Lambda_c^+ \to \Sigma^0 K^+$	0	−1.48	−1.48	0	2.30	2.30	7.18×10^{-4}	$(5.2\pm0.8)10^{-4}$	−0.73
$\Lambda_c^+ \to \Sigma^+ K^0$	0	−2.10	−2.10	0	3.25	3.25	1.44×10^{-3}		−0.74

Ξ_c decays: CF

J. Zou, FX, G. Meng and H.-Y. Cheng, 1910.13626

Channel	$A^{\rm fac}$	$A^{\rm com}$	$A^{\rm tot}$	$B^{\rm fac}$	$B^{\rm ca}$	$B^{\rm tot}$	$\mathcal{B}_{\rm theo}$	$\mathcal{B}_{\rm exp}$	$\alpha_{\rm theo}$	$\alpha_{\rm exp}$
$\Xi_c^+ \to \Sigma^+\overline{K}^0$	2.98	−4.48	−1.50	−9.95	12.28	2.32	0.20	–	−0.80	–
$\Xi_c^+ \to \Xi^0\pi^+$	−7.41	5.36	−2.05	28.07	−14.03	14.04	1.72	1.57 ± 0.83	−0.78	–
$\Xi_c^0 \to \Lambda\overline{K}^0$	−1.11	−5.41	−6.52	3.66	6.87	10.52	1.33	–	−0.86	–
$\Xi_c^0 \to \Sigma^0\overline{K}^0$	−2.11	3.12	1.02	7.05	−9.39	−2.33	0.04	–	−0.96	–
$\Xi_c^0 \to \Sigma^+K^-$	0	−4.42	−4.42	0	−11.33	−11.33	0.78	–	0.98	–
$\Xi_c^0 \to \Xi^0\pi^0$	0	−7.58	−7.58	0	11.79	11.79	1.82	–	−0.77	–
$\Xi_c^0 \to \Xi^0\eta$	0	−10.80	−10.80	0	−6.17	−6.17	2.67	–	0.30	–
$\Xi_c^0 \to \Xi^-\pi^+$	−7.42	−5.36	−12.78	28.24	2.65	30.89	6.47	1.80 ± 0.52	−0.95	-0.6 ± 0.4

$\Xi_c^+ \to \Xi^0\pi^+$: consistent well with Belle experiment

$\Xi_c^0 \to \Xi^-\pi^+$: has a tension with Belle experiment

Ξ_c decays: SCS

J. Zou, FX, G. Meng and H.-Y. Cheng, 1910.13626

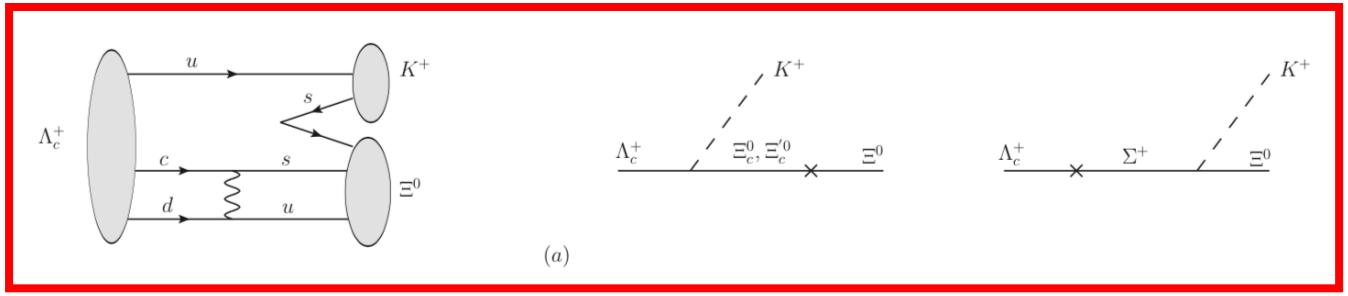
Channel	$A^{\rm fac}$	$A^{\rm com}$	$A^{\rm tot}$	$B^{\rm fac}$	$B^{\rm ca}$	$B^{\rm tot}$	$\mathcal{B}_{\rm theo}$	$\alpha_{\rm theo}$
$\Xi_c^+ \to \Lambda\pi^+$	0.46	−1.50	−1.04	−1.69	2.16	0.47	0.85	−0.33
$\Xi_c^+ \to \Sigma^0\pi^+$	−0.90	−1.00	−1.90	3.29	0.74	4.03	4.30	−0.95
$\Xi_c^+ \to \Sigma^+\pi^0$	0.32	0.99	1.32	−1.16	1.61	0.44	1.36	0.23
$\Xi_c^+ \to \Sigma^+\eta$	−0.74	1.42	0.68	2.58	−2.19	0.39	0.32	0.36
$\Xi_c^+ \to p\overline{K}^0$	0	−2.10	−2.10	0	2.64	2.64	3.96	−0.83
$\Xi_c^+ \to \Xi^0 K^+$	−2.30	1.16	−1.14	8.43	−3.46	4.97	2.20	−0.98
$\Xi_c^0 \to \Lambda\pi^0$	−0.12	1.06	0.95	0.42	−0.96	−0.53	0.24	−0.41
$\Xi_c^0 \to \Lambda\eta$	0.27	1.51	1.78	−0.94	−0.27	−1.20	0.77	−0.45
$\Xi_c^0 \to \Sigma^0\pi^0$	−0.23	−0.70	−0.93	0.82	1.36	2.18	0.38	−0.98
$\Xi_c^0 \to \Sigma^0\eta$	0.53	−1.00	−0.48	−1.83	1.55	−0.28	0.05	0.36
$\Xi_c^0 \to \Sigma^-\pi^+$	−1.28	−1.41	−2.69	4.67	0.22	4.89	2.62	−0.90
$\Xi_c^0 \to \Sigma^+\pi^-$	0	1.41	1.41	0	2.49	2.49	0.71	0.89
$\Xi_c^0 \to pK^-$	0	−0.94	−0.94	0	−1.86	−1.86	0.35	0.99
$\Xi_c^0 \to n\overline{K}^0$	0	−2.10	−2.10	0	2.96	2.96	1.40	−0.89
$\Xi_c^0 \to \Xi^0 K^0$	0	2.10	2.10	0	−4.17	−4.17	1.32	−0.85
$\Xi_c^0 \to \Xi^- K^+$	−2.31	−0.94	−3.24	8.49	0.71	9.20	3.90	−0.97

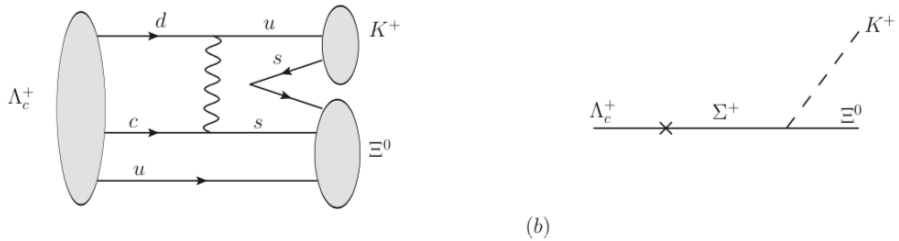
Discussion

1. $\Lambda_c^+ \to \Xi^0 K^+$ puzzle
2. $\Xi_c^+ \to \Xi^0 \pi^+$ and $\Xi_c^0 \to \Xi^- \pi^+$ tension

$\Lambda_c^+ \to \Xi^0 K^+$ puzzle

Type-III
W-exchange





$$A^{\rm com}(\Lambda_c^+ \to \Xi^0 K^+) = \frac{1}{f_K}\left(a_{\Sigma^+\Lambda_c^+} - a_{\Xi^0\Xi_c^0}\right),$$

identical under SU(3)

$$B^{\rm ca}(\Lambda_c^+ \to \Xi^0 K^+) = \frac{1}{f_K}\left(g^{A(K^+)}_{\Xi^0\Sigma^+}\frac{m_{\Xi^0}+m_{\Sigma^+}}{m_{\Lambda_c^+}-m_{\Sigma^+}}a_{\Sigma^+\Lambda_c^+} + a_{\Xi^0\Xi_c^0}\frac{m_{\Xi_c^0}+m_{\Lambda_c^+}}{m_{\Xi^0}-m_{\Xi_c^0}}\cancel{g^{A(K^+)}_{\Xi_c^0\Lambda_c^+}} + a_{\Xi^0\Xi_c'^0}\frac{m_{\Xi_c'^0}+m_{\Lambda_c^+}}{m_{\Xi^0}-m_{\Xi_c'^0}}g^{A(K^+)}_{\Xi_c'^0\Lambda_c^+}\right).$$

cancellation

$\Lambda_c^+ \to \Xi^0 K^+$ puzzle

Exclusive non-leptonic charm baryon decays

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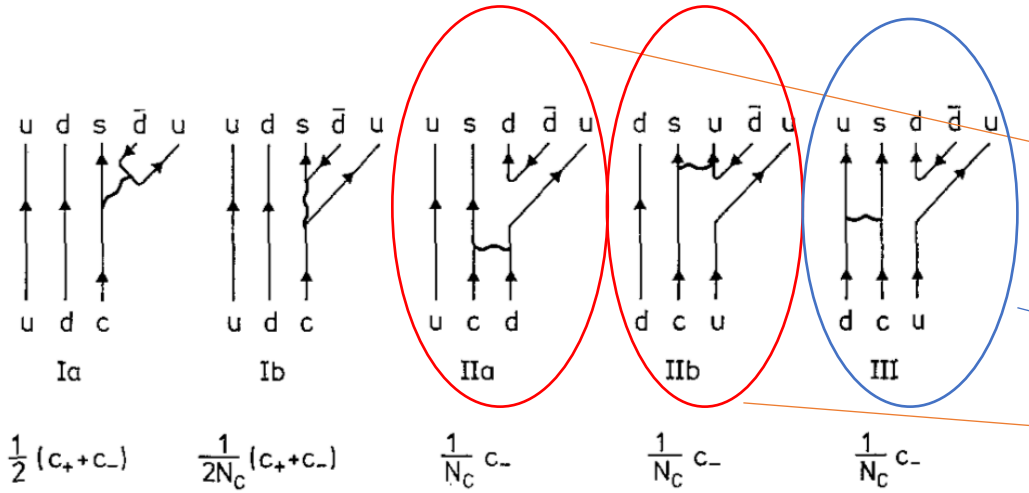

Fig. 1. Quark diagrams contributing to n.l. decay $\Lambda_c^+ \to \Lambda\pi^+$ including colour-flavour weight factors

$$A = A^{\mathrm{fac}} - \frac{H_2}{4M_1M_2} c_W c_- (M_1 P_1 \cdot P_2 - M_1 M_2^2 - M_1 M_2 M_3) 3 I_3 + \frac{H_2}{4M_1M_2} c_W c_- (M_2 P_1 \cdot P_2 - M_1^2 M_2 - M_1 M_2 M_3) 3 \hat{I}_3,$$

$$B = B^{\mathrm{fac}} + \frac{H_2}{4M_1M_2} c_W c_- M_1 Q_+ \tfrac{1}{2} \boxed{(I_3 + 2I_4)} + \frac{H_2}{4M_1M_2} c_W c_- M_2 Q_+ \tfrac{1}{2} \boxed{(\hat{I}_3 + 2\hat{I}_4)} + \frac{H_3}{4M_1M_2} c_W c_- M_1 M_2 (M_1 + M_2 + M_3) 12 \boxed{I_5}. \quad (7)$$

$\Lambda_c^+ \to \Xi^0 K^+$ puzzle

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Nonleptonic charmed-baryon decays: Symmetry properties of parity-violating amplitudes

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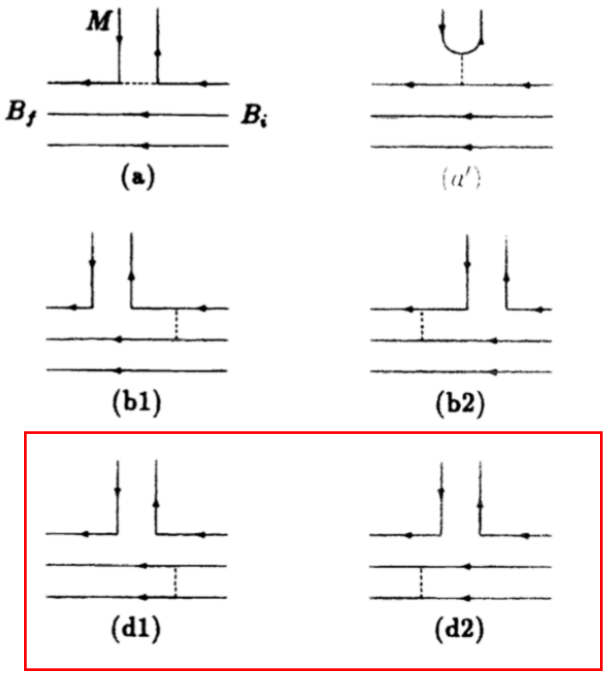
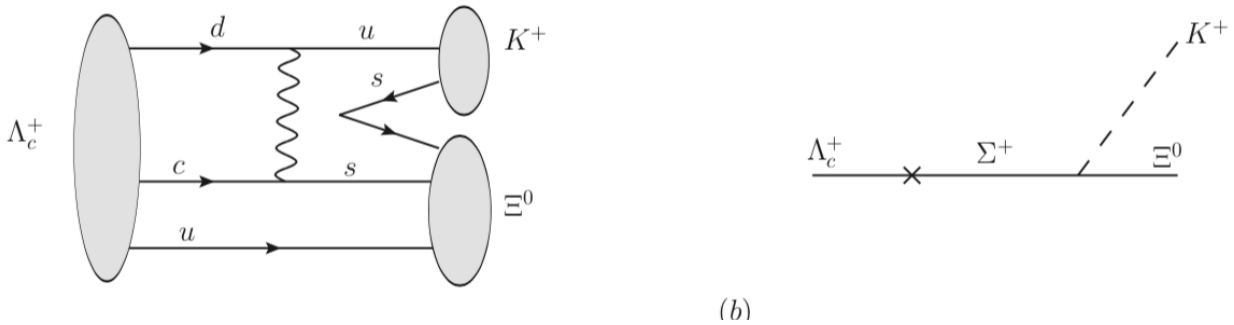
(Received 1 March 1994)



The quark diagrams relevant for the nonleptonic charmed-baryon decays are shown in Fig. 1. Diagrams (a) and (a') correspond to the factorization amplitudes. For the parity-violating amplitudes, the contribution from diagrams (d) vanishes. The pole model contribution from the intermediate $\frac{1}{2}^-$ baryons is contained in the W-exchange diagrams $(b1)$ and $(b2)$. In Ref. [4] the quark model technique of Refs. [8,9] was used to deter-

$\Lambda_c^+ \to \Xi^0 K^+$ puzzle



$$A^{\rm com}(\Lambda_c^+ \to \Xi^0 K^+) = \frac{1}{f_K} a_{\Sigma^+\Lambda_c^+},$$

different from Korner-Kramer: SU(4)

$$B^{\rm ca}(\Lambda_c^+ \to \Xi^0 K^+) = \frac{1}{f_K}\left(g^{A(K^+)}_{\Xi^0\Sigma^+} \frac{m_{\Xi^0}+m_{\Sigma^+}}{m_{\Lambda_c^+}-m_{\Sigma^+}} a_{\Sigma^+\Lambda_c^+}\right)$$

similar

big and positive alpha

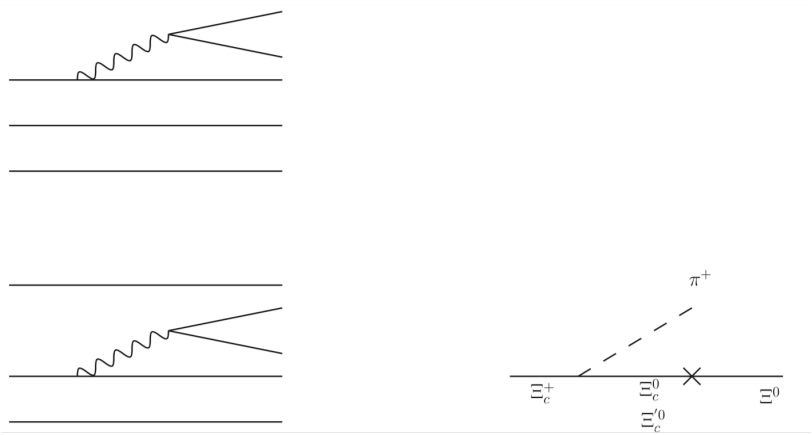
Channel	$A^{\rm fac}$	$A^{\rm com}$	$A^{\rm tot}$	$B^{\rm fac}$	$B^{\rm ca}$	$B^{\rm tot}$	$\mathcal{B}_{\rm theo}$	$\mathcal{B}_{\rm exp}$ [7]	$\alpha_{\rm theo}$	$\alpha_{\rm exp}$
$\Lambda_c^+ \to \Xi^0 K^+$	0	-4.48	-4.48	0	-12.10	-12.10	0.73×10^{-2}	$(0.55\pm0.07)10^{-2}$	0.90	0.77 ± 0.78

$$\Xi_c^0 \to \Sigma^+ K^-$$

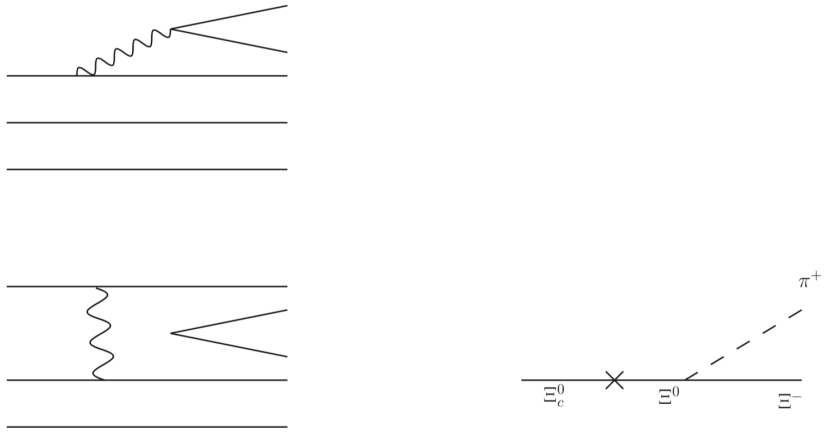
$$\Xi_c^0 \to pK^-, \Sigma^+\pi^-$$

$\Xi_c^+ \to \Xi^0\pi^+$ and $\Xi_c^0 \to \Xi^-\pi^+$

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



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



$$A^{\rm com}(\Xi_c^+ \to \Xi^0\pi^+) = -\frac{1}{f_\pi} a_{\Xi^0\Xi_c^0}$$

$$B^{\rm ca}(\Xi_c^+ \to \Xi^0\pi^+) = \frac{1}{f_\pi}\left(a_{\Xi^0\Xi_c^0}\frac{m_{\Xi_c^+}+m_{\Xi_c^0}}{m_{\Xi^0}-m_{\Xi_c^0}} g^{A(\pi^+)}_{\Xi_c^0\Xi_c^+} + a_{\Xi^0\Xi_c'^0}\frac{m_{\Xi_c^+}+m_{\Xi_c'^0}}{m_{\Xi^0}-m_{\Xi_c'^0}} g^{A(\pi^+)}_{\Xi_c'^0\Xi_c^+}\right)$$

$$A^{\rm com}(\Xi_c^0 \to \Xi^-\pi^+) = \frac{1}{f_\pi} a_{\Xi^0\Xi_c^0}$$

$$B^{\rm ca}(\Xi_c^0 \to \Xi^-\pi^+) = \frac{1}{f_\pi}\left(g^{A(\pi^+)}_{\Xi^-\Xi^0}\frac{m_{\Xi^-}+m_{\Xi^0}}{m_{\Xi_c^0}-m_{\Xi^0}} a_{\Xi^0\Xi_c^0}\right)$$

Channel	$A^{\rm fac}$	$A^{\rm com}$	$A^{\rm tot}$	$B^{\rm fac}$	$B^{\rm ca}$	$B^{\rm tot}$	$\mathcal{B}_{\rm theo}$	$\mathcal{B}_{\rm exp}$	$\alpha_{\rm theo}$	$\alpha_{\rm exp}$
$\Xi_c^0 \to \Xi^-\pi^+$	-7.42	-5.36	-12.78	28.24	2.65	30.89	6.47	1.80 ± 0.52	-0.95	-0.6 ± 0.4
$\Xi_c^+ \to \Xi^0\pi^+$	-7.41	5.36	-2.05	28.07	-14.03	14.04	1.72	1.57 ± 0.83	-0.78	$-$

constructive

distructive

Comparison

Modes	This work	Geng *et al.* [14, 46]	Expt.
$\Lambda_c^+ \to \Lambda\pi^+$	$1.30\ (-0.93)$	$1.27 \pm 0.07\ (-0.77 \pm 0.07)$	$1.30 \pm 0.07\ (-0.84 \pm 0.09)$
$\Lambda_c^+ \to \Sigma^0\pi^+$	$2.24\ (-0.76)$	$1.26 \pm 0.06\ (-0.58 \pm 0.10)$	$1.29 \pm 0.07\ (-0.73 \pm 0.18)$
$\Lambda_c^+ \to \Sigma^+\pi^0$	$2.24\ (-0.76)$	$1.26 \pm 0.06\ (-0.58 \pm 0.10)$	$1.25 \pm 0.10\ (-0.55 \pm 0.11)$
$\Lambda_c^+ \to \Sigma^+\eta$	$0.74\ (-0.95)$	$0.29 \pm 0.12\ \ (-0.70^{+0.59}_{-0.30})$	0.53 ± 0.15
$\Lambda_c^+ \to p\overline{K}^0$	$2.11\ (-0.75)$	$3.14 \pm 0.15\ \ (-0.99^{+0.09}_{-0.01})$	$3.18 \pm 0.16\ \ (0.18 \pm 0.45)$
$\Lambda_c^+ \to \Xi^0 K^+$	$0.73\ \ (0.90)$	$0.57 \pm 0.09\ \ (1.00^{+0.00}_{-0.02})$	$0.55 \pm 0.07\ \ (0.77 \pm 0.78)$
$\Lambda_c^+ \to p\pi^0$	$0.13\ (-0.97)$	$0.11^{+0.13}_{-0.11}\ \ (0.24 \pm 0.68)$	< 0.27
$\Lambda_c^+ \to p\eta$	$1.28\ (-0.55)$	$1.12 \pm 0.28\ \ (-1.00^{+0.06}_{-0.00})$	1.24 ± 0.29
$\Lambda_c^+ \to n\pi^+$	$0.09\ (-0.73)$	$0.76 \pm 0.11\ \ (0.27 \pm 0.11)$	
$\Lambda_c^+ \to \Lambda K^+$	$1.07\ (-0.96)$	$0.66 \pm 0.09\ \ (0.09 \pm 0.26)$	0.61 ± 0.12
$\Lambda_c^+ \to \Sigma^0 K^+$	$0.72\ (-0.73)$	$0.52 \pm 0.07\ \ (-0.98^{+0.05}_{-0.02})$	0.52 ± 0.08
$\Lambda_c^+ \to \Sigma^+ K^0$	$1.44\ (-0.73)$	$1.05 \pm 0.14\ \ (-0.98^{+0.05}_{-0.02})$	

- Now most predictions for branching fraction and decay asymmetry are consistent with fitting results based on SU(3) symmetry.
- The difference in $\Lambda_c^+ \to n\,\pi^+$ requires

Comparison

Modes	This work	Geng *et al.* [14, 46]		Expt.
$\Xi_c^+ \to \Sigma^+ \overline{K}^0$	$0.20\ (-0.80)$	$0.78^{+1.02}_{-0.78}$	$(0.93^{+0.07}_{-0.14})$	
$\Xi_c^+ \to \Xi^0 \pi^+$	$1.72\ (-0.78)$	0.42 ± 0.17	(-0.43 ± 0.57)	1.57 ± 0.83
$\Xi_c^0 \to \Lambda \overline{K}^0$	$1.33\ (-0.86)$	1.42 ± 0.09	$(-0.85^{+0.16}_{-0.15})$	
$\Xi_c^0 \to \Sigma^0 \overline{K}^0$	$0.04\ (-0.94)$	$0.09^{+0.11}_{-0.09}$	$(0.30^{+0.70}_{-0.84})$	
$\Xi_c^0 \to \Sigma^+ K^-$	$0.78\ (\ 0.98)$	0.76 ± 0.14	$(\ 0.93^{+0.07}_{-0.08})$	
$\Xi_c^0 \to \Xi^0 \pi^0$	$1.82\ (-0.77)$	1.00 ± 0.14	$(-0.96^{+0.05}_{-0.04})$	
$\Xi_c^0 \to \Xi^0 \eta$	$2.67\ (\ 0.30)$	1.30 ± 0.23	$(\ 0.80 \pm 0.16)$	
$\Xi_c^0 \to \Xi^- \pi^+$	$6.47\ (-0.95)$	2.95 ± 0.14	$(-1.00^{+0.01}_{-0.00})$	$1.80 \pm 0.52\ (-0.6 \pm 0.4)$

- The signs of α are consistent, except $\Xi_c^+ \to \Sigma^+ \overline{K^0}$
- Both groups have the same tension with $\Xi_c^+ \to \Xi^0 \pi^+$ and $\Xi_c^0 \to \Xi^- \pi^+$, waiting for further confirmation from experiment.

Modes	This work	Geng *et al.* [14, 46]	Expt.
$\Xi_c^+ \to \Lambda\pi^+$	0.85 (−0.33)	1.23 ± 0.42 (0.03 ± 0.18)	
$\Xi_c^+ \to \Sigma^0\pi^+$	4.30 (−0.95)	2.65 ± 0.25 (-0.61 ± 0.12)	
$\Xi_c^+ \to \Sigma^+\pi^0$	1.36 (0.23)	2.61 ± 0.67 (-0.18 ± 0.36)	
$\Xi_c^+ \to \Sigma^+\eta$	0.32 (0.36)	1.50 ± 1.06 (0.30 ± 0.60)	
$\Xi_c^+ \to p\overline{K}^0$	3.96 (−0.83)	4.64 ± 0.72 (-0.83 ± 0.06)	
$\Xi_c^+ \to \Xi^0 K^+$	2.20 (−0.98)	0.76 ± 0.12 (0.39 ± 0.16)	
$\Xi_c^0 \to \Lambda\pi^0$	0.24 (−0.41)	0.31 ± 0.11 (0.08 ± 0.22)	
$\Xi_c^0 \to \Lambda\eta$	0.76 (−0.45)	0.79 ± 0.27 (-0.17 ± 0.26)	
$\Xi_c^0 \to \Sigma^0\pi^0$	0.38 (−0.98)	0.50 ± 0.09 (-0.74 ± 0.25)	
$\Xi_c^0 \to \Sigma^0\eta$	0.05 (0.36)	0.18 ± 0.11 (-0.20 ± 0.76)	
$\Xi_c^0 \to \Sigma^-\pi^+$	2.62 (−0.90)	1.83 ± 0.09 (-0.99 ± 0.01)	
$\Xi_c^0 \to \Sigma^+\pi^-$	0.71 (0.89)	0.49 ± 0.09 (0.91 ± 0.09)	
$\Xi_c^0 \to pK^-$	0.35 (0.99)	0.60 ± 0.13 (0.82 ± 0.11)	
$\Xi_c^0 \to n\overline{K}^0$	1.40 (−0.89)	1.07 ± 0.06 (-0.74 ± 0.12)	
$\Xi_c^0 \to \Xi^0 K^0$	1.32 (−0.85)	0.96 ± 0.04 (-0.53 ± 0.09)	
$\Xi_c^0 \to \Xi^- K^+$	3.90 (−0.97)	1.28 ± 0.06 $(-1.00^{+0.01}_{-0.00})$	

Summary

- Weak decays of anti-triplet of charmed baryons are predicted.
- The sign of form factors can be discriminated.
- Several Λ_c^+ decays are in agreement with BESIII.
- The $\Lambda_c^+ \to \Xi^0 K^+$ puzzle is resolved.
- A tension exists in $\Xi_c^+ \to \Xi^0 \pi^+$ and $\Xi_c^0 \to \Xi^- \pi^+$.
- Wait for more BESIII, Belle/Belle-II data to examine $\Lambda_c^+, \Xi_c^{+,0}$ decay theory.