第17届全国重味物理与CP破坏研讨会

Weak Decays of Anti-triplet Charmed Baryon

徐繁荣

2019. 7. 31

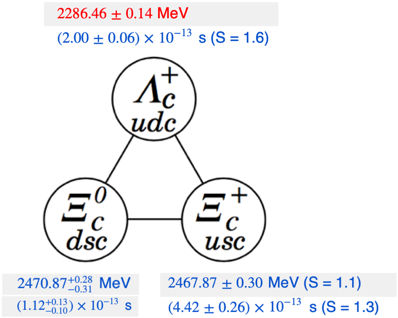
合作者：郑海扬、康现伟、蒙观保、邹晋祺

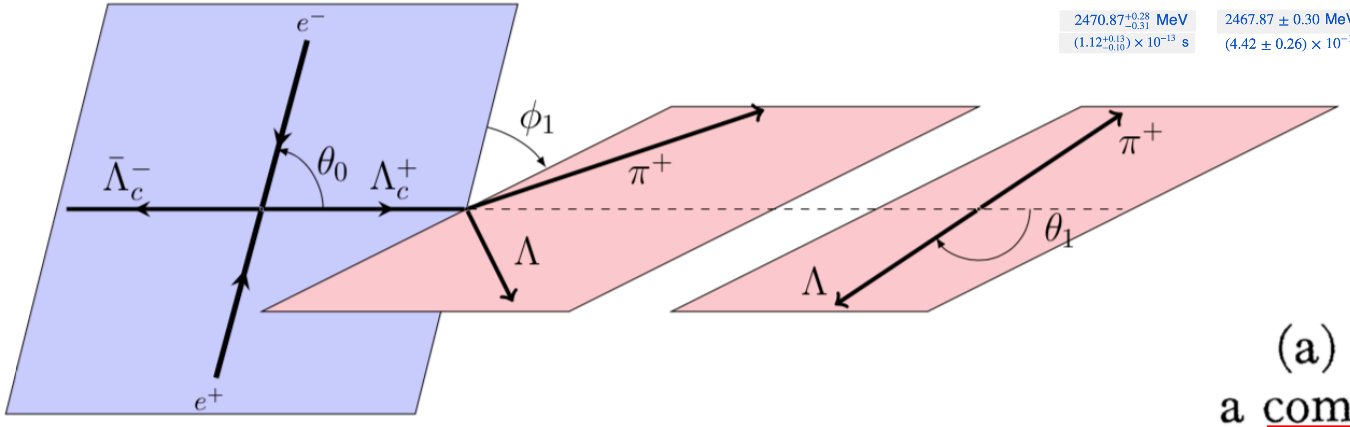
暨南大學
JINAN UNIVERSITY

Introduction

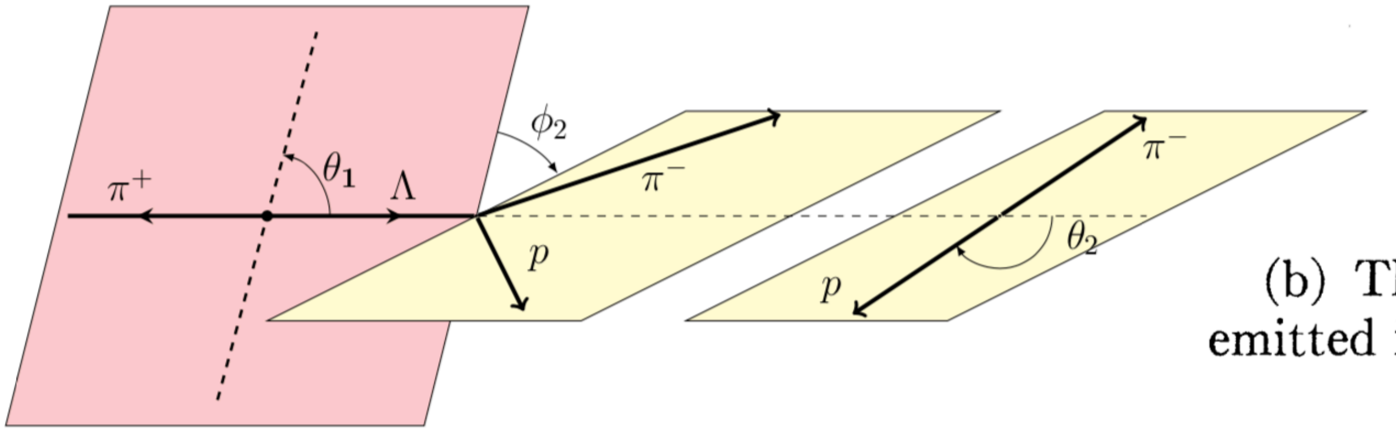
新瓶

Review: Talk by 耿朝强





CM frame Λ_c^+ rest frame



Λ_c^+ rest frame Λ rest frame

旧酒

Branching fraction

Polarization

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

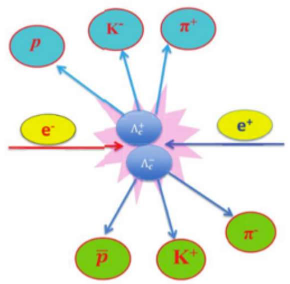
It has been pointed out before[1] that the distribution is proportional to

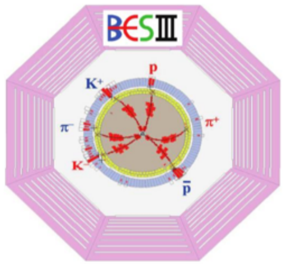
$$[1+\alpha\cos\chi]d\Omega, \tag{1}$$

(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

Talk by 王滨龙

Λ_c^+ @BESIII 4.6 GeV, 567/pb

- More precise measurement of Cabibbo-favored process

$$\mathcal{B}(\Lambda_c^+ \to \Xi^0 K^+) = (5.90 \pm 0.86 \pm 0.39) \times 10^{-3}$$

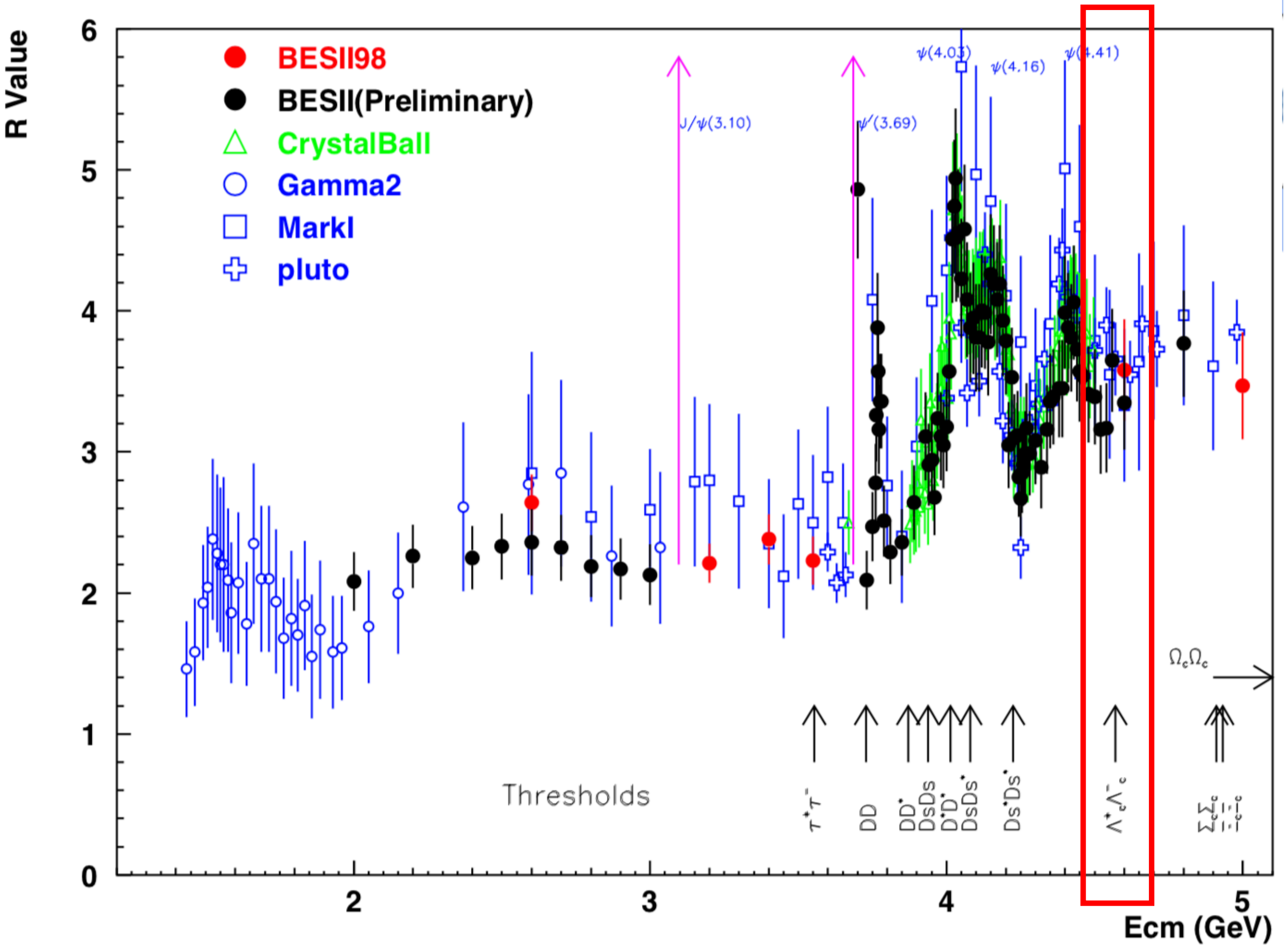
BESIII, PLB 783（2018), 200-206

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

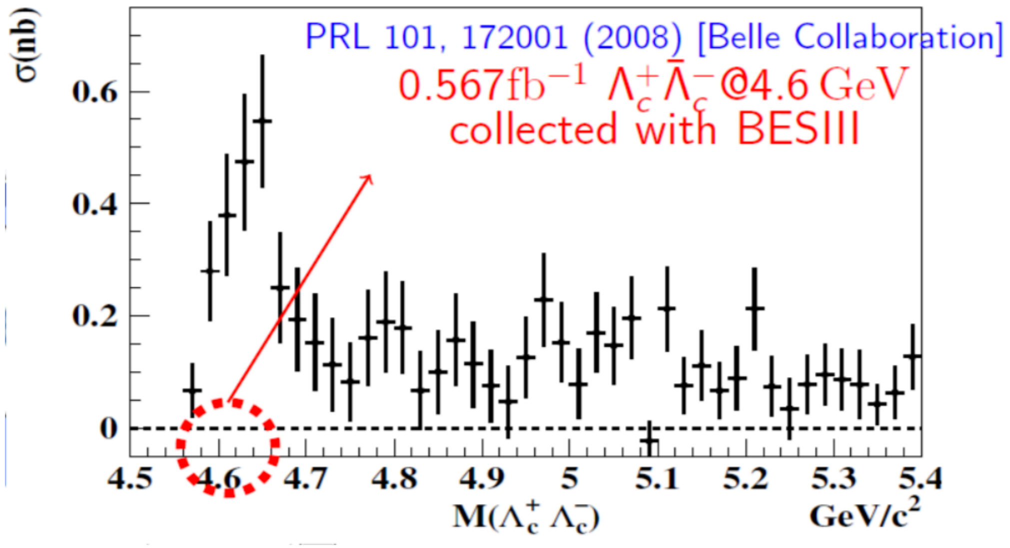
$$\mathcal{B}(\Lambda_c^+ \to \Sigma^+ \eta') = (1.34 \pm 0.53 \pm 0.21)\% \ (< 1.9\%)$$

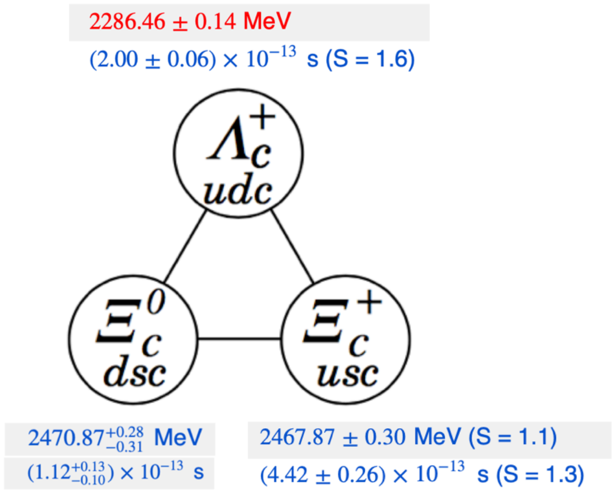
BESIII, 1811.08028

The future of Λ_c^+



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





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

Talk by 房双世

Ξ_c@Belle

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

Talk by 沈成平

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

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

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

Belle, PRL 122 (2019) 082001

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

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

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

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

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

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

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

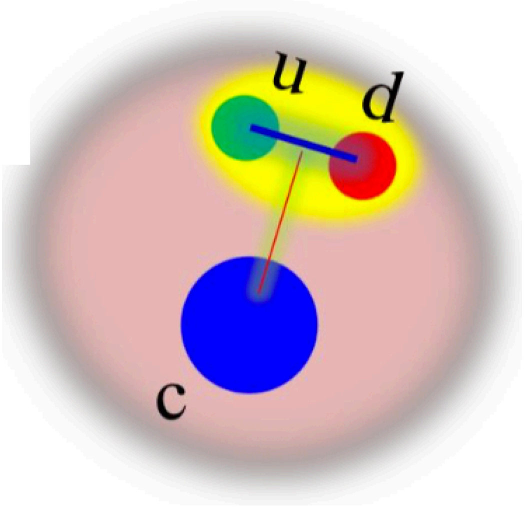
3.3 σ larger

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
  - heavy to apply ChPT
  - light to apply HQET
  - **Model estimation** cannot avoid



BF of Cabbibo-favored decays in 1990s

Decay	RQM Körner, Krämer [8]	Pole Xu, Kamal [9]	Pole Cheng, Tseng [10] CA	 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	RQM Körner, Krämer [16]	Pole Xu, Kamal [18]	Pole Cheng, Tseng [19] CA	 Pole	RQM Ivanov et al [17]	Pole Żenczykowski [20]	C.A. Sharma, Verma [21]	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	new
$\Xi_c^0 \to \Lambda \bar{K}^0$	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	new
$\Xi_c^0 \to \Xi^0 \eta$	0.24				0.28	0.69	0.09		
$\Xi_c^0 \to \Xi^0 \eta'$	0.85				0.31	0.01	0.14		

- 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

	RQM	Pole	Pole		RQM	Pole	C.A.		
Decay	Körner, Krämer [8]	Xu, Kamal [9]	Cheng, Tseng [10] CA	Cheng, Tseng [10] Pole	Ivanov et al [11]	Żenczykowski [12]	Sharma, Verma [13]	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 ⇒ $\alpha = 0$
    - ❑ Can be improved
  - Experiment ?

BESIII, PLB 783（2018), 200-206

Decay asymmetry α of Cabbibo-favored decays in 1990s

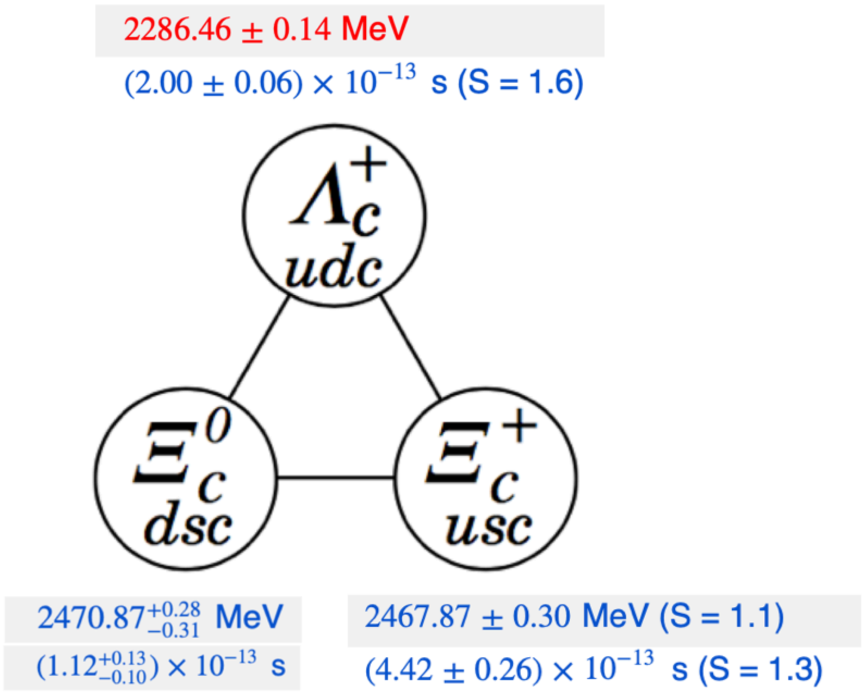
Decay	Körner, Krämer [16]	Xu, Kamal [18]	Cheng, Tseng [19]		Ivanov et al [17]	Żenczykowski [20]	Sharma, Verma [21]	Expt. [6]
	RQM	Pole	Pole		RQM	Pole	C.A.	
			CA	Pole				
$\Xi_c^+ \to \Sigma^+ \bar{K}^0$	-1.0	0.24	0.43	-0.09	-0.99	1.0	0.54	
$\Xi_c^+ \to \Xi^0 \pi^+$	-0.78	-0.81	-0.77	-0.77	-0.97	1.0	-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 ?

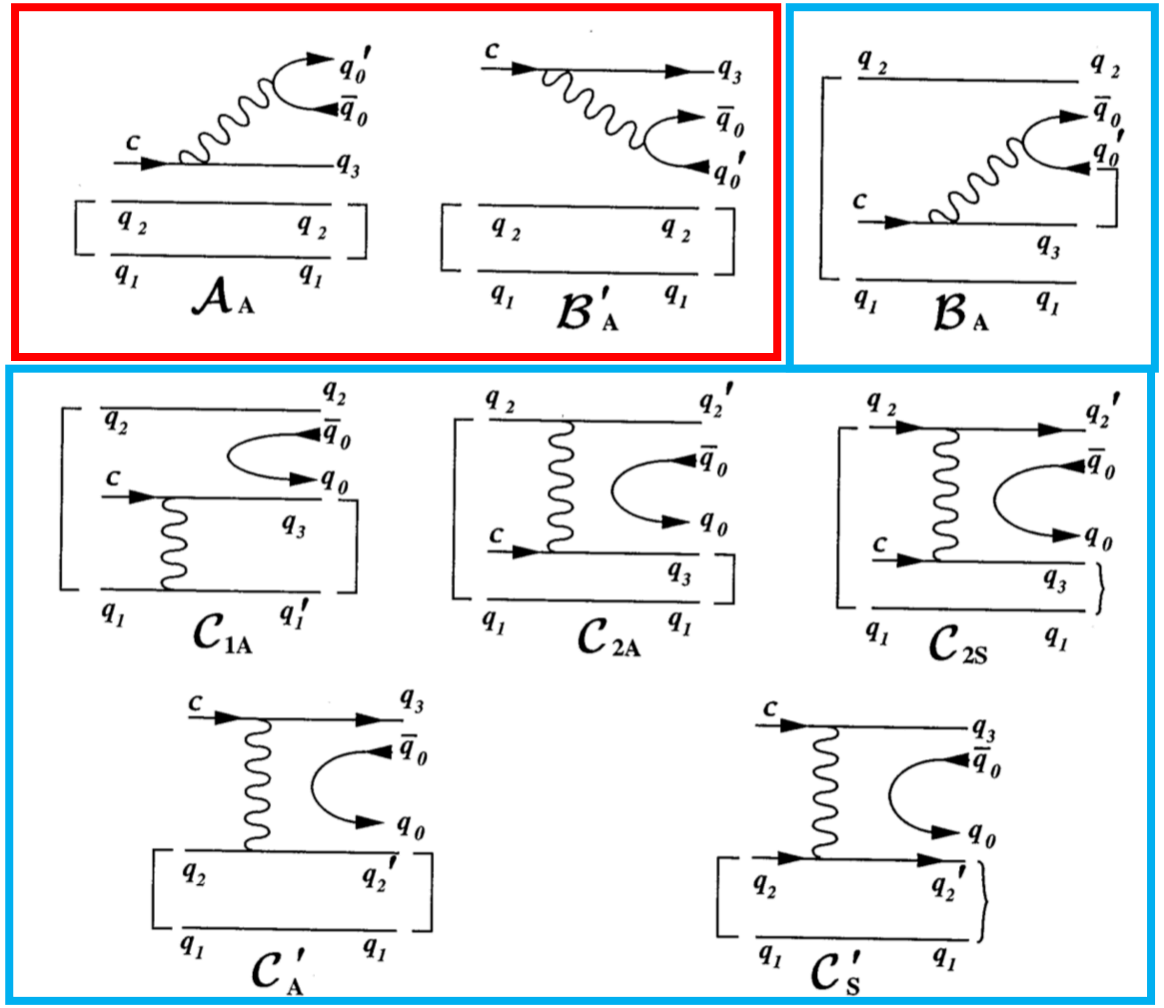
Our strategy

- 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

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

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

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

→ $N_c^{\text{eff}} \approx 7$

Factorizable part: form factor

- FF sign issue
- MIT bag model estimation

Static limit

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

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

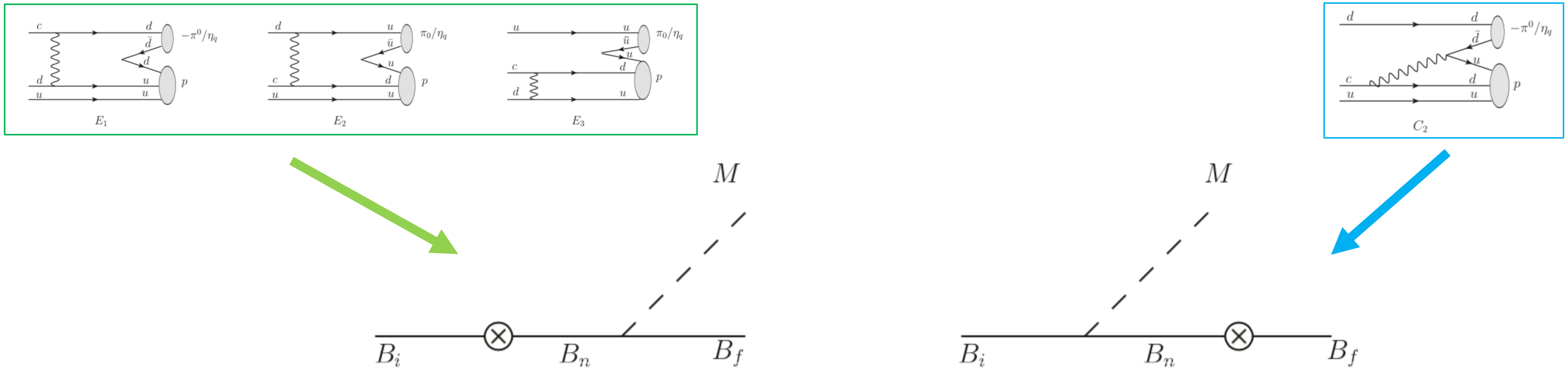
Run

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

- More efforts on FF required

modes	$(c\bar q)$	$f_1(q^2_{\rm max})$	$f_1(m_P^2)/f_1(q^2_{\rm max})$	$g_1(q^2_{\rm max})$	$g_1(m_P^2)/g_1(q^2_{\rm max})$
$\Xi_c^+ \to \Sigma^+ \overline{K}^0$	$(c\bar s)$	$-\frac{\sqrt6}{2}Y_1$	0.44907	$-\frac{\sqrt6}{2}Y_2$	0.60286
$\Xi_c^+ \to \Xi^0 \pi^+$	$(c\bar s)$	$-\frac{\sqrt6}{2}Y_1^s$	0.49628	$-\frac{\sqrt6}{2}Y_2^s$	0.63416
$\Xi_c^0 \to \Lambda \overline{K}^0$	$(c\bar s)$	$\frac12 Y_1$	0.38700	$\frac12 Y_2$	0.55337
$\Xi_c^0 \to \Sigma^0 \overline{K}^0$	$(c\bar s)$	$\frac{\sqrt3}{2}Y_1$	0.44929	$\frac{\sqrt3}{2}Y_2$	0.60304
$\Xi_c^0 \to \Xi^- \pi^+$	$(c\bar s)$	$-\frac{\sqrt6}{2}Y_1^s$	0.49911	$-\frac{\sqrt6}{2}Y_2^s$	0.63636
$\Xi_c^+ \to \Sigma^0 \pi^+$	$(c\bar d)$	$\frac{\sqrt3}{2}Y_1$	0.36045	$\frac{\sqrt3}{2}Y_2$	0.52523
$\Xi_c^+ \to \Lambda \pi^+$	$(c\bar d)$	$-\frac12 Y_1$	0.30260	$-\frac12 Y_2$	0.47622
$\Xi_c^+ \to \Sigma^+ \pi^0$	$(c\bar d)$	$-\frac{\sqrt6}{2}Y_1$	0.35774	$-\frac{\sqrt6}{2}Y_2$	0.52294
$\Xi_c^+ \to \Sigma^+ \eta_8$	$(c\bar d)$	$-\frac{\sqrt6}{2}Y_1$	0.41371	$-\frac{\sqrt6}{2}Y_2$	0.57735
$\Xi_c^+ \to \Xi^0 K^+$	$(c\bar s)$	$-\frac{\sqrt6}{2}Y_1^s$	0.55058	$-\frac{\sqrt6}{2}Y_2^s$	0.68080
$\Xi_c^0 \to \Lambda \eta_8$	$(c\bar s)$, $(c\bar d)$	$\frac12 Y_1$	0.39685, 0.34715	$\frac12 Y_2$	0.56286, 0.52343
$\Xi_c^0 \to \Sigma^0 \eta_8$	$(c\bar s)$, $(c\bar d)$	$\frac{\sqrt3}{2}Y_1$	0.46073, 0.41395	$\frac{\sqrt3}{2}Y_2$	0.61338, 0.57754
$\Xi_c^0 \to \Lambda \pi^0$	$(c\bar d)$	$\frac12 Y_1$	0.30019	$\frac12 Y_2$	0.47410
$\Xi_c^0 \to \Sigma^0 \pi^0$	$(c\bar d)$	$\frac{\sqrt3}{2}Y_1$	0.35795	$\frac{\sqrt3}{2}Y_2$	0.52311
$\Xi_c^0 \to \Sigma^- \pi^+$	$(c\bar d)$	$\frac{\sqrt6}{2}Y_1$	0.36183	$\frac{\sqrt6}{2}Y_2$	0.52638
$\Xi_c^0 \to \Xi^- K^+$	$(c\bar s)$	$-\frac{\sqrt6}{2}Y_1^s$	0.55371	$-\frac{\sqrt6}{2}Y_2^s$	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

- Advance: avoid ½⁻

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

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

- S-wave: commutator

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

$$V_+\Lambda = -\frac{\sqrt{6}}{2}p$$

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

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

- P-wave: generalized Goldberg-Treinman 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

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

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

$$c_- = c_1 - c_2$$

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

Hard working ...

Results for anti-triplet decays

Λ_c^+ decays

TABLE II. The predicted S- and P-wave amplitudes of singly Cabibbo-suppressed decays $\Lambda_c^+ \to \mathcal{B} + P$ in units of $G_F 10^{-2}$ GeV^2. Branching fractions and the asymmetry parameter α are shown in the last three columns. Experimental results are taken from [7,19].

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

- $\Lambda_c^+ \to p\pi^0, \Lambda_c^+ \to p\eta$: consistent well with BESIII experiment
- $\Lambda_c^+ \to n\pi^+$: wait for new result from BESIII
- $\Lambda_c^+ \to \Lambda K^+$: may resort to form factor

Hai-Yang Cheng, Xian-Wei Kang, FRX, PRD 97, 074028 (2018)

Ξ_c decays: CF

TABLE III. The Cabibbo-favored decays $\Xi_c \to \mathcal{B}_f P$ in units of $10^{-2} G_F \mathrm{GeV}^2$. Branching fractions (in percent) and the up-down spin asymmetry α in theory and experiment are shown in the last four columns.

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	−4.42	−1.44	−9.95	12.33	2.38	0.18	–	−0.83	–
$\Xi_c^+ \to \Xi^0 \pi^+$	−7.41	5.43	−1.98	28.07	−13.97	14.11	1.66	1.57 ± 0.83	−0.76	–
$\Xi_c^0 \to \Lambda \overline{K}^0$	−1.11	−5.49	−6.60	3.66	6.70	10.36	0.98	–	−0.85	–
$\Xi_c^0 \to \Sigma^0 \overline{K}^0$	−2.11	3.17	1.06	7.05	−9.36	−2.30	0.03	–	−0.94	–
$\Xi_c^0 \to \Sigma^+ K^-$	0	−0.06	−0.06	0	−11.48	−11.48	0.24	–	0.03	–
$\Xi_c^0 \to \Xi^0 \pi^0$	0	−7.68	−7.68	0	11.77	11.77	1.36	–	−0.76	–
$\Xi_c^0 \to \Xi^0 \eta_8$	0	−10.95	−10.95	0	−5.99	−5.99	2.00	–	0.29	–
$\Xi_c^0 \to \Xi^- \pi^+$	−7.42	−5.43	−12.85	28.24	2.68	30.92	4.77	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

Hai-Yang Cheng, G. Meng, FRX, J. Zou, to appear

Comparison of FF

TABLE VI. MBM predictions for the bare form factors evaluated at $q^2=0$ of the $c \to s$ decays. The upper value corresponds to monopole approximation and the lower one to dipole approximation.

$B_1 \to B_2 + e + \nu_e$	f_1	f_2	f_3	g_1	g_2	g_3
$\Xi_{cc}^{++} \to \Xi_c^{A\,+}$	0.97	−0.06	−0.45	0.28	−0.01	−0.92
	0.68	−0.04	−0.32	0.22	−0.00	−0.73
$\Xi_{cc}^{++} \to \Xi_c^{+}$	0.48	1.19	−0.02	0.79	−0.02	−2.64
	0.34	0.84	−0.02	0.63	−0.02	−2.08
$\Xi_{cc}^{+} \to \Xi_c^{0}$	0.52	1.29	−0.06	0.84	0.03	−2.83
	0.39	0.97	−0.04	0.70	0.03	−2.34
$\Omega_{cc}^{+} \to \Omega_c^{0}$	0.75	1.94	−0.11	1.20	0.06	−4.51
	0.56	1.46	−0.08	0.99	0.05	−3.72
$\Xi_{cc}^{+} \to \Xi_c^{A\,0}$	0.97	−0.06	−0.45	0.28	−0.01	−0.92
	0.68	−0.04	−0.32	0.22	−0.00	−0.73
$\Sigma_c^{0} \to \Sigma^{-}$	0.80	−0.78	−0.37	−0.20	0.03	0.22
	0.51	−0.50	−0.24	−0.15	0.02	0.16
$\Xi_c^{0} \to \Xi^{-}$	0.57	−0.56	−0.27	−0.14	0.02	0.18
	0.38	−0.37	−0.18	−0.11	0.01	0.14
$\Xi_c^{A\,0} \to \Xi^{-}$	0.84	0.44	−0.04	0.80	−0.07	−0.93
	0.59	0.31	−0.03	0.63	−0.05	−0.74
$\Lambda_c^{+} \to \Lambda$	0.66	0.27	0.00	0.64	−0.07	−0.56
	0.46	0.19	0.00	0.50	−0.05	−0.44
$\Xi_c^{A\,+} \to \Xi^{0}$	0.84	0.44	−0.04	0.80	−0.07	−0.93
	0.58	0.31	−0.03	0.63	−0.05	−0.73
$\Sigma_c^{+} \to \Sigma^{0}$	0.80	−0.78	−0.37	−0.20	0.03	0.22
	0.52	−0.50	−0.24	−0.15	0.02	0.16
$\Xi_c^{+} \to \Xi^{0}$	0.61	−0.58	−0.28	−0.15	0.01	0.18
	0.43	−0.41	−0.20	−0.12	0.01	0.14
$\Sigma_c^{++} \to \Sigma^{+}$	0.80	−0.78	−0.37	−0.20	0.03	0.21
	0.52	−0.50	−0.24	−0.15	0.02	0.16

R.Perez-Marcial et. al., PRD 40 (1989)2955

Ξ_c decays: SCS

TABLE IV. The singly Cabibbo-suppressed decays $\Xi_c \to \mathcal{B}_f P$ in units of $10^{-2} G_F \mathrm{GeV}^2$. Branching fractions (in unit of 10^{-4}) and the asymmetry parameter α are shown in the last three columns.

Channel	A^{fac}	A^{com}	A^{tot}	B^{fac}	B^{ca}	B^{tot}	$\mathcal{B}_{theo}$	$\mathcal{B}_{expt}$	α_{theo}
$\Xi_c^+ \to \Sigma^0\pi^+$	−0.90	−0.99	−1.89	3.29	0.76	4.05	41.59	–	−0.96
$\Xi_c^+ \to \Lambda\pi^+$	0.46	−1.52	−1.05	−1.69	2.16	0.47	8.50	–	−0.33
$\Xi_c^+ \to \Sigma^+\pi^0$	1.27	0.99	2.26	−4.63	1.59	−3.04	46.67	–	−0.77
$\Xi_c^+ \to p\overline{K}^0$	0	−2.10	−2.10	0	2.63	2.63	38.02	–	−0.84
$\Xi_c^+ \to \Sigma^+\eta_8$	−0.74	1.41	0.67	2.58	−2.21	0.37	3.02	–	0.34
$\Xi_c^+ \to \Xi^0 K^+$	0.82	1.15	1.97	−3.00	−6.14	−9.14	68.72	–	−0.97
$\Xi_c^0 \to \Lambda\eta_8$	0.27	1.53	1.80	−0.94	−1.54	−2.48	6.72	–	−0.78
$\Xi_c^0 \to \Sigma^0\eta_8$	0.53	−1.00	−0.47	−1.83	−0.81	−2.64	1.55	–	0.85
$\Xi_c^0 \to \Lambda\pi^0$	−0.46	1.07	0.61	1.68	−0.95	0.73	0.85	–	0.75
$\Xi_c^0 \to \Sigma^0\pi^0$	−0.90	−0.70	−1.60	3.28	1.37	4.65	9.82	–	−1.00
$\Xi_c^0 \to \Xi^0 K^0$	0	2.11	2.11	0	−4.16	−4.16	9.73	–	−0.84
$\Xi_c^0 \to \Sigma^-\pi^+$	−1.28	−1.40	−2.68	4.67	0.24	4.91	19.13	–	−0.90
$\Xi_c^0 \to \Xi^- K^+$	0.82	−0.96	−0.14	−3.02	0.69	−2.33	0.73	–	0.40
$\Xi_c^0 \to pK^-$	0	−0.01	−0.01	0	−1.88	−1.88	1.11	–	0.025
$\Xi_c^0 \to n\overline{K}^0$	0	−2.11	−2.11	0	2.94	2.94	10.26	–	−0.88
$\Xi_c^0 \to \Sigma^+\pi^-$	0	0	0	0	2.50	2.50	1.43	–	0

$\Xi_c^0 \to \Sigma^+\pi^-$: vanished α; only nonfactorizable p-wave amplitudes contributes.

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.
- One mode of Ξ_c^+ decay agree well with Belle, tension exists in Ξ_c^0 decay.
- Wait for more BESIII data to examine Λ_c^+ decay theory.

第四届强子与重味物理理论实验联合研讨会：粲物理

23-24 November 2019
暨南大学校友楼4楼
Asia/Shanghai timezone

网址：https://indico.ihep.ac.cn/event/10408/overview