2024年BESIII粲强子物理研讨会

粲重子弱衰变的拓扑图方案

徐繁荣

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2401.15926; 2404.01350

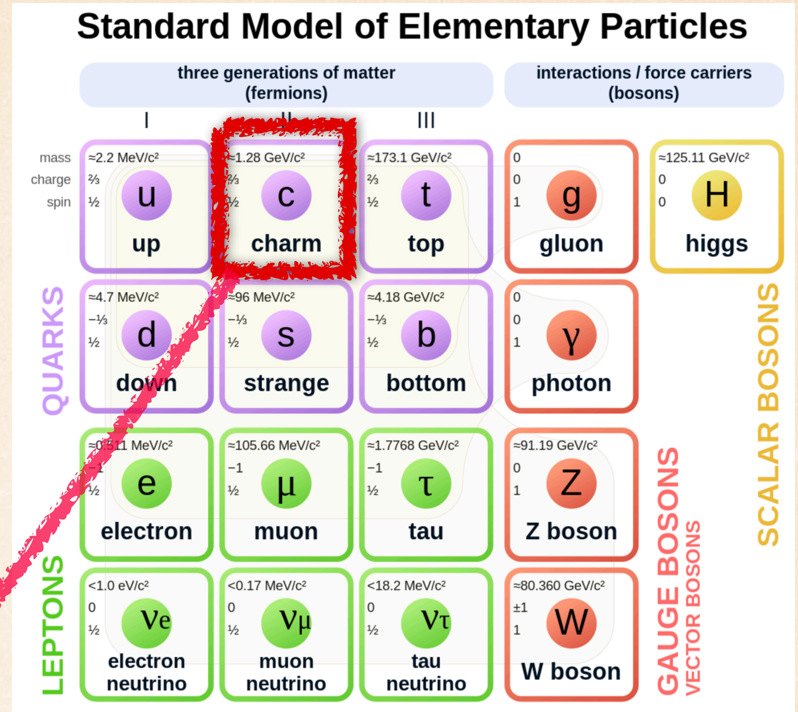
2024年5月11-13日，河南郑州

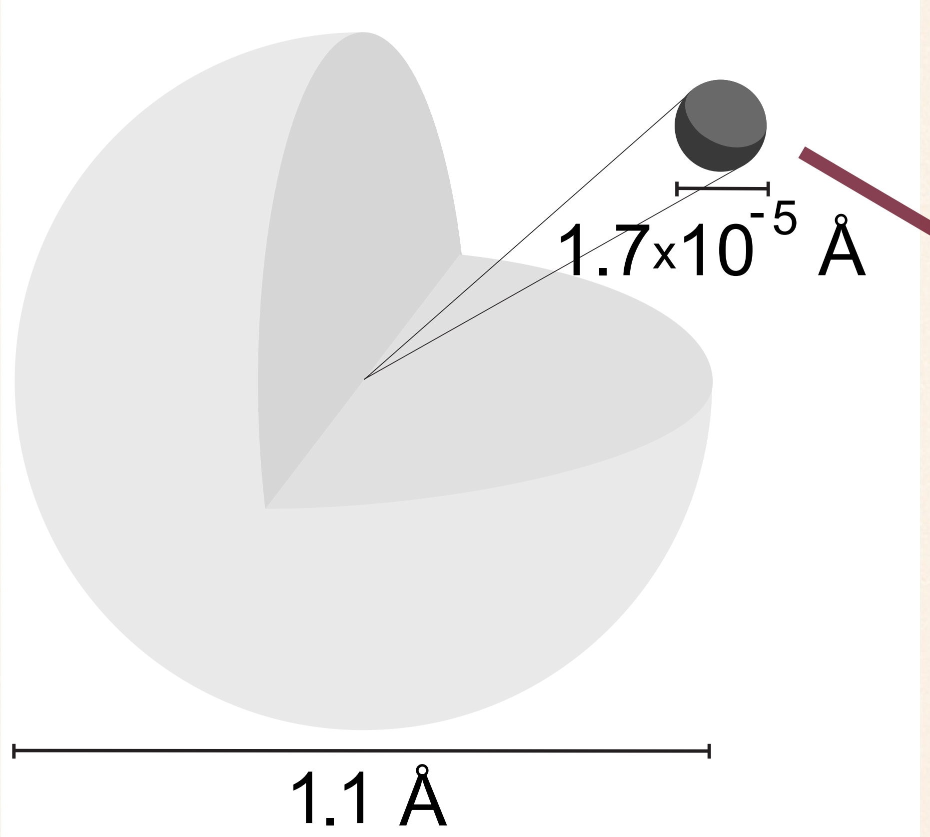
OUTLINE

- Introduction
- Topological diagram approach (TDA)
- Some remarks
- Summary

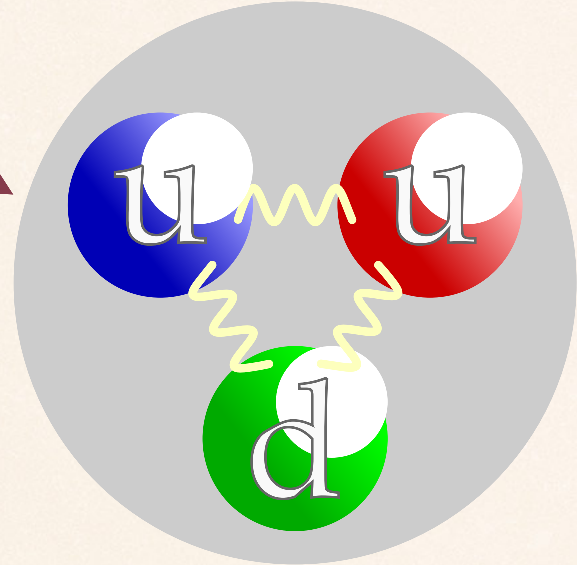
INTRODUCTION

The role of baryons

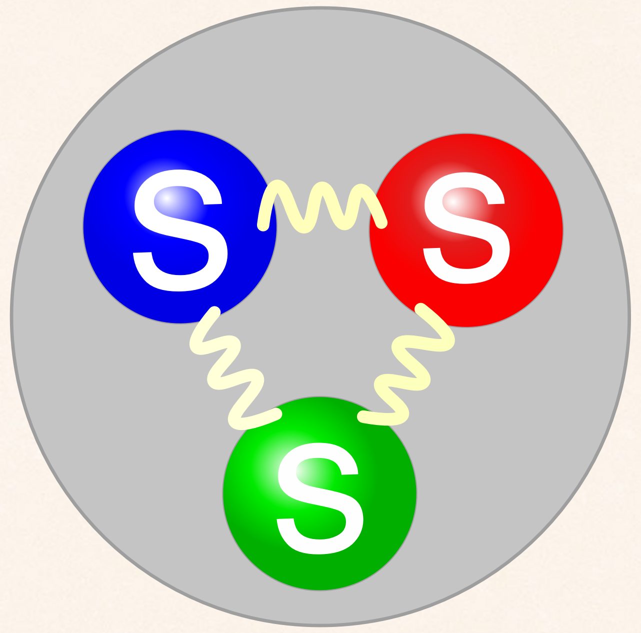




hydrogen atom

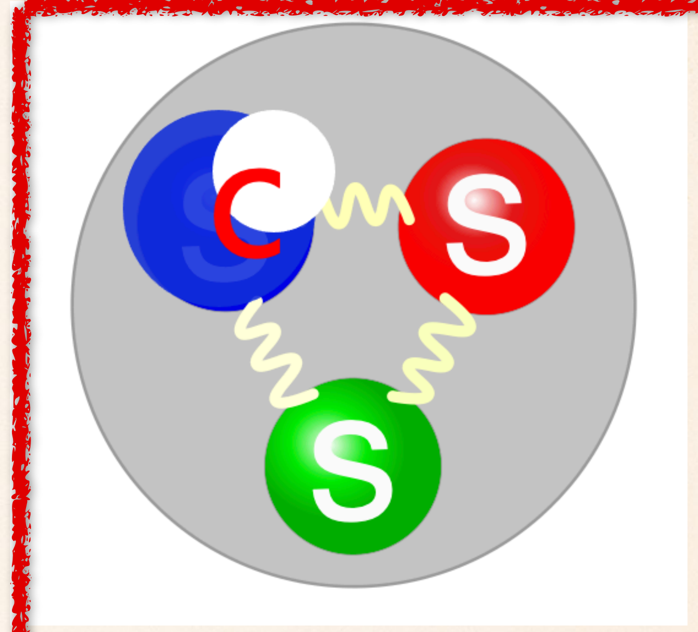


proton



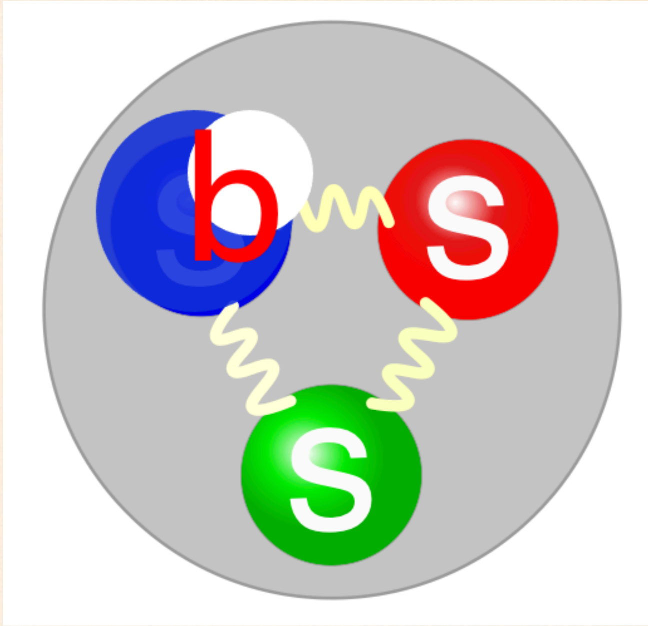
hyperon

e.g., Ω discovered at BNL in 1964



charmed baryon

e.g., charmed Ω discovered in 1985



bottom(ed) baryon

e.g., bottom Ω discovered in 2008 by DΦ

Watershed of charmed baryon experiments

PRL **113,** 042002 (2014) PHYSICAL REVIEW LETTERS week ending 25 JULY 2014

Measurement of the Branching Fraction $\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$

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(Belle Collaboration)

Belle

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We present the first model-independent measurement of the absolute branching fraction of the $\Lambda_c^+ \to pK^-\pi^+$ decay using a data sample of 978 fb^{-1} collected with the Belle detector at the KEKB asymmetric-energy e^+e^- collider. The number of Λ_c^+ baryons is determined by reconstructing the recoiling $D^{(*)-}\bar{p}\pi^+$ system in events of the type $e^+e^- \to D^{(*)-}\bar{p}\pi^+\Lambda_c^+$. The branching fraction is measured to be $\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+) = (6.84 \pm 0.24^{+0.21}_{-0.27})\%$, where the first and second uncertainties are statistical and systematic, respectively.

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Measurements of Absolute Hadronic Branching Fractions of the Λ_c^+ Baryon

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Sarantsev,[23,f] M. Savrié,[21b] K. Schoenning,[50] S. Schumann,[22] W. Shan,[31] M. Shao,[46,a] C. P. Shen,[2] P. X. Shen,[30] X. Y. Shen,[1] H. Y. Sheng,[1] W. M. Song,[1] X. Y. Song,[1] S. Sosio,[49a,49c] S. Spataro,[49a,49c] G. X. Sun,[1] J. F. Sun,[15] S. S. Sun,[1] Y. J. Sun,[46,a] Y. Z. Sun,[1] Z. J. Sun,[1,a] Z. T. Sun,[19] C. J. Tang,[36] X. Tang,[1] I. Tapan,[40c] E. H. Thorndike,[44] M. Tiemens,[25] M. Ullrich,[24] I. Uman,[40d] G. S. Varner,[42] B. Wang,[30] B. L. Wang,[41] D. Wang,[31] D. Y. Wang,[31] K. Wang,[1,a] L. L. Wang,[1] L. S. Wang,[1] M. Wang,[33] P. Wang,[1] P. L. Wang,[1] S. G. Wang,[31] W. Wang,[1,a] W. P. Wang,[46,a] X. F. Wang,[39] Y. D. Wang,[14] Y. F. Wang,[1,a] Y. Q. Wang,[22] Z. Wang,[1,a] Z. G. Wang,[1,a] Z. H. Wang,[46,a] Z. Y. Wang,[1] T. Weber,[22] D. H. Wei,[11] J. B. Wei,[31] P. Weidenkaff,[22] S. P. Wen,[1] U. Wiedner,[4] M. Wolke,[50] L. H. Wu,[1] Z. Wu,[1,a] L. Xia,[46,a] L. G. Xia,[39] Y. Xia,[18] D. Xiao,[1] H. Xiao,[47] Z. J. Xiao,[28] Y. G. Xie,[1,a] Q. L. Xiu,[1,a] G. F. Xu,[1] L. Xu,[1] Q. J. Xu,[13] Q. N. Xu,[41] X. P. Xu,[37] L. Yan,[49a,49c] W. B. Yan,[46,a] W. C. Yan,[46,a] Y. H. Yan,[18] H. J. Yang,[34] H. X. Yang,[1] L. Yang,[51] Y. X. Yang,[11] M. Ye,[1,a] M. H. Ye,[7] J. H. Yin,[1] B. X. Yu,[1,a] C. X. Yu,[30] J. S. Yu,[26] C. Z. Yuan,[1] W. L. Yuan,[29] Y. Yuan,[1] A. Yuncu,[40b,b] A. A. Zafar,[48] A. Zallo,[20a] Y. Zeng,[18] Z. Zeng,[46,a] B. X. Zhang,[1] B. Y. Zhang,[1,a] C. Zhang,[29] C. C. Zhang,[1] D. H. Zhang,[1] H. H. Zhang,[38] H. Y. Zhang,[1,a] J. J. Zhang,[1] J. L. Zhang,[1] J. Q. Zhang,[1] J. W. Zhang,[1,a] J. Y. Zhang,[1] J. Z. Zhang,[1] K. Zhang,[1] L. Zhang,[1] X. Y. Zhang,[33] Y. Zhang,[1] Y. H. Zhang,[1,a] Y. N. Zhang,[41] Y. T. Zhang,[46,a] Yu Zhang,[41] Z. H. Zhang,[6] ... J. W. Zhao,[1,a] J. Y. Zhao,[1] J. Z. Zhao,[1,a] Lei Zhao,[46,a] Ling Zhao,[1] M. G. Zh... T. C. Zhao,[1] Y. B. Zhao,[1,a] Z. G. Zhao,[46,a] A. Zhemchugov,[23,c] B. Zheng,[47] J. ... B. Zhong,[28] L. Zhou,[1,a] X. Zhou,[51] X. K. Zhou,[46,a] X. R. Zhou,[46,a] X. Y. Zhou,[1] ... X. L. Zhu,[39] Y. C. Zhu,[46,a] Y. S. Zhu,[1] Z. A. Zhu,[1] J. Zhuang,[1,a] L. Zo...

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BESIII

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We report the first measurement of absolute hadronic branching fractions of Λ_c^+ baryon at the $\Lambda_c^+\bar{\Lambda}_c^-$ production threshold, in the 30 years since the Λ_c^+ discovery. In total, 12 Cabibbo-favored Λ_c^+ hadronic decay modes are analyzed with a double-tag technique, based on a sample of 567 pb^{-1} of e^+e^- collisions at $\sqrt{s} = 4.599$ GeV recorded with the BESIII detector. A global least-squares fitter is utilized to improve the measured precision. Among the measurements for twelve Λ_c^+ decay modes, the branching fraction for $\Lambda_c^+ \to pK^-\pi^+$ is determined to be $(5.84 \pm 0.27 \pm 0.23)\%$, where the first uncertainty is statistical and the second is systematic. In addition, the measurements of the branching fractions of the other 11 Cabibbo-favored hadronic decay modes are significantly improved.

After the breakthrough

Reference/normalization mode

$\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$

- ARGUS + CLEO : $(5.0 \pm 1.3)\%$ PDG 2014
- Belle: $(6.84 \pm 0.24^{+0.21}_{-0.27})\%$ obsolete

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

  BESIII, PRL 116 (2016), 052001

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

PDG 2023 update $(6.26 \pm 0.29)\%$

$\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)$

1. PDG 2023 updated

$(1.43 \pm 0.32)\ \%$

	Mode (*)	Fraction (Γ_i / Γ)	Scale Factor/ Conf. Level	P(MeV/c)
Γ_{13}	$\Xi_c^0 \to \Xi^-\pi^+$	0.0143 ± 0.0032	S=1.1	875

Category: No absolute branching fractions have been measured. The following are branching *ratios* relative to $\Xi^-\pi^+$.

The following data is related to the above value: ▸ expand all datablocks

$\Gamma(\Xi_c^0 \to pK^-\overline{K}^*(892)^0, \overline{K}^{*0} \to K^-\pi^+)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_2/Γ_{13}	+
$\Gamma(\Xi_c^0 \to pK^-K^-\pi^+$ (no $\overline{K}^{*0}$) $)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_3/Γ_{13}	+
$\Gamma(\Xi_c^0 \to \Lambda K_S^0)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_4/Γ_{13}	+
$\Gamma(\Xi_c^0 \to \Lambda K^-\pi^+)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_5/Γ_{13}	+
$\Gamma(\Xi_c^0 \to \Lambda \overline{K}^*(892)^0)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_6/Γ_{13}	+
$\Gamma(\Xi_c^0 \to \Sigma^0 K_S^0)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_9/Γ_{13}	+
$\Gamma(\Xi_c^0 \to \Sigma^+ K^-)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_{10}/Γ_{13}	+
$\Gamma(\Xi_c^0 \to \Sigma^0 \overline{K}^*(892)^0)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_{11}/Γ_{13}	+
$\Gamma(\Xi_c^0 \to \Sigma^+ K^*(892)^-)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_{12}/Γ_{13}	+
$\Gamma(\Xi_c^0 \to \Xi^-\pi^+)/\Gamma_{total}$	Γ_{13}/Γ	+

2. Belle 2019

$(1.80 \pm 0.50 \pm 0.14)\%$

PHYSICAL REVIEW LETTERS **122,** 082001 (2019)

First Measurements of Absolute Branching Fractions of the Ξ_c^0 Baryon at Belle

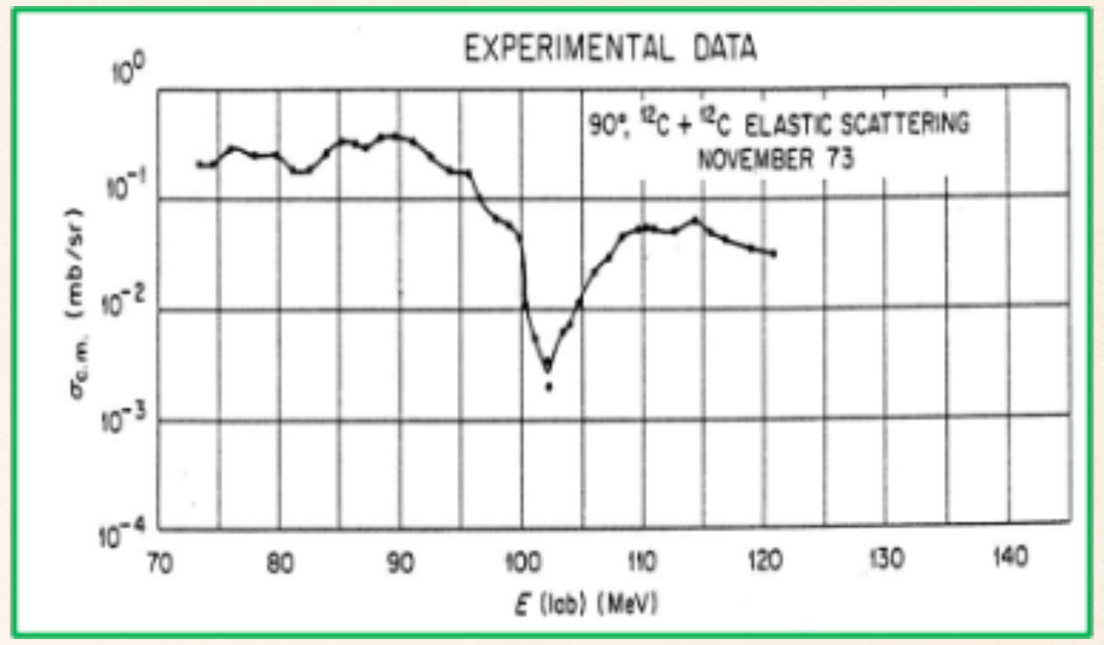
Y. B. Li,[69] C. P. Shen,[2,10] C. Z. Yuan,[26] I. Adachi,[17,13] H. Aihara,[84] S. Al Said,[79,35] D. M. Asner,[3] T. Aushev,[54] R. Ayad,[79] I. Badhrees,[79,34] Y. Ban,[69] V. Bansal,[67] C. Beleño,[12] M. Berger,[76] V. Bhardwaj,[21] B. Bhuyan,[22] T. Bilka,[5] J. Biswal,[31] A. Bondar,[4,65] A. Bozek,[62] M. Bračko,[48,31] L. Cao,[32] D. Červenkov,[5] A. Chen,[59] B. G. Cheon,[15] K. Chilikin,[43] K. Cho,[37] S.-K. Choi,[14] Y. Choi,[77] D. Cinabro,[88] S. Cunliffe,[8] S. Di Carlo,[41] Z. Doležal,[5] T. V. Dong,[17,13] Z. Drásal,[5] S. Eidelman,[4,65,43] J. E. Fast,[67] B. G. Fulsom,[67] R. Garg,[68] V. Gaur,[87] N. Gabyshev,[4,65] A. Garmash,[4,65] A. Giri,[23] P. Goldenzweig,[32] D. Greenwald,[81] B. Grube,[81] K. Hayasaka,[64] H. Hayashii,[58] C.-L. Hsu,[78] T. Iijima,[56,55] K. Inami,[55] G. Inguglia,[8] A. Ishikawa,[82] R. Itoh,[17,13] M. Iwasaki,[66] Y. Iwasaki,[17] W. W. Jacobs,[25] S. Jia,[2] Y. Jin,[84] D. Joffe,[33] K. K. Joo,[6] G. Karyan,[8] T. Kawasaki,[36] H. Kichimi,[17] D. Y. Kim,[75] H. J. Kim,[40] J. B. Kim,[38] K. T. Kim,[38] S. H. Kim,[15] K. Kinoshita,[7] P. Kodyš,[5] S. Korpar,[48,31] D. Kotchetkov,[16] P. Križan,[44,31] R. Kroeger,[51] P. Krokovny,[4,65] T. Kumita,[86] A. Kuzmin,[4,65] Y.-J. Kwon,[90] J. Y. Lee,[73] S. C. Lee,[40] L. K. Li,[26] L. Li Gioi,[49] J. Libby,[24] D. Liventsev,[87,17] M. Lubej,[31] J. MacNaughton,[52] M. Masuda,[83] T. Matsuda,[52] M. Merola,[28,57] K. Miyabayashi,[58] H. Miyata,[64] R. Mizuk,[43,53,54] G. B. Mohanty,[80] R. Mussa,[29] E. Nakano,[66] M. Nakao,[17,13] K. J. Nath,[22] M. Nayak,[88,17] M. Niiyama,[39] S. Nishida,[17,13] H. Ono,[63,64] Y. Onuki,[84] P. Pakhlov,[43,53] G. Pakhlova,[43,54] B. Pal,[3] S. Pardi,[28] S.-H. Park,[90] S. Paul,[81] T. K. Pedlar,[46] R. Pestotnik,[31] L. E. Piilonen,[87] V. Popov,[43,54] E. Prencipe,[19] G. Russo,[28] Y. Sakai,[17,13] M. Salehi,[47,45] S. Sandilya,[7] L. Santelj,[17] T. Sanuki,[82] V. Savinov,[70] O. Schneider,[42] G. Schnell,[1,20] J. Schueler,[16] C. Schwanda,[27] A. J. Schwartz,[7] Y. Seino,[64] K. Senyo,[89] M. E. Sevior,[50] T.-A. Shibata,[85] J.-G. Shiu,[61] B. Shwartz,[4,65] E. Solovieva,[43,54] M. Starič,[31] M. Sumihama,[11] T. Sumiyoshi,[86] W. Sutcliffe,[32] M. Takizawa,[74,18,71] K. Tanida,[30] Y. Tao,[9] F. Tenchini,[8] K. Trabelsi,[17,13] M. Uchida,[85] T. Uglov,[43,54] Y. Unno,[15] S. Uno,[17,13] P. Urquijo,[50] R. Van Tonder,[32] G. Varner,[16] B. Wang,[7] C. H. Wang,[60] M.-Z. Wang,[61] P. Wang,[26] X. L. Wang,[10] E. Won,[38] S. B. Yang,[38] H. Ye,[8] J. Yelton,[9] J. H. Yin,[26] Y. Yusa,[64] Z. P. Zhang,[72] V. Zhilich,[4,65] and V. Zhukova[43]

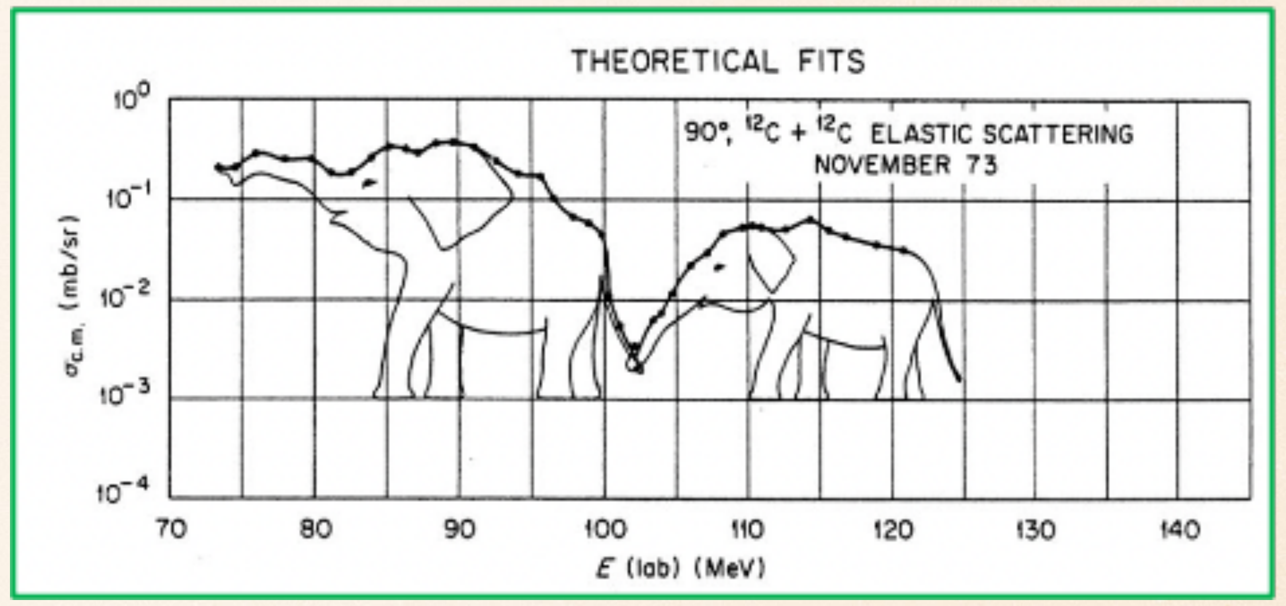
(Belle Collaboration)

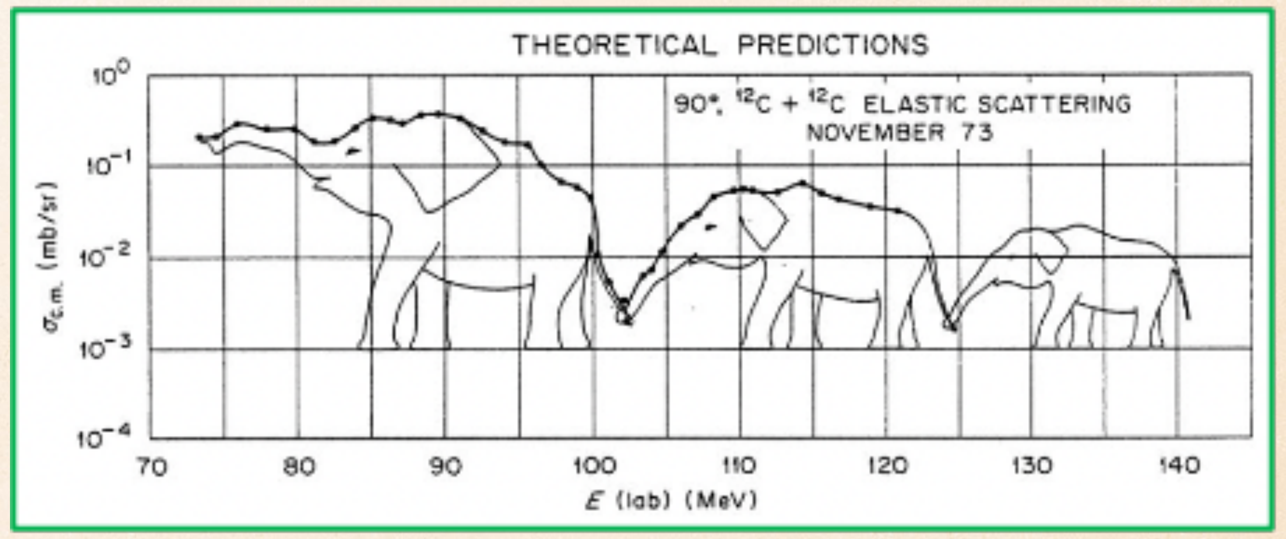
All 30 available experimental results till 2023

Observable	PDG [42]	BESIII	Belle	Average
$10^2\mathcal{B}(\Lambda_c^+ \to \Lambda^0\pi^+)$	1.29 ± 0.05			1.29 ± 0.05
$10^2\mathcal{B}(\Lambda_c^+ \to \Sigma^0\pi^+)$	1.27 ± 0.06			1.27 ± 0.06
$10^2\mathcal{B}(\Lambda_c^+ \to \Sigma^+\pi^0)$	1.25 ± 0.09			1.25 ± 0.09
$10^2\mathcal{B}(\Lambda_c^+ \to \Sigma^+\eta)$	0.44 ± 0.20		0.314 ± 0.044 [49]	0.32 ± 0.04 [42, 49]
$10^2\mathcal{B}(\Lambda_c^+ \to \Sigma^+\eta')$	1.5 ± 0.6		0.416 ± 0.086 [49]	0.44 ± 0.15 [42, 49]
$10^2\mathcal{B}(\Lambda_c^+ \to \Xi^0 K^+)$	0.55 ± 0.07			0.55 ± 0.07
$10^4\mathcal{B}(\Lambda_c^+ \to \Lambda^0 K^+)$	6.0 ± 0.5	$6.21 \pm 0.61^*$ [50]	6.57 ± 0.40 [51]	6.35 ± 0.31 [42, 51]
$10^4\mathcal{B}(\Lambda_c^+ \to \Sigma^0 K^+)$	4.9 ± 0.6	$4.7 \pm 0.95^*$ [52]	3.58 ± 0.28 [51]	3.82 ± 0.51 [42, 51]
$10^4\mathcal{B}(\Lambda_c^+ \to \Sigma^+ K_S)$	4.7 ± 1.4	$4.8 \pm 1.5^*$ [52]		4.7 ± 1.4
$10^4\mathcal{B}(\Lambda_c^+ \to n\pi^+)$	6.6 ± 1.3			6.6 ± 1.3
$10^4\mathcal{B}(\Lambda_c^+ \to p\pi^0)$	< 0.8	$1.56^{+0.72}_{-0.58} \pm 0.20$ [47]		$1.56^{+0.75}_{-0.61}$ [47]
$10^2\mathcal{B}(\Lambda_c^+ \to pK_S)$	1.59 ± 0.07			1.59 ± 0.07
$10^3\mathcal{B}(\Lambda_c^+ \to p\eta)$	1.41 ± 0.11	1.63 ± 0.33 [47], 1.57 ± 0.12 [53]		1.49 ± 0.08 [42, 47, 53]
$10^4\mathcal{B}(\Lambda_c^+ \to p\eta')$	4.9 ± 0.9			4.9 ± 0.9
$10^2\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)$	1.43 ± 0.32		$1.80 \pm 0.52^*$ [46]	1.80 ± 0.52 [46]
$10^2\frac{\mathcal{B}(\Xi_c^0 \to \Xi^- K^+)}{\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)}$	2.75 ± 0.57			2.75 ± 0.57
$10^2\frac{\mathcal{B}(\Xi_c^0 \to \Lambda K_S^0)}{\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)}$	22.5 ± 1.3		$22.9 \pm 1.4^*$ [48]	22.9 ± 1.4 [48]
$10^2\frac{\mathcal{B}(\Xi_c^0 \to \Sigma^0 K_S^0)}{\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)}$	3.8 ± 0.7			3.8 ± 0.7
$10^2\frac{\mathcal{B}(\Xi_c^0 \to \Sigma^+ K^-)}{\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)}$	12.3 ± 1.2			12.3 ± 1.2
$10^2\mathcal{B}(\Xi_c^+ \to \Xi^0\pi^+)$	1.6 ± 0.8			1.6 ± 0.8
$\alpha(\Lambda_c^+ \to \Lambda^0\pi^+)$	-0.84 ± 0.09		-0.755 ± 0.006 [51]	-0.76 ± 0.01 [42, 51]
$\alpha(\Lambda_c^+ \to \Sigma^0\pi^+)$	-0.73 ± 0.18		-0.463 ± 0.018 [51]	-0.47 ± 0.03 [42, 51]
$\alpha(\Lambda_c^+ \to pK_S)$	0.18 ± 0.45			0.18 ± 0.45
$\alpha(\Lambda_c^+ \to \Sigma^+\pi^0)$	-0.55 ± 0.11		-0.48 ± 0.03 [49]	-0.49 ± 0.03 [42, 49]
$\alpha(\Xi_c^0 \to \Xi^-\pi^+)$	-0.64 ± 0.05			-0.64 ± 0.05
$\alpha(\Lambda_c^+ \to \Sigma^+\eta)$			-0.99 ± 0.06 [49]	-0.99 ± 0.06 [49]
$\alpha(\Lambda_c^+ \to \Sigma^+\eta')$			-0.46 ± 0.07 [49]	-0.46 ± 0.07 [49]
$\alpha(\Lambda_c^+ \to \Lambda^0 K^+)$			-0.585 ± 0.052 [51]	-0.585 ± 0.052 [51]
$\alpha(\Lambda_c^+ \to \Sigma^0 K^+)$			-0.55 ± 0.20 [51]	-0.55 ± 0.20 [51]
$\alpha(\Lambda_c^+ \to \Xi^0 K^+)$		0.01 ± 0.16 [33]		0.01 ± 0.16 [33]

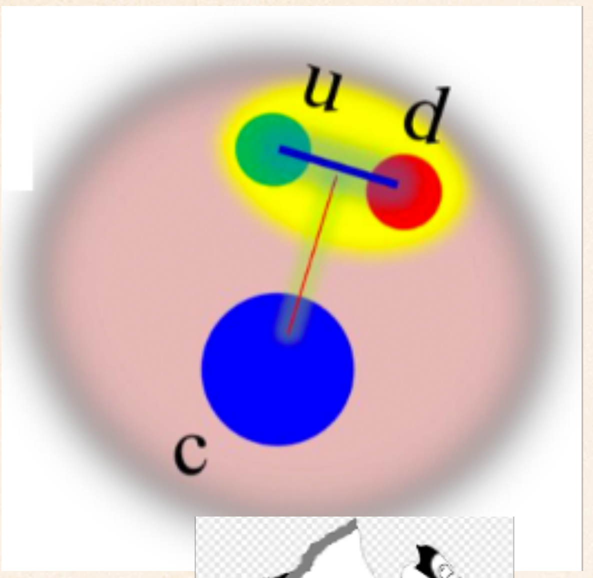
time to interpret data

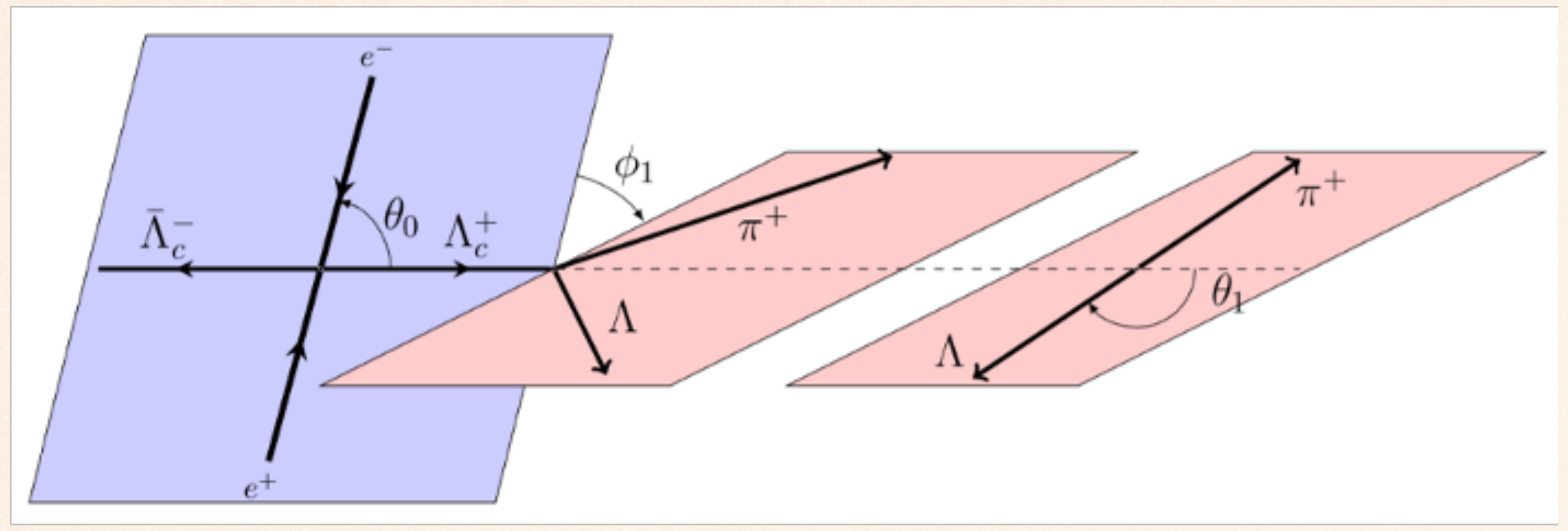






To explore physics around charm scale





Branching Fractions

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

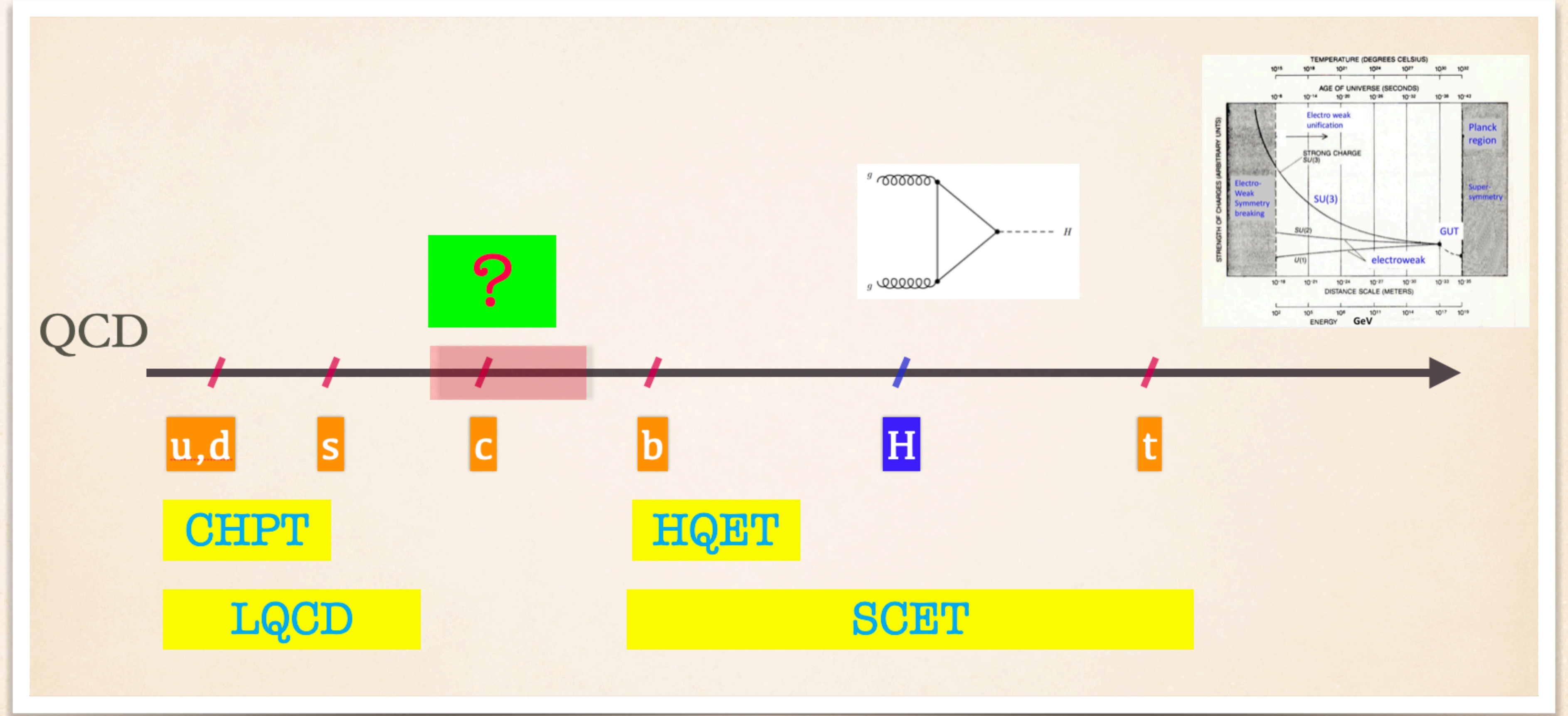
$$\Gamma = \frac{p_c}{8\pi}\frac{(m_i+m_f)^2 - m_P^2}{m_i^2}\left(|A|^2 + \kappa^2|B|^2\right),$$

$$\alpha = \frac{2\kappa|A^*B|\cos(\delta_P - \delta_S)}{|A|^2 + \kappa^2|B|^2}, \quad \beta = \frac{2\kappa|A^*B|\sin(\delta_P - \delta_S)}{|A|^2 + \kappa^2|B|^2},$$

$$\gamma = \frac{|A|^2 - \kappa^2|B|^2}{|A|^2 + \kappa^2|B|^2},$$

Decay Asymmetries (longitudinal, transvere)

more observables, including CPV — talk by C.-W. Liu



The puzzle(s) in $\Lambda_c^+ \to \Xi^0 K^+$ (I)

1. Theory in 1990s, small BF & zero α, due to smallness of S-wave amplitude

PHYSICAL REVIEW D VOLUME 46, NUMBER 1 1 JULY 1992

Cabibbo-favored nonleptonic decays of charmed baryons

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Theoretical Physics Institute and Department of Physics, University of Alberta, Edmonton, Alberta, Canada T6G 2J1
(Received 5 February 1992)

PHYSICAL REVIEW D VOLUME 48, NUMBER 9 1 NOVEMBER 1993

Cabibbo-allowed nonleptonic weak decays of charmed baryons

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and Institute for Theoretical Physics, State University of New York, Stony Brook, New York 11794

B. Tseng
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(Received 23 April 1993)

PHYSICAL REVIEW D VOLUME 50, NUMBER 1 1 JULY 1994

Quark and pole models of nonleptonic decays of charmed baryons

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(Received 12 October 1993)

Quark and pole models of nonleptonic decays of charmed baryons are analyzed from the point of view of their symmetry properties. The symmetry structure of the parity-conserving amplitudes that corresponds to the contribution of the ground-state intermediate baryons is shown to differ from the one hitherto employed in the symmetry approach. It is pointed out that the "subtraction" of sea quark effects in hyperon decays leads to an estimate of W-exchange contributions in charmed baryon decays that is significantly smaller than naively expected on the basis of SU(4). An $SU(2)_W$ constraint questioning the reliability of the factorization technique is exhibited. Finally, a successful fit to the available data is presented.

PACS number(s): 13.30.Eg, 14.20.Lq

Z. Phys. C – Particles and Fields 55, 659–670 (1992)

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Exclusive non-leptonic charm baryon decays

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Received 23 March 1992

Eur. Phys. J. C 7, 217–224 (1999)
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A study of weak mesonic decays of Λ_c and Ξ_C baryons on the basis of HQET results

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Centre for Advanced Study in Physics, Department of Physics, Panjab University, Chandigarh – 160014, India

Received: 14 May 1998 / Revised version: 25 August 1998 / Published online: 3 December 1998

2. BF was measured, not that small

PDG

$\Gamma(\Lambda_c^+ \to \Xi^0 K^+)/\Gamma_{\text{total}}$	
VALUE (10^{-3})	
5.5 ± 0.7	OUR FIT

Physics Letters B 783 (2018) 200–206

Contents lists available at ScienceDirect

Physics Letters B

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ELSEVIER

Measurements of absolute branching fractions for $\Lambda_c^+ \to \Xi^0 K^+$ and $\Xi(1530)^0 K^+$

BESIII Collaboration

The puzzle(s) in $\Lambda_c^+ \to \Xi^0 K^+$ (2)

3. large BF can be explained, α is predicted to be unity

dynamic calculation

PHYSICAL REVIEW D **101,** 014011 (2020)

Two-body hadronic weak decays of antitriplet charmed baryons

Jinqi Zou, Fanrong Xu,* and Guanbao Meng
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Institute of Physics, Academia Sinica, Taipei, Taiwan 115, Republic of China

(Received 31 October 2019; published 14 January 2020; corrected 29 January 2021)

fit

Physics Letters B 794 (2019) 19–28

Contents lists available at ScienceDirect

Physics Letters B

ELSEVIER

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Asymmetries of anti-triplet charmed baryon decays

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JHEP

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RECEIVED: *December 29, 2021*
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A global analysis of charmless two body hadronic decays for anti-triplet charmed baryons

Fei Huang,[a] Zhi-Peng Xing[b,1] and Xiao-Gang He[a,b,c]

JHEP

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Weak decays of antitriplet charmed baryons from the perspective of flavor symmetry

Huiling Zhong, Fanrong Xu, Qiaoyi Wen and Yu Gu
Department of Physics, Jinan University, Guangzhou 510632, P.R. China

The puzzle(s) in $\Lambda_c^+ \to \Xi^0 K^+$ (3)

4. α is measured to be small

PHYSICAL REVIEW LETTERS **132,** 031801 (2024)

First Measurement of the Decay Asymmetry in the Pure W-Boson-Exchange Decay $\Lambda_c^+ \to \Xi^0 K^+$

M. Ablikim *et al.**
(BESIII Collaboration)

(Received 6 September 2023; accepted 30 November 2023; published 17 January 2024)

$$\alpha_{\Xi^0 K^+} = 0.01 \pm 0.16(\text{stat}) \pm 0.03(\text{syst})$$

$$\delta_p - \delta_s = -1.55 \pm 0.25(\text{stat}) \pm 0.05(\text{syst})\ \text{rad}$$

$$1.59 \pm 0.25(\text{stat}) \pm 0.05(\text{syst})\ \text{rad.}$$

5. small α can be accommodated recently

Complete determination of $SU(3)_F$ amplitudes and strong phase in $\Lambda_c^+ \to \Xi^0 K^+$

Chao-Qiang Geng,[1,*] Xiao-Gang He,[2,3,†] Xiang-Nan Jin,[1,‡] Chia-Wei Liu,[2,§] and Chang Yang[2,¶]

[1] *School of Fundamental Physics and Mathematical Sciences, Hangzhou Institute for Advanced Study, UCAS, Hangzhou 310024*
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(Dated: February 29, 2024)

2310.05491

Topological Diagrams and Hadronic Weak Decays of Charmed Baryons

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Department of Physics, College of Physics & Optoelectronic Engineering, Jinan University, Guangzhou 510632, P.R. China

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Institute of Physics, Academia Sinica, Taipei, Taiwan 11529, Republic of China

(Dated: March 5, 2024)

2401.15926

6. the dynamic origin of strong phase?

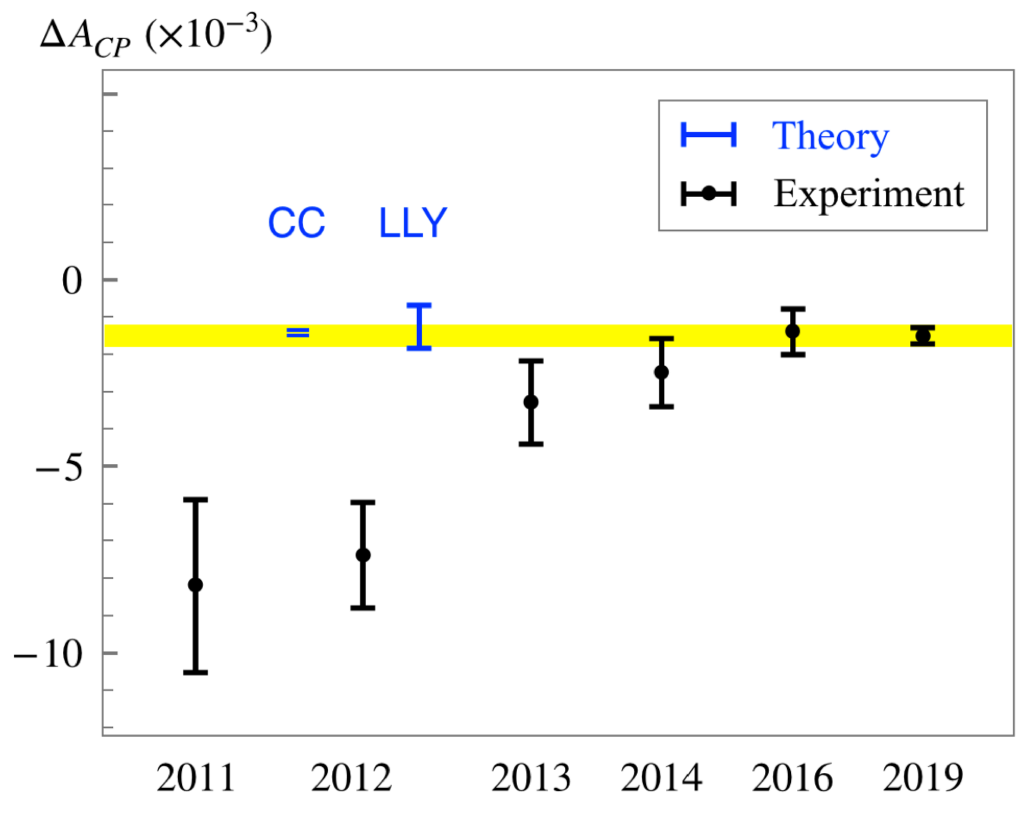
TOPOLOGICAL DIAGRAMS & CHARMED BARYONS

Its triumph in meson sector

Branching fractions

Direct CPV

$$\Delta A_{CP} = A_{CP}(D^0 \to K^+K^-) - A_{CP}(D^0 \to \pi^+\pi^-)$$



Saur, **FSY**, Sci.Bull.2020

Th: the only predictions of O(10^-3)

CC: topological approach + QCDF

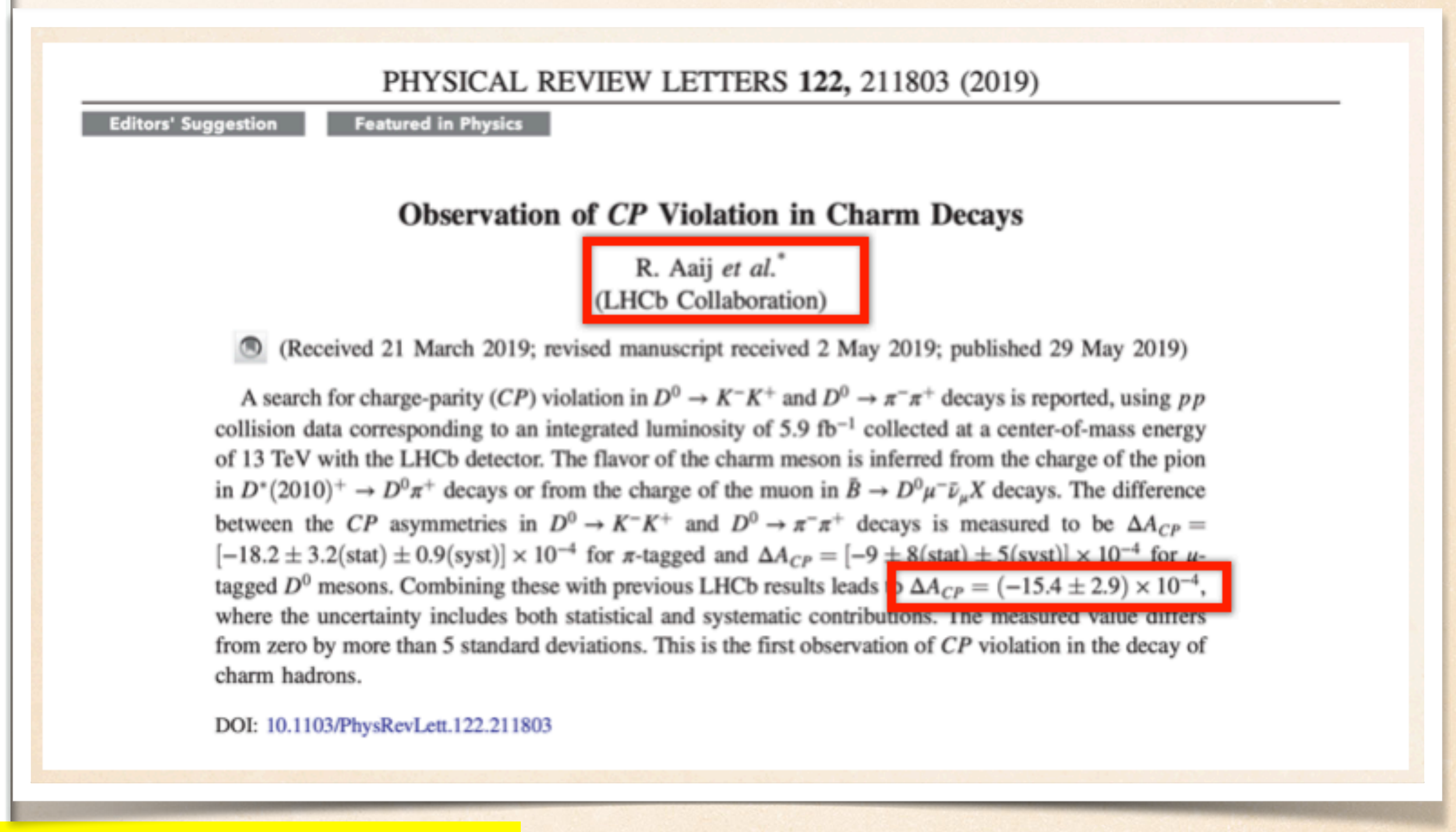
Cheng, Chiang, 2012

LLY: factorization-assisted topology (FAT)

Li, Lu, **FSY**, 2012

Exp: LHCb, PRL122, 211803 (2019)

Topological diagrammatic approach successfully predicted the charm CPV !!!



PHYSICAL REVIEW LETTERS **122,** 211803 (2019)

Editors' Suggestion | Featured in Physics

Observation of *CP* Violation in Charm Decays

R. Aaij *et al.**
(LHCb Collaboration)

(Received 21 March 2019; revised manuscript received 2 May 2019; published 29 May 2019)

A search for charge-parity (CP) violation in $D^0 \to K^-K^+$ and $D^0 \to \pi^-\pi^+$ decays is reported, using pp collision data corresponding to an integrated luminosity of 5.9 fb^{-1} collected at a center-of-mass energy of 13 TeV with the LHCb detector. The flavor of the charm meson is inferred from the charge of the pion in $D^*(2010)^+ \to D^0\pi^+$ decays or from the charge of the muon in $\bar{B} \to D^0\mu^-\bar{\nu}_\mu X$ decays. The difference between the CP asymmetries in $D^0 \to K^-K^+$ and $D^0 \to \pi^-\pi^+$ decays is measured to be $\Delta A_{CP} = [-18.2 \pm 3.2(\text{stat}) \pm 0.9(\text{syst})] \times 10^{-4}$ for π-tagged and $\Delta A_{CP} = [-9 \pm 8(\text{stat}) \pm 5(\text{syst})] \times 10^{-4}$ for μ-tagged D^0 mesons. Combining these with previous LHCb results leads to $\Delta A_{CP} = (-15.4 \pm 2.9) \times 10^{-4}$, where the uncertainty includes both statistical and systematic contributions. The measured value differs from zero by more than 5 standard deviations. This is the first observation of CP violation in the decay of charm hadrons.

DOI: 10.1103/PhysRevLett.122.211803

— talk by F.-S. Yu @Charm2023

Early seeking in baryon sector

- Y. Kohara, 1991

PHYSICAL REVIEW D VOLUME 44, NUMBER 9 1 NOVEMBER 1991

Quark-diagram analysis of charmed-baryon decays

Yoji Kohara
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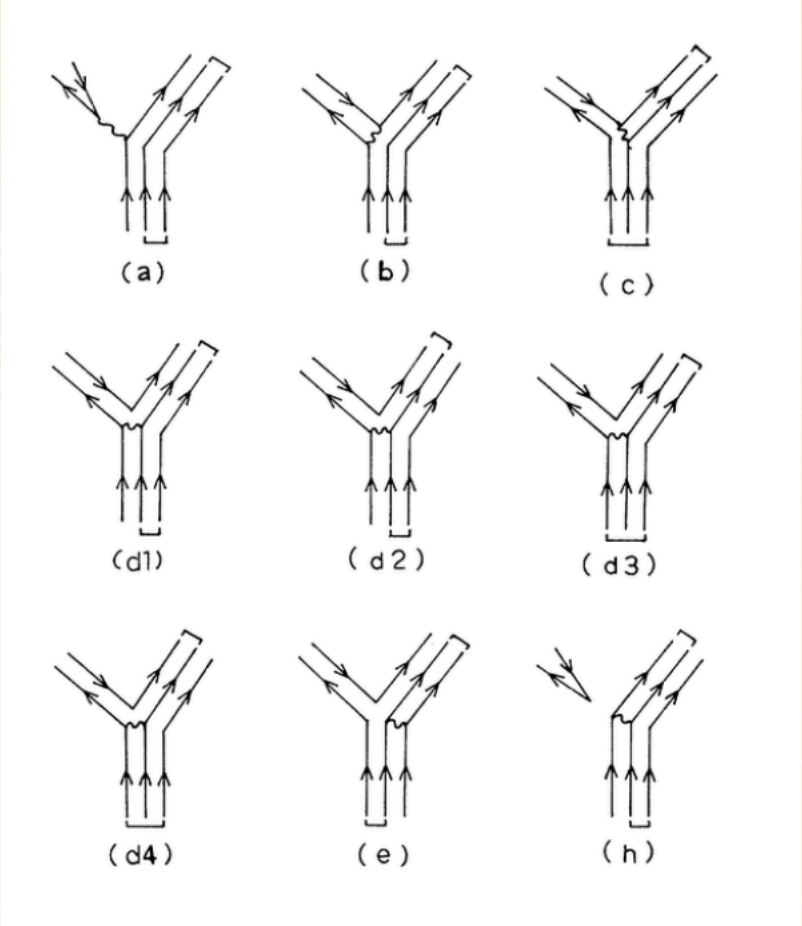
(Received 29 May 1991)

The Cabibbo-allowed two-body nonleptonic decays of charmed baryons to a SU(3)-octet (or -decuplet) baryon and a pseudoscalar meson are examined on the basis of the quark-diagram scheme. Some relations among the decay amplitudes or rates of various decay modes are derived. The decays of Ξ_c^+ to a decuplet baryon are forbidden.



$$|\tilde{\mathcal{B}}^{m,k}(8)\rangle = \alpha|\chi^m(1/2)_{A_{12}}\rangle|\psi^k(8)_{A_{12}}\rangle + \beta|\chi^m(1/2)_{A_{23}}\rangle|\psi^k(8)_{A_{23}}\rangle$$

$$\mathcal{A} = a\bar{B}^{3[ab]}B_{[ab]}M^1_2 + b\bar{B}^{1[ab]}B_{[ab]}M^3_2 + c\bar{B}^{b[13]}B_{[ab]}M^a_2 + d_1\bar{B}^{a[1b]}B_{[2b]}M^3_a + d_2\bar{B}^{b[1a]}B_{[2b]}M^3_a + d_3\bar{B}^{a[3b]}B_{[2b]}M^1_a + d_4\bar{B}^{b[3a]}B_{[2b]}M^1_a + e\bar{B}^{a[13]}B_{[2b]}M^b_a + h\bar{B}^{b[13]}B_{[2b]}M^a_a\ ,$$

- L.-L. Chau, H.-Y. Cheng, B. Tseng, 1996

PHYSICAL REVIEW D VOLUME 54, NUMBER 3 1 AUGUST 1996

Analysis of two-body decays of charmed baryons using the quark-diagram scheme

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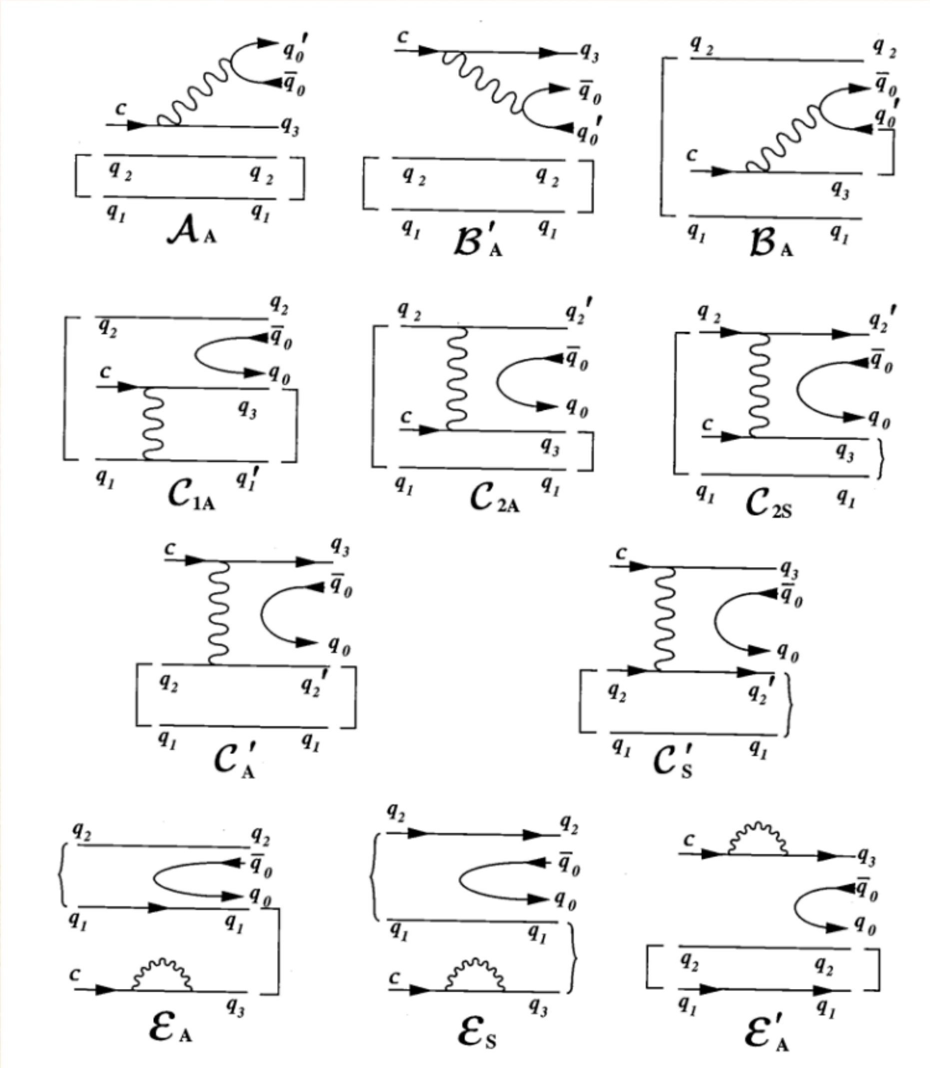
Physics Department, University of California at Davis, California 95616

Hai-Yang Cheng and B. Tseng*
Institute of Physics, Academia Sinica, Taipei, Taiwan 115
(Received 25 August 1995)



$$|\mathcal{B}^{m,k}(8)\rangle = a|\chi^m(1/2)_{A_{12}}\rangle|\psi^k(8)_{A_{12}}\rangle + b|\chi^m(1/2)_{S_{12}}\rangle|\psi^k(8)_{S_{12}}\rangle$$

Recent seeking in baryon sector

- Y.-K. Hsiao's group, since 2020

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A diagrammatic analysis of two-body charmed baryon decays with flavor symmetry

H.J. Zhao,[a] Yan-Li Wang,[a] Y.K. Hsiao[a] and Yao Yu[b]

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PUBLISHED: September 5, 2022

Equivalent $\mathrm{SU}(3)_f$ approaches for two-body anti-triplet charmed baryon decays

Y.K. Hsiao, Y.L. Wang and H.J. Zhao

Eur. Phys. J. C (2020) 80:1067
https://doi.org/10.1140/epjc/s10052-020-08659-4
THE EUROPEAN PHYSICAL JOURNAL C
Regular Article - Theoretical Physics

Two-body charmed baryon decays involving decuplet baryon in the quark-diagram scheme

Y. K. Hsiao[a], Qian Yi, Shu-Ting Cai, H. J. Zhao
School of Physics and Information Engineering, Shanxi Normal University, Linfen 041004, China

- X.-G. He, Y.-J. Shi and W. Wang, 2020

Eur. Phys. J. C (2020) 80:359
https://doi.org/10.1140/epjc/s10052-020-7862-5
THE EUROPEAN PHYSICAL JOURNAL C
Check for updates
Regular Article - Theoretical Physics

Unification of flavor SU(3) analyses of heavy Hadron weak decays

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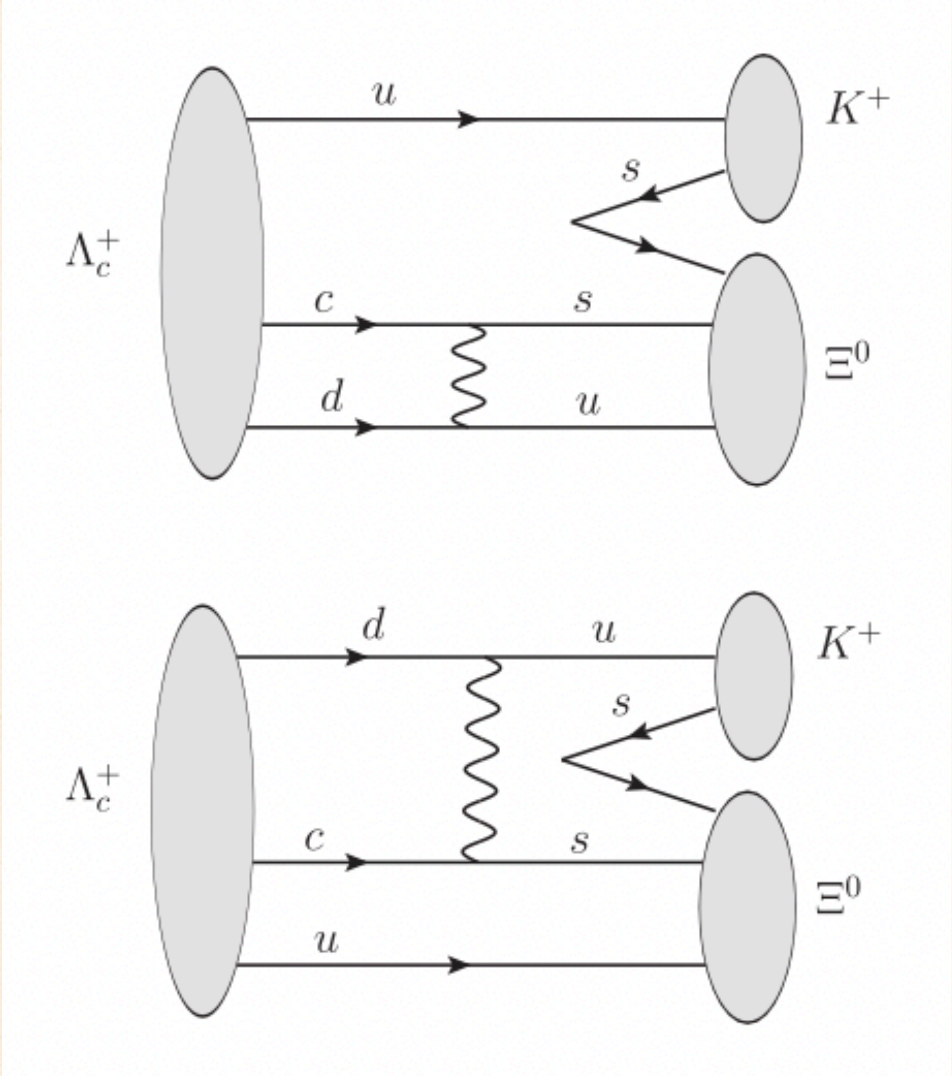
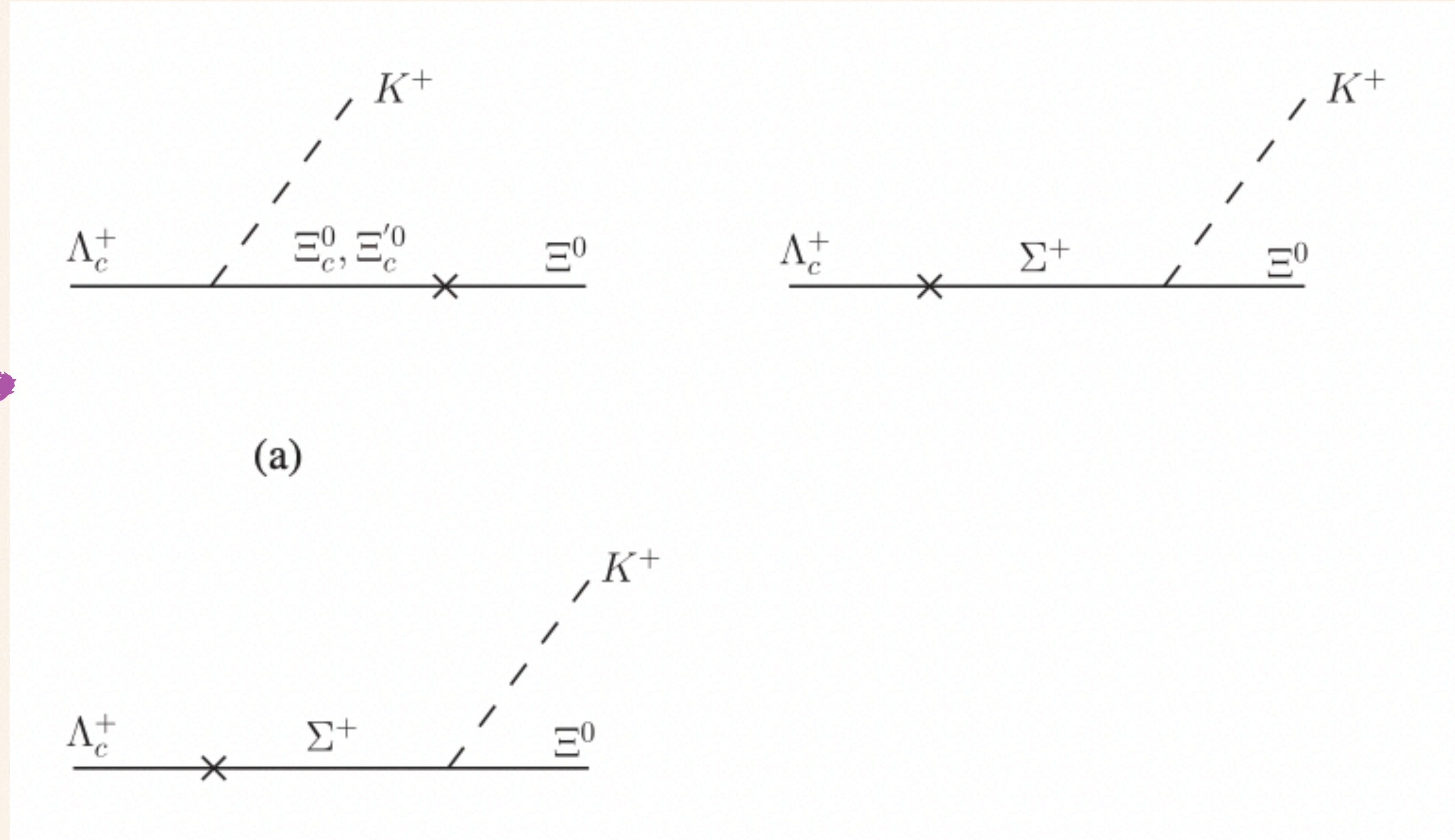
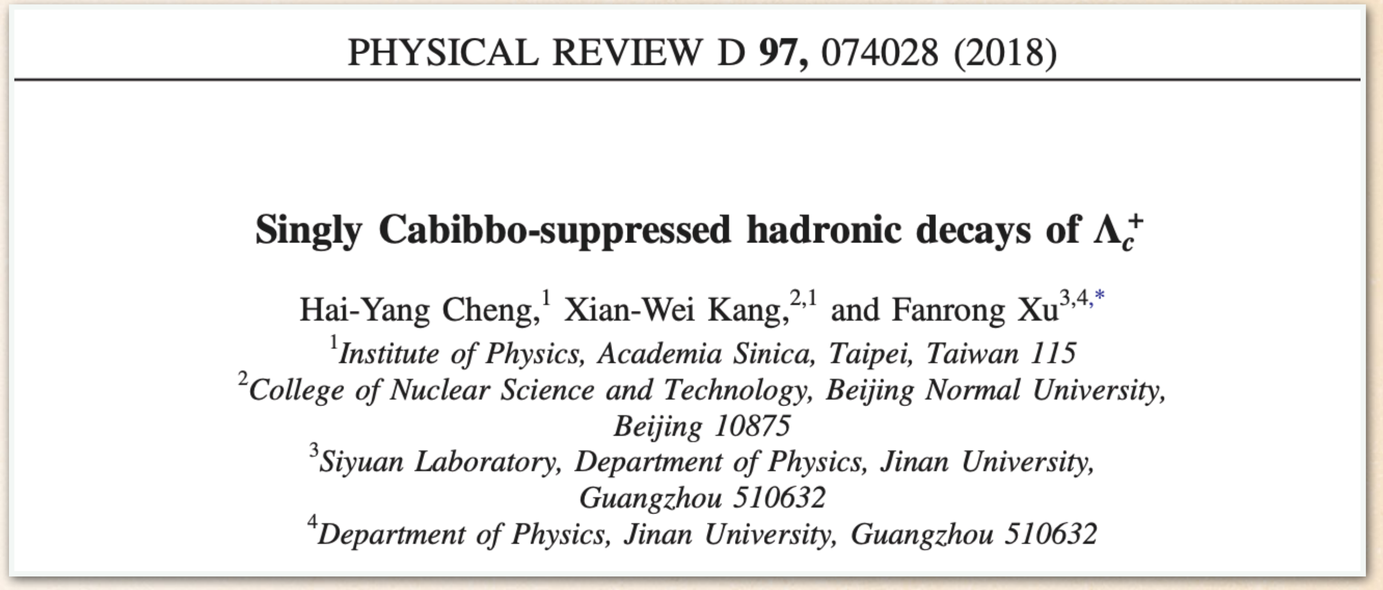
A role as an assisted tool to dynamic calculation






PHYSICAL REVIEW D **97,** 074028 (2018)

Singly Cabibbo-suppressed hadronic decays of Λ_c^+

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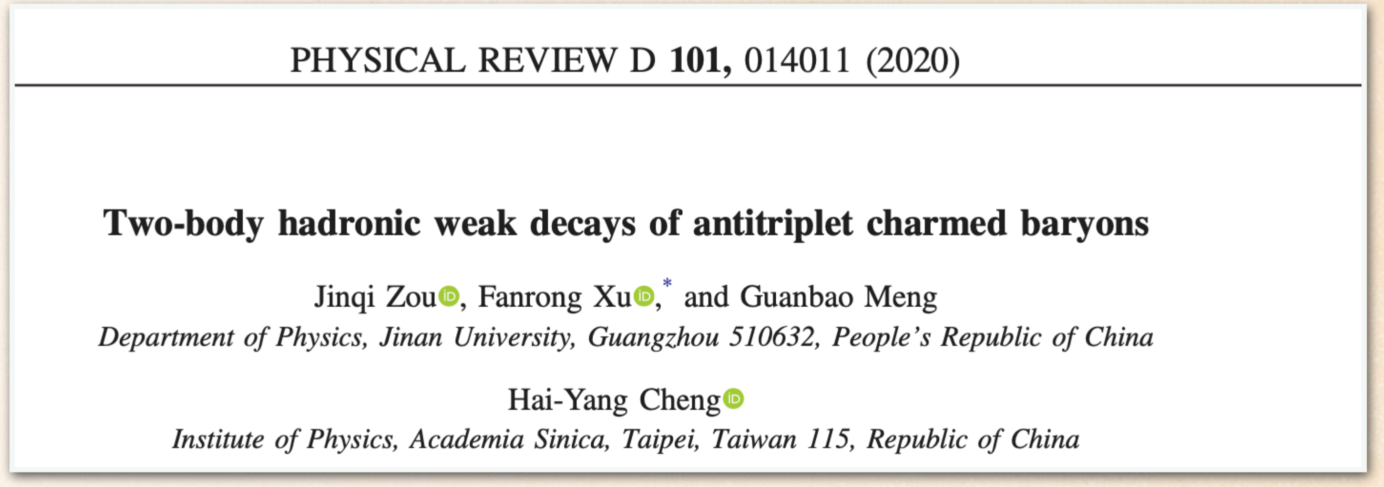
PHYSICAL REVIEW D **101,** 014011 (2020)

Two-body hadronic weak decays of antitriplet charmed baryons

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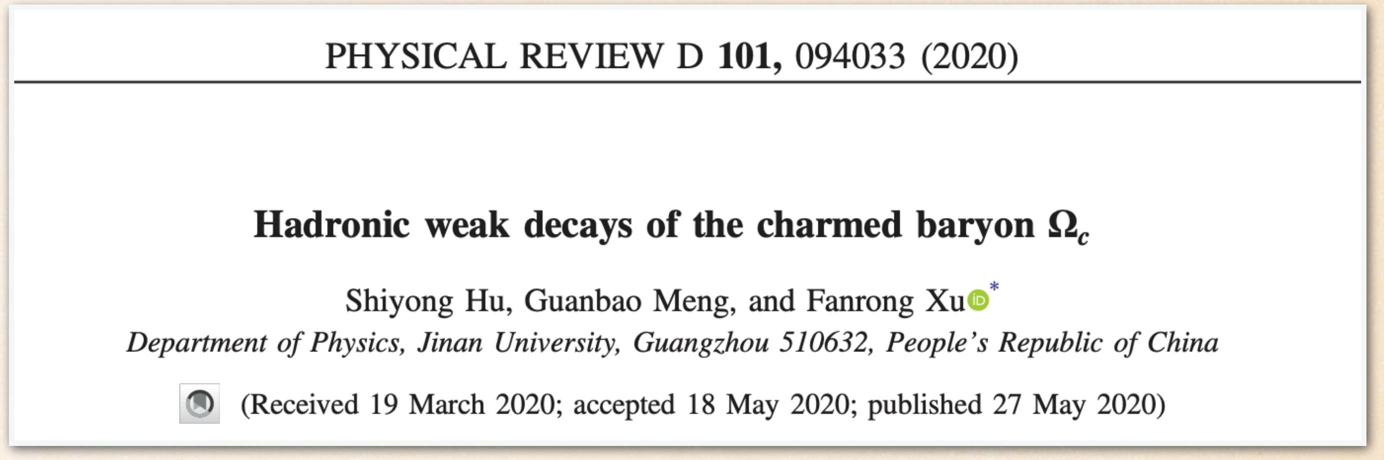
PHYSICAL REVIEW D **101,** 094033 (2020)

Hadronic weak decays of the charmed baryon Ω_c

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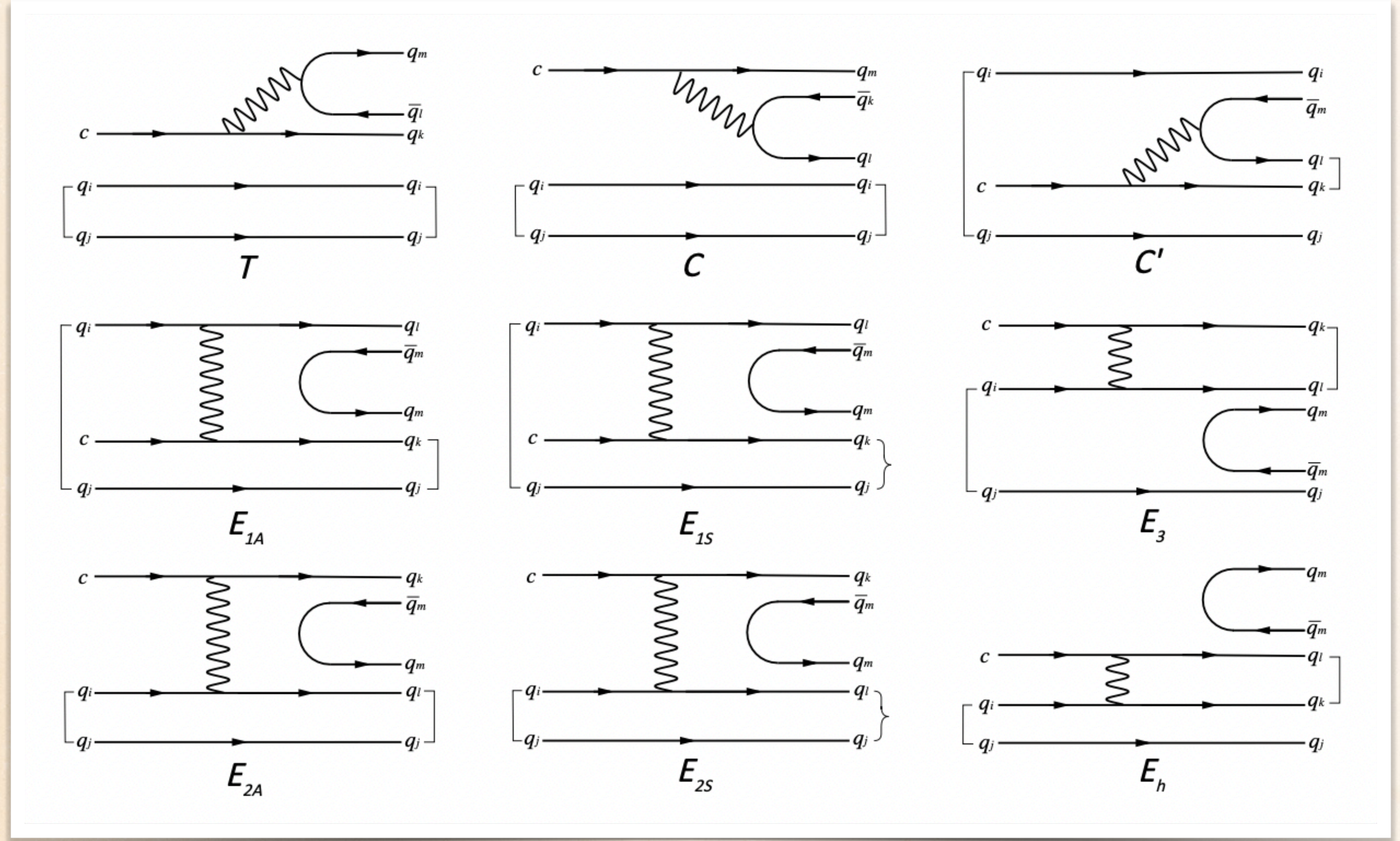
$$\Gamma = \frac{p_c}{8\pi}\left[\frac{(m_i+m_f)^2-m_P^2}{m_i^2}|A|^2 + \frac{(m_i-m_f)^2-m_P^2}{m_i^2}|B|^2\right]$$

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

$$A = A^{\mathrm{fac}} + A^{\mathrm{nf}}, \qquad B = B^{\mathrm{fac}} + B^{\mathrm{nf}}.$$

what if the amplitudes are complex?

Completeness
vs. Redundancy



$$
\begin{aligned}
\mathcal{A}_{\rm TDA} = \; & T(\mathcal{B}_c)^{ij} H^{km}_l M^l_m \left[b_1\,(\mathcal{B}_8)_{ijk} + b_2\,(\mathcal{B}_8)_{ikj} + b_3\,(\mathcal{B}_8)_{jki}\right] \\
& + C(\mathcal{B}_c)^{ij} H^{ml}_k M^k_m \left[b_4\,(\mathcal{B}_8)_{ijl} + b_5\,(\mathcal{B}_8)_{ilj} + b_6\,(\mathcal{B}_8)_{jli}\right] \\
& + C'(\mathcal{B}_c)^{ij} H^{kl}_m M^m_i \left[b_7\,(\mathcal{B}_8)_{klj} + b_8\,(\mathcal{B}_8)_{kjl} + b_9\,(\mathcal{B}_8)_{ljk}\right] \\
& + E_1(\mathcal{B}_c)^{ij} H^{kl}_i M^m_l \left[b_{10}\,(\mathcal{B}_8)_{jkm} + b_{11}\,(\mathcal{B}_8)_{jmk} + b_{12}\,(\mathcal{B}_8)_{kmj}\right] \\
& + E_2(\mathcal{B}_c)^{ij} H^{kl}_i M^m_k \left[b_{13}\,(\mathcal{B}_8)_{jlm} + b_{14}\,(\mathcal{B}_8)_{jml} + b_{15}\,(\mathcal{B}_8)_{lmj}\right] \\
& + E_3(\mathcal{B}_c)^{ij} H^{kl}_i M^m_j \left[b_{16}\,(\mathcal{B}_8)_{klm} + b_{17}\,(\mathcal{B}_8)_{kml} + b_{18}\,(\mathcal{B}_8)_{lmk}\right] \\
& + E_h(\mathcal{B}_c)^{ij} H^{kl}_i M^m_m \left[b_{19}\,(\mathcal{B}_8)_{jkl} + b_{20}\,(\mathcal{B}_8)_{jlk} + b_{21}\,(\mathcal{B}_8)_{klj}\right],
\end{aligned}
$$

$$
(\mathcal{B}_8)^i_j = \begin{pmatrix} \frac{1}{\sqrt{6}}\Lambda^0 + \frac{1}{\sqrt{2}}\Sigma^0 & \Sigma^+ & p \\ \Sigma^- & \frac{1}{\sqrt{6}}\Lambda^0 - \frac{1}{\sqrt{2}}\Sigma^0 & n \\ \Xi^- & \Xi^0 & -\sqrt{\frac{2}{3}}\Lambda^0 \end{pmatrix}
$$

$$
(\mathcal{B}_8)_{ijk} = \epsilon_{ijl}(\mathcal{B}_8^T)^l_k
$$

$$
(\mathcal{B}_c)^{ij} = \begin{pmatrix} 0 & \Lambda_c^+ & \Xi_c^+ \\ -\Lambda_c^+ & 0 & \Xi_c^0 \\ -\Xi_c^+ & -\Xi_c^0 & 0 \end{pmatrix}
$$

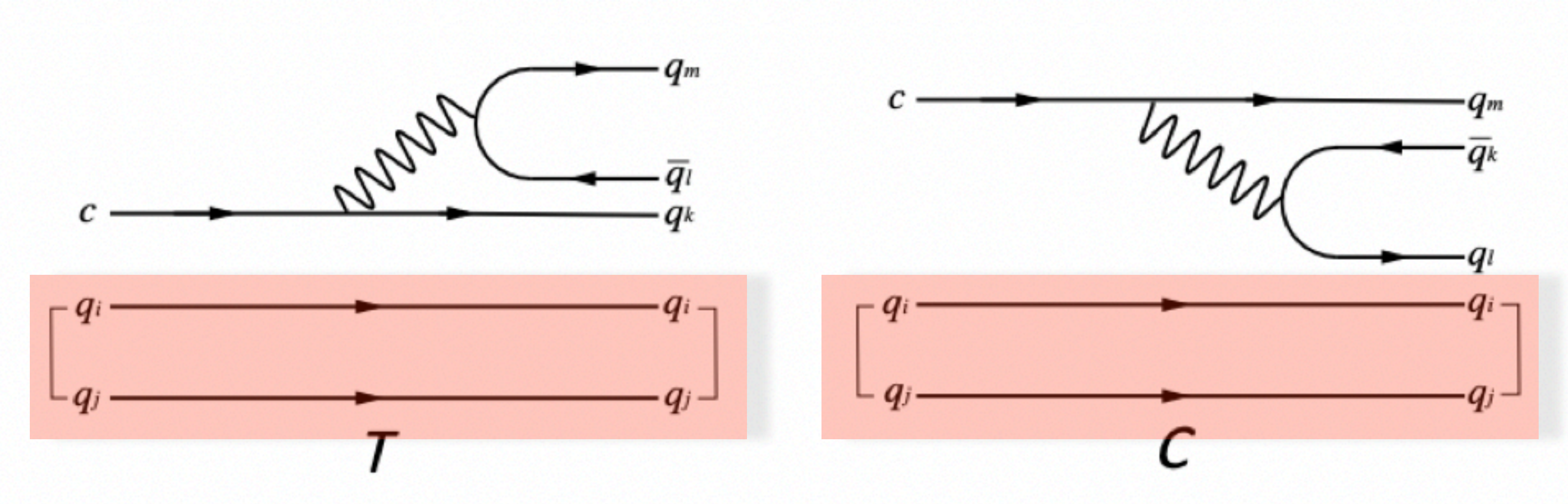
$$
M^i_j = \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \frac{\eta_8}{\sqrt{6}} + \frac{\eta_1}{\sqrt{3}} & \pi^+ & K^+ \\ \pi^- & -\frac{\pi^0}{\sqrt{2}} + \frac{\eta_8}{\sqrt{6}} + \frac{\eta_1}{\sqrt{3}} & K^0 \\ K^- & \overline{K}^0 & -\frac{2\eta_8}{\sqrt{6}} + \frac{\eta_1}{\sqrt{3}} \end{pmatrix}
$$

$$
H^{31}_2 = V^*_{cs}V_{ud}, \quad H^{31}_3 = V^*_{cs}V_{us}, \quad H^{21}_2 = V^*_{cd}V_{ud}, \quad H^{21}_3 = V^*_{cd}V_{us}.
$$

$$
\begin{aligned}
\mathcal{A}_{\rm TDA} = \; & T(\mathcal{B}_c)^{ij} H^{km}_{l} M^{l}_{m} \left[b_1 (\mathcal{B}_8)_{ijk} + b_2 (\mathcal{B}_8)_{ikj} + b_3 (\mathcal{B}_8)_{jki} \right] \\
& + C(\mathcal{B}_c)^{ij} H^{ml}_{k} M^{k}_{m} \left[b_4 (\mathcal{B}_8)_{ijl} + b_5 (\mathcal{B}_8)_{ilj} + b_6 (\mathcal{B}_8)_{jli} \right] \\
& + C'(\mathcal{B}_c)^{ij} H^{kl}_{m} M^{m}_{i} \left[b_7 (\mathcal{B}_8)_{klj} + b_8 (\mathcal{B}_8)_{kjl} + b_9 (\mathcal{B}_8)_{ljk} \right] \\
& + E_1(\mathcal{B}_c)^{ij} H^{kl}_{i} M^{m}_{l} \left[b_{10} (\mathcal{B}_8)_{jkm} + b_{11} (\mathcal{B}_8)_{jmk} + b_{12} (\mathcal{B}_8)_{kmj} \right] \\
& + E_2(\mathcal{B}_c)^{ij} H^{kl}_{i} M^{m}_{k} \left[b_{13} (\mathcal{B}_8)_{jlm} + b_{14} (\mathcal{B}_8)_{jml} + b_{15} (\mathcal{B}_8)_{lmj} \right] \\
& + E_3(\mathcal{B}_c)^{ij} H^{kl}_{i} M^{m}_{j} \left[b_{16} (\mathcal{B}_8)_{klm} + b_{17} (\mathcal{B}_8)_{kml} + b_{18} (\mathcal{B}_8)_{lmk} \right] \\
& + E_h(\mathcal{B}_c)^{ij} H^{kl}_{i} M^{m}_{m} \left[b_{19} (\mathcal{B}_8)_{jkl} + b_{20} (\mathcal{B}_8)_{jlk} + b_{21} (\mathcal{B}_8)_{klj} \right],
\end{aligned}
$$

$$b_3 = -b_2$$

$$b_6 = -b_5$$



$$(\mathcal{B}_8)_{ijk} = \epsilon_{ijl} (\mathcal{B}_8^T)^l_k$$

$$
\begin{aligned}
\mathcal{A}_{\rm TDA} = \; & T(\mathcal{B}_c)^{ij} H^{km}_{l} M^{l}_{m} \left[b_1 (\mathcal{B}_8)_{ijk} + b_2 (\mathcal{B}_8)_{ikj} + b_3 (\mathcal{B}_8)_{jki}\right] \\
& + C(\mathcal{B}_c)^{ij} H^{ml}_{k} M^{k}_{m} \left[b_4 (\mathcal{B}_8)_{ijl} + b_5 (\mathcal{B}_8)_{ilj} + b_6 (\mathcal{B}_8)_{jli}\right] \\
& + C'(\mathcal{B}_c)^{ij} H^{kl}_{m} M^{m}_{i} \left[b_7 (\mathcal{B}_8)_{klj} + b_8 (\mathcal{B}_8)_{kjl} + b_9 (\mathcal{B}_8)_{ljk}\right] \\
& + E_1(\mathcal{B}_c)^{ij} H^{kl}_{i} M^{m}_{l} \left[b_{10} (\mathcal{B}_8)_{jkm} + b_{11} (\mathcal{B}_8)_{jmk} + b_{12} (\mathcal{B}_8)_{kmj}\right] \\
& + E_2(\mathcal{B}_c)^{ij} H^{kl}_{i} M^{m}_{k} \left[b_{13} (\mathcal{B}_8)_{jlm} + b_{14} (\mathcal{B}_8)_{jml} + b_{15} (\mathcal{B}_8)_{lmj}\right] \\
& + E_3(\mathcal{B}_c)^{ij} H^{kl}_{i} M^{m}_{j} \left[b_{16} (\mathcal{B}_8)_{klm} + b_{17} (\mathcal{B}_8)_{kml} + b_{18} (\mathcal{B}_8)_{lmk}\right] \\
& + E_h(\mathcal{B}_c)^{ij} H^{kl}_{i} M^{m}_{m} \left[b_{19} (\mathcal{B}_8)_{jkl} + b_{20} (\mathcal{B}_8)_{jlk} + b_{21} (\mathcal{B}_8)_{klj}\right],
\end{aligned}
$$

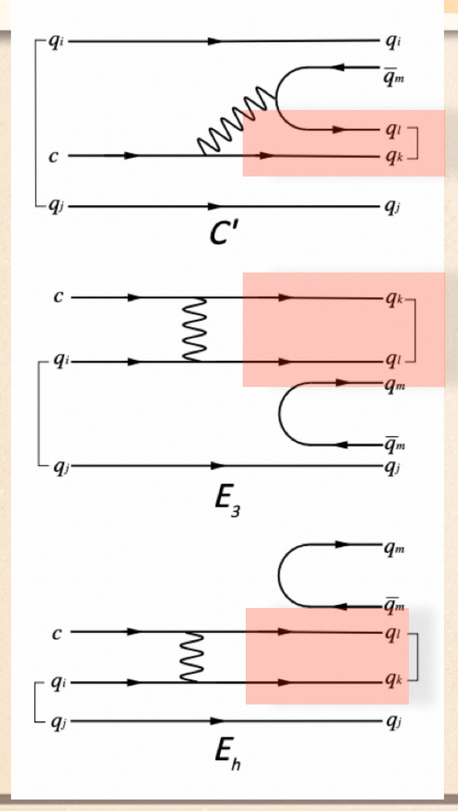
$b_3 = -b_2$

$b_6 = -b_5$

$b_9 = -b_8$

$b_{18} = -b_{17}$

$b_{20} = -b_{19}$



Korner-Pati-Woo theorem:

[l,k] index should be asymmetric

$$
\begin{aligned}
\mathcal{A}_{\rm TDA} = \; & T(\mathcal{B}_c)^{ij} H^{km}_{l} M^{l}_{m} \left[b_1 (\mathcal{B}_8)_{ijk} + b_2 (\mathcal{B}_8)_{ikj} + b_3 (\mathcal{B}_8)_{jki}\right] \\
& + C(\mathcal{B}_c)^{ij} H^{ml}_{k} M^{k}_{m} \left[b_4 (\mathcal{B}_8)_{ijl} + b_5 (\mathcal{B}_8)_{ilj} + b_6 (\mathcal{B}_8)_{jli}\right] \\
& + C'(\mathcal{B}_c)^{ij} H^{kl}_{m} M^{m}_{i} \left[b_7 (\mathcal{B}_8)_{klj} + b_8 (\mathcal{B}_8)_{kjl} + b_9 (\mathcal{B}_8)_{ljk}\right] \\
& + E_1(\mathcal{B}_c)^{ij} H^{kl}_{i} M^{m}_{l} \left[b_{10} (\mathcal{B}_8)_{jkm} + b_{11} (\mathcal{B}_8)_{jmk} + b_{12} (\mathcal{B}_8)_{kmj}\right] \\
& + E_2(\mathcal{B}_c)^{ij} H^{kl}_{i} M^{m}_{k} \left[b_{13} (\mathcal{B}_8)_{jlm} + b_{14} (\mathcal{B}_8)_{jml} + b_{15} (\mathcal{B}_8)_{lmj}\right] \\
& + E_3(\mathcal{B}_c)^{ij} H^{kl}_{i} M^{m}_{j} \left[b_{16} (\mathcal{B}_8)_{klm} + b_{17} (\mathcal{B}_8)_{kml} + b_{18} (\mathcal{B}_8)_{lmk}\right] \\
& + E_h(\mathcal{B}_c)^{ij} H^{kl}_{i} M^{m}_{m} \left[b_{19} (\mathcal{B}_8)_{jkl} + b_{20} (\mathcal{B}_8)_{jlk} + b_{21} (\mathcal{B}_8)_{klj}\right] ,
\end{aligned}
$$

$b_3 = -b_2$

$b_6 = -b_5$

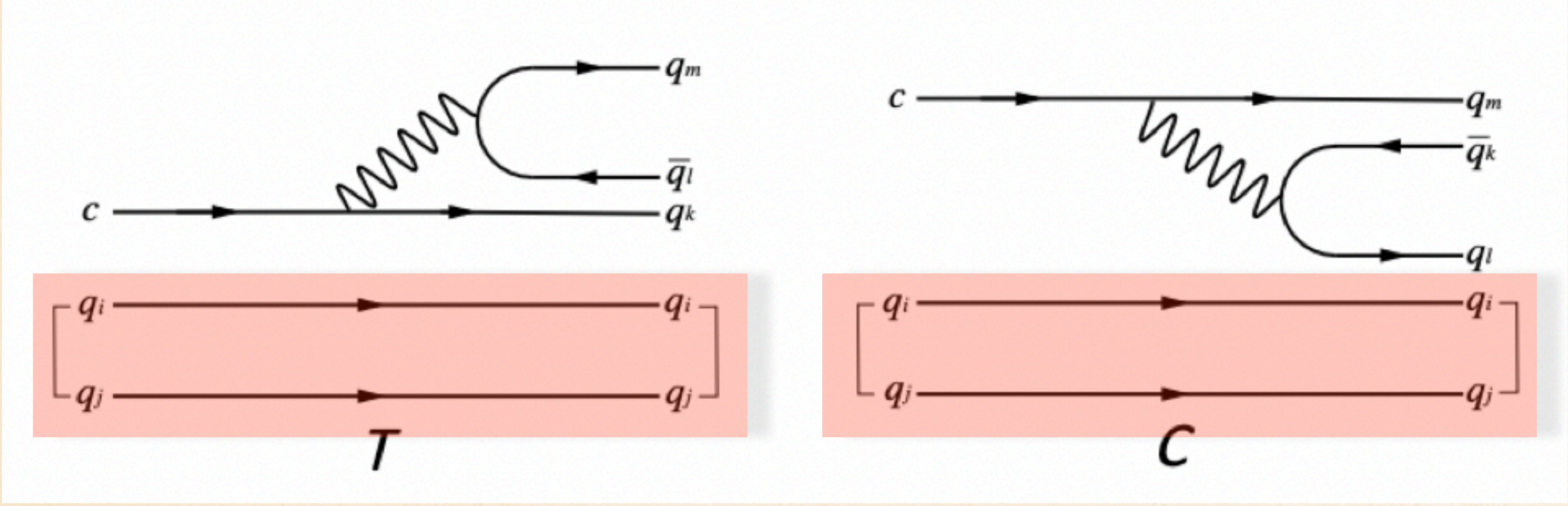
$b_9 = -b_8$

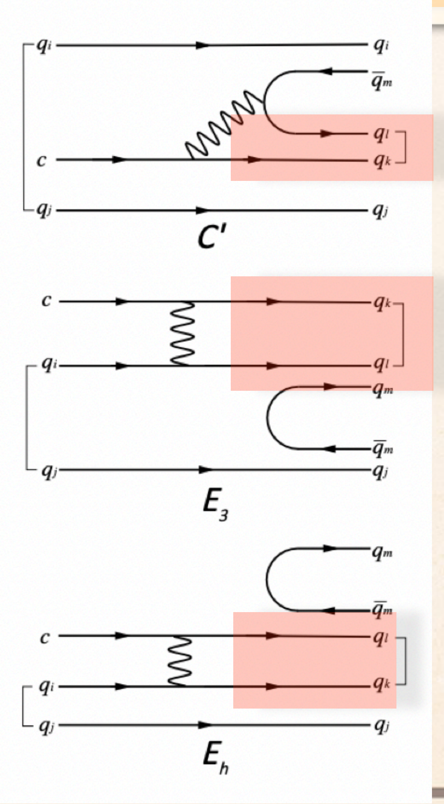
$b_{12} = b_{11}$

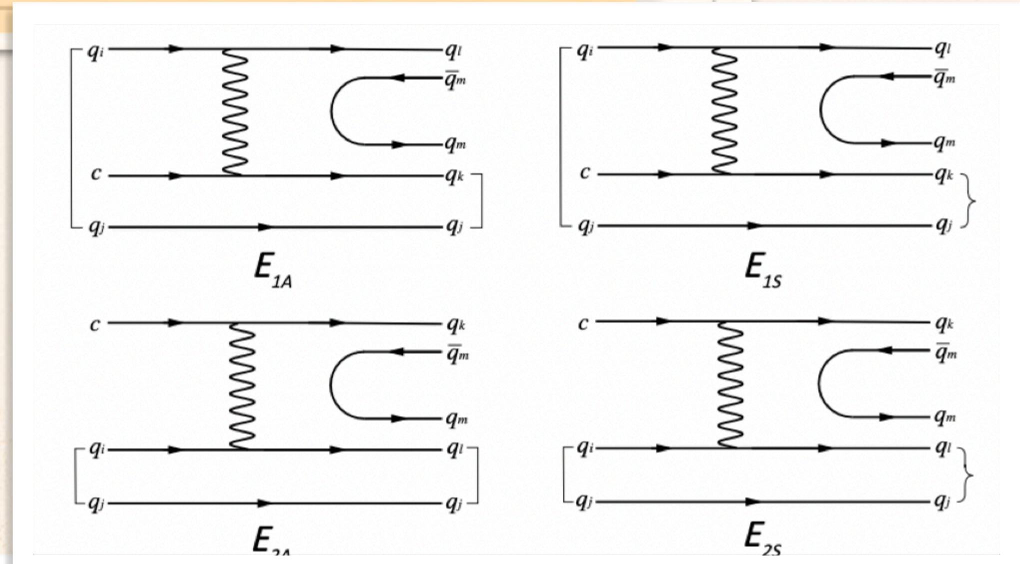
$b_{15} = b_{14}$

$b_{18} = -b_{17}$

$b_{20} = -b_{19}$



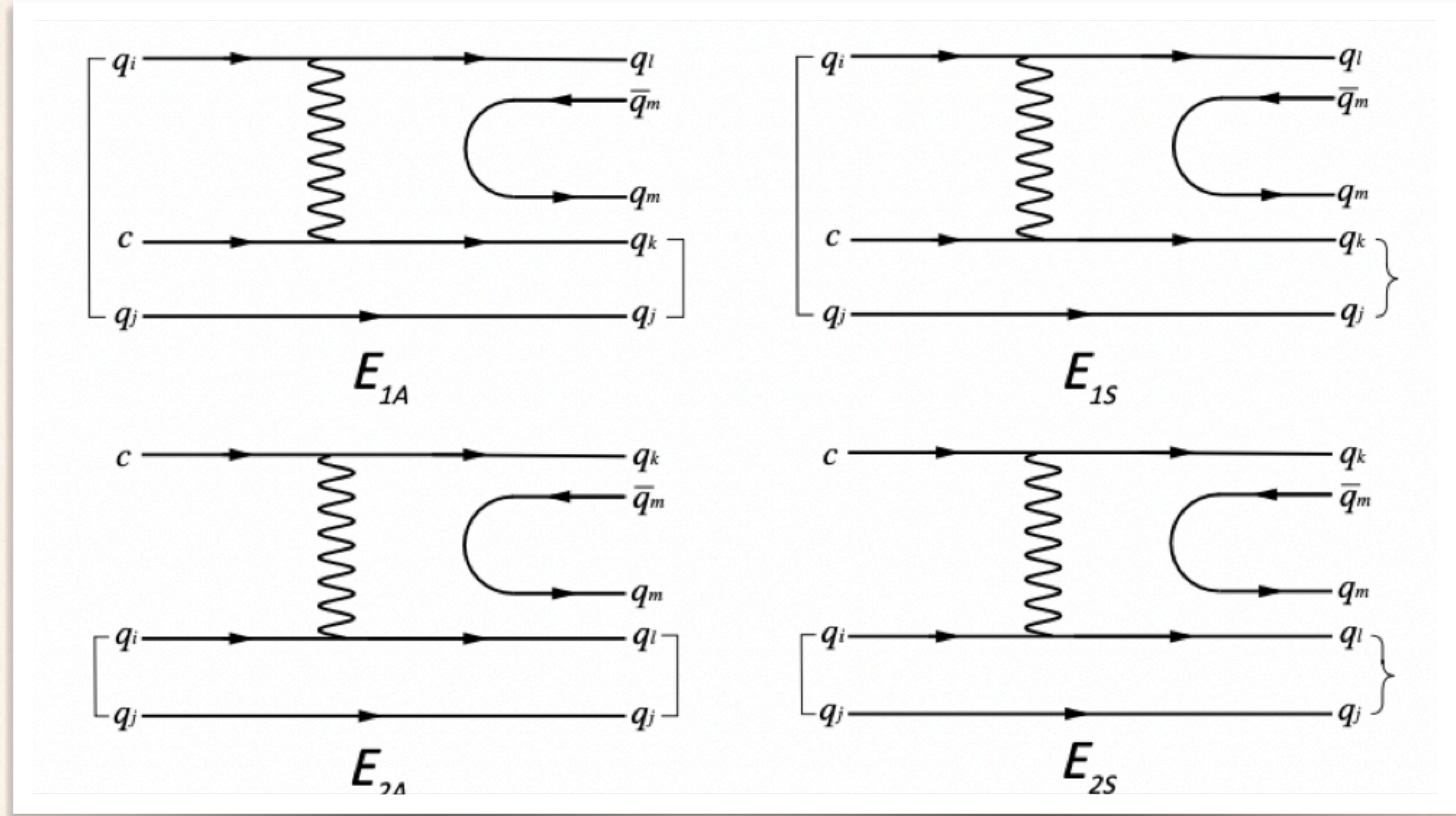




$$|\mathcal{B}^{m,k}(8)\rangle = a|\chi^m(1/2)_{A_{12}}\rangle|\psi^k(8)_{A_{12}}\rangle + b|\chi^m(1/2)_{S_{12}}\rangle|\psi^k(8)_{S_{12}}\rangle$$

A further simplification

$$
\begin{aligned}
\mathcal{A}_{\rm TDA} = \;& T(\mathcal{B}_c)^{ij} H^{km}_{l} (\mathcal{B}_8)_{ijk} M^l_m + C(\mathcal{B}_c)^{ij} H^{ml}_{k} (\mathcal{B}_8)_{ijl} M^k_m + C'(\mathcal{B}_c)^{ij} H^{kl}_{m} (\mathcal{B}_8)_{klj} M^m_i \\
& + E_{1A}(\mathcal{B}_c)^{ij} H^{kl}_{i} (\mathcal{B}_8)_{jkm} M^m_l + E_{1S}(\mathcal{B}_c)^{ij} H^{kl}_{i} M^m_l \left[(\mathcal{B}_8)_{jmk} + (\mathcal{B}_8)_{kmj}\right] \\
& + E_{2A}(\mathcal{B}_c)^{ij} H^{kl}_{i} (\mathcal{B}_8)_{jlm} M^m_k + E_{2S}(\mathcal{B}_c)^{ij} H^{kl}_{i} M^m_k \left[(\mathcal{B}_8)_{jml} + (\mathcal{B}_8)_{lmj}\right] \\
& + E_3(\mathcal{B}_c)^{ij} H^{kl}_{i} (\mathcal{B}_8)_{klm} M^m_j + E_h(\mathcal{B}_c)^{ij} H^{kl}_{i} (\mathcal{B}_8)_{klj} M^m_m ,
\end{aligned}
$$



$$E_{2A} = -E_{1A}, \qquad E_{2S} = -E_{1S}.$$

Korner-Pati-Woo theorem:

diagrams: 7

$$\tilde{T} = T - E_{1S}, \quad \tilde{C} = C + E_{1S}, \quad \tilde{C}' = C' - 2E_{1S},$$
$$\tilde{E}_1 = E_{1A} + E_{1S} - E_3, \quad \tilde{E}_h = E_h + 2E_{1S}.$$

diagrams: 5; parameters: 19

$$|\tilde{T}|_S e^{i\delta^{\tilde{T}}_S}, \quad |\tilde{C}|_S e^{i\delta^{\tilde{C}}_S}, \quad \cdots$$

$$|\tilde{T}|_P e^{i\delta^{\tilde{T}}_P}, \quad \cdots, \quad |\tilde{E}_h|_P e^{i\delta^{\tilde{E}_h}_P}$$

Amplitudes and their relations

Channel	TDA	$\widetilde{\text{TDA}}$
$\Lambda_c^+ \to \Lambda\pi^+$	$\frac{1}{\sqrt{6}}(-4T + C' + E_{1A} + 3E_{1S} - E_3)$	$\frac{1}{\sqrt{6}}(-4\tilde{T} + \tilde{C}' + \tilde{E}_1)$
$\Lambda_c^+ \to \Sigma^0\pi^+$	$\frac{1}{\sqrt{2}}(-C' - E_{1A} + E_{1S} + E_3)$	$\frac{1}{\sqrt{2}}(-\tilde{C}' - \tilde{E}_1)$
$\Lambda_c^+ \to \Sigma^+\pi^0$	$\frac{1}{\sqrt{2}}(C' + E_{1A} - E_{1S} - E_3)$	$\frac{1}{\sqrt{2}}(\tilde{C}' + \tilde{E}_1)$
$\Lambda_c^+ \to \Sigma^+\eta_8$	$\frac{1}{\sqrt{6}}(-C' + E_{1A} + 3E_{1S} - E_3)$	$\frac{1}{\sqrt{6}}(-\tilde{C}' + \tilde{E}_1)$
$\Lambda_c^+ \to \Sigma^+\eta_1$	$\frac{1}{\sqrt{3}}(-C' + E_{1A} - 3E_{1S} - E_3 - 3E_h)$	$\frac{1}{\sqrt{3}}(-\tilde{C}' + \tilde{E}_1 - 3\tilde{E}_h)$
$\Lambda_c^+ \to \Xi^0 K^+$	$E_{1A} + E_{1S} - E_3$	$\tilde{E}_1$
$\Lambda_c^+ \to p\bar{K}^0$	$2C + 2E_{1S}$	$2\tilde{C}$
$\Xi_c^0 \to \Lambda\bar{K}^0$	$\frac{1}{\sqrt{6}}(2C - C' - E_{1A} + 3E_{1S} + E_3)$	$\frac{1}{\sqrt{6}}(2\tilde{C} - \tilde{C}' - \tilde{E}_1)$
$\Xi_c^0 \to \Sigma^0\bar{K}^0$	$\frac{1}{\sqrt{2}}(2C + C' + E_{1A} + E_{1S} - E_3)$	$\frac{1}{\sqrt{2}}(2\tilde{C} + \tilde{C}' + \tilde{E}_1)$
$\Xi_c^0 \to \Sigma^+ K^-$	$-E_{1A} - E_{1S} + E_3$	$-\tilde{E}_1$
$\Xi_c^0 \to \Xi^0\pi^0$	$\frac{1}{\sqrt{2}}(-C' + 2E_{1S})$	$\frac{1}{\sqrt{2}}(-\tilde{C}')$
$\Xi_c^0 \to \Xi^0\eta_8$	$\frac{1}{\sqrt{6}}(C' + 2E_{1A} - 2E_3)$	$\frac{1}{\sqrt{6}}(\tilde{C}' + 2\tilde{E}_1)$
$\Xi_c^0 \to \Xi^0\eta_1$	$\frac{1}{\sqrt{3}}(C' + 3E_{1S} - E_{1A} + E_3 + 3E_h)$	$\frac{1}{\sqrt{3}}(\tilde{C}' - \tilde{E}_1 + 3\tilde{E}_h)$
$\Xi_c^0 \to \Xi^-\pi^+$	$2T - 2E_{1S}$	$2\tilde{T}$
$\Xi_c^+ \to \Sigma^+\bar{K}^0$	$-2C - C'$	$-2\tilde{C} - \tilde{C}'$
$\Xi_c^+ \to \Xi^0\pi^+$	$-2T + C'$	$-2\tilde{T} + \tilde{C}'$

1. $\tilde{T}$: $\Xi_c^0 \to \Xi^-\pi^+, \Sigma^-\pi^+, \Xi^-K^+, \Sigma^-K^+$; $\Xi_c^+ \to \Xi^0 K^+$.
2. $\tilde{C}$: $\Lambda_c^+ \to p\overline{K}^0$; $\Xi_c^0 \to \Xi^0 K^0$; $\Xi_c^+ \to \Sigma^+ K^0$.
3. $\tilde{C}'$: $\Lambda_c^+ \to \Sigma^+ K^0, \Sigma^0 K^+$; $\Xi_c^+ \to p\overline{K}^0$.
4. $\tilde{E}_1$: $\Lambda_c^+ \to \Xi^0 K^+$; $\Xi_c^0 \to \Sigma^+K^-, \Sigma^+\pi^-, pK^-, p\pi^-, n\pi^0$; $\Xi_c^+ \to p\pi^0, n\pi^+$.

$$\frac{\tau_{\Lambda_c^+}}{\tau_{\Xi_c^0}}\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+) = 3\mathcal{B}(\Lambda_c^+ \to \Lambda\pi^+) + \mathcal{B}(\Lambda_c^+ \to \Sigma^0\pi^+) - \frac{1}{\sin^2\theta_C}\mathcal{B}(\Lambda_c^+ \to n\pi^+),$$

$$\frac{\tau_{\Xi_c^0}}{\tau_{\Lambda_c^+}}\mathcal{B}(\Lambda_c^+ \to p\overline{K}^0) = 3\mathcal{B}(\Xi_c^0 \to \Lambda\overline{K}^0) + \mathcal{B}(\Xi_c^0 \to \Sigma^0\overline{K}^0) - \frac{1}{\sin^2\theta_C}\mathcal{B}(\Xi_c^0 \to \Xi^0 K^0),$$

$$A(\mathcal{B}_c \to \mathcal{B}K_S^0) = -\frac{1}{\sqrt{2}}[A(\mathcal{B}_c \to \mathcal{B}\overline{K}^0) - A(\mathcal{B}_c \to \mathcal{B}K^0)],$$

$$A(\mathcal{B}_c \to \mathcal{B}K_L^0) = \frac{1}{\sqrt{2}}[A(\mathcal{B}_c \to \mathcal{B}\overline{K}^0) + A(\mathcal{B}_c \to \mathcal{B}K^0)].$$

Fitted parameters

Observable	PDG [42]	BESIII	Belle	Average
$10^2\mathcal{B}(\Lambda_c^+ \to \Lambda^0\pi^+)$	1.29 ± 0.05			1.29 ± 0.05
$10^2\mathcal{B}(\Lambda_c^+ \to \Sigma^0\pi^+)$	1.27 ± 0.06			1.27 ± 0.06
$10^2\mathcal{B}(\Lambda_c^+ \to \Sigma^+\pi^0)$	1.25 ± 0.09			1.25 ± 0.09
$10^2\mathcal{B}(\Lambda_c^+ \to \Sigma^+\eta)$	0.44 ± 0.20		0.314 ± 0.044 [49]	0.32 ± 0.04 [42, 49]
$10^2\mathcal{B}(\Lambda_c^+ \to \Sigma^+\eta')$	1.5 ± 0.6		0.416 ± 0.086 [49]	0.44 ± 0.15 [42, 49]
$10^2\mathcal{B}(\Lambda_c^+ \to \Xi^0 K^+)$	0.55 ± 0.07			0.55 ± 0.07
$10^4\mathcal{B}(\Lambda_c^+ \to \Lambda^0 K^+)$	6.0 ± 0.5	$6.21 \pm 0.61^*$ [50]	6.57 ± 0.40 [51]	6.35 ± 0.31 [42, 51]
$10^4\mathcal{B}(\Lambda_c^+ \to \Sigma^0 K^+)$	4.9 ± 0.6	$4.7 \pm 0.95^*$ [52]	3.58 ± 0.28 [51]	3.82 ± 0.51 [42, 51]
$10^4\mathcal{B}(\Lambda_c^+ \to \Sigma^+ K_S)$	4.7 ± 1.4	$4.8 \pm 1.5^*$ [52]		4.7 ± 1.4
$10^4\mathcal{B}(\Lambda_c^+ \to n\pi^+)$	6.6 ± 1.3			6.6 ± 1.3
$10^4\mathcal{B}(\Lambda_c^+ \to p\pi^0)$	< 0.8	$1.56^{+0.72}_{-0.58} \pm 0.20$ [47]		$1.56^{+0.75}_{-0.61}$ [47]
$10^2\mathcal{B}(\Lambda_c^+ \to pK_S)$	1.59 ± 0.07			1.59 ± 0.07
$10^3\mathcal{B}(\Lambda_c^+ \to p\eta)$	1.41 ± 0.11	1.63 ± 0.33 [47], 1.57 ± 0.12 [53]		1.49 ± 0.08 [42, 47, 53]
$10^4\mathcal{B}(\Lambda_c^+ \to p\eta')$	4.9 ± 0.9			4.9 ± 0.9
$10^2\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)$	1.43 ± 0.32		$1.80 \pm 0.52^*$ [46]	1.80 ± 0.52 [46]
$10^2\frac{\mathcal{B}(\Xi_c^0 \to \Xi^- K^+)}{\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)}$	2.75 ± 0.57			2.75 ± 0.57
$10^2\frac{\mathcal{B}(\Xi_c^0 \to \Lambda K_S^0)}{\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)}$	22.5 ± 1.3		$22.9 \pm 1.4^*$ [48]	22.9 ± 1.4 [48]
$10^2\frac{\mathcal{B}(\Xi_c^0 \to \Sigma^0 K_S^0)}{\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)}$	3.8 ± 0.7			3.8 ± 0.7
$10^2\frac{\mathcal{B}(\Xi_c^0 \to \Sigma^+ K^-)}{\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)}$	12.3 ± 1.2			12.3 ± 1.2
$10^2\mathcal{B}(\Xi_c^+ \to \Xi^0\pi^+)$	1.6 ± 0.8			1.6 ± 0.8
$\alpha(\Lambda_c^+ \to \Lambda^0\pi^+)$	-0.84 ± 0.09		-0.755 ± 0.006 [51]	-0.76 ± 0.01 [42, 51]
$\alpha(\Lambda_c^+ \to \Sigma^0\pi^+)$	-0.73 ± 0.18		-0.463 ± 0.018 [51]	-0.47 ± 0.03 [42, 51]
$\alpha(\Lambda_c^+ \to pK_S)$	0.18 ± 0.45			0.18 ± 0.45
$\alpha(\Lambda_c^+ \to \Sigma^+\pi^0)$	-0.55 ± 0.11		-0.48 ± 0.03 [49]	-0.49 ± 0.03 [42, 49]
$\alpha(\Xi_c^0 \to \Xi^-\pi^+)$	-0.64 ± 0.05			-0.64 ± 0.05
$\alpha(\Lambda_c^+ \to \Sigma^+\eta)$			-0.99 ± 0.06 [49]	-0.99 ± 0.06 [49]
$\alpha(\Lambda_c^+ \to \Sigma^+\eta')$			-0.46 ± 0.07 [49]	-0.46 ± 0.07 [49]
$\alpha(\Lambda_c^+ \to \Lambda^0 K^+)$			-0.585 ± 0.052 [51]	-0.585 ± 0.052 [51]
$\alpha(\Lambda_c^+ \to \Sigma^0 K^+)$			-0.55 ± 0.20 [51]	-0.55 ± 0.20 [51]
$\alpha(\Lambda_c^+ \to \Xi^0 K^+)$		0.01 ± 0.16 [33]		0.01 ± 0.16 [33]

$\chi^2_{\text{min}}/\text{dof} \sim 2$

	$\lvert X_i \rvert_S$ (10$^{-2}G_F$ GeV^2)	$\lvert X_i \rvert_P$	$\delta_S^{X_i}$ (in radian)	$\delta_P^{X_i}$
$\tilde{T}$	2.37 ± 0.41	16.56 ± 0.69	$-$	2.76 ± 0.32
$\tilde{C}$	1.04 ± 1.08	13.82 ± 0.58	-1.97 ± 0.79	-0.37 ± 0.44
$\tilde{C}'$	2.59 ± 0.95	24.97 ± 1.67	0.29 ± 0.19	2.86 ± 0.36
$\tilde{E}_1$	4.10 ± 0.20	2.56 ± 2.21	1.18 ± 0.38	-0.96 ± 0.43
$\tilde{E}_h$	1.54 ± 1.22	19.16 ± 3.00	-1.35 ± 0.60	0.37 ± 0.41

iminuit

$$\chi^2 = [\mathcal{O}_{\text{theor}}(c_i) - \mathcal{O}_{\text{expt}}]^{\text{T}}\, \Sigma^{-1}\, [\mathcal{O}_{\text{theor}}(c_i) - \mathcal{O}_{\text{expt}}]$$

Part of predictions

Channel	$10^2\mathcal{B}$	α	$\lvert A\rvert$	$\lvert B\rvert$	$\delta_P-\delta_S$	$10^2\mathcal{B}_{\rm exp}$	$\alpha_{\rm exp}$
$\Lambda_c^+\to\Lambda^0\pi^+$	1.31 ± 0.05	-0.76 ± 0.01	2.76 ± 0.24	16.97 ± 0.38	0.21 ± 0.30	1.29 ± 0.05	-0.76 ± 0.01 [19, 26]
$\Lambda_c^+\to\Sigma^0\pi^+$	1.26 ± 0.05	-0.48 ± 0.02	4.09 ± 0.86	15.42 ± 2.32	-1.07 ± 0.04	1.27 ± 0.06	-0.47 ± 0.03 [19, 26]
$\Lambda_c^+\to\Sigma^+\pi^0$	1.27 ± 0.05	-0.48 ± 0.02	4.09 ± 0.86	15.42 ± 2.32	-1.07 ± 0.04	1.25 ± 0.09	-0.49 ± 0.03 [19, 25]
$\Lambda_c^+\to\Sigma^+\eta$	0.33 ± 0.04	-0.93 ± 0.05	2.30 ± 0.35	9.50 ± 1.16	0.34 ± 0.16	0.32 ± 0.04 [19, 25]	-0.99 ± 0.06 [25]
$\Lambda_c^+\to\Sigma^+\eta'$	0.39 ± 0.12	-0.45 ± 0.07	3.83 ± 1.44	23.00 ± 3.85	2.03 ± 0.08	0.44 ± 0.15 [19, 25]	-0.46 ± 0.07 [25]
$\Lambda_c^+\to\Xi^0K^+$	0.41 ± 0.03	-0.16 ± 0.13	3.89 ± 0.19	2.49 ± 2.13	-2.14 ± 0.63	0.55 ± 0.07	0.01 ± 0.16 [7]
$\Lambda_c^+\to\Lambda^0K^+$	0.0639 ± 0.0030	-0.56 ± 0.05	1.09 ± 0.18	3.30 ± 0.59	-0.97 ± 0.06	0.0635 ± 0.0031 [19, 26]	-0.585 ± 0.052 [26]
$\Lambda_c^+\to\Sigma^0K^+$	0.0377 ± 0.0032	-0.54 ± 0.08	0.40 ± 0.15	3.86 ± 0.26	-0.59 ± 0.43	0.0382 ± 0.0051 [19, 26]	-0.55 ± 0.20 [26]
$\Lambda_c^+\to\Sigma^+K_S$	0.038 ± 0.003	-0.54 ± 0.08	0.57 ± 0.21	5.46 ± 0.37	-0.59 ± 0.43	0.047 ± 0.014	
$\Lambda_c^+\to n\pi^+$	0.063 ± 0.009	-0.78 ± 0.13	1.00 ± 0.14	2.44 ± 0.39	0.67 ± 0.21	0.066 ± 0.013	
$\Lambda_c^+\to p\pi^0$	0.0174 ± 0.0034	-0.12 ± 0.75	0.63 ± 0.14	0.96 ± 0.68	-1.70 ± 0.87	$0.0156^{+0.0075}_{-0.0061}$ [20]	
$\Lambda_c^+\to pK_S$	1.55 ± 0.07	0.00 ± 0.30	2.08 ± 2.10	26.21 ± 1.18	-1.56 ± 0.77	1.59 ± 0.07	0.18 ± 0.45
$\Lambda_c^+\to p\eta$	0.151 ± 0.007	0.08 ± 0.37	1.04 ± 0.54	5.42 ± 0.70	-1.67 ± 1.28	0.149 ± 0.008 [19, 20, 27]	
$\Lambda_c^+\to p\eta'$	0.052 ± 0.009	-0.54 ± 0.19	0.76 ± 0.30	4.73 ± 0.73	2.28 ± 0.14	0.049 ± 0.009	
$\Xi_c^0\to\Xi^-\pi^+$	2.83 ± 0.10	-0.72 ± 0.03	4.53 ± 0.81	31.46 ± 1.34	-0.39 ± 0.32	1.80 ± 0.52 [21]	-0.64 ± 0.05
$\Xi_c^+\to\Xi^0\pi^+$	0.9 ± 0.2	-0.93 ± 0.07	2.27 ± 0.30	8.18 ± 1.17	-0.36 ± 0.23	1.6 ± 0.8	
Channel	$10^2\mathcal{R}_X$	α	$\lvert A\rvert$	$\lvert B\rvert$	$\delta_P-\delta_S$	$10^2(\mathcal{R}_X)_{\rm exp}$	$\alpha_{\rm exp}$
$\Xi_c^0\to\Xi^-K^+$	4.10 ± 0.05	-0.76 ± 0.03	1.04 ± 0.19	7.25 ± 0.31	-0.39 ± 0.32	2.75 ± 0.57	
$\Xi_c^0\to\Lambda K_S^0$	24.1 ± 1.0	-0.24 ± 0.18	3.18 ± 1.25	19.54 ± 1.76	-1.24 ± 0.29	22.9 ± 1.4 [22]	
$\Xi_c^0\to\Sigma^0K_S^0$	3.9 ± 0.7	-0.11 ± 0.67	2.74 ± 0.59	4.17 ± 2.93	-1.70 ± 0.87	3.8 ± 0.7 [22]	
$\Xi_c^0\to\Sigma^+K^-$	13.0 ± 1.1	-0.21 ± 0.17	3.89 ± 0.19	2.49 ± 2.13	-2.14 ± 0.63	12.3 ± 1.2 [22]	

if phase shift vanishes, global fit $\to\alpha\sim1$; non-unity $\alpha\to$ non-vanishing phase shift

Part of predictions

Channel	$10^3\mathcal{B}$	α	β	γ	$\|A\|$	$\|B\|$	$\delta_P - \delta_S$
$\Lambda_c^+ \to pK_L$	15.37 ± 0.62	-0.03 ± 0.22	0.37 ± 0.33	-0.93 ± 0.13	1.38 ± 1.27	18.48 ± 0.71	1.65 ± 0.62
	15.49 ± 0.65	-0.02 ± 0.22	0.41 ± 0.41	-0.91 ± 0.18	1.54 ± 1.60	18.47 ± 0.97	1.62 ± 0.55
$\Xi_c^+ \to \Sigma^+ K_S$	2.08 ± 2.12	0.94 ± 0.22	-0.17 ± 0.80	0.28 ± 1.15	1.39 ± 0.92	3.19 ± 1.80	-0.18 ± 0.84
	4.77 ± 3.82	0.88 ± 0.14	-0.42 ± 0.45	-0.24 ± 0.55	1.62 ± 0.90	6.35 ± 2.81	-0.44 ± 0.47
$\Xi_c^+ \to pK_{S/L}$	2.00 ± 0.20	-0.38 ± 0.07	0.25 ± 0.25	-0.89 ± 0.09	0.40 ± 0.15	3.86 ± 0.26	2.56 ± 0.44
	2.10 ± 0.19	-0.38 ± 0.07	0.07 ± 0.39	-0.92 ± 0.05	0.34 ± 0.11	4.00 ± 0.21	2.95 ± 0.98
$\Xi_c^+ \to \Sigma^+\pi^0$	2.16 ± 0.20	-0.07 ± 0.30	0.93 ± 0.14	-0.35 ± 0.37	0.96 ± 0.29	3.96 ± 0.51	1.64 ± 0.32
	2.32 ± 0.27	0.12 ± 0.20	0.94 ± 0.16	-0.33 ± 0.48	1.01 ± 0.37	4.07 ± 0.73	1.44 ± 0.21
$\Xi_c^+ \to \Sigma^+\eta$	0.75 ± 0.26	-0.02 ± 0.57	-0.64 ± 0.43	-0.77 ± 0.35	0.36 ± 0.24	3.09 ± 0.76	-1.60 ± 0.89
	1.09 ± 0.47	-0.01 ± 0.56	-0.23 ± 0.64	-0.97 ± 0.15	0.15 ± 0.39	3.95 ± 0.96	-1.60 ± 2.40
$\Xi_c^+ \to \Sigma^+\eta'$	1.19 ± 0.21	-0.31 ± 0.11	0.92 ± 0.10	-0.24 ± 0.47	0.99 ± 0.35	5.27 ± 0.94	1.90 ± 0.10
	1.31 ± 0.29	-0.32 ± 0.13	0.81 ± 0.37	-0.49 ± 0.61	0.85 ± 0.52	6.07 ± 1.41	1.95 ± 0.21
$\Xi_c^+ \to \Sigma^0\pi^+$	3.12 ± 0.13	-0.59 ± 0.04	0.72 ± 0.13	-0.36 ± 0.28	1.13 ± 0.24	4.80 ± 0.56	2.26 ± 0.08
	2.89 ± 0.21	-0.56 ± 0.04	0.69 ± 0.28	-0.46 ± 0.40	1.01 ± 0.36	4.78 ± 0.75	2.26 ± 0.22
$\Xi_c^+ \to \Xi^0 K^+$	1.00 ± 0.16	-0.73 ± 0.12	-0.57 ± 0.17	0.38 ± 0.22	1.01 ± 0.14	2.43 ± 0.39	-2.47 ± 0.21
	1.51 ± 0.62	-0.62 ± 0.31	-0.29 ± 1.10	0.73 ± 0.23	1.38 ± 0.32	1.98 ± 0.86	-2.70 ± 1.62
$\Xi_c^0 \to \Sigma^0 K_L$	1.24 ± 0.19	-0.20 ± 0.61	-0.63 ± 0.41	0.75 ± 0.43	2.02 ± 0.33	2.35 ± 1.97	-1.88 ± 1.02
	1.87 ± 0.44	-0.74 ± 1.01	-0.49 ± 1.04	0.47 ± 0.54	2.31 ± 0.44	4.29 ± 2.27	-2.56 ± 1.61
$\Xi_c^0 \to \Xi^0\pi^0$	7.45 ± 0.64	-0.51 ± 0.08	0.34 ± 0.33	-0.79 ± 0.15	1.74 ± 0.64	16.78 ± 1.11	2.56 ± 0.44
	7.72 ± 0.65	-0.51 ± 0.09	0.10 ± 0.53	-0.85 ± 0.10	1.49 ± 0.47	17.37 ± 0.93	2.95 ± 0.98
$\Xi_c^0 \to \Xi^0\eta$	2.87 ± 0.66	0.08 ± 0.20	0.86 ± 0.18	0.50 ± 0.30	3.12 ± 0.45	6.61 ± 2.16	1.48 ± 0.24
	2.28 ± 0.53	0.24 ± 0.24	0.86 ± 0.24	0.45 ± 0.44	2.73 ± 0.55	6.20 ± 2.51	1.30 ± 0.28
$\Xi_c^0 \to \Xi^0\eta'$	5.31 ± 1.33	-0.59 ± 0.08	0.79 ± 0.07	0.18 ± 0.41	4.87 ± 1.38	23.13 ± 3.82	2.22 ± 0.08
	5.66 ± 1.62	-0.59 ± 0.09	0.79 ± 0.20	-0.16 ± 0.71	4.24 ± 2.23	28.35 ± 6.88	2.21 ± 0.19

SOME REMARKS

I. $\Lambda_c^+ \to \Xi^0 K^+$

(1) BF & longitudinal decay asymmetry

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

$$\alpha = \frac{2\kappa|A^*B|\cos(\delta_P-\delta_S)}{|A|^2+\kappa^2|B|^2}$$

BESIII

$$\text{I.}\ \begin{cases} |A| = 1.6^{+1.9}_{-1.6} \pm 0.4\,, \\ |B| = 18.3 \pm 2.8 \pm 0.7\,, \end{cases} \qquad \text{II.}\ \begin{cases} |A| = 4.3^{+0.7}_{-0.2} \pm 0.4\,, \\ |B| = 6.7^{+8.3}_{-6.7} \pm 1.6\,, \end{cases}$$

$$\mathcal{B}(\Lambda_c^+ \to \Xi^0 K^+) = (0.55 \pm 0.07)\%$$

$$\alpha_{\Xi^0 K^+} = 0.01 \pm 0.16$$

$$\delta_P - \delta_S = -1.55 \pm 0.25 \pm 0.05 \quad \text{or} \quad 1.59 \pm 0.25 \pm 0.05 \text{ rad.}$$

Our fit

$$|A| = 3.89 \pm 0.19,\ |B| = 2.43 \pm 2.12$$

prefers amplitude solution II

$$\mathcal{B}(\Lambda_c^+ \to \Xi^0 K^+) = (0.41 \pm 0.03)\%$$

$$\alpha_{\Xi^0 K^+} = -0.16 \pm 0.13$$

I. $\Lambda_c^+ \to \Xi^0 K^+$

(2) phase shift & transverse decay asymmetry

$$\beta = \frac{2\kappa |A^* B| \sin(\delta_P - \delta_S)}{|A|^2 + \kappa^2 |B|^2}$$

BESIII

$$\beta_{\Xi^0 K^+} = -0.64 \pm 0.69$$

$$\delta_P - \delta_S = -1.55 \pm 0.25 \pm 0.05 \text{ or } 1.59 \pm 0.25 \pm 0.05 \text{ rad.}$$

$$\delta_P - \delta_S = \arctan(\beta/\alpha)$$

Our fit

$$\beta_{\Xi^0 K^+} = -0.24 \pm 0.28$$

$$\delta_P - \delta_S = -2.15 \pm 0.65 \text{ rad}$$

$$(\delta_S^{X_i}, \delta_P^{X_i}) \to (-\delta_S^{X_i}, -\delta_P^{X_i})$$

$$\delta_P - \delta_S = 2 \arctan \frac{\beta}{\sqrt{\alpha^2 + \beta^2} + \alpha}$$

phase-shift sign ambiguity
needs to be discerned
by upcoming β measurement

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

Observable	PDG [42]	Belle	Average
$10^2 \mathcal{B}(\Xi_c^0 \to \Xi^- \pi^+)$	1.43 ± 0.32	$1.80 \pm 0.52^*$ [46]	1.80 ± 0.52 [46]

- $\Gamma(\Xi_c^0 \to p K^- \overline{K}^*(892)^0, \overline{K}^{*0} \to K^- \pi^+)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+)$
- $\Gamma(\Xi_c^0 \to p K^- K^- \pi^+$ (no $\overline{K}^{*0}$)$)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+)$
- $\Gamma(\Xi_c^0 \to \Lambda K_S^0)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+)$
- $\Gamma(\Xi_c^0 \to \Lambda K^- \pi^+)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+)$
- $\Gamma(\Xi_c^0 \to \Lambda \overline{K}^*(892)^0)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+)$
- $\Gamma(\Xi_c^0 \to \Sigma^0 K_S^0)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+)$
- $\Gamma(\Xi_c^0 \to \Sigma^+ K^-)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+)$
- $\Gamma(\Xi_c^0 \to \Sigma^0 \overline{K}^*(892)^0)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+)$
- $\Gamma(\Xi_c^0 \to \Sigma^+ K^*(892)^-)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+)$
- $\Gamma(\Xi_c^0 \to \Xi^- \pi^+)/\Gamma_{\text{total}}$
- $\Gamma(\Xi_c^0 \to \Xi^- \pi^+)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+ \pi^+ \pi^-)$
- $\Gamma(\Xi_c^0 \to \Omega^- K^+)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+)$
- $\Gamma(\Xi_c^0 \to \Xi^0 \phi, \phi \to K^+ K^-)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+)$
- $\Gamma(\Xi_c^0 \to \Xi^0 K^+ K^-$ nonresonant$)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+)$
- $\Gamma(\Xi_c^0 \to \Xi^- e^+ \nu_e)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+)$
- $\Gamma(\Xi_c^0 \to \Xi^- \mu^+ \nu_\mu)/\Gamma(\Xi_c^0 \to \Xi^- \pi^+)$

Our fit

Channel	$10^2 \mathcal{B}$	α	$\lvert A \rvert$	$\lvert B \rvert$	$\delta_P - \delta_S$
$\Xi_c^0 \to \Xi^- \pi^+$	2.83 ± 0.10	-0.72 ± 0.03	4.51 ± 0.79	31.47 ± 1.31	2.76 ± 0.32

Other support:

$$\frac{\tau_{\Lambda_c^+}}{\tau_{\Xi_c^0}} \mathcal{B}(\Xi_c^0 \to \Xi^- \pi^+) = 3\mathcal{B}(\Lambda_c^+ \to \Lambda \pi^+) + \mathcal{B}(\Lambda_c^+ \to \Sigma^0 \pi^+) - \frac{1}{\sin^2 \theta_C} \mathcal{B}(\Lambda_c^+ \to n \pi^+)$$

$\tau(\Lambda_c^+) = (202.9 \pm 1.1)$ fs,

$\tau(\Xi_c^0) = (150.5 \pm 1.9)$ fs.

	$\mathcal{B}(\Lambda_c^+ \to \Lambda \pi^+)$	$\mathcal{B}(\Lambda_c^+ \to \Sigma^0 \pi^+)$	$\mathcal{B}(\Lambda_c^+ \to n \pi^+)$
fitted results	1.31 ± 0.05	1.26 ± 0.05	0.063 ± 0.009
measured values	1.29 ± 0.05	1.27 ± 0.06	0.066 ± 0.013

$$\mathcal{B}(\Xi_c^0 \to \Xi^- \pi^+) = (2.85 \pm 0.30)\%$$

3. $\Xi_c^0 \to \Xi^- K^+$

Channel	$10^2\mathcal{R}_X$	α	$\lvert A\rvert$	$\lvert B\rvert$	$\delta_P - \delta_S$	$10^2(\mathcal{R}_X)_{\rm exp}$
$\Xi_c^0 \to \Xi^- K^+$	4.10 ± 0.05	-0.76 ± 0.03	1.04 ± 0.18	7.25 ± 0.30	2.76 ± 0.32	2.75 ± 0.57

Channel	TDA	$\widetilde{\rm TDA}$
$\Xi_c^0 \to \Xi^- \pi^+$	$2T - 2E_{1S}$	$2\tilde{T}$
$\Xi_c^0 \to \Xi^- K^+$	$2T - 2E_{1S}$	$2\tilde{T}$

$$\mathcal{R}_{\Xi^- K^+} = \sin^2\theta_C$$

0.045

measurement of $\Xi_c^0 \to \Xi^- \pi^+$ needs to be improved!

Reference/normalization mode

$\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$

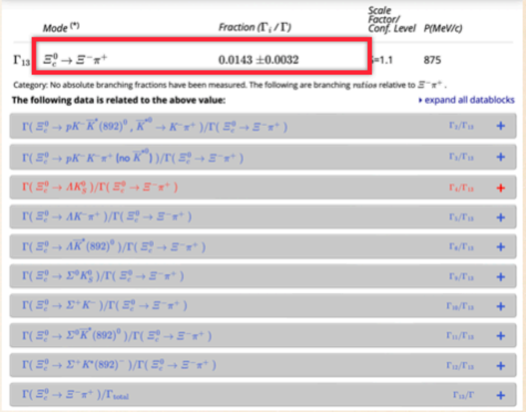
- ARGUS + CLEO : $(5.0 \pm 1.3)\%$ PDG 2014 obsolete
- Belle: $(6.84 \pm 0.24^{+0.21}_{-0.27})\%$ Belle, PRL 113 (2014), 042002
- BESIII: $(5.84 \pm 0.27 \pm 0.23)\%$ BESIII, PRL 116 (2016), 052001

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

PDG 2023 update $(6.26 \pm 0.29)\%$

$\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)$

1. PDG 2023 updated $(1.43 \pm 0.32)\,\%$



2. Belle 2019 $(1.80 \pm 0.50 \pm 0.14)\%$

Mode	Fraction (Γ_i/Γ)	Scale Factor/ Conf. Level	P(MeV/c)
Γ_{13} $\Xi_c^0 \to \Xi^-\pi^+$	0.0143 ± 0.0032	S=1.1	875

Category: No absolute branching fractions have been measured. The following are branching *ratios* relative to $\Xi^-\pi^+$.

The following data is related to the above value: ‣ expand all datablocks

$\Gamma(\Xi_c^0 \to pK^-\overline{K}^*(892)^0, \overline{K}^{*0} \to K^-\pi^+)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_2/Γ_{13} +
$\Gamma(\Xi_c^0 \to pK^-K^-\pi^+$ (no $\overline{K}^{*0}$)$)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_3/Γ_{13} +
$\Gamma(\Xi_c^0 \to \Lambda K_S^0)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_4/Γ_{13} +
$\Gamma(\Xi_c^0 \to \Lambda K^-\pi^+)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_5/Γ_{13} +
$\Gamma(\Xi_c^0 \to \Lambda\overline{K}^*(892)^0)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_6/Γ_{13} +
$\Gamma(\Xi_c^0 \to \Sigma^0 K_S^0)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_9/Γ_{13} +
$\Gamma(\Xi_c^0 \to \Sigma^+ K^-)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_{10}/Γ_{13} +
$\Gamma(\Xi_c^0 \to \Sigma^0\overline{K}^*(892)^0)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_{11}/Γ_{13} +
$\Gamma(\Xi_c^0 \to \Sigma^+ K^*(892)^-)/\Gamma(\Xi_c^0 \to \Xi^-\pi^+)$	Γ_{12}/Γ_{13} +
$\Gamma(\Xi_c^0 \to \Xi^-\pi^+)/\Gamma_{\rm total}$	Γ_{13}/Γ +

4. prediction on $\Xi_c^0 \to \Xi^0(\pi^0, \eta, \eta')$

Channel	$10^3\mathcal{B}$	α	β	γ	$\|A\|$	$\|B\|$	$\delta_P - \delta_S$
$\Xi_c^0 \to \Xi^0\pi^0$	7.45 ± 0.64	-0.51 ± 0.08	0.34 ± 0.33	-0.79 ± 0.15	1.74 ± 0.64	16.78 ± 1.11	2.56 ± 0.44
	7.72 ± 0.65	-0.51 ± 0.09	0.10 ± 0.53	-0.85 ± 0.10	1.49 ± 0.47	17.37 ± 0.93	2.95 ± 0.98
$\Xi_c^0 \to \Xi^0\eta$	2.87 ± 0.66	0.08 ± 0.20	0.86 ± 0.18	0.50 ± 0.30	3.12 ± 0.45	6.61 ± 2.16	1.48 ± 0.24
	2.28 ± 0.53	0.24 ± 0.24	0.86 ± 0.24	0.45 ± 0.44	2.73 ± 0.55	6.20 ± 2.51	1.30 ± 0.28
$\Xi_c^0 \to \Xi^0\eta'$	5.31 ± 1.33	-0.59 ± 0.08	0.79 ± 0.07	0.18 ± 0.41	4.87 ± 1.38	23.13 ± 3.82	2.22 ± 0.08
	5.66 ± 1.62	-0.59 ± 0.09	0.79 ± 0.20	-0.16 ± 0.71	4.24 ± 2.23	28.35 ± 6.88	2.21 ± 0.19

$$\mathcal{B}(\Xi_c^0 \to \Xi^0\pi^0) = (6.9 \pm 0.3(\text{stat.}) \pm 0.5(\text{syst.}) \pm 1.5(\text{norm.})) \times 10^{-3}$$
$$\mathcal{B}(\Xi_c^0 \to \Xi^0\eta) = (1.6 \pm 0.2(\text{stat.}) \pm 0.2(\text{syst.}) \pm 0.4(\text{norm.})) \times 10^{-3}$$
$$\mathcal{B}(\Xi_c^0 \to \Xi^0\eta') = (1.2 \pm 0.3(\text{stat.}) \pm 0.1(\text{syst.}) \pm 0.3(\text{norm.})) \times 10^{-3}$$

★ Belle II new results

$$\alpha(\Xi_c^0 \to \Xi^0\pi^0) = -0.90 \pm 0.15 \pm 0.23$$

IRA

$$\mathcal{H}_{\rm eff} = \frac{G_F}{\sqrt{2}} \sum_{q_1,q_2}^{d,s} V_{cq_1} V_{uq_2} (c_1 O_1^{q_1 q_2} + c_2 O_2^{q_1 q_2}) + h.c.$$
$$= \frac{G_F}{\sqrt{2}} \sum_{q_1,q_2}^{d,s} V_{cq_1} V_{uq_2} (c_+ O_+^{q_1 q_2} + c_- O_-^{q_1 q_2}) + h.c.,$$

$$\mathcal{A}_{\rm IRAa} = a_1 (\mathcal{B}_c)_i (H_6)^{ik}_j (\mathcal{B}_8)^j_k M^l_l + a_2 (\mathcal{B}_c)_i (H_6)^{ik}_j (\mathcal{B}_8)^l_k M^j_l + a_3 (\mathcal{B}_c)_i (H_6)^{ik}_j (\mathcal{B}_8)^j_l M^l_k$$
$$+ a_4 (\mathcal{B}_c)_i (H_6)^{jk}_l (\mathcal{B}_8)^i_j M^l_k + a_5 (\mathcal{B}_c)_i (H_6)^{jk}_l (\mathcal{B}_8)^l_j M^i_k$$
$$+ a_6 (\mathcal{B}_c)_i (H_{\overline{15}})^{ik}_j (\mathcal{B}_8)^j_k M^l_l + a_7 (\mathcal{B}_c)_i (H_{\overline{15}})^{ik}_j (\mathcal{B}_8)^l_k M^j_l + a_8 (\mathcal{B}_c)_i (H_{\overline{15}})^{ik}_j (\mathcal{B}_8)^j_l M^l_k$$
$$+ a_9 (\mathcal{B}_c)_i (H_{\overline{15}})^{jk}_l (\mathcal{B}_8)^i_j M^l_k + a_{10} (\mathcal{B}_c)_i (H_{\overline{15}})^{jk}_l (\mathcal{B}_8)^l_j M^i_k.$$

redundant dof: $a'_1 = a_1 - a_5, \quad a'_2 = a_2 + a_5, \quad a'_3 = a_3 + a_5, \quad a'_4 = a_4 + a_5,$

KPW theorem: $a_6 = a_7 = a_8 = a_{10} = 0$

Minimal set of IRA

$$\mathcal{A}_{\rm IRAa} = a_1 (\mathcal{B}_c)_i (H_6)^{ik}_j (\mathcal{B}_8)^j_k M^l_l + a_2 (\mathcal{B}_c)_i (H_6)^{ik}_j (\mathcal{B}_8)^l_k M^j_l + a_3 (\mathcal{B}_c)_i (H_6)^{ik}_j (\mathcal{B}_8)^j_l M^l_k$$
$$+ a_4 (\mathcal{B}_c)_i (H_6)^{jk}_l (\mathcal{B}_8)^i_j M^l_k + a_5 (\mathcal{B}_c)_i (H_6)^{jk}_l (\mathcal{B}_8)^l_j M^i_k$$
$$+ a_6 (\mathcal{B}_c)_i (H_{\overline{15}})^{ik}_j (\mathcal{B}_8)^j_k M^l_l + a_7 (\mathcal{B}_c)_i (H_{\overline{15}})^{ik}_j (\mathcal{B}_8)^l_k M^j_l + a_8 (\mathcal{B}_c)_i (H_{\overline{15}})^{ik}_j (\mathcal{B}_8)^j_l M^l_k$$
$$+ a_9 (\mathcal{B}_c)_i (H_{\overline{15}})^{jk}_l (\mathcal{B}_8)^i_j M^l_k + a_{10} (\mathcal{B}_c)_i (H_{\overline{15}})^{jk}_l (\mathcal{B}_8)^l_j M^i_k.$$

$$\mathcal{A}_{\rm IRAb} = \tilde{f}^a (\mathcal{B}_c)^{ik} (H_6)_{ij} (\mathcal{B}_8)^j_k M^l_l + \tilde{f}^b (\mathcal{B}_c)^{ik} (H_6)_{ij} (\mathcal{B}_8)^l_k M^j_l + \tilde{f}^c (\mathcal{B}_c)^{ik} (H_6)_{ij} (\mathcal{B}_8)^j_l M^l_k$$
$$+ \tilde{f}^d (\mathcal{B}_c)^{kl} (H_6)_{ij} (\mathcal{B}_8)^i_k M^j_l + \tilde{f}^e (\mathcal{B}_c)_j (H_{\overline{15}})^{ik}_l (\mathcal{B}_8)^j_i M^l_k.$$

Unification

Equivalence

$$\tilde{T} = \frac{1}{2}(-a_2 + a_4 + a_9), \qquad \tilde{C} = \frac{1}{2}(a_2 - a_4 + a_9),$$
$$\tilde{C}' = -a_2 - a_5, \qquad \tilde{E}_1 = a_3 + a_5, \qquad \tilde{E}_h = -a_1 + a_5.$$

$$\tilde{T} = \frac{1}{2}(\tilde{f}^b + \tilde{f}^e), \qquad \tilde{C} = \frac{1}{2}(-\tilde{f}^b + \tilde{f}^e),$$
$$\tilde{C}' = \tilde{f}^b - \tilde{f}^d, \qquad \tilde{E}_1 = -\tilde{f}^c, \qquad \tilde{E}_h = -\tilde{f}^a,$$

Fitted parameters

	$\lvert X_i\rvert_S$ ($10^{-2}G_F$ GeV^2)	$\lvert X_i\rvert_P$	$\delta_S^{X_i}$ (in radian)	$\delta_P^{X_i}$
$\tilde{T}$	2.37 ± 0.41	16.56 ± 0.69	–	2.76 ± 0.32
$\tilde{C}$	1.04 ± 1.08	13.82 ± 0.58	-1.97 ± 0.79	-0.37 ± 0.44
$\tilde{C}'$	2.59 ± 0.95	24.97 ± 1.67	0.29 ± 0.19	2.86 ± 0.36
$\tilde{E}_1$	4.10 ± 0.20	2.56 ± 2.21	1.18 ± 0.38	-0.96 ± 0.43
$\tilde{E}_h$	1.54 ± 1.22	19.16 ± 3.00	-1.35 ± 0.60	0.37 ± 0.41
$\tilde{f}^a$	0.81 ± 1.89	23.02 ± 4.04	–	2.12 ± 1.03
$\tilde{f}^b$	2.89 ± 1.50	30.56 ± 1.30	2.03 ± 0.61	-1.78 ± 0.98
$\tilde{f}^c$	4.20 ± 0.18	1.95 ± 2.21	-0.06 ± 1.03	-2.68 ± 1.16
$\tilde{f}^d$	0.98 ± 0.90	7.25 ± 2.07	2.72 ± 1.29	-2.55 ± 1.00
$\tilde{f}^e$	2.06 ± 0.62	4.73 ± 2.11	1.09 ± 0.99	-0.94 ± 0.99

Part of predictions

Channel	$10^2\mathcal{B}$	α	β	γ	$\lvert A\rvert$	$\lvert B\rvert$	$\delta_P-\delta_S$	$\mathcal{B}_{\rm exp}$	$\alpha_{\rm exp}$
$\Lambda_c^+\to\Lambda^0\pi^+$	1.31 ± 0.05	-0.76 ± 0.01	-0.17 ± 0.24	-0.63 ± 0.06	2.76 ± 0.25	16.96 ± 0.39	-2.92 ± 0.30	1.29 ± 0.05	-0.76 ± 0.01
	1.31 ± 0.05	-0.76 ± 0.01	-0.28 ± 0.33	-0.59 ± 0.16	2.91 ± 0.57	16.78 ± 0.82	-2.79 ± 0.39		
$\Lambda_c^+\to\Sigma^0\pi^+$	1.26 ± 0.05	-0.48 ± 0.02	0.86 ± 0.07	-0.17 ± 0.35	4.07 ± 0.86	15.48 ± 2.30	2.08 ± 0.04	1.27 ± 0.06	-0.47 ± 0.03
	1.25 ± 0.05	-0.48 ± 0.02	0.79 ± 0.23	-0.39 ± 0.47	3.49 ± 1.35	16.81 ± 2.85	2.11 ± 0.13		
$\Lambda_c^+\to\Sigma^+\pi^0$	1.27 ± 0.05	-0.48 ± 0.02	0.86 ± 0.07	-0.17 ± 0.35	4.07 ± 0.86	15.48 ± 2.30	2.08 ± 0.04	1.25 ± 0.09	-0.49 ± 0.03
	1.26 ± 0.05	-0.48 ± 0.02	0.79 ± 0.23	-0.39 ± 0.47	3.49 ± 1.35	16.81 ± 2.85	2.11 ± 0.13		
$\Lambda_c^+\to\Sigma^+\eta$	0.33 ± 0.04	-0.93 ± 0.04	-0.34 ± 0.15	-0.13 ± 0.24	2.30 ± 0.35	9.48 ± 1.12	-2.80 ± 0.15	0.32 ± 0.04	-0.99 ± 0.06
	0.31 ± 0.04	-0.95 ± 0.05	-0.30 ± 0.15	0.09 ± 0.29	2.51 ± 0.39	8.29 ± 1.35	-2.83 ± 0.16		
$\Lambda_c^+\to\Sigma^+\eta'$	0.39 ± 0.12	-0.45 ± 0.07	0.89 ± 0.04	0.03 ± 0.51	3.81 ± 1.45	23.04 ± 3.76	2.03 ± 0.08	0.44 ± 0.15	-0.46 ± 0.07
	0.41 ± 0.13	-0.46 ± 0.07	0.80 ± 0.39	-0.38 ± 0.82	3.03 ± 2.33	28.15 ± 6.48	2.09 ± 0.22		
$\Lambda_c^+\to\Xi^0K^+$	0.41 ± 0.03	-0.16 ± 0.13	-0.24 ± 0.28	0.96 ± 0.07	3.89 ± 0.19	2.43 ± 2.12	-2.15 ± 0.65	0.55 ± 0.07	0.01 ± 0.16
	0.42 ± 0.03	-0.19 ± 0.12	-0.11 ± 0.42	0.98 ± 0.05	3.99 ± 0.18	1.85 ± 2.10	-2.62 ± 1.68		
$\Lambda_c^+\to\Lambda^0K^+$	0.0639 ± 0.0030	-0.56 ± 0.05	0.83 ± 0.04	0.04 ± 0.35	1.09 ± 0.18	3.32 ± 0.59	2.17 ± 0.06	0.0635 ± 0.0031	-0.585 ± 0.052
	0.0639 ± 0.0030	-0.57 ± 0.05	0.82 ± 0.08	-0.11 ± 0.50	1.00 ± 0.29	3.57 ± 0.80	2.18 ± 0.08		
$\Lambda_c^+\to\Sigma^0K^+$	0.0376 ± 0.0032	-0.54 ± 0.08	0.35 ± 0.34	-0.76 ± 0.17	0.40 ± 0.15	3.86 ± 0.26	2.56 ± 0.44	0.0382 ± 0.0051	-0.55 ± 0.20
	0.0388 ± 0.0032	-0.54 ± 0.09	0.11 ± 0.56	-0.83 ± 0.11	0.34 ± 0.11	4.00 ± 0.21	2.95 ± 0.98		
$\Lambda_c^+\to\Sigma^+K_S$	0.0377 ± 0.0032	-0.54 ± 0.08	0.35 ± 0.34	-0.77 ± 0.17	0.40 ± 0.15	3.86 ± 0.26	2.56 ± 0.44	0.047 ± 0.014	
	0.0389 ± 0.0032	-0.54 ± 0.09	0.11 ± 0.56	-0.83 ± 0.11	0.34 ± 0.11	4.00 ± 0.21	2.95 ± 0.98		
$\Lambda_c^+\to n\pi^+$	0.063 ± 0.009	-0.78 ± 0.13	-0.62 ± 0.16	0.00 ± 0.26	1.01 ± 0.14	2.43 ± 0.39	-2.47 ± 0.30	0.066 ± 0.013	
	0.059 ± 0.008	-0.81 ± 0.14	-0.57 ± 0.23	0.12 ± 0.37	1.03 ± 0.17	2.19 ± 0.53	-2.52 ± 0.27		
$\Lambda_c^+\to p\pi^0$	0.0176 ± 0.0032	-0.11 ± 0.69	-0.88 ± 0.29	0.46 ± 0.63	0.64 ± 0.12	0.94 ± 0.59	-1.69 ± 0.76	$0.0156^{+0.0075}_{-0.0061}$	
	0.0208 ± 0.0045	-0.69 ± 0.31	-0.61 ± 0.54	-0.40 ± 0.75	0.45 ± 0.25	1.64 ± 0.57	-2.42 ± 0.58		
$\Lambda_c^+\to pK_S$	1.55 ± 0.06	0.01 ± 0.24	0.37 ± 0.34	-0.93 ± 0.13	1.41 ± 1.34	18.68 ± 0.71	1.54 ± 0.65	1.59 ± 0.07	0.18 ± 0.45
	1.57 ± 0.06	0.03 ± 0.24	0.42 ± 0.41	-0.91 ± 0.19	1.64 ± 1.67	18.69 ± 1.00	1.50 ± 0.54		
$\Lambda_c^+\to p\eta$	0.151 ± 0.008	0.07 ± 0.30	0.77 ± 0.26	-0.63 ± 0.33	1.01 ± 0.44	5.46 ± 0.57	1.48 ± 0.38	0.149 ± 0.008	
	0.149 ± 0.008	0.36 ± 0.29	0.75 ± 0.28	-0.56 ± 0.44	1.09 ± 0.55	5.31 ± 0.75	1.12 ± 0.32		
$\Lambda_c^+\to p\eta'$	0.052 ± 0.008	-0.54 ± 0.19	0.62 ± 0.19	-0.56 ± 0.35	0.77 ± 0.30	4.72 ± 0.73	2.29 ± 0.13	0.049 ± 0.009	
	0.053 ± 0.009	-0.01 ± 0.37	0.96 ± 0.08	-0.26 ± 0.64	1.01 ± 0.43	4.28 ± 1.22	1.59 ± 0.38		
$\Xi_c^0\to\Xi^-\pi^+$	2.83 ± 0.10	-0.72 ± 0.03	0.29 ± 0.27	-0.63 ± 0.13	4.51 ± 0.79	31.47 ± 1.31	2.76 ± 0.32	1.80 ± 0.52	-0.64 ± 0.05
	2.87 ± 0.10	-0.72 ± 0.03	0.13 ± 0.45	-0.68 ± 0.10	4.21 ± 0.64	32.19 ± 1.07	2.96 ± 0.60		
$\Xi_c^+\to\Xi^0\pi^+$	0.9 ± 0.2	-0.93 ± 0.07	0.35 ± 0.20	-0.09 ± 0.22	2.27 ± 0.31	8.21 ± 1.17	2.79 ± 0.23	1.6 ± 0.8	
	0.8 ± 0.1	-0.93 ± 0.09	0.35 ± 0.28	-0.14 ± 0.28	2.12 ± 0.33	8.05 ± 1.31	2.78 ± 0.29		

SUMMARY

- In theory
  - TDA approach to charmed baryon is established.
  - The unification of TDA & IRA is demonstrated.
  - The predictions on $\Xi_c^0 \to \Xi^-(\pi^0, \eta, \eta')$ is confirmed by LHCb.
  - A further understanding of strong phase dynamically is required.
- For experiment
  - The measurement of β, either of $\Lambda_c^+ \to \Xi^0 K^+$ or other modes, is highlighted.
  - Improved measurement of $\Xi_c^0 \to \Xi^- \pi^+$ and its related are highly expected.