高能物理牧野论坛
第 17 期

HEAVY-FLAVOR-CONSERVING WEAK DECAYS OF HEAVY BARYONS

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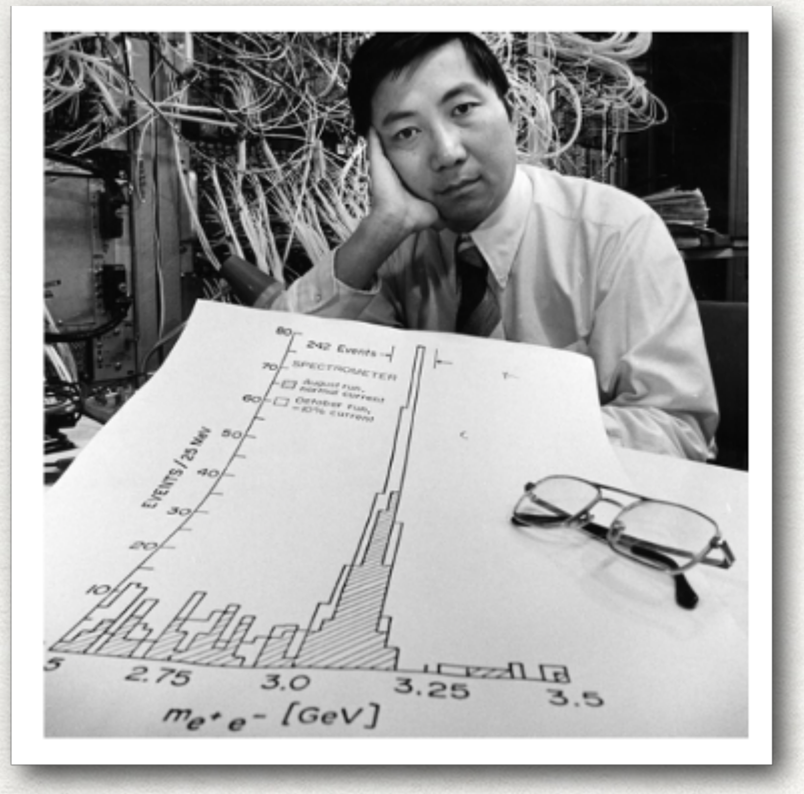
2022年5月19日

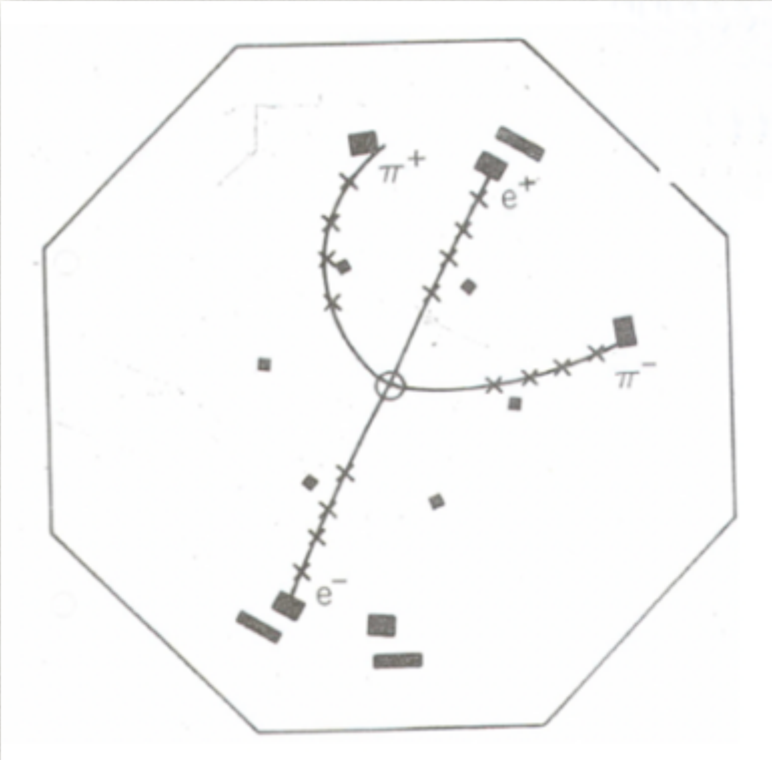
OUTLINE

- Introduction
- General remarks
- S-wave amplitudes
- P-wave amplitudes
- Numerical results
- Summary and discussion

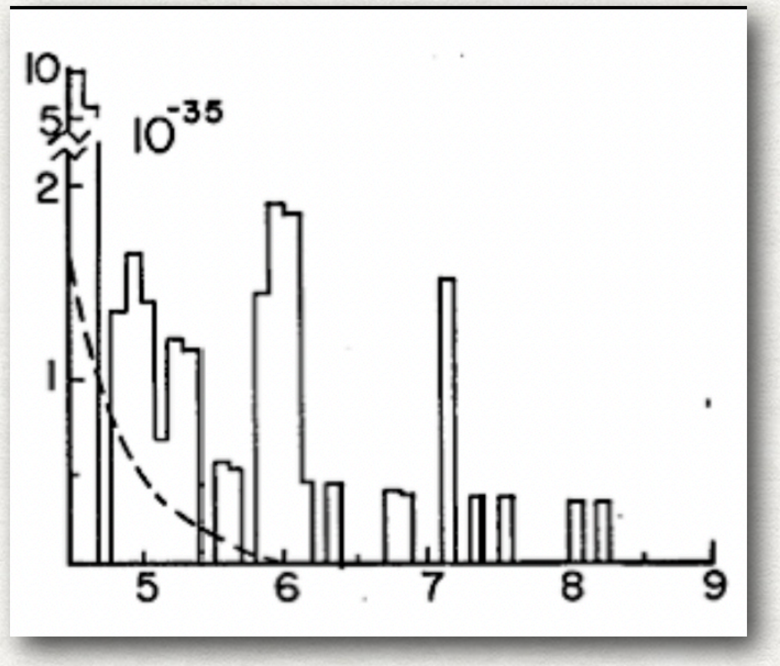
INTRODUCTION

FROM QUARK TO BARYON



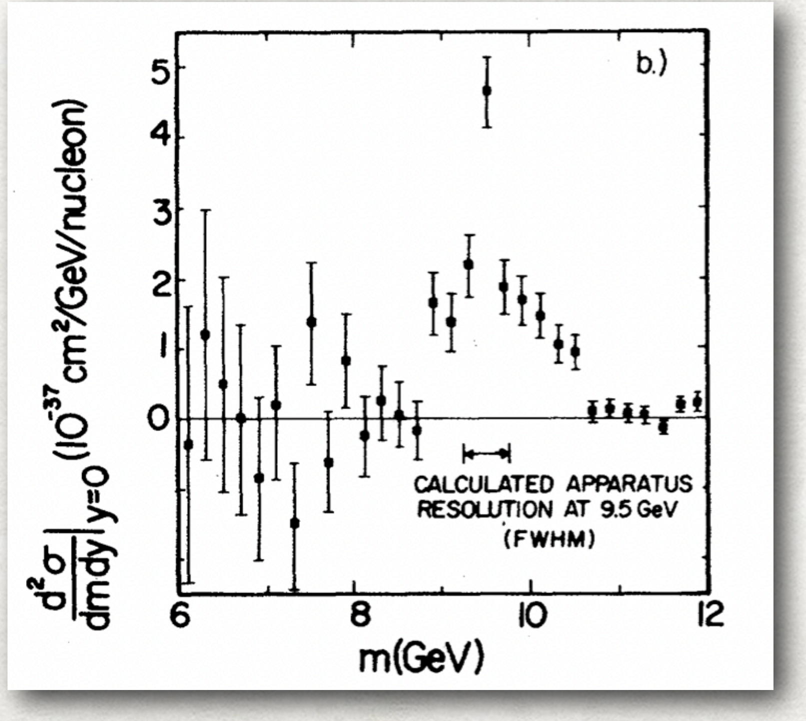


1974

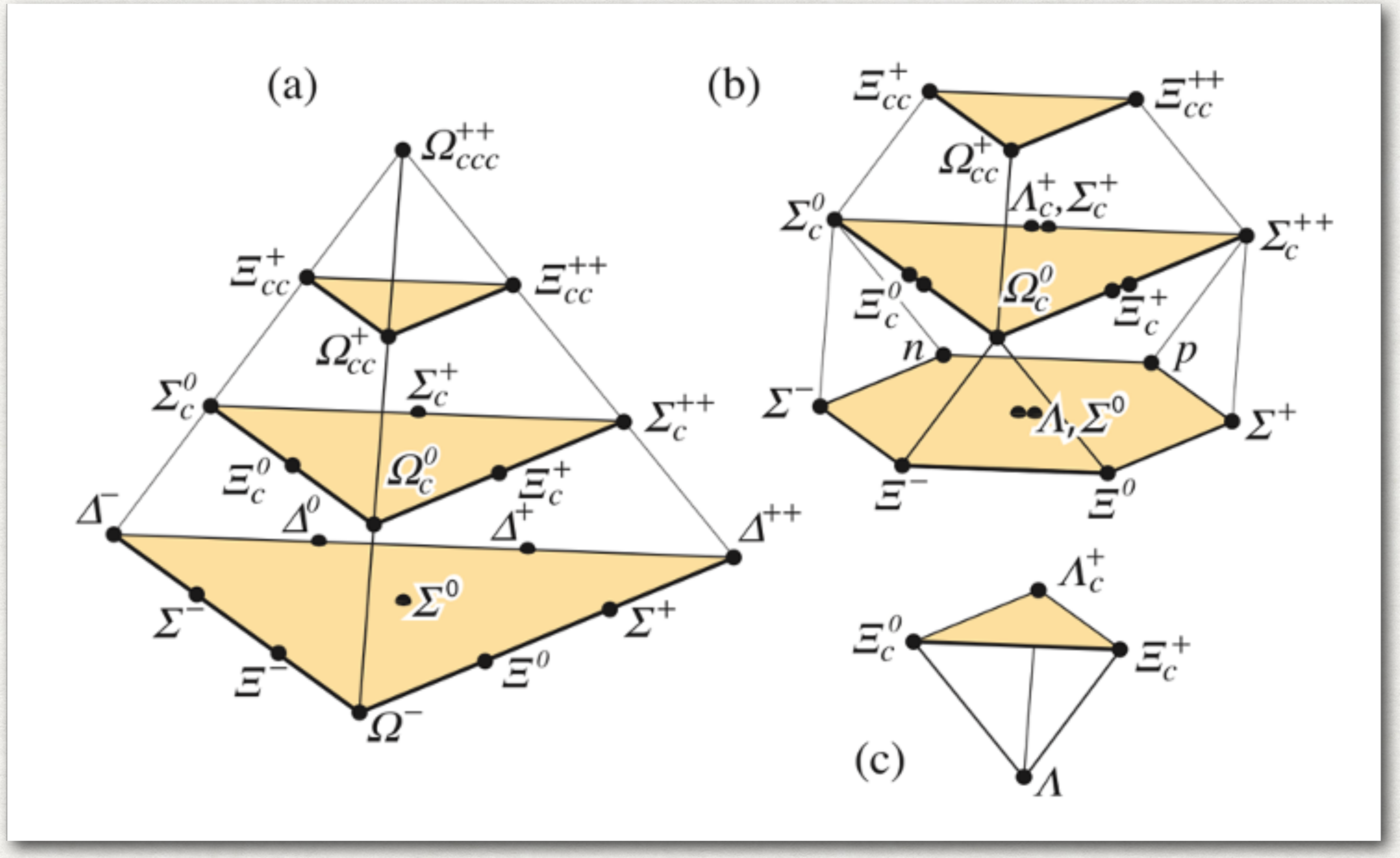


Oops-Leon

1976

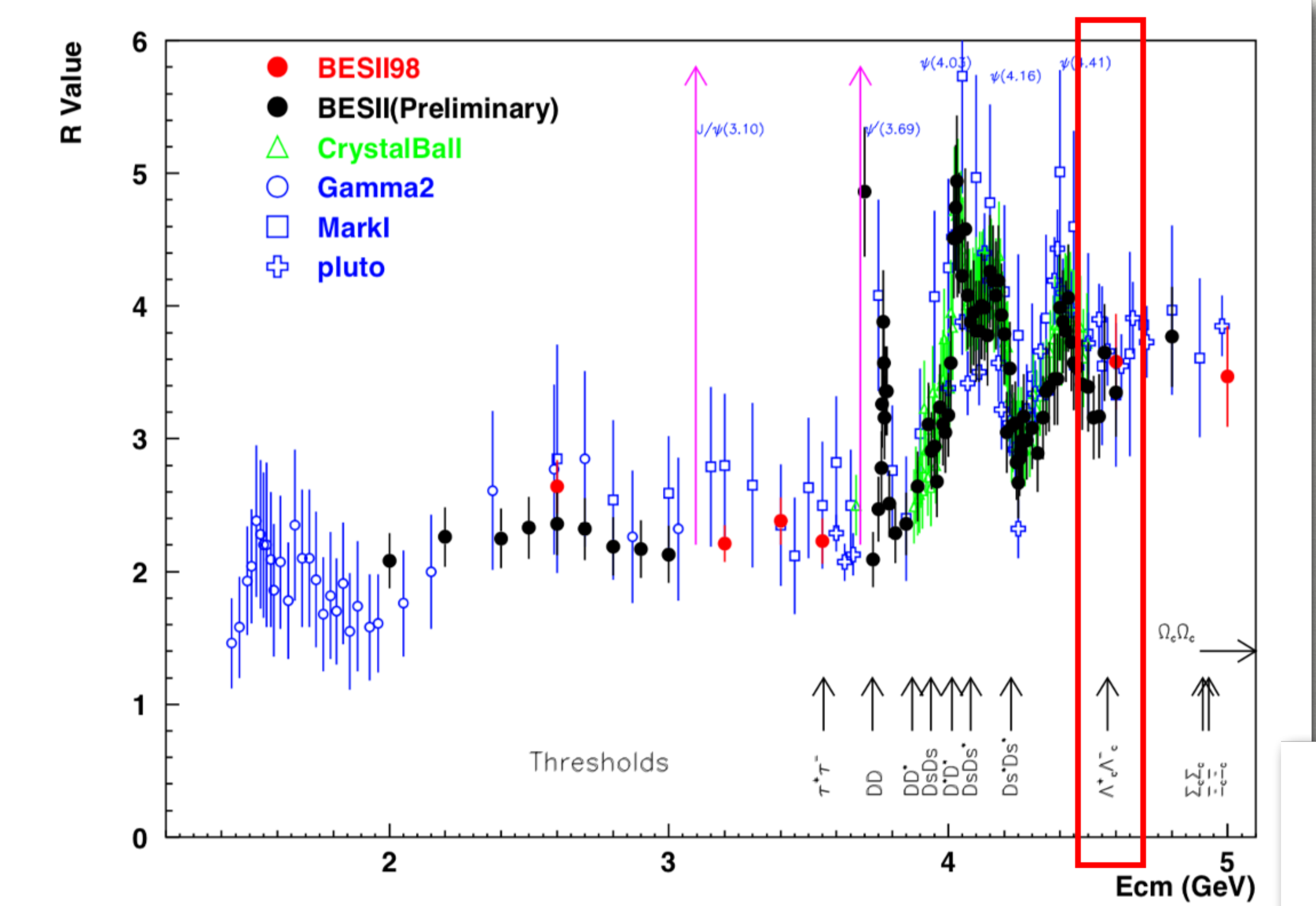


1977



CHARMED BARYON: RECENT PROGRESSES (I)

- Opportunities brought by BESIII: Λ_c^+



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

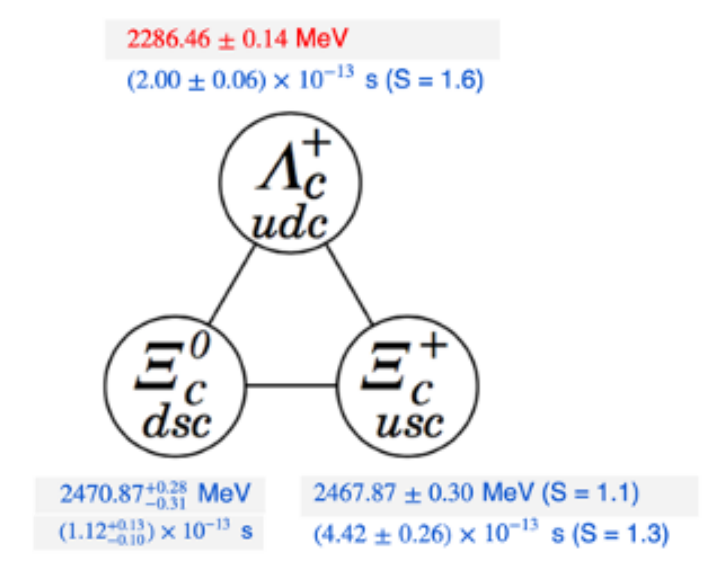
PRL 116, 052001 (2016) PHYSICAL REVIEW LETTERS week ending 5 FEBRUARY 2016

4.6 GeV, 567/pb

(BESIII Collaboration)

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

2014



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

PDG 2021: $(6.28 \pm 0.32)\,\%$

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

CHARMED BARYON: RECENT PROGRESSES (II)

- Progresses made by Belle/Belle-II
  - competitive role in Λ_c measurement (benchmarking channel, DCS decays)
  - one important provider for Ξ_c & Ω_c

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

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

PRL **117,** 011801 (2016) PHYSICAL REVIEW LETTERS week ending 1 JULY 2016

First Observation of the Doubly Cabibbo-Suppressed Decay of a Charmed Baryon: $\Lambda_c^+ \to pK^+\pi^-$

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

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

PHYSICAL REVIEW D **100,** 031101(R) (2019)

Rapid Communications

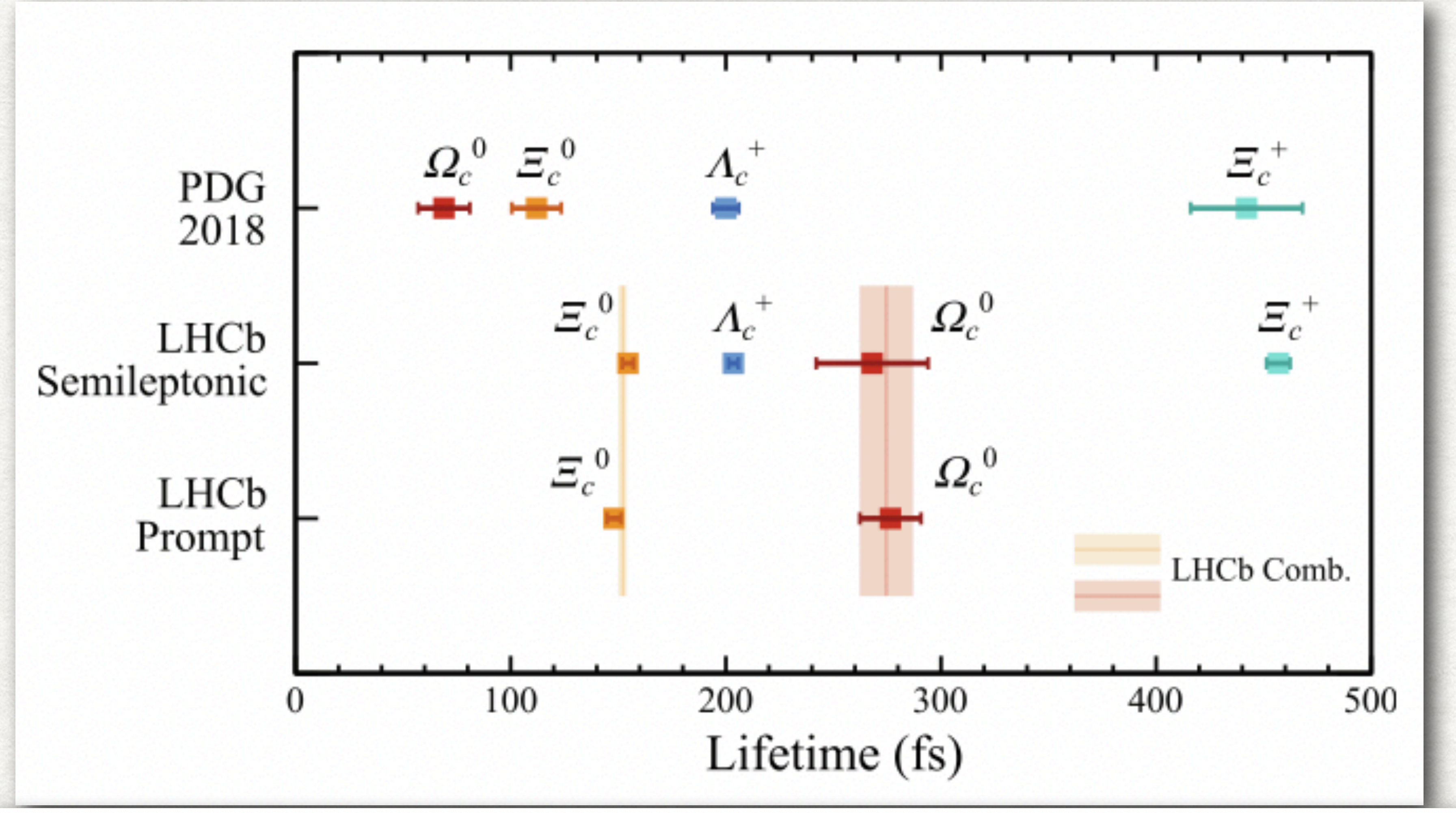
First measurements of absolute branching fractions of the Ξ_c^+ baryon at Belle

PHYSICAL REVIEW D **97,** 032001 (2018)

Measurement of branching fractions of hadronic decays of the Ω_c^0 baryon

CHARMED BARYON: RECENT PROGRESSES (III)

- Progresses made by LHCb
  - one important provider for Ξ_c & Ω_c : decays vs. lifetimes
  - discovery and measurement of doubly charmed baryons
  - measurement of **bottom baryons**



PHYSICAL REVIEW LETTERS **121,** 092003 (2018)

Measurement of the Ω_c^0 Baryon Lifetime

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

(Received 5 July 2018; revised manuscript received 31 July 2018; published 31 August 2018)

Selected for a Viewpoint in *Physics*

PRL **119,** 112001 (2017) PHYSICAL REVIEW LETTERS week ending 15 SEPTEMBER 2017

Observation of the Doubly Charmed Baryon Ξ_{cc}^{++}

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

PHYSICAL REVIEW LETTERS **123,** 031801 (2019)

First Observation of the Radiative Decay $\Lambda_b^0 \to \Lambda\gamma$

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

(Received 23 April 2019; published 15 July 2019)

PRL **115,** 241801 (2015) PHYSICAL REVIEW LETTERS week ending 11 DECEMBER 2015

Evidence for the Strangeness-Changing Weak Decay $\Xi_b^- \to \Lambda_b^0\pi^-$

R. Aaij *et al.**
(LHCb Collaboration)
(Received 13 October 2015; published 11 December 2015)

CHARMED BARYON WEAK DECAYS

- The Pioneering work has been done in 1990s.

(Hai-Yang Cheng, B Tseng, '92 & '93 PRD)

- More modes have been studied and completed in recent years.

ZOU, XU, MENG, and CHENG PHYS. REV. D **101,** 014011 (2020)

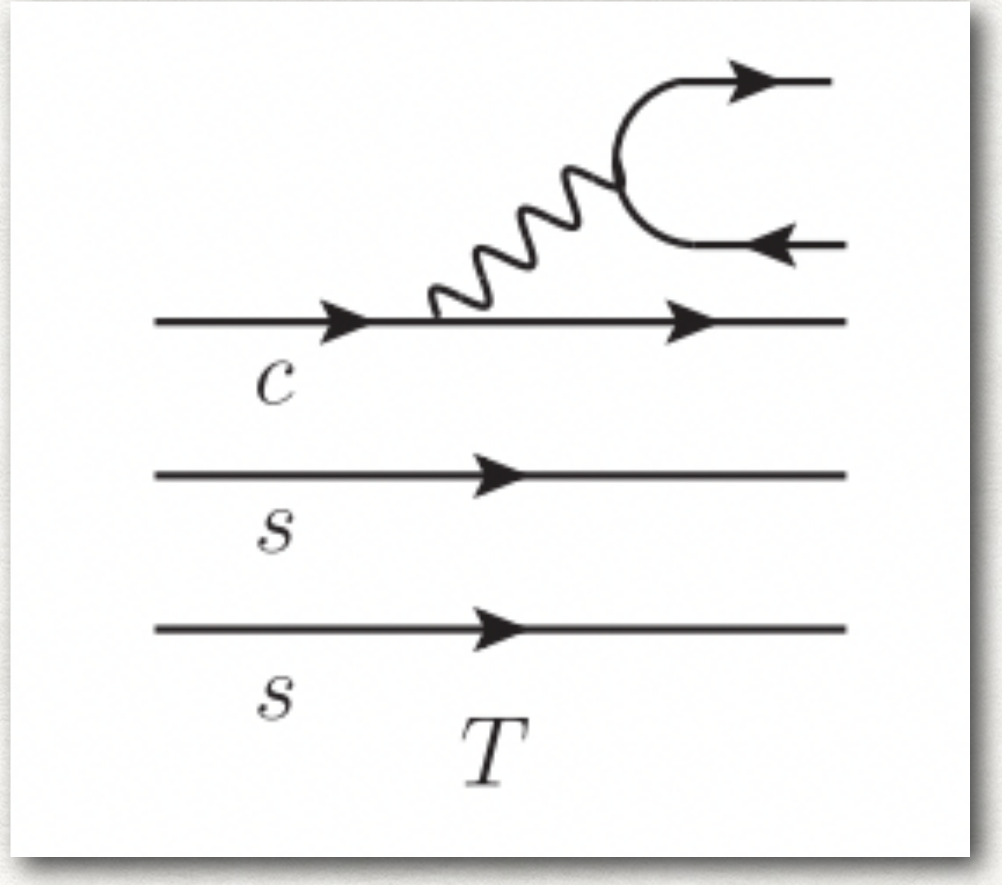
TABLE V. The singly Cabibbo-suppressed decays $\Xi_c \to \mathcal{B}_f P$ in units of $10^{-2} G_F\ \mathrm{GeV}^2$. Branching fractions (in unit of 10^{-3}) and the asymmetry parameter α are shown in the last two columns.

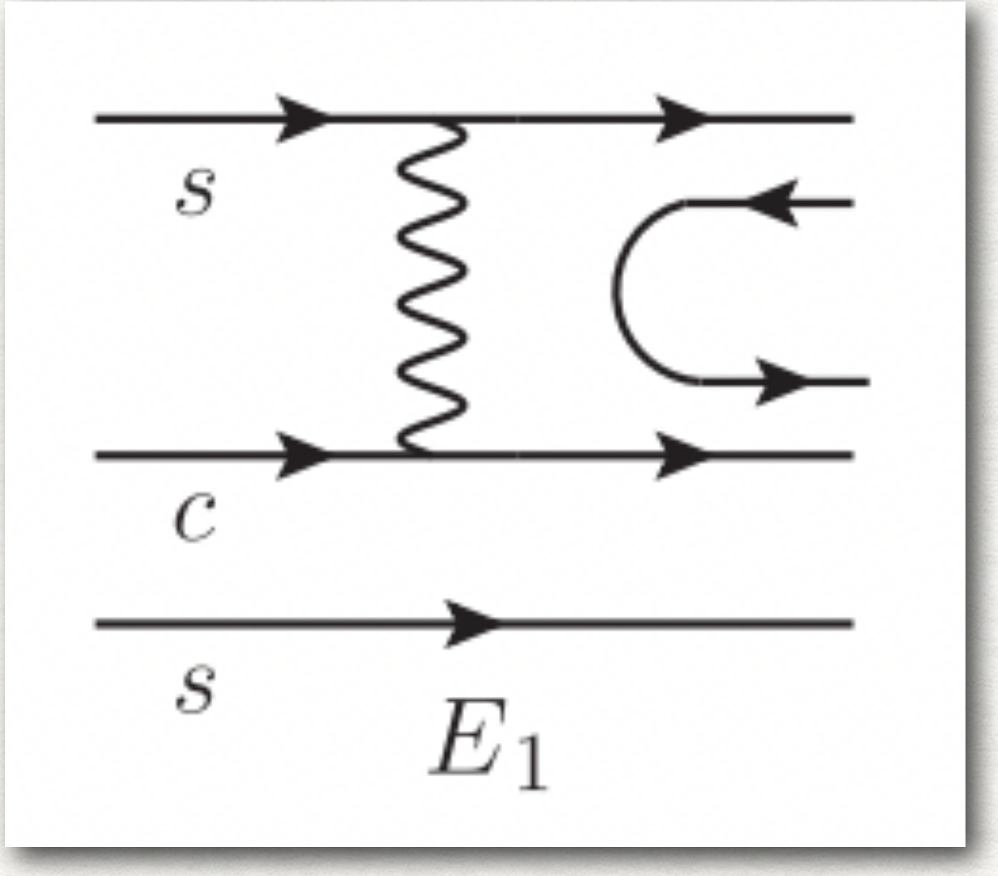
Channel	A^{fac}	A^{com}	A^{tot}	B^{fac}	B^{ca}	B^{tot}	$\mathcal{B}_{\mathrm{theo}}$	α_{theo}
$\Xi_c^+ \to \Lambda\pi^+$	0.46	−1.50	−1.04	−1.69	2.16	0.47	0.85	−0.33
$\Xi_c^+ \to \Sigma^0\pi^+$	−0.90	−1.00	−1.90	3.29	0.74	4.03	4.30	−0.95
$\Xi_c^+ \to \Sigma^+\pi^0$	0.32	1.00	1.32	−1.16	1.61	0.44	1.36	0.23
$\Xi_c^+ \to \Sigma^+\eta$	−0.74	1.42	0.68	2.58	−2.19	0.39	0.32	0.36
$\Xi_c^+ \to p\bar{K}^0$	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	−0.71	−1.65	0.81	−0.59
$\Xi_c^0 \to \Sigma^0\pi^0$	−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	−1.01	−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
$\Xi_c^0 \to n\bar{K}^0$	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

H.-Y. Cheng, F. Xu et. al.
series of works, 2018-2020

HEAVY BARYON WEAK DECAYS

- Weak decay via heavy quark





- Weak decay via light quark: Heavy-Flavor-Conserving weak decays

  the heavy quark behaves as a spectator [heavy quark symmetry, chiral symmetry]

  emitted light mesons are soft [effective Hamiltonian, current algebra]

EXPERIMENTS OF HFC WEAK DECAYS

- $\Xi_b^- \to \Lambda_b^0 \pi^-$

PRL **115,** 241801 (2015) PHYSICAL REVIEW LETTERS week ending 11 DECEMBER 2015

Evidence for the Strangeness-Changing Weak Decay $\Xi_b^- \to \Lambda_b^0 \pi^-$

R. Aaij *et al.**
(LHCb Collaboration)
(Received 13 October 2015; published 11 December 2015)

$$\frac{f_{\Xi_b^-}}{f_{\Lambda_b^0}} \mathcal{B}(\Xi_b^- \to \Lambda_b^0 \pi^-) = (5.7 \pm 1.8^{+0.8}_{-0.9}) \times 10^{-4}$$

0.1 ~ 0.3

$$\mathcal{B}(\Xi_b^- \to \Lambda_b^0 \pi^-) = (0.57 \pm 0.21) \sim (0.19 \pm 0.07)\%$$

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

PHYSICAL REVIEW D **102,** 071101(R) (2020)

Rapid Communications

First branching fraction measurement of the suppressed decay $\Xi_c^0 \to \pi^- \Lambda_c^+$

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

$$\mathcal{B}(\Xi_c^0 \to \pi^- \Lambda_c^+) = (0.55 \pm 0.02 \pm 0.18)\%$$

Order: 10^{-3}

THEORETICAL STUDIES OF HFC WEAK DECAYS

- The early considerations
  - Cheng [(CLY)^2)] 1992

heavy quark plays the role of spectator quark

PHYSICAL REVIEW D VOLUME 46, NUMBER 11 1 DECEMBER 1992

Heavy-flavor-conserving nonleptonic weak decays of heavy baryons

Hai-Yang Cheng, Chi-Yee Cheung, and Guey-Lin Lin
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Hoi-Lai Yu
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(Received 22 June 1992)

PHYSICAL REVIEW D VOLUME 46, NUMBER 3 1 AUGUST 1992

Heavy-quark symmetry and chiral dynamics

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(Received 2 March 1992)

$$B(\Xi_c^0 \to \Lambda_c^+ \pi^-) = 3.8\times 10^{-4}\,,$$
$$B(\Xi_c^+ \to \Lambda_c^+ \pi^0) = 5.0\times 10^{-4}\,,$$
$$B(\Omega_c^0 \to \Xi_c'^+ \pi^-) = 0.9\times 10^{-5}\,.$$

- Some properties
  - PV S-wave: $1/2^-$ poles
  - PC P-wave: $1/2^+$ poles; the amplitudes vanish for antitriplet in heavy quark limit

diquark of antitriplet is scalar: $J^P = 0^+$

angular momentum conservation forbids $0^+ \to 0^+ + 0^-$

$$\Sigma_c^+ = \frac{1}{\sqrt{6}}[(udc + duc)\chi_S + (13) + (23)],$$
$$\Xi_c^+ = \frac{1}{\sqrt{6}}[(usc - suc)\chi_A + (13) + (23)],$$

THEORETICAL STUDIES OF HFC WEAK DECAYS

- The early considerations
  - Gronau-Rosner 2016

    constructive interference: W-exchange & S-wave amp.

PHYSICAL REVIEW D **93**, 034020 (2016)

S-wave nonleptonic hyperon decays and $\Xi_b^- \to \pi^- \Lambda_b$

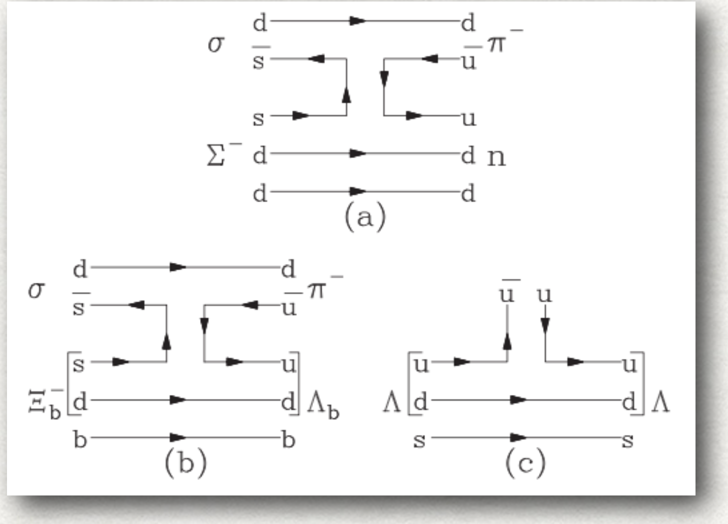
Michael Gronau
Physics Department, Technion, Haifa 32000, Israel

Jonathan L. Rosner
Enrico Fermi Institute and Department of Physics, University of Chicago Chicago, Illinois 60637, USA
(Received 4 January 2016; published 10 February 2016)

$$\mathcal{B}(\Xi_b^- \to \pi^- \Lambda_b) = (6.32 \pm 4.24 \pm 0.16) \times 10^{-3} = (6.3 \pm 4.2) \times 10^{-3},$$

→

$$(1.76^{+2.26}_{-1.34}) \times 10^{-4}$$
$$(1.34 \pm 0.53) \times 10^{-3}$$



  - Cheng [(CLY)^2)] 2016

    destructive interference: W-exchange & S-wave amp.

Mode	$\|A\|$	$\mathcal{B}$	Mode	$\|A\|$	$\mathcal{B}$
$\Xi_c^0 \to \Lambda_c^+ \pi^-$	1.7×10^{-7}	0.87×10^{-4}	$\Xi_b^0 \to \Lambda_b^0 \pi^-$	2.3×10^{-7}	2.0×10^{-3}
				4.3×10^{-7}	6.9×10^{-3}
$\Xi_c^+ \to \Lambda_c^+ \pi^0$	0.9×10^{-7}	0.93×10^{-4}	$\Xi_b^- \to \Lambda_b^0 \pi^0$	1.3×10^{-7}	5.9×10^{-4}
				2.7×10^{-7}	2.5×10^{-3}

branching ratio order: 10^{-4}

THEORETICAL STUDIES OF HFC WEAK DECAYS

- After 2021: spectator W-exchange enhance P-wave amplitude
  - Niu-Wang-Zhao, 2022


Contents lists available at ScienceDirect
Physics Letters B
www.elsevier.com/locate/physletb

Study of heavy quark conserving weak decays in the quark model

Peng-Yu Niu [a,b,c,d], Qian Wang [b,c], Qiang Zhao [a,d,*]
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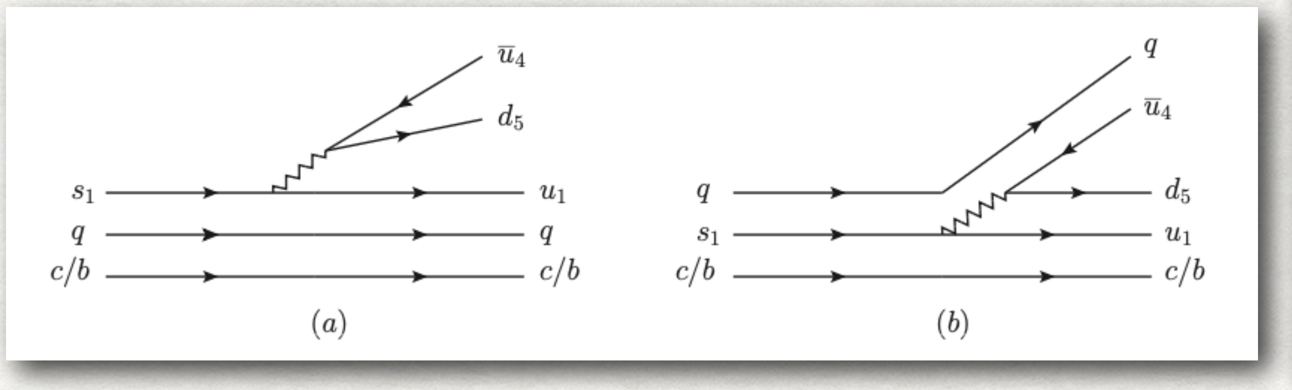
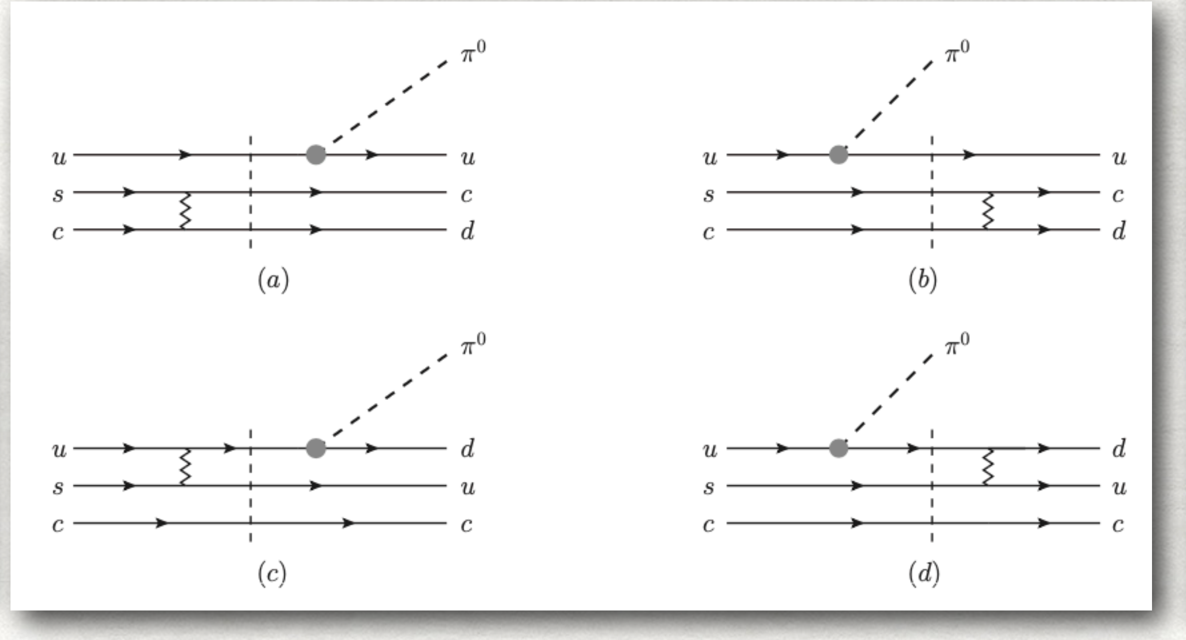
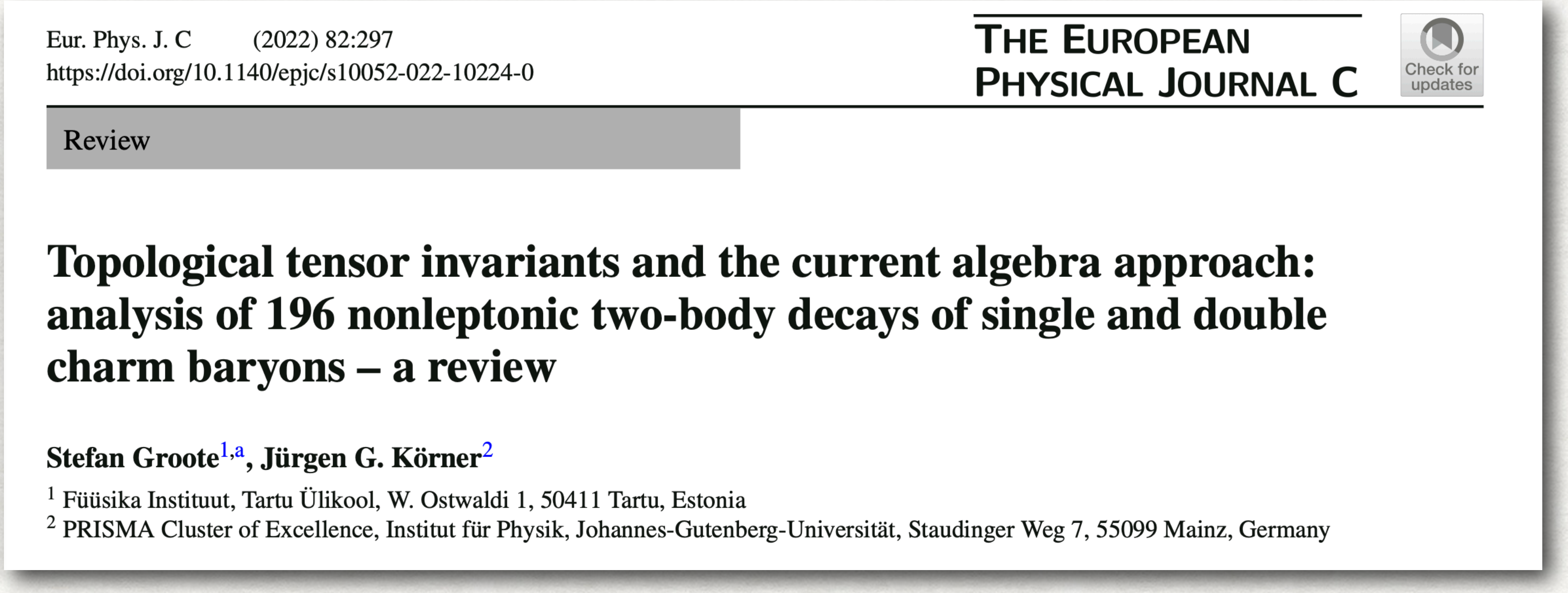
[b] Guangdong Provincial Key Laboratory of Nuclear Science, Institute of Quantum Matter, South China Normal University, Guangzhou 510006, China
[c] Guangdong-Hong Kong Joint Laboratory of Quantum Matter, Southern Nuclear Science Computing Center, South China Normal University, Guangzhou 510006, China
[d] University of Chinese Academy of Sciences, Beijing 100049, China

calculate in NR constitute quark model

Σ_c pole terms enhance $\Xi_c \to \Lambda_c^+ \pi$






Eur. Phys. J. C (2022) 82:297
https://doi.org/10.1140/epjc/s10052-022-10224-0
THE EUROPEAN PHYSICAL JOURNAL C
Review

Topological tensor invariants and the current algebra approach: analysis of 196 nonleptonic two-body decays of single and double charm baryons – a review

Stefan Groote[1,a], Jürgen G. Körner[2]
[1] Füüsika Instituut, Tartu Ülikool, W. Ostwaldi 1, 50411 Tartu, Estonia
[2] PRISMA Cluster of Excellence, Institut für Physik, Johannes-Gutenberg-Universität, Staudinger Weg 7, 55099 Mainz, Germany

  - Groote-Korner, 2021
  - How about make use of Current Algebra?

Don’t forget the origin!

GENERAL DESCRIPTION

DEPICT THE TWO-BODY WEAK DECAY

- at quark level

light quark

$$H_{\rm eff} = \frac{G_F}{\sqrt{2}} V_{ud}^* V_{us} (c_1 O_1 + c_2 O_2) + \text{H.c.}$$

$$O_1 = (\bar{d}u)(\bar{u}s), \qquad O_2 = (\bar{d}s)(\bar{u}u),$$

"spectator" quark

$$H_{\rm eff}^{(c)} = \frac{G_F}{\sqrt{2}} V_{cd}^* V_{cs} (c_1 \tilde{O}_1 + c_2 \tilde{O}_2) + \text{H.c.},$$

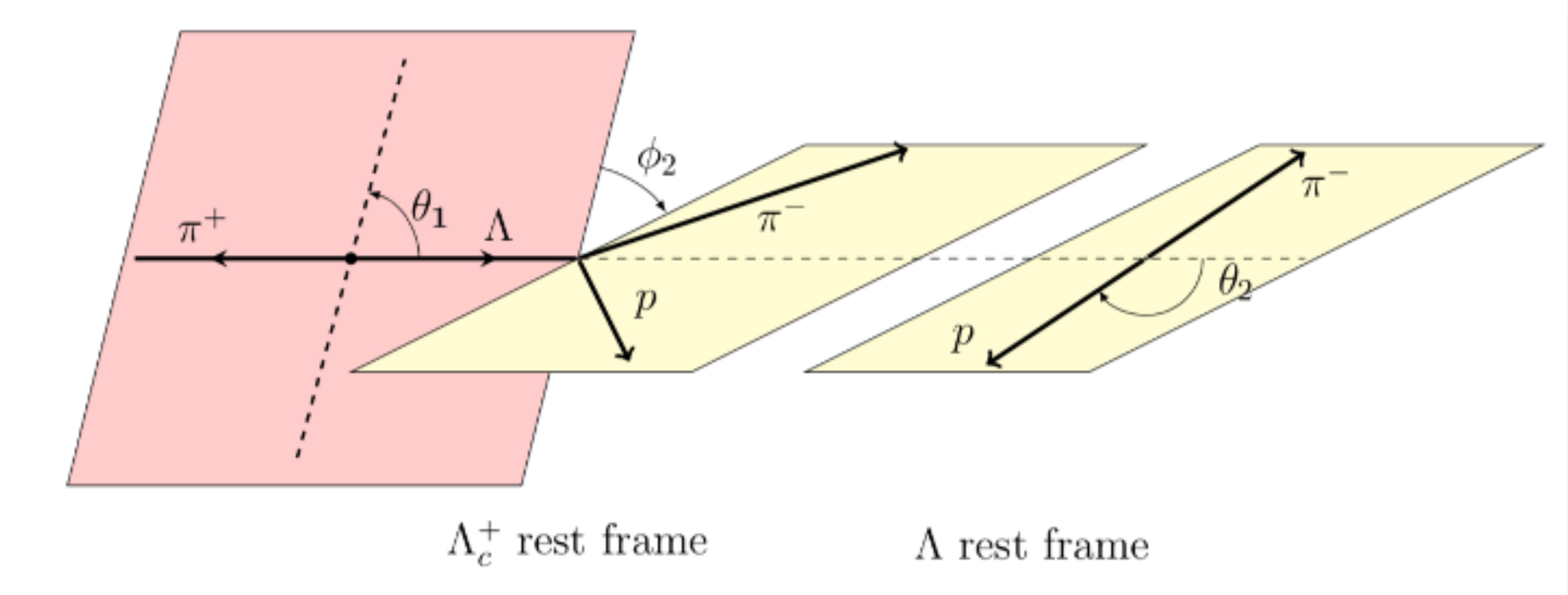
$$\tilde{O}_1 = (\bar{d}c)(\bar{c}s) \text{ and } \tilde{O}_2 = (\bar{c}c)(\bar{d}s)$$

- at hadron level

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

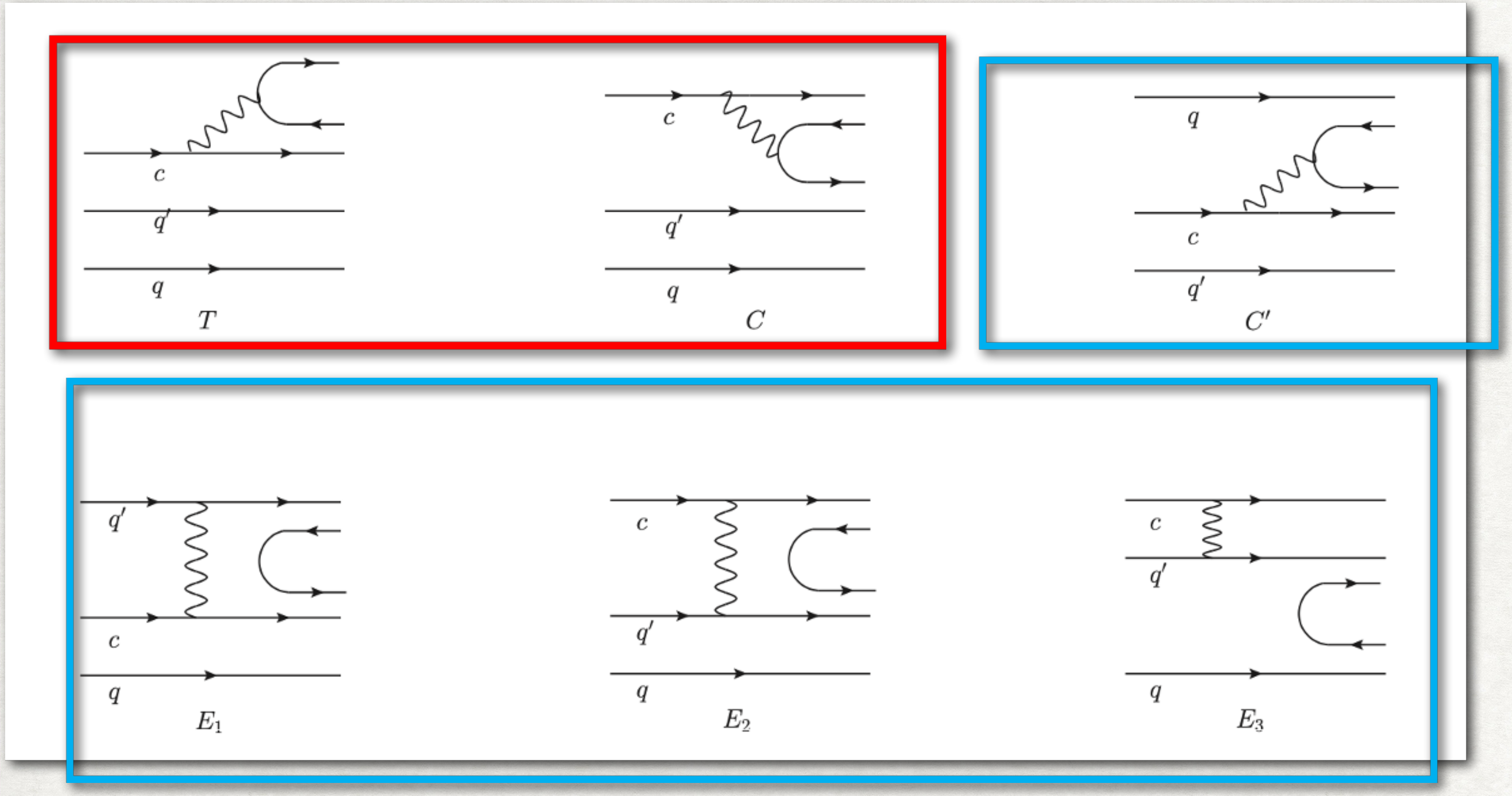
$$\Gamma = \frac{p_c}{8\pi} \left[\frac{(m_i + m_f)^2 - m_P^2}{m_i^2} |A|^2 + \frac{(m_i - m_f)^2 - m_P^2}{m_i^2} |B|^2 \right]$$

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



TOPOLOGICAL APPROACH

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

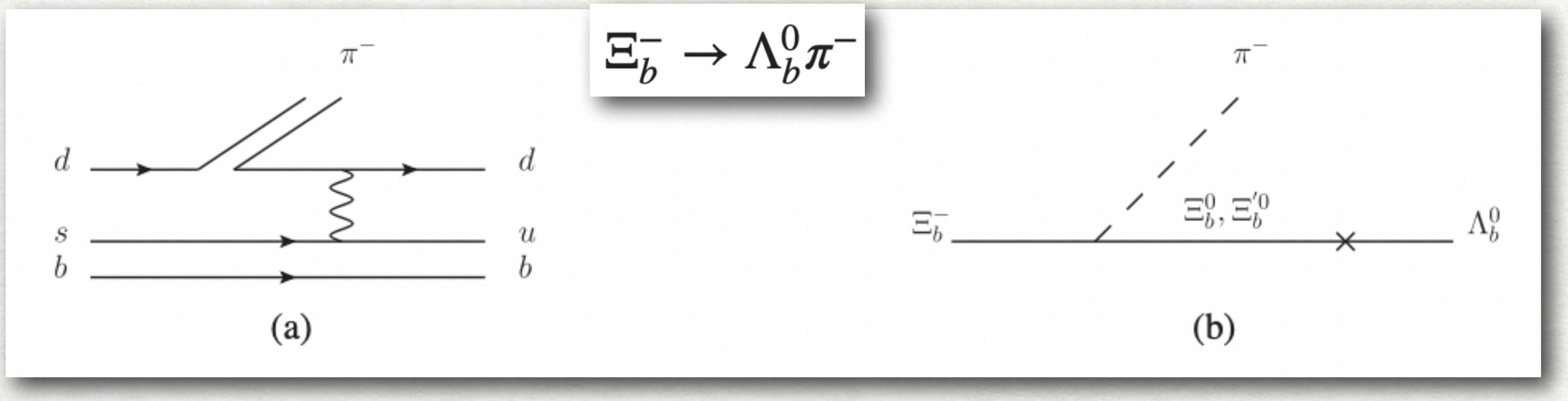


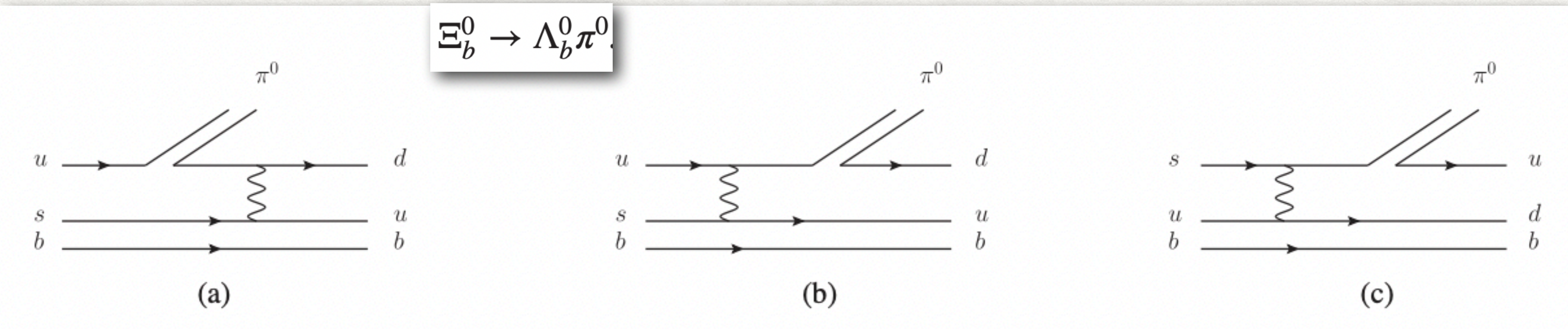
$$A = A^{\rm fac} + A^{\rm nf}$$

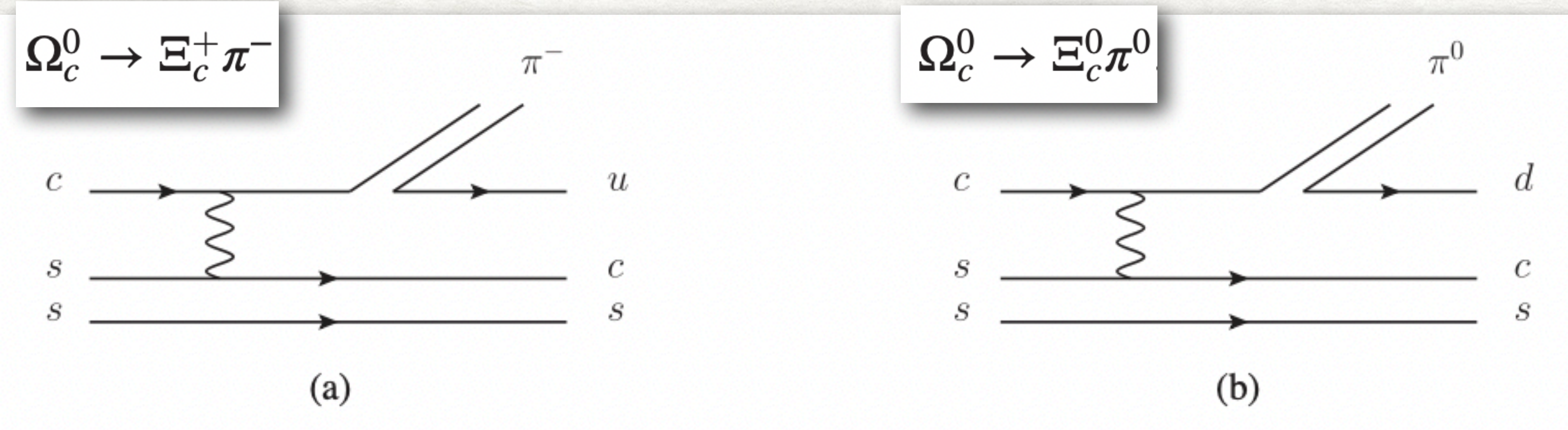
$$B = B^{\rm fac} + B^{\rm nf}$$

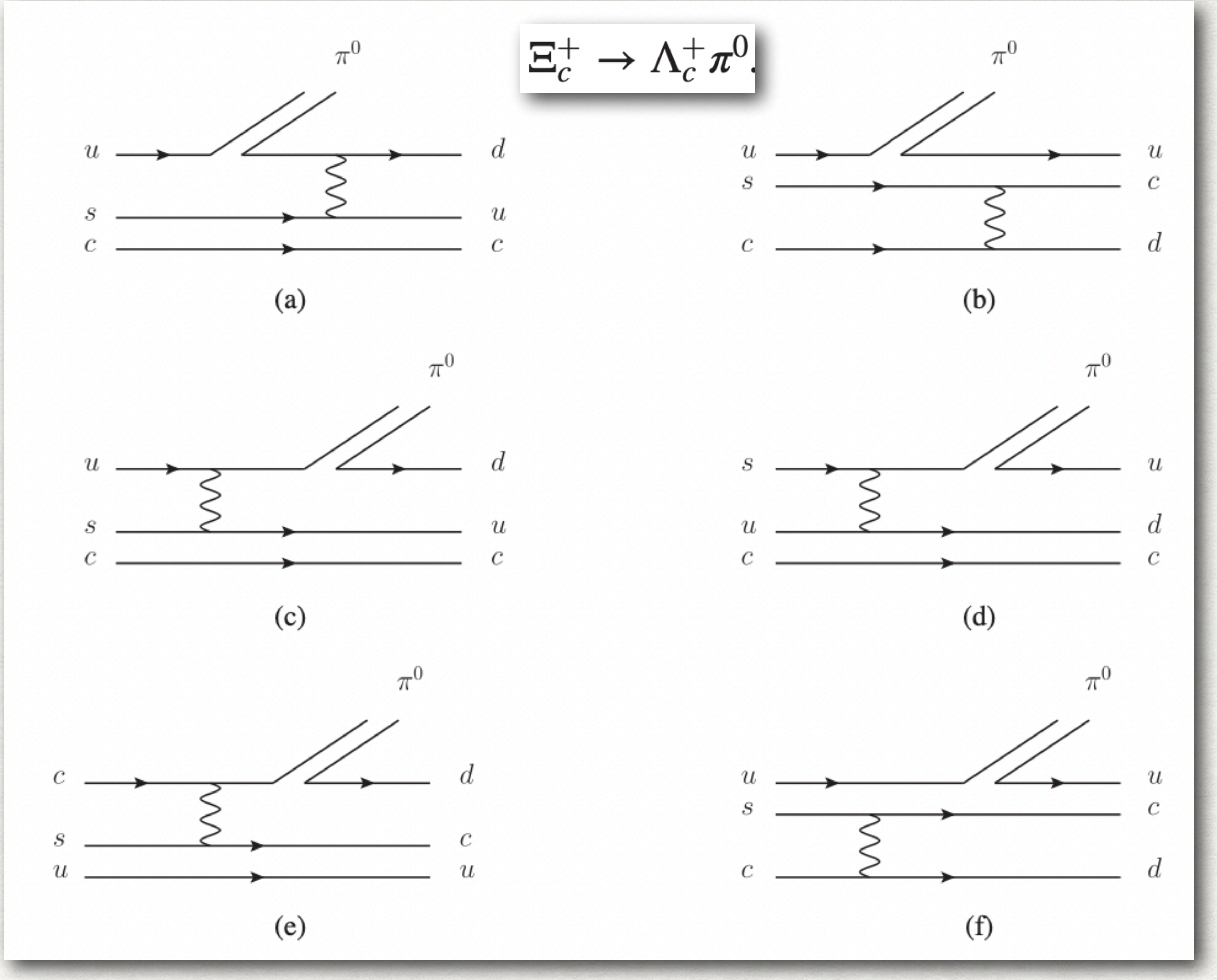
L.-L. Chau, H.-Y. Cheng and B. Tseng, Phys. Rev. D 54(1996)2132

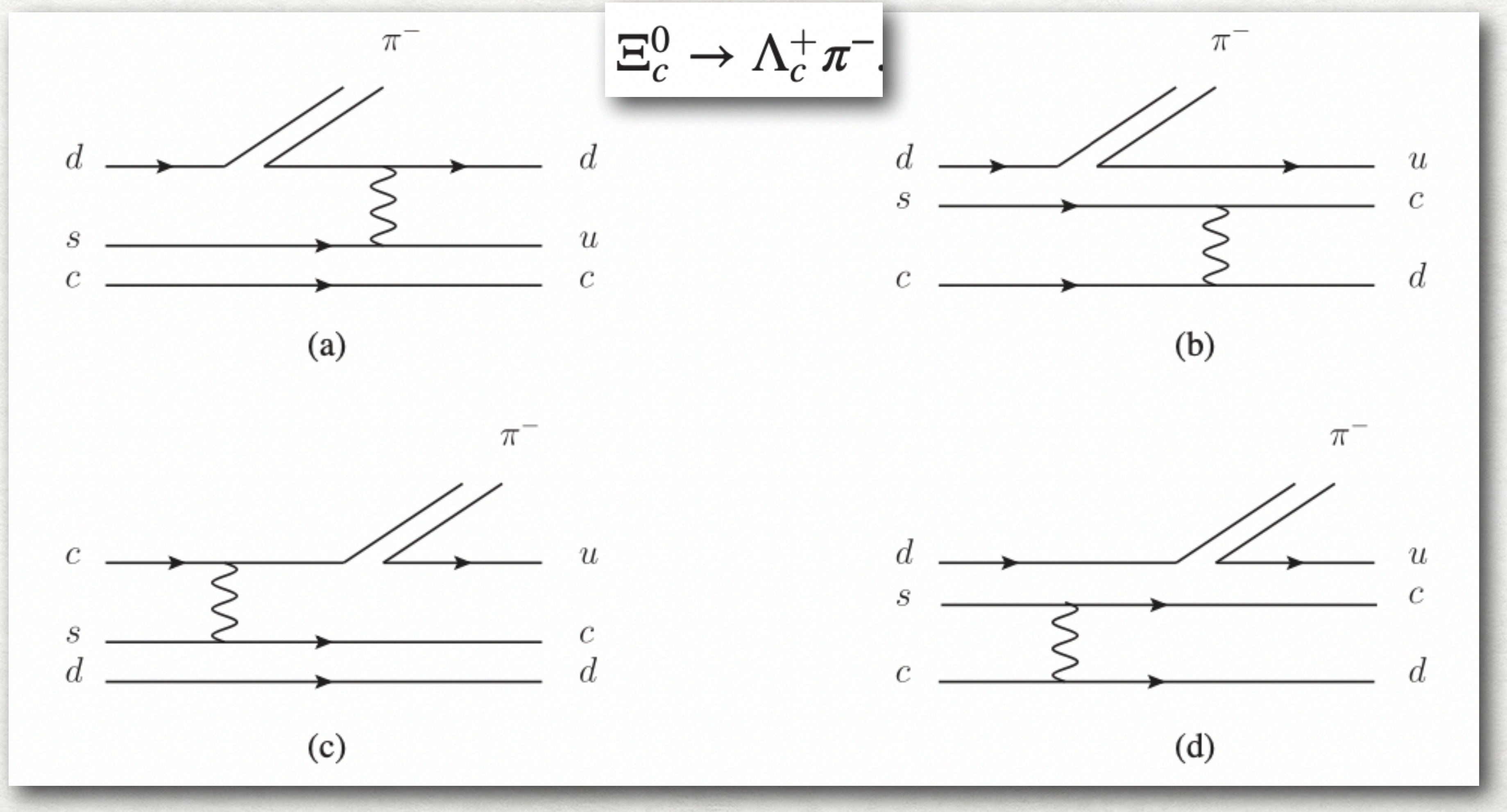
TOPOLOGICAL APPROACH











S-WAVE AMPLITUDES

FACTORIZABLE S-WAVE AMP.

Ξ_c decays： s decay

$$\langle \pi^- \Lambda_c^+ | H_{\rm eff} | \Xi_c^0 \rangle^{\rm fac} = \frac{G_F}{\sqrt{2}} V_{ud}^* V_{us} a_1 \langle \pi^- | (\bar{d}u) | 0 \rangle \langle \Lambda_c^+ | (\bar{u}s) | \Xi_c^0 \rangle$$

$$\langle \pi^0 \Lambda_c^+ | H_{\rm eff} | \Xi_c^+ \rangle^{\rm fac} = \frac{G_F}{\sqrt{2}} V_{ud}^* V_{us} a_2 \langle \pi^0 | (\bar{u}u) | 0 \rangle \langle \Lambda_c^+ | (\bar{d}s) | \Xi_c^+ \rangle$$

$$a_1 = c_1 + \frac{c_2}{N_c}, \qquad a_2 = c_2 + \frac{c_1}{N_c}$$

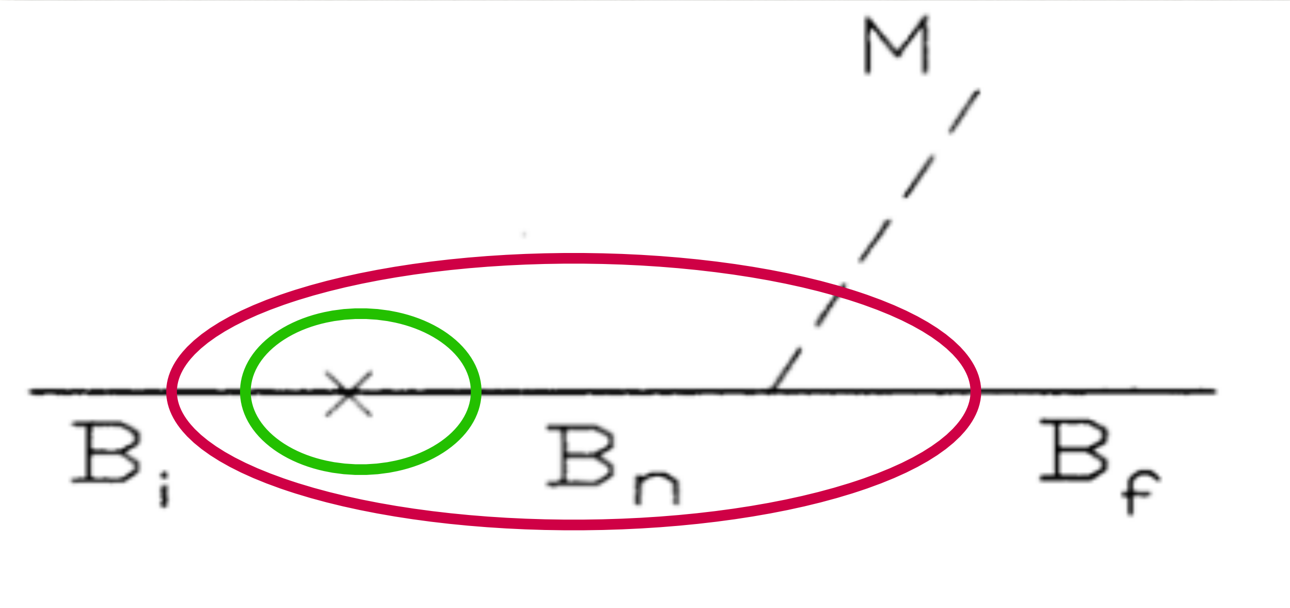
$$\langle \Lambda_c^+ | (\bar{u}s) | \Xi_c^0 \rangle = \bar{u}_{\Lambda_c} \Big[f_1^{\Lambda_c \Xi_c}(q^2) \gamma_\mu + f_2^{\Lambda_c \Xi_c}(q^2) i\sigma_{\mu\nu} q^\nu + f_3^{\Lambda_c \Xi_c}(q^2) q_\mu - g_1^{\Lambda_c \Xi_c}(q^2) \gamma_\mu \gamma_5 - g_2^{\Lambda_c \Xi_c}(q^2) i\sigma_{\mu\nu} q^\nu \gamma_5 - g_3^{\Lambda_c \Xi_c}(q^2) q_\mu \gamma_5 \Big] u_{\Xi_c}$$

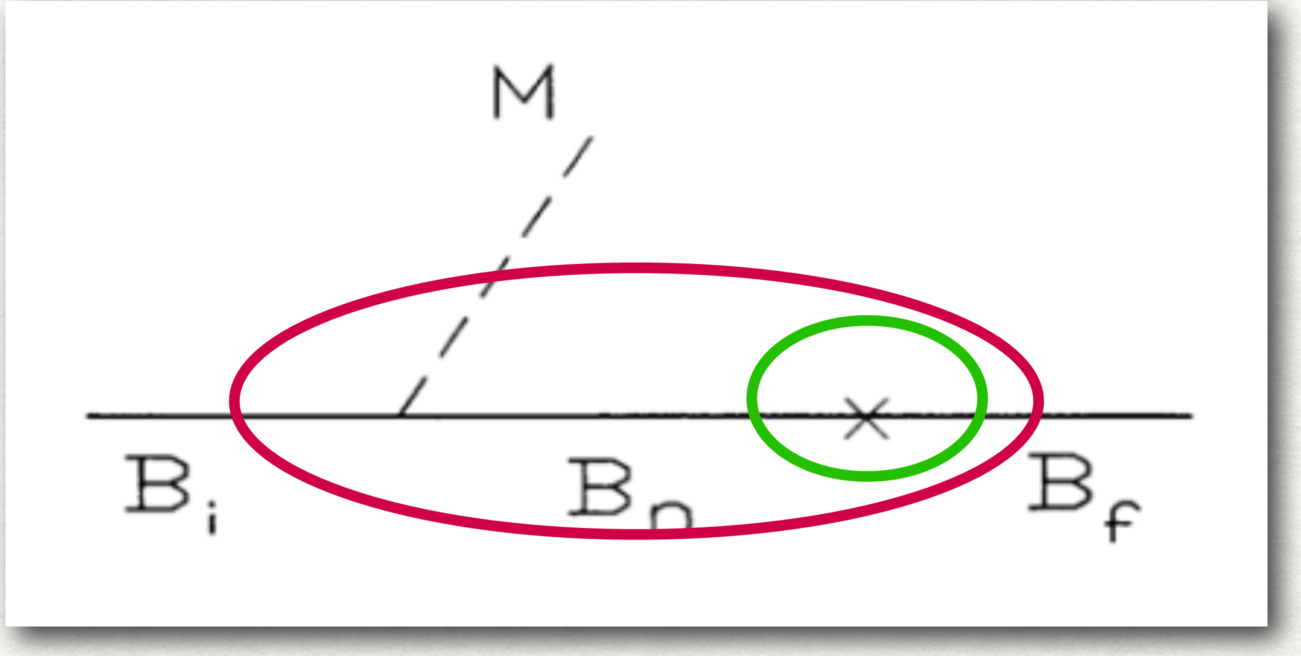
$$A(\Xi_c^0 \to \Lambda_c^+ \pi^-)^{\rm fac} = -\frac{G_F}{\sqrt{2}} V_{ud}^* V_{us}\, a_1 f_\pi (m_{\Xi_c} - m_{\Lambda_c}) f_1^{\Lambda_c^+ \Xi_c^0}(m_\pi^2),$$

$$A(\Xi_c^+ \to \Lambda_c^+ \pi^0)^{\rm fac} = -\frac{G_F}{2} V_{ud}^* V_{us}\, a_2 f_\pi (m_{\Xi_c} - m_{\Lambda_c}) f_1^{\Lambda_c^+ \Xi_c^+}(m_\pi^2).$$

NONFACTORIZABLE S-WAVE AMP.

Pole model





$$\langle \mathcal{B}_i | H_{\rm eff} | \mathcal{B}_j \rangle = \bar{u}_i (a_{ij} + b_{ij}\gamma_5) u_j$$

$$\langle \mathcal{B}_i^*(1/2^-) | H_{\rm eff}^{\rm pv} | \mathcal{B}_i \rangle = b_{i^*j} \bar{u}_i u_j$$

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

$$A^{\rm pole} = -\sum_{\mathcal{B}_n^*(1/2^-)} \left[\frac{g_{\mathcal{B}_f \mathcal{B}_{n^*} M} b_{n^* i}}{m_i - m_{n^*}} + \frac{b_{f n^*} g_{\mathcal{B}_{n^*} \mathcal{B}_i M}}{m_f - m_{n^*}} \right] + \cdots ,$$

$$B^{\rm pole} = -\sum_{\mathcal{B}_n} \left[\frac{g_{\mathcal{B}_f \mathcal{B}_n M} a_{ni}}{m_i - m_n} + \frac{a_{fn} g_{\mathcal{B}_n \mathcal{B}_i M}}{m_f - m_n} \right] + \cdots ,$$

intermediate state: $1/2^-$ complicated!

NONFACTORIZABLE S-WAVE AMP.

current algebra technique

Goldberger-Treiman relation:
$$g_{\mathcal{B}'\mathcal{B}P^a} = \frac{\sqrt{2}}{f_{P^a}}(m_{\mathcal{B}'} + m_{\mathcal{B}})g^A_{\mathcal{B}'\mathcal{B}}, \qquad g_{\mathcal{B}^*\mathcal{B}P^a} = \frac{\sqrt{2}}{f_{P^a}}(m_{\mathcal{B}^*} - m_{\mathcal{B}})g^A_{\mathcal{B}^*\mathcal{B}},$$

soft-pion limit: $A^{\rm pole} \to A^{\rm com}$

$$b_{ji^*} = -b_{i^*j}$$

$$A^{\rm pole} = -\sum_{\mathcal{B}^*_n(1/2^-)}\left[\frac{g_{\mathcal{B}_f\mathcal{B}_{n^*}M}b_{n^*i}}{m_i - m_{n^*}} + \frac{b_{fn^*}g_{\mathcal{B}_{n^*}\mathcal{B}_iM}}{m_f - m_{n^*}}\right] + \cdots$$

↓

$$A^{\rm com} = -\frac{\sqrt{2}}{f_{P^a}}\langle\mathcal{B}_f|[Q^a_5, \mathcal{H}^{\rm pv}_{\rm eff}]|\mathcal{B}_i\rangle = -\frac{\sqrt{2}}{f_{P^a}}\langle\mathcal{B}_f|[Q^a, \mathcal{H}^{\rm pc}_{\rm eff}]|\mathcal{B}_i\rangle$$

$$Q^a = \int d^3x\bar{q}\gamma^0\frac{\lambda^a}{2}q, \qquad Q^a_5 = \int d^3x\bar{q}\gamma^0\gamma_5\frac{\lambda^a}{2}q.$$

tedious calculation related to $1/2^-$ can be avoided

NONFACTORIZABLE S-WAVE AMP.

An example

$$A^{\rm com} = -\frac{\sqrt{2}}{f_{P^a}}\langle \mathcal{B}_f|[Q^a, \mathcal{H}_{\rm eff}^{\rm pc}]|\mathcal{B}_i\rangle$$

$$\begin{aligned} A(\Xi_c^0 \to \Lambda_c^+\pi^-)^{\rm nf} &= -\frac{1}{f_\pi}\langle \Lambda_c^+|\,[I_+, \mathcal{H}_{\rm eff} + \mathcal{H}_{\rm eff}^{(c)}]\,|\Xi_c^0\rangle \\ &= \frac{1}{f_\pi}\langle \Lambda_c^+|\mathcal{H}_{\rm eff}|\Xi_c^+\rangle + \frac{1}{f_\pi}\langle \Lambda_c^+|\mathcal{H}_{\rm eff}^{(c)}|\Xi_c^+\rangle, \\ &\equiv A^{\rm nf}_{su\to ud} + A^{\rm nf}_{cs\to cd} \end{aligned}$$

$$I_+|d\rangle = |u\rangle$$

$$\left.\begin{matrix} A^{\rm nf}_{su\to ud} \\ A^{\rm nf}_{cs\to cd} \end{matrix}\right\} = \frac{G_F}{2\sqrt{2}f_\pi}V_{ud}^*V_{us}(c_1-c_2)\left\{\begin{matrix} X \\ -Y, \end{matrix}\right.$$

$$\begin{aligned} X &\equiv \langle \Lambda_c^+|(\bar{d}u)(\bar{u}s) - (\bar{u}u)(\bar{d}s)|\Xi_c^+\rangle, \\ Y &\equiv \langle \Lambda_c^+|(\bar{d}c)(\bar{s}c) - (\bar{c}c)(\bar{d}s)|\Xi_c^+\rangle. \end{aligned}$$

$$V_{cd}^*V_{cs} = -V_{ud}^*V_{us}$$

total s-wave amp.

$$\begin{aligned} A(\Xi_c^0 \to \Lambda_c^+\pi^-) &= A^{\rm fac} + A^{\rm nf}_{su\to ud} + A^{\rm nf}_{sc\to cd} \\ &= \frac{G_F}{\sqrt{2}f_\pi}V_{ud}^*V_{us}\left[-a_1 f_\pi (m_{\Xi_c} - m_{\Lambda_c}) f_1^{\Lambda_c^+\Xi_c^0}(m_\pi^2) + \frac{1}{2}(c_1-c_2)(X-Y)\right] \end{aligned}$$

NONFACTORIZABLE S-WAVE AMP.

other results

$$A(\Xi_c^0 \to \Lambda_c^+ \pi^-) = A^{\rm fac} + A^{\rm nf}_{su\to ud} + A^{\rm nf}_{sc\to cd}$$
$$= \frac{G_F}{\sqrt{2} f_\pi} V_{ud}^* V_{us} \left[-a_1 f_\pi (m_{\Xi_c} - m_{\Lambda_c}) f_1^{\Lambda_c^+ \Xi_c^0}(m_\pi^2) + \frac{1}{2}(c_1 - c_2)(X - Y) \right]$$

$$A(\Xi_c^+ \to \Lambda_c^+ \pi^0) = \frac{G_F}{2 f_\pi} V_{ud}^* V_{us} \left[-a_2 f_\pi^2 (m_{\Xi_c} - m_{\Lambda_c}) f_1^{\Lambda_c^+ \Xi_c^+}(m_\pi^2) + \frac{1}{2}(c_1 - c_2)(X - Y) \right]$$
$$A(\Xi_b^- \to \Lambda_b^0 \pi^-) = \frac{G_F}{\sqrt{2} f_\pi} V_{ud}^* V_{us} \left[-a_1 f_\pi^2 (m_{\Xi_b} - m_{\Lambda_b}) f_1^{\Lambda_b^0 \Xi_b^-}(m_\pi^2) + \frac{1}{2}(c_1 - c_2) X \right],$$
$$A(\Xi_b^0 \to \Lambda_b^0 \pi^0) = \frac{G_F}{2 f_\pi} V_{ud}^* V_{us} \left[-a_2 f_\pi^2 (m_{\Xi_b} - m_{\Lambda_b}) f_1^{\Lambda_b^0 \Xi_b^0}(m_\pi^2) + \frac{1}{2}(c_1 - c_2) X \right].$$

heavy quark W-exchange

$$A(\Omega_c^0 \to \Xi_c^+ \pi^-) = -\frac{G_F}{\sqrt{2}} V_{ud}^* V_{us} a_1 f_\pi (m_{\Omega_c} - m_{\Xi_c}) f_1^{\Xi_c^+ \Omega_c^0}(m_\pi^2) - \frac{1}{f_\pi} \langle \Xi_c^0 | \mathcal{H}_{\rm eff} + \mathcal{H}_{\rm eff}^{(c)} | \Omega_c^0 \rangle,$$
$$A(\Omega_c^0 \to \Xi_c^0 \pi^0) = -\frac{G_F}{2} V_{ud}^* V_{us} a_2 f_\pi (m_{\Omega_c} - m_{\Xi_c}) f_1^{\Xi_c^0 \Omega_c^0}(m_\pi^2) + \frac{1}{\sqrt{2} f_\pi} \langle \Xi_c^0 | \mathcal{H}_{\rm eff} + \mathcal{H}_{\rm eff}^{(c)} | \Omega_c^0 \rangle$$

$$\langle \Xi_c^+ | b_u^\dagger b_s | \Omega_c^0 \rangle \qquad \langle \Xi_c^0 | b_d^\dagger b_s | \Omega_c^0 \rangle \qquad \langle \mathcal{B}_{\bar 3} | \mathcal{H}_{\rm eff} | \mathcal{B}_6 \rangle = 0$$

$$A(\Omega_c^0 \to \Xi_c^+ \pi^-) = -\frac{1}{f_\pi} a_{\Xi_c^0 \Omega_c^0}, \qquad A(\Omega_c^0 \to \Xi_c^0 \pi^0) = \frac{1}{\sqrt{2} f_\pi} a_{\Xi_c^0 \Omega_c^0}$$

$$A(\Omega_b^- \to \Xi_b \pi) = 0$$

$$a_{\Xi_c^0 \Omega_c^0} = \langle \Xi_c^0 | \mathcal{H}_{\rm eff}^{(c)} | \Omega_c^0 \rangle$$

P-WAVE AMPLITUDES

FACTORIZABLE P-WAVE AMP.

Ξ_c decays： s decay

$$\langle \pi^- \Lambda_c^+ | H_{\rm eff} | \Xi_c^0 \rangle^{\rm fac} = \frac{G_F}{\sqrt{2}} V_{ud}^* V_{us} a_1 \langle \pi^- | (\bar{d}u) | 0 \rangle \langle \Lambda_c^+ | (\bar{u}s) | \Xi_c^0 \rangle$$
$$\langle \pi^0 \Lambda_c^+ | H_{\rm eff} | \Xi_c^+ \rangle^{\rm fac} = \frac{G_F}{\sqrt{2}} V_{ud}^* V_{us} a_2 \langle \pi^0 | (\bar{u}u) | 0 \rangle \langle \Lambda_c^+ | (\bar{d}s) | \Xi_c^+ \rangle$$

$$a_1 = c_1 + \frac{c_2}{N_c}, \qquad a_2 = c_2 + \frac{c_1}{N_c}$$

$$\langle \Lambda_c^+ | (\bar{u}s) | \Xi_c^0 \rangle = \bar{u}_{\Lambda_c} \Big[f_1^{\Lambda_c \Xi_c}(q^2) \gamma_\mu + f_2^{\Lambda_c \Xi_c}(q^2) i\sigma_{\mu\nu} q^\nu + f_3^{\Lambda_c \Xi_c}(q^2) q_\mu - g_1^{\Lambda_c \Xi_c}(q^2) \gamma_\mu \gamma_5 - g_2^{\Lambda_c \Xi_c}(q^2) i\sigma_{\mu\nu} q^\nu \gamma_5 - g_3^{\Lambda_c \Xi_c}(q^2) q_\mu \gamma_5 \Big] u_{\Xi_c}$$

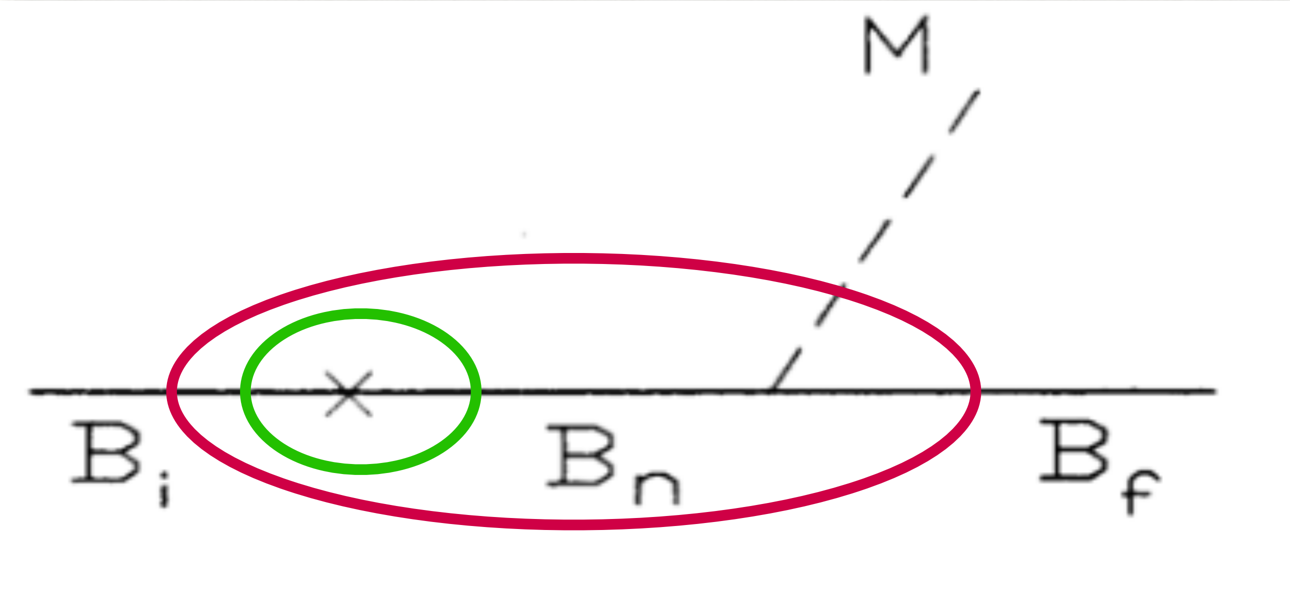
$$A(\Xi_c^0 \to \Lambda_c^+ \pi^-)^{\rm fac} = -\frac{G_F}{\sqrt{2}} V_{ud}^* V_{us} a_1 f_\pi (m_{\Xi_c} - m_{\Lambda_c}) f_1^{\Lambda_c^+ \Xi_c^0}(m_\pi^2),$$
$$B(\Xi_c^0 \to \Lambda_c^+ \pi^-)^{\rm fac} = \frac{G_F}{\sqrt{2}} V_{ud}^* V_{us} a_1 f_\pi (m_{\Xi_c} + m_{\Lambda_c}) g_1^{\Lambda_c \Xi_c}(m_\pi^2)$$

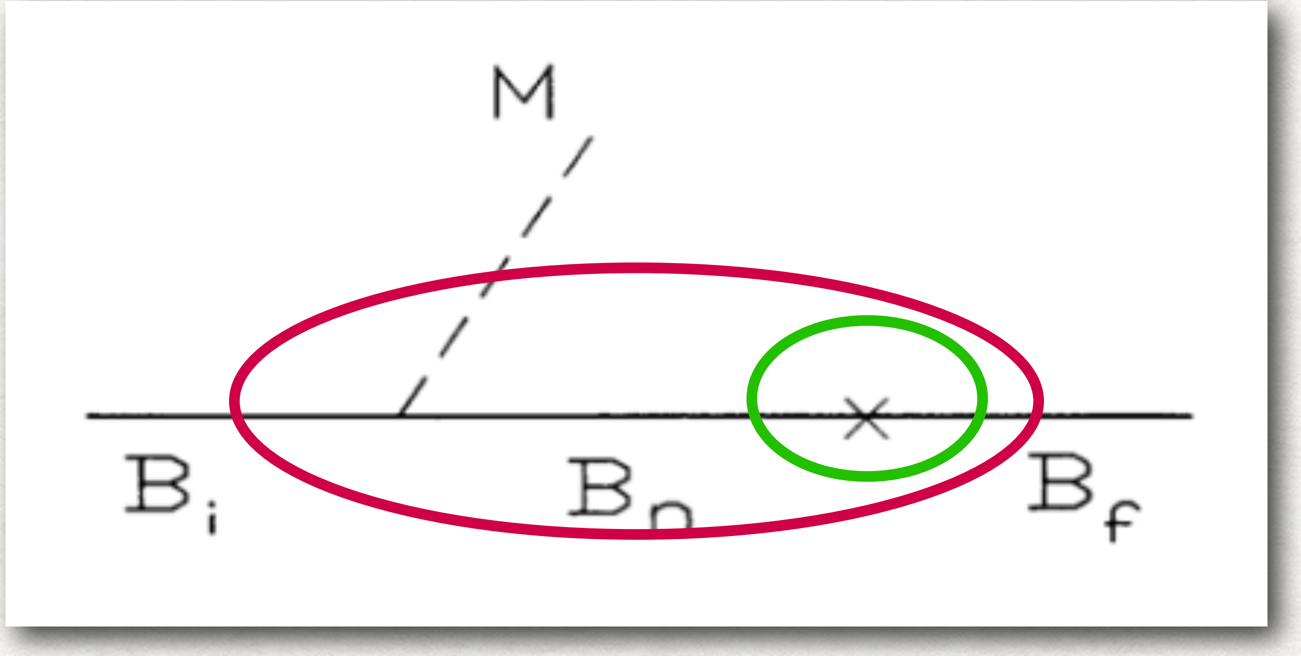
$$\langle B_{\bar{3}}(v',s') | q^\mu A_\mu^a | B_{\bar{3}}(v,s) \rangle = \langle 0 | \bar{u}(v',s') \phi_{v'} h_{v'} (q^\mu A_\mu^a) \bar{h}_v \phi_v^\dagger u(v,s) | 0 \rangle = \langle 0 | \bar{u}(v',s') h_{v'} \bar{h}_v u(v,s) | 0 \rangle \langle 0 | \phi_{v'} (q^\mu A_\mu^a) \phi_v^\dagger | 0 \rangle$$

vanishes in heavy quark limit

NONFACTORIZABLE S-WAVE AMP.

Pole model





$$A^{\rm pole} = -\sum_{\mathcal{B}_n^*(1/2^-)} \left[\frac{g_{\mathcal{B}_f\mathcal{B}_{n^*}M}\, b_{n^*i}}{m_i - m_{n^*}} + \frac{b_{fn^*}\, g_{\mathcal{B}_{n^*}\mathcal{B}_iM}}{m_f - m_{n^*}}\right] + \cdots,$$

$$B^{\rm pole} = -\sum_{\mathcal{B}_n} \left[\frac{g_{\mathcal{B}_f\mathcal{B}_nM}\, a_{ni}}{m_i - m_n} + \frac{a_{fn}\, g_{\mathcal{B}_n\mathcal{B}_iM}}{m_f - m_n}\right] + \cdots,$$

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

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

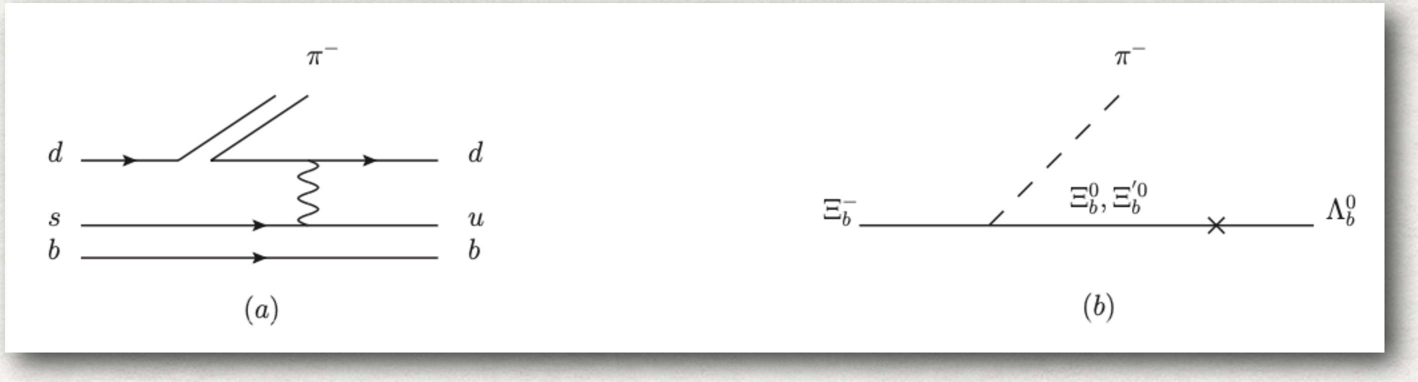
NONFACTORIZABLE P-WAVE AMP.

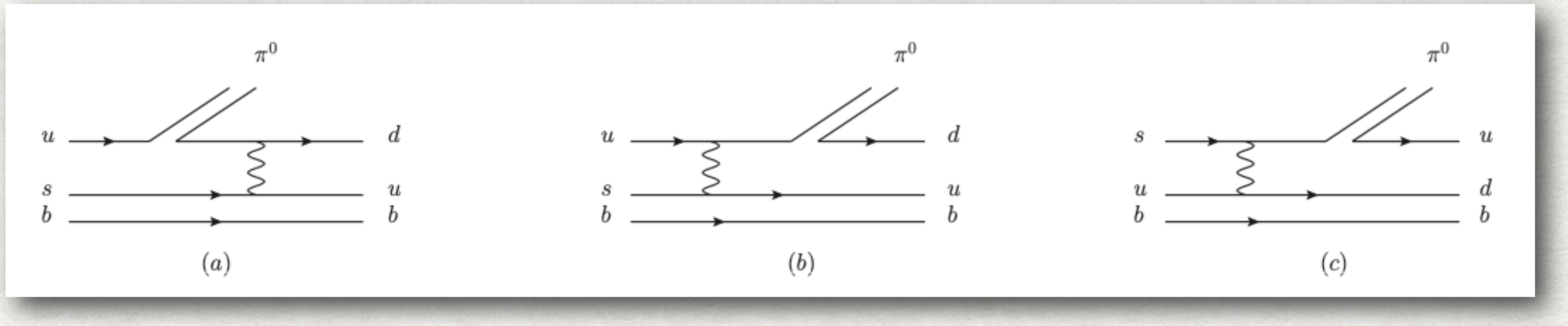
Ξ_b decays

$$a_{\Lambda_b^0\Xi_b^0} = \langle \Lambda_b^0|\mathcal{H}_{\rm eff}|\Xi_b^0\rangle$$

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

$$B(\Xi_b^0 \to \Lambda_b^0\pi^0)^{\rm pole} = -\frac{\sqrt{2}}{f_\pi}\left(g^{A(\pi^0)}_{\Lambda_b^0\Sigma_b^0}\frac{m_{\Lambda_b^0}+m_{\Sigma_b^0}}{m_{\Xi_b^0}-m_{\Sigma_b^0}}a_{\Sigma_b^0\Xi_b^0} + g^{A(\pi^0)}_{\Lambda_b^0\Lambda_b^0}\frac{2m_{\Lambda_b^0}}{m_{\Xi_b^0}-m_{\Lambda_b^0}}a_{\Lambda_b^0\Xi_b^0}\right.$$
$$\left. + a_{\Lambda_b^0\Xi_b^0}\frac{2m_{\Xi_b^0}}{m_{\Lambda_b^0}-m_{\Xi_b^0}}g^{A(\pi^0)}_{\Xi_b^0\Xi_b^0} + a_{\Lambda_b^0\Xi_b'^0}\frac{m_{\Xi_b^0}+m_{\Xi_b'^0}}{m_{\Lambda_b^0}-m_{\Xi_b'^0}}g^{A(\pi^0)}_{\Xi_b'^0\Xi_b^0}\right),$$





no extra W-exchange diagram

$$\langle \mathcal{B}_{\bar 3}|\mathcal{H}_{\rm eff}|\mathcal{B}_6\rangle = 0$$

$$\mathrm{Tr}(\bar{\mathcal{B}}_{\bar 3}\gamma_\mu\gamma_5 A^\mu \mathcal{B}_{\bar 3}) \to 0$$ (heavy quark limit)

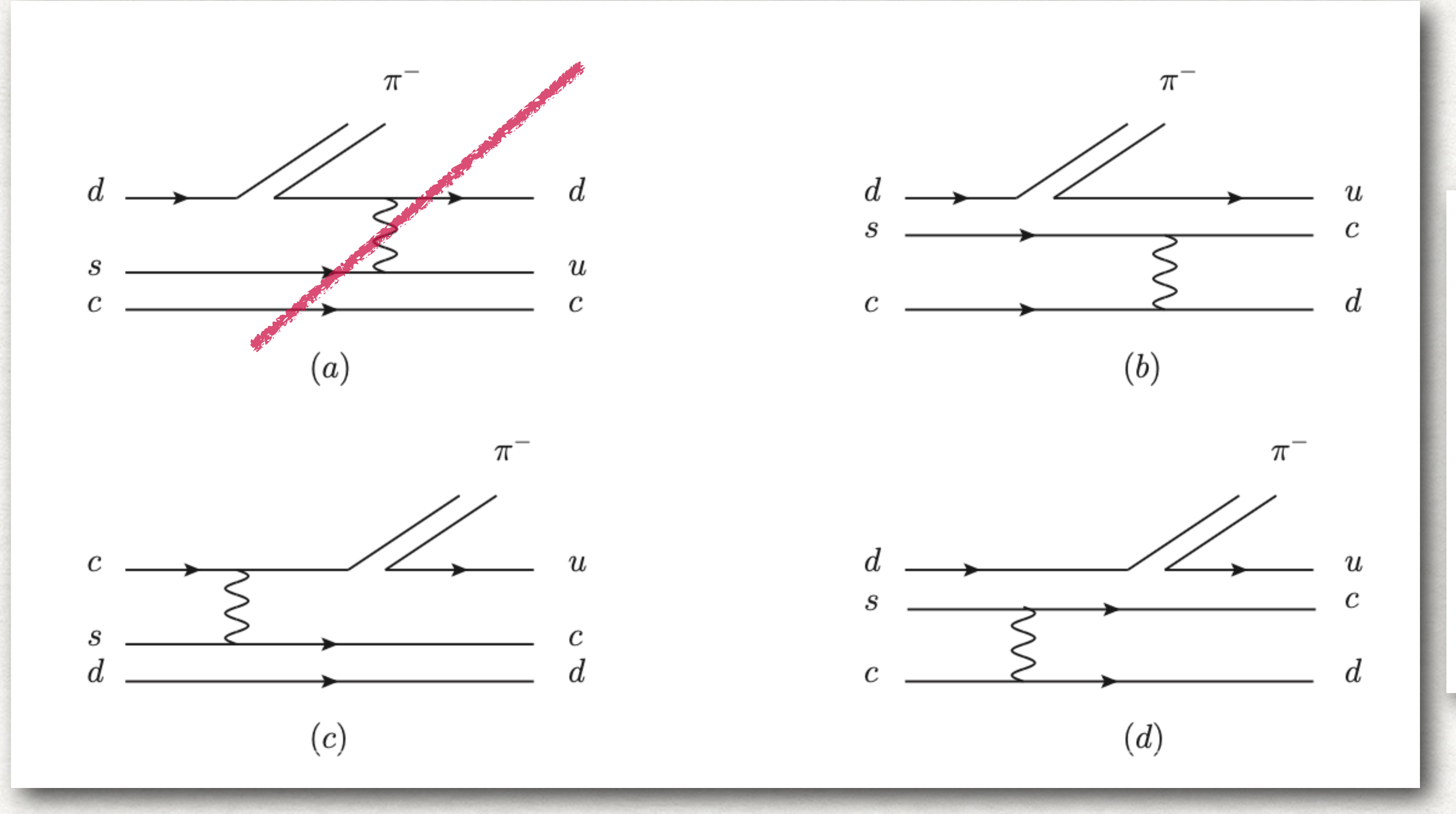
$\Longrightarrow$ no P-wave contributions!

- $J^P(\text{diquark in } \bar 3) = 0^+$, $\quad 0^+ \to 0^+ + 0^-$ for $\mathscr{B}_{\bar 3} \to \mathscr{B}_{\bar 3} + P$ is forbidden for p-wave, angular momentum conservation

NONFACTORIZABLE P-WAVE AMP.

Ξ_c decays: only non-spectator W-exchange diagrams contribute

- factorizable amplitudes vanish



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

$$B(\Xi_c^+ \to \Lambda_c^+ \pi^0)^{\rm pole} = -\frac{\sqrt{2}}{f_\pi}\left(g^{A(\pi^0)}_{\Lambda_c^+\Sigma_c^+} \frac{m_{\Lambda_c^+} + m_{\Sigma_c^+}}{m_{\Xi_c^+} - m_{\Sigma_c^+}} a_{\Sigma_c^+ \Xi_c^+} + a_{\Lambda_c^+ \Xi_c'^+} \frac{m_{\Xi_c^+} + m_{\Xi_c'^+}}{m_{\Lambda_c^+} - m_{\Xi_c'^+}} g^{A(\pi^0)}_{\Xi_c'^+ \Xi_c^+} \right)$$

$$a_{\Sigma_c^{0(+)}\Xi_c^{0(+)}} = \langle \Sigma_c^{0(+)} | \mathcal{H}_{\rm eff}^{(c)} | \Xi_c^{0(+)} \rangle, \qquad a_{\Lambda_c^+ \Xi_c'^+} = \langle \Lambda_c^+ | \mathcal{H}_{\rm eff}^{(c)} | \Xi_c'^+ \rangle$$

$$(m_{\Lambda_c^+} + m_{\Sigma_c^+})/(m_{\Xi_c^+} - m_{\Sigma_c^+}) = 315$$

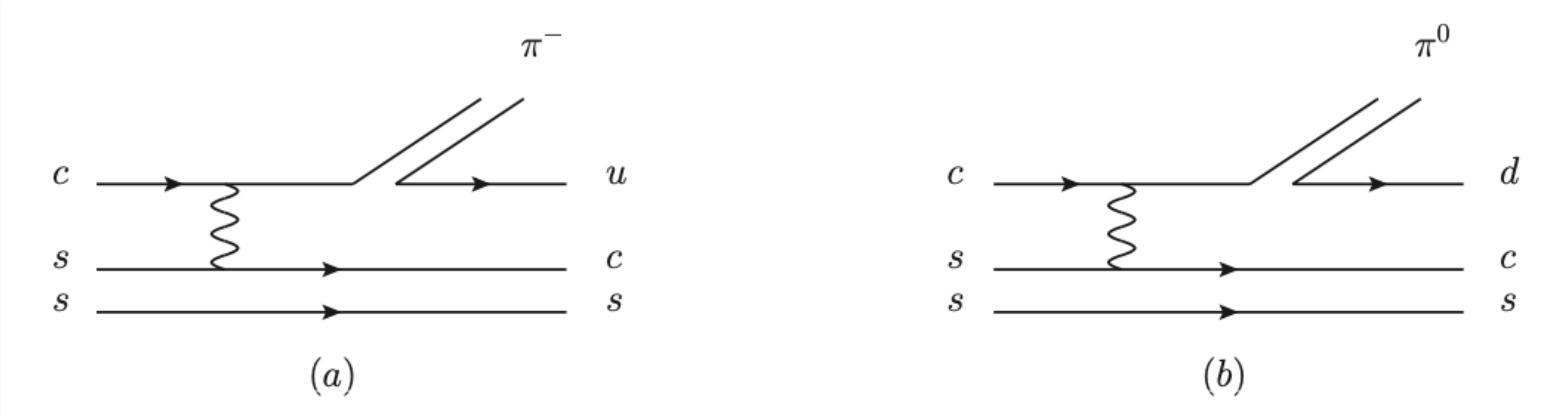
enhanced P-wave contributions!

NONFACTORIZABLE P-WAVE AMP.

Ω_c and Ω_b decays

- receive factorizable amplitudes

$$1^+ \to 0^+ + 0^-$$



- non-factorizable amplitudes

$$B(\Omega_c^0 \to \Xi_c^+ \pi^-) = \frac{G_F}{\sqrt{2}} V_{ud}^* V_{us}\, a_1 f_\pi (m_{\Omega_c} + m_{\Xi_c}) g_1^{\Xi_c^+ \Omega_c^0}(m_\pi^2) - \frac{1}{f_\pi} g^{A(\pi^-)}_{\Xi_c^+ \Xi'^0_c} \frac{m_{\Xi_c^+} + m_{\Xi'^0_c}}{m_{\Omega_c^0} - m_{\Xi'^0_c}} a_{\Xi'^0_c \Omega_c^0},$$

$$B(\Omega_c^0 \to \Xi_c^0 \pi^0) = \frac{G_F}{2} V_{ud}^* V_{us}\, a_2 f_\pi (m_{\Omega_c} + m_{\Xi_c}) g_1^{\Xi_c^0 \Omega_c^0}(m_\pi^2) - \frac{\sqrt{2}}{f_\pi} g^{A(\pi^0)}_{\Xi_c^0 \Xi'^0_c} \frac{m_{\Xi_c^0} + m_{\Xi'^0_c}}{m_{\Omega_c^0} - m_{\Xi'^0_c}} a_{\Xi'^0_c \Omega_c^0},$$

$$B(\Omega_b^- \to \Xi_b^0 \pi^-) = \frac{G_F}{\sqrt{2}} V_{ud}^* V_{us}\, a_1 f_\pi (m_{\Omega_b} + m_{\Xi_b}) g_1^{\Xi_b^0 \Omega_b^-}(m_\pi^2),$$

$$B(\Omega_b^- \to \Xi_b^- \pi^0) = \frac{G_F}{2} V_{ud}^* V_{us}\, a_2 f_\pi (m_{\Omega_b} + m_{\Xi_b}) g_1^{\Xi_b^- \Omega_b^-}(m_\pi^2),$$

$$a_{\Xi'^0_c \Omega_c^0} = \langle \Xi'^0_c | \mathcal{H}_{\rm eff}^{(c)} | \Omega_c^0 \rangle$$

MODEL ESTIMATIONS

THE REMAINING TASK:
FORM FACTORS AND MATRIX ELEMENTS

MIT bag model

$$\psi = \begin{pmatrix} iu(r)\chi \\ v(r)\boldsymbol{\sigma}\cdot\hat{\mathbf{r}}\chi \end{pmatrix}$$

$$f_1^{\mathcal{B}_f\mathcal{B}_i}(q^2_{\text{max}}) = \langle \mathcal{B}_f \uparrow | b^\dagger_{q_1} b_{q_2} | \mathcal{B}_i \uparrow \rangle \int d^3\mathbf{r} (u_{q_1}(r) u_{q_2}(r) + v_{q_1}(r) v_{q_2}(r)),$$

$$g_1^{\mathcal{B}_f\mathcal{B}_i}(q^2_{\text{max}}) = \langle \mathcal{B}_f \uparrow | b^\dagger_{q_1} b_{q_2} \sigma_z | \mathcal{B}_i \uparrow \rangle \int d^3\mathbf{r} \left(u_{q_1}(r) u_{q_2}(r) - \frac{1}{3} v_{q_1}(r) v_{q_2}(r) \right),$$

$$g^A_{\mathcal{B}'\mathcal{B}} = \langle \mathcal{B}' \uparrow | b^\dagger_{q1} b_{q2} \sigma_z | \mathcal{B} \uparrow \rangle \int d^3 r \left(u_{q1} u_{q2} - \frac{1}{3} v_{q1} v_{q2} \right)$$

$$a_{\mathcal{B}\mathcal{B}_c} = \frac{G_F}{2\sqrt{2}} \sum_{q=d,s} V_{cq} V_{uq} (c_1 - c_2) \langle \mathcal{B} | O^q_- | \mathcal{B}_c \rangle$$

THE RESULTS: FORM FACTORS AND MATRIX ELEMENTS

Form factors

$$f_1^{\Lambda_b^0\Xi_b^-} = f_1^{\Lambda_c^+\Xi_c^0} = \langle\Lambda_c^+|b_u^\dagger b_s|\Xi_c^0\rangle \int d^3\mathbf{r}(u_u u_s + v_u v_s) = 4\pi Z_3,$$

$$f_1^{\Lambda_b^0\Xi_b^0} = f_1^{\Lambda_c^+\Xi_c^+} = \langle\Lambda_c^+|b_d^\dagger b_s|\Xi_c^+\rangle \int d^3\mathbf{r}(u_d u_s + v_d v_s) = -4\pi Z_3$$

$$g_1^{\Xi_b^0\Omega_b^-} = g_1^{\Xi_c^+\Omega_c^0} = \langle\Xi_c^+|b_u^\dagger b_s\sigma_z|\Omega_c^0\rangle \int d^3\mathbf{r}(u_u u_s - \frac{1}{3}v_u v_s) = -\sqrt{\frac{2}{3}}(4\pi Z_2)$$

$$g_1^{\Xi_b^-\Omega_b^-} = g_1^{\Xi_c^0\Omega_c^0} = \langle\Xi_c^0|b_d^\dagger b_s\sigma_z|\Omega_c^0\rangle \int d^3\mathbf{r}(u_d u_s - \frac{1}{3}v_d v_s) = -\sqrt{\frac{2}{3}}(4\pi Z_2)$$

$$\frac{1}{\sqrt{2}}g^{A(\pi^-)}_{\Lambda_c^+\Sigma_c^0} = g^{A(\pi^0)}_{\Lambda_c^+\Sigma_c^+} = -g^{A(\pi^-)}_{\Xi'^+_c\Xi_c^0} = -g^{A(\pi^-)}_{\Xi_c^+\Xi'^0_c} = -2g^{A(\pi^0)}_{\Xi'^+_c\Xi_c^+} = 2g^{A(\pi^0)}_{\Xi_c^0\Xi'^0_c} = \frac{1}{\sqrt{3}}(4\pi Z_1)$$

$$Z_1 = \int_0^R r^2 dr\left(u_u^2 - \frac{1}{3}v_u^2\right)$$

$$Z_2 = \int_0^R r^2 dr\left(u_u u_s - \frac{1}{3}v_u v_s\right)$$

$$Z_3 = \int_0^R r^2 dr\,(u_u u_s + v_u v_s)$$

$$4\pi Z_1 = 0.65\,, \qquad 4\pi Z_2 = 0.71, \qquad 4\pi Z_3 = 0.985$$

THE RESULTS:
FORM FACTORS AND MATRIX ELEMENTS

Matrix elements

$$X \equiv \langle \Lambda_c^+ | (\bar{d}u)(\bar{u}s) - (\bar{u}u)(\bar{d}s) | \Xi_c^+ \rangle,$$
$$Y \equiv \langle \Lambda_c^+ | (\bar{d}c)(\bar{s}c) - (\bar{c}c)(\bar{d}s) | \Xi_c^+ \rangle.$$

$$X = 32\pi X_2, \qquad Y = 8\pi(Y_1 + Y_2)$$

$$a_{\Sigma_c^+ \Xi_c^+} = \frac{1}{\sqrt{2}} a_{\Sigma_c^0 \Xi_c^0} = -a_{\Lambda_c^+ \Xi_c'^+} = \frac{G_F}{2\sqrt{2}} V_{cd}^* V_{cs} (c_1 - c_2) \frac{2}{\sqrt{3}} (-Y_1 + 3Y_2)(4\pi)$$

$$a_{\Xi_c^0 \Omega_c^0} = \frac{G_F}{2\sqrt{2}} V_{cd}^* V_{cs} (c_1 - c_2) 2 \sqrt{\frac{2}{3}} (Y_1 - 3Y_2)(4\pi)$$

$$a_{\Xi_c'^0 \Omega_c^0} = -\frac{G_F}{2\sqrt{2}} V_{cd}^* V_{cs} (c_1 - c_2) \frac{2\sqrt{2}}{3} (Y_1 + 9Y_2)(4\pi)$$

$$X_2 = \int_0^R r^2 dr (u_d u_u + v_d v_u)(u_s u_u + v_s v_u),$$
$$Y_1 = \int_0^R r^2 dr (u_d v_c - v_d u_c)(u_s v_c - v_s u_c),$$
$$Y_2 = \int_0^R r^2 dr (u_d u_c + v_d v_c)(u_s u_c + v_s v_c),$$

$$X_2 = 1.66 \times 10^{-4}\,\mathrm{GeV}^3, \qquad Y_1 = 8.37 \times 10^{-6}\,\mathrm{GeV}^3, \qquad Y_2 = 2.11 \times 10^{-4}\,\mathrm{GeV}^3,$$

- diquark model

$$X_{\mathrm{di}} = \frac{2}{3\, m_{\mathrm{di}}} g_{du} g_{us}$$

$$(c_1 - c_2) g_{du} g_{us} = 0.066 \pm 0.013\ \mathrm{GeV}^4$$

$$X_{\mathrm{di}} = \frac{1}{c_1 - c_2} (5.6 \pm 1.1) 10^{-2} \mathrm{GeV}^3$$

RESULTS & SUMMARY

PREDICTIONS

	$\Xi_c^0 \to \Lambda_c^+\pi^-$	$\Xi_c^+ \to \Lambda_c^+\pi^0$	$\Xi_b^- \to \Lambda_b^0\pi^-$	$\Xi_b^0 \to \Lambda_b^0\pi^0$
A (in units of 10^{-7})	2.53 ± 0.75	2.02 ± 0.53	3.43 ± 0.76	2.80 ± 0.53
B (in units of 10^{-7})	244	181	0	0
α	$0.70^{+0.13}_{-0.17}$	$0.74^{+0.11}_{-0.16}$	0	0
$\mathcal{B}$	$(1.76^{+0.18}_{-0.12}) \times 10^{-3}$	$(3.03^{+0.29}_{-0.22}) \times 10^{-3}$	$(4.67^{+2.29}_{-1.83}) \times 10^{-3}$	$(2.87^{+1.20}_{-0.99}) \times 10^{-3}$
$\mathcal{B}_{\text{expt}}$	$(5.5 \pm 1.8) \times 10^{-3}$	–	see Eq. (1.2) $(0.57 \pm 0.21) \sim (0.19 \pm 0.07)\%$.	–

- matrix element result of X is taken in diquark model
- $\Xi_b^- \to \Lambda_b^0\pi^-$ is consistent with LHCb measurement, $\Xi_c^0 \to \Lambda_c^+\pi^-$ is close to exp.

	$\Omega_c^0 \to \Xi_c^+\pi^-$	$\Omega_c^0 \to \Xi_c^0\pi^0$	$\Omega_b^- \to \Xi_b^0\pi^-$	$\Omega_b^- \to \Xi_b^-\pi^0$
A	-1.72	1.21	0	0
B	40.12	-32.19	-15.96	-3.48
$\mathcal{B}$	5.1×10^{-4}	2.8×10^{-4}	6.5×10^{-5}	2.8×10^{-6}
α	-0.98	-0.99	0	0

COMPARISON I: $\Xi_c^0 \to \Lambda_c^+ \pi^-$

	$A^{\rm fac} + A^{\rm nf}_{su\to ud}$	$A^{\rm nf}_{sc\to cd}$	$A^{\rm tot}$	$\mathcal{B}_{\rm S-wave}$
This work	3.27 ± 0.75 [a]	-0.74	2.53 ± 0.75	$(2.53^{+1.74}_{-1.28}) \times 10^{-4}$
Gronau, Rosner [10]	3.97 ± 0.59	-1.86 ± 0.91	2.11 ± 1.08	$(1.76^{+2.26}_{-1.34}) \times 10^{-4}$
	3.97 ± 0.59	1.86 ± 0.91	5.83 ± 1.08	$(1.34 \pm 0.53) \times 10^{-3}$

[a] Explicitly, $A^{\rm fac} = -0.56$ and $A^{\rm nf}_{su\to ud} = 3.83 \pm 0.75$ in unit of 10^{-7}.

- factorizable and W-exchange (light quark): this work destructive while GR constructive
- spectator W-exchange diagram contribution is destructive
- only S-wave contribution is considered, and predicted branching fraction is smaller than experimental measurement.

COMPARISON II: Ξ_c DECAYS

Branching fractions (in units of 10^{-3}) of charm-flavor-conserving decays $\Xi_c \to \Lambda_c^+ \pi$.

Mode	$(\mathrm{CLY})_a^2$ [1]	$(\mathrm{CLY})_b^2$ [8]	Faller [7]	Gronau [10]	Voloshin [11]	Niu [12]	This work	Experiment [15]
$\Xi_c^0 \to \Lambda_c^+ \pi^-$	0.39	0.17	< 3.9	$0.18^{+0.23}_{-0.13}$ 1.34 ± 0.53	$> 0.25 \pm 0.15$	5.8 ± 2.1	$1.76^{+0.18}_{-0.12}$	$5.5 \pm 0.2 \pm 1.8$
$\Xi_c^+ \to \Lambda_c^+ \pi^0$	0.69	0.11	< 6.1	< 0.2 2.01 ± 0.80	–	11.1 ± 4.0	$3.03^{+0.29}_{-0.22}$	–

- the order is correct and approaches to experimental value

SUMMARY

- P-wave amplitudes of $\Xi_Q \to \Lambda_Q \pi$ vanish, provided heavy quark does not participate weak interaction.

- In presence of nonspectator W-exchange, S-wave amplitude receive destructive contribution.

- $\Xi_b^- \to \Lambda_b^0 \pi^-$ will be smaller than experimental value when X is evaluated in bag model hence diquark model is adopted.

- $\Xi_c \to \Lambda_c \pi$ is dominated by PC pole terms, induced by nonspectator W-exchange.

- $\Omega_b^- \to \Xi_b^0 \pi$ receive only factorizable P-wave contributions; $\Omega_c \to \Xi_c \pi$ acquire additional nonspectator W-exchange for both PV and PC amplitudes.

谢谢