



The hadronic weak decay of Λ_c and Ξ_c

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贵州·贵阳 2025. 08. 14

01 Introduction

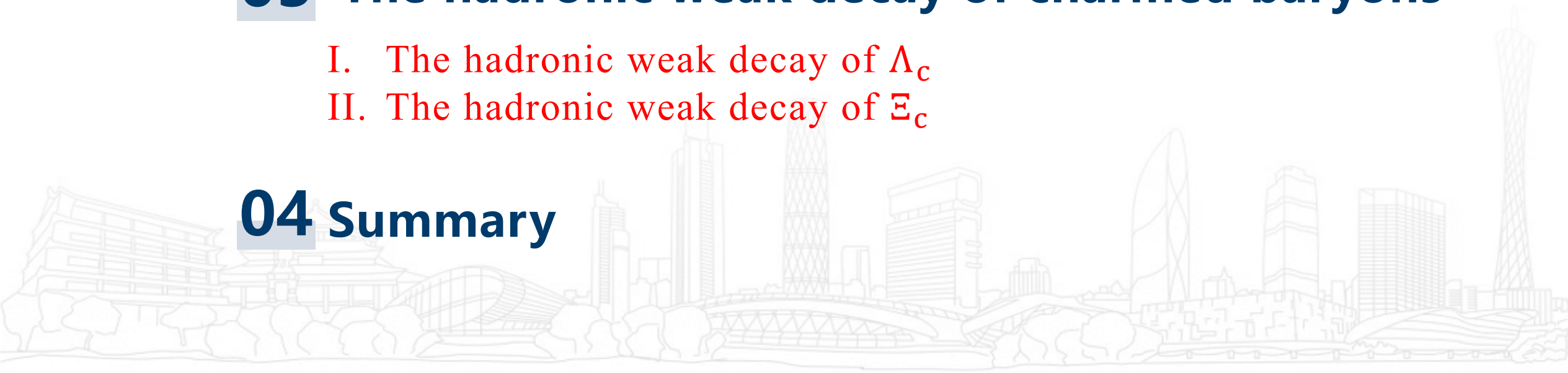
02 Frame Work: non-relativistic constituent quark model

- I. Wave Functions of Hadrons
- II. The Effective Hamiltonian

03 The hadronic weak decay of charmed baryons

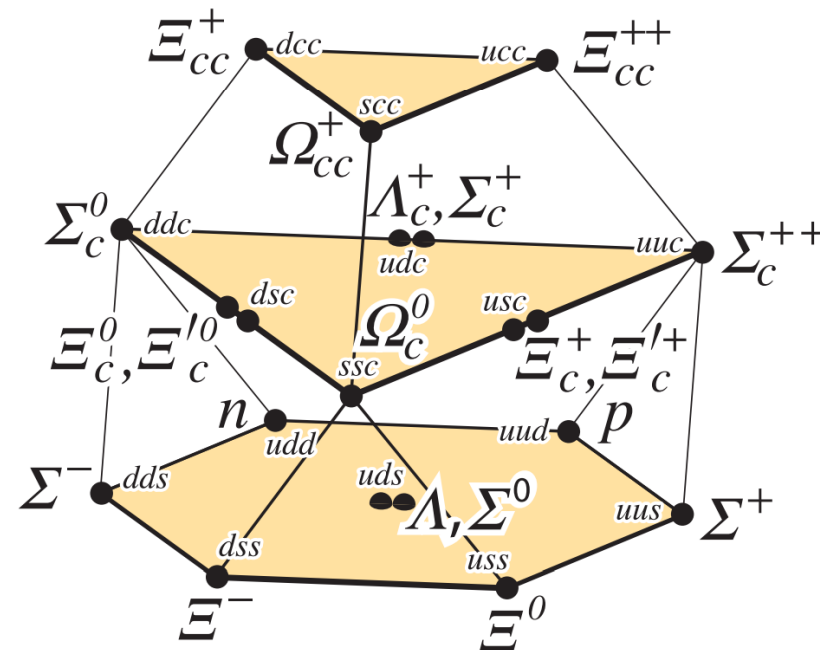
- I. The hadronic weak decay of Λ_c
- II. The hadronic weak decay of Ξ_c

04 Summary





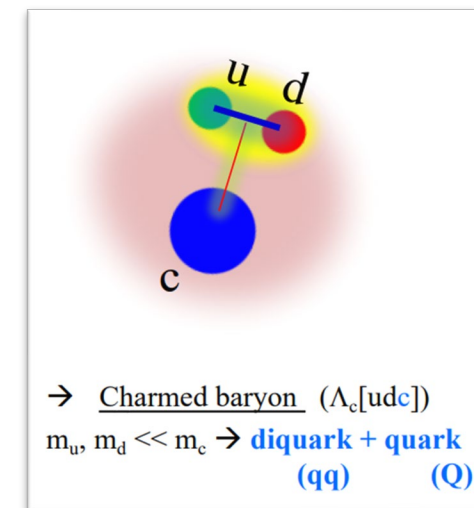
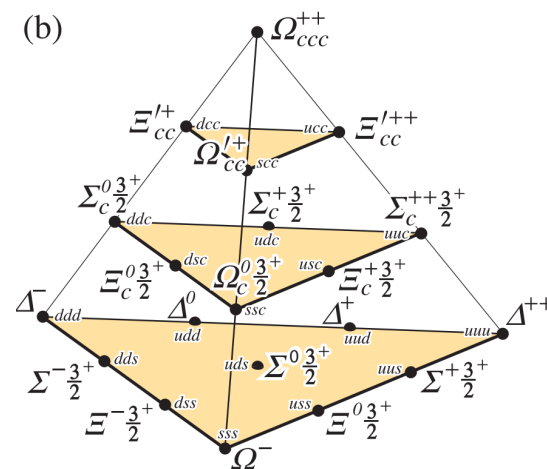
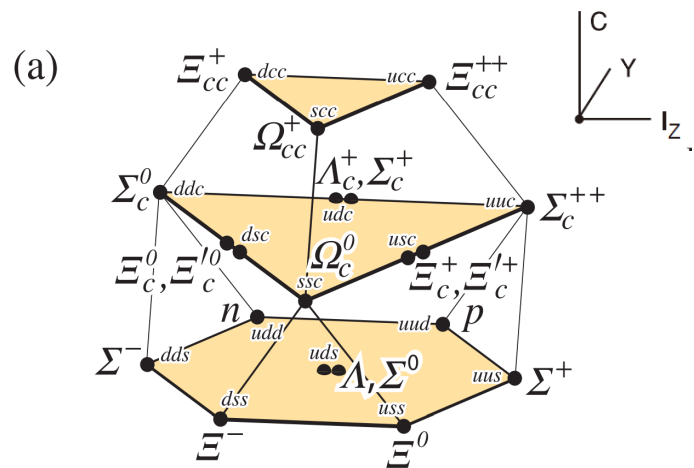
Introduction



1. Introduction

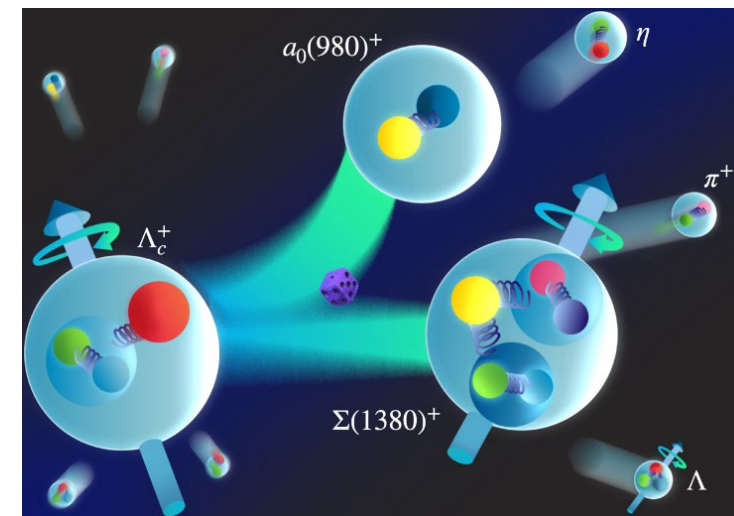
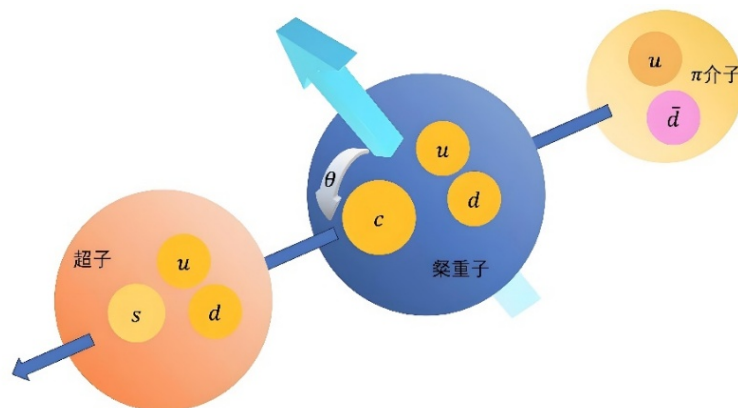
Charmed baryons

◆ Spectrum & Structure



◆ Decay: $B_c \rightarrow B M$

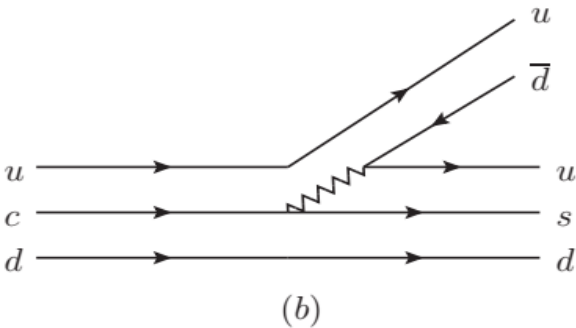
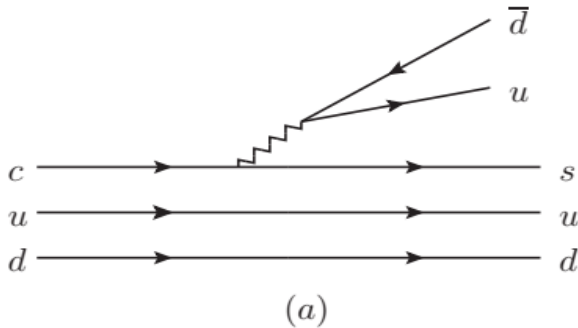
- Decay mechanism
- Spectrum / Structure
- SM、CPV
- New Physics
- ...



- Weak interaction
- Strong interaction

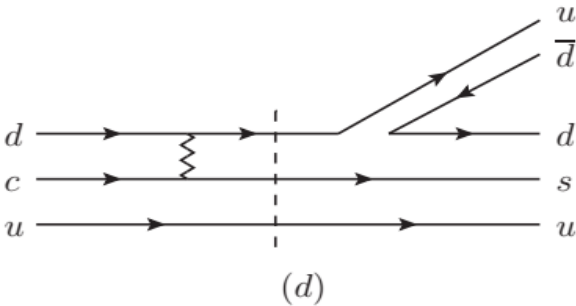
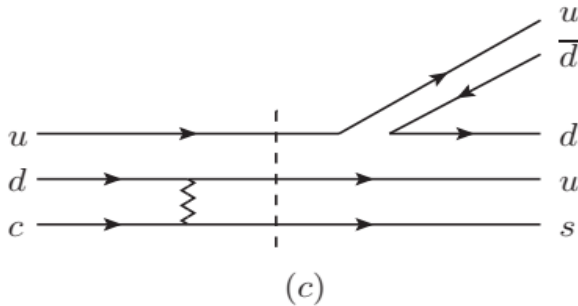
- Non-factorizable transition mechanisms:
 - Color suppressed contribution
 - Pole term contribution
- The property of light diquark

◆ $\Lambda_c/\Xi_c \rightarrow B\ M$

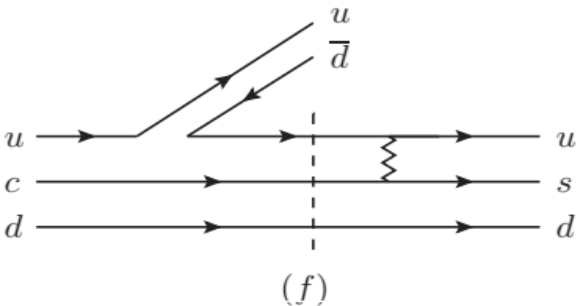
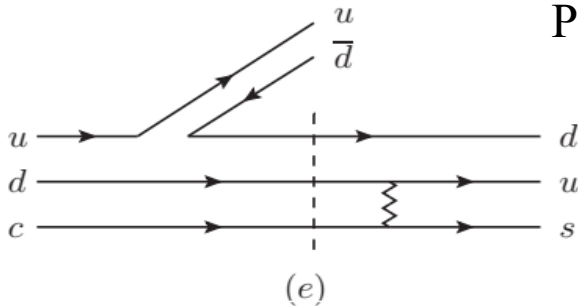


DPE/DME

Color suppressed



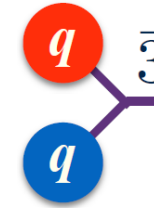
Pole terms



‡ **Diquark:** strong color correlation between quarks

S-wave color $\bar{3}$ diquarks: **S(0⁺)** and **A(1⁺)**

color $3 \otimes 3 = \bar{3} \oplus 6$ spin : $\frac{1}{2} \otimes \frac{1}{2} = 0 \oplus 1$



‡ Spin dependent force from magnetic gluon exchange predicts strong attraction in **S(0⁺)**.

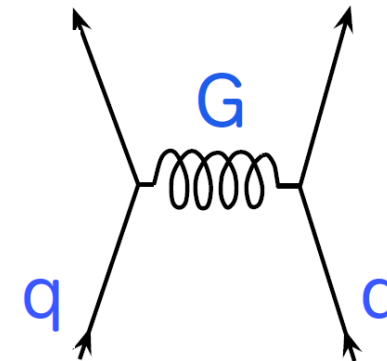
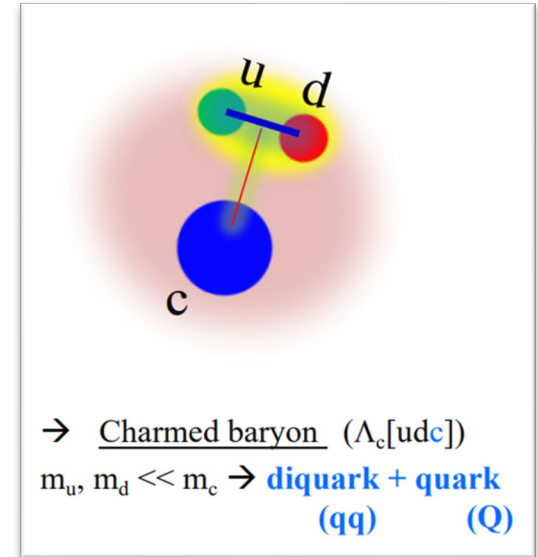
Color-Magnetic Interaction $\Delta_{CM} \equiv \langle - \sum_{i < j} (\vec{\lambda}_i \cdot \vec{\lambda}_j) (\vec{\sigma}_i \cdot \vec{\sigma}_j) \rangle$

S(0⁺) color $\bar{3}$ $\Delta_{CM} = -8$ *aka good diquark*

A(1⁺) color $\bar{3}$ $\Delta_{CM} = +8/3$ *aka bad diquark*

$M(A) - M(S) = (2/3) [M(\Delta) - M(N)] \sim 200 \text{ MeV}$
consistent with the splitting of $\Lambda_c - \Sigma_c$

$M_\Sigma - M_\Lambda = 80 \text{ MeV}$



three-quark system
or with compact
diquark degrees of
freedom ?

➤ BES III:

- Phys. Rev. D 111.012014 (2025)
- Phys. Rev. Lett 134.021901(2025)
- Phys. Rev. D 111. L051101(2024)
- Phys. Rev. Lett 132.031801(2024)
- Phys. Rev. Lett 128.142001(2022)
- ...

➤ Belle II and Belle:

- arXiv: 2503.17643v1
- Phys. Rev. D 110.032021(2025)
- JHEP 03. 061(2025)
- JHEP 10. 045 (2024)
- Phys. Rev. D 107.032008(2023)
- ...

➤ LHCb:

- Phys. Rev. Lett 132.081802(2024)
- Eur. Phys. J. C 84.237 (2024)
- Eur. Phys. J. C 84.575 (2024)
- Phys. Rev. Lett 133.261804(2024)
- Phys. Rev. D 108.072002(2023)
- ...

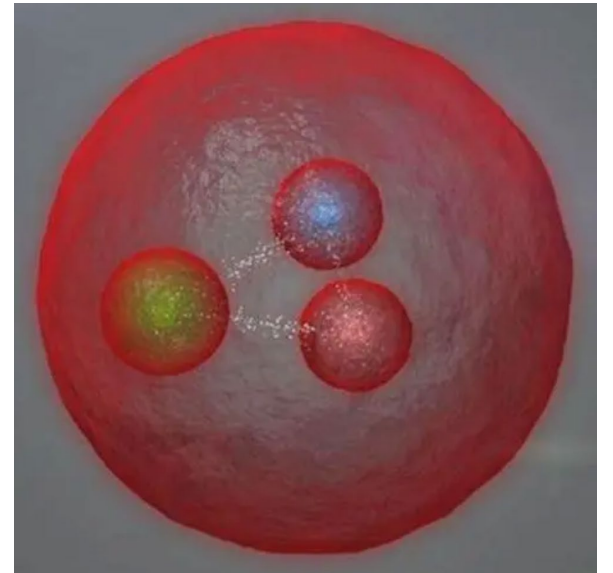
◆ Spectrum, Structure and Decay

- Ying Zhang, Qing-Fu Song, Qi-Fang Lü, et al. arXiv: 2507.06611
- Mikhail Shifman, Nucl.Part.Phys.Proc. 347 (2024) 86-89
- Frank Wilczek, arXiv: hep-ph/0409168v2
- ...
- Di Wang, arXiv: 2507: 06914
- Hai-Yang Cheng, Fanrong Xu, Huiling Zhong, arXiv: 2505.07150
- Hai-Yang Cheng, Fanrong Xu, Huiling Zhong, Phys. Rev. D 109.114027
- C. P. Jia, D. Wang, and F. S. Yu, Nucl. Phys. B 56, 115048.
- H. Liu and C. Yang, Phys. Rev. D 108, 093011.
- Xiao-Gang He, Yu-Ji Shi1, Wei Wang, Eur. Phys. J. C (2020) 80:359
- Wei Wang , Zhi-Peng Xing , Zhen-Xing Zhao, Phys. Rev. D 111, 053006.
- ...

02

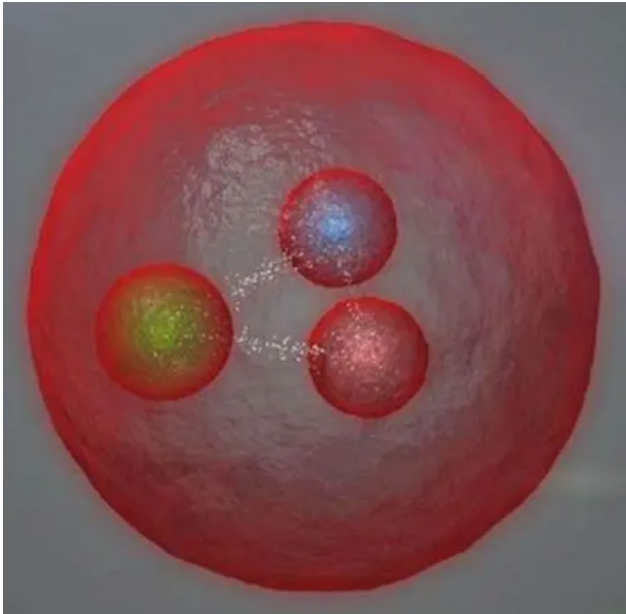
Frame Work

- The wave functions of hadrons
- The effective Hamiltonian



Nonrelativistic constituent quark model

Color	$SU(3)$	$3 \otimes 3 \otimes 3$	$= 10_s + 8_\rho + 8_\lambda + 1_a$
Spin	$SU(2)$	$2 \otimes 2 \otimes 2$	$= 4_s + 2_\rho + 2_\lambda,$
Flavor	$SU(3)$	$3 \otimes 3 \otimes 3$	$= 10_s + 8_\rho + 8_\lambda + 1_a,$
Spin-flavor	$SU(6)$	$6 \otimes 6 \otimes 6$	$= 56_s + 70_\rho + 70_\lambda + 20_a,$
Spatial	$O(3)$	L^P	s, ρ, λ, a



ISGUR N, KARL G. Phys.Rev.D, 1978, 18:4187
 F. Hussain and M. Scadron, Nuovo Cim. A **79**, 248 (1984)
 LE YAOUANC A, OLIVER L, PENE O, et al. HADRON TRANSITIONS IN THE QUARK MODEL[M]. 1988.

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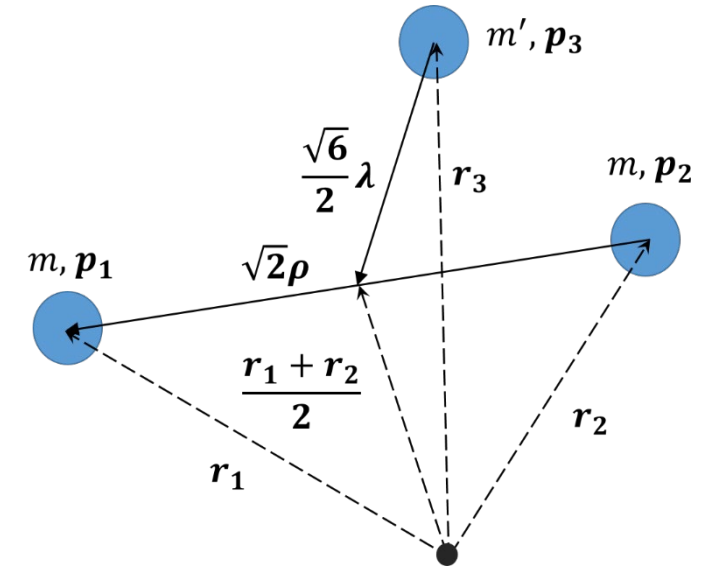
The Hamiltonian of three quark system

$$H = \sum_i \left(m_i + \frac{\mathbf{p}_i^2}{2m_i} \right) + \sum_{i<j} V_{conf}^{ij} + H_{hyp}^{ij},$$

where

$$V_{conf}^{ij} = C_{qqq} + \frac{1}{2} b r_{ij} - \frac{2}{3} \frac{\alpha_s}{r_{ij}} = \frac{1}{2} \beta r_{ij}^2 + U_{ij},$$

$$H_{hyp}^{ij} = \sum_{i<j} \frac{2\alpha_s(r_{ij})}{3m_i m_j} \left[\frac{8\pi}{3} \mathbf{s}_i \cdot \mathbf{s}_j \delta^3(\mathbf{r}_{ij}) + \frac{1}{r_{ij}^3} \left(\frac{3\mathbf{s}_i \cdot \mathbf{r}_{ij} \mathbf{s}_j \cdot \mathbf{r}_{ij}}{r_{ij}^2} - \mathbf{s}_i \cdot \mathbf{s}_j \right) \right].$$



Harmonic oscillator potential: $H = \sum_i \left(m_i + \frac{\mathbf{p}_i^2}{2m_i} \right) + \frac{1}{2} K \sum_{i<j} (\mathbf{r}_i - \mathbf{r}_j)^2$

Jacobi coordinates:

$$\begin{aligned} \mathbf{R} &= \frac{m(\mathbf{r}_1 + \mathbf{r}_2) + m'\mathbf{r}_3}{M}, & \mathbf{P} &= \mathbf{p}_1 + \mathbf{p}_2 + \mathbf{p}_3, \\ \boldsymbol{\rho} &= \frac{1}{\sqrt{2}}(\mathbf{r}_1 - \mathbf{r}_2), & \mathbf{p}_\rho &= \frac{1}{\sqrt{2}}(\mathbf{p}_1 - \mathbf{p}_2), \\ \boldsymbol{\lambda} &= \frac{1}{\sqrt{6}}(\mathbf{r}_1 + \mathbf{r}_2 - 2\mathbf{r}_3), & \mathbf{p}_\lambda &= \frac{1}{\sqrt{6}M}(3m'\mathbf{p}_1 + 3m'\mathbf{p}_2 - 6m\mathbf{p}_3). \end{aligned}$$

⇒

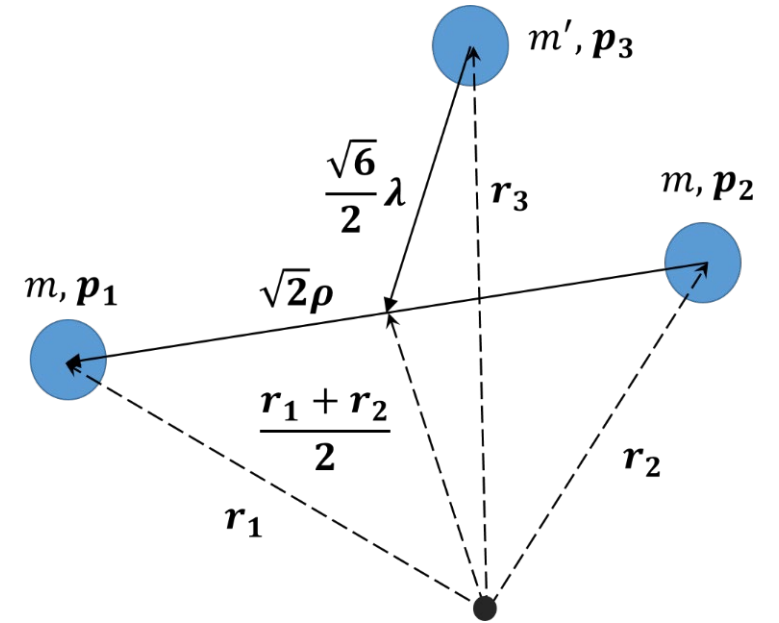
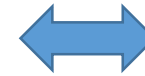
$$H = \frac{\mathbf{P}^2}{2M^2} + \frac{\mathbf{p}_\lambda^2}{2m_\lambda^2} + \frac{\mathbf{p}_\rho^2}{2m_\rho^2} + \frac{1}{2}m_\rho\omega_\rho^2\boldsymbol{\rho}^2 + \frac{1}{2}m_\lambda\omega_\lambda^2\boldsymbol{\lambda}^2,$$

The total wave function of the momentum space

$$\Psi_{NLM}(\mathbf{P}, \mathbf{p}_\rho, \mathbf{p}_\lambda) = \delta^3(\mathbf{P} - \mathbf{P}') \left[\psi_{n_\rho l_\rho m_\rho}(\mathbf{p}_\rho, \alpha_\rho) \psi_{n_\lambda l_\lambda m_\lambda}(\mathbf{p}_\lambda, \alpha_\lambda) \right]_{l_\rho, l_\lambda; L},$$

where

$$\psi_{nlm}(\mathbf{p}, \alpha) = i^l (-1)^n \left[\frac{2n!}{\left(n + l + \frac{1}{2}\right)!} \right]^{\frac{1}{2}} \frac{1}{\alpha^{l+\frac{3}{2}}} e^{-\frac{\mathbf{p}^2}{2\alpha^2}} L_n^{l+\frac{1}{2}} \left(\frac{\mathbf{p}^2}{\alpha^2} \right) \mathcal{Y}_{lm}(\mathbf{p}).$$



$$\begin{aligned} \langle \boldsymbol{\rho}^2 / \lambda^2 \rangle &= \frac{3}{2} \frac{1}{\alpha_{\rho/\lambda}^2} \\ \langle \mathbf{r}_{qc}^2 \rangle &= \frac{3}{2} \langle \lambda^2 \rangle + \frac{1}{2} \langle \boldsymbol{\rho}^2 \rangle \end{aligned}$$

Color	$SU(3)$	$3 \otimes 3 \otimes 3$	$= 10_s + 8_\rho + 8_\lambda + \boxed{1_a}$
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Spatial	$O(3)$	L^P	s, ρ, λ, a

$$\phi_c|SU(6) \otimes O(3)\rangle = \phi_c|N_6, {}^{2S+1}N_3, N, L, J\rangle$$

Light baryons $|56, {}^28, 0, 0, \frac{1}{2}\rangle$:

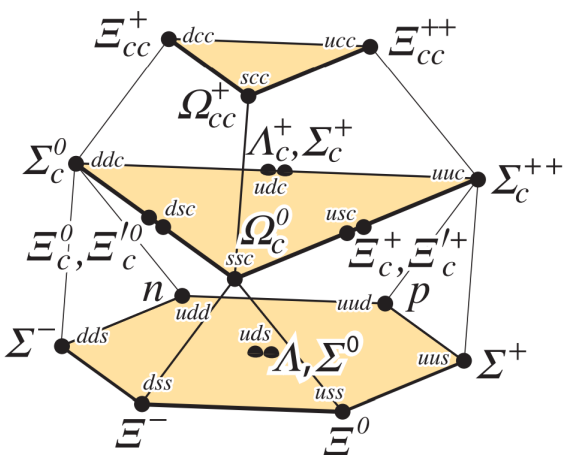
$$\frac{1}{\sqrt{2}}(\phi^\rho\chi^\rho + \phi^\lambda\chi^\lambda)\Psi_{000}(\boldsymbol{p}_\rho,\boldsymbol{p}_\lambda)$$



Baryon wave function as representation of 3-dimension permutation group.

$$3 \otimes 3 = \bar{3} \oplus 6$$

$$\phi_3^c = \begin{cases} \frac{1}{\sqrt{2}}(ud - du)c & \text{for } \Lambda_c^+, \\ \frac{1}{\sqrt{2}}(us - su)c & \text{for } \Xi_c^+, \\ \frac{1}{\sqrt{2}}(ds - sd)c & \text{for } \Xi_c^0; \end{cases}$$



$$\phi_6^c = \begin{cases} uuc & \text{for } \Sigma_c^{++}, \\ \frac{1}{\sqrt{2}}(ud + du)c & \text{for } \Sigma_c^+, \\ ddc & \text{for } \Sigma_c^0, \\ \frac{1}{\sqrt{2}}(us + su)c & \text{for } \Xi_c'^+, \\ \frac{1}{\sqrt{2}}(ds + sd)c & \text{for } \Xi_c'^0, \\ ssc & \text{for } \Omega_c^0; \end{cases}$$

Anti-triplet

$ ^{2S+1}L_\sigma J^P\rangle$	Wave function
$ ^2S_{\frac{1}{2}}^{+-}\rangle$	$\Psi_{00}^s \chi_{S_z}^\rho \phi_B$
$ ^2P_{\lambda \frac{1}{2}}^{--}\rangle$	$\Psi_{1L_z}^\lambda \chi_{S_z}^\rho \phi_B$
$ ^2P_{\rho \frac{1}{2}}^{--}\rangle$	$\Psi_{1L_z}^\rho \chi_{S_z}^\lambda \phi_B$
$ ^4P_{\rho \frac{1}{2}}^{--}\rangle$	$\Psi_{1L_z}^\rho \chi_{S_z}^s \phi_B$

Sextet

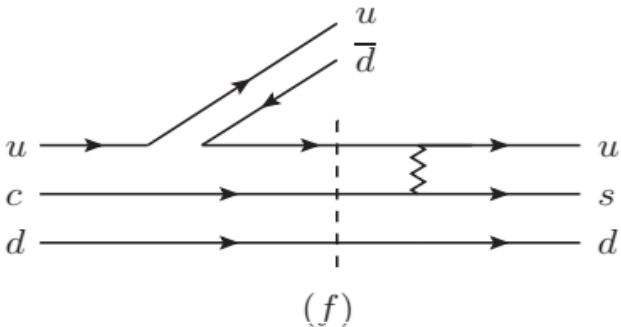
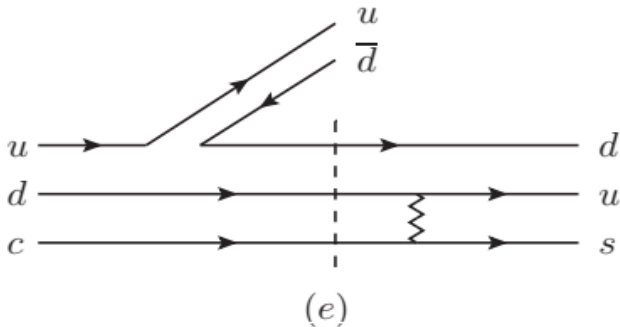
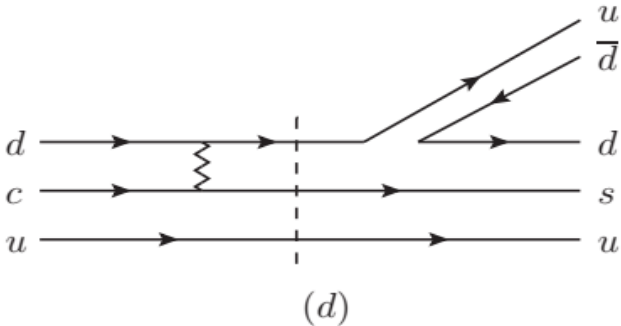
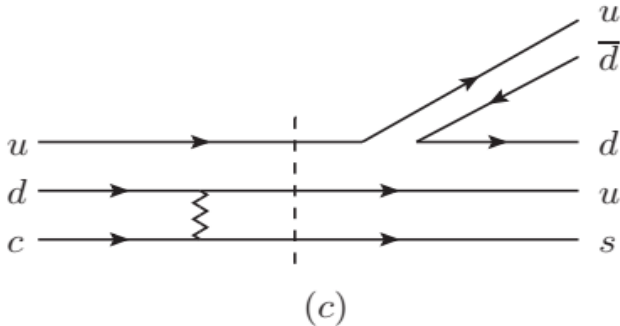
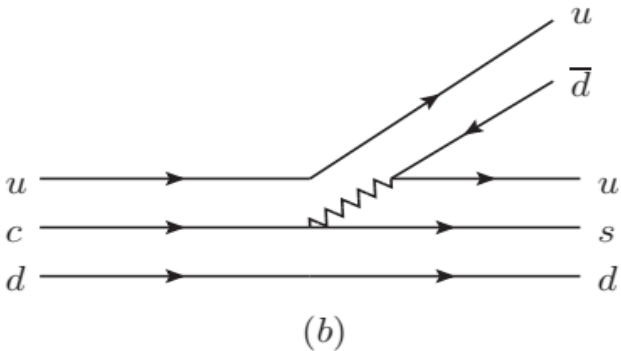
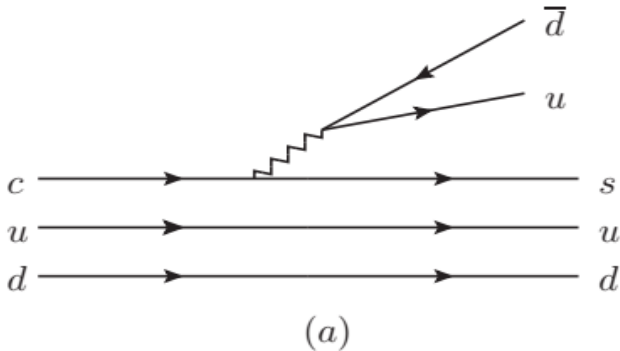
$ ^{2S+1}L_\sigma J^P\rangle$	Wave Function
$ ^2S_{\frac{1}{2}}^{+-}\rangle$	$\Psi_{00}^s \chi_{S_z}^\lambda \phi_B$
$ ^2P_{\lambda \frac{1}{2}}^{--}\rangle$	$\Psi_{1L_z}^\lambda \chi_{S_z}^\lambda \phi_B$
$ ^2P_{\rho \frac{1}{2}}^{--}\rangle$	$\Psi_{1L_z}^\rho \chi_{S_z}^\rho \phi_B$
$ ^4P_{\lambda \frac{1}{2}}^{--}\rangle$	$\Psi_{1L_z}^\lambda \chi_{S_z}^s \phi_B$

L.A Copley, Isgur N, Karl G. Phys.Rev.D, 20, 758(1978)
Xian-Hui Zhong and Qiang Zhao, PHYSICAL REVIEW D **77**, 074008 (2008)

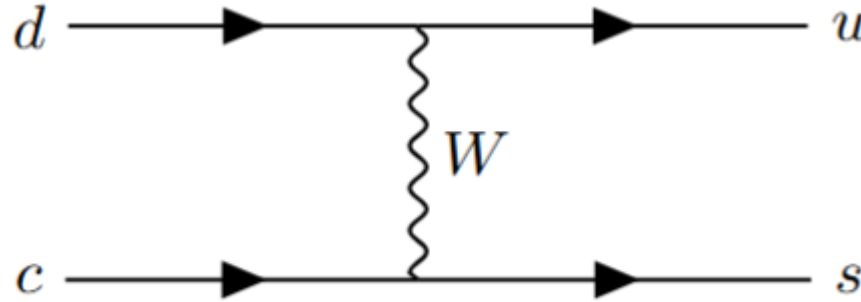
$$\Lambda_c \rightarrow \Lambda \pi$$

$$\langle B \ M | H_{eff} | B_c \rangle$$

- Weak interaction
- Strong interaction



$H_{W,2\rightarrow 2} :$

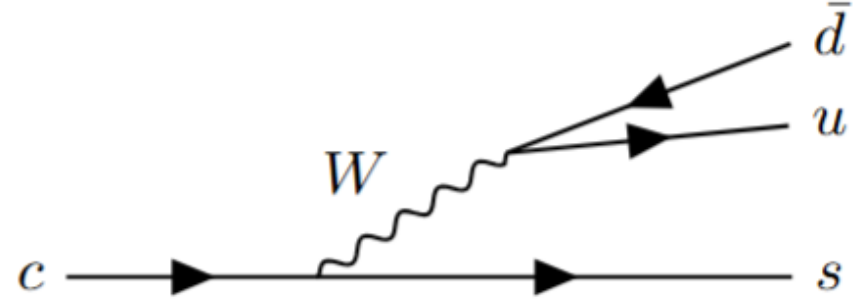


$$H_{W,2\rightarrow 2} = \frac{G_F}{\sqrt{2}} V_{ud} V_{cs} \frac{1}{(2\pi)^3} \delta^3(\mathbf{p}'_i + \mathbf{p}'_j - \mathbf{p}_i - \mathbf{p}_j) \bar{u}(\mathbf{p}'_i) \gamma_\mu (1 - \gamma_5) u(\mathbf{p}_i) \bar{u}(\mathbf{p}'_j) \gamma^\mu (1 - \gamma_5) u(\mathbf{p}_j).$$

$$H_{W,2\rightarrow 2}^{PC} = \frac{G_F}{\sqrt{2}} V_{ud} V_{cs} \frac{1}{(2\pi)^3} \sum_{i \neq j} \hat{\alpha}_i^{(-)} \hat{\beta}_j^{(+)} \delta^3(\mathbf{p}'_i + \mathbf{p}'_j - \mathbf{p}_i - \mathbf{p}_j) (1 - \langle s'_{z,i} | \boldsymbol{\sigma}_i | s_{z,i} \rangle \langle s'_{z,j} | \boldsymbol{\sigma}_j | s_{z,j} \rangle),$$

$$H_{W,2\rightarrow 2}^{PV} = \frac{G_F}{\sqrt{2}} V_{ud} V_{cs} \frac{1}{(2\pi)^3} \sum_{i \neq j} \hat{\alpha}_i^{(-)} \hat{\beta}_j^{(+)} \delta^3(\mathbf{p}'_i + \mathbf{p}'_j - \mathbf{p}_i - \mathbf{p}_j) \\ \times \left\{ -(\langle s'_{z,i} | \boldsymbol{\sigma}_i | s_{z,i} \rangle - \langle s'_{z,j} | \boldsymbol{\sigma}_j | s_{z,j} \rangle) \left[\left(\frac{\mathbf{p}_i}{2m_i} - \frac{\mathbf{p}_j}{2m_j} \right) + \left(\frac{\mathbf{p}'_i}{2m'_i} - \frac{\mathbf{p}'_j}{2m'_j} \right) \right] \right. \\ \left. + i(\langle s'_{z,i} | \boldsymbol{\sigma}_i | s_{z,i} \rangle \times \langle s'_{z,j} | \boldsymbol{\sigma}_j | s_{z,j} \rangle) \left[\left(\frac{\mathbf{p}_i}{2m_i} - \frac{\mathbf{p}_j}{2m_j} \right) - \left(\frac{\mathbf{p}'_i}{2m'_i} - \frac{\mathbf{p}'_j}{2m'_j} \right) \right] \right\},$$

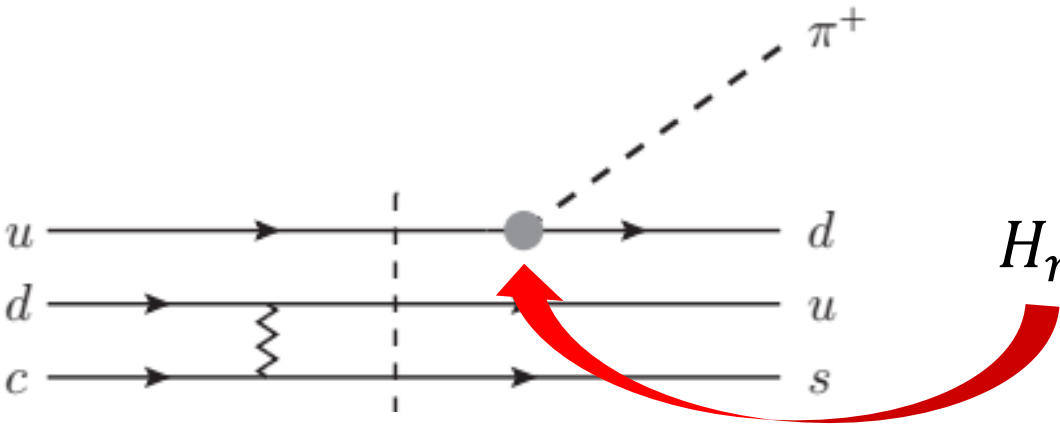
$H_{W,1\rightarrow 3} :$



$$H_{W,1\rightarrow 3} = \frac{G_F}{\sqrt{2}} V_{ud} V_{cs} \frac{\beta}{(2\pi)^3} \delta^3(\mathbf{p}_3 - \mathbf{p}'_3 - \mathbf{p}_5 - \mathbf{p}_4) \bar{u}(\mathbf{p}'_3, m'_3) \gamma_\mu (1 - \gamma_5) u(\mathbf{p}_3, m_3) \bar{u}(\mathbf{p}_5, m_5) \gamma^\mu (1 - \gamma_5) v(\mathbf{p}_4, m_4)$$

$$\begin{aligned} H_{W,1\rightarrow 3}^{PC} = & \frac{G_F}{\sqrt{2}} V_{ud} V_{cs} \frac{\beta}{(2\pi)^3} \delta^3(\mathbf{p}_3 - \mathbf{p}'_3 - \mathbf{p}_4 - \mathbf{p}_5) \left\{ \langle s'_3 | I | s_3 \rangle \langle s_5 \bar{s}_4 | \sigma | 0 \rangle \left(\frac{\mathbf{p}_5}{2m_5} + \frac{\mathbf{p}_4}{2m_4} \right) \right. \\ & - \left[\left(\frac{\mathbf{p}'_3}{2m'_3} + \frac{\mathbf{p}_3}{2m_3} \right) \langle s'_3 | I | s_3 \rangle - i \langle s'_3 | \sigma | s_3 \rangle \times \left(\frac{\mathbf{p}_3}{2m_3} - \frac{\mathbf{p}'_3}{2m'_3} \right) \right] \langle s_5 \bar{s}_4 | \sigma | 0 \rangle \\ & - \langle s'_3 | \sigma | s_3 \rangle \left[\left(\frac{\mathbf{p}_5}{2m_5} + \frac{\mathbf{p}_4}{2m_4} \right) \langle s_5 \bar{s}_4 | I | 0 \rangle - i \langle s_5 \bar{s}_4 | \sigma | 0 \rangle \times \left(\frac{\mathbf{p}_4}{2m_4} - \frac{\mathbf{p}_5}{2m_5} \right) \right] \\ & \left. + \langle s'_3 | \sigma | s_3 \rangle \left(\frac{\mathbf{p}'_3}{2m'_3} + \frac{\mathbf{p}_3}{2m_3} \right) \langle s_5 \bar{s}_4 | I | 0 \rangle \right\} \hat{\alpha}_3^{(-)} \hat{I}'_\pi, \end{aligned}$$

$$H_{W,1\rightarrow 3}^{PV} = \frac{G_F}{\sqrt{2}} V_{ud} V_{cs} \frac{\beta}{(2\pi)^3} \delta^3(\mathbf{p}_3 - \mathbf{p}'_3 - \mathbf{p}_4 - \mathbf{p}_5) (-\langle s'_3 | I | s_3 \rangle \langle s_5 \bar{s}_4 | I | 0 \rangle + \langle s'_3 | \sigma | s_3 \rangle \langle s_5 \bar{s}_4 | \sigma | 0 \rangle) \hat{\alpha}_3^{(-)} \hat{I}'_\pi,$$



$$H_m = \sum_j \int d\mathbf{x} \frac{1}{f_m} \bar{q}_j(\mathbf{x}) \gamma_\mu^j \gamma_5^j q_j(\mathbf{x}) \partial^\mu \phi_m(\mathbf{x})$$

In the non-relativistic limit:

$$H_m = \frac{1}{\sqrt{(2\pi)^3 2\omega_m}} \sum_j \frac{1}{f_m} \left[\omega_m \left(\frac{\boldsymbol{\sigma} \cdot \mathbf{p}_f^j}{2m_f} + \frac{\boldsymbol{\sigma} \cdot \mathbf{p}_i^j}{2m_i} \right) - \boldsymbol{\sigma} \cdot \mathbf{k} \right] \hat{l}_m^j \delta^3(\mathbf{p}_f^j + \mathbf{k} - \mathbf{p}_i^j)$$

The isospin operator $\hat{l}_m^j$ is written as

$$\hat{l}_\pi^j = \begin{cases} b_u^\dagger b_d & \text{for } \pi^- \\ b_d^\dagger b_u & \text{for } \pi^+ \\ \frac{1}{\sqrt{2}} [b_u^\dagger b_d - b_d^\dagger b_u] & \text{for } \pi^0 \end{cases}$$

Normalization:

$$\langle M(\mathbf{P}'_c)_{J,J_z} | M(\mathbf{P}'_c)_{J,J_z} \rangle = \delta^3(\mathbf{P}'_c - \mathbf{P}_c),$$

$$\langle B(\mathbf{P}'_c)_{J,J_z} | B(\mathbf{P}'_c)_{J,J_z} \rangle = \delta^3(\mathbf{P}'_c - \mathbf{P}_c).$$

Decay width:

$$\Gamma(A \rightarrow B + C) = 8\pi^2 \frac{|\mathbf{k}| E_B E_C}{M_A} \frac{1}{2J_A + 1} \sum_{spin} |M|^2,$$

where

$$\delta^3(\mathbf{P}_A - \mathbf{P}_B - \mathbf{P}_C) M \equiv \langle BC | H | A \rangle.$$

The parity asymmetry parameter

$$M = G_F m_\pi^2 \bar{B}_f (A - B \gamma_5) B_i$$

The transition rate is proportional to

$$R = 1 + \gamma \hat{\omega}_f \cdot \hat{\omega}_i + (1 - \gamma)(\hat{\omega}_f \cdot \hat{\mathbf{n}})(\hat{\omega}_i \cdot \hat{\mathbf{n}}) + \alpha(\hat{\omega}_f \cdot \hat{\mathbf{n}} + \hat{\omega}_i \cdot \hat{\mathbf{n}}) + \beta \hat{\mathbf{n}} \cdot (\hat{\omega}_f \times \hat{\omega}_i),$$

$$\alpha = \frac{2\text{Re}(s^* p)}{|s|^2 + |p|^2} \quad \begin{array}{l} s = A, \\ p = B \frac{|\mathbf{p}_f|}{E_f + m_f} \end{array}$$



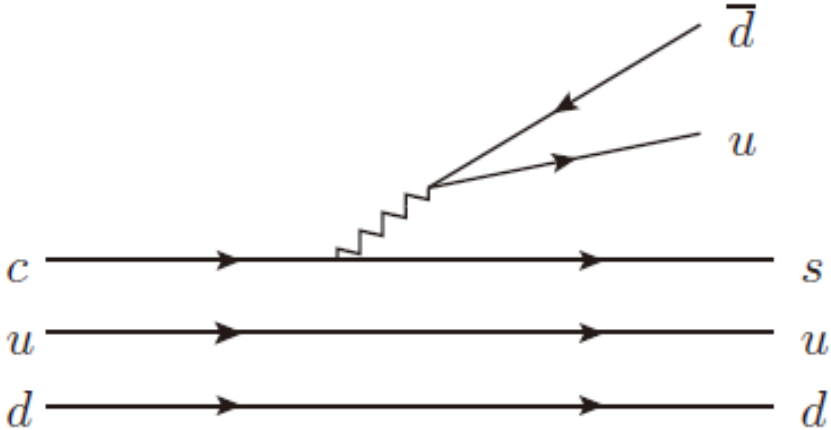
$$\alpha = \frac{2\text{Re}(M_{PV}^* M_{PC})}{|M_{PC}|^2 + |M_{PV}|^2}$$

03

The hadronic weak decay of charmed baryons

- The hadronic weak decay of Λ_c
- The hadronic weak decay of Ξ_c

Processes	$\Lambda_c \rightarrow \Lambda\pi^+$	$\Lambda_c \rightarrow \Sigma^+\pi^0$	$\Lambda_c \rightarrow \Sigma^0\pi^+$
DME	✓	✗	✗
CS	✓	✓	✓
Pole term	✓	✓	✓
Br	1.30%	1.29%	1.24%



$$\phi_{\Lambda_c} = \frac{1}{\sqrt{2}}(ud - du)c, \phi_{\Lambda} = \frac{1}{\sqrt{2}}(ud - du)s, \phi_{\Sigma^0} = \frac{1}{\sqrt{2}}(ud + du)s$$

- DPE process should not be the only dominant processes.
- The important of non-factorizable processes

TABLE V: The amplitudes with $J_f^z = J_i^z = -1/2$ for different processes and the unit is $10^{-9} \text{ GeV}^{-1/2}$. Amplitudes $A1(PV)$ and $A2(PV)$ are given by the parity-violating intermediate states $\Sigma^{*+}(1620)$ ($[\mathbf{70}, \mathbf{28}]$) and $\Sigma^{*+}(1750)$ ($[\mathbf{70}, \mathbf{48}]$), respectively.

Processes	$A(PC)$	$A1(PV)$	$A2(PV)$	$B(PC)$	$B(PV)$	$CS(PC)$	$CS(PV)$	$DPE(PC)$	$DPE(PV)$
$\Lambda_c \rightarrow \Lambda\pi^+$	-16.50	$0.74 - 0.023i$	$-2.57 + 0.10i$	$22.33 + 0.021i$	$-10.72 - 0.33i$	3.50	-4.17	-42.47	24.07
$\Lambda_c \rightarrow \Sigma^0\pi^+$	19.67	$-3.21 + 0.10i$	$-2.23 + 0.090i$	$-40.73 - 0.040i$	$19.16 + 0.60i$	-6.04	7.53	0	0
$\Lambda_c \rightarrow \Sigma^+\pi^0$	19.64	$-3.15 + 0.098i$	$-2.19 + 0.088$	$-40.65 - 0.10i$	$19.28 + 0.52i$	-6.04	7.51	0	0

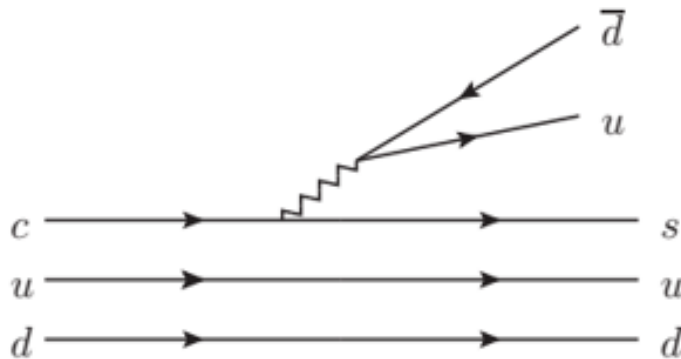
- The parity-conserving amplitudes of the pole terms are dominant.
- The interferences between factorizable and non-factorizable processes are essential.

	$\text{BR}(\Lambda_c \rightarrow \Lambda\pi^+)$	$\text{BR}(\Lambda_c \rightarrow \Sigma^0\pi^+)$	$\text{BR}(\Lambda_c \rightarrow \Sigma^+\pi^0)$
PDG data [24]	1.30 ± 0.07	1.29 ± 0.07	1.24 ± 0.10
BESIII [20]	$1.24 \pm 0.07 \pm 0.03$	$1.27 \pm 0.08 \pm 0.03$	$1.18 \pm 0.10 \pm 0.03$
SU(3) [39]	1.3 ± 0.2	1.3 ± 0.2	1.3 ± 0.2
Pole model [4]	1.30 ± 0.07	1.29 ± 0.07	1.24 ± 0.10
Current algebra [4]	1.30 ± 0.07	1.29 ± 0.07	1.24 ± 0.10
This work	1.30	1.24	1.26

$(1.31 \pm 0.08 \pm 0.05)\%$

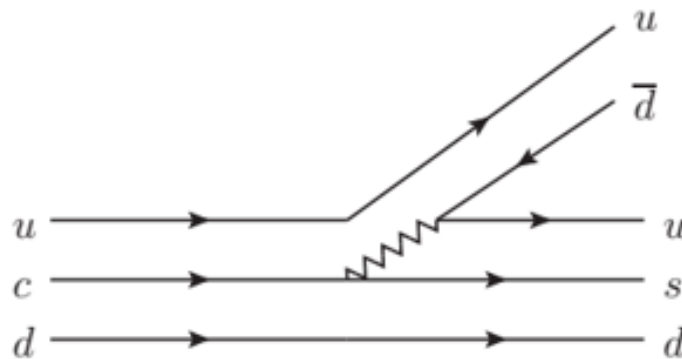
$(1.22 \pm 0.08 \pm 0.07)\%$

BESIII PRL.128.142001(2022)



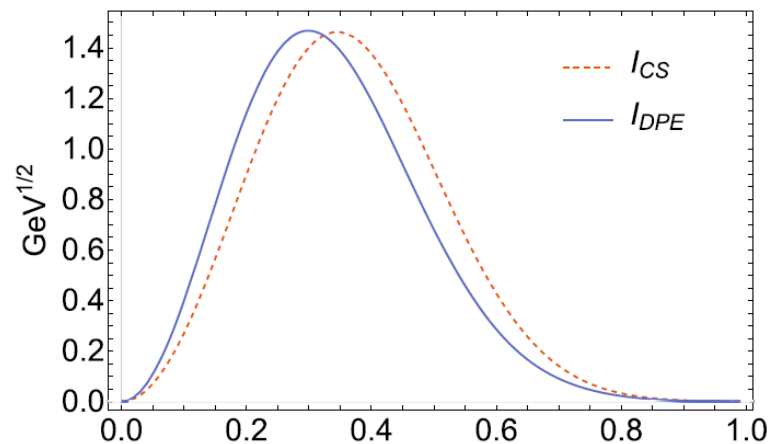
(a)

DPE

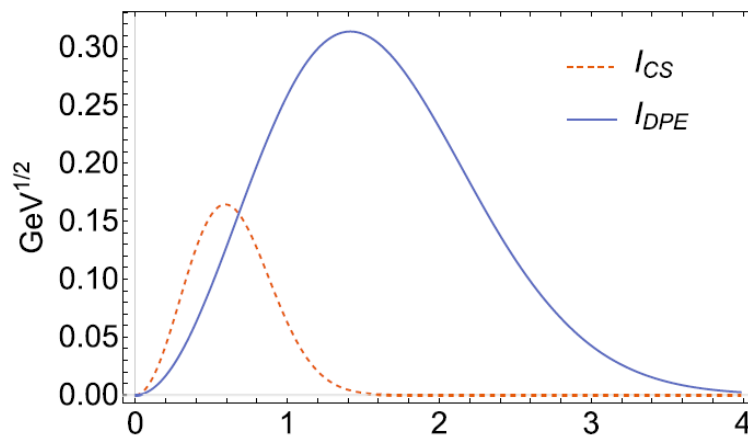


(b)

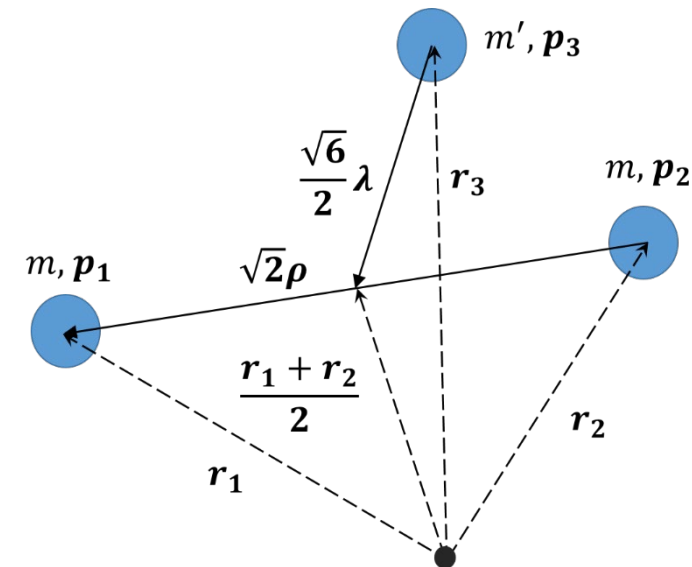
CS



(a) $|p_\rho|/\text{GeV}$



(b) $|p_\rho|/\text{GeV}$



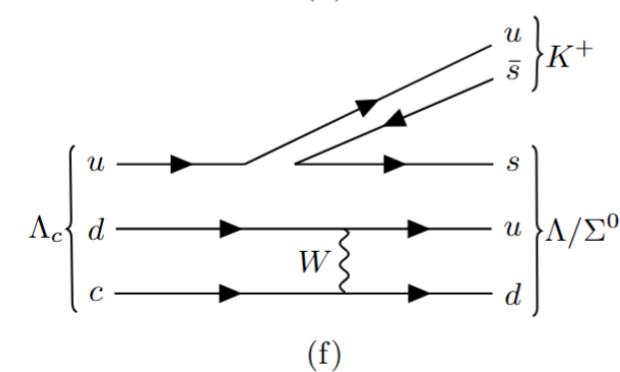
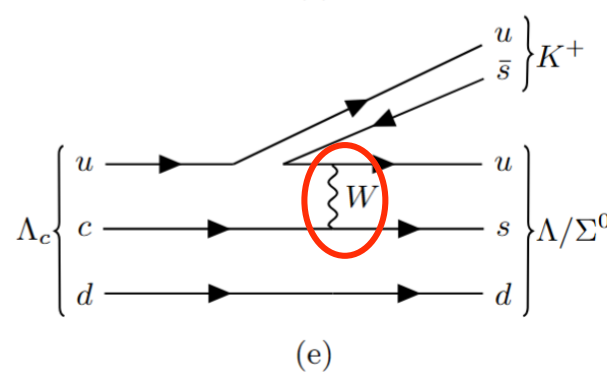
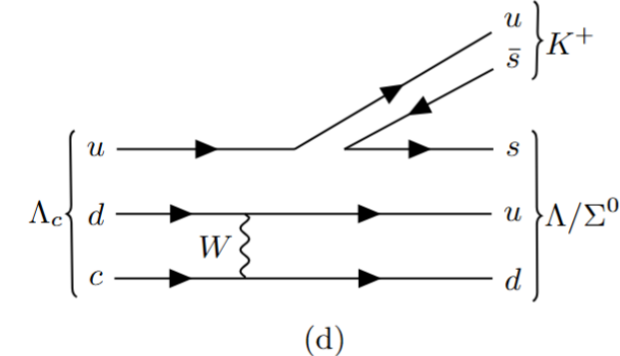
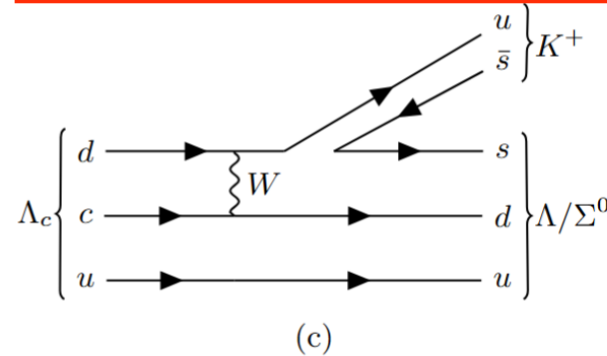
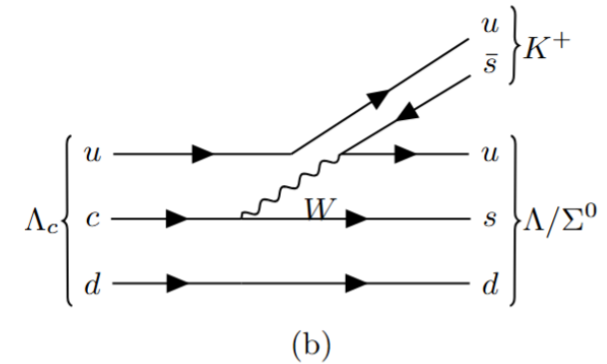
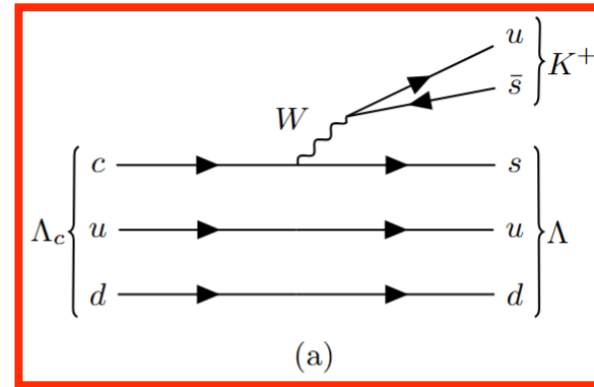
$$\langle \rho^2 \rangle \propto \frac{1}{\alpha_\rho^2}$$

3. $\Lambda_c \rightarrow \Lambda/\Sigma K^+$ 3.2 The diquark revisit

$$\Lambda_c \rightarrow \Lambda/\Sigma K^+$$

The constituent quarks of the final baryons are the same but with different isospins carried by the light quarks.

- p, Ξ_c^0 , and $\Xi_c'^0$ for the PC processes,
- $N(1535), N(1650), |\Xi_c^0, {}^2P_\lambda\rangle, |\Xi_c^0, {}^2P_\rho\rangle, |\Xi_c^0, {}^4P_\rho\rangle, |\Xi_c'^0, {}^2P_\lambda\rangle, |\Xi_c'^0, {}^2P_\rho\rangle$, and $|\Xi_c'^0, {}^4P_\lambda\rangle$ for the PV processes.



$$\begin{aligned} |\Lambda_c\rangle &= |0, 0\rangle \\ \langle\Lambda| &= \langle 0, 0| \\ \langle\Sigma^0| &= \langle 1, 0| \end{aligned}$$

The weak Hamiltonian

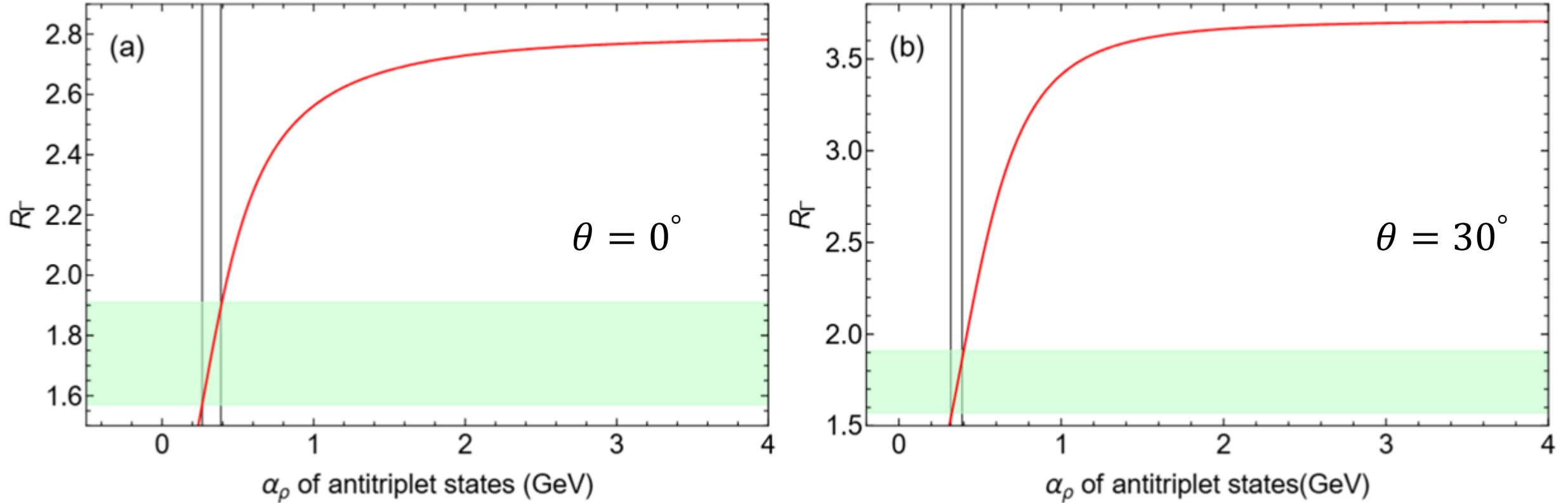
$cs \rightarrow su, cd \rightarrow du$ and $c \rightarrow s \bar{u} s$:

$$\Delta I = \frac{1}{2}, \Delta I_3 = \frac{1}{2} \Rightarrow |H_W\rangle = \left| \frac{1}{2}, \frac{1}{2} \right\rangle$$

$$R_\Gamma \approx \frac{|M(\Lambda_c \rightarrow \Lambda K^+)|^2}{|M(\Lambda_c \rightarrow \Sigma^0 K^+)|^2} = \frac{|\langle \Lambda K^+ | H_W | \Lambda_c \rangle|^2}{|\langle \Sigma^0 K^+ | H_W | \Lambda_c \rangle|^2} = \frac{|\langle 0, 0; \frac{1}{2}, \frac{1}{2} | 0, 0; \frac{1}{2}, \frac{1}{2} \rangle|^2}{|\langle 1, 0; \frac{1}{2}, \frac{1}{2} | 0, 0; \frac{1}{2}, \frac{1}{2} \rangle|^2} = 3.$$

3. $\Lambda_c \rightarrow \Lambda/\Sigma K^+$ 3.2 The diquark revisit

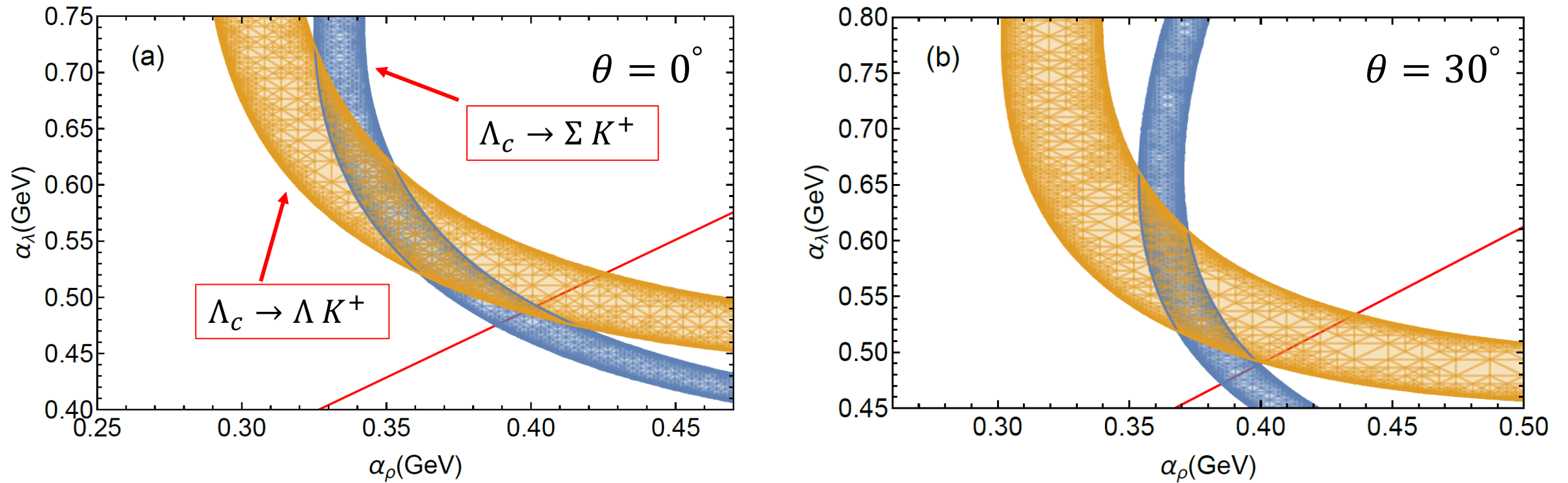
Only the α_ρ of anti-triplet charmed baryon are changed.



$$R_\Gamma \approx \frac{|M(\Lambda_c \rightarrow \Lambda K^+)|^2}{|M(\Lambda_c \rightarrow \Sigma^0 K^+)|^2} = \frac{|\langle \Lambda K^+ | H_W | \Lambda_c \rangle|^2}{|\langle \Sigma^0 K^+ | H_W | \Lambda_c \rangle|^2} = \frac{|\langle 0, 0; \frac{1}{2}, \frac{1}{2} | 0, 0; \frac{1}{2}, \frac{1}{2} \rangle|^2}{|\langle 1, 0; \frac{1}{2}, \frac{1}{2} | 0, 0; \frac{1}{2}, \frac{1}{2} \rangle|^2} = 3.$$

3. $\Lambda_c \rightarrow \Lambda/\Sigma K^+$ 3.2 The diquark revisit

The α_ρ and α_λ of are treated as free parameters



Neither the $[ud]$ quark pair nor the heavy-light diquark in the single charmed baryons is point-like structure.

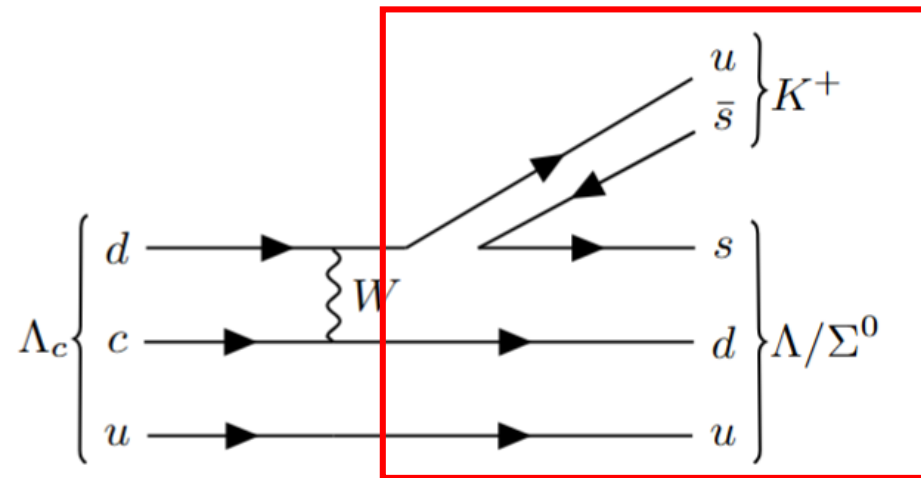
The amplitudes (in unit of $10^{-9} \text{ GeV}^{-1/2}$)

Parity	Processes	States	$\Lambda_c \rightarrow \Lambda K^+$		$\Lambda_c \rightarrow \Sigma^0 K^+$	
			$\theta = 0^\circ$	$\theta = 30^\circ$	$\theta = 0^\circ$	$\theta = 30^\circ$
PC	DPE	-	-6.71	-6.29	0	0
	CS	-	0.67	0.63	-1.16	-1.08
	WS	p	-1.89	-2.30	0.36	0.44
	SW	Ξ_c^0	(0, 0)	(0, 0)	(0, 0)	(0, 0)
		$\Xi_c^{\prime 0}$	(0.60, 1.13)	1.33	(-1.14, 0)	(-2.45, 0)
	Total	-	-6.21	-4.11	-1.94	-3.10
PV	DPE	-	4.93	4.48	0	0
	CS	-	-1.10	-1.08	1.97	1.91
	WS	$N(1535)$	$2.67 - 0.15i$	$3.23 - 0.18i$	$0.58 - 0.32i$	$-0.65 + 0.084i$
		$N(1650)$	0	$0.87 - 0.048i$	$4.37 - 0.40i$	$5.24 - 0.47i$
	SW	$\Xi_c^0 ^2 P_\rho\rangle$	(-0.36, 0.82)	(-0.99, 2.20)	(0.89, 0.096)	(2.28, 0.20)
		$\Xi_c^0 ^2 P_\lambda\rangle$	(0, 0)	(0, 0)	(0, 0)	(0, 0)
		$\Xi_c^0 ^4 P_\rho\rangle$	(0.55, -1.05)	(1.45, -2.75)	(-1.05, 0)	(-2.67, 0)
		$\Xi_c^{\prime 0} ^2 P_\rho\rangle$	(0, 0)	(0, 0)	(0, 0)	(0, 0)
		$\Xi_c^{\prime 0} ^2 P_\lambda\rangle$	(-0.45, -0.80)	(-1.19, -2.11)	(0.78, 0.043)	(2.03, 0.091)
		$\Xi_c^{\prime 0} ^4 P_\lambda\rangle$	(0.56, 1.06)	(1.45, 2.75)	(-1.05, 0)	(-2.66, 0)
	Total	-	$6.68 - 0.15i$	$8.32 - 0.23i$	$6.63 - 0.43i$	$5.77 - 0.39i$

The mixing angle of $N(1535)$ and $N(1650)$ is 30° .

Selection Rules

3. $\Lambda_c \rightarrow \Lambda/\Sigma K^+$ 3.2 The diquark revisit



$$N(1535): [70,^2 8]$$

$$N(1650): [70,^4 8]$$

The spin of u and d must be persevered.

$$|56,^2 8, 0, 0, \frac{1}{2}\rangle = \frac{1}{\sqrt{2}}(\phi_B^\rho \chi_{S,S_z}^\rho + \phi_B^\lambda \chi_{S,S_z}^\lambda) \Psi_{0,0,0},$$

$$|70,^2 8, 1, 1, J\rangle = \sum_{L_z+S_z=J_z} \langle 1, L_z; \frac{1}{2}, S_z | J J_z \rangle \frac{1}{2} \left[(\phi_B^\rho \chi_{S,S_z}^\lambda + \phi_B^\lambda \chi_{S,S_z}^\rho) \Psi_{1,1,L_z}^\rho + (\phi_B^\rho \chi_{S,S_z}^\rho - \phi_B^\lambda \chi_{S,S_z}^\lambda) \Psi_{1,1,L_z}^\lambda \right],$$

$$|70,^4 8, 1, 1, J\rangle = \sum_{L_z+S_z=J_z} \langle 1, L_z; \frac{3}{2}, S_z | J J_z \rangle \frac{1}{\sqrt{2}} \left[\phi_B^\rho \chi_{S,S_z}^s \Psi_{1,1,L_z}^\rho + \phi_B^\lambda \chi_{S,S_z}^s \Psi_{1,1,L_z}^\lambda \right].$$

Λ selection rule: leads to the vanishing transition matrix element between $N(1650)$ of $[70,^4 8]$ and $[56,^2 8]$ in $N(1650) \rightarrow \Lambda K / K^*$.

The amplitudes (in unit of $10^{-9} \text{ GeV}^{-1/2}$)

Parity	Processes	States	$\Lambda_c \rightarrow \Lambda K^+$		$\Lambda_c \rightarrow \Sigma^0 K^+$	
			$\theta = 0^\circ$	$\theta = 30^\circ$	$\theta = 0^\circ$	$\theta = 30^\circ$
PC	DPE	-	-6.71	-6.29	0	0
	CS	-	0.67	0.63	-1.16	-1.08
	WS	p	-1.89	-2.30	0.36	0.44
	SW	Ξ_c^0	(0, 0)	(0, 0)	(0, 0)	(0, 0)
		$\Xi_c^{\prime 0}$	(0.60, 1.13)	1.33	(-1.14, 0)	(-2.45, 0)
	Total	-	-6.21	-4.11	-1.94	-3.10
PV	DPE	-	4.93	4.48	0	0
	CS	-	-1.10	-1.08	1.97	1.91
	WS	$N(1535)$	$2.67 - 0.15i$	$3.23 - 0.18i$	$0.58 - 0.32i$	$-0.65 + 0.084i$
		$N(1650)$	0	$0.87 - 0.048i$	$4.37 - 0.40i$	$5.24 - 0.47i$
	SW	$\Xi_c^0 ^2 P_\rho\rangle$	(-0.36, 0.82)	(-0.99, 2.20)	(0.89, 0.096)	(2.28, 0.20)
		$\Xi_c^0 ^2 P_\lambda\rangle$	(0, 0)	(0, 0)	(0, 0)	(0, 0)
		$\Xi_c^0 ^4 P_\rho\rangle$	(0.55, -1.05)	(1.45, -2.75)	(-1.05, 0)	(-2.67, 0)
		$\Xi_c^{\prime 0} ^2 P_\rho\rangle$	(0, 0)	(0, 0)	(0, 0)	(0, 0)
		$\Xi_c^{\prime 0} ^2 P_\lambda\rangle$	(-0.45, -0.80)	(-1.19, -2.11)	(0.78, 0.043)	(2.03, 0.091)
		$\Xi_c^{\prime 0} ^4 P_\lambda\rangle$	(0.56, 1.06)	(1.45, 2.75)	(-1.05, 0)	(-2.66, 0)
		Total	$6.68 - 0.15i$	$8.32 - 0.23i$	$6.63 - 0.43i$	$5.77 - 0.39i$

The mixing angle of $N(1535)$ and $N(1650)$ is 30° .

Selection Rules

Evidence for the strangeness-changing weak decay $\Xi_b^- \rightarrow \Lambda_b^0 \pi^-$

#1

LHCb Collaboration • Roel Aaij (CERN) et al. (Oct 13, 2015)

Published in: *Phys.Rev.Lett.* 115 (2015) 24, 241801 • e-Print: [1510.03829](#) [hep-ex]

 pdf  links  DOI  cite

 21 citations

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

$$\frac{f_{\Xi_b^-}}{f_{\Lambda_b}} \approx 0.1 \sim 0.3 \Rightarrow \mathcal{B}(\Xi_b^- \rightarrow \Lambda_b \pi^-) = (0.57 \pm 0.21)\% \sim (0.19 \pm 0.07)\%$$

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

#1

LHCb Collaboration • Roel Aaij (NIKHEF, Amsterdam) et al. (Jul 23, 2020)

Published in: *Phys.Rev.D* 102 (2020) 7, 071101 • e-Print: [2007.12096](#) [hep-ex]

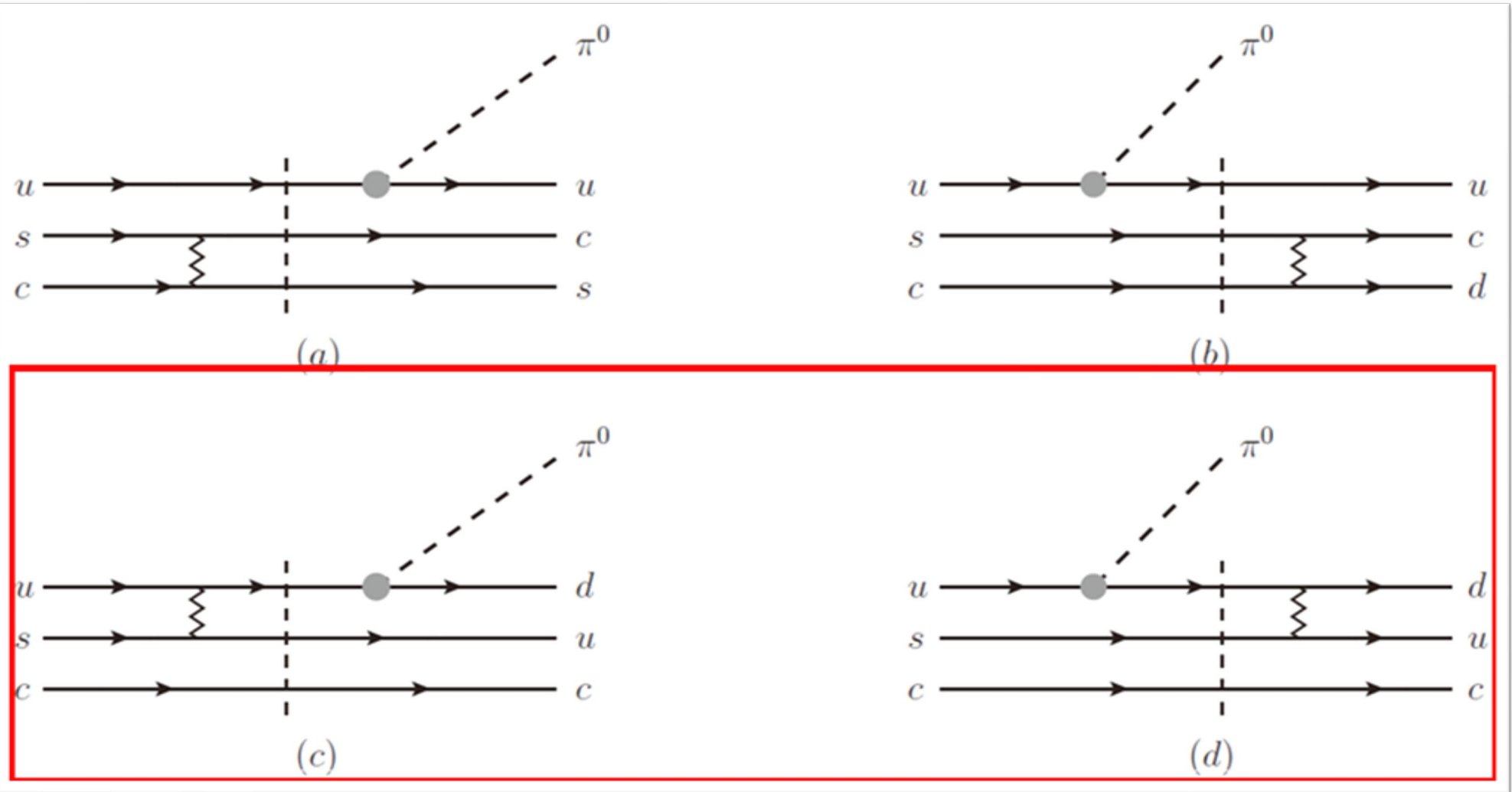
 pdf  DOI  cite

 0 citations

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

Processes	$\Xi_c^+ \rightarrow \Lambda_c \pi^0$	$\Xi_c^0 \rightarrow \Lambda_c \pi^-$	$\Xi_b^0 \rightarrow \Lambda_b \pi^0$	$\Xi_b^- \rightarrow \Lambda_b \pi^-$
Exp. Data	...	0.55 ± 0.20 [1]	...	$0.19 \pm 0.07 \sim 0.57 \pm 0.21$ [2]
MIT bag model [4]	0.0093	0.0087	0.059	0.2
Diquark model [4]	...	...	0.25	0.69
Duality [5]	...	...	...	0.63 ± 0.42
Current algebra [11]	0.386 ± 0.135	0.194 ± 0.07	...	...
Current algebra [6]	...	...	$1 \sim 4$	$2 \sim 8$
Current algebra [10]	< 0.6	< 0.3	$0.09 - 0.37$	$0.19 - 0.76$
Our results	1.11	0.58	0.017	0.14

Larger than the theoretical values



		$\Xi_c^+ \rightarrow \Lambda_c \pi^0$		$\Xi_c^0 \rightarrow \Lambda_c \pi^-$		$\Xi_b^0 \rightarrow \Lambda_b \pi^0$		$\Xi_b^- \rightarrow \Lambda_b \pi^-$	
PC	Pole-A	Σ_c^+	$116.76 - 17.80i$	Σ_c^0	$146.77 - 7.80i$	Σ_b^0	Spin(weak)		
		Λ_c^+	Isospin			Λ_b	Spin(CQM)		
	Pole-B	Ξ_c^+	Spin(CQM)	Ξ_c^+	Spin(CQM)	Ξ_b^0	Spin(CQM)	Ξ_b^0	Spin(CQM)
		$\Xi_c'^+$	-2.61	$\Xi_c'^+$	-3.67	$\Xi_b'^0$	Spin(weak)	$\Xi_b'^0$	Spin(weak)
	DPE		Spin(weak)		Spin(weak)		Spin(weak)		Spin(weak)
	CS		Spin(weak)		Spin(weak)		Spin(weak)		Spin(weak)
Total			$114.15 - 17.80i$		$143.10 - 7.80i$		0		0
PV	Pole-A	$\Sigma_c^+ ^2 P_\rho\rangle$	Spin(CQM)	$\Sigma_c^0 ^2 P_\rho\rangle$	Spin(CQM)	$\Sigma_b^0 ^2 P_\rho\rangle$	Spin(weak)		
		$\Sigma_c^+ ^2 P_\lambda\rangle$	1.59	$\Sigma_c^0 ^2 P_\lambda\rangle$	2.72	$\Sigma_b^0 ^2 P_\lambda\rangle$	Spatial		
		$\Sigma_c^+ ^4 P_\rho\rangle$	-0.94	$\Sigma_c^0 ^4 P_\rho\rangle$	-1.34	$\Sigma_b^0 ^4 P_\rho\rangle$	Spatial		
		$\Lambda_c^+ ^2 P_\rho\rangle$	Isospin			$\Lambda_b ^2 P_\rho\rangle$	Isospin		
		$\Lambda_c^+ ^2 P_\lambda\rangle$	Isospin			$\Lambda_b ^2 P_\lambda\rangle$	Isospin		
		$\Lambda_c^+ ^4 P_\rho\rangle$	Isospin			$\Lambda_b ^4 P_\rho\rangle$	Isospin		
	Pole-B	$\Xi_c^+ ^2 P_\rho\rangle$	-3.32	$\Xi_c^+ ^2 P_\rho\rangle$	-6.02	$\Xi_b^0 ^2 P_\rho\rangle$	-7.95	$\Xi_b^0 ^2 P_\rho\rangle$	-11.25
		$\Xi_c^+ ^2 P_\lambda\rangle$	Spin(CQM)	$\Xi_c^+ ^2 P_\lambda\rangle$	Spin(CQM)	$\Xi_b^0 ^2 P_\lambda\rangle$	Spin(CQM)	$\Xi_b^0 ^2 P_\lambda\rangle$	Spin(CQM)
		$\Xi_c^+ ^4 P_\rho\rangle$	-1.26	$\Xi_c^+ ^4 P_\rho\rangle$	-1.77	$\Xi_b^0 ^4 P_\rho\rangle$	-3.57	$\Xi_b^0 ^4 P_\rho\rangle$	-5.06
		$\Xi_c'^+ ^2 P_\rho\rangle$	Spin(CQM)	$\Xi_c'^+ ^2 P_\rho\rangle$	Spin(CQM)	$\Xi_b'^0 ^2 P_\rho\rangle$	Spin(CQM)	$\Xi_b'^0 ^2 P_\rho\rangle$	Spin(CQM)
		$\Xi_c'^+ ^2 P_\lambda\rangle$	0.55	$\Xi_c'^+ ^2 P_\lambda\rangle$	0.77	$\Xi_b'^0 ^2 P_\lambda\rangle$	Spatial	$\Xi_b'^0 ^2 P_\lambda\rangle$	Spatial
		$\Xi_c'^+ ^4 P_\lambda\rangle$	-0.41	$\Xi_c'^+ ^4 P_\lambda\rangle$	-0.58	$\Xi_b'^0 ^4 P_\lambda\rangle$	Spatial	$\Xi_b'^0 ^4 P_\lambda\rangle$	Spatial
	DPE		0		-9.73		0		-9.79
	CS		3.40		4.81		4.32		6.11
Total			$-1.32 + 0.0038i$		$-11.58 + 0.0055i$		$-7.20 - 0.0048i$		$-19.99 - 0.0068$

explain the sizable branching ratio for $\Xi_c^0 \rightarrow \Lambda_c \pi$

Processes	$\Xi_c^+ \rightarrow \Lambda_c \pi^0$	$\Xi_c^0 \rightarrow \Lambda_c \pi^-$	$\Xi_b^0 \rightarrow \Lambda_b \pi^0$	$\Xi_b^- \rightarrow \Lambda_b \pi^-$
Exp. Data	...	0.55 ± 0.20 [1]	...	$0.19 \pm 0.07 \sim 0.57 \pm 0.21$ [2]
MIT bag model [4]	0.0093	0.0087	0.059	0.2
Diquark model [4]	...	...	0.25	0.69
Duality [5]	...	...	...	0.63 ± 0.42
Current algebra [11]	0.386 ± 0.135	0.194 ± 0.07	...	...
Current algebra [6]	...	...	$1 \sim 4$	$2 \sim 8$
Current algebra [10]	< 0.6	< 0.3	$0.09 - 0.37$	$0.19 - 0.76$
Our results	1.11	0.58	0.017	0.14

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

- The parity-conserving amplitudes of the pole terms are dominant for $\Xi_c \rightarrow \Lambda_c \pi$.
- The importance of non-factorizable terms for $\Xi_b \rightarrow \Lambda_b \pi$.



First Study of $\Xi_c^0 \rightarrow \Xi^0 \pi^0 / \eta / \eta'$
PRELIMINARY at Belle + Belle II $\sim 1.4/\text{ab}$:



preliminary

First measurements of the branching fractions using combined data:

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

taking $\Xi_c^0 \rightarrow \Xi^- \pi^+$ as reference mode (BR error dominate the uncertainties), favoring predictions in SU(3) flavor symmetry [JHEP 02, 235 (2023)]

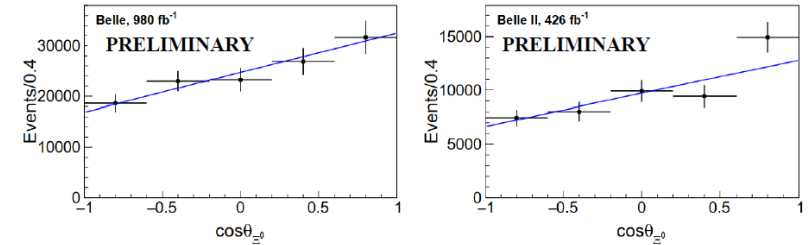
First asymmetry parameter $\alpha(\Xi_c^0 \rightarrow \Xi^0 \pi^0)$ measurement depending on

$$\frac{dN}{d\cos\theta_{\Xi^0}} \propto 1 + \alpha(\Xi_c^0 \rightarrow \Xi^0 h^0) \alpha(\Xi^0 \rightarrow \Lambda \pi^0) \cos\theta_{\Xi^0}$$

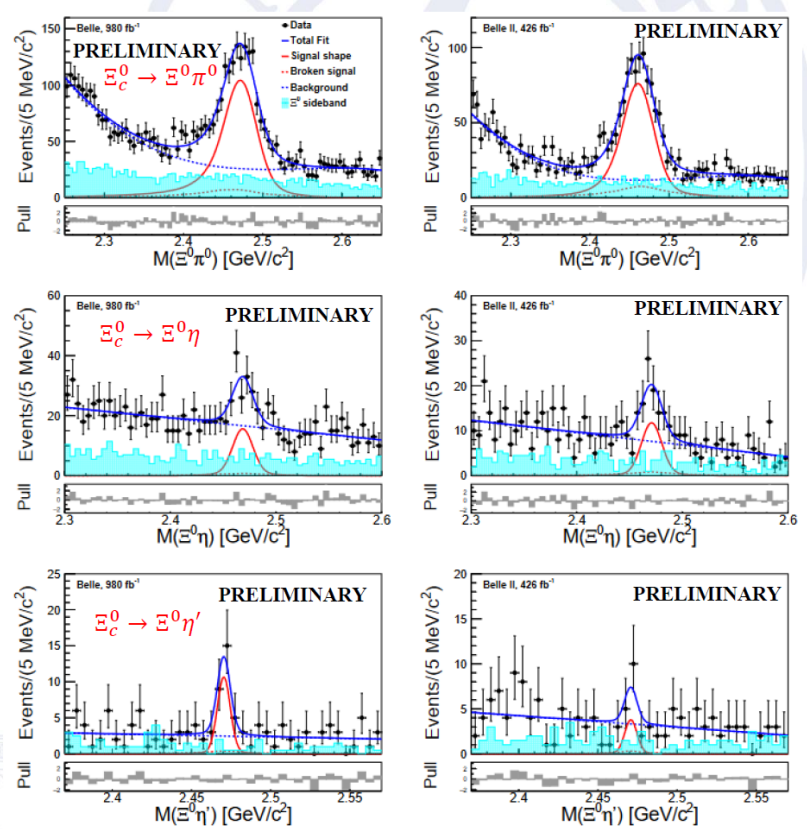
through a simultaneous fit to Belle and Belle II data samples

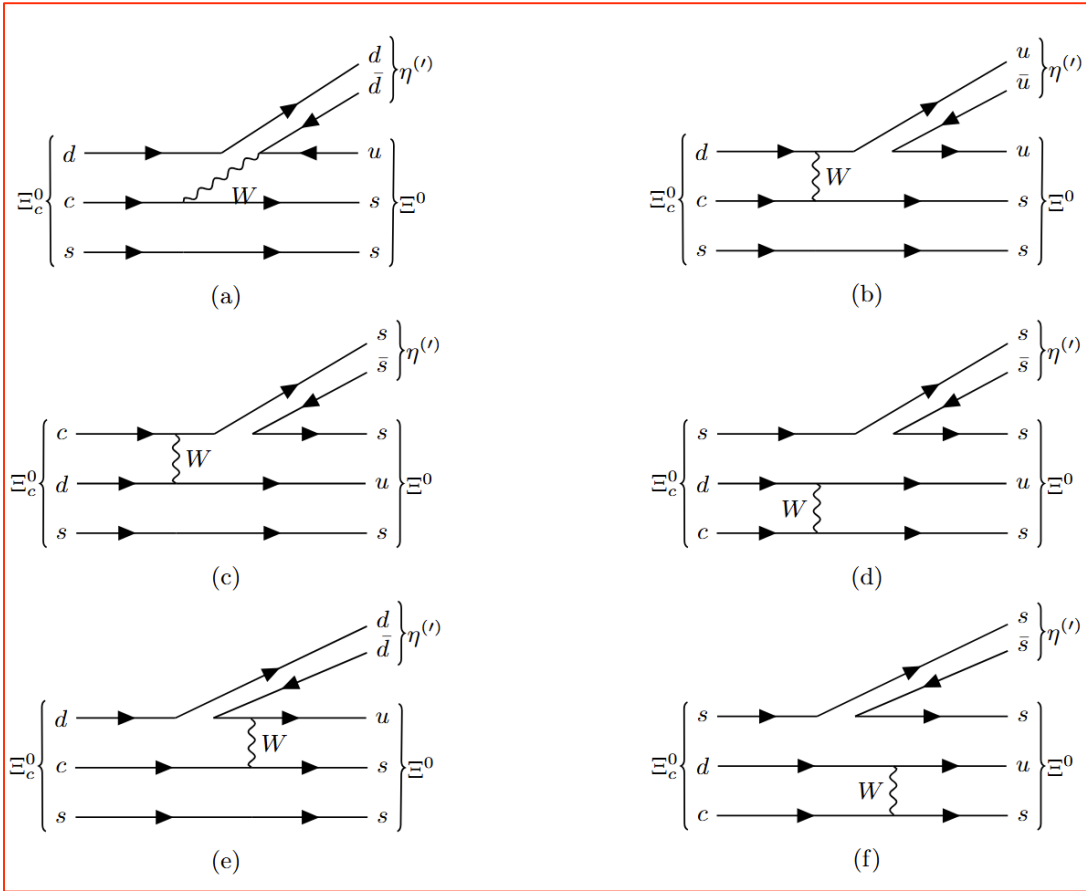
$$\alpha(\Xi_c^0 \rightarrow \Xi^0 \pi^0) = -0.90 \pm 0.15(\text{stat.}) \pm 0.23(\text{syst.})$$

taking $\alpha(\Xi^0 \rightarrow \Lambda \pi^0) = -0.349 \pm 0.009(\text{PDG})$

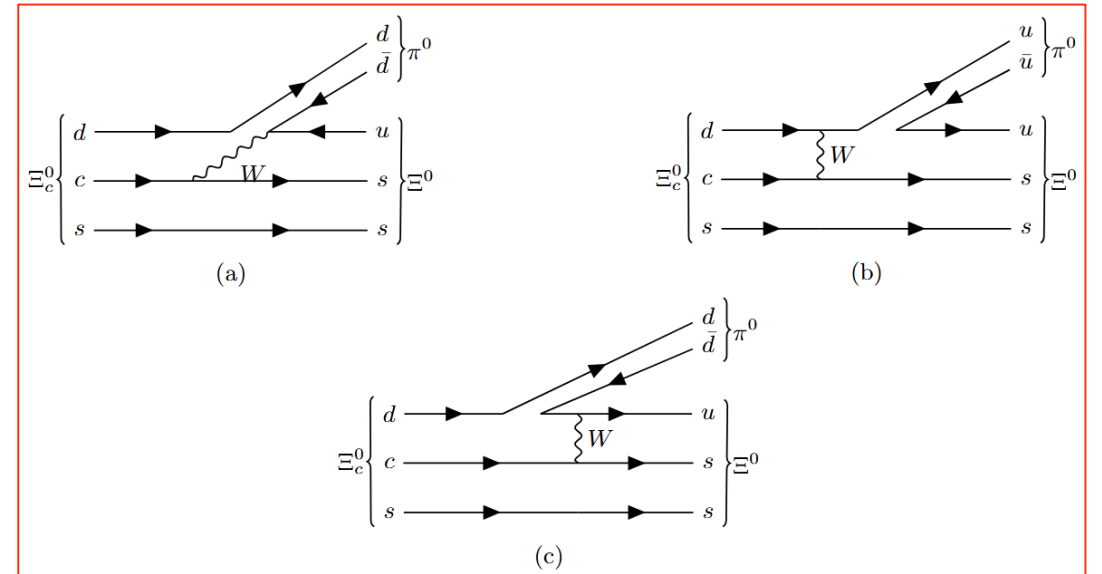


Invariant mass spectra for Ξ_c^0 candidates

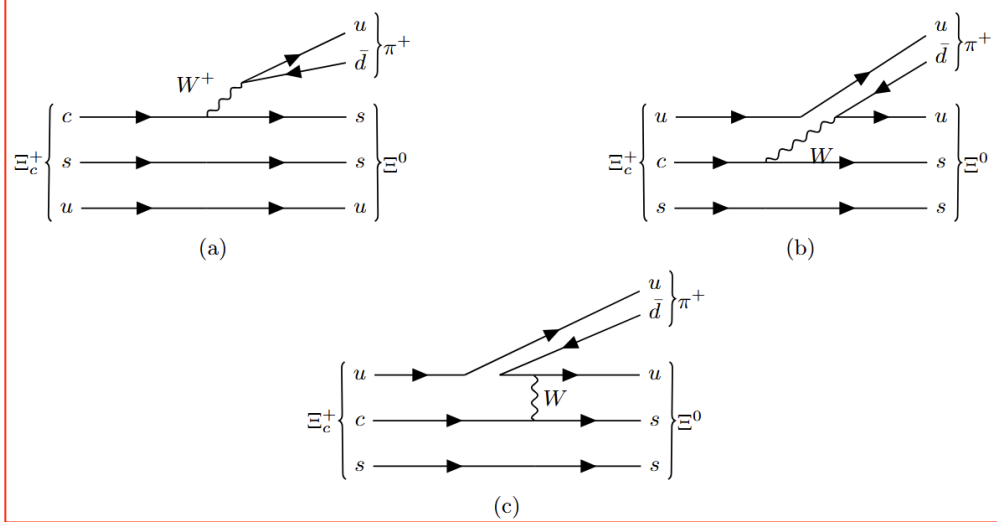




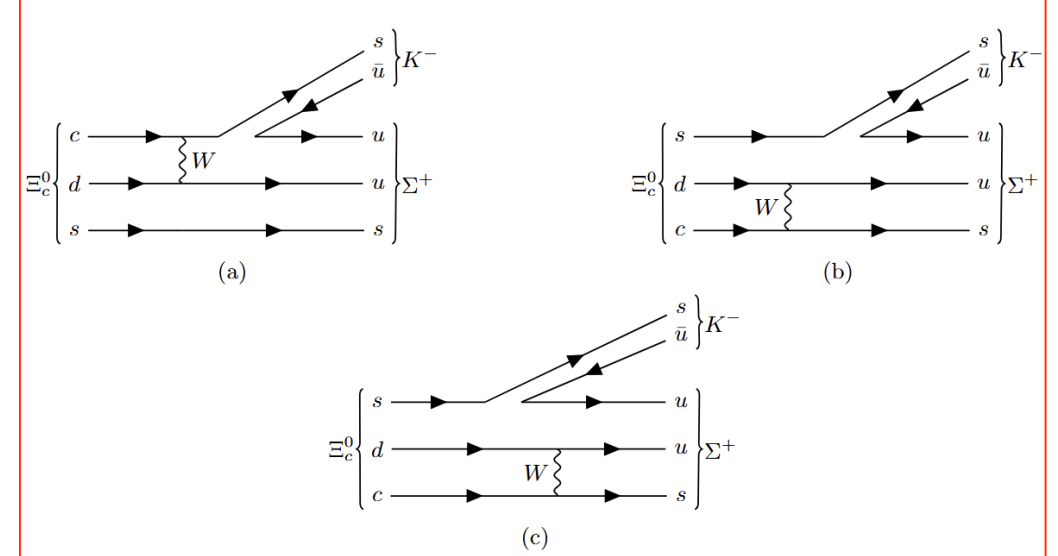
$$\Xi_c^0 \rightarrow \Xi^0 \eta'$$



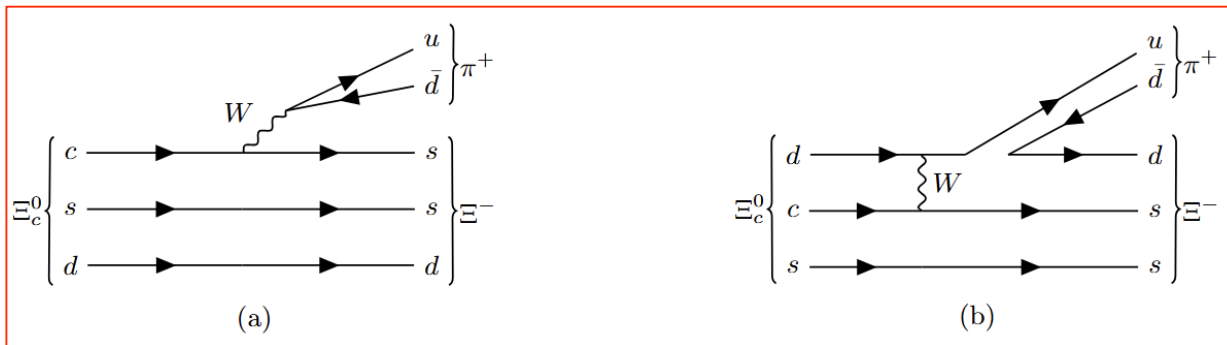
$$\Xi_c^0 \rightarrow \Xi^0 \pi^0$$



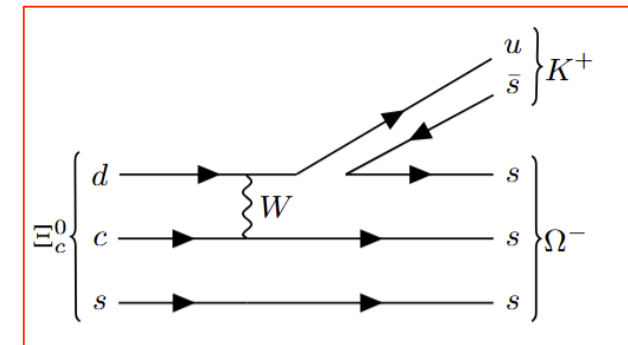
$$\Xi_c^+ \rightarrow \Xi^0 \pi^+$$



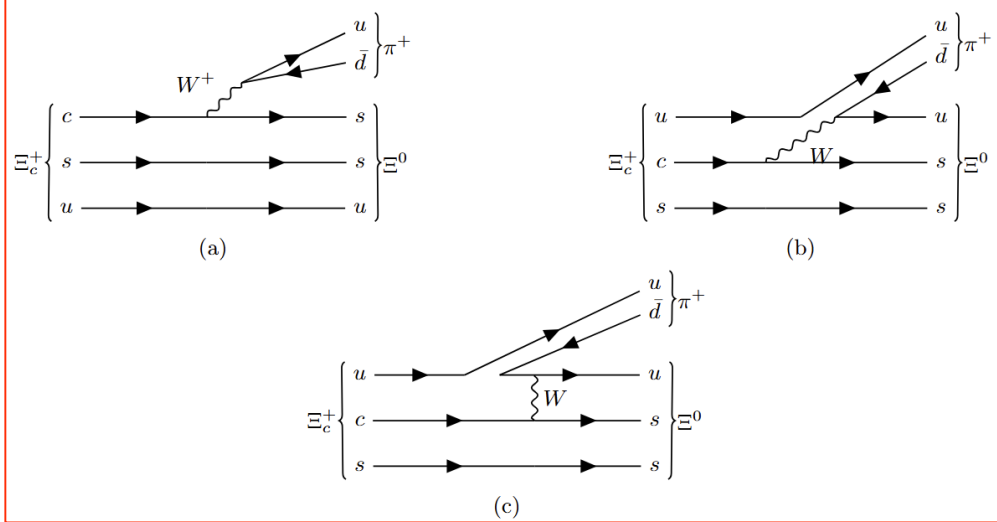
$$\Xi_c^0 \rightarrow \Sigma^+ K^-$$



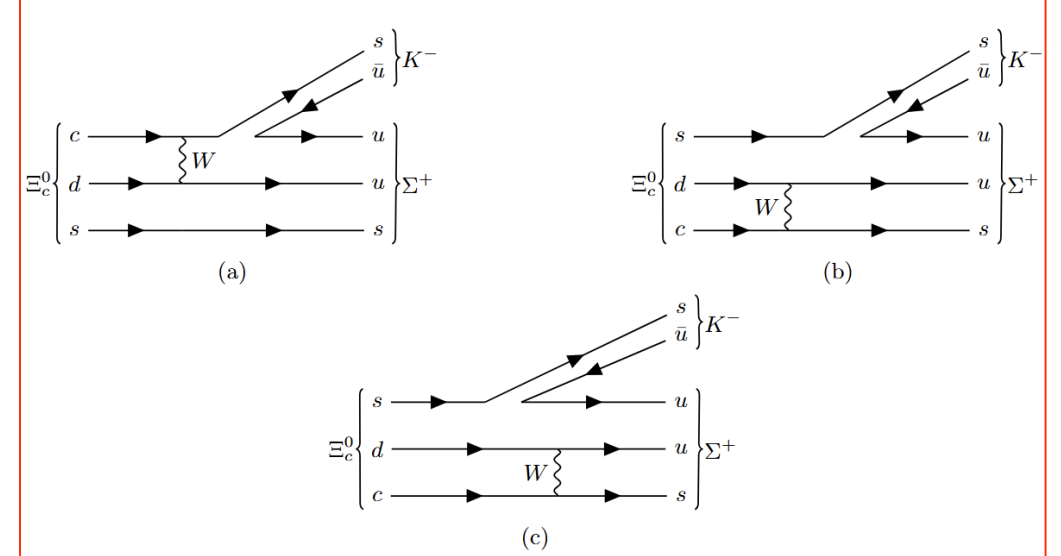
$$\Xi_c^0 \rightarrow \Xi^- \pi^+$$



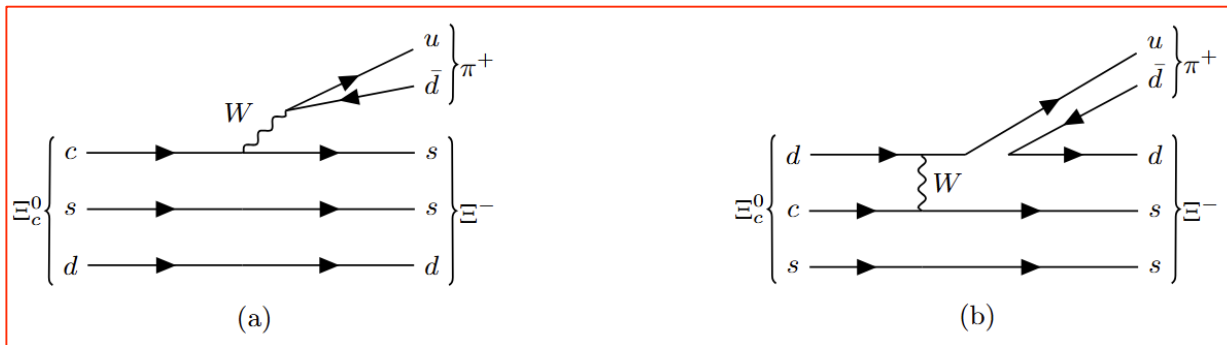
$$\Xi_c^0 \rightarrow \Omega^- K^+$$



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



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



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

$$\text{Br}(\Xi_c^0 \rightarrow \Xi^- \pi^+) = (14.3 \pm 2.7) \times 10^{-3}$$

$$\text{Br}(\Xi_c^0 \rightarrow \Sigma^+ K^-) = (1.8 \pm 0.4) \times 10^{-3}$$

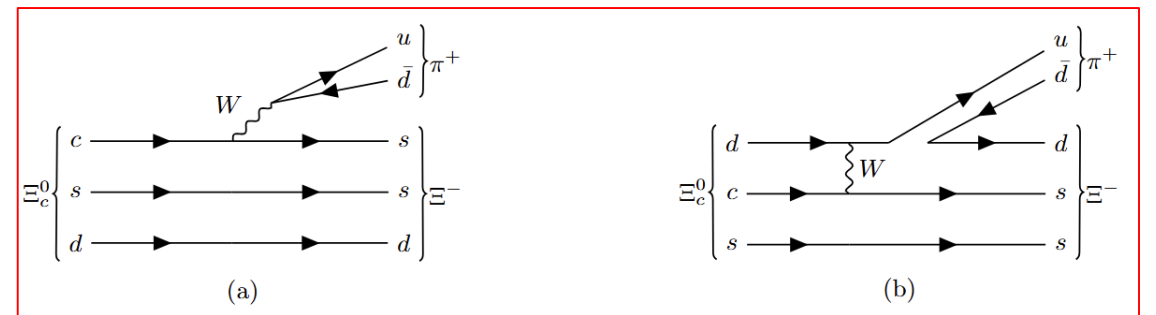
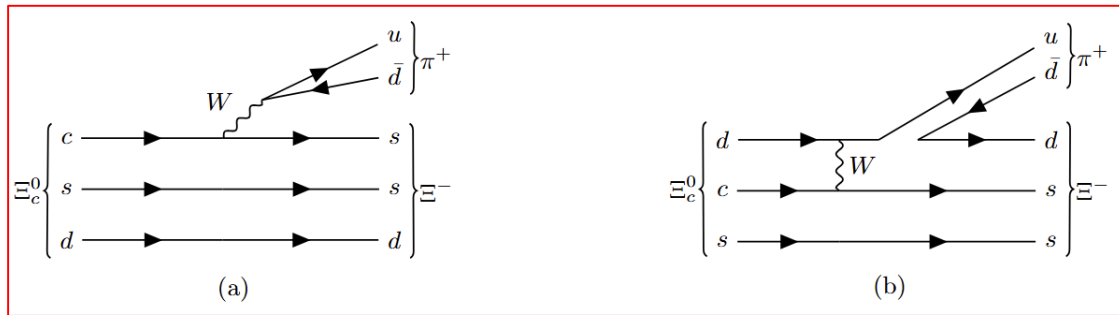
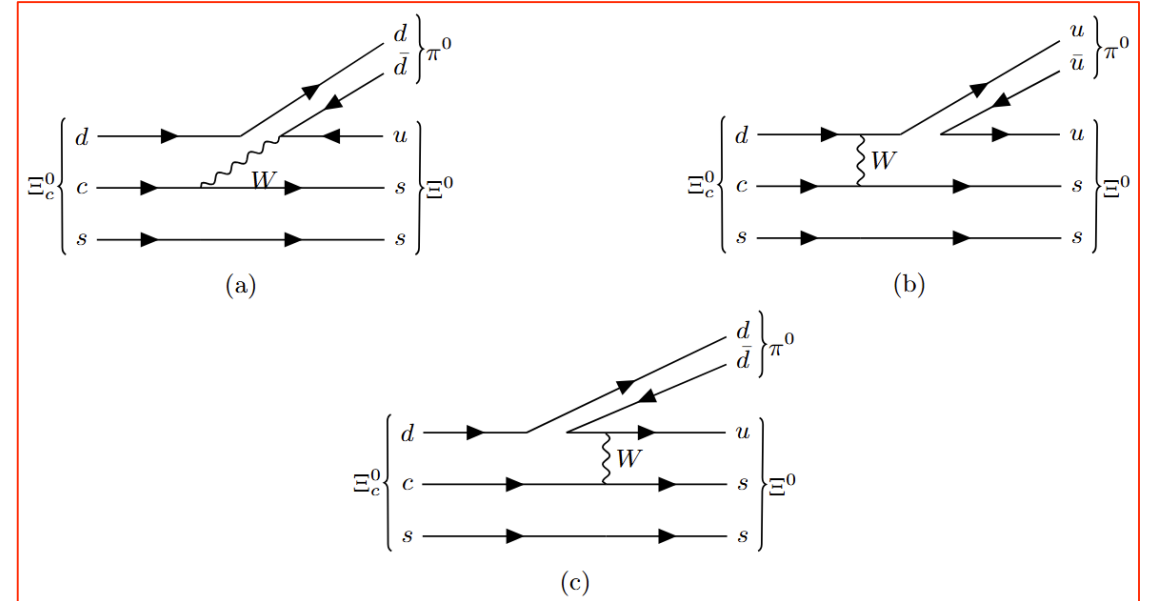
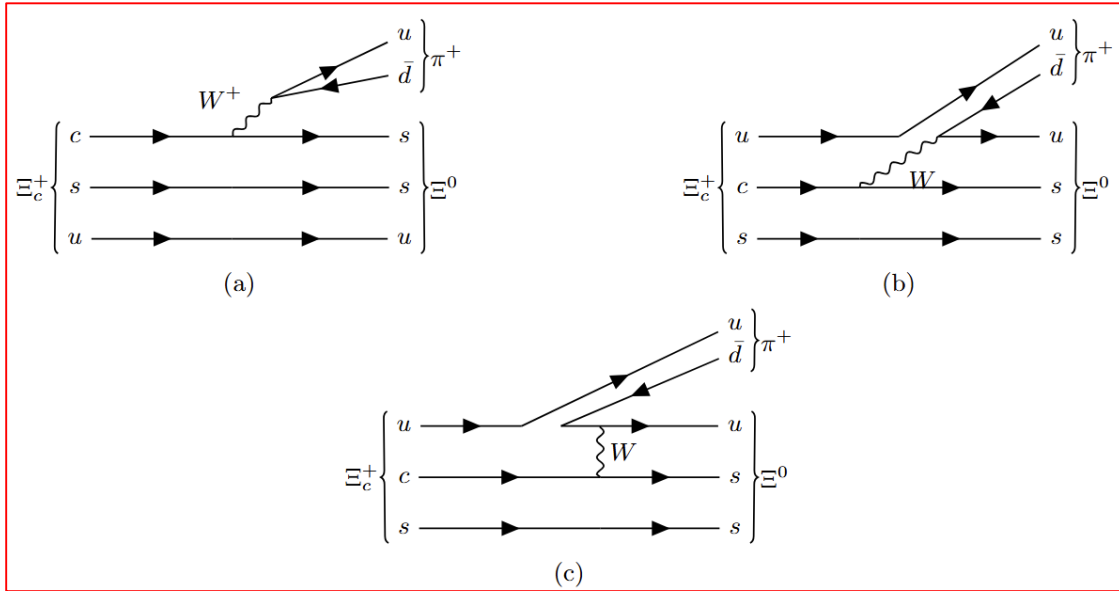
$$\frac{\Gamma_{\Xi_c^+ \rightarrow \Xi^0 \pi^+}}{\Gamma_{\Xi_c^0 \rightarrow \Xi^- \pi^+}} = \frac{\tau_{\Xi_c^0} \times \text{Br}(\Xi_c^+ \rightarrow \Xi^0 \pi^+)}{\tau_{\Xi_c^+} \times \text{Br}(\Xi_c^0 \rightarrow \Xi^- \pi^+)} \approx 0.38$$

TABLE X: The amplitudes of $\Xi_c^+ \rightarrow \Xi^0 \pi^+$ (in unit of $10^{-9} \text{ GeV}^{-1/2}$ for the real part and $10^{-13} \text{ GeV}^{-1/2}$ for the imaginary part). WS (SW) is used to label the pole terms that baryon weak transition either preceding (following) the strong meson emission.

	DME	CS	WS	SW						Total
	✓	✓	✗	Ξ_c^0	$\Xi_c^{\prime 0}$					
PC	(34.41, 0)	(−5.62, 0)	(0,0)	(0, 0)	(−8.47, 0)					(20.32, 0)
	✓	✓	✗	$ ^2P_\rho\rangle$	$ ^2P_\lambda\rangle$	$ ^4P_\rho\rangle$	$ ^2P_\rho\rangle$	$ ^2P_\lambda\rangle$	$ ^4P_\lambda\rangle$	
PV	(−18.98, 0)	(5.34, 0)	(0,0)	(2.84, 6.04i)	(0,0)	(−4.22, −8.80i)	(0,0)	(4.12, 8.98i)	(−6.22, −13.26i)	(−17.11, −7.03i)

TABLE XI: The amplitudes of the $\Xi_c^0 \rightarrow \Xi^- \pi^+$ in unit of $10^{-9} \text{ GeV}^{-1/2}$.

	DME	CS	WS	SW	Total
	✓	✗	Ξ_c^0	✗	
PC	(34.41, 0)	(0,0)	(3.37, $-3.04 \times 10^{-2}i$)	(0,0)	(37.78, $-3.04 \times 10^{-2}i$)
	✓	✗	Ξ_c^{*0}	$\Xi_c^0(1690)$	
PV	(−19.02, 0)	(0,0)	(0.36, $-5.37 \times 10^{-3}i$)	(2.92, $-3.04 \times 10^{-2}i$)	(−15.74, $-3.58 \times 10^{-2}i$)



$$\frac{\Gamma_{\Xi_c^+ \rightarrow \Xi^0 \pi^+}}{\Gamma_{\Xi_c^0 \rightarrow \Xi^- \pi^+}} = \frac{\tau_{\Xi_c^0} \times \text{Br}(\Xi_c^+ \rightarrow \Xi^0 \pi^+)}{\tau_{\Xi_c^+} \times \text{Br}(\Xi_c^0 \rightarrow \Xi^- \pi^+)} \approx 0.38$$

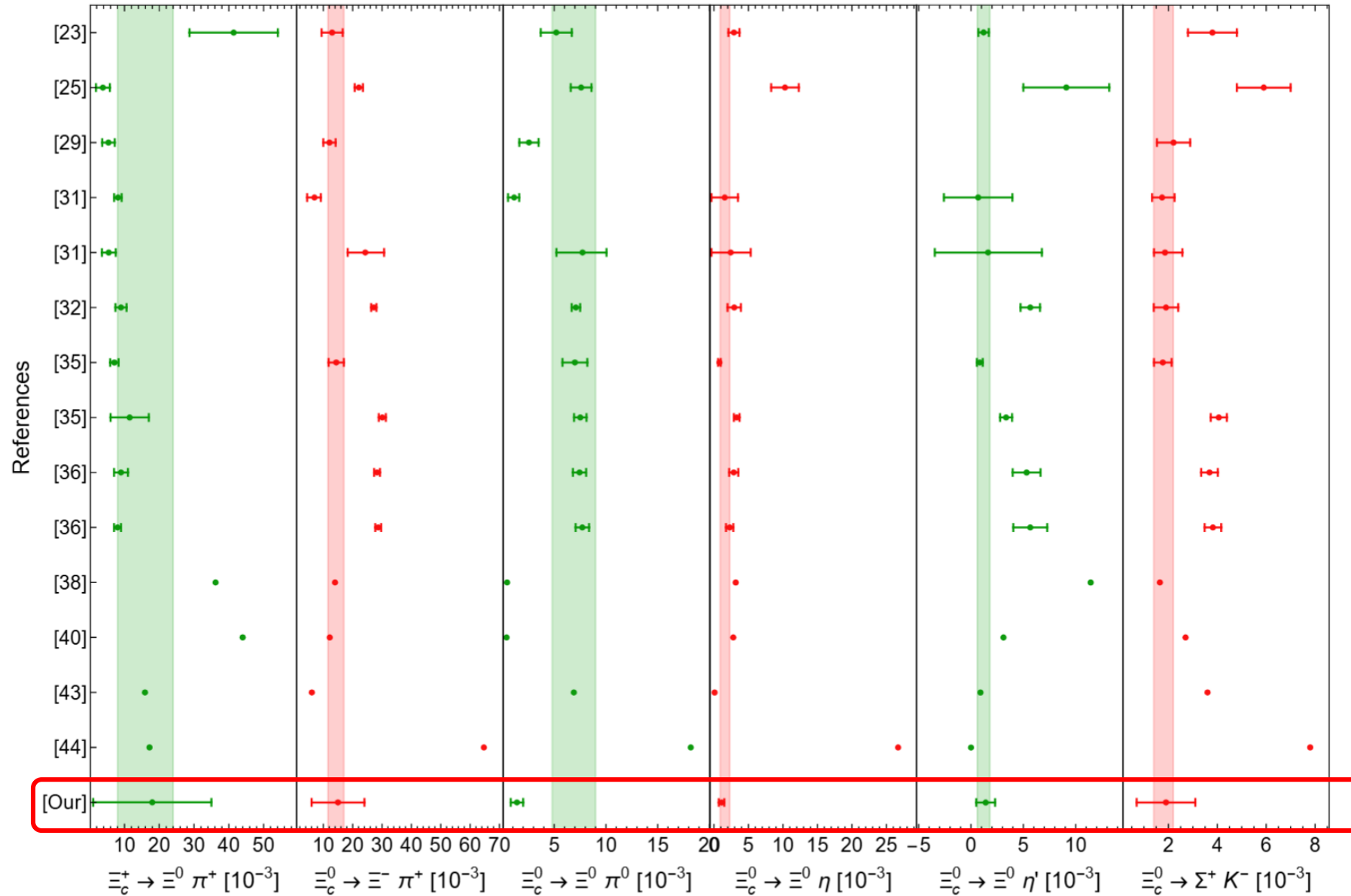
$$\frac{\Gamma_{\Xi_c^0 \rightarrow \Xi^- \pi^+}}{\Gamma_{\Xi_c^0 \rightarrow \Xi^0 \pi^0}} = \frac{\text{Br}(\Xi_c^0 \rightarrow \Xi^- \pi^+)}{\text{Br}(\Xi_c^0 \rightarrow \Xi^0 \pi^0)} \approx 2.61$$

TABLE XI: The amplitudes of the $\Xi_c^0 \rightarrow \Xi^- \pi^+$ in unit of $10^{-9} \text{ GeV}^{-1/2}$.

	DME	CS	WS	SW	Total
PC	✓ (34.41, 0)	✗ (0,0)	Ξ_c^0 (3.37, $-3.04 \times 10^{-2}i$)	✗ (0,0)	(37.78, $-3.04 \times 10^{-2}i$)
PV	✓ (-19.02, 0)	✗ (0,0)	Ξ_c^{*0} (0.36, $-5.37 \times 10^{-3}i$)	$\Xi_c^0(1690)$ (2.92, $-3.04 \times 10^{-2}i$)	(-15.74, $-3.58 \times 10^{-2}i$)

TABLE XII: The amplitudes of $\Xi_c^0 \rightarrow \Xi^0 \pi^0$ (in unit of $10^{-9} \text{ GeV}^{-1/2}$ for the real part and $10^{-12} \text{ GeV}^{-1/2}$ for the imaginary part).

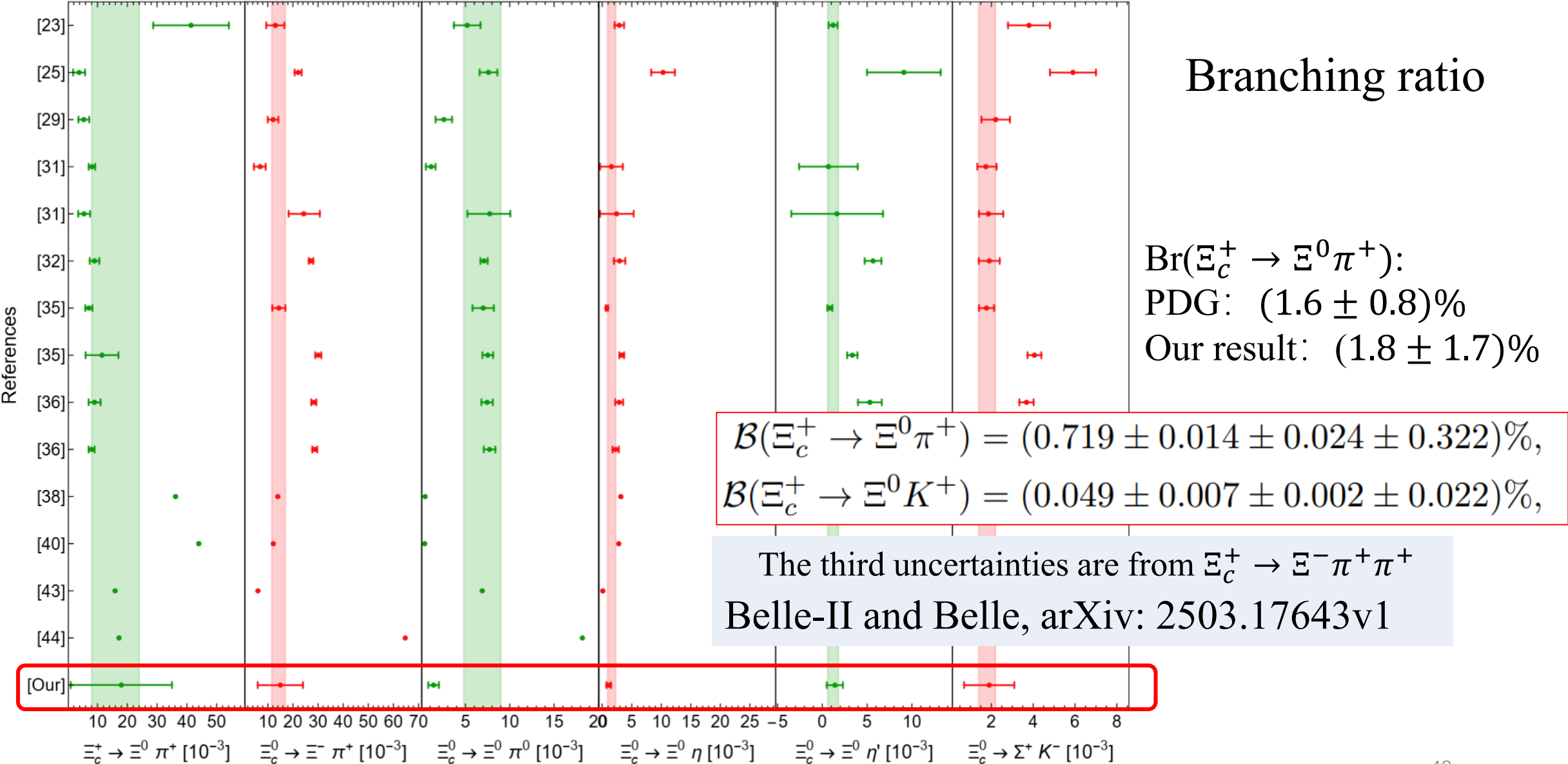
	DME	CS	WS	SW						Total
	✗	✓	Ξ^0	Ξ_c^0	$\Xi_c^{'0}$					
PC	(0, 0)	(3.98, 0)	(2.37, $-21.34i$)	(0, 0)	(5.95, 0)					(12.29, $-21.34i$)
	✗	✓	Ξ^{*0}	$\Xi^0(1690)$	$ ^2P_\rho\rangle$	$ ^2P_\lambda\rangle$	$ ^4P_\rho\rangle$	$ ^2P_\rho\rangle$	$ ^2P_\lambda\rangle$	$ ^4P_\lambda\rangle$
PV	(0, 0)	(-3.77, 0)	(0.25, $-3.66i$)	(1.99, $-20.73i$)	(-1.99, $-0.42i$)	(0, 0)	(2.97, $0.62i$)	(0, 0)	(-2.90, $-0.63i$)	(4.38, $0.93i$)
										(0.92, $-23.90i$)

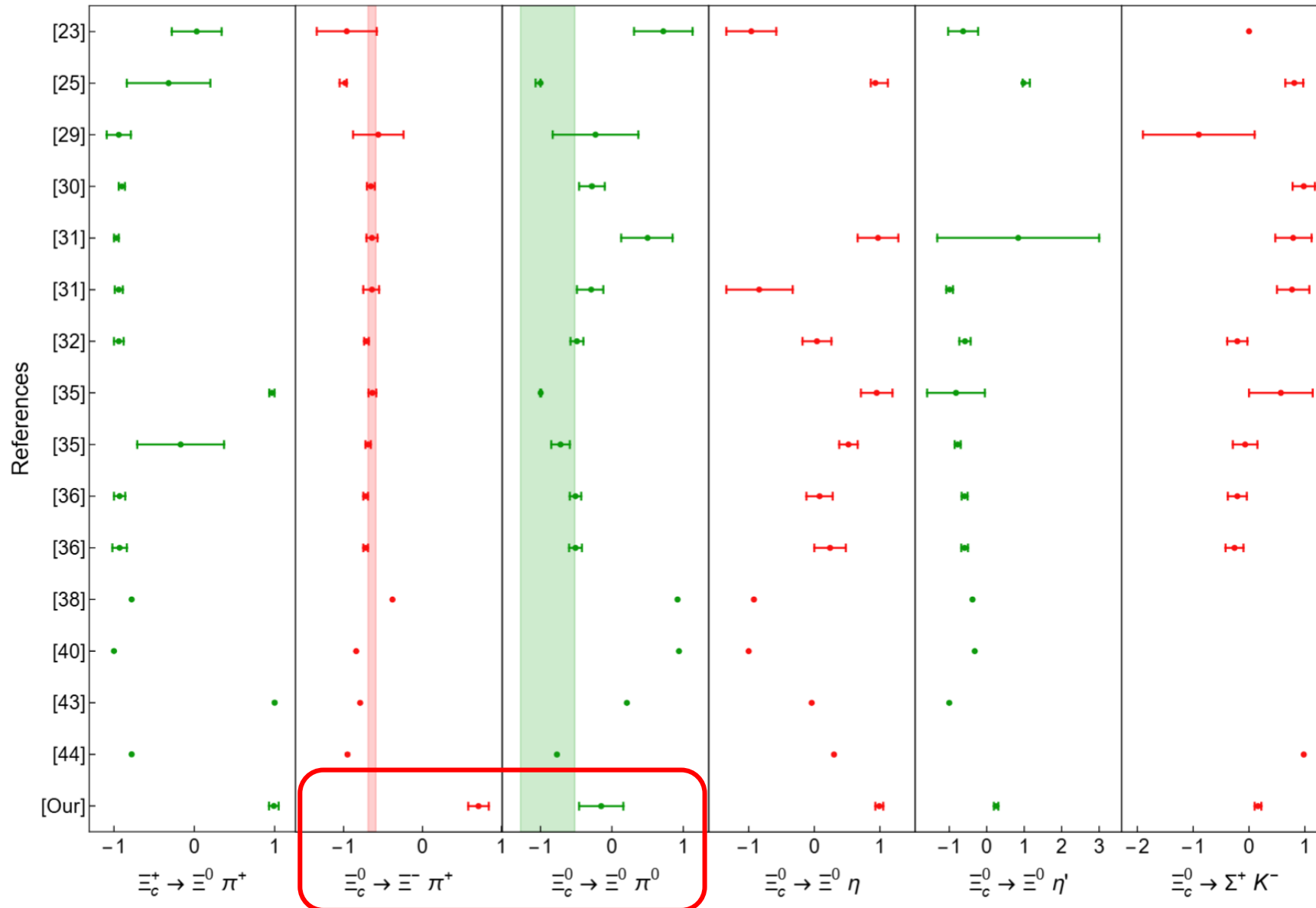


Branching ratio

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

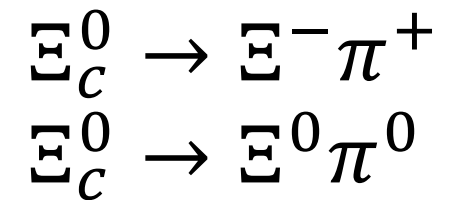
3.4 The Cabibbo-favored hadronic weak decays of the Ξ_c





Asymmetry
parameter:

$$\alpha = \frac{2\text{Re}(M_{\text{PV}}^* M_{\text{PC}})}{|M_{\text{PC}}|^2 + |M_{\text{PV}}|^2}$$



04

Summary

- ◆ The hadronic weak decay can be described with the NRCQM framework
- ◆ Pole terms play a crucial role. There is direct evidence for pole terms which play a crucial role in Ξ_c
- ◆ Prob the light quark correlations inside hadrons

Thank you !

