The hadronic weak decay of charmed baryons

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第八届强子谱和强子结构研讨会 广西·桂林

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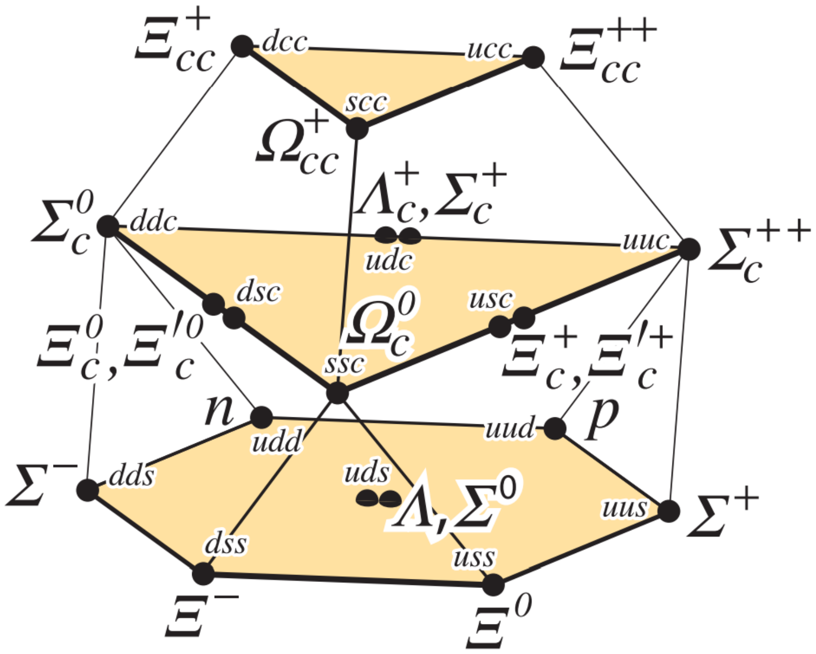
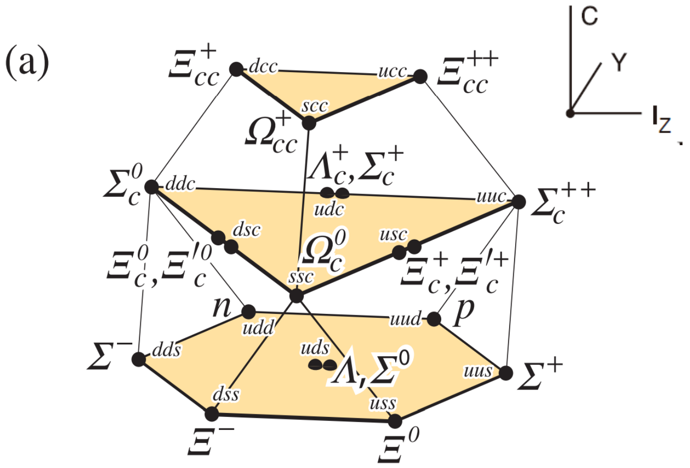
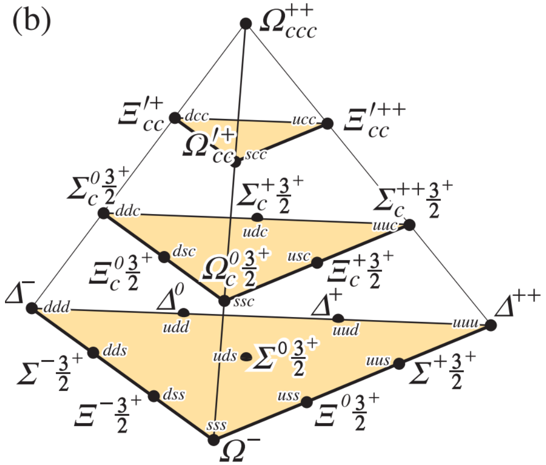
01 Introduction

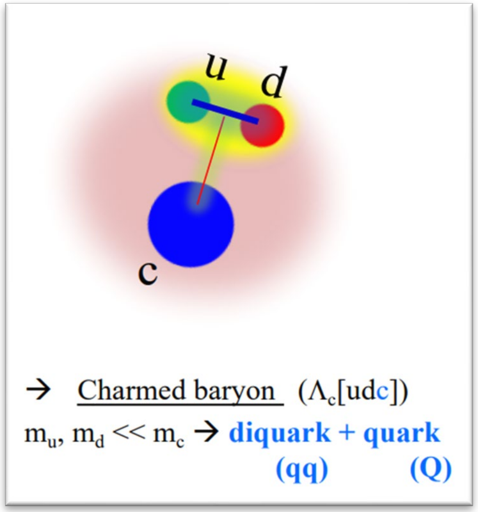


Charmed baryons

◆ Spectrum & Structure

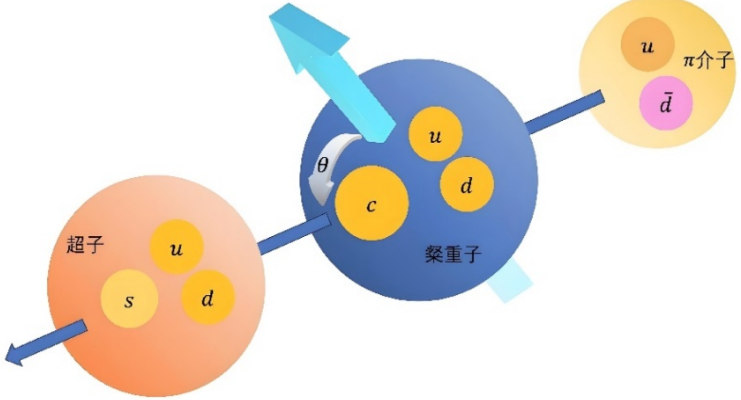


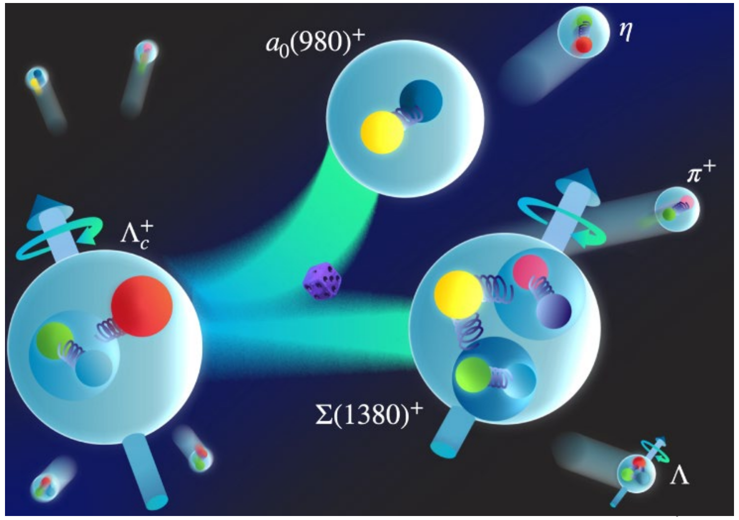




◆ Decay: $B_c \to B\ M$

- ➢ Decay mechanism
- ➢ Spectrum
- ➢ Structure
- ➢ CPV
- ➢ …





1. Introduction

Motivation

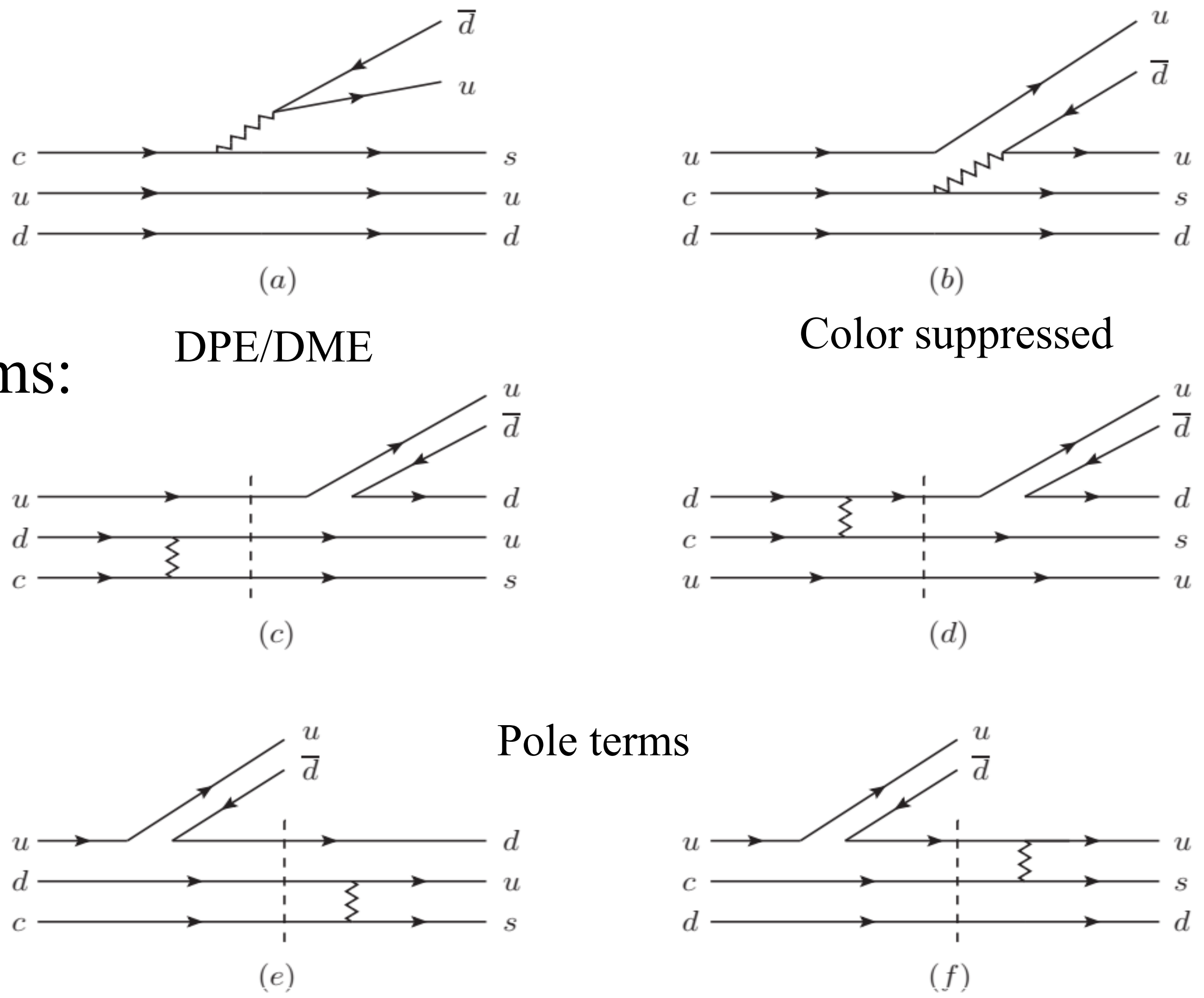
- ☐ Weak interaction
- ☐ Strong interaction

➢ Non-factorizable transition mechanisms:

- Color suppressed contribution
- Pole term contribution

➢ The property of light diquark

◆ $\Lambda_c/\Xi_c \rightarrow B\ M$

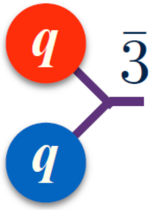


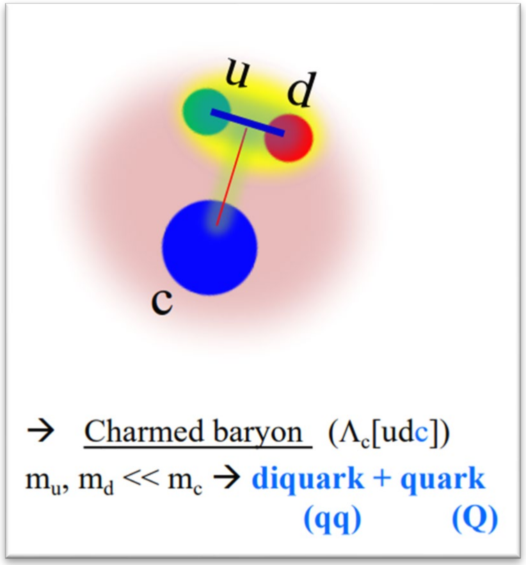
Diquark

- **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 :** $\frac{1}{2} \otimes \frac{1}{2} = 0 \oplus 1$



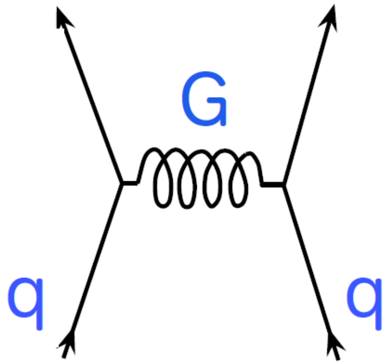


- **Spin dependent force from magnetic gluon exchange predicts strong attraction in S(0+).**

  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***



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

M(A)-M(S) = (2/3) [M(Δ)- M(N)] ~ 200 MeV

consistent with the splitting of $\Lambda_c - \Sigma_c$

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

1. Introduction Experimental data and theoretical works

- 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)
  - …

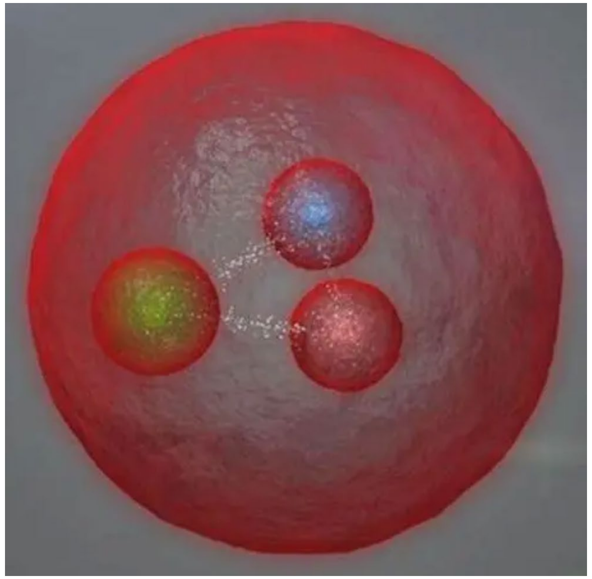
Spectrum, Structure and Decay

- 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

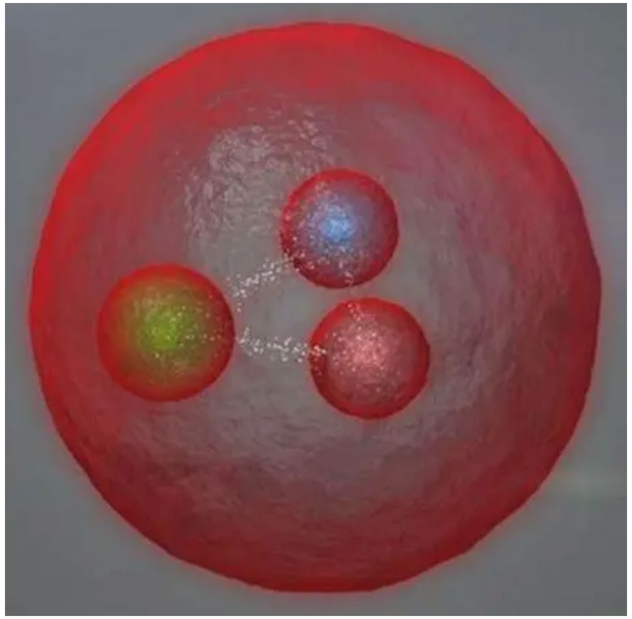
- The wave functions of hadrons
- The effective Hamiltonian



2.1 Wave function of light baryons

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

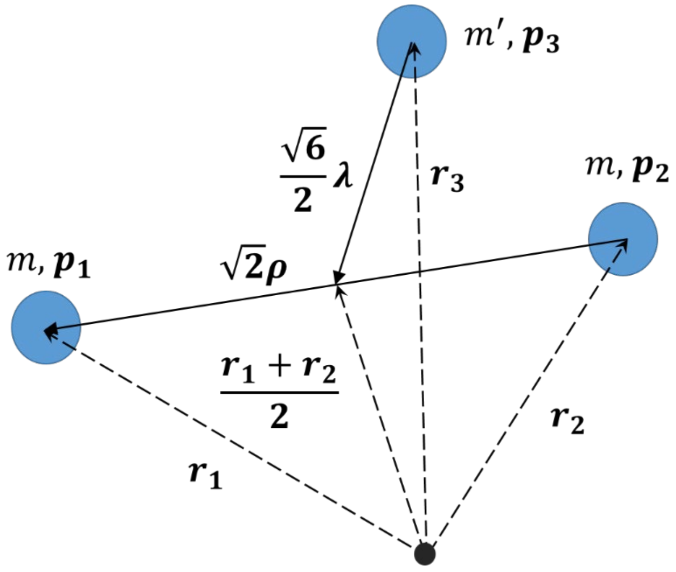


ISGUR N, KARL G. Phys.Rev.D, 1978, 18:4187
F. Hussain and M. Scadron, Nuovo Cim. A **79**, 248 (1984)
LE YAOUANC A, OLIVER L, PENE O, et al. HADRON TRANSITIONS IN THE QUARK MODEL[M]. 1988.

2.1 Wave function of light baryons

The Hamiltonian of three quark system

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



where

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

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

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

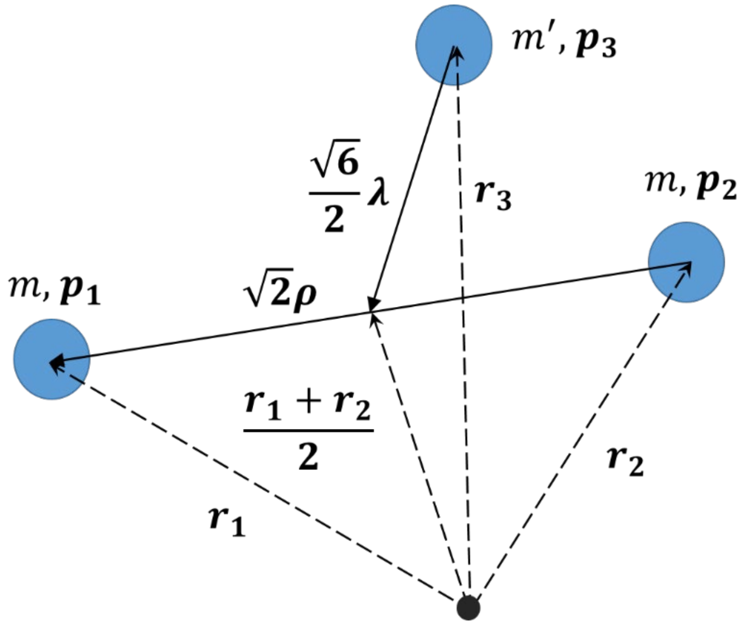
2.1 The wave functions of hadrons

Jacobi coordinates:

$$\boldsymbol{R} = \frac{m(\boldsymbol{r}_1+\boldsymbol{r}_2)+m'\boldsymbol{r}_3}{M}, \qquad \boldsymbol{P} = \boldsymbol{p}_1+\boldsymbol{p}_2+\boldsymbol{p}_3,$$

$$\boldsymbol{\rho} = \frac{1}{\sqrt{2}}(\boldsymbol{r}_1-\boldsymbol{r}_2), \qquad \boldsymbol{p}_\rho = \frac{1}{\sqrt{2}}(\boldsymbol{p}_1-\boldsymbol{p}_2),$$

$$\boldsymbol{\lambda} = \frac{1}{\sqrt{6}}(\boldsymbol{r}_1+\boldsymbol{r}_2-2\boldsymbol{r}_3), \qquad \boldsymbol{p}_\lambda = \frac{1}{\sqrt{6}M}(3m'\boldsymbol{p}_1+3m'\boldsymbol{p}_2-6m\boldsymbol{p}_3).$$



$\Rightarrow$

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

The total wave function of the momentum space

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

where

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

$$\langle\boldsymbol{\rho}^2/\boldsymbol{\lambda}^2\rangle = \frac{3}{2}\frac{1}{\alpha_{\rho/\lambda}^2}$$

$$\langle\boldsymbol{r}_{qc}^2\rangle = \frac{3}{2}\langle\boldsymbol{\lambda}^2\rangle+\frac{1}{2}\langle\boldsymbol{\rho}^2\rangle$$

2.1 Wave function of light baryons

Color	$SU(3)$	$3 \otimes 3 \otimes 3$	$= 10_s + 8_\rho + 8_\lambda + \boxed{1_a}$
Spin	$SU(2)$	$2 \otimes 2 \otimes 2$	$= 4_s + 2_\rho + 2_\lambda,$
Flavor	$SU(3)$	$3 \otimes 3 \otimes 3$	$= 10_s + 8_\rho + 8_\lambda + 1_a,$
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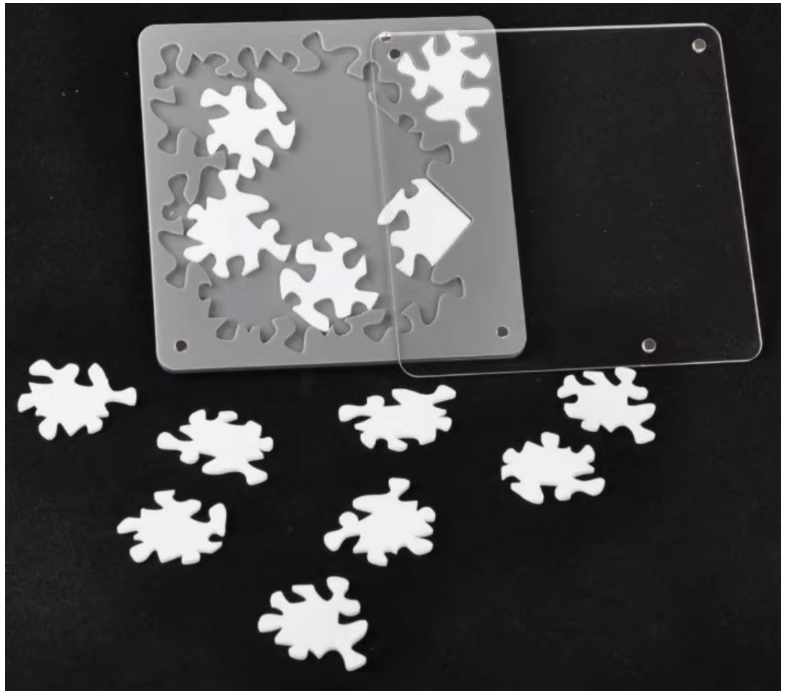
Spatial	$O(3)$	L^P	s, ρ, λ, a

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

Light baryons $\left|56, {}^2 8, 0, 0, \frac{1}{2}\right\rangle$:

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

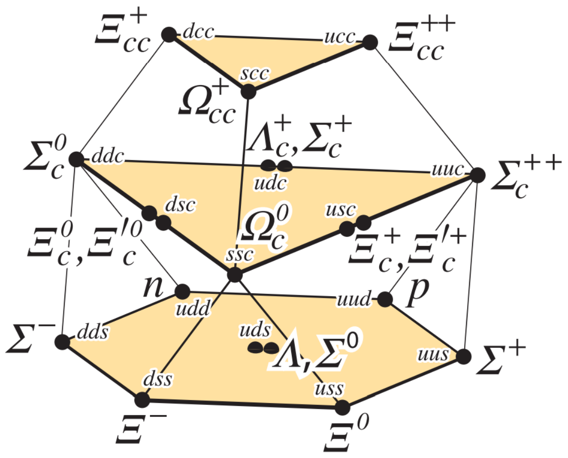


Baryon wave function as representation of 3-dimension permutation group.

2.1 Wave function of light baryons

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

$$\phi^c_{\bar{3}} = \begin{cases} \frac{1}{\sqrt{2}}(ud - du)c & \text{for } \Lambda_c^+, \\ \frac{1}{\sqrt{2}}(us - su)c & \text{for } \Xi_c^+, \\ \frac{1}{\sqrt{2}}(ds - sd)c & \text{for } \Xi_c^0; \end{cases}$$



$$\phi^c_{6} = \begin{cases} uuc & \text{for } \Sigma_c^{++}, \\ \frac{1}{\sqrt{2}}(ud + du)c & \text{for } \Sigma_c^+, \\ ddc & \text{for } \Sigma_c^0, \\ \frac{1}{\sqrt{2}}(us + su)c & \text{for } \Xi_c^{\prime +}, \\ \frac{1}{\sqrt{2}}(ds + sd)c & \text{for } \Xi_c^{\prime 0}, \\ ssc & \text{for } \Omega_c^0; \end{cases}$$

Anti-triplet

$\lvert ^{2S+1}L_\sigma J^P \rangle$	Wave function
$\lvert ^2S\frac{1}{2}^+ \rangle$	$\Psi^s_{00}\chi^\rho_{S_z}\phi_B$
$\lvert ^2P_\lambda\frac{1}{2}^- \rangle$	$\Psi^\lambda_{1L_z}\chi^\rho_{S_z}\phi_B$
$\lvert ^2P_\rho\frac{1}{2}^- \rangle$	$\Psi^\rho_{1L_z}\chi^\lambda_{S_z}\phi_B$
$\lvert ^4P_\rho\frac{1}{2}^- \rangle$	$\Psi^\rho_{1L_z}\chi^s_{S_z}\phi_B$

Sextet

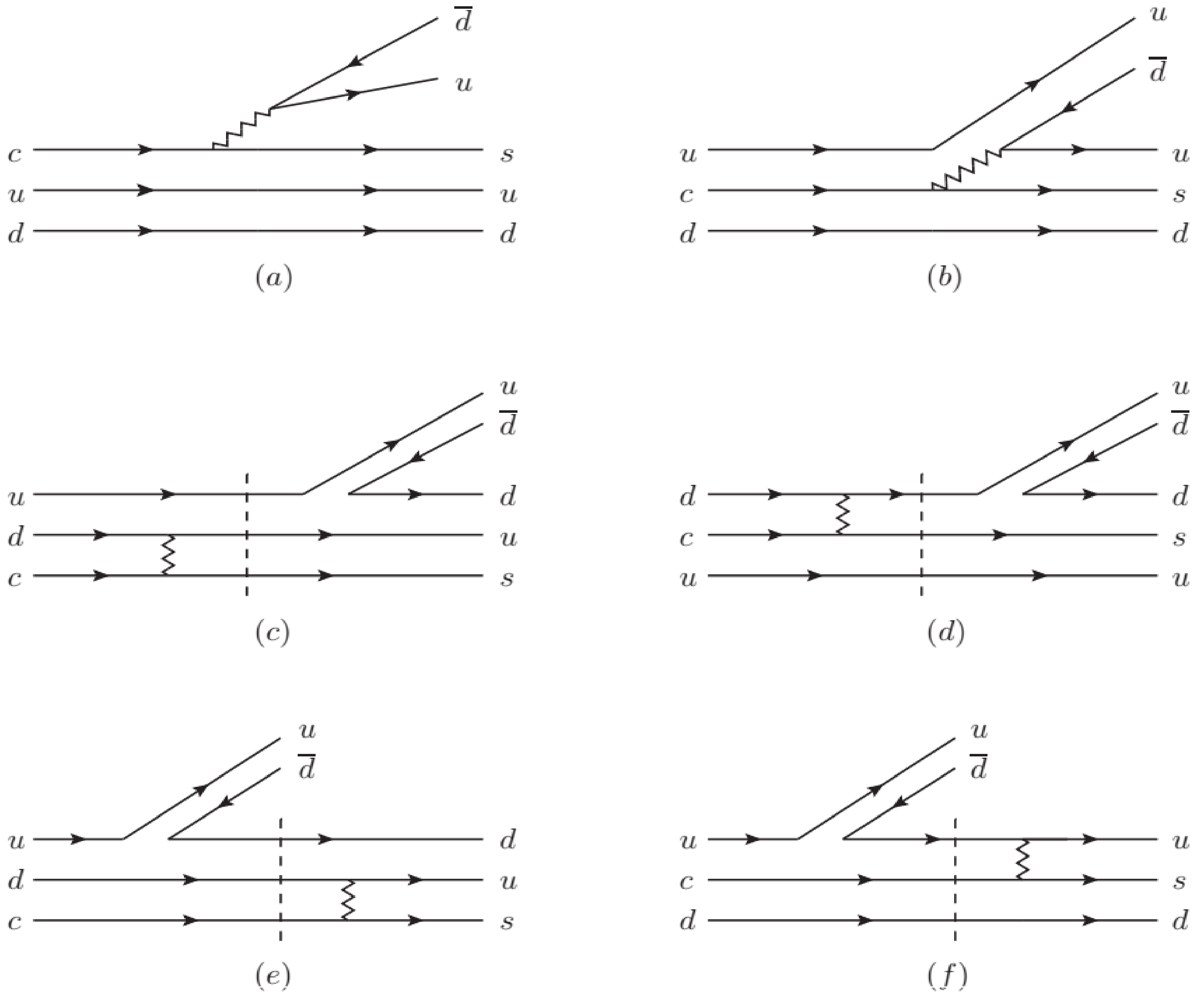
$\lvert ^{2S+1}L_\sigma J^P \rangle$	Wave Function
$\lvert ^2S\frac{1}{2}^+ \rangle$	$\Psi^s_{00}\chi^\lambda_{S_z}\phi_B$
$\lvert ^2P_\lambda\frac{1}{2}^- \rangle$	$\Psi^\lambda_{1L_z}\chi^\lambda_{S_z}\phi_B$
$\lvert ^2P_\rho\frac{1}{2}^- \rangle$	$\Psi^\rho_{1L_z}\chi^\rho_{S_z}\phi_B$
$\lvert ^4P_\lambda\frac{1}{2}^- \rangle$	$\Psi^\lambda_{1L_z}\chi^s_{S_z}\phi_B$

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)

2.2 Operators

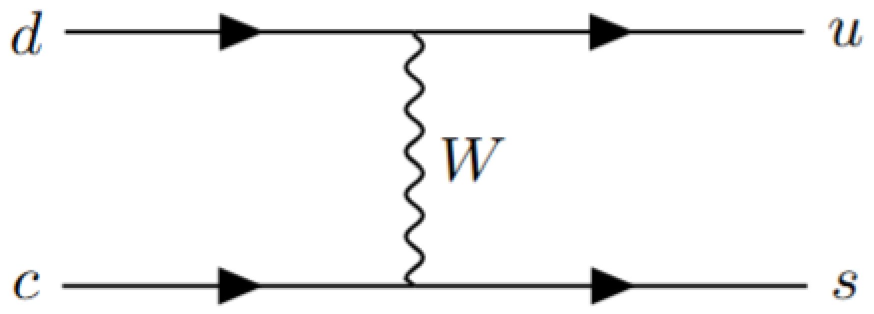
$\Lambda_c \to \Lambda\pi$

- Weak interaction
- Strong interaction



2.2 Operators: weak interaction

$H_{W,2\to2}$:



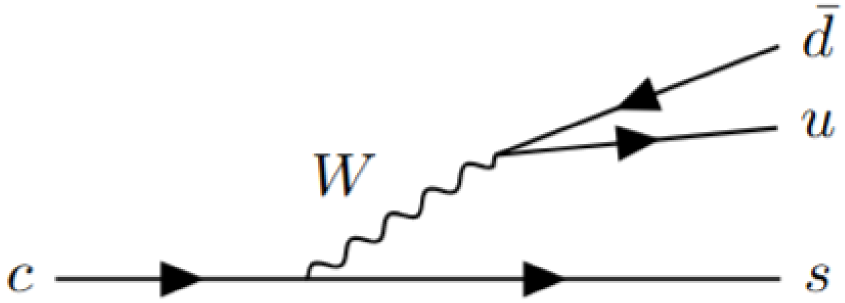
$$H_{W,2\to2} = \frac{G_F}{\sqrt{2}} V_{ud} V_{cs} \frac{1}{(2\pi)^3} \delta^3(\boldsymbol{p}_i' + \boldsymbol{p}_j' - \boldsymbol{p}_i - \boldsymbol{p}_j) \bar{u}(\boldsymbol{p}_i') \gamma_\mu (1-\gamma_5) u(\boldsymbol{p}_i) \bar{u}(\boldsymbol{p}_j') \gamma^\mu (1-\gamma_5) u(\boldsymbol{p}_j).$$

$$H_{W,2\to2}^{PC} = \frac{G_F}{\sqrt{2}} V_{ud} V_{cs} \frac{1}{(2\pi)^3} \sum_{i\neq j} \hat{\alpha}_i^{(-)} \hat{\beta}_j^{(+)} \delta^3(\boldsymbol{p}_i' + \boldsymbol{p}_j' - \boldsymbol{p}_i - \boldsymbol{p}_j) \left(1 - \langle s_{z,i}' | \boldsymbol{\sigma}_i | s_{z,i} \rangle \langle s_{z,j}' | \boldsymbol{\sigma}_j | s_{z,j} \rangle \right),$$

$$\begin{aligned} H_{W,2\to2}^{PV} = & \frac{G_F}{\sqrt{2}} V_{ud} V_{cs} \frac{1}{(2\pi)^3} \sum_{i\neq j} \hat{\alpha}_i^{(-)} \hat{\beta}_j^{(+)} \delta^3(\boldsymbol{p}_i' + \boldsymbol{p}_j' - \boldsymbol{p}_i - \boldsymbol{p}_j) \\ & \times \left\{ -(\langle s_{z,i}' | \boldsymbol{\sigma}_i | s_{z,i} \rangle - \langle s_{z,j}' | \boldsymbol{\sigma}_j | s_{z,j} \rangle) \left[\left(\frac{\boldsymbol{p}_i}{2m_i} - \frac{\boldsymbol{p}_j}{2m_j} \right) + \left(\frac{\boldsymbol{p}_i'}{2m_i'} - \frac{\boldsymbol{p}_j'}{2m_j'} \right) \right] \right. \\ & \left. + i(\langle s_{z,i}' | \boldsymbol{\sigma}_i | s_{z,i} \rangle \times \langle s_{z,j}' | \boldsymbol{\sigma}_j | s_{z,j} \rangle) \left[\left(\frac{\boldsymbol{p}_i}{2m_i} - \frac{\boldsymbol{p}_j}{2m_j} \right) - \left(\frac{\boldsymbol{p}_i'}{2m_i'} - \frac{\boldsymbol{p}_j'}{2m_j'} \right) \right] \right\}, \end{aligned}$$

2.2 Operators: weak interaction

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

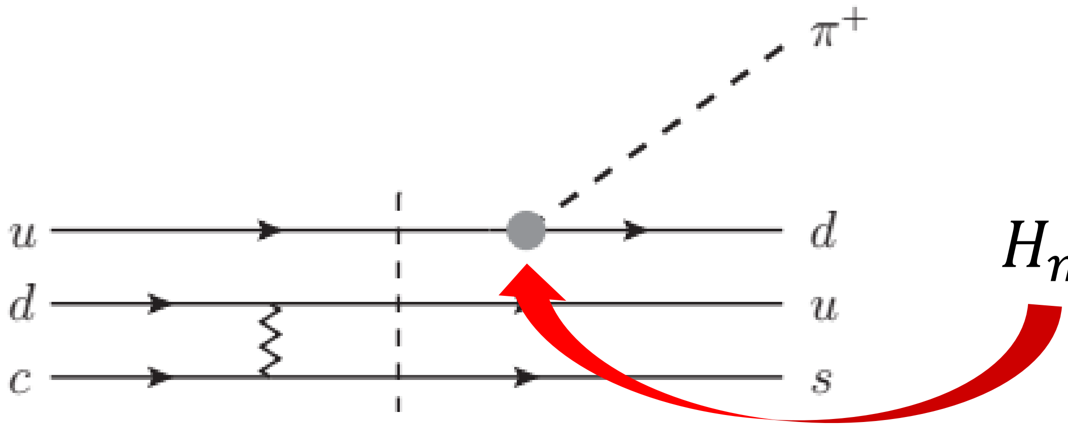


$$H_{W,1\to 3} = \frac{G_F}{\sqrt{2}} V_{ud} V_{cs} \frac{\beta}{(2\pi)^3} \delta^3(\boldsymbol{p}_3 - \boldsymbol{p}'_3 - \boldsymbol{p}_5 - \boldsymbol{p}_4) \bar{u}(\boldsymbol{p}'_3, m'_3) \gamma_\mu (1-\gamma_5) u(\boldsymbol{p}_3, m_3) \bar{u}(\boldsymbol{p}_5, m_5) \gamma^\mu (1-\gamma_5) v(\boldsymbol{p}_4,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

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

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

2.2 Operators: chiral quark model



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

In the non-relativistic limit:

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

The isospin operator $\hat{I}_m^j$ is written as
$$\hat{I}_\pi^j = \begin{cases} b_u^\dagger\, b_d & \text{for } \pi^- \\ b_d^\dagger\, b_u & \text{for } \pi^+ \\ \frac{1}{\sqrt{2}} \left[b_u^\dagger\, b_d - b_d^\dagger\, b_u \right] & \text{for } \pi^0 \end{cases}$$

2.3 Amplitudes and parity asymmetry parameter

Normalization:

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

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

Decay width:

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

where

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

The parity asymmetry parameter

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

The transition rate is proportional to

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

$$\alpha = \frac{2\mathrm{Re}(s^* p)}{|s^2| + |p^2|} \qquad s = A, \quad p = B\frac{|\boldsymbol{p}_f|}{E_f + m_f}$$

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

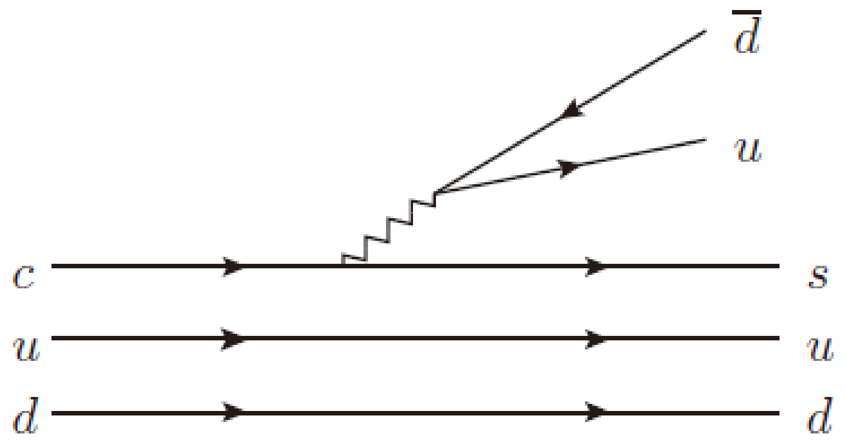
03

The hadronic weak decay of charmed baryons

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

3.1 Previous works: hadronic weak decays of Λ_c

Processes	$\Lambda_c \to \Lambda\pi^+$	$\Lambda_c \to \Sigma^+\pi^0$	$\Lambda_c \to \Sigma^0\pi^+$
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

Peng-Yu Niu, Jean-Marc Richard, Qian Wang, and Qiang Zhao, Phys. Rev. D.102.073005

3.1 Previous works: hadronic weak decays of Λ_c

TABLE V: The amplitudes with $J_f^z = J_i^z = -1/2$ for different processes and the unit is 10^{-9} GeV$^{-1/2}$. Amplitudes $A1(PV)$ and $A2(PV)$ are given by the parity-violating intermediate states $\Sigma^{*+}(1620)$ ($[\mathbf{70}, {}^2\mathbf{8}]$) and $\Sigma^{*+}(1750)$ ($[\mathbf{70}, {}^4\mathbf{8}]$), respectively.

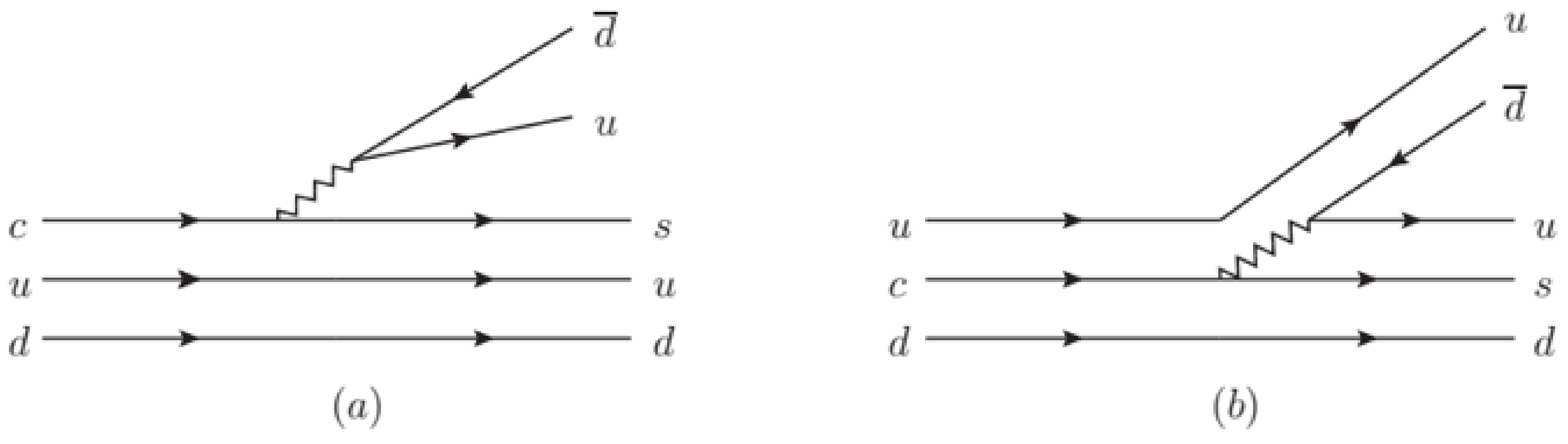
Processes	$A(PC)$	$A1(PV)$	$A2(PV)$	$B(PC)$	$B(PV)$	$CS(PC)$	$CS(PV)$	$DPE(PC)$	$DPE(PV)$
$\Lambda_c \to \Lambda\pi^+$	-16.50	$0.74 - 0.023i$	$-2.57 + 0.10i$	$22.33 + 0.021i$	$-10.72 - 0.33i$	3.50	-4.17	-42.47	24.07
$\Lambda_c \to \Sigma^0\pi^+$	19.67	$-3.21 + 0.10i$	$-2.23 + 0.090i$	$-40.73 - 0.040i$	$19.16 + 0.60i$	-6.04	7.53	0	0
$\Lambda_c \to \Sigma^+\pi^0$	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.

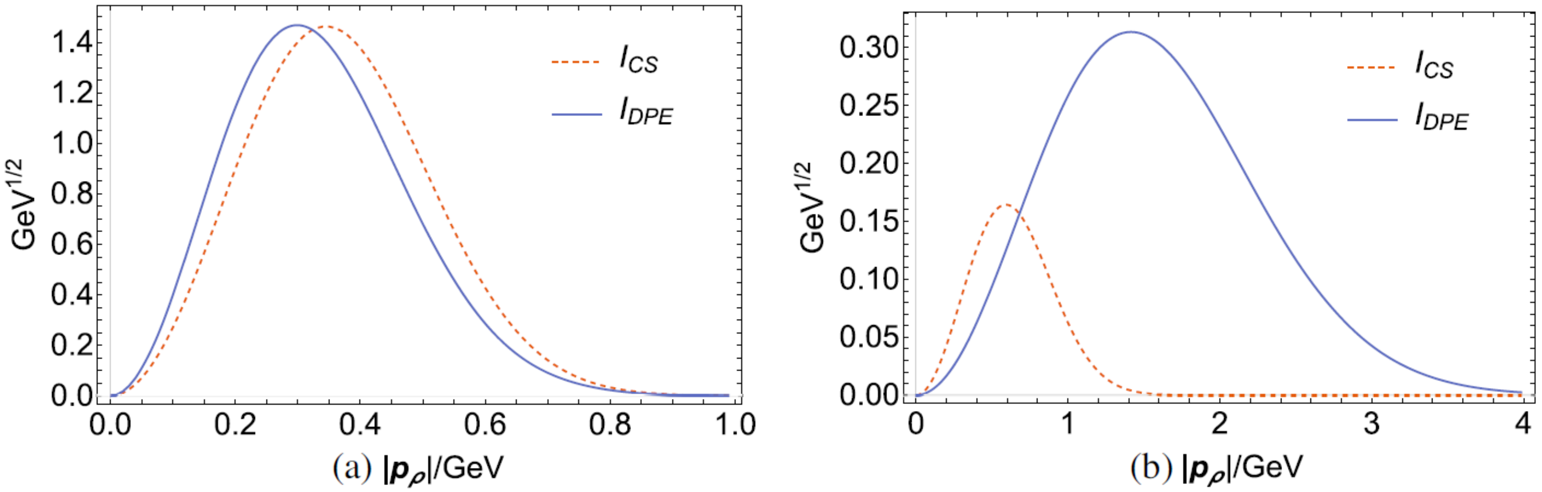
	$\mathrm{BR}(\Lambda_c \to \Lambda\pi^+)$	$\mathrm{BR}(\Lambda_c \to \Sigma^0\pi^+)$	$\mathrm{BR}(\Lambda_c \to \Sigma^+\pi^0)$
PDG data [24]	1.30 ± 0.07	1.29 ± 0.07	1.24 ± 0.10
BESIII [20]	$1.24 \pm 0.07 \pm 0.03$	$1.27 \pm 0.08 \pm 0.03$	$1.18 \pm 0.10 \pm 0.03$
SU(3) [39]	1.3 ± 0.2	1.3 ± 0.2	1.3 ± 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

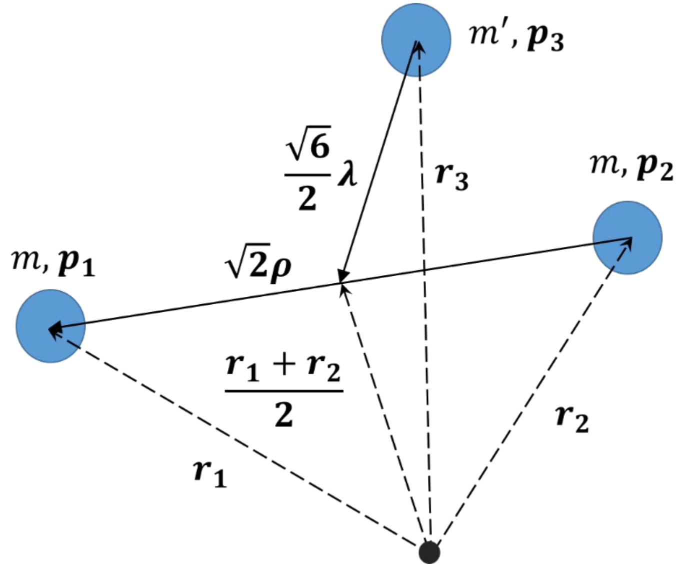
$(1.31 \pm 0.08 \pm 0.05)\%$ $(1.22 \pm 0.08 \pm 0.07)\%$ BESIII PRL.128.142001(2022)

3.1 Previous works: hadronic weak decays of Λ_c



DPE CS





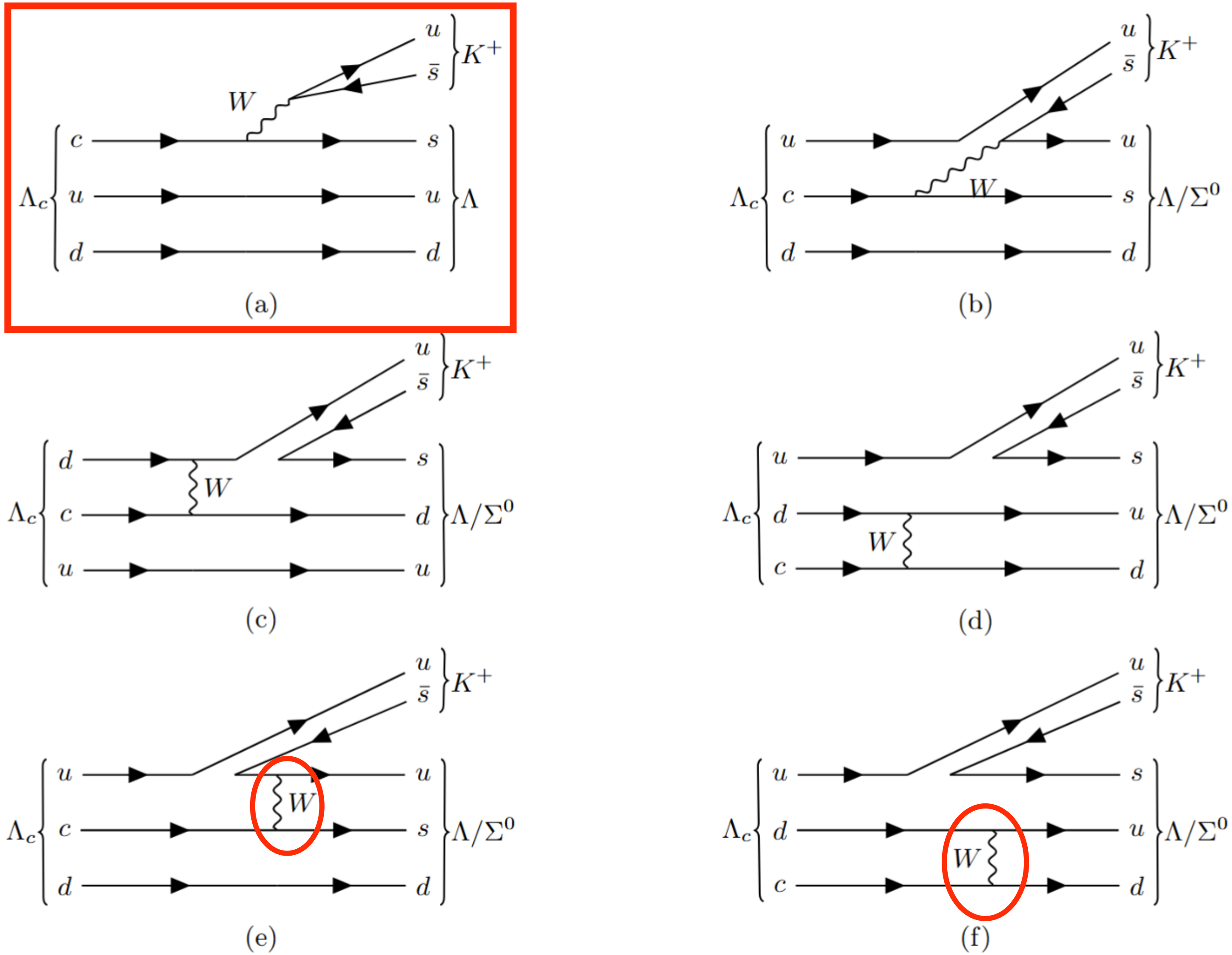
$$\langle \rho^2 \rangle \propto \frac{1}{\alpha_\rho^2}$$

3.2 The diquark revisit

$\Lambda_c \to \Lambda/\Sigma\, K^+$

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.



Pengyu Niu, Qian wang and Qiang Zhao arXiv: 2507.04393

3.2 The diquark revisit

$$|\Lambda_c\rangle = |0,0\rangle$$
$$\langle\Lambda| = \langle 0,0|$$
$$\langle\Sigma^0| = \langle 1,0|$$

The weak Hamiltonian

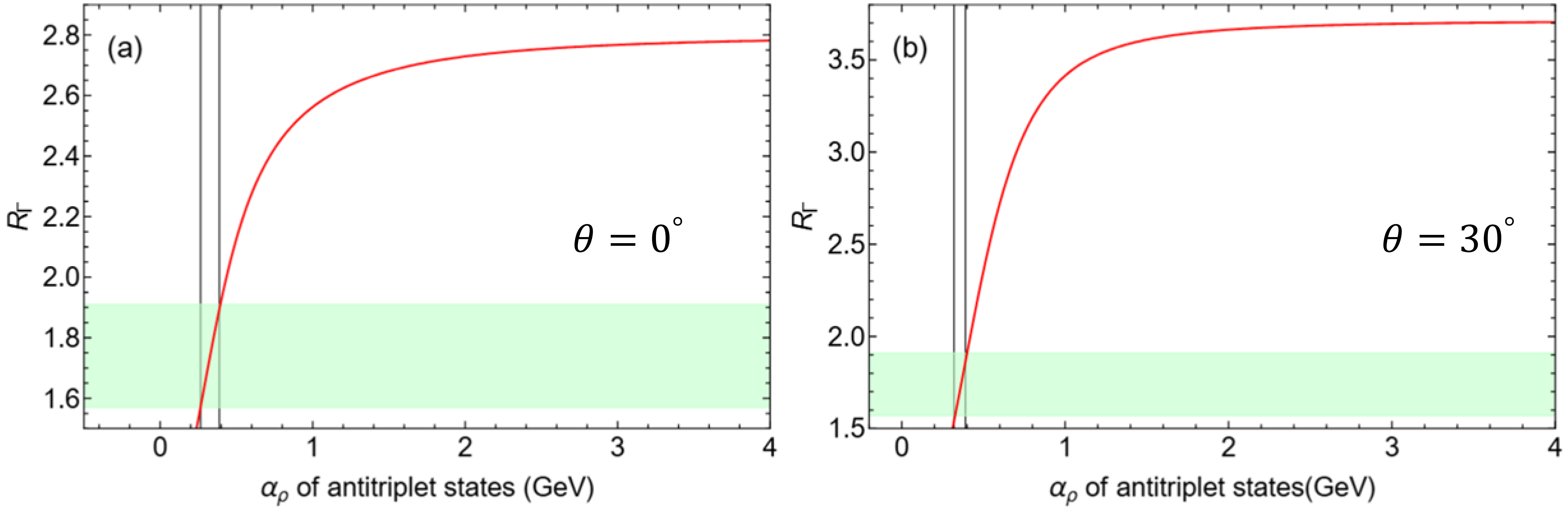
$cs \to su, cd \to du$ and $c \to s\,\bar{u}\,s$:

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

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

3.2 The diquark revisit

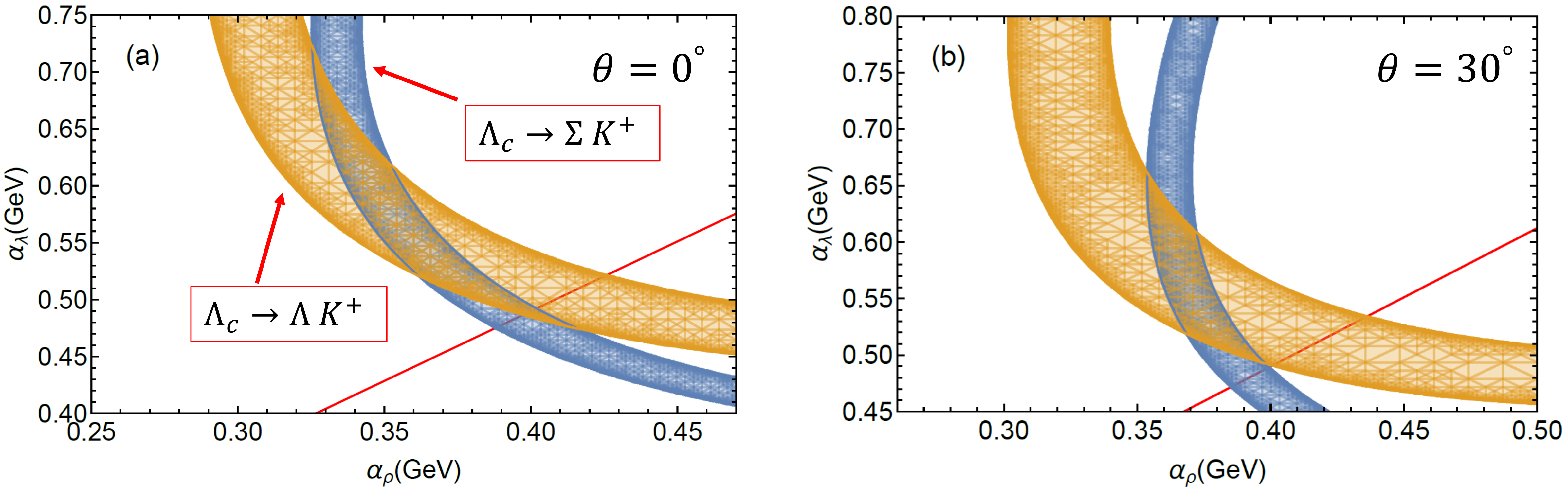
Only the α_ρ of anti-triplet charmed baryon are changed.



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

3.2 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.

3.2 The diquark revisit

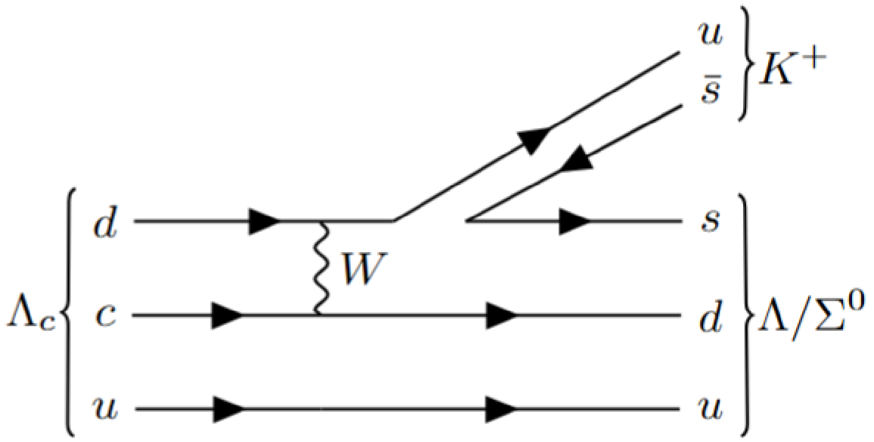
The amplitudes (in unit of 10^{-9} GeV$^{-1/2}$)

Parity	Processes	States	$\Lambda_c \to \Lambda K^+$ $\theta = 0^\circ$	$\Lambda_c \to \Lambda K^+$ $\theta = 30^\circ$	$\Lambda_c \to \Sigma^0 K^+$ $\theta = 0^\circ$	$\Lambda_c \to \Sigma^0 K^+$ $\theta = 30^\circ$
		-				
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	$(0, 0)$	$(0, 0)$	$(0, 0)$	$(0, 0)$
		$\Xi_c'^0$	$(0.60, 1.13)$	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	$\Xi_c^0\|^2P_\rho\rangle$	$(-0.36, 0.82)$	$(-0.99, 2.20)$	$(0.89, 0.096)$	$(2.28, 0.20)$
		$\Xi_c^0\|^2P_\lambda\rangle$	$(0, 0)$	$(0, 0)$	$(0, 0)$	$(0, 0)$
		$\Xi_c^0\|^4P_\rho\rangle$	$(0.55, -1.05)$	$(1.45, -2.75)$	$(-1.05, 0)$	$(-2.67, 0)$
		$\Xi_c'^0\|^2P_\rho\rangle$	$(0, 0)$	$(0, 0)$	$(0, 0)$	$(0, 0)$
		$\Xi_c'^0\|^2P_\lambda\rangle$	$(-0.45, -0.80)$	$(-1.19, -2.11)$	$(0.78, 0.043)$	$(2.03, 0.091)$
		$\Xi_c'^0\|^4P_\lambda\rangle$	$(0.56, 1.06)$	$(1.45, 2.75)$	$(-1.05, 0)$	$(-2.66, 0)$
	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

3.2 The diquark revisit



$N(1535)$: $[\,70,^2 8]$
$N(1650)$: $[\,70,^4 8]$

The spin of u and d must be persevered.

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

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

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

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

Qiang Zhao and Frank E. Close, arXiv:0711.0151v1

3.3 Heavy quark conserving hadronic weak decays

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

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

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

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

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

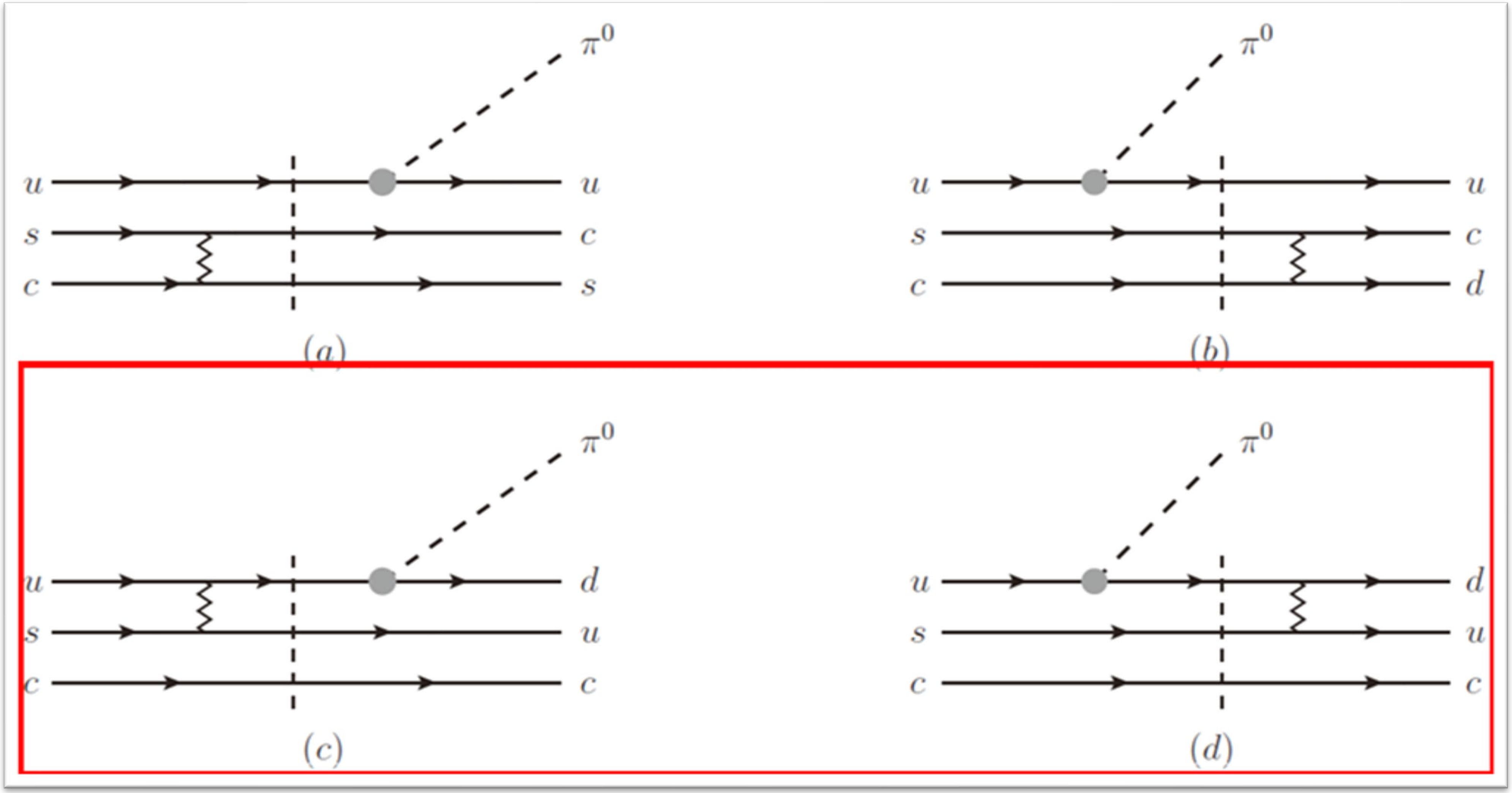
Peng-Yu Niu, Qian Wang, and Qiang Zhao, Phys. Lett. B 826(2022)136916

3.3 Heavy quark conserving hadronic weak decays

Processes	$\Xi_c^+ \to \Lambda_c \pi^0$	$\Xi_c^0 \to \Lambda_c \pi^-$	$\Xi_b^0 \to \Lambda_b \pi^0$	$\Xi_b^- \to \Lambda_b \pi^-$
Exp. Data	$\cdots$	0.55 ± 0.20 [1]	$\cdots$	$0.19 \pm 0.07 \sim 0.57 \pm 0.21$ [2]
MIT bag model [4]	0.0093	0.0087	0.059	0.2
Diquark model [4]	$\cdots$	$\cdots$	0.25	0.69
Duality [5]	$\cdots$	$\cdots$	$\cdots$	0.63 ± 0.42
Current algebra [11]	0.386 ± 0.135	0.194 ± 0.07	$\cdots$	$\cdots$
Current algebra [6]	$\cdots$	$\cdots$	$1 \sim 4$	$2 \sim 8$
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

3.3 Heavy quark conserving hadronic weak decays



3.3 Heavy quark conserving hadronic weak decays

			$\Xi_c^+ \to \Lambda_c \pi^0$		$\Xi_c^0 \to \Lambda_c \pi^-$		$\Xi_b^0 \to \Lambda_b \pi^0$		$\Xi_b^- \to \Lambda_b \pi^-$
	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)
PC		$\Xi_c'^+$	-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
	Pole-A	$\Sigma_c^+\vert{}^2P_\rho\rangle$	Spin(CQM)	$\Sigma_c^0\vert{}^2P_\rho\rangle$	Spin(CQM)	$\Sigma_b^0\vert{}^2P_\rho\rangle$	Spin(weak)		
		$\Sigma_c^+\vert{}^2P_\lambda\rangle$	1.59	$\Sigma_c^0\vert{}^2P_\lambda\rangle$	2.72	$\Sigma_b^0\vert{}^2P_\lambda\rangle$	Spatial		
		$\Sigma_c^+\vert{}^4P_\rho\rangle$	-0.94	$\Sigma_c^0\vert{}^4P_\rho\rangle$	-1.34	$\Sigma_b^0\vert{}^4P_\rho\rangle$	Spatial		
		$\Lambda_c^+\vert{}^2P_\rho\rangle$	Isospin			$\Lambda_b\vert{}^2P_\rho\rangle$	Isospin		
		$\Lambda_c^+\vert{}^2P_\lambda\rangle$	Isospin			$\Lambda_b\vert{}^2P_\lambda\rangle$	Isospin		
		$\Lambda_c^+\vert{}^4P_\rho\rangle$	Isospin			$\Lambda_b\vert{}^4P_\rho\rangle$	Isospin		
	Pole-B	$\Xi_c^+\vert{}^2P_\rho\rangle$	-3.32	$\Xi_c^+\vert{}^2P_\rho\rangle$	-6.02	$\Xi_b^0\vert{}^2P_\rho\rangle$	-7.95	$\Xi_b^0\vert{}^2P_\rho\rangle$	-11.25
PV		$\Xi_c^+\vert{}^2P_\lambda\rangle$	Spin(CQM)	$\Xi_c^+\vert{}^2P_\lambda\rangle$	Spin(CQM)	$\Xi_b^0\vert{}^2P_\lambda\rangle$	Spin(CQM)	$\Xi_b^0\vert{}^2P_\lambda\rangle$	Spin(CQM)
		$\Xi_c^+\vert{}^4P_\rho\rangle$	-1.26	$\Xi_c^+\vert{}^4P_\rho\rangle$	-1.77	$\Xi_b^0\vert{}^4P_\rho\rangle$	-3.57	$\Xi_b^0\vert{}^4P_\rho\rangle$	-5.06
		$\Xi_c'^+\vert{}^2P_\rho\rangle$	Spin(CQM)	$\Xi_c'^+\vert{}^2P_\rho\rangle$	Spin(CQM)	$\Xi_b'^0\vert{}^2P_\rho\rangle$	Spin(CQM)	$\Xi_b'^0\vert{}^2P_\rho\rangle$	Spin(CQM)
		$\Xi_c'^+\vert{}^2P_\lambda\rangle$	0.55	$\Xi_c'^+\vert{}^2P_\lambda\rangle$	0.77	$\Xi_b'^0\vert{}^2P_\lambda\rangle$	Spatial	$\Xi_b'^0\vert{}^2P_\lambda\rangle$	Spatial
		$\Xi_c'^+\vert{}^4P_\lambda\rangle$	-0.41	$\Xi_c'^+\vert{}^4P_\lambda\rangle$	-0.58	$\Xi_b'^0\vert{}^4P_\lambda\rangle$	Spatial	$\Xi_b'^0\vert{}^4P_\lambda\rangle$	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 $\Xi_c^0 \to \Lambda_c \pi$

3.3 Heavy quark conserving hadronic weak decays

Processes	$\Xi_c^+ \to \Lambda_c \pi^0$	$\Xi_c^0 \to \Lambda_c \pi^-$	$\Xi_b^0 \to \Lambda_b \pi^0$	$\Xi_b^- \to \Lambda_b \pi^-$
Exp. Data	$\cdots$	0.55 ± 0.20 [1]	$\cdots$	$0.19 \pm 0.07 \sim 0.57 \pm 0.21$ [2]
MIT bag model [4]	0.0093	0.0087	0.059	0.2
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Duality [5]	$\cdots$	$\cdots$	$\cdots$	0.63 ± 0.42
Current algebra [11]	0.386 ± 0.135	0.194 ± 0.07	$\cdots$	$\cdots$
Current algebra [6]	$\cdots$	$\cdots$	$1 \sim 4$	$2 \sim 8$
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

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

3.4 The first study of $\Xi_c^0 \to \Xi^0\pi^0/\eta/\eta'$ @ Belle and Belle II

复旦大學 FUDAN UNIVERSITY

核科学与技术系

First Study of $\Xi_c^0 \to \Xi^0\pi^0/\eta/\eta'$

PRELIMINARY at Belle + Belle II ~1.4/ab:

BELLE Belle II

First measurements of the branching fractions using combined data:

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

$$\mathcal{B}(\Xi_c^0 \to \Xi^0\eta) = (1.6 \pm 0.2(\text{stat.}) \pm 0.2(\text{syst.}) \pm 0.4(\text{norm.})) \times 10^{-3}$$

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

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

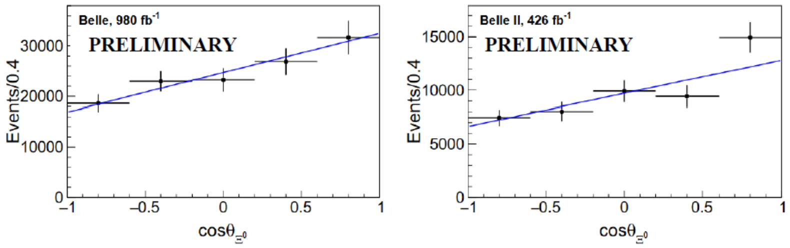
First asymmetry parameter $\alpha(\Xi_c^0 \to \Xi^0\pi^0)$ measurement depending on

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

through a simultaneous fit to Belle and Belle II data samples

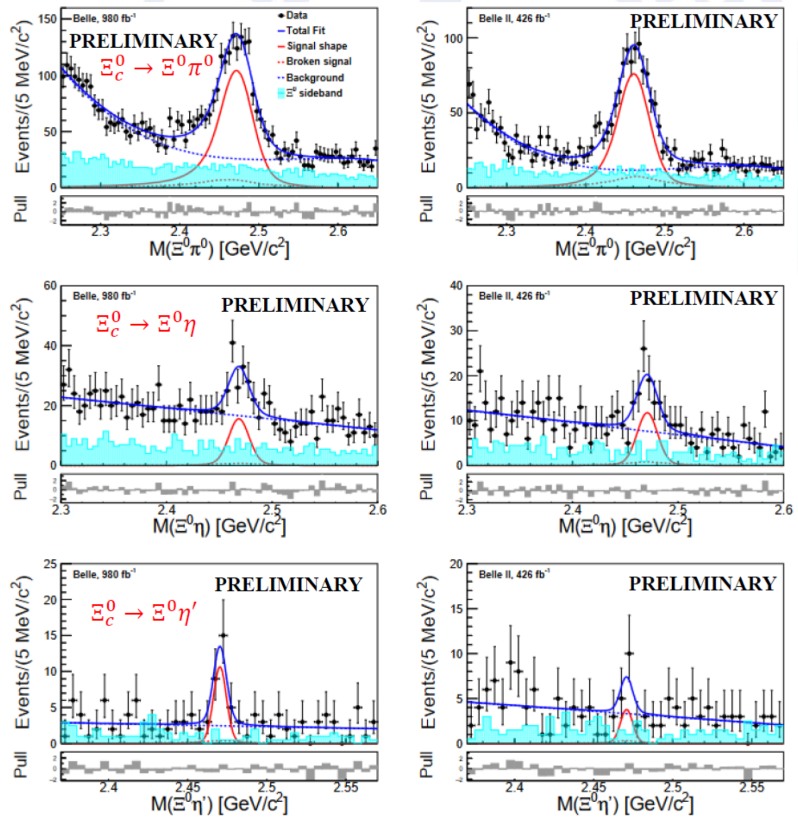
$$\alpha(\Xi_c^0 \to \Xi^0\pi^0) = -0.90 \pm 0.15(\text{stat.}) \pm 0.23(\text{syst.})$$

taking $\alpha(\Xi^0 \to \Lambda\pi^0) = -0.349 \pm 0.009$(PDG)



preliminary

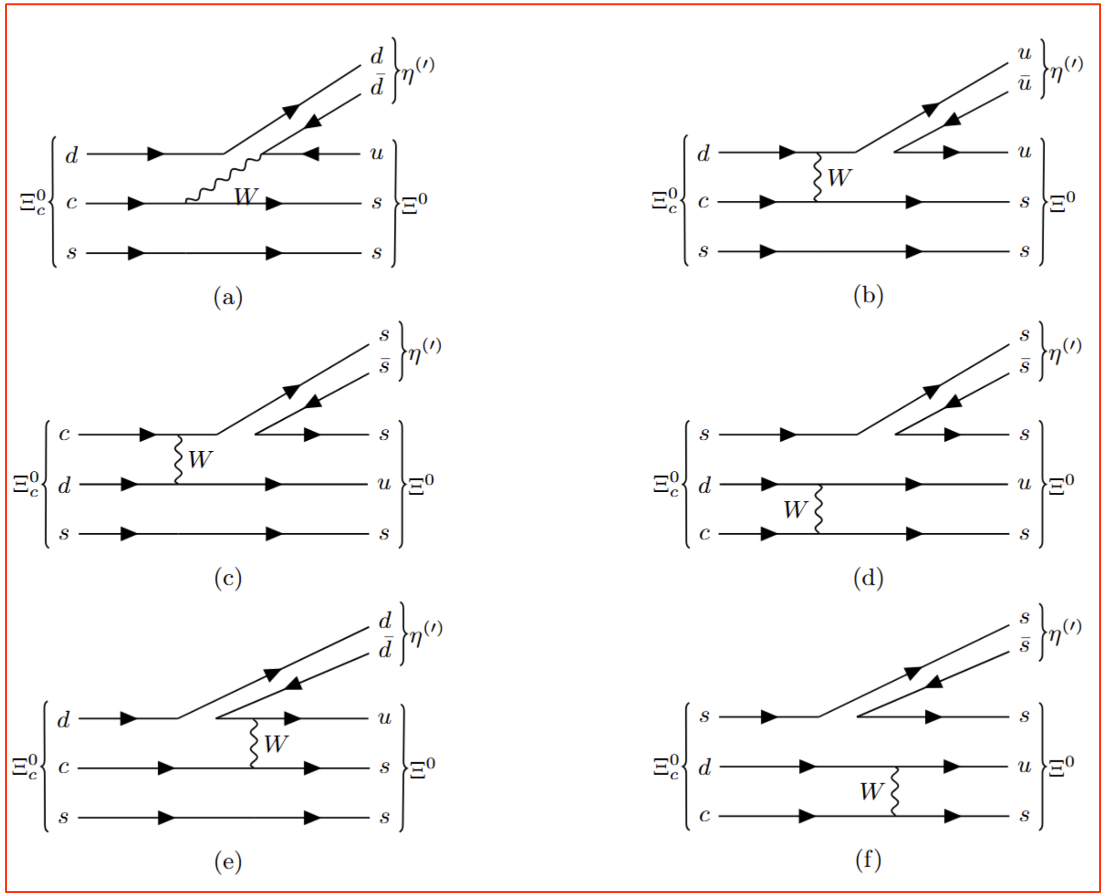
Invariant mass spectra for Ξ_c^0 candidates



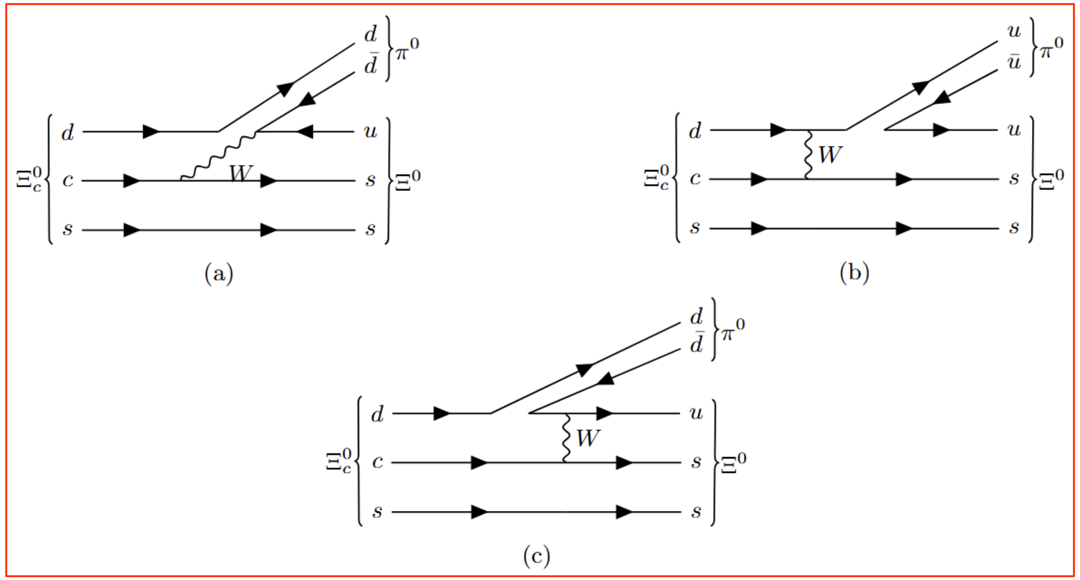
From Chengping Shen 第七届强子谱和强子结构研讨会 · 成都

Belle and Belle-II, JHEP10(2024)045

3.4 The Cabibbo-favored hadronic weak decays of the Ξ_c



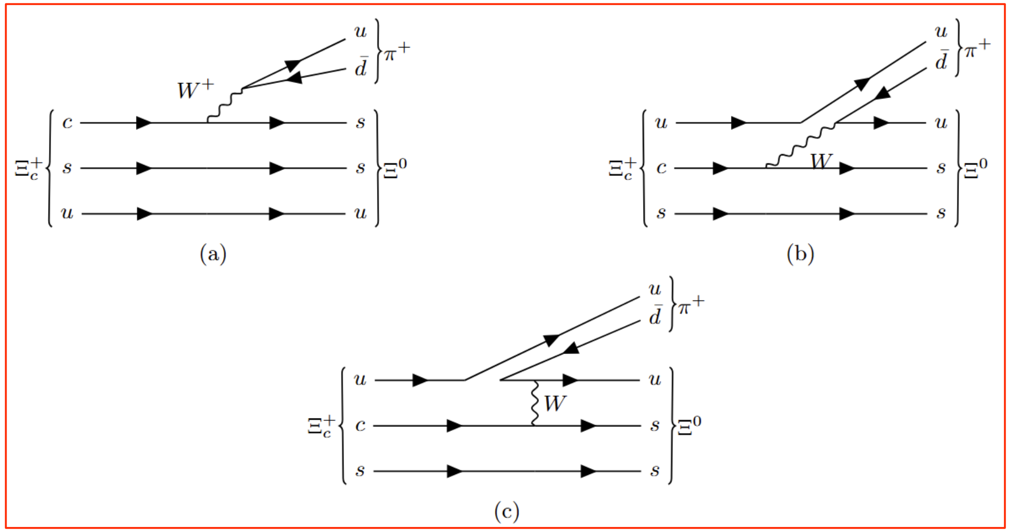
$$\Xi_c^0 \to \Xi^0 \eta^{(\prime)}$$



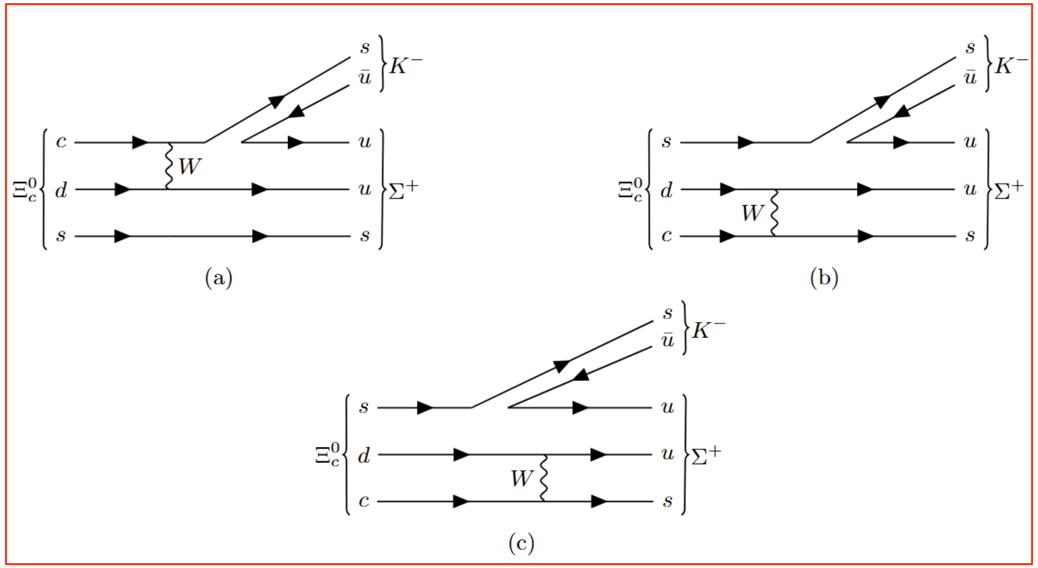
$$\Xi_c^0 \to \Xi^0 \pi^0$$

Peng-Yu Niu, Qian Wang, and Qiang Zhao, Phys. Rev. D 111, 093004 (2025)

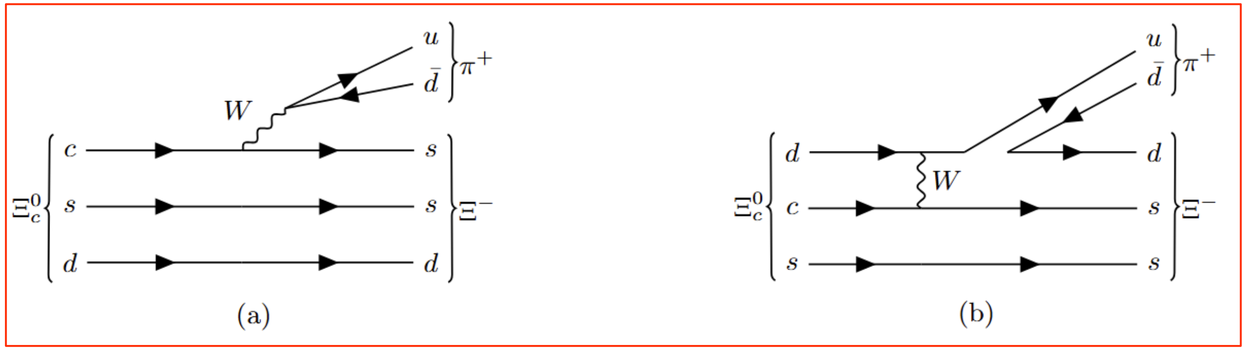
3.4 The Cabibbo-favored hadronic weak decays of the Ξ_c



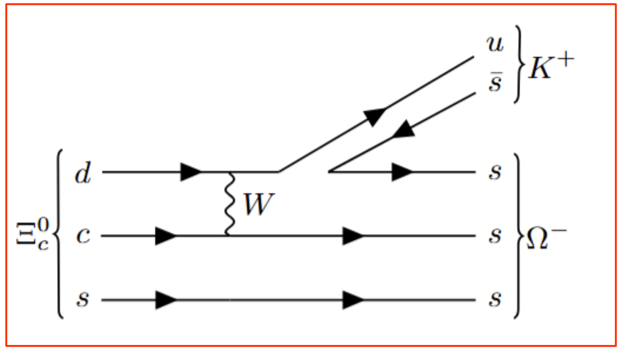
$$\Xi_c^+ \to \Xi^0 \pi^+$$



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

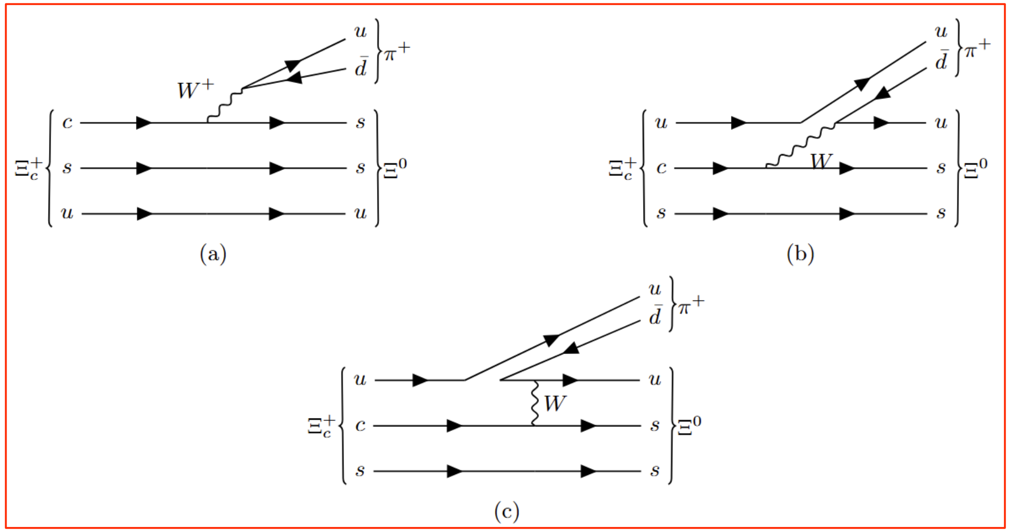


$$\Xi_c^0 \to \Xi^- \pi^+$$

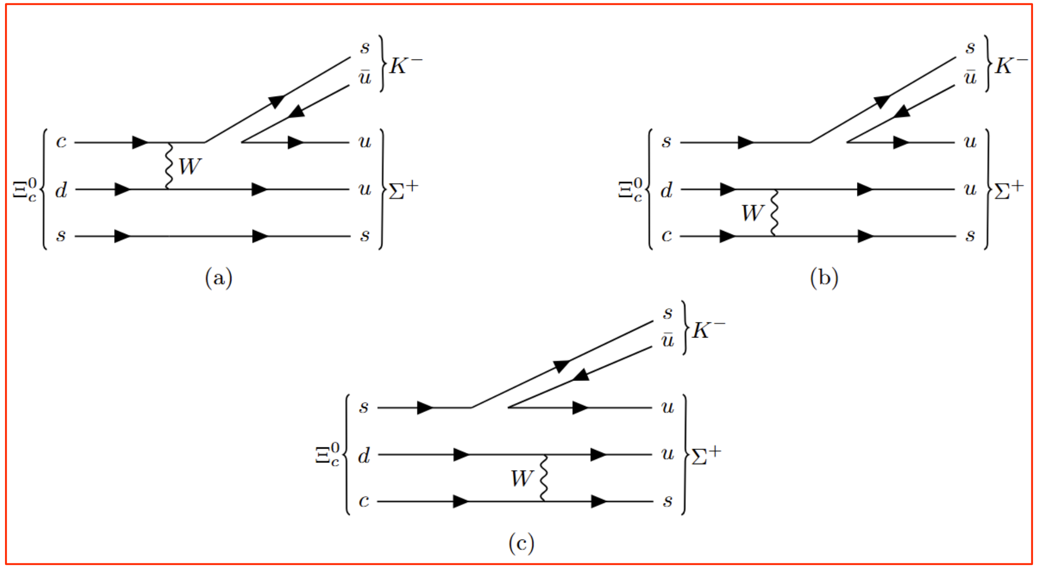


$$\Xi_c^0 \to \Omega^- K^+$$

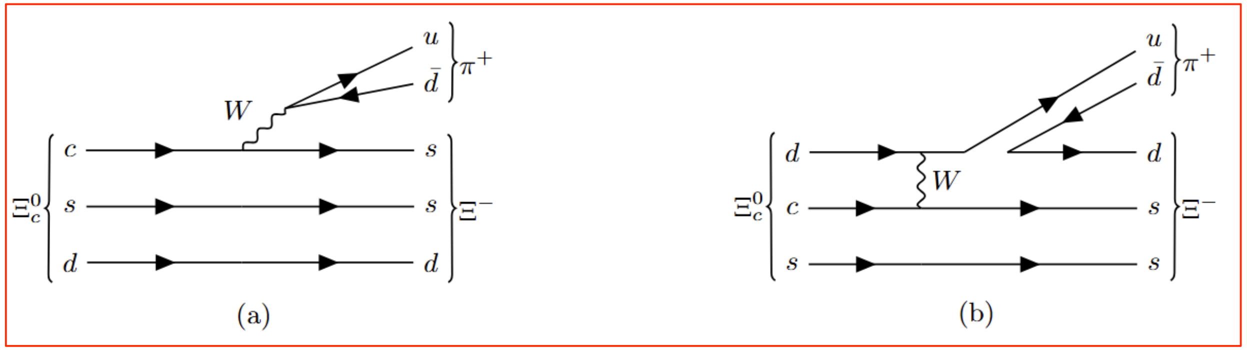
3.4 The Cabibbo-favored hadronic weak decays of the Ξ_c



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



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



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

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

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

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

3.4 The Cabibbo-favored hadronic weak decays of the Ξ_c

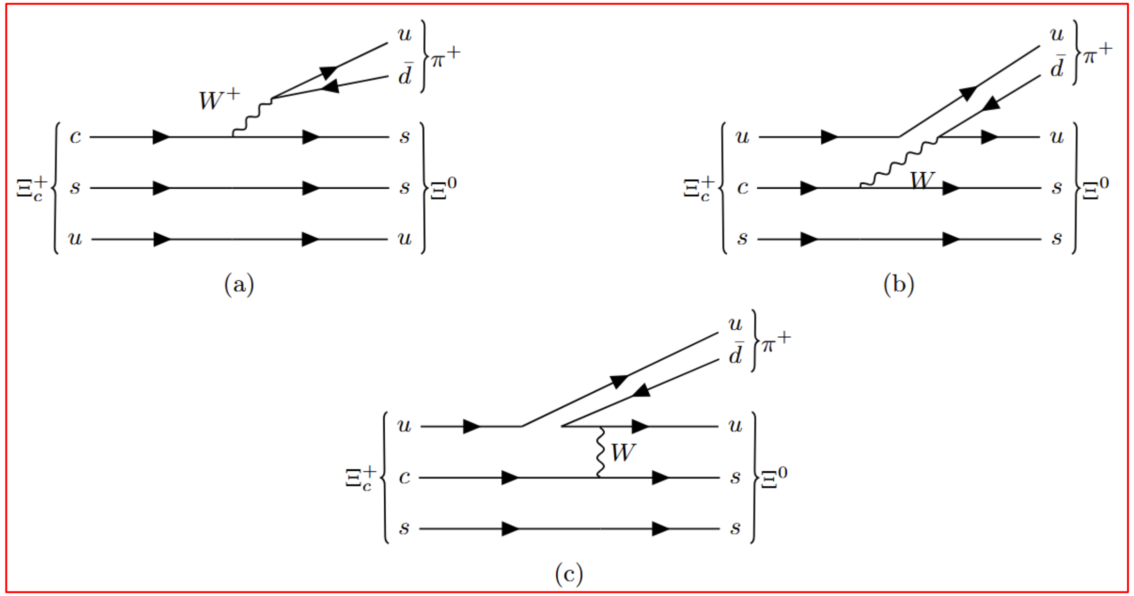
TABLE X: The amplitudes of $\Xi_c^+ \to \Xi^0\pi^+$ (in unit of 10^{-9} GeV$^{-1/2}$ for the real part and 10^{-13} GeV$^{-1/2}$ for the imaginary part). WS (SW) is used to label the pole terms that baryon weak transition either preceding (following) the strong meson emission.

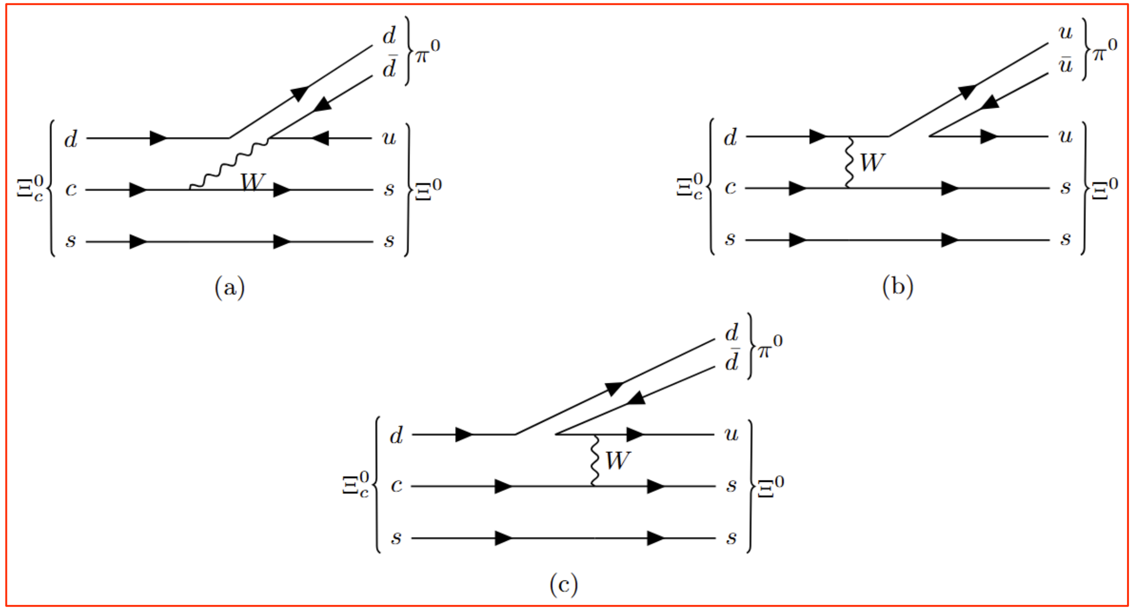
	DME	CS	WS	SW						Total
	✔	✔	✘	Ξ_c^0			$\Xi_c'^0$			
PC	$(34.41, 0)$	$(-5.62, 0)$	(0,0)	$(0, 0)$			$(-8.47, 0)$			$(20.32, 0)$
	✔	✔	✘	$\vert{}^2P_\rho\rangle$	$\vert{}^2P_\lambda\rangle$	$\vert{}^4P_\rho\rangle$	$\vert{}^2P_\rho\rangle$	$\vert{}^2P_\lambda\rangle$	$\vert{}^4P_\lambda\rangle$	
PV	$(-18.98,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

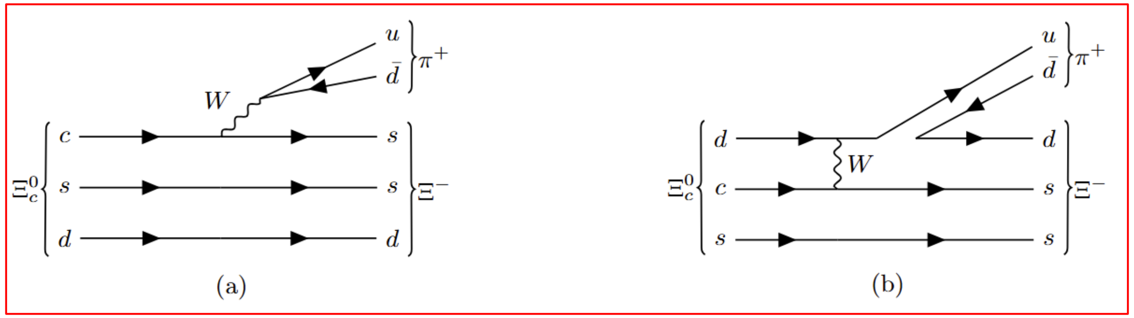
TABLE XI: The amplitudes of the $\Xi_c^0 \to \Xi^-\pi^+$ in unit of 10^{-9} GeV$^{-1/2}$.

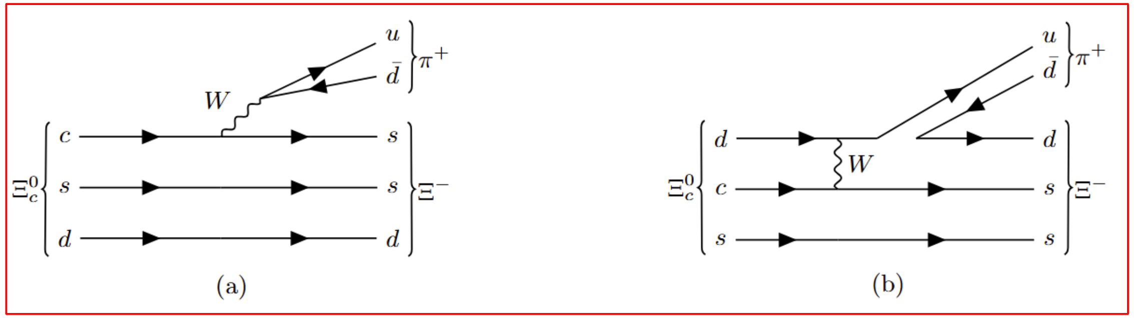
	DME	CS	WS		SW	Total
	✔	✘	Ξ_c^0		✘	
PC	$(34.41, 0)$	(0,0)	$(3.37, -3.04 \times 10^{-2}i)$		(0,0)	$(37.78, -3.04 \times 10^{-2}i)$
	✔	✘	Ξ_c^{*0}	$\Xi_c^0(1690)$	✘	
PV	$(-19.02, 0)$	(0,0)	$(0.36, -5.37 \times 10^{-3}i)$	$(2.92, -3.04 \times 10^{-2}i)$	(0,0)	$(-15.74, -3.58 \times 10^{-2}i)$

3.4 The Cabibbo-favored hadronic weak decays of the Ξ_c









$$\frac{\Gamma_{\Xi_c^+\to\Xi^0\pi^+}}{\Gamma_{\Xi_c^0\to\Xi^-\pi^+}} = \frac{\tau_{\Xi_c^0}\times \mathrm{Br}\left(\Xi_c^+\to\Xi^0\pi^+\right)}{\tau_{\Xi_c^+}\times \mathrm{Br}\left(\Xi_c^0\to\Xi^-\pi^+\right)} \approx 0.38$$

$$\frac{\Gamma_{\Xi_c^0\to\Xi^-\pi^+}}{\Gamma_{\Xi_c^0\to\Xi^0\pi^0}} = \frac{\mathrm{Br}\left(\Xi_c^0\to\Xi^-\pi^+\right)}{\mathrm{Br}\left(\Xi_c^0\to\Xi^0\pi^0\right)} \approx 2.61$$

3.4 The Cabibbo-favored hadronic weak decays of the Ξ_c

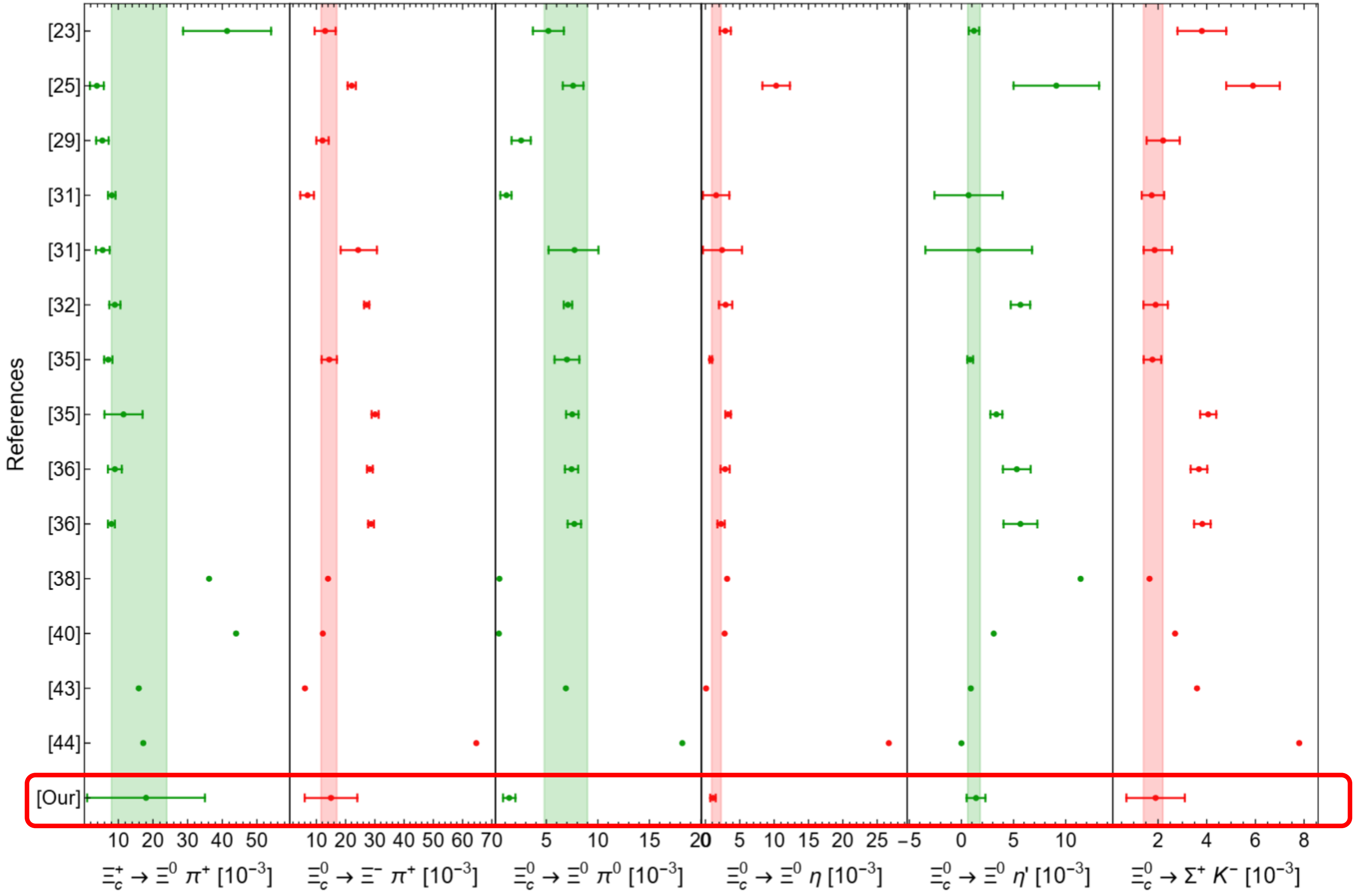
TABLE XI: The amplitudes of the $\Xi_c^0 \to \Xi^- \pi^+$ in unit of 10^{-9} GeV$^{-1/2}$.

	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)	$(0.36, -5.37 \times 10^{-3}i)$	$(2.92, -3.04 \times 10^{-2}i)$	(0,0)	$(-15.74, -3.58 \times 10^{-2}i)$

TABLE XII: The amplitudes of $\Xi_c^0 \to \Xi^0 \pi^0$ (in unit of 10^{-9} GeV$^{-1/2}$ for the real part and 10^{-12} 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	$(0, 0)$	$(-3.77, 0)$	$(0.25, -3.66i)$	$(1.99, -20.73i)$	$(-1.99, -0.42i)$	$(0, 0)$	$(2.97, 0.62i)$	$(0, 0)$	$(-2.90, -0.63i)$	$(4.38, 0.93i)$	$(0.92, -23.90i)$

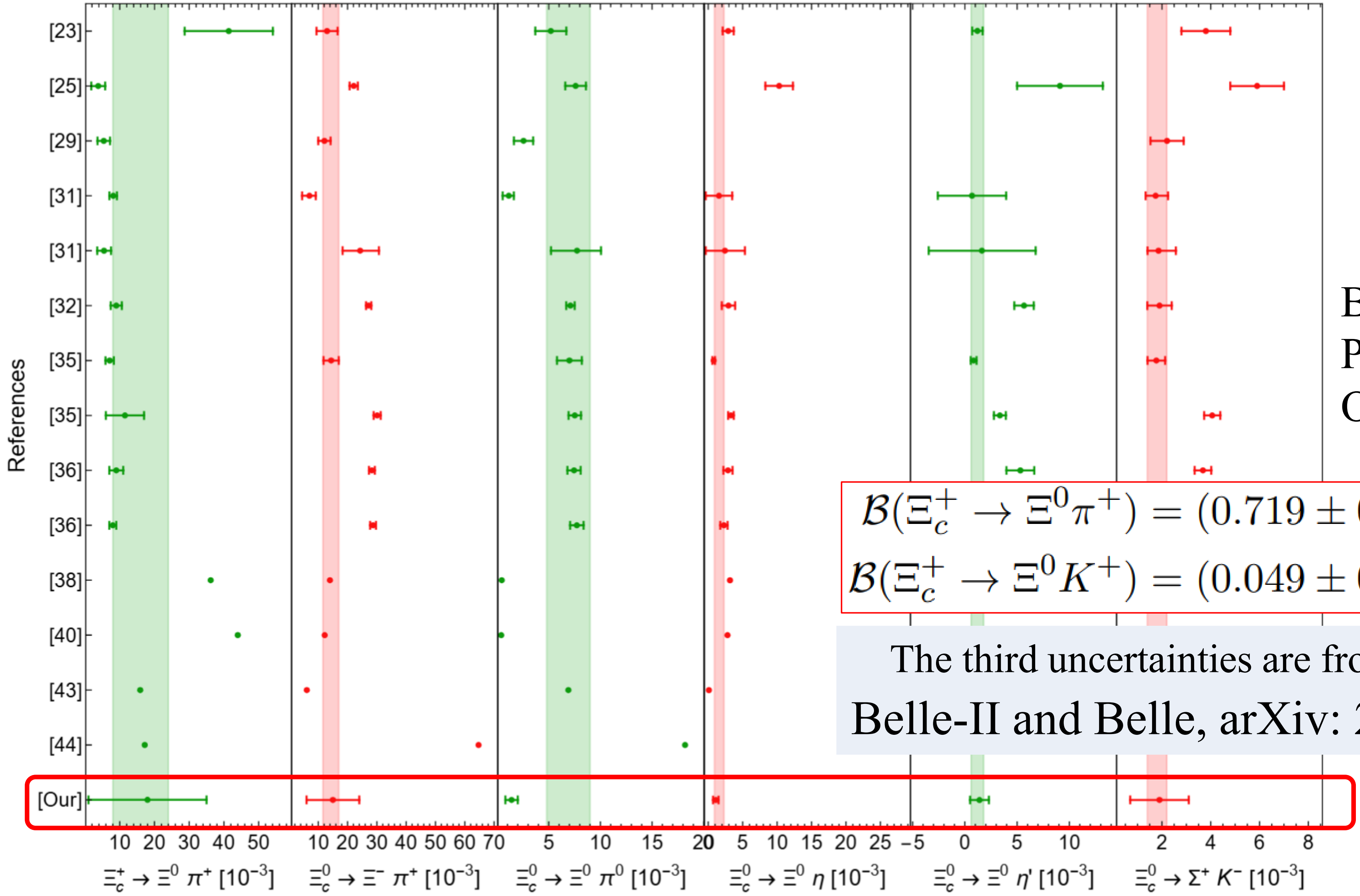
3.4 The Cabibbo-favored hadronic weak decays of the Ξ_c



Branching ratio

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

3.4 The Cabibbo-favored hadronic weak decays of the Ξ_c



Branching ratio

Br($\Xi_c^+ \to \Xi^0 \pi^+$):

PDG： $(1.6 \pm 0.8)\%$

Our result： $(1.8 \pm 1.7)\%$

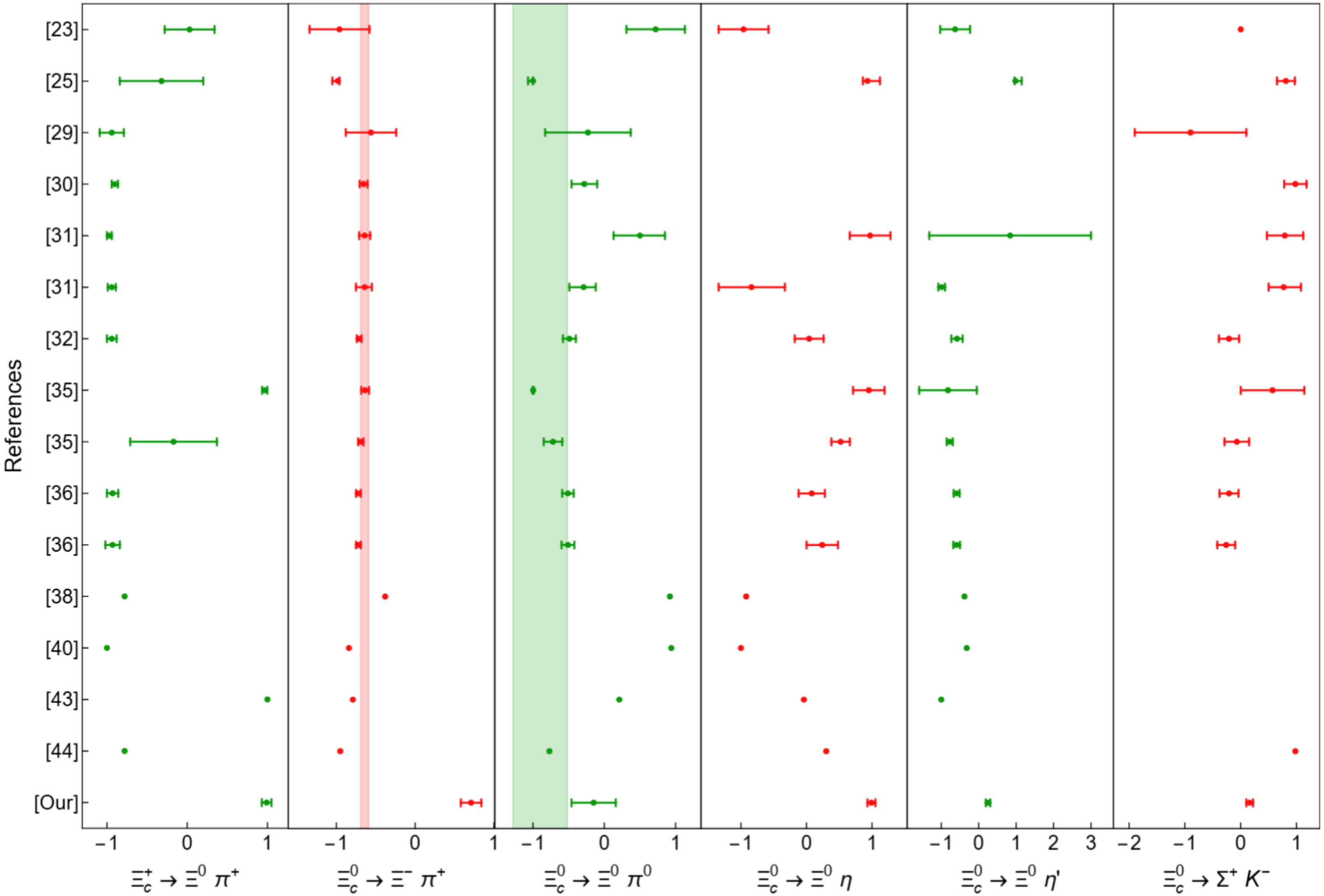
$$\mathcal{B}(\Xi_c^+ \to \Xi^0 \pi^+) = (0.719 \pm 0.014 \pm 0.024 \pm 0.322)\%,$$

$$\mathcal{B}(\Xi_c^+ \to \Xi^0 K^+) = (0.049 \pm 0.007 \pm 0.002 \pm 0.022)\%,$$

The third uncertainties are from $\Xi_c^+ \to \Xi^- \pi^+ \pi^+$

Belle-II and Belle, arXiv: 2503.17643v1

3.4 The Cabibbo-favored hadronic weak decays of the Ξ_c



Asymmetry parameter

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

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 !