Discovery Potentials of Doubly Charmed Baryons

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全国第十五届重味物理和CP破坏研讨会
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- Decay modes of $\Xi_{cc}^{++}, \Xi_{cc}^{+}$
- Semi-leptonic decays
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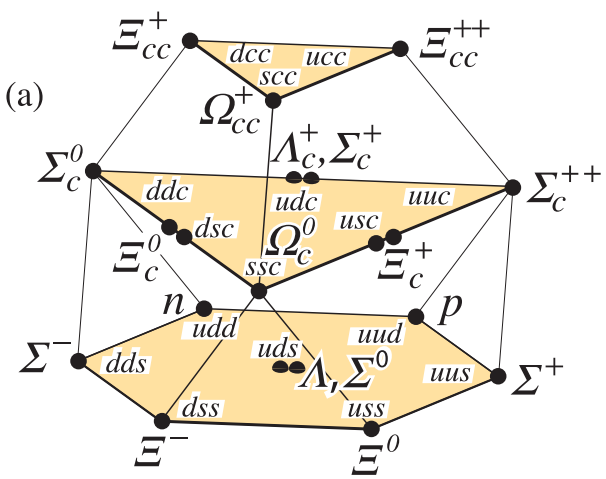
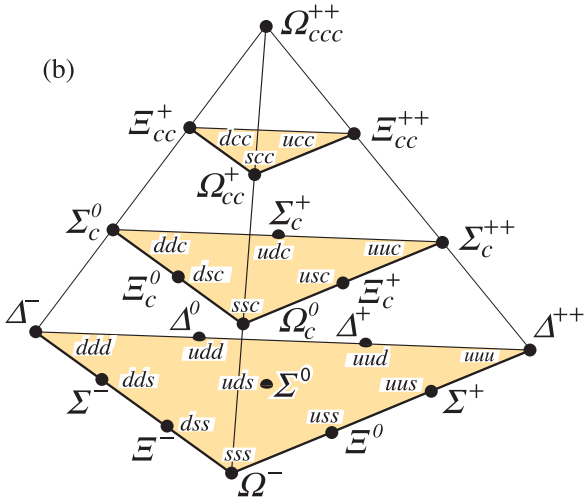
Overview

强相互作用的低能结构可以由夸克模型确定。

- 由四种味道(u, d, s, c)，可以构成$J^P=1/2^+$和$J^P=3/2^+$的20重态。

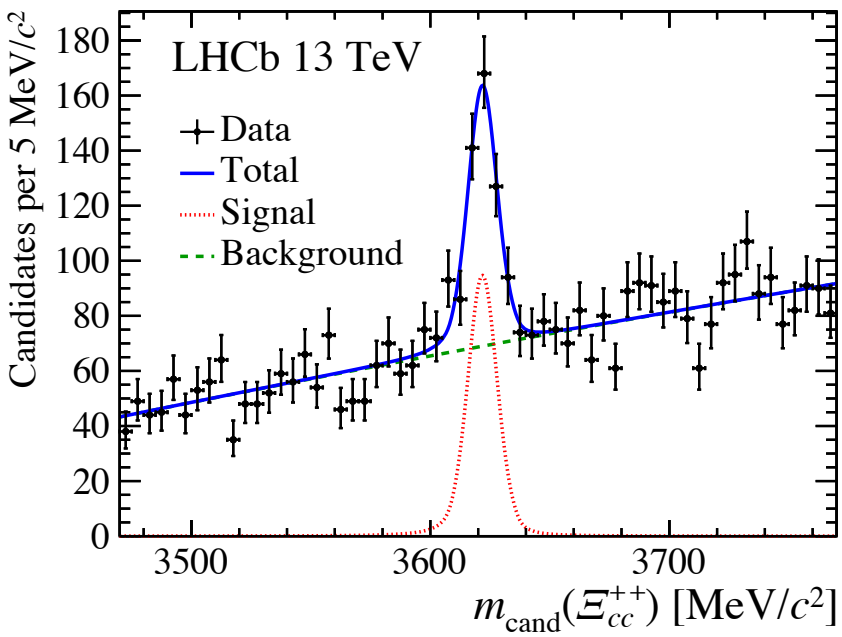


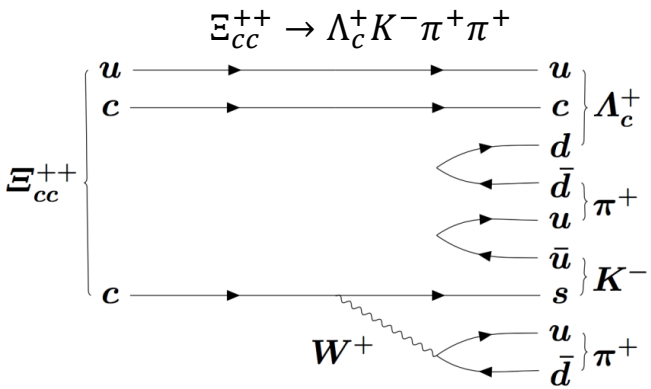
$J^P=1/2^+$



$J^P=3/2^+$

LHCb observation of Ξ_{cc}^{++}





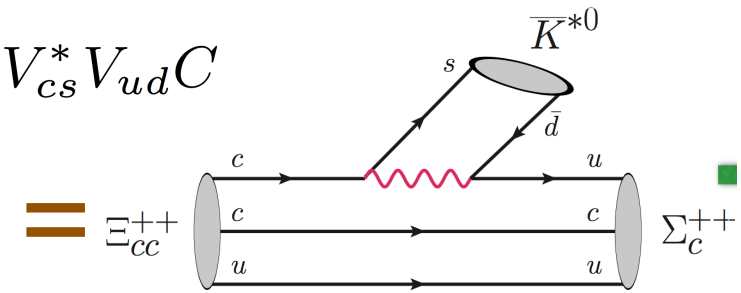
LHCb, PRL119, 112001

Discovery Potentials of Doubly Charmed Baryons,
F.S. Yu, H.Y. Jiang, R.H. Li, C.D. Lü, WW, Z.X. Zhao, arXiv:1703.09086

Ξ_{cc}^{+} decay modes

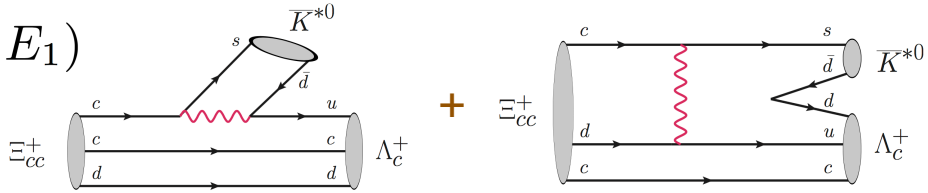
$$\boxed{\Xi_{cc}^{++} \to \Sigma_c^{++}\overline{K}^{*0}} \to \Lambda_c^{+} K^{-}\pi^{+}\pi^{+}$$

$$V_{cs}^{*}V_{ud}C$$



$$\boxed{\Xi_{cc}^{+} \to \Lambda_c^{+}\overline{K}^{*0}} \to \Lambda_c^{+} K^{-}\pi^{+}$$

$$V_{cs}^{*}V_{ud}(C+E_1)$$

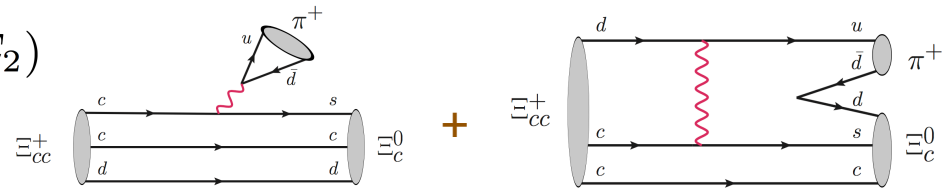


Ξ_{cc}^{+} decay modes

$$\Xi_{cc}^{+} \to \Xi_{c}^{0}\pi^{+}$$

$V_{cs}^{*}V_{ud}(T+E_2)$

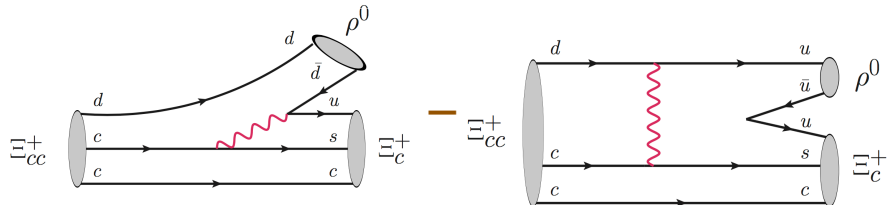
$=$



$$\Xi_{cc}^{+} \to \Xi_{c}^{+}\rho^{0} \quad \to \Xi_{c}^{+}\pi^{+}\pi^{-}$$

$\frac{1}{\sqrt{2}}V_{cs}^{*}V_{ud}(C'-E_2)$

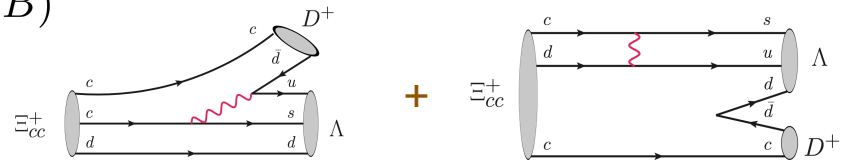
$=$



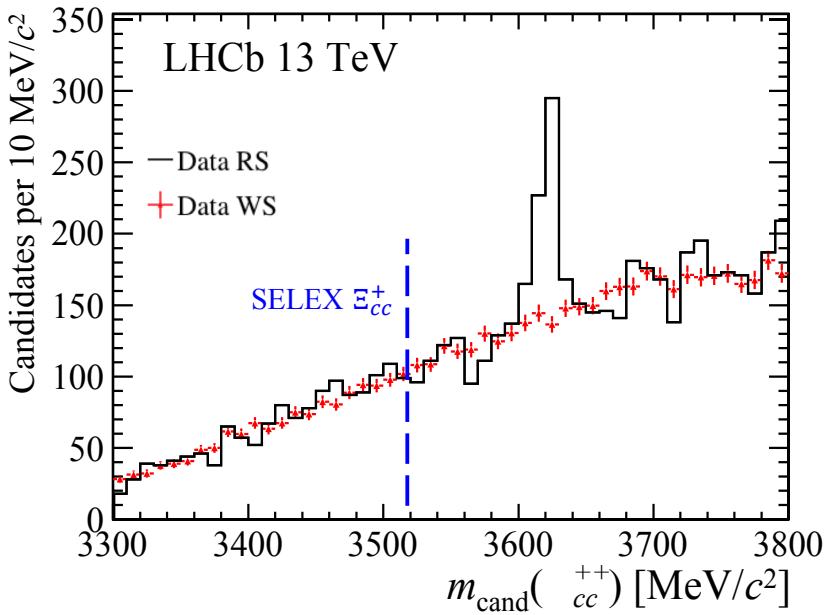
$$\Xi_{cc}^{+} \to \Lambda^{0}D^{+}$$

$V_{cs}^{*}V_{ud}(C'+B)$

$=$



Ξ_{cc}^{+} decay modes



Large Isospin Symmetry Breaking?

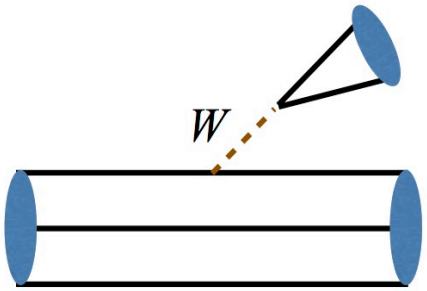
Ξ_{cc}^{+} decay modes

Large Isospin Symmetry Breaking?

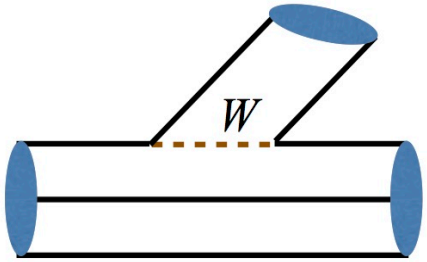
Resolving the SELEX–LHCb Double-Charm Baryon Conflict: The Impact of Intrinsic Heavy-Quark Hadroproduction and Supersymmetric Light-Front Holographic QCD

S. J. Brodsky[1], S. Groote[2], S. Koshkarev[2], H. G. Dosch[3] and G. F. de Téramond[4]

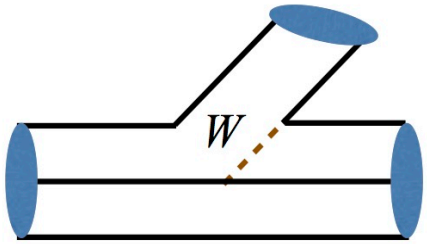
Topology



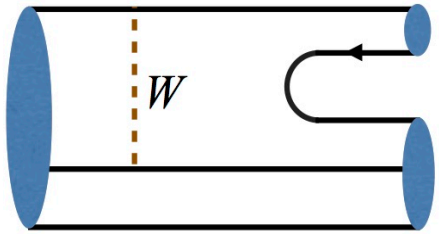
(T)
color-favored tree



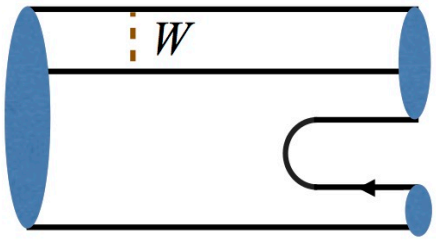
(C)
color-suppressed tree



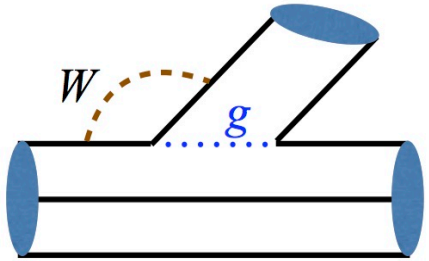
(C′)
color-commensurate



(E)
W-exchange

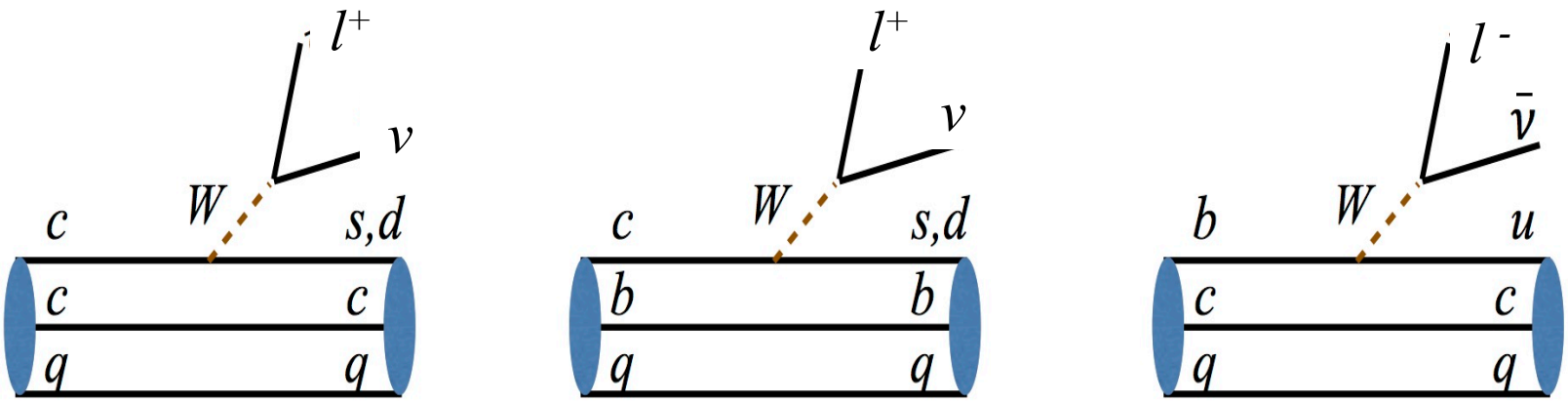


(B)
Bow tie



(P)
penguin

Semi-leptonic decays



Key point: form factors

WW, F. S. Yu, Z. X. Zhao, arxiv:1707.02834

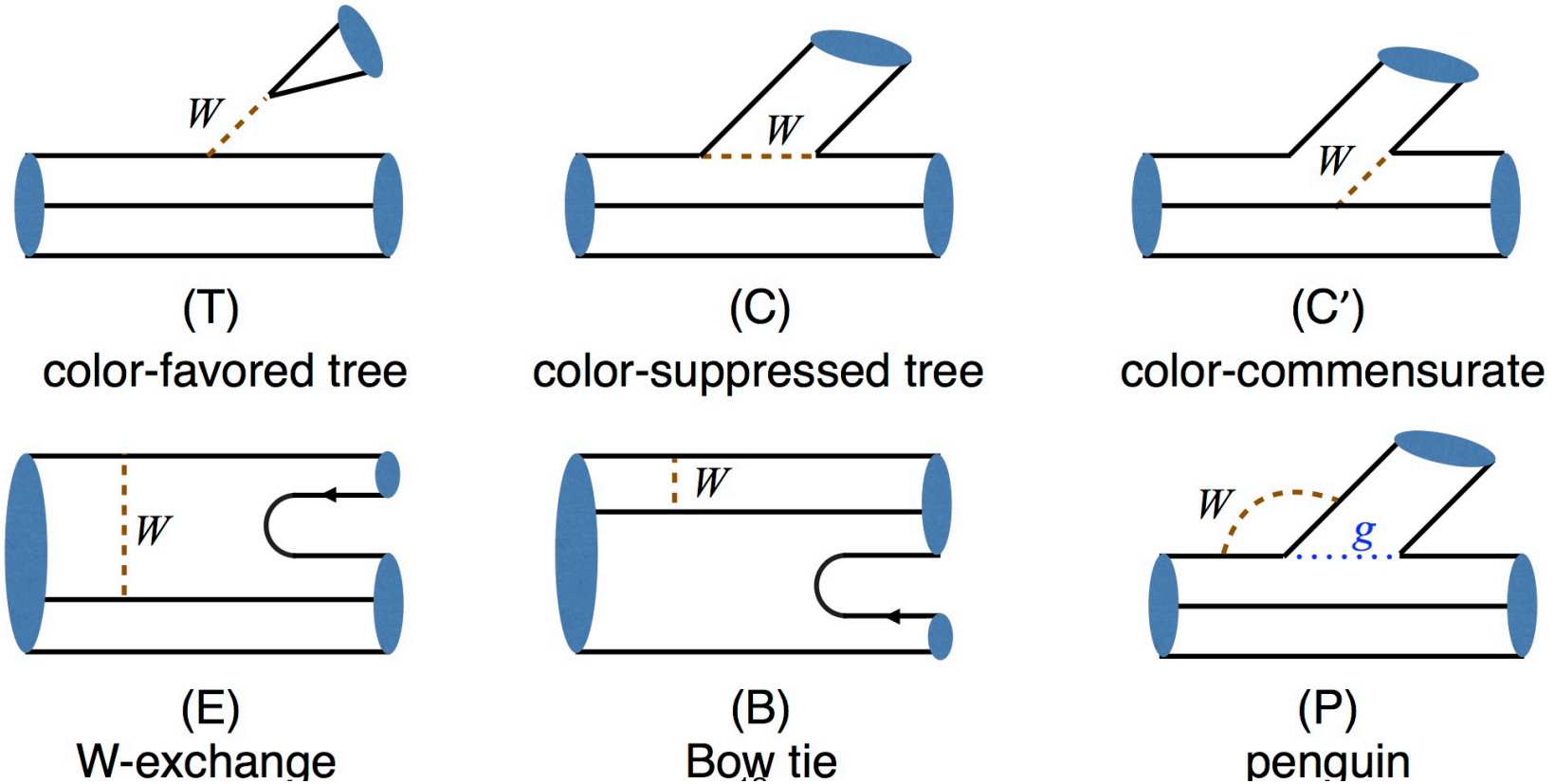
Semi-leptonic decays

channels	Γ/ GeV	$\mathcal{B}$	Γ_L/Γ_T
$\Xi_{cc}^{++} \to \Xi_c^+ l^+ \nu_l$	1.15×10^{-13}	5.25×10^{-2}	9.99
$\Xi_{cc}^{++} \to \Xi_c'^+ l^+ \nu_l$	1.28×10^{-13}	5.84×10^{-2}	1.42
$\Xi_{cc}^{+} \to \Xi_c^0 l^+ \nu_l$	1.14×10^{-13}	1.73×10^{-2}	9.99
$\Xi_{cc}^{+} \to \Xi_c'^0 l^+ \nu_l$	1.27×10^{-13}	1.93×10^{-2}	1.42
$\Omega_{cc}^{+} \to \Omega_c^0 l^+ \nu_l$	2.55×10^{-13}	10.5×10^{-2}	1.42
$\Xi_{cc}^{++} \to \Lambda_c^+ l^+ \nu_l$	1.05×10^{-14}	4.81×10^{-3}	8.52
$\Xi_{cc}^{++} \to \Sigma_c^+ l^+ \nu_l$	9.60×10^{-15}	4.38×10^{-3}	1.28
$\Xi_{cc}^{+} \to \Sigma_c^0 l^+ \nu_l$	1.91×10^{-14}	2.91×10^{-3}	1.28
$\Omega_{cc}^{+} \to \Xi_c^0 l^+ \nu_l$	8.06×10^{-15}	3.31×10^{-3}	8.84
$\Omega_{cc}^{+} \to \Xi_c'^0 l^+ \nu_l$	9.34×10^{-15}	3.83×10^{-3}	1.28

$|Vcs|^2 \sim 1$

$|Vcd|^2 \sim 0.04$

Topology



Weak Decays of Doubly Heavy Baryons: the SU(3) Analysis

WW, J. Xu, Z.P.Xing, 1707.06570

SU(3) Analysis

$$\mathcal{H}_{eff} = b_3(T_{cc})^i(\overline{T}_{c\bar{3}})_{[ij]}M^k_l(H_{\overline{6}})^{jl}_k + b_4(T_{cc})^i(\overline{T}_{c\bar{3}})_{[jl]}M^k_i(H_{\overline{6}})^{jl}_k + b_5(T_{cc})^i(\overline{T}_{c\bar{3}})_{[jk]}M^k_l(H_{\overline{6}})^{jl}_i$$
$$+b_6(T_{cc})^i(\overline{T}_{c\bar{3}})_{[ij]}M^k_l(H_{15})^{jl}_k + b_7(T_{cc})^i(\overline{T}_{c\bar{3}})_{[jk]}M^k_l(H_{15})^{jl}_i. \quad ($$

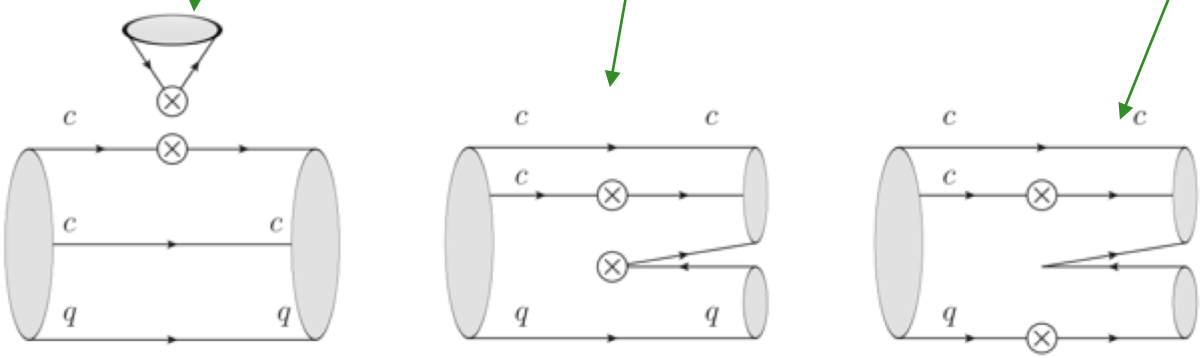


FIG. 4: Feynman diagrams for Ξ_{cc} and Ω_{cc} decays into a charmed baryon and a light meson.

SU(3) Analysis

TABLE V: Doubly charmed baryons decays into a cqq (antitriplet) and a light meson.

channel	amplitude	channel	amplitude
$\Xi_{cc}^{++} \to \Xi_c^+ \pi^+$	$b_3 - 2b_4 + b_6$	$\Xi_{cc}^{++} \to \Lambda_c^+ \pi^+$	$(b_3 - 2b_4 + b_6)\,(-\sin(\theta_C))$
$\Xi_{cc}^{+} \to \Lambda_c^+ \overline{K}^0$	$b_3 - b_5 - b_6 + b_7$	$\Xi_{cc}^{++} \to \Xi_c^+ K^+$	$(b_3 - 2b_4 + b_6)\sin(\theta_C)$
$\Xi_{cc}^{+} \to \Xi_c^+ \pi^0$	$\frac{2b_4 - b_5 - b_7}{\sqrt{2}}$	$\Xi_{cc}^{+} \to \Lambda_c^+ \pi^0$	$\frac{(b_3 - 2b_4 - b_6 + 2b_7)\sin(\theta_C)}{\sqrt{2}}$
$\Xi_{cc}^{+} \to \Xi_c^+ \eta$	$\frac{-2b_4 + b_5 - 3b_7}{\sqrt{6}}$	$\Xi_{cc}^{+} \to \Lambda_c^+ \eta$	$\frac{(-3b_3 + 2b_4 + 2b_5 + 3b_6)\sin(\theta_C)}{\sqrt{6}}$
$\Xi_{cc}^{+} \to \Xi_c^0 \pi^+$	$b_3 - b_5 + b_6 - b_7$	$\Xi_{cc}^{+} \to \Xi_c^+ K^0$	$(2b_4 - b_5 + b_7)\,(-\sin(\theta_C))$
$\Omega_{cc}^{+} \to \Xi_c^+ \overline{K}^0$	$b_3 - 2b_4 - b_6$	$\Xi_{cc}^{+} \to \Xi_c^0 K^+$	$(b_3 - b_5 + b_6 - b_7)\sin(\theta_C)$
$\Xi_{cc}^{++} \to \Lambda_c^+ K^+$	$(b_3 - 2b_4 + b_6)\sin^2(\theta_C)$	$\Omega_{cc}^{+} \to \Lambda_c^+ \overline{K}^0$	$(2b_4 - b_5 + b_7)\sin(\theta_C)$
$\Xi_{cc}^{+} \to \Lambda_c^+ K^0$	$(b_3 - 2b_4 - b_6)\sin^2(\theta_C)$	$\Omega_{cc}^{+} \to \Xi_c^+ \pi^0$	$\frac{(b_3 - b_5 - b_6 - b_7)\sin(\theta_C)}{\sqrt{2}}$
$\Omega_{cc}^{+} \to \Lambda_c^+ \pi^0$	$-\sqrt{2} b_7 \sin^2(\theta_C)$	$\Omega_{cc}^{+} \to \Xi_c^+ \eta$	$\frac{(-3b_3 + 4b_4 + b_5 + 3b_6 - 3b_7)\sin(\theta_C)}{\sqrt{6}}$
$\Omega_{cc}^{+} \to \Lambda_c^+ \eta$	$\sqrt{\frac{2}{3}}\,(2b_4 - b_5)\sin^2(\theta_C)$	$\Omega_{cc}^{+} \to \Xi_c^0 \pi^+$	$(b_3 - b_5 + b_6 - b_7)\sin(\theta_C)$
$\Omega_{cc}^{+} \to \Xi_c^+ K^0$	$(b_3 - b_5 - b_6 + b_7)\sin^2(\theta_C)$		
$\Omega_{cc}^{+} \to \Xi_c^0 K^+$	$(b_3 - b_5 + b_6 - b_7)\left(-\sin^2(\theta_C)\right)$		

$$\Gamma(\Xi_{cc}^{++} \to \Lambda_c^+ \pi^+) = \Gamma(\Xi_{cc}^{++} \to \Xi_c^+ K^+),$$

$$\Gamma(\Xi_{cc}^{+} \to \Xi_c^+ K^0) = \Gamma(\Omega_{cc}^{+} \to \Lambda_c^+ \overline{K}^0),$$

$$\Gamma(\Omega_{cc}^{+} \to \Xi_c^0 \pi^+) = \Gamma(\Xi_{cc}^{+} \to \Xi_c^0 K^+).$$

Summary

- LHCb observation will play an important role in the study of doubly charmed baryons
- Ξ_{cc}^{+} :Large Isospin symmetry breaking?
- Semi-Leptonic decays: theoretical models?
- SU(3) analysis

Publication List

- Weak decays of doubly-heavy baryon: $\Xi^0_{bc} \to pK^-$ and $\Xi^+_{cc} \to \Sigma^{++}_c K^-$,
  R.H.Li, C.D.Lü, WW, F.S.Yu, Z.T.Zou, arXiv: 1701.03284

- Discovery Potentials of Doubly Charmed Baryons
  F.S. Yu, H.Y. Jiang, R.H. Li, C.D. Lü, WW, Z.X. Zhao, arXiv:1703.09086

- Weak Decays of Doubly Heavy Baryons: the ½ to ½ case
  WW, F.S.Yu, Z.X.Zhao, arxiv:1707.02834

- Weak Decays of Doubly Heavy Baryons: the SU(3) Analysis
  WW, J.Xu, Z.P.Xing, arxiv:1707.06570

Prospects

- Searching for Ξ_{cc}^{++} with more channels: $\Xi_c^+\pi^+$, $\Lambda_c^+\pi^+, pD^+K^-\pi^+\ldots$
- Measurement of the Ξ_{cc}^{++} lifetime
- Measurement of the production cross-section
- Confirming its spin-parity: $½^+$
- Searching for its isospin partner Ξ_{cc}^+ in a larger sample than the previous measurement
- Searching for Ω_{cc}^+
- Doubly heavy baryons with bottom quark: $\Xi_{bc}, \Omega_{bc}, \Xi_{bb}\ \ldots$
- The excited states?
- And new systems for CP violations

A long list of programs

感谢各位专家！

请批评指正！