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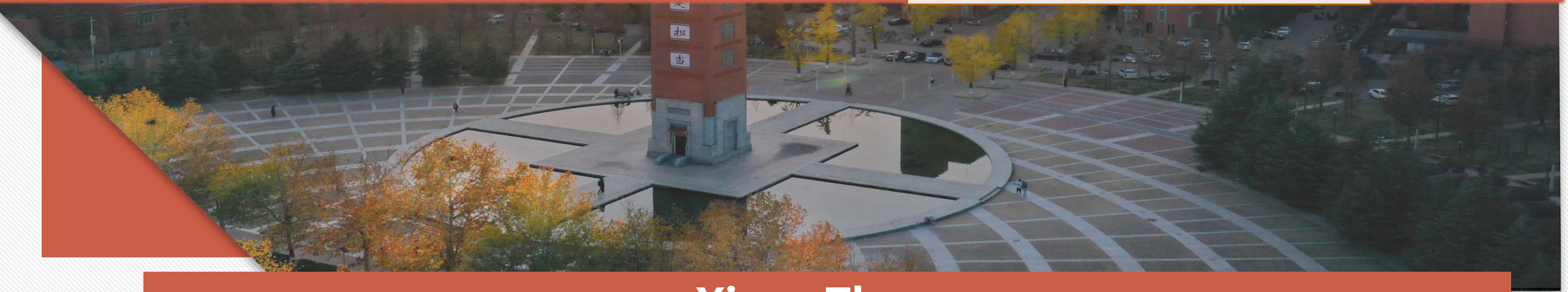
Deciphering Weak Decays of Doubly and Triply Heavy Baryons by SU(3) Analysis



Xiruo Zhang

HFCPV 2021

In collaboration with De-Min Li, Ji Xu, Ye Xing and Fei Huang

2021.11.12 广州 暨南大学

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Summary

Part.1 Background

01

Discovery of Ξ_{cc}^{++}

02

Quark Model

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Discovery of Ξ_{cc}^{++}

Observation of the doubly charmed baryon Ξ_{cc}^{++}

LHCb Collaboration • Roel Aaij (CERN) Show All(809)

Jul 5, 2017

10 pages
Published in: *Phys.Rev.Lett.* 119 (2017) 11, 112001
Published: Sep 11, 2017
e-Print: 1707.01621 [hep-ex]
DOI: 10.1103/PhysRevLett.119.112001
Report number: LHCB-PAPER-2017-018, CERN-EP-2017-156
Experiments: CERN-LHC-LHCb
View in: HAL Archives Ouvertes, CERN Document Server, ADS Abstract Service

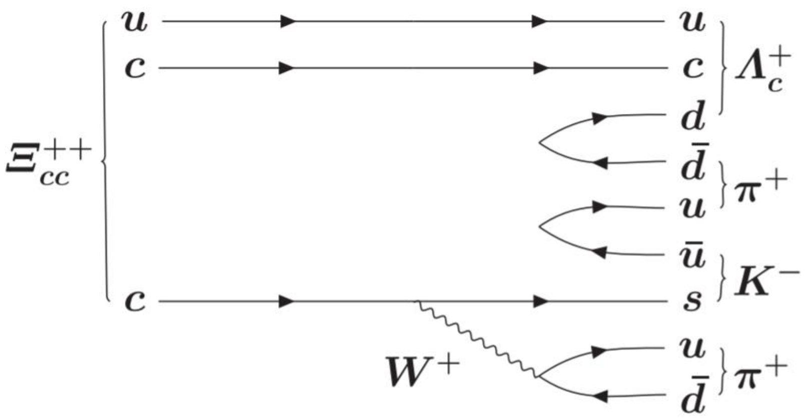
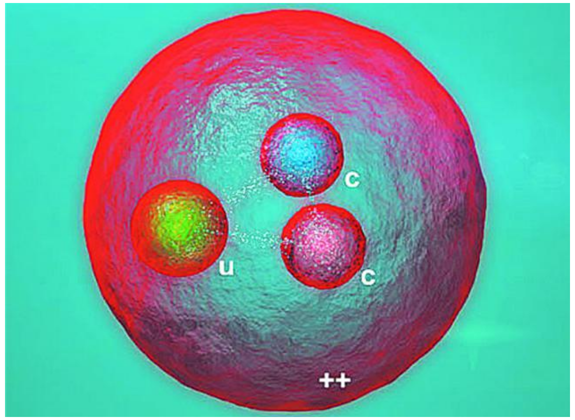
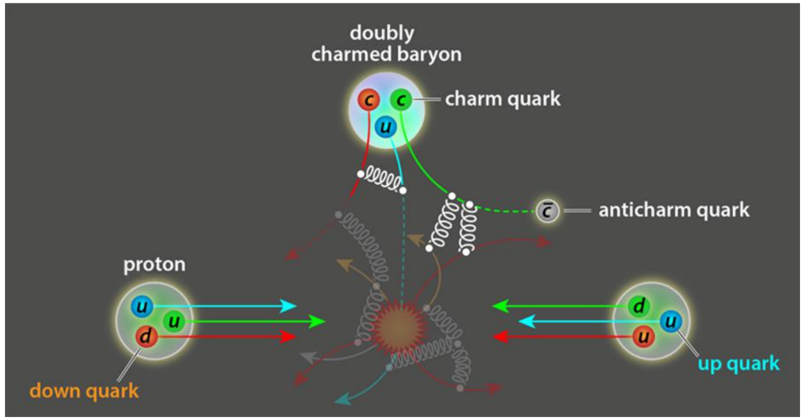


FIG. 1. Example Feynman diagram contributing to the decay $\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$.

$$m_{\Xi_{cc}^{++}} = (3621.40 \pm 0.72 \pm 0.27 \pm 0.14)\mathrm{MeV}.$$





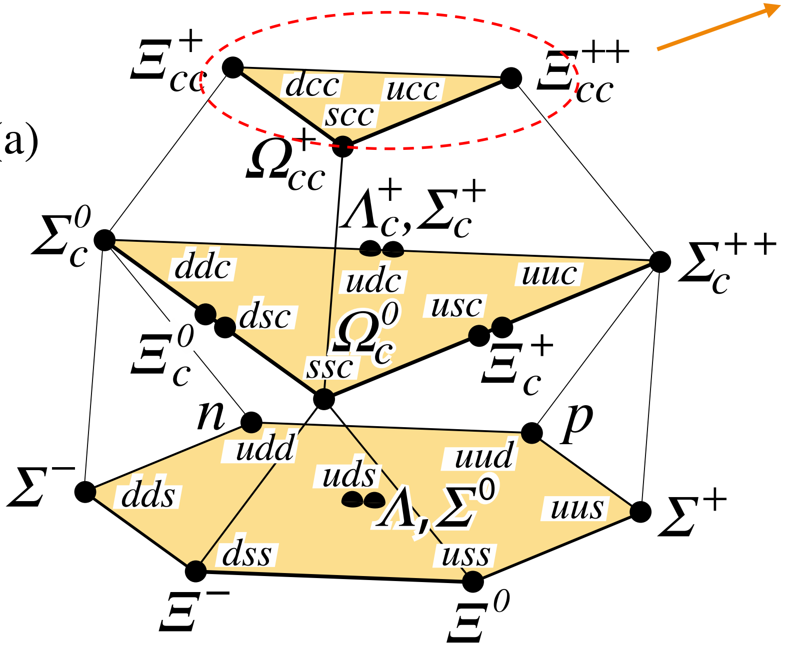
Fu-Sheng Yu, Hua-Yu Jiang, Run-Hui Li, Cai-Dian Lv, Wei Wang et al, Chin.Phys.C 42 (2018) 5, 051001

Quark Model

While the existence of this particle was expected, the finding is the first high-precision observation of a baryon containing two heavy quarks.

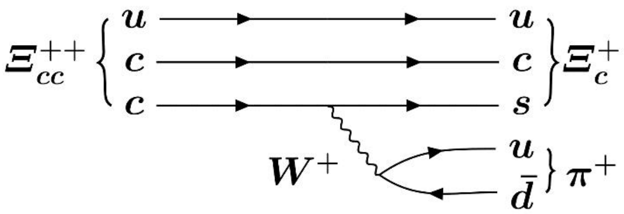
Found!

$J^P = 1/2^+$



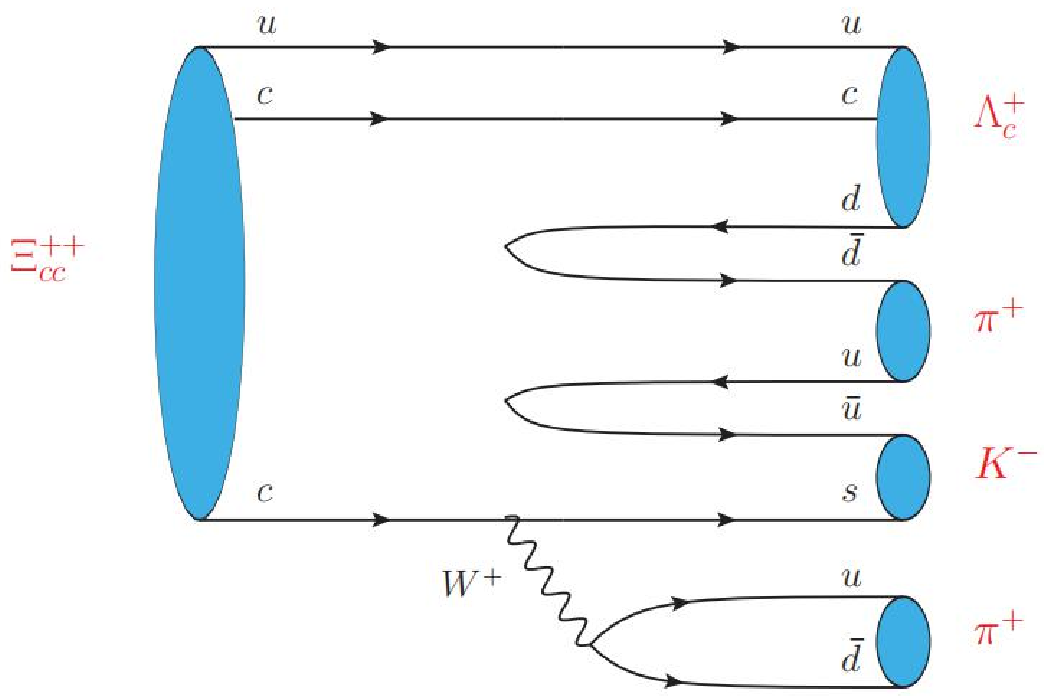
With no doubt, this observation will make a great impact on the hadron spectroscopy and it will also trigger more interests in this research field.

W. Wang, Z. P. Xing and J. Xu, Eur. Phys. J. C (2017)
Y. J. Shi, W. Wang, Y. Xing and J. Xu, Eur. Phys. J. C (2018)

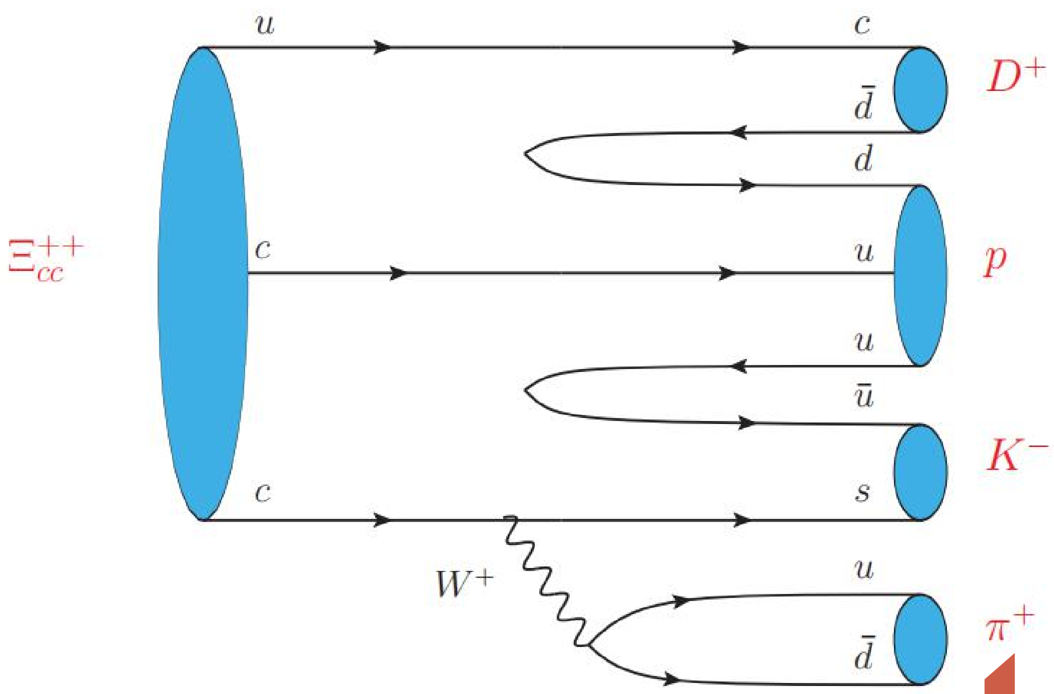


LHCb, Phys. Rev. Lett. 121 (2018)

Decay type representation



LHCb, PRL 119, 112001 (2017)



LHCb, JHEP 10 (2019)

Part.2 Doubly Heavy Baryons

01

SU(3) Analysis

02

Nonleptonic Decays

SU(3) Analysis

SU(3) light flavor symmetry is a powerful tool to analyse decays of heavy hadrons.

$$T_{cc} = \begin{pmatrix} \Xi_{cc}^{++}(ccu) \\ \Xi_{cc}^{+}(ccd) \\ \Omega_{cc}^{+}(ccs) \end{pmatrix}, \quad T_{bc} = \begin{pmatrix} \Xi_{bc}^{+}(bcu) \\ \Xi_{bc}^{0}(bcd) \\ \Omega_{bc}^{0}(bcs) \end{pmatrix}, \quad T_{bb} = \begin{pmatrix} \Xi_{bb}^{0}(bbu) \\ \Xi_{bb}^{-}(bbd) \\ \Omega_{bb}^{-}(bbs) \end{pmatrix}.$$

$$T_{\mathbf{c\bar{3}}} = \begin{pmatrix} 0 & \Lambda_c^+ & \Xi_c^+ \\ -\Lambda_c^+ & 0 & \Xi_c^0 \\ -\Xi_c^+ & -\Xi_c^0 & 0 \end{pmatrix}.$$

$$M_8 = \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} & \pi^+ & K^+ \\ \pi^- & -\frac{\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} & K^0 \\ K^- & \bar{K}^0 & -2\frac{\eta}{\sqrt{6}} \end{pmatrix}.$$

……

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CKM matrix elements

In general, charm quarks decay to light quarks into three categories:

1. Cabibbo allowed: $c \to s\bar{d}u$ $\quad V_{cs}^* V_{ud} \sim 1$
2. singly Cabibbo suppressed: $c \to u\bar{d}d/\bar{s}s$ $\quad |V_{cs}^* V_{us}|, |V_{cd}^* V_{ud}| \sim \sin\theta_C$
3. doubly Cabibbo suppressed: $c \to d\bar{s}u$ $\quad V_{cd}^* V_{us} \sim \sin^2\theta_C$

$$\begin{bmatrix} |V_{ud}| & |V_{us}| & |V_{ub}| \\ |V_{cd}| & |V_{cs}| & |V_{cb}| \\ |V_{td}| & |V_{ts}| & |V_{tb}| \end{bmatrix} = \begin{bmatrix} 0.97370 \pm 0.00014 & 0.2245 \pm 0.0008 & 0.00382 \pm 0.00024 \\ 0.221 \pm 0.004 & 0.987 \pm 0.011 & 0.0410 \pm 0.0014 \\ 0.0080 \pm 0.0003 & 0.0388 \pm 0.0011 & 1.013 \pm 0.030 \end{bmatrix}$$

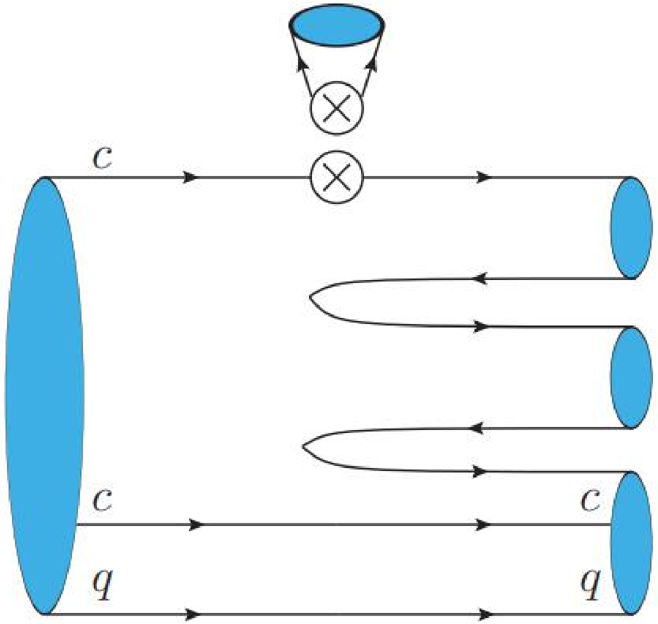
These operators transform under the flavor SU(3) symmetry as

$$\mathbf{3} \otimes \bar{\mathbf{3}} \otimes \mathbf{3} = \mathbf{3} \oplus \mathbf{3} \oplus \bar{\mathbf{6}} \oplus \mathbf{15}. \qquad \to H_3 \qquad H_{\bar{6}} \qquad H_{15}$$

Nonleptonic Decays

- **Decays into a singly charmed baryon and three light pseudo-scalar mesons**

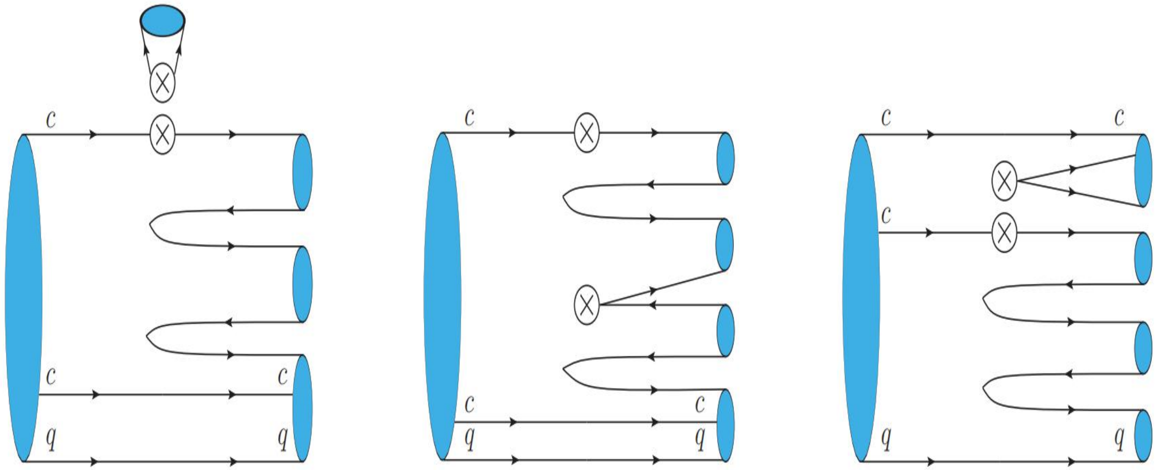
$$\mathcal{H}_{eff} \;=\; a_1 (T_{cc})^i (\overline{T}_{c\bar{3}})_{[ij]} M^j_k M^k_l M^n_m (H_{\bar{6}})^{lm}_n + a_2 (T_{cc})^i (\overline{T}_{c\bar{3}})_{[ij]} M^j_k M^m_n M^n_l (H_{\bar{6}})^{kl}_m + \ldots$$



The effective Hamiltonian can be derived as

$$
\begin{aligned}
\mathcal{H}_{eff} \;=\; & a_1(T_{cc})^i(\overline{T}_{c\bar{3}})_{[ij]}M^j_kM^k_lM^n_m(H_{\bar{6}})^{lm}_n + a_2(T_{cc})^i(\overline{T}_{c\bar{3}})_{[ij]}M^j_kM^m_nM^n_l(H_{\bar{6}})^{kl}_m \\
& + a_3(T_{cc})^i(\overline{T}_{c\bar{3}})_{[ij]}M^n_mM^m_nM^l_k(H_{\bar{6}})^{jk}_l + a_4(T_{cc})^i(\overline{T}_{c\bar{3}})_{[ij]}M^n_mM^l_nM^m_k(H_{\bar{6}})^{jk}_l \\
& + a_5(T_{cc})^i(\overline{T}_{c\bar{3}})_{[jk]}M^j_iM^k_lM^n_m(H_{\bar{6}})^{lm}_n + a_6(T_{cc})^i(\overline{T}_{c\bar{3}})_{[jk]}M^j_iM^m_lM^n_m(H_{\bar{6}})^{kl}_n \\
& + a_7(T_{cc})^i(\overline{T}_{c\bar{3}})_{[kl]}M^j_iM^k_jM^n_m(H_{\bar{6}})^{lm}_n + a_8(T_{cc})^i(\overline{T}_{c\bar{3}})_{[mn]}M^j_iM^k_jM^l_k(H_{\bar{6}})^{mn}_l \\
& + a_9(T_{cc})^i(\overline{T}_{c\bar{3}})_{[ln]}M^j_iM^k_jM^n_m(H_{\bar{6}})^{lm}_k + a_{10}(T_{cc})^i(\overline{T}_{c\bar{3}})_{[kl]}M^j_iM^m_nM^n_m(H_{\bar{6}})^{kl}_j \\
& + a_{11}(T_{cc})^i(\overline{T}_{c\bar{3}})_{[km]}M^j_iM^n_lM^m_n(H_{\bar{6}})^{kl}_j + a_{12}(T_{cc})^i(\overline{T}_{c\bar{3}})_{[mn]}M^j_iM^m_kM^n_l(H_{\bar{6}})^{kl}_j \\
& + a_{13}(T_{cc})^i(\overline{T}_{c\bar{3}})_{[jk]}M^l_mM^n_lM^m_n(H_{\bar{6}})^{jk}_i + a_{14}(T_{cc})^i(\overline{T}_{c\bar{3}})_{[jl]}M^l_kM^m_nM^n_m(H_{\bar{6}})^{jk}_i \\
& + a_{15}(T_{cc})^i(\overline{T}_{c\bar{3}})_{[jl]}M^n_kM^l_mM^m_n(H_{\bar{6}})^{jk}_i + a_{16}(T_{cc})^i(\overline{T}_{c\bar{3}})_{[lm]}M^l_jM^n_kM^m_n(H_{\bar{6}})^{jk}_i \\
& + \Big((H_{\bar{6}}) \to (H_{15}), a \to b\Big).
\end{aligned}
$$

Feynman diagrams for some channels can be presented



We can find the relations for decay widths in the SU(3) symmetry limit

$$\Gamma(\Omega_{cc}^{+} \to \Lambda_c^{+}\pi^{+}\overline{K}^{0}K^{-}) = \Gamma(\Omega_{cc}^{+} \to \Lambda_c^{+}\pi^{0}\overline{K}^{0}\overline{K}^{0}) = 3\Gamma(\Omega_{cc}^{+} \to \Lambda_c^{+}\overline{K}^{0}\overline{K}^{0}\eta)\,,$$

$$\Gamma(\Xi_{cc}^{++} \to \Lambda_c^{+}\pi^{+}\pi^{+}K^{-}) = 4\Gamma(\Xi_{cc}^{+} \to \Lambda_c^{+}\pi^{+}\pi^{0}K^{-}) = 4\Gamma(\Xi_{cc}^{++} \to \Lambda_c^{+}\pi^{+}\pi^{0}\overline{K}^{0})\,,$$

$$\Gamma(\Xi_{cc}^{++} \to \Xi_c^{+}\pi^{+}\pi^{0}\eta) = \Gamma(\Xi_{cc}^{+} \to \Xi_c^{0}\pi^{+}\pi^{0}\eta) = \frac{1}{4}\Gamma(\Xi_{cc}^{++} \to \Xi_c^{0}\pi^{+}\pi^{+}\eta) = \frac{1}{3}\Gamma(\Xi_{cc}^{++} \to \Xi_c^{0}\pi^{+}K^{+}\overline{K}^{0})\,,$$

$$\Gamma(\Omega_{cc}^{+} \to \Xi_c^{+}\pi^{+}\pi^{0}K^{-}) = \Gamma(\Omega_{cc}^{+} \to \Xi_c^{0}\pi^{+}\pi^{0}\overline{K}^{0}) = \Gamma(\Omega_{cc}^{+} \to \Xi_c^{+}\pi^{0}\pi^{-}K^{+}) = \frac{1}{4}\Gamma(\Omega_{cc}^{+} \to \Xi_c^{0}\pi^{+}\pi^{+}K^{-})$$

What we're showing here is the decay channel of Cabibbo-allowed.
These circled decay channels might be helpful to search for Ξ_{cc}^{+} , and new decay channels for Ξ_{cc}^{++} at LHC, since their branching fractions are sizeable, and the productions are easy identifiable.

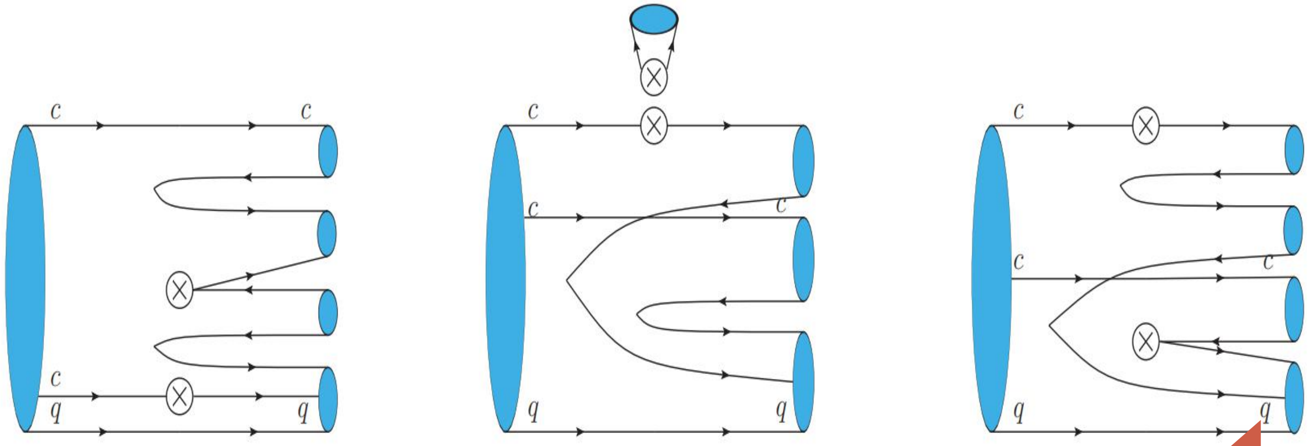
Nonleptonic Decays

- **Decays into an octet light baryon with charmed meson and two light pseudo-scalar mesons**

The effective Hamiltonian can be derived as

$$
\begin{aligned}
\mathcal{H}_{eff} = & +c_1(T_{cc})^i\epsilon_{ijk}(T_8)^k_l\overline{D}^j M^l_m M^r_n(H_{\overline{6}})^{mn}_r + c_2(T_{cc})^i\epsilon_{ijk}(T_8)^k_l\overline{D}^j M^n_r M^r_m(H_{\overline{6}})^{lm}_n + c_3(T_{cc})^i\epsilon_{ijk}(T_8)^k_l\overline{D}^l M^j_m M^r_n(H_{\overline{6}})^{mn}_r \\
& +c_4(T_{cc})^i\epsilon_{ijk}(T_8)^k_l\overline{D}^m M^j_n M^l_r(H_{\overline{6}})^{nr}_m + c_5(T_{cc})^i\epsilon_{ijk}(T_8)^k_l\overline{D}^n M^j_m M^r_n(H_{\overline{6}})^{lm}_r + c_6(T_{cc})^i\epsilon_{ijk}(T_8)^k_l\overline{D}^l M^m_n M^n_r(H_{\overline{6}})^{jr}_m \\
& +c_7(T_{cc})^i\epsilon_{ijk}(T_8)^k_l\overline{D}^l M^m_n M^r_m(H_{\overline{6}})^{jn}_r + c_8(T_{cc})^i\epsilon_{ijk}(T_8)^k_l\overline{D}^m M^l_m M^n_r(H_{\overline{6}})^{jr}_n + c_9(T_{cc})^i\epsilon_{ijk}(T_8)^k_l\overline{D}^n M^l_m M^m_r(H_{\overline{6}})^{jr}_n \\
& +c_{10}(T_{cc})^i\epsilon_{ijk}(T_8)^k_l\overline{D}^r M^l_m M^n_r(H_{\overline{6}})^{jm}_n + c_{11}(T_{cc})^i\epsilon_{ijk}(T_8)^k_l\overline{D}^m M^n_r M^r_n(H_{\overline{6}})^{jl}_m + c_{12}(T_{cc})^i\epsilon_{ijk}(T_8)^k_l\overline{D}^n M^m_r M^r_n(H_{\overline{6}})^{jl}_m \\
& +c_{13}(T_{cc})^l\epsilon_{ijk}(T_8)^k_l\overline{D}^i M^j_m M^r_n(H_{\overline{6}})^{mn}_r + c_{14}(T_{cc})^r\epsilon_{ijk}(T_8)^k_l\overline{D}^i M^j_m M^l_n(H_{\overline{6}})^{mn}_r + c_{15}(T_{cc})^n\epsilon_{ijk}(T_8)^k_l\overline{D}^i M^j_r M^r_m(H_{\overline{6}})^{lm}_n \\
& +c_{16}(T_{cc})^r\epsilon_{ijk}(T_8)^k_l\overline{D}^i M^j_r M^n_m(H_{\overline{6}})^{lm}_n + c_{17}(T_{cc})^r\epsilon_{ijk}(T_8)^k_l\overline{D}^i M^j_m M^n_r(H_{\overline{6}})^{lm}_n + c_{18}(T_{cc})^l\epsilon_{ijk}(T_8)^k_l\overline{D}^i M^r_m M^n_r(H_{\overline{6}})^{jm}_n \\
& +c_{19}(T_{cc})^n\epsilon_{ijk}(T_8)^k_l\overline{D}^i M^l_r M^r_m(H_{\overline{6}})^{jm}_n + c_{20}(T_{cc})^r\epsilon_{ijk}(T_8)^k_l\overline{D}^i M^l_r M^n_m(H_{\overline{6}})^{jm}_n + c_{21}(T_{cc})^r\epsilon_{ijk}(T_8)^k_l\overline{D}^i M^l_m M^n_r(H_{\overline{6}})^{jm}_n \\
& +c_{22}(T_{cc})^m\epsilon_{ijk}(T_8)^k_l\overline{D}^i M^n_r M^r_n(H_{\overline{6}})^{jl}_m + c_{23}(T_{cc})^r\epsilon_{ijk}(T_8)^k_l\overline{D}^i M^n_r M^m_n(H_{\overline{6}})^{jl}_m + c_{24}(T_{cc})^l\epsilon_{ijk}(T_8)^k_l\overline{D}^r M^i_m M^j_n(H_{\overline{6}})^{mn}_r \\
& +c_{25}(T_{cc})^r\epsilon_{ijk}(T_8)^k_l\overline{D}^l M^i_m M^j_n(H_{\overline{6}})^{mn}_r + c_{26}(T_{cc})^n\epsilon_{ijk}(T_8)^k_l\overline{D}^r M^i_r M^j_m(H_{\overline{6}})^{lm}_n + c_{27}(T_{cc})^r\epsilon_{ijk}(T_8)^k_l\overline{D}^n M^i_r M^j_m(H_{\overline{6}})^{lm}_n \\
& +c_{28}(T_{cc})^l\epsilon_{ijk}(T_8)^k_l\overline{D}^n M^i_r M^r_m(H_{\overline{6}})^{jm}_n + c_{29}(T_{cc})^l\epsilon_{ijk}(T_8)^k_l\overline{D}^r M^i_r M^n_m(H_{\overline{6}})^{jm}_n + c_{30}(T_{cc})^l\epsilon_{ijk}(T_8)^k_l\overline{D}^r M^i_m M^n_r(H_{\overline{6}})^{jm}_n \\
& +c_{31}(T_{cc})^n\epsilon_{ijk}(T_8)^k_l\overline{D}^l M^i_r M^r_m(H_{\overline{6}})^{jm}_n + c_{32}(T_{cc})^r\epsilon_{ijk}(T_8)^k_l\overline{D}^l M^i_r M^n_m(H_{\overline{6}})^{jm}_n + c_{33}(T_{cc})^r\epsilon_{ijk}(T_8)^k_l\overline{D}^l M^i_m M^n_r(H_{\overline{6}})^{jm}_n \\
& +c_{34}(T_{cc})^n\epsilon_{ijk}(T_8)^k_l\overline{D}^r M^i_r M^l_m(H_{\overline{6}})^{jm}_n + c_{35}(T_{cc})^n\epsilon_{ijk}(T_8)^k_l\overline{D}^r M^i_m M^l_r(H_{\overline{6}})^{jm}_n + c_{36}(T_{cc})^r\epsilon_{ijk}(T_8)^k_l\overline{D}^n M^i_m M^l_r(H_{\overline{6}})^{jm}_n \\
& +c_{37}(T_{cc})^r\epsilon_{ijk}(T_8)^k_l\overline{D}^n M^i_r M^l_m(H_{\overline{6}})^{jm}_n + c_{38}(T_{cc})^m\epsilon_{ijk}(T_8)^k_l\overline{D}^n M^i_m M^r_n(H_{\overline{6}})^{jl}_r + c_{39}(T_{cc})^m\epsilon_{ijk}(T_8)^k_l\overline{D}^n M^i_n M^r_m(H_{\overline{6}})^{jl}_r \\
& +c_{40}(T_{cc})^m\epsilon_{ijk}(T_8)^k_l\overline{D}^n M^i_r M^r_m(H_{\overline{6}})^{jl}_n + c_{41}(T_{cc})^m\epsilon_{ijk}(T_8)^k_l\overline{D}^n M^i_r M^r_n(H_{\overline{6}})^{jl}_m + c_{42}(T_{cc})^l\epsilon_{ijk}(T_8)^k_l\overline{D}^m M^n_m M^r_n(H_{\overline{6}})^{ij}_r \\
& +c_{43}(T_{cc})^l\epsilon_{ijk}(T_8)^k_l\overline{D}^m M^n_r M^r_n(H_{\overline{6}})^{ij}_m + c_{44}(T_{cc})^m\epsilon_{ijk}(T_8)^k_l\overline{D}^l M^n_m M^r_n(H_{\overline{6}})^{ij}_r + c_{45}(T_{cc})^m\epsilon_{ijk}(T_8)^k_l\overline{D}^l M^r_n M^n_r(H_{\overline{6}})^{ij}_m \\
& +c_{46}(T_{cc})^m\epsilon_{ijk}(T_8)^k_l\overline{D}^n M^l_m M^r_n(H_{\overline{6}})^{ij}_r + c_{47}(T_{cc})^m\epsilon_{ijk}(T_8)^k_l\overline{D}^n M^l_r M^r_m(H_{\overline{6}})^{ij}_n + c_{48}(T_{cc})^m\epsilon_{ijk}(T_8)^k_l\overline{D}^n M^l_n M^r_m(H_{\overline{6}})^{ij}_r \\
& +\Big((H_{\overline{6}}) \to (H_{15}), c \to d\Big). \qquad (10)
\end{aligned}
$$

Feynman diagrams for some channels can be presented



Nonleptonic Decays

By expanding this effective Hamiltonian, several relations for decay widths can be found in the SU(3) symmetry limit:

$$\Gamma(\Xi_{cc}^{++} \to D^0\Lambda^0\pi^+\pi^+) = 4\Gamma(\Xi_{cc}^{++} \to D^+\Lambda^0\pi^+\pi^0) = 4\Gamma(\Xi_{cc}^{+} \to D^0\Lambda^0\pi^+\pi^0)\,,$$
$$\Gamma(\Xi_{cc}^{++} \to D^0\Sigma^0\pi^+\pi^+) = 2\Gamma(\Xi_{cc}^{++} \to D^0\Sigma^+\pi^+\pi^0)\,.$$

$\Xi_{cc}^{++} \to D^+ P K^- \pi^+$ process is not found

Part.3 Triply Heavy Baryons

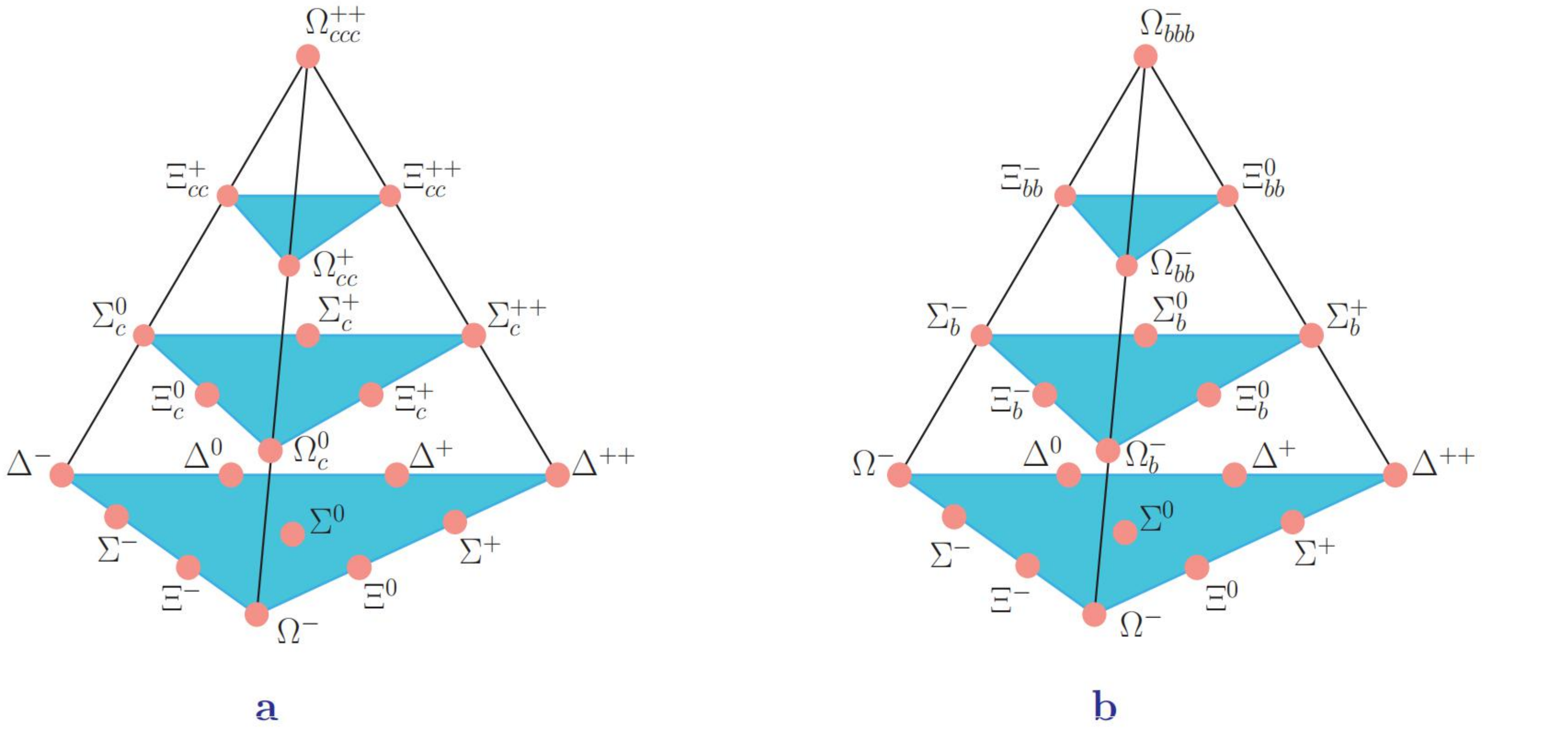
01

Nonleptonic Decays

02

Golden channels

Quark Model



The last missing pieces of the lowest-lying baryon multiplets in quark model!

W. Wang and J. Xu, Phys. Rev. D (2018)

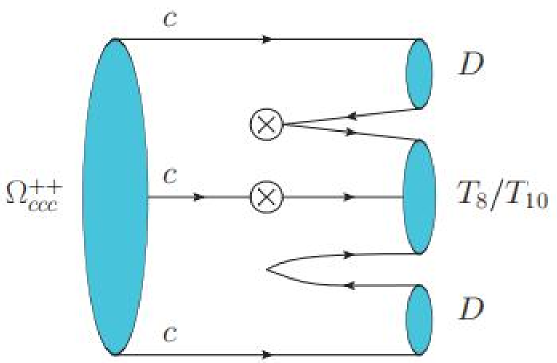
Nonleptonic Decays

- **Ω^{++}_{ccc} decays into two D-mesons and a light baryon**

The corresponding Hamiltonian can be constructed as:

$$\mathcal{H}_{\rm eff} = a_1\Omega^{++}_{ccc}\varepsilon_{ijk}(\overline{T}_8)^k_l\overline{D}^i\overline{D}^m(H_{\overline{6}})^{il}_m + a_2\Omega^{++}_{ccc}\varepsilon_{ijk}(\overline{T}_8)^k_l\overline{D}^l\overline{D}^m(H_{\overline{6}})^{ij}_m$$
$$+a_3\Omega^{++}_{ccc}\varepsilon_{ijk}(\overline{T}_8)^k_l\overline{D}^i\overline{D}^m(H_{15})^{il}_m + a_4\Omega^{++}_{ccc}(\overline{T}_{10})_{ijk}\overline{D}^k\overline{D}^l(H_{15})^{ij}_l\,.$$

Feynman diagrams for some channels can be presented:



A number of relations for decay widths can be readily deduced :

$$\Gamma(\Omega^{++}_{ccc}\to D^0D^+_s\Sigma^+) = \Gamma(\Omega^{++}_{ccc}\to D^+D^0p)\,,$$
$$\Gamma(\Omega^{++}_{ccc}\to D^+D^+n) = \Gamma(\Omega^{++}_{ccc}\to D^+_sD^+_s\Xi^0)\,,$$
$$\Gamma(\Omega^{++}_{ccc}\to D^0D^+\Sigma^+) = \Gamma(\Omega^{++}_{ccc}\to D^+D^+\Sigma^0)\,,$$
$$\Gamma(\Omega^{++}_{ccc}\to D^+D^+_s\Lambda^0) = \frac{1}{3}\Gamma(\Omega^{++}_{ccc}\to D^+_sD^+\Sigma^0)\,,$$
$$\Gamma(\Omega^{++}_{ccc}\to D^0D^+\Sigma'^+) = \Gamma(\Omega^{++}_{ccc}\to D^+_sD^+\Xi'^0) = \Gamma(\Omega^{++}_{ccc}\to D^+D^+\Sigma'^0)\,,$$
$$\Gamma(\Omega^{++}_{ccc}\to D^0D^+_s\Delta^+) = \Gamma(\Omega^{++}_{ccc}\to D^+_sD^+\Delta^0) = \Gamma(\Omega^{++}_{ccc}\to D^+_sD^+_s\Sigma'^0)\,,$$
$$\Gamma(\Omega^{++}_{ccc}\to D^0D^+\Delta^+) = \Gamma(\Omega^{++}_{ccc}\to D^0D^+_s\Sigma'^+)$$
$$= \frac{1}{2}\Gamma(\Omega^{++}_{ccc}\to D^+D^+\Delta^0) = \frac{1}{2}\Gamma(\Omega^{++}_{ccc}\to D^+_sD^+_s\Xi'^0)\,.$$

Nonleptonic Decays

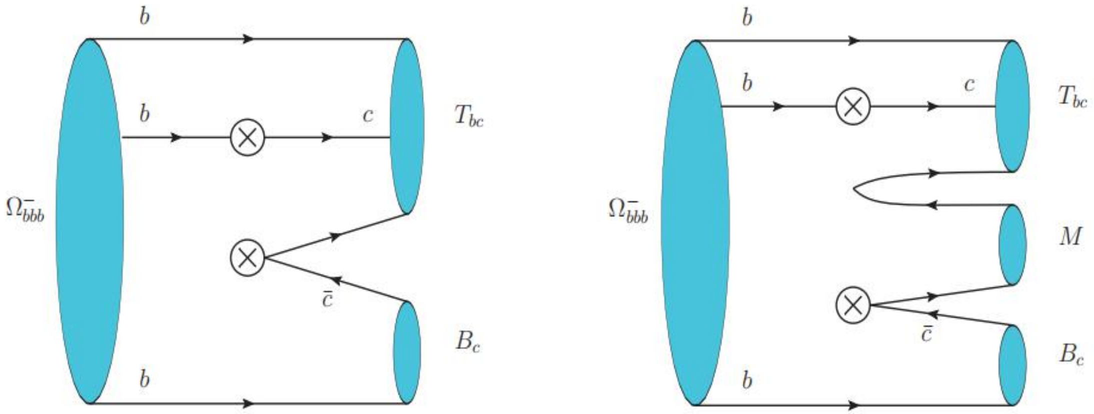
- Ω_{bbb}^{-} **decays into** T_{bc} **and a** B_c **meson plus a light meson**

$b \to c\bar{c}d/s$

The corresponding Hamiltonian can be constructed as:

$$\mathcal{H}_{\rm eff} = b_1 \Omega_{bbb}^{-} (\overline{T}_{bc})_i B_c (H_3)^i + b_2 \Omega_{bbb}^{-} (\overline{T}_{bc})_i B_c M_j^i (H_3)^j \, .$$

Feynman diagrams for some channels can be presented:



A number of relations for decay widths can be readily deduced:

$$\Gamma(\Omega_{bbb}^{-} \to \Xi_{bc}^{0} \pi^{0} B_c) = \frac{1}{2}\Gamma(\Omega_{bbb}^{-} \to \Xi_{bc}^{+} \pi^{-} B_c)$$
$$= \frac{1}{2}\Gamma(\Omega_{bbb}^{-} \to \Omega_{bc}^{0} K^{0} B_c) = 3\Gamma(\Omega_{bbb}^{-} \to \Xi_{bc}^{0} \eta B_c) \, .$$

Nonleptonic Decays

- **Ω_{bbb}^{-} decays into a T_{bc} and a B-meson and a light meson.**

$b \to c\bar{u}d/s$

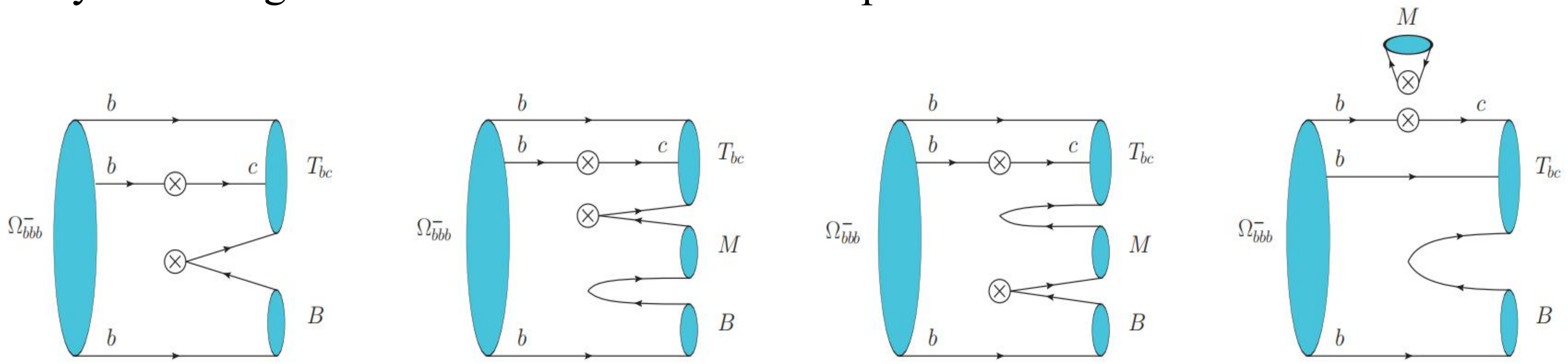
The corresponding Hamiltonian can be constructed as:

$$\mathcal{H}_{\text{eff}} = c_1 \Omega_{bbb}^{-} (\overline{T}_{bc})_i \overline{B}^j (H_8)^i_j + c_2 \Omega_{bbb}^{-} (\overline{T}_{bc})_i \overline{B}^i M^j_k (H_8)^k_j$$
$$+ c_3 \Omega_{bbb}^{-} (\overline{T}_{bc})_i \overline{B}^j M^i_k (H_8)^k_j + c_4 \Omega_{bbb}^{-} (\overline{T}_{bc})_i \overline{B}^j M^k_j (H_8)^i_k .$$

A number of relations for decay widths can be readily deduced:

$$\Gamma(\Omega_{bbb}^{-} \to \Omega_{bc}^{0} B^{-} \pi^{0}) = \frac{1}{2} \Gamma(\Omega_{bbb}^{-} \to \Omega_{bc}^{0} \overline{B}^{0} \pi^{-}) .$$

Feynman diagrams for some channels can be presented:



Nonleptonic Decays

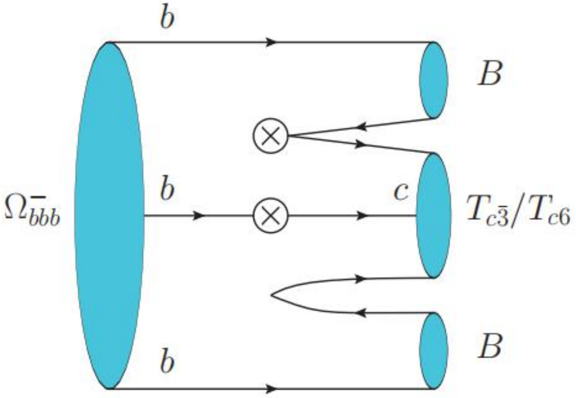
- Ω^-_{bbb} **decays into two B-mesons and a singly charmed baryon (antitriplet or sextet)**

$b \to c\bar{u}d/s$

The corresponding Hamiltonian can be constructed as:

$$\mathcal{H}_{eff} = d_1\Omega^-_{bbb}\overline{B}^i\overline{B}^j(\overline{T}_{c\bar{3}})_{[ik]}(H_8)^k_j + d_2\Omega^-_{bbb}\overline{B}^i\overline{B}^j(\overline{T}_{c6})_{[ik]}(H_8)^k_j$$

Feynman diagrams for some channels can be presented:



A number of relations for decay widths can be readily deduced:

$$\Gamma(\Omega^-_{bbb} \to B^-B^-\Lambda_c^+) = 2\Gamma(\Omega^-_{bbb} \to B^-\overline{B}^0_s\Xi_c^0),$$

$$\Gamma(\Omega^-_{bbb} \to B^-B^-\Xi_c^+) = 2\Gamma(\Omega^-_{bbb} \to B^-\overline{B}^0\Xi_c^0),$$

$$\Gamma(\Omega^-_{bbb} \to B^-B^-\Sigma_c^+) = 2\Gamma(\Omega^-_{bbb} \to \overline{B}^0_sB^-\Xi_c^{\prime 0}) = \Gamma(\Omega^-_{bbb} \to B^-\overline{B}^0\Sigma_c^0),$$

$$\Gamma(\Omega^-_{bbb} \to B^-B^-\Xi_c^{\prime +}) = 2\Gamma(\Omega^-_{bbb} \to B^-\overline{B}^0\Xi_c^{\prime 0}) = \Gamma(\Omega^-_{bbb} \to B^-\overline{B}^0_s\Omega_c^0).$$

Nonleptonic Decays

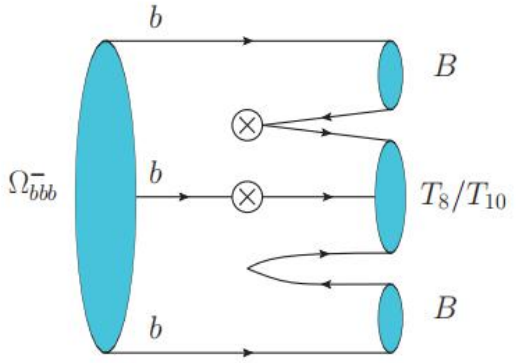
- Ω_{bbb}^{-} **decays into two B-mesons and a light baryon**

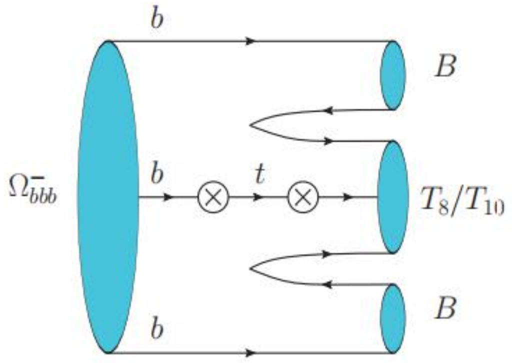
$b \to q\bar{q}q$

The effective Hamiltonian is given as:

$$\begin{aligned}\mathcal{H}_{eff} = \; & f_1 \Omega_{bbb}^{-} \overline{B}^i \overline{B}^j \varepsilon_{ijk} (\overline{T}_8)^k_l (H_3)^l + f_2 \Omega_{bbb}^{-} \overline{B}^i \overline{B}^l \varepsilon_{ijk} (\overline{T}_8)^k_l (H_3)^j \\ & + f_3 \Omega_{bbb}^{-} \overline{B}^i \overline{B}^m \varepsilon_{ijk} (\overline{T}_8)^k_l (H_{\overline{6}})^{jl}_m + f_4 \Omega_{bbb}^{-} \overline{B}^m \overline{B}^l \varepsilon_{ijk} (\overline{T}_8)^k_l (H_{\overline{6}})^{ij}_m \\ & + f_5 \Omega_{bbb}^{-} \overline{B}^i \overline{B}^m \varepsilon_{ijk} (\overline{T}_8)^k_l (H_{15})^{jl}_m \,.\end{aligned}$$

Feynman diagrams for Ω_{bbb}^{-} decays into two B-mesons and a light baryon (octet or decuplet):





Two relations for decay widths can be read off

$$\Gamma(\Omega_{bbb}^{-} \to \overline{B}^0 \overline{B}^0_s \Sigma^-) = \frac{1}{2}\Gamma(\Omega_{bbb}^{-} \to \overline{B}^0_s \overline{B}^0_s \Xi^-)\,,$$

$$\Gamma(\Omega_{bbb}^{-} \to \overline{B}^0 \overline{B}^0 \Sigma^-) = 2\Gamma(\Omega_{bbb}^{-} \to \overline{B}^0 \overline{B}^0_s \Xi^-)\,.$$

Golden Channels

TABLE IX: Cabibbo-allowed decay channels for Ω_{ccc}^{++} and CKM-allowed decay channels for Ω_{bbb}^{-}

Channel	Channel	Channel	Channel
$\Omega_{ccc}^{++} \to D^0 D^+ \Sigma^+$	$\Omega_{ccc}^{++} \to D^+ D^+ \Lambda^0$	$\Omega_{ccc}^{++} \to D^+ D^+ \Sigma^0$	$\Omega_{ccc}^{++} \to D^+ D_s^+ \Xi^0$
$\Omega_{ccc}^{++} \to D^0 D^+ \Sigma'^+$	$\Omega_{ccc}^{++} \to D^+ D^+ \Sigma'^0$	$\Omega_{ccc}^{++} \to D_s^+ D^+ \Xi'^0$	
$\Omega_{bbb}^{-} \to \Xi_{bc}^0 B_c$	$\Omega_{bbb}^{-} \to \Xi_{bc}^0 B^-$		
$\Omega_{bbb}^{-} \to \Omega_{bc}^0 K^0 B_c$	$\Omega_{bbb}^{-} \to \Xi_{bc}^+ \pi^- B_c$	$\Omega_{bbb}^{-} \to \Xi_{bc}^0 \pi^0 B_c$	$\Omega_{bbb}^{-} \to \Xi_{bc}^0 \eta B_c$
$\Omega_{bbb}^{-} \to \Omega_{bc}^0 \overline{B}_s^0 \pi^-$	$\Omega_{bbb}^{-} \to \Xi_{bc}^+ B^- \pi^-$	$\Omega_{bbb}^{-} \to \Xi_{bc}^0 B^- \pi^0$	$\Omega_{bbb}^{-} \to \Xi_{bc}^0 B^- \eta$
$\Omega_{bbb}^{-} \to \Xi_{bc}^0 \overline{B}^0 \pi^-$	$\Omega_{bbb}^{-} \to \Xi_{bc}^0 \overline{B}_s^0 K^-$	$\Omega_{bbb}^{-} \to \Omega_{bc}^0 B^- K^0$	$\Omega_{bbb}^{-} \to B^- B^- \Lambda_c^+$
$\Omega_{bbb}^{-} \to B^- \overline{B}_s^0 \Xi_c^0$	$\Omega_{bbb}^{-} \to B^- B^- \Sigma_c^+$	$\Omega_{bbb}^{-} \to B^- \overline{B}^0 \Sigma_c^0$	$\Omega_{bbb}^{-} \to B^- \overline{B}_s^0 \Xi_c'^0$

- **For the Ω_{ccc}^{++} decay, the branching fractions for the Cabibbo-allowed processes might reach a few percent, thus presumably lead to discovery of triply charmed baryon.**
- **For the Ω_{bbb}^{-} decay, the CKM-allowed largest branching fraction might reach 10^{-3}, which would be even much smaller when considering detecting charmless final states in experiment.**

Part.4 Summary

- The background is the discovery of Ξ_{cc}^{++} by LHCb group
- We use SU(3) light flavor symmetry analysis to provide reference for searching doubly baryon or even triply baryon decay channels
- Investigate the relationship between decay widths
- Find the golden decay channels

[感谢观看]

Zhengzhou University

THANKS