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北京航空航天大学
BEIHANG UNIVERSITY

P-wave charmed baryons of the SU(3) flavor 6_F

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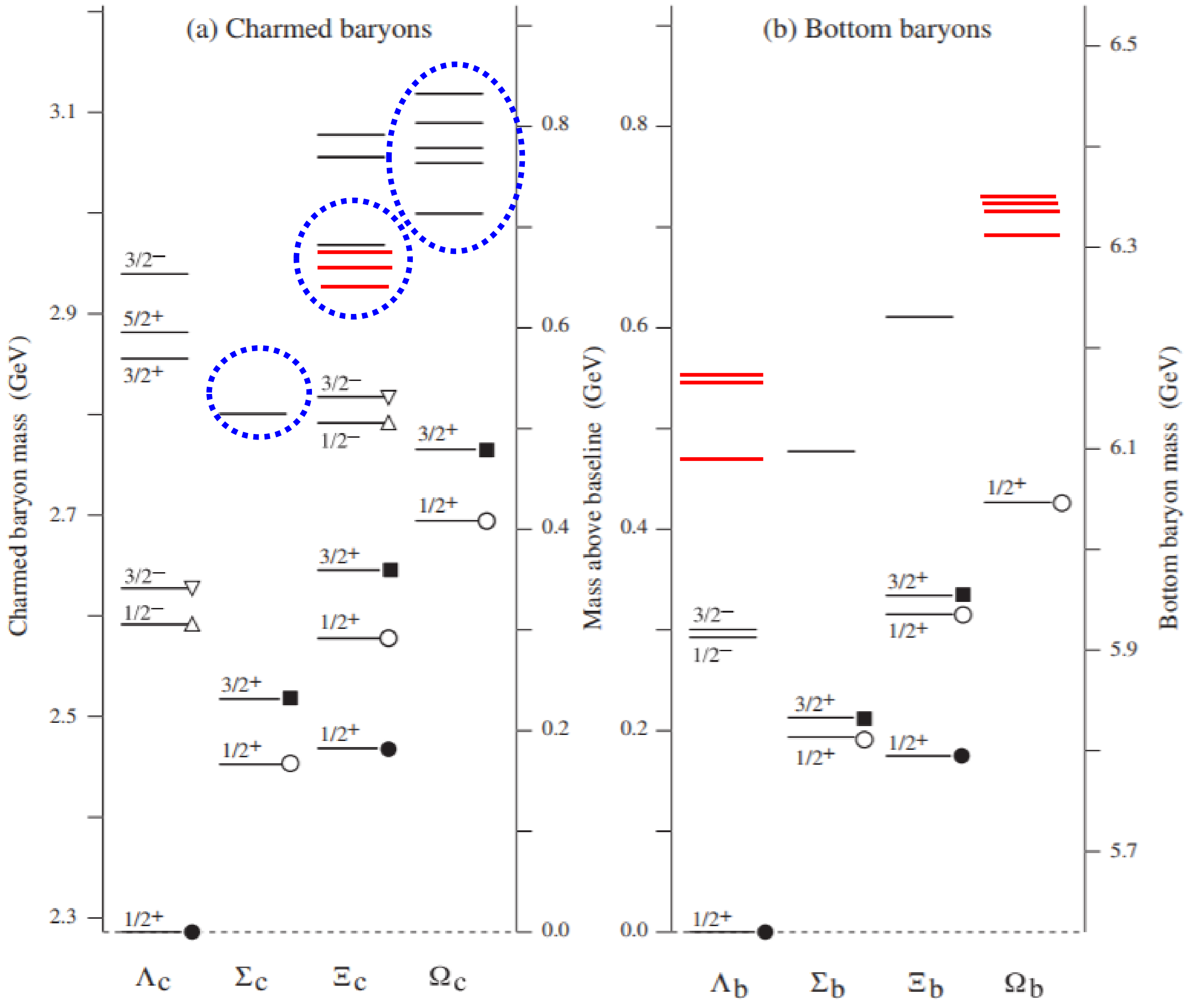
The heavy baryon spectra(PDG)2020

- (a)The spectra of singly-charmed baryons, (b)The spectra of singly-bottom baryons



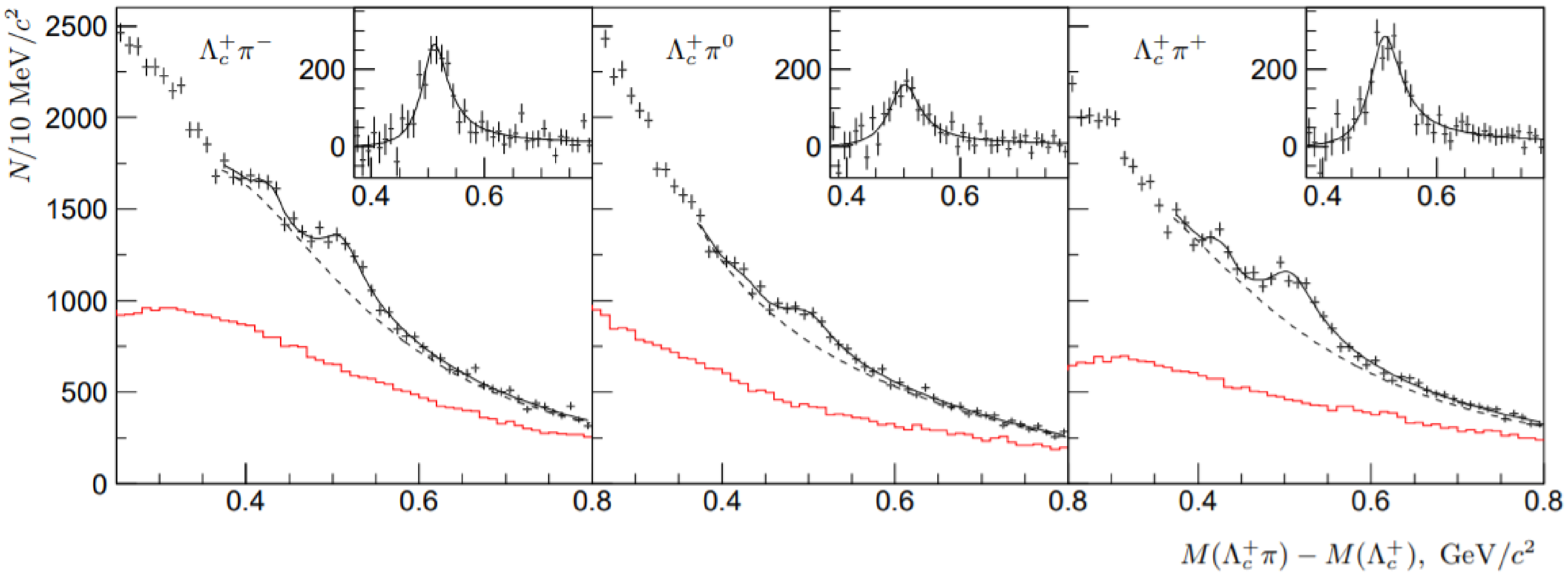
PDG.2020

Belle Experiment for Σ_c

Belle collaboration, Phys. Rev. Lett. 94, 122002 (2005)

- **The three Σ_c baryons were discovered from the $\Lambda_c^+\pi^-$/ $\Lambda_c^+\pi^0$/ $\Lambda_c^+\pi^+$ mass spectrum at the KEKB asymmetric energy $e^+ e^-$ collider.**

State	△M, MeV/c^2	Width(MeV)	yield/10^3
$\Sigma_c(2800)^0$	$515.4^{+3.2+2.1}_{-3.1-6.0}$	61^{+18+22}_{-13-13}	$2.24^{+0.79+1.03}_{-0.55-0.50}$
$\Sigma_c(2800)^+$	$505.4^{+5.8+12.4}_{-4.6-2.0}$	62^{+37+52}_{-23-38}	$1.54^{+1.05+1.40}_{-0.57-0.88}$
$\Sigma_c(2800)^{++}$	$514.5^{+3.4+2.8}_{-3.1-4.9}$	75^{+18+12}_{-13-11}	$2.81^{+0.82+0.71}_{-0.60-0.49}$

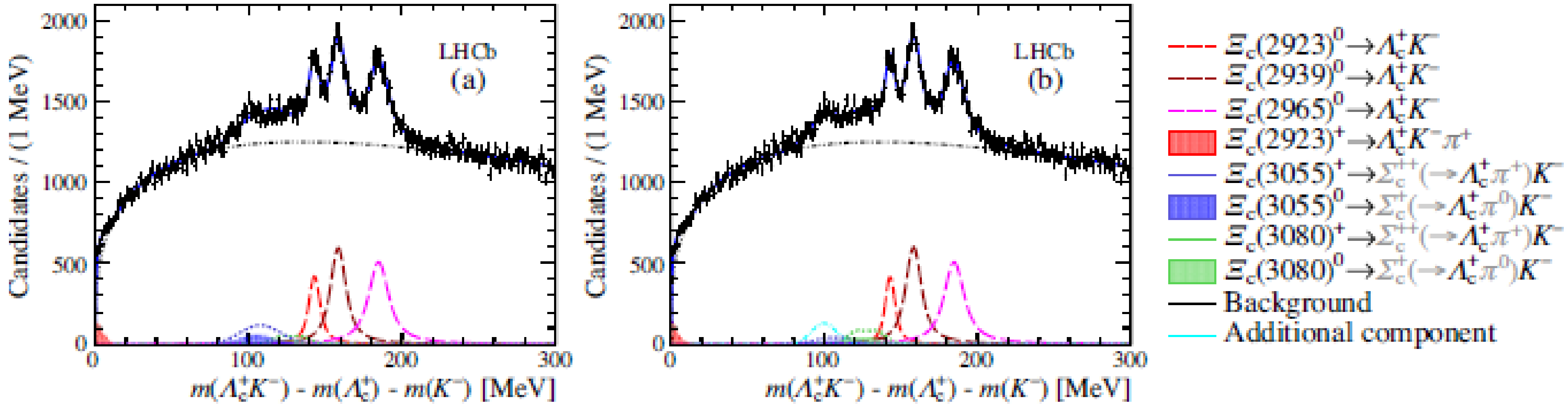


LHCb Experiment for Ξ_c

LHCb collaboration, Phys. Rev. Lett. 124, 222001 (2020)

- **The three Ξ_c baryons were discovered from the $\Lambda_c^+ K^-$ mass spectrum studied with a data sample of pp collisions .**

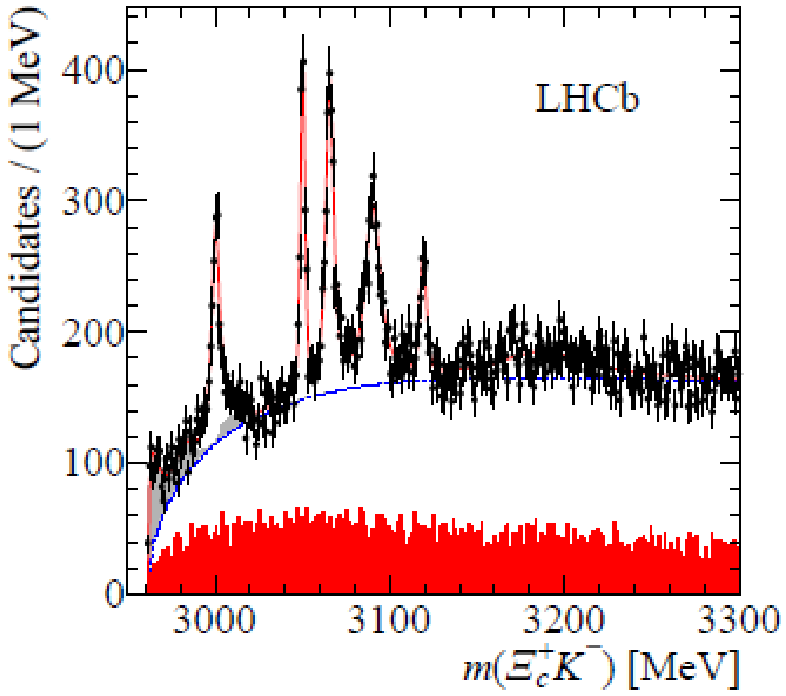
State	Mass(MeV)	Width(MeV)	Signal yields
$\Xi_c(2923)^0$	2923.04±0.25±0.20±0.14	7.1±0.8±1.8	5400±400
$\Xi_c(2939)^0$	2938.55±0.21±0.17±0.14	10.2±0.8±1.1	10400±600
$\Xi_c(2965)^0$	2964.88±0.26 ±0.14±0.14	14.1±0.9±1.3	11700±600



LHCb Experiment for Ω_c

LHCb collaboration, Phys. Rev. Lett. 118, 182001 (2017)
Belle collaboration, Phys. Rev. D. 97, 051102 (2018)

- **The five Ω_c baryons were observed by LHCb from $\Xi_c^+ K^-$ mass spectrum with a sample of pp collision.**
- **Belle confirmed the first four states**

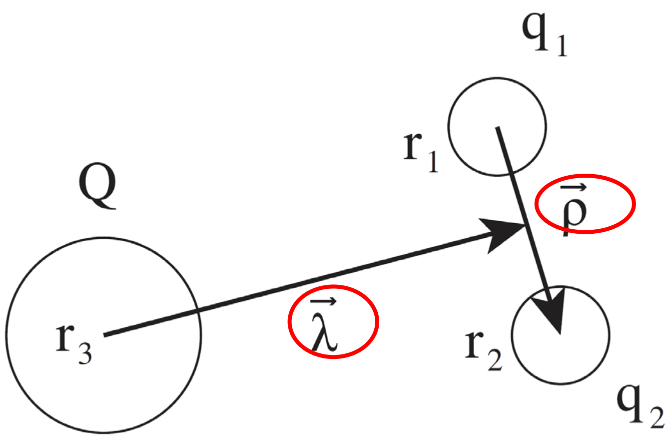


Resonance	Mass (MeV)	Γ (MeV)	Yield	N_σ
$\Omega_c(3000)^0$	$3000.4 \pm 0.2 \pm 0.1^{+0.3}_{-0.5}$	$4.5 \pm 0.6 \pm 0.3$	$1300 \pm 100 \pm 80$	20.4
$\Omega_c(3050)^0$	$3050.2 \pm 0.1 \pm 0.1^{+0.3}_{-0.5}$	$0.8 \pm 0.2 \pm 0.1$	$970 \pm 60 \pm 20$	20.4
		< 1.2 MeV, 95% CL		
$\Omega_c(3066)^0$	$3065.6 \pm 0.1 \pm 0.3^{+0.3}_{-0.5}$	$3.5 \pm 0.4 \pm 0.2$	$1740 \pm 100 \pm 50$	23.9
$\Omega_c(3090)^0$	$3090.2 \pm 0.3 \pm 0.5^{+0.3}_{-0.5}$	$8.7 \pm 1.0 \pm 0.8$	$2000 \pm 140 \pm 130$	21.1
$\Omega_c(3119)^0$	$3119.1 \pm 0.3 \pm 0.9^{+0.3}_{-0.5}$	$1.1 \pm 0.8 \pm 0.4$	$480 \pm 70 \pm 30$	10.4
		< 2.6 MeV, 95% CL		
$\Omega_c(3188)^0$	$3188 \pm 5 \pm 13$	$60 \pm 15 \pm 11$	$1670 \pm 450 \pm 360$	
$\Omega_c(3066)^0_{fd}$			$700 \pm 40 \pm 140$	
$\Omega_c(3090)^0_{fd}$			$220 \pm 60 \pm 90$	
$\Omega_c(3119)^0_{fd}$			$190 \pm 70 \pm 20$	

Internal structure of heavy baryons

- Based on **the heavy quark effective theory**, the leading order Lagrangian does not depend on m_Q. The internal structure of heavy baryons(Q-q_1–q_2) is :

$$
\begin{aligned}
\boldsymbol{J} &= s_Q + s_{q1} + s_{q2} + l_\rho + l_\lambda \\
&= s_Q + \left(s_{q1} + s_{q2} + l_\rho + l_\lambda\right)_{j_l}
\end{aligned}
$$



λ-excitation and ρ-excitation

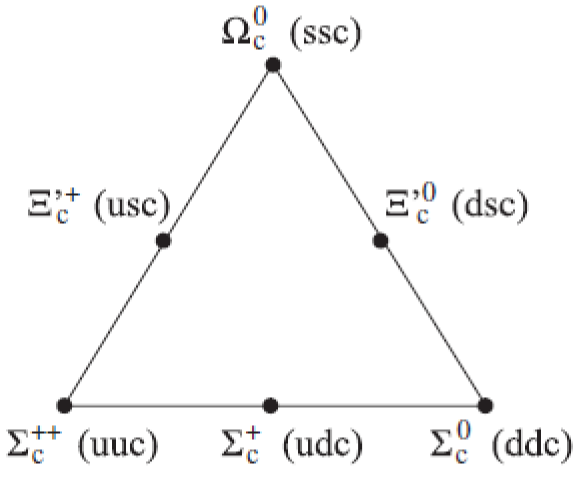
Categorization of p-wave charmed baryons

Thus the state function can be written as :

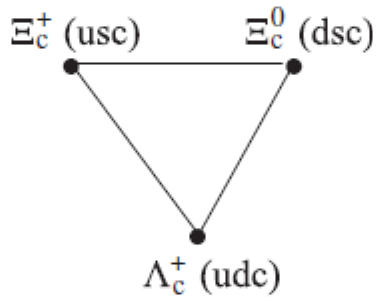
$$|\,qqq\,\rangle_A = |\,\mathrm{color}\,\rangle_A \times |\,\mathrm{space,\ spin,\ flavor}\,\rangle_S$$

The Pauli principle can be directly applied to **the two light quarks**:

- **color⟶$\bar{3}_C$ antisymmetric**
- **orbital⟶l_ρ $\begin{cases}\text{symmetric}\\ \text{antisymmetric}\end{cases}$**
- **spin⟶$s_{qq} = \begin{cases}1\ \text{symmetric}\\ 0\ \text{antisymmetric}\end{cases}$**
- **SU(3) flavor⟶$\begin{cases}6_F\ \text{symmetric}\\ \bar{3}_F\ \text{antisymmetric}\end{cases}$**



6_F



$\bar{3}_F$

Categorization of p-wave charmed baryons

We define notation of the baryons multiplet : [F,j_l,s_l,ρ/λ]

P-wave baryons : $l_\rho + l_\lambda = 1$

- color$\longrightarrow \bar{3}_C$ antisymmetric
- orbital$\longrightarrow l_\rho \begin{cases} 0 \text{ symmetric} \\ 1 \text{ antisymmetric} \end{cases}$
- spin$\longrightarrow s_{qq} = \begin{cases} 1 \text{ symmetric} \\ 0 \text{ antisymmetric} \end{cases}$
- SU(3) flavor$\longrightarrow \begin{cases} 6_F \text{ symmetric} \\ \bar{3}_F \text{ antisymmetric} \end{cases}$

Categorization of p-wave charmed baryons

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P-wave baryons : $l_\rho+l_\lambda=1$

- color⟶$\bar{3}_C$ antisymmetric
- orbital⟶l_ρ {0 symmetric; 1 antisymmetric}
- spin⟶s_{qq} = {1 symmetric; 0 antisymmetric}
- SU(3) flavor⟶{6_F symmetric; $\bar{3}_F$ antisymmetric}

$l_\rho=0$, $l_\lambda=1$:

- $s_{qq}=0,\bar{3}_F$ ⟶ $j_l=1$: $\Lambda_{c1}(\frac{1}{2}^-,\frac{3}{2}^-)\Xi_{c1}(\frac{1}{2}^-,\frac{3}{2}^-)$[$\bar{3}_F$,1,0,λ]
- $s_{qq}=1$, 6_F ⟶
  - $j_l=0$: $\Sigma_{c0}(\frac{1}{2}^-)\Xi'_{c0}(\frac{1}{2}^-)\Omega_{c0}(\frac{1}{2}^-)$ [6_F,0,1,λ]
  - $j_l=1$: $\Sigma_{c1}(\frac{1}{2}^-,\frac{3}{2}^-)\Xi'_{c1}(\frac{1}{2}^-,\frac{3}{2}^-)\Omega_{c1}(\frac{1}{2}^-,\frac{3}{2}^-)$[$6_F$,1,1,λ]
  - $j_l=2$: $\Sigma_{c2}(\frac{3}{2}^-,\frac{5}{2}^-)\Xi'_{c2}(\frac{3}{2}^-,\frac{5}{2}^-)\Omega_{c2}(\frac{3}{2}^-,\frac{5}{2}^-)$[$6_F$,2,1,λ]

$l_\rho=1$, $l_\lambda=0$:

- $s_{qq}=0,6_F$ ⟶ $j_l=1$: $\Sigma_{c1}(\frac{1}{2}^-,\frac{3}{2}^-)\Xi'_{c1}(\frac{1}{2}^-,\frac{3}{2}^-)$ $\Omega_{c1}(\frac{1}{2}^-,\frac{3}{2}^-)$[$6_F$,1,0,ρ]
- $s_{qq}=1$, $\bar{3}_F$ ⟶
  - $j_l=0$: $\Lambda_{c0}(\frac{1}{2}^-)\Xi_{c0}(\frac{1}{2}^-)$ [$\bar{3}_F$,0,1,ρ]
  - $j_l=1$: $\Lambda_{c1}(\frac{1}{2}^-,\frac{3}{2}^-)\Xi_{c1}(\frac{1}{2}^-,\frac{3}{2}^-)$[$\bar{3}_F$,1,1,ρ]
  - $j_l=2$: $\Lambda_{c2}(\frac{3}{2}^-,\frac{5}{2}^-)\Xi_{c2}(\frac{3}{2}^-,\frac{5}{2}^-)$[$\bar{3}_F$,2,1,ρ]

Categorization of p-wave charmed baryons

Multiplet	Baryon(J^P)
$[6_F, 0,1, \lambda]$	$\Xi_c^{\prime 0}\left(\frac{1}{2}^-\right), \Sigma_c^0\left(\frac{1}{2}^-\right), \Omega_c^0\left(\frac{1}{2}^-\right)$
$[6_F, 1,0, \rho]$	$\Xi_c^{\prime 0}\left(\frac{1}{2}^-\right), \Sigma_c^0\left(\frac{1}{2}^-\right), \Omega_c^0\left(\frac{1}{2}^-\right)$ $\Xi_c^{\prime 0}\left(\frac{3}{2}^-\right), \Sigma_c^0\left(\frac{3}{2}^-\right), \Omega_c^0\left(\frac{3}{2}^-\right)$
$[6_F, 1,1, \lambda]$	$\Xi_c^{\prime 0}\left(\frac{1}{2}^-\right), \Sigma_c^0\left(\frac{1}{2}^-\right), \Omega_c^0\left(\frac{1}{2}^-\right)$ $\Xi_c^{\prime 0}\left(\frac{3}{2}^-\right), \Sigma_c^0\left(\frac{3}{2}^-\right), \Omega_c^0\left(\frac{3}{2}^-\right)$
$[6_F, 2,1, \lambda]$	$\Xi_c^{\prime 0}\left(\frac{3}{2}^-\right), \Sigma_c^0\left(\frac{3}{2}^-\right), \Omega_c^0\left(\frac{3}{2}^-\right)$ $\Xi_c^{\prime 0}\left(\frac{5}{2}^-\right), \Sigma_c^0\left(\frac{5}{2}^-\right), \Omega_c^0\left(\frac{5}{2}^-\right)$

→

Mass	Difference	Decay width
$\Xi_c^{\prime 0}/\Sigma_c^0/\Omega_c^0\left(\frac{1}{2}^-\right)$: M1(QCDSR),	0	Γ1(LCSR)
$\Xi_c^{\prime 0}/\Sigma_c^0/\Omega_c^0\left(\frac{1}{2}^-\right)$: M1(QCDSR), $\Xi_c^{\prime 0}/\Sigma_c^0/\Omega_c^0\left(\frac{3}{2}^-\right)$: M2(QCDSR),	△M	Γ1(LCSR) Γ2(LCSR)
$\Xi_c^{\prime 0}/\Sigma_c^0/\Omega_c^0\left(\frac{1}{2}^-\right)$: M1(QCDSR), $\Xi_c^{\prime 0}/\Sigma_c^0/\Omega_c^0\left(\frac{3}{2}^-\right)$: M2(QCDSR),	△M	Γ1(LCSR) Γ2(LCSR)
$\Xi_c^{\prime 0}/\Sigma_c^0/\Omega_c^0\left(\frac{3}{2}^-\right)$: M1(QCDSR), $\Xi_c^{\prime 0}/\Sigma_c^0/\Omega_c^0\left(\frac{5}{2}^-\right)$: M2(QCDSR),	△M	Γ1(LCSR) Γ2(LCSR)

Mass spectra of p-wave charmed baryons

Multiplet	B	ω_c (GeV)	Working region (GeV)	$\overline{\Lambda}$ (GeV)	Baryon (j^P)	Mass (GeV)	Difference (MeV)	Decay constant (GeV^4)
$[\mathbf{6}_F, 1, 0, \rho]$	Σ_c	1.74	$0.27 < T < 0.32$	1.25 ± 0.11	$\Sigma_c(1/2^-)$	2.77 ± 0.14	15 ± 6	0.067 ± 0.017 ($\Sigma_c^-(1/2^-)$)
					$\Sigma_c(3/2^-)$	2.79 ± 0.14		0.031 ± 0.008 ($\Sigma_c^-(3/2^-)$)
	Ξ_c'	1.87	$0.26 < T < 0.34$	1.36 ± 0.10	$\Xi_c'(1/2^-)$	2.88 ± 0.14	13 ± 5	0.059 ± 0.014 ($\Xi_c'^-(1/2^-)$)
					$\Xi_c'(3/2^-)$	2.89 ± 0.14		0.028 ± 0.007 ($\Xi_c'^-(3/2^-)$)
	Ω_c	2.00	$0.26 < T < 0.35$	1.48 ± 0.09	$\Omega_c(1/2^-)$	2.99 ± 0.15	12 ± 5	0.105 ± 0.023 ($\Omega_c^-(1/2^-)$)
					$\Omega_c(3/2^-)$	3.00 ± 0.15		0.049 ± 0.011 ($\Omega_c^-(3/2^-)$)
$[\mathbf{6}_F, 0, 1, \lambda]$	Σ_c	1.35	$T = 0.27$	1.10 ± 0.04	$\Sigma_c(1/2^-)$	2.83 ± 0.05	–	0.045 ± 0.008 ($\Sigma_c^-(1/2^-)$)
	Ξ_c'	1.57	$0.27 < T < 0.29$	1.22 ± 0.08	$\Xi_c'(1/2^-)$	2.90 ± 0.13	–	0.041 ± 0.009 ($\Xi_c'^-(1/2^-)$)
	Ω_c	1.78	$0.27 < T < 0.31$	1.37 ± 0.09	$\Omega_c(1/2^-)$	3.03 ± 0.18	–	0.081 ± 0.020 ($\Omega_c^-(1/2^-)$)
$[\mathbf{6}_F, 1, 1, \lambda]$	Σ_c	1.72	$T = 0.33$	1.03 ± 0.12	$\Sigma_c(1/2^-)$	2.73 ± 0.17	41 ± 16	0.045 ± 0.011 ($\Sigma_c^-(1/2^-)$)
					$\Sigma_c(3/2^-)$	2.77 ± 0.17		0.021 ± 0.005 ($\Sigma_c^-(3/2^-)$)
	Ξ_c'	1.72	$T = 0.34$	1.14 ± 0.09	$\Xi_c'(1/2^-)$	2.91 ± 0.12	38 ± 14	0.041 ± 0.008 ($\Xi_c'^-(1/2^-)$)
					$\Xi_c'(3/2^-)$	2.95 ± 0.12		0.019 ± 0.004 ($\Xi_c'^-(3/2^-)$)
	Ω_c	1.72	$T = 0.35$	1.22 ± 0.07	$\Omega_c(1/2^-)$	3.04 ± 0.10	36 ± 13	0.069 ± 0.011 ($\Omega_c^-(1/2^-)$)
					$\Omega_c(3/2^-)$	3.07 ± 0.09		0.032 ± 0.005 ($\Omega_c^-(3/2^-)$)
$[\mathbf{6}_F, 2, 1, \lambda]$	Σ_c	1.58	$0.27 < T < 0.30$	1.14 ± 0.12	$\Sigma_c(3/2^-)$	2.86 ± 0.19	75 ± 31	0.064 ± 0.018 ($\Sigma_c^-(3/2^-)$)
					$\Sigma_c(5/2^-)$	2.94 ± 0.18		0.038 ± 0.011 ($\Sigma_c^-(5/2^-)$)
	Ξ_c'	1.72	$0.27 < T < 0.32$	1.24 ± 0.12	$\Xi_c'(3/2^-)$	2.96 ± 0.20	66 ± 27	0.057 ± 0.016 ($\Xi_c'^-(3/2^-)$)
					$\Xi_c'(5/2^-)$	3.02 ± 0.18		0.034 ± 0.009 ($\Xi_c'^-(5/2^-)$)
	Ω_c	1.85	$0.26 < T < 0.33$	1.35 ± 0.11	$\Omega_c(3/2^-)$	3.08 ± 0.16	59 ± 24	0.103 ± 0.026 ($\Omega_c^-(3/2^-)$)
					$\Omega_c(5/2^-)$	3.14 ± 0.15		0.062 ± 0.016 ($\Omega_c^-(5/2^-)$)

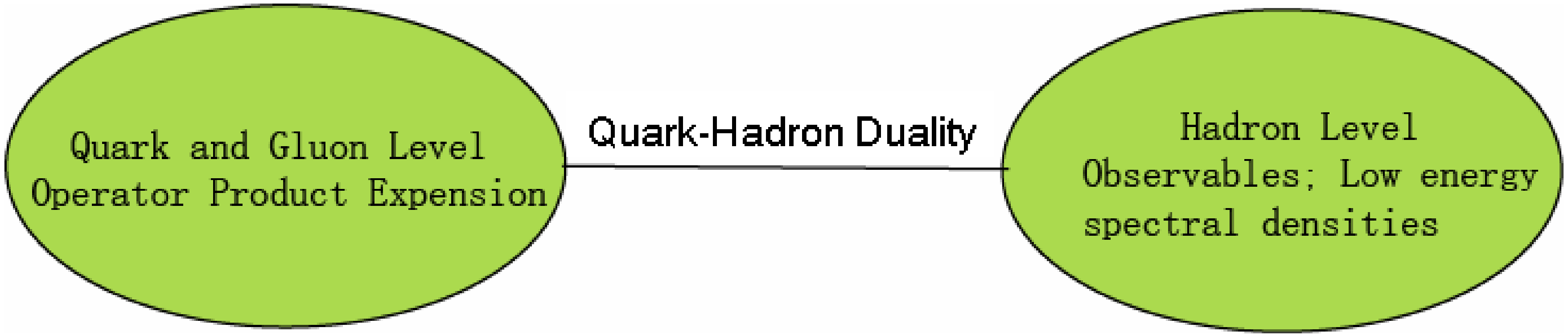
Light-cone sum rules

- In sum rule analyses, we consider three-point correlation functions:

$$\Pi_\alpha(q^2) = i\int d^4x e^{ipx}\langle 0|T\eta(x)\bar{\eta}(0)|\rho\backslash K^*\rangle$$

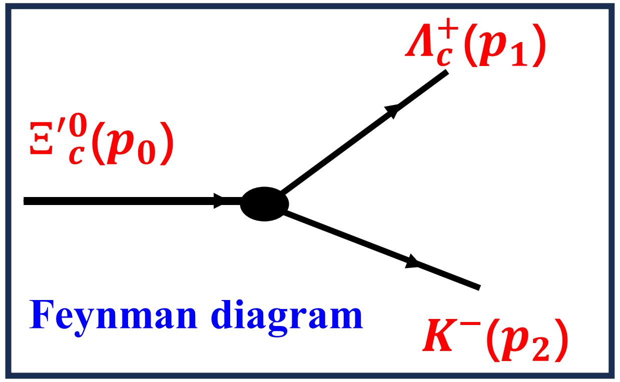
where η is the current which can couple to hadronic states.

- In sum rule, we can calculate these matrix elements from QCD (OPE) and relate them to observables by using dispersion relation.



Light-cone sum rules studies on the charmed baryons

- For example, we consider the state of $[\Xi_c'(\frac{3}{2}^-), 6_F, 2, 1, \lambda]$ D-wave decaying into $\Lambda_c K$ using the method of the light-cone sum rules. First, the three-point correlation function can be written as:



$$\Pi^\alpha(\omega,\omega') = \int d^4x\, e^{-ik\cdot x}\, \langle 0| J^\alpha_{3/2,-,\Xi_c^0,2,1,\lambda}(0) \bar{J}_{\Lambda_c^+}(x) |K^-(q)\rangle = \frac{1+\not{v}}{2} G^\alpha_{\Xi_c^0[\frac{3}{2}^-]\to\Lambda_c^+K^-}(\omega,\omega') \,. \quad (1)$$

- At the hadronic level, we can rewrite the correlation function by using double dispersion relation:

$$G^D_{\Xi_c'^0[\frac{3}{2}^-]\to\Lambda_c^+K^-}(\omega,\omega') = \frac{g_{\Xi_c'^0[\frac{3}{2}^-]\to\Lambda_c^+K^-} f_{\Xi_c'^0[\frac{3}{2}^-]} f_{\Lambda_c^+}}{(\bar{\Lambda}_{\Xi_c'^0[\frac{3}{2}^-]} - \omega')(\bar{\Lambda}_{\Lambda_c^+} - \omega)} \quad (2)$$

Light-cone sum rules studies on the charmed baryons

- **At the quark-gluon level, we can calculate the correlation function in terms of distribution amplitudes :**

$$
\begin{aligned}
&G^{D}_{\Xi_c^{\prime 0}[\frac{3}{2}^-]\to\Lambda_c^+K^-}(\omega,\omega') = \frac{g_{\Xi_c^{\prime 0}[\frac{3}{2}^-]\to\Lambda_c^+K^-} f_{\Xi_c^{\prime 0}[\frac{3}{2}^-]} f_{\Lambda_c^+}}{(\bar{\Lambda}_{\Xi_c^{\prime 0}[\frac{3}{2}^-]}-\omega')(\bar{\Lambda}_{\Lambda_c^+}-\omega)} \\
&= \int_0^\infty dt \int_0^1 du e^{i(1-u)\omega' t} e^{iu\omega t} \times 4 \times \Big(\frac{f_K m_K^2 u}{12(m_u+m_s)\pi^2 t^2}\phi^\sigma_{3;K}(u) + \frac{f_K u}{12}\langle\bar{q}q\rangle\phi_{2;K}(u) \\
&+ \frac{f_K u t^2}{192}\langle\bar{q}q\rangle\phi_{4;K}(u) + \frac{f_K u t^2}{192}\langle g_s\bar{q}\sigma Gq\rangle\phi_{2;K}(u) + \frac{f_K u t^4}{3072}\langle g_s\bar{q}\sigma Gq\rangle\phi_{4;K}(u)\Big) \\
&- \int_0^\infty dt \int_0^1 du \int \mathcal{D}\underline{\alpha} e^{i\omega' t(\alpha_2+u\alpha_3)} e^{i\omega t(1-\alpha_2-u\alpha_3)} \times \frac{1}{2} \times \Big(\frac{f_{3K} u}{2\pi t^2}\Phi_{3;K}(\underline{\alpha}) - \frac{f_{3K}}{2\pi^2 t^2}\Phi_{3;K}(\underline{\alpha}) \\
&+ \frac{i f_{3K} u^2 \alpha_3 v\cdot q}{2\pi^2 t}\Phi_{3;K}(\underline{\alpha}) + \frac{i f_{3K} u \alpha_2 v\cdot q}{2\pi^2 t}\Phi_{3;K}(\underline{\alpha}) - \frac{i f_{3K} u v\cdot q}{2\pi^2 t}\Phi_{3;K}(\underline{\alpha})\Big)\,, \qquad (3)
\end{aligned}
$$

Light-cone sum rules studies on the charmed baryons

- After Wick rotations and double Borel transformation we obtain

$$
\begin{aligned}
& g^D_{\Xi_c^0[\frac{3}{2}^-]\to\Lambda_c^+K^-} f_{\Xi_c^0[\frac{3}{2}^-]} f_{\Lambda_c^+} e^{-\frac{\bar\Lambda_{\Xi_c^0[\frac{3}{2}^-]}}{T_1}} e^{-\frac{\bar\Lambda_{\Lambda_c^+}}{T_2}} \\
= \; & 4\times\Big(-\frac{if_K m_s u_0}{4\pi^2}T^3 f_2(\frac{\omega_c}{T})\phi_{2;K} - \frac{if_K m_K^2 u_0}{12(m_u+m_s)\pi^2}T^3 f_2(\frac{\omega_c}{T})\phi^\sigma_{3;K} + \frac{if_K m_s u_0}{64\pi^2}T f_0(\frac{\omega_c}{T})\phi_{4;K} \\
& + \frac{if_K u_0}{12}\langle\bar q q\rangle T f_0(\frac{\omega_c}{T})\phi_{2;K} - \frac{if_K m_s m_K^2 u_0}{288(m_u+m_s)}\langle\bar q q\rangle\frac{1}{T}\phi^\sigma_{3;K} - \frac{if_K u_0}{192}\langle\bar q q\rangle\frac{1}{T}\phi_{4;K} \\
& - \frac{if_K u_0}{192}\langle g_s\bar q\sigma G q\rangle\frac{1}{T}\phi_{2;K} + \frac{if_K u_0}{3072}\langle g_s\bar q\sigma G q\rangle\frac{1}{T^3}\phi_{4;K}\Big) \\
- \; & \frac{1}{2}\times\Big(-\frac{if_{3K}}{2\pi^2}T^3 f_2(\frac{\omega_c}{T})\int_0^{\frac{1}{2}} d\alpha_2\int_{\frac{1}{2}-\alpha_2}^{1-\alpha_2} d\alpha_3(\frac{u_0}{\alpha_3}\Phi_{3;K}(\underline{\alpha}) - \frac{1}{\alpha_3}\Phi_{3;K}(\underline{\alpha})) \\
& + \frac{if_{3K}}{2\pi^2}T^3 f_2(\frac{\omega_c}{T})\int_0^{\frac{1}{2}}\int_{\frac{1}{2}-\alpha_2}^{1-\alpha_2}\frac{1}{\alpha_3}\frac{\partial}{\partial\alpha_3}(u_0\alpha_3\Phi_{3;K}(\underline{\alpha}) + \alpha_2\Phi_{3;K}(\underline{\alpha}) + \Phi_{3;K}(\underline{\alpha}))\Big) \qquad (4)
\end{aligned}
$$

⇒ $g^D_{\Xi_c^0[\frac{3}{2}^-]\to\Lambda_c^+K^-}$ ⇒ $g^D_{\Xi'_c[\frac{3}{2}^-]\to\Lambda_c[\frac{1}{2}^+]K} = 4.02\,^{+2.73}_{-1.95}\ \text{GeV}^{-2}$

Light-cone sum rules studies on the bottom baryons

Lagrangian:

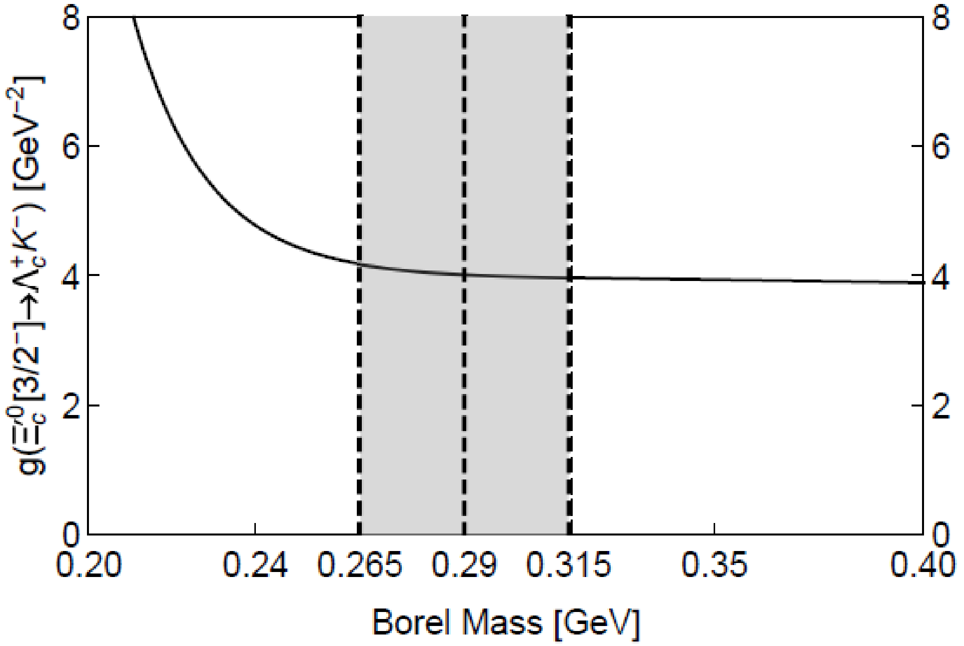
$$\mathcal{L}^{D}_{X_c(3/2^-)\to Y_c(1/2^+)P} = g\bar{X}_{c\mu}(3/2^-)\gamma_\nu\gamma_5 Y_c(1/2^+)\partial^\mu\partial^\nu P\,,$$

Partial decay width

$$\Gamma(\Xi_c'^0\to\Lambda_c^+K^-) \quad (5)$$

$$= \frac{|\vec{p}_2|}{32\pi^2 m_0^2}\times g^2_{\Xi_c'[\frac{3}{2}^-]\to\Lambda_c K^-}\times p_{2,\mu}p_{2,\nu}p_{2,\rho}p_{2,\sigma}$$
$$\times\,\mathrm{Tr}\Big[\gamma^\nu\gamma_5\left(\not{p}_1+m_1\right)\gamma^\sigma\gamma_5$$
$$\left(g^{\rho\mu}-\frac{\gamma^\rho\gamma^\mu}{3}-\frac{p_0^\rho\gamma^\mu-p_0^\mu\gamma^\rho}{3m_0}-\frac{2p_0^\rho p_0^\mu}{3m_0^2}\right)(\not{p}_0+m_0)\Big],$$

$$\Gamma^D_{\Xi_c'[\frac{3}{2}^-]\to\Lambda_c[\frac{1}{2}^+]K} = 9.83\,^{+17.88}_{-\ 7.22}\ \mathrm{MeV}$$



The coupling constant $g^D_{\Xi_c'^0[\frac{3}{2}^-]\to\Lambda_c^+K^-}$ as function of the Borel mass T :

Probable decay channels

- We have been studied the S-wave and D-wave decays of P-wave Ξ_c' baryons into ground-state charmed baryons by a pseudoscalar meson(π or K) . We also studied the S-wave decay of P-wave Ξ_c' baryons into ground-state charmed baryons by a vector meson(ρ or K^*).

- S-wave(->ground-state +pseudoscalar)

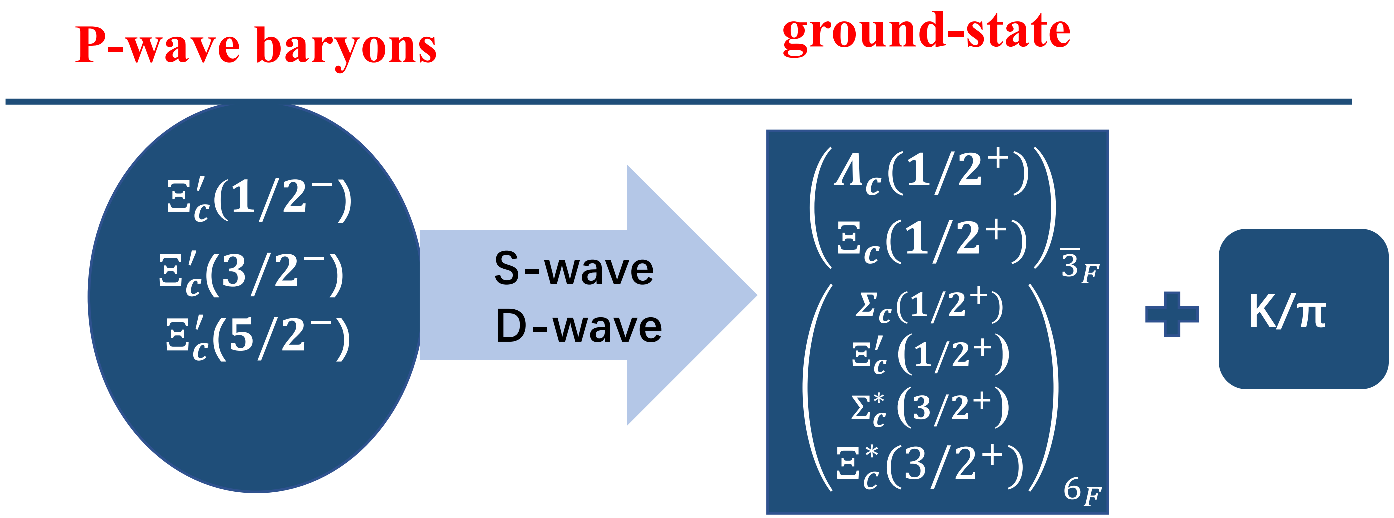
$$(a1)\ \Gamma\Big[\Xi_c'[1/2^-]\to\Xi_c/\Xi_c'+\pi\Big]=\frac{3}{2}\times\Gamma\Big[\Xi_c'^0[1/2^-]\to\Xi_c^+/\Xi_c'^+/+\pi^-\Big]$$

$$(a2)\ \Gamma\Big[\Xi_c'[1/2^-]\to\Lambda_c+\pi\Big]=\Gamma\Big[\Xi_c'^0[1/2^-]\to\Lambda_c^++K^-\Big],$$

$$(a3)\ \Gamma\Big[\Xi_c'[1/2^-]\to\Sigma_c+K\Big]=3\times\Gamma\Big[\Xi_c'^0[1/2^-]\to\Sigma_c^++K^-\Big],$$

$$(c4)\ \Gamma\Big[\Xi_c'[3/2^-]\to\Xi_c^*+\pi\Big]=\frac{3}{2}\times\Gamma\Big[\Xi_c'^0[3/2^-]\to\Xi_c^{*+}+\pi^-\Big],$$

$$(c5)\ \Gamma\Big[\Xi_c'[3/2^-]\to\Sigma_c^*+K\Big]=3\times\Gamma\Big[\Xi_c'^0[3/2^-]\to\Sigma_c^{*+}+K^-\Big],$$



- D-wave(-> ground-state +pseudoscalar)

$$(a4)\ \Gamma\Big[\Xi_c'[1/2^-]\to\Xi_c^*+\pi\Big]=\frac{3}{2}\times\Gamma\Big[\Xi_c'^0[1/2^-]\to\Xi_c^{*+}+\pi^-\Big],$$

$$(a5)\ \Gamma\Big[\Xi_c'[1/2^-]\to\Sigma_c^*+K\Big]=3\times\Gamma\Big[\Xi_c'^0[1/2^-]\to\Sigma_c^{*+}+K^-\Big],$$

$$(c1)\ \Gamma\Big[\Xi_c'[3/2^-]\to\Xi_c/\Xi_c'+\pi\Big]=\frac{3}{2}\times\Gamma\Big[\Xi_c'^0[3/2^-]\to\Xi_c^+/\Xi_c'^++\pi^-\Big],$$

$$(c2)\ \Gamma\Big[\Xi_c'[3/2^-]\to\Lambda_c+K\Big]=\Gamma\Big[\Xi_c'^0[3/2^-]\to\Lambda_c^++K^-\Big],$$

$$(c3)\ \Gamma\Big[\Xi_c'[3/2^-]\to\Sigma_c+K\Big]=3\times\Gamma\Big[\Xi_c'^0[3/2^-]\to\Sigma_c^++K^-\Big],$$

$$(c4)\ \Gamma\Big[\Xi_c'[3/2^-]\to\Xi_c^*+\pi\Big]=\frac{3}{2}\times\Gamma\Big[\Xi_c'^0[3/2^-]\to\Xi_c^{*+}+\pi^-\Big],$$

$$(c5)\ \Gamma\Big[\Xi_c'[3/2^-]\to\Sigma_c^*+K\Big]=3\times\Gamma\Big[\Xi_c'^0[3/2^-]\to\Sigma_c^{*+}+K^-\Big],$$

$$(e1)\ \Gamma\Big[\Xi_c'[5/2^-]\to\Xi_c/\Xi_c'+\pi\Big]=\frac{3}{2}\times\Gamma\Big[\Xi_c'^0[5/2^-]\to\Xi_c^+/\Xi_c'^++\pi^-\Big],$$

$$(e2)\ \Gamma\Big[\Xi_c'[5/2^-]\to\Lambda_c+K\Big]=\Gamma\Big[\Xi_c'^0[5/2^-]\to\Lambda_c^++K^-\Big],$$

$$(e3)\ \Gamma\Big[\Xi_c'[5/2^-]\to\Sigma_c+K\Big]=3\times\Gamma\Big[\Xi_c'^0[5/2^-]\to\Sigma_c^++K^-\Big],$$

$$(e4)\ \Gamma\Big[\Xi_c'[5/2^-]\to\Xi_c^*+\pi\Big]=\frac{3}{2}\times\Gamma\Big[\Xi_c'^0[5/2^-]\to\Xi_c^{*+}+\pi^-\Big],$$

$$(e5)\ \Gamma\Big[\Xi_c'[5/2^-]\to\Sigma_c^*+K\Big]=3\times\Gamma\Big[\Xi_c'^0[5/2^-]\to\Sigma_c^{*+}+K^-\Big],$$

Probable decay channels

- S-wave(->ground-state+ vector -> ground-state + double pseudoscalar)

$$(b1)\quad \mathbf{\Gamma}\left[\Xi_c'[1/2^-]\to\Xi_c/\Xi_c'+\rho\to\Xi_c/\Xi_c'+\pi+\pi\right]=\frac{3}{2}\times\mathbf{\Gamma}\left[\Xi_c'^0[1/2^-]\to\Xi_c^+/\Xi_c'+\pi^0+\pi^-\right],$$

$$(b2)\quad \mathbf{\Gamma}\left[\Xi_c'[1/2^-]\to\Lambda_c+K^*\to\Lambda_c+K+\pi\right]=\frac{3}{2}\times\mathbf{\Gamma}\left[\Xi_c'^0[1/2^-]\to\Lambda_c^++K^0+\pi^-\right],$$

$$(b3)\quad \mathbf{\Gamma}\left[\Xi_c'[1/2^-]\to\Sigma_c+K^*\to\Sigma_c+K+\pi\right]=\frac{9}{2}\times\mathbf{\Gamma}\left[\Xi_c'^0[1/2^-]\to\Sigma_c^++K^0+\pi^-\right],$$

$$(b4)\quad \mathbf{\Gamma}\left[\Xi_c'[1/2^-]\to\Xi_c^*+\rho\to\Xi_c^*+\pi+\pi\right]=\frac{3}{2}\times\mathbf{\Gamma}\left[\Xi_c'^0[1/2^-]\to\Xi_c^{*+}+\pi^0+\pi^-\right],$$

$$(b5)\quad \mathbf{\Gamma}\left[\Xi_c'[1/2^-]\to\Sigma_c^*+K^*\to\Sigma_c^*+K+\pi\right]=\frac{9}{2}\times\mathbf{\Gamma}\left[\Xi_c'^0[1/2^-]\to\Sigma_c^{*+}+K^0+\pi^-\right],$$

$$(d1)\quad \mathbf{\Gamma}\left[\Xi_c'[3/2^-]\to\Xi_c/\Xi_c'+\rho\to\Xi_c+\pi+\pi\right]=\frac{3}{2}\times\mathbf{\Gamma}\left[\Xi_c'^0[3/2^-]\to\Xi_c^+/\Xi_c'^++\pi^0+\pi^-\right],$$

$$(d2)\quad \mathbf{\Gamma}\left[\Xi_c'[3/2^-]\to\Lambda_c+K^*\to\Lambda_c+K+\pi\right]=\frac{3}{2}\times\mathbf{\Gamma}\left[\Xi_c'^0[3/2^-]\to\Lambda_c^++K^0+\pi^-\right],$$

$$(d3)\quad \mathbf{\Gamma}\left[\Xi_c'[3/2^-]\to\Sigma_c+K^*\to\Sigma_c'+K+\pi\right]=\frac{9}{2}\times\mathbf{\Gamma}\left[\Xi_c'^0[3/2^-]\to\Sigma_c'^++K^0+\pi^-\right],$$

$$(d4)\quad \mathbf{\Gamma}\left[\Xi_c'[3/2^-]\to\Xi_c^*+\rho\to\Xi_c^*+\pi+\pi\right]=\frac{3}{2}\times\mathbf{\Gamma}\left[\Xi_c'^0[3/2^-]\to\Xi_c^{*+}+\pi^0+\pi^-\right],$$

$$(d5)\quad \mathbf{\Gamma}\left[\Xi_c'[3/2^-]\to\Sigma_c^*+K^*\to\Sigma_c^*+K+\pi\right]=\frac{9}{2}\times\mathbf{\Gamma}\left[\Xi_c'^0[3/2^-]\to\Sigma_c^{*+}+K^0+\pi^-\right],$$

$$(f1)\quad \mathbf{\Gamma}\left[\Xi_c'[5/2^-]\to\Sigma_c^*+K^*\to\Sigma_c^*+K+\pi\right]=\frac{9}{2}\times\mathbf{\Gamma}\left[\Xi_c'^0[5/2^-]\to\Sigma_c^{*+}+K^0+\pi^-\right],$$

$$(f2)\quad \mathbf{\Gamma}\left[\Xi_c'[5/2^-]\to\Xi_c^*+\rho\to\Xi_c^*+\pi+\pi\right]=\frac{3}{2}\times\mathbf{\Gamma}\left[\Xi_c'^0[5/2^-]\to\Xi_c^{*+}+\pi^0+\pi^-\right].$$

Decay widths of P-wave charmed baryons

- S and D-wave decay of P-wave charmed baryons belonging to **[6_F,2,1,λ]** doublet.

Baryon (j^P)	Mass (GeV)	Difference (MeV)	Decay channels	S-wave width (MeV)	D-wave width (MeV)	Total width (MeV)
$\Sigma_c(\frac{3}{2}^-)$	$2.86^{+0.22}_{-0.16}$	75^{+33}_{-29}	$\Sigma_c(\frac{3}{2}^-) \to \Lambda_c\pi$	–	$56.6^{+97.7}_{-40.3}$	$69.6^{+98.8}_{-40.8}$
			$\Sigma_c(\frac{3}{2}^-) \to \Sigma_c\pi$	–	$5.5^{+11.4}_{-4.6}$	
			$\Sigma_c(\frac{3}{2}^-) \to \Sigma_b^*\pi$	$(6^{+11}_{-5}) \times 10^{-4}$	$0.54^{+1.0}_{-0.53}$	
			$\Sigma_c(\frac{3}{2}^-) \to \Sigma_c\rho \to \Sigma_c\pi\pi$	$5.8^{+9.9}_{-4.3}$		
			$\Sigma_c(\frac{3}{2}^-) \to \Sigma_c^*\rho \to \Sigma_c^*\pi\pi$	0.01		
$\Sigma_c(\frac{5}{2}^-)$	$2.94^{+0.21}_{-0.14}$		$\Sigma_c(\frac{5}{2}^-) \to \Lambda_c\pi$	–	$33.4^{+38.7}_{-23.8}$	$41.9^{+40.5}_{-24.3}$
			$\Sigma_c(\frac{5}{2}^-) \to \Sigma_c\pi$	–	$2.1^{+4.3}_{-1.7}$	
			$\Sigma_c(\frac{5}{2}^-) \to \Sigma_c^*\pi$	–	$5.2^{+10.8}_{-4.4}$	
			$\Sigma_c(\frac{5}{2}^-) \to \Sigma_c^*\rho \to \Sigma_c^*\pi\pi$	$1.2^{+2.1}_{-0.9}$		
$\Xi_c'(\frac{3}{2}^-)$	$2.96^{+0.24}_{-0.15}$	66^{+29}_{-25}	$\Xi_c'(\frac{3}{2}^-) \to \Lambda_c K$	–	$9.8^{+17.9}_{-7.2}$	$30.7^{+35.0}_{-14.2}$
			$\Xi_c'(\frac{3}{2}^-) \to \Xi_c\pi$	–	$17.0^{+29.7}_{-12.0}$	
			$\Xi_c'(\frac{3}{2}^-) \to \Sigma_c K$	–	$(3^{+15}_{-3}) \times 10^{-3}$	
			$\Xi_c'(\frac{3}{2}^-) \to \Xi_c'\pi$	–	$2.3^{+4.0}_{-1.7}$	
			$\Xi_c'(\frac{3}{2}^-) \to \Xi_c^*\pi$	2×10^{-4}	$0.19^{+0.33}_{-0.14}$	
			$\Xi_c'(\frac{3}{2}^-) \to \Xi_c'\rho \to \Xi_c'\pi\pi$	$1.4^{+2.2}_{-1.0}$		
			$\Xi_c'(\frac{3}{2}^-) \to \Xi_c^*\rho \to \Xi_c^*\pi\pi$	1×10^{-3}		
$\Xi_c'(\frac{5}{2}^-)$	$3.02^{+0.23}_{-0.14}$		$\Xi_c'(\frac{5}{2}^-) \to \Lambda_c K$	–	$6.3^{+11.4}_{-4.6}$	$18.1^{+19.7}_{-8.3}$
			$\Xi_c'(\frac{5}{2}^-) \to \Xi_c\pi$	–	$9.6^{+15.8}_{-6.8}$	
			$\Xi_c'(\frac{5}{2}^-) \to \Sigma_c K$	–	$0.02^{+0.09}_{-0.02}$	
			$\Xi_c'(\frac{5}{2}^-) \to \Xi_c'\pi$	–	$0.70^{+1.30}_{-0.54}$	
			$\Xi_c'(\frac{5}{2}^-) \to \Sigma_c^* K$	–	4×10^{-3}	
			$\Xi_c'(\frac{5}{2}^-) \to \Xi_c^*\pi$	–	$1.5^{+2.6}_{-1.1}$	
			$\Xi_c'(\frac{3}{2}^-) \to \Xi_c^*\rho \to \Xi_c^*\pi\pi$	0.02		
$\Omega_c(\frac{3}{2}^-)$	$3.08^{+0.15}_{-0.17}$	59^{+26}_{-21}	$\Omega_c(\frac{3}{2}^-) \to \Xi_c K$	–	$9.9^{+17.4}_{-7.4}$	$10.0^{+17.4}_{-7.4}$
			$\Omega_c(\frac{3}{2}^-) \to \Xi_c' K$	–	$0.10^{+0.26}_{-0.09}$	
$\Omega_C(\frac{5}{2}^-)$	$3.14^{+0.15}_{-0.15}$		$\Omega_c(\frac{5}{2}^-) \to \Xi_c K$	–	$5.5^{+9.6}_{-4.1}$	$5.5^{+9.6}_{-4.1}$
			$\Omega_c(\frac{5}{2}^-) \to \Xi_c' K$	–	$0.03^{+0.07}_{-0.02}$	

Mixed sates

- We consider two states mixing between the $[\Sigma_c\left(\frac{3}{2}^-\right)/\Xi_c'\left(\frac{3}{2}^-\right)/\Omega_c\left(\frac{3}{2}^-\right), 6_F, 1, 1, \lambda]$ and the $[\Sigma_c\left(\frac{3}{2}^-\right)/\Xi_c'\left(\frac{3}{2}^-\right)/\Omega_c\left(\frac{3}{2}^-\right), 6_F, 2, 1, \lambda]$, where θ2 is the mixing angle:

$$\begin{pmatrix} |\Sigma_c(\frac{3}{2}^-)\rangle_1/|\Xi_c'(\frac{3}{2}^-)\rangle_1/|\Omega_c(\frac{3}{2}^-)\rangle_1 \\ |\Sigma_c(\frac{3}{2}^-)\rangle_2/|\Xi_c'(\frac{3}{2}^-)\rangle_2/|\Omega_c(\frac{3}{2}^-)\rangle_2 \end{pmatrix} = \begin{pmatrix} \cos\theta_2 & \sin\theta_2 \\ -\sin\theta_2 & \cos\theta_2 \end{pmatrix} \times \begin{pmatrix} |\Sigma_c(\frac{3}{2}^-)/\Xi_c'(\frac{3}{2}^-)/\Omega_c(\frac{3}{2}^-), 1, 1, \lambda\rangle \\ |\Sigma_c(\frac{3}{2}^-)/\Xi_c'(\frac{3}{2}^-)/\Omega_c(\frac{3}{2}^-), 2, 1, \lambda\rangle \end{pmatrix} \quad (6)$$

$\theta 2 = 37 \pm 5^0$

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Mixed sates

- S and D-wave decay of mixed Ξ_c' and Ω_c baryons

Mixed state	Mass (GeV)	Difference (MeV)	Main Decay channel (MeV)	Width (MeV)	Candidate
$[\Xi_c'(\frac{1}{2}^-),1,1,\lambda]$	$2.91^{+0.13}_{-0.12}$	27^{+16}_{-27}	$\Gamma_S\left(\Xi_c'(1/2^-)\to\Xi_c'\pi\right)=11.7^{+15.0}_{-\ 8.0}$ $\Gamma_S\left(\Xi_c'(1/2^-)\to\Xi_c\rho\to\Xi_c\pi\pi\right)=1.7^{+7.6}_{-1.7}$	$13.9^{+16.8}_{-\ 8.2}$	$\Xi_c(2923)^0$
$\Xi_c'(\frac{3}{2}^-)_1$	$2.94^{+0.12}_{-0.11}$		$\Gamma_D\left(\Xi_c'(3/2^-)\to\Lambda_cK\right)=2.3^{+4.3}_{-1.7}$ $\Gamma_D\left(\Xi_c'(3/2^-)\to\Xi_c\pi\right)=4.6^{+8.1}_{-3.3}$ $\Gamma_D\left(\Xi_c'(3/2^-)\to\Xi_c'\pi\right)=2.0^{+2.2}_{-1.2}$ $\Gamma_S\left(\Xi_c'(3/2^-)\to\Xi_c^*\pi\right)=2.1^{+2.6}_{-1.5}$	$11.8^{+9.8}_{-4.2}$	$\Xi_c(2939)^0$
$\Xi_c'(\frac{3}{2}^-)_2$	$2.97^{+0.24}_{-0.15}$	56^{+30}_{-35}	$\Gamma_D\left(\Xi_c'(3/2^-)\to\Lambda_cK\right)=6.3^{+11.6}_{-\ 4.7}$ $\Gamma_D\left(\Xi_c'(3/2^-)\to\Xi_c\pi\right)=10.9^{+19.1}_{-\ 7.8}$ $\Gamma_S\left(\Xi_c'(3/2^-)\to\Xi_c^*\pi\right)=1.3^{+1.80}_{-0.94}$	$19.4^{+22.5}_{-\ 9.1}$	$\Xi_c(2965)^0$
$[\Xi_c'(\frac{5}{2}^-),2,1,\lambda]$	$3.02^{+0.23}_{-0.14}$		$\Gamma_D\left(\Xi_c'(5/2^-)\to\Lambda_cK\right)=6.3^{+11.4}_{-\ 4.6}$ $\Gamma_D\left(\Xi_c'(5/2^-)\to\Xi_c\pi\right)=9.6^{+15.8}_{-\ 6.8}$ $\Gamma_D\left(\Xi_c'(5/2^-)\to\Xi_c^*\pi\right)=1.5^{+2.6}_{-1.1}$	$18.1^{+19.7}_{-\ 8.3}$	–
$[\Omega_c(\frac{1}{2}^-),1,1,\lambda]$	$3.04^{+0.11}_{-0.09}$	27^{+15}_{-23}	–	~ 0	$\Omega_c(3050)^0$
$\Omega_c(\frac{3}{2}^-)_1$	$3.06^{+0.10}_{-0.09}$		$\Gamma_D\left(\Omega_c(3/2^-)\to\Xi_cK\right)=2.0^{+3.5}_{-1.5}$	$2.0^{+3.5}_{-1.5}$	$\Omega_c(3066)^0$
$\Omega_c(\frac{3}{2}^-)_2$	$3.09^{+0.15}_{-0.17}$	51^{+26}_{-28}	$\Gamma_D\left(\Omega_c(3/2^-)\to\Xi_cK\right)=6.3^{+11.2}_{-\ 4.8}$	$6.4^{+11.2}_{-\ 4.8}$	$\Omega_c(3090)^0$
$[\Omega_c(\frac{5}{2}^-),2,1,\lambda]$	$3.14^{+0.15}_{-0.15}$		$\Gamma_D\left(\Omega_c(3/2^-)\to\Xi_cK\right)=5.5^{+9.6}_{-4.1}$	$5.5^{+9.6}_{-4.1}$	$\Omega_c(3119)^0$

Exp

- $\Xi_c(2923)^0$: $M = 2923.04 \pm 0.25 \pm 0.20 \pm 0.14$ MeV
  $\Gamma = 7.1 \pm 0.8 \pm 1.8$ MeV,
  $\Xi_c(2939)^0$: $M = 2938.55 \pm 0.21 \pm 0.17 \pm 0.14$ MeV
  $\Gamma = 10.2 \pm 0.8 \pm 1.1$ MeV,
  $\Xi_c(2965)^0$: $M = 2964.88 \pm 0.26 \pm 0.14 \pm 0.14$ MeV
  $\Gamma = 14.1 \pm 0.9 \pm 1.3$ MeV.

- $\Omega_c(3050)^0$: $M = 3050.2 \pm 0.1 \pm 0.1^{+0.3}_{-0.5}$ MeV,
  $\Gamma = 0.8 \pm 0.2 \pm 0.1$ MeV,
  $\Omega_c(3066)^0$: $M = 3065.6 \pm 0.1 \pm 0.3^{+0.3}_{-0.5}$ MeV,
  $\Gamma = 3.5 \pm 0.4 \pm o.2$ MeV,
  $\Omega_c(3090)^0$: $M = 3090.2 \pm 0.3 \pm 0.5^{+0.3}_{-0.5}$ MeV,
  $\Gamma = 8.7 \pm 1.0 \pm 0.8$ MeV,
  $\Omega_c(3119)^0$: $M = 3119.1 \pm 0.3 \pm 0.9^{+0.3}_{-0.5}$ MeV,
  $\Gamma = 1.1 \pm 0.8 \pm 0.4$ MeV.

Summary

□ Decay properties of P-wave Σ_c baryons of SU(3) flavor 6_F

HQET state	Mixing	Mixed state	Mass (GeV)	Difference (MeV)	Main Decay channel (MeV)	Width (MeV)	Candidate
$[\Sigma_c(\frac{1}{2}^-),1,0,\rho]$	–	$[\Sigma_c(\frac{1}{2}^-),1,0,\rho]$	$2.77^{+0.16}_{-0.12}$	15^{+6}_{-5}	$\Gamma_S\left(\Sigma_c(1/2^-)\to\Sigma_c\pi\right)=380^{+630}_{-270}$ $\Gamma_D\left(\Sigma_c(1/2^-)\to\Sigma_c^*\pi\right)=0.82^{+1.4}_{-0.59}$ $\Gamma_S\left(\Sigma_c(1/2^-)\to\Lambda_c\rho\to\Lambda_c\pi\pi\right)=0.06$ $\Gamma_S\left(\Sigma_c(1/2^-)\to\Sigma_c\rho\to\Sigma_c\pi\pi\right)=3.4\times10^{-5}$	390^{+630}_{-270}	–
$[\Sigma_c(\frac{3}{2}^-),1,0,\rho]$	–	$[\Sigma_c(\frac{3}{2}^-),1,0,\rho]$	$2.79^{+0.16}_{-0.12}$		$\Gamma_D\left(\Sigma_c(3/2^-)\to\Sigma_c\pi\right)=3.1^{+4.6}_{-2.3}$ $\Gamma_S\left(\Sigma_c(3/2^-)\to\Sigma_c^*\pi\right)=220^{+360}_{-150}$ $\Gamma_D\left(\Sigma_c(3/2^-)\to\Sigma_c^*\pi\right)=0.21^{+0.34}_{-0.15}$ $\Gamma_S\left(\Sigma_c(3/2^-)\to\Lambda_c\rho\to\Lambda_c\pi\pi\right)=0.08$ $\Gamma_S\left(\Sigma_c(3/2^-)\to\Sigma_c\rho\to\Sigma\pi\pi\right)=3.5\times10^{-5}$	220^{+360}_{-150}	–
$[\Sigma_c(\frac{1}{2}^-),0,1,\lambda]$		$[\Sigma_c'(\frac{1}{2}^-),0,1,\lambda]$	$2.83^{+0.06}_{-0.04}$	–	$\Gamma_S\left(\Sigma_c(1/2^-)\to\Lambda_c\pi\right)=610^{+860}_{-410}$	610^{+860}_{-410}	–
$[\Sigma_c(\frac{1}{2}^-),1,1,\lambda]$	$\theta_1\approx0^\circ$	$[\Sigma_c(\frac{1}{2}^-),1,1,\lambda]$	$2.73^{+0.17}_{-0.18}$		$\Gamma_S\left(\Sigma_c(1/2^-)\to\Sigma_c\pi\right)=37.4^{+59.8}_{-27.8}$ $\Gamma_S\left(\Sigma_c(1/2^-)\to\Lambda_c\rho\to\Lambda_c\pi\pi\right)=9.2^{+37.0}_{-9.2}$ $\Gamma_S\left(\Sigma_c(1/2^-)\to\Sigma_c\rho\to\Sigma_c\pi\pi\right)=1.2^{+2.1}_{-1.0}$	$47.9^{+70.4}_{-29.3}$	$\Sigma_c(2800)^0$
$[\Sigma_c(\frac{3}{2}^-),1,1,\lambda]$	$\theta_2=37\pm5^\circ$	$\Sigma_c(\frac{3}{2}^-)_1$	$2.65^{+0.18}_{-0.34}$	-81^{+65}_{-294}	$\Gamma_D\left(\Sigma_c(3/2^-)\to\Lambda_c\pi\right)=11.7^{+20.6}_{-8.6}$ $\Gamma_D\left(\Sigma_c(3/2^-)\to\Sigma_c\pi\right)=3.1^{+4.2}_{-2.2}$ $\Gamma_S\left(\Sigma_c(3/2^-)\to\Sigma_c^*\pi\right)=6.4^{+10.3}_{-4.7}$	$22.8^{+23.5}_{-10.0}$	$\Sigma_c(2800)^0$
$[\Sigma_c(\frac{3}{2}^-),2,1,\lambda]$		$\Sigma_c(\frac{3}{2}^-)_2$	$2.97^{+0.32}_{-0.17}$		$\Gamma_D\left(\Sigma_c(3/2^-)\to\Lambda_c\pi\right)=21.1^{+36.7}_{-15.1}$ $\Gamma_S\left(\Sigma_c(3/2^-)\to\Sigma_c^*\pi\right)=3.5^{+6.1}_{-2.7}$	$25.5^{+37.3}_{-15.4}$	$\Sigma_c(2800)^0$
$[\Sigma_c(\frac{5}{2}^-),2,1,\lambda]$	–	$[\Sigma_c(\frac{3}{2}^-),2,1,\lambda]$	$2.94^{+0.21}_{-0.14}$	-37^{+66}_{-239}	$\Gamma_D\left(\Sigma_c(5/2^-)\to\Lambda_c\pi\right)=33.4^{+38.7}_{-23.8}$ $\Gamma_D\left(\Sigma_c(5/2^-)\to\Sigma_c\pi\right)=2.1^{+4.3}_{-1.7}$ $\Gamma_D\left(\Sigma_c(5/2^-)\to\Sigma_c^*\pi\right)=5.2^{+10.8}_{-4.4}$ $\Gamma_S\left(\Sigma_c(5/2^-)\to\Sigma_c^*\rho\Sigma_c^*\pi\pi\right)=1.2^{+2.1}_{-0.9}$	$41.9^{+40.5}_{-26.9}$	–

Summary

☐ Decay properties of P-wave Ξ_c' baryons of SU(3) flavor 6_F

HQET state	Mixing	Mixed state	Mass (GeV)	Difference (MeV)	Main Decay channel (MeV)	Width (MeV)	Candidate
$[\Xi_c'(\frac{1}{2}^-),1,0,\rho]$	–	$[\Xi_c'(\frac{1}{2}^-),1,0,\rho]$	$2.88^{+0.15}_{-0.13}$	13^{+6}_{-5}	$\Gamma_S\,(\Xi_c'(1/2^-)\to\Xi_c'\pi)=110^{+170}_{-800}$ $\Gamma_D\,(\Xi_c'(1/2^-)\to\Xi_c^*\pi)=0.15^{+0.23}_{-0.11}$ $\Gamma_S\,(\Xi_c'(1/2^-)\to\Xi_c\rho\to\Xi_c\pi\pi)=2\times10^{-4}$ $\Gamma_S\,(\Xi_c'(1/2^-)\to\Xi_c'\rho\to\Xi_c'\pi\pi)=5\times10^{-9}$	110^{+170}_{-80}	–
$[\Xi_c'(\frac{3}{2}^-),1,0,\rho]$	–	$[\Xi_c'(\frac{3}{2}^-),1,0,\rho]$	$2.89^{+0.15}_{-0.13}$		$\Gamma_D\,(\Xi_c'(3/2^-)\to\Xi_c'\pi)=0.63^{+0.99}_{-0.45}$ $\Gamma_S\,(\Xi_c'(3/2^-)\to\Xi_c^*\pi)=58^{+88}_{-39}$ $\Gamma_D\,(\Xi_c'(3/2^-)\to\Xi_c^*\pi)=0.03^{+0.05}_{-0.02}$ $\Gamma_S\,(\Xi_c'(3/2^-)\to\Xi_c\rho\to\Xi_c\pi\pi)=5\times10^{-4}$ $\Gamma_S\,(\Xi_c'(3/2^-)\to\Xi_c'\rho\to\Xi_c'\pi\pi)=2\times10^{-9}$	$58.5^{+88.4}_{-39.4}$	–
$[\Xi_c'(\frac{1}{2}^-),0,1,\lambda]$		$[\Xi_c'(\frac{1}{2}^-),0,1,\lambda]$	$2.90^{+0.13}_{-0.12}$	–	$\Gamma_S\,(\Xi_c'(1/2^-)\to\Lambda_c K)=400^{+610}_{-270}$ $\Gamma_S\,(\Xi_c'(1/2^-)\to\Xi_c\pi)=360^{+550}_{-250}$	760^{+820}_{-370}	–
$[\Xi_c'(\frac{1}{2}^-),1,1,\lambda]$	$\theta_1\approx0^\circ$	$[\Xi_c'(\frac{1}{2}^-),1,1,\lambda]$	$2.91^{+0.13}_{-0.12}$	27^{+16}_{-27}	$\Gamma_S\,(\Xi_c'(1/2^-)\to\Xi_c'\pi)=11.7^{+15.0}_{-8.0}$ $\Gamma_S\,(\Xi_c'(1/2^-)\to\Xi_c\rho\to\Xi_c\pi\pi)=1.7^{+7.6}_{-1.7}$	$13.9^{+16.8}_{-8.2}$	$\Xi_c(2923)^0$
$[\Xi_c'(\frac{3}{2}^-),1,1,\lambda]$	$\theta_2=37\pm5^\circ$	$\Xi_c'(\frac{3}{2}^-)_1$	$2.94^{+0.12}_{-0.11}$		$\Gamma_D\,(\Xi_c'(3/2^-)\to\Lambda_c K)=2.3^{+4.3}_{-1.7}$ $\Gamma_D\,(\Xi_c'(3/2^-)\to\Xi_c\pi)=4.6^{+8.1}_{-3.3}$ $\Gamma_D\,(\Xi_c'(3/2^-)\to\Xi_c'\pi)=2.0^{+2.2}_{-1.2}$ $\Gamma_S\,(\Xi_c'(3/2^-)\to\Xi_c^*\pi)=2.1^{+2.6}_{-1.5}$	$11.8^{+9.8}_{-4.2}$	$\Xi_c(2939)^0$
$[\Xi_c'(\frac{3}{2}^-),2,1,\lambda]$		$\Xi_c'(\frac{3}{2}^-)_2$	$2.97^{+0.24}_{-0.15}$	56^{+30}_{-35}	$\Gamma_D\,(\Xi_c'(3/2^-)\to\Lambda_c K)=6.3^{+11.6}_{-4.7}$ $\Gamma_D\,(\Xi_c'(3/2^-)\to\Xi_c\pi)=10.9^{+19.1}_{-7.8}$ $\Gamma_S\,(\Xi_c'(3/2^-)\to\Xi_c^*\pi)=1.3^{+1.80}_{-0.94}$	$19.4^{+22.5}_{-9.1}$	$\Xi_c(2965)^0$
$[\Xi_c'(\frac{5}{2}^-),2,1,\lambda]$	–	$[\Xi_c'(\frac{5}{2}^-),2,1,\lambda]$	$3.02^{+0.23}_{-0.14}$		$\Gamma_D\,(\Xi_c'(5/2^-)\to\Lambda_c K)=6.3^{+11.4}_{-4.6}$ $\Gamma_D\,(\Xi_c'(5/2^-)\to\Xi_c\pi)=9.6^{+15.8}_{-6.8}$ $\Gamma_D\,(\Xi_c'(5/2^-)\to\Xi_c^*\pi)=1.5^{+2.6}_{-1.1}$	$18.1^{+19.7}_{-8.3}$	–

- $\Xi_c(2923)^0$ → **P-wave Ξ_c' baryon** $\in[6_F(\Xi_c),1,1,\lambda]$, $J^P=1/2^-$

- $\Xi_c(2939)^0\,\Xi_c(2965)^0$ → **P-wave mixed Ξ_c' baryons** between $[6_F(\Xi_c),1,1,\lambda]$ and $[6_F(\Xi_c),2,1,\lambda]$, $\theta_2=37\pm5^0$, $J^P=3/2^-$

- **a partner state** → **P-wave Ξ_c'** $\in[6_F(\Xi_c),2,1,\lambda]$, $J^P=5/2^-$,
  M=M $[\Xi_c(2965)^0]$+ 56^{+30}_{-35}MeV,
  $\Gamma=18.1^{+19.7}_{-8.3}$ MeV,
  main decay channel:
  $\Xi_c'(5/2^-)\to\Lambda_c K$
  $\Xi_c'(5/2^-)\to\Xi_c\pi$

Summary

- Decay properties of P-wave Ω_c baryons of SU(3) flavor 6_F

HQET state	Mixing	Mixed state	Mass (GeV)	Difference (MeV)	Main Decay channel (MeV)	Width (MeV)	Candidate
$[\Omega_c(\frac{1}{2}^-),1,0,\rho]$	–	$[\Omega_c(\frac{1}{2}^-),1,0,\rho]$	$2.99^{+0.15}_{-0.15}$	12^{+5}_{-5}	–	~ 0	$\Omega_c(3000)^0$
$[\Omega_c(\frac{3}{2}^-),1,0,\rho]$	–	$[\Omega_c(\frac{3}{2}^-),1,0,\rho]$	$3.00^{+0.15}_{-0.15}$		–	~ 0	$\Omega_c(3000)^0$
$[\Omega_c(\frac{1}{2}^-),0,1,\lambda]$	$\theta_3 \approx 0°$	$[\Omega_c(\frac{1}{2}^-),0,1,\lambda]$	$3.03^{+0.18}_{-0.19}$	–	$\Gamma_S\left(\Omega_c(1/2^-)\to\Xi_c K\right) = 980^{+1250}_{-\ 670}$	$980^{+1250}_{-\ 670}$	–
$[\Omega_c(\frac{1}{2}^-),1,1,\lambda]$		$[\Omega_c(\frac{1}{2}^-),1,1,\lambda]$	$3.04^{+0.11}_{-0.09}$	27^{+15}_{-23}	–	~ 0	$\Omega_c(3050)^0$
$[\Omega_c(\frac{3}{2}^-),1,1,\lambda]$	$\theta_4 \approx 37 \pm 5°$	$\Omega_c(\frac{3}{2}^-)_1$	$3.06^{+0.10}_{-0.09}$		$\Gamma_D\left(\Omega_c(3/2^-)\to\Xi_c K\right) = 2.0^{+3.5}_{-1.5}$	$2.0^{+3.5}_{-1.5}$	$\Omega_c(3066)^0$
$[\Omega_c(\frac{3}{2}^-),2,1,\lambda]$		$\Omega_c(\frac{3}{2}^-)_2$	$3.09^{+0.15}_{-0.17}$	51^{+26}_{-28}	$\Gamma_D\left(\Omega_c(3/2^-)\to\Xi_c K\right) = 6.3^{+11.2}_{-\ 4.8}$	$6.4^{+11.2}_{-\ 4.8}$	$\Omega_c(3090)^0$
$[\Omega_c(\frac{5}{2}^-),2,1,\lambda]$	–	$[\Omega_c(\frac{5}{2}^-),2,1,\lambda]$	$3.14^{+0.15}_{-0.15}$		$\Gamma_D\left(\Omega_c(3/2^-)\to\Xi_c K\right) = 5.5^{+9.6}_{-4.1}$	$5.5^{+9.6}_{-4.1}$	$\Omega_c(3119)^0$

- **$\Omega_c(3000)^0$ → P-wave Ω_c baryon ∈ $[6_F(\Omega_c),1,0,\rho]$, J^P=1/2⁻ or 3/2⁻**
- **$\Omega_c(3050)^0$ → P-wave Ω_c baryon ∈ $[6_F(\Omega_c),1,1,\lambda]$, J^P=1/2⁻**
- **$\Omega_c(3066)^0$, $\Omega_c(3090)^0$ → P-wave mixed Ω_c baryons between $[6_F(\Xi_c),1,1,\lambda]$ and $[6_F(\Xi_c),2,1,\lambda]$, θ2 =37 ±5⁰, J^P=3/2⁻**
- **$\Omega_c(3119)^0$ → P-wave Ω_c baryon ∈ $[6_F(\Omega_c),2,1,\lambda]$, J^P=5/2⁻**

Thank you