W-exchange contribution to the decays $\Xi_{cc}^{++} \to \Xi_{c}^{+(\prime)}\pi^{+}$ using light-cone sum rule

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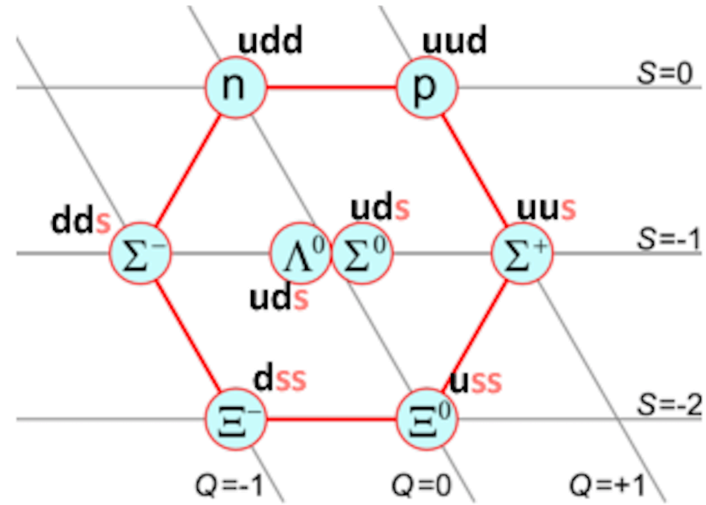
Outline

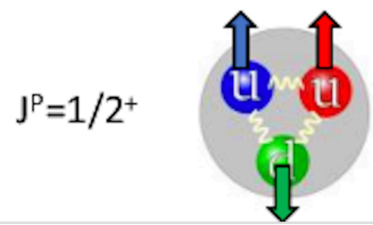
- Observation of doubly charmed baryon
- Status of the theoretical studies on $\Xi_{cc}^{++} \to \Xi_c^{+(\prime)}\pi^+$:
  W-emission and W-exchange contribution
- Light-cone sum rules calculation for the
  W-exchange diagram
- Numerical Results: Amplitudes and branching fraction

Motivation

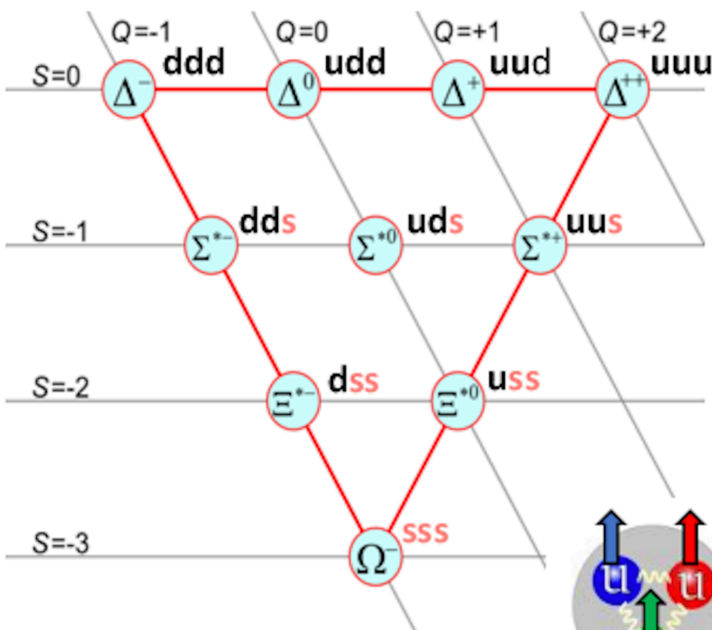
Observation of doubly charmed baryon

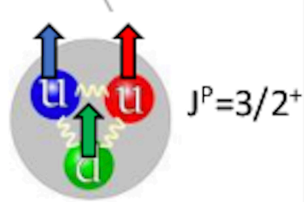
Prediction from the quark model





Octet





Decuplet

Searching for the doubly charmed baryon

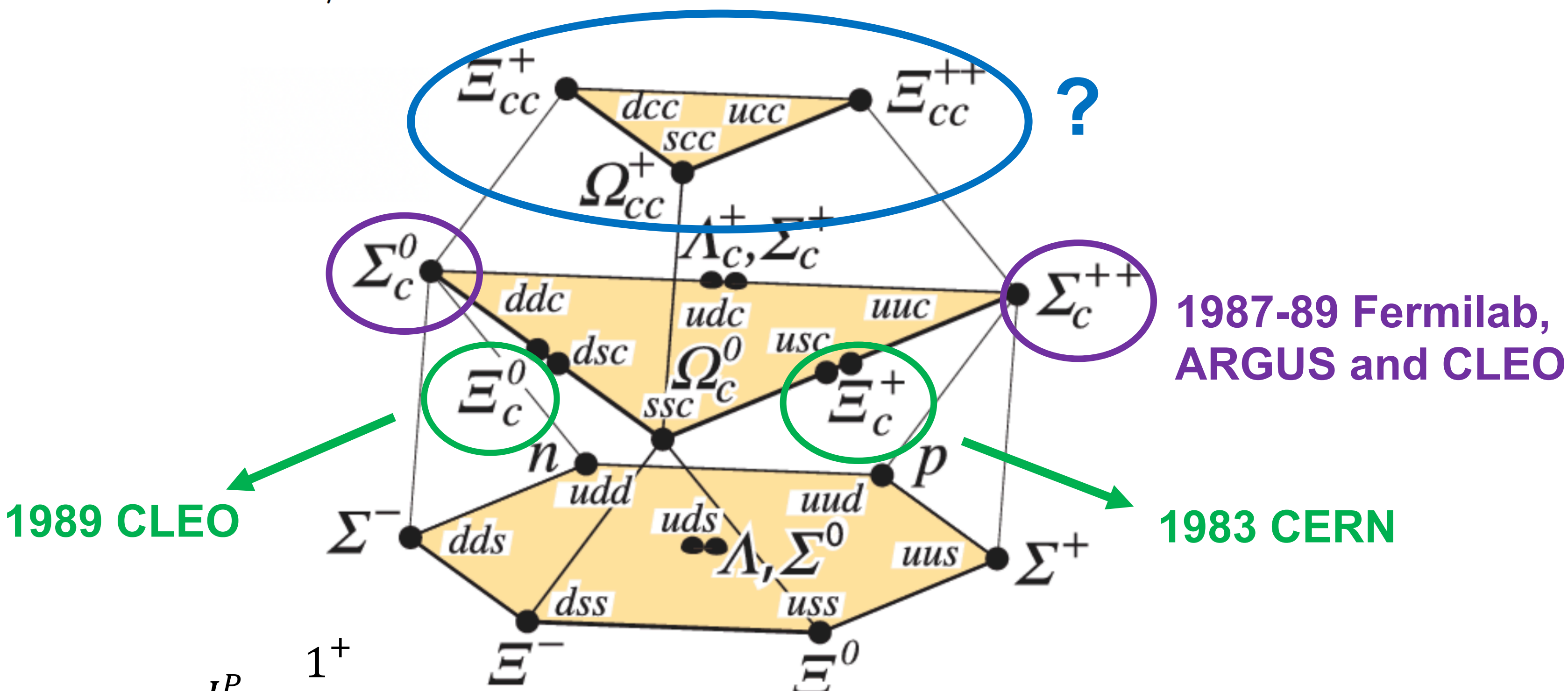
The SELEX collaboration: Phys. Rev. Lett. **89**, 112001 (2002) $\Xi_{cc}^{+} \to \Lambda_c^{+} K^{-} \pi^{+}$

Phys. Lett. B 628, 18 (2005) $\Xi_{cc}^{+} \to p D^{+} K^{-}$

Mass:

$3518.7 \pm 1.7\ \mathrm{MeV/c^2}$

Not confirmed by other experiments !



$J^P = \frac{1}{2}^{+}$

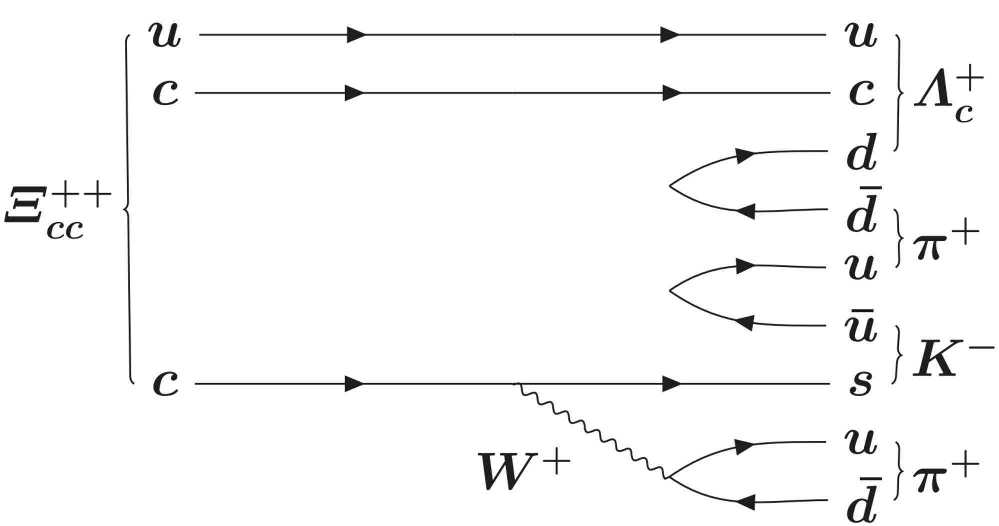
Searching for the doubly charmed baryon

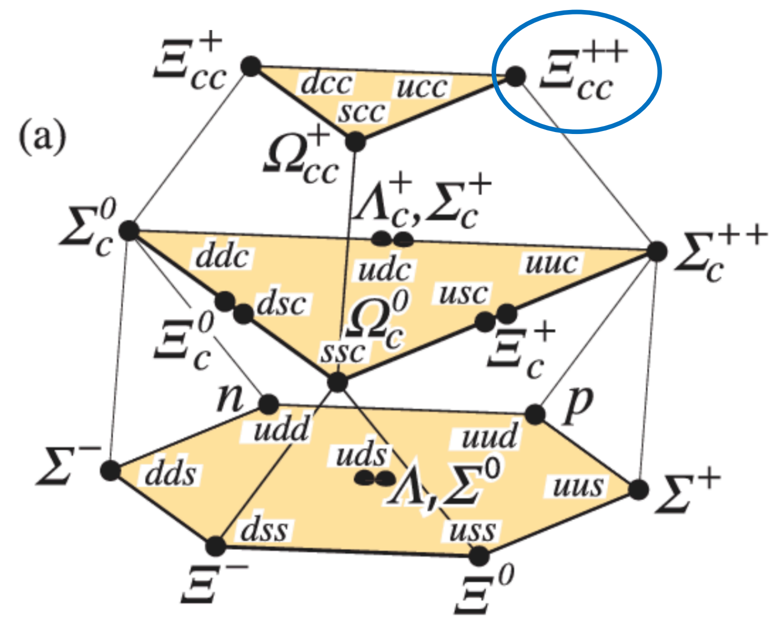
In 2017, the LHCb collaboration observed the Ξ_{cc}^{++} baryon.

Mass: $3620.6 \pm 1.5(\text{stat}) \pm 0.4(\text{syst}) \pm 0.3(\Xi_c^+)\,\text{MeV}/c^2$

Phys. Rev. Lett. 112001 (2017)

$$\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$$





It is firstly predicted by: F.-S. Yu, H.-Y. Jiang, R.-H. Li, C.-D. Lü, W. Wang and Z.-X. Zhao, Chin. Phys. C 42, 051001 (2018)

Searching for the doubly charmed baryon

In 2018, the LHCb collaboration observed a two-body decay of Ξ_{cc}^{++} :

Phys. Rev. Lett. 121, 162002 (2018)

$$\Xi_{cc}^{++} \to \Xi_c^+ \pi^+$$

$$\mathcal{R}(\mathcal{B}) \equiv \frac{\mathcal{B}(\Xi_{cc}^{++} \to \Xi_c^+ \pi^+) \times \mathcal{B}(\Xi_c^+ \to pK^-\pi^+)}{\mathcal{B}(\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+) \times \mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)}$$
$$= 0.035 \pm 0.009(\text{stat}) \pm 0.003(\text{syst})$$

Also predicted by:
Chin. Phys. C 42, 051001 (2018)

In 2022, a similar two-body decay of Ξ_{cc}^{++} was observed by LHCb:

JHEP 05 (2022) 038

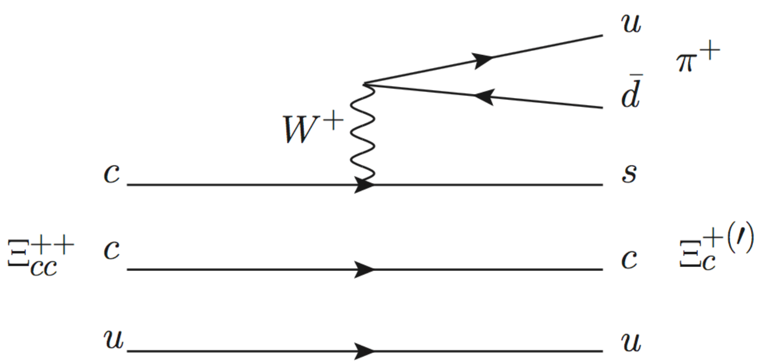
$$\Xi_{cc}^{++} \to \Xi_c^{+\prime} \pi^+$$

$$\frac{\mathcal{B}(\Xi_{cc}^{++} \to \Xi_c^{+\prime} \pi^+)}{\mathcal{B}(\Xi_{cc}^{++} \to \Xi_c^+ \pi^+)} \equiv \frac{\mathcal{B}'}{\mathcal{B}} = 1.41 \pm 0.17 \pm 0.1$$

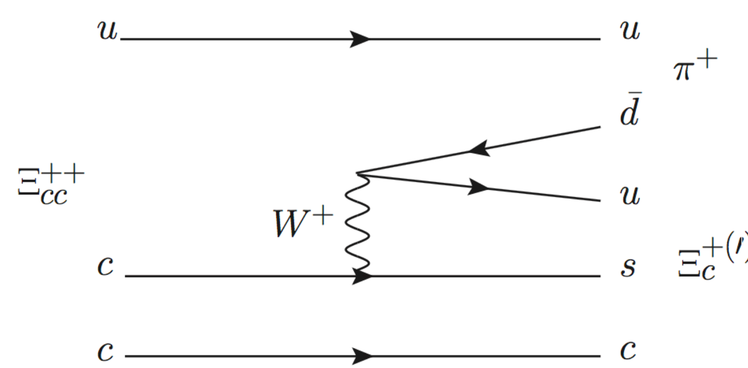
Not consistent with theoretical predictions

The weak decay of $\Xi_{cc}^{++} \longrightarrow \Xi_c^{+(\prime)}\pi^+$

$\Xi_{cc}^{++} \longrightarrow \Xi_c^{+(\prime)}\pi^+$ receives contributions from two topological diagrams: the **W-emission diagram (left)** and the **W-exchange diagram (right):**



Factorizable (fac)



Non-factorizable (nf)

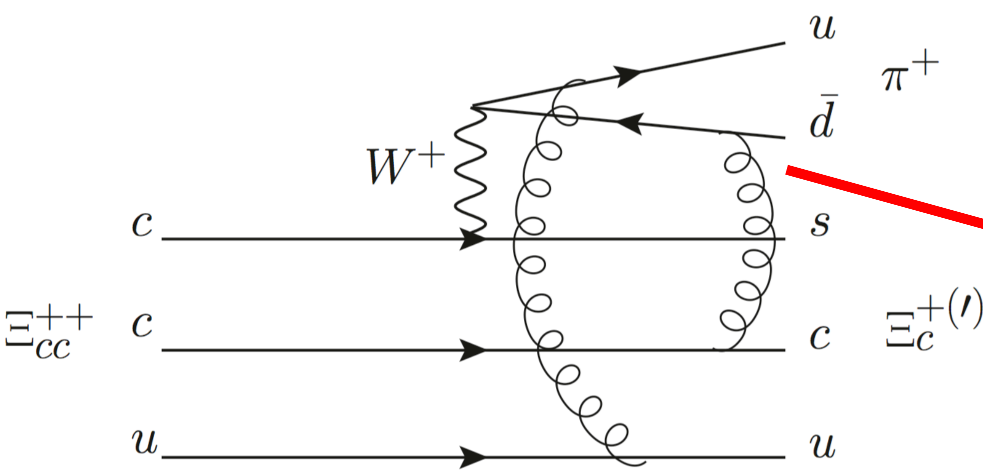
Recently, the theoretical prediction show that:

fac + nf :

Method	$\mathcal{B}(\Xi_{cc}^{++} \to \Xi_c^+\pi^+)$	$\mathcal{B}(\Xi_{cc}^{++} \to \Xi_c^{+\prime}\pi^+)$	$\mathcal{B}'/\mathcal{B}$
LFQM+PM	0.69 %	4.65 %	6.74
3LCQM	0.71 %	3.39 %	4.77
HQET+PM	6.64 %	5.39 %	0.81
NRQM+PM	9.19 %	7.34 %	0.8

Too small or too large

The W-emission diagram



Color transparency:

The fast running pion can hardly be caught up by the soft gluons.

Naïve factorization: $\mathcal{A}_{\rm fac} \propto \underbrace{\langle \pi^+ | \bar{u}\gamma_\mu(1-\gamma_5)d|0\rangle}_{\text{Pion decay constant}} \underbrace{\langle \Xi_c^{+(\prime)} | \bar{s}\gamma^\mu(1-\gamma_5)c|\Xi_{cc}^{++}\rangle}_{\text{Form factors}}$

$$\langle \pi(q)|\bar{u}\gamma_\mu(1-\gamma_5)d|0\rangle = if_\pi q_\mu$$

$$\boxed{\begin{aligned}\bar{u}_2 \Big[& f_1(q^2)\gamma_\mu - f_2(q^2) i\sigma_{\mu\nu}\frac{q^\nu}{M} + f_3(q^2)\frac{q_\mu}{M} \\ & - \left(g_1(q^2)\gamma_\mu - g_2(q^2) i\sigma_{\mu\nu}\frac{q^\nu}{M} + g_3(q^2)\frac{q_\mu}{M}\right)\gamma_5 \Big] u_1\end{aligned}}$$

The W-emission diagram

$$\langle \Xi_c^{+(\prime)}(p-q)\pi^+(q)|\mathcal{H}_{\rm eff}(0)|\Xi_{cc}^{++}(p)\rangle_{\rm fac,nf} = i\ \bar{u}(p-q)\left[A^{(\prime){\rm fac,nf}} + B^{(\prime){\rm fac,nf}}\gamma_5\right]u(p)$$

$\Xi_{cc}^{++} \to \Xi_c^{+(\prime)}\pi^+$	$A^{\rm fac}$	$B^{\rm fac}$	$A^{\prime\rm fac}$	$B^{\prime\rm fac}$
QCDSR	-8.74	16.76	-3.55	34.13
LFQM	7.40	15.06	4.49	48.50
3LQM	-8.13	-12.97	-4.34	-37.59
NRQM	7.38	16.77	4.29	53.65
HQET	9.52	19.45	5.10	62.37

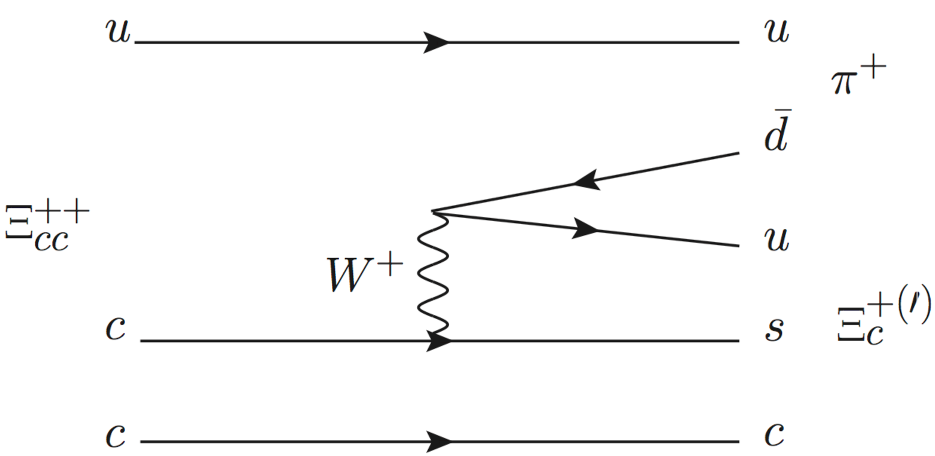
QCDSR: Y. J. Shi, W. Wang and Z. X. Zhao, Eur. Phys. J. C **80**, no.6, 568 (2020)

LFQM: H. Y. Cheng, G. Meng, F. Xu and J. Zou, Phys. Rev. D **101**, no.3, 034034 (2020)

3LQM: T. Gutsche et al. Phys. Rev. D **99**, no.5, 056013 (2019)

NRQM:
HQET: R. Dhir and N. Sharma, Eur. Phys. J. C **78**, no.9, 743 (2018)

The W-exchange diagram



It is non-factorizable and has only been evaluated by the Pole Model in the literature.

Pole Model:

$$A^{\text{pole}} = -\sum_{B_n^*(1/2^-)} \left[\frac{g_{B_f B_n^* P}\, b_{n^* i}}{m_i - m_{n^*}} + \frac{b_{f n^*}\, g_{B_n^* B_i P}}{m_f - m_{n^*}} \right]$$

Strong couplings

$$B^{\text{pole}} = \sum_{B_n} \left[\frac{g_{B_f B_n P}\, a_{ni}}{m_i - m_n} + \frac{a_{fn}\, g_{B_n B_i P}}{m_f - m_n} \right],$$

N. Sharma and R. Dhir, Phys. Rev. D **96**, no.11, 113006 (2017)

H. Y. Cheng, G. Meng, F. Xu and J. Zou, Phys. Rev. D **101**, no.3, 034034 (2020)

Theoretical Method

Light-cone sum rules

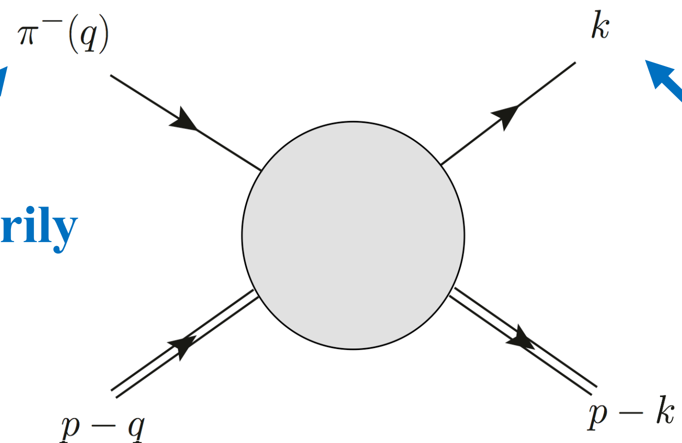
Proposed by: A. Khodjamirian for $B \to \pi\pi$:

Nucl. Phys. B 605, 558-578 (2001)

The framework of light-cone sum rules

Calculate: $\langle \Xi_c^{+(\prime)}(p-q)\pi^+(q)|\mathcal{O}_i(0)|\Xi_{cc}^{++}(p)\rangle = i\ \bar{u}(p-q)(A^{(\prime)i} + B^{(\prime)i}\gamma_5)u(p)$

The pion is temporarily set as an initial state



k is an auxiliary momentum

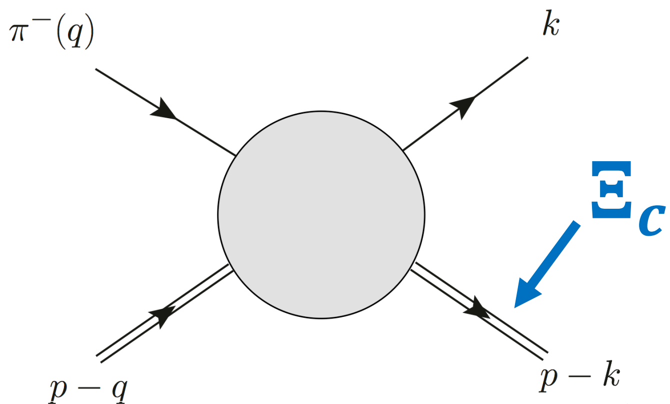
$$\Pi^{\mathcal{O}_i}(p,q,k) = i^2 \int d^4x\ e^{-i(p-q)\cdot x} \int d^4y\ e^{i(p-k)\cdot y} \langle 0|T\left\{J_{\Xi_c^{(\prime)}}(y)\mathcal{O}_i(0)\bar{J}_{\Xi_{cc}}(x)\right\}|\pi^-(q)\rangle$$

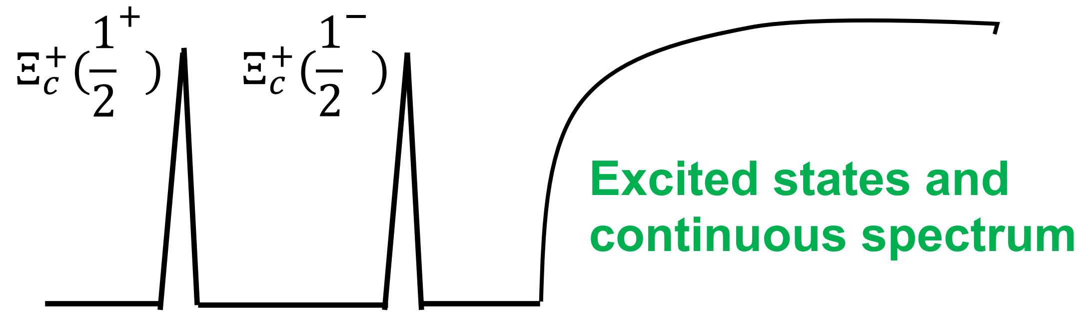
Hadron level = **Quark-Gluon level**

Expressed by $A^{(\prime)i}, B^{(\prime)i}$

Operator product expansion (OPE)

Hadron Level: insert Ξ_c





$$\Pi_H^{\mathcal{O}_i}(p,q,k)_{\rm WE} = i^3 \int d^4x\, e^{-i(p-q)\cdot x} \sum_{\pm',\sigma'} \frac{1}{(p-k)^2 - m_{\Xi_c}^{\pm' 2}}$$

$$\times\, \lambda_{\Xi_c}^{\pm'} u^{\pm'}(p-k,\sigma') \boxed{\langle p-k,\sigma',\pm'|\mathcal{O}_i(0)\bar{J}_{\Xi_{cc}}(x)|\pi^-(q)\rangle}$$

$$\underbrace{+\int_{s_{\Xi_c}}^{\infty} ds' \frac{\rho_{\Xi_c}(s',(p-q)^2,P^2)}{s'-(p-k)^2}}_{\text{Excited states and continuous spectrum}},$$

Only depends on

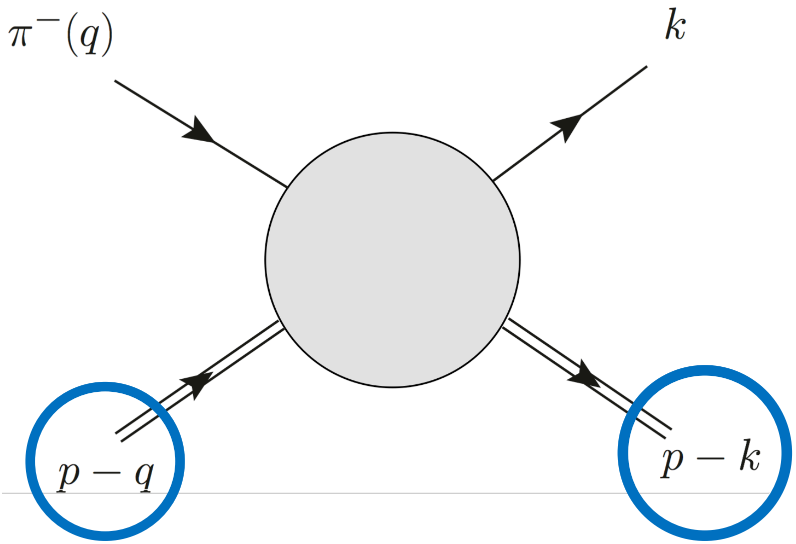
$(p-q)^2$ and $P^2 = (p-k-q)^2$

$p^2 = k^2 = 0 \quad q^2 = m_\pi^2 \approx 0.$

Hadron Level: Quark-hadron duality

Set the external momentums at the deep Euclidean region:

$$(p-k)^2 \sim (p-q)^2 \sim P^2 \ll 0$$



Calculated by OPE

$$\Pi_H^{\mathcal{O}_i}(p,q,k)_{\mathrm{WE}} = \Pi_{QCD}^{\mathcal{O}_i}(p,q,k)_{\mathrm{WE}} = \frac{1}{\pi}\int_{(m_c+m_s)^2}^{\infty} ds' \frac{\mathrm{Im}\Pi_{QCD}^{\mathcal{O}_i}(s',(p-q)^2,P^2)_{\mathrm{WE}}}{s'-(p-k)^2}$$

Threshold to produce Ξ_c

Expressed by dispersion integration

Hadron Level: Quark-hadron duality

Quark-Hadron duality

$$\Pi_H^{\mathcal{O}_i}(p,q,k)_{\rm WE} = \Pi_{QCD}^{\mathcal{O}_i}(p,q,k)_{\rm WE} = \frac{1}{\pi}\int_{(m_c+m_s)^2}^{s_{\Xi_c}} ds' \frac{{\rm Im}\Pi_{QCD}^{\mathcal{O}_i}(s',(p-q)^2,P^2)_{\rm WE}}{s'-(p-k)^2} + \boxed{\frac{1}{\pi}\int_{s_{\Xi_c}}^{\infty} ds' \frac{{\rm Im}\Pi_{QCD}^{\mathcal{O}_i}(s',(p-q)^2,P^2)_{\rm WE}}{s'-(p-k)^2}}$$

$$\int_{s_{\Xi_c}}^{\infty} ds' \frac{\rho_{\Xi_c}(s',(p-q)^2,P^2)}{s'-(p-k)^2}$$

Canceled above s_{Ξ_c} $\quad s_{\Xi_c} > (m_c + m_s)^2$

Borel Transformation for $(p-k)^2$

$$\mathcal{B}_{T'^2}\left[(p-k)^{2n}\right] = 0$$

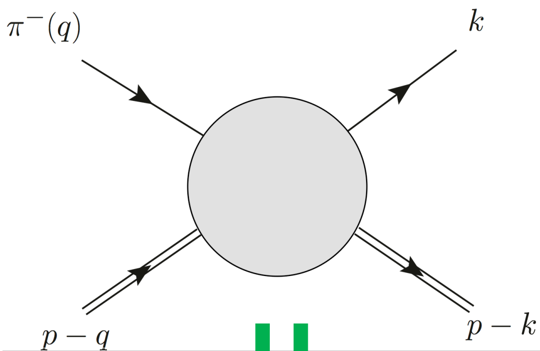
$$\mathcal{B}_{T'^2}\left[\frac{1}{[s'-(p-k)^2]^n}\right] = \frac{1}{(n-1)!}\frac{\exp[-s'/T'^2]}{(p-k)^{2(n-1)}}$$

Excited states (large s') can be suppressed

Hadron Level: Analytical continuity

We have to move the pion to the final state

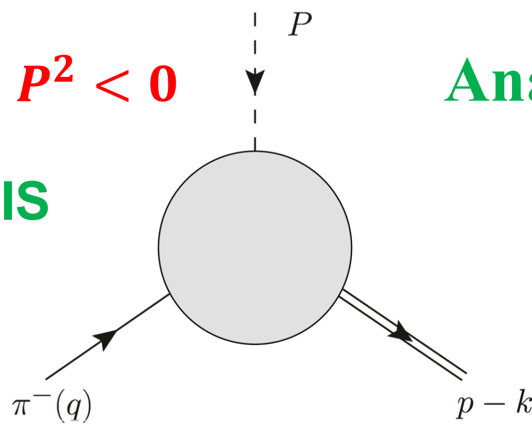
$$\Pi_H^{\mathcal{O}_i}(p,q,k)_{\rm WE} = \frac{1}{\pi}\int_{(m_c+m_s)^2}^{\infty} ds' \frac{{\rm Im}\Pi_{QCD}^{\mathcal{O}_i}(s',(p-q)^2,P^2)_{\rm WE}}{s'-(p-k)^2}$$



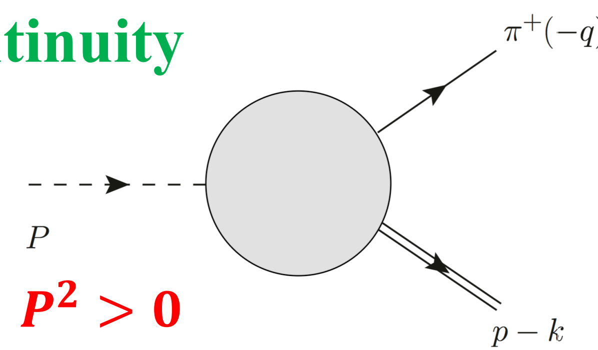
An analytical function of P^2

$P^2 < 0$

Like DIS



Analytical continuity



$P^2 > 0$

Hadron Level: insert Ξ_{cc}

The sum rules equation:

$$\sum_{\pm',\pm,\sigma',\sigma} e^{-m_{\Xi_c}^{\pm'2}/T'^2 - m_{\Xi_{cc}}^{\pm 2}/T^2} \lambda_{\Xi_c}^{\pm'} \lambda_{\Xi_{cc}}^{\pm}$$

$$\times\, u^{\pm'}(p-k,\sigma') \boxed{\langle p-k,\sigma',\pm';\pi^+(-q)|\mathcal{O}_i(0)|p-q,\sigma,\pm\rangle_{\rm WE}}\, \bar{u}^{\pm}(p-q,\sigma)$$

$$= \frac{1}{\pi^2}\int_{(m_c+m_s)^2}^{s_{\Xi_c}} ds' \int_{4m_c^2}^{s_{\Xi_{cc}}} ds\; e^{-s'/T'^2} e^{-s/T^2}\, {\rm Im}^2\Pi_{QCD}^{\mathcal{O}_i}(s',s,P^2).$$

Only depends on P^2

Parameterizaed as:

$$i\; \bar{u}^{\pm'}(p-k,\sigma')\left[A_{1,i}^{\pm'\pm}(P^2) + B_{1,i}^{\pm'\pm}(P^2)\gamma_5 + \underline{A_{2,i}^{\pm'\pm}(P^2)\frac{\not{q}}{m_{\Xi_{cc}}^{\pm}} + B_{2,i}^{\pm'\pm}(P^2)\frac{\not{q}\gamma_5}{m_{\Xi_{cc}}^{\pm}}}\right] u^{\pm}(p-q,\sigma)$$

Two extra terms due to the non-vanishing k

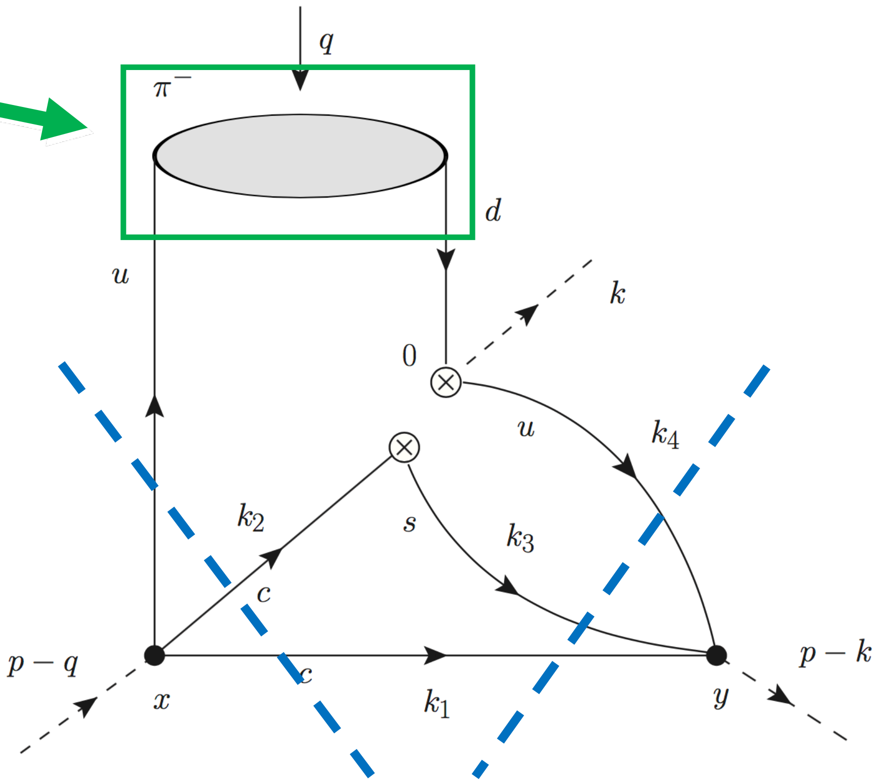
Quark-Gluon Level

$$-2\sqrt{2}\varepsilon_{abc}\varepsilon_{ebc}\int d^4x d^4y\ e^{-i(p-q)\cdot x}e^{i(p-k)\cdot y}$$

$$\times\left[S_Q(y-x)\gamma^\nu C S_Q^T(-x)C(1-\gamma_5)\gamma_\mu C S_s^T(y)C\gamma_5 S_u(y)\gamma^\mu(1-\gamma_5)\right]_{\alpha\beta}(\gamma_\nu\gamma_5)_{\rho\sigma}$$

$$\times\underline{\langle 0|\bar{u}_e^\rho(x)d_a^\beta(0)|\pi^-(q)\rangle}$$

Parameterized by light-cone distribution amplitudes (LCDA)



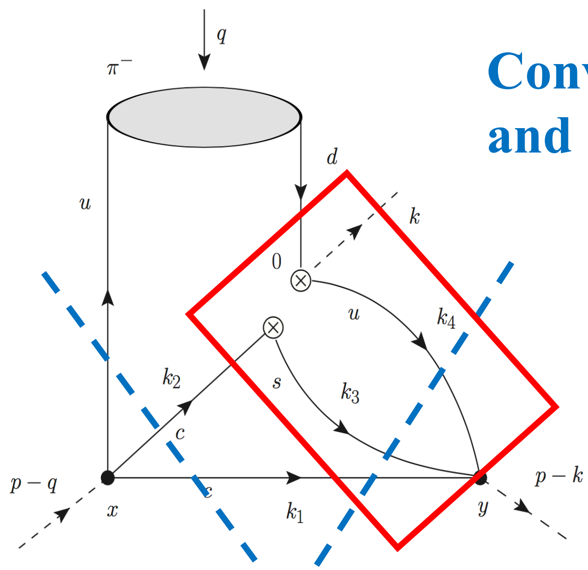
$$\mathrm{Im}^2\Pi_{QCD}^{\mathcal{O}_i}(s', s, P^2)$$

Cutting Rules

$$\frac{1}{l^2-m^2}\to(-2\pi i)\delta(l^2-m^2)$$

Each propagator is set on shell

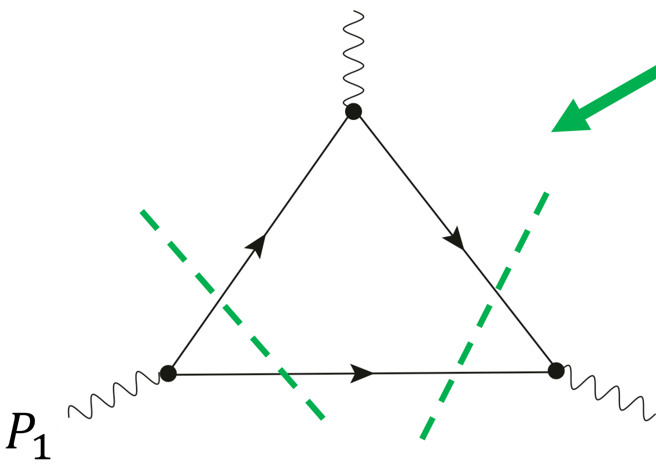
Quark-Gluon Level: Double imaginary part



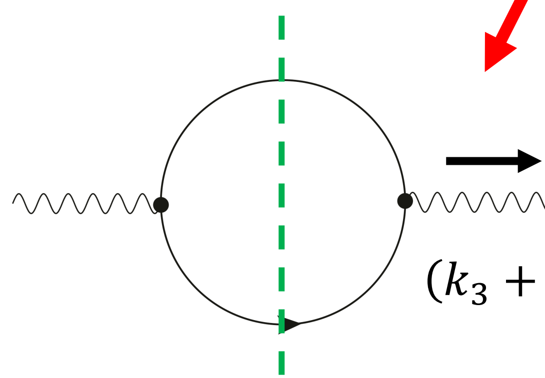
Convolution of an on-shell triangle integration and a two-body phase integration:

$$\propto \int_0^1 du\ \varphi_\pi(u) \int dm_{34}^2 \underbrace{\int d\Phi_\Delta(P_1^2, p_2^2)} \underbrace{\int d\Phi_2(m_{34}^2)}$$

$$\times \cdots\cdots$$



$\otimes$



$(k_3 + k_4)^2 \equiv m_{34}^2$

triangle integration **two-body phase space integration**

Numerical Results

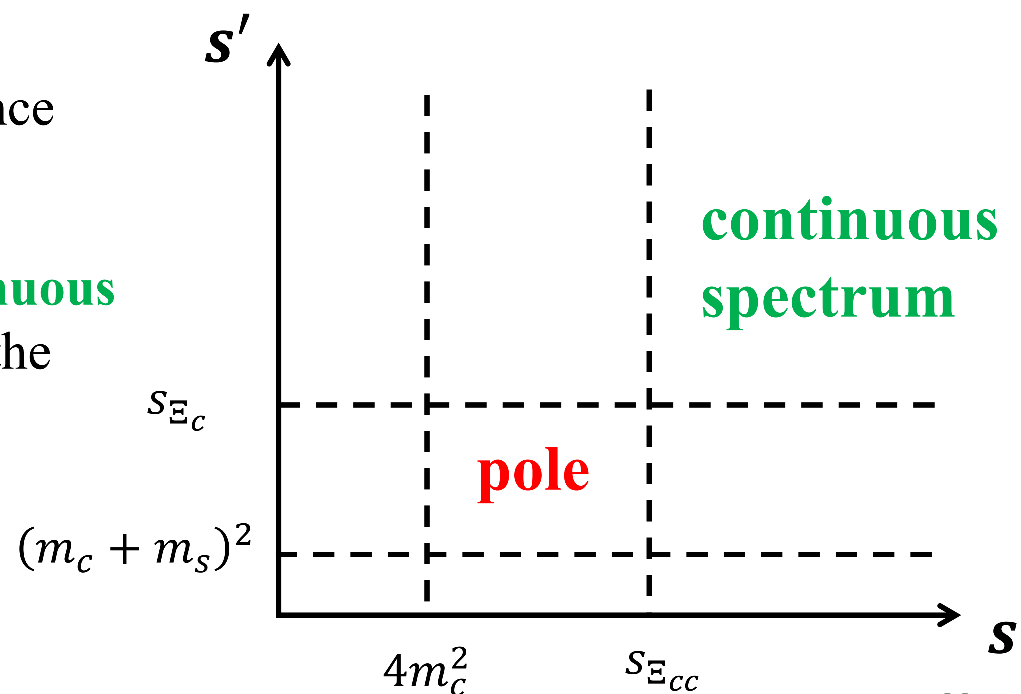
Numerical Result: Borel parameters

$$i\sum_{\pm\pm'} e^{-m^{\pm'2}_{\Xi_c}/T'^2 - m^{\pm 2}_{\Xi_{cc}}/T^2}\lambda^{\pm'}_{\Xi_c}\lambda^{\pm}_{\Xi_{cc}}(\not p_2 + m^{\pm'}_{\Xi_c})\left[A^{\pm'\pm}_{1,i}+B^{\pm'\pm}_{1,i}\gamma_5 + A^{\pm'\pm}_{2,i}\frac{\not q}{m^{\pm}_{\Xi_{cc}}} + B^{\pm'\pm}_{2,i}\frac{\not q\gamma_5}{m^{\pm}_{\Xi_{cc}}}\right](\not p_1 + m_{\Xi_{cc}})$$

$$=\frac{1}{\pi^2}\int_{(m_c+m_s)^2}^{s_{\Xi_c}} ds' \int_{4m_c^2}^{s_{\Xi_{cc}}} ds\; e^{-s'/T'^2} e^{-s/T^2}\mathrm{Im}^2\Pi^{\mathcal{O}_i}_{QCD}(s',s,P^2)_{\mathrm{WE}},$$

The choice of Borel parameter T, T' must satisfy:

1. The result has little dependence on T, T'
2. The contribution from **continuous spectrum** must be less than the **pole** contribution



Numerical Result: Borel parameters

Two assumptions :

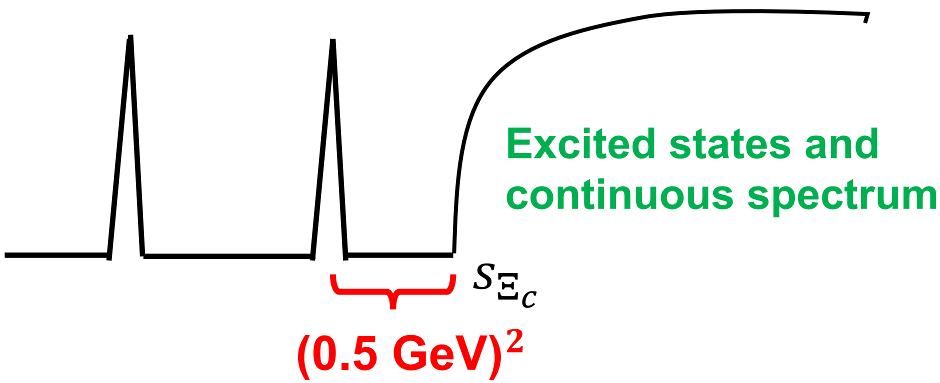
(1) $$\frac{T^2}{T'^2} \approx \frac{M_1^2 - m_1^2}{M_2^2 - m_2}$$

$M_{1(2)}$ is the mass of the initial (final) baryon and $m_{1(2)}$ is the mass of the quark before(after) the weak decay.

Used in the study of D meson decays

P. Ball, V. M. Braun and H. G. Dosch, Phys. Rev. D **44**, 3567-3581 (1991)

(2) $$\left.\begin{aligned} s_{\Xi_{cc}} &= (4.1 \pm 0.1)^2 \ \mathrm{GeV}^2 \\ s_{\Xi_c} &= (3.2 \pm 0.1)^2 \ \mathrm{GeV}^2 \\ s_{\Xi_c'} &= (3.3 \pm 0.1)^2 \ \mathrm{GeV}^2 \end{aligned}\right\}$$



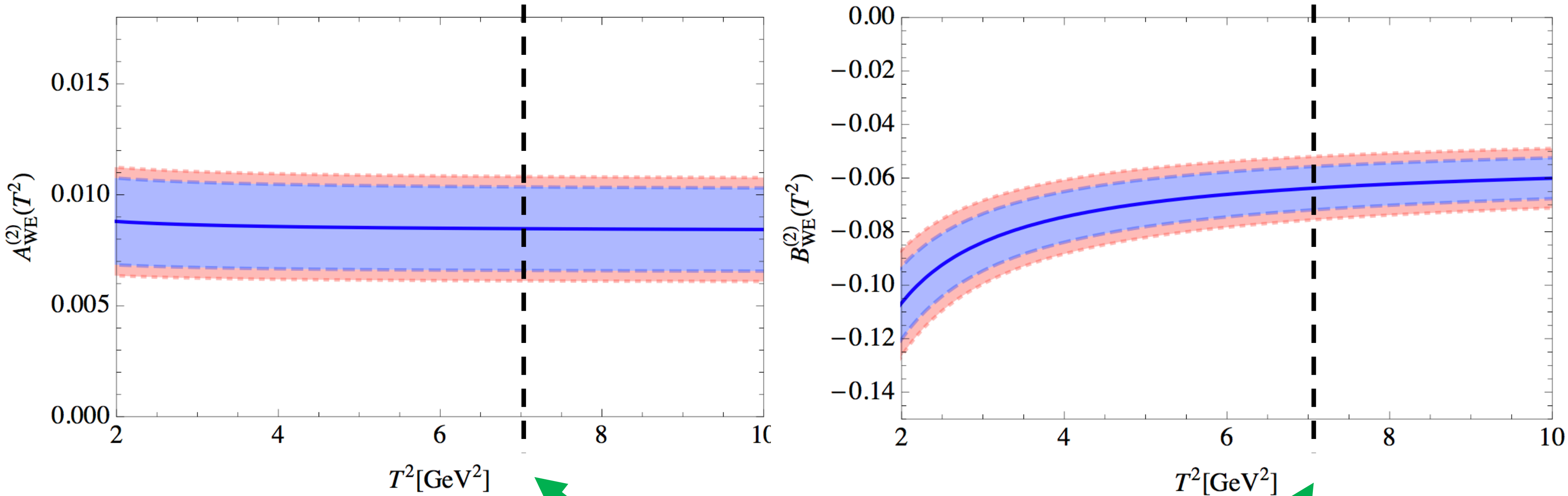
An empirical value from the study of B_c decays

Z. G. Wang, Eur. Phys. J. A **49**, 131 (2013)

Numerical Result: Borel parameters

Blue band: uncertainty of the $s_{\Xi_{cc}}$ and s_{Ξ_c}

Red band: uncertainty of MC integration



Use " Pole > Continuous" to determine the upper bound.

Numerical Result: W-exchange Amplitudes

$$6 < T^2 < 8\ \mathrm{GeV}^2 \text{ for } \Xi_{cc}^{++} \to \Xi_c^{+}\pi^{+}$$

$$5 < T^2 < 7\ \mathrm{GeV}^2 \text{ for } \Xi_{cc}^{++} \to \Xi_c^{+\prime}\pi^{+}$$

$$s_{\Xi_{cc}} = (4.1 \pm 0.1)^2\ \mathrm{GeV}^2$$

$$s_{\Xi_c} = (3.2 \pm 0.1)^2\ \mathrm{GeV}^2$$

$$s_{\Xi_c'} = (3.3 \pm 0.1)^2\ \mathrm{GeV}^2$$

The uncertainties are used to evaluate the numerical error.

$\Xi_{cc}^{++} \to \Xi_c^{+}\pi^{+}$	Twist-2	Twist-3p	Twist-3σ	Total
A_{WE}	0.0084 ± 0.0024	-0.077 ± 0.01	-0.056 ± 0.002	-0.124 ± 0.011
B_{WE}	-0.064 ± 0.01	0.052 ± 0.01	0.165 ± 0.025	0.153 ± 0.029

$\Xi_{cc}^{++} \to \Xi_c^{+\prime}\pi^{+}$	Twist-2	Twist-3p	Twist-3σ	Total
A'_{WE}	0.0027 ± 0.0005	0.0089 ± 0.002	-0.018 ± 0.0003	-0.0062 ± 0.002
B'_{WE}	0.0023 ± 0.0006	0.052 ± 0.016	0.011 ± 0.003	0.066 ± 0.016

Numerical Result: W-exchange Amplitudes

$$\langle \Xi_c^{+(\prime)}(p-q)\pi^+(q)|\mathcal{H}_{\rm eff}(0)|\Xi_{cc}^{++}(p)\rangle_{\rm fac,nf} = i\ \bar{u}(p-q)\left[A^{(\prime)\rm fac,nf} + B^{(\prime)\rm fac,nf}\gamma_5\right]u(p)$$

fac+nf

$\Xi_{cc}^{++} \to \Xi_c^{+}\pi^+$	$A^{\rm fac}$	$A^{\rm nf}$	$A^{\rm tot}$	$B^{\rm fac}$	$B^{\rm nf}$	$B^{\rm tot}$
This work	$--$	-16.67 ± 1.41	$--$	$--$	20.47 ± 3.89	$--$
QCDSR	-8.74 ± 2.91	$--$	$--$	16.76 ± 5.36	$--$	$--$
LFQM + PM	7.40	-10.79	-3.38	15.06	-18.91	-3.85
3LQM	-8.13	10.50	3.37	-12.97	18.53	5.56
NRQM + PM	7.38	0	7.38	16.77	24.95	41.72
HQET + PM	9.52	0	9.52	19.45	24.95	44.40
$\Xi_{cc}^{++} \to \Xi_c^{+\prime}\pi^+$	$A^{\prime\rm fac}$	$A^{\prime\rm nf}$	$A^{\prime\rm tot}$	$B^{\prime\rm fac}$	$B^{\prime\rm nf}$	$B^{\prime\rm tot}$
This work	$--$	-0.83 ± 0.28	$--$	$--$	8.86 ± 2.16	$--$
QCDSR	-3.55 ± 0.68	$--$	$--$	34.13 ± 11.6	$--$	$--$
LFQM + PM	4.49	-0.04	4.45	48.50	-0.06	48.44
3LQM	-4.34	-0.11	-4.45	-37.59	-1.37	-38.96
NRQM + PM	4.29	0	4.29	53.65	0	53.65
HQET + PM	5.10	0	5.10	62.37	0	62.37

in unit $10^{-2} G_F\ \text{GeV}^2$

Numerical Result: Branching fraction

"fac" from literature and "nf" from this work

Method	A^{tot}	B^{tot}	$\mathcal{B}(\Xi_{cc}^{++} \to \Xi_c^+ \pi^+)$	A'^{tot}	B'^{tot}	$\mathcal{B}(\Xi_{cc}^{++} \to \Xi_c^{+\prime} \pi^+)$	$\mathcal{B}'/\mathcal{B}$
QCDSR+LCSR	-25.4 ± 4.32	37.23 ± 9.25	40 ± 14 %	-4.38 ± 0.96	42.99 ± 13.76	3.91 ± 2.5 %	0.098 ± 0.14
LFQM+LCSR	-9.27 ± 1.41	35.53 ± 3.89	7.54 ± 2.22 %	3.66 ± 0.28	57.36 ± 2.16	5.83 ± 0.5 %	0.77 ± 0.42
3LCQM+LCSR	-24.8 ± 1.41	7.5 ± 3.89	35.55 ± 4.29 %	-5.17 ± 0.28	-28.73 ± 2.16	2.75 ± 0.35 %	0.08 ± 0.02
NRQM+LCSR	-9.29 ± 1.41	37.24 ± 3.89	7.82 ± 2.25 %	3.46 ± 0.28	62.51 ± 2.16	6.70 ± 0.54 %	0.85 ± 0.44
HQET+LCSR	-7.18 ± 1.41	39.92 ± 3.89	6.22 ± 1.94 %	4.27 ± 0.28	71.23 ± 2.16	8.85 ± 0.62 %	$\boxed{1.42 \pm 0.78}$
LFQM+PM	-3.83	3.85	0.69 %	4.45	48.44	4.65 %	6.74
3LCQM	3.37	5.56	0.71 %	-4.45	-38.96	3.39 %	4.77
HQET+PM	7.38	41.72	6.64 %	4.29	53.65	5.39 %	0.81
NRQM+PM	9.52	44.40	9.19 %	5.1	62.37	7.34 %	0.8
FSR($\eta = 1.0$)	$--$	$--$	7.11%	$--$	$--$	4.72 %	0.66
FSR($\eta = 1.5$)	$--$	$--$	8.48%	$--$	$--$	4.72 %	0.56
FSR($\eta = 2.0$)	$--$	$--$	10.75%	$--$	$--$	4.74 %	0.44

Final state rescattering

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Consistent with experiment

$$(\mathcal{B}'/\mathcal{B})_{\text{expt}} = 1.41 \pm 0.17 \pm 0.1$$

The interference between B^{fac} and B^{nf} tends to be constructive

Summary

- The W-exchange amplitudes of $\Xi_{cc}^{++} \to \Xi_c^{+(\prime)}\pi^+$ are calculated by light-cone sum rules.

- The possible branching fractions are obtained by combining our W-exchange amplitudes with the factorizable amplitudes from various theoretical works in the literature.

- One of the possible branching fractions is consistent with the experimental result. The interference between B^{fac} and B^{nf} tends to be constructive.

Thank you for your attention !