



Doubly heavy baryon decays in Light-Front Quark Model

Zhen-Xing Zhao
Shanghai Jiao Tong University
2017. 10

HFCPV-2017@CCNU

arXiv:1707.02834
[Wei Wang, Fu-Sheng Yu and Zhen-Xing Zhao](#)

Outline



Basic ideas

Overview of LFQM

Form factors

Semi-leptonic decays

Non-leptonic decays

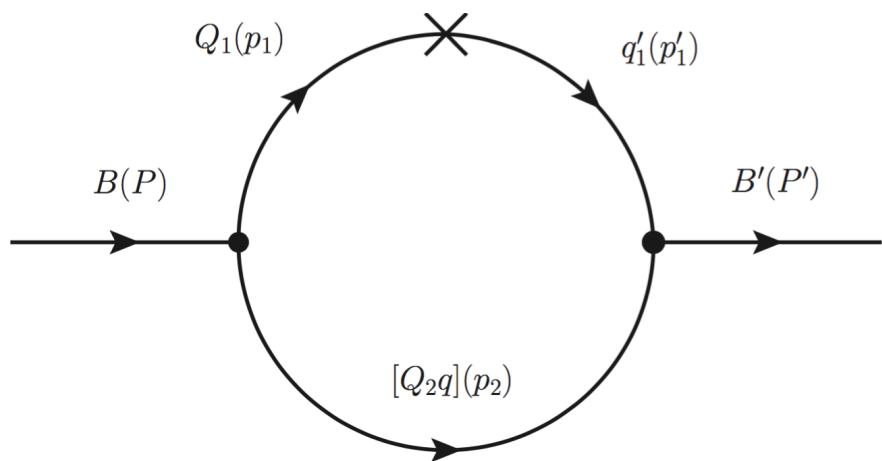
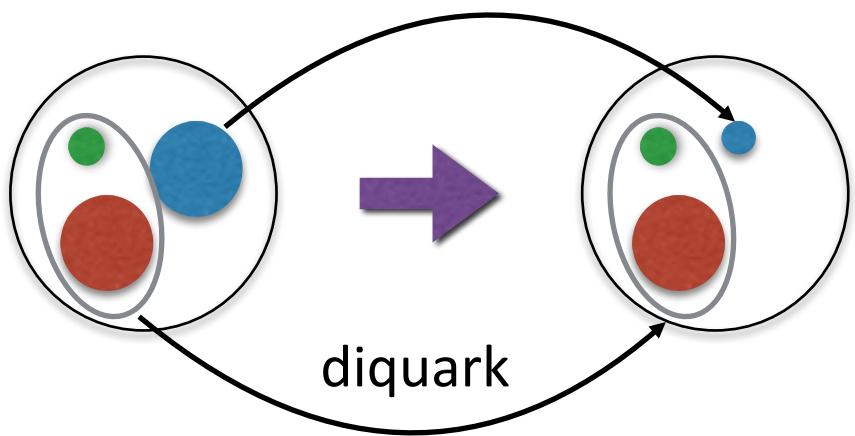
Summary and Outlook



basic ideas

doubly heavy baryon decays: $Q_1 Q_2 q \rightarrow q'_1 Q_2 q$

- Weak decay: $Q_1 \rightarrow q'_1$, spectator $[Q_2 q]$: diquark ($J^P = 0^+, 1^+$)
- Ground state: $L = 0$





- cc sector

$$\Xi_{cc}^{++}(ccu) \rightarrow \Lambda_c^+(dcu)/\Sigma_c^+(dcu)/\Xi_c^+(scu)/\Xi_c'^+(scu),$$

$$\Xi_{cc}^+(ccd) \rightarrow \Sigma_c^0(dcd)/\Xi_c^0(scd)/\Xi_c'^0(scd),$$

$$\Omega_{cc}^+(ccs) \rightarrow \Xi_c^0(dcs)/\Xi_c'^0(dcs)/\Omega_c^0(scs),$$

bb sector: ...

bc sector: ...

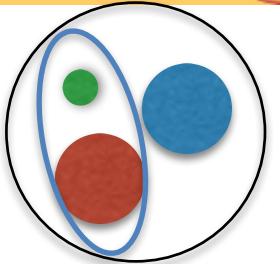


Overview of LFQM

H. W. Ke, X. Q. Li and Z. T. Wei, Phys. Rev. D 77, 014020 (2008)

H. W. Ke, X. H. Yuan, X. Q. Li, Z. T. Wei and Y. X. Zhang, Phys. Rev. D 86, 114005 (2012)

Overview of LFQM



$$\begin{aligned} |B(P, S, S_z)\rangle &= \int \{d^3 p_1\} \{d^3 p_2\} 2(2\pi)^3 \delta^3(\tilde{P} - \tilde{p}_1 - \tilde{p}_2) \\ &\quad \times \sum_{\lambda_1, \lambda_2} \boxed{\Psi^{SS_z}(\tilde{p}_1, \tilde{p}_2, \lambda_1, \lambda_2)} |q_1(p_1, \lambda_1)[di](p_2, \lambda_2)\rangle \end{aligned}$$

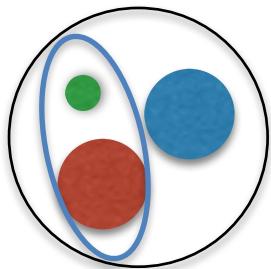
$$\tilde{p} = (p^+, p_\perp), \quad \{d^3 p\} \equiv \frac{dp^+ d^2 p_\perp}{2(2\pi)^3}, \quad \delta^3(\tilde{p}) = \delta(p^+) \delta^2(p_\perp).$$

$$p^- = \frac{p_\perp^2 + m^2}{p^+}$$



$$p_1^+ = x_1 P^+, \quad p_2^+ = x_2 P^+, \quad x_1 + x_2 = 1$$

$$\vec{p}_{1\perp} = x_1 \vec{P}_\perp - \vec{k}_\perp, \quad \vec{p}_{2\perp} = x_2 \vec{P}_\perp + \vec{k}_\perp$$



P :4-momentum of baryon

M :Mass of baryon

p_1, p_2 :4-Momentum of $Q_1, [Q_2 q]$

m_1, m_2 :Masses of $Q_1, [Q_2 q]$

$$\bar{P} \equiv p_1 + p_2$$

$$M_0^2 \equiv \bar{P}^2$$



In \bar{P} rest frame,

$$\bar{P}^\mu = (M_0, \vec{0})$$

e_1, e_2 : Energy of Q_1 , $[Q_2 q]$

\vec{k}_\perp, k_z : 3-momentum of $[Q_2 q]$

$-\vec{k}_\perp, -k_z$: 3-momentum of Q_1



$$\begin{aligned}
 M_0^2 &= \bar{P}^+ \bar{P}^- - \vec{P}_\perp^2 \\
 &= P^+ (p_1^- + p_2^-) \\
 &= P^+ \left(\frac{m_1^2 + \vec{k}_\perp^2}{p_1^+} + \frac{m_2^2 + \vec{k}_\perp^2}{p_2^+} \right) \\
 &= \frac{m_1^2 + \vec{k}_\perp^2}{x_1} + \frac{m_2^2 + \vec{k}_\perp^2}{x_2}
 \end{aligned}$$

$$\begin{cases} e_1 + e_2 = M_0 \\ e_1^2 = m_1^2 + \vec{k}_\perp^2 + k_z^2 \implies e_1, e_2, k_z \\ e_2^2 = m_2^2 + \vec{k}_\perp^2 + k_z^2 \end{cases}$$

Overview of LFQM



$$\Psi^{SS_z}(\tilde{p}_1, \tilde{p}_2, \lambda_1, \lambda_2) = \sum_{s_1, s_2} \langle \lambda_1 | \mathcal{R}_M^\dagger(x_1, -k_\perp, m_1) | s_1 \rangle \langle \lambda_2 | \mathcal{R}_M^\dagger(x_2, k_\perp, m_2) | s_2 \rangle$$

$$\times \langle \frac{1}{2} s_1; s_{[di]} s_2 | \frac{1}{2} S_z \rangle \varphi(x, k_\perp),$$

↓

$$\frac{1}{\sqrt{2(p_1 \cdot \bar{P} + m_1 M_0)}} \bar{u}(p_1, \lambda_1) \Gamma u(\bar{P}, S_z)$$

$$0^+ \quad \Gamma = 1$$

$$1^+ \quad \Gamma = -\frac{1}{\sqrt{3}} \gamma_5 \not{\epsilon}^*(p_2, \lambda_2)$$

H. W. Ke, X. H. Yuan, X. Q. Li, Z. T. Wei and Y. X. Zhang, Phys. Rev. D 86, 114005 (2012)

Overview of LFQM



$$\Psi^{SS_z}(\tilde{p}_1, \tilde{p}_2, \lambda_1, \lambda_2) = \sum_{s_1, s_2} \langle \lambda_1 | \mathcal{R}_M^\dagger(x_1, -k_\perp, m_1) | s_1 \rangle \langle \lambda_2 | \mathcal{R}_M^\dagger(x_2, k_\perp, m_2) | s_2 \rangle$$

$$\times \langle \frac{1}{2} s_1; s_{[di]} s_2 | \frac{1}{2} S_z \rangle \varphi(x, k_\perp),$$

$\varphi(x, k_\perp)$

$$0^+ \quad A = 1$$

$$1^+ \quad A = \sqrt{\frac{3(M_0 m_1 + p_1 \cdot \bar{P})}{3M_0 m_1 + p_1 \cdot \bar{P} + (2p_1 \cdot p_2 p_2 \cdot \bar{P})/m_2^2}}$$

$$\phi(x, \vec{k}_\perp) = 4 \left(\frac{\pi}{\beta^2} \right)^{3/4} \sqrt{\frac{e_1 e_2}{x_1 x_2 M_0}} \exp \left(-\frac{\vec{k}_\perp^2 + k_z^2}{2\beta^2} \right)$$



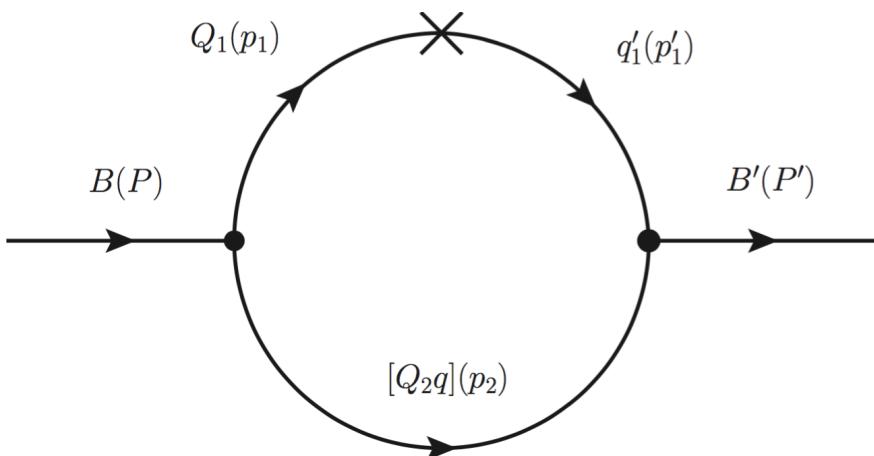
Form factors

Form factors



$$\begin{aligned} \langle B'(P', S'_z) | (V - A)_\mu | B(P, S_z) \rangle &= \bar{u}(P', S'_z) \left[\gamma_\mu f_1(q^2) + i\sigma_{\mu\nu} \frac{q^\nu}{M} f_2(q^2) + \frac{q_\mu}{M} f_3(q^2) \right] u(P, S_z) \\ &\quad - \bar{u}(P', S'_z) \left[\gamma_\mu g_1(q^2) + i\sigma_{\mu\nu} \frac{q^\nu}{M} g_2(q^2) + \frac{q_\mu}{M} g_3(q^2) \right] \gamma_5 u(P, S_z) \end{aligned}$$

$$\begin{aligned} \langle B'(P', S'_z) | (V - A)_\mu | B(P, S_z) \rangle &= \int \{d^3 p_2\} \frac{\phi'^*(x', k'_\perp) \phi(x, k_\perp)}{2\sqrt{p_1^+ p_1'^+} (p_1 \cdot \bar{P} + m_1 M_0) (p_1' \cdot \bar{P}' + m_1' M_0')} \\ &\quad \times \bar{u}(\bar{P}', S'_z) \bar{\Gamma}'(\not{p}_1' + m_1') \gamma_\mu (1 - \gamma_5) (\not{p}_1 + m_1) \Gamma u(\bar{P}, S_z) \end{aligned}$$





Form factors

$$f_1(q^2) = \int \frac{dx_2 d^2 k_\perp}{2(2\pi)^3} \frac{\phi'(x', \vec{k}'_\perp) \phi(x, \vec{k}_\perp) [\vec{k}_\perp \cdot \vec{k}'_\perp + (x_1 M_0 + m_1)(x'_1 M'_0 + m'_1)]}{\sqrt{[(m_1 + x_1 M_0)^2 + \vec{k}_\perp^2] [(m'_1 + x'_1 M'_0)^2 + \vec{k}'_\perp^2]}} \quad 0^+$$

$$g_1(q^2) = \int \frac{dx_2 d^2 k_\perp}{2(2\pi)^3} \frac{\phi'(x', \vec{k}'_\perp) \phi(x, \vec{k}_\perp) [-\vec{k}_\perp \cdot \vec{k}'_\perp + (x_1 M_0 + m_1)(x'_1 M'_0 + m'_1)]}{\sqrt{[(m_1 + x_1 M_0)^2 + \vec{k}_\perp^2] [(m'_1 + x'_1 M'_0)^2 + \vec{k}'_\perp^2]}}$$

$$\frac{f_2(q^2)}{M} = \frac{1}{\vec{q}_\perp^2} \int \frac{dx_2 d^2 k_\perp}{2(2\pi)^3} \frac{\phi'(x', \vec{k}'_\perp) \phi(x, \vec{k}_\perp) [-(m_1 + x_1 M_0) \vec{k}'_\perp \cdot \vec{q}_\perp + (m'_1 + x'_1 M'_0) \vec{k}_\perp \cdot \vec{q}_\perp]}{\sqrt{[(m_1 + x_1 M_0)^2 + \vec{k}_\perp^2] [(m'_1 + x'_1 M'_0)^2 + \vec{k}'_\perp^2]}}$$

$$\frac{g_2(q^2)}{M} = \frac{1}{\vec{q}_\perp^2} \int \frac{dx_2 d^2 k_\perp}{2(2\pi)^3} \frac{\phi'(x', \vec{k}'_\perp) \phi(x, \vec{k}_\perp) [-(m_1 + x_1 M_0) \vec{k}'_\perp \cdot \vec{q}_\perp - (m'_1 + x'_1 M'_0) \vec{k}_\perp \cdot \vec{q}_\perp]}{\sqrt{[(m_1 + x_1 M_0)^2 + \vec{k}_\perp^2] [(m'_1 + x'_1 M'_0)^2 + \vec{k}'_\perp^2]}}$$

$$x_2^{(\prime)} \equiv x^{(\prime)} = 1 - x_1^{(\prime)}$$

$$x'_1 = x_1 = 1 - x_2$$

$$\vec{k}'_\perp = \vec{k}_\perp + x_2 \vec{q}_\perp$$

$$q^2 = -\vec{q}_\perp^2$$

$\mathbf{q}^+ = 0$



Form factors

$$\begin{aligned}
f_1(q^2) &= \frac{1}{8P^+P'^+} \int \frac{dx_2 d^2 k_\perp}{2(2\pi)^3} \frac{\varphi'(x', k'_\perp) \varphi(x, k_\perp)}{6\sqrt{x_1 x'_1 (p_1 \cdot \bar{P} + m_1 M_0)(p'_1 \cdot \bar{P}' + m'_1 M'_0)}}, \\
&\quad \times \text{Tr}[(\bar{P} + M_0)\gamma^+(\bar{P}' + M'_0)\gamma_5\gamma_\alpha(\not{p}_1' + m'_1)\gamma^+(\not{p}_1 + m_1)\gamma_5\gamma_\beta](\frac{p_2^\alpha p_2^\beta}{m_2^2} - g^{\alpha\beta}), \tag{1+} \\
g_1(q^2) &= \frac{1}{8P^+P'^+} \int \frac{dx_2 d^2 k_\perp}{2(2\pi)^3} \frac{\varphi'(x', k'_\perp) \varphi(x, k_\perp)}{2\sqrt{x_1 x'_1 (p_1 \cdot \bar{P} + m_1 M_0)(p'_1 \cdot \bar{P}' + m'_1 M'_0)}} \\
&\quad \times \text{Tr}[(\bar{P} + M_0)\gamma^+\gamma_5(\bar{P}' + M'_0)\gamma_5\gamma_\alpha(\not{p}_1' + m'_1)\gamma^+\gamma_5(\not{p}_1 + m_1)\gamma_5\gamma_\beta](\frac{p_2^\alpha p_2^\beta}{m_2^2} - g^{\alpha\beta}), \\
\frac{f_2(q^2)}{M} &= -\frac{1}{8P^+P'^+} \frac{i q_\perp^i}{q_\perp^2} \int \frac{dx_2 d^2 k_\perp}{2(2\pi)^3} \frac{\varphi'(x', k'_\perp) \varphi(x, k_\perp)}{2\sqrt{x_1 x'_1 (p_1 \cdot \bar{P} + m_1 M_0)(p'_1 \cdot \bar{P}' + m'_1 M'_0)}} \\
&\quad \times \text{Tr}[(\bar{P} + M_0)\sigma^{i+}(\bar{P}' + M'_0)\gamma_5\gamma_\alpha(\not{p}_1' + m'_1)\gamma^+(\not{p}_1 + m_1)\gamma_5\gamma_\beta](\frac{p_2^\alpha p_2^\beta}{m_2^2} - g^{\alpha\beta}), \\
\frac{g_2(q^2)}{M} &= \frac{1}{8P^+P'^+} \frac{i q_\perp^i}{q_\perp^2} \int \frac{dx_2 d^2 k_\perp}{2(2\pi)^3} \frac{\varphi'(x', k'_\perp) \varphi(x, k_\perp)}{2\sqrt{x_1 x'_1 (p_1 \cdot \bar{P} + m_1 M_0)(p'_1 \cdot \bar{P}' + m'_1 M'_0)}} \\
&\quad \times \text{Tr}[(\bar{P} + M_0)\sigma^{i+}\gamma_5(\bar{P}' + M'_0)\gamma_5\gamma_\alpha(\not{p}_1' + m'_1)\gamma^+\gamma_5(\not{p}_1 + m_1)\gamma_5\gamma_\beta](\frac{p_2^\alpha p_2^\beta}{m_2^2} - g^{\alpha\beta}).
\end{aligned}$$

Form factors



baryons	Ξ_{cc}^{++}	Ξ_{cc}^+	Ω_{cc}^+	Ξ_{bc}^+	Ξ_{bc}^0	Ω_{bc}^0	Ξ_{bb}^0	Ξ_{bb}^-	Ω_{bb}^-
masses	3.621 [9]	3.621 [9]	3.738 [58]	6.943 [58]	6.943 [58]	6.998 [58]	10.143[58]	10.143 [58]	10.273[58]
lifetimes	300 [21]	100 [21]	270 [61]	244 [46]	93 [46]	220 [61]	370 [46]	370 [46]	800[61]

TABLE I: Masses of quarks and diquarks adopted in this work

m_u	m_d	m_s	m_c	m_{cu}	m_{cd}	m_{cs}
0.25	0.25	0.37	1.4	1.4 + 0.25	1.4 + 0.25	1.4 + 0.37

TABLE II: The parameters β 's adopted in this work

$\beta_{c[cu]}, \beta_{c[cd]}, \beta_{c[cs]}$	$\beta_{d[cu]}, \beta_{d[cd]}, \beta_{d[cs]}$	$\beta_{s[cu]}, \beta_{s[cd]}, \beta_{s[cs]}$
0.753	0.470	0.535

$$F(q^2) = \frac{F(0)}{1 - \frac{q^2}{m_{\text{fit}}^2} + \delta(\frac{q^2}{m_{\text{fit}}^2})^2}$$

Form factors



F	$F(0)$	m_{fit}	δ	F	$F(0)$	m_{fit}	δ
$f_1^{\Xi_{cc}^{++} \rightarrow \Lambda_c^+}$	0.653	1.72	0.27	$f_2^{\Xi_{cc}^{++} \rightarrow \Lambda_c^+}$	-0.738	1.56	0.32
$g_1^{\Xi_{cc}^{++} \rightarrow \Lambda_c^+}$	0.533	2.03	0.38	$g_2^{\Xi_{cc}^{++} \rightarrow \Lambda_c^+}$	-0.053	1.12	1.10
$f_1^{\Xi_{cc}^{++} \rightarrow \Sigma_c^+}$	0.653	1.72	0.27	$f_2^{\Xi_{cc}^{++} \rightarrow \Sigma_c^+}$	-0.738	1.56	0.32
$g_1^{\Xi_{cc}^{++} \rightarrow \Sigma_c^+}$	0.533	2.03	0.38	$g_2^{\Xi_{cc}^{++} \rightarrow \Sigma_c^+}$	-0.053	1.12	1.10
$f_1^{\Xi_{cc}^{++} \rightarrow \Xi_c^+}$	0.754	1.84	0.25	$f_2^{\Xi_{cc}^{++} \rightarrow \Xi_c^+}$	-0.782	1.67	0.30
$g_1^{\Xi_{cc}^{++} \rightarrow \Xi_c^+}$	0.620	2.16	0.35	$g_2^{\Xi_{cc}^{++} \rightarrow \Xi_c^+}$	-0.080	1.29	0.52
$f_1^{\Xi_{cc}^{++} \rightarrow \Xi_c'^+}$	0.754	1.84	0.25	$f_2^{\Xi_{cc}^{++} \rightarrow \Xi_c'^+}$	-0.782	1.67	0.30
$g_1^{\Xi_{cc}^{++} \rightarrow \Xi_c'^+}$	0.620	2.16	0.35	$g_2^{\Xi_{cc}^{++} \rightarrow \Xi_c'^+}$	-0.080	1.29	0.52

Form factors



F	$F(0)$	m_{fit}	δ	F	$F(0)$	m_{fit}	δ
$f_1^{\Xi_{cc}^{++} \rightarrow \Lambda_c^+}$	0.637	1.49	0.37	$f_2^{\Xi_{cc}^{++} \rightarrow \Lambda_c^+}$	0.725	1.53	0.32
$g_1^{\Xi_{cc}^{++} \rightarrow \Lambda_c^+}$	-0.167	1.99	0.23	$g_2^{\Xi_{cc}^{++} \rightarrow \Lambda_c^+}$	-0.028*	2.03*	2.62*
$f_1^{\Xi_{cc}^{++} \rightarrow \Sigma_c^+}$	0.637	1.49	0.37	$f_2^{\Xi_{cc}^{++} \rightarrow \Sigma_c^+}$	0.725	1.53	0.32
$g_1^{\Xi_{cc}^{++} \rightarrow \Sigma_c^+}$	-0.167	1.99	0.23	$g_2^{\Xi_{cc}^{++} \rightarrow \Sigma_c^+}$	-0.028*	2.03*	2.62*
$f_1^{\Xi_{cc}^{++} \rightarrow \Xi_c^+}$	0.739	1.58	0.36	$f_2^{\Xi_{cc}^{++} \rightarrow \Xi_c^+}$	0.801	1.62	0.31
$g_1^{\Xi_{cc}^{++} \rightarrow \Xi_c^+}$	-0.198	2.10	0.21	$g_2^{\Xi_{cc}^{++} \rightarrow \Xi_c^+}$	-0.018*	1.62*	1.37*
$f_1^{\Xi_{cc}^{++} \rightarrow \Xi_c'^+}$	0.739	1.58	0.36	$f_2^{\Xi_{cc}^{++} \rightarrow \Xi_c'^+}$	0.801	1.62	0.31
$g_1^{\Xi_{cc}^{++} \rightarrow \Xi_c'^+}$	-0.198	2.10	0.21	$g_2^{\Xi_{cc}^{++} \rightarrow \Xi_c'^+}$	-0.018*	1.62*	1.37*

1⁺

Form factors



$$\Xi_{cc}^{++} = \frac{1}{\sqrt{2}} \left[\left(-\frac{\sqrt{3}}{2} c^1 (c^2 u)_S + \frac{1}{2} c^1 (c^2 q)_A \right) + (c^1 \leftrightarrow c^2) \right]$$

$$\Lambda_c^+ = -\frac{1}{2} d(cu)_S + \frac{\sqrt{3}}{2} d(cu)_A$$

$$\langle \Lambda_c^+ | (V - A)_\mu | \Xi_{cc}^{++} \rangle = c_S \langle d[cu]_S | (V - A)_\mu | c[cu]_S \rangle + c_A \langle d[cu]_A | (V - A)_\mu | c[cu]_A \rangle$$

$$c_S = c_A = \sqrt{6}/4$$

$$F(q^2) = c_S F^S(q^2) + c_A F^A(q^2)$$

$$F = f_{1,2}, g_{1,2}$$

Form factors



	$\langle q_1[cq]_S (V - A)_\mu c[cq]_S \rangle$	$\langle q_1[cq]_A (V - A)_\mu c[cq]_A \rangle$
$\langle \Lambda_c^+ (V - A)_\mu \Xi_{cc}^{++} \rangle$	$\frac{\sqrt{6}}{4}$	$\frac{\sqrt{6}}{4}$
$\langle \Sigma_c^+ (V - A)_\mu \Xi_{cc}^{++} \rangle$	$-\frac{3\sqrt{2}}{4}$	$\frac{\sqrt{2}}{4}$
$\langle \Xi_c^+ (V - A)_\mu \Xi_{cc}^{++} \rangle$	$\frac{\sqrt{6}}{4}$	$\frac{\sqrt{6}}{4}$
$\langle \Xi_c'^+ (V - A)_\mu \Xi_{cc}^{++} \rangle$	$-\frac{3\sqrt{2}}{4}$	$\frac{\sqrt{2}}{4}$
$\langle \Sigma_c^0 (V - A)_\mu \Xi_{cc}^+ \rangle$	$-\frac{3}{2}$	$\frac{1}{2}$
$\langle \Xi_c^0 (V - A)_\mu \Xi_{cc}^+ \rangle$	$\frac{\sqrt{6}}{4}$	$\frac{\sqrt{6}}{4}$
$\langle \Xi_c'^0 (V - A)_\mu \Xi_{cc}^+ \rangle$	$-\frac{3\sqrt{2}}{4}$	$\frac{\sqrt{2}}{4}$
$\langle \Xi_c^0 (V - A)_\mu \Omega_{cc}^+ \rangle$	$-\frac{\sqrt{6}}{4}$	$-\frac{\sqrt{6}}{4}$
$\langle \Xi_c'^0 (V - A)_\mu \Omega_{cc}^+ \rangle$	$-\frac{3\sqrt{2}}{4}$	$\frac{\sqrt{2}}{4}$
$\langle \Omega_c^0 (V - A)_\mu \Omega_{cc}^+ \rangle$	$-\frac{3}{2}$	$\frac{1}{2}$

C_S

C_A



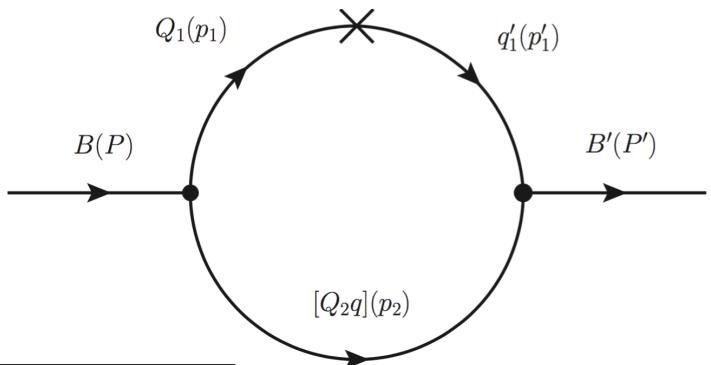
Semi-leptonic decays

Semi-leptonic decays



$$\frac{d\Gamma_L}{d\omega} = \frac{G_F^2 |V_{CKM}|^2}{(2\pi)^3} \frac{q^2 p M'}{12M} (|H_{\frac{1}{2},0}|^2 + |H_{-\frac{1}{2},0}|^2)$$

$$\frac{d\Gamma_T}{d\omega} = \frac{G_F^2 |V_{CKM}|^2}{(2\pi)^3} \frac{q^2 p M'}{12M} (|H_{\frac{1}{2},1}|^2 + |H_{-\frac{1}{2},-1}|^2)$$



channels	Γ / GeV	\mathcal{B}	Γ_L/Γ_T
$\Xi_{cc}^{++} \rightarrow \Lambda_c^+ l^+ \nu_l$	1.05×10^{-14}	4.81×10^{-3}	8.52
$\Xi_{cc}^{++} \rightarrow \Sigma_c^+ l^+ \nu_l$	9.60×10^{-15}	4.38×10^{-3}	1.28
$\Xi_{cc}^{++} \rightarrow \Xi_c^+ l^+ \nu_l$	1.15×10^{-13}	5.25×10^{-2}	9.99
$\Xi_{cc}^{++} \rightarrow \Xi_c' l^+ \nu_l$	1.28×10^{-13}	5.84×10^{-2}	1.42
$\Xi_{cc}^+ \rightarrow \Sigma_c^0 l^+ \nu_l$	1.91×10^{-14}	2.91×10^{-3}	1.28
$\Xi_{cc}^+ \rightarrow \Xi_c^0 l^+ \nu_l$	1.14×10^{-13}	1.73×10^{-2}	9.99
$\Xi_{cc}^+ \rightarrow \Xi_c'^0 l^+ \nu_l$	1.27×10^{-13}	1.93×10^{-2}	1.42
$\Omega_{cc}^+ \rightarrow \Xi_c^0 l^+ \nu_l$	8.06×10^{-15}	3.31×10^{-3}	8.84
$\Omega_{cc}^+ \rightarrow \Xi_c'^0 l^+ \nu_l$	9.34×10^{-15}	3.83×10^{-3}	1.28
$\Omega_{cc}^+ \rightarrow \Omega_c^0 l^+ \nu_l$	2.55×10^{-13}	1.05×10^{-1}	1.42



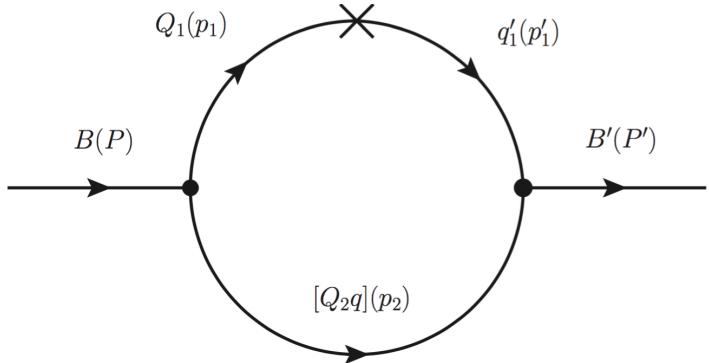
Non-leptonic decays

Non-leptonic decays

$$\Gamma = \frac{p}{8\pi} \left(\frac{(M + M')^2 - m^2}{M^2} |A|^2 + \frac{(M - M')^2 - m^2}{M^2} |B|^2 \right)$$

$$A = -\lambda f_P(M - M') f_1(m^2)$$

$$B = -\lambda f_P(M + M') g_1(m^2)$$



channels	Γ / GeV	\mathcal{B}	channels	Γ / GeV	\mathcal{B}
$\Xi_{cc}^{++} \rightarrow \Lambda_c^+ \pi^+$	8.87×10^{-15}	4.05×10^{-3}	$\Xi_{cc}^{++} \rightarrow \Lambda_c^+ \rho^+$	2.32×10^{-14}	1.06×10^{-2}
$\Xi_{cc}^{++} \rightarrow \Lambda_c^+ a_1^+$	1.02×10^{-14}	4.66×10^{-3}	$\Xi_{cc}^{++} \rightarrow \Lambda_c^+ K^+$	7.79×10^{-16}	3.55×10^{-4}
$\Xi_{cc}^{++} \rightarrow \Lambda_c^+ K^{*+}$	1.09×10^{-15}	4.98×10^{-4}			
$\Xi_{cc}^{++} \rightarrow \Sigma_c^+ \pi^+$	5.75×10^{-15}	2.62×10^{-3}	$\Xi_{cc}^{++} \rightarrow \Sigma_c^+ \rho^+$	2.47×10^{-14}	1.13×10^{-2}
$\Xi_{cc}^{++} \rightarrow \Sigma_c^+ K^{*+}$	1.28×10^{-15}	5.83×10^{-4}	$\Xi_{cc}^{++} \rightarrow \Sigma_c^+ K^+$	4.22×10^{-16}	1.92×10^{-4}
$\Xi_{cc}^{++} \rightarrow \Xi_c^+ \pi^+$	1.57×10^{-13}	7.14×10^{-2}	$\Xi_{cc}^{++} \rightarrow \Xi_c^+ \rho^+$	3.03×10^{-13}	1.38×10^{-1}
$\Xi_{cc}^{++} \rightarrow \Xi_c^+ K^{*+}$	1.19×10^{-14}	5.44×10^{-3}	$\Xi_{cc}^{++} \rightarrow \Xi_c^+ K^+$	1.31×10^{-14}	5.97×10^{-3}
$\Xi_{cc}^{++} \rightarrow \Xi_c'^+ \pi^+$	1.10×10^{-13}	5.00×10^{-2}	$\Xi_{cc}^{++} \rightarrow \Xi_c'^+ \rho^+$	4.12×10^{-13}	1.88×10^{-1}
$\Xi_{cc}^{++} \rightarrow \Xi_c'^+ K^{*+}$	1.87×10^{-14}	8.54×10^{-3}	$\Xi_{cc}^{++} \rightarrow \Xi_c'^+ K^+$	7.48×10^{-15}	3.41×10^{-3}



Summary and outlook



- diquark picture: $J^P = 0^+, 1^+$
- form factors $f_{1,2}$ and $g_{1,2}$
- semi-leptonic processes
- non-leptonic processes
- The $1/2 \rightarrow 3/2$ transition
- Penguin dominated processes

Acknowledgements



Thank you for your attention!