$ccq, \quad q = u, d, s$ $\qquad Q = c.$

$$J_{ccq} = \epsilon_{abc}(Q_a^T C \gamma^\mu Q_b)\gamma_\mu \gamma_5 q_c$$

$$\bar{J}_{ccq} = J_{ccq}^\dagger \gamma_0$$

忽略T 即T(-1) → $= \epsilon_{abc}\, q_c^\dagger \gamma_5 \gamma_\mu^\dagger \gamma_0 (Q_b^\dagger \gamma^{\mu\dagger} \gamma_0\gamma_0 C^\dagger (Q_a^\dagger)^T)$ $\qquad \gamma_0 C^\dagger = C\gamma_0^T$

$$= \epsilon_{abc}\, \bar{q}_c (-\gamma_5)\gamma_\mu (\bar{Q}_b \gamma^\mu C \bar{Q}_a^T)$$

$$= \epsilon_{abc}\, \bar{q}_c \gamma_\mu \gamma_5 (\bar{Q}_b \gamma^\mu C \bar{Q}_a^T)$$

$\langle H(q,s)|\bar{J}|0\rangle = \lambda_H \bar{u}(q,s)$

$\langle 0|J|H(q,s)\rangle = \lambda_H u(q,s)$

两点关联函数

$$\Pi(p) = i\int d^4x\, e^{ip\cdot x}\langle 0|T[J(x)\bar{J}(0)]|0\rangle$$

强子层次：$\Pi(p) = i\int d^4x\, e^{ip\cdot x} \sum_s \int \frac{d^4q}{(2\pi)^4}\frac{i}{q^2-m_H^2}\langle 0|J(x)|H(q,s)\rangle\langle H(q,s)|\bar{J}(0)|0\rangle$

$$= i\int d^4x\, e^{ip\cdot x}\sum_s\int\frac{d^4q}{(2\pi)^4}\frac{i}{q^2-m_H^2}\lambda_H u(q,s)e^{-iq\cdot x}\lambda_H \bar{u}(q,s)$$

$$= i\int\frac{d^4q}{\cancel{(2\pi)^4}}\frac{i}{q^2-m_H^2}\lambda_H^2(\not{q}+m_H)\cancel{(2\pi)^4}\delta^4(p-q)$$

$$= \frac{\lambda_H^2(\not{p}+m_H)}{m_H^2-p^2}$$

若考虑负宇称贡献后 → 2010.07150 (6)式

$$\Pi^{had}(p) = \lambda_+^2\frac{\not{p}+M_+}{M_+^2-p^2} + \lambda_-^2\frac{\not{p}-M_-}{M_-^2-p^2}+\cdots$$

$$\Pi^{QCD}(p) = A(p^2)\not{p} + B(p^2)$$

$$A(p^2) = \int ds\frac{\rho^A(s)}{s-p^2}, \quad B(p^2) = \int ds\frac{\rho^B(s)}{s-p^2}$$

用下面公式可计算 λ_+ (9)式

$$(M_+ + M_-)\,\underline{\underline{\lambda_+^2}}\, \exp(-M_+^2/T_+^2) = \int_\Delta^{s_+} ds\, (M_- \rho^A + \rho^B) \exp(-s/T_+^2)$$

用2010.07150中的(10)式估计22等质量

下面从QCD层次计算$\Pi(p)$

$$\bar{Q}_{a'}^T Q_a^T = (-1)(Q_a \bar{Q}_{a'})^T = (-1)(S^Q_{aa'})^T$$

$$\Pi(p) = i\int d^4x\, e^{ip\cdot x} \langle 0| T\{ \underbrace{\epsilon_{abc}(Q_a^T C\gamma^\mu Q_b)\gamma_\mu\gamma_5 q_c}_{x}\; \underbrace{\epsilon_{a'b'c'}\bar{q}_{c'}\gamma_\nu\gamma_5(\bar{Q}_{b'}\gamma^\nu C \bar{Q}_{a'}^T)}_{0} |0\rangle$$

$$= i\,\epsilon_{abc}\epsilon_{a'b'c'} \int d^4x\, e^{ip\cdot x}$$

$$\gamma_\mu\gamma_5 \underline{S^q_{cc'}(x)}\gamma_\nu\gamma_5\; 2(-1)\,\mathrm{Tr}[C\gamma^\mu \underline{S^Q_{bb'}(x)}\gamma^\nu C (-1)\underline{(S^Q_{aa'}(x))^T}]$$

$$= i\,\epsilon_{abc}\epsilon_{a'b'c'} \underline{\int d^4x\, e^{ip\cdot x}}$$

$$\int\frac{d^4k_3}{(2\pi)^4}\underline{e^{-ik_3\cdot x}}\frac{i}{k_3^2-m_3^2}\delta_{cc'}$$

$$\int\frac{d^4k_2}{(2\pi)^4}\underline{e^{-ik_2\cdot x}}\frac{i}{k_2^2-m_2^2}\delta_{bb'}$$

$$\int\frac{d^4k_1}{(2\pi)^4}\underline{e^{-ik_1\cdot x}}\frac{i}{k_1^2-m_1^2}\delta_{aa'}$$

$$\underbrace{\gamma_\mu\gamma_5(\not{k}_3+m_3)\gamma_\nu\gamma_5\; 2(-1)\,\mathrm{Tr}[C\gamma^\mu(\not{k}_2+m_2)\gamma^\nu C(-1)(\not{k}_1+m_1)^T]}_{\equiv N}$$

$$= i\,\epsilon_{abc}\epsilon_{a'b'c'}\delta_{cc'}\delta_{bb'}\delta_{aa'}\cdot i^3$$

$$\int\frac{d^4k_1}{(2\pi)^4}\int\frac{d^4k_2}{(2\pi)^4}\int\frac{d^4k_3}{(2\pi)^4}\frac{N}{(k_1^2-m_1^2)(k_2^2-m_2^2)(k_3^2-m_3^2)}(2\pi)^4\delta^4(p-k_1-k_2-k_3)$$

$$\rho(p) = \frac{(-2\pi i)^3}{2\pi i}\, i\,\epsilon_{abc}\epsilon_{a'b'c'}\delta_{cc'}\delta_{bb'}\delta_{aa'}\cdot i^3\cdot\frac{1}{(2\pi)^8}$$

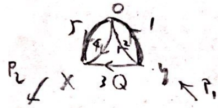
$$\int d^4k_1\int d^4k_2\int d^4k_3\, \delta(k_1^2-m_1^2)\,\delta(k_2^2-m_2^2)\,\delta(k_3^2-m_3^2)\,\delta^4(p-k_1-k_2-k_3)\,N$$

$\langle \Xi_{cc}^{+} | \Gamma_6 | \Xi_{cc}^{+} \rangle$ $\boxed{\Gamma_6 = \bar{c}\gamma^\mu(1-\gamma_5) d\, \bar{d}\gamma_\mu(1-\gamma_5)c}$

QCD层次的计算

$$\Pi(p_1,p_2) = i^2\int d^4x\, d^4y\, e^{ip_2\cdot x - ip_1\cdot y}\langle 0|T\{J(x)\,\Gamma_6(0)\,\bar J(y)\}|0\rangle$$

$$= i^2 \int d^4x\, d^4y\, e^{ip_2\cdot x-ip_1\cdot y}$$



$$\langle 0|T\{\underbrace{\epsilon_{abc}(Q_a^T C\gamma^\mu Q_b)\gamma_\mu\gamma_5 q_c}_{x}\ \underbrace{\bar Q^i\gamma^\rho(1-\gamma_5)d^i\,\bar d^j\gamma_\rho(1-\gamma_5)Q^j}_{0}\ \underbrace{\epsilon_{a'b'c'}\bar q_{c'}\gamma_\nu\gamma_5(\bar Q_{b'}\gamma^\nu C\bar Q_{a'}^T)}_{y}\}|0\rangle$$

$$= i^2\epsilon_{abc}\epsilon_{a'b'c'}\int d^4x\, d^4y\, e^{ip_2\cdot x-ip_1\cdot y}$$

✓

$$4\cdot\gamma_\mu\gamma_5 S^d_{cj}(x)\gamma_\rho(1-\gamma_5)S^Q_{jb'}(-y)\gamma^\nu C\,(-1)\,(S^Q_{aa'}(x-y))^T C\gamma^\mu S^Q_{bi}(x)\gamma^\rho(1-\gamma_5)S^d_{ic'}(-y)\gamma_\nu\gamma_5$$

$$= i^2\epsilon_{abc}\epsilon_{a'b'c'}\int d^4x\, d^4y\, e^{ip_2\cdot x-ip_1\cdot y}$$

✓

$$\int\frac{d^4k_4}{(2\pi)^4}e^{-ik_4\cdot x}\frac{i}{k_4^2-m_4^2}\delta_{cj}\cdot\int\frac{d^4k_1}{(2\pi)^4}e^{-ik_1\cdot(-y)}\frac{i}{k_1^2-m_1^2}\delta_{jb'}$$

$$\int\frac{d^4k_3}{(2\pi)^4}e^{-ik_3\cdot(x-y)}\frac{i}{k_3^2-m_3^2}\delta_{aa'}\cdot\int\frac{d^4k_5}{(2\pi)^4}e^{-ik_5\cdot x}\frac{i}{k_5^2-m_5^2}\delta_{bi}$$

$$\int\frac{d^4k_2}{(2\pi)^4}e^{-ik_2\cdot(-y)}\frac{i}{k_2^2-m_2^2}\delta_{ic'}$$

$\equiv N$

$$\underline{4\cdot\gamma_\mu\gamma_5(\not{k}_4+m_4)\gamma_\rho(1-\gamma_5)(\not{k}_1+m_1)\gamma^\nu C\,(-1)\,(\not{k}_3+m_3)^T C\gamma^\mu(\not{k}_5+m_5)\gamma^\rho(1-\gamma_5)}$$

$$(\not{k}_2+m_2)\gamma_\nu\gamma_5$$

$$= i^2\epsilon_{abc}\epsilon_{a'b'c'}\delta_{cj}\delta_{jb'}\delta_{aa'}\delta_{bi}\delta_{ic'}\cdot i^5.$$

✓

$$\int\frac{d^4k_1}{(2\pi)^4}\int\frac{d^4k_2}{(2\pi)^4}\int\frac{d^4k_3}{(2\pi)^4}\int\frac{d^4k_4}{(2\pi)^4}\int\frac{d^4k_5}{(2\pi)^4}\frac{N}{(k_1^2-m_1^2)(k_2^2-m_2^2)(k_3^2-m_3^2)(k_4^2-m_4^2)(k_5^2-m_5^2)}$$

$$(2\pi)^4\delta^4(p_1-k_1-k_2-k_3)$$

$$(2\pi)^4\delta^4(p_2-k_3-k_4-k_5)$$

✓