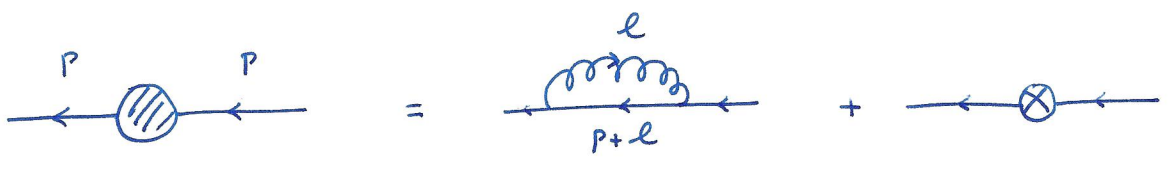


QUARK SELF-ENERGY



$$-i \sum_Q (P) = -i \sum_{Q,g} (P) - i \sum_{Q,ct} (P)$$

$$\Rightarrow -i \sum_{Q,g} (P) = \int \frac{d^D l}{(2\pi)^D} \frac{i}{l^2} \left[ -g_{uv} + \xi \frac{l_u l_v}{l^2} \right]$$

$$\underbrace{\left( \frac{\lambda_a \lambda_a}{2} \right)}_{\frac{4}{3} \pi} \left[ -ig \gamma^u \right] \frac{i (p+l+m)}{(p+l)^2 - m^2} \left[ -ig \gamma^v \right]$$

$$= \frac{4}{3} g^2 \int \frac{d^D l}{(2\pi)^D} \frac{1}{l^2 [(p+l)^2 - m^2]} \left\{ -\gamma_u (p+l+m) \gamma^u + \frac{(1-\xi)}{l^2} \not{l} (p+l+m) \not{l} \right\}$$

$$= \frac{4}{3} g^2 \int \frac{d^D l}{(2\pi)^D} \frac{1}{l^2 [(p+l)^2 - m^2]} \left\{ -(2-D)(p+l) - Dm + (1-\xi)(-p+m) + (1-\xi) \frac{2p \cdot l + l^2}{l^2} \not{l} \right\}$$

$$= \frac{4}{3} g^2 \int_0^1 dx \int \frac{d^D l}{(2\pi)^D} \frac{1}{\left[ (l+px)^2 + p^2 x(1-x) - m^2 x \right]^2}$$

$$\cdot \left\{ -(2-D)(p+l) - Dm + (1-\xi)(-p+m) + (1-\xi) \not{l} \left( 1 + \frac{2p \cdot l}{l^2} \right) \right\}$$

$$\begin{aligned}
 &= \frac{4}{3} g^2 \int_0^1 dx \left\{ \int \frac{d^D \ell}{(2\pi)^D} \frac{1}{\left[ \ell^2 + p^2 x(1-x) - m^2 x \right]^2} \right. \\
 &\quad \cdot \left\{ - (2-D) (\cancel{p} (1-x) + \cancel{p}) - D m \right. \\
 &\quad \left. \left. + (1-\xi) (-\cancel{p} + m) + (1-\xi) (\cancel{p} - \cancel{p} x) \right\} \right. \\
 &\quad \left. + 2(1-x) \int \frac{d^D \ell}{(2\pi)^D} \frac{(1-\xi)}{\left[ \ell^2 + p^2 x(1-x) - m^2 x \right]^3} \underbrace{\left[ 2p \cdot (\ell - px)(\ell - px) \right]}_{2p \cdot \ell \ell + 2p^2 x^2 p} \right\} \\
 &= \frac{4}{3} g^2 \frac{i}{(4\pi)^2} \frac{1}{\epsilon} \left\{ \int_0^1 dx \left[ 2p(1-x) - 4m + (1-\xi)(-\cancel{p}(1+x) + m) \right. \right. \\
 &\quad \left. \left. + \frac{1}{2}(1-x)(2\cancel{p})(1-\xi) \right] \right\} + \text{FINITE TERMS} \\
 &= \frac{4}{3} g^2 \frac{i}{(4\pi)^2} \frac{1}{\epsilon} \left\{ \cancel{p} \xi - m(3 + \xi) \right\} + \text{FINITE TERMS.}
 \end{aligned}$$

$$-i \sum_{Q, \ell} (P) = \frac{4}{3} i \frac{g^2}{(4\pi)^2} \frac{1}{\epsilon} \left\{ \cancel{p} \xi - m(3 + \xi) \right\} + \text{FINITE TERMS}$$

$$\Rightarrow -i \sum_{Q, ct} (P) = i \left[ (Z_2 - 1) \cancel{p} - (Z_2 Z_m - 1) m \right]$$



DIVERGENT TERM OF  $\sum_{Q, \ell}$  IS CANCELLED BY COUNTERTERM

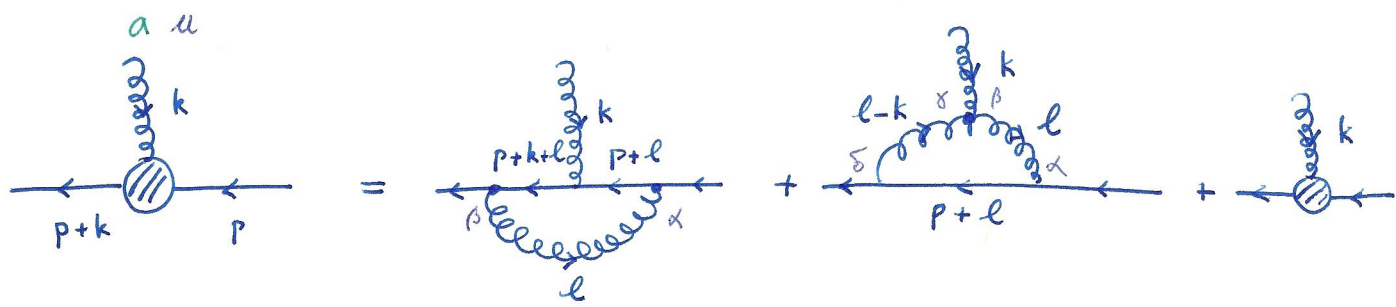
$$Z_2 = 1 - \frac{g^2}{(4\pi)^2} \frac{1}{\epsilon} \frac{4}{3} \xi + O(g^4)$$

$$Z_2 Z_m = 1 - \frac{g^2}{(4\pi)^2} \frac{1}{\epsilon} \frac{4}{3} (3 + \xi) + O(g^4)$$

$$Z_m = \left[ 1 - \frac{g^2}{(4\pi)^2} \frac{1}{\epsilon} \frac{4}{3} (3 + \xi) + O(g^4) \right] \left[ 1 + \frac{g^2}{(4\pi)^2} \frac{1}{\epsilon} \frac{4}{3} \xi + O(g^4) \right]$$

$$Z_m = 1 - \frac{g^2}{(4\pi)^2} \frac{1}{\epsilon} 3 \cdot \frac{4}{3} + O(g^4)$$

# QUARK - GLUON VERTEX



$$\Lambda_{a, QGL}^u(p+k, p, k) = \Lambda_{a, QGL}^{u(1)} + \Lambda_{a, QGL}^{u(2)} + \Lambda_{a, QGL}^{u(3)}$$

$$\Rightarrow \Lambda_{a, QGL}^{u(1)}(p+k, p, k)$$

$$= \int \frac{d^D l}{(2\pi)^D} \left[ -ig \frac{\lambda_b}{2} \gamma^\beta \right] \frac{i [(\not{p} + \not{k} + \not{l}) + m]}{(p+k+l)^2 - m^2} \left[ -ig \frac{\lambda_a}{2} \gamma^\mu \right]$$

$$\cdot \frac{i [\not{p} + \not{l} + m]}{(p+l)^2 - m^2} \left[ -ig \frac{\lambda_b}{2} \gamma^\alpha \right] \frac{i}{l^2} \left[ -g_{\alpha\beta} + (1-\xi) \frac{l_\alpha l_\beta}{l^2} \right]$$

$$= g^3 \frac{\lambda_b}{2} \frac{\lambda_a}{2} \frac{\lambda_b}{2}$$

$$\int \frac{d^D l}{(2\pi)^D} \frac{\gamma^\beta [\not{p} + \not{k} + \not{l} + m] \gamma^\mu [\not{p} + \not{l} + m] \gamma^\alpha}{[(p+k+l)^2 - m^2] [(p+l)^2 - m^2] l^2} \left[ -g_{\alpha\beta} + (1-\xi) \frac{l_\alpha l_\beta}{l^2} \right]$$

↓  
TO CALCULATE ONLY DIVERGENT PART

$$= g^3 \left( \frac{\lambda_b}{2} \frac{\lambda_a}{2} \frac{\lambda_b}{2} \right) \rightarrow -\frac{1}{6} \left( \frac{\lambda_a}{2} \right)$$

$$\int \frac{d^D l}{(2\pi)^D} \frac{-\gamma^\alpha \not{l} \gamma^\mu \not{l} \gamma_\alpha + (1-\xi) \gamma^\mu l^2}{[(p+k+l)^2 - m^2] [(p+l)^2 - m^2] l^2} + \text{FINITE TERMS}$$

$$= -\frac{1}{6} \left( \frac{\lambda_a}{2} \right) g^3 \int \frac{d^D l}{(2\pi)^D} \frac{2 \not{l} \gamma^\mu \not{l} + (1-\xi) l^2 \gamma^\mu}{[(p+k+l)^2 - m^2] [(p+l)^2 - m^2] l^2} + \text{FINITE TERMS}$$

$$= -\frac{1}{6} \left( \frac{\lambda_a}{2} \right) g^3 2 \int_0^1 dx \times \int_0^1 dy \int \frac{d^D l}{(2\pi)^D} \frac{2 \not{l} \gamma^\mu \not{l} + (1-\xi) l^2 \gamma^\mu}{[l^2 + \dots]^3} + \text{FINITE TERMS}$$

$$= -\frac{1}{6} \left( \frac{\lambda_a}{2} \right) g^3 \frac{i}{(4\pi)^2} \frac{1}{\epsilon} \frac{1}{4} \left\{ + 4 \gamma^\alpha \gamma^\mu \gamma_\alpha + (1-\xi) 4 \gamma^\mu \right\} + \text{FINITE TERMS}$$

$$\Lambda_{a, Q-GL}^{\mu(1)}(p+k, p, k) = -ig \frac{\lambda_a}{2} \gamma^\mu \left[ \frac{1}{\epsilon} \frac{g^2}{(4\pi)^2} \left( -\frac{\xi}{6} \right) \right] + \text{FINITE TERMS}$$

$$\frac{\lambda_b}{2} \frac{\lambda_a}{2} \frac{\lambda_b}{2}$$

$$= i f_{bac} \frac{\lambda_c}{2} \frac{\lambda_b}{2} + \frac{\lambda_a}{2} \underbrace{\frac{\lambda_b}{2} \frac{\lambda_b}{2}}_{\frac{4}{3} \mathbb{I}}$$

$$\Rightarrow f_{bac} \frac{\lambda_c}{2} \frac{\lambda_b}{2} = f_{bac} \frac{1}{2} \left( \frac{1}{3} \delta_{bc} + (d_{cbd} + i f_{cbd}) \frac{\lambda_d}{2} \right)$$

$$= \frac{i}{2} \underbrace{f_{bac} f_{cbd}}_{3\delta_{ad}} \frac{\lambda_d}{2}$$

$$= \frac{3}{2} i \frac{\lambda_a}{2}$$

$$\circ \circ \quad \frac{\lambda_b}{2} \frac{\lambda_a}{2} \frac{\lambda_b}{2} = - \frac{3}{2} \frac{\lambda_a}{2} + \frac{4}{3} \frac{\lambda_a}{2}$$

$$\frac{\lambda_b}{2} \frac{\lambda_a}{2} \frac{\lambda_b}{2} = - \frac{1}{6} \frac{\lambda_a}{2}$$



$$\Rightarrow \Lambda_{a, Q-GL}^{u(2)}(p+k, p, k)$$

$$= \int \frac{d^D l}{(2\pi)^D} \frac{i}{(l-k)^2} \left[ -g_{\gamma\delta} + (1-\xi)(l-k)_\gamma (l-k)_\delta / (l-k)^2 \right]$$

$$\cdot \frac{i}{l^2} \left[ -g_{\beta\alpha} + (1-\xi) l_\alpha l_\beta / l^2 \right]$$

$$\cdot \left[ -g f_{bac} V^{\gamma\mu\beta}(l-k, k, -l) \right]$$

$$\cdot \left[ -ig \gamma^\delta \frac{\lambda_b}{2} \right] i \frac{(p+l)_\alpha + m}{(p+l)^2 - m^2} \left[ -ig \gamma^\alpha \frac{\lambda_c}{2} \right]$$

$$= + i g^3 f_{abc} \frac{\lambda_b}{2} \frac{\lambda_c}{2}$$

$$\int \frac{d^D l}{(2\pi)^D} \frac{1}{(l-k)^2 l^2 [(p+l)^2 - m^2]}$$

$$\cdot \left[ -g_{\gamma\delta} + (1-\xi)(l-k)_\gamma (l-k)_\delta / (l-k)^2 \right]$$

$$\cdot \left[ -g_{\alpha\beta} + (1-\xi) l_\alpha l_\beta / l^2 \right] V^{\gamma\mu\beta}(l-k, k, -l)$$

$$\cdot \gamma^\delta \left[ (p+l)_\alpha + m \right] \gamma^\alpha$$



IF ONE IS ONLY INTERESTED IN THE DIVERGENT PART  $\sim \frac{1}{\epsilon}$

$$\Lambda_{a, Q-GL}^{\mu(2)}(p+k, p, k)$$

$$= i g^3 f_{abc} \frac{\lambda_b}{2} \frac{\lambda_c}{2}$$

$$\int \frac{d^D l}{(2\pi)^D} \frac{1}{(l-k)^2 l^2 [(p+l)^2 - m^2]}$$

$$\cdot \left\{ 2\gamma^\mu l^2 + 4l^\mu l \right.$$

$$\left. - \frac{(1-\xi)}{(l-k)^2} l^2 [l^2 \gamma^\mu - l^\mu l] \right.$$

$$\left. - \frac{(1-\xi)}{l^2} l^2 [l^2 \gamma^\mu - l^\mu l] \right\} + \text{FINITE TERMS}$$

$$= i g^3 f_{abc} \frac{\lambda_b}{2} \frac{\lambda_c}{2}$$

$$\cdot \left\{ 2 \int_0^1 dx \times \int_0^1 dy \frac{i}{(4\pi)^2} \frac{1}{4} \frac{1}{\epsilon} [2\gamma^\mu \cdot 4 + 4\gamma^\mu] \right.$$

$$\left. - (1-\xi) 2 \int_0^1 dx (1-x) \frac{i}{(4\pi)^2} \frac{1}{4} \frac{1}{\epsilon} [4\gamma^\mu - \gamma^\mu] \times 2 \right\}$$

+ FINITE TERMS



$$\begin{aligned} & \rightarrow \frac{i}{2} f_{bcd} \frac{\lambda_d}{2} + \frac{1}{2} d_{bcd} \frac{\lambda_d}{2} + \frac{1}{6} \delta_{bc} \quad \text{Q-GL} \quad \sqrt{5} \\ = & \quad i g^3 \left( f_{abc} \frac{\lambda_b}{2} \frac{\lambda_c}{2} \right) = i \frac{3}{2} \frac{\lambda_a}{2} \end{aligned}$$

$$\begin{aligned} & \cdot \frac{i}{(4\pi)^2} \frac{1}{\epsilon} \left\{ 3 \gamma^\mu - (1 - \xi) \frac{3}{2} \gamma^\mu \right\} + \text{FINITE TERMS} \\ & \qquad \qquad \qquad \frac{3}{2} \gamma^\mu (1 + \xi) \end{aligned}$$

$$\Lambda_{a, \text{Q-GL}}^{\mu(2)}(p+k, p, k) = -ig \frac{\lambda_a}{2} \gamma^\mu \left[ \frac{1}{\epsilon} \frac{g^2}{(4\pi)^2} \frac{g}{4} (1 + \xi) \right] + \text{FINITE TERMS}$$

$$\Rightarrow \Lambda_{a, \text{Q-GL}}^{\mu(3)}(p+k, p, k) = -ig \frac{\lambda_a}{2} \gamma^\mu (Z_{1F} - 1)$$

$$\circ \circ \quad Z_{1F} = 1 - \frac{g^2}{(4\pi)^2} \frac{1}{\epsilon} \left[ \frac{g}{4} + \frac{25}{12} \xi \right] + O(g^4)$$