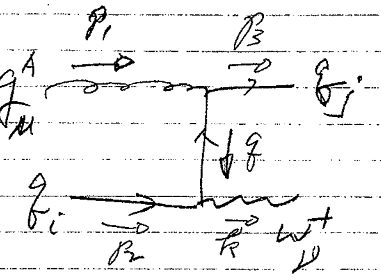
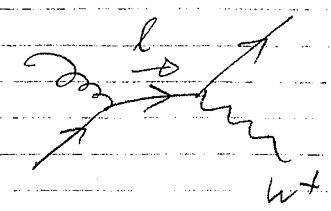
3 $\quad g q_i \to W^+ q_j$





$$i\mathcal{M} = -i\frac{g}{2\sqrt{2}}\left(-i g_s\right) \epsilon^A_\mu(p_1)\, \epsilon_\nu(k)$$

$$\bar{u}(p_3)\left[\gamma^\mu T^A \frac{i}{\not p_3 - \not p_1}\gamma^\nu(1-\gamma_5) + \gamma^\nu(1-\gamma_5)\frac{i}{\not p_1 + \not p_2}\gamma^\mu T^A\right] u(p_2)$$

Squaring and summing over spins and colors, we obtain

$$|\mathcal{M}|^2 = \frac{g^2}{8} g_s^2 \,\mathrm{Tr}(T^A T^A)\cdot(\mu^2)^\epsilon$$

$$\cdot\Big\{ \mathrm{Tr}\big(\not p_3 \gamma^\mu(\not p_3 - \not p_1)\gamma^\nu(1-\gamma_5)\not p_2 \gamma_\nu(1-\gamma_5)(\not p_3 - \not p_1)\gamma_\mu\big)\frac{1}{\hat{t}^2}$$

$$+ \mathrm{Tr}\big(\not p_3 \gamma^\nu(1-\gamma^5)(\not p_1 + \not p_2)\gamma^\mu \not p_2 \gamma_\mu(\not p_1 + \not p_2)\gamma_\nu(1-\gamma_5)\big)\frac{1}{\hat{s}^2}$$

$$+ \mathrm{Tr}\big(\not p_3 \gamma^\mu(\not p_3 - \not p_1)\gamma^\nu(1-\gamma^5)\not p_2 \gamma_\mu(\not p_1 + \not p_2)\gamma_\nu(1-\gamma^5)\big)\frac{2}{\hat{s}\hat{t}} \Big\},$$

with

$$\hat{s} = (p_1+p_2)^2 = 2\, p_1\cdot p_2$$

$$\hat{t} = (p_1 - p_3)^2 = -2\, p_1\cdot p_3 \qquad \hat{s}+\hat{t}+\hat{u} = M^2$$

$$\hat{u} = (p_2 - p_3)^2 = -2\, p_2\cdot p_3 ,$$

1) We shall do the γ-matrices in $N = 4-2\epsilon$ dimensions,

$$\{\gamma^\mu, \gamma^\nu\} = 2 g^{\mu\nu}, \qquad g^{\mu\nu} = \mathrm{diag}(\underbrace{1,-1,\ldots,-1}_{N \text{ terms}})$$

$$g^{\mu\nu} g_{\mu\nu} = N$$

$$\gamma^\mu \gamma_\mu = N$$

$$\gamma^\mu \not a \gamma_\mu = -2(1-\epsilon)\not a$$

$$\gamma^\mu \not a \not b \gamma_\mu = 4\, a\cdot b - 2\epsilon\, \not a \not b \qquad \mathrm{Tr}(\not a \not b) = 4\, a\cdot b$$

$$\gamma^\mu \not a \not b \not c \gamma_\mu = -2\, \not c \not b \not a + 2\epsilon\, \not a \not b \not c$$

$$\mathrm{Tr}(\not a \not b \not c \not d) = 4\left(a\cdot b\, c\cdot d + a\cdot d\, b\cdot c - a\cdot c\, b\cdot d\right).$$

The Dirac matrices have dimension $2^{N/2}$ for N even

$2^{(N-1)/2}$ for N odd.

However we will use $\mathrm{Tr}\,\mathbb{1} = 4$.

Also
$$\{\gamma_\mu, \gamma_5\} = 0 \;, \quad \gamma_5^2 = 1$$
$$\mathrm{Tr}(\gamma_5 \not{a} \not{b}) = 0$$

2) The first trace gives $\quad -16(1-\epsilon)^2\, \hat{s}\hat{t}$

The 2^{nd} may be obtained from the 1^{st} by $p_2 \leftrightarrow -p_3$, or $s \leftrightarrow t$,

Hence, it gives
$$-16(1-\epsilon)^2\, \hat{t}\hat{s}$$

The 3^{rd} trace gives
$$16(1-\epsilon)\left(-\hat{u}M^2 + \epsilon\, \hat{s}\hat{t}\right)$$

3) Therefore
$$|\mathcal{M}|^2 = 2g^2 g_s^2 (\mu^2)^\epsilon\, \mathrm{Tr}(T^A T^A)\,(1-\epsilon)\left[(1-\epsilon)\left(\frac{\hat{s}}{-\hat{t}} + \frac{-\hat{t}}{\hat{s}}\right) - 2\frac{\hat{u}M^2}{\hat{s}\hat{t}} + 2\epsilon\right]$$

Now $\mathrm{Tr}(T^A T^A) = C_A C_F = 3 \times \frac{4}{3} = 4$ (in QCD).

4) There are $(N-2)$ transverse spatial dimensions in N dimensions,
so the gluon has $(N-2) = 2(1-\epsilon)$ spin component.
The quark has only 2 spin components, since we have chosen to use $\mathrm{Tr}(\mathbb{1}) = 4$ in calculating Dirac matrices.

Thus the spin- and color-averaged
$$\boxed{\begin{aligned} \overline{|\mathcal{M}|^2} &= \left[\frac{1}{2(1-\epsilon)}\,\frac{1}{2}\right]\left[\frac{1}{8}\,\frac{1}{3}\,C_A C_F\right] |\mathcal{M}|^2 \\ &= \frac{1}{4}\,\frac{1}{6}\, 2g^2 g_s^2 (\mu^2)^\epsilon \left[(1-\epsilon)\left(\frac{\hat{s}}{-\hat{t}} + \frac{-\hat{t}}{\hat{s}}\right) - 2\frac{\hat{u}M^2}{\hat{s}\hat{t}} + 2\epsilon\right] \end{aligned}}$$

自旋平均 色平均.

<u>Note</u> If $f(x)$ depends only on $r = \sqrt{x_1^2 + \cdots + x_n^2}$, then

$$\int d^n x\, f(x) = \int_0^\infty f(x)\cdot r^{n-1} dr \underbrace{\int_0^\pi \sin^{n-2}\theta_{n-1}\, d\theta_{n-1} \int_0^\pi \cdots \int_0^\pi \sin\theta_2\, d\theta_2 \int_0^{2\pi} d\theta_1}_{\overset{\shortparallel}{d^n\Omega}}$$

Using $\displaystyle\int_0^\pi \sin^m\theta\, d\theta = \sqrt{\pi}\,\frac{\Gamma\left(\frac{m+1}{2}\right)}{\Gamma\left(\frac{m+2}{2}\right)}$,

get

$$\int d^n\Omega = \sqrt{\pi}\,\frac{\Gamma\left(\frac{n-1}{2}\right)}{\Gamma\left(\frac{n}{2}\right)}\sqrt{\pi}\,\frac{\Gamma\left(\frac{n-2}{2}\right)}{\Gamma\left(\frac{n-1}{2}\right)}\cdots\sqrt{\pi}\,\frac{\Gamma\left(\frac{2}{2}\right)}{\Gamma\left(\frac{3}{2}\right)}\cdot(2\pi)$$

$$= \left(\sqrt{\pi}\right)^{n-2}\cdot\frac{\Gamma(1)}{\Gamma\left(\frac{n}{2}\right)}\cdot(2\pi)$$

$$= \frac{2\pi^{\frac{n}{2}}}{\Gamma\left(\frac{n}{2}\right)}$$

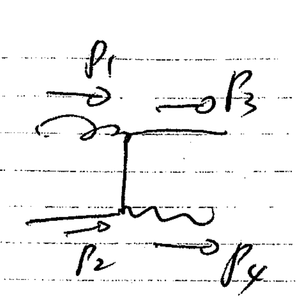
$$\int d^N p\, \delta^+(p^2) = \int dp_0\, \delta^+(p_0^2 - |p|^2)\int d^{n-1}p$$

$$= \frac{1}{2p_0}\int_0^\infty d|p|\cdot |p|^{(N-1)-1}\cdot \int_0^\pi \sin^{(N-1)-2}\theta_{N-2}\, d\theta_{N-2} \underbrace{\int_0^\pi \sin^{(N-1)-3}\theta_{N-3}\, d\theta_{N-3}\cdots\int d\theta_1}_{\overset{\shortparallel}{\left[\int d^{N-2}\Omega\right]}}$$

$(\because\ p_0 = |p|)$

$$= \frac{1}{2}\int_0^\infty d|p|\cdot |p|^{N-3}\cdot \int_0^\pi \sin^{N-3}\theta\, d\theta\cdot\left[\int d^{N-2}\Omega\right]$$

5) N-dimensional phase space gives



$$P.S. = \int \frac{d^{N-1}p_3}{(2\pi)^{N-1}\,2E_3}\,\frac{d^{N-1}p_4}{(2\pi)^{N-1}\,2E_4}\,(2\pi)^N\delta^{(N)}(p_1+p_2-p_3-p_4)$$

$$= \int\frac{d^Np_3}{(2\pi)^{N-1}}\int\frac{d^Np_4}{(2\pi)^{N-1}}(2\pi)^N\delta^{(N)}(p_1+p_2-p_3-p_4)\,\delta^+(p_3^2)\,\delta^+(p_4^2-M^2)$$

with $\delta^+(p_4^2-M^2)=\delta(p_4^2-M^2)\,\theta(E_4)$

In (g, q_i) c.m.s with (q_j) moving along the $(N-1)^{th}$ direction, we may write

$$p_3=(|p_3|, \dots, |p_3|\cos\theta),$$

where the dots indicate $(N-2)$ unspecified momenta.

First, we use $\delta^{(N)}$ to integrate out $\int d^N p_4$, then perform the $(N-2)$ angular integration for $\int d^N p_3$.

For breviation, let's denote $p \equiv p_3$, then

$$\int d^N p = \int d|p|\cdot |p|^{N-1}\int \sin^{N-2}\theta_{N-1}\, d\theta_{N-1}\int \sin^{N-3}\theta_{N-2}\, d\theta_{N-2}\int\cdots\int 1\cdot d\theta_1$$

with $0\le\theta_i\le\pi$, except $0\le\theta_1\le 2\pi$.

$$\int d^N p\,\delta^+(p^2) = \int_0^\infty d|p|\,|p|^{N-3}\left[\int_0^\pi \sin^{N-3}\theta\, d\theta\right]\left[\frac{1}{2}\int d^{N-2}\Omega\right], \qquad N=4-2\epsilon$$

$$= \left(\int_0^\infty d|p|\,|p|^{1-2\epsilon}\right)\left[\int_{-1}^1 d(\cos\theta)\,(1-\cos^2\theta)^{-\epsilon}\right]\left[\frac{1}{2}\cdot\frac{2\pi^{\frac{N-2}{2}}}{\Gamma\left(\frac{N-2}{2}\right)}\right]$$

$$= \int_0^\infty d|p|\,|p|^{1-2\epsilon}\int_{-1}^1 d(\cos\theta)\,(1-\cos^2\theta)^{-\epsilon}\;\frac{\pi^{1-\epsilon}}{\Gamma(1-\epsilon)}$$

$$\int_0^\pi \sin^{N-3}\theta\, d\theta = -\int_0^\pi \sin^{N-4}\theta\, d\cos\theta = +\int_\pi^0 (1-\cos^2\theta)^{\frac{N-4}{2}}\, d\cos\theta = \int_{-1}^1 (1-\cos^2\theta)^{-\epsilon}\, d\cos\theta$$

$$\frac{\frac{1}{4\pi}\,\frac{(4\pi)^{\epsilon}}{\Gamma(1-\epsilon)}}{\frac{1}{(2\pi)^{2N-2}}\cdot(2\pi)^{n}} = \frac{1}{4\pi}\,\frac{1}{\Gamma(1-\epsilon)}\,\frac{(4\pi)^{\epsilon}(2\pi)^{n-2}}{}$$

$n = 4-2\epsilon$

$n-2 = 2-2\epsilon$

$$\pi^{-\epsilon}\ \frac{(2\pi)^{2\epsilon}\cdot(2\pi)^{2-2\epsilon}}{4\pi^{2}}$$

$$= \pi^{1-\epsilon}\,\frac{1}{\Gamma\left(\frac{n-2}{2}\right)} = \boxed{\frac{\pi^{\frac{n-2}{2}}}{\Gamma\left(\frac{n-2}{2}\right)}}$$

Hence

$$P.S. = \frac{(2\pi)^N}{(2\pi)^{N-1}(2\pi)^{N-1}} \frac{\pi^{1-\epsilon}}{\Gamma(1-\epsilon)} \cdot \int_0^\infty d|p_3|\,|p_3|^{1-2\epsilon} \int_{-1}^{1} d(\cos\theta)\,(1-\cos^2\theta)^{-\epsilon}$$

$M_3 \simeq 0$

$$\cdot\ \delta\left(\hat{s} - M^2 - 2\sqrt{\hat{s}}\,|p_3|\right)$$

$$\left(\text{Since}\quad |p_3| = E_3 = \frac{\hat{s}-M^2}{2\sqrt{\hat{s}}},\ \Rightarrow \hat{s} = 2\sqrt{\hat{s}}\,|p_3| + M^2\right)$$

Furthermore,

$$\int_0^\infty d|p_3|\,|p_3|^{1-2\epsilon}\,\delta(\hat{s}-M^2-2\sqrt{\hat{s}}\,|p_3|) \Rightarrow \boxed{|p_3| = \frac{\hat{s}-M^2}{2\sqrt{\hat{s}}}}$$

$$= \frac{1}{2\sqrt{\hat{s}}}\left(\frac{\hat{s}-M^2}{2\sqrt{\hat{s}}}\right)^{1-2\epsilon} = \frac{1}{2^{2-2\epsilon}}\left(\frac{\hat{s}-M^2}{\hat{s}}\right)^{1-2\epsilon} \cdot \left(\frac{1}{\sqrt{\hat{s}}}\right)^{2\epsilon} \qquad \boxed{\delta(ax) = \frac{1}{a}\delta(x)}$$

Since

$$\pi^{1-\epsilon}(2\pi)^{-N+2} = 2^{-2+2\epsilon}\,\pi^{-1+\epsilon} = (4\pi)^{-1+\epsilon}$$

So

$$P.S. = \left[\frac{1}{4\pi}(4\pi)^{\epsilon}\frac{1}{\Gamma(1-\epsilon)}\right]\cdot\left[\frac{1}{4^{1-\epsilon}}\left(1-\frac{M^2}{\hat{s}}\right)^{1-2\epsilon}\cdot\left(\frac{1}{\hat{s}}\right)^{\epsilon}\right]$$

$$\cdot\left[\int_{-1}^{1} d(\cos\theta)\,(1-\cos^2\theta)^{-\epsilon}\right]$$

Let $y = \frac{1}{2}(1+\cos\theta)$, then $dy = \frac{1}{2}d(\cos\theta)$

$\cos\theta = 2y-1$

$$1-\cos^2\theta = 1-(2y-1)^2 = (1-(2y-1))(1+2y-1) = 2y(2-2y) = 4y(1-y)$$

then

$$\left[\int_{-1}^{1} d\cos\theta\,(1-\cos^2\theta)^{-\epsilon}\right] = \left[2\int_0^1 dy\cdot(4^{-\epsilon})\cdot(y(1-y))^{-\epsilon}\right]$$

Therefore

$$P.S. = \left[\frac{1}{4\pi}(4\pi)^{\epsilon}\frac{1}{\Gamma(1-\epsilon)}\right]\left[\frac{1}{4}\frac{1}{(4^{-\epsilon})}\left(1-\frac{M^2}{\hat{s}}\right)^{1-2\epsilon}\cdot\left(\frac{1}{\hat{s}}\right)^{\epsilon}\right]$$

$$\cdot\left[2\,(4^{-\epsilon})\int_0^1 dy\,(y(1-y))^{-\epsilon}\right]$$

$$= \frac{1}{8\pi}\left(\frac{4\pi}{\hat{s}}\right)^{\epsilon}\frac{1}{\Gamma(1-\epsilon)}\left(1-\frac{M^2}{\hat{s}}\right)^{1-2\epsilon}\int_0^1 dy\,(y(1-y))^{-\epsilon}$$

6) $\hat{t} = -2p_1 \cdot p_3 = -2\frac{\sqrt{\hat{s}}}{2}\frac{\sqrt{\hat{s}}}{2}\left(1-\frac{M^2}{\hat{s}}\right)(1-\cos\theta)$

$\quad = -\hat{s}\left(1-\frac{M^2}{\hat{s}}\right)(1-y)$

$\hat{u} = -2p_2 \cdot p_3 = -\hat{s}\left(1-\frac{M^2}{\hat{s}}\right)y$; (since $\hat{s}+\hat{t}+\hat{u} = M^2$)

7) Therefore, the cross section for $g\, q_i \to W^+ q_j$ is

$$\hat{\sigma} = \frac{1}{2\hat{s}}\overline{|\mathcal{M}|^2}\,(\text{P.S.}) \quad \text{where,}$$

$$= \left(\frac{1}{\hat{s}}\right)\left[\frac{1}{4}\cdot\frac{1}{6}\,2\,g^2 g_s^2 (\mu^2)^\epsilon\right]\left[\frac{1}{8\pi}\frac{1}{\Gamma(1-\epsilon)}\left(\frac{4\pi}{M^2}\right)^\epsilon\left(\frac{M^2}{\hat{s}}\right)^\epsilon\left(1-\frac{M^2}{\hat{s}}\right)^{1-2\epsilon}\right].$$

$$\cdot\left\{\int_0^1 dy\, y^{-\epsilon}(1-y)^{-\epsilon}\left[(1-\epsilon)\left(\frac{1}{\left(1-\frac{M^2}{\hat{s}^2}\right)(1-y)}+\left(1-\frac{M^2}{\hat{s}}\right)(1-y)\right)\right.\right.$$

$$\left.\left. -2\left(\frac{M^2}{\hat{s}}\right)\frac{y}{1-y} + 2\epsilon\right]\right\}$$

Note: The collinear singularity resides in the y integral, in the limit of $\epsilon \to 0$.

$\to 0$ (drop it)

Use $$\int_0^1 dy\, y^\alpha (1-y)^\beta = \frac{\Gamma(1+\alpha)\,\Gamma(1+\beta)}{\Gamma(2+\alpha+\beta)}$$

$$\Gamma(-\epsilon) \sim \frac{-1}{\epsilon}$$

$$\Gamma(x+1) = x\,\Gamma(x), \quad \Gamma(n) = (n-1)! \quad n = \text{integer} \geq 1$$

The above y integral gives

$$\{\ \} = \frac{-1}{\epsilon}\frac{\Gamma^2(1-\epsilon)}{\Gamma(1-2\epsilon)}\left(\frac{1-\epsilon}{1-\hat{\tau}} - 2\hat{\tau}(1+\epsilon)\right) + \frac{1}{2}(1-\hat{\tau}),$$

$$\hat{\tau} \equiv \frac{M^2}{\hat{s}}$$

Use $$\frac{-1}{\epsilon}\left(\frac{4\pi\mu^2}{M^2}\right)^\epsilon \hat{\tau}^\epsilon (1-\hat{\tau})^{-2\epsilon} = \frac{-1}{\epsilon}\left[1+\epsilon\left(\ln\frac{4\pi\mu^2}{M^2}\frac{\hat{\tau}}{(1-\hat{\tau})^2}\right)+\cdots\right]$$

$$= \frac{-1}{\epsilon} + \left(\ln\frac{M^2}{4\pi\mu^2}\frac{(1-\hat{\tau})^2}{\hat{\tau}}\right)$$

In the limit of $\epsilon \to 0$.

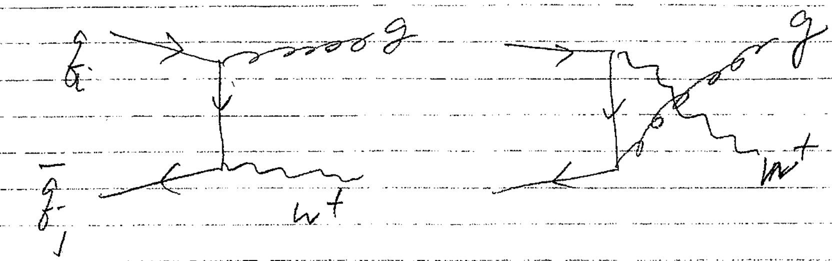
$$\hat{\sigma}(g q_i \to W^+ q_j) = \frac{\pi}{12} \alpha_s \frac{\alpha}{S_W^2} \frac{1}{\hat{s}} \cdot \left\{ \left(\hat{\tau}^2 + (1-\hat{\tau})^2 \right) \left(\frac{-1}{\epsilon} \frac{\Gamma(1-\epsilon)}{\Gamma(1-2\epsilon)} + \ln \frac{M^2 (1-\hat{\tau})^2}{4\pi\mu^2 \hat{\tau}} \right) + \frac{3}{2} + \hat{\tau} - \frac{3}{2} \hat{\tau}^2 \right\}$$

$$\left(\hat{\tau} \equiv \frac{M^2}{\hat{s}} \right)$$

<u>Note</u> $(\ln M^2)$ comes from the decomposition of

$$\left(\frac{4\pi\mu^2}{\hat{s}} \right)^\epsilon = \left(\frac{4\pi\mu^2}{M^2} \right)^\epsilon \left(\frac{M^2}{\hat{s}} \right)^\epsilon$$

4 $q_i \bar{q}_j \to W^+ g$



1) In the previous section, we did

$$g(p_1) + q_i(p_2) \to q_j(p_3) + W^+(p_4),$$

now, it is

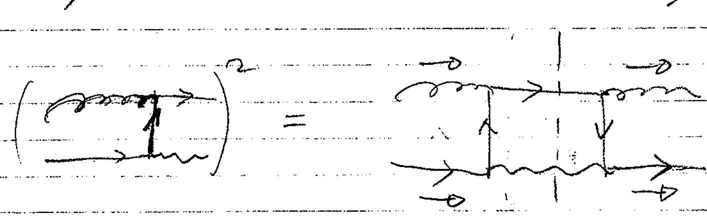
$$q_i(p_1') + \bar{q}_j(p_2') \to g(p_3') + W^+(p_4')$$

Therefore, we can relabel the momenta

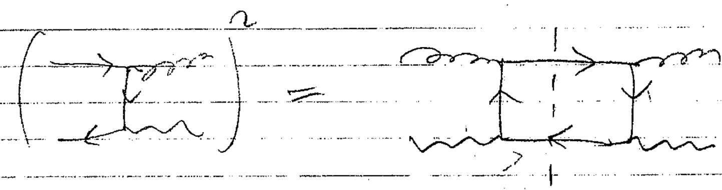
$$\left\{ \begin{array}{l} p_1 \to -p_3' \\ p_2 \to p_1' \\ p_3 \to -p_2' \\ p_4 \to p_4' \end{array} \right\} \Rightarrow \left\{ \begin{array}{l} s \to t \\ t \to u \\ u \to s \end{array} \right\}$$

to get this $|M|^2$ from previous one.

But, there is an overall minus sign should be included, because



$$z^{2\epsilon}(1-z)^{-1-2\epsilon}$$



(This fermion loop gives a relative minus sign to the above one.)

2) Use the relation $z \equiv \frac{M^2}{\hat{s}} \equiv \hat{\tau}$

$$z^{2\epsilon}(1-z)^{-1-2\epsilon} = \frac{-1}{\epsilon}\delta(1-z) + \frac{1}{(1-z)_+} - \epsilon\left(\frac{\ln(1-z)}{1-z}\right)_+ + \epsilon\frac{\ln z}{1-z} + O(\epsilon^2)$$

$$z^{\epsilon}(1-z)^{-\epsilon} = 1 + \epsilon \ln\frac{z}{1-z} + O(\epsilon^2),$$

with $\int_0^1 dz \left(g(z)\right)_+ h(z) \equiv \int_0^1 dz\, g(z)\left(h(z) - h(1)\right)$, which is finite at $z=1$.

get

$$\hat{\sigma}(q_{b_i}\bar{q}_{b_j} \to W^+ g) = \frac{\pi^2}{3}\frac{\alpha}{S_W^2}\frac{\alpha_s}{2\pi}\frac{4}{3}\left(\frac{4\pi\mu^2}{M^2}\right)^{\epsilon}\frac{\Gamma(1-\epsilon)}{\Gamma(1-2\epsilon)}\frac{1}{\hat{s}}$$

$$\cdot\left\{\frac{2}{\epsilon^2}\delta(1-\hat{\tau}) - \frac{2}{\epsilon}\frac{1+\hat{\tau}^2}{(1-\hat{\tau})_+} + 4(1+\hat{\tau}^2)\left(\frac{\ln(1-\hat{\tau})}{1-\hat{\tau}}\right)_+ - 2\frac{1+\hat{\tau}^2}{1-\hat{\tau}}\ln\hat{\tau}\right\}$$

Note ① In this case, the spin average factor is

$$\left(\frac{1}{2}\cdot\frac{1}{2}\right),$$

which should be compared with the $(qg \to Wq)$ case, there it is

$$\left(\frac{1}{2}\cdot\frac{1}{N-2}\right) = \left(\frac{1}{2}\frac{1}{2(1-\epsilon)}\right), \qquad (N = 4-2\epsilon)$$

② Also, the color factor is

$$\left(\frac{1}{3}\cdot\frac{1}{3}\right), \quad \text{instead of} \quad \left(\frac{1}{3}\frac{1}{8}\right) \text{ as in } (qg \to W^+ q)$$

$$\frac{-2}{\epsilon}\frac{1+\hat{\tau}^2}{(1-\hat{\tau})_+} = \frac{-2}{\epsilon}\left[\left(\frac{1+\hat{\tau}^2}{1-\hat{\tau}}\right)_+ - \frac{3}{2}\delta(1-\hat{\tau})\right]$$

$$= \underbrace{\frac{-2}{\epsilon}\left[\left(\frac{1+\hat{\tau}^2}{1-\hat{\tau}}\right)_+\right]}_{\text{collinear}} + \underbrace{\frac{3}{\epsilon}\delta(1-\hat{\tau})}_{\text{soft}}$$

$$\frac{1+\hat{\tau}^2}{(1-\hat{\tau})_+} = \left(\frac{1+\hat{\tau}^2}{1-\tau}\right)_+ - \frac{3}{2}\delta(1-\hat{\tau})$$

$\tau = \frac{M^2}{\hat{s}}$, $\hat{\tau} \to 1$, $k \to 0$

if $M^2 = \hat{s}$.

This is soft

$$\frac{1+\hat{\tau}}{(1-\hat{\tau})_+} = \left(\frac{1+\hat{\tau}}{1-\hat{\tau}}\right)_+ + \frac{3}{2}\delta\left(\ \right)$$