Subprocess $e^-q \to e^-q$
Formula Source: J.-M. Virey; Eur.Phys.J C8 (99) 283 (A.5-11)

$$\frac{d\hat{\sigma}^{\lambda_1\lambda_2}}{d\hat{t}}(e^-q \to e^-q) = \frac{\pi}{\hat{s}^2}\sum_{\alpha,\beta} T^{\lambda_1\lambda_2}_{\alpha,\beta}(e^-q \to e^-q) \tag{1}$$

for α and β boson exchange; $\alpha, \beta = \gamma, Z, CI$

Standard Model Squared Matrix Elements $T^{\lambda_1\lambda_2}_{\alpha,\beta}(e^-q \to e^-q) = |\mathcal{M}^{\lambda_1\lambda_2}_{\alpha,\beta}(e^-q \to e^-q)|^2$

$$\begin{aligned}
T_{\gamma\gamma}(e^-q \to e^-q) &= 2e_q^2\frac{\alpha}{\hat{t}^2}\{(1+\lambda_1\lambda_2)\hat{s}^2 + (1-\lambda_1\lambda_2)\hat{u}^2\}, && (2)\\
T_{ZZ}(e^-q \to e^-q) &= \left(\frac{\alpha}{\sin^2\theta_W\cos^2\theta_W}\right)^2\frac{1}{(\hat{t}-M_Z^2)^2}\\
&\quad \{(C_{eL}^2C_{qL}^2(1-\lambda_1)(1-\lambda_2) + C_{eR}^2C_{qR}^2(1+\lambda_1)(1+\lambda_2))\hat{s}^2\\
&\quad +(C_{eL}^2C_{qR}^2(1-\lambda_1)(1+\lambda_2) + C_{eR}^2C_{qL}^2(1+\lambda_1)(1-\lambda_2))\hat{u}^2\}, && (3)\\
T_{\gamma Z}(e^-q \to e^-q) &= -2e_q\frac{\alpha^2}{\sin^2\theta_W\cos^2\theta_W}\frac{1}{\hat{t}(\hat{t}-M_Z^2)}\\
&\quad \{(C_{eL}C_{qL}(1-\lambda_1)(1-\lambda_2) + C_{eR}C_{qR}(1+\lambda_1)(1+\lambda_2))\hat{s}^2\\
&\quad +(C_{eL}C_{qR}(1-\lambda_1)(1+\lambda_2) + C_{eR}C_{qL}(1+\lambda_1)(1-\lambda_2))\hat{u}^2\}, && (4)
\end{aligned}$$

eeqq Contact Interaction Squared Matrix Elements

$$\begin{aligned}
T_{CICI}(e^-q \to e^-q) &= \frac{1}{2\Lambda_{eq}^4}\{((1+\eta\eta')(1+\lambda_1\lambda_2)) + (-\eta-\eta')(\lambda_1+\lambda_2))\hat{s}^2\\
&\quad +((1-\eta\eta')(1-\lambda_1\lambda_2)) + (\eta-\eta')(-\lambda_1+\lambda_2))\hat{u}^2\}, && (5)\\
T_{\gamma CI}(e^-q \to e^-q) &= -\epsilon_{\eta\eta'}\frac{1}{\Lambda_{eq}^2}e_q\frac{\alpha}{\hat{t}}\{((1+\eta\eta')(1+\lambda_1\lambda_2)) + (-\eta-\eta')(\lambda_1+\lambda_2))\hat{s}^2\\
&\quad +((1-\eta\eta')(1-\lambda_1\lambda_2)) + (\eta-\eta')(-\lambda_1+\lambda_2))\hat{u}^2\}, && (6)\\
T_{ZCI}(e^-q \to e^-q) &= \epsilon_{\eta\eta'}\frac{1}{2\Lambda_{eq}^2}\frac{\alpha}{\sin^2\theta_W\cos^2\theta_W}\frac{1}{(\hat{t}-M_Z^2)}\\
&\quad \{(C_{eL}C_{qL}(1+\eta)(1+\eta')(1-\lambda_1)(1-\lambda_2)\\
&\quad +C_{eR}C_{qR}(1-\eta)(1-\eta')(1+\lambda_1)(1+\lambda_2))\hat{s}^2\\
&\quad +\{(C_{eL}C_{qR}(1+\eta)(1-\eta')(1-\lambda_1)(1+\lambda_2)\\
&\quad +C_{eR}C_{qL}(1-\eta)(1+\eta')(1+\lambda_1)(1-\lambda_2))\hat{u}^2\}, && (7)
\end{aligned}$$

Left(Right)-handed fermion-Z coupling

$$C_{fL} = I_3^f - e_f\sin^2\theta_W, C_{fR} = -e_f\sin^2\theta_W \tag{8}$$

CI chiral structure parameters η, η' and CI-SM Interference parameter ϵ

$$\eta, \eta', \epsilon_{\eta\eta'} = \pm 1 \tag{9}$$

Compositeness Scale for eeqqCI ; $\Lambda_{eq} = 1 \sim 10$ TeV ?

Subprocess $q\bar{q} \to e^+e^-$
Formula Calclated by J. Murata, Crossing J.-M. Virey; Eur.Phys.J C8 (99) 283 (A.5-11)
Notation: $(e,q) \to (1,2) = (\bar{q},q)$, $(\bar{q}^{\lambda_1} q^{\lambda_2} \to e^+e^-)$.

$$(\hat{s},\hat{t},\hat{u}) \to (\hat{u},\hat{s},\hat{t}), \tag{10}$$

$$\lambda_e \to -\lambda_1, \tag{11}$$

except for terms with $\hat{u}^2$

$$\frac{1}{\hat{t}-M_Z^2} \to \frac{\hat{s}-M_Z^2}{(\hat{s}-M_Z^2)^2+M_Z^2\Gamma_Z^2}; \frac{1}{(\hat{t}-M_Z^2)^2} \to \frac{1}{(\hat{s}-M_Z^2)^2+M_Z^2\Gamma_Z^2} \tag{12}$$

$$\frac{d\hat{\sigma}^{\lambda_1\lambda_2}}{d\hat{t}}(q\bar{q} \to e^+e^-) = \frac{\pi}{\hat{s}^2}\sum_{\alpha,\beta} T_{\alpha,\beta}^{\lambda_1\lambda_2}(q\bar{q} \to e^+e^-) \tag{13}$$

Standard Model Squared Matrix Elements

$$\begin{aligned}
T_{\gamma\gamma}(q\bar{q} \to e^+e^-) &= 2e_q^2\frac{\alpha}{\hat{s}^2}\{(1-\lambda_1\lambda_2)\hat{u}^2+(1-\lambda_1\lambda_2)\hat{t}^2\}, && (14)\\
T_{ZZ}(q\bar{q} \to e^+e^-) &= \left(\frac{\alpha}{\sin^2\theta_W\cos^2\theta_W}\right)^2\frac{1}{(\hat{s}-M_Z^2)^2+M_Z^2\Gamma_Z^2}\\
&\quad \{(C_{eL}^2C_{qL}^2(1+\lambda_1)(1-\lambda_2)+C_{eR}^2C_{qR}^2(1-\lambda_1)(1+\lambda_2))\hat{u}^2\\
&\quad +(C_{eL}^2C_{qR}^2(1-\lambda_1)(1+\lambda_2)+C_{eR}^2C_{qL}^2(1+\lambda_1)(1-\lambda_2))\hat{t}^2\}, && (15)\\
T_{\gamma Z}(q\bar{q} \to e^+e^-) &= -2e_q\frac{\alpha^2}{\sin^2\theta_W\cos^2\theta_W}\frac{\hat{s}-M_Z^2}{\hat{s}((\hat{s}-M_Z^2)^2+M_Z^2\Gamma_Z^2)}\\
&\quad \{(C_{eL}C_{qL}(1+\lambda_1)(1-\lambda_2)+C_{eR}C_{qR}(1-\lambda_1)(1+\lambda_2))\hat{u}^2\\
&\quad +(C_{eL}C_{qR}(1-\lambda_1)(1+\lambda_2)+C_{eR}C_{qL}(1+\lambda_1)(1-\lambda_2))\hat{t}^2\}, && (16)
\end{aligned}$$

eeqq Contact Interaction Squared Matrix Elements

$$\begin{aligned}
T_{CICI}(q\bar{q} \to e^+e^-) &= \frac{1}{2\Lambda_{eq}^4}\{((1+\eta\eta')(1-\lambda_1\lambda_2)+(-\eta-\eta')(-\lambda_1+\lambda_2))\hat{u}^2\\
&\quad +((1-\eta\eta')(1-\lambda_1\lambda_2))+(\eta-\eta')(-\lambda_1+\lambda_2))\hat{t}^2\}, && (17)\\
T_{\gamma CI}(q\bar{q} \to e^+e^-) &= -\epsilon_{\eta\eta'}\frac{1}{\Lambda_{eq}^2}e_q\frac{\alpha}{\hat{s}}\{((1+\eta\eta')(1-\lambda_1\lambda_2)+(-\eta-\eta')(-\lambda_1+\lambda_2))\hat{u}^2\\
&\quad +((1-\eta\eta')(1-\lambda_1\lambda_2))+(\eta-\eta')(-\lambda_1+\lambda_2))\hat{t}^2\}, && (18)\\
T_{ZCI}(q\bar{q} \to e^+e^-) &= \epsilon_{\eta\eta'}\frac{1}{2\Lambda_{eq}^2}\frac{\alpha}{\sin^2\theta_W\cos^2\theta_W}\frac{\hat{s}-M_Z^2}{(\hat{s}-M_Z^2)^2+M_Z^2\Gamma_Z^2}\\
&\quad \{(C_{eL}C_{qL}(1+\eta)(1+\eta')(1+\lambda_1)(1-\lambda_2)\\
&\quad +C_{eR}C_{qR}(1-\eta)(1-\eta')(1-\lambda_1)(1+\lambda_2))\hat{u}^2\\
&\quad +(C_{eL}C_{qR}(1+\eta)(1-\eta')(1-\lambda_1)(1+\lambda_2)\\
&\quad +C_{eR}C_{qL}(1-\eta)(1+\eta')(1+\lambda_1)(1-\lambda_2))\hat{t}^2\}. && (19)
\end{aligned}$$

Unpolarized Standard Model Squared Matrix Elements ($\lambda_{1,2} = 0$)

$$
\begin{aligned}
T_{\gamma\gamma}(q\bar{q} \to e^+e^-) &= 2e_q^2 \frac{\alpha}{\hat{s}^2}\{\hat{u}^2 + \hat{t}^2\}, && (20)\\
T_{ZZ}(q\bar{q} \to e^+e^-) &= \left(\frac{\alpha}{\sin^2\theta_W \cos^2\theta_W}\right)^2 \frac{1}{(\hat{s} - M_Z^2)^2 + M_Z^2\Gamma_Z^2} \\
&\quad \{(C_{eL}^2 C_{qL}^2 + C_{eR}^2 C_{qR}^2)\hat{u}^2 + (C_{eL}^2 C_{qR}^2 + C_{eR}^2 C_{qL}^2)\hat{t}^2\}, && (21)\\
T_{\gamma Z}(q\bar{q} \to e^+e^-) &= -2e_q \frac{\alpha^2}{\sin^2\theta_W \cos^2\theta_W} \frac{\hat{s} - M_Z^2}{\hat{s}((\hat{s} - M_Z^2)^2 + M_Z^2\Gamma_Z^2)} \\
&\quad \{(C_{eL}C_{qL} + C_{eR}C_{qR})\hat{u}^2 + (C_{eL}C_{qR} + C_{eR}C_{qL})\hat{t}^2\}, && (22)
\end{aligned}
$$

Unpolarized eeqq Contact Interaction Squared Matrix Elements ($\lambda_{1,2} = 0$)

$$
\begin{aligned}
T_{CICI}(q\bar{q} \to e^+e^-) &= \frac{1}{2\Lambda_{eq}^4} \\
&\quad \times\{(1 + \eta\eta')\hat{u}^2 + (1 - \eta\eta')\hat{t}^2\}, && (23)\\
T_{\gamma CI}(q\bar{q} \to e^+e^-) &= -\epsilon_{\eta\eta'} \frac{1}{\Lambda_{eq}^2} e_q \frac{\alpha}{\hat{s}} \\
&\quad \times\{(1 + \eta\eta')\hat{u}^2 + (1 - \eta\eta')\hat{t}^2\}, && (24)\\
T_{ZCI}(q\bar{q} \to e^+e^-) &= \epsilon_{\eta\eta'} \frac{1}{2\Lambda_{eq}^2} \frac{\alpha}{\sin^2\theta_W \cos^2\theta_W} \frac{\hat{s} - M_Z^2}{(\hat{s} - M_Z^2)^2 + M_Z^2\Gamma_Z^2} \\
&\quad \times\{(C_{eL}C_{qL}(1+\eta)(1+\eta') + C_{eR}C_{qR}(1-\eta)(1-\eta'))\hat{u}^2 \\
&\quad +(C_{eL}C_{qR}(1+\eta)(1-\eta') + C_{eR}C_{qL}(1-\eta)(1+\eta'))\hat{t}^2\}. && (25)
\end{aligned}
$$

Helicity Selected Squared Matrix Elements for $q\bar{q} \to e^+e^-$
Formula Calclated by J. Murata

$$\{\forall(\alpha,\beta)\}; T^{--}_{\alpha\beta}(q\bar{q} \to e^+e^-) = T^{++}_{\alpha\beta}(q\bar{q} \to e^+e^-) = 0 \tag{26}$$

Standard Model Squared Matrix Elements

$$\begin{aligned}
T^{-+}_{\gamma\gamma}(q\bar{q} \to e^+e^-) &= T^{+-}_{\gamma\gamma}(q\bar{q} \to e^+e^-) = 4e_q^2\frac{\alpha}{\hat{s}^2}(\hat{u}^2+\hat{t}^2), && (27)\\
T^{-+}_{ZZ}(q\bar{q} \to e^+e^-) &= 4\left(\frac{\alpha}{\sin^2\theta_W\cos^2\theta_W}\right)^2\frac{1}{(\hat{s}-M_Z^2)^2+M_Z^2\Gamma_Z^2}\\
&\quad (C_{eR}^2C_{qR}^2\hat{u}^2+C_{eL}^2C_{qR}^2\hat{t}^2), && (28)\\
T^{+-}_{ZZ}(q\bar{q} \to e^+e^-) &= 4\left(\frac{\alpha}{\sin^2\theta_W\cos^2\theta_W}\right)^2\frac{1}{(\hat{s}-M_Z^2)^2+M_Z^2\Gamma_Z^2}\\
&\quad (C_{eL}^2C_{qL}^2\hat{u}^2+C_{eR}^2C_{qL}^2\hat{t}^2), && (29)\\
T^{-+}_{\gamma Z}(q\bar{q} \to e^+e^-) &= -8e_q\frac{\alpha^2}{\sin^2\theta_W\cos^2\theta_W}\frac{\hat{s}-M_Z^2}{\hat{s}((\hat{s}-M_Z^2)^2+M_Z^2\Gamma_Z^2)}\\
&\quad (C_{eR}C_{qR}\hat{u}^2+C_{eL}C_{qR}\hat{t}^2), && (30)\\
T^{+-}_{\gamma Z}(q\bar{q} \to e^+e^-) &= -8e_q\frac{\alpha^2}{\sin^2\theta_W\cos^2\theta_W}\frac{\hat{s}-M_Z^2}{\hat{s}((\hat{s}-M_Z^2)^2+M_Z^2\Gamma_Z^2)}\\
&\quad (C_{eL}C_{qL}\hat{u}^2+C_{eR}C_{qL}\hat{t}^2), && (31)
\end{aligned}$$

eeqq Contact Interaction Squared Matrix Elements

$$\begin{aligned}
T^{-+}_{CICI}(q\bar{q} \to e^+e^-) &= \frac{1}{\Lambda_{eq}^4}\{(1-\eta)(1-\eta')\hat{u}^2+(1+\eta)(1-\eta')\hat{t}^2\}, && (32)\\
T^{+-}_{CICI}(q\bar{q} \to e^+e^-) &= \frac{1}{\Lambda_{eq}^4}\{(1+\eta)(1+\eta')\hat{u}^2+(1-\eta)(1+\eta')\hat{t}^2\}, && (33)\\
T^{-+}_{\gamma CI}(q\bar{q} \to e^+e^-) &= -\epsilon_{\eta\eta'}\frac{1}{\Lambda_{eq}^2}e_q\frac{\alpha}{\hat{s}}2\Lambda_{eq}^4T^{-+}_{\gamma CI}(q\bar{q} \to e^+e^-), && (34)\\
T^{+-}_{\gamma CI}(q\bar{q} \to e^+e^-) &= -\epsilon_{\eta\eta'}\frac{1}{\Lambda_{eq}^2}e_q\frac{\alpha}{\hat{s}}2\Lambda_{eq}^4T^{+-}_{\gamma CI}(q\bar{q} \to e^+e^-), && (35)\\
T^{-+}_{ZCI}(q\bar{q} \to e^+e^-) &= \epsilon_{\eta\eta'}\frac{2}{\Lambda_{eq}^2}\frac{\alpha}{\sin^2\theta_W\cos^2\theta_W}\frac{\hat{s}-M_Z^2}{(\hat{s}-M_Z^2)^2+M_Z^2\Gamma_Z^2}\\
&\quad (C_{eR}C_{qR}(1-\eta)(1-\eta')\hat{u}^2+C_{eL}C_{qR}(1+\eta)(1-\eta')\hat{t}^2), && (36)\\
T^{+-}_{ZCI}(q\bar{q} \to e^+e^-) &= \epsilon_{\eta\eta'}\frac{2}{\Lambda_{eq}^2}\frac{\alpha}{\sin^2\theta_W\cos^2\theta_W}\frac{\hat{s}-M_Z^2}{(\hat{s}-M_Z^2)^2+M_Z^2\Gamma_Z^2}\\
&\quad (C_{eL}C_{qL}(1+\eta)(1+\eta')\hat{u}^2+C_{eR}C_{qL}(1-\eta)(1+\eta')\hat{t}^2), && (37)
\end{aligned}$$

SM Interference, Chirarity & Helicity Selected Squared Matrix Elements
$(\eta,\eta') = LL(+1,+1), RR(-1,-1), LR(+1,-1), RL(+1,+1)$

$$
\begin{aligned}
T^{-+}_{CICI}(q\bar{q}\to e^+e^-) &= 0;\ LL(\eta=+1,\eta'=+1) \\
&= \frac{1}{\Lambda^4_{eq}}4\hat{u}^2;\ RR(\eta=-1,\eta'=-1) \\
&= \frac{1}{\Lambda^4_{eq}}4\hat{t}^2;\ LR(\eta=+1,\eta'=-1) \\
&= 0;\ RL(\eta=-1,\eta'=+1) \qquad (38)\\
T^{+-}_{CICI}(q\bar{q}\to e^+e^-) &= \frac{1}{\Lambda^4_{eq}}4\hat{u}^2; LL(\eta=+1,\eta'=+1) \\
&= 0;\ RR(\eta=-1,\eta'=-1) \\
&= 0;\ LR(\eta=+1,\eta'=-1) \\
&= \frac{1}{\Lambda^4_{eq}}4\hat{t}^2;\ RL(\eta=-1,\eta'=+1) \qquad (39)\\
T^{-+}_{\gamma CI}(q\bar{q}\to e^+e^-) &= 0;\ LL(\eta=+1,\eta'=+1) \\
&= -\epsilon_{\eta\eta'}\frac{1}{\Lambda^2_{eq}}e_q\frac{\alpha}{\hat{s}}4\hat{u}^2;\ RR(\eta=-1,\eta'=-1) \\
&= -\epsilon_{\eta\eta'}\frac{1}{\Lambda^2_{eq}}e_q\frac{\alpha}{\hat{s}}4\hat{t}^2;\ LR(\eta=+1,\eta'=-1) \\
&= 0;\ RL(\eta=-1,\eta'=+1) \qquad (40)\\
T^{+-}_{\gamma CI}(q\bar{q}\to e^+e^-) &= -\epsilon_{\eta\eta'}\frac{1}{\Lambda^2_{eq}}e_q\frac{\alpha}{\hat{s}}4\hat{u}^2;\ LL(\eta=-1,\eta'=-1) \\
&= 0;\ RR(\eta=-1,\eta'=-1) \\
&= 0;\ LR(\eta=+1,\eta'=-1) \\
&= -\epsilon_{\eta\eta'}\frac{1}{\Lambda^2_{eq}}e_q\frac{\alpha}{\hat{s}}4\hat{t}^2;\ RL(\eta=-1,\eta'=-1) \qquad (41)\\
T^{-+}_{ZCI}(q\bar{q}\to e^+e^-) &= \epsilon_{\eta\eta'}\frac{2}{\Lambda^2_{eq}}\frac{\alpha}{\sin^2\theta_W\cos^2\theta_W}\frac{\hat{s}-M_Z^2}{(\hat{s}-M_Z^2)^2+M_Z^2\Gamma_Z^2} \\
&\times\ 0;\ LL(\eta=+1,\eta'=+1) \\
&\times\ 4C_{eR}C_{qR}\hat{u}^2;\ RR(\eta=-1,\eta'=-1) \\
&\times\ 4C_{eL}C_{qR}\hat{t}^2;\ LR(\eta=+1,\eta'=-1) \\
&\times\ 0;\ RL(\eta=-1,\eta'=+1) \qquad (42)\\
T^{+-}_{ZCI}(q\bar{q}\to e^+e^-) &= \epsilon_{\eta\eta'}\frac{2}{\Lambda^2_{eq}}\frac{\alpha}{\sin^2\theta_W\cos^2\theta_W}\frac{\hat{s}-M_Z^2}{(\hat{s}-M_Z^2)^2+M_Z^2\Gamma_Z^2} \\
&\times\ 4C_{eL}C_{qL}\hat{u}^2;\ LL(\eta=+1,\eta'=+1) \\
&\times\ 0;\ RR(\eta=-1,\eta'=-1) \\
&\times\ 0;\ LR(\eta=+1,\eta'=-1) \\
&\times\ 4C_{eR}C_{qL}\hat{t}^2;\ RL(\eta=-1,\eta'=+1) \qquad (43)
\end{aligned}
$$

Chirarity Selected Unpolarized Squared Matrix Element

$$
\begin{aligned}
T_{CICI}(q\bar{q} \to e^+e^-) &= \frac{1}{\Lambda_{eq}^4} 4\hat{u}^2;\ LL(\eta = +1, \eta' = +1);\ RR(\eta = -1, \eta' = -1) \\
&= \frac{1}{\Lambda_{eq}^4} 4\hat{t}^2;\ LR(\eta = +1, \eta' = -1);\ RL(\eta = -1, \eta' = +1) \qquad (44) \\
T_{\gamma CI}(q\bar{q} \to e^+e^-) &= -\epsilon_{\eta\eta'} \frac{1}{\Lambda_{eq}^2} e_q \frac{\alpha}{\hat{s}} \\
& \quad 4\hat{u}^2;\ LL(\eta = +1, \eta' = +1);\ RR(\eta = -1, \eta' = -1) \\
&= -\epsilon_{\eta\eta'} \frac{1}{\Lambda_{eq}^2} e_q \frac{\alpha}{\hat{s}} \\
& \quad 4\hat{t}^2;\ LR(\eta = +1, \eta' = -1);\ RL(\eta = -1, \eta' = +1) \qquad (45) \\
T_{ZCI}(q\bar{q} \to e^+e^-) &= \frac{2}{\Lambda_{eq}^2} \frac{\alpha}{\sin^2\theta_W \cos^2\theta_W} \frac{\hat{s} - M_Z^2}{(\hat{s} - M_Z^2)^2 + M_Z^2 \Gamma_Z^2} \\
&\times\ \epsilon_{++} 4 C_{eL} C_{qL} \hat{u}^2;\ LL(\eta = +1, \eta' = +1) \\
&\times\ \epsilon_{--} 4 C_{eR} C_{qR} \hat{u}^2;\ RR(\eta = -1, \eta' = -1) \\
&\times\ \epsilon_{+-} 4 C_{eL} C_{qR} \hat{u}^2;\ LR(\eta = +1, \eta' = -1) \\
&\times\ \epsilon_{-+} 4 C_{eR} C_{qL} \hat{u}^2;\ RL(\eta = -1, \eta' = +1) \\
& \qquad (46)
\end{aligned}
$$

Cross Section Asymmetry for $q\bar{q} \to e^+e^-$
Formula Calclated by J. Murata
Asymmetry Definition

$$\begin{aligned}
\hat{a}_L &\equiv \frac{T^-_{\alpha\beta} - T^+_{\alpha\beta}}{T^-_{\alpha\beta} + T^+_{\alpha\beta}} = \frac{(T^{--}_{\alpha\beta} + T^{-+}_{\alpha\beta}) - (T^{+-}_{\alpha\beta} + T^{++}_{\alpha\beta})}{(T^{--}_{\alpha\beta} + T^{-+}_{\alpha\beta}) + (T^{+-}_{\alpha\beta} + T^{++}_{\alpha\beta})} \\
&\to \frac{T^{-+}_{\alpha\beta} - T^{+-}_{\alpha\beta}}{T^{-+}_{\alpha\beta} + T^{+-}_{\alpha\beta}} = \hat{a}^{PV}_{LL};\ (T^{\lambda\lambda}_{\alpha\beta} = 0), \qquad (47) \\
\hat{a}^{PV}_{LL} &\equiv \frac{T^{--}_{\alpha\beta} - T^{++}_{\alpha\beta}}{T^{--}_{\alpha\beta} + T^{++}_{\alpha\beta}} \\
&\to 0;\ (T^{\lambda\lambda}_{\alpha\beta} = 0), \qquad (48) \\
\hat{a}_{LL} &\equiv \frac{(T^{--}_{\alpha\beta} + T^{++}_{\alpha\beta}) - (T^{-+}_{\alpha\beta} + T^{+-}_{\alpha\beta})}{(T^{--}_{\alpha\beta} + T^{++}_{\alpha\beta}) + (T^{-+}_{\alpha\beta} + T^{+-}_{\alpha\beta})} \\
&\to -1;\ (T^{\lambda\lambda}_{\alpha\beta} = 0) \qquad (49)
\end{aligned}$$

Standard Model Asymmetry

$$\begin{aligned}
\hat{\hat{a}}^{PV}_{LL}(\gamma\gamma) &= 0, \qquad (50) \\
\hat{\hat{a}}^{PV}_{LL}(ZZ) &= \frac{(C^2_{eR}C^2_{qR} - C^2_{eL}C^2_{qL})\hat{u}^2 + (C^2_{eL}C^2_{qR} - C^2_{eR}C^2_{qL})\hat{t}^2}{(C^2_{eR}C^2_{qR} + C^2_{eL}C^2_{qL})\hat{u}^2 + (C^2_{eL}C^2_{qR} + C^2_{eR}C^2_{qL})\hat{t}^2}, \qquad (51) \\
\hat{\hat{a}}^{PV}_{LL}(\gamma Z) &= \frac{(C_{eR}C_{qR} - C_{eL}C_{qL})\hat{u}^2 + (C_{eL}C_{qR} - C_{eR}C_{qL})\hat{t}^2}{(C_{eR}C_{qR} + C_{eL}C_{qL})\hat{u}^2 + (C_{eL}C_{qR} + C_{eR}C_{qL})\hat{t}^2}, \qquad (52)
\end{aligned}$$

eeqq Contact Interaction Asymmetry

$$\begin{aligned}
\hat{\hat{a}}^{PV}_{LL}(CICI) &= \frac{-(\eta + \eta')\hat{u}^2 + (\eta - \eta')\hat{t}^2}{(1 + \eta\eta')\hat{u}^2 + (1 - \eta\eta')\hat{t}^2}, \qquad (53) \\
\hat{\hat{a}}^{PV}_{LL}(\gamma CI) &= \hat{\hat{a}}^{PV}_{LL}(CICI), \qquad (54) \\
\hat{\hat{a}}^{PV}_{LL}(ZCI) &= \frac{\begin{array}{c}(C_{eR}C_{qR}(1-\eta)(1-\eta') - (C_{eL}C_{qL}(1+\eta)(1+\eta'))\hat{u}^2 + \\ (C_{eL}C_{qR}(1+\eta)(1-\eta') - (C_{eR}C_{qL}(1-\eta)(1+\eta'))\hat{t}^2\end{array}}{\begin{array}{c}(C_{eR}C_{qR}(1-\eta)(1-\eta') + (C_{eL}C_{qL}(1+\eta)(1+\eta'))\hat{u}^2 + \\ (C_{eL}C_{qR}(1+\eta)(1-\eta') + (C_{eR}C_{qL}(1-\eta)(1+\eta'))\hat{t}^2\end{array}} \qquad (55)
\end{aligned}$$

SM Interference & Chirarity Selected Asymmetry
$(\eta, \eta') = LL(+1,+1), RR(-1,-1), LR(+1,-1), RL(+1,+1)$

$$\begin{aligned}
\hat{\hat{a}}^{PV}_{LL}(\forall\alpha = CI) &= -1;\ LL(\eta = +1, \eta' + 1) \\
&= +1;\ RR(\eta = -1, \eta' - 1) \\
&= +1;\ LR(\eta = +1, \eta' - 1) \\
&= -1;\ RL(\eta = -1, \eta' + 1) \qquad (56)
\end{aligned}$$

i.e. Independent on η !

$$\begin{aligned}
\hat{\hat{a}}^{PV}_{LL}(\forall\alpha = CI) &= -1;\ L(\eta' = +1) \\
&= +1;\ R(\eta' = -1) \qquad (57)
\end{aligned}$$

Cross Section to Spin Asymmetries
Double Spin Selected Cross Section

$$\begin{aligned}
\sigma^{++} &= \hat{\sigma}^{++}q^+\bar{q}^+ + \hat{\sigma}^{--}q^-\bar{q}^- + \hat{\sigma}^{+-}q^+\bar{q}^- + \hat{\sigma}^{-+}q^-\bar{q}^+ \\
&+ \hat{\sigma}^{++}\bar{q}^+q^+ + \hat{\sigma}^{--}\bar{q}^-q^- + \hat{\sigma}^{+-}\bar{q}^-q^+ + \hat{\sigma}^{-+}\bar{q}^+q^- \qquad (58)\\
\sigma^{--} &= \hat{\sigma}^{++}q^-\bar{q}^- + \hat{\sigma}^{--}q^+\bar{q}^+ + \hat{\sigma}^{+-}q^-\bar{q}^+ + \hat{\sigma}^{-+}q^+\bar{q}^- \\
&+ \hat{\sigma}^{++}\bar{q}^-q^- + \hat{\sigma}^{--}\bar{q}^+q^+ + \hat{\sigma}^{+-}\bar{q}^+q^- + \hat{\sigma}^{-+}\bar{q}^-q^+ \qquad (59)\\
\sigma^{+-} &= \hat{\sigma}^{++}q^+\bar{q}^- + \hat{\sigma}^{--}q^-\bar{q}^+ + \hat{\sigma}^{+-}q^+\bar{q}^+ + \hat{\sigma}^{-+}q^-\bar{q}^- \\
&+ \hat{\sigma}^{++}\bar{q}^+q^- + \hat{\sigma}^{--}\bar{q}^-q^+ + \hat{\sigma}^{+-}\bar{q}^-q^- + \hat{\sigma}^{-+}\bar{q}^+q^+ \qquad (60)\\
\sigma^{-+} &= \hat{\sigma}^{++}q^-\bar{q}^+ + \hat{\sigma}^{--}q^+\bar{q}^- + \hat{\sigma}^{+-}q^-\bar{q}^- + \hat{\sigma}^{-+}q^+\bar{q}^+ \\
&+ \hat{\sigma}^{++}\bar{q}^-q^+ + \hat{\sigma}^{--}\bar{q}^+q^- + \hat{\sigma}^{+-}\bar{q}^+q^+ + \hat{\sigma}^{-+}\bar{q}^-q^- \qquad (61)
\end{aligned}$$

Single Spin Selected Cross Section

$$\begin{aligned}
2\sigma^{+0} = \sigma^{++} + \sigma^{+-} &= \hat{\sigma}^{++}(q^+\bar{q} + \bar{q}^+q) + \hat{\sigma}^{--}(q^-\bar{q} + \bar{q}^-q) \\
&+ \hat{\sigma}^{+-}(q^+\bar{q} + \bar{q}^-q) + \hat{\sigma}^{-+}(q^-\bar{q} + \bar{q}^+q) \qquad (62)\\
2\sigma^{-0} = \sigma^{--} + \sigma^{-+} &= \hat{\sigma}^{++}(q^-\bar{q} + \bar{q}^-q) + \hat{\sigma}^{--}(q^+\bar{q} + \bar{q}^+q) \\
&+ \hat{\sigma}^{+-}(q^-\bar{q} + \bar{q}^+q) + \hat{\sigma}^{-+}(q^+\bar{q} + \bar{q}^-q) \qquad (63)
\end{aligned}$$

The partonic cross section can be expressed as;

$$\hat{\sigma}^{\lambda_1\lambda_2} = \sum_{\alpha,\beta} T^{\lambda_1\lambda_2}_{\alpha,\beta} \qquad (64)$$

For DY process (SM + CI),

$$\hat{\sigma}^{++} = \hat{\sigma}^{--} = 0 \qquad (65)$$

In case of Event Generation, $(q\bar{q} + \bar{q}q) \to q_1q_2)$, then

For DY type Event Generation,

$$\begin{aligned}
\sigma^{++} &= \hat{\sigma}^{+-}q^+q^- + \hat{\sigma}^{-+}q^-q^+ \qquad (66)\\
\sigma^{--} &= \hat{\sigma}^{+-}q^-q^+ + \hat{\sigma}^{-+}q^+q^- \qquad (67)\\
\sigma^{+-} &= \hat{\sigma}^{+-}q^+q^+ + \hat{\sigma}^{-+}q^-q^- \qquad (68)\\
\sigma^{-+} &= \hat{\sigma}^{+-}q^-q^- + \hat{\sigma}^{-+}q^+q^+ \qquad (69)\\
2\sigma^{+0} &= \hat{\sigma}^{+-}q^+q + \hat{\sigma}^{-+}q^-q \qquad (70)\\
2\sigma^{-0} &= \hat{\sigma}^{+-}q^-q + \hat{\sigma}^{-+}q^+q \qquad (71)
\end{aligned}$$

Asymmetries for DY processes

$$
\begin{aligned}
\bar{A}_{LL}^{PV} &= \frac{\sigma^{-+} - \sigma^{+-}}{\sigma^{-+} + \sigma^{+-}} \\
&= \frac{(q^+\bar{q}^+ - q^-\bar{q}^-)(\hat{\sigma}^{-+} - \hat{\sigma}^{+-})}{(2\bar{q}^-q^- + q^+\bar{q}^+ + q^-\bar{q}^-)\hat{\sigma}^{-+} + (2\bar{q}^+q^+ + q^+\bar{q}^+ + q^-\bar{q}^-)\hat{\sigma}^{+-}} \qquad (72) \\
A_{LL}^{PV} &= \frac{\sigma^{--} - \sigma^{++}}{\sigma^{-+} + \sigma^{++}} \\
&= \frac{(q^+\bar{q}^- - q^-\bar{q}^+)(\hat{\sigma}^{-+} - \hat{\sigma}^{+-})}{(2\bar{q}^+q^- + q^+\bar{q}^- + q^-\bar{q}^+)\hat{\sigma}^{-+} + (2\bar{q}^-q^+ + q^-\bar{q}^+ + q^+\bar{q}^-)\hat{\sigma}^{+-}} \qquad (73) \\
A_{LL} &= \frac{\sigma^{--} + \sigma^{++} - \sigma^{-+} - \sigma^{+-}}{\sigma^{--} + \sigma^{++} + \sigma^{-+} + \sigma^{+-}} \\
&= -\frac{\Delta q\Delta\bar{q} + \Delta\bar{q}\Delta q}{q\bar{q} + \bar{q}q} \qquad (74) \\
A_L &= \frac{\sigma^{-0} - \sigma^{+0}}{\sigma^{-0} + \sigma^{+0}} \\
&= \frac{\Delta q\bar{q} - \Delta\bar{q}q}{q\bar{q} + \bar{q}q}\, \bar{a}_{LL}^{PV};\ (\hat{\bar{a}}_{LL}^{PV} = \hat{a}_L) \qquad (75)
\end{aligned}
$$

Weight Factor W in Event Generator for DY processes

$$
\begin{aligned}
W(\bar{A}_{LL}^{PV}) &= \frac{(q^+q^+ - q^-q^-)(\hat{\sigma}^{-+} - \hat{\sigma}^{+-})}{(q^+q^+ + q^-q^-)(\hat{\sigma}^{-+} + \hat{\sigma}^{+-})} \\
&= \frac{q^+q^+ - q^-q^-}{q^+q^+ + q^-q^-}\, \hat{\bar{a}}_{LL}^{PV} \qquad (76) \\
W(A_{LL}^{PV}) &= \frac{(q^+q^- - q^-q^+)(\hat{\sigma}^{-+} - \hat{\sigma}^{+-})}{(q^+q^- + q^-q^+)(\hat{\sigma}^{-+} + \hat{\sigma}^{+-})} \\
&= \frac{q^+q^- - q^-q^+}{q^+q^- + q^-q^+}\, \hat{\bar{a}}_{LL}^{PV} \qquad (77) \\
W(A_{LL}) &= \frac{(q^+q^- + q^-q^+ - q^+q^+ - q^-q^-)(\hat{\sigma}^{+-} + \hat{\sigma}^{-+})}{(q^+q^- + q^-q^+ + q^+q^+ + q^-q^-)(\hat{\sigma}^{+-} + \hat{\sigma}^{-+})} \\
&= -\frac{\Delta q\Delta q}{qq} \qquad (78) \\
W(A_L) &= \frac{(q^-q - q^+q)(\hat{\sigma}^{-+} - \hat{\sigma}^{+-})}{(q^-q + q^+q)(\hat{\sigma}^{-+} + \hat{\sigma}^{+-})} \\
&= \frac{\Delta q}{q}\, \hat{\bar{a}}_{LL}^{PV}\ (\hat{\bar{a}}_{LL}^{PV} = \hat{a}_L) \qquad (79)
\end{aligned}
$$

How to include into Event Generator; for $A_x = A_L, A_{LL}, A_{LL}^{PV}, \bar{A}_{LL}^{PV}$

$$
\begin{aligned}
A_x &= (\sum_{event=SM} W_{SM}^{event} + \sum_{event=CI} W_{CI}^{event}) / \sum_{event=SM+CI} && (80)\\
W_{SM}^{event} &= \sum_{event=SM} PDF(x)_{event}\, \hat{a}_x^{event} \\
W_{CI}^{event} &= \sum_{event=CI} PDF(x)_{event}\, \hat{a}_x^{event} && (81)\\
PDF(\bar{A}_{LL}^{PV}) &= \frac{q^+q^+ - q^-q^-}{q^+q^+ + q^-q^-} && (82)\\
PDF(A_{LL}^{PV}) &= \frac{q^+q^- - q^-q^+}{q^+q^- + q^-q^+} && (83)\\
PDF(A_{LL}) &= \frac{\Delta q \Delta q}{qq} && (84)\\
PDF(A_L) &= \frac{\Delta q}{q} && (85)\\
& && (86)
\end{aligned}
$$

Event generation for SM ; ISUB=1 & for CI ; ISUB=165 in Pythia

- ISUB=1; $f_i\bar{f}_i \to \gamma^* Z^0$
- ISUB=165; $f_i\bar{f}_i \to f_k\bar{f}_k$ (via $\gamma^* Z^0$)

- MSTP(5)=0
  Standard Model
- MSTP(5)=1
  left-left isoscalar model
  only u & d quarks are composite
- MSTP(5)=2
  left-left isoscalar model
  all quarks are composite
- MSTP(5)=3
  Helicity-non-conserving model (Eic84,Lan91)
  only u & d quarks are composite
- MSTP(5)=4
  Helicity-non-conserving model (Eic84,Lan91)
  all quarks are composite
- PARU(155)=Λ
  D=1000GeV (Eic84,Lan91), Need study on Λ_{eq}.

- PARU(156)=η
  D=+1 (Eic84,Lan91), Need study on the definition.
- ϵ, η'
- KFPR(165,1)=KF
  D=11 (electron channel)

Direct photon production
Subprocess $q\bar{q} \to g\gamma$ & $qg \to q\gamma$
Formula Source: P. Taxil; Nuo. Cim. Vol.16 Num.11 (93) (91-92)

$$
\begin{aligned}
T(q^{\lambda_1}\bar{q}^{\lambda_2} \to g\gamma) &= \frac{8\pi e_q^2 \alpha\alpha_s}{9\hat{s}}\left(\frac{\hat{u}}{\hat{t}} + \frac{\hat{t}}{\hat{u}}\right) && (87)\\
&\quad \{(1-\lambda_1\lambda_2)(C_q^2 + D_q^2) + 2(\lambda_1 - \lambda_2)C_q D_q\} && (88)\\
C_q &= 1 + \frac{\hat{u}\hat{t}}{2e_q\Lambda^4} && (89)\\
D_q &= C_q - 1 && (90)\\
T(q^{\lambda_1}g^{\lambda_2} \to q\gamma) &= \frac{\pi e_q^2 \alpha\alpha_s}{-3\hat{u}\hat{s}^3}((\hat{u}^2 + \hat{s}^2)(C_q^2 + D_q^2) && (91)\\
&\quad -2\lambda_1 C_q D_q \lambda_2(\hat{u}^2 - \hat{s}^2)(\lambda_1(C_q^2 + D_q^2) - 2C_q D_q)) && (92)\\
T(\bar{q}^{\lambda_1}g^{\lambda_2} \to \bar{q}\gamma) &= \frac{\pi e_q^2 \alpha\alpha_s}{-3\hat{u}\hat{s}^3}((\hat{u}^2 + \hat{s}^2)(C_q^2 + D_q^2) && (93)\\
&\quad +2\lambda_1 C_q D_q - \lambda_2(\hat{u}^2 - \hat{s}^2)(-\lambda_1(C_q^2 + D_q^2) - 2C_q D_q)) && (94)
\end{aligned}
$$

One jet production
Subprocess
$q\bar{q}' \to q\bar{q}'$, $qq' \to qq'$, $\bar{q}\bar{q}' \to \bar{q}\bar{q}'$, $qq \to qq$, $\bar{q}\bar{q} \to \bar{q}\bar{q}$, $q\bar{q} \to q\bar{q}$, $q\bar{q} \to q'\bar{q}'$
and considering gluons as elementary,
$q\bar{q} \to gg$, $gg \to q\bar{q}$, $qg \to qg$
Formula Source: P. Taxil; Nuo. Cim. Vol.16 Num.11 (93) (91-92)

Interference Term (gCI, ZCI, WCI) for $(qq \to qq)$ P. Taxil and J.M.Virey; Phys.Lett.B364 (95) 181

Compositeness Scale for qqqqCI ; $\Lambda_{qq} < \Lambda_{eq}$?