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Scalar and Vector Leptoquark Parir Production in e^+e^- and $\gamma\gamma$ Collisions

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DESY

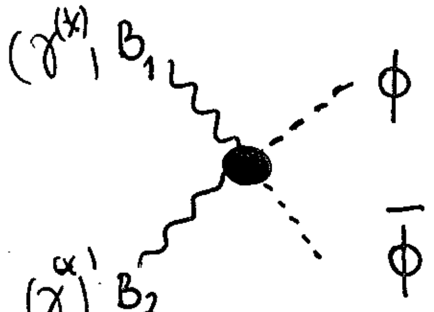
1. Introduction
2. Basic Notation
3. Production Cross Sections
4. Numerical Results
5. Comparison with Future Search Limits at other Colliders

1 Introduction

WHY LQ PAIR PRODUCTION?

- SINGLE PRODUCTION (real or virtual):

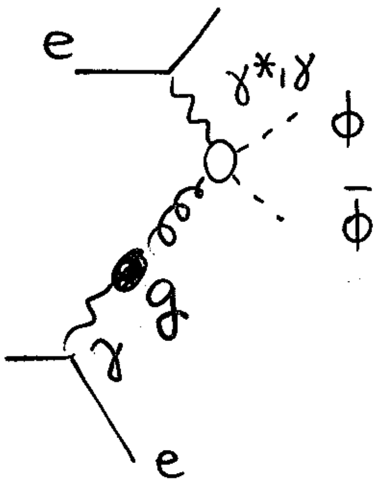
$$\sigma \propto \lambda_{\ell q} \ll e \ , \ M \lesssim 1\ldots2\,\text{TeV}.$$



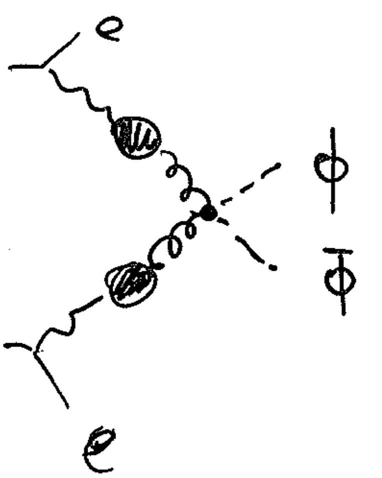
DIR

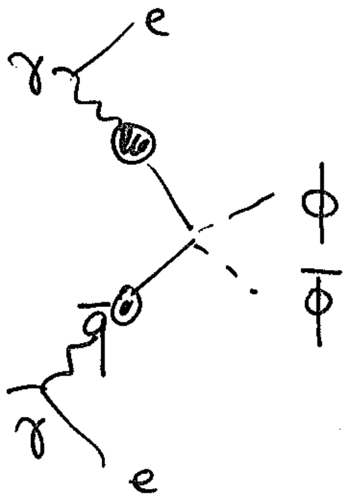
ONLY GAUGE COUPLINGS

& ANOMALOUS COUPLINGS (V)



DIR/RES





RES / RES

SCALARS: DIRECT MASS LIMITS

VECTORS: MASS LIMITS AND LIMITS ON $\kappa_{A,G}$; $\lambda_{A,G}$

2 Basic Notation

$$\mathcal{L} = \mathcal{L}_S^g + \mathcal{L}_V^g, \tag{2}$$

$$\mathcal{L}_S^g = \sum_{scalars} \left[\left(D_{ij}^{\mu} \Phi^j \right)^{\dagger} \left(D_{\mu}^{ik} \Phi_k \right) - M_S^2 \Phi^{i\dagger} \Phi_i \right], \tag{3}$$

$$\mathcal{L}_V^g = \sum_{vectors} \left\{ -\frac{1}{2} G_{\mu\nu}^{i\dagger} G_i^{\mu\nu} + M_V^2 \Phi_{\mu}^{i\dagger} \Phi_i^{\mu} - i g_s \left[(1-\kappa_G) \Phi_{\mu}^{i\dagger} t_{ij}^a \Phi_{\nu}^j \mathcal{G}_a^{\mu\nu} + \frac{\lambda_G}{M_V^2} G_{\sigma\mu}^{i\dagger} t_{ij}^a G_{\nu}^{j\mu} \mathcal{G}_a^{\nu\sigma} \right] \right\}. \tag{4}$$

$$\begin{aligned} \mathcal{G}_{\mu\nu}^a &= \partial_\mu \mathcal{A}_\nu^a - \partial_\nu \mathcal{A}_\mu^a + g_s f^{abc} \mathcal{A}_{\mu b} \mathcal{A}_{\nu c}, \\ G_{\mu\nu}^i &= D_\mu^{ik} \Phi_{\nu k} - D_\nu^{ik} \Phi_{\mu k}, \end{aligned} \tag{5}$$

$$D_\mu^{ij} = \partial_\mu \delta^{ij} - i g_s t_a^{ij} \mathcal{A}_\mu^a. \tag{6}$$

$$\begin{aligned} \mu_{\Phi,G} &= \frac{g_s}{2M_\Phi} \left(2 - \kappa_G + \lambda_G \right), \\ q_{\Phi,G} &= -\frac{g_s}{M_\Phi^2} \left(1 - \kappa_G - \lambda_G \right). \end{aligned} \tag{7}$$

3 Production Cross Sections

$$\sigma \equiv [\gamma\gamma] \oplus [\gamma g] \oplus [gg + q\bar{q}]$$

For $\gamma\gamma$ scattering three terms contribute to the cross section: the direct process $\gamma\gamma \to \Phi\overline{\Phi}$, σ_{dir}, a term in which one of the photons is resolved and the second couples directly to the leptoquarks, $\sigma_{dir/res}$, and the resolved contribution, σ_{res},

$$\sigma_{S,V}^{\gamma\gamma,tot} = \sigma_{S,V}^{\gamma\gamma,dir} + \sigma_{S,V}^{\gamma\gamma,dir/res} + \sigma_{S,V}^{\gamma\gamma,res}. \tag{51}$$

The third term (eq. (56)) is charge independent, but the first and the second terms behave $\propto Q_\Phi^4$ and $\propto Q_\Phi^2$, respectively. The cross section for the direct contribution reads [11]

$$\sigma_{S,V}^{\gamma\gamma,dir}(s, M_\Phi) = \int_{y_{min}/y_{max}}^{y_{max}} dy_1 \int_{y_{min}/y_1}^{y_{max}} dy_2 \Phi_{\gamma/e}(y_1)\Phi_{\gamma/e}(y_2)\hat{\sigma}_{S,V}^{dir}(\hat{s}, M_\Phi)\theta(\hat{s} - 4M_\Phi^2). \tag{52}$$

Here the subsystem cross sections are:

$$\hat{\sigma}_{S,V}^{dir}(\hat{s}, M_\Phi) = \frac{\pi\alpha^2}{\hat{s}} Q_\Phi^4 N_c R_{S,V}^*(\hat{s}, M_\Phi), \tag{53}$$

with $\hat{s} = y_1 y_2 S, S = 4E_{e^+}E_{e^-}$, and

$$\begin{aligned} R_S^* &= 2R_S, \\ R_V^* &= 2\sum_{j=0}^{20} \chi_j^*(\kappa_A, \kappa_A, \lambda_A, \lambda_A)\widetilde{H}_j(\hat{s}, \beta). \end{aligned} \tag{54}$$

κ_A, λ_A

$\kappa_A, \lambda_A, \kappa_G, \lambda_G$

$$\begin{aligned} \sigma_{S,V}^{\gamma\gamma,dir/res}(s, M_\Phi) &= 2\int_{y_{min}/y_{max}}^{y_{max}} dy_1 \int_{y_{min}/y_1}^{y_{max}} dy_2 \int_{4M_\Phi^2/Sy_1y_2}^{1} dz \Phi_{\gamma/e}(y_1)\Phi_{\gamma/e}(y_2)G_\gamma(z, \mu) \\ &\times \hat{\sigma}_{S,V}^{\gamma g}(\hat{s}, M_\Phi)\theta(\hat{s} - 4M_\Phi^2). \end{aligned} \tag{55}$$

with μ the factorization scale. Note that due to the smallness of the couplings $\lambda_{lq} \ll e$ only the subprocess due to gluon-photon fusion contributes.

The double-resolved contribution reads:

$$\begin{aligned} \sigma_{S,V}^{\gamma\gamma,res}(s, M_\Phi) &= \int_{y_{min}/y_{max}}^{y_{max}} dy_1 \int_{y_{min}/y_1}^{y_{max}} dy_2 \int_{4M_\Phi^2/Sy_1y_2}^{1} dz_1 \int_{4M_\Phi^2/Sy_1y_2z_1}^{1} dz_2 \Phi_{\gamma/e}(y_1)\Phi_{\gamma/e}(y_2) \\ &\times \left\{ \sum_{f=1}^{N_f} \left[q_f^\gamma(z_1, \mu_1)\overline{q}_f^\gamma(z_2, \mu_2) + \overline{q}_f^\gamma(z_1, \mu_1)q_f^\gamma(z_2, \mu_2) \right] \hat{\sigma}_{S,V}^{q}(\hat{s}, M_\Phi) \right. \\ &+ \left. G^\gamma(z_1, \mu_1)G^\gamma(z_2, \mu_2)\hat{\sigma}_{S,V}^{g}(\hat{s}, M_\Phi) \right\} \theta(\hat{s} - 4M_\Phi^2). \end{aligned} \tag{56}$$

κ_G, λ_G

Scalar Leptoquarks

The differential and integral pair production cross sections for gg and $q\bar{q}$ scattering are

$$\begin{aligned} \frac{d\hat{\sigma}^{gg}_{S\bar{S}}}{d\cos\theta} &= \frac{\pi\alpha_s^2}{6\hat{s}}\beta\left\{\frac{1}{32}\left[25+9\beta^2\cos^2\theta-18\beta^2\right]\right. \\ &- \left.\frac{1}{16}\frac{(25-34\beta^2+9\beta^4)}{1-\beta^2\cos^2\theta}+\frac{(1-\beta^2)^2}{(1-\beta^2\cos^2\theta)^2}\right\}, \end{aligned} \tag{17}$$

$$\hat{\sigma}^{gg}_{S\bar{S}} = \frac{\pi\alpha_s^2}{96\hat{s}}\left\{\beta\left(41-31\beta^2\right)-\left(17-18\beta^2+\beta^4\right)\log\left|\frac{1+\beta}{1-\beta}\right|\right\}, \tag{18}$$

and

$$\frac{d\hat{\sigma}^{q\bar{q}}_{S\bar{S}}}{d\cos\theta} = \frac{\pi\alpha_s^2}{18\hat{s}}\beta^3\sin^2\theta, \tag{19}$$

$$\hat{\sigma}^{qq}_{S\bar{S}} = \frac{2\pi\alpha_s^2}{27\hat{s}}\beta^3, \tag{20}$$

Vector Leptoquarks

The differential and integral pair production cross sections for gg scattering are

$$\frac{d\hat{\sigma}^{gg}_{V\bar{V}}}{d\cos\theta} = \frac{\pi\alpha_s^2}{192\hat{s}}\beta\sum_{i=0}^{14}\chi_i^g(\kappa_G,\lambda_G)\frac{F_i(\hat{s},\beta,\cos\theta)}{(1-\beta^2\cos^2\theta)^2}, \tag{21}$$

with

$$\begin{aligned} \sum_{i=0}^{14}\chi_i^g(\kappa_G,\lambda_G)F_i \;=\;& F_0 + \kappa_G F_1 + \lambda_G F_2 + \kappa_G^2 F_3 + \kappa_G\lambda_G F_4 \\ & \lambda_G^2 F_5 \quad \kappa_G^3 F_6 + \kappa_G^2\lambda_G F_7 + \kappa_G\lambda_G^2 F_8 + \lambda_G^3 F_9 \\ & \kappa_G^4 F_{10} + \kappa_G^3\lambda_G F_{11} + \kappa_G^2\lambda_G^2 F_{12} + \kappa_G\lambda_G^3 F_{13} + \lambda_G^4 F_{14}, \end{aligned} \tag{22}$$

$$\hat{\sigma}^{gg}_{V\bar{V}} = \frac{\pi\alpha_s^2}{96M_V^2}\sum_{i=0}^{14}\chi_i(\kappa_G,\lambda_G)\tilde{F}_i(\hat{s},\beta), \tag{23}$$

$$\tilde{F}_i = \frac{M_V^2}{\hat{s}}\int_0^\beta d\xi\,\frac{F_i(\xi=\beta\cos\theta)}{(1-\xi^2)^2}. \tag{24}$$

[γγ]dir

Nucl. Phys. B (Proc. Suppl.) 37B (1994) 181

and

$$\hat{\sigma}_s(\hat{s},\beta) = \frac{\pi\alpha^2}{\hat{s}} Q_\Phi^4 N_c \left\{ 2(2-\beta^2)\beta - (1-\beta^4)\log\left|\frac{1+\beta}{1-\beta}\right| \right\} \qquad (25)$$

where $N_c = 3$. Numerical results have been derived for the case of a $\gamma\gamma$ collider operating at $\sqrt{s} = 500\,\mathrm{GeV}$ in [13]. As seen in figure 13 only leptoquarks with large charges can be pair produced at a sufficient rate in this reaction.

In [21] single production of scalar leptoquarks is considered for $\gamma\gamma$ fusion via $\gamma\gamma \to \bar{l}qS$. At typical luminosities the search limits reach 0.8 to $0.9\sqrt{s}$ for M_s.

6.2. Vector Leptoquarks

The differential and integral production cross section for vector leptoquarks are

$$\frac{d\hat{\sigma}_v}{d\cos\theta} = \frac{\pi\alpha^2}{\hat{s}} Q_\Phi^4 N_c \sum_{j=0}^{14} \chi_j \frac{F_j(\hat{s},\beta,\cos\theta)}{(1-\beta^2\cos^2\theta)^2} \qquad (26)$$

with $\chi_j = \chi_j(\kappa_A,\lambda_A)$ and

$$\begin{array}{lcrcr}
\sum_{j=0}^{14}\chi_j F_j & = & F_0 & + & \kappa_A F_1 \\
+\kappa_A^2 F_2 & + & \kappa_A^3 F_3 & + & \kappa_A^4 F_4 \\
+\lambda_A F_5 & + & \lambda_A^2 F_6 & + & \lambda_A^3 F_7 \\
+\lambda_A^4 F_8 & + & \kappa_A\lambda_A F_9 & + & \kappa_A\lambda_A^2 F_{10} \\
+\kappa_A\lambda_A^3 F_{11} & + & \kappa_A^2\lambda_A F_{12} & + & \kappa_A^3\lambda_A F_{13} \\
+\kappa_A^2\lambda_A^2 F_{14} & & & &
\end{array}$$

and

$$\hat{\sigma}_v = \frac{2\pi\alpha^2}{M_v^2} Q_\Phi^4 N_c \sum_{j=0}^{14} \chi_j(\kappa_A,\lambda_A)\widetilde{F}_j(\hat{s},\beta) \qquad (27)$$

with

$$\widetilde{F}_j = \frac{M_v^2}{\hat{s}} \int_0^\beta d\xi \frac{F_j(\xi = \beta\cos\theta)}{(1-\xi^2)^2} \qquad (28)$$

Eq. (26) agrees analytically with a result obtained in [28]. The functions $F_j(\hat{s},\beta,\cos\theta)$ are not given here but can be obtained as linear combinations from relations given in eqs. (12,13) and (17) in [9].

$$\begin{aligned}
\widetilde{F}_0 &= \beta\left(\frac{11}{2} - \frac{9}{4}\beta^2 + \frac{3}{4}\beta^4\right) \\
&- \frac{3}{8}\left(1-\beta^2-\beta^4+\beta^6\right)\ln\left|\frac{1+\beta}{1-\beta}\right| \\
\widetilde{F}_1 &= -8\beta - \frac{3}{2}\left(1-\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right| \\
\widetilde{F}_2 &= 3\beta + \frac{1}{4}\beta\frac{\hat{s}}{M_\Phi^2} + \left(\frac{7}{2} - 2\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right| \\
\widetilde{F}_3 &= -\frac{1}{4}\beta\frac{\hat{s}}{M_\Phi^2} + \left(-2 + \frac{3}{4}\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right| \\
\widetilde{F}_4 &= -\frac{1}{96}\beta + \frac{5}{48}\beta\frac{\hat{s}}{M_\Phi^2} + \frac{4-\beta^2}{16}\log\left|\frac{1+\beta}{1-\beta}\right| \\
\widetilde{F}_5 &= -\left(1-\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right| \\
\widetilde{F}_6 &= -\frac{1}{6}\beta + \frac{17}{12}\beta\frac{\hat{s}}{M_\Phi^2} \\
&+ \left(-3 - \frac{\beta^2}{2} + \frac{1}{2}\frac{\hat{s}}{M_\Phi^2}\right)\log\left|\frac{1+\beta}{1-\beta}\right| \\
\widetilde{F}_7 &= -\beta + \frac{11}{6}\beta\frac{\hat{s}}{M_\Phi^2} - \frac{1}{3}\beta\frac{\hat{s}^2}{M_\Phi^4} \\
&- \frac{3+\beta^2}{4}\log\left|\frac{1+\beta}{1-\beta}\right| \\
\widetilde{F}_8 &= -\frac{1}{96}\beta + \frac{59}{80}\beta\frac{\hat{s}}{M_\Phi^2} - \frac{113}{320}\beta\frac{\hat{s}^2}{M_\Phi^4} + \frac{43}{960}\beta\frac{\hat{s}^3}{M_\Phi^6} \\
&+ \left(-\frac{1}{2} - \frac{1}{16}\beta^2 + \frac{1}{8}\frac{\hat{s}}{M_\Phi^2}\right)\log\left|\frac{1+\beta}{1-\beta}\right| \\
\widetilde{F}_9 &= 2\beta + (2+\beta^2)\log\left|\frac{1+\beta}{1-\beta}\right| \\
\widetilde{F}_{10} &= 2\beta - \frac{7}{3}\beta\frac{\hat{s}}{M_\Phi^2} \\
&+ \left(3 + \frac{5}{4}\beta^2 - \frac{1}{2}\frac{\hat{s}}{M_\Phi^2}\right)\log\left|\frac{1+\beta}{1-\beta}\right| \\
\widetilde{F}_{11} &= \frac{1}{24}\beta - \frac{59}{48}\beta\frac{\hat{s}}{M_\Phi^2} + \frac{5}{32}\beta\frac{\hat{s}^2}{M_\Phi^4} \\
&+ \frac{5+\beta^2}{4}\log\left|\frac{1+\beta}{1-\beta}\right| \\
\widetilde{F}_{12} &= -\beta - \frac{1}{2}\beta\frac{\hat{s}}{M_\Phi^2} \\
&+ \left(-\frac{1}{4} - \frac{7}{4}\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right| \\
\widetilde{F}_{13} &= \frac{1}{24}\beta + \frac{1}{3}\beta\frac{\hat{s}}{M_\Phi^2} - \frac{1}{4}\left(1-\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right|
\end{aligned}$$

Mod. Phys. Lett. A9 (1994) 3007

$[\gamma g]_{dir}$

20 fcts.

Appendix

The functions $F_i(\hat{s}, \beta, \cos\theta)$ of (12) are:

$$F_0 = 19 - 6\beta^2 + 6\beta^4 + (16 - 6\beta^2)\beta^2\cos^2\theta + 3\beta^4\cos^4\theta\,,$$

$$F_1 = -22 - 10\beta^2\cos^2\theta\,,$$

$$F_2 = 4 + \frac{\hat{s}}{M_\Phi^2}\frac{1-\beta^4\cos^4\theta}{2} + \frac{\hat{s}^2}{M_\Phi^4}\frac{(1-\beta^2\cos^2\theta)^2}{16}\,,$$

$$F_3 = 28 + 4\beta^2\cos^2\theta + \frac{\hat{s}}{M_\Phi^2}\beta^2\cos^2\theta(1-\beta^2\cos^2\theta) + \frac{\hat{s}^2}{M_\Phi^4}\frac{(1-\beta^2\cos^2\theta)^2}{8}\,,$$

$$F_4 = -5 + \beta^2\cos^2\theta + \frac{\hat{s}}{M_\Phi^2}\frac{-3+\beta^2\cos^2\theta+2\beta^4\cos^4\theta}{4} - \frac{\hat{s}^2}{M_\Phi^4}\frac{(1-\beta^2\cos^2\theta)^2}{8}\,,$$

$$F_5 = \frac{3-\beta^2\cos^2\theta}{4} + \frac{\hat{s}}{M_\Phi^2}\frac{5-4\beta^2\cos^2\theta-\beta^4\cos^4\theta}{16} + \frac{\hat{s}^2}{M_\Phi^4}\frac{13-25\beta^2\cos^2\theta+11\beta^4\cos^4\theta+\beta^6\cos^6\theta}{128}\,,$$

$$F_6 = -4 + 4\beta^2\cos^2\theta\,,$$

$$F_7 = 4 + \frac{\hat{s}}{M_\Phi^2}\frac{-7+8\beta^2\cos^2\theta-\beta^4\cos^4\theta}{2} + \frac{\hat{s}^2}{M_\Phi^4}\frac{(1-\beta^2\cos^2\theta)^2}{2} + \frac{\hat{s}^3}{M_\Phi^6}\frac{(1-\beta^2\cos^2\theta)^3}{16}\,,$$

$$F_8 = -\frac{\hat{s}}{M_\Phi^2}(1-\beta^2\cos^2\theta) + \frac{\hat{s}^2}{M_\Phi^4}\frac{11-13\beta^2\cos^2\theta+\beta^4\cos^4\theta+\beta^6\cos^6\theta}{8} - \frac{\hat{s}^2}{M_\Phi^4}\frac{(1-\beta^2\cos^2\theta)^3}{8}\,,$$

$$F_9 = 1 - \beta^2\cos^2\theta + \frac{\hat{s}}{M_\Phi^2}\frac{-3+4\beta^2\cos^2\theta-\beta^4\cos^4\theta}{2} + \frac{\hat{s}^2}{M_\Phi^4}(1-\beta^2\cos^2\theta)^2 + \frac{\hat{s}^3}{M_\Phi^6}\frac{-3+7\beta^2\cos^2\theta-5\beta^4\cos^4\theta+\beta^6\cos^6\theta}{16}\,,$$

$$F_{10} = \frac{3-\beta^2\cos^2\theta}{4} + \frac{\hat{s}}{M_\Phi^2}\frac{-19+20\beta^2\cos^2\theta-\beta^4\cos^4\theta}{16} + \frac{\hat{s}^2}{M_\Phi^4}\frac{141-249\beta^2\cos^2\theta+107\beta^4\cos^4\theta+\beta^6\cos^6\theta}{128} + \frac{\hat{s}^3}{M_\Phi^6}\frac{-53+119\beta^2\cos^2\theta-79\beta^4\cos^4\theta+13\beta^6\cos^6\theta}{128} + \frac{\hat{s}^4}{M_\Phi^8}\frac{27-68\beta^2\cos^2\theta+58\beta^4\cos^4\theta-20\beta^6\cos^6\theta+3\beta^8\cos^8\theta}{512}\,,$$

$$F_{11} = -8 + \frac{\hat{s}}{M_\Phi^2}(3-4\beta^2\cos^2\theta+\beta^4\cos^4\theta)\,,$$

$$F_{12} = \frac{\hat{s}}{M_\Phi^2}(2-3\beta^2\cos^2\theta+4\beta^4\cos^4\theta)\,,$$

$$F_{13} = -2(1-\beta^2\cos^2\theta) + \frac{\hat{s}}{M_\Phi^2}\frac{9-13\beta^2\cos^2\theta+4\beta^4\cos^4\theta}{4} - \frac{\hat{s}^2}{M_\Phi^4}\frac{2-3\beta^2\cos^2\theta+\beta^4\cos^4\theta}{2} + \frac{\hat{s}^3}{M_\Phi^6}\frac{(1-\beta^2\cos^2\theta)^3}{16}\,,$$

$$F_{14} = -5 + \beta^2\cos^2\theta + \frac{\hat{s}}{M_\Phi^2}\frac{7-8\beta^2\cos^2\theta+\beta^4\cos^4\theta}{2} - 3\frac{\hat{s}^2}{M_\Phi^4}\frac{(1-\beta^2\cos^2\theta)^2}{8} - \frac{(1-\beta^2\cos^2\theta)^3}{16}\,,$$

$$F_{15} = -\frac{3-\beta^2\cos^2\theta}{2} + \frac{\hat{s}}{M_\Phi^2}\frac{13-14\beta^2\cos^2\theta+\beta^4\cos^4\theta}{8} - \frac{\hat{s}^2}{M_\Phi^4}\frac{41-81\beta^2\cos^2\theta+39\beta^4\cos^4\theta+\beta^6\cos^6\theta}{64} + \frac{\hat{s}^3}{M_\Phi^6}\frac{11-25\beta^2\cos^2\theta+17\beta^4\cos^4\theta-3\beta^6\cos^6\theta}{128}\,,$$

$$F_{16} = 1 - \beta^2\cos^2\theta - \frac{\hat{s}}{M_\Phi^2}\frac{3-5\beta^2\cos^2\theta+2\beta^4\cos^4\theta}{4}\,,$$

$$F_{17} = \frac{3-\beta^2\cos^2\theta}{4} - \frac{\hat{s}}{M_\Phi^2}\frac{7-8\beta^2\cos^2\theta+\beta^4\cos^4\theta}{16} - \frac{\hat{s}^2}{M_\Phi^4}\frac{3-7\beta^2\cos^2\theta+5\beta^4\cos^4\theta-\beta^6\cos^6\theta}{128} + \frac{\hat{s}^3}{M_\Phi^6}\frac{(1-\beta^2\cos^2\theta)^3}{32}\,,$$

$$F_{18} = 2(5-\beta^2\cos^2\theta) - \frac{\hat{s}}{M_\Phi^2}\frac{11-15\beta^2\cos^2\theta+4\beta^4\cos^4\theta}{4} - \frac{\hat{s}^2}{M_\Phi^4}\frac{(1-\beta^2\cos^2\theta)^2}{4},$$

$$F_{19} = 3-\beta^2\cos^2\theta - \frac{\hat{s}}{M_\Phi^2}\frac{7-8\beta^2\cos^2\theta+\beta^4\cos^4\theta}{4} + \frac{\hat{s}^2}{M_\Phi^4}\frac{11-13\beta^2\cos^2\theta+\beta^4\cos^4\theta+\beta^6\cos^6\theta}{32} + \frac{\hat{s}^3}{M_\Phi^6}\frac{5-7\beta^2\cos^2\theta-\beta^4\cos^4\theta+3\beta^6\cos^6\theta}{128}, \tag{A.1}$$

$$F_{20} = -\frac{3-\beta^2\cos^2\theta}{2} + \frac{\hat{s}}{M_\Phi^2}\frac{(1-\beta^2\cos^2\theta)^2}{8} + \frac{\hat{s}^2}{M_\Phi^4}\frac{11-23\beta^2\cos^2\theta+13\beta^4\cos^4\theta-\beta^6\cos^6\theta}{64}.$$

The functions $\widetilde{F}_i(\hat{s},\beta)$, which describe the different contributions to the integrated cross-section (13), are:

$$\widetilde{F}_0 = \beta\left(\frac{11}{2}-\frac{9}{4}\beta^2+\frac{3}{4}\beta^4\right) - \frac{3}{8}\left(1-\beta^2-\beta^4+\beta^6\right)\ln\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_1 = -4\beta - \frac{3}{4}(1-\beta^2)\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_2 = \frac{1}{16}\beta\frac{\hat{s}}{M_\Phi^2} + \frac{3-\beta^2}{4}\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_3 = 3\beta + \frac{1}{8}\beta\frac{\hat{s}}{M_\Phi^2} + \left(2-\frac{3}{2}\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_4 = -\frac{1}{8}\beta\frac{\hat{s}}{M_\Phi^2} + \left(-1+\frac{3}{8}\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_5 = -\frac{1}{96}\beta + \frac{5}{48}\beta\frac{\hat{s}}{M_\Phi^2} + \frac{4-\beta^2}{16}\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_6 = -\frac{1}{2}(1-\beta^2)\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_7 = \frac{7}{12}\beta\frac{\hat{s}}{M_\Phi^2} + \frac{1}{24}\beta\frac{\hat{s}^2}{M_\Phi^4} - \frac{5+\beta^2}{4}\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_8 = -\frac{1}{6}\beta + \frac{1}{4}\beta\frac{\hat{s}}{M_\Phi^2} - \frac{1}{12}\beta\frac{\hat{s}^2}{M_\Phi^4} + \left(-\frac{1}{2}+\frac{1}{2}\frac{\hat{s}}{M_\Phi^2}\right)\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_9 = -\frac{1}{2}\beta + \frac{11}{12}\beta\frac{\hat{s}}{M_\Phi^2} - \frac{1}{6}\beta\frac{\hat{s}^2}{M_\Phi^4} - \frac{3+\beta^2}{8}\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_{10} = -\frac{1}{96}\beta + \frac{59}{80}\beta\frac{\hat{s}}{M_\Phi^2} - \frac{113}{320}\beta\frac{\hat{s}^2}{M_\Phi^4} + \frac{43}{960}\beta\frac{\hat{s}^3}{M_\Phi^6} + \left(-\frac{1}{2}-\frac{1}{16}\beta^2+\frac{1}{8}\frac{\hat{s}}{M_\Phi^2}\right)\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_{11} = \frac{1}{2}(1+\beta^2)\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_{12} = \beta + \frac{1}{2}\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_{13} = \beta - \frac{5}{12}\beta\frac{\hat{s}}{M_\Phi^2} + \frac{1}{24}\beta\frac{\hat{s}^2}{M_\Phi^4} + \left[-\frac{1}{4}\frac{\hat{s}}{M_\Phi^2} + \left(\frac{3}{8}+\frac{1}{4}\beta^2\right)\right]\log\left|\frac{1+\beta}{1-\beta}\right|, \tag{A.2}$$

$$\widetilde{F}_{14} = -\frac{11}{24}\beta\frac{\hat{s}}{M_\Phi^2} - \frac{1}{24}\beta\frac{\hat{s}^2}{M_\Phi^4} + \frac{9+3\beta^2}{8}\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_{15} = \frac{1}{48}\beta - \frac{59}{96}\beta\frac{\hat{s}}{M_\Phi^2} + \frac{5}{64}\beta\frac{\hat{s}^2}{M_\Phi^4} + \frac{5+\beta^2}{8}\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_{16} = -\frac{1}{2}\beta - \frac{1}{8}\beta^2\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_{17} = -\frac{1}{96}\beta + \frac{1}{48}\beta\frac{\hat{s}}{M_\Phi^2} + \frac{1}{48}\beta\frac{\hat{s}^2}{M_\Phi^4} - \frac{2+\beta^2}{16}\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_{18} = -\frac{1}{4}\beta\frac{\hat{s}}{M_\Phi^2} - \frac{1-6\beta^2}{8}\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_{19} = -\frac{1}{24}\beta + \frac{7}{96}\beta\frac{\hat{s}}{M_\Phi^2} + \frac{3}{64}\beta\frac{\hat{s}^2}{M_\Phi^4} + \left[\frac{1}{8}\frac{\hat{s}}{M_\Phi^2} - \frac{2+\beta^2}{4}\right]\log\left|\frac{1+\beta}{1-\beta}\right|,$$

$$\widetilde{F}_{20} = \frac{1}{48}\beta + \frac{1}{6}\beta\frac{\hat{s}}{M_\Phi^2} - \frac{1}{8}(1-\beta^2)\log\left|\frac{1+\beta}{1-\beta}\right|.$$

B Coefficients of the production cross section of vector leptoquarks

The functions $F_i(\hat{s}, \beta, \cos\theta)$ of (21) which determine the differential pair production cross section for $gg \to V\overline{V}$ are: $[gg]_{rr}$: 14 fcts.

$$F_0 = \left[19 - 6\beta^2 + 6\beta^4 + \left(16 - 6\beta^2\right)\beta^2\cos^2\theta + 3\beta^4\cos^4\theta\right] \cdot \left(7 + 9\beta^2\cos^2\theta\right) \tag{85}$$

$$F_1 = -4 \cdot \left(77 + 143\beta^2\cos^2\theta + 36\beta^4\cos^4\theta\right) \tag{86}$$

$$F_2 = -8 \cdot \left(7 + 11\beta^2\cos^2\theta - 18\beta^4\cos^4\theta\right) \tag{87}$$

$$\begin{aligned} F_3 = {} & 2 \cdot \left(117 + 185\beta^2\cos^2\theta + 18\beta^4\cos^4\theta\right) + 2\frac{\hat{s}}{M_\Phi^2}\left(8 - \beta^2\cos^2\theta - 7\beta^4\cos^4\theta\right) \\ & + \frac{7}{4}\frac{\hat{s}^2}{M_\Phi^4}\left(1 - \beta^2\cos^2\theta\right)^2 \end{aligned} \tag{88}$$

$$F_4 = -4 \cdot \left(19 + 27\beta^2\cos^2\theta + 18\beta^4\cos^4\theta\right) + 10\frac{\hat{s}}{M_\Phi^2}\left(1 - \beta^2\cos^2\theta\right)\left(7 - \beta^2\cos^2\theta\right) \tag{89}$$

$$\begin{aligned} F_5 = {} & 2 \cdot \left(19 + 27\beta^2\cos^2\theta + 18\beta^4\cos^4\theta\right) - \frac{\hat{s}}{M_\Phi^2}\left(1 - \beta^2\cos^2\theta\right)\left(65 + 29\beta^2\cos^2\theta\right) \\ & + \frac{1}{8}\frac{\hat{s}^2}{M_\Phi^4}\left(1 - \beta^2\cos^2\theta\right)\left(97 + 2\beta^2\cos^2\theta - 115\beta^4\cos^4\theta\right) + \frac{\hat{s}^3}{M_\Phi^6}\frac{9}{4}\left(1 - \beta^2\cos^2\theta\right)^3 \end{aligned} \tag{90}$$

$$\begin{aligned} F_6 = {} & -61 - 67\beta^2\cos^2\theta - \frac{1}{2}\frac{\hat{s}}{M_\Phi^2}\left(1 - \beta^2\cos^2\theta\right)\left(39 + 14\beta^2\cos^2\theta\right) \\ & - \frac{7}{4}\frac{\hat{s}^2}{M_\Phi^4}\left(1 - \beta^2\cos^2\theta\right)^2 \end{aligned} \tag{91}$$

$$\begin{aligned} F_7 = {} & 127 + 129\beta^2\cos^2\theta - \frac{1}{2}\frac{\hat{s}}{M_\Phi^2}\left(1 - \beta^2\cos^2\theta\right)\left(89 + 3\beta^2\cos^2\theta\right) \\ & + \frac{1}{4}\frac{\hat{s}^2}{M_\Phi^4}\left(1 - \beta^2\cos^2\theta\right)^2\left(-23 + 18\beta^2\cos^2\theta\right) \end{aligned} \tag{92}$$

$$\begin{aligned} F_8 = {} & -71 - 57\beta^2\cos^2\theta + \frac{1}{2}\frac{\hat{s}}{M_\Phi^2}\left(1 - \beta^2\cos^2\theta\right)\left(170 + 21\beta^2\cos^2\theta\right) \\ & + \frac{1}{4}\frac{\hat{s}^2}{M_\Phi^4}\left(1 - \beta^2\cos^2\theta\right)\left(-59 + 40\beta^2\cos^2\theta + 27\beta^4\cos^4\theta\right) - \frac{9}{4}\frac{\hat{s}^3}{M_\Phi^6}\left(1 - \beta^2\cos^2\theta\right)^3 \end{aligned} \tag{93}$$

$$\begin{aligned} F_9 = {} & 5\left(1 - \beta^2\cos^2\theta\right) - \frac{\hat{s}}{M_\Phi^2}\left(1 - \beta^2\cos^2\theta\right)\left(21 + 2\beta^2\cos^2\theta\right) \\ & + \frac{1}{4}\frac{\hat{s}^2}{M_\Phi^4}\left(1 - \beta^2\cos^2\theta\right)^2\left(74 + 9\beta^2\cos^2\theta\right) \\ & + \frac{1}{4}\frac{\hat{s}^3}{M_\Phi^6}\left(1 - \beta^2\cos^2\theta\right)^2\left(-15 + 8\beta^2\cos^2\theta\right) \end{aligned} \tag{94}$$

$$\begin{aligned} F_{10} = {} & 3 + 5\beta^2\cos^2\theta + \frac{5}{4}\frac{\hat{s}}{M_\Phi^2}\left(1 - \beta^2\cos^2\theta\right)\left(4 - \beta^2\cos^2\theta\right) \\ & + \frac{1}{32}\frac{\hat{s}^2}{M_\Phi^4}\left(1 - \beta^2\cos^2\theta\right)^2\left(25 + 13\beta^2\cos^2\theta\right) \end{aligned} \tag{95}$$

$$
\begin{aligned}
F_{11} &= -4\cdot\left(3+5\beta^2\cos^2\theta\right)-5\frac{\hat{s}}{M_\Phi^2}\left(1-\beta^2\cos^2\theta\right)^2 \\
&+ \frac{1}{8}\frac{\hat{s}^2}{M_\Phi^4}\left(1-\beta^2\cos^2\theta\right)^2\left(35-13\beta^2\cos^2\theta\right) && (96)\\
F_{12} &= 6\cdot\left(3+5\beta^2\cos^2\theta\right)-\frac{15}{2}\frac{\hat{s}}{M_\Phi^2}\left(1-\beta^2\cos^2\theta\right)\left(2+\beta^2\cos^2\theta\right) \\
&+ \frac{1}{16}\frac{\hat{s}^2}{M_\Phi^4}\left(1-\beta^2\cos^2\theta\right)\left(-23+54\beta^2\cos^2\theta-39\beta^4\cos^4\theta\right) \\
&+ \frac{1}{64}\frac{\hat{s}^3}{M_\Phi^6}\left(1-\beta^2\cos^2\theta\right)^2\left(113-49\beta^2\cos^2\theta\right) && (97)\\
F_{13} &= -4\cdot\left(3+5\beta^2\cos^2\theta\right)+5\frac{\hat{s}}{M_\Phi^2}\left(1-\beta^2\cos^2\theta\right)\left(5+\beta^2\cos^2\theta\right) \\
&- \frac{1}{8}\frac{\hat{s}^2}{M_\Phi^4}\left(1-\beta^2\cos^2\theta\right)^2\left(119+13\beta^2\cos^2\theta\right) \\
&+ \frac{1}{32}\frac{\hat{s}^3}{M_\Phi^6}\left(1-\beta^2\cos^2\theta\right)^2\left(79-15\beta^2\cos^2\theta\right) && (98)\\
F_{14} &= 3+5\beta^2\cos^2\theta-\frac{5}{4}\frac{\hat{s}}{M_\Phi^2}\left(1-\beta^2\cos^2\theta\right)\left(8+\beta^2\cos^2\theta\right) \\
&+ \frac{1}{32}\frac{\hat{s}^2}{M_\Phi^4}\left(1-\beta^2\cos^2\theta\right)\left(321-324\beta^2\cos^2\theta-13\beta^4\cos^4\theta\right) \\
&+ \frac{11}{64}\frac{\hat{s}^3}{M_\Phi^6}\left(1-\beta^2\cos^2\theta\right)^2\left(-23+7\beta^2\cos^2\theta\right) \\
&+ \frac{1}{256}\frac{\hat{s}^4}{M_\Phi^8}\left(1-\beta^2\cos^2\theta\right)^2\left(135-22\beta^2\cos^2\theta+15\beta^4\cos^4\theta\right). && (99)
\end{aligned}
$$

The coefficients $\widetilde{F}_i(\hat{s},\beta)$ for the integrated cross section for $gg\to V\overline{V}$ are:

$$
\begin{aligned}
\widetilde{F}_0 &= \beta\left(\frac{523}{4}-90\beta^2+\frac{93}{4}\beta^4\right)-\frac{3}{4}(65-83\beta^2+19\beta^4-\beta^6)\log\left|\frac{1+\beta}{1-\beta}\right| \\
\widetilde{F}_1 &= -4\beta(41-9\beta^2)-\frac{87}{2}(1-\beta^2)\log\left|\frac{1+\beta}{1-\beta}\right| && (100)\\
\widetilde{F}_2 &= 36\beta(1-\beta^2)-25(1-\beta^2)\log\left|\frac{1+\beta}{1-\beta}\right| && (101).\\
\widetilde{F}_3 &= \beta(75-9\beta^2)+\frac{7}{4}\beta\frac{\hat{s}}{M_\Phi^2}-\frac{1}{4}(1-61\beta^2)\log\left|\frac{1+\beta}{1-\beta}\right| && (102)\\
\widetilde{F}_4 &= -2\beta(20-9\beta^2)+\frac{1}{2}(91-31\beta^2)\log\left|\frac{1+\beta}{1-\beta}\right| && (103)\\
\widetilde{F}_5 &= \beta\left(\frac{209}{6}-9\beta^2\right)+\frac{263}{12}\beta\frac{\hat{s}}{M_\Phi^2}+\frac{3}{2}\beta\frac{\hat{s}^2}{M_\Phi^4}-\left(\frac{219}{4}-\frac{31}{4}\beta^2+\frac{\hat{s}}{M_\Phi^2}\right)\log\left|\frac{1+\beta}{1-\beta}\right| && (104)\\
\widetilde{F}_6 &= -9\beta-\frac{7}{4}\beta\frac{\hat{s}}{M_\Phi^2}-\left(\frac{103}{8}+\frac{3}{8}\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right| && (105)\\
\widetilde{F}_7 &= \frac{55}{2}\beta-\frac{17}{4}\beta\frac{\hat{s}}{M_\Phi^2}-\left(\frac{185}{8}-\frac{1}{8}\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right| && (106)
\end{aligned}
$$

$$\tilde{F}_8 = -\frac{35}{2}\beta - 22\beta\frac{\hat{s}}{M_\Phi^2} - \frac{3}{2}\beta\frac{\hat{s}^2}{M_\Phi^4} + \left(\frac{375}{8} + \frac{7}{8}\beta^2 + \frac{\hat{s}}{M_\Phi^2}\right)\log\left|\frac{1+\beta}{1-\beta}\right| \tag{107}$$

$$\tilde{F}_9 = -\beta + \frac{199}{12}\beta\frac{\hat{s}}{M_\Phi^2} - \frac{37}{12}\beta\frac{\hat{s}^2}{M_\Phi^4} - \left(\frac{87}{8} + \frac{5}{8}\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right| \tag{108}$$

$$\tilde{F}_{10} = \frac{41}{24}\beta + \frac{11}{12}\beta\frac{\hat{s}}{M_\Phi^2} + \left(\frac{7}{4} + \frac{1}{8}\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right| \tag{109}$$

$$\tilde{F}_{11} = -\frac{41}{6}\beta + \frac{23}{6}\beta\frac{\hat{s}}{M_\Phi^2} + \frac{1}{2}(1-\beta^2)\log\left|\frac{1+\beta}{1-\beta}\right| \tag{110}$$

$$\tilde{F}_{12} = \frac{41}{4}\beta + \frac{43}{48}\beta\frac{\hat{s}}{M_\Phi^2} + \frac{145}{96}\beta\frac{\hat{s}^2}{M_\Phi^4} - \left(12 - \frac{3}{4}\beta^2 + \frac{1}{4}\frac{\hat{s}}{M_V^2}\right)\log\left|\frac{1+\beta}{1-\beta}\right| \tag{111}$$

$$\tilde{F}_{13} = -\frac{41}{6}\beta - \frac{355}{24}\beta\frac{\hat{s}}{M_V^2} + \frac{37}{16}\beta\frac{\hat{s}^2}{M_\Phi^4} + \left(\frac{31}{2} - \frac{1}{2}\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right| \tag{112}$$

$$\tilde{F}_{14} = \frac{41}{24}\beta + \frac{37}{4}\beta\frac{\hat{s}}{M_\Phi^2} - \frac{113}{32}\beta\frac{\hat{s}^2}{M_\Phi^4} + \frac{49}{96}\beta\frac{\hat{s}^3}{M_\Phi^6} - \left(\frac{23}{4} - \frac{1}{8}\beta^2 + \frac{1}{4}\frac{\hat{s}}{M_\Phi^2}\right)\log\left|\frac{1+\beta}{1-\beta}\right|. \tag{113}$$

$$\tag{114}$$

Finally, the coefficients for the differential and the integrated cross section for $q\bar{q} \to V\bar{V}$, $G_i(\hat{s},\beta,\cos\theta)$ and $\tilde{G}_i(\hat{s},\beta)$, are given by $[q\bar{q}]_r$: 5 fcts.

$$G_0 = 1 + \frac{1}{16}\left[\frac{\hat{s}}{M_\Phi^2} - (1+3\beta^2)\right]\sin^2\theta \tag{115}$$

$$G_1 = -1 - \frac{1}{8}\left[\frac{\hat{s}}{M_\Phi^2} - 2\right]\sin^2\theta \tag{116}$$

$$G_2 = 1 \tag{117}$$

$$G_3 = \frac{1}{4} + \frac{1}{16}\left[\frac{\hat{s}}{M_\Phi^2} - 2\right]\sin^2\theta \tag{118}$$

$$G_4 = -\frac{1}{2} + \frac{1}{4}\sin^2\theta \tag{119}$$

$$G_5 = \frac{1}{4} + \frac{1}{8}\left[\frac{\hat{s}}{M_\Phi^2} - 1\right]\sin^2\theta \tag{120}$$

$$\tilde{G}_0 = \frac{1}{24}\frac{\hat{s}}{M_\Phi^2} + \frac{23-3\beta^2}{24} \tag{121}$$

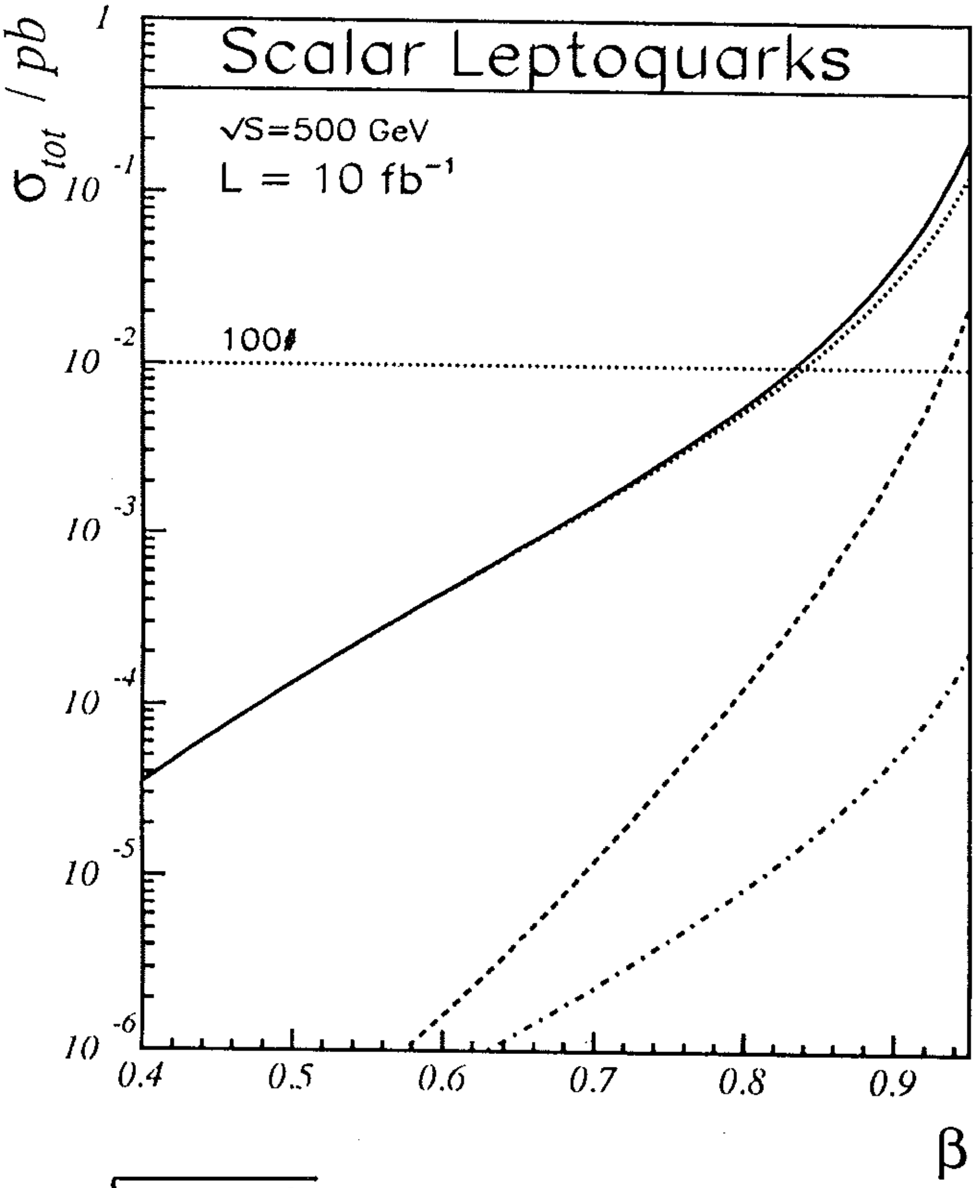
$$\tilde{G}_1 = -\frac{1}{12}\frac{\hat{s}}{M_\Phi^2} - \frac{5}{6} \tag{122}$$

$$\tilde{G}_2 = 1 \tag{123}$$

$$\tilde{G}_3 = \frac{1}{24}\frac{\hat{s}}{M_\Phi^2} + \frac{1}{6} \tag{124}$$

$$\tilde{G}_4 = -\frac{1}{3} \tag{125}$$

$$\tilde{G}_5 = \frac{1}{12}\frac{\hat{s}}{M_\Phi^2} + \frac{1}{6}. \tag{126}$$



$$\beta = \sqrt{1 - \frac{4M^2}{S}}$$

Figure 11a: Integrated cross sections for scalar leptoquark pair production through $\gamma^*\gamma^* \to S\bar{S}$ (WWA spectrum) at future e^+e^- colliders for $\sqrt{S} = 500$ GeV as afunction of β. Full line: σ_{tot} for $|Q_\Phi| = 5/3$; dotted line: σ_{dir} for $|Q_\Phi| = 5/3$; dashed line: σ_{tot} for $|Q_\Phi| = 1/3$; dash–dotted line: σ_{dir} for $|Q_\Phi| = 1/3$.

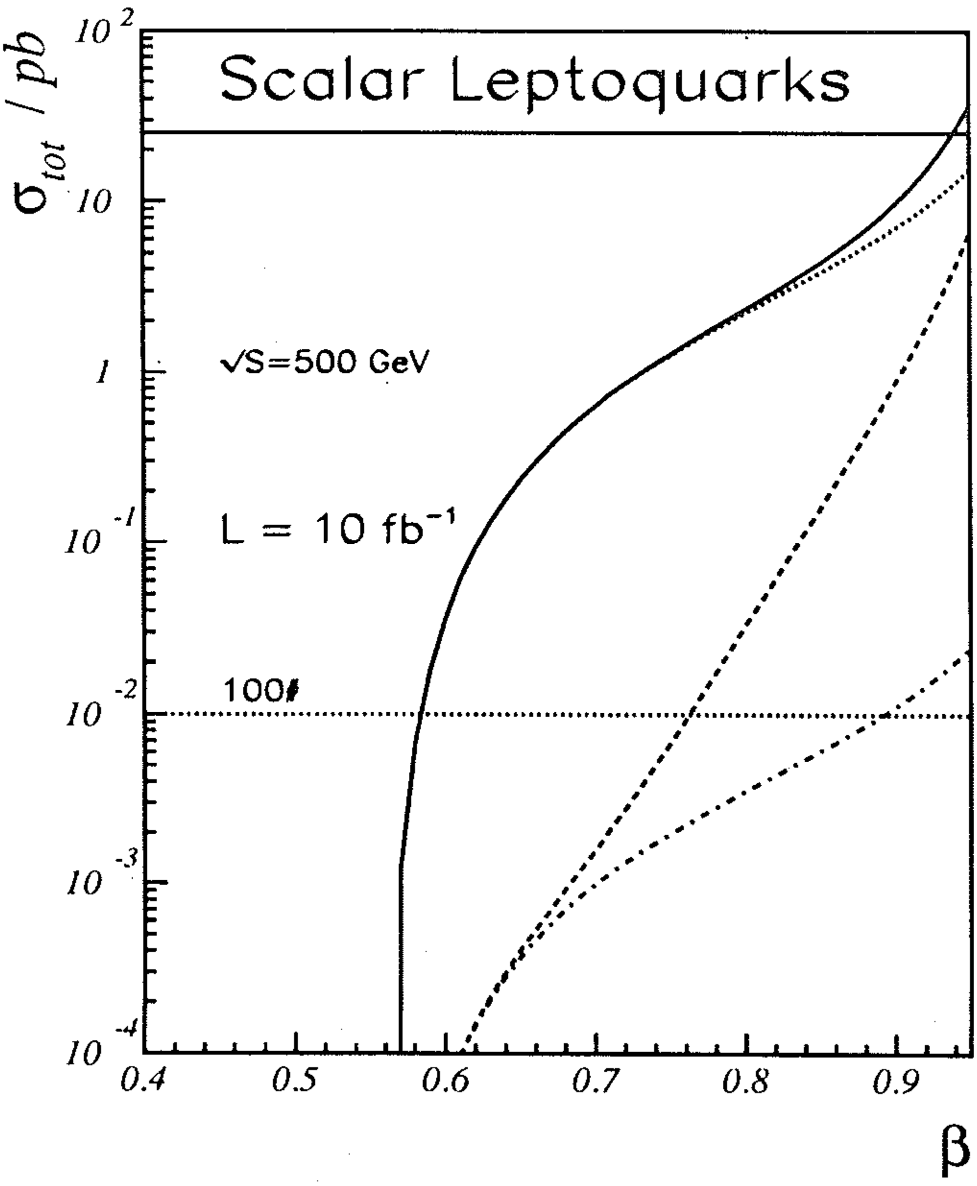


Figure 11b: Integrated cross sections for scalar leptoquark pair production at future $\gamma\gamma$ colliders using Laser back scattering for electron beam conversion. The parameters are the same as in figure 10a.

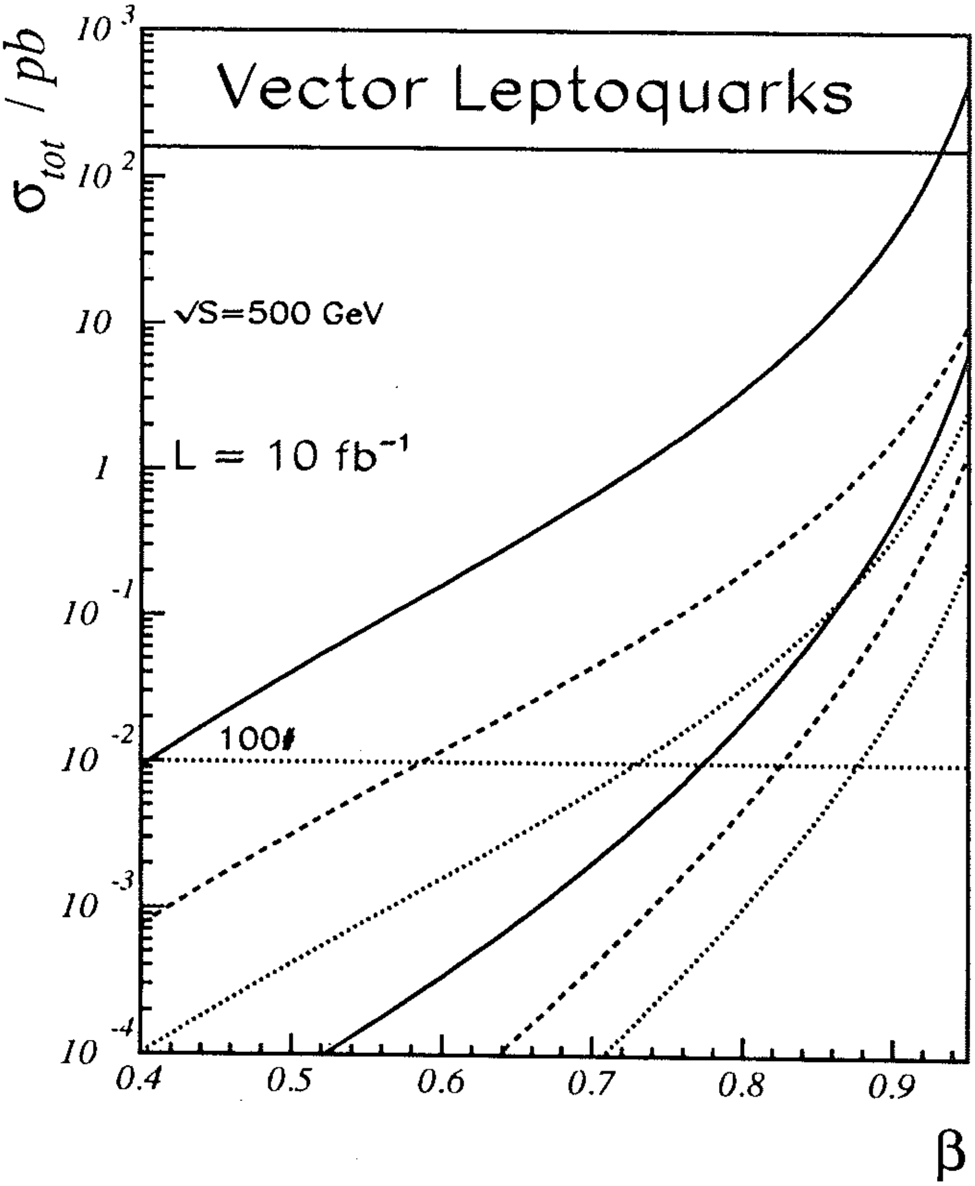


Figure 12a: Integrated cross sections for vector leptoquark pair production through $\gamma^*\gamma^* \to S\overline{S}$ (WWA spectrum) at future e^+e^- colliders for $\sqrt{S} = 500$ GeV as a function of β. Integrated cross Upper full line: $|Q_\Phi| = 5/3, \kappa_{A,G} = \lambda_{A,G} = -1$ (MM5); Upper dashed line: $|Q_\Phi| = 5/3, \kappa_{A,G} = \lambda_{A,G} = 0$ (YM5); Upper dotted line: $|Q_\Phi| = 5/3, \kappa_{A,G} = 1, \lambda_{A,G} = 0$ (MC5); The corresponding lower lines are those for $|Q_\Phi = 1/3$.

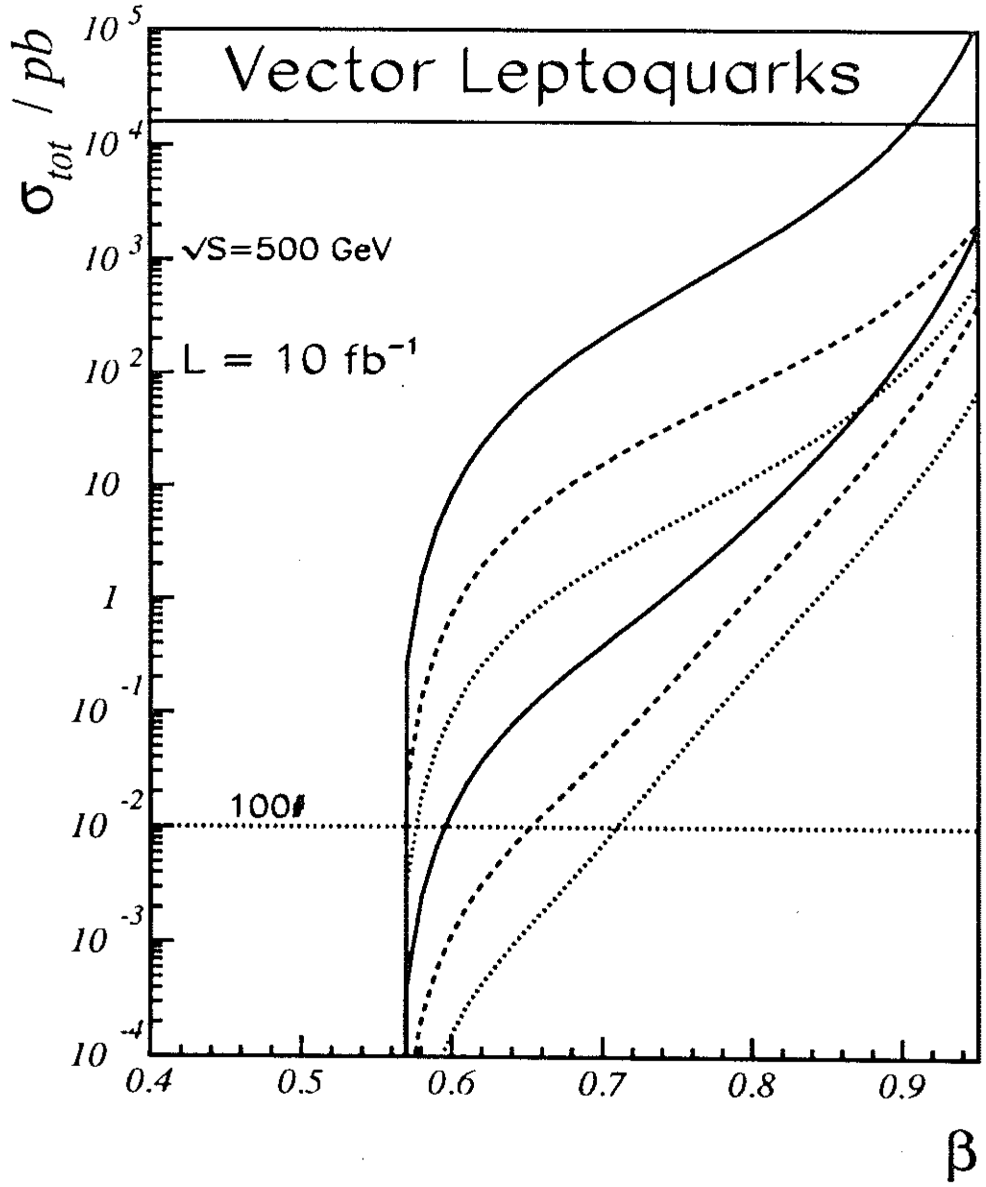


Figure 12b: Integrated cross sections for vector leptoquark pair production at future $\gamma\gamma$ colliders using Laser back scattering for electron beam conversion. The parameters are the same as in figure 12a.

5 Comparison with Future Search Limits at other Colliders

Collider	Mode	$\sqrt{S}$	Luminosity	Q	Scalar Leptoquarks		Vector Leptoquarks	
					100#	10#	100#	10#
TEVATRON	$p\bar{p}$	1.8 TeV	$100pb^{-1}$		140	200	195	270
TEV33	$p\bar{p}$	2.0 TeV	$1fb^{-1}$		210	290	290	370
LHC	pp	14 TeV	$10fb^{-1}$		900	1200	1200	1500
HERA	ep	314 GeV	$100pb^{-1}$	1/3	-	-	-	50
				5/3	45	60	55	70
LEP $\otimes$ LHC	ep	1.26 TeV	$1fb^{-1}$	1/3	90	130	130	180
				5/3	105	220	200	260
LINAC e^+e^-	$\gamma^*\gamma^*$ WWA	500 GeV	$10fb^{-1}$	1/3	90	125	120	155
				5/3	135	185	170	210
LINAC e^+e^-	$\gamma\gamma$ Compton	500 GeV	$10fb^{-1}$	1/3	160	185	175	190
				5/3	200	205	200	205
LINAC e^+e^-	$\gamma^*\gamma^*$ WWA	1 TeV	$10fb^{-1}$	1/3	140	195	285	345
				5/3	220	325	435	470
LINAC e^+e^-	$\gamma\gamma$ Compton	1 TeV	$10fb^{-1}$	1/3	300	340	390	405
				5/3	400	405	410	410

V: MC.