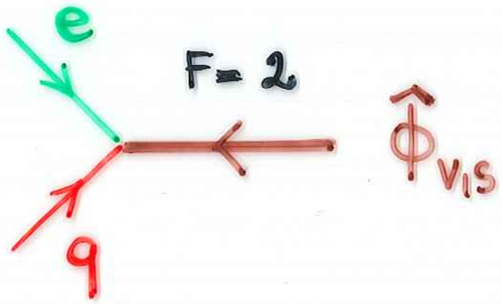
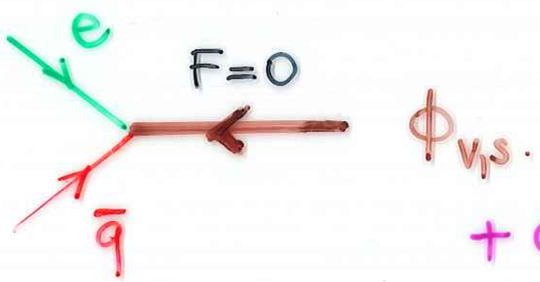
LEPTOQUARKS





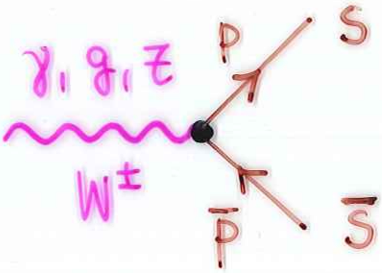
+ cc.

$\mathbb{1}$: S
γ_μ : V

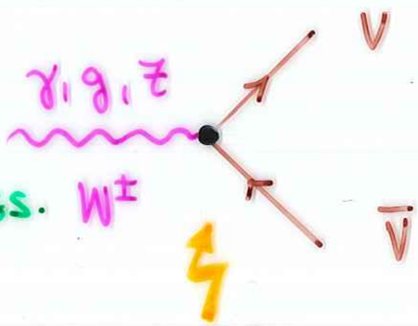
$\mathbb{1}$: S
γ_μ : V

FERMIONIC COUPLINGS

BUCHMÜLLER, RÜCKL, WYLER 1987



BOSONIC (GAUGE) COUPLINGS.

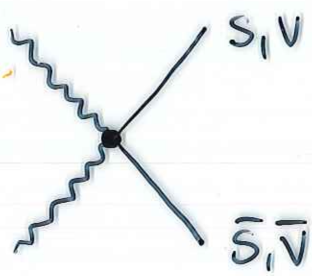


K_i, λ_i

POMAROL et al. 1993 K

JB, E. BOOS, A. KRYUKOV
$\geq$ 1994 ; K, λ

&



OFTEN CONSIDERED:
- B & L CONSERVING COUPLINGS
- FAMILY DIAGONAL
- $SU_{2L} \times U_{1Y} \times SU_{3C}$ INVARIANT
- DIMENSIONLESS COUPLINGS

$\Phi_{V,S}$ EITHER 3_c OR $\bar{3}_c$

EXCLUDED MASS RANGES

$\longrightarrow$ NEXT TALK

- CURRENTLY BEST LIMITS: TEVATRON

1^{ST} GENERATION LQ'S:

DO S: $M > 175, 147, 71$ GeV 95% CL.

$Br(eq)$: 1, 0.5, 0

$\mu \equiv \sqrt{\hat{s}}$, ! (BORN)

V: LARGER BOUNDS, DEPENDING ON κ_G, λ_G.

CDF or DO:

2^{nd} GEN. S: $M < 141$ GeV 95% CL

3^{rd} GEN. S: $M < 99$ GeV —"—

V: $M < 170$ GeV (MC case only!

INTERPRETING THE HIGH Q^2 EXCESS @ HERA AS $\sigma(S,V \to eq)$

$$\Gamma_S = \frac{\lambda_S^2}{16\pi} M_S \quad , \quad \Gamma_V = \frac{\lambda_V^2}{24\pi} M_V$$

WUDKA
BWR
DOBADO et al } '87

$\Gamma \ll M$

$$\boxed{\sigma(eq) = \frac{\pi^2}{s} \alpha \left(\frac{\lambda}{e}\right)^2 q\left(x = \frac{M^2}{s}, \langle Q^2 \rangle\right) J(\phi)\, b(\phi)}$$

$$J(\phi) = \begin{cases} 1 : S \\ 2 : V \end{cases} \qquad b(\phi) = Br(\phi_{V,S} \to eq)$$

$$\sigma(eq) = 338\,pb \;\; b(\phi) \left(\frac{\lambda}{e}\right)^2 \begin{cases} V : 2 \\ S : 1 \end{cases} \begin{cases} u : \times \;\; 0.56 \ldots 0.25 \\ \bar{u} : \times \;\; 0.005 \ldots 0.001 \\ d : \times \;\; 0.15 \ldots 0.05 \\ \bar{d} : \times \;\; 0.014 \ldots 0.003 \end{cases}$$

x: 0.4 ... 0.5

$\langle Q^2 \rangle \sim 20000\ GeV^2$.

$$\mathcal{L}_{H1} = 14\,pb^{-1}, \quad \mathcal{L}_{ZEUS} = 20\,pb^{-1}, \quad \varepsilon = 0.8$$

H1: $\dfrac{\lambda_S}{e\sqrt{b}}$: 0.06 ... 0.09   0.61 ... 1.36   0.11 ... 0.19   0.36 ... .79 (BORN)

u $\bar{u}$ d $\bar{d}$

7 # NC   ↑   # 4 NC   ↑

$$\lambda_V = \lambda_S / \sqrt{2} \qquad \lambda_{ZEUS} = 0.55\, \lambda_{H1}$$

$SU_{2L} \times U_{1Y}$ QUANTUM NUMBERS

$F = 0.$

				ℓq	νq	
$e^+ u \longrightarrow$	$Q_{em} = \frac{5}{3}$	S:	R_2^+	λ_L	0	
		V:	$\tilde{U}_{1\mu}$	λ_R	0	
		:	$U_{3\mu}^+$	$\sqrt{2}\,\lambda_L$	0	

$$\mathrm{Br}\,(\phi_{S,V} \to e^+ q) \underset{\text{BORN}}{=} 1$$

				ℓq	νq	
$e^+ d \longrightarrow$	$Q_{em} = \frac{2}{3}$	S:	R_2^-	$-\lambda_R$	λ_L	$\mathrm{Br}(e^+ q) = 1$
			$\tilde{R}_2^+$	λ_L	0	"
		V:	$U_{1\mu}$	λ_L, λ_R	λ_L	
			$U_{3\mu}^0$	$-\lambda_L$	λ_L	

π^0-decay: BUCHMÜLLER, WYLER 1986 : R_2^- : $\lambda_L \lambda_R \ll 1$

$U_{3\mu}^0$: $\mathrm{Br}\,(e^+ q) = \frac{1}{2}$

$U_{1\mu}$: $\mathrm{Br}\,(e^+ q) \geq \frac{1}{2}$

LOW ENERGY BOUNDS ON THE FERMIONIC COUPLINGS

BUCHMÜLLER, WYLER '86
DAVIDSON et al. '94
LEURER '94

$\lambda = \lambda_L, \lambda_R$

1ST GENERATION:

S: $\frac{\lambda}{e} \lesssim 0.4 \frac{M}{200\text{ GeV}}$ $\quad S_0, \tilde{S}_0, \tilde{S}_{1/2}$

V: $\frac{\lambda}{e} \lesssim 0.2 \frac{M}{200\text{ GeV}}$ $\quad V_1, V_{1/2}$

$(e \sim 0.3)$

SOMETIMES $\lambda_L \gg \lambda_R$ or $\lambda_R \gg \lambda_L$ REQUESTED

- MESON DECAYS, MESON-ANTIMESON MIXING, LEPTON DECAYS etc.

$O(\alpha_s)$ K-FACTOR

KUNSZT
STIRLING, '97

PLEHN et al.
'97
($\Gamma \ll M$)

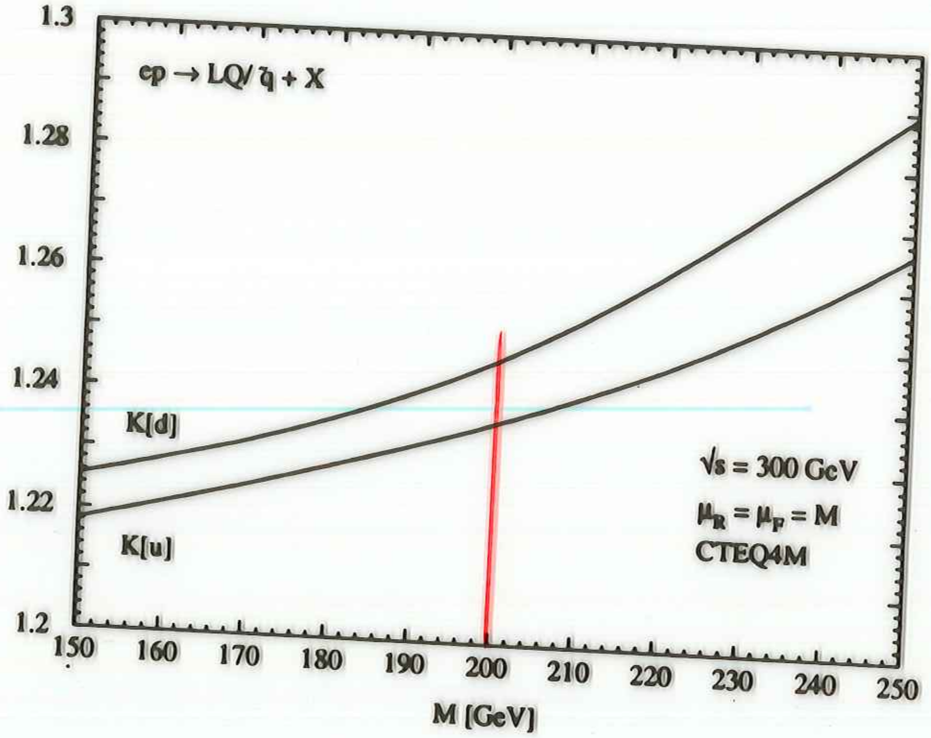
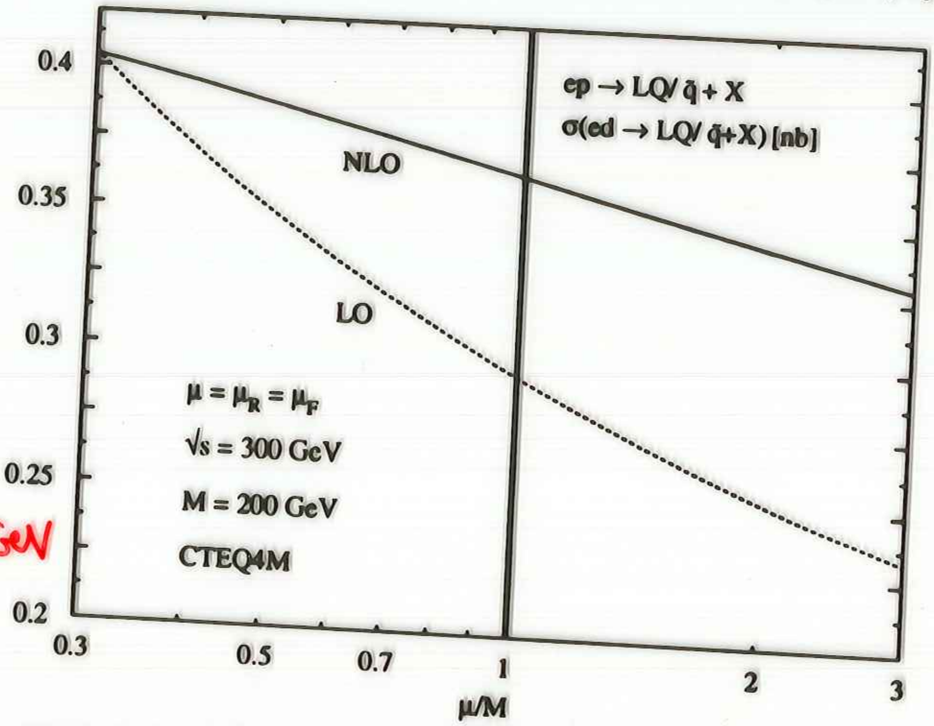


Figure 2: *K-factors for ed, eu → LQ/$\tilde{q}$ as a function of the leptoquark/squark mass.*



$\sqrt{\langle k_\perp^2 \rangle_\phi} \sim 3 \ldots 4$ GeV

i.e. $\frac{\lambda}{e}$ IS EVEN SMALLER THAN ESTIMATED @ BORN LEVEL.

Figure 3: *Comparison of the renormalization and factorization scale dependence in LO and NLO for the cross section for $\sigma(e + d \to LQ/\tilde{q})$.*

$\langle y \rangle$:

BUCHMÜLLER, RÜCKL, WYLER '87.

S : const.

V : $\propto (1-y)^2$

$\therefore$ H1 : $\langle y \rangle = 0.59 \pm 0.02$ $\quad y \in [0.4, 0.9]$

S : $\langle y \rangle_S = 0.65$

V : $\langle y \rangle_V = 0.55$; $\langle y \rangle^{e^+p}_{DIS} = 0.54$!

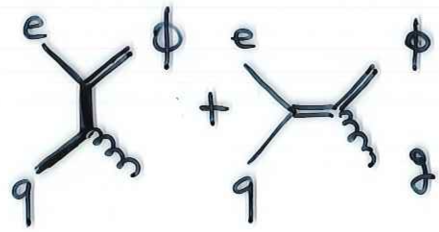
JB '97

HOW CAN HERA FIND OUT WHETHER THE EVENTS WERE DUE TO LEPTOQUARKS ?

$\longrightarrow$ HIGHER $\mathcal{L}$

LOOK FOR : $eq \to \phi g$ BY FAR DOMINANT.

$eg \to \phi q$

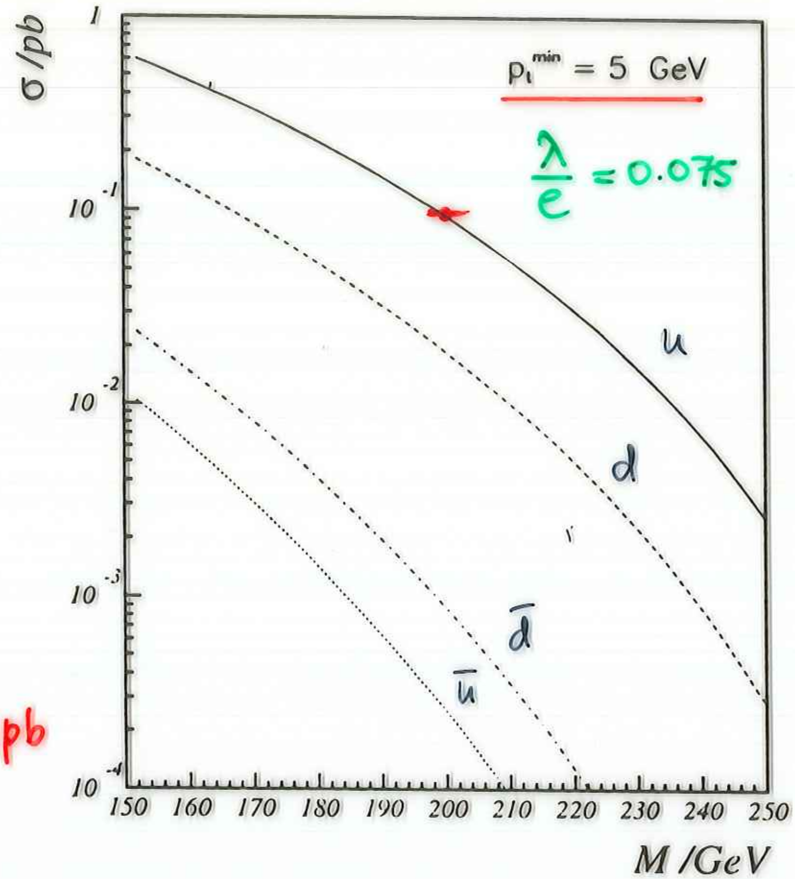


e.g.
$p_\perp > 5$ GeV : $M(e\,\text{jet}) \sim$ '200 GeV'

\+ 1 jet

$\boxed{\text{TEST OF LQ PROPAGATION !}}$

JB, A. KRYUKOV, DESY 97-067



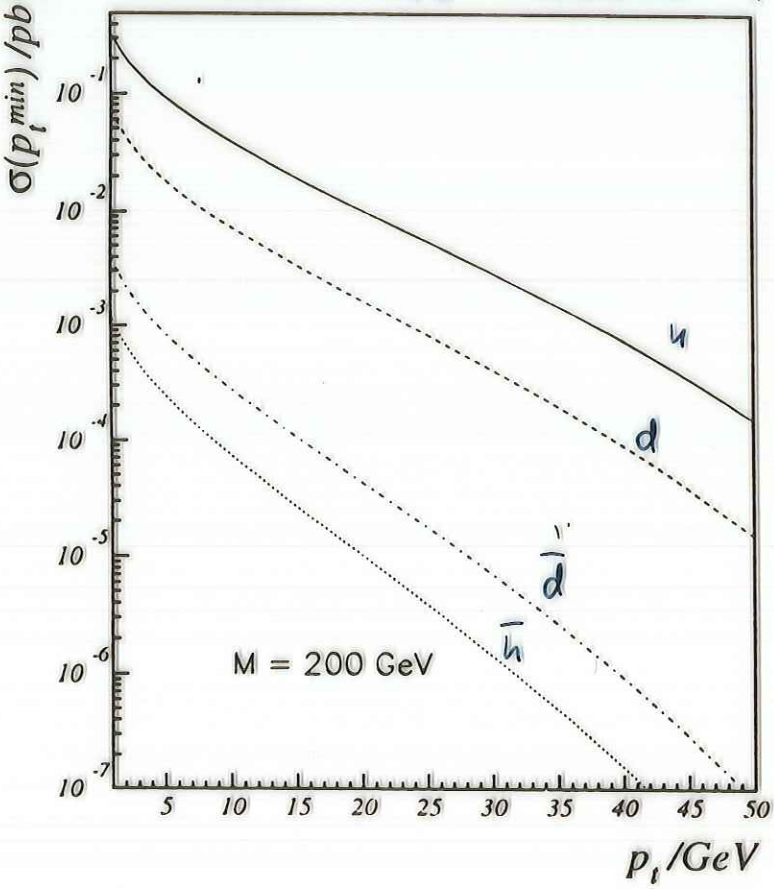
JB, A. KRYUKOV
DESY 97-067.

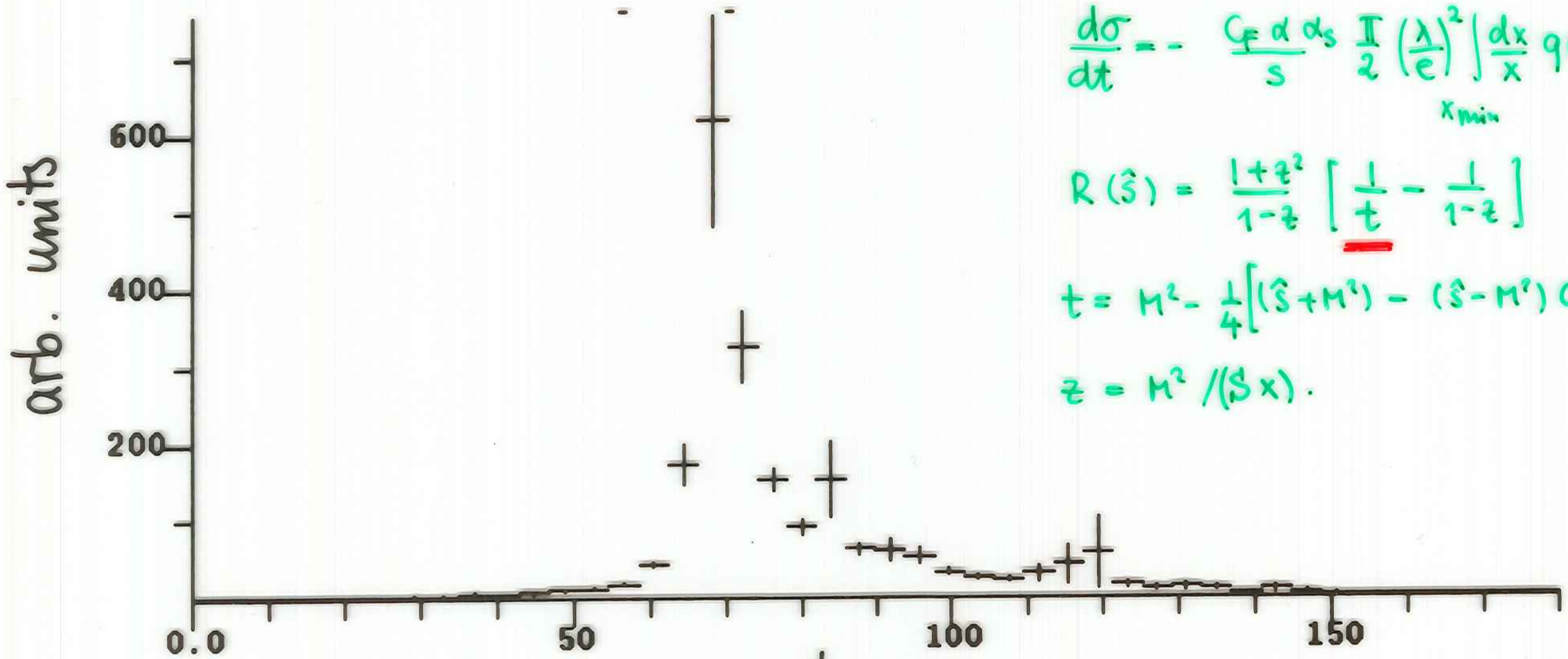
(eq)
DOBADO et al.
'87

$\sigma(eq \to Sq) \sim 0.09\,pb$
$q = u$

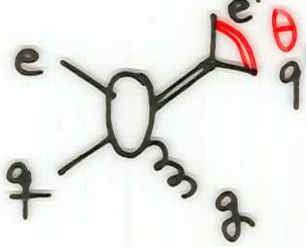
CTEQ 3 LO
$\mu = M$

THE ABOVE CURVES FOR $d, \bar{d}, \bar{u}$ SCALE UP FOR CORRESPONDINGLY LARGER λ/e – VALUES (cf. ABOVE).





$\Theta^{LAB}_{e'q'}$ / dgr.



$$\frac{d\sigma}{dt} = - \frac{C_F \alpha \alpha_s}{s} \frac{\pi}{2} \left(\frac{\lambda}{e}\right)^2 \int_{x_{min}}^{1} \frac{dx}{x} q(x) \; R(\hat{s})$$

$$R(\hat{s}) = \frac{1+z^2}{1-z} \left[\frac{1}{t} - \frac{1}{1-z} \right]$$

$$t = M^2 - \frac{1}{4}\left[(\hat{s} + M^2) - (\hat{s} - M^2) \cos\theta^* \right]$$

$$z = M^2 / (\hat{s} x).$$

$\lambda = 0, \quad \kappa \neq 0$ POMAROL et al. '93

$\lambda, \kappa \neq 0$ JB, BOOS, KRYUKOV '96.

$\boxed{\lambda = 0}$ DOES NOT YIELD THE SMALLEST CROSS SECT!

- $\min\limits_{\kappa,\lambda} \sigma_{q\bar{q}}$ DOES NOT CONTAIN $\left(\frac{s}{M^2}\right)^{\alpha}$ TERMS ANYMORE!

JB, BOOS, KRYUKOV '96A.

RELEVANT FOR TEVATRON !

$$\sigma_{S\bar{S}} \; (\mu = M = 200 \text{ GeV}) \sim 0.16 \text{ pb}$$

$$\min_{\kappa,\lambda} \sigma_{V\bar{V}} \; (\mu = M = 200 \text{ GeV}) \sim 0.3 \text{ pb}$$

$(\sigma_{MC} \; (\kappa = 1, \lambda = 0) \sim 0.4 \text{ pb})$.

JB, E. BOOS, A. KRYUKOV
Oct. 1996

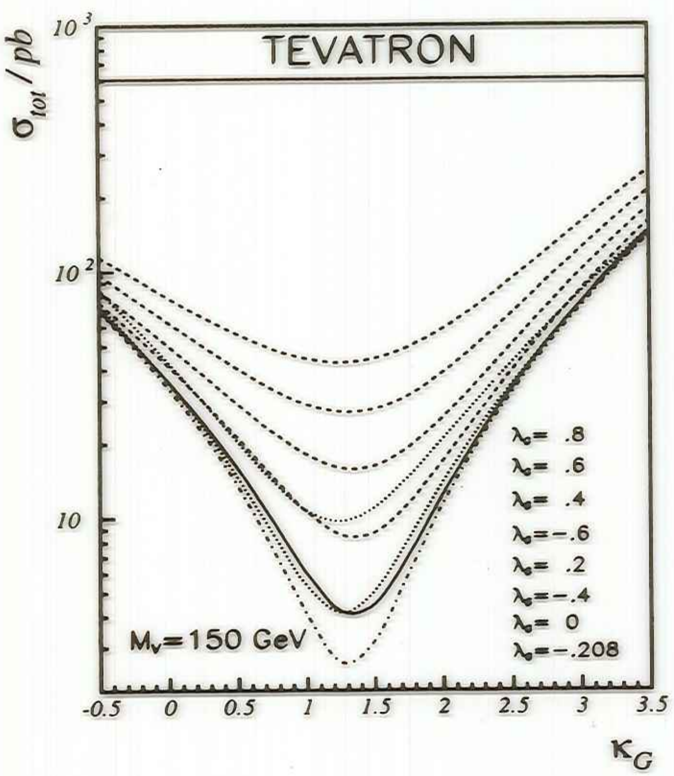


Figure 6a: Dependence of the integrated cross sections for vector leptoquark pair production on the anomalous couplings κ_G and λ_G at the TEVATRON, $\sqrt{S}$ = 1.8 TeV for M_V = 150 GeV. The order of the values of λ_G follows the position of the respective minimum. Dashed lines: $\lambda_G > 0$, dotted lines: $\lambda_G < 0$, full line: $\lambda_G = 0$, dash-dotted line: $\lambda_G = -0.208$.

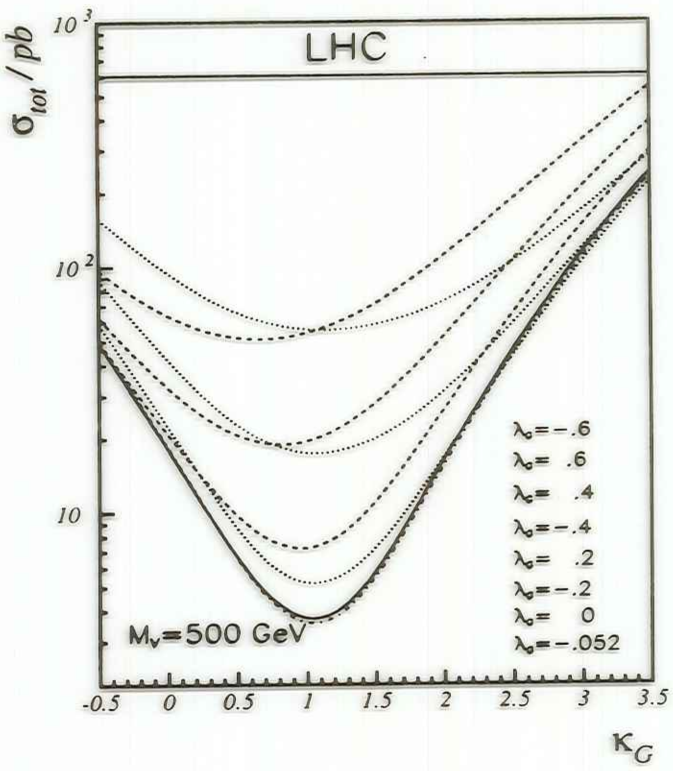
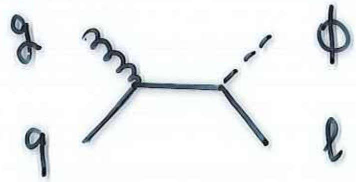


Figure 6b: Dependence of the integrated cross sections for vector leptoquark pair production on the anomalous couplings κ_G and λ_G at LHC, $\sqrt{S}$ = 14 TeV for M_V = 500 GeV. The dash-dotted line corresponds to $\lambda_G = -0.052$. The other parameters are the same as in figure 6a.

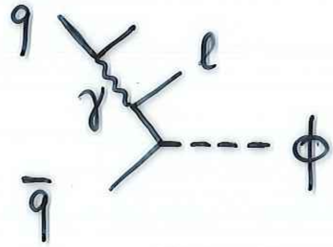
$p\bar{p}$ PRODUCTION

1) SINGLE PRODUCTION



HEWETT, PAKVASA '89
(MANY OTHERS LATER
cf. JB '97)

$\sigma \propto \lambda^2 \ll 1.$



OHNEMUS et al. '94
REYA (priv. comm.)

$\sigma \approx 0.7 \ldots 1.3\ fb$

$\sigma \sim 0.4\ fb$, $M \sim 200$ GeV

$\therefore \frac{\lambda}{e}\sqrt{b} = 0.075.$

2) PAIR PRODUCTION

$\frac{\lambda}{e} \ll 1$: DECOUPLING OF FERMIONIC VERTICES

$\rightarrow g_s$ KNOWN COUPLING
COMPLETE PREDICTION FOR SCALARS

$\rightarrow$ VECTOR LEPTOQUARKS ARE NOT NECESSARILY COUPLING YANG-MILLS LIKE TO GLUONS

κ_G, λ_G – ANOMALOUS COUPLINGS

$\exists \min_{\kappa_G, \lambda_G} \sigma_{V\bar{V}} > 0.$ JB, BOOS, KRYUKOV '96.

IN THIS SENSE: MODEL 'INDEPENDENT' LIMIT.

SCALARS :

$$\sigma^{q\bar q}_{S\bar S} = \frac{2\pi\alpha_s^2}{27\hat s}\beta^3$$

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

∴ SUSY: SQUARKS

CORRECT IN:

GRIFOLS, MENDEZ '82

ANTONIADIS et al. '84

EHLQ '84

ALTARELLI, RÜCKL '84

DAWSON, EICHTEN, QUIGG '85

JB, KRYUKOV, BOOS '96

HARRISON, LLEWELLYN SMITH '83 (E!)

VECTORS :

$$\sigma^{q\bar q}_{V\bar V} = \frac{4\pi\alpha_s^2}{9M_V^2}\sum_{i=0}^{5}\chi_i^q(\kappa,\lambda)\,\tilde G_i(\hat s,\beta)$$

$$\sigma^{q\bar q}_{V\bar V} = \frac{\pi\alpha_s^2}{96 M_V^2}\sum_{i=0}^{14}\chi_i^g(\kappa,\lambda)\,\tilde F_i(s,\beta)$$

$\lambda = \kappa = 0$:

(Y-M-type)

$$\sigma^{q\bar q}_{V\bar V} = \frac{4\pi\alpha_s^2}{9M_V^2}\left[\frac{1}{24}\frac{\hat s}{M_V^2} + \frac{23-3\beta^2}{24}\right] \;!$$

$$\sigma^{gg}_{V\bar V} = \frac{\pi\alpha_s^2}{96 M_V^2}\left[\beta A - L(\beta)\cdot B\right]$$

$$A = \frac{523}{4} - 90\beta^2 + \frac{93}{4}\beta^4$$

$$B = \frac{3}{4}\left(65 - 83\beta^2 + 19\beta^4 - \beta^6\right).$$

ARNOLD, WENDT '86.

BORISOV et al '87.

JB, BOOS, KRYUKOV '96

B Coefficients of the production cross section of vector leptoquarks

The functions $F_i(\hat{s},\beta,\cos\theta)$ which determine the differential pair production cross section for $gg \to V\bar{V}$ are:

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

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

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

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

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

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

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

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

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

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

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

$$\begin{aligned} F_{11} &= -4\cdot\left(3 + 5\beta^2\cos^2\theta\right) - 5\frac{\hat{s}}{M_V^2}\left(1 - \beta^2\cos^2\theta\right)^2\\ &+ \frac{1}{8}\frac{\hat{s}^2}{M_V^4}\left(1 - \beta^2\cos^2\theta\right)^2\left(35 - 13\beta^2\cos^2\theta\right) \end{aligned} \tag{96}$$

$$\begin{aligned} F_{12} &= 6\cdot\left(3 + 5\beta^2\cos^2\theta\right) - \frac{15}{2}\frac{\hat{s}}{M_V^2}\left(1 - \beta^2\cos^2\theta\right)\left(2 + \beta^2\cos^2\theta\right)\\ &+ \frac{1}{16}\frac{\hat{s}^2}{M_V^4}\left(1 - \beta^2\cos^2\theta\right)\left(-23 + 54\beta^2\cos^2\theta - 39\beta^4\cos^4\theta\right)\\ &+ \frac{1}{64}\frac{\hat{s}^3}{M_V^6}\left(1 - \beta^2\cos^2\theta\right)^2\left(113 - 49\beta^2\cos^2\theta\right) \end{aligned} \tag{97}$$

$$\begin{aligned} F_{13} &= -4\cdot\left(3 + 5\beta^2\cos^2\theta\right) + 5\frac{\hat{s}}{M_V^2}\left(1 - \beta^2\cos^2\theta\right)\left(5 + \beta^2\cos^2\theta\right)\\ &- \frac{1}{8}\frac{\hat{s}^2}{M_V^4}\left(1 - \beta^2\cos^2\theta\right)^2\left(119 + 13\beta^2\cos^2\theta\right)\\ &+ \frac{1}{32}\frac{\hat{s}^3}{M_V^6}\left(1 - \beta^2\cos^2\theta\right)^2\left(79 - 15\beta^2\cos^2\theta\right) \end{aligned} \tag{98}$$

$$\begin{aligned} F_{14} &= 3 + 5\beta^2\cos^2\theta - \frac{5}{4}\frac{\hat{s}}{M_V^2}\left(1 - \beta^2\cos^2\theta\right)\left(8 + \beta^2\cos^2\theta\right)\\ &+ \frac{1}{32}\frac{\hat{s}^2}{M_V^4}\left(1 - \beta^2\cos^2\theta\right)\left(321 - 324\beta^2\cos^2\theta - 13\beta^4\cos^4\theta\right)\\ &+ \frac{11}{64}\frac{\hat{s}^3}{M_V^6}\left(1 - \beta^2\cos^2\theta\right)^2\left(-23 + 7\beta^2\cos^2\theta\right)\\ &+ \frac{1}{256}\frac{\hat{s}^4}{M_V^8}\left(1 - \beta^2\cos^2\theta\right)^2\left(135 - 22\beta^2\cos^2\theta + 15\beta^4\cos^4\theta\right). \end{aligned} \tag{99}$$

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

$$\bar{F}_0 = \beta\left(\frac{523}{4} - 90\beta^2 + \frac{93}{4}\beta^4\right) - \frac{3}{4}(65 - 83\beta^2 + 19\beta^4 - \beta^6)\log\left|\frac{1+\beta}{1-\beta}\right|$$

$$\bar{F}_1 = -4\beta(41 - 9\beta^2) - \frac{87}{2}(1 - \beta^2)\log\left|\frac{1+\beta}{1-\beta}\right| \tag{100}$$

$$\bar{F}_2 = 36\beta(1 - \beta^2) - 25(1 - \beta^2)\log\left|\frac{1+\beta}{1-\beta}\right| \tag{101}$$

$$\bar{F}_3 = \beta(75 - 9\beta^2) + \frac{7}{4}\beta\frac{\hat{s}}{M_V^2} - \frac{1}{4}(1 - 61\beta^2)\log\left|\frac{1+\beta}{1-\beta}\right| \tag{102}$$

$$\bar{F}_4 = -2\beta(20 - 9\beta^2) + \frac{1}{2}(91 - 31\beta^2)\log\left|\frac{1+\beta}{1-\beta}\right| \tag{103}$$

$$\bar{F}_5 = \beta\left(\frac{209}{6} - 9\beta^2\right) + \frac{263}{12}\beta\frac{\hat{s}}{M_V^2} + \frac{3}{2}\beta\frac{\hat{s}^2}{M_V^4} - \left(\frac{219}{4} - \frac{31}{4}\beta^2 + \frac{\hat{s}}{M_V^2}\right)\log\left|\frac{1+\beta}{1-\beta}\right| \tag{104}$$

$$\bar{F}_6 = -9\beta - \frac{7}{4}\beta\frac{\hat{s}}{M_V^2} - \left(\frac{103}{8} + \frac{3}{8}\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right| \tag{105}$$

$$\bar{F}_7 = \frac{55}{2}\beta - \frac{17}{4}\beta\frac{\hat{s}}{M_V^2} - \left(\frac{185}{8} - \frac{1}{8}\beta^2\right)\log\left|\frac{1+\beta}{1-\beta}\right| \tag{106}$$

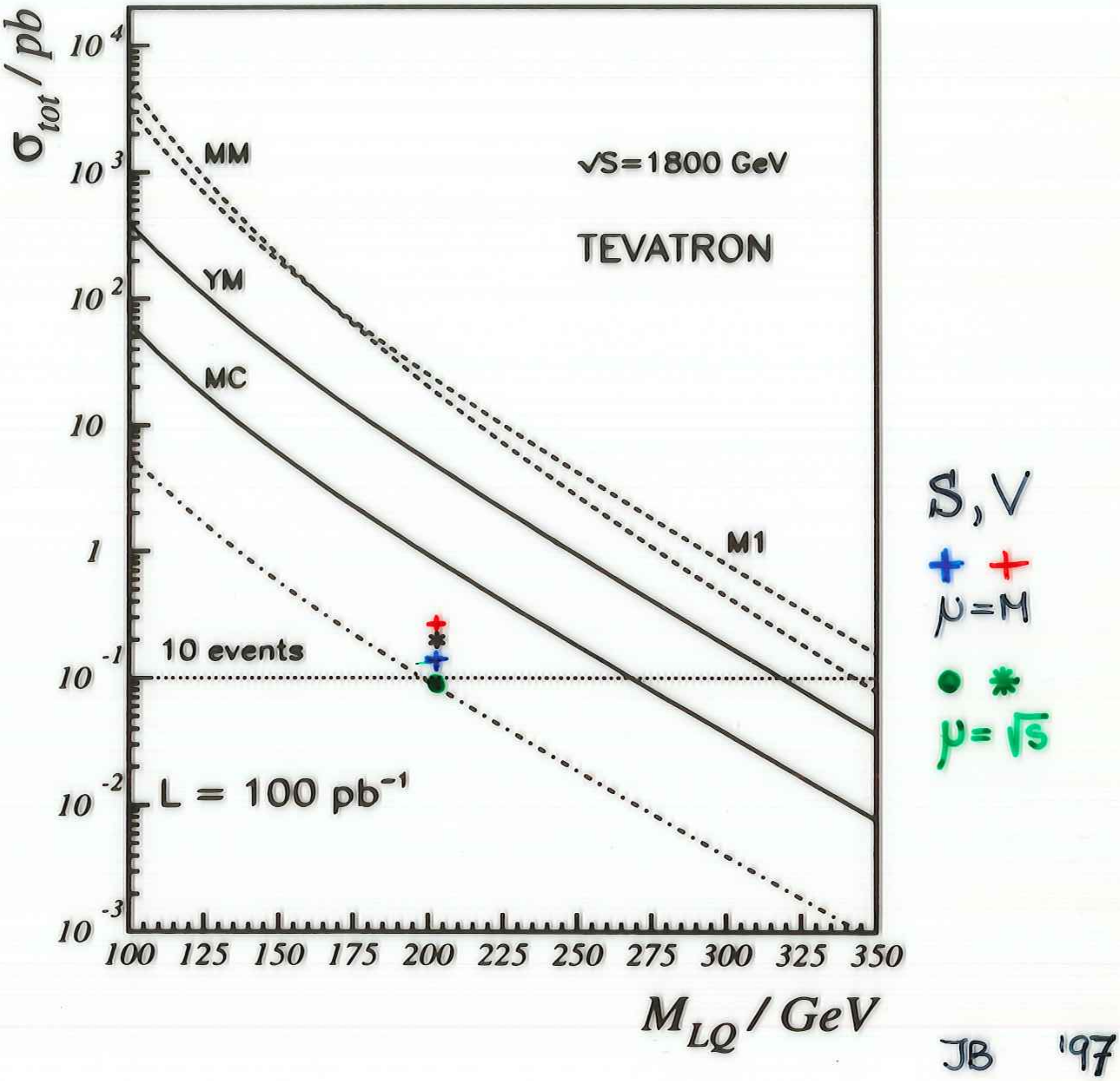


Figure 1: Integrated cross sections for scalar vector leptoquark pair production at the TEVATRON, $\sqrt{s}$ = 1.8 TeV choosing the renormalization and factorization scale by $\mu = \sqrt{\hat{s}}$. Dash-dotted line : scalar leptoquarks; fill lines : YM : Yang-Mills type coupling $\kappa_G = \lambda_G \equiv 0$; MC : minmal vector coupling $\kappa_G = 1, \lambda_G = 0$; dashed lines : other choices for the anomalous couplings : MM : $\kappa_G = \lambda_G = -1$, M1 : $\kappa_G = -1, \lambda_G = +1$. The asterisk denotes the minimum of the pairproduction cross section for vector leptoquarks with respect to the anomalous couplings at $M_V = 200$ GeV.

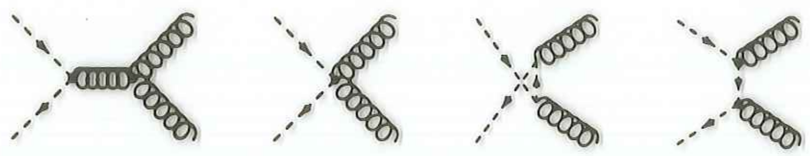


Figure 1: Diagrams describing leptoquark pair production via gluon–gluon fusion. Here the dashed lines denote both scalar and vector leptoquarks.

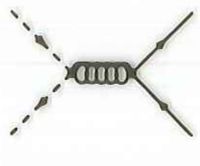


Figure 2: Diagram for the subprocess $q\bar{q} \to \Phi_{S,V}\bar{\Phi}_{S,V}$.