Cross Section and Forward-Backward Asymmetry of $t\bar{t}$ Production in the Model with Four Color Symmetry

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Contents

The search for a new physics beyond the Standard Model (SM) is now one of the aims of the high energy physics. One of the new physics can be induced by the possible four color symmetry treating leptons as quarks of the fourth color [J. C. Pati, A. Salam. PRD, 1974]. This symmetry can be unified with the SM by the gauge group

$$G_{new} = G_c \times SU_L(2) \times U_R(1)$$

where G_c is the group of the four color symmetry. The color group G_c can be the vectorlike group

$$G_c = SU_V(4)$$

or the general chiral group

$$G_c = SU_L(4) \times SU_R(4)$$

or one of the special groups of the left or right four color symmetry

$$G_c = SU_L(4) \times SU_R(3), \quad G_c = SU_L(3) \times SU_R(4).$$

Minimal model with the four color symmetry

The Minimal four color Quark - Lepton Symmetry model (MQLS-model) is based on the gauge group

$$G_{new} = SU_V(4) \times SU_L(2) \times U_R(1)$$

as on the minimal group containing the four color symmetry of quarks and leptons [A. D. Smirnov. PLB, 1995; YaF,1995]. According to this group in addition to gluons G^j_μ, $j = 1, 2, \ldots, 8$ and $W^{\pm}$-, Z-bosons the gauge sector predicts the new gauge particles: vector leptoquarks $V^{\pm}_{\alpha\mu}$, $\alpha = 1, 2, 3$ with charges $Q^{em}_V = \pm 2/3$ and an extra Z'-boson originating from the four color quark - lepton symmetry.

Fermion sector of the model

In MQLS-model quarks and leptons form the $SU_V(4)$-quartets ψ_{paA}, A = 1, 2, 3, 4, a = 1, 2, p = 1, 2, 3, ...

$$\psi'_{p1A} \;:\quad \begin{pmatrix} u'_\alpha \\ \nu'_e \end{pmatrix}, \begin{pmatrix} c'_\alpha \\ \nu'_\mu \end{pmatrix}, \begin{pmatrix} t'_\alpha \\ \nu'_\tau \end{pmatrix}, \dots$$

$$\psi'_{p2A} \;:\quad \begin{pmatrix} d'_\alpha \\ e^{-\prime} \end{pmatrix}, \begin{pmatrix} s'_\alpha \\ \mu^{-\prime} \end{pmatrix}, \begin{pmatrix} b'_\alpha \\ \tau^{-\prime} \end{pmatrix}, \dots$$

Each lepton have $SU_V(4)$ "color" $A = 4$

Fermion mixing in MQLS

The basic left and right quark and lepton fields $Q'^{L,R}_{pa\alpha}$, $\ell'^{L,R}_{pa}$ can be written, in general, as superpositions

$$Q'^{L,R}_{pa\alpha} = \sum_q \left(A^{L,R}_{Q_a}\right)_{pq} Q^{L,R}_{qa\alpha}, \qquad l'^{L,R}_{pa} = \sum_q \left(A^{L,R}_{l_a}\right)_{pq} l^{L,R}_{qa},$$

of mass eigenstates $Q^{L,R}_{qa\alpha}$, $\ell^{L,R}_{qa}$. Here $A^{L,R}_{Q_a}$ and $A^{L,R}_{\ell_a}$ are unitary matrices diagonalizing the mass matrices of quarks and leptons respectively.

$(A^L_{Q_1})^+ A^L_{Q_2} \equiv C_Q = V_{CKM}$ is Cabibbo-Kobayashi-Maskawa matrix

$(A^L_{\ell_1})^+ A^L_{\ell_2} \equiv C_\ell$ is the analogous lepton mixing matrix ($(C_l)^+ = U_{PMNS}$)

$(A^{L,R}_{Q_a})^+ A^{L,R}_{\ell_a} \equiv K^{L,R}_a$ are the new mixing matrices which are specific for the models with the four color symmetry.

Features of Z'-boson originating from the four color symmetry

$$\mathcal{L}_{\rm NC}^{\rm gauge} = -eZ_{1\mu}J_\mu^{Z_1} - \frac{e}{c_W}Z_{2\mu}J_\mu^{Z_2},$$

$$\begin{aligned} J_\mu^{Z_1} &= \bar{f}\gamma_\mu(v_f^{Z_1} + a_f^{Z_1}\gamma_5)f, \\ J_\mu^{Z_2} &= \bar{f}\gamma_\mu(v_f^{Z_2} + a_f^{Z_2}\gamma_5)f \end{aligned}$$

$$\begin{aligned} v_{f_a}^{Z_2} &= \frac{1}{s_S\sqrt{1 - s_W^2 - s_S^2}}\left[c_W^2\sqrt{\frac{2}{3}}(t_{15})_f - \left(Q_{f_a} - \frac{(\tau_3)_{aa}}{4}\right)s_S^2\right] \\ a_{f_a}^{Z_2} &= \frac{s_S}{\sqrt{1 - s_W^2 - s_S^2}}\frac{(\tau_3)_{aa}}{4} \end{aligned}$$

The scalar sector contains in general four multiplets [A. D. Smirnov. PLB, 1995; YaF,1995; A.V. Povarov, A. D. Smirnov, YaF, 2001]

$$(4,1,1):\Phi^{(1)} = \begin{pmatrix} S_\alpha^{(1)} \\ \frac{\eta_1+\chi^{(1)}+i\omega^{(1)}}{\sqrt{2}} \end{pmatrix},$$

$$(1,2,1):\Phi_a^{(2)} = \delta_{a2}\frac{\eta_2}{\sqrt{2}} + \phi_a^{(2)},$$

$$\mathbf{(15,2,1)}:\Phi_a^{(3)} = \begin{pmatrix} (\mathbf{F_a})_{\alpha\beta} & \mathbf{S}_{\mathbf{a}\alpha}^{(+)} \\ \mathbf{S}_{\mathbf{a}\alpha}^{(-)} & 0 \end{pmatrix} + \Phi_{15,a}^{(3)} t_{15},$$

$$(15,1,0):\Phi^{(4)} = \begin{pmatrix} F_{\alpha\beta}^{(4)} & \frac{1}{\sqrt{2}}S_\alpha^{(4)} \\ \overset{*}{S}{}_\alpha^{(4)} & 0 \end{pmatrix} + (\eta_4+\chi^{(4)})t_{15},$$

transforming according to the (4,1,1)-,(1,2,1)-,(15,2,1)-,(15,1,0)-representations of the $SU_V(4)\times SU_L(2)\times U_R(1)$-group respectively. Here $\Phi_{15,a}^{(3)} = \delta_{a2}\eta_3 + \phi_{15,a}^{(3)}$, η_1, η_2, η_3, η_4 are the vacuum expectation values.

$$(15.2.1) : \Phi^{(3)} : \qquad \begin{pmatrix} S_{1\alpha}^{(+)} \\ S_{2\alpha}^{(+)} \end{pmatrix}; \begin{pmatrix} S_{1\alpha}^{(-)} \\ S_{2\alpha}^{(-)} \end{pmatrix}; \begin{pmatrix} F_{1k} \\ F_{2k} \end{pmatrix}; \begin{pmatrix} \Phi_{1,15}^{(3)} \\ \Phi_{1,15}^{(3)} \end{pmatrix},$$

where $\mathbf{S_{a\alpha}^{(\pm)}}$ and $\mathbf{F_{ak}}$ (k=1,2...8) are the scalar leptoquark and scalar gluons doublets. $\Phi_{15}^{(3)} - \Phi^{(2)}$-mixing gives the SM Higgs doublet $\Phi^{(SM)}$ and an additional Φ' doublet. These scalar doublets have the electric charges

$$Q_{em} : \qquad \begin{pmatrix} 5/3 \\ 2/3 \end{pmatrix}; \begin{pmatrix} 1/3 \\ -2/3 \end{pmatrix}; \begin{pmatrix} 1 \\ 0 \end{pmatrix}; \begin{pmatrix} 1 \\ 0 \end{pmatrix}.$$

In general

$$S_{2\alpha}^{(+)} = \sum_{m=0}^{3} c_m^{(+)} S_m, \qquad \overset{*}{S}{}_2^{(-)} = \sum_{m=0}^{3} c_m^{(-)} S_m$$

where S_m are three physical leptoquarks with electric charge 2/3 and S_0 is the Goldstone mode, $c_m^{(\pm)}$ are the elements of the unitary scalar leptoquark mixing matrix, $|c_0^{(\pm)}|^2 = \frac{1}{3} g_4^2 \eta_3^2 / m_V^2 \ll 1$.

The experimental lower mass limits for the scalar leptoquarks from their direct search are [PDG. C. Amsler et al. , Physics Letters B667, 1 (2008)]

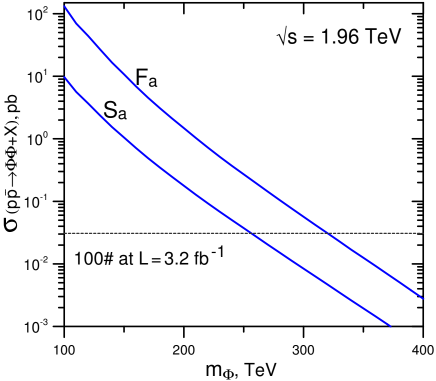
$$\mathbf{m_{LQ}} \gtrsim \mathbf{250\ GeV}.$$

The indirect data set the limits on the relations of scalar leptoquark coupling constants to their masses.

In MQLS-model the leptoquark Yukawa coupling constants are (due their Higgs origin) proportional to the ratios m_f/η of the fermion masses m_f to the SM VEV η. As a result these coupling constants are known (up to mixing parameters) and are small for light quarks. So, the indirect mass limits for MQLS scalar leptoquarks are weaker then those from direct searchers.

The partonic cross sections of scalar gluon pair production are known ([A.V Manohar, M.B. Wise, PRD 74, 035009 (2006); MM, A. D. Smirnov, Mod. Phys. Lett., 2008, A23, 2907-2913]), which gives now possibility to calculate cross section of scalar gluon pair production at the Tevatron in dependence on scalar gluon mass.

In these calculations we use PDF's set AL'03 ([S.I. Alekhin PR**D** **67 014002, 2003]**) (NLO, variable-favor-number) with the K-factor chosen as $K = 1.45$ for consistency with theoretically predicted dependence of $\sigma^{NLO}(t\bar{t})$ on m_t ([M. Cacciari et al. JHEP **09**, 127 (2008). arXiv:0804.2800], [N. Kidonakis,R. Vogt, PR**D** 78, (2008) 074005. arXiv:0805.3844]).



Cross sections of SS^*-,FF^*-pair production at the Tevatron as functions of the masses of scalar particles

Our estimate for mass limits for scalar gluons F_a from direct searches at Tevatron is

$$\mathbf{m_{F_a}} \gtrsim \mathbf{320}\ \text{GeV}.$$

The interactions of the scalar leptoquarks $S_{a\alpha}^{(\pm)}$ with quarks and leptons:

$$
\begin{aligned}
L_{S_1^{(+)}u_i l_j} &= \bar{u}_{i\alpha}\Big[(h_{+}^{L})_{ij}P_L + (h_{+}^{R})_{ij}P_R\Big] l_j S_{1\alpha}^{(+)} + \text{h.c.},\\
L_{S_1^{(-)}\nu_i d_j} &= \bar{\nu}_{i}\Big[(h_{-}^{L})_{ij}P_L + (h_{-}^{R})_{ij}P_R\Big] d_{j\alpha} S_{1\alpha}^{(-)} + \text{h.c.},\\
L_{S_m u_i \nu_j} &= \bar{u}_{i\alpha}\Big[(h_{1m}^{L})_{ij}P_L + (h_{1m}^{R})_{ij}P_R\Big] \nu_j S_{m\alpha} + \text{h.c.}\\
L_{S_m d_i l_j} &= \bar{d}_{i\alpha}\Big[(h_{2m}^{L})_{ij}P_L + (h_{2m}^{R})_{ij}P_R\Big] l_j S_{m\alpha} + \text{h.c.}
\end{aligned}
$$

The interactions of the scalar gluons with quarks:

$$
\begin{aligned}
L_{F_1 u_i d_j} &= \bar{u}_{i\alpha}\Big[(h_{F_1}^{L})_{ij}P_L + (h_{F_1}^{R})_{ij}P_R\Big] (t_k)_{\alpha\beta} d_{j\beta} F_{1k} + \text{h.c.},\\
L_{F_2 u_i u_j} &= \bar{u}_{i\alpha}\Big[(h_{1F_2}^{L})_{ij}P_L\Big] (t_k)_{\alpha\beta} u_{j\beta} F_{2k} + \text{h.c.},\\
L_{F_2 d_i d_j} &= \bar{d}_{i\alpha}\Big[(h_{2F_2}^{R})_{ij}P_R\Big] (t_k)_{\alpha\beta} d_{j\beta} F_{2k} + \text{h.c.}
\end{aligned}
$$

Scalar leptoquarks $S_1^{(\pm)}$, S_m couplings to fermions

$$
\begin{aligned}
(h_+^L)_{ij} &= \sqrt{3/2}\frac{1}{\eta\sin\beta}\Big[m_{u_i}(K_1^L C_l)_{ij} - (K_1^R)_{ik} m_{\nu_i}(C_l)_{kj}\Big],\\
(h_+^R)_{ij} &= -\sqrt{3/2}\frac{1}{\eta\sin\beta}\Big[(C_Q)_{ik} m_{d_k}(K_2^R)_{kj} - m_{l_j}(C_Q K_2^L)_{ij}\Big],\\
(h_-^L)_{ij} &= \sqrt{3/2}\frac{1}{\eta\sin\beta}\Big[(\overset{+}{K}{}_1^R)_{ik} m_{u_k}(C_Q)_{kj} - m_{\nu_j}(\overset{+}{K}{}_1^L C_Q)_{ij}\Big],\\
(h_-^R)_{ij} &= -\sqrt{3/2}\frac{1}{\eta\sin\beta}\Big[(C_l \overset{+}{K}{}_2^L)_{ij} m_{d_j} - (C_l)_{ik} m_{l_k}(\overset{+}{K}{}_2^R)_{kj}\Big],\\
(h_{1m}^{L,R})_{ij} &= -\sqrt{3/2}\frac{1}{\eta\sin\beta}\Big[m_{u_i}(K_1^{L,R})_{ij} - (K_1^{R,L})_{ij} m_{\nu_j}\Big] c_m^{(\pm)},\\
(h_{2m}^{L,R})_{ij} &= -\sqrt{3/2}\frac{1}{\eta\sin\beta}\Big[m_{d_i}(K_2^{L,R})_{ij} - (K_2^{R,L})_{ij} m_{l_j}\Big] c_m^{(\mp)},
\end{aligned}
$$

where β is $\Phi_a^{(2)} - \Phi_{15}^{(3)}$ mixing angle in MQLS model, $tg\beta = \eta_3/\eta_2$, $C_Q = V_{CKM}$, $C_l = U_{PMNS}$ and $K_a^{L,R} = (A_{Q_a}^{L,R})^+ A_{l_a}^{L,R}$ are the mixing matrices specific for the MQLS model.

Scalar gluons F_a couplings to fermions

$$
\begin{aligned}
(h^L_{F_1})_{ij} &= \sqrt{3}\frac{1}{\eta\sin\beta}\Big[m_{u_i}(C_Q)_{ij} - (K_1^R)_{ik} m_{\nu_k}(\overset{+}{K}{}_1^L C_l)_{kj}\Big] \\
(h^R_{F_1})_{ij} &= -\sqrt{3}\frac{1}{\eta\sin\beta}\Big[(C_Q)_{ij} m_{d_i} - (C_l K_2^L)_{ik} m_{l_k}(\overset{+}{K}{}_2^R)_{kj}\Big] \\
(h^L_{1F_2})_{ij} &= -\sqrt{3}\frac{1}{\eta\sin\beta}\Big[m_{u_i}\delta_{ij} - (K_1^R)_{ik} m_{\nu_k}(\overset{+}{K}{}_1^L)_{kj}\Big] \\
(h^R_{2F_2})_{ij} &= -\sqrt{3}\frac{1}{\eta\sin\beta}\Big[m_{d_i}\delta_{ij} - (K_1^L)_{ik} m_{l_k}(\overset{+}{K}{}_1^R)_{kj}\Big] \\
(h^R_{1F_2})_{ij} &= 0 \\
(h^L_{2F_2})_{ij} &= 0
\end{aligned}
$$

The largest couplings $h \sim m_t/\eta$

$$
\begin{aligned}
S_1^{(+)}\bar{t}\tau : \quad & (h_+^L)_{33} &=& \sqrt{3/2}\frac{m_t}{\eta\sin\beta}(K_1^L C_l)_{33}, \\
S_1^{(-)}\bar{\nu_\tau} b : \quad & (h_-^L)_{33} &=& \sqrt{3/2}\frac{m_t}{\eta\sin\beta}\overset{+}{(K_1^R)}_{33}(C_Q)_{33} \\
S_m\bar{t}\nu_\tau : \quad & (h_{1m}^{L,R})_{33} &=& -\sqrt{3/2}\frac{m_t}{\eta\sin\beta}(K_1^{L,R})_{33}c_m^{(\pm)} \\
F_1\bar{t}b : \quad & (h_{F_1}^L)_{33} &=& \sqrt{3}\frac{m_t}{\eta\sin\beta}(C_Q)_{33} \\
F_2\bar{t}t : \quad & (h_{1F_2}^L)_{33} &=& -\sqrt{3}\frac{m_t}{\eta\sin\beta}
\end{aligned}
$$

$m_t/\eta \sim 0.7!$

These particles may give significant contribution in $t\bar{t}$-quark production at Tevatron.

The latest CDF data on cross section and forward-backward asymmetry of the $t\bar{t}$ production at the Tevatron (CDF 2009 $L = 3.2\ fb^{-1}$)

$$\sigma_{t\bar{t}} = 7.5 \pm 0.31(stat) \pm 0.34(syst) \pm 0.15(lumi) pb$$
$$A_{\rm FB}^{t\bar{t}} = 0.193 \pm 0.065\ ({\rm stat}) \pm 0.024\ ({\rm sys})$$

$\sigma_{t\bar{t}}$ SM prediction [M. Cacciari et al. JHEP **09**, 127 (2008).arXiv:0804.2800,...]

$$\sigma_{t\bar{t}}^{SM} = 7.35\ ^{+0.38}_{-0.80}\ ({\rm scale})\ ^{+0.49}_{-0.34}\ ({\rm PDFs})[{\rm CTEQ6.5}]\,{\rm pb} \div$$
$$7.93\ ^{+0.34}_{-0.56}\ ({\rm scale})\ ^{+0.24}_{-0.20}\ ({\rm PDFs})[{\rm MRST2006nnlo}]\,{\rm pb}$$

$A_{\rm FB}^{t\bar{t}}$ SM prediction [O. Antunano et al. PR**D77**, 014003 (2008)]

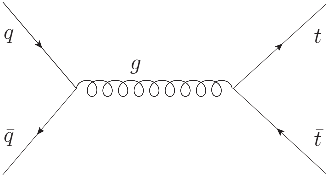
$$A_{\rm FB}^{t\bar{t}} = 0.051(6)$$

$$A_{\rm FB}^{t\bar{t}} = \frac{N_t(\cos\theta > 0) - N_t(\cos\theta < 0)}{N_t(\cos\theta > 0) + N_t(\cos\theta < 0)}$$

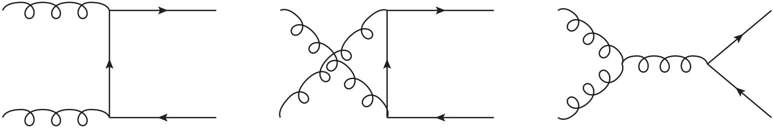
$p\bar{p} \longrightarrow t\bar{t}$

SM Diagrams of order α_s^2

$q\bar{q} \rightarrow t\bar{t}$



$gg \rightarrow t\bar{t}$



$p\bar{p} \longrightarrow t\bar{t}$ LO Cross Section

$$\frac{d\sigma(q\bar{q}\to t\bar{t})}{d\cos\hat{\theta}} = \frac{\alpha_s^2\pi\beta}{9\hat{s}}\left(1+\beta^2c^2+4m_t^2/\hat{s}\right)$$

$$\sigma(q\bar{q}\to t\bar{t}) = \frac{4\pi\alpha_s^2\beta}{27\hat{s}}\left(3-\beta^2\right)$$

$$\frac{d\sigma(gg\to t\bar{t})}{d\cos\hat{\theta}} = \alpha_s^2\,\frac{\pi\beta}{6\hat{s}}\left(\frac{1}{1-\beta^2c^2}-\frac{9}{16}\right)\left(1+\beta^2c^2+2(1-\beta^2)-\frac{2(1-\beta^2)^2}{1-\beta^2c^2}\right)$$

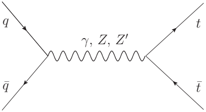
$$\sigma(gg\to t\bar{t}) = \frac{\pi\alpha_s^2}{48\hat{s}}\left[\left(\beta^4-18\beta^2+33\right)\log\left(\frac{1+\beta}{1-\beta}\right)+\beta\left(31\beta^2-59\right)\right]$$

where $c=\cos\hat{\theta}$, $\hat{\theta}$ is the scattering angle of t-quark in the parton center of mass frame, $\hat{s}$ is the invariant mass of $t\bar{t}$ system,
$\beta=\sqrt{1-4m_t^2/\hat{s}}$
No sources of order α_s^2 for the forward-backward asymmetry

MQLS Contributions in $t\bar{t}$-production

1. Z' tree s-channel process
2. Scalar gluons tree processes
3. 1-loop $gt\bar{t}$ effective vertex

Z' tree s-channel process



Singlet color state $q\bar{q} \overset{\gamma, Z, Z'}{\longrightarrow} t\bar{t}$

$$\frac{d\sigma(q\bar{q} \overset{\gamma, Z, Z'}{\longrightarrow} t\bar{t})}{d\cos\hat{\theta}} = \frac{\pi\alpha_{em}^2 \hat{s}\beta}{2} \sum_{i,j=\gamma,Z,Z'} K_{ij} Re(P_i(\hat{s})P_j^*(\hat{s}))$$

$$\cos\hat{\theta} \equiv c$$

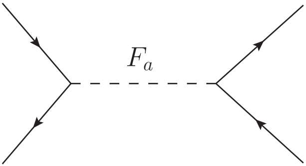
$$\begin{aligned}
K_{ij} &= A_{ij}\left(2 + \beta^2(c^2 - 1)\right) + B_{ij}\beta^2(c^2 + 1) + 2C_{ij}\beta c \\
A_{ij} &= (a_i^q a_j^q + v_i^q v_j^q) v_i^t v_j^t \\
B_{ij} &= (a_i^q a_j^q + v_i^q v_j^q) a_i^t a_j^t \\
C_{ij} &= (a_i^q v_j^q + v_i^q a_j^q)(a_i^t v_j^t + v_i^t a_j^t) \\
P_i(\hat{s}) &= \frac{1}{\hat{s} - M_i^2 + iM_i\Gamma_i}
\end{aligned}$$

For $M_{Z'} > 1.4$ TeV (current experimental limit [PDG. C. Amsler et al. , Physics Letters B667, 1 (2008)])

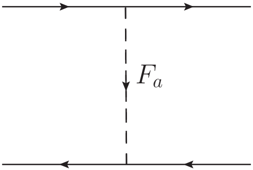
Contributions of Z' is small due smallness of couplings

$$\Delta\sigma(p\bar{p} \to t\bar{t}) \quad \sim \quad +0.05 \div 0.1\,\text{pb}$$
$$\Delta A_{FB}^{t\bar{t}} \quad \sim \quad +0.003$$

Scalar gluons tree processes



$\sigma \sim m_q^2/\hat{s}$

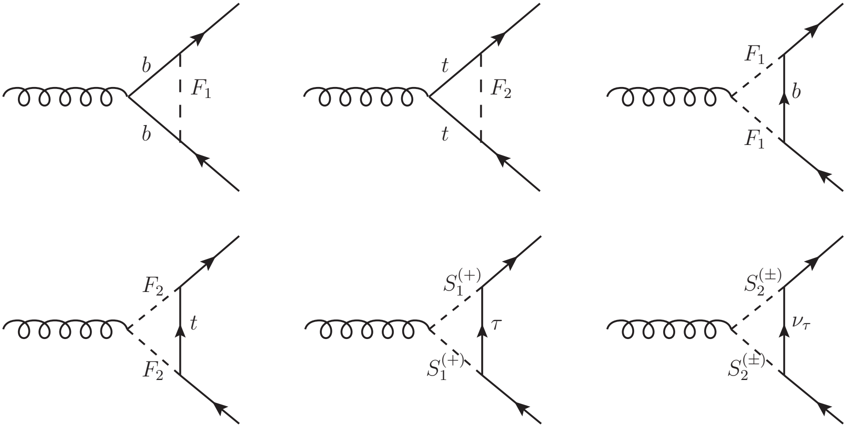


$\sigma \sim |(C_Q)_{i3}|^4$

Contributions are suppressed by factors $m_q^2/\hat{s}$ or $|(V_{CKM})_{i3}|^4$

$$\begin{aligned} \Delta\sigma(p\bar{p} \to t\bar{t}) &\sim 0.0001\,\text{pb} \\ \Delta A_{FB}^{t\bar{t}} &\sim 10^{-6} \end{aligned}$$

1-loop $gt\bar{t}$ effective vertex



Main contributions into effective $gt\bar{t}$-vertex

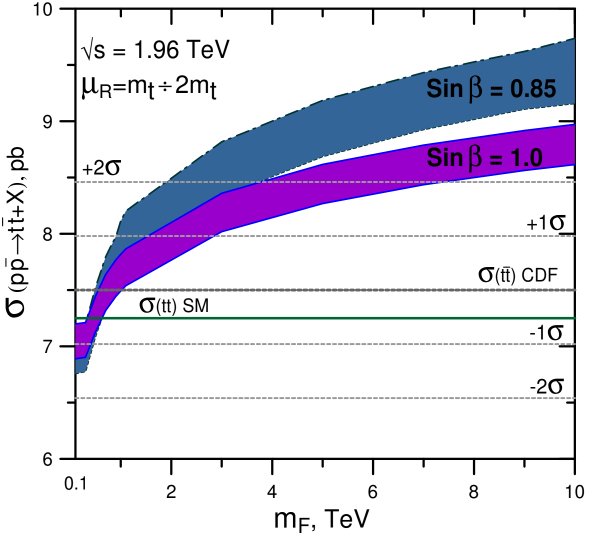
$$(V_a^\mu)_{\alpha\beta} = g_{st}(t_a)_{\alpha\beta}\sum_{i=1}^{6} C_i\left[(a_i^2+v_i^2)\gamma^\mu - 2a_iv_i\gamma^\mu\gamma^5\right] I(\hat{s},\{m_1,m_2,m_3\}_i,\mu_R),$$

$$I(\hat{s},m_1,m_2,m_3,\mu_R) =$$

$$\frac{-1}{16\pi^2}\int_0^1 dxdy \ln\left(\frac{-(\hat{s}x^2+m_1^2y^2+\hat{s}xy)+\hat{s}x+y(m_1^2+m_2^2-m_3^2)-m_2^2}{\mu_R^2}\right)$$

where color factors $C_i = -\frac{1}{6}$ for $i = 1,2$ and $C_i = -\frac{3}{2}$ for $i = 3,4,5,6$
$\{m_1,m_2,m_3\}_1 = \{m_t,m_b,m_F\}$, $\{m_1,m_2,m_3\}_2 = \{m_t,m_t,m_F\}$,
$\{m_1,m_2,m_3\}_3 = \{m_t,m_F,m_b\}$, $\{m_1,m_2,m_3\}_4 = \{m_t,m_F,m_t\}$,
$\{m_1,m_2,m_3\}_5 = \{m_t,m_S,m_\tau\}$, $\{m_1,m_2,m_3\}_6 = \{m_t,m_S,m_{\nu_\tau}\}$
μ_R – renormalization scale in $\overline{MS}$-scheme

Cross Section of $t\bar{t}$ Production at Tevatron



Limits on masses of scalar particles

We assume $m_F \approx m_S$

$$
\begin{aligned}
0.3\,\text{TeV} \lesssim \quad m_F \quad &\lesssim 3.6 \div 6.8\,\text{TeV},\ \mu_R = m_t \div 2m_t,\ \sin\beta = 1 \\
0.3\,\text{TeV} \lesssim \quad m_F \quad &\lesssim 1.8 \div 3.7\,\text{TeV},\ \mu_R = m_t \div 2m_t,\ \sin\beta = 0.85 \\
0.3\,\text{TeV} \lesssim \quad m_F \quad &\lesssim 1.3 \div 2.6\,\text{TeV},\ \mu_R = m_t \div 2m_t,\ \sin\beta = 0.77
\end{aligned}
$$

Possibility of the direct searches scalar gluon at the LHC

The production cross section of scalar gluons F at the LHC with masses $m_F \lesssim 1300\, GeV$ is shown to be sufficient for the effective ($N_{events} \gtrsim 100$) production of these particles at the LHC ($L = 10\, fb^{-1}$). [MM, A.D. Smirnov, Mod. Phys. Lett., 2008, A23, 2907-2913].

At $m_{F_1} \lesssim 1130\, GeV$ from analysis statistical significance the number of the signal $t\bar{t}b\bar{b}$ events will exceed the SM background by 3σ (LHC $L = 10\, fb^{-1}$).[MM, A.D. Smirnov, Phys. of Atomic Nucl. 2010, 73, No.7, to be published].

Summary

- The contributions to the cross section $\sigma_{t\bar{t}}$ and to the forward-backward asymmetry $A_{\rm FB}^{t\bar{t}}$ of $t\bar{t}$ production at the Tevatron from new Z',$S_a^{(\pm)}$, F_a particles predicted by the MQLS-model are calculated.
- These contributions in tree approximation are shown to be small ($\Delta\sigma \sim 0.1$ pb, $\Delta A_{\rm FB}^{t\bar{t}} \sim 0.003$).
- The scalar doublets $S_a^{(\pm)}$, F_a give the logarithmically rising contributions to the 1-loop $gt\bar{t}$ effective vertex.

Summary

- With account of the $gt\bar{t}$ effective vertex the upper mass limits for scalar leptoquarks and scalar gluons are obtained from CDF data on $\sigma_{t\bar{t}}$.

$$m_S,\, m_F \lesssim a\, few\, TeV$$

in dependence on model parameters and regularization scale.

- The lower mass limits for scalar gluons

$$m_F \gtrsim 320\, GeV$$

are obtained from the data on direct searches at Tevatron.

- At $m_{F_1} \lesssim 1130\, GeV$ the scalar gluon F_1 can be evident at LHC at the significance not less that 3σ (for $L = 10\, fb^{-1}$).

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For all parton integration we use PDF's Set AL'03 ([S.I. Alekhin PRD **67 014002, 2003**]) (NLO, variable-favor-number) with the appropriate K-factor $K = 1.45$ for consistency with theoretically predicted dependence of $\sigma^{NLO}(t\bar{t})$ on m_t ([M. Cacciari et al. JHEP **09**, 127 (2008). arXiv:0804.2800], [N. Kidonakis,R. Vogt, PRD 78, (2008) 074005. arXiv:0805.3844]).