Non-resonant new physics in top pair production at hadron colliders

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C. D, J.-M. Gérard, C. Grojean, F. Maltoni and G. Servant, arXiv:1010.6304

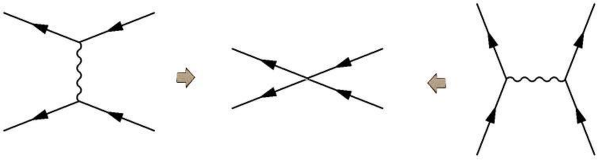
Outline

Motivations

top-philic : top mass

Effective approach :

- Describe a large class of models



- The new interaction is strong (Composite models)

The effective Lagrangian for top pair production

$$\mathcal{L}_{t\bar{t}} = \mathcal{L}_{t\bar{t}}^{SM} + \frac{1}{\Lambda^2}\Big(\left(c_{hg}\mathcal{O}_{hg} + h.c.\right)$$
$$+ \left(c_{Rv}\mathcal{O}_{Rv} + c_{Ra}\mathcal{O}_{Ra} + c'_{Rr}\mathcal{O}'_{Rr} + R \leftrightarrow L\right) + c_{Qq}^{(8,3)}\mathcal{O}_{Qq}^{(8,3)}\Big)$$

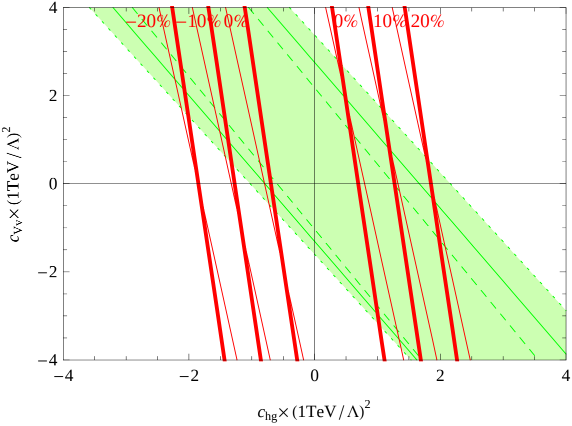
$$\mathcal{O}_{hg} = \left[\left(H\bar{Q}\right)\sigma^{\mu\nu}T^A P_R t\right] G_{\mu\nu}^A$$

$$\mathcal{O}_{Rv} = \left[\bar{t}\gamma^\mu T^A t\right]\sum_q\left[\bar{q}\gamma_\mu T^A q\right] \qquad \mathcal{O}_{Ra} = \left[\bar{t}\gamma^\mu T^A t\right]\sum_q\left[\bar{q}\gamma_\mu\gamma_5 T^A q\right]$$

$$\mathcal{O}'_{Rr} = \left[\bar{t}\gamma^\mu T^A t\right]\left[\bar{u}\gamma_\mu T^A P_R u - \bar{d}\gamma_\mu T^A P_R d\right]$$

$$\mathcal{O}_{Qq}^{(8,3)} = \left[\bar{Q}\gamma^\mu T^A \sigma^I Q\right]\left[\bar{q}_L\gamma_\mu T^A\sigma^I q_L\right]$$

Total cross-section

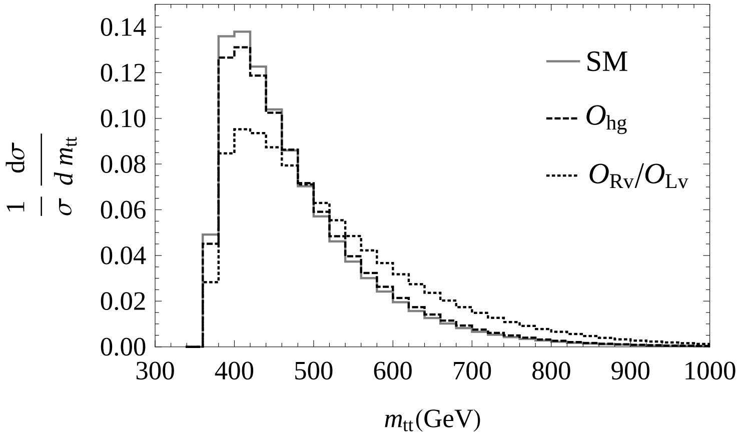


$c_{Vv} = c_{Rv} + c_{Lv}$

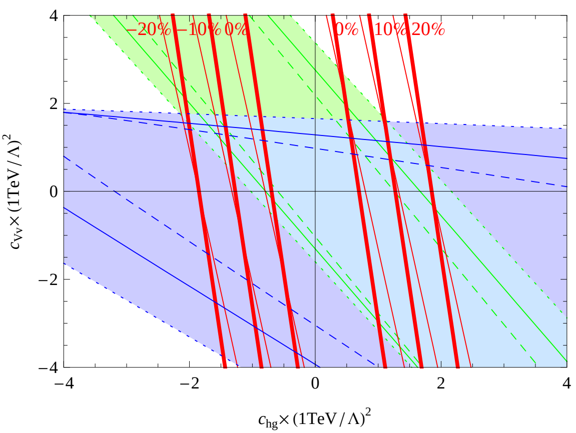
$\sigma(gg \to t\bar{t})$ depends on c_{hg} only

$$\sigma_{obs}^{1.96\ \mathrm{TeV}} = 7.5 \pm 0.31(\mathrm{stat}) \pm 0.34(\mathrm{syst}) \pm 0.15(\mathrm{lumi})\ \mathrm{pb}$$

Invariant mass distribution



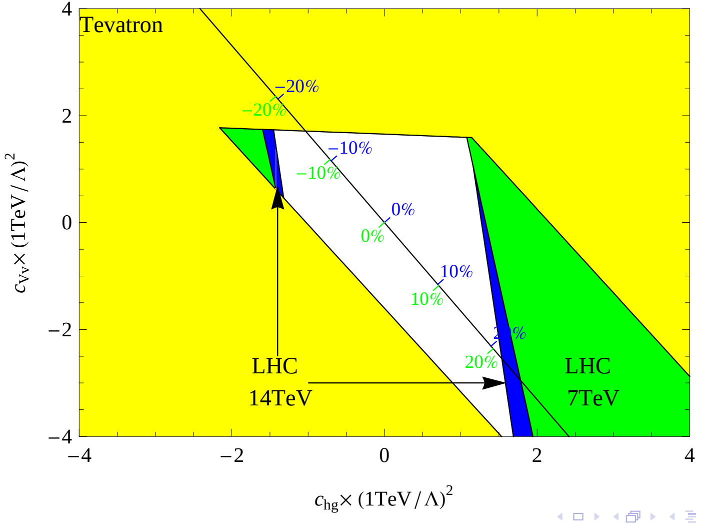
Invariant mass constraints



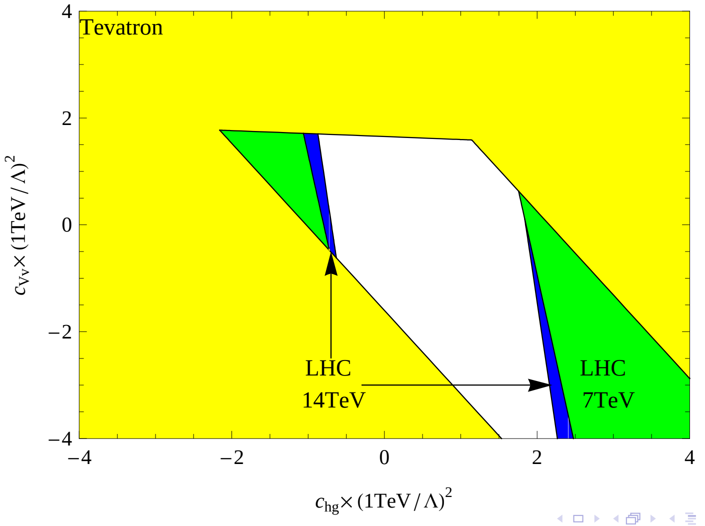
4.8 fb^{-1}

CDF Collaboration, *N. Goldschmidt*, *Search for T-Tbar Resonances at the Tevatron*, Proceedings of Science (2010), Talk 35th ICHEP.

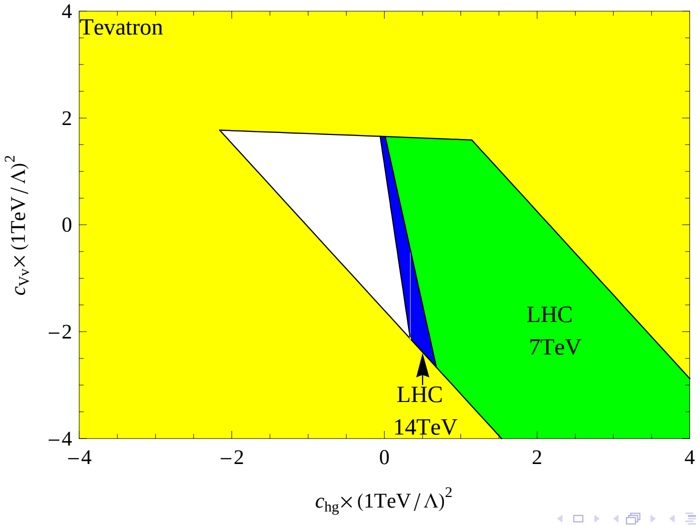
Cross section and invariant mass constraints (central)



Cross section and invariant mass constraints (+10%)



Cross section and invariant mass constraints (-20%)



Forward-backward asymmetry

The forward-backward asymmetry measured at the Tevatron,

$$A^t_{FB} = 0.15 \pm 0.05(\text{stat}) \pm 0.024(\text{syst}),$$

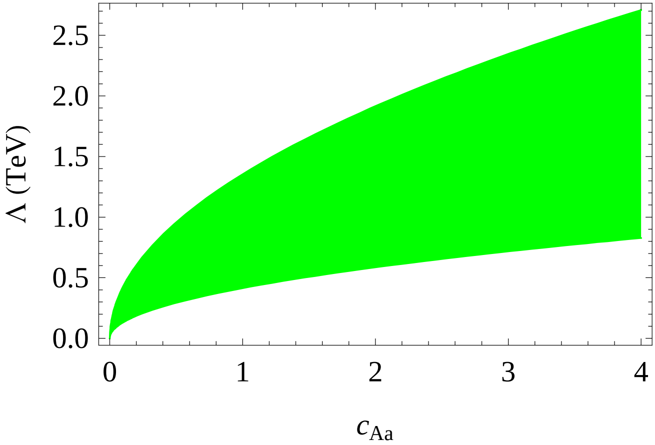
is about 2σ away from the SM value,

$$A^t_{FB} = 0.05 \pm 0.015.$$

$$\delta A^t_{FB} = 0.0342^{+0.016}_{-0.009}\, c_{Aa} \left(\frac{1\ \text{TeV}}{\Lambda}\right)^2$$

where $c_{Aa} = c_{Ra} - c_{La}$

Forward-backward asymmetry



$\rightarrow 1\sigma$

$\Rightarrow \Lambda \sim 1$ TeV

Spin correlation at the LHC

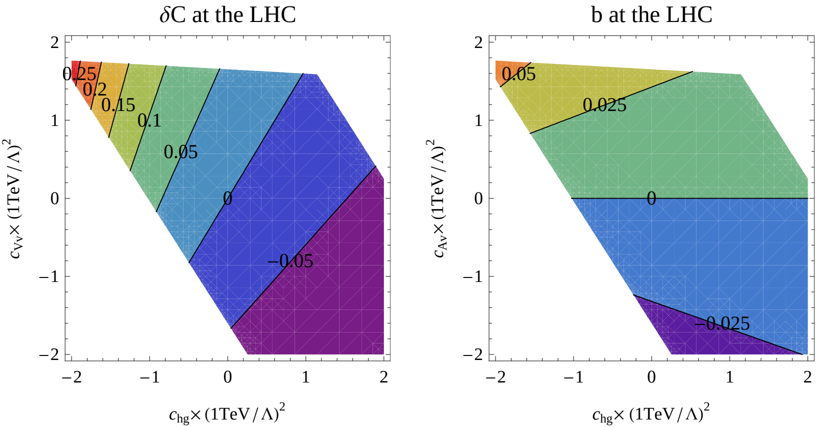
$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\theta_+ d\cos\theta_-} = \frac{1}{4}\left(1 + C\cos\theta_+\cos\theta_- + b_+\cos\theta_+ + b_-\cos\theta_-\right)$$

In the helicity basis,

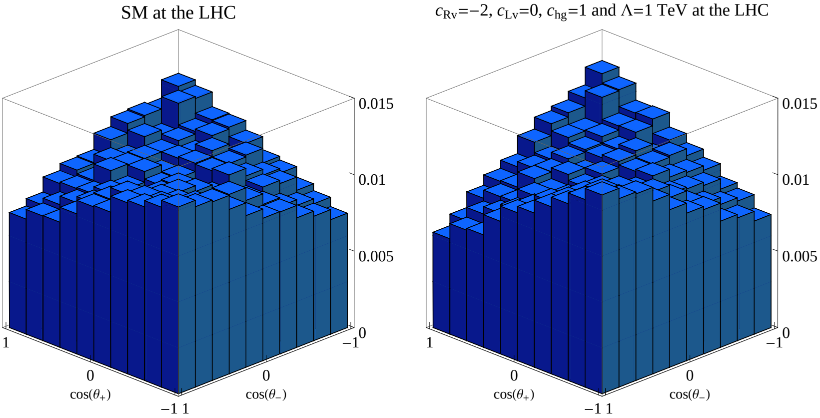
$$\begin{aligned} C &= \frac{1}{\sigma}\left(\sigma_{RL} + \sigma_{LR} - \sigma_{RR} - \sigma_{LL}\right), \\ b_+ &= \frac{1}{\sigma}\left(\sigma_{RL} - \sigma_{LR} + \sigma_{RR} - \sigma_{LL}\right), \\ b_- &= \frac{1}{\sigma}\left(\sigma_{RL} - \sigma_{LR} - \sigma_{RR} + \sigma_{LL}\right). \end{aligned}$$

Spin correlation at the LHC

$$c_{Av} = c_{Rv} - c_{Lv}$$



Spin correlation at the LHC



4-top and $t\bar{t}b\bar{b}$ productions

Dominant operators $\mathcal{O}\left(g_\rho^2\right)$ for composite models:

- If only the right-handed top is composite

$$\mathcal{O}_R = \left(\bar{t}\gamma^\mu t\right)\left(\bar{t}\gamma_\mu t\right)$$

- If only the left-handed top is composite

$$\mathcal{O}_L^{(1)} = \left(\bar{Q}\gamma^\mu Q\right)\left(\bar{Q}\gamma_\mu Q\right) \qquad \mathcal{O}_L^{(8)} = \left(\bar{Q}\gamma^\mu T^A Q\right)\left(\bar{Q}\gamma_\mu T^A Q\right)$$

- If both chirality are composite

$$\mathcal{O}_S^{(1)} = \left(\bar{Q}t\right)\left(\bar{t}Q\right) \qquad \mathcal{O}_S^{(8)} = \left(\bar{Q}T^A t\right)\left(\bar{t}T^A Q\right)$$

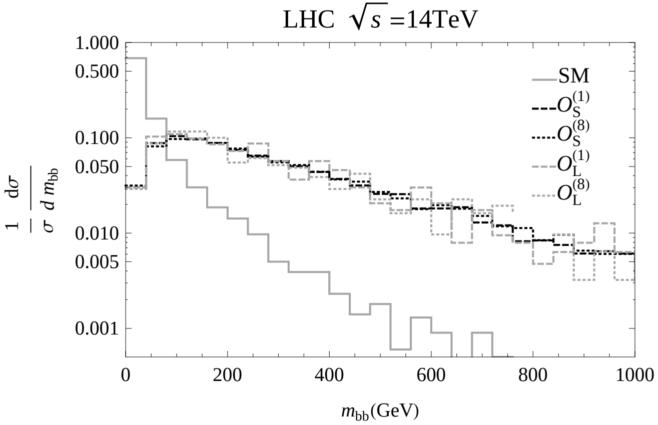
4-top and $t\bar{t}b\bar{b}$ productions

If Q_L is composite $\Rightarrow$ modification of $t\bar{t}b\bar{b}$ cross-section

	σ_{4t} (fb)	$\sigma_{t\bar{t}b\bar{b}}$ (pb)	$\sigma^{cut}_{t\bar{t}b\bar{b}}$ (pb)	$\sigma^{cut}_{t\bar{t}b\bar{b}}/\sigma_{4t}$
SM	4.86	7.2	0.348	71.6
$\mathcal{O}_R^{(1)}$	138	-	-	-
$\mathcal{O}_S^{(1)}$	48	7.6	4.4	92
$\mathcal{O}_S^{(8)}$	11	1.28	0.76	71
$\mathcal{O}_L^{(1)}$	138	3.61	2.12	15.6
$\mathcal{O}_L^{(8)}$	15	0.77	0.42	28.2

for $c_i = 4\pi$ and $\Lambda = 1$ TeV $\left(\sigma \sim \left(\frac{c_i}{\Lambda^2}\right)^2\right)$

4-top and $t\bar{t}b\bar{b}$



Conclusion

$t\bar{t}$ is a good probe for the new physics

$\sigma(gg \to t\bar{t}), d\sigma(gg \to t\bar{t})/dt$	$\leftrightarrow$	c_{hg}
$\sigma(q\bar{q} \to t\bar{t})$	$\leftrightarrow$	c_{hg}, c_{Vv}
$d\sigma(q\bar{q} \to t\bar{t})/dm_{tt}$	$\leftrightarrow$	c_{hg}, c_{Vv}
A_{FB}	$\leftrightarrow$	c_{Aa}
spin correlations	$\leftrightarrow$	c_{hg}, c_{Vv}, c_{Av}

With 4-top and $t\bar{t}b\bar{b}$, it can probe the hierarchy of the operators.