SQEEZED NEW PHYSICS IN TOP-QUARK PAIR PRODUCTION

Susanne Westhoff

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

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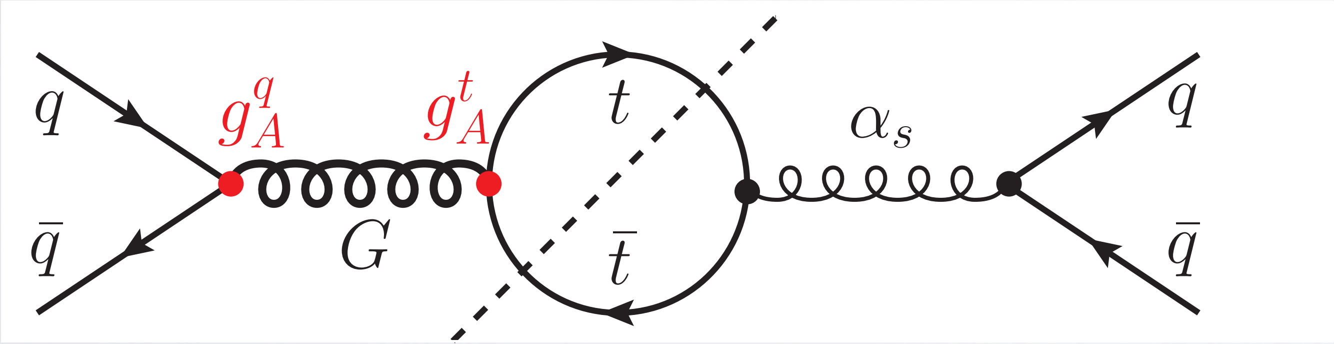
MASSIVE GLUONS IN TOP PAIR PRODUCTION

Strong couplings to top quarks in models of

- warped extra dimensions (Kaluza-Klein gluons): $g_V^q, g_{V,A}^t$
- technicolor (colorons): g_V^q, g_V^t
- chiral color (axigluons): g_A^q, g_A^t ...



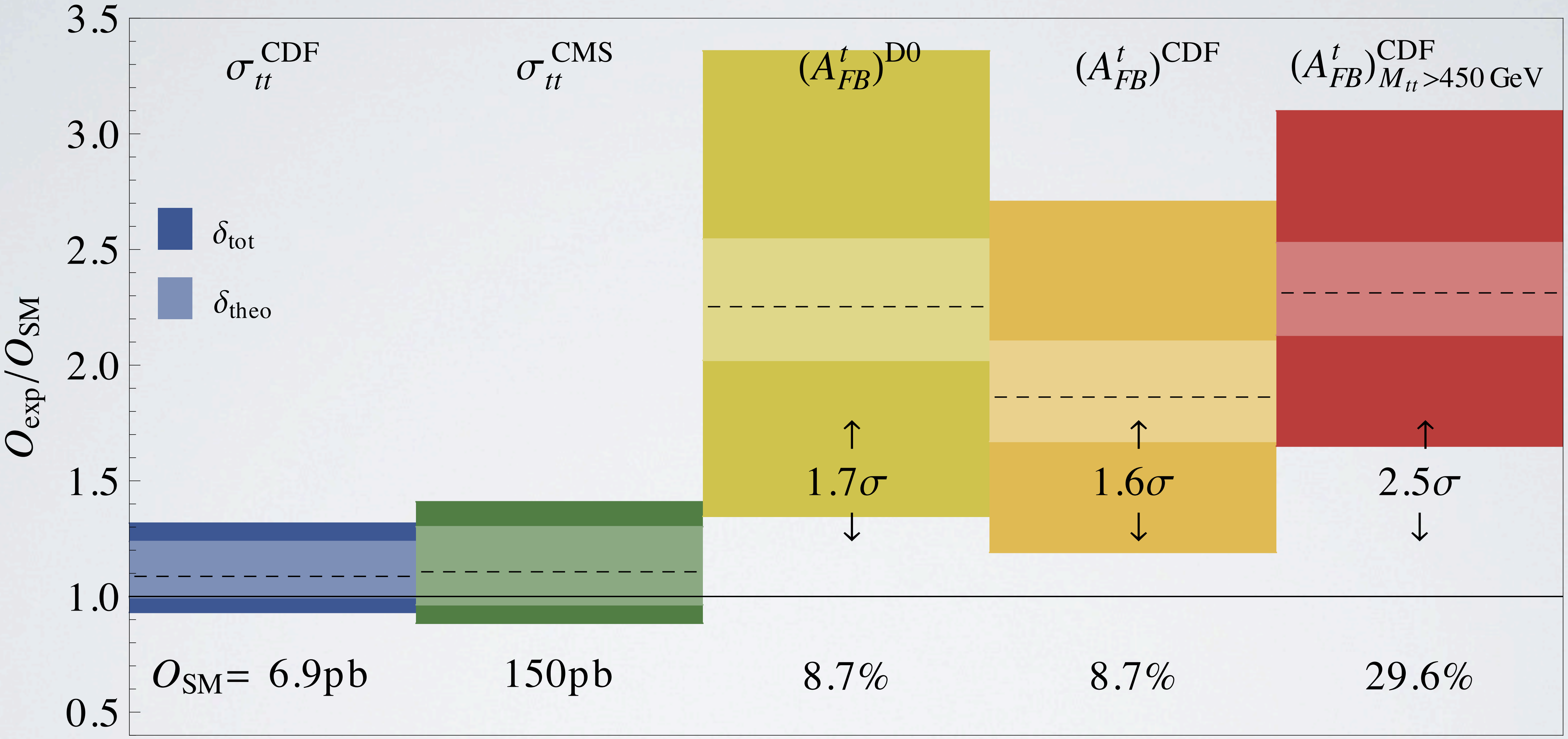
$$\mathcal{L} = i g_s \bar{q}\, \gamma^\mu T^a (g_V^q + \gamma_5 g_A^q)\, q$$

Tree-level contributions to top-pair cross section

tt symmetric: $\sigma_s^{\rm INT} \sim \alpha_s^2\, g_V^q g_V^t \dfrac{1}{M_{t\bar{t}}^2 - M_G^2}$ $\quad \sigma_s^{\rm NP} \sim \alpha_s^2\, (g_{V,A}^q)^2 (g_{V,A}^t)^2 \dfrac{M_{t\bar{t}}^2}{(M_{t\bar{t}}^2 - M_G^2)^2}$

tt asymmetric: $\sigma_a^{\rm INT} \sim \alpha_s^2\, g_A^q g_A^t \dfrac{1}{M_{t\bar{t}}^2 - M_G^2}$ $\quad \sigma_a^{\rm NP} \sim \alpha_s^2\, g_V^q g_A^q\, g_V^t g_A^t \dfrac{M_{t\bar{t}}^2}{(M_{t\bar{t}}^2 - M_G^2)^2}$

TOP PAIR PRODUCTION IN MAY 2012



CONSTRAINTS ON MASSIVE COLOR OCTETS

Model-dependent:

[Bai et al., JHEP 1103 (2011) 003][Haisch, SW, JHEP 1108 (2011) 088]

- Flavor precision observables (flavor non-universal couplings)

Light new bosons ($M_G < 1\,\mathrm{TeV}$): LEP and Tevatron

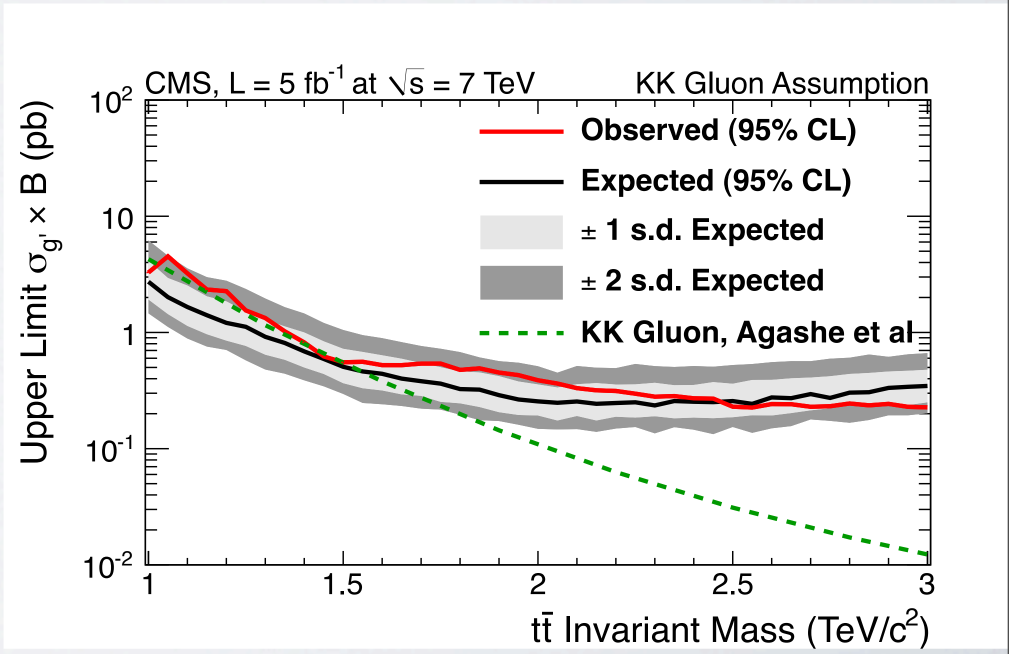
[Haisch, SW, JHEP 1108 (2011) 088][Hill, Zhang, PRD 51 (1995) 3563]

- Electroweak precision observables Zbb, oblique corrections
- Top pair cross section (and Mtt spectrum)

Heavy new bosons ($M_G > 1\,\mathrm{TeV}$): LHC

- Top pair cross section
- Resonance searches in Mtt spectrum
- Dijet resonance searches
- Dijet angular distributions

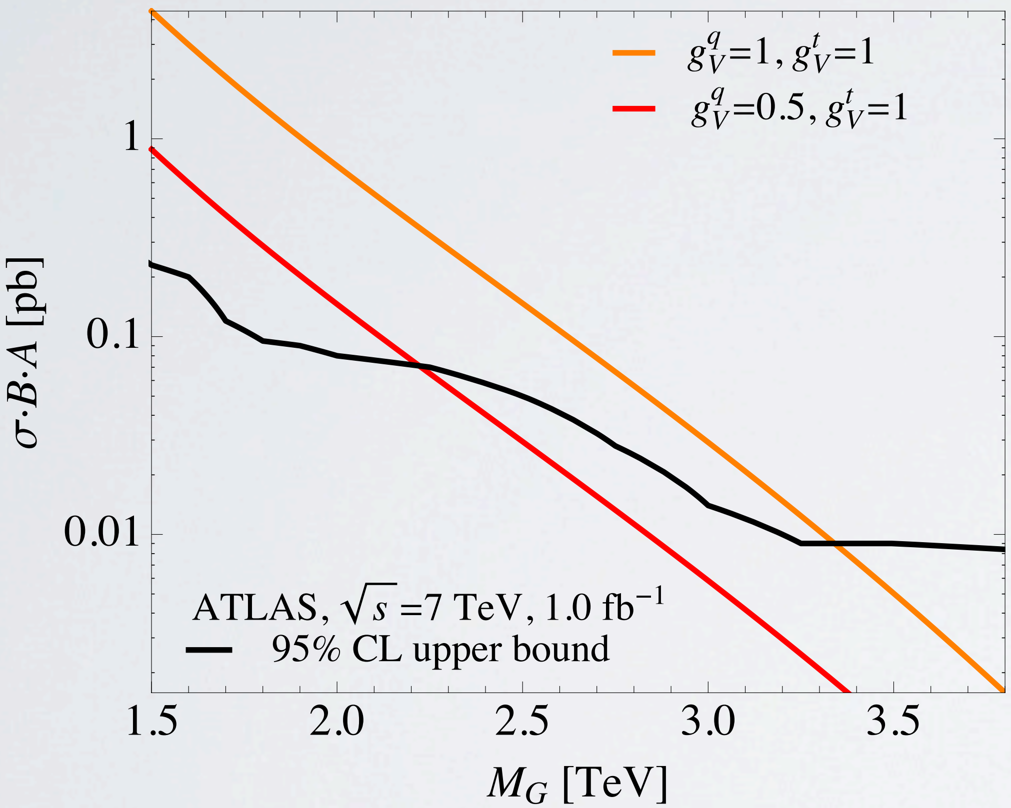
[cf. J. Serra, talk at Planck 2012]

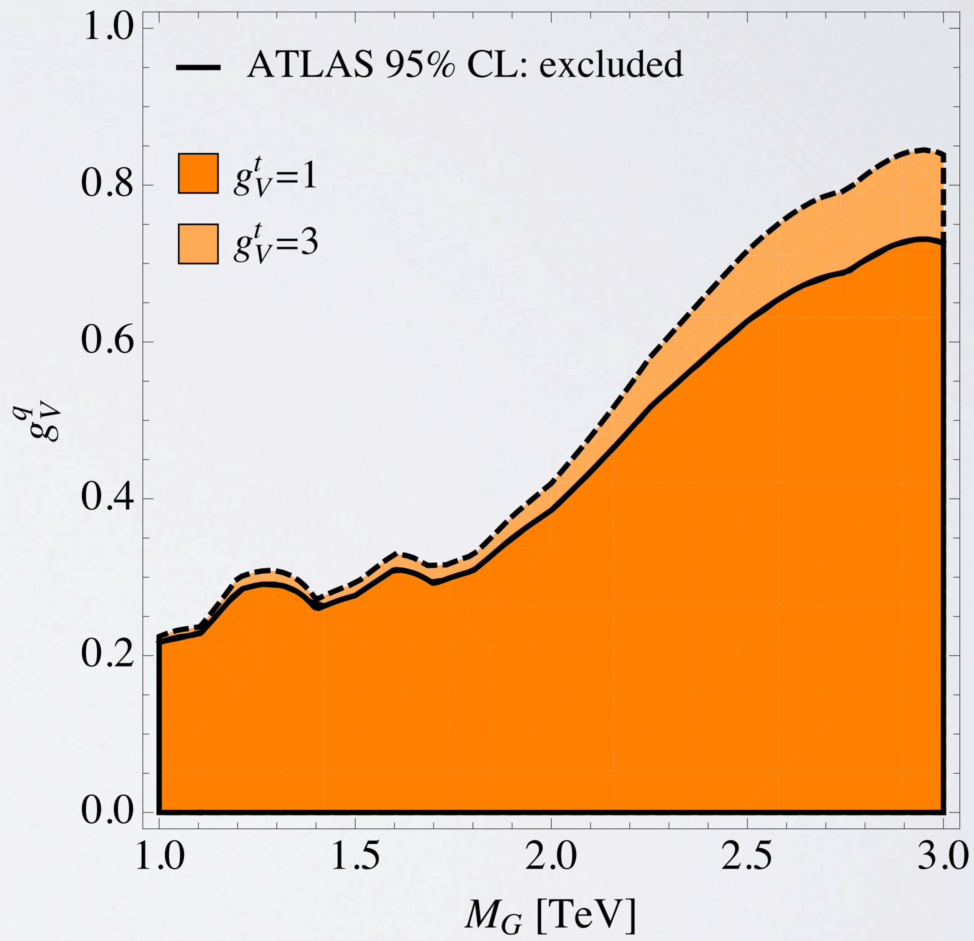


DIJET RESONANCE SEARCHES

Constraints on the production of a narrow jj resonance:

$$\sigma(pp \to G) \cdot \mathcal{B}(G \to q\bar{q}) \sim [(g_V^q)^2 + (g_A^q)^2]$$





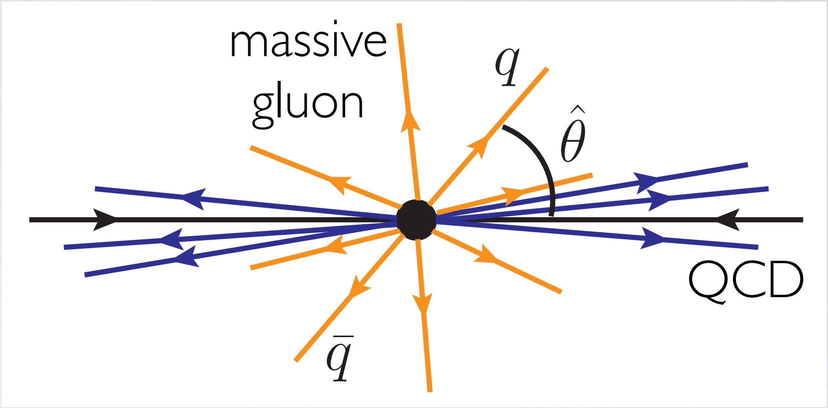
[ATLAS, PLB 708 (2012) 37][CMS, PLB 704 (2011) 123, 1fb^-1]

Evade dijet bounds on effects in tt production by rescaling:

$$g^q_{V,A} \to \xi \cdot g^q_{V,A}, \;\; g^t_{V,A} \to g^t_{V,A}/\xi$$

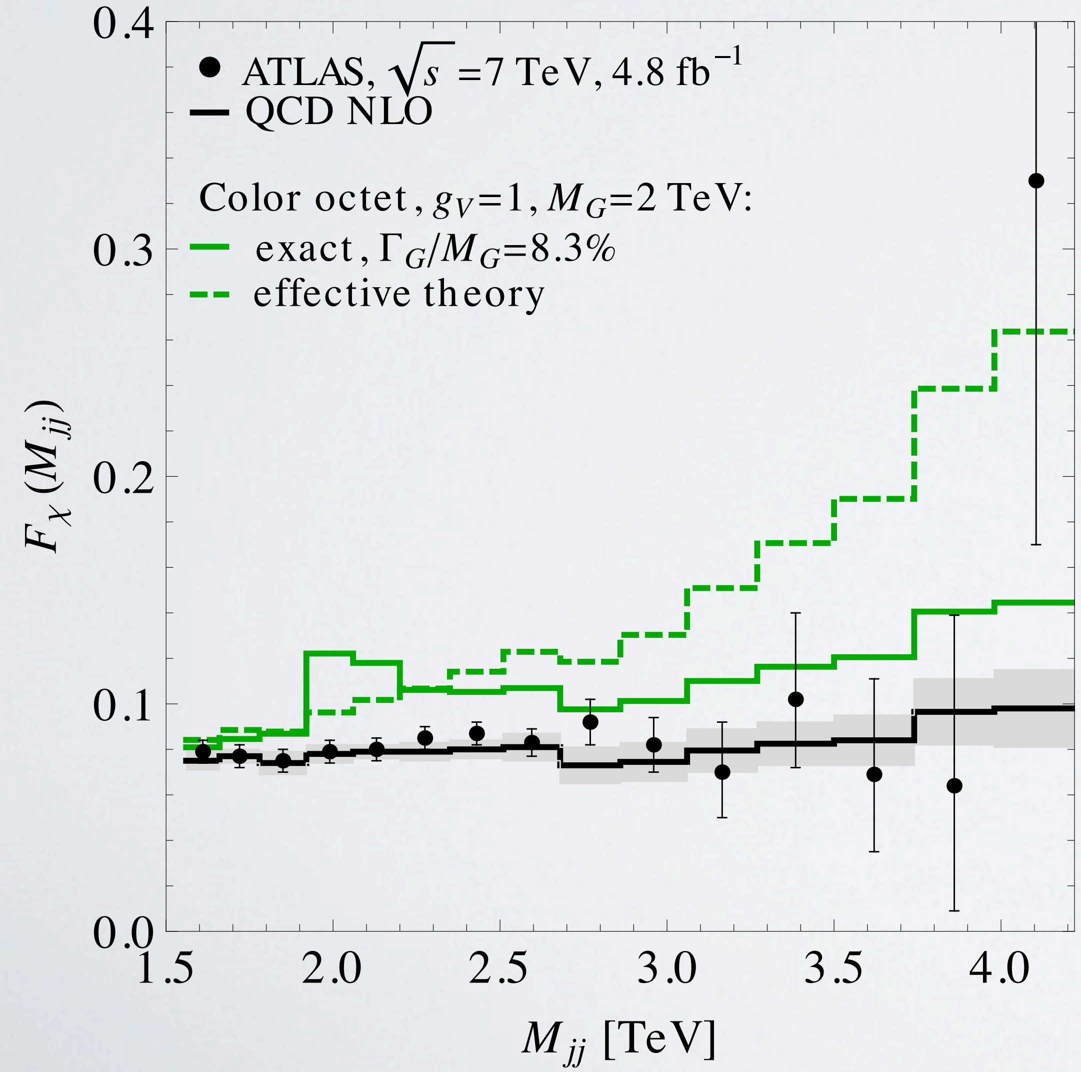
DIJET ANGULAR DISTRIBUTION

Dijet excess in central region:

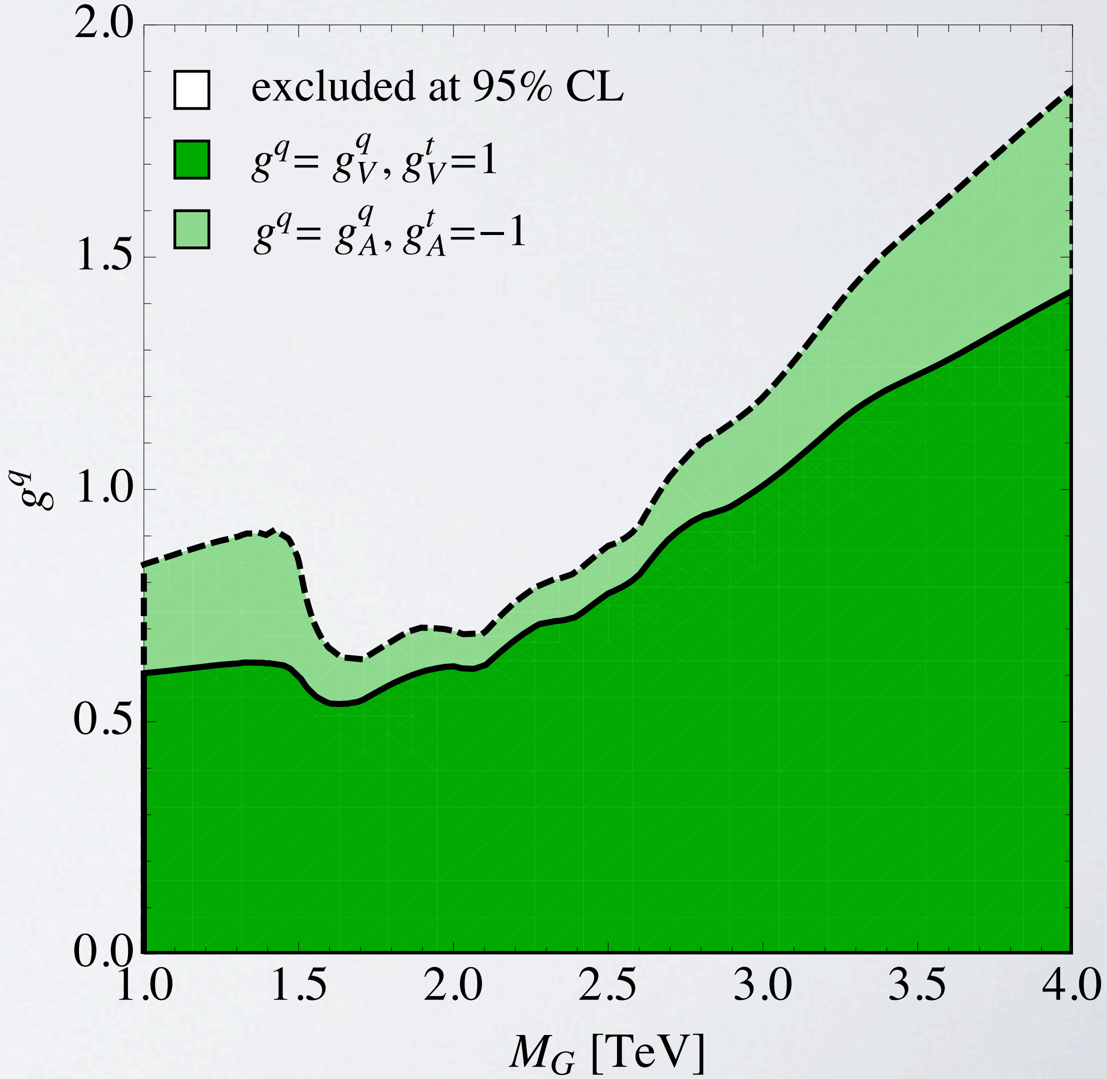


$$F_\chi(M_{jj}) = \frac{\sigma(\chi < 3.3, M_{jj})}{\sigma(\chi < 30, M_{jj})}, \ \chi = \frac{1 + |\cos\theta|}{1 - |\cos\theta|}$$

[ATLAS-CONF-2012-038, 4.8fb^-1][CMS-EXO-11-017, 2.2fb^-1]



$\chi^2\ [F_\chi(M_{jj})]$ /ndf < 25.0/15

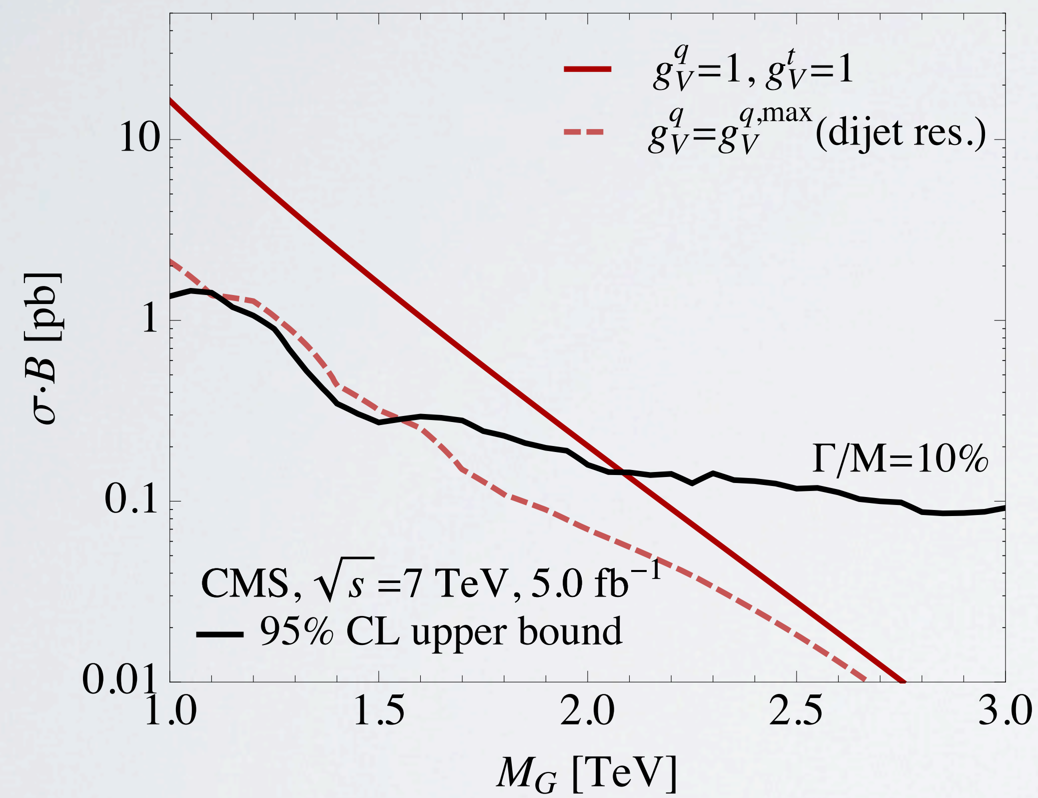


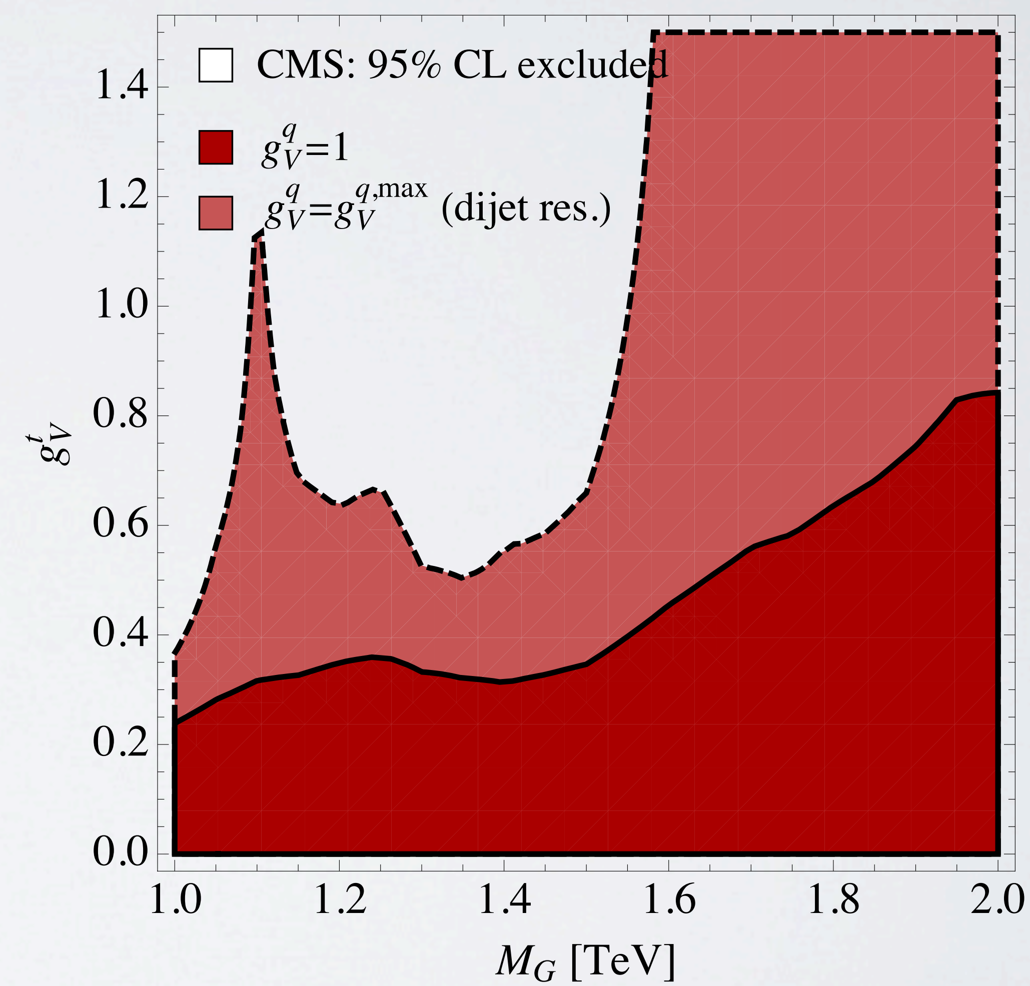
TOP-ANTITOP RESONANCE SEARCHES

Constraints on the production of a narrow tt̲ resonance:

$$\sigma(pp \to G)\cdot\mathcal{B}(G \to t\bar{t}) \sim [(g_V^t)^2 + (g_A^t)^2] \qquad (g_{V,A}^q \gtrsim g_{V,A}^t)$$

$$\sim [(g_V^q)^2 + (g_A^q)^2] \qquad (g_{V,A}^q \ll g_{V,A}^t)$$





[CMS-EXO-11-006, 5fb^-1, hadronic. Courtesy of S. Rappoccio]

[ATLAS, arXiv:1205.5371, 2.05fb^-1, l+jets]

$\sigma \cdot \mathcal{B}$ becomes insensitive to $g_{V,A}^t$ for small $g_{V,A}^q$.

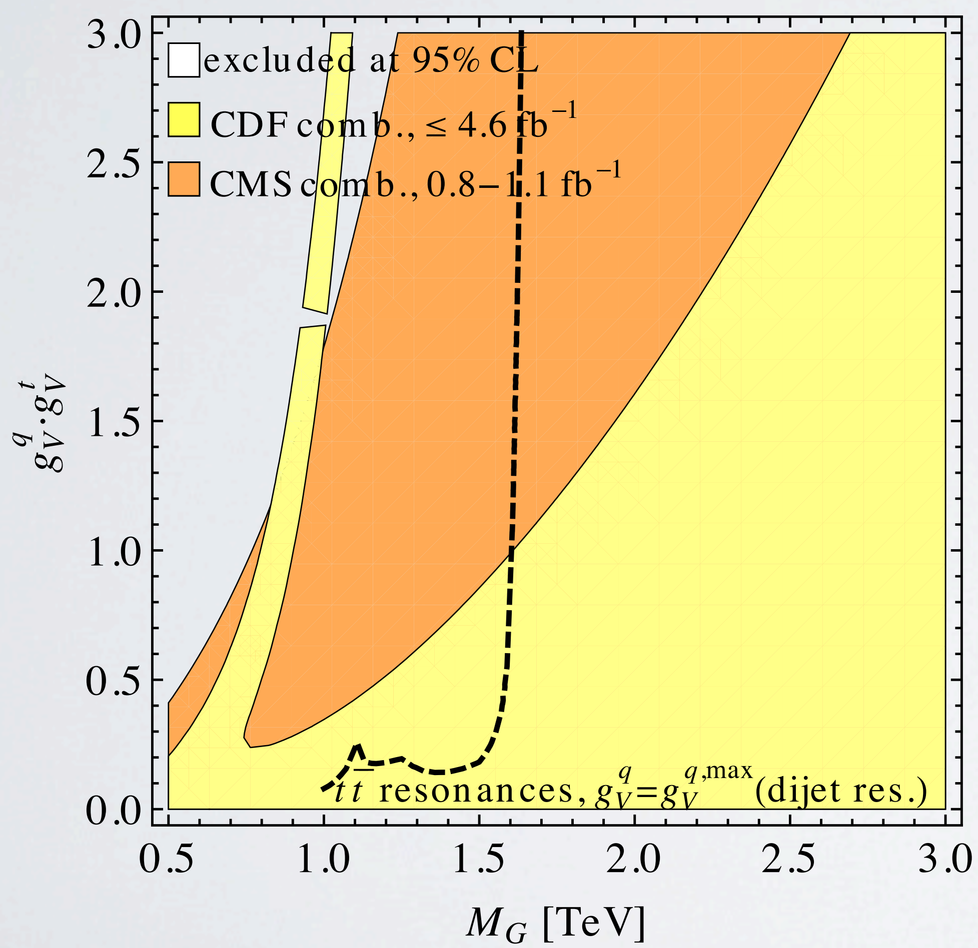
→No constraints for $M_G \gtrsim 1.6\,\mathrm{TeV}$, if $g_{V,A}^q$ respects dijet bounds.

TOP-ANTITOP TOTAL CROSS SECTION

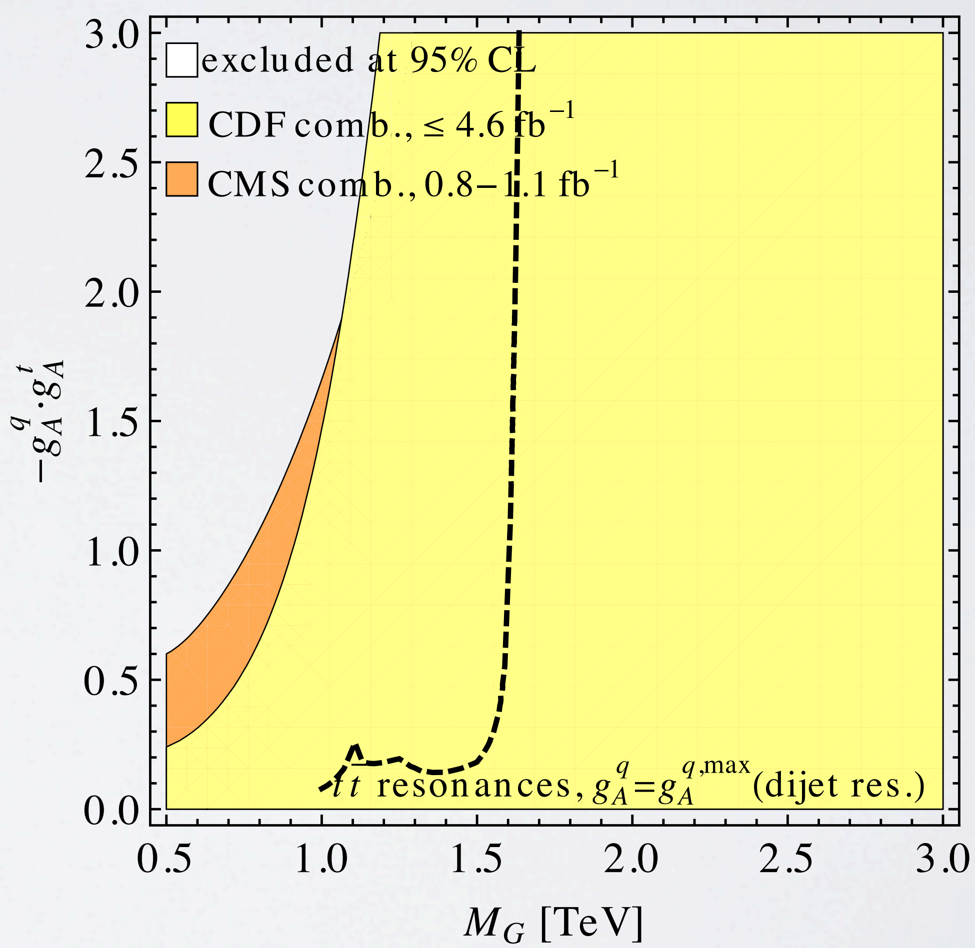
- Tevatron: $\sigma_{t\bar{t}}^{\rm CDF}(\sqrt{s} = 1.96\,{\rm TeV}) = 7.50 \pm 0.48\,{\rm pb}$ $\quad \sigma_{t\bar{t}}^{\rm QCD} = 6.90\,^{+0.40}_{-0.74}\,^{+0.50}_{-0.40}\,{\rm pb}$
- LHC7: $\sigma_{t\bar{t}}^{\rm CMS}(\sqrt{s} = 7\,{\rm TeV}) = 165.8 \pm 13.3\,{\rm pb}$ $\quad \sigma_{t\bar{t}}^{\rm QCD} = 150\,^{+18}_{-19}\,^{+13}_{-12}\,{\rm pb}$

[Ahrens et al., PRD 84 (2011) 074004, rescaled]

interference w/ QCD



no interference

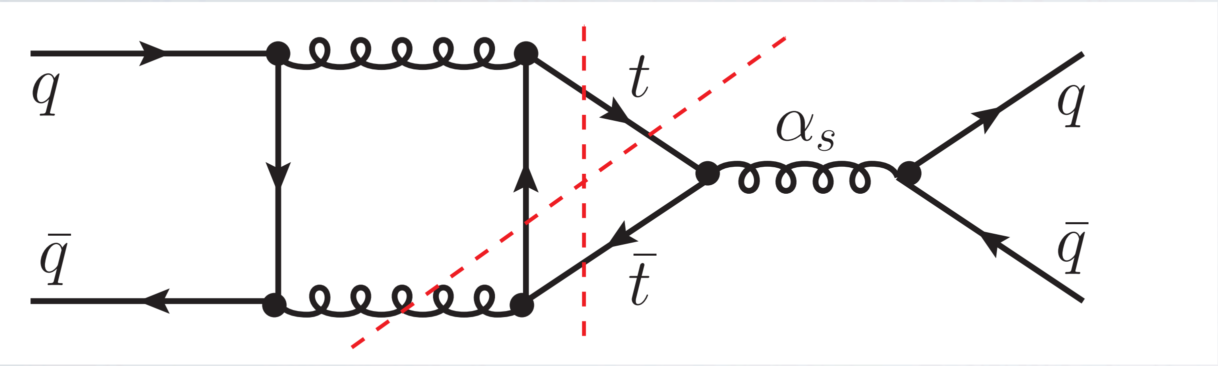


Constraints from $t\bar{t}$ resonance searches dominate for $M_G \lesssim 1.6$ TeV.

[CDF-CONF-9913,<4.6fb^-1][D0, PLB 704 (2011) 403, 5.4fb^-1, lj+ll] [CMS PAS TOP-11-024,<1.1fb^-1][ATLAS-CONF-2012-024,<1.0fb^-1]

FORWARD-BACKWARD ASYMMETRY AT TEVATRON

QCD: charge asymmetry at NLO

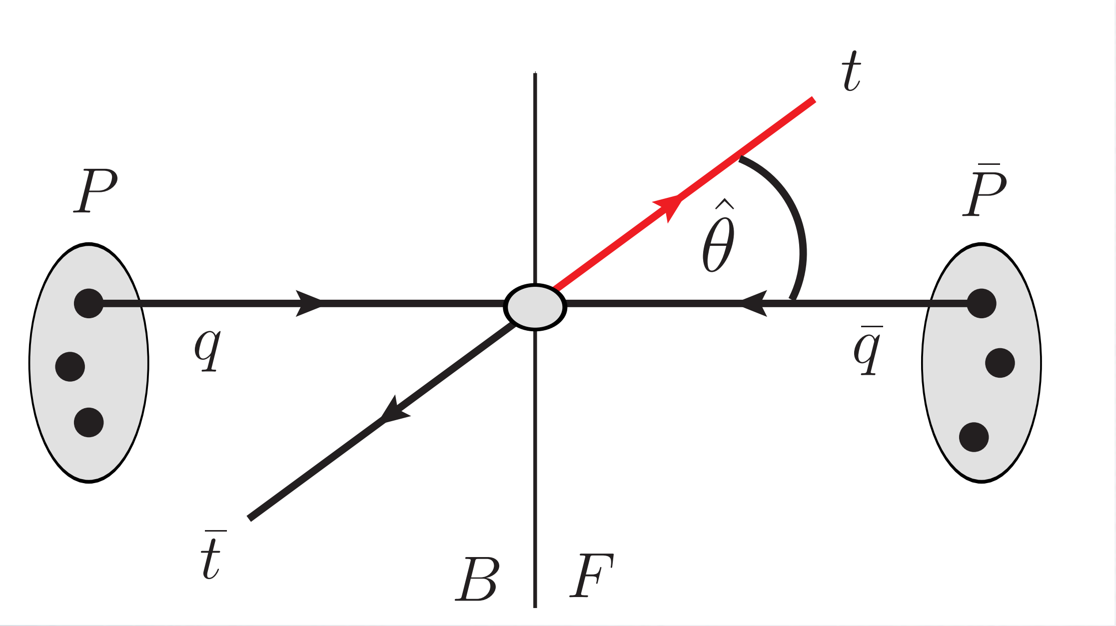


$$A_C^t = \frac{\sigma_a}{\sigma_s}$$
$$= (7.24^{+1.06}_{-0.72})\%_{\mathrm{NNLOappr}} \cdot 1.22_{\mathrm{EW}}$$

$$A_C^t(M_{t\bar{t}} > 450\mathrm{GeV}) = (10.8^{+1.7}_{-0.9})\%_{\mathrm{NNLOappr}} \cdot 1.23_{\mathrm{EW}}$$

[Ahrens et al., PRD 84 (2011) 074004][Hollik, Pagani, PRD 84 (2011) 093003]

$p\bar{p} \rightarrow t\bar{t}$: measure charge asymmetry as FB asymmetry



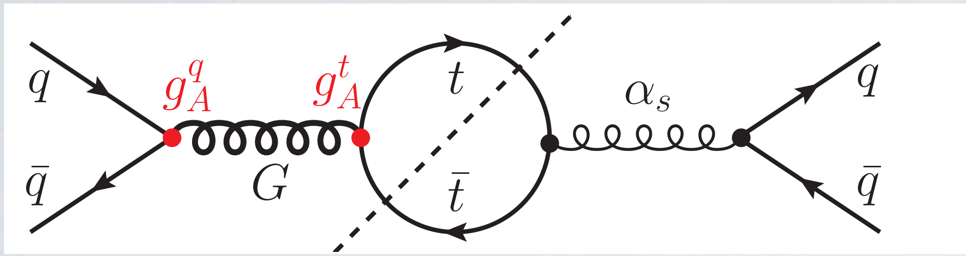
$$A_{\mathrm{FB}}^t = \frac{N(y_t > y_{\bar{t}}) - N(y_t < y_{\bar{t}})}{N(y_t > y_{\bar{t}}) + N(y_t < y_{\bar{t}})} \equiv A_C^t$$

$$A_{\mathrm{FB}}^{t,\mathrm{CDF}} = 16.2 \pm 4.1 \pm 2.2\%$$

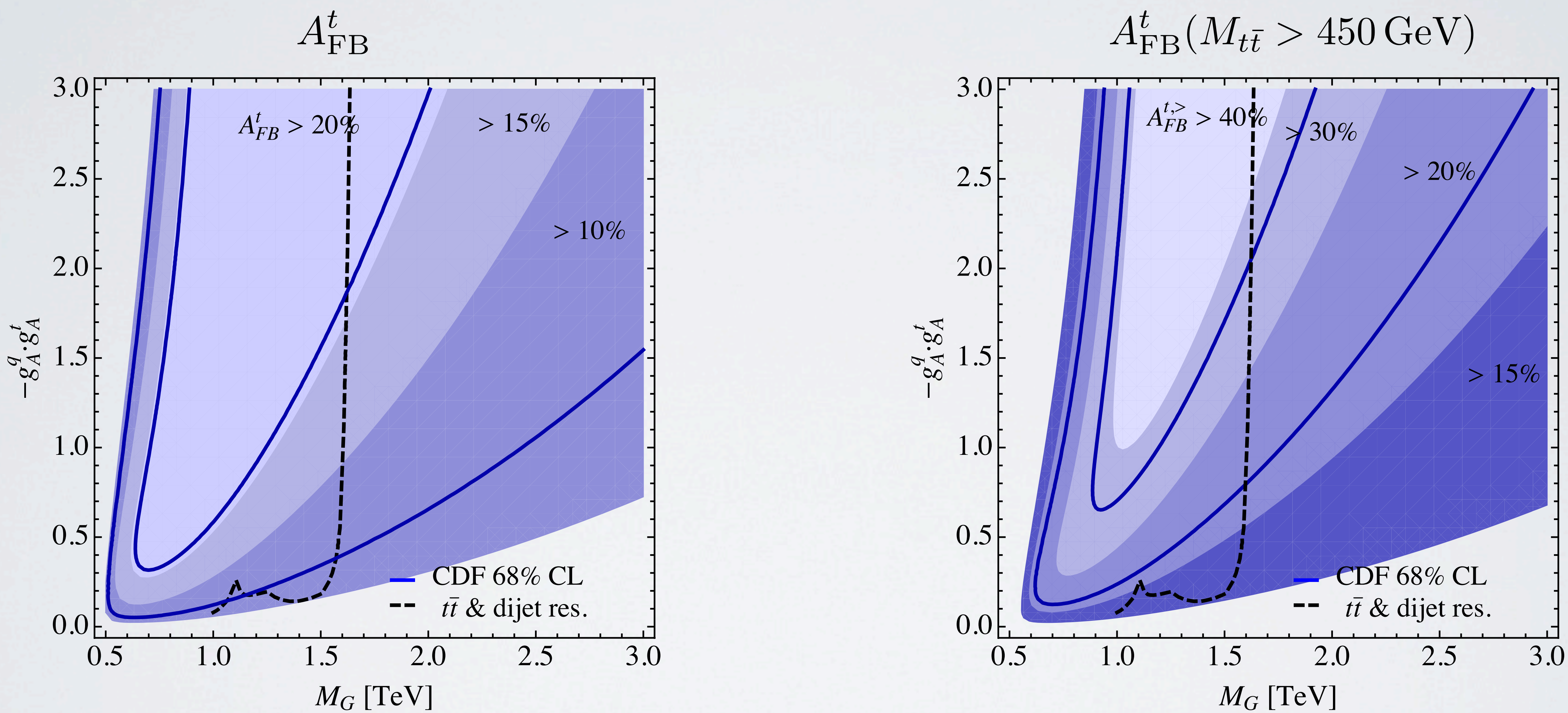
$$A_{\mathrm{FB}}^{t,\mathrm{CDF}}(M_{t\bar{t}} > 450\mathrm{GeV}) = 29.6 \pm 6.7\%$$

[CDF, note 10807, 8.7fb^-1][D0, PRD 84 (2011) 112055, 5.4fb^-1]

AXIGLUON EFFECTS ON FB ASYMMETRY



$$g_A^q \cdot g_A^t < 0$$



An axigluon with $M_G \sim 2\,\mathrm{TeV}$ and strong top couplings can accommodate the CDF measurement.

CHARGE ASYMMETRY AT LHC

Boosted q in proton ⟶ more t than t̲ in beam direction.

$$A_C^y = \frac{N(|y_t| > |y_{\bar{t}}|) - N(|y_t| < |y_{\bar{t}}|)}{N(|y_t| > |y_{\bar{t}}|) + N(|y_t| < |y_{\bar{t}}|)}$$

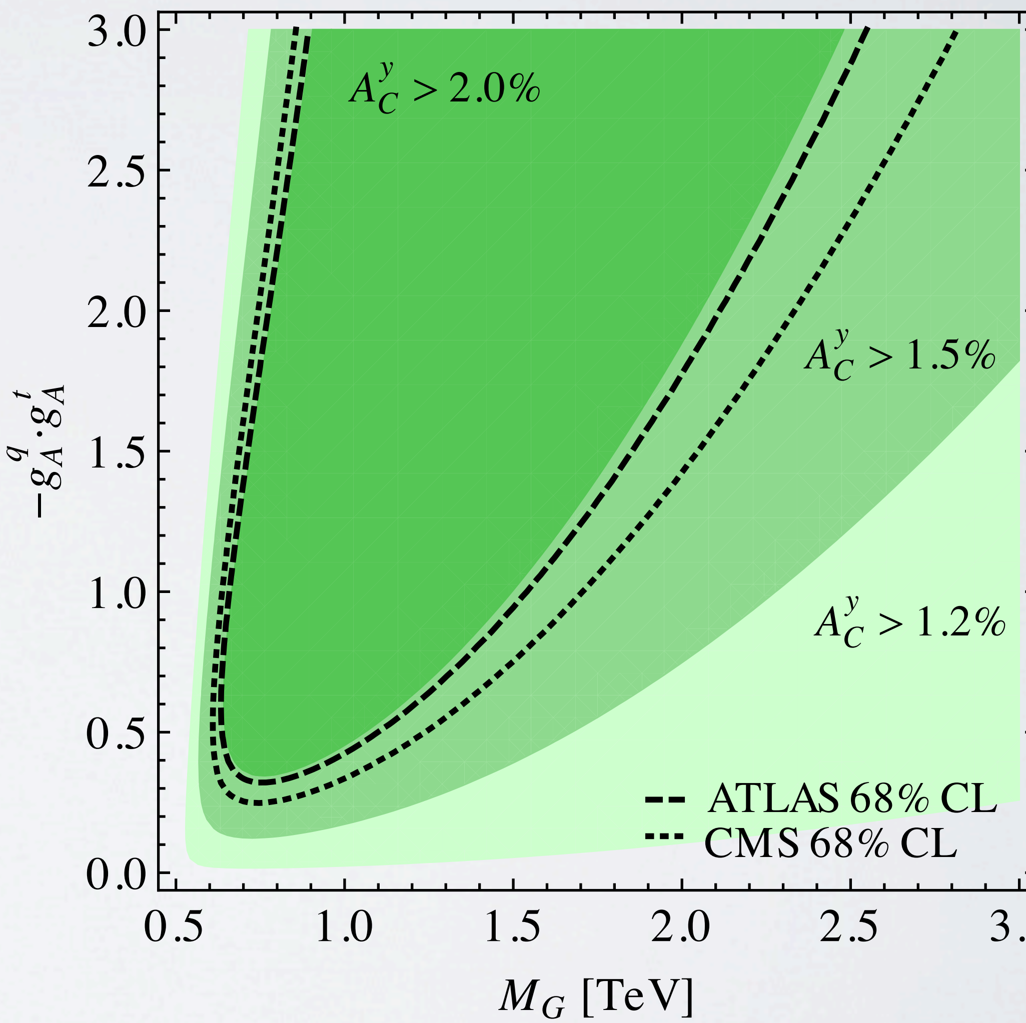
$$A_C^{y,\mathrm{QCD}} = 1.15 \pm 0.06\,\%$$

[Kühn, Rodrigo, JHEP 1201 (2012) 063]

$$A_C^{y,\mathrm{ATLAS}} = -1.8 \pm 2.8 \pm 2.3\,\%$$

$$A_C^{y,\mathrm{CMS}} = 0.4 \pm 1.0 \pm 1.2\,\%$$

[CMS-PAS-TOP-11-030, 4.7fb^-1][ATLAS, arXiv:1203.4211, 1.04fb^-1]



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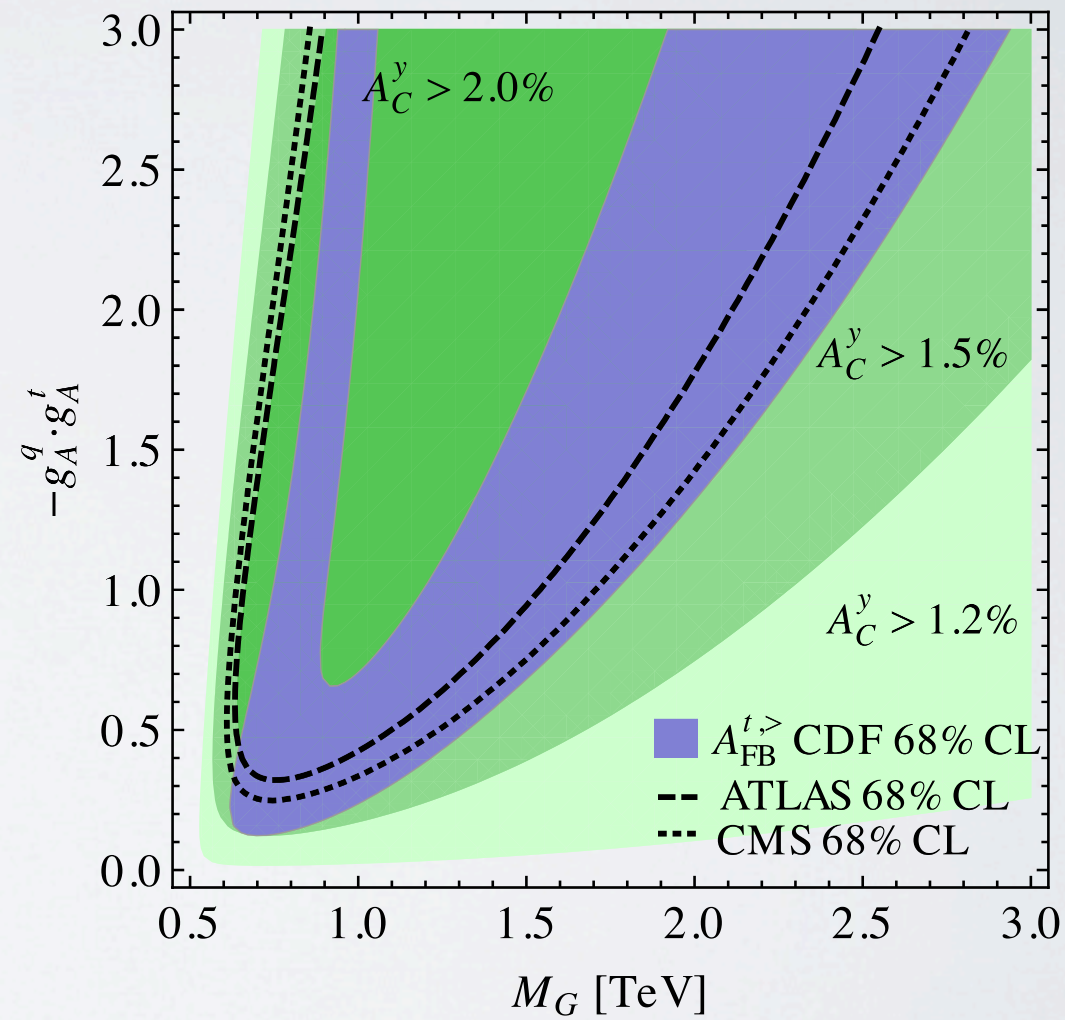
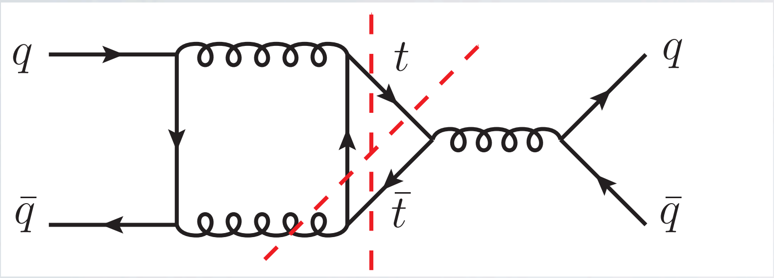


A_C^y does not (yet) rule out the axigluon solution to A_{FB}^t and $A_{\mathrm{FB}}^{t,>}$.

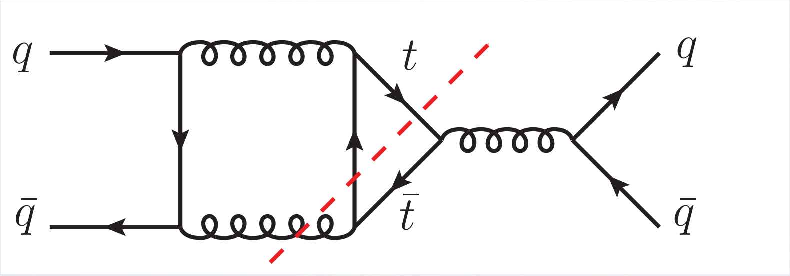
CHARGE ASYMMETRY WITH A JET HANDLE

Inclusive $t\bar{t}$ + X: QCD asymmetry at NLO



virtual & real contributions

Exclusive $t\bar{t}$ + jet: asymmetry at LO



separate access to
real contributions

Asymmetry in $t\bar{t}$ + jet known to NLO.

[Dittmaier, Uwer, Weinzierl, Eur. Phys. J. C59 (2009) 625]
[Melnikov, Schulze, Nucl. Phys. B840 (2010) 129]

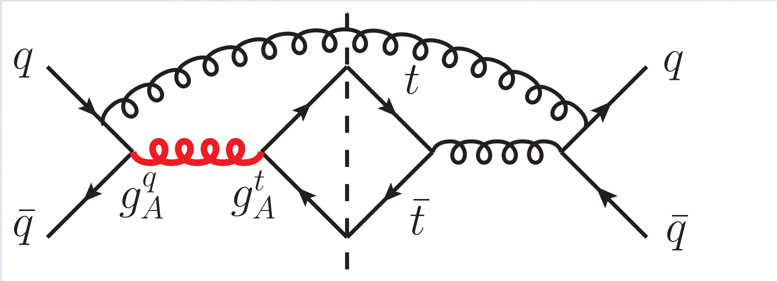
Tevatron: $A_C^{t,\mathrm{LO}} = -8\%$ $\quad A_C^{t,\mathrm{NLO}} = -2\%$

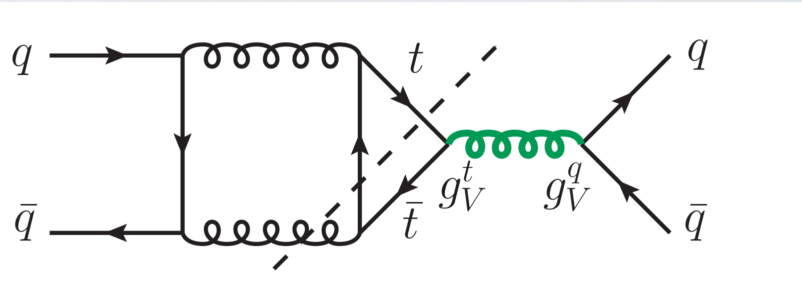
$(p_T^{j,\mathrm{cut}} = 20\,\mathrm{GeV})$

LHC 7: $A_C^{y,\mathrm{LO}} = -0.6\%$

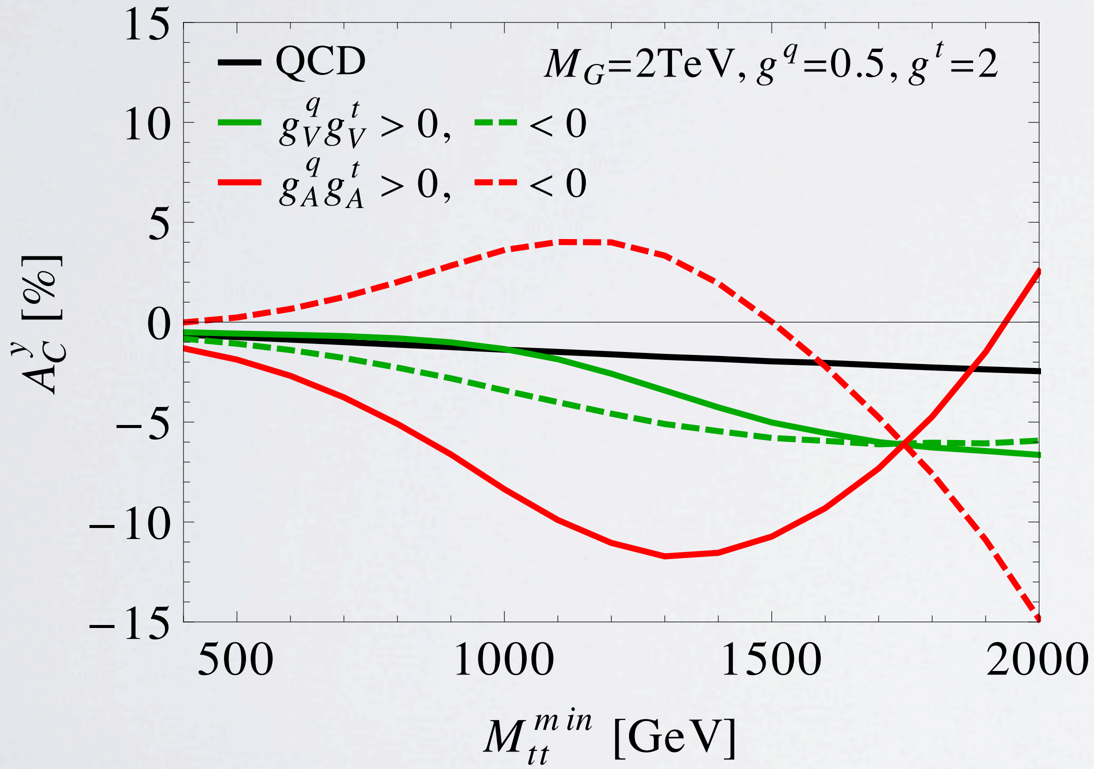
MASSIVE GLUONS IN TOP-PAIR PLUS JET

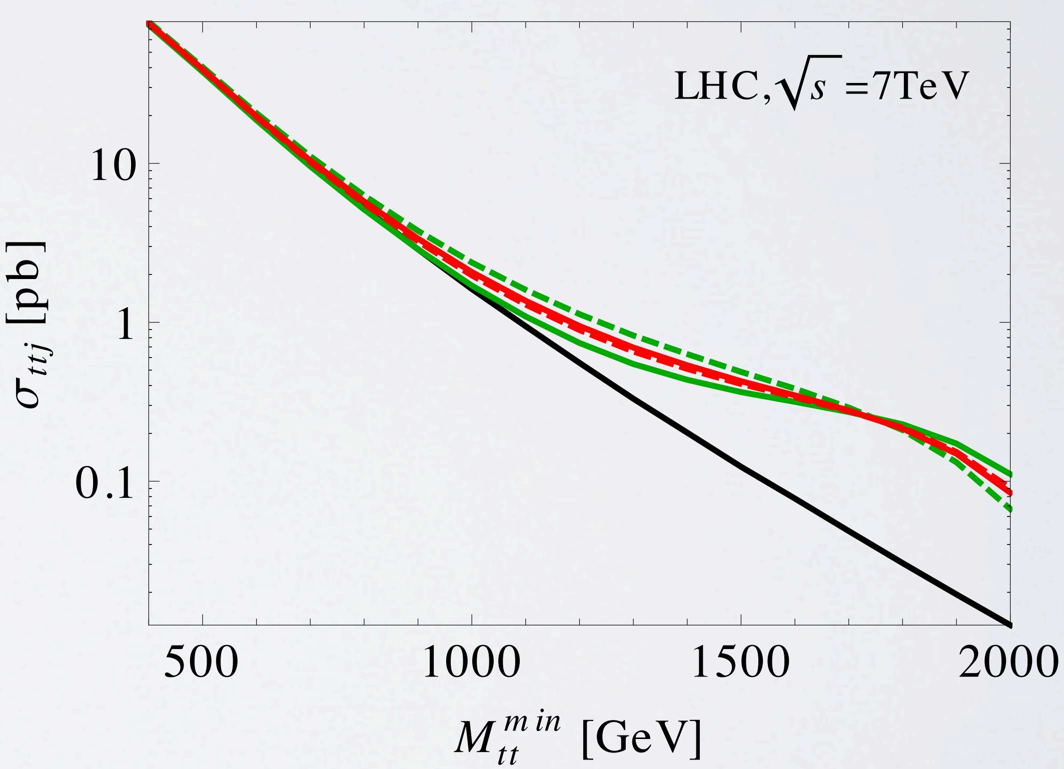
Axial-vector and vector contributions to asymmetry at LO:





A cut on $M_{t\bar{t}}$ enhances the sensitivity to massive resonances.





Disentangle vector and axial-vector effects via their spectra.

[Berge, SW, in preparation][Ferrario, Rodrigo, JHEP 1002 (2010) 051]

TO BE TAKEN HOME

Constraints on massive gluons from LHC7:

- Dijet resonances $\sim (g^q_{V,A})^2$
- Dijet angular distribution $\sim (g^q_{V,A})^2 + \mathcal{O}((g^q_{V,A})^4)$
- tt̲ resonances $\sim (g^t_{V,A})^2$ (requires sizeable $g^q_{V,A}$)
- tt̲ cross section $\sim g^q_V g^t_V + \mathcal{O}((g^q_{V,A})^2 (g^t_{V,A})^2)$

Axigluon effects on charge asymmetries $\sim -g^q_A g^t_A$:

- Tevatron FB asymmetry $A^t_{\rm FB} \approx 15\%$ (requires strong top cplg.)
- LHC tt̲ charge asymmetry $A^y_C \approx 2\%$

LHC tt̲+jet charge asymmetry probes $g^q_A g^t_A$ and $g^q_V g^t_V$.