

SQUEEZED NEW PHYSICS IN TOP-QUARK PAIR PRODUCTION

Susanne Westhoff



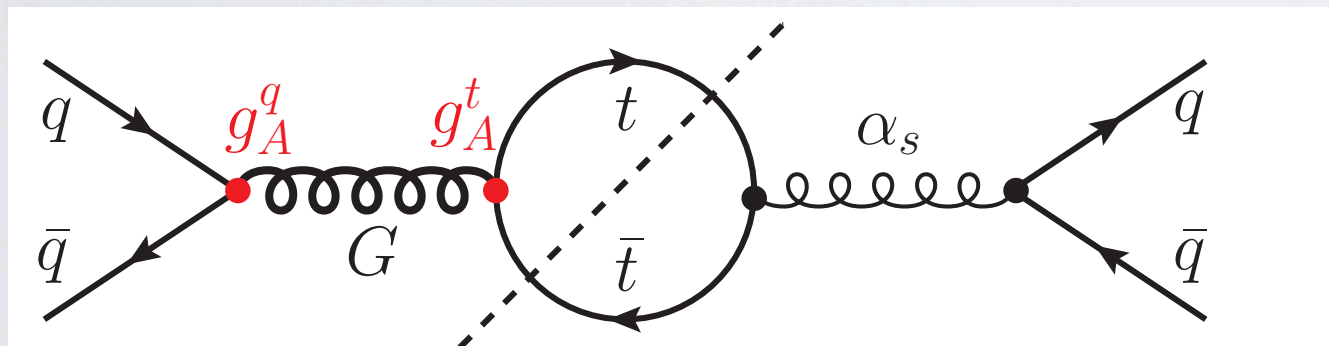
JOHANNES GUTENBERG
UNIVERSITÄT MAINZ

Pheno 2012 --- University of Pittsburgh --- 7-9 May 2012

MASSIVE GLUONS IN TOP PAIR PRODUCTION

Strong couplings to top quarks in models of

- warped extra dimensions (Kaluza-Klein gluons)
- technicolor (colorons)
- chiral color (axigluons) ...



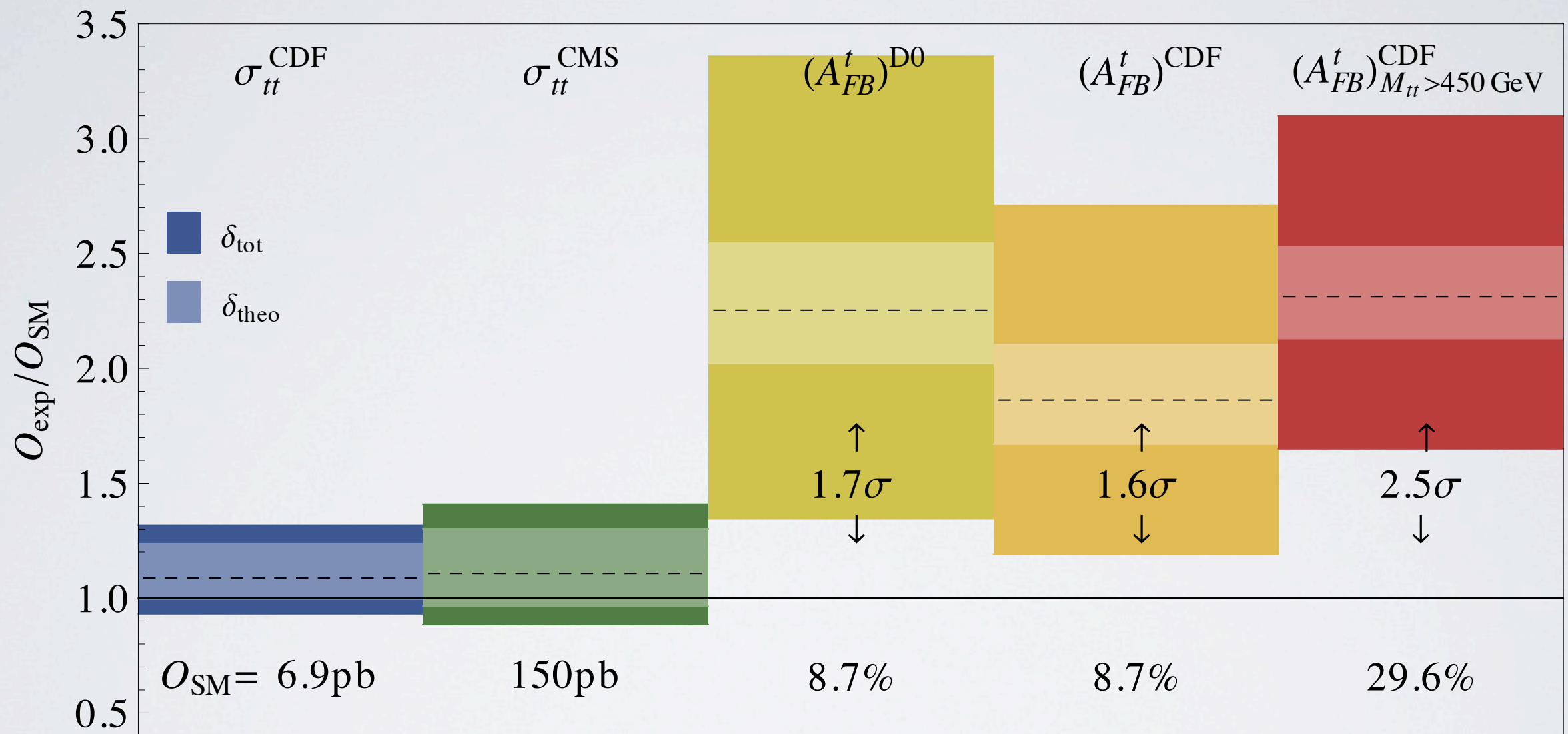
$$\mathcal{L} = ig_s \bar{q} \gamma^\mu T^a (g_V^q + \gamma_5 g_A^q) q$$

Tree-level contributions to $t\bar{t}$ cross section

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

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

TOP PAIR PRODUCTION IN SPRING 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)

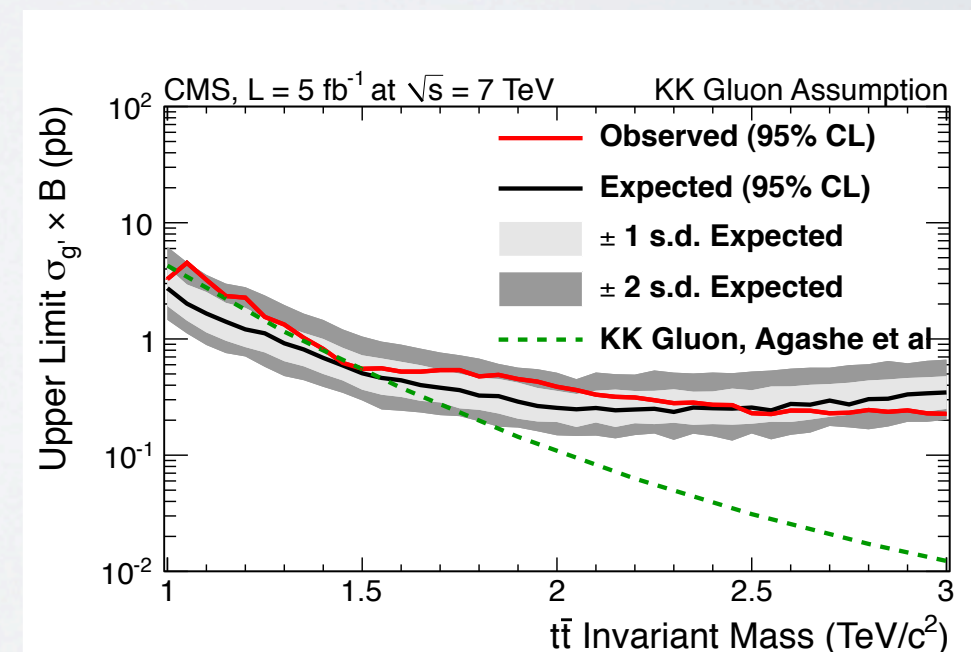
Light new bosons ($M_G < 1 \text{ TeV}$): LEP and Tevatron

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

- Electroweak precision observables $Zb\bar{b}$, oblique corrections
- Top pair cross section (and $M_{t\bar{t}}$ spectrum)

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

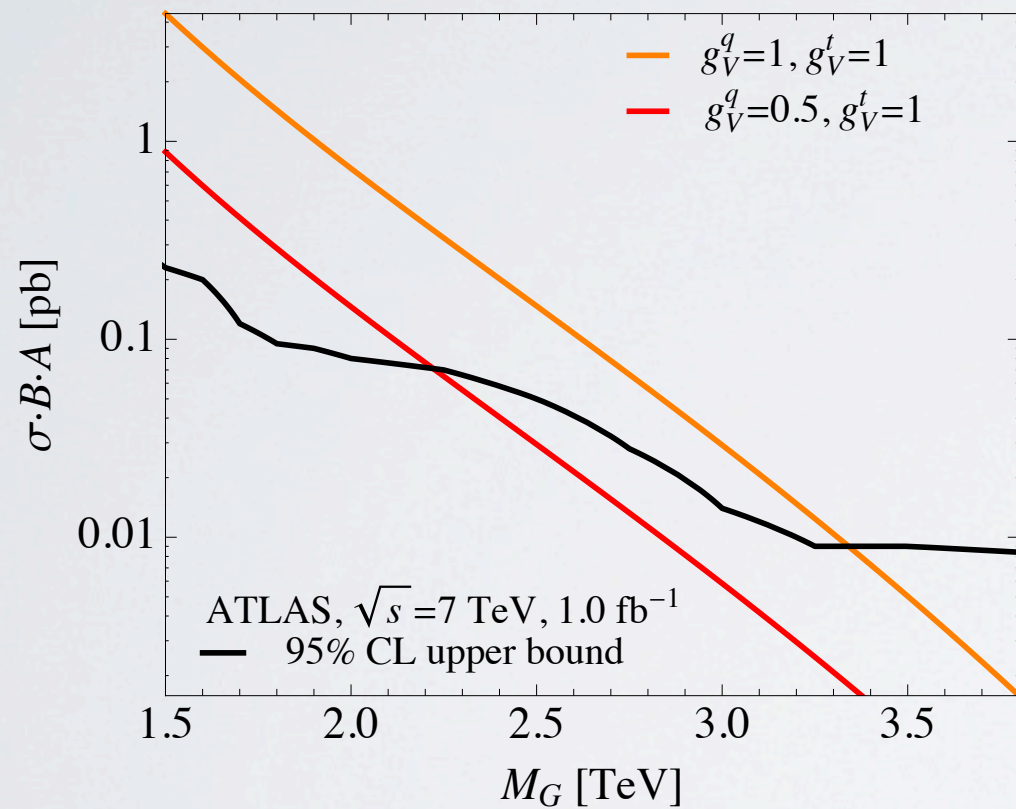
- Top pair cross section
- Resonance searches in $M_{t\bar{t}}$ spectrum
- Dijet resonance searches
- Dijet angular distributions



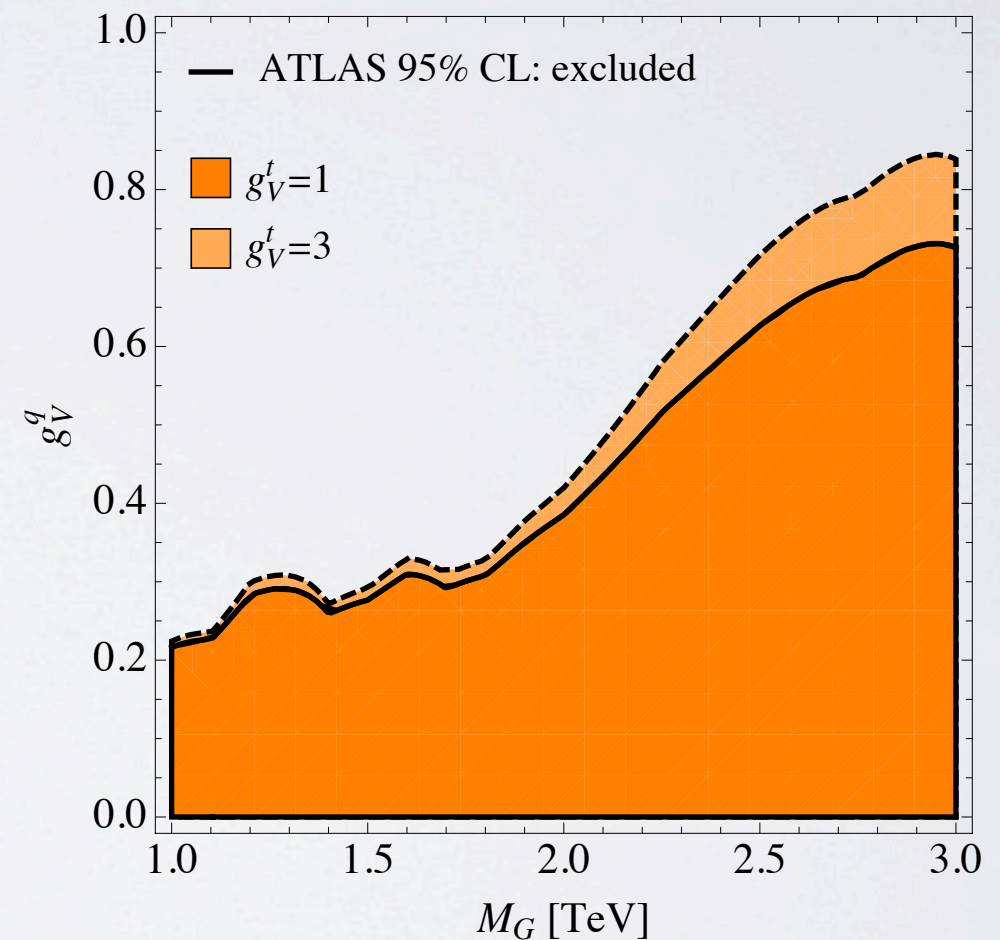
DIJET RESONANCE SEARCHES

Constraints on the production of a narrow jj resonance:

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



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



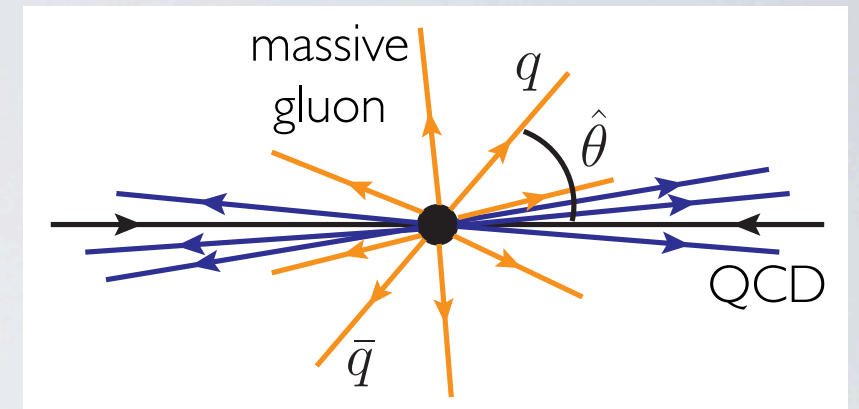
Evade dijet bounds on effects in $t\bar{t}$ production by rescaling:

$$g_{V,A}^q \rightarrow \xi \cdot g_{V,A}^q, \quad g_{V,A}^t \rightarrow g_{V,A}^t / \xi$$

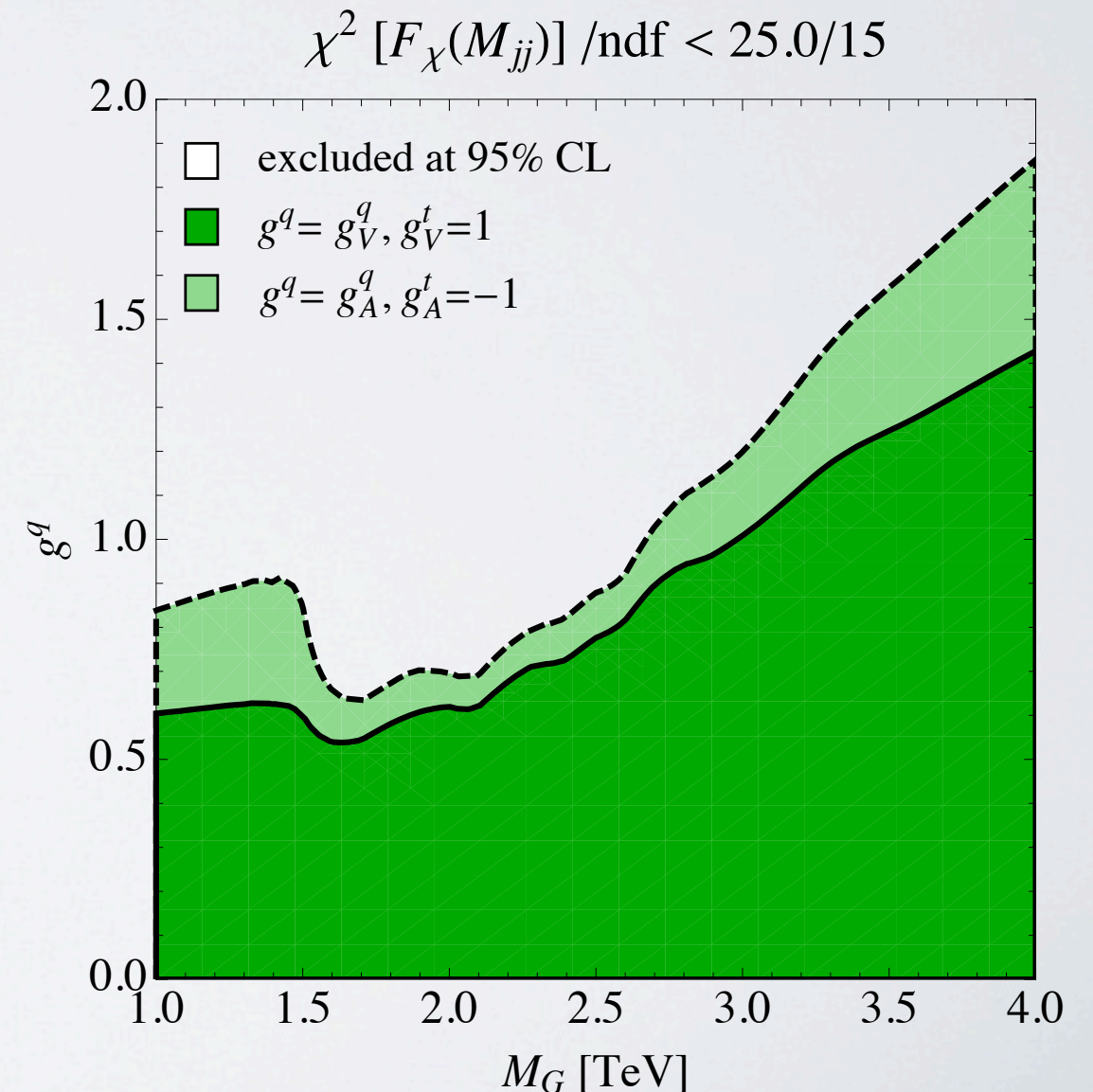
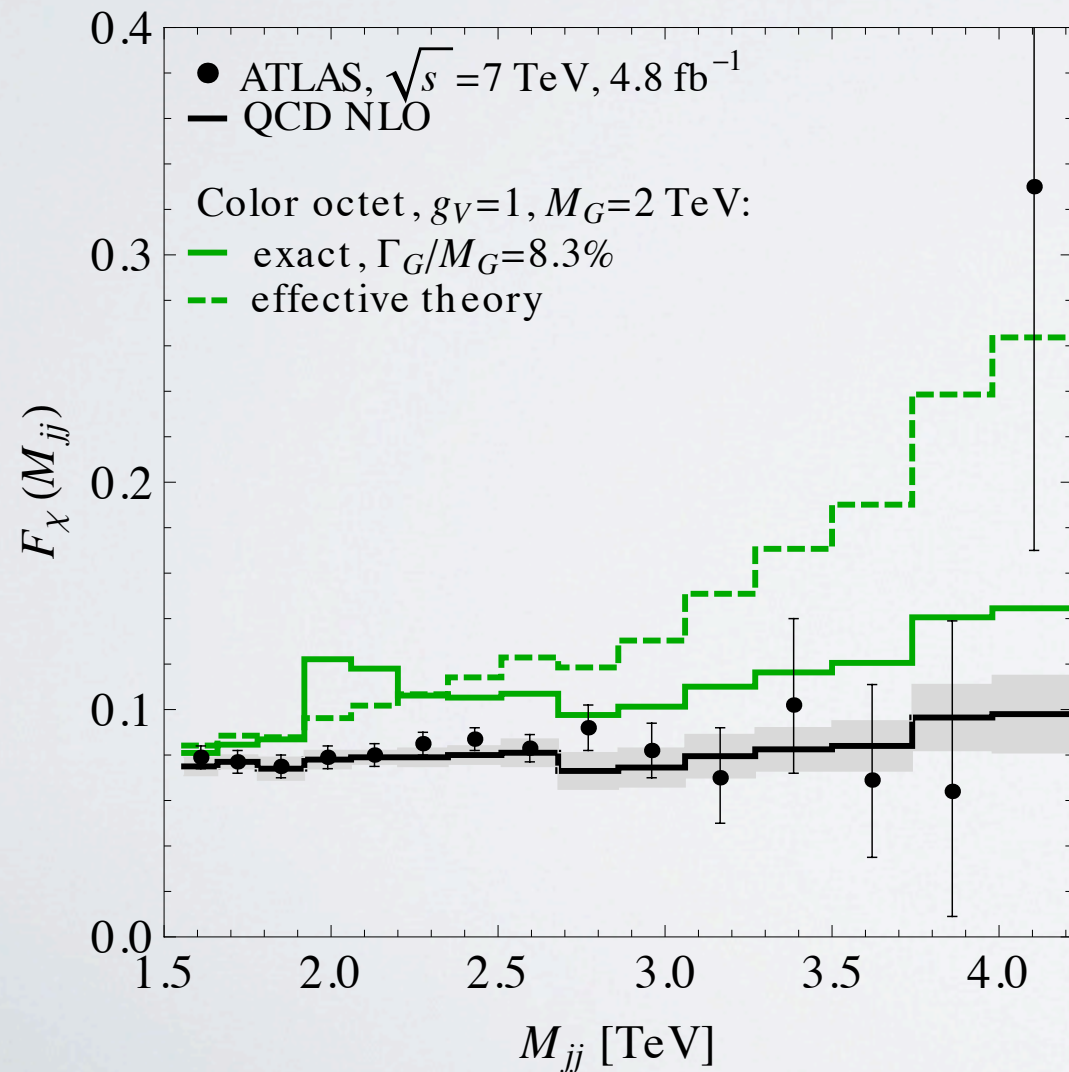
DIJET ANGULAR DISTRIBUTION

Dijet excess in central region:

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



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

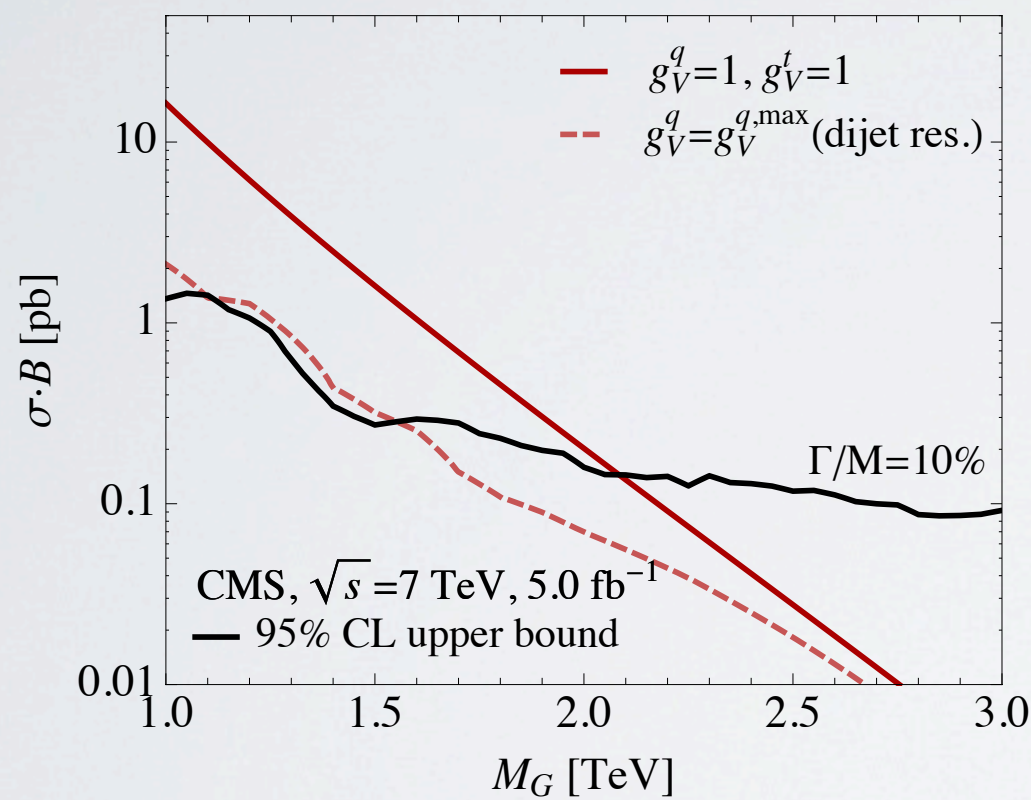


TOP-ANTITOP RESONANCE SEARCHES

Constraints on the production of a narrow $t\bar{t}$ resonance:

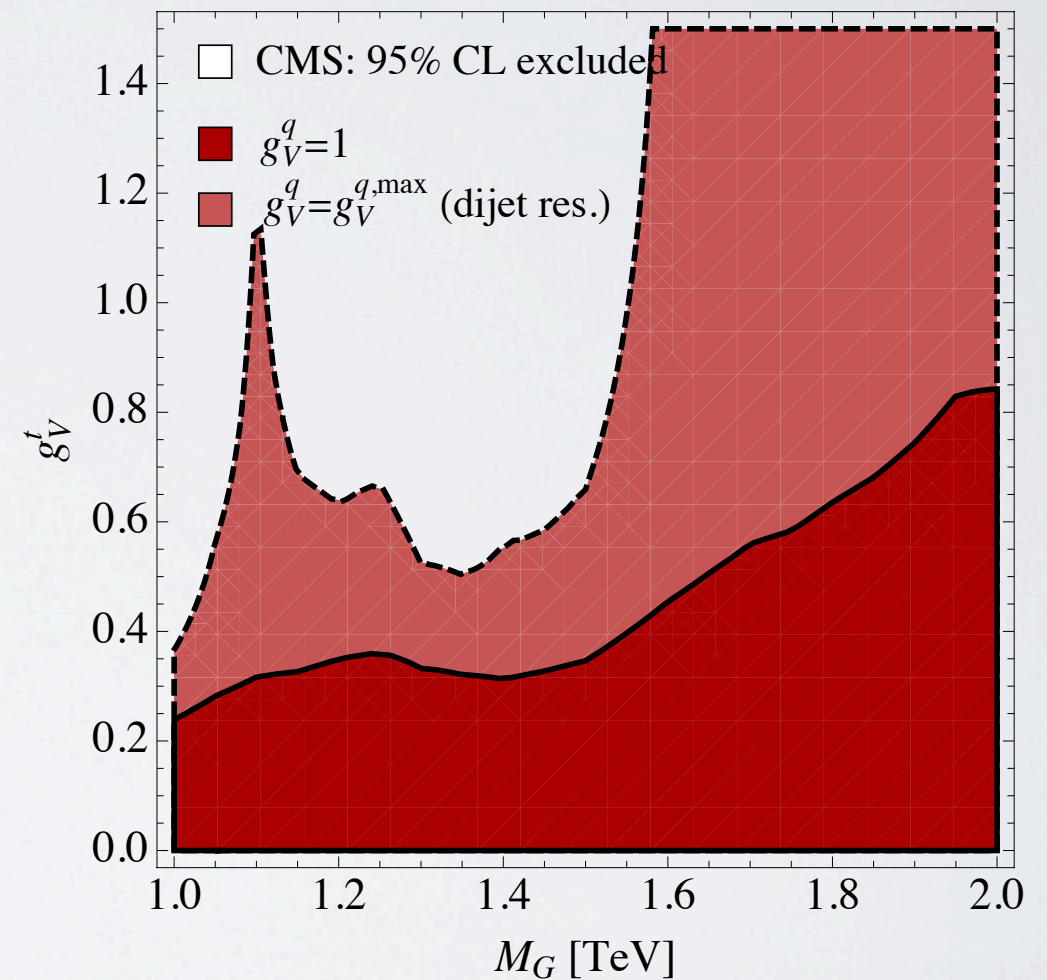
$$\sigma(pp \rightarrow G) \cdot \mathcal{B}(G \rightarrow t\bar{t}) \sim [(g_V^t)^2 + (g_A^t)^2] \quad (g_{V,A}^q \gtrsim g_{V,A}^t)$$

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



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

[ATLAS-CONF-2012-029, 2.05 fb^{-1} , $l+l$ jets]



$\sigma \cdot \mathcal{B}$ becomes insensitive to $g_{V,A}^t$ for small $g_{V,A}^q$.
 \rightarrow No constraints for $M_G \gtrsim 1.6$ TeV, if $g_{V,A}^q$ respects dijet bounds.

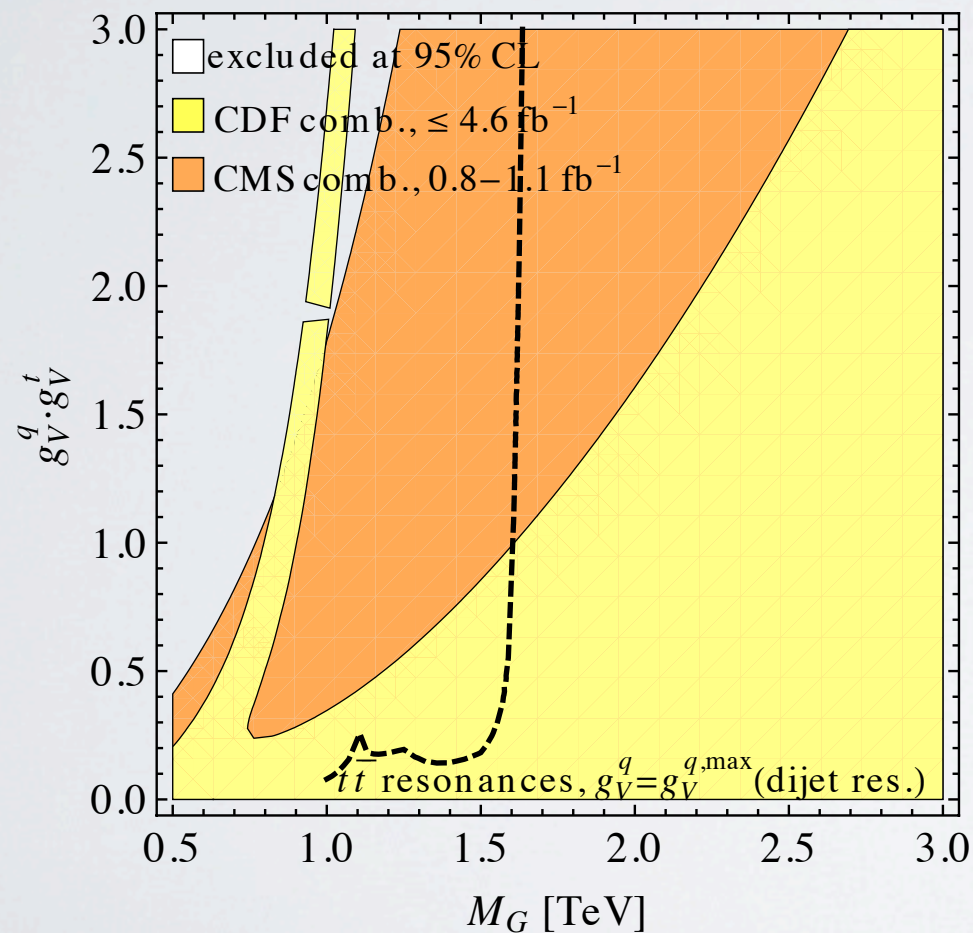
TOP-ANTITOP TOTAL CROSS SECTION

■ Tevatron: $\sigma_{t\bar{t}}^{\text{CDF}}(\sqrt{s} = 1.96\text{TeV}) = 7.50 \pm 0.48 \text{ pb}$ $\sigma_{t\bar{t}}^{\text{QCD}} = 6.90^{+0.40}_{-0.74} {}^{+0.50}_{-0.40} \text{ pb}$

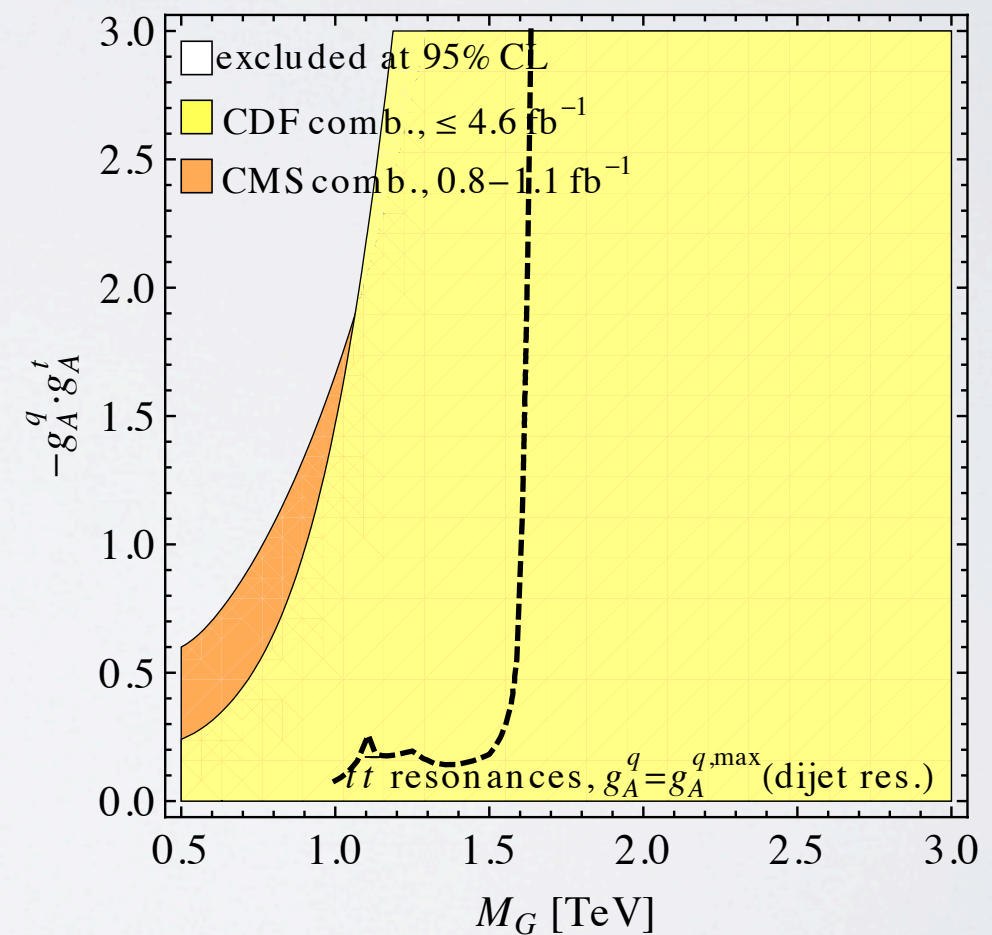
■ LHC7: $\sigma_{t\bar{t}}^{\text{CMS}}(\sqrt{s} = 7\text{TeV}) = 165.8 \pm 13.3 \text{ pb}$ $\sigma_{t\bar{t}}^{\text{QCD}} = 150^{+18}_{-19} {}^{+13}_{-12} \text{ pb}$

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

interference w/ QCD



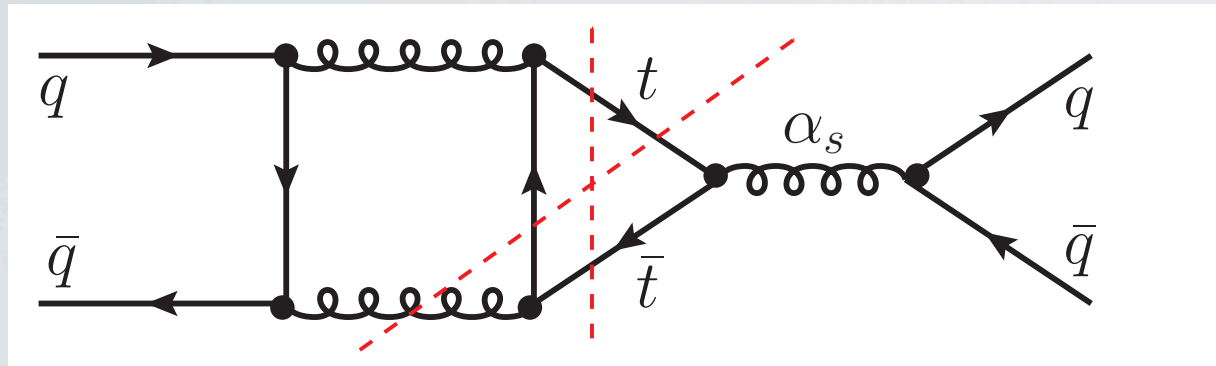
no interference



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

FORWARD-BACKWARD ASYMMETRY AT TEVATRON

QCD: charge asymmetry at NLO

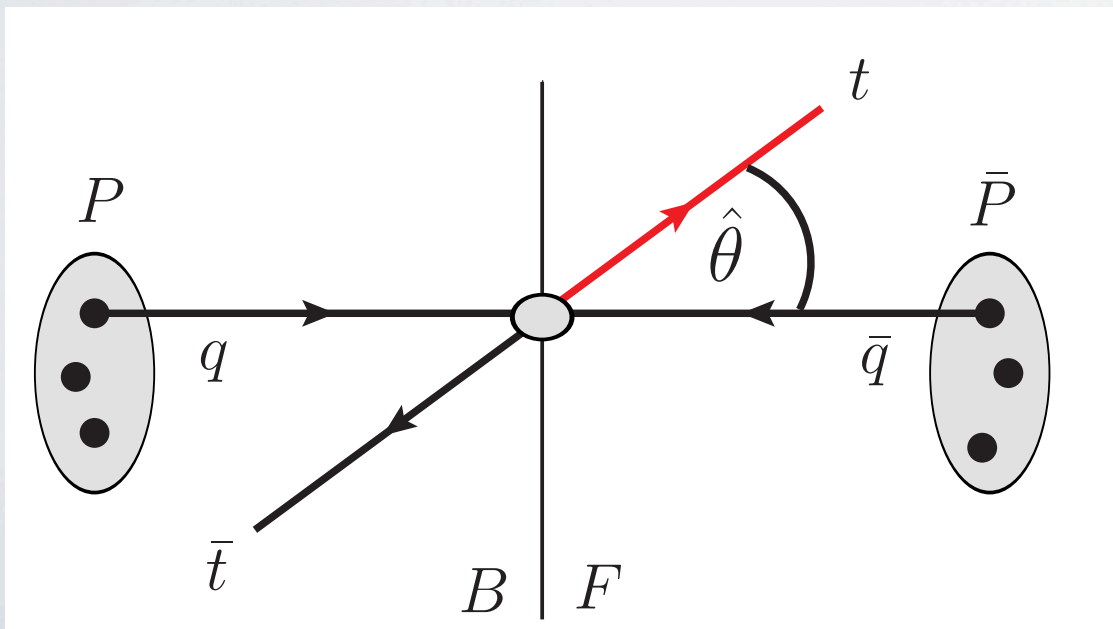


[Ahrens et al., PRD 84 (2011) 074004][Hollik, Pagani, PRD 84 (2011) 093003]

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

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

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

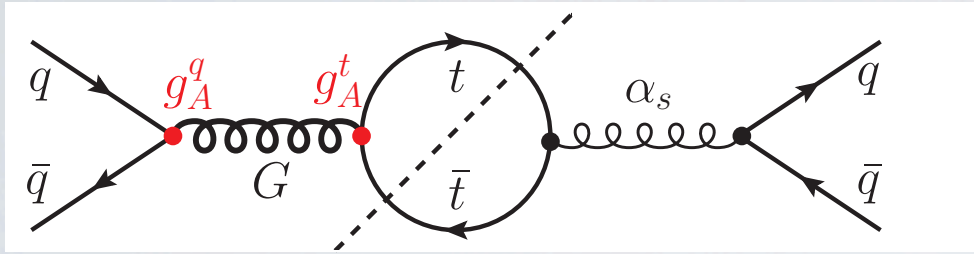


$$A_{\text{FB}}^t = \frac{N_t(F) - N_t(B)}{N_t(F) + N_t(B)} \equiv A_C^t$$

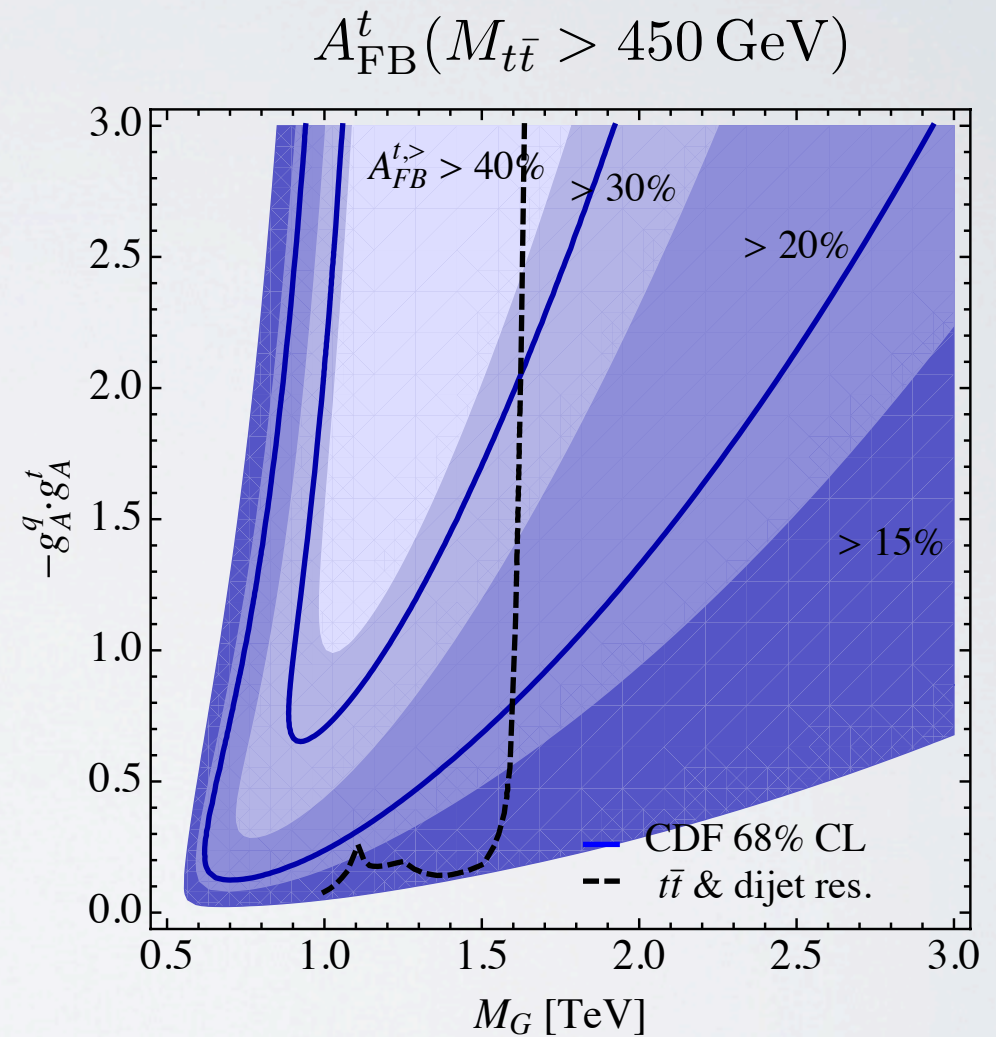
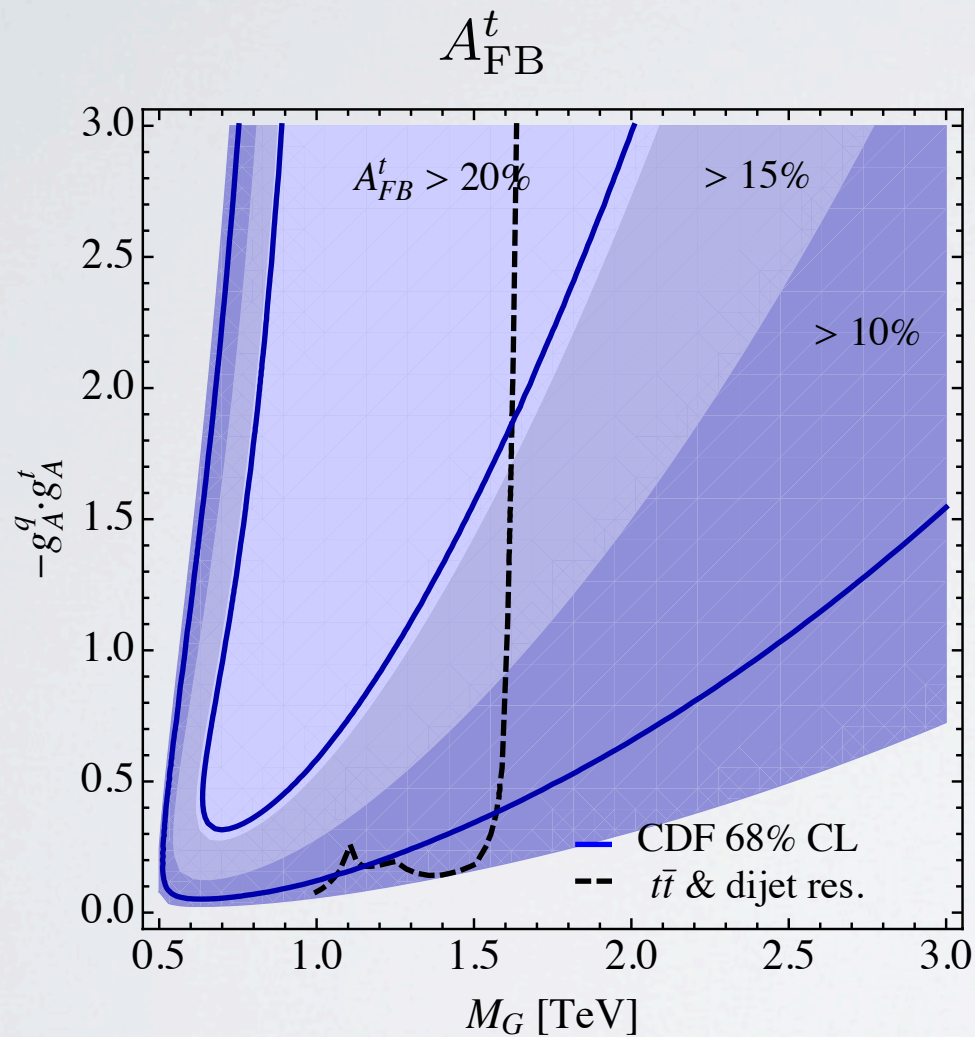
$$A_{\text{FB}}^{t,\text{CDF}} = 16.2 \pm 4.1 \pm 2.2\%$$

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

AXIGLUON EFFECTS ON FB ASYMMETRY



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



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

CHARGE ASYMMETRY AT LHC

Boosted q in proton \rightarrow more t than \bar{t} in beam direction.

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

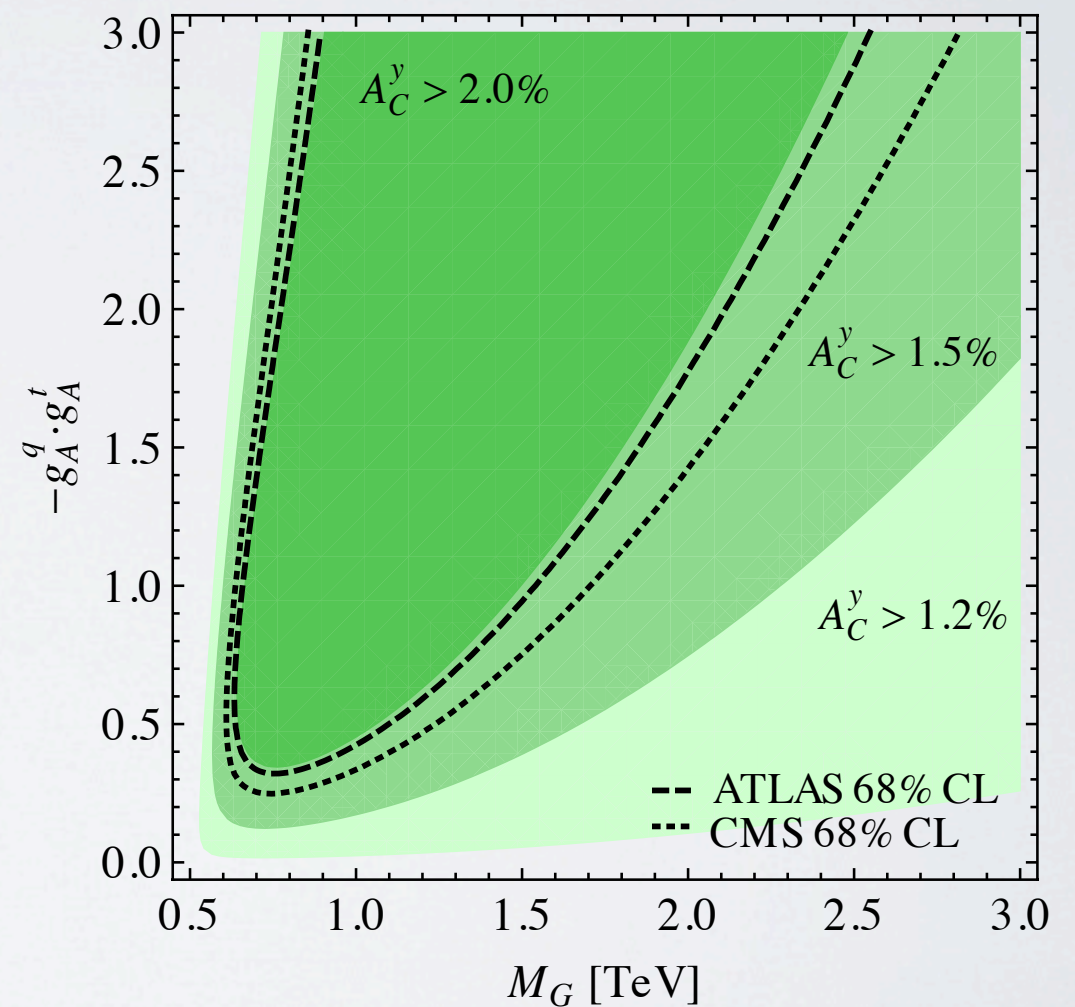
$$A_C^{y, \text{QCD}} = 1.15 \pm 0.06 \%$$

[Kühn, Rodrigo, JHEP 1201 (2012) 063]

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

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

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



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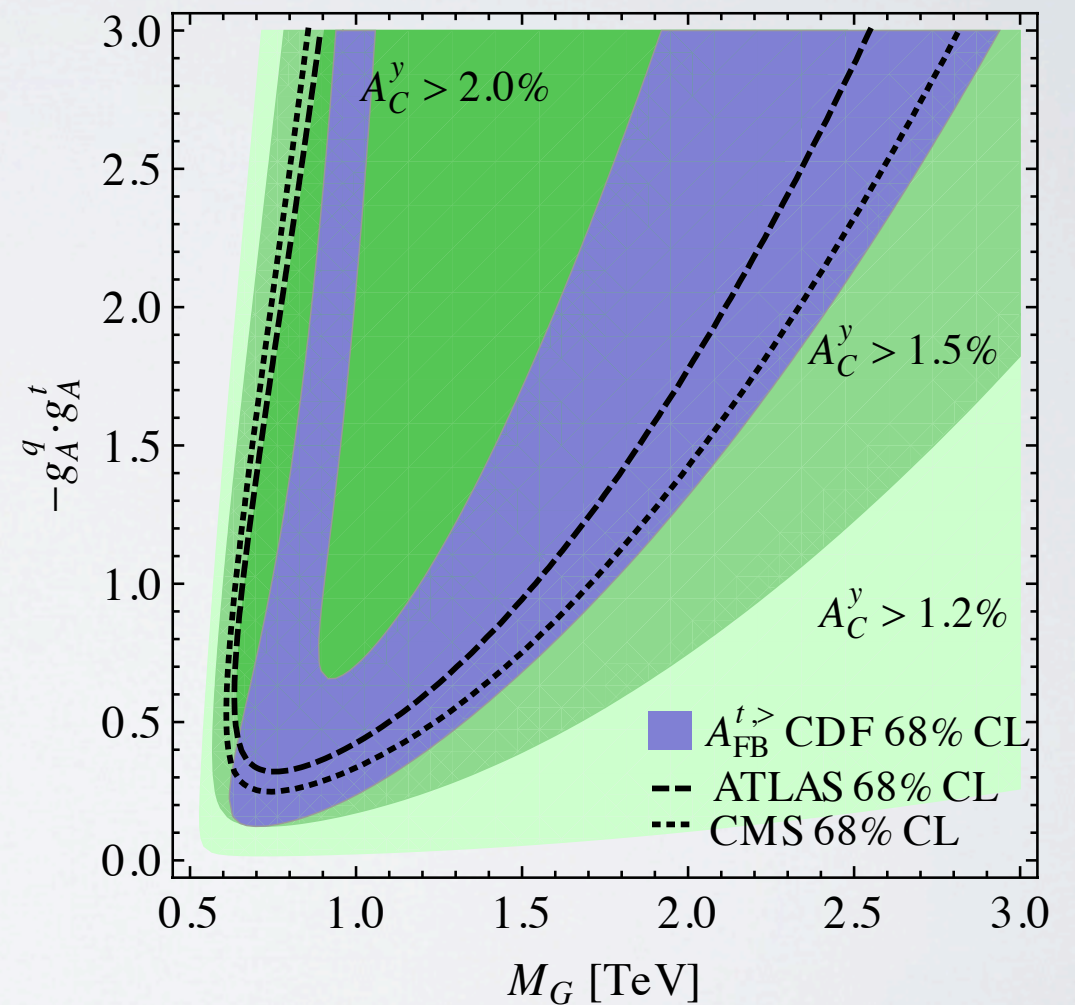
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[CMS-PAS-TOP-11-030, 4.7fb⁻¹][ATLAS, arXiv:1203.4211, 1.04fb⁻¹]



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

TO BE TAKEN HOME

Constraints on massive gluons from LHC7:

- Dijet resonances $\sim (g_{V,A}^q)^2$
- Dijet angular distribution $\sim (g_{V,A}^q)^2$
- $t\bar{t}$ resonances $\sim (g_{V,A}^t)^2$ (requires sizeable $g_{V,A}^q$)
- $t\bar{t}$ cross section $\sim g_V^q g_V^t + \mathcal{O}((g_{V,A}^q)^2 (g_{V,A}^t)^2)$

Axigluon effects on charge asymmetries $\sim -g_A^q g_A^t$:

- Tevatron FB asymmetry $A_{\text{FB}}^t \approx 15\%$ (requires strong top cplg.)
- LHC charge asymmetry $A_C^y \approx 1.5\%$