

Top A_{FB} from Heavy New Physics

Model Independent Lessons

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in collaboration w/ the Weizmann dreamteam:

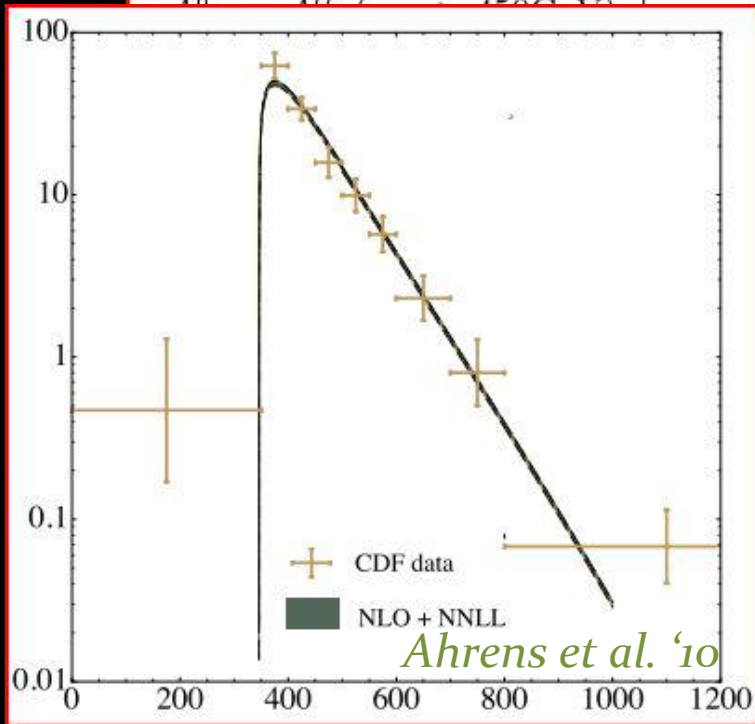
K. Blum, O. Gedalia, Y. Hochberg,
S.J. Lee, Y. Nir, G. Perez & Y. Soreq

August 31, 2011 | CERN

Tevatron Data

Basic fact: $o(5)$ A_{FB} measurements differ from SM:
 CDF: $l+j$ & ll (incl+diff) | DØ: $l+j$ (incl) & lep A_{FB}
 while Xsec (incl+diff) is consistent with it.

Observable	Measurement	SM predict.
A_{FB}^{incl}	$0.158 \pm 0.072 \pm 0.017$ [1]	$(7.24^{+1.04+0.20}_{-0.67-0.27}) \cdot 10^{-2}$ [5]
	$0.42 \pm 0.15 \pm 0.05$ [2]	
	$0.196 \pm 0.060^{+0.018}_{-0.026}$ [3]	
	$\simeq 0.200 \pm 0.047$	
	$0.475 \pm 0.101 \pm 0.049$ [1]	$(11.1^{+1.7}_{-0.9}) \cdot 10^{-2}$ [5]
	$-0.116 \pm 0.146 \pm 0.047$ [1]	$(5.2^{+0.9}_{-0.6}) \cdot 10^{-2}$ [5]
	$0.026 \pm 0.104 \pm 0.056$ [1]	$(4.77^{+0.39}_{-0.35}) \cdot 10^{-2}$ [5]
		$(14.59^{+2.16}_{-1.30}) \cdot 10^{-2}$ [5]
		$(6.63^{+0.00}_{-0.27})$ pb [17]
		$(7.08^{+0.00+0.36}_{-0.24-0.27})$ pb [19]



$(A_{FB}^t)^>$	$(A_{FB}^t)^{lab}$	A_{FB}^l
\uparrow 3.3σ \downarrow	\uparrow 1.8σ \downarrow	\uparrow 3.3σ \downarrow
48%	15%	15.2%

Kamenik et al. '11

**O(1) effects,
 more pronounced
 @higher energies**

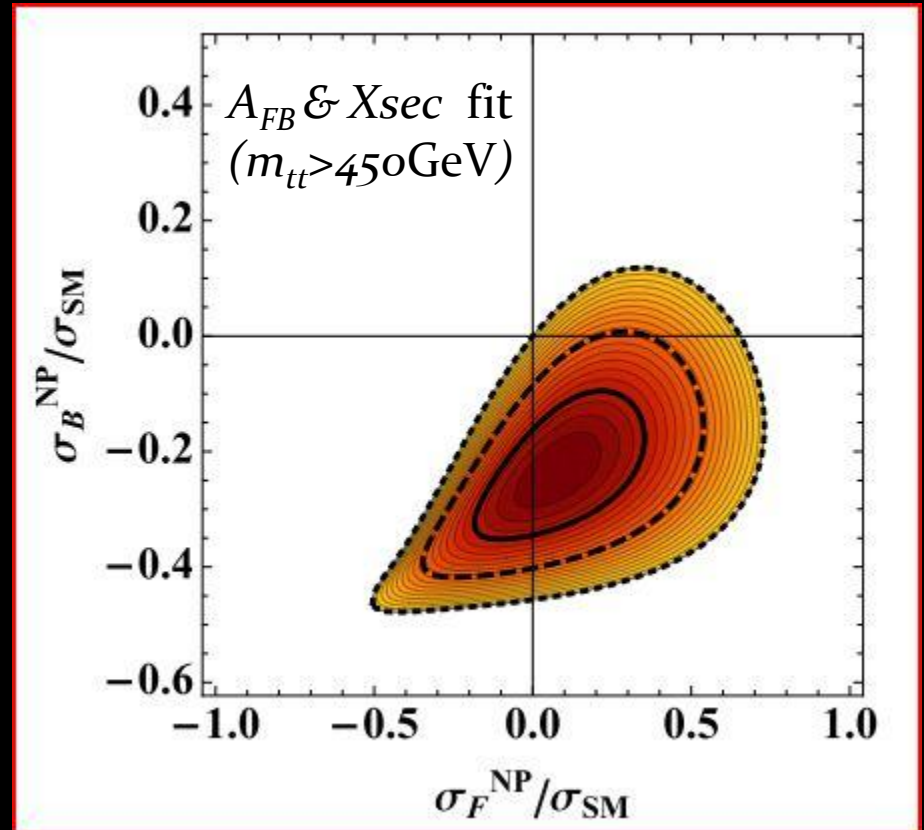


New Physics ??

Westhoff '11

New Physics Interpretation

- Let's assume experiments are correct \rightarrow it **is** new physics
- zeroth order lessons from $O(1)$ NP effects in tt production:
 - strong production
 - tree-level (*i.e.* LO QCD)
 - must interfere w/ SM source
if not, $>2\sigma$ tension with data!
- 2 paths to explain data:
 - light NP | $\Lambda_{NP} < \text{TeV}$
 - heavy NP | $\Lambda_{NP} > \text{few TeV}$
(w/ stronger NP couplings)
- this talk focuses on the latter



Grinstein et al. '11

Heavy NP & EFT approach

Blum et al. '11
Delaunay et al. '11

- effective operators relevant to $qq \rightarrow tt$ transitions @high m_{tt}
above 450GeV, $q \approx u$ ($dd/uu \approx 20\%$, which we neglect here)
non SM-like NLO corrections also neglected (*this is pQCD after all*)

$\mathcal{O}(\Lambda^2)$:

$$\mathcal{O}_A^8 = (\bar{u}\gamma_\mu\gamma^5 T^a u)(\bar{t}\gamma^\mu\gamma^5 T^a t),$$

$$\mathcal{O}_V^8 = (\bar{u}\gamma_\mu T^a u)(\bar{t}\gamma^\mu T^a t).$$

interfere w/ SM gluon production

$$\mathcal{O}_V^1 = (\bar{u}\gamma_\mu u)(\bar{t}\gamma^\mu t), \quad \mathcal{O}_A^1 = (\bar{u}\gamma_\mu\gamma^5 u)(\bar{t}\gamma^\mu\gamma^5 t),$$

$$\mathcal{O}_{AV}^1 = (\bar{u}\gamma_\mu\gamma^5 u)(\bar{t}\gamma^\mu t), \quad \mathcal{O}_{VA}^1 = (\bar{u}\gamma_\mu u)(\bar{t}\gamma^\mu\gamma^5 t).$$

don't interfere w/ SM

$$\mathcal{O}_S^{1,8} = (\bar{u} T_{1,8} u)(\bar{t} T_{1,8} t), \quad \mathcal{O}_P^{1,8} = (\bar{u} T_{1,8} \gamma^5 u)(\bar{t} T_{1,8} \gamma^5 t),$$

$$\mathcal{O}_{SP}^{1,8} = i(\bar{u} T_{1,8} u)(\bar{t} T_{1,8} \gamma^5 t), \quad \mathcal{O}_{PS}^{1,8} = i(\bar{u} T_{1,8} \gamma^5 u)(\bar{t} T_{1,8} t),$$

$$\mathcal{O}_T^{1,8} = (\bar{u} T_{1,8} \sigma^{\mu\nu} u)(\bar{t} T_{1,8} \sigma_{\mu\nu} t),$$

$\mathcal{O}(\Lambda^4)$: none (if NP couplings to qq/tt are *strong*)
(in the perturbative sense, see later)

Heavy NP & EFT approach

Blum et al. '11

- $o(m_{tt}^2/\Lambda^2)$ effects: $\mathcal{O}_A^8 = (\bar{u}\gamma_\mu\gamma^5 T^a u)(\bar{t}\gamma^\mu\gamma^5 T^a t)$, \square SM
 $\mathcal{O}_V^8 = (\bar{u}\gamma_\mu T^a u)(\bar{t}\gamma^\mu T^a t)$.

- CDF $A_{FB}(m_{tt}>450) \approx 50\%$ \longrightarrow $c_A^8 \approx 2.4/\text{TeV}^2$
($c_V^8 = 0$, so that Xsec is ok)

So far, we learn that:

1. since $\Lambda > 1-2 \text{ TeV}$, NP couplings are sizable, at least $o(1)$
2. from perturbativity $\Lambda < 4\pi/\sqrt{2.4} \approx 8 \text{ TeV}$
 \longrightarrow there is a region where EFT expansion makes sense.

- Implications for other observables | 1st hints from $(O_A^8)^2$
 - boosted top excess @CDF (*Alon et al '10* | see also Gilad's talk)
 A_{FB} implies $NP/SM \sim 2 \approx \text{observed} - 1\sigma$
 - enhancement of the tt-tail @LHC
again, A_{FB} implies $NP/SM \sim 5$ @ $m_{tt} = 1.5 \text{ TeV}$

Heavy NP & EFT approach

Delaunay et al. '11

- $o(m_{tt}^4/\Lambda^4)$ effects: all ($4f$ -operators)²

kinematical diff. $\sim 4m_{top}^2/m_{tt}^2 \approx o(20/50\%)$ for $m_{tt}=800/450\text{GeV}$,
but further suppressed (if not vanishing) when A_{FB} is maximized.

- If neglected, a simple polar basis *for non-interfering ops* emerges

$$w_{\pm}^2 \equiv \frac{1}{2} \left\{ (c_{VA}^8 \pm c_{AV}^8)^2 + \frac{9}{2} \left[(c_V^1 \pm c_A^1)^2 + (c_{VA}^1 \pm c_{AV}^1)^2 \right] \right\},$$
$$R^2 \equiv w_+^2 + w_-^2, \quad \tan \theta \equiv w_-/w_+.$$

within which NP/SM Xsec ratio & top AFB read:

$$N_X \simeq a_X c_V^8 + b_X (c_V^8)^2 + d_X (c_A^8)^2 + e_X R^2,$$
$$A_{450}^{t\bar{t}} = \left(\alpha c_A^8 + \beta c_A^8 c_V^8 + \frac{\beta}{2} R^2 \cos 2\theta \right) (1 + N_{450})^{-1},$$

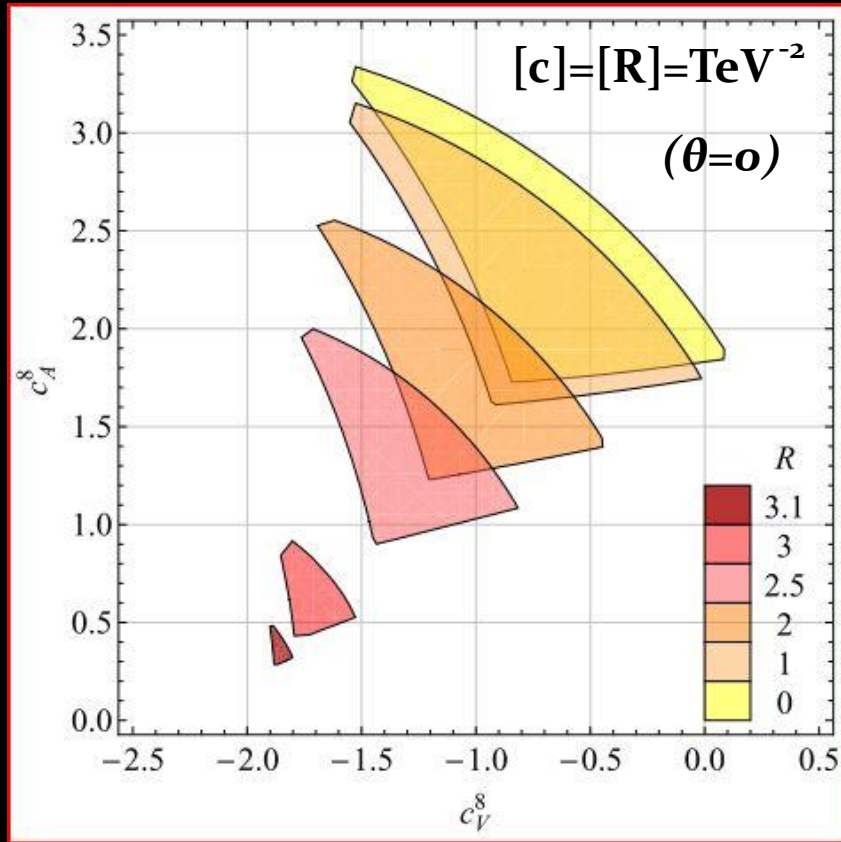
$a, b, d, e, \alpha, \beta$
= kinematical #'s

- Now, one can start do physics & draw generic lessons about heavy NP as a explanation of A_{FB} anomalies.

Model Independent Lessons from EFT

Delaunay et al. '11

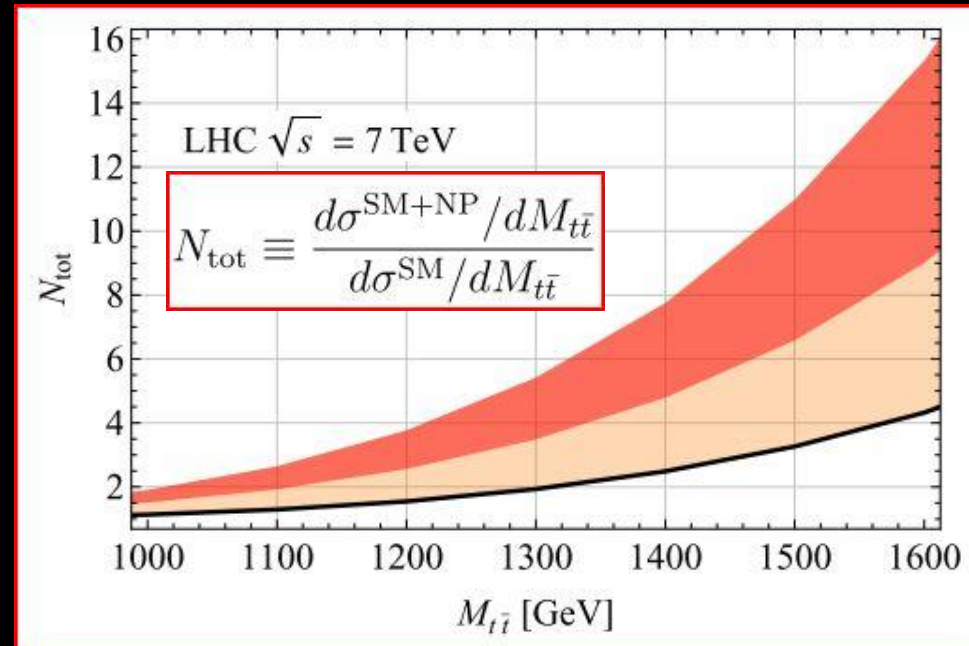
$A_{FB}^{>45^\circ} \sim 50\%$ & $NP/SM \text{ diff-}Xsec < 1\sigma$



we learn that:

- $c_A^8 > 0.3/\text{TeV}^2$ (recall NP must interfere)
- $R < 3.1/\text{TeV}^2$
- single chiral operator can't reproduce A_{FB}

Implications for LHC tt-tail



smoking gun: $NP/SM > 2 @ 1.5\text{TeV}$
(LHC verdict available soon...?)

Last words

- implication for boosted tops @CDF:
 A_{FB} w/in 1σ implies NP/SM > 50%
- dijets production @LHC?
 - from qqt it self via loop: ok!
 - @tree-level from $qqqq$: ok, provided NP couplings $g_{qq}/g_{tt} < 1/5$!
- any questions?