Constraints on BSM scenarios from tt-bar resonance and heavy quark searches

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TOP2011 | Sant Feliu de Guixols September, 27th 2011

No new physics resonance in top pair production, so what?

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Top is special

theoretically:

- heaviest particle = most sensitive to EWSB dynamics
- natural EWSB = new physics states @ TeV scale
  strongly coupled to top

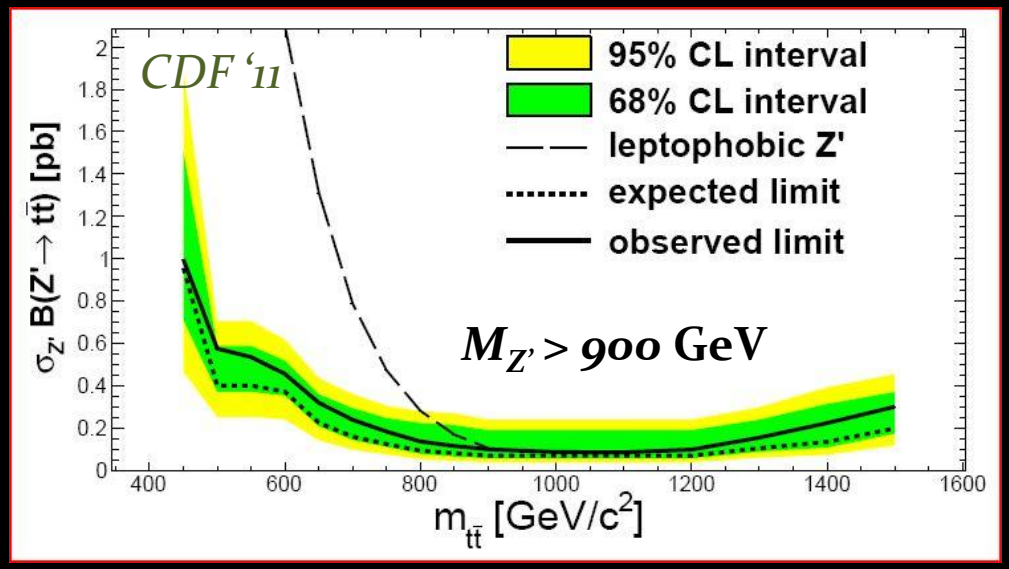
→ tt-bar production is a dedicated window on BSM world!

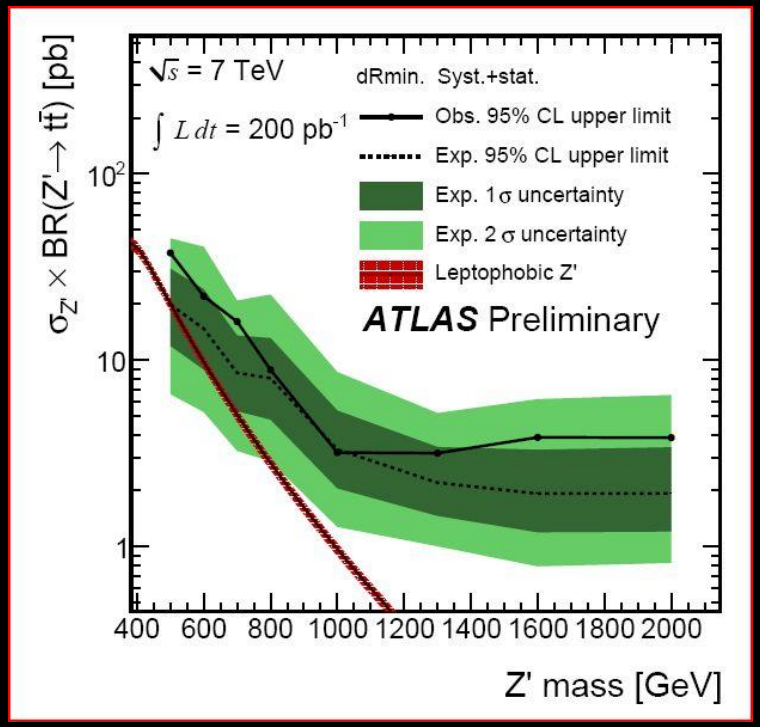
experimentally (yet from an enthusiastic theorist point of view):

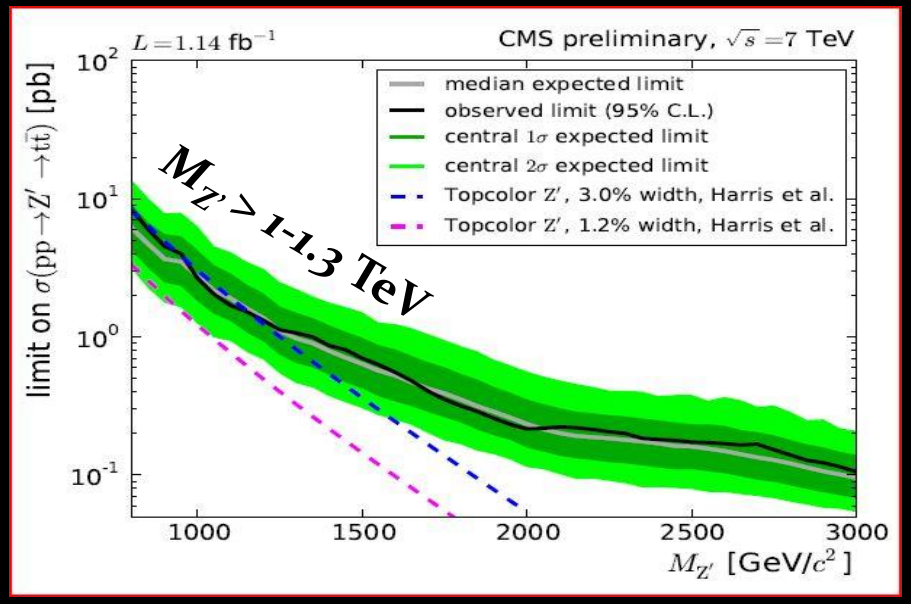
- anomalous forward-backward asymmetry @Tevatron
  first (only one so far...) hint of BSM physics?

Example #1 | Z' searches

CDF - hep-ex/11075063
ATLAS-CONF-2011-087
CMS-PAS-EXO-11-055





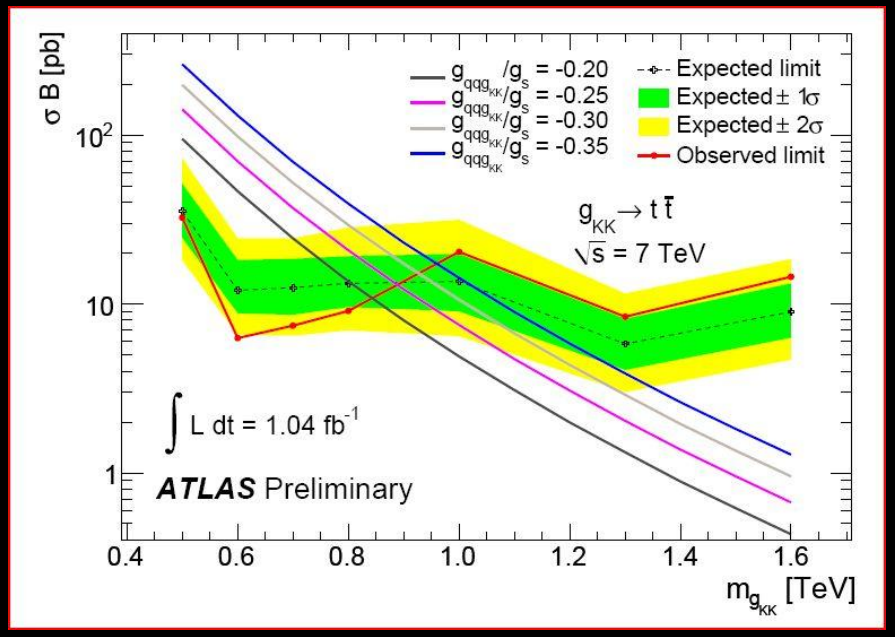


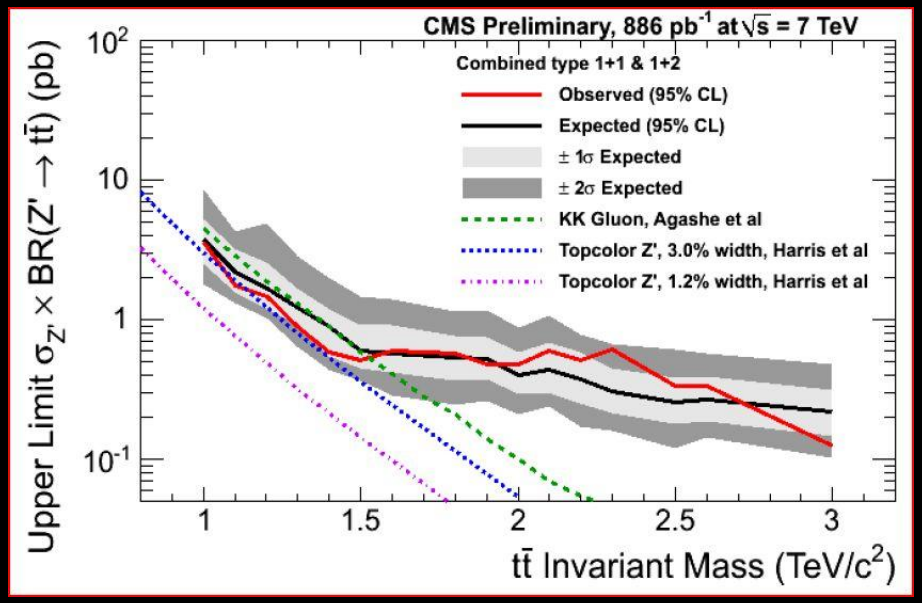
main assumptions: *Z' has almost no width & only couples to top like hypercharge*

- LHC has taken the lead
- exclusion power of o(TeV)

Example #2 | KK-gluon searches

ATLAS-CONF-2011-123
CMS-PAS-EXO-11-006





- Anarchic RS | KKg-mass **> 1.5TeV !!** (CMS) (weaker ATLAS bound: > 840GeV)
- However , KKg production is quite suppressed in those models
  a priori $g_{q\text{-}q\text{-}gKK}/g_{strong}$ could be o(1)

→ constraints could be much stronger!

...but hard to guess since width effects become important

No resonance yet, but…

- present LHC bounds: ***M_{NP} >~ 1-1.5* TeV**

& typical bounds from EWPTs (*mostly S parameter*): $M_{NP} > 3\text{-}5$ TeV

⟶ *no surprises* *(according to typical/well motivated EWSB scenarios)*

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& typical bounds from EWPTs (*mostly S parameter*): $M_{NP} >$ 3-5 TeV

→ *no surprises* *(according to typical/well motivated EWSB scenarios)*

- search only for narrow resonances, which misses o(TeV)
  - broader (width/mass>10-15%) resonances,
  - t/u channel exchanged states

→ alternative RS scenarios:
e.g. Flavor triviality, soft wall…

Delaunay et al. '10/'11
Quiros et al. '10/'11

- assumed pure NP production
  - no interference w/ SM strong-production

→ which is motivated by top A_{FB} *!*

…knowledge of the tt-bar invariant mass distribution typically required

Top A_{FB} | Tevatron's facts

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.

Kamenik et al. '11

Observable	Measurement	SM predict.
$A_{\rm FB}^{\rm incl}$	$0.158 \pm 0.072 \pm 0.017$ [1] $0.42 \pm 0.15 \pm 0.05$ [2] $0.196 \pm 0.060^{+0.018}_{-0.026}$ [3] $\simeq 0.200 \pm 0.047$	$(7.24^{+1.04+0.20}_{-0.67-0.27}) \cdot 10^{-2}$ [5]
$A_{\rm FB}^{\rm h} \equiv A_{\rm FB}^{t\bar{t}}(m_{t\bar{t}} > 450{\rm GeV})$	$0.475 \pm 0.101 \pm 0.049$ [1]	$(11.1^{+1.7}_{-0.9}) \cdot 10^{-2}$ [5]
$A_{\rm FB}^{\rm low} \equiv A_{\rm FB}^{t\bar{t}}(m_{t\bar{t}} < 450{\rm GeV})$	$-0.116 \pm 0.146 \pm 0.047$ [1]	$(5.2^{+0.9}_{-0.6}) \cdot 10^{-2}$ [5]
$A_{\rm FB}^{t\bar{t}}(\lvert\Delta y\rvert < 1.0)$	$0.026 \pm 0.104 \pm 0.056$ [1]	$(4.77^{+0.39}_{-0.35}) \cdot 10^{-2}$ [5]
$A_{\rm FB}^{t\bar{t}}(\lvert\Delta y\rvert > 1.0)$	$0.611 \pm 0.210 \pm 0.147$ [1]	$(14.59^{+2.16}_{-1.30}) \cdot 10^{-2}$ [5]
$\sigma_{t\bar{t}}^{\rm incl.}$	(6.9 ± 1.0)pb [20]	$(6.63^{+0.00}_{-0.27})$pb [17] $(7.08^{+0.00+0.36}_{-0.24-0.27})$pb [19]

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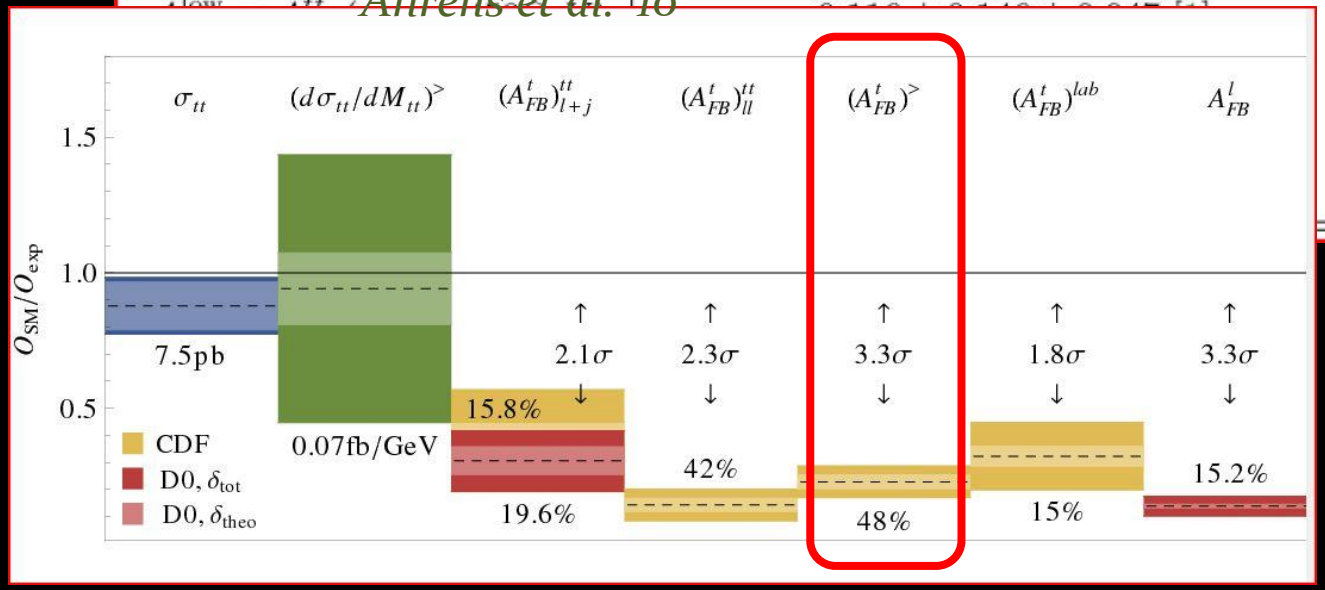
Ahrens et al. '10



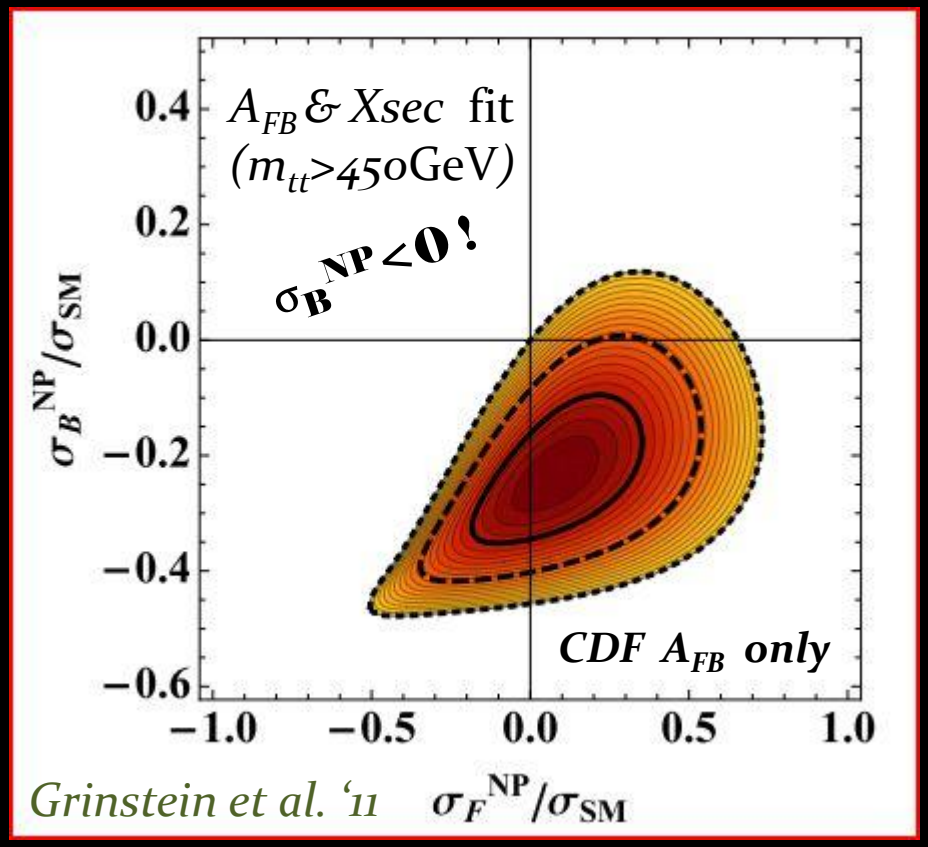
Westhoff '11

O(1) effects, more pronounced @higher energies

⬇

New Physics ??

Top A_{FB} | New Physics interpretation



Grinstein et al. '11

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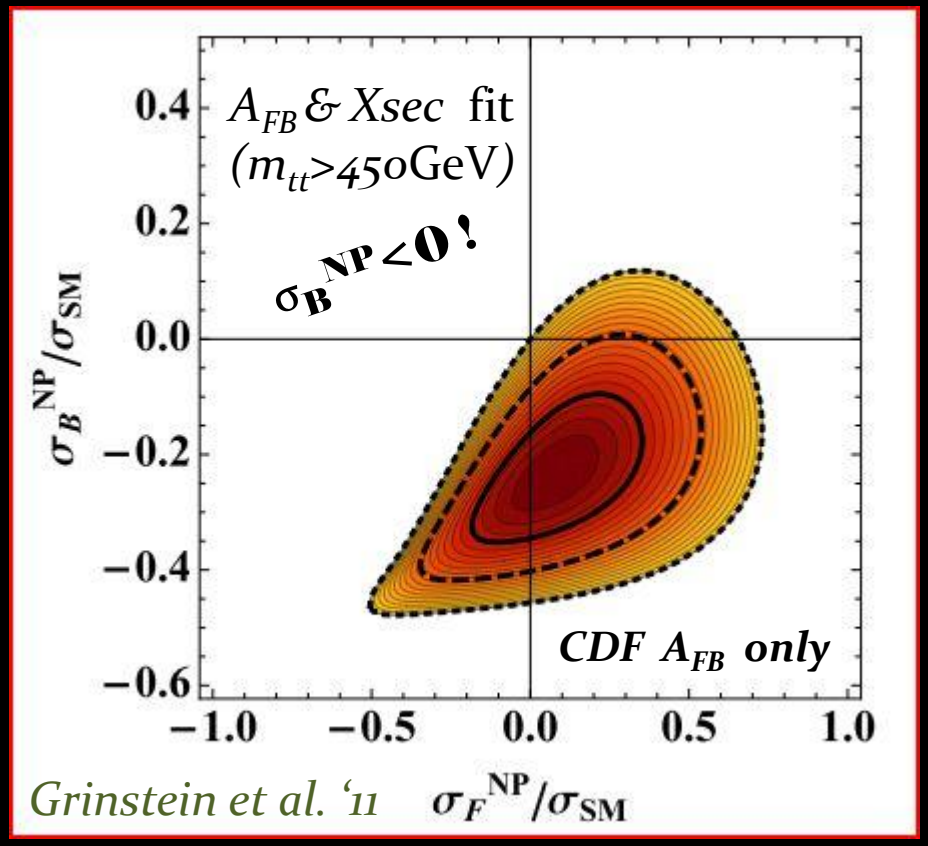

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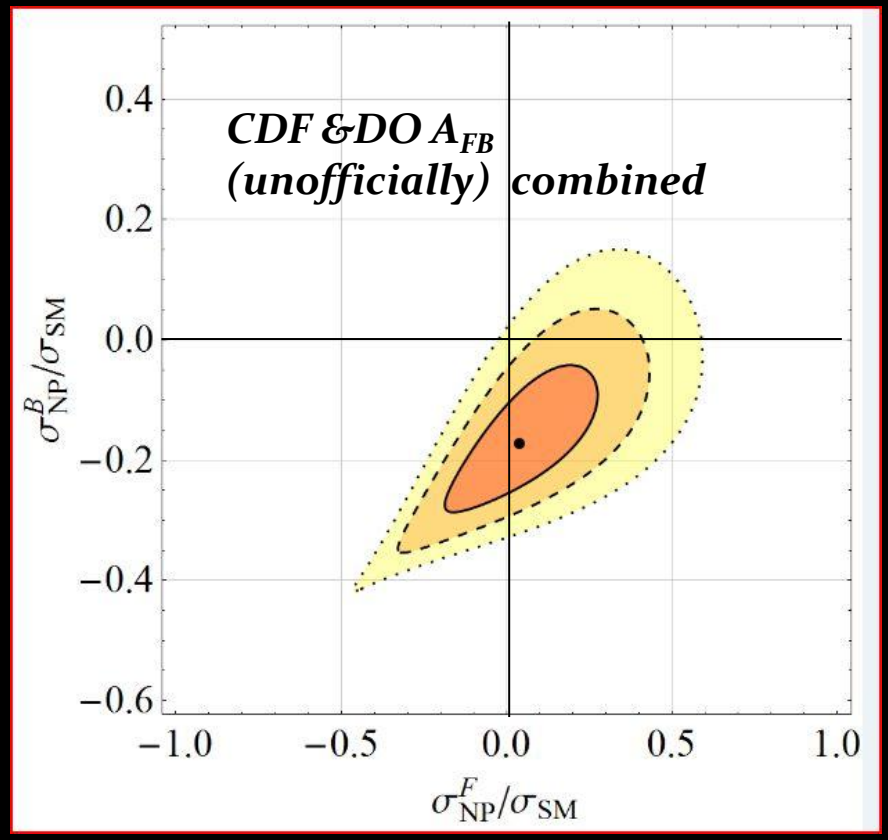


zeroth-order lesson: NP should interfere w/ SM gluon production, and this effect is potentially dominating tt-bar production above 450 GeV.

Top A_{FB} | Heavy New Physics interpretation

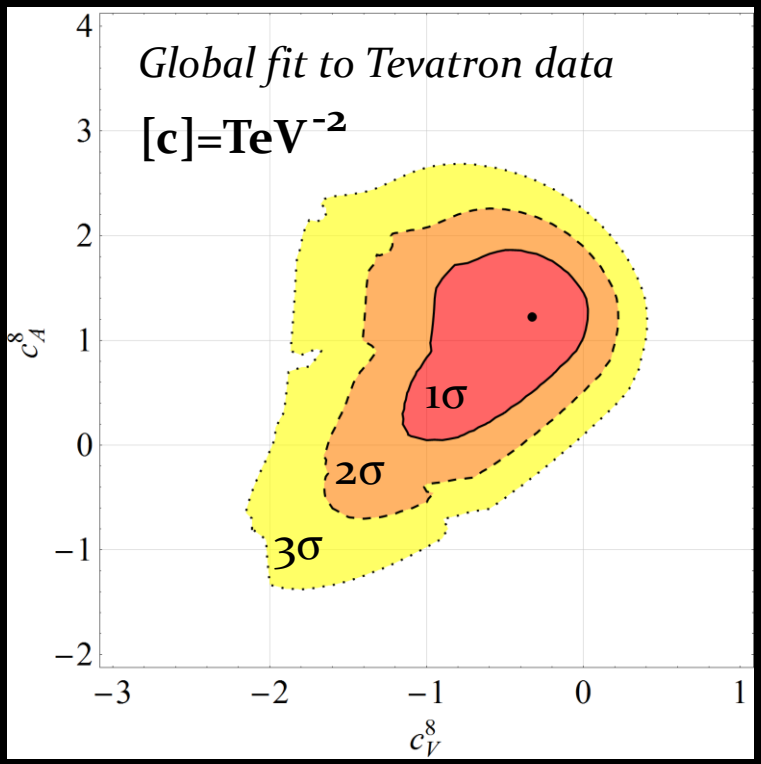
- If NP explaining A_{FB} is > 1-2TeV, EFT rules apply:

$o(\Lambda^2)$:

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

+ 14 non-interfering operators

perturbativity: *Λ < 8-10* TeV



updates of Delaunay et al. '11

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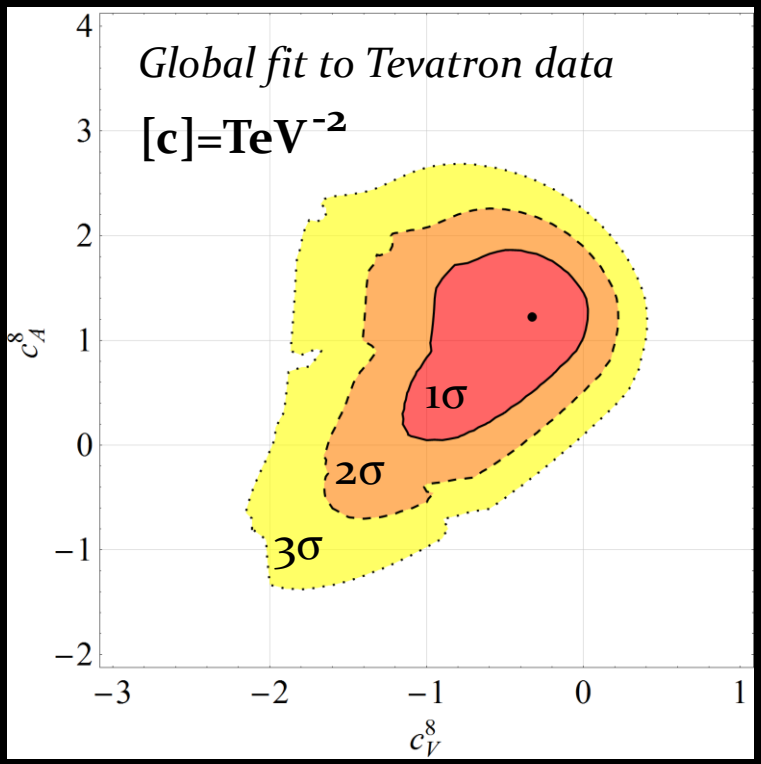
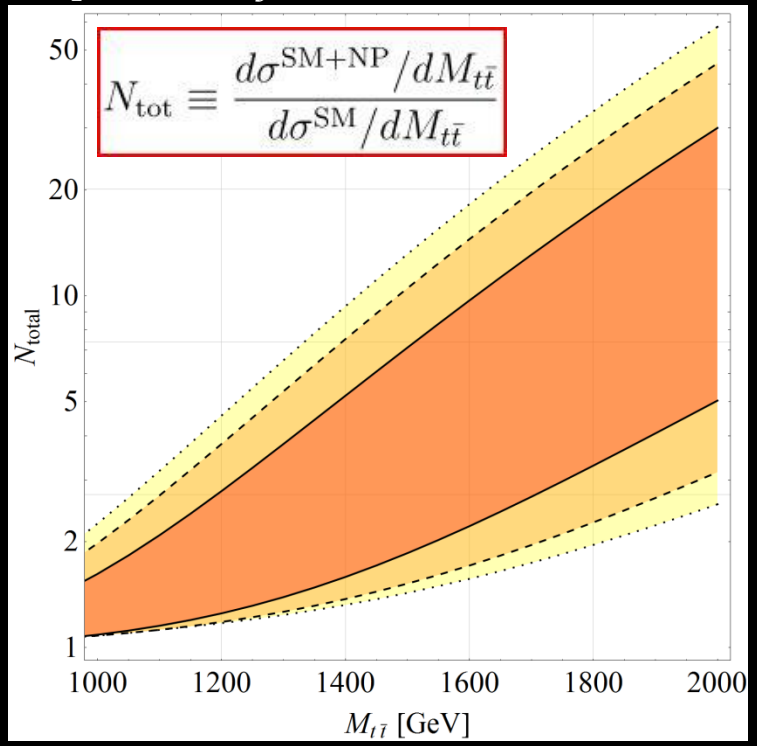


updates of Delaunay et al. '11

implications for tt-bar tail @LHC



smoking gun: *NP/SM > 50% @1.5*TeV

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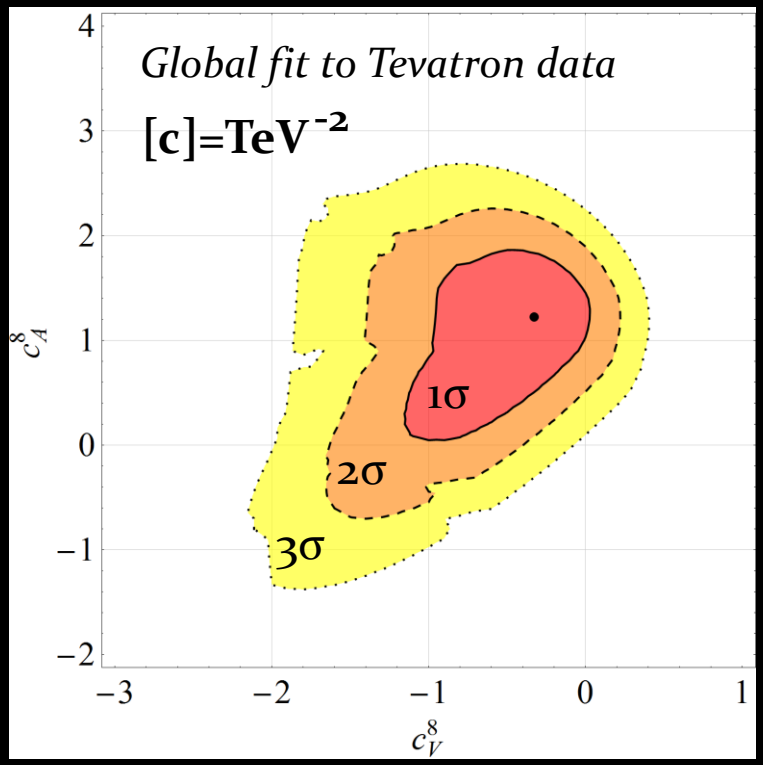
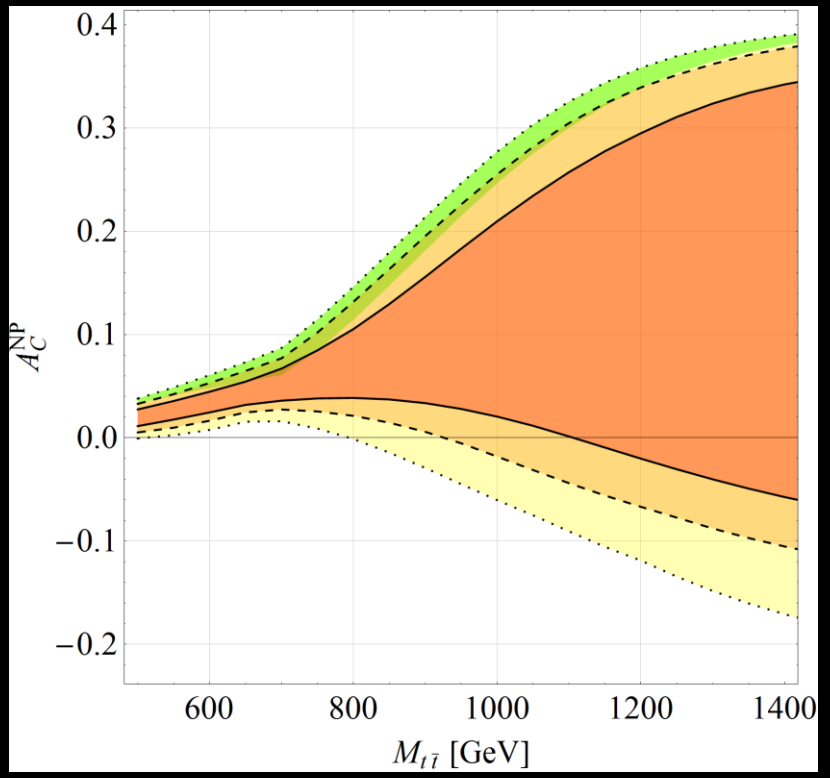


updates of Delaunay et al. '11

implications for A_C @LHC



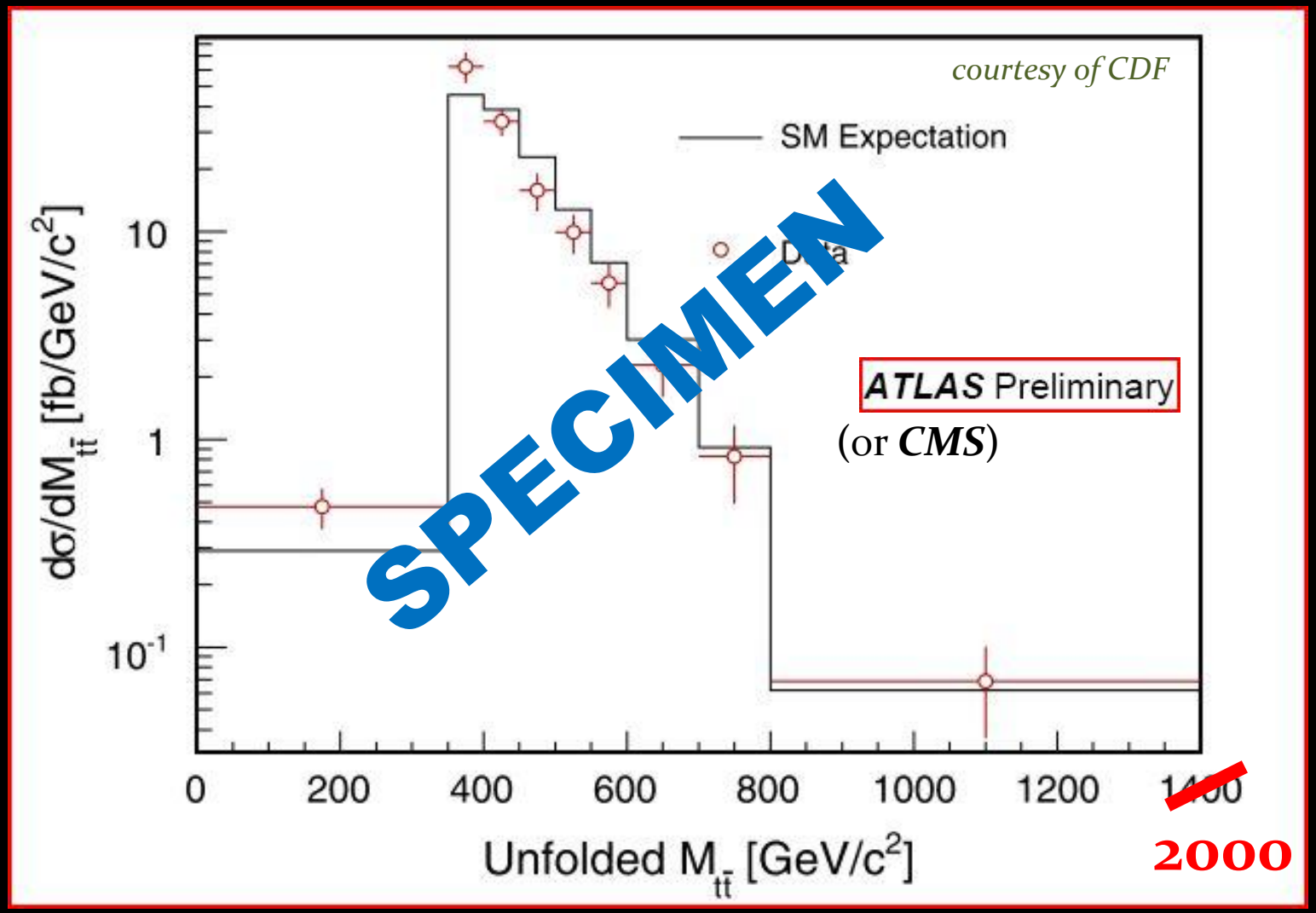
Conclusions

- reg' tt-bar, LHC has stepped into the TeV territory!

- however, most theory motivated models involve either
  - heavier (3-5 TeV) narrow resonances
    e.g. anarchic RS, composite higgs
  - light (1-2 TeV) but much broader resonances
    e.g. alternative RS scenarios
  - light but t-channel exchanged
    e.g. models for the top A_{FB}

- need to add both width/interference effects in the searches

Conclusions

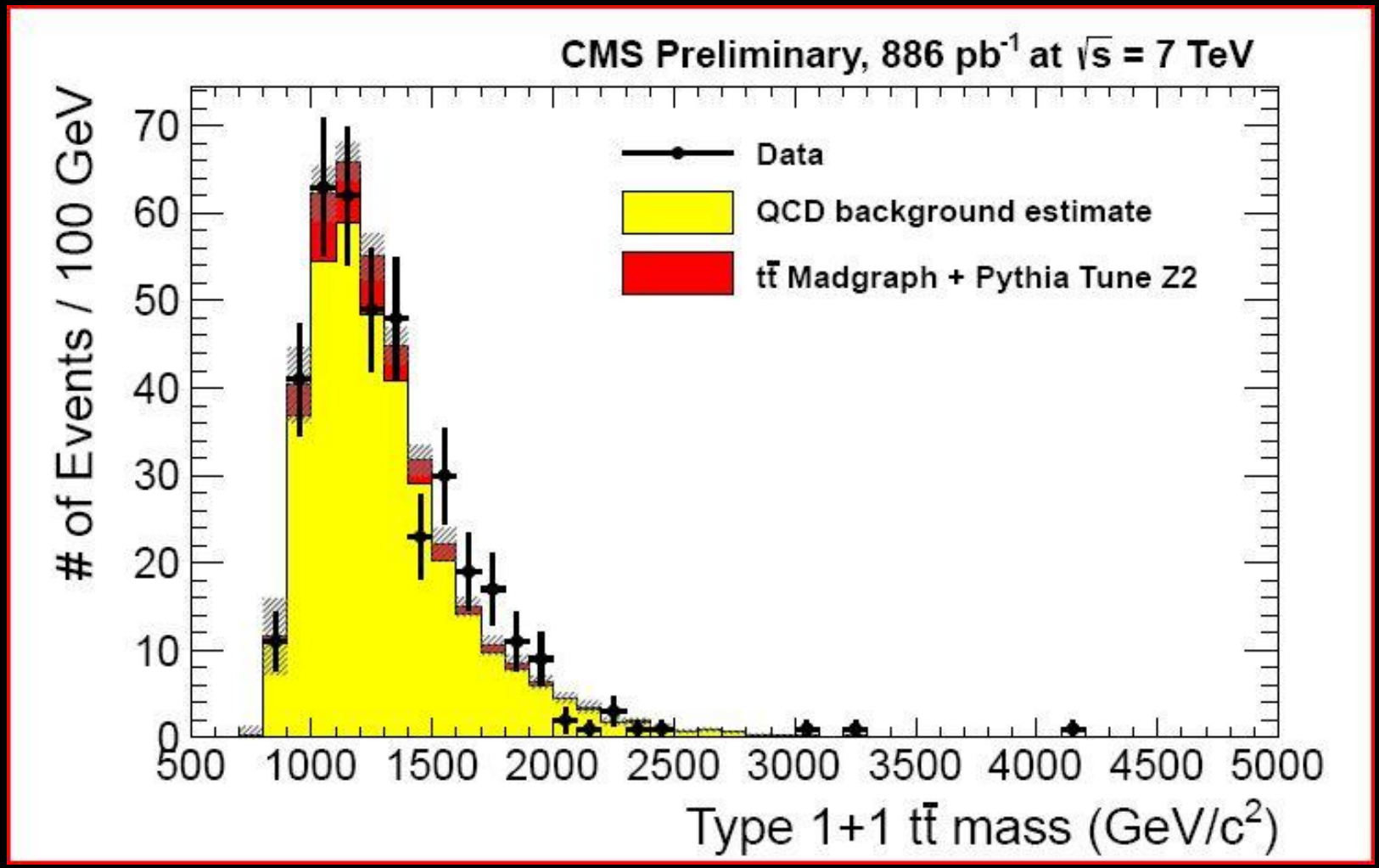


Thank you!

more anything?

using boosted techniques:

CMS-PAS-EXO-11-006



no evidence for NP there…

…but can we really trust the BG estimation, and the shape?

- effective operators relevant to $qq \to tt$ transitions @high m_{tt}

above 450GeV, $q \approx u$ (dd/uu≈20%, which we neglect here)

non SM-like NLO corrections also neglected *(this is pQCD after all)*

$o(\Lambda^2)$:

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

interfere w/ SM
gluon production

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

don't interfere w/ SM

$$\mathcal{O}_S^{1,8} = (\bar{u}\,T_{1,8}u)\,(\bar{t}\,T_{1,8}t)\,, \qquad \mathcal{O}_P^{1,8} = (\bar{u}\,T_{1,8}\gamma^5 u)\,(\bar{t}\,T_{1,8}\gamma^5 t)\,,$$
$$\mathcal{O}_{SP}^{1,8} = i\,(\bar{u}\,T_{1,8}u)\,(\bar{t}\,T_{1,8}\gamma^5 t)\,, \qquad \mathcal{O}_{PS}^{1,8} = i\,(\bar{u}\,T_{1,8}\gamma^5 u)\,(\bar{t}\,T_{1,8}t)\,,$$
$$\mathcal{O}_T^{1,8} = (\bar{u}\,T_{1,8}\sigma^{\mu\nu}u)\,(\bar{t}\,T_{1,8}\sigma_{\mu\nu}t)\,,$$

$o(\Lambda^4)$: none (if NP couplings to qq/tt are *strong*)

(in the perturbative sense, see later)