# *Top $A_{FB}$ @Tevatron from non-resonant new physics*

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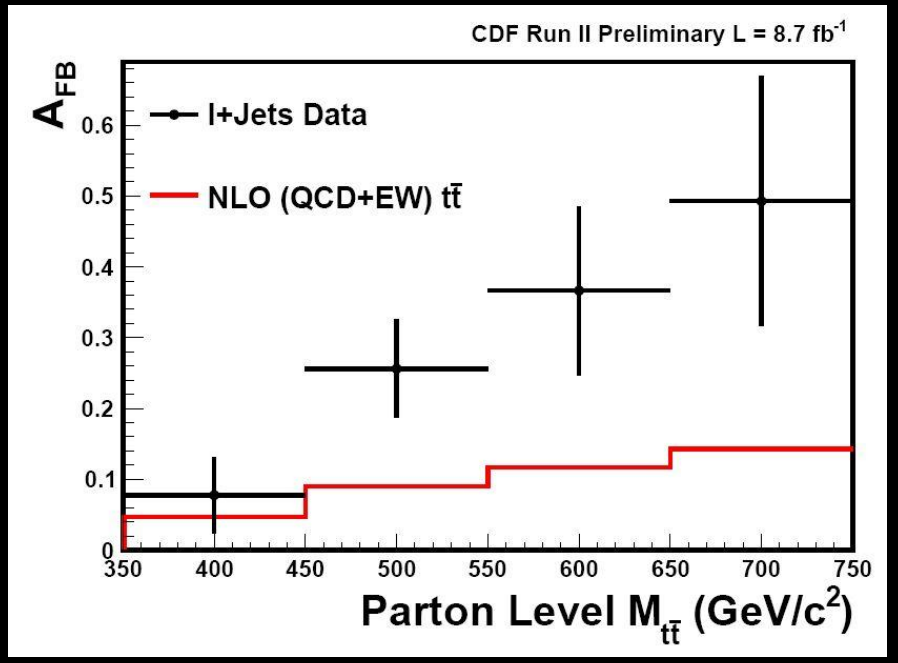
**JHEP 1108 (2011) 031**
**Phys.Lett. B703 (2011) 486-490**
***+ work in progress***
*in collaboration w/ K. Blum, O. Gedalia, S.J. Lee, G. Perez, Y. Nir, Y. Hochberg, Y. Soreq, C. Grojean & L. Da Rold*

24th Rencontres de Blois
Blois| 30 May 2012

# *Tevatron facts*

top quarks are produced preferentially along the direction of the incoming proton




CDF+DO results: $A_{FB}^{\text{inclusive}} \approx (18\pm4)\%$ *in ttbar rest frame*

post-Moriond 2012 $A_{FB}^{>450\text{GeV}} \approx (28\pm6)\%$

QCD+EW state of the art: $A_{FB}^{[\text{incl}|>450]} \approx [6.6|10]\% \pm ??$ (NLOx30%?)

see Mitov et al. '12

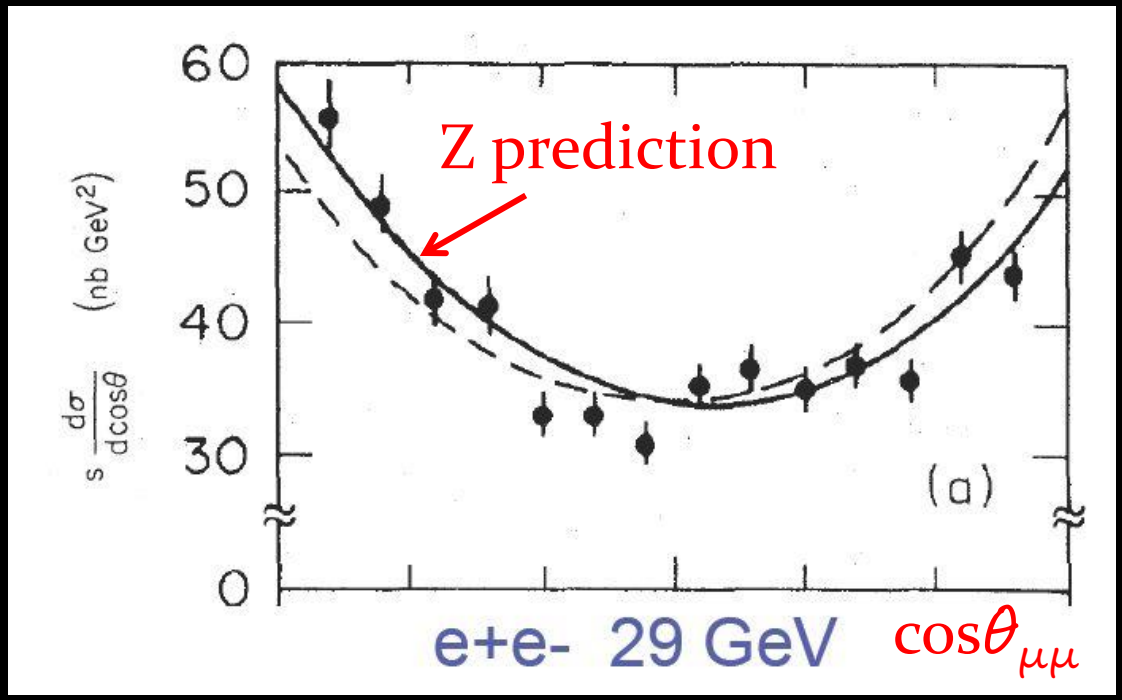
→ ~3σ tension Q: *is it new physics?*

# *Why is this interesting?*

- naturalness: top comes w/ a top sector to soften the UV sensitivity of $m_H$

  → deviation from SM in top observables expected

- historically: that's how the Z showed its nose @E<<$m_Z$




- presently the only (possibly) new physics hint @colliders

# *Synopsis*

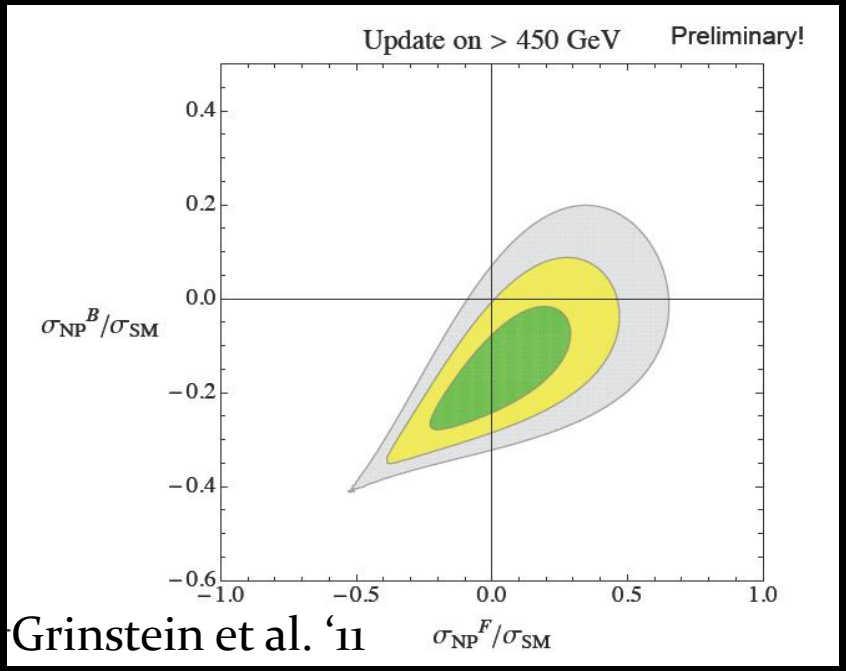
- Let's assume anomalous $A_{FB}$ **is** new physics
- then 2 possibles paths: *light* or **heavy** new physics

**this talk**

- Can large $A_{FB}$ effects be due to non-resonant NP?
  → generic lessons from Effective Field Theory
  → EFT implications for the LHC

- What $A_{FB}$ has to say about naturalness?
  → SUSY: possible via top from stop decays [Kamenik & Isodori '11]
  *or* RPV couplings [Allanach & Sridhar '12]
  → Warped extra-dimension (4D strong dynamics):
  needs to deviate from the anarchic flavor paradigm

**(maybe not) this talk**




Grinstein et al. '11

model independently,
NP should interfere w/ QCD

*Model independent lessons from Effective Field Theory*

# *EFT from top pair production*

see *e.g. Degrande et al. '10* for an SU2 invariant basis

operators relevant to $q\bar{q} \to t\bar{t}$ transition @high $m_{tt}$

above 450GeV $q \simeq u$ since $d\bar{d}/u\bar{u} \lesssim 20\%$

**[$\mathcal{O}$]=6:**

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

*interfere w/ SM gluon exchange production*

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

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

*don't interfere w/ SM*

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

**[$\mathcal{O}$]=8:** only derivative operators, whose effects are *parametrically* less important than $(\text{dim6})^2$ if NP couplings to u/t are *strong-ish* *(NDA rules)*

# *First EFT lessons*

*Blum, CD, Gedalia, Hochberg, Lee, Nir,Perez & Soreq '11*
*CD, Gedalia, Hochberg, Perez & Soreq '11*

interference effects $\mathcal{O}(\alpha_s/\Lambda^2)$ dominates

accomodating $A_{FB}^{>450} \simeq 28\%$ requires $c_A^8 \sim \frac{1}{\mathrm{TeV}^2}$

we learn that:

- NP couplings to up & top are sizable
- but still perturbative $\Lambda_{\mathrm{NDA}} \sim 4\pi \times \mathrm{TeV} \sim 10\,\mathrm{TeV}$
- pure NP effects $\mathcal{O}(1/\Lambda^4)$ are non-negligible

- NP couplings are not flavor universal

dijet searches contrain $g_{up}/g_{top} \sim 1/16$

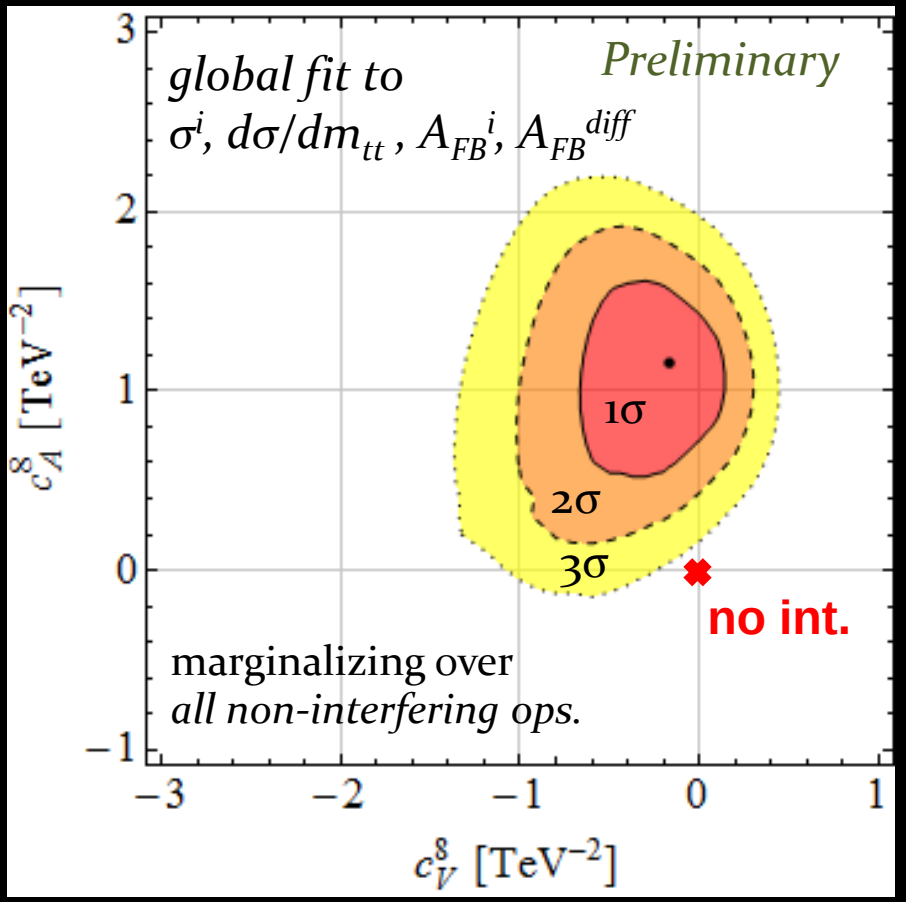
→ large flavor hierarchy

# *Combining Tevatron data*

Let's fit the EFT parameters to Tevatron data

CD, Gedalia, Hochberg & Soreq – to appear

→ no interference with QCD
(~via axial/octet operator)
is in ~3σ tension
*(strong constraint from $d\sigma/dm_{tt}$)*



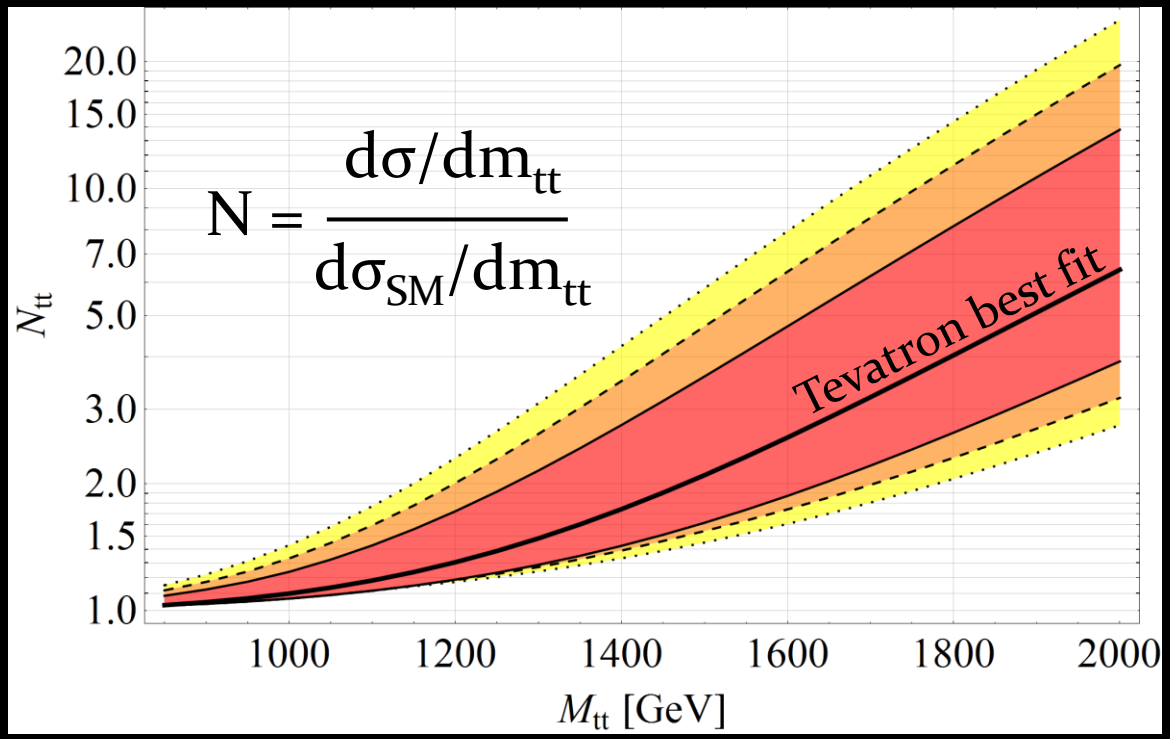

→ not much freedom from (yet many) non-interfering operators *(again strongly constrained by $d\sigma/dm_{tt}$)*

# *EFT implications for LHC: ttbar spectrum*

- LHC higher energies should unveil the hard NP for $A_{FB}$
- But ttbar @LHC is gluon fusion dominated → unclear
- more sensitivity to qqbar at high $M_{tt}$

→ EFT leaves a visible imprint ttbar spectrum tail

*CD, Gedalia, Hochberg, Perez & Soreq '11*



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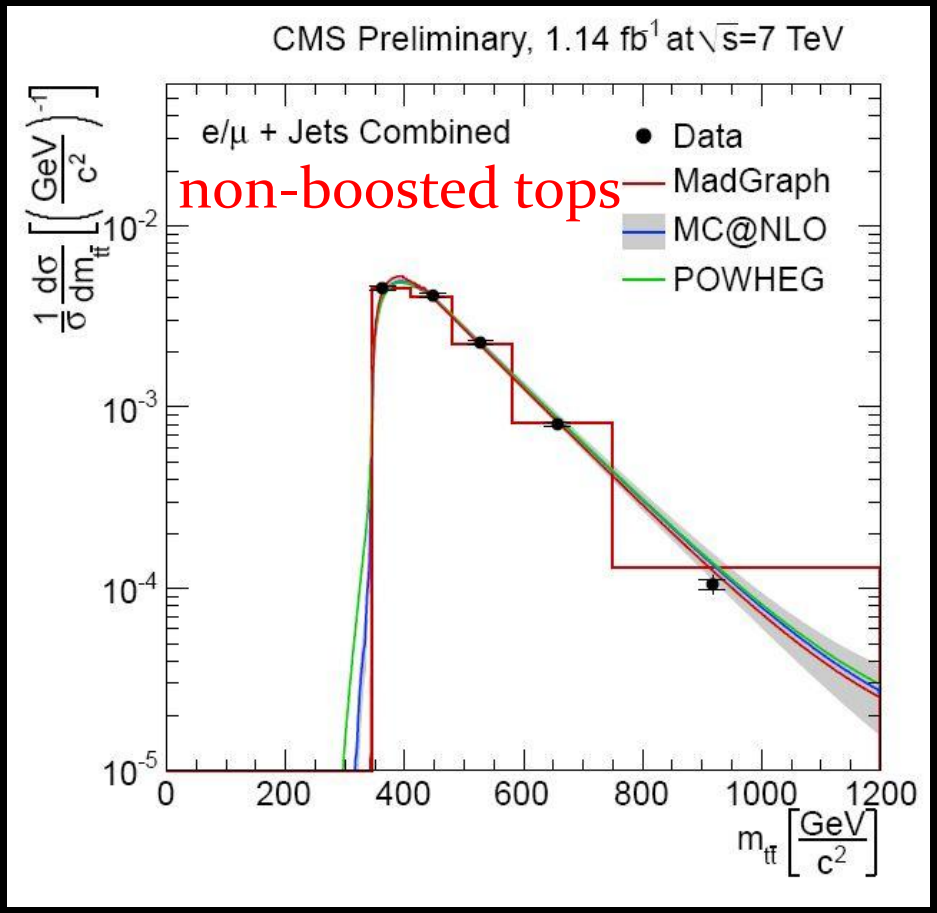
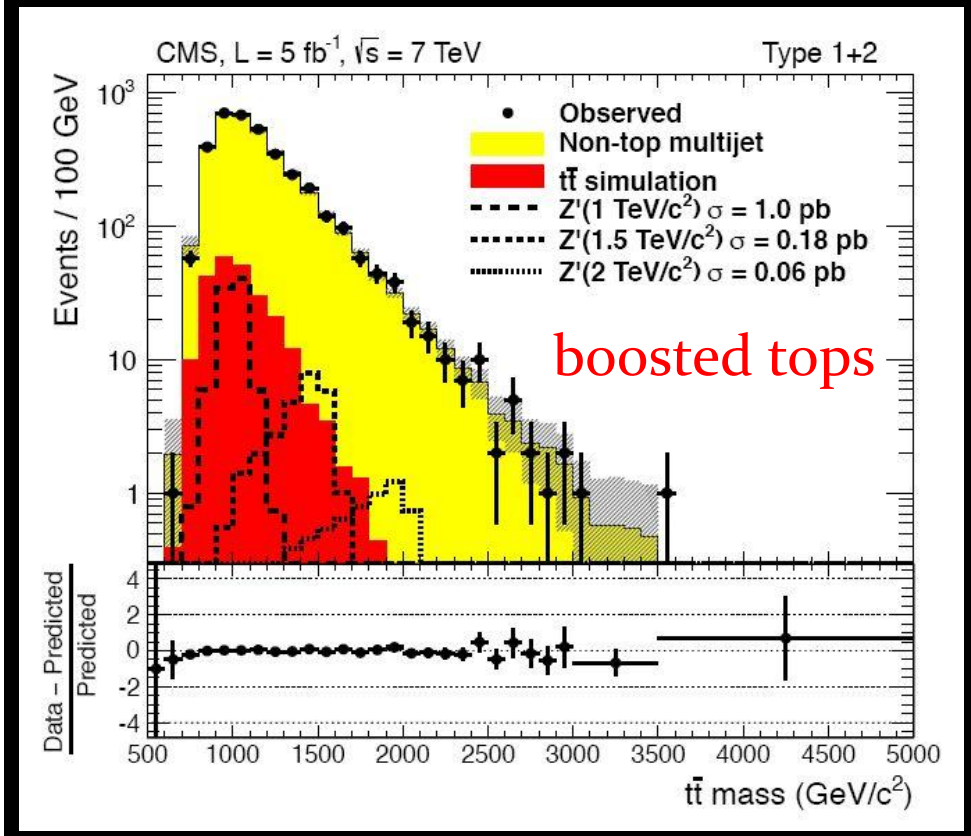



bkg not substracted, not unfolded
→ good for resonance search

presently no measurement of the ttbar spectrum >800GeV

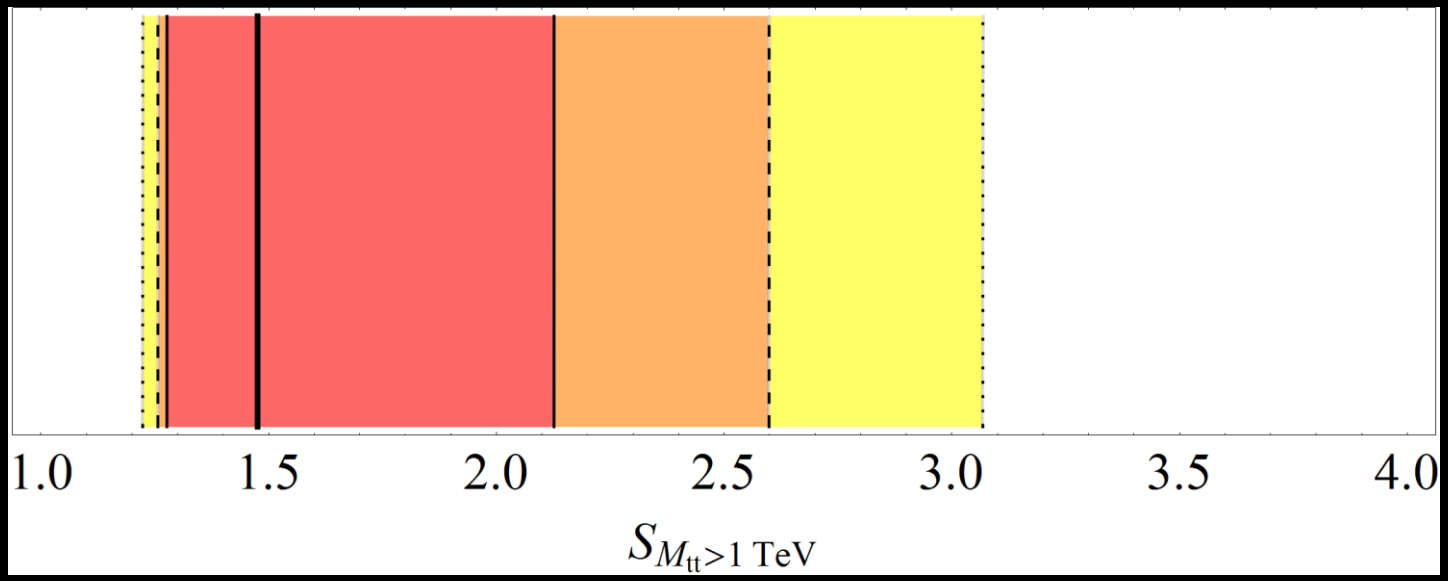
# *EFT implications for LHC: ttbar spectrum*

CMS bound on the integrated ttbar tail above 1TeV:

arxiv:1204.2488

$$\mathcal{S} = \frac{\int_{m_{t\bar{t}}>1\,\mathrm{TeV}/c^2} \frac{d\sigma_{SM+NP}}{dm_{t\bar{t}}} dm_{t\bar{t}}}{\int_{m_{t\bar{t}}>1\,\mathrm{TeV}/c^2} \frac{d\sigma_{SM}}{dm_{t\bar{t}}} dm_{t\bar{t}}}$$

< 2.6 @95%CL



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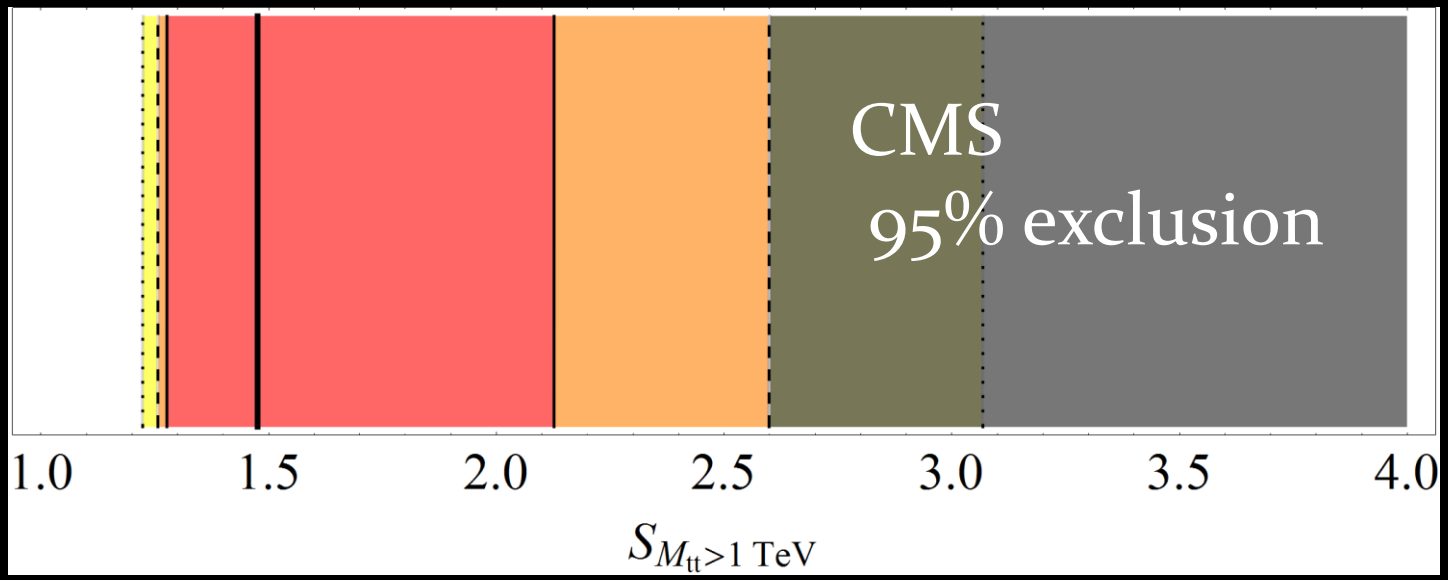


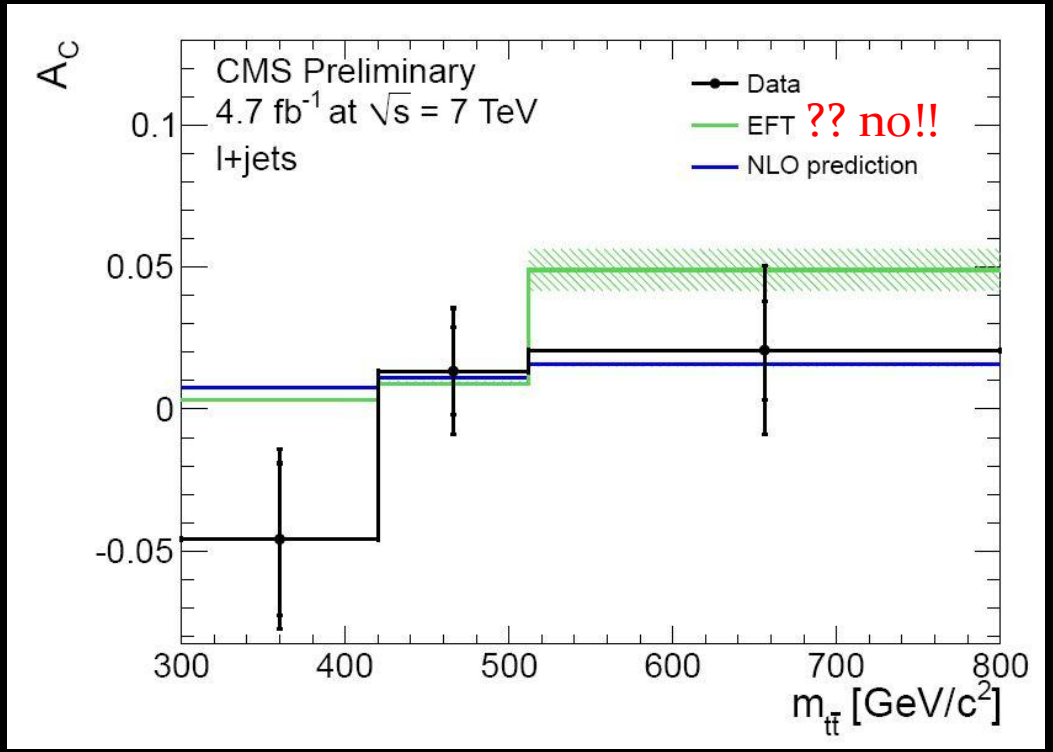
# *EFT implications for LHC: charge asymmetry*

@pp coll. no $A_{FB}$, but $A_C$! though suppressed by gg fusion @LHC

$A_C^{\text{inclusive}} \approx (0.4 \pm 1[\text{stat}] \pm 1.2[\text{syst}])\%$ CMS (4.7/fb)
$A_C^{\text{inclusive}} \approx (-1.8 \pm 2.8[\text{stat}] \pm 2.3[\text{syst}])\%$ ATLAS (1.04/fb)

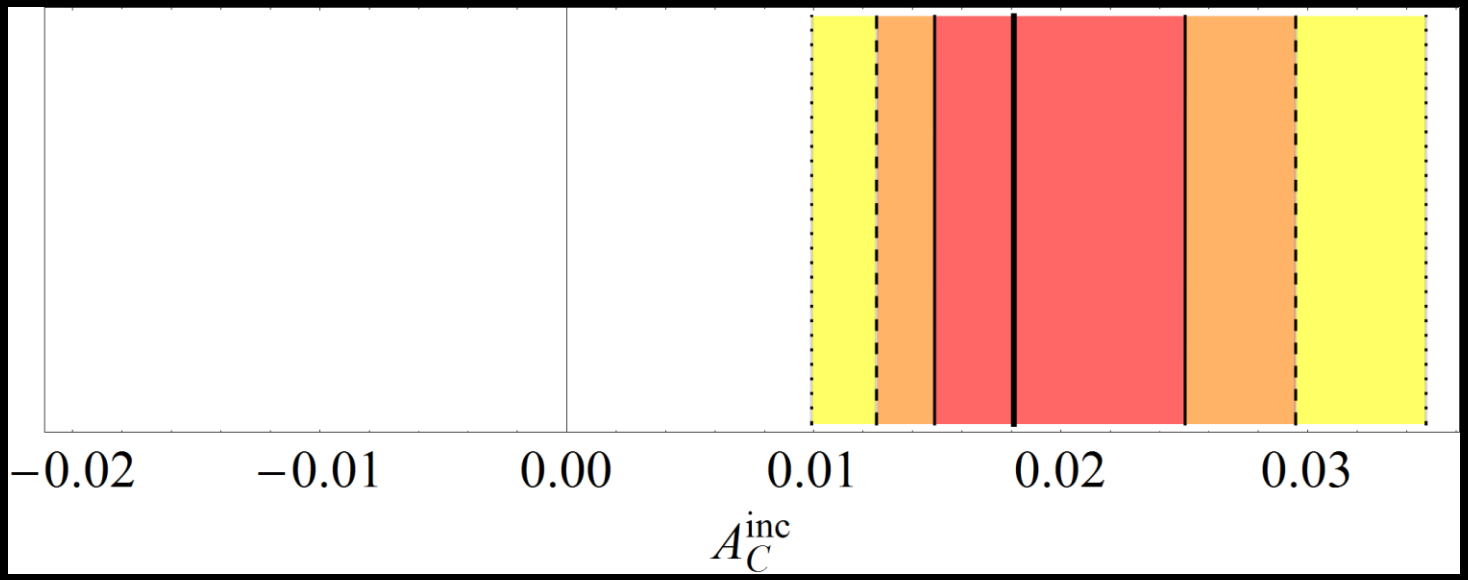
QCD $A_C^{\text{inclusive}} \approx 0.6\%$

→ consistent with QCD
but large uncertainties...
...hard to interpret



# *EFT implications for LHC: charge asymmetry*

- inclusive $A_C$ prediction:



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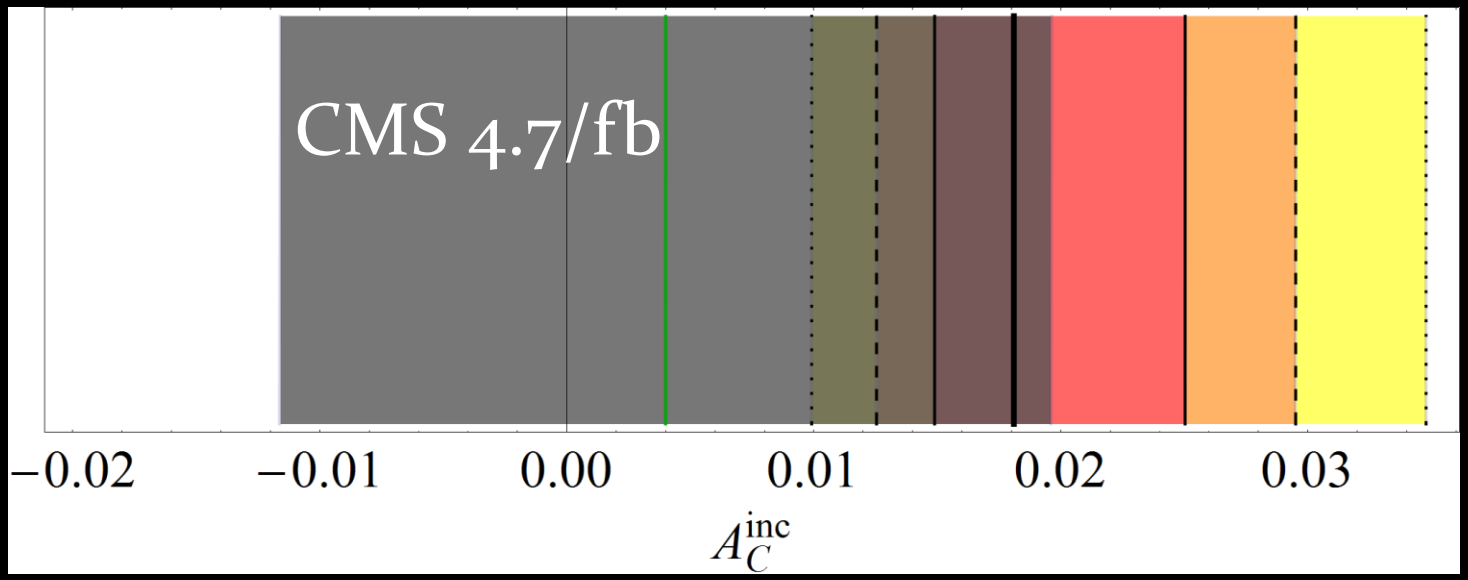
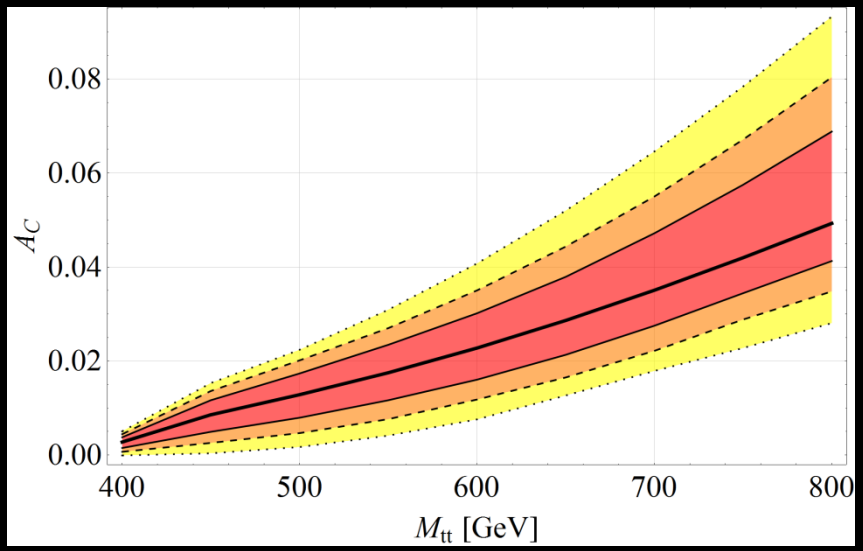
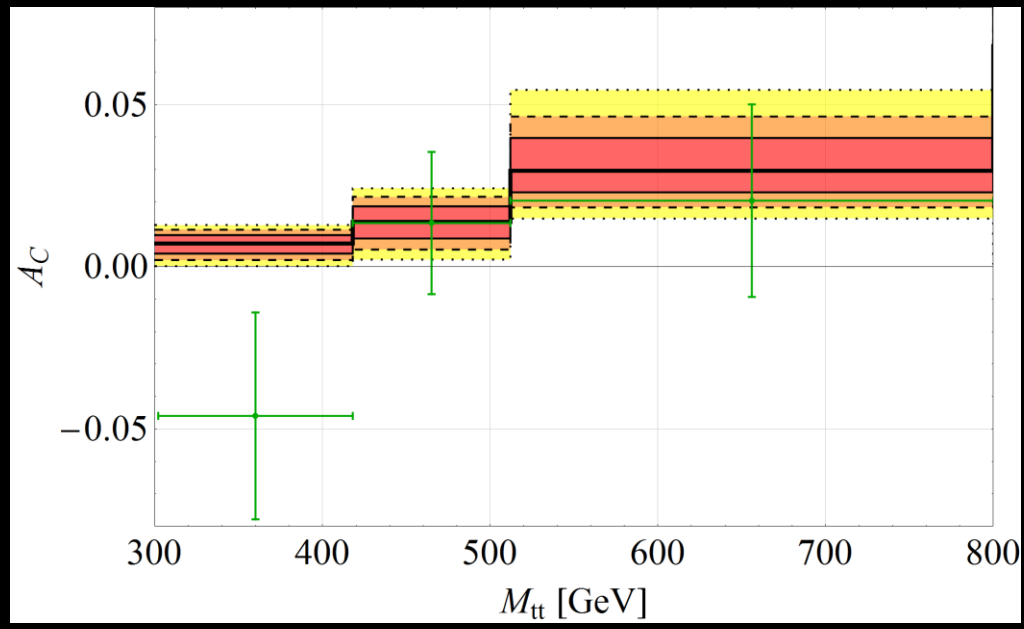


# *EFT implications for LHC: charge asymmetry*

- differential $A_C$ → more sensitivity to EFT




→Tevatron $A_{FB}$ from EFT predicts *positive* $A_C$ @LHC

→LHC7 measurements *are consistent* with Tevatron

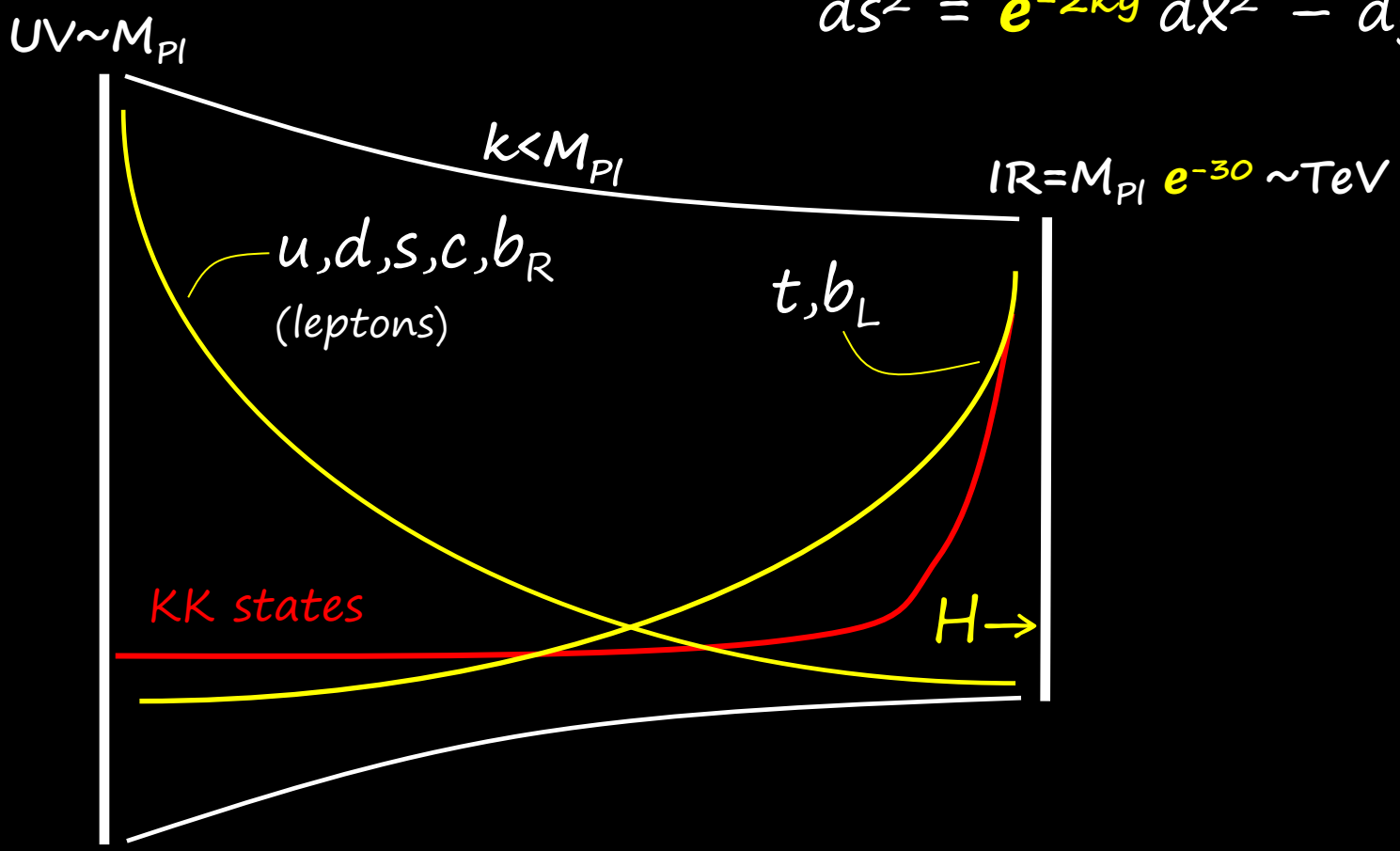
→2012 data should settle the case

*Towards a natural model for $A_{FB}$ from strong dynamics*

# *Warped/composite essentials*

**RS'99:** «Hierarchy problem is solved in AdS5 bckg»

$ds^2 = e^{-2ky} dx^2 - dy^2$




main player @ hadron collider = ~3TeV KK-gluon
light SM quarks are elementary

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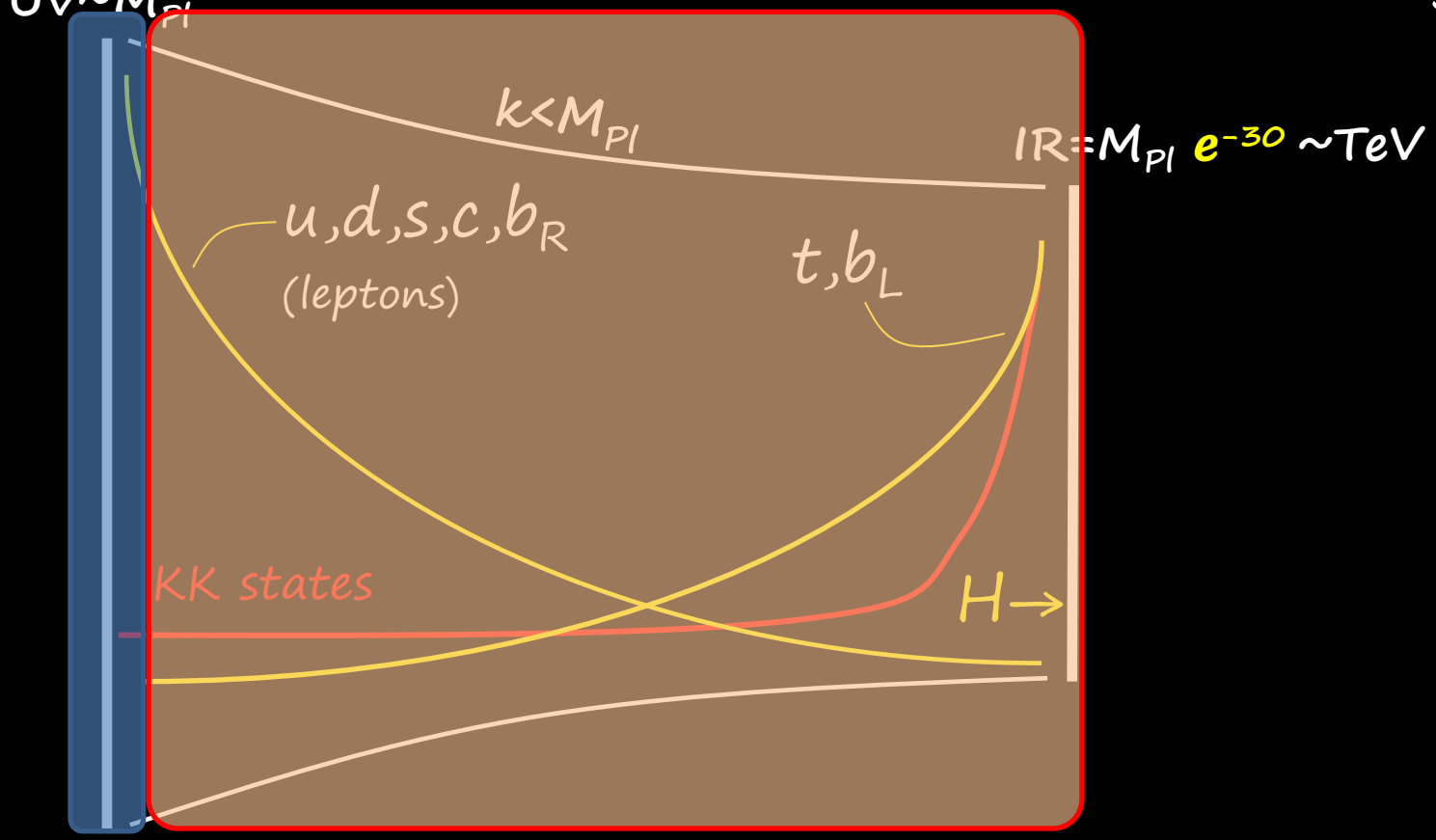



4D dual

elementary sector

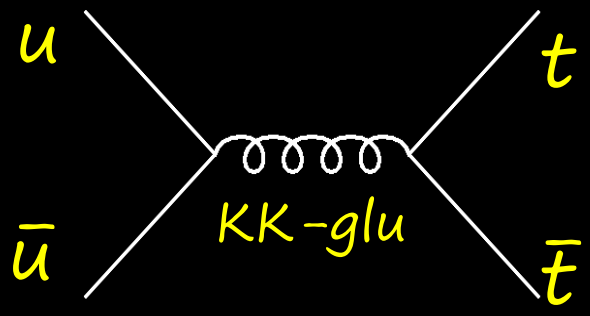
← linear mixing →

strong sector

# $A_{FB}$ from strong dynamics near the TeV scale

EFT → we need $1/\text{TeV}^2$ axial color octet 4F operator

leading contribution from




- 5D flavor anarchy → up is ~elementary →suppressed (+vector-like) KK-gluon production → no $A_{FB}$!
- way out? increase up compositeness (EWPT → $u_R$)

  yet only RL operator induced → $d\sigma/dM_{tt}$ distorded

  + up coupling further constrained by dijets searches

*e.g. CMS-EXP-11017*

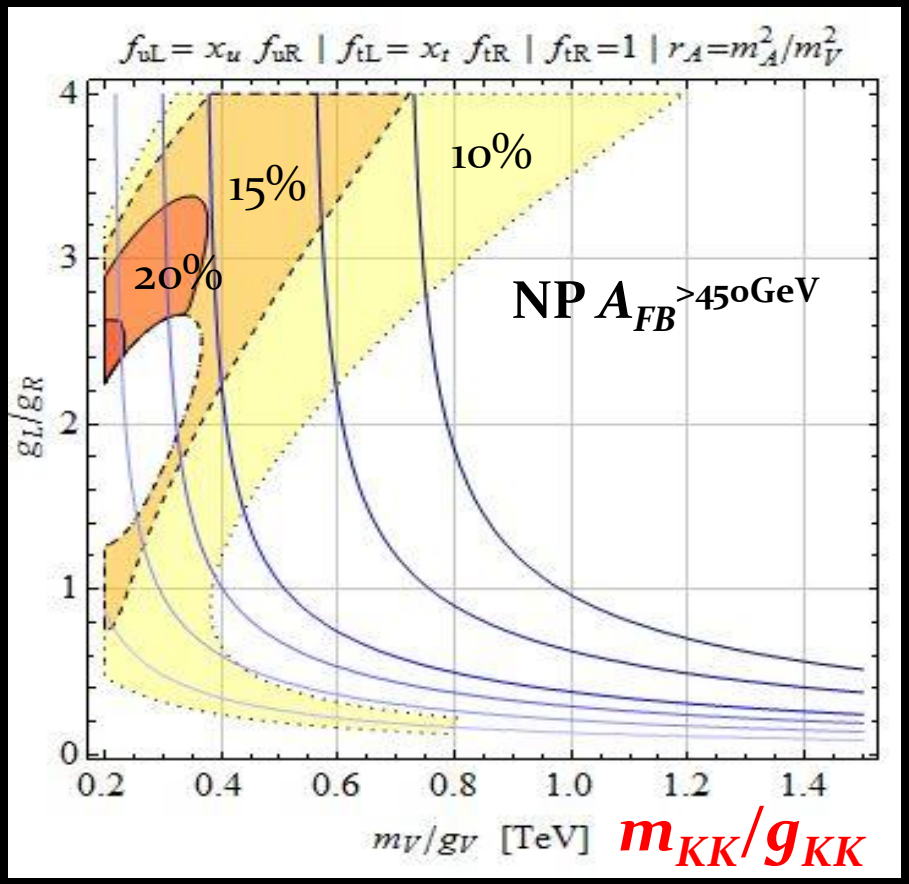
→ $A_{FB}^{>450} < 6\%$

could be enough, but what if not?

# *Larger $A_{FB}$ from strong dynamics?*

- one way is to add an axial resonance
  → color SU3 extended to $SU3_L x SU3_R$ in the bulk
  broken in the IR by $\langle\phi\rangle=(3,3^*)$ to get masses

*Da rold, CD, Grojean & Perez – to appear*




total $A_{FB}$~25%
above 450GeV

consistent w/
ttbar cross section
& dijet constraint

prediction:
dijets around the corner !

# *Conclusions*

- heavy $\mathcal{O}$(few TeV) new physics is still a viable explanation of the Tevatron $A_{FB}$ after LHC7

- two *generic* predictions @LHC:
  → enhancement of the ttbar (boosted!) tail
  → positive $A_C$ growing w/ $M_{tt}$
  2012 data should see any of them

- interesting interplay between $A_{FB}$ & naturalness
  *qualitative* lessons to TeV-scale strong dynamics:
  → RH light quark are ~composite *(charm CPV supported)*
  → dijets expected right around the corner
  observable in 2012 as well