Top A_{FB} from new physics: implications of a hard scale

Cédric Delaunay
CERN-TH

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+ 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

Top workshop
cern| 3 May 2012

Synopsis

- Combined 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: $A_{FB}^{[\text{inclusive}|>450\text{GeV}]} \approx [6.6|10]\% \pm ??$ (NLOx30%?)
see A. Mitov talk

- If QCD is small, can such large effects be due to heavy (non-resonant) new physics?
  → first lessons from Effective Field Theory
  → EFT implications for the LHC

- What naturalness has to say about A_{FB}?
  → SUSY: ?? (see maybe Kamenik & Isodori '11)
  → warped extra-dimension or 4D strong dynamics: need to deviate from the generic flavor paradigm → **this talk**

Model independent lessons from Effective Field Theory

Leading effective operators

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

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

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

o(Λ^{-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

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

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

don't interfere w/ SM

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

o(Λ^{-4}): derivative operators less important than (dim6)^2

if NP couplings to u/t are *strong-ish*

First EFT lessons

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

- from interference effects $\mathcal{O}(M_{t\bar{t}}^2/\Lambda^2)$

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

  so we learn that:

  - NP couplings to up+top are sizable
  - but still well perturbative $\Lambda_{\mathrm{NDA}} \sim 4\pi \times \mathrm{TeV} \sim 10\,\mathrm{TeV}$

  (+interplay with dijet: $g_{up}/g_{top} \sim 1/16$)

- pure NP effects $\mathcal{O}(M_{t\bar{t}}^4/\Lambda^4)$ could be non-negligible

  all non-interfering operators yield similar effects up to kinematical differences $\propto 4m_{\mathrm{top}}^2/M_{t\bar{t}}^2$ → irrelevant @high energies

  a simple «polar» basis emerges:

$$w_\pm^2 \equiv \frac{1}{2}\left\{\left(c_{VA}^8 \pm c_{AV}^8\right)^2 + \frac{9}{2}\left[\left(c_V^1 \pm c_A^1\right)^2 + \left(c_{VA}^1 \pm c_{AV}^1\right)^2\right]\right\},$$

$$R^2 \equiv w_+^2 + w_-^2\,, \qquad \tan\theta \equiv w_-/w_+\,.$$

  all NP effects are parameterized by only 4 parameters: c_V^8, c_A^8, R, θ

Combining Tevatron data

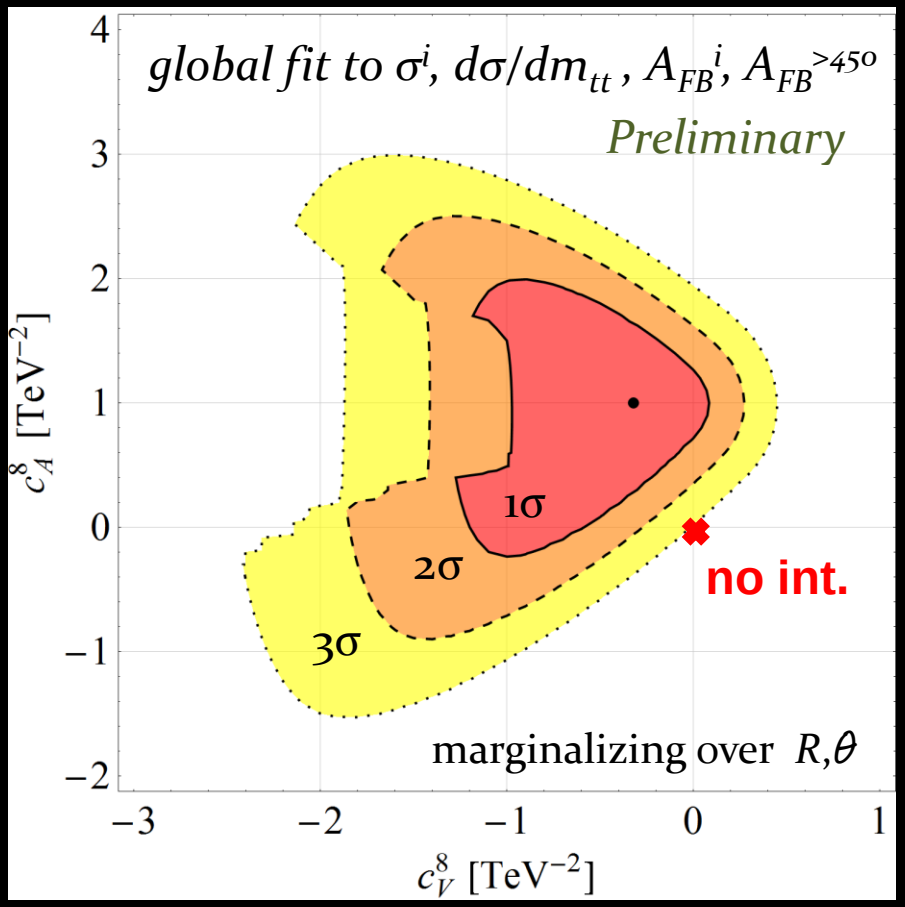
Fitting the EFT parameters to Tevatron data, we learn:

→ no interference with QCD is in ~3σ tension

→ axial-octet operator is only slightly favored (~1σ), no longer necessary (*A_{FB} went down*)

→ chiral new physics couplings are still strongly disfavored (~3σ) (*strong constraint from $d\sigma/dm_{tt}$*)

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



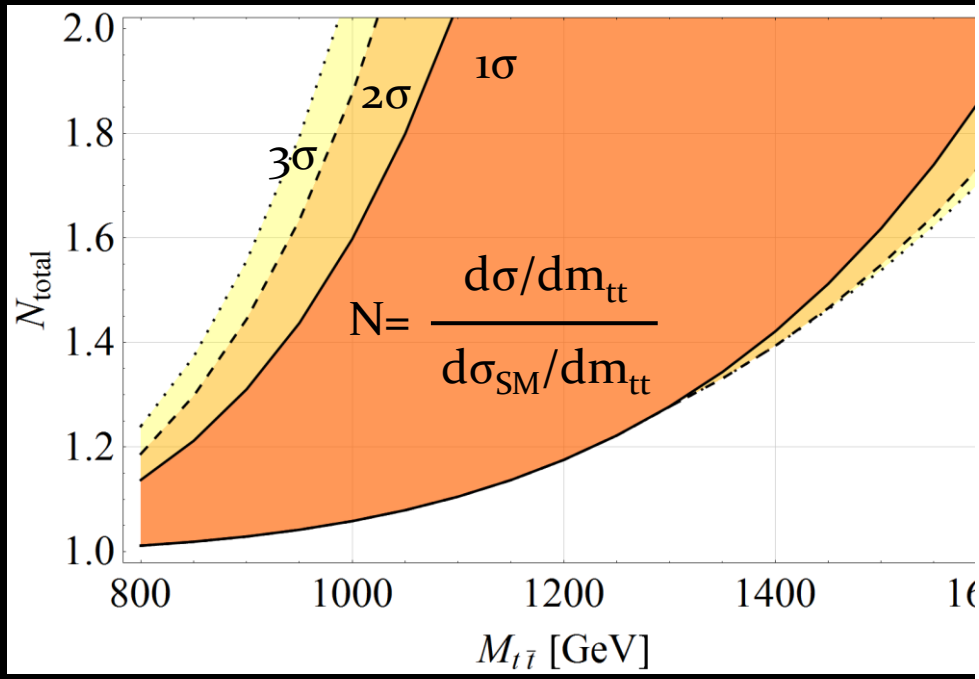
EFT implications for LHC I

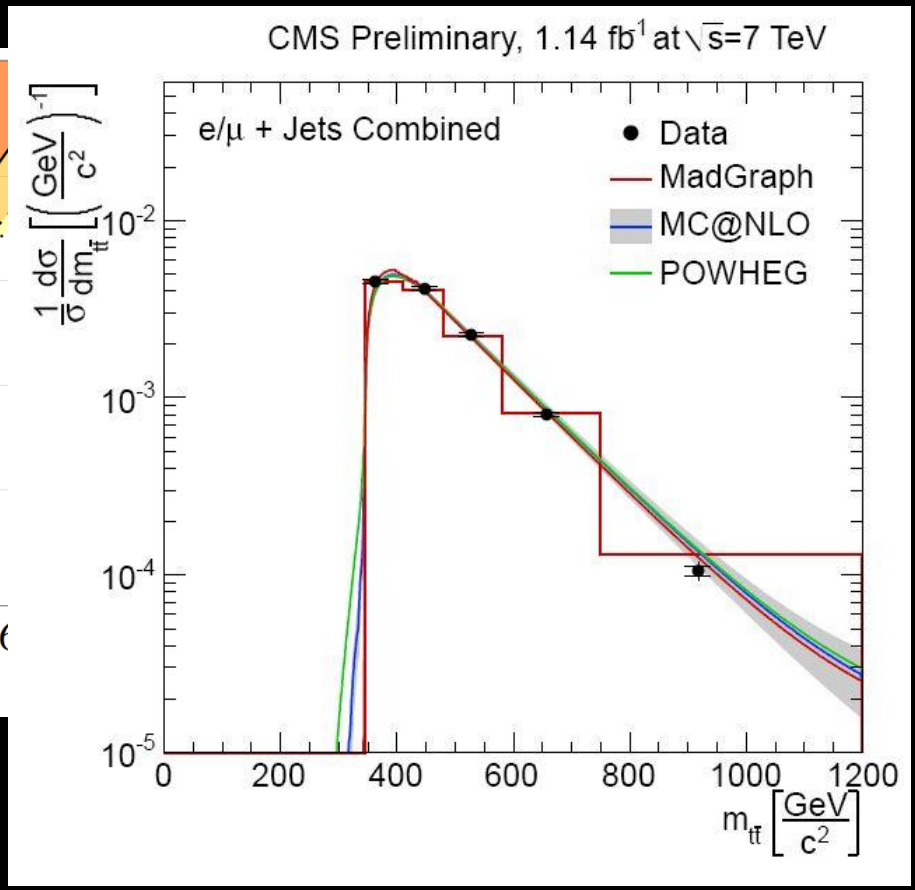
EFT explanation of Tevatron could be non-resonant @LHC

→ visible through enhancement in the ttbar spectrum

CD, Gedalia, Hochberg, Perez & Soreq '11

Predictions from Tevatron fit





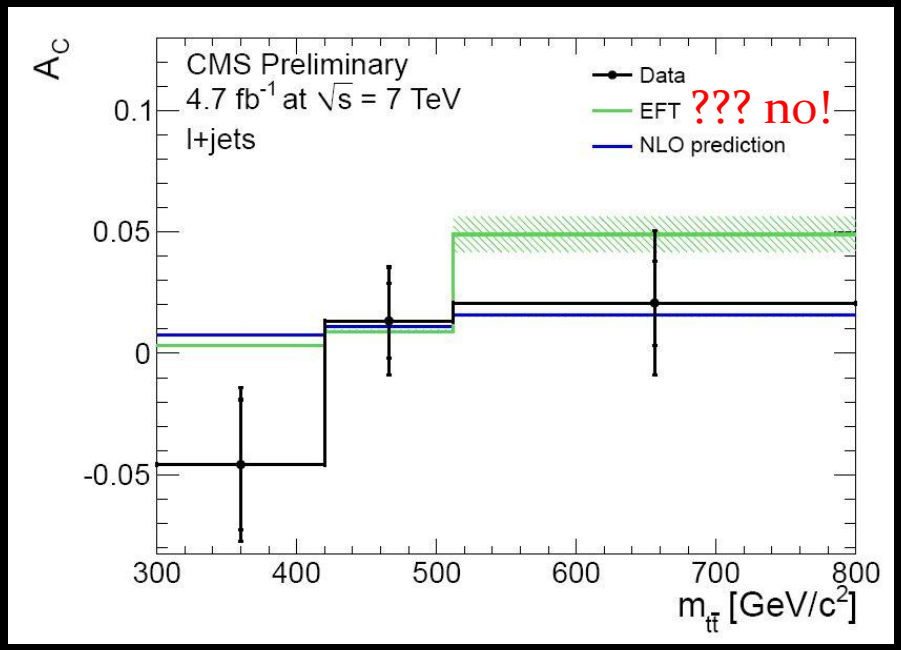
EFT implications for LHC II

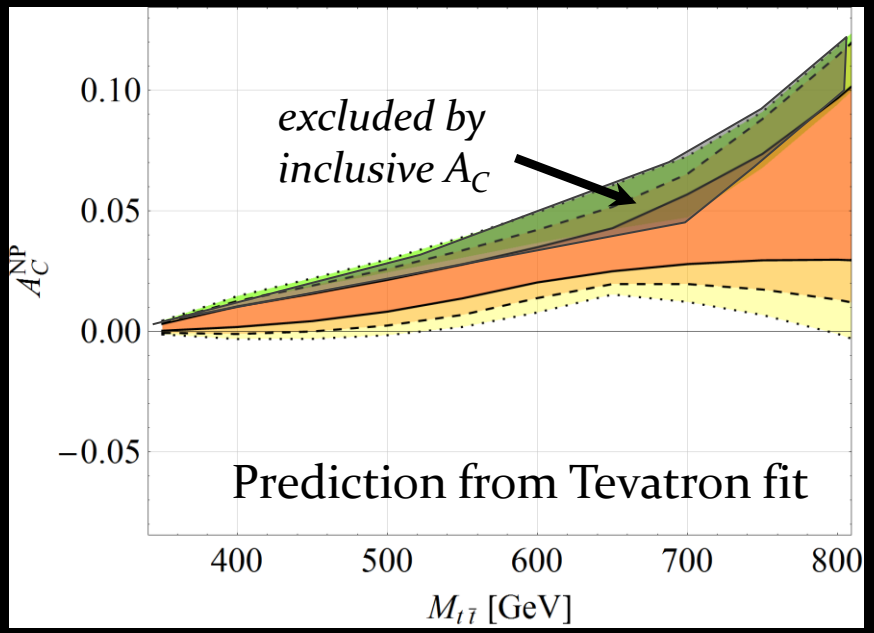
No A_{FB}, but A_C! (though suppressed due to gluon-fusion dominance)

$A_C^{\text{inclusive}} \approx (0.4 \pm 1[\text{stat}] \pm 1.2[\text{syst}])\%$ 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)

→ consistent with QCD but large uncertainties...

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





→ Tevatron A_{FB} + EFT predicts positive A_C @LHC

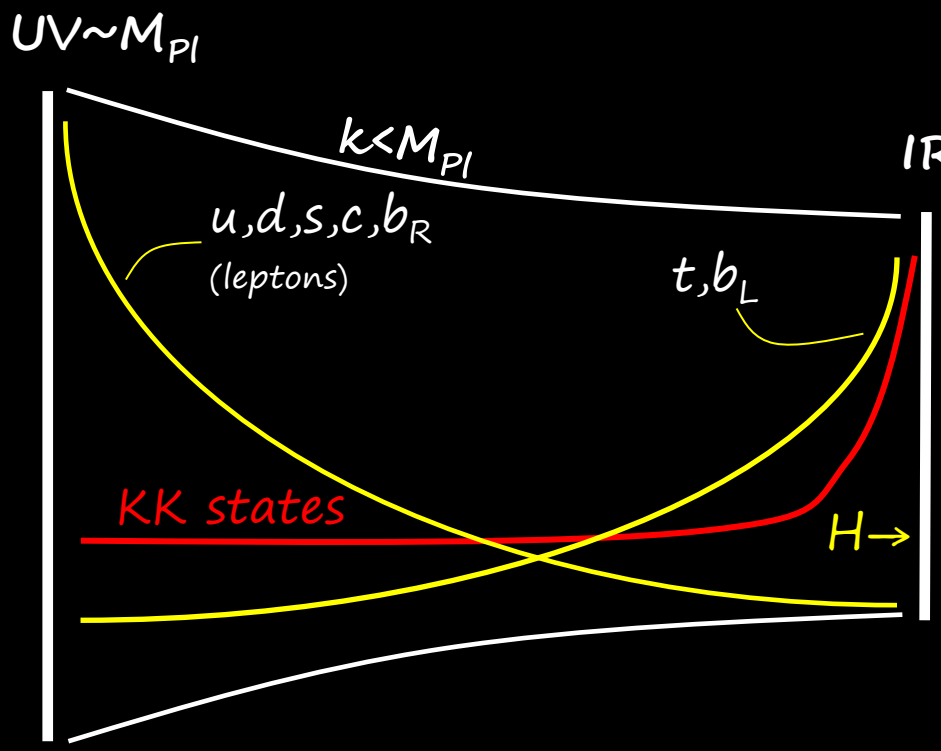
→ present LHC measurements are consistent with Tevatron

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

Warped/composite essentials

RS'99: « Hierarchy problem is solved in AdS$_5$ bckg: $ds^2 = e^{-2ky} dx^2 - dy^2$ »

Flavor anarchy = $Y_{u,d}$ & $C_{Q,u,d}$ are generic, structureless flavor matrices



thanks to color strength couplings
KK-gluon is the main player @ hadron collider

- EWPTs → m_{KK}>3-4TeV
  custodial symmetry @work
- SM flavor puzzle addressed
- NP flavor problem almost solved
  RSGIM @work, yet:

$Im[\epsilon_K]+Im[\epsilon'/\epsilon]$ → m_{KK}>5TeV

- a way out *(supported by Daya bay)*:

down alignment, but up anarchy

Warped essentials

RS'99: « Hierarchy problem is solved in AdS$_5$ bckg: $ds^2 = e^{-2ky} dx^2 - dy^2$ »

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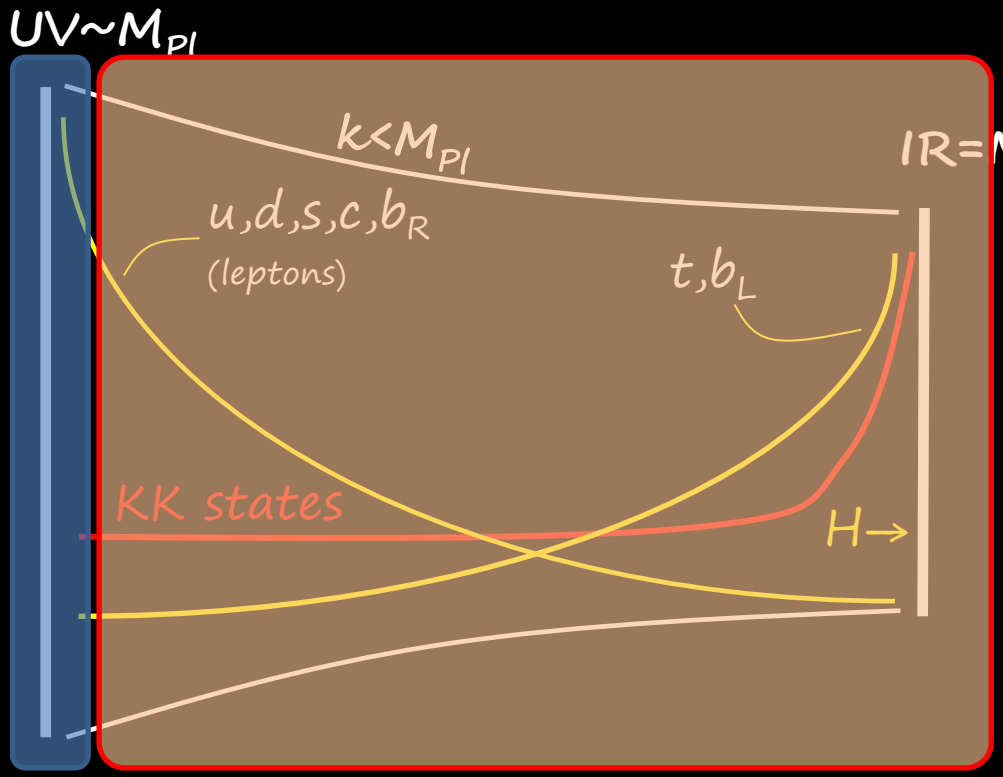
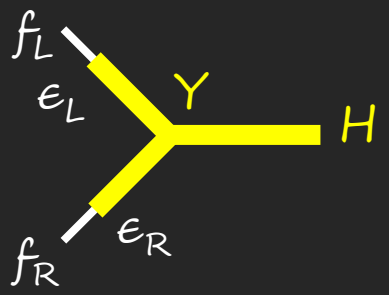


elementary sector ← linear mixing → strong sector

Partial compositeness in 4D:



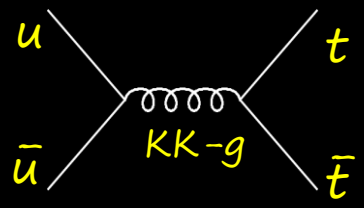
$$Y_{SM} = \epsilon_L Y \epsilon_R$$

→ light quarks are ~elementary

Top A_{FB} from strong dynamics @TeV scale

we need $(\bar{u}u)_A(\bar{t}t)_A$ w/ $\Lambda \approx$ TeV *thanks to EFT study*

leading contribution =



- flavor anarchy: elementary up has suppressed
  & vector-like coupling to KK-g → no AFB!
- simple way out: increase up compositeness (most RH)

concrete models consistent with flavor+LEP: CD, Gedalia, Perez & Ponton '10
Redi & Weiler '11

→ larger AFB possible but from «chiral» KK-gluon:

$(uu)_{V+A}(tt)_{V-A}$ → @interference level: $\delta A_{FB}^{>450} \approx -0.2 \times \delta\sigma_{700-800} < 10\%$

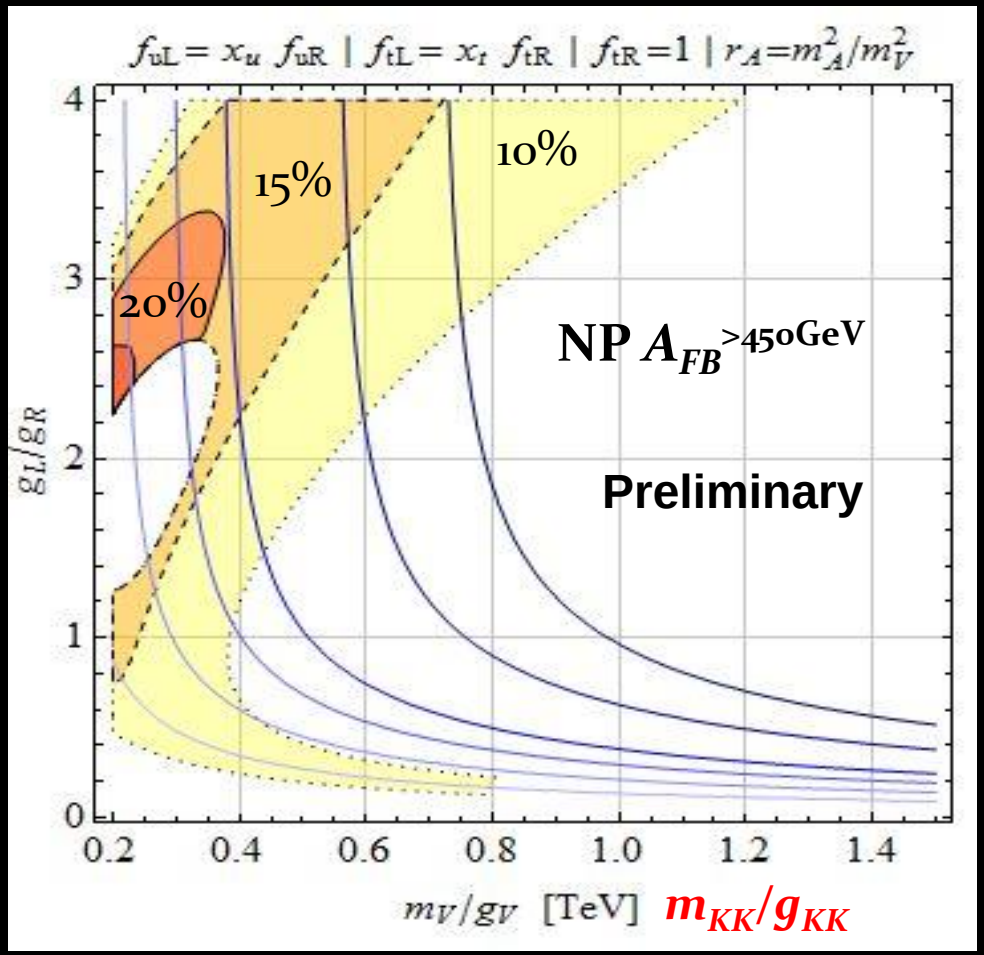
+ dijet constraints: «u_R compositeness scale > 3TeV»
e.g. CMS-EXP-11017

→ max $\delta A_{FB}^{>450} \approx 6\%$ (m_{KK}=3TeV | g_5=7) could be enough...

...but what if larger NP A_{FB} is still required?

Larger A_{FB} from strong dynamics

- color SU3 extended to $SU3_L x SU3_R$ in the bulk
- broken in the IR by $\langle\phi\rangle=(3,3^*)$ to get quark masses
- KK spectrum = vector KK-gluon + axial KK-gluon



Da rold, CD, Grojean & Perez – to appear

possible to achieve a total A_{FB}~25% after 450GeV mass cut

consistently with:

- ttbar cross section
- dijet constraint

but dijets right around the corner !

Conclusions

- main EFT lesson = heavy new physics (above the ~TeV scale) can still be a viable explanation of the Tevatron A_{FB}

- There are two *generic* predictions @LHC:
  → enhancement of the ttbar (boosted!) tail over the SM
  → positive A_C mostly at high energies
  full 2011 + 2012 data should see any of them…

- There is an interesting interplay between A_{FB} & naturalness when the EW scale is stabilized by strong dynamics @TeV:
  → need to increase RH light quark compositeness
  → dijets expected right around the corner
  observable in 2012 as well