The Higgs (125 GeV) in a warped theory of flavor: Physics case for a Gigantic International Hadron Collider

[Hints for the most important questions of the day from a geometric theory of flavor]

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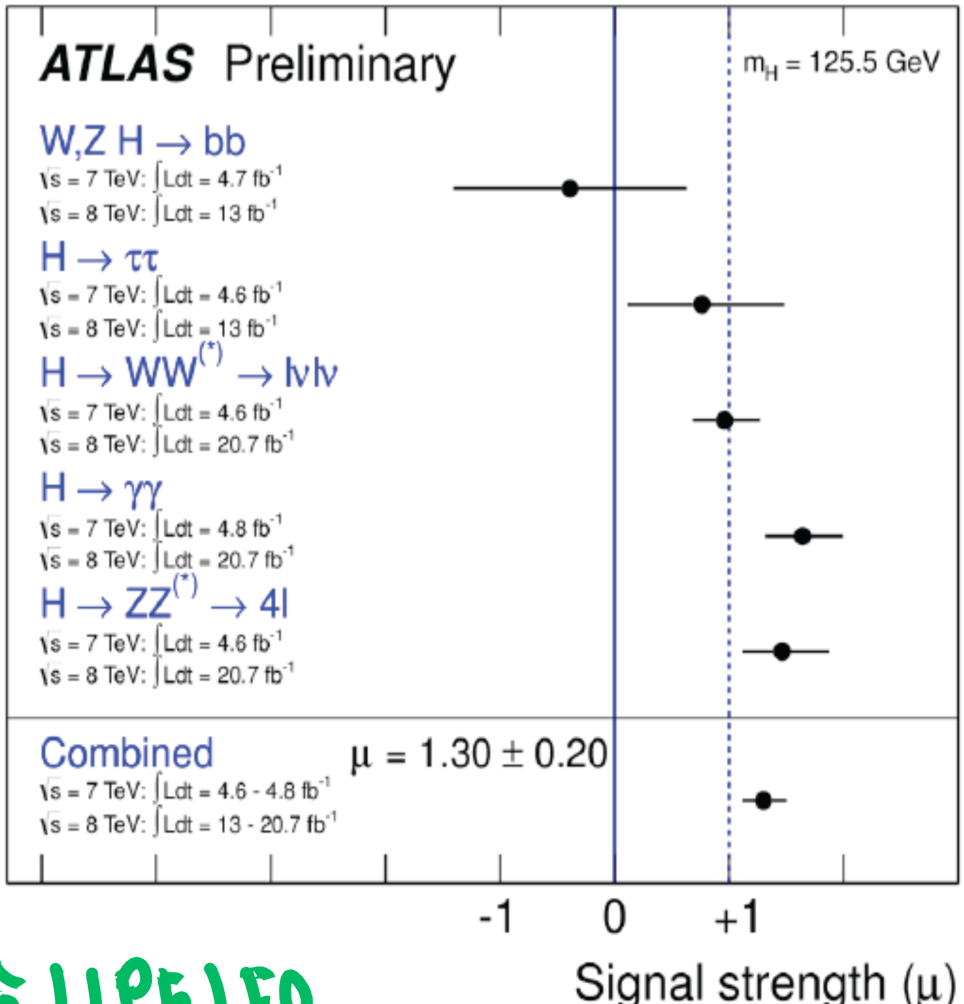
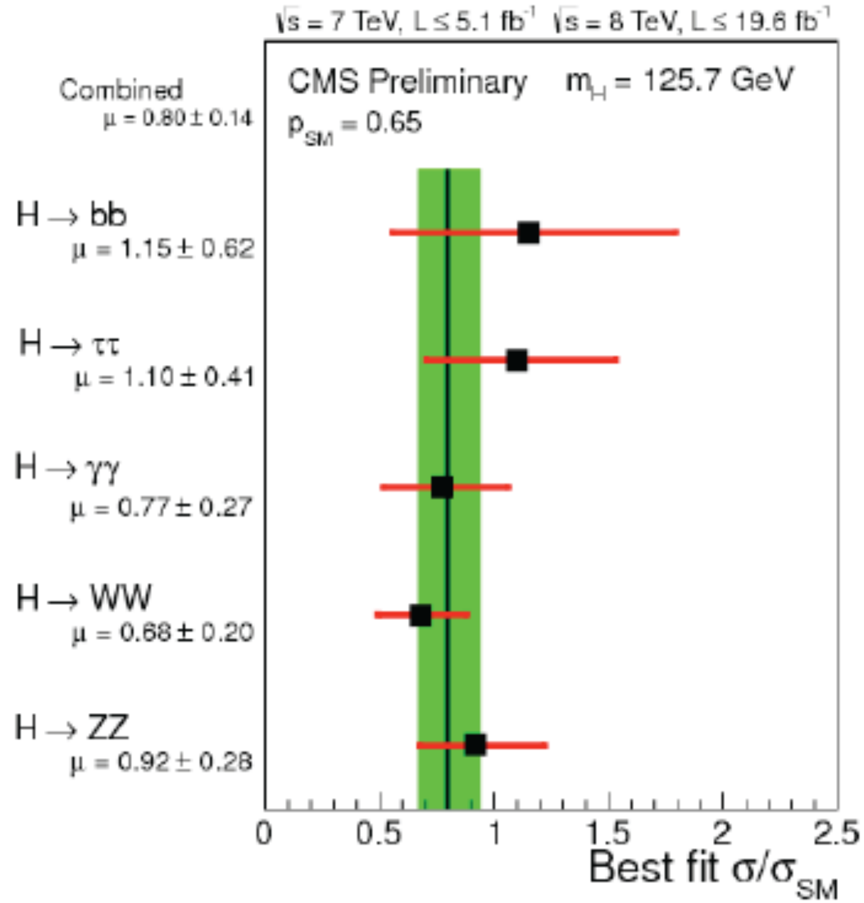
EPS HEP, Stockholm, Sweden, 18th – 24th July 2013

Fits like a glove!   [or does it?]





μ=0.80±0.14

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Is Nature Unnatural?

Decades of confounding experiments have physicists considering a startling possibility: The universe might not make sense.

by: Natalie Wolchover

May 24, 2013

email print

Is the universe natural or do we live in an atypical bubble in a multiverse? Recent results at the Large Hadron Collider have forced many physicists to confront the latter possibility. (Illustration: Giovanni Villadoro)

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Gee, don't see no NP signals

Flavor: Told you so

Higgs is SM-like =>

- Light SM-like Higgs strengthens case for mKK > ~ 10 TeV in warped framework

See Azatov, Toharia, Zhu, arXiv 1006.5939
Goertz, Haisch, Neubert, 1204.0008
Davoudiasl, McElmurry, A. S. 1206.4062

- With mKK> 10 TeV resulting set up is simpler and economical but at LHC only (at best) radion (Higgs-like scalar) possible
- Provides a strong rationale for higher energy hadron collider for direct experimental verification

RS framework provides a compelling simultaneous resolution of weak-planck hierarchy and flavor puzzle via an elegant geometric interpretation but flavor constraints suggest mKK > ~ 10 TeV

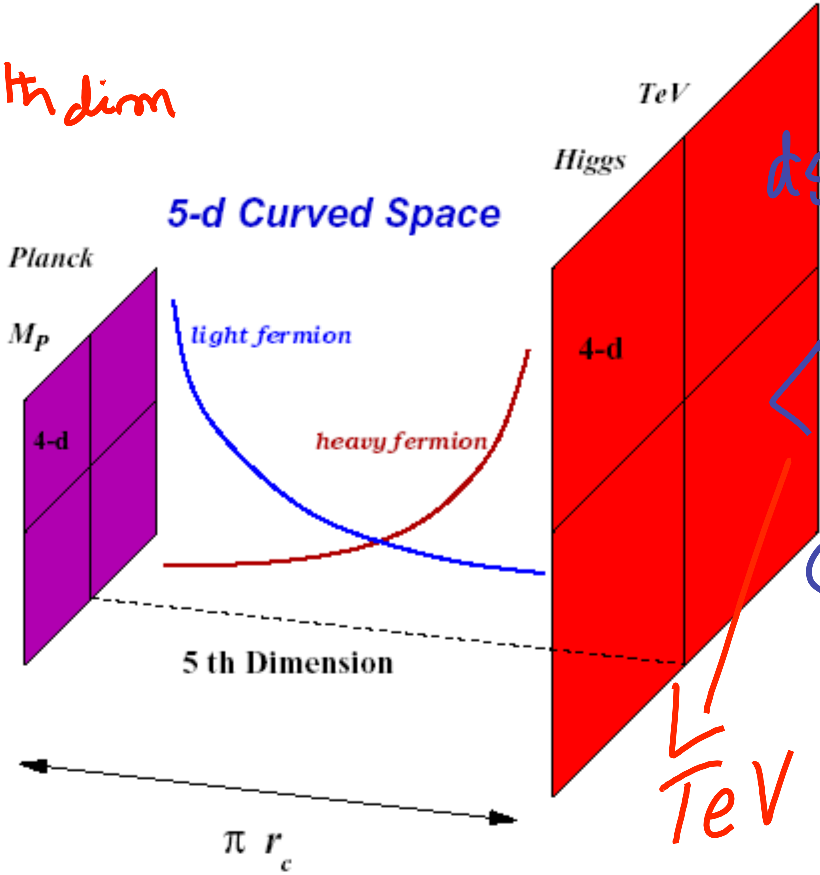
CKM matrix => Flavor alignment is a serious issue; Flavor constraints shouldn't be trifled with

INSIGHTS from a Modern Theory of flavor

RANDALL+SUNDRUM '99

[FIG BY H DAVOUDIASL]

Points along 5th dim correspond to diff. eff. 4d scale!



$$ds^2 = e^{-2\sigma}\eta_{\mu\nu}dx^\mu dx^\nu - r_c^2 d\phi^2$$

$$\langle H_4\rangle = e^{-\sigma}\langle H_5\rangle$$

TeV ← $\langle H_4\rangle$; $\langle H_5\rangle$ → M_P

$$\sigma = k r_c \pi$$

$kr_c\pi \sim 12$

Figure 1: Warped geometry with flavor from fermion localization. The Higgs field resides on the TeV-brane. The size of the extra dimension is $\pi r_c \sim M_P^{-1}$.

Simultaneous resolution to hierarchy and flavor puzzles

Fermion "geography" (localization) naturally explains:

Grossman&Neubert; Gherghetta&Pomarol; Davoudiasl, Hewett & Rizzo

- **Why they are light (or heavy)**
- **FCNC for light quarks are severely suppressed automatically**
- **RS-GIM MECHANISM (Agashe, Perez,AS'04) flavor changing transitions though at the *tree level* (resulting from rotation from interaction to mass basis)are suppressed roughly to the same level as the loop in SM=> CKM hierarchy**
- **O(1) CP ubiquitous;.....nedm, in fact ALL DIR-CP [ε'/ε, γ, ΔACP (B=>Kπ),Δ(Sin2β);S[B=>K* ργ]; ΔACP(D)..] are an exceedingly important path to BSM-phase and new physics**
- **Most flavor violations are driven by the top**

-> ENHANCED t-> cZ(h) ....A VERY IMPORTANT "GENERIC" PREDICTION..Agashe, Perez, AS'06

$\Delta m_K \cdot 10^3$ TeV $\Longrightarrow \sim 10$ TeV

EXTENSIVE RECENT STUDIES by BURAS et al and NEUBERT et al

Agashe, Perez, AS; Assumed $m_{KK} \sim 3$ TeV

VOLUME 93, NUMBER 20 PHYSICAL REVIEW LETTERS week ending 12 NOVEMBER 2004

TABLE I. Contrasting signals from RS1 with the SM.

	Δm_{B_s}	$S_{B_s \to \psi\phi}$	$S_{B_d \to \phi K_s}$	$Br[b \to s l^+ l^-]$	$S_{B_{d,s} \to K^*, \phi\gamma}$	$S_{B_{d,s} \to \rho, K^*\gamma}$
RS1	$\Delta m_{B_s}^{SM}[1 + O(1)]$	$O(1)$	$\sin 2\beta \pm O(0.2)$	$Br^{SM}[1 + O(1)]$	$O(1)$	$O(1)$
SM	$\Delta m_{B_s}^{SM}$	λ_c^2	$\sin 2\beta$	Br^{SM}	$\frac{m_s}{m_b}(\sin 2\beta, \lambda_c^2)$	$\frac{m_d}{m_b}(\lambda_c^2, \sin 2\beta)$

→ Beall, Bander, AS PRL '82

But LR Currents cause conflict with $\Delta m_K, \epsilon_K$

$\Rightarrow m_{KK} \gtrsim 10$ TeV

Above signals all become a lot smaller.

Key messages from a candidate theory of flavor

- **I. In a candidate theory, the gigantic tension between hierarchy and flavor puzzle gets dramatically amieliorated.** ***Thus remarkably RS-leads to lowering of Λ_{flavor} from ~1000 to ~10 TeV***

- **II. O(1) BSM phases occur naturally; => direct CP is an extremely powerful probe of flavor alignment and holds the key to unlocking new physics. For this purpose, fortunately, there are many observables : Nedm; ϵ'/ϵ; γ; ΔSin 2 β from Bd=> eta' Ks, phi Ks, 3 Ks....; ACP(B=>Kπ), S[B=>K^* $\rho\gamma$]; ΔACP(D)**

III. Top quark is very sensitive to flavor violation; t=>c Z; t=> c h, pp => t c h X etc need to be vigorously pursued

IV. Lepton flavor violation is a natural prediction=> Searches for $\tau = \mu\gamma$, 3 μ...; B_s=> τ μ.... are very important.

V. Expected size of corrections to Higgs couplings

- Deviation from SM ~ V^2 / m^2_{KK} < 0.2% !!!
  [assuming m_{KK} > ~ 5 TeV]
- > ~ 10^7 higgs needed to establish.

EXTREMELY small corrections should be a concern for studies at a Higgs factory.

- VI. For direct observation of KK-particles of mass > ~ 10 TeV need a Gigantic International Hadron Collider (GIHC) ~ 100 TeV cm energy

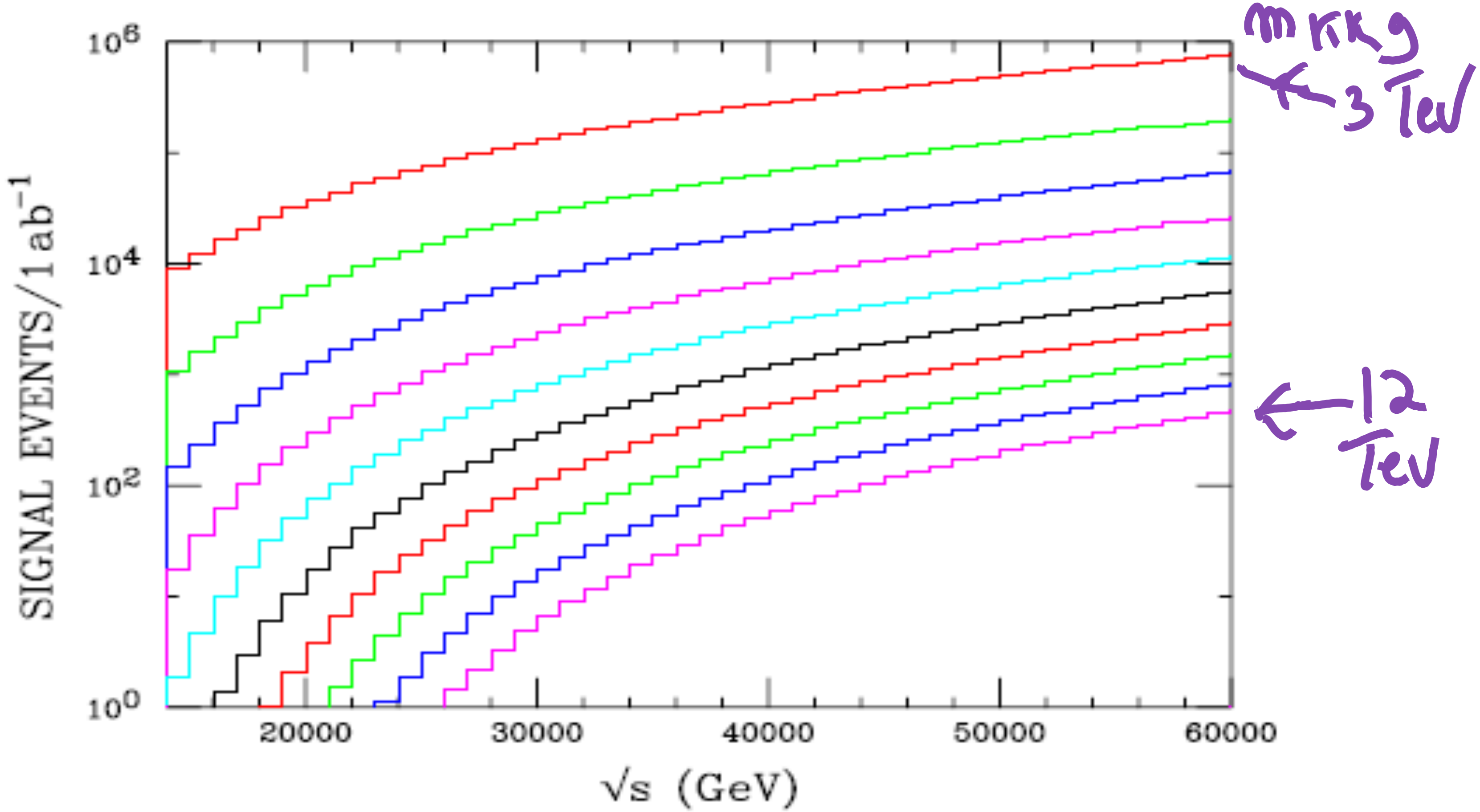


FIG. 10 (color online). Signal rate for a possible gluon KK resonance as a function of the collider energy employing the cuts described in the text. Branching fractions and efficiencies have been neglected. From top to bottom, the results are shown for gluon KK masses in the range from 3 to 12 TeV in steps of 1 TeV.

Davoudiasl,Rizzo,AS,PRD'08

KKg → $t\bar{t}$

Lesson learnt from ν's

~ Circa 1983, after long and arduous efforts, Δm^2 upper bound used to be around a few ev^2 but efforts to Search oscillations continued basically because there was no good theoretical reason for m_ν to be zero.

- *Recall it took more than a decade beyond '83* and Δm^2 had to be lowered by almost 4 orders of magnitude (!) before osc were discovered.
- Moral: Physical "principles" shouldn't be abandoned easily …..We'll just have to work harder to get to it

Recall SSC ~40 TeV ~1990 technologically completely feasible

We should be SERIOUSLY

THINKING of

GIGANTIC INTERNATIONAL HADRON COLLIDER [GIHC] ~ 100 TeV CM

"GEEK"

Summary & Outlook

- **While naturalness is not tangible, [clearly 10^{-2} OR 10^{-4} are very different from 10^{-34}], flavor places specific constraints...Its been telling us for long that scale of NP >>1 TeV**
- **Specifically RS-flavor (which gives a nice geometric understanding of flavor & simultaneously of EW-Plank hierarchy) strongly suggests scale is unlikely less than ~10 TeV and the following deserve attention:**
- **Dir CP probes [e.g. nedm, ε'/ε, S[B=>K $\rho\gamma$]; γ**
- **Top FV via e.g. t=>c Z, t=> c h; pp => t c h**
- **τFV: τ=>μ γ; 3 μ; Bs => τ μ**
- **Expected deviation to higgs couplings < ~O(0.2%) should be a cause for serious concern.**
- **We need high sensitivity flavor experiments AND we should be seriously thinking of a GIHC as the next step in our adventure.**

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