Repercussions of a geometric theory of flavor for future directions in High Energy Physics

Amarjit Soni, HET, BNL

Snowmass @ Univ of Minnesota 7/31/13

- **Talk is primarily based on arXiv: 1303.5056**

  see also Davoudiasl, McElmurry and A.S. arXiv:1206.4062
- **See also talks at**
- **FPCP 2012, Hefei China, May 2012**
- **ICHEP 2012 Melbourne (July 2012)**
- **Solvay workshop on "Facing the Scalar Sector" , Brussels, May 29-31, 2013**

Main point

- **Expt results on Higgs –SM like as well as flavor suggest scale of new physics is not ~ 1 TeV**

So what is it ….?

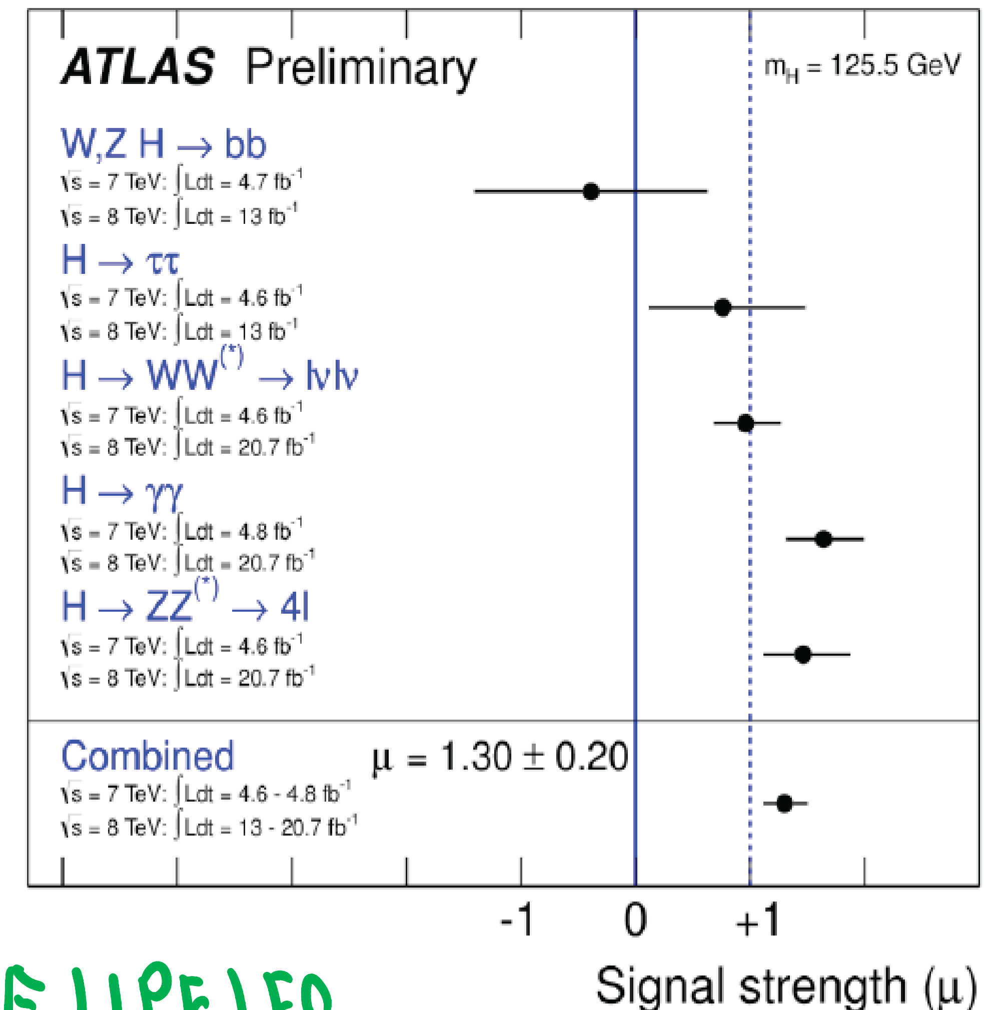
What are its consequences?

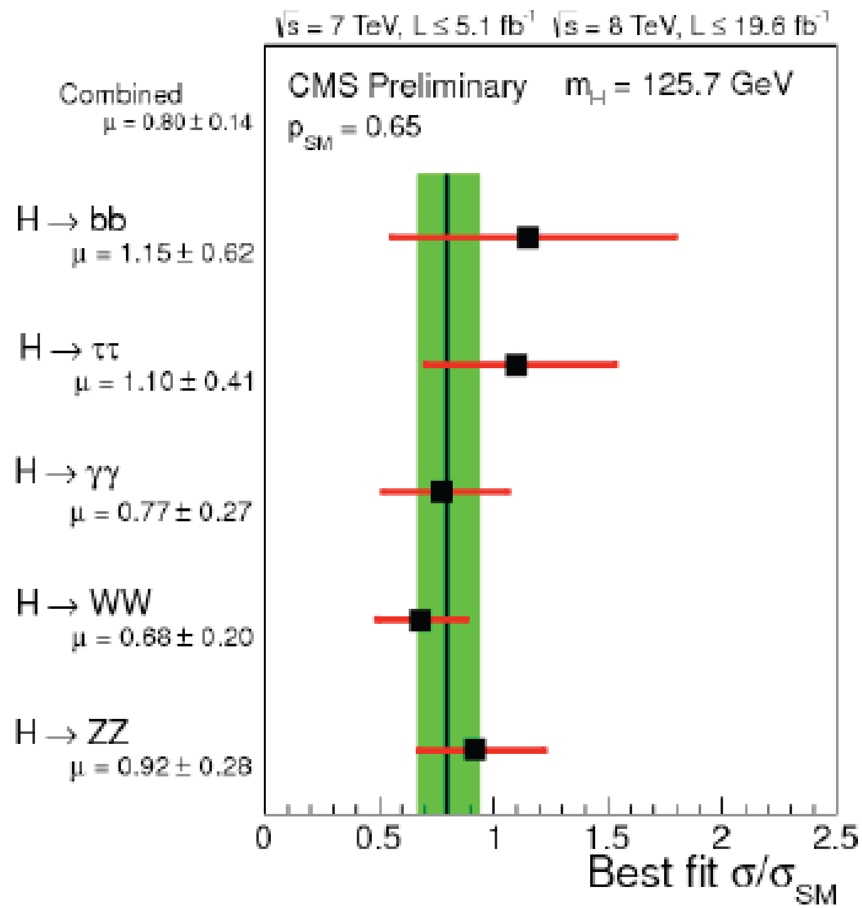
Outline

- **Works but ....**
- **Scale of NP=> future directions**
- **From the vantage point of a geometric theory of flavor scale was not expected to be less than around 10 TeV** *
- **summary**

* Flavor is not a footprint and, in particular flavor-alignment is a serious issue

FITS LIKE A GLOVE! [OR DOES IT?]

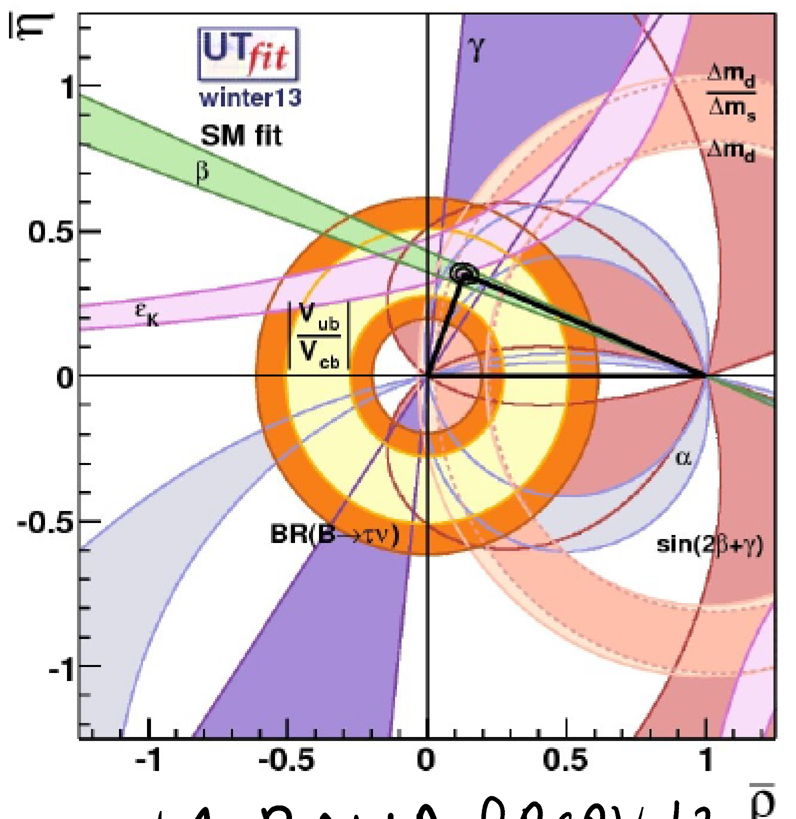




$\mu=0.80\pm0.14$

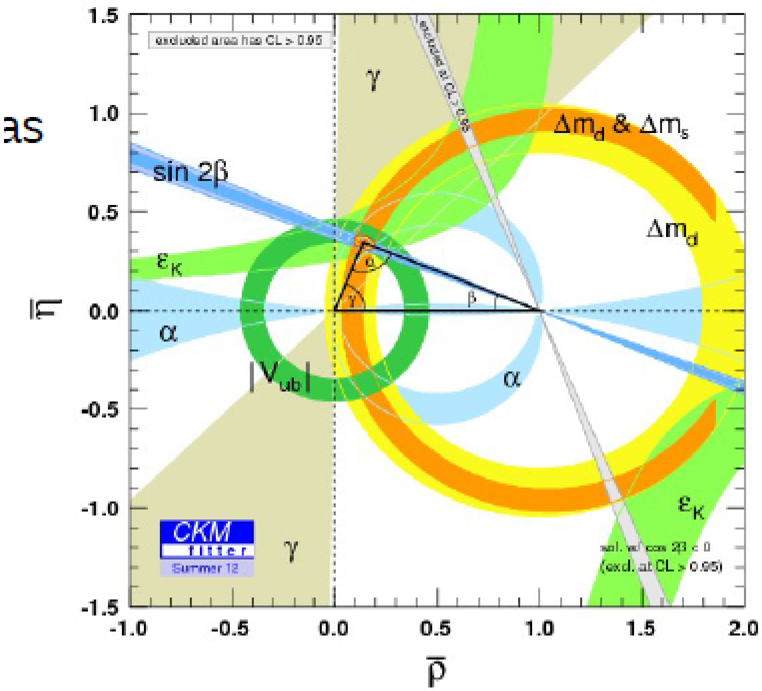
E. LIPELES
@ BF2013

S. BOSE @BF2013



M. BONA @CPCV13

http://ckmfitter.in2p3.fr
see also http://www.utfit.org



T. GERSHON
@BF2013

SM-CKM paradigm works rather well.
No glaring discrepancy
OTOH tests only ~ 10–15% accuracy

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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Science Lives

Adapted from Browder

A lesson from history (I)

"A special search at Dubna was carried out by E. Okonov and his group. They did not find a single $K_L \to \pi^+ \pi^-$ event among 600 decays into charged particles [12] (Anikira et al., JETP 1962). At that stage the search was terminated by the administration of the Lab. The group was unlucky."

-Lev Okun, "The Vacuum as Seen from Moscow"

1964: BF= 2×10^{-3}

A failure of imagination ? Lack of patience ?

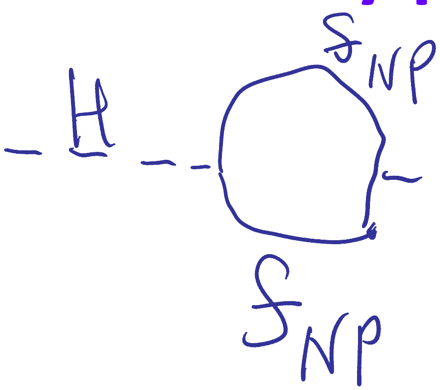
Christenson, Cronin, FITCH + TURLAY BNL '64

DRAWING STRONG CONCLUSIONS BASED on 20% tests is too risky.

SHOULD WE BE SHOCKED TO FIND THAT THE SCALE OF NEW PHYSICS IS NOT ~ 1 TEV & APPEARS TO BE BIGGER?

Outstanding Th.puzzles of our times

- **Hierarchy puzzle**

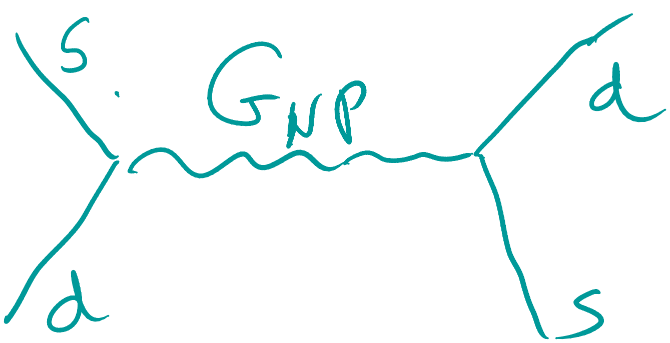


$\sim \frac{g_{NP}^2}{16\pi^2} \Lambda_{NP}^2 \Rightarrow \Lambda_{NP} \lesssim \text{TeV}$

to avoid fine tuning m_H

- **Flavor puzzle**

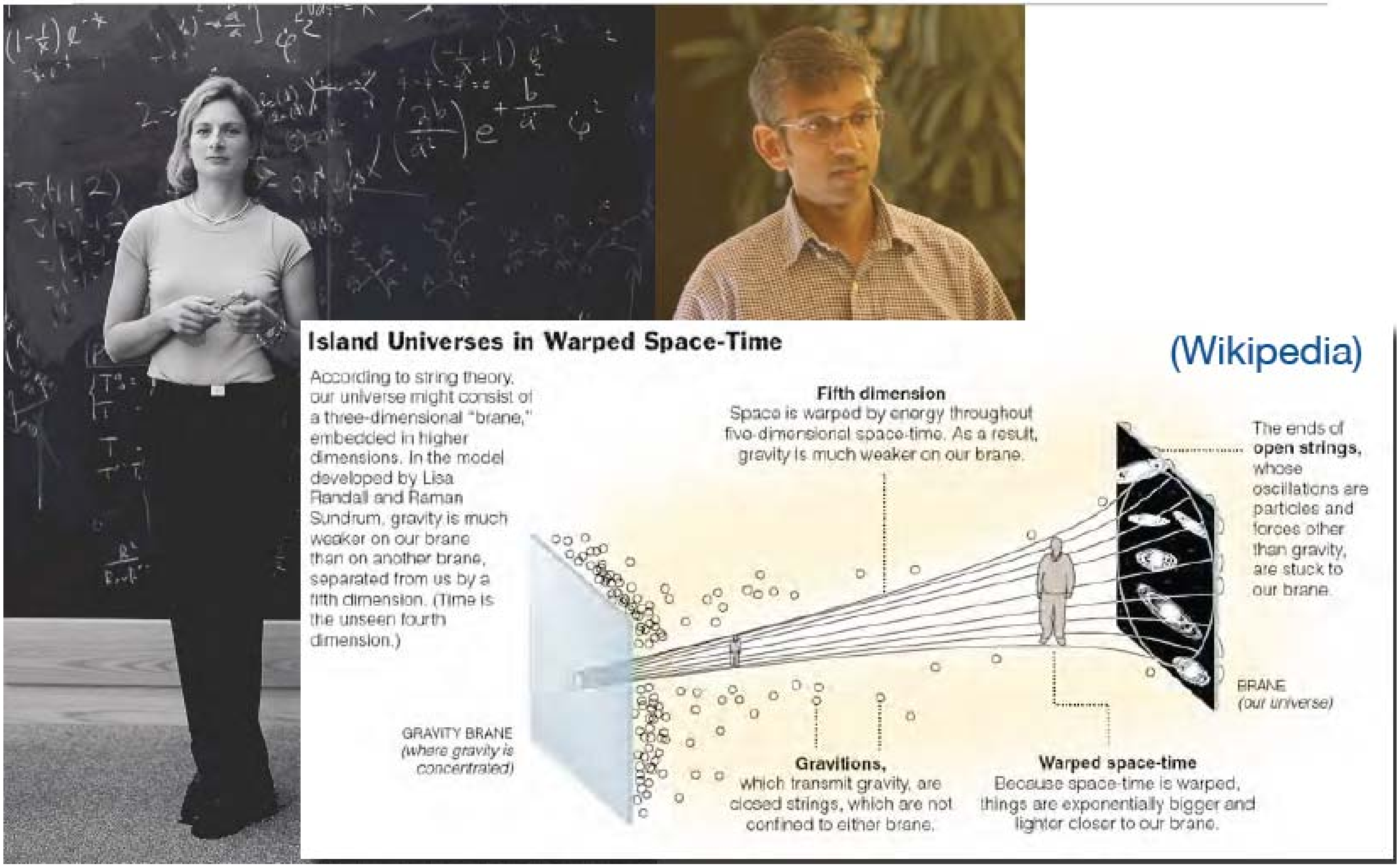
Δ flavor $= 2$ e.g.



$\sim \frac{g_{NP}^2}{\Lambda_{NP}^2} \Rightarrow \Lambda_{NP} \gtrsim 10^3$ TeV

to avoid constraint from Δm_K

The Randall-Sundrum (RS) idea



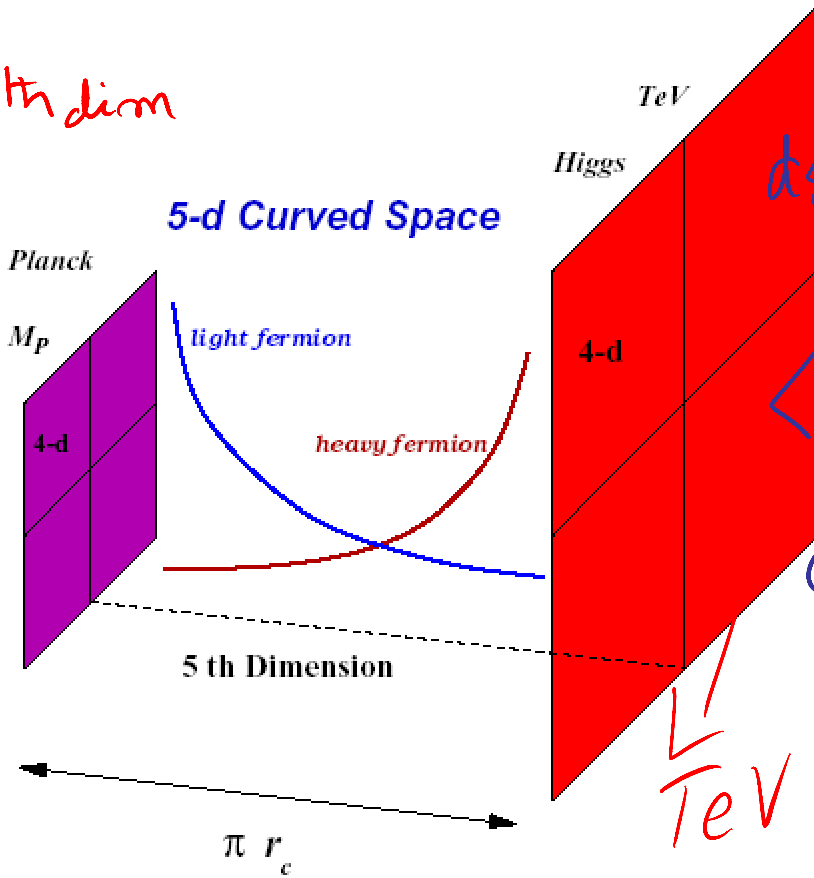
[Stolen from Neubert]

INSIGHTS FROM A GEOMETRIC THEORY OF FLAVOR

RANDALL+SUNDRUM '99

[FIG BY H DAVOUDIASL]

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



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

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

$$\sigma = k r_c \pi$$

$k r_c \sim 12$

TeV

M_P

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^* $\rho\gamma$]; 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

$\Delta m_K : 10^3$ TeV $\Longrightarrow RS_{Fl} \sim 10$ TeV

EXTENSIVE RECENT STUDIES by BURAS et al and NEUBERT et al

Localization parameters of the 3-families of quarks

$c_{Q_1} = -0.579\,,$	$c_{Q_2} = -0.517\,,$	$c_{Q_3} = -0.473$
$c_{u_1} = -0.742\,,$	$c_{u_2} = -0.558\,,$	$c_{u_3} = +0.339$
$c_{d_1} = -0.711\,,$	$c_{d_2} = -0.666\,,$	$c_{d_3} = -0.553$

Table from M. Neubert @Moriond09

⇒ masses of the 6 quarks in RS!

REMINISCENT OF CHENG-SHER ANZATS

$$\xi_{ij} = \lambda_{ij}\sqrt{m_i m_j}/v$$

Minimal tuning anzatz & natuaralness

- RS_{Fl} is the scale at which all flavor constraints are satisfied….
- This scale seems to be set by Kaon mixings and

is around 10 TeV. This is high enough that EWPC are automatically satisfied.

- While scale of new physics could be bigger than this, its likely that it is close to RS_{Fl} so as to minimize the degree of tuning needed…:

$$v^2 / [RS_{Fl}]^2 \sim 10^{-3} >>>> [v/M_{pl}]^2$$

Natuaralness is not at stake at least not yet!

B-Factory Signals for a Warped Extra Dimension

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$m_{KK} \sim 3$ TeV

We study predictions for B physics in a class of warped extra dimension models recently introduced, where few (~3) TeV Kaluza-Klein masses are consistent with electroweak data due to custodial symmetry. As in the standard model (SM), flavor violations arise due to the heavy top quark leading to striking signals: (i) New physics contributions to $\Delta F = 2$ transitions are comparable to the SM, so the success of the SM unitarity triangle fit is a "coincidence." Thus, clean extractions of unitarity angles are likely to be affected, in addition to $O(1)$ deviation from the SM prediction in B_s mixing. (ii) $O(1)$ deviation from various SM predictions for $B \to X_s l^+ l^-$. (iii) Large mixing-induced CP asymmetry in radiative B decays. Also, the neutron electric dipole moment is roughly 20 times larger than the current bound so that this framework has a "CP problem."

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}	$\frac{m_s}{m_b}(\sin 2\beta, \lambda_c^2)$	$\frac{m_d}{m_b}(\lambda_c^2, \sin 2\beta)$

3 TeV scale was an unfortunate oversight

- FC KK-glu exchanges give rise to LR currents
- LR currents cause enhanced Kaon mixings…..
- [Beall, Bander, AS, PRL '82]….
- C also M.Bona et al [UTFit] arXiv:0707.0636
- Agashe, Papucci, Perez and Pirjol, hep-ph/0509117
- Gedalia, Isidori and Perez, arXiv: 0905.3264

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

EWPC/Little Hierarchy

- **Imposing custodial symmetry, by enlarging SU2 => SU2 X SU2 and by adding additional fermions, m_{KK} > ~ 3 TeV [see Agashe,Delgado,May & Sundrum'03]**

- **Once RS_{FI} > 10 TeV is imposed, EWPC likely automatically satisfied; there is now "Little Hierarchy" i.e. tuning $O(10^{-3})$ is somewhat worse but the setup is more economical & simpler; perhaps the experimental indications to date are that this simplicity is preferred. However, not the last word yet.**

Higgs is SM-like =>

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

See Azatov, Toharia, Zhu, arXiv 1006.5939
M. Carena et al, 1204.0008
Davoudiasl, McElmurry, A. S. 1206.4062

1. With mKK ~ 10 TeV resulting set up is simpler and economical as then may NOT need to enforce custodial symmetry

   (which requires introducing more dofs….see Agashe et al…)

2. With mKK ~ 10 TeV, tuning is somewhat worse but has the advantage of a more economical theoretical framework and may well be preferable.

3. At LHC at best only radion may be accessible.

Updated expectations (some based on APS'04)

- nedm within factors of O(few) close to Expt bound < 6 X 10^{-26} e-cm
- Null tests extremely important ; Gershon & A. S. '07
- Time dependent CP Bd=> $K(\pi)\pi\gamma$; Bs => $\phi\gamma$ ~ O(10%) …Atwood, Gronau, AS, '97; Atwood,GHS'04; Grinstein,Grossman,Ligeti,Pirjol'05…
- Δsin2β(penguins) ~ O(few %) i.e. comparable to QCD uncertainties…..Grossman & Worah; London & AS ……may need lattice
- $\Delta\gamma$ ~ O(2X10^{-3}) GLW; ADS, GGSZ; comp to theo uncertainties
- Charm CP esp. modes where SM predicts 0…e,g D=>KKX, $\phi\pi^+$, $\pi^+\pi^0$….. See Brod,Grossman,Kagan,Zupan'12; Feldmann, Nandi , AS'12; Atwood, A.S. '13..
- ε'/ε see also Gedalia, Isidori, Perez'09…RBC-UKQCD lattice
- K=> $\pi^+ \nu \nu$; KL->$\pi^0 \nu\nu$
- t=> c Z, ch Br O(10^{-7}); t=>c g O(10^{-5}); t=>c γ O(10^{-6}) ; APS'06
- ee=> tc [Atwood, Reina, AS'95]; APS'07; R_{tc} ~ 10^{-6} - 10^{-5}
- tedm ~ O(10^{-20}) Atwood et al Phys Rpt
- Triple correlation in ee=> tth ; Bar-Shalom et al'95; Atwood et al Phys Rpt
- Δ SM in h=> bb

Null Tests of SM-CKM

Table 2. Illustrative sample of *approximate null tests (ANTs)*, with rough SM expectations and theoretical errors, current experimental uncertainties and estimates of numbers of B mesons needed for a Super B Factory to approach the SM uncertainty. More details for each mode can be found in the text.

Observable	SM expectation	Current experimental uncertainty ($B\bar{B}$ pairs used)	$B\bar{B}$ pairs needed
$\Delta S[\eta' K^0, \phi K^0, K^0\bar{K}^0K^0, \ldots]$	$\sim(0 \pm 2)\%$	20% (6×10^8)	5×10^{10}
$\mathcal{A}_{CP}^{s+d}[M^0 X_{s+d}]$	$\lesssim 0.1\%$	–	$> 10^{12}$
$\mathcal{A}_{CP}[X_s\gamma]$	$(0.5 \pm 0.2)\%$	4% (2.4×10^8)	10^{11}
$\mathcal{A}_{CP}[X_d\gamma]$	$(-10 \pm 5)\%$	–	10^{11}
$\mathcal{A}_{CP}[X_{s+d}\gamma]$	$(0.000 \pm 0.001)\%$	12% (10^8)	$> 10^{12}$
$\mathcal{A}_{CP}[X_s l^+ l^-]$	$(-0.2 \pm 0.2)\%$	26% (10^8)	10^{12}
$\mathcal{A}_{CP}[X_d l^+ l^-]$	$(4 \pm 4)\%$	–	10^{12}
$\mathcal{A}_{CP}[X_{(s,d)} l^+ l^-]$		–	$> 10^{12}$
$\Sigma(\mathcal{A}_{CP}(\pi K))$	$(0 \pm 1)\%$	15% (6×10^8)	$> 10^{11}$
$\mathcal{A}_{CP}(\pi^+\pi^0)$	$\lesssim 1\%$	6% (6×10^8)	10^{10}
$S[K_S\pi^0\gamma, \ldots]$	$\sim(0 \pm 5)\%$	28% (6×10^8)	$> 10^{10}$
$\langle p_t^\tau \rangle (D(X_c)\tau\nu_\tau)$	0	–	$> 10^{12}$

T. Gershon + AS JHEP'07

Expected deviations tend to be very small, strongly suggesting we need to strengthen both our computational AND measurement infrastructure

D. Atwood et al. / Physics Reports 347 (2001) 1–222

CP VIOLATION IN TOP PHYSICS

David ATWOOD[a], Shaouly BAR-SHALOM[b], Gad EILAM[c], Amarjit SONI[d]

Contains studies of many reactions for e^+e^- & pp e.g. tedm; $e^+e^- \to tc$; $t\bar{t}h$ .....

Table 2: *Real and Imaginary parts of* d_t^γ *and* d_t^Z *in units of* 10^{-19} *e-cm, for* $m_h = 100$, 200 *and* 300 *GeV and for* $\sqrt{s} = 500$ *GeV and* $\sqrt{s} = 1$ *TeV (in parenthesis).* $\tan\beta = 0.3$ *and Set I,II,III means* $\{\alpha_1, \alpha_2\} = \{\pi/4, \pi/2\}, \{\pi/4, 3\pi/4\}, \{\pi/4, \pi/4\}$, *respectively.*

Type of moment (10^{-19} e − cm) ⇓	m_h (GeV) ⇓	The different Sets of $\{\alpha_1, \alpha_2\}$, $\tan\beta = 0.3$		
		Set I	Set II	Set III
$\Re e(d_t^\gamma)$	100	1.97(3.77)	1.40(2.66)	1.40(2.66)
	200	−3.36(2.26)	−2.38(1.60)	−2.38(1.60)
	300	−4.75(1.27)	−3.36(0.90)	−3.36(0.90)
$\Im m(d_t^\gamma)$	100	−23.89(−5.44)	−16.88(−3.84)	−16.88(−3.84)
	200	−16.56(−4.91)	−11.70(−3.47)	−11.70(−3.47)
	300	−11.34(−4.33)	−8.02(−3.06)	−8.02(−3.06)
$\Re e(d_t^Z)$	100	0.62(1.25)	0.36(0.83)	0.52(0.93)
	200	−1.17(0.74)	−0.87(0.47)	−0.78(0.57)
	300	−1.57(0.40)	−1.04(0.24)	−1.18(0.33)
$\Im m(d_t^Z)$	100	−7.96(−1.81)	−5.41(−1.21)	−5.85(−1.34)
	200	−5.45(−1.62)	−3.58(−1.08)	−4.12(−1.22)
	300	−3.64(−1.42)	−2.22(−0.93)	−2.91(−1.08)

$e^+e^- \to t\bar{t}h$

Triple Correlations

See also Gunion, Grzadkowski & He, PRL 96

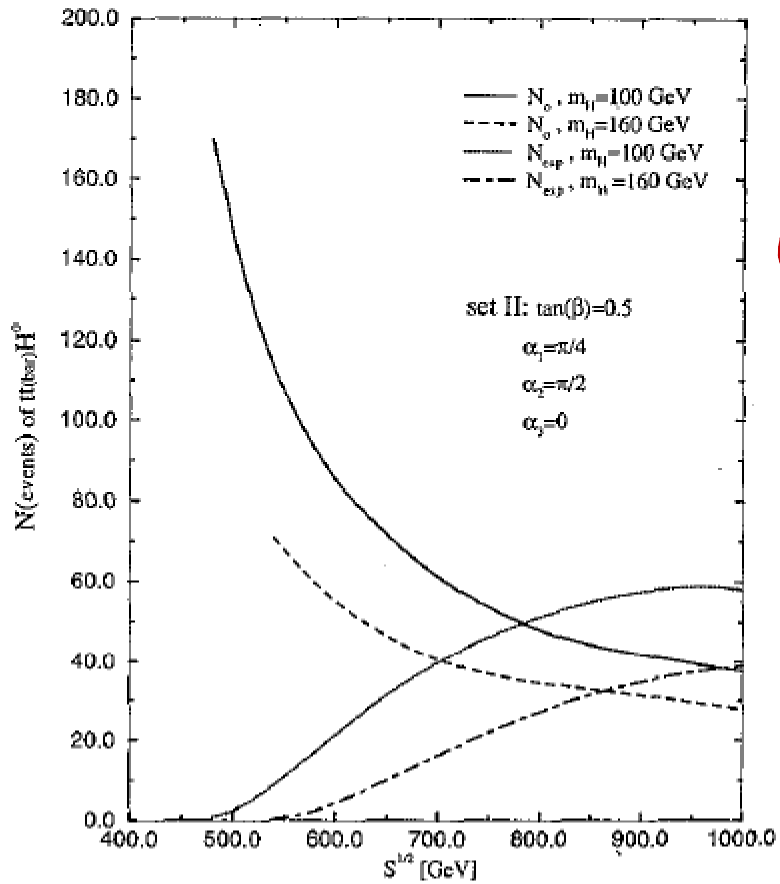


FIG. 3. Number of events, N_O ($N_{\rm exp}$) required (expected yearly), as a function of total beam energy for set II of the parameters and for $m_{H^0} = 100$ and 160 GeV with unpolarized electron and positron beams.

Atwood et al PRD 96

Constraining the FC htc(u) vertex in the context of RS [i.e. (partial) compositeness] is of special significance

tc(u)h(z) vertex should be beaten to death!

Constraining FCNC: Exploit (PARTIAL) COMPOSITENESS

Agashe et al'06

CSAKI ET AL JHEP'08

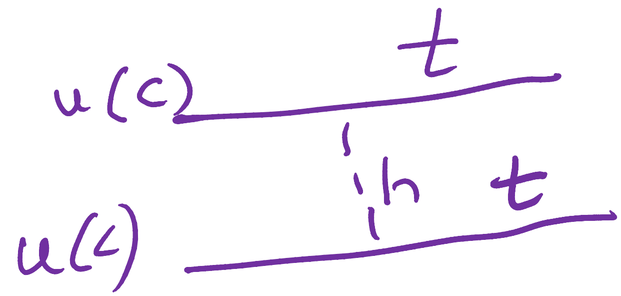
AGASHE ET AL PRD'07

AGASHE, CONTINO, PRD'09

AZATOV ET AL PRD'09

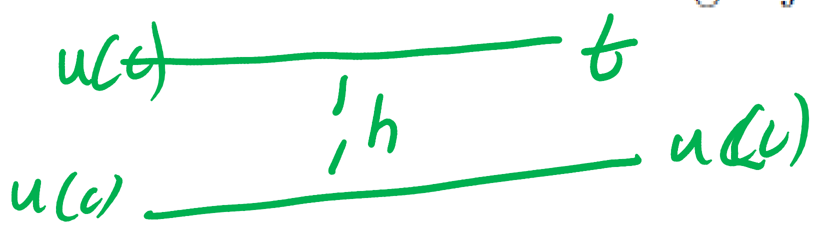
KEREN-ZUR ET AL, NPB '13

Atwood, Gupta, AS, arXiv:1305.2427

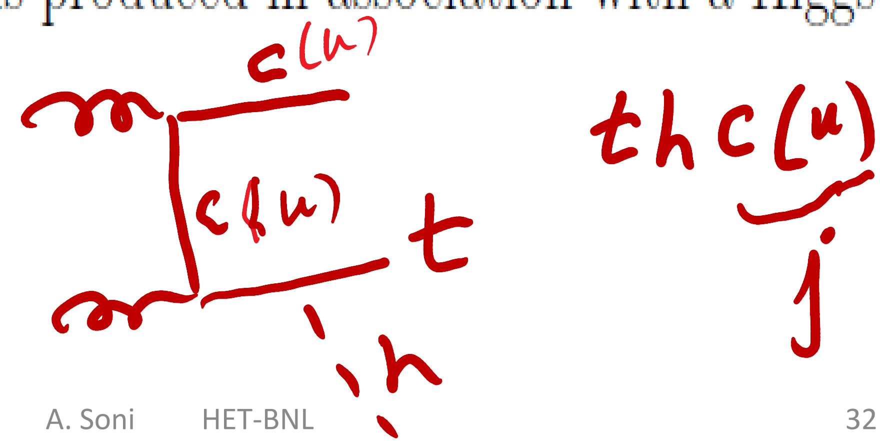


- (a) the same-sign top-pair, e.g. $pp \to tt(\bar{t}\bar{t})$,

- (b) processes where a top-quark is produced in association with a light jet, e.g. $pp \to t\bar{j}_u(\bar{t}j_u)$, where $j_u = u, c$, and,



- (c) processes where the top-quark is produced in association with a Higgs and a light jet, e.g. $pp \to t\bar{j}_u h(\bar{t}j_u h)$.



Effective tree-level

$$\sqrt{\xi_{tc}^2 + \xi_{tu}^2} \lesssim \begin{cases} 0.25\ (0.2) & \text{for process (a)} \\ 0.9\ (0.9) & \text{for process (b)}\ . \\ 0.26\ (0.1) \times 10^{-4} & \text{for process (c)} \end{cases}$$

$\sqrt{s} = 7$ TeV, 5/fb

$\sqrt{s} = 8$ TeV, 22/fb

Production level constraints

[RS bias $\xi_{tc} \gg \xi_{tu}$]

Technique	Coupling	Constraint
D^0 oscillations [48]	$\lvert Y_{uc}\rvert^2,\ \lvert Y_{cu}\rvert^2$	$< 5.0 \times 10^{-9}$
	$\lvert Y_{uc}Y_{cu}\rvert$	$< 7.5 \times 10^{-10}$
B_d^0 oscillations [48]	$\lvert Y_{db}\rvert^2,\ \lvert Y_{bd}\rvert^2$	$< 2.3 \times 10^{-8}$
	$\lvert Y_{db}Y_{bd}\rvert$	$< 3.3 \times 10^{-9}$
B_s^0 oscillations [48]	$\lvert Y_{sb}\rvert^2,\ \lvert Y_{bs}\rvert^2$	$< 1.8 \times 10^{-6}$
	$\lvert Y_{sb}Y_{bs}\rvert$	$< 2.5 \times 10^{-7}$
K^0 oscillations [48]	$\mathrm{Re}(Y_{ds}^2),\ \mathrm{Re}(Y_{sd}^2)$	$[-5.9 \ldots 5.6] \times 10^{-10}$
	$\mathrm{Im}(Y_{ds}^2),\ \mathrm{Im}(Y_{sd}^2)$	$[-2.9 \ldots 1.6] \times 10^{-12}$
	$\mathrm{Re}(Y_{ds}^* Y_{sd})$	$[-5.6 \ldots 5.6] \times 10^{-11}$
	$\mathrm{Im}(Y_{ds}^* Y_{sd})$	$[-1.4 \ldots 2.8] \times 10^{-13}$
single-top production [49]	$\sqrt{\lvert Y_{tc}^2\rvert + \lvert Y_{ct}\rvert^2}$	< 3.7
	$\sqrt{\lvert Y_{tu}^2\rvert + \lvert Y_{ut}\rvert^2}$	< 1.6
$t \to hj$ [50]	$\sqrt{\lvert Y_{tc}^2\rvert + \lvert Y_{ct}\rvert^2}$	< 0.34
	$\sqrt{\lvert Y_{tu}^2\rvert + \lvert Y_{ut}\rvert^2}$	< 0.34
D^0 oscillations [48]	$\lvert Y_{ut}Y_{ct}\rvert,\ \lvert Y_{tu}Y_{tc}\rvert$	$< 7.6 \times 10^{-3}$
	$\lvert Y_{tu}Y_{ct}\rvert,\ \lvert Y_{ut}Y_{tc}\rvert$	$< 2.2 \times 10^{-3}$
	$\lvert Y_{ut}Y_{tu}Y_{ct}Y_{tc}\rvert^{1/2}$	$< 0.9 \times 10^{-3}$
neutron EDM [37]	$\mathrm{Im}(Y_{ut}Y_{tu})$	$< 4.4 \times 10^{-8}$

Harnik, Kopp, Zupan
arXiv:1209.1397

} $pp \to thj$ gives much tighter Constraints.

Table 2. Constraints on flavor violating Higgs couplings to quarks. We have assumed a Higgs mass $m_h = 125$ GeV, and we have taken the diagonal Yukawa couplings at their SM values.

$$\sqrt{\xi_{tc}^2 + \xi_{tu}^2} \lesssim \begin{cases} 0.47\ (0.36) & \text{for } pp \to l^{\pm}l^{\pm} + 2b - jets + \not{E}_T \\ 0.9\ (0.9) & \text{for } pp \to l^{\pm} + j + b - jet + \not{E}_T \\ 4.5\ (1.8) \times 10^{-4} & \text{for } pp \to l^{\pm} + j + 3b - jets + \not{E}_T \\ 52.5\ (19.8) \times 10^{-4} & \text{for } pp \to l^{\pm} + j + b - jets + 2\gamma + \not{E}_T \end{cases} \quad (5.2)$$

*

$\sqrt{s} = 7$ TeV, 5/fb

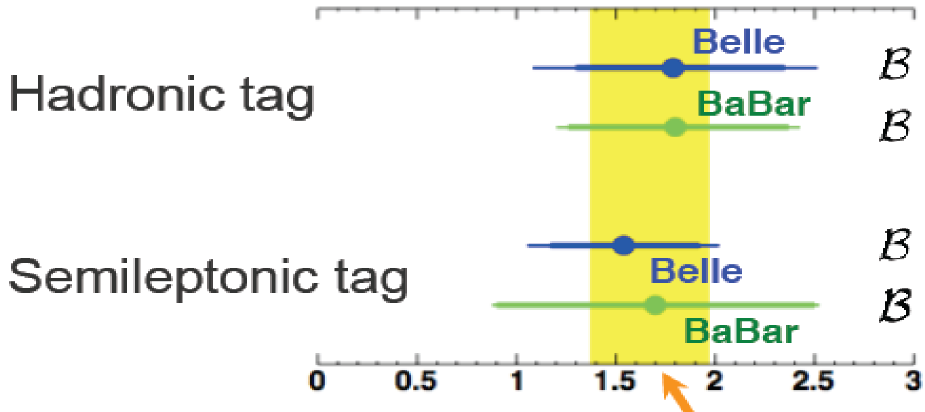
($\sqrt{s} = 8$ TeV, 22/fb)

Observable	Value	Experiment
Γ_t	2 ± 0.7 GeV	Tevatron [17]
m_h	$125.5 \pm 0.2\ (\text{stat})^{+0.5}_{-0.6}\ (\text{sys})$ GeV	ATLAS [3]
	$125.8 \pm 0.5\ (\text{stat}) \pm 0.2\ (\text{sys})$ GeV	CMS [4]
	125.7 ± 0.4 GeV	Combined
$\mathcal{R}_{gg\gamma\gamma}$	$1.65^{+0.34}_{-0.30}$	ATLAS [24, 25]
	$1.11^{+0.32}_{-0.30}$	CMS [26, 27]
	1.36 ± 0.23	Combined
$\mathcal{R}_{gg2l2\nu}$	1.01 ± 0.31	ATLAS [28, 29]
	$0.76^{+0.21}_{-0.21}$	CMS [30, 31]
	0.84 ± 0.17	Combined
$\mathcal{R}_{gg4l}$	$1.7^{+0.5}_{-0.4}$	ATLAS [24, 32]
	$0.91^{+0.30}_{-0.24}$	CMS [30, 33]
	1.12 ± 0.26	Combined
$D0$-oscillations	$\lvert\xi_{tu}\xi_{tc}\rvert < 0.9 \times 10^{-3}$	UTfit Collaboration [34]

Table 3: Measured values of various observables used in our analysis; combined here means weighted average of ATLAS and CMS values for a given observable.

ANOMALIES (A SAMPLE)

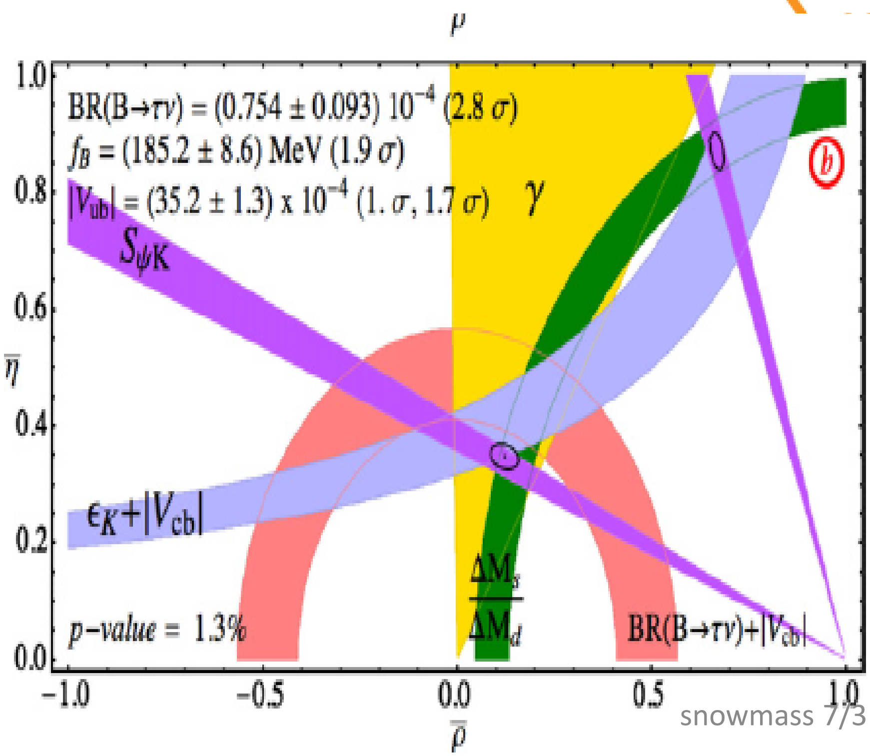
Status for B→ τ ν before ICHEP 2012



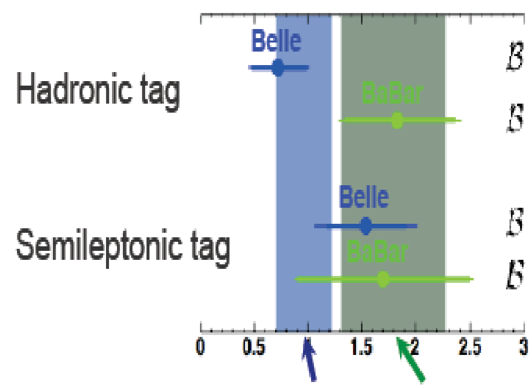
$$\mathcal{B} = [1.79^{+0.56}_{-0.49}(\text{stat})^{+0.46}_{-0.51}(\text{syst})] \times 10^{-4}$$
$$\mathcal{B} = [1.80^{+0.57}_{-0.54}(\text{stat}) \pm 0.26(\text{syst})] \times 10^{-4}$$

$$\mathcal{B} = [1.54^{+0.38}_{-0.37}(\text{stat})^{+0.29}_{-0.31}(\text{syst})] \times 10^{-4}$$
$$\mathcal{B} = [1.7 \pm 0.8(\text{stat}) \pm 0.2(\text{syst})] \times 10^{-4}$$

(HFAG): $\mathcal{B} = (1.67 \pm 0.30) \times 10^{-4}$



Status for B→ τ ν after ICHEP 2012



$$\mathcal{B} = [0.72^{+0.27}_{-0.25}(\text{stat}) \pm 0.11(\text{syst})] \times 10^{-4}$$
$$\mathcal{B} = [1.83^{+0.53}_{-0.49}(\text{stat}) \pm 0.24(\text{syst})] \times 10^{-4}$$

$$\mathcal{B} = [1.54^{-0.38}_{-0.37}(\text{stat})^{+0.29}_{-0.31}(\text{syst})] \times 10^{-4}$$
$$\mathcal{B} = [1.7 \pm 0.8(\text{stat}) \pm 0.2(\text{syst})] \times 10^{-4}$$

Belle combined: $\mathcal{B}$=(0.96±0.26)x10^{-4} BaBar combined: $\mathcal{B}$=(1.79±0.48)x10^{-4}

A naive world average: $\mathcal{B}$=(1.15±0.23)x10^{-4}

LUNGHI + AS PLB '11

$B \to D^{(*)} \tau \nu$ from BaBar and SM

$$\mathcal{R}(D)_{\rm exp} = 0.440 \pm 0.072 \quad \mathcal{R}(D^*)_{\rm exp} = 0.332 \pm 0.030$$

↕ 2.0σ ↕ 2.7σ

$$\mathcal{R}(D)_{\rm SM} = 0.297 \pm 0.017 \quad \mathcal{R}(D^*)_{\rm SM} = 0.252 \pm 0.003$$

SM expectations in S. Fajfer, J. Kamenik, I. Nisandzic, PRD 85, 094025 (2012).

$B \to D^{(*)} \tau \nu$ from Belle

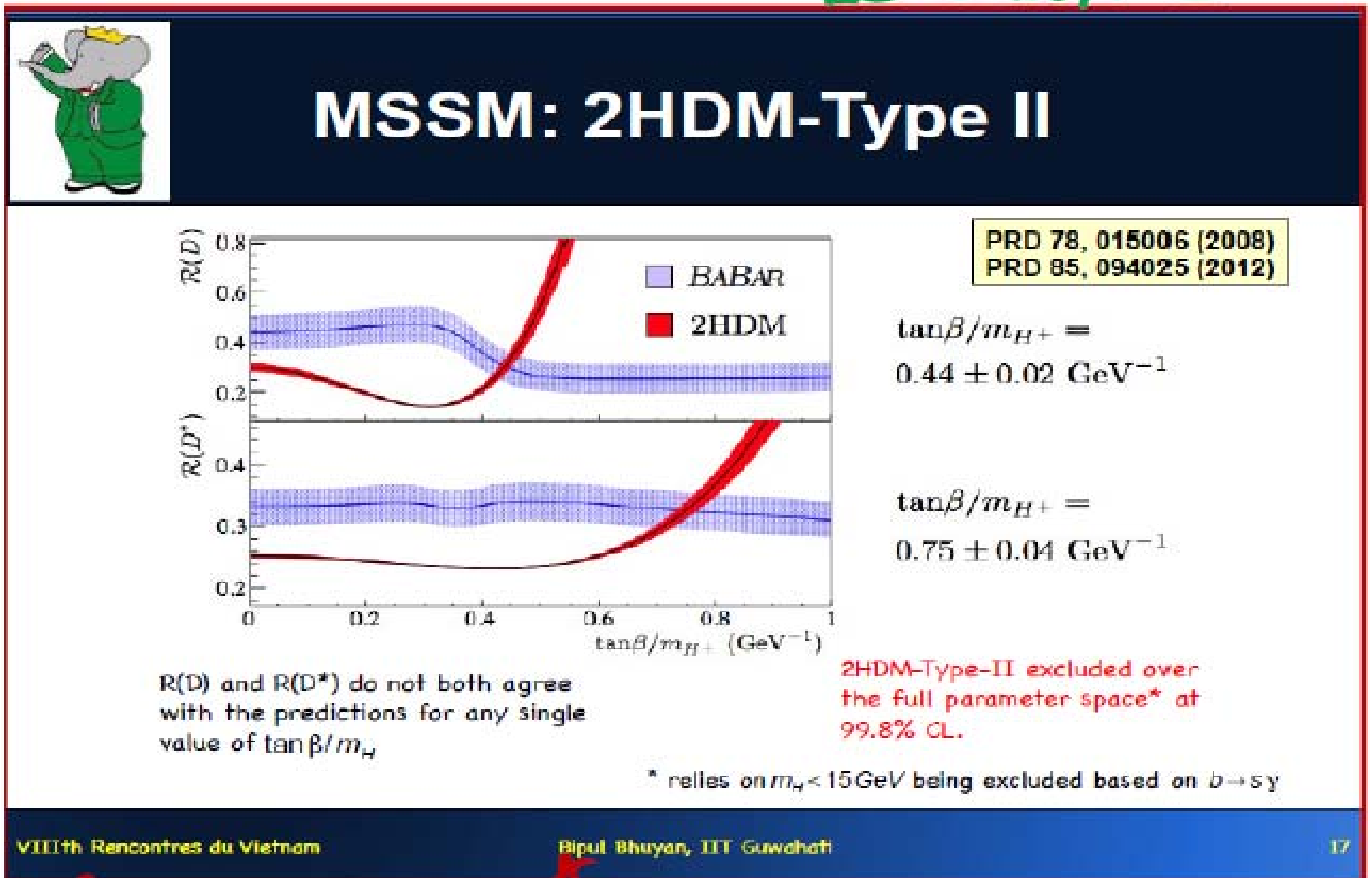
A. Bozek's averages (KEK-FF 2013):

(naive averages for inclusive and exclusive hadronic tags)

	Deviation from SM
$R(D) = 0.430 \pm 0.091$	1.4 σ
$R(D^*) = 0.405 \pm 0.047$	3.0 σ
Combined	3.3 σ

Correlation btw R(D) and R(D*) neglected conservatively.

[B BHUYAN]



VIIIth Rencontres VN, Dec '12; A. Soni 17

Perhaps premature

If true another huge stab at SUSY

FORWARD-BACKWARD TOP ASY

SM @ NNLO+
0.072 ± .011/.007

~2

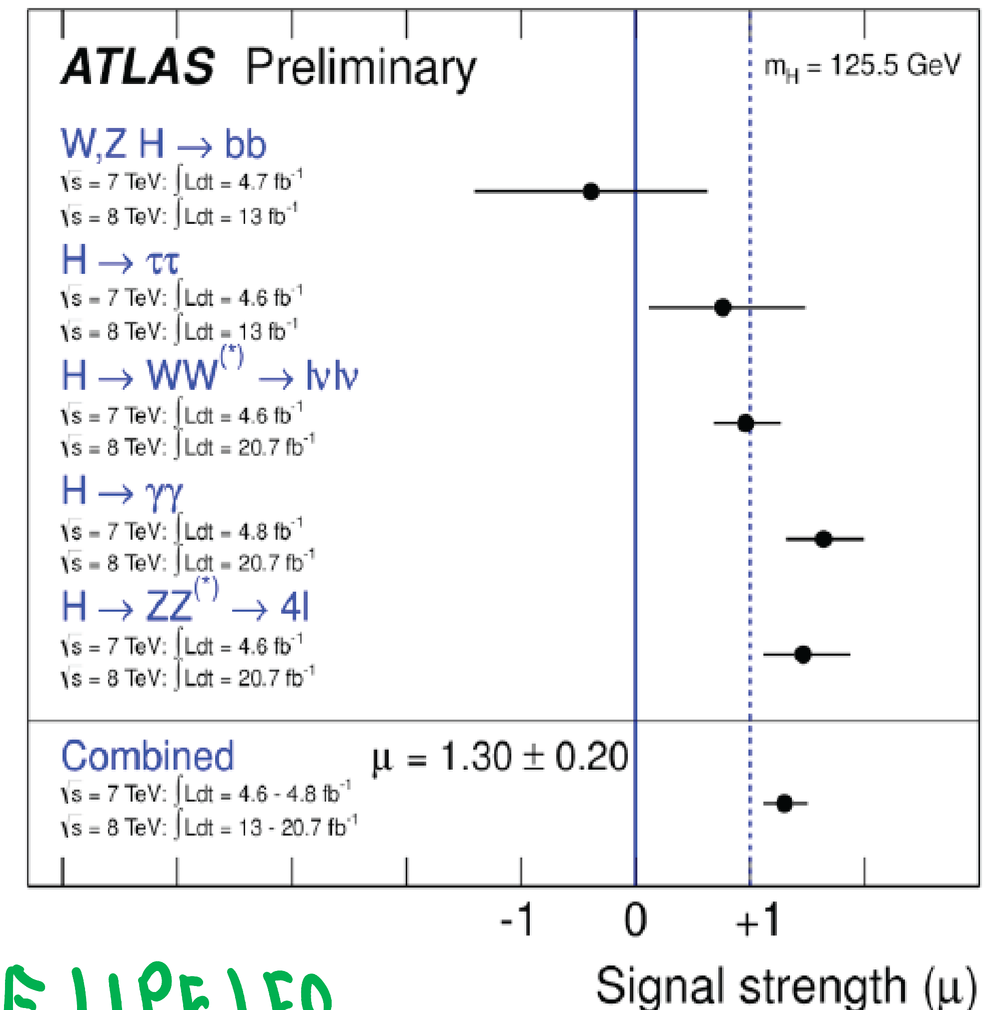
Observable	Values	Experiment
$\mathcal{A}_{FB}^{t}$	0.19 ± 0.065	DØ Collaboration [1]
	0.158 ± 0.074	CDF Collaboration [2]
	0.176 ± 0.05	Combined
$\mathcal{A}_{FB}^{t,low}$	0.078 ± 0.048	DØ Collaboration [1]
	-0.022 ± 0.043	CDF Collaboration [2]
	0.023 ± 0.032	Combined
$\mathcal{A}_{FB}^{t,high}$	0.115 ± 0.060	DØ Collaboration [1]
	0.266 ± 0.062	CDF Collaboration [2]
	0.188 ± 0.043	Combined
$\sigma_{t\bar{t}}^{Tevatron}$	$8.18^{+0.98}_{-0.87}$ pb	DØ Collaboration [8]
$\sigma_{l^{\pm}l^{\pm}}^{LHC}$	< 1 fb	ATLAS & CMS Collaborations [9]

Table 1: Measured values of various observables used in our analysis; combined here mea weighted averages.

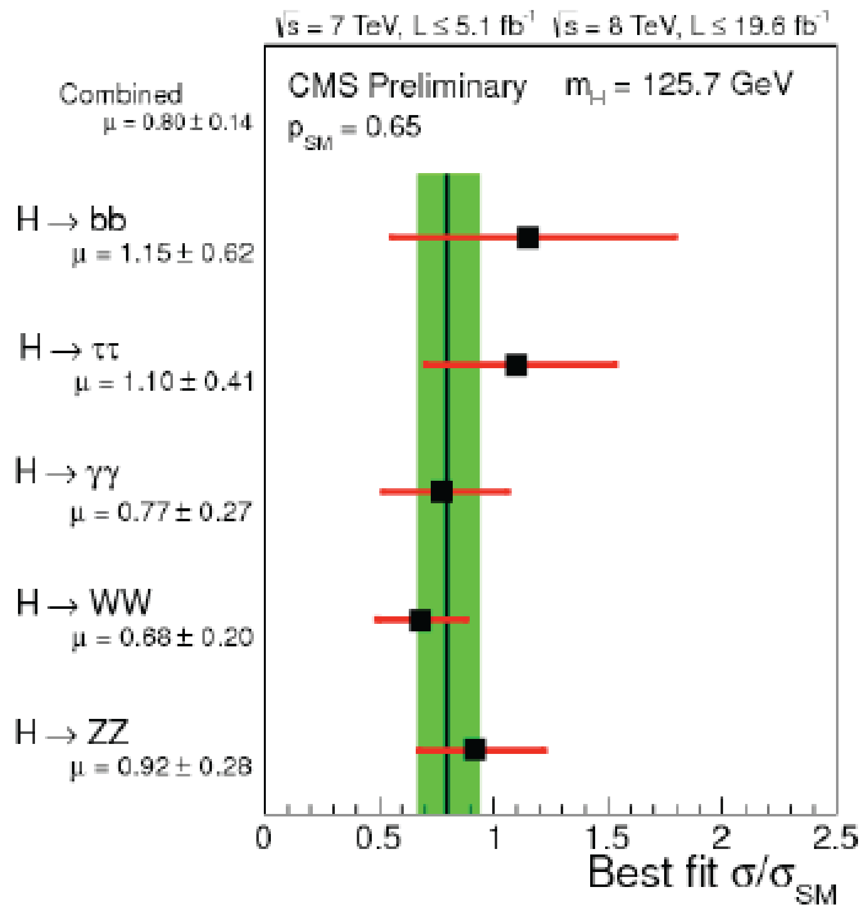
+ V. Ahrens, A. Ferroglia, M. Neubert, B. D. Pecjak and L. L. Yang, JHEP **1009**, 097 (2010) [arxiv:1003.5827 [hep-ph]].

Atwood,Gupta, AS, arXiv1301.2250
Berger et al 1101.5625
Aguilar-Saavedra, Perez-Victoria,1104.1385
Degrande et al 1104.1798

powerful discriminator SST



E. LIPELES
CBF2013



μ=0.80±0.14

S. BOSE CBF2013

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)

Highlighted Articles

Solid or Liquid? Physicists Redefine States of Matter

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Science Lives

Gee, don't see no NP signals

Flavor: Told you so!

KEY MESSAGES FROM A CANDIDATE THEORY OF FLAVOR

Key messages from a candidate theory of flavor

1. 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. Due to flavor mis-alignment, 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^* (ρ)γ]; ΔACP(D)....but expected signals tend to be small.

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

Agashe, Blechman, Petriello '06

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 ~ O(1%)

  [assuming m_{KK} > ~ 10 TeV]
- Small corrections are a concern.

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

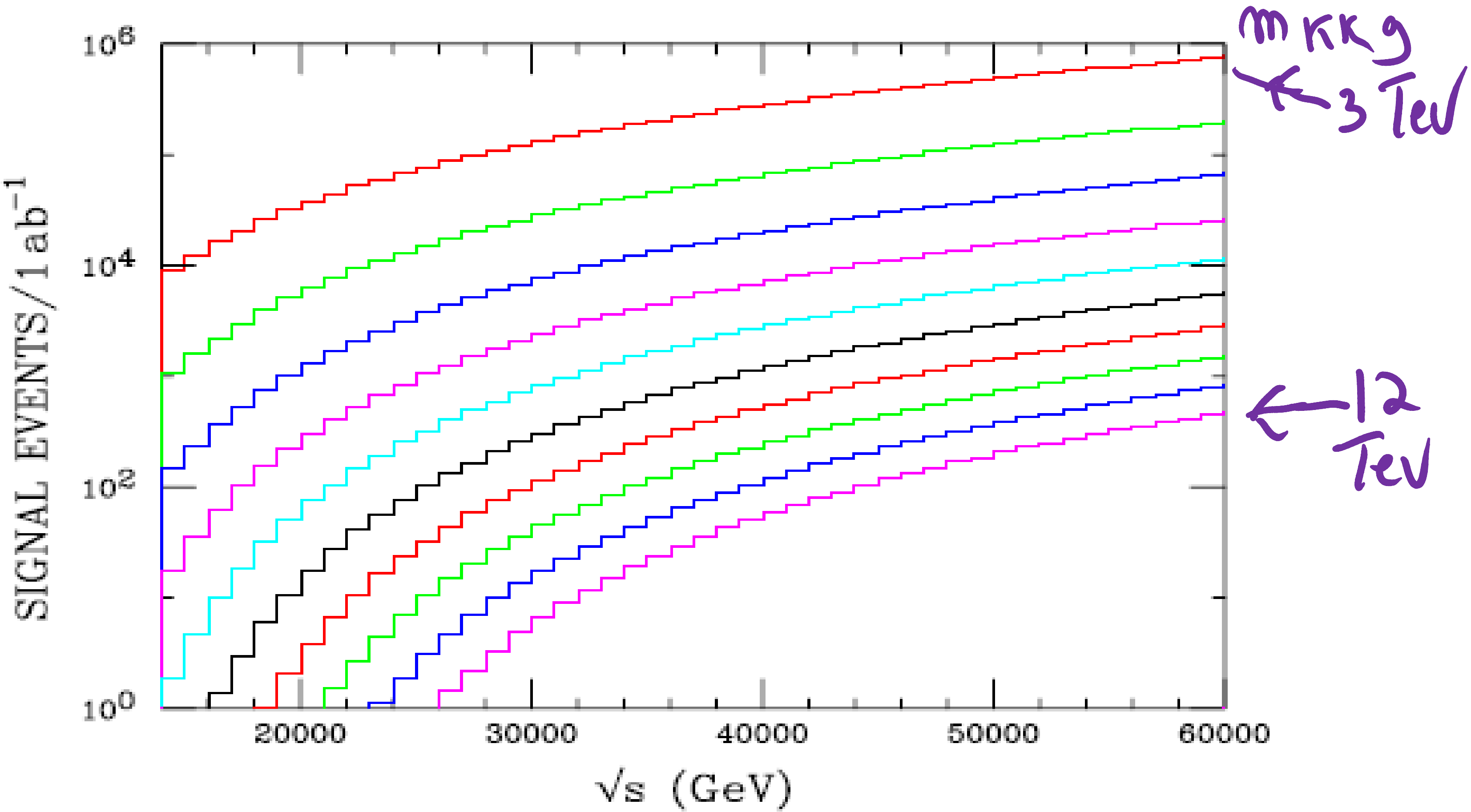

FIG. 10 (color online). Signal rate for a possible gluon KK resonance as a function of the collider energy employing the cuts described in the text. Branching fractions and efficiencies have been neglected. From top to bottom, the results are shown for gluon KK masses in the range from 3 to 12 TeV in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

KKg → $t\bar{t}$

Davoudiasl,Rizzo,AS,PRD'08

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" [i.e Naturalness in this instance] shouldn't be abandoned easily …..We'll just have to work harder to get to it but this should have been anticipated if enough attention had been paid to flavor alignment**

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-alignment places specific constraints…has 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; Null Tests, D-CP…
- Top FV via e.g. t=>c Z; t=> c h; pp => t c h; $e^+ e^-$ => t c
- τFV: τ=>μ γ; 3 μ; Bs => τ μ
- Expected deviation to higgs couplings ~O(1%) need attetion.
- Precise measurements & precise computations deserve high priority.
- It is essential to have high sensitivity flavor experiments AND we should be seriously thinking of a GIHC as the next step in our adventure.

XTRA