

Flavor in the scalar sector of Warped Extra Dimensions^a

by

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at the

University of Virginia, Dec. 2, 2009

^aBased on **PRD80:035016('09)** *A.Azatov, M.T., L.Zhu*
PRD80:031701('09) *A.Azatov, M.T., L.Zhu*

Outline

- Introduction
- Flavor “Anarchy”
- Radion Pheno and Flavor
- Higgs FCNC’s
- Conclusions

Introduction

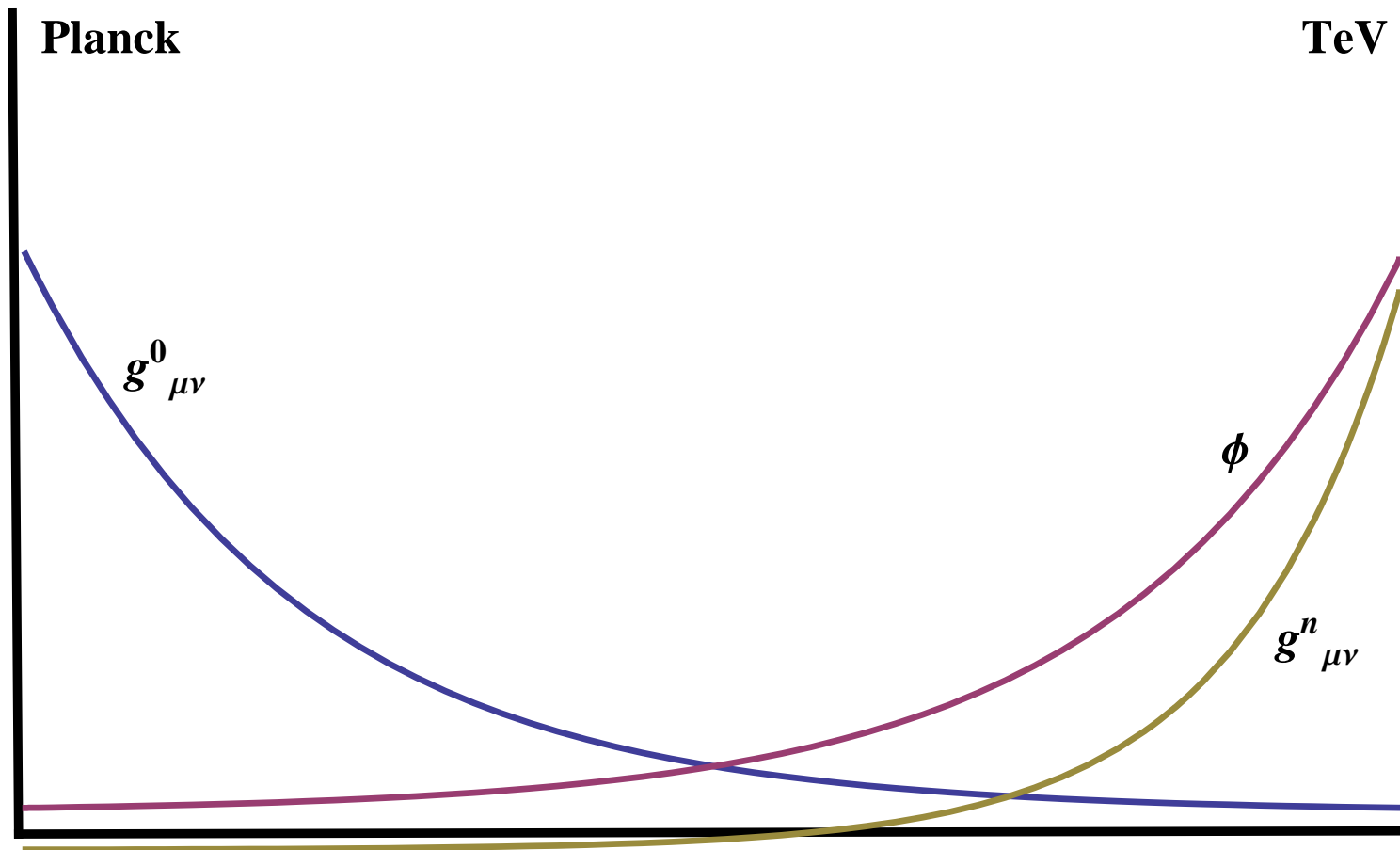
Warped Extra Dimension's double motivation

- Address **Planck-TeV hierarchy** [*Randall,Sundrum*](RS)
- Bulk SM with Fermion localization: **Flavor hierarchies**
[*Davoudiasl,Hewett,Rizzo*];[*Pomarol,Gherghetta*];[*Neubert,Grossman*];....

RS Metric Background : $ds^2 = e^{-2ky} \eta_{\mu\nu} dx^\mu dx^\nu - dy^2$

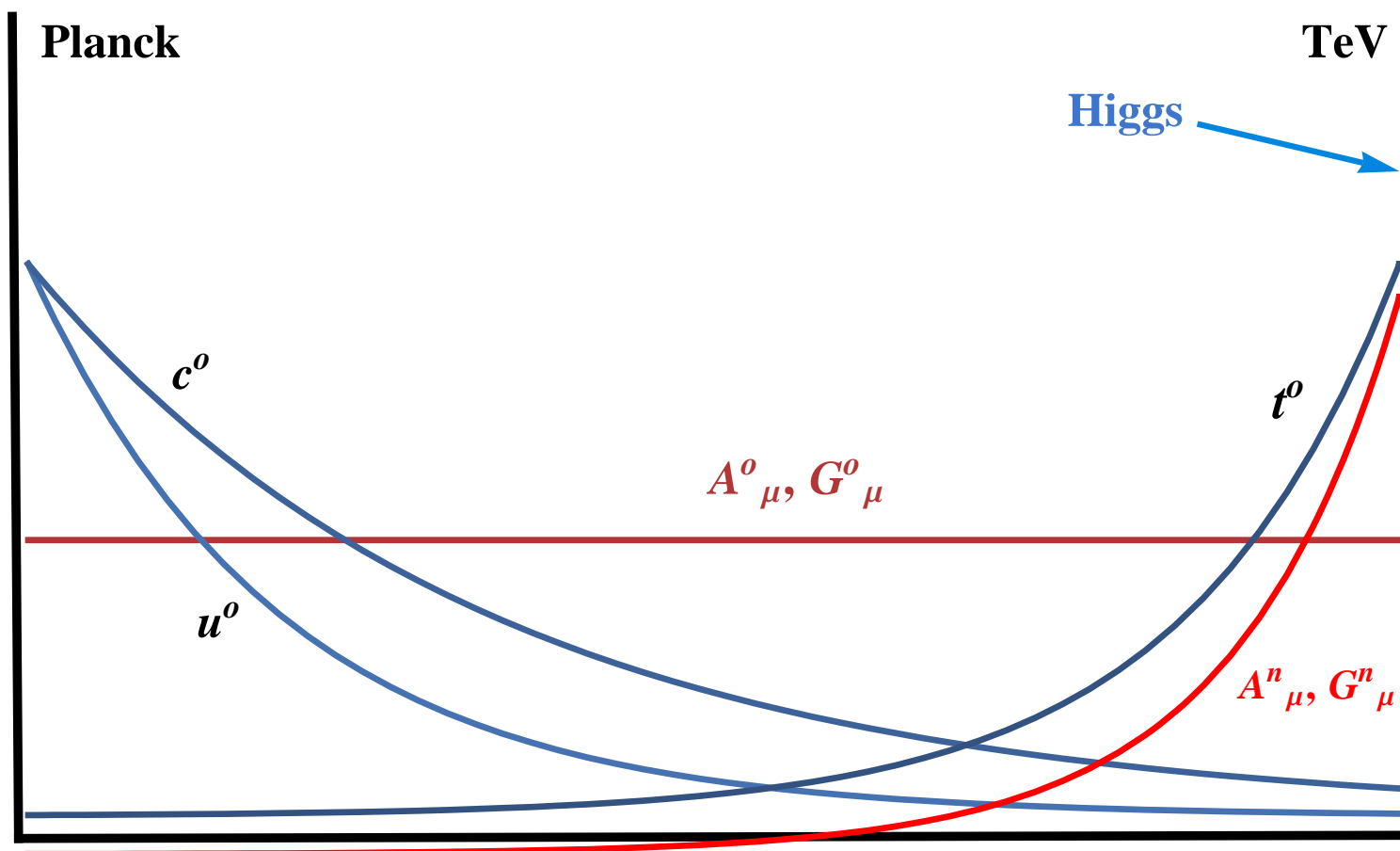
- Exponential factor “warps” down mass scales
- graviton localized near $y = 0$ Boundary (Planck or UV brane)
- Higgs localized near the other Boundary (TeV or IR brane)

Gravity Sector



RS Metric Background : $ds^2 = e^{-2ky} \eta_{\mu\nu} dx^\mu dx^\nu - dy^2$

Matter in the Bulk



Precision Electroweak Constraints $M_{KK} > 3$ TeV

[Agashe,Delgado,May,Sundrum](03);[Agashe,Contino(06)]; [Carena,Ponton,Santiago,Wagner(06)(07)]

[Contino,DaRold,Pomarol(07)]..

Fermion localization: Flavor!

$$S = \int d^4x dy \sqrt{g} \left[\frac{i}{2} (\bar{Q} \Gamma^A \mathcal{D}_A Q - D_A \bar{Q} \Gamma^A Q) + \frac{i}{2} (\bar{U} \Gamma^A \mathcal{D}_A U - \mathcal{D}_A \bar{U} \Gamma^A U) \right. \\ \left. + c_Q k \bar{Q} Q - c_u k \bar{U} U + (Y \bar{Q} \mathcal{H} U + h.c.) \right]$$

- Massless Fermion mode profiles

$$Q_L^0(y) \propto e^{(1/2 - c_Q)ky}$$

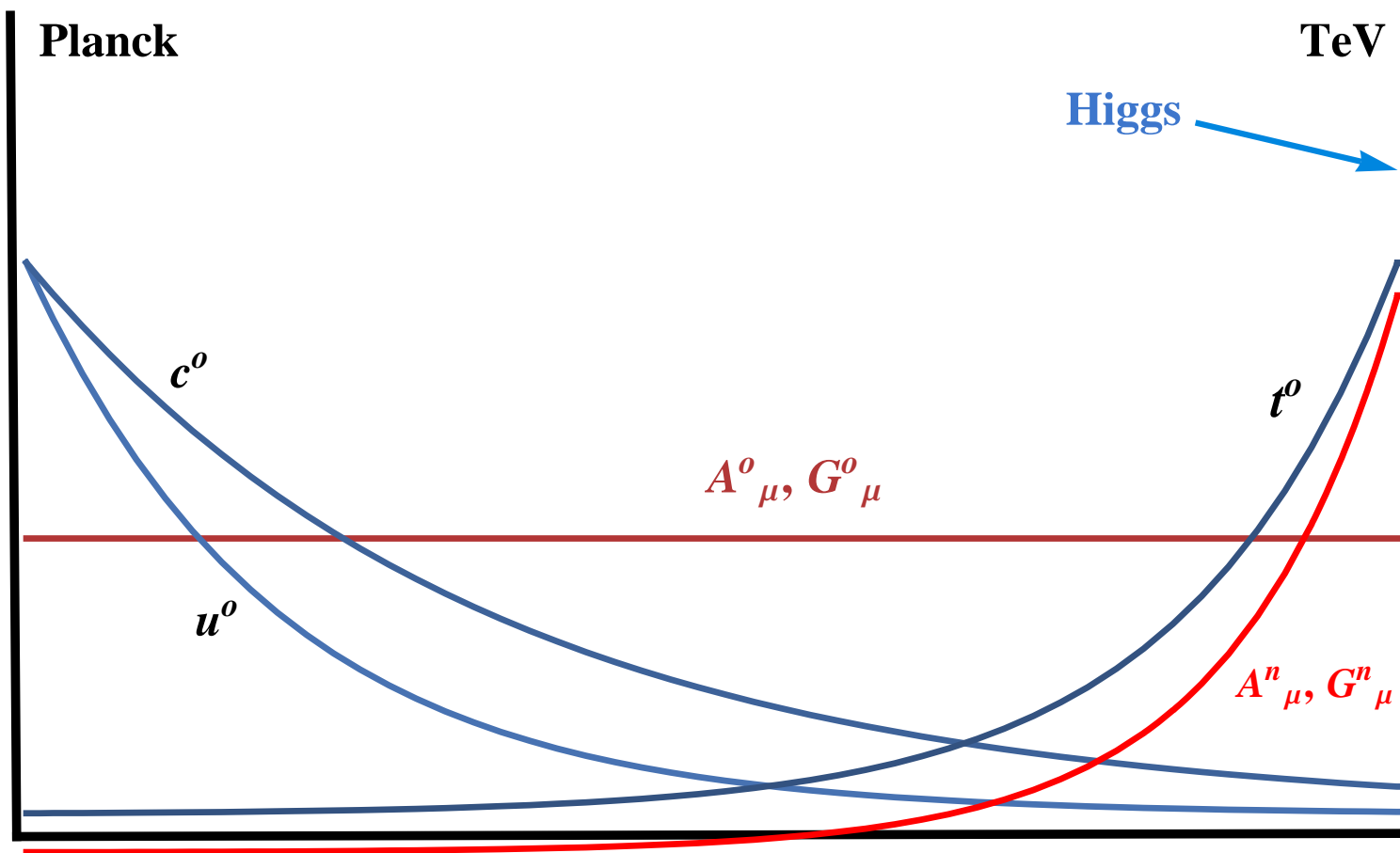
$$U_R^0(y) \propto e^{(1/2 - c_u)ky}$$

In flat ED, SEVERE flavor problem $M_{KK} > 100 - 5000$ TeV

[[Delgado, Pomarol, Quiros](#)]

Much milder in Warped case $M_{KK} > 5 - 40$ TeV [[Csaki, Falkowski, Weiler](#)];

[[Agashe, Azatov, Zhu](#)]



Flavor Anarchy

- Fermion profiles $\Psi_i(y) \propto e^{(1/2-c_i)ky}$
- Let $f_i = \Psi_i(y_{TeV})$ (\equiv profile at the TeV brane)
- SMALL hierarchy in c_i 's \Rightarrow LARGE hierarchy in f_i 's
- Fermion mass matrix from $Y_{ij} H Q_i U_j$

$$\mathbf{m}_{ij} = \frac{v}{2} f_{Q_i} Y_{ij} f_{u_j}$$

- 5D Yukawa Y_{ij} anarchic and $\mathcal{O}(1)$

\Rightarrow Mass matrices still hierarchical

$$\mathbf{m}_u \sim \begin{pmatrix} f_{Q1} f_{u1} & f_{Q1} f_{u2} & f_{Q1} f_{u3} \\ f_{Q2} f_{u1} & f_{Q2} f_{u2} & f_{Q2} f_{u3} \\ f_{Q3} f_{u1} & f_{Q3} f_{u2} & f_{Q3} f_{u3} \end{pmatrix} \sim \begin{pmatrix} \epsilon^4 & \epsilon^3 & \epsilon^2 \\ \epsilon^3 & \epsilon^2 & \epsilon \\ \epsilon^2 & \epsilon & 1 \end{pmatrix}$$

- Diagonalize mass matrices:

$$U_{Q_u} \mathbf{m}_u W_u^\dagger = \mathbf{m}_u^{\text{diag}}$$

$$U_{Q_d} \mathbf{m}_d W_d^\dagger = \mathbf{m}_d^{\text{diag}}$$

- SM Fermion physical masses hierarchical $m_{u_i} \sim v f_{Q_i} f_{u_i}$

$$U_{Q_d}, U_{Q_u} \sim \begin{pmatrix} 1 & \frac{f_{Q1}}{f_{Q2}} & \frac{f_{Q1}}{f_{Q3}} \\ \frac{f_{Q1}}{f_{Q2}} & 1 & \frac{f_{Q2}}{f_{Q3}} \\ \frac{f_{Q1}}{f_{Q3}} & \frac{f_{Q2}}{f_{Q3}} & 1 \end{pmatrix}$$

$$W_u \sim \begin{pmatrix} 1 & \frac{f_{u1}}{f_{u2}} & \frac{f_{u1}}{f_{u3}} \\ \frac{f_{u1}}{f_{u2}} & 1 & \frac{f_{u2}}{f_{u3}} \\ \frac{f_{u1}}{f_{u3}} & \frac{f_{u2}}{f_{u3}} & 1 \end{pmatrix} \quad W_d \sim \begin{pmatrix} 1 & \frac{f_{d1}}{f_{d2}} & \frac{f_{d1}}{f_{d3}} \\ \frac{f_{d1}}{f_{d2}} & 1 & \frac{f_{d2}}{f_{d3}} \\ \frac{f_{d1}}{f_{d3}} & \frac{f_{d2}}{f_{d3}} & 1 \end{pmatrix}$$

- SM CKM matrix

$$V_{CKM} = U_{Q_u}^\dagger U_{Q_d} = \begin{pmatrix} 1 & \lambda & \lambda^3 \\ \lambda & 1 & \lambda^2 \\ \lambda^3 & \lambda^2 & 1 \end{pmatrix} \Rightarrow U_{Q_u} \sim U_{Q_d} \sim \begin{pmatrix} 1 & \lambda & \lambda^3 \\ \lambda & 1 & \lambda^2 \\ \lambda^3 & \lambda^2 & 1 \end{pmatrix}$$

$$W_u \sim \begin{pmatrix} 1 & \frac{m_u}{m_c} \frac{1}{\lambda} & \frac{m_u}{m_t} \frac{1}{\lambda^3} \\ \frac{m_u}{m_c} \frac{1}{\lambda} & 1 & \frac{m_c}{m_t} \frac{1}{\lambda^2} \\ \frac{m_u}{m_t} \frac{1}{\lambda^3} & \frac{m_c}{m_t} \frac{1}{\lambda^2} & 1 \end{pmatrix} \quad W_d \sim \begin{pmatrix} 1 & \frac{m_d}{m_s} \frac{1}{\lambda} & \frac{m_d}{m_b} \frac{1}{\lambda^3} \\ \frac{m_d}{m_s} \frac{1}{\lambda} & 1 & \frac{m_s}{m_b} \frac{1}{\lambda^2} \\ \frac{m_d}{m_b} \frac{1}{\lambda^3} & \frac{m_s}{m_b} \frac{1}{\lambda^2} & 1 \end{pmatrix}$$

with $\lambda \sim .22$ cabibbo angle

The Radion and its interactions

In the RS1 model [[Randall,Sundrum,\('98\)](#)] the background metric g_{AB}^o is defined by

$$ds^2 = e^{-2\sigma} \eta_{\mu\nu} dx^\mu dx^\nu - dy^2 = \frac{R^2}{z^2} (\eta_{\mu\nu} dx^\mu dx^\nu - dz^2)$$

with $\sigma(y) = ky$ (and $R = 1/k$). Hierarchy created between the two boundaries at $y = 0$ and $y = \pi r_0$ ($z = R$ and $z = R'$).

The linear metric perturbations $h_{AB}(x, y)$ can be reduced to

$$ds^2 = (e^{-2\sigma} \eta_{\mu\nu} + [e^{-2\sigma} h_{\mu\nu}^{TT}(x, y) - \eta_{\mu\nu} r(x)]) dx^\mu dx^\nu + (1 + 2e^{2\sigma} r(x)) dy^2$$

(the graviscalar $r(x)$ is massless. A stabilization mechanism providing it with mass is assumed [for example\[Golberger,Wise\('99\)\]](#))

Ex. RS1 - Matter on the brane

Higgs **H**

$$S_{int}(r) = \frac{1}{\Lambda_r} \int dx^4 T^\mu_\mu \phi_0(x)$$

Higgs-like couplings!

Gluon $\frac{\alpha_s}{8\pi} \left[\sum_i F_{1/2}(\tau_i)/2 - b_3 \right] \frac{\phi_0}{\Lambda_r} G_{\mu\nu} G^{\mu\nu}$

γ $\frac{\alpha}{8\pi} \left[\sum_i e_i^2 N_c^i F_i(\tau_i) - (b_2 + b_Y) \right] \frac{\phi_0}{\Lambda_r} F_{\mu\nu} F^{\mu\nu}$

W, Z $\frac{\phi_0}{\Lambda_r} M_V^2 V^\alpha V_\alpha$

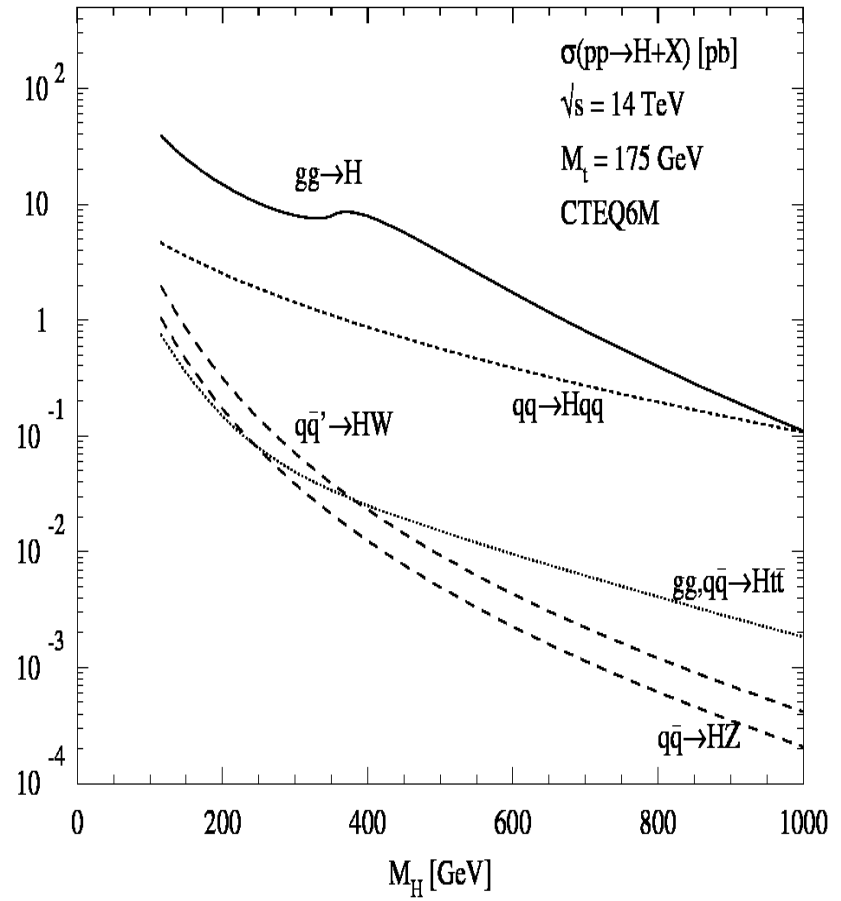
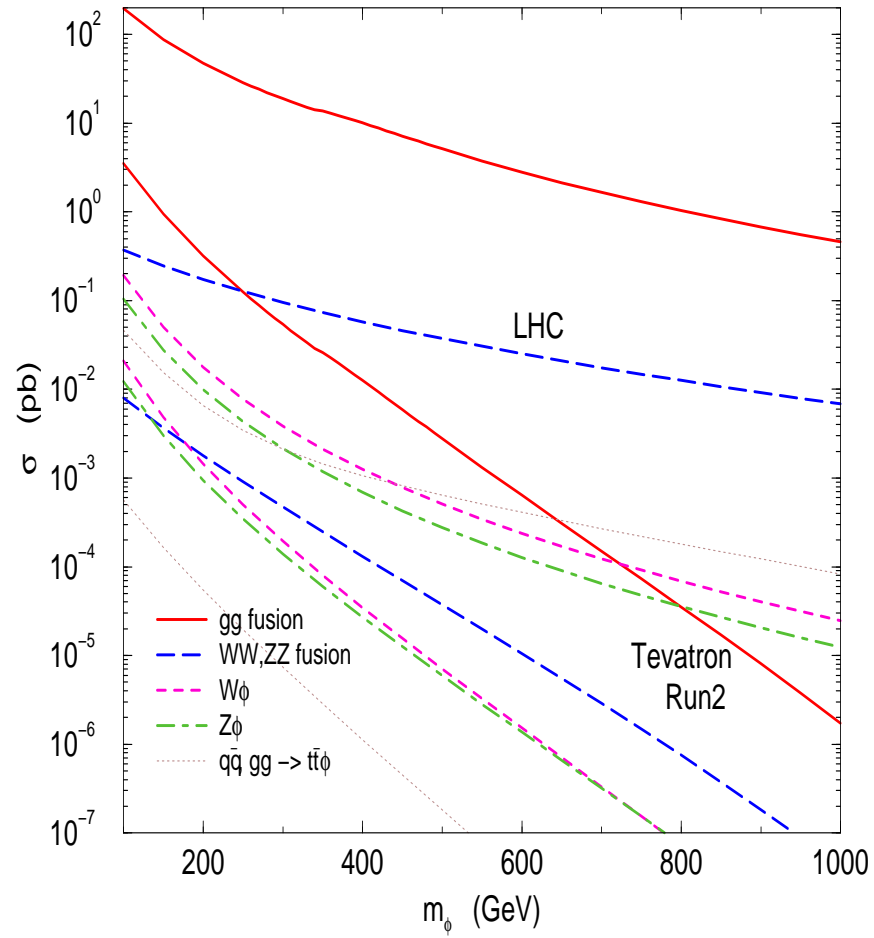
f $\frac{\phi_0}{\Lambda_r} m_f \bar{f} f$

$\frac{\alpha_s}{8\pi} \left[\sum_i F_{1/2}(\tau_i)/2 \right] \frac{H}{v} G_{\mu\nu} G^{\mu\nu}$
$\frac{\alpha}{8\pi} \left[\sum_i e_i^2 N_c^i F_i(\tau_i) \right] \frac{H}{v} F_{\mu\nu} F^{\mu\nu}$
$\frac{H}{v} M_V^2 V^\alpha V_\alpha$
$\frac{H}{v} m_f \bar{f} f$

Radion Production

vs.

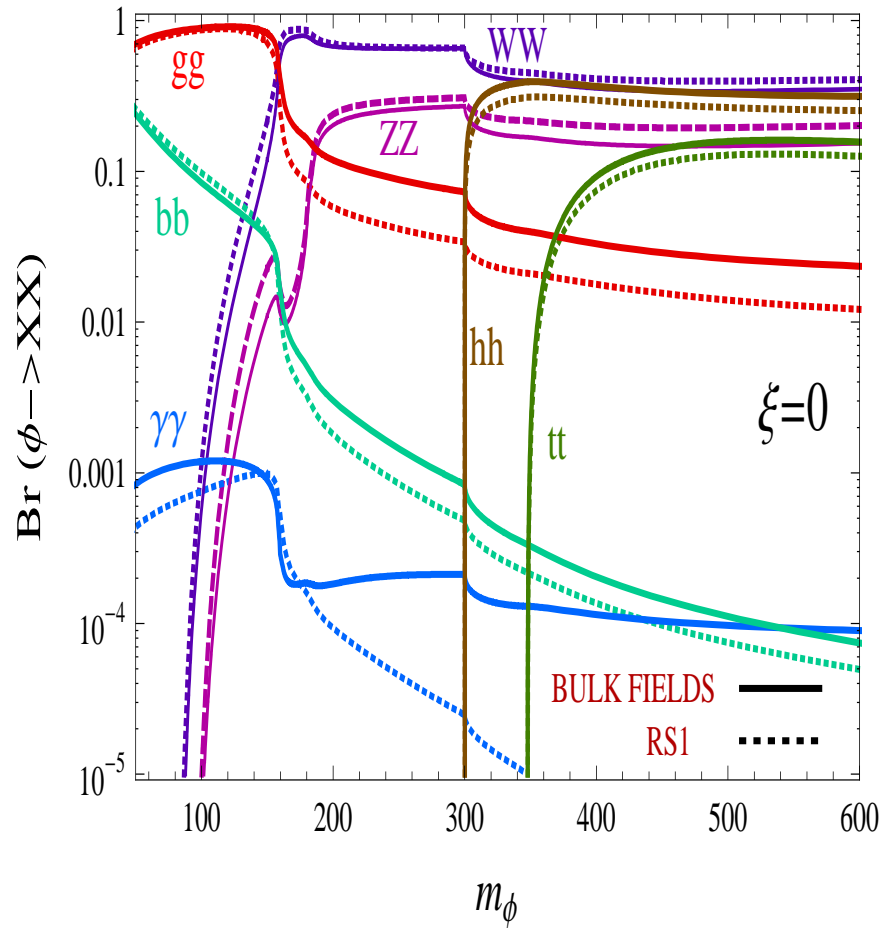
Higgs production



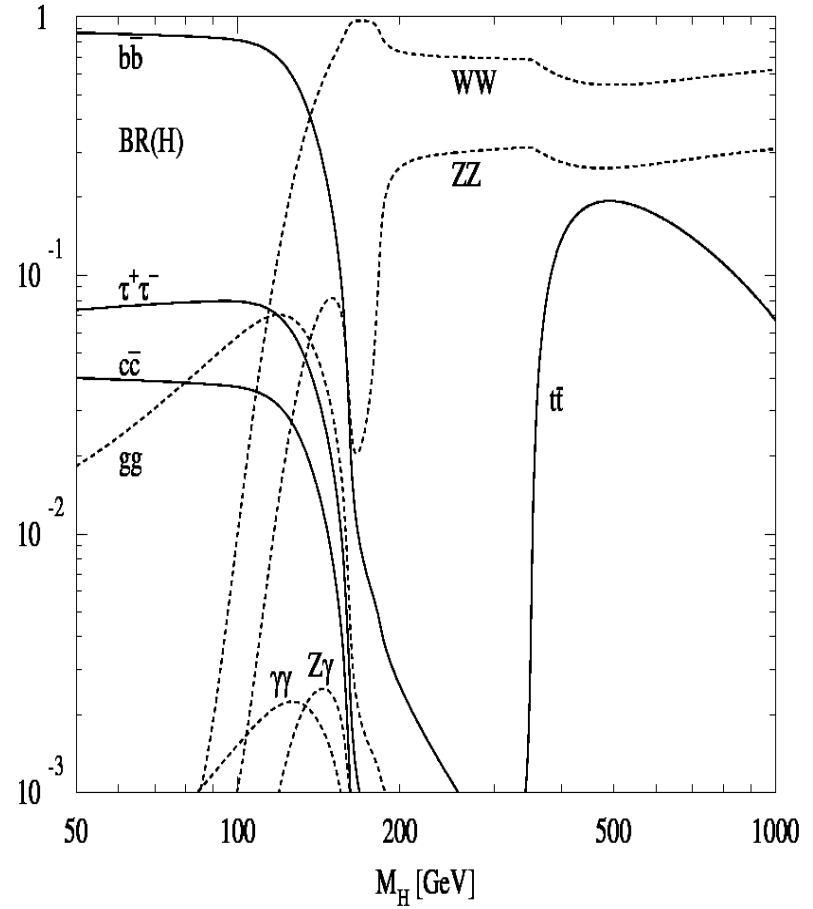
K.Cheung ('00) ($\Lambda_\phi = 1$ TeV)

(CMS TDR)

Radion Branchings vs. Higgs Branchings

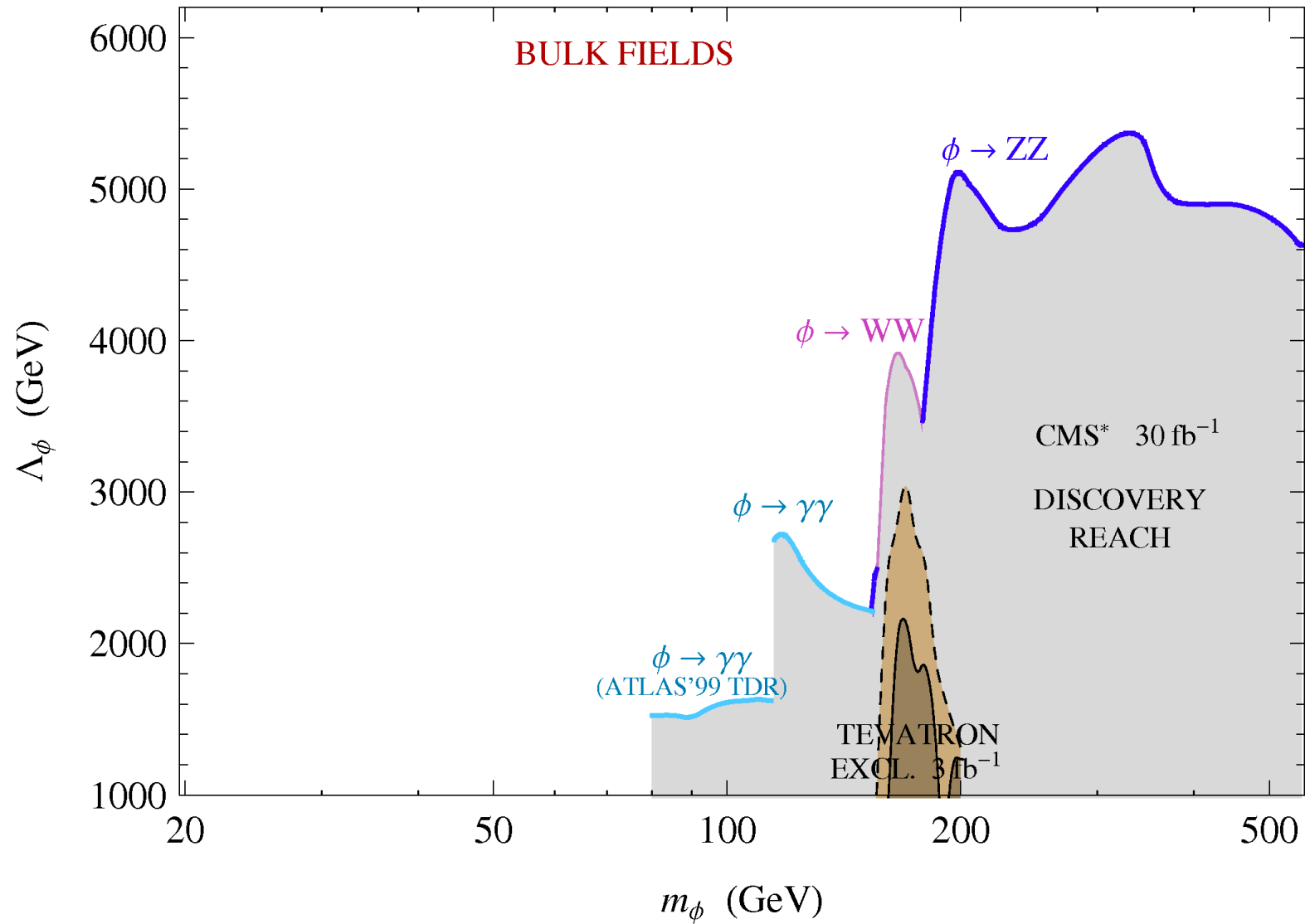


Branchings of the radion vs. its mass m_ϕ



Branchings of Higgs vs. its mass (from CMS TDR)

LHC REACH in $(m_\phi - \Lambda_\phi)$



Radion couplings to 5D fermions

- 1 family of bulk fermions and a Brane Higgs: [Csaki,Hubisz,Lee(07)]

$$-\frac{\phi_0}{\Lambda_r}(c_U + c_Q)m_u\bar{u}u$$

- 5D Computation involved. Simple explanation, L dependence

$$m_u(L) \sim Yv(L)f_Q(L)f_u(L) \sim Yv(L)e^{(1-c_Q-c_U)kL} \sim m_o e^{-(c_U+c_Q)kL}$$

- Radion can be understood as a fluctuation of the “radius” L .

$$k(L + \delta L) \rightarrow kL + \frac{\phi}{\Lambda_r}$$

The linear radion fluctuation in the mass term is

$$\begin{aligned} m_u(L + \delta L) &= m_u(kL) - \frac{\phi}{\Lambda_r}(c_U + c_Q) m_o e^{-(c_U+c_Q)kL} \\ &= m_u(kL) - \frac{\phi}{\Lambda_r}(c_U + c_Q) m_u \end{aligned}$$

- We extend to 3 families and allow for bulk Higgs (localized towards IR brane) *A. Azatov, M. T., L. Zhu* PRD80;031701('09)

$$-\frac{\phi_0}{\Lambda_r} (c_Q^i + c_D^j) m_d^{ij} \bar{d}_L^i d_R^j + h.c$$

$$-\frac{\phi_0}{\Lambda_r} \bar{\mathbf{d}}_L (\mathbf{c}_Q \mathbf{m}_d + \mathbf{m}_d \mathbf{c}_D) \mathbf{d}_R$$

- \mathbf{m}_d not in the diagonal physical basis;
- $\mathbf{c}_{Q,D}$ are NON-DEGENERATE diagonal matrices.

\Rightarrow tree-level FCNC's!

Diagonalize fermion mass matrix means here

$$-\frac{\phi_0}{\Lambda_r} \bar{\mathbf{d}}_L^{\text{phys}} \left[(U_{Q_d}^\dagger \mathbf{c}_Q U_{Q_d}) \mathbf{m}_{\text{diag}}^d + \mathbf{m}_{\text{diag}}^d (W_d^\dagger \mathbf{c}_D W_d) \right] \mathbf{d}_R^{\text{phys}}$$

In the physical basis we obtain the estimate:

$$\mathcal{L}_{rFV} = \frac{1}{\Lambda_r} a_{ij}^d \sqrt{m_i^d m_j^d} \phi_0 \bar{d}_L^i d_R^j + h.c.$$

$$a_{ij}^d \sim \begin{pmatrix} (c_{Q_1} + c_{D_1}) & (c_{Q_1} - c_{Q_2}) \lambda \sqrt{\frac{m_s}{m_d}} & G(c_{Q_i}) \lambda^3 \sqrt{\frac{m_b}{m_d}} \\ (c_{D_1} - c_{D_2}) \frac{1}{\lambda} \sqrt{\frac{m_d}{m_s}} & (c_{Q_2} + c_{D_2}) & (c_{Q_2} - \frac{1}{2}) \lambda^2 \sqrt{\frac{m_b}{m_s}} \\ F(c_{D_i}) \frac{1}{\lambda^3} \sqrt{\frac{m_d}{m_b}} & (c_{D_2} - c_{D_3}) \frac{1}{\lambda^2} \sqrt{\frac{m_s}{m_b}} & (\frac{1}{2} + c_{D_3}) \end{pmatrix}$$

where we have taken $c_{Q_3} = \frac{1}{2}$ (IR localized) and $\lambda \sim 0.22$.

F and G are $\mathcal{O}(.1)$ functions of the c_i 's

$$\Rightarrow a_{ds} \sim a_{sd} \sim 0.06$$

Tree level RADION exchange will induce $s_L d_R s_R d_L$ with coefficient

$$C_4 = a_{ds} a_{sd} m_d m_s \frac{1}{m_\phi^2 \Lambda_r^2} \Rightarrow K - \bar{K} \text{ mixing and } \epsilon_K \text{ put tight bounds}$$

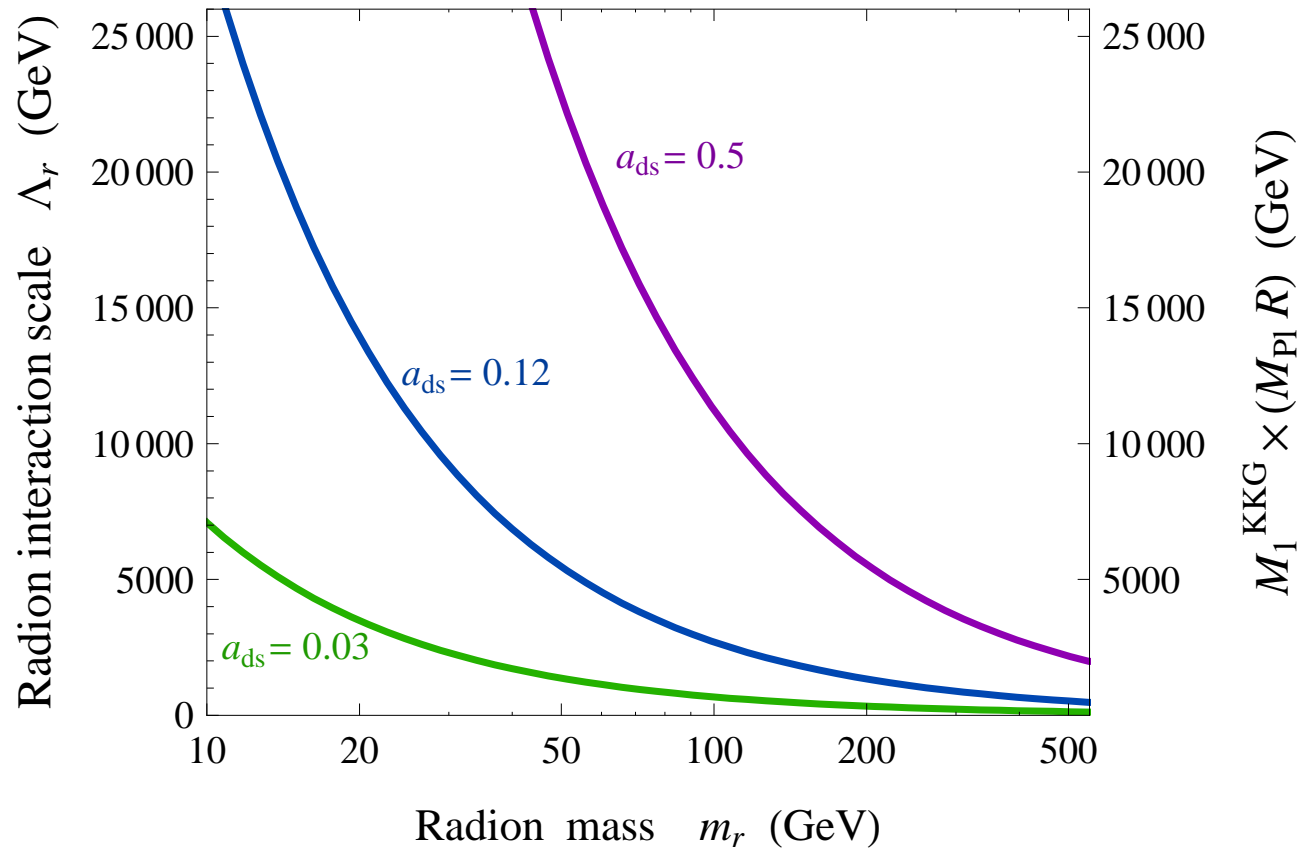


Figure 1: Bounds in $m_\phi - \Lambda_r$ plane from ϵ_K . [A.Azatov, M.T., L.Zhu]

Bounds on lighter radion even stronger [Ponton, Davoudiasl]

Tree level Higgs FCNC's

Effective Theory Approach [[Buchmuller,Wyler\(86\)](#)], [[delAguila,Perez-Victoria,Santiago\(00\)](#)]
[[Agashe,Contino\(09\)](#)]

Consider in 4D effective action, Dim 6 operators (down sector):

$$\lambda_{ij} \frac{H^2}{\Lambda^2} H \bar{Q}_{L_i} D_{R_j}$$

\Rightarrow Corrections to mass matrix

$$v_4 \left(y_{ij} + \lambda_{ij} \frac{v_4^2}{\Lambda^2} \right)$$

\Rightarrow Correction to Higgs Yukawa couplings

$$\left(y_{ij} + 3\lambda_{ij} \frac{v_4^2}{\Lambda^2} \right) \frac{h}{\sqrt{2}} \bar{Q}_{L_i} D_{R_j}$$

Tree level Higgs FCNC's

Effective Theory Approach [Buchmuller,Wyler(86)], [delAguila,Perez-Victoria,Santiago(00)]
 [Agashe,Contino(09)]

Consider in 4D effective action, Dim 6 operators (down sector):

$$\lambda_{ij} \frac{H^2}{\Lambda^2} H \bar{Q}_{L_i} D_{R_j} \quad k_{ij}^D \frac{H^2}{\Lambda^2} \bar{D}_{R_i} \not{\partial} D_{R_j} \quad k_{ij}^Q \frac{H^2}{\Lambda^2} \bar{Q}_{L_i} \not{\partial} Q_{L_j}$$

⇒ Corrections to mass matrix (also from canonical normalization)

$$v_4 \left(y_{ij} + \lambda_{ij} \frac{v_4^2}{\Lambda^2} \right) \bar{Q}_{L_i} D_{R_j} \quad \left(\delta_{ij}/2 + k_{ij}^D \frac{v_4^2}{\Lambda^2} \right) \bar{D}_{R_i} \not{\partial} D_{R_j} \quad \left(\delta_{ij}/2 + k_{ij}^Q \frac{v_4^2}{\Lambda^2} \right) \bar{Q}_{L_i} \not{\partial} Q_{L_j}$$

⇒ Correction to Higgs Yukawa couplings

$$\left(y_{ij} + 3\lambda_{ij} \frac{v_4^2}{\Lambda^2} \right) \frac{h}{\sqrt{2}} \bar{Q}_{L_i} D_{R_j} \quad \left(2k_{ij}^D \frac{v_4}{\Lambda^2} \right) \frac{h}{\sqrt{2}} \bar{D}_{R_i} \not{\partial} D_{R_j} \quad \left(2k_{ij}^Q \frac{v_4}{\Lambda^2} \right) \frac{h}{\sqrt{2}} \bar{Q}_{L_i} \not{\partial} Q_{L_j}$$

Higgs Couplings

Q and U 5d fermions $\rightarrow Q = Q_L + Q_R$ and $U = U_L + U_R$

- Bulk Higgs

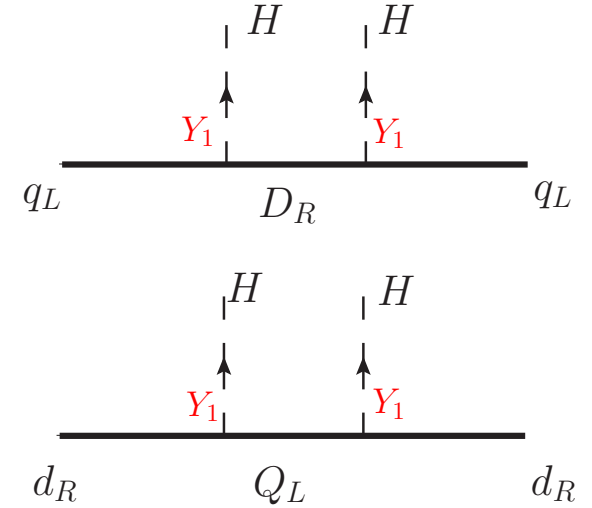
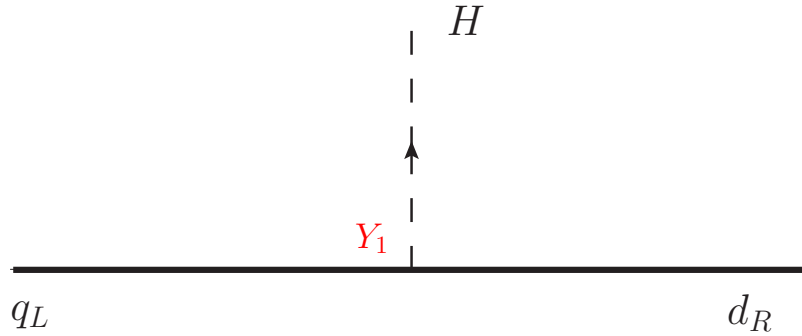
$$\int d^5x \mathbf{Y} H \bar{Q} U \Rightarrow Y_1 H Q_L U_R + Y_2 H Q_R U_L \quad \text{with} \quad Y_1 = Y_2$$

- Brane Higgs

$$\int dx^4 Y_1 H Q_L U_R + Y_2 H Q_R U_L \quad \text{with} \quad Y_1 \neq Y_2$$

Higgs FCNC's in RS

[Casagrande et.al.(08); Blanke et.al.(09); Buras et.al.(09)]



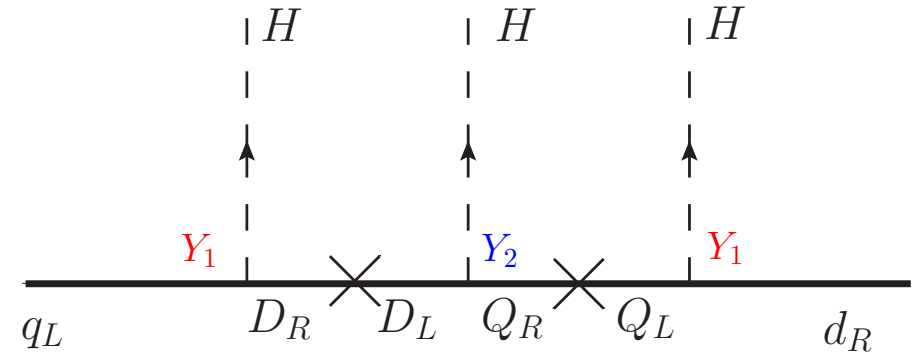
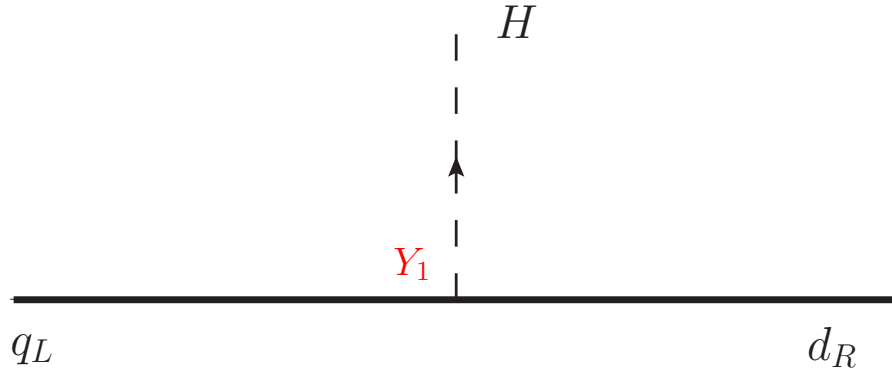
$$m_{SM}^d \approx v f_Q Y_1 f_d \left(1 - f_Q^2 \frac{Y_1^2 v^2}{M_{KK}^2} - f_d^2 \frac{Y_1^2 v^2}{M_{KK}^2} \right)$$

$$Y_{SM}^d \approx f_Q Y_1 f_d \left(1 - 2f_Q^2 \frac{Y_1^2 v^2}{M_{KK}^2} - 2f_d^2 \frac{Y_1^2 v^2}{M_{KK}^2} \right)$$

$$m_{SM}^d - Y_{SM}^d v \approx m_{SM}^d \frac{Y_1^2 v^2}{M_{KK}^2} (f_Q^2 + f_d^2)$$

Higgs FCNC's in RS

[Agashe, Contino(09); Azatov,M.T.,Zhu(09)]



$$m_{SM}^d \approx v f_Q Y_1 f_d \left(1 - \frac{Y_1 Y_2 v^2}{M_{KK}^2} \right)$$

$$Y_{SM}^d \approx f_Q Y_1 f_d \left(1 - 3 \frac{Y_1 Y_2 v^2}{M_{KK}^2} \right)$$

$$m_{SM}^d - Y_{SM}^d v \approx m_{SM}^d 2 \frac{Y_1 Y_2 v^2}{M_{KK}^2}$$

Tree-level Higgs FCNC's!

Define :

$$\mathcal{L}_{HFV} = a_{ij}^d \sqrt{\frac{m_i^d m_j^d}{v_4^2}} H \bar{d}_L^i d_R^j + h.c.$$

Solve perturbatively in $(Y v_4/M_{KK})$:

$$a_{ij}^d \sim \delta_{ij} - \bar{Y}^2 \frac{v_4^2}{M_{KK}^2} \begin{pmatrix} 1 & \lambda \sqrt{\frac{m_s}{m_d}} & \lambda^3 \sqrt{\frac{m_b}{m_d}} \\ \frac{1}{\lambda} \sqrt{\frac{m_d}{m_s}} & 1 & \lambda^2 \sqrt{\frac{m_b}{m_s}} \\ \frac{1}{\lambda^3} \sqrt{\frac{m_d}{m_b}} & \frac{1}{\lambda^2} \sqrt{\frac{m_s}{m_b}} & 1 \end{pmatrix}$$

$$a_{ij}^u \sim \delta_{ij} - \bar{Y}^2 \frac{v_4^2}{M_{KK}^2} \begin{pmatrix} 1 & \lambda \sqrt{\frac{m_c}{m_u}} & \lambda^3 \sqrt{\frac{m_t}{m_u}} \\ \frac{1}{\lambda} \sqrt{\frac{m_u}{m_c}} & 1 & \lambda^2 \sqrt{\frac{m_t}{m_c}} \\ \frac{1}{\lambda^3} \sqrt{\frac{m_u}{m_t}} & \frac{1}{\lambda^2} \sqrt{\frac{m_c}{m_t}} & 1 \end{pmatrix}$$

Tree level HIGGS exchange will induce $s_L d_R s_R d_L$ with coefficient

$$C_4 = a_{ds} a_{sd} m_d m_s \frac{1}{m_h^2 v^2} \Rightarrow K - \bar{K} \text{ mixing and } \epsilon_K \text{ put tight bounds}$$

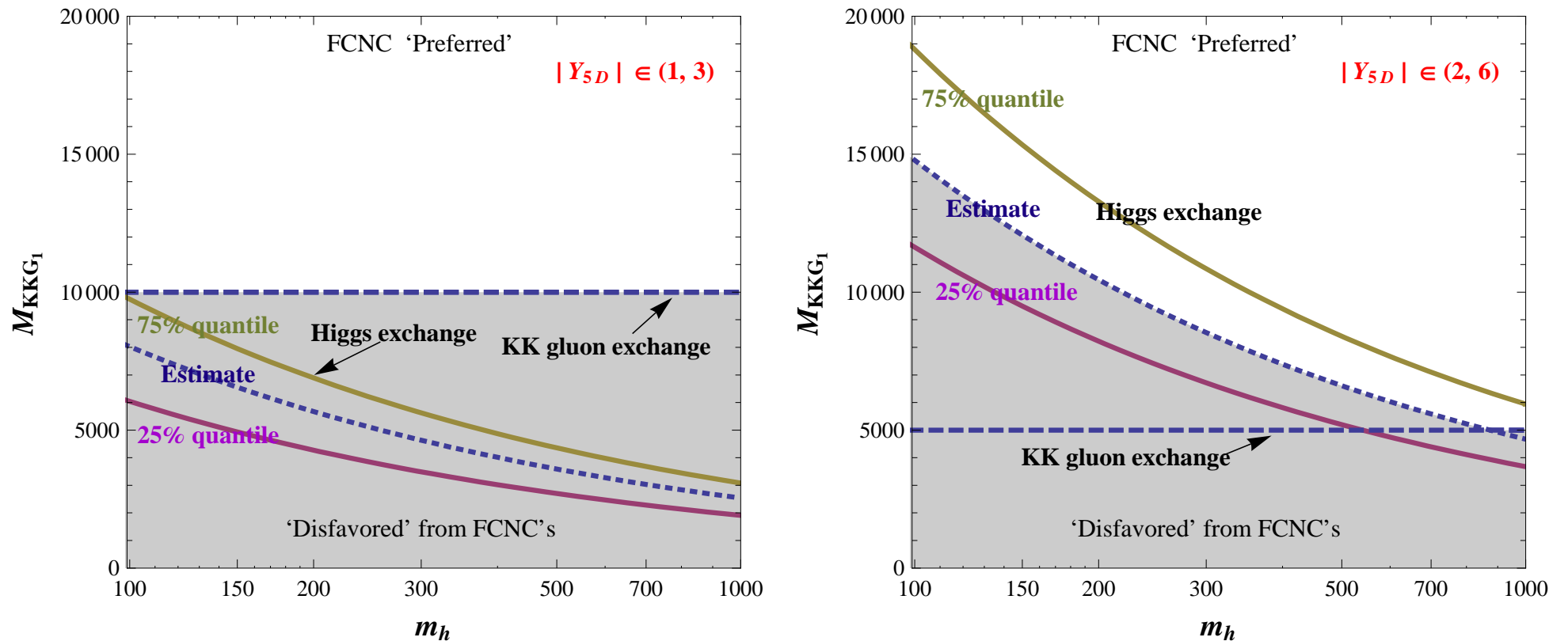


Figure 2: "Bounds" from ϵ_K in $(m_h - M_{KK})$ plane from Higgs exchange

LHC Reach for $t \rightarrow ch$

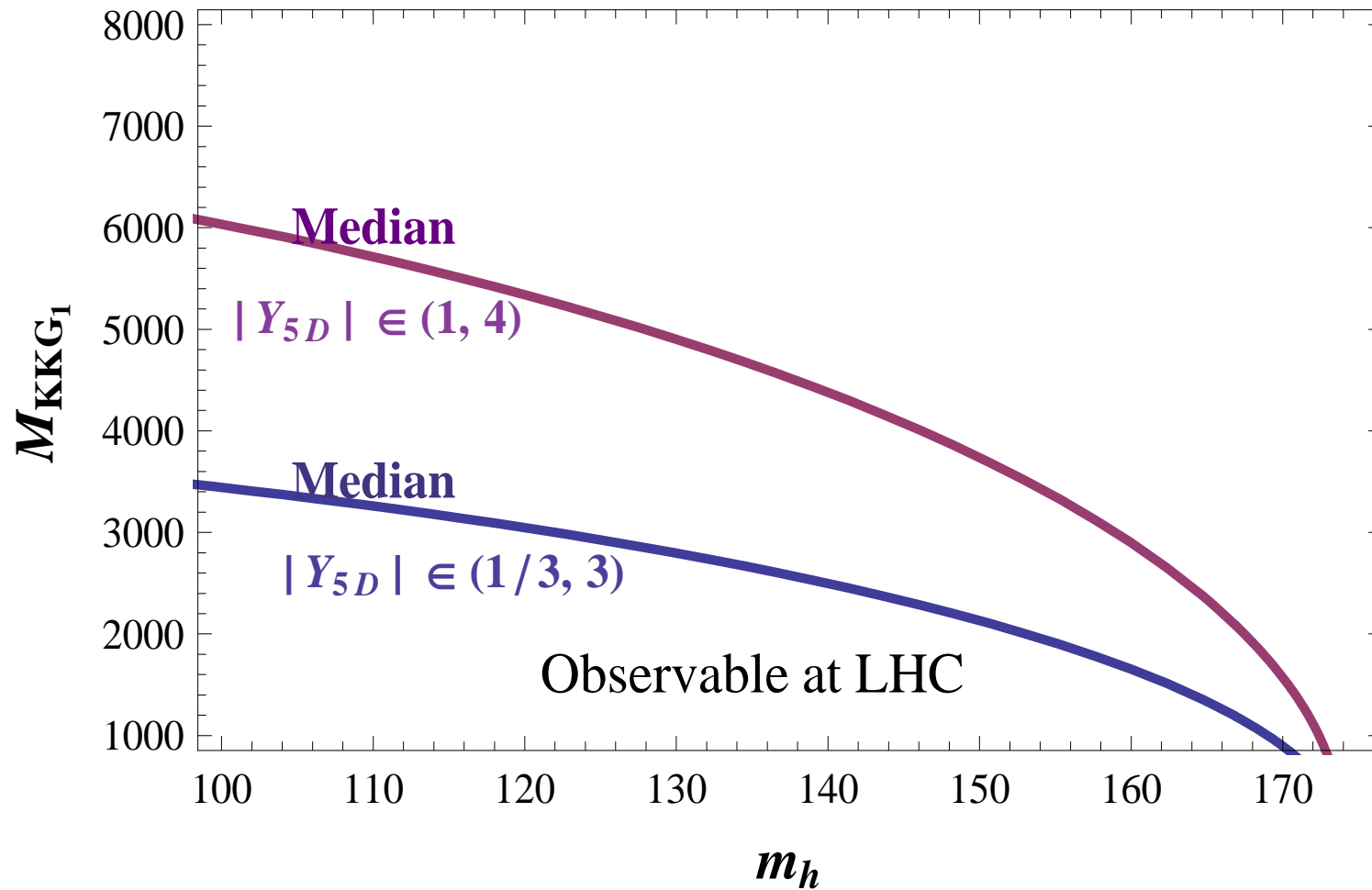


Figure 3: LHC observability $t \rightarrow ch$ in the plane (m_h, M_{KKG_1}) .
(using [\[Aguilar–Saavedra, Branco\(00\)\]](#) study)

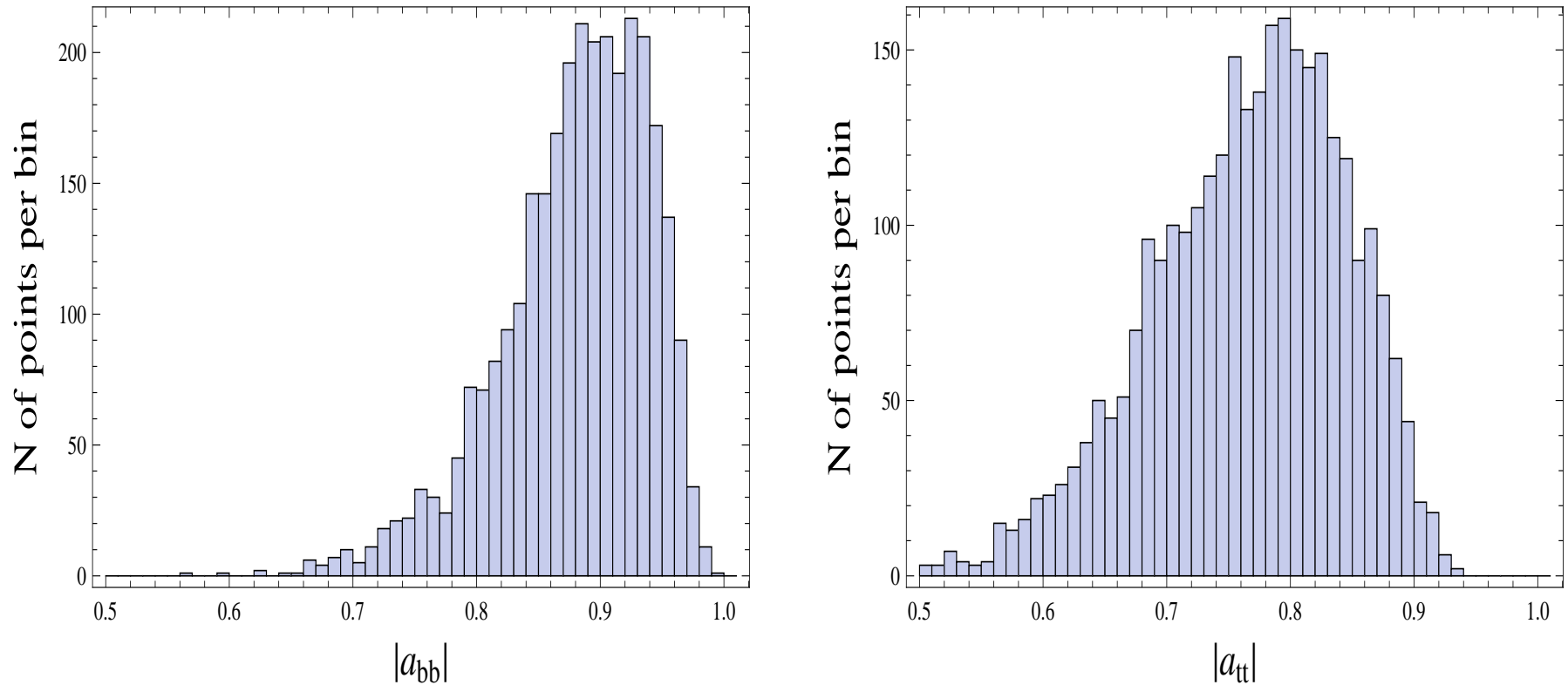


Figure 4: Distribution of a_{tt} and a_{bb} , in our numerical scan, with a fixed KK scale of $R'^{-1} = 1500$ GeV (KK gluon mass $M_{KKG} = 2.45R'^{-1}$) and for 5D Yukawas $|Y_{5D}^{ij}| \in [0.3, 3]$.

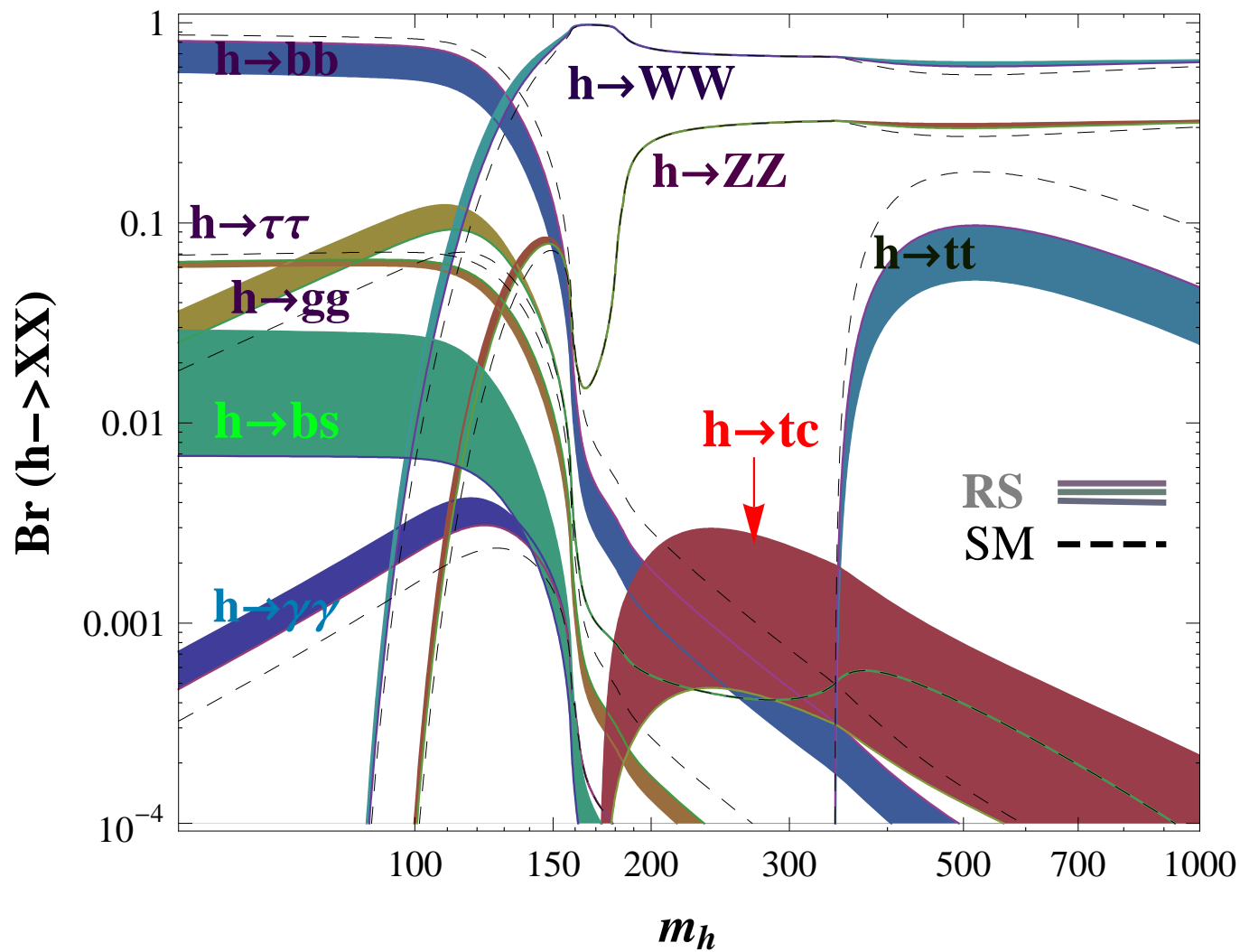


Figure 5: Higgs Branchings, for $\bar{Y} \sim 3$ and $1/R' = 1500$ GeV.
 ($KKG_1 \sim 3.5\text{TeV}$)

Outlook

Maybe LHC discovers just one (or two) scalar(s) and that's **IT**.

Is it the **SM Higgs?** (or a 2 Higgs doublet model?)
or is it the radion of **RS**? (or radion plus a Higgs?)

- Probing couplings to fermions important (and hard).
- Higgs production may be significantly enhanced (**work in progress**)
- Probing the size of the Flavor structure also important.
- Flavor at LHC? ($t \rightarrow ch$, $(h, \phi) \rightarrow t c$, $(h, \phi) \rightarrow \mu\tau..$)
- Linear Collider? Muon Collider?
- Higgs-radion mixing..

Backup – Calculation

Down quark Action with a Bulk Higgs, in RS:

$$S = \int d^4x dz \sqrt{g} \left[\frac{i}{2} (\bar{Q} \Gamma^A \mathcal{D}_A Q - D_A \bar{Q} \Gamma^A Q) + \frac{i}{2} (\bar{U} \Gamma^A \mathcal{D}_A U - \mathcal{D}_A \bar{U} \Gamma^A U) \right. \\ \left. + \frac{c_Q}{R} \bar{Q} Q + \frac{c_U}{R} \bar{U} U + (Y \bar{Q} \mathcal{H} U + h.c.) \right]$$

Decompose $Q = \begin{pmatrix} \mathcal{Q}_L \\ \mathcal{Q}_R \end{pmatrix}$ and $D = \begin{pmatrix} \mathcal{D}_L \\ \mathcal{D}_R \end{pmatrix}$ and perform a mixed KK expansion:

$$\mathcal{Q}_L(x, z) = q_L(z) Q_L(x) + \dots$$

$$\mathcal{Q}_R(x, z) = q_R(z) D_R(x) + \dots$$

$$\mathcal{D}_L(x, z) = d_L(z) Q_L(x) + \dots$$

$$\mathcal{D}_R(x, z) = d_R(z) D_R(x) + \dots$$

⇒ Mixed profile equations

$$-m_d q_L - q'_R + \frac{c_q + 2}{z} q_R + \left(\frac{R}{z}\right) v(z) Y_d d_R = 0$$

$$-m_d^* q_R + q'_L + \frac{c_q - 2}{z} q_L + \left(\frac{R}{z}\right) v(z) Y_d d_L = 0$$

$$-m_d d_L - d'_R + \frac{c_d + 2}{z} d_R + \left(\frac{R}{z}\right) v(z) Y_d^* q_R = 0$$

$$-m_d^* d_R + d'_L + \frac{c_d - 2}{z} d_L + \left(\frac{R}{z}\right) v(z) Y_d^* q_L = 0$$

Massaging them we arrive at:

$$m_d = R^4 \int_R^{R'} dz \left(\frac{m_d}{z^4} (|d_L|^2 + |q_R|^2) + \frac{Rv(z)}{z^5} (Y_d d_R q_L^* - Y_d^* q_R d_L^*) \right)$$

4D Higgs Yukawa is : $y_4^d = R^5 \int_R^{R'} dz \frac{h(z)}{z^5} (Y_d d_R q_L^* + Y_d^* q_R d_L^*)$

Misalignment between 4D fermion mass matrix and Yukawas!

$$\Delta^d = R^4 \int_R^{R'} dz \left(\frac{m_d}{z^4} (|d_L|^2 + |q_R|^2) - 2Y_d^* \frac{Rv(z)}{z^5} q_R d_L^* \right).$$

Higgs Production - work in progress

H glu glu coupling:

- top quark and KK tower

Even if top Yukawa reduced, extra KK tops render the coupling SM-like

- light quarks and KK tower

If shifts in the light quarks yukawa is δ , the KK tower contributes by (δ)

Overall coupling becomes $1 + 5\delta$ wrt SM contribution.