LRS@LHC

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Based on: H. D., G. Perez, and A. Soni

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Introduction

- Warped 5D Randall-Sundrum (RS) model: Planck-weak hierarchy.

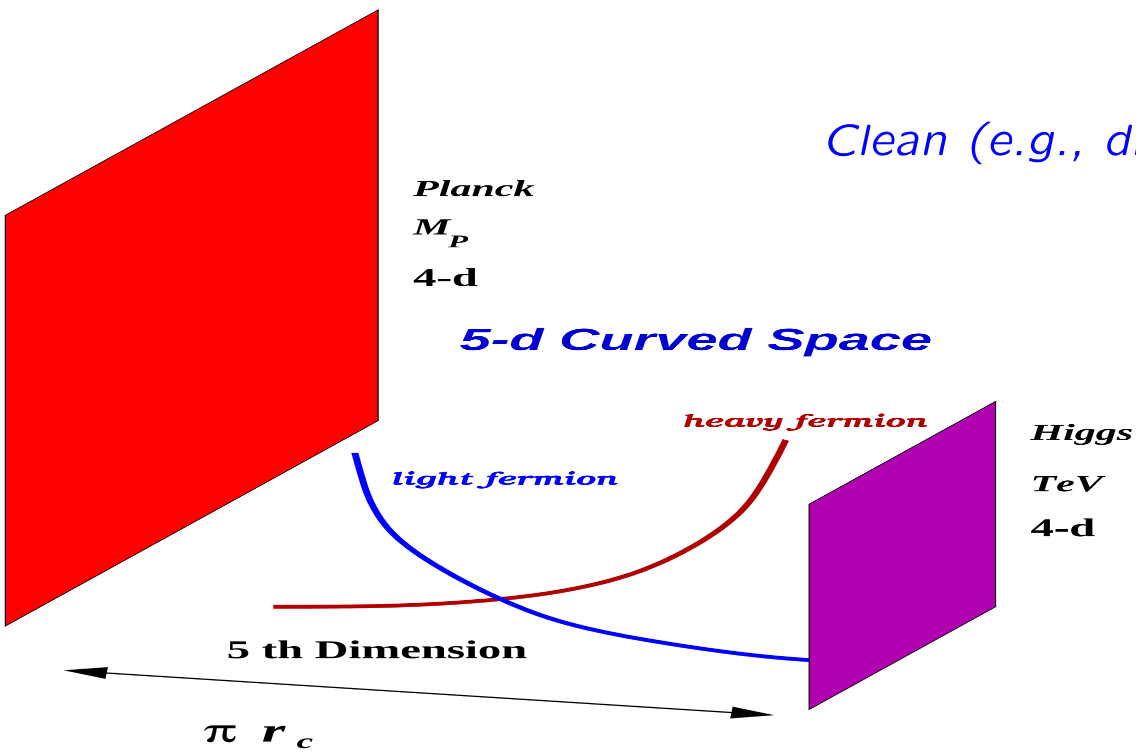
- $e^{-kr_c\pi}M_5 \sim$ TeV, $kr_c\pi \approx 35$ for $M_5 \sim M_P$. Randall, Sundrum, 1999

- Distinct signatures: spin-2,... TeV-scale resonances.

- SM in 5D bulk, fermion profiles $\rightarrow$ Realistic model of flavor.

- Bulk fermion masses: light (heavy) fermions UV(IR)-localized.

Clean (e.g., di-lepton) KK signals suppressed.



Oblique Corrections

$$S_{tree} \approx 2\pi\,(v/\kappa)^2 \quad ; \qquad T_{tree} \approx \frac{\pi}{2\cos\theta_W^2}(v/\kappa)^2\underbrace{(kr_c\pi)}_{\approx 35}$$

- $\kappa \equiv ke^{-kr_c\pi} \sim m_{KK}^{\text{gauge}}/2.5$
- KK-tower mixing via EWSB (modified zero-modes) $\propto kr_c\pi$
- $m_{KK}^{\text{gauge}} \sim 3$ TeV $\rightarrow T_{tree} \sim 3$ (RS); data: $|S| \sim |T| \sim 0.1 - 0.3$.

Little Randall-Sundrum (LRS) Model:

- Truncated; $kr_c\pi = 6$ ($M_5 \sim 10^3$ TeV).
- Flavor same as RS: λ_5 (5D Yukawa) and fermion IR-profiles.
- Suppression of T_{tree} in LRS.

$m_{KK}^{\text{gauge}} \sim 3$ **TeV** $\rightarrow T_{tree} \sim 3/y$

LRS truncation factor: $y \equiv (kr_c\pi|_{RS})/(kr_c\pi|_{LRS}) \approx 6.$

• S_{tree}: Largely *universal* shift in light fermion-gauge coupling.

(i) zero-mode-KK mixing $\sim \sqrt{kr_c\pi}$.

(ii) Fermion coupling to KK modes $\sim 1/\sqrt{kr_c\pi}$.

$\Rightarrow$ S_{tree} unchanged after LRS truncation.

• δT: *UV-sensitive* loops, cutoff operators: $m_{KK} \gtrsim 10$ TeV.

- LRS: δT loop and cutoff contributions same as RS.

Need *gauged 5D custodial symmetry*:

$SU(2)_L \times SU(2)_R \times U(1)_X$.

- T: Eliminate tree, cutoff, UV-sensitive loops.

- $S, T \Rightarrow m_{KK} \gtrsim 3$ TeV. Agashe, Delgado, May, Sundrum, 2003

- Same for RS and LRS.

Non-Oblique Corrections & Flavor Physics

- LRS: λ_5 unscaled $\rightarrow$ non-universality unchanged vis-à-vis RS.

- RS and $Zb\bar{b}$:

- $m_{KK} \gtrsim 3$ TeV with custodial symmetry and $\mathbb{Z}_2$.

- Otherwise: $m_{KK} \gtrsim 5$ TeV. Agashe, Contino, Da Rold, Pomarol, 2006

- LRS and $Zb\bar{b}$:

- Gauge KK-mixing: truncated.

- Untruncated: $\underbrace{b_L - b_R^{KK}}_{\text{Yukawa}} \propto m_{KK}(b_R)^{-2} \rightarrow m_{KK}(b_R) \gtrsim 4$ TeV

- Implies m_{KK}(gauge) $\gtrsim 3$ TeV in LRS! (no $\mathbb{Z}_2$, but custodial for T)

- $\Delta F = 2$: tree-level KK gluon exchange contribution to ϵ_K.

Agashe, Perez, Soni, 2004

- Dominant contribution from $(V - A) \times (V + A)$: UTfit Collaboration, 2007

$\rightarrow m_{KK} \gtrsim 20$ TeV (RS); $\mathcal{O}(30\%)$ uncertainty Csaki, Falkowski, Weiler, 2008

LRS bound smaller by $1/\sqrt{y} \approx 1/2.5$.

LRS Phenomenology and Golden Modes

- $\boldsymbol{g_{KK}|_{UV} \sim g_4/\sqrt{kr_c\pi}, \quad g_{KK}|_{IR} \sim g_4\sqrt{kr_c\pi}.}$

(i) Broad KK states become narrower by y.

(ii) Width into light states $(e^+e^-, u\bar{u}, \ldots)$ enhanced by $y \to$ BR$\sim y^2$.

(iii) $\sigma(f_i\bar{f}_j \to KK \to f_k\bar{f}_l) \propto \Gamma(KK \to f_i\bar{f}_j)\mathrm{BR}(KK \to f_k\bar{f}_l)$

(i) $\oplus$ (ii) $\oplus$ (iii) $\Rightarrow \mathcal{S} \sim y^3$ and $\mathcal{B} \sim 1/y$ (over the width); $\mathcal{S}/\mathcal{B} \sim y^4$.

LRS, $y \approx 6 \Rightarrow \mathcal{S} \to \mathcal{O}(100)\mathcal{S}$; $\mathcal{S}/\mathcal{B} \to \mathcal{O}(1000)\mathcal{S}/\mathcal{B}$!

$M_{Z'} \sim 4-5$ TeV and L = 100 fb^{-1}: $Z' \to \ell^+\ell^-$, $\ell = e, \mu$.

Compare with RS: $M_{Z'} \sim 2$ TeV and L = 1000 fb^{-1}. Agashe *et al.*, 2007

Revived prospects for golden modes!

Holography

- $1/g_4^2 = \tau_{\text{UV}} + \tau_{\text{IR}} + \underbrace{\log(k/\kappa)}_{kr_c\pi}/(kg_5^2)$ $\tau_{UV,IR}$ small QM corrections

- Dual large N CFT: $kg_5^2 \sim 16\pi^2/N$.

LRS dual to *larger* N CFT : $N^{LRS} \sim yN^{RS}$.

- $N \to \infty$: inter-composite interactions weaker (*e.g.* T_{tree}).

- S_{tree}: mainly universal vertex correction, unchanged.

[Mixing] $\times$ [light fermion coupling]: $\sim 1/\sqrt{N} \times \sqrt{N}$.

- LRS: λ_5 unchanged $\to$ *separate* "Flavor CFT": $N_F \sim N^{RS} < N^{LRS}$.

Non-universality from compositeness held fixed.

Truncation & IR Probes of UV Scales:

- Other truncations are possible:

- TeV$\rightarrow 10^{10}$ GeV (ν_R mass, ...): $y \approx 2$; $\mathcal{S} \rightarrow 10\mathcal{S}$.

- TeV$\rightarrow 10^{15}$ GeV (GUT): $y \approx 1.3$; $\mathcal{S} \rightarrow 2\mathcal{S}$.

- TeV data: Relative BR into IR $(H, t, \ldots)$ and UV $(e, \mu, \ldots)$ channels.

$\Rightarrow$ Size of 5D slice/conformal window.

UV-Completion:

- Recent LRS UV-model: K. McDonald arXiv:0804.0654 [hep-th].

- 6D geometry, 2 warped directions.

- LRS a 5D slice (4-brane), with $M_5 \sim 10^3$ TeV $\rightarrow$ TeV.

- Warping along the 6$^{\text{th}}$ dimension: $M_6 \sim M_P \rightarrow 10^3$ TeV.

- Generalized to n-warped spacetime.

Summary & Conclusions

- LRS: predictive warped model of flavor, cutoff at $\mathcal{O}(10^3)$ TeV.

- Separate gauge and flavor dynamics.

- Many contributions to precision data suppressed.

- Return of the golden modes (*e.g.* di-leptons)!

- LHC discovery prospects much better than the RS counterpart.

- Dual CFT: larger N dynamics for the weakly gauged sector.

- Collider physics very sensitive to truncation.

- TeV data $\rightarrow$ UV-scale/conformal window.

- UV-completion: stabilize $\Lambda_{UV}^{LRS} \sim 10^3$ TeV (hierarchy).