ν Masses from an A_4 Symmetry in Holographic Composite Higgs Models

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arXiv:1001.5151 [hep-ph]
and arXiv:1007.xxxx [hep-ph, hep-ex]

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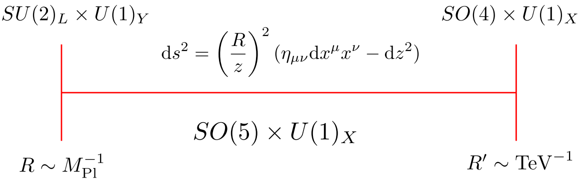
- We can identify the Higgs as the scalar component of a 5D gauge field to solve the hierarchy problem.

$$\text{vector field} \rightarrow A_\mu^{\hat{a}} \overset{\text{gauge symmetry}}{\longleftrightarrow} A_5^{\hat{a}} \leftarrow \text{scalar field}$$

- We consider a 5D model in a slice of AdS_5



- $SO(5)/SO(4)$ is broken at both branes $\longrightarrow$ Massless modes for $A_5^{\hat{a}}$

$$T^{\hat{a}} \in \mathrm{Alg}\{SO(5)/SO(4)\}, \qquad a = 1, 2, 3, 4.$$

4 real scalar fields $\sim$ Higgs doublet

- In extra dimension models fermion masses are naturally hierarchical [*Arkani-Hamed '00*] and also the mixings [*J. Huber '03*]
- This works well with the quark sector but, the PMNS matrix is not hierarchical but it has a certain structure $\rightarrow$ Compatible with TBM

$$|U_{\mathrm{TBM}}| = \begin{pmatrix} 0.81 & 0.58 & 0 \\ 0.41 & 0.58 & 0.71 \\ 0.41 & 0.58 & 0.71 \end{pmatrix}$$

One possible solution to explain the pattern of lepton mixing is to assume a global discrete symmetry acting on this sector.

- We use an A_4 symmetry which can predict a TBM pattern to leading order and protect us against large LFV.

A_4 and the leptonic spectra

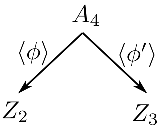
- A_4 has 3 inequivalent one-dimensional representations, $\mathbf{1}$,$\mathbf{1}'$,$\mathbf{1}''$, and one three-dimensional one $\mathbf{3}$:

Each RH charged lepton transforms as one different one-dimensional representation while the other fields span A_4-triplets.

- We add localized scalars:

UV	A_4	IR	A_4
ϕ	$\mathbf{3}$	ϕ'	$\mathbf{3}$

that couple the different fields between them at both branes and break down A_4



This produces differentiated structures for the neutrino Majorana mass (UV) and the charged lepton Dirac mass (IR) that lead to the TBM mixing matrix.

Experimental constraints

We have checked lepton masses and mixings, EWPT and tree-level and one-loop LFV processes with the IR scale fixed to 1.5 TeV.

They impose a relatively small value of v'/Λ', where $\langle\phi'\rangle = (v', v', v')$, but the charged lepton mass is

$$\mathcal{M}_D^e \propto v_H \frac{v'}{\Lambda'} f_{L;IR} f_{R;IR}$$

τ_R more composite than expected

$$\zeta_\tau = \underbrace{\begin{pmatrix} \nu_\tau[+-] & \tilde{e}_\tau[+-] \\ e_\tau[+-] & \widetilde{Y}_\tau[+-] \end{pmatrix}} \oplus e'_\tau[--], \qquad c_\tau > -0.5$$

The bidoublet has, for $c_\tau \sim 0.5$, an ultra-light KK mode with almost degenerate leptons T^1, T^2, Y and N, with masses $\gtrsim 0.2$ TeV and large couplings to τ [*Del Águila, Santiago '02*] arXiv:1007.xxxx

Conclusions

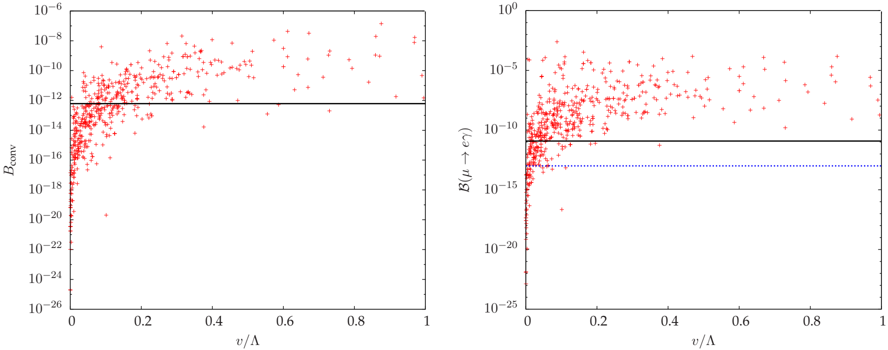
Composite Higgs models from 5D provide:

- Natural EWSB and hierarchical quark spectrum
- Correct lepton spectrum (A_4)
  - Hierarchical charged lepton masses
  - Correct neutrino masses and mixing
- Double layer of flavor protection
  - A_4 symmetry
  - Custodial symmetry
- New physics at $\sim 2-3$ TeV compatible with current EW precision and flavor data
- New leptonic resonances with masses of $\gtrsim 0.2$ TeV and large couplings to τ_R at LHC

Thank you!

Additional slides

Constraints on the model



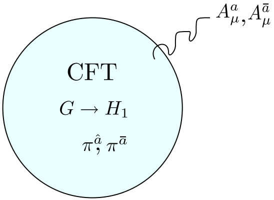
Composite pseudo-Goldstone bosons

- New gauge interactions can become strongly coupled at the TeV scale, breaking some global symmetry G down to H_1

$$G \to H_1, \qquad \pi^{\hat{a}}, \pi^{\bar{a}} \ \ \mathrm{GBs}, \qquad T^{\hat{a}}, T^{\bar{a}} \in \mathrm{Alg}\{G/H_1\}$$

- External gauge fields weakly gauge the subgroup H_0 of G:

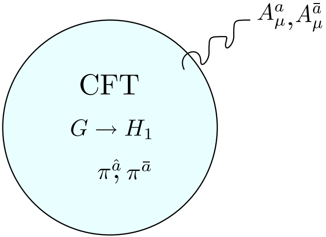
$$\mathcal{L} = \mathcal{L}_{\mathrm{CFT}} - \frac{1}{4}\left(F^{\alpha}_{\mu\nu}\right)^2 + A^{\alpha}_{\mu} J^{\mu\alpha}, \quad \alpha = a, \bar{a}.$$

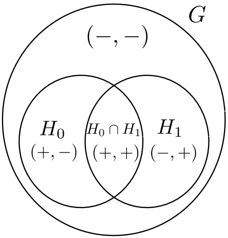


- The GBs in $\frac{H_0}{H_0 \cap H_1}$, $\pi^{\bar{a}}$, are eaten by the corresponding gauge bosons. The rest, $\pi^{\hat{a}}$, are PGBs

The AdS/CFT correspondence

Models with warped extra dimensions are weakly coupled duals to strongly coupled 4D conformal theories [*Maldacena '98*]





CFT

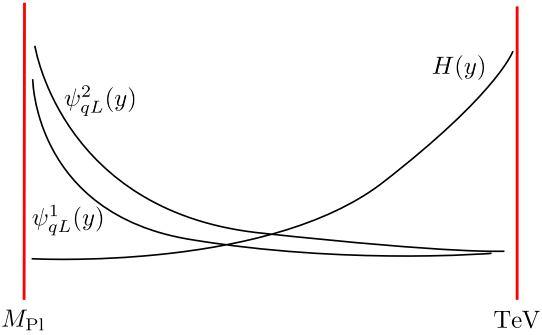
- Global symmetry group G
- Strong dynamics at $\mathcal{O}$(TeV)
- Weakly gauge of G_{EW}
- PGBs $\pi^{\hat{a}}$

$\Longleftrightarrow$

AdS

- Bulk gauge group G
- Neumann BCs at IR brane
- Neumann BCs at UV for G_{EW}
- $A_5^{\hat{a}}$ massless modes (GHU)

In extra dimension models fermion masses are naturally hierarchical [*Arkani-Hamed '00*]



$$m_u^{ij} \sim v_H \psi^i_{qL}(IR)\psi^j_{uR}(IR), \quad m_d^{ij} \sim v_H \psi^i_{qL}(IR)\psi^j_{dR}(IR),$$

and also the mixings [*J. Huber '03*]

$$V^{ij}_{\rm CKM} \sim \psi^i_{qL}(IR)/\psi^j_{qL}(IR)$$

- All the fermions are in fundamental representations of $SO(5) \to \mathbf{5} = (\mathbf{2}, \mathbf{2}) \oplus \mathbf{1}$
- 4 multiplets per family are required to have independent localizations for left and right-handed zero modes

$$\begin{aligned} \zeta_1 &= (\tilde{l}_1[-+]\ l_1[++]) \oplus \nu_1'[-+], \qquad \zeta_2 = (\tilde{l}_2\ [+-]\ l_2[+-]) \oplus \nu_1'[--], \\ \zeta_3 &= (l_3[-+]\ \tilde{l}_3[-+]) \oplus e_3'[-+], \qquad \zeta_\alpha = (l_\alpha[+-]\ \tilde{l}_\alpha[+-]) \oplus e_\alpha'[--], \end{aligned}$$

Three copies for each $\zeta_{1,2,3}$, but only one ζ_α set with $\alpha = e, \mu, \tau$.

$\zeta_{1,2}$ and $\zeta_{3,\alpha}$ have $U(1)_X$ charge 0 and -1 respectively

$[+/-]$ denotes a Dirichlet boundary condition for the RH/LH chirality