Higgs couplings in composite models

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based on work in progress with

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14 + 14, two-site model

$$\mathcal{L} = (\text{kin terms}) - M_1 \overline{\psi}_1 \psi_1 - M_4 \overline{\psi}_4 \psi_4 - M_9 \,\text{Tr}\,[\overline{\psi}_9 \psi_9]$$
$$- F_q \,\text{Tr}\,[\overline{\mathcal{Q}}_L U^T \psi_R U] - F_u \,\text{Tr}\,[U^T \overline{\psi}_L U \mathcal{T}_R] + \text{h.c.}$$

where ψ is a complete **14** of *SO(5)*. Recall that **14 ~ 9 + 4 + 1** under *SO(4)*.
U is the Goldstone matrix. $q_L = (t_L, b_L)^T \in \mathcal{Q}_L$ and $t_R \in \mathcal{T}_R$

Higgs potential is

$$V \simeq \alpha \sin^2(h/f) + \beta \sin^4(h/f)$$

where α, β are $\mathcal{O}(\epsilon^2)$ and logarithmically divergent, for example

$$\beta = 2N_c \int \frac{d^4p}{(2\pi^4)} \left(F_q^2 - 5F_u^2/4\right) \left(\frac{5/4}{p^2+M_1^2} - \frac{2}{p^2+M_4^2} + \frac{3/4}{p^2+M_9^2}\right)$$

$$(\epsilon \sim F_{q,u}/M_i)$$

Estimate of tuning and Higgs mass

$$V \sim \frac{N_c}{16\pi^2}\epsilon^2 m_\psi^4 \left[\alpha s_h^2 + \beta s_h^4\right]$$

$\xi \equiv v^2/f^2 = -a/2b$ tuning needed is 'minimal', $\sim \xi \lesssim 0.2$

However, the potential is generically large (arises at quadratic order in the breaking), giving a large Higgs mass $(g_\psi = m_\psi/f)$

$$m_h^2 \gtrsim \frac{N_c}{2\pi^2} y_t^2 g_\psi^2 v^2 \quad \longrightarrow \quad m_h \gtrsim 400\,\mathrm{GeV}\left(\frac{g_\psi}{5}\right)$$

therefore need small $g_\psi \sim 1$: all resonances should be light,

around 1 ÷ 1.5 TeV for $\xi \sim 0.1\,(f \simeq 800\,\mathrm{GeV})$.

Panico, Redi, Tesi and Wulzer, 1210.7114

Higgs couplings

$$\frac{\lambda_{hgg}}{\lambda_{hgg}^{\mathrm{SM}}} \simeq 1 + \frac{3M_1M_4 - 11M_1M_9 + 8M_4M_9}{2M_9(M_1 - M_4)}\,\xi$$

BSM correction depends strongly on resonance spectrum

$$\frac{\lambda_{hWW}}{\lambda_{hWW}^{\mathrm{SM}}} = \sqrt{1-\xi} \simeq 1 - \frac{\xi}{2}$$

dictated by *SO(5)/SO(4)*

$$\frac{\lambda_{h\gamma\gamma}}{\lambda_{h\gamma\gamma}^{\mathrm{SM}}} \simeq 1.27\,\frac{\lambda_{hWW}}{\lambda_{hWW}^{\mathrm{SM}}} - 0.27\,\frac{\lambda_{hgg}}{\lambda_{hgg}^{\mathrm{SM}}}$$

fermionic contribution is same as for *hgg* : no colorless el. charged states (no partners for leptons)

$$\frac{\lambda_{hbb}}{\lambda_{hbb}^{\mathrm{SM}}} = \frac{1-2\xi}{\sqrt{1-\xi}} \simeq 1 - \frac{3}{2}\xi$$

assume $q_L, b_R \sim \mathbf{5}_{-1/3}$ and neglect effects of bottom partners (link with Higgs potential is much weaker than for top)

Bottom line: the most relevant couplings are fixed by **3** parameters

$$\xi, \quad r_{41} = \frac{M_4}{M_1}, \quad r_{91} = \frac{M_9}{M_1}$$

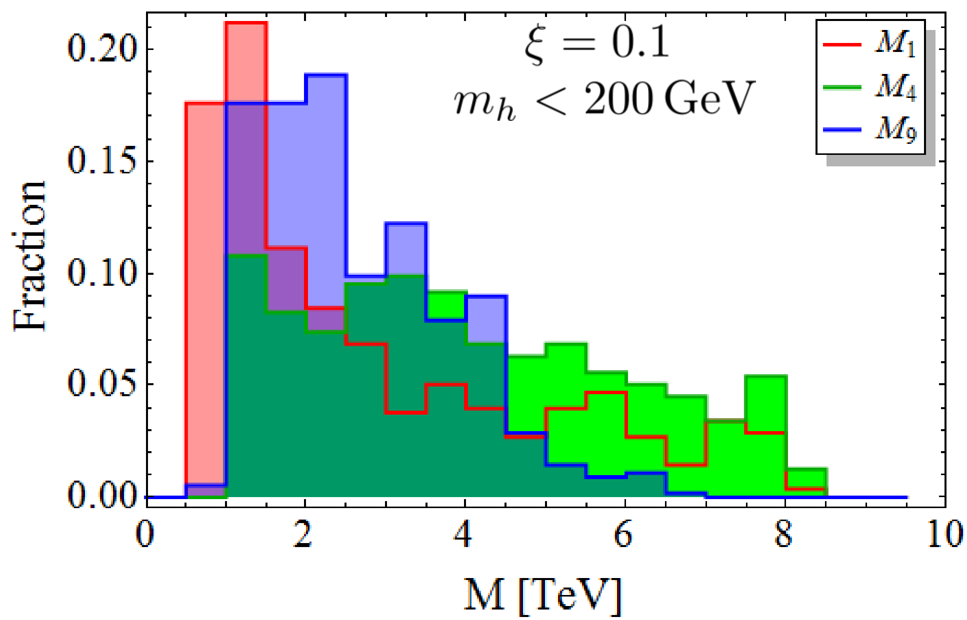
Spectrum

- In the two-site model, all the Higgs potential is logarithmically divergent.
  To make it finite, need to go to 3 sites.
- But to study Higgs couplings, all we need is the distribution of M_4/M_1 and M_9/M_1 for realistic points.
- So go for very simplified treatment: regularize divergences with a UV cutoff Λ (roughly representing the mass of the next layer of resonances).

Overall scale of resonances is sensitive to the choice of Λ, but it cancels out in the mass ratios.

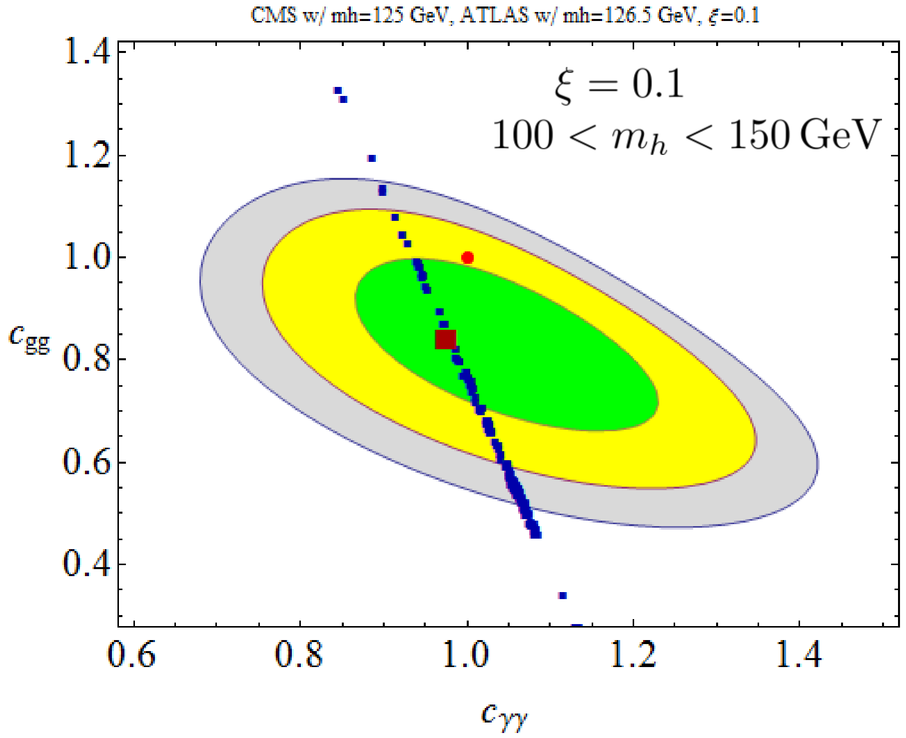
- Typical mass hierarchy is

$$M_1^p < M_9^p < M_4^p$$



Fit to Higgs data

- Fit to current Higgs data, assuming the value quoted before for $hb\bar{b},\ hWW$ couplings and leaving $hgg,\ h\gamma\gamma$ as free parameters:



Relation between *hgg* and *htt*

- In partial compositeness, the *hgg* coupling does not receive corrections of $\mathcal{O}(\epsilon)$
- The *htt* coupling is equal to *hgg* at leading order, but does receive corrections:

$$\frac{\lambda_{htt}}{\lambda_{htt}^{\rm SM}} \simeq \frac{\lambda_{hgg}}{\lambda_{hgg}^{\rm SM}} + \left[\frac{5F_q^2}{4}\left(\frac{2}{M_4^2} - \frac{1}{M_1^2} - \frac{1}{M_9^2}\right) + \frac{5F_u^2}{2}\left(\frac{1}{M_1^2} - \frac{1}{M_4^2}\right)\right]\xi$$