Evasive maneuvers for a sequential fourth generation to circumvent the Higgs data

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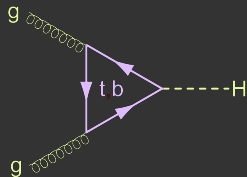
2nd September, 2019

Why evasive maneuver?

- Higgs coupling modification factors relative to the SM:

$$\kappa_x = \frac{g_{xxh}}{(g_{xxh})_{\rm SM}} \ .$$

- The modification factor for the $gg \to h$ production

$$R_{gg} \quad = \quad \frac{\left| \kappa_t F_{1/2}(\tau_t) + \displaystyle\sum_{f=t',b'} \kappa_f F_{1/2}(\tau_f) \right|^2}{\left| F_{1/2}(\tau_t) \right|^2} \approx 9$$

when $\kappa_t = \kappa_{t'} = \kappa_{b'} = 1$ in the SM-like limit.

Consequences

High Energy Physics - Phenomenology

Sealing the fate of a fourth generation of fermions

Abdelhak Djouadi, Alexander Lenz

High Energy Physics - Phenomenology

The rise and fall of the fourth quark-lepton generation

M.I.Vysotsky

High Energy Physics - Phenomenology

Implications of Higgs Searches on the Four Generation Standard Model

Eric Kuflik, Yosef Nir, Tomer Volansky

The maneuver

- NP contribution to $gg \to h$ is proportional to $\kappa_{gg} = (\kappa_{t'} + \kappa_{b'})$.
- Wrong sign limit:

$$\kappa_V = 1 \qquad (V = W, Z)$$
$$\kappa_u = 1 \qquad \text{(for up type quarks)}$$
$$\kappa_d = -1 \qquad \text{(for down type quarks and charged leptons)}.$$

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\kappa_{\gamma\gamma} &= \sum_{f=t',b',\tau'} Q_f^2 \, N_c^f \, \kappa_f \\
&= \left(+\frac{2}{3}\right)^2 \cdot 3 \cdot (+1) + \left(-\frac{1}{3}\right)^2 \cdot 3 \cdot (-1) + (-1)^2 \cdot 1 \cdot (-1) = 0.
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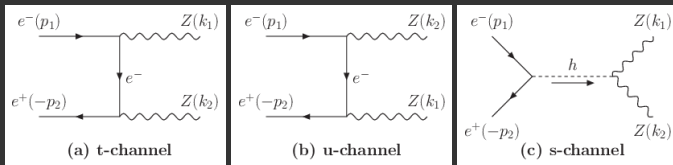
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- The NP contribution to $h \to Z\gamma$

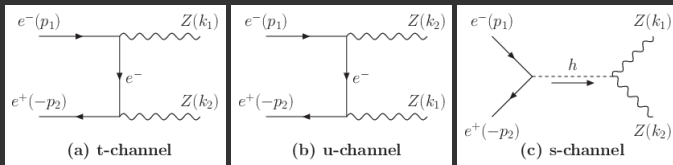$$\kappa_{Z\gamma} = \sum_{f=t',b',\tau'} Q_f \, T_3^f \, N_c^f \, \kappa_f = 0.$$

Implementation

- Not possible in the SM with only one scalar doublet.

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- Type II 2HDM:

$$\kappa_V = \sin(\beta - \alpha), \quad (V = W, Z)$$
$$\kappa_u = \sin(\beta - \alpha) + \cot\beta\cos(\beta - \alpha), \quad \text{(up quarks)}$$
$$\kappa_d = \sin(\beta - \alpha) - \tan\beta\cos(\beta - \alpha). \quad \text{(down quarks and charged leptons)}$$
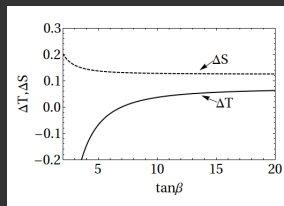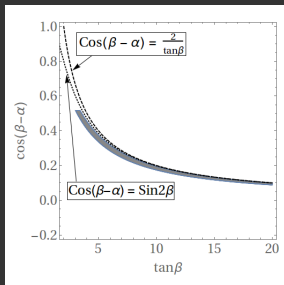
- Wrong sign is achieved by

$$\cos(\beta - \alpha) = \frac{2}{\tan\beta}, \quad \text{with, } \tan\beta \gg 2.$$

Results

Benchmark:

$$m_{t'} = 550\,\text{GeV},\ m_{b'} = 510\,\text{GeV},\ m_{\tau'} = 400\,\text{GeV},\ m_{\nu'} = 200\,\text{GeV},$$
$$m_H = 400\,\text{GeV},\ m_A = 810\,\text{GeV},\ m_{H+} = 600\,\text{GeV}.$$

Caveat emptor

> " Whoever thinks a faultless piece to see,
> Thinks what ne'er was, nor is, nor e'er shall be, "
>
> Alexander Pope

- Direct searches at the LHC? Sometimes relies on assumptions about V_{i4} and/or V_{4i}. (1205.0575).
- What about perturbative unitarity once LHC pushes too far?
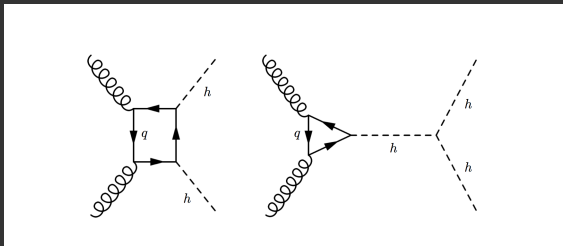- What about vacuum stability? More scalars?

Conclusion

- A sequential fourth generation of fermions faces constraints from many different considerations.

- But, at least, we know how to survive the constraints arising from measurements of Higgs signal strengths.

- This scenario can be tested in the di-Higgs production. Substantially higher no. of events expected. (Work in progress!)
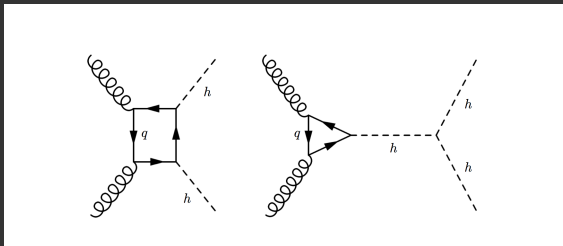
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THANK   YOU !