Higgs physics in the Composite Higgs models

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Outline

1. $h \to Z\gamma$ in the Composite Higgs models, arXiv:1308.6601
2. Resoving degeneracies in the Higgs couplings using high p_T Higgs production, arXiv:1309.5273

Operators contributing to the $h \to Z\gamma$ coupling

- SILH Lagrangian, parametrizes effects of new physics in terms of the higher dimensional operators, the operators relevant for the $h\gamma\gamma, hZ\gamma$ interactions are

$$O_{HW} = \frac{ig}{m_W^2}(D^\mu H)^\dagger \sigma^i (D^\nu H) W^i_{\mu\nu}, \quad O_{HB} = \frac{ig'}{m_W^2}(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$$

$$O_{BB} = \frac{g'^2}{m_W^2}(HH^\dagger) B_{\mu\nu} B^{\mu\nu}$$

- O_{BB} is contributing to the $h\gamma\gamma, hZ\gamma$. O_{HW}, O_{HB} contribute to the $hZ\gamma$
- By simple dimensional analysis $c_{HW,HB} \sim \frac{m_w^2}{M^2}$ so that

$$\frac{\Delta\Gamma_{HW,HB}}{\Gamma^{SM}} \sim \frac{16\pi^2 v^2}{M^2}$$

- O_{BB} violates Goldstone symmetry of the Higgs boson $\Rightarrow$ $c_{BB} \sim \frac{m_w^2}{M^2} \times \left(\frac{\lambda}{M}\right)^2, \Rightarrow \frac{\Delta\Gamma_{BB}}{\Gamma^{SM}} \sim \frac{16\pi^2 v^2}{M^2} \times \frac{\lambda^2}{M^2}$

Symmetry properties of $hZ\gamma$ interaction

- Composite sector must be invariant under $SU(2)_L \times SU(2)_R$ symmetry because of the $\Delta\rho$ constraints
- SM B_μ couples to the T^3_R of the composite sector.
- $Z \sim B - W^L_3, \quad A \sim B + W^L_3 \Rightarrow$ we can introduce the spurious symmetry P_{LR} under, which $L \Leftrightarrow R$

$$Z \Leftrightarrow -Z, \quad A \Leftrightarrow A, \quad < H > \Leftrightarrow < H >$$

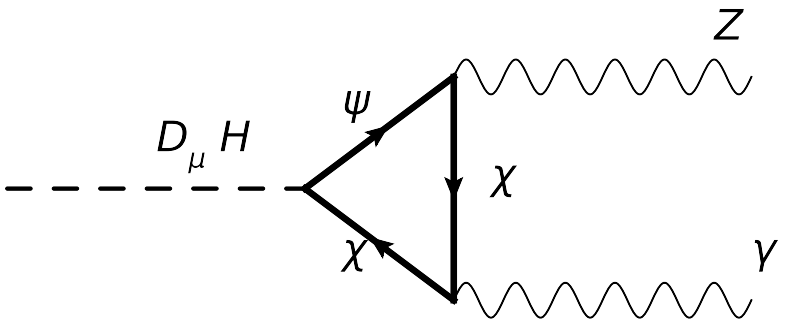
Higgs vev $< H >$ is invariant because it has vev along the $(\pm 1/2, \mp 1/2)$ components, $hZ\gamma$ interaction violates P_{LR}

- $P_{LR} : O_{BH(WH)} = O_{WH(BH)}$ and $(O_{BH} - O_{WH})$ is P_{LR} odd operator

$$C_{z\gamma} \propto C_{BH} - C_{WH}$$

$h \to Z\gamma$ in the Composite Higgs models

- Composite Higgs based on the partial compositeness (*Kaplan*) predict at the scale of a few TeV large multiplicity of the composite states $\sim N_F D$. These states interact with the Higgs boson and can contribute to the $h \to Z\gamma$



$hZ\gamma$ interaction can be generated with Higgs coupled only derivatively to the fermions

$SO(5)/SO(4)$ model with 10

In the $SO(5)/SO(4)$ coset the minimal set up with P_{LR} breaking in the fermion sector is based on the **10** representation

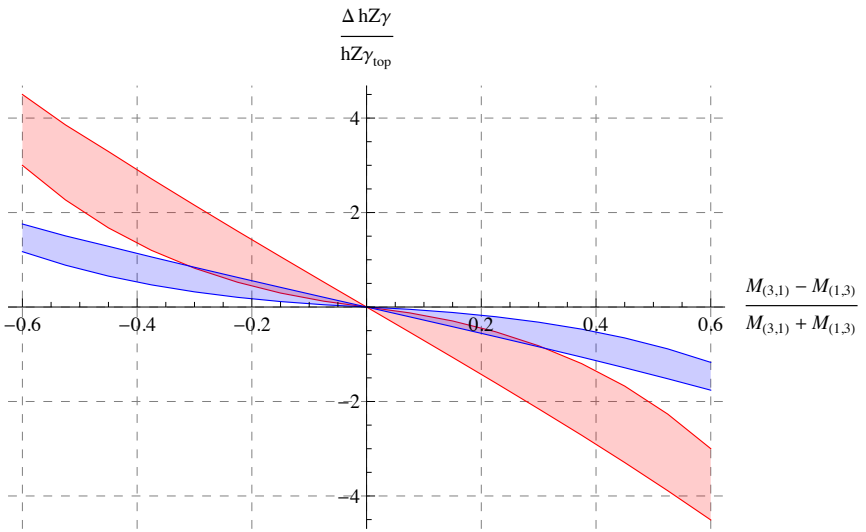


Figure : ratio of the A_{NP}/A_{top} for the model with 10 for one generation, red $f = 500$, blue $f = 800$ GeV

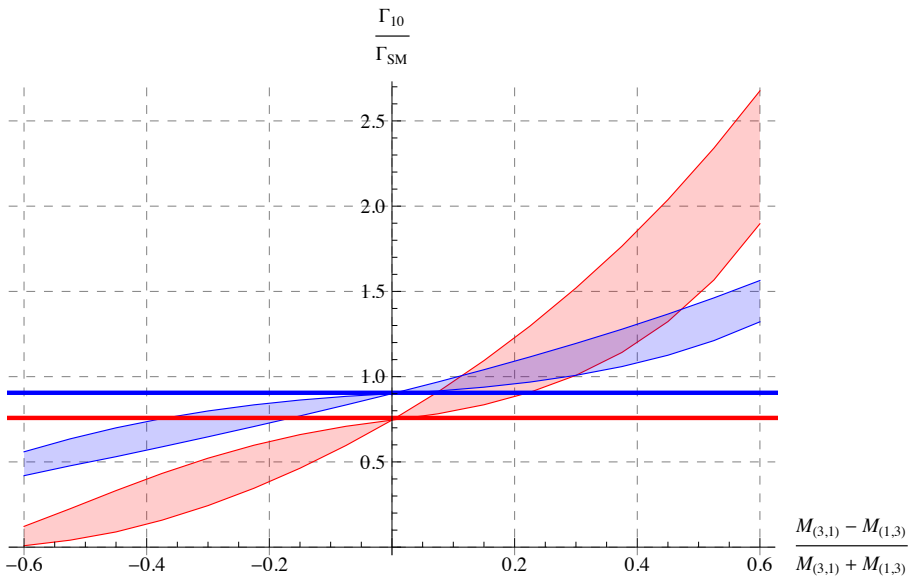
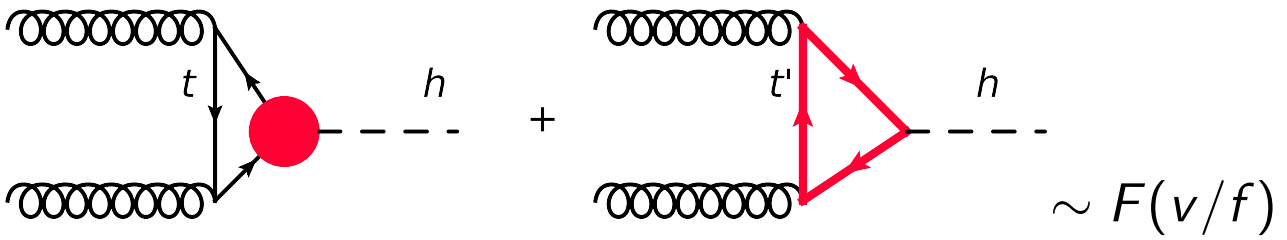


Figure : ratio of the Γ_{NP}/Γ_{SM} in the model with 10 with three generations

Higgs production in the Composite Higgs models

The Higgs production in the Composite Higgs models is described



Overall rate modification is independent of the details of the spectrum of top partners

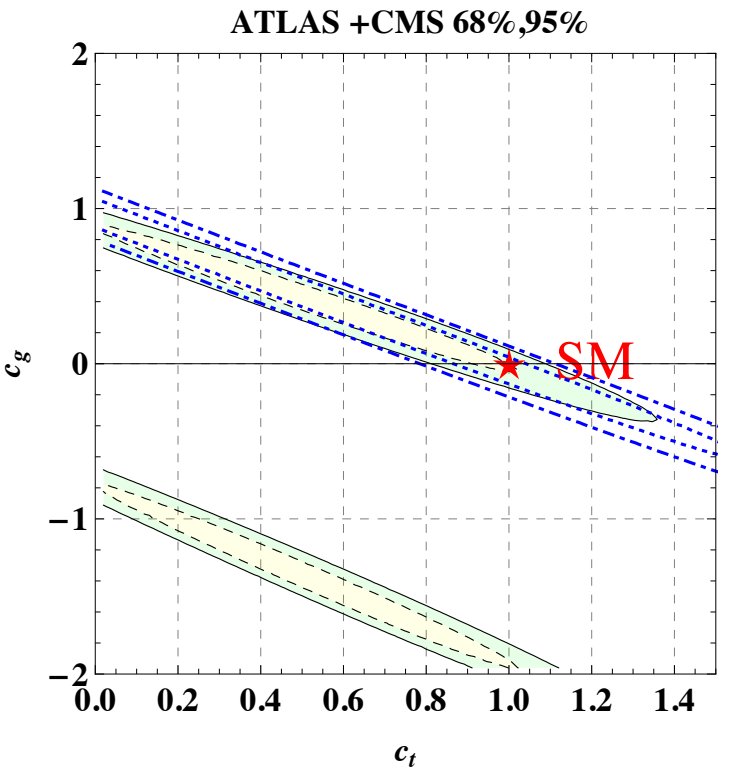
- One way is to measure the top coupling directly is to study *tth* production
- Is there another way to probe directly Higgs coupling to gluons and top quarks?

c_t, c_g degeneracy

- $\mathcal{L} = c_t \frac{m_t}{v} \bar{t} t h + \frac{g_s^2}{48\pi^2} c_g \frac{h}{v} G_{\mu\nu} G^{\mu\nu} + \frac{e^2}{18\pi^2} c_g \frac{h}{v} \gamma_{\mu\nu} \gamma^{\mu\nu}$

Since $m_h^2 \ll 4m_t^2$, we can integrate out top quark for the singel Higgs production and Higgs low energy theorems enforce

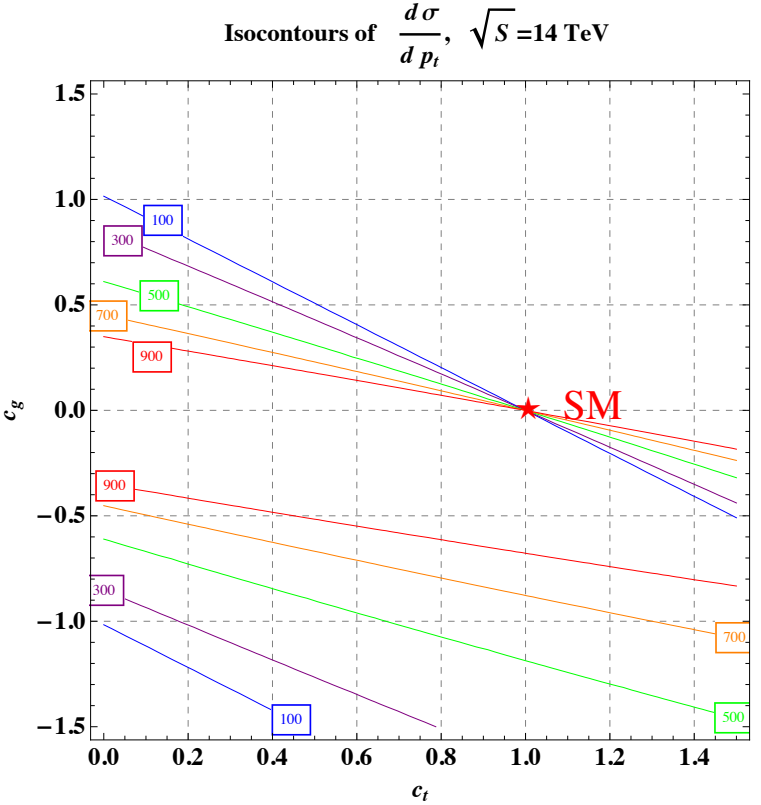
$$\sigma(pp \to h) \propto |c_t + c_g|^2$$



Higgs production at high p_T

We cannot integrate out top quark any more

$$\frac{d\sigma(h+X)}{dP_T} = \sum_i \kappa_i |c_t f_i(p_t) + c_g|^2$$



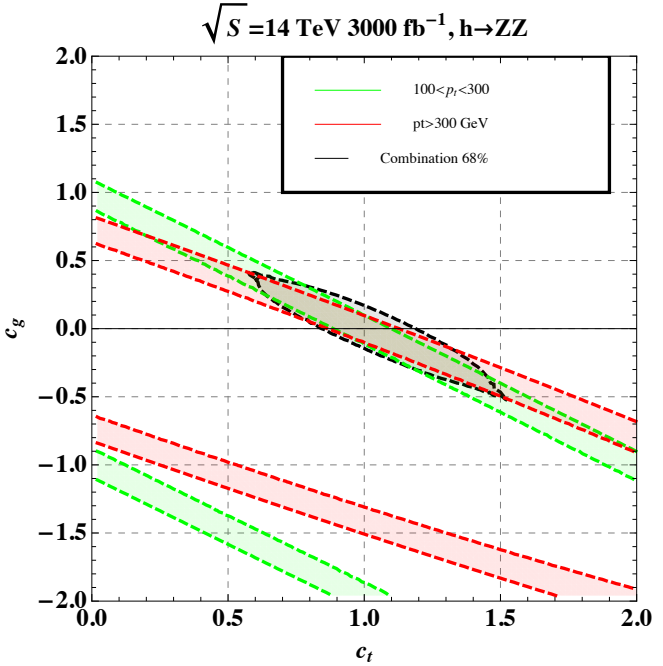
(See also Grojean,Salvioni,Shaffer,Weiler; Banfi,Martin,Sanz)

LHC high luminosity prospects

$$pp \to h+j \to ZZ*+j \to lll^+l^++j$$

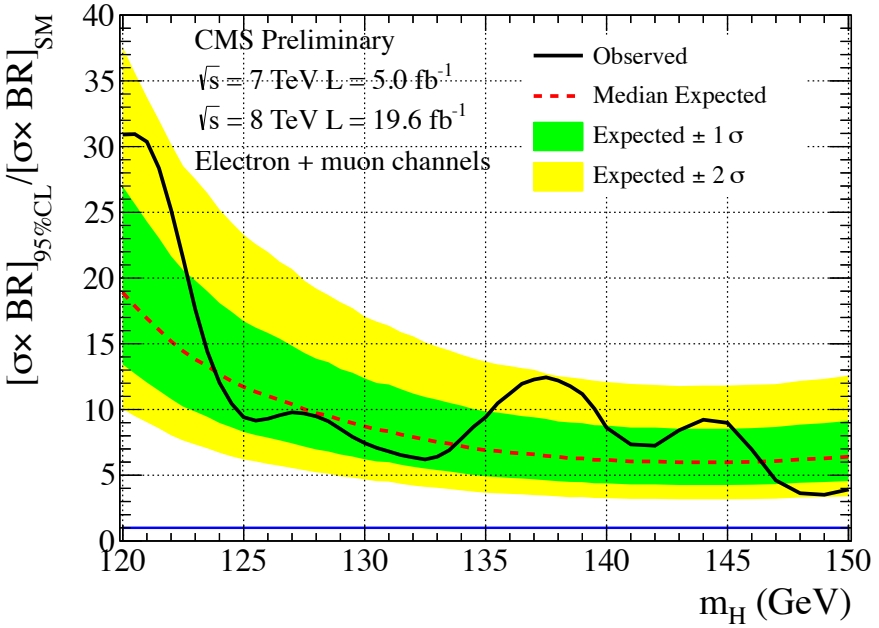
- The full SM calculation for the h+jet at NLO with finite m_t effects is absent
- to estimate NLO effects we have used K factor

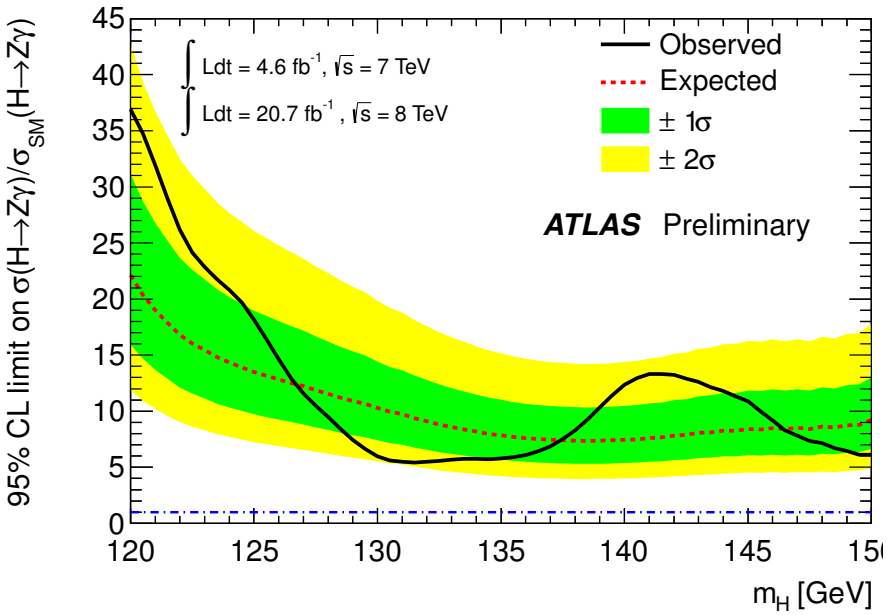
$$K(p_t) = \frac{d\sigma^{NLO}(m_t \to \infty)/dp_T}{d\sigma^{LO}(m_t \to \infty)/dp_T}$$



Conclusion

- Composite Higgs models predict nontrivial modification of the $h \to Z\gamma$ partial decay width. Even with all the new resonances above the scale of a few TeV we can get an order one modification of the SM rate.
- Studies of the Higgs production at high p_T can shed light on the couplings of the Higgs boson. These measurements at high luminosity can become complementary to the direct measurements of the top Yukawa coupling in $pp \to tth$.


CMS Preliminary
√s = 7 TeV L = 5.0 fb-1
√s = 8 TeV L = 19.6 fb-1
Electron + muon channels
Observed
Median Expected
Expected ± 1 σ
Expected ± 2 σ
[σ× BR]95%CL/[σ× BR]SM
mH (GeV)


∫ Ldt = 4.6 fb-1, √s = 7 TeV
∫ Ldt = 20.7 fb-1, √s = 8 TeV
Observed
Expected
± 1σ
± 2σ
ATLAS Preliminary
95% CL limit on σ(H→Zγ)/σSM(H→Zγ)
mH [GeV]