Taming the off-shell Higgs boson

Ennio Salvioni

UC Davis

LHC Higgs XSWG2 meeting

CERN

July 18, 2014

based on 1406.6338 *with A. Azatov, C. Grojean and A. Paul*

High-mass $gg \to VV$ constrains Higgs couplings

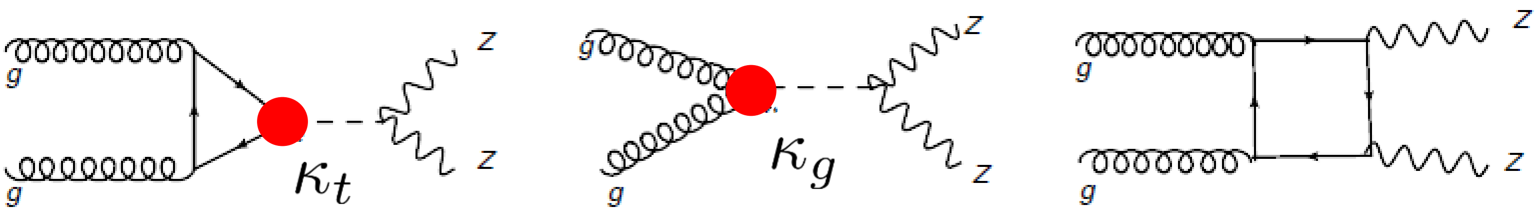
Assume:

- No invisible Higgs decay width
- Higher-dimensional operators modifying Higgs couplings:

$$\mathcal{L}_6 = c_y \frac{y_t H^\dagger H}{v^2} \overline{q}_L \widetilde{H} t_R + \text{h.c.} + c_g \frac{g_s^2}{48\pi^2 v^2} H^\dagger H G_{\mu\nu} G^{\mu\nu}$$

$$\mathcal{L}_{\text{couplings}} = -\kappa_t \frac{m_t}{v} \bar{t} t h + \kappa_g \frac{\alpha_s}{12\pi} \frac{h}{v} G_{\mu\nu} G^{\mu\nu}$$

$$(\kappa_t = 1 - \text{Re}\, c_y, \;\; \kappa_g = c_g)$$

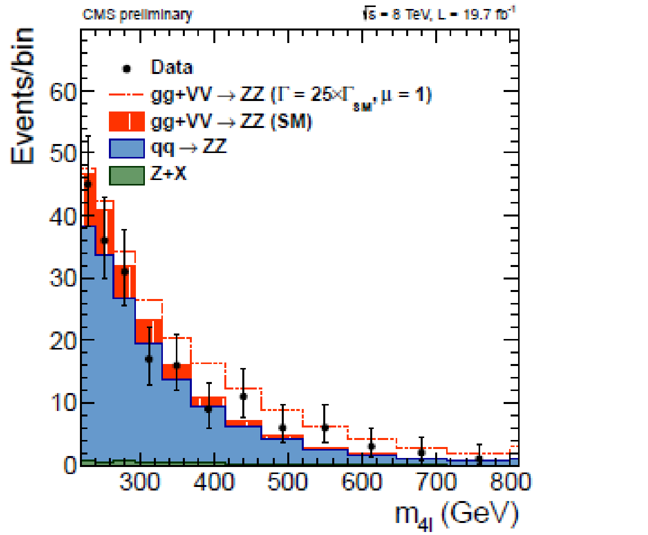


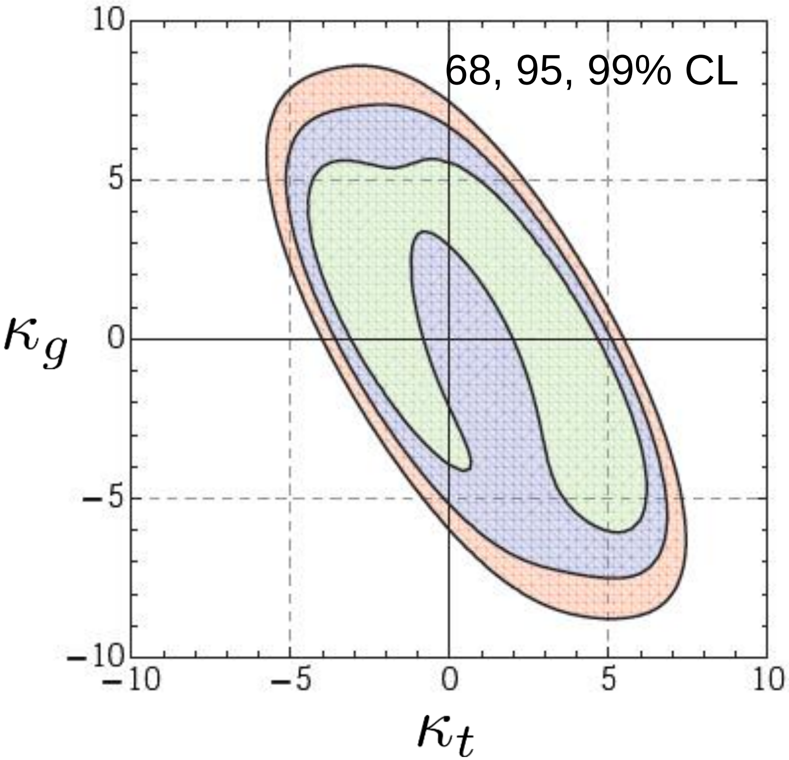
$$\mathcal{M}_{gg \to ZZ} \;\; = \;\; \kappa_t \mathcal{M}_{\kappa_t} + \kappa_g \mathcal{M}_{\kappa_g} + \mathcal{M}_{\text{background}}$$

Example: CMS 8 TeV 4*l* data

CMS PAS - HIG - 14 - 002

- Use MCFM to extract $\frac{d\sigma}{dm_{4l}}(\kappa_t, \kappa_g)$
- Take $q\bar{q}$ background and observed yields from CMS' first note (cut and count, no MELA)

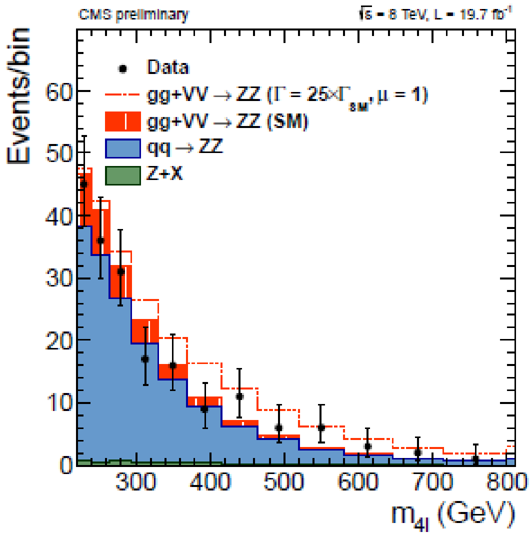


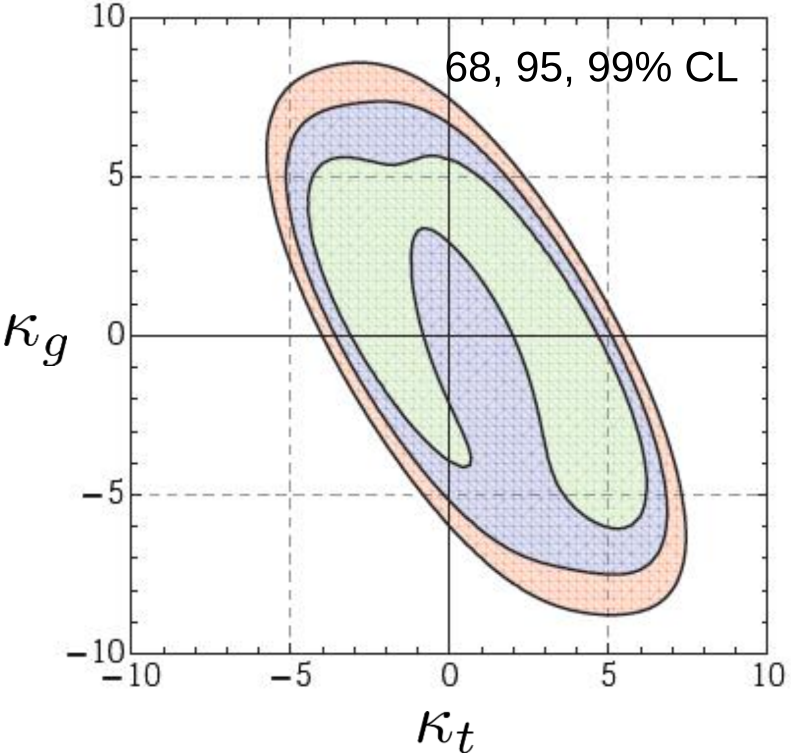


Example: CMS 8 TeV 4l data

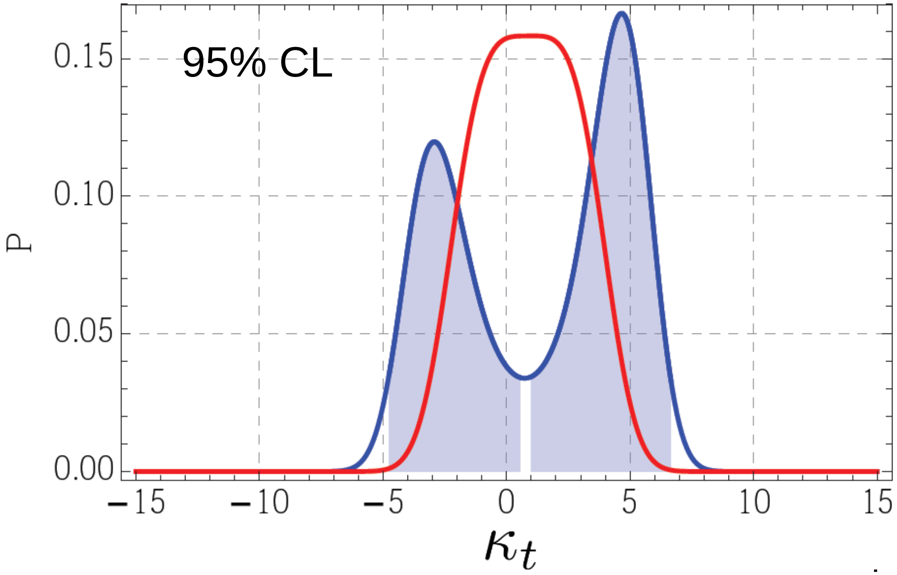
CMS PAS - HIG - 14 - 002

- Use MCFM to extract $\frac{d\sigma}{dm_{4l}}(\kappa_t, \kappa_g)$
- Take $q\bar{q}$ background and observed yields from CMS' first note (cut and count, no MELA)





Assuming $\kappa_t + \kappa_g = 1$



$$\kappa_t \in [-4.7, 0.5] \cup [1, 6.7]$$

EFT validity

- Current bounds are weak, no interpretation in terms of EFT.

  With increasing precision, important to check validity of the expansion.

- Our analysis neglects dim-8 operators, e.g. corrections to box diagrams

$$c_8 \frac{g_s^2}{16\pi^2 v^4} G_{\mu\nu} G^{\mu\nu} (D_\lambda H)^\dagger D^\lambda H$$

- Fully model-independent results include only interference of dim-6

  operators with SM: **'linear'** analysis, valid up to scale

$$\sqrt{\hat{s}} \sim \sqrt{\frac{c_y, c_g}{c_8}}\, v$$

  (e.g. for fermionic top partner, ~ mass of the resonance).

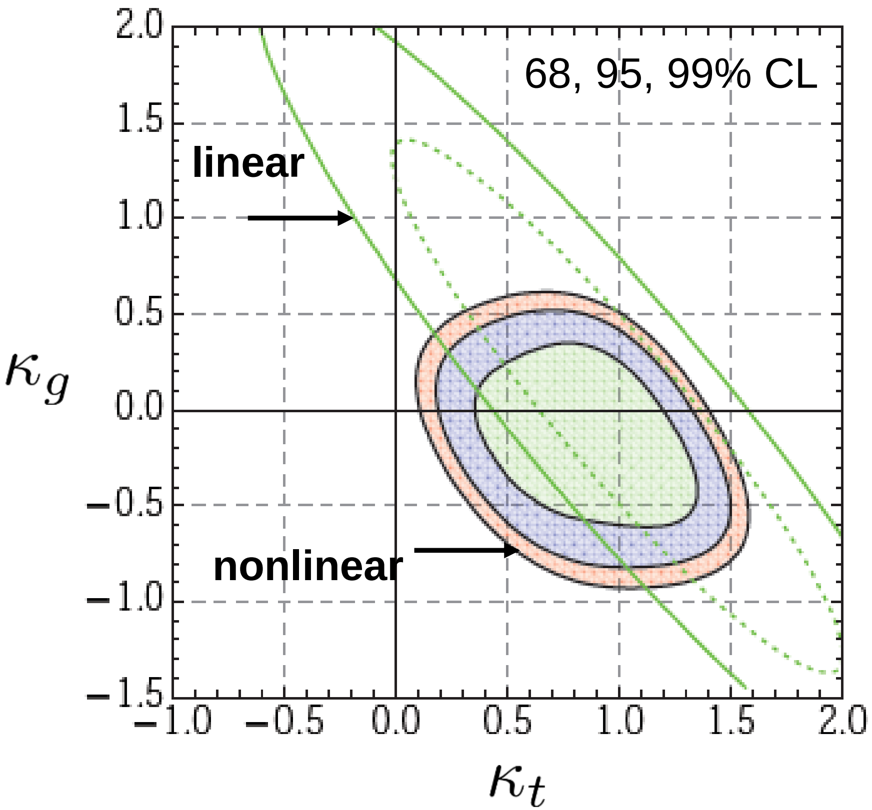
- Stronger bounds obtained retaining also terms ~ (dim-6)^2 :

  'nonlinear' analysis, valid provided

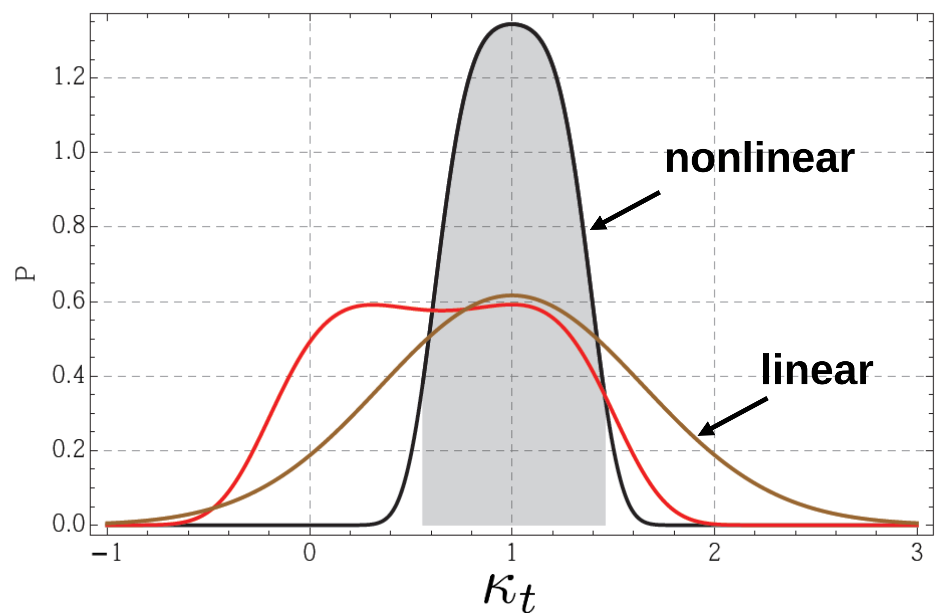
$$c_{y,g}^2 \gg c_8$$

  So applicability of the nonlinear bound is model-dependent.

14 TeV, 3/ab results (MCFM)



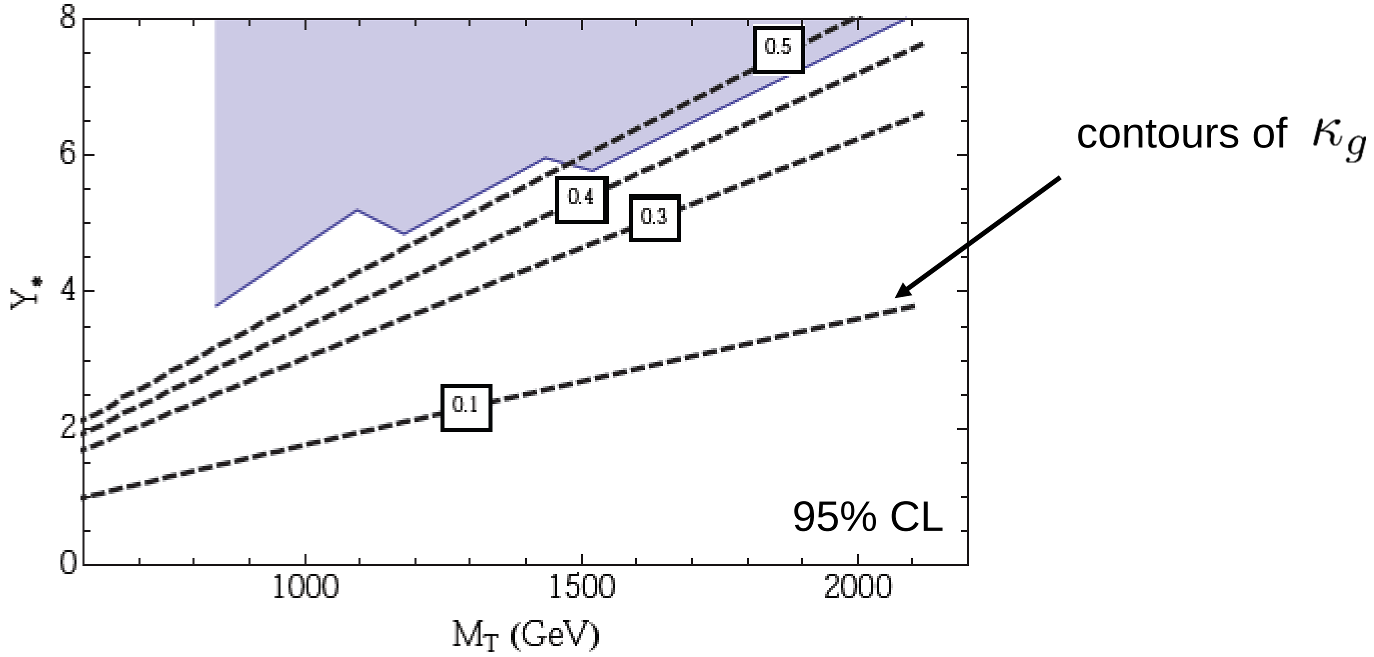
assuming $\kappa_t + \kappa_g = 1$



$$95\% : \quad \kappa_t \in [0.56, 1.46]$$

Backup

Example: fermionic top partner



$$-\mathcal{L} = y\bar{q}_L \widetilde{H} t_R + Y_* \bar{q}_L \widetilde{H} T_R + M_* \overline{T}_L T_R + \text{h.c.}$$

$$\kappa_t + \kappa_g = 1$$

Future *pp* colliders

	33 TeV	50 TeV	80 TeV	100 TeV
non-linear < 2TeV	[0.92,1.14]	[0.95,1.11]	[0.96,1.08]	[0.97,1.07]
linear < 2 TeV	[0.83,1.18]	[0.9,1.11]	[0.94,1.07]	[0.95,1.05]
non-linear all	[0.94,1.11]	[0.96,1.08]	[0.98,1.05]	[0.98,1.04]
linear all	[0.84,1.16]	[0.91,1.09]	[0.95,1.05]	[0.96,1.04]

Table 2: 68% probability intervals on the value of c_t, obtained assuming $c_t + c_g = 1$ and injecting the SM signal at various collider energies. In all cases an integrated luminosity of $3\,\mathrm{ab}^{-1}$ was assumed. The numbers in the second and the third row present the non-linear and linear analysis, respectively, for the low-energy bins only, $\sqrt{s} < 2\,\mathrm{TeV}$. The fourth and the fifth rows contain the corresponding numbers obtained including all the bins up to 5 TeV.