
STXS
NLO EFT
FXS
LO EFT
LHCHXSWG2
PO

Some Higgs couplings probed by LHC

Higgs couplings to 2 gauge bosons:

$$\begin{aligned}\mathcal{L}_{\rm hvv} =& \frac{h}{v}[2(1+\delta c_w)m_W^2 W_\mu^+ W_\mu^- + (1+\delta c_z)m_Z^2 Z_\mu Z_\mu \\ &+ c_{ww}\frac{g_L^2}{2}W_{\mu\nu}^+ W_{\mu\nu}^- + \tilde{c}_{ww}\frac{g_L^2}{2}W_{\mu\nu}^+ \tilde{W}_{\mu\nu}^- + c_{w\Box}g_L^2\left(W_\mu^- \partial_\nu W_{\mu\nu}^+ + \text{h.c.}\right) \\ &+ c_{gg}\frac{g_s^2}{4}G_{\mu\nu}^a G_{\mu\nu}^a + c_{\gamma\gamma}\frac{e^2}{4}A_{\mu\nu}A_{\mu\nu} + c_{z\gamma}\frac{eg_L}{2c_\theta}Z_{\mu\nu}A_{\mu\nu} + c_{zz}\frac{g_L^2}{4c_\theta^2}Z_{\mu\nu}Z_{\mu\nu} \\ &+ c_{z\Box}g_L^2 Z_\mu \partial_\nu Z_{\mu\nu} + c_{\gamma\Box}g_L g_Y Z_\mu \partial_\nu A_{\mu\nu} \\ &+ \tilde{c}_{gg}\frac{g_s^2}{4}G_{\mu\nu}^a \tilde{G}_{\mu\nu}^a + \tilde{c}_{\gamma\gamma}\frac{e^2}{4}A_{\mu\nu}\tilde{A}_{\mu\nu} + \tilde{c}_{z\gamma}\frac{eg_L}{2c_\theta}Z_{\mu\nu}\tilde{A}_{\mu\nu} + \tilde{c}_{zz}\frac{g_L^2}{4c_\theta^2}Z_{\mu\nu}\tilde{Z}_{\mu\nu}]\end{aligned}$$

Higgs couplings to 2 fermions:

$$\mathcal{L}_{\rm hff} = -\frac{h}{v}\sum_{f=u,d,e} m_f f^c (I + \delta y_f e^{i\phi_f}) f + \text{h.c.}$$

•••

Higgs couplings to 2 fermions and 1 gauge boson:

$$\mathcal{L}_{\rm hvff} = \frac{h}{v}\sum_f \sum_{V\in W,Z} \delta g^{hZf} V_\mu \bar{f}\gamma_\mu f + \frac{h}{v^2}\left(\sum_f \sum_{V\in W,Z,\gamma} d^{hZf} V_{\mu\nu}\bar{f}\gamma_{\mu\nu} f + \text{h.c.}\right)$$

Higgs couplings probed by LHC in κ-formalism

Higgs couplings to 2 gauge bosons:

$$\mathcal{L}_{\rm hvv} = \frac{h}{v}[2(1+\delta c_w)m_W^2 W_\mu^+ W_\mu^- + (1+\delta c_z)m_Z^2 Z_\mu Z_\mu$$
$$+c_{ww}\frac{g_L^2}{2}W_{\mu\nu}^+ W_{\mu\nu}^- + \tilde{c}_{ww}\frac{g_L^2}{2}W_{\mu\nu}^+ \tilde{W}_{\mu\nu}^- + c_{w\Box}g_L^2\left(W_\mu^- \partial_\nu W_{\mu\nu}^+ + \text{h.c.}\right)$$
$$+c_{gg}\frac{g_s^2}{4}G_{\mu\nu}^a G_{\mu\nu}^a + c_{\gamma\gamma}\frac{e^2}{4}A_{\mu\nu}A_{\mu\nu} + c_{z\gamma}\frac{eg_L}{2c_\theta}Z_{\mu\nu}A_{\mu\nu} + c_{zz}\frac{g_L^2}{4c_\theta^2}Z_{\mu\nu}Z_{\mu\nu}$$
$$+c_{z\Box}g_L^2 Z_\mu \partial_\nu Z_{\mu\nu} + c_{\gamma\Box}g_L g_Y Z_\mu \partial_\nu A_{\mu\nu}$$
$$+\tilde{c}_{gg}\frac{g_s^2}{4}G_{\mu\nu}^a \tilde{G}_{\mu\nu}^a + \tilde{c}_{\gamma\gamma}\frac{e^2}{4}A_{\mu\nu}\tilde{A}_{\mu\nu} + \tilde{c}_{z\gamma}\frac{eg_L}{2c_\theta}Z_{\mu\nu}\tilde{A}_{\mu\nu} + \tilde{c}_{zz}\frac{g_L^2}{4c_\theta^2}Z_{\mu\nu}\tilde{Z}_{\mu\nu}]$$

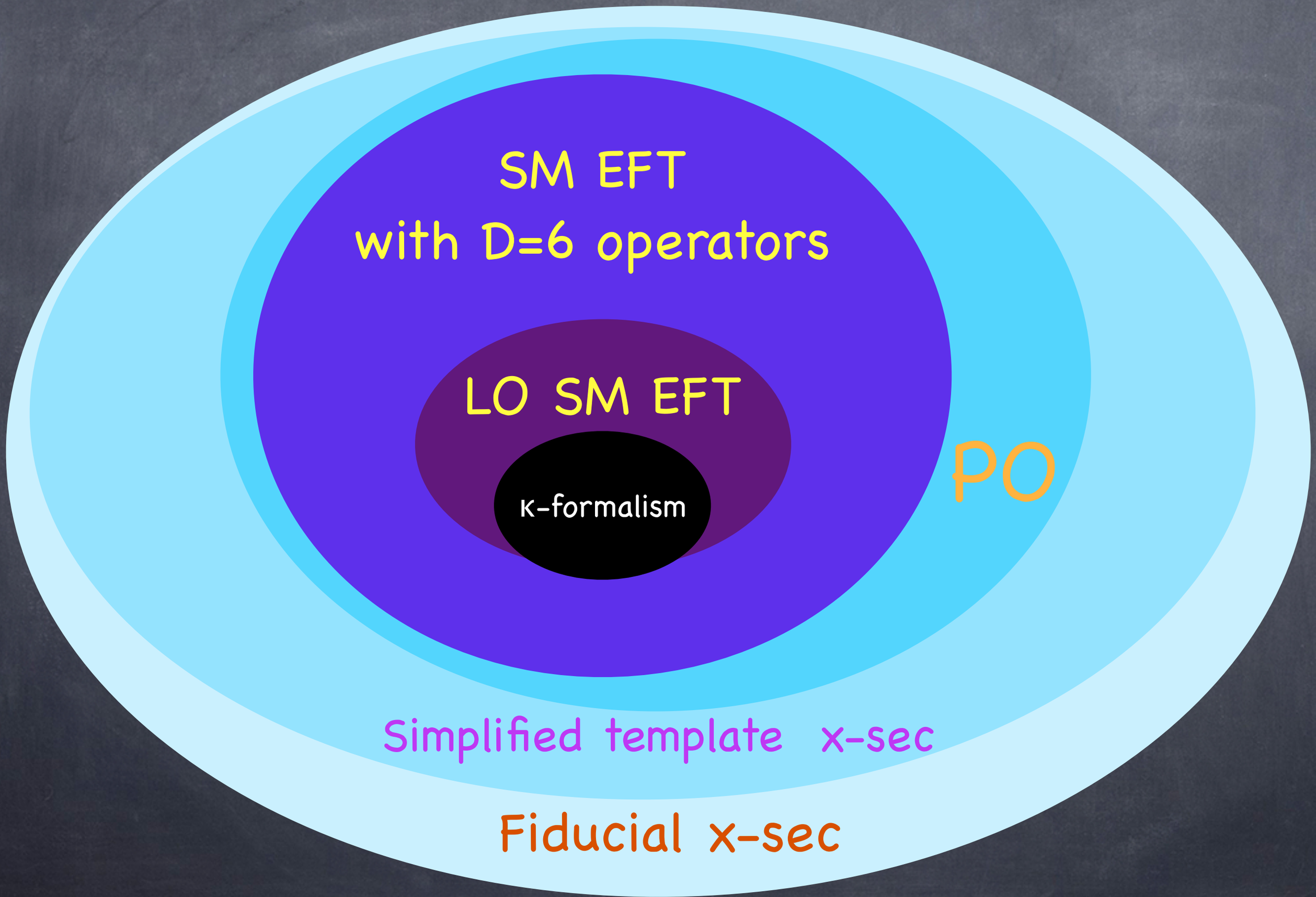
Higgs couplings to 2 fermions:

$$\mathcal{L}_{\rm hff} = -\frac{h}{v}\sum_{f=u,d,e} m_f f^c (I + \delta y_f e^{i\phi_f}) f + \text{h.c.}$$

Higgs couplings to 2 fermions and 1 gauge boson:

$$\mathcal{L}_{\rm hvff} = \frac{h}{v}\sum_f \sum_{V\in W,Z} \delta g^{hZf} V_\mu \bar{f}\gamma_\mu f + \frac{h}{v^2}\left(\sum_f \sum_{V\in W,Z,\gamma} d^{hZf} V_{\mu\nu}\bar{f}\gamma_{\mu\nu} f + \text{h.c.}\right)$$

The Onion of WG2



Higgs couplings probed by LO SM EFT

Higgs couplings to 2 gauge bosons:

$$\begin{aligned}\mathcal{L}_{\rm hvv} =& \frac{h}{v}[2(1+\delta c_w)m_W^2 W_\mu^+ W_\mu^- + (1+\delta c_z)m_Z^2 Z_\mu Z_\mu \\ &+ c_{ww}\frac{g_L^2}{2}W_{\mu\nu}^+ W_{\mu\nu}^- + \tilde{c}_{ww}\frac{g_L^2}{2}W_{\mu\nu}^+ \tilde{W}_{\mu\nu}^- + c_{w\Box}g_L^2\left(W_\mu^- \partial_\nu W_{\mu\nu}^+ + \text{h.c.}\right) \\ &+ c_{gg}\frac{g_s^2}{4}G_{\mu\nu}^a G_{\mu\nu}^a + c_{\gamma\gamma}\frac{e^2}{4}A_{\mu\nu}A_{\mu\nu} + c_{z\gamma}\frac{eg_L}{2c_\theta}Z_{\mu\nu}A_{\mu\nu} + c_{zz}\frac{g_L^2}{4c_\theta^2}Z_{\mu\nu}Z_{\mu\nu} \\ &+ c_{z\Box}g_L^2 Z_\mu \partial_\nu Z_{\mu\nu} + c_{\gamma\Box}g_L g_Y Z_\mu \partial_\nu A_{\mu\nu} \\ &+ \tilde{c}_{gg}\frac{g_s^2}{4}G_{\mu\nu}^a \tilde{G}_{\mu\nu}^a + \tilde{c}_{\gamma\gamma}\frac{e^2}{4}A_{\mu\nu}\tilde{A}_{\mu\nu} + \tilde{c}_{z\gamma}\frac{eg_L}{2c_\theta}Z_{\mu\nu}\tilde{A}_{\mu\nu} + \tilde{c}_{zz}\frac{g_L^2}{4c_\theta^2}Z_{\mu\nu}\tilde{Z}_{\mu\nu}]\end{aligned}$$

Higgs couplings to 2 fermions:

$$\mathcal{L}_{\rm hff} = -\frac{h}{v}\sum_{f=u,d,e} m_f f^c (I + \delta y_f e^{i\phi_f}) f + \text{h.c.}$$

Assuming MFV, 9(7) combinations of CP-even (odd) EFT parameters can affect LHC Higgs observables at LO

Higgs constraints on EFT

Run-1+2 fit

	Ellipses	DC tth	DC tth+Vh
δc_z	-0.02 ± 0.13	-0.01 ± 0.12	-0.08 ± 0.12
c_{zz}	-0.29 ± 0.38	-0.29 ± 0.38	-0.50 ± 0.33
$c_{z\Box}$	0.07 ± 0.17	0.06 ± 0.16	0.18 ± 0.12
$c_{\gamma\gamma}$	0.0007 ± 0.0089	0.0006 ± 0.0085	-0.0024 ± 0.0078
$c_{z\gamma}$	-0.011 ± 0.076	-0.011 ± 0.074	-0.010 ± 0.077
c_{gg}	-0.0037 ± 0.0010	-0.0041 ± 0.0010	-0.0040 ± 0.0009
δy_u	0.22 ± 0.16	0.26 ± 0.15	0.22 ± 0.15
δy_d	-0.38 ± 0.21	-0.39 ± 0.21	-0.47 ± 0.20
δy_e	-0.11 ± 0.13	-0.12 ± 0.13	-0.11 ± 0.13

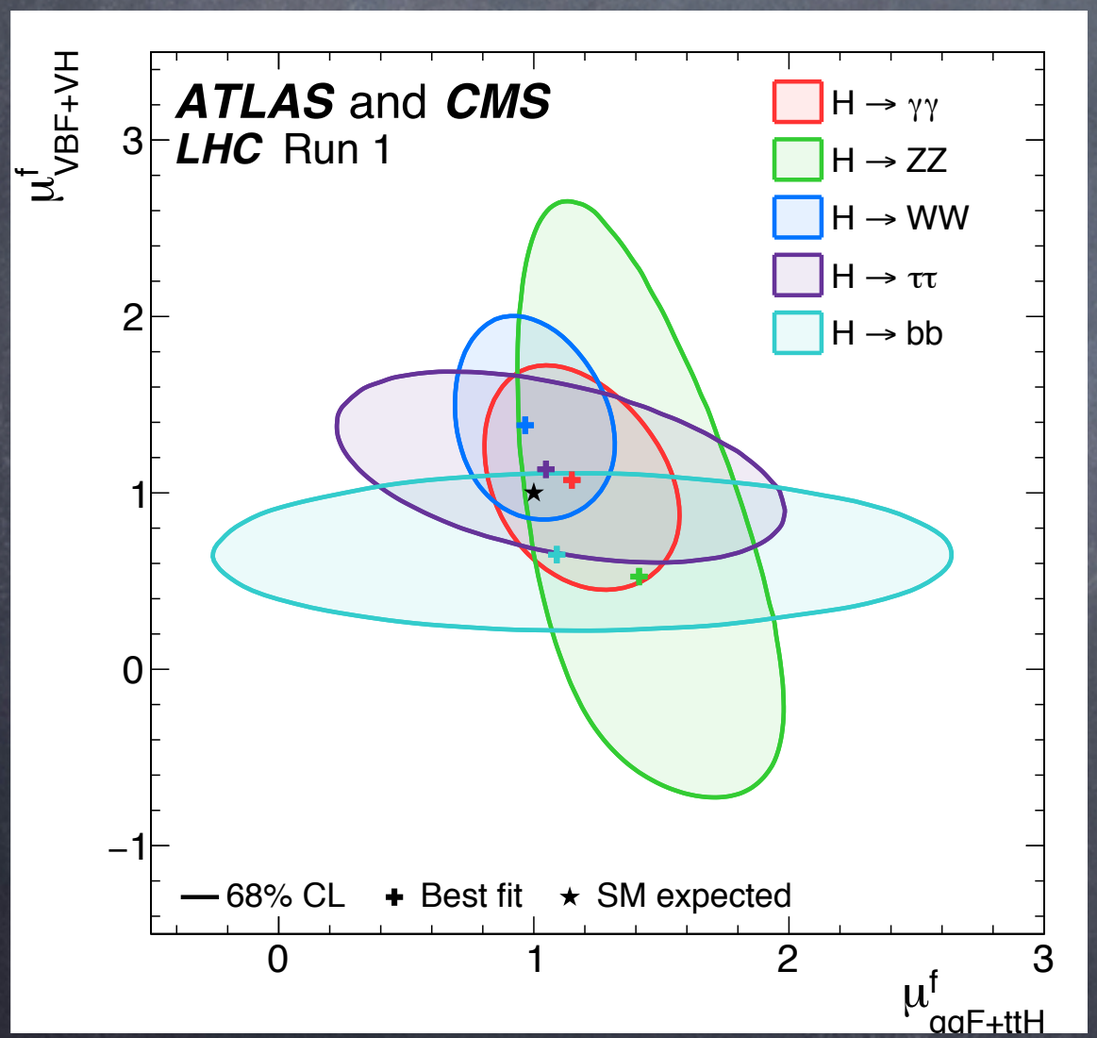
Run-1 fit

DC tth+Vh
-0.13 ± 0.18
0.76 ± 0.69
-0.38 ± 0.44
-0.0040 ± 0.0089
-0.001 ± 0.054
-0.0060 ± 0.0029
0.62 ± 0.45
-0.55 ± 0.27
-0.32 ± 0.28

Given existing LHC Run1&2 data, the 9 combinations of CP-even EFT parameters affecting LHC Higgs observables at LO can already be constrained with decent precision

What else would be useful for LO EFT fits

#1 Separate signal strength in main production (ggh,VBF,Wh,Zh,tth) and decay channels (WW/ZZ/γγ/Zγ/bb/ττ), including correlations



- Usual 2D likelihood plot erases vital information because it dumps together different production modes that depend on different combinations of EFT parameters

What else would be useful for LO EFT fits

#2 Separate signal strength for WH and ZH production*

- WH and ZH depend on different combinations of EFT parameters even when custodial symmetry is imposed

* Already done for ATLAS/CMS run-1 combination, but not for all run-2 results so far

What else would be useful for LO EFT fits

#3 Separate signal strength for different LHC energies (7/8/13/14/15 TeV)

- VBF/WH/ZH cross sections depend on different combinations of EFT parameters for different proton collision energies

What else would be useful for LO EFT fits

#4 Zγ

- One of the 9 parameters strongly constrained by Zγ signal strength, even if no Higgs signal is observed in this channel

What else would be useful for LO EFT fits

#5 Tails

- 2-derivative Higgs couplings to gauge bosons strongly constrained by tails of VBF/WH/ZH distribution, even before Higgs signal is observed there

What else would be useful for LO EFT fits

#6 Four-lepton events

- Multi-dimensional mass and angular distributions contain a lot of complementary information about Higgs couplings to Z and γ

What else would be useful for LO EFT fits

#7 Combined TGC likelihood

- In LO EFT, corrections to triple gauge couplings g1z and κγ depend on same EFT parameters as corrections to Higgs couplings to gauge bosons