

CP probes of the Higgs-top interaction

Top LHC France 2021

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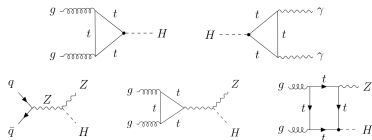
more details in [JHEP 11 \(2020\) 127](#)



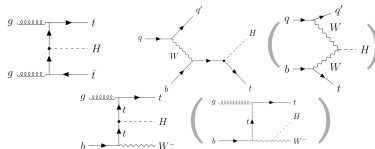
Motivation & Model description

- CP structure of Higgs Yukawa-like couplings not constrained with high precision
- New source of CP violation required to explain baryon asymmetry
- Pheno study focusing on **Higgs-Top coupling at the LHC**: ¹

intermediate tops (ggH , $H \rightarrow \gamma\gamma$, $gg \rightarrow ZH$)



final state tops (ttH , tHq , tWH)



- CP-odd introduced using the Higgs characterization model - JHEP 11(2013) 043:

$$\mathcal{L}_{\text{yuk}} = -\frac{y_t^{\text{SM}}}{\sqrt{2}} \bar{t} (\boxed{c_t} + i\gamma_5 \boxed{\tilde{c}_t}) t H,$$

- $+ c_V$
rescale CP-even coupling to W, Z
- $+ c_\gamma, c_g$
BSM direct coupling to γ and g

¹ not considered here although also relevant: intermediate Higgs with final state tops, e.g. 4 tops

Coupling dependence

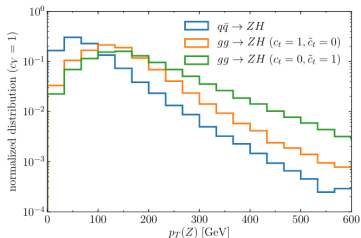
- Production cross sections / decay rates parametrized w.r.t c_t , \tilde{c}_t , c_V , c_g , c_γ .

Ex:

$$\mu_{t\bar{t}H} \equiv \frac{\sigma_{pp \rightarrow t\bar{t}H}}{\sigma_{pp \rightarrow t\bar{t}H}^{\text{SM}}} = 1.00c_t^2 + 0.42\tilde{c}_t^2, \quad \mu_{tH} \equiv \frac{\sigma_{pp \rightarrow tH}}{\sigma_{pp \rightarrow tH}^{\text{SM}}} = 3.28c_t^2 + 1.00\tilde{c}_t^2 + 3.82c_V^2 - 6.10c_Vc_t,$$

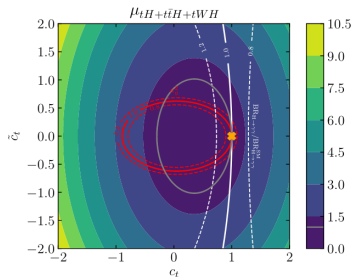
$$\mu_{tWH} \equiv \frac{\sigma_{pp \rightarrow tWH}}{\sigma_{pp \rightarrow tWH}^{\text{SM}}} = 2.73c_t^2 + 2.07\tilde{c}_t^2 + 2.01c_V^2 - 3.74c_Vc_t.$$

p_T^Z distribution in $pp \rightarrow ZH$



- sensitivity of gg component at high p_T
- impact on p_T^Z shape
- fraction of events in each STXS bin

Signal strengths μ of ' $t\bar{t}H + ttH + tWH$ '

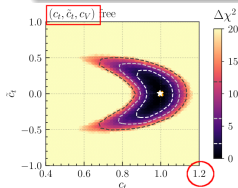


- orange cross: SM, gray line: $\mu = 1$
- red contour: $\kappa_g = 1.0 \pm 0.2$, ($c_g = 0$)
- white contour: $\text{BR}(\gamma\gamma) \pm 20\%$ wrt SM ($c_\gamma = 0$)

Current LHC constraints

- Fit model based on all relevant inclusive & differential Higgs boson rate measurements available ^a
- Focus on fit results with c_t , \tilde{c}_t , c_v , c_g , c_γ free (5D parameter space)

^adedicated ATLAS/CMS CP analysis in $ttH(\rightarrow \gamma\gamma)$ channel excluded due to differences in the fit model

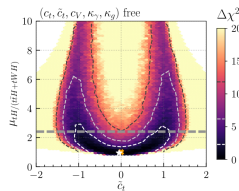
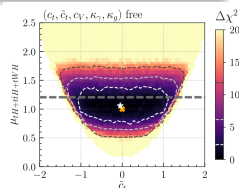
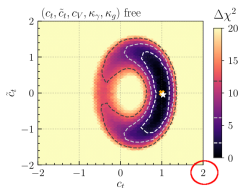


← still room for CP-odd if $c_\gamma = c_g = 0$

← becomes largely unconstrained if $c_\gamma, c_g \neq 0$

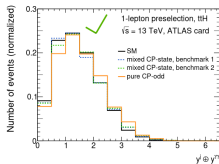
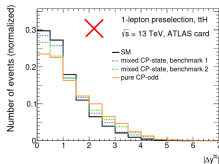
measuring more precisely $ttH + tH + tWH$ (what we measure now) does not help →

probing $tH/(ttH + tWH)$ ratio allows to scan unexplored range of $\tilde{c}_t \neq 0$ parameter space →

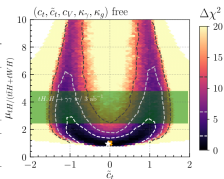


Future sensitivity

- Exploring the idea of a clean, independent measurement of $ttH + tWH$ (2-lepton) and tH (1-lepton) production. Use $H \rightarrow \gamma\gamma$ only.
- Result **shall not depend on CP** to be able to use it in global fit (i.e. selection acceptance of $ttH + tWH$ and tH)



Selection Process	1-lepton preselection	1-lepton selection	2-lepton selection
SM ttH	300.4	7.2	29.3
SM tH	19.0	6.7	< 0.1
SM tWH	8.0	0.4	0.8
SM tH	3.6	0.4	< 0.1
SM $qqZH$	0.8	< 0.1	0.1
SM total	331.8	14.7	30.2
CP-odd, tWH	140.2	3.3	13.9
CP-odd, tH	120.7	42.7	0.1
CP-odd, tWH	37.8	1.4	3.9
CP-odd total (incl. SM $tH + qqZH$)	303.1	47.8	18.0



- 2L region pure in $ttH+tWH$, but 1L region $tH/ttH+tWH$ mixed
 ← careful choice of discriminating observable to reject $ttH + tWH$
- Requires HL-LHC high statistics
 ← $O(10-100)$ events / region with 3 ab^{-1}
- May lead to clear hint at a non-zero CP-odd top-Yukawa coupling (and lower CP-even) than SM
 in addition, $\mu_{tH} < 2.21$ if σ^{tH} is SM-like.
Result largely independent from CP.