More light on Higgs flavor at the LHC: Higgs couplings to light quarks through h+γ production

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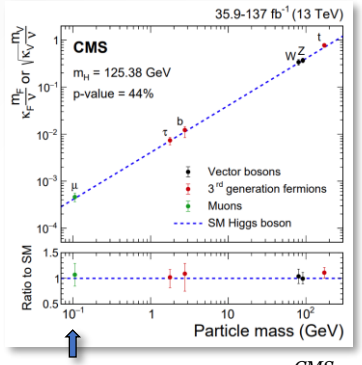
Motivation

- While the couplings of the 125 GeV Higgs boson to EW bosons and third-generation fermions have been measured rather precisely at the LHC...
- Yukawa couplings to the lighter SM fermions remain weakly constrained (or very weakly, for the first-generation fermions).
- Yet, given our current lack of understanding of the Higgs flavor structure, their measurement is key to further test the SM mass generation paradigm!

New strategies at the LHC?



Now including the muon too!

CMS Collaboration 2009.04363

Dominant Backgrounds

$h \to WW^* \to \ell^+\nu\ell^-\bar{\nu} + \gamma$

$(\ell = e/\mu)$

Preselection of events involves a di-lepton trigger and p_T^γ cut + $\not{E}_T$ cut + Z-mass window veto to suppress $Z(\to \ell\ell)\gamma$

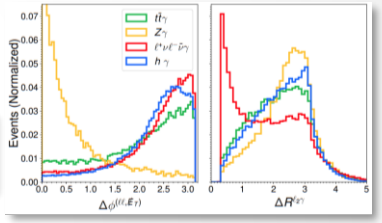
Very rich event kinematics!

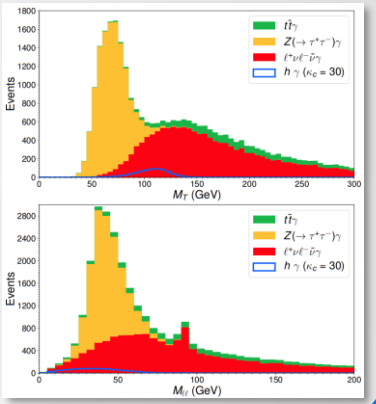
$M_T\,, M_{\ell\ell}\,, M_{\ell\ell\gamma}\,, p_T^{\ell_1}\,, p_T^{\ell_2}\,, p_T^\gamma\,, \not{E}_T\,,$
$\Delta\phi^{\ell\ell}\,, \Delta\phi^{\ell_1\gamma}\,, \Delta\phi^{\ell_2\gamma}\,, \Delta\phi^{(\ell\ell,\not{E}_T)}\,, \eta^{\ell_1}\,, \eta^{\ell_2}\,, \eta^\gamma$

$\ell^+\nu\ell^-\bar{\nu}\gamma$

$pp \to Z\gamma \quad Z \to \tau^+\tau^-$

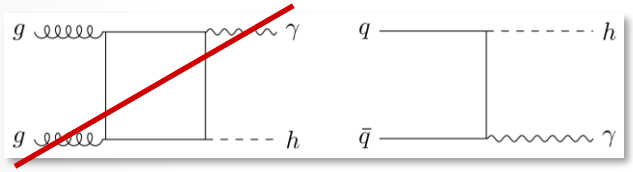
$t\bar{t}\gamma \quad t \to bW$





h+γ Production

The gluon-initiated contribution vanishes due to Furry's theorem.



- If no extra partons bottom and charm-initiated contributions lead the production.
- The SM cross-section is unsurprisingly small, but quadratically sensitive to any BSM enhancement of the light quark Yukawa couplings: $y_u(m_h) \sim y_c^{\rm SM}(m_h)$ ➡ $\sigma_{u\bar{u}} \sim 1.3$ fb
- A $(Q_u/Q_d)^2 = 4$ factor enhances up-type quarks contributions w.r.t. that of down-type quarks, so focus on the first.
- For its relatively large branching ratio and clean experimental profile, we focus on:

$h \to WW^* \to \ell^+\nu\ell^-\bar{\nu}$

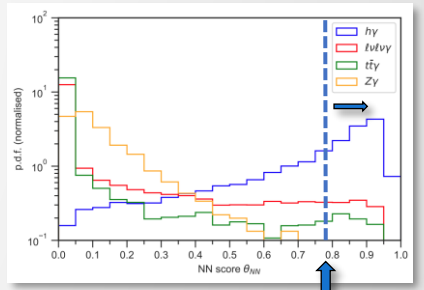
Multivariate Analysis & Results

To exploit them, we train a NN to discriminate the hγ signal from SM backgrounds.

HL-LHC ($3\ ab^{-1}$) reach:

$$|\kappa_c| < 11.8$$
$$|\kappa_u| < 1930 \quad 95\%\ \text{C.L.}$$

➡ Not far from testing up-charm universality!



Optimal region: $\theta_{\rm NN} > 0.78$

Key points

- hγ is a very rare process, yet unobserved at the LHC... but also a very sensitive probe of the Higgs couplings to light quarks!
- While it may not be competitive with the most sensitive probes for the charm... powerful tool to constrain the up quark Yukawa!
- High complementarity! associated production with a photon differentiates between up and down-type quarks.

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Thanks for your attention!