EFT approach to top–Higgs FCNC production

Gauthier Durieux
(Cornell and Louvain)

CP3
April 22, 2015

EFT approach to top–Higgs FCNC production

Modelling NP in the standard-model EFT

The top FCNC EFT

Signal features

Modelling new physics

Two approaches theoretically satisfactory

- constraints from several sectors can be combined
- predictions in terms of theory parameters are perturbatively improvable

– Specific BSM models
    - new states lighter than directly accessible energies

– SM effective field theory
    - new states heavier than directly accessible energies

The standard-model EFT for new physics

Construct *all* operators, with unquestionable ingredients

- Lorentz and SM gauge symmetries
- SM fields

Get the most general QFT based on those two requirements!

with an infinite number of terms...

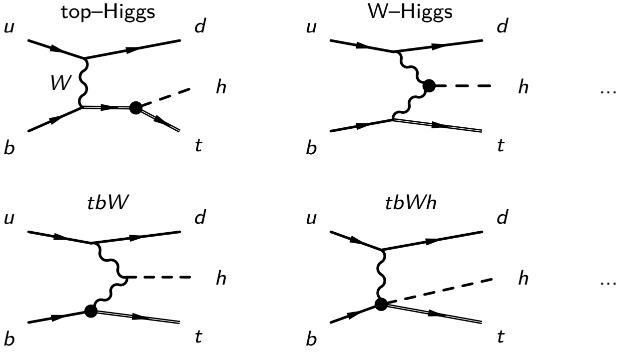
Put yourself in a low-energy regime: $C\left(\frac{E}{\Lambda}\right)^{d-4} \ll 1$

where the ones of lowest dimension are the most relevant!

Still, *all* of these have to be taken into account!

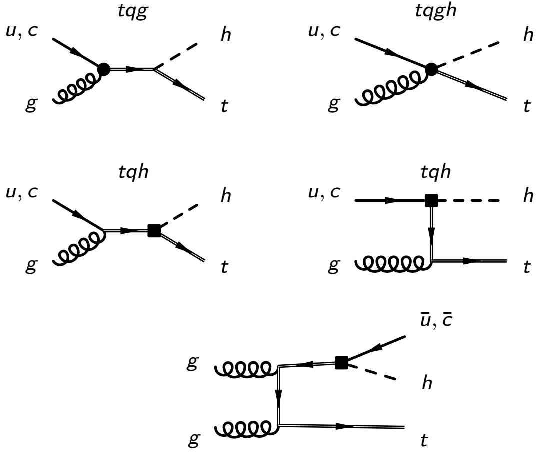
- to ensure renormalizability
- to ensure the low-energy limit of any NP can be modelled

SM EFT for top-Higgs production



A consistent EFT treatment is rarely straightforward!
Many observables have to be combined to constrain the full dim-6 EFT.
... but more and more effort is devoted to this task.

FCNC top-Higgs production



The FCNC and FCCC processes are separable!

A consistent treatment of the top FCNC EFT is manageable!

Rates could be large!

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The top FCNC EFT

[Grzadkowski et al 10']

Two-quark operators (10 × 2 complex parameters):

$$
\begin{array}{llcll}
\text{Scalar:} & O_{u\varphi} & \equiv & -y_t^3 & \bar{q}\,u\,\tilde{\varphi}\quad(\varphi^\dagger\varphi - v^2/2), \\
\text{Vector:} & [O^+_{\varphi q} + O^-_{\varphi q}]/2 & \equiv & y_t^2/2 & \bar{q}\gamma^\mu q\quad \varphi^\dagger i\overleftrightarrow{D}_\mu\,\varphi, \\
 & [O^+_{\varphi q} - O^-_{\varphi q}]/2 & \equiv & y_t^2/2 & \bar{q}\gamma^\mu\tau^I q\quad \varphi^\dagger i\overleftrightarrow{D}^I_\mu\,\varphi, \\
 & O_{\varphi u} & \equiv & y_t^2/2 & \bar{u}\gamma^\mu u\quad \varphi^\dagger i\overleftrightarrow{D}_\mu\,\varphi, \\
\text{Tensor:} & O_{uB} & \equiv & y_t g_Y & \bar{q}\sigma^{\mu\nu}u\,\tilde{\varphi}\quad B_{\mu\nu}, \\
 & O_{uW} & \equiv & y_t g_W & \bar{q}\sigma^{\mu\nu}\tau^I u\,\tilde{\varphi}\quad W^I_{\mu\nu}, \\
 & O_{uG} & \equiv & y_t g_s & \bar{q}\sigma^{\mu\nu}T^A u\,\tilde{\varphi}\quad G^A_{\mu\nu}.
\end{array}
$$

Two-quark–two-lepton operators ($9 \times 2 \times 3^2$ complex parameters):

$$
\begin{array}{llcll}
\text{Scalar:} & O^1_{lequ} & \equiv & \bar{l}e\;\varepsilon\;\bar{q}u, \\
\text{Vector:} & [O^+_{lq} + O^-_{lq}]/2 & \equiv & \bar{l}\gamma_\mu l\quad \bar{q}\gamma^\mu q, \\
 & [O^+_{lq} - O^-_{lq}]/2 & \equiv & \bar{l}\gamma_\mu\tau^I l\quad \bar{q}\gamma^\mu\tau^I q, \\
 & O_{lu} & \equiv & \bar{l}\gamma_\mu l\quad \bar{u}\gamma^\mu u, \\
 & O_{eq} & \equiv & \bar{e}\gamma^\mu e\quad \bar{q}\gamma_\mu q, \\
 & O_{eu} & \equiv & \bar{e}\gamma_\mu e\quad \bar{u}\gamma^\mu u, \\
\text{Tensor:} & O^3_{lequ} & \equiv & \bar{l}\sigma_{\mu\nu}e\;\varepsilon\;\bar{q}\sigma^{\mu\nu}u.
\end{array}
$$

Four-quark operators: ...

$$\overleftrightarrow{D}^{(I)}_\mu \equiv (\tau^I)\overrightarrow{D}_\mu - \overleftarrow{D}_\mu(\tau^I)$$

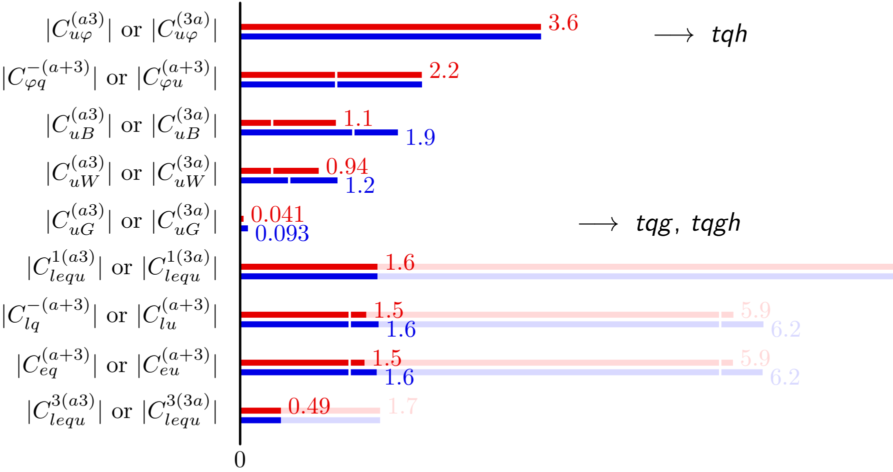
Observables

	Interactions:		tqg,	$tqgh$	$tq\gamma$	tqZ	$tq\ell\ell$	$tqqq$	tqh	...
	Lorentz structures of the quark bilinears:		T	T	T	V,T	S,V,T	S,V,T	S	
production	• $e^+e^- \to t\, j$	OPAL, DELPHI, ALEPH, L3			✓	✓,✗	✗			
	$e^-p \to e^-t$	**H1**, ZEUS			✓	✗	✗			
	• $p\overset{(-)}{p} \to t$	CDF, **ATLAS**	✓							
	$p\overset{(-)}{p} \to t\, j$	D0, **CMS**	✓		✗	✗		✗		
	• $p\, p \to t\, \gamma$	CMS	✗		✓					
	$p\, p \to t\, \ell^+\ell^-$	CMS	✓		✗	✗,✓	✗			
	$p\, p \to t\, \gamma\gamma$	—	✗	✗	✗				✗	
decay	$t \to j\gamma$	**CDF**, D0, ATLAS, CMS			✓					
	• $t \to j\ell^+\ell^-$	CDF, D0, ATLAS, **CMS**			✗	✓,✗	✗			
	• $t \to j\gamma\gamma$	**CMS**, ATLAS			✗				✓	

The experimental analyses often assumed one single contribution while the EFT consistency requires them *all*.

Constraints at NLO in QCD

[GD, Maltoni, Zhang 14']



$\Lambda = 1$ TeV

red: top–up, blue: top-charm FCNCs, two-quark+bosons, and +two-electron

pale: two-quark+two-muon operators

white: other coefficients assumed vanishing

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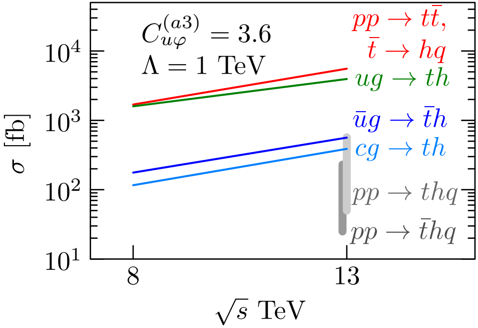
Rates at NLO

[Maltoni, Zhang 13']

[Degrande, Maltoni, Wang, Zhang 14']



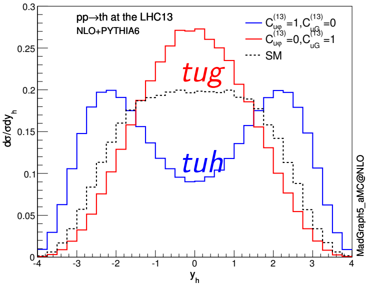
It would be a pity not to constrain FCNCs!

Discriminating *tqg* and *tqh*

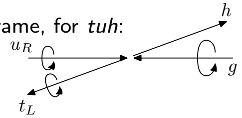
Use the relative proportion of $pp \to j$

$pp \to th + \bar{t}h$

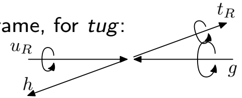
Use $|\eta_h|$ in $pp \to th + \bar{t}h$ [Degrande, Maltoni, Wang, Zhang 14']



— In the rest-frame, for *tuh*:



— In the rest-frame, for *tug*:



— The PDF favours $E_u > E_g$ in the lab-frame

— The *tug* matrix element favours large E_g

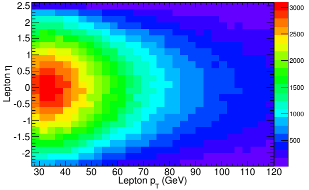
Discriminating up- and charm-top FCNCs

Use the relative proportion of $pp \to t\bar{t},\ \bar{t} \to hj$
$pp \to th$

Use the $pp \to th/\bar{t}h$ asymmetry

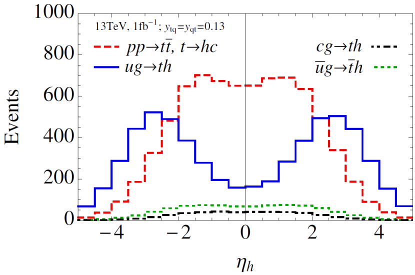
[Khatibi, Najafabadi 2013]

- generated by up-top only
- measurable with lept. t decay and h reco.
  or, through $\sum Q_\ell$ with lept. t and t decays
- increasing with $p_{T\ell}$ or $|\eta_\ell|$



Use $|\eta_h|$ if h reco., or $|\eta_{\ell^+\ell^-}|$ in multileptons

[Greljo, Kamenik, Kopp, 14']



Summary and conclusions

A consistent EFT analysis of top FCNC is manageable.

A dedicated experimental search for $pp \to th$ is still lacking.

A significant improvement on the 'tuh' bound would derive
(from the $h \to \gamma\gamma$ channel). [Greljo, Kamenik, Kopp, 14']

Several feature of the signal
would allow to disentangle its components.