Theory aspects in global EFT fits

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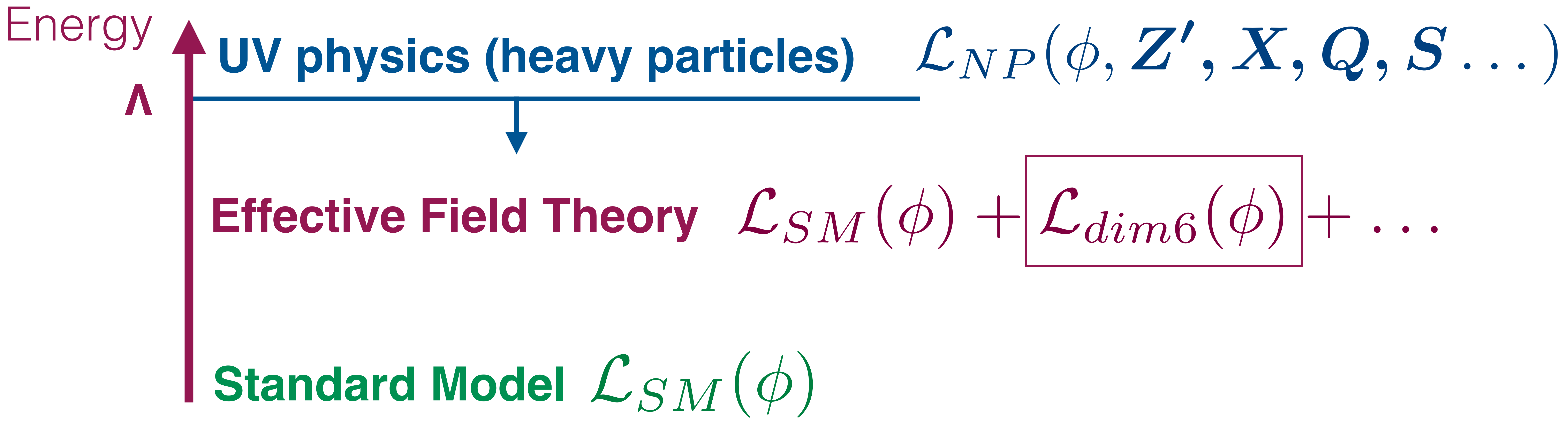
EFT

A model independent probe of heavy New Physics



Effective Field Theory reveals high energy physics through precise measurements at low energy.

SMEFT basics

A theoretically consistent framework

→ New Interactions of SM particles

Buchmuller, Wyler Nucl.Phys. B268 (1986) 621-653

Grzadkowski et al JHEP 1010 (2010) 085

$$\mathcal{L}_{EFT} = \mathcal{L}_{SM} + \sum_i \frac{C_i^{(6)} O_i^{(6)}}{\Lambda^2} + \mathcal{O}(\Lambda^{-4})$$

X^3		φ^6 and $\varphi^4 D^2$		$\psi^2\varphi^3$	
Q_G	$f^{ABC} G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	Q_φ	$(\varphi^\dagger\varphi)^3$	$Q_{e\varphi}$	$(\varphi^\dagger\varphi)(\bar l_p e_r \varphi)$
$Q_{\widetilde G}$	$f^{ABC} \widetilde G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	$Q_{\varphi\Box}$	$(\varphi^\dagger\varphi)\Box(\varphi^\dagger\varphi)$	$Q_{u\varphi}$	$(\varphi^\dagger\varphi)(\bar q_p u_r \widetilde\varphi)$
Q_W	$\varepsilon^{IJK} W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$	$Q_{\varphi D}$	$\left(\varphi^\dagger D^\mu\varphi\right)^\star \left(\varphi^\dagger D_\mu\varphi\right)$	$Q_{d\varphi}$	$(\varphi^\dagger\varphi)(\bar q_p d_r \varphi)$
$Q_{\widetilde W}$	$\varepsilon^{IJK} \widetilde W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$				

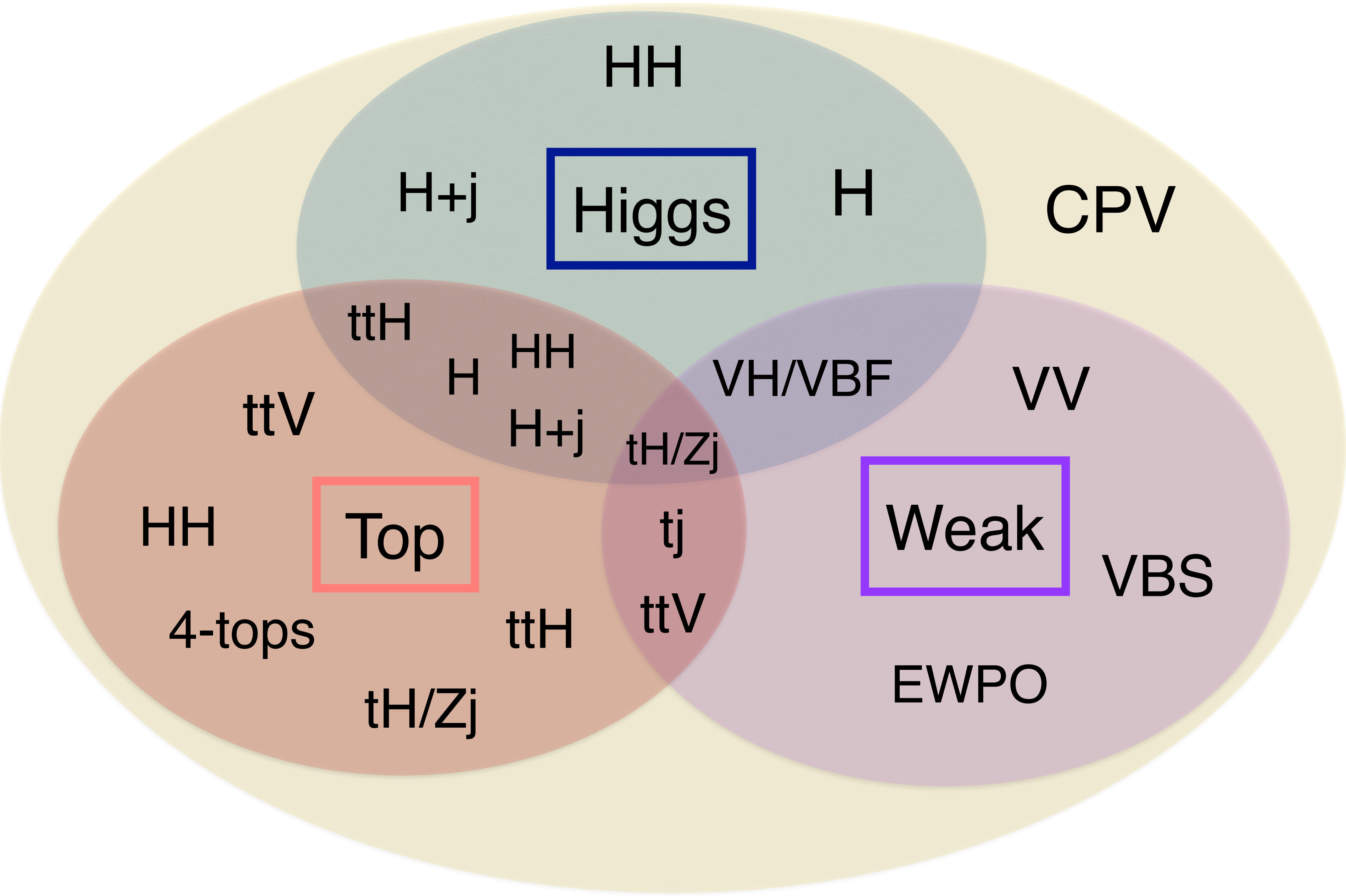
$X^2\varphi^2$		$\psi^2 X\varphi$		$\psi^2\varphi^2 D$	
$Q_{\varphi G}$	$\varphi^\dagger\varphi\, G_{\mu\nu}^A G^{A\mu\nu}$	Q_{eW}	$(\bar l_p \sigma^{\mu\nu} e_r)\tau^I \varphi W_{\mu\nu}^I$	$Q_{\varphi l}^{(1)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar l_p \gamma^\mu l_r)$
$Q_{\varphi\widetilde G}$	$\varphi^\dagger\varphi\, \widetilde G_{\mu\nu}^A G^{A\mu\nu}$	Q_{eB}	$(\bar l_p \sigma^{\mu\nu} e_r)\varphi B_{\mu\nu}$	$Q_{\varphi l}^{(3)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu^I \varphi)(\bar l_p \tau^I \gamma^\mu l_r)$
$Q_{\varphi W}$	$\varphi^\dagger\varphi\, W_{\mu\nu}^I W^{I\mu\nu}$	Q_{uG}	$(\bar q_p \sigma^{\mu\nu} T^A u_r)\widetilde\varphi\, G_{\mu\nu}^A$	$Q_{\varphi e}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar e_p \gamma^\mu e_r)$
$Q_{\varphi\widetilde W}$	$\varphi^\dagger\varphi\, \widetilde W_{\mu\nu}^I W^{I\mu\nu}$	Q_{uW}	$(\bar q_p \sigma^{\mu\nu} u_r)\tau^I \widetilde\varphi\, W_{\mu\nu}^I$	$Q_{\varphi q}^{(1)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar q_p \gamma^\mu q_r)$
$Q_{\varphi B}$	$\varphi^\dagger\varphi\, B_{\mu\nu} B^{\mu\nu}$	Q_{uB}	$(\bar q_p \sigma^{\mu\nu} u_r)\widetilde\varphi\, B_{\mu\nu}$	$Q_{\varphi q}^{(3)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu^I \varphi)(\bar q_p \tau^I \gamma^\mu q_r)$
$Q_{\varphi\widetilde B}$	$\varphi^\dagger\varphi\, \widetilde B_{\mu\nu} B^{\mu\nu}$	Q_{dG}	$(\bar q_p \sigma^{\mu\nu} T^A d_r)\varphi\, G_{\mu\nu}^A$	$Q_{\varphi u}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar u_p \gamma^\mu u_r)$
$Q_{\varphi WB}$	$\varphi^\dagger \tau^I \varphi\, W_{\mu\nu}^I B^{\mu\nu}$	Q_{dW}	$(\bar q_p \sigma^{\mu\nu} d_r)\tau^I \varphi\, W_{\mu\nu}^I$	$Q_{\varphi d}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar d_p \gamma^\mu d_r)$
$Q_{\varphi\widetilde W B}$	$\varphi^\dagger \tau^I \varphi\, \widetilde W_{\mu\nu}^I B^{\mu\nu}$	Q_{dB}	$(\bar q_p \sigma^{\mu\nu} d_r)\varphi\, B_{\mu\nu}$	$Q_{\varphi ud}$	$i(\widetilde\varphi^\dagger D_\mu \varphi)(\bar u_p \gamma^\mu d_r)$

$(\bar LL)(\bar LL)$		$(\bar RR)(\bar RR)$		$(\bar LL)(\bar RR)$	
Q_{ll}	$(\bar l_p \gamma_\mu l_r)(\bar l_s \gamma^\mu l_t)$	Q_{ee}	$(\bar e_p \gamma_\mu e_r)(\bar e_s \gamma^\mu e_t)$	Q_{le}	$(\bar l_p \gamma_\mu l_r)(\bar e_s \gamma^\mu e_t)$
$Q_{qq}^{(1)}$	$(\bar q_p \gamma_\mu q_r)(\bar q_s \gamma^\mu q_t)$	Q_{uu}	$(\bar u_p \gamma_\mu u_r)(\bar u_s \gamma^\mu u_t)$	Q_{lu}	$(\bar l_p \gamma_\mu l_r)(\bar u_s \gamma^\mu u_t)$
$Q_{qq}^{(3)}$	$(\bar q_p \gamma_\mu \tau^I q_r)(\bar q_s \gamma^\mu \tau^I q_t)$	Q_{dd}	$(\bar d_p \gamma_\mu d_r)(\bar d_s \gamma^\mu d_t)$	Q_{ld}	$(\bar l_p \gamma_\mu l_r)(\bar d_s \gamma^\mu d_t)$
$Q_{lq}^{(1)}$	$(\bar l_p \gamma_\mu l_r)(\bar q_s \gamma^\mu q_t)$	Q_{eu}	$(\bar e_p \gamma_\mu e_r)(\bar u_s \gamma^\mu u_t)$	Q_{qe}	$(\bar q_p \gamma_\mu q_r)(\bar e_s \gamma^\mu e_t)$
$Q_{lq}^{(3)}$	$(\bar l_p \gamma_\mu \tau^I l_r)(\bar q_s \gamma^\mu \tau^I q_t)$	Q_{ed}	$(\bar e_p \gamma_\mu e_r)(\bar d_s \gamma^\mu d_t)$	$Q_{qu}^{(1)}$	$(\bar q_p \gamma_\mu q_r)(\bar u_s \gamma^\mu u_t)$
		$Q_{ud}^{(1)}$	$(\bar u_p \gamma_\mu u_r)(\bar d_s \gamma^\mu d_t)$	$Q_{qu}^{(8)}$	$(\bar q_p \gamma_\mu T^A q_r)(\bar u_s \gamma^\mu T^A u_t)$
		$Q_{ud}^{(8)}$	$(\bar u_p \gamma_\mu T^A u_r)(\bar d_s \gamma^\mu T^A d_t)$	$Q_{qd}^{(1)}$	$(\bar q_p \gamma_\mu q_r)(\bar d_s \gamma^\mu d_t)$
				$Q_{qd}^{(8)}$	$(\bar q_p \gamma_\mu T^A q_r)(\bar d_s \gamma^\mu T^A d_t)$

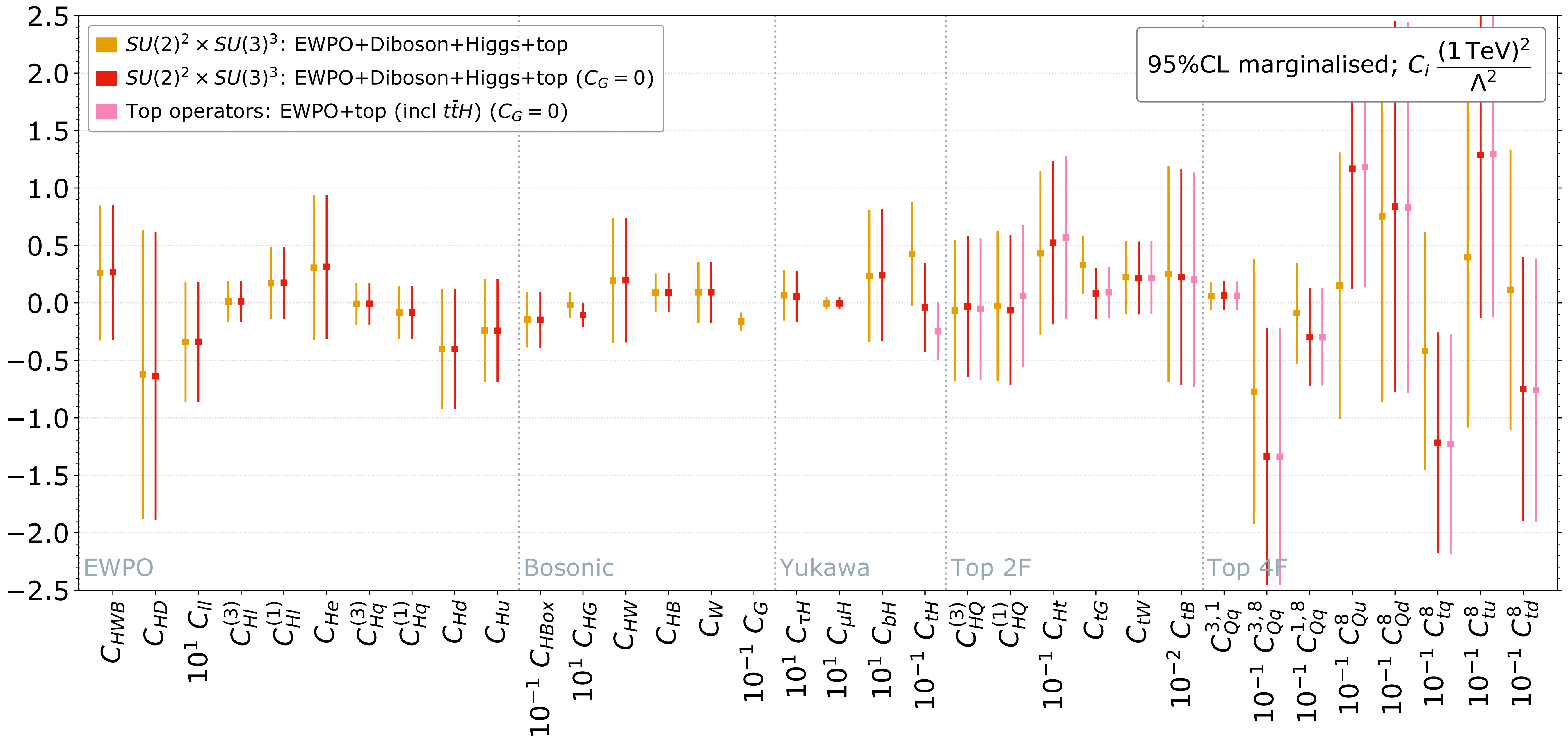
$(\bar LR)(\bar RL)$ and $(\bar LR)(\bar LR)$		B-violating	
Q_{ledq}	$(\bar l_p^j e_r)(\bar d_s q_t^j)$	Q_{duq}	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\left[(d_p^\alpha)^T C u_r^\beta\right]\left[(q_s^{\gamma j})^T C l_t^k\right]$
$Q_{quqd}^{(1)}$	$(\bar q_p^j u_r)\varepsilon_{jk}(\bar q_s^k d_t)$	Q_{qqu}	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\left[(q_p^{\alpha j})^T C q_r^{\beta k}\right]\left[(u_s^\gamma)^T C e_t\right]$
$Q_{quqd}^{(8)}$	$(\bar q_p^j T^A u_r)\varepsilon_{jk}(\bar q_s^k T^A d_t)$	$Q_{qqq}^{(1)}$	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\varepsilon_{mn}\left[(q_p^{\alpha j})^T C q_r^{\beta k}\right]\left[(q_s^{\gamma m})^T C l_t^n\right]$
$Q_{lequ}^{(1)}$	$(\bar l_p^j e_r)\varepsilon_{jk}(\bar q_s^k u_t)$	$Q_{qqq}^{(3)}$	$\varepsilon^{\alpha\beta\gamma}(\tau^I\varepsilon)_{jk}(\tau^I\varepsilon)_{mn}\left[(q_p^{\alpha j})^T C q_r^{\beta k}\right]\left[(q_s^{\gamma m})^T C l_t^n\right]$
$Q_{lequ}^{(3)}$	$(\bar l_p^j \sigma_{\mu\nu} e_r)\varepsilon_{jk}(\bar q_s^k \sigma^{\mu\nu} u_t)$	Q_{duu}	$\varepsilon^{\alpha\beta\gamma}\left[(d_p^\alpha)^T C u_r^\beta\right]\left[(u_s^\gamma)^T C e_t\right]$

SMEFT

The global aspect



Adapted from K. Mimasu



First global fit of the top+Higgs+EW sectors

Ellis, Madigan, Mimasu, Sanz, You arXiv:2012.02779

SMEFT correlates different sectors: Global interpretations are needed

Aspects of EFT predictions

And how to improve them

* Higher Orders in $1/\Lambda^4$
  * squared dim-6 contributions
  * double insertions of dim-6
  * dim-8 contributions
* Higher Orders in QCD and EW
  * EFT is a QFT, renormalisable order-by-order $1/\Lambda^2$

$$\mathcal{O}(\alpha_s, \alpha_{ew}) + \mathcal{O}\left(\frac{1}{\Lambda^2}\right) + \mathcal{O}\left(\frac{\alpha_s}{\Lambda^2}\right) + \mathcal{O}\left(\frac{\alpha_{ew}}{\Lambda^2}\right)$$

Why bother with higher orders?

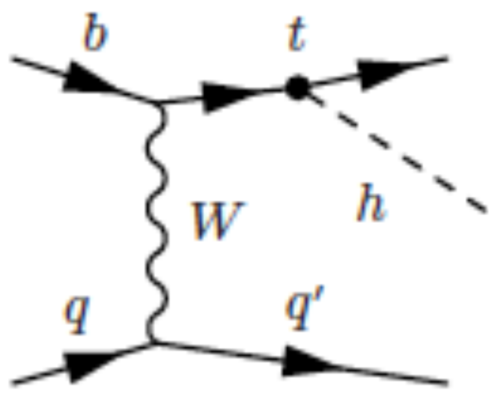
Higher orders in SMEFT bring:

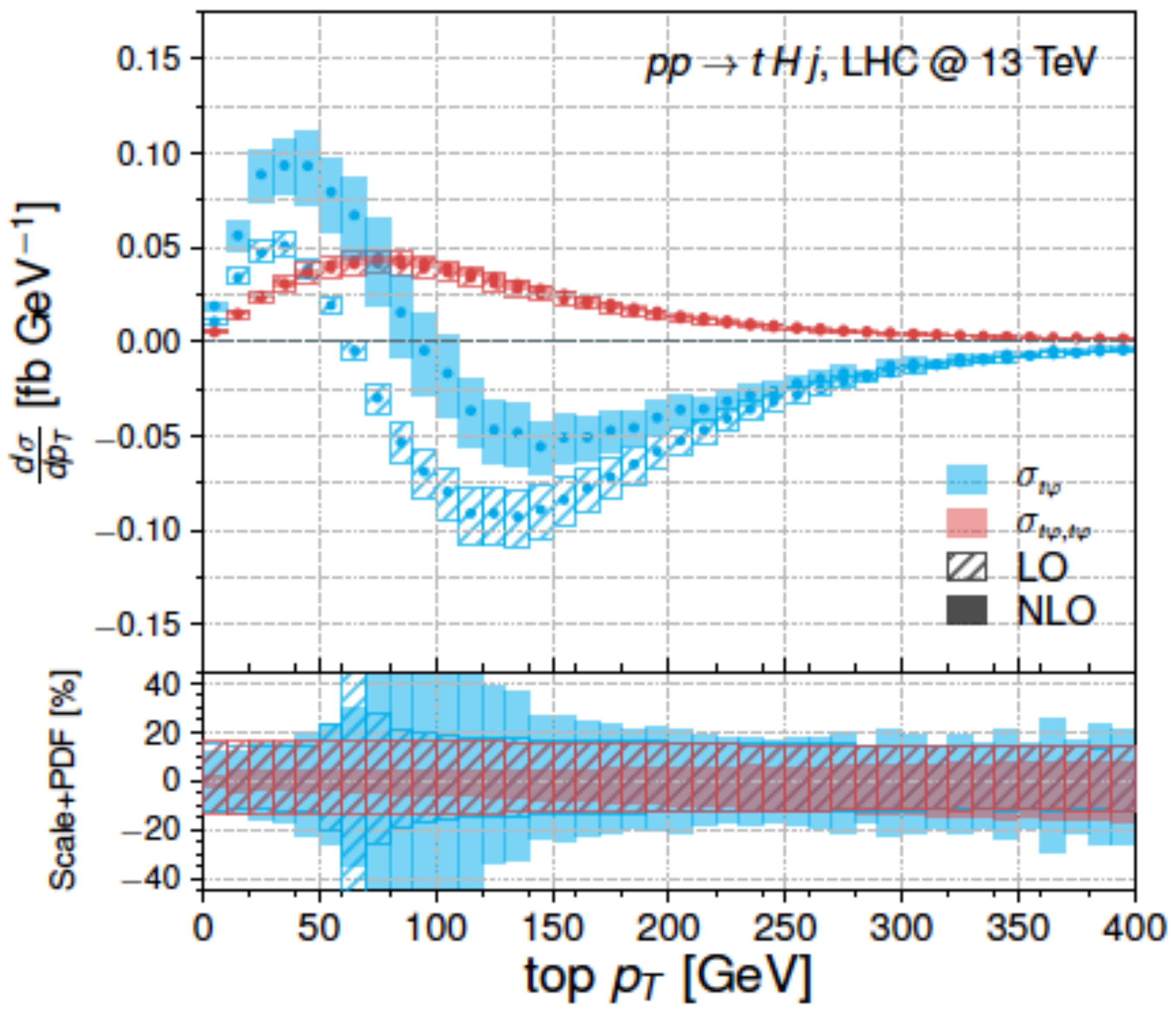
* Accuracy
* Precision
* Improved sensitivity
  * Accurate knowledge of the deviations (distribution shapes, correlations between observables, etc.) can be the key to disentangle them from the SM.
  * Loop-induced new sensitivity: operators entering at one-loop

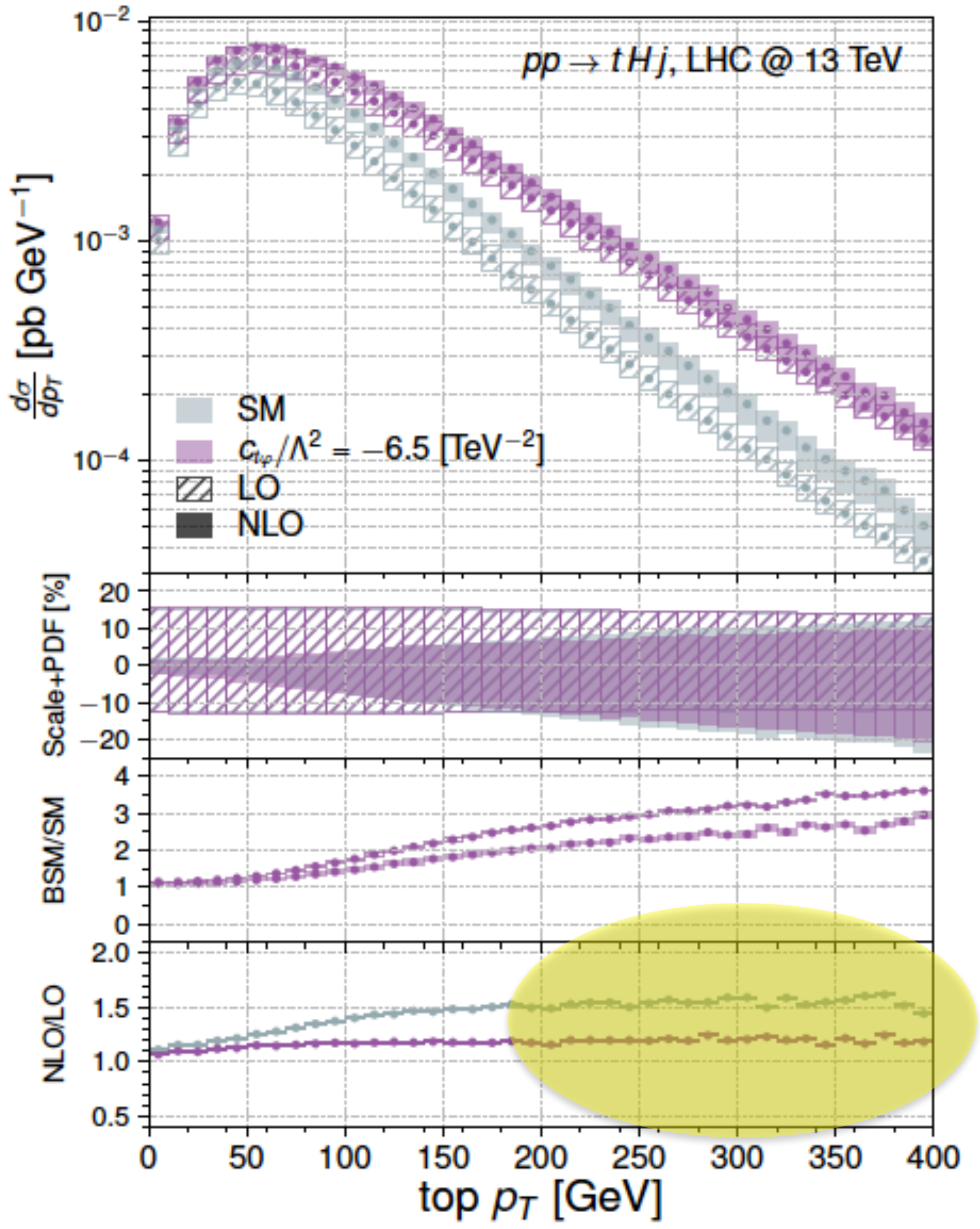
Accuracy and precision

Example 1:

tHj







Different shapes at NLO

Degrande, Maltoni, Mimasu, EV, Zhang arXiv:1804.07773

ttH

13 TeV	σ NLO	K
σ_{SM}	$0.507^{+0.030+0.000+0.007}_{-0.048-0.000-0.008}$	1.09
$\sigma_{t\phi}$	$-0.062^{+0.006+0.001+0.001}_{-0.004-0.001-0.001}$	1.13
$\sigma_{\phi G}$	$0.872^{+0.131+0.037+0.013}_{-0.123-0.035-0.016}$	1.39
σ_{tG}	$0.503^{+0.025+0.001+0.007}_{-0.046-0.003-0.008}$	1.07
$\sigma_{t\phi,t\phi}$	$0.0019^{+0.0001+0.0001+0.0000}_{-0.0002-0.0000-0.0000}$	1.17
$\sigma_{\phi G,\phi G}$	$1.021^{+0.204+0.096+0.024}_{-0.178-0.085-0.029}$	1.58
$\sigma_{tG,tG}$	$0.674^{+0.036+0.004+0.016}_{-0.067-0.007-0.019}$	1.04
$\sigma_{t\phi,\phi G}$	$-0.053^{+0.008+0.003+0.001}_{-0.008-0.004-0.001}$	1.42
$\sigma_{t\phi,tG}$	$-0.031^{+0.003+0.000+0.000}_{-0.002-0.000-0.000}$	1.10
$\sigma_{\phi G,tG}$	$0.859^{+0.127+0.021+0.017}_{-0.126-0.020-0.022}$	1.37

$$\sigma = \sigma_{\rm SM} + \sum_i \frac{1{\rm TeV}^2}{\Lambda^2} C_i \sigma_i + \sum_{i \le j} \frac{1{\rm TeV}^4}{\Lambda^4} C_i C_j \sigma_{ij}.$$

Different K-factors for different operators, different from the SM

Maltoni, EV, Zhang arXiv:1607.05330

QCD corrections in Monte Carlo

SMEFT@NLO

Automated one-loop computations in the SMEFT

Céline Degrande,[1,*] Gauthier Durieux,[2,†] Fabio Maltoni,[1,3,‡]
Ken Mimasu,[1,§] Eleni Vryonidou,[4,¶] and Cen Zhang[5,6,**]

We present the automation of one-loop computations in the standard-model effective field theory at dimension six. Our implementation, dubbed SMEFT@NLO, contains ultraviolet and rational counterterms for bosonic, two- and four-fermion operators. It presently allows for fully differential predictions, possibly matched to parton shower, up to one-loop accuracy in QCD. We illustrate the potential of the implementation with novel loop-induced and next-to-leading order computations relevant for top-quark, electroweak, and Higgs-boson phenomenology at the LHC and future colliders.

Degrande, Durieux, Maltoni, Mimasu, EV, Zhang
arXiv:2008.11743

Standard Model Effective Theory at One-Loop in QCD

Céline Degrande, Gauthier Durieux, Fabio Maltoni, Ken Mimasu, Eleni Vryonidou & Cen Zhang, arXiv:2008.11743

The implementation is based on the Warsaw basis of dimension-six SMEFT operators, after canonical normalization. Electroweak input parameters are taken to be G_F, M_Z, M_W. The CKM matrix is approximated as a unit matrix, and a $U(2)_q \times U(2)_u \times U(3)_d \times (U(1)_l \times U(1)_e)^3$ flavor symmetry is enforced. It forbids all fermion masses and Yukawa couplings except that only of the top quark. The model therefore implements the five-flavor scheme for PDFs.

A new coupling order, `NP=2`, is assigned to SMEFT interactions. The cutoff scale `Lambda` takes a default value of 1 TeV^{-2} and can be modified along with the Wilson coefficients in the `param_card`. Operators definitions, normalisations and coefficient names in the UFO model are specified in definitions.pdf. The notations and normalizations of top-quark operator coefficients comply with the LHC TOP WG standards of 1802.07237. Note however that the flavor symmetry enforced here is slightly more restrictive than the baseline assumption there (see the dim6top page for more information). This model has been validated at tree level against the `dim6top` implementation (see 1906.12310 and the comparison details).

Current implementation

UFO model: SMEFTatNLO_v1.0.tar.gz

- 2020/08/24 - v1.0: Official release including notably four-quark operators at NLO.

Support

Please direct any questions to smeftatnlo-dev**[at]**cern**[dot]**ch.

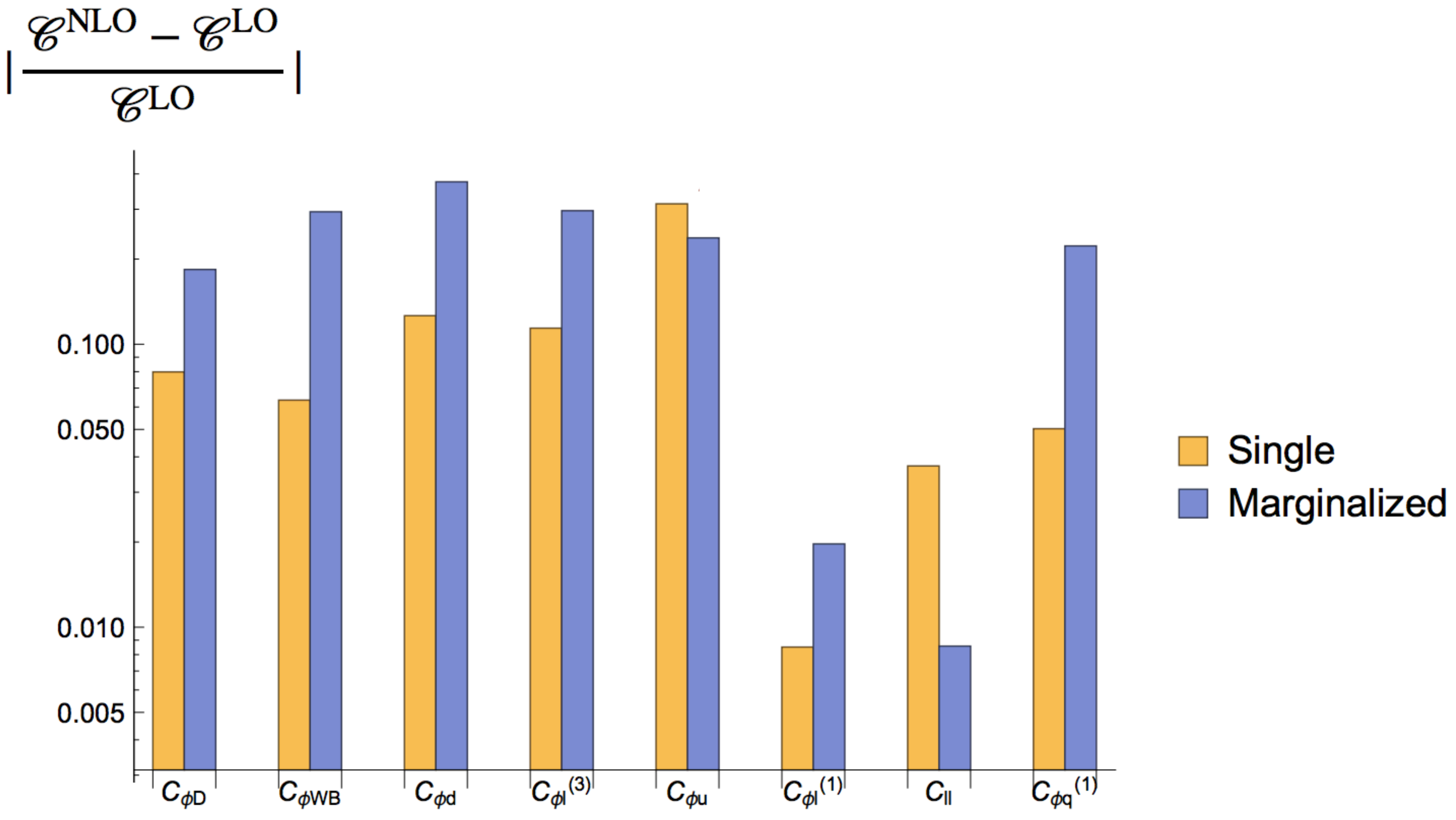
http://feynrules.irmp.ucl.ac.be/wiki/SMEFTatNLO

Accuracy and precision

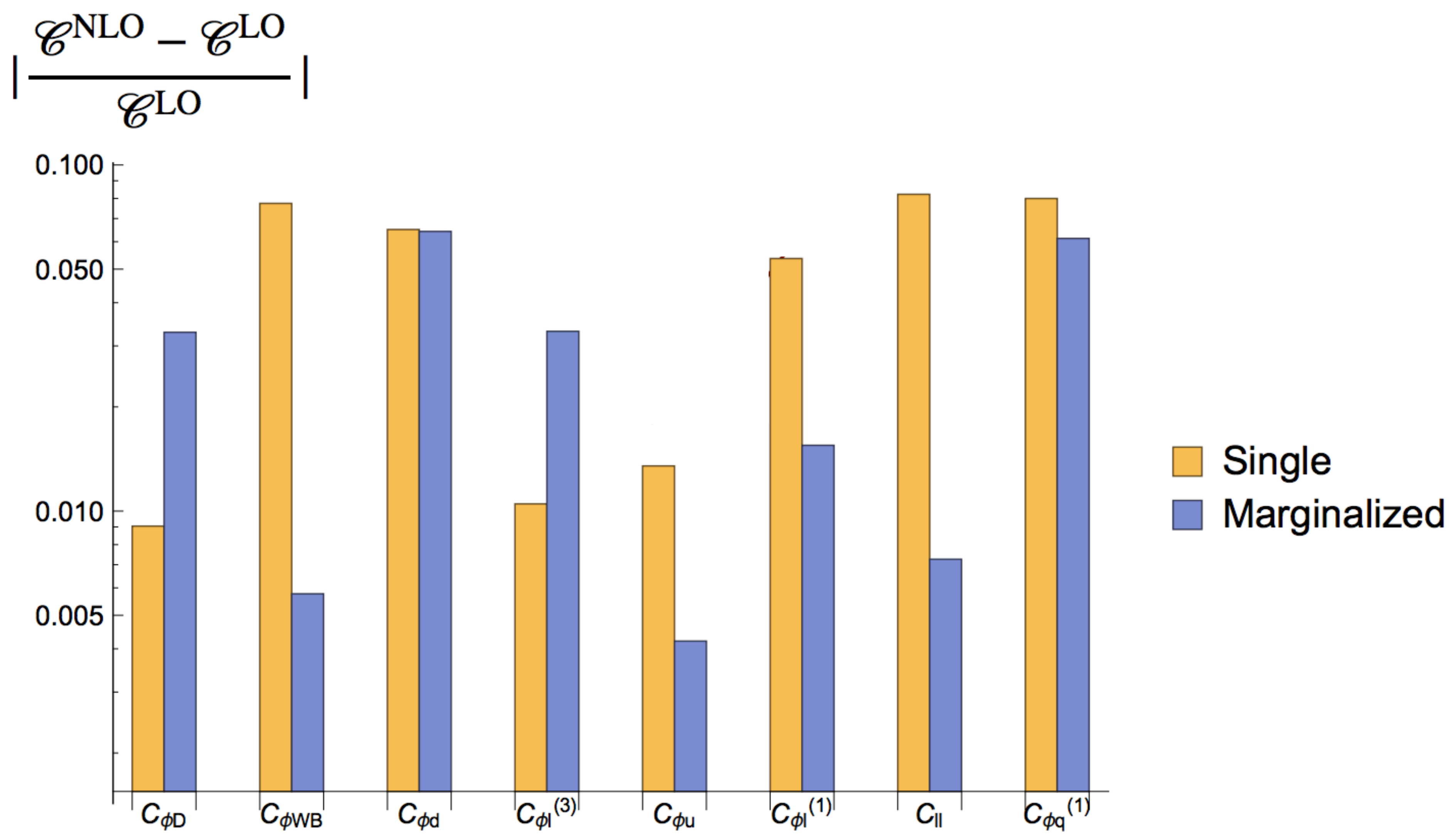
Example 2: EWPO

Impact of NLO corrections on W, Z pole observables:

LEP



ILC GigaZ [arXiv:1908.11299]



Dawson and Giardino arXiv:1909.02000 & Giardino@HEFT2020

Even EW corrections lead to ~20% difference

Improved sensitivity

New operators opening up at NLO

4-heavy operators in top pair production

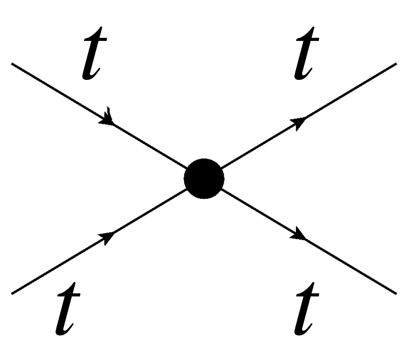
$\mathcal{O}^{8}_{QQ} = (\bar{Q}\gamma^{\mu}T^{A}Q)(\bar{Q}\gamma_{\mu}T^{A}Q)$

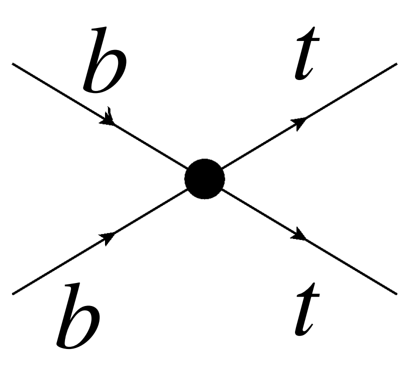
$\mathcal{O}^{1}_{QQ} = (\bar{Q}\gamma^{\mu}Q)(\bar{Q}\gamma_{\mu}Q)$

$\mathcal{O}^{8}_{Qt} = (\bar{Q}\gamma^{\mu}T^{A}Q)(\bar{t}\gamma_{\mu}T^{A}t)$

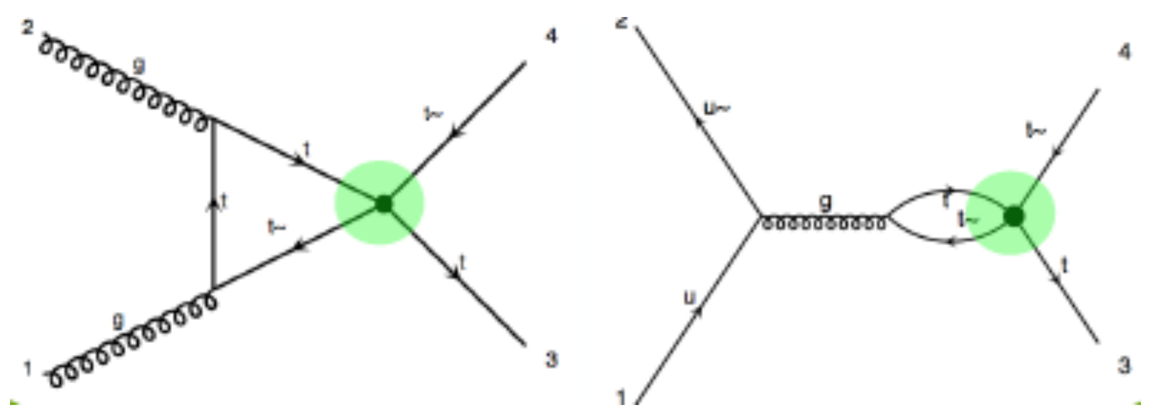
$\mathcal{O}^{1}_{Qt} = (\bar{Q}\gamma^{\mu}Q)(\bar{t}\gamma_{\mu}t)$

$\mathcal{O}^{1}_{tt} = (\bar{t}\gamma^{\mu}t)(\bar{t}\gamma_{\mu}t)$

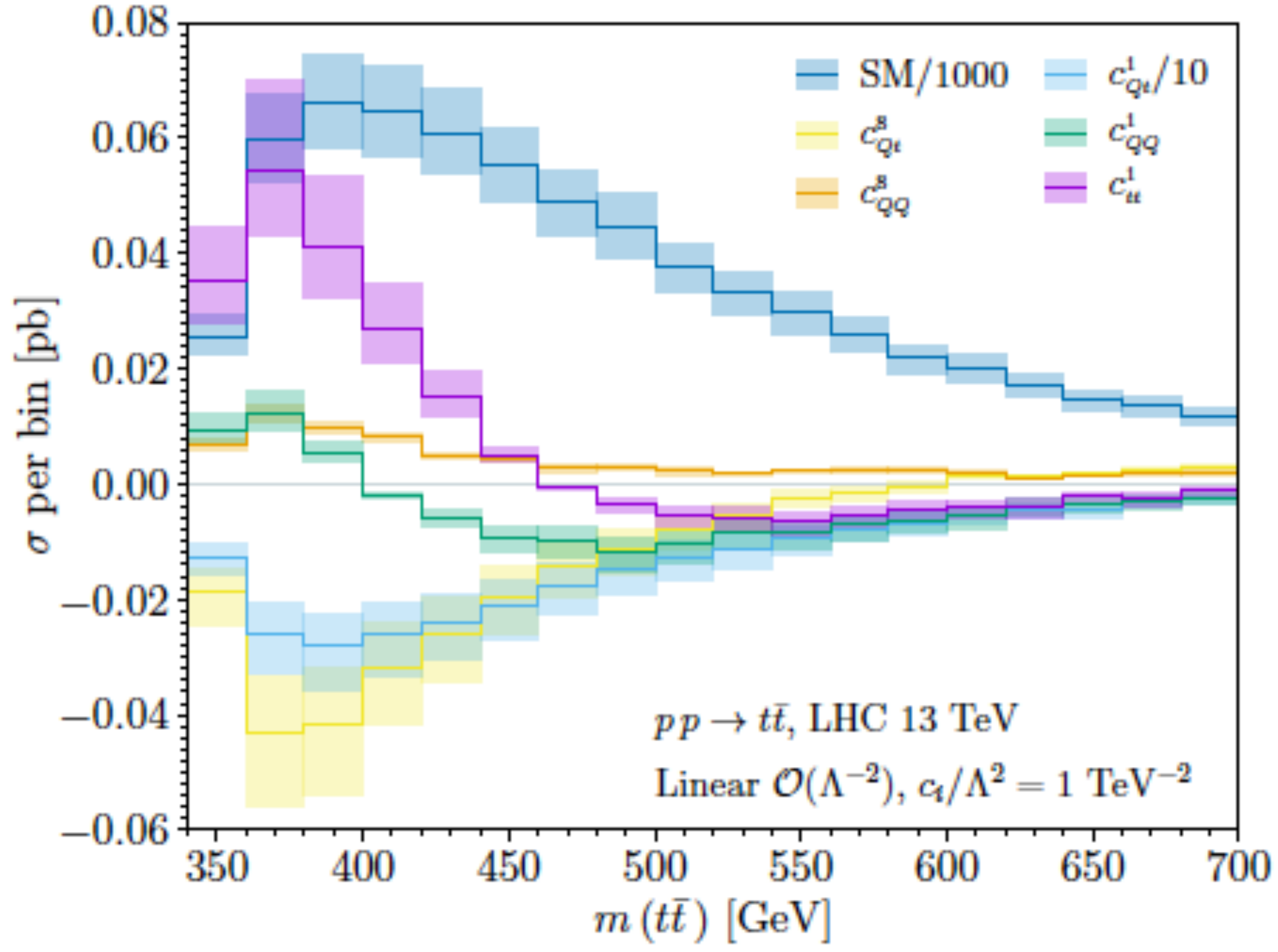




At NLO:



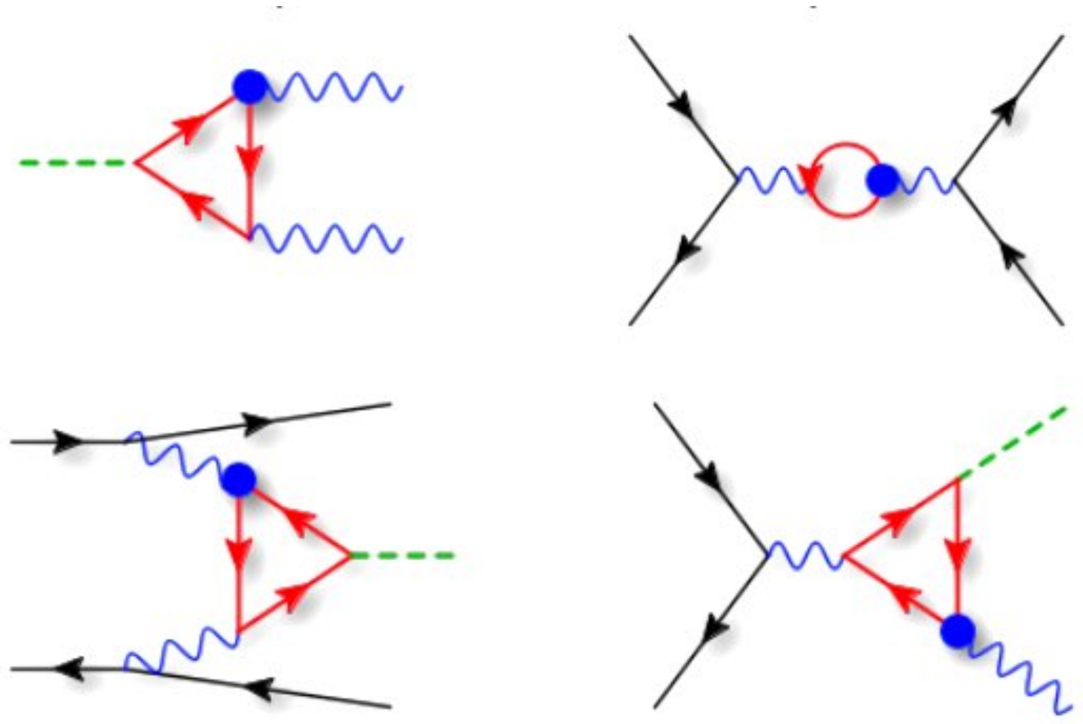
c^{8}_{QQ}	$0.0586^{+27\%}_{-25\%}$	$0.125^{+10\%}_{-11\%}$		$0.00628^{+13\%}_{-16\%}$	$0.0133^{+7\%}_{-5\%}$
c^{8}_{Qt}	$0.0583^{+27\%}_{-25\%}$	$-0.107(6)^{+40\%}_{-33\%}$		$0.00619^{+13\%}_{-16\%}$	$0.0118^{+8\%}_{-5\%}$
c^{1}_{QQ}	$[-0.11^{+15\%}_{-18\%}]$	$-0.039(4)^{+51\%}_{-33\%}$	$[-0.12^{+7\%}_{-5\%}]$	$0.0282^{+13\%}_{-16\%}$	$0.0651^{+5\%}_{-6\%}$
c^{1}_{Qt}	$[-0.068^{+16\%}_{-18\%}]$	$-2.51^{+29\%}_{-21\%}$	$[-0.12^{+3\%}_{-6\%}]$	$0.0283^{+13\%}_{-16\%}$	$0.066^{+5\%}_{-6\%}$
c^{1}_{tt}	×	$0.215^{+23\%}_{-18\%}$		×	×



Complimentary information to ttbb and 4top production

Loop-induced sensitivity

Top operators in Higgs observables



+

$$O_{t\varphi} = \bar{Q}t\tilde{\varphi}\,(\varphi^\dagger\varphi) + h.c.,$$
$$O^{(3)}_{\varphi Q} = (\varphi^\dagger i\overleftrightarrow{D}^I_\mu\varphi)(\bar{Q}\gamma^\mu\tau^I Q),$$
$$O_{\varphi tb} = (\tilde{\varphi}^\dagger iD_\mu\varphi)(\bar{t}\gamma^\mu b) + h.c.,$$
$$O_{tB} = (\bar{Q}\sigma^{\mu\nu}t)\,\tilde{\varphi}B_{\mu\nu} + h.c.,$$
$$O_{\varphi t} = (\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar{t}\gamma^\mu t),$$
$$O^{(1)}_{\varphi Q} = (\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar{Q}\gamma^\mu Q),$$
$$O_{tW} = (\bar{Q}\sigma^{\mu\nu}\tau^I t)\,\tilde{\varphi}W^I_{\mu\nu} + h.c.,$$

+ **Relatively loose constraints from top LHC measurements (tZ, ttZ, tj, …)**

	$\gamma\gamma$	γZ	bb	WW*	ZZ*
gg	(-100%,1980%)	(-88%,200%)	(-40%,48%)	(-40%,47%)	(-40%,46%)
VBF	(-100%,1880%)	(-88%,170%)	(-6.1%,5.3%)	(-6.8%,6.7%)	(-8.8%,9.2%)
WH	(-100%,1880%)	(-88%,170%)	(-5.5%,4.2%)	(-6.1%,5.6%)	(-7.8%,7.9%)
ZH	(-100%,1880%)	(-87%,170%)	(-6.5%,5.9%)	(-7.1%,7.1%)	(-9.4%,9.9%)

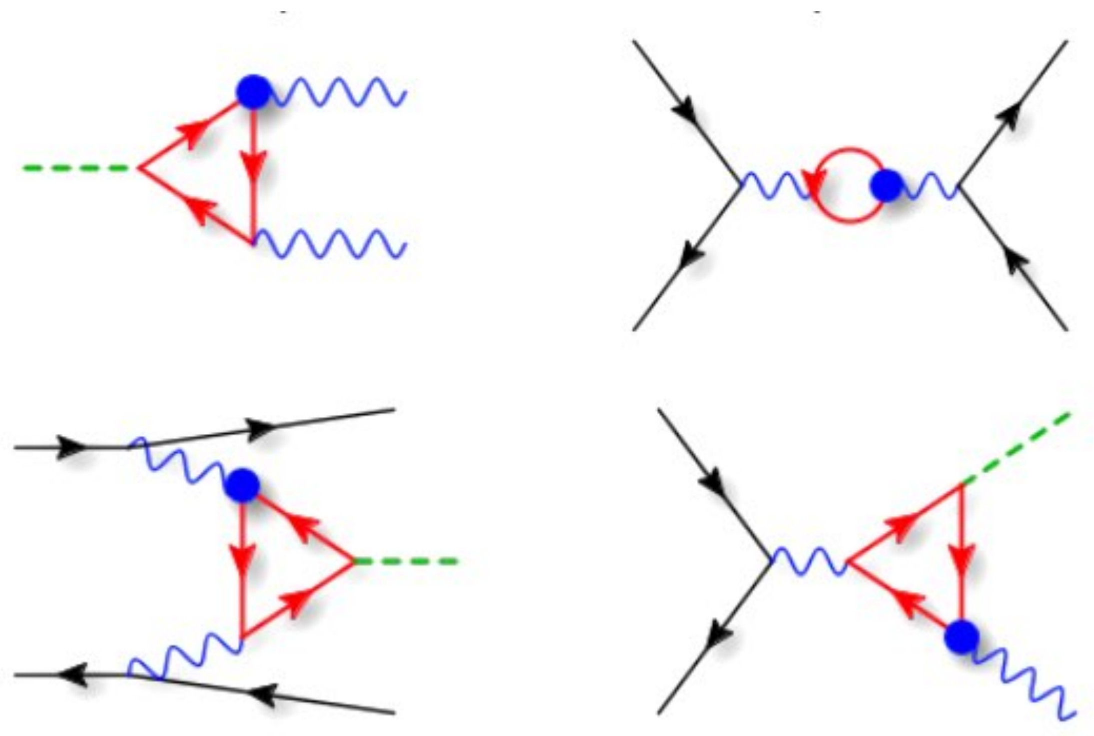
loop-induced ($\gamma\gamma$, γZ columns) — tree-level (ZZ* column, VBF/WH/ZH)

EV, Zhang arXiv:1804.09766

Poor knowledge of top couplings leads to uncertainties on Higgs measurements at the LHC

Loop-induced sensitivity

Top operators in Higgs observables



+

$$O_{t\varphi} = \bar{Q}t\tilde{\varphi}\,(\varphi^\dagger\varphi) + h.c.,$$
$$O_{\varphi Q}^{(3)} = (\varphi^\dagger i\overleftrightarrow{D}^I_\mu\varphi)(\bar{Q}\gamma^\mu\tau^I Q),$$
$$O_{\varphi tb} = (\tilde{\varphi}^\dagger iD_\mu\varphi)(\bar{t}\gamma^\mu b) + h.c.,$$
$$O_{tB} = (\bar{Q}\sigma^{\mu\nu}t)\,\tilde{\varphi}B_{\mu\nu} + h.c.,$$
$$O_{\varphi t} = (\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar{t}\gamma^\mu t),$$
$$O_{\varphi Q}^{(1)} = (\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar{Q}\gamma^\mu Q),$$
$$O_{tW} = (\bar{Q}\sigma^{\mu\nu}\tau^I t)\,\tilde{\varphi}W^I_{\mu\nu} + h.c.,$$

+ **Relatively loose constraints from top LHC measurements (tZ, ttZ, tj, …)**

→

	$\gamma\gamma$	γZ	bb	WW*	ZZ*
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loop-induced ($\gamma\gamma$, γZ columns) — tree-level (ZZ* column, VBF/WH/ZH)

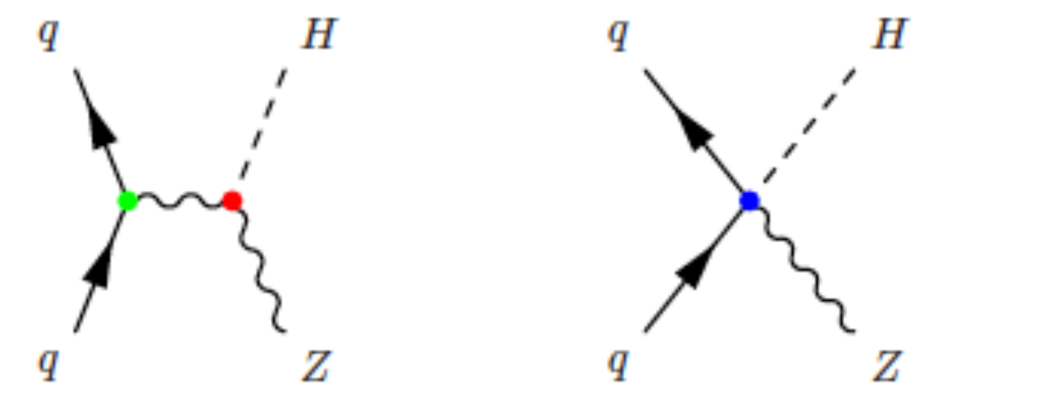
EV, Zhang arXiv:1804.09766

Or… maybe one should use Higgs measurements to bound top couplings?

Loop & tree sensitivity

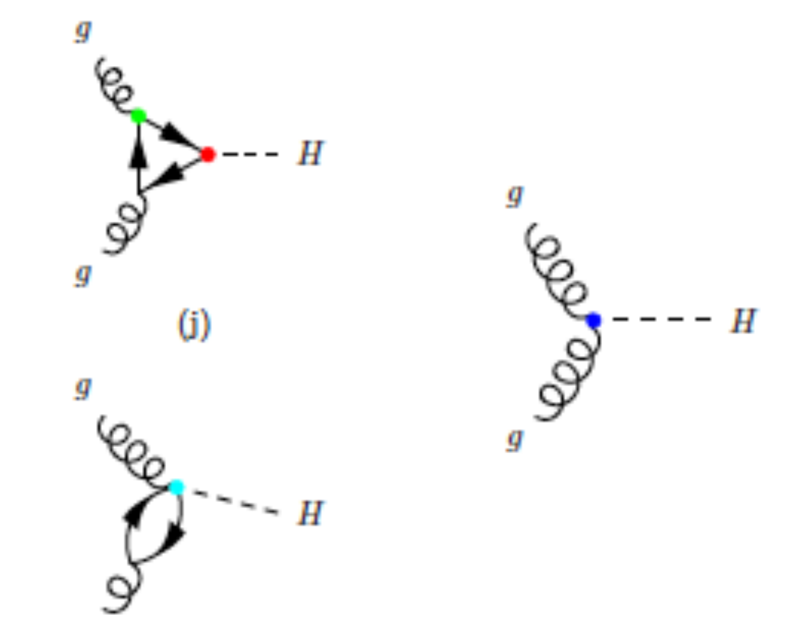
Higgs production and decay

ZH



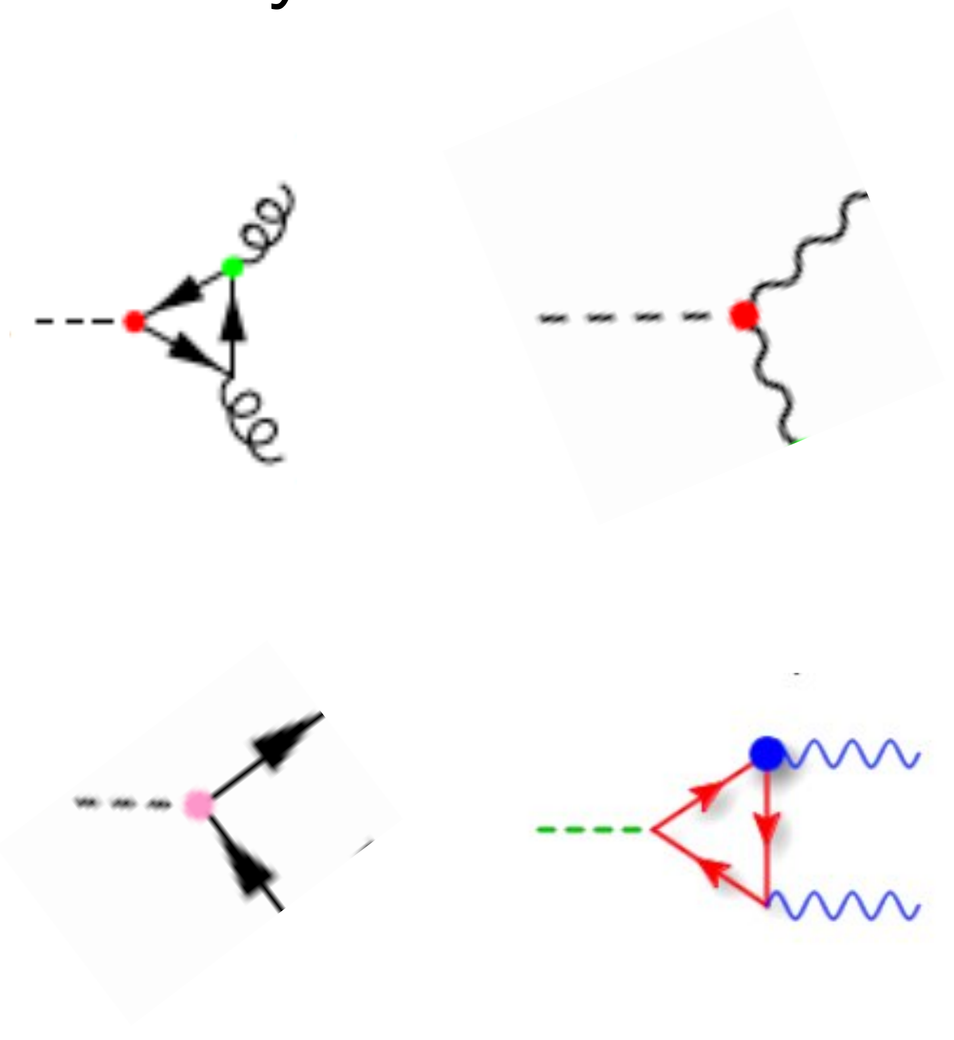
$\mathcal{O}_{\varphi W}$, $\mathcal{O}_{\varphi B}$, $\mathcal{O}_{\varphi D}$, $\mathcal{O}^{(3)}_{\varphi q_i}$, $\mathcal{O}^{(1)}_{\varphi q_i}$, $\mathcal{O}^{(1)}_{\varphi Q}$, $\mathcal{O}^{(3)}_{\varphi Q}$, $\mathcal{O}_{\varphi d}$, $\mathcal{O}_{\varphi WB}$, $\mathcal{O}^{(3)}_{\varphi l_1}$, $\mathcal{O}^{(3)}_{\varphi l_2}$, $\mathcal{O}_{\varphi u_i}$, $\mathcal{O}_{\varphi d_i}$

ggH



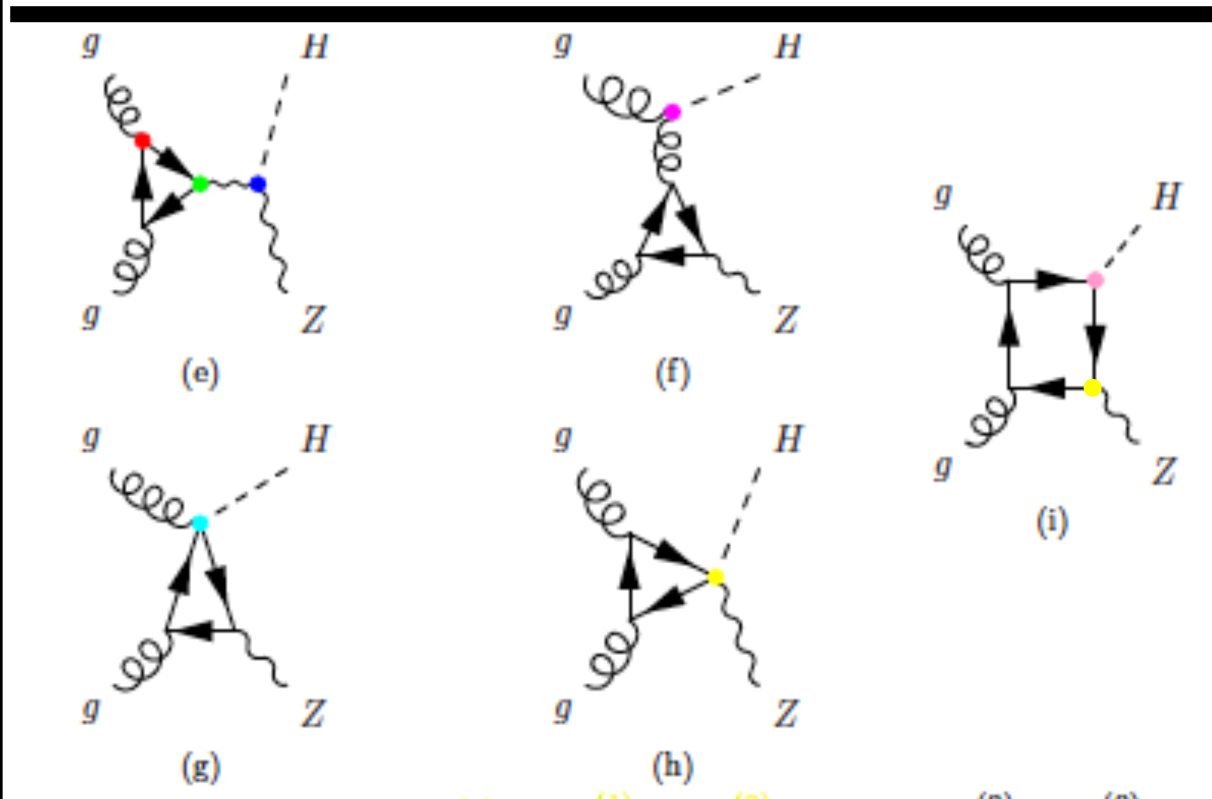
$\mathcal{O}_{\varphi D}$, $\mathcal{O}_{\varphi d}$, $\mathcal{O}^{(3)}_{\varphi l_1}$, $\mathcal{O}^{(3)}_{\varphi l_2}$, $\mathcal{O}_{t\varphi}$, $\mathcal{O}_{tG}$, $\mathcal{O}_{\varphi G}$, $\mathcal{O}_{ll}$

H decays



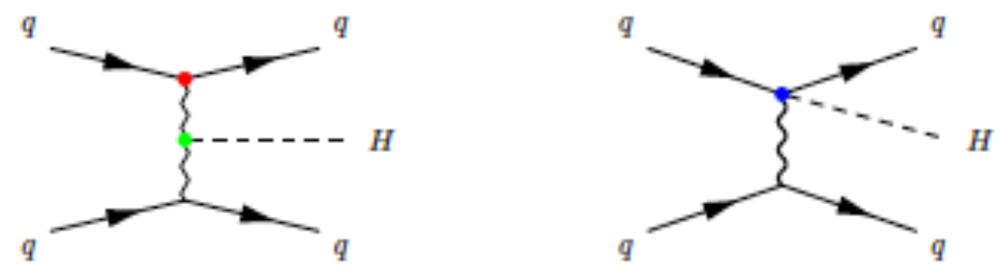
$\mathcal{O}_{\varphi D}$, $\mathcal{O}^{(1)}_{\varphi q_i}$, $\mathcal{O}^{(1)}_{\varphi Q}$, $\mathcal{O}^{(3)}_{\varphi Q}$, $\mathcal{O}_{\phi d}\cdots$

ZH



$\mathcal{O}_{\varphi D}$, $\mathcal{O}^{(1)}_{\varphi q_i}$, $\mathcal{O}^{(1)}_{\varphi Q}$, $\mathcal{O}^{(3)}_{\varphi Q}$, $\mathcal{O}_{\varphi d}$, $\mathcal{O}^{(3)}_{\varphi l_1}$, $\mathcal{O}^{(3)}_{\varphi l_2}$, $\mathcal{O}_{\varphi u_i}$, $\mathcal{O}_{\varphi t}$, $\mathcal{O}_{\varphi d_i}$, $\mathcal{O}_{t\varphi}$, $\mathcal{O}_{tG}$, $\mathcal{O}_{\varphi G}$, $\mathcal{O}_{ll}$

VBF



$\mathcal{O}_{\varphi W}$, $\mathcal{O}_{\varphi B}$, $\mathcal{O}_{\varphi D}$, $\mathcal{O}^{(3)}_{\varphi q_i}$, $\mathcal{O}^{(1)}_{\varphi q_i}$, $\mathcal{O}^{(1)}_{\varphi Q}$, $\mathcal{O}^{(3)}_{\varphi Q}$, $\mathcal{O}_{\varphi d}$, $\mathcal{O}_{\varphi WB}$, $\mathcal{O}^{(3)}_{\varphi l_1}$, $\mathcal{O}^{(3)}_{\varphi l_2}$, $\mathcal{O}_{\varphi u_i}$, $\mathcal{O}_{\varphi d_i}$

from L. Mantani

Global Higgs-top fit

Higgs data

Run I & 2 signal strengths (CMS+ATLAS):

* gluon fusion
* VH
* VBF
* ttH
* H decays

Differential distributions & STXS

Top data

Run I & 2 results (CMS+ATLAS):

* pair production
* tt+V, tttt, ttbb
* single top
* tZj
* W helicity fractions

Cross-sections & Differential distributions

New operators

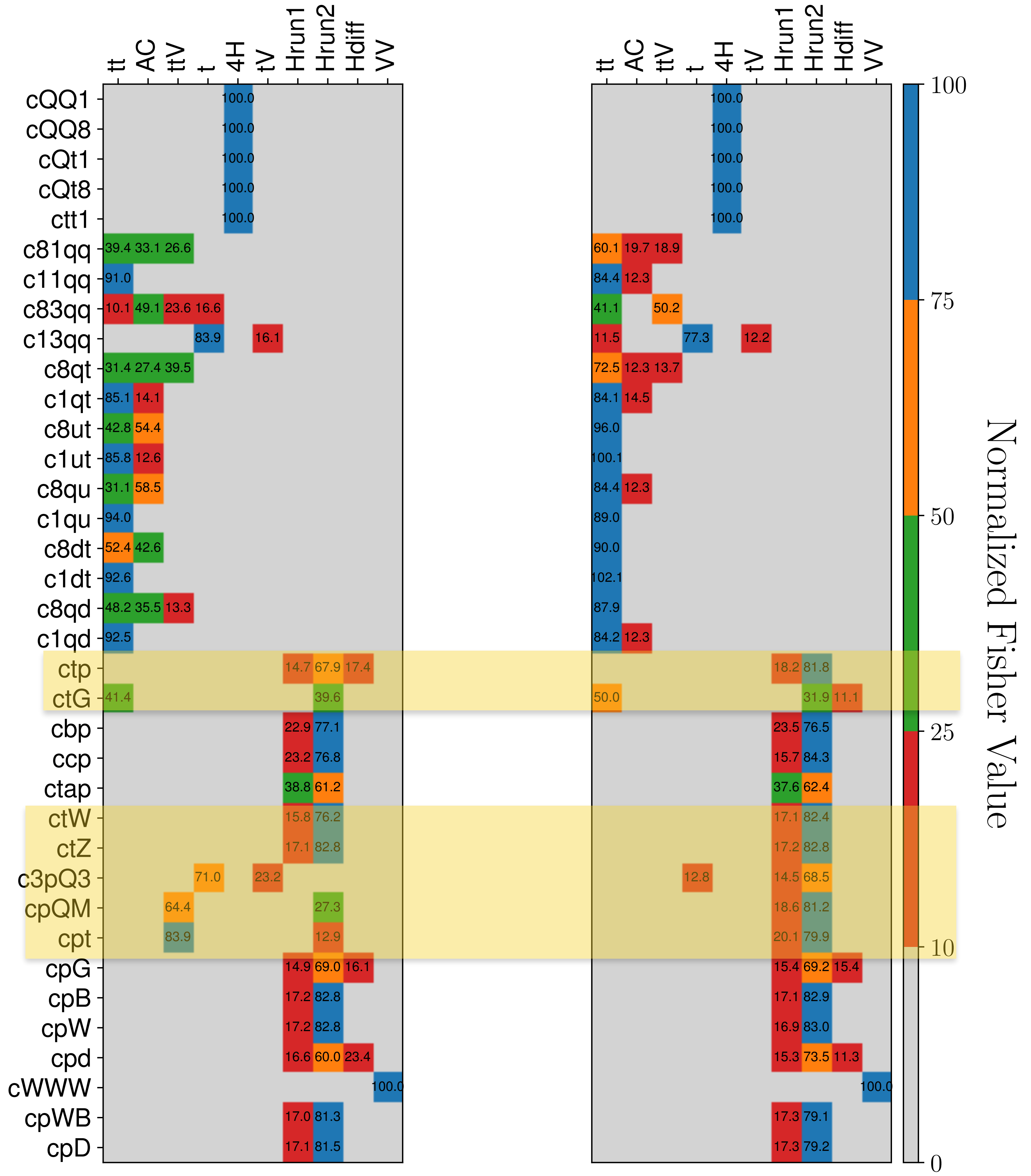
Bosonic					
$\mathcal{O}_{\phi G}$	OpG	$\left(\phi^\dagger\phi - \frac{v^2}{2}\right) G_A^{\mu\nu} G^A_{\mu\nu}$	$\mathcal{O}_{\phi B}$	OpB	$\left(\phi^\dagger\phi - \frac{v^2}{2}\right) B^{\mu\nu} B_{\mu\nu}$
$\mathcal{O}_{\phi W}$	OpW	$\left(\phi^\dagger\phi - \frac{v^2}{2}\right) W_I^{\mu\nu} W^I_{\mu\nu}$	$\mathcal{O}_{\phi WB}$	OpWB	$(\phi^\dagger \tau_I \phi) B^{\mu\nu} W^I_{\mu\nu}$
$\mathcal{O}_{\phi d}$	Opd	$\partial_\mu(\phi^\dagger\phi)\partial^\mu(\phi^\dagger\phi)$	$\mathcal{O}_{\phi D}$	OpD	$(\phi^\dagger D^\mu \phi)^\dagger (\phi^\dagger D_\mu \phi)$

2 Fermions					
$\mathcal{O}_{t\varphi}$	Otp	$\left(\phi^\dagger\phi - \frac{v^2}{2}\right) \bar{Q}\, t\, \tilde{\phi} + \text{h.c.}$	$\mathcal{O}_{tG}$	OtG	$igs\,(\bar{Q}\tau^{\mu\nu} T_A\, t)\, \tilde{\phi}\, G^A_{\mu\nu} + \text{h.c.}$
$\mathcal{O}_{b\varphi}$	Obp	$\left(\phi^\dagger\phi - \frac{v^2}{2}\right) \bar{Q}\, b\, \phi + \text{h.c.}$	$\mathcal{O}_{c\varphi}$	Ocp	$\left(\phi^\dagger\phi - \frac{v^2}{2}\right) \bar{Q}\, c\, \phi + \text{h.c.}$
$\mathcal{O}_{\tau\varphi}$	Otap	$\left(\phi^\dagger\phi - \frac{v^2}{2}\right) \bar{Q}\, \tau\, \tilde{\phi} + \text{h.c.}$	$\mathcal{O}_{tW}$	OtW	$i(\bar{Q}\tau^{\mu\nu}\, \tau_I\, t)\, \tilde{\phi}\, W^I_{\mu\nu} + \text{h.c.}$
$\mathcal{O}_{tB}$	-	$i(\bar{Q}\tau^{\mu\nu}\, t)\, \tilde{\phi}\, B_{\mu\nu} + \text{h.c.}$	$\mathcal{O}_{tZ}$	OtZ	$-\sin\theta_W \mathcal{O}_{tB} + \cos\theta_W \mathcal{O}_{tW}$
$\mathcal{O}^{(1)}_{\varphi l_1}$	Opl1	$i(\phi^\dagger \overleftrightarrow{D}_\mu \phi)(\bar{l}_1 \gamma^\mu l_1)$	$\mathcal{O}^{(3)}_{\varphi l_1}$	O3pl1	$i(\phi^\dagger \overleftrightarrow{D}_\mu \tau_I \phi)(\bar{l}_1 \gamma^\mu \tau^I l_1)$
$\mathcal{O}^{(1)}_{\varphi l_2}$	Opl2	$i(\phi^\dagger \overleftrightarrow{D}_\mu \phi)(\bar{l}_2 \gamma^\mu l_2)$	$\mathcal{O}^{(3)}_{\varphi l_2}$	O3pl2	$i(\phi^\dagger \overleftrightarrow{D}_\mu \tau_I \phi)(\bar{l}_2 \gamma^\mu \tau^I l_2)$
$\mathcal{O}^{(1)}_{\varphi l_3}$	Opl3	$i(\phi^\dagger \overleftrightarrow{D}_\mu \phi)(\bar{l}_3 \gamma^\mu l_3)$	$\mathcal{O}^{(3)}_{\varphi l_3}$	O3pl3	$i(\phi^\dagger \overleftrightarrow{D}_\mu \tau_I \phi)(\bar{l}_3 \gamma^\mu \tau^I l_3)$
$\mathcal{O}_{\varphi e}$	Ope	$i(\phi^\dagger \overleftrightarrow{D}_\mu \phi)(\bar{e} \gamma^\mu e)$	$\mathcal{O}_{\varphi \mu}$	Opmu	$i(\phi^\dagger \overleftrightarrow{D}_\mu \phi)(\bar{\mu} \gamma^\mu \mu)$
$\mathcal{O}_{\varphi \tau}$	Opta	$i(\phi^\dagger \overleftrightarrow{D}_\mu \phi)(\bar{\tau} \gamma^\mu \tau)$			
$\mathcal{O}^{(1)}_{\varphi q_i}$	-	$\sum_{i=1,2} i(\phi^\dagger \overleftrightarrow{D}_\mu \phi)(\bar{q}_i \gamma^\mu q_i)$	$\mathcal{O}^{(3)}_{\varphi q_i}$	O3pq	$\sum_{i=1,2} i(\phi^\dagger \overleftrightarrow{D}_\mu \tau_I \phi)(\bar{q}_i \gamma^\mu \tau^I q_i)$
$\mathcal{O}^{(1)}_{\varphi Q}$	-	$i(\phi^\dagger \overleftrightarrow{D}_\mu \phi)(\bar{Q} \gamma^\mu Q)$	$\mathcal{O}^{(3)}_{\varphi Q}$	O3pQ3	$i(\phi^\dagger \overleftrightarrow{D}_\mu \tau_I \phi)(\bar{Q} \gamma^\mu \tau^I Q)$
$\mathcal{O}^{(-)}_{\varphi q_i}$	OpqMi	$\mathcal{O}^{(1)}_{\varphi q_i} - \mathcal{O}^{(3)}_{\varphi q_i}$	$\mathcal{O}^{(-)}_{\varphi Q}$	OpQM	$\mathcal{O}^{(1)}_{\varphi Q} - \mathcal{O}^{(3)}_{\varphi Q}$
$\mathcal{O}_{\varphi u_i}$	Opui	$\sum_{i=1,2} i(\phi^\dagger \overleftrightarrow{D}_\mu \phi)(\bar{u}_i \gamma^\mu u_i)$	$\mathcal{O}_{\varphi d_i}$	Opdi	$\sum_{i=1,2} i(\phi^\dagger \overleftrightarrow{D}_\mu \phi)(\bar{d}_i \gamma^\mu d_i)$
$\mathcal{O}_{\phi t}$	Opt	$i(\phi^\dagger \overleftrightarrow{D}_\mu \phi)(\bar{t} \gamma^\mu t)$			
$\mathcal{O}_{ll}$	Oll	$(l\gamma_\mu l)(l\gamma^\mu l)$			

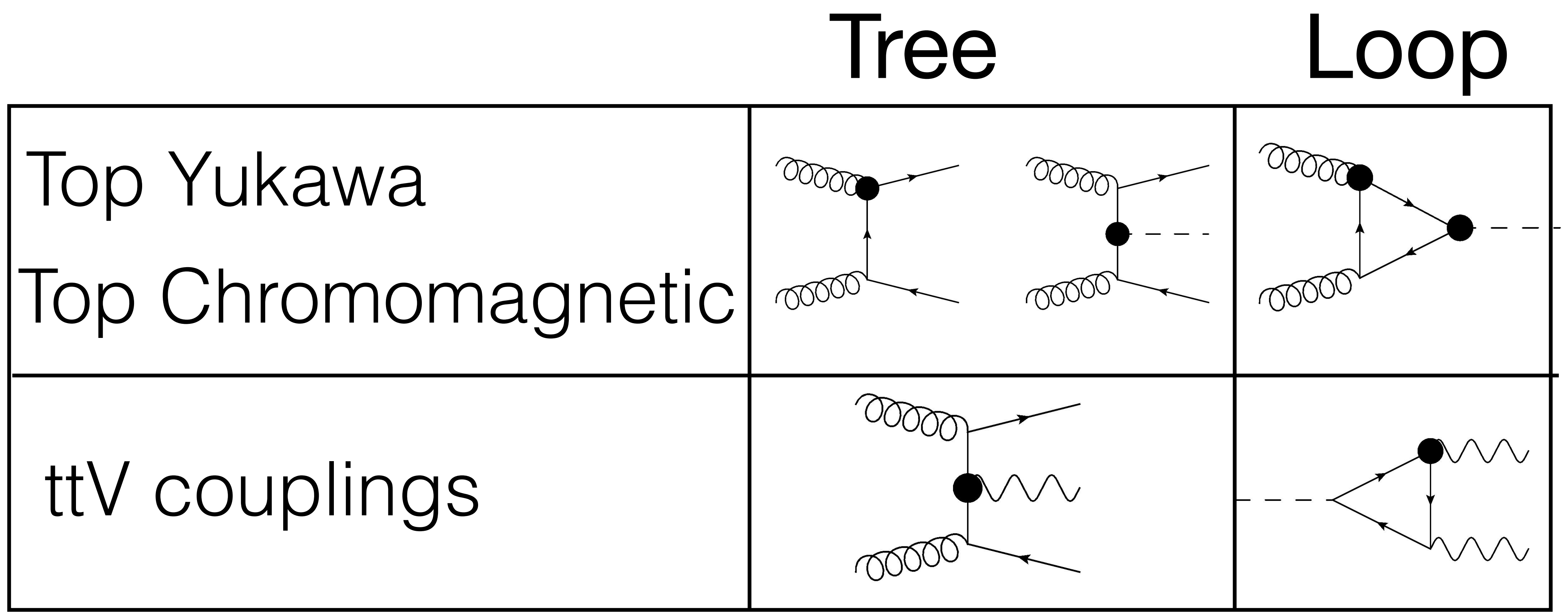
Ethier, Maltoni, Mantani, Nocera, Rojo, Slade, EV and Zhang arXiv:2105.00006

Global Higgs-top fit

Tree-loop interplay



4F mostly top

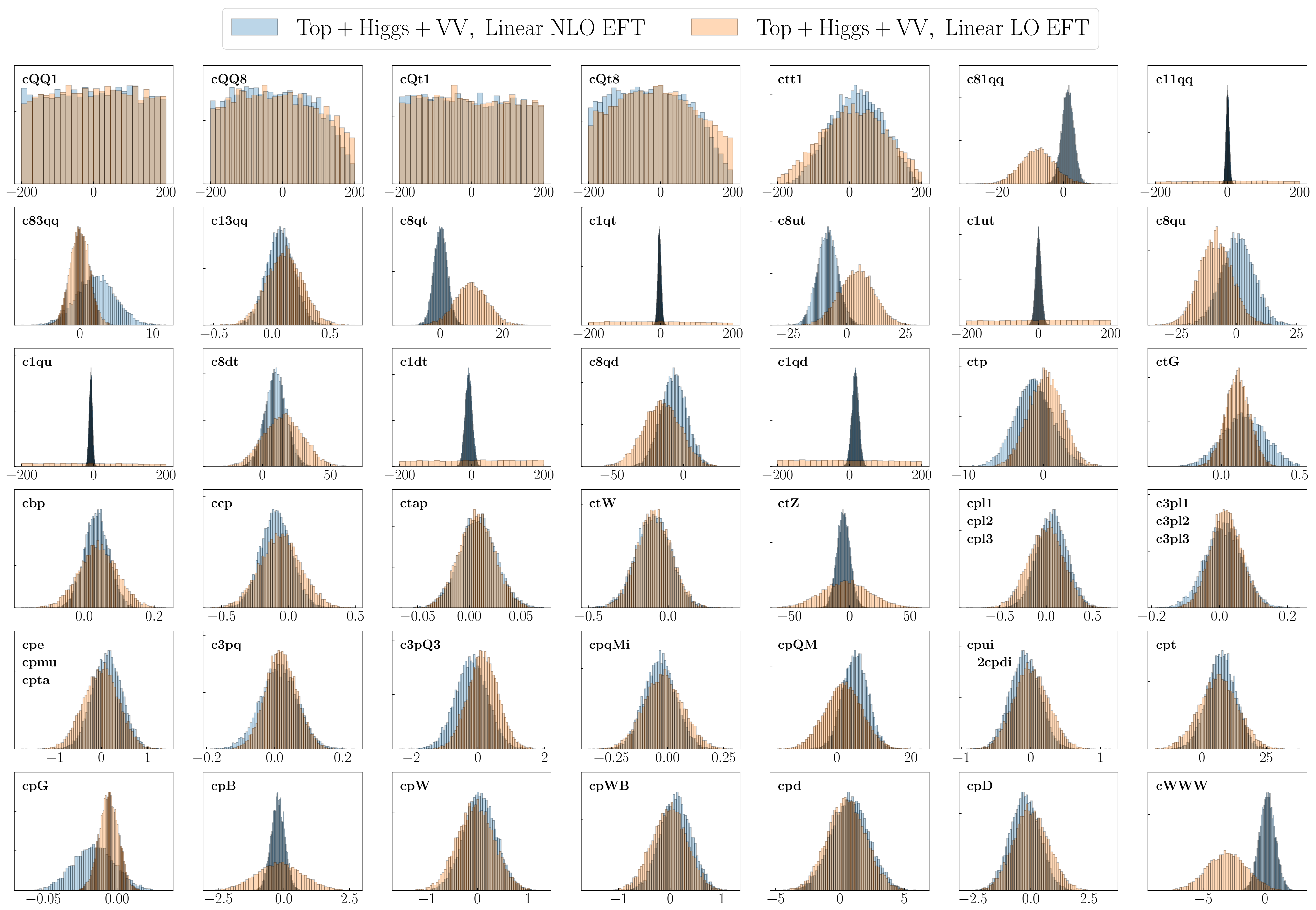


Tree-loop interface

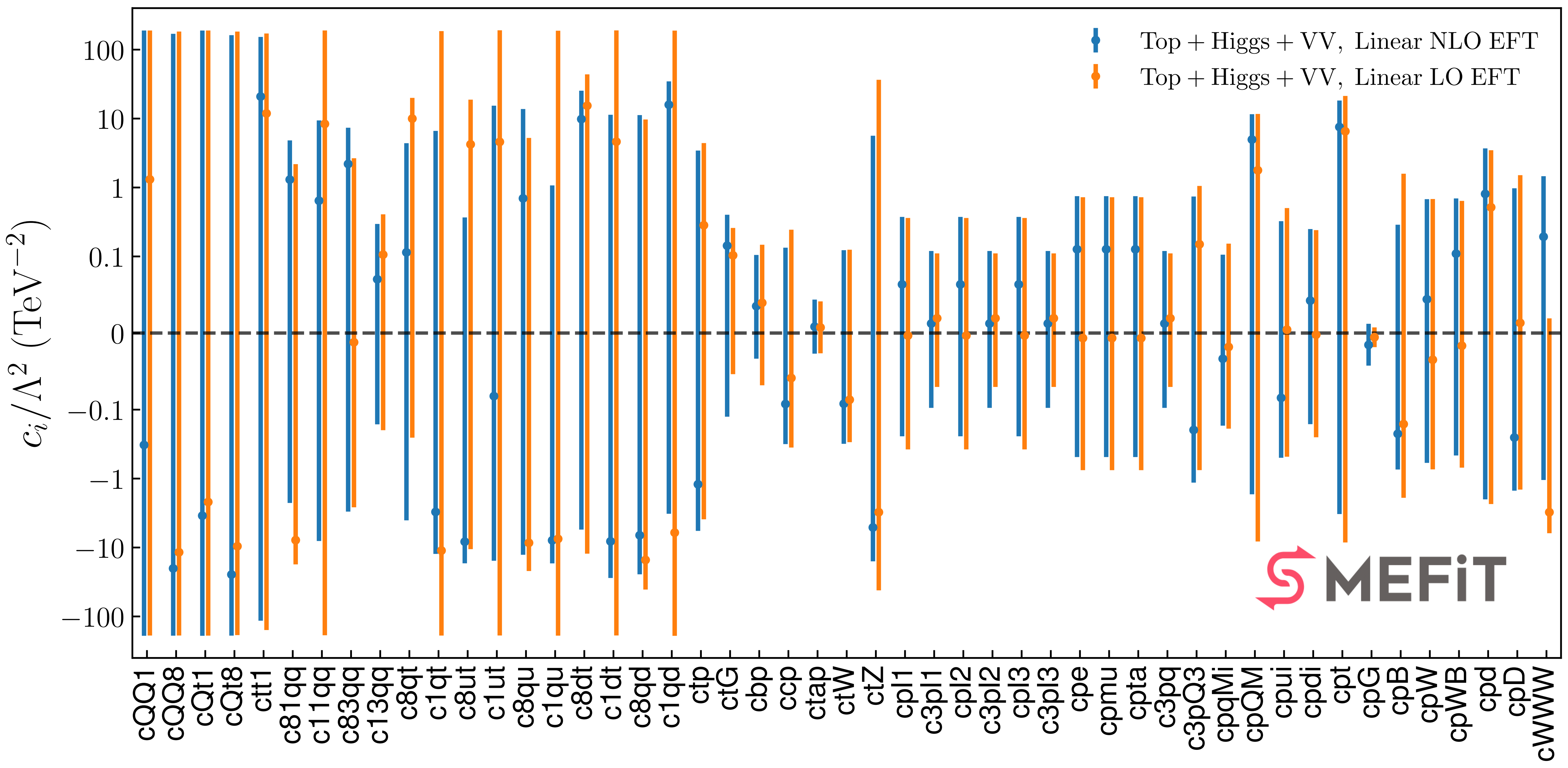
Ethier, Maltoni, Mantani, Nocera, Rojo, Slade, EV and Zhang arXiv:2105.00006

Impact of NLO predictions in global fits

Marginalised constraints: Linear



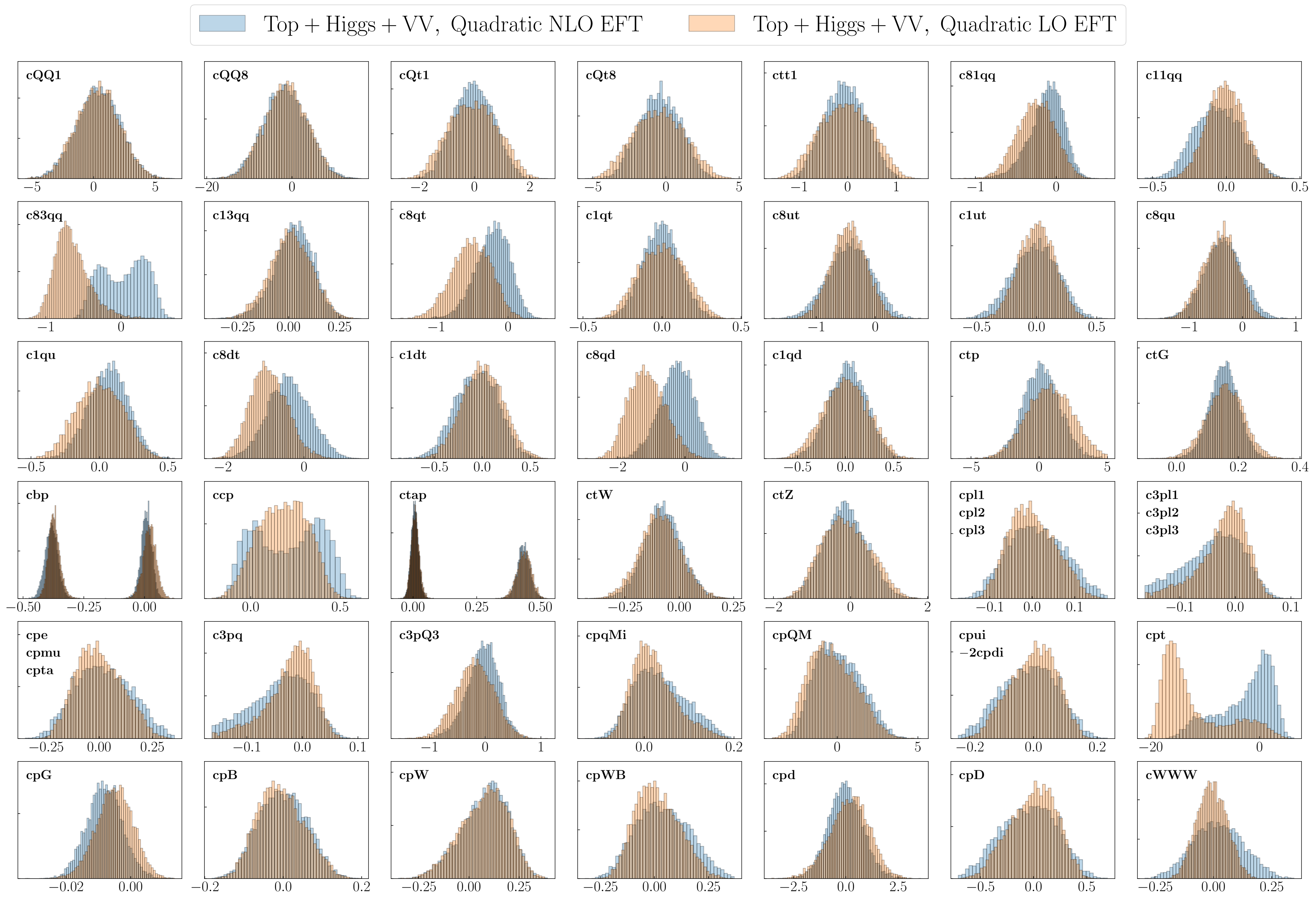
Posterior distributions



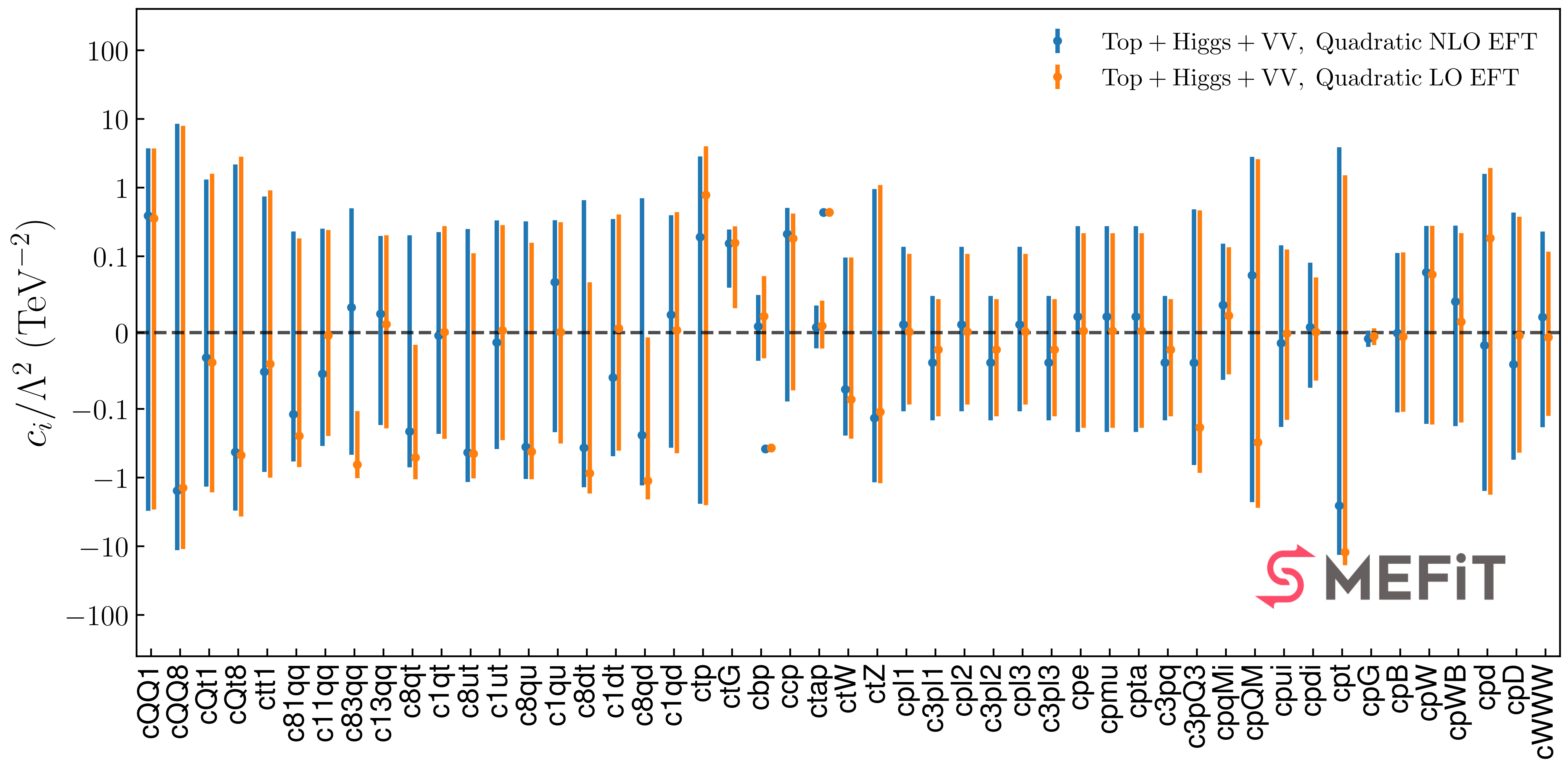
Significant impact of NLO for some operators

Impact of NLO predictions in global fits

Marginalised constraints: Quadratic



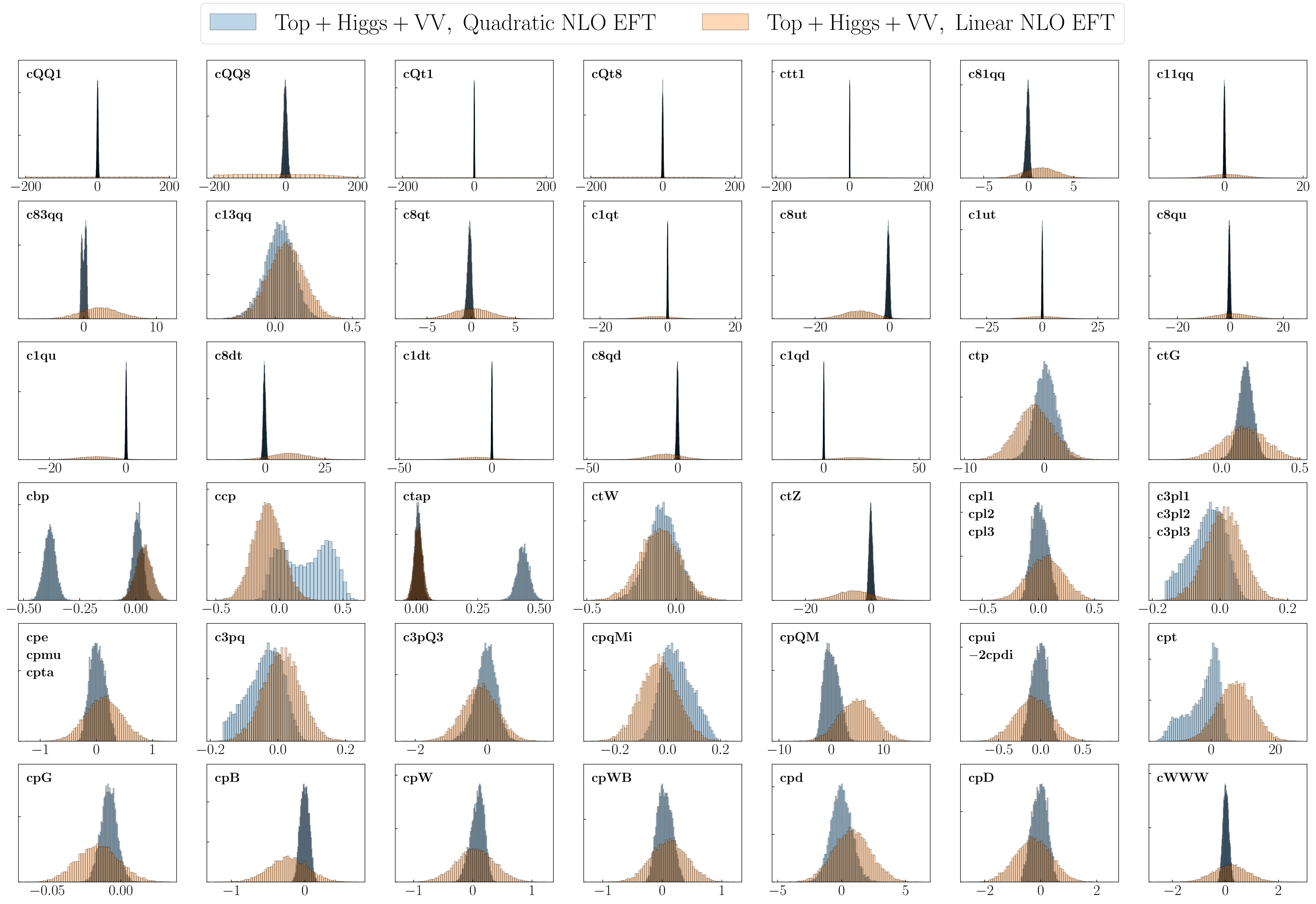
Posterior distributions



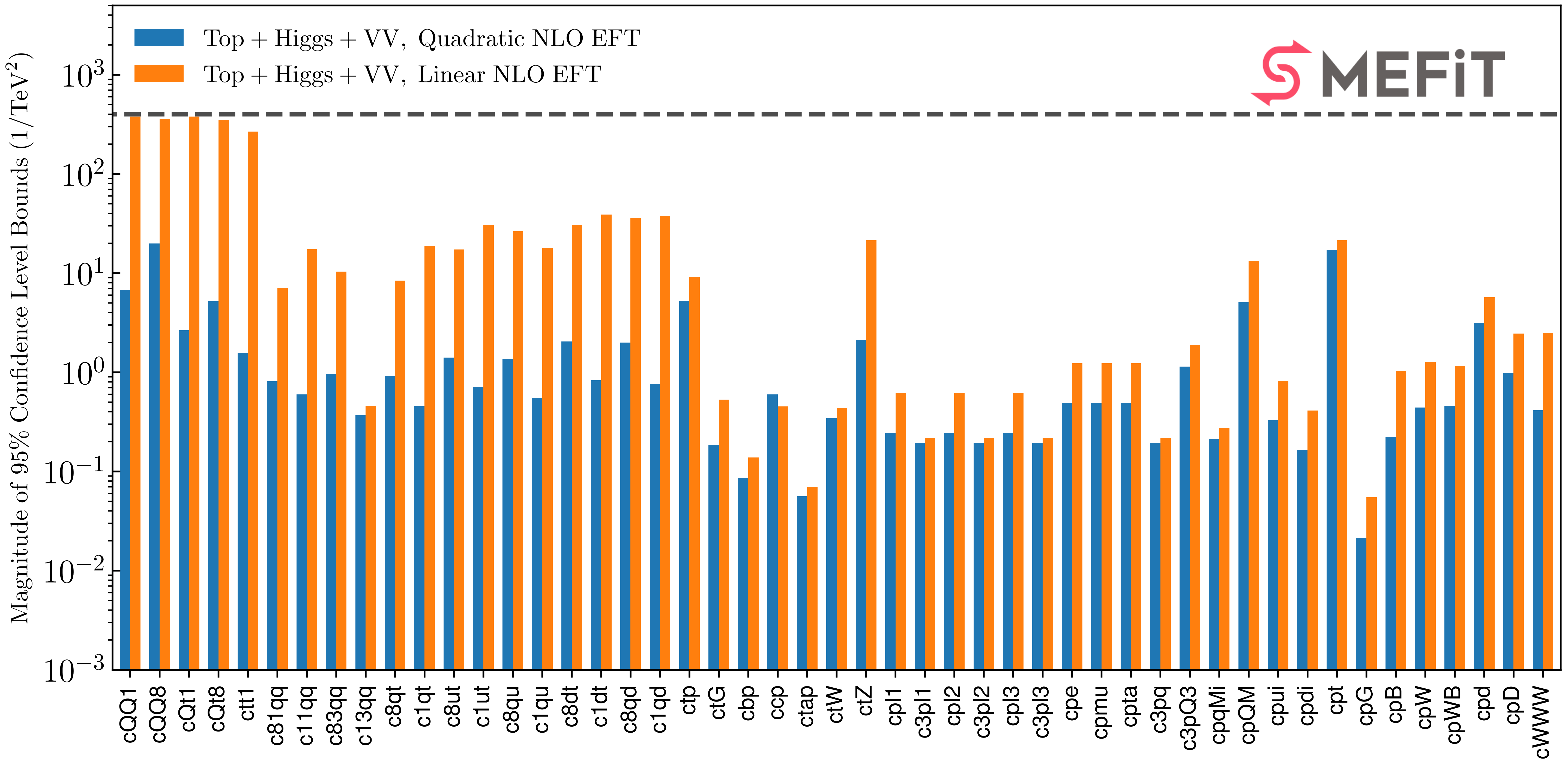
Significant impact of NLO for some operators

Impact of quadratic terms in global fits

Marginalised constraints



Posterior distributions



Significant impact for most operators

in particular the ones non-interfering due to colour

Open questions

Theory aspects in global fits

- Bases, notations, input schemes
  - common conventions, translations, common EW inputs
- Assumptions
  - flavour structures, classes of BSM, symmetries
- Truncation, uncertainties, validity
  - linear/quadratic, double ins., dim-8, truncation errors, etc.
- Theory constraints
  - unitarity, positivity

LHC EFT WG effort:

https://indico.cern.ch/category/12671/