EFT interpretation workflow: tools and higher orders

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LHCHWG meeting, online, 9/11/20

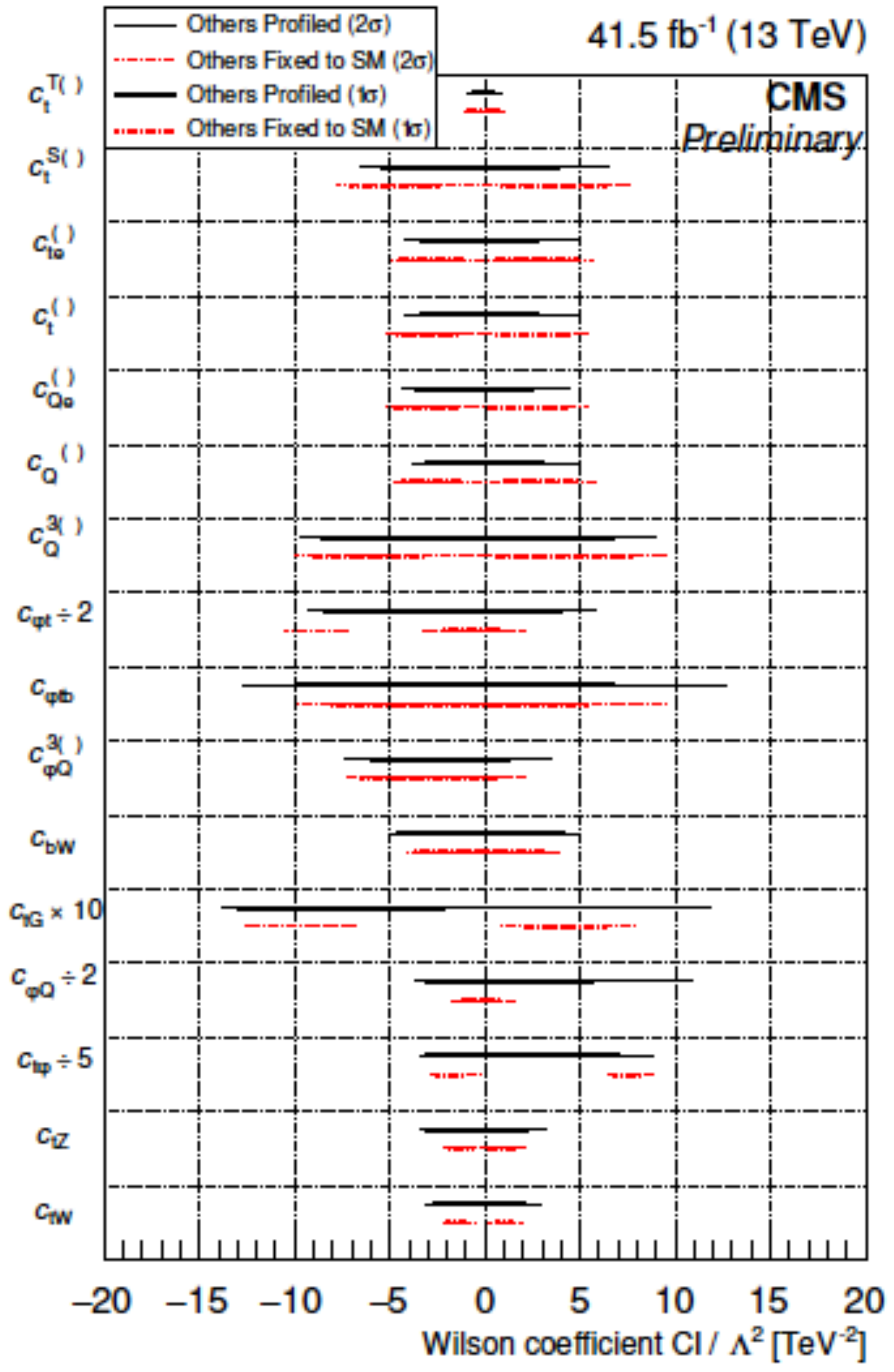
Introduction

EFT interpretations spreading in top, Higgs and EW sectors

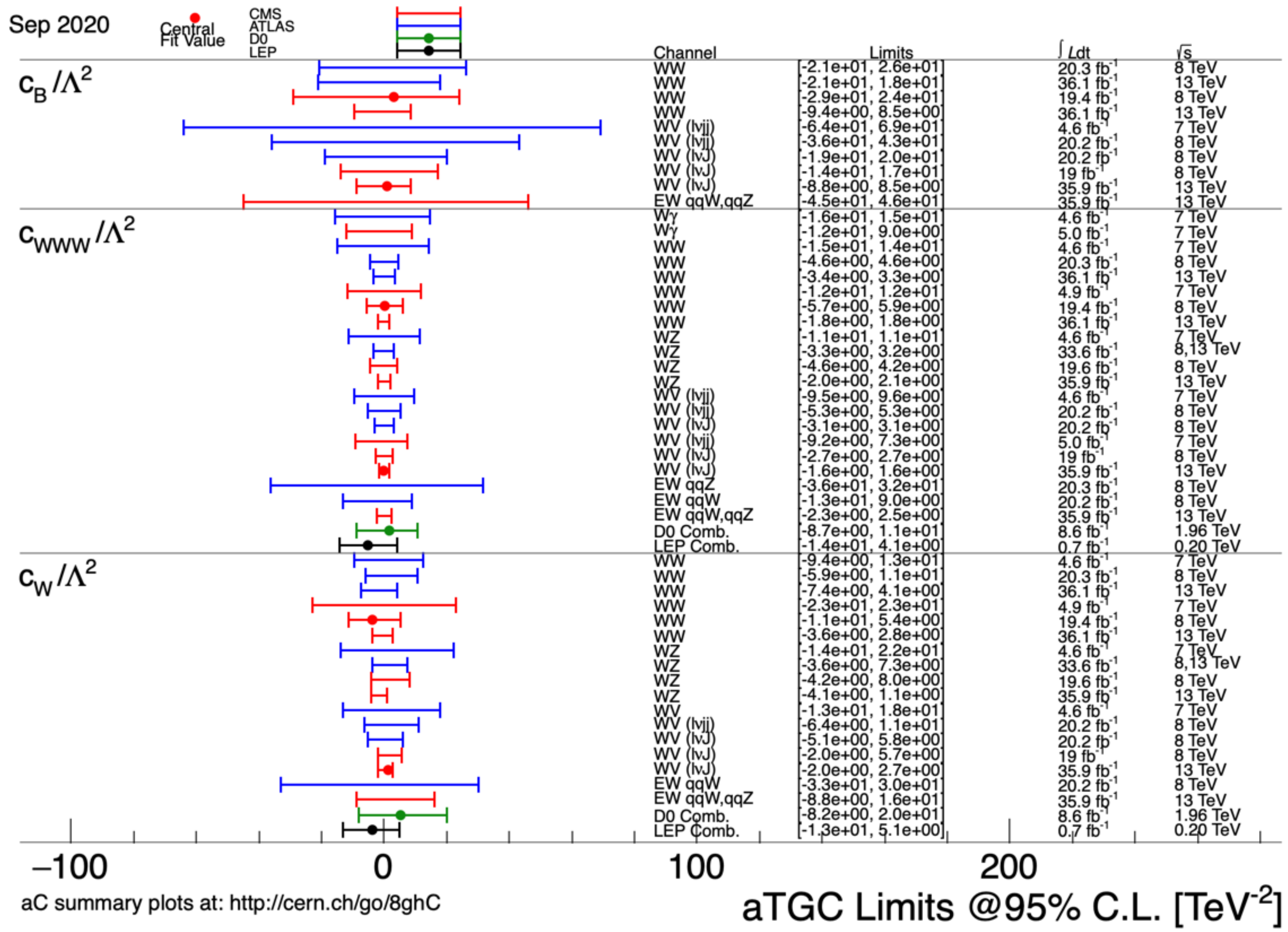
CMS TOP-19-001

$t\bar{t}l\nu, t\bar{t}l\bar{l}, tl\bar{l}q, tHq$

* 16 operators, 5 processes, 10 signal regions!!!
  The most broad analysis todate.

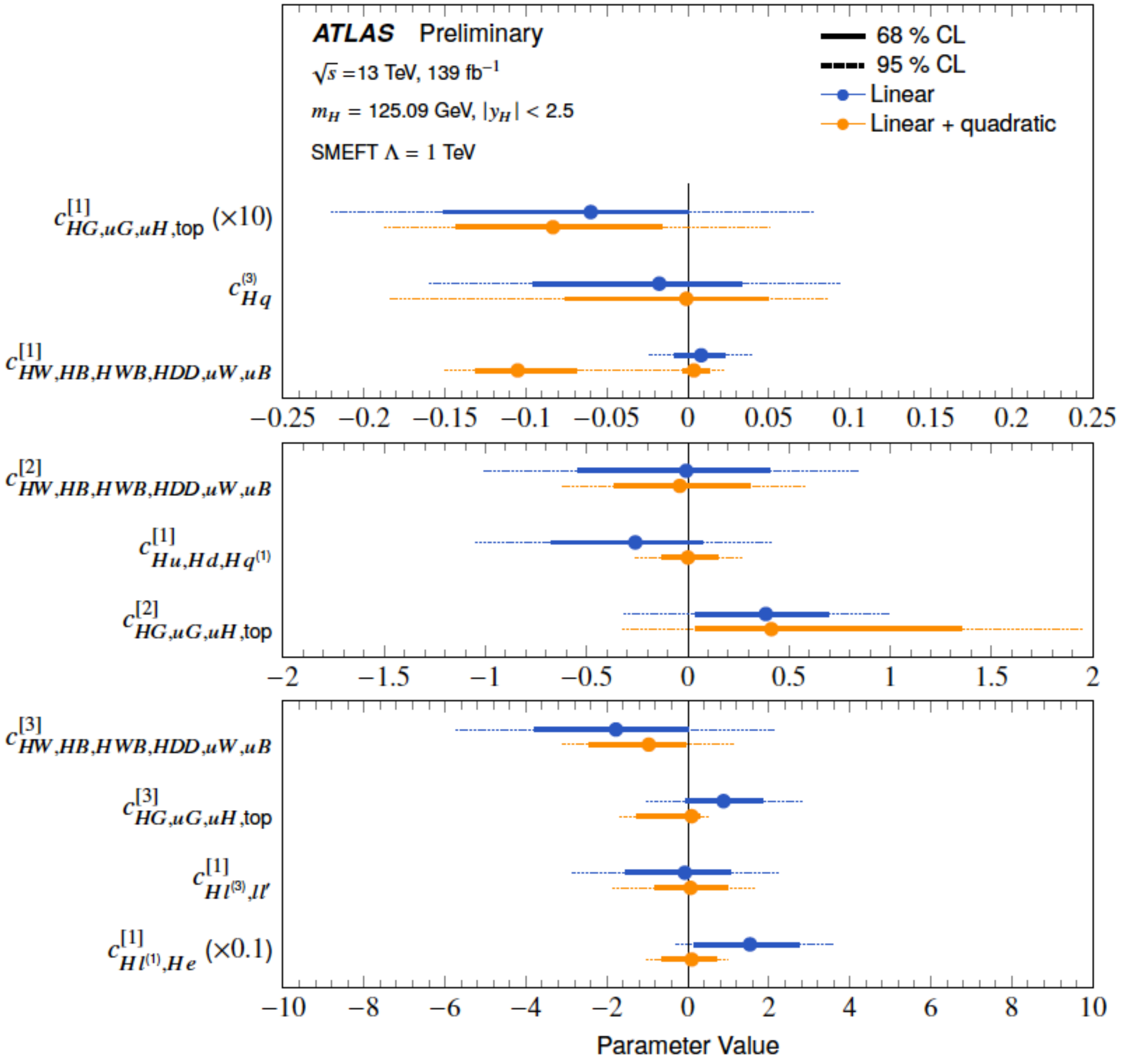


LHC EW Multiboson Subgroup

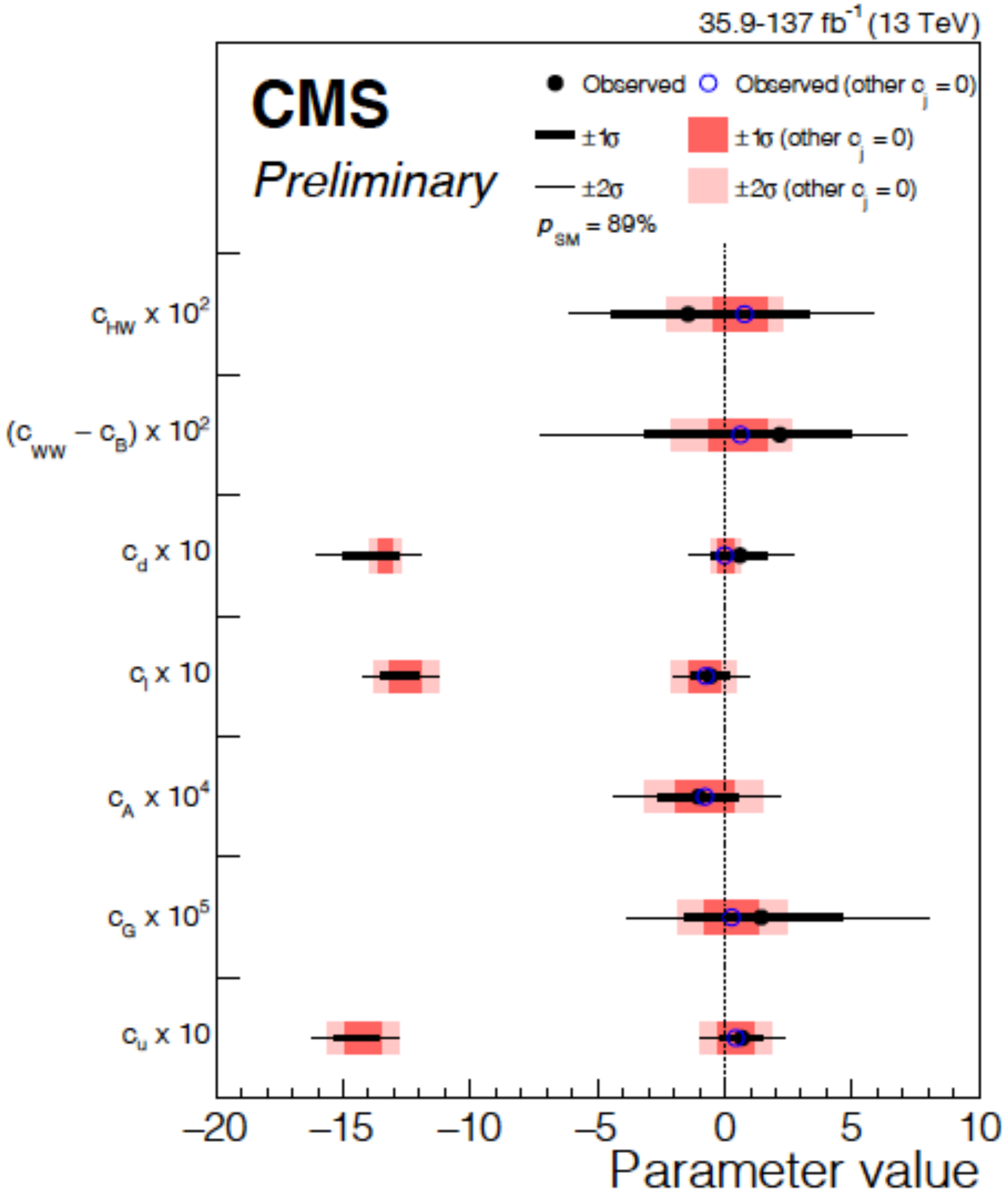


EFT in Higgs measurements

ATLAS CONF-2020-053



CMS PAS HIG-19-005



Issues and questions

How to proceed with combined/global analyses?

Need to address:

* Choice of basis
* Choice of flavour assumption
* Choice of which operators to fit and which to ignore
* How to present the results to allow combinations?

Basis and Flavour

Basis

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Warsaw basis (smeftsim & SMEFT@NLO implementations)

c.f.

CMS PAS HIG-19-005

SILH basis (HEL implementation)

c.f.

CMS TOP-19-001

Warsaw basis (dim6top implementation)

Flavour assumption

	e.g. $Q_{Hu,pr} = (Hi\overleftrightarrow{D}_\mu H)(\bar{u}_p\gamma^\mu u_r)$		tot
general	$(C_{Hu})_{pr}$	9	2499
$U(3)^5$	$C_{Hu}\,\delta_{pr}$	1	~ 85
$U(3)^2_{\ell,e} \times U(2)^3_{q,u,d}$	$C_{Hu}\,\delta_{pr},\ \ p,r = 1,2$ $C_{Ht}\qquad p = r = 3$	2	~ 180

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CMS TOP-19-001

How to combine?

From I. Brivio

Operator selection

How to select operators?

Various options followed by the experimental analyses:

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“operators for which the Λ^{-2}-suppressed contribution to any of the STXS categories exceeds 1‰ with respect to the SM prediction at $c_i = 1$” → **How about non-interfering operators?**

CMS TOP-19-001

“16 operators chosen because they are expected to have a relatively large impact on the signal processes but not on the tt background process. To determine if a process is affected by an operator, we check whether the cross section of the process is scaled by more than five times the SM cross-section when the WC set to $16\pi^2$.” →

How about relevant operators which affect the background? Operator normalisation?

CMS PAS HIG-19-005

“The parameters cWW and cB are fit together in the combination cWW-cB, since the orthogonal combination (S = cWW + cB) is strongly constrained at zero by electroweak precision data.” → **How about other constraints?**

Need for some guidance and common strategy

First attempts towards guidelines

The LHC Top WG EFT note

Interpreting top-quark LHC measurements
in the standard-model effective field theory

J. A. Aguilar Saavedra,[1] C. Degrande,[2] G. Durieux,[3]
F. Maltoni,[4] E. Vryonidou,[2] C. Zhang[5] (editors),
D. Barducci,[6] I. Brivio,[7] V. Cirigliano,[8] W. Dekens,[8,9] J. de Vries,[10] C. Englert,[11]
M. Fabbrichesi,[12] C. Grojean,[3,13] U. Haisch,[2,14] Y. Jiang,[7] J. Kamenik,[15,16]
M. Mangano,[2] D. Marzocca,[12] E. Mereghetti,[8] K. Mimasu,[4] L. Moore,[4] G. Perez,[17]
T. Plehn,[18] F. Riva,[2] M. Russell,[18] J. Santiago,[19] M. Schulze,[13] Y. Soreq,[20]
A. Tonero,[21] M. Trott,[7] S. Westhoff,[18] C. White,[22] A. Wulzer,[2,23,24] J. Zupan.[25]

Abstract

This note proposes common standards and prescriptions for the effective-field-theory interpretation of top-quark measurements at the LHC.

arXiv:1802.07237

Input from a lot of theorists

Warsaw basis

3 scenarios with different flavour assumptions

Constraints from LHC, EWPO, indirect constraints

Public UFO implementations and benchmark results already given for LHC13

Separate discussion of FCNC

Baseline flavour scenario singles out the 3rd generation

$$U(2)_q \times U(2)_u \times U(2)_d$$

four heavy quarks	$11 + 2$ CPV
two light and two heavy quarks	14
two heavy quarks and bosons	$9 + 6$ CPV
two heavy quarks and two leptons	$(8 + 3$ CPV$) \times 3$ lepton flavours

Monte Carlo tools and validation

A systematic effort to cross-validate different implementations

CERN-LPCC-2019-02

Proposal for the validation of Monte Carlo implementations of the standard model effective field theory

Gauthier Durieux[1] (ed.), Ilaria Brivio[2,3] (ed.), Fabio Maltoni[4,5] (ed. ex officio), Michael Trott[2] (ed. ex officio), Simone Alioli,[6] Andy Buckley,[7] Mauro Chiesa,[8] Jorge de Blas,[9,10] Athanasios Dedes,[11] Céline Degrande,[4] Ansgar Denner,[8] Christoph Englert,[7] James Ferrando,[12] Benjamin Fuks,[13,14] Peter Galler,[7] Admir Greljo,[15] Valentin Hirschi,[16] Gino Isidori,[17] Wolfgang Kilian,[18] Frank Krauss,[19] Jean-Nicolas Lang,[17] Jonas Lindert,[19] Michelangelo Mangano,[15] David Marzocca,[20] Olivier Mattelaer,[4] Kentarou Mawatari,[21] Emanuele Mereghetti,[22] David J. Miller,[7] Ken Mimasu,[4] Michael Paraskevas,[23] Tilman Plehn,[3] Laura Reina,[24] Janusz Rosiek,[23] Jürgen Reuter,[12] José Santiago,[25] Kristaq Suxho,[11] Lampros Trifyllis,[11] Eleni Vryonidou,[15] Christopher White,[27] Cen Zhang,[28,29] Hantian Zhang[17]

arXiv:1906.12310

Examples of implementations:

- DIM6TOP is a UFO implementation of top-quark interactions following the conventions of the LHC top Working Group [3]. It is available at this url[1].
- SMEFTSIM is a complete UFO implementation of the Warsaw basis [4] of dimension-six operators [5]. It is available at this url[2].
- SMEFT@NLO is a UFO implementation, to next-to-leading order in QCD, of of CP- and $U(2)_q \times U(2)_u \times U(3)_d \times U(3)_l \times U(3)_e$-conserving dimension-six interactions, available at this url[3].
- SMEFTFR [6, 7] is a package generating Feynman rules, in FEYNRULES and UFO formats, for the dimension-six operators of the Warsaw basis [4] (or any subset), in unitary or linear R_ξ gauges, in terms of physical fields (mass eigenstates), for general flavour structures. It is available at this url[4].
- HEL [8] is an implementation of dimension-six operators in the SILH basis [9] available at this url[5].
- BSMC [10] is an implementation of dimension-six operators in the Higgs basis [11] associated with the ROSETTA package (here[6]). It is available at this url[7].

A large number of implementations:

need for systematic comparison and validation

EFT WG efforts

First outline of the WG activities and targets

(larger # of *s reflects higher level of priority)

1. EFT Formalism

The starting point for the calculations and fits: what operators, what bases, what perturbation orders, how to combine operators of different dimensions, what constraints to be put in the EFT bases preparation, practical considerations in connection to experimental analyses, flavour and symmetry assumptions. The following issues will be discussed:

- SMEFT bases/notation/normalization/input schemes, etc (***): common conventions, consistency checks among the experiments and streamlining translations among conventions will be required, before any combination is considered. These will be defined on a case by case basis, depending on the specific set of observables included in a given combination.
- Assumptions about the flavour symmetries, and other symmetries like CP
- Definition of scenarios, also for the purposes of doing fit with limited data, and as benchmarks for the presentation of experimental results
- Truncation, quadratic dependences, double insertions, dimension eight contributions, uncertainty prescription, EFT validity (information required from experiments to ensure validity at the interpretation stage) (**)
- TH constraints (unitarity, positivity, etc.) and incorporation into fit results (**)
- Consideration of beyond-SMEFT EFT frameworks, where relevant

2. Predictions and tools

Addressing all issues of how to simulate EFT and generate events; understanding of the limitations of the models and agreements on the way to proceed in the EFT publications and calculations. Identification and estimation of all relevant theory systematics, and calculation in a form which is usable in likelihood fits by the experimental community; investigation of matters related to the computational limitations in the events production for experimentalÂ analyses.

- Guidance
  - Availability (analytic & numeric), usage, assumptions, uncertainties, interplay of tools (**)
  - Reweighting techniques to reduce the full detector simulation sample size (and validation of those techniques) (***)
  - Higher-order corrections in SM couplings (**)
- Deliverables
  - Cross-validation at tree and loop levels (**)
  - Common MC generation and/or settings across experiments
  - Observable calculations (including e.g. fiducial cross-sections, see Area 3.) and analytical parameterizations (also to NLO), comparisons between tools, uncertainties (**)
  - Tools to relate parameters, measured quantities, etc

Dedicated meetings expected 7th and 14th of December

Uncertainties in EFT predictions

* Missing Higher Orders in 1/Λ^4
  * squared dim-6 contributions
  * double insertions of dim-6
  * dim-8 contributions
* Missing 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 NLO?

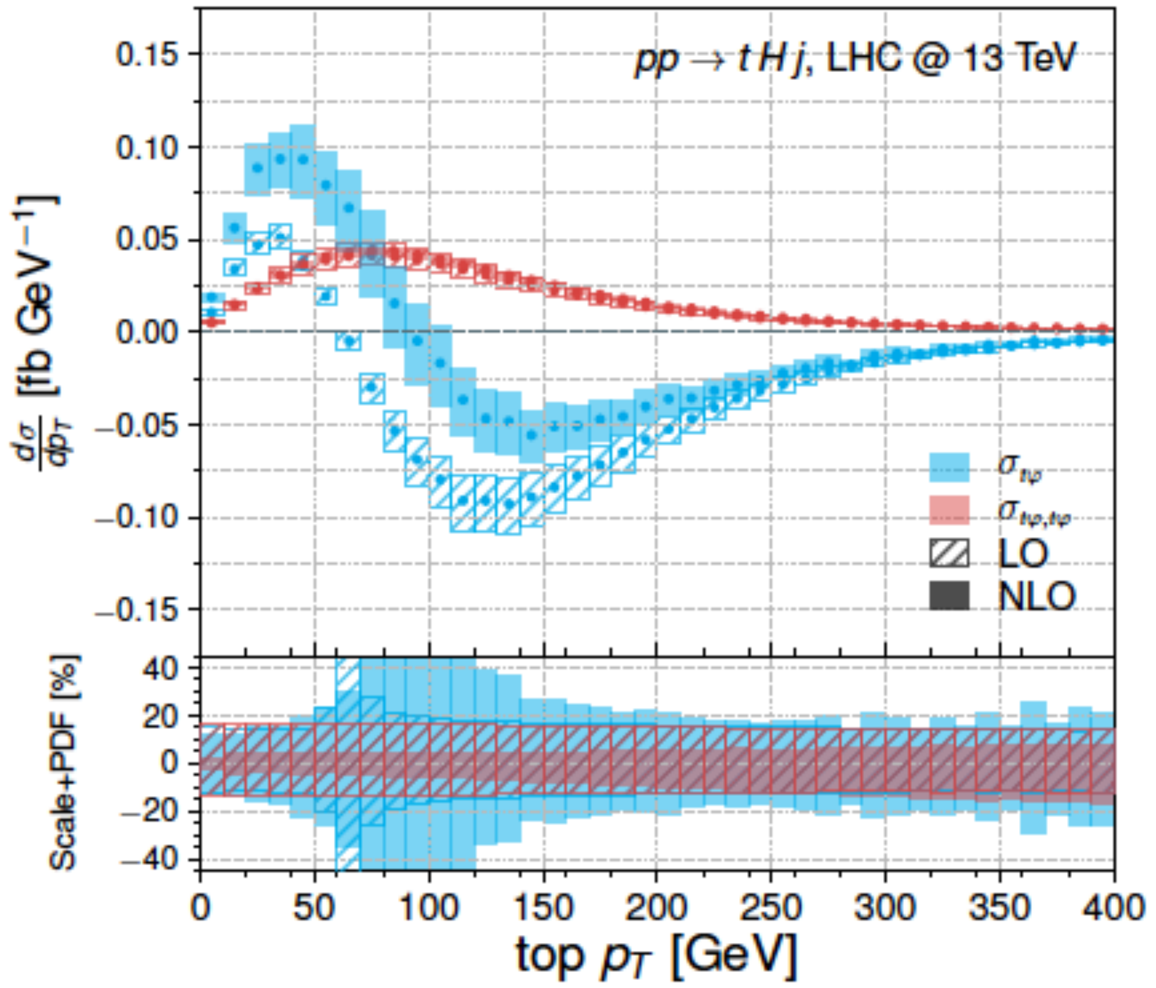
Higher orders in SMEFT bring:

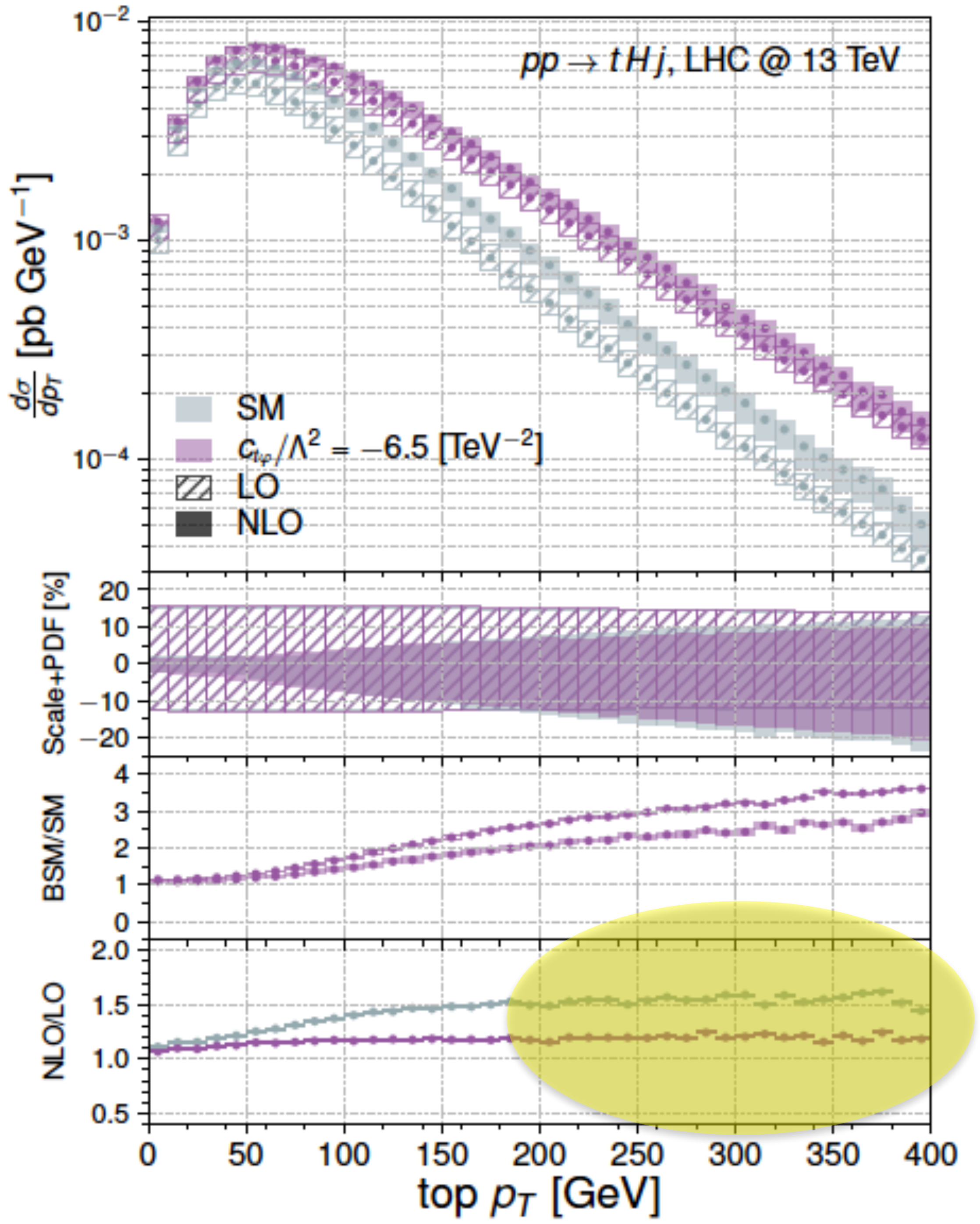
* Accuracy
* Precision
* Improved sensitivity
  * Accurate knowledge of the deviations (distribution shapes, correlations between observables, etc.) can be the key to disentangle them from the SM.
  * Loop-induced new sensitivity.

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

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

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

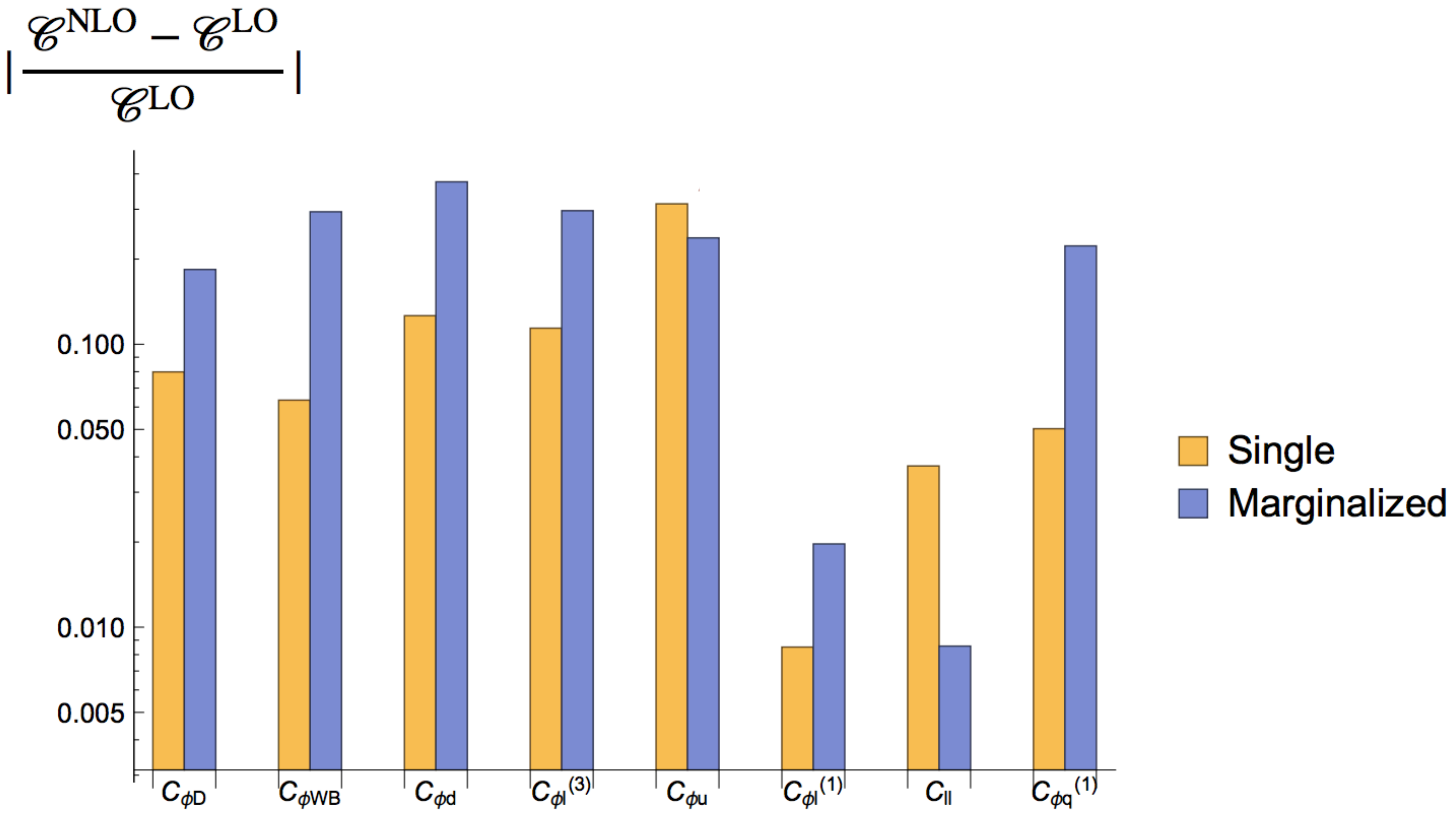
Maltoni, EV, Zhang arXiv:1607.05330

Accuracy and precision

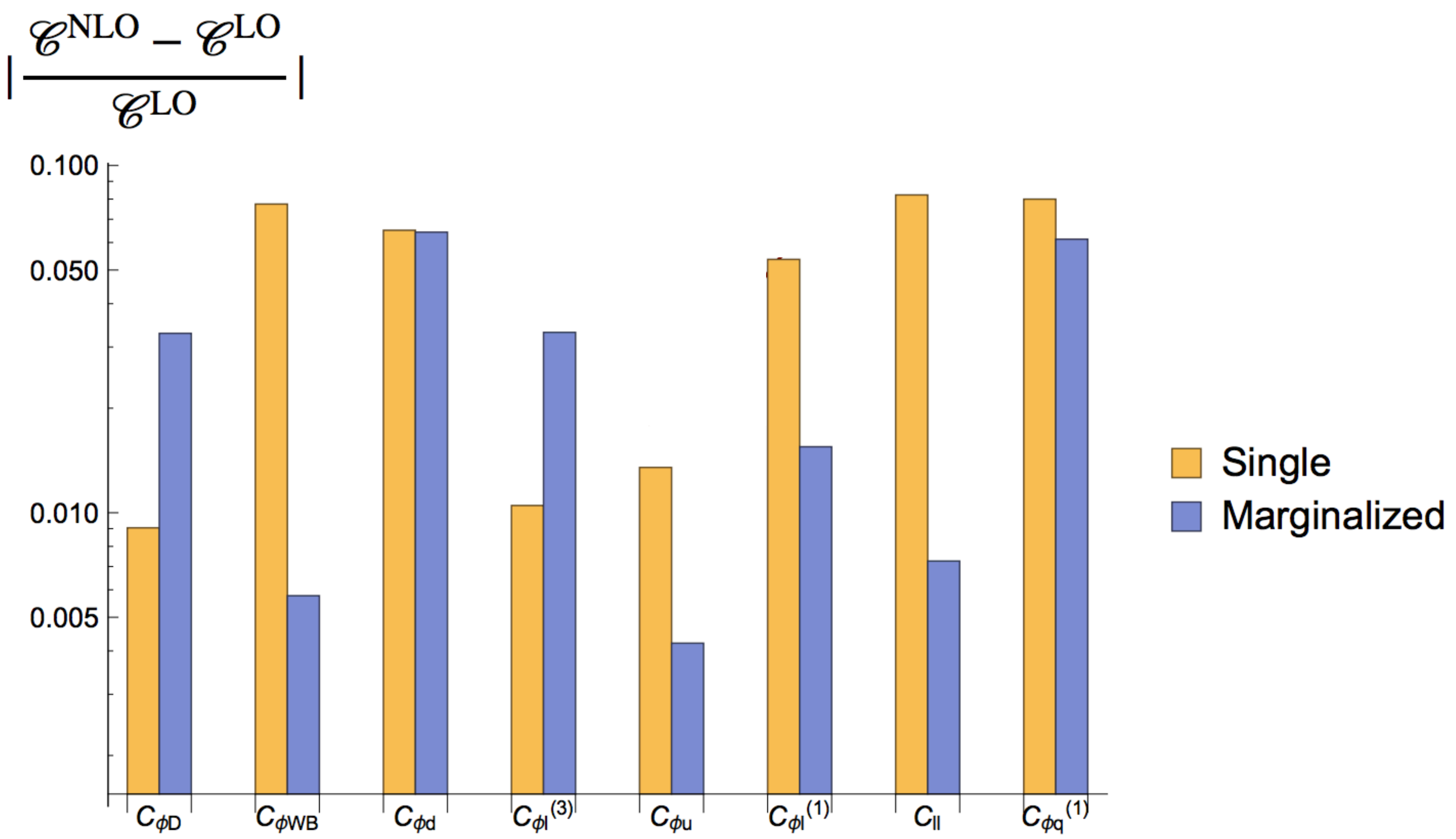
Example 2: EWPO

Impact of NLO corrections on W, Z pole observables:

LEP



ILC GigaZ [arXiv:1908.11299]



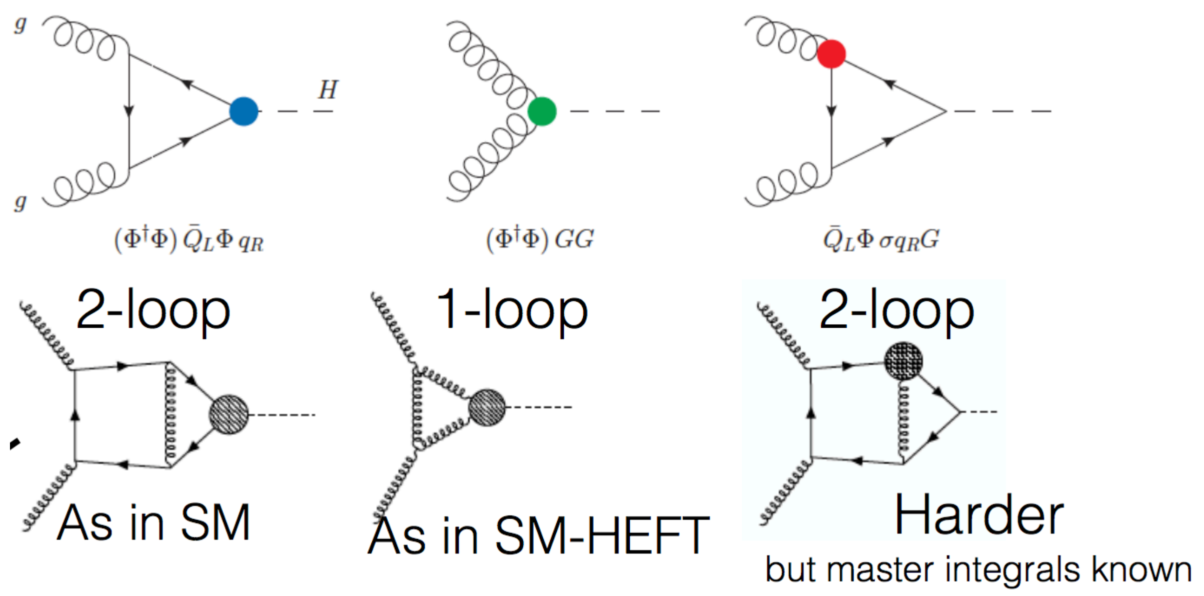
Dawson and Giardino arXiv:1909.02000 & Giardino@HEFT2020

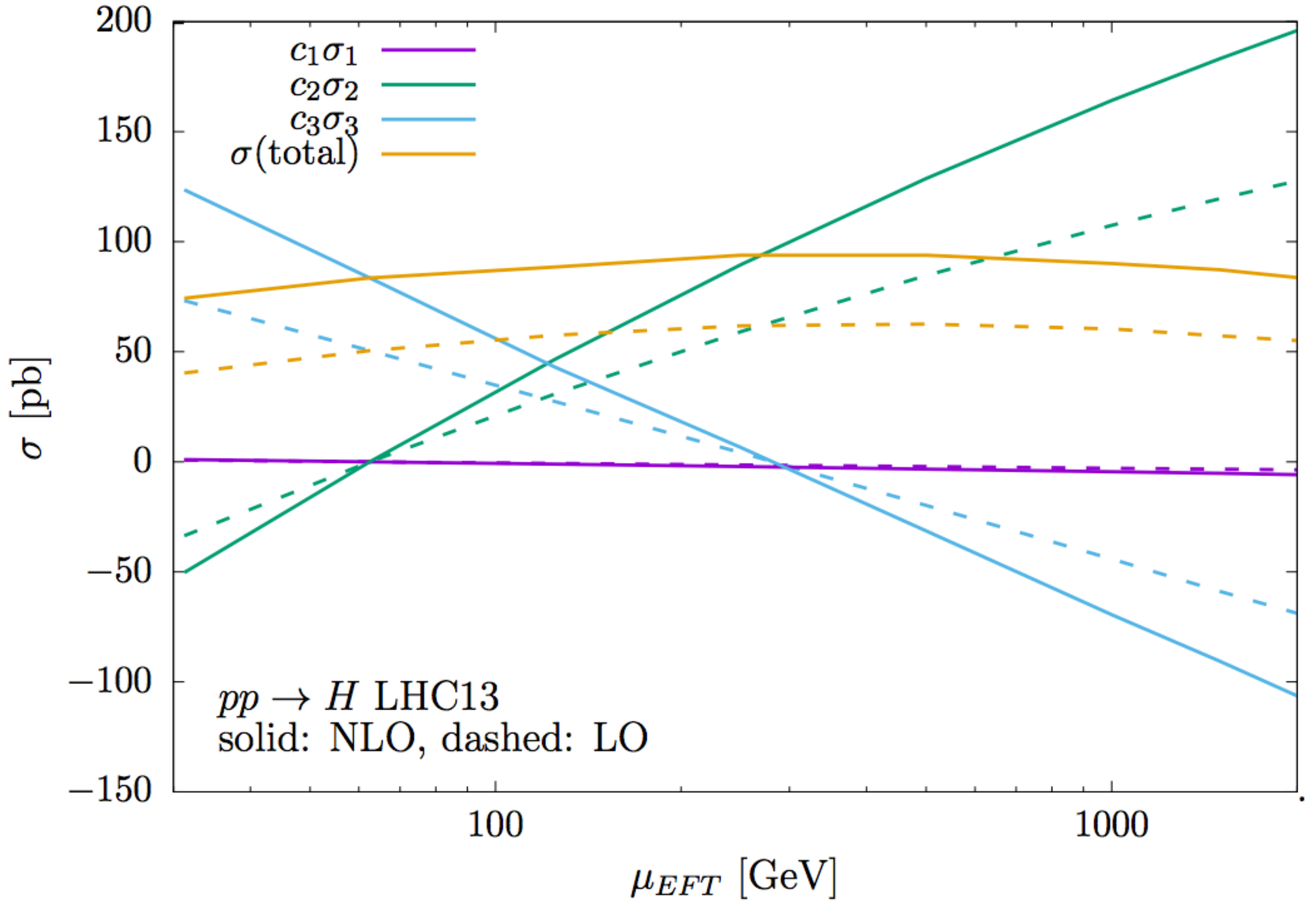
Even EW corrections lead to ~20% difference

Accuracy and precision

Reduction of scale uncertainty

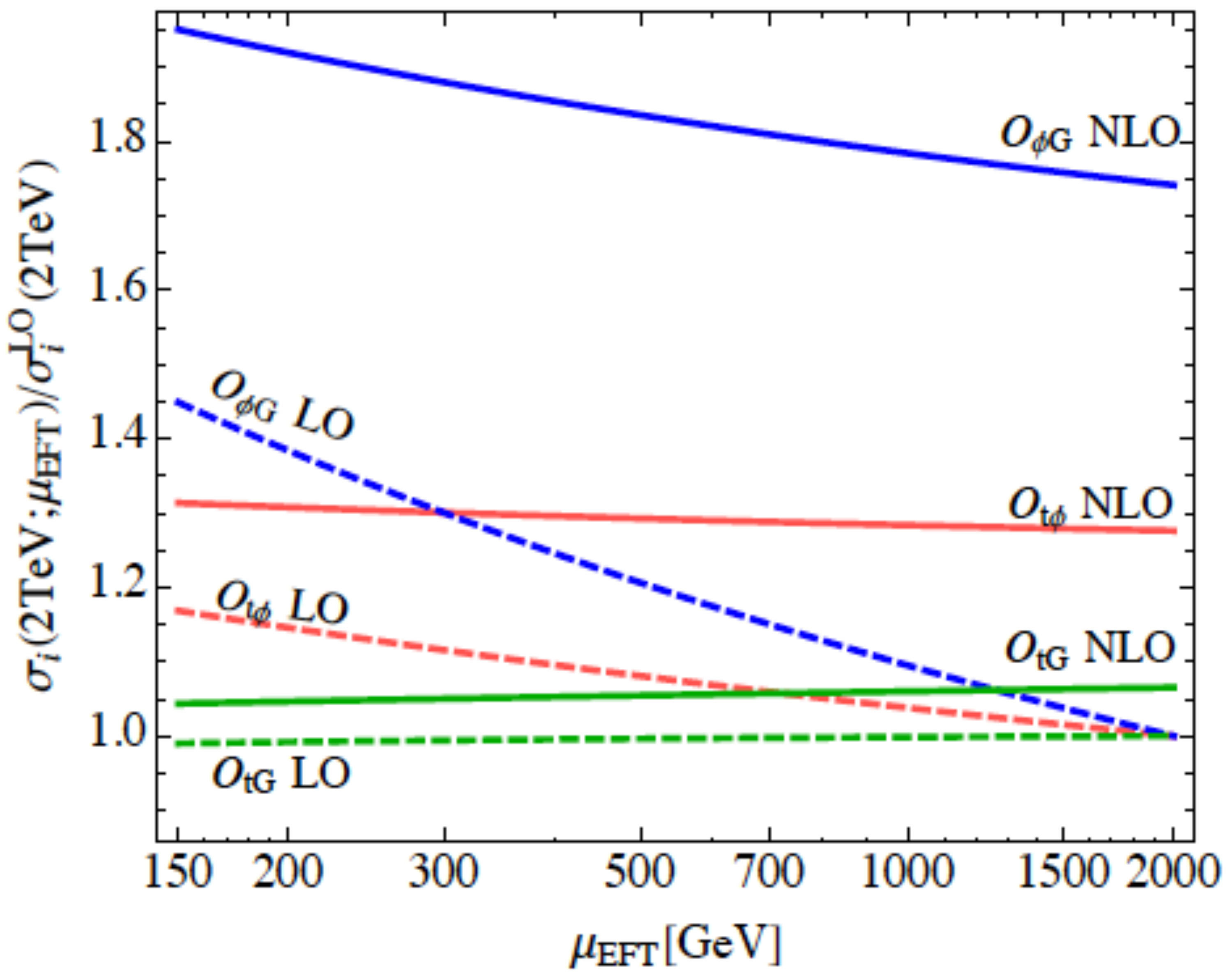
ggH





Deutschmann, Duhr, Maltoni, EV arXiv:1708.00460

ttH



RG corrections not a good approximation to the NLO result, underestimate the NLO corrections

Milder EFT scale dependence at NLO, when mixing effects also taken into account

Comparison of exact NLO with LO improved by 1-loop RG running

Maltoni, EV, Zhang arXiv:1607.05330

Improved sensitivity

New operators opening up at NLO

4-heavy operators in top pair production

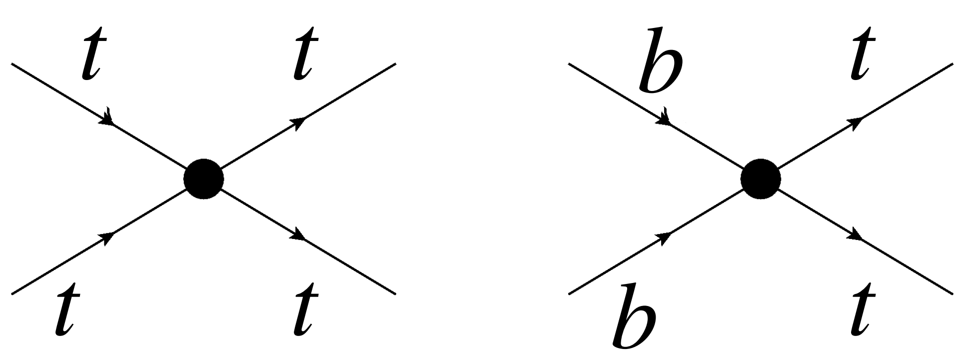
$$\mathcal{O}^8_{QQ} = (\bar{Q}\gamma^\mu T^A Q)(\bar{Q}\gamma_\mu T^A Q)$$

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

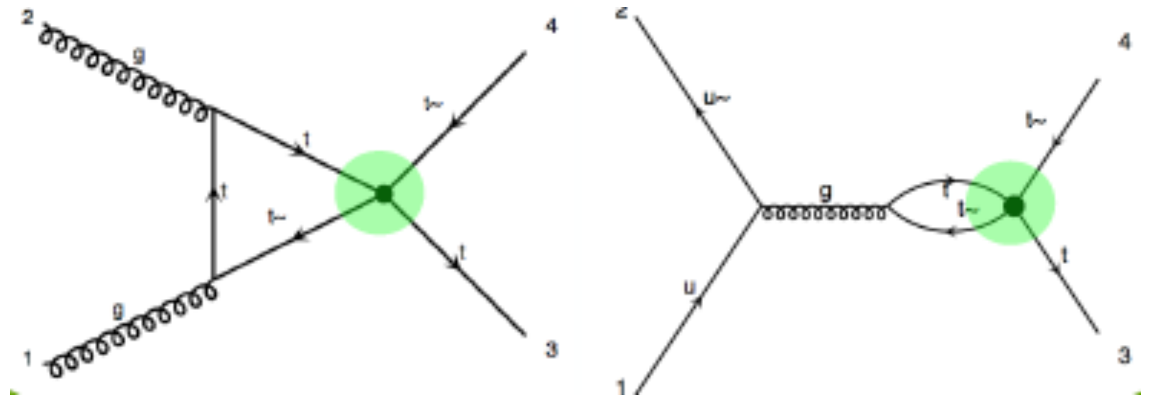
$$\mathcal{O}^8_{Qt} = (\bar{Q}\gamma^\mu T^A Q)(\bar{t}\gamma_\mu T^A t)$$

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

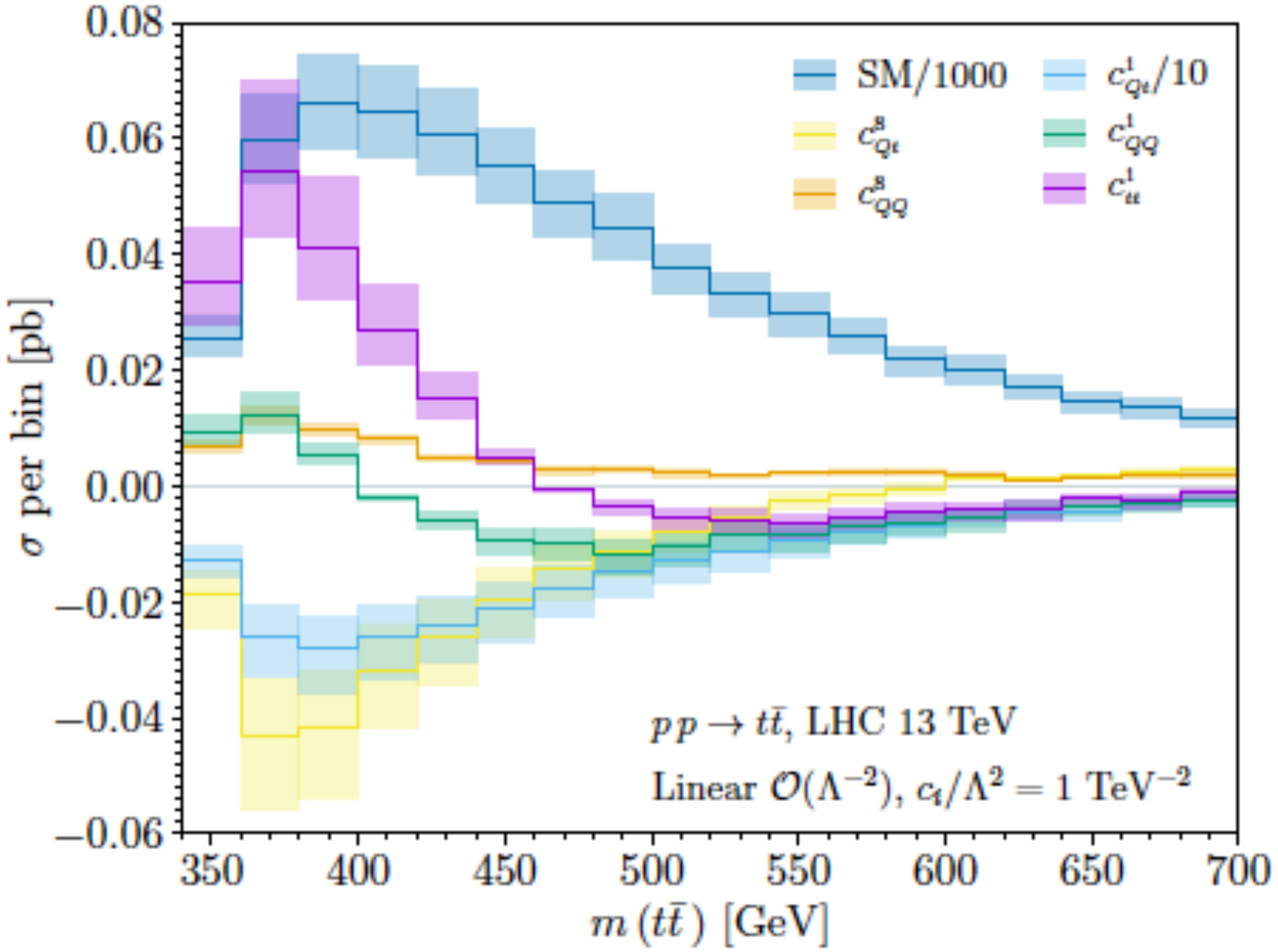
$$\mathcal{O}^1_{tt} = (\bar{t}\gamma^\mu t)(\bar{t}\gamma_\mu t)$$



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}	$\times$	$0.215^{+23\%}_{-18\%}$		$\times$	$\times$

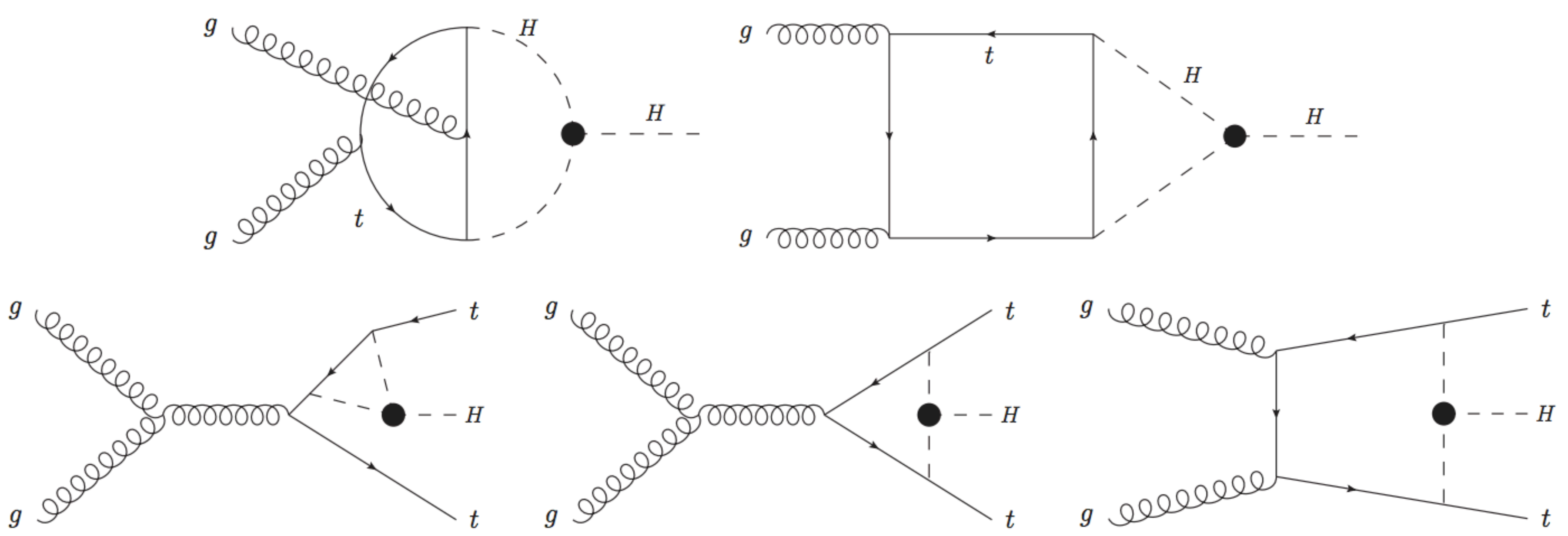


Complimentary information to ttbb and 4top production

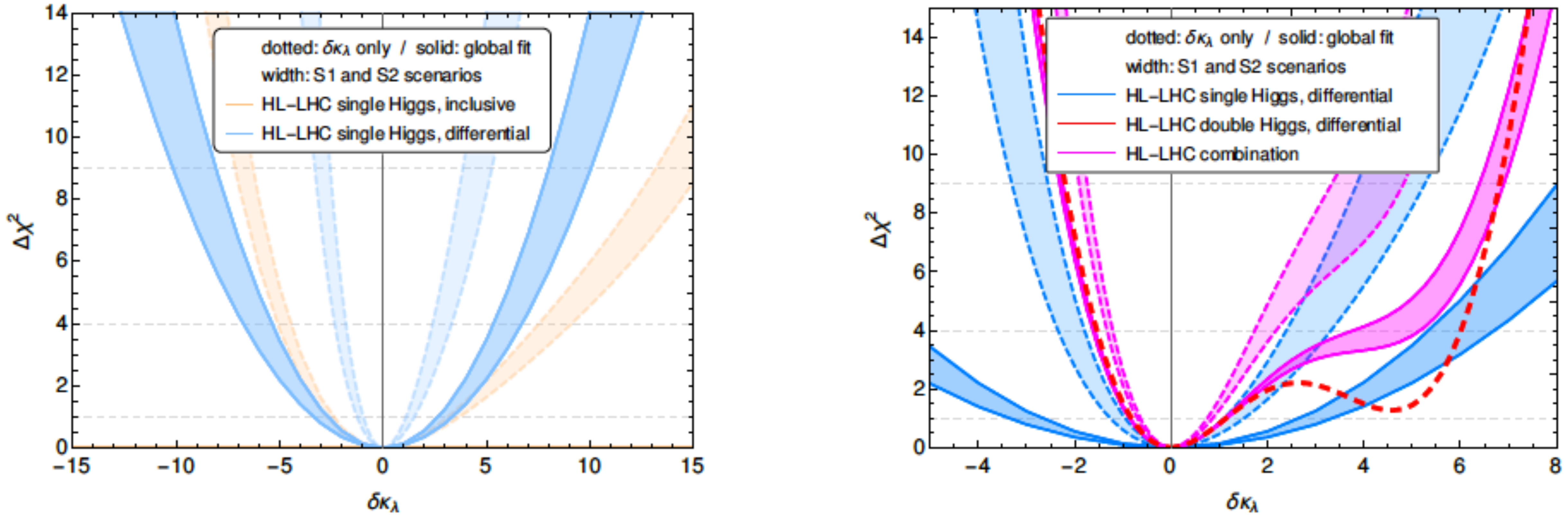
Loop-induced sensitivity (1)

Trilinear H coupling

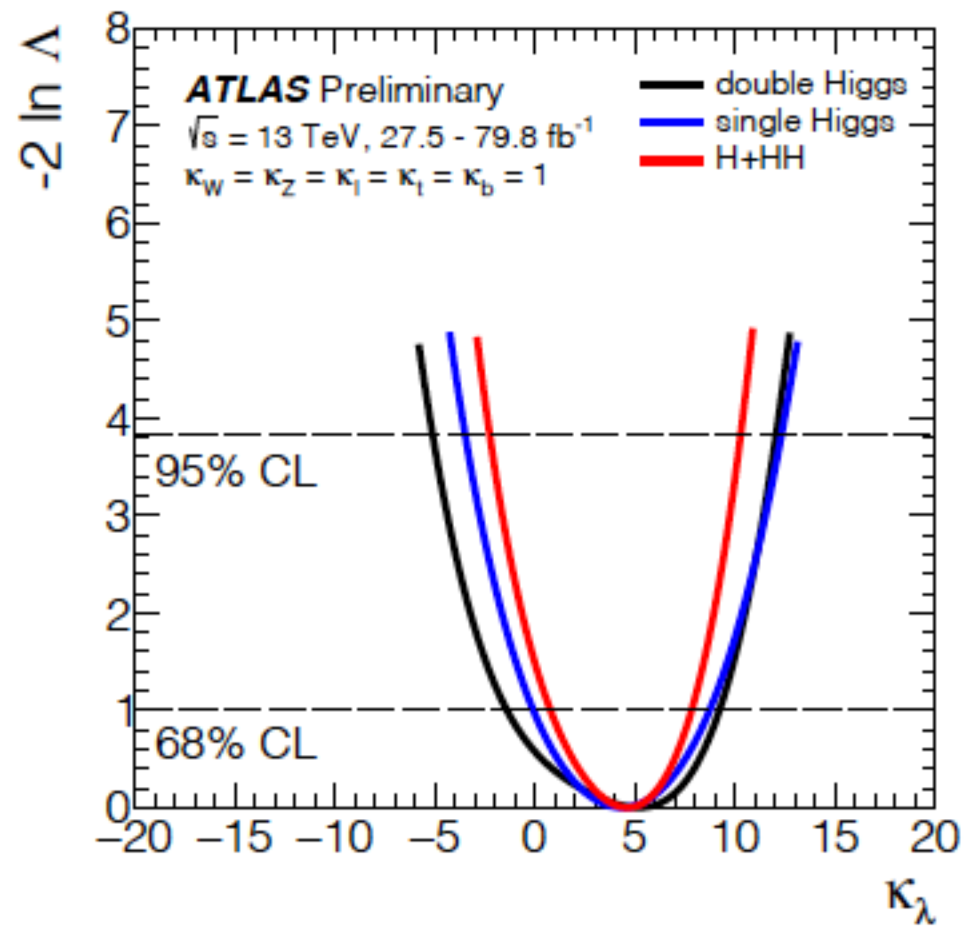
- Sensitivity through 1-loop EW corrections to single Higgs production.
- A new opportunity to extract information, beyond the typical probe of HH production.



Degrassi et al. arXiv:1607.04251, Gorbahn, Haisch 1607.03773, Bizon et al 1610.05771, Maltoni et al 1709.08649



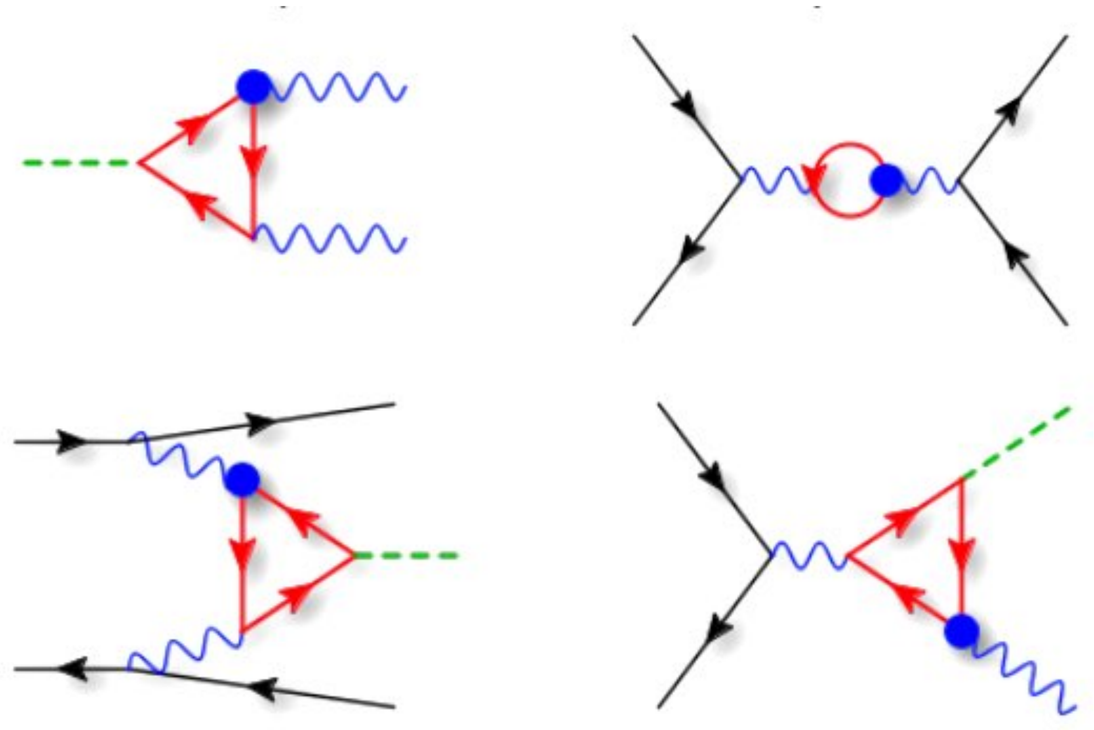
Di Vita et al. arXiv:1704.01953 and HH white paper



ATLAS-CONF-2019-049

Loop-induced sensitivity (2)

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*
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

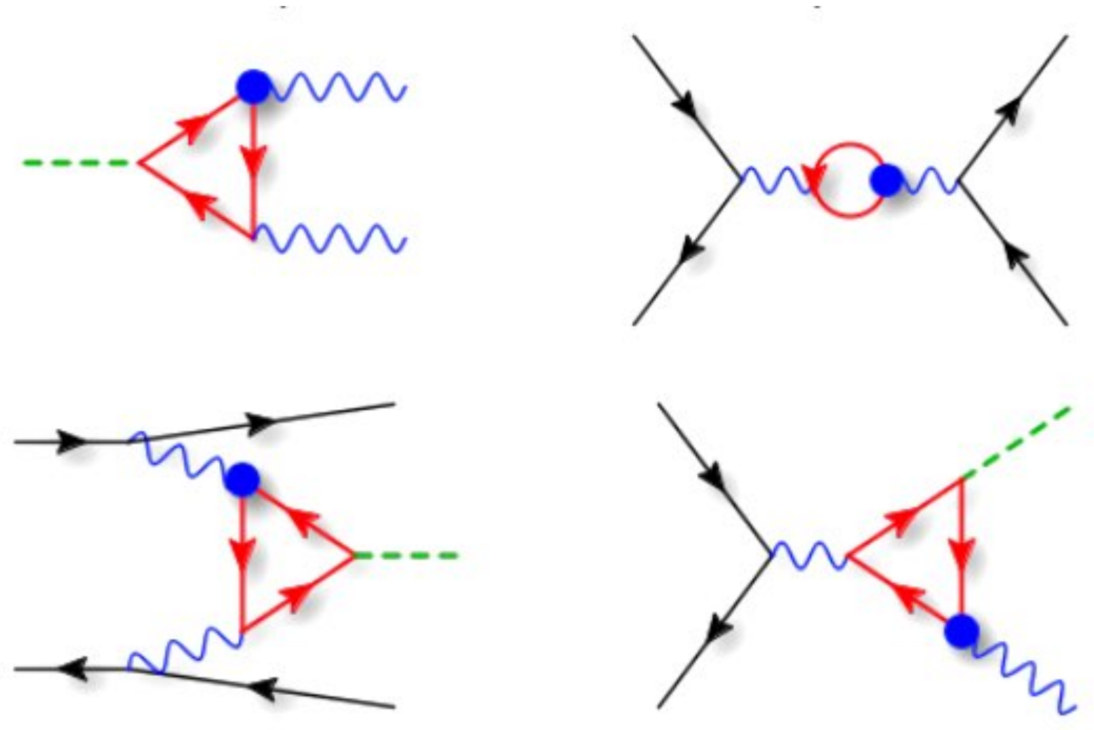
tree-level

EV, Zhang arXiv:1804.09766

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

Loop-induced sensitivity (2)

Top operators in Higgs observables



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

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

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loop-induced

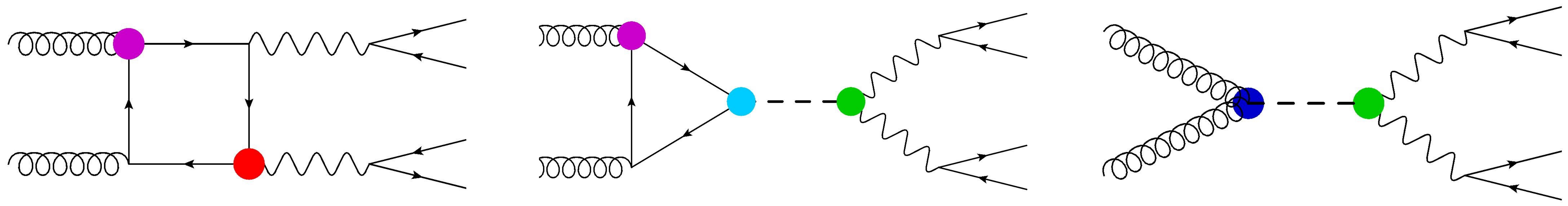
tree-level

EV, Zhang arXiv:1804.09766

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

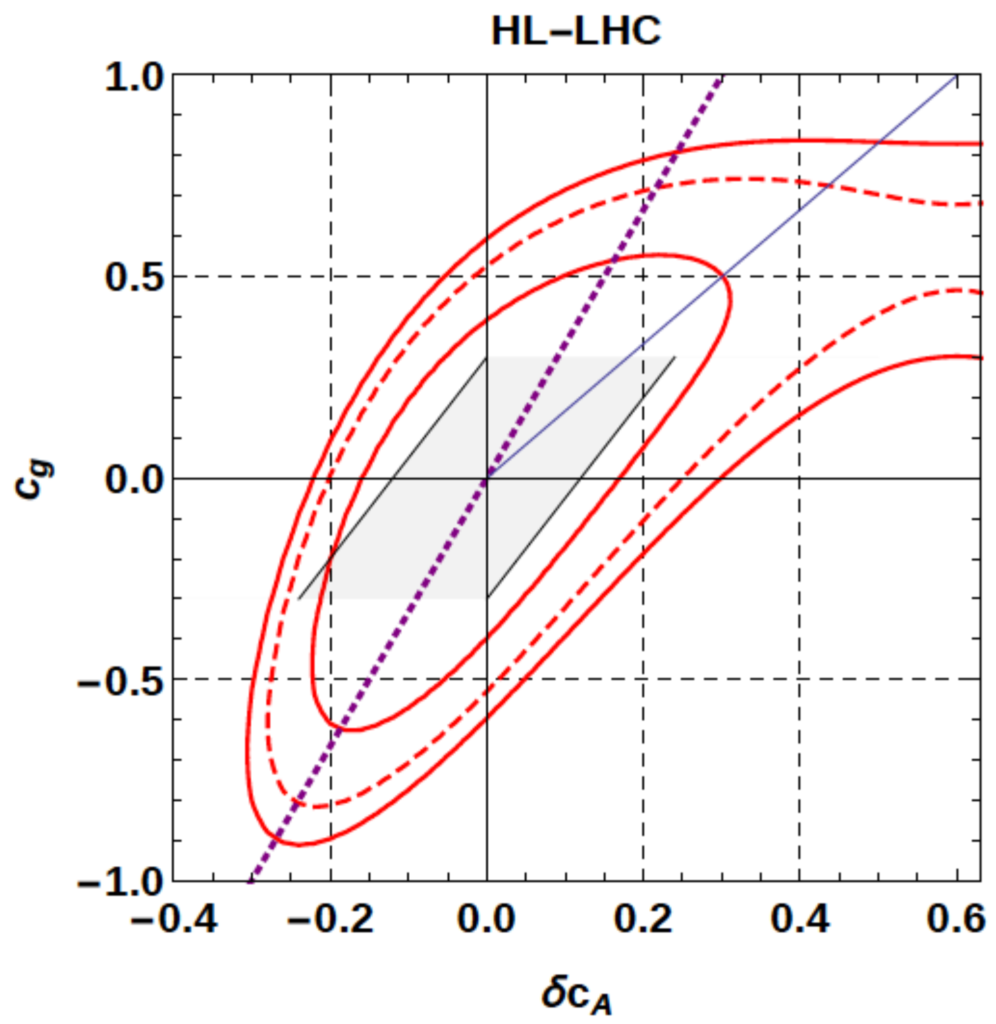
More loop-induced sensitivities

Diboson (off-shell Higgs) sensitivity to top couplings



Azatov, Grojean, Paul, Salvioni arXiv:1608.00977

See also: Englert, Soreq, Spannowsky arXiv:1410.5440 and Cao et al 2004.02031



Azatov, Grojean, Paul, Salvioni arXiv:1608.00977

4-parameter fit:

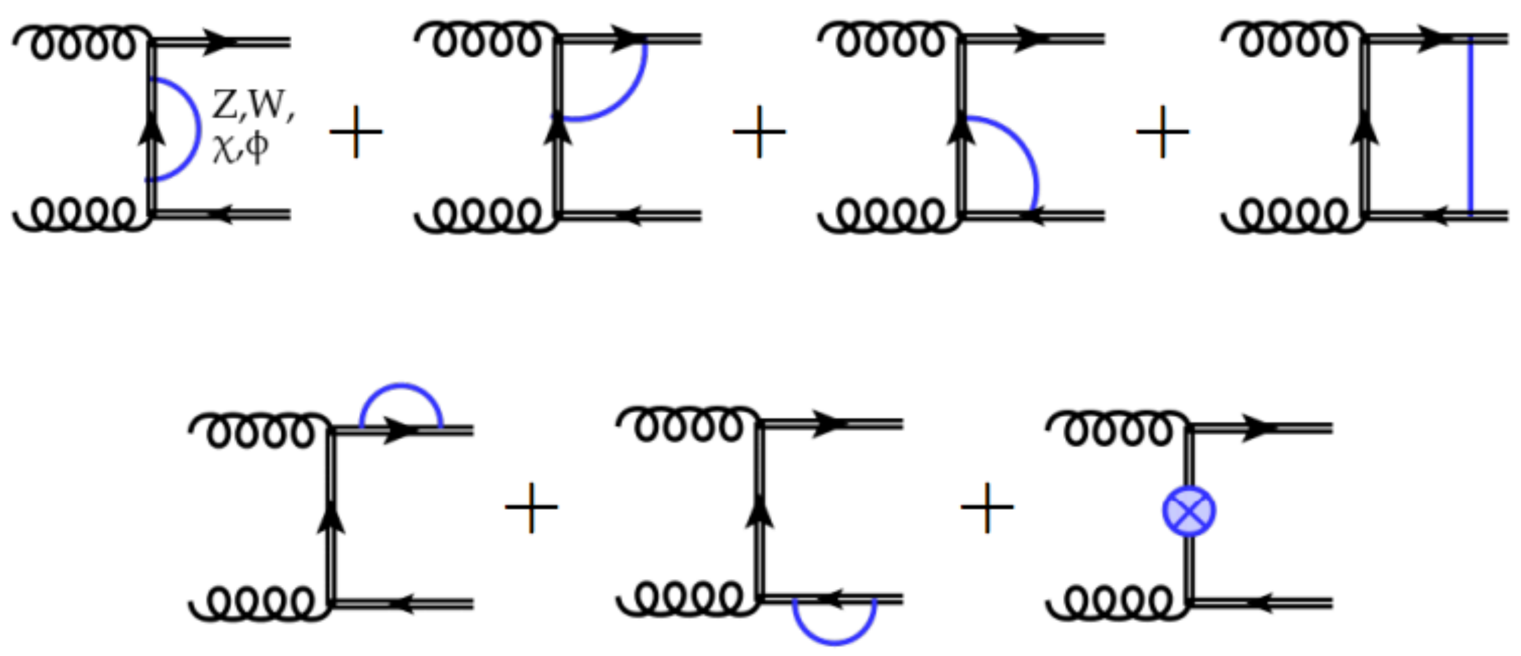
c_t, c_g, c_V, c_A

Constraint from gg to ZH
Englert et al arXiv:1603.05304

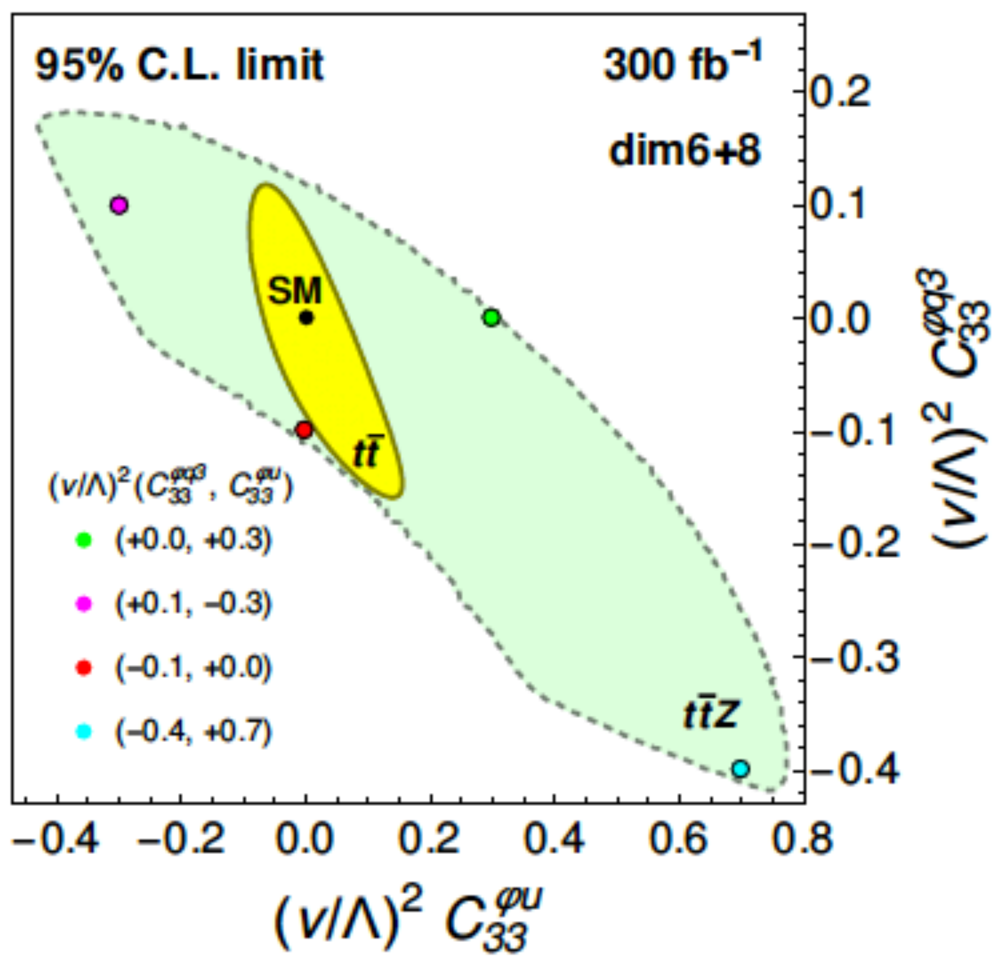
Constraints on ttZ couplings competitive with ttZ process

Top pair production sensitivity to EW top couplings

EW corrections:



Martini and Schulze arXiv:1911.11244



Higher orders 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.

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

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What can the code do?

Example processes

Multi-boson production

quark-initiated

```
> p p > W+ W-     QED=2 QCD=0 NP=2 [QCD]
> p p > W+ Z      QED=2 QCD=0 NP=2 [QCD]
> p p > Z  Z      QED=2 QCD=0 NP=2 [QCD]
```

loop-induced

```
> g g > W+ W-     QED=2 QCD=2 NP=2 [QCD]
> g g > Z  Z      QED=2 QCD=2 NP=2 [QCD]
> g g > W+ W- Z   QED=3 QCD=2 NP=2 [QCD]
> g g > Z  Z  Z   QED=3 QCD=2 NP=2 [QCD]
```

loop-induced

```
> g g > H         QED=1 QCD=2 NP=2 [QCD]
> g g > H H       QED=2 QCD=2 NP=2 [QCD]
> g g > H H H     QED=3 QCD=2 NP=2 [QCD]
> g g > H j       QED=1 QCD=3 NP=2 [QCD]
```

Top quark production

```
> e+ e- > t t~            QED=2 QCD=0 NP=2 [QCD]
> p p > t t~              QED=0 QCD=2 NP=2 [QCD]
> p p > t t~ h            QED=1 QCD=2 NP=2 [QCD]
> p p > t t~ Z            QED=1 QCD=2 NP=2 [QCD]
> p p > t t~ W+           QED=1 QCD=2 NP=2 [QCD]
> p p > t W-      $$ t~   QED=1 QCD=1 NP=2 [QCD]
> p p > t W- j    $$ t~   QED=1 QCD=2 NP=2 [QCD]
> p p > t j       $$ W-   QED=2 QCD=0 NP=2 [QCD]
> p p > t h j     $$ W-   QED=3 QCD=0 NP=2 [QCD]
> p p > t Z j     $$ W-   QED=3 QCD=0 NP=2 [QCD]
> p p > t a j     $$ W-   QED=3 QCD=0 NP=2 [QCD]
```

What's in the box?

Warsaw basis operators

Flavour assumption:

$U(2)_q \times U(2)_u \times U(3)_d \times (U(1)_l \times U(1)_e)^3$

Includes Higgs, top, gauge boson interactions

Conventions matching dim6top (LHC Top WG)

CP & Flavour conserving

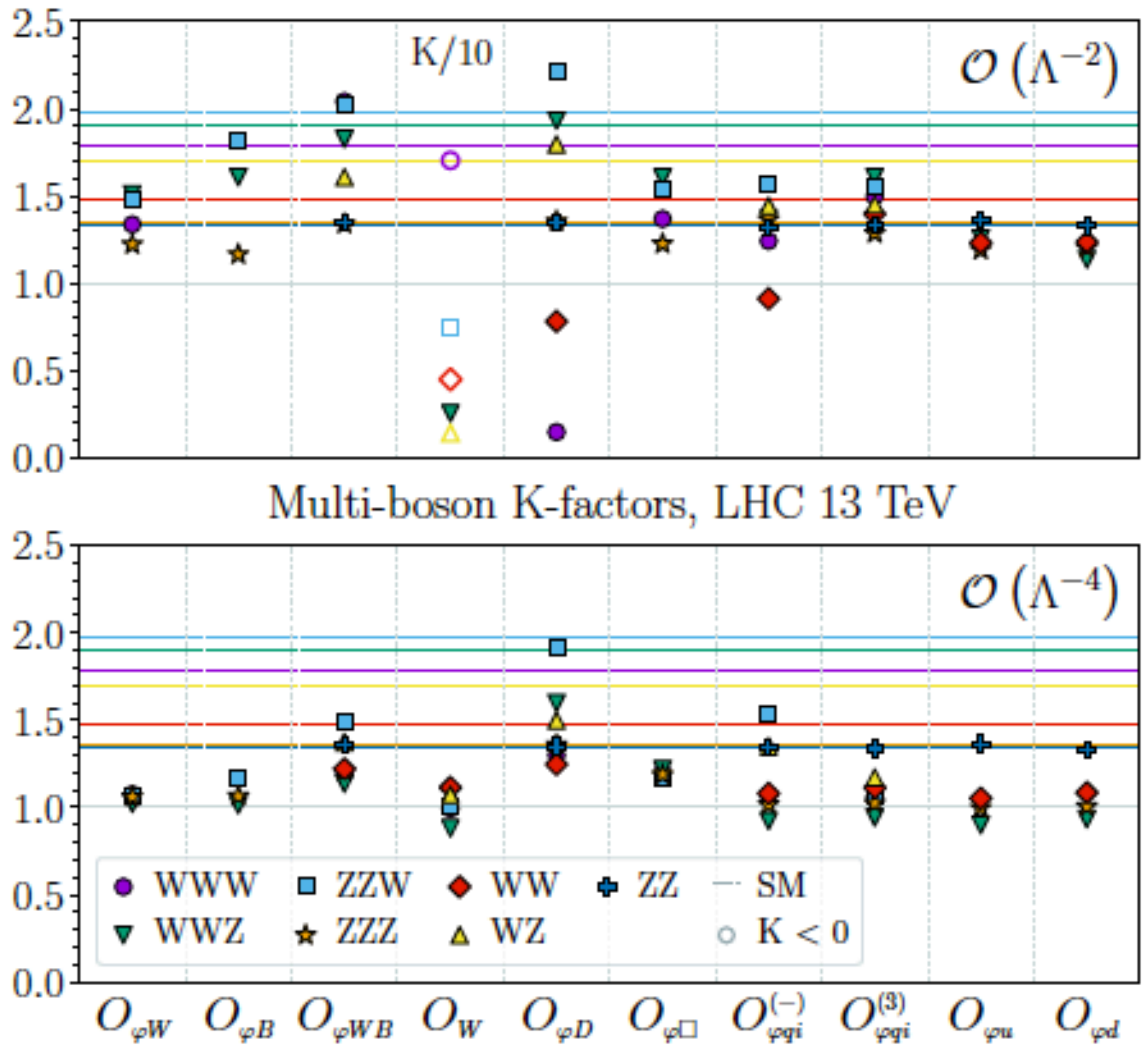
→ Including 4-fermion operators ★

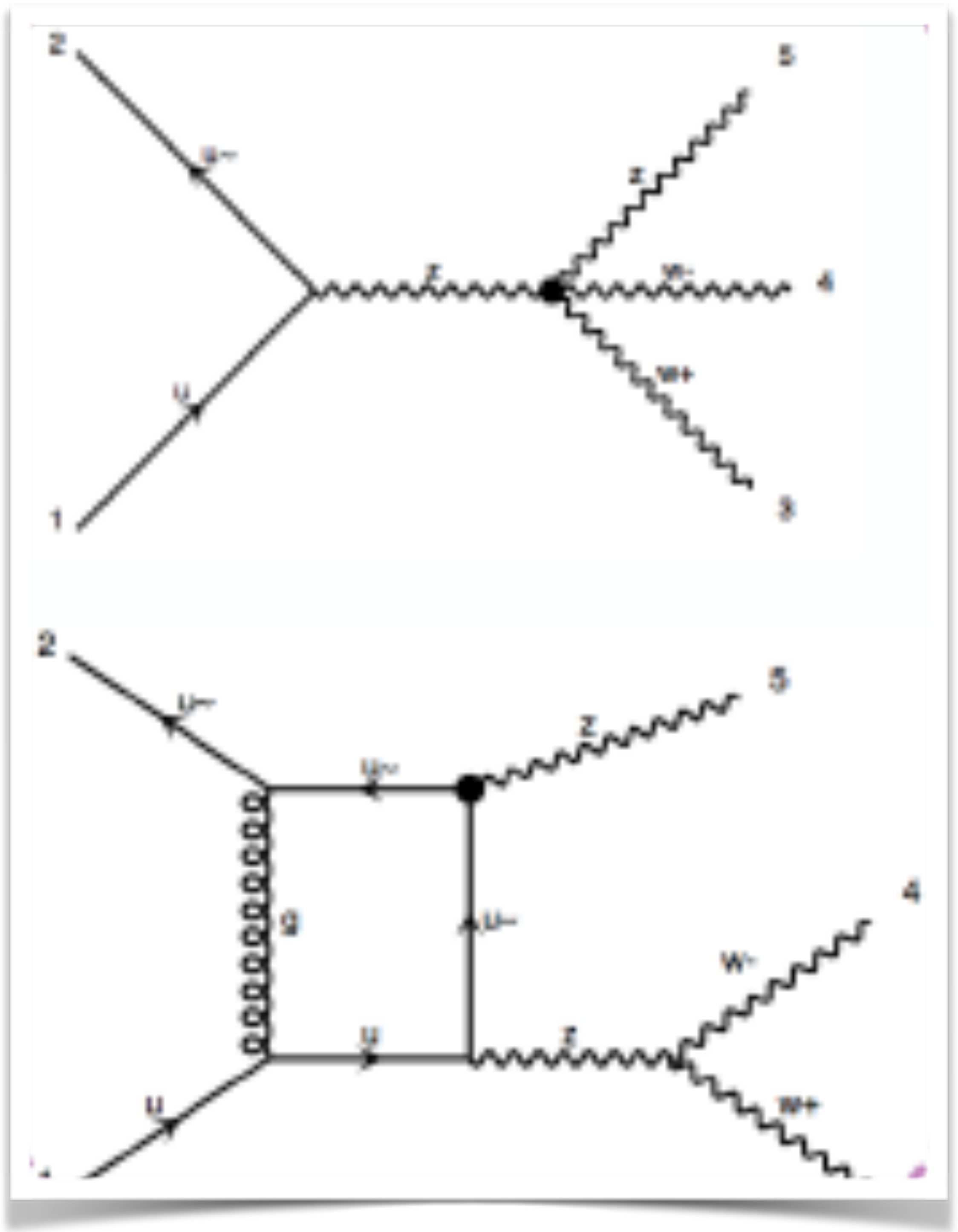
And many more on the website…

Applications at NLO

Examples: Triboson production

NEW



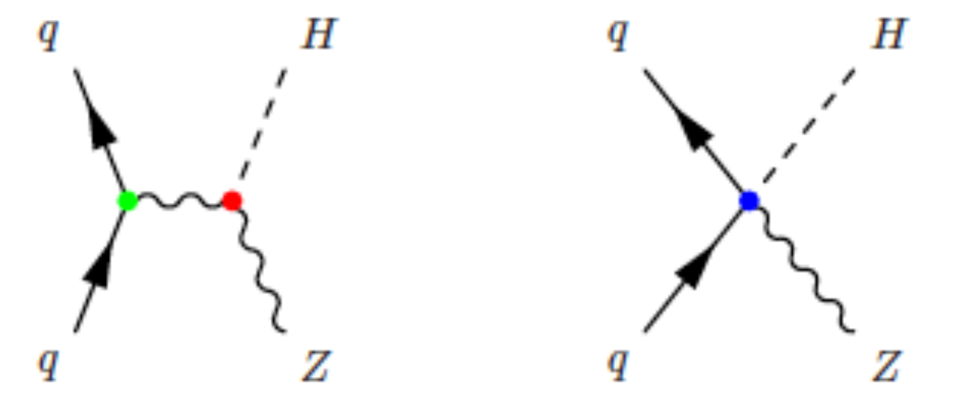


First computation of VVV@NLO in the SMEFT

c.f. first observation by CMS: arXiv:2006.11191

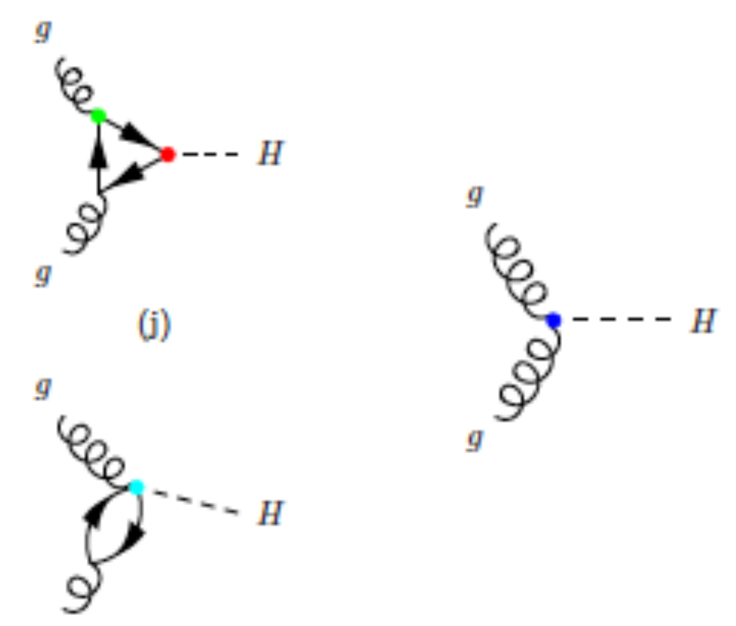
Loop & tree sensitivity

ZH



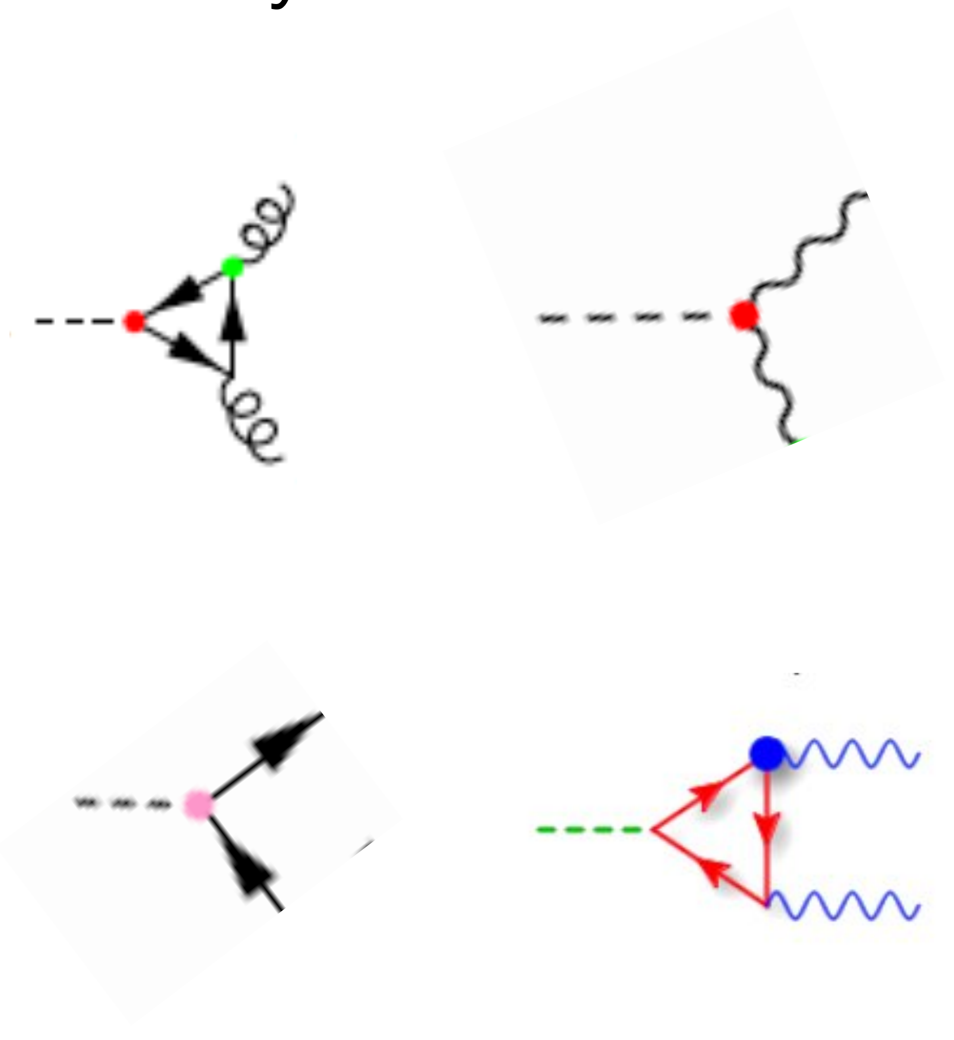
$\mathcal{O}_{\varphi W}$, $\mathcal{O}_{\varphi B}$, $\mathcal{O}_{\varphi D}$, $\mathcal{O}^{(3)}_{\varphi q_i}$, $\mathcal{O}^{(1)}_{\varphi q_i}$, $\mathcal{O}^{(1)}_{\varphi Q}$, $\mathcal{O}^{(3)}_{\varphi Q}$, $\mathcal{O}_{\varphi d}$, $\mathcal{O}_{\varphi WB}$, $\mathcal{O}^{(3)}_{\varphi l_1}$,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

ggH



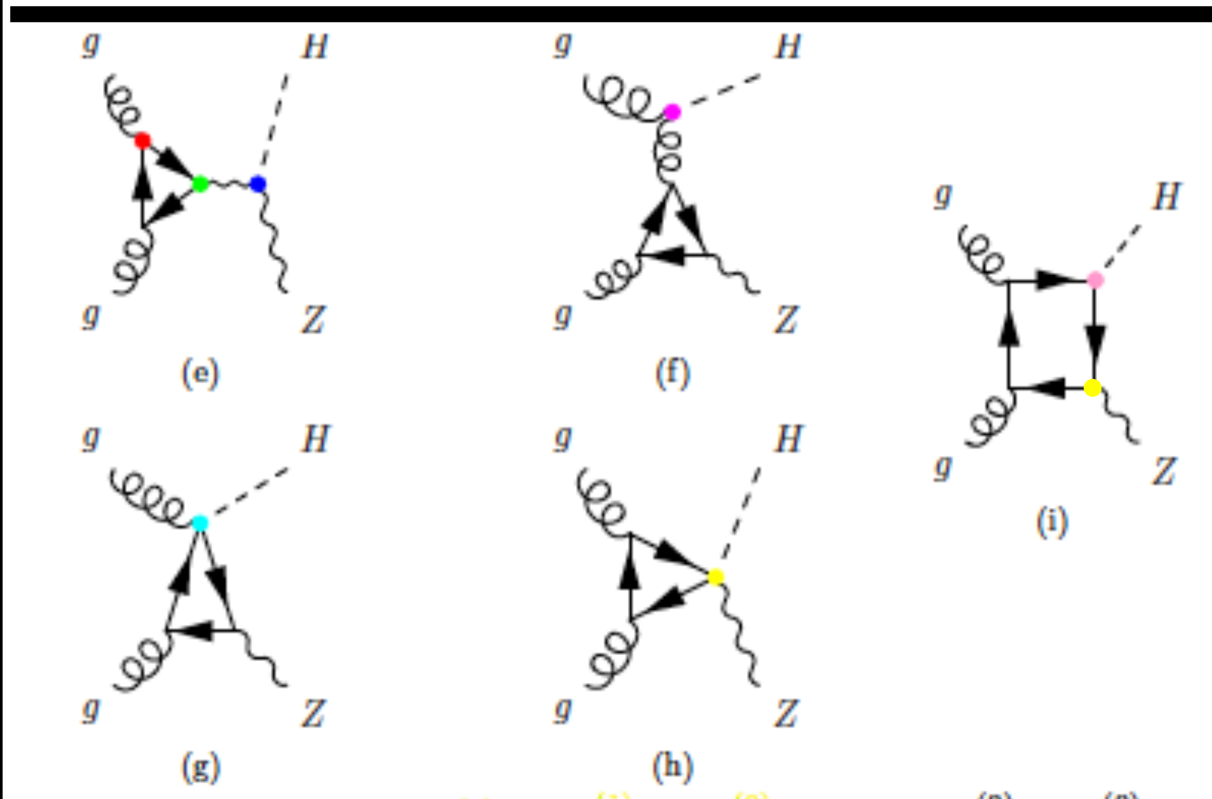
$\mathcal{O}_{\varphi D}$, $\mathcal{O}_{\varphi d}$, $\mathcal{O}^{(3)}_{\varphi l_1}$, $\mathcal{O}^{(3)}_{\varphi l_2}$, $\mathcal{O}_{t\varphi}$, $\mathcal{O}_{tG}$, $\mathcal{O}_{\varphi G}$, $\mathcal{O}_{ll}$

H decays



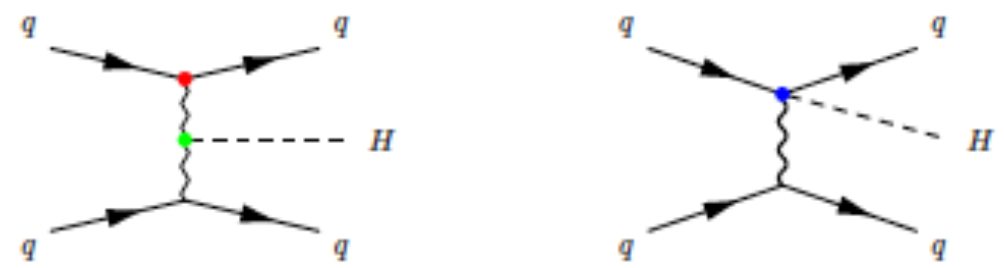
$\mathcal{O}_{\varphi D}, \mathcal{O}^{(1)}_{\varphi q_i}, \mathcal{O}^{(1)}_{\varphi Q}, \mathcal{O}^{(3)}_{\varphi Q}, \mathcal{O}_{\phi d} \cdots$

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

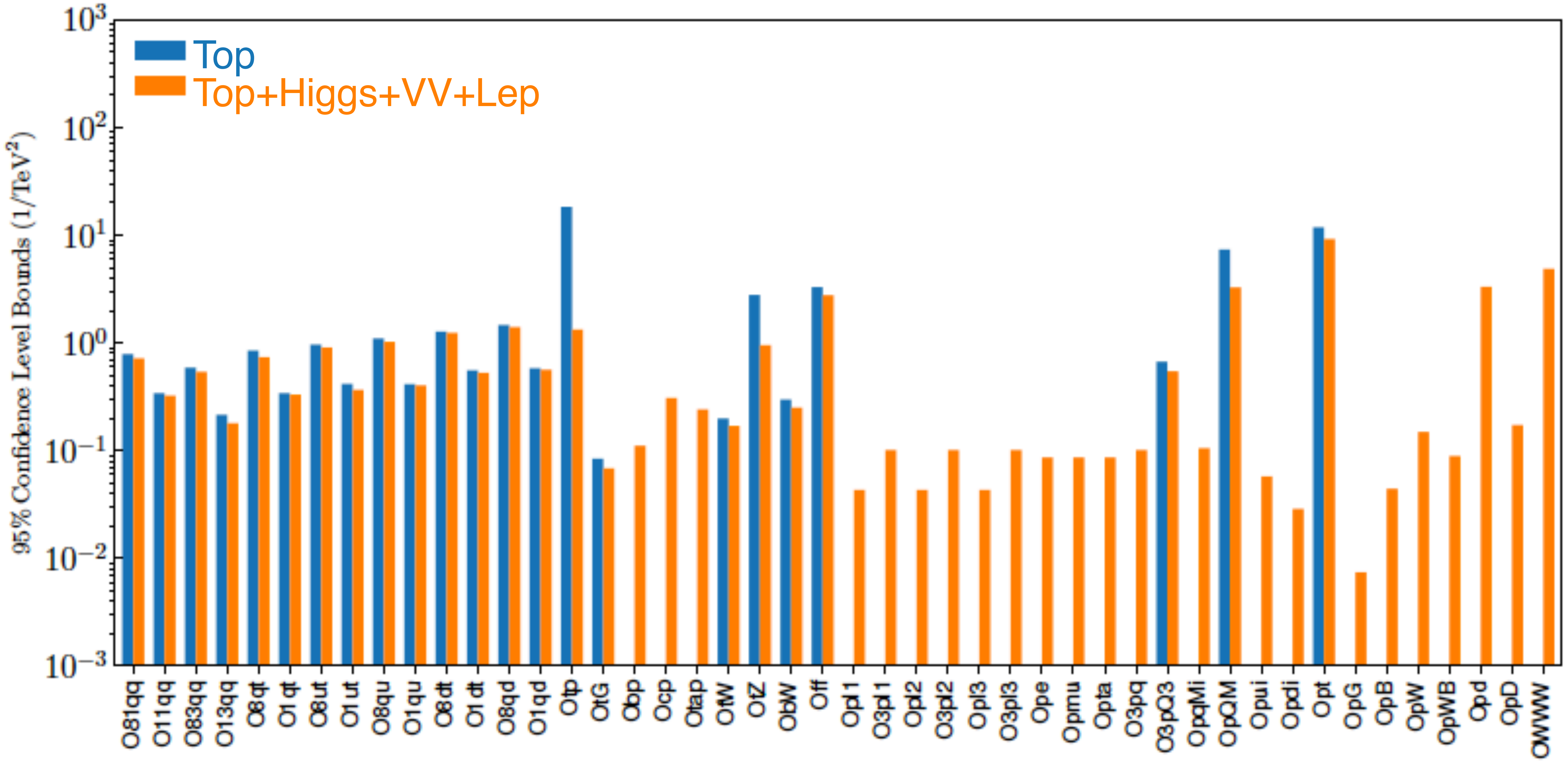
Towards a global Higgs-top fit

PRELIMINARY

Added Higgs data

Run I & 2 signal strengths (CMS+ATLAS):
* gluon fusion
* VH
* VBF
* ttH
* H decays

Differential distributions & STXS



New operators

Ethier, Maltoni, Mantani, Nocera, Rojo, EV and Zhang in preparation

Towards a global Higgs-top fit

		Processes							
Class	Coefficient	tt	ttV	t	tV	Hrun1	Hrun2	Hdiff	VV
2L2H	O81qq	81.7(96.0)	16.4(2.4)	×(×)	×(×)	0.1(-0.0)	1.7(0.8)	0.1(0.7)	×(×)
	O11qq	100.0(98.8)	0.0(0.5)	×(×)	×(×)	×(0.0)	0.0(0.6)	×(0.2)	×(×)
	O83qq	48.3(46.2)	25.9(50.6)	23.9(2.6)	0.0(0.3)	0.1(-0.0)	1.7(0.2)	0.1(0.1)	×(×)
	O13qq	0.4(13.8)	0.0(1.2)	96.5(82.7)	3.1(2.1)	×(-0.1)	0.0(0.1)	×(0.2)	×(×)
	O8qt	56.1(47.0)	38.9(31.4)	×(×)	×(×)	0.3(0.2)	4.5(12.2)	0.2(9.2)	×(×)
	O1qt	100.0(94.6)	0.0(3.3)	×(×)	×(×)	×(0.0)	0.0(1.7)	×(0.4)	×(×)
	O8ut	97.7(97.9)	0.4(0.3)	×(×)	×(×)	0.1(0.0)	1.7(0.8)	0.1(0.9)	×(×)
	O1ut	100.0(98.3)	0.0(0.3)	×(×)	×(×)	×(0.0)	0.0(1.1)	×(0.3)	×(×)
	O8qu	88.8(80.1)	3.6(5.2)	×(×)	×(×)	0.4(0.1)	6.8(8.3)	0.4(6.2)	×(×)
	O1qu	100.0(97.9)	0.0(0.7)	×(×)	×(×)	×(0.0)	0.0(1.1)	×(0.3)	×(×)
	O8dt	95.0(97.9)	1.4(0.7)	×(×)	×(×)	0.2(0.0)	3.3(0.9)	0.2(0.5)	×(×)
	O1dt	100.0(98.9)	0.0(0.2)	×(×)	×(×)	×(0.0)	0.0(0.7)	×(0.2)	×(×)
	O8qd	94.3(69.0)	2.6(9.5)	×(×)	×(×)	0.1(0.3)	2.8(12.6)	0.1(8.6)	×(×)
	O1qd	100.0(97.6)	0.0(1.0)	×(×)	×(×)	×(0.0)	0.0(1.2)	×(0.2)	×(×)
2FB	Otp	×(×)	×(×)	×(×)	×(×)	13.7(18.6)	46.2(67.9)	40.1(13.4)	×(×)
	OtG	61.1(23.2)	0.2(0.1)	×(×)	×(×)	5.9(10.4)	17.5(29.5)	15.2(36.8)	×(×)
	Obp	×(×)	×(×)	×(×)	×(×)	26.6(26.8)	73.4(73.2)	×(×)	×(×)
	Ocp	×(×)	×(×)	×(×)	×(×)	26.8(26.3)	73.2(73.7)	×(×)	×(×)
	Otap	×(×)	×(×)	×(×)	×(×)	39.1(38.5)	60.9(61.5)	×(×)	×(×)
	OtW	9.1(0.4)	0.0(0.0)	0.4(0.0)	0.2(0.0)	18.9(20.8)	71.5(78.7)	×(×)	×(×)
	OtZ	×(×)	0.0(0.0)	×(×)	0.0(0.0)	21.0(21.0)	79.0(79.0)	×(×)	×(×)
	O3pQ3	×(0.0)	0.0(0.0)	80.0(4.7)	14.3(0.8)	1.2(18.2)	4.5(76.1)	0.0(0.1)	×(×)
	OpQM	×(×)	41.8(0.0)	×(×)	0.6(0.0)	11.9(20.0)	45.7(79.9)	0.0(0.0)	×(×)
	Opt	×(×)	64.5(0.0)	×(×)	0.2(0.0)	7.4(21.0)	27.9(79.0)	0.0(0.0)	×(×)
B	OpG	×(×)	×(×)	×(×)	×(×)	15.3(15.5)	42.9(42.3)	41.8(42.2)	×(×)
	OpB	×(×)	×(×)	×(×)	×(×)	21.0(21.0)	79.0(79.0)	0.0(0.0)	×(×)
	OpW	×(×)	×(×)	×(×)	×(×)	21.0(21.1)	78.9(78.9)	0.0(0.0)	×(×)
	Opd	×(×)	×(×)	×(×)	×(×)	25.4(27.4)	67.2(72.6)	7.4(0.0)	×(×)
	OWWW	×(×)	×(×)	×(×)	×(×)	×(×)	×(×)	×(×)	100.0(100.0)
	OpWB	×(×)	×(×)	×(×)	×(×)	21.1(21.1)	78.8(78.8)	0.1(0.1)	0.0(0.0)
	OpD	×(×)	×(×)	×(×)	×(×)	21.1(21.1)	78.8(78.8)	0.1(0.1)	0.0(0.0)

PRELIMINARY

4F mostly top

Top Yukawa

Top Chromomagnetic

ttV couplings
impacted by Higgs

Unique interplay
Lots to learn with more
measurements coming in

Ethier, Maltoni, Mantani, Nocera, Rojo, EV and Zhang in preparation

Conclusions

* Efforts towards EFT interpretations for the LHC are ongoing on both theory and experimental side.
* To allow combination of different analyses common conventions about bases, flavour assumptions etc are needed.
* Tools play an important role and their validation and comparison is crucial.
* Higher-order corrections in the EFT predictions can play a crucial role and including them as much as possible can improve our sensitivity.
* LHCEFTWG aims to address these topics through a series of meetings.

http://simba3.web.cern.ch/simba3/SelfSubscription.aspx?groupName=lhc-eftwg