Top, Higgs, Diboson and Electroweak Fit to the Standard Model Effective Field Theory

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LHC data as a probe of new physics

Experimental probes of physics beyond the Standard Model have been taken to a new level by the LHC:

- ATLAS & LHCb measurements of M_W *1701.07240, 2109.01113*
- STXS measurements of Higgs production and decays *e.g. ATLAS 1909.02845*
- Triple gauge coupling measurements in diboson *WW, WZ* production
- **Top quark production measurements**

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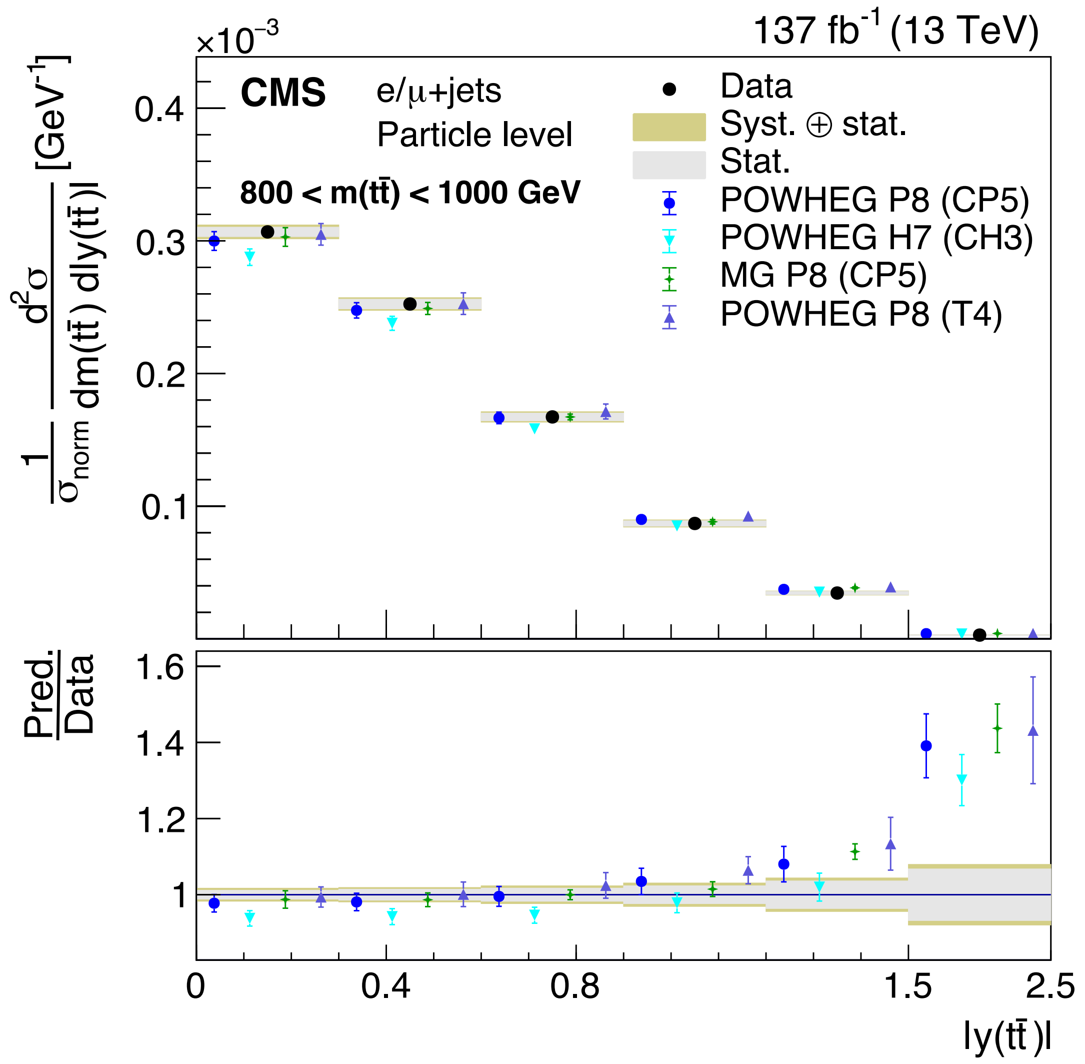
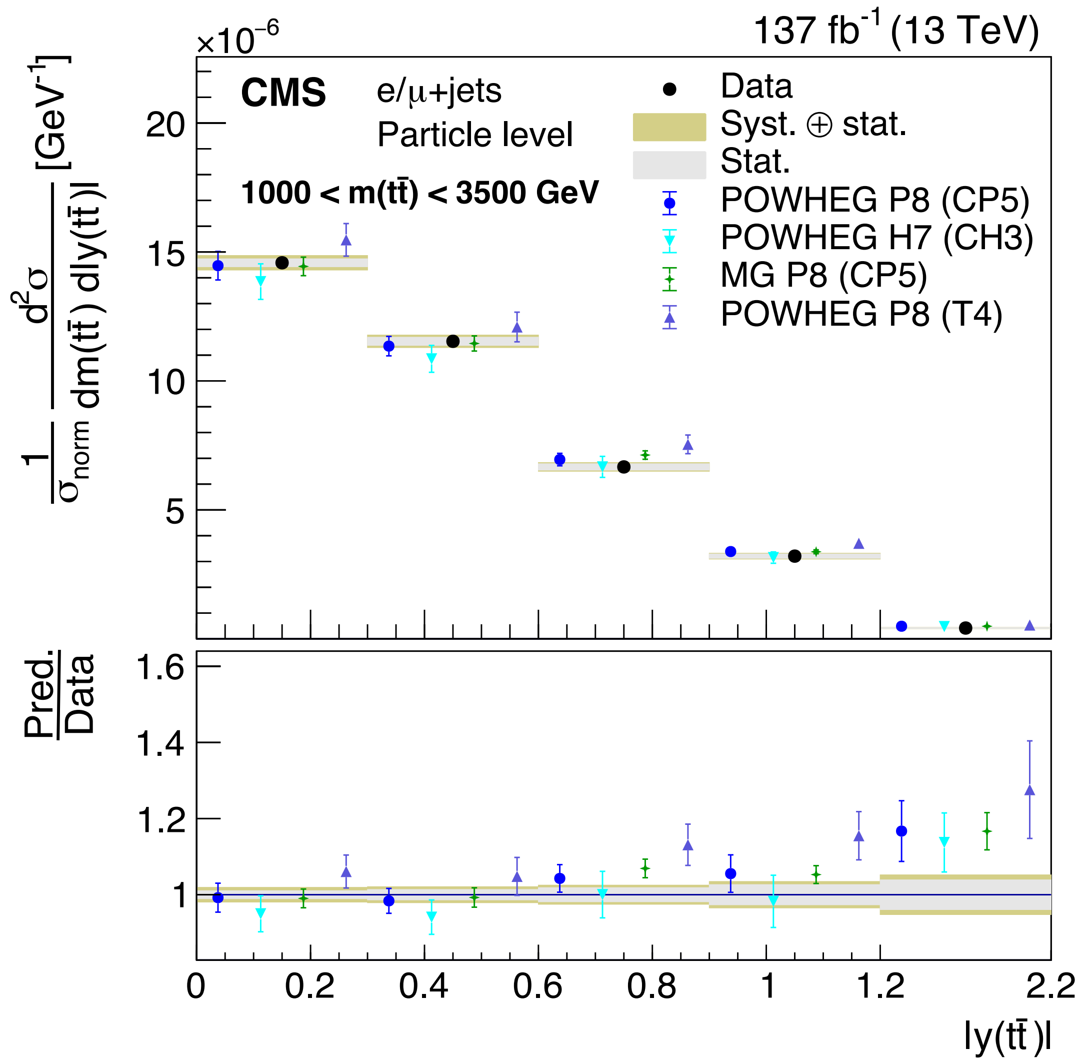
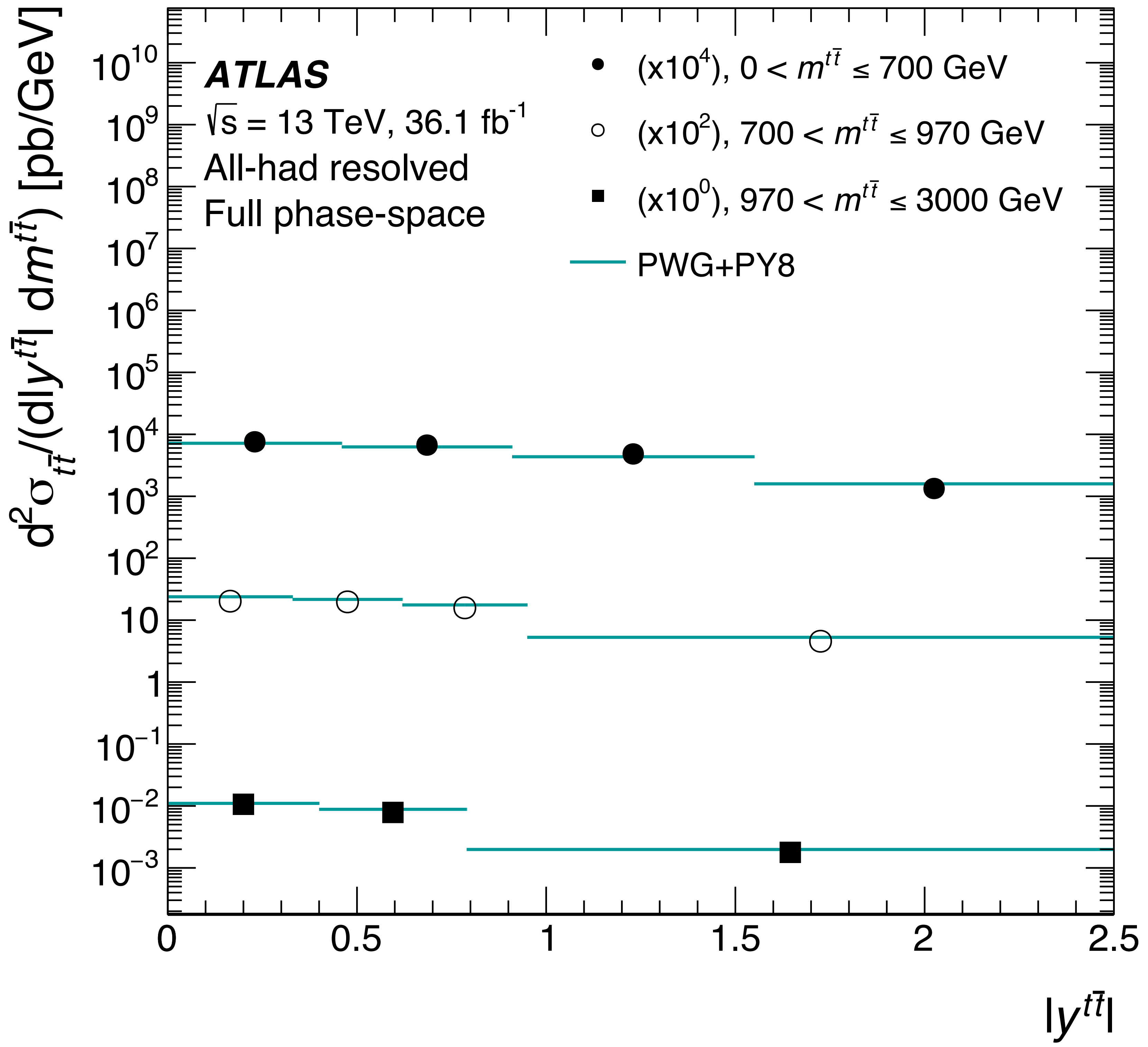
- **Top quark production measurements**

e.g. CMS measurement of top pair production in the *l+jets channel* binned in both $m_{t\bar{t}}$ and $|y_{t\bar{t}}|$ 2108.02803







e.g. ATLAS measurement of top pair production in the hadronic channel binned in both $m_{t\bar{t}}$ and $|y_{t\bar{t}}|$ 2006.09274

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These add to previous precision measurements, including:

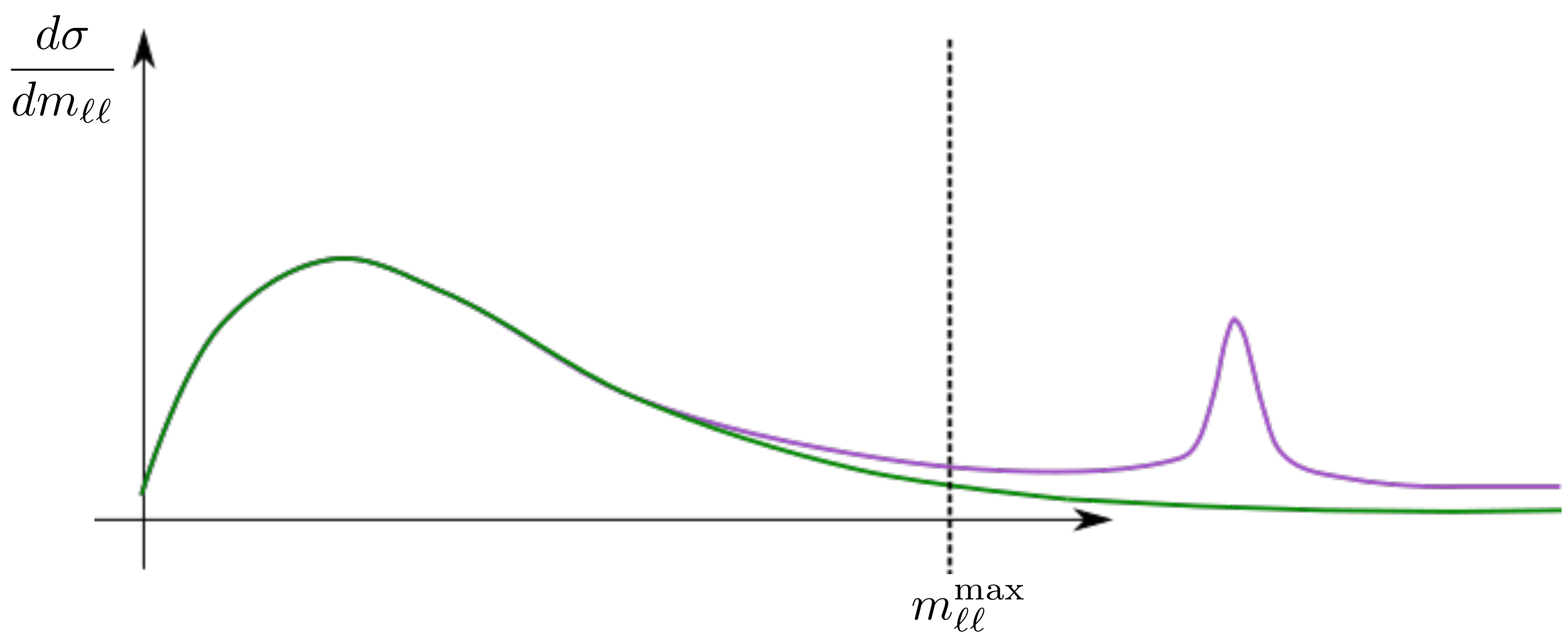
- LEP Z-pole measurements, diboson *WW* production
- Tevatron top quark, M_W measurements

The Standard Model Effective Field Theory

$$\mathcal{L}_{\rm SMEFT} = \mathcal{L}_{\rm SM} + \frac{C^{(5)}}{\Lambda}\mathcal{O}^{(5)} + \sum_i \frac{C_i^{(6)}}{\Lambda^2}\mathcal{O}_i^{(6)} + \ldots$$

this talk

- Assuming $\Lambda \gg E$
- A powerful theoretical framework for capturing the indirect effect of NP on LHC observables



X^3		H^6 and H^4D^2		ψ^2H^3	
$\mathcal{O}_G$	$f^{ABC}G_\mu^{A\nu}G_\nu^{B\rho}G_\rho^{C\mu}$	$\mathcal{O}_H$	$(H^\dagger H)^3$	$\mathcal{O}_{eH}$	$(H^\dagger H)(\bar l_p e_r H)$
$\mathcal{O}_{\widetilde G}$	$f^{ABC}\widetilde G_\mu^{A\nu}G_\nu^{B\rho}G_\rho^{C\mu}$	$\mathcal{O}_{H\Box}$	$(H^\dagger H)\Box(H^\dagger H)$	$\mathcal{O}_{uH}$	$(H^\dagger H)(\bar q_p u_r \widetilde H)$
$\mathcal{O}_W$	$\varepsilon^{IJK}W_\mu^{I\nu}W_\nu^{J\rho}W_\rho^{K\mu}$	$\mathcal{O}_{HD}$	$(H^\dagger D^\mu H)^\star(H^\dagger D_\mu H)$	$\mathcal{O}_{dH}$	$(H^\dagger H)(\bar q_p d_r H)$
$\mathcal{O}_{\widetilde W}$	$\varepsilon^{IJK}\widetilde W_\mu^{I\nu}W_\nu^{J\rho}W_\rho^{K\mu}$				

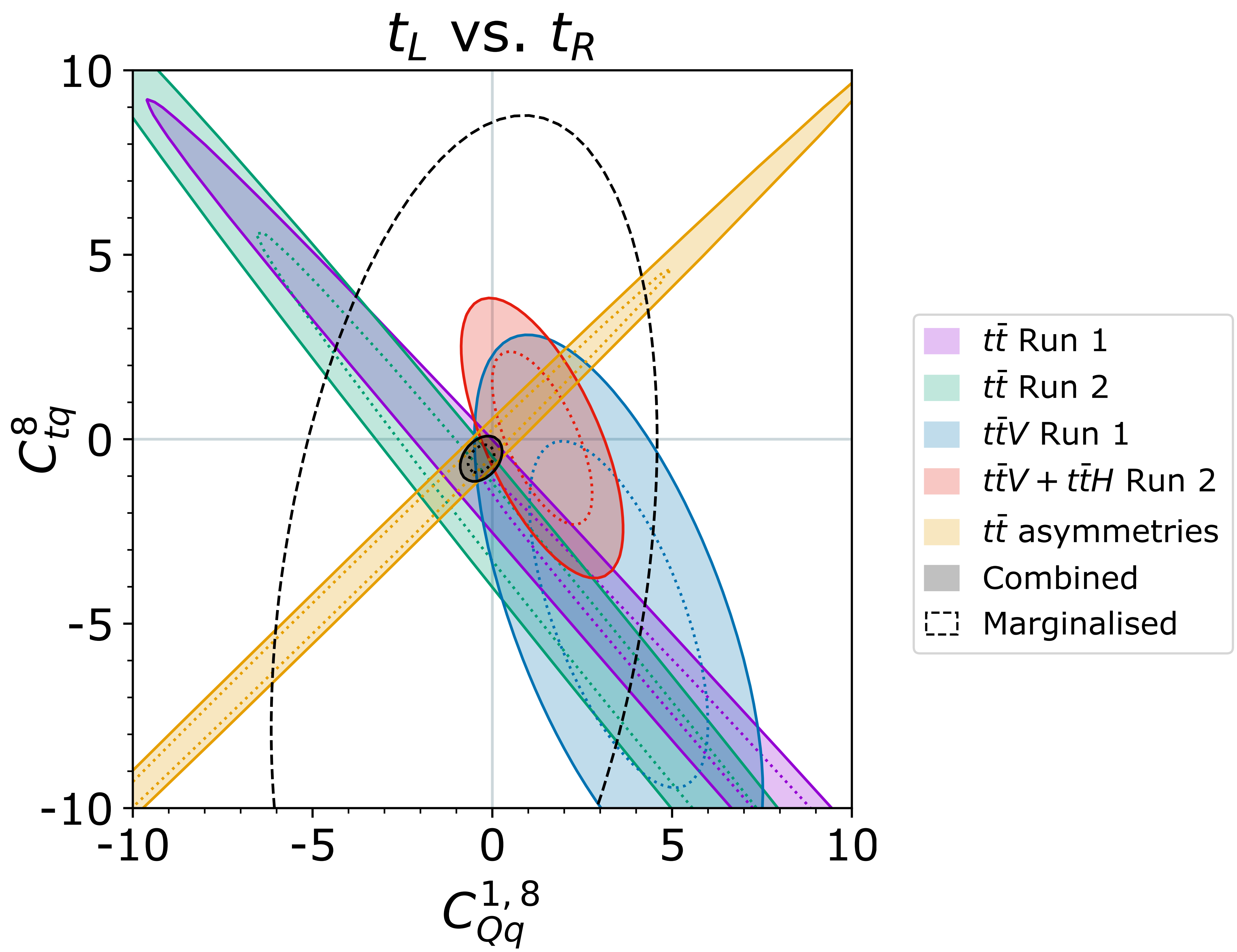
X^2H^2		ψ^2XH		ψ^2H^2D	
$\mathcal{O}_{HG}$	$H^\dagger H\, G_{\mu\nu}^A G^{A\mu\nu}$	$\mathcal{O}_{eW}$	$(\bar l_p\sigma^{\mu\nu}e_r)\tau^I H W_{\mu\nu}^I$	$\mathcal{O}_{Hl}^{(1)}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar l_p\gamma^\mu l_r)$
$\mathcal{O}_{H\widetilde G}$	$H^\dagger H\, \widetilde G_{\mu\nu}^A G^{A\mu\nu}$	$\mathcal{O}_{eB}$	$(\bar l_p\sigma^{\mu\nu}e_r)H B_{\mu\nu}$	$\mathcal{O}_{Hl}^{(3)}$	$(H^\dagger i\overleftrightarrow{D}_\mu^I H)(\bar l_p\tau^I\gamma^\mu l_r)$
$\mathcal{O}_{HW}$	$H^\dagger H\, W_{\mu\nu}^I W^{I\mu\nu}$	$\mathcal{O}_{uG}$	$(\bar q_p\sigma^{\mu\nu}T^A u_r)\widetilde H\, G_{\mu\nu}^A$	$\mathcal{O}_{He}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar e_p\gamma^\mu e_r)$
$\mathcal{O}_{H\widetilde W}$	$H^\dagger H\, \widetilde W_{\mu\nu}^I W^{I\mu\nu}$	$\mathcal{O}_{uW}$	$(\bar q_p\sigma^{\mu\nu}u_r)\tau^I\widetilde H\, W_{\mu\nu}^I$	$\mathcal{O}_{Hq}^{(1)}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar q_p\gamma^\mu q_r)$
$\mathcal{O}_{HB}$	$H^\dagger H\, B_{\mu\nu}B^{\mu\nu}$	$\mathcal{O}_{uB}$	$(\bar q_p\sigma^{\mu\nu}u_r)\widetilde H\, B_{\mu\nu}$	$\mathcal{O}_{Hq}^{(3)}$	$(H^\dagger i\overleftrightarrow{D}_\mu^I H)(\bar q_p\tau^I\gamma^\mu q_r)$
$\mathcal{O}_{H\widetilde B}$	$H^\dagger H\, \widetilde B_{\mu\nu}B^{\mu\nu}$	$\mathcal{O}_{dG}$	$(\bar q_p\sigma^{\mu\nu}T^A d_r)H\, G_{\mu\nu}^A$	$\mathcal{O}_{Hu}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar u_p\gamma^\mu u_r)$
$\mathcal{O}_{HWB}$	$H^\dagger\tau^I H\, W_{\mu\nu}^I B^{\mu\nu}$	$\mathcal{O}_{dW}$	$(\bar q_p\sigma^{\mu\nu}d_r)\tau^I H\, W_{\mu\nu}^I$	$\mathcal{O}_{Hd}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar d_p\gamma^\mu d_r)$
$\mathcal{O}_{H\widetilde WB}$	$H^\dagger\tau^I H\, \widetilde W_{\mu\nu}^I B^{\mu\nu}$	$\mathcal{O}_{dB}$	$(\bar q_p\sigma^{\mu\nu}d_r)H\, B_{\mu\nu}$	$\mathcal{O}_{Hud}$	$i(\widetilde H^\dagger D_\mu H)(\bar u_p\gamma^\mu d_r)$

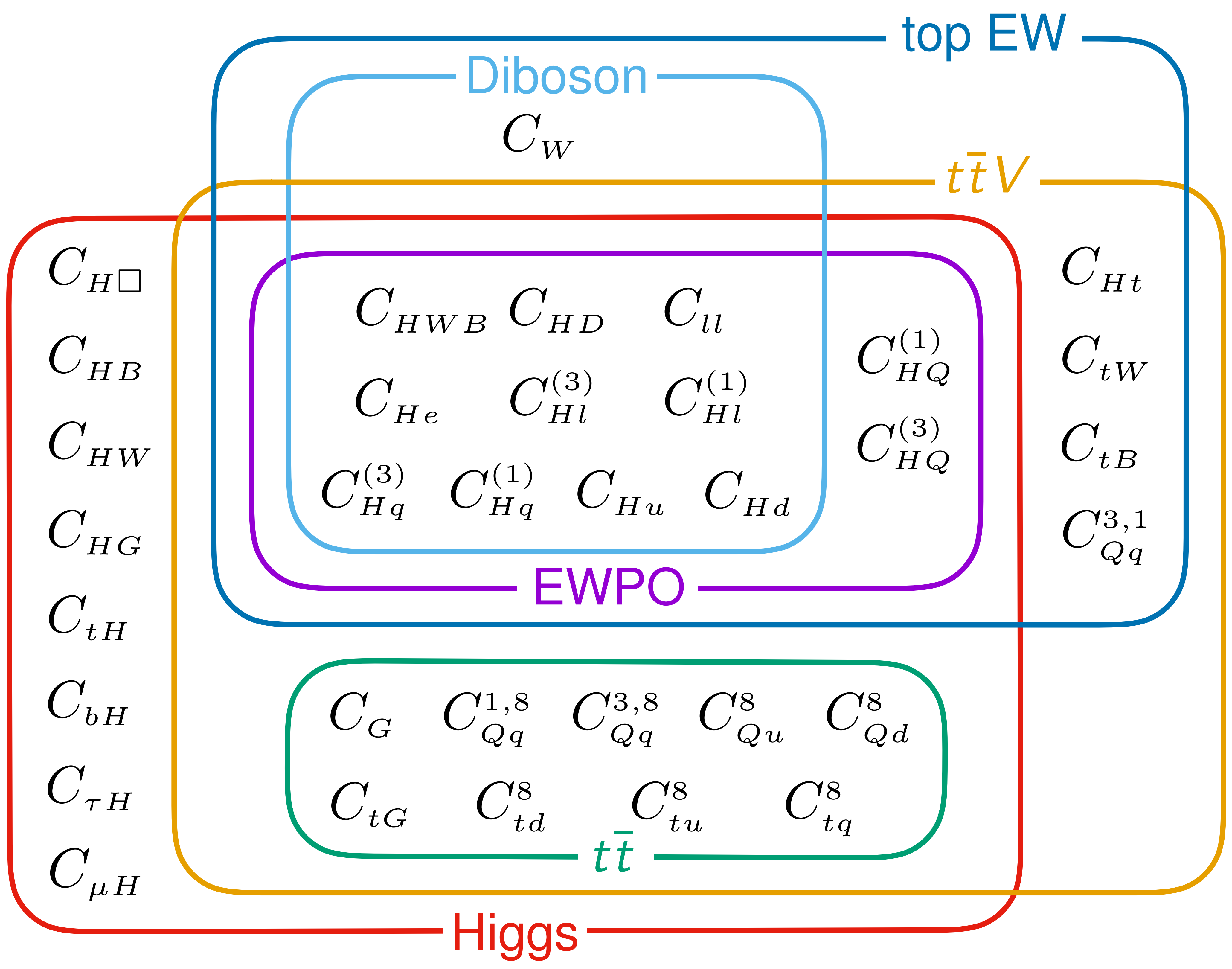
$(\bar LL)(\bar LL)$		$(\bar RR)(\bar RR)$		$(\bar LL)(\bar RR)$	
$\mathcal{O}_{ll}$	$(\bar l_p\gamma_\mu l_r)(\bar l_s\gamma^\mu l_t)$	$\mathcal{O}_{ee}$	$(\bar e_p\gamma_\mu e_r)(\bar e_s\gamma^\mu e_t)$	$\mathcal{O}_{le}$	$(\bar l_p\gamma_\mu l_r)(\bar e_s\gamma^\mu e_t)$
$\mathcal{O}_{qq}^{(1)}$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

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

Global fits

The SMEFT framework connects different sectors of observables measured at the LHC.





2012.02779, J. Ellis, MM, K. Mimasu, V. Sanz, T. You

Global fits

Where do we see an interplay? Is the overlap between data sectors visible in a global fit?

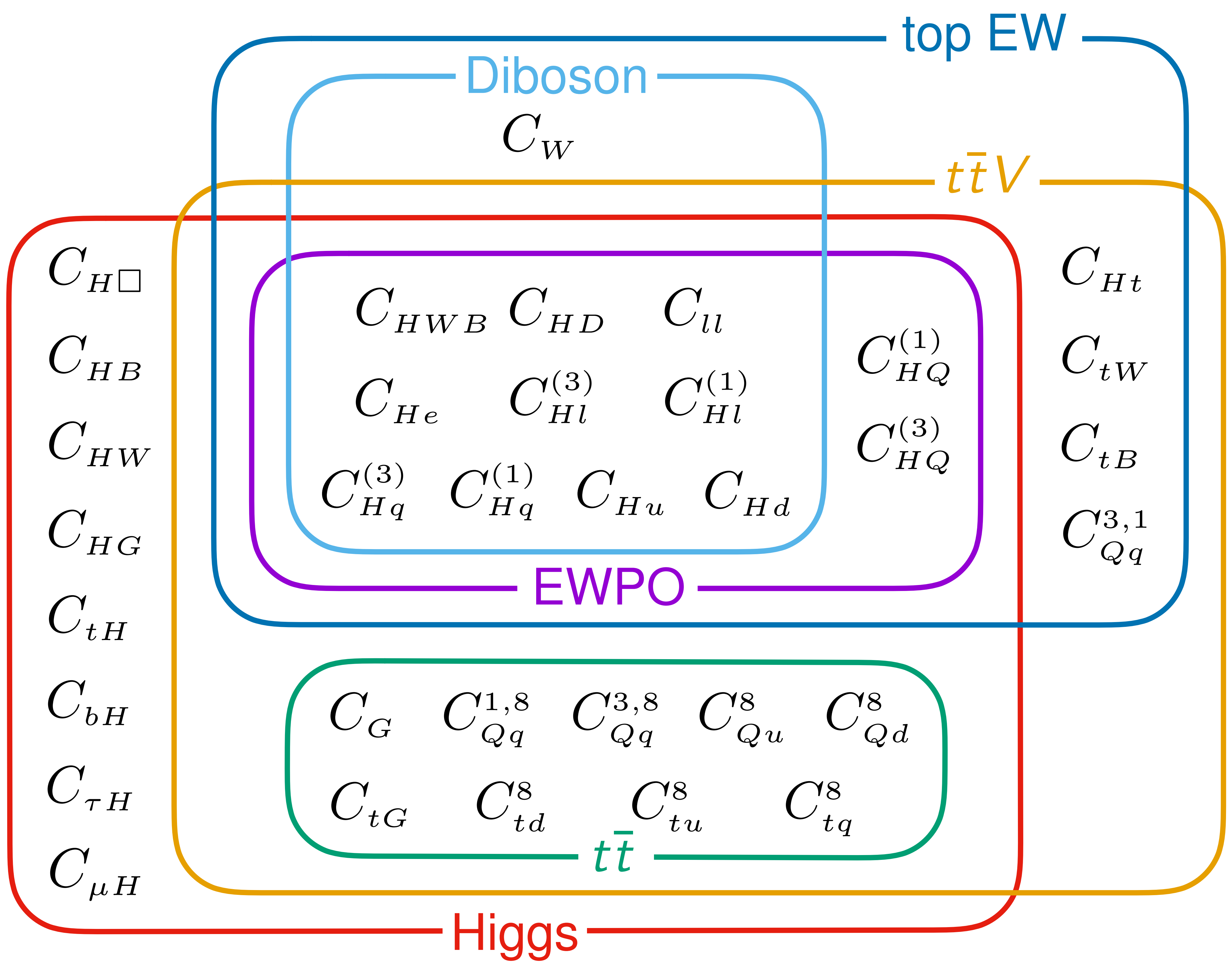
- **Top-Higgs interplay**

Fitmaker *J. Ellis, K. Mimasu, MM, V. Sanz, T. You, 2012.02779*

The same data is used to constrain SMEFT and PDFs: what is the impact?

- **PDF-SMEFT interplay**

Z. Kassabov, MM, L. Mantani, J. Moore, M. Morales, J. Rojo, M. Ubiali, work in progress



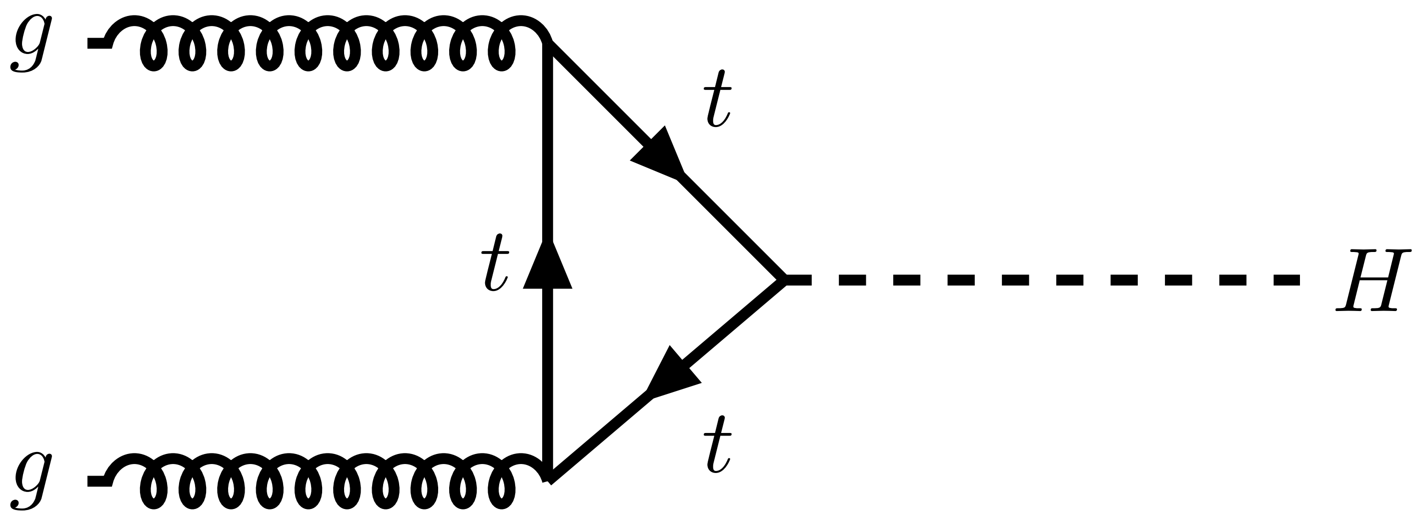
The global approach

Where do we see an interplay? Is the overlap between sectors visible in a global fit?

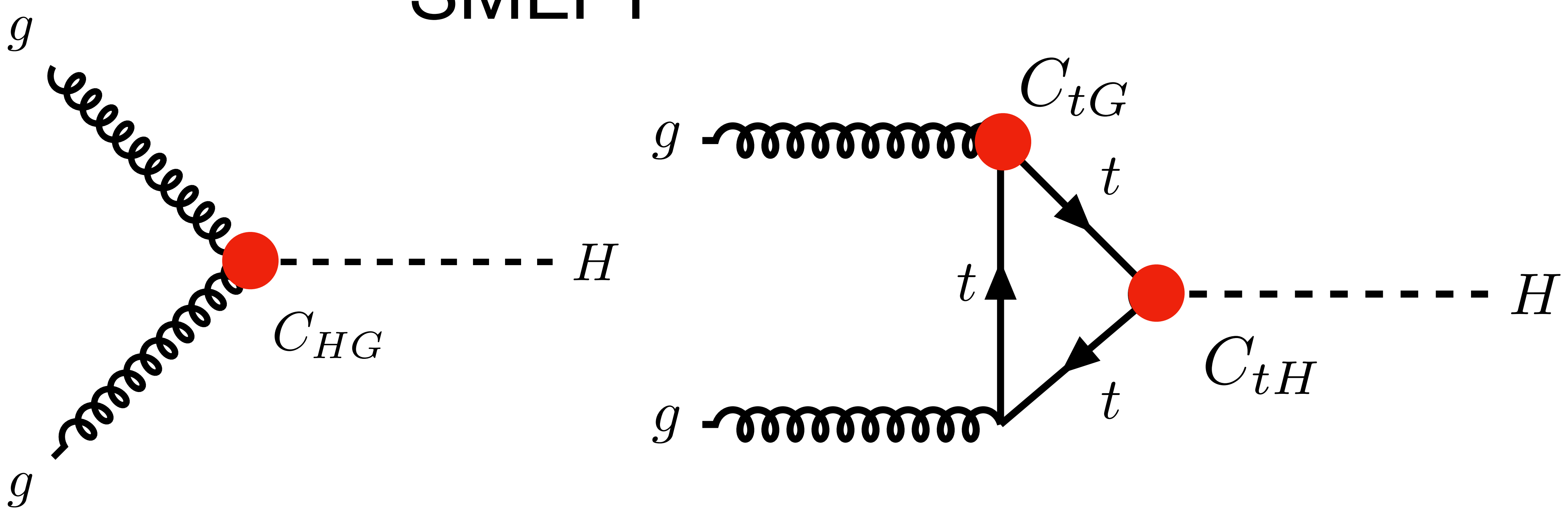
- **Top-Higgs interplay**

e.g. Higgs production via ggF is modified by top operators:

Standard Model



SMEFT



Top, Higgs, diboson and electroweak fit to the SMEFT

`Fitmaker` code, J. Ellis, K. Mimasu, MM, V. Sanz, T. You, 2012.02779

See also J. Ethier et. al, 2105.00006, SMEFiT

+ thanks to SMEFiT for sharing top quark predictions!

- 341 statistically independent measurements:

Higgs: 72

- Signal strength combinations (LHC Run I and Run II)
- STXS combination (LHC Run II)
- Measurements of $H \to Z\gamma$ $H \to \mu\mu$

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EWPO: 14

- LEP, Tevatron, LHC measurements

$$\{\Gamma_Z, \sigma^0_{\text{had.}}, R^0_l, A^l_{FB}, A_l, R^0_b, R^0_c, A^b_{FB}, A^c_{FB}, A_b, A_c, M_W\}.$$

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Diboson: 118

- LHC and LEP measurements of

$$WW, WZ, Zjj$$

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Diboson: 118

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Top: 137

- LHC measurements of

$$t\bar{t}, \quad t\bar{t}+V, \quad \text{single top}$$

Top, Higgs, diboson and electroweak fit to the SMEFT

`Fitmaker` code, J. Ellis, K. Mimasu, MM, V. Sanz, T. You, 2012.02779

See also J. Ethier et. al, 2105.00006, SMEFiT

+ *thanks to SMEFiT for sharing top quark predictions!*

- Correlation information included from published covariance matrices

Information on the covariance matrices & likelihood is important for EFT fits, Cranmer et. al, 2109.04981

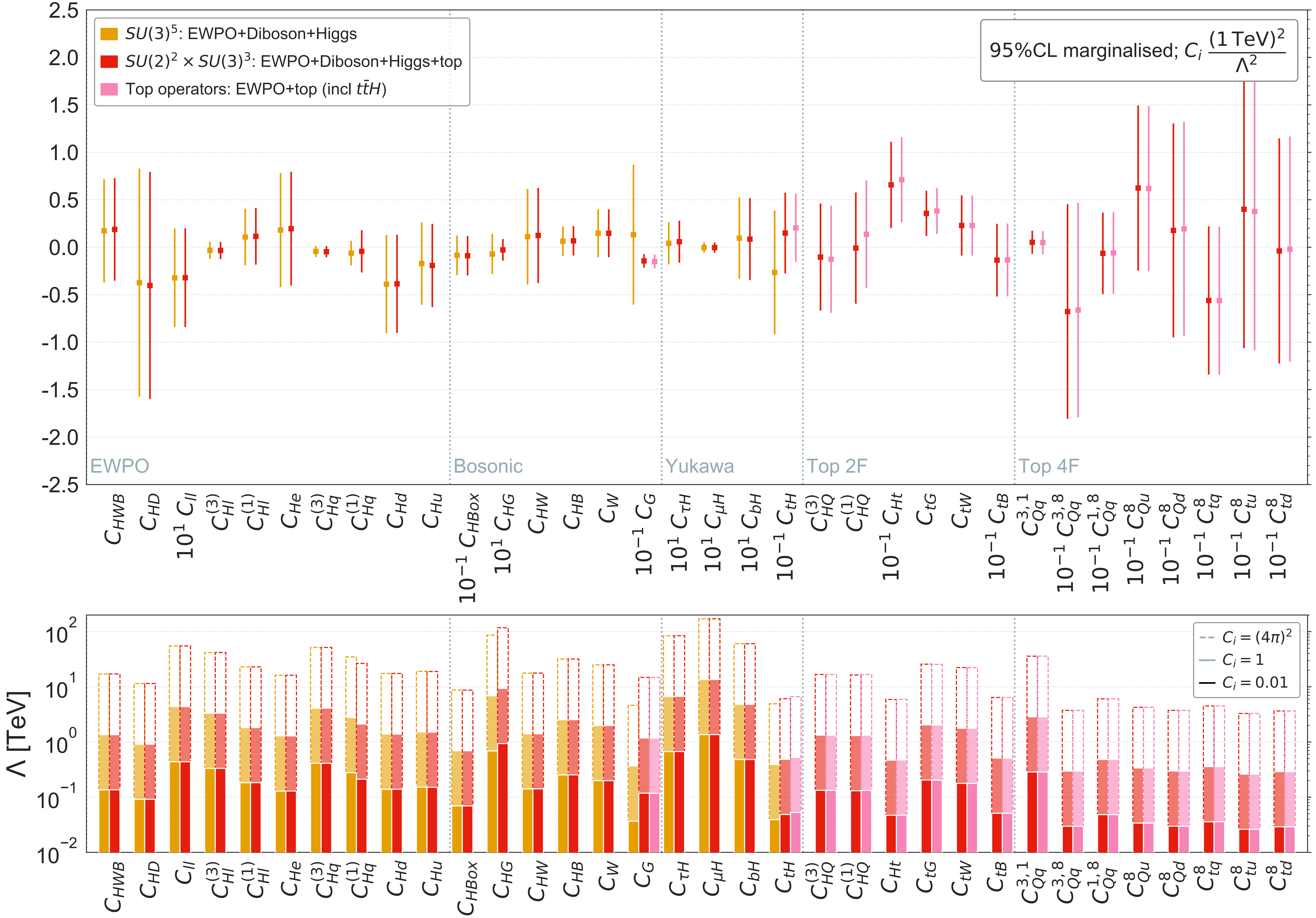
- Fit using a simple χ^2 methodology, working in the linear EFT approx. $\sigma = \sigma_{\rm SM} + \sum_i \frac{C_i}{\Lambda^2}\sigma_i + \mathcal{O}(\Lambda^{-4})$

- Top-specific flavour symmetry $SU(2)_q \times SU(2)_u \times SU(3)_d \times SU(3)_l \times SU(3)_e$ *based on LHC top WG 1802.07237*

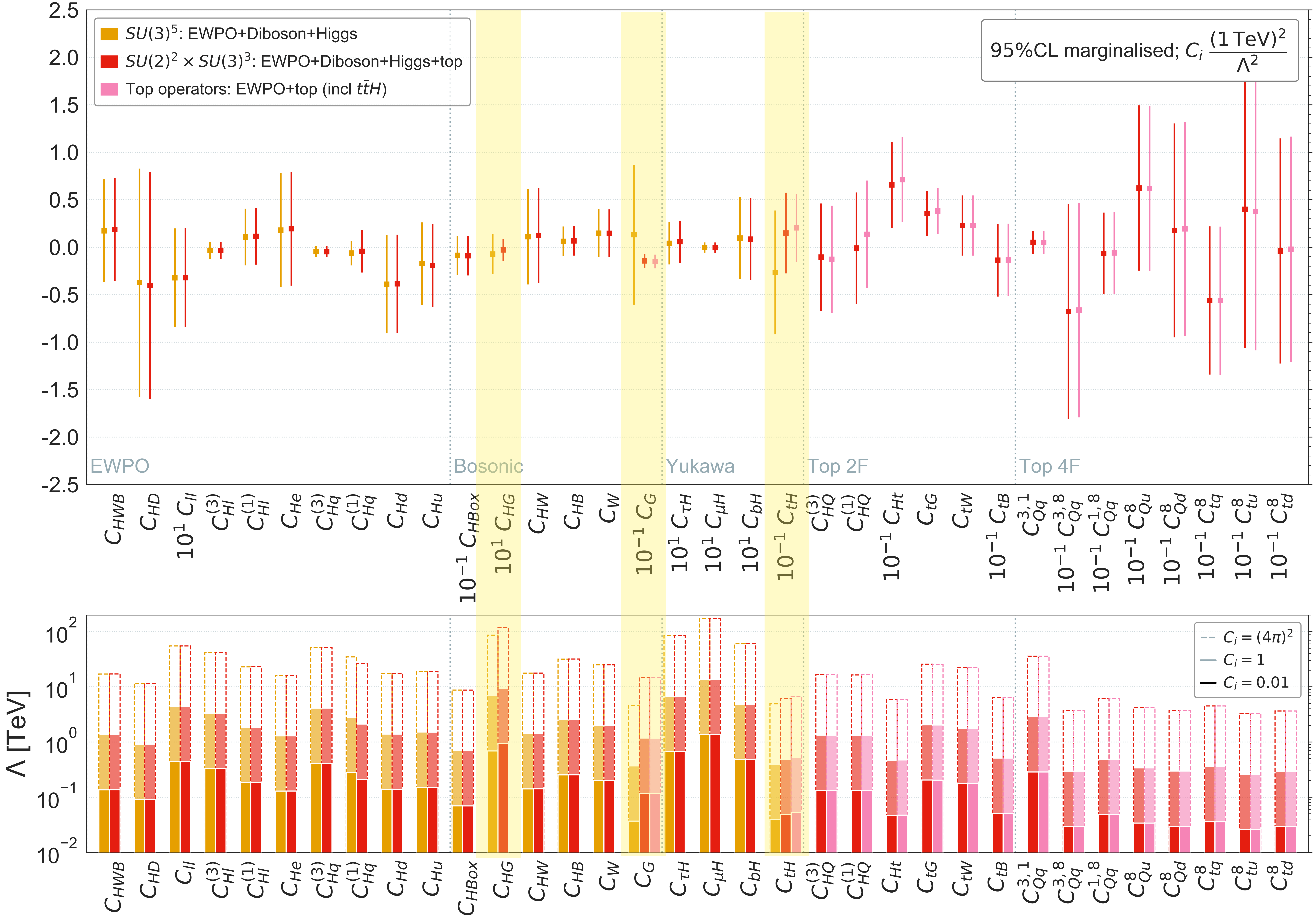
= 34 dimension-6 operators

e.g. $\mathcal{O}_{Hu}$: symmetric in 1st, 2nd generation

$\mathcal{O}_{Ht}$ singles out the top quark



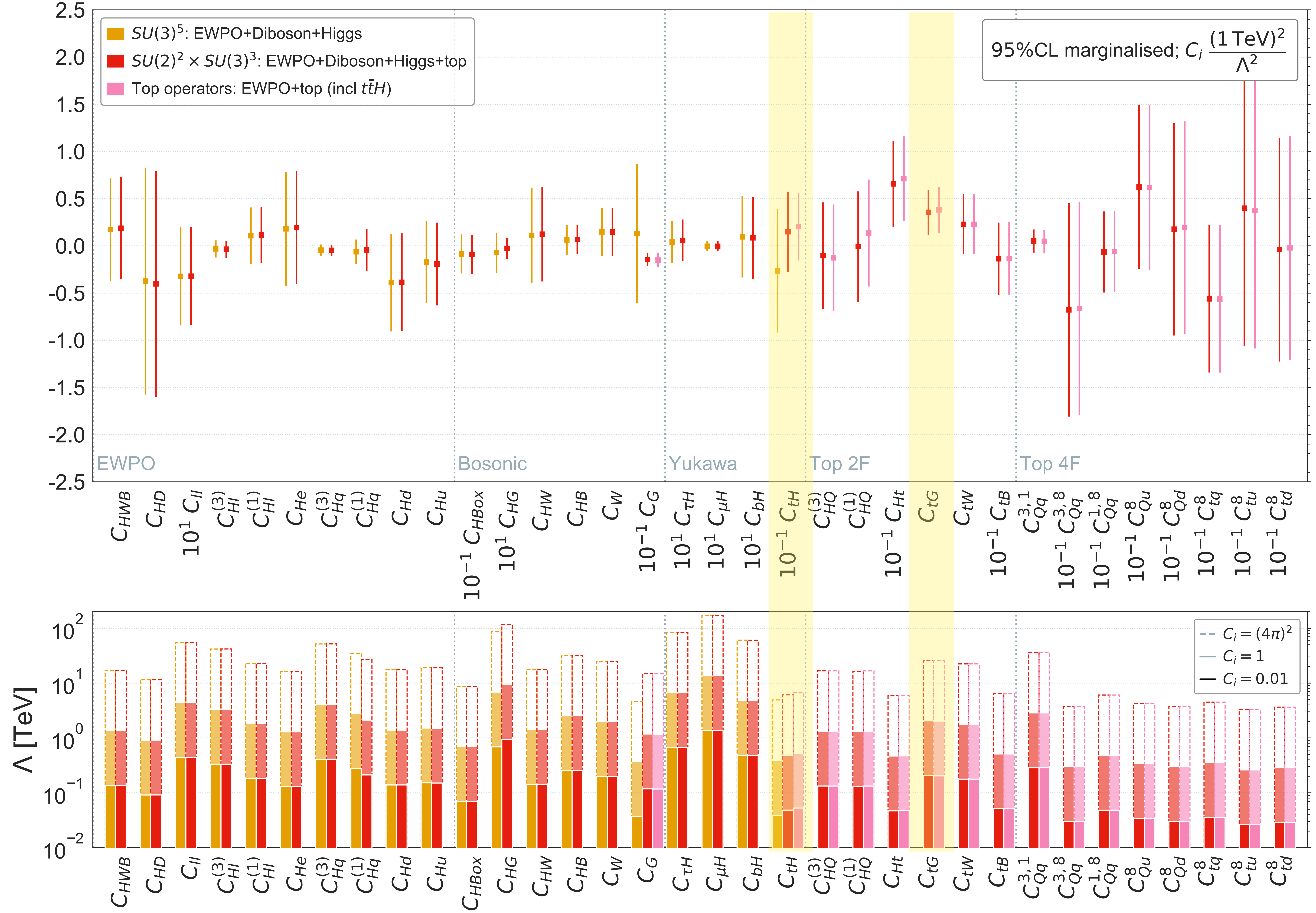
- 34 dimension-6 SMEFT ops constrained at linear-order only
- top-specific flavour symmetry, following the *LHC top WG 1802.07237*
- RED: the full fit



- 34 dimension-6 SMEFT ops constrained at linear-order only
- top-specific flavour symmetry, following the *LHC top WG 1802.07237*
- ORANGE: by removing the top data we see some shift in the constraints, particularly on

$$C_{HG}, C_G, C_{tH}$$

important for both ggF and $t\bar{t}$



- 34 dimension-6 SMEFT ops constrained at linear-order only
- top-specific flavour symmetry, following the *LHC top WG 1802.07237*
- PINK: by removing the Higgs+diboson data we see some shift in the constraints, including on

$$C_{tH}\,,C_{tG}$$

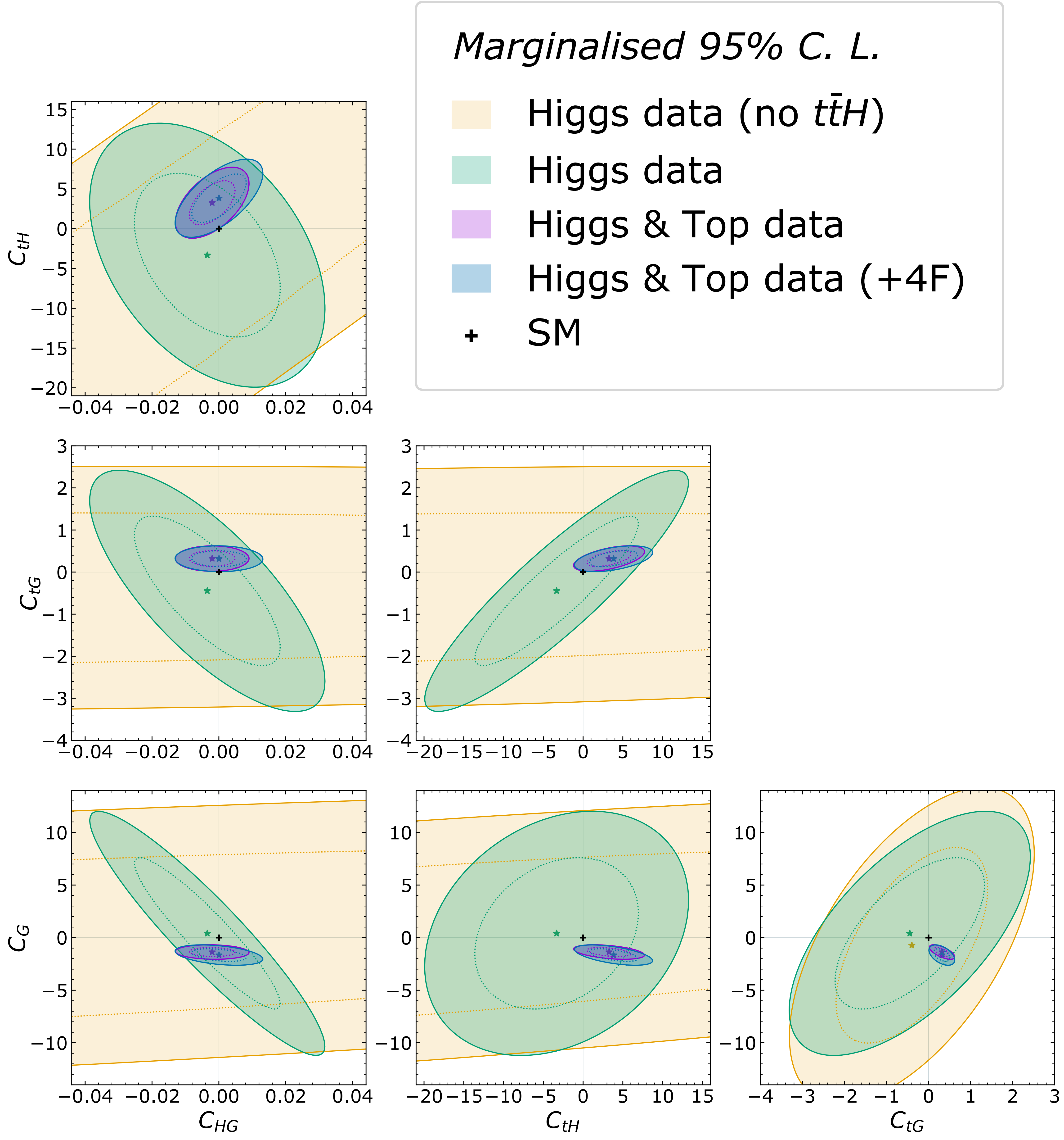
important for both ggF and $t\bar{t}$

Top-Higgs interplay

How do the constraints on $C_{HG}, C_{tG}, C_G, C_{tH}$ change as we include more top quark data?

We marginalise over
$C_{H\Box}, C_{HW}, C_{HB}, C_{bH}, C_{\tau H}, C_{\mu H}(+\text{ 4-fermion operators})$

- *ttH* removes the degeneracy between C_{HG}, C_{tH}.
- top quark data substantially **reduces the area** constrained at 95 % CL and **suppresses some correlations**.
- this is true even when marginalising over all 4-fermion operators involving top quarks.



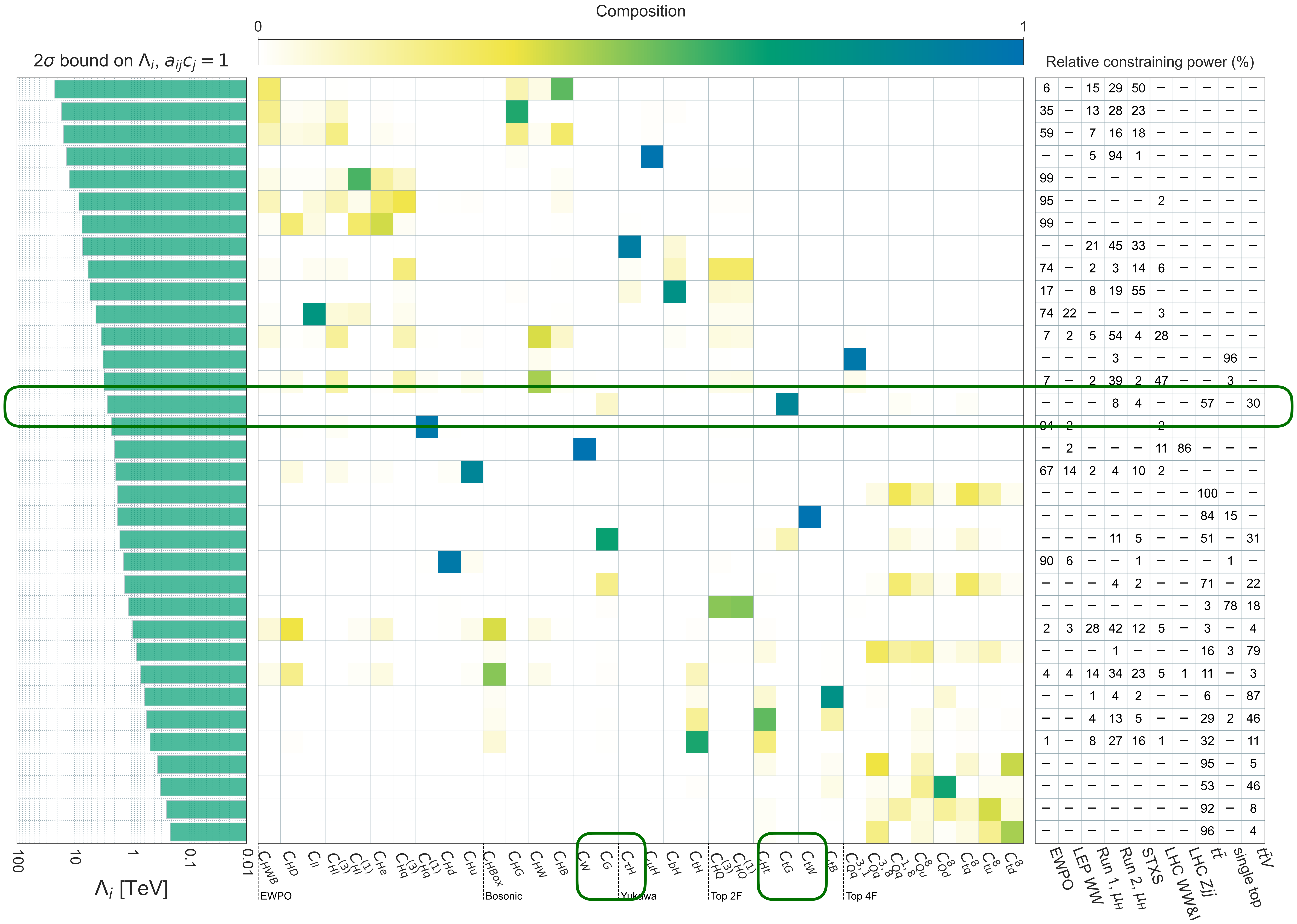
Principal component analysis

Relative constraining power (%)

	EWPO	LEP WW	Run 1, μ_H	Run 2, μ_H	STXS	LHC WW&l	LHC Zjj	$t\bar{t}$	single top	$t\bar{t}V$
	6	–	15	29	50	–	–	–	–	–
	35	–	13	28	23	–	–	–	–	–
	59	–	7	16	18	–	–	–	–	–
	–	–	5	94	1	–	–	–	–	–
	99	–	–	–	–	–	–	–	–	–
	95	–	–	–	–	2	–	–	–	–
	99	–	–	–	–	–	–	–	–	–
	–	–	21	45	33	–	–	–	–	–
	74	–	2	3	14	6	–	–	–	–
	17	–	8	19	55	–	–	–	–	–
	74	22	–	–	–	3	–	–	–	–
	7	2	5	54	4	28	–	–	–	–
	–	–	–	3	–	–	–	–	96	–
	7	–	2	39	2	47	–	–	3	–
	–	–	–	8	4	–	–	57	–	30
	94	2	–	–	–	2	–	–	–	–
	–	2	–	–	–	11	86	–	–	–
	67	14	2	4	10	2	–	–	–	–
	–	–	–	–	–	–	–	100	–	–
	–	–	–	–	–	–	–	84	15	–
	–	–	–	11	5	–	–	51	–	31
	90	6	–	–	1	–	–	–	1	–
	–	–	–	4	2	–	–	71	–	22
	–	–	–	–	–	–	–	3	78	18
	2	3	28	42	12	5	–	3	–	4
	–	–	–	1	–	–	–	16	3	79
	4	4	14	34	23	5	1	11	–	3
	–	–	1	4	2	–	–	6	–	87
	–	–	4	13	5	–	–	29	2	46
	1	–	8	27	16	1	–	32	–	11
	–	–	–	–	–	–	–	95	–	5
	–	–	–	–	–	–	–	53	–	46
	–	–	–	–	–	–	–	92	–	8
	–	–	–	–	–	–	–	96	–	4

$$\mathcal{O}_{tG} = (\bar{Q}\sigma^{\mu\nu}T^{A}t)\tilde{H}G^{A}_{\mu\nu}$$

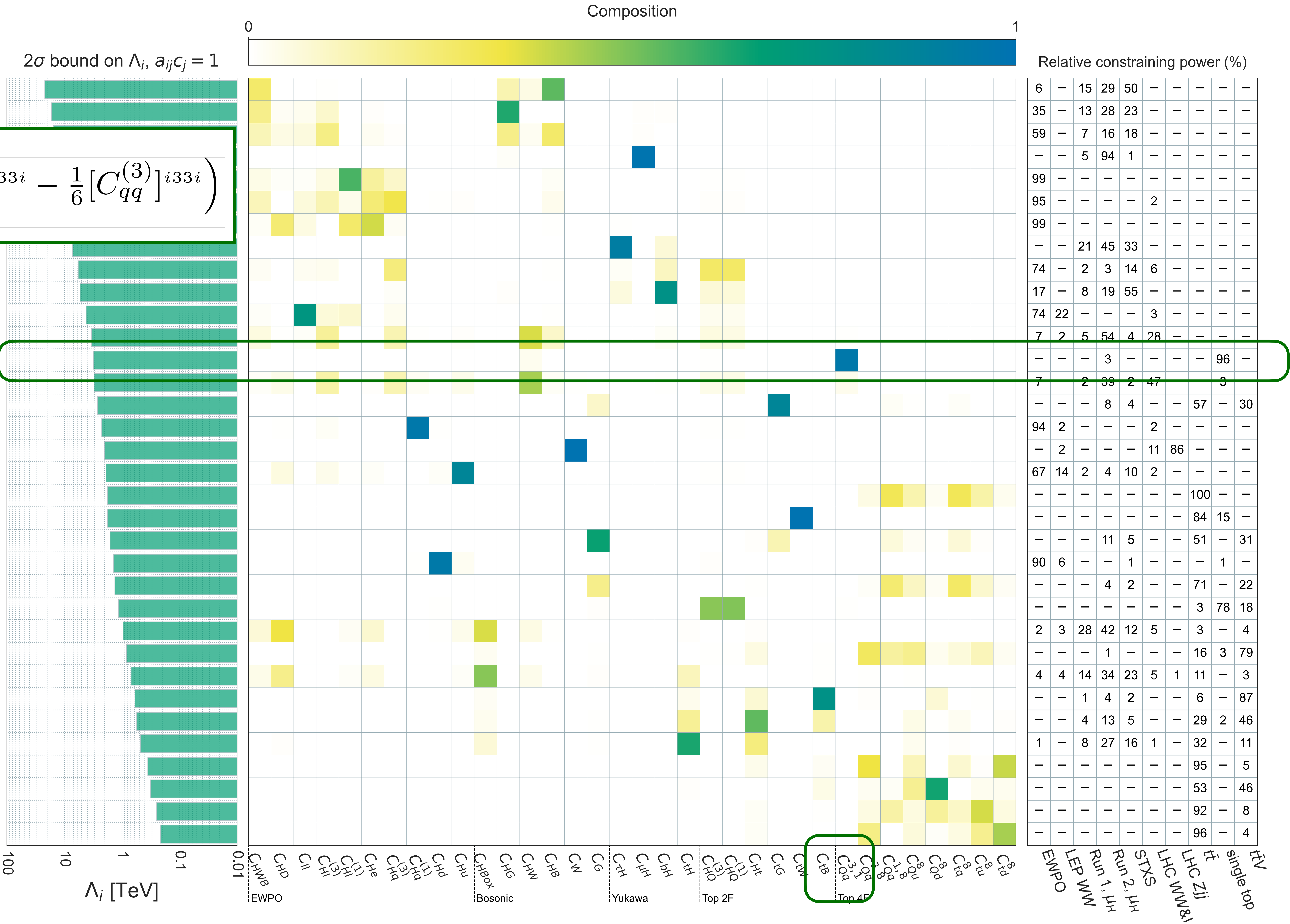
$$\mathcal{O}_{G} = f^{ABC}G^{A\nu}_{\mu}G^{B\rho}_{\nu}G^{C\mu}_{\rho}$$



- Constrained to $\Lambda > 2$ TeV
- Constrained almost entirely by $t\bar{t}$ data + small contributions from the Higgs sector

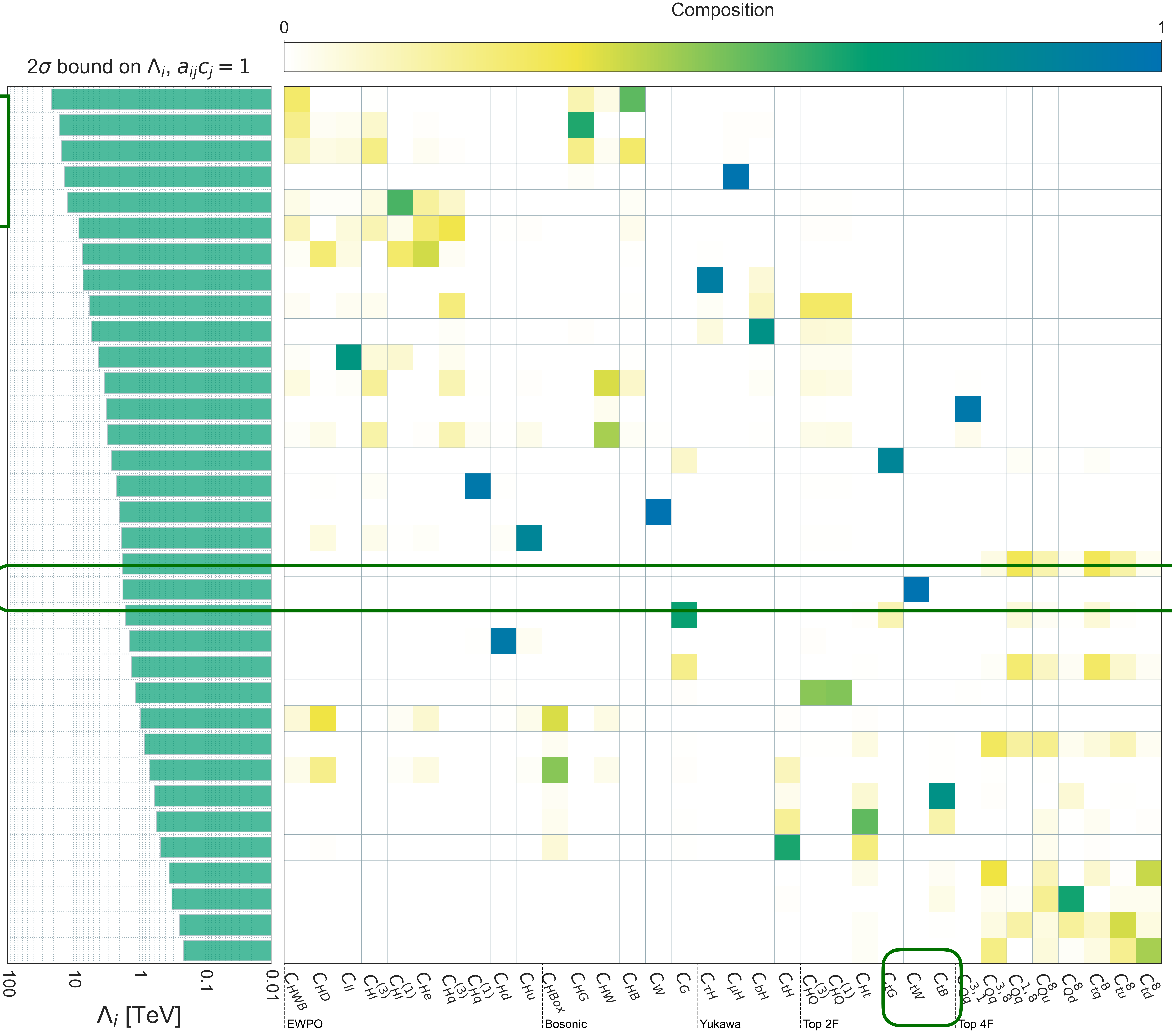
$$\mathcal{O}_{Qq}^{3,1} = \sum_{i=1,2} \left([C_{qq}^{(3)}]^{ii33} + \frac{1}{6}[C_{qq}^{(1)}]^{i33i} - \frac{1}{6}[C_{qq}^{(3)}]^{i33i} \right)$$

- Constrained to $\Lambda > 2\ \text{TeV}$
- Constrained almost entirely by single top data



$$\mathcal{O}_{tW} = (\bar{Q}\sigma^{\mu\nu}t)\tau^I \tilde{H} W^I_{\mu\nu}$$

- Constrained to $\Lambda > 1$ TeV
- Constrained almost entirely by W helicity fractions in $t\bar{t}$ data



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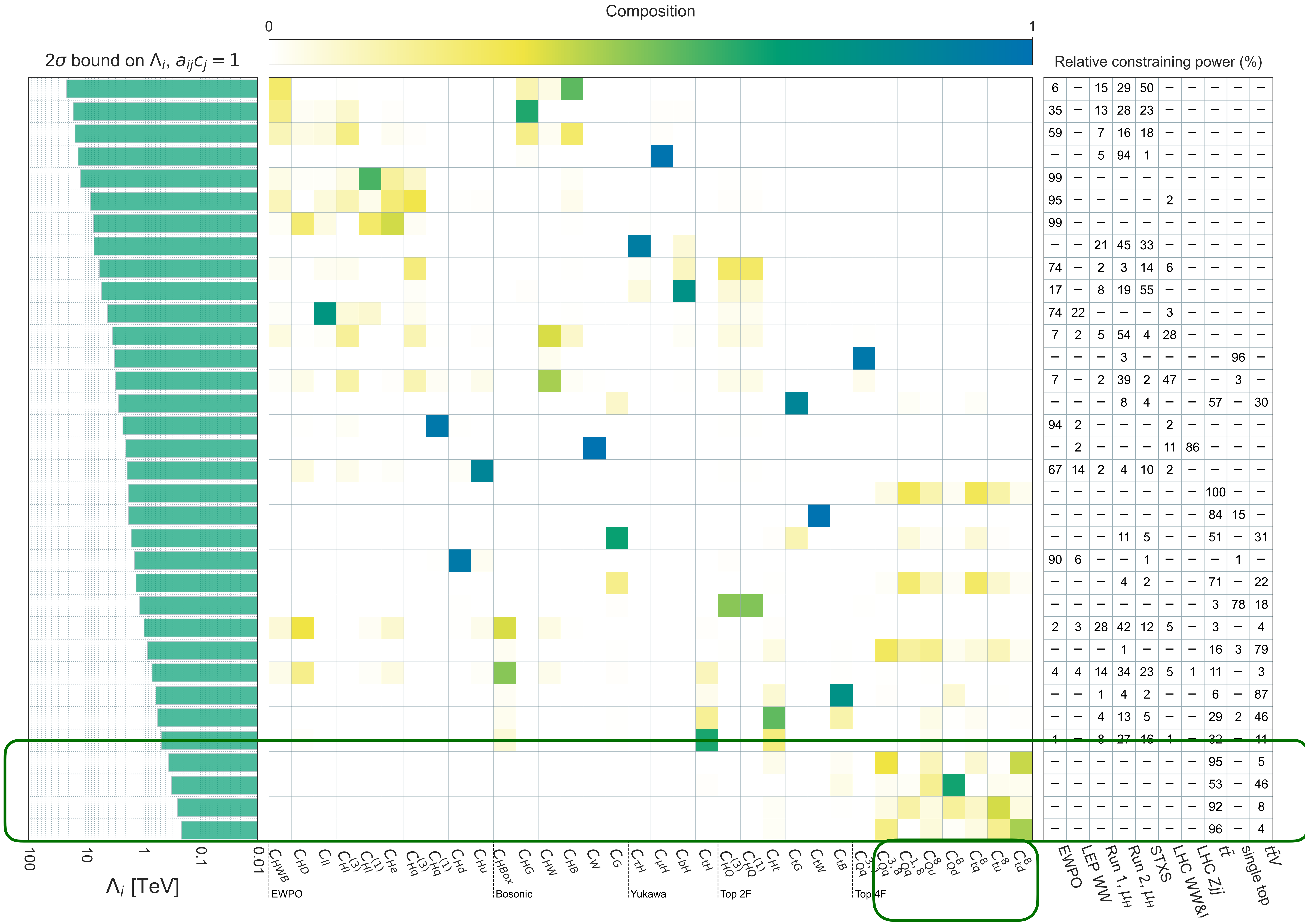
–	2	–	–	–	11	86	–	–	–
67	14	2	4	10	2	–	–	–	–
–	–	–	–	–	–	–	100	–	–
–	–	–	–	–	–	–	84	15	–
–	–	–	11	5	–	–	51	–	31
90	6	–	–	1	–	–	–	1	–
–	–	–	4	2	–	–	71	–	22
–	–	–	–	–	–	–	3	78	18
2	3	28	42	12	5	–	3	–	4
–	–	–	1	–	–	–	16	3	79
4	4	14	34	23	5	1	11	–	3
–	–	1	4	2	–	–	6	–	87
–	–	4	13	5	–	–	29	2	46
1	–	8	27	16	1	–	32	–	11
–	–	–	–	–	–	–	95	–	5
–	–	–	–	–	–	–	53	–	46
–	–	–	–	–	–	–	92	–	8
–	–	–	–	–	–	–	96	–	4

4-fermion operators involving top quarks

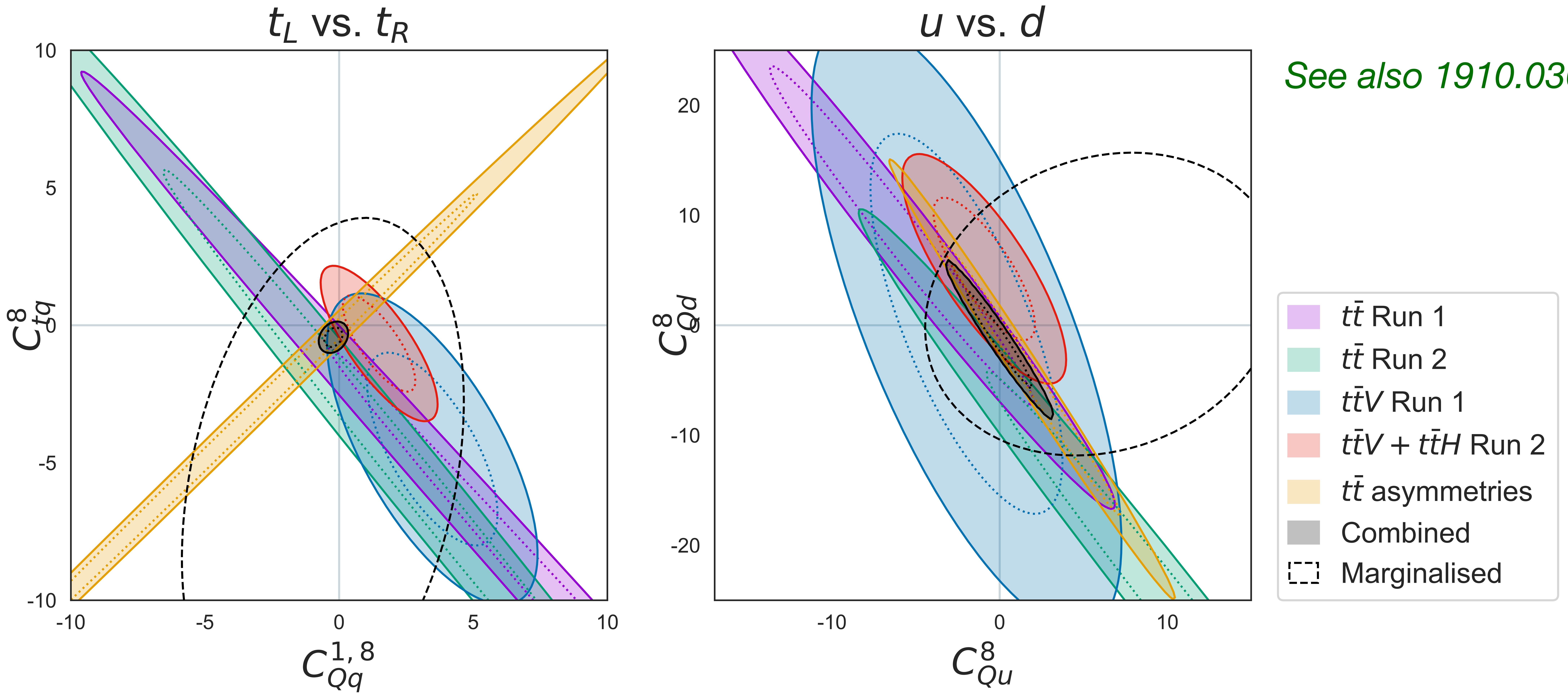
- Constrained by $t\bar{t}$ and $t\bar{t}V$
- $\Lambda \gtrsim 100 - 300 \text{ GeV}$

➡ SMEFT validity in question here for *C=1,* but should be valid for the strong coupling regime

$$C \sim (4\pi)^2$$



Complementarity of top pair production measurements

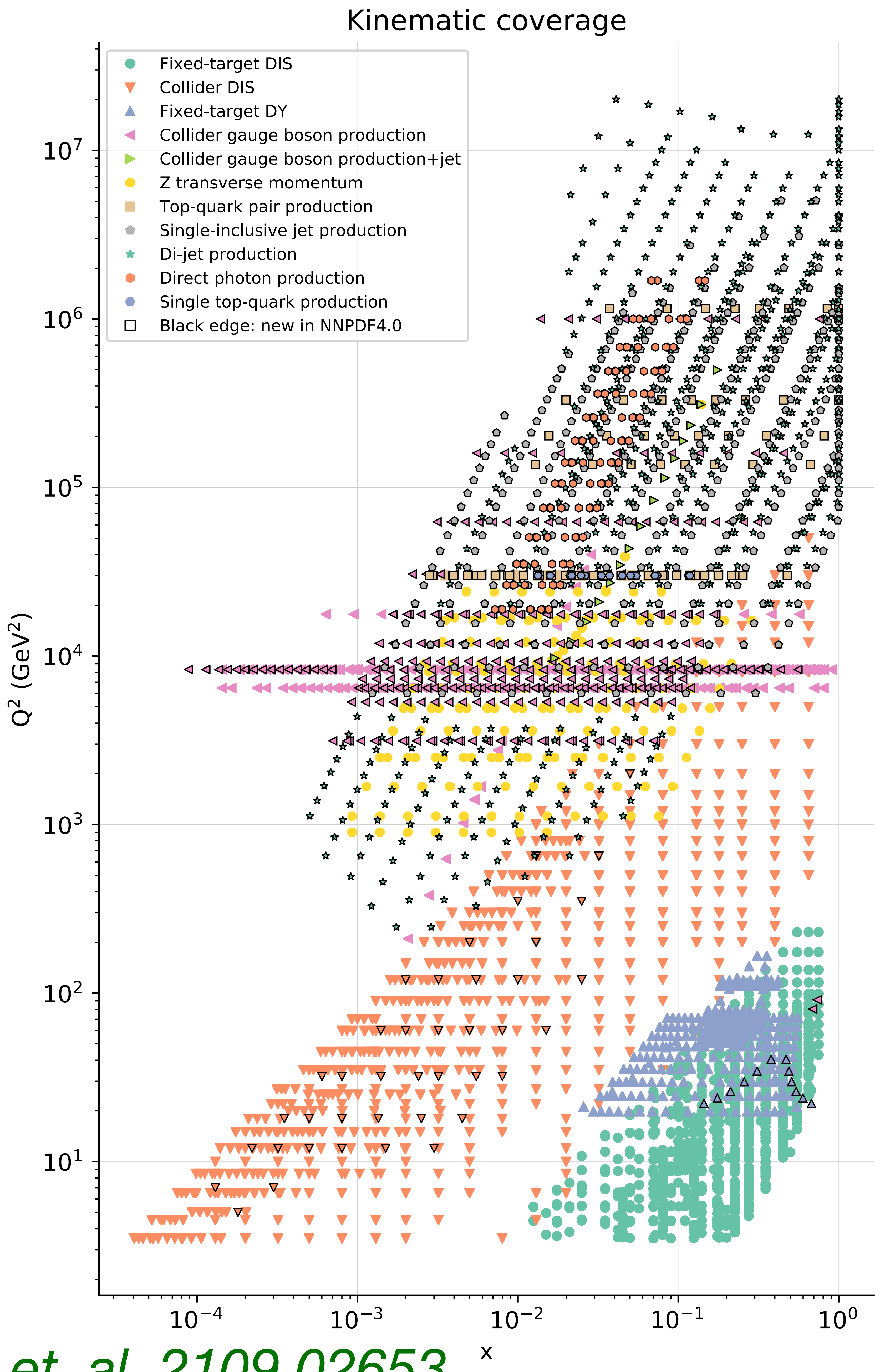


See also 1910.03606

PDF-EFT interplay

Often the data used in PDF fits are also used in EFT fits.

This overlap will grow as we take the global approach to constraining the SMEFT.



R. Ball et. al, 2109.02653

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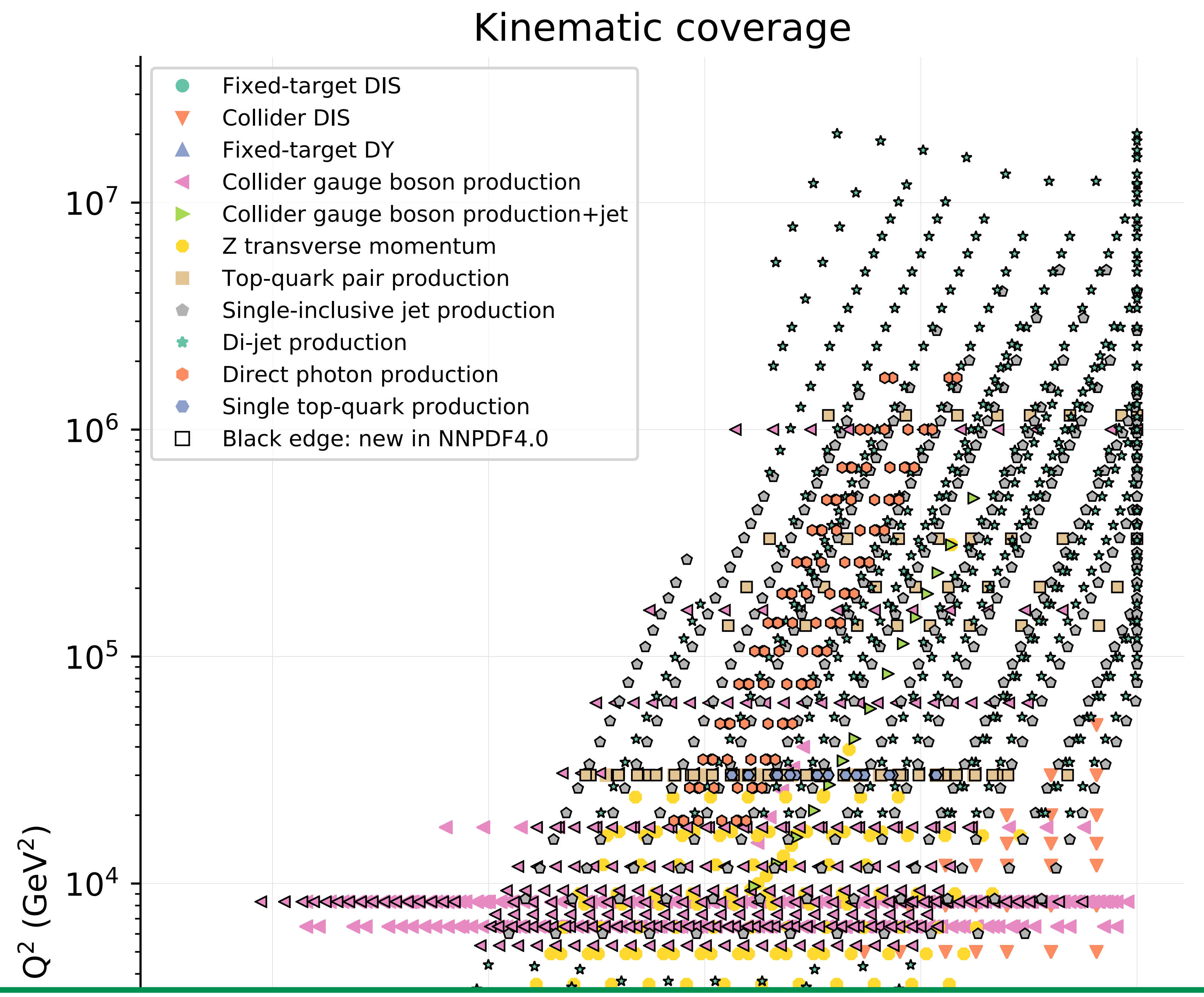
Theoretical inconsistencies:



PDFs are an input to SMEFT fits: $\sigma_{\text{SMEFT}}(C) = f_1 \otimes f_2 \otimes \hat{\sigma}_{\text{SMEFT}}(C)$

But PDFs are found assuming the SM: $\sigma = f_1 \otimes f_2 \otimes \hat{\sigma}_{SM}$

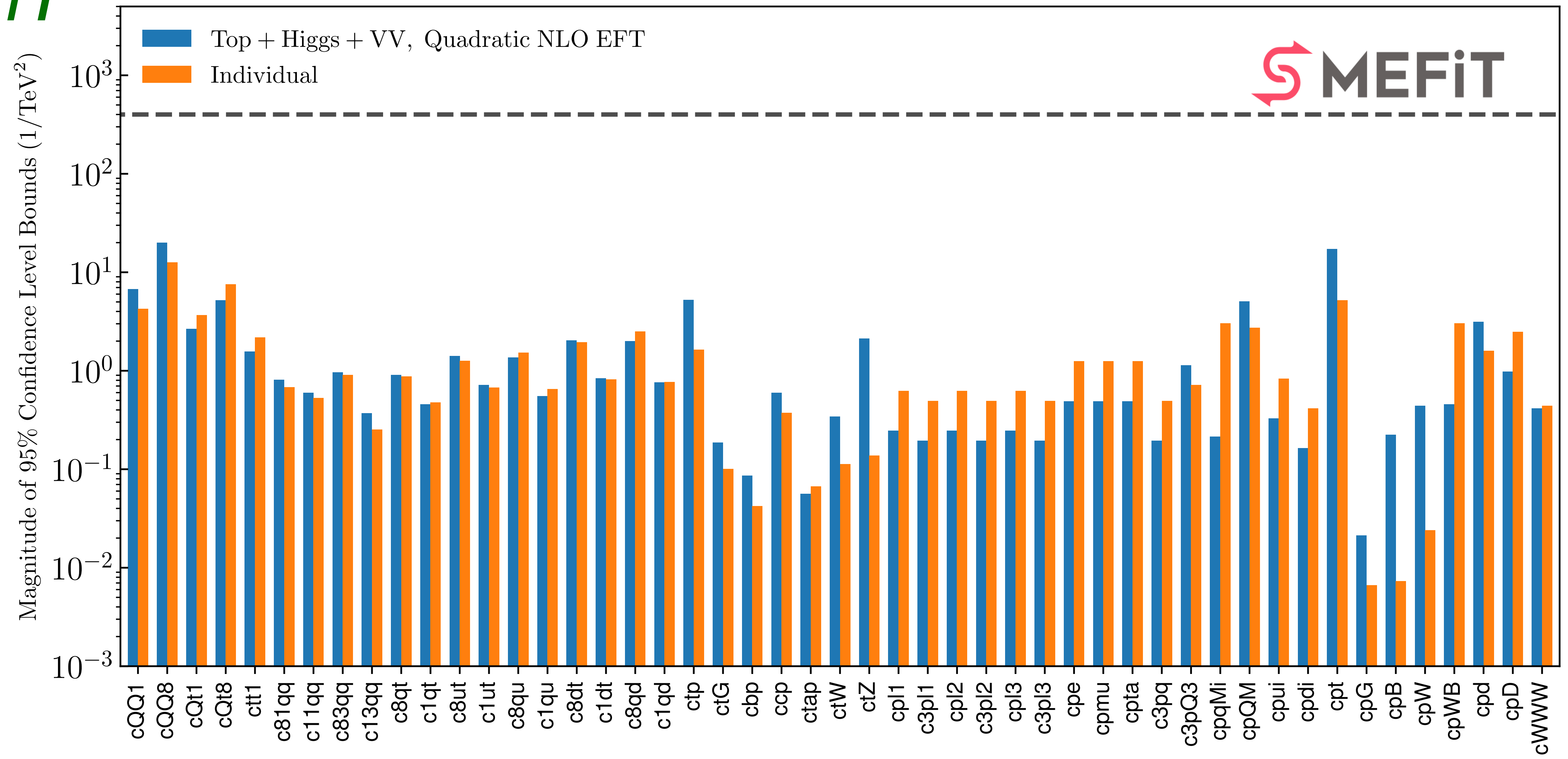
'Standard Model PDFs'

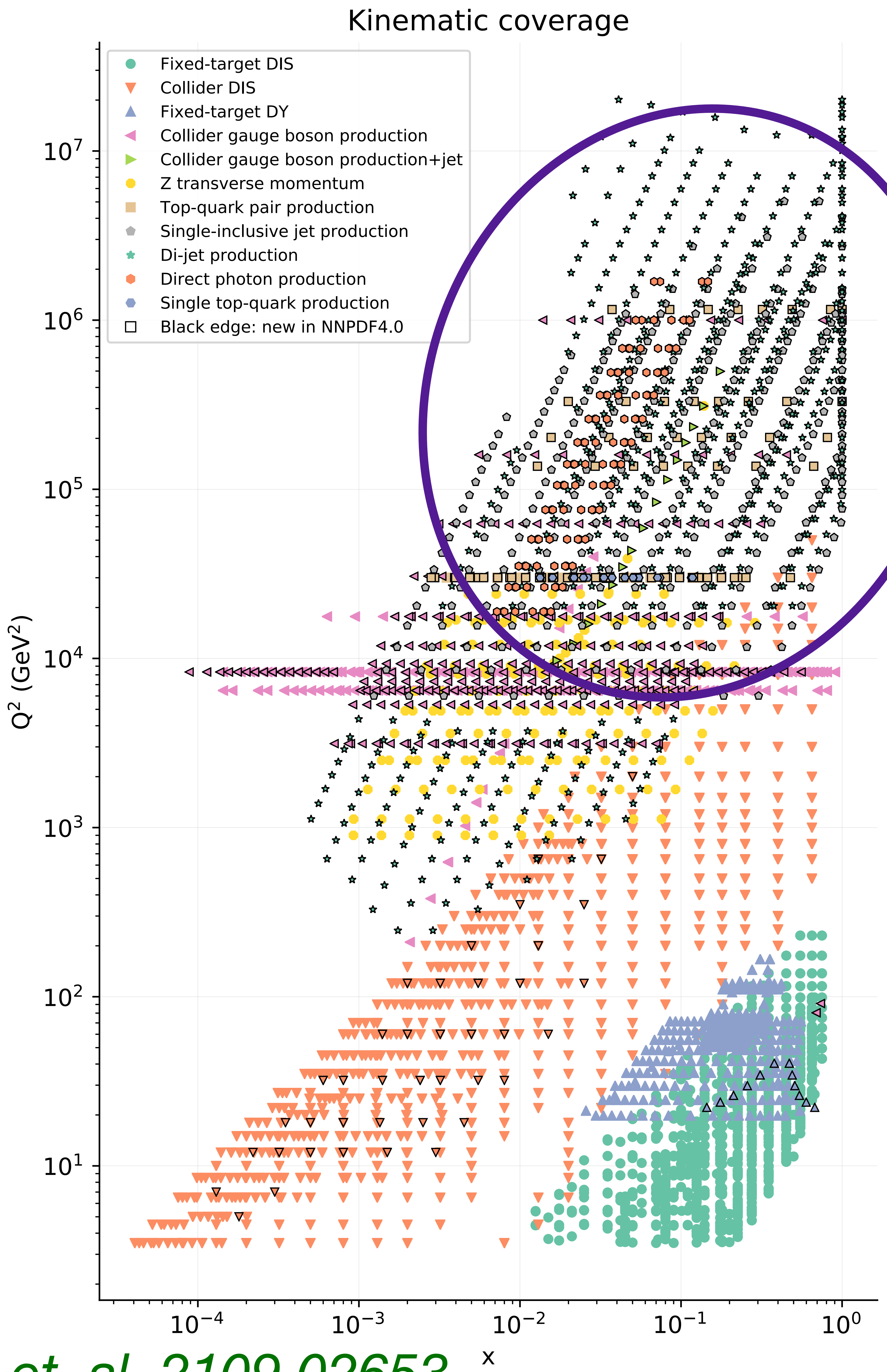
PDF-EFT interplay

Often the data used in PDF fits are also used in EFT fits.

This overlap will grow as we take the global approach to constraining the SMEFT.

- e.g. top quark data is excluded from the PDFs used in the global fit of *J. Ethier et. al, 2105.00006, SMEFiT*





R. Ball et. al, 2109.02653

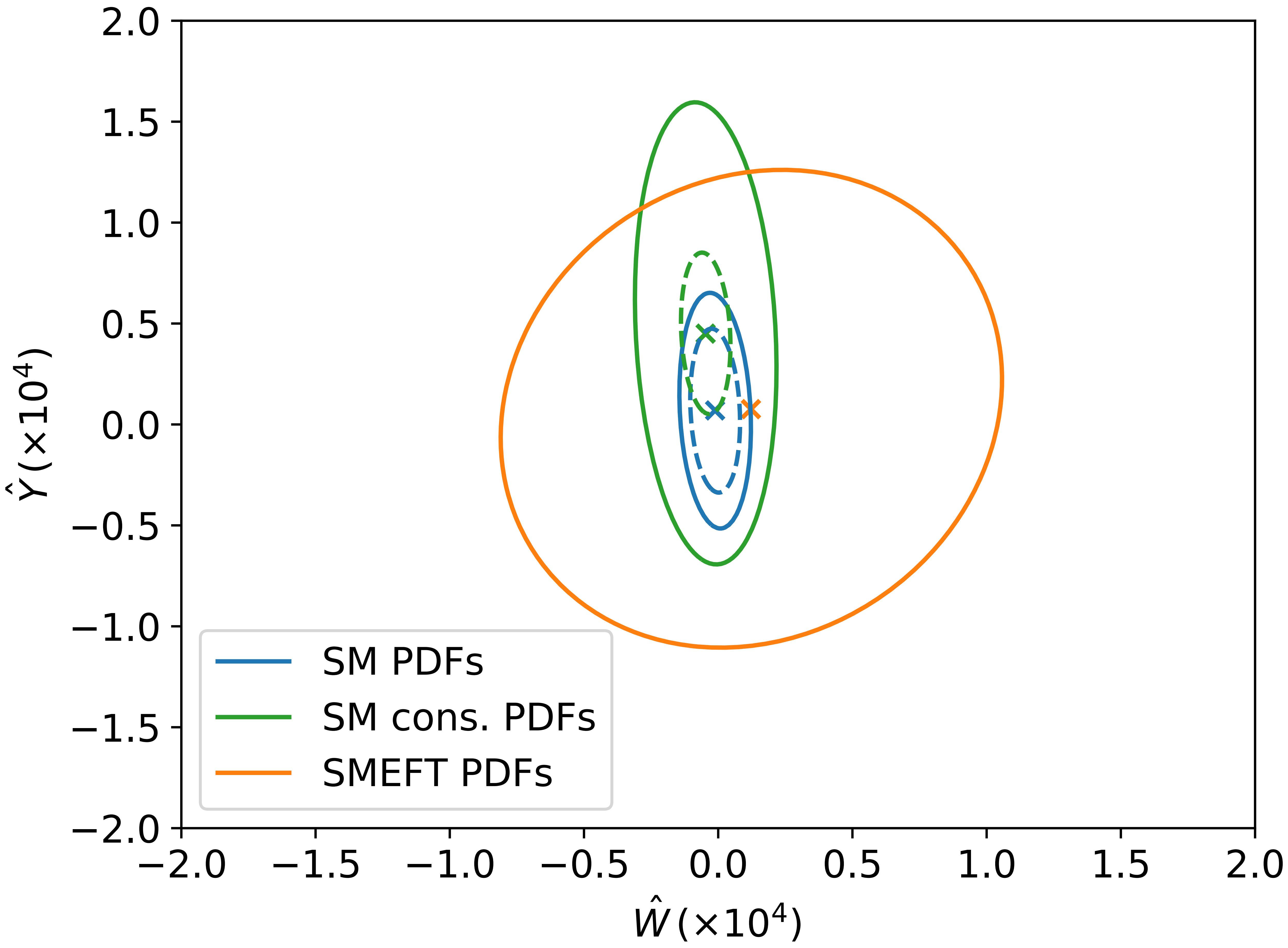
PDF-EFT interplay

Deep inelastic scattering, *Carrazza et al.: PRL 123 (2019) 13, 132001*

High mass Drell-Yan tails, *Greljo et. al 2104.02723*

Neglecting the PDF-EFT interplay may lead to a significant overestimate of the EFT constraints.

HL-LHC projections:



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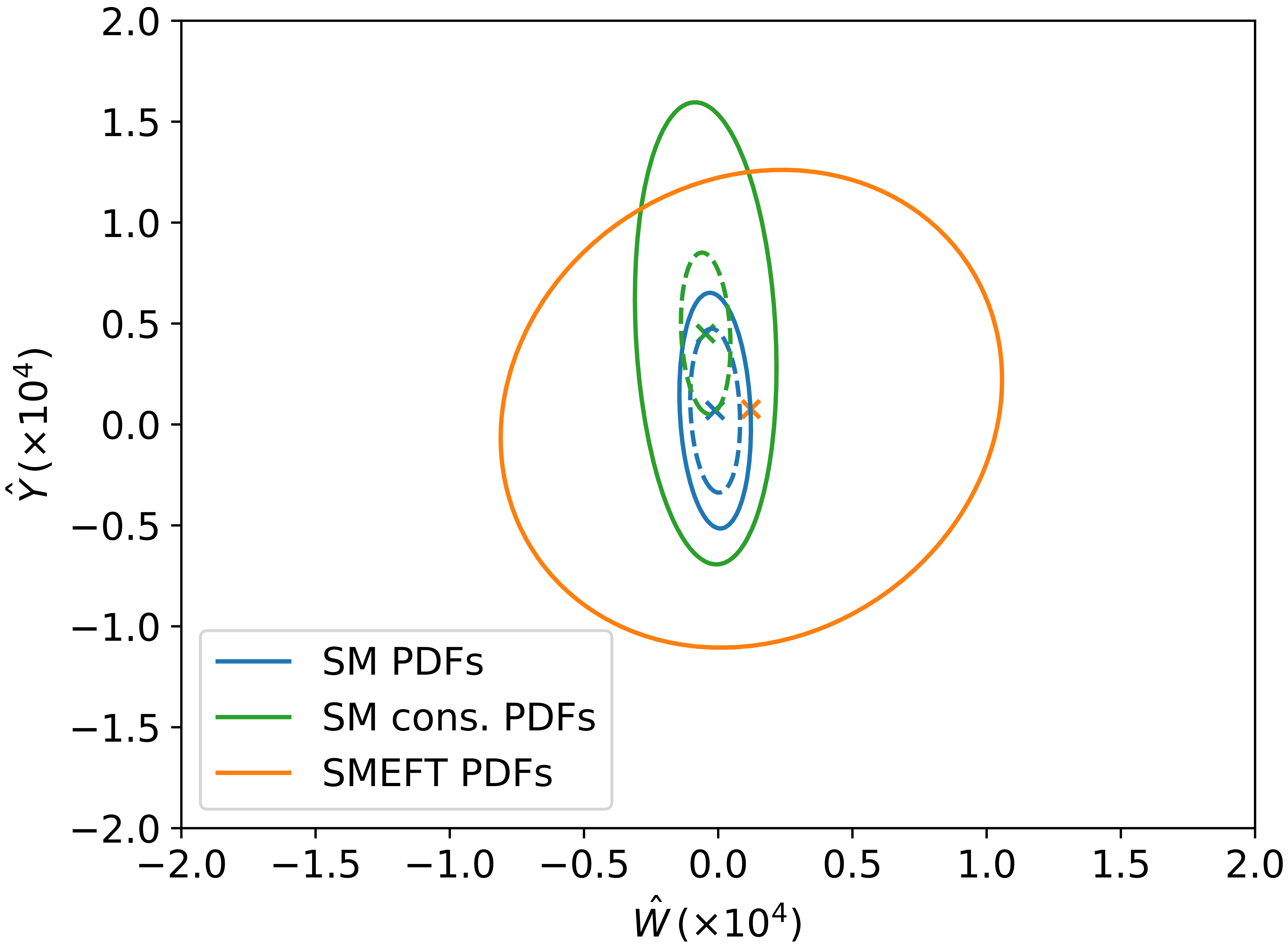

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→ **Next steps: top quark data**

PDF-EFT interplay **in the top sector**

Work in progress by Zahari Kassabov, MM, Luca Mantani, James Moore, Manuel Morales, Juan Rojo, Maria Ubiali

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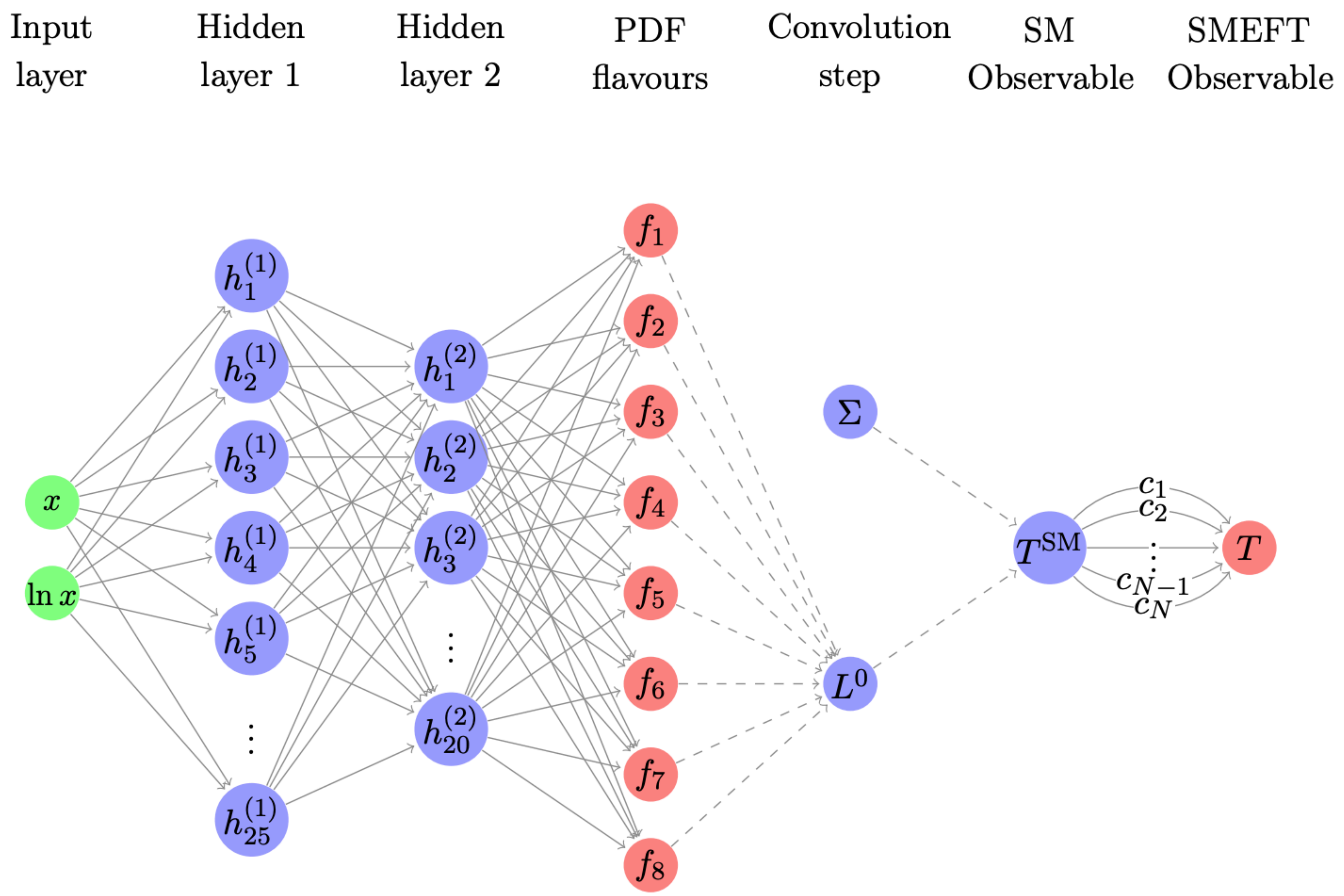
`SIMUnet` methodology

S. Iranipour, M. Ubiali - arXiv: 2201.07240



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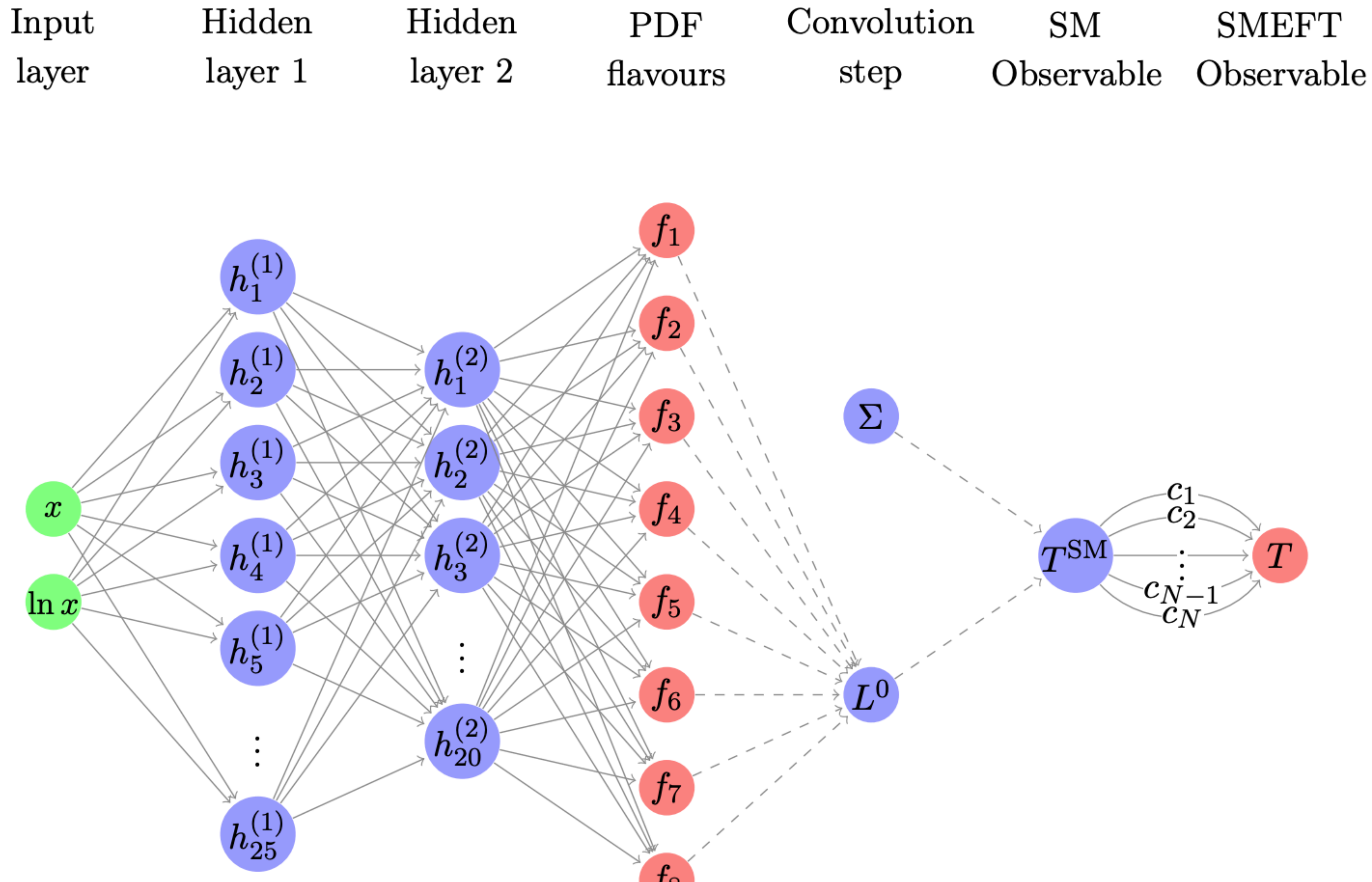
`SIMUnet` methodology
S. Iranipour, M. Ubiali - arXiv: 2201.07240

Data: 209 datapoints including LHC Run II measurements of $t\bar{t}$ incl. A_C and W_{hel}, $t\bar{t}V$, single top, tW, $t\bar{t}t\bar{t}$, $t\bar{t}b\bar{b}$

➡A superset of the measurements included in:

- NNPDF 4.0 2 *R. Ball et. al, 2109.02653*
- SMEFiT *J. Ethier et. al, 2105.00006*
- Fitmaker *J. Ellis et. al, 2012.02779*



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Preliminary:

- Individual fit to the operator $\mathcal{O}_{tG}$

- LO in QCD
- Linear in dimension-6 operators

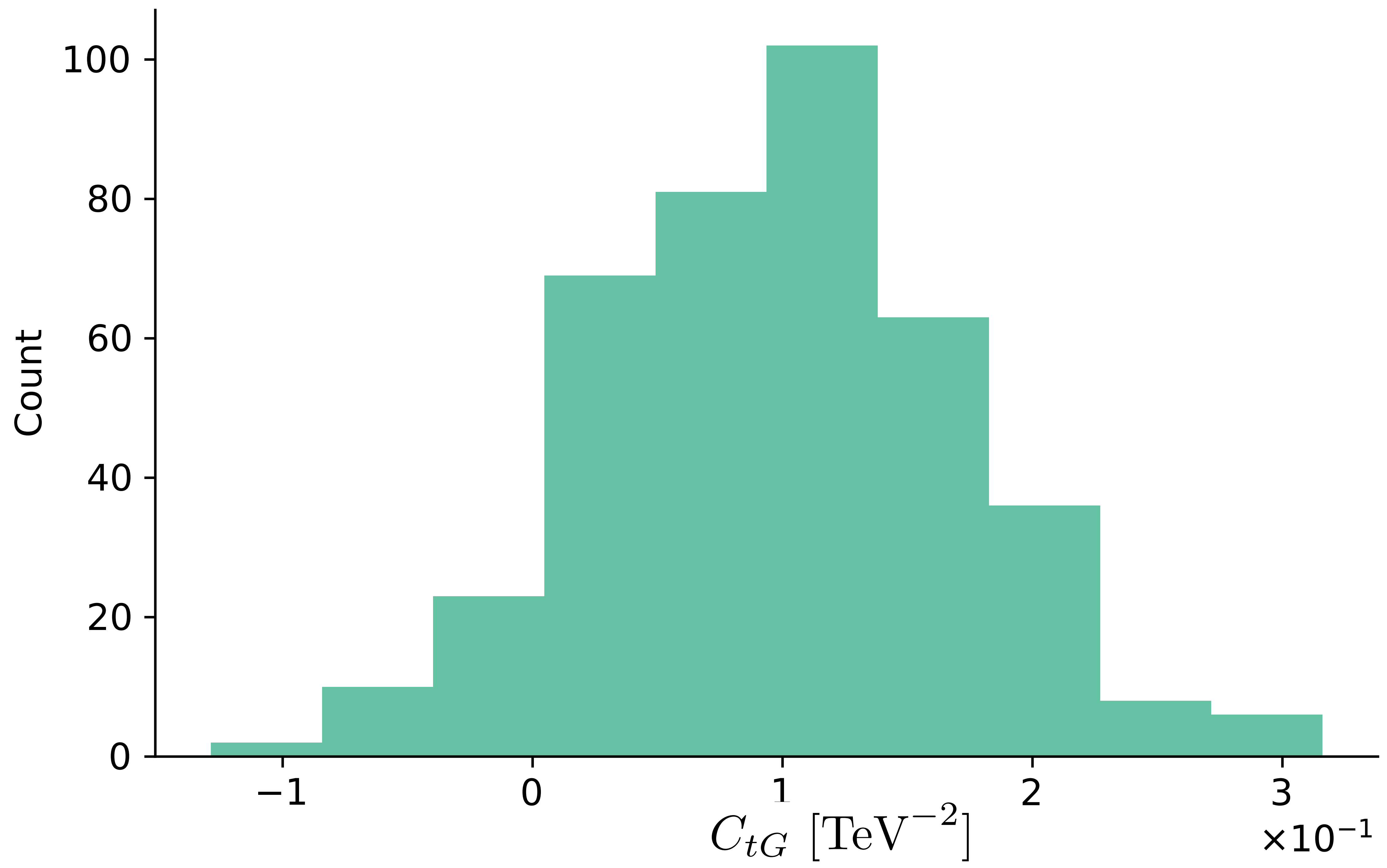
  (final fit will go to NLO in QCD and include quadratic contributions from dimension-6 SMEFT)

- Constraint:

$$C_{tG} \in [-0.045, 0.24]\ \mathrm{TeV}^{-2}$$

comparable with the constraints of 2105.00006, 2012.02779

Distribution for CtG coefficient



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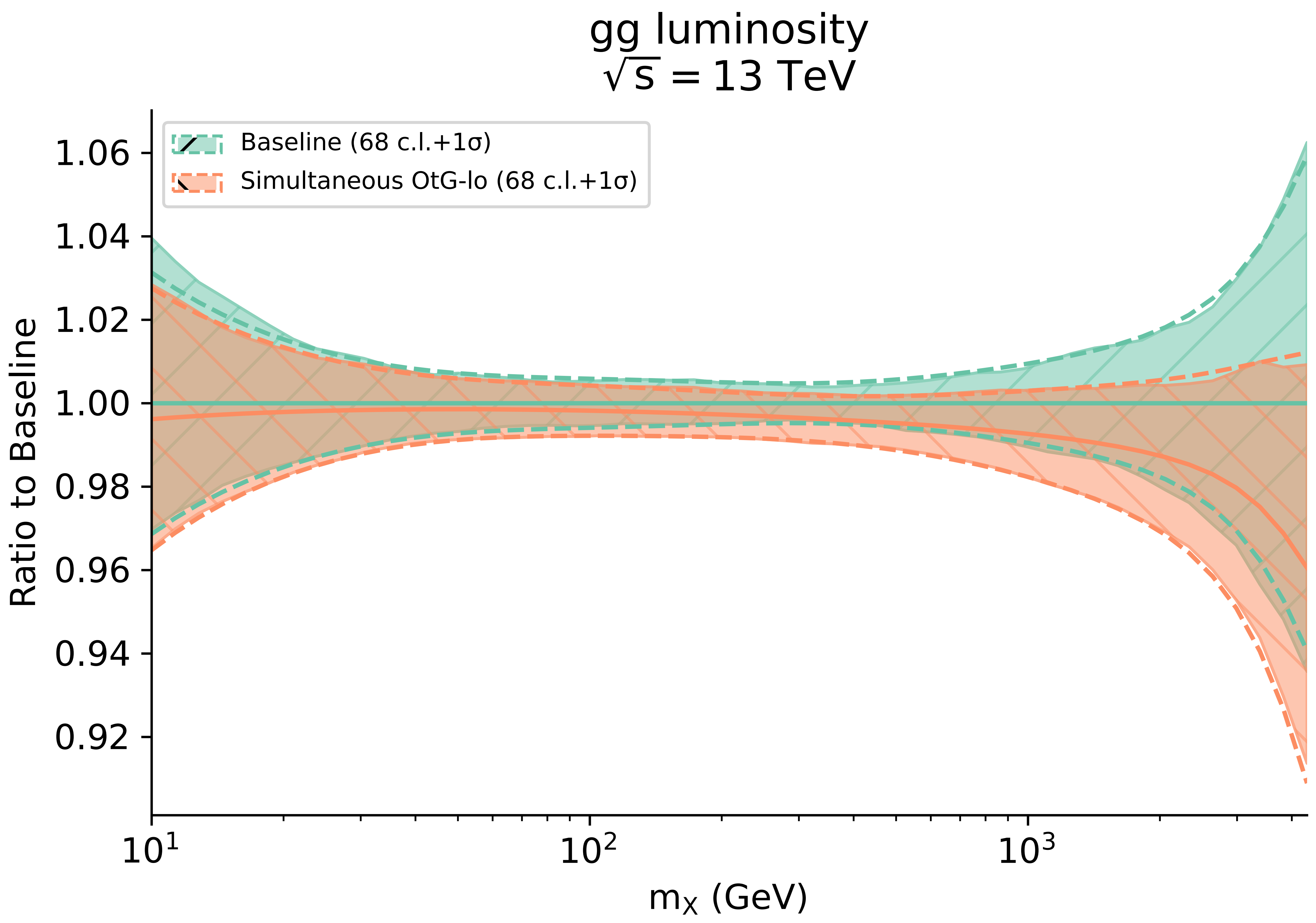
- Impact on PDFs:



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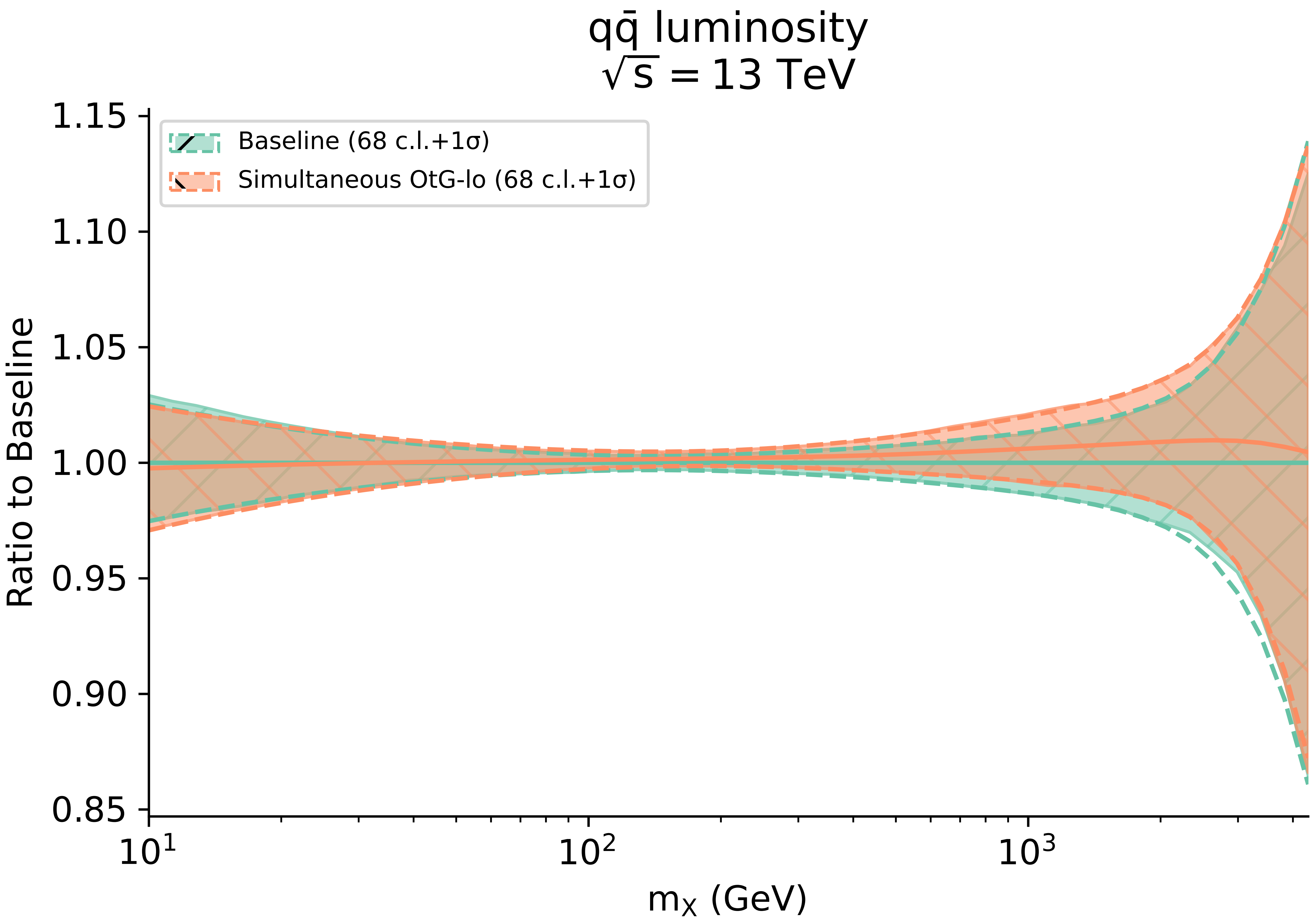

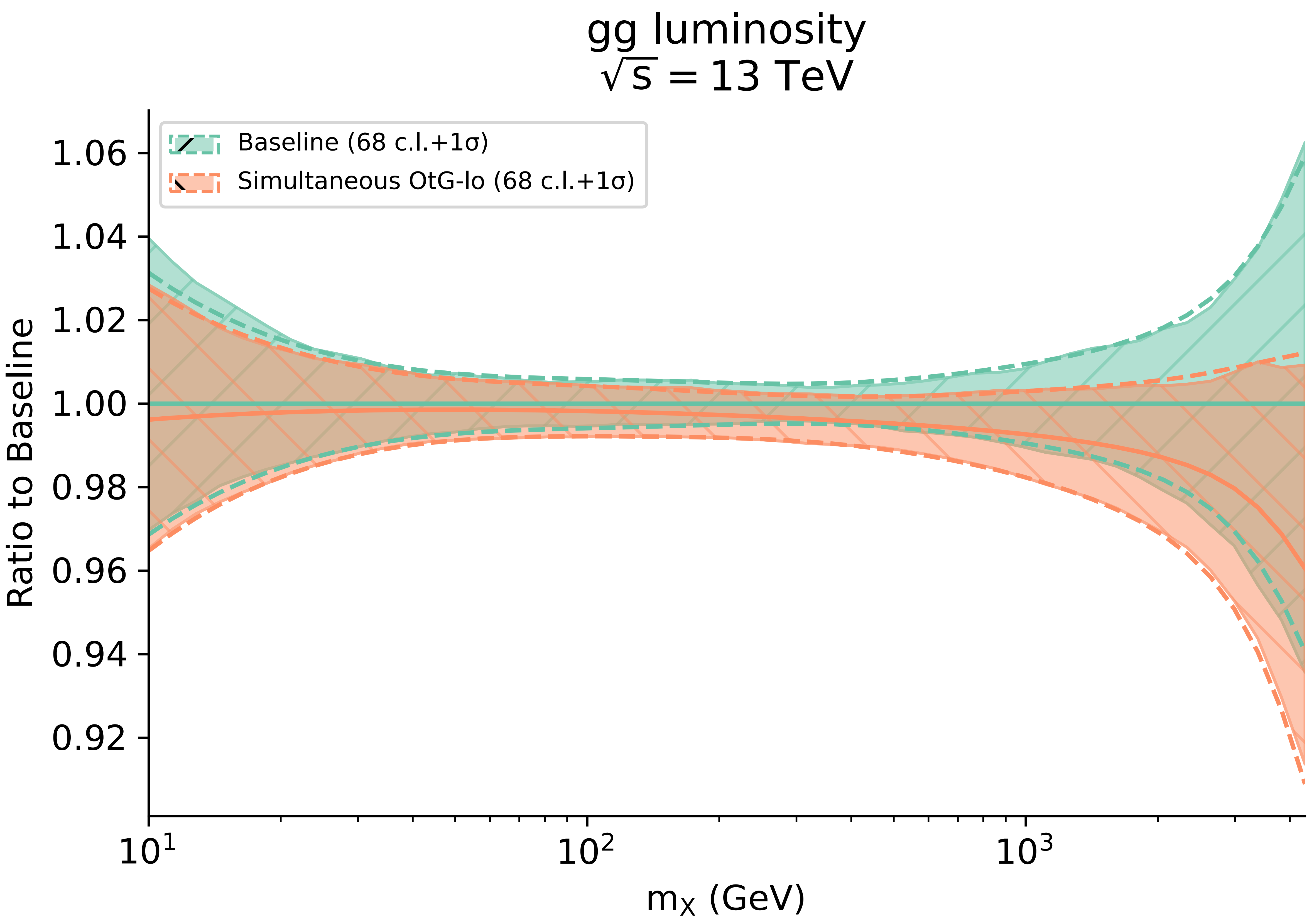

Conclusions

In a global interpretation of electroweak precision observables, Higgs, diboson, and top data in the dimension-6 SMEFT we see:

- Small but visible interplay between the Higgs and top sector
- Top quark data constraining some SMEFT operators operators to $\gtrsim 1$ TeV $\longrightarrow \mathcal{O}_{tG}, \mathcal{O}_{tW}$

By neglecting PDF-SMEFT interplay we have the potential to significantly overestimate SMEFT constraints.

- A dedicated simultaneous PDF-EFT fit in the top sector will quantify this - *to appear soon*
- Preliminary fits already indicate an impact on the gluon PDF

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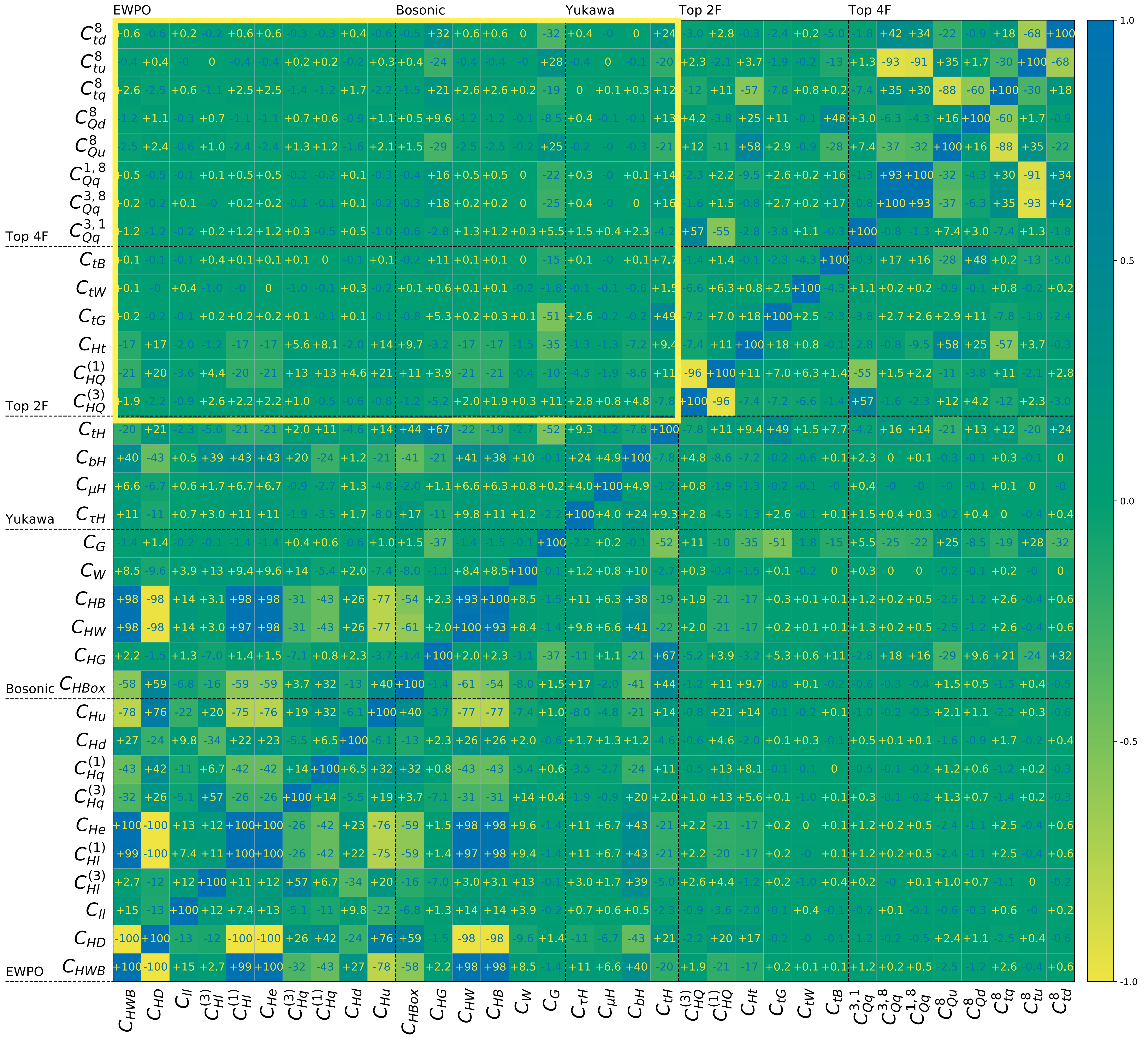
Thank you for listening!

Correlation matrix (%)

- Substantial correlations between EWPO, bosonic and Yukawa observables
- Substantial correlations within the top sector

Interplay between top and Higgs, diboson, EW:

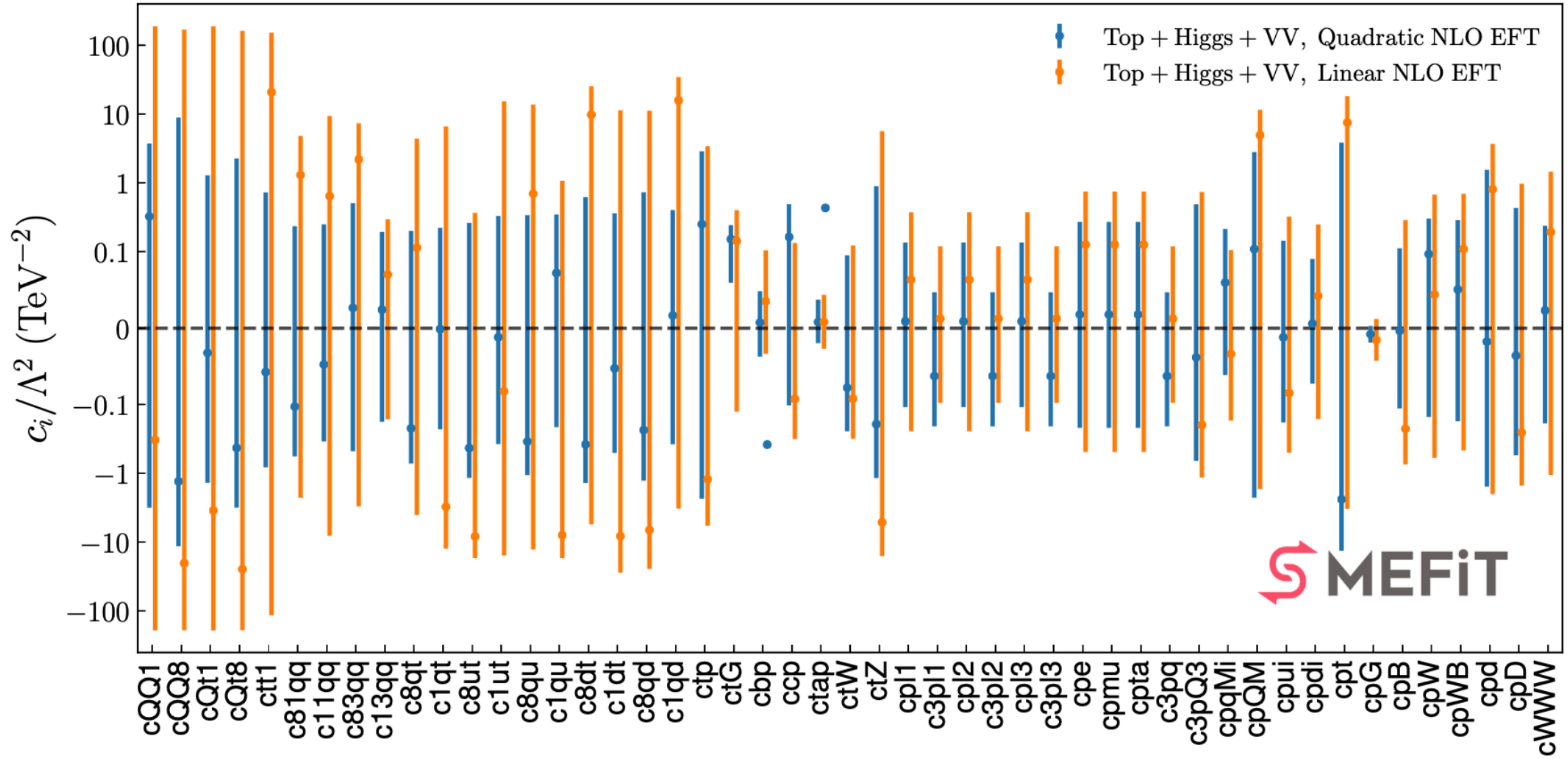
- 22 correlation coefficients with magnitude > 22% between these sectors



Quadratic contributions from dimension-6 SMEFT

The top sector is sensitive to the inclusion of $\mathcal{O}(\Lambda^{-4})$ contributions from dimension-6 operators.

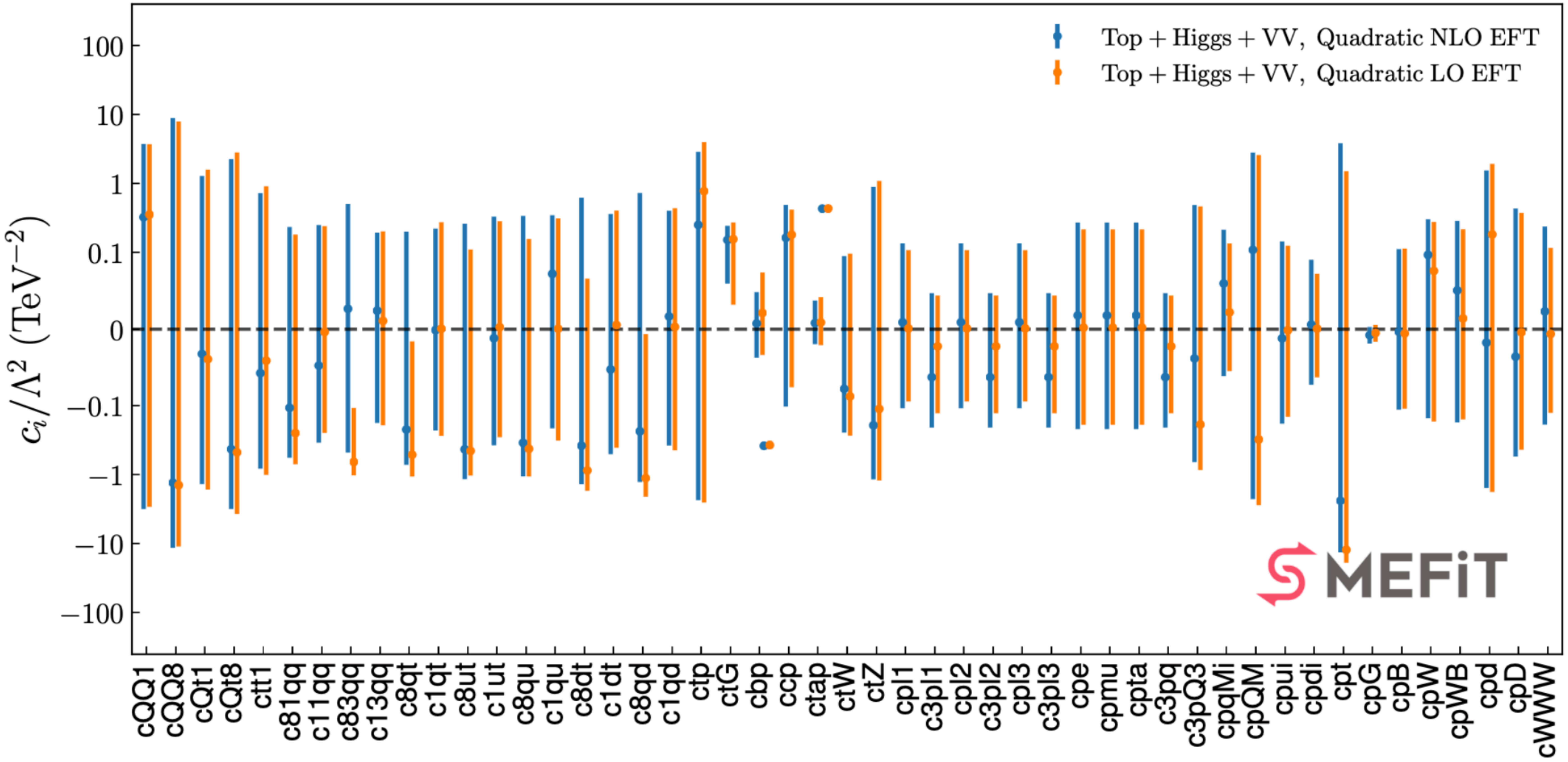
J. Ethier et. al, 2105.00006, SMEFiT

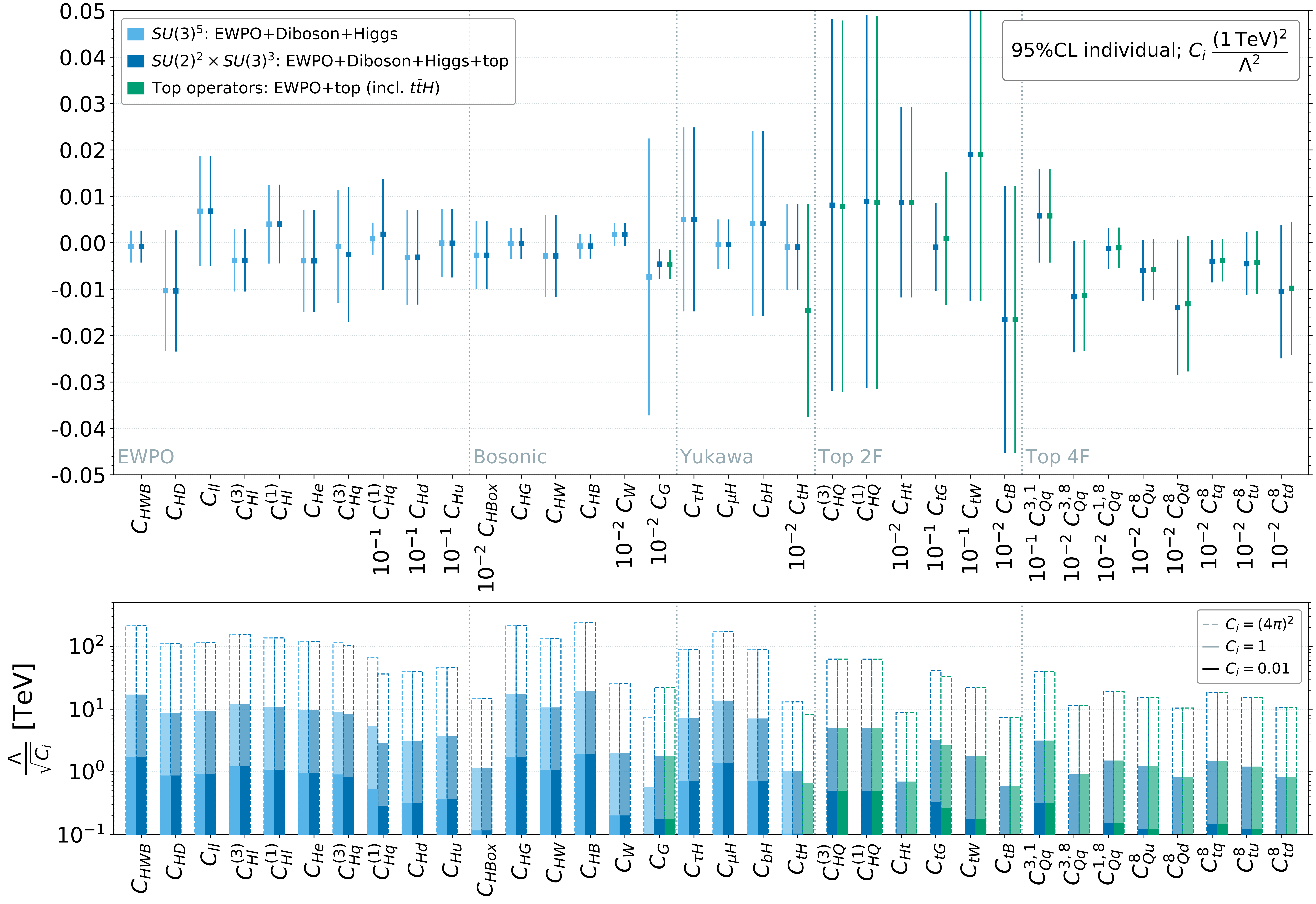


SMEFT at NLO in QCD in the top sector

Constraints in the top sector show improvement when SMEFT calculations are performed at NLO vs LO in QCD:

J. Ethier et. al, 2105.00006, SMEFiT





SU(3)^5: EWPO+Diboson+Higgs
SU(2)^2 × SU(3)^3: EWPO+Diboson+Higgs+top
Top operators: EWPO+top (incl. ttH)
95%CL individual; C_i (1 TeV)^2/Λ^2
EWPO
Bosonic
Yukawa
Top 2F
Top 4F
C_i = (4π)^2
C_i = 1
C_i = 0.01
Λ/√C_i [TeV]