

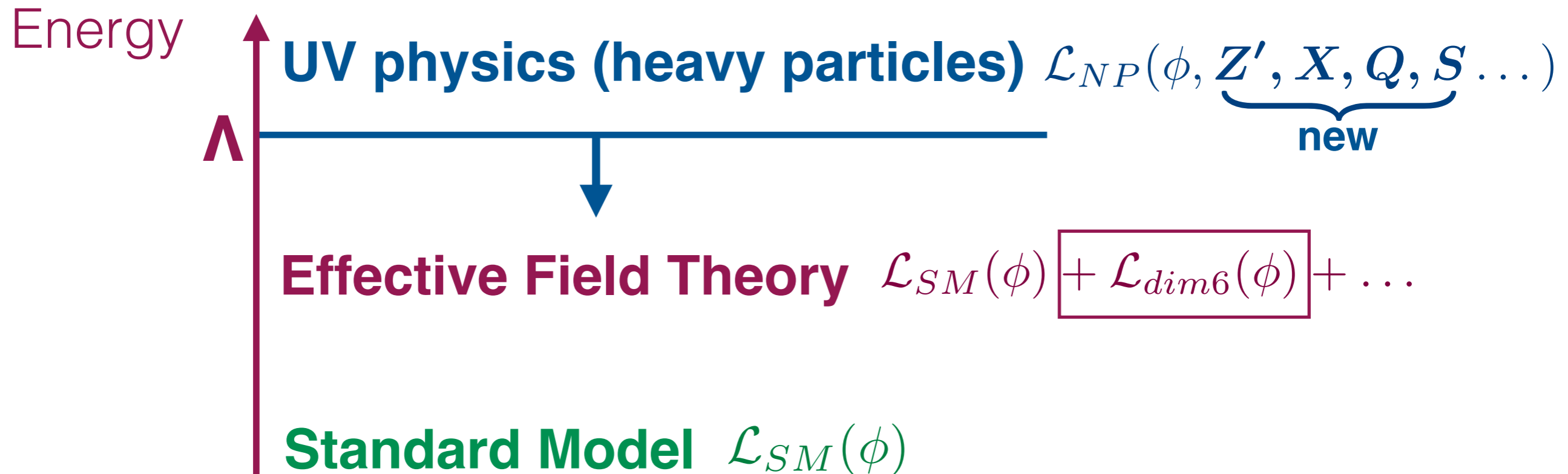
# Global EFT fits for future lepton colliders

Eleni Vryonidou  
University of Manchester



LCW2024  
9/7/2024

# Effective Field Theory



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

# EFT pathway to New Physics

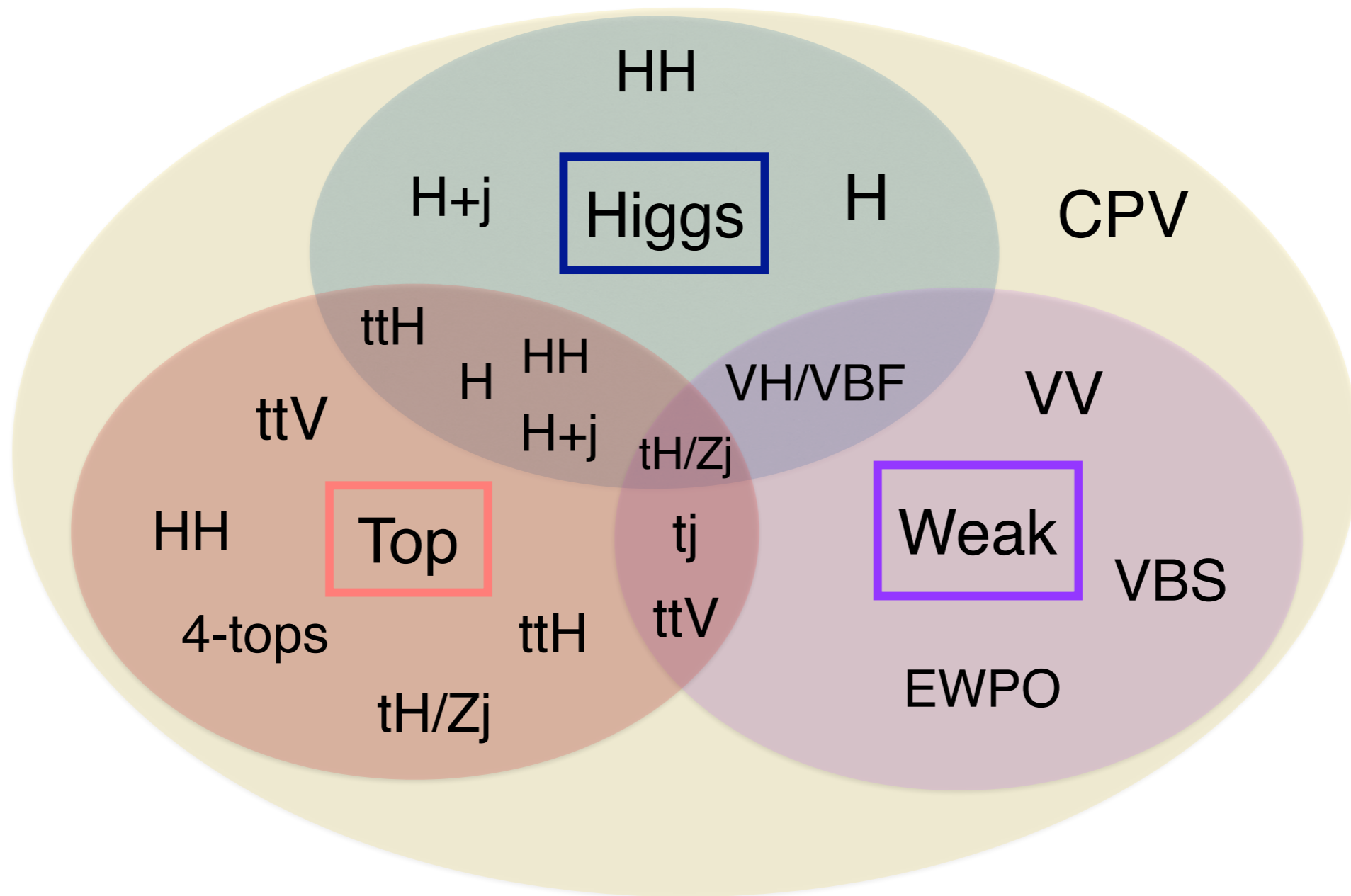
$$\Delta \text{Obs}_n = \text{Obs}_n^{\text{EXP}} - \text{Obs}_n^{\text{SM}} = \frac{1}{\Lambda^2} \sum_i c_i^6(\mu) a_{n,i}^6(\mu) + \mathcal{O}\left(\frac{1}{\Lambda^4}\right)$$

Precise experimental measurements

Precise SM predictions

Precise EFT predictions

# Global nature of EFT



Adapted from K. Mimasu

# Global fit Setup

## Theory

Accurate predictions for the SM and the EFT

SM: (N)NLO QCD + NLO EW

EFT: NLO QCD, linear and quadratics, with SMEFT@NLO NNPDF4.0 no top

## Experimental data

445 data points from: Higgs, top, diboson (LHC) & EWPO (LEP).

Inclusive and differential: mostly parton level

Experimental uncertainties and their correlations as provided by experiments



Giani, Magni, Rojo arXiv:2302.06660

## Methodology

Nested Sampling for quadratic fits

Analytic solution for linear fits

Faithful uncertainty estimate

Avoid under- and over-fitting, validated on pseudo-data (closure test)

## Output

Fit reports with bounds on coefficients, posterior distributions, PCA, Fisher information

Constraints on New Physics scale

Fit results can be used to bound specific UV complete models

# Experimental input

LEP &  
LHC

Category	Processes	$n_{\text{dat}}$	
		SMEFiT2.0	SMEFiT3.0
Top quark production	$t\bar{t} + X$	94	115
	$t\bar{t}Z, t\bar{t}W$	14	21
	$t\bar{t}\gamma$	-	2
	single top (inclusive)	27	28
	$tZ, tW$	9	13
	$t\bar{t}\bar{t}, t\bar{t}\bar{b}$	6	12
	<b>Total</b>	<b>150</b>	<b>191</b>
Higgs production and decay	Run I signal strengths	22	22
	Run II signal strengths	40	36 (*)
	Run II, differential distributions & STXS	35	71
	<b>Total</b>	<b>97</b>	<b>129</b>
Diboson production	LEP-2	40	40
	LHC	30	41
	<b>Total</b>	<b>70</b>	<b>81</b>
EWPOs	LEP-2	-	44
Baseline dataset	<b>Total</b>	<b>317</b>	<b>445</b>

SMEFiT3.0 Celada, Giani, Mantani, Rojo, Rossia, Thomas, EV, ter Hoeve arXiv:2404.12809

SMEFiT2.0: Ethier, Maltoni, Mantani, Nocera, Rojo, Slade, EV and Zhang arXiv:2105.00006

# Experimental input

LEP &  
LHC

Category	Processes	$n_{\text{dat}}$	
		SMEFIT2.0	SMEFIT3.0
Top quark production	$t\bar{t} + X$	94	115
	$t\bar{t}Z, t\bar{t}W$	14	21
	$t\bar{t}\gamma$	-	2
	single top (inclusive)	27	28
	$tZ, tW$	9	13
	$t\bar{t}\bar{t}, t\bar{t}\bar{b}$	6	12
	<b>Total</b>	<b>150</b>	<b>191</b>
Higgs production and decay	Run I signal strengths	22	22
	Run II signal strengths	40	36 (*)
	Run II, differential distributions & STXS	35	71
	<b>Total</b>	<b>97</b>	<b>129</b>
Diboson production	LEP-2	40	40
	LHC	30	41
	<b>Total</b>	<b>70</b>	<b>81</b>
EWPOs	LEP-2	-	44
Baseline dataset	<b>Total</b>	<b>317</b>	<b>445</b>

SMEFIT3.0 Celada, Giani, Mantani, Rojo, Rossia, Thomas, EV, ter Hoeve arXiv:2404.12809

SMEFIT2.0: Ethier, Maltoni, Mantani, Nocera, Rojo, Slade, EV and Zhang arXiv:2105.00006

# Experimental input

LEP &  
LHC

Category	Processes	$n_{\text{dat}}$	
		SMEFIT2.0	SMEFIT3.0
Top quark production	$t\bar{t} + X$	94	115
	$t\bar{t}Z, t\bar{t}W$	14	21
	$t\bar{t}\gamma$	-	2
	single top (inclusive)	27	28
	$tZ, tW$	9	13
	$t\bar{t}\bar{t}, t\bar{t}\bar{b}$	6	12
	<b>Total</b>	<b>150</b>	<b>191</b>
Higgs production and decay	Run I signal strengths	22	22
	Run II signal strengths	40	36 (*)
	Run II, differential distributions & STXS	35	71
	<b>Total</b>	<b>97</b>	<b>129</b>
Diboson production	LEP-2	40	40
	LHC	30	41
	<b>Total</b>	<b>70</b>	<b>81</b>
EWPOs	LEP-2	-	44
Baseline dataset	<b>Total</b>	<b>317</b>	<b>445</b>

SMEFIT3.0 Celada, Giani, Mantani, Rojo, Rossia, Thomas, EV, ter Hoeve arXiv:2404.12809

SMEFIT2.0: Ethier, Maltoni, Mantani, Nocera, Rojo, Slade, EV and Zhang arXiv:2105.00006



# Which operators?

Flavour assumption:

$$U(2)_q \times U(3)_d \times U(2)_u \times (U(1)_\ell \times U(1)_e)^3 \quad + \text{Yukawa of bottom, charm and tau}$$

Operator	Coefficient	Definition	Operator	Coefficient	Definition
3rd generation quarks					
$\mathcal{O}_{\varphi Q}^{(1)}$	$c_{\varphi Q}^{(1)}$ (*)	$i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi)(\bar{Q} \gamma^\mu Q)$	$\mathcal{O}_{tW}$	$c_{tW}$	$i(\bar{Q} \tau^{\mu\nu} \tau_I t) \tilde{\varphi} W_{\mu\nu}^I + \text{h.c.}$
$\mathcal{O}_{\varphi Q}^{(3)}$	$c_{\varphi Q}^{(3)}$	$i(\varphi^\dagger \overleftrightarrow{D}_\mu \tau_I \varphi)(\bar{Q} \gamma^\mu \tau^I Q)$	$\mathcal{O}_{tB}$	$c_{tB}$ (*)	$i(\bar{Q} \tau^{\mu\nu} t) \tilde{\varphi} B_{\mu\nu} + \text{h.c.}$
$\mathcal{O}_{\varphi t}$	$c_{\varphi t}$	$i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi)(\bar{t} \gamma^\mu t)$	$\mathcal{O}_{tG}$	$c_{tG}$	$igs(\bar{Q} \tau^{\mu\nu} T_A t) \tilde{\varphi} G_{\mu\nu}^A + \text{h.c.}$
$\mathcal{O}_{t\varphi}$	$c_{t\varphi}$	$(\varphi^\dagger \varphi) \bar{Q} t \tilde{\varphi} + \text{h.c.}$	$\mathcal{O}_{b\varphi}$	$c_{b\varphi}$	$(\varphi^\dagger \varphi) \bar{Q} b \varphi + \text{h.c.}$
1st, 2nd generation quarks					
$\mathcal{O}_{\varphi q}^{(1)}$	$c_{\varphi q}^{(1)}$ (*)	$\sum_{i=1,2} i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi)(\bar{q}_i \gamma^\mu q_i)$	$\mathcal{O}_{\varphi d}$	$c_{\varphi d}$	$\sum_{i=1,2,3} i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi)(\bar{d}_i \gamma^\mu d_i)$
$\mathcal{O}_{\varphi q}^{(3)}$	$c_{\varphi q}^{(3)}$	$\sum_{i=1,2} i(\varphi^\dagger \overleftrightarrow{D}_\mu \tau_I \varphi)(\bar{q}_i \gamma^\mu \tau^I q_i)$	$\mathcal{O}_{c\varphi}$	$c_{c\varphi}$	$(\varphi^\dagger \varphi) \bar{q}_2 c \tilde{\varphi} + \text{h.c.}$
$\mathcal{O}_{\varphi u}$	$c_{\varphi u}$	$\sum_{i=1,2} i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi)(\bar{u}_i \gamma^\mu u_i)$			
two-leptons					
$\mathcal{O}_{\varphi \ell_i}$	$c_{\varphi \ell_i}$	$i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi)(\bar{\ell}_i \gamma^\mu \ell_i)$	$\mathcal{O}_{\varphi \mu}$	$c_{\varphi \mu}$	$i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi)(\bar{\mu} \gamma^\mu \mu)$
$\mathcal{O}_{\varphi \ell_i}^{(3)}$	$c_{\varphi \ell_i}^{(3)}$	$i(\varphi^\dagger \overleftrightarrow{D}_\mu \tau_I \varphi)(\bar{\ell}_i \gamma^\mu \tau^I \ell_i)$	$\mathcal{O}_{\varphi \tau}$	$c_{\varphi \tau}$	$i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi)(\bar{\tau} \gamma^\mu \tau)$
$\mathcal{O}_{\varphi e}$	$c_{\varphi e}$	$i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi)(\bar{e} \gamma^\mu e)$	$\mathcal{O}_{\tau\varphi}$	$c_{\tau\varphi}$	$(\varphi^\dagger \varphi) \bar{\ell}_3 \tau \varphi + \text{h.c.}$
four-leptons					
$\mathcal{O}_{\ell\ell}$	$c_{\ell\ell}$	$(\bar{\ell}_1 \gamma_\mu \ell_2)(\bar{\ell}_2 \gamma^\mu \ell_1)$			

DoF	Definition (in Warsaw basis notation)	DoF	Definition (in Warsaw basis notation)
$c_{QQ}^1$	$2c_{qq}^{1(3333)} - \frac{2}{3}c_{qq}^{3(3333)}$	$c_{QQ}^8$	$8c_{qq}^{3(3333)}$
$c_{Qt}^1$	$c_{qu}^{1(3333)}$	$c_{Qt}^8$	$8c_{qu}^{3(3333)}$
$c_{Qq}^{1,8}$	$c_{qq}^{1(ii33)} + 3c_{qq}^{3(ii33)}$	$c_{Qq}^{1,1}$	$c_{qq}^{1(ii33)} + \frac{1}{6}c_{qq}^{1(ii33)} + \frac{1}{2}c_{qq}^{3(ii33)}$
$c_{Qq}^{3,8}$	$c_{qq}^{1(ii33)} - c_{qq}^{3(ii33)}$	$c_{Qq}^{3,1}$	$c_{qq}^{3(ii33)} + \frac{1}{6}(c_{qq}^{1(ii33)} - c_{qq}^{3(ii33)})$
$c_{tq}^8$	$c_{qu}^{8(ii33)}$	$c_{tq}^1$	$c_{qu}^{1(ii33)}$
$c_{tu}^8$	$2c_{uu}^{(ii33)}$	$c_{tu}^1$	$c_{uu}^{(ii33)} + \frac{1}{3}c_{uu}^{(ii33)}$
$c_{Qu}^8$	$c_{qu}^{8(33ii)}$	$c_{Qu}^1$	$c_{qu}^{1(33ii)}$
$c_{td}^8$	$c_{ud}^{8(33jj)}$	$c_{td}^1$	$c_{ud}^{1(33jj)}$
$c_{Qd}^8$	$c_{qd}^{8(33jj)}$	$c_{Qd}^1$	$c_{qd}^{1(33jj)}$

Operator	Coefficient	Definition	Operator	Coefficient	Definition
$\mathcal{O}_{\varphi G}$	$c_{\varphi G}$	$(\varphi^\dagger \varphi) G_A^{\mu\nu} G_{\mu\nu}^A$	$\mathcal{O}_{\varphi \square}$	$c_{\varphi \square}$	$\partial_\mu(\varphi^\dagger \varphi) \partial^\mu(\varphi^\dagger \varphi)$
$\mathcal{O}_{\varphi B}$	$c_{\varphi B}$	$(\varphi^\dagger \varphi) B^{\mu\nu} B_{\mu\nu}$	$\mathcal{O}_{\varphi D}$	$c_{\varphi D}$	$(\varphi^\dagger D^\mu \varphi)^\dagger (\varphi^\dagger D_\mu \varphi)$
$\mathcal{O}_{\varphi W}$	$c_{\varphi W}$	$(\varphi^\dagger \varphi) W_I^{\mu\nu} W_{\mu\nu}^I$	$\mathcal{O}_W$	$c_{WWW}$	$\epsilon_{IJK} W_{\mu\nu}^I W^{\nu\rho J} W_\rho^{K,\mu}$
$\mathcal{O}_{\varphi WB}$	$c_{\varphi WB}$	$(\varphi^\dagger \tau_I \varphi) B^{\mu\nu} W_{\mu\nu}^I$			

50 degrees of freedom

# Which operators?

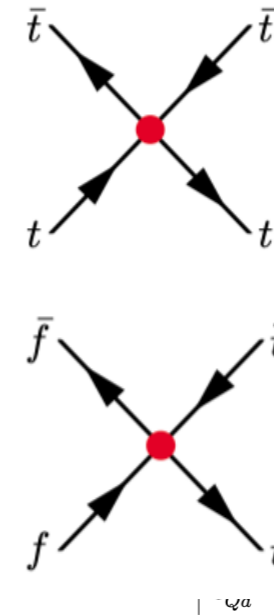
## Flavour assumption:

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

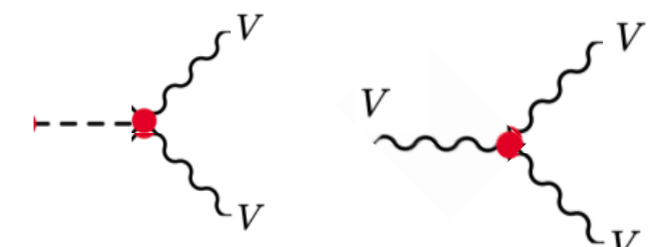
+ Yukawa of bottom, charm and tau

Operator	Coefficient	Definition	Operator	Coefficient	Definition
3rd generation quarks					
$\mathcal{O}_{\varphi Q}^{(1)}$	$c_{\varphi Q}^{(1)}$		$\tau_I t) \tilde{\varphi} W_{\mu\nu}^I + \text{h.c.}$		
$\mathcal{O}_{\varphi Q}^{(3)}$	$c_{\varphi Q}^{(3)}$		$t) \tilde{\varphi} B_{\mu\nu} + \text{h.c.}$		
$\mathcal{O}_{\varphi t}$	$c_{\varphi t}$		${}^{\mu\nu} T_A t) \tilde{\varphi} G_{\mu\nu}^A + \text{h.c.}$		
$\mathcal{O}_{t\varphi}$	$c_{t\varphi}$		$\bar{t} b \varphi + \text{h.c.}$		
$\mathcal{O}_{\varphi q}^{(1)}$	$c_{\varphi q}^{(1)}$ (*)	$\sum_{i=1,2} i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi) (\bar{q}_i \gamma^\mu q_i)$	$\mathcal{O}_{\varphi d}$	$c_{\varphi d}$	$\sum_{i=1,2,3} i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi) (\bar{d}_i \gamma^\mu d_i)$
$\mathcal{O}_{\varphi q}^{(3)}$	$c_{\varphi q}^{(3)}$	$\sum_{i=1,2} i(\varphi^\dagger \overleftrightarrow{D}_\mu \tau_I \varphi) (\bar{q}_i \gamma^\mu \tau^I q_i)$	$\mathcal{O}_{c\varphi}$	$c_{c\varphi}$	$(\varphi^\dagger \varphi) \bar{q}_2 c \tilde{\varphi} + \text{h.c.}$
$\mathcal{O}_{\varphi u}$	$c_{\varphi u}$	$\sum_{i=1,2} i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi) (\bar{f}_R \gamma^\mu f_L)$	$\mathcal{O}_{\tau\varphi}$	$c_{\tau\varphi}$	$(\varphi^\dagger \varphi) \bar{\ell}_3 \tau \varphi + \text{h.c.}$
$\mathcal{O}_{\varphi l_i}$	$c_{\varphi l_i}$	$i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi) (\bar{l}_i \gamma^\mu l_i)$			
$\mathcal{O}_{\varphi l_i}^{(3)}$	$c_{\varphi l_i}^{(3)}$	$i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi) (\bar{\tau} \gamma^\mu \tau)$			
$\mathcal{O}_{\varphi e}$	$c_{\varphi e}$	$i(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi) (e \gamma^\mu e)$			
four-leptons					
$\mathcal{O}_{\ell\ell}$	$c_{\ell\ell}$	$(\bar{l}_1 \gamma_\mu l_2) (\bar{l}_2 \gamma^\mu l_1)$			

DoF	Definition (in Warsaw)	Definition (in Warsaw basis notation)
$c_{QQ}^1$	$2c_{qq}^{1(3333)} - \frac{2}{3}c_{qq}^{3(3333)}$	$8c_{qq}^{3(3333)}$
$c_{Qt}^1$	$c_{qu}^{1(3333)}$	$8c_{qu}^{3(3333)}$
$c_{Qq}^{1,8}$	$c_{qq}^{1(ii33)} + 3c_{qq}^{3(ii33)}$	$c_{qq}^{1(ii33)} + \frac{1}{6}c_{qq}^{1(ii33)} + \frac{1}{2}c_{qq}^{3(ii33)}$
$c_{Qq}^{3,8}$	$c_{qq}^{1(ii33)} - c_{qq}^{3(ii33)}$	$c_{qq}^{3(ii33)} + \frac{1}{6}(c_{qq}^{1(ii33)} - c_{qq}^{3(ii33)})$
$c_{tq}^8$	$c_{qu}^{8(ii33)}$	$c_{qu}^{1(ii33)}$
$c_{tu}^8$	$2c_{uu}^{(ii33)}$	$c_{uu}^{(ii33)} + \frac{1}{3}c_{uu}^{(ii33)}$
$c_{Qu}^8$	$c_{qu}^{8(33ii)}$	$c_{qu}^{1(33ii)}$
$c_{td}^8$	$c_{ud}^{8(33jj)}$	$c_{ud}^{1(33jj)}$
$c_{Qd}^8$	$c_{qd}^{8(33jj)}$	$c_{qd}^{1(33jj)}$

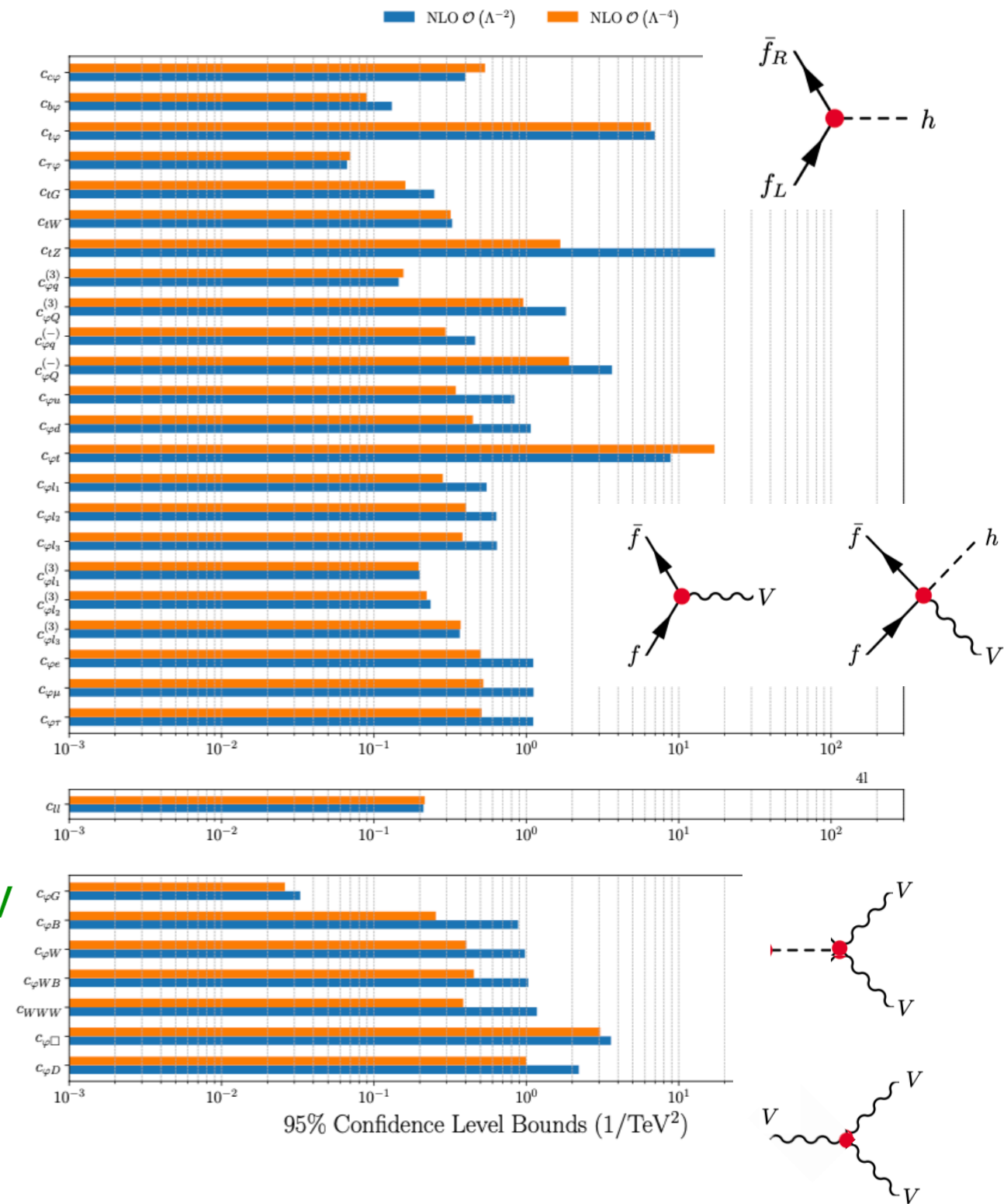
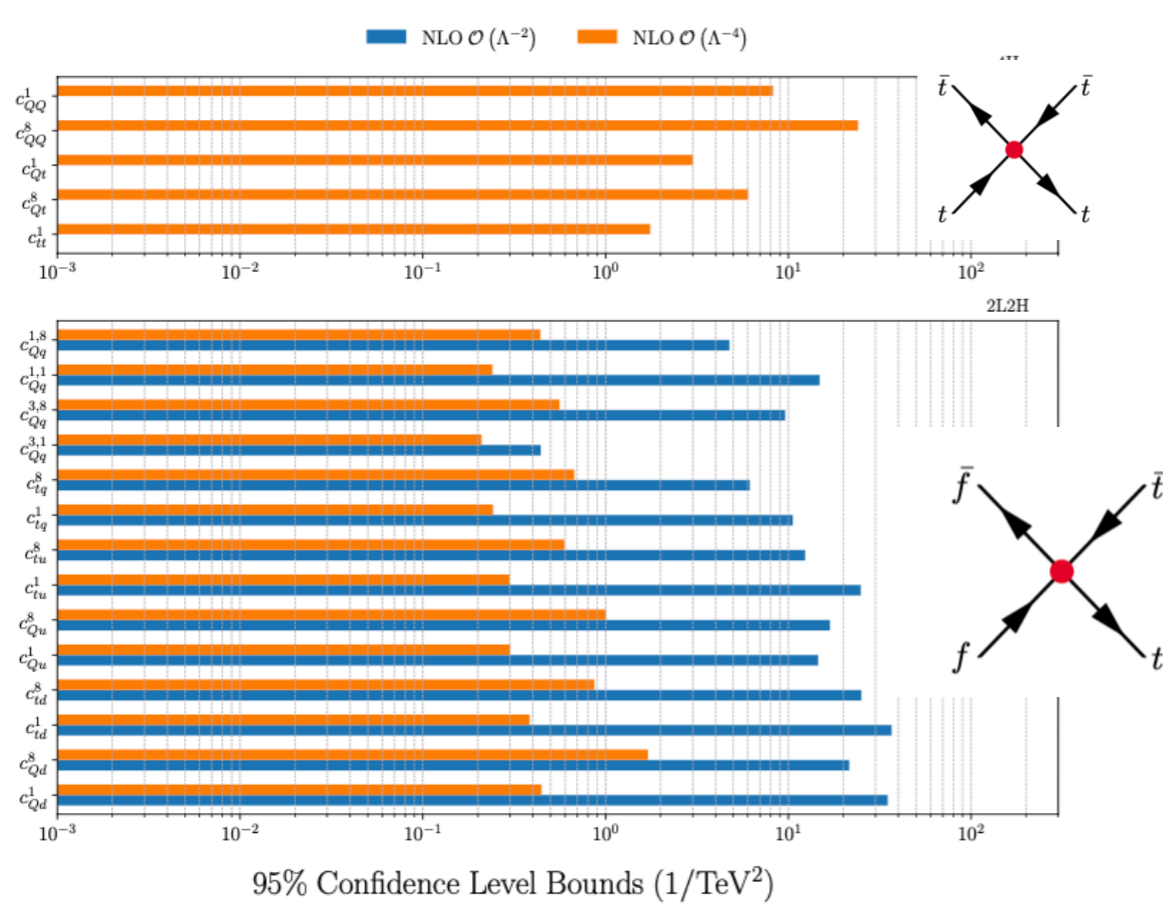


Operator	Coeff	Definition
$\mathcal{O}_{\varphi G}$	$c_{\varphi G}$	$\partial_\mu (\varphi^\dagger \varphi) \partial^\mu (\varphi^\dagger \varphi)$
$\mathcal{O}_{\varphi B}$	$c_{\varphi B}$	$(\varphi^\dagger D^\mu \varphi)^\dagger (\varphi^\dagger D_\mu \varphi)$
$\mathcal{O}_{\varphi W}$	$c_{\varphi W}$	$\epsilon_{IJK} W_{\mu\nu}^I W^{J,\nu\rho} W_\rho^{K,\mu}$
$\mathcal{O}_{\varphi WB}$	$c_{\varphi WB}$	



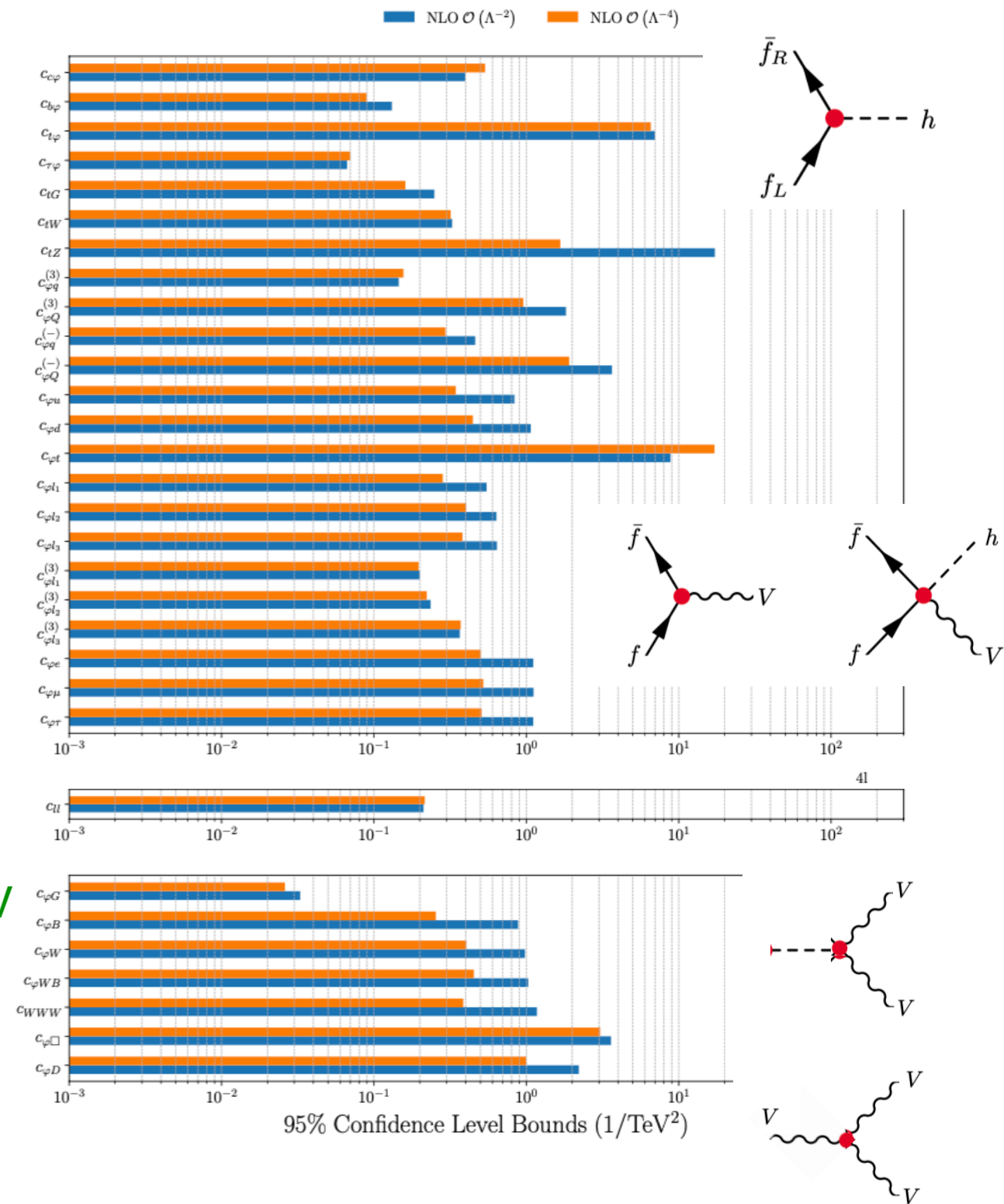
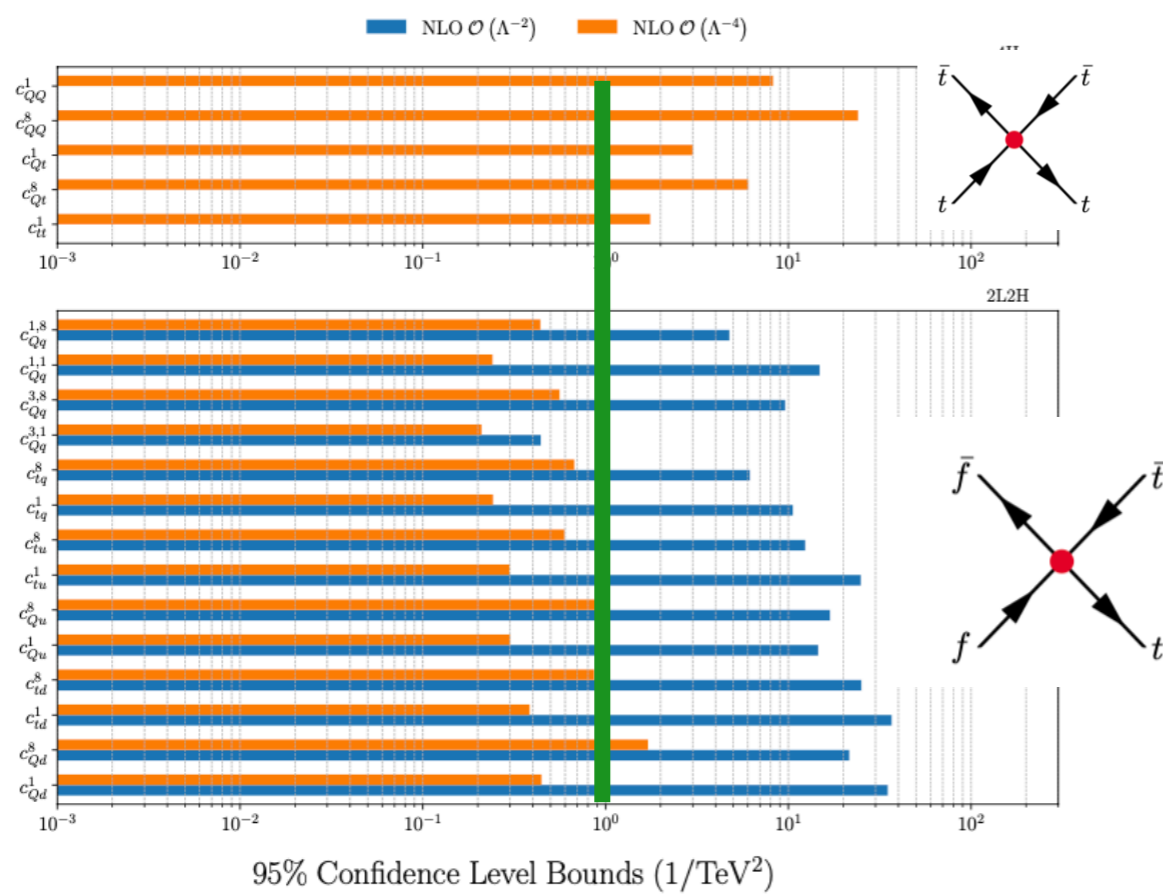
50 degrees of freedom

# Current global fit results



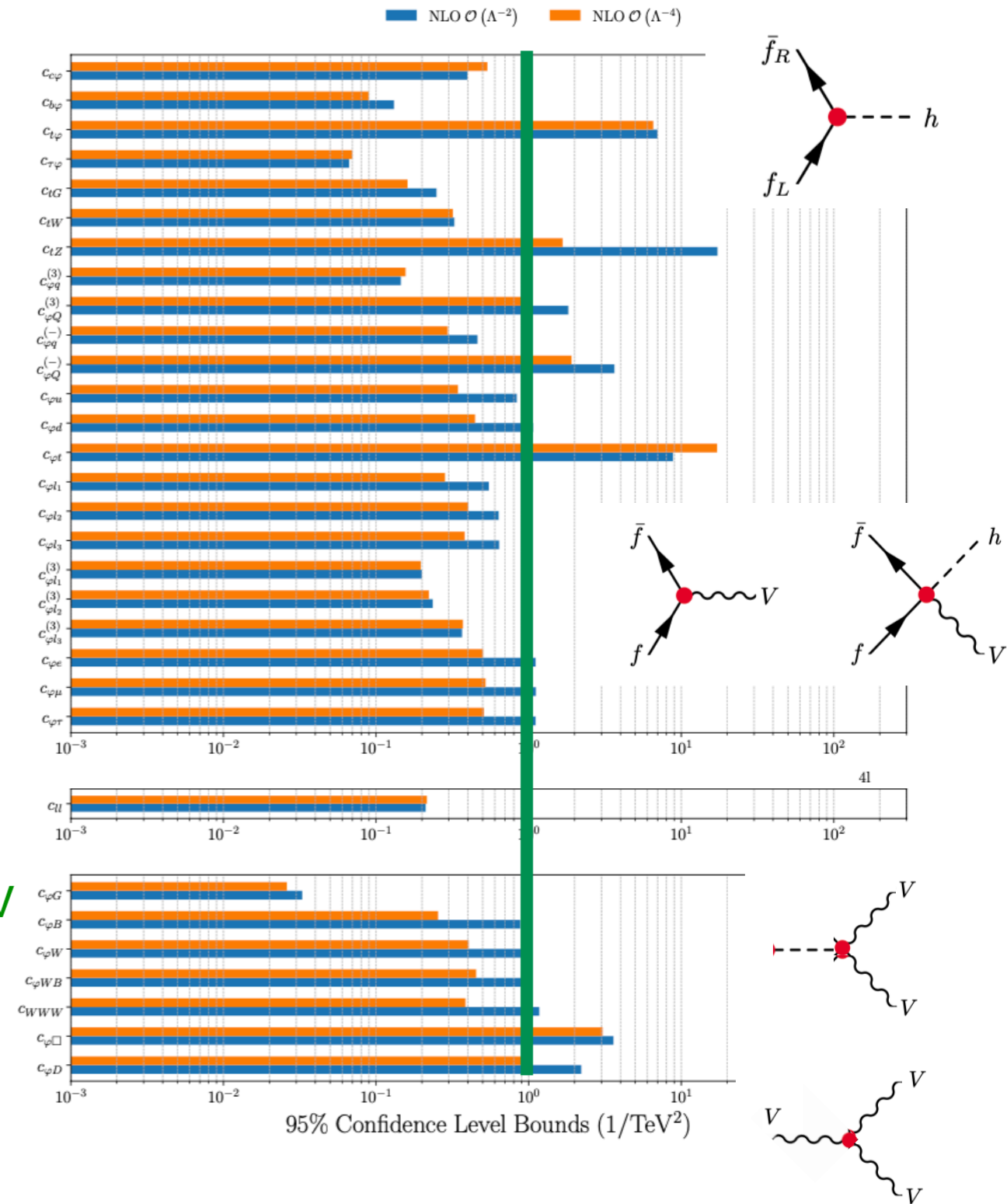
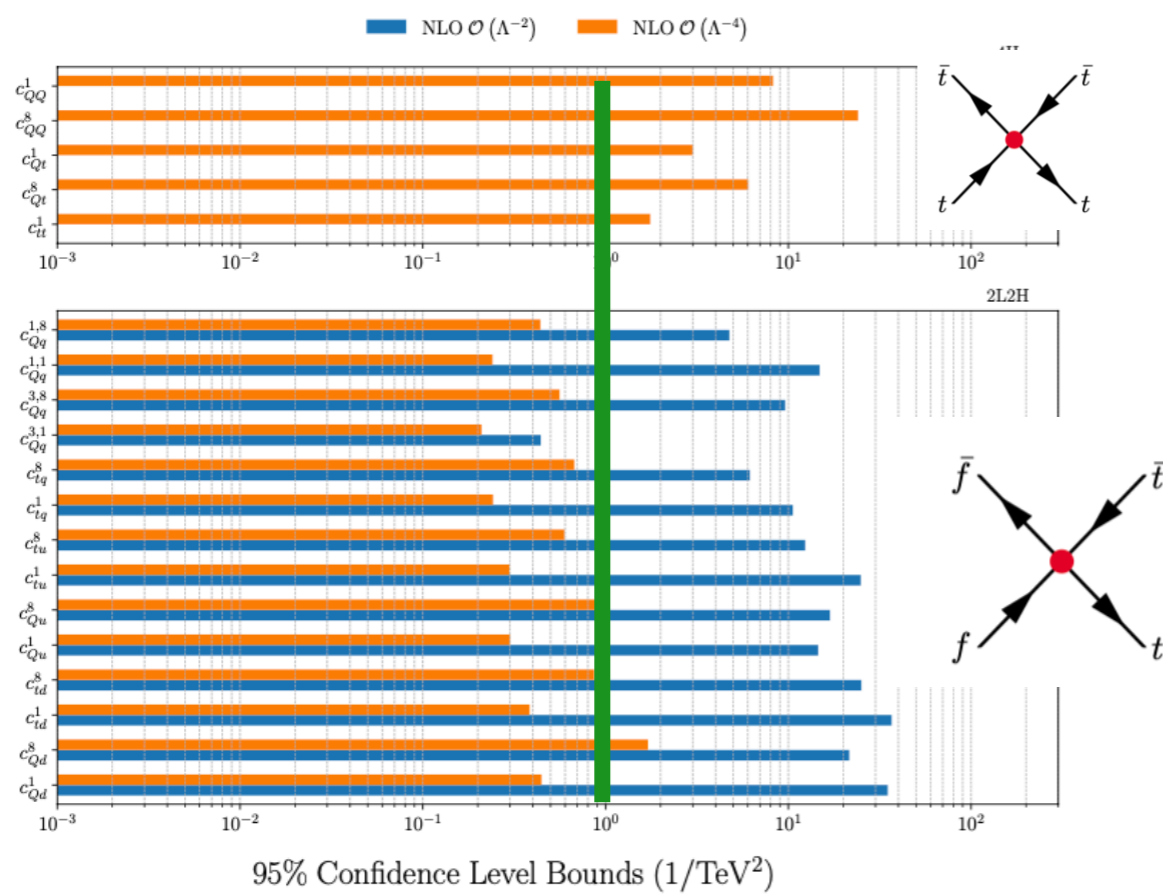
- Bounds varying between operators
- Most Wilson coefficient bounds **below 1 for  $\Lambda=1$  TeV**
- Quadratic terms important
- Least constrained coefficients are 4-top operators

# Current global fit results



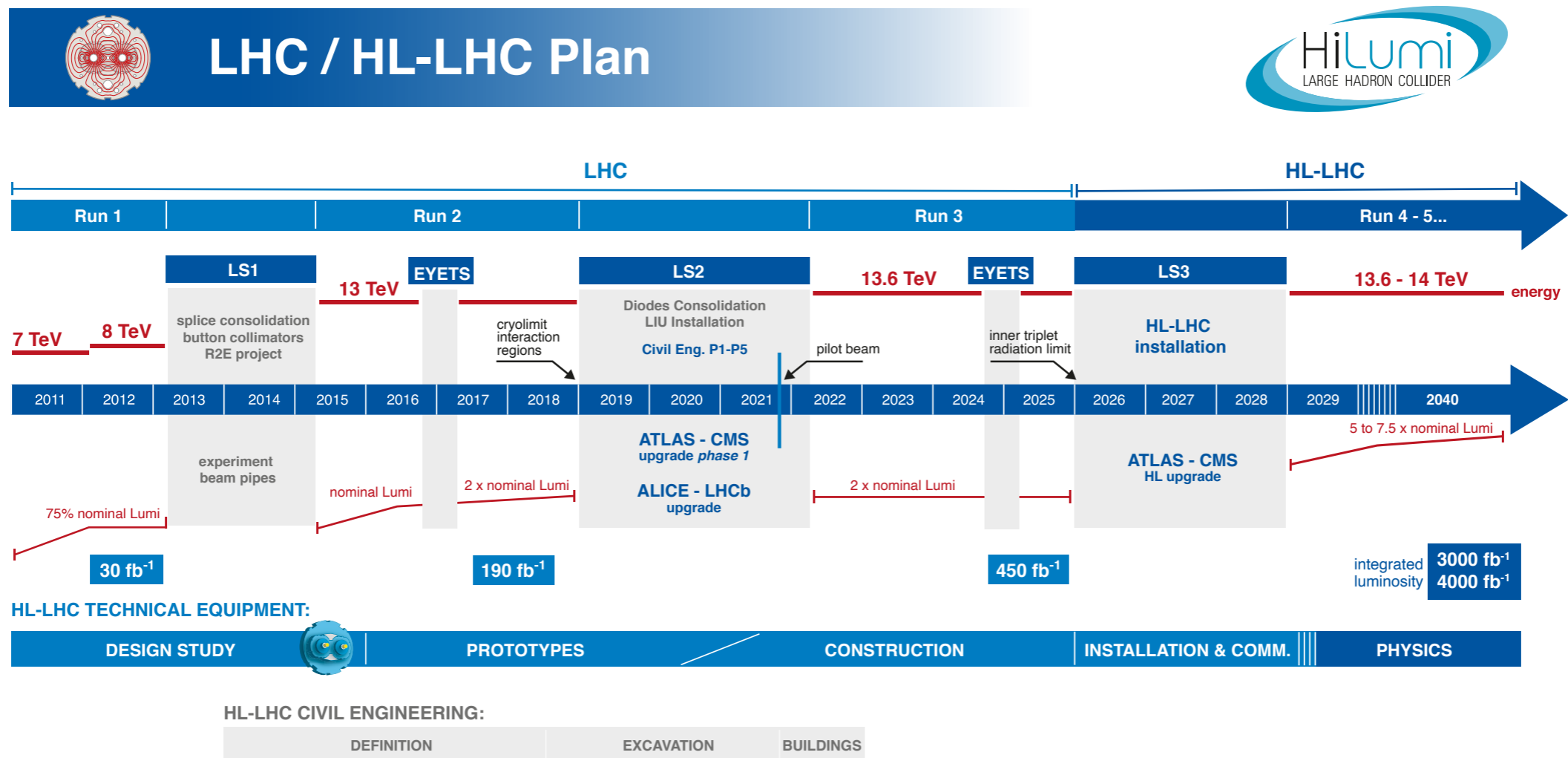
- Bounds varying between operators
- Most Wilson coefficient bounds **below 1 for  $\Lambda=1$  TeV**
- Quadratic terms important
- Least constrained coefficients are 4-top operators

# Current global fit results



- Bounds varying between operators
- Most Wilson coefficient bounds **below 1 for  $\Lambda=1$  TeV**
- Quadratic terms important
- Least constrained coefficients are 4-top operators

# How about the HL-LHC?

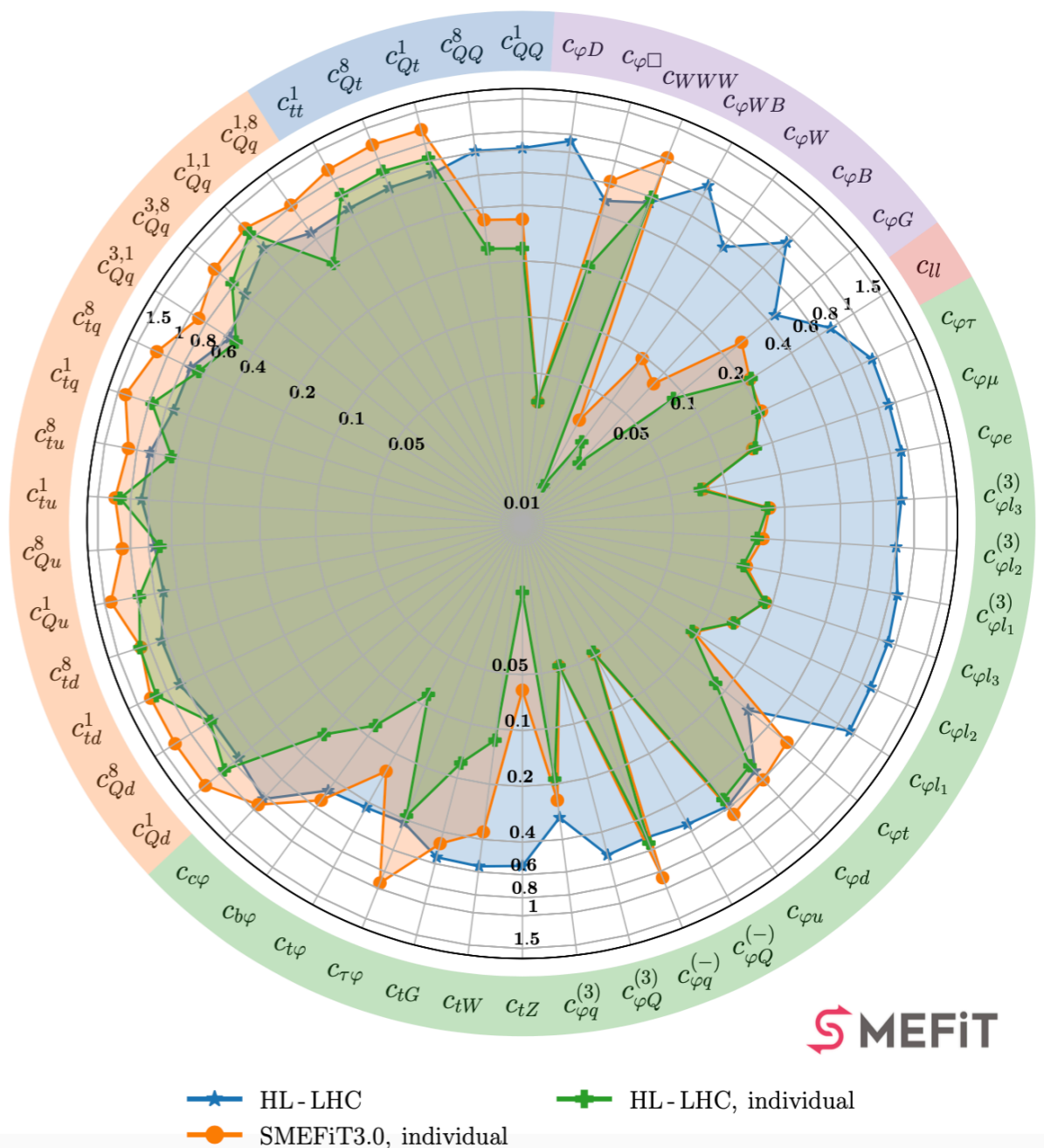


- HL-LHC will collect 3000ab<sup>-1</sup> over the next 20 years
- Any future project will come after that
- How will the constraints look at the end of the HL-LHC?

# Constraints at the HL-LHC

- We project all Run II datasets: one for each process and final state
- Scaling of uncertainties:
  - Statistical ones scaling with Luminosity
  - Systematics reduced by a factor of 2
- Explore relative improvement compared to current LHC fit
- We see an improvement ranging from 20% to a factor of 3 in the marginalised fit
- Improvement also through marginalisation
- No dedicated binning: Expect further improvement over LHC due to access to statistically limited high energy tails

Ratio of Uncertainties to SMEFiT3.0 Baseline,  $\mathcal{O}(\Lambda^{-4})$ , Marginalised



# The future





# The future



# Future circular lepton colliders



Energy ( $\sqrt{s}$ )	$\mathcal{L}_{\text{int}}$ (Run time)		$\mathcal{L}_{\text{FCC-ee}}/\mathcal{L}_{\text{CEPC}}$
	FCC-ee (4 IPs)	CEPC (2 IPs)	
91 GeV ( $Z$ -pole)	300 $\text{ab}^{-1}$ (4 years)	100 $\text{ab}^{-1}$ (2 years)	3
161 GeV ( $2m_W$ )	20 $\text{ab}^{-1}$ (2 years)	6 $\text{ab}^{-1}$ (1 year)	3.3
240 GeV	10 $\text{ab}^{-1}$ (3 years)	20 $\text{ab}^{-1}$ (10 years)	0.5
350 GeV	0.4 $\text{ab}^{-1}$ (1 year)	0.2 $\text{ab}^{-1}$	2
365 GeV ( $2m_t$ )	3 $\text{ab}^{-1}$ (4 years)	1 $\text{ab}^{-1}$ (5 years)	3

# Future Circular Colliders

## What will the FCC-ee measure?

- EWPOs at the Z-pole
- Light fermion pair prediction
- Higgsstrahlung and VBF
- W boson pair production
- Top-quark pair production (365GeV)

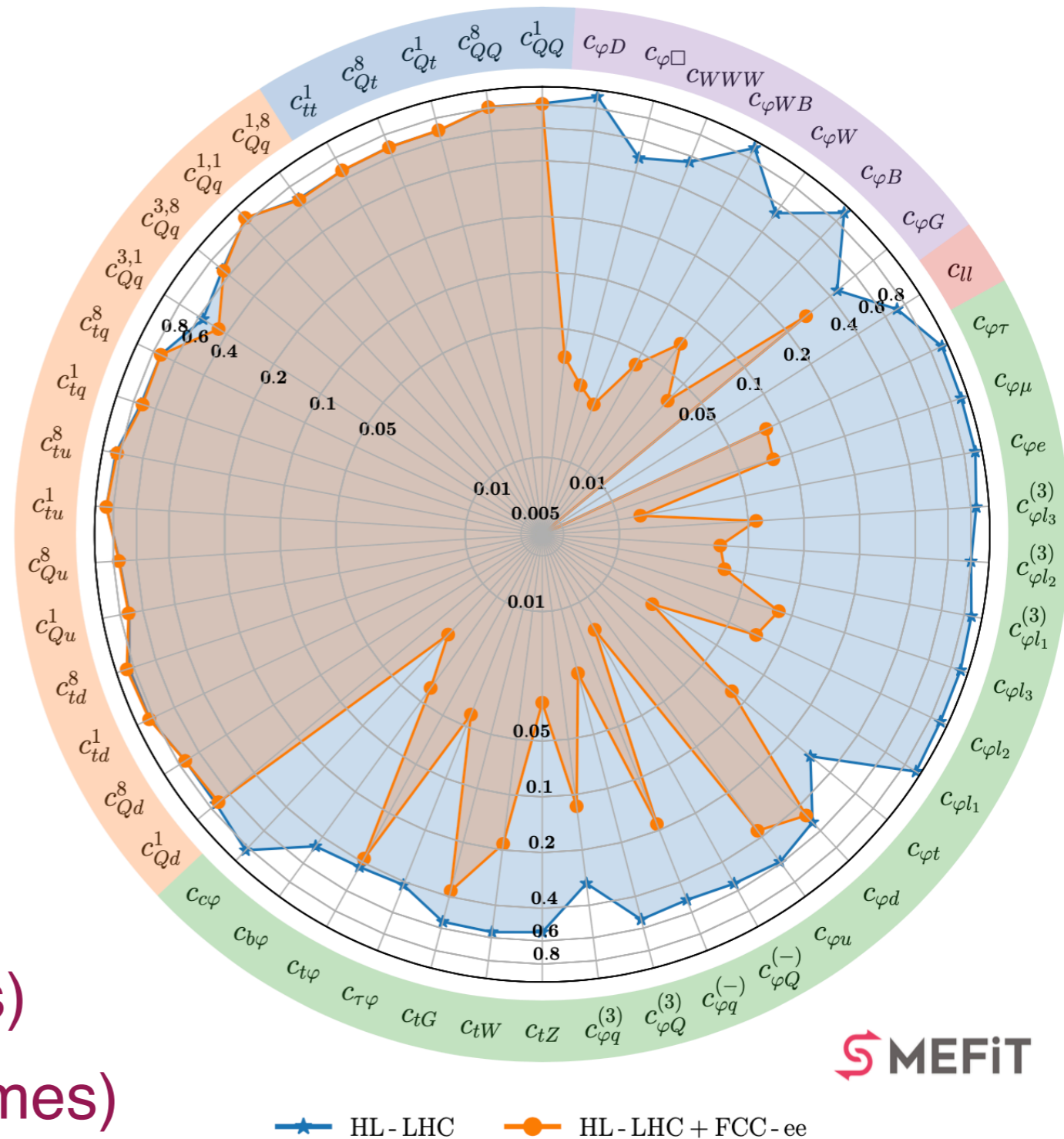
Uncertainty projections from  
Snowmass study:  
[arXiv:2206.08326](https://arxiv.org/abs/2206.08326)

See also Jorge's talk on Monday

## Significant improvement for:

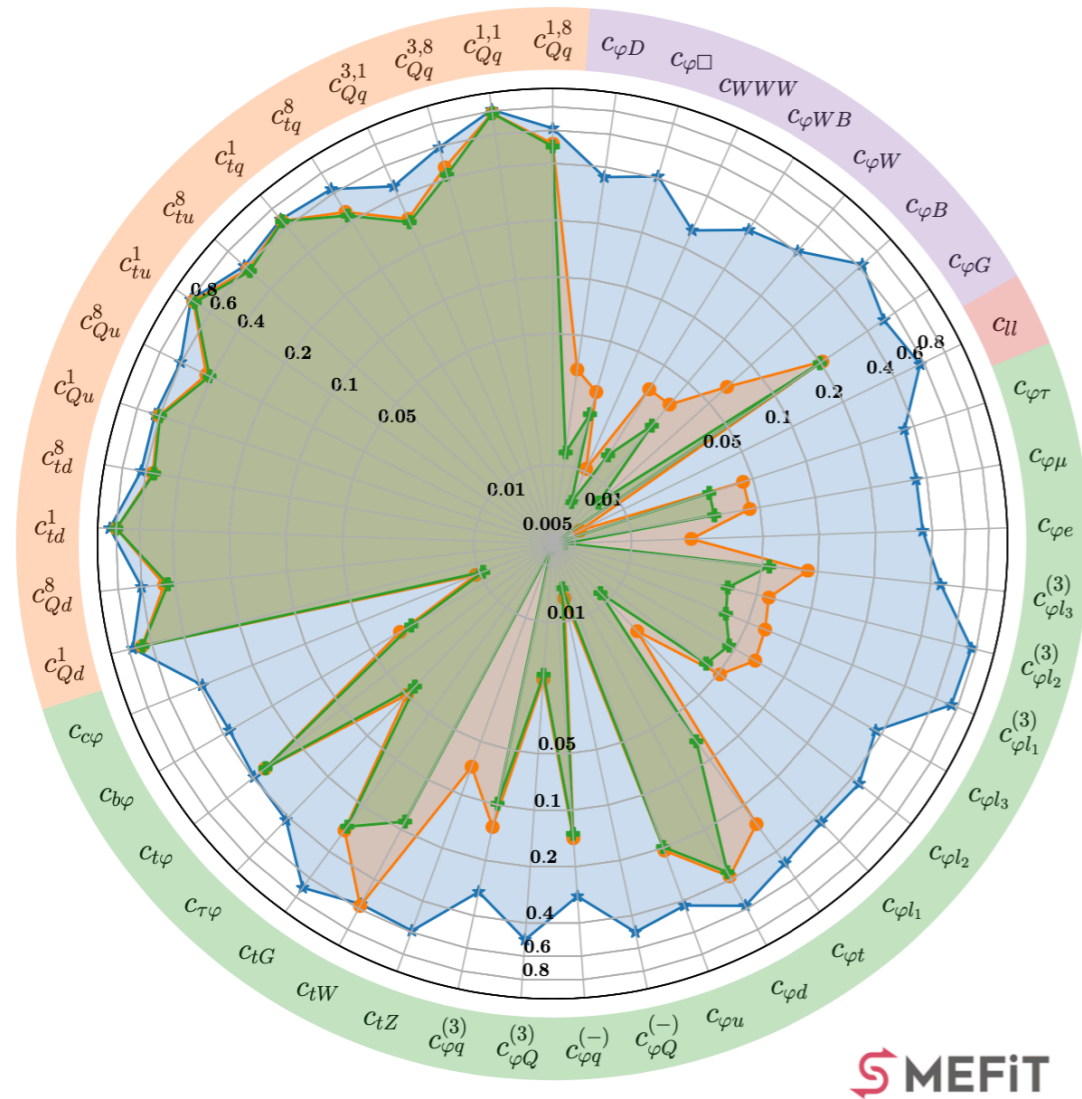
- gauge operators (up to 30 times)
- 2-fermion operators (up to 50 times)

Ratio of Uncertainties to SMEFiT3.0 Baseline,  $\mathcal{O}(\Lambda^{-4})$ , Marginalised



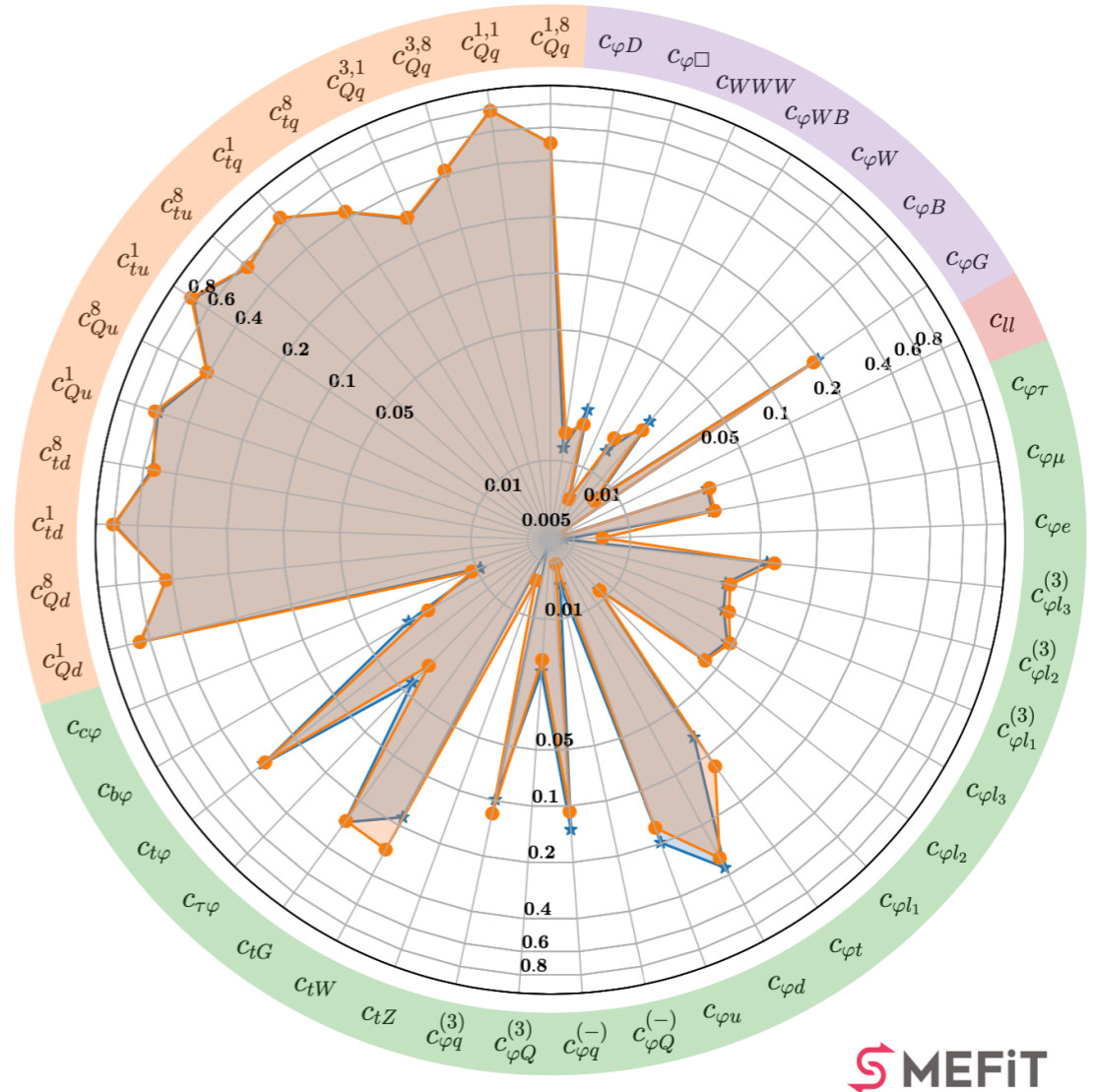
# FCC-ee: Energy Runs & CEPC

Ratio of Uncertainties to SMEFiT3.0 Baseline,  $\mathcal{O}(\Lambda^{-2})$ , Marginalised



- ★ HL-LHC + FCC-ee (91 GeV)
- HL-LHC + FCC-ee (91 + 240 GeV)
- ★ HL-LHC + FCC-ee (91 + 161 + 240 + 365 GeV)

Ratio of Uncertainties to SMEFiT3.0 Baseline,  $\mathcal{O}(\Lambda^{-2})$ , Marginalised



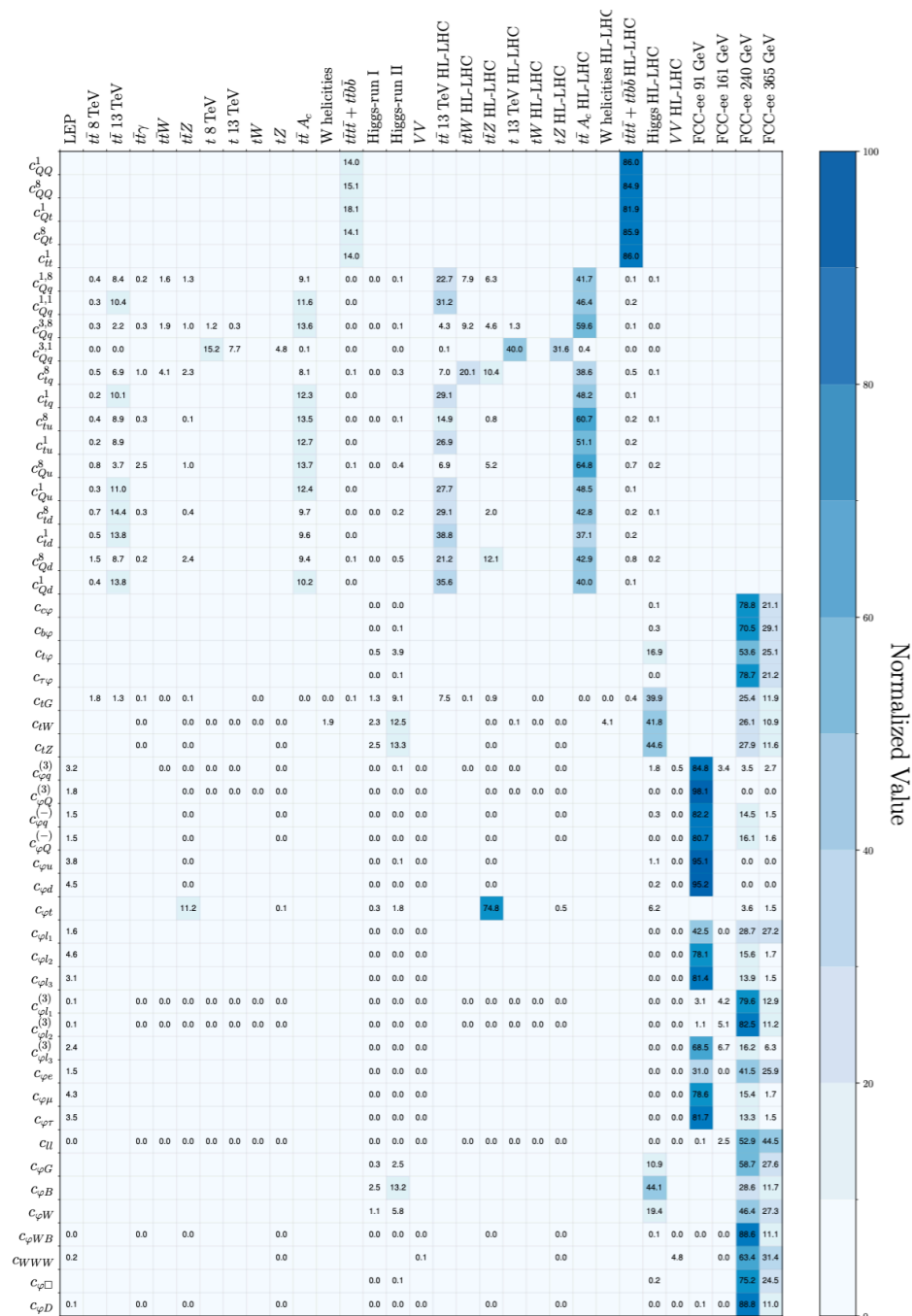
- ★ HL-LHC + FCC-ee
- HL-LHC + CEPC

Significant impact of 240 GeV run, 365 GeV run also helps

Very similar results for CEPC



# Fisher information



- Fisher information shows which process gives more sensitivity for a given operator
- Proxy for a linear individual fit
- **FCC-ee dominates nearly all operators** except for 4-quark operators, only accessible at in pp collisions (tree level)
- Global fit picture more complicated due to correlations
- Both Z-pole run and run at 240 GeV important to pin down 2-fermion and gauge operators

# What do we learn from global fits?

Bounds on new physics scale vary from 0.1 TeV (unconstrained) to 10s of TeV.

Bounds depend on:

- the operator
- assumption of a strongly or weakly coupled theory
- individual or marginalised bounds (reality is somewhere in-between)
- linear or quadratic bounds

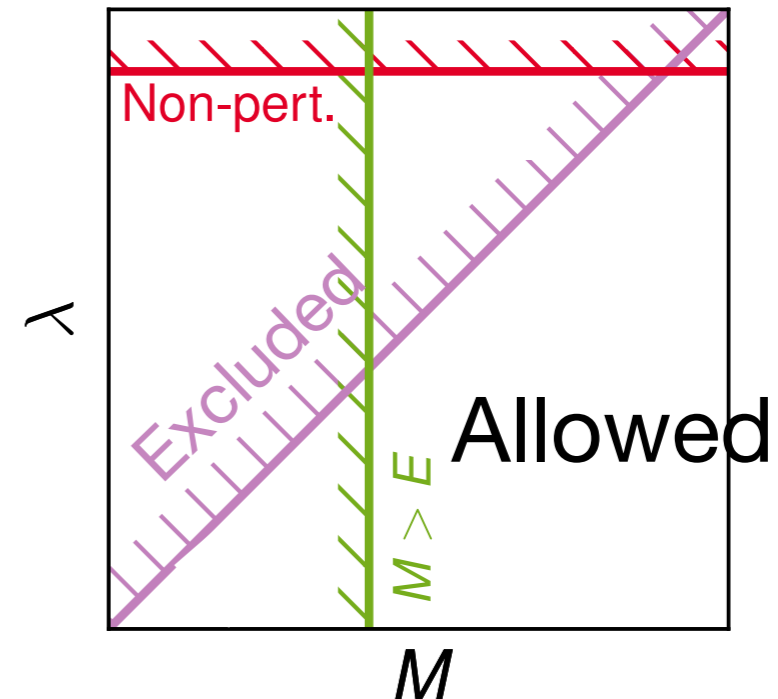
# What do we learn from global fits?

Bounds on new physics scale vary from 0.1 TeV (unconstrained) to 10s of TeV.

Bounds depend on:

- the operator
- assumption of a strongly or weakly coupled theory
- individual or marginalised bounds (reality is somewhere in-between)
- linear or quadratic bounds

**constraint:**  $\frac{c_i^6(\mu)}{\Lambda^2} = \frac{\lambda^2}{M^2} < X$

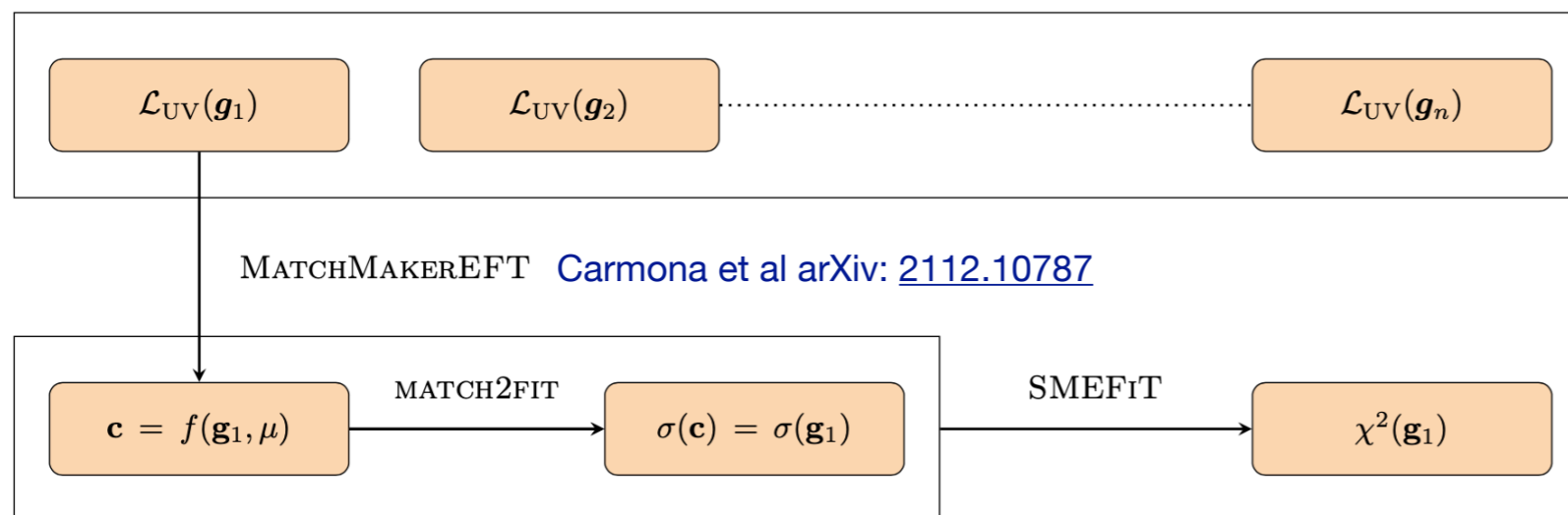


# From SMEFT to the UV

Global fit constrains parameters of UV models

Matching condition

$$\frac{c_i^6(\mu)}{\Lambda^2} = \frac{\lambda^2}{M^2} < X$$

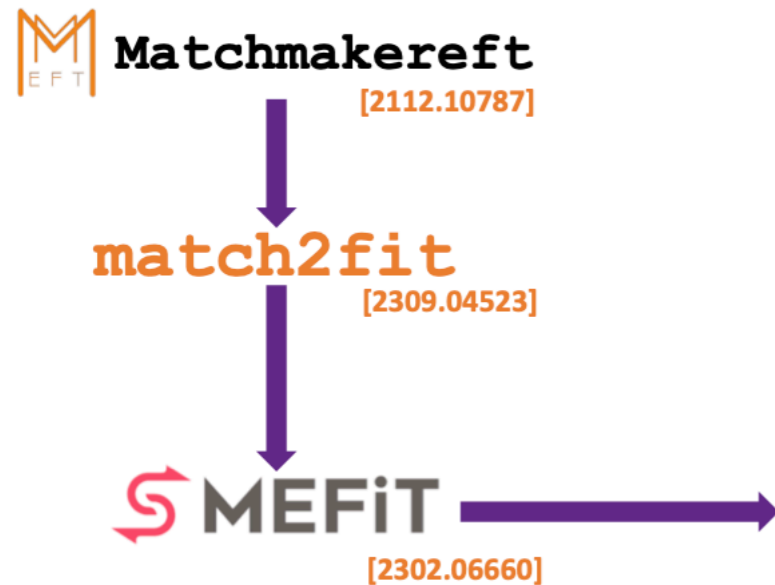


- Automate chain with final output constraints on the UV parameters
- Simplest case: single-field extensions of the SM [de Blas arXiv:1711.10391](#)
- Assume mass, constrain the coupling or vice versa

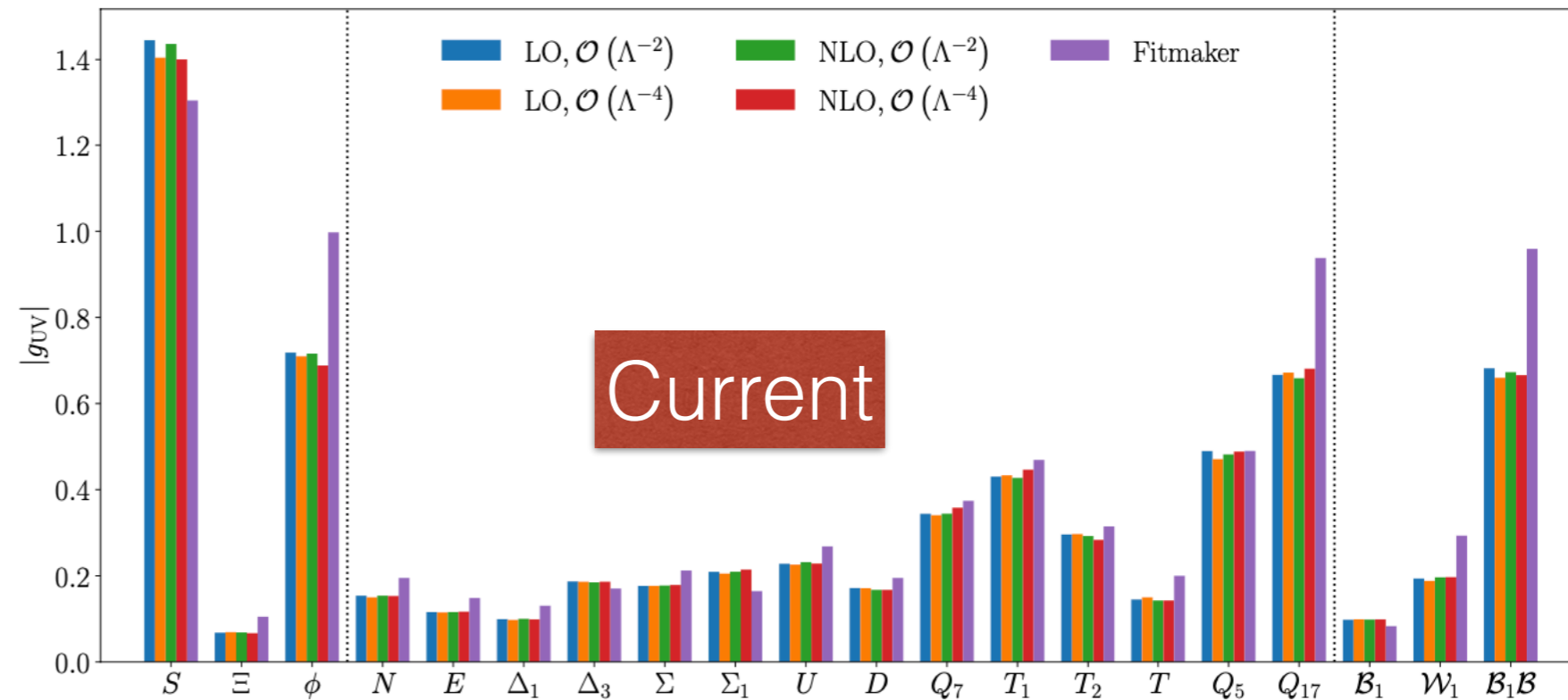
[ter Hoeve, Magni, Rojo, Rossia, EV arXiv: 2309.04523](#)



# What can we learn from these fits?



Scalars		Fermions		Vectors	
Particle	Irrep	Particle	Irrep	Particle	Irrep
$S$	$(1, 1)_0$	$N$	$(1, 1)_0$	$B$	$(1, 1)_0$
$S_1$	$(1, 1)_1$	$E$	$(1, 1)_{-1}$	$B_1$	$(1, 1)_1$
$\phi$	$(1, 2)_{1/2}$	$\Delta_1$	$(1, 2)_{-1/2}$	$W$	$(1, 3)_0$
$\Xi$	$(1, 3)_0$	$\Delta_3$	$(1, 2)_{-3/2}$	$W_1$	$(1, 3)_1$
$\Xi_1$	$(1, 3)_1$	$\Sigma$	$(1, 3)_0$	$\mathcal{G}$	$(8, 1)_0$
$\omega_1$	$(3, 1)_{-1/3}$	$\Sigma_1$	$(1, 3)_{-1}$	$\mathcal{H}$	$(8, 3)_0$
$\omega_4$	$(3, 1)_{-4/3}$	$U$	$(3, 1)_{2/3}$	$Q_5$	$(8, 3)_0$
$\zeta$	$(3, 3)_{-1/3}$	$D$	$(3, 1)_{-1/3}$	$\mathcal{Y}_5$	$(\bar{6}, 2)_{-5/6}$
$\Omega_1$	$(6, 1)_{1/3}$	$Q_1$	$(3, 2)_{1/6}$		
$\Omega_4$	$(6, 1)_{4/3}$	$Q_7$	$(3, 2)_{7/6}$		
$\Upsilon$	$(6, 3)_{1/3}$	$T_1$	$(3, 3)_{-1/3}$		
$\Phi$	$(8, 2)_{1/2}$	$T_2$	$(3, 3)_{2/3}$		
		$Q_5$	$(3, 2)_{-5/6}$		



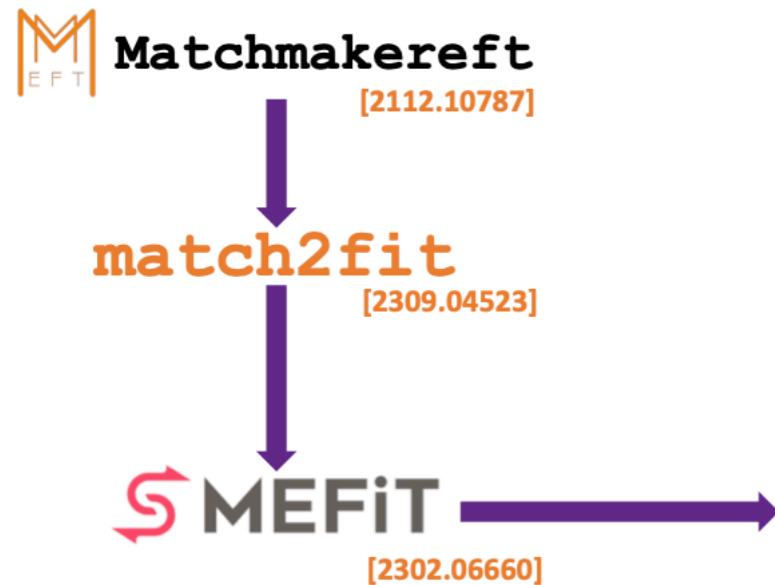
ter Hoeve, Magni, Rojo, Rossia, EV arXiv: 2309.04523

Automated constraints on UV models (also 1-loop and multiparticle models) from global EFT fit

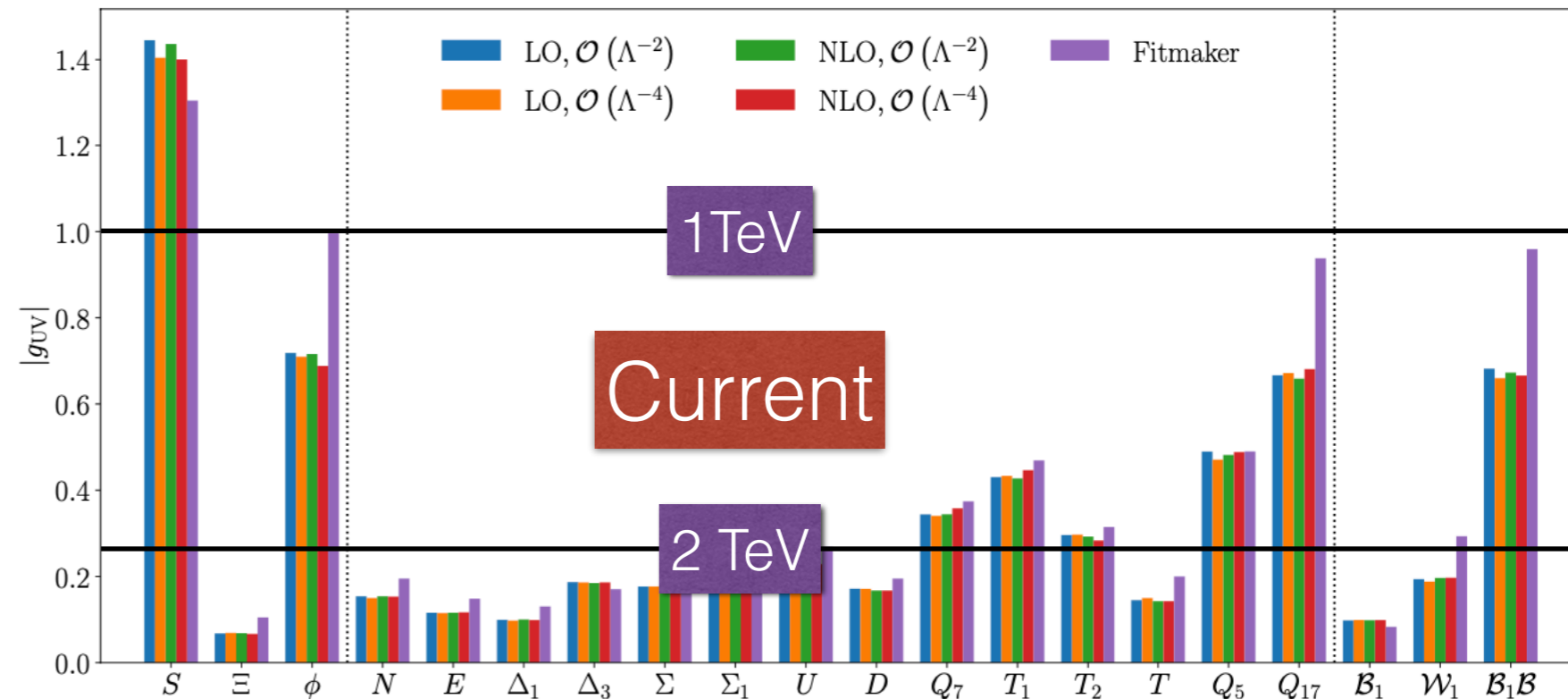
Current mass constraints on single particle extensions: 1TeV to 10TeV

Best constraints for models modifying EWPOs, worst for those only changing 4-top operators

# What can we learn from these fits?



Scalars		Fermions		Vectors	
Particle	Irrep	Particle	Irrep	Particle	Irrep
$S$	$(1, 1)_0$	$N$	$(1, 1)_0$	$B$	$(1, 1)_0$
$S_1$	$(1, 1)_1$	$E$	$(1, 1)_{-1}$	$B_1$	$(1, 1)_1$
$\phi$	$(1, 2)_{1/2}$	$\Delta_1$	$(1, 2)_{-1/2}$	$W$	$(1, 3)_0$
$\Xi$	$(1, 3)_0$	$\Delta_3$	$(1, 2)_{-3/2}$	$W_1$	$(1, 3)_1$
$\Xi_1$	$(1, 3)_1$	$\Sigma$	$(1, 3)_0$	$\mathcal{G}$	$(8, 1)_0$
$\omega_1$	$(3, 1)_{-1/3}$	$\Sigma_1$	$(1, 3)_{-1}$	$\mathcal{H}$	$(8, 3)_0$
$\omega_4$	$(3, 1)_{-4/3}$	$U$	$(3, 1)_{2/3}$	$Q_5$	$(8, 3)_0$
$\zeta$	$(3, 3)_{-1/3}$	$D$	$(3, 1)_{-1/3}$	$\mathcal{Y}_5$	$(\bar{6}, 2)_{-5/6}$
$\Omega_1$	$(6, 1)_{1/3}$	$Q_1$	$(3, 2)_{1/6}$		
$\Omega_4$	$(6, 1)_{4/3}$	$Q_7$	$(3, 2)_{7/6}$		
$\Upsilon$	$(6, 3)_{1/3}$	$T_1$	$(3, 3)_{-1/3}$		
$\Phi$	$(8, 2)_{1/2}$	$T_2$	$(3, 3)_{2/3}$		
		$Q_5$	$(3, 2)_{-5/6}$		



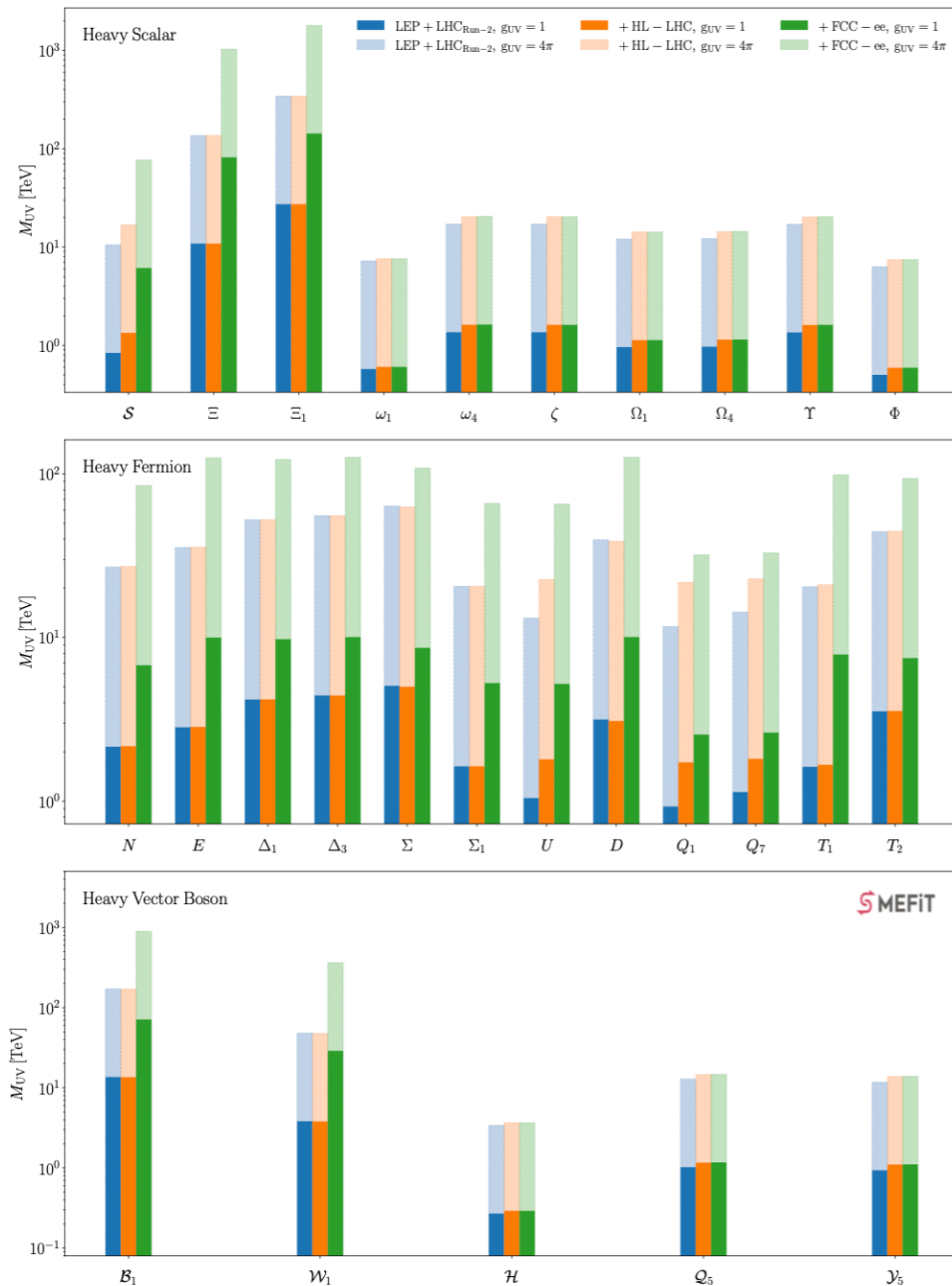
ter Hoeve, Magni, Rojo, Rossia, EV arXiv: 2309.04523

Automated constraints on UV models (also 1-loop and multiparticle models) from global EFT fit

Current mass constraints on single particle extensions: 1TeV to 10TeV

Best constraints for models modifying EWPOs, worst for those only changing 4-top operators

# From SMEFT to the UV



Scalars		Fermions		Vectors	
Particle	Irrep	Particle	Irrep	Particle	Irrep
$S$	$(1, 1)_0$	$N$	$(1, 1)_0$	$B$	$(1, 1)_0$
$S_1$	$(1, 1)_1$	$E$	$(1, 1)_{-1}$	$B_1$	$(1, 1)_1$
$\phi$	$(1, 2)_{1/2}$	$\Delta_1$	$(1, 2)_{-1/2}$	$\mathcal{W}$	$(1, 3)_0$
$\Xi$	$(1, 3)_0$	$\Delta_3$	$(1, 2)_{-3/2}$	$\mathcal{W}_1$	$(1, 3)_1$
$\Xi_1$	$(1, 3)_1$	$\Sigma$	$(1, 3)_0$	$\mathcal{G}$	$(8, 1)_0$
$\omega_1$	$(3, 1)_{-1/3}$	$\Sigma_1$	$(1, 3)_{-1}$	$\mathcal{H}$	$(8, 3)_0$
$\omega_4$	$(3, 1)_{-4/3}$	$U$	$(3, 1)_{2/3}$	$\mathcal{Q}_5$	$(8, 3)_0$
$\zeta$	$(3, 3)_{-1/3}$	$D$	$(3, 1)_{-1/3}$	$\mathcal{Y}_5$	$(\bar{6}, 2)_{-5/6}$
$\Omega_1$	$(6, 1)_{1/3}$	$Q_1$	$(3, 2)_{1/6}$		
$\Omega_4$	$(6, 1)_{4/3}$	$Q_7$	$(3, 2)_{7/6}$		
$\Upsilon$	$(6, 3)_{1/3}$	$T_1$	$(3, 3)_{-1/3}$		
$\Phi$	$(8, 2)_{1/2}$	$T_2$	$(3, 3)_{2/3}$		
		$Q_5$	$(3, 2)_{-5/6}$		

- Large improvements in mass reach for models modifying EWPOs at the FCC
- Bounds reaching 100 TeV for some models at the FCC-ee
- HL-LHC improving models generating 4-quark operators (expect better improvement with dedicated HL-LHC analysis)

# Conclusions

- SMEFT is a consistent way to look for new interactions
- Global fits results already available: important to combine as many processes as possible to extract maximal information
- Eventually global fit results give us a clear indication of the scale of potential new physics and the reach of future colliders
- Significant improvements in New Physics reach at the HL-LHC and especially at future circular lepton colliders
- Plan to extend this to other future projects

[https://lhcfitsnikhef.github.io/smefit\\_release/previous\\_releases/smefit30.html](https://lhcfitsnikhef.github.io/smefit_release/previous_releases/smefit30.html)

Thank you for your attention