SMEFT fits

International Workshop on the High Energy Circular Electron Positron Collider 2026

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Víctor Miralles

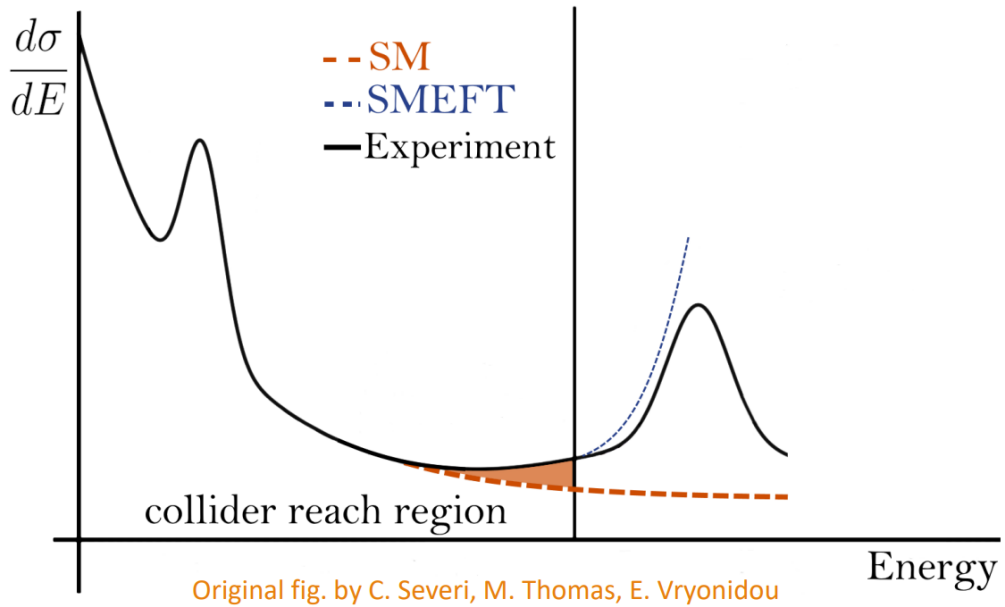




Universitat d'Alacant

The SMEFT framework

- Model agnostic approaches are an excellent alternative to particular NP extensions
- The SMEFT offers an excellent framework for testing new physics



Original fig. by C. Severi, M. Thomas, E. Vryonidou

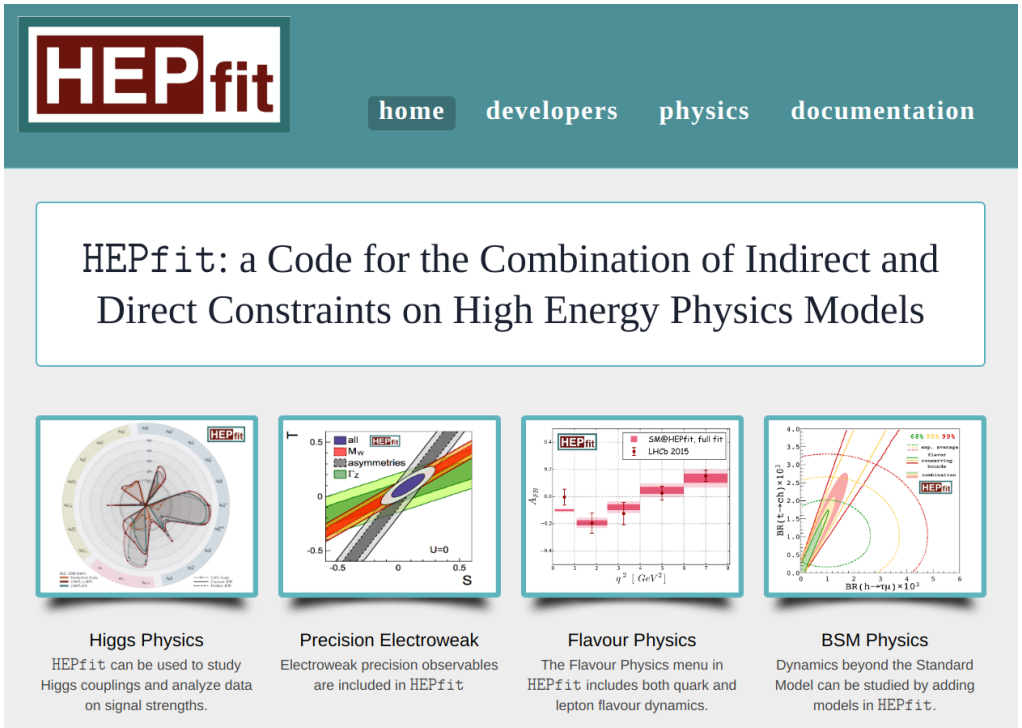
$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \frac{1}{\Lambda^2}\sum_i C_i^{(6)} O_i + \mathcal{O}\left(\Lambda^{-4}\right)$$

SMEFT fits

- The SMEFT already at dimension-six contains **2499 WC**
- The **NP** may respect some flavour symmetry $\Rightarrow$ **Fewer** parameters
- **Combining data** from all sectors is **essential**
- Robust numerical **tools** $\Rightarrow$ `HEPfit`
- `HEPfit` includes **EWPO**, **Diboson**, **Higgs**, **Top**, **DY**, **LEP-II** cross sections and **flavour** observables
- Fitting **both SM** parameters and **dim-6 WC**
- The WC are fitted **at the NP scale**
- Running with `RGESolver` for all the **2499 WC** to relevant scale

The HEPfit code

- **Open source** written in C++
- Available under the GPL on **GitHub**: https://github.com/silvest/HEPfit
- The **MCMC** sampling based on BAT
- **Sampling** likelihoods with MCMC
- **Parallelised** with MPI



HEPfit webpage [J. de Blas et al., 1910.14012]

Flavour hypotheses

HEPfit currently supports the following flavour assumptions

No flavour violation $U(3)^5$

Universal models [2507.06191]

$$\left(\bar{\psi}^i_{L/R}\psi^j_{L/R}\right) \propto \delta^{ij} \qquad \left(\bar{\psi}^i_{R/L}\psi^j_{L/R}\right) = 0$$

Flavour violation only in the 3rd family $U(2)^5$

Third-generation-philic models [2507.06191]

$$\left(\bar{\psi}^i_{L/R}\psi^j_{L/R}\right) \propto \delta^{ij} \quad \left(\bar{\psi}^3_{L/R}\psi^j_{L/R}\right) \neq 0 \quad \left(\bar{\psi}^3_{L/R}\psi^3_{L/R}\right) \neq 0 \quad (i,j=1,2)$$

Minimal flavor violation

Yukawas only source of flavour violation [in preparetion]

$$\left(\bar{\psi}^i_{L/R}\psi^j_{L/R}\right) \propto (Y^2)^{ij} \quad \left(\bar{\psi}^i_{R/L}\psi^j_{L/R}\right) \propto Y^{ij}_{\psi}$$

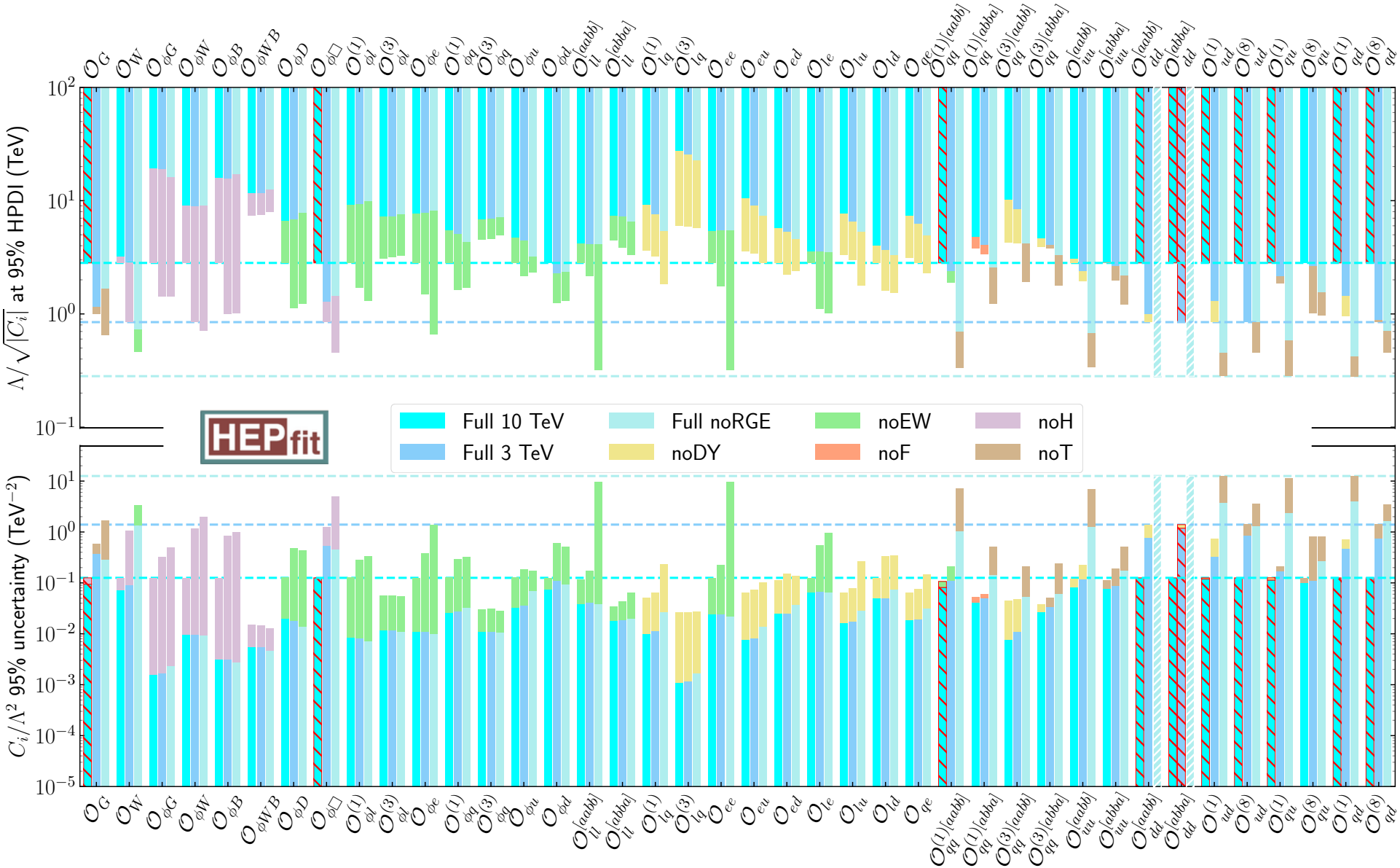
Current constraints

Observables included

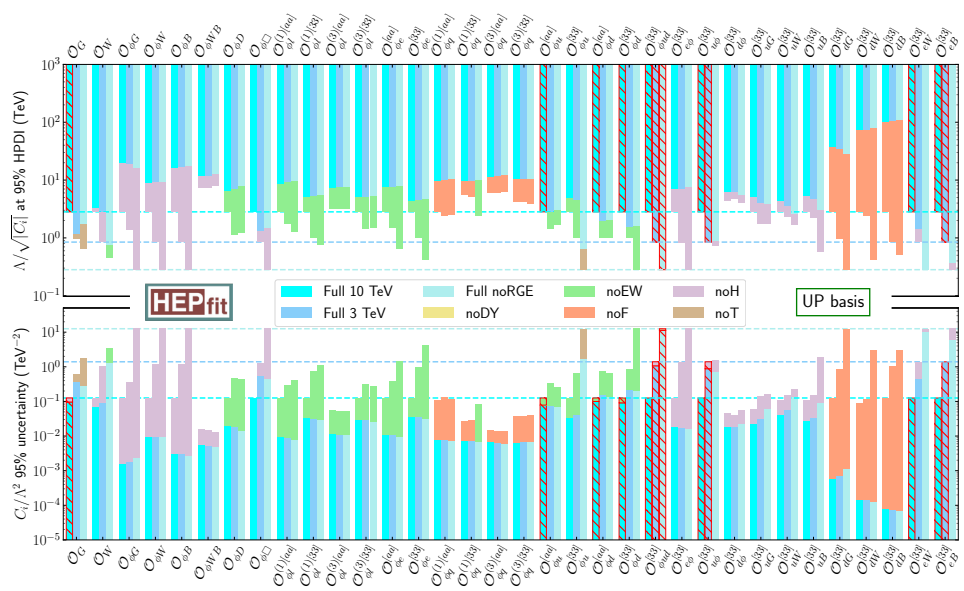
- **Electroweak precision observables** at LEP, SLD, Tevatron, and LHC
- **Di-boson** production cross sections at LEP
- **Higgs boson** measurements at LHC
- **Top-quark** measurements at LHC and Tevatron
- **Drell-Yan** measurements at LHC
- **LEP-II** production of leptons and quarks
- **Flavour observables** measurements at Flavour Factories and LHC

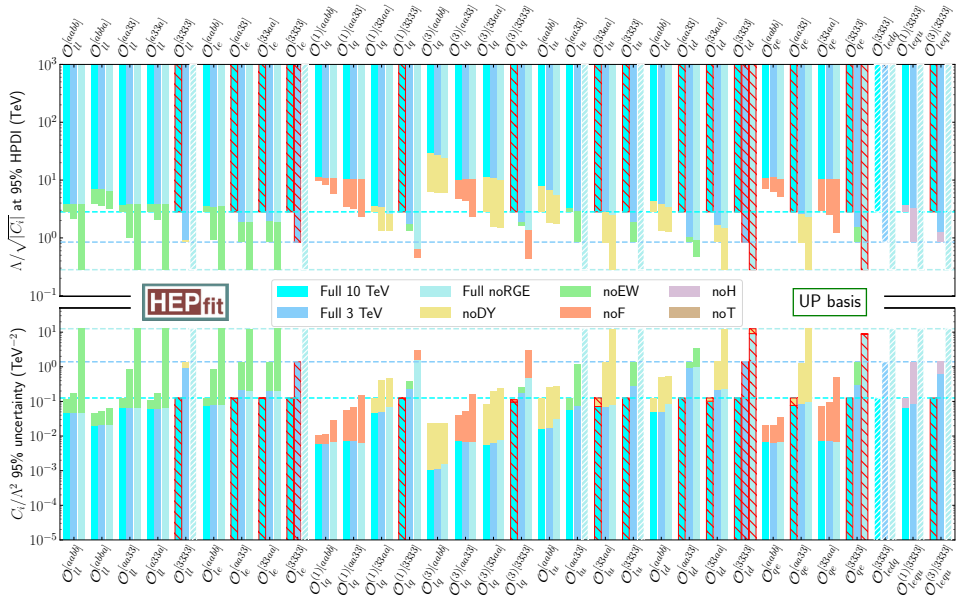
Fits for $U(3)^5$ flavour symmetry: Individual

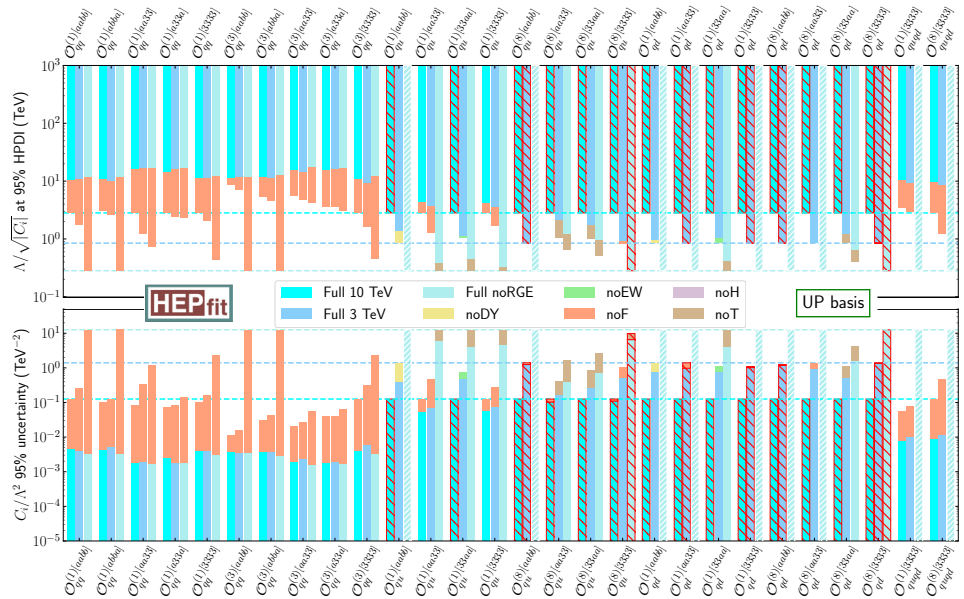
[2507.06191]

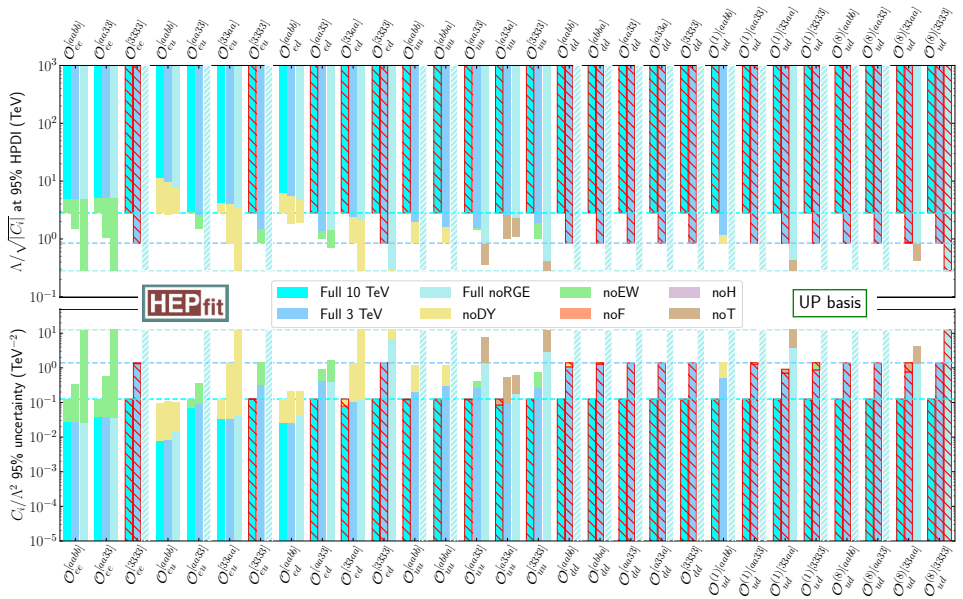


Fits for $U(2)^5$ flavour symmetry: Individual [2507.06191]









Future lepton circular collider

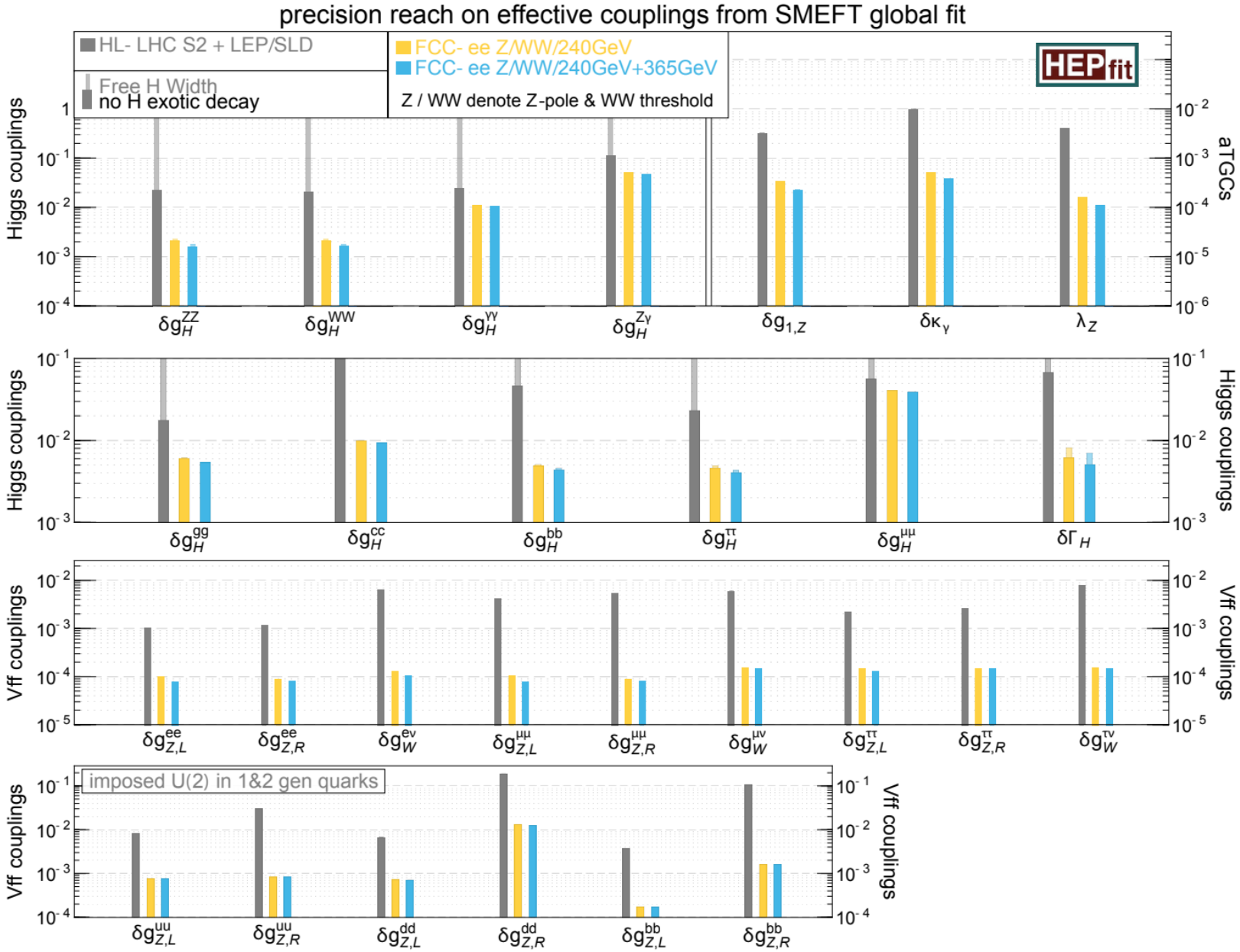
Precision physics at CEPC and FCC-ee

- **CEPC and FCC-ee**: high-luminosity e^+e^- colliders for **precision Higgs and electroweak physics**
- Runs at the Z **pole** ($\sqrt{s} \simeq 91$ GeV), the WW **threshold** (around 160 GeV), and the **Higgs-factory energy** (240 GeV)
- $e^+e^- \to W^+W^-$: a threshold scan for m_W, and precise tests of **triple-gauge interactions** at $\sqrt{s} = 240$ GeV
- $e^+e^- \to ZH$: precision probes of **Higgs interactions** at $\sqrt{s} = 240$ GeV

I will show some results from the recent FCC-ee feasibility study which address physics questions shared with CEPC.

Global fit results

[2505.00272]



FCC-ee: origin of the constraints [2505.00272]

- Vff **couplings**: mainly constrained by Z-**pole widths** and **asymmetries**, supplemented by W **widths and branching ratios** for the $W\ell\nu$ couplings

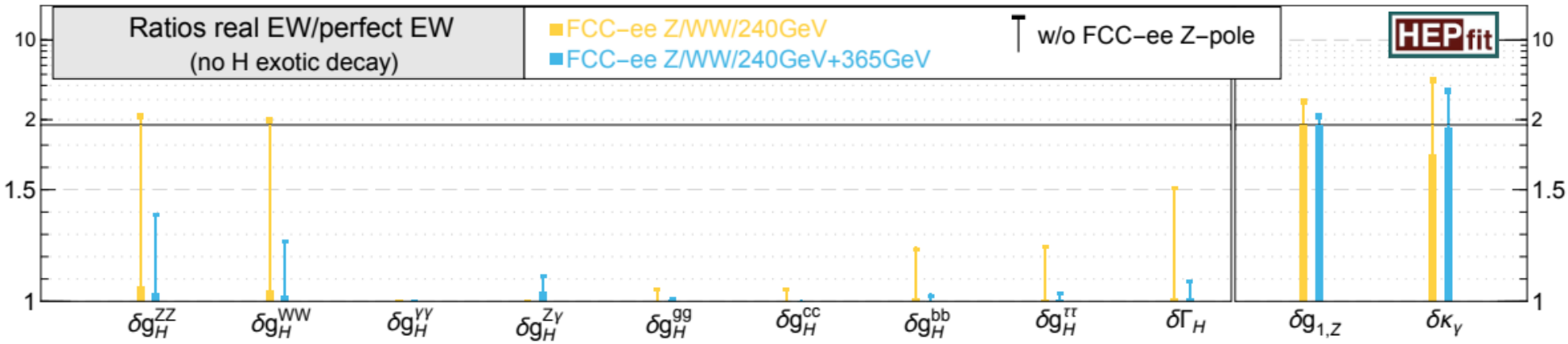
- **Higgs couplings and** Γ_H: mainly constrained by ZH **production** and **Higgs decay** measurements

- **Anomalous triple-gauge couplings** ($\delta g_{1,Z}$, $\delta\kappa_\gamma$, λ_Z): mainly constrained by W^+W^- **production** rates and **angular distributions** at 240 GeV

- **Complementarity**: SMEFT correlations connect these sectors, so each bound benefits from the **combined global fit**

Impact of Z-pole in Higgs

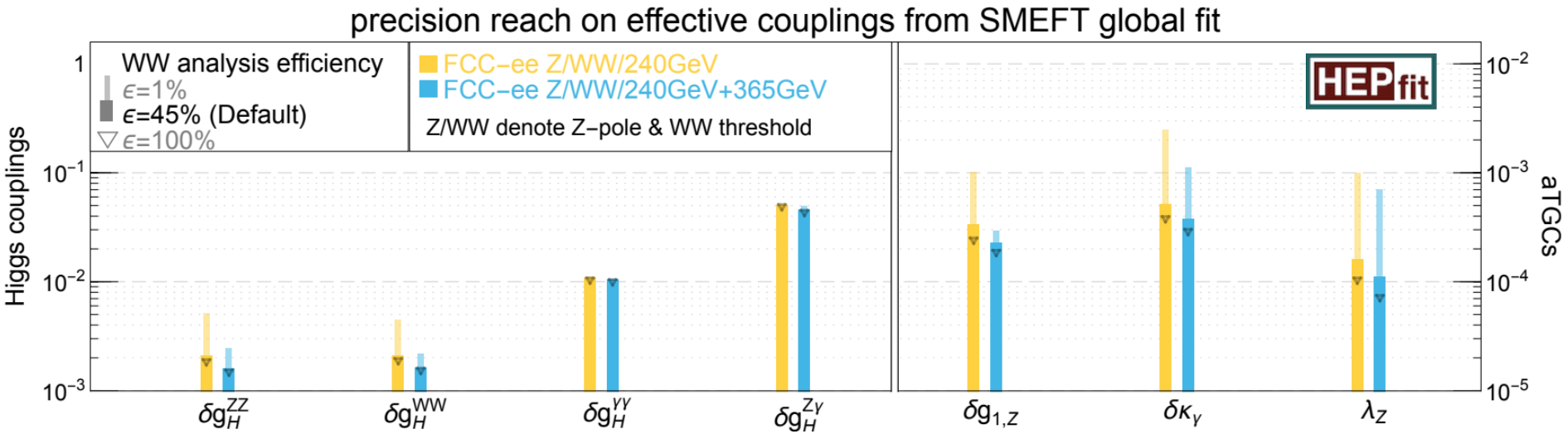
[2505.00272]



- Precise Z-pole is clearly needed since *Zee* enters the *ZH* production
- Some Higgs measurements worsen by a factor of two without the FCCee Z-pole run
- Not all the 6×10^{12} Z bosons expected are needed to reduce the impact in the Higgs sector (with 1‰ of that amount is enough)

Impact of diboson in Higgs

[2505.00272]

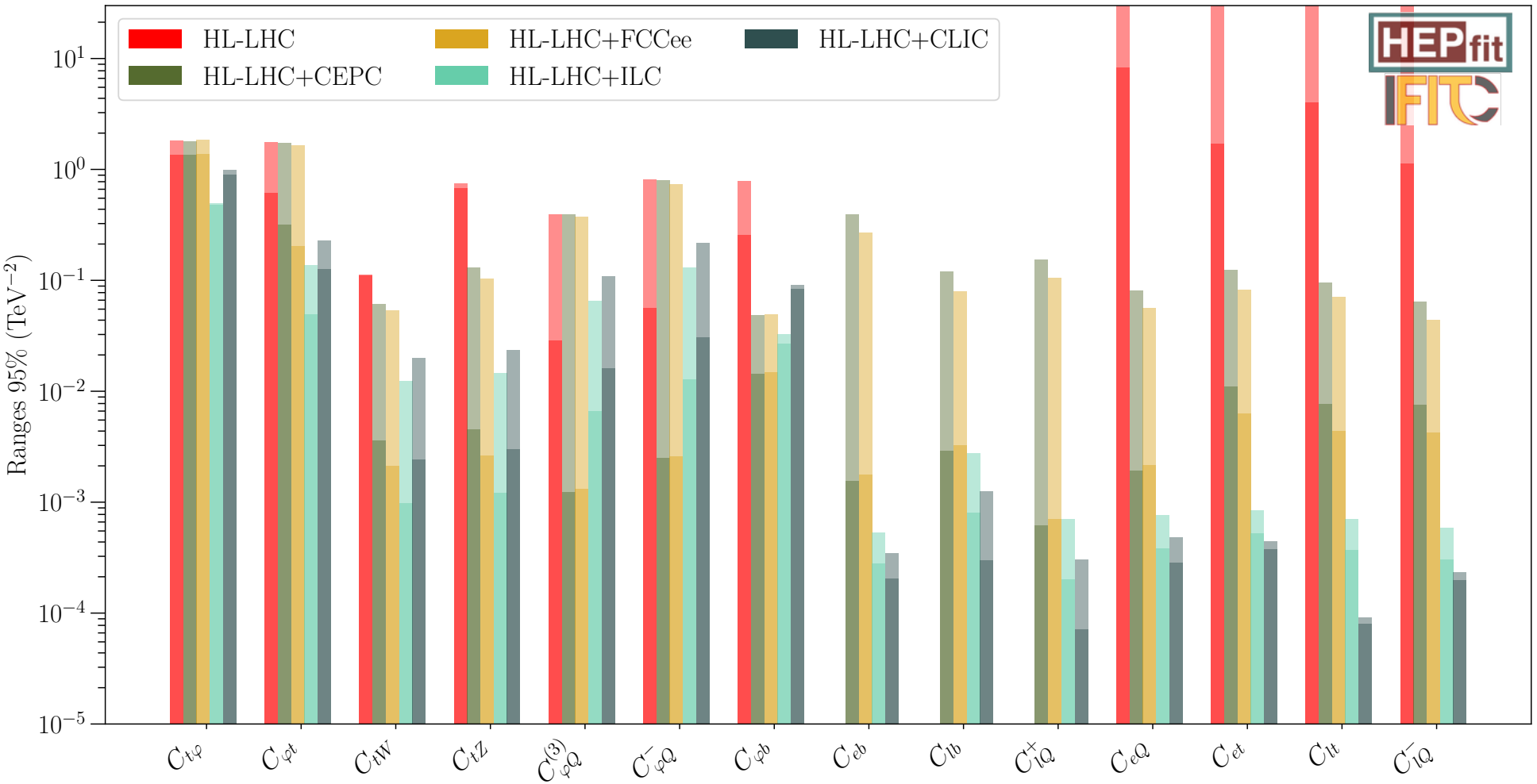


- All angular information from $e^+e^- \to W^+W^-$ encoded in optimal observables
- The bounds vary according to the assumed efficiency

$t\bar{t}$ production at e^+e^- colliders

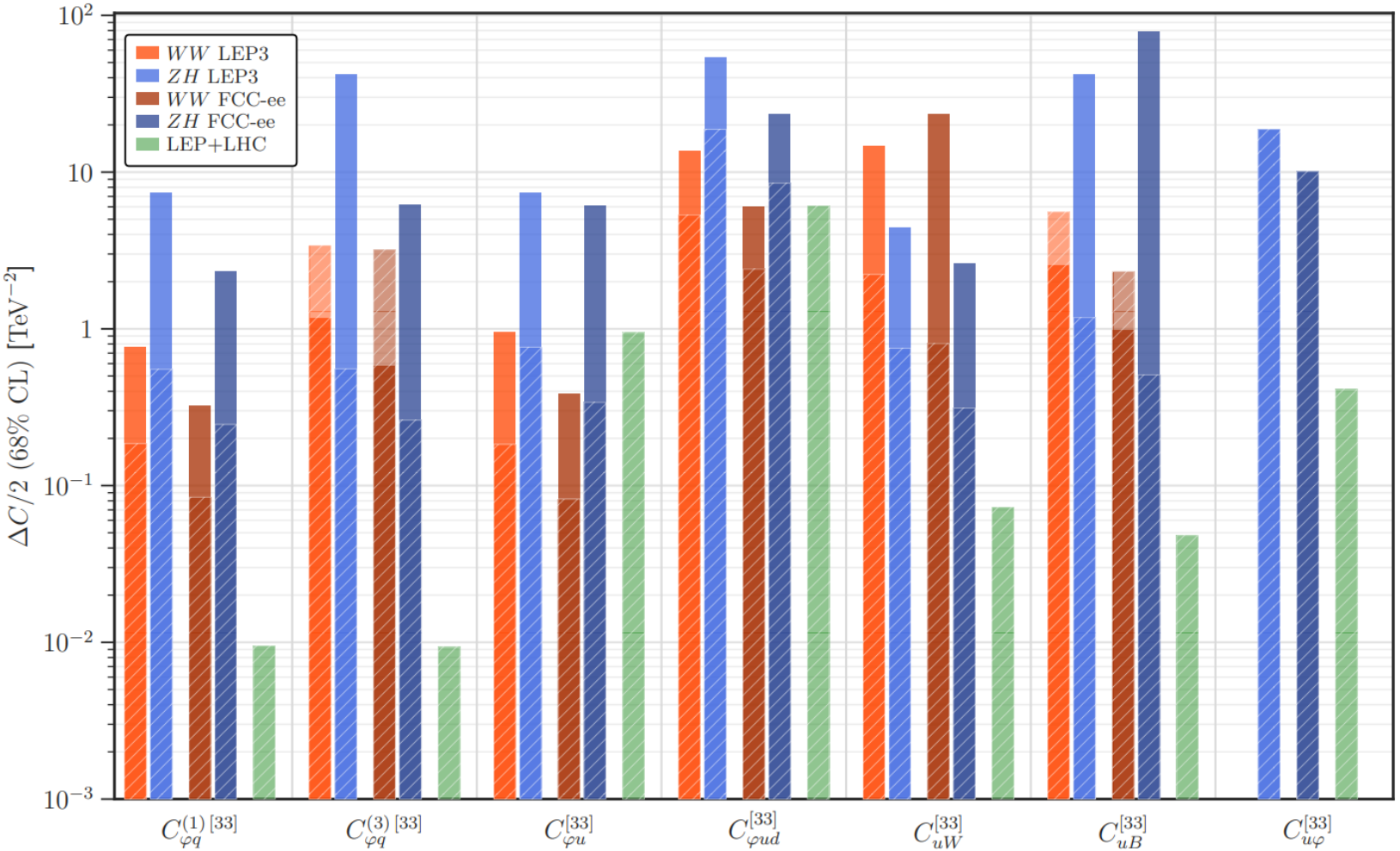
- Running at 365 GeV would allow accessing to $t\bar{t}$ production
- Optimal observables maximally exploit the information in the fully differential $e^+e^- \to t\bar{t} \to bW^+\bar{b}W^-$ distribution [1807.02121]
- These constrain the 2-fermion operators $C^-_{\varphi Q}$, $C_{\varphi t}$, C_{tW} and C_{tZ}
- Also the 2-quark 2-lepton operators C^-_{lQ}, C_{lt}, C_{et} and C_{eQ}
- With these we eliminate blind directions in the $C^{(1)}_{\varphi Q} - C^{(3)}_{\varphi Q}$ plane
- Two different energies above the $t\bar{t}$ threshold allow to disentangle the 2- and 4-fermion operators

Comparison of future e^+e^- colliders



What if we do not reach the $t\bar{t}$-threshold? [2606.12312]

- Best constraints from $e^+e^- \to t\bar{t}$ at 365 GeV [2503.11518]
- If 365 GeV not reached $\Rightarrow$ access from diboson through NLO EW corrections [2606.12312]



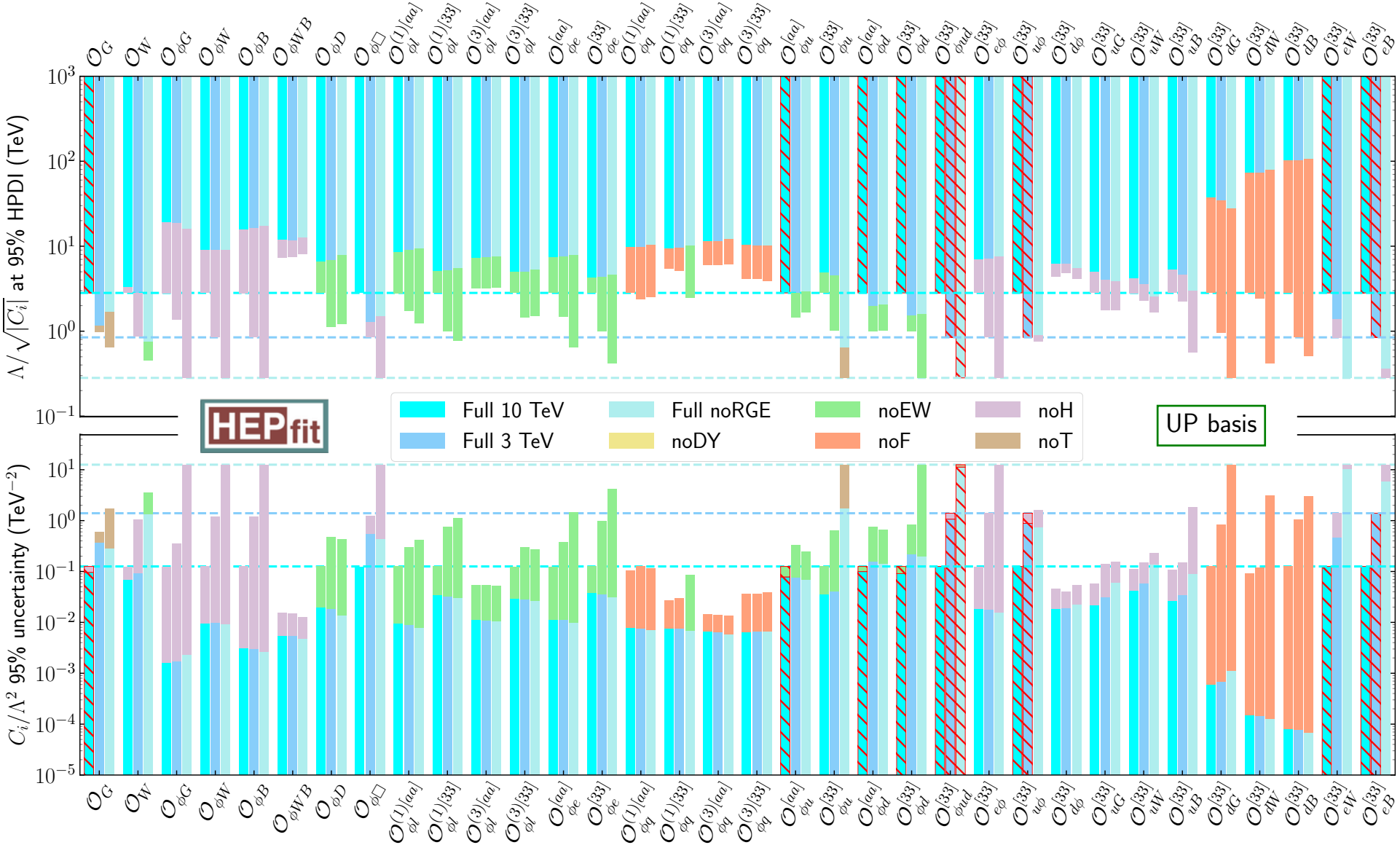
Summary

- **SMEFT fits with `HEPfit`** combine complementary datasets with **consistent RG evolution**, under $U(3)^5$, $U(2)^5$, and MFV flavour hypotheses
- At **CEPC and FCC-ee**, combining Z-**pole,** ZH **and** WW **measurements** is essential to disentangle **Higgs and electroweak effects**
- **Direct** $t\bar{t}$ **production** probes top-quark interactions. Angular information and measurements at **different energies** help disentangle two- and four-fermion operators
- **Top-quark couplings remain accessible below the** $t\bar{t}$ **threshold** through **NLO EW corrections** to diboson production but with **limited** accuracy

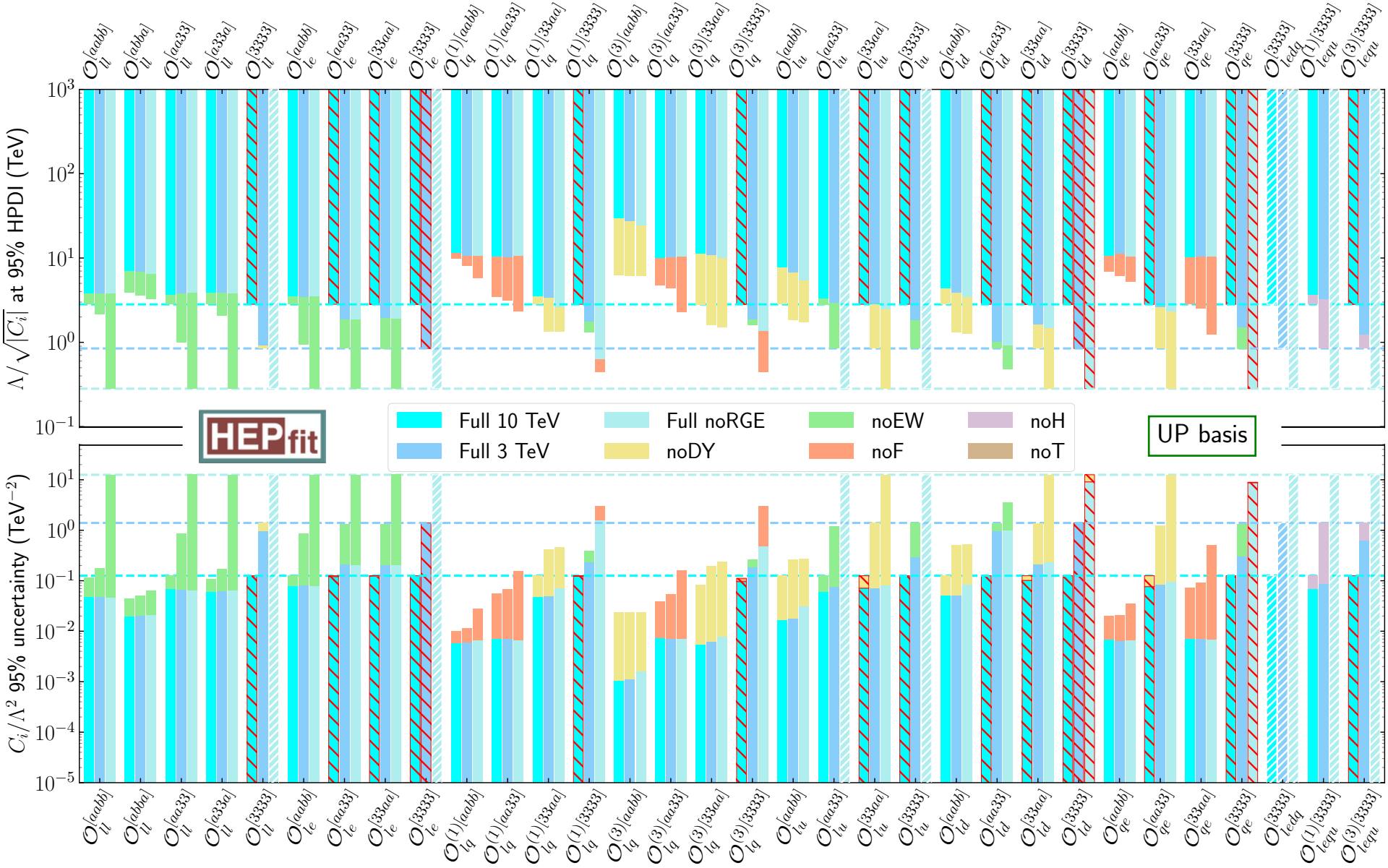
Thanks for your attention!

Back up

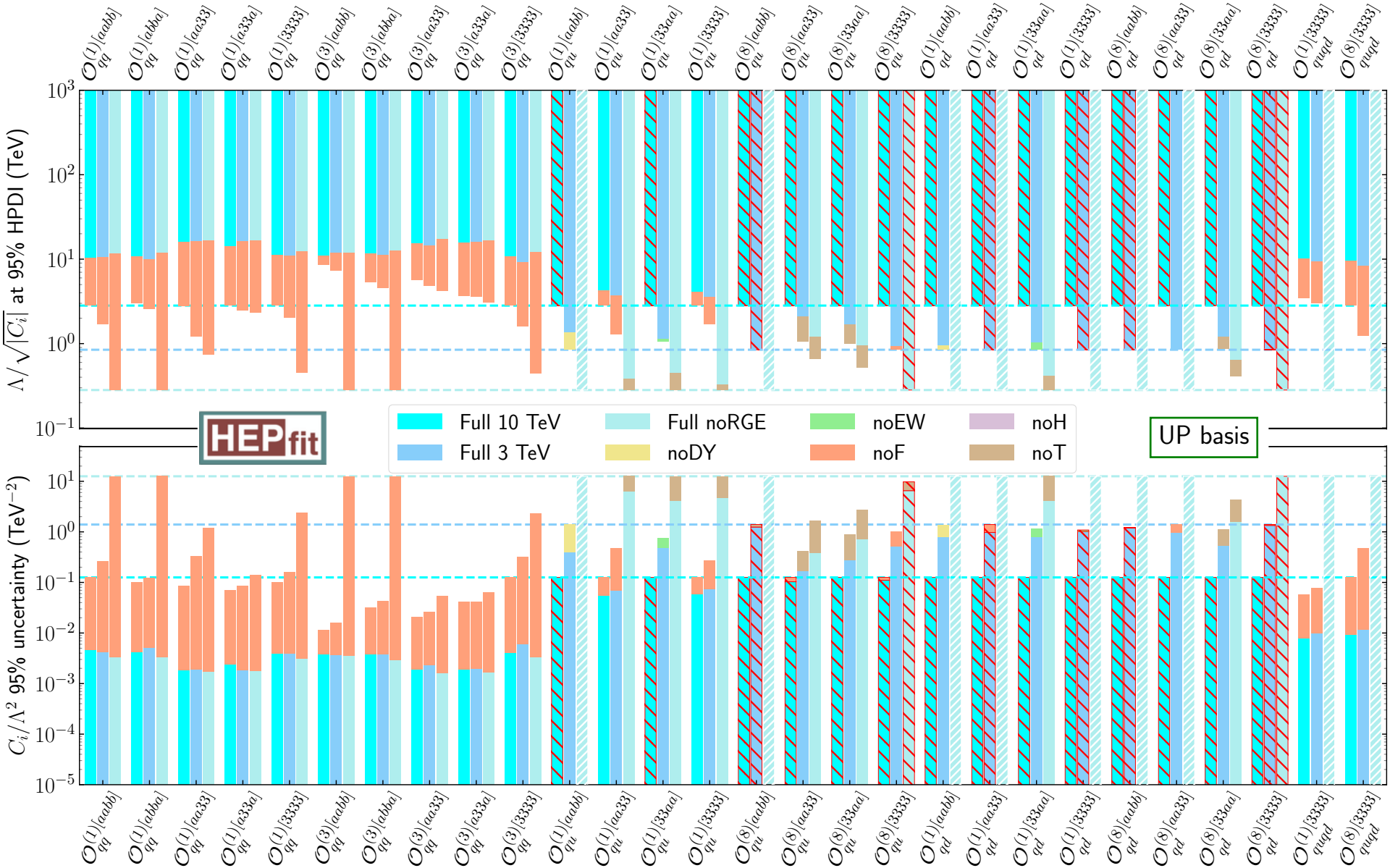
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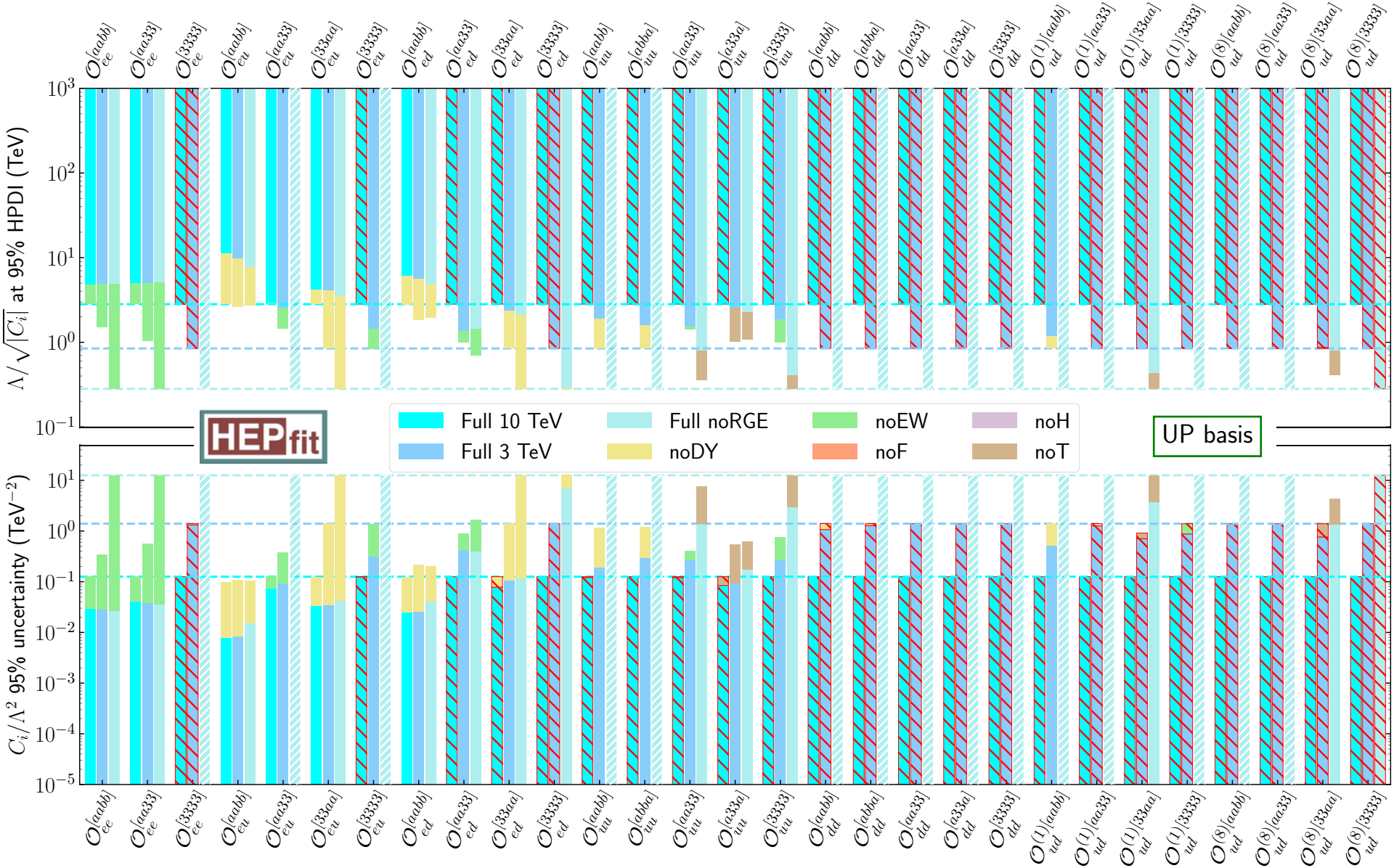
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Anomalous Triple Gauge Couplings

[Falkowski et al., 1609.06312]

$$\mathcal{L}_{tgc} = ie\left(W^+_{\mu\nu}W^-_{\mu} - W^-_{\mu\nu}W^+_{\mu}\right)A_\nu + ie\frac{c_\theta}{s_\theta}(1+\delta g_{1,z})\left(W^+_{\mu\nu}W^-_{\mu} - W^-_{\mu\nu}W^+_{\mu}\right)Z_\nu$$
$$+ ie(1+\delta\kappa_\gamma)A_{\mu\nu}W^+_\mu W^-_\nu + ie\frac{c_\theta}{s_\theta}(1+\delta\kappa_z)Z_{\mu\nu}W^+_\mu W^-_\nu$$
$$+ i\frac{\lambda_z e}{m_W^2}\left[W^+_{\mu\nu}W^-_{\nu\rho}A_{\rho\mu} + \frac{c_\theta}{s_\theta}W^+_{\mu\nu}W^-_{\nu\rho}Z_{\rho\mu}\right],$$

$$\delta g_{1,z} = -\frac{v^2}{\Lambda^2}\frac{g_L^2+g_Y^2}{4(g_L^2-g_Y^2)}\left(\frac{4g_Y}{g_L}C_{HWB} + C_{HD} - [C_{\ell\ell}]_{1221} + 2[C^{(3)}_{H\ell}]_{11} + 2[C^{(3)}_{H\ell}]_{22}\right)$$

$$\delta\kappa_\gamma = \frac{v^2}{\Lambda^2}\frac{g_L}{g_Y}C_{HWB}, \qquad \lambda_z = -\frac{v^2}{\Lambda^2}\frac{3}{2}g_L C_W, \qquad \delta\kappa_Z = \delta g_{1,z} - \frac{s_\theta^2}{c_\theta^2}\delta\kappa_\gamma$$