Global fit to electroweak, Drell-Yan, Higgs, top, and flavour observables

LHC EFT & Higgs WG Workshop

3rd December 2025

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Based on [2507.06191] and [LHCHWG-2025-013]

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Laura Reina, Luca Silvestrini, Mauro Valli

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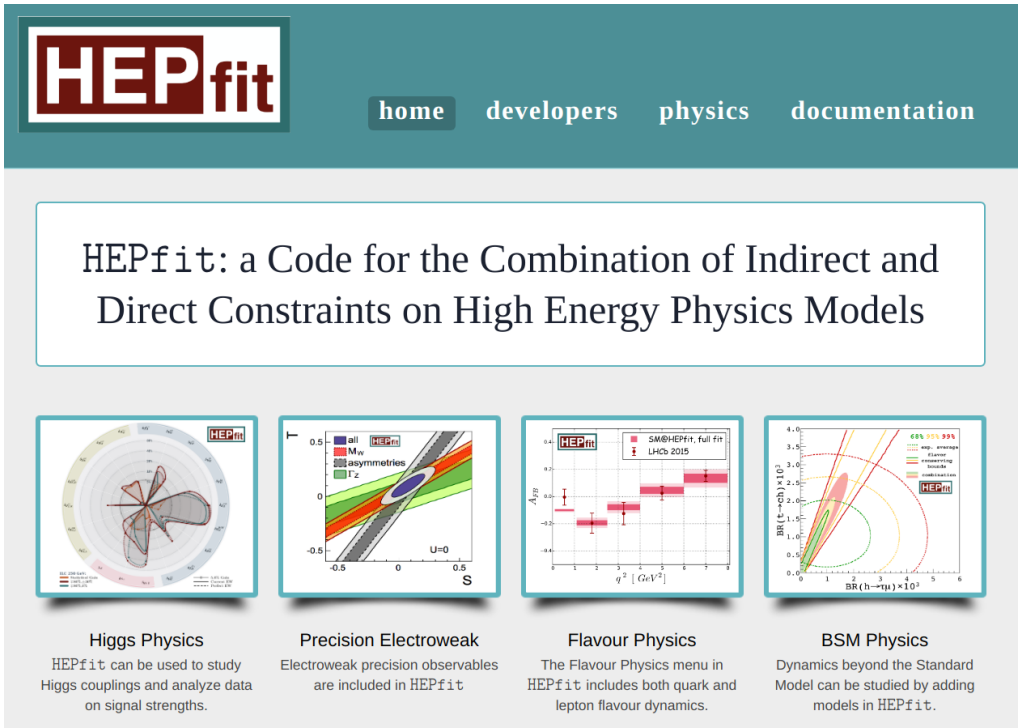
Fit setup

- Fitting **both SM** parameters and **dim-6 WC**
- We assume **CP-conservation** and $\mathbf{U(3)^5}$ or $\mathbf{U(2)^5}$ flavour symmetries in the NP
- The WC are fitted **at the NP scale**
- Running with `RGESolver` for all the **2499 WC** to relevant scale
- Fit includes **EWPO**, **Diboson**, **Higgs**, **Top**, **DY**, **LEP-II** cross sections and **flavour** observables
- The **observables** contain the (NP) **SMEFT contributions at LO**, consistently neglecting $\mathcal{O}(\Lambda^{-4})$ contributions from the WC
- For the **SM**, **NLO or higher** prediction is included
- Fit is performed using `HEPfit`

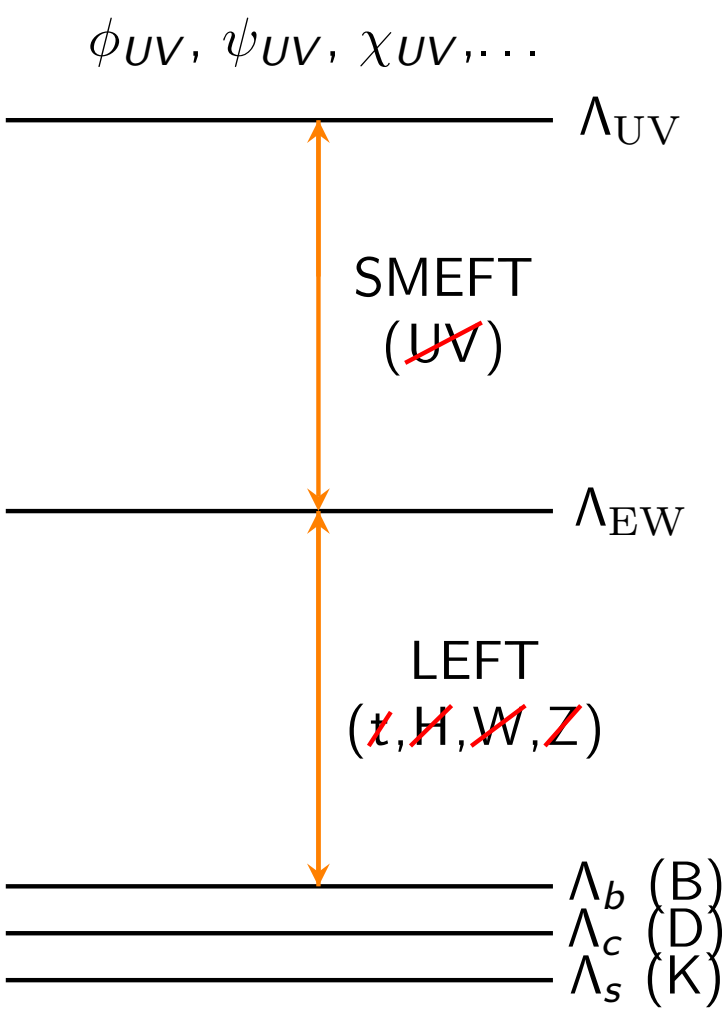
The HEPfit code

- **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]

Global picture



The flavour symmetry assumptions are imposed at the UV scale

$$\mathcal{L}_{\rm SMEFT} = \mathcal{L}_{\rm SM} + \sum_{i,d} \frac{C_{i,d}^{\rm SMEFT}}{\Lambda^2} \mathcal{O}_{i,d}^{\rm SMEFT}$$

SMEFT RGE

$$\mathcal{L}_{\rm LEFT} = \mathcal{L}_{\rm QCD+QED} + \sum_{i,d} \frac{C_{i,d}^{\rm LEFT}}{v^2} \mathcal{O}_{i,d}^{\rm LEFT}$$

LEFT RGE

Operators mix through RGE what
We want to know the SMEFT
structure at the high scale

Important remarks for our fit

- The **simultaneous** determination of **SM + NP** parameters is **crucial**
- The **NP corrections** to **SM Yukawas** and **CKM** must be **included**
- These corrections **might be sizeable** for some flavour assumptions $\Rightarrow$ requiring to **float the SM parameters** in the fit
- The $U(2)^5$ requires **specifying** the structure of the **SM Yukawa** at the **UV** $\Rightarrow$ SM parameters **cannot be replaced** by experimental values
- The **degeneracies** between SM parameters and NP coefficients **break** the Gaussian approximation, **calling for a full MC simulation**.

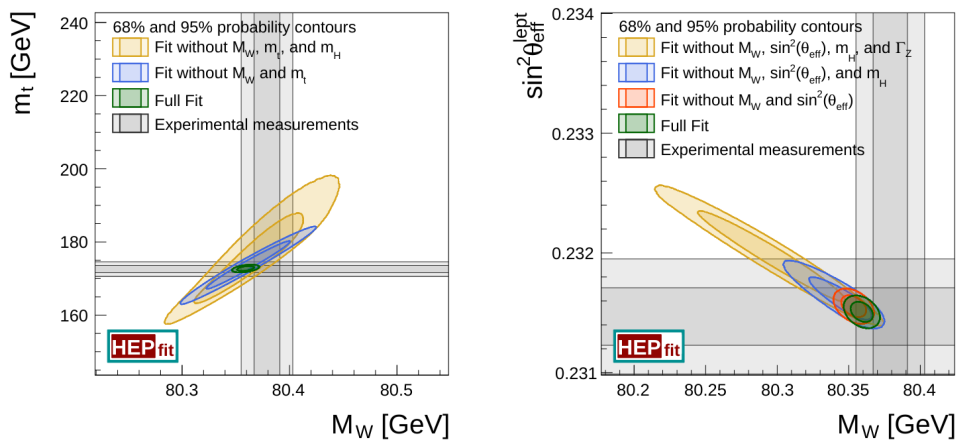
Observables included

- **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

Observables included: EWPO and Di-boson

- **Electroweak precision observables**
  - Z-pole observables (LEP/SLD): Γ_Z,$\sin^2\theta_{\text{eff}}$, A_l, A_{FB},...
  - W observables (LEP-II, Tevatron, LHC):M_W, Γ_W
  - m_t, M_H, $\sin\theta_{\text{eff}}$ (Tevatron/LHC)

  `HEPfit` contains all the predictions to EWPO in the SM at highest available precision [J. de Blas, M. Ciuchini, E. Franco, A. Goncalves, S. Mishima, M. Pierini, L. Reina, and L. Silvestrini, 2112.07274]

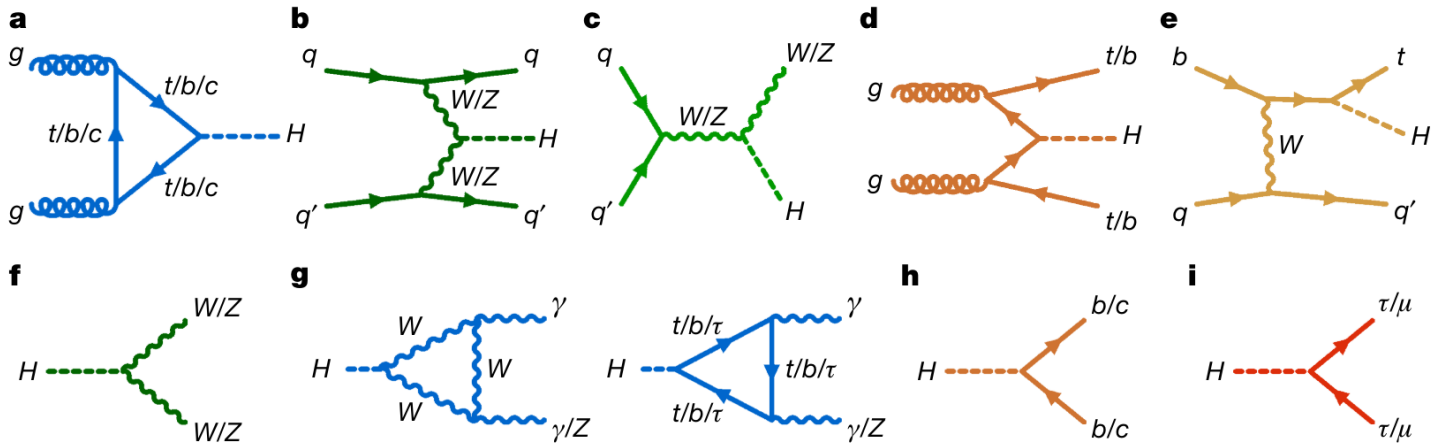


  Same framework for the SMEFT including LO contributions on top

- **Di-boson** production
  - $e^+e^- \to W^+W^-$ [Berthier, Bjørn, Trott, 1606.06693]

Observables included: Higgs and Top quark

- **Higgs boson** observables
  - Simplified Template Cross Sections (ATLAS and CMS)

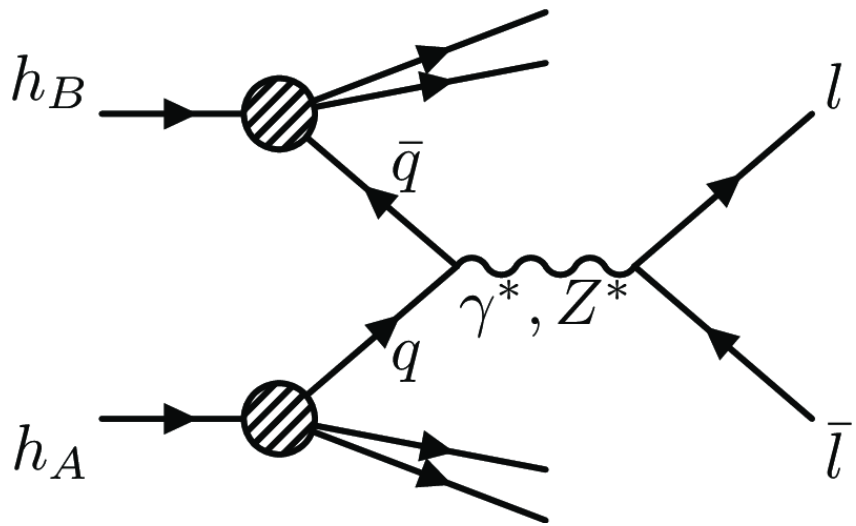


- **Top-quark** measurements
  - Asymmetries plus inclusive and differential cross sections
    $pp \to t\bar{t}, t\bar{t}Z, t\bar{t}W, t\bar{t}\gamma, tZq, t\gamma q, tW, \ldots$

The SMEFT parametrisations are obtained using `MG5_aMC@NLO` with the UFOs `SMEFTsim3.0` [I. Brivio, 2012.11343] and `SMEFT@NLO` [Degrande et al., 2008.11743]

Observables included: Drell-Yan and LEP-II

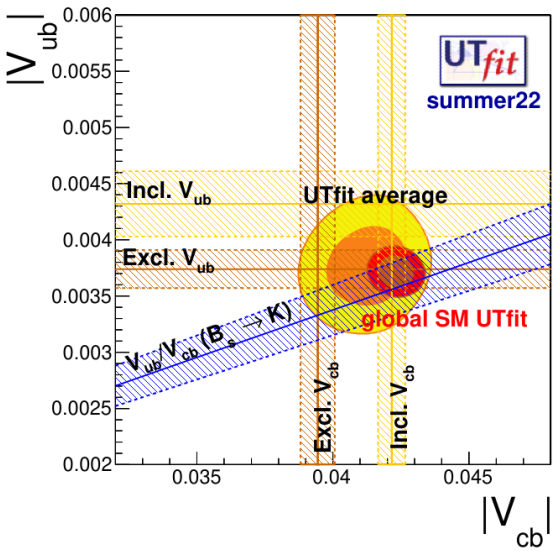
- **Drell-Yan:**
  - Cross sections for Drell-Yan dilepton ($pp \to \bar{\ell}\ell$) and mono-lepton ($pp \to \bar{\ell}\nu$) searches by ATLAS and CMS
  - Added using the package `HighPT` [L. Allwicher, D. A. Faroughy, F. Jaffredo, O. Sumensari, F. Wilsch, 2207.10756, 2207.10714]

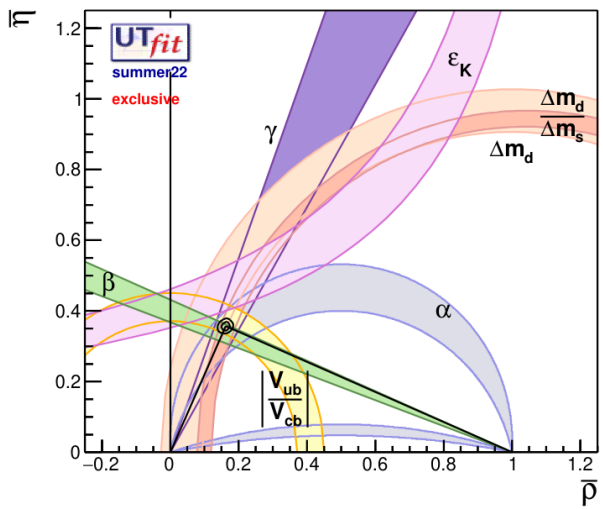


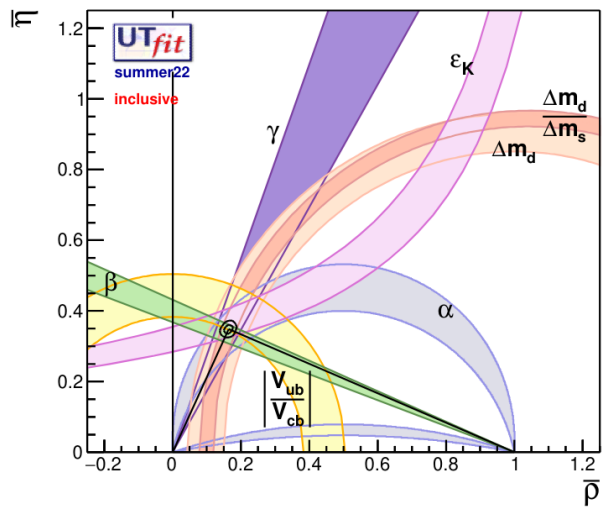
- **LEP-II** production cross sections computed analytically by J. de Blas
  - $e^+e^- \to \mu^+\mu^-, \tau^+\tau^-$, hadrons

Observables included: Flavour

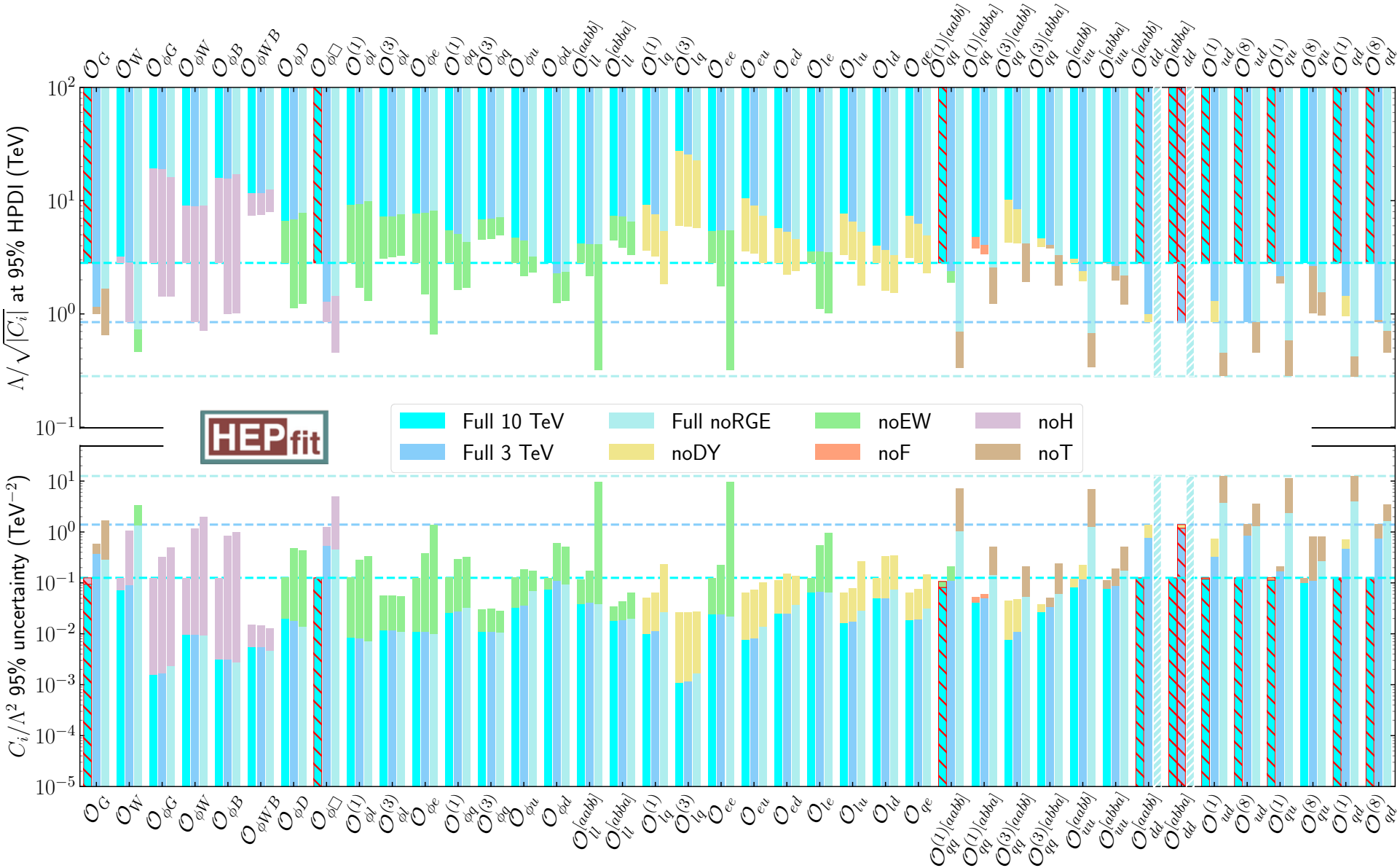
- $|\Delta F| = 2$: Δm_{B_d}, Δm_{B_s}, ϵ_k, $D - \bar{D}$
- $|\Delta F| = 1$: $B \to X_{s,d}\gamma$ plus leptonic ($B_s \to \mu^+\mu^-$, $B \to \tau\nu$, $K \to \ell\nu$, $\pi \to \ell\nu$) and semileptonic ($B_s \to D^{(*)}\ell\nu$, $B \to \pi\ell\nu$, $K \to \pi\ell\nu$) mesonic decays
- These observables are used to determine the V_{CKM} in the SM fits
- The **UT***fit* collaboration (including L. Silvestrini and M. Valli) has been performing these fits in the SM [UTfit Collab., 2212.03894]
- `HEPfit` uses a similar framework (including the mentioned observables) to constrain the (SM +) SMEFT parameters



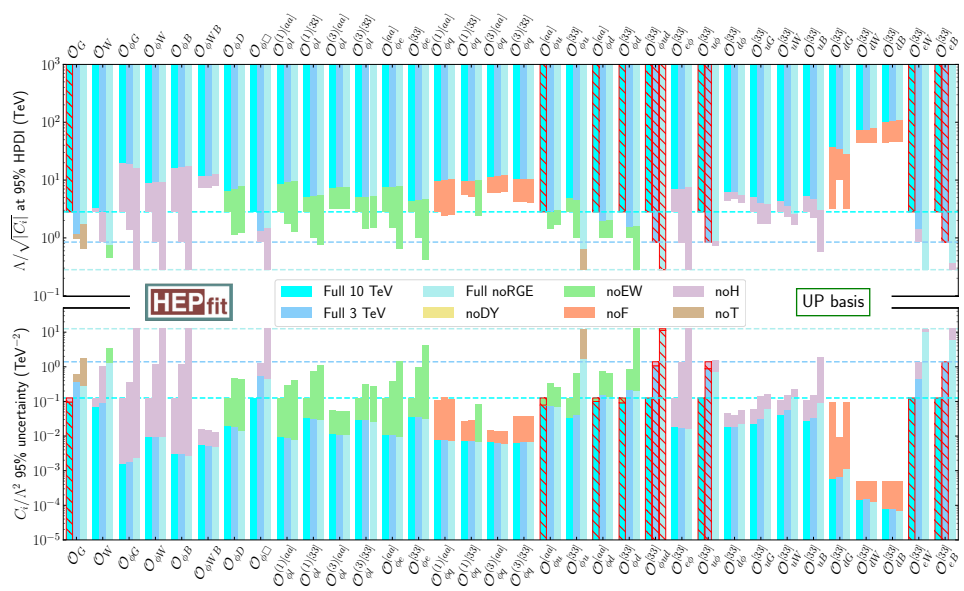


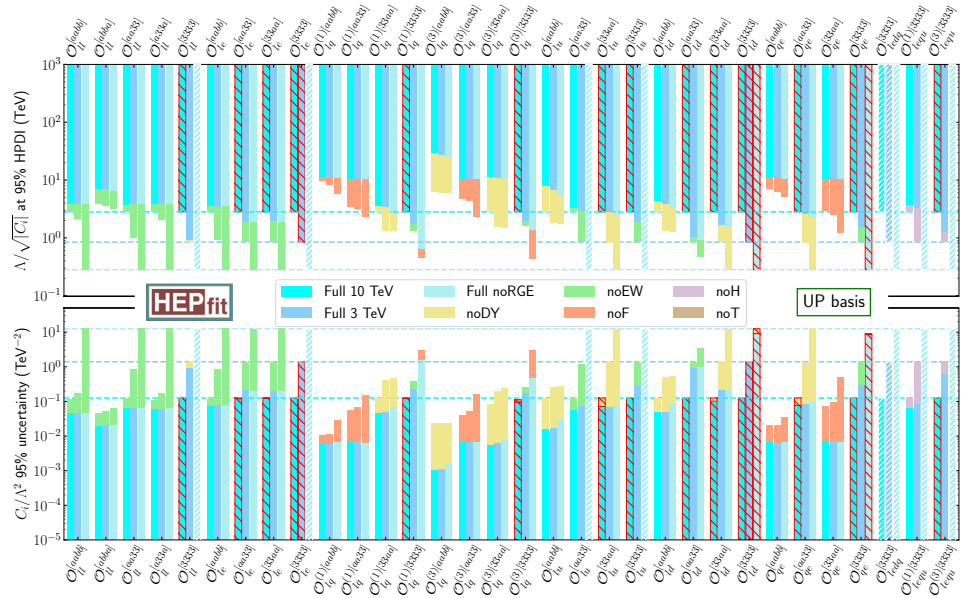


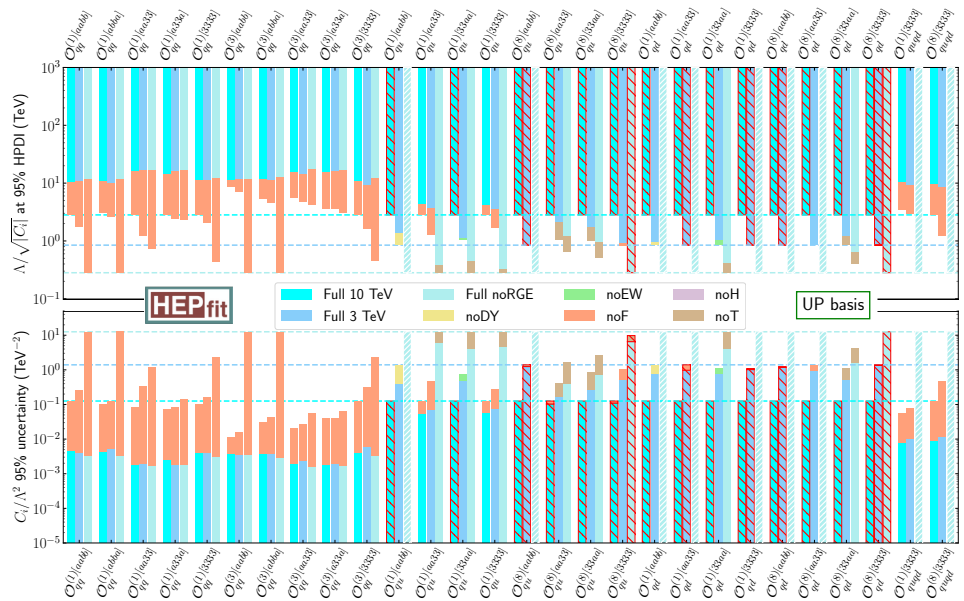
Fits for $U(3)^5$ flavour symmetry: Individual

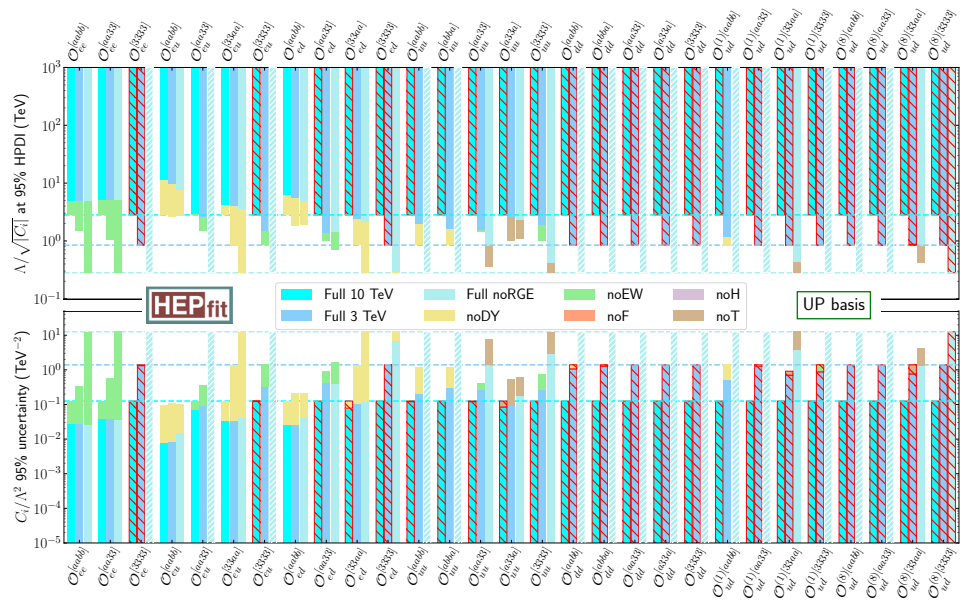


Fits for $U(2)^5$ flavour symmetry: Individual

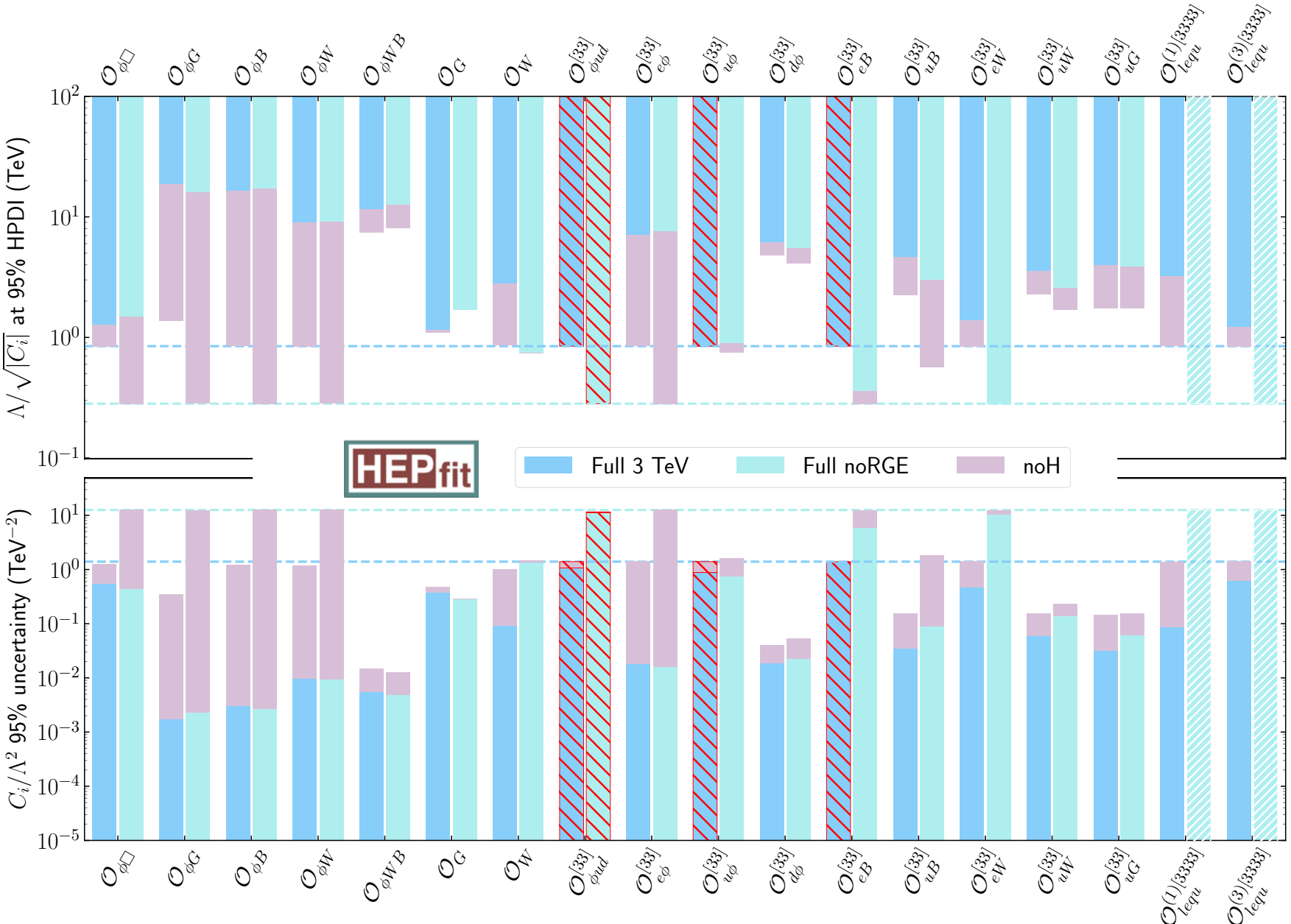








Operators mainly constrained by Higgs data

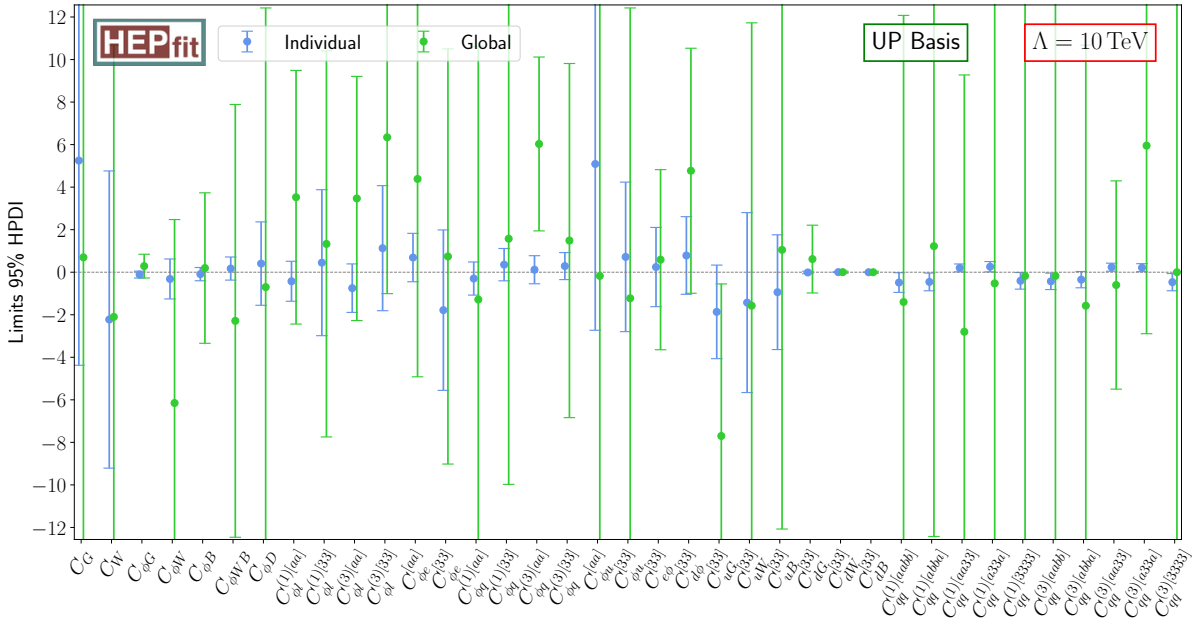


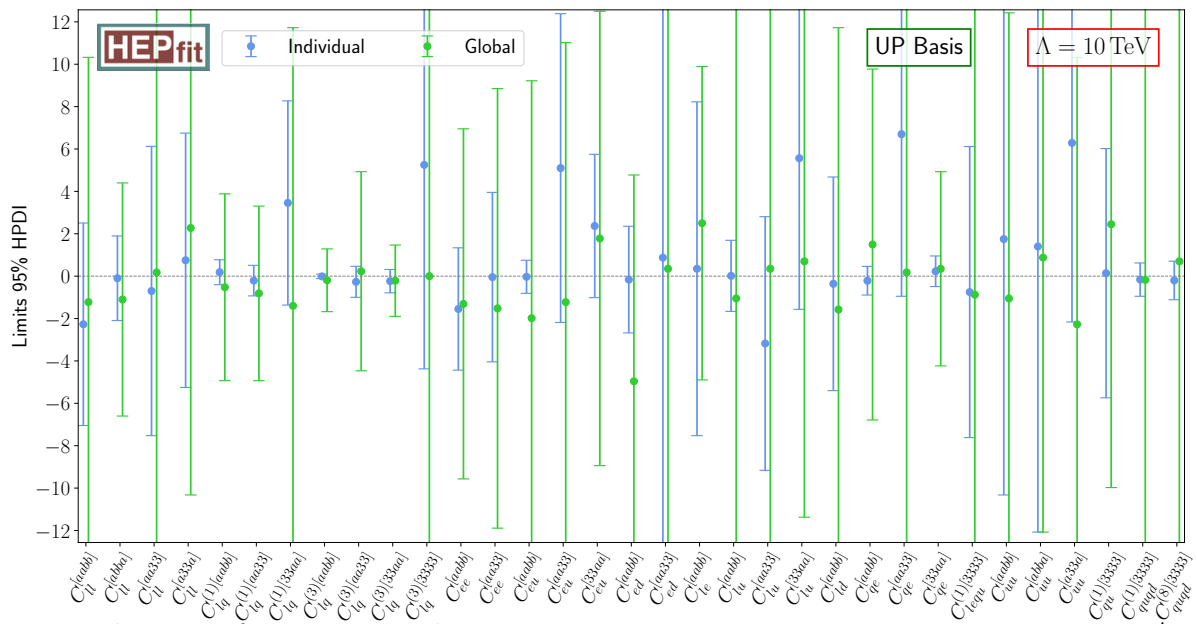
Effects of Higgs data

- $t\bar{t}H$ sensitive to $\left\{C_{u\phi}^{[33]}, C_{uG}^{[33]}\right\}$
- ggF more precisely measured yields the leading constraint on $\left\{C_{u\phi}^{[33]}, C_{uG}^{[33]}, C_{\phi G}\right\}$
- $H \to \gamma\gamma$ leading bounds on $\left\{C_{\phi B}, C_{\phi W}, C_{\phi WB}, C_{W}, C_{eB}^{[33]}, C_{uB}^{[33]}, C_{uW}^{[33]}, C_{eW}^{[33]}\right\}$
- $H \to \tau^+\tau^-$ constrains $\left\{C_{eW}^{[33]}, C_{u\phi}^{[33]}, C_{uW}^{[33]}, C_{lequ}^{(1)[3333]}, C_{lequ}^{(3)[3333]}\right\}$
- $H \to b\bar{b}$ provides the leading constraint on $\left\{C_{d\phi}^{[33]}, C_{\phi ud}^{[33]}\right\}$
- Other channels are relevant in the context of a global fit to lift flat directions

Fits for $U(2)^5$ flavour symmetry: Global

- Huge number of d.o.f. for the $U(2)^5$ case $\rightarrow$ challenging to obtain constraints within perturbative limit
- Still some operators can be constrained even for $\Lambda = 10$ TeV
- Additional observables and improvement of experimental precision are crucial





Summary and outlook

- `HEPfit` has proven to be a **robust and efficient** code extremely useful to fit the SMEFT
- With our framework we **fit the SM parameters and the WC** at the same time
- We are able to provide the values of all the parameters in a **well-defined flavour basis** at the NP scale
- For the demanding $U(2)^5$ case `HEPfit` is **able to perform a fit** with EW, di-boson, Higgs, top, Drell-Yan, LEP-II, and flavour data, **including around 200 parameters**
- Given the current data included **few coefficients** can be constrained for the $U(2)^5$ case **beyond the perturbative limit** in the **global fit**

Let's meet again in Valencia for HEFT 2026!

All the information in the HEFT2026 indico page

Dates: from 8th to 12th of **June 2026**

Location: Jardi Botànic of the **Universitat de València**

Abstract submission will be open from **January**

LOC: Luca Mantani, María Moreno Llácer, Ben Stefanek, Marco Ardu, Suraj Prakash, Ajdin Palavric

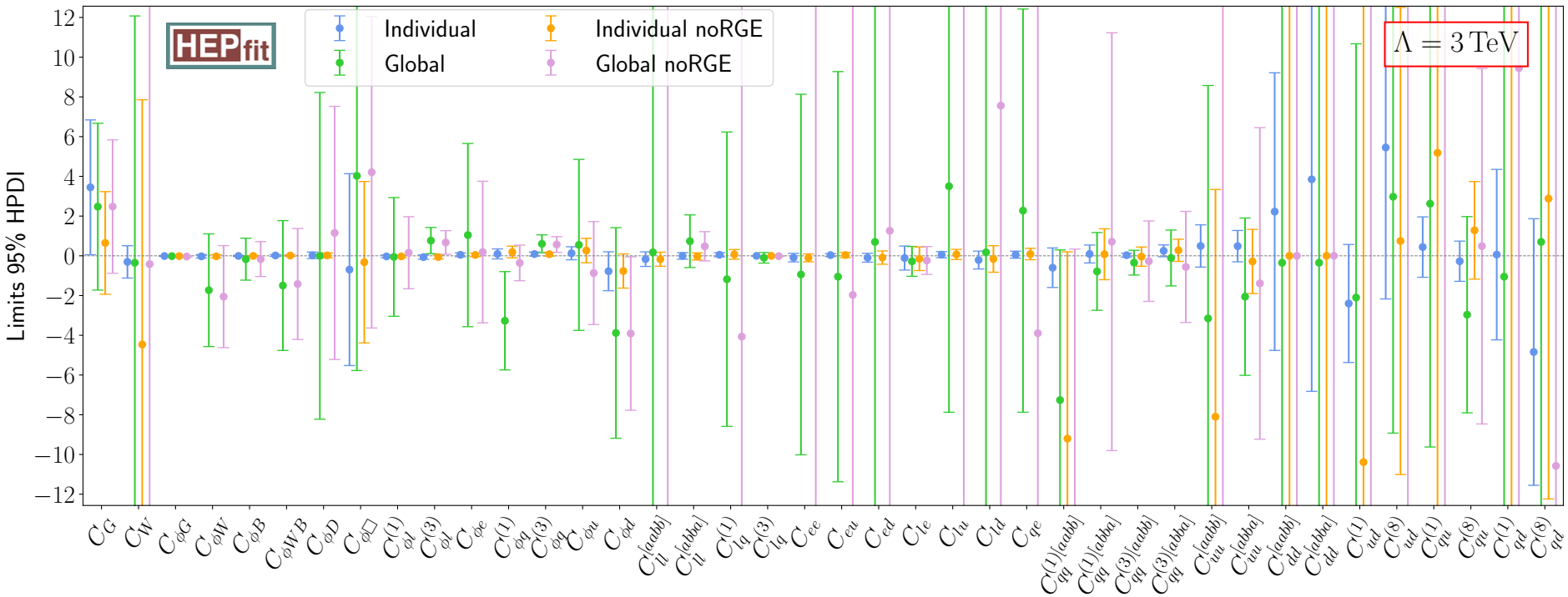
Programme Committee: Ana Rosario Cueto Gómez, Javier Fuentes Martín, Javier Virto, Víctor Miralles + LOC

Thanks for your attention!

Back up

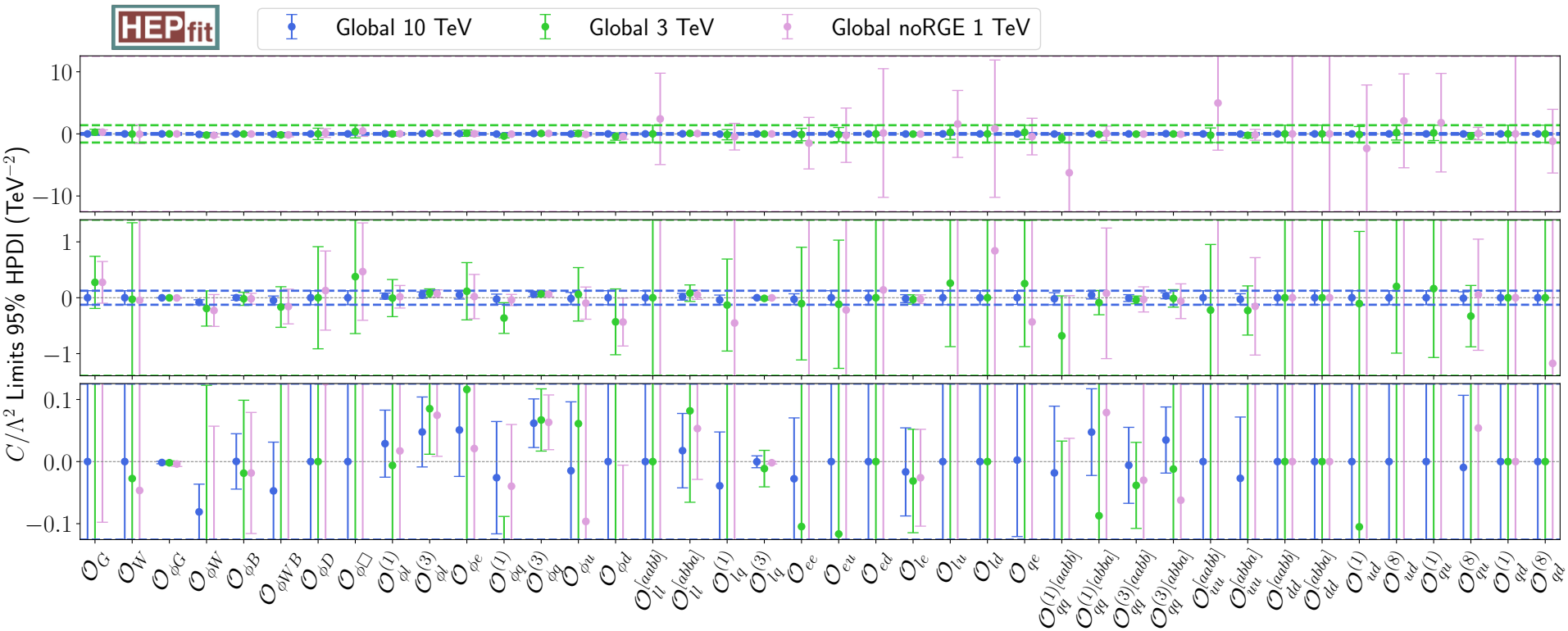
Fits for $U(3)^5$ flavour symmetry: Global vs Individual

- Significant worsening of the limits due to correlations
- Still meaningful limits for most of them with $\Lambda = 3$ TeV

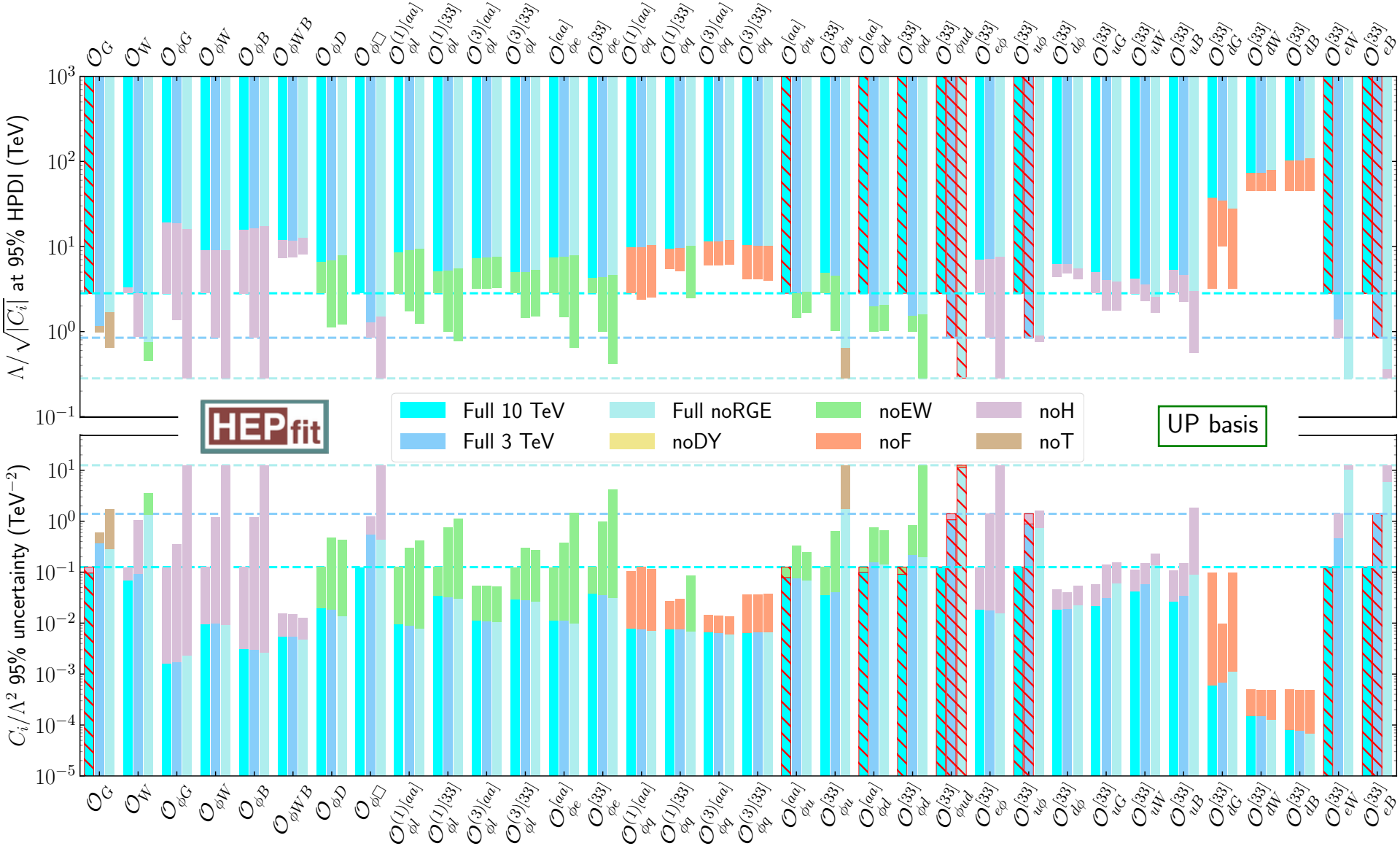


Fits for $U(3)^5$ flavour symmetry: Global

- For $\Lambda = 10$ TeV challenging to constrain the operators within their perturbative range $\rightarrow$ still some are constrained even in the global fit



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



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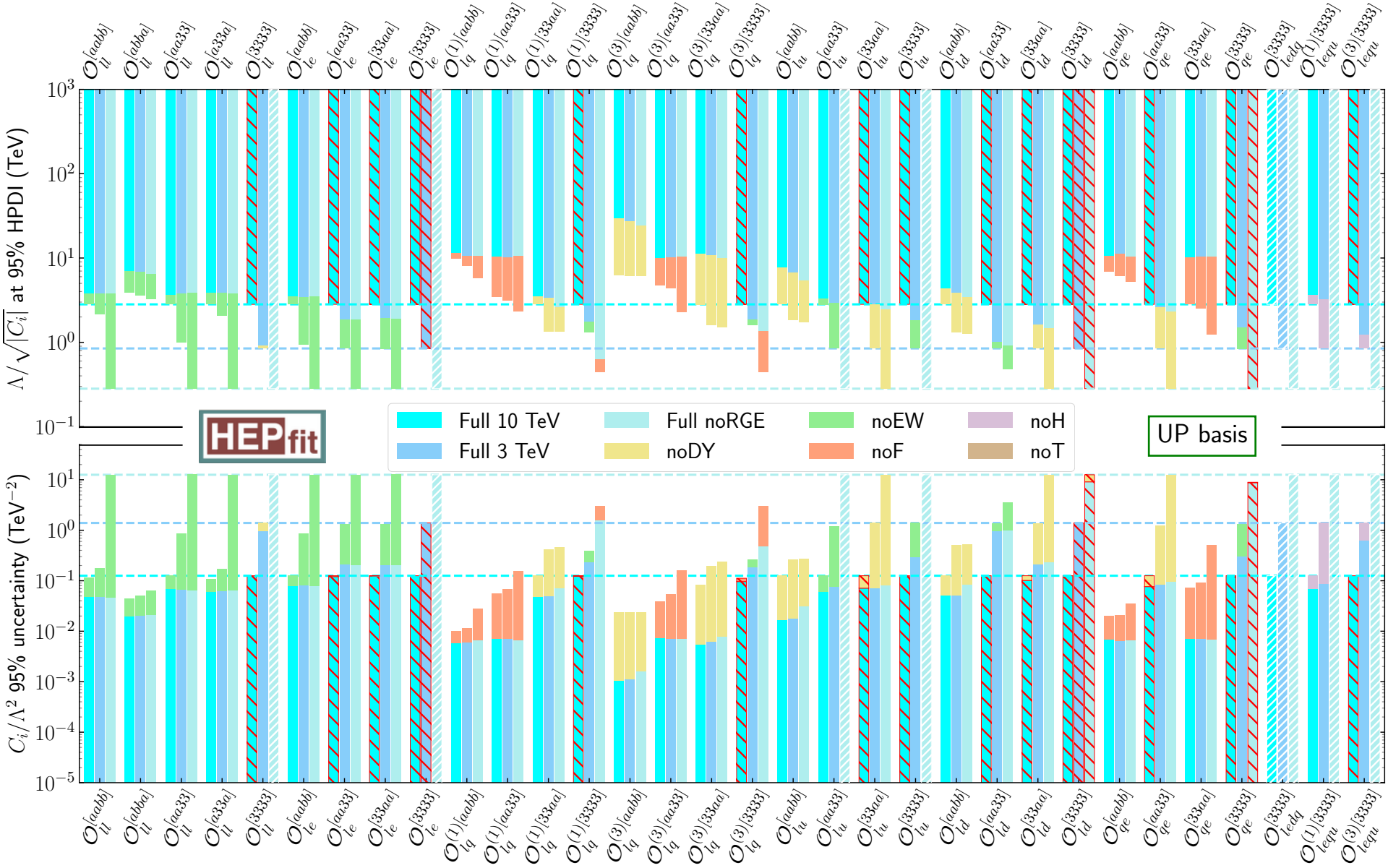

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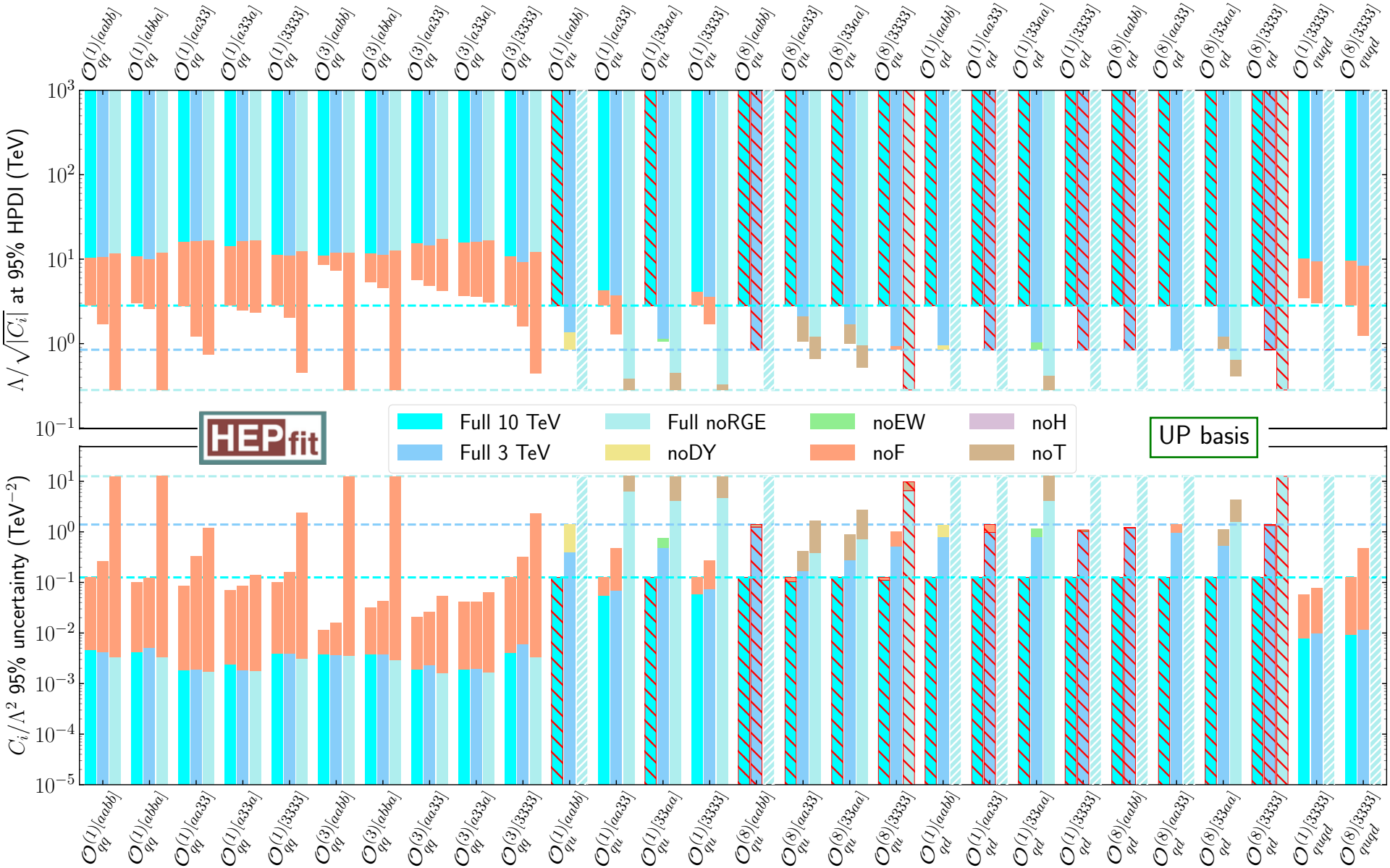
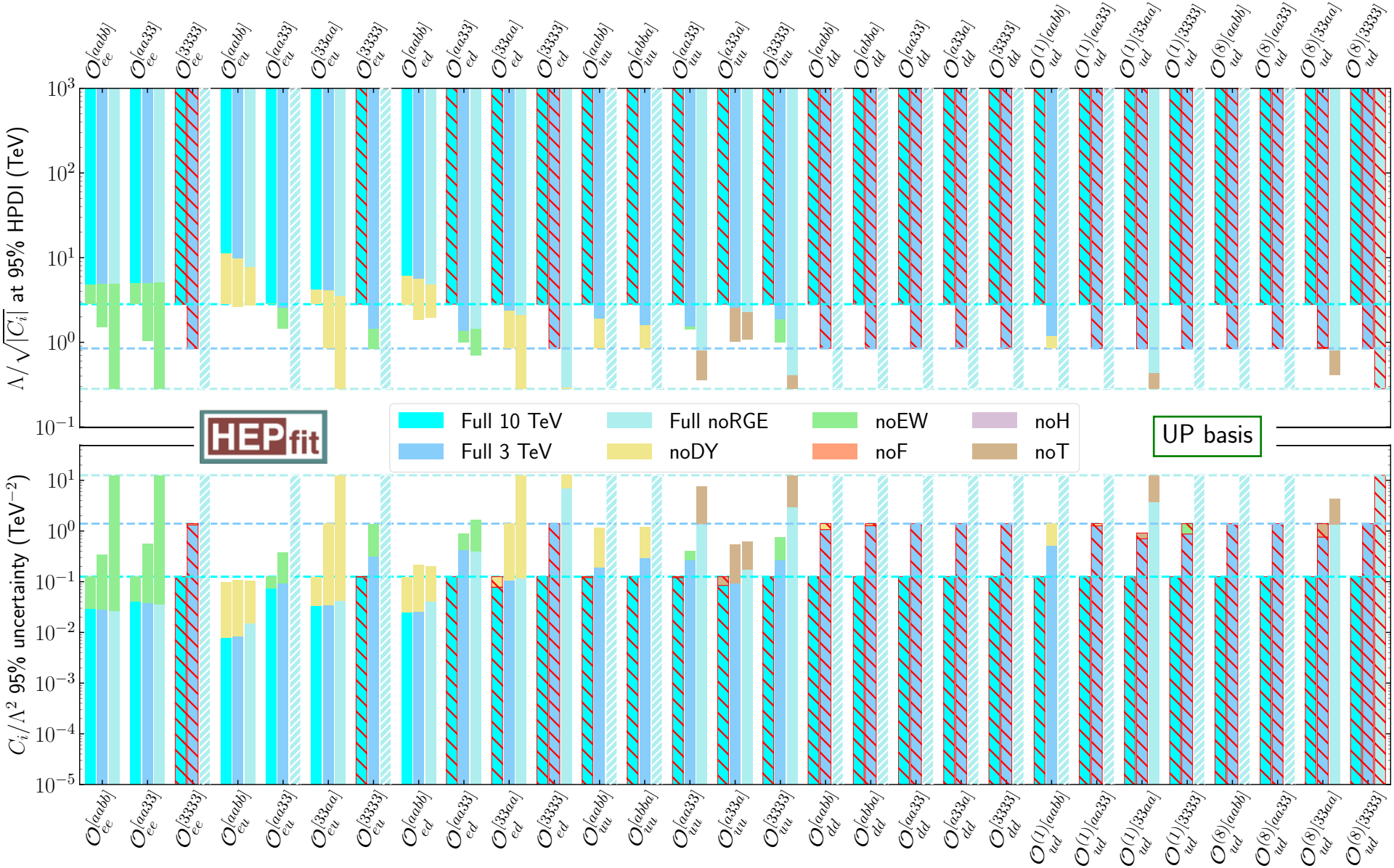
Fits for $U(2)^5$ flavour symmetry: Individual