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The role of Flavour in global SMEFT fits

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Based on arXiv: 2507.06191 [hep-ph], in collaboration with
A. Goncalves, V. Miralles, L. Reina, L. Silvestrini, M. Valli

Introduction

Disclaimer(s)

- I am not a Flavour expert (not even close to…)
- This talk could be seen as the second part of the talk yesterday in the Joint "Top and Electroweak physics" + "Higgs physics session" → *Electroweak, Higgs and Top physics in SMEFT fits*
  - There will be some overlap to set the stage and introduce the tools but different focus on the discussion

- With few exceptions*, flavour is one of the sectors that receives less attention in global SMEFT combinations of different types of data sets
  - Not because it is not relevant but because it difficult to treat!
  - As long as one departs from trivial flavour assumptions and/or goes beyond leading-order studies, flavour measurements enter the game
- The purpose of this talk is to illustrate this, with a global study combining ***EW+Higgs+Top+Flavour*** in the SMEFT, floating ***simultaneously all the SMEFT parameters and the SM parameters*** (+ including RGE effects, matching SMEFT/LEFT,…)

*See e.g. R. Aoude et al., JHEP 12 (2020) 113, R. Bartocci et al. JHEP 05 (2024) 074, S. Bruggisser et al. JHEP 02 (2023) 225, L. Allwicher et al. JHEP 03 (2024) 049, C. Grunwald et al., JHEP 11 (2023) 110

Introduction

- With some minimal assumptions about the UV, the IR effects of new physics can be parameterized via *the SMEFT Lagrangian*:

$$\mathcal{L}_{\mathrm{Eff}} = \sum_{d=4}^{\infty} \frac{1}{\Lambda^{d-4}} \mathcal{L}_d = \mathcal{L}_{\mathrm{SM}} + \frac{1}{\Lambda}\mathcal{L}_5 + \frac{1}{\Lambda^2}\mathcal{L}_6 + \cdots \longleftarrow \mathcal{L}_{\mathrm{UV}}(?)$$

$$\mathcal{L}_d = \sum_i C_i^d \mathcal{O}_i \qquad [\mathcal{O}_i] = d \longrightarrow \left(\frac{q}{\Lambda}\right)^{d-4} \qquad E \ll \Lambda$$

$$q = v, E < \Lambda$$

- ***What is not Flavour in the SMEFT?*** To dimension 6 (2499 operators assuming B and L conservation)

4 Fermion

$\mathcal{O}_{ll}$ $\mathcal{O}_{ee}$ $\mathcal{O}_{le}$

$\mathcal{O}_{lq}^{(1)}$ $\mathcal{O}_{lq}^{(3)}$ $\mathcal{O}_{lu}$ $\mathcal{O}_{qe}$ $\mathcal{O}_{eu}$ $\mathcal{O}_{ld}$ $\mathcal{O}_{ed}$

$\mathcal{O}_{qq}^{(1)}$ $\mathcal{O}_{qq}^{(3)}$ $\mathcal{O}_{uu}$ $\mathcal{O}_{dd}$ $\mathcal{O}_{ud}^{(1)}$ $\mathcal{O}_{ud}^{(8)}$

$\mathcal{O}_{qu}^{(1)}$ $\mathcal{O}_{qd}^{(1)}$ $\mathcal{O}_{qu}^{(8)}$ $\mathcal{O}_{qd}^{(8)}$

$\mathcal{O}_{lequ}^{(1)}$ $\mathcal{O}_{lequ}^{(3)}$ $\mathcal{O}_{ledq}$

$\mathcal{O}_{quqd}^{(1)}$ $\mathcal{O}_{quqd}^{(8)}$

2F-Vector

$\mathcal{O}_{\phi l}^{(1)}$ $\mathcal{O}_{\phi l}^{(3)}$ $\mathcal{O}_{\phi e}$

$\mathcal{O}_{\phi q}^{(1)}$ $\mathcal{O}_{\phi q}^{(3)}$ $\mathcal{O}_{\phi u}$ $\mathcal{O}_{\phi d}$ $\mathcal{O}_{\phi ud}$

2F-Scalar

$\mathcal{O}_{e\phi}$ $\mathcal{O}_{u\phi}$ $\mathcal{O}_{d\phi}$

2F-Dipoles

$\mathcal{O}_{eB}$ $\mathcal{O}_{eW}$

$\mathcal{O}_{uB}$ $\mathcal{O}_{uW}$ $\mathcal{O}_{uG}$

$\mathcal{O}_{dB}$ $\mathcal{O}_{dW}$ $\mathcal{O}_{dG}$

Bosonic

$\mathcal{O}_G$ $\mathcal{O}_W$ $\longleftrightarrow$ CP $\longleftrightarrow$ $\mathcal{O}_{\tilde{G}}$ $\mathcal{O}_{\tilde{W}}$

$\mathcal{O}_\phi$ $\mathcal{O}_{\phi\Box}$ $\mathcal{O}_{\phi D}$

$\mathcal{O}_{\phi B}$ $\mathcal{O}_{\phi W}$ $\mathcal{O}_{\phi WB}$ $\mathcal{O}_{\phi G}$ $\longleftrightarrow$ CP $\longleftrightarrow$ $\mathcal{O}_{\phi\tilde{B}}$ $\mathcal{O}_{\phi\tilde{W}}$ $\mathcal{O}_{\phi\tilde{W}B}$ $\mathcal{O}_{\phi\tilde{G}}$

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$$E \ll \Lambda$$

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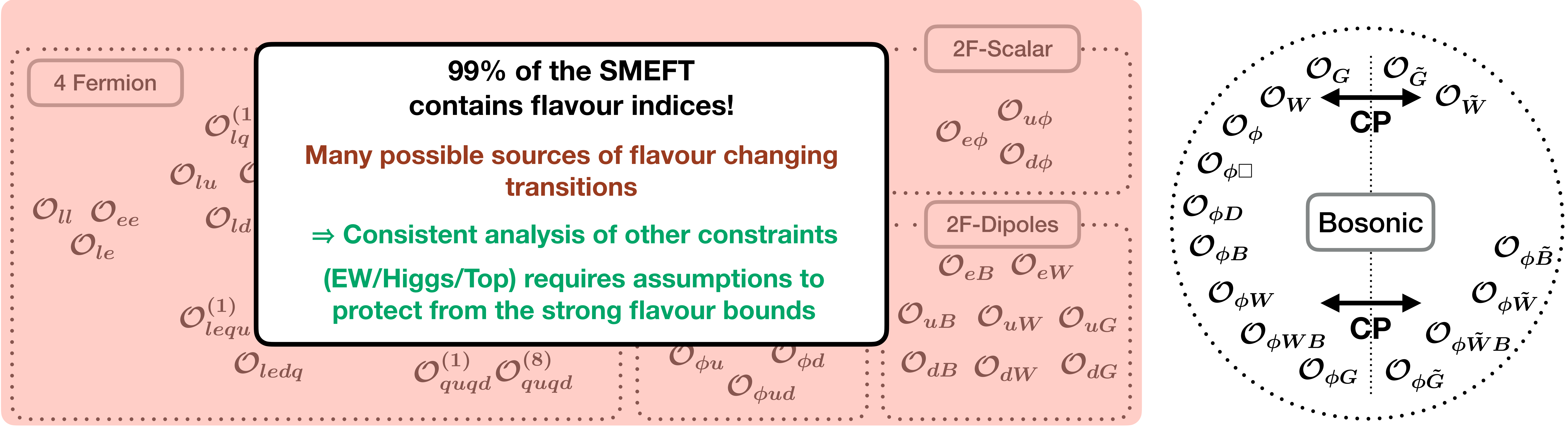
- ***What is not Flavour in the SMEFT?*** To dimension 6 (2499 operators assuming B and L conservation)



Introduction

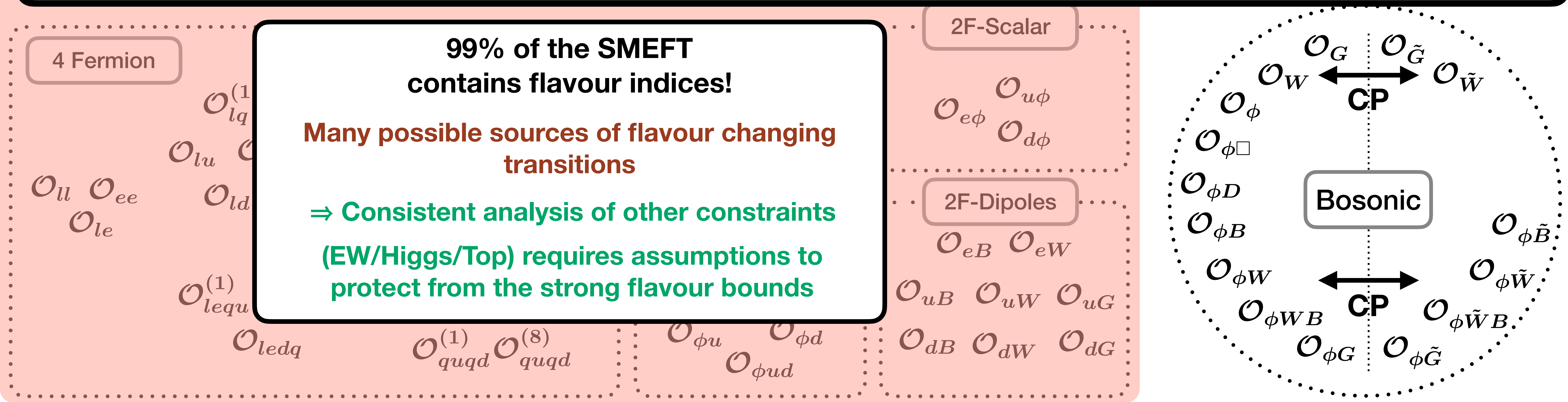
Common choices motivated by "realistic" BSM scenarios

- Assume New Physics is flavour blind and respects a $U(3)^5$ flavour symmetry
- Assume New Physics respects the approximate U(2) quark flavour symmetries of the SM

⇒ No new sources of flavour mixing but separate 3rd and light generations

$$U(2)^5 = U(2)_{q_L} \times U(2)_{u_R} \times U(2)_{d_R} \times U(2)_{l_L} \times U(2)_{e_R}$$

Even under these assumptions, Flavour can play an important role in SMEFT analysis and must be carefully implemented in fitting tools



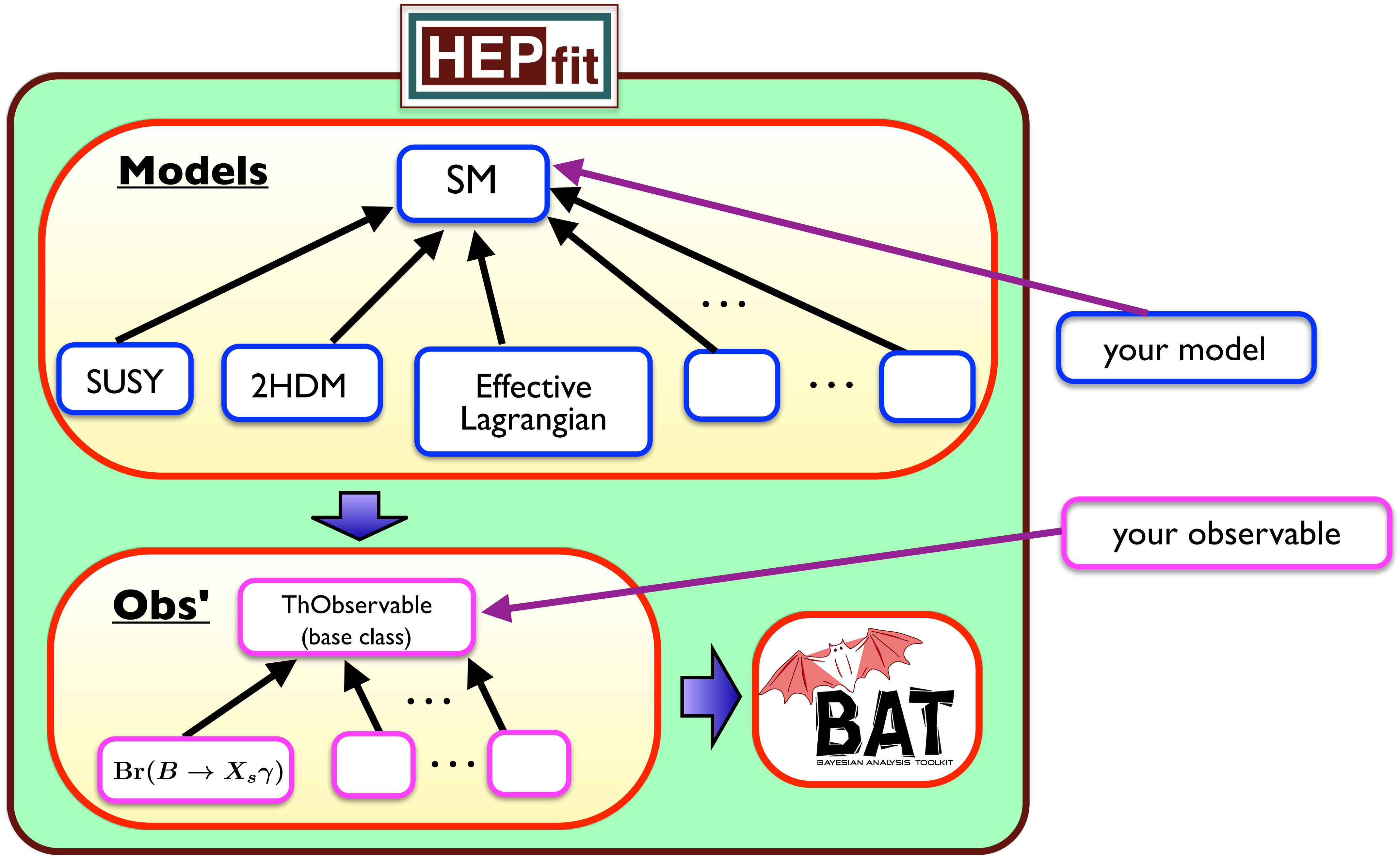
The Fitting Framework

The HEPfit code

- General **H**igh **E**nergy **P**hysics **fit**ting tool to combine indirect and direct searches of new physics (available under GPL on GitHub)

https://github.com/silvest/HEPfit

- Main Reference: **JB et al., Eur. Phys. J. C (2020) 80:456, arXiv: 1910.14012 [hep-ph]**



Designed as flexible open-source tool
(e.g. easy to add external models/observables)

Stand-alone mode to compute observable predictions
(In the SM & BSM)

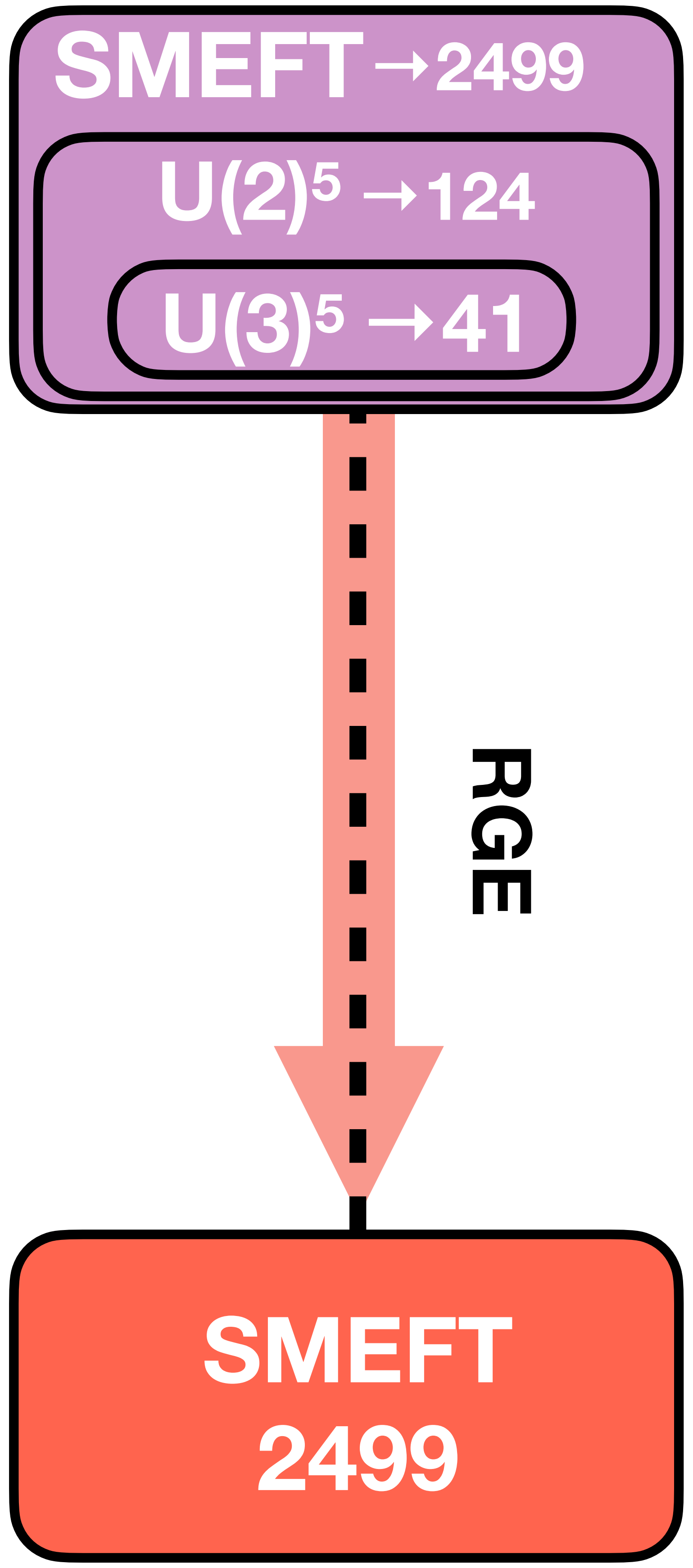
MCMC implementation for Bayesian Statistical Analyses
(Via modified version of BAT)
A. Caldwell et al., Comput. Phys. Commun. 180 (2009) 2197-2209

- Original code already containing a base SMEFT class with a setup for EW/Higgs LO studies

➡ Massive upgrades in the work presented here

The HEPfit code

- The **SMEFT class** in HEPfit :
- Implementation of full dimension-6 SMEFT basis:
  - Warsaw basis: All 2499 operators
  - Restrictions assuming different flavour assumptions available
    - $U(3)^5$ flavour symmetry
    - $U(2)^5$ flavour symmetry: both in the "UP" and "DOWN" bases
- Calculations in both "α" and "M_W" scheme for most observables
- RGE evolution included via **RGESolver** S. Di Noi, L. Silvestrini, Eur. Phys.J.C 83 (2023) 3, 200
  - Multiple possibilities: Exact integration / Matrix Evolution (much faster)
  - Possibility of RGE to multiple scales
    - **Careful:** RGE available only at LO (1-loop). Running between similar scales $<$ TH unc.
- NLO SMEFT finite terms available for several of the most precise observables
  - **Careful:** Consistent NLO study requires 2-loop RGE. Not available in literature (yet)

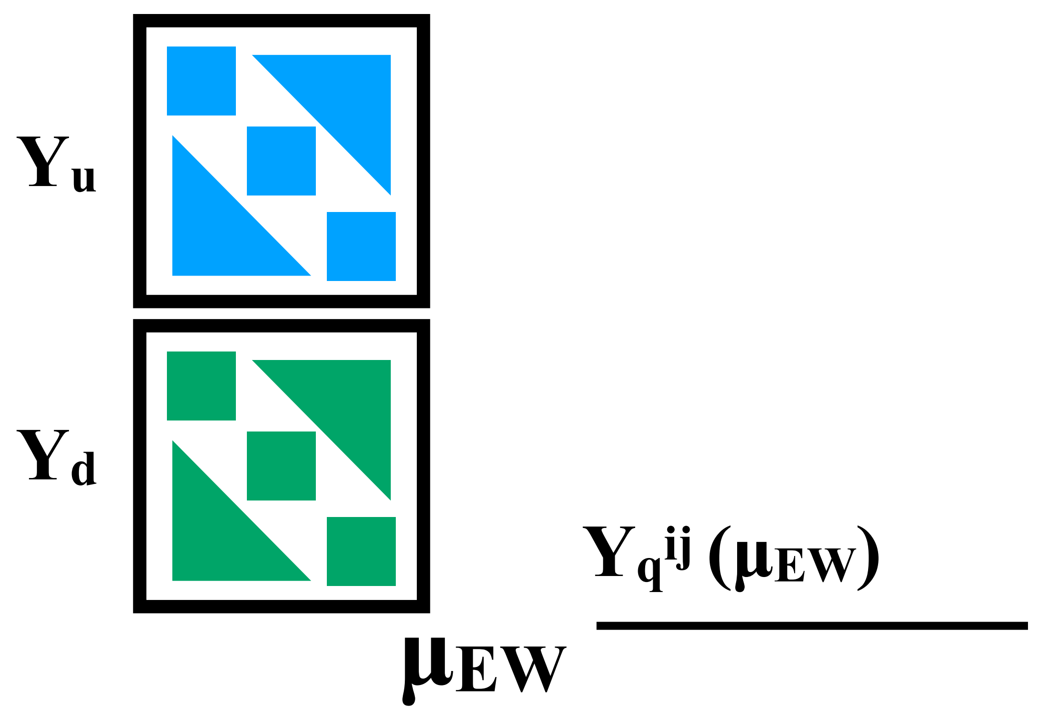


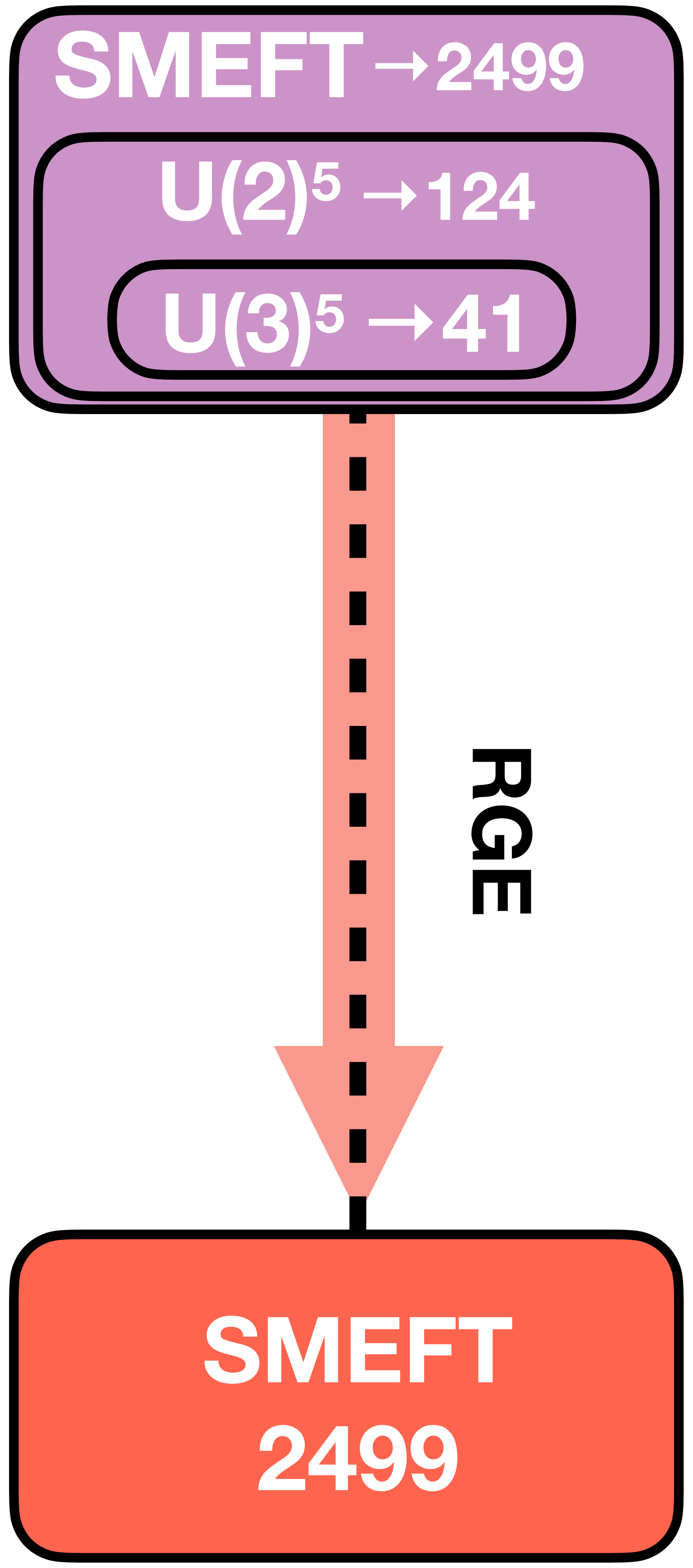
The HEPfit code

- The SMEFT class in HEPfit :

RGE and Flavour assumptions

- Scale-dependent assumption:
  - Assumed valid at Λ → Broken at any other scale (at least by SM interactions)
- U(2)^5 : Third generation treated separately
  - Need to specify direction of 3rd family in flavour space! → Follow SM Yukawas





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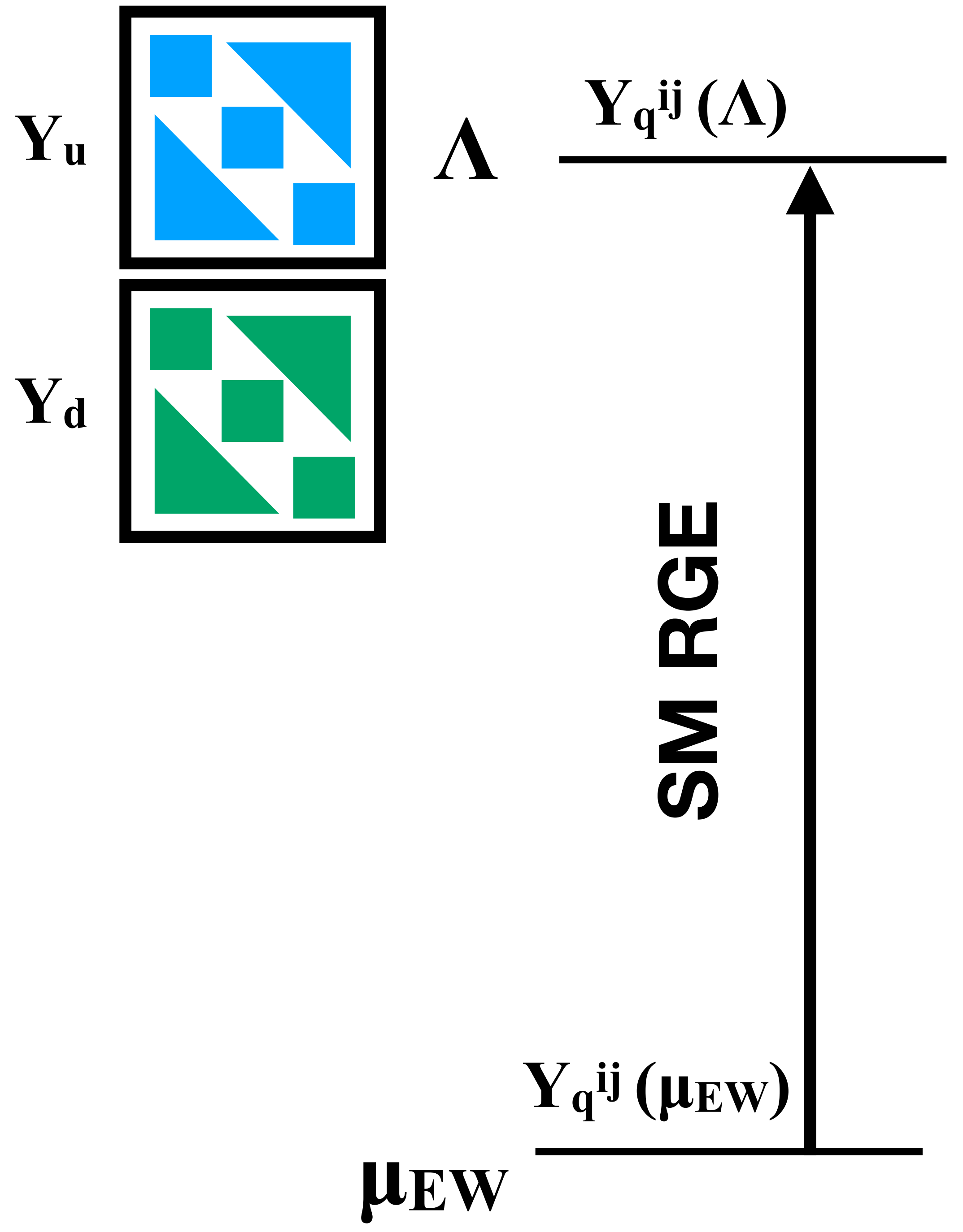

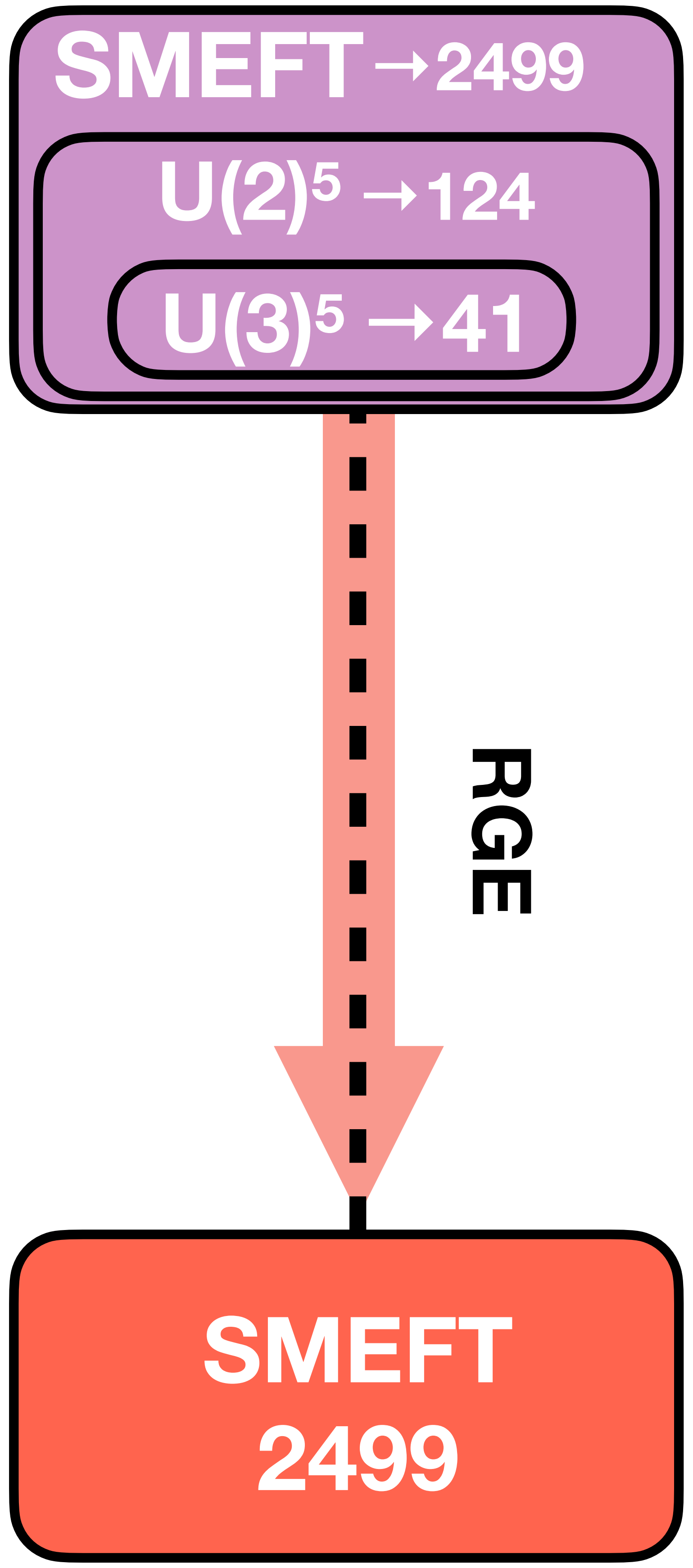

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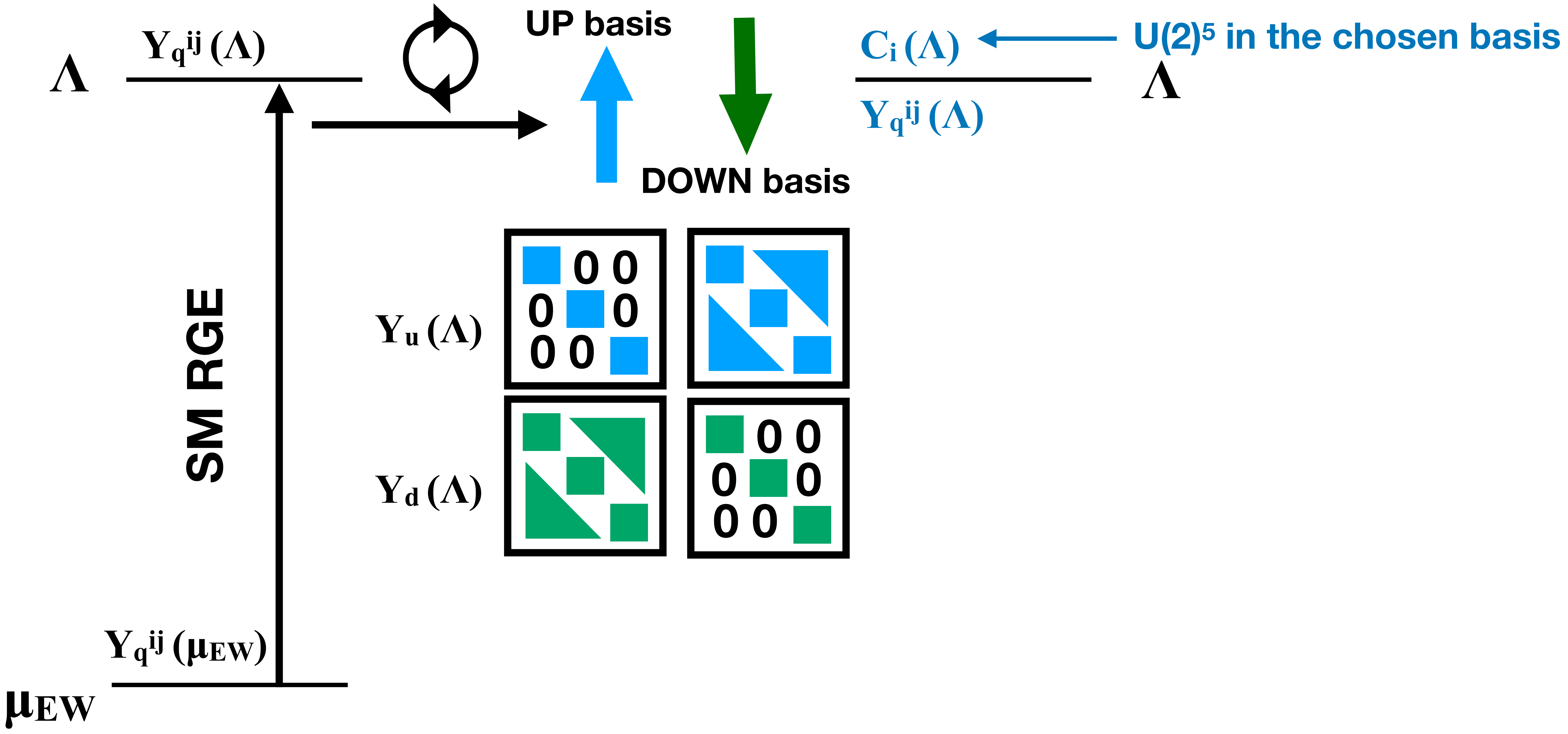

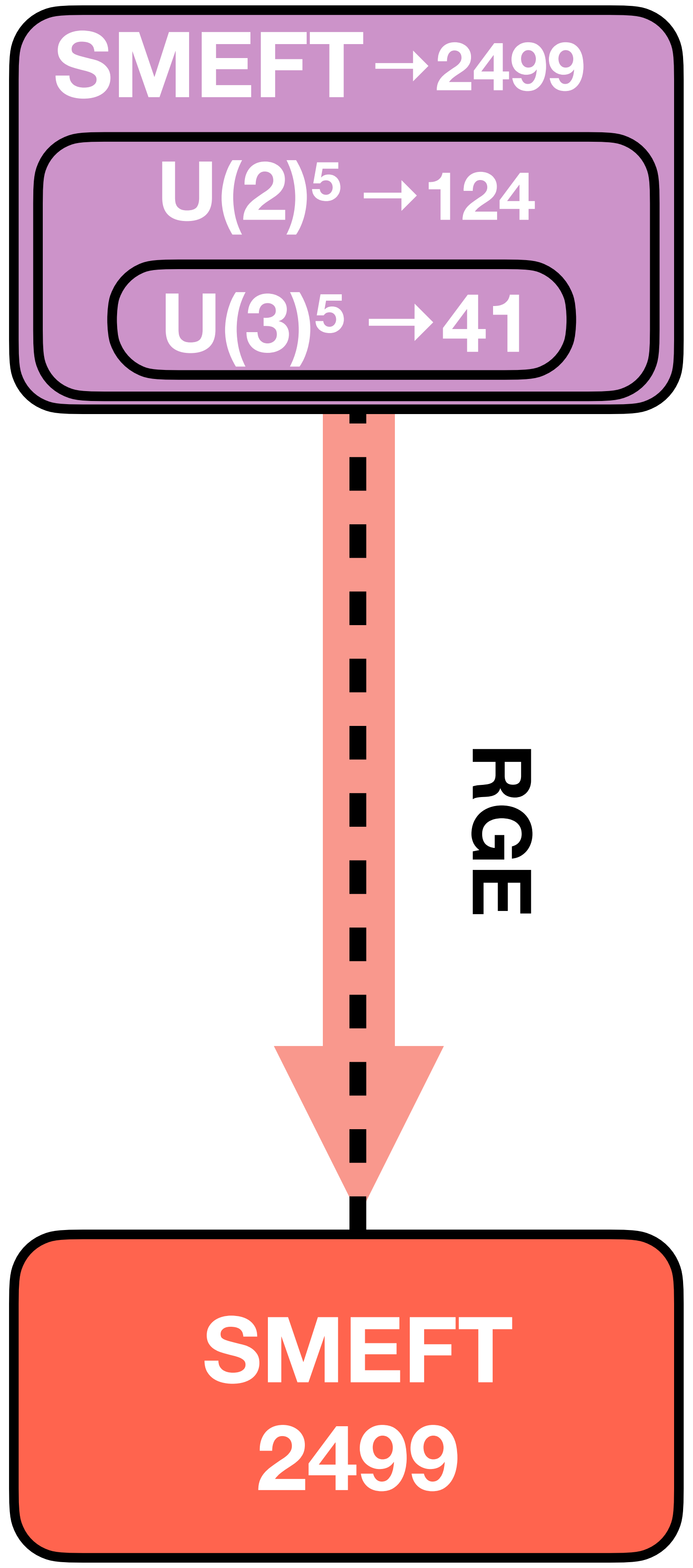

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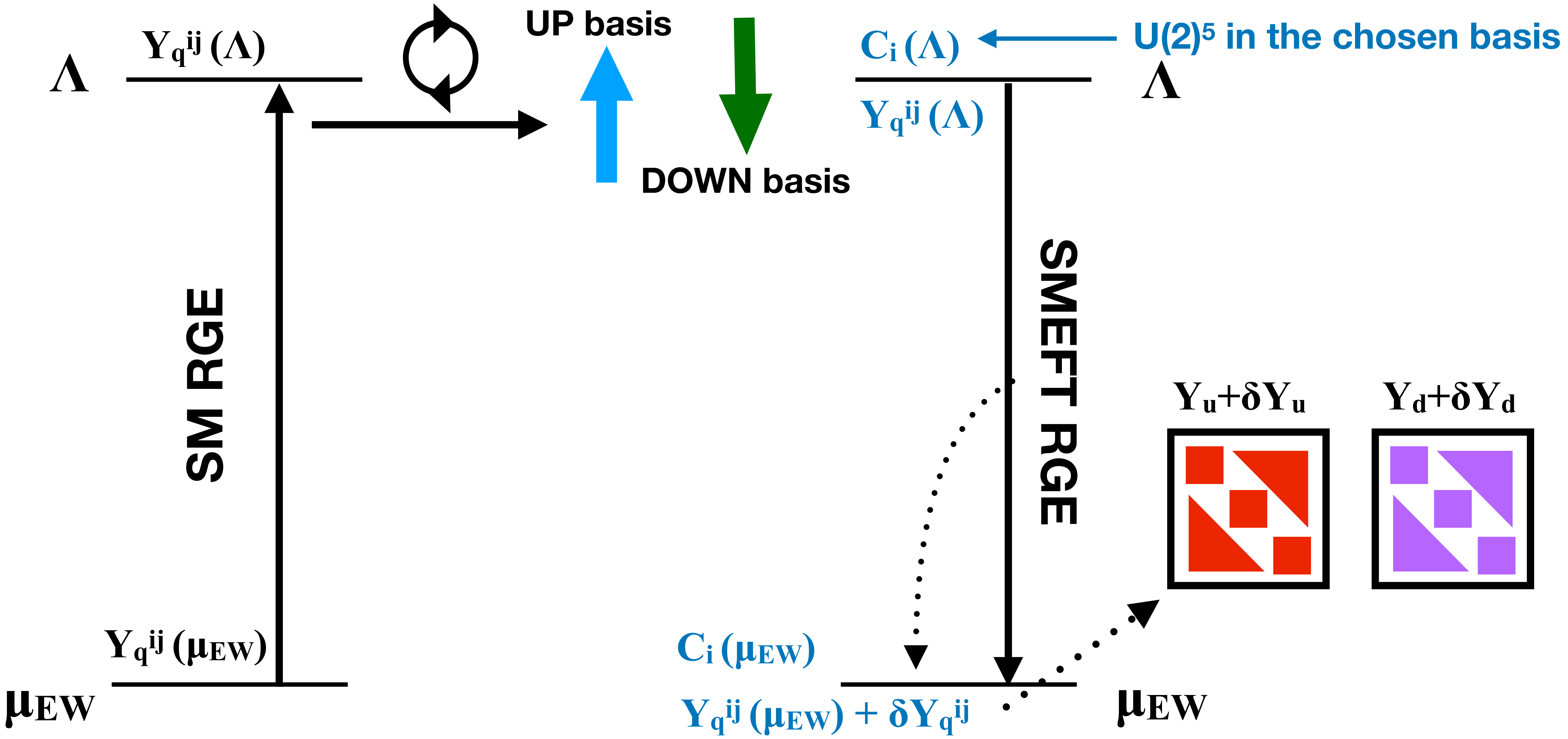

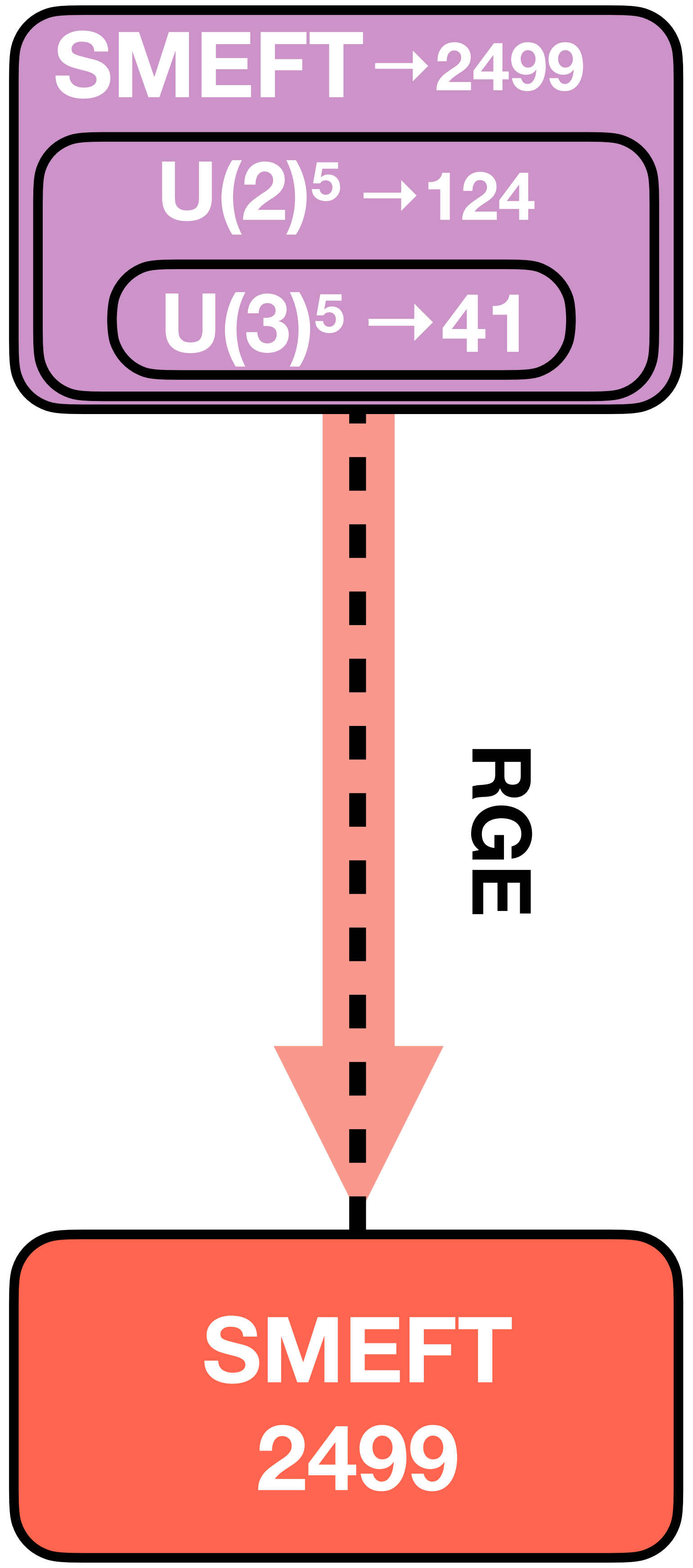

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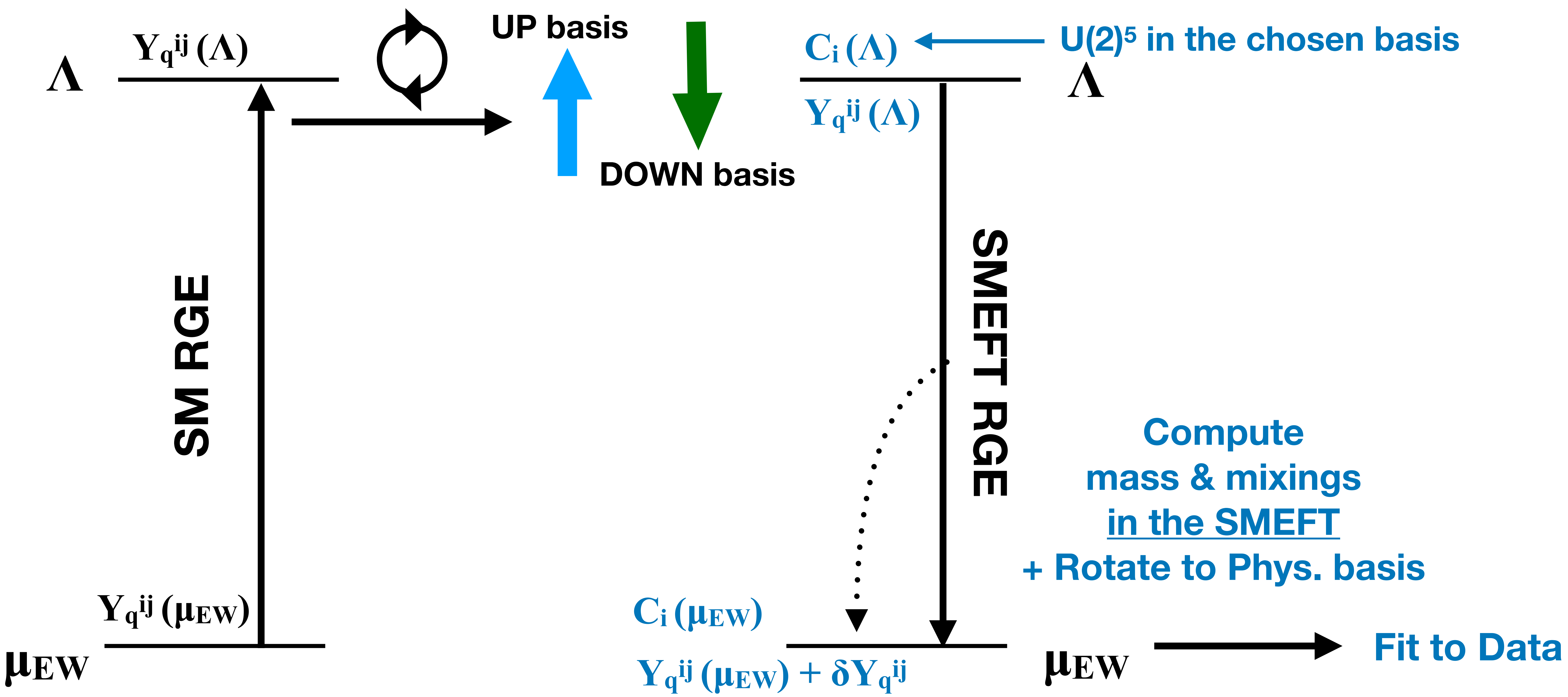
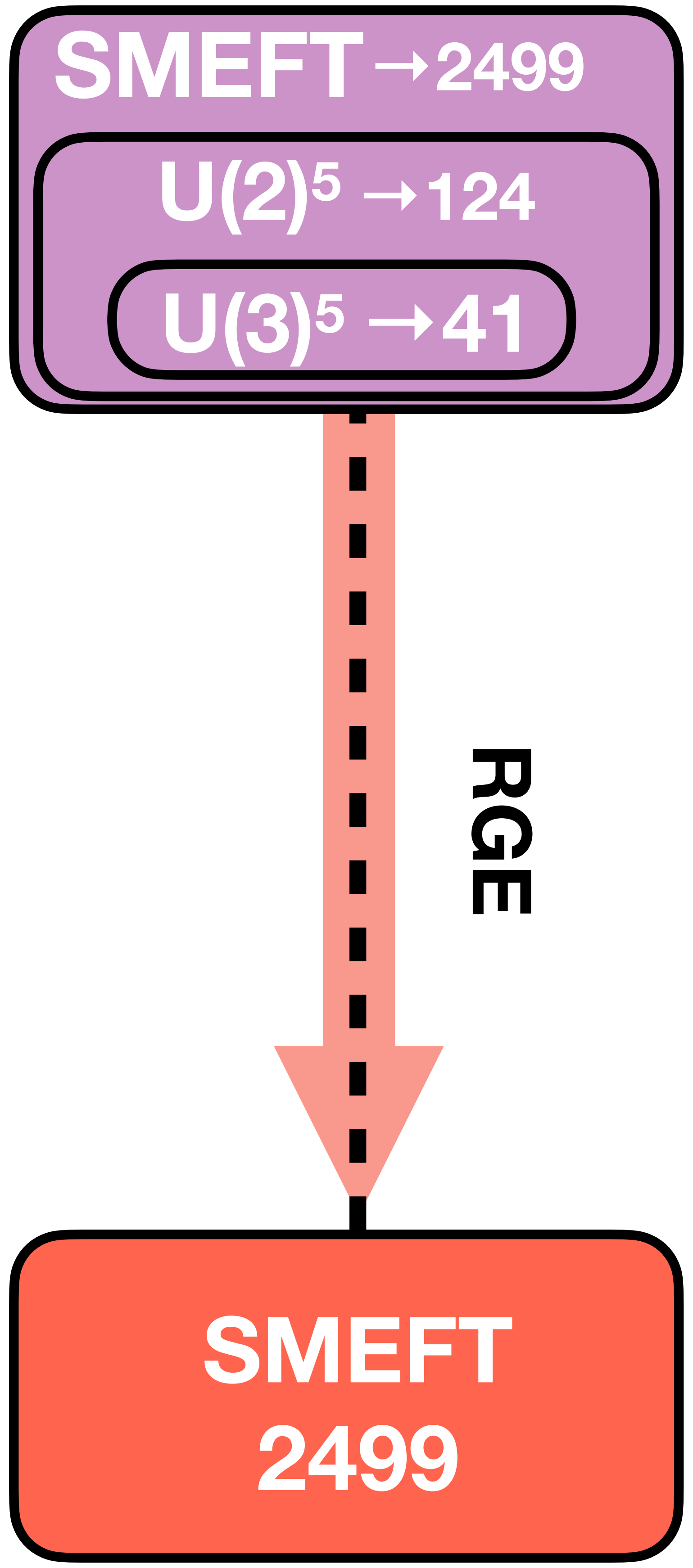
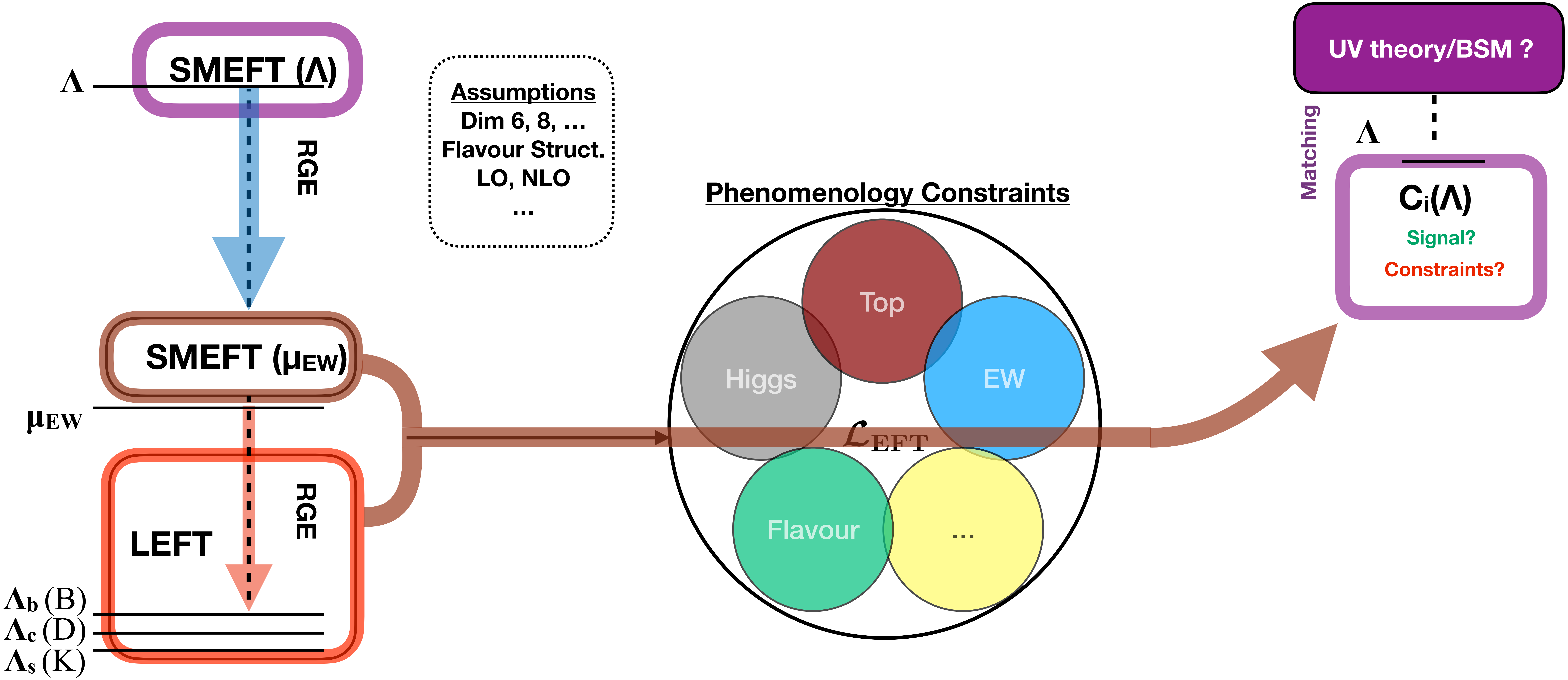




The Global Fit Setup

Combining EW/Higgs/Top/Flavour

The Global SMEFT fit



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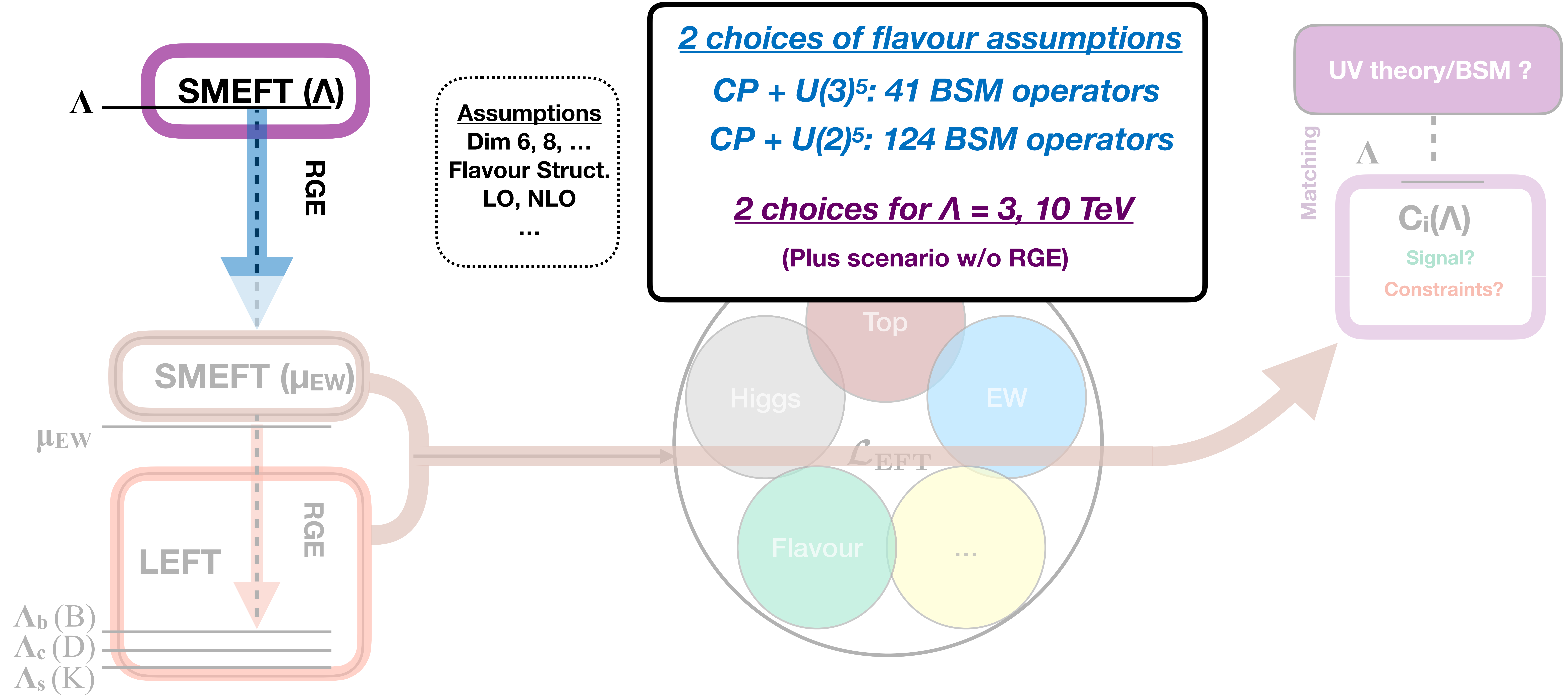

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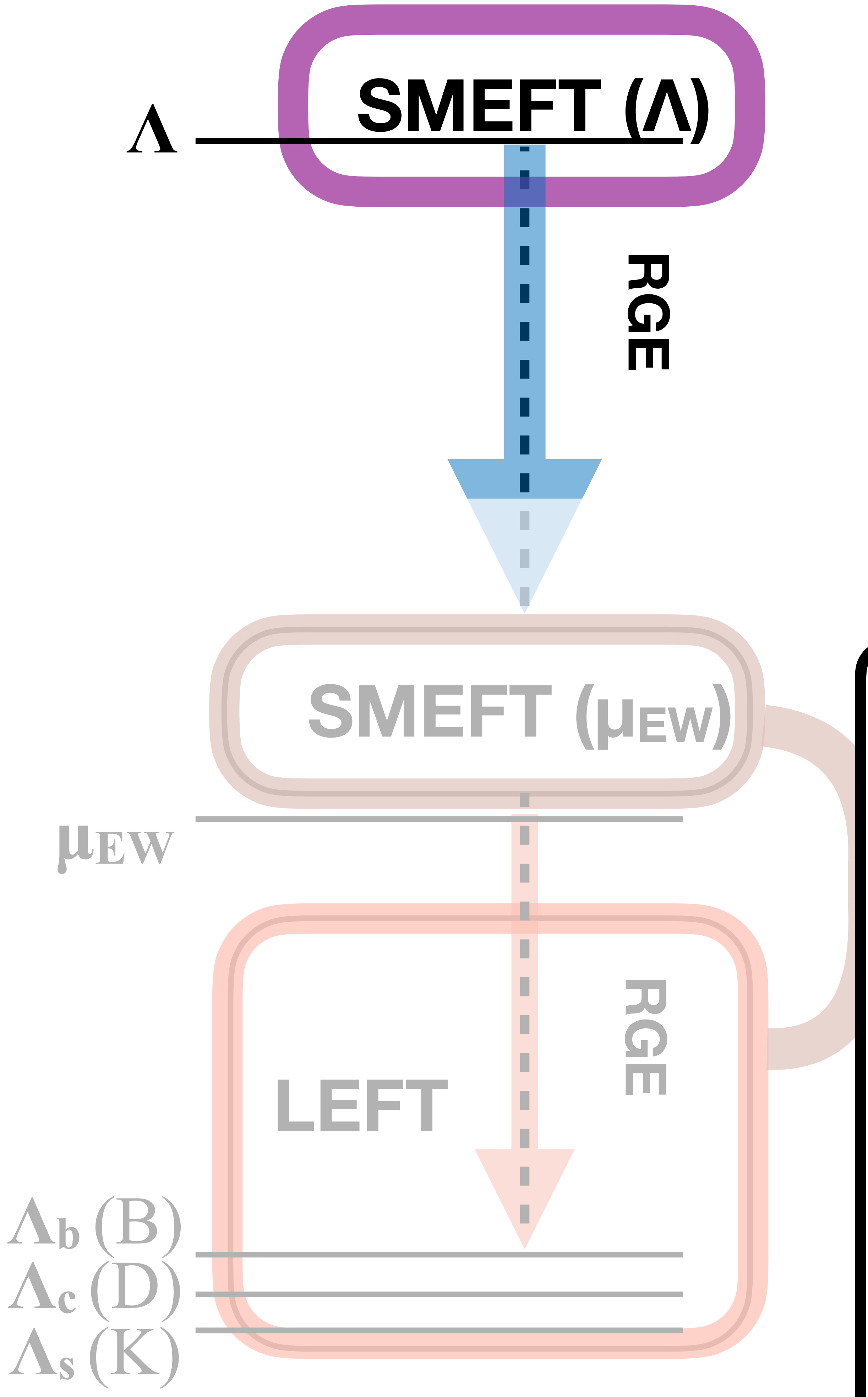


Assumptions
Dim 6, 8, …
Flavour Struct.
LO, NLO
…

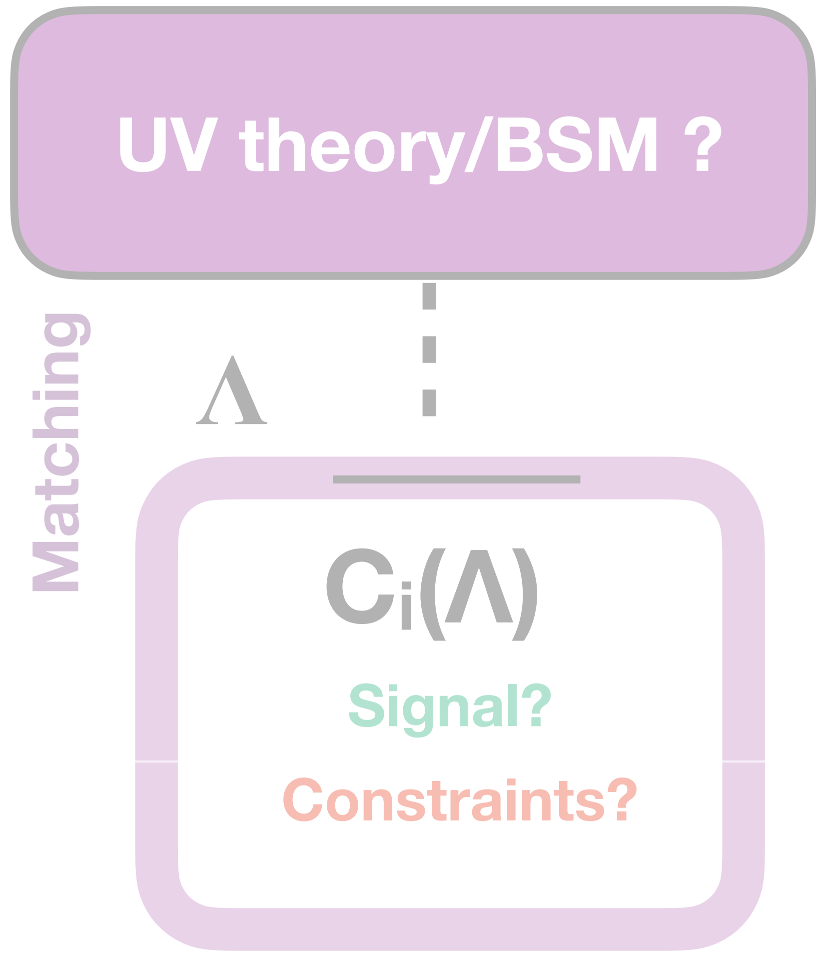
2 choices of flavour assumptions

CP + U(3)^5: 41 BSM operators

CP + U(2)^5: 124 BSM operators

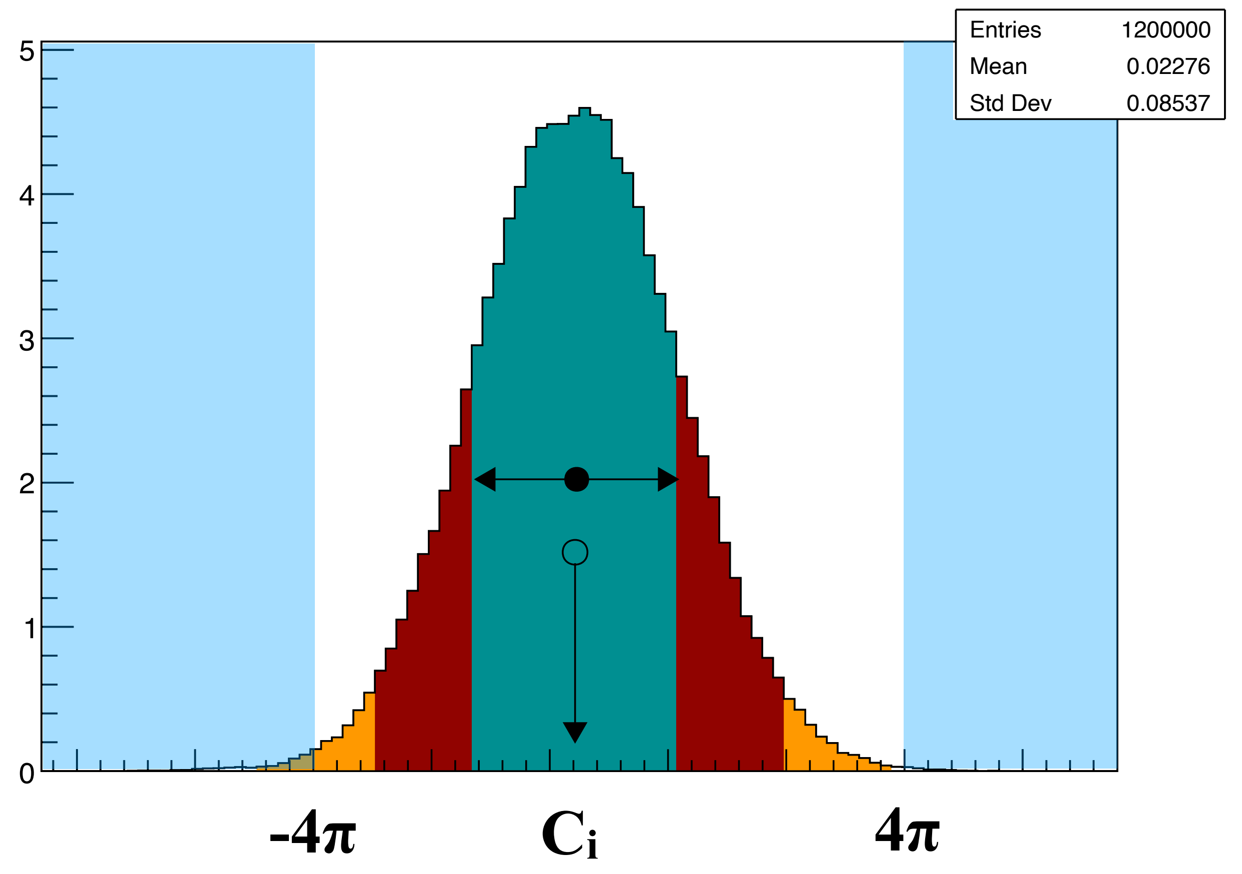
2 choices for Λ = 3, 10 TeV

(Plus scenario w/o RGE)



Top

New Physics priors

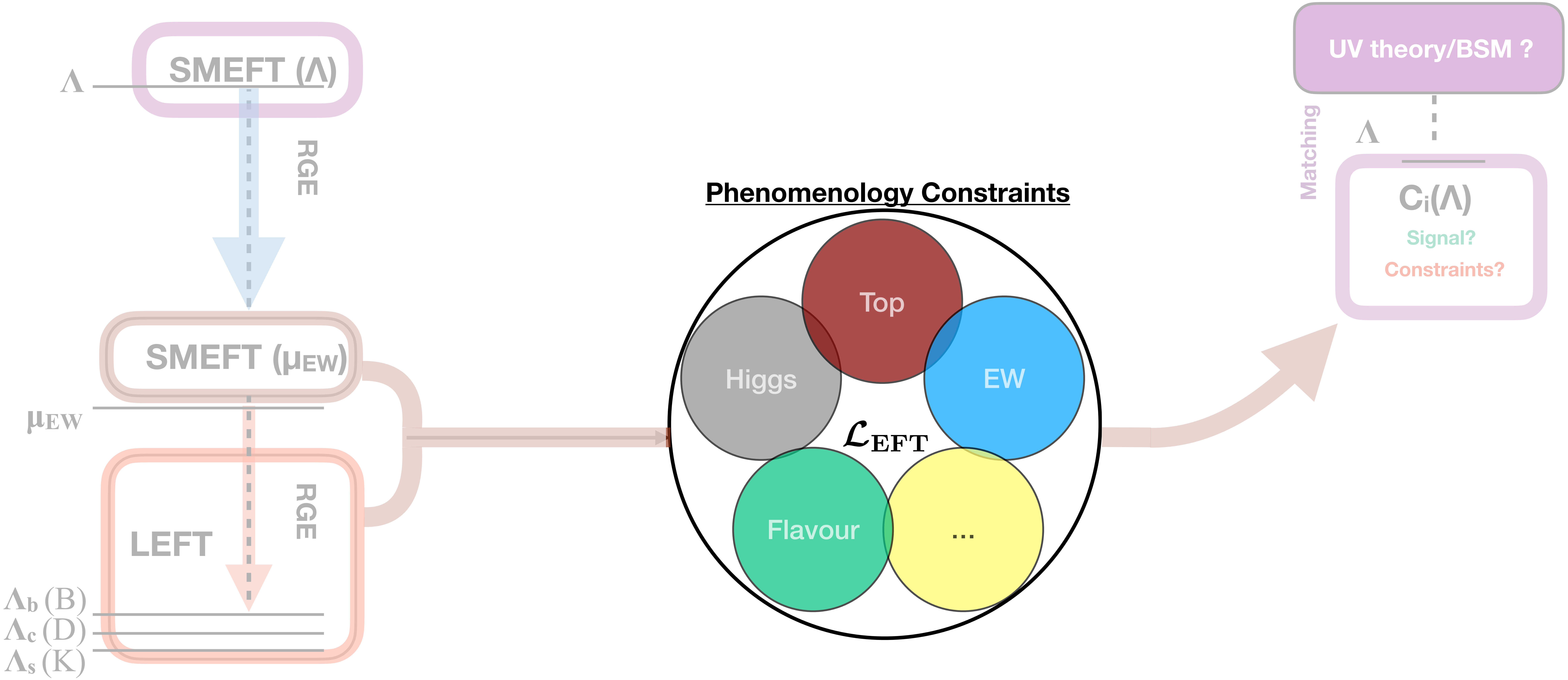


To ensure perturbative EFT expansion we impose flat prior for all WC:

$C_i(\Lambda) \in [-4\pi, 4\pi]$

(Other choices possible within HEPfit)

The Global SMEFT fit



The Global SMEFT fit

All Observables computed consistently to dimension 6

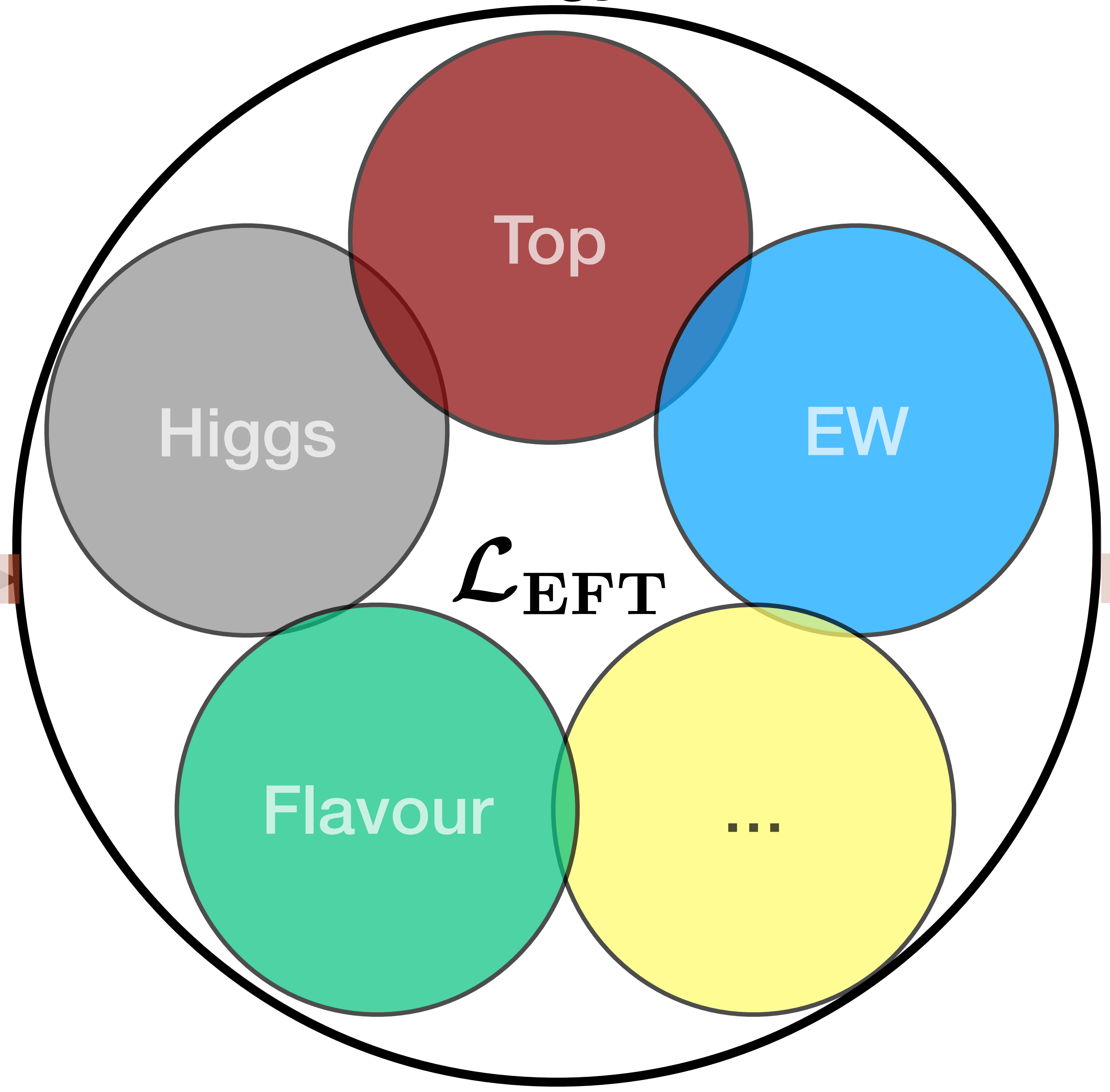
$$O = O_{\rm SM} + \delta O_{\rm NP}\frac{1}{\Lambda^2}$$

$$O_{\rm SM}$$

State-of-the-art for SM predictions in most precise observables (EWPO, Flavour)

SM parameters (EW and flavour) floated in the fit, together with all the Wilson Coefficients

Phenomenology Constraints



$$\delta O_{\rm NP}\frac{1}{\Lambda^2}$$

Current knowledge of SMEFT RGE (1-loop) limits a consistent calculation to an RG improved LO analysis:

$\Lambda \rightarrow \mu_{EW} \rightarrow \Lambda_{b,c,s}$

LO computed in M_W scheme:

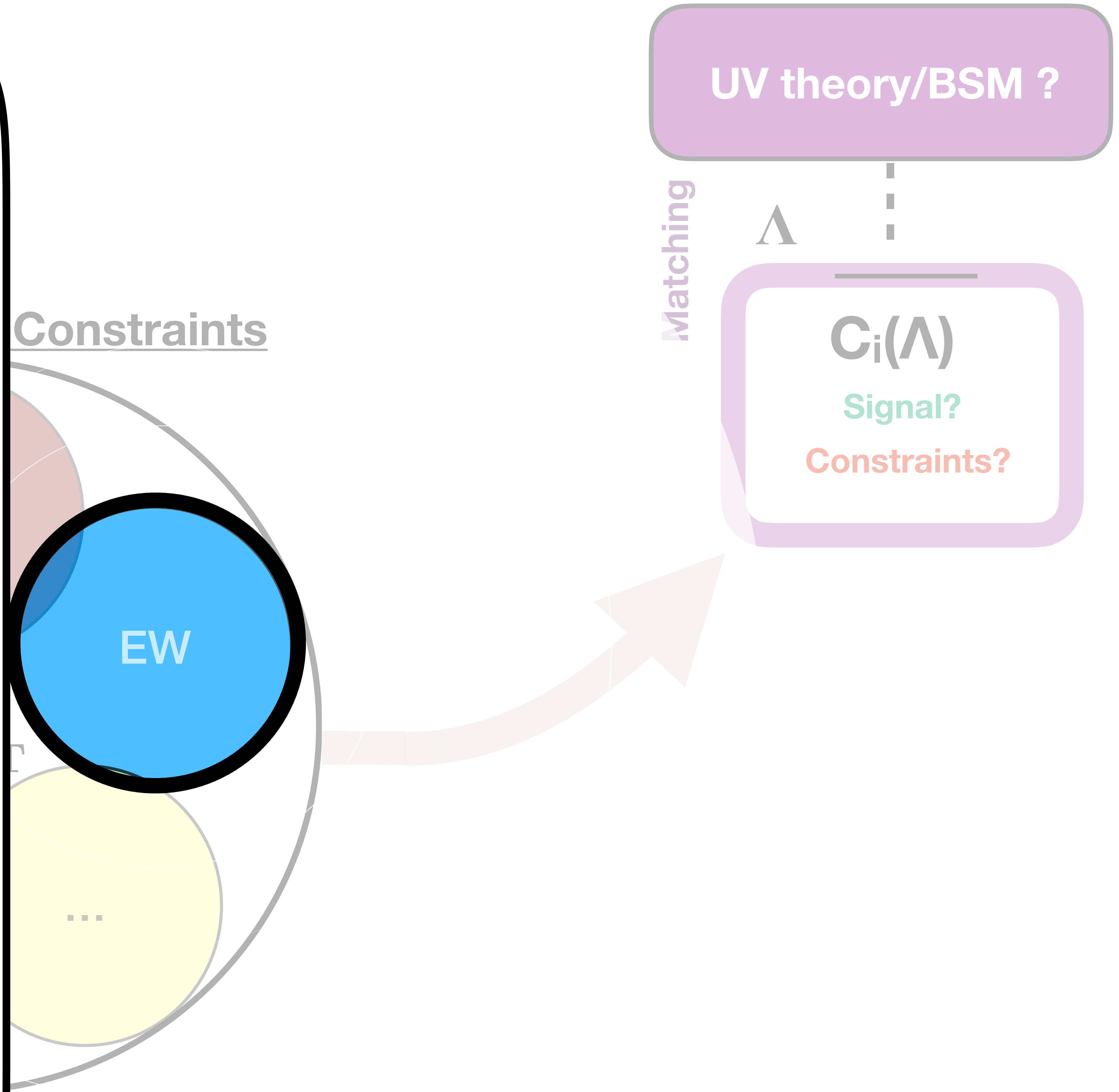
- *Analytically for most EW/ Flavour observables*
- *Via MG5@NLO or **HighPT** for LHC observables*

The Global SMEFT fit

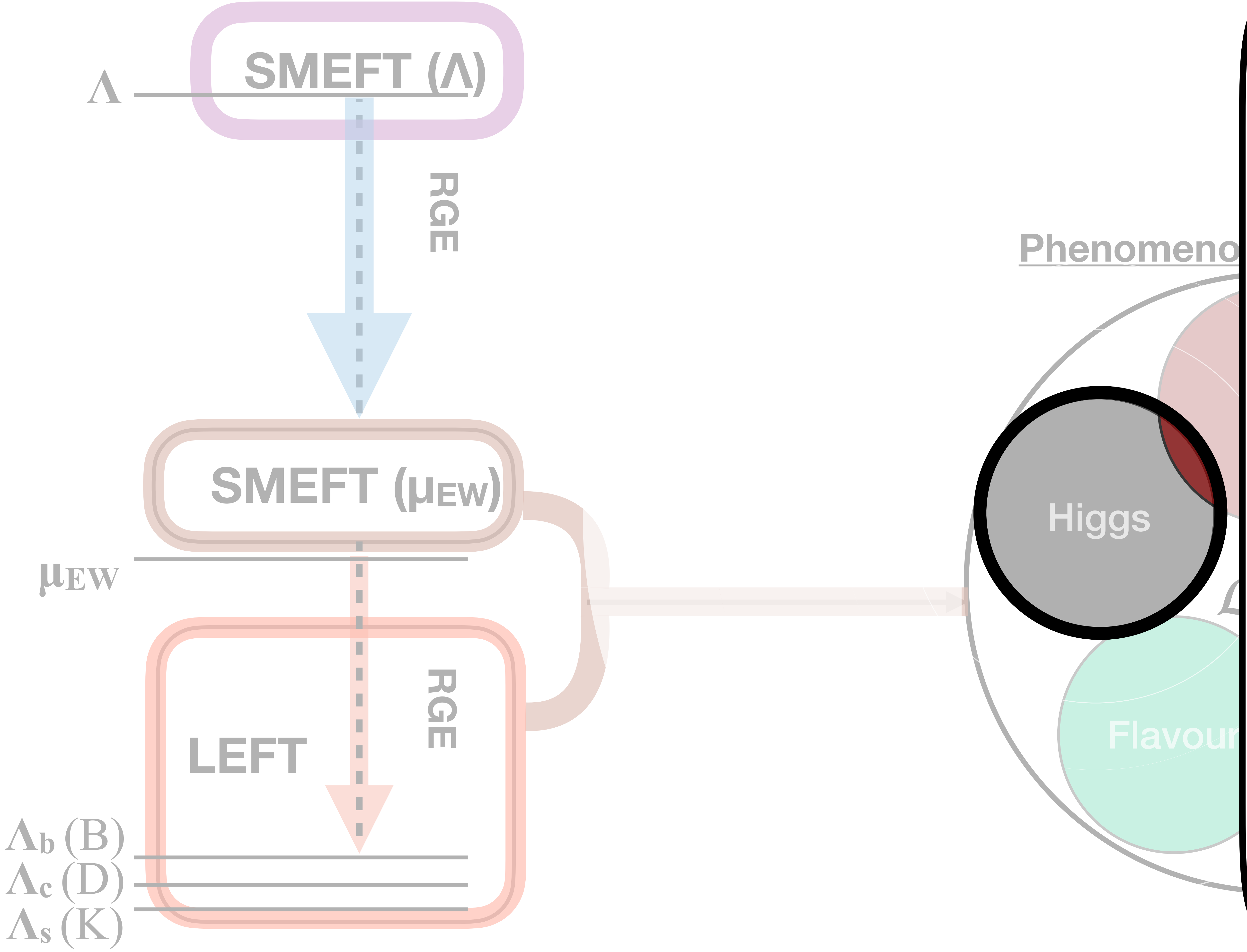
Electroweak Observables

- Electroweak Precision Observables:
  - Z-pole (LEP/SLD): $\Gamma_Z,\ A_f,\ A_{FB}^f,\ R_f,\ \ldots$
  - W properties (LEP2/Tevatron/LHC):
  - Higgs and Top properties (Tevatron/LHC): $M_H,\ m_t$
  - Tests of lepton universality from Tevatron & LHC
- LEP2 observables
  - Di-Boson: $e^+e^- \to W^+W^-$ Berthier et al., 1606.06693 [hep-ph]
  - $e^+e^- \to f\bar{f}$: leptonic cross sections and asymmetries, hadronic cross section
- Drell-Yan at LHC: $pp \to \ell^+\ell^-,\ \ell\nu$
  - Differential distributions
  - Implemented from HighPT code

L. Allwicher et al., 2207.10756, 2207.10714 [hep-ph]



The Global SMEFT fit

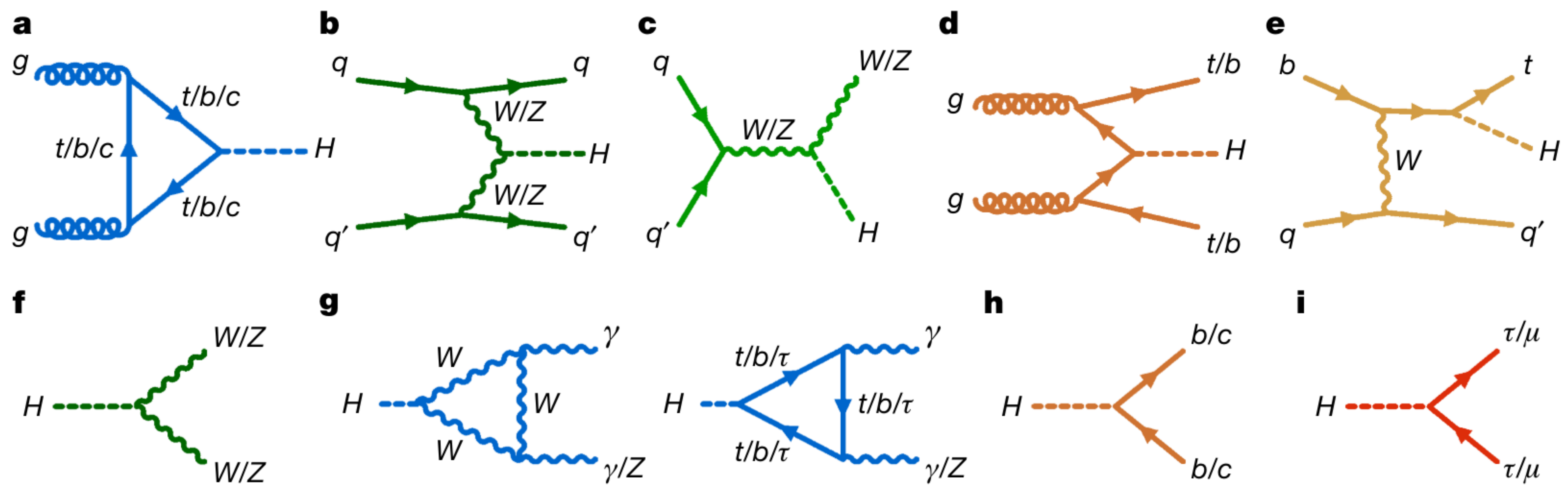


Higgs Boson Observables

- ATLAS+CMS 8 TeV combination for single strengths:

$$\mu_{ij} = \frac{\sigma_i \times BR_j}{(\sigma_i \times BR_j)_{\rm SM}}$$

- ATLAS and CMS 13 TeV results (139 fb^{-1})
  - STXS Stage 1.2 binning
- Including full information on all available channels (production and decay)



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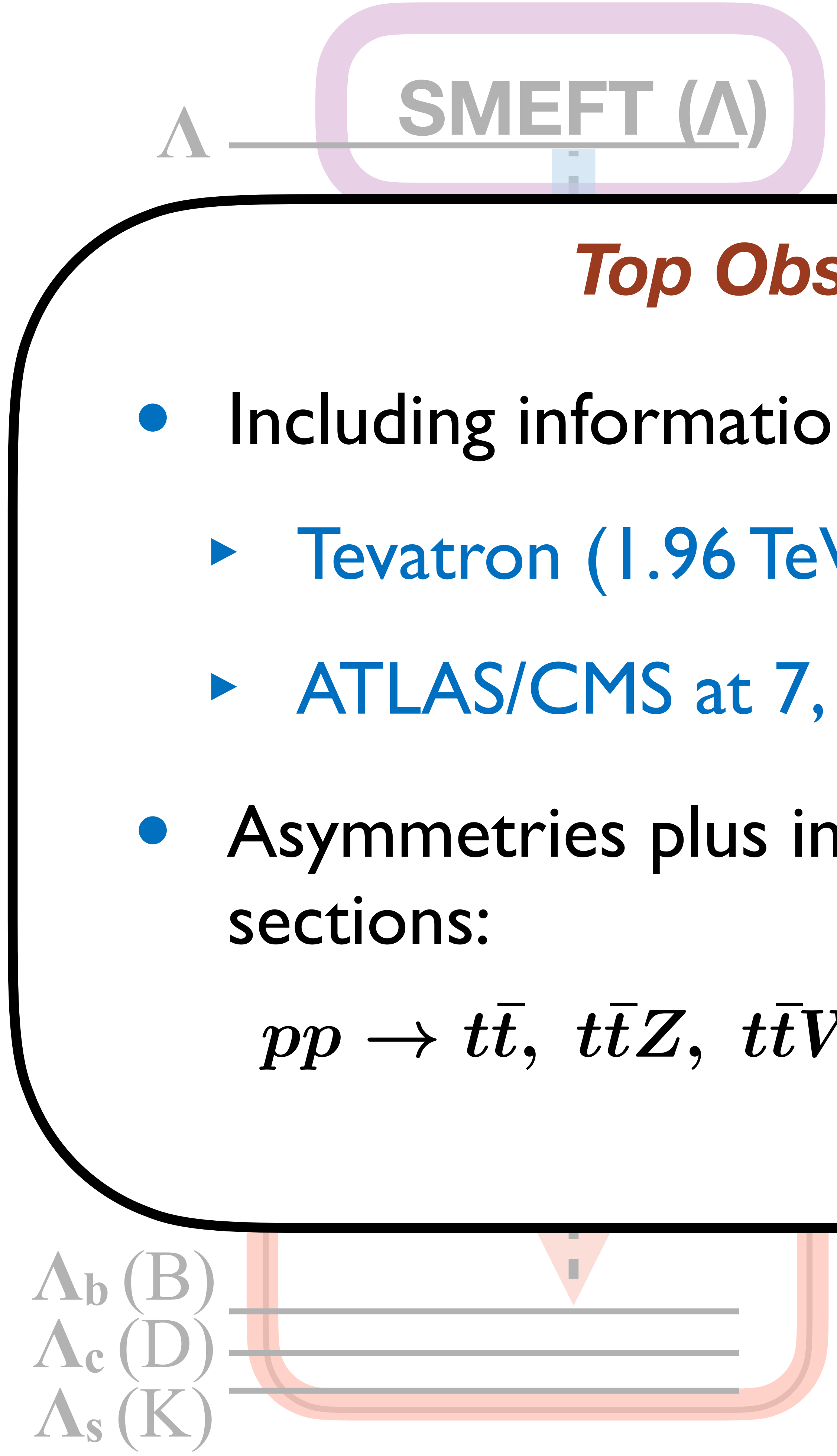
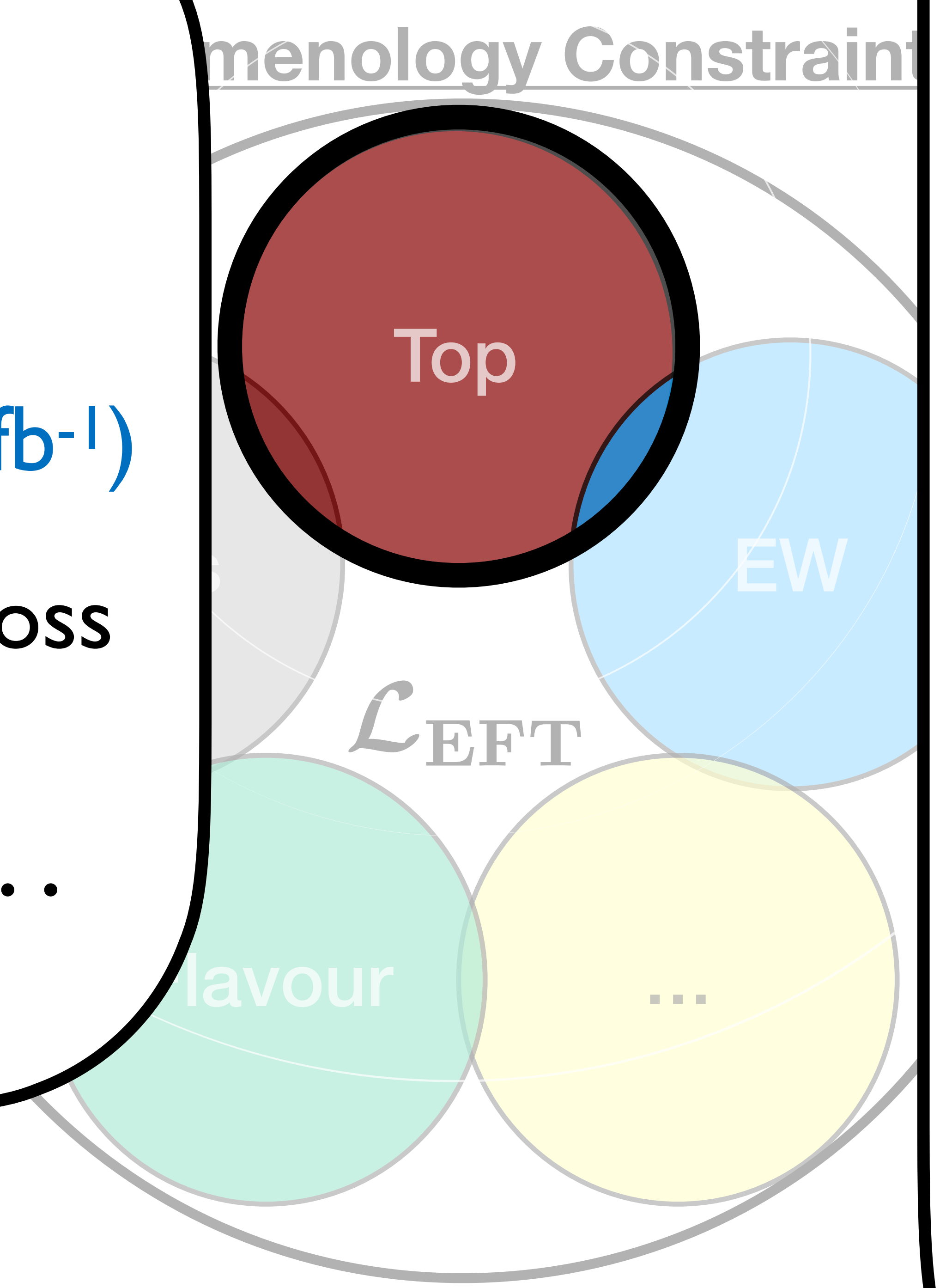




Top Observables

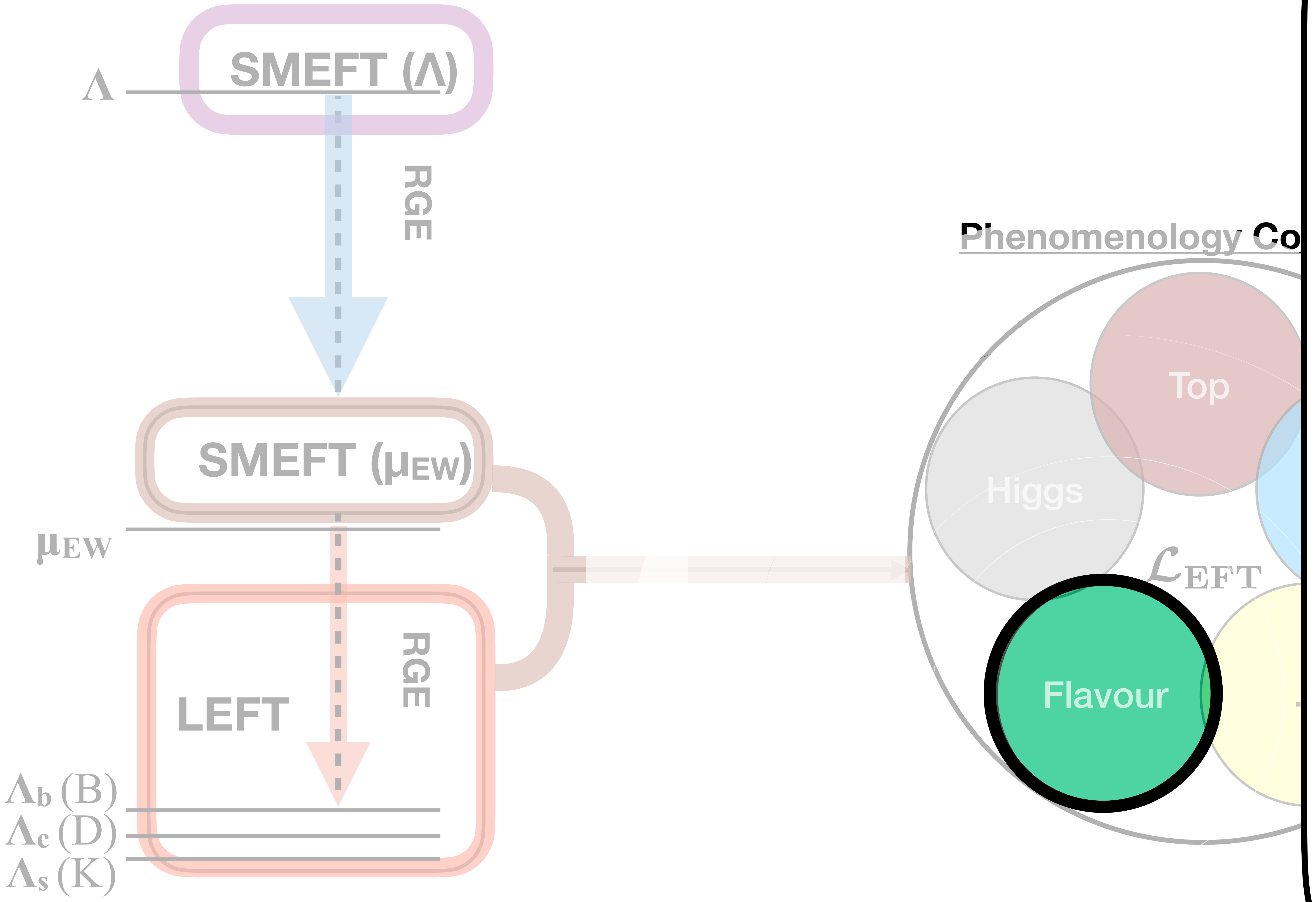
- Including information from:
  - Tevatron (1.96 TeV)
  - ATLAS/CMS at 7, 8 and 13 TeV (up to 140 fb^{-1})
- Asymmetries plus inclusive and differential cross sections:

$$pp \to t\bar{t},\ t\bar{t}Z,\ t\bar{t}W,\ t\bar{t}\gamma,\ tZq,\ t\gamma q,\ tW, \ldots$$

Top Observables

Process	Observable	$\sqrt{s}$	$\int\mathcal{L}$
$p\bar{p} \to t\bar{t}$	$\mathrm{dA_{FB}^{t\bar{t}}/dm_{t\bar{t}}}$	1.96 TeV	9.7 fb^{-1}
$pp \to t\bar{t}$	$\sigma_{t\bar{t}}^{13\mathrm{TeV}}/\sigma_{t\bar{t}}^{8\mathrm{TeV}}$ $\sigma_{t\bar{t}}^{8\mathrm{TeV}}/\sigma_{t\bar{t}}^{7\mathrm{TeV}}$ $\sigma_{t\bar{t}}$ $\mathrm{d}\sigma_{t\bar{t}}/\mathrm{dm}_{t\bar{t}}$ $(\mathrm{d}\sigma_{t\bar{t}}/\mathrm{dm}_{t\bar{t}})/\sigma_{t\bar{t}}$ $\mathrm{dA_C/dm_{t\bar{t}}}$	13 & 8 TeV 8 & 7 TeV 13 TeV 13 TeV 13 TeV 13 TeV	20 & 36 fb^{-1} 20 & 5 fb^{-1} 36/139 fb^{-1} 36 fb^{-1} 36/137 fb^{-1} 140 fb^{-1}
$pp \to t\bar{t}Z$	$d\sigma/dp_T^Z$	13 TeV	77.5/140 fb^{-1}
$pp \to t\bar{t}\gamma$	$d\sigma/dp_T^\gamma$	13 TeV	140 fb^{-1}
$pp \to t\bar{t}W$	$\sigma_{ttW^\pm}$ $\sigma_{ttW^+}/\sigma_{ttW^-}$	13 TeV	140 fb^{-1}
$t \to Wb$	$F_0,\ F_L$	8 TeV 13 TeV	20 fb^{-1} 140 fb^{-1}
$pp \to tW$	σ	7 TeV 8 TeV 13 TeV	4.6 & 1.5 fb^{-1} 20 fb^{-1} 3.2/140 fb^{-1}
$pp \to t\bar{b}$ (s-ch)	σ	8 TeV 13 TeV	20 fb^{-1} 140 fb^{-1}
$pp \to tq$ (t-ch)	σ	7 TeV 8 TeV 13 TeV	4.6 & 1.5 fb^{-1} 20 fb^{-1} 36/140 fb^{-1}
$pp \to t\gamma q$	σ	13 TeV	140/36 fb^{-1}
$pp \to tZq$	σ	13 TeV	140 fb^{-1}
$pp \to t\bar{t}b\bar{b}$	σ	13 TeV	36 fb^{-1}
$pp \to t\bar{t}t\bar{t}$	σ	13 TeV	140 fb^{-1}

The Global SMEFT fit



Flavour Observables

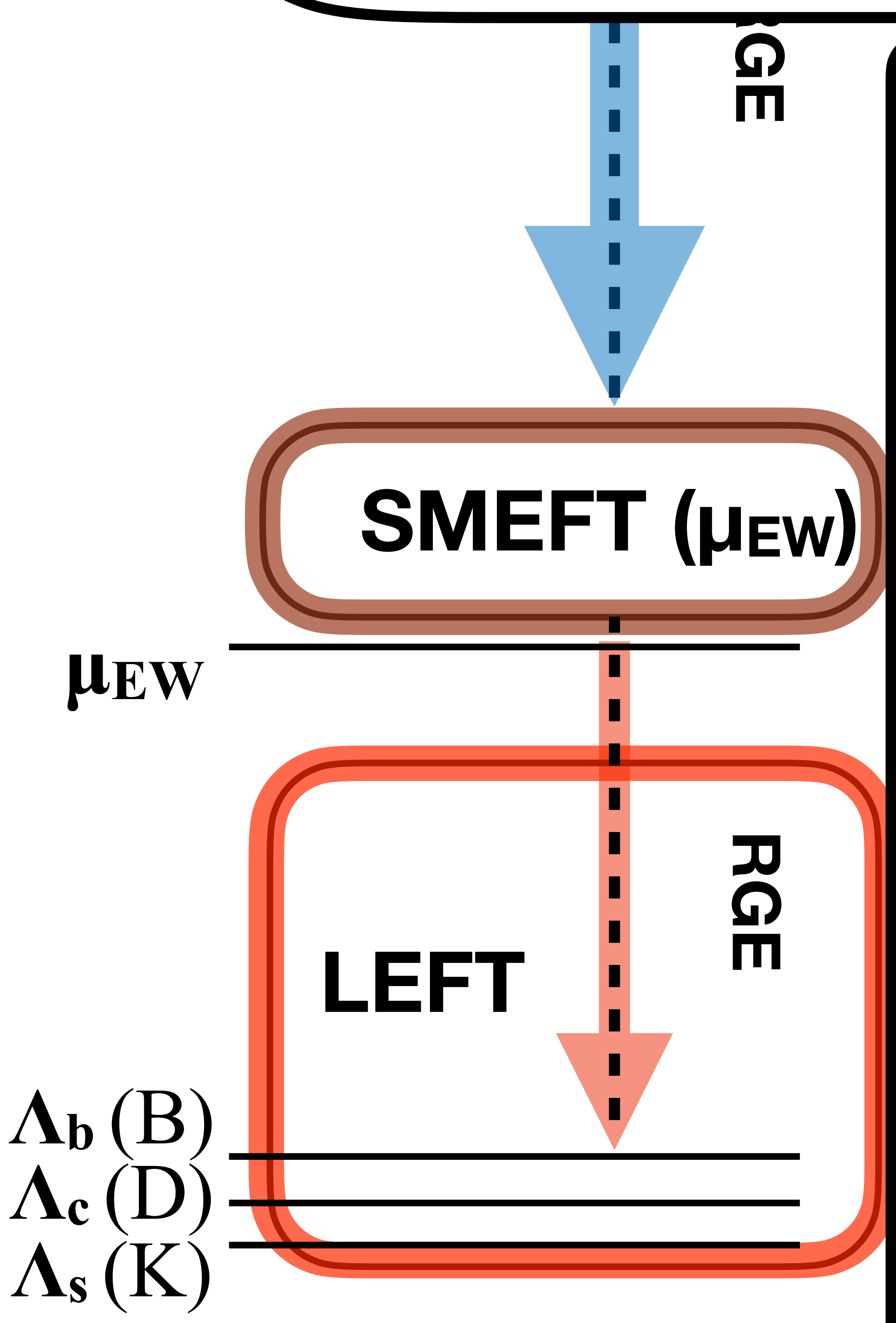
Observable	Value
$\Delta m_{B_s}\ (ps^{-1})$	17.765 ± 0.006
ϕ_s	-0.049 ± 0.019
A_{sl}^s	-0.0006 ± 0.00028
$\Delta m_{B_d}\ (ps^{-1})$	0.5069 ± 0.0019
$S_{J/\psi K_S}$	0.692 ± 0.016
A_{sl}^d	-0.0021 ± 0.0017
$\Delta M_K\ (ns^{-1})$	5.293 ± 0.009
ϵ_K	$(2.228 \pm 0.011) \times 10^{-3}$
$\phi_{12}^M(^\circ)$	1.9 ± 1.6
$\text{BR}(B \to \tau\nu) \times 10^4$	1.09 ± 0.24
$\text{BR}(D \to \tau\nu) \times 10^4$	9.9 ± 1.2
$\text{BR}(D \to \mu\nu) \times 10^4$	3.981 ± 0.089
$\text{BR}(D_s \to \tau\nu) \times 10^3$	5.31 ± 0.11
$\text{BR}(D_s \to \mu\nu) \times 10^2$	5.37 ± 0.10
$\Gamma(K \to \mu\nu)/\Gamma(\pi \to \mu\nu)$	1.3367 ± 0.0029
$\text{BR}(\pi \to \mu\nu) \times 10^5$	3.8408 ± 0.0007
$d\Gamma(B \to D\ell\nu)/dw$	$[\Delta\Gamma_i/\Delta w]_{10\times 10}$
$\text{BR}(K^+ \to \pi^+\nu\bar{\nu}) \times 10^{10}$	1.175 ± 0.365
$\text{BR}(B \to X_s\gamma) \times 10^4$	3.49 ± 0.19
$\overline{\text{BR}}(B_s \to \mu^+\mu^-) \times 10^9$	3.41 ± 0.29

- Several ΔF=1, 2 observables included
- Relevant for determination of CKM elements and to set bounds on FCNC

The Global SMEFT fit

Flavour Observables

- Computed in the LEFT (integrate W/Z/H/Top)
  - RGE to each relevant scale implemented directly for the different observables



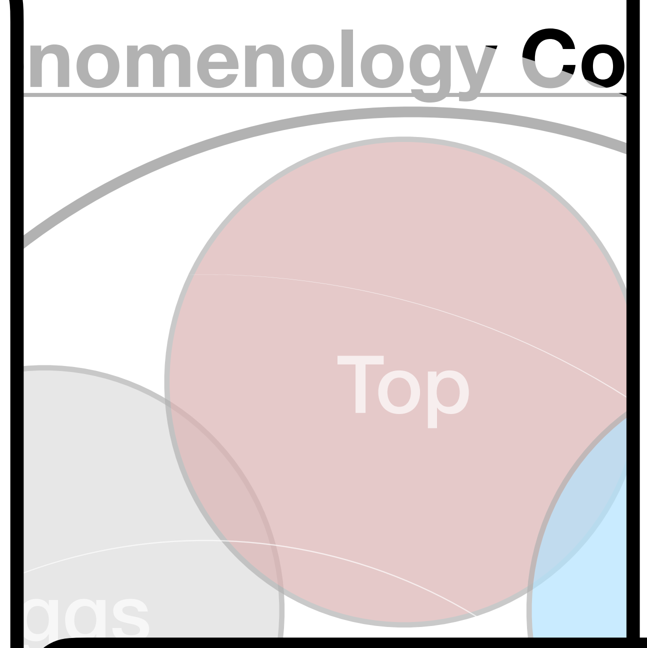
ΔF=1

$$Q_{\nu edu}^{VLL[kkij]} = (\bar{\nu}_k \gamma_\mu P_L e_k)(\bar{d}_i \gamma^\mu P_L u_j)\,,$$
$$Q_{\nu edu}^{VLR[kkij]} = (\bar{\nu}_k \gamma_\mu P_L e_k)(\bar{d}_i \gamma^\mu P_R u_j)\,,$$
$$Q_{\nu edu}^{SRR[kkij]} = (\bar{\nu}_k P_R e_k)(\bar{d}_i P_R u_j)\,,$$
$$Q_{\nu edu}^{SRL[kkij]} = (\bar{\nu}_k P_R e_k)(\bar{d}_i P_L u_j)\,,$$
$$Q_{\nu edu}^{TRR[kkij]} = (\bar{\nu}_k \sigma_{\mu\nu} P_R e_k)(\bar{d}_i \sigma^{\mu\nu} P_R u_j)\,.$$

$$Q_{d\gamma}^{[ij]} = (\bar{d}_i \sigma_{\mu\nu} P_R d_j)\, F^{\mu\nu}\,,$$
$$Q_{dG}^{[ij]} = (\bar{d}_i \sigma_{\mu\nu} T_A P_R d_j)\, G_A^{\mu\nu}\,,$$
$$Q_{ud}^{V1LL[ijkl]} = (\bar{u}_i \gamma_\mu P_L u_j)\,(\bar{u}_k \gamma^\mu P_L d_l)\,,$$
$$Q_{ud}^{V8LL[ijkl]} = (\bar{u}_i \gamma_\mu T^A P_L u_j)\,(\bar{u}_k \gamma^\mu T^A P_L d_l)\,,$$
$$Q_{ud}^{V1RR[ijkl]} = (\bar{u}_i \gamma_\mu P_R u_j)\,(\bar{u}_k \gamma^\mu P_R d_l)\,,$$
$$Q_{ud}^{V8RR[ijkl]} = (\bar{u}_i \gamma_\mu T^A P_R u_j)\,(\bar{u}_k \gamma^\mu T^A P_R d_l)\,,$$

$$Q_{ed}^{VLL[kkij]} = (\bar{e}_k \gamma_\mu P_L e_k)\,(\bar{d}_i \gamma^\mu P_L d_j)\,,$$
$$Q_{de}^{VLR[ijkk]} = (\bar{d}_i \gamma_\mu P_L d_j)\,(\bar{e}_k \gamma^\mu P_R e_k)\,.$$

$$Q_{\nu d}^{VLL[kkij]} = (\bar{\nu}_k \gamma_\mu P_L \nu_k)\,(\bar{d}_i \gamma^\mu P_L d_j)$$



ΔF=2

$$Q_1^{q_iq_j} = (\bar{q}_i^\alpha \gamma_\mu P_L q_j^\alpha)(\bar{q}_i^\beta \gamma^\mu P_L q_j^\beta)\,,$$
$$Q_4^{q_iq_j} = (\bar{q}_i^\alpha P_L q_j^\alpha)(\bar{q}_i^\beta P_R q_j^\beta)\,,$$
$$Q_5^{q_iq_j} = (\bar{q}_i^\alpha P_L q_j^\beta)(\bar{q}_i^\beta P_L q_j^\alpha)\,,$$
$$\tilde{Q}_1^{q_iq_j} = (\bar{q}_i^\alpha \gamma_\mu P_R q_j^\alpha)(\bar{q}_i^\beta \gamma^\mu P_R q_j^\beta)\,,$$

Negligible under $U(2)^5$

Flavour Observables

Observable	Value
$\Delta m_{B_s}\ (ps^{-1})$	17.765 ± 0.006
ϕ_s	-0.049 ± 0.019
A_{sl}^s	-0.0006 ± 0.00028
$\Delta m_{B_d}\ (ps^{-1})$	0.5069 ± 0.0019
$S_{J/\psi K_S}$	0.692 ± 0.016
A_{sl}^d	-0.0021 ± 0.0017
$\Delta M_K\ (ns^{-1})$	5.293 ± 0.009
ϵ_K	$(2.228 \pm 0.011) \times 10^{-3}$
$\phi_{12}^M(^\circ)$	1.9 ± 1.6
$\mathrm{BR}(B \to \tau\nu) \times 10^4$	1.09 ± 0.24
$\mathrm{BR}(D \to \tau\nu) \times 10^4$	9.9 ± 1.2
$\mathrm{BR}(D \to \mu\nu) \times 10^4$	3.981 ± 0.089
$\mathrm{BR}(D_s \to \tau\nu) \times 10^3$	5.31 ± 0.11
$\mathrm{BR}(D_s \to \mu\nu) \times 10^2$	5.37 ± 0.10
$\Gamma(K \to \mu\nu)/\Gamma(\pi \to \mu\nu)$	1.3367 ± 0.0029
$\mathrm{BR}(\pi \to \mu\nu) \times 10^5$	3.8408 ± 0.0007
$d\Gamma(B \to D\ell\nu)/dw$	$[\Delta\Gamma_i/\Delta w]_{10\times 10}$
$\mathrm{BR}(K^+ \to \pi^+\nu\bar{\nu}) \times 10^{10}$	1.175 ± 0.365
$\mathrm{BR}(B \to X_s\gamma) \times 10^4$	3.49 ± 0.19
$\overline{\mathrm{BR}}(B_s \to \mu^+\mu^-) \times 10^9$	3.41 ± 0.29

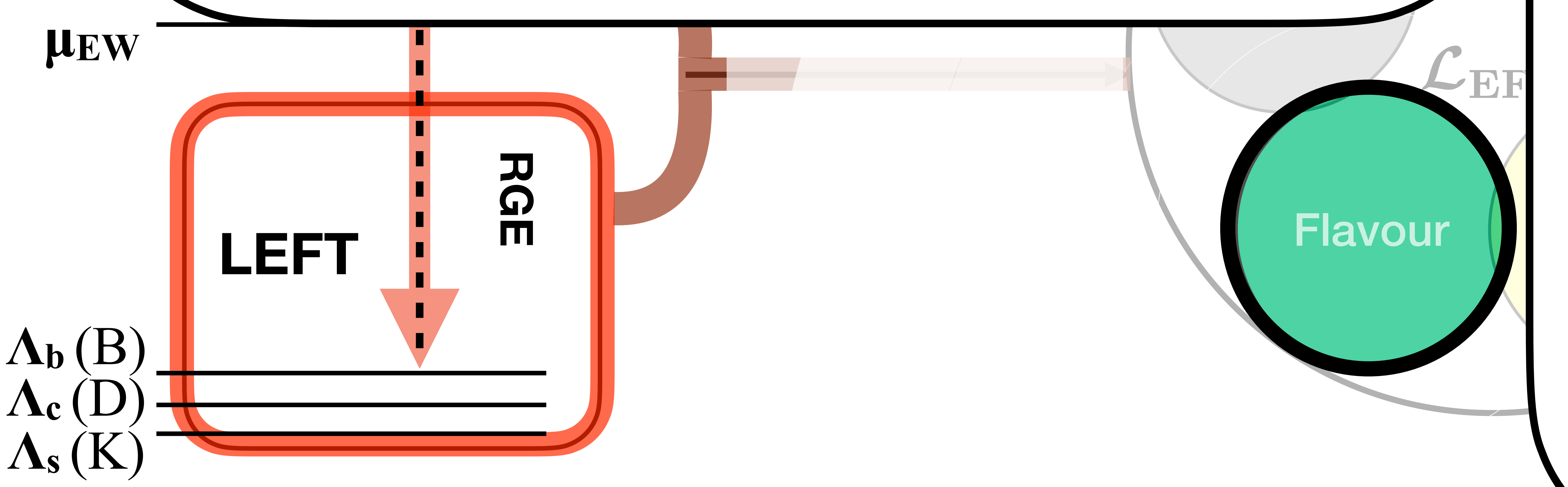
- Several ***ΔF=1, 2*** observables included
- Relevant for determination of CKM elements and to set bounds on FCNC

The Global SMEFT fit

Flavour Observables

- Computed in the LEFT (integrate W/Z/H/Top)
  - RGE to each relevant scale implemented directly for the different observables
- All SM parameters are floated in the fit and obtained simultaneously with the WC
  - CKM and masses
  - Hadronic parameters

SM parametric and theory uncertainties are of particular relevance in the flavour sector



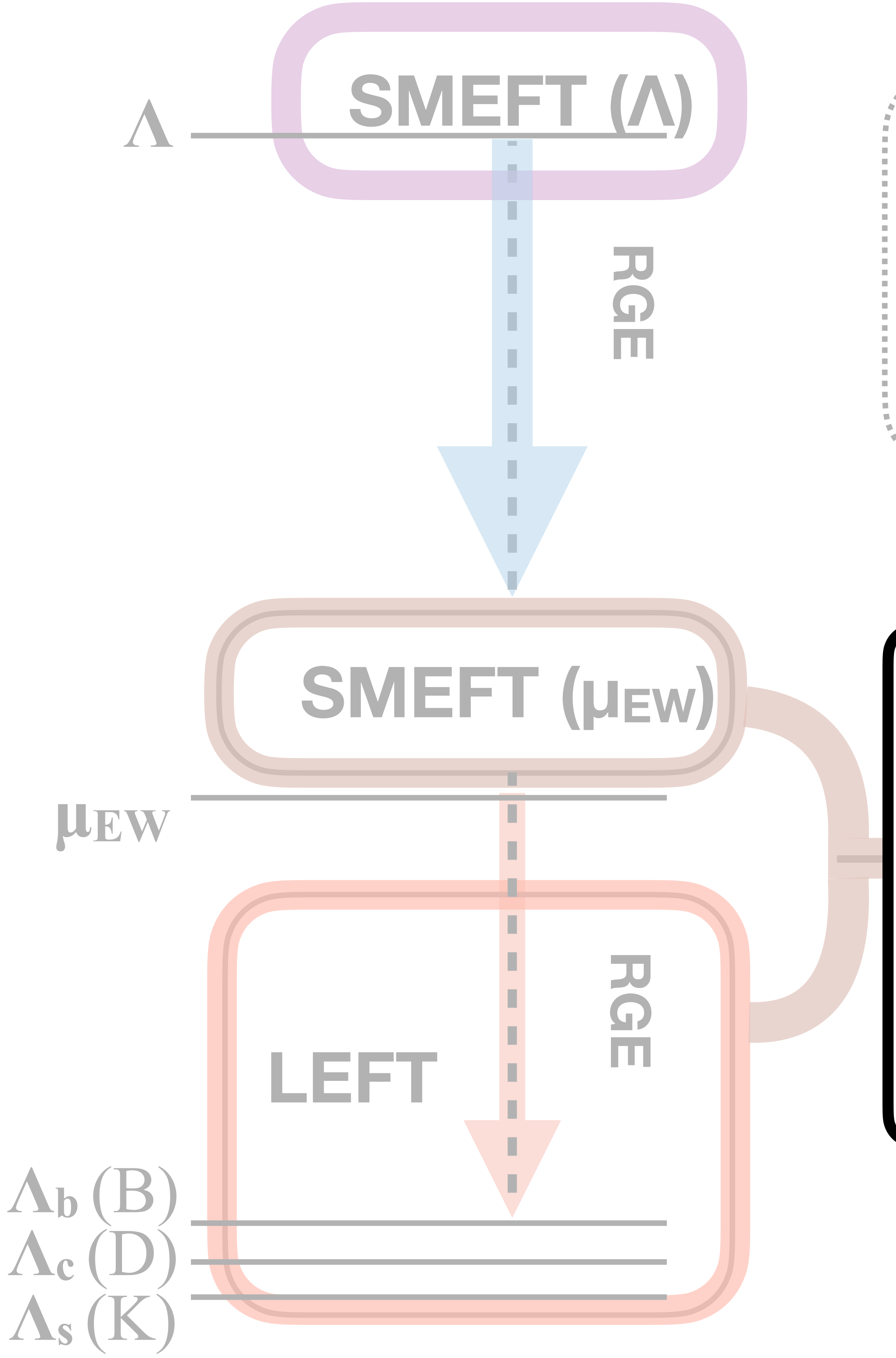
Key hadronic parameters included in SM predictions

Computed in Lattice QCD

Negligible effect expected from SMEFT (within current uncertainties)

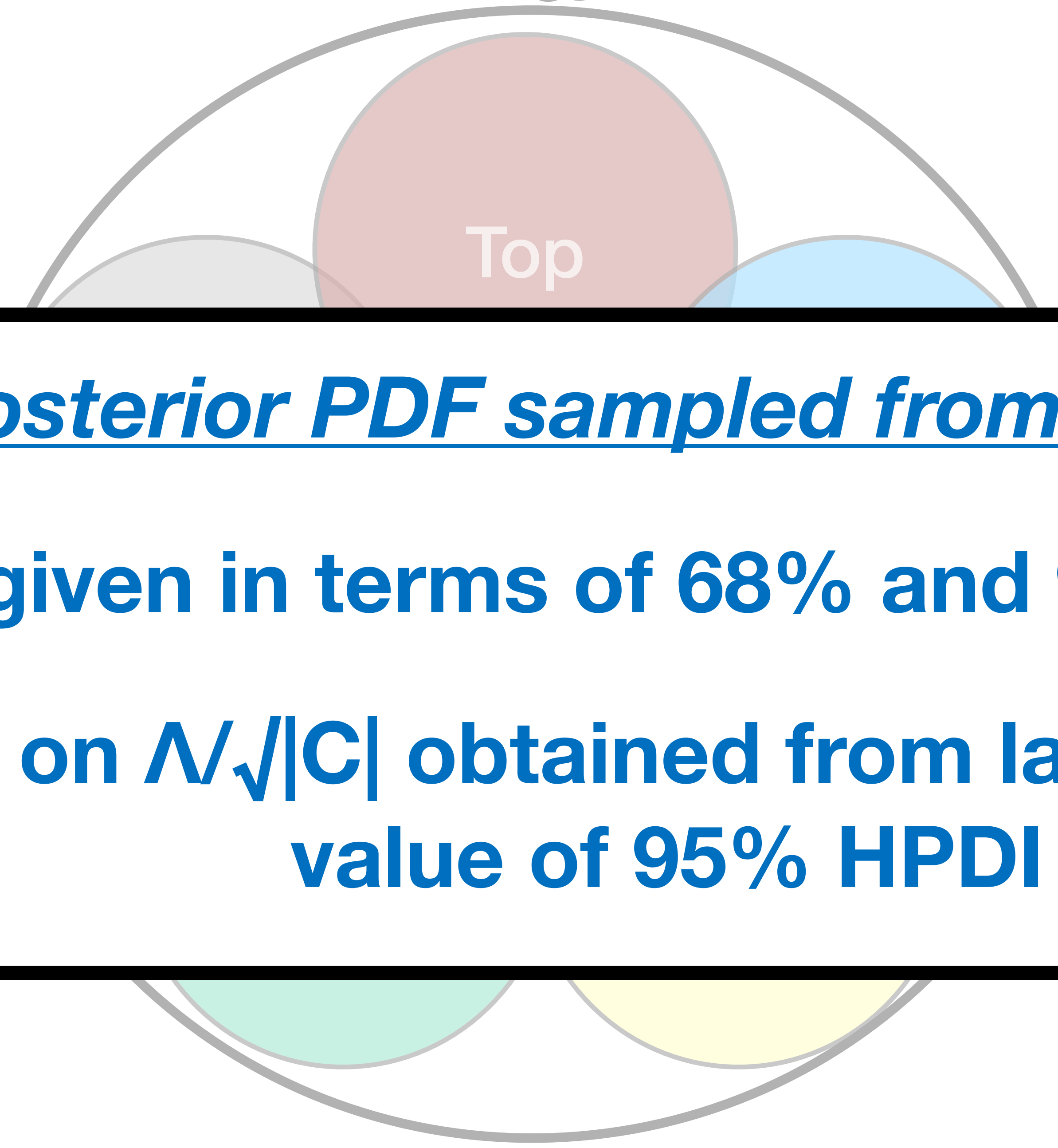
Parameter	Value
F_{B_s} (GeV)	0.2301 ± 0.0012
F_{B_s}/F_{B_d}	1.208 ± 0.005
$B_{B_s}(4.2\,\text{GeV})$	0.888 ± 0.040
B_{B_s}/B_{B_d}	1.015 ± 0.021
$B_{B_s,4}(4.2\,\text{GeV})$	0.98 ± 0.08
$B_{B_s,5}(4.2\,\text{GeV})$	1.66 ± 0.13
$B_{B_d,4}(4.2\,\text{GeV})$	0.99 ± 0.08
$B_{B_d,5}(4.2\,\text{GeV})$	1.58 ± 0.18
$B_K(2\,\text{GeV})$	0.552 ± 0.012
$B_{K,4}(2\,\text{GeV})$	0.904 ± 0.053
$B_{K,5}(2\,\text{GeV})$	0.618 ± 0.114
$\phi_{\varepsilon_K}(^\circ)$	43.51 ± 0.05
$\overline{\kappa}_{\varepsilon_K}$	0.97 ± 0.02
$(\Delta M_K)^{\text{SM}}$ (ns^{-1})	8.8 ± 3.6
$B_{D,1}(3\,\text{GeV})$	0.765 ± 0.025
$B_{D,4}(3\,\text{GeV})$	0.98 ± 0.06
$B_{D,5}(3\,\text{GeV})$	1.05 ± 0.09
F_D (GeV)	0.2120 ± 0.0007
$(\Delta M_D)^{\text{SM}}$ (ps^{-1})	0.005 ± 0.005
f_K (GeV)	0.15611 ± 0.00021
f_K/f_π	1.1966 ± 0.0018
$\delta R_\pi^{\text{phys}}$	0.0153 ± 0.0019
$\delta P_{c,u}$	0.04 ± 0.02

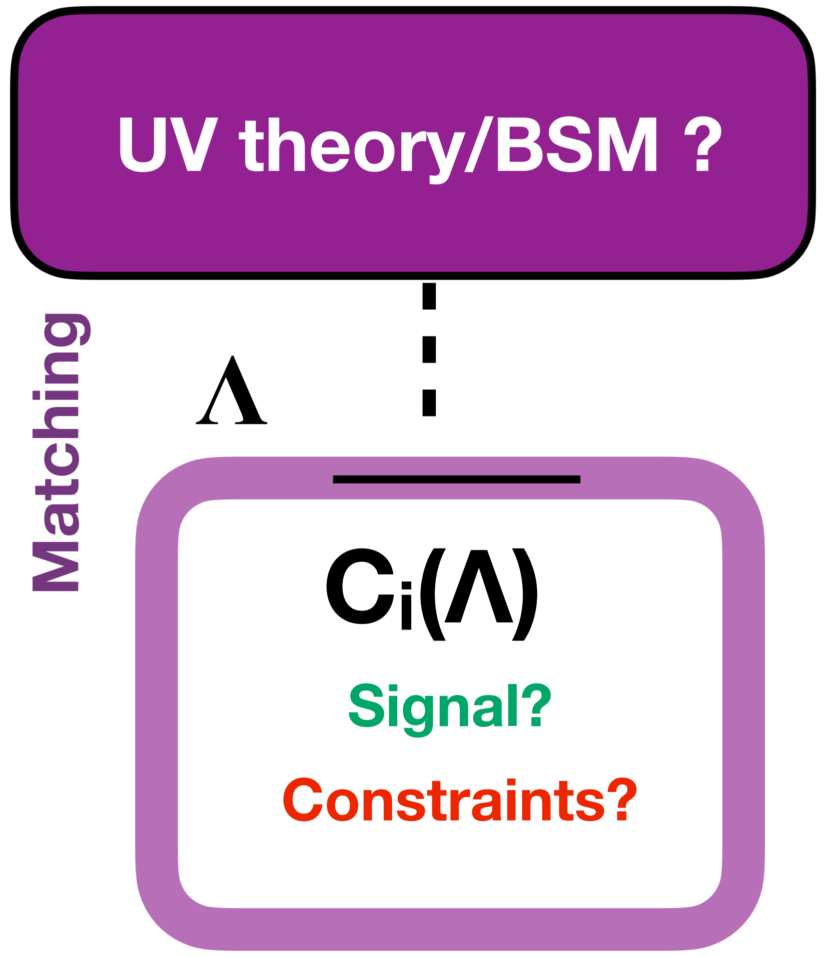
The Global SMEFT fit



Assumptions
Dim 6, 8, …
Flavour Struct.
LO, NLO
…

Phenomenology Constraints





Posterior PDF sampled from MCMC

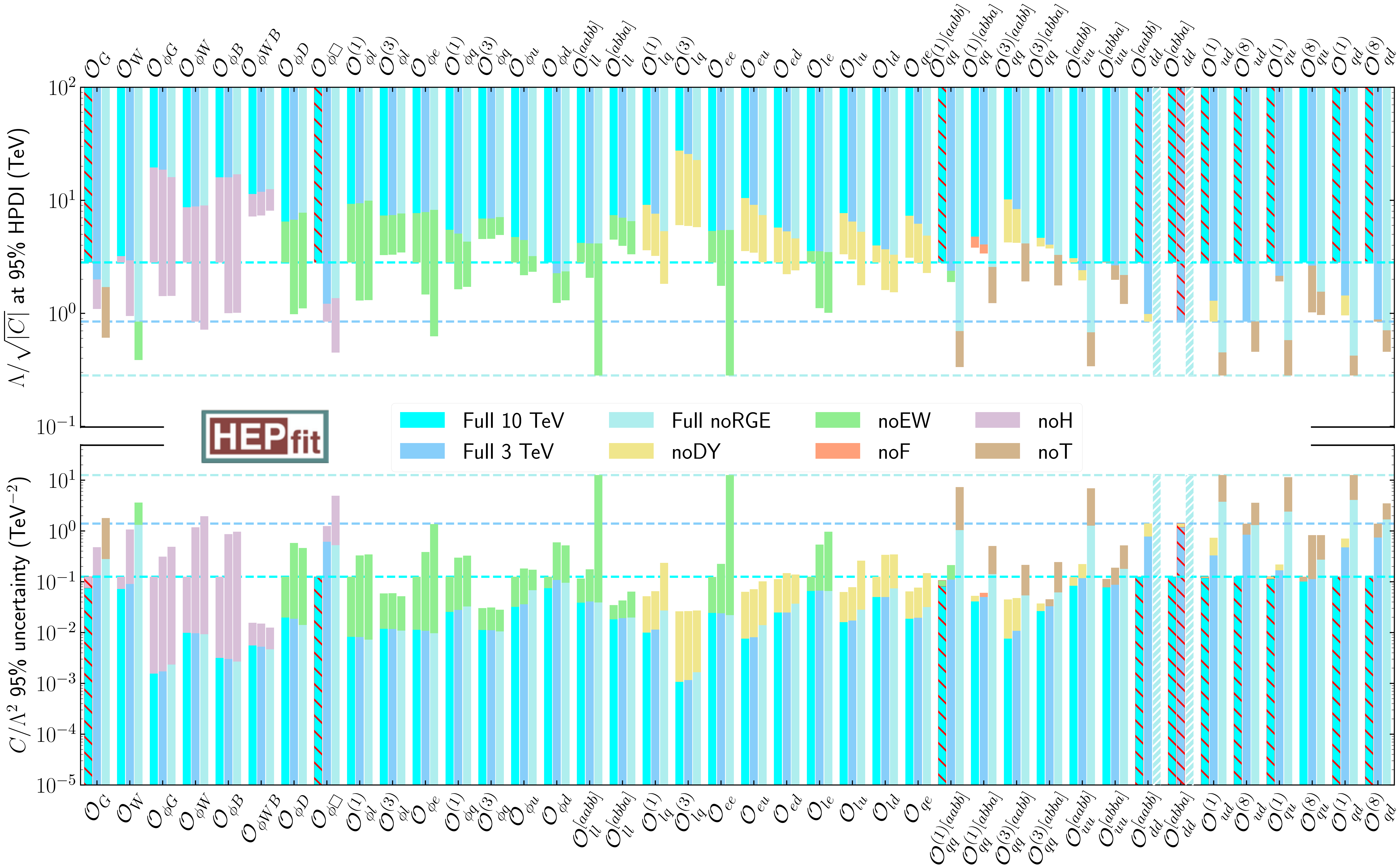
Results given in terms of 68% and 95% HPDI on $C_i(\Lambda)$

Bounds on $\Lambda/\sqrt{|C|}$ obtained from largest absolute value of 95% HPDI

The role of Flavour in combined EW+Higgs+Top+Flavour studies

The role of Flavour in SMEFT fits: $U(3)^5$

Individual fit results: Impact of data sets



Bounds controlled mostly by EW/Higgs observables

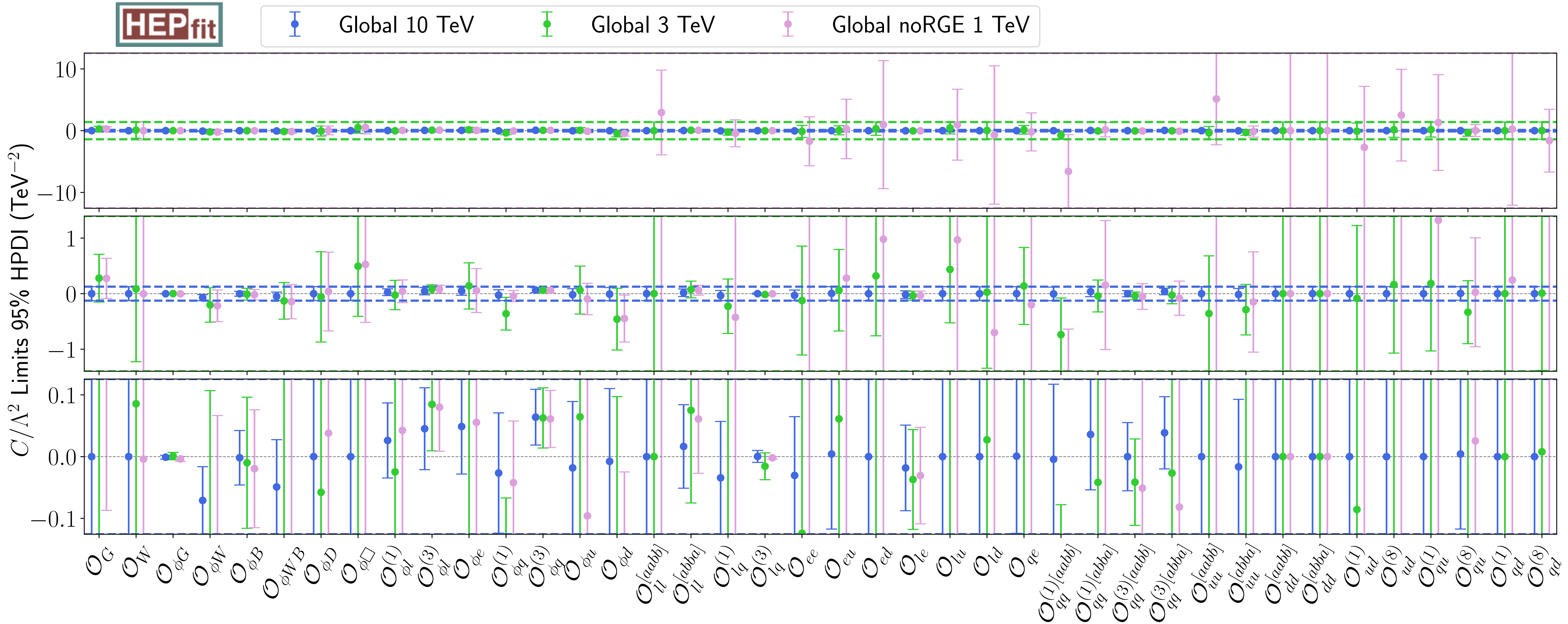
noF
Orange means "Flavour" controlling the bound

Not surprisingly, in the $U(3)^5$ -symmetric limit contributions to flavour observables are very suppressed

Picture changes dramatically when we relax the hypotheses to $U(2)^5$

SMEFT fit results: U(3)⁵

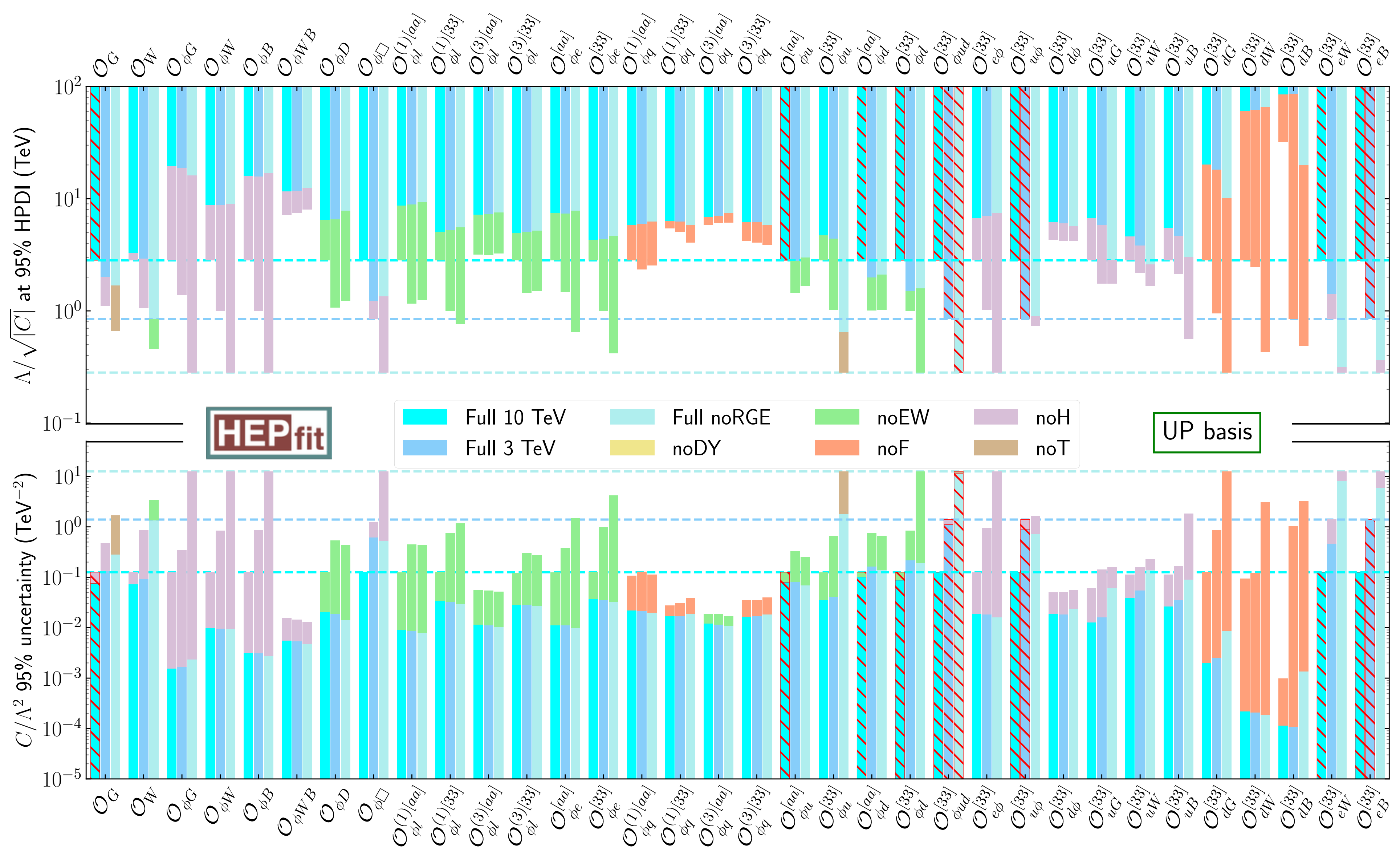
Global fit: comparison of different choices of Λ

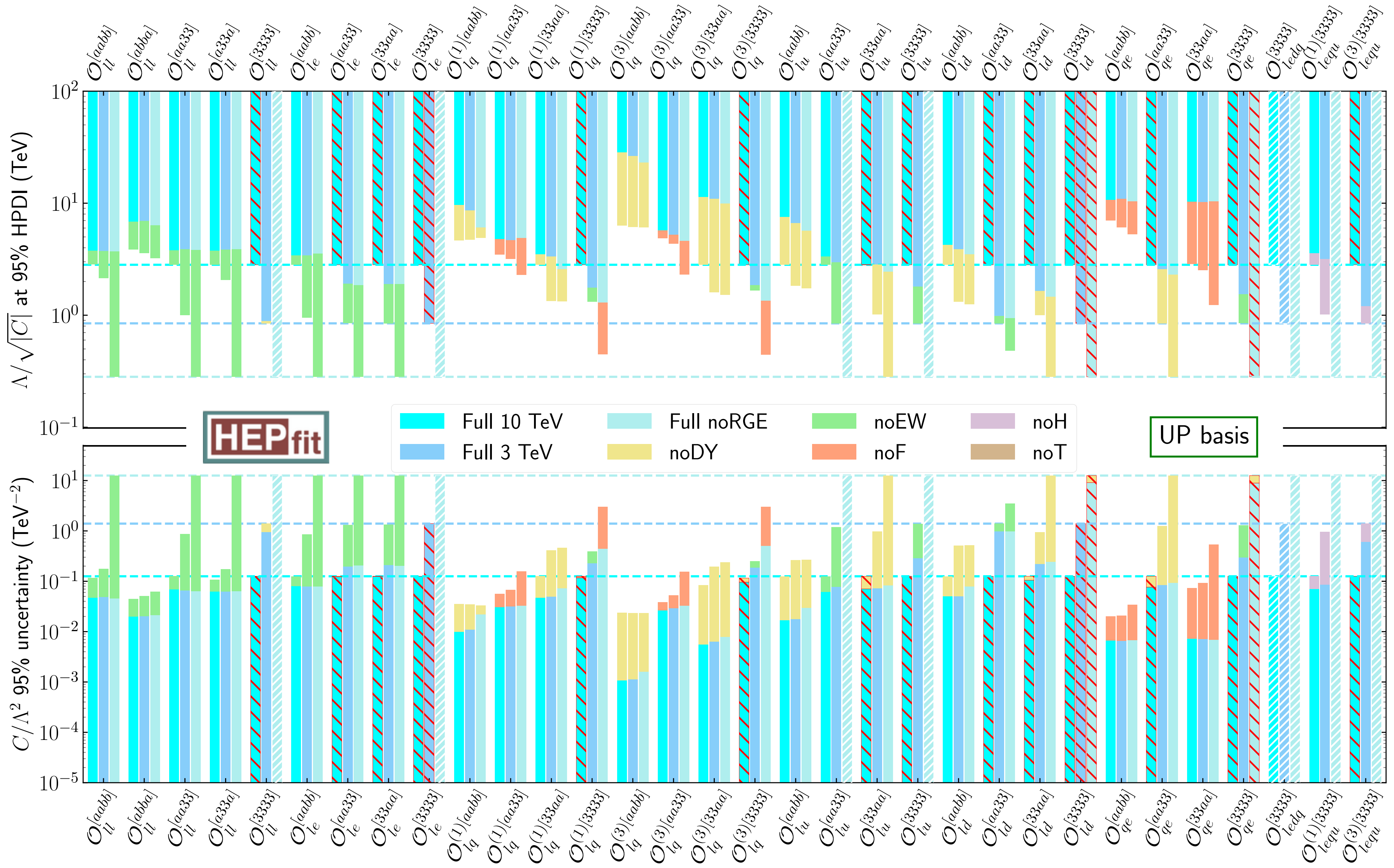


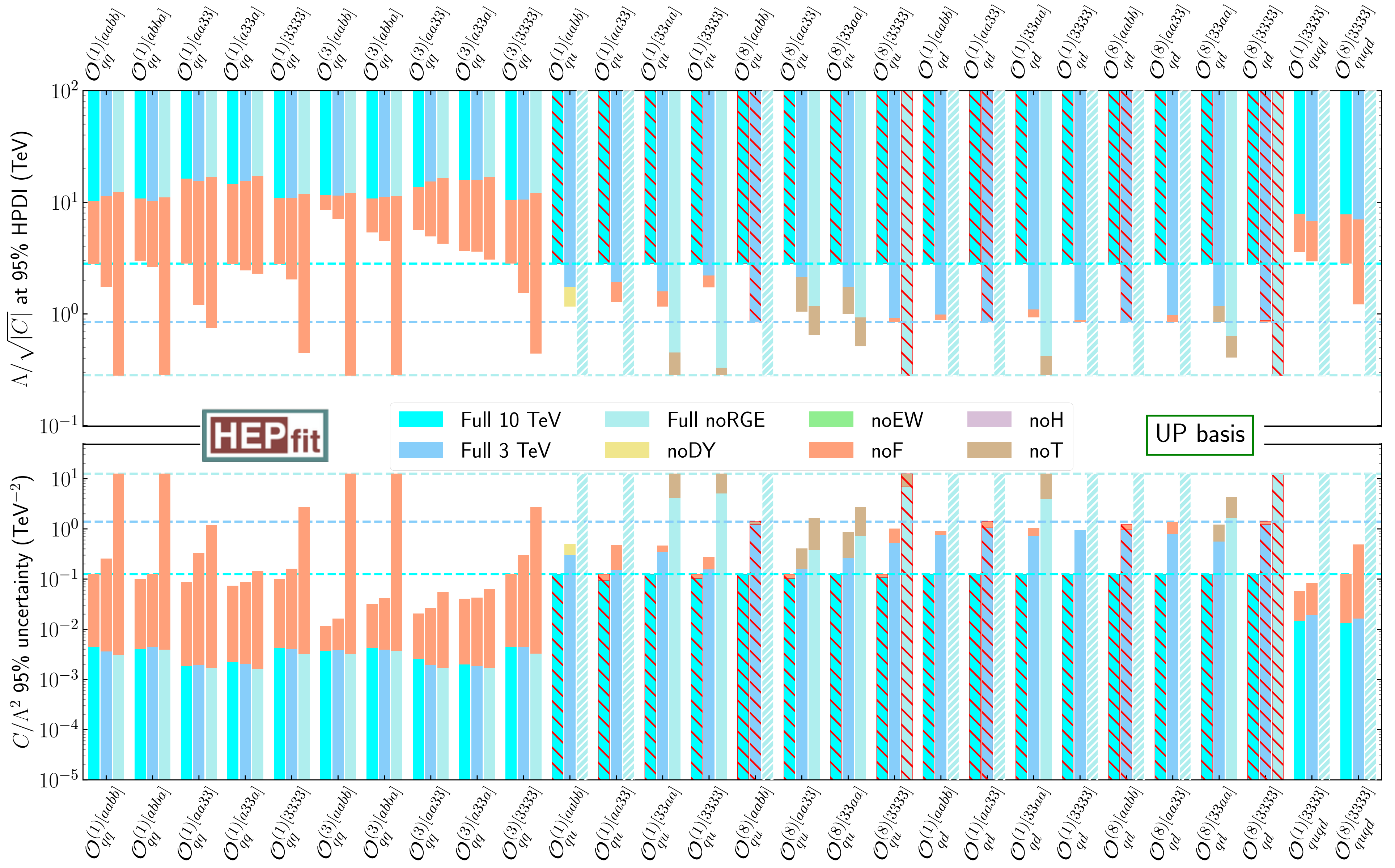
Strong correlations between coefficients significantly relax the bounds but many operators can still be constrained within the perturbative regime (especially for Λ=3 TeV)

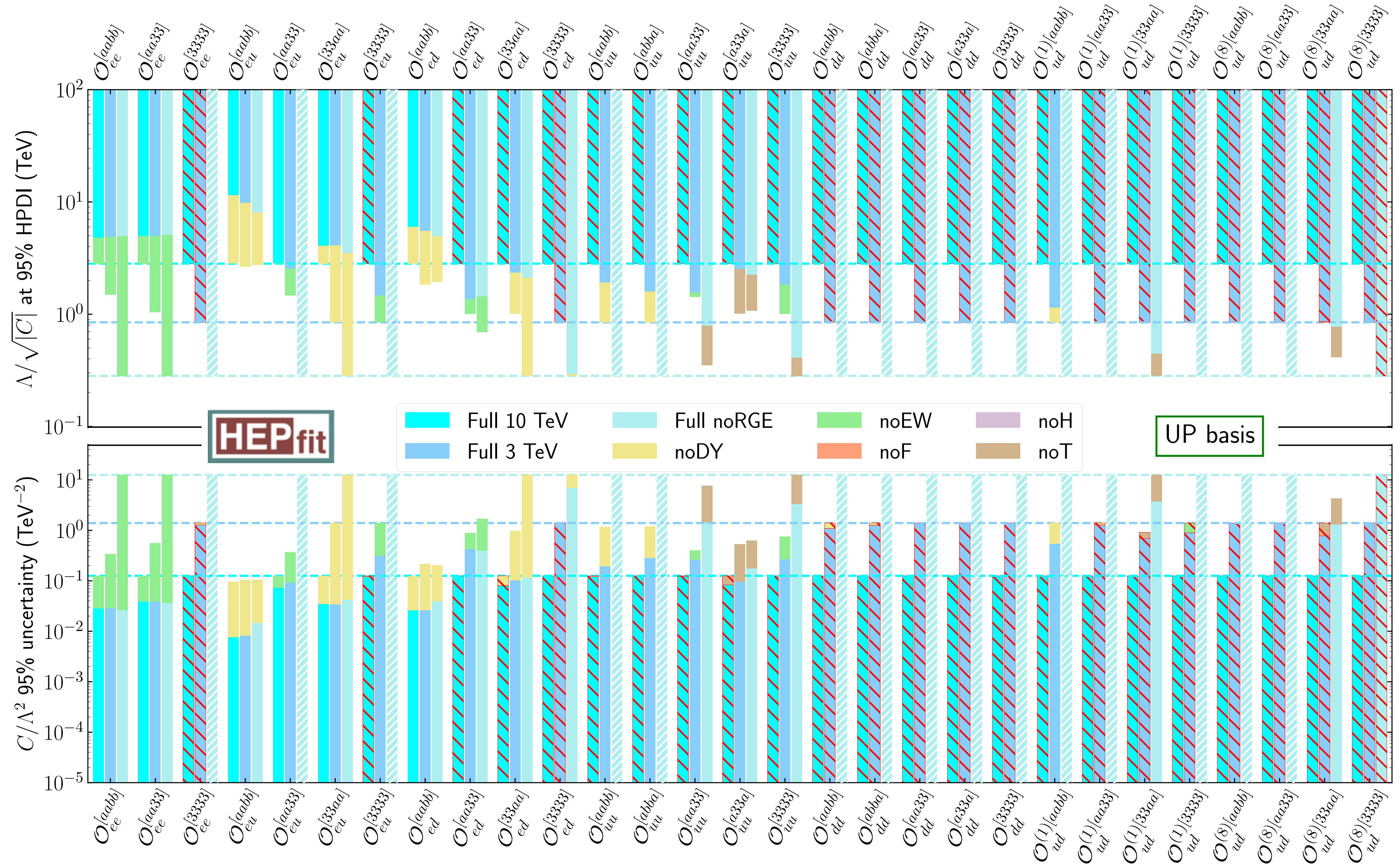
The role of Flavour in SMEFT fits: U(2)⁵

Individual fit results: Impact of data sets



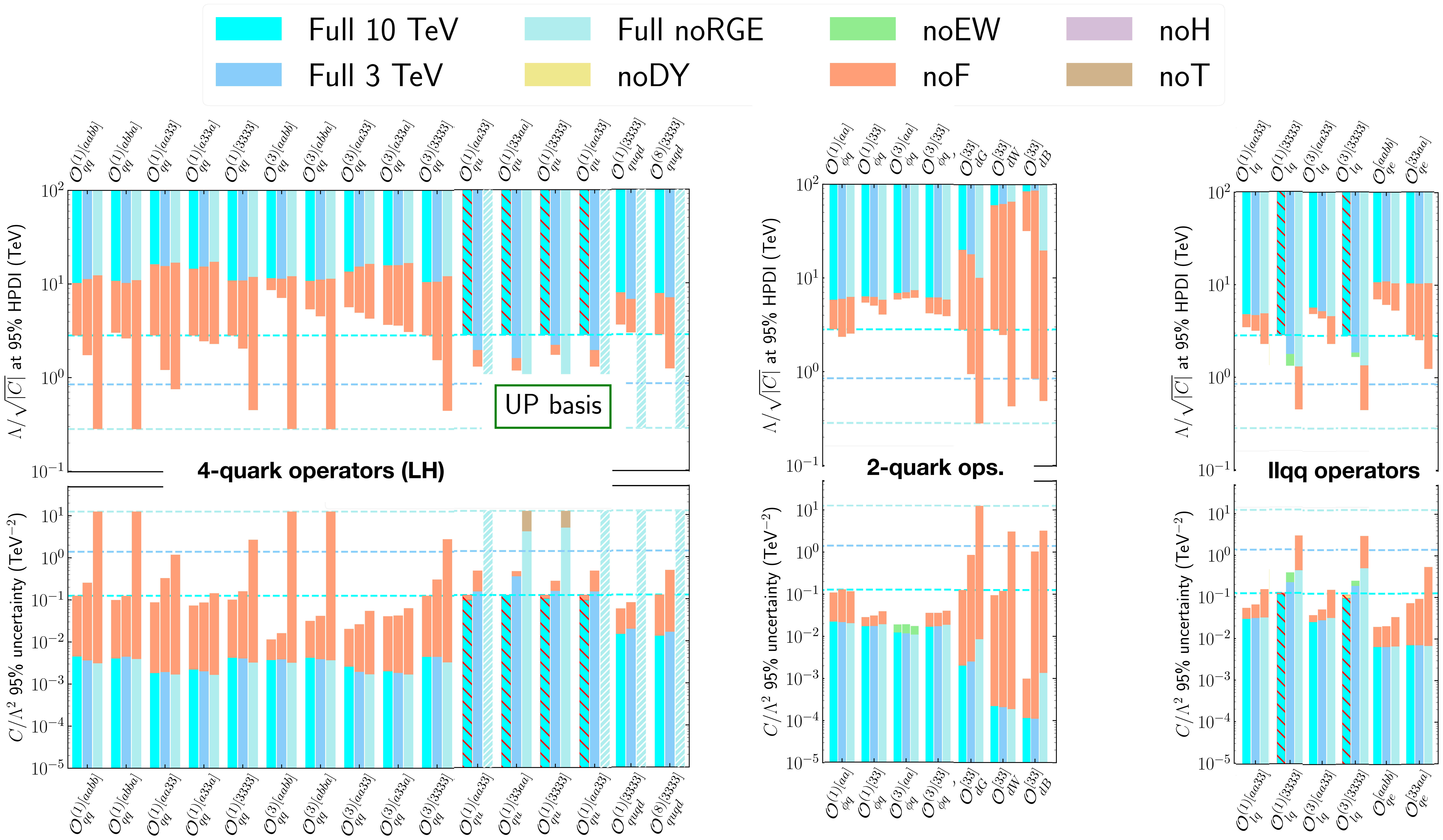






The role of Flavour in SMEFT fits: $U(2)^5$

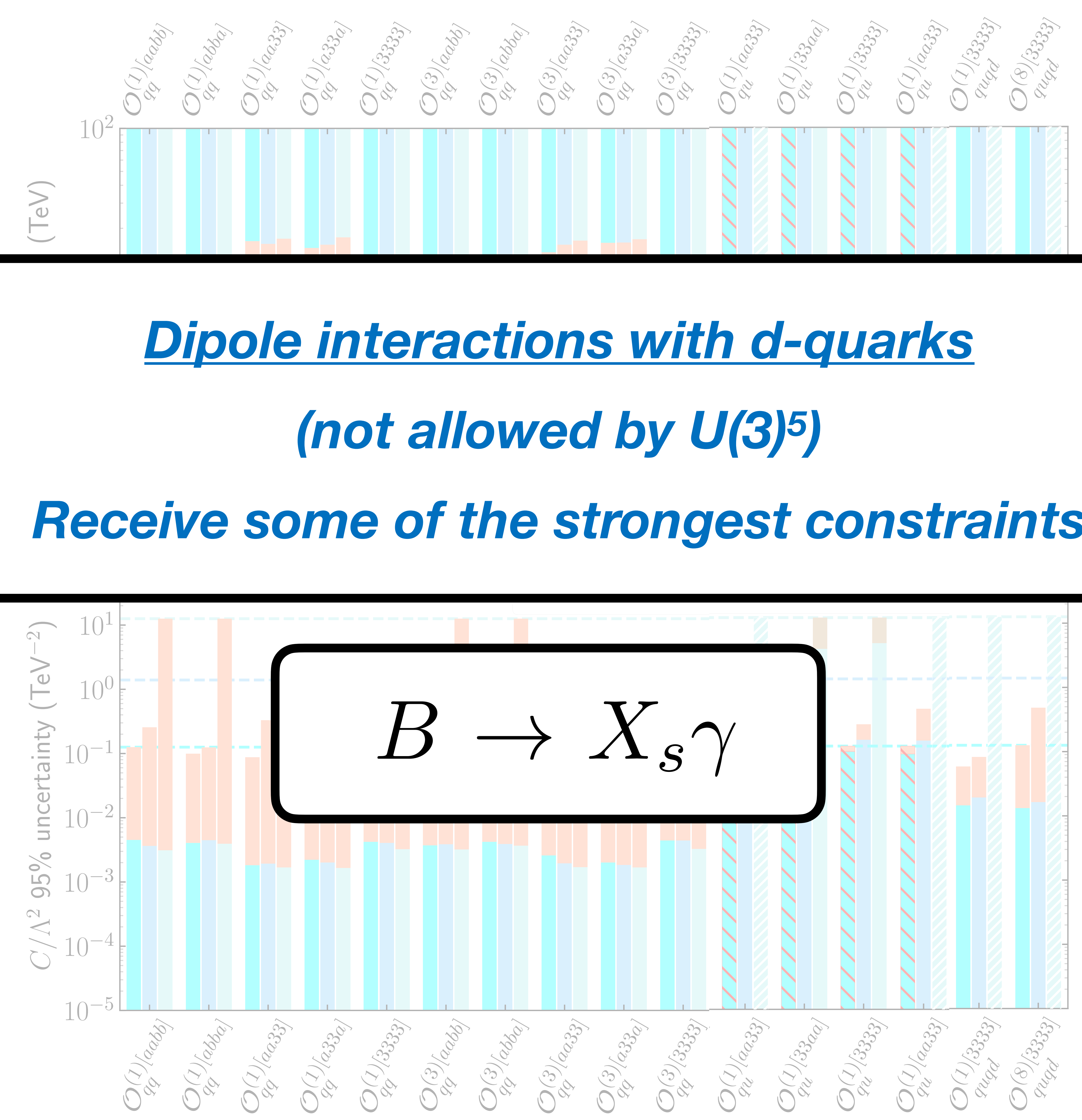
Individual fit results: Impact of data sets



(Very small contributions from RH operators to Flavour either in the UP or DOWN bases)

The role of Flavour in SMEFT fits: U(2)⁵

Individual fit results: Impact of data sets

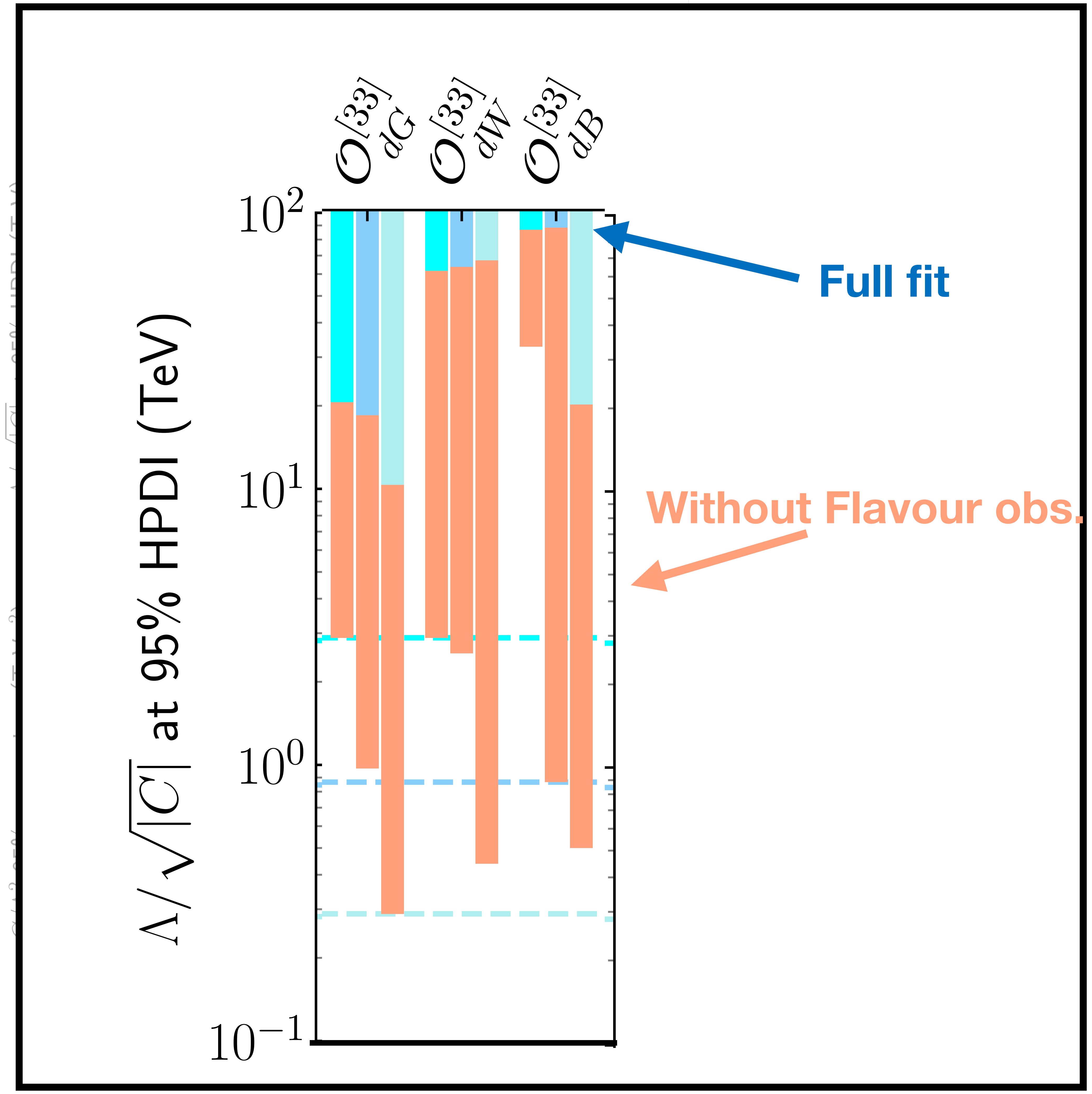


Dipole interactions with d-quarks

(not allowed by U(3)⁵)

Receive some of the strongest constraints

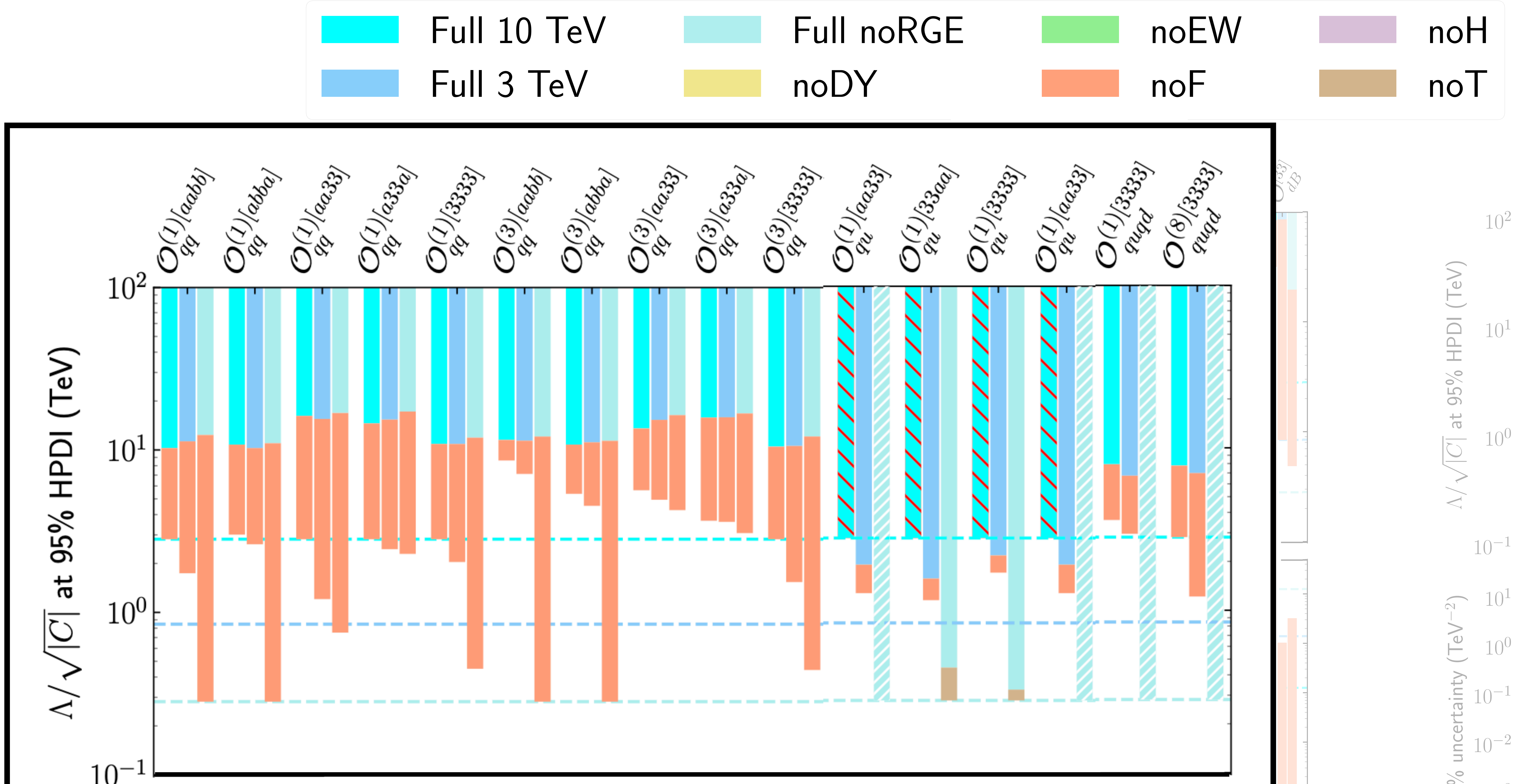
$$B \to X_s \gamma$$

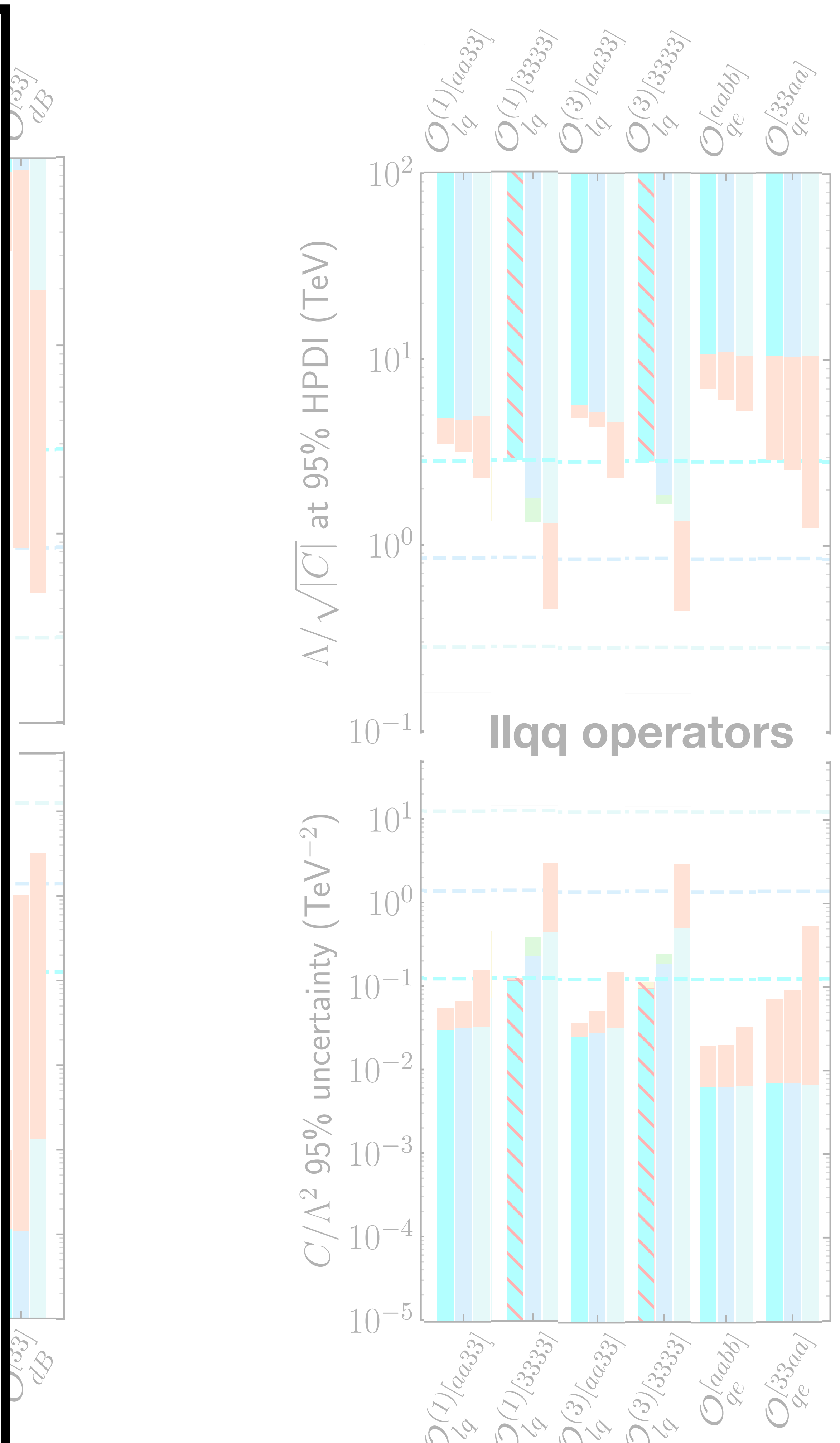


(Very small contributions from RH operators to Flavour either in the UP or DOWN bases)

The role of Flavour in SMEFT fits: U(2)⁵

Individual fit results: Impact of data sets





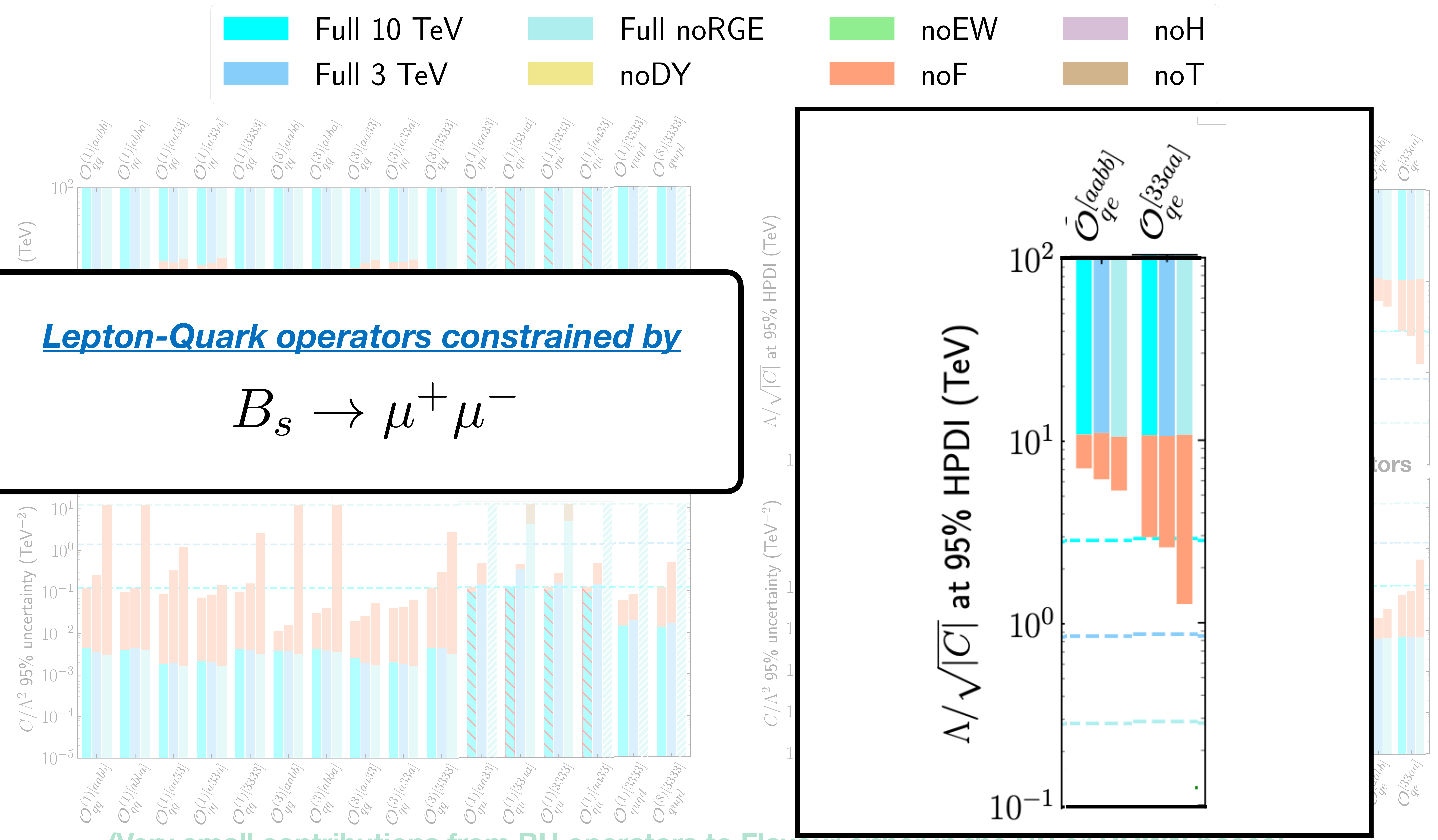
$O_{qq}^{(1)}$, $O_{qq}^{(3)}$ strongly constrained by meson-anti meson mixing

$$\Delta m_{B_s}\,,\ \Delta M_K\,,\ldots$$

(very small contributions from RH operators to Flavour either in the UP or DOWN bases)

The role of Flavour in SMEFT fits: U(2)^5

Individual fit results: Impact of data sets



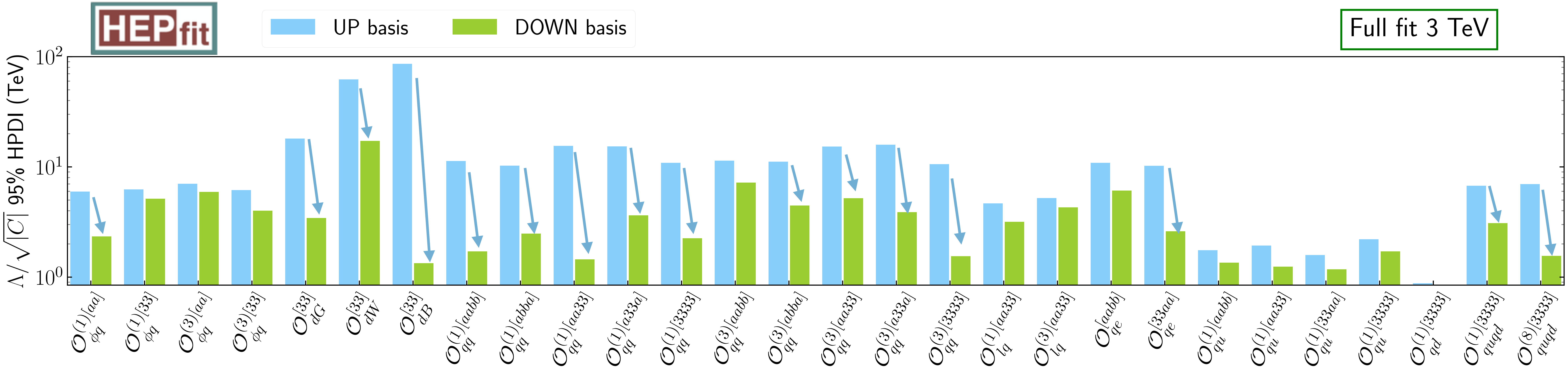
Lepton-Quark operators constrained by

$$B_s \to \mu^+\mu^-$$

(Very small contributions from RH operators to Flavour either in the UP or DOWN bases)

The role of Flavour in SMEFT fits: U(2)^5

UP vs. DOWN: Individual fits



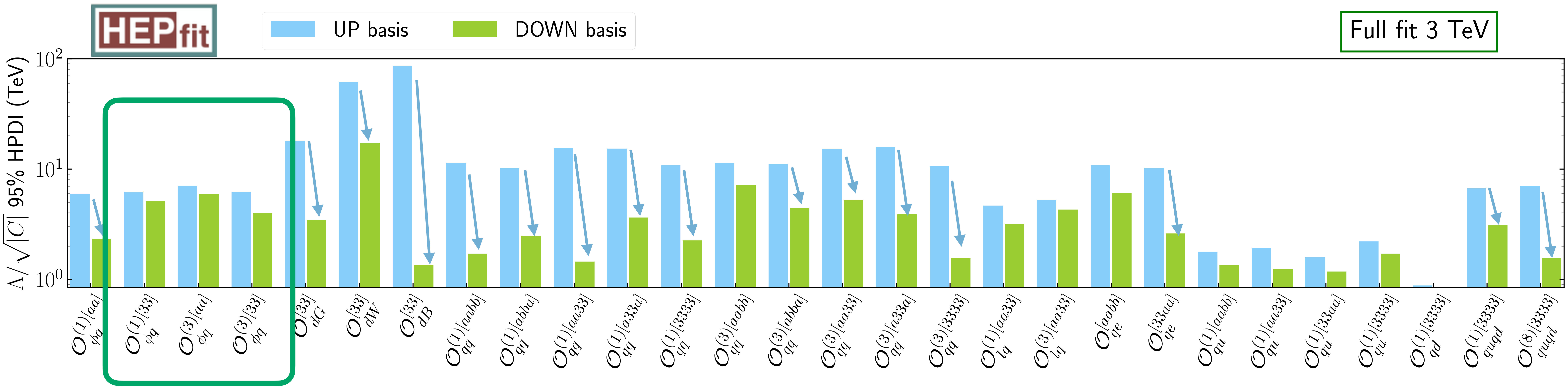
Strong dependence on choice of "basis"

- Alignment of New Physics with the DOWN sector in the U(2)^5 limit ⇒ Strong suppresion to flavour-changing b-quark processes ⇒ Systematic relaxation of flavour bounds

(Still providing the leading constraint in dipole interactions)

The role of Flavour in SMEFT fits: U(2)⁵

UP vs. DOWN: Individual fits



Strong dependence on choice of "basis"

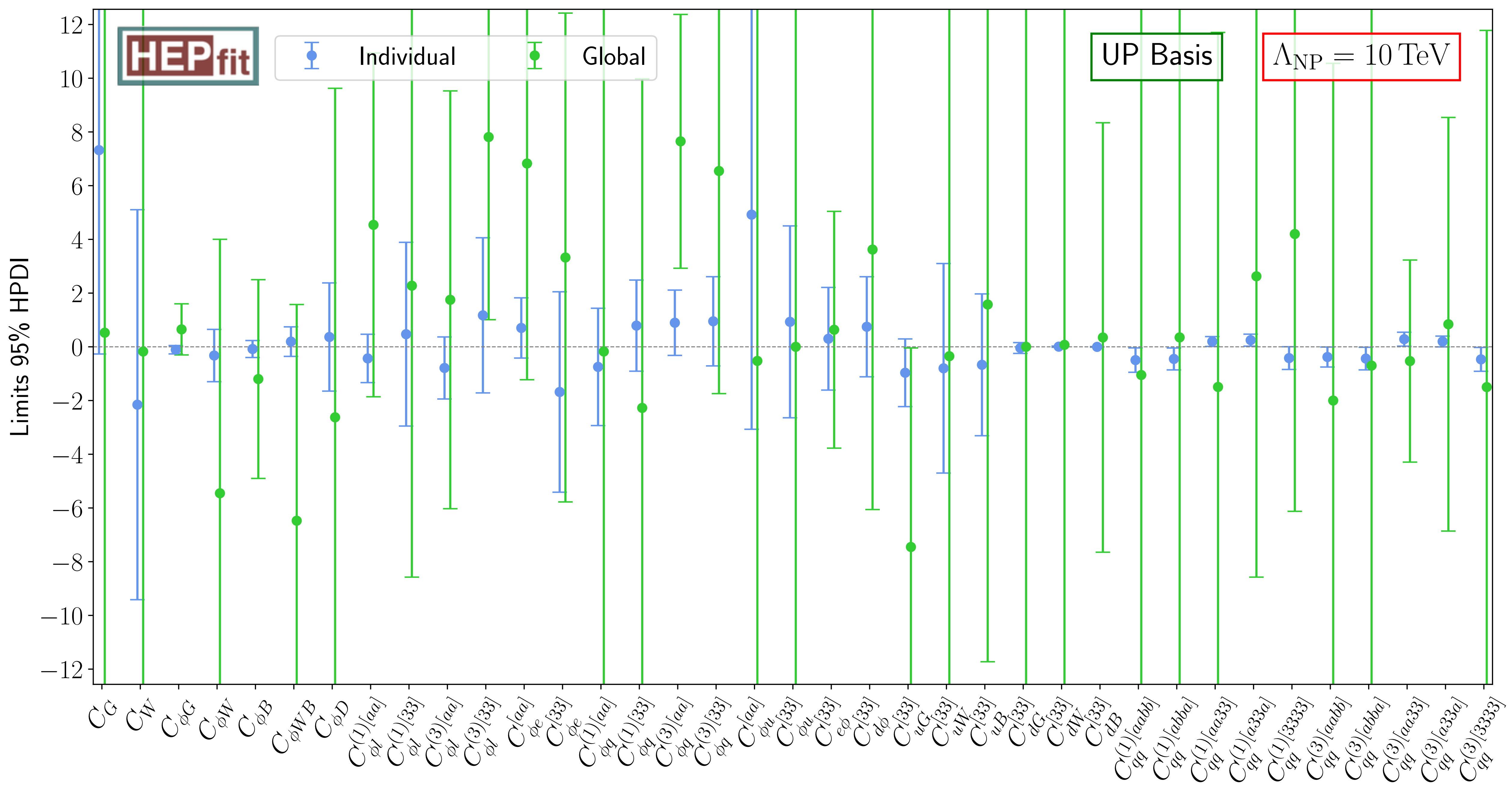
- Alignment of New Physics with the DOWN sector in the U(2)⁵ limit ⇒ Strong suppresion to flavour-changing b-quark processes ⇒ Systematic relaxation of flavour bounds

  (Still providing the leading constraint in dipole interactions)

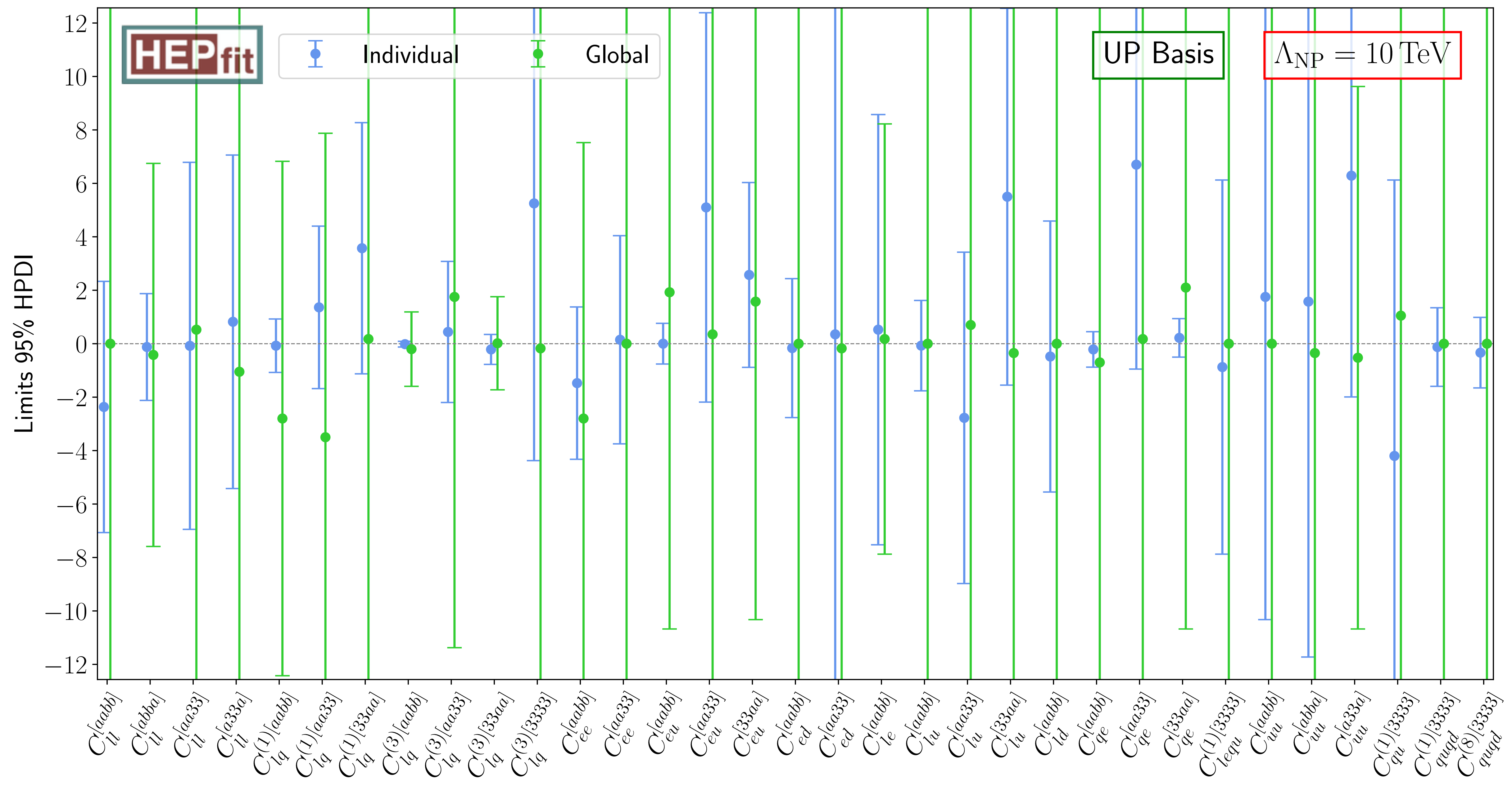
- **Exception:** $O_{\phi q}^{(1)}$, $O_{\phi q}^{(3)}$: EWPO still imposes strong flavour-blind bounds

SMEFT fit results: U(2)⁵

Comparison of individual vs. global fit results

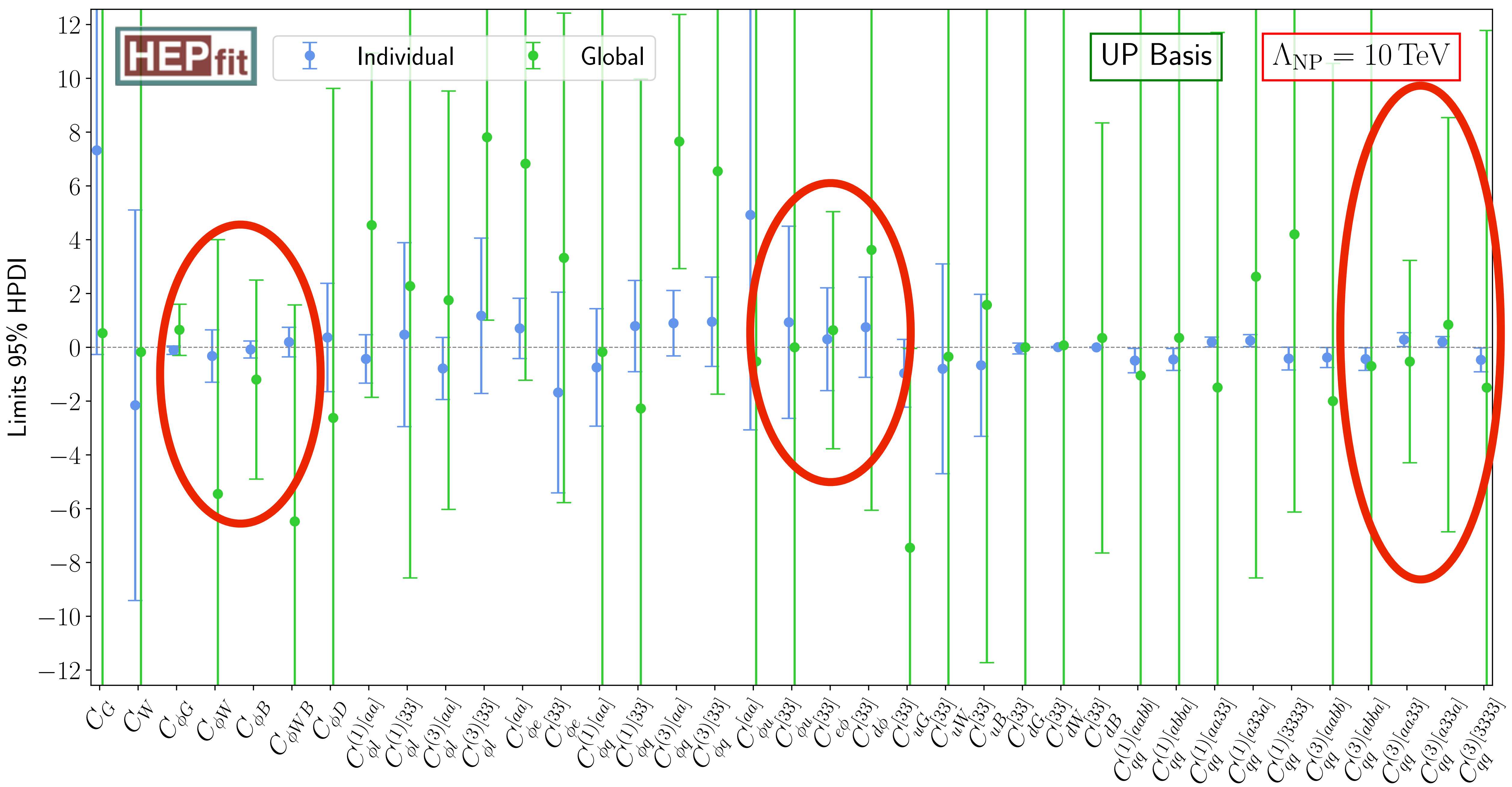


- Results shown (for illustration) only for those operators where a given WC can be constrained at least individually
- The larger number of degrees of freedom ***in the U(2)⁵ case weakens even more the global bounds*** compared to the individual limits



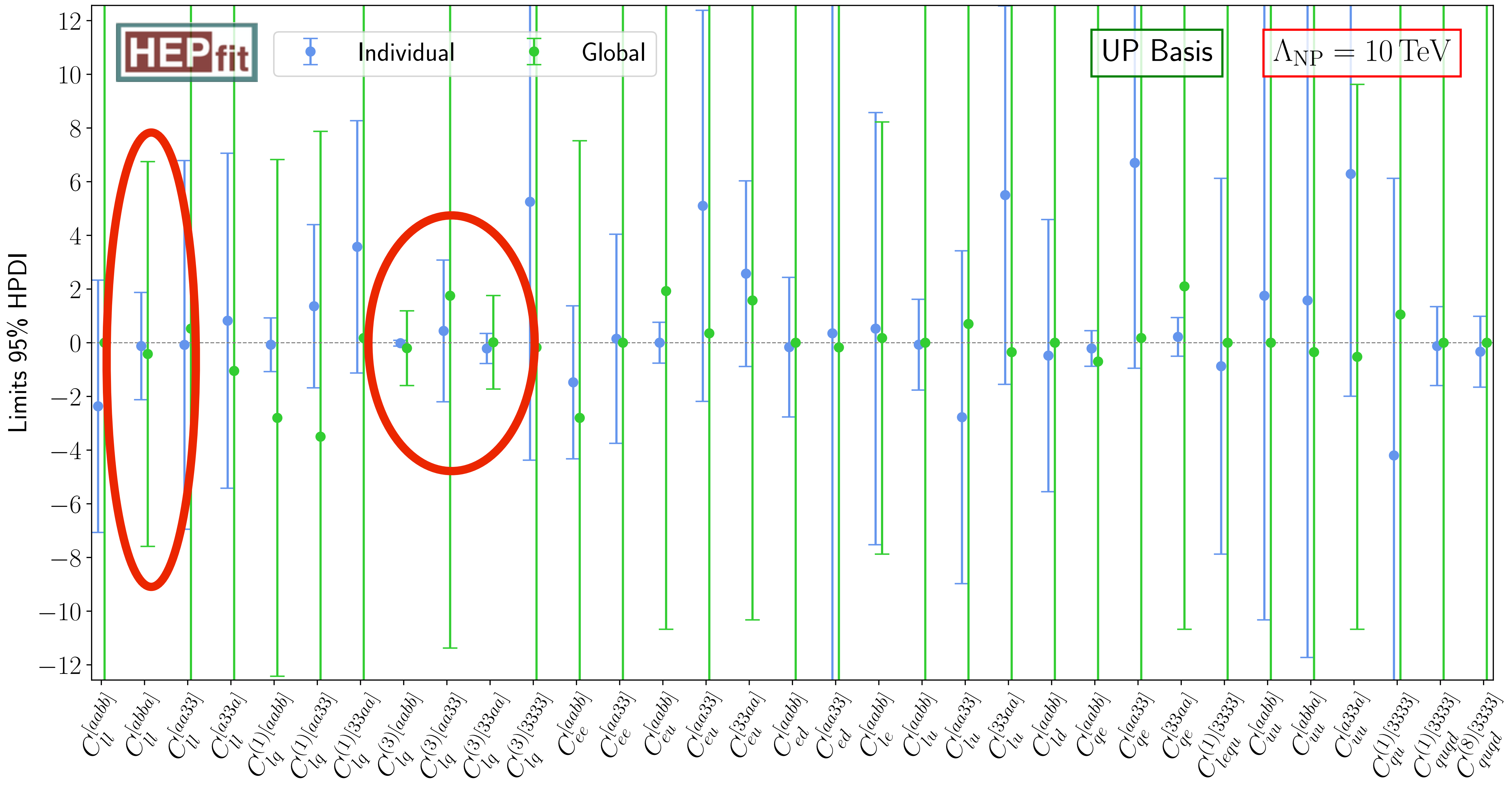
SMEFT fit results: U(2)⁵

Comparison of individual vs. global fit results



- Results shown (for illustration) only for those operators where a given WC can be constrained at least individually
- The larger number of degrees of freedom ***in the U(2)⁵ case weakens even more the global bounds*** compared to the individual limits

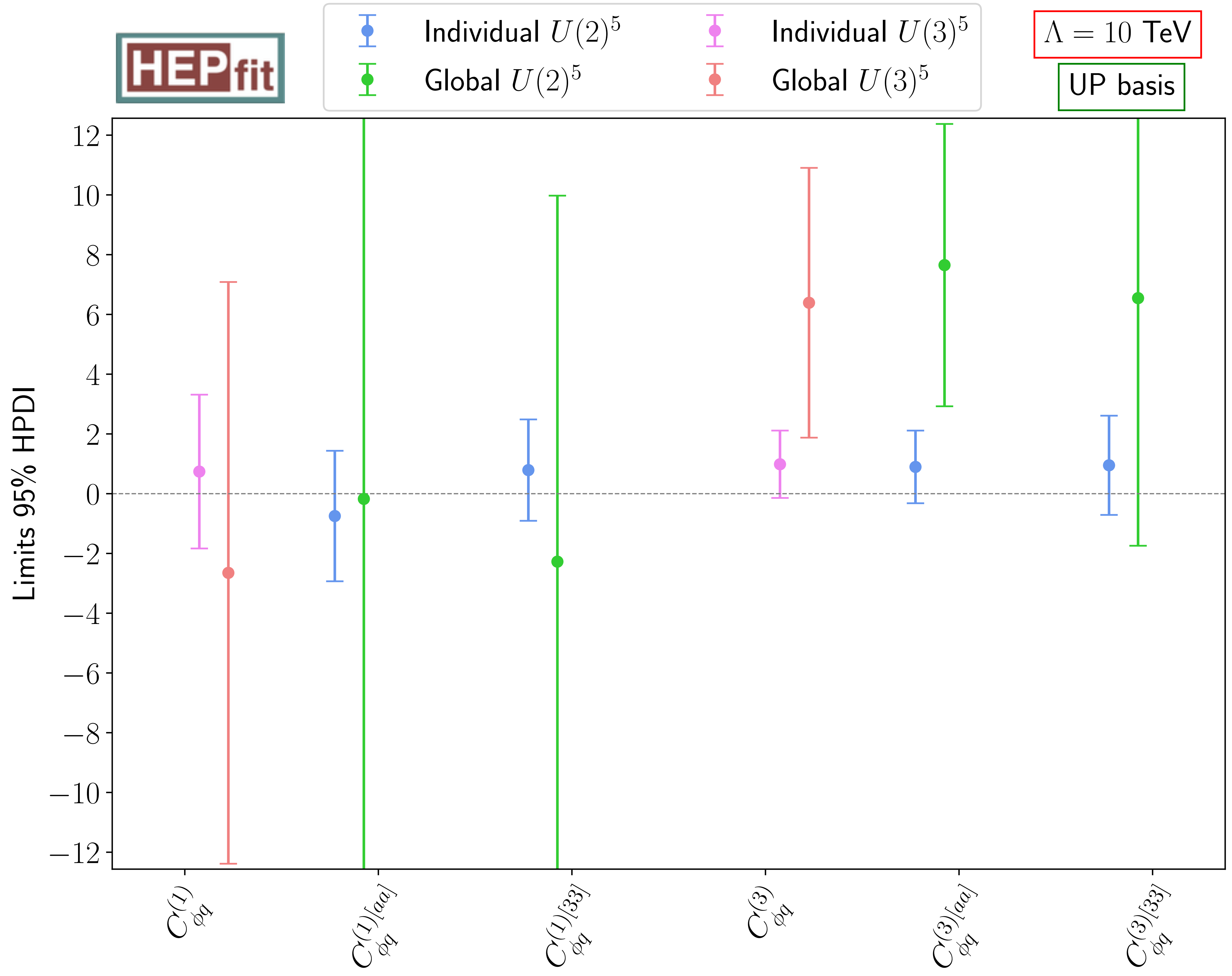
- With current precision, constraining the ***U(2)⁵*** SMEFT becomes challenging for Λ~10 TeV
- Meaningful constraints of several interactions can still be placed when restricting to the perturbative regime



SMEFT fit results: $U(2)^5$

Comparison of individual vs. global fit results

Flavour protection: $U(3)^5$ vs. $U(2)^5$



- Despite the very different hypotheses and prominent role of flavour measurements in the $U(2)^5$ fit, these assumptions ***still provide a good flavour "protection"***

$C_{\phi q}^{(1)}$, $C_{\phi q}^{(3)}$ → Modify NC quark interactions

Comparable results in $U(3)^5$ and $U(2)^5$ limits (both in individual and global fits)

Controlled by EW/Top observables

- Relevant for building new physics models not (too) far from the EW scale!

Summary

Conclusions

Summary and Conclusions

- In this study, we have presented a consistent combination of EW/Higgs/Top/Flavour constraints in the dimension-6 SMEFT:
  - ✓ Including variations of the SMEFT Wilson coefficients and all the SM parameters (inputs + TH uncert.)
  - ✓ Including RGE evolution both in the SMEFT and LEFT starting from a full basis of SMEFT effects in the UV:
    - $U(3)^5$ flavour symmetry (41 operators)
    - $U(2)^5$ flavour symmetry (124 operators)

    Around 200 parameters in the fit !
  - ✓ Including prior information to ensure the EFT is studied within its perturbative regime
- The role of flavour in the global fit
  - ✓ Strong dependence of the result on flavour assumptions
  - ✓ $U(2)^5$: beyond the trivial $U(3)^5$ limit, flavour measurements play a leading role in setting very strong limits in new interactions…
  - ✓ …though results depend on the direction of the 3rd family in flavour space chosen to define the $U(2)^5$ symmetry
  - ✓ $U(2)^5$ symmetry provides a good flavour protection ⇒ Important for EW scale BSM models!