Exploring New Physics — *Rome, 15 February 2024*

Flavor, EW precision & BSM

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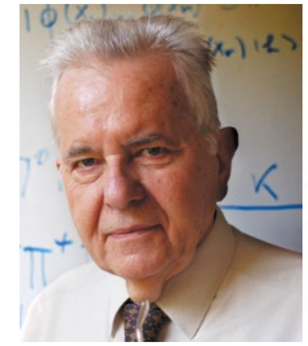
Flavor Metrology:

- Flavor violation in SM in charged weak-current <—> V_{CKM}

—> Flavor Changing Neutral Currents (FCNCs) **ONLY** @ one loop

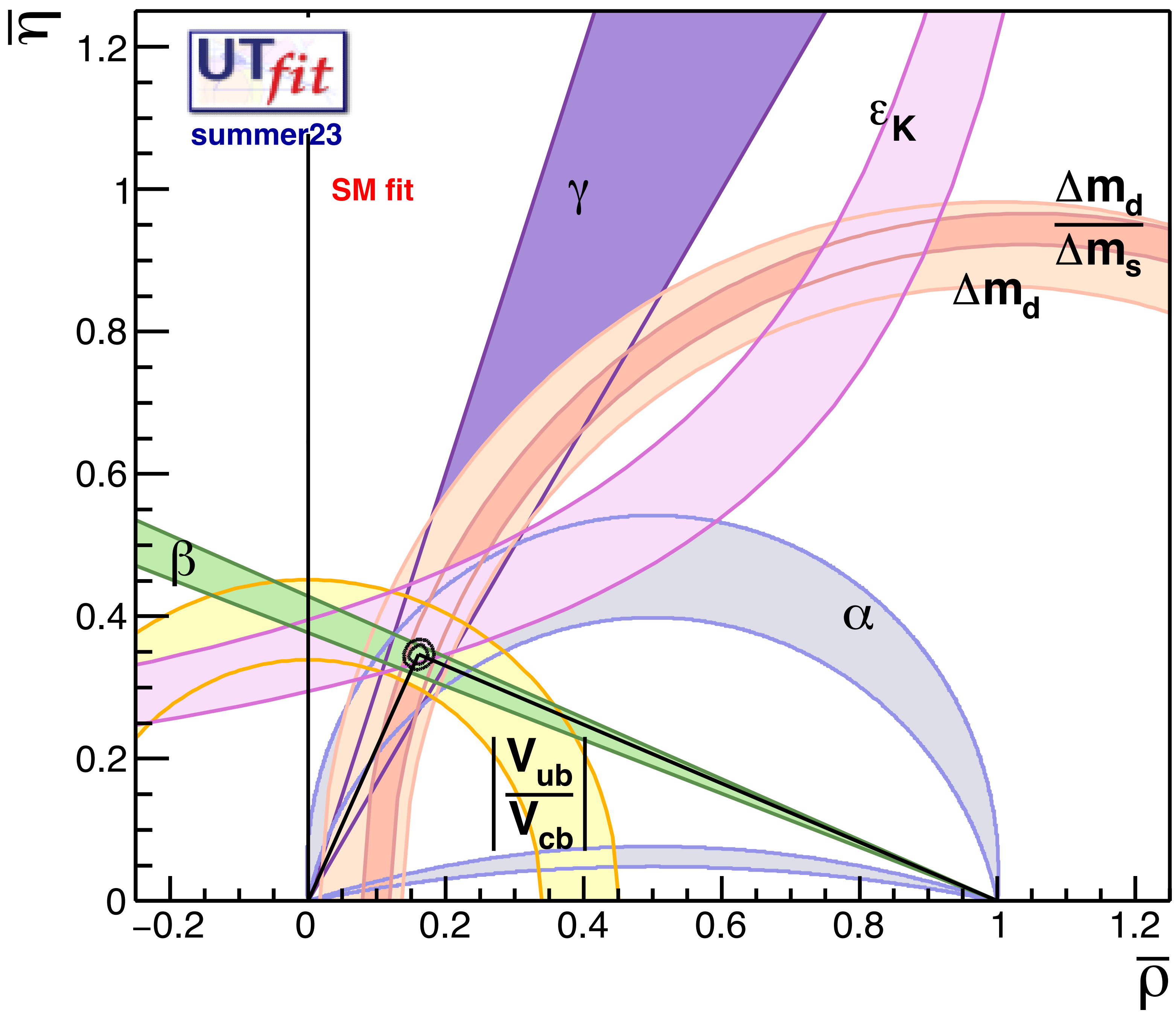
- CKM matrix described by 4 params (3 angles and a $\not{CP}$ phase)

$$V_{\rm CKM} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\bar\rho - i\bar\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\bar\rho - i\bar\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$

$(\bar\rho,\bar\eta)$ apex of $V_{ub}^* V_{ud} + V_{cb}^* V_{cd} + V_{tb}^* V_{td} = 0$

SM UT Analysis — 2023

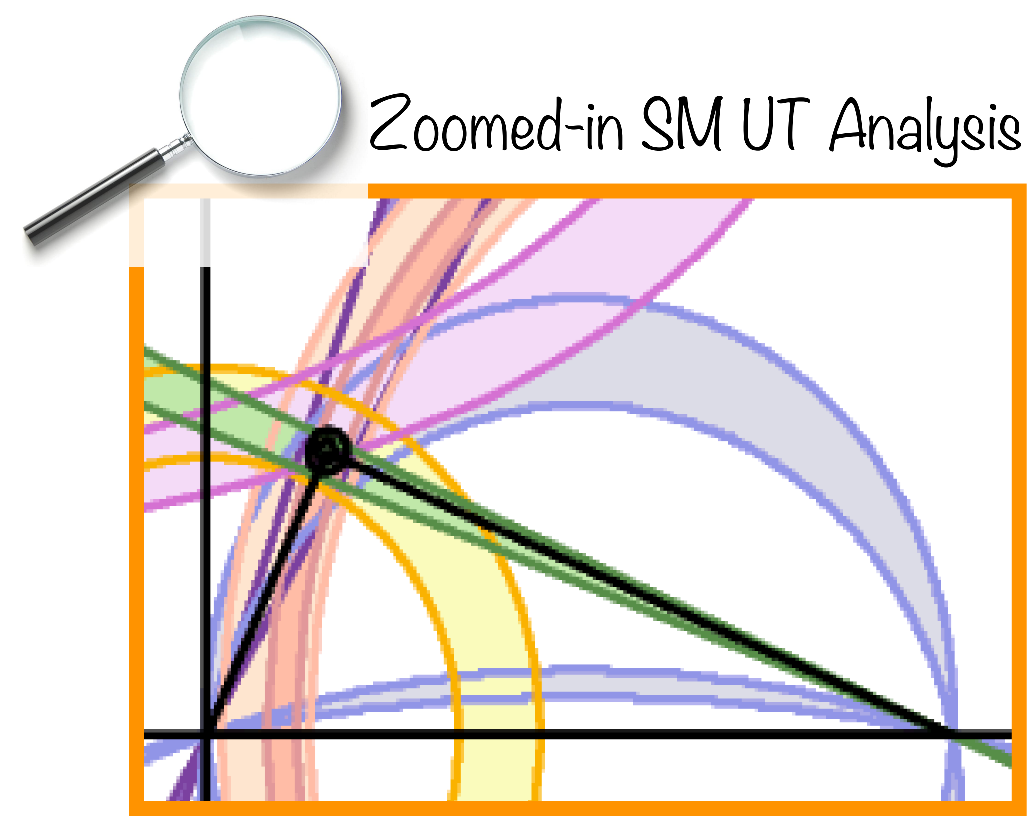
@ 95% prob



$$\bar{\rho} = 0.160 \pm 0.009 \sim 6\%$$
$$\bar{\eta} = 0.346 \pm 0.009 \sim 3\%$$

$$\lambda = 0.2251 \pm 0.0008$$
$$A = 0.827 \pm 0.010$$

Zoomed-in SM UT Analysis



Rend.Lincei Sci.Fis.Nat. 34 (2023) 37

A closer look to the fit

Observable	Measurement	Full Fit	Prediction	Pull (#σ)
$\lvert V_{ud}\rvert$	0.97433 ± 0.00017	0.97431 ± 0.00017	0.9737 ± 0.0011	0.6
$\lvert V_{ub}\rvert$	0.00375 ± 0.00026	0.003702 ± 0.000081	0.003696 ± 0.000087	0.2
$\lvert V_{cb}\rvert$	0.04132 ± 0.00073	0.04194 ± 0.00041	0.04221 ± 0.00051	1.0
α [°]	93.8 ± 4.5	92.4 ± 1.4	92.3 ± 1.5	0.9
$\sin 2\beta$	0.689 ± 0.019	0.705 ± 0.014	0.739 ± 0.027	1.5
γ [°]	65.4 ± 3.3	65.1 ± 1.3	65.2 ± 1.5	0.1
ΔM_d [ps^{-1}]	0.5065 ± 0.0019	0.5067 ± 0.0020	0.519 ± 0.022	0.6
ΔM_s [ps^{-1}]	17.741 ± 0.020	17.741 ± 0.021	17.89 ± 0.65	0.2
ε	0.002228 ± 0.000011	0.002227 ± 0.000014	0.00200 ± 0.00014	1.6
$\mathrm{Re}\,(\varepsilon'/\varepsilon)$	0.00166 ± 0.00033	0.00160 ± 0.00028	0.00146 ± 0.00045	0.3
$\overline{\mathrm{BR}}(B_s \to \mu\mu) \times 10^9$	3.41 ± 0.29	3.44 ± 0.12	3.45 ± 0.13	0.1
$\mathrm{BR}(B \to \tau\nu) \times 10^4$	1.06 ± 0.19	0.872 ± 0.041	0.865 ± 0.041	1.0

$$\mathrm{pull}(\#\sigma) = 2.4\,(0.1) \text{ for } |V_{cb}^{\mathrm{excl}}| \times 10^3 = 40.55 \pm 0.46 \ (\text{for } |V_{cb}^{\mathrm{incl}}| \times 10^3 = 42.16 \pm 0.50)\,,$$

$$\mathrm{pull}(\#\sigma) = 1.6\,(0.3) \text{ for } |V_{ub}^{\mathrm{incl}}| \times 10^3 = 4.13 \pm 0.26 \ (\text{for } |V_{ub}^{\mathrm{excl}}| \times 10^3 = 3.64 \pm 0.16)\,,$$

UT Bounds on NP

|ΔF|=2 Weak EFT

SM/MFV

$$O_1^{q_i q_j} = \bar{q}_{jL}^{\alpha} \gamma_\mu q_{iL}^{\alpha} \, \bar{q}_{jL}^{\beta} \gamma^\mu q_{iL}^{\beta}$$

$$O_2^{q_i q_j} = \bar{q}_{jR}^{\alpha} q_{iL}^{\alpha} \, \bar{q}_{jR}^{\beta} q_{iL}^{\beta}$$

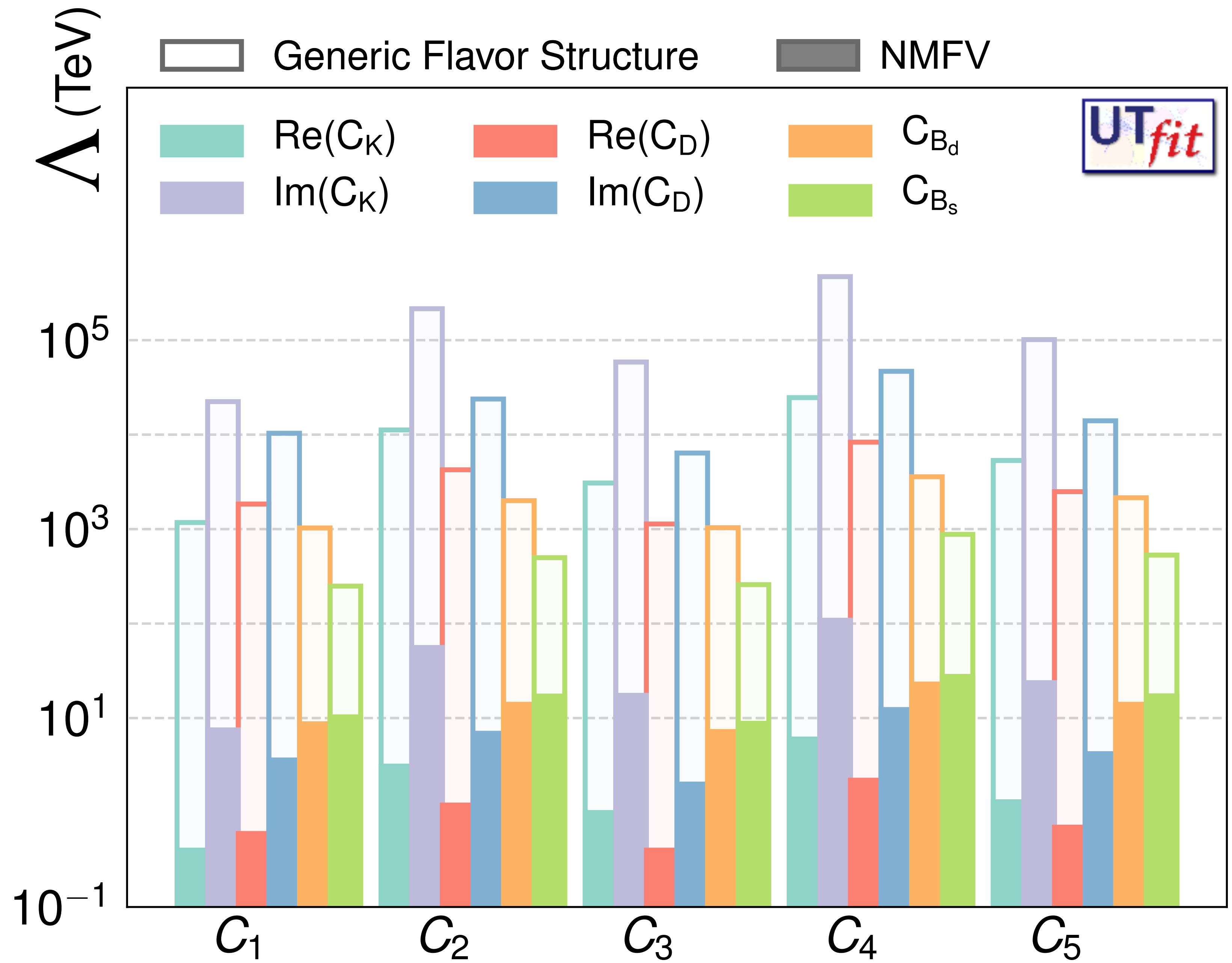
$$O_3^{q_i q_j} = \bar{q}_{jR}^{\alpha} q_{iL}^{\beta} \, \bar{q}_{jR}^{\beta} q_{iL}^{\alpha}$$

$$O_4^{q_i q_j} = \bar{q}_{jR}^{\alpha} q_{iL}^{\alpha} \, \bar{q}_{jL}^{\beta} q_{iR}^{\beta}$$

$$O_5^{q_i q_j} = \bar{q}_{jR}^{\alpha} q_{iL}^{\beta} \, \bar{q}_{jL}^{\beta} q_{iR}^{\alpha}$$

+ chirally flipped $\widetilde{O}_{1,2,3}^{q_i q_j}$

see, e.g. arXiv:/0707.0636



- **Generic NP** = no SM protection, i.e.: $C(\Lambda) \sim 1/\Lambda^2$ ⇨ $\Lambda > 4.7 \times 10^5$ TeV
- **Next-to-MFV** = SM-like protection + O(1) phases ➡ $\Lambda > 108$ TeV

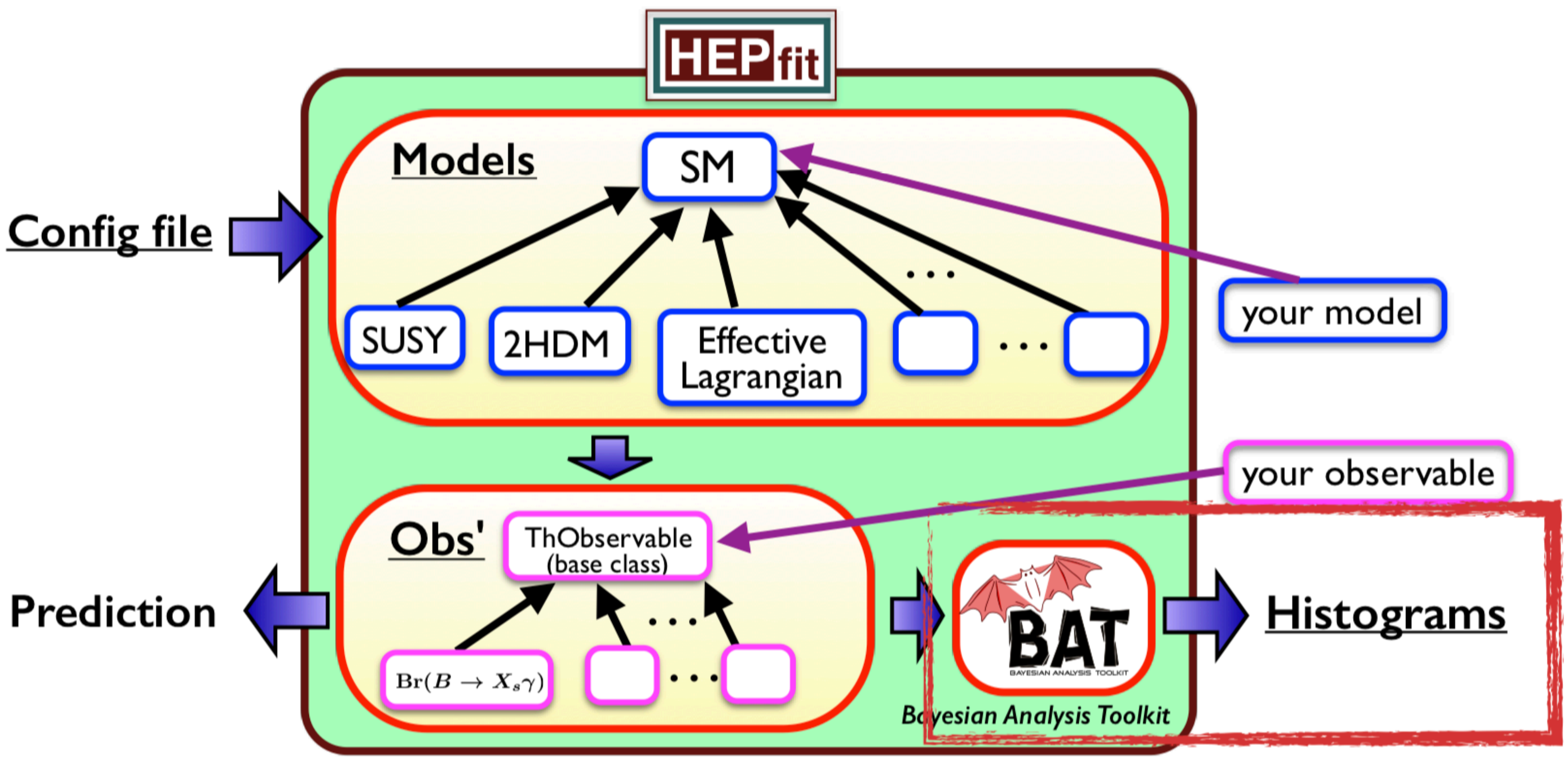
Eur. Phys. J. C (2020) 80:456
https://doi.org/10.1140/epjc/s10052-020-7904-z

THE EUROPEAN PHYSICAL JOURNAL C

Special Article - Tools for Experiment and Theory

HEPfit: a code for the combination of indirect and direct constraints on high energy physics models

J. de Blas[1,2], D. Chowdhury[3,4], M. Ciuchini[5], A. M. Coutinho[6], O. Eberhardt[7], M. Fedele[8], E. Franco[9], G. Grilli di Cortona[10], V. Miralles[7], S. Mishima[11], A. Paul[12,13,a], A. Peñuelas[7], M. Pierini[14], L. Reina[15], L. Silvestrini[9,16], M. Valli[17], R. Watanabe[5], N. Yokozaki[18]



[1910.14012]   https://hepfit.roma1.infn.it   https://github.com/silvest/HEPfit

B ANOMALIES : CIRCA 2023

SMEFT GLOBAL ANALYSIS:
KEY **NP** OPERATORS

$$O_{2223}^{LQ} = \bar{L}_2 \gamma_\mu L_2 \bar{Q}_2 \gamma^\mu Q_3$$
$$O_{2322}^{Qe} = \bar{Q}_2 \gamma_\mu Q_3 \bar{e}_2 \gamma^\mu e_2$$

$$C_9 \propto C^{Qe} + C^{LQ}$$
$$C_{10} \propto C^{Qe} - C^{LQ}$$

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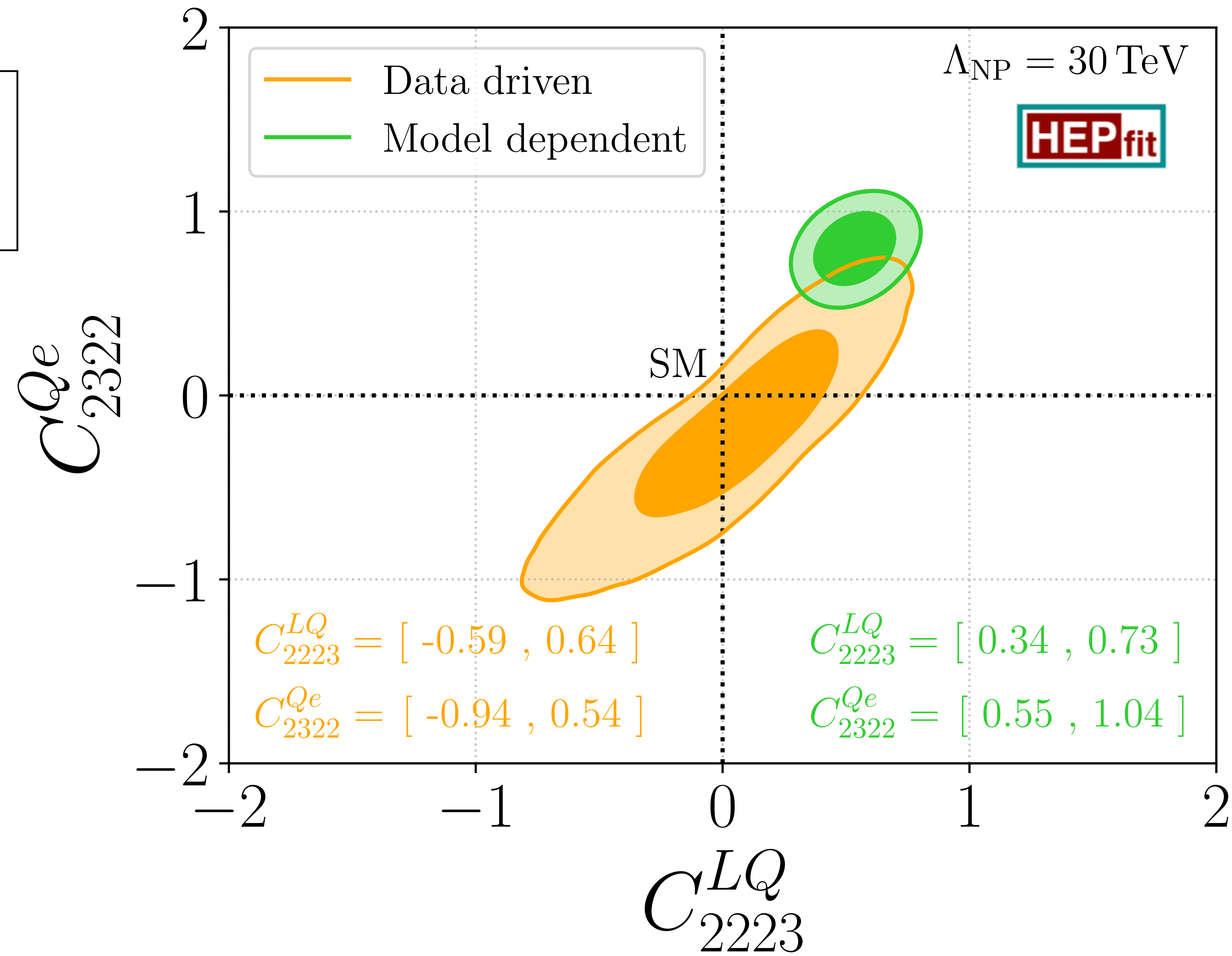

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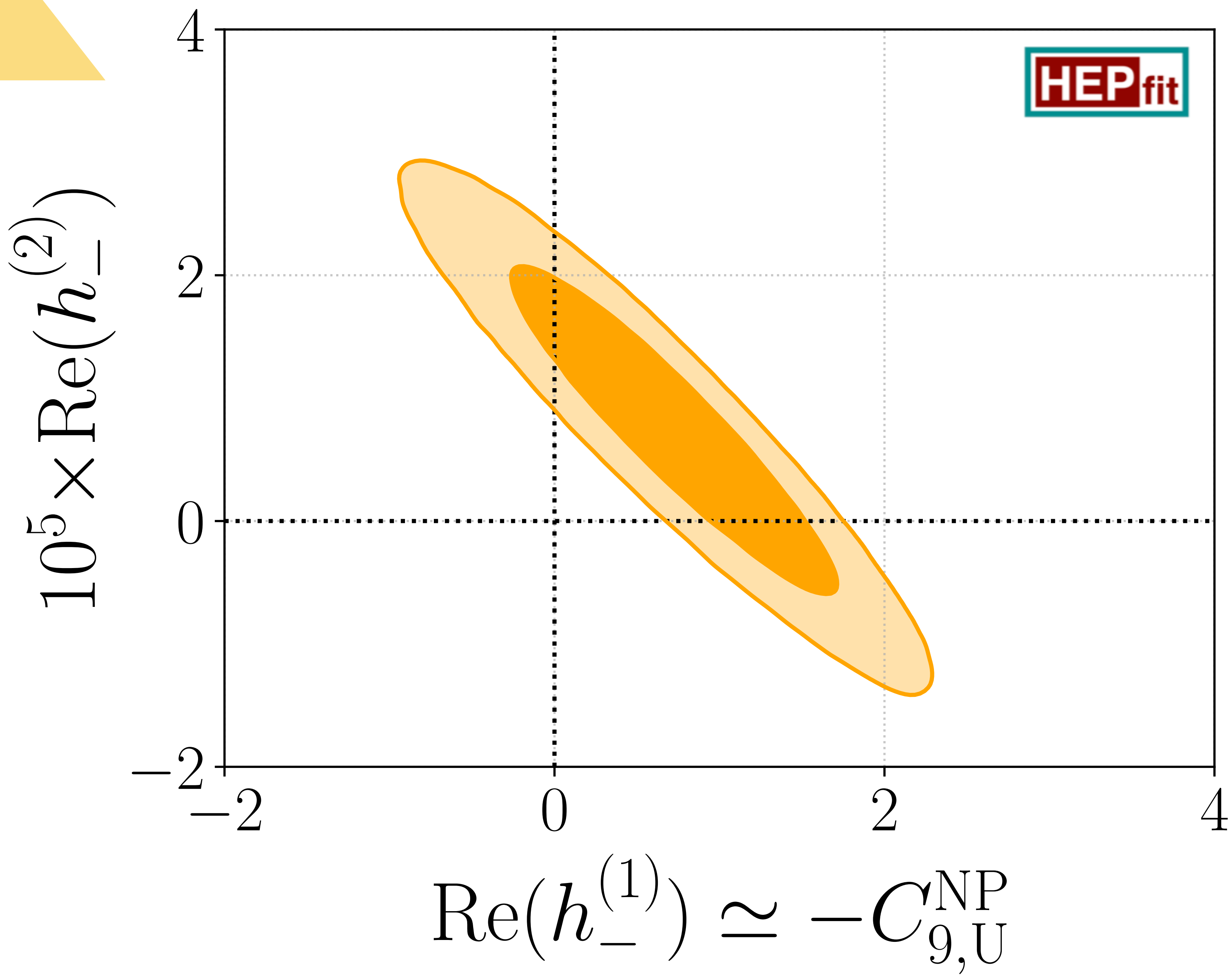
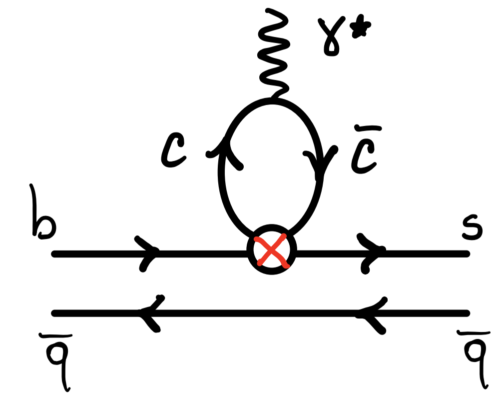
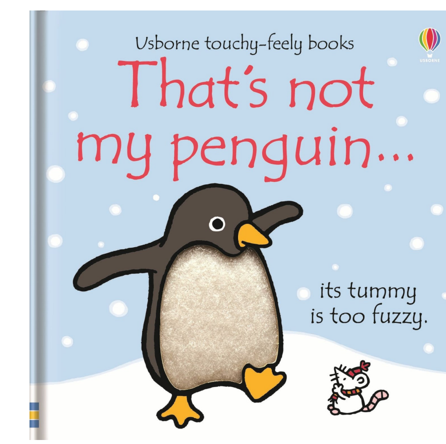
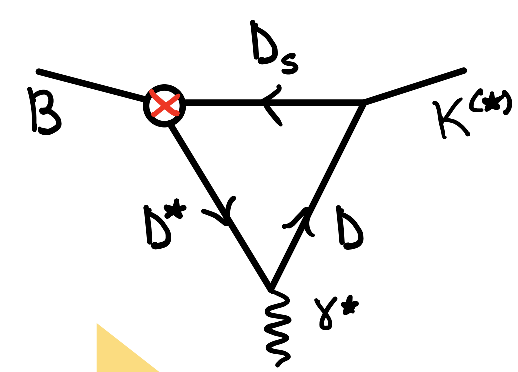








QCD ONLY

QCD ~ LEPTON UNIVERSAL NP

The EW fit: Key test of the selection rules of the SM

SM analysis

$$G_F, \alpha, M_Z, M_H, m_t, \alpha_S(M_Z), \Delta\alpha^{(5)}_{\rm had}$$

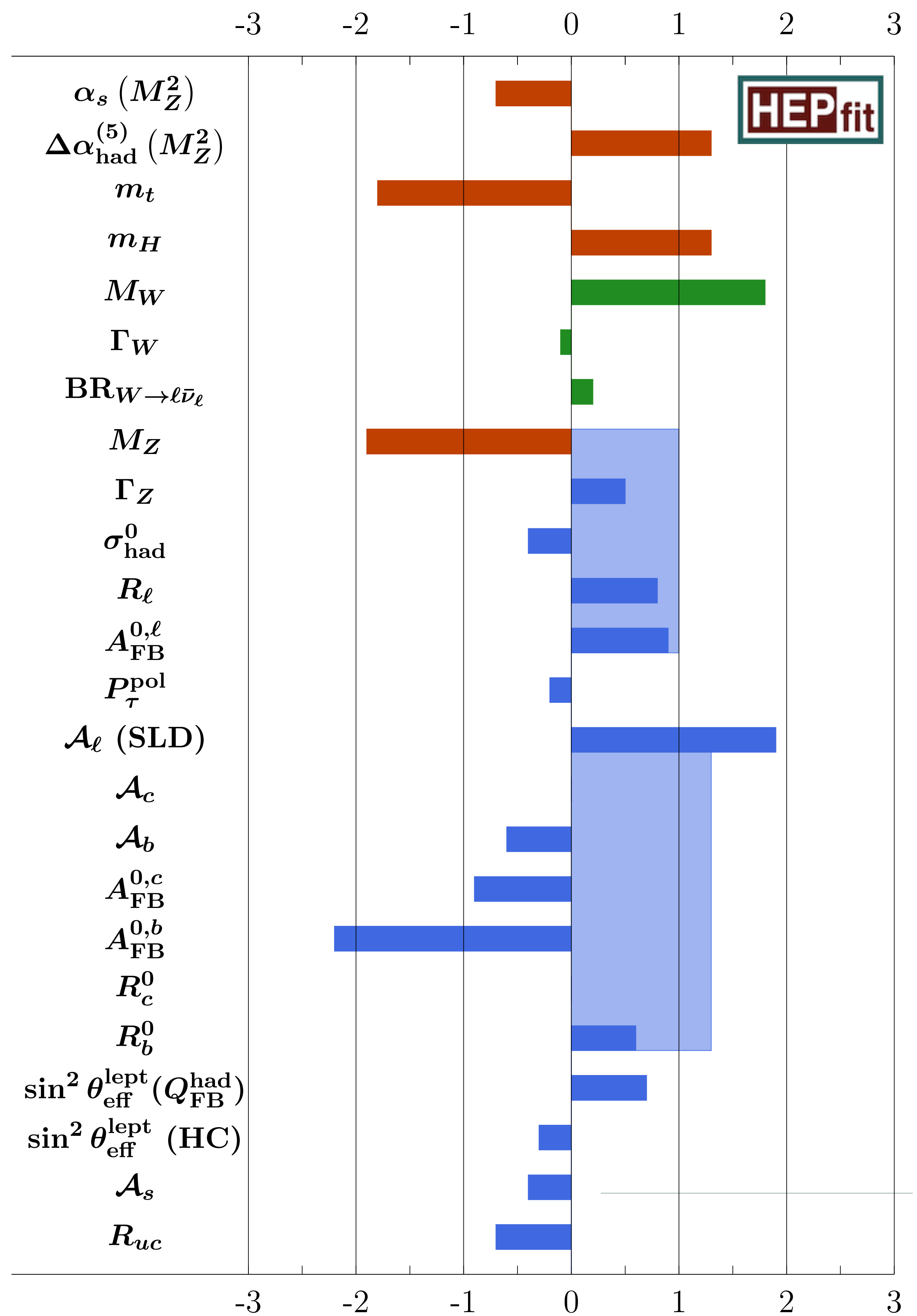
- predict EWPO (Z-pole, W obs.) as function of these quantities

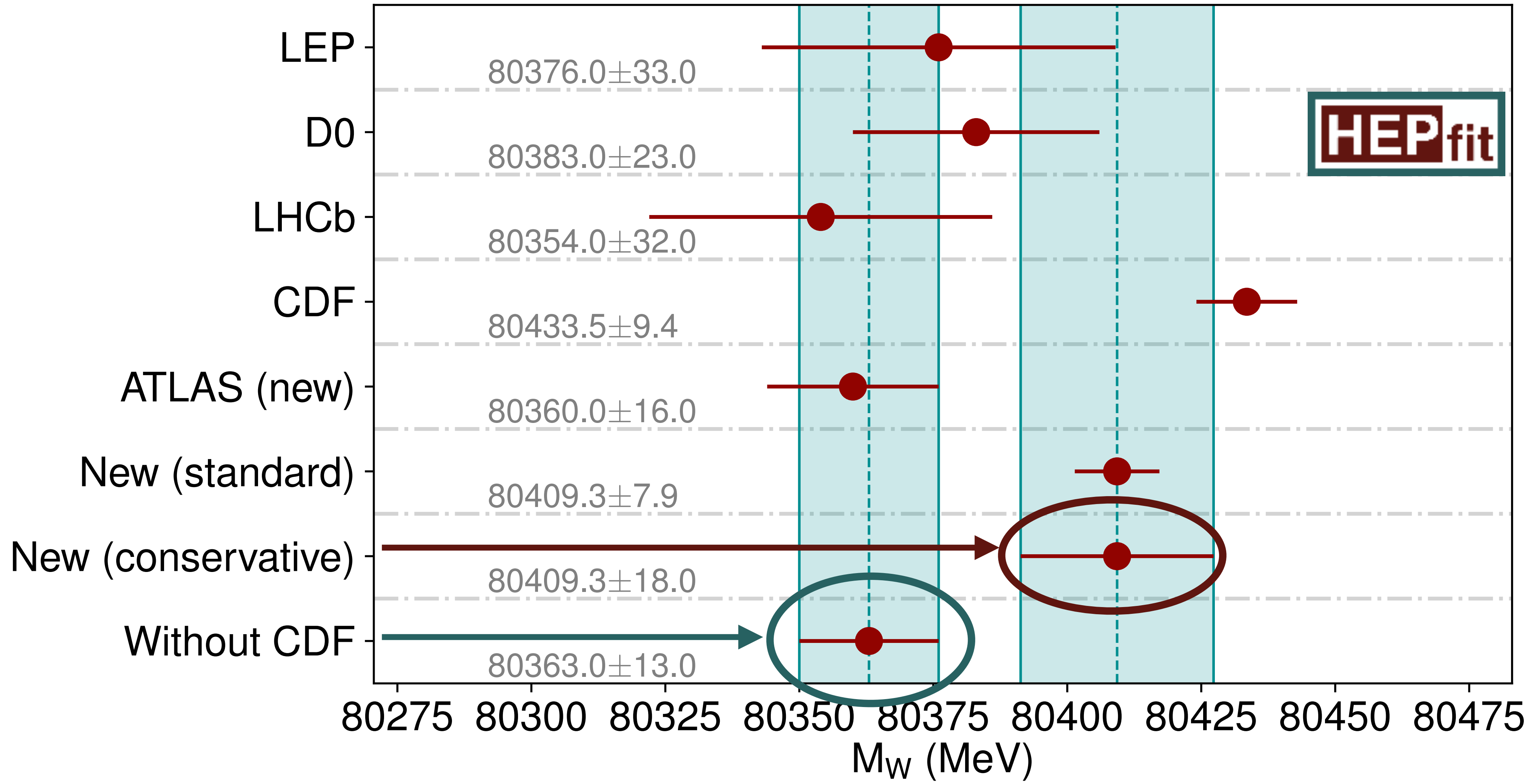
- compare with data in order to determine posteriors (Bayesian)

NP analysis

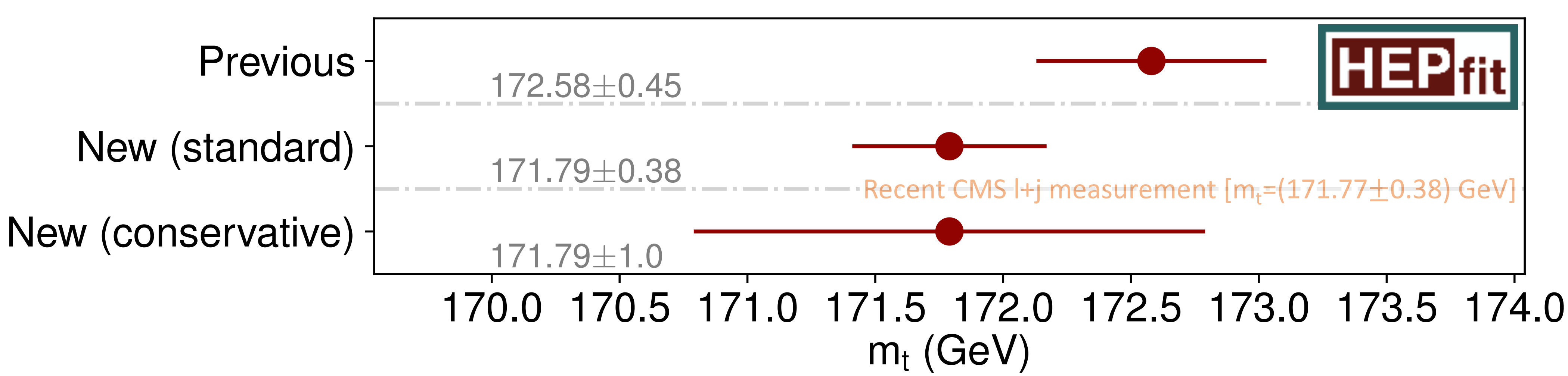
SM inputs + NP parameters

- predict EWPO generalized to NP
- constraints on / discovery of NP





new average	*new average*	*new average*
$M_W = (80.4093 \pm 0.0079)\text{GeV}$	$M_W = (80.4093 \pm 0.0180)\text{GeV}$	$M_W = (80.3630 \pm 0.0130)\text{GeV}$
“standard”	*“conservative”*	*w/o CDF*



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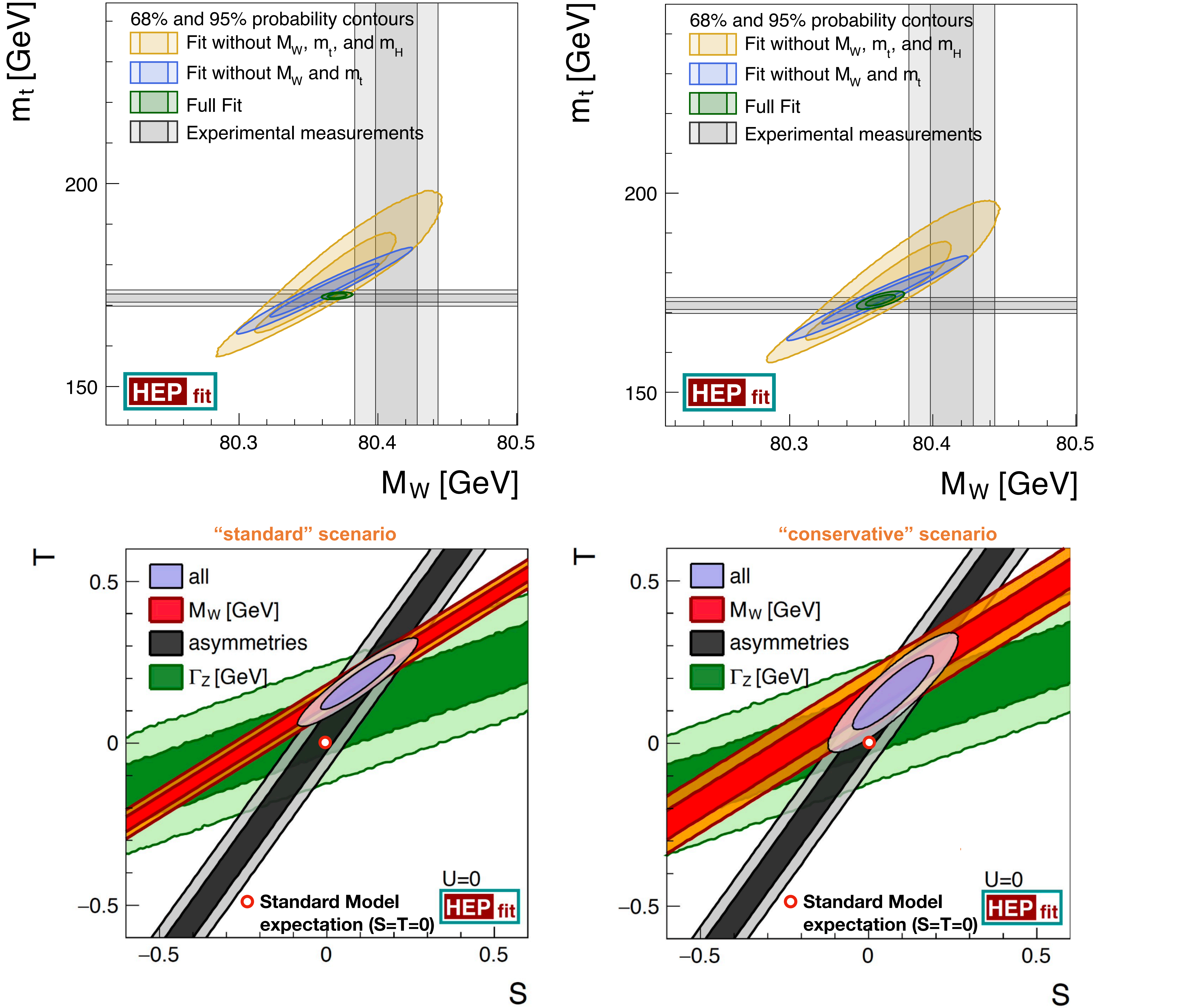


Chiral Exotic Leptons

«Chiral» fermion
↓
Get mass from the SM Higgs
↓
Highly constrained by Higgs observables

<u>Advantage:</u>
Induce harmless Wess-Zumino terms otherwise potentially dangerous in $U(1)_X$-extension of the SM

Dror, Lasenby, Pospelov [arxiv:1705.06726]

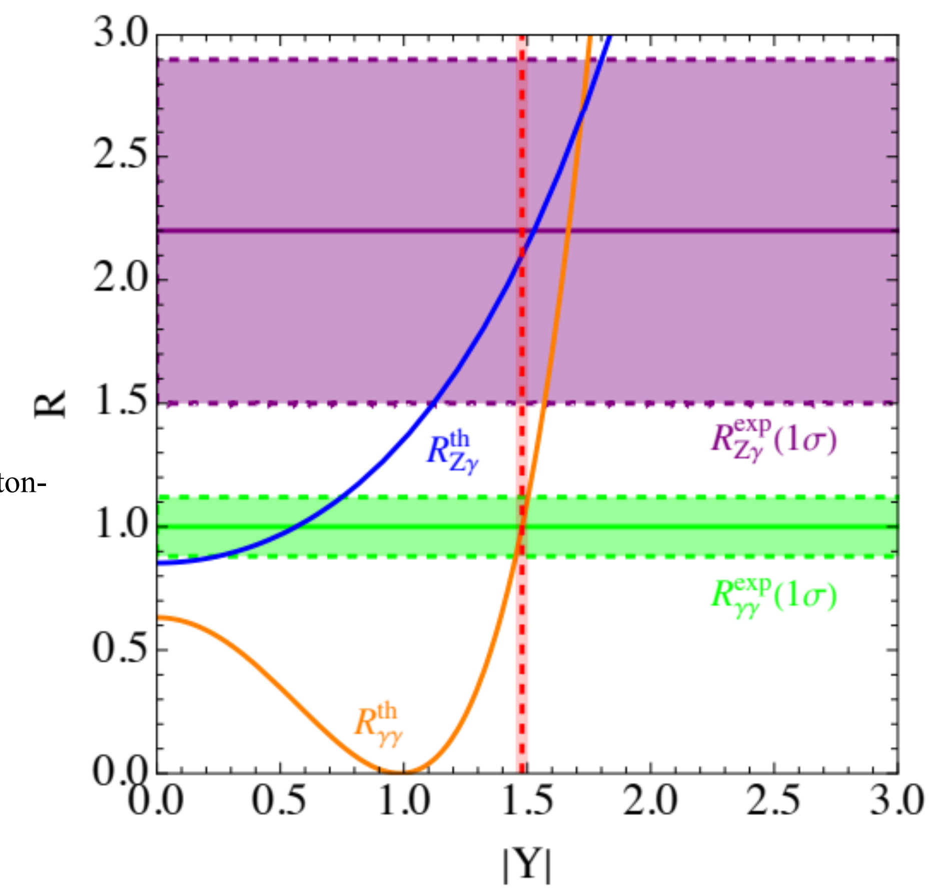
We considered an explicit viable content of chiral exotic leptons

$$\mathcal{L}_{L,R} = \begin{pmatrix} \mathcal{N}_{\mathcal{L}} \\ \mathcal{E}_{\mathcal{L}} \end{pmatrix}_{L,R} \sim (\mathbf{1},\mathbf{2})_Y\,, \quad \mathcal{E}_{L,R} \sim (\mathbf{1},\mathbf{1})_{Y-\frac{1}{2}}\,, \quad \mathcal{N}_{L,R} \sim (\mathbf{1},\mathbf{1})_{Y+\frac{1}{2}}$$

$$R_{\gamma\gamma,Z\gamma} = \frac{|A^{\rm SM}_{\gamma\gamma,Z\gamma} + A^{\rm BSM}_{\gamma\gamma,Z\gamma}|^2}{|A^{\rm SM}_{\gamma\gamma,Z\gamma}|^2}$$

ATLAS+CMS first evidence of photon-Z Higgs decay channel:

$$R_{Z\gamma} = 2.2 \pm 0.7$$



Di Luzio, Nardecchia, Toni *Phys.Rev.D* 105 (2022) 11

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Barducci, Di Luzio, Nardecchia, Toni
JHEP 12 (2023) 154

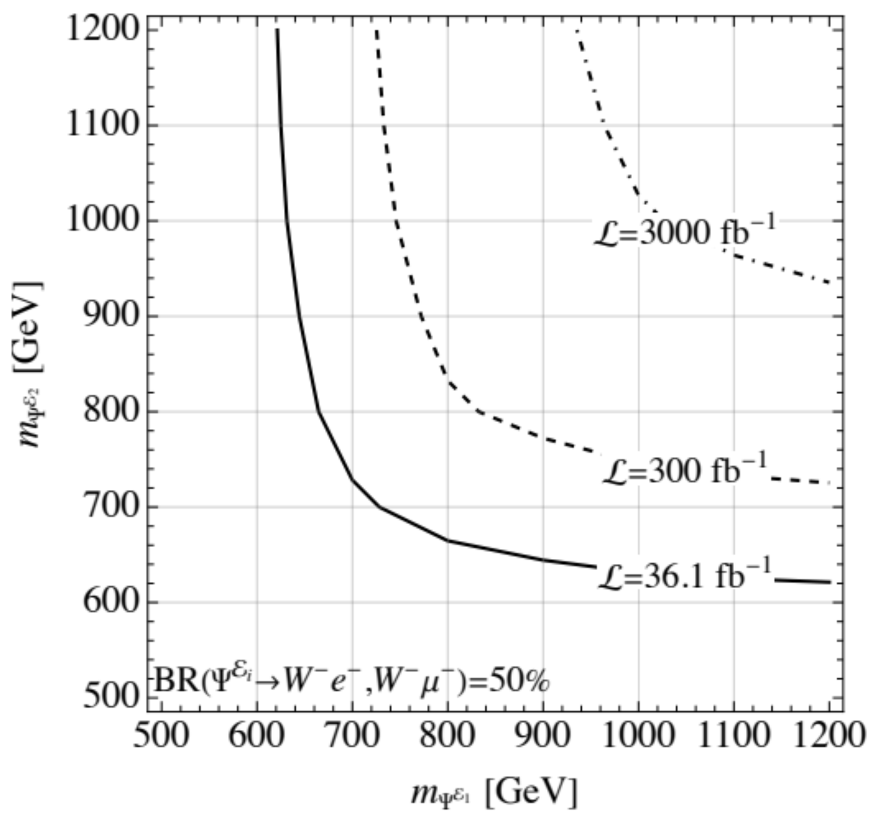
The model is perturbatively excluded by recast of direct searches constraints!

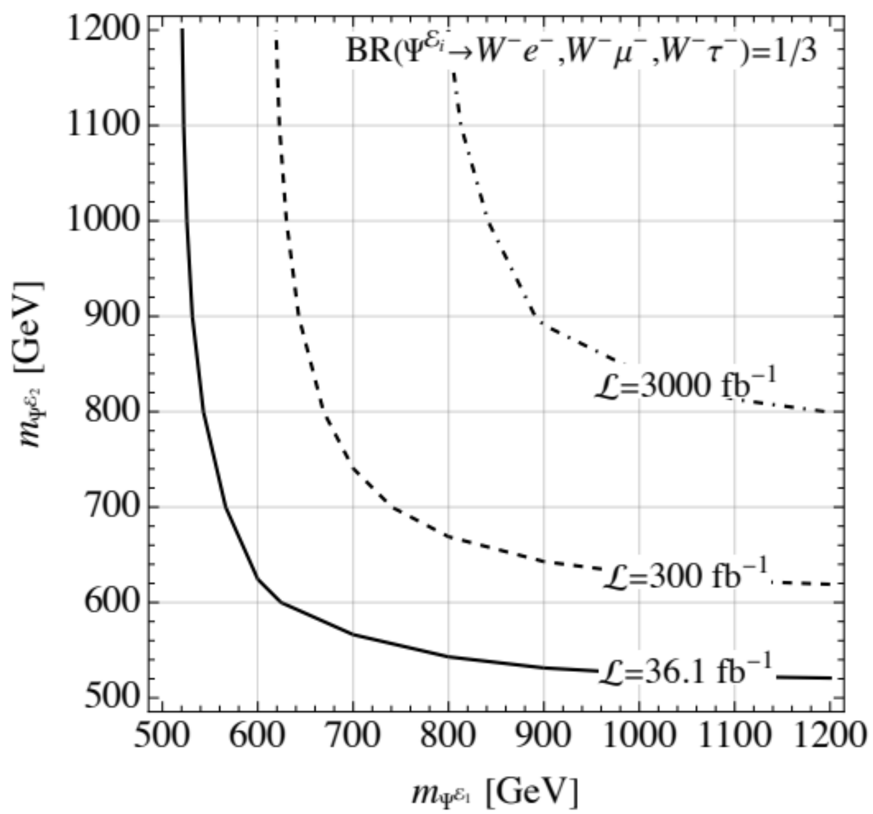
Same sign leptons exp. signature

$$\Psi^{\mathcal{E}_i} \to W^- \ell^- \to \ell^- \ell^- \not{E}_T$$

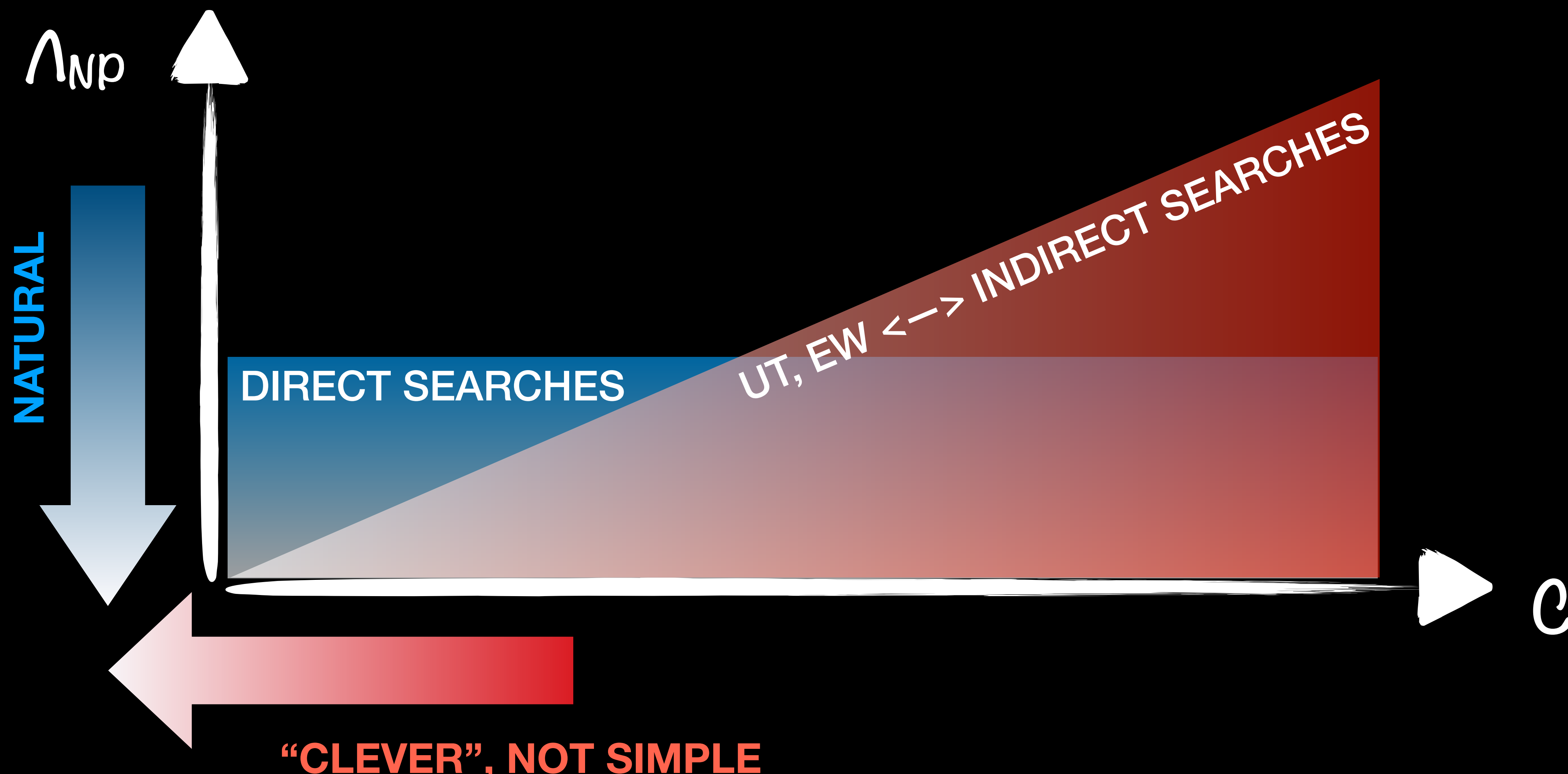
Perturbative bound on Yukawa couplings:

$$m_{\Psi^{\mathcal{E}_{1,2}}} \lesssim 400 \text{ GeV}$$





Take Home



… CAN WE SLEEP WELL AT NIGHT ?