m_W in the SMEFT

[E. Bagnaschi, J. Ellis, M. Madigan, KM, V. Sanz, T. You; JHEP 08 (2022) 308]
J. Ellis, KM, F. Zampedri; 2304.06663]

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MWDays23 workshop, CERN

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Outline

Predicting m_W & interpreting measurements in the SMEFT

Global fits with EWPO, Higgs & Diboson data

Mapping to single field extensions of the SM

Interplay with CKM unitarity

Beyond dimension-6: scalar triplet model

SMEFT is…

$$\mathcal{L}_{\rm eff} = \sum_i \frac{c_i \mathcal{O}_i^D}{\Lambda^{D-4}}$$

Model independent

- Underlying assumptions

Heavy new physics: $M > E_{exp}$
SM field content & gauge symmetries
Linear EWSB: Higgs = doublet

Systematically improvable

- Double expansion *higher dim.* $\frac{E^2}{\Lambda^2}$ & $\{g_S,\, g,\, g'\}$ *more loops*

Global

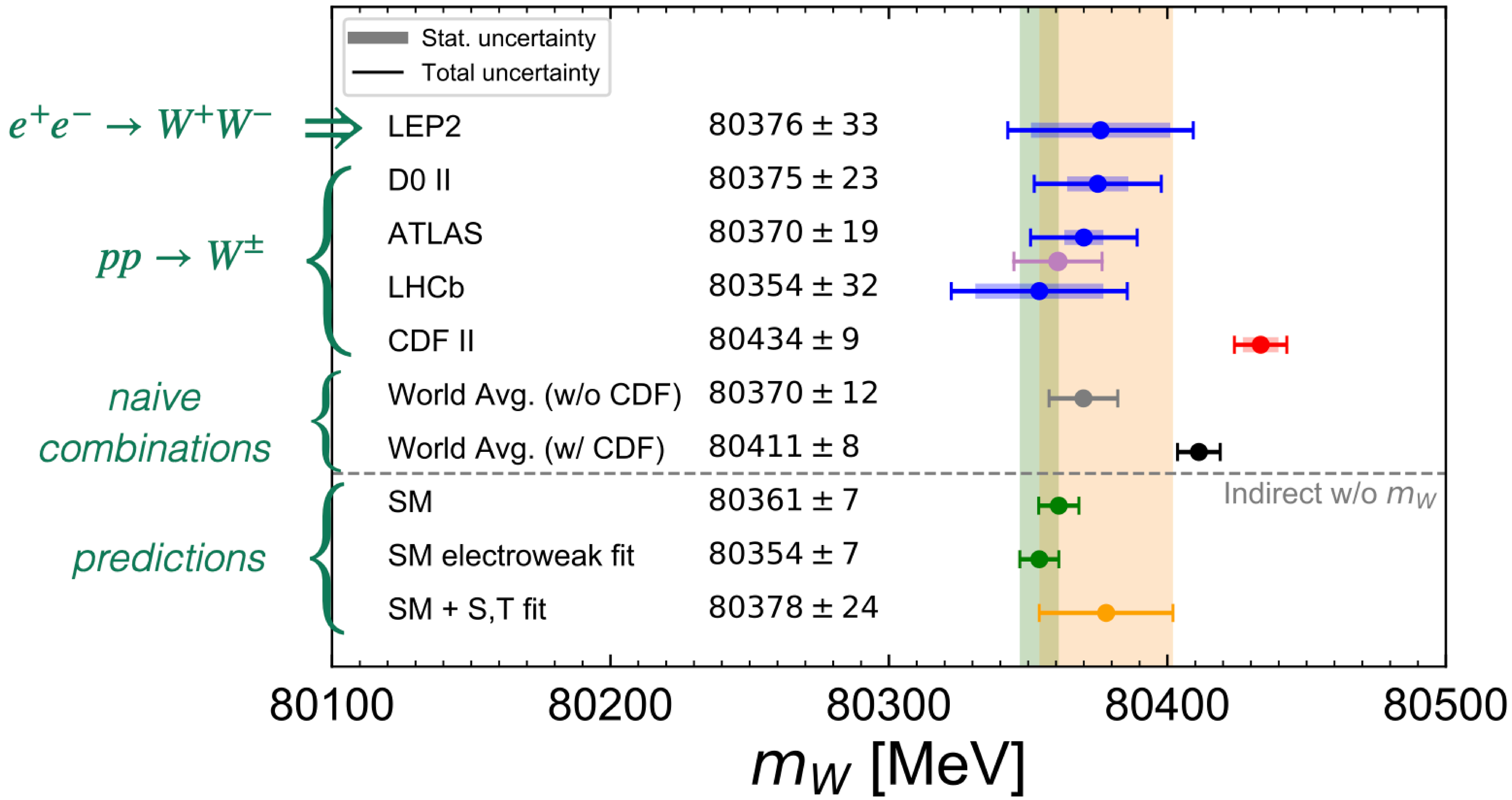
- Model independence: we don't know what operators NP will generate
- Patterns & correlations among observables are key
- Ultimate goal: complete SMEFT likelihood confronted with HEP data

EWPO, Higgs, multiboson, top, DY, flavor,…

$\mathscr{L}(c_i) \Rightarrow$ **indirectly constrain many UV models**

m_W measurements

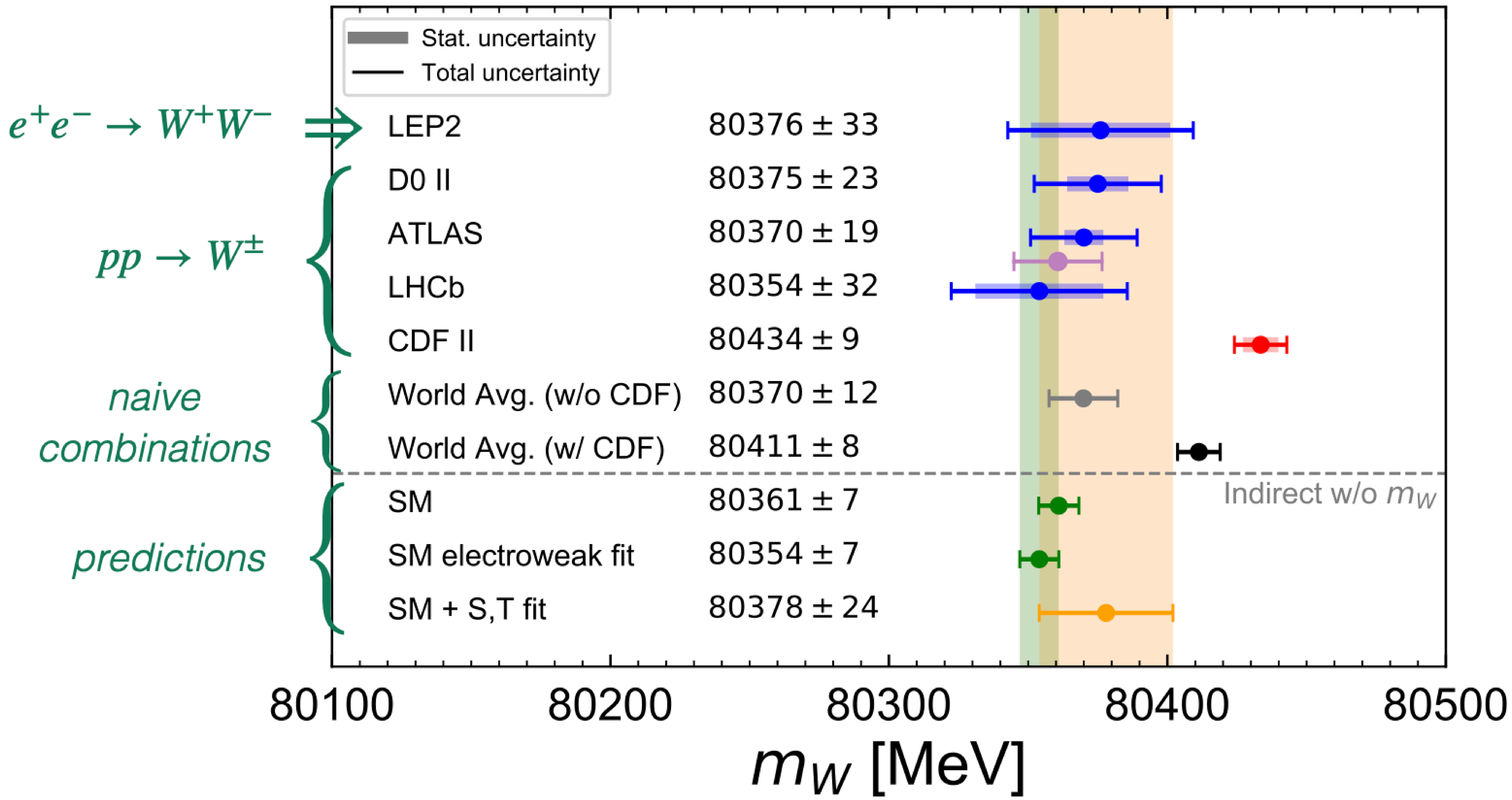
[Bagnaschi, Ellis, Madigan, KM, Sanz & You; JHEP 08 (2022) 308]



ATLAS update, Run 1 re-analysis: $m_W = 80360 \pm 16$ MeV

m_W measurements

[Bagnaschi, Ellis, Madigan, KM, Sanz & You; JHEP 08 (2022) 308]



SM + fit to S & T parameters: $m_W = 80378 \pm 24$ MeV

m_W prediction in SMEFT

$$\frac{\delta m_W^2}{m_W^2} = -\frac{\sin 2\hat{\theta}_w}{\cos 2\hat{\theta}_w}\frac{\hat{v}^2}{4\Lambda^2}\left(\frac{\cos\hat{\theta}_w}{\sin\hat{\theta}_w}C_{HD} + \frac{\sin\hat{\theta}_w}{\cos\hat{\theta}_w}\left(4C_{Hl}^{(3)} - 2C_{ll}\right) + 4C_{HWB}\right)$$

Dimension-6: 4 operators modify $m_W(G_F, \alpha_{EW}, m_Z)$

- Shift input parameter relations w.r.t SM $\Rightarrow m_W(G_F, \alpha_{EW}, m_Z, C_i)$

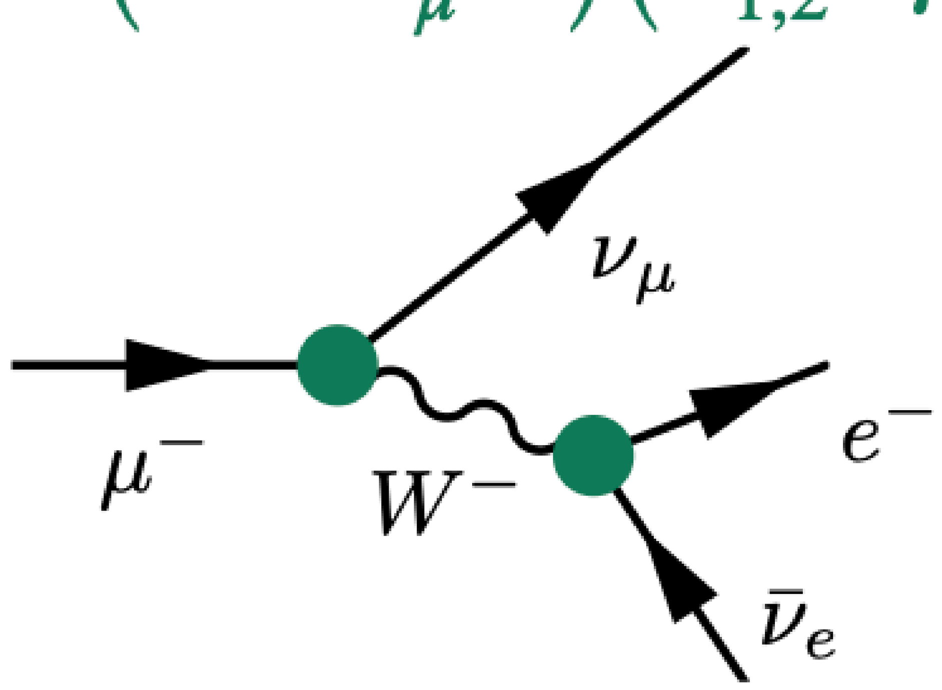
Δm_Z^2

$\mathcal{O}_{HWB} \equiv H^\dagger \tau^I H\, W^I_{\mu\nu} B^{\mu\nu} \propto S$

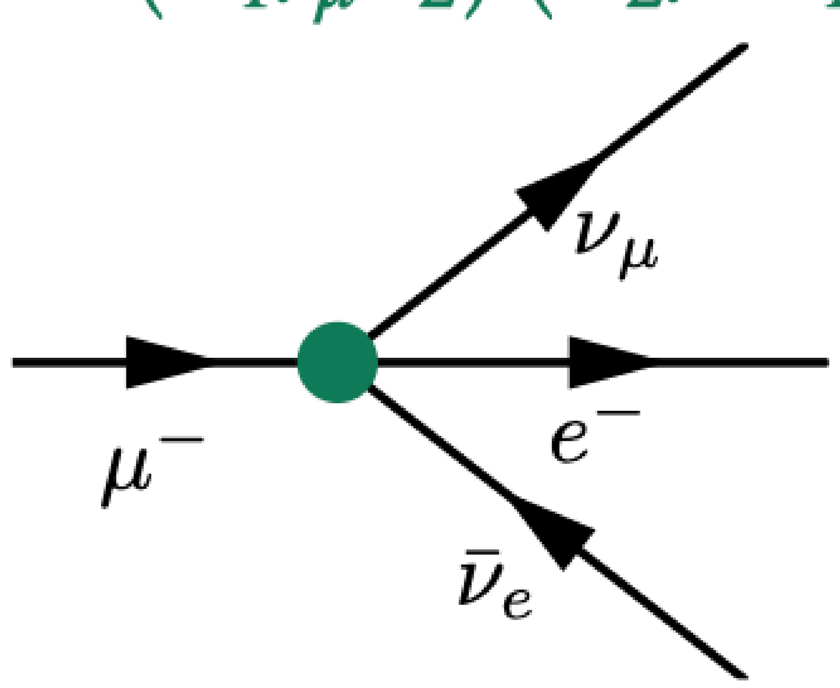
$\mathcal{O}_{HD} \equiv \left(H^\dagger D^\mu H\right)^\star \left(H^\dagger D_\mu H\right) \propto T$

ΔG_F

$\mathcal{O}_{H\ell}^{(3)} \equiv \left(H^\dagger i \overleftrightarrow{D}^I_\mu H\right)\left(\bar{\ell}_{1,2}\tau^I\gamma^\mu \ell_{1,2}\right)$



$\mathcal{O}_{\ell\ell} \equiv \left(\bar{\ell}_1\gamma_\mu \ell_2\right)\left(\bar{\ell}_2\gamma^\mu \ell_1\right)$



m_W interpretation in SMEFT

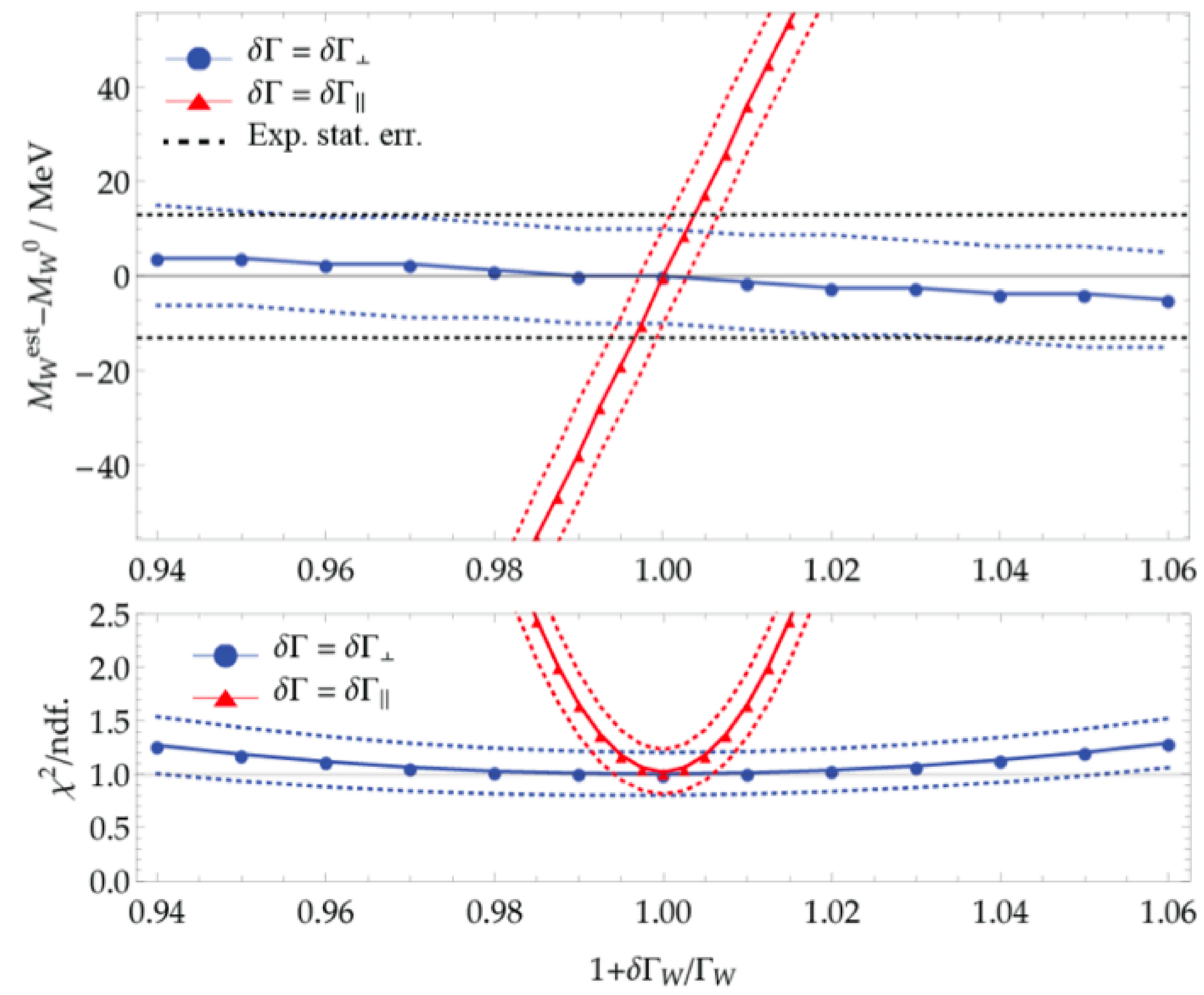
New physics can yield correlated effects in many places

- SMEFT motivates global approach $\Rightarrow$ δm_W^2 does not occur in isolation
- *e.g.* modified widths/branching fractions, production & decay kinematics,…
- Biases in interpreting data that hasn't accounted for such effects?

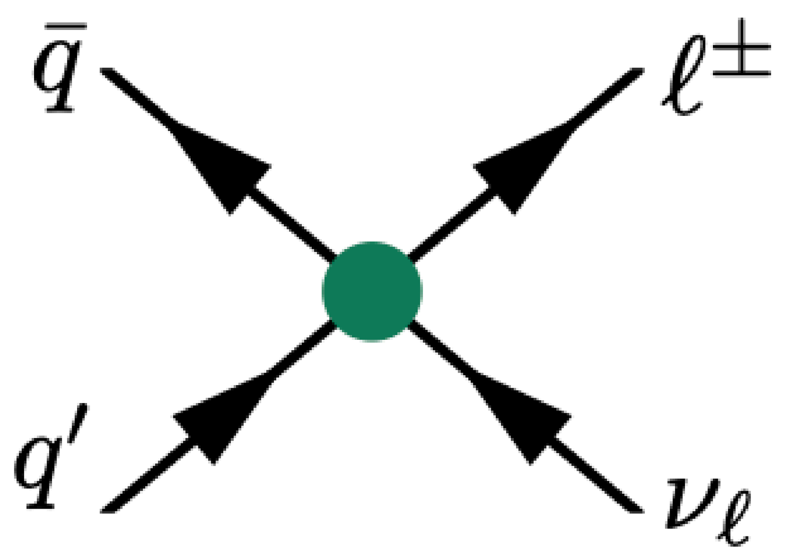
W boson width shift: $$\frac{\delta\Gamma_W}{\Gamma_W} = \frac{\hat{v}^2}{\Lambda^2}\left(\frac{8}{3}C_{Hl}^{(3)} + \frac{4}{3}C_{Hq}^{(3)} - C_{ll}\right) - \frac{3}{2}\frac{\delta m_W^2}{m_W^2}$$

[Bjorn & Trott; PLB 762 (2016) 426-431]

- Affects overall normalisation & shape of template m_T & p_T^l distributions
- Estimated bias dominated by normalisation, which is left to float in experimental analyses
- No significant bias expected form Γ_W



m_W interpretation in SMEFT



Other contact interactions?

- Interference effects with charged-current 4F operators
- May be overwhelmed by narrow W peak…
- Constrained by charged current Drell Yan. Not studied so far…

LEP II extraction: $\sigma\left(e^+e^- \to W^+W^-\right)$

As discussed in [Bjorn & Trott; PLB 762 (2016) 426-431]

- Various methods to extract m_W, assuming the SM for $\sigma(W^+W^-)$
- Other possible SMEFT effects not accounted for
- Triple gauge coupling modifications ($\mathcal{O}_W$), W- coupling shifts, dipoles?

Safest to do a simultaneous fit to m_W & C_i

Input scheme

m_W is a prediction when using, *e.g.*, $\{\alpha_{EW}, G_F, m_Z\}$ as inputs

- We use: $\alpha_{EW}^{-1} = 127.95\,, \quad G_F = 1.16638 \times 10^{-5}\ \mathrm{GeV}^{-2}\,, \quad m_Z = 91.1876\ \mathrm{GeV}$

If m_W is part of the input set…

- Other data must be used to compensate
- *e.g.*, $\{m_W, G_F, M_Z\}$ input scheme: use $a_{EW}(m_Z)$ instead

$$\left.\frac{\delta\alpha_{EW}}{\alpha_{EW}}\right|_{\{m_W,G_F,m_Z\}} \propto \left.\frac{\delta m_W^2}{m_W^2}\right|_{\{\alpha_{EW},G_F,m_Z\}}$$

α_{EW} prediction deviates from SM if CDF m_W is input

- α_{EW} uncertainty dominated by parametric m_W error
- Similar constraints expected in this case

Global context

Global new physics searches via high precision/energy

- Z & W-pole data: handle on the EW gauge sector

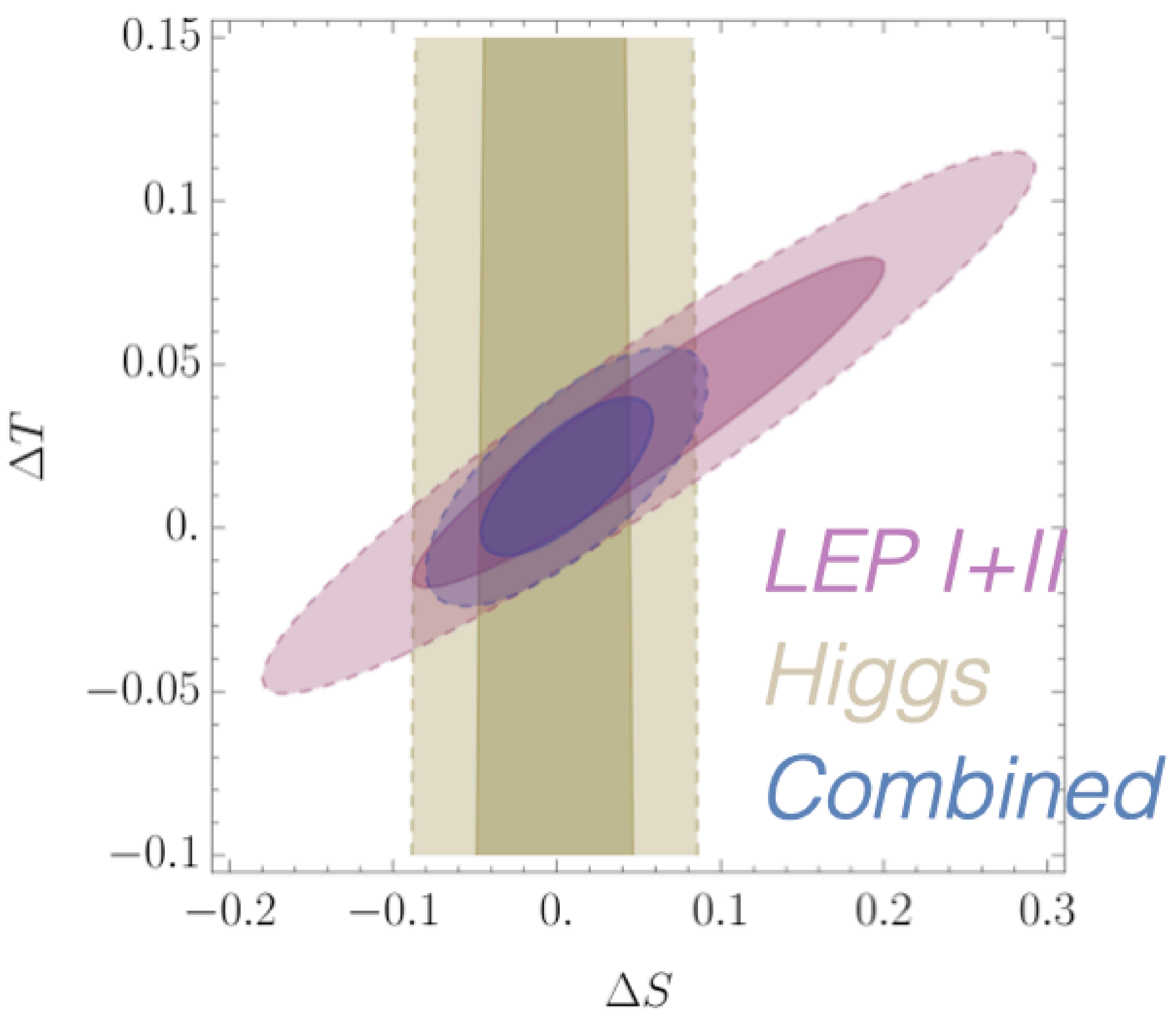
[Han & Skiba; PRD 71 (2005) 075009]
[Falkowski & Riva; JHEP 02 (2015) 039]

- LHC: thriving Higgs & top programmes
- Probing gauge interactions at high energy (VV, VBS, VVV, …)

Cross-talk between EWPO, Diboson & Higgs data

- Significant correlations among operators ⇒ data
- Allows for a closed fit to flavor-universal SMEFT

[Corbett et al.; PRD 87 (2013) 015022]
[Pomarol & Riva; JHEP 01 (2014) 151]
[Ellis, Sanz & You; JHEP 03 (2015) 157]
[Biekötter, Corbett & Plehn; SciPost Phys 6 (2019) 6, 064]
[Ellise, Madigan, KM, Sanz, You; JHEP 04 (2021) 279]…



[Ellis et al.; JHEP 06 (2018) 146]

Can the SMEFT accomodate the m_W measurements alongside other data?

The fit

`fitmaker` *https://gitlab.com/kenmimasu/fitrepo*

public-friendly version w/ example notebooks in progress

Top, Higgs, Diboson and Electroweak Fit to the Standard Model Effective Field Theory

John Ellis,[a,b,c] Maeve Madigan,[d] Ken Mimasu,[a] Veronica Sanz[e,f] and Tevong You[b,d,g]

[JHEP 04 (2021) 279]

Global SMEFT interpretation of 4 categories of data

Based on [Ellis et al.; JHEP 06 (2018) 146]

- 14 • Electroweak Precision Observables (EWPO): Z-pole & W-mass
- 118 • LEP2 & LHC diboson production: differential WW, WZ, Zjj
- 72 • Higgs measurements: signal strengths & STXS
- ~~137 • Top data: single-top, ttbar & asymmetries, ttV, tZ, tW~~

204 measurements across categories

- Chosen to be statistically independent & maximise reach
- Correlations included when publicly available (mostly are)

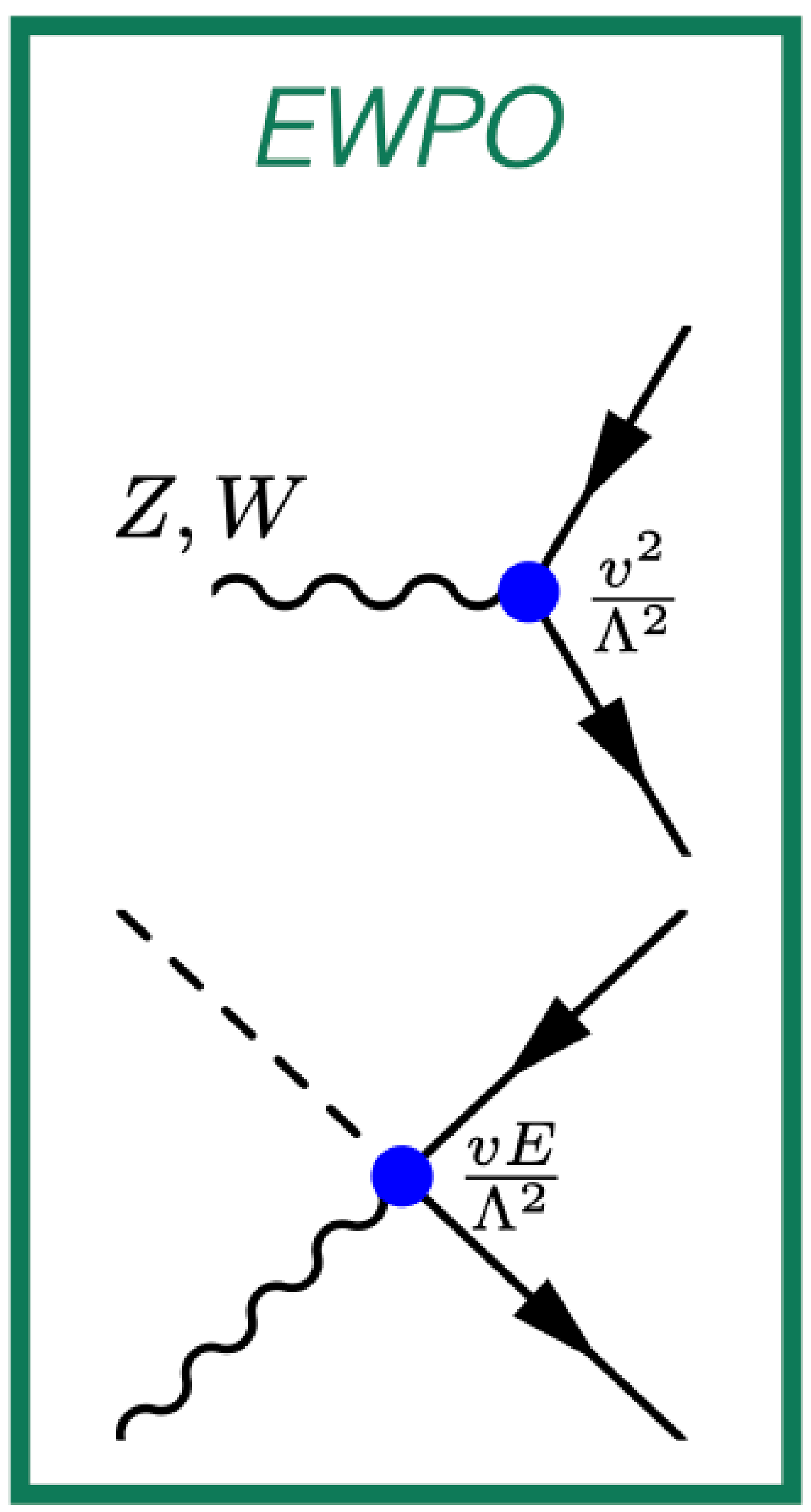
Linear EFT approximation: $\mu_X \equiv \frac{X}{X_{SM}} = 1 + \sum_i a_i^X \frac{C_i}{\Lambda^2} + \mathcal{O}\left(\frac{1}{\Lambda^4}\right)$

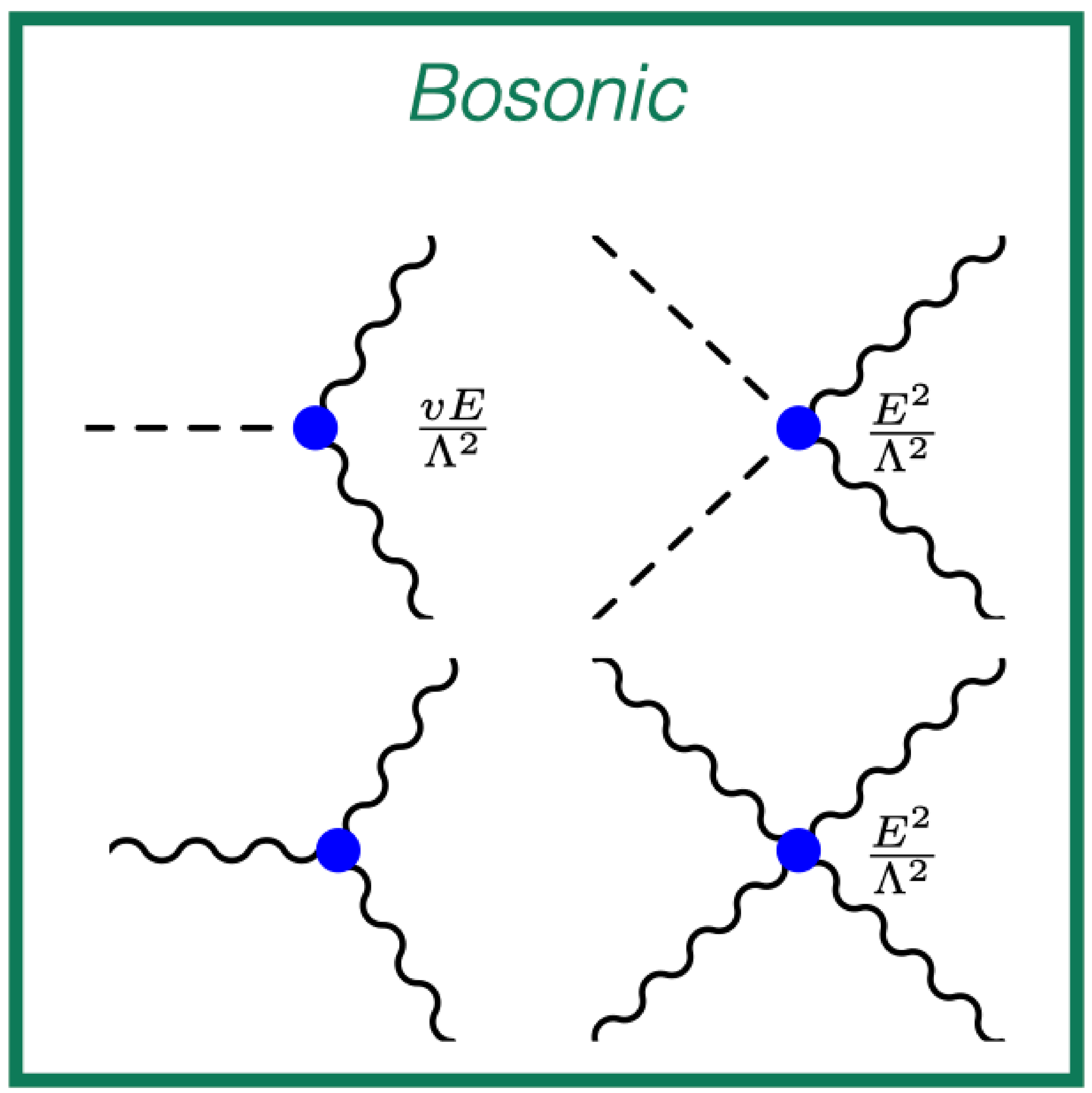
Degrees of freedom

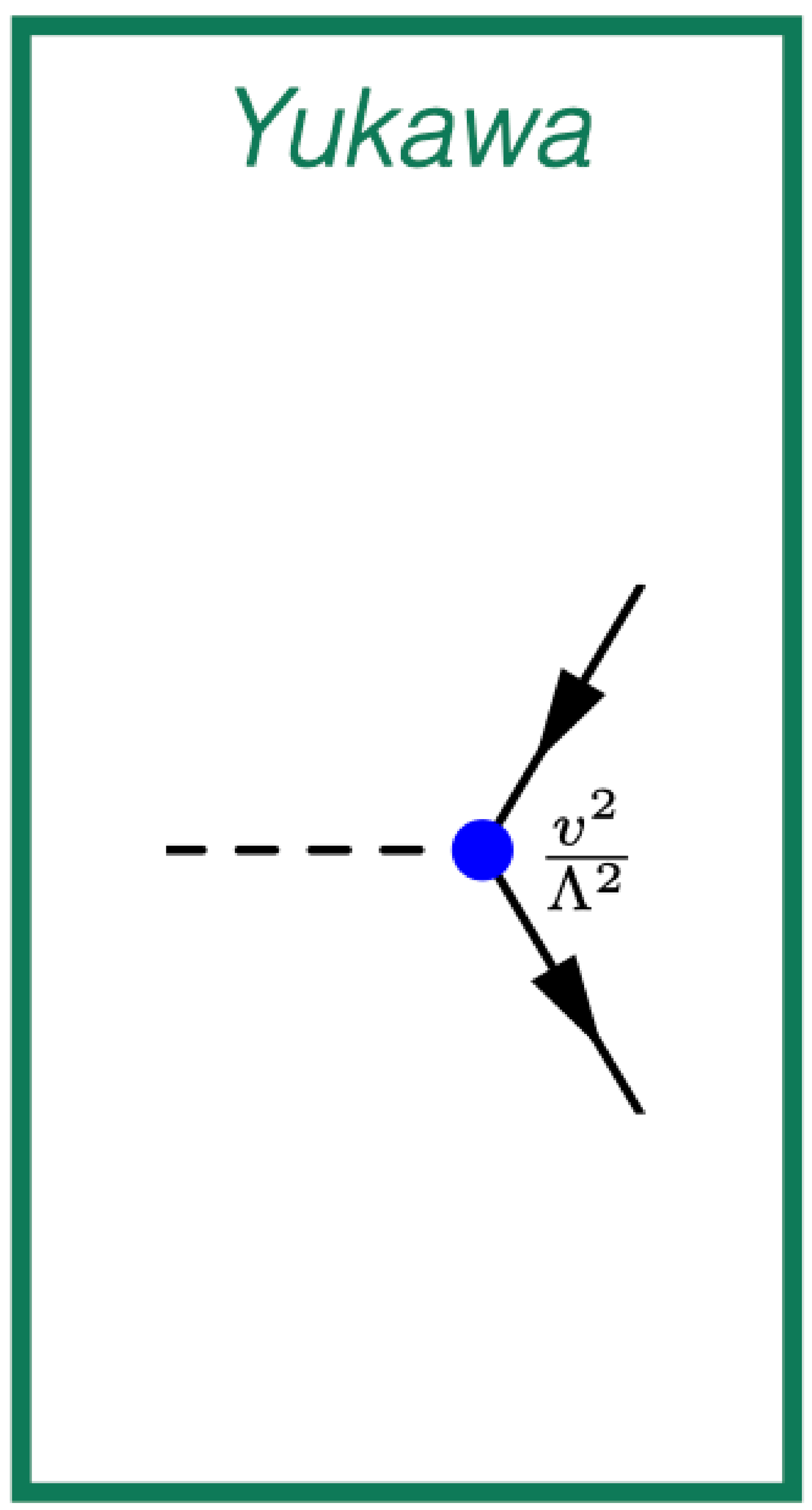
EWPO:	$\mathcal{O}_{HWB}\,, \mathcal{O}_{HD}\,, \mathcal{O}_{ll}\,, \mathcal{O}_{Hl}^{(3)}\,, \mathcal{O}_{Hl}^{(1)}\,, \mathcal{O}_{He}\,, \mathcal{O}_{Hq}^{(3)}\,, \mathcal{O}_{Hq}^{(1)}\,, \mathcal{O}_{Hd}\,, \mathcal{O}_{Hu}\,,$
Bosonic:	$\mathcal{O}_{H\Box}\,, \mathcal{O}_{HG}\,, \mathcal{O}_{HW}\,, \mathcal{O}_{HB}\,, \mathcal{O}_{W}\,, \mathcal{O}_{G}\,,$
Yukawa:	$\mathcal{O}_{\tau H}\,, \mathcal{O}_{\mu H}\,, \mathcal{O}_{bH}\,, \mathcal{O}_{tH}\,,$

20

Universal $U(3)^5$ flavor scenario + Yukawa







S & T parameter fit

$$\frac{v^2}{\Lambda^2} C_{HWB} = \frac{g g'}{16\pi} S$$

$$\frac{v^2}{\Lambda^2} C_{HD} = -\frac{g^2 g'^2}{2\pi(g^2 + g'^2)} T$$

No m_W data

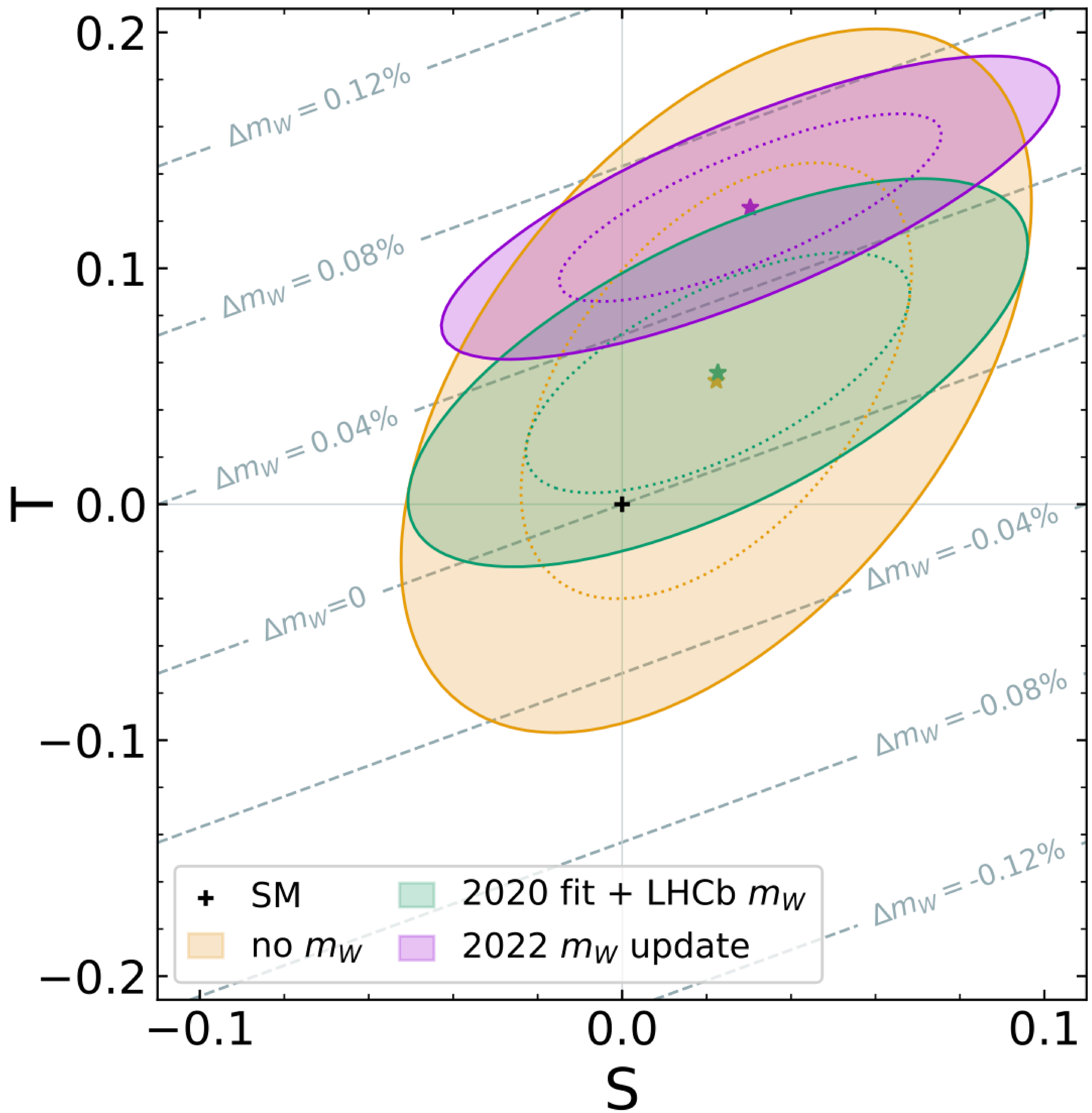
SM compatible $< 1\sigma$

Without CDF m_W

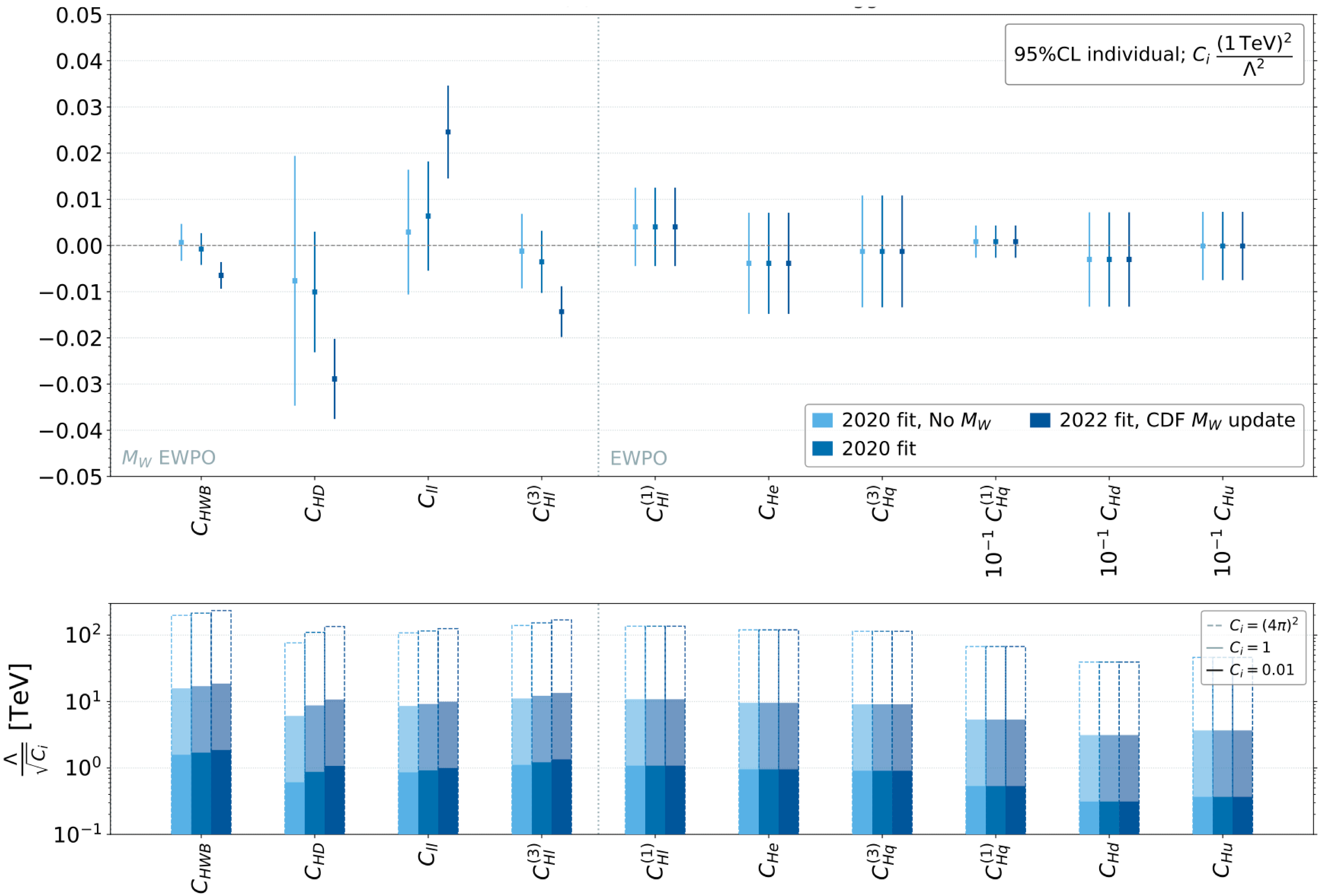
SM compatible $< 2\sigma$

With CDF m_W

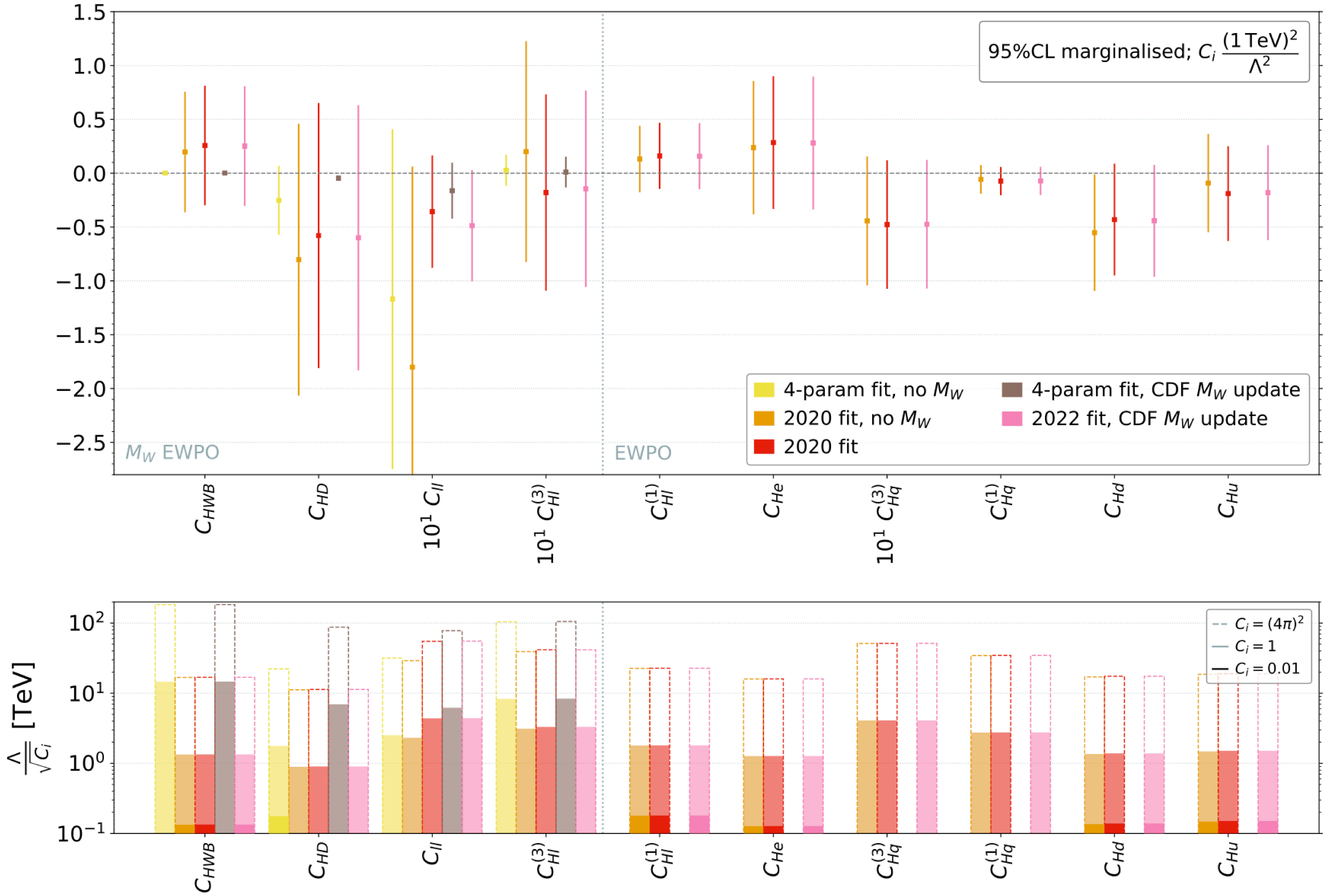
SM incompatible $\gg 3\sigma$



SMEFT fit (individual)

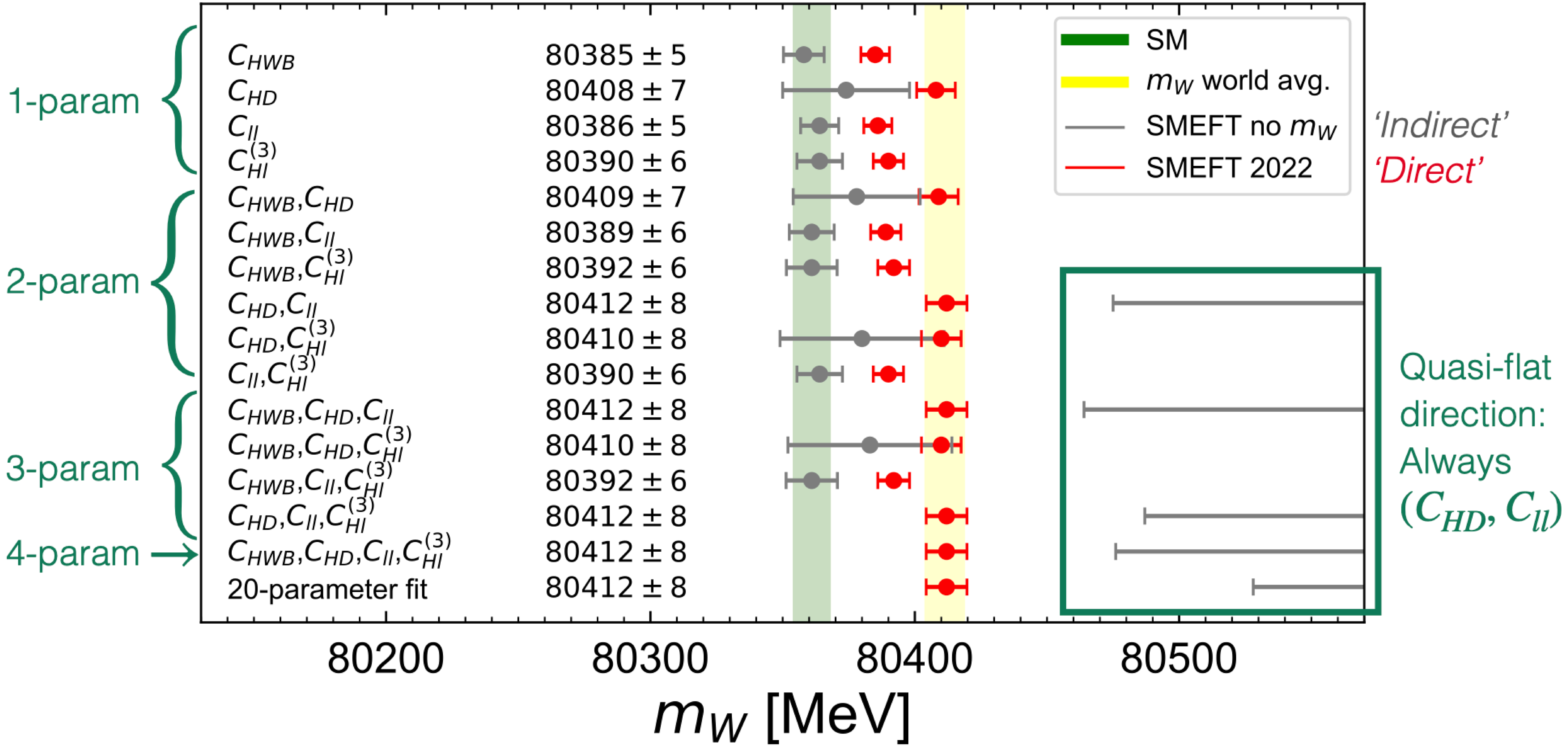


SMEFT fit (marginalised)

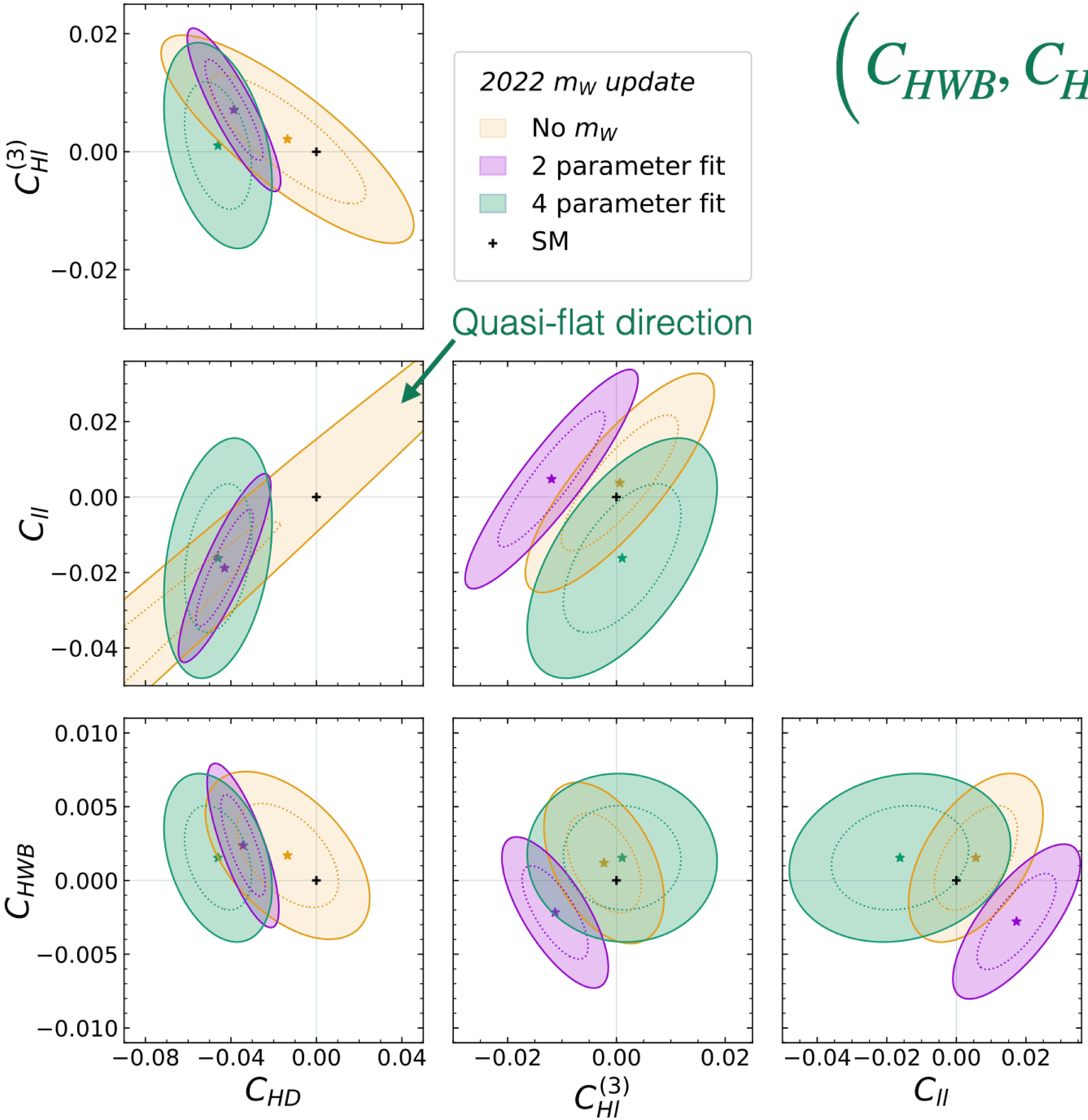


Direct vs indirect m_W

Focus on 4-parameter subspace: all possible combinations



$$\left(C_{HWB}, C_{HD}, C_{Hl}^{(3)}, C_{ll}\right)$$

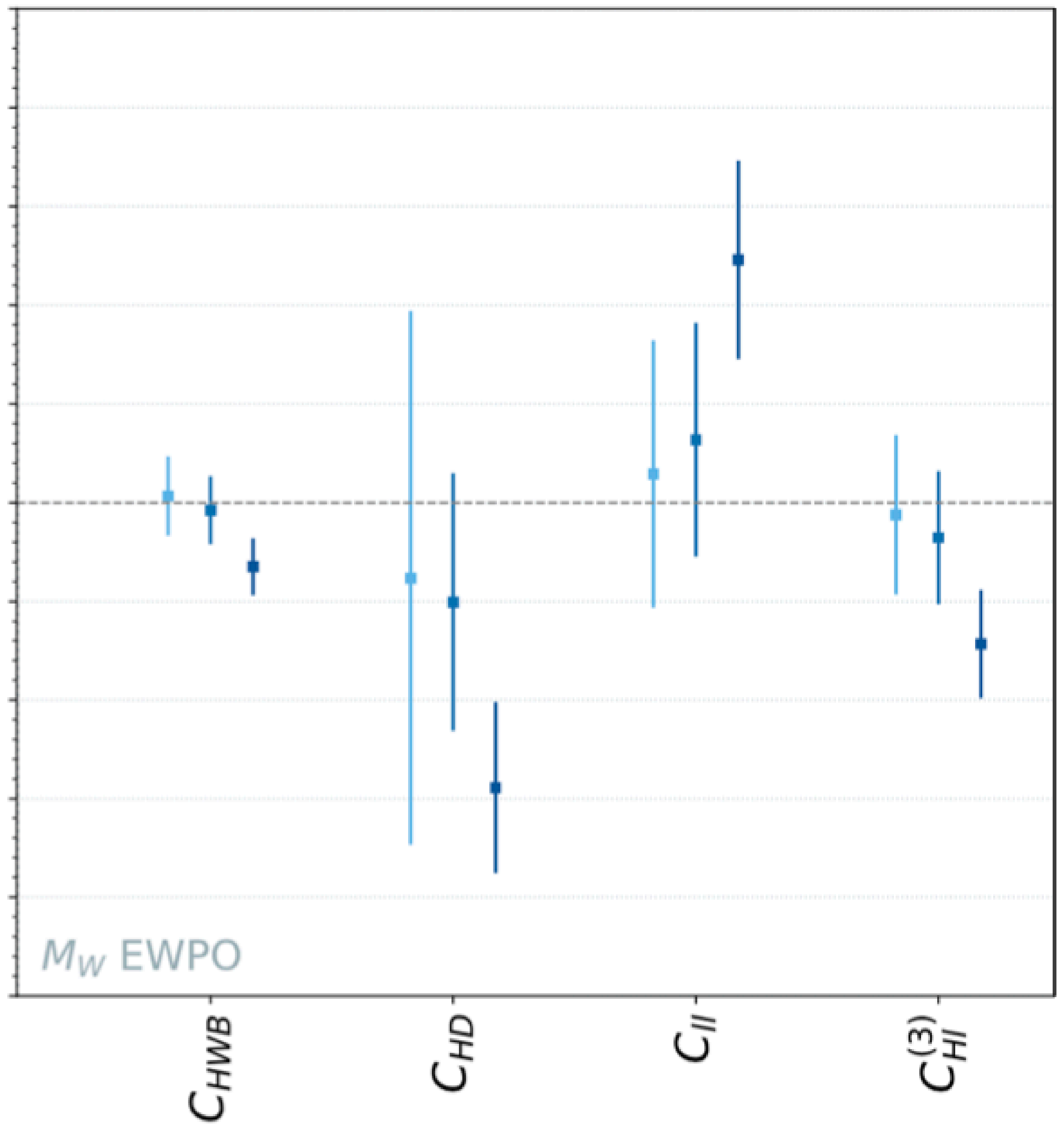


Single-field SM extensions

What SM extensions can account for the anomaly at tree-level?

Fit preference:

- Negative C_{HWB}, C_{HD}, $C^{(3)}_{Hl}$ & positive C_{ll}



Considered single field extensions

[de Blas et al.; JHEP 03 (2018) 109]

- Complete tree-level matching dictionary is known
- Interpret in terms of simplified 1 parameter versions of the models

Model	Spin	SU(3)	SU(2)	U(1)	Parameters
S_1	0	1	1	1	$(M_S,\ \kappa_S)$
Σ	$\frac{1}{2}$	1	3	0	$(M_\Sigma, \lambda_\Sigma)$
Σ_1	$\frac{1}{2}$	1	3	-1	$(M_{\Sigma_1}, \lambda_{\Sigma_1})$
N	$\frac{1}{2}$	1	1	0	(M_N, λ_N)
E	$\frac{1}{2}$	1	1	-1	(M_E, λ_E)

Model	Spin	SU(3)	SU(2)	U(1)	Parameters
B	1	1	1	0	$(M_B, \hat{g}^B_H)$
B_1	1	1	1	1	(M_{B_1}, λ_{B_1})
Ξ	0	1	3	0	(M_Ξ, κ_Ξ)
W_1	1	1	3	1	$(M_{W_1}, \hat{g}^\varphi_{W_1})$
W	1	1	3	0	$(M_W, \hat{g}^H_W)$

Dimension-6 matching

δm_W (C_{HD}, C_{ll}, $C_{Hl}^{(3)}$)

VLL (Σ, Σ_1, N, E) · Z' (B_1, B) · Spin-0,1 Triplets (Ξ, W_1, W)

Model	C_{HD}	C_{ll}	$C_{Hl}^{(3)}$	$C_{Hl}^{(1)}$	C_{He}	$C_{H\Box}$	$C_{\tau H}$	C_{tH}	C_{bH}
S_1		-1							
Σ			$\frac{1}{16}$	$\frac{3}{16}$			$\frac{y_\tau}{4}$		
Σ_1			$\frac{1}{16}$	$-\frac{3}{16}$			$\frac{y_\tau}{8}$		
N			$-\frac{1}{4}$	$\frac{1}{4}$					
E			$-\frac{1}{4}$	$-\frac{1}{4}$			$\frac{y_\tau}{2}$		
B_1	1					$-\frac{1}{2}$	$-\frac{y_\tau}{2}$	$-\frac{y_t}{2}$	$-\frac{y_b}{2}$
B	-2						$-y_\tau$	$-y_t$	$-y_b$
Ξ	$-2\left(\frac{1}{M_\Xi}\right)^2$					$\frac{1}{2}\left(\frac{1}{M_\Xi}\right)^2$	$y_\tau\left(\frac{1}{M_\Xi}\right)^2$	$y_t\left(\frac{1}{M_\Xi}\right)^2$	$y_b\left(\frac{1}{M_\Xi}\right)^2$
W_1	$-\frac{1}{4}$					$-\frac{1}{8}$	$-\frac{y_\tau}{8}$	$-\frac{y_t}{8}$	$-\frac{y_b}{8}$
W	$\frac{1}{2}$					$-\frac{1}{2}$	$-y_\tau$	$-y_t$	$-y_b$

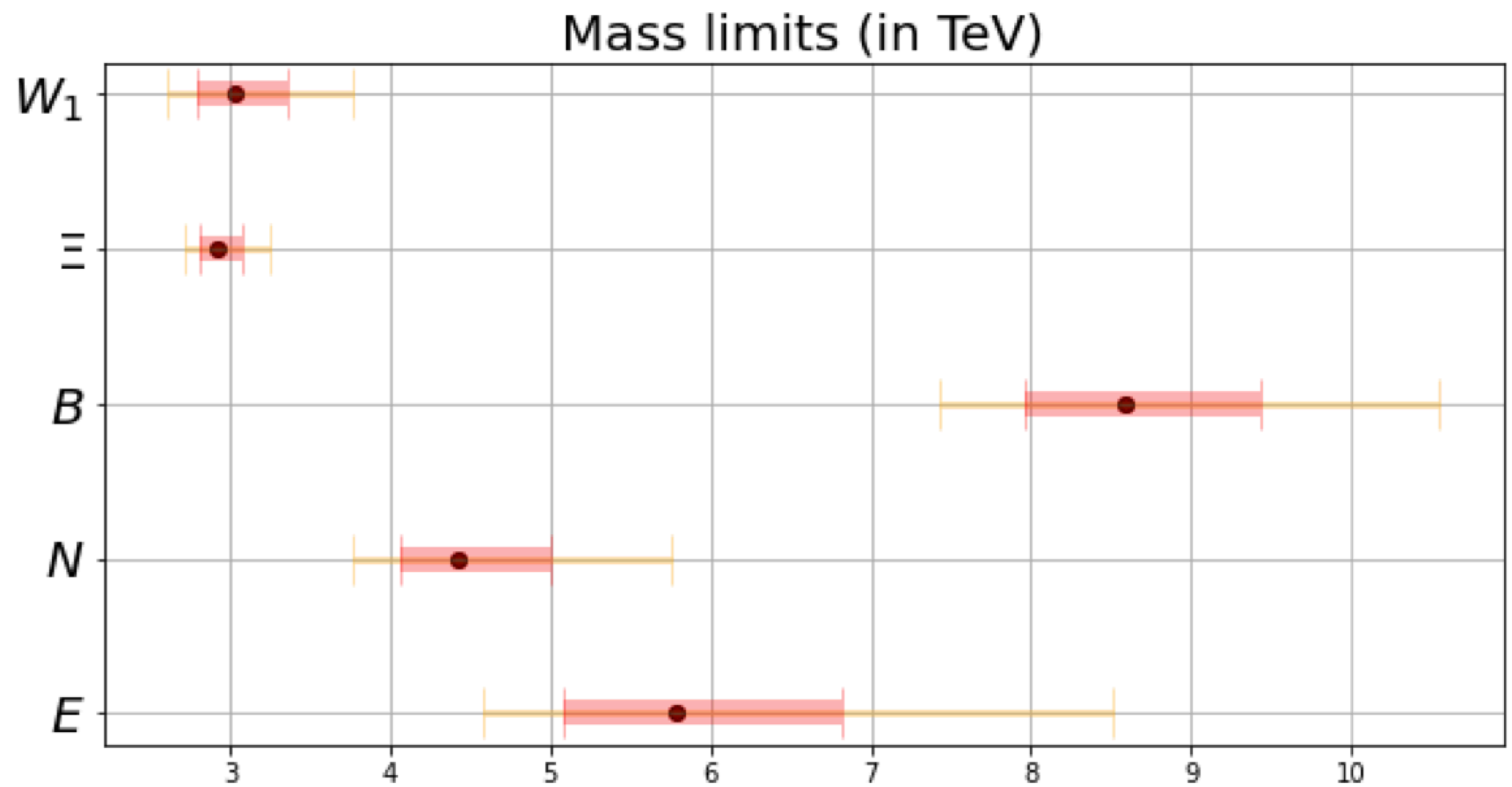
C_{HWB} is loop-generated by weakly coupled models

[Arzt, Einhorn & Wudka; Nucl.Phys.B 433 (1995) 41-66]

All models can generate one of the required coefficients

*Only 5 predict them with the right sign

Masses and couplings



BSM Higgs coupling $g = 1$

$g = 1$ $\Lambda = 1\,\text{TeV}$

Model	Pull	Best-fit mass (TeV)	1-σ mass range (TeV)	2-σ mass range (TeV)	1-σ coupling^2 range
W_1	6.4	3.0	[2.8, 3.6]	[2.6, 3.8]	[0.09, 0.13]
B	6.4	8.6	[8.0, 9.4]	[7.4, 10.6]	[0.011, 0.016]
Ξ	6.4	2.9	[2.8, 3.1]	[2.7, 3.2]	[0.011, 0.016]
N	5.1	4.4	[4.1, 5.0]	[3.8, 5.8]	[0.040, 0.060]
E	3.5	5.8	[5.1, 6.8]	[4.6, 8.5]	[0.022, 0.039]

[Blennow, Coloma, Fernandez-Martinez & Gonzalez-Lopez; 2204.04559]
[Cirigliano, Dekens, de Vries, Mereghetti & Tong; 2204.08440]

CKM unitarity

β-decay + CKM unitarity imposes significant constraint on one combination of coefficients in $U(3)^5$

extra $q\bar{q}\ell\bar{\ell}$ 4F operator

- Semi-leptonic analogue of muon decay:

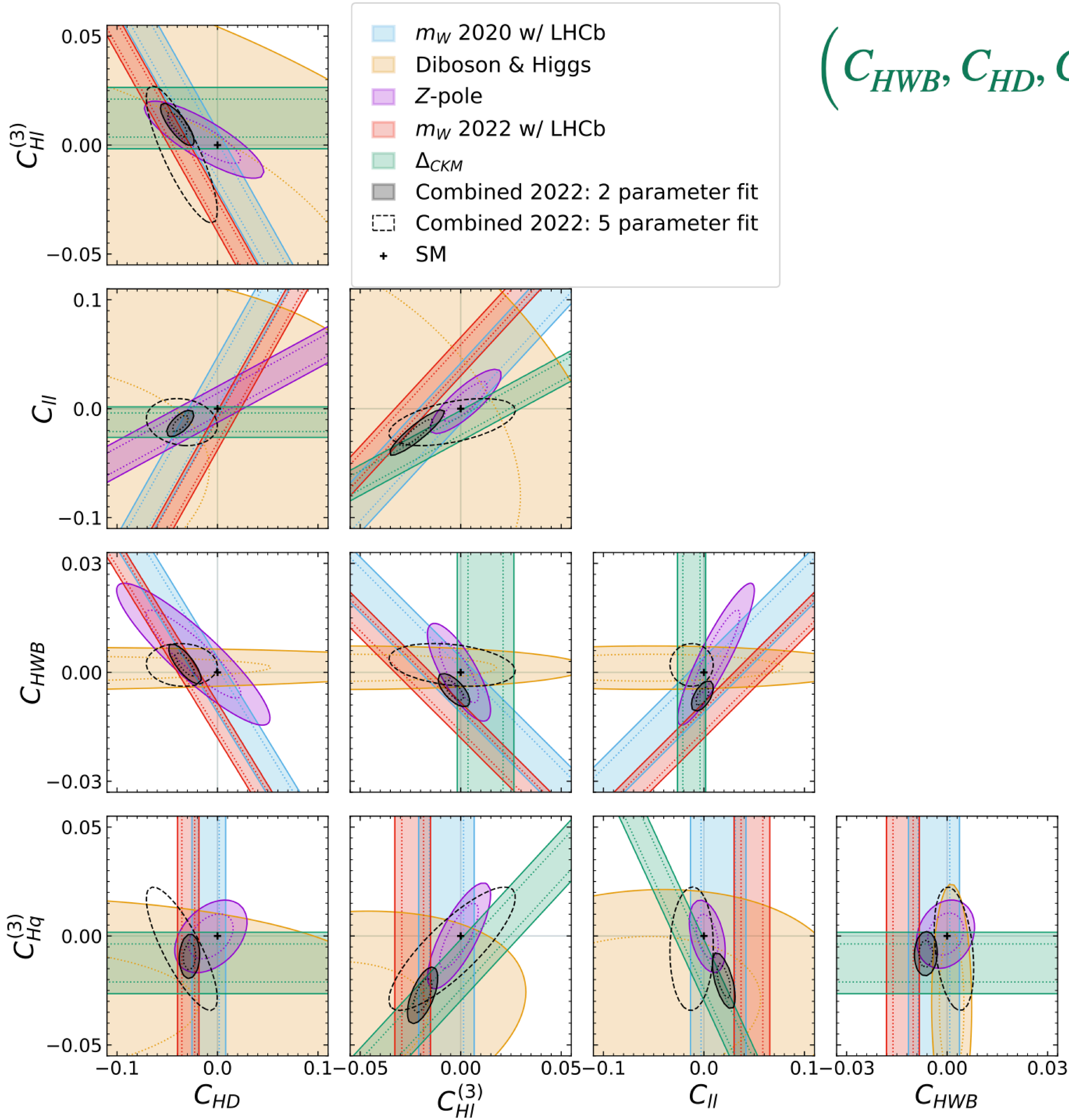
$$\Delta_{CKM} \equiv |V_{ud}|^2 + |V_{us}|^2 - 1 = \frac{2\hat{v}^2}{\Lambda^2}\left(C_{Hq}^{(3)} - C_{Hl}^{(3)} + C_{ll} - C_{lq}^{(3)}\right)$$

- Measurements of nuclear transitions and kaon decays indicate:

$$\Delta_{CKM} = -0.0015 \pm 0.0007$$

Δ_{CKM} probes a direction that is correlated with δm_W^2

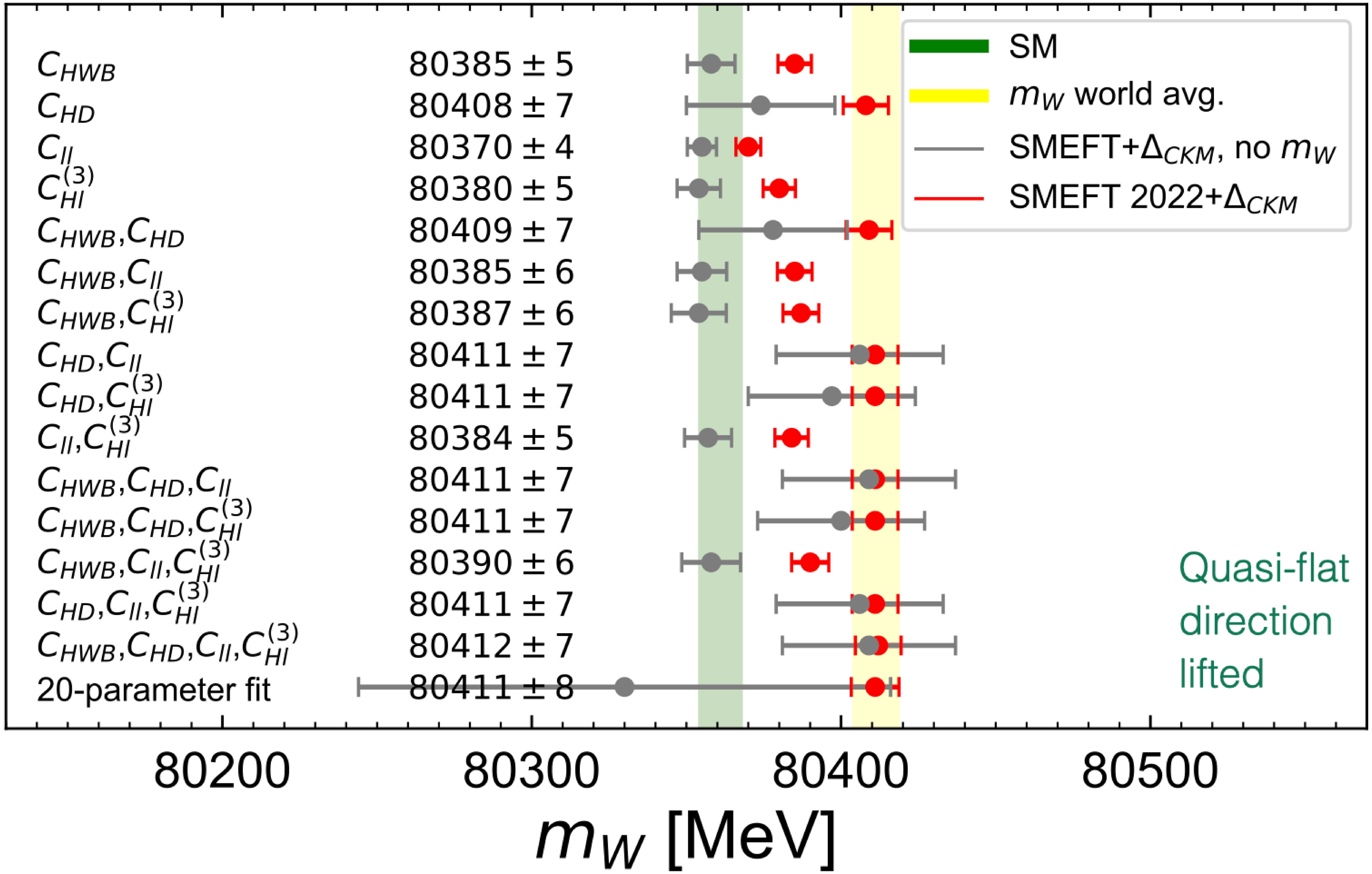
- Per-mille level constraint should compete with $m_W \Rightarrow$ new information
- Also sensitive to irrelevant parameters for m_W, bring correlations with, *e.g.*, Drell Yan & other EWPO, Diboson rates…



$$\left(C_{HWB}, C_{HD}, C_{Hl}^{(3)}, C_{ll}, C_{Hq}^{(3)}\right)$$

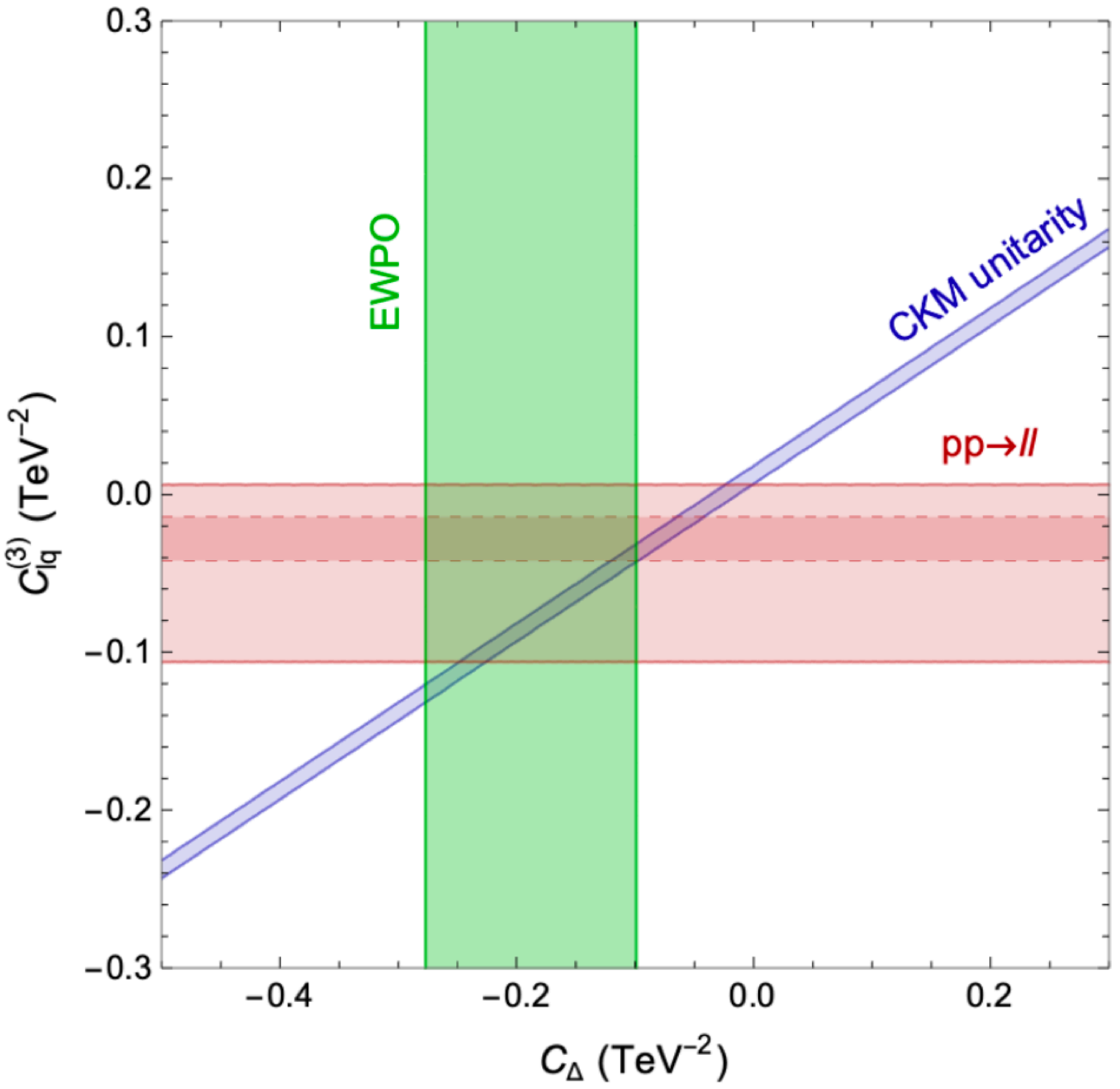
$$C_{ql}^{(3)} = 0$$

m_W after CKM unitarity



CKM unitarity & DY

[Cirigliano, Dekens, de Vries, Mereghetti & Tong; 2204.08440]



[Ellis, KM, & Zampedri; 2304.06663]
[See also Corbett, Helset, Martin & Trott; JHEP 06 (2021) 076]

Beyond Dimension-6

Are dimension-8 effects important?

Precision?

EFT validity?

- Explicit study of Y=0 triplet scalar, Ξ

$$\mathscr{L}_\Xi = \frac{1}{2}(D_\mu \Xi^a)(D^\mu \Xi^a) - \frac{1}{2}M_\Xi^2(\Xi^a\Xi^a) - \kappa_\Xi H^\dagger \Xi^a \sigma^a H - \lambda_\Xi(\Xi^a\Xi^a)(H^\dagger H) - \frac{1}{4}\eta_\Xi(\Xi^a\Xi^a)^2$$

- m_W dominates the constraints on this model

Dim-6: $\mathcal{O}_{HD} \equiv \left(H^\dagger D^\mu H\right)^\star \left(H^\dagger D_\mu H\right)$ **Dim-8:** $\mathcal{O}_{H^6}^{(2)} \equiv (H^\dagger H)(H^\dagger \sigma^I H)(D_\mu H^\dagger \sigma^I D^\mu H)$

$$\left.\frac{\delta m_W^2}{m_W^2}\right|_{D=6} = -\frac{\hat{c}_W}{\hat{c}_{2W}}\frac{C_{HD}}{2} \qquad \left.\frac{\delta m_W^2}{m_W^2}\right|_{D=8} = \frac{\hat{c}_W}{2\hat{c}_{2W}}\left(\frac{\hat{c}_W^2(\hat{c}_{2W} - \hat{s}_W^2)}{\hat{c}_{2W}^2}\frac{C_{HD}^2}{2} - C_{H^6}^{(2)}\right)$$

Dim-6:

$$C_{HD} = -2\frac{\kappa_\Xi^2}{M_\Xi^2}$$

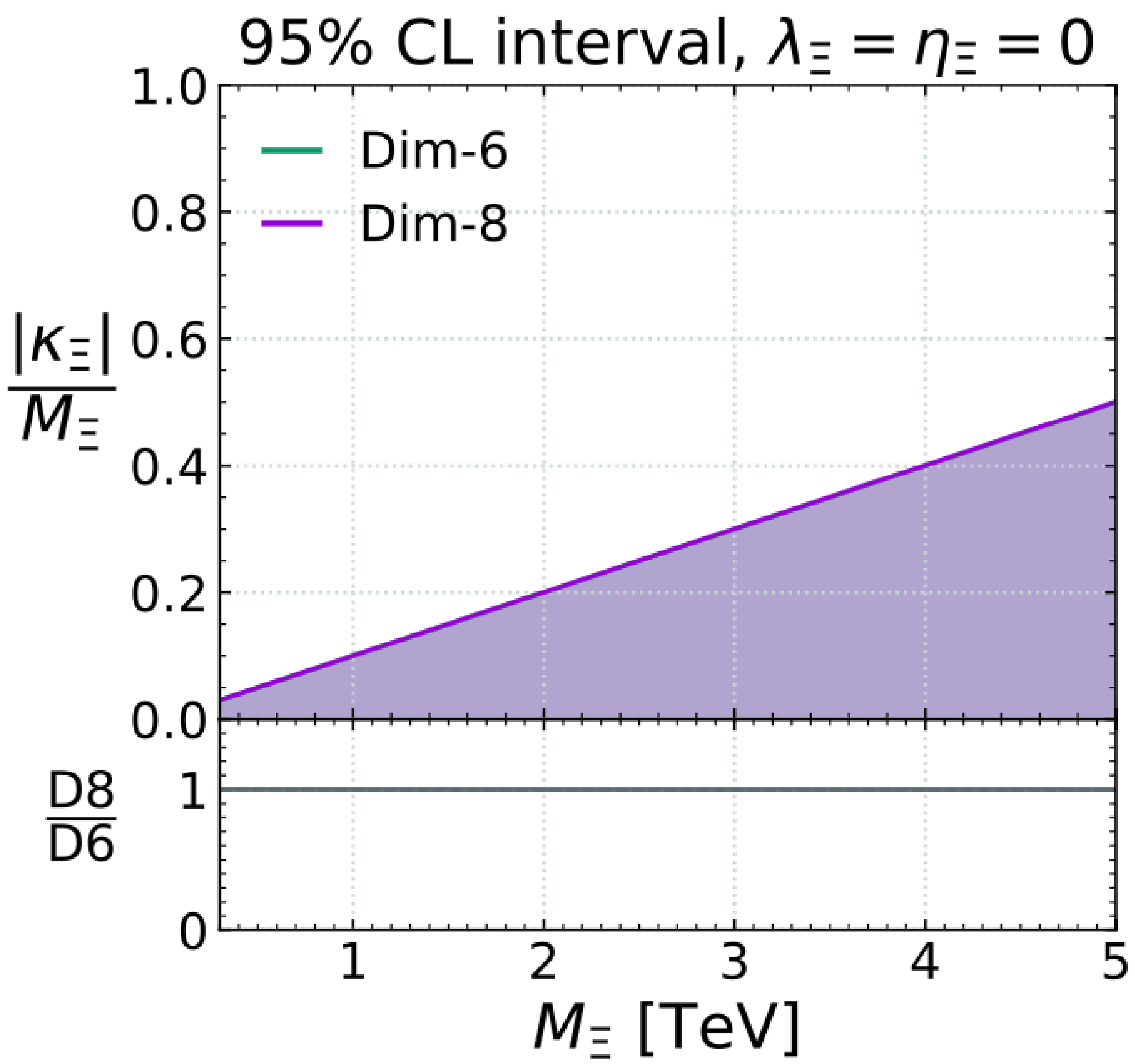
$\Rightarrow$

Dim-8:

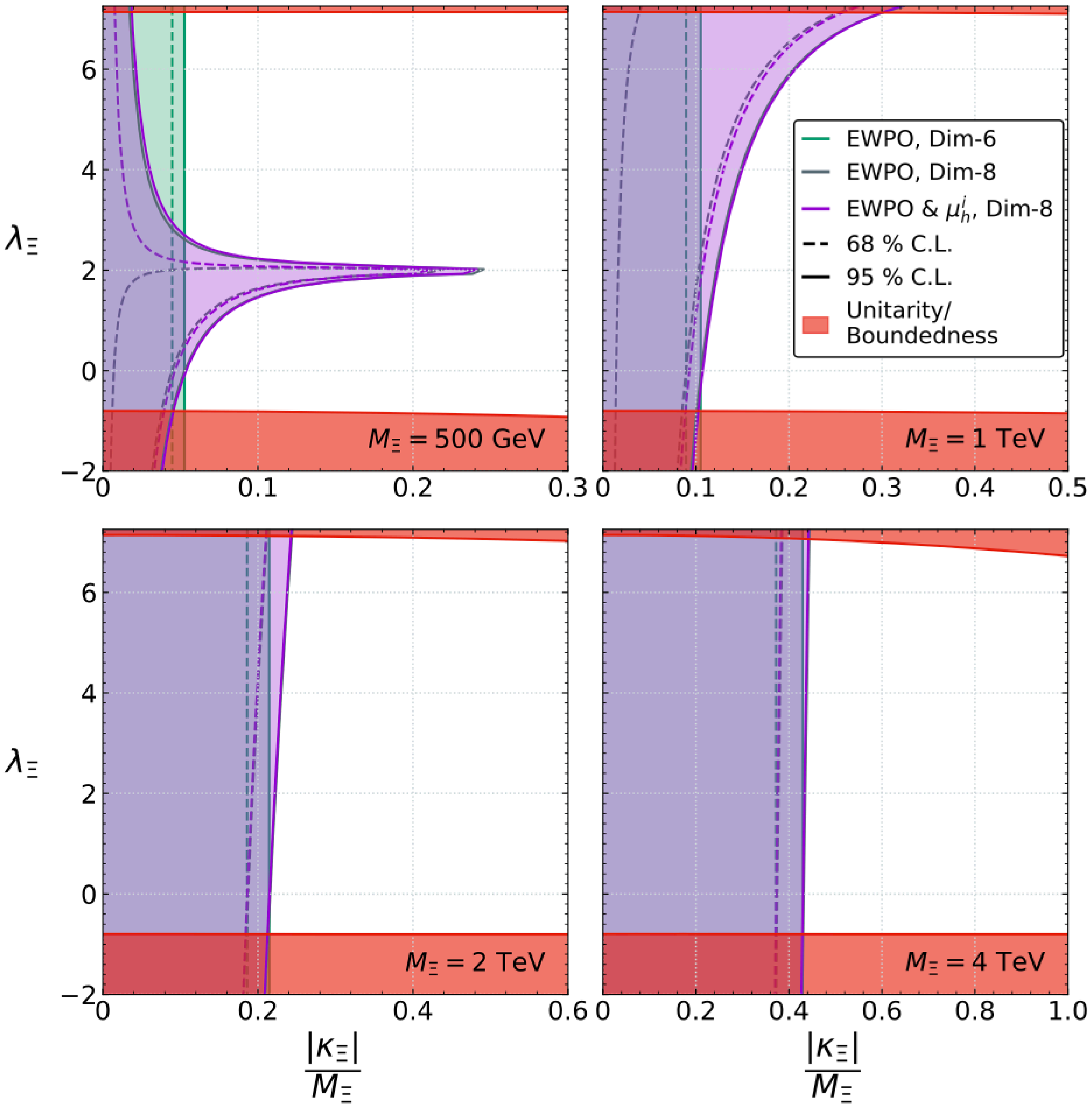
$$C_{HD} = -2\frac{\kappa_\Xi^2}{M_\Xi^2}\left(1 - \frac{4\mu^2}{M_\Xi^2}\right) \qquad C_{H^6}^{(2)} = 4\frac{\kappa_\Xi^2}{M_\Xi^2}\left(\lambda_\Xi - 2\lambda + \frac{\kappa_\Xi^2}{M_\Xi^2}\right)$$

Pre-CDF

Single parameter: κ_Ξ

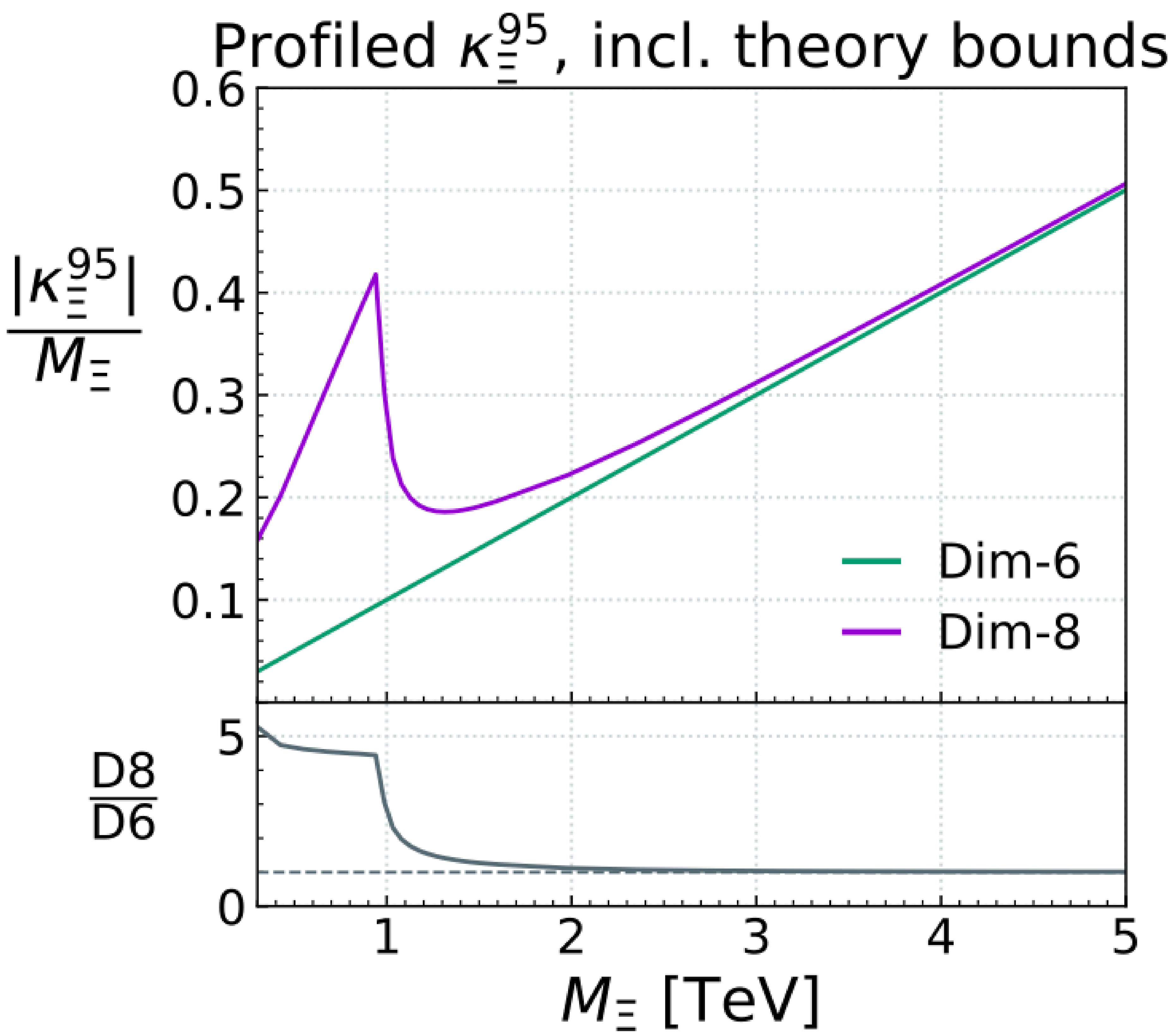


Two parameter: κ_Ξ, λ_Ξ

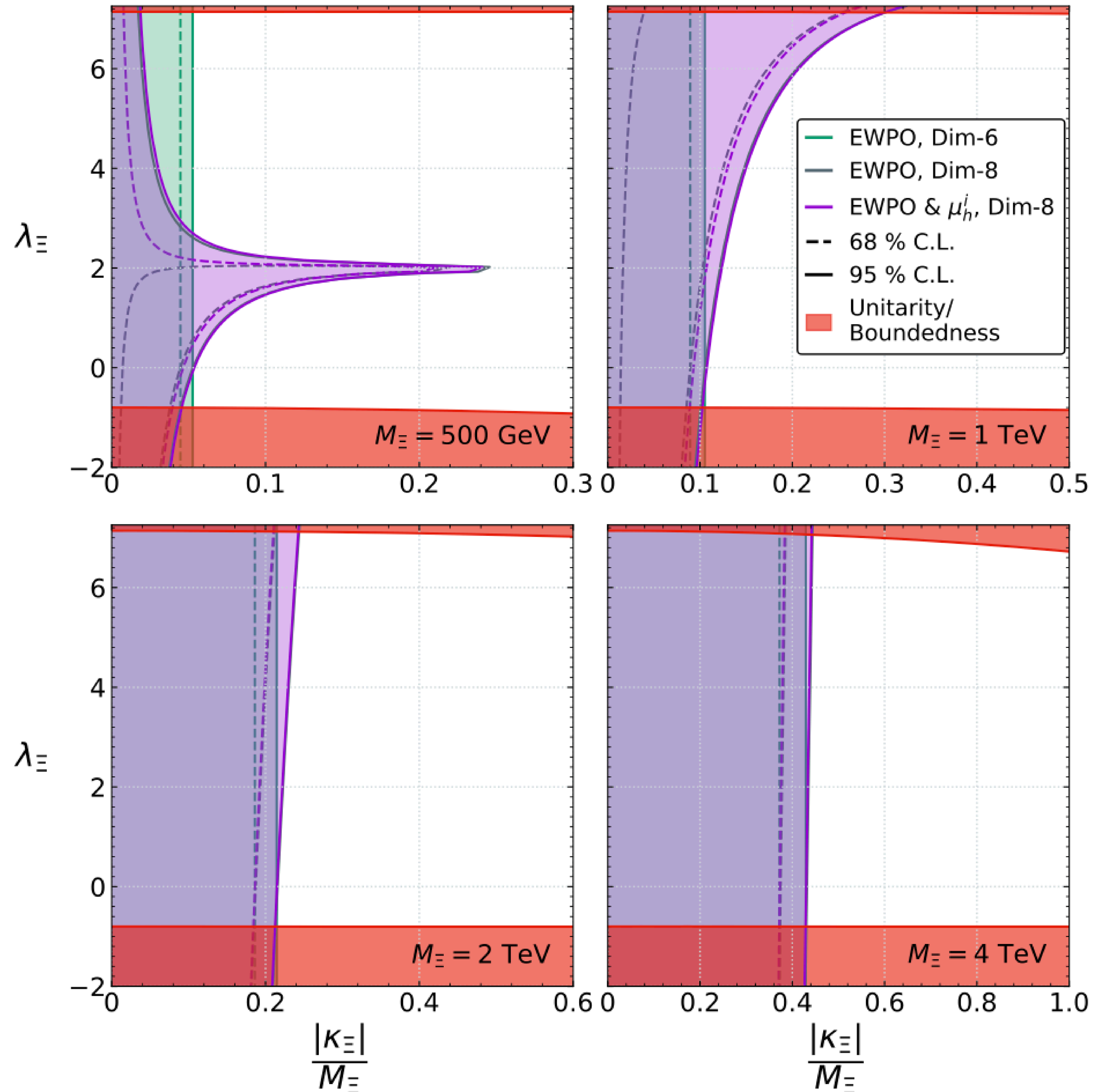


Profiled

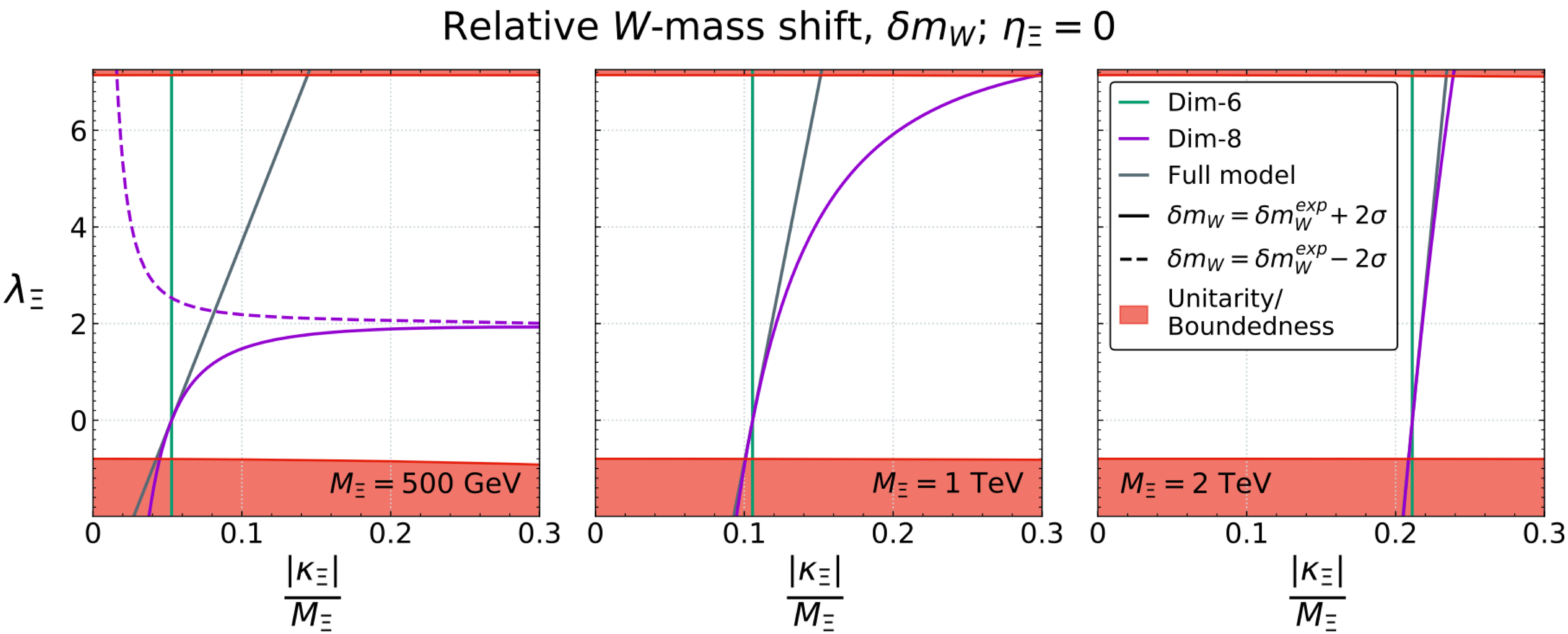
Single parameter: κ_Ξ



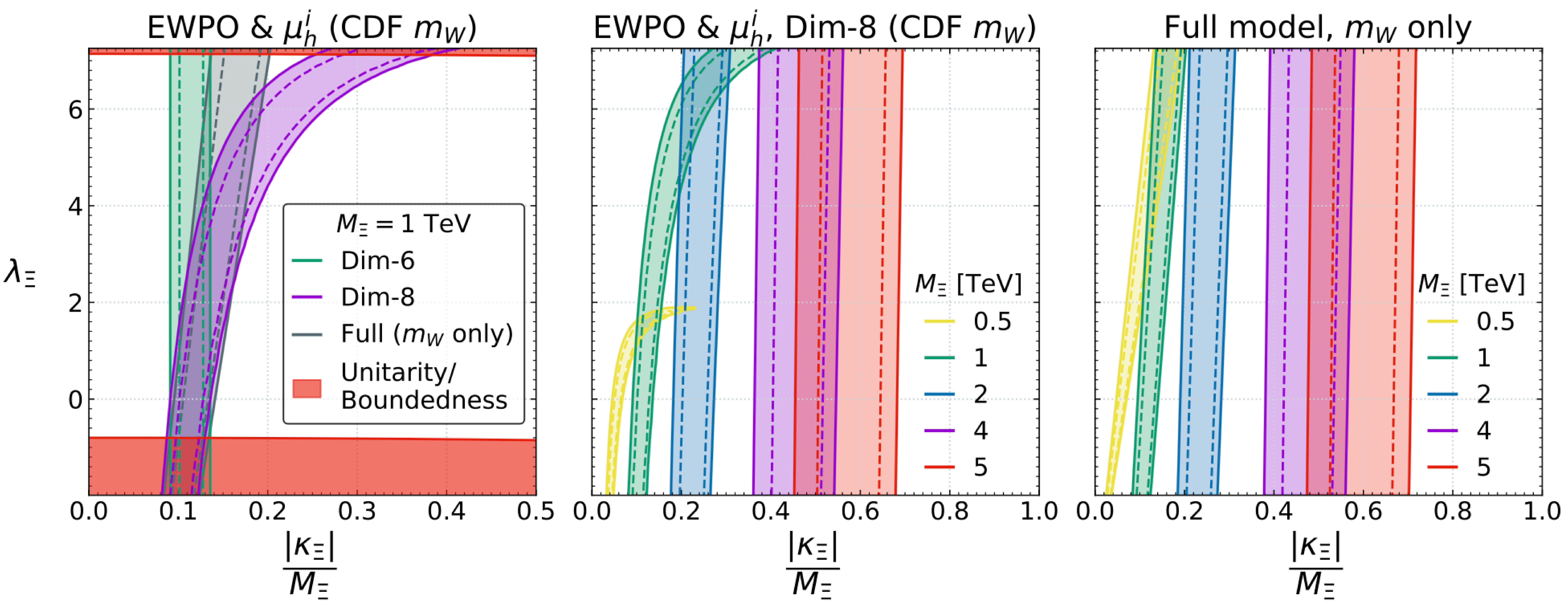
Two parameter: κ_Ξ, λ_Ξ



EFT Validity



Post-CDF


EWPO & μ_h^i (CDF m_W)
EWPO & μ_h^i, Dim-8 (CDF m_W)
Full model, m_W only
λ_Ξ
$\frac{|\kappa_\Xi|}{M_\Xi}$
$M_\Xi = 1$ TeV
Dim-6
Dim-8
Full (m_W only)
Unitarity/ Boundedness
M_Ξ [TeV]
0.5
1
2
4
5

Conclusions

m_W is a precise probe of a direction in SMEFT space

- Crucial input to global fits, lifts a quasi-flat direction

SMEFT can globally accommodate m_W^{CDF}

- Higgs & Diboson data relatively less precise ⇒ Full 20-parameter fit remains consistent with SM
- SMEFT can help to pinpoint specific tree-level UV completions
- Beyond tree-level? *EWPO @ NLO* *[Dawson & Giardino; PRD 101 (2020) 1, 013001]* *RGE effects in interpreting CDF m_W* *[Gupta; 2204.13690]*

Interplay with CKM unitarity

Study of Dimension-8 effects in the scalar triplet model

- Dim-8 better reflects the constraints w.r.t full model
- Until the SMEFT expansion breaks down in strong coupling regions

Backup

SMEFT: SM v2.0

$$\mathcal{L} = \mathcal{L}_{\text{SM}} + \sum_{i,D} \frac{c_i^{(D)} \mathcal{O}_i^{(D)}}{\Lambda^{D-4}}$$

BSM particle masses M ⇔ *Generic new physics scale Λ*

Taylor expansion of $\mathscr{A}_{BSM}$ ⇔ *Tower of operators $\mathcal{O}_i^{(D)}$*

$\mathcal{O}_i^{(D)} \supset$ SM: $W^\pm$, Z, H, t … — *Low energy (SM) fields & symmetries*

Model parameters $\{g^i_{\text{BSM}}, M_k\}$ ⇔ *Wilson coefficients $\frac{c_j^{(D)}}{\Lambda^{D-4}}(g^i_{\text{BSM}}, M_k)$*

measure g_i : new physics model parameters

"Matching"

measure c_i : coupling strengths of new BSM interactions

SMEFT: SM v2.0

$$\mathcal{L}_{\rm eff} = \sum_i \frac{c_i \mathcal{O}_i^D}{\Lambda^{D-4}}$$

SM = low energy effective description

- New physics = tower of irrelevant (D>4) operators
- Respecting low energy field content & symmetries

$SU(3)_C \times SU(2)_L \times U(1)_Y$

$$\varphi = \begin{pmatrix} G^+ \\ v + h + iG^0 \end{pmatrix} : \mathbf{2}_{\frac{1}{2}}$$

aTGC	$X^3 : \epsilon_{IJK} W^I_{\mu\nu} W^{J,\nu\rho} W^{K,\mu}_{\rho}$	$X^2 H^2 : (\varphi^\dagger \varphi)^2 G^a_{\mu\nu} G^{\mu\nu}_a$	ggh(h)
λ_h	$H^6 : (\varphi^\dagger \varphi)^3$	$H^4 D^2 : (\varphi^\dagger D^\mu \varphi)^* (\varphi^\dagger D^\mu \varphi)$	δM_Z
y_f	$\psi^2 H^3 : (\varphi^\dagger \varphi)^2 (\bar{q}_i u_j \tilde{\varphi})$	$\psi^2 X H : (\bar{q}_i \sigma^{\mu\nu} u_j \tilde{\varphi}) B_{\mu\nu}$	'dipole'
ffV	$\psi^2 H^2 D : (\varphi^\dagger \overleftrightarrow{D}_\mu \varphi)(\bar{q}_i \gamma^\mu q_j)$	$\psi^4 : (\bar{q}_i \gamma^\mu q_j)(\bar{q}_k \gamma_\mu q_l)$	4F

More than 'just' a parametrisation of ignorance

- Unlike anomalous couplings
- Finite energy range ($\sim\Lambda$)
- Renormalisable QFT (order-by-order)
- Well defined matching procedure

SMEFT interpretation

Improving sensitivity means improving…

$$\Delta o_n = o_n^{\mathrm{EXP}} - o_n^{\mathrm{SM}} = \sum_i \frac{a_{n,i}^{(6)}(\mu)\, c_i^{(6)}(\mu)}{\Lambda^2} + \mathcal{O}\left(\frac{1}{\Lambda^3}\right)$$

Global nature

As many observables as possible

Identify patterns & correlations in fits

Exploit energy-growth

Sensitivity

Experiment:
Best measurements & understanding of uncertainties and correlations

Theory:
Best available predictions for observables (NLO, NNLO, N3LO,…)

Interpretation

Relies on accurate knowledge of the size & correlation among a_i

Determining $c_i^{(6)}$ requires most precise available SMEFT predictions

Theory

[Grzadkowski et al.; JHEP 10 (2010) 085]

X^3		H^6 and H^4D^2		ψ^2H^3	
$\mathcal{O}_G$	$f^{ABC}G_\mu^{A\nu}G_\nu^{B\rho}G_\rho^{C\mu}$	$\mathcal{O}_H$	$(H^\dagger H)^3$	$\mathcal{O}_{eH}$	$(H^\dagger H)(\bar l_p e_r H)$
$\mathcal{O}_{\widetilde G}$	$f^{ABC}\widetilde G_\mu^{A\nu}G_\nu^{B\rho}G_\rho^{C\mu}$	$\mathcal{O}_{H\Box}$	$(H^\dagger H)\Box(H^\dagger H)$	$\mathcal{O}_{uH}$	$(H^\dagger H)(\bar q_p u_r \widetilde H)$
$\mathcal{O}_W$	$\varepsilon^{IJK}W_\mu^{I\nu}W_\nu^{J\rho}W_\rho^{K\mu}$	$\mathcal{O}_{HD}$	$(H^\dagger D^\mu H)^\star(H^\dagger D_\mu H)$	$\mathcal{O}_{dH}$	$(H^\dagger H)(\bar q_p d_r H)$
$\mathcal{O}_{\widetilde W}$	$\varepsilon^{IJK}\widetilde W_\mu^{I\nu}W_\nu^{J\rho}W_\rho^{K\mu}$				
X^2H^2		ψ^2XH		ψ^2H^2D	
$\mathcal{O}_{HG}$	$H^\dagger H\, G^A_{\mu\nu}G^{A\mu\nu}$	$\mathcal{O}_{eW}$	$(\bar l_p\sigma^{\mu\nu}e_r)\tau^I H W^I_{\mu\nu}$	$\mathcal{O}^{(1)}_{Hl}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar l_p\gamma^\mu l_r)$
$\mathcal{O}_{H\widetilde G}$	$H^\dagger H\, \widetilde G^A_{\mu\nu}G^{A\mu\nu}$	$\mathcal{O}_{eB}$	$(\bar l_p\sigma^{\mu\nu}e_r)H B_{\mu\nu}$	$\mathcal{O}^{(3)}_{Hl}$	$(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar l_p\tau^I\gamma^\mu l_r)$
$\mathcal{O}_{HW}$	$H^\dagger H\, W^I_{\mu\nu}W^{I\mu\nu}$	$\mathcal{O}_{uG}$	$(\bar q_p\sigma^{\mu\nu}T^A u_r)\widetilde H\, G^A_{\mu\nu}$	$\mathcal{O}_{He}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar e_p\gamma^\mu e_r)$
$\mathcal{O}_{H\widetilde W}$	$H^\dagger H\, \widetilde W^I_{\mu\nu}W^{I\mu\nu}$	$\mathcal{O}_{uW}$	$(\bar q_p\sigma^{\mu\nu}u_r)\tau^I\widetilde H\, W^I_{\mu\nu}$	$\mathcal{O}^{(1)}_{Hq}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar q_p\gamma^\mu q_r)$
$\mathcal{O}_{HB}$	$H^\dagger H\, B_{\mu\nu}B^{\mu\nu}$	$\mathcal{O}_{uB}$	$(\bar q_p\sigma^{\mu\nu}u_r)\widetilde H\, B_{\mu\nu}$	$\mathcal{O}^{(3)}_{Hq}$	$(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar q_p\tau^I\gamma^\mu q_r)$
$\mathcal{O}_{H\widetilde B}$	$H^\dagger H\, \widetilde B_{\mu\nu}B^{\mu\nu}$	$\mathcal{O}_{dG}$	$(\bar q_p\sigma^{\mu\nu}T^A d_r)H\, G^A_{\mu\nu}$	$\mathcal{O}_{Hu}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar u_p\gamma^\mu u_r)$
$\mathcal{O}_{HWB}$	$H^\dagger\tau^I H\, W^I_{\mu\nu}B^{\mu\nu}$	$\mathcal{O}_{dW}$	$(\bar q_p\sigma^{\mu\nu}d_r)\tau^I H\, W^I_{\mu\nu}$	$\mathcal{O}_{Hd}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar d_p\gamma^\mu d_r)$
$\mathcal{O}_{H\widetilde WB}$	$H^\dagger\tau^I H\, \widetilde W^I_{\mu\nu}B^{\mu\nu}$	$\mathcal{O}_{dB}$	$(\bar q_p\sigma^{\mu\nu}d_r)H\, B_{\mu\nu}$	$\mathcal{O}_{Hud}$	$i(\widetilde H^\dagger D_\mu H)(\bar u_p\gamma^\mu d_r)$

$(\bar LL)(\bar LL)$		$(\bar RR)(\bar RR)$		$(\bar LL)(\bar RR)$	
$\mathcal{O}_{ll}$	$(\bar l_p\gamma_\mu l_r)(\bar l_s\gamma^\mu l_t)$	$\mathcal{O}_{ee}$	$(\bar e_p\gamma_\mu e_r)(\bar e_s\gamma^\mu e_t)$	$\mathcal{O}_{le}$	$(\bar l_p\gamma_\mu l_r)(\bar e_s\gamma^\mu e_t)$
$\mathcal{O}^{(1)}_{qq}$	$(\bar q_p\gamma_\mu q_r)(\bar q_s\gamma^\mu q_t)$	$\mathcal{O}_{uu}$	$(\bar u_p\gamma_\mu u_r)(\bar u_s\gamma^\mu u_t)$	$\mathcal{O}_{lu}$	$(\bar l_p\gamma_\mu l_r)(\bar u_s\gamma^\mu u_t)$
$\mathcal{O}^{(3)}_{qq}$	$(\bar q_p\gamma_\mu\tau^I q_r)(\bar q_s\gamma^\mu\tau^I q_t)$	$\mathcal{O}_{dd}$	$(\bar d_p\gamma_\mu d_r)(\bar d_s\gamma^\mu d_t)$	$\mathcal{O}_{ld}$	$(\bar l_p\gamma_\mu l_r)(\bar d_s\gamma^\mu d_t)$
$\mathcal{O}^{(1)}_{lq}$	$(\bar l_p\gamma_\mu l_r)(\bar q_s\gamma^\mu q_t)$	$\mathcal{O}_{eu}$	$(\bar e_p\gamma_\mu e_r)(\bar u_s\gamma^\mu u_t)$	$\mathcal{O}_{qe}$	$(\bar q_p\gamma_\mu q_r)(\bar e_s\gamma^\mu e_t)$
$\mathcal{O}^{(3)}_{lq}$	$(\bar l_p\gamma_\mu\tau^I l_r)(\bar q_s\gamma^\mu\tau^I q_t)$	$\mathcal{O}_{ed}$	$(\bar e_p\gamma_\mu e_r)(\bar d_s\gamma^\mu d_t)$	$\mathcal{O}^{(1)}_{qu}$	$(\bar q_p\gamma_\mu q_r)(\bar u_s\gamma^\mu u_t)$
		$\mathcal{O}^{(1)}_{ud}$	$(\bar u_p\gamma_\mu u_r)(\bar d_s\gamma^\mu d_t)$	$\mathcal{O}^{(8)}_{qu}$	$(\bar q_p\gamma_\mu T^A q_r)(\bar u_s\gamma^\mu T^A u_t)$
		$\mathcal{O}^{(8)}_{ud}$	$(\bar u_p\gamma_\mu T^A u_r)(\bar d_s\gamma^\mu T^A d_t)$	$\mathcal{O}^{(1)}_{qd}$	$(\bar q_p\gamma_\mu q_r)(\bar d_s\gamma^\mu d_t)$
				$\mathcal{O}^{(8)}_{qd}$	$(\bar q_p\gamma_\mu T^A q_r)(\bar d_s\gamma^\mu T^A d_t)$

$(\bar LR)(\bar RL)$ and $(\bar LR)(\bar LR)$		B-violating	
$\mathcal{O}_{ledq}$	$(\bar l^j_p e_r)(\bar d_s q^j_t)$	$\mathcal{O}_{duq}$	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\left[(d^\alpha_p)^T C u^\beta_r\right]\left[(q^{\gamma j}_s)^T C l^k_t\right]$
$\mathcal{O}^{(1)}_{quqd}$	$(\bar q^j_p u_r)\varepsilon_{jk}(\bar q^k_s d_t)$	$\mathcal{O}_{qqu}$	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\left[(q^{\alpha j}_p)^T C q^{\beta k}_r\right]\left[(u^\gamma_s)^T C e_t\right]$
$\mathcal{O}^{(8)}_{quqd}$	$(\bar q^j_p T^A u_r)\varepsilon_{jk}(\bar q^k_s T^A d_t)$	$\mathcal{O}_{qqq}$	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jn}\varepsilon_{km}\left[(q^{\alpha j}_p)^T C q^{\beta k}_r\right]\left[(q^{\gamma m}_s)^T C l^n_t\right]$
$\mathcal{O}^{(1)}_{lequ}$	$(\bar l^j_p e_r)\varepsilon_{jk}(\bar q^k_s u_t)$	$\mathcal{O}_{duu}$	$\varepsilon^{\alpha\beta\gamma}\left[(d^\alpha_p)^T C u^\beta_r\right]\left[(u^\gamma_s)^T C e_t\right]$
$\mathcal{O}^{(3)}_{lequ}$	$(\bar l^j_p\sigma_{\mu\nu}e_r)\varepsilon_{jk}(\bar q^k_s\sigma^{\mu\nu}u_t)$		

Warsaw basis with CP & B conservation

- Full ‘bosonic’ sector: Higgs, triple-gauge & gauge-Higgs
- Scenario 1: Flavor-**universal** degrees of freedom

$U(3)_L \times U(3)_e \times U(3)_Q \times U(3)_u \times U(3)_d$ + Yukawas: $\mathcal{O}_{tH}, \mathcal{O}_{bH}, \mathcal{O}_{\tau H}, \mathcal{O}_{\mu H}$

- Scenario 2: **top**-centric flavor symmetry

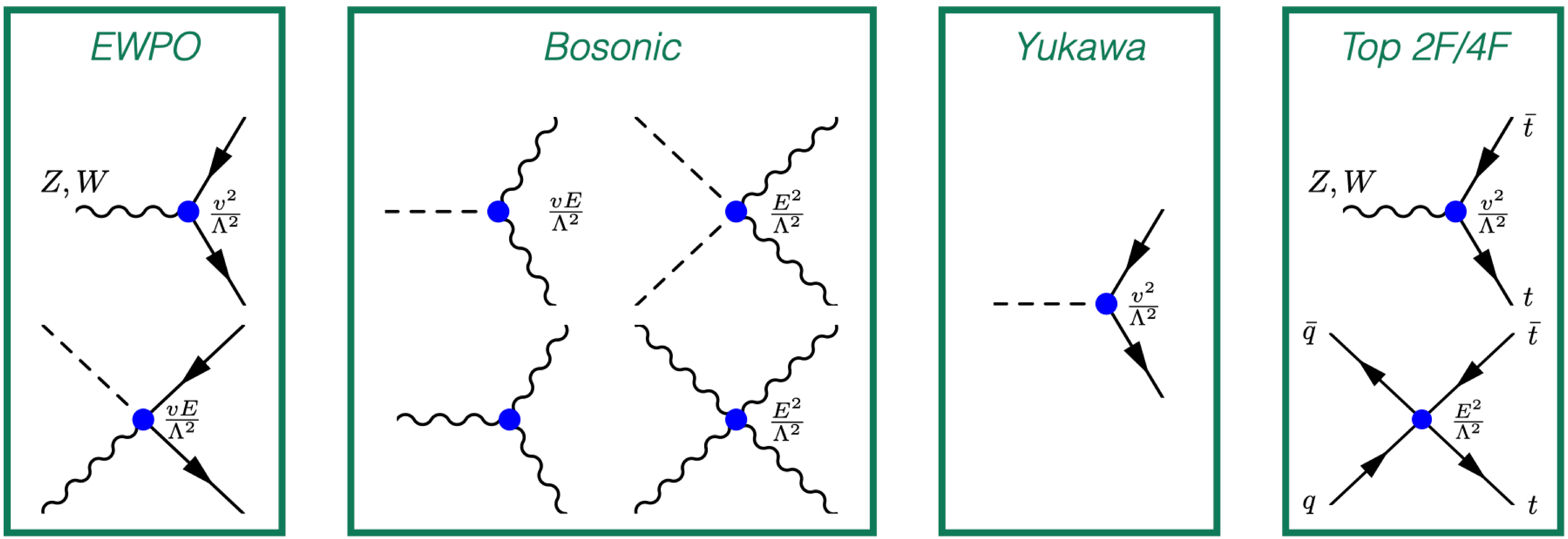
$U(3)_L \times U(3)_e \times U(2)_Q \times U(2)_u \times U(3)_d$

cf. Minimal flavor violation

[Buras et al.; PLB 500 (2001) 161]
[D’Ambrosio et al.; NPB 645 (2002) 155]
[Aguilar-Saavedra et al.; arXiv:1802.07237]

Degrees of freedom

Flavor scenario			
Universal	EWPO:	$\mathcal{O}_{HWB}\,,\ \mathcal{O}_{HD}\,,\ \mathcal{O}_{ll}\,,\ \mathcal{O}_{Hl}^{(3)}\,,\ \mathcal{O}_{Hl}^{(1)}\,,\ \mathcal{O}_{He}\,,\ \mathcal{O}_{Hq}^{(3)}\,,\ \mathcal{O}_{Hq}^{(1)}\,,\ \mathcal{O}_{Hd}\,,\ \mathcal{O}_{Hu}\,,$	
	Bosonic:	$\mathcal{O}_{H\Box}\,,\ \mathcal{O}_{HG}\,,\ \mathcal{O}_{HW}\,,\ \mathcal{O}_{HB}\,,\ \mathcal{O}_{W}\,,\ \mathcal{O}_{G}\,,$	
	Yukawa:	$\mathcal{O}_{\tau H}\,,\ \mathcal{O}_{\mu H}\,,\ \mathcal{O}_{bH}\,,\ \mathcal{O}_{tH}\,,$	20
'Top specific'	Top 2F:	$\mathcal{O}_{HQ}^{(3)}\,,\ \mathcal{O}_{HQ}^{(1)}\,,\ \mathcal{O}_{Ht}\,,\ \mathcal{O}_{tG}\,,\ \mathcal{O}_{tW}\,,\ \mathcal{O}_{tB}\,,$	
	Top 4F:	$\mathcal{O}_{Qq}^{3,1}\,,\ \mathcal{O}_{Qq}^{3,8}\,,\ \mathcal{O}_{Qq}^{1,8}\,,\ \mathcal{O}_{Qu}^{8}\,,\ \mathcal{O}_{Qd}^{8}\,,\ \mathcal{O}_{tQ}^{8}\,,\ \mathcal{O}_{tu}^{8}\,,\ \mathcal{O}_{td}^{8}\,.$	+14



SMEFT fit

	Individual			Marginalised		
SMEFT Coeff.	Best fit [$\Lambda = 1$ TeV]	95% CL range	Scale $\frac{\Lambda}{\sqrt{C}}$ [TeV]	Best fit [$\Lambda = 1$ TeV]	95% CL range	Scale $\frac{\Lambda}{\sqrt{C}}$ [TeV]
C_{HWB}	-0.01	[-0.009, -0.0034]	19.0	0.25	[-0.3, +0.81]	1.3
C_{HD}	-0.03	[-0.035, -0.019]	11.0	-0.6	[-1.8, +0.63]	0.9
C_{ll}	0.02	[+0.014, +0.034]	10.0	-0.05	[-0.099, +0.0043]	4.4
$C_{Hl}^{(3)}$	-0.01	[-0.019, -0.0083]	14.0	-0.01	[-0.11, +0.076]	3.3
$C_{Hl}^{(1)}$	0.00	[-0.0045, +0.013]	11.0	0.16	[-0.15, +0.47]	1.8
C_{He}	0.00	[-0.015, +0.0071]	9.6	0.28	[-0.34, +0.9]	1.3
$C_{Hq}^{(3)}$	0.00	[-0.013, +0.011]	9.1	-0.05	[-0.11, +0.012]	4.1
$C_{Hq}^{(1)}$	0.01	[-0.027, +0.043]	5.4	-0.07	[-0.2, +0.06]	2.8
C_{Hd}	-0.03	[-0.13, +0.072]	3.1	-0.44	[-0.96, +0.079]	1.4
C_{Hu}	0.00	[-0.075, +0.073]	3.7	-0.18	[-0.62, +0.26]	1.5
C_{HBox}	-0.27	[-1, +0.47]	1.2	-1.1	[-3.2, +1]	0.69
C_{HG}	0.00	[-0.0034, +0.0032]	17.0	-0.01	[-0.026, +0.013]	7.2
C_{HW}	0.00	[-0.012, +0.006]	11.0	0.18	[-0.33, +0.7]	1.4
C_{HB}	0.00	[-0.0034, +0.002]	19.0	0.09	[-0.074, +0.24]	2.5
C_{W}	0.18	[-0.072, +0.42]	2.0	0.15	[-0.1, +0.4]	2.0
C_{G}	-0.75	[-4, +2.5]	0.56	1.3	[-6.1, +8.7]	0.37
$C_{\tau H}$	0.01	[-0.015, +0.025]	7.1	0.00	[-0.017, +0.027]	6.7
$C_{\mu H}$	0.00	[-0.0057, +0.005]	14.0	0.00	[-0.0056, +0.0052]	14.0
C_{bH}	0.00	[-0.016, +0.024]	7.1	0.02	[-0.027, +0.058]	4.8
C_{tH}	-0.09	[-1, +0.84]	1.0	-2.7	[-8.8, +3.3]	0.41

Operators

Dim - 4	$\mathcal{O}_{H4}$	$(H^\dagger H)^2$
Dim - 6	H^6 and H^4D^2	
	$\mathcal{O}_{H}$	$(H^\dagger H)^3$
	$\mathcal{O}_{HD}$	$(H^\dagger D^\mu H)^*(H^\dagger D^\mu H)$
	$\mathcal{O}_{H\Box}$	$(H^\dagger H)\Box(H^\dagger H)$
	$\psi^2 H^3$	
	$\mathcal{O}_{eH}$	$(H^\dagger H)(\bar{l}_p e_r H)$
	$\mathcal{O}_{uH}$	$(H^\dagger H)(\bar{q}_p u_r \widetilde{H})$
	$\mathcal{O}_{dH}$	$(H^\dagger H)(\bar{q}_p d_r H)$

Dim - 8	H^8, H^6D^2 and H^4D^4		$(\bar{L}R)(\bar{L}R)H^2$ + h.c	
	$\mathcal{O}_{H^8}$	$(H^\dagger H)^4$	$\mathcal{O}^{(1)}_{lequH^2}$	$(\bar{l}^j_p e_r)\epsilon_{jk}(\bar{q}^k_s u_t)(H^\dagger H)$
	$\mathcal{O}^{(1)}_{H^6}$	$(H^\dagger H)^2(D_\mu H^\dagger D^\mu H)$	$\mathcal{O}^{(2)}_{lequH^2}$	$(\bar{l}^j_p e_r)(\sigma^I\epsilon)_{jk}(\bar{q}^k_s u_t)(H^\dagger \sigma^I H)$
	$\mathcal{O}^{(2)}_{H^6}$	$(H^\dagger H)(H^\dagger \sigma^I H)(D_\mu H^\dagger \sigma^I D^\mu H)$	$\mathcal{O}^{(1)}_{q^2udH^2}$	$(\bar{q}^j_p u_r)\epsilon_{jk}(\bar{q}^k_s d_t)(H^\dagger H)$
	$\mathcal{O}^{(1)}_{H^4}$	$(D_\mu H^\dagger D_\nu H)(D^\nu H^\dagger D^\mu H)$	$\mathcal{O}^{(2)}_{q^2udH^2}$	$(\bar{q}^j_p u_r)(\sigma^I\epsilon)_{jk}(\bar{q}^k_s d_t)(H^\dagger \sigma^I H)$
	$\mathcal{O}^{(3)}_{H^4}$	$(D_\mu H^\dagger D^\mu H)(D_\nu H^\dagger D^\nu H)$	$\mathcal{O}^{(3)}_{leqdH^2}$	$(\bar{l}_p e_r H)(\bar{q}_s d_t H)$
	$\psi^2 H^5$		$\mathcal{O}^{(3)}_{l^2e^2H^2}$	$(\bar{l}_p e_r H)(\bar{l}_s e_t H)$
	$\mathcal{O}_{leH^5}$	$(H^\dagger H)^2(\bar{l}_p e_r H)$	$\mathcal{O}^{(5)}_{q^2u^2H^2}$	$(\bar{q}_p u_r \widetilde{H})(\bar{q}_s u_t \widetilde{H})$
	$\mathcal{O}_{quH^5}$	$(H^\dagger H)^2(\bar{q}_p u_r \widetilde{H})$	$\mathcal{O}^{(5)}_{q^2d^2H^2}$	$(\bar{q}_p d_r H)(\bar{q}_s u_t H)$
	$\mathcal{O}_{qdH^5}$	$(H^\dagger H)^2(\bar{q}_p d_r H)$		
	$\psi^2 H^3 D^2$ + h.c.		$(\bar{L}L)(\bar{R}R)H^2$	
	$\mathcal{O}^{(1)}_{leH^3D^2}$	$(D_\mu H^\dagger D^\mu H)(\bar{l}_p e_r H)$	$\mathcal{O}^{(1)}_{l^2e^2H^2}$	$(\bar{l}_p \gamma^\mu l_r)(\bar{e}_s \gamma_\mu e_t)(H^\dagger H)$
	$\mathcal{O}^{(2)}_{leH^3D^2}$	$(D_\mu H^\dagger \sigma^I D^\mu H)(\bar{l}_p e_r \sigma^I H)$	$\mathcal{O}^{(2)}_{l^2e^2H^2}$	$(\bar{l}_p \gamma^\mu \sigma^I l_r)(\bar{e}_s \gamma_\mu e_t)(H^\dagger \sigma^I H)$
	$\mathcal{O}^{(1)}_{quH^3D^2}$	$(D_\mu H^\dagger D^\mu H)(\bar{q}_p u_r H)$	$\mathcal{O}^{(1)}_{q^2u^2H^2}$	$(\bar{q}_p \gamma^\mu q_r)(\bar{u}_s \gamma_\mu u_t)(H^\dagger H)$
	$\mathcal{O}^{(2)}_{quH^3D^2}$	$(D_\mu H^\dagger \sigma^I D^\mu H)(\bar{q}_p u_r \sigma^I H)$	$\mathcal{O}^{(2)}_{q^2u^2H^2}$	$(\bar{q}_p \gamma^\mu \sigma^I q_r)(\bar{u}_s \gamma_\mu u_t)(H^\dagger \sigma^I H)$
	$\mathcal{O}^{(1)}_{qdH^3D^2}$	$(D_\mu H^\dagger D^\mu H)(\bar{q}_p d_r H)$	$\mathcal{O}^{(1)}_{q^2d^2H^2}$	$(\bar{q}_p \gamma^\mu q_r)(\bar{d}_s \gamma_\mu d_t)(H^\dagger H)$
	$\mathcal{O}^{(2)}_{qdH^3D^2}$	$(D_\mu H^\dagger \sigma^I D^\mu H)(\bar{q}_p d_r \sigma^I H)$	$\mathcal{O}^{(2)}_{q^2d^2H^2}$	$(\bar{q}_p \gamma^\mu \sigma^I q_r)(\bar{d}_s \gamma_\mu d_t)(H^\dagger \sigma^I H)$
	$(\bar{L}R)(\bar{R}L)H^2$ + h.c.			
	$\mathcal{O}^{(1)}_{leqdH^2}$	$(\bar{l}^j_p e_r)(\bar{d}_s q_{tj})(H^\dagger H)$	$\mathcal{O}^{(5)}_{lequH^2}$	$(\bar{l}_p e_r H)(\widetilde{H}^\dagger \bar{u}_s q_t)$
	$\mathcal{O}^{(2)}_{leqdH^2}$	$(\bar{l}_p e_r)\sigma^I(\bar{d}_s q_t)(H^\dagger \sigma^I H)$	$\mathcal{O}^{(5)}_{q^2u^2H^2}$	$(\bar{q}_p d_r H)(\widetilde{H}^\dagger \bar{u}_s q_t)$

Triplet matching

Dim - 6	C_H	$\frac{\kappa_\Xi^2}{M_\Xi^2}\left((4\lambda-\lambda_\Xi)\left(1-\frac{4\mu^2}{M_\Xi^2}\right)-\frac{5\mu^2\kappa_\Xi^2}{M_\Xi^6}\right)$
	C_{HD}	$-\frac{2\kappa_\Xi^2}{M_\Xi^2}\left(1-\frac{4\mu^2}{M_\Xi^2}\right)$
	$C_{H\square}$	$\frac{\kappa_\Xi^2}{2M_\Xi^2}\left(1-\frac{4\mu^2}{M_\Xi^2}\right)$
	$[C_{\psi H}]_{\rm wx}$	$[y_\psi]_{\rm wx}\frac{\kappa_\Xi^2}{M_\Xi^2}\left(1-\frac{4\mu^2}{M_\Xi^2}\right);\ \psi=u,d,e$

Dim - 8	C_{H^8}	$\frac{2\kappa_\Xi^2}{M_\Xi^2}\left((2\lambda-\lambda_\Xi)^2+\frac{\kappa_\Xi^2}{M_\Xi^2}(3\lambda_\Xi-5\lambda-\frac{\eta_\Xi}{8})\right)$
	$C_{H^6}^{(1)}$	$-\frac{\kappa_\Xi^4}{M_\Xi^4}$
	$C_{H^6}^{(2)}$	$\frac{4\kappa_\Xi^2}{M_\Xi^2}\left(\lambda_\Xi-2\lambda+\frac{\kappa_\Xi^2}{M_\Xi^2}\right)$
	$C_{H^4}^{(1)}$	$\frac{4\kappa_\Xi^2}{M_\Xi^2}$
	$C_{H^4}^{(3)}$	$-\frac{2\kappa_\Xi^2}{M_\Xi^2}$
	$[C_{l\psi H^5}/C_{q\psi H^5}]_{\rm wx}$	$-[y_\psi]_{\rm wx}\frac{2\kappa_\Xi^2}{M_\Xi^2}\left(\lambda_\Xi-2\lambda+\frac{\kappa_\Xi^2}{2M_\Xi^2}\right);\ \psi=u,d,e$
	$[C_{l^2\psi^2H^2}^{(1)}/C_{q^2\psi^2H^2}^{(1)}]_{\rm wxyz}$	$-[y_\psi]_{\rm wz}[y_\psi^\dagger]_{\rm yx}\frac{3\kappa_\Xi^2}{4M_\Xi^2};\ \psi=u,d,e$
	$[C_{l^2e^2H^2}^{(2)}/C_{q^2d^2H^2}^{(2)}]_{\rm wxyz}$	$[y_\psi]_{\rm wz}[y_\psi^\dagger]_{\rm yx}\frac{\kappa_\Xi^2}{4M_\Xi^2};\ \psi=d,e$
	$[C_{q^2u^2H^2}^{(2)}]_{\rm wxyz}$	$-[y_u]_{\rm wz}[y_u^\dagger]_{\rm yx}\frac{\kappa_\Xi^2}{4M_\Xi^2}$
	$[C_{l^2\psi^2H^2}^{(3)}/C_{q^2\psi^2H^2}^{(5)}]_{\rm wxyz}$	$[y_\psi]_{\rm wx}[y_\psi]_{\rm yz}\frac{\kappa_\Xi^2}{2M_\Xi^2};\ \psi=u,d,e$
	$[C_{lequH^2}^{(1)}]_{\rm wxyz}$	$[y_e]_{\rm wx}[y_u]_{\rm yz}\frac{5\kappa_\Xi^2}{2M_\Xi^2}$
	$[C_{leqdH^2}^{(1)}]_{\rm wxyz}$	$[y_e]_{\rm wx}[y_d^\dagger]_{\rm yz}\frac{5\kappa_\Xi^2}{2M_\Xi^2}$
	$[C_{q^2udH^2}^{(1)}]_{\rm wxyz}$	$-[y_u]_{\rm wx}[y_d]_{\rm yz}\frac{5\kappa_\Xi^2}{2M_\Xi^2}$
	$[C_{lequH^2}^{(2)}]_{\rm wxyz}$	$[y_e]_{\rm wx}[y_u]_{\rm yz}\frac{\kappa_\Xi^2}{2M_\Xi^2}$
	$[C_{leqdH^2}^{(2)}]_{\rm wxyz}$	$-[y_e]_{\rm wx}[y_d^\dagger]_{\rm yz}\frac{\kappa_\Xi^2}{2M_\Xi^2}$
	$[C_{q^2udH^2}^{(2)}]_{\rm wxyz}$	$[y_u]_{\rm wx}[y_d]_{\rm yz}\frac{\kappa_\Xi^2}{2M_\Xi^2}$
	$[C_{lequH^2}^{(5)}]_{\rm wxyz}$	$[y_e]_{\rm wx}[y_u^\dagger]_{\rm yz}\frac{\kappa_\Xi^2}{M_\Xi^2}$
	$[C_{leqdH^2}^{(3)}]_{\rm wxyz}$	$[y_e]_{\rm wx}[y_d]_{\rm yz}\frac{\kappa_\Xi^2}{M_\Xi^2}$
	$[C_{q^2udH^2}^{(5)}]_{\rm wxyz}$	$[y_d]_{\rm wx}[y_u^\dagger]_{\rm yz}\frac{\kappa_\Xi^2}{M_\Xi^2}$
	$[C_{l\psi H^3D^2}^{(2)}/C_{q\psi H^3D^2}^{(2)}]_{\rm wx}$	$-[y_\psi]_{\rm wx}\frac{4\kappa_\Xi^2}{M_\Xi^2};\ \psi=u,d,e$