Linear Standard Model extensions in the SMEFT at one loop and Tera-Z

Based on arXiv: 2412.01759

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In collaboration with John Gargalionis, Jérémie Quevillon and Tevong You

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Outline of this talk

- EFT paradigms: Bottom-up and Top-down approach
- Top-down approach: Mapping linear SM extensions to the SMEFT at one-loop => sensitivity to new physics at Tera-Z factory at FCC-ee

EFT Paradigms: Bottom-up approach

- Effective Field Theories (EFTs):
  - Without knowledge of UV-complete theory, any QFT is just an EFT
  - Use effective operators to parametrise new physics at higher energy scale

- Possible EFT deformation: The Standard Model Effective Field Theory (SMEFT)

#Assumptions: SM fields only, SM gauge symmetries are linear-realised, defined in unbroken phase

$$\mathcal{L}^{EFT} = \mathcal{L}^{SM}_{d=4} + \sum_{d,\ i} \frac{c_i}{\Lambda^{d-4}} \mathcal{O}^i_{d>4}$$

Wilson coefficients

Encapsulate effect of new physics

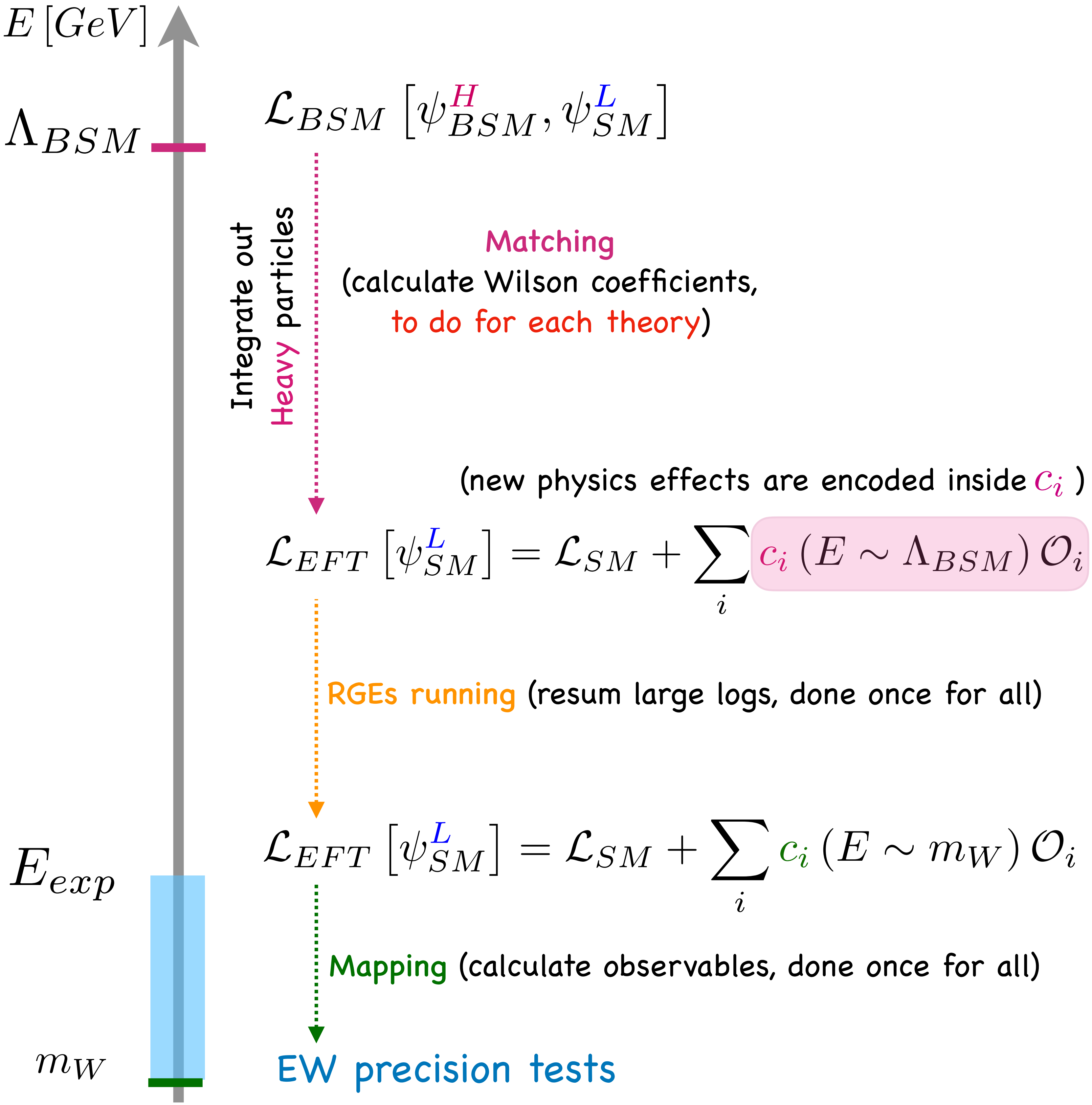
Cut-off energy scale

Non-renormalizable operators

Made up of gauge-invariant combination of SM fields

- Main goals:
  - Compare with physical observables: Higgs measurments, Electroweak precision tests, ...
  - Once deviation with SM => BSM theory

EFT Paradigms: Top-down Approach



$E\,[GeV]$

Λ_{BSM}

$$\mathcal{L}_{BSM}\left[\psi^{H}_{BSM}, \psi^{L}_{SM}\right]$$

Integrate out Heavy particles

Matching
(calculate Wilson coefficients,
to do for each theory)

(new physics effects are encoded inside c_i)

$$\mathcal{L}_{EFT}\left[\psi^{L}_{SM}\right] = \mathcal{L}_{SM} + \sum_i \boxed{c_i\left(E \sim \Lambda_{BSM}\right)\mathcal{O}_i}$$

RGEs running (resum large logs, done once for all)

E_{exp}

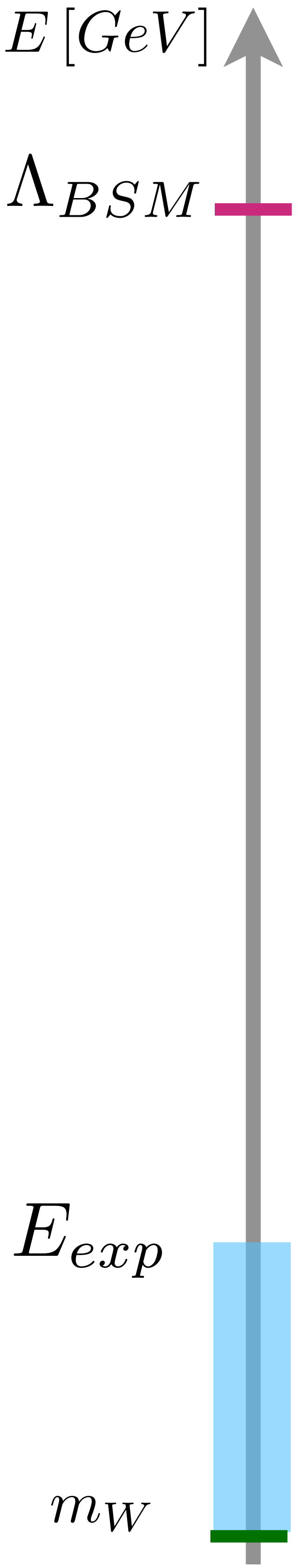
$$\mathcal{L}_{EFT}\left[\psi^{L}_{SM}\right] = \mathcal{L}_{SM} + \sum_i c_i\left(E \sim m_W\right)\mathcal{O}_i$$

Mapping (calculate observables, done once for all)

m_W

EW precision tests

EFT Paradigms: Top-down Approach



Back to 2014-2020, one-loop matching is mainly carried out by Functional matching method

B. Henning, X. Lu, H. Murayama [1412.1837]

Universal One-Loop Effective Action (UOLEA) results

A. Drozd, J. Ellis, J. Quevillon, T. You [1512.03003]

S. A. R. Ellis, J. Quevillon, T. You, Z. Zhang [1706.07765]

S.A.R. Ellis, J. Quevillon, P.N.H. Vuong, T. You, Z. Zhang [2006.16260]

- CoDeX (UOLEA results)

Das Bakshi, Chakrabortty, Patra [1808.04403]

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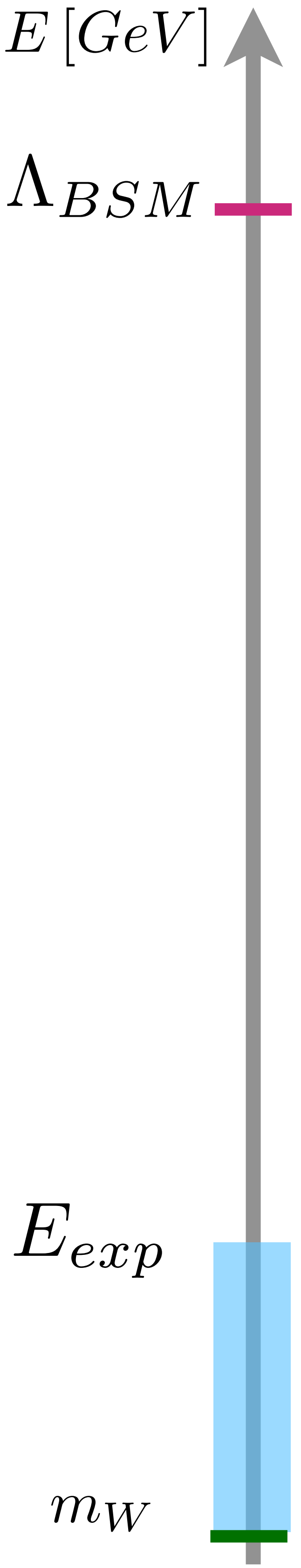
Mapping (calculate observables, done once for all)

EW precision tests

EFT Paradigms: Top-down Approach



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- CoDeX (UOLEA results)

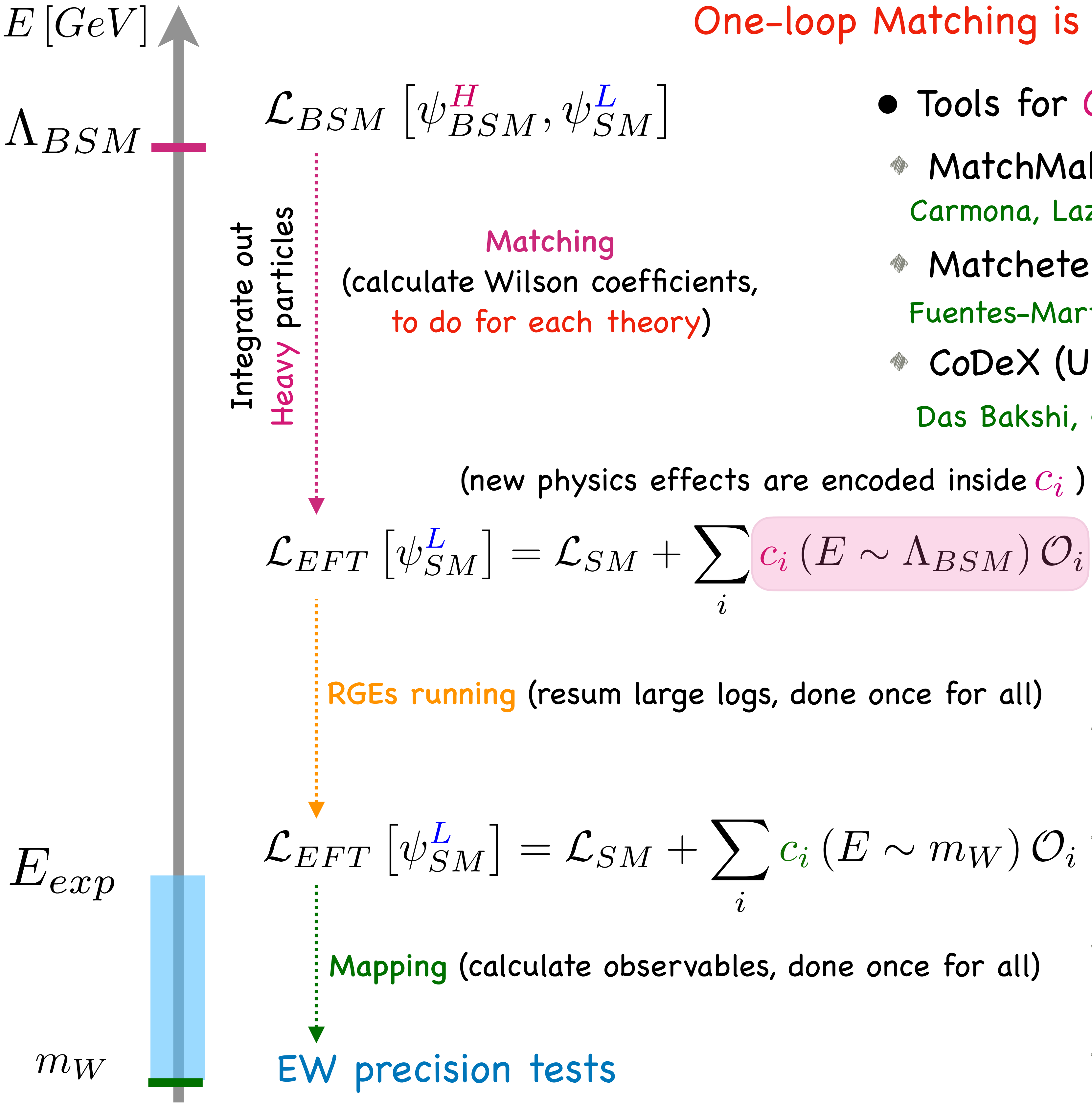
Das Bakshi, Chakrabortty, Patra [1808.04403]

However,

NO realistic automation tools for Loop Matching!

EFT Paradigms: Top-down Approach

One-loop Matching is fully automatised just 3 years ago!



$$\mathcal{L}_{BSM}\left[\psi^H_{BSM}, \psi^L_{SM}\right]$$

Integrate out
Heavy particles

Matching
(calculate Wilson coefficients,
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(new physics effects are encoded inside c_i)

$$\mathcal{L}_{EFT}\left[\psi^L_{SM}\right] = \mathcal{L}_{SM} + \sum_i \boxed{c_i\left(E \sim \Lambda_{BSM}\right)\mathcal{O}_i}$$

RGEs running (resum large logs, done once for all)

$$\mathcal{L}_{EFT}\left[\psi^L_{SM}\right] = \mathcal{L}_{SM} + \sum_i c_i\left(E \sim m_W\right)\mathcal{O}_i$$

Mapping (calculate observables, done once for all)

EW precision tests

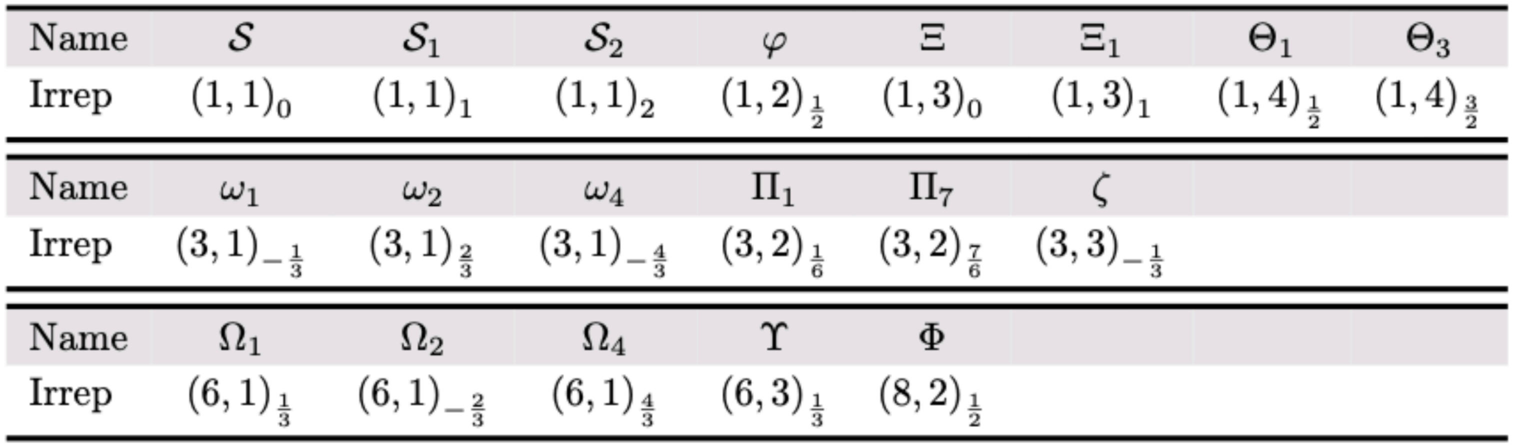
- Tools for One-loop Matching & Running
  - MatchMakerEFT (Feynman diagram)
    Carmona, Lazopoulos, Olgoso, Santiago [2112.10787]
  - Matchete (functional method)
    Fuentes-Martín, Konig, Pagès, Thomsen, Wilsch [2212.04510]
  - CoDeX (UOLEA results)
    Das Bakshi, Chakrabortty, Patra [1808.04403]

- Tools for Mapping
  - Fitmaker
    Ellis, Madigan, Mimasu, Sanz, You [2012.02779]
  - SMEFiT
    Giani, Magni, Rojo [2302.06660]
  - Flavio
    D.M. Straub [1810.08132]
  - Smelli
    P. Stangl [2012.12211]

Linear Standard Model extensions

- Granada dictionary: de Blas, Criado, Pérez-Victoria, Santiago [1711.10391]
  - 32 exotic multiplets (considering scalars and fermions only)
  - Since we will consider loop effects, vector fields extensions are ignored at the moment

- Scalar extensions:

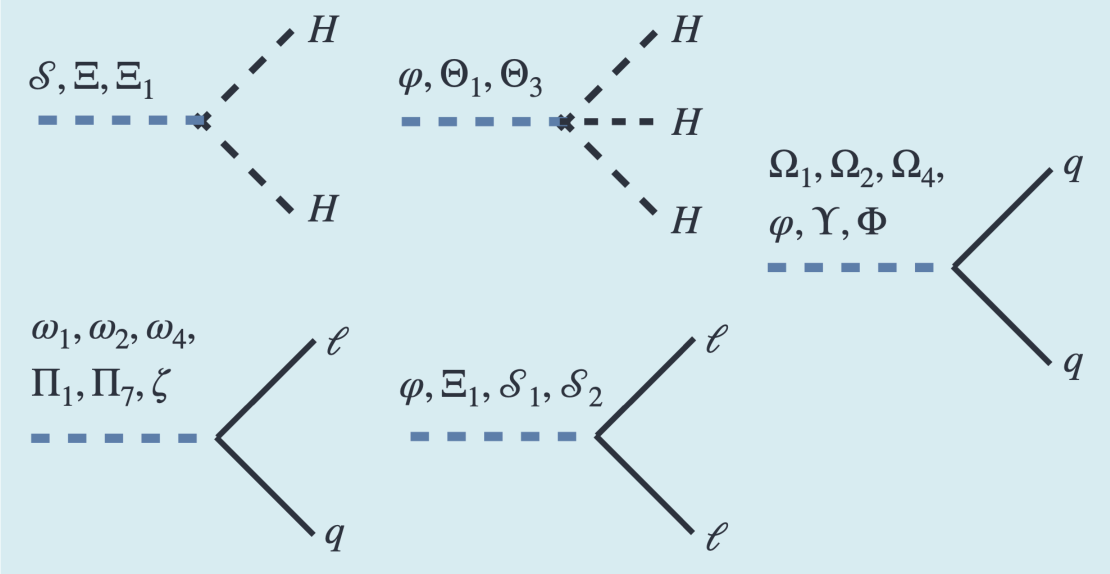


Name	$\mathcal{S}$	$\mathcal{S}_1$	$\mathcal{S}_2$	φ	Ξ	Ξ_1	Θ_1	Θ_3
Irrep	$(1,1)_0$	$(1,1)_1$	$(1,1)_2$	$(1,2)_{\frac{1}{2}}$	$(1,3)_0$	$(1,3)_1$	$(1,4)_{\frac{1}{2}}$	$(1,4)_{\frac{3}{2}}$

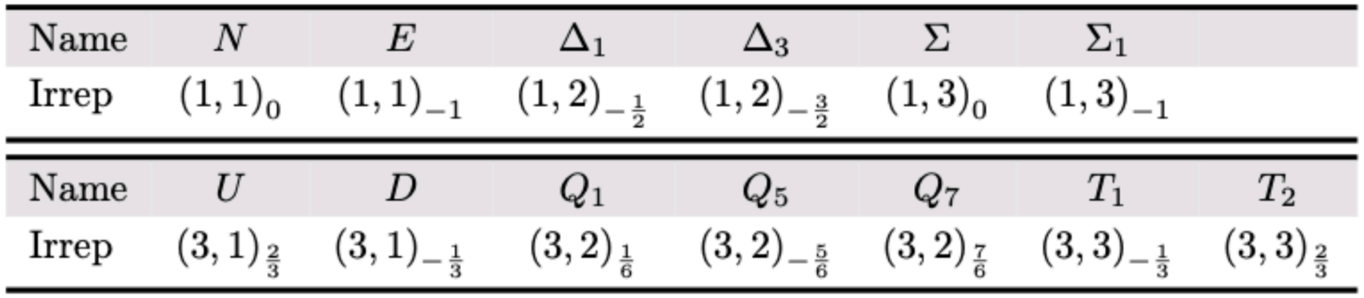
Name	ω_1	ω_2	ω_4	Π_1	Π_7	ζ
Irrep	$(3,1)_{-\frac{1}{3}}$	$(3,1)_{\frac{2}{3}}$	$(3,1)_{-\frac{4}{3}}$	$(3,2)_{\frac{1}{6}}$	$(3,2)_{\frac{7}{6}}$	$(3,3)_{-\frac{1}{3}}$

Name	Ω_1	Ω_2	Ω_4	Υ	Φ
Irrep	$(6,1)_{\frac{1}{3}}$	$(6,1)_{-\frac{2}{3}}$	$(6,1)_{\frac{4}{3}}$	$(6,3)_{\frac{1}{3}}$	$(8,2)_{\frac{1}{2}}$

Table 1. New scalar bosons contributing to the dimension-six SMEFT at tree level.



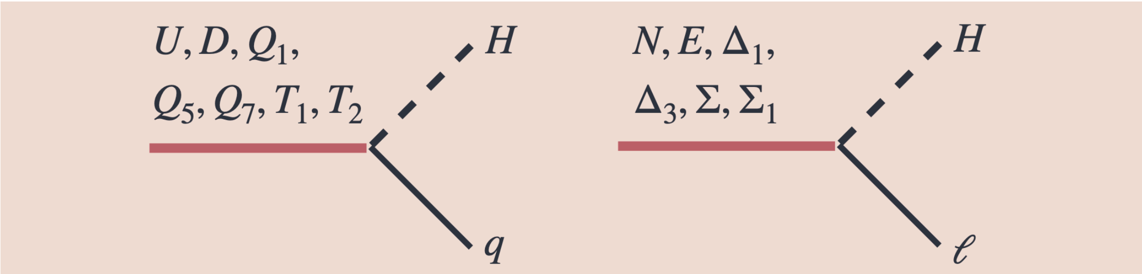
- Fermion extensions:



Name	N	E	Δ_1	Δ_3	Σ	Σ_1
Irrep	$(1,1)_0$	$(1,1)_{-1}$	$(1,2)_{-\frac{1}{2}}$	$(1,2)_{-\frac{3}{2}}$	$(1,3)_0$	$(1,3)_{-1}$

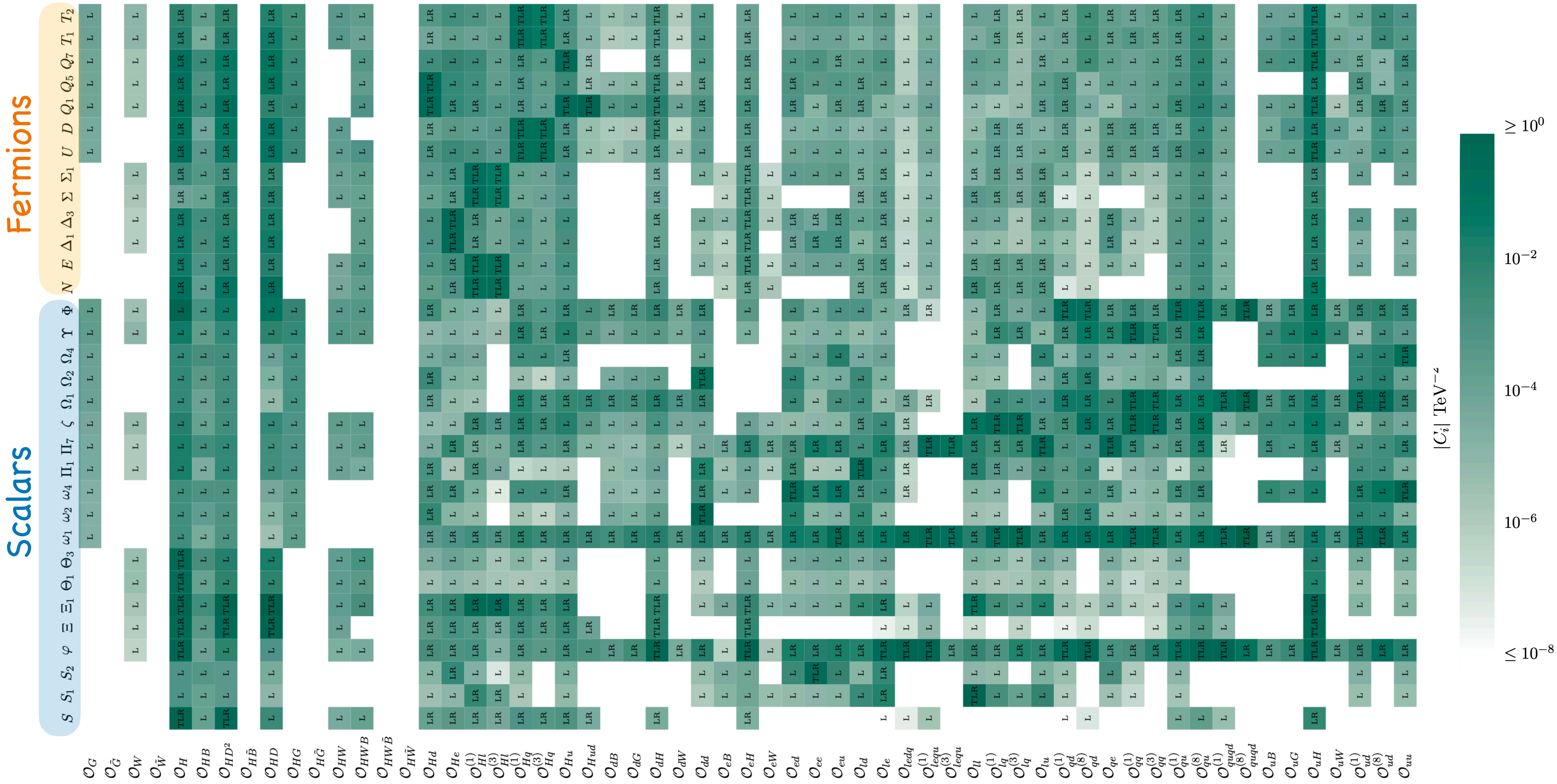
Name	U	D	Q_1	Q_5	Q_7	T_1	T_2
Irrep	$(3,1)_{\frac{2}{3}}$	$(3,1)_{-\frac{1}{3}}$	$(3,2)_{\frac{1}{6}}$	$(3,2)_{-\frac{5}{6}}$	$(3,2)_{\frac{7}{6}}$	$(3,3)_{-\frac{1}{3}}$	$(3,3)_{\frac{2}{3}}$

Table 2. New vector-like fermions contributing to the dimension-six SMEFT at tree level.



- **T**: Tree-lvl generated
- **L**: One-loop generated
- **R**: RGEs induced

- Full results are published in our GitHub repo
- Each entry is clickable and importable in Python with Isme package



Further detail see Ref. 2412.01759

Matching ⇢ RGEs running

See also G. Guedes, P. Olgoso for UV/IR one-loop dictionary [2412.14253]

- **T**: Tree-lvl generated
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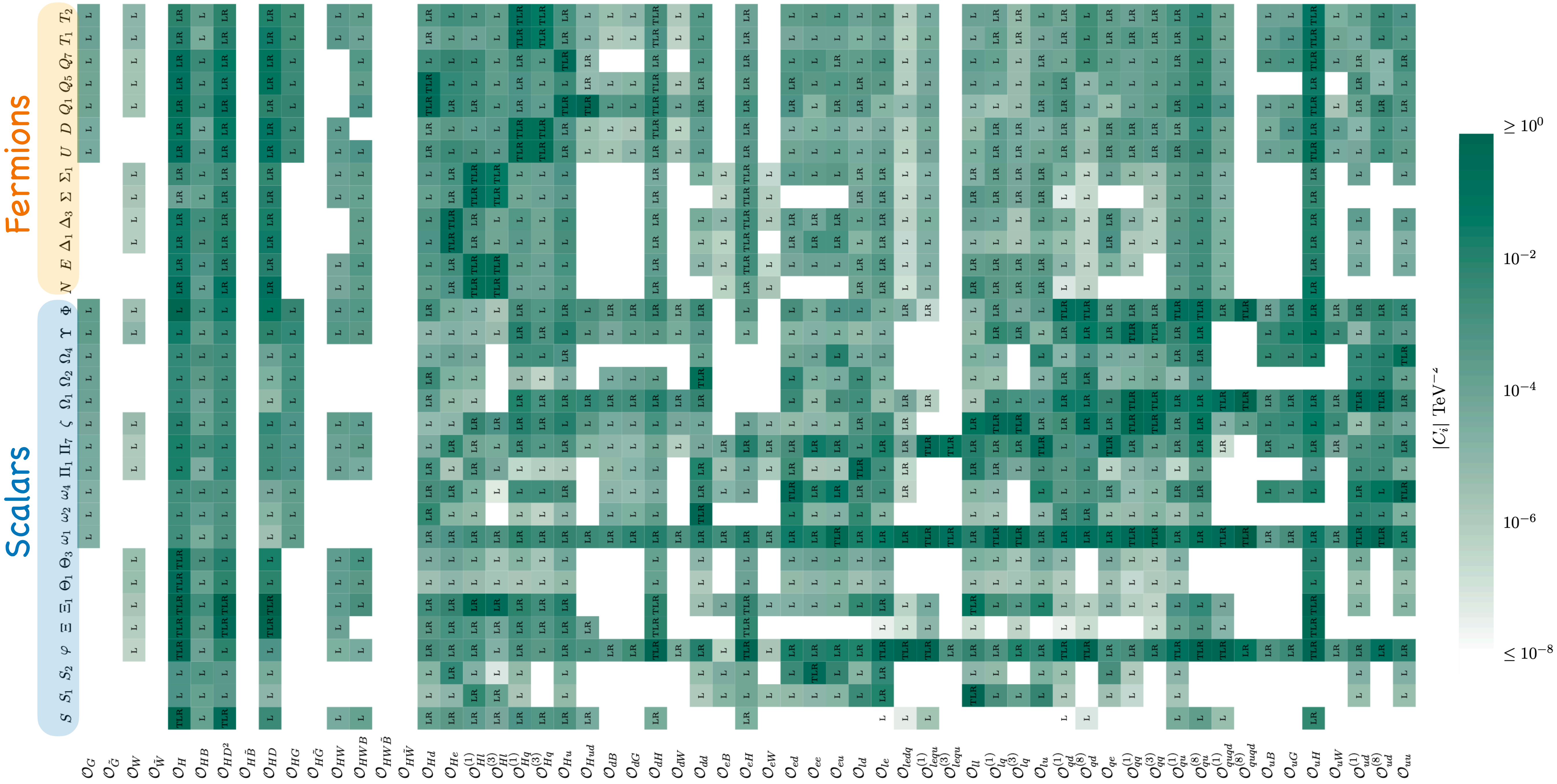
- **R**: RGEs induced

Assumptions:

- All new physics couplings set to 1
- All dimensionful UV parameters set to 1 TeV
- Only one multiplet studied at a time



Matching ⋯⋯→ RGEs running

Further detail see Ref. 2412.01759

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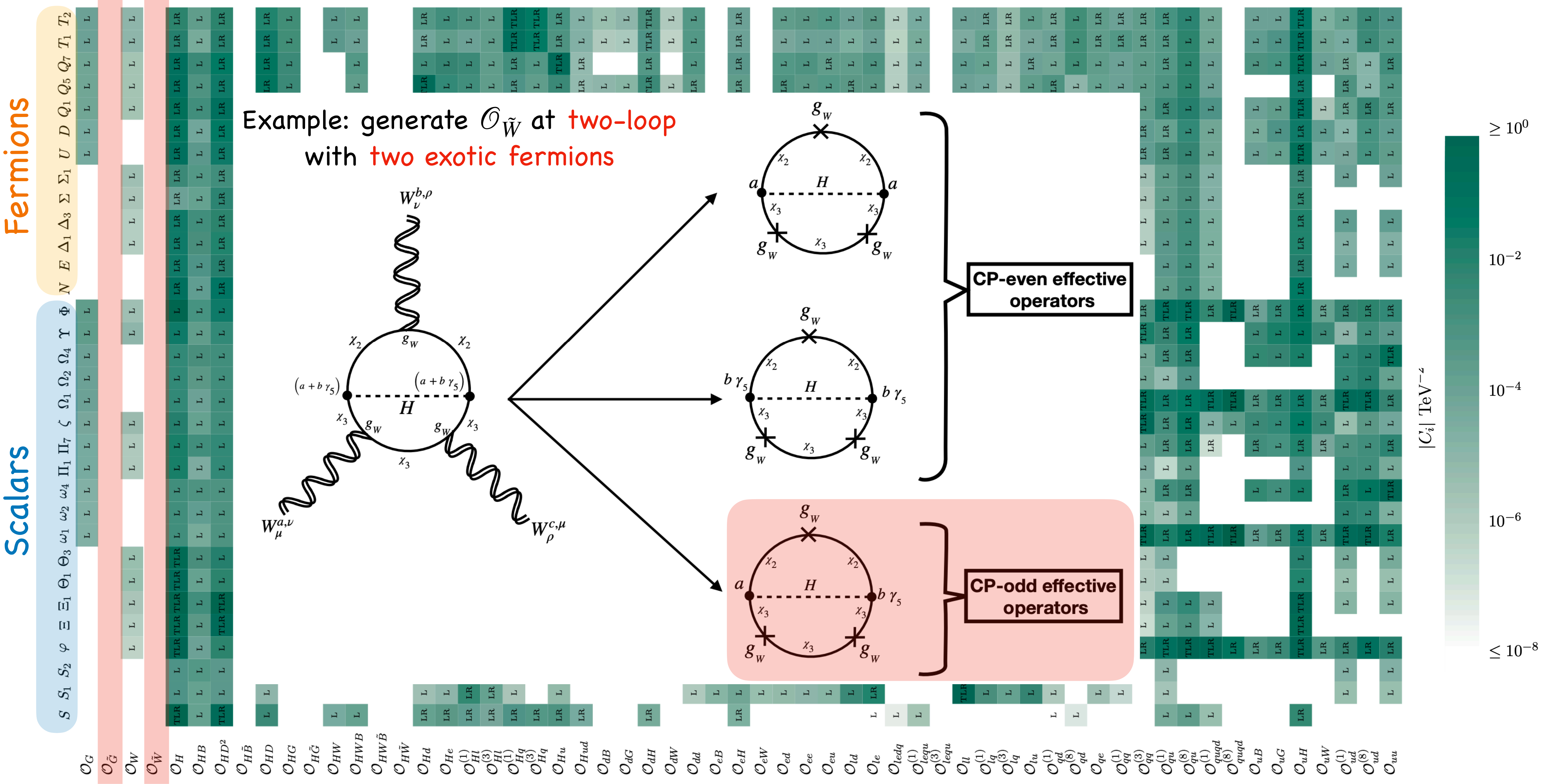
CP-odd Triple-Gauge operators not generated at one-loop (general proof from UOLEA results)

S.A.R. Ellis, J. Quevillon, P.N.H. Vuong, T. You, Z. Zhang [2006.16260]



Example: generate $\mathcal{O}_{\tilde{W}}$ at two-loop with two exotic fermions

CP-even effective operators

CP-odd effective operators

Matching ⋯⋯→ RGEs running

Bakshi, Chakrabortty, Englert, Spannowsky, Stylianou [2103.15861]

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- **L**: One-loop generated
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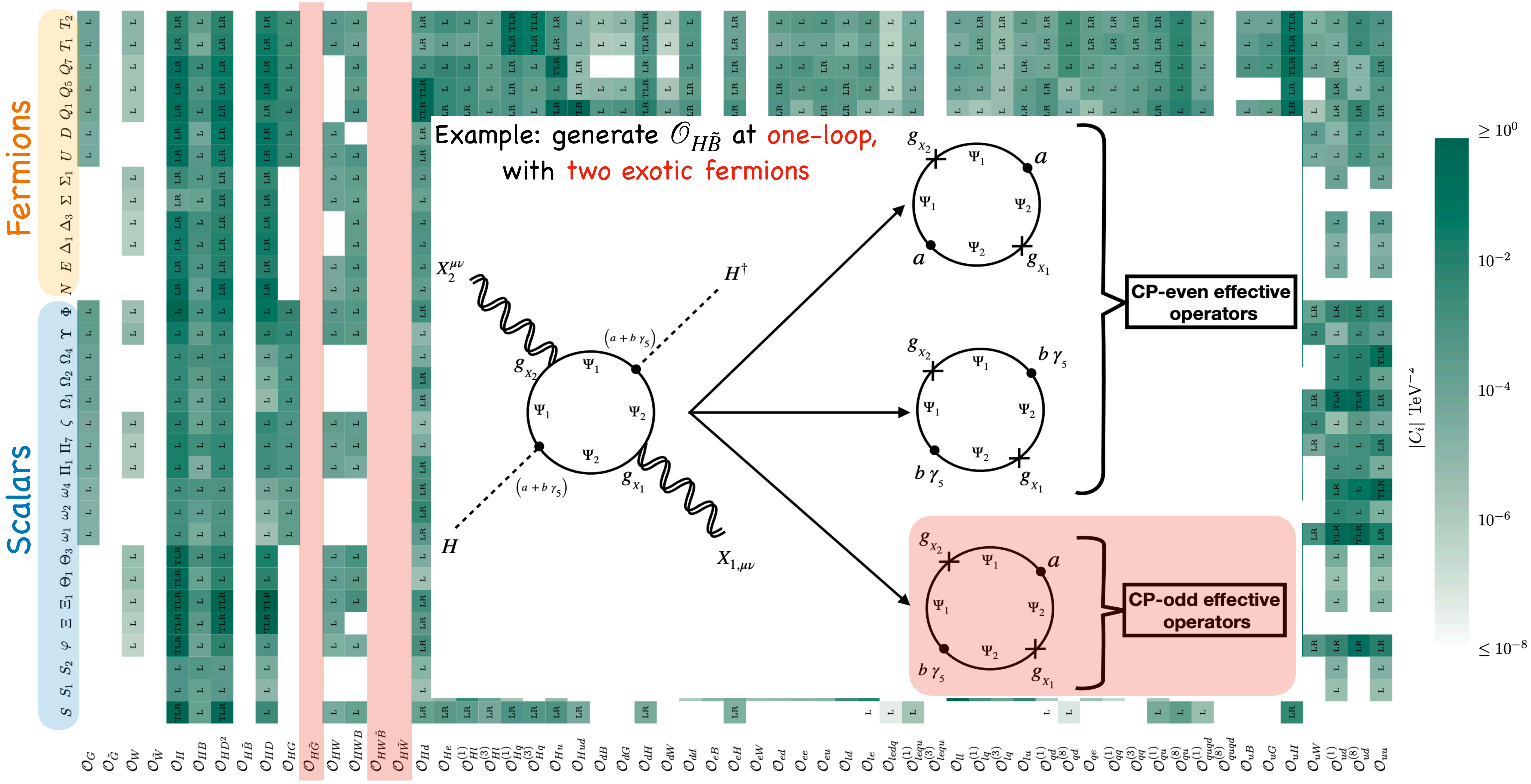
Other CP-odd bosonic operators can be generated at one-loop, Require two fields extensions



Example: generate $\mathcal{O}_{H\tilde{B}}$ at one-loop, with two exotic fermions

CP-even effective operators

CP-odd effective operators

Matching ⟶ RGEs running

Bakshi, Chakrabortty, Englert, Spannowsky, Stylianou [2103.15861]

Electroweak precision observables (EWPOs)

- **EWPOs** at the **Z-pole**:

$$\{\Gamma_Z,\, \sigma^0_{\text{had}},\, R^0_l\,,\, A_l\,,\, R^0_b\,,\, A^b_{FB}\}$$

- 10 operators contributing to these EWPOs at leading order in the SMEFT:

$$\left\{\mathcal{O}_{HWB},\, \mathcal{O}_{HD},\, \mathcal{O}_{ll},\, \mathcal{O}^{(3)}_{Hl},\, \mathcal{O}^{(1)}_{Hl},\, \mathcal{O}_{He},\, \mathcal{O}^{(3)}_{Hq},\, \mathcal{O}^{(1)}_{Hq},\, \mathcal{O}_{Hu},\, \mathcal{O}_{Hd}\right\}$$

Matching ⋯⋯▸ RGEs running ⋯⋯▸ Mapping

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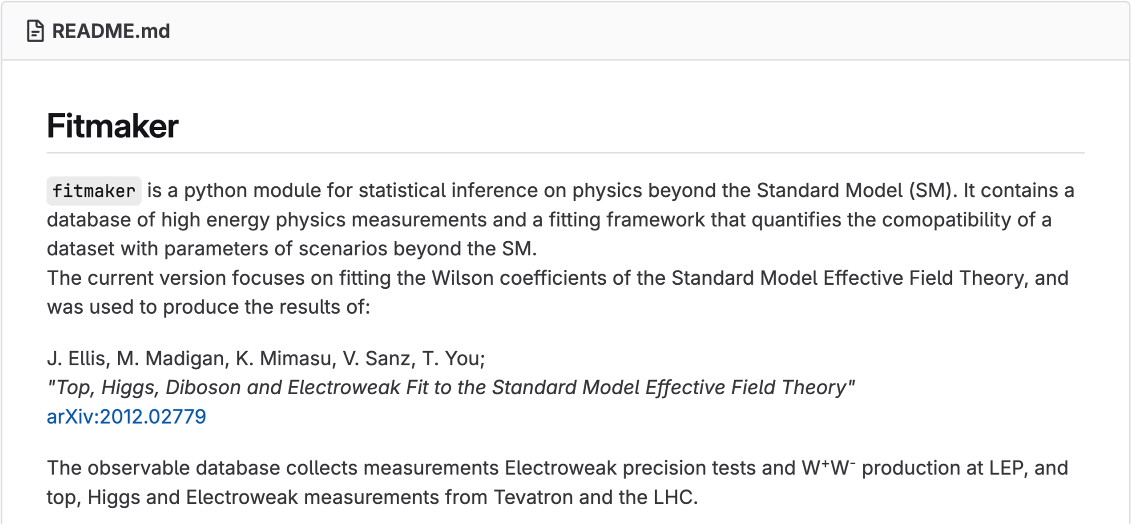
UV models matched on SMEFT via MatchMakerEFT



README.md

Fitmaker

`fitmaker` is a python module for statistical inference on physics beyond the Standard Model (SM). It contains a database of high energy physics measurements and a fitting framework that quantifies the comopatibility of a dataset with parameters of scenarios beyond the SM.
The current version focuses on fitting the Wilson coefficients of the Standard Model Effective Field Theory, and was used to produce the results of:

J. Ellis, M. Madigan, K. Mimasu, V. Sanz, T. You;
"Top, Higgs, Diboson and Electroweak Fit to the Standard Model Effective Field Theory"
arXiv:2012.02779

The observable database collects measurements Electroweak precision tests and W^+W^- production at LEP, and top, Higgs and Electroweak measurements from Tevatron and the LHC.

Projected bounds on linear SM extensions at one-loop

J. Ellis, M. Madigan, K. Mimasu, V. Sanz, T. You [2012.02779]

MatchMakerParser package: translate the matching results (Mathematica expressions) from MatchMakerEFT into a Python class

Matching → RGEs running → Mapping

Further detail see Ref. 2412.01759

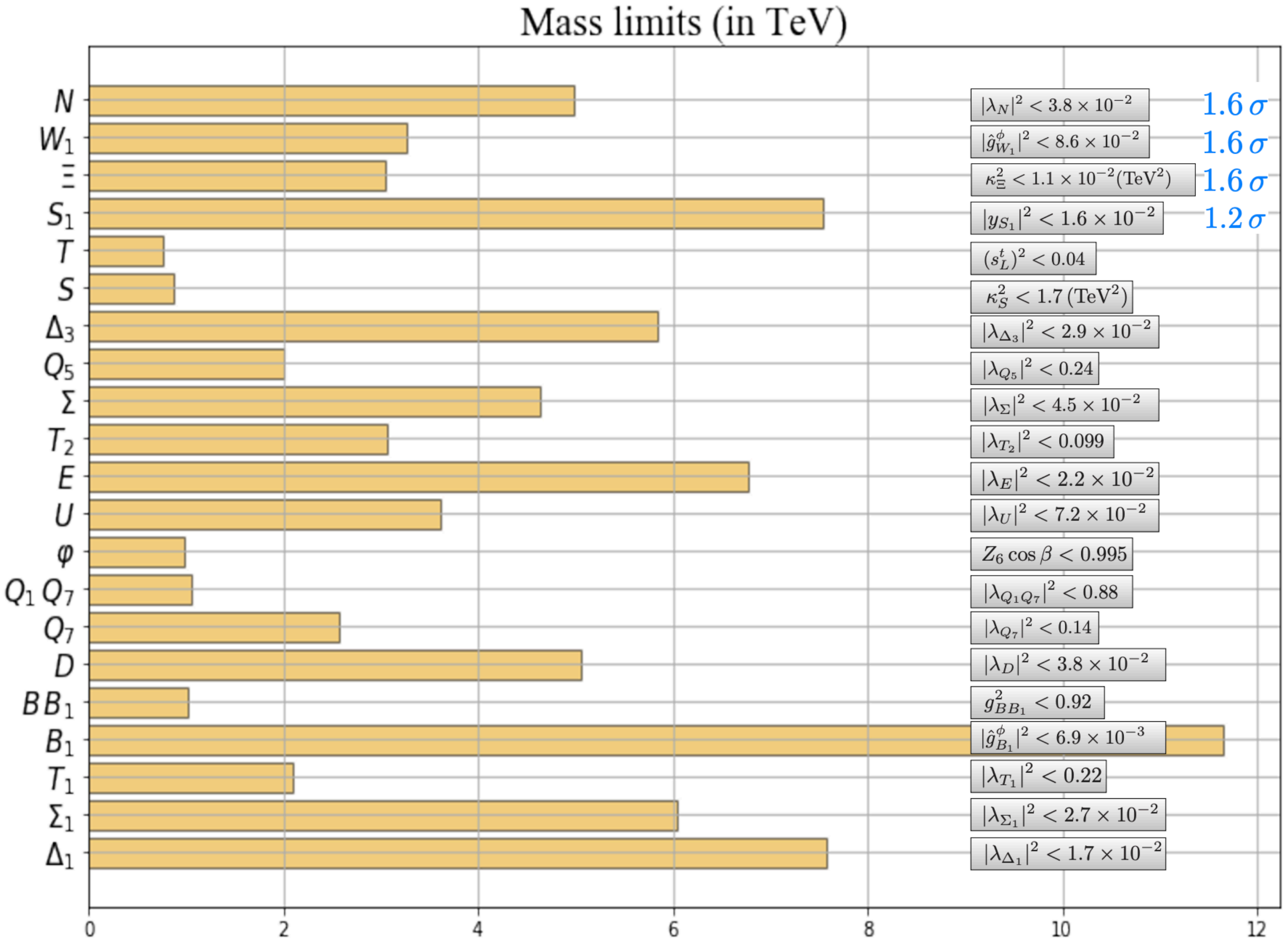
Electroweak precision observables (EWPOs)

At tree-level

Only 16 out of 32 exotic multiplets (scalar & fermion) are constrained by EWPOs

Model	C_{HD}	C_{ll}	C^3_{Hl}	C^1_{Hl}	C_{He}	$C_{H\Box}$	$C_{\tau H}$	C_{tH}	C_{bH}
S						$-\frac{1}{2}$			
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			$-\frac{1}{4}$	$-\frac{1}{4}$			$\frac{y_\tau}{2}$		
Δ_1					$\frac{1}{2}$		$\frac{y_\tau}{2}$		
Δ_3					$-\frac{1}{2}$		$\frac{y_\tau}{2}$		
B_1	1					$-\frac{1}{2}$	$-\frac{y_\tau}{2}$	$-\frac{y_t}{2}$	$-\frac{y_b}{2}$
Ξ	-2					$\frac{1}{2}$	y_τ	y_t	y_b
W_1	$-\frac{1}{4}$					$-\frac{1}{8}$	$-\frac{y_\tau}{8}$	$-\frac{y_t}{8}$	$-\frac{y_b}{8}$
φ							$-y_\tau$	$-y_t$	$-y_b$
$\{B, B_1\}$						$-\frac{3}{2}$	$-\ y_\tau$	$-\ y_t$	$-\ y_b$
$\{Q_1, Q_7\}$								y_t	

Model	C^3_{Hq}	C^1_{Hq}	$(C^3_{Hq})_{33}$	$(C^1_{Hq})_{33}$	C_{Hu}	C_{Hd}	C_{tH}	C_{bH}	
U	$-\frac{1}{4}$	$\frac{1}{4}$	$-\frac{1}{4}$	$\frac{1}{4}$			$\frac{y_t}{2}$		
D	$-\frac{1}{4}$	$-\frac{1}{4}$	$-\frac{1}{4}$	$-\frac{1}{4}$				$\frac{y_b}{2}$	
Q_5						$-\frac{1}{2}$		$\frac{y_b}{2}$	
Q_7					$\frac{1}{2}$		$\frac{y_t}{2}$		
T_1	$-\frac{1}{16}$	$-\frac{3}{16}$	$-\frac{1}{16}$	$-\frac{3}{16}$			$\frac{y_t}{4}$	$\frac{y_b}{8}$	
T_2	$-\frac{1}{16}$	$\frac{3}{16}$	$-\frac{1}{16}$	$\frac{3}{16}$			$\frac{y_t}{8}$	$\frac{y_b}{4}$	
T			$-\frac{1}{2}\frac{M_T^2}{v^2}$	$\frac{1}{2}\frac{M_T^2}{v^2}$			$y_t\frac{M_T^2}{v^2}$		



Matching ⟶ RGEs running ⟶ Mapping

J. Ellis, M. Madigan, K. Mimasu, V. Sanz, T. You [2012.02779]

- **T**: Tree-lvl generated
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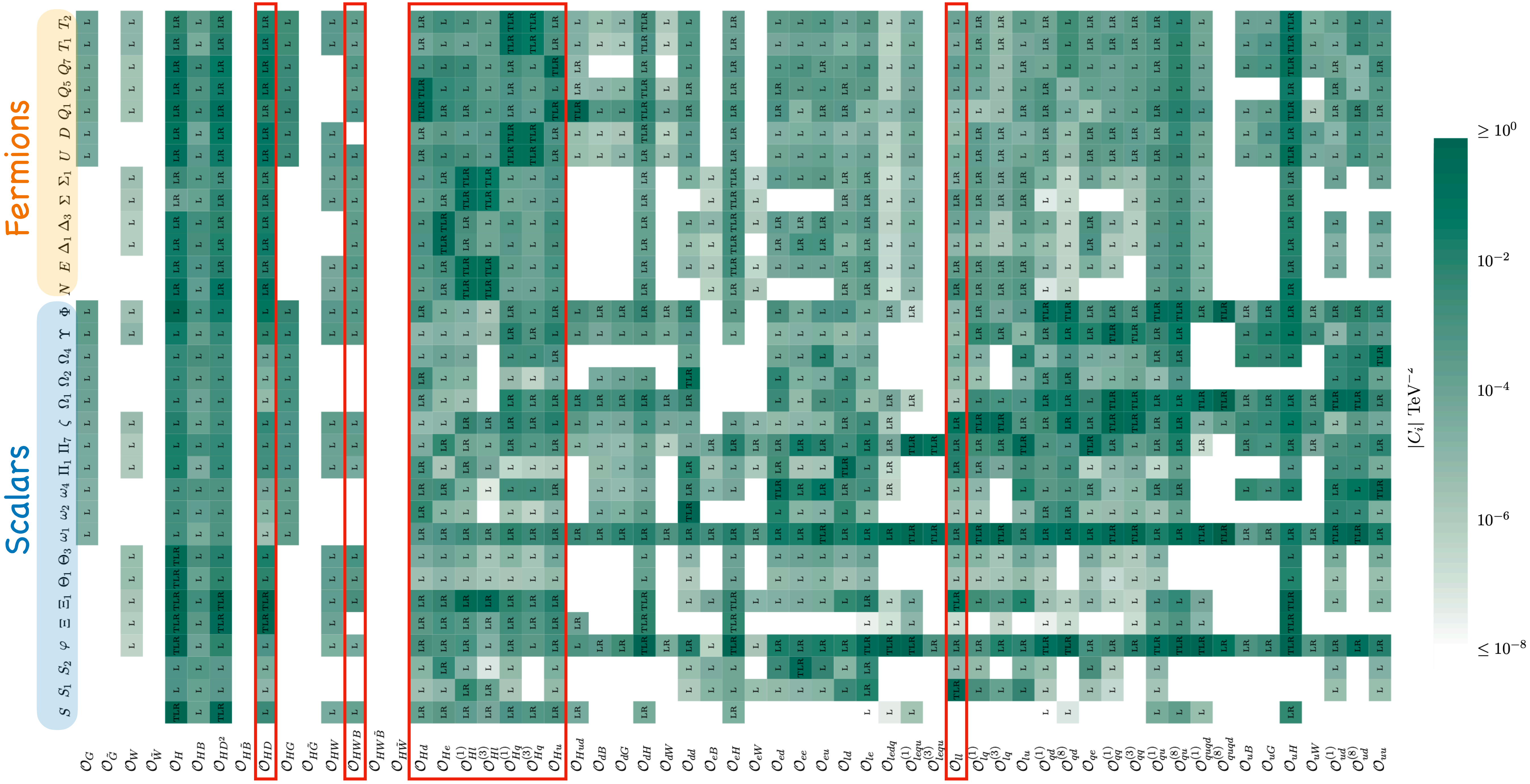
At one-loop order

All Linear SM extensions can be probed by Z-pole at FCC-ee



Operators contributing to EWPOs

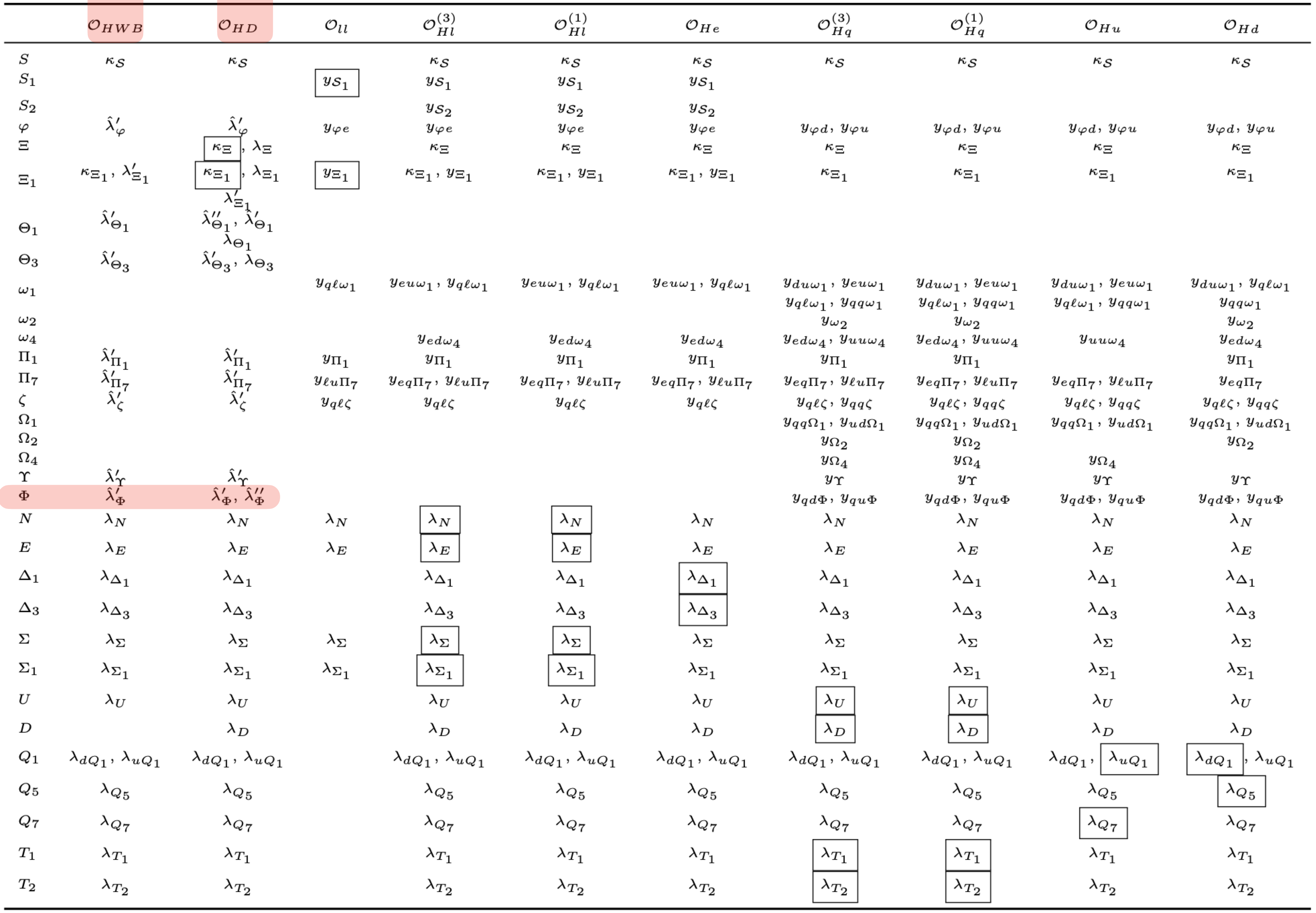
Matching ⟶ RGEs running ⟶ Mapping

Electroweak precision observables (EWPOs)

- **EWPOs** at the **Z-pole**:

Example: which model received stronger constrains from finite one-loop matching?

S and T parameters



	$\mathcal{O}_{HWB}$	$\mathcal{O}_{HD}$	$\mathcal{O}_{ll}$	$\mathcal{O}_{Hl}^{(3)}$	$\mathcal{O}_{Hl}^{(1)}$	$\mathcal{O}_{He}$	$\mathcal{O}_{Hq}^{(3)}$	$\mathcal{O}_{Hq}^{(1)}$	$\mathcal{O}_{Hu}$	$\mathcal{O}_{Hd}$
S	κ_S	κ_S		κ_S	κ_S	κ_S	κ_S	κ_S	κ_S	κ_S
S_1			$\boxed{y_{S_1}}$	y_{S_1}	y_{S_1}	y_{S_1}				
S_2				y_{S_2}	y_{S_2}	y_{S_2}				
φ	$\hat{\lambda}'_\varphi$	$\hat{\lambda}'_\varphi$	$y_{\varphi e}$	$y_{\varphi e}$	$y_{\varphi e}$	$y_{\varphi e}$	$y_{\varphi d}$, $y_{\varphi u}$	$y_{\varphi d}$, $y_{\varphi u}$	$y_{\varphi d}$, $y_{\varphi u}$	$y_{\varphi d}$, $y_{\varphi u}$
Ξ		$\boxed{\kappa_\Xi}$, λ_Ξ		κ_Ξ	κ_Ξ	κ_Ξ	κ_Ξ	κ_Ξ	κ_Ξ	κ_Ξ
Ξ_1	κ_{Ξ_1}, λ'_{Ξ_1}	$\boxed{\kappa_{\Xi_1}}$, λ_{Ξ_1} λ'_{Ξ_1}	$\boxed{y_{\Xi_1}}$	κ_{Ξ_1}, y_{Ξ_1}	κ_{Ξ_1}, y_{Ξ_1}	κ_{Ξ_1}, y_{Ξ_1}	κ_{Ξ_1}	κ_{Ξ_1}	κ_{Ξ_1}	κ_{Ξ_1}
Θ_1	$\hat{\lambda}'_{\Theta_1}$	$\hat{\lambda}''_{\Theta_1}$, $\hat{\lambda}'_{\Theta_1}$ λ_{Θ_1}								
Θ_3	$\hat{\lambda}'_{\Theta_3}$	$\hat{\lambda}'_{\Theta_3}$, λ_{Θ_3}								
ω_1			$y_{q\ell\omega_1}$	$y_{eu\omega_1}$, $y_{q\ell\omega_1}$	$y_{eu\omega_1}$, $y_{q\ell\omega_1}$	$y_{eu\omega_1}$, $y_{q\ell\omega_1}$	$y_{du\omega_1}$, $y_{eu\omega_1}$ $y_{q\ell\omega_1}$, $y_{qq\omega_1}$	$y_{du\omega_1}$, $y_{eu\omega_1}$ $y_{q\ell\omega_1}$, $y_{qq\omega_1}$	$y_{du\omega_1}$, $y_{eu\omega_1}$ $y_{q\ell\omega_1}$, $y_{qq\omega_1}$	$y_{du\omega_1}$, $y_{q\ell\omega_1}$ $y_{qq\omega_1}$
ω_2							y_{ω_2}	y_{ω_2}		y_{ω_2}
ω_4				$y_{ed\omega_4}$	$y_{ed\omega_4}$	$y_{ed\omega_4}$	$y_{ed\omega_4}$, $y_{uu\omega_4}$	$y_{ed\omega_4}$, $y_{uu\omega_4}$	$y_{uu\omega_4}$	$y_{ed\omega_4}$
Π_1	$\hat{\lambda}'_{\Pi_1}$	$\hat{\lambda}'_{\Pi_1}$	y_{Π_1}	y_{Π_1}	y_{Π_1}	y_{Π_1}	y_{Π_1}	y_{Π_1}		y_{Π_1}
Π_7	$\hat{\lambda}'_{\Pi_7}$	$\hat{\lambda}'_{\Pi_7}$	$y_{\ell u\Pi_7}$	$y_{eq\Pi_7}$, $y_{\ell u\Pi_7}$	$y_{eq\Pi_7}$, $y_{\ell u\Pi_7}$	$y_{eq\Pi_7}$, $y_{\ell u\Pi_7}$	$y_{eq\Pi_7}$, $y_{\ell u\Pi_7}$	$y_{eq\Pi_7}$, $y_{\ell u\Pi_7}$	$y_{eq\Pi_7}$, $y_{\ell u\Pi_7}$	$y_{eq\Pi_7}$
ζ	$\hat{\lambda}'_\zeta$	$\hat{\lambda}'_\zeta$	$y_{q\ell\zeta}$	$y_{q\ell\zeta}$	$y_{q\ell\zeta}$	$y_{q\ell\zeta}$	$y_{q\ell\zeta}$, $y_{qq\zeta}$	$y_{q\ell\zeta}$, $y_{qq\zeta}$	$y_{q\ell\zeta}$, $y_{qq\zeta}$	$y_{q\ell\zeta}$, $y_{qq\zeta}$
Ω_1							$y_{qq\Omega_1}$, $y_{ud\Omega_1}$	$y_{qq\Omega_1}$, $y_{ud\Omega_1}$	$y_{qq\Omega_1}$, $y_{ud\Omega_1}$	$y_{qq\Omega_1}$, $y_{ud\Omega_1}$
Ω_2							y_{Ω_2}	y_{Ω_2}		y_{Ω_2}
Ω_4							y_{Ω_4}	y_{Ω_4}	y_{Ω_4}	
Υ	$\hat{\lambda}'_\Upsilon$	$\hat{\lambda}'_\Upsilon$					y_Υ	y_Υ	y_Υ	y_Υ
Φ	$\hat{\lambda}'_\Phi$	$\hat{\lambda}'_\Phi$, $\hat{\lambda}''_\Phi$					$y_{qd\Phi}$, $y_{qu\Phi}$	$y_{qd\Phi}$, $y_{qu\Phi}$	$y_{qd\Phi}$, $y_{qu\Phi}$	$y_{qd\Phi}$, $y_{qu\Phi}$
N	λ_N	λ_N	λ_N	$\boxed{\lambda_N}$	$\boxed{\lambda_N}$	λ_N	λ_N	λ_N	λ_N	λ_N
E	λ_E	λ_E	λ_E	$\boxed{\lambda_E}$	$\boxed{\lambda_E}$	λ_E	λ_E	λ_E	λ_E	λ_E
Δ_1	λ_{Δ_1}	λ_{Δ_1}		λ_{Δ_1}	λ_{Δ_1}	$\boxed{\lambda_{\Delta_1}}$	λ_{Δ_1}	λ_{Δ_1}	λ_{Δ_1}	λ_{Δ_1}
Δ_3	λ_{Δ_3}	λ_{Δ_3}		λ_{Δ_3}	λ_{Δ_3}	$\boxed{\lambda_{\Delta_3}}$	λ_{Δ_3}	λ_{Δ_3}	λ_{Δ_3}	λ_{Δ_3}
Σ	λ_Σ	λ_Σ	λ_Σ	$\boxed{\lambda_\Sigma}$	$\boxed{\lambda_\Sigma}$	λ_Σ	λ_Σ	λ_Σ	λ_Σ	λ_Σ
Σ_1	λ_{Σ_1}	λ_{Σ_1}	λ_{Σ_1}	$\boxed{\lambda_{\Sigma_1}}$	$\boxed{\lambda_{\Sigma_1}}$	λ_{Σ_1}	λ_{Σ_1}	λ_{Σ_1}	λ_{Σ_1}	λ_{Σ_1}
U	λ_U	λ_U		λ_U	λ_U	λ_U	$\boxed{\lambda_U}$	$\boxed{\lambda_U}$	λ_U	λ_U
D		λ_D		λ_D	λ_D	λ_D	$\boxed{\lambda_D}$	$\boxed{\lambda_D}$	λ_D	λ_D
Q_1	λ_{dQ_1}, λ_{uQ_1}	λ_{dQ_1}, λ_{uQ_1}		λ_{dQ_1}, λ_{uQ_1}	λ_{dQ_1}, λ_{uQ_1}	λ_{dQ_1}, λ_{uQ_1}	λ_{dQ_1}, λ_{uQ_1}	λ_{dQ_1}, λ_{uQ_1}	λ_{dQ_1}, $\boxed{\lambda_{uQ_1}}$	$\boxed{\lambda_{dQ_1}}$, λ_{uQ_1}
Q_5	λ_{Q_5}	λ_{Q_5}		λ_{Q_5}	λ_{Q_5}	λ_{Q_5}	λ_{Q_5}	λ_{Q_5}	λ_{Q_5}	$\boxed{\lambda_{Q_5}}$
Q_7	λ_{Q_7}	λ_{Q_7}		λ_{Q_7}	λ_{Q_7}	λ_{Q_7}	λ_{Q_7}	λ_{Q_7}	$\boxed{\lambda_{Q_7}}$	λ_{Q_7}
T_1	λ_{T_1}	λ_{T_1}		λ_{T_1}	λ_{T_1}	λ_{T_1}	$\boxed{\lambda_{T_1}}$	$\boxed{\lambda_{T_1}}$	λ_{T_1}	λ_{T_1}
T_2	λ_{T_2}	λ_{T_2}		λ_{T_2}	λ_{T_2}	λ_{T_2}	$\boxed{\lambda_{T_2}}$	$\boxed{\lambda_{T_2}}$	λ_{T_2}	λ_{T_2}

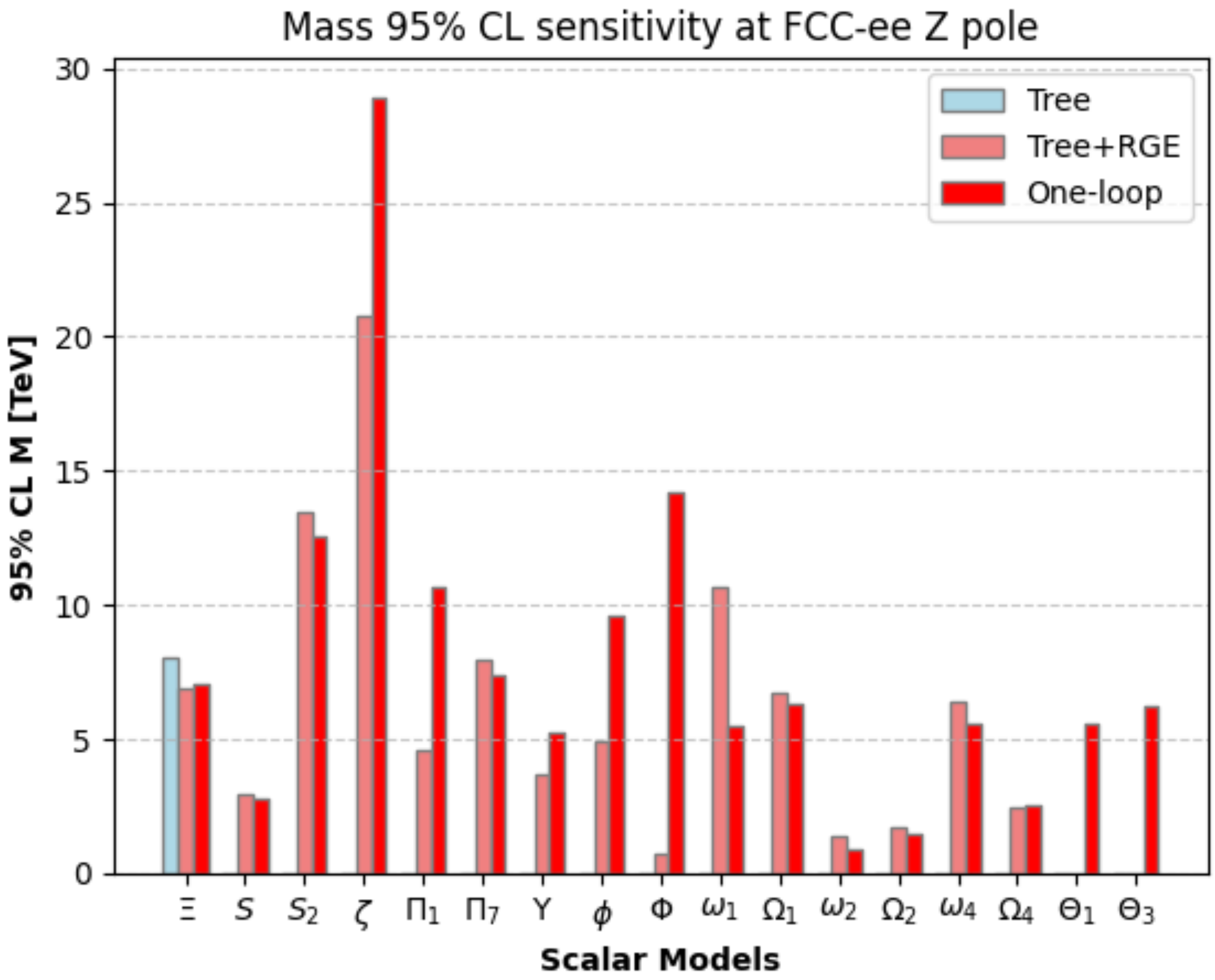
Table 6: The table shows the exotic couplings appearing in the matching expressions for the operators shown. Coupling constants appearing at tree level are shown boxed. Flavour indices have been suppressed.

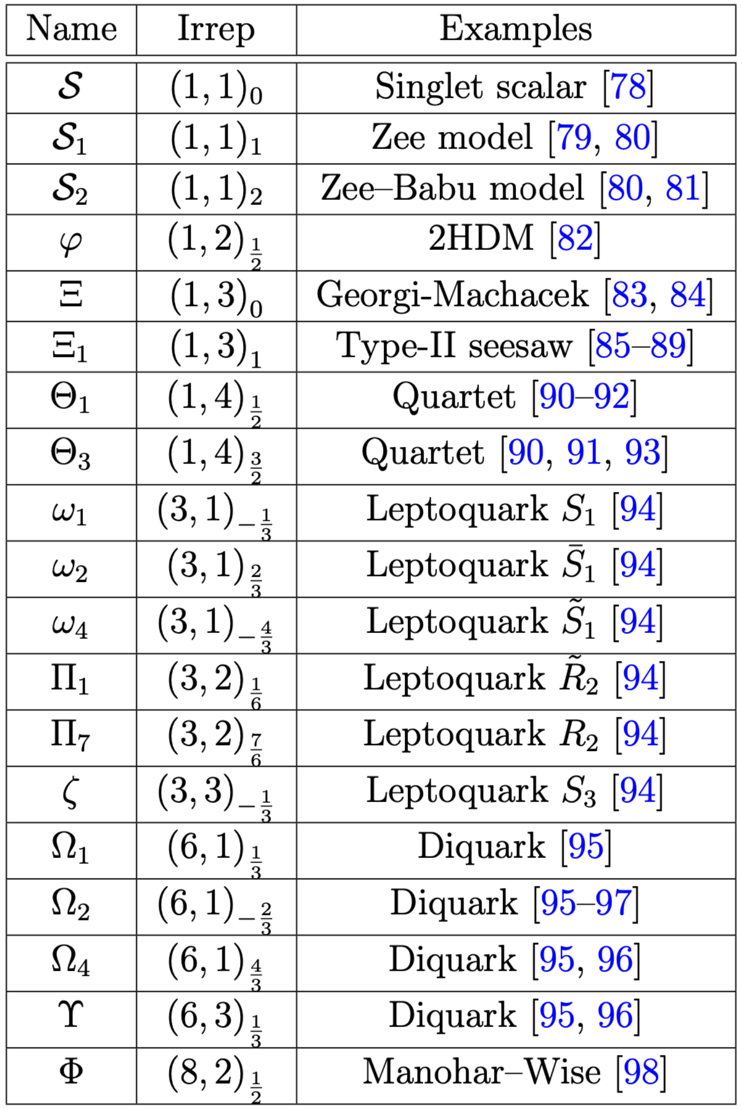
Matching → RGEs running → Mapping

Tera-Z sensitivity to linear SM extensions

- **Scalars**

See also Mathew's plenary talk on Monday
and Lukas's talk on Tuesday





Name	Irrep	Examples
$\mathcal{S}$	$(1,1)_0$	Singlet scalar [78]
$\mathcal{S}_1$	$(1,1)_1$	Zee model [79, 80]
$\mathcal{S}_2$	$(1,1)_2$	Zee–Babu model [80, 81]
φ	$(1,2)_{\frac{1}{2}}$	2HDM [82]
Ξ	$(1,3)_0$	Georgi-Machacek [83, 84]
Ξ_1	$(1,3)_1$	Type-II seesaw [85–89]
Θ_1	$(1,4)_{\frac{1}{2}}$	Quartet [90–92]
Θ_3	$(1,4)_{\frac{3}{2}}$	Quartet [90, 91, 93]
ω_1	$(3,1)_{-\frac{1}{3}}$	Leptoquark S_1 [94]
ω_2	$(3,1)_{\frac{2}{3}}$	Leptoquark $\bar{S}_1$ [94]
ω_4	$(3,1)_{-\frac{4}{3}}$	Leptoquark $\tilde{S}_1$ [94]
Π_1	$(3,2)_{\frac{1}{6}}$	Leptoquark $\tilde{R}_2$ [94]
Π_7	$(3,2)_{\frac{7}{6}}$	Leptoquark R_2 [94]
ζ	$(3,3)_{-\frac{1}{3}}$	Leptoquark S_3 [94]
Ω_1	$(6,1)_{\frac{1}{3}}$	Diquark [95]
Ω_2	$(6,1)_{-\frac{2}{3}}$	Diquark [95–97]
Ω_4	$(6,1)_{\frac{4}{3}}$	Diquark [95, 96]
Υ	$(6,3)_{\frac{1}{3}}$	Diquark [95, 96]
Φ	$(8,2)_{\frac{1}{2}}$	Manohar–Wise [98]

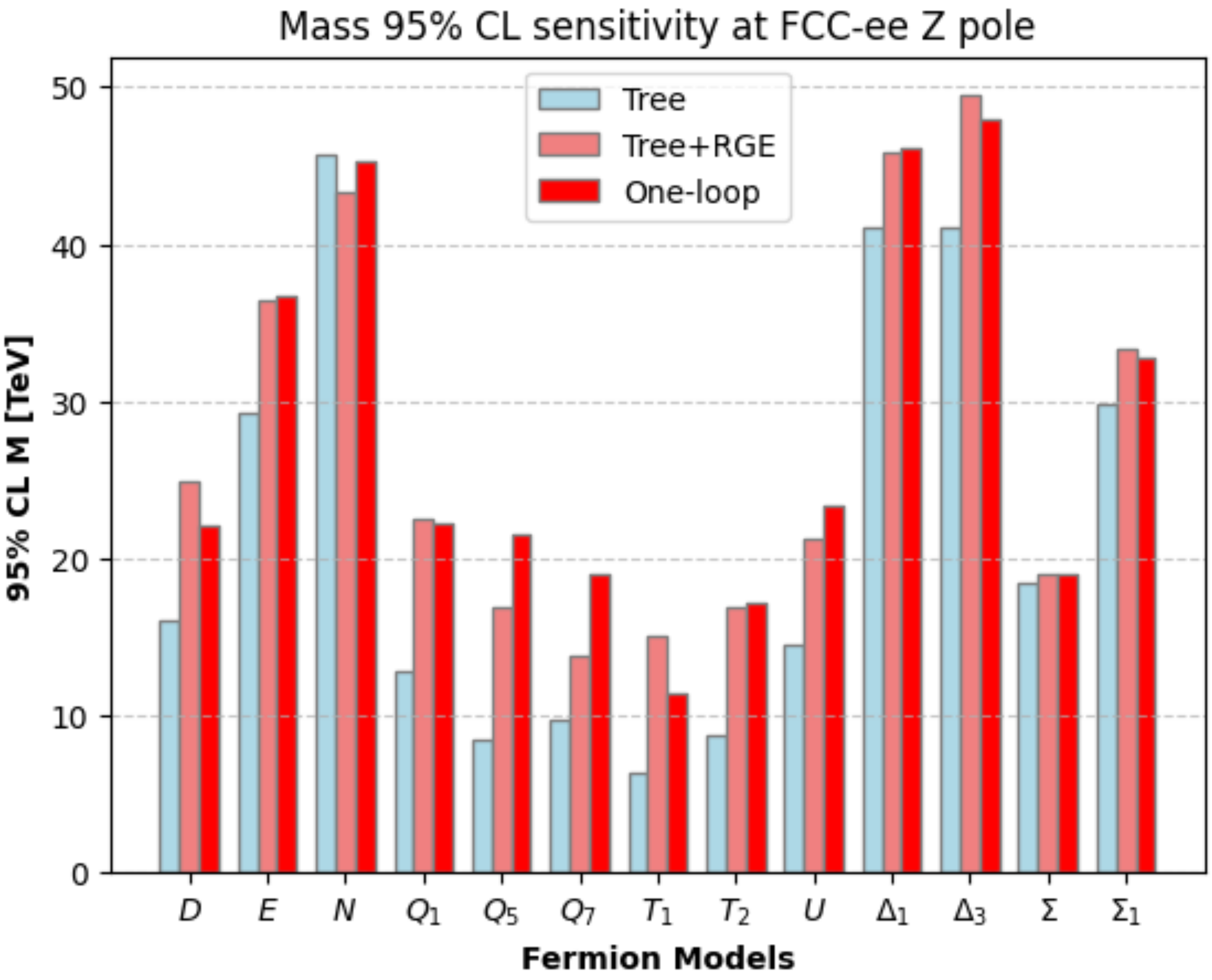
Matching ⋯⋯→ RGEs running ⋯⋯→ Mapping

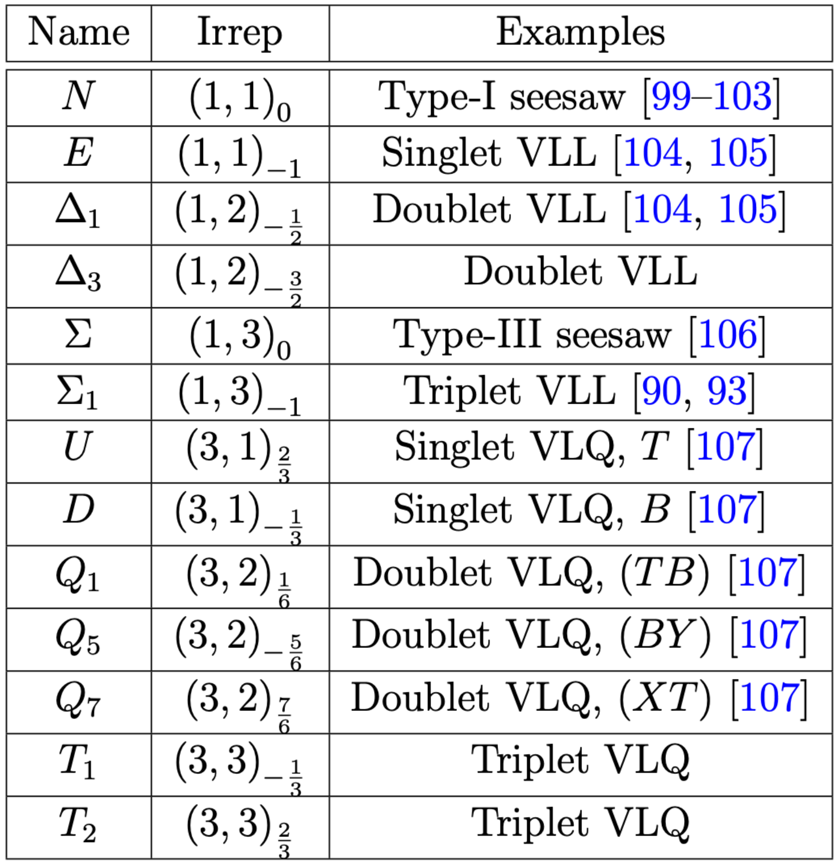
See also Allwicher, McCullough, Renner [2408.03992]

Tera-Z sensitivity to linear SM extensions

Fermions

See also Mathew's plenary talk on Monday
and Lukas's talk on Tuesday





Name	Irrep	Examples
N	$(1,1)_0$	Type-I seesaw [99–103]
E	$(1,1)_{-1}$	Singlet VLL [104, 105]
Δ_1	$(1,2)_{-\frac{1}{2}}$	Doublet VLL [104, 105]
Δ_3	$(1,2)_{-\frac{3}{2}}$	Doublet VLL
Σ	$(1,3)_0$	Type-III seesaw [106]
Σ_1	$(1,3)_{-1}$	Triplet VLL [90, 93]
U	$(3,1)_{\frac{2}{3}}$	Singlet VLQ, T [107]
D	$(3,1)_{-\frac{1}{3}}$	Singlet VLQ, B [107]
Q_1	$(3,2)_{\frac{1}{6}}$	Doublet VLQ, (TB) [107]
Q_5	$(3,2)_{-\frac{5}{6}}$	Doublet VLQ, (BY) [107]
Q_7	$(3,2)_{\frac{7}{6}}$	Doublet VLQ, (XT) [107]
T_1	$(3,3)_{-\frac{1}{3}}$	Triplet VLQ
T_2	$(3,3)_{\frac{2}{3}}$	Triplet VLQ

Matching ⋯⋯▸ RGEs running ⋯⋯▸ Mapping

See also Allwicher, McCullough, Renner [2408.03992]

Summary

- Computational tools are essential for both EFT bottom-up and top-down approach.
- We use MatchMakerEFT and our MatchMakerParser to present our mapping for the linear SM extensions to the SMEFT at one loop => An overview of the relevant phenomenology for each model and operator of interest.
- Our results strengthen the case for the potential of a Tera-Z run to constrain a wide range of new-physics models.