Probing New Physics using SMEFT

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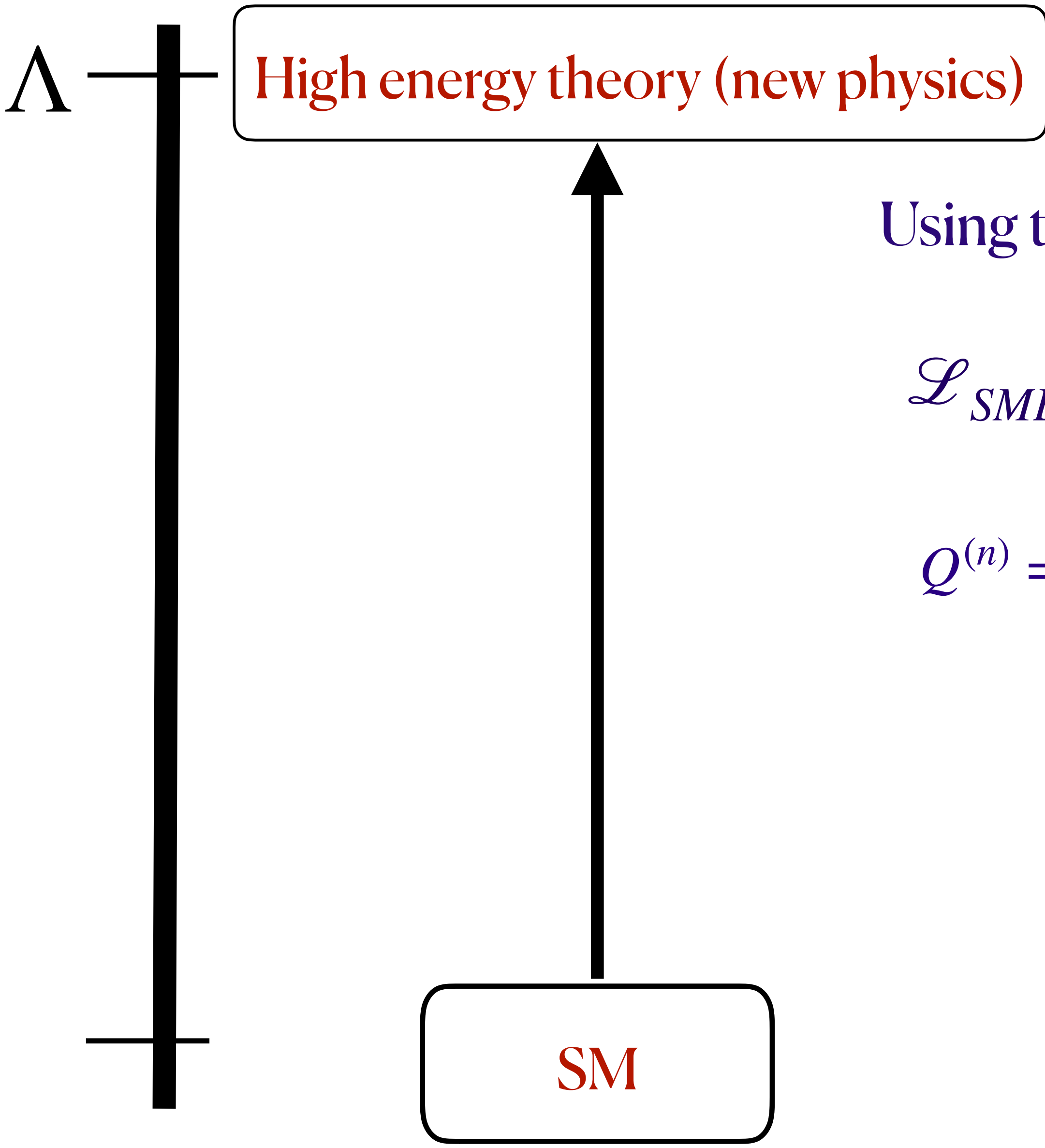
Based upon arXiv: 2111.05876, in collaboration with
S. D. Bakshi, S. Banerjee, A. Biekötter, J. Chakrabortty, S. K. Patra, M. Spannowsky

June 17, 2022

Plan of the talk

- Framework to probe New Physics using SMEFT and Bayesian statistics.
  - Model-independent analysis in SMEFT (Bottom- up approach)
  - Model-dependent analysis (top- down approach).
  - Connecting both approaches and BSM parameter exploration.
  - Model dependent WCs allowed regions.
- Conclusion & Future Prospects

SMEFT path to New Physics



Using the Bottom-up approach

$$\mathscr{L}_{SMEFT} = \mathscr{L}_{SM} + \frac{1}{\Lambda}\sum_i C_i^{(5)} Q_i^{(5)} + \frac{1}{\Lambda^2}\sum_i C_i^{(6)} Q_i^{(6)} + \ldots$$

$Q^{(n)}$ = **effective operators** $\quad$ $C^{(n)}$ = **Wilson coefficients**

Modification in the observables is written in a model independent manner are written as:

$$\Delta obs = obs^{Exp} - obs^{SM} = \frac{1}{\Lambda^2}\sum_i C_i^{(6)} Q_i^{(6)} + \ldots$$

Thus can act as an efficient way for data interpretation.

Warsaw basis operators

Grzadkowski et al. 1008.4884

H^6	
Q_H	$(H^\dagger H)^3$

$H^4 D^2$	
$Q_{H\Box}$	$(H^\dagger H)\Box(H^\dagger H)$
Q_{HD}	$(H^\dagger \mathcal{D}_\mu H)^* (H^\dagger \mathcal{D}^\mu H)$

X^3	
Q_G	$f^{ABC} G_\rho^{A,\mu} G_\mu^{B,\nu} G_\nu^{C,\rho}$
$Q_{\tilde G}$	$f^{ABC} \tilde G_\rho^{A,\mu} G_\mu^{B,\nu} G_\nu^{C,\rho}$
Q_W	$\epsilon^{IJK} W_\rho^{I,\mu} W_\mu^{J,\nu} W_\nu^{K,\rho}$
$Q_{\tilde W}$	$\epsilon^{IJK} \tilde W_\rho^{I,\mu} W_\mu^{J,\nu} W_\nu^{K,\rho}$

$H^2 X^2$	
Q_{HG}	$(H^\dagger H)\, G_{\mu\nu}^A G^{A,\mu\nu}$
$Q_{H\tilde G}$	$(H^\dagger H)\, \tilde G_{\mu\nu}^A G^{A,\mu\nu}$
Q_{HW}	$(H^\dagger H)\, W_{\mu\nu}^I W^{I,\mu\nu}$
$Q_{H\tilde W}$	$(H^\dagger H)\, \tilde W_{\mu\nu}^I W^{I,\mu\nu}$
Q_{HB}	$(H^\dagger H)\, B_{\mu\nu} B^{\mu\nu}$
$Q_{H\tilde B}$	$(H^\dagger H)\, \tilde B_{\mu\nu} B^{\mu\nu}$
Q_{HWB}	$(H^\dagger \tau^I H)\, W_{\mu\nu}^I B^{\mu\nu}$
$Q_{H\tilde W B}$	$(H^\dagger \tau^I H)\, \tilde W_{\mu\nu}^I B^{\mu\nu}$

$H^3 \psi^2$	
Q_{eH}	$(H^\dagger H)\, (\bar l_L e_R H)$
Q_{uH}	$(H^\dagger H)\, (\bar q_L\, u_R\, \tilde H)$
Q_{dH}	$(H^\dagger H)(\bar q_L\, d_R\, H)$

$H^2 \psi^2 D$	
$Q_{Hl}^{(1)}$	$(H^\dagger i \overleftrightarrow{\mathcal{D}}_\mu H)\, (\bar l_L \gamma^\mu l_L)$
$Q_{Hl}^{(3)}$	$(H^\dagger i \tau^I \overleftrightarrow{\mathcal{D}}_\mu H)\, (\bar l_L \tau^I \gamma^\mu l_L)$
Q_{He}	$(H^\dagger i \overleftrightarrow{\mathcal{D}}_\mu H)\, (\bar e_R \gamma^\mu e_R)$
$Q_{Hq}^{(1)}$	$(H^\dagger i \overleftrightarrow{\mathcal{D}}_\mu H)\, (\bar q_L \gamma^\mu q_L)$
$Q_{Hq}^{(3)}$	$(H^\dagger i \tau^I \overleftrightarrow{\mathcal{D}}_\mu H)\, (\bar q_L \tau^I \gamma^\mu q_L)$
Q_{Hu}	$(H^\dagger i \overleftrightarrow{\mathcal{D}}_\mu H)\, (\bar u_R \gamma^\mu u_R)$
Q_{Hd}	$(H^\dagger i \overleftrightarrow{\mathcal{D}}_\mu H)\, (\bar d_R \gamma^\mu d_R)$
Q_{Hud}	$(\tilde H^\dagger i \overleftrightarrow{\mathcal{D}}_\mu H)\, (\bar u_R \gamma^\mu d_R) + \text{h.c.}$

$H \psi^2 X$	
Q_{eW}	$(\bar l_L \sigma^{\mu\nu} e_R) \tau^I H W_{\mu\nu}^I$
Q_{eB}	$(\bar l_L \sigma^{\mu\nu} e_R)\; H\; B_{\mu\nu}$
Q_{uG}	$(\bar q_L \sigma^{\mu\nu} \frac{\lambda^A}{2} u_R)\, \tilde H G_{\mu\nu}^A$
Q_{uW}	$(\bar q_L \sigma^{\mu\nu} u_R)\, \tau^I \tilde H W_{\mu\nu}^I$
Q_{uB}	$(\bar q_L \sigma^{\mu\nu} u_R)\, \tilde H B_{\mu\nu}$
Q_{dG}	$(\bar q_L \sigma^{\mu\nu} \frac{\lambda^A}{2} d_R)\; H\; G_{\mu\nu}^A$
Q_{dW}	$(\bar q_L \sigma^{\mu\nu} d_R) \tau^I H W_{\mu\nu}^I$
Q_{dB}	$(\bar q_L \sigma^{\mu\nu} d_R)\; H\; B_{\mu\nu}$

ψ^4	
Q_{ll}	$(\bar l_L \gamma_\mu l_L)\, (\bar l_L \gamma^\mu l_L)$
$Q_{qq}^{(1)}$	$(\bar q_L \gamma_\mu q_L)(\bar q_L \gamma^\mu q_L)$
$Q_{qq}^{(3)}$	$(\bar q_L \tau^I \gamma_\mu q_L)\, (\bar q_L \tau^I \gamma^\mu q_L)$

ψ^4	
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Q_{ee}	$(\bar e_R \gamma^\mu e_R)(\bar e_R \gamma_\mu e_R)$
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Q_{qe}	$(\bar q_L \gamma^\mu q_L)(\bar e_R \gamma_\mu e_R)$
$Q_{qu}^{(1)}$	$(\bar q_L \gamma_\mu q_L)(\bar u_R \gamma^\mu u_R)$
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$Q_{qd}^{(1)}$	$(\bar q_L \gamma_\mu q_L)(\bar d_R \gamma^\mu d_R)$
$Q_{qd}^{(8)}$	$(\bar q_L \frac{\lambda^A}{2} \gamma^\mu q_L)(\bar d_R \frac{\lambda^A}{2} \gamma_\mu d_R)$
Q_{ledq}	$(\bar l_L^j e_R)(\bar d_R q_{Lj})$
$Q_{quqd}^{(1)}$	$(\bar q_L^j u_R)\epsilon_{jk} (\bar q_L^k d_R)$
$Q_{quqd}^{(8)}$	$(\bar q_L^j \frac{\lambda^A}{2} u_R)\, \epsilon_{jk}\, (\bar q_L^k \frac{\lambda^A}{2} d_R)$
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Q_{He}	$(H^\dagger i \overleftrightarrow{\mathcal{D}}_\mu H)\,(\bar{e}_R \gamma^\mu e_R)$
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Q_{Hud}	$(\tilde{H}^\dagger i \overleftrightarrow{\mathcal{D}}_\mu H)\,(\bar{u}_R \gamma^\mu d_R) +$ h.c.
$H \psi^2 X$	
Q_{eW}	$(\bar{l}_L \sigma^{\mu\nu} e_R)\tau^I H W_{\mu\nu}^I$
Q_{eB}	$(\bar{l}_L \sigma^{\mu\nu} e_R)\; H\; B_{\mu\nu}$
Q_{uG}	$(\bar{q}_L \sigma^{\mu\nu} \frac{\lambda^A}{2} u_R)\, \tilde{H} G_{\mu\nu}^A$
Q_{uW}	$(\bar{q}_L \sigma^{\mu\nu} u_R)\, \tau^I \tilde{H} W_{\mu\nu}^I$
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$Q_{lequ}^{(3)}$	$(\bar{l}_L^j \sigma_{\mu\nu} e_R)\,\epsilon_{jk}\,(\bar{q}_L^k \sigma_{\mu\nu} d_R)$

Anisha, Bakshi, Banerjee, Biekötter, Chakrabortty, Patra, Spannowsky 2111.05876

✤ Model Independent Analysis in SMEFT

Ellis, (Madigan), (Mimasu), (Murphy), Sanz & You 1803.03252, 2012.02779

Dawson, Homiller & Lane 2007.01296

Ethier, Magni, Maltoni, Mantani, Nocera Rojo, Slade, Vryonidou & Zhang 2105.00006

Brivio, Bruggiser, Geoffray, Killian, Kramer 2108.01094

da Silva Almeida, Alves, Éboli & Gonzalez-Garcia 2108.04828

Anisha, Bakshi, Banerjee, Biekötter, Chakrabortty, Patra, Spannowsky 2111.05876

Contribution of operators on different observables

$$O_{NP} = O_{SM} + \sum_i \frac{\mathscr{A}_i}{\Lambda^2} C_i \,.$$

Leading order contributions

Linear in $\frac{1}{\Lambda^2}$

EWPO

Using input parameter scheme $\{\alpha, G_F, M_Z\}$, tree level contributions are calculated.

$$\delta G_F = \frac{G_F}{\Lambda^2}\left(2v^2 C_{Hl}^3 - v^2 C_{ll}\right),$$

$$\delta\alpha = \frac{2\,\alpha\, g_W g_Y v^2}{(g_W^2 + g_Y^2)}\frac{C_{HWB}}{\Lambda^2},$$

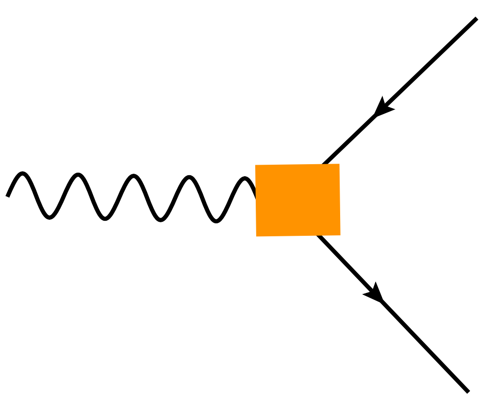
$$\delta m_Z^2 = \frac{1}{2\sqrt{2}}\frac{m_Z^2}{G_F}\frac{C_{HD}}{\Lambda^2} + \frac{2^{1/4}\sqrt{\pi\alpha}\, m_Z}{G_F^{3/2}}\frac{C_{HWB}}{\Lambda^2}\,.$$

$+$ $H^2\psi^2 D$

$Q_{Hl}^{(1)},\ Q_{Hl}^{(3)},\ Q_{Hq}^{(1)},\ Q_{Hq}^{(3)},\ Q_{Hu},\ Q_{Hd},\ Q_{He}$

$H^2\psi^2 D$	
$Q_{Hl}^{(1)}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{l}_L\gamma^\mu l_L)$
$Q_{Hl}^{(3)}$	$(H^\dagger i\tau^I\overleftrightarrow{D}_\mu H)(\bar{l}_L\tau^I\gamma^\mu l_L)$
Q_{He}	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{e}_R\gamma^\mu e_R)$
$Q_{Hq}^{(1)}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{q}_L\gamma^\mu q_L)$
$Q_{Hq}^{(3)}$	$(H^\dagger i\tau^I\overleftrightarrow{D}_\mu H)(\bar{q}_L\tau^I\gamma^\mu q_L)$
Q_{Hu}	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{u}_R\gamma^\mu u_R)$
Q_{Hd}	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{d}_R\gamma^\mu d_R)$

Couplings of pair of fermions with gauge bosons are modified



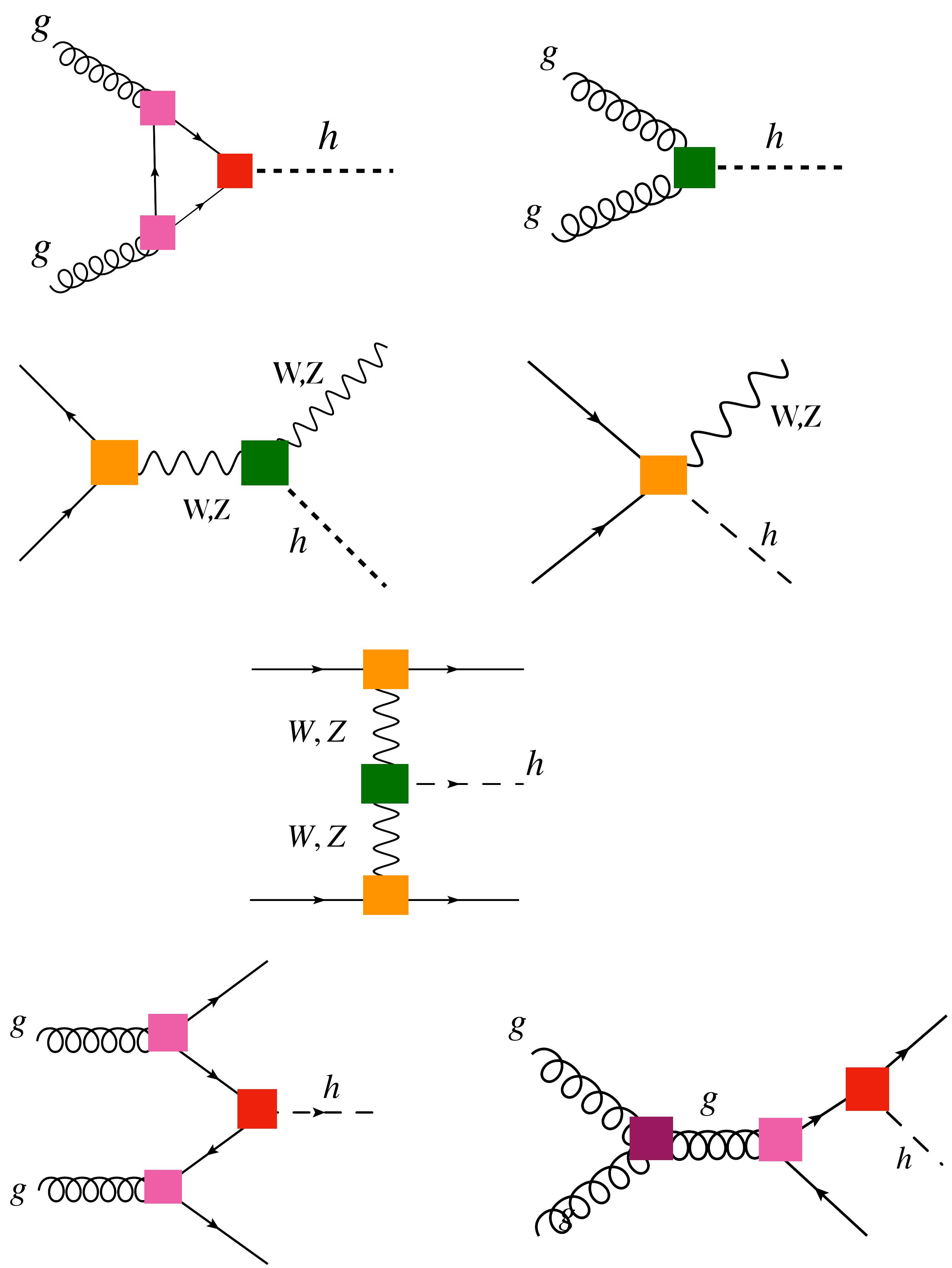
Assuming flavour independence

Brivio & Trott 1706.08945
Dawson & Giardino 1909.02000

Dim-6 operators affecting Higgs Production and decays

ATLAS-CONF-2020-053

Higgs Production channels at leading order



- Higgs coupling with gauge bosons

$$Q_{HG} = \left(H^\dagger H\right) G_{\mu\nu}{}^{a} G^{a,\mu\nu} \rightarrow C_{HG} v h\, G_{\mu}{}^{a} G^{a,\nu}$$
$$Q_{HW} = \left(H^\dagger H\right) W_{\mu\nu}{}^{I} W^{I,\mu\nu} \rightarrow C_{HW} v h\, W_{\mu} W^{\nu}$$
$$Q_{HWB} = \left(H^\dagger \tau^I H\right) W_{\mu\nu}{}^{I} B^{\mu\nu}$$
$$Q_{HB} = \left(H^\dagger H\right) B_{\mu\nu} B^{\mu\nu}$$
$$Q_{HD} = (H^\dagger D_\mu H)^* (H^\dagger D^\mu H)$$

- Higgs coupling with top pairs

$$Q_{tH} = \left(H^\dagger H\right)(\bar{q}_{L}\, t_R\, \widetilde{H}) \rightarrow C_{tH} v^2\, \bar{t} t h$$

- Couplings of pair of fermions with gauge bosons & $\bar{\psi}\psi W(Z)H$ new contact interactions

$$Q_{Hu} = (H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{u}_R \gamma^\mu u_R) \rightarrow C_{Hu} v^2\, \bar{u}_R \gamma_\mu u_R Z^\mu$$
$$\rightarrow C_{Hu} v\, \bar{u}_R \gamma_\mu u_R Z^\mu h$$

$Q_{Hq}^{(1)},\ Q_{Hq}^{(3)},\ Q_{Hu},\ Q_{Hd}$

- Couplings of top pairs with gluons $\bar{t}tg$

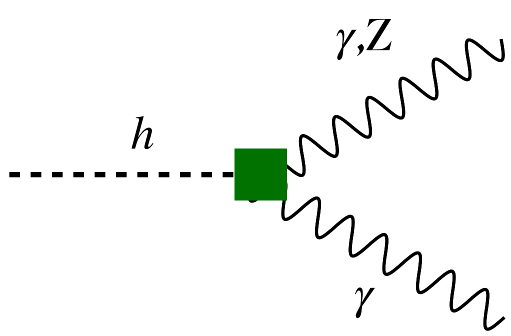
$$Q_{tG} = (\bar{q}_{L} \sigma^{\mu\nu} \frac{\lambda^a}{2} t_R) \widetilde{H} G_{\mu\nu}{}^{a}$$

- For triple gluon couplings

$$Q_G = f^{abc} G_{\rho}{}^{a,\mu} G_{\mu}{}^{b,\nu} G_{\nu}{}^{c,\rho}$$

Dim-6 operators affecting Higgs Production and decays

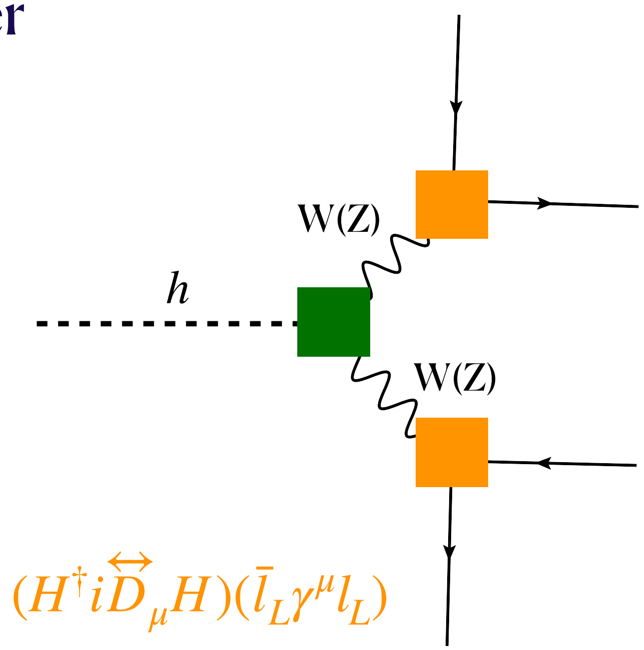
Higgs decay channels at leading order



$$Q_{HB} = \left(H^\dagger H\right) B_{\mu\nu} B^{\mu\nu}$$

$$Q_{HWB} = \left(H^\dagger \tau^I H\right) W_{\mu\nu}{}^I B^{\mu\nu}$$

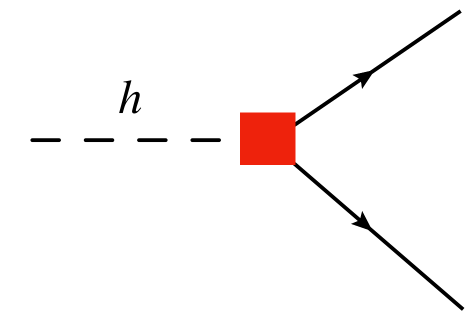
$$Q_{HW} = \left(H^\dagger H\right) W_{\mu\nu}{}^I W^{I,\mu\nu}$$



$$Q_{Hl}^{(1)} = (H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{l}_L \gamma^\mu l_L)$$

$$Q_{Hl}^{(3)} = (H^\dagger i\tau^I \overleftrightarrow{D}_\mu H)(\bar{l}_L \tau^I \gamma^\mu l_L)$$

$$Q_{He} = (H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{e}_R \gamma^\mu e_R)$$



$$Q_{bH} = (H^\dagger H)(\bar{q}_L\ b_R\ H)$$

$$Q_{\tau H} = (H^\dagger H)(\bar{l}_L\ \tau_R\ H)$$

$$Q_{\mu H} = (H^\dagger H)(\bar{l}_L\ \mu_R\ H)$$

Brivio, Corbett & Trott 1906.06949

From these combinations of production and decay channels, μ is given.

$$\mu = \frac{\sigma\left(pp \to h\right)}{\sigma\left(pp \to h\right)_{SM}} \frac{BR\left(h \to f\right)}{BR\left(h \to f\right)_{SM}} .$$

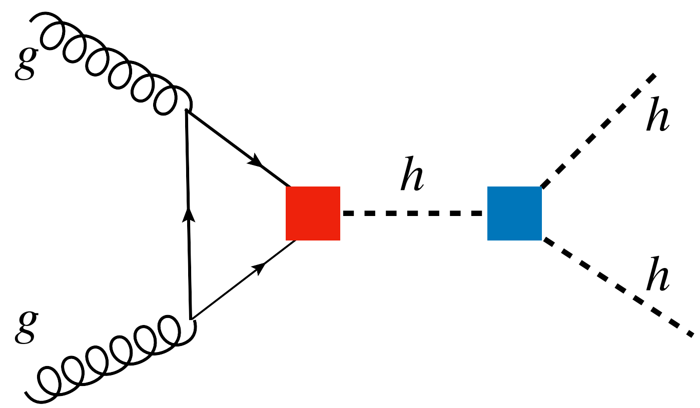
keeping terms linear in $\frac{1}{\Lambda^2}$

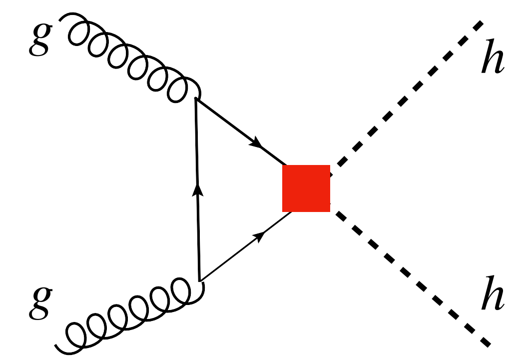
Using SMEFTsim, the theoretical predictions are obtained.

Brivio 2012.11343
ATLAS-CONF-2020-053
Fitmaker- Ellis, Madigan, Mimasu, Sanz & You, 2012.02779

Dim-6 operators affecting DiHiggs

At leading order $gg \to hh$



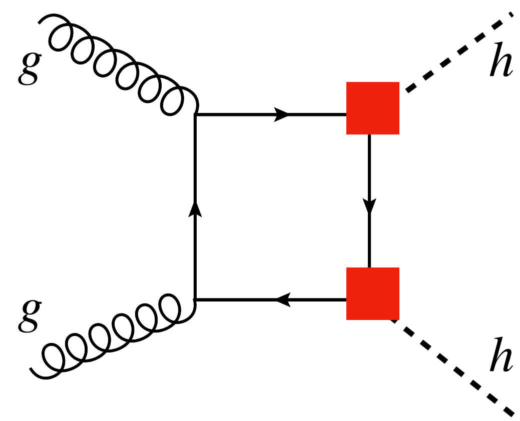


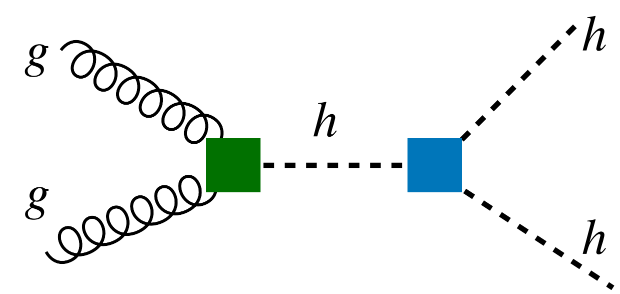
- Tri-linear Higgs coupling get affected

  $Q_H = \left(H^\dagger H\right)^3 \to C_H v^3 h^3$

- Higgs gluon coupling get affected

  $Q_{HG} = \left(H^\dagger H\right) G_{\mu\nu}{}^{a} G^{a,\mu\nu} \to C_{HG} v h\, G_{\mu}{}^{a} G^{a,\nu}$
  $\to C_{HG}\, h^2\, G_{\mu}{}^{a} G^{a,\nu}$



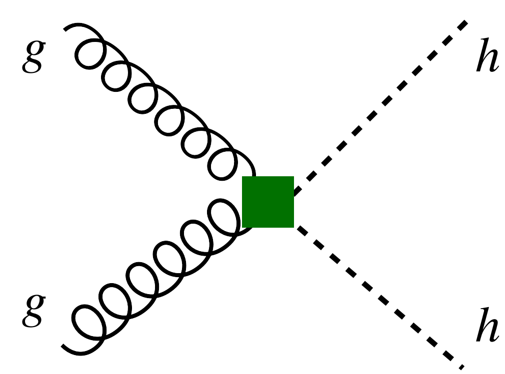


- Higgs coupling with top pairs get affected

  $Q_{tH} = \left(H^\dagger H\right)(\bar{q}_L\, t_R\, \widetilde{H}) \to C_{tH} v^2\, \bar{t} t h$

- Field redefinition of Higgs

  $Q_{H\Box} = (H^\dagger H)\Box(H^\dagger H)$



Buchalla, Capozi, Celis, Heinrich & Scyboz 1806.05162

Heinrich, Jones, Kerner & Scyboz 2006.16877

Operators relevant to Diboson (WW/ WZ) process.

- For triple gauge couplings

$$Q_W = \epsilon^{IJK} W_\rho^{\ I,\mu} W_\mu^{\ J,\nu} W_\nu^{\ K,\rho}$$

$$Q_{HWB} = \left(H^\dagger \tau^I H\right) W_{\mu\nu}^{\ \ I} B^{\mu\nu}$$

- Couplings of pair of fermions with gauge bosons $\bar{\psi}\psi V$ get affected

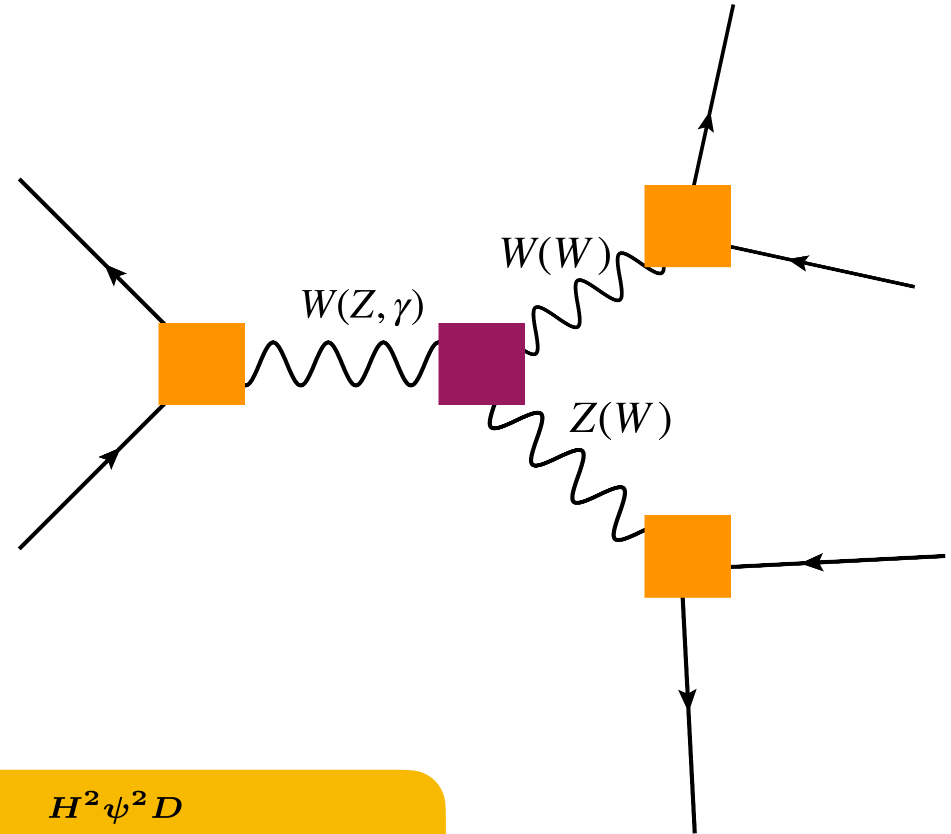
$$H^2\psi^2 D: \; Q_{Hl}^{(1)},\; Q_{Hl}^{(3)},\; Q_{Hq}^{(1)},\; Q_{Hq}^{(3)},\; Q_{Hu},\; Q_{Hd},\; Q_{He}$$

- Due to input parameter scheme

$$Q_{HD} = (H^\dagger D_\mu H)^*(H^\dagger D^\mu H)$$

$$Q_{ll} = (\bar{l}_L \gamma_\mu l_L)(\bar{l}_L \gamma^\mu l_L)\,.$$

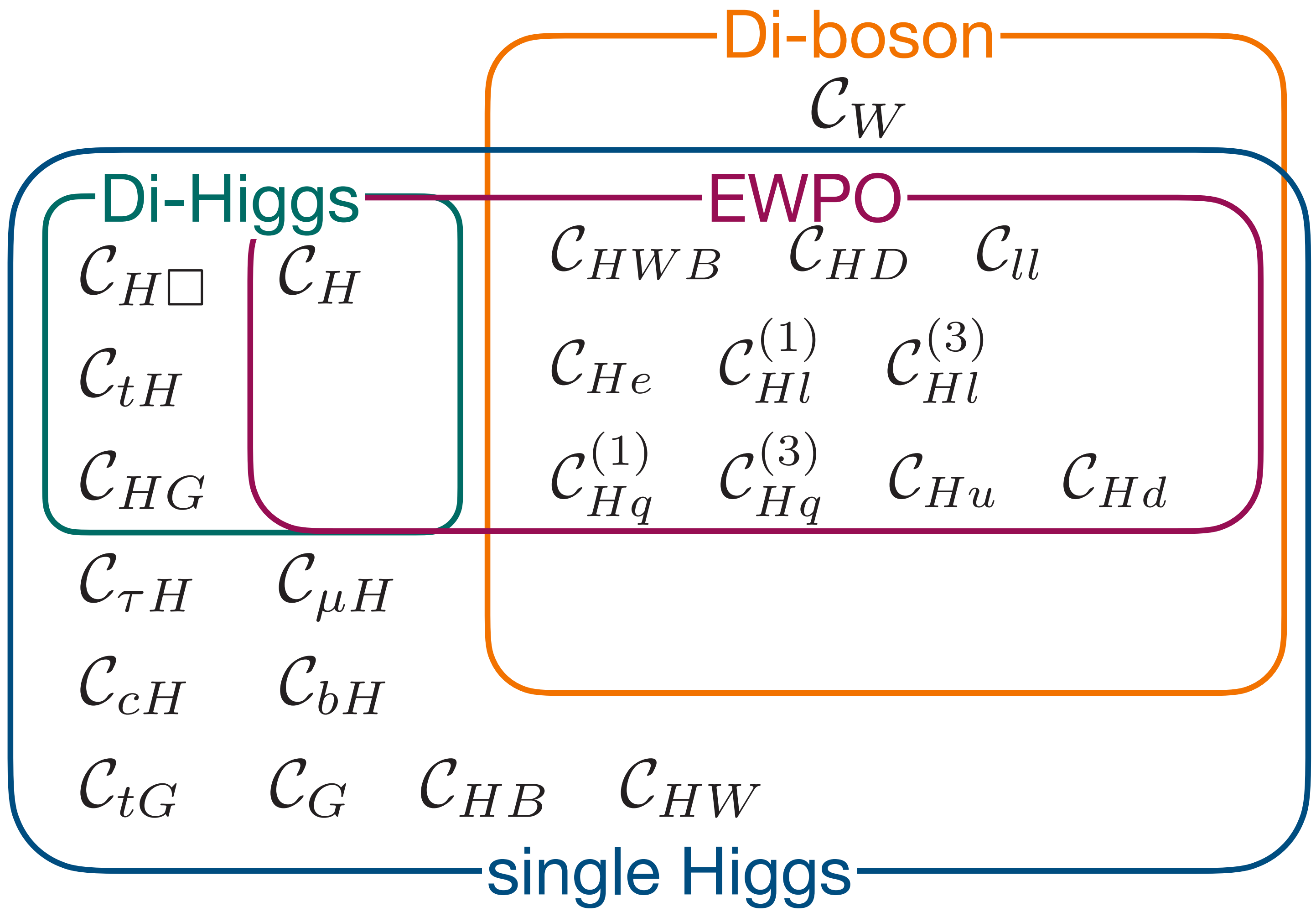
WW/ WZ production with leptonic decays



$H^2\psi^2 D$	
$Q_{Hl}^{(1)}$	$\left(H^\dagger i \overleftrightarrow{D}_\mu H\right)(\bar{l}_L \gamma^\mu l_L)$
$Q_{Hl}^{(3)}$	$\left(H^\dagger i \tau^I \overleftrightarrow{D}_\mu H\right)(\bar{l}_L \tau^I \gamma^\mu l_L)$
Q_{He}	$\left(H^\dagger i \overleftrightarrow{D}_\mu H\right)(\bar{e}_R \gamma^\mu e_R)$
$Q_{Hq}^{(1)}$	$\left(H^\dagger i \overleftrightarrow{D}_\mu H\right)(\bar{q}_L \gamma^\mu q_L)$
$Q_{Hq}^{(3)}$	$\left(H^\dagger i \tau^I \overleftrightarrow{D}_\mu H\right)(\bar{q}_L \tau^I \gamma^\mu q_L)$
Q_{Hu}	$\left(H^\dagger i \overleftrightarrow{D}_\mu H\right)(\bar{u}_R \gamma^\mu u_R)$
Q_{Hd}	$\left(H^\dagger i \overleftrightarrow{D}_\mu H\right)(\bar{d}_R \gamma^\mu d_R)$

Baglio, Dawson & Homiller 1909.11576
Berthier, Bjørn & Trott 1606.06693

Relevant SMEFT dimension-6 operators



Anisha, Bakshi, Banerjee, Biekötter, Chakrabortty, Patra, Spannowsky 2111.05876

Data sets considered

LEP-1 and 2 data

- EWPO
- Diboson data

LHC Run-I and II data

- Higgs signal strengths
- Simplified template cross-sections
- Diboson production distribution
- Di-Higgs signal strengths

277 measurements

Observables		no. of measurements	2020
Electroweak Precision Observables (EWPO)			
Γ_Z, σ^0_{had}, R^0_l, A_l, A_l(SLD), A^l_{FB}, $\sin^2\theta^l_{\rm eff}$(Tev),		15	✓
R^0_c, A_c, A^c_{FB}, R^0_b, A_b, A^b_{FB}, m_W, Γ_W			✓
LEP-2 WW data		74	✓
Higgs Data			
7 and 8 TeV Run-I data	ATLAS & CMS combination	20	✓
	ATLAS & CMS combination $\mu(h\to\mu\mu)$	1	✓
	ATLAS $\mu(h\to Z\gamma)$	1	✓
13 TeV ATLAS Run-II data	$\mu(h\to Z\gamma)$ at 139 fb^{-1}	1	✓
	$\mu(h\to\mu\mu)$ at 139 fb^{-1}	1	✓
	$\mu(h\to\tau\tau)$ at 139 fb^{-1}	4	
	$\mu(h\to bb)$ in VBF and ttH at 139 fb^{-1}	1+1	
	STXS Higgs combination	25	✓
	STXS $h\to\gamma\gamma/ZZ/b\bar{b}$ at 139 fb^{-1}	42	
	STXS $h\to WW$ in ggF, VBF at 139 fb^{-1}	11	
13 TeV CMS Run-II data	CMS combination at up to 137 fb^{-1}	23	✓
	$\mu(h\to b\bar{b})$ in Vh at 35.9/41.5 fb^{-1}	2	
	$\mu(h\to WW)$ in ggF at 137 fb^{-1}	1	
	$\mu(h\to\mu\mu)$ at 137 fb^{-1}	4	
	$\mu(h\to\tau\tau/WW)$ in $t\bar{t}h$ at 137 fb^{-1}	3	
	STXS $h\to WW$ at 137 fb^{-1} in Vh	4	
	STXS $h\to\tau\tau$ at 137 fb^{-1}	11	
	STXS $h\to\gamma\gamma$ at 137 fb^{-1}	27	
	STXS $h\to ZZ$ at 137 fb^{-1}	18	
ATLAS WZ 13 TeV m_T^{WZ} at 36.1 fb^{-1}		6 bins	✓
ATLAS Zjj 13 TeV $\Delta\phi_{jj}$ at 139 fb^{-1}		12 bins	✓
ATLAS WW 13 TeV $p_T^{\ell 1}$ at 36.1 fb^{-1}		7 bins	✓
Di-Higgs signal strengths ATLAS & CMS 13 TeV data $\mu^{b\bar{b}b\bar{b}}_{HH}$, $\mu^{b\bar{b}\tau\bar{\tau}}_{HH}$, $\mu^{b\bar{b}\gamma\gamma}_{HH}$		6	

Fitting Terminology

For parameter estimation, Bayesian framework is followed:

$$p(\vec{C} \,|\, D) \propto p(D \,|\, \vec{C}) \; p(\vec{C}) \,.$$

Prior Probability distribution: Initial knowledge about the $\vec{C}$. Uninformative priors are used for WCs taken as to be uniform distributions with large range

- for WCs {-10,10}.

Likelihood: Information about the theory and data. For Gaussian data:

$$Log\ Likelihood = -\frac{1}{2}\sum_i (O_{exp} - O_{th}(\vec{C}))_i \; V_{ij}^{-1} \; (O_{exp} - O_{th}(\vec{C}))_j \,.$$

Posterior: Probability distribution of parameters $\vec{C}$ given the data D.
Unnormalised posterior is sampled using MCMC using the Mathematica package OptEx.

OptEx, S K Patra, under development
https://doi.org/10.5281/zenodo.3404311

How inferences are presented

✦ **Marginalisation :**

From unnormalised posterior consisting of n parameters, any single parameter is estimated by integrating the posterior over rest of the parameters.

- This is done by neglecting other parameters from the generated data sample.
- In this way, 1 D and 2D marginalised (correlation) posterior are obtained and plots are shown to demonstrate the parameter spaces.
- Point estimates : the median of the sample as the central tendency and uncertainties as fixed quantiles around the median of the sample.

✦ **Credible intervals**

- The interval within which a parameter has a specific probability. 68 % and 95 % CIs are shown.
- In case of 2D, these regions are constant probability contours which encapsulate a particular percentage of total sampled points.

Fit results of Model independent analysis

WCs	95% CI Individual limits	95% CI Global limits
$\mathcal{C}_{HWB}$	$[-0.0035, 0.0028]$	$[-0.19, 0.15]$
$\mathcal{C}_{HD}$	$[-0.022, 0.0042]$	$[-0.40, 0.39]$
$\mathcal{C}_{ll}$	$[-0.006, 0.016]$	$[-0.10, 0.00]$
$\mathcal{C}_{Hl}^{(1)}$	$[-0.005, 0.012]$	$[-0.08, 0.12]$
$\mathcal{C}_{Hl}^{(3)}$	$[-0.010, 0.003]$	$[-0.054, 0.063]$
$\mathcal{C}_{He}$	$[-0.013, 0.008]$	$[-0.20, 0.19]$
$\mathcal{C}_{Hq}^{(1)}$	$[-0.023, 0.047]$	$[-0.057, 0.096]$
$\mathcal{C}_{Hq}^{(3)}$	$[-0.008, 0.016]$	$[-0.033, 0.063]$
$\mathcal{C}_{Hd}$	$[-0.15, 0.04]$	$[-0.29, 0.11]$
$\mathcal{C}_{Hu}$	$[-0.056, 0.081]$	$[-0.13, 0.25]$
$\mathcal{C}_{H}$	$[-9.6, 6.9]$	$[-11., 7.0]$
$\mathcal{C}_{H\Box}$	$[-0.96, -0.13]$	$[-1.6, 5.6]$
$\mathcal{C}_{HG}$	$[-0.0038, -0.0002]$	$[-0.013, 0.010]$
$\mathcal{C}_{HW}$	$[-0.010, 0.005]$	$[-0.28, 0.12]$
$\mathcal{C}_{HB}$	$[-0.0031, 0.0016]$	$[-0.050, 0.061]$
$\mathcal{C}_{W}$	$[-0.17, 0.34]$	$[-0.18, 0.33]$
$\mathcal{C}_{G}$	$[-0.8, 1.2]$	$[-1.1, 1.3]$
$\mathcal{C}_{\mu H}$	$[-0.0042, 0.0027]$	$[-0.0045, 0.0025]$
$\mathcal{C}_{\tau H}$	$[-0.0040, 0.028]$	$[-0.009, 0.029]$
$\mathcal{C}_{bH}$	$[-0.036, 0.004]$	$[-0.029, 0.069]$
$\mathcal{C}_{cH}$	$[-0.15, -0.01]$	$[-1.1, 0.20]$
$\mathcal{C}_{tH}$	$[0.02, 1.2]$	$[-2.6, 2.6]$
$\mathcal{C}_{tG}$	$[-0.11, -0.01]$	$[-0.28, 0.21]$

WCs	Correlations																						
	$\mathcal{C}_{HWB}$	$\mathcal{C}_{HD}$	$\mathcal{C}_{ll}$	$\mathcal{C}_{Hl}^{(1)}$	$\mathcal{C}_{Hl}^{(3)}$	$\mathcal{C}_{He}$	$\mathcal{C}_{Hq}^{(1)}$	$\mathcal{C}_{Hq}^{(3)}$	$\mathcal{C}_{Hd}$	$\mathcal{C}_{Hu}$	$\mathcal{C}_{H}$	$\mathcal{C}_{H\Box}$	$\mathcal{C}_{HG}$	$\mathcal{C}_{HW}$	$\mathcal{C}_{HB}$	$\mathcal{C}_{W}$	$\mathcal{C}_{G}$	$\mathcal{C}_{\mu H}$	$\mathcal{C}_{\tau H}$	$\mathcal{C}_{bH}$	$\mathcal{C}_{cH}$	$\mathcal{C}_{tH}$	$\mathcal{C}_{tG}$
$\mathcal{C}_{HWB}$	1																						
$\mathcal{C}_{HD}$	-0.98	1																					
$\mathcal{C}_{ll}$	-0.03	0.06	1																				
$\mathcal{C}_{Hl}^{(1)}$	0.96	-0.98	-0.22	1																			
$\mathcal{C}_{Hl}^{(3)}$	0.09	-0.24	0.31	0.17	1																		
$\mathcal{C}_{He}$	0.98	-1.00	-0.07	0.98	0.24	1																	
$\mathcal{C}_{Hq}^{(1)}$	-0.41	0.34	-0.13	-0.31	0.20	-0.35	1																
$\mathcal{C}_{Hq}^{(3)}$	-0.24	0.13	0.02	-0.13	0.54	-0.13	-0.06	1															
$\mathcal{C}_{Hd}$	-0.01	0.02	-0.05	-0.02	-0.08	-0.02	0.37	0.09	1														
$\mathcal{C}_{Hu}$	-0.31	0.25	-0.15	-0.22	0.16	-0.25	0.59	-0.29	0.26	1													
$\mathcal{C}_{H}$	-0.10	0.09	-0.02	-0.09	0.01	-0.10	0.08	-0.01	0.03	0.12	1												
$\mathcal{C}_{H\Box}$	-0.60	0.58	-0.03	-0.56	0	-0.58	0.43	-0.02	0.12	0.55	0.23	1											
$\mathcal{C}_{HG}$	0.07	-0.05	0.02	0.04	-0.13	0.05	-0.06	-0.13	-0.03	-0.10	-0.28	-0.12	1										
$\mathcal{C}_{HW}$	0.88	-0.85	-0.02	0.83	0.02	0.85	-0.38	-0.24	-0.03	-0.33	-0.11	-0.62	0.07	1									
$\mathcal{C}_{HB}$	0.87	-0.86	-0.03	0.85	0.14	0.86	-0.35	-0.13	0	-0.26	-0.09	-0.54	0.07	0.53	1								
$\mathcal{C}_{W}$	0.15	-0.15	0.02	0.14	0.07	0.15	-0.02	-0.03	0.01	0	-0.01	-0.07	0	0.12	0.13	1							
$\mathcal{C}_{G}$	-0.05	0.06	0	-0.06	-0.04	-0.06	0.03	-0.03	0	0.03	0.01	0.02	-0.11	-0.03	-0.07	-0.01	1						
$\mathcal{C}_{\mu H}$	0	0	-0.01	0	0	0	0.01	-0.02	0.01	0.02	-0.01	0.02	0	0	0	0	0.04	1					
$\mathcal{C}_{\tau H}$	0	0	-0.01	0	-0.01	0	0.03	-0.05	0.01	0.05	-0.04	0.01	-0.16	0.01	0.01	0	0.05	0.07	1				
$\mathcal{C}_{bH}$	0.04	-0.11	-0.05	0.11	0.37	0.11	0.01	0.35	0.03	0.09	0.01	0.05	-0.40	0.07	0	0.02	-0.01	0.05	0.28	1			
$\mathcal{C}_{cH}$	0.51	-0.48	0.04	0.45	-0.08	0.48	-0.37	-0.06	-0.12	-0.51	-0.22	-0.95	0.15	0.52	0.48	0.06	0	0	0.08	-0.15	1		
$\mathcal{C}_{tH}$	-0.21	0.22	0	-0.21	-0.07	-0.22	0.15	-0.08	0.03	0.15	-0.19	0.21	0.37	-0.24	-0.14	-0.03	-0.39	-0.02	0.09	-0.01	-0.08	1	
$\mathcal{C}_{tG}$	-0.04	0.02	-0.01	-0.02	0.11	-0.02	0.04	0.10	0.02	0.08	0.16	0.09	-0.78	-0.06	-0.03	0	-0.17	-0.05	0.05	0.27	-0.12	0.14	1

- **23 WCs treated as free and independent parameters.**
- **$\Lambda = 1$ TeV**

Individual & Global fit results

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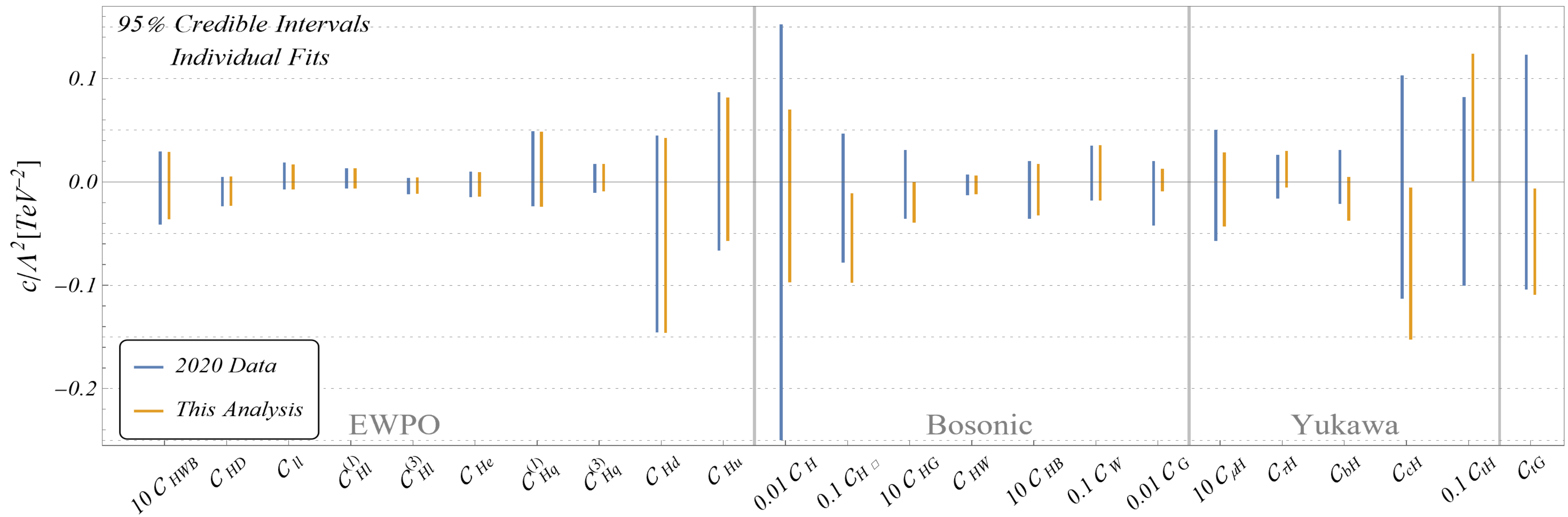

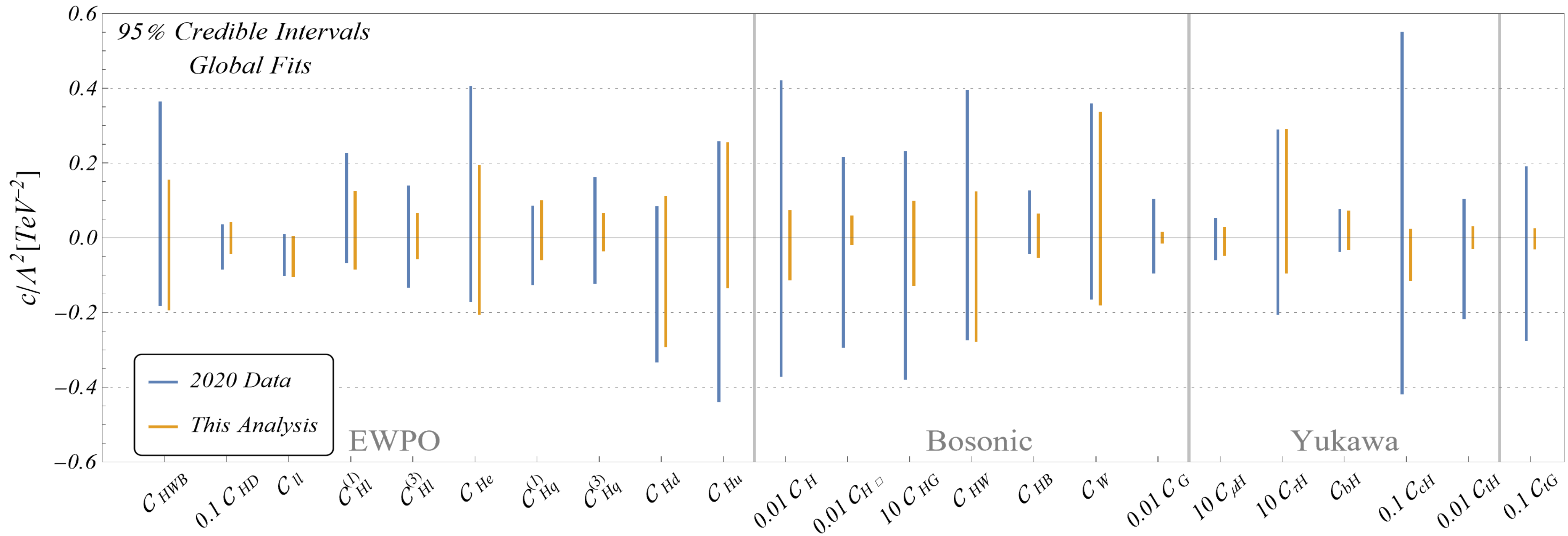

✤ Model dependent analysis using SMEFT

Dawson, Homiller & Lane 2007.01296

Ellis, Madigan, Mimasu, Murphy, Sanz & You 2012.02779

Brivio, Bruggiser, Geoffray, Killian, Kramer 2108.01094

Bakshi, Chakrabortty, (Englert), Spannowsky, (Stylianou) (2009.13394), 2012.03839

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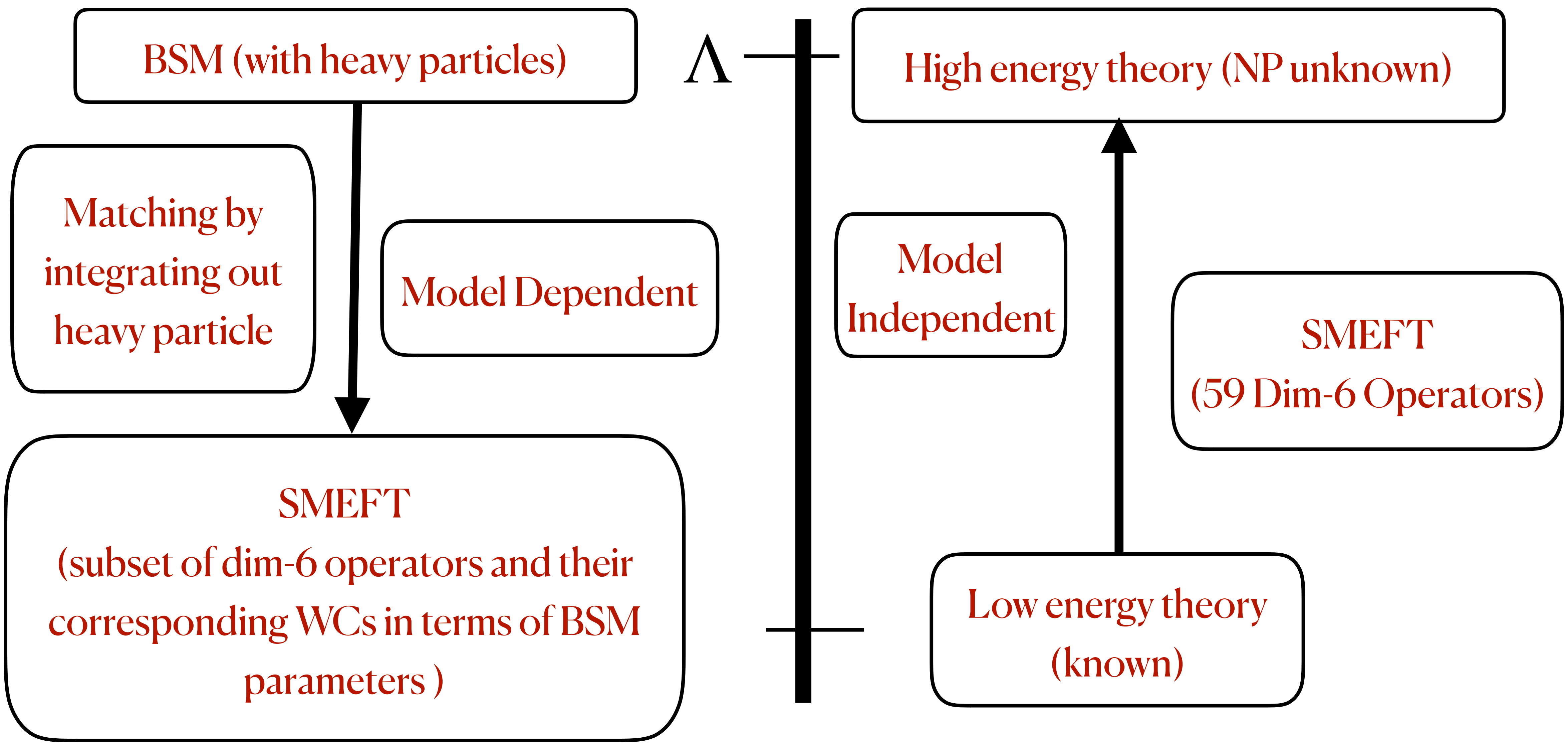
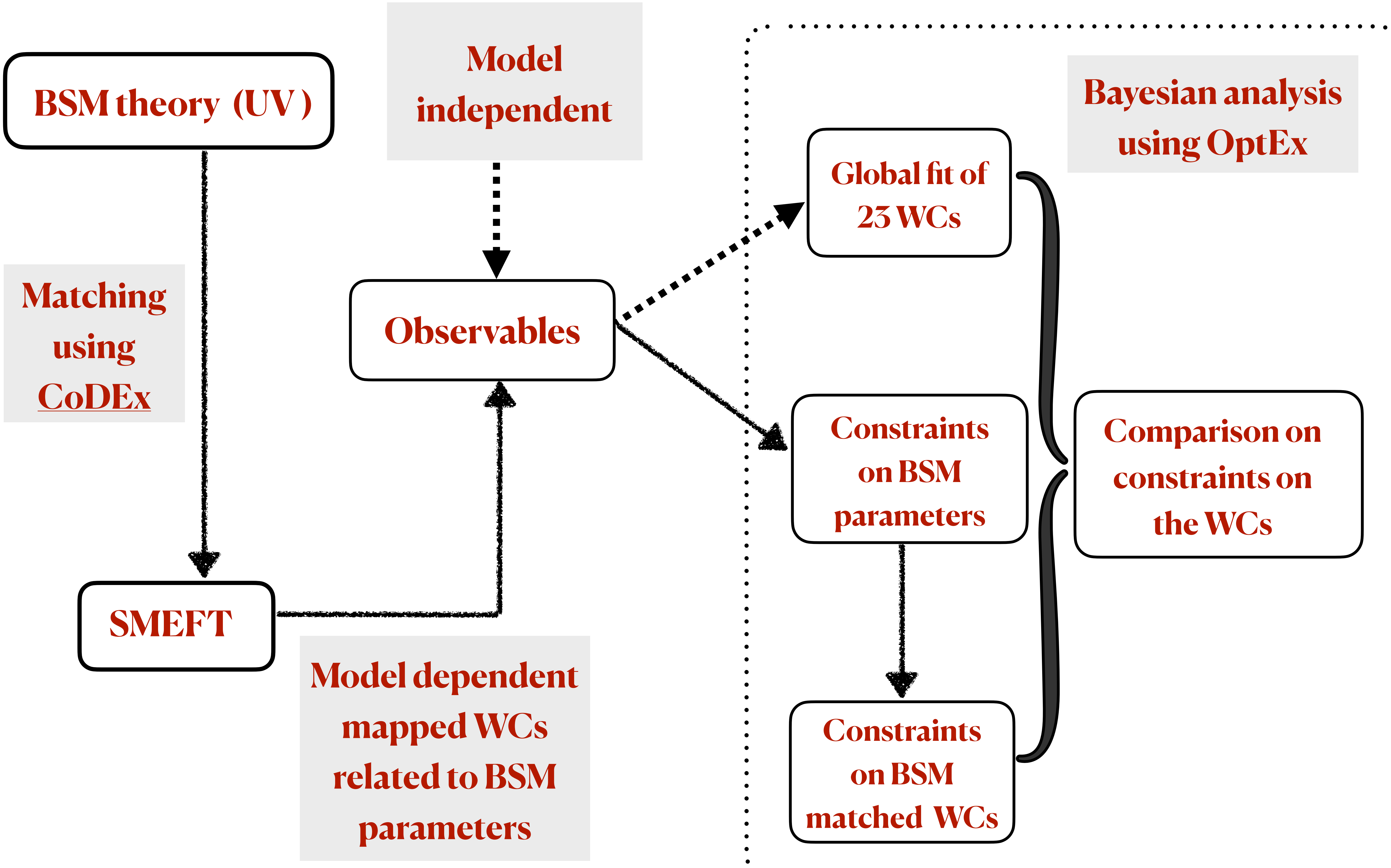
Top-Down Approach

Bottom-Up Approach



✤ Connecting Bottom-up approach with Top-down approach



CoDEx- Bakshi, Chakrabortty & Patra 1808.04403

Anisha, Bakshi, Banerjee, Biekötter, Chakrabortty, Patra, Spannowsky, 2111.05876

SM extended with Extra Scalar Doublet $\mathscr{H}_2(1,2,-1/2)$

$$\mathscr{L}_{\mathscr{H}_2} \supset \frac{1}{2}|\mathscr{D}_\mu \mathscr{H}_2|^2 - m^2_{\mathscr{H}_2}|\mathscr{H}_2|^2 - \frac{\lambda_{\mathscr{H}_2}}{4}|\mathscr{H}_2|^4 - (\eta_H|\widetilde{H}|^2 + \eta_{\mathscr{H}_2}|\mathscr{H}_2|^2)(\widetilde{H}^\dagger \mathscr{H}_2 + \mathscr{H}_2^\dagger \widetilde{H})$$
$$-\lambda_{\mathscr{H}_2,1}|\widetilde{H}|^2|\mathscr{H}_2|^2 - \lambda_{\mathscr{H}_2,2}|\widetilde{H}^\dagger \mathscr{H}_2|^2 - \lambda_{\mathscr{H}_2,3}\left[(\widetilde{H}^\dagger \mathscr{H}_2)^2 + (\mathscr{H}_2^\dagger \widetilde{H})^2\right]$$
$$-\left\{ Y^{(e)}_{\mathscr{H}_2} \bar{l}_L \widetilde{\mathscr{H}}_2 e_R + Y^{(u)}_{\mathscr{H}_2} \bar{q}_L \mathscr{H}_2 u_R + Y^{(d)}_{\mathscr{H}_2} \bar{q}_L \widetilde{\mathscr{H}}_2 d_R + h.c. \right\}.$$

- $m_{\mathscr{H}_2}$ is the mass of the heavy scalar doublet taken to be cut-off Λ.
- After integrating out this doublet at one loop using CoDEx, the WCs are generated in terms of model parameters.
- For simplification, assumed Z_2 symmetry i.e $\mathscr{H}_2 \to -\mathscr{H}_2$ and the number of parameters are reduced.

https://github.com/effExTeam/Precision-Observables-and-Higgs-Signals-Effective-passageto-select-BSM

SMEFT Matching results

Dim-6 Ops.	Wilson coefficients
Q_{dH}	$\frac{\lambda^2_{\mathcal{H}_2,2} Y_d^{\rm SM}}{192\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3} Y_d^{\rm SM}}{48\pi^2 m^2_{\mathcal{H}_2}}$
Q_{eH}	$\frac{\lambda^2_{\mathcal{H}_2,2} Y_e^{\rm SM}}{192\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3} Y_e^{\rm SM}}{48\pi^2 m^2_{\mathcal{H}_2}}$
Q_{uH}	$\frac{\lambda^2_{\mathcal{H}_2,2} Y_u^{\rm SM}}{192\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3} Y_u^{\rm SM}}{48\pi^2 m^2_{\mathcal{H}_2}}$
Q_H	$-\frac{\lambda^3_{\mathcal{H}_2,1}}{48\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda_H^{\rm SM}\lambda^2_{\mathcal{H}_2,2}}{96\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda^2_{\mathcal{H}_2,1}\lambda_{\mathcal{H}_2,2}}{32\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda_{\mathcal{H}_2,1}\lambda^2_{\mathcal{H}_2,2}}{32\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda_H^{\rm SM}\lambda^2_{\mathcal{H}_2,3}}{24\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda^3_{\mathcal{H}_2,2}}{96\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda_{\mathcal{H}_2,1}\lambda^2_{\mathcal{H}_2,3}}{8\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda_{\mathcal{H}_2,2}\lambda^2_{\mathcal{H}_2,3}}{8\pi^2 m^2_{\mathcal{H}_2}}$
$Q_{H\Box}$	$-\frac{g_W^4}{7680\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda^2_{\mathcal{H}_2,1}}{96\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda_{\mathcal{H}_2,1}\lambda_{\mathcal{H}_2,2}}{96\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3}}{48\pi^2 m^2_{\mathcal{H}_2}}$
Q_{HD}	$-\frac{g_Y^4}{1920\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda^2_{\mathcal{H}_2,2}}{96\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3}}{24\pi^2 m^2_{\mathcal{H}_2}}$
Q_{HB}	$\frac{g_Y^2\lambda_{\mathcal{H}_2,1}}{384\pi^2 m^2_{\mathcal{H}_2}} + \frac{g_Y^2\lambda_{\mathcal{H}_2,2}}{768\pi^2 m^2_{\mathcal{H}_2}}$
Q_{HW}	$\frac{g_W^2\lambda_{\mathcal{H}_2,1}}{384\pi^2 m^2_{\mathcal{H}_2}} + \frac{g_W^2\lambda_{\mathcal{H}_2,2}}{768\pi^2 m^2_{\mathcal{H}_2}}$
Q_{HWB}	$\frac{g_W g_Y\lambda_{\mathcal{H}_2,2}}{384\pi^2 m^2_{\mathcal{H}_2}}$

Dim-6 Ops.	Wilson coefficients
$Q_{Hl}^{(1)}$	$\frac{g_Y^4}{3840\pi^2 m^2_{\mathcal{H}_2}}$
$Q_{Hq}^{(1)}$	$-\frac{g_Y^4}{11520\pi^2 m^2_{\mathcal{H}_2}}$
$Q_{\rm Hd}$	$\frac{g_Y^4}{5760\pi^2 m^2_{\mathcal{H}_2}}$
Q_{He}	$\frac{g_Y^4}{1920\pi^2 m^2_{\mathcal{H}_2}}$
Q_{Hu}	$-\frac{g_Y^4}{2880\pi^2 m^2_{\mathcal{H}_2}}$
$Q_{Hl}^{(3)}$	$-\frac{g_W^4}{1920\pi^2 m^2_{\mathcal{H}_2}}$
$Q_{Hq}^{(3)}$	$-\frac{g_W^4}{1920\pi^2 m^2_{\mathcal{H}_2}}$
Q_W	$\frac{g_W^3}{5760\pi^2 m^2_{\mathcal{H}_2}}$
Q_{ll}	$-\frac{g_W^4}{7680\pi^2 m^2_{\mathcal{H}_2}} - \frac{g_Y^4}{7680\pi^2 m^2_{\mathcal{H}_2}}$

Dim-6 Ops.	Wilson coefficients
$Q_{ud}^{(1)}$	$\frac{g_Y^4}{4320\pi^2 m^2_{\mathcal{H}_2}}$
$Q_{lq}^{(3)}$	$-\frac{g_W^4}{3840\pi^2 m^2_{\mathcal{H}_2}}$
$Q_{qq}^{(3)}$	$-\frac{g_W^4}{7680\pi^2 m^2_{\mathcal{H}_2}}$
Q_{dd}	$-\frac{g_Y^4}{17280\pi^2 m^2_{\mathcal{H}_2}}$
Q_{ed}	$-\frac{g_Y^4}{2880\pi^2 m^2_{\mathcal{H}_2}}$
Q_{ee}	$-\frac{g_Y^4}{1920\pi^2 m^2_{\mathcal{H}_2}}$
Q_{eu}	$\frac{g_Y^4}{1440\pi^2 m^2_{\mathcal{H}_2}}$
Q_{uu}	$-\frac{g_Y^4}{4320\pi^2 m^2_{\mathcal{H}_2}}$
Q_{lu}	$\frac{g_Y^4}{2880\pi^2 m^2_{\mathcal{H}_2}}$
Q_{qe}	$\frac{g_Y^4}{5760\pi^2 m^2_{\mathcal{H}_2}}$
Q_{ld}	$-\frac{g_Y^4}{5760\pi^2 m^2_{\mathcal{H}_2}}$
$Q_{qq}^{(1)}$	$-\frac{g_Y^4}{69120\pi^2 m^2_{\mathcal{H}_2}}$
Q_{le}	$-\frac{g_Y^4}{1920\pi^2 m^2_{\mathcal{H}_2}}$
$Q_{qd}^{(1)}$	$\frac{g_Y^4}{17280\pi^2 m^2_{\mathcal{H}_2}}$
$Q_{qu}^{(1)}$	$-\frac{g_Y^4}{8640\pi^2 m^2_{\mathcal{H}_2}}$
$Q_{lq}^{(1)}$	$\frac{g_Y^4}{11520\pi^2 m^2_{\mathcal{H}_2}}$

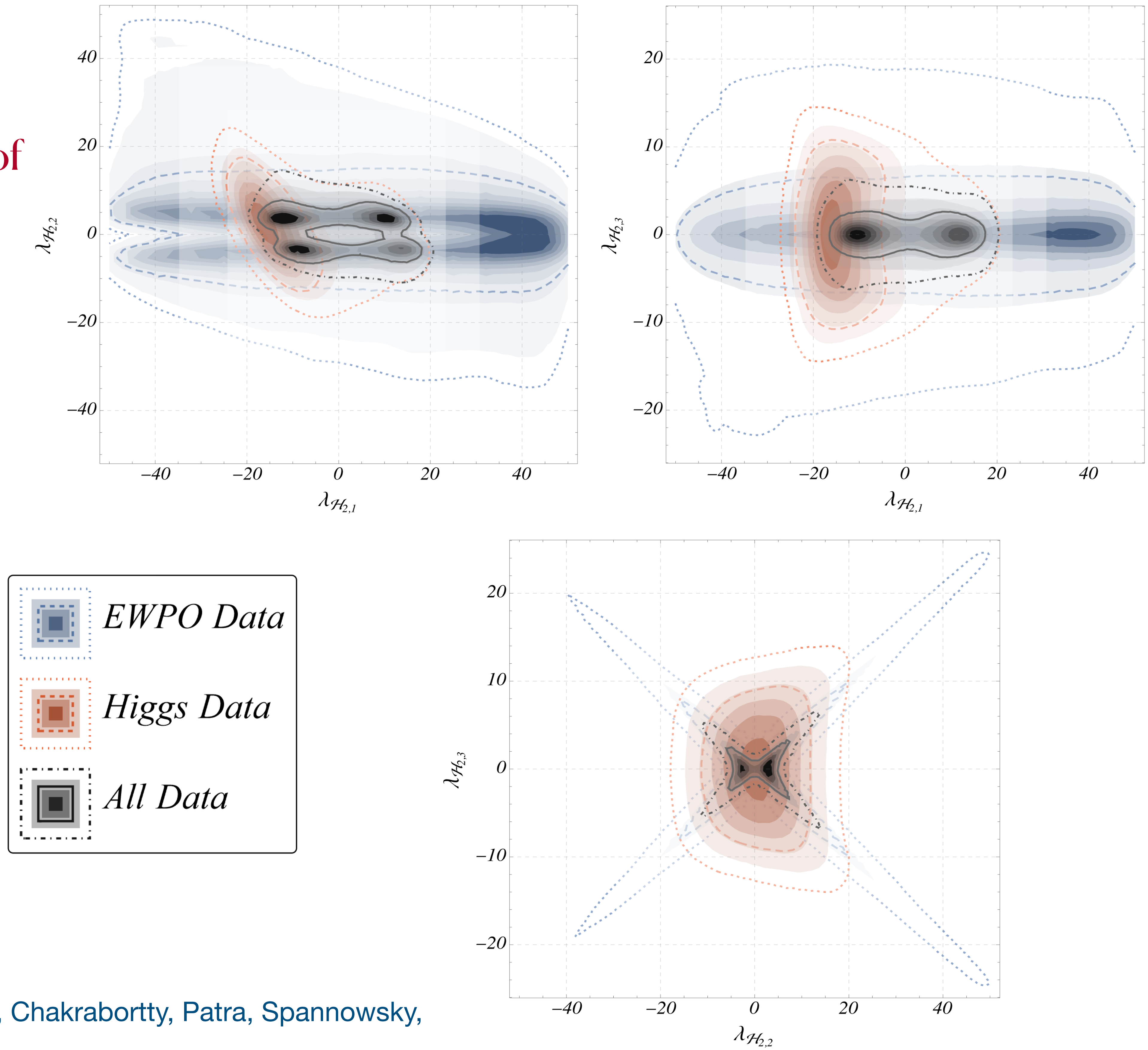
18 operators contribute in model dependent analysis

CoDEx SMEFT Matching Result

Bakshi, Chakrabortty & Patra 1808.04403

Constraints on the model parameters - 2D posteriors

- 3 model parameters
- Uniform distributions of range {-50,50}.
- Effects on different datasets.

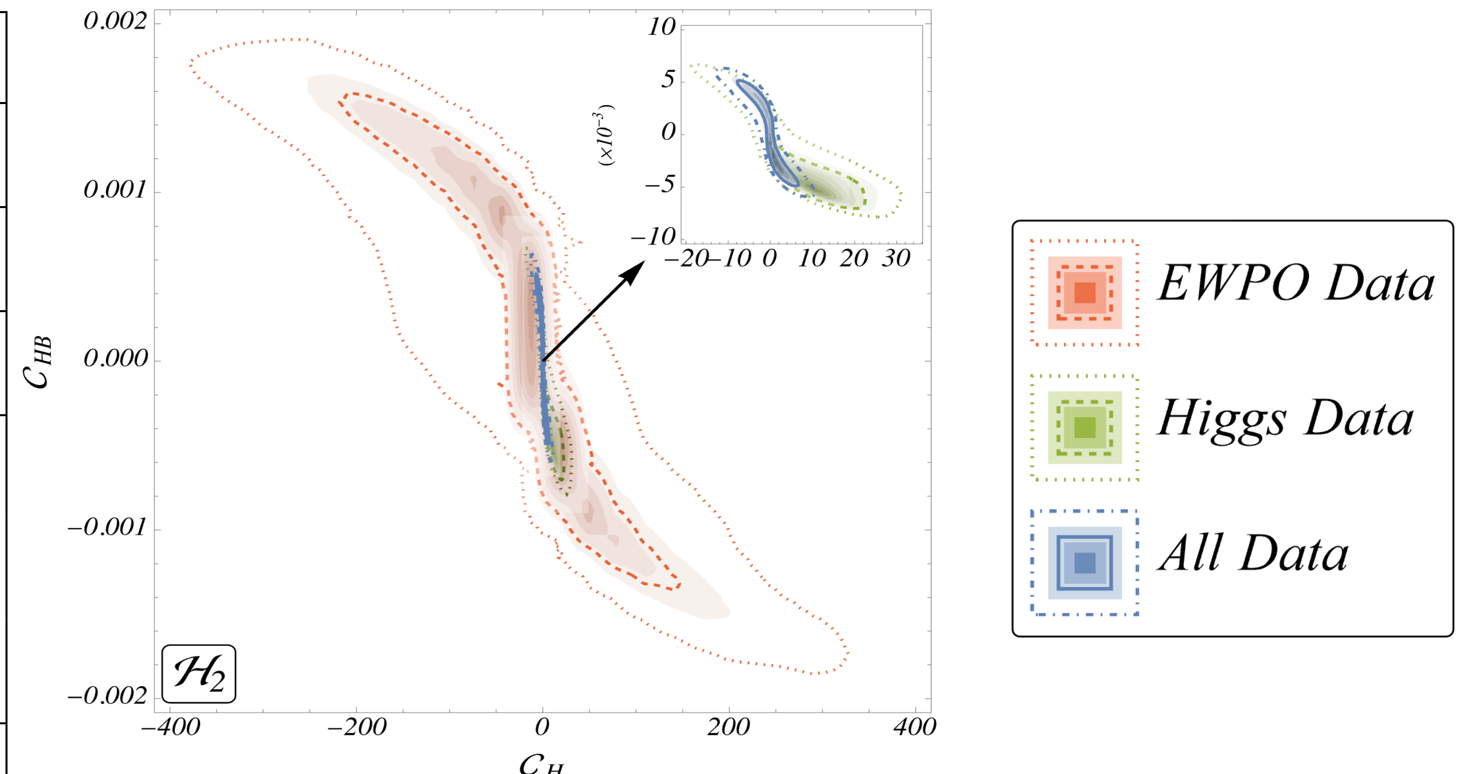


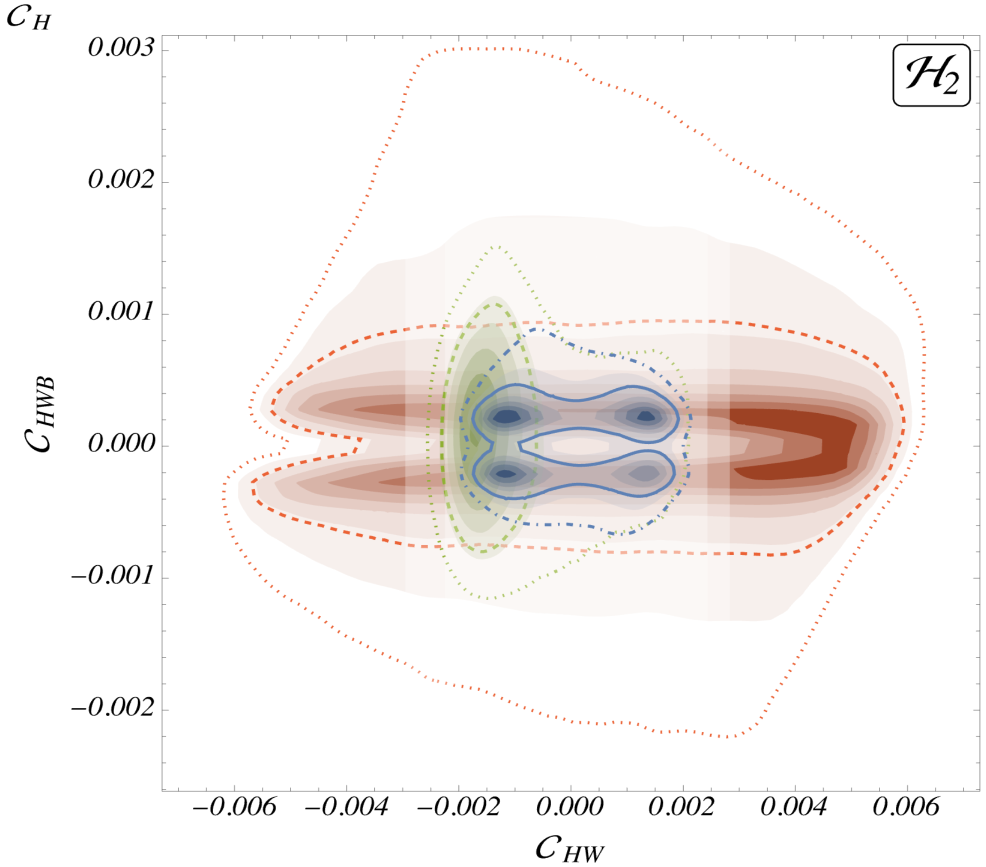
Anisha, Bakshi, Banerjee, Biekötter, Chakrabortty, Patra, Spannowsky, 2111.05876

BSM dependent WC space

Using the samples of points generated for $\lambda_{\mathscr{H}_2,1}$, $\lambda_{\mathscr{H}_2,2}$, $\lambda_{\mathscr{H}_2,3}$, the distributions for the 9 WCs are obtained. These correspond to the bounds from the model information.

Dim-6 Ops.	Wilson coefficients
Q_{dH}	$\frac{\lambda^2_{\mathcal{H}_2,2} Y^{\rm SM}_d}{192\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3} Y^{\rm SM}_d}{48\pi^2 m^2_{\mathcal{H}_2}}$
Q_{eH}	$\frac{\lambda^2_{\mathcal{H}_2,2} Y^{\rm SM}_e}{192\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3} Y^{\rm SM}_e}{48\pi^2 m^2_{\mathcal{H}_2}}$
Q_{uH}	$\frac{\lambda^2_{\mathcal{H}_2,2} Y^{\rm SM}_u}{192\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3} Y^{\rm SM}_u}{48\pi^2 m^2_{\mathcal{H}_2}}$
Q_H	$-\frac{\lambda^3_{\mathcal{H}_2,1}}{48\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^{\rm SM}_H \lambda^2_{\mathcal{H}_2,2}}{96\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda^2_{\mathcal{H}_2,1}\lambda_{\mathcal{H}_2,2}}{32\pi^2 m^2_{\mathcal{H}_2}}$ $-\frac{\lambda_{\mathcal{H}_2,1}\lambda^2_{\mathcal{H}_2,2}}{32\pi^2 m^2_{\mathcal{H}_2}} \frac{\lambda^{\rm SM}_H \lambda^2_{\mathcal{H}_2,3}}{24\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda^3_{\mathcal{H}_2,2}}{96\pi^2 m^2_{\mathcal{H}_2}}$ $-\frac{\lambda_{\mathcal{H}_2,1}\lambda^2_{\mathcal{H}_2,3}}{8\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda_{\mathcal{H}_2,2}\lambda^2_{\mathcal{H}_2,3}}{8\pi^2 m^2_{\mathcal{H}_2}}$
$Q_{H\Box}$	$-\frac{g_W^4}{7680\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda^2_{\mathcal{H}_2,1}}{96\pi^2 m^2_{\mathcal{H}_2}}$ $-\frac{\lambda_{\mathcal{H}_2,1}\lambda_{\mathcal{H}_2,2}}{96\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3}}{48\pi^2 m^2_{\mathcal{H}_2}}$
Q_{HD}	$-\frac{g_Y^4}{1920\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda^2_{\mathcal{H}_2,2}}{96\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3}}{24\pi^2 m^2_{\mathcal{H}_2}}$
Q_{HB}	$\frac{g_Y^2 \lambda_{\mathcal{H}_2,1}}{384\pi^2 m^2_{\mathcal{H}_2}} + \frac{g_Y^2 \lambda_{\mathcal{H}_2,2}}{768\pi^2 m^2_{\mathcal{H}_2}}$
Q_{HW}	$\frac{g_W^2 \lambda_{\mathcal{H}_2,1}}{384\pi^2 m^2_{\mathcal{H}_2}} + \frac{g_W^2 \lambda_{\mathcal{H}_2,2}}{768\pi^2 m^2_{\mathcal{H}_2}}$
Q_{HWB}	$\frac{g_W g_Y \lambda_{\mathcal{H}_2,2}}{384\pi^2 m^2_{\mathcal{H}_2}}$



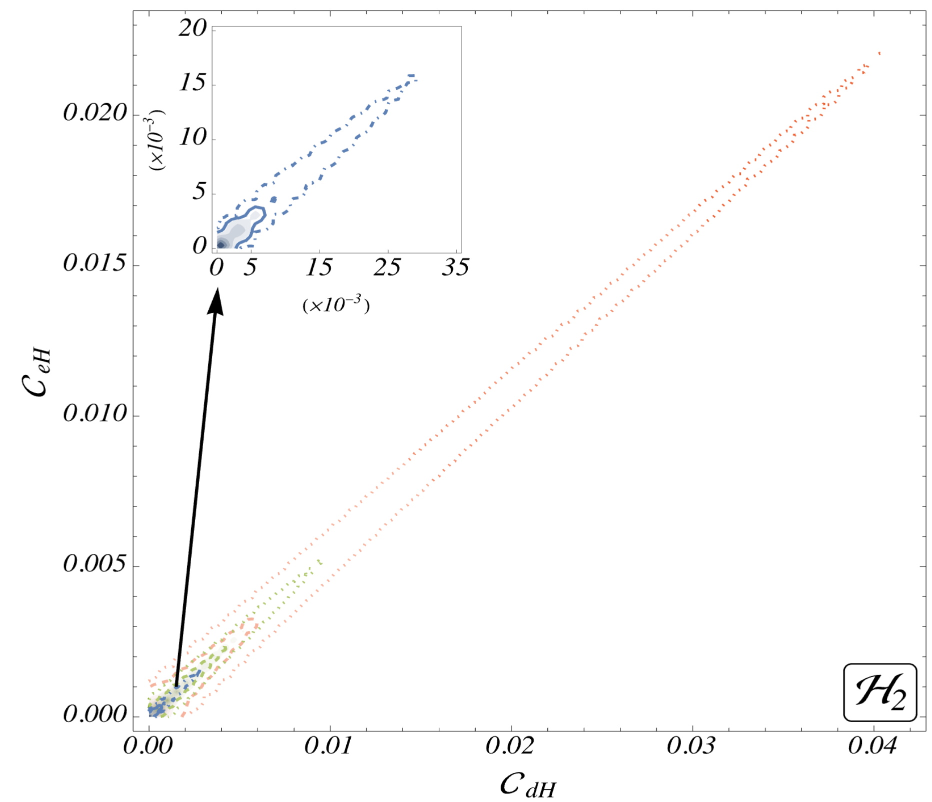


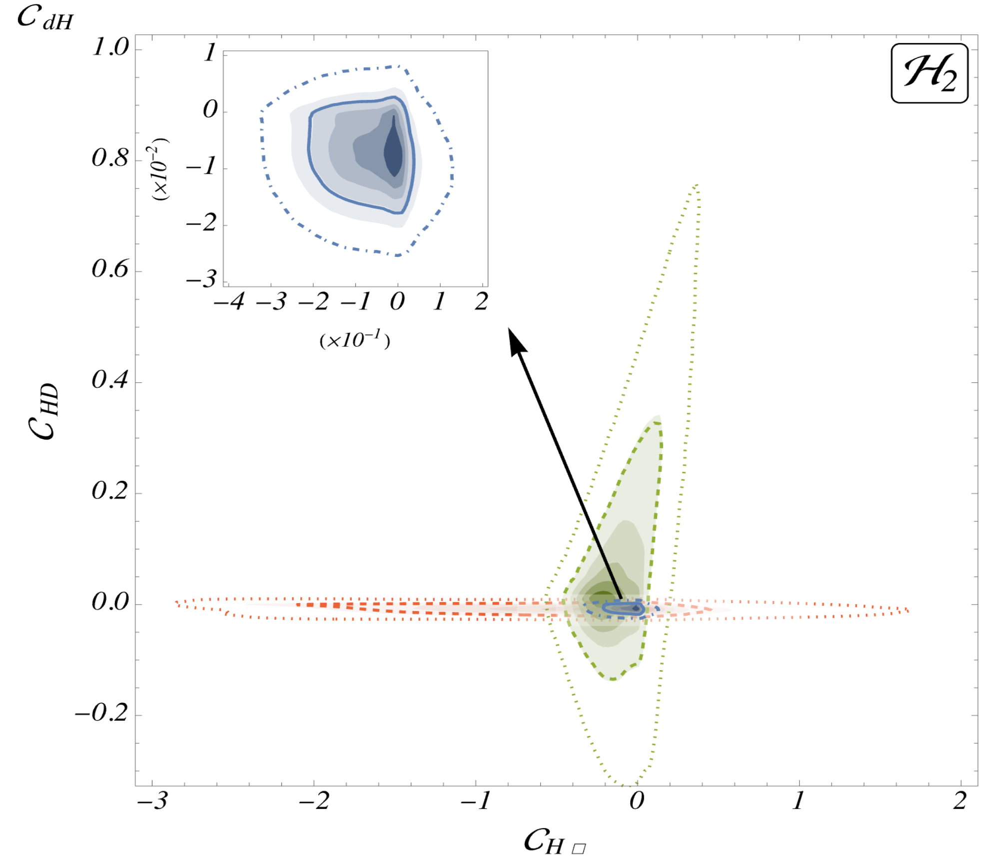
Anisha, Bakshi, Banerjee, Biekötter, Chakrabortty, Patra, Spannowsky
2111.05876

BSM dependent WC space

Using the samples of points generated for $\lambda_{\mathcal{H}_2,1}$, $\lambda_{\mathcal{H}_2,2}$, $\lambda_{\mathcal{H}_2,3}$, the distributions for the WCs are obtained. These correspond to the bounds from the model information.

Dim-6 Ops.	Wilson coefficients
Q_{dH}	$\frac{\lambda^2_{\mathcal{H}_2,2} Y_d^{\rm SM}}{192\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3} Y_d^{\rm SM}}{48\pi^2 m^2_{\mathcal{H}_2}}$
Q_{eH}	$\frac{\lambda^2_{\mathcal{H}_2,2} Y_e^{\rm SM}}{192\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3} Y_e^{\rm SM}}{48\pi^2 m^2_{\mathcal{H}_2}}$
Q_{uH}	$\frac{\lambda^2_{\mathcal{H}_2,2} Y_u^{\rm SM}}{192\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3} Y_u^{\rm SM}}{48\pi^2 m^2_{\mathcal{H}_2}}$
Q_H	$-\frac{\lambda^3_{\mathcal{H}_2,1}}{48\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda_H^{\rm SM}\lambda^2_{\mathcal{H}_2,2}}{96\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda^2_{\mathcal{H}_2,1}\lambda_{\mathcal{H}_2,2}}{32\pi^2 m^2_{\mathcal{H}_2}}$ $-\frac{\lambda_{\mathcal{H}_2,1}\lambda^2_{\mathcal{H}_2,2}}{32\pi^2 m^2_{\mathcal{H}_2}} \frac{\lambda_H^{\rm SM}\lambda^2_{\mathcal{H}_2,3}}{24\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda^3_{\mathcal{H}_2,2}}{96\pi^2 m^2_{\mathcal{H}_2}}$ $-\frac{\lambda_{\mathcal{H}_2,1}\lambda^2_{\mathcal{H}_2,3}}{8\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda_{\mathcal{H}_2,2}\lambda^2_{\mathcal{H}_2,3}}{8\pi^2 m^2_{\mathcal{H}_2}}$
$Q_{H\Box}$	$-\frac{g_W^4}{7680\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda^2_{\mathcal{H}_2,1}}{96\pi^2 m^2_{\mathcal{H}_2}}$ $-\frac{\lambda_{\mathcal{H}_2,1}\lambda_{\mathcal{H}_2,2}}{96\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3}}{48\pi^2 m^2_{\mathcal{H}_2}}$
Q_{HD}	$-\frac{g_Y^4}{1920\pi^2 m^2_{\mathcal{H}_2}} - \frac{\lambda^2_{\mathcal{H}_2,2}}{96\pi^2 m^2_{\mathcal{H}_2}} + \frac{\lambda^2_{\mathcal{H}_2,3}}{24\pi^2 m^2_{\mathcal{H}_2}}$
Q_{HB}	$\frac{g_Y^2\lambda_{\mathcal{H}_2,1}}{384\pi^2 m^2_{\mathcal{H}_2}} + \frac{g_Y^2\lambda_{\mathcal{H}_2,2}}{768\pi^2 m^2_{\mathcal{H}_2}}$
Q_{HW}	$\frac{g_W^2\lambda_{\mathcal{H}_2,1}}{384\pi^2 m^2_{\mathcal{H}_2}} + \frac{g_W^2\lambda_{\mathcal{H}_2,2}}{768\pi^2 m^2_{\mathcal{H}_2}}$
Q_{HWB}	$\frac{g_W g_Y \lambda_{\mathcal{H}_2,2}}{384\pi^2 m^2_{\mathcal{H}_2}}$





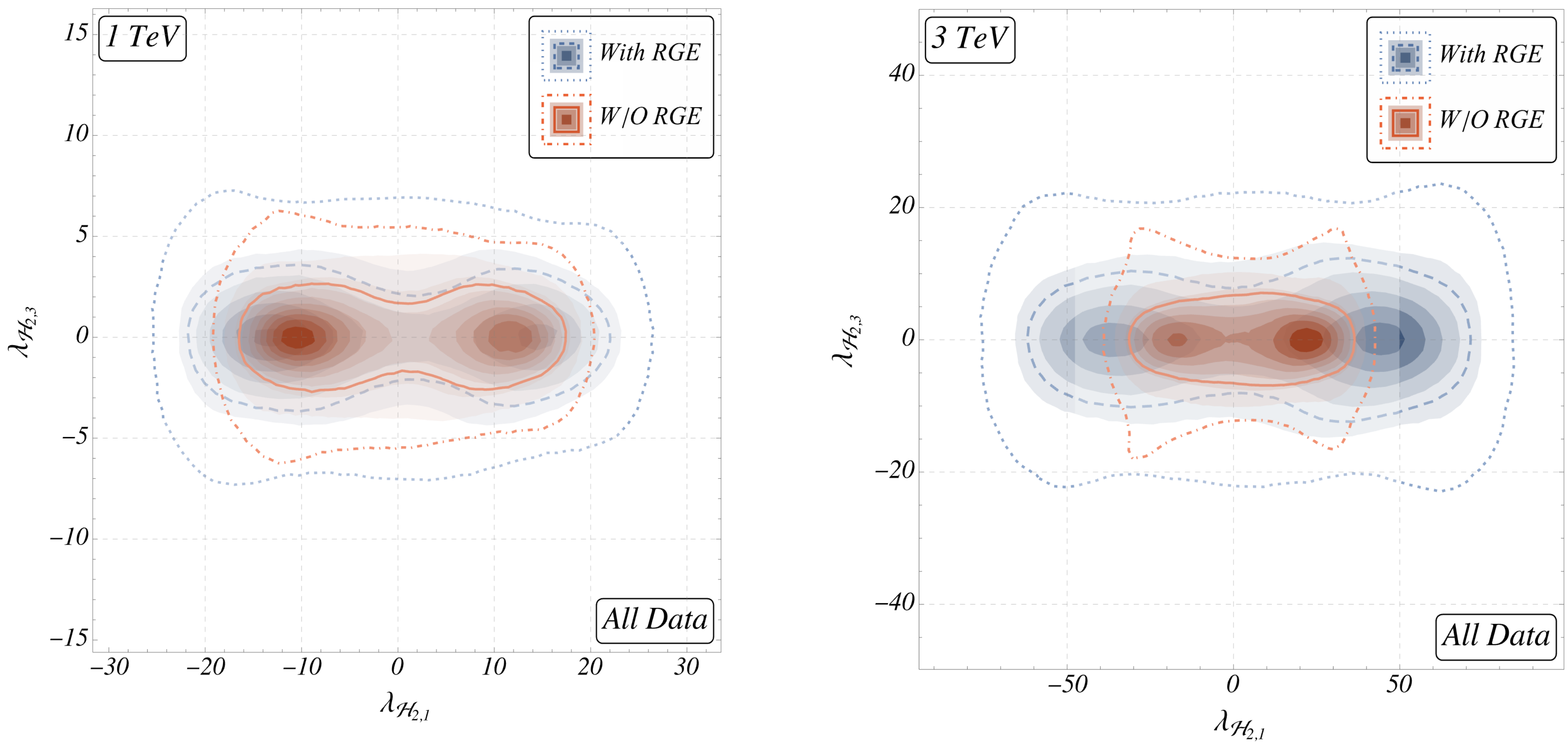
https://github.com/effExTeam/Precision-Observables-and-Higgs-Signals-Effective-passageto-select-BSM

Effect of RGE on model dependent analysis

(Alonso),Jenkins, Manohar & Trott
1308.2627,1310.4838, (1312.2014)

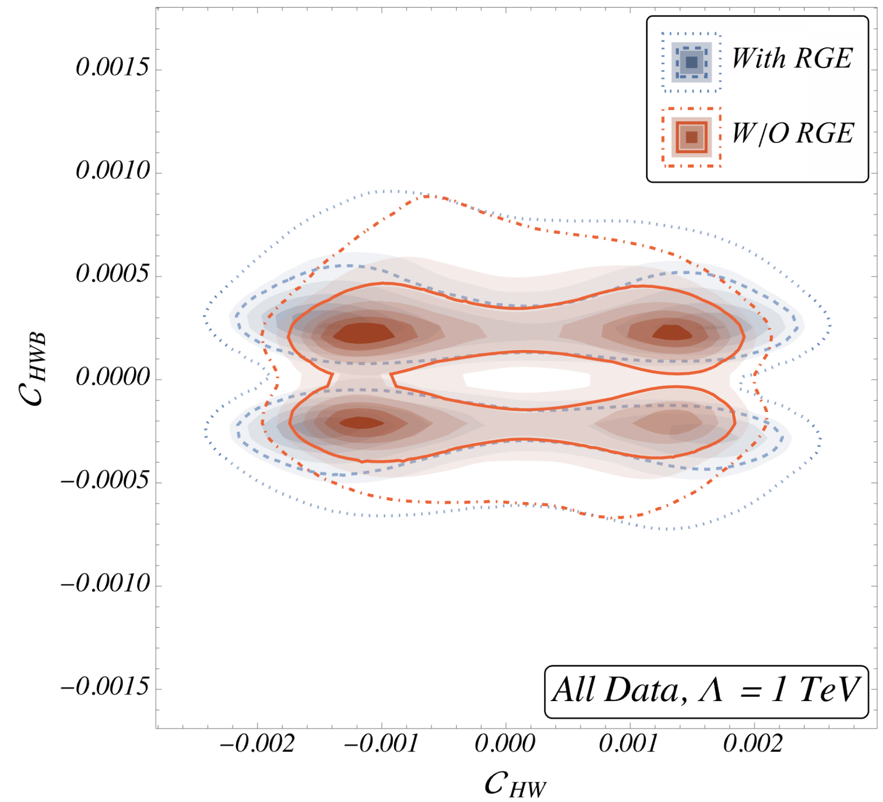
37 SMEFT operators —RG running→ **51 SMEFT operators**

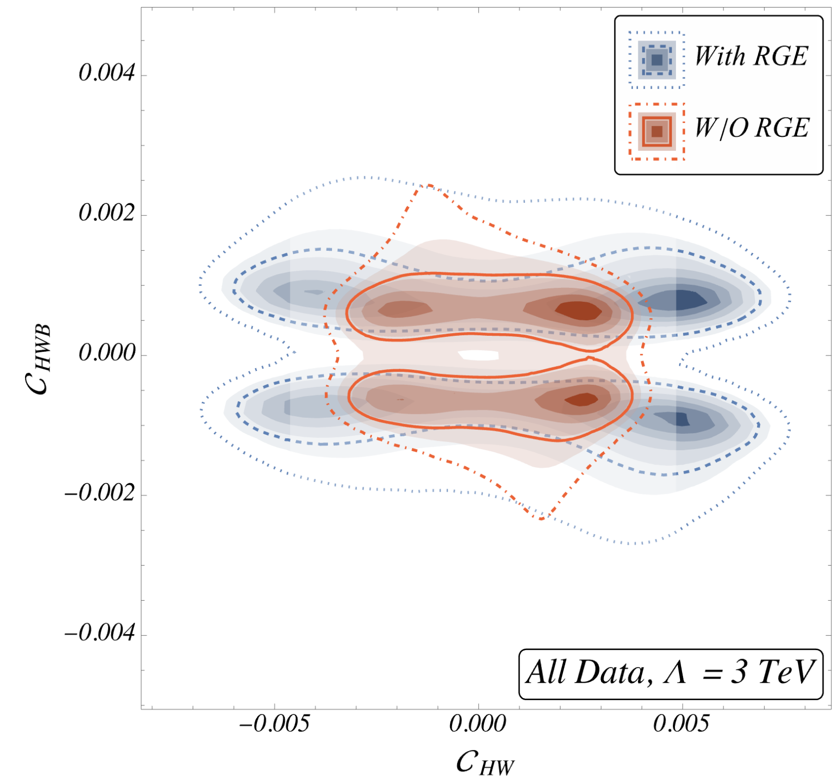
- With assumptions of Z_2 symmetry, 18 operators contribute in 3 model parameter constraints.
- Modification in matching expressions lead to relaxed BSM parameter bounds.
- With increase in $m_{\mathscr{H}_2}$, the model parameter spaces are becoming more relaxed.



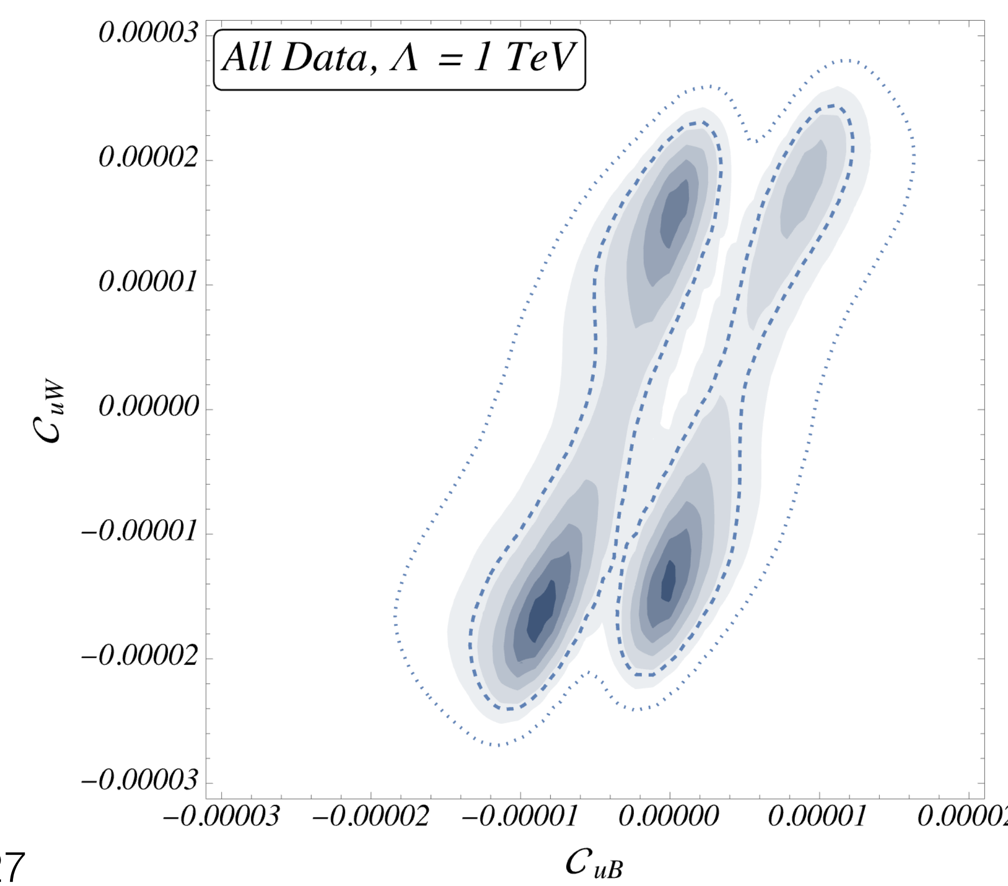
Model dependent WCs spaces

- Similar behaviour is observed for the model generated WCs.





- After including RGE of WCs, parameter spaces of WCs not constrained by data are obtained using BSM parameter spaces.



Conclusions

- Constraints on WCs obtained using the *bottom up* approach of SMEFT.
- Connecting *bottom up* approach with *top down* approach.
  - Bounds on BSM parameters.
  - Model dependent WCs Parameter spaces are more constrained as compared to those obtained when WCs are treated free.

Future Prospects

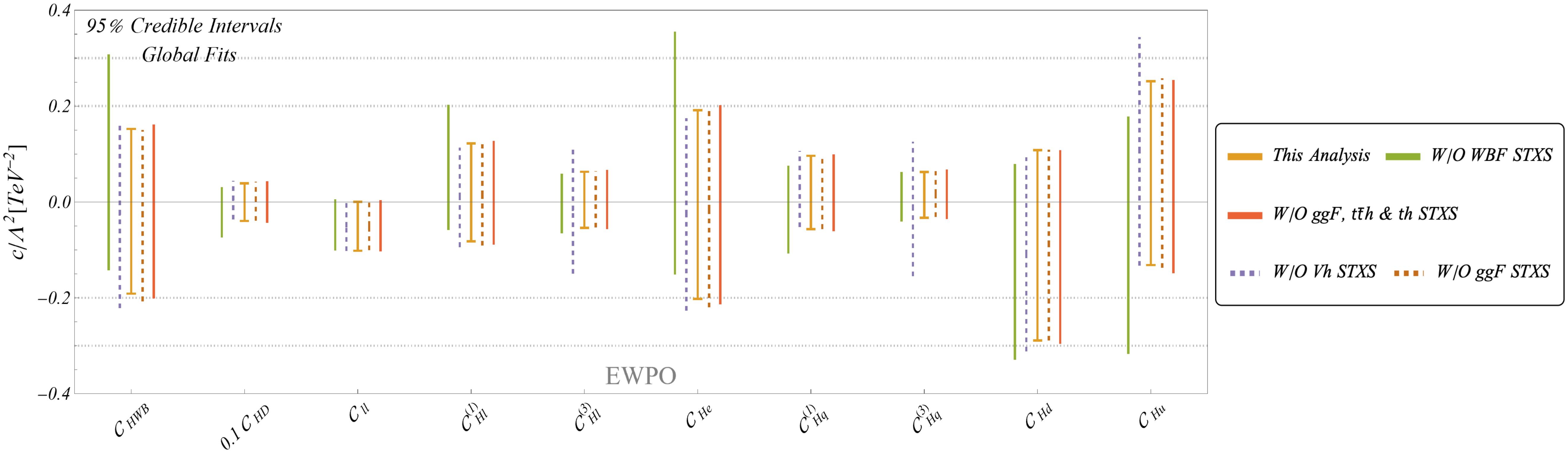
- Aim to include top sector data and flavour observables in the global fit.
- Studying the effects of dim-6 squared and dim-8 contributions.
- Include observables which can affect four-fermi operators.
- Build a framework to compare BSM theories using the matching results.

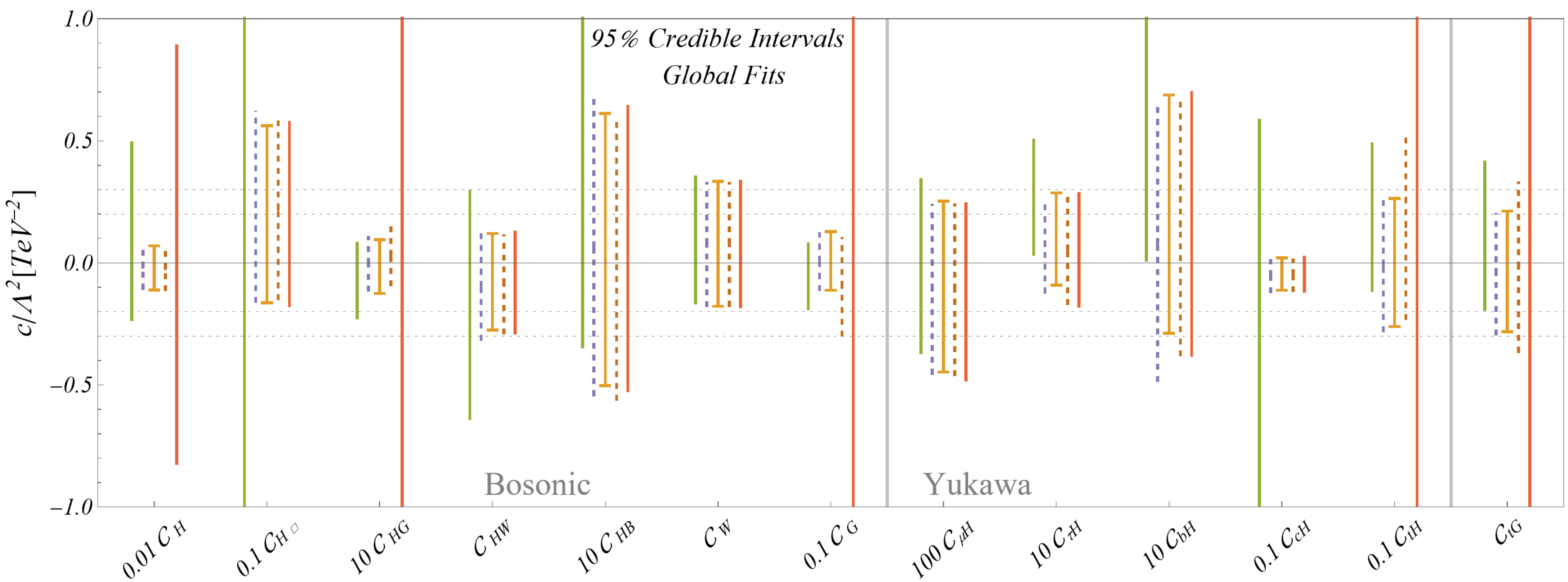
Thank you for the attention !

Back up

Constraining effects of different datasets

Anisha, Bakshi, Banerjee, Biekötter, Chakrabortty, Patra, Spannowsky 2111.05876





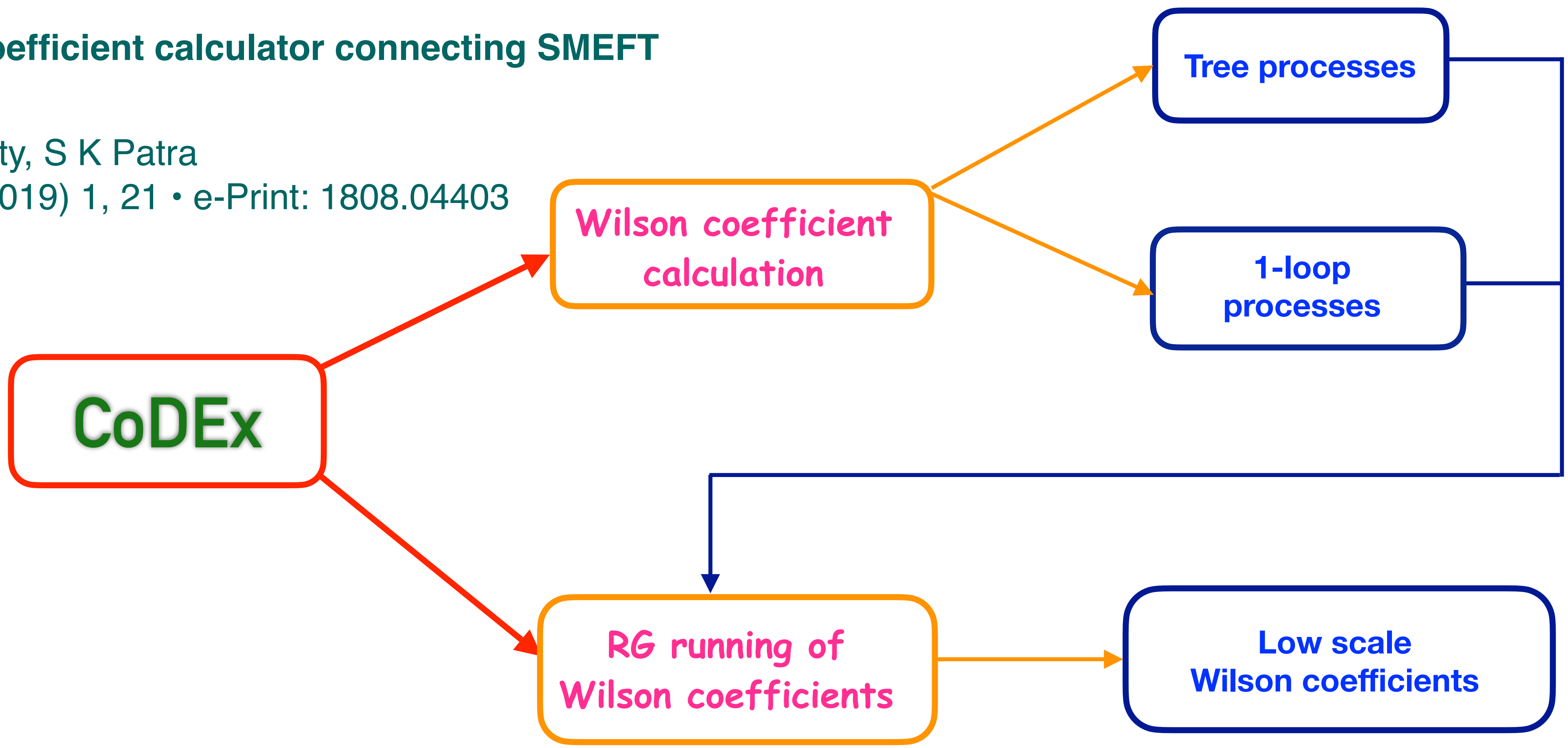
CoDEx : Wilson coefficient calculator

Complete 1-loop Wilson coefficients within seconds !

Manually matching BSMs to SMEFT is involved.
Package for automization is much needed.

CoDEx: Wilson coefficient calculator connecting SMEFT to UV theory

SDB, J Chakrabortty, S K Patra
Eur.Phys.J.C 79 (2019) 1, 21 • e-Print: 1808.04403



https://effexteam.github.io/CoDEx/

CoDEx: Extra Scalar Doublet

Heavy field properties

{Name, Color, Isospin, Hypercharge, Spin, Mass}

```
list = { hf,   1,    2,    -1/2,    0,   mH2}
```

Heavy field representation

φ = defineHeavyFields[list]

BSM Lagrangian

$$\mathcal{L}_{\mathcal{H}_2} = \mathcal{L}_{SM} + |D_\mu \mathcal{H}_2|^2 - m^2_{\mathcal{H}_2}|\mathcal{H}_2|^2 - \frac{\lambda_{\mathcal{H}_2}}{4}|\mathcal{H}_2|^4 - (\eta_H|\widetilde{H}|^2 + \eta_{\mathcal{H}_2}|\mathcal{H}_2|^2)(\widetilde{H}^\dagger\mathcal{H}_2 + \mathcal{H}_2^\dagger\widetilde{H})$$
$$- \lambda_{\mathcal{H}_2,1}|\widetilde{H}|^2|\mathcal{H}_2|^2 - \lambda_{\mathcal{H}_2,2}|\widetilde{H}^\dagger\mathcal{H}_2|^2 - \lambda_{\mathcal{H}_2,3}\left[(\widetilde{H}^\dagger\mathcal{H}_2)^2 + (\mathcal{H}_2^\dagger\widetilde{H})^2\right]$$
$$- \left\{Y^{(e)}_{\mathcal{H}_2}\overline{L}_L\,\widetilde{\mathcal{H}}_2 e_R + Y^{(u)}_{\mathcal{H}_2}\overline{q}_L\,\mathcal{H}_2\,u_R + Y^{(d)}_{\mathcal{H}_2}\overline{q}_L\,\widetilde{\mathcal{H}}_2\,d_R + \text{h.c.}\right\}$$

```
LH2 = - λH2/4 (dag[φ].φ)^2 - (ηH dag[Ht].Ht + ηH2 dag[φ].φ) (dag[Ht].φ + dag[φ].Ht)

   -λH21 (dag[Ht].Ht) * (dag[φ].φ)  - λ𝓗22 (dag[Ht].φ) * (dag[φ].Ht) - λ𝓗23 ((dag[Ht].φ)^2 + (dag[φ].Ht)^2)

   -yH2e ((lepb[1][[1]] * φt[[1]] + lepb[1][[2]] * φt[[2]]).eR[1]
       + eRb[1].(hermitianConjugate[φtilde[[1]]] * lep[1][[1]] + hermitianConjugate[φtilde[[2]]] * lep[1][[2]]))
   +yH2u ((qdubb[1, 1][[1]] * φ[[1]] + qdubb[1, 1][[2]] * φ[[2]]).uR[1, 1]
       + uRb[1, 1].(hermitianConjugate[φ[[1]]] * qdub[1, 1][[1]] + hermitianConjugate[φ[[2]]] * qdub[1, 1][[2]]))
   +yH2d ((qdubb[1, 1][[1]] * φt[[1]] + qdubb[1, 1][[2]] * φt[[2]]).dR[1, 1]
       + dRb[1, 1].(hermitianConjugate[φt[[1]]] * qdub[1, 1][[1]] + hermitianConjugate[φt[[2]]] * qdub[1, 1][[2]]))
```

Tree-level Wilson coefficients

```
In[4]:   codexOutput[ LH2, list, model —> “2HDM”, outRange —> ”Tree”,
operBasis —> ”Warsaw” ]
```

Matching scale = mass of heavy field = mH2

Q_H	$(H^\dagger H)^3$	$\frac{\eta\text{H}^2}{\text{mH2}^2}$
Q_{eH}	$(H^\dagger H)(\bar{l}\ \text{e}\ H)$+h.c.	$-\frac{\eta\text{H yH2e}}{\text{mH2}^2}$
Q_{uH}	$(H^\dagger H)(\bar{q}\ \text{u}\ \tilde{H})$+h.c.	$\frac{\eta\text{H yH2u}}{\text{mH2}^2}$
Q_{dH}	$(H^\dagger H)(\bar{q}\ \text{d}\ H)$+h.c.	$-\frac{\eta\text{H yH2d}}{\text{mH2}^2}$
Q_{le}	$(\bar{l}\ \gamma_\mu\ \text{l})(\bar{e}\ \gamma_\mu\ \text{e})$	$-\frac{\text{yH2e}^2}{4\ \text{mH2}^2}$
$Q_{\text{qu}}{}^{(1)}$	$(\bar{q}\ \gamma^\mu\ \text{q})(\bar{u}\ \gamma_\mu\ \text{u})$	$-\frac{\text{yH2u}^2}{4\ \text{mH2}^2}$
$Q_{\text{qd}}{}^{(1)}$	$(\bar{q}\ \gamma_\mu\ \text{q})(\bar{d}\ \gamma_\mu\ \text{d})$	$-\frac{\text{yH2d}^2}{4\ \text{mH2}^2}$
Q_{ledq}	$(\bar{l}^j\ \text{e})(\bar{d}\ q_j)$+h.c.	$\frac{\text{yH2d yH2e}}{2\ \text{mH2}^2}$
$Q_{\text{quqd}}{}^{(1)}$	$(\bar{q}^j\ \text{u})\epsilon_{\text{jk}}(\bar{q}^k\ \text{d})$+h.c.	$-\frac{\text{yH2d yH2u}}{2\ \text{mH2}^2}$
$Q_{\text{lequ}}{}^{(1)}$	$(\bar{l}^j\ \text{e})\epsilon_{\text{jk}}(\bar{q}^k\ \text{u})$+h.c.	$\frac{\text{yH2e yH2u}}{2\ \text{mH2}^2}$

1-loop level Wilson coefficients

In[5]: initializeLop["2HDM" , list]

In[6]: codexOutput[LH2, list, model —> "2HDM", outRange —> "Loop", operBasis —> "Warsaw"]

Out[6]:

Matching scale = heavy field mass

*1-loop processes involving only heavy propagators in the loop.

RGFlow of the Wilson coefficients

In[7]: RGFlow[Wilson coefficients, mH2, μ]

Out[7]:

SMEFT Matching results

Dim-6 Ops.	Wilson coefficients
Q_{dH}	$\frac{\eta_H^2 Y_d^{\mathrm{SM}}}{16\pi^2 m_{\mathcal{H}_2}^2} - \frac{3\eta_H \eta_{\mathcal{H}_2} Y_d^{\mathrm{SM}}}{16\pi^2 m_{\mathcal{H}_2}^2} - \frac{\eta_H Y_{\mathcal{H}_2}^{(d)}}{m_{\mathcal{H}_2}^2} - \frac{3\eta_H \lambda_{\mathcal{H}_2} Y_{\mathcal{H}_2}^{(d)}}{32\pi^2 m_{\mathcal{H}_2}^2} + \frac{3\eta_H \lambda_{\mathcal{H}_2,1} Y_{\mathcal{H}_2}^{(d)}}{16\pi^2 m_{\mathcal{H}_2}^2} - \frac{3\eta_{\mathcal{H}_2} \lambda_{\mathcal{H}_2,1} Y_{\mathcal{H}_2}^{(d)}}{16\pi^2 m_{\mathcal{H}_2}^2} \frac{\eta_H \lambda_{\mathcal{H}_2,2} Y_{\mathcal{H}_2}^{(d)}}{4\pi^2 m_{\mathcal{H}_2}^2} - \frac{3\eta_{\mathcal{H}_2} \lambda_{\mathcal{H}_2,2} Y_{\mathcal{H}_2}^{(d)}}{16\pi^2 m_{\mathcal{H}_2}^2} + \frac{\lambda_{\mathcal{H}_2,2}^2 Y_d^{\mathrm{SM}}}{192\pi^2 m_{\mathcal{H}_2}^2} \frac{5\eta_H \lambda_{\mathcal{H}_2,3} Y_{\mathcal{H}_2}^{(d)}}{8\pi^2 m_{\mathcal{H}_2}^2} + \frac{\lambda_{\mathcal{H}_2,3}^2 Y_d^{\mathrm{SM}}}{48\pi^2 m_{\mathcal{H}_2}^2}$
Q_{eH}	$\frac{\eta_H^2 Y_e^{\mathrm{SM}}}{16\pi^2 m_{\mathcal{H}_2}^2} - \frac{3\eta_H \eta_{\mathcal{H}_2} Y_e^{\mathrm{SM}}}{16\pi^2 m_{\mathcal{H}_2}^2} - \frac{\eta_H Y_{\mathcal{H}_2}^{(e)}}{m_{\mathcal{H}_2}^2} - \frac{3\eta_H \lambda_{\mathcal{H}_2} Y_{\mathcal{H}_2}^{(e)}}{32\pi^2 m_{\mathcal{H}_2}^2} + \frac{3\eta_H \lambda_{\mathcal{H}_2,1} Y_{\mathcal{H}_2}^{(e)}}{16\pi^2 m_{\mathcal{H}_2}^2} - \frac{3\eta_{\mathcal{H}_2} \lambda_{\mathcal{H}_2,1} Y_{\mathcal{H}_2}^{(e)}}{16\pi^2 m_{\mathcal{H}_2}^2} \frac{\eta_H \lambda_{\mathcal{H}_2,2} Y_{\mathcal{H}_2}^{(e)}}{4\pi^2 m_{\mathcal{H}_2}^2} - \frac{3\eta_{\mathcal{H}_2} \lambda_{\mathcal{H}_2,2} Y_{\mathcal{H}_2}^{(e)}}{16\pi^2 m_{\mathcal{H}_2}^2} + \frac{\lambda_{\mathcal{H}_2,2}^2 Y_e^{\mathrm{SM}}}{192\pi^2 m_{\mathcal{H}_2}^2} \frac{5\eta_H \lambda_{\mathcal{H}_2,3} Y_{\mathcal{H}_2}^{(e)}}{8\pi^2 m_{\mathcal{H}_2}^2} + \frac{\lambda_{\mathcal{H}_2,3}^2 Y_e^{\mathrm{SM}}}{48\pi^2 m_{\mathcal{H}_2}^2}$
Q_{uH}	$\frac{\eta_H^2 Y_u^{\mathrm{SM}}}{16\pi^2 m_{\mathcal{H}_2}^2} + \frac{3\eta_H \lambda_{\mathcal{H}_2} Y_{\mathcal{H}_2}^{(u)}}{32\pi^2 m_{\mathcal{H}_2}^2} + \frac{\eta_H Y_{\mathcal{H}_2}^{(u)}}{m_{\mathcal{H}_2}^2} - \frac{3\eta_H \eta_{\mathcal{H}_2} Y_u^{\mathrm{SM}}}{16\pi^2 m_{\mathcal{H}_2}^2} - \frac{3\eta_H \lambda_{\mathcal{H}_2,1} Y_{\mathcal{H}_2}^{(u)}}{16\pi^2 m_{\mathcal{H}_2}^2} + \frac{3\eta_{\mathcal{H}_2} \lambda_{\mathcal{H}_2,1} Y_{\mathcal{H}_2}^{(u)}}{16\pi^2 m_{\mathcal{H}_2}^2} - \frac{\eta_H \lambda_{\mathcal{H}_2,2} Y_{\mathcal{H}_2}^{(u)}}{4\pi^2 m_{\mathcal{H}_2}^2} + \frac{3\eta_{\mathcal{H}_2} \lambda_{\mathcal{H}_2,2} Y_{\mathcal{H}_2}^{(u)}}{16\pi^2 m_{\mathcal{H}_2}^2} + \frac{\lambda_{\mathcal{H}_2,2}^2 Y_u^{\mathrm{SM}}}{192\pi^2 m_{\mathcal{H}_2}^2} \frac{\lambda_{\mathcal{H}_2,3}^2 Y_u^{\mathrm{SM}}}{48\pi^2 m_{\mathcal{H}_2}^2} - \frac{5\eta_H \lambda_{\mathcal{H}_2,3} Y_{\mathcal{H}_2}^{(u)}}{8\pi^2 m_{\mathcal{H}_2}^2}$
Q_H	$\frac{3\eta_H^2 \lambda_{\mathcal{H}_2}}{32\pi^2 m_{\mathcal{H}_2}^2} + \frac{17\eta_H^2 \lambda_H^{\mathrm{SM}}}{16\pi^2 m_{\mathcal{H}_2}^2} + \frac{\eta_H^2}{m_{\mathcal{H}_2}^2} - \frac{3\eta_H^2 \lambda_{\mathcal{H}_2,1}}{4\pi^2 m_{\mathcal{H}_2}^2} - \frac{3\eta_H \eta_{\mathcal{H}_2} \lambda_H^{\mathrm{SM}}}{8\pi^2 m_{\mathcal{H}_2}^2} + \frac{3\eta_H \eta_{\mathcal{H}_2} \lambda_{\mathcal{H}_2,1}}{8\pi^2 m_{\mathcal{H}_2}^2} - \frac{13\eta_H^2 \lambda_{\mathcal{H}_2,2}}{16\pi^2 m_{\mathcal{H}_2}^2} + \frac{3\eta_H \eta_{\mathcal{H}_2} \lambda_{\mathcal{H}_2,2}}{8\pi^2 m_{\mathcal{H}_2}^2} - \frac{\lambda_{\mathcal{H}_2,1}^3}{48\pi^2 m_{\mathcal{H}_2}^2} \frac{\lambda_H^{\mathrm{SM}} \lambda_{\mathcal{H}_2,2}^2}{96\pi^2 m_{\mathcal{H}_2}^2} - \frac{\lambda_{\mathcal{H}_2,1}^2 \lambda_{\mathcal{H}_2,2}}{32\pi^2 m_{\mathcal{H}_2}^2} - \frac{\lambda_{\mathcal{H}_2,1} \lambda_{\mathcal{H}_2,2}^2}{32\pi^2 m_{\mathcal{H}_2}^2} - \frac{7\eta_H^2 \lambda_{\mathcal{H}_2,3}}{4\pi^2 m_{\mathcal{H}_2}^2} + \frac{\lambda_H^{\mathrm{SM}} \lambda_{\mathcal{H}_2,3}^2}{24\pi^2 m_{\mathcal{H}_2}^2} - \frac{\lambda_{\mathcal{H}_2,2}^3}{96\pi^2 m_{\mathcal{H}_2}^2} - \frac{\lambda_{\mathcal{H}_2,1} \lambda_{\mathcal{H}_2,3}^2}{8\pi^2 m_{\mathcal{H}_2}^2} - \frac{\lambda_{\mathcal{H}_2,2} \lambda_{\mathcal{H}_2,3}^2}{8\pi^2 m_{\mathcal{H}_2}^2}$
$Q_{H\Box}$	$-\frac{g_W^4}{7680\pi^2 m_{\mathcal{H}_2}^2} - \frac{3\eta_H^2}{32\pi^2 m_{\mathcal{H}_2}^2} - \frac{\lambda_{\mathcal{H}_2,1}^2}{96\pi^2 m_{\mathcal{H}_2}^2} - \frac{\lambda_{\mathcal{H}_2,1} \lambda_{\mathcal{H}_2,2}}{96\pi^2 m_{\mathcal{H}_2}^2} + \frac{\lambda_{\mathcal{H}_2,2}^2}{384\pi^2 m_{\mathcal{H}_2}^2} + \frac{\lambda_{\mathcal{H}_2,3}^2}{96\pi^2 m_{\mathcal{H}_2}^2}$
Q_{HD}	$-\frac{g_Y^4}{1920\pi^2 m_{\mathcal{H}_2}^2} - \frac{\lambda_{\mathcal{H}_2,2}^2}{96\pi^2 m_{\mathcal{H}_2}^2} + \frac{\lambda_{\mathcal{H}_2,3}^2}{24\pi^2 m_{\mathcal{H}_2}^2}$
Q_{HB}	$\frac{g_Y^2 \lambda_{\mathcal{H}_2,1}}{384\pi^2 m_{\mathcal{H}_2}^2} + \frac{g_Y^2 \lambda_{\mathcal{H}_2,2}}{768\pi^2 m_{\mathcal{H}_2}^2}$
Q_{HW}	$\frac{g_W^2 \lambda_{\mathcal{H}_2,1}}{384\pi^2 m_{\mathcal{H}_2}^2} + \frac{g_W^2 \lambda_{\mathcal{H}_2,2}}{768\pi^2 m_{\mathcal{H}_2}^2}$
Q_{HWB}	$\frac{g_W g_Y \lambda_{\mathcal{H}_2,2}}{384\pi^2 m_{\mathcal{H}_2}^2}$

Dim-6 Ops.	Wilson coefficients
$Q_{Hl}^{(1)}$	$\frac{g_Y^4}{3840\pi^2 m_{\mathcal{H}_2}^2}$
$Q_{Hq}^{(1)}$	$-\frac{g_Y^4}{11520\pi^2 m_{\mathcal{H}_2}^2}$
Q_{Hd}	$\frac{g_Y^4}{5760\pi^2 m_{\mathcal{H}_2}^2}$
Q_{He}	$\frac{g_Y^4}{1920\pi^2 m_{\mathcal{H}_2}^2}$
Q_{Hu}	$-\frac{g_Y^4}{2880\pi^2 m_{\mathcal{H}_2}^2}$
$Q_{Hl}^{(3)}$	$-\frac{g_W^4}{1920\pi^2 m_{\mathcal{H}_2}^2}$
$Q_{Hq}^{(3)}$	$-\frac{g_W^4}{1920\pi^2 m_{\mathcal{H}_2}^2}$
Q_W	$\frac{g_W^3}{5760\pi^2 m_{\mathcal{H}_2}^2}$
Q_{ll}	$-\frac{g_W^4}{7680\pi^2 m_{\mathcal{H}_2}^2} - \frac{g_Y^4}{7680\pi^2 m_{\mathcal{H}_2}^2}$

CoDEx SMEFT Matching Result

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Dim-6 Ops.	Wilson coefficients
${Q_{\mathrm{ud}}}^{(1)}$	$\frac{g_Y^4}{4320\pi^2 m_{\mathcal{H}_2}^2}$
${Q_{\mathrm{lq}}}^{(3)}$	$-\frac{g_W^4}{3840\pi^2 m_{\mathcal{H}_2}^2}$
${Q_{\mathrm{qq}}}^{(3)}$	$-\frac{g_W^4}{7680\pi^2 m_{\mathcal{H}_2}^2}$
Q_{dd}	$-\frac{g_Y^4}{17280\pi^2 m_{\mathcal{H}_2}^2}$
Q_{ed}	$-\frac{g_Y^4}{2880\pi^2 m_{\mathcal{H}_2}^2}$
Q_{ee}	$-\frac{g_Y^4}{1920\pi^2 m_{\mathcal{H}_2}^2}$
Q_{eu}	$\frac{g_Y^4}{1440\pi^2 m_{\mathcal{H}_2}^2}$
Q_{uu}	$-\frac{g_Y^4}{4320\pi^2 m_{\mathcal{H}_2}^2}$
Q_{lu}	$\frac{g_Y^4}{2880\pi^2 m_{\mathcal{H}_2}^2}$
Q_{qe}	$\frac{g_Y^4}{5760\pi^2 m_{\mathcal{H}_2}^2}$
Q_{ld}	$-\frac{g_Y^4}{5760\pi^2 m_{\mathcal{H}_2}^2}$
${Q_{\mathrm{qq}}}^{(1)}$	$-\frac{g_Y^4}{69120\pi^2 m_{\mathcal{H}_2}^2}$
Q_{le}	$-\frac{g_Y^4}{1920\pi^2 m_{\mathcal{H}_2}^2} - \frac{3\lambda_{\mathcal{H}_2} Y_{\mathcal{H}_2}^{(e)2}}{128\pi^2 m_{\mathcal{H}_2}^2} - \frac{Y_{\mathcal{H}_2}^{(e)2}}{4m_{\mathcal{H}_2}^2}$
${Q_{\mathrm{qd}}}^{(1)}$	$\frac{g_Y^4}{17280\pi^2 m_{\mathcal{H}_2}^2} - \frac{3\lambda_{\mathcal{H}_2} Y_{\mathcal{H}_2}^{(d)2}}{128\pi^2 m_{\mathcal{H}_2}^2} - \frac{Y_{\mathcal{H}_2}^{(d)2}}{4m_{\mathcal{H}_2}^2}$
${Q_{\mathrm{qu}}}^{(1)}$	$-\frac{g_Y^4}{8640\pi^2 m_{\mathcal{H}_2}^2} - \frac{3\lambda_{\mathcal{H}_2} Y_{\mathcal{H}_2}^{(u)2}}{128\pi^2 m_{\mathcal{H}_2}^2} - \frac{Y_{\mathcal{H}_2}^{(u)2}}{4m_{\mathcal{H}_2}^2}$
${Q_{\mathrm{quqd}}}^{(1)}$	$-\frac{3\lambda_{\mathcal{H}_2} Y_{\mathcal{H}_2}^{(d)} Y_{\mathcal{H}_2}^{(u)}}{64\pi^2 m_{\mathcal{H}_2}^2} - \frac{Y_{\mathcal{H}_2}^{(d)} Y_{\mathcal{H}_2}^{(u)}}{2m_{\mathcal{H}_2}^2}$
${Q_{\mathrm{lequ}}}^{(1)}$	$\frac{3\lambda_{\mathcal{H}_2} Y_{\mathcal{H}_2}^{(e)} Y_{\mathcal{H}_2}^{(u)}}{64\pi^2 m_{\mathcal{H}_2}^2} + \frac{Y_{\mathcal{H}_2}^{(e)} Y_{\mathcal{H}_2}^{(u)}}{2m_{\mathcal{H}_2}^2}$
${Q_{\mathrm{lq}}}^{(1)}$	$\frac{g_Y^4}{11520\pi^2 m_{\mathcal{H}_2}^2}$
Q_{ledq}	$\frac{3\lambda_{\mathcal{H}_2} Y_{\mathcal{H}_2}^{(d)} Y_{\mathcal{H}_2}^{(e)}}{64\pi^2 m_{\mathcal{H}_2}^2} + \frac{Y_{\mathcal{H}_2}^{(d)} Y_{\mathcal{H}_2}^{(e)}}{2m_{\mathcal{H}_2}^2}$

BSM scenarios considered

BSM field	Spin	SM quantum numbers			Mass
		$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	
$\mathcal{S}$	0	1	1	0	$m_{\mathcal{S}}$
Δ	0	1	3	0	m_{Δ}
$\mathcal{S}_1$	0	1	1	1	$m_{\mathcal{S}_1}$
$\mathcal{S}_2$	0	1	1	2	$m_{\mathcal{S}_2}$
Δ_1	0	1	3	1	m_{Δ_1}
$\mathcal{H}_2$	0	1	2	$-\frac{1}{2}$	$m_{\mathcal{H}_2}$
Σ	0	1	4	$\frac{1}{2}$	m_{Σ}
φ_1	0	3	1	$-\frac{1}{3}$	m_{φ_1}
φ_2	0	3	1	$-\frac{4}{3}$	m_{φ_2}
Θ_1	0	3	2	$\frac{1}{6}$	m_{Θ_1}
Θ_2	0	3	2	$\frac{7}{6}$	m_{Θ_2}
Ω	0	3	3	$-\frac{1}{3}$	m_{Ω}
χ_1	0	6	3	$\frac{1}{3}$	m_{χ_1}
χ_2	0	6	1	$\frac{4}{3}$	m_{χ_2}
χ_3	0	6	1	$-\frac{2}{3}$	m_{χ_3}
χ_4	0	6	1	$\frac{1}{3}$	m_{χ_4}

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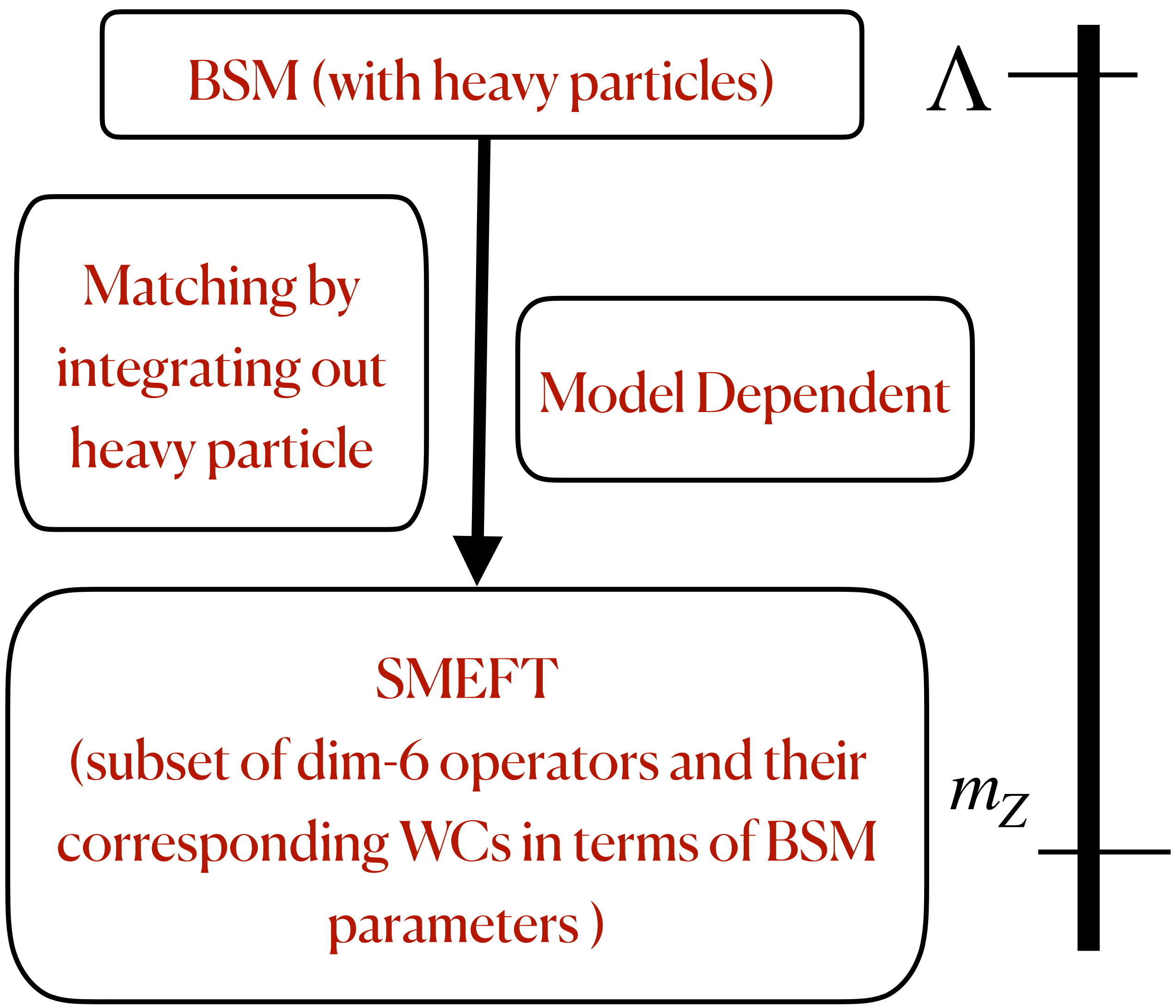
https://github.com/effExTeam/Precision-Observables-and-Higgs-Signals-Effective-passageto-select-BSM

DiHiggs measurements

channel	ATLAS	CMS
$b\bar{b}b\bar{b}$	-12.7 ± 12.8	-3.9 ± 3.8
$b\bar{b}\gamma\gamma$	$-6.3^{+9.9}_{-7.5}$	2.5 ± 2.6
$b\bar{b}\tau\tau$	-4.1 ± 8.4	-5 ± 15

Running of WCs

(Alonso),Jenkins, Manohar & Trott
1308.2627,1310.4838, (1312.2014)



Leading order solution

$$c_i(m_Z) = c_i(\Lambda) - \sum_j \frac{1}{16\pi^2}\gamma_{ij}\, c_j(\Lambda)\ \log\frac{\Lambda}{m_Z}$$

37 SMEFT operators —**RG running**→ **51 SMEFT operators**