CONSIDERATIONS FOR SMEFT FITS

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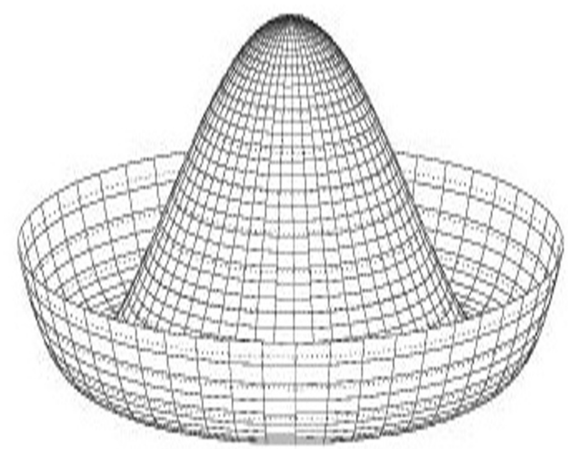
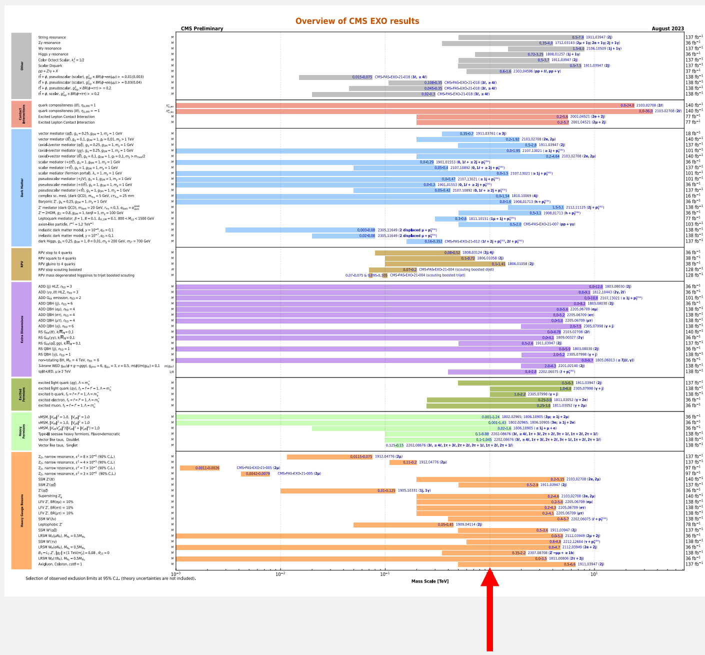


Complaints, suggestions to dawson@bnl.gov

IT APPEARS THAT NEW PHYSICS IS HEAVY (> 1 TEV)

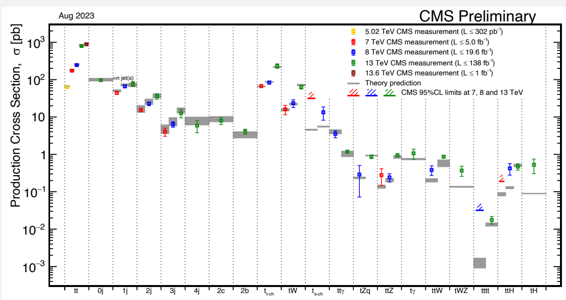


1 TeV

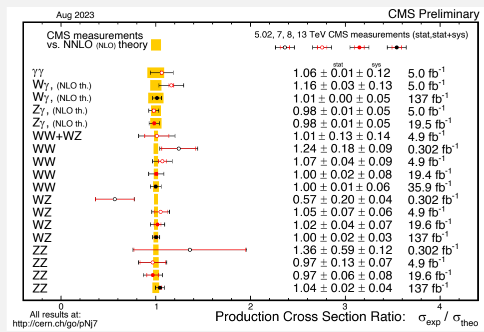
Searching for new physics as an expansion around the SM assuming no new light particles is reasonable

EVERYTHING LOOKS LIKE THE SM

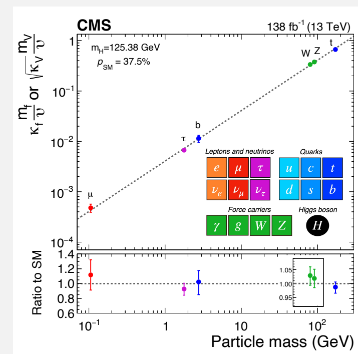
Top quark physics



Di-boson physics



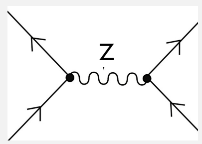
Higgs physics



- Suggests that the SM is a good approximation to physics at the weak scale
- Power of SMEFT is potential to combine this information

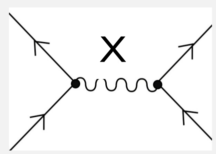
HIGH SCALE DECOUPLING

- Suppose there is a new particle X, with mass $M_X >> M_W$
- SM scattering:



$$A_{SM} \sim \frac{g^2}{M_Z^2}$$

- Contribution from X:



$$A_X \sim \frac{g_X^2}{M_X^2}$$

- Scattering rate:

$$\sigma \sim \sigma_{SM} + \frac{g^2 g_X^2}{M_X^2} \to \sigma_{SM}$$

Effects of X vanish as $1/M_X^2$ for ***weak coupling***

This is implicit assumption as we construct SMEFT

*Note: Higgs is example of non-decoupling particle

ASSUME A HIERARCHY OF SCALES

$\Lambda >> M_W$ where complete theory exists

- Any new particles or symmetries are at this scale
- Expect effects of heavy particles at low scales to be suppressed

This is sad scenario where there is no intermediate scale physics

M_W Only SM particles in theory at low scales

Learn about high scale physics by measuring coefficients of effective operators with global fits

SMEFT: SM EFFECTIVE FIELD THEORY

- Assumptions: New physics decouples Λ >> v, E
- At the weak scale: SM SU(3) x SU(2) x U(1) symmetry and SM particles only
- New physics described by

$$L_{SMEFT} = L_{SM} + \frac{L_5}{\Lambda} + \frac{L_6}{\Lambda^2} + \frac{L_7}{\Lambda^3} + \frac{L_8}{\Lambda^4}$$

$$L_n = \Sigma_i C_i^n O_i^n$$

Assume Higgs is in an SU(2) doublet

- New physics contributions contained in coefficients C (can calculate in specific models)
- Operators form a complete basis (not unique)
- L_5 and L_7 are lepton number violating

WARSAW BASIS

X^3		φ^6 and $\varphi^4 D^2$		$\psi^2\varphi^3$	
Q_G	$f^{ABC} G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	Q_φ	$(\varphi^\dagger\varphi)^3$	$Q_{e\varphi}$	$(\varphi^\dagger\varphi)(\bar l_p e_r \varphi)$
$Q_{\widetilde G}$	$f^{ABC} \widetilde G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	$Q_{\varphi\Box}$	$(\varphi^\dagger\varphi)\Box(\varphi^\dagger\varphi)$	$Q_{u\varphi}$	$(\varphi^\dagger\varphi)(\bar q_p u_r \widetilde\varphi)$
Q_W	$\varepsilon^{IJK} W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$	$Q_{\varphi D}$	$\left(\varphi^\dagger D^\mu\varphi\right)^\star \left(\varphi^\dagger D_\mu\varphi\right)$	$Q_{d\varphi}$	$(\varphi^\dagger\varphi)(\bar q_p d_r \varphi)$
$Q_{\widetilde W}$	$\varepsilon^{IJK} \widetilde W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$				
$X^2\varphi^2$		$\psi^2 X\varphi$		$\psi^2\varphi^2 D$	
$Q_{\varphi G}$	$\varphi^\dagger\varphi\, G^A_{\mu\nu} G^{A\mu\nu}$	Q_{eW}	$(\bar l_p \sigma^{\mu\nu} e_r)\tau^I \varphi W^I_{\mu\nu}$	$Q_{\varphi l}^{(1)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar l_p \gamma^\mu l_r)$
$Q_{\varphi\widetilde G}$	$\varphi^\dagger\varphi\, \widetilde G^A_{\mu\nu} G^{A\mu\nu}$	Q_{eB}	$(\bar l_p \sigma^{\mu\nu} e_r)\varphi B_{\mu\nu}$	$Q_{\varphi l}^{(3)}$	$(\varphi^\dagger i\overleftrightarrow{D}^I_\mu \varphi)(\bar l_p \tau^I \gamma^\mu l_r)$
$Q_{\varphi W}$	$\varphi^\dagger\varphi\, W^I_{\mu\nu} W^{I\mu\nu}$	Q_{uG}	$(\bar q_p \sigma^{\mu\nu} T^A u_r)\widetilde\varphi\, G^A_{\mu\nu}$	$Q_{\varphi e}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar e_p \gamma^\mu e_r)$
$Q_{\varphi\widetilde W}$	$\varphi^\dagger\varphi\, \widetilde W^I_{\mu\nu} W^{I\mu\nu}$	Q_{uW}	$(\bar q_p \sigma^{\mu\nu} u_r)\tau^I \widetilde\varphi\, W^I_{\mu\nu}$	$Q_{\varphi q}^{(1)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar q_p \gamma^\mu q_r)$
$Q_{\varphi B}$	$\varphi^\dagger\varphi\, B_{\mu\nu} B^{\mu\nu}$	Q_{uB}	$(\bar q_p \sigma^{\mu\nu} u_r)\widetilde\varphi\, B_{\mu\nu}$	$Q_{\varphi q}^{(3)}$	$(\varphi^\dagger i\overleftrightarrow{D}^I_\mu \varphi)(\bar q_p \tau^I \gamma^\mu q_r)$
$Q_{\varphi\widetilde B}$	$\varphi^\dagger\varphi\, \widetilde B_{\mu\nu} B^{\mu\nu}$	Q_{dG}	$(\bar q_p \sigma^{\mu\nu} T^A d_r)\varphi\, G^A_{\mu\nu}$	$Q_{\varphi u}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar u_p \gamma^\mu u_r)$
$Q_{\varphi WB}$	$\varphi^\dagger \tau^I \varphi\, W^I_{\mu\nu} B^{\mu\nu}$	Q_{dW}	$(\bar q_p \sigma^{\mu\nu} d_r)\tau^I \varphi\, W^I_{\mu\nu}$	$Q_{\varphi d}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar d_p \gamma^\mu d_r)$
$Q_{\varphi\widetilde WB}$	$\varphi^\dagger \tau^I \varphi\, \widetilde W^I_{\mu\nu} B^{\mu\nu}$	Q_{dB}	$(\bar q_p \sigma^{\mu\nu} d_r)\varphi\, B_{\mu\nu}$	$Q_{\varphi ud}$	$i(\widetilde\varphi^\dagger D_\mu\varphi)(\bar u_p \gamma^\mu d_r)$

$(\bar LL)(\bar LL)$		$(\bar RR)(\bar RR)$		$(\bar LL)(\bar RR)$	
Q_{ll}	$(\bar l_p\gamma_\mu l_r)(\bar l_s\gamma^\mu l_t)$	Q_{ee}	$(\bar e_p\gamma_\mu e_r)(\bar e_s\gamma^\mu e_t)$	Q_{le}	$(\bar l_p\gamma_\mu l_r)(\bar e_s\gamma^\mu e_t)$
$Q_{qq}^{(1)}$	$(\bar q_p\gamma_\mu q_r)(\bar q_s\gamma^\mu q_t)$	Q_{uu}	$(\bar u_p\gamma_\mu u_r)(\bar u_s\gamma^\mu u_t)$	Q_{lu}	$(\bar l_p\gamma_\mu l_r)(\bar u_s\gamma^\mu u_t)$
$Q_{qq}^{(3)}$	$(\bar q_p\gamma_\mu \tau^I q_r)(\bar q_s\gamma^\mu \tau^I q_t)$	Q_{dd}	$(\bar d_p\gamma_\mu d_r)(\bar d_s\gamma^\mu d_t)$	Q_{ld}	$(\bar l_p\gamma_\mu l_r)(\bar d_s\gamma^\mu d_t)$
$Q_{lq}^{(1)}$	$(\bar l_p\gamma_\mu l_r)(\bar q_s\gamma^\mu q_t)$	Q_{eu}	$(\bar e_p\gamma_\mu e_r)(\bar u_s\gamma^\mu u_t)$	Q_{qe}	$(\bar q_p\gamma_\mu q_r)(\bar e_s\gamma^\mu e_t)$
$Q_{lq}^{(3)}$	$(\bar l_p\gamma_\mu \tau^I l_r)(\bar q_s\gamma^\mu \tau^I q_t)$	Q_{ed}	$(\bar e_p\gamma_\mu e_r)(\bar d_s\gamma^\mu d_t)$	$Q_{qu}^{(1)}$	$(\bar q_p\gamma_\mu q_r)(\bar u_s\gamma^\mu u_t)$
		$Q_{ud}^{(1)}$	$(\bar u_p\gamma_\mu u_r)(\bar d_s\gamma^\mu d_t)$	$Q_{qu}^{(8)}$	$(\bar q_p\gamma_\mu T^A q_r)(\bar u_s\gamma^\mu T^A u_t)$
		$Q_{ud}^{(8)}$	$(\bar u_p\gamma_\mu T^A u_r)(\bar d_s\gamma^\mu T^A d_t)$	$Q_{qd}^{(1)}$	$(\bar q_p\gamma_\mu q_r)(\bar d_s\gamma^\mu d_t)$
				$Q_{qd}^{(8)}$	$(\bar q_p\gamma_\mu T^A q_r)(\bar d_s\gamma^\mu T^A d_t)$
$(\bar LR)(\bar RL)$ and $(\bar LR)(\bar LR)$		B-violating			
Q_{ledq}	$(\bar l_p^j e_r)(\bar d_s q_t^j)$	Q_{duq}	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\left[(d_p^\alpha)^T C u_r^\beta\right]\left[(q_s^{\gamma j})^T C l_t^k\right]$		
$Q_{quqd}^{(1)}$	$(\bar q_p^j u_r)\varepsilon_{jk}(\bar q_s^k d_t)$	Q_{qqu}	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\left[(q_p^{\alpha j})^T C q_r^{\beta k}\right]\left[(u_s^\gamma)^T C e_t\right]$		
$Q_{quqd}^{(8)}$	$(\bar q_p^j T^A u_r)\varepsilon_{jk}(\bar q_s^k T^A d_t)$	Q_{qqq}	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jn}\varepsilon_{km}\left[(q_p^{\alpha j})^T C q_r^{\beta k}\right]\left[(q_s^{\gamma m})^T C l_t^n\right]$		
$Q_{lequ}^{(1)}$	$(\bar l_p^j e_r)\varepsilon_{jk}(\bar q_s^k u_t)$	Q_{duu}	$\varepsilon^{\alpha\beta\gamma}\left[(d_p^\alpha)^T C u_r^\beta\right]\left[(u_s^\gamma)^T C e_t\right]$		
$Q_{lequ}^{(3)}$	$(\bar l_p^j \sigma_{\mu\nu} e_r)\varepsilon_{jk}(\bar q_s^k \sigma^{\mu\nu} u_t)$				

+…..

- The interesting operators are those with derivatives
- Derivative operators introduce new structures into kinematic distributions
- Most of 2499 operators come from flavor permutations (76 baryon number conserving operators for 1 generation)

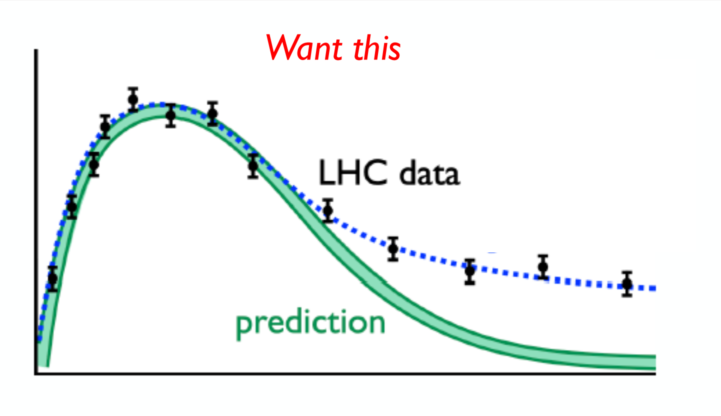
LEARNING FROM SMEFT

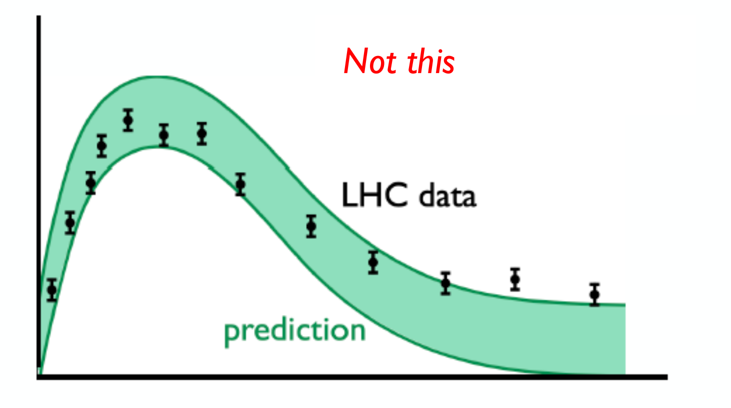
$$\text{Experiment} = \text{Theory}_{SM} + \sum \frac{x_i C_i^6}{\Lambda^2} + \ldots$$

Precise experimental measurements

Precise SM calculations

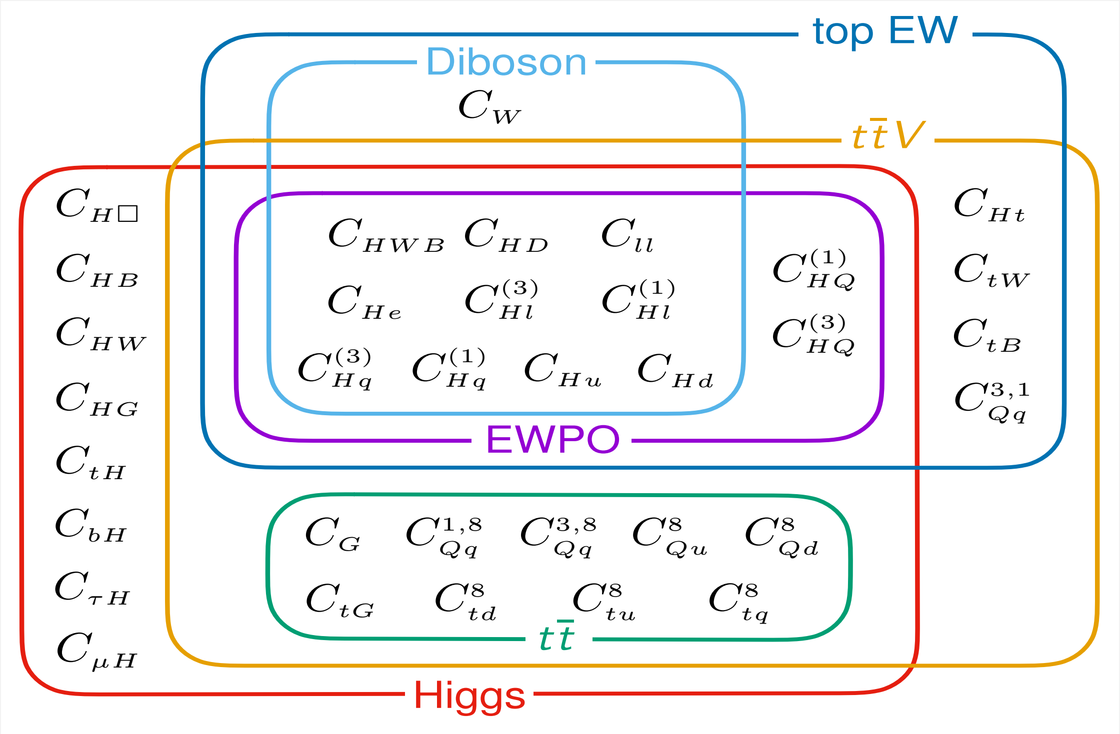
Precise SMEFT calculations





COMPLICATED

- Power of SMEFT is connection of data from different processes



DIMENSION-8

- We now have complete dimension-8 basis
- Too many operators to be useful for global fits
  - 895 (36,971) baryon number preserving for 1 (3) generation
- Study impact of some (cherry picked) operators to get a feel for relevance
- Try to limit number of operators by assuming specific structures for UV scenarios

DIMENSION-6 VS DIMENSION-8?

$$L \to L_{SM} + \Sigma_i \frac{C_{6i}}{\Lambda^2} O_{6i} + \Sigma_i \frac{C_{8i}}{\Lambda^4} O_{8i} + ...$$

- SMEFT

$$A^2 \sim \mid A_{SM} + \frac{A_6}{\Lambda^2} + ... \mid^2 \sim A_{SM}^2 + \frac{A_{SM} A_6}{\Lambda^2} + \frac{A_6^2}{\Lambda^4} + ...$$

- Problem is that $(A_6)^2$ terms are the same order as A_8 terms that we have dropped when counting in $1/\Lambda$
- If we only keep A_6/Λ^2 terms and drop $(A_6/\Lambda^2)^2$, the cross section is not guaranteed to be positive-definite
- Corrections are $O(s/\Lambda^2)$ or $O(v^2/\Lambda^2)$

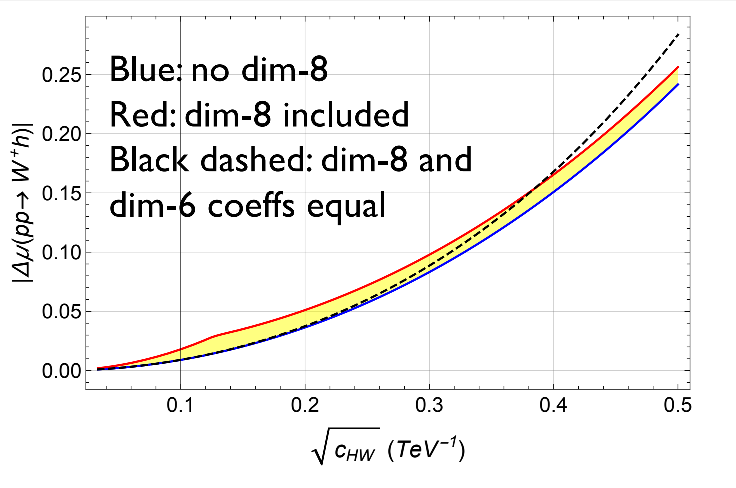
AGNOSTIC APPROACH TO EFFECTS OF DIM-8 TERMS

- Measurable effects in WH production by searching for maximum allowed values of dimension-8 coefficients consistent with a valid EFT expansion, O(10%)

- C_{HW} is dim-6 coefficient with values allowed by global fits

- Can try to enhance dim-8 effects by going to high M_{HW}

- Dimension-8 operators $D^3(\overline{q}_L q_L H^\dagger H)$ have linear growth with energy



Can this happen in a real model?

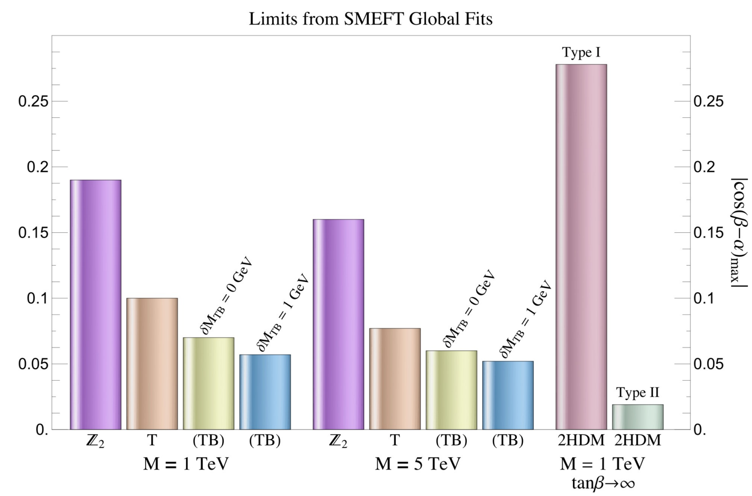
Hays, Martin, Sanz, Setford, 1808.00442

GOAL IS TO INFER BSM PHYSICS FROM PATTERNS OF COEFFICIENTS

- Compare models with new scalars or new heavy top/bottom VLQs at the high energy scale
- Do global fits to just the sets of operators generated in these models
- Fits can restrict high scale models

Do dimension-8 terms invalidate this type of study?

Coupling strength (mixing angle) of high scale new physics



Scale of new physics

SD, Homiller, Lane, 2007.01296

*These are particularly simple toy models

2HDM IS A GOOD TESTING GROUND

- Consider model with 2 Higgs doublets, Φ_1 and Φ_2 with a softly broken Z_2 symmetry: $\Phi_1 \rightarrow \Phi_1$ and $\Phi_2 \rightarrow -\Phi_2$
- 5 physical Higgs bosons, h_{125}, H_0, A, $H^\pm$
- Rotate to the Higgs basis

$$\begin{pmatrix} H_1 \\ H_2 \end{pmatrix} = \begin{pmatrix} \cos\beta & \sin\beta \\ -\sin\beta & \cos\beta \end{pmatrix} \begin{pmatrix} \Phi_1 \\ \Phi_2 \end{pmatrix},$$

- In this basis $\langle H_2 \rangle = 0$, $\langle H_1 \rangle = v/\sqrt{2}$
- Very convenient for SMEFT studies

$$\begin{aligned} V =& Y_1 H_1^\dagger H_1 + Y_2 H_2^\dagger H_2 + \left(Y_3 H_1^\dagger H_2 + \text{h.c.}\right) + \frac{Z_1}{2}\left(H_1^\dagger H_1\right)^2 \\ &+ \frac{Z_2}{2}\left(H_2^\dagger H_2\right)^2 + Z_3\left(H_1^\dagger H_1\right)\left(H_2^\dagger H_2\right) + Z_4\left(H_1^\dagger H_2\right)\left(H_2^\dagger H_1\right) \\ &+ \left\{\frac{Z_5}{2}\left(H_1^\dagger H_2\right)^2 + Z_6\left(H_1^\dagger H_1\right)\left(H_1^\dagger H_2\right) + Z_7\left(H_2^\dagger H_2\right)\left(H_1^\dagger H_2\right) + \text{h.c.}\right\} \end{aligned}$$

- Z's can be written in terms of physical parameters $v,\ \beta-\alpha,\ m_{h_{125}},\ Y_2,\ m_{H_0},\ m_A,\ m_{H^\pm}$

2HDM CONTINUED

- 4 choices for fermion Yukawas (avoid tree level FCNC)

$$\mathcal{L}_Y \sim -\lambda_u^{(1)} \bar{u}_R \tilde{H}_1^\dagger q_L - \lambda_u^{(2)} \bar{u}_R \tilde{H}_2^\dagger q_L - \lambda_d^{(1)} \bar{d}_R H_1^\dagger q_L - \lambda_d^{(2)} \bar{d}_R H_2^\dagger q_L + h.c.$$

$$\lambda_f^{(1)} = \frac{\sqrt{2}}{v} m_f \qquad \lambda_f^{(2)} = \frac{\eta_f}{\tan\beta} \lambda_f^{(1)}$$

	Type-I	Type-II	Type-L	Type-F
η_u	1	1	1	1
η_d	1	$-\tan^2\beta$	1	$-\tan^2\beta$
η_l	1	$-\tan^2\beta$	$-\tan^2\beta$	1

- Type II is MSSM-like
- Type I has enhanced (suppressed) couplings to b quarks at small (large) tan β

MATCH TO SMEFT AT DIMENSION-6

- At dimension-6, observables depend on C/Λ^2 (ie you can't determine a scale independently of assumptions about coefficients, C)
- Decoupling limit: $(Y_3/Y_2) << 1$ [which implies $\cos(\beta-\alpha)$ M^2/v^2]
- At tree level dimension-6, 2HDM SMEFT matching generates:

$$\frac{v^2 C_H}{\Lambda^2} = \frac{\cos^2(\beta-\alpha) M^2}{v^2} \qquad \frac{v^2 C_{tH}}{\Lambda^2} = -\frac{\eta_t \sqrt{2} m_t \cos(\beta-\alpha)}{v \tan\beta}$$

$$\frac{v^2 C_{bH}}{\Lambda^2} = -\frac{\eta_b \sqrt{2} m_b \cos(\beta-\alpha)}{v \tan\beta} \qquad \frac{v^2 C_{\tau H}}{\Lambda^2} = -\frac{\eta_\tau \sqrt{2} m_\tau \cos(\beta-\alpha)}{v \tan\beta}$$

- Dimension-6 matching does NOT generate 2HDM VVh_{125} couplings!

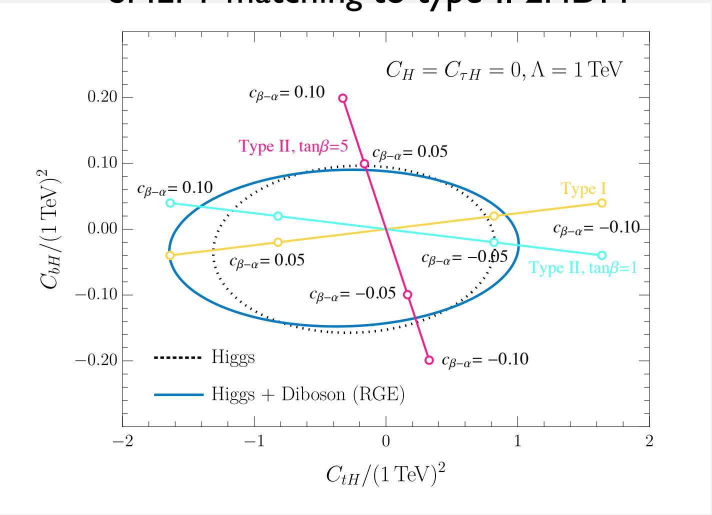
$$O_{fH} = (H^\dagger H)(\overline{q}_L \tilde{H} f_R) \qquad O_H = (H^\dagger H)^3 \qquad \frac{C_H}{\Lambda^2} \sim (...)\delta\lambda_3$$

* M is common mass of heavy scalars

2HDM SMEFT AND RGE

- Operators generated from 2HDM matching don't contribute to EWPOs at tree level
- Limits from Higgs data
- Matching done at high scale, then coefficients evolved to M_Z using renormalization group running
- This generates new operators which contribute to diboson production
- Effect of RGE running small for O_{fH} operators

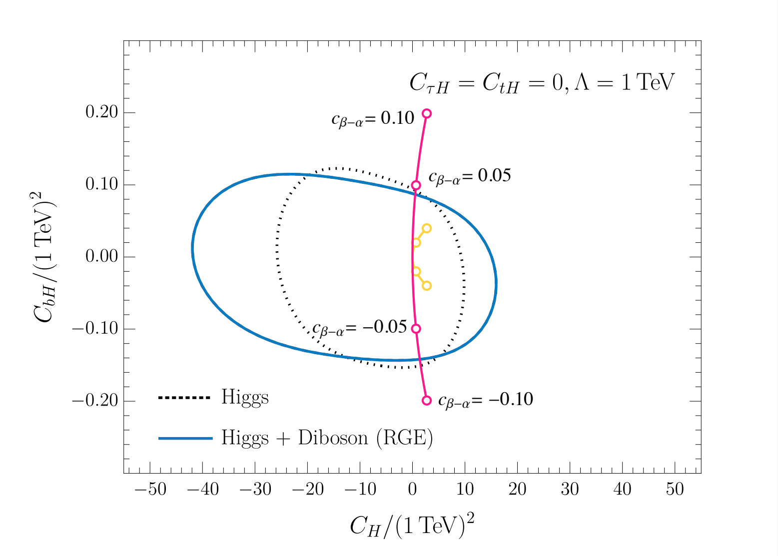
SMEFT matching to type-II 2HDM



Model predictions are straight lines

2HDM SMEFT AND HIGGS TRI-LINEAR

- Higgs tri-linear coupling limited from Higgs measurements at 1-loop
- Effects of RGE running more significant here



MATCH 2HDM TO DIMENSION-8

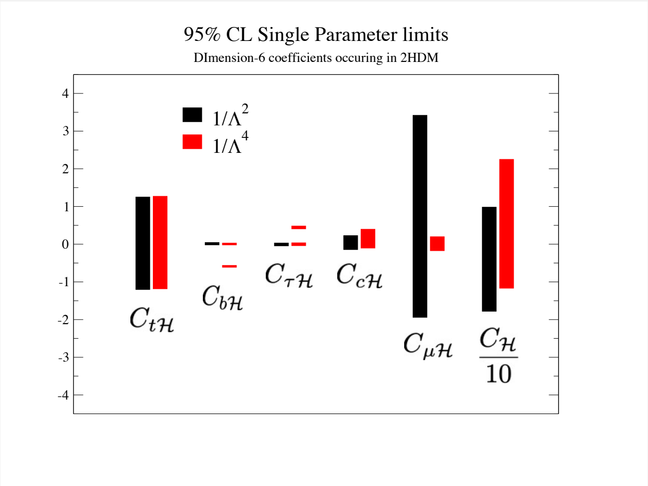
- Matching generates new operators, some with new kinematic structures
- Dimension-8 coefficients can all be written in terms of parameters of 2HDM
- Also need relations between gauge couplings and input parameters (G_F, M_W, M_Z) to dimension-8

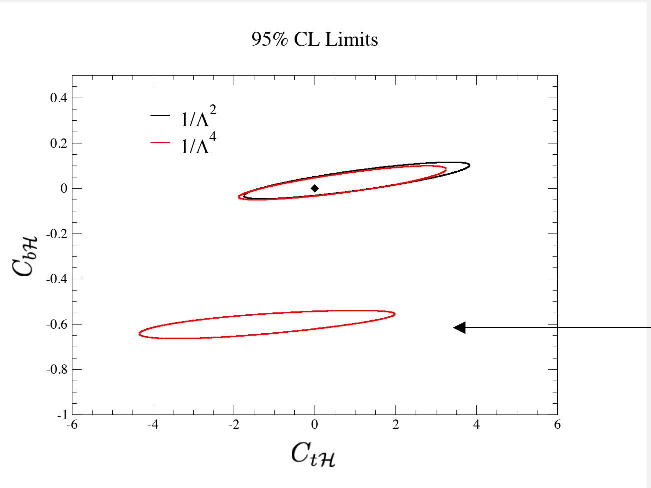
$$L_8 \sim \frac{1}{\Lambda^4}\Big\{ C_{H^8}(H^\dagger H)^4 + C^{(1)}_{H^6}(H^\dagger H)^2 (D_\mu H)^\dagger (D^\mu H) + \Big\{ C_{quH^5}(H^\dagger H)^2 \bar{q}_L u_R \tilde{H}$$
$$+ C^{(1)}_{quH^3D^2}(D_\mu H)^\dagger (D^\mu H)\bar{q}_L u_R \tilde{H} + C^{(2)}_{quH^3D^2}\Big[(D_\mu H)^\dagger \tau^a (D^\mu H)\Big]\Big[\bar{q}_L u_R \tau^a \tilde{H}\Big]$$
$$+ C^{(5)}_{quH^3D^2}\Big[(D_\mu H)^\dagger H\Big]\Big[\bar{q}_L u_R \widetilde{D^\mu H}\Big] + C_{qdH^5}(H^\dagger H)^2 \bar{q}_L d_R H$$
$$+ C^{(1)}_{qdH^3D^2}(D_\mu H)^\dagger (D^\mu H)\bar{q}_L d_R H + C^{(2)}_{qdH^3D^2}\Big[(D_\mu H)^\dagger \tau^a (D^\mu H)\Big]\Big[\bar{q}_L d_R \tau^a H\Big]$$
$$+ C^{(5)}_{qdH^3D^2}(H^\dagger D_\mu H)(\bar{q}_L d_R D^\mu H) + h.c.\Big\} + 4\ Fermion\Big\}$$

Note: $O_{H6}^{(1)}$ gives VVh_{125} coupling

DIMENSION-8 MATTERS IN 2HDM

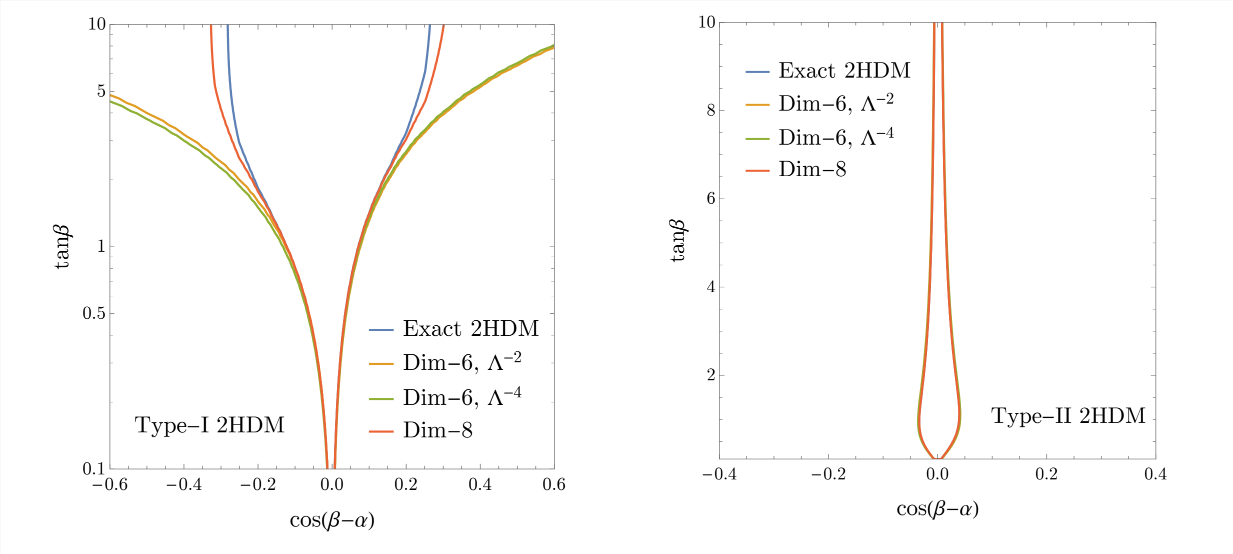
- Single parameter fits to coefficients that occur at dimension-6.
- Including $1/\Lambda^4$ (dim-6 + dim-8) matters for some coefficients





Wrong sign solution at $1/\Lambda^4$

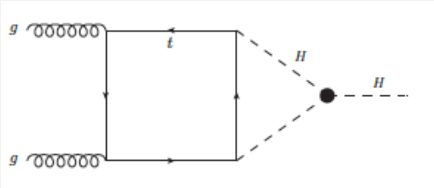
DIMENSION-8 MATTERS IN 2HDM

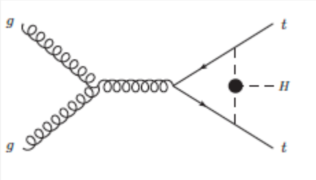


SD, D. Fontes, S. Homiller, and M. Sullivan, [2205.01561](2205.01561)

SCALE DEPENDENCE FOR C_H

- C_H modifies Higgs tri-linear
- Affects Higgs coupling limits through loop contributions





- C_H scaling different than Yukawa like terms

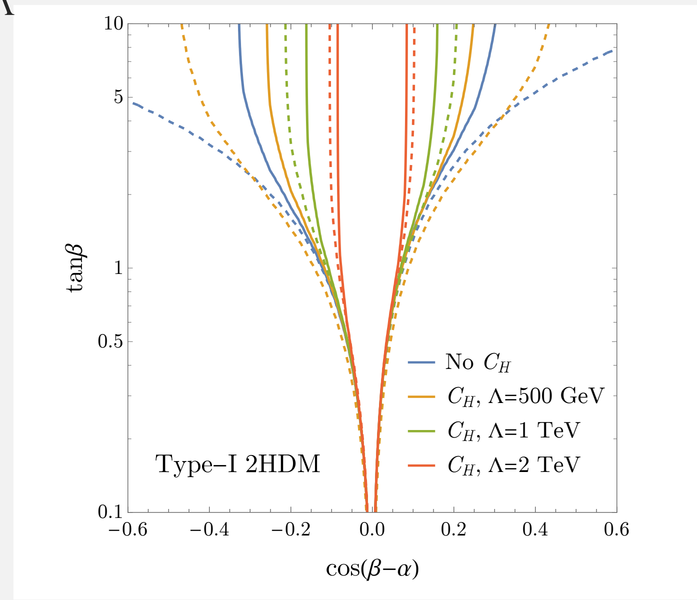
$$\frac{v^2 C_{tH}}{M^2} \sim \frac{\cos(\beta-\alpha)\eta_t m_t}{v\tan\beta}$$

$$\frac{v^2 C_H}{M^2} \sim \frac{\cos^2(\beta-\alpha)M^2}{v^2}$$

Degrassi, Giardino, Maltoni, Pagani, 1607.04251

HIGGS TRI-LINEAR AT DIMENSION-8

- C_H fits have dependence on scale Λ
- Fits sensitive to inclusion of CH



Dashed: $1/\Lambda^2$
Solid: $1/\Lambda^4$

BOTTOM LINE ON DIMENSION-8 AND 2HDM

- Dimension-8 terms are important in matching SMEFT to type-I 2H2m
- This is for a well-understood physics reason (VVh_{125} first arises at dimension-8)

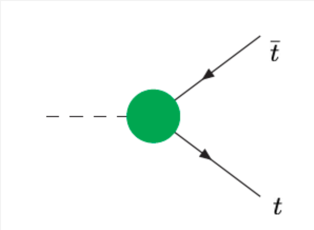
CASE STUDY T VECTOR-LIKE QUARK

- Top vector-like quark T (SM top is t)

$$V = -\lambda_t \bar{q}_L \tilde{H} t_R - \lambda_T \bar{q}_L \tilde{H} T_R - M \overline{T}_L T_R + hc$$

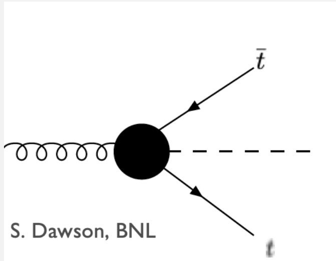
- Integrate out T keeping terms to O(1/M^4)
- At dimension-6 new tth interaction

$$-i\frac{Y_t}{\sqrt{2}} + i\frac{\lambda_T^2 v m_t}{4M^4}(p_1 - p_2)\cdot p_h \gamma_5$$



- At dimension-8, new contributions

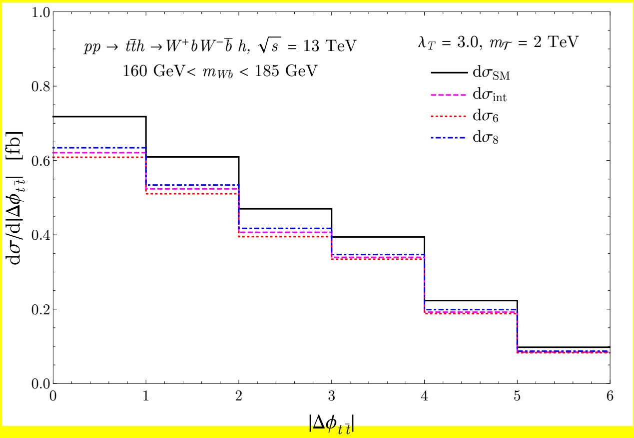
$$+ig_s\frac{\lambda_T^2 v m_t}{2M^4} p_h^\mu \gamma_5$$

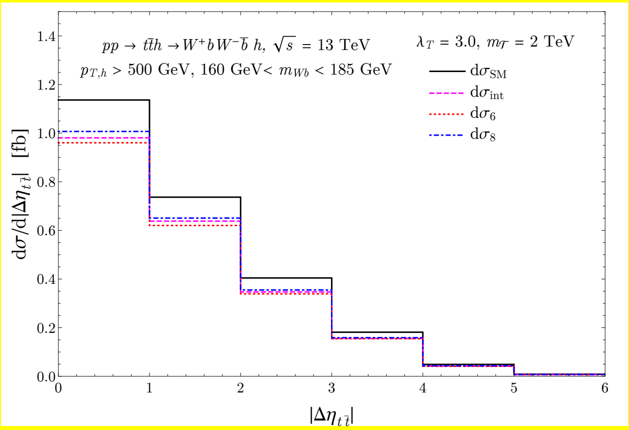


SD, S. Homiller, M. Sullivan, 2110.06929

DIM-8 IN TVLQ

- Very small effects from dim-8 …..





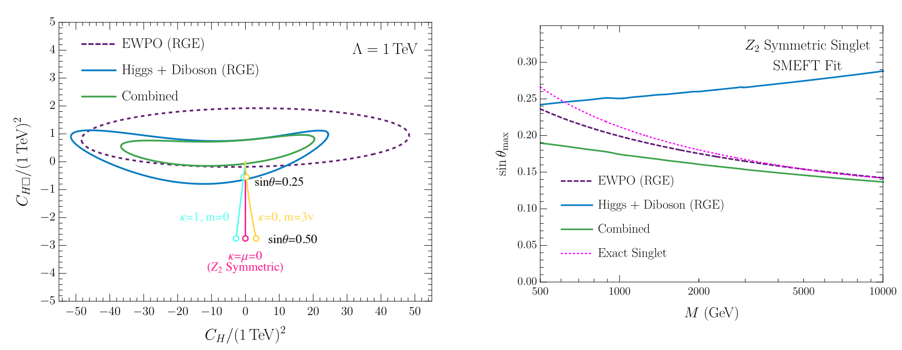
SD, S. Homiller, M. Sullivan, [2110.06929]

LAST EXAMPLE: HIGGS SINGLET MODEL WITHOUT Z_2

$$V(\phi, S) = V_{SM}(\phi) + V_{\phi S}(\phi, S) + V_S(S)$$
$$V_{\phi S}(\phi, S) = \kappa_S(\phi^\dagger\phi)S + \lambda_S(\phi^\dagger\phi)S^2$$
$$V_S(S) = \frac{M_S^2}{2}S^2 + \kappa_{S^3}S^3 + \kappa_{S^4}S^4$$

- Models without Z_2 symmetry motived by desire to explain electroweak baryogenesis
- (They typically prefer negative a_1, b_3 and lighter H)
- 2 neutral Higgs particles
- Parameters limited by theoretical considerations (unitarity, vacuum stability)
- Integrate out heavy scalar and match to SMEFT

AT DIMENSION-6, SINGLET MATCHING ONLY GENERATES ON 2 COEFFICIENTS



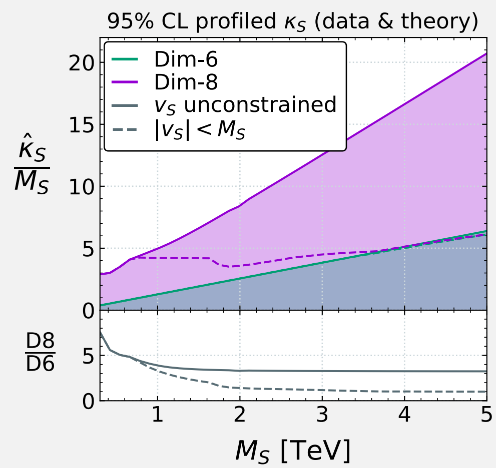
- C_H modifies Higgs tri-linear and is poorly constrained
- $C_{H\Box}$ is global scaling factor

- Dimensionb-6 fits don't use data effectively (No kinematic information)

Interpret fit results in terms of model parameters
Information from RGE running of coefficients from Λ to M_Z

AT DIMENSION-8 DEPENDENCE ON MORE COMBINATIONS OF OPERATORS

- Trade off between dimension-6 (where C_H limited from poorly constrained hh measurements) and dimension-8 where Higgs measurements contribute in different ways
- Fit includes Higgs data, di-boson, EWPO



k_S is portal term SH H^+

Ellis, Mimasu, Zampedri, 2304.06663

CONCLUSIONS

- Lots of theoretical work on impact of dimension-8 operators!
- In specific matchings to UV models, goal is to understand underlying reasons why dimension-8 is or is not important
  - No general statement yet
- Important to present data in a manner such that theorists can continue doing dimension-8 fits
  - Doing fits using dimension-6 operators to $1/\Lambda^2$ and $1/\Lambda^4$ is useful

Stay tuned