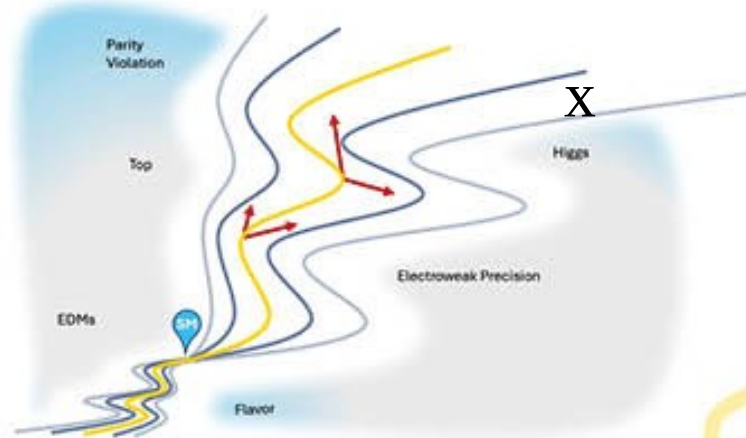




September 7 – 18, 2026

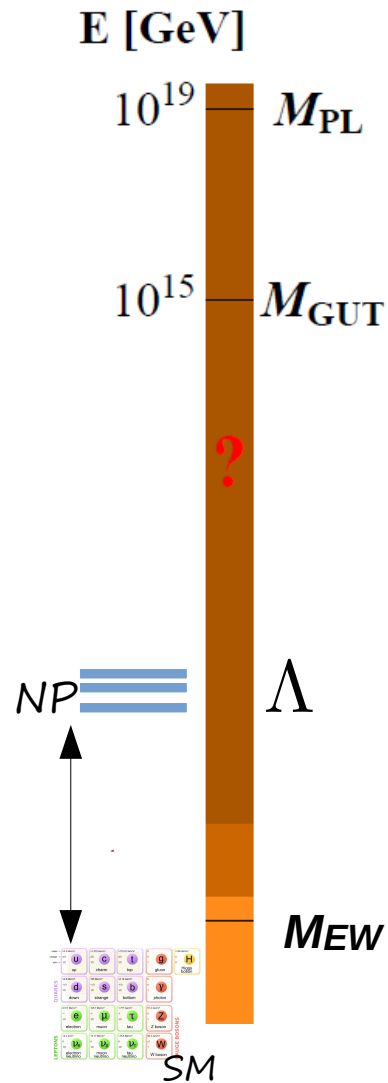
<https://indico.mitp.uni-mainz.de/event/456/>



Discussion: EFTs with dynamical BSM states

15.09.2026

Extending SMEFT



$$\mathcal{L} = \mathcal{L}_{\text{SM}}^{D \leq 4} + \sum_i \frac{c_i}{\Lambda^{d_i-4}} \mathcal{O}_i$$

SMEFT:
SM field content
+ symmetries

X^3		φ^6 and $\varphi^2 D^2$		$\varphi^3 \varphi^3$	
Q_C	$f^{ABC} C^A_{\alpha\beta} C^B_{\beta\gamma} C^C_{\gamma\alpha}$	Q_C	$(\varphi^3 \varphi^3)$	Q_C	$(\varphi^3 \varphi^3)_{(\mu\nu\rho)}$
Q_D	$f^{ABC} C^A_{\alpha\beta} C^B_{\beta\gamma} C^C_{\gamma\alpha}$	Q_D	$(\varphi^3 \varphi^3)_{[\alpha\beta] \gamma}$	Q_D	$(\varphi^3 \varphi^3)_{[\alpha\beta\gamma]}$
Q_E	$f^{ABC} W^A_{\alpha\beta} W^B_{\beta\gamma} W^C_{\gamma\alpha}$	Q_E	$(\varphi^3 D^2 \varphi^3)$	Q_E	$(\varphi^3 \varphi^3)_{(\mu\nu\rho)}$
Q_F	$f^{ABC} W^A_{\alpha\beta} W^B_{\beta\gamma} W^C_{\gamma\alpha}$	Q_F	$(\varphi^3 D^2 \varphi^3)$	Q_F	$(\varphi^3 \varphi^3)_{[\alpha\beta\gamma]}$
$X^3 \varphi^3$		$\varphi^3 X \varphi^3$		$\varphi^3 \varphi^3 D$	
$Q_{C\varphi}$	$\varphi^3_{\alpha\beta} C^A_{\beta\gamma} C^A_{\gamma\alpha}$	$Q_{C\varphi}$	$(\varphi^3_{(\mu\nu\rho)} \varphi^3)_{\gamma}$	$Q_{C\varphi}^{(1)}$	$(\varphi^3 \varphi^3 D)_{(\gamma^1 \mu^1 \nu^1)}$
$Q_{D\varphi}$	$\varphi^3_{\alpha\beta} C^A_{\beta\gamma} C^A_{\gamma\alpha}$	$Q_{D\varphi}$	$(\varphi^3_{(\mu\nu\rho)} \varphi^3)_{\gamma}$	$Q_{D\varphi}^{(2)}$	$(\varphi^3 \varphi^3 D)_{(\gamma^2 \mu^2 \nu^2)}$
$Q_{E\varphi}$	$\varphi^3_{\alpha\beta} W^A_{\beta\gamma} W^A_{\gamma\alpha}$	$Q_{E\varphi}$	$(\varphi^3_{(\mu\nu\rho)} T^{\alpha\beta})_{\gamma} C^A_{\alpha\beta}$	$Q_{E\varphi}$	$(\varphi^3 \varphi^3 D)_{(\gamma^1 \mu^1 \nu^1)}$
$Q_{F\varphi}$	$\varphi^3_{\alpha\beta} W^A_{\beta\gamma} W^A_{\gamma\alpha}$	$Q_{F\varphi}$	$(\varphi^3_{(\mu\nu\rho)} T^{\alpha\beta})_{\gamma} W^A_{\alpha\beta}$	$Q_{F\varphi}^{(2)}$	$(\varphi^3 \varphi^3 D)_{(\gamma^2 \mu^2 \nu^2)}$
$Q_{G\varphi}$	$\varphi^3_{\alpha\beta} D_{\beta\gamma} D_{\gamma\alpha}$	$Q_{G\varphi}$	$(\varphi^3_{(\mu\nu\rho)} T^{\alpha\beta})_{\gamma} C^A_{\alpha\beta}$	$Q_{G\varphi}^{(1)}$	$(\varphi^3 \varphi^3 D)_{(\gamma^1 \mu^1 \nu^1)}$
$Q_{H\varphi}$	$\varphi^3_{\alpha\beta} D_{\beta\gamma} D_{\gamma\alpha}$	$Q_{H\varphi}$	$(\varphi^3_{(\mu\nu\rho)} T^{\alpha\beta})_{\gamma} C^A_{\alpha\beta}$	$Q_{H\varphi}^{(2)}$	$(\varphi^3 \varphi^3 D)_{(\gamma^2 \mu^2 \nu^2)}$
$Q_{I\varphi B}$	$\varphi^3_{\alpha\beta} W^A_{\beta\gamma} W^B_{\gamma\alpha}$	$Q_{I\varphi B}$	$(\varphi^3_{(\mu\nu\rho)} T^{\alpha\beta})_{\gamma} W^B_{\alpha\beta}$	$Q_{I\varphi B}$	$(\varphi^3 \varphi^3 D)_{(\gamma^1 \mu^1 \nu^1)}$
$Q_{J\varphi B}$	$\varphi^3_{\alpha\beta} W^A_{\beta\gamma} W^B_{\gamma\alpha}$	$Q_{J\varphi B}$	$(\varphi^3_{(\mu\nu\rho)} T^{\alpha\beta})_{\gamma} W^B_{\alpha\beta}$	$Q_{J\varphi B}^{(2)}$	$(\varphi^3 \varphi^3 D)_{(\gamma^2 \mu^2 \nu^2)}$

Table 2: Dimension-six operators other than the four-fermion ones

$Q_{\text{quf}}^{(S)}$	$(\bar{\psi}_\mu^S T^a u_\nu)_\mu (\bar{\psi}_\mu^S T^a d_\nu)$	$Q_{\text{qu}}^{(1)}$	$\epsilon^{\alpha\beta\gamma} \epsilon_{\mu\nu\lambda} (\bar{\psi}_\mu^S T^a u_\nu)_\alpha (\bar{\psi}_\nu^S T^a d_\mu)_\beta$
$Q_{\text{qu}}^{(1)}$	$(\bar{\psi}_\mu^S T^a u_\nu)_\mu (\bar{\psi}_\nu^S T^a d_\mu)$	$Q_{\text{qu}}^{(2)}$	$\epsilon^{\alpha\beta\gamma} (\tau^c)_\mu (\tau^c)_{\nu\lambda} (\bar{\psi}_\mu^S T^a u_\nu)_\alpha (\bar{\psi}_\nu^S T^a d_\lambda)_\beta$
$Q_{\text{qu}}^{(2)}$	$(\bar{\psi}_\mu^S T^a u_\nu)_\mu (\bar{\psi}_\nu^S T^a d_\mu)$	$Q_{\text{qu}}^{(3)}$	$\epsilon^{\alpha\beta\gamma} (\tau^c)_\mu (\tau^c)_{\nu\lambda} (\bar{\psi}_\mu^S T^a u_\nu)_\alpha (\bar{\psi}_\nu^S T^a d_\lambda)_\beta$

Table 3: Four-fermion operators

(RR)		$(LL)(RR)$
$\gamma_1(e, \gamma^* c_1)$	Q_{1c}	$(\tilde{\gamma}_{1\gamma} l_1, l_1)(e, \gamma^* c_1)$
$\gamma_1(\tilde{u}, \gamma^* u_1)$	Q_{1u}	$(\tilde{\gamma}_{1\gamma} l_1, l_1)(\tilde{u}, \gamma^* u_1)$
$\gamma_1(\tilde{d}, \gamma^* d_1)$	Q_{1d}	$(\tilde{\gamma}_{1\gamma} l_1, l_1)(\tilde{d}, \gamma^* d_1)$
$\gamma_1(\tilde{u}, \gamma^* u_1)$	Q_{q_1}	$(\tilde{q}_{1\gamma} \gamma, q_1)(e, \gamma^* c_1)$
$\gamma_1(\tilde{d}, \gamma^* d_1)$	$Q_{q_1}^{(1)}$	$(\tilde{q}_{1\gamma} \gamma, q_1)(\tilde{u}, \gamma^* u_1)$
$\gamma_1(\tilde{d}, \gamma^* d_1)$	$Q_{q_1}^{(2)}$	$(\tilde{q}_{1\gamma} \gamma, T^* q_1)(\tilde{u}, \gamma^* T^* u_1)$
$\gamma_1(\tilde{d}, \gamma^* T^* d_1)$	$Q_{q_1}^{(1)}$	$(\tilde{q}_{1\gamma} \gamma, T^* q_1)(\tilde{d}, \gamma^* T^* d_1)$
	$Q_{q_1}^{(2)}$	$(\tilde{q}_{1\gamma} \gamma, T^* q_1)(\tilde{d}, \gamma^* T^* d_1)$

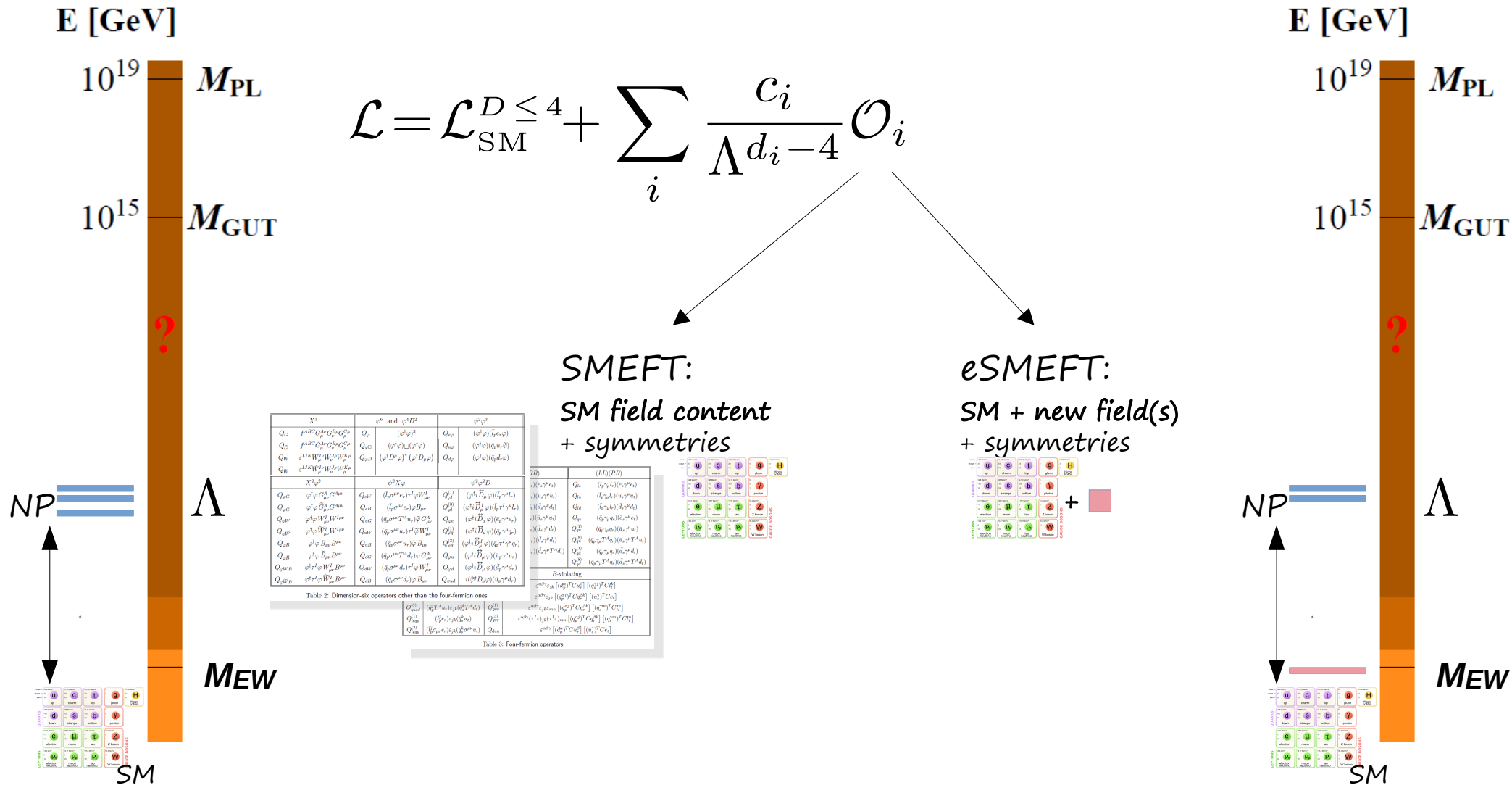
LEPTONS	QUARKS	GAUGE BOSONS	
e^- electron	u up	γ photon	H Higgs boson
μ^- muon	d down	g gluon	
τ^- tau	s strange	$W^\pm$ W boson	
ν_e electron neutrino	c charm	Z Z boson	
ν_μ muon neutrino	b bottom		
ν_τ tau neutrino	t top		

$$\begin{array}{l}
 B\text{-violating} \\
 \varepsilon^{\alpha\beta\gamma} \varepsilon_{ijk} \left[(d_{\alpha}^{\beta})^T C u_{\gamma}^{\delta\delta} \right] \left[(q_{\alpha}^{\beta})^T C l_{\gamma}^{\delta\delta} \right] \\
 e^{\alpha\beta\gamma} \varepsilon_{ijk} \left[(q_{\alpha}^{\beta})^T C e_{\gamma}^{\delta\delta} \right] \left[(u_{\alpha}^{\beta})^T C e_{\gamma}^{\delta\delta} \right] \\
 e^{\alpha\beta\gamma} \varepsilon_{j\ell c m n} \left[(q_{\alpha}^{\beta})^T C q_{\gamma}^{\delta\delta} \right] \left[(q_{\ell}^m)^T C l_{n}^{\ell} \right] \\
 e^{\alpha\beta\gamma} (\tau^{\ell} c)_{j\ell} (\tau^{\ell} c)_{m n} \left[(q_{\alpha}^{\beta})^T C q_{\gamma}^{\delta\delta} \right] \left[(q_{\ell}^m)^T C l_{n}^{\ell} \right] \\
 \varepsilon^{\alpha\beta\gamma} \left[(d_{\alpha}^{\beta})^T C u_{\gamma}^{\delta\delta} \right] \left[(u_{\alpha}^{\beta})^T C e_{\gamma}^{\delta\delta} \right]
 \end{array}$$

Wikipedia

Buchmuller, Wyler, NPB 268(1986)621-653
Grzadkowski, Iskrzynski, Misiak, Rosiek, 1008.4884
Alonso, Jenkins, Manohar, Trott, 1312.2014

Extending SMEFT



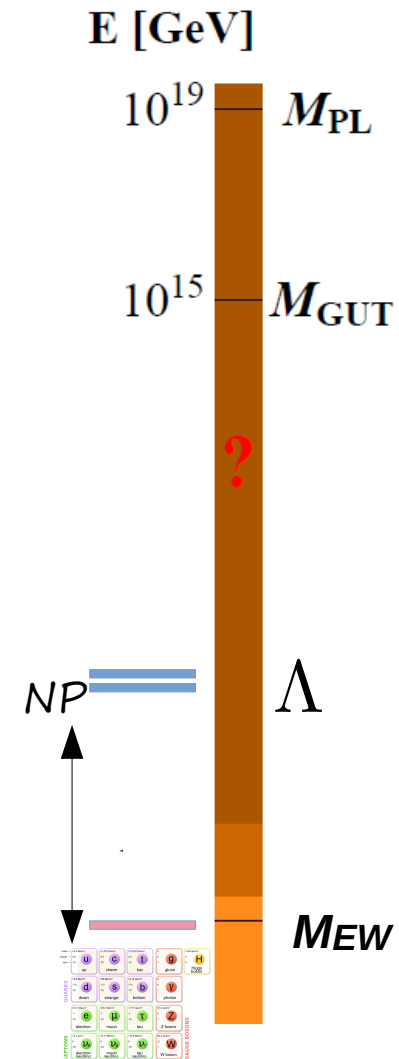
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Extending SMEFT

$$\mathcal{L} = \mathcal{L}_{\text{SM}}^{D \leq 4} + \sum_i \frac{c_i}{\Lambda^{d_i-4}} \mathcal{O}_i$$

eSMEFT:

SM + new field(s)
+ symmetries



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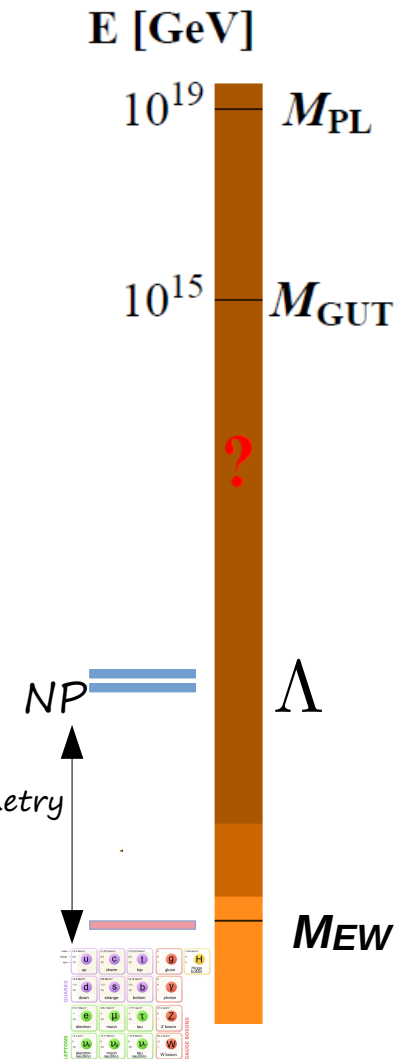
SM + new field(s)
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Why?

- One (few) state(s) could be lighter

- approx. symmetry
- seesaw-like
- accidental



Extending SMEFT

$$\mathcal{L} = \mathcal{L}_{\text{SM}}^{D \leq 4} + \sum_i \frac{C_i}{\Lambda^{d_i-4}} \mathcal{O}_i$$

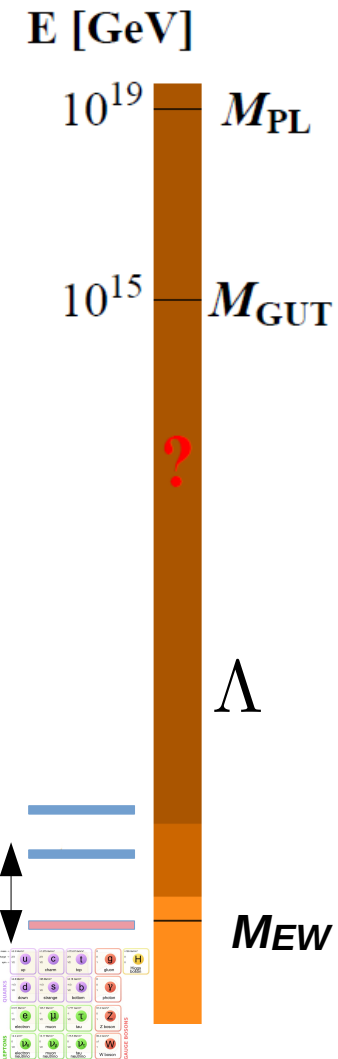
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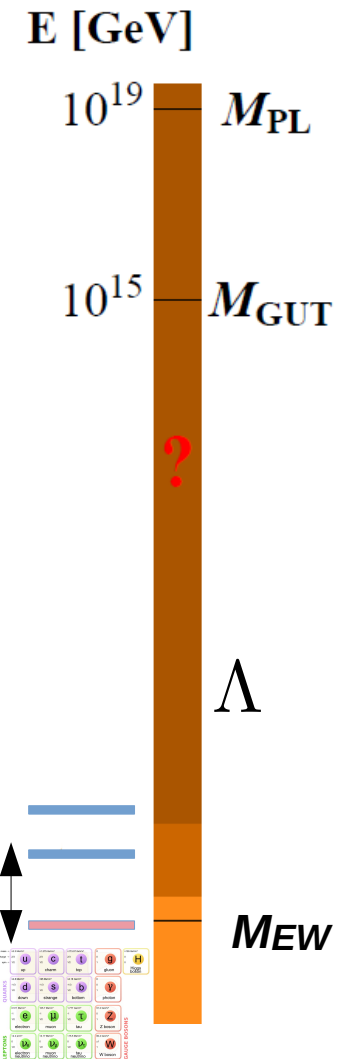
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- One (few) state(s) could be lighter (sym,...)
- See sth at the LHC → characterize 



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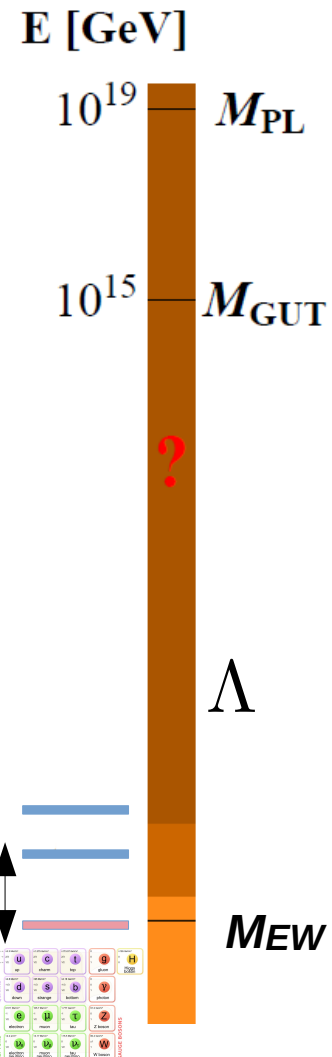
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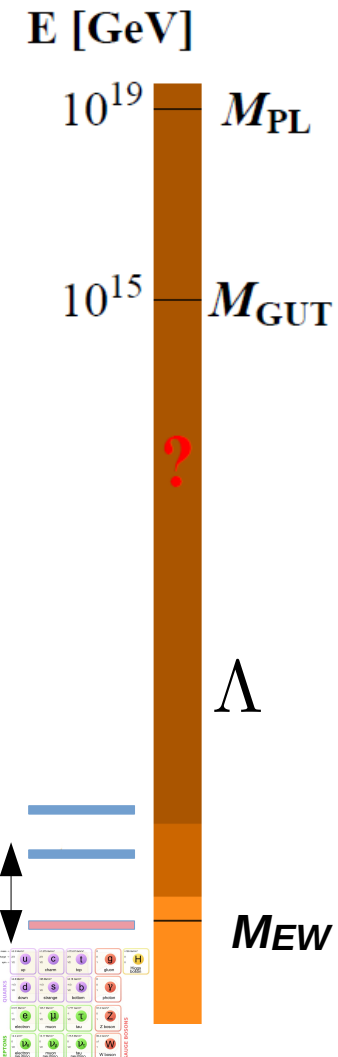
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SM + new field(s)
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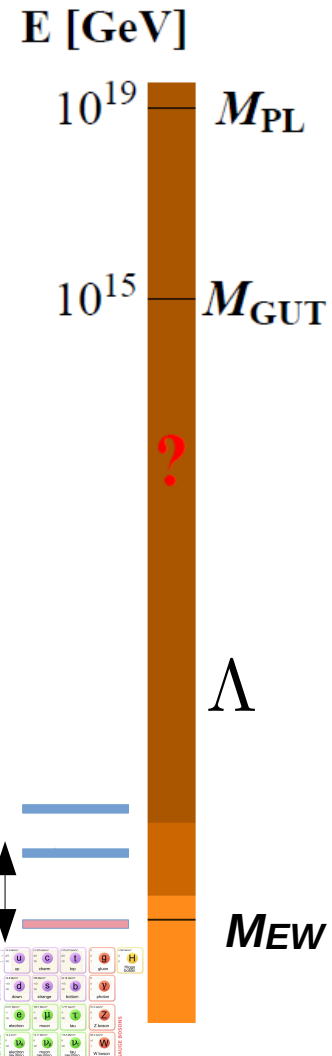
+



Fermion	ψ
Scalar	S
Vector-Boson	V_μ

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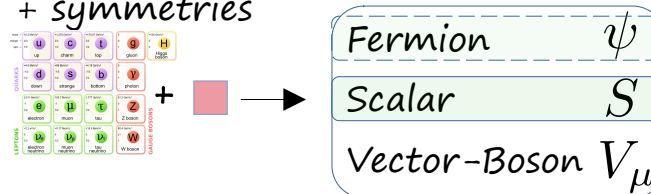


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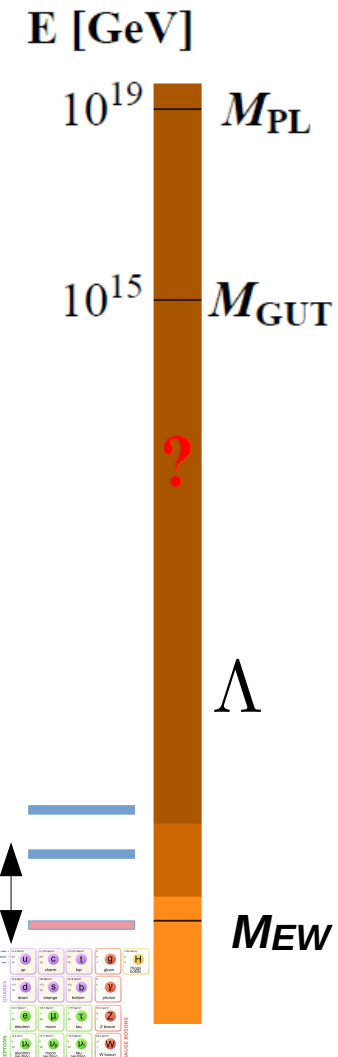
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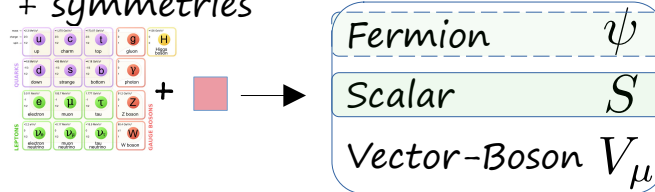


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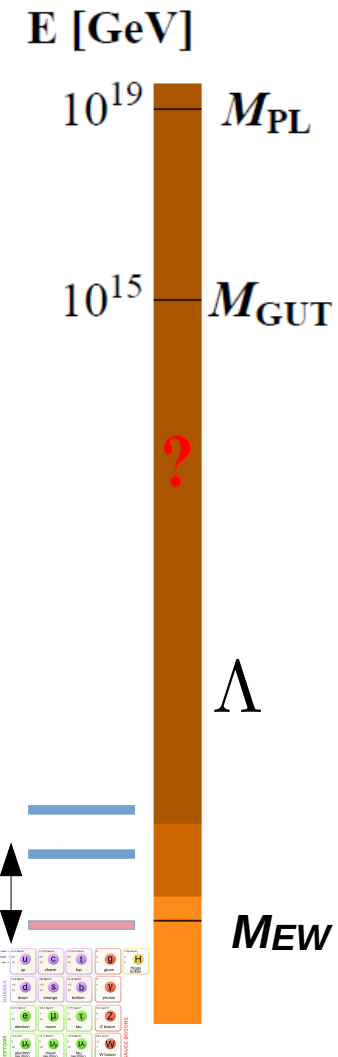
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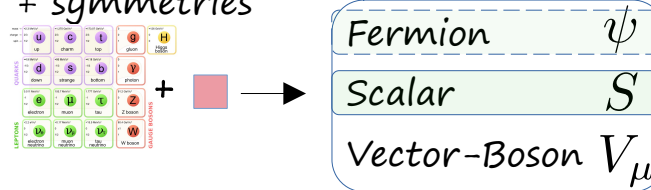


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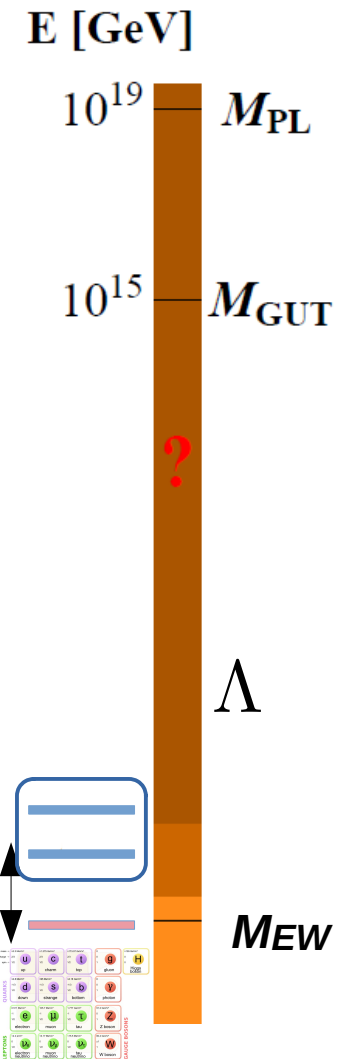
eSMEFT:

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Why EFT?

- If there's a new state, there's probably more

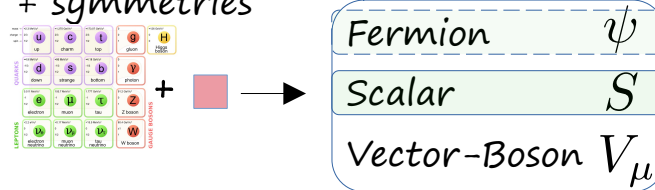


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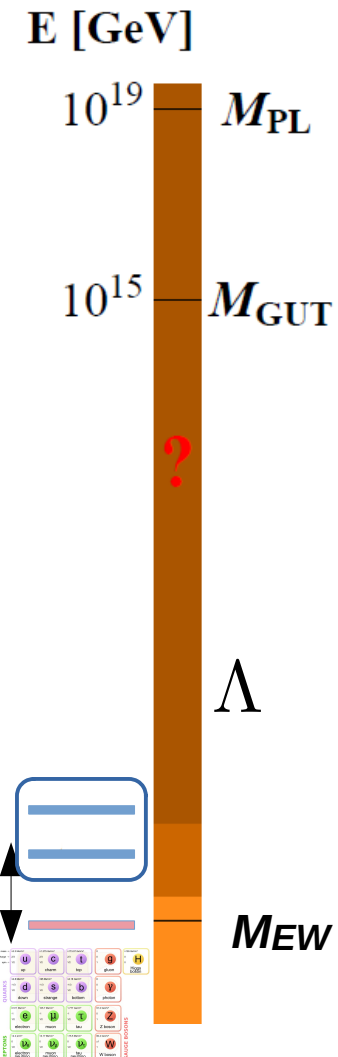
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Why EFT?

- If there's a new state, there's probably more
- Interesting couplings arise at $D \geq 5$

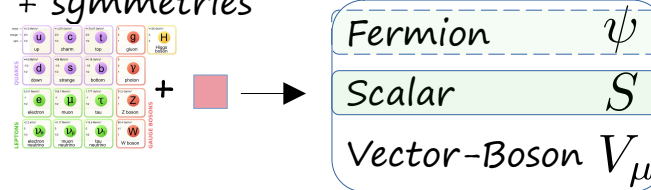


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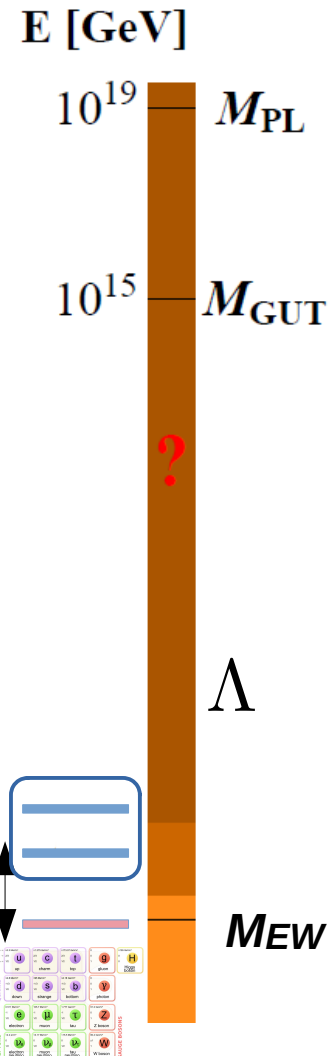


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Gauge invariant completion of simplified models

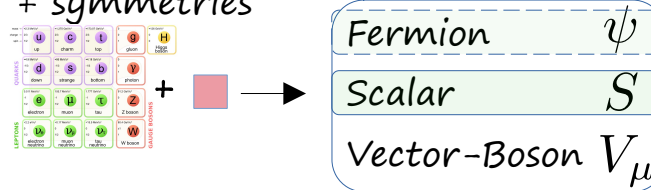


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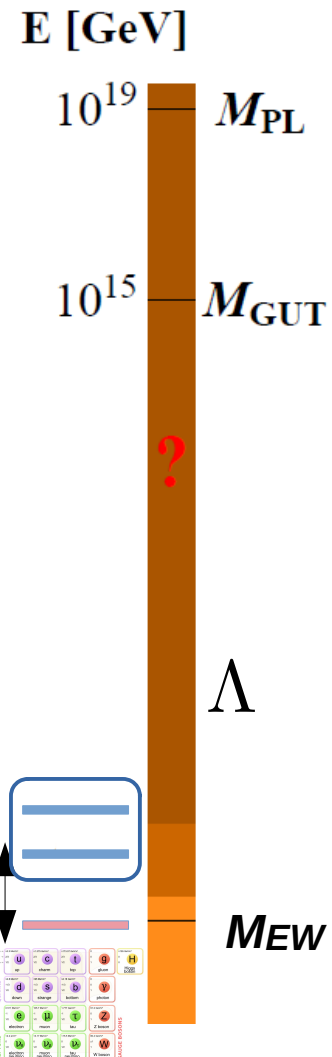
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Gauge invariant completion of simplified models

-

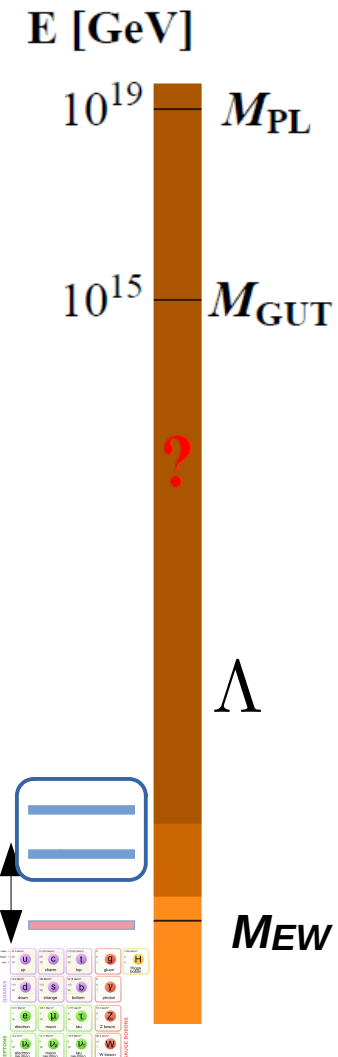
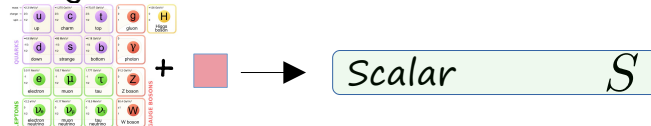


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$$\mathcal{L} = \mathcal{L}_{\text{SM}}^{D \leq 4} + \sum_i \frac{c_i}{\Lambda^{d_i-4}} \mathcal{O}_i$$

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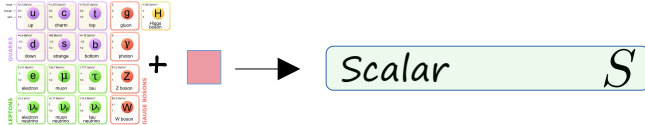
SM + new field(s)
+ symmetries



Extending SMEFT

eSMEFT:

SM + new field(s)
+ symmetries



- Leading EFT effects at $D=5$!

SM + scalar singlet EFT

Franceschini, Giudice, Kamenik, McCullough, Riva, Strumia, Torre, 1604.06446

Gripaios, Sutherland, 1604.07365

Carmona, FG, Papaefstathiou, 1606.02716

Adhikari, Lewis, Sullivan, 2003.10449

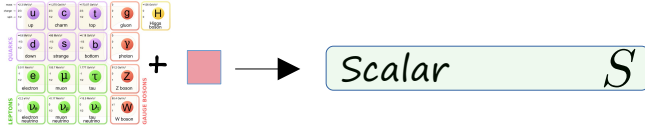
...

$$\begin{aligned}
 \mathcal{L}_{\text{eff}} = & \mathcal{L}_{\text{SM}} + \frac{1}{2} \partial_\mu S \partial^\mu S - \frac{1}{2} \mu_S^2 S^2 \\
 & - \frac{\lambda'_S}{2\sqrt{2}} v S^3 - \frac{\lambda_S}{4} S^4 - \lambda'_{HS} v |H|^2 S - \lambda_{HS} |H|^2 S^2 \\
 & - \frac{S}{\Lambda} [c_{\lambda S} S^4 + c_{HS} |H|^2 S^2 + c_{\lambda H} |H|^4] \\
 & - (y_d^S)^{ij} \frac{S}{\Lambda} \bar{Q}_L^i H d_R^j - (y_u^S)^{ij} \frac{S}{\Lambda} \bar{Q}_L^i \tilde{H} u_R^j + \text{h.c.} \\
 & - \frac{S}{\Lambda} \frac{1}{16\pi^2} [g'^2 c_B^S B_{\mu\nu} B^{\mu\nu} + g^2 c_W^S W^{I\mu\nu} W_{\mu\nu}^I \\
 & + g_S^2 c_G^S G^{a\mu\nu} G_{\mu\nu}^a] + \mathcal{O}(\Lambda^{-2})
 \end{aligned} \tag{A1}$$

Extending SMEFT

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SM + scalar singlet EFT

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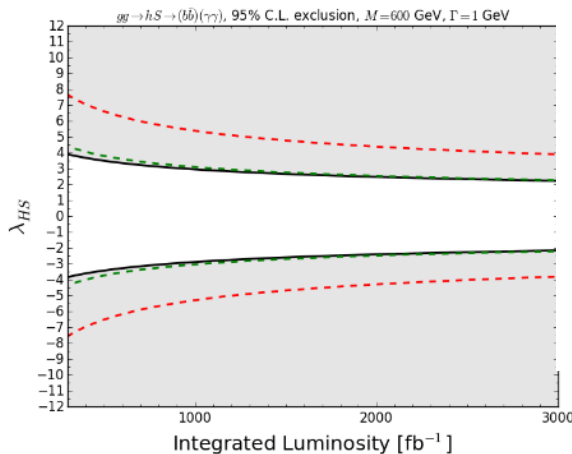
Carmona, FG, Papaefstathiou, 1606.02716

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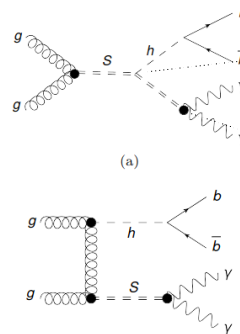
...

- Leading EFT effects at $D=5$!

pheno example



Carmona, FG, Papaefstathiou, 1606.02716

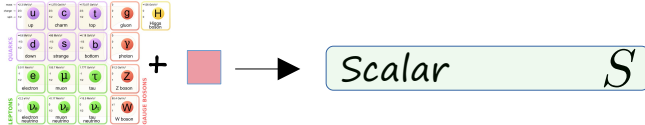


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 & - (y_d^S)^{ij} \frac{S}{\Lambda} \bar{Q}_L^i H d_R^j - (y_u^S)^{ij} \frac{S}{\Lambda} \bar{Q}_L^i \tilde{H} u_R^j + \text{h.c.} \\
 & - \frac{S}{\Lambda} \frac{1}{16\pi^2} [g'^2 c_B^S B_{\mu\nu} B^{\mu\nu} + g^2 c_W^S W^{I\mu\nu} W_{\mu\nu}^I \\
 & + g_S^2 c_G^S G^{a\mu\nu} G_{\mu\nu}^a] + \mathcal{O}(\Lambda^{-2})
 \end{aligned} \tag{A1}$$

Extending SMEFT

eSMEFT:

SM + new field(s)
+ symmetries



- Leading effects at $D=5$!
- CP-odd version: ALP-EFT

Brivio, Gavela, Merlo, Mimasu, No, del Rey, Sanz,
1701.05379, ...

Georgi, Kaplan, Randall, PLB 169 (1986)

Tisa's talk

Fabian's talk

SM + scalar singlet EFT

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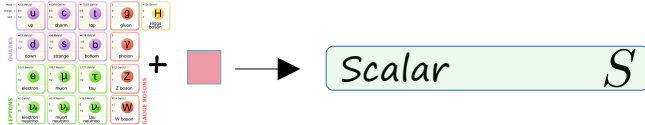
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 & - \frac{S}{\Lambda} [c_{\lambda S} S^4 + c_{HS} |H|^2 S^2 + c_{\lambda H} |H|^4] \\
 & - (y_d^S)^{ij} \frac{S}{\Lambda} \bar{Q}_L^i H d_R^j - (y_u^S)^{ij} \frac{S}{\Lambda} \bar{Q}_L^i \tilde{H} u_R^j + \text{h.c.} \\
 & - \frac{S}{\Lambda} \frac{1}{16\pi^2} [g'^2 c_B^S B_{\mu\nu} B^{\mu\nu} + g^2 c_W^S W^{I\mu\nu} W_{\mu\nu}^I \\
 & + g_S^2 c_G^S G^{a\mu\nu} G_{\mu\nu}^a] + \mathcal{O}(\Lambda^{-2})
 \end{aligned} \tag{A1}$$

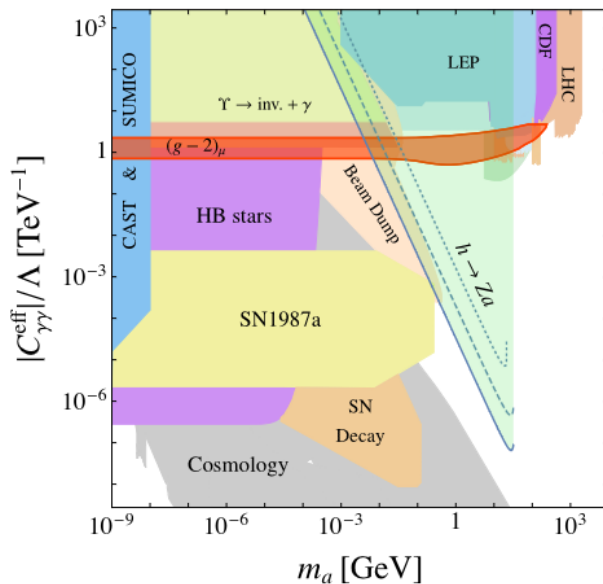
Extending SMEFT

eSMEFT:

SM + new field(s)
+ symmetries



- Leading effects at $D=5$!
- CP-odd version: ALP-EFT



Bauer, Neubert, Thamm, 1708.00443

SM + scalar singlet EFT

Franceschini, Giudice, Kamenik, McCullough, Riva, Strumia, Torre, 1604.06446

Gripaios, Sutherland, 1604.07365

Carmona, FG, Papaefstathiou, 1606.02716

Adhikari, Lewis, Sullivan, 2003.10449

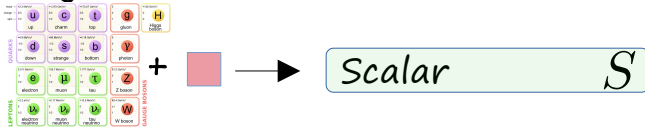
...

$$\begin{aligned}
 \mathcal{L}_{\text{eff}} = & \mathcal{L}_{\text{SM}} + \frac{1}{2} \partial_\mu S \partial^\mu S - \frac{1}{2} \mu_S^2 S^2 \\
 & - \frac{\lambda'_S}{2\sqrt{2}} v S^3 - \frac{\lambda_S}{4} S^4 - \lambda'_{HS} v |H|^2 S - \lambda_{HS} |H|^2 S^2 \\
 & - \frac{S}{\Lambda} [c_{\lambda S} S^4 + c_{HS} |H|^2 S^2 + c_{\lambda H} |H|^4] \\
 & - (y_d^S)^{ij} \frac{S}{\Lambda} \bar{Q}_L^i H d_R^j - (y_u^S)^{ij} \frac{S}{\Lambda} \bar{Q}_L^i \tilde{H} u_R^j + \text{h.c.} \\
 & - \frac{S}{\Lambda} \frac{1}{16\pi^2} [g'^2 c_B^S B_{\mu\nu} B^{\mu\nu} + g^2 c_W^S W^{I\mu\nu} W_{\mu\nu}^I \\
 & + g_S^2 c_G^S G^{a\mu\nu} G_{\mu\nu}^a] + \mathcal{O}(\Lambda^{-2})
 \end{aligned} \tag{A1}$$

Extending SMEFT

eSMEFT:

SM + new field(s)
+ symmetries



- Leading effects at $D=5$!
- CP-odd version: ALP-EFT
- S could trigger strong 1^{st} order EWPhT $\rightarrow$ collider test

Papaefstathiou, White, 2108.11394, ...

[pure SMEFT: very low cutoff...]

Grojean, Servant, Wells, hep-ph/0407019

Delaunay, Grojean, Wells, 0711.2511

Goertz, 1504.00355: $\mu=0$?

SM + scalar singlet EFT

Franceschini, Giudice, Kamenik, McCullough, Riva, Strumia, Torre, 1604.06446

Gripaios, Sutherland, 1604.07365

Carmona, FG, Papaefstathiou, 1606.02716

Adhikari, Lewis, Sullivan, 2003.10449

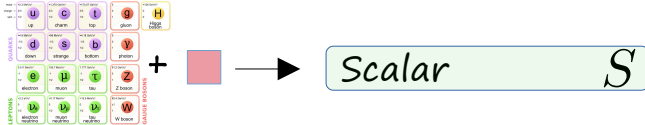
...

$$\begin{aligned}
 \mathcal{L}_{\text{eff}} = & \mathcal{L}_{\text{SM}} + \frac{1}{2} \partial_\mu S \partial^\mu S - \frac{1}{2} \mu_S^2 S^2 \\
 & - \frac{\lambda'_S}{2\sqrt{2}} v S^3 - \frac{\lambda_S}{4} S^4 - \lambda'_{HS} v |H|^2 S - \lambda_{HS} |H|^2 S^2 \\
 & - \frac{S}{\Lambda} [c_{\lambda S} S^4 + c_{HS} |H|^2 S^2 + c_{\lambda H} |H|^4] \\
 & - (y_d^S)^{ij} \frac{S}{\Lambda} \bar{Q}_L^i H d_R^j - (y_u^S)^{ij} \frac{S}{\Lambda} \bar{Q}_L^i \tilde{H} u_R^j + \text{h.c.} \\
 & - \frac{S}{\Lambda} \frac{1}{16\pi^2} [g'^2 c_B^S B_{\mu\nu} B^{\mu\nu} + g^2 c_W^S W^{I\mu\nu} W_{\mu\nu}^I \\
 & + g_S^2 c_G^S G^{a\mu\nu} G_{\mu\nu}^a] + \mathcal{O}(\Lambda^{-2})
 \end{aligned} \tag{A1}$$

Generalization: Extended HEFT

eSMEFT:

SM + new field(s)
+ symmetries



SM + scalar EFT

Arcadi, Cabo-Almeida, FG, Hager, 2512.11764

Maya's talk

$$\begin{aligned} \mathcal{L} \supset & \frac{1}{2} \sum_{\phi=S,h} \partial_\mu \phi \partial^\mu \phi - \mathcal{F}_{c_s} + \frac{v^2}{4} \text{Tr} \left[\Sigma^\dagger (D^\mu \Sigma) \sigma^3 \right] \text{Tr} \left[\Sigma^\dagger (D_\mu \Sigma) \sigma^3 \right] \mathcal{F}_{c_T} \\ & + i \frac{v^2}{4} \text{Tr} \left[\Sigma^\dagger (D^\mu \Sigma) \sigma^3 \right] (\partial_\mu S \mathcal{F}_S) + \frac{v^2}{4} \text{Tr} \left[(D_\mu \Sigma)^\dagger (D^\mu \Sigma) \right] \mathcal{F}_\kappa \\ & - \frac{v}{\sqrt{2}} \left((\overline{u_{i,L}} \quad \overline{d_{i,L}}) \Sigma \begin{pmatrix} Y_{ij}^u u_{j,R} \\ Y_{ij}^d d_{j,R} \end{pmatrix} \mathcal{F}_{c_q} + (\overline{\nu_{i,L}} \quad \overline{\ell_{i,L}}) \Sigma \frac{1-\sigma_3}{2} Y_{ij}^\ell \begin{pmatrix} \nu_{j,R} \\ \ell_{j,R} \end{pmatrix} \mathcal{F}_{c_\ell} + \text{h.c.} \right) \\ & - \frac{1}{16\pi^2} \left[g'^2 B^{\mu\nu} B_{\mu\nu} \mathcal{F}_{c_B} + g^2 W^{I\mu\nu} W_{\mu\nu}^I \mathcal{F}_{c_W} + gg' B_{\mu\nu} \text{Tr} \left[\Sigma \sigma^3 \Sigma^\dagger W^{\mu\nu} \right] \mathcal{F}_{c_{WB}} + g_s^2 G^{a\mu\nu} G_{\mu\nu}^a \mathcal{F}_{c_G} \right] \end{aligned}$$

$$\mathcal{F}_C \equiv \mathcal{F}_C(h, S) \equiv \sum_{i=0}^2 \sum_{j=0}^{2-i} C_{i,j} h^i S^j + \mathcal{O}((h, S)^3) \quad \Sigma(x) = e^{i\sigma^j G^j(x)/v}$$

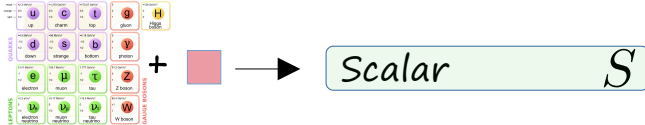
$$\Sigma(x) \rightarrow e^{i\varphi_L^j \sigma^j / 2} \Sigma e^{-i\varphi_Y \sigma^3 / 2}$$

→ generic characterization framework for new scalars

Extended HEFT

eSMEFT:

SM + new field(s)
+ symmetries



SM + scalar EFT

Arcadi, Cabo-Almeida, FG, Hager, 2512.11764

Maya's talk

- Example application:

$$m_S = ?$$

$$\begin{aligned} \mathcal{L} \supset & \frac{1}{2} \sum_{\phi=S,h} \partial_\mu \phi \partial^\mu \phi - \mathcal{F}_{c_s} + \frac{v^2}{4} \text{Tr} [\Sigma^\dagger (D^\mu \Sigma) \sigma^3] \text{Tr} [\Sigma^\dagger (D_\mu \Sigma) \sigma^3] \mathcal{F}_{c_T} \\ & + i \frac{v^2}{4} \text{Tr} [\Sigma^\dagger (D^\mu \Sigma) \sigma^3] (\partial_\mu S \mathcal{F}_S) + \frac{v^2}{4} \text{Tr} [(D_\mu \Sigma)^\dagger (D^\mu \Sigma)] \mathcal{F}_\kappa \\ & - \frac{v}{\sqrt{2}} \left((\overline{u_{i,L}} \quad \overline{d_{i,L}}) \Sigma \begin{pmatrix} Y_{ij}^u u_{j,R} \\ Y_{ij}^d d_{j,R} \end{pmatrix} \mathcal{F}_{c_q} + (\overline{\nu_{i,L}} \quad \overline{\ell_{i,L}}) \Sigma \frac{1-\sigma_3}{2} Y_{ij}^\ell \begin{pmatrix} \nu_{j,R} \\ \ell_{j,R} \end{pmatrix} \mathcal{F}_{c_\ell} + \text{h.c.} \right) \\ & - \frac{1}{16\pi^2} \left[g'^2 B^{\mu\nu} B_{\mu\nu} \mathcal{F}_{c_B} + g^2 W^{I\mu\nu} W_{\mu\nu}^I \mathcal{F}_{c_W} + gg' B_{\mu\nu} \text{Tr} [\Sigma \sigma^3 \Sigma^\dagger W^{\mu\nu}] \mathcal{F}_{c_{WB}} + g_s^2 G^{a\mu\nu} G_{\mu\nu}^a \mathcal{F}_{c_G} \right] \end{aligned}$$

$$\mathcal{F}_C \equiv \mathcal{F}_C(h, S) \equiv \sum_{i=0}^2 \sum_{j=0}^{2-i} C_{i,j} h^i S^j + \mathcal{O}((h, S)^3) \quad \Sigma(x) = e^{i\sigma^j G^j(x)/v}$$

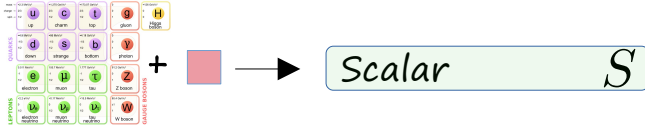
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→ generic characterization framework for new scalars

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SM + scalar EFT

Arcadi, Cabo-Almeida, FG, Hager, 2512.11764

Maya's talk

- Example application:

$$m_S = ?$$

$$(m_S \neq 750 \text{ GeV})$$

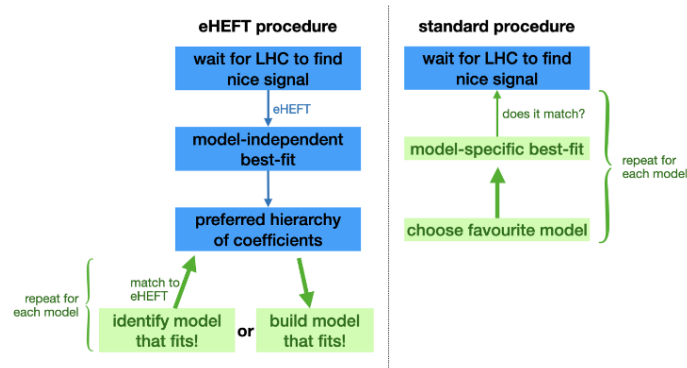
$$\begin{aligned} \mathcal{L} \supset & \frac{1}{2} \sum_{\phi=S,h} \partial_\mu \phi \partial^\mu \phi - \mathcal{F}_{c_s} + \frac{v^2}{4} \text{Tr} [\Sigma^\dagger (D^\mu \Sigma) \sigma^3] \text{Tr} [\Sigma^\dagger (D_\mu \Sigma) \sigma^3] \mathcal{F}_{c_T} \\ & + i \frac{v^2}{4} \text{Tr} [\Sigma^\dagger (D^\mu \Sigma) \sigma^3] (\partial_\mu S \mathcal{F}_S) + \frac{v^2}{4} \text{Tr} [(D_\mu \Sigma)^\dagger (D^\mu \Sigma)] \mathcal{F}_\kappa \\ & - \frac{v}{\sqrt{2}} \left((\overline{u_{i,L}} \quad \overline{d_{i,L}}) \Sigma \begin{pmatrix} Y_{ij}^u u_{j,R} \\ Y_{ij}^d d_{j,R} \end{pmatrix} \mathcal{F}_{c_q} + (\overline{\nu_{i,L}} \quad \overline{\ell_{i,L}}) \Sigma \frac{1-\sigma_3}{2} Y_{ij}^\ell \begin{pmatrix} \nu_{j,R} \\ \ell_{j,R} \end{pmatrix} \mathcal{F}_{c_\ell} + \text{h.c.} \right) \\ & - \frac{1}{16\pi^2} [g'^2 B^{\mu\nu} B_{\mu\nu} \mathcal{F}_{c_B} + g^2 W^{I\mu\nu} W_{\mu\nu}^I \mathcal{F}_{c_W} + gg' B_{\mu\nu} \text{Tr} [\Sigma \sigma^3 \Sigma^\dagger W^{\mu\nu}] \mathcal{F}_{c_{WB}} + g_s^2 G^{a\mu\nu} G_{\mu\nu}^a \mathcal{F}_{c_G}] \end{aligned}$$

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$$\Sigma(x) \rightarrow e^{i\varphi_L^j \sigma^j / 2} \Sigma e^{-i\varphi_Y \sigma^3 / 2}$$

→ generic characterization framework for new scalars

Extending HEFT



SM + scalar EFT

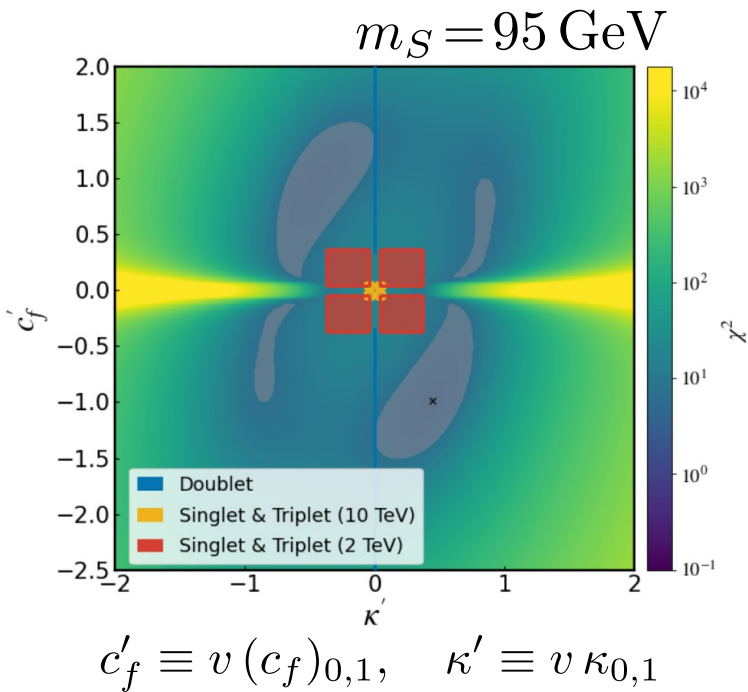
Arcadi, Cabo-Almeida, FG, Hager, 2512.11764

Maya's talk

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$$\mathcal{F}_C \equiv \mathcal{F}_C(h, S) \equiv \sum_{i=0}^2 \sum_{j=0}^{2-i} C_{i,j} h^i S^j + \mathcal{O}((h, S)^3) \quad \Sigma(x) = e^{i\sigma^j G^j(x)/v}$$

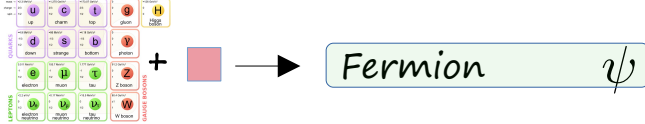
$$\Sigma(x) \rightarrow e^{i\varphi_L^j \sigma^j / 2} \Sigma e^{-i\varphi_Y \sigma^3 / 2}$$



SMEFT + Fermions

eSMEFT:

SM + new field(s)
+ symmetries

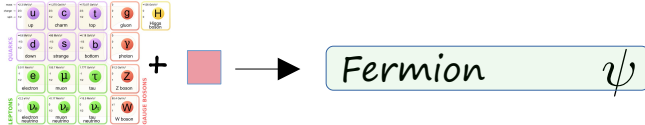


SM + Fermion EFT: ν_R , DM, ...

SMEFT + Fermions

eSMEFT:

SM + new field(s)
+ symmetries



SM + Fermion EFT: ψ_R , DM, ...

VSMEFT

del Aguila, Bar-Shalom, Soni, Wudka, 0806.0876

Bhattacharya, Wudka, 1505.05264

Liao, Ma, 1612.04527

Chala, Titov, 2001.07732

Li, Ren, Xiao, Yu, Zheng, 2105.09329

...

Fabian's talk

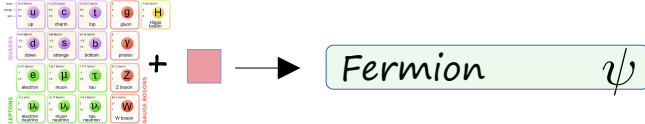
$\psi^2 H^3$		$\psi^2 H^2 D$		$\psi^2 H X (+h.c.)$	
$\mathcal{O}_{LNH} (+h.c.)$	$(\bar{L}N)\tilde{H}(H^\dagger H)$	$\mathcal{O}_{HN}$ $\mathcal{O}_{HNe} (+h.c.)$	$(\bar{N}\gamma^\mu N)(H^\dagger i\overleftrightarrow{D}_\mu H)$ $(\bar{N}\gamma^\mu e)(\tilde{H}^\dagger iD_\mu H)$	$\mathcal{O}_{NB}$ $\mathcal{O}_{NW}$	$(\bar{L}\sigma_{\mu\nu}N)\tilde{H}B^{\mu\nu}$ $(\bar{L}\sigma_{\mu\nu}N)\tau^I\tilde{H}W^{I\mu\nu}$
$(\bar{R}R)(\bar{R}R)$		$(\bar{L}L)(\bar{R}R)$		$(\bar{L}R)(\bar{L}R) (+h.c.)$	
$\mathcal{O}_{NN}$	$(\bar{N}\gamma^\mu N)(\bar{N}\gamma_\mu N)$	$\mathcal{O}_{LN}$	$(\bar{L}\gamma^\mu L)(\bar{N}\gamma_\mu N)$	$\mathcal{O}_{LNLe}$	$(\bar{L}N)\varepsilon(\bar{L}e)$
$\mathcal{O}_{eN}$	$(\bar{e}\gamma^\mu e)(\bar{N}\gamma_\mu N)$	$\mathcal{O}_{QN}$	$(\bar{Q}\gamma^\mu Q)(\bar{N}\gamma_\mu N)$	$\mathcal{O}_{LNQd}$	$(\bar{L}N)\varepsilon(\bar{Q}d)$
$\mathcal{O}_{uN}$	$(\bar{u}\gamma^\mu u)(\bar{N}\gamma_\mu N)$			$\mathcal{O}_{LdQN}$	$(\bar{L}d)\varepsilon(\bar{Q}N)$
$\mathcal{O}_{dN}$	$(\bar{d}\gamma^\mu d)(\bar{N}\gamma_\mu N)$				
$\mathcal{O}_{duNe} (+h.c.)$	$(\bar{d}\gamma^\mu u)(\bar{N}\gamma_\mu e)$				
$(\bar{L}R)(\bar{R}L)$		$(\bar{L}\cap B)(+h.c.)$		$(\bar{L}\cap \bar{B})(+h.c.)$	
$\mathcal{O}_{QuNL} (+h.c.)$	$(\bar{Q}u)(\bar{N}L)$	$\mathcal{O}_{NNNN}$	$(NCN)(NCN)$	$\mathcal{O}_{QQdN}$ $\mathcal{O}_{uddN}$	$\varepsilon_{ij}\varepsilon_{\alpha\beta\sigma}(Q_\alpha^i C Q_\beta^j)(d_\sigma CN)$ $\varepsilon_{\alpha\beta\sigma}(u_\alpha C d_\beta)(d_\sigma CN)$

Liao, Ma, 1612.04527

SMEFT + Fermions

eSMEFT:

SM + new field(s)
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SM + Fermion EFT: ψ_R , DM, ...

VSMEFT

del Aguila, Bar-Shalom, Soni, Wudka, 0806.0876

Bhattacharya, Wudka, 1505.05264

Liao, Ma, 1612.04527

Chala, Titov, 2001.07732

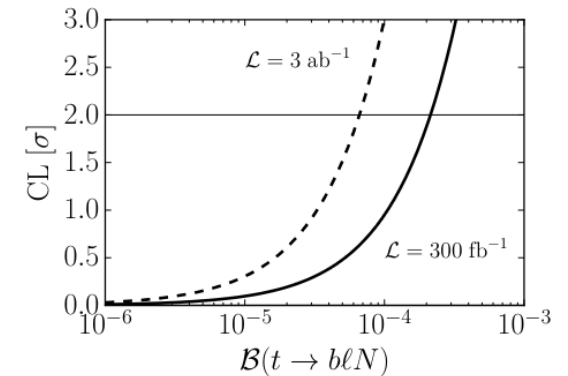
Li, Ren, Xiao, Yu, Zheng, 2105.09329

...

$\psi^2 H^3$		$\psi^2 H^2 D$		$\psi^2 H X (+h.c.)$	
$\mathcal{O}_{LNH} (+h.c.)$	$(\bar{L}N)\tilde{H}(H^\dagger H)$	$\mathcal{O}_{HN}$ $\mathcal{O}_{HNe} (+h.c.)$	$(\bar{N}\gamma^\mu N)(H^\dagger i\overleftrightarrow{D}_\mu H)$ $(\bar{N}\gamma^\mu e)(\tilde{H}^\dagger iD_\mu H)$	$\mathcal{O}_{NB}$ $\mathcal{O}_{NW}$	$(\bar{L}\sigma_{\mu\nu}N)\tilde{H}B^{\mu\nu}$ $(\bar{L}\sigma_{\mu\nu}N)\tau^I\tilde{H}W^{I\mu\nu}$
$(\bar{R}R)(\bar{R}R)$		$(\bar{L}L)(\bar{R}R)$		$(\bar{L}R)(\bar{L}R) (+h.c.)$	
$\mathcal{O}_{NN}$	$(\bar{N}\gamma^\mu N)(\bar{N}\gamma_\mu N)$	$\mathcal{O}_{LN}$	$(\bar{L}\gamma^\mu L)(\bar{N}\gamma_\mu N)$	$\mathcal{O}_{LNLe}$	$(\bar{L}N)\varepsilon(\bar{L}e)$
$\mathcal{O}_{eN}$	$(\bar{e}\gamma^\mu e)(\bar{N}\gamma_\mu N)$	$\mathcal{O}_{QN}$	$(\bar{Q}\gamma^\mu Q)(\bar{N}\gamma_\mu N)$	$\mathcal{O}_{LNQd}$	$(\bar{L}N)\varepsilon(\bar{Q}d)$
$\mathcal{O}_{uN}$	$(\bar{u}\gamma^\mu u)(\bar{N}\gamma_\mu N)$			$\mathcal{O}_{LdQN}$	$(\bar{L}d)\varepsilon(\bar{Q}N)$
$\mathcal{O}_{dN}$	$(\bar{d}\gamma^\mu d)(\bar{N}\gamma_\mu N)$				
$\mathcal{O}_{duNe} (+h.c.)$	$(\bar{d}\gamma^\mu u)(\bar{N}\gamma_\mu e)$				
$(\bar{L}R)(\bar{R}L)$		$(\bar{L}\cap B)(+h.c.)$		$(\bar{L}\cap \bar{B})(+h.c.)$	
$\mathcal{O}_{QuNL} (+h.c.)$	$(\bar{Q}u)(\bar{N}L)$	$\mathcal{O}_{NNNN}$	$(NCN)(NCN)$	$\mathcal{O}_{QQdN}$ $\mathcal{O}_{uddN}$	$\varepsilon_{ij}\varepsilon_{\alpha\beta\sigma}(Q_\alpha^i C Q_\beta^j)(d_\sigma CN)$ $\varepsilon_{\alpha\beta\sigma}(u_\alpha C d_\beta)(d_\sigma CN)$

Liao, Ma, 1612.04527

Fabian's talk

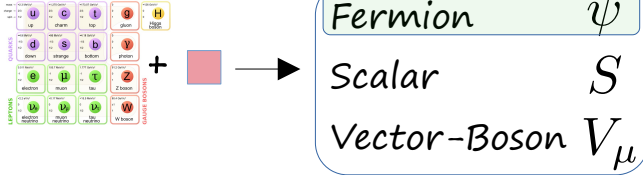


Biekötter, Chala, Spannowsky, 2007.00673

SMEFT + Fermions

eSMEFT:

SM + new field(s)
+ symmetries



SM + Fermion EFT: ν_R , $\boxed{DM}$, ...

- Lightest SUSY partner (Neutralino ...)
- Lightest Kaluza-Klein excitation (KK parity)
- Composite
- Sterile neutrino
- Extended Higgs sectors
- Axions, ALPs
- Dark Photon
- ...

DMEFT

eSMEFT:

SM + new field(s)
+ symmetries



Fermion	ψ
Scalar	S
Vector-Boson	V_μ

SM + Fermion EFT: ν_R , **DM**, ...

DMEFT

Shepherd, Tait, Zaharijas, 0901.2125

Beltran, Hooper, Kolb, Krusberg, Tait, 1002.4137

Goodman, Ibe, Rajaraman, Shepherd,

Tait, Yu, 1005.1286, 1008.1783

Bai, Fox, Harnik, 1005.3797

Busoni, De Simone, (Gramling), Morgante, Riotto,

1307.2253, 1402.1275

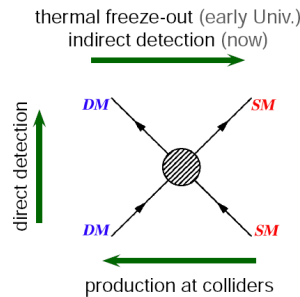
Bruggisser, Riva, Urbano, 1607.02475

...

Fatemeh's talk

DM Fermion χ

- Lightest SUSY partner (Neutralino ...)
- Lightest Kaluza-Klein excitation (KK parity)
- Composite
- Sterile neutrino
- Extended Higgs sectors
- Axions, ALPs
- Dark Photon
- ...



$O_{\phi 1}$	$(\bar{\chi}_L \chi_R)(\phi^\dagger \phi)$
$O_{\phi 2}$	$(\bar{\chi}_L T^a \chi_R)(\phi^\dagger \sigma^a \phi)$
$O_{\phi 3}$	$(\bar{\chi}_L T^a \tilde{\chi}_L)(\tilde{\phi}^\dagger \sigma^a \phi)$
$O_{\phi 4}$	$(\bar{\chi}_R T^a \tilde{\chi}_R)(\tilde{\phi}^\dagger \sigma^a \phi)$
$O_{\phi 5}$	$(\bar{\chi}_L \gamma^\mu \chi_L)(\phi^\dagger \overleftrightarrow{D}_\mu \phi)$
$O_{\phi 6}$	$(\bar{\chi}_R \gamma^\mu \chi_R)(\phi^\dagger \overleftrightarrow{D}_\mu \phi)$
$O_{\phi 7}$	$(\bar{\chi}_L T^a \gamma^\mu \chi_L)(\phi^\dagger \overleftrightarrow{D}_\mu^a \phi)$
$O_{\phi 8}$	$(\bar{\chi}_R T^a \gamma^\mu \chi_R)(\phi^\dagger \overleftrightarrow{D}_\mu^a \phi)$
$O_{\phi 9}$	$(\bar{\chi}_L \gamma^\mu \tilde{\chi}_R)(\tilde{\phi}^\dagger \overleftrightarrow{D}_\mu \phi)$
O_B	$\bar{\chi}_L \sigma^{\mu\nu} \chi_R B_{\mu\nu}$
O_W	$\bar{\chi}_L \sigma^{\mu\nu} T^a \chi_R W_{\mu\nu}^a$

Carlos Criadoa, Djouadib,
Pérez-Victoria, Santiago,
2104.14443

O_{e1}	$(\bar{\chi}_L \gamma^\mu \chi_L)(\bar{e} \gamma_\mu e)$
O_{e2}	$(\bar{\chi}_R \gamma^\mu \chi_R)(\bar{e} \gamma_\mu e)$
O_{d1}	$(\bar{\chi}_L \gamma^\mu \chi_L)(\bar{d} \gamma_\mu d)$
O_{d2}	$(\bar{\chi}_R \gamma^\mu \chi_R)(\bar{d} \gamma_\mu d)$
O_{u1}	$(\bar{\chi}_L \gamma^\mu \chi_L)(\bar{u} \gamma_\mu u)$
O_{u2}	$(\bar{\chi}_R \gamma^\mu \chi_R)(\bar{u} \gamma_\mu u)$
O_{ud}	$(\bar{\chi}_L^c \gamma^\mu \chi_R)(\bar{u} \gamma_\mu d)$
O_{l1}	$(\bar{\chi}_L \gamma^\mu \chi_L)(\bar{l} \gamma_\mu l)$
O_{l2}	$(\bar{\chi}_R \gamma^\mu \chi_R)(\bar{l} \gamma_\mu l)$
O_{l3}	$(\bar{\chi}_L T^a \gamma^\mu \chi_L)(\bar{l} \sigma^a \gamma_\mu l)$
O_{l4}	$(\bar{\chi}_R T^a \gamma^\mu \chi_R)(\bar{l} \sigma^a \gamma_\mu l)$
O_{l5}	$(\bar{\chi}_L \tilde{\chi}_L)(\bar{l} l)$
O_{l6}	$(\bar{\chi}_L T^a \tilde{\chi}_L)(\bar{l} \sigma^a \tilde{l})$
O_{l7}	$(\bar{\chi}_R \tilde{\chi}_R)(\bar{l} l)$
O_{q1}	$(\bar{\chi}_L \gamma^\mu \chi_L)(\bar{q} \gamma_\mu q)$
O_{q2}	$(\bar{\chi}_R \gamma^\mu \chi_R)(\bar{q} \gamma_\mu q)$
O_{q3}	$(\bar{\chi}_L T^a \gamma^\mu \chi_L)(\bar{q} \sigma^a \gamma_\mu q)$
O_{q4}	$(\bar{\chi}_R T^a \gamma^\mu \chi_R)(\bar{q} \sigma^a \gamma_\mu q)$

https://www.mpi-hd.mpg.de/lin/images/research_theory5.png

DMEFT

From full theories to EFT

SUSY
UED
little Higgs

Effective field
theory (EFT)

$$\frac{m_q}{\Lambda^3} \bar{\chi} \chi \bar{q} q$$



Pre-LHC

LHC

2010

2011

see G. Polesello, U. Haisch
+ pixabay.com (license: free)

DMEFT

Spencer's talk

From full theories to EFT

SUSY
UED
little Higgs



Pre-LHC



LHC

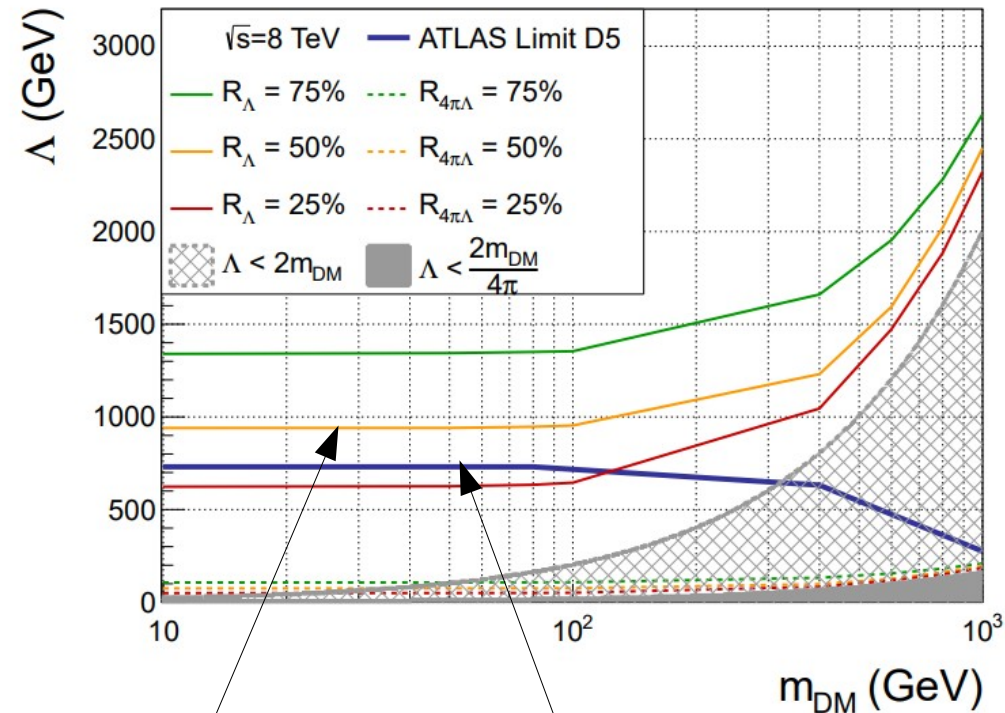
Effective field
theory (EFT)

$$\frac{m_q}{\Lambda^3} \bar{\chi} \chi \bar{q} q$$



2010 2011

EFT vs. LHC



50% of all events lie above Λ $\longleftrightarrow$ LHC limit very questionable...

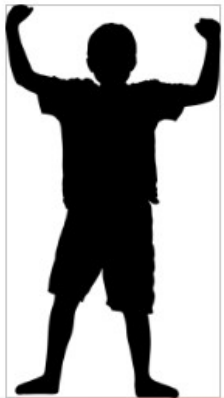
see G. Polesello, U. Haisch
+ pixabay.com (license: free)

Morgante, 1409.6668
Busoni, De Simone, Morgante, Riotto, 1307.2253

DMEFT

From full theories to EFT and back

SUSY
UED
little Higgs



Pre-LHC



LHC

Effective field
theory (EFT)

$$\frac{m_q}{\Lambda^3} \bar{\chi} \chi \bar{q} q$$



2010

2011

Simplified
models

$$g_\chi \bar{\chi} \chi S + \frac{g_q y_q}{\sqrt{2}} \bar{q} q S$$



2013

2014

‘Consistent’
simplified models / ‘UV complete’
models

$$g_\chi \bar{\chi} \chi s + Y_q \bar{q} H q + \mu s |H|^2$$



2015

2016

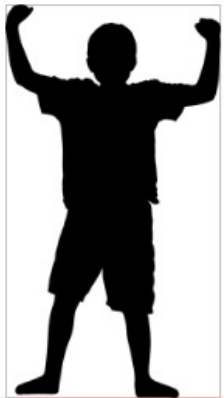
2017

see G. Polesello, U. Haisch
+ pixabay.com (license: free)

DMEFT

From full theories to EFT (and back)

SUSY
UED
little Higgs



Pre-LHC



LHC

Effective field
theory (EFT)

$$\frac{m_q}{\Lambda^3} \bar{\chi} \chi \bar{q} q$$



Simplified
models

$$g_\chi \bar{\chi} \chi S + \frac{g_q y_q}{\sqrt{2}} \bar{q} q S$$



‘Consistent’
simplified models

‘UV complete’
models

$$g_\chi \bar{\chi} \chi S + Y_q \bar{q} H q + \mu s |H|^2$$

eDMEFT

$$-y_S S \bar{\chi}_L \chi_R - \frac{S}{\Lambda} (y_d^S)^{ij} \bar{Q}_L^i H d_R^j - \frac{S}{\Lambda} c_G^S G^{a\mu\nu} G_{\mu\nu}^a + \dots$$



2010

2011

2012

2013

2014

2015

2016

2017

DMEFT

DM EFT	Simpl. Models
'model independent'	rather specific
'proper' QFT	gauge inv./unitarity?
LHC validity questionable	valid for LHC searches

$$\frac{m_q}{\Lambda^3} \bar{\chi} \chi \bar{q} q$$

DM

$$g_\chi \bar{\chi} \chi S + \frac{g_q y_q}{\sqrt{2}} \bar{q} q S$$

DM

mediator

Shepherd, Tait, Zaharijas, 0901.2125

Beltran, Hooper, Kolb, Krusberg,

Tait, 1002.4137

Goodman, Ibe, Rajaraman, Shepherd,

Tait, Yu, 1005.1286, 1008.1783

Bai, Fox, Harnik, 1005.3797

Busoni, De Simone, (Gramling), Morgante, Riotto, 1307.2253, 1402.1275

Bruggisser, Riva, Urbano, 1607.02475, ...

Alwall, Schuster, Toro, 0810.3921

De Simone, Giudice, Strumia, 1402.6287

Abdallah et al, 1506.03116

Kahlhoefer, S-Hoberg, Schwetz, Vogl, 1510.02110

Boveia et al, 1603.04156

De Simone, Jacques, 1603.08002

Englert, McCullough, Spannowsky, 1604.07975, ...

eDMEFT

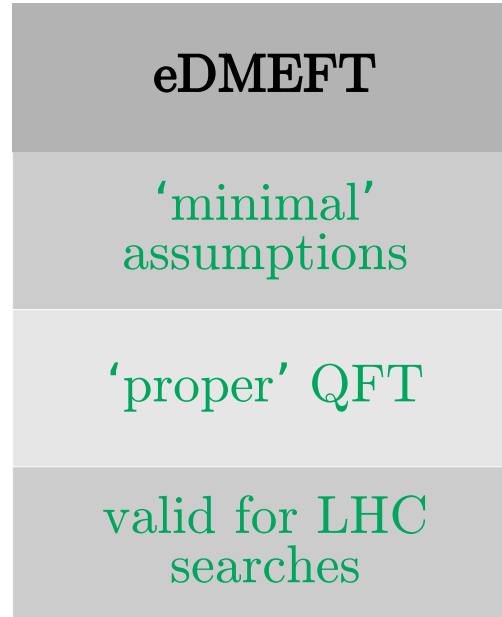
eDMEFT:

SM + new field(s)
+ symmetries



+

DM Fermion χ
Scalar med. S



Alanne, FG, 1712.07626

Alanne, Arcadi, FG, Tenorth, Vogl, 2006.07174

SMEFT + DM + mediator

$$\begin{aligned}\mathcal{L}_{\text{eff}}^{S\chi} = & \mathcal{L}_{\text{SM}} + \frac{1}{2}\partial_\mu S \partial^\mu S - \frac{1}{2}\mu_S^2 S^2 + \bar{\chi} i \not{\partial} \chi - m_\chi \bar{\chi} \chi \\ & - \lambda'_{S1} v^3 S - \frac{\lambda'_S}{2\sqrt{2}} v S^3 - \frac{\lambda_S}{4} S^4 \\ & - \lambda'_{HS} v |H|^2 S - \lambda_{HS} |H|^2 S^2 \\ & - y_S S \bar{\chi}_L \chi_R + \text{h.c.} \\ & - \frac{S}{\Lambda} [c_{\lambda S} S^4 + c_{HS} |H|^2 S^2 + c_{\lambda H} |H|^4] \\ & - \frac{S}{\Lambda} \left[(y_d^S)^{ij} \bar{Q}_L^i H d_R^j + (y_u^S)^{ij} \bar{Q}_L^i \tilde{H} u_R^j \right. \\ & \quad \left. + (y_\ell^S)^{ij} \bar{L}_L^i H \ell_R^j + \text{h.c.} \right] \\ & - \frac{y_S^{(2)} S^2 + y_H^{(2)} |H|^2}{\Lambda} \bar{\chi}_L \chi_R + \text{h.c.} \\ & - \frac{S}{\Lambda} \frac{1}{16\pi^2} \left[g'^2 c_B^S B_{\mu\nu} B^{\mu\nu} + g^2 c_W^S W^{I\mu\nu} W_{\mu\nu}^I \right. \\ & \quad \left. + g_s^2 c_G^S G^{a\mu\nu} G_{\mu\nu}^a \right] .\end{aligned}$$

Leading EFT effects at $D=5$!

eDMEFT

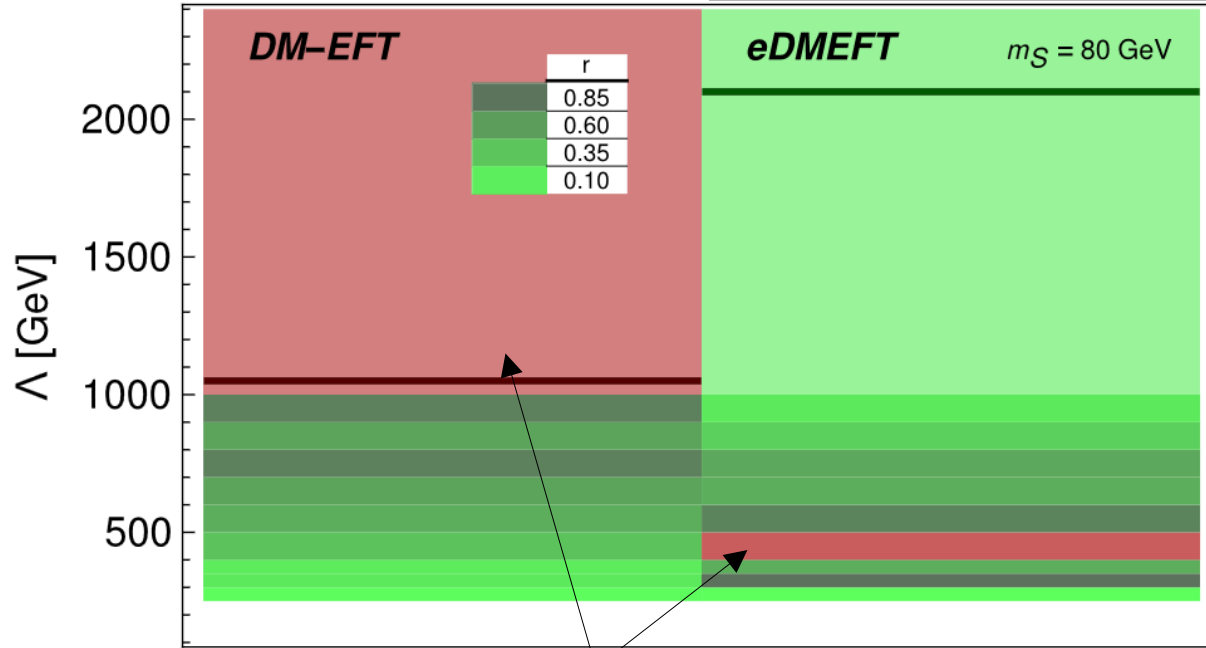
eDMEFT:

SM + new field(s)
+ symmetries



DM Fermion χ
Scalar med. S

eDMEFT



bins driving exclusion

SMEFT + DM + mediator

$$\begin{aligned}
 \mathcal{L}_{\text{eff}}^{S\chi} = & \mathcal{L}_{\text{SM}} + \frac{1}{2} \partial_\mu S \partial^\mu S - \frac{1}{2} \mu_S^2 S^2 + \bar{\chi} i \not{\partial} \chi - m_\chi \bar{\chi} \chi \\
 & - \lambda'_{S1} v^3 S - \frac{\lambda'_S}{2\sqrt{2}} v S^3 - \frac{\lambda_S}{4} S^4 \\
 & - \lambda'_{HS} v |H|^2 S - \lambda_{HS} |H|^2 S^2 \\
 & - y_S S \bar{\chi}_L \chi_R + \text{h.c.} \\
 & - \frac{S}{\Lambda} [c_{\lambda S} S^4 + c_{HS} |H|^2 S^2 + c_{\lambda H} |H|^4] \\
 & - \frac{S}{\Lambda} \left[(y_d^S)^{ij} \bar{Q}_L^i H d_R^j + (y_u^S)^{ij} \bar{Q}_L^i \tilde{H} u_R^j \right. \\
 & \quad \left. + (y_\ell^S)^{ij} \bar{L}_L^i H \ell_R^j + \text{h.c.} \right] \\
 & - \frac{y_S^{(2)} S^2 + y_H^{(2)} |H|^2}{\Lambda} \bar{\chi}_L \chi_R + \text{h.c.} \\
 & - \frac{S}{\Lambda} \frac{1}{16\pi^2} \left[g'^2 c_B^S B_{\mu\nu} B^{\mu\nu} + g^2 c_W^S W^{I\mu\nu} W_{\mu\nu}^I \right. \\
 & \quad \left. + g_s^2 c_G^S G^{a\mu\nu} G_{\mu\nu}^a \right].
 \end{aligned}$$

Leading EFT effects at $D=5$!

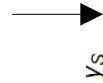
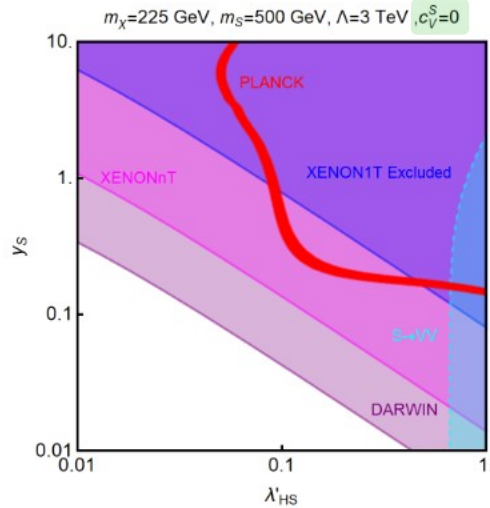
eDMEFT

eDMEFT:

SM + new field(s)
+ symmetries

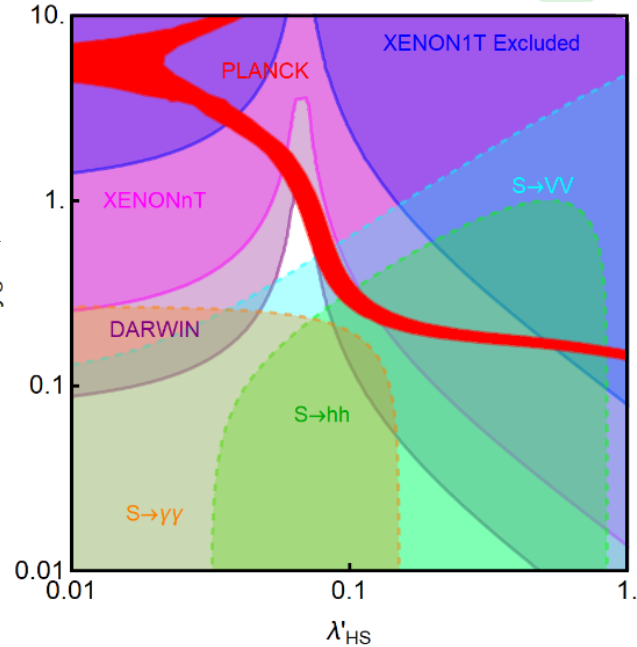


DM Fermion χ
Scalar med. S



eDMEFT

$m_\chi=225 \text{ GeV}, m_S=500 \text{ GeV}, \Lambda=3 \text{ TeV}, c_V^S=5$



Alanne, Arcadi, FG, Tenorth, Vogl, 2006.07174

SMEFT + DM + mediator

$$\begin{aligned} \mathcal{L}_{\text{eff}}^{S\chi} = & \mathcal{L}_{\text{SM}} + \frac{1}{2} \partial_\mu S \partial^\mu S - \frac{1}{2} \mu_S^2 S^2 + \bar{\chi} i \not{\partial} \chi - m_\chi \bar{\chi} \chi \\ & - \lambda'_{S1} v^3 S - \frac{\lambda'_S}{2\sqrt{2}} v S^3 - \frac{\lambda_S}{4} S^4 \\ & - \lambda'_{HS} v |H|^2 S - \lambda_{HS} |H|^2 S^2 \\ & - y_S S \bar{\chi}_L \chi_R + \text{h.c.} \\ & - \frac{S}{\Lambda} [c_{\lambda S} S^4 + c_{HS} |H|^2 S^2 + c_{\lambda H} |H|^4] \\ & - \frac{S}{\Lambda} [(y_d^S)^{ij} \bar{Q}_L^i H d_R^j + (y_u^S)^{ij} \bar{Q}_L^i \tilde{H} u_R^j \\ & \quad + (y_\ell^S)^{ij} \bar{L}_L^i H \ell_R^j + \text{h.c.}] \\ & - \frac{y_S^{(2)} S^2 + y_H^{(2)} |H|^2}{\Lambda} \bar{\chi}_L \chi_R + \text{h.c.} \\ & - \frac{S}{\Lambda} \frac{1}{16\pi^2} [g'^2 c_B^S B_{\mu\nu} B^{\mu\nu} + g^2 c_W^S W^{I\mu\nu} W_{\mu\nu}^I \\ & \quad + g_s^2 c_G^S G^{a\mu\nu} G_{\mu\nu}^a] . \end{aligned}$$

Leading EFT effects at $D=5$!

eDMEFT

eDMEFT:

SM + new field(s)
+ symmetries



+

DM Fermion χ
Scalar med. S



eDMEFT

'minimal'
assumptions

'proper' QFT

valid for LHC
searches

Alanne, FG, 1712.07626

Alanne, Arcadi, FG, Tenorth, Vogl, 2006.07174

SMEFT + DM + mediator

$$\begin{aligned} \mathcal{L}_{\text{eff}}^{\tilde{S}\chi} = & \mathcal{L}_{\text{SM}} + \frac{1}{2} \partial_\mu \tilde{S} \partial^\mu \tilde{S} - \frac{1}{2} \mu_{\tilde{S}}^2 \tilde{S}^2 + \bar{\chi} i \not{\partial} \chi - m_\chi \bar{\chi} \chi \\ & - \frac{\lambda_{\tilde{S}}}{4} \tilde{S}^4 - \lambda_{H\tilde{S}} |H|^2 \tilde{S}^2 - y_{\tilde{S}} \tilde{S} i \bar{\chi}_L \chi_R + \text{h.c.} \\ & - \frac{\tilde{S}}{\Lambda} \left[(y_d^{\tilde{S}})^{ij} i \bar{Q}_L^i H d_R^j + (y_u^{\tilde{S}})^{ij} i \bar{Q}_L^i \tilde{H} u_R^j \right. \\ & \quad \left. + (y_\ell^{\tilde{S}})^{ij} i \bar{L}_L^i H \ell_R^j + \text{h.c.} \right] \\ & - \frac{y_{\tilde{S}}^{(2)} \tilde{S}^2 + y_H^{(2)} H^\dagger H}{\Lambda} \bar{\chi}_L \chi_R + \text{h.c.} \\ & - \frac{\tilde{S}}{\Lambda} \frac{1}{16\pi^2} \left[g'^2 c_B^{\tilde{S}} B_{\mu\nu} \tilde{B}^{\mu\nu} + g^2 c_W^{\tilde{S}} W^{I\mu\nu} \tilde{W}_{\mu\nu}^I \right. \\ & \quad \left. + g_s^2 c_G^{\tilde{S}} G^{a\mu\nu} \tilde{G}_{\mu\nu}^a \right]. \end{aligned}$$

CP-odd: ALP mediator

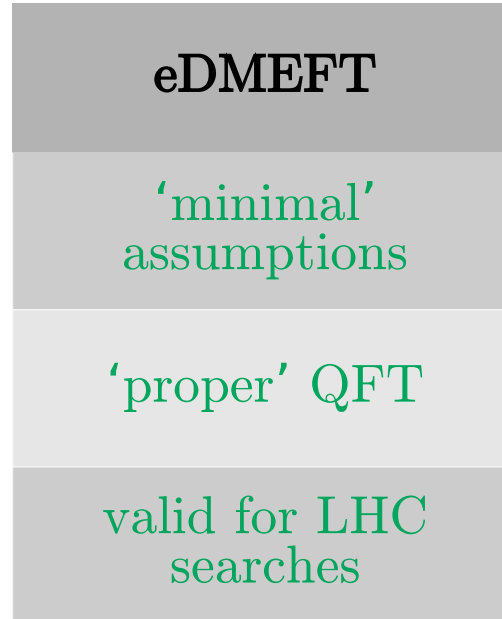
eDMEFT

eDMEFT:

SM + new field(s)
+ symmetries



DM Fermion χ
Scalar med. S



Alanne, FG, 1712.07626

Alanne, Arcadi, FG, Tenorth, Vogl, 2006.07174

SMEFT + DM + mediator

$$\begin{aligned}\mathcal{L}_{\text{eff}}^{\tilde{S}\chi} = & \mathcal{L}_{\text{SM}} + \frac{1}{2}\partial_\mu \tilde{S}\partial^\mu \tilde{S} - \frac{1}{2}\mu_{\tilde{S}}^2 \tilde{S}^2 + \bar{\chi}i\not{\partial}\chi - m_\chi \bar{\chi}\chi \\ & - \frac{\lambda_{\tilde{S}}}{4}\tilde{S}^4 - \lambda_{H\tilde{S}}|H|^2\tilde{S}^2 - y_{\tilde{S}}\tilde{S}i\bar{\chi}_L\chi_R + \text{h.c.} \\ & - \frac{\tilde{S}}{\Lambda}\left[(y_d^{\tilde{S}})^{ij}i\bar{Q}_L^i H d_R^j + (y_u^{\tilde{S}})^{ij}i\bar{Q}_L^i \tilde{H} u_R^j \right. \\ & \quad \left. + (y_\ell^{\tilde{S}})^{ij}i\bar{L}_L^i H \ell_R^j + \text{h.c.}\right] \\ & - \frac{y_{\tilde{S}}^{(2)}\tilde{S}^2 + y_H^{(2)}H^\dagger H}{\Lambda}\bar{\chi}_L\chi_R + \text{h.c.} \\ & - \frac{\tilde{S}}{\Lambda}\frac{1}{16\pi^2}\left[g'^2 c_B^{\tilde{S}}B_{\mu\nu}\tilde{B}^{\mu\nu} + g^2 c_W^{\tilde{S}}W^{I\mu\nu}\tilde{W}_{\mu\nu}^I \right. \\ & \quad \left. + g_s^2 c_G^{\tilde{S}}G^{a\mu\nu}\tilde{G}_{\mu\nu}^a\right].\end{aligned}$$

CP-odd: ALP mediator

see also 1901.09966 and refs therein

$$\mathcal{L}_{\text{axion}} = \mathcal{L}_{\text{SM}} + \mathcal{L}_{\text{DS}} + \frac{a}{4f_\gamma}F_{\mu\nu}\tilde{F}_{\mu\nu} + \frac{a}{4f_G}\text{Tr}G_{\mu\nu}\tilde{G}_{\mu\nu} + \frac{\partial_\mu a}{f_l}\sum_\alpha \bar{l}_\alpha\gamma_\mu\gamma_5 l_\alpha + \frac{\partial_\mu a}{f_q}\sum_\beta \bar{q}_\beta\gamma_\mu\gamma_5 q_\beta$$

Non-Linear (HEFT-like) eDMEFT

SMEFT + DM + generic scalar mediator(s)

Arcadi, Cabo-Almeida, Fabian, FG, 2411.05914

$$\begin{aligned} \mathcal{L} \supset & \frac{1}{2} \sum_{\phi=S,h} \partial_\mu \phi \partial^\mu \phi - \mathcal{F}_{c_s} + \frac{v^2}{4} \text{Tr} \left[\Sigma^\dagger (D^\mu \Sigma) \sigma^3 \right] \text{Tr} \left[\Sigma^\dagger (D_\mu \Sigma) \sigma^3 \right] \mathcal{F}_{c_T} \\ & + i \frac{v^2}{4} \text{Tr} \left[\Sigma^\dagger (D^\mu \Sigma) \sigma^3 \right] (\partial_\mu \mathcal{S} \mathcal{F}_S) + \frac{v^2}{4} \text{Tr} \left[(D_\mu \Sigma)^\dagger (D^\mu \Sigma) \right] \mathcal{F}_\kappa \\ & - \frac{v}{\sqrt{2}} \left(\begin{pmatrix} \overline{u}_{i,L} & \overline{d}_{i,L} \end{pmatrix} \Sigma \begin{pmatrix} Y_{ij}^u u_{j,R} \\ Y_{ij}^d d_{j,R} \end{pmatrix} \mathcal{F}_{c_q} + \begin{pmatrix} \overline{\nu}_{i,L} & \overline{\ell}_{i,L} \end{pmatrix} \Sigma \frac{1-\sigma_3}{2} Y_{ij}^\ell \begin{pmatrix} \nu_{j,R} \\ \ell_{j,R} \end{pmatrix} \mathcal{F}_{c_\ell} + \text{h.c.} \right) \\ & - \frac{1}{16\pi^2} \left[g'^2 B^{\mu\nu} B_{\mu\nu} \mathcal{F}_{c_B} + g^2 W^{I\mu\nu} W_{\mu\nu}^I \mathcal{F}_{c_W} + gg' B_{\mu\nu} \text{Tr} \left[\Sigma \sigma^3 \Sigma^\dagger W^{\mu\nu} \right] \mathcal{F}_{c_{WB}} + g_s^2 G^{a\mu\nu} G_{\mu\nu}^a \mathcal{F}_{c_G} \right] \end{aligned}$$

$$\mathcal{L}_\chi = \bar{\chi} i \not{\partial} \chi - \mathcal{F}_{y_\chi} \left[\overline{\chi L \chi R} \right] \cdot \quad \mathcal{F}_C \equiv \sum_{k=0}^d \sum_{j=0}^{d-k} \sum_{i=0}^j C_{i,j-i}^{(k)} \left[h^k S_1^i S_2^{j-i} \right]$$

SMEFT + DM + singlet mediator

$$\begin{aligned} \mathcal{L}_{\text{eff}}^{\tilde{S}\chi} = & \mathcal{L}_{\text{SM}} + \frac{1}{2} \partial_\mu \tilde{S} \partial^\mu \tilde{S} - \frac{1}{2} \mu_{\tilde{S}}^2 \tilde{S}^2 + \bar{\chi} i \not{\partial} \chi - m_\chi \bar{\chi} \chi \\ & - \frac{\lambda_{\tilde{S}}}{4} \tilde{S}^4 - \lambda_{H\tilde{S}} |H|^2 \tilde{S}^2 - y_{\tilde{S}} \tilde{S} i \bar{\chi}_L \chi_R + \text{h.c.} \\ & - \frac{\tilde{S}}{\Lambda} \left[(y_d^{\tilde{S}})^{ij} i \bar{Q}_L^i H d_R^j + (y_u^{\tilde{S}})^{ij} i \bar{Q}_L^i \tilde{H} u_R^j \right. \\ & \quad \left. + (y_\ell^{\tilde{S}})^{ij} i \bar{L}_L^i H \ell_R^j + \text{h.c.} \right] \\ & - \frac{y_{\tilde{S}}^{(2)} \tilde{S}^2 + y_H^{(2)} H^\dagger H}{\Lambda} \bar{\chi}_L \chi_R + \text{h.c.} \\ & - \frac{\tilde{S}}{\Lambda} \frac{1}{16\pi^2} \left[g'^2 c_B^{\tilde{S}} B_{\mu\nu} \tilde{B}^{\mu\nu} + g^2 c_W^{\tilde{S}} W^{I\mu\nu} \tilde{W}_{\mu\nu}^I \right. \\ & \quad \left. + g_s^2 c_G^{\tilde{S}} G^{a\mu\nu} \tilde{G}_{\mu\nu}^a \right] . \end{aligned}$$



Non-Linear (HEFT-like) eDMEFT

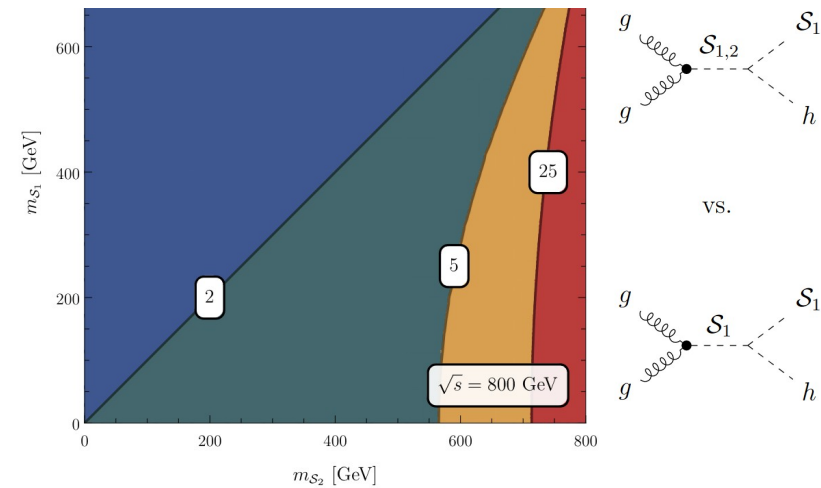
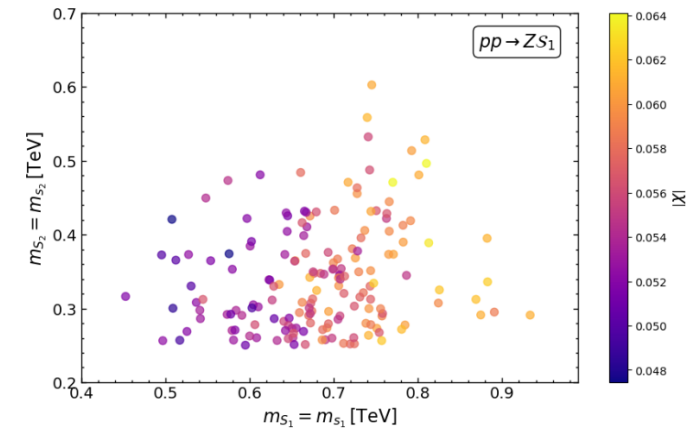
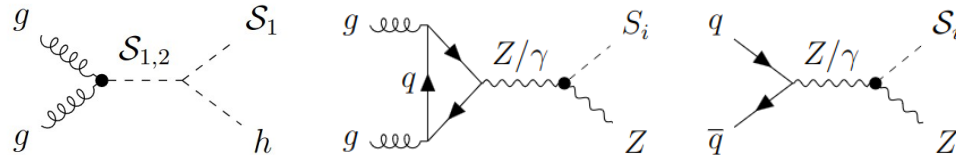
SMEFT + DM + generic scalar mediator(s)

Arcadi, Cabo-Almeida, Fabian, FG, 2411.05914

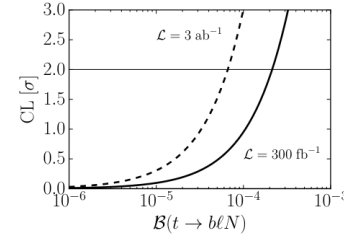
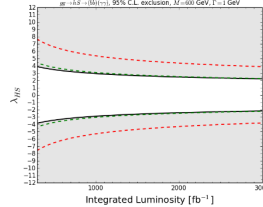
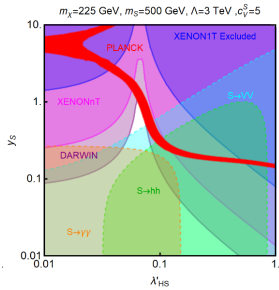
$$\begin{aligned} \mathcal{L} \supset & \frac{1}{2} \sum_{\phi=S,h} \partial_\mu \phi \partial^\mu \phi - \mathcal{F}_{c_s} + \frac{v^2}{4} \text{Tr} [\Sigma^\dagger (D^\mu \Sigma) \sigma^3] \text{Tr} [\Sigma^\dagger (D_\mu \Sigma) \sigma^3] \mathcal{F}_{c_T} \\ & + i \frac{v^2}{4} \text{Tr} [\Sigma^\dagger (D^\mu \Sigma) \sigma^3] (\partial_\mu S \mathcal{F}_S) + \frac{v^2}{4} \text{Tr} [(D_\mu \Sigma)^\dagger (D^\mu \Sigma)] \mathcal{F}_K \\ & - \frac{v}{\sqrt{2}} \left((\overline{u_{i,L}} \quad \overline{d_{i,L}}) \Sigma \begin{pmatrix} Y_{ij}^u u_{j,R} \\ Y_{ij}^d d_{j,R} \end{pmatrix} \mathcal{F}_{c_q} + (\overline{\nu_{i,L}} \quad \overline{\ell_{i,L}}) \Sigma \frac{1-\sigma_3}{2} Y_{ij}^\ell \begin{pmatrix} \nu_{j,R} \\ \ell_{j,R} \end{pmatrix} \mathcal{F}_{c_\ell} + \text{h.c.} \right) \\ & - \frac{1}{16\pi^2} \left[g'^2 B^{\mu\nu} B_{\mu\nu} \mathcal{F}_{c_B} + g^2 W^{I\mu\nu} W_{\mu\nu}^I \mathcal{F}_{c_W} + gg' B_{\mu\nu} \text{Tr} [\Sigma \sigma^3 \Sigma^\dagger W^{\mu\nu}] \mathcal{F}_{c_{WB}} + g_s^2 G^{a\mu\nu} G_{\mu\nu}^a \mathcal{F}_{c_G} \right] \end{aligned}$$

$$\mathcal{L}_\chi = \overline{\chi} i \not{\partial} \chi - \mathcal{F}_{y_\chi} \left[\overline{\chi} L \chi R \right] \quad \mathcal{F}_C \equiv \sum_{k=0}^d \sum_{j=0}^{d-k} \sum_{i=0}^j C_{i,j-i}^{(k)} h^k S_1^i S_2^{j-i}$$

Allows for large mono- X rates (matches to 2HDM+s/a)



Conclusions



- EFTs with light new states can be very useful for not missing opportunities in between SMEFT (or DMEFT) and UV-complete constructions and for characterizing new particles ...

- More thoughts/avenues ?!

