Equations of motion for the SMEFT: Theory and Application

1st Workshop on High Energy Theory and Gender

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based on `arxiv:1806.06354` with M. Trott and A. Barzinji

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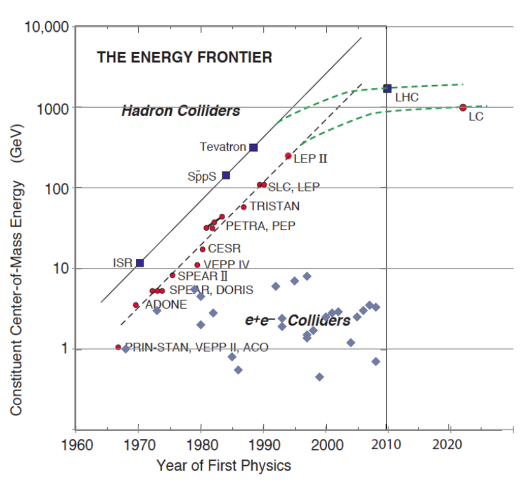
Introduction



Source:http://www.hep.ucl.ac.uk/iop2010/talks/14.pdf

- EFTs are a model-independent approach to capturing the low-energy impact of new physics
- When BSM physics is present at scales $\Lambda > \bar{v}_T$, an EFT can be constructed using SM symmetries $SU(3) \times SU(2)_L \times U(1)_Y$

$$\mathscr{L}_{SMEFT} = \mathscr{L}_{SM} + \mathscr{L}^{(5)} + \mathscr{L}^{(6)} + \cdots$$

$$\mathscr{L}^{(d)} = \sum_i \frac{C_i^{(d)}}{\Lambda^{d-4}} \mathcal{Q}_i^d \ , d > 4$$

- The Warsaw basis uses field redefinitions and flavour symmetries to restrict the full set of operators to just 79 [Grzadkowski et al. 2010]

Equations of Motion for the Standard Model

- EOM are based on the principle of least action

$$\delta S = \int d^4x \left[\frac{\partial \mathcal{L}_{SMEFT}}{\partial \mathcal{F}} + \partial_\mu \frac{\partial \mathcal{L}_{SMEFT}}{\partial(\partial_\mu \mathcal{F})} \right] \delta\mathcal{F} = 0$$

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- SM before EWSB

$$\begin{aligned} \mathcal{L}_{\rm SM} = & -\frac{1}{4} G^A_{\mu\nu} G^{A\mu\nu} - \frac{1}{4} W^I_{\mu\nu} W^{I\mu\nu} - \frac{1}{4} B_{\mu\nu} B^{\mu\nu}, \\ & + \sum_\psi \overline{\psi}\, i \not{D}\, \psi + (D_\mu H)^\dagger (D^\mu H) - \lambda \left(H^\dagger H - \frac{1}{2} v^2 \right)^2 \\ & - \left[H^{\dagger j} \overline{d}\, Y_d\, q_j + \widetilde{H}^{\dagger j} \overline{u}\, Y_u\, q_j + H^{\dagger j} \overline{e}\, Y_e\, \ell_j + \text{h.c.} \right], \end{aligned}$$

- Equation of motion for the Higgs

$$D^2 H^j = \lambda v^2 H^j - 2\lambda (H^\dagger H) H^j - \overline{q}^n_k\, [Y_u]^\star_{mn}\, u^m \epsilon^{kj} - \overline{d}^n [Y_d]_{nm} q^j_m - \overline{e}^n [Y_e]_{nm} \ell^{m,j}$$

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$$+ \sum_\psi \overline{\psi}\, i \not{D}\, \psi + (D_\mu H)^\dagger (D^\mu H) - \lambda \left(H^\dagger H - \frac{1}{2} v^2 \right)^2$$
$$- \left[H^{\dagger j} \overline{d}\, Y_d\, q_j + \widetilde{H}^{\dagger j} \overline{u}\, Y_u\, q_j + H^{\dagger j} \overline{e}\, Y_e\, \ell_j + \text{h.c.} \right],$$

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- In EFTs, the EOM relates different operators, which can then be reduced to arrive at a non-redundant basis and relate different bases

SMEFT corrections to the EOM

- The full set of corrections to the SMEOM due to $\mathscr{L}^{(5)}$ and $\mathscr{L}^{(6)}$ were presented in `arxiv:1806.06354`
- As an example, here are the corrections due to the Weinberg operator

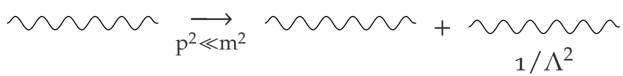
$$\mathbb{Q}^{(5)}_{mn} = \left(\overline{\ell^{c,m}}\, \tilde{H}^{\star}\right)\left(\tilde{H}^{\dagger}\, \ell^{n}\right)$$

- Corrections to the leptonic and Higgs fields

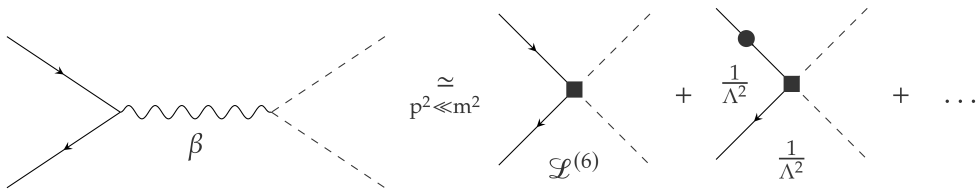
$$\begin{aligned}
\Delta^{j,(5)}_{\ell,m} &= -2\, C^{(5)\star}_{nm}\, \tilde{H}^{j}\left(\tilde{H}^{T}\, \ell^{c}_{n}\right), \\
\Delta^{j,(5)}_{H} &= -C^{(5)\star}_{nm}\, \epsilon^{jk}\left[\overline{\ell^{m}_{k}}\,(\tilde{H}^{T}\, \ell^{c}_{n}) + (\overline{\ell^{m}}\tilde{H})\, \ell^{c,k}_{n}\right]
\end{aligned}$$

Subleading effects on matching

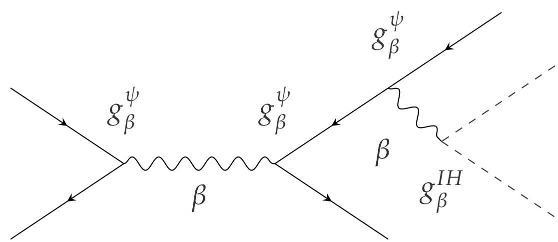
- Fields are redefined order by order in the EFT expansion



- Simply expanding the vector propagator in $p^2/m^2 \ll 1$ leads to an incomplete description of subleading SMEFT physics



- The scalings of the Wilson coefficients with the couplings is a non-intuitive EOM effect



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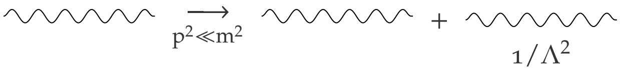

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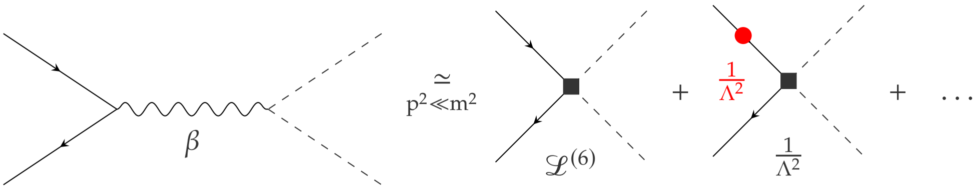

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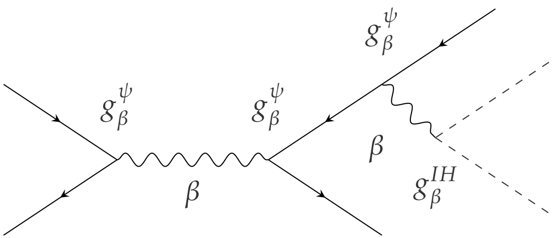

Conclusions

- Full set of EOM for the SM fields due to $\mathscr{L}^{(5)}$ and $\mathscr{L}^{(6)}$ in the Warsaw basis has been published in `arxiv:1806.06354`
- Corrections lead to non-intuitive effects which must be considered when looking at subleading order EFT studies
- In general, matching coefficients for $\mathscr{L}^{(n)}$ depend on the basis choice for operators in $\mathscr{L}^{(m<n)}$
- An example was considered for operators that would be relevant for LU anomaly interepretations using the SMEFT