EFT : Applicabilities and Viabilities

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5$^{\mathrm{th}}$ General Meeting of LHC Effective Field Theory WG

2$^{\mathrm{nd}}$ December 2022

Towards a consistent EFT analysis of data...

- SMEFT is a field theory that describes the low energy of an underlying UV completion in terms of only the SM particles. Assumption: new physics nearly decoupled: $\Lambda \gg (v, E)$.

$$\mathcal{L} = \mathcal{L}_{SM}^{(4)} + \frac{1}{\Lambda}\sum_k C_k^{(5)} Q_k^{(5)} + \frac{1}{\Lambda^2}\sum_k C_k^{(6)} Q_k^{(6)} + \frac{1}{\Lambda^3}\sum_k C_k^{(7)} Q_k^{(7)} + \mathcal{O}\left(\frac{1}{\Lambda^4}\right)$$

- Identify the SMEFT coefficients. Fit of coefficients can be done model independently.
  Results should be reported as functions of $\mathrm{M_{cut}}$ = max characteristic energy scale.

$$C_i < \delta_i^{exp}(M_{cut})$$

- Interpretation of results require assumptions on UV dynamics.Not really model independent.
- Combination of LHC Higgs & EW production, lower energy observables, EWPTs.

Precision

- Precision of SMEFT should match that of the SM.
  eg. NLO QCD corrections + EW corrections, tree $\rightarrow$ loops EFT.
- One loop SMEFT QCD corrections automated in `SMEFTNLO` Mimasu et. al. [2008.11743]. One loop SMEFT EW corrections. Dawson et. al.[1909.02000,1909.11576,2003.07862]

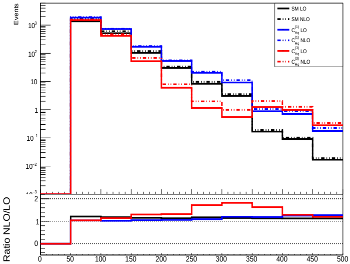


Figure: LO and NLO contributions in bins of p_{T12} for $pp \rightarrow h(\rightarrow \gamma\gamma)jj$ at 14 TeV HL-LHC

k-factors in differential distributions are not the same as in the SM.

T. Biswas, A. Datta, B. Mukhopadhyaya [2107.05503]

- We need to push harder in this direction. We need more calculations and MC implementations.

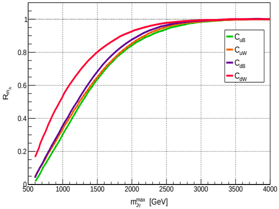
Is the EFT valid?

$$\mathcal{A}^2 \sim \mathcal{A}_{SM}^2 + \mathcal{A}_{SM}\mathcal{A}_{dim-6} + \mathcal{A}_{dim-6}^2 + \mathcal{A}_{SM}\mathcal{A}_{dim-8} + ..$$

- Case 1: $|\mathcal{A}_{dim-6}|^2 > \mathcal{A}_{SM}\mathcal{A}_{dim-6}$. Is it the breakdown of EFT? The relative departures from the SM, which are roughly controlled by $\frac{|\mathcal{A}_{dim-6}|^2}{\mathcal{A}_{SM}\mathcal{A}_{dim-6}} \sim \frac{C_i E^2}{g_{SM}^2 \Lambda^2}$ can be larger than 1 in the range $\Lambda \frac{g_{SM}}{\sqrt{C_i}} < E < \Lambda$. As long as the interference of the subsequent dimension-8 terms with the SM amplitude remains smaller that the dim-6 quadratic terms, convergence of EFT is ensured.
  $\implies$ Strongly coupled theory for large Λ.
- Assessing the values of the coefficients requires making assumptions of the UV dynamics.
- Case 2: $|\mathcal{A}_{dim-6}|^2 < \mathcal{A}_{SM}\mathcal{A}_{dim-6}$. Contribution of higher dimensional operator is always subdominant compared to the contribution of lower-dimensional operators.
- Dominance of linear term (over quadratic terms) is neither sufficient nor a necessary condition for EFT to be valid. [1604.06444] In general, more the data (consistent with the SM) we have, lesser space for large deviation and better convergence.

Is the EFT valid?

- The validity of an EFT analysis can be ensured by restricting the transfer of energy in the process to be less than the cut-off scale (Λ). Put a cut on the maximum energy where the SMEFT is assumed to be valid.
- Process $pp \rightarrow h\gamma$ at 14 TeV LHC in presence of dipole operators:



T. Biswas, A. Datta [2208.08432]

When $m_{J\gamma}$ remains smaller than Λ for most of the collisions taking place, the ratio $R_{m_{J\gamma}}$, defined in the following, would tend to 1.

$$R_{m_{J\gamma}} \equiv \frac{\int^{m_{J\gamma}<m_{J\gamma}^{max}} \frac{d\sigma}{dm_{J\gamma}}\, dm_{J\gamma}}{\int \frac{d\sigma}{dm_{J\gamma}}\, dm_{J\gamma}}$$

- Suitable energy variable $\rightarrow$ we need experimental analyses to adopt the 'clipping procedure' so that data and predictions are compared in the same phase-space region.
- Several assumptions into play : For linear order analysis, we should not consider the negative cross-section to be a valid EFT. The analysis here also assumes SM efficiencies in each bin (which may not be true).

Large number of parameters!

- Different models can induce energy growths in different kinematic quantities.
- For eg. s- and t- channel mediators in a $2 \to 2$ process, both leading to four-fermion operators. Is the EFT limit of the t-channel model under investigation has similar phenomenology to these s-channel operators?

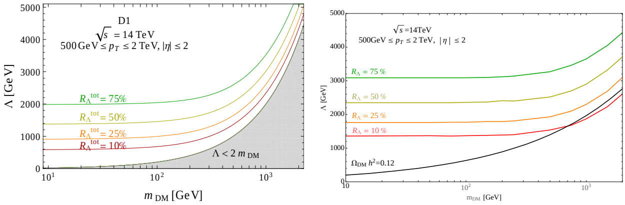


Figure: Left: Contours for the ratio R_Λ^{tot} on plane (m_{DM}, Λ) for an s-channel process [1402.1275] and Right: t-channel process[1405.3101]

- Several open questions... : Which are the best choice variables and what are the uppper cut values compatible on combining different processes? What's the most efficicent numerical approach to sample the parameter space ?

Thank You!