PRELIMINARY

LHC EFT WG, Area 1
Truncation, validity, uncertainties

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The truncation of the standard-model effective field theory (SMEFT), its validity and related uncertainties have been discussed in a meeting of the LHC EFT WG on January 19, 2021. Answering a call issued before, three proposals were presented: A., B., and C.. Each of them was discussed at this meeting. The purpose of this document is to summarize the issues in a clear fashion, not to make specific recommendations.

1 Common ground

In general, there are many points of agreement between proponents of various schemes for dealing with truncation uncertainties. All participants agree that:

1. most near-future experimental analyses will not aim at probing simultaneously both dimension-six and dimension-eight operator contributions. The SMEFT truncation of interest is then at the level of dimension-six operators.

2. although they only constitute a partial set of $1/\Lambda^4$ corrections, the squares of amplitudes featuring a single dimension-six operator insertion are well defined. In particular, they can be translated unambiguously from one dimension-six operator basis to the other.

3. there is no model-independent means to estimate the relative contributions of dimension-six and dimension-eight operators. A power-counting rule that covers a given range of new-physics scenarios can be employed for that purpose. Being able to compute the dimension-eight dependence of observables is insufficient, as a prescription

determining the relative magnitude of dimension-six and dimension-eight operator contributions is still needed.

2 Proposals

Specific points made in each proposal are succinctly summarized under Arabic numbers. Additional considerations highlighting pros and cons are listed under Latin lowercases.

Experimental results obtained by following one of the proposals would not be sufficient to allow for the application of the other prescription a posteriori.

2.1 Proposals A. and B.

Proposal A. and B. are similar thus discussed together. They advocate:

1. full multidimensional information on the constrained EFT parameter space is required for proper interpretations in (classes of) new-physics scenarios, and therefore for the validity assessment too.

   (a) Providing individual and marginalized constraints, on single coefficients and in two dimension, is a first but insufficient step. Full likelihoods, or correlations in Gaussian cases, should be published.

   (b) Correlations between operator coefficients deriving from specific new-physics assumptions may exclude parameter-space region where linear and quadratic dimension-six truncations diverge significantly and therefore improve validity.

2. including squared dimension-six dependences by default and comparing results with those obtained in the linear SMEFT approximation.

   (a) The conclusions drawn from this comparison are more qualitative than quantitative.

   In case the two sets of results match each other, one can conclude on the general validity of dimension-six truncation, as situation in which dimension-eight contributions would dominate over linear dimension-six ones are likely pathological. No additional assumption is required on new physics.

   When the linear and quadratic results differ significantly, constraints can only be applied in scenarios where dimension-eight contributions are generically suppressed with respect to quadratic dimension-six ones.

   (b) The linear-quadratic comparison does not reflect the convergence of the EFT series when interference contributions suffer (accidental or understood) suppressions.

3. providing experimental results as functions of the maximal energy probed in the data employed, introducing where necessary an upper cut (often referred to as E_{cut}

or M_{cut}). This ensures that the EFT is only applied in regions where the expansion is valid.

(a) For different cut values, different analysis strategies may be required. While rate measurements could provide the highest sensitivities at high energies, differential observables may be required to probe the relevant operators at moderate energies. Upper energy cuts should therefore be considered from the onset in the analysis design.

(b) The reconstruction of the relevant variable to cut on may complicate experimental analyses and result in additional systematic uncertainties (e.g. in final states featuring missing energy).

(c) Combining different observables from different processes, each using an upper cut on a different variable, might also raise questions. What variables and cut values are compatible in different processes?

(d) Repeating global analyses for several upper cut values would be more costly computationally.

4. assessing, a posteriori, the range of models for which the extracted constraints apply, using this E_{cut} information. The experimental results themselves would therefore not incorporate assumptions about new-physics models. This approach allows theorists to interpret the results in the context of specific (classes of) models.

   (a) Quantifying missing dimension-eight contributions would require more effort.

   A posteriori, one could approximately reproduce the experimental analysis and include estimates of dimension-eight contributions in the relevant phase-space region to assess their impact.

   A priori, one could consider treating linear and quadratic contributions as independent in experimental analyses and, in interpretations, rescale the quadratic contribution to estimate dimension-eight effects. The significant increase in the number of parameters to be fitted may however not be practical.

2.2 Proposal C.

Proposal C. advocates:

1. using squared dimension-six contributions, which can readily be computed with existing tools, as proxies for missing dimension-eight terms at order $1/\Lambda^4$.

   (a) As the dimension-eight contributions at that order arise from interferences with SM amplitudes, the dimension-eight contributions could have different kinematic distributions or suffer some accidental suppressions.

2. employing a power-counting rule that would encompass many new-physics models, to estimate dimension-eight contributions from squared dimension-six ones.

(a) The line drawn between classes of models that are, and are not, covered by the chosen power-counting rule is somewhat arbitrary.

(b) For specific classes of scenarios, this will necessarily be overly conservative. Employing different power-counting rules for different classes of scenarios would permit to quote tighter constraints in the specific cases where they apply.

3. considering the known squared dimension-six terms together with the dimension-eight estimates as theoretical uncertainty on the linear dimension-six signal.

   (a) As the dimension-six squared contributions are known, they may not need to be included in uncertainties.

   (b) This uncertainty depends on the SMEFT parameter point and could therefore be practically difficult to include in analyses.

4. folding these uncertainties directly into experimental analyses.

   (a) This renders experimental results model dependent, as they then rely on a specific scaling between dimension-six and dimension-eight operator coefficients.

5. multiplying the squared dimension-six terms by the following factor to obtain truncation uncertainties:

$$1+\sqrt{N_8}\frac{g_{\mathrm{SM}}^2}{\mathfrak{C}_6\Lambda^2}\sqrt{1+\frac{1}{\mathfrak{C}_6^2\Lambda^4}} \tag{1}$$

   where N_8 is an estimate of the number of contributing dimension-eight operators, g_{SM} is the relevant SM coupling, $\mathfrak{C}_6$ is a dimensionful dimension-six operator coefficient, and Λ is a scale (such that, if identified with the physical BSM mass scale in a two-to-two process, one expects $\mathfrak{C}_6\Lambda^2 \sim g_{\mathrm{BSM}}^2$).

   (a) The classes of models which are covered by this choice is yet to be determined. Without motivation from new-physics models, the various factors may seem ad hoc.

3 Experimental considerations

1. Re-designing analyses is expensive.
2. Linear truncations and limited sensitivities may allow cross-sections to turn negative and break fitting procedures.
3. Upper energy cuts are complicated to include on the data. Could one impose this cut on the signal prediction instead?
4. Uncertainties that depend on the operator coefficients are cumbersome to include.
5. ...