Darius A. Faroughy
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Module 2

We will learn how to use `MadGraph` to generate parton-level events from the ME for BSM models. Then we will extract upper-limits on $d = 6$ SMEFT Wilson Coefficients (WC) using the latest CMS data from a heavy resonance search in $pp \to \mu^+\mu^-$.

The LHC is a counting experiment where the number of BSM events coming from a particular process $pp \to X$ is given by:

$$N(\theta) = \mathcal{L}_{int} \cdot \epsilon \cdot \sigma(\theta) \tag{1}$$

where σ is the hadronic cross-section of $pp \to X$ in units of femto-barns constrained to the signal region[1], θ are the BSM parameters we want to extract limits for, $\mathcal{L}_{int}$ is the integrated Luminosity in units of inverse femto-barns, $\sigma(\theta)$ and ϵ is the total acceptance$\times$efficiency of the signal. In this module we will initially assume $\epsilon = 1$ implying perfect reconstruction efficiencies and and perfect detector.

Task 1.

1) Import to `MadGraph` the SMEFT `UFO` file you prepared in Module 1. We will now use `Madgraph` to compute the cross-sections of $pp \to \mu^+\mu^-$ in the SMEFT for valence quarks. Recall that the cross-section has the following form up to $\mathcal{O}(1/\Lambda^4)$ at $d = 6$:

$$\sigma(pp \to \mu^+\mu^-) = \sigma_{\mathrm{DY,\,SM}} + \frac{\mathcal{C}_{\ell q}^{(1\pm 3)}}{\Lambda^2} A_{\mathrm{int}} + \frac{\left[\mathcal{C}_{\ell q}^{(1\pm 3)}\right]^2}{\Lambda^4} A_{\mathrm{NP}^2}$$

Since we are interested in the tails of the invariant mass distribution (where contact intreractions grow) generate the events with dimuons that have an invariant mass cut above $m_{\mu\mu} = 1000$ GeV.

Tips: *Use the `MG` generation syntax to target the SM term, interference term and NP^2 term separately. Compute the A coefficients for each valence quark separately. Generate at least 30k events for each run in order to have enough statistics. Remember always to x-check your results, e.g. does $\sigma_{\mathrm{tot}} = \sigma_{\mathrm{SM}} + \sigma_{int} + \sigma_{\mathrm{NP}^2}$?*

2) Compute the number of expected events for a luminosity of 140 fb^{-1} and efficiency 1 in the signal region defined by $m_{\ell\ell} > 1$ TeV. In order to perform a χ^2 fit we need the number of observed events N_{obs}, the number of background N_b events and the uncertainty ΔN_b in the background events. This information can be extracted from the CMS search dataset in www.hepdata.net/record/ins1849964 "dimuon mass distribution". Plot the 1, 2 and 3 sigma regions in the $\mathcal{C}_{\ell q}^{(1)} - \mathcal{C}_{\ell q}^{(3)}$ plane.

BSM TOOLS FOR HIGH-p_T STUDIES

[1] Signal region refers to a subspace of phase-space defined by a set of "cuts" where the searched BSM signal is enhanced with respect to the backgrounds.