

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 $pp \rightarrow \mu^+ \mu^-$.

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

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

where σ is the hadronic cross-section of $pp \rightarrow X$ in units of femto-barns constrained to the signal region¹, 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 $pp \rightarrow \mu^+ \mu^-$ in the SMEFT for valence quarks. Recall that the cross-section has the following form up to $\mathcal{O}(1/\Lambda^4)$ at $d = 6$:

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

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 *NP²* 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 $\sigma_{tot} = \sigma_{SM} + \sigma_{int} + \sigma_{NP^2}$?

- 2) Compute the number of expected events for a luminosity of 140 fb^{-1} and efficiency 1 in the signal region defined by $m_{\ell\ell} > 1 \text{ TeV}$. In order to perform a χ^2 we need the number of observed events N_{obs} , the number of background events and the uncertainty 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

¹Signal 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.