Modified: December 10, 2025

USMEFT at the HL-LHC

1 Neutral vector mediator

1.1 Model Lagrangian

Here we consider the following Lagrangian

$$\mathcal{L} = \mathcal{L}_{\rm SM} - \frac{1}{4} X_{\mu\nu}^2 + \frac{1}{2} M^2 X_\mu^2 - g_1 \beta \mathcal{H}_\mu X^\mu - g_1 \Psi_\mu X^\mu + g_1^2 Y_H^2 \beta^2 \left(H^\dagger H\right) X_\mu^2 \,, \tag{1.1}$$

where we have defined

$$\mathcal{H}_\mu = i Y_H \left(H^\dagger \overleftrightarrow{D}_\mu H\right) \,, \tag{1.2}$$

$$\Psi_\mu = \sum_\psi Y_\psi \left(\overline{\psi} \gamma_\mu \psi\right) \,. \tag{1.3}$$

1.2 Matching at dimension-6

Below, we show the matching of the Wilson coefficients with the model parameters of the dimension-6 operators that affect EWPO and DY production.

Wilson Coefficient	Operator
$c_{2JB} \;=\; -\dfrac{\beta^2}{2}$	$Q_{2JB} \;=\; J_{B,\mu} J_B^\mu$
$c_{\phi,1} \;=\; 2 g_1^2 Y_H^2 \beta^2$	$Q_{\phi,1} \;=\; \left(D_\mu H^\dagger H\right)\left(H^\dagger D^\mu H\right)$
$c_{BW} \;=\; -g_1 g_2 \beta^2 Y_H$	$Q_{BW} \;=\; H^\dagger B_{\mu\nu} \tau^I W^{I,\mu\nu} H$

1.3 Current limits and benchmark points

This model only generates the oblique parameter Y, which means that the main limits come from NC DY. In Fig. 1, we show the exclusion limits obtained from EWPO and NC DY, as well as the benchmark points—marked by red circles—that we considered for generating the model.

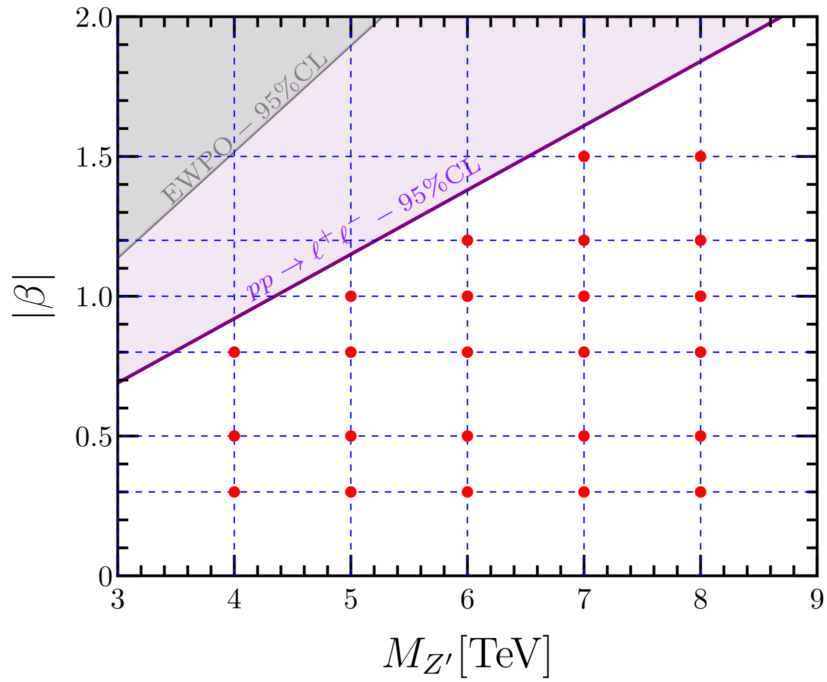

Figure 1: *95% CL exclusion regions from EWPO (gray) and NC DY (purple). The points in red represent the benchmark points we consider for the model parameters to generate the pseudo-data.*

1.4 Global fits

The fits were performed using parton-level distributions for NC and CC DY, as well as including EWPO. For each benchmark point shown in Fig. 1, we treated as data the SM prediction plus the contribution of the model, with parameter values corresponding to the benchmark point considered. This was done for the NC DY channel and EWPO. We verified that the contribution to the CC DY – which occurs do to the renormalization of the input parameters – is very small and it can be neglected. As an example, we show the NC DY distribution in Fig. 2.

The chi-square for the DY distributions was the following

$$\chi^2 = \sum_i \frac{(\sigma_i^{\text{pseudo-data}} - \sigma_i^{\text{EFT}})^2}{\delta^2_{\text{stat},\,i} + \delta^2_{\text{syst},\,i}}\,, \tag{1.4}$$

where

$$\delta^2_{\text{stat},\,i} = \frac{\sigma_i^{\text{pseudo-data}}}{\epsilon\,\mathcal{L}}\,, \tag{1.5}$$

$$\delta_{\text{syst},\,i} = 0.05 \times m\,[\text{TeV}] \times \sigma_i^{\text{pseudo-data}}\,, \tag{1.6}$$

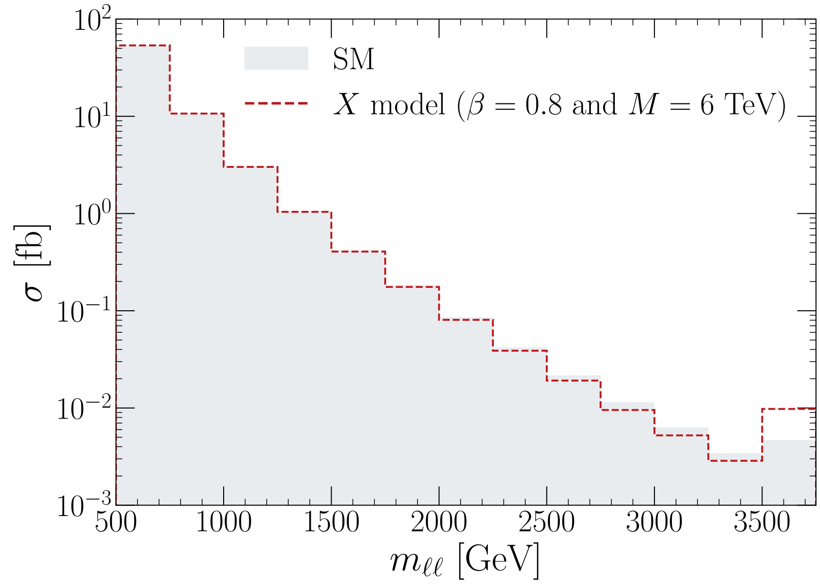

Figure 2: *Parton level distribution for the NC DY channel. The SM prediction is shown in gray, while the model prediction is shown by the dashed red line. The model prediction contains also the SM contribution.*

where $\mathcal{L}$ denotes the luminosity, which we take to be 3000 fb^{-1}, and ϵ denotes the acceptance $\times$ efficiency, which we set to 1 for the moment. The systematical uncertainty $\delta_{\rm syst}$ increases with the invariant (transverse) mass of the NC (CC) DY channel. For all the distributions we considered, and for the value of the luminosity we are assuming, all the bins contain more than 10 events, which justifies the use of the Gaussian approximation. At dimension-6, the global fit depends on four parameters:

$$\begin{aligned}\chi^2(c_{2JB},\, \Delta_{4F},\, c_{BW},\, c_{\phi,1}) = \chi^2_{\rm NC}(c_{2JB},\, \Delta_{4F},\, c_{BW},\, c_{\phi,1}) + \chi^2_{\rm CC}(\Delta_{4F},\, c_{BW},\, c_{\phi,1}) \\ + \chi^2_{\rm EWPO}(\Delta_{4F},\, c_{BW},\, c_{\phi,1})\,.\end{aligned} \tag{1.7}$$

We asses if the global fit is enable to capture the effects of the model in two ways:

- Accuracy: For that we define

$$f_{{\rm Accuracy},\,i} = \frac{|c_i^{\text{best-fit}} - c_i^{\rm true}|}{\Delta c_i}\,, \tag{1.8}$$

  where $\Delta c_i = (c_i^{\rm UL,\,68\%} - c_i^{\rm LL,\,68\%})/2$, with $c_i^{\rm UL,\,68\%}$ and $c_i^{\rm LL,\,68\%}$ denoting the 68% CL upper and lower limits, respectively.

- NP reach: We are also interested in checking if the global fit is able to point out indirect

NP contributions. For this, we define

$$f_{\mathrm{NP},\,i} = \frac{|c_i^{\text{best-fit}} - c_i^{\mathrm{SM}}|}{\Delta c_i}\,, \tag{1.9}$$

where $c_i^{\mathrm{SM}} = 0$.

We show the values of these quantities for each benchmark point we considered, including only the linear dimension-6 contribution (Fig. 3), and also including the dimension-6 squared terms (Fig. 4). Note that the Wilson coefficient with the largest potential to signal NP is c_{2JB} for smaller masses and large values of the coupling β, as expected.

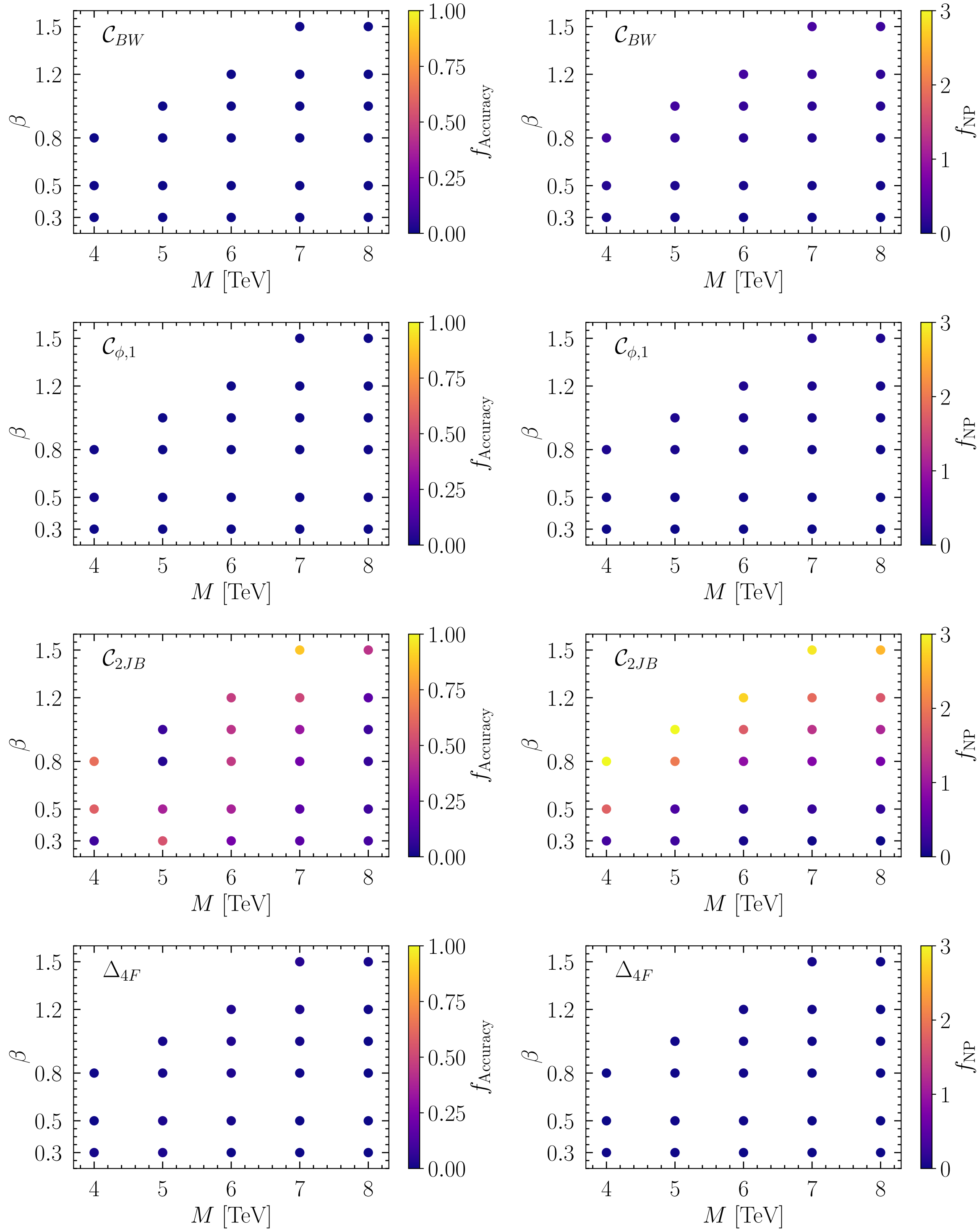

Figure 3: *The first column shows the values of $f_{Accuracy}$ for each coupling and for each benchmark point we considered, while the second shows f_{NP}. The fit was performed including only the linear dimension-6 effects.*

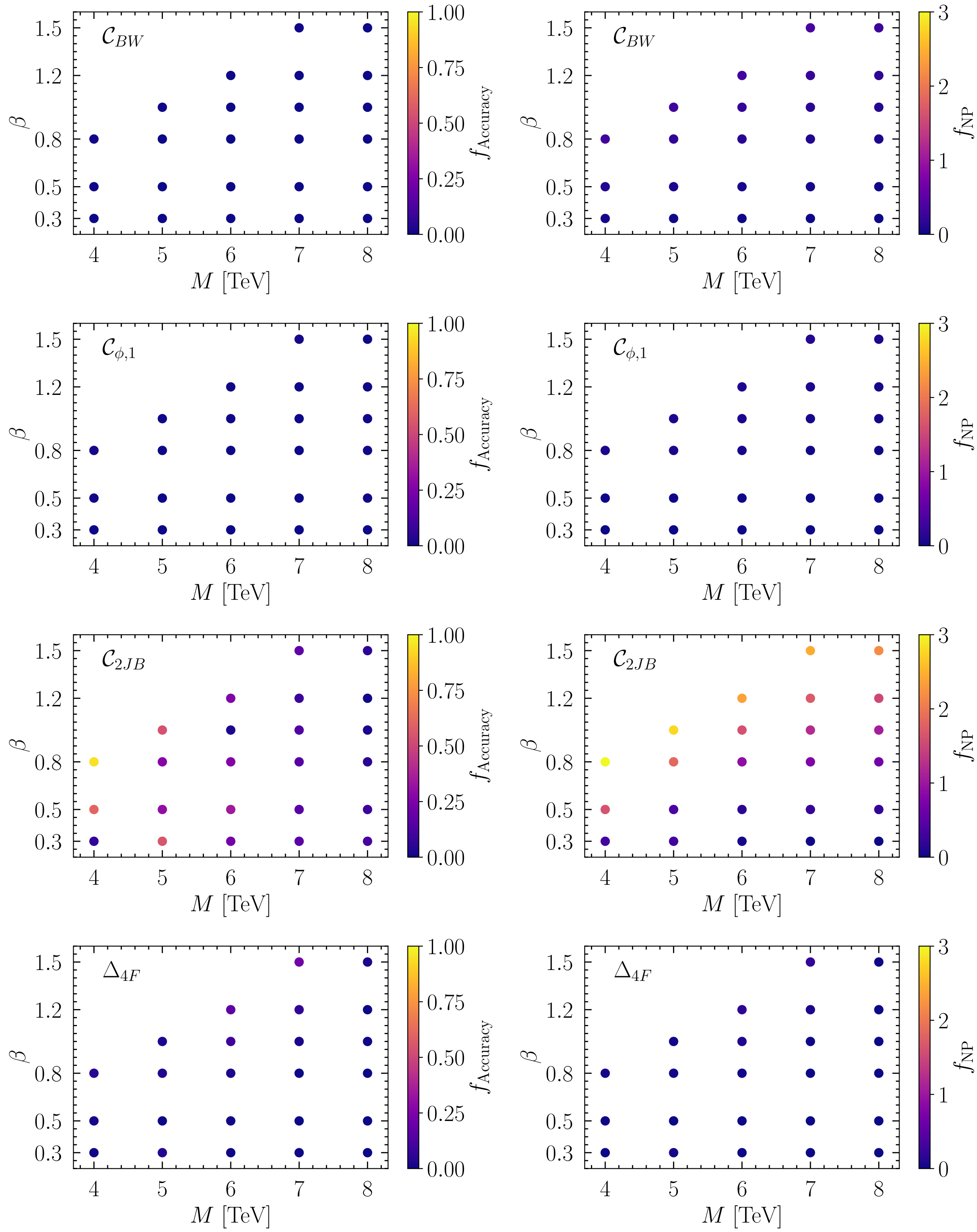

Figure 4: *The first column shows the values of f_{Accuracy} for each coupling and for each benchmark point we considered, while the second shows f_{NP}. The fit was performed including the linear dimension-6 effects and dimension-6 squared contributions.*