1 User Manual for Reinterpretation

The results presented in this analysis[1] can be used for future interpretation of models not considered in this analysis. We recommend the following recipe. Given a specific BSM model, a particular model-independent scheme as described in the analysis should be selected. The fundamental $L_{\mathrm{T}} + p_{\mathrm{T}}^{\mathrm{miss}}$ scheme will be sensitive to BSM models that produce primarily leptons and missing transverse momentum, while the advanced schemes will be more sensitive for models which populate final states with several jets, which may or may not arise from b-quarks. The yield for the model should be obtained in the various categories of the chosen scheme.

To obtain this yield, the acceptance and efficiency for the model is required. In this HepData record, we provide the product of acceptance and efficiency for a few major SM backgrounds (WZ, ZZ, and $t\bar{t}$Z) and all the BSM models probed in this analysis. These are calculated in the inclusive signal regions of all seven multilepton channels separately. The product is defined as the ratio of the total reconstructed yield in a given channel (after all the corrections and scale factor implementation) to the product of luminosity and the production cross section of the given simulation sample.

In addition we also provide reconstruction efficiency maps for the leptons selected in this analysis, so that the yield of a given BSM process can be predicted using generator-level information. Section 1.1 describes the measurement of the lepton reconstruction efficiency maps in detail, and Section 1.2 discusses the procedure to derive the signal yields in our signal regions.

1.1 Detailed description of the efficiency maps

The lepton reconstruction efficiency maps are obtained from a simulation of the ZZ process. For a given input generator-level p_{T}, the efficiency map provides the probability distribution of the reconstructed p_{T}, accounting for reconstruction and identification efficiency, and the p_{T} resolution.

1. Separate maps are produced for electrons, muons, 1-prong τ_{h}, and 3-prong τ_{h}. Further, separate maps are produced for light leptons arising from τ decay and from SM gauge bosons W,Z,h decay (equivalently a promptly-decaying signal particle) without intermediate τ decay.

2. For muons, maps are produced in two regions of pseudorapidity: Barrel ($|\eta| \leq$1.2) and Endcap (1.2$<|\eta|<$2.4). For electrons and τ_{h}, maps are defined in three regions of pseudorapidity: Barrel ($|\eta| \leq$1.1), Transition (1.1$<|\eta|\leq$1.6), and Endcap ($|\eta|>$1.6), to account for the efficiency losses in the transition between the barrel and endcap regions of ECAL.

3. In addition, the topology of the event plays an important role in the efficiency determination. To account for this, we produce each map in two cases.

   - N_j maps: N_j is the number of generator level jets passing selection criteria outlined in item 4 of Section 1.2. We produce maps in separate N_j regions ($N_j \leq 1$ and $N_j \geq 2$) for each lepton flavor.

   - dRmin maps: We define dRmin as the minimum angular separation (dR) between any pair of selected light leptons at generator level in the event. We produce maps in sepa-

[1] http://arxiv//DUMMY

rate dRmin regions ($0.2 <$dRmin< 0.4 and dRmin> 0.4) for electrons and muons (for τ_h, a single map for dRmin> 0.2 is sufficient).

The user has to choose appropriately between the N_j maps and the dRmin maps. We recommend using the N_j maps for signals where the multilepton final state is usually accompanied by jets from gauge boson decay. We recommend using the dRmin maps for signals where the multilepton state has no accompanying jets from gauge boson decay. For example, we recommend using N_j maps in decays such as for the VLL model $\tau'^{+}\nu'(\tau'^{-}\bar{\nu}') \to Z\tau W\tau \to \ell\ell\tau\tau qq$ or the leptoquarks model $SS \to t\tau t\tau \to Wb\tau Wb\tau \to \ell\ell\nu\nu\tau\tau bb$. For example, we recommend using the dRmin maps in decays such as for the Seesaw model $\Sigma^{\pm}\Sigma^{0} \to W\nu W\ell \to \ell\ell\ell\nu\nu\nu$ or models with sterile right handed neutrinos (N) $WN \to \ell\ell\nu\nu$.

Figure 1 shows an example lepton reconstruction efficiency map estimated in a simulated event sample for the ZZ process. This efficiency map is that of muons in the barrel region arising from the decay of gauge bosons in events with dRmin $>$ 0.4. The x-axis and the y-axis represent bins in the reconstructed and generated lepton p_T, respectively. All the efficiency maps can be found elsewhere in this HepData record[2].

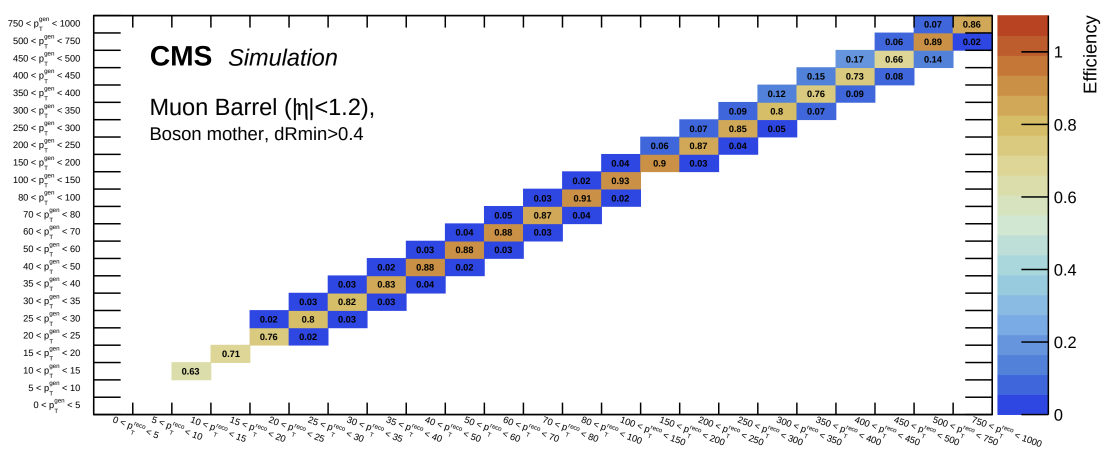

Figure 1: An example reconstruction efficiency map for barrel muons arising from the decay of gauge bosons with dRmin $>$ 0.4 in the event. The lepton efficiency is estimated in a simulated event sample for the ZZ process. The x-axis and the y-axis represent bins in the reconstructed and generated lepton p_T, respectively.

To aid the end-user, we release the efficiency maps as a ROOT file along with a helper script (written in C++). The script provides an implementation of a method, for which the inputs are generated lepton p_T, η, flavor, decay mode for τ_h, dRmin, mother information, and choice of N_j or dRmin binning, and the output is the predicted level p_T. In events with no light lepton pair, the dRmin should be set to 1. If the predicted level p_T is returned as -1, then the lepton has been predicted to fail reconstruction/identification. We also provide an example script which uses the DELPHES libraries to analyze a signal simulation file in the DELPHES TTREE format, and which gives as output the event yield in each of the 43 categories of the fundamental $L_\mathrm{T} + p_\mathrm{T}^\mathrm{miss}$ table, along with a histogram of $L_\mathrm{T} + p_\mathrm{T}^\mathrm{miss}$ in each category.

[2] https://www.hepdata.net/record/110691

1.2 Workflow for deriving yield in signal regions

To calculate the signal yield in the various categories of the model-independent schemes, one should proceed as follows:

1. Leptons should be selected at the generator level passing the following criteria: $p_{\mathrm{T}} > 5$ GeV, $|\eta| < 2.4$ for electrons and muons, and $p_{\mathrm{T}} > 15$ GeV, $|\eta| < 2.3$ for hadronically decaying taus. The leptons must originate from an appropriate source: either the mother is a SM gauge boson (W, Z, h) or a promptly-decaying signal particle, or additionally the mother is a τ lepton in case of electrons and muons. Leptons from any other source should be rejected.

2. The provided efficiency maps should be applied to each generator level lepton, thus giving a predicted p_{T} for each lepton ($= -1$) in cases where the lepton is predicted to fail reconstruction/identification). Henceforth, only the predicted p_{T} should be used in subsequent analysis. In the rest of this document, we use p_{T} to refer to the predicted lepton p_{T} after application of efficiency map.

3. The number and flavor of the leptons should now be used to determine the channel in which the event falls. In addition the p_{T} should be used to calculate the L_{T}. An example of this would be as follows. Suppose at the generator level, an event has two electrons (e_1, e_2), two muons (μ_1, μ_2) and two τ_{h} ($\tau_{\mathrm{h1}}, \tau_{\mathrm{h2}}$).

   - Case 1: suppose the two electrons and two muons pass and have a $p_{\mathrm{T}} > 0$, and say τ_{h1} does as well. This event is thus predicted to be a $e_1 e_2 \mu_1 \mu_2 \tau_{\mathrm{h1}}$ event - and thus should be classified as a 4L event.

   - Case 2: suppose e_1 and μ_2 and both τ_{h} have $p_{\mathrm{T}} > 0$. This event is thus predicted to be a $e_1 \mu_1 \tau_{\mathrm{h1}} \tau_{\mathrm{h2}}$ event - and thus should be classified as a 2L2T event.

   Thus it may also happen that an event which has sufficient leptons at generator level, does not have enough leptons predicted to pass reconstruction to be selected in the analysis.

4. The $p_{\mathrm{T}}^{\mathrm{miss}}$ should be calculated from a 4-vector sum of all neutrinos and other invisible particles specific to the model. The H_T should be calculated from a scalar sum of all generator level jets [jet clustering algorithm implemented at the particle level]. These jets should pass the requirement of $p_{\mathrm{T}} > 30$ GeV and $|\eta|$ $\leq$2.4, with a minimum angular separation of 0.4 from the selected leptons in the event. We recommend no further corrections for the $p_{\mathrm{T}}^{\mathrm{miss}}$ and H_T. The number of reconstructed b-tagged jets (N_b) can be estimated by first selecting all generator level jets containing at least one b hadron, and then applying the efficiencies measured by the CMS collaboration[3].

5. Any remaining analysis selections can be imposed on the leptons (such as additional p_{T} or invariant mass selections), and along with using $p_{\mathrm{T}}^{\mathrm{miss}}$ and H_T one can thus determine the signal yield in any particular signal region of the analysis.

We find that the procedure described here typically predicts the analysis level yields within 20 to 25% and we recommend a conservative uncertainty of 25% on the yield predicted from this procedure to account for the choices of parameterization for the different lepton flavors and event topologies.

[3] `https://arxiv.org/abs/1712.07158`