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While the search presented specifically addresses two benchmark models described in the paper, its results may be applied to other models predicting long-lived particles that decay to final states with a pair of oppositely charged muons. In Figs. A18–A19 we provide a set of generator-level efficiency maps that approximate the reconstruction-level efficiencies of this analysis and allow for reinterpretation of the results in the framework of other models.

Signal efficiencies are provided as a function of the smaller of the two values of generated muon p_{T}, $\min(p_{\mathrm{T}})$, and of generated muon d_0, $\min(d_0)$, in three intervals of the generated transverse decay length L_{xy} of the signal dimuon, $L_{\mathrm{xy}} < 20$ cm, $20 < L_{\mathrm{xy}} < 70$ cm, and $70 < L_{\mathrm{xy}} < 500$ cm. The efficiencies are given separately for the HAHM and RPV SUSY signal models used in the paper. Efficiency maps obtained from HAHM samples are recommended for models featuring $\mu\mu$ decay vertices and collinear signatures, while maps obtained from RPV SUSY samples are recommended for models featuring $\mu\mu\nu$ decay vertices and non-collinear signatures. The 3D efficiency maps $\epsilon\,(\min(p_{\mathrm{T}})\,;\min(d_0)\,;L_{\mathrm{xy}})$ are provided separately for the two dimuon categories, TMS-TMS and STA-STA, and are shown in Fig. A18 for the HAHM signal model and Fig. A19 for the RPV SUSY signal model. They are valid to approximate the efficiencies in the analysis of the 2022 data set.

The efficiency in each $(\min(p_{\mathrm{T}}); \min(d_0); L_{\mathrm{xy}})$ bin of the 3D efficiency map is computed as the ratio of the number of simulated signal dimuons in that bin that pass the trigger requirements and selection criteria applied for a given dimuon category to the total number of simulated signal dimuons in that bin and within the geometric acceptance. The computation is performed separately using the ensemble of all generated HAHM and RPV SUSY signal samples listed in the paper. The geometric acceptance is defined as $\min(d_0) < 300$ cm, $L_{\mathrm{xy}} < 500$ cm, generated longitudinal decay length L_{z} smaller than 800 cm, and $|\eta|$ of both generated muons forming the dimuon smaller than 2.0. The efficiencies obtained from simulation are further corrected by the data-to-simulation scale factors described in the paper.

When applied to the previously untested models, the signal efficiency in each dimuon category j, ϵ_j, can be obtained from the 3D efficiency maps using the p_{T}, d_0, and L_{xy} at generator level:

$$\epsilon_j = \frac{1}{N} \sum_{n=1}^{N^{\mathrm{acc}}} [1 - [1 - \epsilon_j^n\,(\min(p_{\mathrm{T}})\,;\min(d_0)\,;L_{\mathrm{xy}})]^{k_n}], \tag{1}$$

where k_n is the number of dimuons in the n-th event, the sum is over the number of generated signal events N^{acc} in the geometric acceptance defined above and with the true mass larger than 10 GeV, and N is the total number of generated signal events. In cases where more than one dimuon is present in the event, the one with the larger of the two $\min(d_0)$ values should be taken as a reference to apply the efficiency map.

In the TMS-TMS category, where the signal region is divided into three bins in the minimum of the two d_0/σ_{d_0} values, ϵ_j should be subdivided into three efficiencies depending on $\min(d_0)$, namely 90–150 μm, 150–300 μm, and > 300 μm approximately corresponding to the three chosen $\min(d_0/\sigma_{d_0})$ bins. The combined signal efficiency, ϵ_{tot}, can be computed as the sum of signal efficiencies in the two

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dimuon categories:

$$\epsilon_{\text{tot}} = \sum_j \epsilon_j, \tag{2}$$

where j runs over the TMS-TMS and STA-STA categories.

We have checked that the generator-level efficiency ϵ_{tot} obtained from the provided 3D efficiency maps approximates the reconstruction-level efficiencies for the HAHM and RPV SUSY signal, shown in Fig. A13 and Figs. A14–A15, respectively, with an accuracy of 20% or better when the ratio of the LLP mass m(LLP) to the mediator mass m(M) is between 0.05 and 0.35. The method tends to overestimate the efficiency of signal events with a large Lorentz boost (m(LLP)/m(M) $<$ 0.05), and that of non-relativistic LLPs (0.35 $<$ m(LLP)/m(M) $<$ 0.5) with $c\tau > 250$ cm. The method is valid for m(LLP) $>$ 20 GeV.

To obtain the exclusions limits, one should use the signal efficiencies ϵ_j in each dimuon category together with the expected number of background events from the paper.