HEPData instructions for reinterpretation*
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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 into a pair of oppositely charged muons. In Figs. A14–A16 we provide a set of generator-level efficiency maps that approximate the reconstruction-level efficiency of this analysis and allow for reinterpretation of the results in the framework of other models.

We provide signal efficiencies 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 $70 < L_{\mathrm{xy}} < 320$ cm. These 3D efficiency maps $\epsilon(\min(p_{\mathrm{T}}); \min(d_0); L_{\mathrm{xy}})$ are provided separately for each of the three dimuon categories, STA-STA, STA-TMS, and TMS-TMS, and are shown in Fig. A14, Fig. A15, and Fig. A16 for dimuons with $L_{\mathrm{xy}} < 20$ cm, $20 < L_{\mathrm{xy}} < 70$ cm, and $70 < L_{\mathrm{xy}} < 320$ cm, respectively. Each figure contains two sets of maps, for 2016 and 2018 data sets, corresponding to integrated luminosities of 36.3 ± 0.4 and 61.3 ± 1.5 fb^{-1}, respectively. The efficiency in each ($\min(p_{\mathrm{T}})$; $\min(d_0)$; L_{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 (Table A6) to the total number of simulated signal dimuons in that bin and within the geometric acceptance. The computation is performed using an ensemble of all generated $\Phi \to \mathrm{XX} \to \mu\mu + anything$ signal samples. The geometric acceptance is defined as $\min(d_0) < 300$ cm, $L_{\mathrm{xy}} < 320$ 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 were 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:

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

where 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 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 three dimuon categories:

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

where j runs over the STA-STA, STA-TMS, and TMS-TMS 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 $\Phi \to \mathrm{XX} \to \mu\mu + anything$ and $\mathrm{H} \to$

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$Z_D Z_D \to \mu\mu + anything$ signal samples, shown in Figs. A1–A4 and Fig. A9, 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.

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 in this category (Tables A1–A3 and Table A5).