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Searching for the lepton-flavor violating $\gamma\gamma e\mu$ interaction at future e^-e^+ colliders

The discovery of charged lepton flavor violation (cLFV) would provide incontrovertible evidence for physics beyond the Standard Model. Among the various cLFV channels, photon-photon interactions offer a remarkably clean probe of electromagnetic phenomena. In this work, we explore the prospects of searching for the cLFV process $e^+e^- \rightarrow e^+e^-e\mu$ at future circular colliders (CEPC and FCC-ee). Adopting an effective field theory (EFT) framework, we investigate the $\gamma\gamma e\mu$ interaction generated by dimension-7 operators, ensuring consistency with stringent experimental limits from the $\mu \rightarrow e\gamma$ decay.

Leveraging the clean environment of e^+e^- collisions, we identify distinctive kinematic distributions—such as the transverse momentum of the scattered electron ($p_T^{(e^- \text{ scattered})}$) and the central muon (p_T^μ)—for efficient signal-background separation. By implementing a neural network classifier, we significantly enhance the sensitivity over traditional cut-based analyses. Our findings indicate that a 5σ discovery is attainable at the CEPC ($\sqrt{s} = 240$ GeV) with 3000 fb^{-1} and the FCC-ee ($\sqrt{s} = 350$ GeV) with just 200 fb^{-1} , probing effective couplings down to $\mathcal{O}(10^{-10})$.

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