

Probing lepton-flavor-violating processes in e^+e^- colliders

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Scenario with a lepton-flavor-violating (LFV) boson, either a scalar or a vector exchange, is an intriguing physics phenomenon beyond Standard Model. This LFV boson coupling in the presence of muons leads to a rich phenomenology including an extra contribution to muon anomalous magnetic moment desirable for alleviating the discrepancy between the SM prediction and the newest combined (Fermilab and BNL) experimental average using data collected until 2023. With the assumption of a positive real number $h_{e\mu} = g_{e\mu}$ in the low-energy effective coupling $calL_{\phi e\mu} = \phi\bar{e}(g_{e\mu} + h_{e\mu}\gamma^5)\mu + \text{h.c.}$, which turns electron into muon or vice versa through the scalar particle ϕ , we derive the $(h_{e\mu}, M_\phi)$ parameter space that could account for the discrepancy mentioned above. Furthermore, we calculate the cross section $e^+e^- \rightarrow e^\pm\mu^\mp\phi \rightarrow e^\pm e^\pm\mu^\mp\mu^\mp$ induced by $calL_{\phi e\mu}$ and SM vertices in the M_ϕ range of 1- 8 GeV. Based on two pairs of same-sign final-state electrons and muons we assume that the search for this LFV scalar at the electron-positron Belle II experiment is background free. For $\text{Br}(\phi \rightarrow e^+\mu^-) = \text{Br}(\phi \rightarrow e^-\mu^+) = 0.5$ and the selection criteria applied to the signal identification of processes $e^+e^- \rightarrow e^\pm e^\pm\mu^\mp\mu^\mp$, we found that for $1 \leq M_\phi/\text{GeV} \leq 8$, the upper limit for $h_{e\mu}$ with $calL = 1 \text{ fb}^{-1}$ at Belle II is already in the favorable parameter range to account for the measured $g_\mu - 2$.

To probe LFV scalar mediator further, we note that this scenario can be constrained by lepton flavor-changing $\mu \rightarrow e$ conversion and muon decays of $\mu \rightarrow e\gamma$, $\mu \rightarrow 3e$ with the most stringent bounds $h_{e\mu} \lesssim 1.4 \times 10^{-4}$ for the mass range $M_\phi \lesssim 8 \text{ GeV}$ from $\mu \rightarrow e\gamma$ decay. Under such constraints, signatures of same-sign and same-flavor lepton pairs can still be searched for at full Belle II luminosity, which offers the possibility of discerning the current scenario from LFV interaction with a vector boson exchange due to significant differences in their event kinematic distributions. We propose an effective method to discriminate between these two scalar and vector scenarios.

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Leptons

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