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Production and Decay Phenomenology of an Exotic Charged Lepton at Electron-Positron Colliders

We study the production and decay phenomenology of a charged exotic lepton E in electron–positron collisions within a simplified leptonic sector inspired by a family nonuniversal $U(1)_X$ extension of the Standard Model. The framework includes mixing between the exotic charged lepton and Standard Model leptons, together with three light neutrino mass eigenstates and a heavy neutral state.

The model is implemented using LanHEP, while CalcHEP is employed to generate the relevant tree-level processes and perform the numerical calculations. Both single production,
$e^+e^- \to e^\pm E^\mp$,
and pair production,
$e^+e^- \to E^+E^-$,

are studied as functions of the center-of-mass energy and the exotic-lepton mass. The subsequent electroweak decays of the exotic lepton through $E^\pm \to Z\ell^\pm$ and $E^\pm \to W^\pm\nu$ are also analyzed, together with representative three- and four-body final states.

For the parameter configuration considered, the dominant decay mode is $E \to W\nu_2$, with a branching ratio of approximately 41%, while the channels $E \to Ze$ and $E \to Z\mu$ contribute about 19% each. Pair production exhibits the expected kinematic threshold at $\sqrt{s} = 2M_E$, whereas single production remains accessible closer to the kinematic mass limit. Among the final states studied, Ze^+e^- provides the clearest signature associated with single production, while Ze^+Ze^- shows the most characteristic behavior of exotic-lepton pair production.

These results provide an exploratory phenomenological characterization of an exotic charged lepton at future electron–positron colliders and illustrate the sensitivity of final states containing Z bosons and charged leptons to physics beyond the Standard Model.

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