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Probing the minimal $U(1)_X$ model at future electron-positron colliders via the fermion pair-production channel

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The minimal $U(1)_X$ extension of the Standard Model (SM) is a well-motivated new physics scenario, where the anomaly cancellation requirement dictates the new neutral gauge boson (Z') couplings with the SM fermions in terms of two scalar charges (x_H and x_Φ). In this paper, we investigate the SM charged fermion pair production mechanism for different values of these scalar charges in the $U(1)_X$ scenario at future electron-positron colliders, i.e. $e^+e^- \to f\bar{f}$. Apart from the standard photon and Z boson exchange for this process, this model features a t-channel (or both s and t-channel for $f = e^-$) Z'-boson exchange, which interferes with the SM processes. Considering the dilepton and dijet signatures from the heavy resonance we estimate the bounds on the U$(1)_X$ coupling (g') and the Z' mass ($M_{Z'}$). Considering the LEP-II results and prospective International Linear Collider (ILC) bounds on the effective scale for the four fermion interaction we estimate the reach on $M_{Z'}/g'$ for different center of mass energies. We study the angular distributions, forward-backward ($\mathcal{A}_{\rm FB}$), left-right ($\mathcal{A}_{\rm LR}$) and left-right forward-backward ($\mathcal{A}_{\rm LR,FB}$) asymmetries of the $f\bar{f}$ final states which can show substantial deviations from the SM results, even for a multi-TeV Z'. This provides a powerful complementary way to probe the heavy Z' parameter space beyond the direct reach of the Large Hadron Collider (LHC), as well as an effective way to determine the $U(1)_X$ charges.

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