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Dark photon effects with the kinetic and mass mixing in Z boson decay processes

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Motivated by the most recent measurement of tau polarization in $Z \to \tau^+\tau^-$ by CMS, we have introduced a new $U(1)_X$ gauge boson field X, which can have renormalizable kinetic mixing with the standard model $U(1)_Y$ gauge boson field Y.
In addition to the kinetic mixing of the dark photon, denoted as σ, there may also be mass mixing introduced by the additional Higgs doublet with a vacuum expectation value (vev) participating in $U(1)_X$ and electroweak symmetry breaking simultaneously.
The interaction of the Z boson with the SM leptons is modified by the introduction of the mixing ratio parameter ϵ, which quantifies the magnitude of both the mass and kinetic mixing of the dark photon.
Initially, we use the tau lepton as an example to explore the Z boson phenomenology of the dark photon model with both kinetic and mass mixing. The goal is to determine the allowed parameter regions by taking into account constraints from the vector and axial-vector couplings $g^{\tau}_{V,A}$, the decay branching ratio $Br(Z \to \tau^-\tau^+)$ and tau lepton polarization in $Z \to \tau^-\tau^+$. We found that the mixing ratio plays important role in the Z boson features by choosing different ϵ values.
Furthermore, we aim to generalize our analysis from the tau-lepton case to include all fermions by conducting global fits. This allows us to identify viable regions by incorporating relevant fermion constraints and the W/Z mass ratio.
Correspondingly, we obtain the fit results with the kinetic mixing parameter $\sigma = 0.074 \pm 0.021$, mixing ratio $\epsilon = -1.37 \pm 0.46$, and dark photon mass $m_X = 275 \pm 39$ GeV. Our global analysis indicates a preference for a dark photon mass larger than m_Z.

Paper info

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