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Leptophilic axionlike particles at forward detectors

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Leptophilic axion-like particles (ALPs) exhibit rich phenomenology, focusing exclusively on interactions between an ALP and Standard Model (SM) leptons. Through integration by parts, it is shown that both the three-point interaction, $a\bar{\ell}\ell$, and the four-point interaction, $a\ell^{-}\nu W^{+}$, play significant roles, making the flavor portal particularly compelling. For ALPs with masses ranging from $\mathcal{O}(1)$ MeV to $\mathcal{O}(1)$ GeV, they can contribute to exotic hadron decays. Suppressed couplings naturally extend the ALP lifetime, presenting opportunities for detection at forward detectors. In this study, we explore ALPs with both electrophilic and muonphilic scenarios. We propose an inclusive search for various hadrons that undergo exotic decays at the Large Hadron Collider (LHC). In the electrophilic scenario, long-lived ALPs are searched in the Forward Search Experiment (FASER) and its upgrading phase, FASER II. In the muonphilic scenario, where the ALP lifetime is significantly reduced due to its coupling to muons, we further investigate its detection potential at LHCb and its high-luminosity upgrade. Several benchmarks are analyzed, including electroweak-preserving, electroweak-violating and left-right softly asymmetric models, to demonstrate possible experimental constraints.

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