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Investigation of the concurrent effects of ALP-photon and ALP-electron couplings in Collider and Beam Dump Searches

Axion-like particles (ALPs) have been studied in numerous experiments to search for their interactions, but most studies have focused on deriving bounds for the single coupling. However, in ultraviolet (UV) models, these couplings can appear simultaneously, and their interplay could have important implications for collider and beam dump searches. In this study, we investigate the concurrent effects of the ALP-photon and ALP-electron couplings in a simplified model and examine how their simultaneous presence modifies existing bounds. We find that modifications to production cross-sections, decaying branching ratios, and the lifetime of the ALP are the major effects. Our results show that low-energy electron-positron colliders such as Belle-II and BaBar are primarily affected by the first two factors, while beam dump experiments such as E137 and NA64 are affected by the cross sections and lifetime. We also consider two UV models - the KSVZ model and a lepton-specific version of the DFSZ model - which have only one of the two couplings at tree-level. However, the other coupling can be generated at loops, and our analysis reveals that the simultaneous presence of the two couplings can significantly modify existing bounds on these models for $10^{-3} < m_a < 10$ GeV, especially for beam dump experiments. Overall, our study highlights the importance of considering the concurrent effects of the ALP-photon and ALP-electron couplings in future collider and beam dump analyses.

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