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Near or Far Detectors? A Case Study for Long-Lived Particle Searches at Electron-Positron Colliders

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We explore the discovery potential for long-lived particles at the 250-GeV ILC. The goal is to investigate possible gains of a dedicated far detector over the main detector ILD. For concreteness, we perform our study for sub-GeV axion-like particles a produced via $e^+e^- \to a\gamma$ or $e^+e^- \to Z\gamma \to (a\gamma)\gamma$ and decaying into pairs of charged leptons.
In the ideal case of zero background and perfect detection efficiency, we find that far detectors placed in the planned underground cavities or a large cuboid on the ground can enhance the sensitivity to long-lived pseudo-scalars at best moderately. On the other hand, the ILD itself is a perfect environment to search for long-lived particles, due to its excellent angular coverage and radial thickness. For long-lived particles produced with cross sections of a few picobarns, the ILD could probe lifetimes up to 300 ns or proper decay lengths up to 100 m in $250\,\text{fb}^{-1}$ of data. For axion-like particles produced through weak interactions, the ILC can reach an even higher sensitivity than searches for displaced vertices in meson decays at \belletwo. Our findings apply similarly to other proposed electron-positron experiments with a high angular coverage, such as the FCC-ee and CEPC.

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