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# Probe CP Structure of Axion-Like Particles at Future Lepton Collider

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We study a charge-parity (CP) violating Axion-like particle (ALP) involved in both CP-even ($aF_{\mu\nu}\tilde{F}^{\mu\nu}$) and CP-odd ($aF_{\mu\nu}F^{\mu\nu}$) ALP-photon interaction at future lepton colliders. We examine the properties of the ALP and its CP structure by analyzing the $e^+e^- \to e^+e^-a \to e^+e^-\gamma\gamma$ channels. A CP-sensitive observable $\Delta\phi_{ee}$, is employed, signifying the azimuthal angular difference between the final state electrons. The constraints on the couplings of CP-violating ALPs at future lepton collider can reach $\mathcal{O}(10^{-3})$ TeV$^{-1}$, surpassing the sensitivity conducted in the electric dipole moment of electron ($e$EDM). Since the contributions originating from purely CP-even, purely CP-odd and CP-violating ALP-photon interactions exhibit distinct behaviors in the differential distribution of the observable $\Delta\phi_{ee}$, a binned likelihood analysis effectively discriminates the CP structure of the ALP. Specifically, if CP-even coupling constants are close to those of the CP-odd ALP-photon interaction under certain new symmetry assumptions, the presence of CP violation in the ALP sector can be tested upon the discovery of direct evidence for ALPs by future lepton colliders. For cases where the two coupling constants are not close to one another, an increased integral luminosity substantially enhances the sensitivity in probing CP-violating ALPs.

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