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Probing SMEFT operators using polarizations and spin correlations at current and future colliders

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The standard Model (SM) is the best currently experimentally tested theory of fundamental particles and their interactions. The discovery of Higgs boson completes the particle spectrum of SM and now the particle physics have officially entered the era of precision measurement. While the SM enjoys robust experimental verification, it falls short in explaining phenomena like the naturalness problem, dark matter, strong CP problem, matter-antimatter asymmetry, and neutrino mass. Various beyond SM models, including supersymmetry, Technicolor, UED, and string theory, have been proposed to address these issues, yet experimental evidence for new particles, symmetries, or dimensions remains elusive.

In response to the null results from the experiments, a shift toward a model-independent formalism becomes imperative. The effective field theory (EFT) serves as a versatile framework, expanding the SM by introducing higher-order gauge symmetric Lorentz terms. While the gauge symmetry imposes constraints on deviations in the fermionic sector, the likelihood of significant deviations in this sector is notably reduced. However, the electroweak sector remains open to exploration. We study the potential of future electron-positron colliders, particularly the International Linear Collider (ILC), to probe higher-order operators affecting the electroweak gauge sector. The study is carried with polarized beams which aid on increasing the signal-to-background ratio.\

To maximize sensitivity to new physics signals, a diverse set of observables is crucial. Here, we delve into the significance of spin-related observables, offering numerous polarization and spin correlation options. These set of observables could also shed light on the CP structure and correlations of new physics. One has to note that the construction of vector polarization and their correlations with the tensorial polarizations demands the proper identification of final daughter of weak bosons. The tagging of daughters becomes non-trivial in case of light flavor jets and to overcome these challenges, we propose employing machine learning techniques such as artificial neural networks, boosted decision trees, and convolutional neural networks. We show for the hadronic decay of W boson an accuracy of 80% can be achieved. The 95% CL bounds on anomalous couplings is found to be tighter than the experimental values. Finally we note that besides playing a dominant role on probing higher order operators, spin-related observables can be directly used to comment on the existence of quantum entanglement at high energy.

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