Editor's Focus

Probing New Physics at future electron positron Higgs factories via $e^+e^- \rightarrow Z\gamma$ process

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Received October 14, 2020; accepted October 28, 2020; published online November 20, 2020

Citation: M. Q. Ruan, Probing New Physics at future electron positron Higgs factories via $e^+e^- \rightarrow Z\gamma$ process, *Sci. China-Phys. Mech. Astron.* **64**, 221064 (2021), <https://doi.org/10.1007/s11433-020-1631-0>

Direct searches and precision measurements are the two main complementary methods for identifying New Physics at colliders. The next generation of e^+e^- Higgs factories, including CEPC, FCC-ee, ILC and CLIC, is designed to deliver millions of clean Higgs events, together with large samples of other physics processes. Through high-precision measurements, possible deviations from the SM predictions can be identified, providing sensitive probes of New Physics. Given the high statistics of clean samples at e^+e^- Higgs factories, the state-of-art detector systems, and accurate theoretical frameworks, the reach for New Physics can be significantly higher than the center-of-mass energies of these facilities.

Using the Standard Model Effective Field Theory (SMEFT) framework, Ellis, He, and Xiao [1] recently analyzed systematically how dimension-8 operators could contribute to neutral triple gauge couplings, which change the differential cross sections of several Standard Model (SM) processes. Focusing on the $e^+e^- \rightarrow Z\gamma$ process with $Z \rightarrow q\bar{q}$ final states at future e^+e^- Higgs factories, they found that with a nominal integrated luminosity of 5 ab^{-1} , the New Physics scale could be probed up to the range of 1-5 TeV for the CEPC, FCC-ee, and ILC with center-of-mass energies 0.2-1 TeV, and up to the range of 10-16 TeV for CLIC with center-of-mass energies 3-5 TeV. In other words, differential cross section measurements of the $e^+e^- \rightarrow Z\gamma$ process at future e^+e^- colliders can serve as powerful probes to explore

the New Physics at energy scales that are typically 3-5 times higher than the corresponding center-of-mass energies.

The SM is a chiral theory that violates parity. In particular, the left-handed and right-handed fermions have different couplings to the W/Z bosons. The linear Higgs factories (ILC and CLIC) could control their longitudinal beam polarization, with which chiral initial states could be selected, and a better signal/noise ratio could be achieved. Ref. [1] analyzes the impact of beam polarization on New Physics searches with the $e^+e^- \rightarrow Z\gamma$ channel, and finds that beam polarization could typically increase the reach for the New Physics scale by about 20%, compared to the unpolarized beams.

Compared to the previous analyses using only leptonic Z decays [2], the physics reach in ref. [1] increases significantly because it focuses on the hadronic Z decays. In general, as the majority of massive SM bosons decay hadronically, many important physics measurements rely on the hadronic final state (a.k.a. the jet final state) reconstruction. Compared to a hadron collider, the precise reconstruction of the hadronic final state is one of the major competitive advantages of e^+e^- Higgs factories, since they are free of QCD backgrounds and the center-of-mass energy of each collision is precisely known. Therefore, a precise reconstruction of the hadronic final states becomes one of the major physics requirements for their detector design and optimization. Significant efforts have been made accordingly, leading to a much better efficiency in identifying the jets (even for low P_T jets) and

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a much better accuracy in reconstructing the 4-momenta of hadronic final states [3, 4]. For this purpose, the modelling of reconstruction performance on hadronic system in ref. [1] is sufficient to show how significantly the kinematic distributions differ from the SM predictions.

To conclude, ref. [1] demonstrates that New Physics can be probed at future e^+e^- colliders via dimension-8 operators to energy scales significantly higher than their center-of-mass energies. Taking advantages of both hadronic Z decays and beam polarizations remarkably increase the physics reach. Ref. [1] also studied the dependence of the New Physics reach

on the event reconstruction efficiency, the center-of-mass energy, and the integrated luminosity. This work has made an important contribution to the quantification of the physics potential and comparative advantages of future facilities.

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