Study of Electroweak Phase Transition in Exotic Higgs Decays with CEPC Detector Simulation

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We propose an a light scalar search topic in exotic Higgs decay final states to be carried out using CEPC detector simulation so as to examine the first-order electroweak phase transition phenomenon search sensitivity in such future lepton collider experiment. The work will not only strengthen the R&D physics program but also provide advice on detector design optimization so as to improve the search sensitivity.

Keywords: Electroweak Phase Transition; Exotic Higgs Decay; Light Scalar; Beyond Standard Model Physics; Future Colliders; CEPC

One of the key questions common to the cosmic and high energy physics frontiers is to determine the thermal history of electroweak symmetry breaking (EWSB). The crossover transition of Standard Model (SM) EWSB, predicted by lattice simulation, can be altered in the case that Beyond Standard Model (BSM) new physics would be present. The first order EWSB transition would be even more particularly important, because it is an essential ingredient for explaining the mystery of cosmic matter-antimatter asymmetry via electroweak baryogenesis (EWBG)[1] and because it may provide the sources for potentially observable gravitational radiation[2]. Any new particle involved in such alternate thermal history cannot have its mass too heavy with respect to the SM electroweak temperature and cannot be too weakly interacting with the SM Higgs boson even if that particle is present in the thermal bath [3]. In the high energy experimental frontier, both the LHC experiment and potential future Higgs-factory-like lepton colliders would be ideally good facilities to examine the presence of such light scalar new particles coupled to the Higgs that would induce a strong first-order electroweak phase transition (EWPT) [4].

In this regard, one interesting regime involves new scalars lighter than half the Higgs boson mass, thereby enabling exotic Higgs decay modes. As shown in Ref. [4], there exists a lower bound on the corresponding exotic Higgs decay branching ratio as a function of the new scalar mass. Moreover, future e^+e^- colliders should have sufficient sensitivity to probe the first order EWPT-viable parameter space for new scalar masses down to at least ~ 10 GeV, with a reach extending far beyond that of the High Luminosity LHC[4, 5].

Under such motivation, we propose to perform a detailed study of a future exotic Higgs decay search with the reference detector simulation of CEPC, which is presently one of the major future candidate lepton collider experiments providing rich e^+e^- collision data at a center-of-mass energy of 240 GeV. [6]. A full consideration of the current CEPC detector geometry and condition effects will be taken into account with the signal simulation model referring to [4]. A thorough study of the search sensitivity and the comparison with other future collider experiments such as FCC-ee *etc.* will be carried out. Such study will help to further strengthen the BSM physics motivation of CEPC in addition to its important role of SM Higgs factory for precision physics. Also it will help to review the current benchmark detector condition and provide more explicit advice to optimize its design so as to enhance the search sensitivity for exotic Higgs decays related to EWPT. Various prompt visible decay final states in such exotic Higgs decayed light scalar final states, such as $bbbb$ and $bb\ell\ell$, will be surveyed so as to conclude on a thorough search sensitivity scan.

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