Available online at www.sciencedirect.com

ScienceDirect

Nuclear Physics B 839 (2010) 294–309

NUCLEAR PHYSICS B

www.elsevier.com/locate/nuclphysb

Pair production of Higgs bosons associated with Z boson in the left–right twin Higgs model at the ILC

Yao-Bei Liu [a,*], Xue-Lei Wang [b]

[a] *Henan Institute of Science and Technology, Xinxiang 453003, PR China*
[b] *College of Physics and Information Engineering, Henan Normal University, Xinxiang 453007, PR China*

Received 29 April 2010; received in revised form 19 June 2010; accepted 21 June 2010

Available online 30 June 2010

Abstract

The left–right twin Higgs (LRTH) model predicts the existence of three additional Higgs bosons: one neutral Higgs ϕ^0 and a pair of charged Higgs bosons $\phi^\pm$. In this paper, we studied the production of a pair of charged and neutral Higgs bosons associated with standard model gauge boson Z at the ILC, i.e., $e^+e^- \to Z\phi^+\phi^-$ and $e^+e^- \to Z\phi^0\phi^0$. We calculate the production rate and present the distributions of the various observables, such as, the distributions of the energy and the transverse momenta of final Z-boson and charged Higgs boson ϕ^-, the differential cross section of the invariant mass of charged Higgs bosons pair, the distribution of the angle between charged Higgs bosons pair and the production angle distributions of Z-boson and charged Higgs boson ϕ^-. Our numerical results show that, for the process $e^+e^- \to Z\phi^+\phi^-$, the production rates are at the level of 10^{-1} fb with reasonable parameter values. For the process of $e^+e^- \to Z\phi^0\phi^0$, we find that the production cross section are smaller than 6×10^{-3} fb in most of parameter space. However, the resonance production cross section can be significantly enhanced.

Keywords: Left–right twin Higgs model; Charged Higgs boson; ILC

1. Introduction

One interesting approach to the hierarchy problem, first proposed in [1,2], is that the Higgs mass parameter is protected because the Higgs is the pseudo-Goldstone boson of an approximate global symmetry. In the last few years several interesting realizations of this idea based on the

* Corresponding author.
E-mail address: liuyaobei@sina.com (Y.-B. Liu).

0550-3213/$ – see front matter
doi:10.1016/j.nuclphysb.2010.06.015

little Higgs mechanism have been constructed [3,4]. These theories stabilize the weak scale up to be above a few TeV. Many alternative new physics theories, such as supersymmetry, topcolor, and little Higgs, predict the existence of new scalar or pseudo-scalar particles. These new particles may have cross sections and branching fractions that differ from those of the SM Higgs boson. Thus, the discovery of the new scalars at the future high energy colliders might shed some light on the new physics models.

Recently, the twin Higgs mechanism has been proposed as an interesting solution to the little hierarchy problem [5–7]. The SM Higgs emerges as a pseudo-Goldstone boson once a global symmetry is spontaneously broken, which is similar to what happens in the little Higgs models [3]. Gauge and Yukawa interactions that explicitly break the global symmetry give mass to the Higgs. Once an additional discrete symmetry is imposed, the leading quadratic divergent term respects the global symmetry, thus does not contribute to the Higgs mass. The twin Higgs mechanism can be implemented in left–right models with the discrete symmetry being identified with left–right symmetry [6]. The left–right twin Higgs (LRTH) model contains $U(4)_1 \times U(4)_2$ global symmetry as well as $SU(2)_L \times SU(2)_R \times U(1)_{B\text{-}L}$ gauge symmetry. In the LRTH model, pair of vector-like heavy top quarks play a key role at triggering electroweak symmetry breaking just as that of the little Higgs theories. Besides, the other Higgs particles acquire large masses not only at quantum level but also at tree level. The phenomenology of the LRTH model are widely discussed in literature [8,9], and constraints on LRTH model parameters are studied in [10]. The LRTH model is also expected to give new significant signatures in future high energy colliders and studied in Ref. [11], due to the new particles which are predicted by this model. Also the pair production of the charged and neutral Higgs bosons at the ILC and LHC in the framework of the LRTH model are studied in [12,13].

The hunt for the Higgs boson and the elucidation of the mechanism of symmetry breaking is one of the most important goals for present and future high energy collider experiments. The most precise measurements will be performed in the clean environment of the future e^+e^- linear colliders, with a center of mass (c.m.) energy in the range of 500 to 1600 GeV, as in the case of the International Linear Collider (ILC) [14], and of 3 TeV to the Compact Linear Collider (CLIC) [15]. In many cases, the ILC can significantly improve the LHC measurements. If a Higgs boson is discovered, it will be crucial to determine its couplings with high accuracy. The running of the high energy and luminosity linear collider will open an unique window for us to reach understanding of the fundamental theory of particle physics. So far, many works have been contributed to studies of the Higgs boson pair production at the ILC, in the SM [16] and in the new physics beyond the SM [17]. In this work, we will study the production of the pair charged and neutral scalars of the LRTH model associated with a Z boson at the future high energy e^+e^- linear colliders.

This paper is organized as follows. In Section 2, we give a briefly review of the LRTH model, and then give the relevant couplings which are related to our calculation. Sections 3 and 4 are devoted to the computation of the production cross sections of the processes $e^+e^- \to Z\phi^+\phi^-$ and $e^+e^- \to Z\phi^0\phi^0$. Some phenomenological analysis are also included in the two sections. The conclusions are given in Section 5. In Appendices A and B, we present the Feynman rules and formulas relevant to our calculations.

2. Review of the LRTH model

In this section we will briefly review the essential features of the LRTH model and focusing on particle content and the couplings relevant to our computation.