Light Higgs Production via Electron-Positron Collision

A Thesis

Submitted for the degree of Doctor of Philosophy of Science (Theoretical Physics) as a partial fulfillment for requirements of the degree of Doctor of Philosophy of Science of Theoretical Physics

By

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Dedication

I lovingly dedicate this dissertation to the spirit of Prof. Dr. Mustafa Shalaby, who supported me in each step of the way.

Thank you.

Summary

The aim of this thesis is devoted to a detailed phenomenological analysis of the production of the lightest neutral Higgs boson h^0 in association with pairs of sleptons which are muon-sneutrino $e^+e^- \to \tilde{\nu}_\mu \bar{\tilde{\nu}}_\mu h^0$ and tau-sneutrino $e^+e^- \to \tilde{\nu}_\tau \bar{\tilde{\nu}}_\tau h^0$ at future e^+e^- colliders in the context of the minimal supersymmetric standard model (MSSM).

The dependence of the lowest order and the virtual one loop radiative corrected total cross sections on the center of mass energy and the other model parameters in the framework of the MSSM would be discussed. The phenomenological analyses are based on the CP-conserving MSSM with real parameters. Numerical results at the SPS1b and SPS 4 benchmark points as proposed in the Supersymmetry Parameter Analysis (SPA) project are presented for demonstration.

This thesis consists of five Chapters:

Chapter 1 gives an overview of the Standard Model (SM) with emphasis on the Higgs sector. An important component of the SM is the Higgs mechanism which enables gauge bosons to have non-zero mass while preserving gauge symmetry. The constraints on the Standard Model Higgs boson mass from the direct searches and from precision measurements in addition to shortcomings of the Standard Model are briefly introduced.

Chapter 2 presents the leading candidate for physics beyond the standard model which is supersymmetry (SUSY) theory. The Minimal Supersymmetric Standard Model (MSSM) is introduced as an extension of the Standard Model and differences between the MSSM and SM Higgs sectors are described. The Chapter sheds lights on the mass spectrum and the renormalization of the MSSM.

Chapter 3 provides the basic modern tools for the calculation of loop diagrams which are the dimensional regularization (DR) and Passarino–Veltman functions. A brief introduction about QuantumElectroDynamics (QED) corrections at one loop and renormalization in QED are presented.

Chapter 4 is devoted to study the associated production of the lightest h^0 boson along with a muon-sneutrino pair at future e^+e^- colliders in the context of the MSSM in each of the SPS 1b and SPS 4 scenarios. The calculation of the Born cross section contribution as well as the full virtual one loop electroweak corrections to the $e^+e^- \to \tilde{\nu}_\mu \bar{\tilde{\nu}}_\mu h^0$ process are presented. The QED contributions can be isolated as a separate subclass.

In the numerical calculation, the MSSM parameters at the two reference points SPS 1b and SPS 4 defined in the SPA project are adopted. Our numerical results show that in each of the SPS 1b and SPS 4 scenarios, the full virtual electroweak corrected total cross sections are always more than the corresponding tree-level cross sections clearly.

The EW relative correction $\Delta\sigma / \sigma_0$ for the $e^+e^- \to \tilde{\nu}_\mu \bar{\tilde{\nu}}_\mu h^0$ channel can be either positive or negative with the increment of the colliding energy $\sqrt{s}$ and the

$\Delta\sigma / \sigma_0$ is always positive with the increment of the supersymmetric Higgs mass μ parameter of the two chosen scenarios.

In the numerical results, one found that M_{SUSY} has evidently a considerable impact on the muon-sneutrino and the lightest neutral Higgs particle masses ($m_{\tilde{\nu}_\tau}$ and m_{h^0}) in addition to its considerable effect on the Born cross section σ_0 of each of the our chosen scenarios. There is weakly effect of $\tan\beta$ parameter on the muon-sneutrino and the lightest neutral Higgs particle masses ($m_{\tilde{\nu}_\tau}$ and m_{h^0}).

One concludes that the cross section values and the EW relative correction for the $e^+e^- \to \tilde{\nu}_\mu \bar{\tilde{\nu}}_\mu h^0$ channel in SPS 1b scenario are always higher than the corresponding values in the SPS 4 scenario and these corrections are so remarkable and cannot be neglected in the precise experiment analysis.

Chapter 5 presents the $e^+e^- \to \tilde{\nu}_\tau \bar{\tilde{\nu}}_\tau h^0$ channel where the associated production of the lightest boson h^0 along with a tau-sneutrino pair at future e^+e^- colliders in the context of the MSSM in each of the SPS 1b and SPS 4 scenarios is discussed. The dependence of the Born cross section, the full electroweak corrected cross sections and the relative correction on the colliding energy $\sqrt{s}$ are analyzed.

Our numerical results show clearly that the radiative corrections for the $e^+e^- \to \tilde{\nu}_\tau \bar{\tilde{\nu}}_\tau h^0$ channel for the two reference points SPS 1b and SPS 4 are always more than the corresponding tree-level cross sections, i.e., the radiative corrections are always positive in our chosen parameter spaces. The relative correction varies in the range of the SPS 1b and SPS 4 scenarios are of order of 90% and 8%,

respectively. This is consistent with our numerical results in the corresponding reaction $e^+e^- \to \tilde{\nu}_\mu \bar{\tilde{\nu}}_\mu h^0$.

The effect of the μ parameter on the total cross section value as a function of the c.m.s energy at the values μ = 150, 200 and 250 GeV is rather minute at the Born approximation level or at the full virtual electroweak corrected total cross section for the two scenarios SPS 1b and SPS 4, respectively. Similar results obtained for the reaction $e^+e^- \to \tilde{\nu}_\mu \bar{\tilde{\nu}}_\mu h^0$ where the μ parameter in each of SPS 1b and SPS 4 scenarios in the same range, from 150 GeV to 250 GeV, has a small effect on the $\Delta\sigma / \sigma_0$.

The influence of the soft-breaking squark mass M_{SUSY} parameter on the tau-sneutrino and the lightest neutral Higgs particle masses at the tree level σ_0 is considerable.

The influence of the vacuum expectation value $\tan\beta$ parameter at the tree level on the tau-sneutrino mass $m_{\tilde{\nu}_\tau}$ is minimal (1 GeV) and its effect on the lightest neutral Higgs particle mass m_{h^0} is considerable when the $\tan\beta$ value is less than 8 for the two chosen parameter spaces. These results are consistent with what we got for the $e^+e^- \to \tilde{\nu}_\mu \bar{\tilde{\nu}}_\mu h^0$ process.

From our numerical calculations, we conclude that the cross section values and the EW relative corrections for the $e^+e^- \to \tilde{\nu}_\tau \bar{\tilde{\nu}}_\tau h^0$ channel are in favor of the SPS 1b scenario and these corrections are so remarkable and they that cannot be neglected if precise experiment of analysis are sought.

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