Abstract

The Standard Model (SM) of particle physics has been remarkably successful to describe strong, weak and electromagnetic forces of nature, as it has agreed with most of the experiments till date. However, there are still some unanswered questions both theoretical and phenomenological in the SM. The present and future colliders will help the physicists learn more about the nature of matter and all forces in the universe. In this thesis work we have mainly focused on the physics case of one of the future linear colliders which has been proposed and will hopefully be a succession of the currently running Large Hadron Collider (LHC) in CERN Geneva.

As an introduction to the thesis work in Chapter 1 we have discussed in detail about the proposed future collider, namely the International Linear Collider (ILC). This collider alongside being a high luminosity machine, will have the advantage of beam polarization as the colliding beams will be linear in this case. In addition, as the initial particles are e+ and e, the collision will take place in a clean environment, with almost negligible QCD background. As physics at the ILC has major dependence on beam polarization, we discuss here the basic physics of beam polarization, helicity amplitudes etc. We also discuss about the basic structure of the Standard Model, Higgs mechanism and explore its unanswered questions. One of the theories proposed to take care of these deficiencies, namely super symmetry has been discussed in this chapter. These theories apart from explaining the shortcomings of the SM, also predict many new particles and are thus phenomenologically rich. There are two ways to look for the physics beyond SM. One is direct search for the new states which are not present in SM, which is the goal of the currently running collider LHC. This is a very efficient way if the new particle state is within the reach of the energy of the collider. The other is an indirect way, where deviations from SM is studied by a thorough scrutinization of the SM processes even without direct detection of the new physical states. The goal of thesis is the search for new physics scenarios in both direct and indirect ways. The full potential of the ILC through initial beam polarization, has been explored in this thesis. The work can be divided into two basic themes pertaining to the effective _field theory (EFT) approach of the search for beyond Standard Model (BSM) physics in the top and gauge sector and the study of Higgs phenomenology in the colliders. Below, these works will be described in some detail and the future research plans related to them.

In Chapter 2, we have discussed model independent EFT analysis of the search for new physics in the process e+e! tt at the ILC. We consider four-Fermi type interaction and look at the effect of different type of new physics (scalar, tensor, vector or axial vector) in addition to the V-A type interaction of SM. We consider initial beams to be polarized (longitudinal or transverse). The availability of beam polarization at the ILC will significantly enhance the sensitivity to new physics. We explore various spin bases (namely helicity basis, beamline basis and o_-diagonal basis) for measuring top and anti-top spin, reconstructed from the spin of their decay products. We find out that the spin correlation between top and anti-top pair is an effective probe to detect and isolate the type of new physics. We also find that the beamline basis is the most sensitive basis for transverse beam polarization and helicity basis is the best for longitudinal beam polarization. We follow helicity amplitude formalism to calculate the angular distributions. We then derive upper limits on the new physics effective couplings achievable at the ILC with realistic polarization and integrated luminosity by calculating various asymmetries.

In Chapter 3 we consider the process e+e□! Z at the ILC. The ZZ and Z couplings are absent at tree level in SM by gauge invariance, and highly suppressed when allowed by internal particle loops, forbidding the s-channel production of ZZ and Z. Therefore, any deviation from the tree-level SM predictions for this process will indicate the presence of BSM physics. We consider all possible dimension-6 and 8 CP-conserving and CP-violating operators. We studied the implication of this at the ILC with polarized beams. Here we reported a dimension-8 CP-conserving ZZ vertex that had not found mention in the literature before. We set up a correspondence between the triple gauge boson couplings and the four-point e+e□! Z contact interactions. We also present sensitivities on these anomalous couplings, which will be achievable at the ILC with realistic polarization and luminosity, by looking at various asymmetries.

In Chapter 4 we explore CP-violation in the Higgs sector. We explore the possibility that 125 GeV Higgs state is not a CP-eigenstate. In this work, we study the possibility of probing departures from the pure CP-even case (SM), by using the decay distributions in the process e+e□! tt_, where _ is the CP-mixed Higgs state mainly decaying into bb pair. In this context we first consider a simple extension of SM, with one additional pseudo scalar degree of freedom (Model I). Next we consider a more realistic scenario, CP-violating Two-Higgs Doublet Model (Model II) that permits a more general description of the couplings. Our study shows that an indefinite CP Higgs would be a sensitive laboratory to search for BSM physics. Top quark being the heaviest state, couples strongly to the Higgs boson, making a precise study of the top Yukawa coupling essential to establish the electroweak sector of SM, and to provide hints of new physics. we study the measurement of top quark Yukawa coupling in case of model I and II with the inclusion of CP-violation in the coupling, in the associated production of tt pair with Higgs at ILC. The issue of the measurement of the Yukawa coupling and the sensitivity achievable at the ILC have been the subject of recent studies, which we extend, by deviating from the SM Higgs (CP-even) hypothesis assuming generalized coupling structure. We conclude that a joint analysis of the CP properties and the Yukawa coupling measurement would be the way forward at the ILC and caution must be taken in Yukawa coupling measurement and while drawing conclusions from it.

In Chapter 5, we explore the invisible decay of Higgs boson predicted by supersymmetric models. We consider the case of MSSM with both universal as well as nonuniversal gaugino masses at the grand unified (GUT) scale. We find that in MSSM it is not possible for 125 GeV Higgs to decay invisibly i.e. decay into a pair of light neutralinos (except for a higher dimensional representation of E6 group) with fixed boundary condition on the gaugino masses at the GUT scale. Even in NMSSM it is not possible for Higgs to decay invisibly with universal boundary condition. But with non-universal and arbitrary boundary condition on the gaugino masses it is possible in NMSSM. We further discuss the decay of Higgs into a pair of lightest pseudo scalars h! a1a1 in NMSSM. The invisible Higgs decay has been constrained by the LHC experiments so far and thereby the NMSSM parameter space got constrained. We further extend our work and study the invisible decay of second lightest CP-even, neutral Higgs boson in MSSM, with universal, nonuniversal and arbitrary boundary condition on the gaugino masses at the GUT scale. We study the MSSM Higgs and neutralino mass spectrum and the branching fractions of heavy Higgs into neutralinos. One way to detect invisible decay in the colliders is through monojet missing energy signature via initial state radiation. Hence the upper limit on Brin visible of heavy Higgs from the monojet searches will put a strong bound on the MSSM parameter space. We propose this and suggest a methodology. This study of invisible decay of Higgs is going to be a promising direction in the collider sector to look for new physics. In Chapter 6, we conclude by summarizing the thesis.