Chapter 8

Summary and conclusions of the thesis

This thesis has aimed to study the collider aspects of some new physics scenarios in context of the Large Hadron Collider using various properties of tau-leptons. In chapter 1 we have tried to outline the existing standard model of particle physics and pointed out both its theoretical and experimental inadequacies. Supersymmetry which is a prototype of new physics scenario, has been discussed in detail in chapter 2.

Chapter 3 contains the cosmological and collider aspects of supersymmetric theories with a right-chiral neutrino superfield for each generation in order to incorporate the non-vanishing neutrino masses and mixings. We consider a supergravity (SUGRA) scenario, with universal scalar and gaugino masses at high scale. Such a scenario can have a lightest supersymmetric particle (LSP) dominated by the right sneutrino and a stau as the next-to lightest supersymmetric particle (NLSP). Since decays of all particles into the LSP are suppressed by the neutrino Yukawa coupling, the signal of supersymmetry consists in charged tracks of stable particles in the muon chamber.

In chapter 4, we demonstrate how neutralinos can be fully reconstructed over substantial areas in the SUGRA parameter space. To reconstruct the neutralino we have considered pair production of neutralinos in SUSY cascades. It further decays into a ττ pair. The final state consists of 2τj + 2τ + E_T + X, where, X comprises of all the hard jets arising from SUSY cascades. Reconstruction of the neutralino requires the knowledge of four-momenta of tau as well as stau. We first reconstruct the two taus in the final state from the knowledge of total
$E_T$ of that event. The four-momentum of the stau (which shows up as a charged track in the muon chamber) is not completely known. From the bending of the track only its three momentum can be measured. To measure the mass of the particle (lighter stau) associated with the charged track we have prescribed a method of extracting it on a event-by-event basis. Then the mass of the neutralino can be obtained from the invariant mass distribution of the $\tilde{\tau}\tilde{\tau}$ pair.

Chapter 5 discusses the reconstruction of the lighter chargino considering the associated production of it with the neutralinos in SUSY cascades. The chargino further decays into a $\tilde{\tau}\nu_\tau$ pair and the neutralino on the other side decays into a $\tilde{\tau}\tilde{\tau}$ pair. The final state in this case consists of $\tau_j + 2\bar{\tau} + E_T + X$. However, this final state can be faked by other SUSY processes. We have suggested a way of reducing these SUSY backgrounds imposing various cuts. The chargino mass, can then be found from the transverse mass distribution of the $\tilde{\tau}\nu_\tau$ pair, where we have also prescribed a way to find the transverse component of the four-momenta of the neutrino out of a chargino decay.

The reconstruction of the left-chiral tau sneutrino ($\tilde{\nu}_\tau_L$) has been discussed in chapter 6 in a way similar to that for the chargino. $\tilde{\nu}_\tau_L$ is predominantly produced in SUSY cascade via the decay of second lightest neutralino or the chargino and it further decays into a $\tilde{\tau}W$ pair. Therefore, we have an additional $W$ in the final state in addition to that considered for chargino case, namely, $\tau_j + W + 2\bar{\tau} + E_T + X$. We have suggested two different methods for reconstructing the mass of the left-chiral tau sneutrino. One of them is independent of the mass of the other SUSY particles whereas, the other one is more model dependent but has better signal to background ratio.

In all the above three cases, we conclude that using the available kinematic information of quasistable charged tracks and making use of various properties of tau-jets, it is possible to reconstruct faithfully the masses of the neutralinos, chargino and left-chiral tau-sneutrino. In some cases, the assumed luminosity is not too large, so that it is possible to explore some region of the parameter space even at the early phase of LHC run.

Chapter 7 discusses large non-universality in the Higgs sector at high scale in supersymmetric theories, in the context of the Large Hadron Collider (LHC). In particular, we note that if $m_{H_u}^2 - m_{H_d}^2$ is large and negative ($\approx 10^6$ GeV$^2$) at high scale, the lighter slepton mass eigenstates at the electroweak scale are mostly left chiral, in contrast to a minimal supergravity (mSUGRA) scenario. We use this feature to distinguish between non-universal Higgs masses (NUHM) and mSUGRA by two methods. First, we study final states with same-sign ditaus. We find that an asymmetry parameter reflecting the polarisation of the taus provides a notable distinction. In addition, we study a charge asymmetry in the jet-lepton invariant mass distribution, arising from decay chains of left-chiral squarks leading to leptons of the first two families, which sets apart such an NUHM scenario.