Synopsis

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Thesis title: Signals of supersymmetry and higgs at the LHC
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My PhD thesis focusses on phenomenological studies and addresses two questions. First, that of looking for Supersymmetry (SUSY) by detecting squarks of the third generation (in theories both with and without R-parity). The problem of Higgs mass stabilisation is solved in theories with SUSY by the cancellation of the corrections to the Higgs mass from the top and stop (top- squark) loops. To avoid fine-tuning, we would require stop mass to be within a TeV, and hence, we expect stops to be produced at the LHC. Search for top-squarks is therefore a robust way to searching for Supersymmetry.

Secondly, I address the question of determining Higgs couplings to gauge bosons. Assuming that a Higgs-like resonance is observed at the LHC, the next step will be to confirm whether it indeed corresponds to the Standard Model (SM) Higgs. For this, one needs to measure its couplings to gauge bosons since it is here that the structure of the underlying theory will be reflected. I propose a solution the question of measuring any anomalous contributions to the HWW vertex and to pinpoint its CP property.

1 Signatures of squarks of the third family

The primary SUSY searches hinge on signatures with jets and missing energy which are tailored to look for squarks of the first two generations and the gluino (which decays into light-quark jets if these squarks are not very heavy). The limits from these searches are then translated to limits on stop mass using a high-scale model like the cMSSM. We address the question of how to detect the stop without any reference to the squarks of the first two generations by using a non-universal scalar sector. In light of recent data from LHC experiments, we reinterpret the 1.04 fb$^{-1}$ data in jets+MET channel and 0.83 fb$^{-1}$ data in b-jets+MET channel from ATLAS to determine the limits on masses of third family squarks [Desai and Mukhopadhyaya, 2011]. Besides this, we have worked on determining the best signatures for discovery if the stop and gluino masses are near the limit of LHC reach [Desai and Mukhopadhyaya, 2009]. We perform a detailed background simulation using alpgen and find that channels with b-tagged jets and channels with like-sign dileptons have the best reach for discovering such scenarios.

2 R-parity violating resonant stop production

Even though R-parity is commonly assumed in models of SUSY, it is not a consistency requirement. Therefore, putting limits on R-parity violating couplings by explicitly searching for signatures is a valid mode of determining the nature of BSM physics. Many of these
couplings are strongly constrained by observation of meson decays, EDMs etc. However, the baryon number violating UDD-type couplings, \( \lambda''_{312} \) is almost entirely unconstrained. Such a coupling would result in resonant production of a stop which could dominate over the pair-production cross section. We study this particular case [Desai and Mukhopadhyaya, 2010] for various possible stop decays using Herwig 6.5 for simulating the signal and alpgen for the background. Due to the Majorana nature of the neutralino, the like-sign top final state occurs 50% of the time and hence, like-sign dilepton signature is a powerful discriminator. We find that we can better the current limit on \( \lambda''_{312} \) by up to two orders of magnitude for stop masses less than a TeV.

3 Anomalous HWW couplings at the LHC

The problem of determining Higgs couplings has been well studied in the case of the HZZ coupling because the Z boson can be cleanly reconstructed in its leptonic decay mode. However, it is a difficult problem in the case of the HWW coupling since (a) the event is not fully reconstructible due to the presence of two neutrinos in the final state, and because (b) the opposite-sign dilepton channel has a large SM background. We show [Desai et al., 2011] that the best production channel to observe this vertex in not \( gg \rightarrow h \) but \( qq \rightarrow Wh \) followed by \( h \rightarrow WW \). We develop certain asymmetry variables that are capable of determining the CP violating nature of the anomalous couplings and also explicitly show that they are largely unaffected by initial state radiation effects. This project involved the use of form to calculate exact matrix elements for both production and decay, writing our own parton-level event generator and interfacing it to Pythia 8 using the Les Houches Event File (LHEF) format for showering and hadronisation.

4 Implementation of SUSY in Pythia 8

Part of my PhD was spent in working on the generator PYTHIA 8. PYTHIA 8 is a general purpose Monte-Carlo Generator written in C++ and is capable of simulating various SM and BSM processes. My work on Pythia 8 consists of implementing the production and decay of SUSY particles. I started by generalising the coupling structure so that any BSM couplings can be implemented as an add on to the Standard Model couplings. Following this, all the production cross sections — gluino-pair, squark-pair, squark-gluino, gaugino-pair, squark-gaugino and R-parity violating resonant squark production — were encoded. I also implemented the two body decays of all SUSY particles, the R-parity violating decays of squarks and the R-parity violating three-body decay of the neutralinos (via UDD coupling). The implementation is available for use in the current public release (version 8.160) of PYTHIA 8. My contribution will be detailed in an Appendix.
Publications included in Thesis

1. **Signals of supersymmetry with inaccessible first two families at the Large Hadron Collider.**
   Nishita Desai, Biswarup Mukhopadhyaya

2. **R-parity violating resonant stop production at the Large Hadron Collider**
   Nishita Desai, Biswarup Mukhopadhyaya

3. **CP-violating HWW couplings at the Large Hadron Collider**
   Nishita Desai, Dilip Kumar Ghosh, Biswarup Mukhopadhyaya

4. **Constraints on supersymmetry with light third family from LHC data**
   Nishita Desai, Biswarup Mukhopadhyaya
   Preprint [arXiv:1111.2830] Submitted to JHEP

Other Publications

1. **Supersymmetry and Generic BSM Models in PYTHIA 8**
   Nishita Desai and Peter Skands
   Preprint [arXiv:1109.5852]