We study the pattern of gluino cascade decays in a class of supersymmetric models where R–parity is spontaneously broken. The multi–lepton and same–sign dilepton rates in these models are compared with those of the Minimal Supersymmetric Standard Model. We show that these rates can be substantially enhanced in models with broken R–parity.

1 Introduction

The search for supersymmetric particles will be one of the main topics in the experimental program of LHC. At LHC gluinos and squarks with masses up to $\lesssim 1.5$ TeV can be discovered. Most studies of gluino production and decays have been performed in the Minimal Supersymmetric Standard Model (MSSM). A characteristic feature of MSSM is the conservation of R–parity implying the stability of the lightest supersymmetric particle (LSP). Effects of R–parity breaking have been explored in. In this contribution we study the impact of spontaneous R–parity breaking on gluino cascade decays.

R–parity can be broken spontaneously through non–zero vacuum expectation values for scalar neutrinos. There are two generic cases of models with spontaneous R–parity breaking. Firstly, if lepton number is part of the gauge symmetry there is a new gauge boson $Z'$ which gets mass via the Higgs mechanism. In this model the LSP is in general a neutralino which decays mostly into Standard Model fermions. Secondly, if spontaneous R–parity violation occurs in the absence of any additional gauge symmetry, it leads to the

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existence of a physical massless Nambu–Goldstone boson, called majoron (J). As a consequence the lightest neutralino $\tilde\chi^0_1$ may decay invisibly as $\tilde\chi^0_1 \rightarrow \nu + J$.

We also consider a specific class of models with explicit R–parity breaking characterized by a single bilinear superpotential term of the type $\ell H u$. These models mimic in many respects the features of models with spontaneous breaking of R–parity containing an additional gauge boson. In the following the class of models containing a majoron will be denoted by J–model, whereas the models without a majoron will be denoted by $\epsilon$–model.

2 Gluino Cascade Decays

In the following we will assume that squarks are heavier than gluinos, so that pair production of gluinos dominates. As an example we consider a gluino with a mass of 500 GeV. At LHC with a centre of mass energy of 14 TeV the production cross section will be $\sim 25$ pb, which corresponds to $2.5 \times 10^6$ gluino–pairs per year for an integrated luminosity of $10^5$ pb$^{-1}$. The gluino has the following decays: $g \rightarrow q\bar{q}\tilde{\chi}^0_1$, $q\bar{q}\tilde{\chi}^\pm_j$, $g\tilde{\chi}^0_i$, where $\tilde{\chi}^0_i$ denotes the neutralinos and $\tilde{\chi}^\pm_j$ the charginos. The charginos and neutralinos decay further, giving rise to cascade decays. In models with spontaneous R–parity breaking one has additional decay modes for neutralinos and charginos compared to the MSSM. They are induced by the mixing between charged leptons and charginos, and between neutrinos and neutralinos.

Among the various signals of gluinos the multi–lepton (ML) and the same–sign dilepton (SSD) signals are experimentally very important. We calculate the rates for the ML and SSD signals in gluino pair production for MSSM, the J–model and the $\epsilon$–model. We count all leptons coming from charginos, neutralinos, t–quarks, W– and Z–bosons, summing over electrons and muons. We take $m_{\tilde{g}} = 500$ GeV, $\tan \beta = 2$, $M_2 = 170$ GeV, $m_A = 500$ GeV. For the parameters characterizing R–parity violation we take $h_{\nu 33} = 0.01$, $v_{R3} = 100$ GeV and $v_{L3} = 10^{-5}$ GeV. In the $\epsilon$–model this corresponds to $\epsilon = 1$ GeV. The $\mu$ parameter is varied between $-1$ TeV and 1 TeV. We take into account the restrictions on these parameters that follow from searches for SUSY particles at LEP and at TEVATRON. Moreover, we fulfil the constraints from neutrino physics and weak interactions phenomenology to which R–parity breaking models are sensitive.

In Fig. 1 we show the branching ratios for the 3–, 4–, 5– and 6–lepton events. Quite generally, the various ML rates in the R–parity violating models can be different from those in the MSSM for two reasons: (i) The lightest neutralino $\tilde{\chi}^0_1$ can decay leptonically as $\tilde{\chi}^0_1 \rightarrow Z^{(*)}\nu_\tau \rightarrow l^+l^-\nu_\tau$, $\tilde{\chi}^0_1 \rightarrow W^{(*)}\tau \rightarrow l^+\nu_l\tau$, leading to an enhancement of the multi–lepton rates. (ii) The R–parity...
Figure 1: Multi-lepton signals (summed over electrons and muons) as a function of $\mu$. The parameters are given in the text. We show a) the 3-lepton, b) the 4-lepton, c) the 5-lepton and d) the 6-lepton signal for the MSSM (full line), the $J$-model (dashed line) and the $\epsilon$-model (dash-dotted line). The shaded area is covered by LEP2.

violating decays of the lightest chargino $\tilde{\chi}_1^\pm$ and the second lightest neutralino $\tilde{\chi}_2^0$ may reduce the leptonic signal, $\tilde{\chi}_2^0 \rightarrow W^{(*)}\tau$, $J\nu_\tau$, $\tilde{\chi}_1^- \rightarrow J\tau$ (we do not count $\tau$ as a lepton). Depending on which of these two effects is dominant, one has an overall enhancement or a reduction of the leptonic rates compared to those expected in the MSSM. Note that even the 6-lepton signal has a rate
up to $5 \times 10^{-5}$ in the range $-300 \text{ GeV} < \mu < -80 \text{ GeV}$, giving 125 events per year.

In Fig. 2 we show the SSD signal which is enhanced in the J–model for $\mu \lesssim -100 \text{ GeV}$ or $\mu \gtrsim 200 \text{ GeV}$. This is due to the fact that at least one of the neutralinos has a sizeable branching ratio into a $W$, leading to the enhancement of the signal. In the $\epsilon$–model the signal is larger by an order of magnitude except for $|\mu| \lesssim 200 \text{ GeV}$.

3 Conclusions

The effects of R–parity violation in gluino cascade decays have been studied for two different classes of models, the J–model and the $\epsilon$–model. We have calculated the rates for the ML and SSD signals. These processes are interesting from the experimental point of view since the 4–, 5–, 6–lepton signals are practically free of background from Standard Model processes. Comparing the J–model with MSSM, the ML and SSD signals can increase or decrease depending on the model parameters, whereas in the $\epsilon$–model all signals are enhanced by one order of magnitude for most of the parameter ranges considered.

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