Search for R-parity violated SUSY at the Tevatron

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Abstract

Results of searches for Supersymmetry in the framework of R-parity violation from the DØ and CDF experiments are presented. No deviation from the standard model is observed. The most recent limits are presented together with the expectations for Tevatron Run II.

1 Introduction

R-parity of any particle [1] is defined as $R_p = (-1)^{3B+L+2S}$, where B, L and S are the baryon, lepton and spin quantum numbers. R_p equals $+1$ for SM particles and -1 for supersymmetric partners. The conservation of R-parity is often assumed in experimental searches, because, without that, simultaneous lepton and baryon number violation would lead to rapid proton decay. However, this argument can be circumvented if lepton and baryon number conservation are treated independently.

In supersymmetry, R-parity violation can occur through terms in the superpotential, that are trilinear or linear in quark and lepton superfields [1]:

$$\lambda_{ijk} L_i L_j \bar{E}^c_k + \lambda'_{ijk} L_i Q_j \bar{D}^c_k + \lambda''_{ijk} \bar{U}^c_i \bar{D}^c_j \bar{D}^c_k + \epsilon_i L_i H_2, \quad (1)$$

where i, j, and k are family indices; L and Q are the SU(2)-doublet lepton and quark superfields; E, U, and D are the singlet-lepton, up-quark, and down-quark superfields, respectively.

We can distinguish two possible experimental consequences or R-parity violation. In the case where the lightest supersymmetric particle (LSP) is assumed to be the only unstable sparticle, it can be assumed that R-parity is conserved at the production level, and the decay of all sparticles down to the LSP will be R-parity conserved. Only the decay of the LSP will be R-parity violated. In that case the cross section is directly proportional to the coupling. If no displaced vertex is observed (λ, λ', $\lambda'' > 10^{-4}$), the couplings are difficult to determine experimentally, and the experimental signature will be the disappearance of missing E_T due to the decay of the LSP, and the increase of the number of jets (resp. leptons) in the case of baryon (resp. lepton) number violation. If a

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displaced vertex is observed ($10^{-9} < \lambda, \lambda', \lambda'' < 10^{-4}$), the coupling can be experimentally measured. On the other hand, it is also possible to produce singly sparticles. In that case, the production also assumes R-parity violation. The sparticle decays with conserved R-parity into the LSP, and the LSP decays with violated R-parity with the same coupling. In this case, the cross section is proportional to the coupling squared, and the sensitivity on the coupling goes down to $10^{-2}, 10^{-3}$. It is possible to measure experimentally the coupling and the sparticle masses. We will distinguish these two kinds of searches in the following.

2 Production of SUSY particles in pair

2.1 Search in the two leptons and four jets channel (DØ)

The DØ Collaboration considered all possible $\tilde{\chi}^0$ pair production, and assumed one dominant R-parity violating coupling for the LSP $\tilde{\chi}^0$ decay. The LSP decays into an electron (resp. muon) and two jets when λ'_{1jk} (resp. λ'_{2jk}) with j=1, 2, and k=1, 2, 3 is the dominant coupling. The experimental signature is thus the observation of at least two electrons or two muons depending on the coupling in addition of at least four jets. The leptons and jets are requested to have a transverse energy greater than 15 GeV. The main background is coming from Drell Yan, $t\bar{t}$, $Z \to \tau\tau \to ee + ...$, $Z \to \mu\mu + jets$, $WW \to \mu\mu$ events, and the misidentication of jets as electrons. To reduce the contamination coming from Z events, it was requested that the dilepton mass is not in the 76-106 GeV mass range.

In the electron channel, 2 events have been observed experimentally for an expected background of $1.8 \pm 0.2 \pm 0.3$ events for a luminosity of 99 ± 4.4 pb^{-1} [2]. In the muon channel, 0 event has been observed for an expected background of $0.18 \pm 0.03 \pm 0.02$ events for a luminosity of 78 ± 4 pb^{-1} [2]. The exclusion contours are given in Fig. 1 and squarks with a mass below 243 GeV, and gluinos below 227 GeV are excluded at 95% C.L. for A_0=0, $\mu < 0$, and $\tan\beta$=2.

At Run II, using the same channels, sgluinos and squarks with a mass higher than respectively 500 and 420 GeV can be probed in the electron channel. In the muon channel, the sensitivity goes up to 800 and 740 GeV for the gluinos and the squarks because of the improved muon detector from the DØ Collaboration.

2.2 Search in the like-sign dielectron and multijet channel (CDF)

The CDF collaboration performed a search in the like-sign dielectron and multijet channel using 107 pb^{-1} of data [3]. This experimental signature can be produced by gluino-gluino or squark-squark production with R-parity violating decays of the charm squark or the lightest neutralino via a non-zero λ'_{121} coupling. Two isolated electrons of $E_T \geq 15$ GeV are requested together with two jets of $E_T \geq 15$ GeV. The dominant background is coming from $t\bar{t}$, $b\bar{b}$, $c\bar{c}$, and Drell-Yan production. No event is found in the data after cuts. Limits are set on the cross sections times branching ratio for the two processes $\sigma(p\bar{p} \to \tilde{g}\tilde{g}/\tilde{q}\tilde{q}).Br(\tilde{g}\tilde{g}/\tilde{q}\tilde{q} \to e^{\pm}e^{\pm} + \geq 2j)$. Limits have been set on $M(\tilde{t}_1)$=135 GeV, for a heavy neutralino ($M(\tilde{\chi_1}^0) = M(\tilde{t}_1) - M(c)$), and for the degenerate squark, $M(\tilde{q}) > 260$

GeV for a heavy neutralino ($M(\tilde{\chi_1}^0) = M(\tilde{q}) - M(q)$) and a light gluino ($M(\tilde{g}) = 200$ GeV).

2.3 Search in the 4-lepton channel (CDF)

In this channel, the production of a neutralino pair with conserved R-parity is assumed. The neutralinos decay via violated R-parity assuming λ_{211} is the dominant coupling. The neutralino decays into a neutrino and a sneutrino, which itself decays via violated R-parity into 2 leptons (electrons or muons). The final state is thus composed of four isolated leptons (muons or electrons) of tranverse energies greater than 12, 5, 5, and 5 GeV, and two neutrinos. One event is found in the data ($ee\mu\mu$) and 1.2 ± 0.2 background event is expected. The exclusion plot in the (M_0, $M_{1/2}$) plane is shown in Fig. 2. Squarks (gluinos) with a mass below 360 GeV are excluded, and lightest neutralinos below 55 GeV.

2.4 Search for R-parity violating decays of stop quarks (CDF)

The production of stop pairs with conserved R-parity is assumed. The stops decay with violated R-parity into $b\tau$ via the λ'_{333} coupling, or into $b\tilde{\chi}_1^+$, which decays via the ϵ_3 coupling into τ^+. The search was performed for the final state with a lepton, missing transverse energy from one τ decay, and two jets. The other τ decays hadronically. The dominant background is coming from $Z \to \tau^+\tau^-$, $W+$ jets and QCD events. The τ efficiency was calculated using the cross section measurement of $Z \to \tau\tau$. To reduce background, cuts on the tranverse mass calculated using the lepton and the missing energy to be less than 35 GeV, and the scalar sum composed of the lepton transverse energy, the missing E_T, and the tranverse momentum of the τ to be greater than 75 GeV. No event is found in the data and the number of background events coming mainly form $z \to \tau\tau$ is 1.91 ± 0.15. The excluded cross section is given in Fig. 3, and stop masses below 111 GeV are excluded.

3 Search for R-parity violated SUSY in the s channel (DØ)

A consequence of R-parity violation is single production of superpartners. Assuming that λ'_{211} is nonzero, the DØ Collaboration searched for single production of smuons and muon sneutrinos via violated R-parity [4]. The lightest supersymmetric particle (LSP) is assumed to be the lightest neutralino. All sparticles cascade-decay into neutralinos, which decay either into leptons and virtual sleptons, or quarks and virtual squarks, conserving R-parity. The virtual objects then decay, respectively, into two quarks or into a quark and a lepton, violating R-parity. Ultimately, all SUSY particles of interest in this search transform into two jets and a muon. Consequently, the final state contains at least two muons and two jets. Events were selected requiring at least two isolated muons with $E_T > 20$ GeV, two isolated jets with $E_T > 20$ GeV, and $H_T = \Sigma_{E_T^j > 15} E_T^j > 50$ GeV. Further selections were done using a neural network which used as an input the isolation

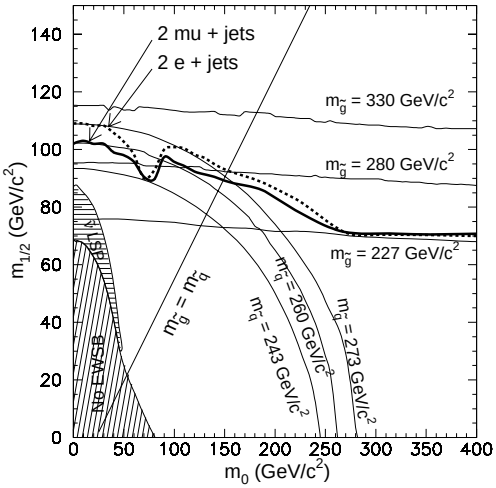

Figure 1: Exclusion contours in the (m_0, $m_{1/2}$) plane assuming the $\tilde{\chi}^0$ decay via the λ' coupling for $\tan\beta$=2, A_0=0, $\mu < 0$ in the electron and muon channels (DØ).

parameters of the muons and jets, the sphericity and the aplanarity of the event. Two events were found in the data for a luminosity of 94 pb^{-1}. The expected standard model background is 1.01 ± 0.02. The exclusion plot is given in Fig. 4 for different values of the coupling $\lambda'_2 11$.

This search is quite promising for Tevatron Run II [5]. As an example, the reach in the ($m_{1/2}$, m_0) plane for a search of like sign dimuons for a luminosity of 2 fb^{-1} and a coupling value of $\lambda'_{211} = 0.05$ is much improved: values of m_0 and $m_{1/2}$ down respectively to 600 GeV and 950 GeV can be probed.

In conclusion, no sign of R-parity violated SUSY has been found at Tevatron run I. Run II luminosity and detector upgrades will allow to increase the sensitivity on sparticle masses by at least a factor two to three, depending on the channels.

References

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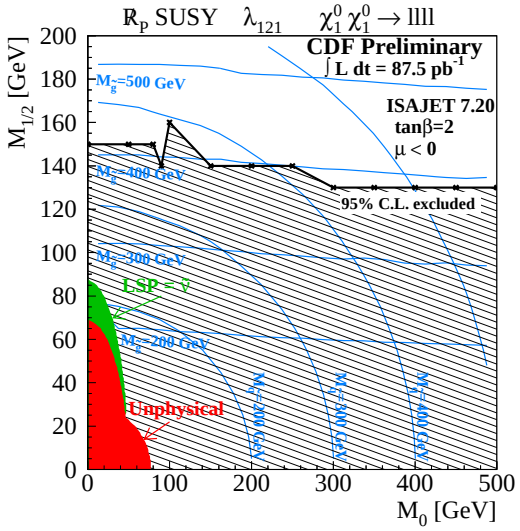

Figure 2: Exclusion contours in the (m_0, M_2) plane obtained for the decay of $\tilde{\chi}_0$ into 4 leptons via λ' coupling (CDF)

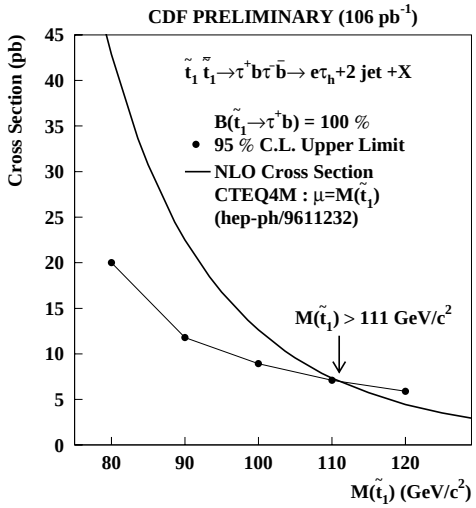

Figure 3: Exclusion contour as a function of the stop mass obtained for the stop decay into $b\tau$ via the λ'_{333} and ϵ_3 couplings (CDF).

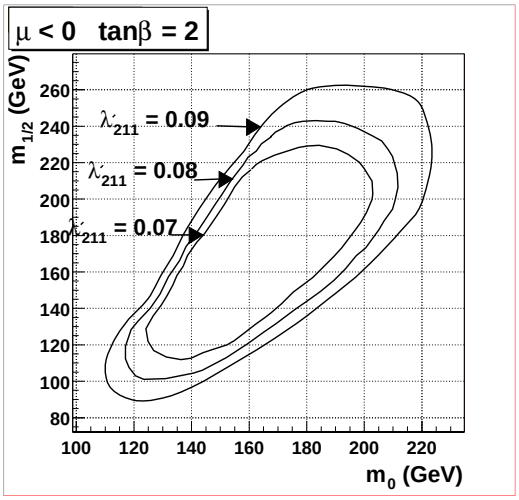

Figure 4: Exclusion contours in the (m_0, $m_{1/2}$) plane for three different values of λ'_{211} obtained for the s-channel production of $\tilde{\mu}$ and$\tilde{\nu_\mu}$ (DØ).