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Search for R-Parity violating SUSY with the DØ Experiment

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We have searched for R-parity violating supersymmetry in final states with electrons and muons, assuming a single non-zero LL$\bar{\text{E}}$ or LQ$\bar{\text{D}}$ coupling, in particular λ_{121}, λ_{122} or λ'_{211}. In the absence of an excess in the data, upper cross-section limits are set as a function of gaugino and slepton masses.

The searches are performed on data collected with the DØ detector in Run II, at a center of mass energy of 1.96 TeV and an integrated luminosity of up to 240 pb^{-1}. All limits are improving significantly compared to the DØ Run I results.

Keywords: R-Parity, Supersymmetrie, mSUGRA and DØ

1. Introduction

The R-parity violating ($\not{R}_p$) extension of the MSSM contains additional terms in the superpotential, which are trilinear in the quark and lepton superfields,

$$W_{\not{R}_p} = \sum_{i,j,k} \left(\frac{1}{2} \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \frac{1}{2} \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k \right), \tag{1}$$

where i, j, k are family indices. We present searches for not vanishing LL$\bar{\text{E}}$ couplings λ_{121}, λ_{122} and LQ$\bar{\text{D}}$ coupling λ'_{211}. All other couplings are considered to be negligibly small.

At hadron colliders Charginos and Neutralinos are produced in pairs or associated. The produced sparticles (cascade) decay to the lightest neutralino $\tilde{\chi}_1^0$. When assuming a non-zero LL$\bar{\text{E}}$ coupling, then this neutralino decays into two charged leptons and one neutrino by violating R-parity. The final state therefore contains at least four charged leptons (electrons or muons for λ_{121} and λ_{122}) and two neutrinos which lead to missing transverse energy in the detector.

The LQ$\bar{\text{D}}$ coupling offers the opportunity to produce supersymmetric particles in p$\bar{\text{p}}$-collisions as resonances. For λ'_{211} this is either a smuon or a muon sneutrino. The muon sneutrino channel leads to final states with missing transverse energy. The smuon can decay into the lightest neutralino $\tilde{\chi}_1^0$ and a high energy muon. The neutralino decays via the same R-parity violating coupling λ'_{211} into a 2^{nd} generation lepton and two jets.

2. Search for R-parity violation via λ_{121} in eel final states

The data used for this analysis corresponds to an integrated luminosity of 238 ± 16 pb^{-1}. The identification of two electrons and a third lepton, an electron or a muon, is required. A fourth lepton is not required, to maintain a high efficiency. The identification of electrons relies on the longitudinal and transverse development of their showers in the calorimeter and an associated track reconstructed in the tracking detectors. The track momentum and the shower energy must be compatible. The background from multijet processes is modelled with data by inverting certain electron cuts. The final selection requires minimal transverse momenta of 15, 10 and 5 GeV for the three leptons. The Z-resonance is cut away and the missing transverse energy should exceed 15 GeV. After these cuts 0 data events are found while $0.45 \pm 0.43 \pm 0.02$ Standard Model events are expected.

3. Search for R-parity violation via λ_{122} in $\mu\mu$l final states

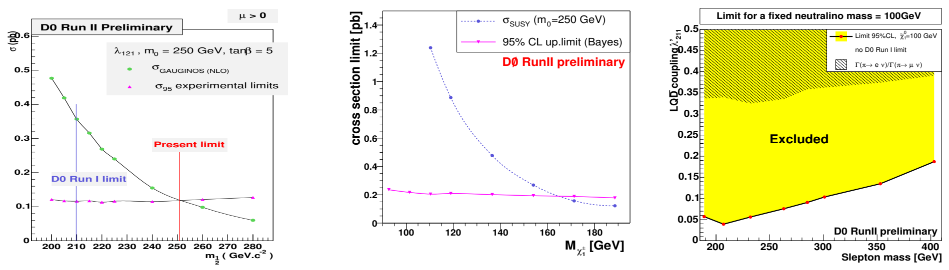
Events with at least two muons and a third lepton are selected from a total data sample of 160 ± 10 pb^{-1}. Again, the fourth lepton is not required, similar to the electron channel. The QCD background of the sample is estimated from the data, using a like sign dimuon sample with loose muon isolation cuts to improve the statistics and to avoid signal contamination. It is necessary to reweight the QCD events, so that the muon momentum spectrum agrees with that of the tight isolated sub-sample and describes the data. Two-dimensional cuts in planes span by the invariant di-muon mass, the missing E_T and the sum of the muon transverse momenta are applied to remove background. After all cuts 2 events are found in the data, while 0.63 ± 1.93 events are expected from Standard Modell processes.

4. Search for R-parity violation via λ'_{211} in $\mu\mu$ jet jet final state

The search in the resonant channel uses data with a luminosity of 154 ± 10 pb^{-1}. On a pre-selection sample consisting of two well measured muons and two jets further cuts are applied, to separate the signal from the SM background. The slepton and neutralino masses can be reconstructed, since all final state particles are detected. The neutralino mass is calculated using the two jets and the next to leading muon. The muon with the highest transverse momentum is with high probability created at the slepton decay vertex together with the neutralino. The cuts on the leading muon and the reconstructed Z, $\tilde{\chi}_1^0$ and $\tilde{l}$ candidate masses depend on the neutralino and slepton masses of the SUSY parameter point under study. No evidence for a signal is found. For each point limits on the coupling λ'_{211} and the cross section are calculated. For instance for the point $m_{\tilde{l}} = 263$ GeV and $m_{\tilde{\chi}_1^0} = 102$ GeV 2 data events are found while $1.1 \pm 0.3 \pm 0.2$ SM events are expected.

5. Results

In the absence of an excess in the data, upper limits are set on the production cross sections, based on a Bayesian approach and using Poisson statistics. The cross section limits (Fig. 1) are translated into limits on the gaugino and slepton masses at 95% CL (Table 1). The coupling parameters λ were chosen large enough to assure negligible lifetime for gauginos.



(a) (b) (c)

Fig. 1. DØ Search for non-vanishing λ_{121} (a), λ_{122}, (b) and λ'_{211} (c) couplings, 95% C.L. on the universal gaugino mass $m_{1/2}$, the lightest chargino mass $m_{\chi^\pm}$ and the slepton mass $m_{\tilde{l}}$.

Table 1. Gaugino and slepton mass exclusion limits with 95% CL for the R-parity violating coupling parameters λ_{121}, λ_{122} and λ'_{211}.

		95% CL limits	
$\boldsymbol{\lambda_{121}}$	$\mu < 0$:	$M_{\tilde{\chi}^\pm} > 184$ GeV	
$\tan\beta = 5$	$\mu > 0$:	$M_{\tilde{\chi}^\pm} > 181$ GeV	
$\boldsymbol{\lambda_{122}}$	$\mu < 0$:	$M_{\tilde{\chi}^0_1} > 84$ GeV,	$M_{\tilde{\chi}^\pm} > 160$ GeV
$\tan\beta = 5$	$\mu > 0$:	$M_{\tilde{\chi}^0_1} > 90$ GeV,	$M_{\tilde{\chi}^\pm} > 163$ GeV
$\boldsymbol{\lambda'_{211}}$	$M_{\tilde{l}} = 200$ GeV:	54 GeV< $M_{\tilde{\chi}^0_1} < 110$ GeV (excl.)	
$\mu < 0$	$M_{\tilde{\chi}^0_1} =$ 75 GeV:	160 GeV< $M_{\tilde{l}} < 255$ GeV (excl.)	
$\tan\beta = 2$	$M_{\tilde{\chi}^0_1} = 100$ GeV:	190 GeV< $M_{\tilde{l}} < 255$ GeV (excl.)	

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