DØ Note 4522-CONF

Search for Supersymmetry with R-parity Violation in the $ee\ell$ Final State

The DØ Collaboration
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A search has been performed for the $ee\ell$ ($\ell = e$ or μ) signature of the R-parity conserving production of supersymmetric particles followed by R-parity violating decays through a λ_{121} coupling . The data used for this analysis corresponds to an integrated luminosity of $238\,\mathrm{pb}^{-1}$ collected with the DØ detector at the Tevatron $p\bar{p}$ collider operating at a center of mass energy of 1.96 TeV. No events were selected, in agreement with the expectation of 0.45 ± 0.43 events from standard model processes. This result has been interpreted within the mSUGRA framework.

Preliminary Results for Summer 2004 Conferences

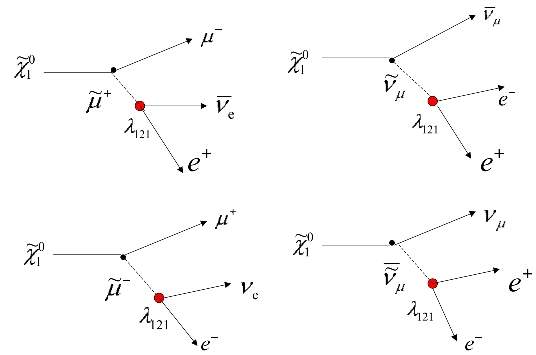


FIG. 1: Diagrams responsible for $\tilde{\chi}_1^0$ decays via an R-parity violating λ_{121} coupling.

I. INTRODUCTION

In this note, pair or associated production of supersymmetric particles in $p\bar{p}$ collisions is investigated, under the hypothesis that R-parity is violated via a λ_{121} coupling. The produced particles are assumed to (cascade) decay to the lightest neutralino $\tilde{\chi}_1^0$, which in turns decays to an electron, a charged lepton (electron or muon), and a neutrino (Fig. 1). The final state therefore contains four charged leptons, of which at least two are electrons, and exhibits missing energy due to the two neutrinos.

The data used for this analysis was collected by the DØ detector at the Tevatron operating at a center-of-mass energy of 1.96 TeV. It corresponds to an integrated luminosity of $238 \pm 16\,\text{pb}^{-1}$. The analysis described below requires the positive identification of two electrons, and of a third lepton as an electron or as a muon. For the sake of efficiency, it is not required that the fourth lepton be identified.

II. EVENT SIMULATION

All signal events were generated using the `SUSYGEN` program [1] in the framework of minimal supergravity (mSUGRA). The low energy parameters were calculated by the `SUSPECT` code [2] from the following inputs: $m_0 = 250\,\text{GeV}/c^2$, A_0=0, $\tan\beta = 5$, and both signs of μ; a scan over values of $m_{1/2}$ in the range from 150 to $300\,\text{GeV}/c^2$ has been performed. The λ_{121} coupling was set to 0.01, which is below the current limit of 0.05 [3] but large enough to ensure a prompt $\tilde{\chi}_1^0$ decay. The parton distribution functions used were `CTEQ5L`, and an average of 0.8 minimum-bias events was superimposed. The signal cross sections were obtained at next-to-leading order using the `GAUGINOS` program of Ref. [4].

The background standard model processes have been generated with `PYTHIA`, version 6.202 [5].

All generated events were processed through the full DØ detector simulation, and reconstructed with the same program as the data.

III. OBJECT IDENTIFICATION

The identification of electromagnetic objects relies on the longitudinal and transverse development of their shower in the calorimeter. Electrons are further identified by an associated track reconstructed in the inner magnetic spectrometer. For so-called *tight* electrons, it is further required that the track momentum and the shower energy be in agreement. A minimum transverse momentum of $5\,\text{GeV}/c$ is required.

The events considered in this analysis were triggered by various conditions on a single or two electromagnetic objects, with or without associated track requirements. The corresponding trigger efficiencies were parametrized using events selected by an independant trigger, based on the muon system.

Muons are identified in the dedicated outer spectrometer. It is required in addition that a matching track be reconstructed in the inner tracker. Here too, a minimum transverse momentum of $5\,\text{GeV}/c$ is required.

Jets are reconstructed in the calorimeter using the cone algorithm, with a radius $\mathcal{R}$ of 0.5 in $\eta - \phi$ space, where η is the pseudorapidity. Energy scale corrections are applied to these jets and to the missing transverse energy, computed

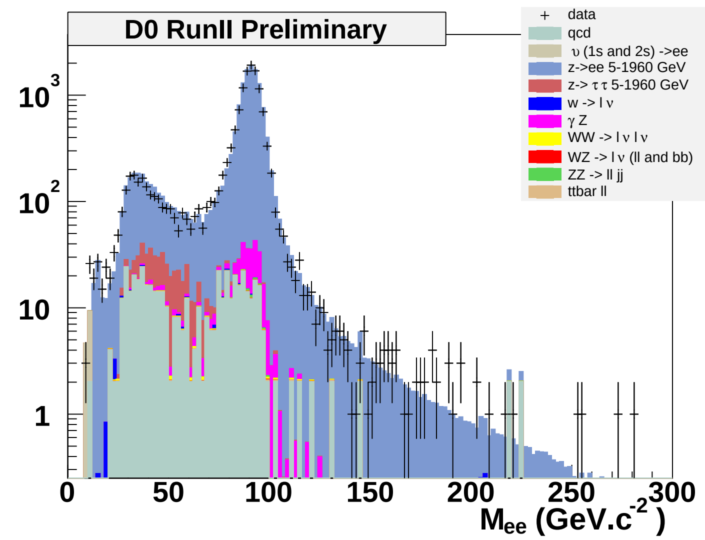


FIG. 2: Invariant mass distribution of the two tight electrons of the control sample.

from all calorimeter cells. The missing energy is also corrected for the presence of any muons.

IV. CONTROL SAMPLE AND QCD BACKGROUND

A control sample of dielectron events was selected by requiring two tight electrons with minimum transverse momenta of 15 and 10 GeV/c. These electrons must furthermore be isolated among themselves and with respect to any jets in the event by at least $\Delta\mathcal{R} = 0.7$. The dielectron mass distribution of this sample is shown in Fig. 2. Good agreement is observed with the expectation from standard model processes, dominated by Z and Drell-Yan production, with the inclusion of a "QCD background".

Here and in the following, this QCD contribution originating from jets misidentified as electrons is determined by applying to the data all selection cuts, except that an *inverted* shower shape requirement has to be fulfilled by one of the electrons. The normalization of this "QCD sample" is performed once and for all using the dielectron control sample, in the mass range from 15 to 60 GeV/c^2 after subtraction of the expected contribution from standard model processes.

V. EVENT SELECTION

To select a possible trilepton signal originating from R-parity violating decays of supersymmetric particles, the following cuts are applied to the sample of events containing at least two tight electrons:

- **cut0** a third lepton (electron or muon) must be found. The transverse momenta of the three leptons must be larger than 15, 10 and 5 GeV/c. The three leptons must be isolated from one another by at least $\Delta\mathcal{R} = 7$;
- **cut1** the muon, if any, must be identified in all layers of the outer spectrometer;
- **cut2** Z events are removed by requiring that no dielectron mass be in the range from 80 to 100 GeV/c^2;
- **cut3** the muon, if any, must be isolated: a transverse energy of less than 5 GeV must be detected in the calorimeter in a hollow cone of radii 0.1 and 0.4 around the muon direction, and the scalar sum of transverse momenta of all tracks (other than the muon) in a cone of radius 0.5 must be smaller than 5 GeV/c;
- **cut4** the electrons must have hits in the innermost layers of the inner tracker. The purpose of this cut is to reject electrons from photon conversion;
- **cut5** the missing transverse energy must exceed 15 GeV.

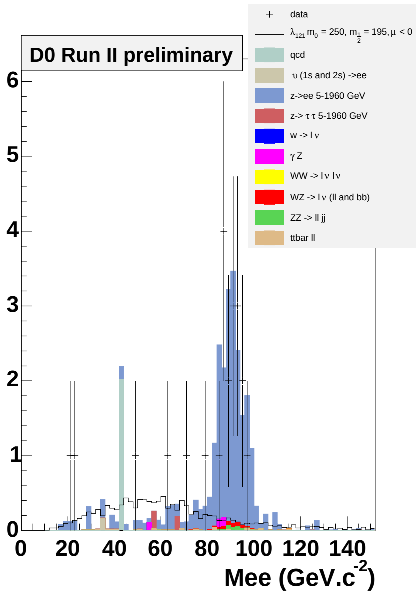


FIG. 3: Dielectron mass distribution after **cut0**. Data, standard model backgrounds and signal ($m_{1/2} = 195\,\mathrm{GeV}/c^2$, $\mu < 0$) are shown.

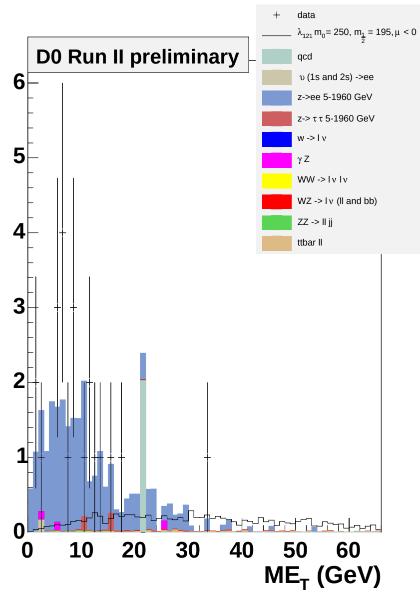


FIG. 4: Missing transverse energy distribution after cut0. Data, standard model backgrounds and signal ($m_{1/2} = 195\,\mathrm{GeV}/c^2$, $\mu < 0$) are shown.

TABLE I: Number of data events and of expected background events after each cut. The first error is statistical, the second is systematic and includes cross section, luminosity, and trigger uncertainties

Process	cut0	cut1	cut2	cut3	cut4	cut5
$\gamma^*/Z \to ee$	24.8	9.6	2.6	0.9	0.6	0.15
	$\pm 2.0 \pm 1.7$	$\pm 1.4 \pm 0.7$	$\pm 0.7 \pm 0.1$	$\pm 0.4 \pm 0.1$	$\pm 0.3 \pm 0.01$	$\pm 0.19 \pm 0.02$
$\gamma^*/Z \to \tau\tau$	0.4	0.2	0.2	0.2	0.2	0.23
	$\pm 0.7 \pm 0.1$	$\pm 0.4 \pm 0.1$	$\pm 0.4 \pm 0.1$	$\pm 0.4 \pm 0.1$	$\pm 0.4 \pm 0.1$	$\pm 0.4 \pm 0.1$
$Z\gamma \to \gamma ee$	0.3	0.10				
	$\pm 0.5 \pm 0.1$	$\pm 0.16 \pm 0.01$				
WW, WZ, ZZ	0.7	0.5	0.053	0.049	0.045	0.044
	$\pm 0.1 \pm 0.1$	$\pm 0.1 \pm 0.1$	$\pm 0.005 \pm 0.005$	$\pm 0.005 \pm 0.005$	$\pm 0.005 \pm 0.004$	$\pm 0.005 \pm 0.004$
$t\bar{t} \to ll$	0.6	0.45	0.37	0.02	0.019	0.019
	$\pm 0.1 \pm 0.1$	$\pm 0.07 \pm 0.05$	$\pm 0.06 \pm 0.04$	$\pm 0.02 \pm 0.01$	$\pm 0.019 \pm 0.002$	$\pm 0.019 \pm 0.002$
Υ	0.2					
	$\pm 0.3 \pm 0.1$					
QCD	2.0					
	± 0.4					
total bkg	29.1	11.0	3.3	1.2	0.87	0.45
	$\pm 2.2 \pm 1.8$	$\pm 1.4 \pm 0.7$	$\pm 0.8 \pm 0.1$	$\pm 0.6 \pm 0.1$	$\pm 0.48 \pm 0.04$	$\pm 0.43 \pm 0.02$
data	22	11	5	2	2	0

Figures 3 and 4 show the dielectron mass and missing transverse energy distributions after **cut0**.

The numbers of data and expected background events are given in Table I. Two events remain after **cut4**, most likely due to the $\gamma^*/Z \to ee$ process with a radiated photon misidentified as an electron. No events remain after **cut5**.

VI. RESULTS

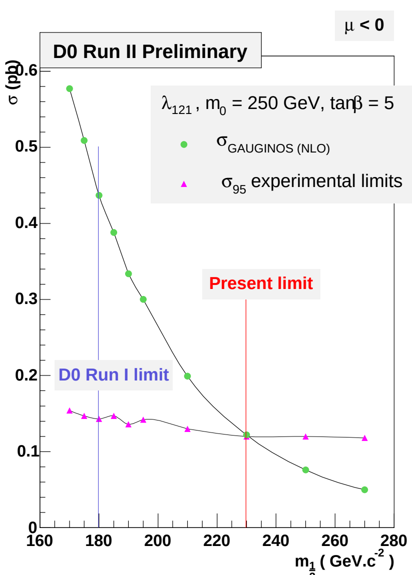
The efficiency of the present analysis is given in Table II for $m_0 = 250\,\mathrm{GeV}/c^2$, $\tan\beta = 5$, $A_0 = 0$, for various $m_{1/2}$ values and for both signs of μ.

The main sources of systematic errors are due to the determination of the integrated luminosity (6.5%), the parametrization of the trigger efficiency (3%), and the knowledge of the cross sections of the standard model processes

TABLE II: For various values of $m_{1/2}$ and for both signs of μ, $\tilde{\chi}_1^0$ mass, selection efficiency, 95% CL cross section upper limit and theoretical cross section. The other mSUGRA parameters are $m_0 = 250\,\mathrm{GeV}/c^2$, $\tan\beta = 5$ and A_0=0.

sign of μ	$m_{1/2}$ GeV/c^2	$m_{\tilde{\chi}_1^0}$ GeV/c^2	efficiency	σ_{95} pb	σ_{th} pb
$\mu < 0$	270	111.3	0.107 ± 0.003	0.119	0.050
	250	103.0	0.105 ± 0.003	0.122	0.076
	230	94.8	0.105 ± 0.003	0.122	0.122
	210	86.4	0.097 ± 0.003	0.132	0.199
	195	80.4	0.089 ± 0.003	0.143	0.300
	190	78.3	0.093 ± 0.003	0.137	0.334
	185	76.2	0.086 ± 0.003	0.148	0.388
	180	74.2	0.088 ± 0.003	0.145	0.437
	175	72.1	0.086 ± 0.003	0.148	0.509
	170	70.1	0.082 ± 0.003	0.156	0.577
$\mu > 0$	280	110.3	0.099 ± 0.003	0.129	0.060
	260	101.7	0.104 ± 0.003	0.123	0.098
	240	93.0	0.110 ± 0.003	0.116	0.157
	225	86.4	0.109 ± 0.003	0.117	0.240
	220	84.3	0.112 ± 0.003	0.114	0.269
	215	82.1	0.108 ± 0.003	0.118	0.316
	210	79.8	0.109 ± 0.003	0.117	0.357
	205	77.6	0.108 ± 0.003	0.118	0.420
	200	75.4	0.104 ± 0.003	0.123	0.477
	180	66.3	0.101 ± 0.003	0.126	0.887

(a)



(b)

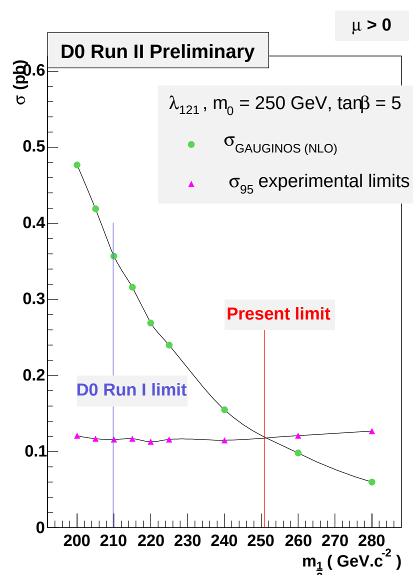


FIG. 5: Comparison of the 95% CL cross section upper limit with the theoretical prediction as a function of $m_{1/2}$ for $m_0 = 250\,\mathrm{GeV}/c^2$,$\tan\beta = 5$, $A_0 = 0$, and for (a) $\mu < 0$ and (b) $\mu > 0$.

(9%).

From the observation of zero events while 0.45 ± 0.43 are expected, 95% CL cross section upper limits have been derived and compared to the theoretical predictions. The result, shown in Fig. 5, allows 95% CL lower limits to be set on $m_{1/2}$: $231\,\mathrm{GeV}/c^2$ for $\mu < 0$ and $251\,\mathrm{GeV}/c^2$ for $\mu > 0$ (Table III).

TABLE III: Cross section upper limits σ_{95} and $m_{1/2}$ lower limits at 95% CL from this analysis and from previous DØ Run I results [6] ($m_0 = 250\,\mathrm{GeV}/c^2$, $\tan\beta = 5$, $A_0 = 0$).

	Preliminary Run II σ_{95} pb	Run I σ_{95} pb	Preliminary Run II 95 % C.L. $m_{1/2}$ limit GeV/c^2	Run I 95 % C.L. $m_{1/2}$ limit GeV/c^2
$\mu < 0$	0.116	0.248	> 231	> 180
$\mu > 0$	0.115	0.215	> 251	> 210

VII. CONCLUSIONS

A search for events containing two electrons and a third lepton (e or μ) with missing transverse energy has been performed in $238\,\mathrm{pb}^{-1}$ of data recorded by the DØ detector. No events have been selected, in agreement with the expectation of 0.45 ± 0.43 from standard model processes. The results have been interpreted in the framework of minimal supergravity with R-parity violation via a λ_{121} coupling. For $m_0 = 250\,\mathrm{GeV}/c^2$, $\tan\beta = 5$ and $A_0 = 0$, values of $m_{1/2}$ smaller than 231 and $251\,\mathrm{GeV}/c^2$ are excluded by this search at 95% CL for $\mu < 0$ and $\mu > 0$, respectively. These results improve on those previously obtained with Run I data.

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