Searches for R-parity Violating Supersymmetry with the DØ Detector

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Outline

- R-parity violating supersymmetry
- Gaugino searches in trileptons
- Resonant slepton production
- Neutral, long-lived particles
- Summary
R-Parity Violating Supersymmetry

\[ R - \text{parity} : R_P = (-1)^{3B+L+2S} \]

- \( R_p = +1 \) for normal particles
- \(-1\) for supersymmetric particles

\[ W = W_{MSSM} + W_{RPV} \]

\[ W_{RPV} = \frac{1}{2} \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k \]

\( \Delta L=1 \): Lepton number violation
Gauge symmetry: \( \lambda_{ijk} = -\lambda_{ijk} \rightarrow 9 \lambda \) couplings

Generally assume only one non-zero coupling at a time

\( \Delta L=1 \): Lepton number violation
27 \( \lambda' \) couplings

B = baryon number
L = lepton number
S = spin

I,j,k = 1,2,3 generation indices

L: lepton doublet superfield
E: lepton singlet superfield
Q: quark doublet superfield
D: down-like quark singlet

\( \lambda, \lambda', \lambda'' \) : Yukawa couplings
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Search for LLE Couplings

Pair Production

$$\bar{q}' \rightarrow W^\pm \tilde{\chi}^\pm_1$$

$$q \rightarrow Z^0 \tilde{\chi}^0_1$$

$\tilde{\chi}^0_1$ is assumed to be LSP

$\lambda > 0.01$ (prompt decay)

mSUGRA:

- $m_0 = 1$ TeV, $m_{1/2} = 280$ GeV
- $\tan\beta = 5$, $\mu > 0$, $A_0 = 0$

RPV Decays

Signal: 4 leptons + 2 neutrinos

Analysis: 3 leptons + missing $E_T$ (MET)
<table>
<thead>
<tr>
<th>Analysis</th>
<th>λ_{121}</th>
<th>λ_{122}</th>
<th>λ_{133}</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>eee or eeµ</strong></td>
<td>electron p_T &gt; 20 GeV</td>
<td>muon p_T &gt; 12 GeV</td>
<td>electron p_T &gt; 10 GeV</td>
</tr>
<tr>
<td></td>
<td>electron p_T &gt; 20 GeV</td>
<td>muon p_T &gt; 8 GeV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>electron or muon p_T &gt; 10 GeV</td>
<td>electron or muon p_T &gt; 5 GeV</td>
<td>electron or muon p_T &gt; 4 GeV</td>
</tr>
<tr>
<td><strong>missing E_T &gt; 15 GeV</strong></td>
<td>missing E_T &gt; 10 GeV</td>
<td>18 &lt; M_{ee} &lt; 80 GeV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Σp_T(lepton) &gt; 50 GeV</td>
<td>MET/√S_T &gt; 1.5 GeV^{1/2}</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2D cut (M_{µµ}, MET)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ee Sample

μμ Sample w/ Z veto

\[ \text{Signal x50} \]

\[ \tau \text{ neural network} \]

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<th>SM Background</th>
<th>Data</th>
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<tr>
<td>eee or eeμ ((\lambda_{121}))</td>
<td>(0.9 \pm 0.4 \pm 0.1)</td>
</tr>
<tr>
<td>μμμ or μμe ((\lambda_{122}))</td>
<td>(0.4 \pm 0.1 \pm 0.1)</td>
</tr>
<tr>
<td>eeτ ((\lambda_{133}))</td>
<td>(1.3 \pm 1.7 \pm 0.5)</td>
</tr>
</tbody>
</table>
SUSY Limits

mSUGRA

unconstrained MSSM
(no relation between $M_1$ and $M_2$)

Mass limits:

$M(\chi_1^0) > 119$ GeV

$M(\chi_1^\pm) > 234$ GeV

$\chi_1^0 - \chi_1^\pm$ plane
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Search for Resonant Slepton Production

RPV Production:

\[ \lambda'_{211} \]

RPV Decay: \( \chi_1^0 \rightarrow \mu qq \)

\[ \tilde{\mu} \rightarrow \tilde{\chi}_1^0 \mu \]
\[ \tilde{\mu} \rightarrow \tilde{\chi}_{2,3,4}^0 \mu \]
\[ \tilde{\nu}_\mu \rightarrow \tilde{\chi}_1^\pm \mu \]

\[ \tilde{\chi}^0 Z \]
\[ \tilde{\chi}_1^0 W^\pm \]

Final state: 2 muons and 2 jets

- 3 channels analyzed separately
- Cross-section limits for each channel
- Combined within mSUGRA

can reconstruct \( \chi_1^0 \) mass
• Selection criteria tuned for each slepton/neutralino mass
  • Example:
    • \( m(\tilde{l}) = 260 \text{ GeV} \)
    • \( m(\tilde{\chi}) = 100 \text{ GeV} \)

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<th>SM Background</th>
<th>Data</th>
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<tr>
<td>( \tilde{\mu} \to \tilde{\chi}_1^0 \mu )</td>
<td>11.9 ± 2.1 ± 1.6</td>
<td>14</td>
</tr>
<tr>
<td>( \tilde{\mu} \to \tilde{\chi}_{2,3,4}^0 \mu )</td>
<td>25.4 ± 3.2 ± 5.4</td>
<td>28</td>
</tr>
<tr>
<td>( \tilde{\nu}<em>\mu \to \tilde{\chi}</em>{1,2}^{\pm} \mu )</td>
<td>6.5 ± 1.6 ± 1.6</td>
<td>8</td>
</tr>
</tbody>
</table>
Limits

Limits on $\sigma \times \text{BR}$

$\tilde{\mu} \rightarrow \tilde{\chi}_1^0 \mu$

Limits on $\lambda'_{211}$
combined within mSUGRA

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Search for Neutral, Long-lived Particles

- Search for pair production of two neutral particles
- Look for decay well away from production point
  - two isolated muons $p_T > 10$ GeV
- Sample signal
  - $\chi_1^0$ pair production
  - lifetime depends on $\lambda_{122}$ and slepton mass
Long Decay Lengths

DCA – distance of closest approach
require: $DCA_{x,y} > 0.01$ and $DCA_{z} > 0.1$ cm

$radius = \sqrt{(X - X_{PV})^2 + (Y - Y_{PV})^2}$
require: $5 < radius < 20$ cm

use $K_S \rightarrow \pi\pi$ for efficiency studies
expected background:
$0.8 \pm 1.1 \pm 1.1$ events
observed 0 events
**Limits on NLLP Production**

**NuTeV**
- neutrino experiment at Fermilab
- observed 3 dimuon events in decay region

**DØ** sets limits on pair production cross-section vs. lifetime

Excludes some interpretations of NuTeV result
Summary

- **DØ** has completed several searches for RPV SUSY
  - LLE: trileptons
  - LLQ: resonant sleptons
  - NLLP: long-lived particles
- No excess is observed in the data
- Significantly improved limits are set
- More data is available and on the way
  - Run II still has a lot of discovery potential
    - 4x statistics already available, 16x possible