Overview

Search for R-Parity violating SUSY with the DØ-Experiment

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on behalf of the DØ-Collaboration

- R-parity violating Supersymmetry
- SUSY pair and resonant production
- Decay channels
- 3 Analyses approaches depending on the R-parity violating coupling $\lambda_{121}$, $\lambda_{122}$, $\lambda'_{211}$
- Preliminary Results

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Großgeräte der physikalischen Grundlagenforschung
Effective Luminosity used for analyses:
\[ \int L \, dt = 160 - 240 \, \text{pb}^{-1} \]
R-parity Violating Supersymmetry

R-parity: \( R_{\rho} = (-1)^{3B+L+2S} \)

\[ W = W_{MSSM} + W_{R_{\rho}} \]

\[ W_{R_{\rho}} = \frac{1}{2} \lambda_{ijk} \epsilon_{ab} L^a_i L^b_j E^c_k + \lambda'_{ijk} \epsilon_{ab} L^a_i Q^b_j D^c_k + \lambda''_{ijk} \epsilon_{xyz} U^c_i D^c_j D^c_k + \kappa_{ijk} \epsilon_{ab} L^a_i H^b_2 \]

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

Trilepton channel
→ multi lepton final state

Resonant production
→ two muon and two jets final state

Chiral superfields:
- \( L \): lepton doublet superfield
- \( E \): lepton singlet superfield
- \( Q \): quark doublet superfield
- \( D \): down-like quark singlet superfield

\( \lambda, \lambda', \lambda'' \): Yukawa couplings

References:
- H. Dreiner, et.al., Search for R-Parity Violation at Run-II of the Tevatron, hep-ph/9906224
Production

- R-parity conserved
- Search for subsequent decays of the neutralinos and charginos via the tri-lepton R-parity violating LLE couplings $\lambda_{121}$, $\lambda_{122}$ and $\lambda_{133}$.
  → Final states with 4 leptons or more; analyses ask for at least 3 leptons.

→ R-parity violating production ($\lambda'_{211}$)
→ Di-muon and di-jet final state

Other modes:
- sneutrino resonance
  → di-jet, muon & missing $E_T$ final state
- t-channel slepton exchange
Neutralino Decay Channels

- Only 1 neutralino in **resonant** channel
- no missing $E_T$
- $\mu\mu$ jet jet

- **Pair produced** neutralinos decay each via LLE couplings $\lambda$ into 2 charged leptons and 1 neutrino.
- More than 1 possible final state for each coupling $\lambda$.
- missing $E_T$ (2 neutrinos in final state)
- $eeee, eee\mu, e\mu\mu, \mu\mu\mu, e\tau\tau, \tau\tau\tau, \tau\tau\tau$ (+$\nu\nu$)
QCD Background ($\lambda_{122}$)

**Dominating:** mostly heavy flavor (bbar and ccbar), hard to simulate

→ estimate from data

**Background-Sample:** like-sign muons, “almost” isolated (avoid signal region!); “QCD”-background dominates compared to other SM-processes

Contamination from a possible signal estimated to be negligible compared to the statistical and systematic uncertainty

<table>
<thead>
<tr>
<th>isolation criteria</th>
<th>tight</th>
<th>soft</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAL: $E_{\text{cal}}(R&lt;0.4) - E_{\text{cal}}(R&lt;0.1)$</td>
<td>$&lt; 2.5 \text{ GeV}$</td>
<td>$2.5 &lt; \text{iso} &lt; 7.0 \text{ GeV}$</td>
</tr>
<tr>
<td>Track: $\sum p_T(R&lt;0.4) - \sum p_T(R&lt;0.1)$</td>
<td>$&lt; 2.5 \text{ GeV}$</td>
<td>$2.5 &lt; \text{iso} &lt; 7.0 \text{ GeV}$</td>
</tr>
</tbody>
</table>

- Create two more sub-samples:
  - two isolated $\mu$'s (A)
  - 1 iso. $\mu$ + 1 almost-iso. $\mu$ (B)

- Weight the events of the almost-iso sample with: $R_{\text{iso}} = A/B$

- Finally normalize to the data
Resonant Channel Signal (\(\lambda'_{211}\))

Final cuts depend on neutralino and slepton mass of the SUSY point under study:

<table>
<thead>
<tr>
<th>cut</th>
<th>range</th>
</tr>
</thead>
<tbody>
<tr>
<td>(p_T(\mu_1))</td>
<td>&gt; 21 GeV+15/80 ((M_\mu - M_\chi))</td>
</tr>
<tr>
<td>91 GeV – (5+(M_\chi/9)) &lt; (M_{\mu\mu}) &lt; 91 GeV+(5+(M_\chi/9))</td>
<td></td>
</tr>
<tr>
<td>(M_\chi - 40) GeV</td>
<td>&lt; (M_{\mu2,jet1,jet2}) &lt; (M_\chi + 20) GeV</td>
</tr>
<tr>
<td>(M_\mu - 0.2\cdot M_\mu)</td>
<td>&lt; (M_{\mu1\mu2,jet1,jet2}) &lt; (M_\mu + 0.2\cdot M_\mu)</td>
</tr>
</tbody>
</table>

After all cuts
2 events found, 1.1±0.5 SM events exp.

\(\widetilde{\chi}_1^0 = 102\) GeV

Invariant mass of 2 jets and the lower energetic muon
- muon is from \(\widetilde{\chi}\)-decay
- muon is from \(\widetilde{\mu}\)-decay
- neither nor

\(\widetilde{\mu} = 262\) GeV

Invariant mass of 2 jets and 2 muons

Generated with SUSYGEN and passed through full detector simulation & reconstruction.
Data Selection and Control Plots ($\lambda_{122}$)

**cut 1:** $p_T(\mu_1) > 11$ GeV, $p_T(\mu_2) > 6$ GeV, matched central track

**cut 2:** tight muon isolation

**cut 3:** separation in $\Delta R$ between muons (and possible jets)

**cut 4:** vertex quality cuts

**2-dimensional cuts:**

**cut 5:** MET – $M_{\mu_1\mu_2}$ plane: Signal tends to have higher MET and lower $M_{\mu_1\mu_2}$ than the bg.

**cut 6:** MET – $p_T(\mu_1) + p_T(\mu_2)$ plane

**cut 7:** $\Delta \phi (\mu_1, \mu_2) - M_{\mu_1\mu_2}$ plane

**Details:**

**cut 5:** $M_{\mu_1\mu_2} < 6$ GeV / $(-6.5 \cdot 10^{-4} \cdot \text{MET} + 0.027 \text{ GeV}) + 240 \text{ GeV}$, $M_{\mu_1\mu_2} > -4.4 \cdot \text{MET} + 75 \text{ GeV}$

**cut 6:** MET $> -4 \cdot (p_T(\mu_1) + p_T(\mu_2)) + 80$ GeV

MET $> 0.5 \cdot (p_T(\mu_1) + p_T(\mu_2)) - 20$ GeV

**cut 7:** $\Delta \phi (\mu_1, \mu_2) < 2.6$ for: 80 GeV $< M_{\mu_1\mu_2} < 100$ GeV

After all cuts
2 events found, 0.6±1.9 events expected

Data Selection and Control Plots ($\lambda_{121}$)

- 3 leptons ($\Delta R > 0.7$ between leptons) with $p_T > 15, > 10, > 5$ GeV
- vertex quality cut
- cut 1: good tracking for muons
- cut 2: cut away $Z$ mass ± 10 GeV
- cut 3: isolated muons
- cut 4: lepton track quality: at least 2 hits in the silicon
- cut 5: missing $E_T > 15$ GeV

After all cuts
0 events found, 0.5±0.4 events expected
Systematic Uncertainties

- **all analyses**
- Luminosity: 6.5% absolute
- **muons**: reconstruction, isolation, trackmatching efficiency corr. 4%
- **electrons**: identification, likelihood
- Uncertainty on Z/γ* cross section (difference NLO/NNLO) 3%

- $\lambda_{121}$
- Electron trigger efficiency $\sim$2%

- $\lambda_{122}$
- Muon trigger efficiency (varied weighting factor): 5% to 12%
- Uncertainty on QCD-background (dominant: low statistics)

- $\lambda'_{211}$
- Muon trigger efficiency (varied weighting factor): 6% to 9%
- Jet Energy Scale (dominant) 30%
Cross Section Limits for $\lambda_{121}$

Channel with at least 2 e’s

$\lambda_{121}$, $m_0 = 250$ GeV, $\tan\beta = 5$

$\tilde{\chi}_1^\pm > 183$ GeV

$\tilde{\chi}_1^\pm > 200$ GeV
Cross Section Limits for \( \lambda_{122} \)

Channel with at least 2 \( \mu \)'s

\[ \mu < 0 \]

This translates to:

\[
\begin{align*}
    m_{\tilde{\chi}_0^0} &> 84 \text{ GeV} \\
    m_{\tilde{\chi}_1^\pm} &> 160 \text{ GeV} \quad \text{for } \mu < 0
\end{align*}
\]

\[ \mu > 0 \]

\[
\begin{align*}
    m_{\tilde{\chi}_0^0} &> 90 \text{ GeV} \\
    m_{\tilde{\chi}_1^\pm} &> 165 \text{ GeV} \quad \text{for } \mu > 0
\end{align*}
\]
Cross Section Limits for $\lambda'_{211}$

**$m_{\tilde{\chi}_1^0} = 75$ GeV**

- Limit for a fixed neutralino mass $= 75$ GeV and $\lambda'_{211} = 0.07$
- Excluded
- Run I
- $\lambda'_{211} = 0.07$

**$m_{\tilde{\mu}} = 200$ GeV**

- Limit for a fixed slepton mass $= 200$ GeV and $\lambda'_{211} = 0.07$
- Excluded
- Run I
- $\lambda'_{211} = 0.07$

Resonant Channel
## Candidate Event ($\lambda_{121}$)

<table>
<thead>
<tr>
<th>Event #2</th>
<th>Runnum</th>
<th>180 116</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evtnum</td>
<td>4 428 470</td>
<td></td>
</tr>
<tr>
<td>type</td>
<td>eee</td>
<td></td>
</tr>
<tr>
<td>MET</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td># of muons</td>
<td>1 (nseg = -2)</td>
<td></td>
</tr>
<tr>
<td>(pt, eta, phi)</td>
<td>(17.4,1.99,2.02)</td>
<td></td>
</tr>
<tr>
<td>Mee 1-2, 2-3, 1-3, ($M_{123}$)</td>
<td>63.4, 17.7, 31.9 (73.1)</td>
<td></td>
</tr>
<tr>
<td>Pt 1, 2, 3</td>
<td>35.6, 28.4, 9.1</td>
<td></td>
</tr>
<tr>
<td>Eta 1, 2, 3</td>
<td>-1.78,-1.83,-1.64</td>
<td></td>
</tr>
<tr>
<td>Phi 1, 2, 3</td>
<td>1.39, 4.36, 5.50</td>
<td></td>
</tr>
<tr>
<td>Charge 1, 2, 3</td>
<td>+1, -1, -1</td>
<td></td>
</tr>
</tbody>
</table>

Fails last cut (MET > 15 GeV)
Conclusions

• Presented Searches for RPV SUSY through
  – LLE couplings $\lambda_{121}, \lambda_{122}$ into multi lepton final state and
  – LQD coupling $\lambda'_{211}$ in the two muons plus two jets final state
• Data agrees well with Standard Model expectation
• Exclusion limits have been set, improving on DØ Run I results
• Already 0.5 fb$^{-1}$ data on tape $\approx$ 2 – 3 times more than used for these analyses

- Conference Notes 4522, 4531 and 4535 with more detailed information are available at
  [http://www-d0.fnal.gov/Run2Physics/WWW/results/NP/np.htm](http://www-d0.fnal.gov/Run2Physics/WWW/results/NP/np.htm)
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