Searches for New Phenomena with Lepton Final States at the Tevatron including charginos, neutralinos, excited leptons and unexpected signatures

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The path to new understanding is through discovery

Historically, lepton final states have led to numerous discoveries

Many possibilities = many searches

Outline

• SUSY Trileptons
  • combined final states
• $W'$
• $Z'$

• Excited electrons
• RS Gravitons
• NLLP
• Summary
Charginos and Neutralinos in Trileptons

Advantages
- small backgrounds

Disadvantages
- 3\textsuperscript{rd} lepton is low $p_T$
- small cross-section $\times$ branching ratio

R-parity conserved

$p\bar{p} \rightarrow \tilde{\chi}_1 \tilde{\chi}_2^0$

Trileptons:

$\tilde{\chi}_1^\pm \rightarrow l\nu\tilde{\chi}_1^0$

$\tilde{\chi}_2^0 \rightarrow l\bar{l}\tilde{\chi}_1^0$

Techniques
- all 3 leptons
- 2 leptons + track
- same-sign leptons
### 14 Combined Results

<table>
<thead>
<tr>
<th>3lep</th>
<th>ee+1 CEM</th>
<th>ee+1 plug</th>
<th>eμ+1</th>
<th>μμ+1 high p_T</th>
<th>μμ+1 CEM</th>
<th>μe+1 plug</th>
<th>ee + track</th>
<th>μμ+1 low p_T</th>
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</thead>
<tbody>
<tr>
<td>Lumi (pb⁻¹)</td>
<td>1034</td>
<td>954</td>
<td>1034</td>
<td>745</td>
<td>745</td>
<td>680</td>
<td>1013</td>
<td>976</td>
</tr>
<tr>
<td>Bkgd</td>
<td>0.44 ± 0.08</td>
<td>0.34 ± 0.10</td>
<td>0.28 ± 0.09</td>
<td>0.64 ± 0.18</td>
<td>0.42 ± 0.08</td>
<td>0.36 ± 0.07</td>
<td>0.97 ± 0.28</td>
<td>0.42 ± 0.12</td>
</tr>
<tr>
<td>Data</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LS lep</th>
<th>ee LS</th>
<th>ee_{si} LS</th>
<th>e_{si}e_{si} LS</th>
<th>e_{si}μ LS</th>
<th>eμ LS</th>
<th>μμ LS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumi (pb⁻¹)</td>
<td>993</td>
<td>993</td>
<td>993</td>
<td>971</td>
<td>971</td>
<td>1087</td>
</tr>
<tr>
<td>Bkgd</td>
<td>0.10 ± 0.10</td>
<td>0.50 ± 0.30</td>
<td>1.30 ± 0.30</td>
<td>1.70 ± 0.20</td>
<td>2.30 ± 0.50</td>
<td>0.90 ± 0.10</td>
</tr>
<tr>
<td>Data</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>
SUSY Interpretation

mSUGRA (inspired)

\[ \tan \beta = 3, \ A_0 = 0, \ \mu > 0, \ m_0 = 60 \]

A. mSUGRA
no limit yet

B. MSSM
same as mSUGRA
without slepton mixing
\[ M(\chi_1^{\pm}) > 130 \text{ GeV} \]

C. MSSM
set lepton BR to
same as W/Z
no limit yet
4 Combined Results

- New channels
  - $\mu\mu l$ and $e\mu l$

<table>
<thead>
<tr>
<th>Channel</th>
<th>Lumi (pb$^{-1}$)</th>
<th>Bkgd</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>$eel$</td>
<td>1000</td>
<td>0.76 ± 0.67</td>
<td>0</td>
</tr>
<tr>
<td>$\mu\mu l$</td>
<td>1100</td>
<td>0.32 ± 1.34</td>
<td>2</td>
</tr>
<tr>
<td>$\mu\mu l$</td>
<td>1100</td>
<td>0.94 ± 0.40</td>
<td>0</td>
</tr>
<tr>
<td>LS $\mu\mu$</td>
<td>1000</td>
<td>1.1 ± 0.4</td>
<td>1</td>
</tr>
</tbody>
</table>
SUSY Limits from Trileptons

- Use 3 SUSY models
  - mSUGRA inspired
  - \( m(\chi_1^\pm) \approx m(\chi_2^0) \approx 2m(\chi_1^0) \)
  - no slepton mixing
  - large \( m_0 \)
    - W/Z decays dominate
    - no sensitivity
  - 3\( \ell \)-max
    - \( m(\text{slepton}) \) slightly larger than \( m(\chi_2^0) \)
    - \( M(\chi_1^\pm) > 141 \text{ GeV} \)
  - heavy squarks
    - relax scalar mass unification
W’ Search

- Search for additional charged gauge boson
- Events w/ electron (E_T>30 GeV, MET>30 GeV, M_T>150 GeV)

Data = 630 events
Bkgd = 623 ± 18 +83 −75 events
MW’ > 965 GeV @ 95% CL
DiElectron High Mass Search

- Select events with two electrons ($E_T > 25$ GeV)
- Search for narrow high mass resonances
  - $150 < M(ee) < 950$ GeV
  - Model independent
  - No excess found
- $Z'$ (spin 1) additional neutral gauge boson
  - $Z'_{SM} > 923$ GeV
  - $Z'_I > 729$ GeV
  - $Z'_\psi > 822$ GeV
  - $Z'_\chi > 822$ GeV
  - $Z'_\eta > 891$ GeV

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RS Gravitons

- Use extra dimensions to address hierarchy problem
- Resonant production of gravitons at Tevatron
- Combine dielectron w/ diphoton search
  - Diphoton is twice as sensitive (spin 2)
- CDF
  - $M_G > 889$ GeV for $k/M_{pl} = 0.1$
- D0
  - $M_G > 865$ GeV for $k/M_{pl} = 0.1$
Excited Electrons

- Some models predict quarks and leptons are made of smaller pieces
  - allows excited states ($e^*$, $\mu^*$, $q^*$, etc)
- Search in $ee\gamma$
  - possible decay mode $e^* \rightarrow e\gamma$
  - $p_T(e_1/e_2/\gamma) > 25/15/15$ GeV
  - observed 259 events
  - expectation $= 232 \pm 3 \pm 29$ events
- $m_{e^*} > 756$ GeV
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
  - RPV SUSY
  - $\chi_1^0$ pair production
Limits on NLLP Production

0 events observed
0.75 ± 1.1 ± 1.1 expected

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

• The Tevatron has an exciting program of searches for new phenomena using leptons
• I’ve shown some of the more recent ones
  • Trileptons, W’, Z’, RS gravitons, NLLP
• Many more not covered
  • RPV SUSY, technicolor, leptoquarks, charged massive stable particles and more
• Significant discovery potential remains
• Also, excellent preparation for initial LHC searches
• Now for some jets and photons…