SEARCHES FOR SQUARKS AND GLUINOS USING DATA FROM DØ

Catherine Biscarat (IN2P3/CNRS), on behalf of the DØ Collaboration
 Covered here:

- **Inclusive search for squarks and gluinos in Jets + MET**
  - PLB, 660, 449 (2008), 2.1 fb$^{-1}$

- **Searches for squarks in Jets + tau + MET**
  - submitted to PLB 2 weeks ago, 1.0-2.1 fb$^{-1}$

- Both are mSUGRA with R-parity conserved

Searches for third generation squarks not covered here

- search for sbottom production at DØ – see talk by Sergei Uzunyan this week
- search for stop production at DØ – see talk by Dennis Mackin this week
• Multi purpose detector (electrons, muons, taus, jets, MET, ...)

• Central tracking system + solenoid (2T)
  - Inner silicon detectors displaced vertex
  - Scintillating fiber tracker track momentum

• Calorimeter
  - Preshower (scintil. fibers)
  - EM and Hadronic Uranium/liquid argon calorimeter
    - High granularity (resolution)
    - Good hermiticity (|η| < 4.2)

• Muon spectrometer + toroid (1.5T)
  - Wire chambers and scintillators
    - large η coverage (|η|<2.0)

• 550 scientists, 89 institutions
• **Produced by strong interaction**, can be abundantly produced at hadron colliders

• **R-parity conserved**: pair produced, large MET signature ($\chi_1^0=$LSP)

Inclusive search:
- $\geq 2$ jets+MET, low $m_0$
- $\geq 3$ jets+MET, intermediate $m_0$
- $\geq 4$ jets+MET, high $m_0$

Dataset: 2.1 fb$^{-1}$, Jets+MET triggers

Model: mSUGRA with $\tan\beta=3$, $A_0=0$, mu<0
JETS+MET BACKGROUNDS

- multijet events “QCD”
- Comes from mismeasurements (jet energy, primary vertex)
- Contribution estimated from data

- W(\nu l)+jets, Z(\nu\nu)+jets, top-pair, diboson production
- Signatures close to the SUSY signal (real MET)
- Contribution estimated from MC simulation, “sim. MC”
### INCLUSIVE SEARCH: JETS + MET SELECTION

#### Preselection Cut

<table>
<thead>
<tr>
<th>$E_T$</th>
<th>All Analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&gt; 40$</td>
<td>$&lt; 60 \text{ cm}$</td>
</tr>
<tr>
<td>$&lt; 165^\circ$</td>
<td></td>
</tr>
</tbody>
</table>

#### Selection Cut

<table>
<thead>
<tr>
<th>&quot;dijet&quot;</th>
<th>&quot;3-jets&quot;</th>
<th>gluino</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trigger</td>
<td>dijet</td>
<td>multijet</td>
</tr>
<tr>
<td>jet 1 $p_T^a$</td>
<td>$\geq 35$</td>
<td>$\geq 35$</td>
</tr>
<tr>
<td>jet 2 $p_T^a$</td>
<td>$\geq 35$</td>
<td>$\geq 35$</td>
</tr>
<tr>
<td>jet 3 $p_T^b$</td>
<td>$-$</td>
<td>$\geq 35$</td>
</tr>
<tr>
<td>jet 4 $p_T^b$</td>
<td>$-$</td>
<td>$\geq 20$</td>
</tr>
</tbody>
</table>

- Electron veto: yes
- Muon veto: yes
- $\Delta \phi(E_T, \text{jet}_1): \geq 90^\circ$
- $\Delta \phi(E_T, \text{jet}_2): \geq 50^\circ$
- $\Delta \phi_{\text{min}}(E_T, \text{any jet}): \geq 40^\circ$

\[ H_T = \Sigma(p_T \text{ jets}) \]
\[ E_T \geq 325 \quad \geq 375 \quad \geq 400 \]
\[ E_T \geq 225 \quad \geq 175 \quad \geq 100 \]

3 analyses

Against W(l$\nu$)

**Optimization** on ($H_T$, MET) by the minimization of the expected upper limit on the x-section in the absence of signal

Larger for signal than SM
QCD estimation with low MET fit and extrapolation at high MET

>=4 jets +MET selection: $N_{QCD} = 1.4 \pm 0.8$ events

- data/SM good agreement

- Full combination of the 3 analyses in 7 independent selections

Systematics

<table>
<thead>
<tr>
<th></th>
<th>Bkg (%)</th>
<th>Signal (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminosity</td>
<td>6.1</td>
<td>6.1</td>
</tr>
<tr>
<td>trigger</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>JES</td>
<td>10-15</td>
<td>6-11</td>
</tr>
<tr>
<td>Jet ID,reco,vertex</td>
<td>2-4</td>
<td>2-3</td>
</tr>
<tr>
<td>Lepton ID</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>X-section</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>PDF (acceptance)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>ISR/FSR</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

PDF (15-60%) and scale (15-20%) uncertainty on signal translated in error bands on limit plots
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Interpretation in the mSUGRA parameter space

- Improvement vs LEP over $m_0 = 70-300$ GeV and $m_{1/2} = 125-165$ GeV

Yellow band: PDF and RF scale uncertainty on the signal NLO cross-section (25-75%).

<table>
<thead>
<tr>
<th>x-section hyp.</th>
<th>M(gluino)</th>
<th>M(squark)</th>
</tr>
</thead>
<tbody>
<tr>
<td>conservative</td>
<td>308 (312)</td>
<td>379 (377)</td>
</tr>
<tr>
<td>nominal</td>
<td>327 (332)</td>
<td>392 (391)</td>
</tr>
<tr>
<td>maximal</td>
<td>349 (354)</td>
<td>406 (404)</td>
</tr>
</tbody>
</table>

Observed (expected) limits on the mSUGRA model, in the 3 cross-section hypotheses

DØ, $L = 2.1$ fb$^{-1}$
$tan\beta = 3, A_0 = 0, \mu < 0$
**INTRODUCTION TO SQUARKS IN JETS+TAU(S)+MET**

**Mixing:**
- In SUSY, the mass difference between the partners of leptons depend on the lepton mass
  \[
  \left(\begin{array}{cc}
  M_{\ell_L}^2 + m_{\ell}^2 & m_\ell \times (A_\ell - \mu \tan \beta) \\
  m_\ell \times (A_\ell - \mu \tan \beta) & M_{\ell_R}^2 + m_{\ell}^2
  \end{array}\right)
  \]
- Large mixing \(\implies\) \(\tilde{\tau}_1^+\) is the lightest slepton and could be the NLSP
- Can be produced in cascade decay of squark (and gluinos)
- Enhancement of final states with taus

**Signature:**
- \(p \bar{p} \rightarrow \tilde{q} \tilde{q} \) dominates
- \(\geq 2\) jets + \(\geq 1\) tau(had) + MET

**Dataset:** 1.0 fb\(^{-1}\), jet+MET trigger

**Model:** mSUGRA with \(\tan \beta = 15, A_0 = -2m_0, \mu < 0\)

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**Selection** similar to the inclusive analyses
- At least 2 jets or at least 3 jets
- No lepton veto

\( \geq 1 \) tau(had)
- Narrow isolated jet with low multiplicity track (NN)
- \( p_T > 15 \text{ GeV}, |\eta| < 2.5 \)
- Non overlapping with 2 leading \( p_T \) jets
- Reject e, mu and jets faking hadronic taus

**Optimization** on MET (>175 GeV) and
\[
S_T = p_T(j_1) + p_T(j_2) + p_T(\tau) \ (>325 \text{ GeV})
\]

<table>
<thead>
<tr>
<th>Selection</th>
<th>( \geq 2 ) jets OR ( \geq 3 ) jets</th>
</tr>
</thead>
<tbody>
<tr>
<td>data</td>
<td>3</td>
</tr>
<tr>
<td>sim. SM</td>
<td>2.3+/-0.4(stat)+/-0.7(syst)</td>
</tr>
<tr>
<td>QCD</td>
<td>negligible</td>
</tr>
</tbody>
</table>

**Main systematics:** JES, cross-sections
Only in the “tau corridor”
- BR of \( \tilde{\chi}_1^+ \) and \( \tilde{\chi}_2^0 \) to taus = 100%
- sensitivity (95% C.L.) exceeds the LEP2 limits
- \( m(\text{squark}) \) excluded up to 340 GeV

Complementary to the search for chargino-neutralino production in the trilepton final state, where one lepton is kinematically undetectable

Orange band: PDF+RF scale uncertainty on the signal NLO cross-section.
• A tau had. is also detected as a jet
• Combination with the inclusive Jets+MET analyses, 2.1 fb⁻¹
  – 10 independent channels
• Only in the “tau corridor”
  – The limit set exceeds the LEP2 limits
  – Reaches squark masses of 410 (408) GeV
• Gain of combination w.r.t. jets+MET alone:
  – Jets+MET (2.1 fb⁻¹) with tau analysis (1 fb⁻¹): 11% gain in x-section exclusion
  – expect the 11% gain to become 33% for tau analysis based on 2.1 fb⁻¹

Orange band: PDF+RF scale uncertainty on the signal NLO cross-section.
SUMMARY

- **Inclusive searches** for squarks and gluinos done in 2.1 \( fb^{-1} \)
  - Stringent limits on squarks and gluinos masses
  - With this amount of data, **systematic** uncertainties matter (JES, cross-sections)

- Searches for squarks in **jets + tau + MET** with 1.0 \( fb^{-1} \)
  - SUSY could be hiding in very **special corner** of phase space
  - In the most promising examples, the tau plays a special role
  - To leave no stone unturned, we explored this scenario with a **dedicated analysis**
  - The best sensitivity is obtained by **combining** the dedicated tau analysis and the generic ones
  - **No significant deviation** from SM in this final state
  - However, the tau analysis is **crucial to get insight** of any New Phenomena that could be soon discovered at the Tevatron or at the LHC.
THE LUMINOSITY

Run II (2001-on)

- 1.96 TeV

- Run IIa: O(50k) Z→ee, O(600k) W→enu, ~10 times more than in Run I
- DØ data taking efficiency > 90%

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PARAMETER SPACE COVERED

\( \tan \beta = 15, \ A_0 = -2m_0, \ \mu < 0 \)

\( \tan \beta = 3, \ A_0 = 0, \ \mu < 0 \)
tau corridor

\[ \text{BR}(\chi_1^+) \rightarrow \text{LSP}^+ \tau + \gamma \]

the « tau corridor »
JETS+TAU(S)+MET : SELECTION

MET \geq 175 \text{ GeV} \quad \text{ST} \geq 325 \text{ GeV}

(a) DØ, 0.96 fb$^{-1}$

- Data
- SUSY
- W(\rightarrow \nu\nu)+jets
- Z(\rightarrow \nu\nu)+jets
- t\bar{t}
- WW,ZZ,ZZ
- Z(\rightarrow l^+l^-)+jets
- single-top

(b) DØ, 0.96 fb$^{-1}$

- Data
- SUSY
- W(\rightarrow \nu\nu)+jets
- Z(\rightarrow \nu\nu)+jets
- t\bar{t}
- WW,ZZ,ZZ
- Z(\rightarrow l^+l^-)+jets
- single-top

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