Searches for New Phenomena
at DØ

High Mass Dileptons/Diphotons

Supersymmetry
Squarks / Gluinos and Charginos / Neutralinos
SUSY with R-parity Violation
Gauge Mediated SUSY Breaking

Long Lived Massive Particles

2nd generation Leptoquarks

SUSY Higgs
Standard Model Higgs – “light” and “heavy”

Arnd Meyer – RWTH Aachen
The Tevatron Connection
Fermilab, June 24 2005
The DØ Experiment

**DØ Strengths:**
Excellent and wide muon coverage, hermetic calorimetry

Collected close to 800 pb\(^{-1}\) so far in Run II

Analyses shown here use up to 400 pb\(^{-1}\)

Electron Acceptance $|\eta| < 3.0$

Muon Acceptance $|\eta| < 2.0$

Precision Tracking (Silicon) $|\eta| < 3.0$

Detector is running stable with ~90% data taking efficiency
Dimuon and dielectron samples are not only among the most important samples for the understanding of the detector.

Their invariant mass spectra (and the diphoton mass spectrum) can also be used to probe a large variety of models:

- “Peak searches”: Z', Randall-Sundrum Gravitons, ...
- Indirect searches: Large Extra Dimensions, quark-lepton compositeness, ...

![Dielectron + diphoton](image1.png)

![Dimuon](image2.png)
**Preliminary results:**

Large Extra Dimensions in $\mu\mu$, ee, $\gamma\gamma$ (200-250 pb$^{-1}$)

Fundamental Planck scale $M_S > 1.43$ TeV (GRW model); TeV$^{-1}$ extra dimensions: $M_C > 1.12$ TeV

Quark-Lepton compositeness in $\mu\mu$ (400 pb$^{-1}$) and ee (270 pb$^{-1}$)

Limits on compositeness scale ranging from 4.2 to 9.8 TeV

Search for a heavy $Z'$ in $\mu\mu$ (250 pb$^{-1}$)

$m(Z') > 680$ GeV for SM-like couplings

Randall-Sundrum Gravitons in $\mu\mu$, ee, $\gamma\gamma$ (260 pb$^{-1}$, publ.)

Exclude graviton masses below 250 – 785 GeV, dep. on coupling

Technicolor: $\rho_T$ and $\omega_T$ in ee (200 pb$^{-1}$)

Exclude $m(\rho_T, \omega_T)$ below 367 GeV, depending on model parameters

**No significant excess anywhere... but potential for future excitement**
Supersymmetry

● Direct searches for SUSY partners at the Tevatron
  ◆ Squarks / Gluinos
    – Strong production – large cross sections
    – Masses possibly relatively high
  ◆ Charginos / Neutralinos
    – Small cross sections
    – Cascade decays can provide clean signatures

● LEP searches for Charginos, Sleptons, Higgs:
  \[ m(\tilde{\chi}^\pm) > 103.5 \text{ GeV}, \ m(\tilde{l}) > 95 \text{ GeV}, \ m(h) > 114.4 \text{ GeV} \]

● Signatures vary with model assumptions
  ◆ MSSM with R-parity conserved: \( E_T' (\text{jets} + E_T', \ \text{trileptons} + E_T') \)
  ◆ MSSM with R-parity violation: Multileptons, leptons + jets
  ◆ GMSB (with Neutralino NLSP): Diphotons
  ◆ Long-lived particles

\[ E_T = 354 \text{ GeV} \]
Squarks and Gluinos

- $p\bar{p}$ collider: strong production of Squarks / Gluinos $\rightarrow$ **large cross section**
- LSP assumed to be stable ($R_p$ conserved) $\rightarrow$ signature: $\text{jets} + E_T$
- Using $\int L \, dt = 310 \text{ pb}^{-1}$ collected with dedicated trigger: acoplanar jets + $E_T$

### 3 search channels

<table>
<thead>
<tr>
<th>Mass region</th>
<th>Main Channel</th>
<th>Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_{\tilde{q}} &lt; m_{\tilde{g}}$</td>
<td>$\tilde{q}\tilde{q}$</td>
<td>$2j + E_T$</td>
</tr>
<tr>
<td>$m_{\tilde{q}} &gt; m_{\tilde{g}}$</td>
<td>$\tilde{g}\tilde{g}$</td>
<td>$4j + E_T$</td>
</tr>
<tr>
<td>$m_{\tilde{q}} \approx m_{\tilde{g}}$</td>
<td>$\tilde{q}\tilde{q}, \tilde{q}\tilde{g}$</td>
<td>$2j/3j + E_T$</td>
</tr>
</tbody>
</table>

**Mass region**
- $m_{\tilde{q}} > m_{\tilde{g}}$: 4 jets
- $m_{\tilde{q}} = m_{\tilde{g}}$: 2 jets
- $m_{\tilde{q}} < m_{\tilde{g}}$: 2 jets
Squarks and Gluinos

Extensive **data quality effort** to eliminate rare calorimeter problems

“Fake” missing $E_T$ can be caused by
- wrong primary vertex
- Energy from additional interactions
- Cosmic ray muons
- Calorimeter noise and beam background

Substantially reduced by requiring a **minimum charged particle fraction** associated with each jet
**Main backgrounds:**
- Multijets with fake $E_T$
- $W$+jets with $W \rightarrow e/\mu/\tau\nu$
- $Z$+jets with $Z \rightarrow \nu\nu$
- 2/3/4 jets + large $E_T$
- Sep. between $E_T$ and jets
- Veto on isolated leptons

**Selection:**

```
2/3/4 jets + large $E_T$
Sep. between $E_T$ and jets
Veto on isolated leptons
```

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**mSUGRA**: $\tan\beta=3$, $A_0=0$, $\mu<0$

<table>
<thead>
<tr>
<th>Mass region</th>
<th>Main Channel</th>
<th>Signature</th>
<th>$E_T$</th>
<th>$H_T = \sum p_T^{jet}$</th>
<th>Exp. Bckgd.</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_{\tilde{q}} &lt; m_{\tilde{g}}$</td>
<td>$\tilde{q}\tilde{q}$</td>
<td>$2j + E_T$</td>
<td>$&gt;175$ GeV</td>
<td>$&gt;250$ GeV</td>
<td>$12.8\pm5.4$</td>
<td>12</td>
</tr>
<tr>
<td>$m_{\tilde{q}} &gt; m_{\tilde{g}}$</td>
<td>$\tilde{g}\tilde{g}$</td>
<td>$4j + E_T$</td>
<td>$&gt;75$ GeV</td>
<td>$&gt;250$ GeV</td>
<td>$7.1\pm0.9$</td>
<td>10</td>
</tr>
<tr>
<td>$m_{\tilde{q}} \approx m_{\tilde{g}}$</td>
<td>$\tilde{q}\tilde{q}, \tilde{q}\tilde{g}$</td>
<td>$2j/3j + E_T$</td>
<td>$&gt;100$ GeV</td>
<td>$&gt;325$ GeV</td>
<td>$6.1\pm3.1$</td>
<td>5</td>
</tr>
</tbody>
</table>
New result

\[ \int L \, dt = 310 \text{ pb}^{-1} \text{ of data collected with acoplanar jets } + E_T \text{ trigger} \]

Signal: generic MSSM, vary \( m(\tilde{b}) \) and \( m(\tilde{\chi}_1^0) \)

Selection:

- 2 or 3 jets (leading jets \( E_T > 40\text{-}70/15\text{-}40 \text{ GeV} \))
- Single tight b-tag \( E_T' > 60\text{-}100 \text{ GeV} \)
- Veto events with isolated \( \mu, e, \) track \( p_T > 5 \text{ GeV} \)
- Cuts against mismeasured \( E_T' \) and other instrumental background

\[
\begin{array}{ccc}
\text{low } m(\tilde{b}) & \text{medium } m(\tilde{b}) & \text{high } m(\tilde{b}) \\
\text{SM expect.} & 38.6 \pm 2.8 & 19.6 \pm 1.7 & 4.4 \pm 0.4 \\
\text{Data} & 36 & 15 & 2
\end{array}
\]
Charginos/Neutralinos

- **Golden channel**: leptonic cascade decays → three leptons + missing $E_T$

- **But**: small event rates ($\sigma \times \text{BR} < 0.5\text{pb}$), and leptons with low transverse momenta

- Six dedicated selections, $\int L \, dt \approx 320 \text{ pb}^{-1}$
  - $e e + \text{track}$, $e\mu + \text{track}$, $\mu\mu + \text{track}$, $\mu^\pm \mu^\pm$
  - $e\tau + \text{track}$, $\mu\tau + \text{track}$

- **Backgrounds**
  - Multijets with “fake” leptons
  - Drell-Yan, Z-production with $Z \to ll$
  - $WW$, $WZ$, $W\gamma$

- **Main selection cuts**
  - Three leptons ($ll + \text{track}$), $p_T > 11 / 5-8 / 3-7 \text{ GeV}$ (depending on channel)
  - Missing transverse energy
  - Veto events with $Z \to ll$ decays
Charginos/Neutralinos: Combined

<table>
<thead>
<tr>
<th>Selection</th>
<th>Expected Background</th>
<th>Observed</th>
<th>Signal ($m_{\tilde{\chi}^\pm} = 110$ GeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ee\ell$</td>
<td>0.21±0.12</td>
<td>0</td>
<td>1.9±0.2</td>
</tr>
<tr>
<td>$e\mu\ell$</td>
<td>0.31±0.13</td>
<td>0</td>
<td>1.6±0.1</td>
</tr>
<tr>
<td>$\mu\mu\ell$</td>
<td>1.75±0.57</td>
<td>2</td>
<td>1.3±0.2</td>
</tr>
<tr>
<td>Is-μμ</td>
<td>0.66±0.37</td>
<td>1</td>
<td>0.7±0.1</td>
</tr>
<tr>
<td>Combined</td>
<td>2.93±0.79</td>
<td>3</td>
<td>5.5±0.3</td>
</tr>
</tbody>
</table>

“3l-max”: maximize leptonic BR ($m(slepton) \approx m(\chi_2^0) \to \text{sfermion decays dominate}$)

“Large $m_0$”: Decays via $W*/Z^*$ dominate $\to$ leptonic BR small

“Heavy squarks” (relaxing mass unification): enhanced cross section

Sensitivity for mSUGRA beyond LEP limits, significant improvement on Run I limits

Exclude Chargino masses below 117 (132) GeV in “3l-max” (heavy squarks) scenario
Charginos/Neutralinos: $\tau$

SUSY with light stau (large tan $\beta$) $\rightarrow$ multiple tau leptons in final state

Reconstruct tau as 1 or 3 tracks pointing to a narrow energy deposition in the calorimeter

Use a set of neural networks to separate tau decays from jets

Interpretation of results in models with light stau in progress

<table>
<thead>
<tr>
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</tr>
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<tbody>
<tr>
<td>$ee\tau$</td>
<td>0.21±0.12</td>
<td>0</td>
<td>1.9±0.2</td>
</tr>
<tr>
<td>$e\mu\mu$</td>
<td>0.31±0.13</td>
<td>0</td>
<td>1.6±0.1</td>
</tr>
<tr>
<td>$\mu\mu\mu$</td>
<td>1.75±0.57</td>
<td>2</td>
<td>1.3±0.2</td>
</tr>
<tr>
<td>$l\mu-l\mu$</td>
<td>0.66±0.37</td>
<td>1</td>
<td>0.7±0.1</td>
</tr>
<tr>
<td>$e\tau\ell$</td>
<td>0.58±0.14</td>
<td>0</td>
<td>0.4±0.1</td>
</tr>
<tr>
<td>$\mu\tau\ell$</td>
<td>0.36±0.13</td>
<td>1</td>
<td>0.7±0.1</td>
</tr>
<tr>
<td>Combined</td>
<td>3.87±0.81</td>
<td>4</td>
<td>6.6±0.3</td>
</tr>
</tbody>
</table>

Search for $\chi^+_1\chi^-_2 \rightarrow 3l+X$  DØ, 320 pb$^{-1}$  Preliminary  

- Expected Limit (no $\tau$)
- Observed Limit
- Heavy-squarks
- 3l-max
- LEP
- Chargino Searches
- Large-$m_0$

Jun 24, 2005
R-parity Violating SUSY

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

Most general Superpotential:

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

\[
W_{R_p} = \frac{1}{2} \lambda_{ijk} \varepsilon_{abc} L_i^a L_j^b E_k^c + \lambda'_{ijk} \varepsilon_{abc} L'_i Q_j^b D_k^c + \lambda''_{ijk} \varepsilon_{xyz} U_i^x D_j^y D_k^z + \kappa_{iab} L_i^a H_2^b
\]

\( i,j,k = 1,2,3 \) generation indices

- \( S \) is the particle spin,
- \( B \) is the baryon number,
- \( L \) is the lepton number

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

Couplings are constrained by searches for L- and B- violation

\( \tilde{\chi}_1^0 \) violated in decay
multilepton final state

Resonant production
two muon and two jets final state

(For non-zero \( L_i L_j E_k \)-coupling)

(For non-zero \( L_i Q_j \bar{D}_k \)-coupling)
Charginos/Neutralinos: RPV

- Associated production of Charginos/Neutralinos, decay via LLE couplings $\lambda_{ijk}$ into 2 charged leptons and 1 neutrino
  - More than one possible final state for each coupling
  - Small missing $E_T$ (neutrinos)
  \[
  \tilde{\chi}^\pm \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 + X \rightarrow 4\ell + E_T + X
  \]

- Analyzed up to 240 pb$^{-1}$ with 5 dedicated selections
  - 3 (of 4) isolated leptons
  - Very low $p_T$ requirement on 3$^{rd}$ lepton (down to 3 GeV)
  - Loose $E_T$ cuts
  - SM Backgrounds dominated by Drell-Yan with “fake” 3$^{rd}$ lepton, and diboson production

- No excess over SM expectation, limits set in several reference scenarios for non-zero couplings $\lambda_{121}$, $\lambda_{122}$, and $\lambda_{133}$

<table>
<thead>
<tr>
<th>Selection</th>
<th>Background</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu\mu\mu$, $e\mu\mu$</td>
<td>0.6±1.4</td>
<td>2</td>
</tr>
<tr>
<td>$ee\mu$, $eee$</td>
<td>0.5±0.4</td>
<td>0</td>
</tr>
<tr>
<td>$eee\tau$</td>
<td>1.0±1.4</td>
<td>0</td>
</tr>
</tbody>
</table>
Charginos/Neutralinos: RPV

\[ \lambda_{121} \neq 0 \]

D0 Run II Preliminary

\[ \lambda_{121}, m_0 = 250 \text{ GeV}, \tan \beta = 5 \]

- \( \sigma_{\text{GAUGINOS (NLO)}} \)
- \( \sigma_{95 \text{ experimental limits}} \)

Present limit

- \( M(\chi_1^{\pm}) > 181 \text{ GeV} \)
- \( M(\chi_1^{0}) > 98 \text{ GeV} \)

Expect update with more data and combination of channels

\[ \mu < 0 \]

\[ \lambda_{122} \neq 0 \]

D\( \Phi \) Run II preliminary

\[ \sigma_{\text{SUSY (m_0=250 GeV)}} \]

95\% CL up.limit (Bayes)

\[ \lambda_{133} \neq 0 \]
RPV: LQD Coupling $\lambda'_{211}$

- Result shown here based on $\int L \, dt = 154 \, \text{pb}^{-1}$
- 2 jets above $\sim 20 \, \text{GeV}$, 2 isolated muons above $\sim 20 \, \text{GeV}$ (depending on point under study)
- Reconstruct Neutralino and smuon candidate invariant mass

$$M_{\tilde{\chi}_1^0} = 75 \, \text{GeV}$$

$$M_{\tilde{\mu}} = 200 \, \text{GeV}$$

Working on update with more data and extended selection, SUSY parameter scan
Gauge Mediated SUSY Breaking

Gauge Mediated SUSY breaking: Gravitino \( \tilde{G} \) is LSP

Assuming Neutralino NLSP: \( \tilde{\chi}_1^0 \rightarrow \gamma \tilde{G} \)

\( \rightarrow \) Chargino/Neutralino production leads to final states containing \( \gamma \gamma + E_T' \)

\( \rightarrow \) Inclusive search for 2 photons plus \( E_T' \) (\( \int L \, dt = 263 \, \text{pb}^{-1} \))

Selection: Two central photons with \( E_T > 20 \, \text{GeV} \)

Optimized cut \( E_T' > 40 \, \text{GeV} \)

Observe 2 events, expect \( 3.7 \pm 0.6 \) events from “fakes”

Mass limits on Chargino and Neutralino (\( N_5 = 1, M_m = 2, \tan \beta = 15, \mu > 0 \)):

\( m(\tilde{\chi}_1^0) > 108 \, \text{GeV} \quad m(\tilde{\chi}^\pm) > 195 \, \text{GeV} \)

Combine with CDF result (202 pb\(^{-1}\)):

\( m(\tilde{\chi}_1^0) > 93 \, \text{GeV} \quad m(\tilde{\chi}^\pm) > 168 \, \text{GeV} \)

First combined Run II result (TEVNPWG):

\( m(\tilde{\chi}_1^0) > 114 \, \text{GeV} \quad m(\tilde{\chi}^\pm) > 209 \, \text{GeV} \)
**Benchmark model:** pair production of stable staus (gauge-mediated SUSY, stau as NLSP, model line “D” from Snowmass 2001)

Massive stable particles can occur in many models

Stable = lifetime long enough to escape the detector

Would look like a **muon, but with inconsistent speed and mass**

Selection:
- Dimuon data set
- Timing in muon system to discriminate slow moving particles
- Kinematic cuts against \( Z \to \mu\mu \) with poorly measured timing

Energy loss not (yet) used

\[
\text{speed significance} = \frac{1 - \text{speed}}{\sigma_{\text{speed}}}
\]
After all cuts, find no events in $\int L \, dt = 390 \text{ pb}^{-1}$ with $0.66 \pm 0.06$ expected background.

Limit on stable stau production does not yet constrain models.

Another interpretation:
The lightest Chargino can live long enough to escape the detector if the mass difference to the lightest neutralino is below $\sim 150$ MeV, e.g. in Anomaly-Mediated Supersymmetry Breaking.
2\textsuperscript{nd} Generation Leptoquarks

Leptoquark: – Boson with third-integer charge, carrying lepton and quark quantum numbers
– 3 generations, each coupling to one fermion generation only
(lepton number violation, FCNC)

This analysis: 2\textsuperscript{nd} generation (1\textsuperscript{st} generation published)
– Pair production $\rightarrow \mu j + \mu j$ channel
– $\int L \, dt = 294$ pb\(^{-1}\), single- and dimuon triggers
– 2 muons with $p_T > 15$ GeV, 2 jets with $p_T > 25$ GeV
– Z Veto $m(\mu\mu) > 105$ GeV
– Refit exploiting expectation of no $E_T$

Observe 6 events, expect $6.8 \pm 2.0$
(dominated by DY/Z + jets)

$S_T = \sum E_T$ of $\mu j + \mu j$ system

New result
2\textsuperscript{nd} Generation Leptoquarks

- 4 bins with different S/B ratio
- Combine 4 bins
- Combine with Run I (includes $\mu j + vj$)
- $m(LQ_2) > 251 \text{ GeV} (\beta = 1)$
- $m(LQ_2) > 247 \text{ GeV} (\beta = 1)$
- Limits for scalar LQ depend on mass and BR only
SUSY Higgs: $hb(b) \rightarrow b\bar{b}b(b)$

- In MSSM, 5 Higgs bosons: neutral $A$, $h$, $H$, charged $H^\pm$
- $hb\bar{b}$ coupling enhanced at large $\tan\beta \rightarrow$ large cross section for $hb\bar{b}$ production (at tree level, $\sim \tan^2\beta$)
- **Selection** requires at least 3 b-tagged jets
- **Backgrounds:** multijet production, modelled using data
- Reconstruct Higgs boson mass in bbbar spectrum

- **No hint for a signal in 260 pb$^{-1}$**
- **Significantly improved limits on $\tan\beta$ as a function of $m_A$**

**Reminder:**
- SUSY predicts at least one Higgs boson with $m < 135$ GeV
- Combination of different analyses should allow a test at 95% CL with 5 fb$^{-1}$ (mhmax scenario)
(SM) Higgs Overview

SM Higgs Production (pb)

- $gg \rightarrow H$
- $WH \rightarrow l\nu bb$
- $ZH \rightarrow \nu\nu bb$
- $bbh \rightarrow bbbb$
- $H \rightarrow \gamma\gamma$
- $ZH \rightarrow l\nu llbb$
- Higgs searches with taus
- $W/Z + \text{jets}$
- $Z \rightarrow bb$
- $H^{++}, H^{--}$

SM Higgs Decay:

- $< 135 \text{ GeV } H \rightarrow bb$ dominant
- $> 135 \text{ GeV } H \rightarrow WW$

Experimental challenges: the full program!

(Lepton ID, missing $E_T$, b-tagging, bbbar mass resolution, angular correlations for WW, ...)

Sensitivity for SM Higgs above LEP limit ($m_H > 114.4 \text{ GeV}$) requires $> 2 \text{ fb}^{-1}$ (per experiment)
$\text{gg}$ → $H$, $H$ → $WW(*)$

- Use $\int L \, dt = 299 - 325 \, \text{pb}^{-1}$ of dilepton data:
  - 2 high $p_T$ isolated leptons with opp. charge: $ee$, $\mu\mu$, $e\mu$, $E_T > 20 \, \text{GeV}$
- Additional kinematic cuts to suppress physics backgrounds, depending on Higgs mass
- Exploit spin correlation in decay

- Remaining backgrounds dominated by $Z$/DY, Diboson production, and $W+$jet/photon
Example: expected and observed number of events for $m_H = 160$ GeV

<table>
<thead>
<tr>
<th>Diboson</th>
<th>W+jet/$\gamma$</th>
<th>Z/\gamma</th>
<th>tt+multijet</th>
<th>Total</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.7±0.2</td>
<td>2.1±0.7</td>
<td>3.3±0.7</td>
<td>0.64±0.1</td>
<td>17.6±1.0</td>
<td>20</td>
</tr>
</tbody>
</table>

$\sigma \times BR(H \rightarrow WW)$ (pb)

Excluded at LEP

DØ Run II Preliminary

$H \rightarrow WW \rightarrow ee/\mu\mu$

Excluded at 95% C.L.

$L = 320 \text{ pb}^{-1}$

4th Generation Model

Topcolor

Standard Model
**The benchmark channel**

**Selection:** Isolated central $e$ \( p_T > 20 \text{ GeV} \), \( E_T > 25 \text{ GeV} \), 2 jets > 20 GeV – then add b-tags

- **Expect**
  - \( Wbb \): \( 18.1 \pm 4.3 \) Wbb
  - \( 0.4 \pm 0.1 \) WH
  - \( 154 \pm 37 \) Background

- **Observe**
  - 172 events

- **Expect**
  - \( WH \): \( 4.29 \pm 1.03 \) Wbb
  - \( 0.14 \pm 0.03 \) WH
  - \( 5.73 \pm 1.45 \) Background

- **Observe**
  - 13 events

- Mostly Z/W + jets
- Mostly ttbar, Z/W + jets, single top
Associated Production: WH  
$W \rightarrow e \nu$, $H \rightarrow b\bar{b}$

**Prospects:**
- Expect gain in sensitivity with **looser and improved b-tagging**
- Also gains from jet energy scale, tau channel, multivariate analysis techniques
- Muon channel being finalized

Limits clearly above SM expectation
Nevertheless, becoming interesting for other models with similar signatures
\[ \rho_T \rightarrow W(\rightarrow e\nu) + \pi_T(\rightarrow bQ) \]

Selection:

- central electron \( p_T > 15 \text{ GeV} \)
- missing \( E_T > 20 \text{ GeV} \)
- \( m_T(e, E_T) > 30 \text{ GeV} \)
- 2 jets, \( p_T > 20 \text{ GeV} \), \( \geq 1 \text{ b-tagged} \)
- Additional selection: \( \Delta \phi(jj) \), \( m(jj) \), \( m(Wjj) \)

Expect \( 6.6 \pm 1.7 \) events
Observe 4 events in \( \int L \, dt = 238 \text{ pb}^{-1} \)

\[ m(\rho_T) = 200 \text{ GeV}, \quad m(\pi_T) = 105 \text{ GeV} \]
\[ \rightarrow \sigma < 6.4 \text{ pb} \quad (95\% \text{ CL}) \]
Associated Production: ZH
\[ Z \rightarrow \nu \nu, \ H \rightarrow \bar{b}b \]

\[ \int L \ dt = 261 \text{ pb}^{-1} \]

Large missing \( E_T > 25 \text{ GeV} \)

2 acoplanar (b-)jets with \( E_T > 20 \text{ GeV} \)

Form various asymmetries to reduce backgrounds

Expected background \( 6.4 \pm 2.1 \text{ events} \)

Observe 9 events

No b-tag

Single b-tag

Double b-tag
Associated Production: ZH
\[ Z \rightarrow \nu\nu, \ H \rightarrow bb \]

Search for an excess in the di-b-jet mass distribution

<table>
<thead>
<tr>
<th>Mass (GeV) Window</th>
<th>105 [70,120]</th>
<th>115 [80,130]</th>
<th>125 [90,140]</th>
<th>135 [100,150]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Acceptance (%)</td>
<td>0.29 ±0.07</td>
<td>0.33 ±0.08</td>
<td>0.35 ±0.09</td>
<td>0.34 ±0.09</td>
</tr>
<tr>
<td>Total bkgd.</td>
<td>2.75 ±0.88</td>
<td>2.19 ±0.72</td>
<td>1.93 ±0.66</td>
<td>1.71 ±0.57</td>
</tr>
<tr>
<td>Expected limit (pb)</td>
<td>8.8</td>
<td>7.5</td>
<td>6.0</td>
<td>6.5</td>
</tr>
<tr>
<td>Limit @95% C.L. (pb)</td>
<td>12.2</td>
<td>9.3</td>
<td>7.7</td>
<td>8.5</td>
</tr>
</tbody>
</table>

![Graph of di-b-jet mass distribution](image1)

![Graph of expected and measured limits](image2)
SM Higgs Summary

Tevatron Run II Preliminary

Expect improvements from:

- Advanced analysis techniques
- Improved b-tagging (e.g. NN)
- Improved calorimeter calibration, esp. hadronic
- Reduced Jet Energy Scale uncertainty
- More efficient and precise object ID
- Reduced backgrounds with better dijet mass resolution (cal-track-jets)
- Longterm: Hardware upgrades (Trigger, Silicon Layer 0)

... and obviously more data

How does this compare to the Higgs Sensitivity Study Working Group (2003)?

- Factor ~ 2 – 3 worse in sensitivity; can be recovered
- See Beate's talk for details
Conclusions

- DØ experiment is running well, and the place to discover or constrain new physics
- Recorded about 0.8 fb⁻¹, analyses shown based on up to ≃ 400 pb⁻¹
- High mass dilepton and diphoton searches in all variations: no surprises, but interesting candidate events
- Searches for non-SM particles have entered uncharted territory (Desert? Jungle?)
  - Probing MSSM with R-parity conservation / non-conservation, GMSB, AMSB, Technicolor, ...
  - With a large variety of experimental tools: Missing Eₜ (+ jets, + trileptons), multileptons incl. taus, leptons + jets, diphotons, b-tags, ...
- New results on sbottom, Higgs searches, long-lived massive particles, 2nd generation leptoquarks, ...
- Preparing for analysis of 1 fb⁻¹ data set
Vancouver, Last Week

Workshop last week in Vancouver – major topics included the preparation of 1fb⁻¹ analyses, and being prepared for multi–fb⁻¹