Measurement of $B(t \rightarrow Wb)/B(t \rightarrow Wq)$ at DØ

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on behalf of the DØ collaboration

APS April Meeting, 4/23/2006
Outline

• Introduction
• Experimental Approach
• Tevatron and DØ detector
• Branching Ratio Measurement
• Conclusions
CKM Matrix element $V_{tb}$

- In SM: (3 generations, unitarity)
  - Top-quark CKM matrix elements indirectly constrained
  $$
  \begin{pmatrix}
  0.9739 \text{ to } 0.9751 & 0.221 \text{ to } 0.227 & 0.0029 \text{ to } 0.0045 \\
  0.221 \text{ to } 0.227 & 0.9730 \text{ to } 0.9744 & 0.039 \text{ to } 0.044 \\
  0.0048 \text{ to } 0.014 & 0.037 \text{ to } 0.043 & 0.9990 \text{ to } 0.9992
  \end{pmatrix}
  $$

- New physics: $>3$ generations, ...
  - Almost no constraint on $V_{tb}$
  $$
  \begin{pmatrix}
  0.9730 \text{ to } 0.9746 & 0.2174 \text{ to } 0.2241 & 0.0030 \text{ to } 0.0044 \ldots \\
  0.213 \text{ to } 0.226 & 0.968 \text{ to } 0.975 & 0.039 \text{ to } 0.044 \ldots \\
  0 \text{ to } 0.08 & 0 \text{ to } 0.11 & 0.07 \text{ to } 0.9993 \ldots
  \end{pmatrix}
  $$
Experimental Approach

High-momentum lepton

b-quark or light-quark jet?

Missing transverse energy

Measure fraction of top decays to b-quarks:

$$ R = \frac{\left| V_{tb} \right|^2}{\left| V_{td} \right|^2 + \left| V_{ts} \right|^2 + \left| V_{tb} \right|^2} = \frac{B(t \rightarrow Wb)}{B(t \rightarrow Wq)} $$

2 light-quark jets
Fermilab Tevatron in Run II
Proton-Antiproton Collider
CM Energy 1.96TeV
→ Energy Frontier
b-quark tagging

- Identification of b-quark jets through decay of long-lived b meson or hadron
  - secondary vertex reconstruction

Probability to tag a jet in a top event:
- b-quark jet: ~55%
- light-quark jet: ~0.5%
Data Sample

• Select $\mu+3$ jets, $\mu + \geq 4$ jets and $e+3$ jets, $e+\geq 4$ jets final states with high MET
  – High $p_T$ isolated lepton from $W$ decay ($>20$ GeV)
  – High missing transverse energy from neutrino ($>20$ GeV)
  – 2 jets from hadronic $W$-decay
  – 2 jets from top decay ($b$?)

• Backgrounds:
  – $W+$jets
  – Multijet
  – Smaller backgrounds:
    • $WW/WZ/ZZ$, $Z+$jets, single top
Analysis

• Count events with 0, 1, 2 b-tagged jets
  – Estimate SM background contributions
  – Measure top pair production above background
  – Simple event count for 1, 2-tags

– Likelihood discriminant in 0-tag sample

• Measure simultaneously: R and N(tt)

230 pb⁻¹
Result

95% CL limit:

\[ R > 0.61 \]

\[ |V_{tb}| > 0.78 \]

\[ (|V_{tb}| = \sqrt{R}) \]

Submitted to PRL, hep-ex/0603002 (2006)
Conclusions

- The top quark decay branching fraction has been measured in 230 pb$^{-1}$ of $D$ data:
  - $|V_{tb}| > 0.78$ at 95% CL
    - Consistent with SM expectation ($\sim 1$)
  - World's best measurement
  - $R$ and $N(tt)$ measured simultaneously
    - No need to assume SM cross section
    - Reduced systematic uncertainty

One more piece in the top quark puzzle!
Backup Slides
### Summary of Systematic Uncertainties

<table>
<thead>
<tr>
<th>Uncertainties on $R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical</td>
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<tr>
<td>$b$-tagging efficiency</td>
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<tr>
<td>Background modeling</td>
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<tr>
<td>Total error</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Uncertainties on $\sigma_{t\bar{t}}$ (pb)</th>
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<tr>
<td>Statistical</td>
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<tr>
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<td>$b$-tagging efficiency</td>
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<tr>
<td>Light-jet tagging rate</td>
</tr>
<tr>
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</tr>
</tbody>
</table>
Topological variables...

- **Sphericity**
  \[ S = \frac{3(\lambda_2 + \lambda_3)}{2} \]
  \[ \lambda_2 \text{ and } \lambda_3 \text{ are the smallest eigenvalues of the normalized momentum tensor } M \text{ (isotropic events like ttbar } S \sim 1) \]

- **\( K_{T \text{min}}' \)**
  \[ K_{T \text{min}}' = \frac{R_{\text{min}}}{E_W T} \text{ with } E_W T = E_T + \text{MET} \]

- **Centrality**
  \[ C = \frac{H_T}{H}, \text{ } H_T \text{ is scalar sum of jets } E_T \text{ and } h \text{ is the sum of the jet energies.} \]

- **\( H_{T2}' \)**
  \[ H_{T2}' = \frac{H_{T2}}{H_z}, \text{ } H_{T2} \text{ is the } p_T \text{ sum of ll jets except leading jet, } Hz \text{ is the scalar sum of all jets } |E_z| \text{ plus } |E_z| \text{ of the neutrino (W-assumption)} \]
Run II Integrated Luminosity

Dataset

Dataset used in this analysis
0.23 fb⁻¹
## Event Yield

<table>
<thead>
<tr>
<th></th>
<th>0-tag</th>
<th>1-tag</th>
<th>≥ 2-tag</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ℓ + 3 jets</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$W+$jets</td>
<td>1040±40</td>
<td>34±5</td>
<td>2.4±0.4</td>
</tr>
<tr>
<td>Multijet</td>
<td>192±23</td>
<td>8.3±1.5</td>
<td>0.1^{+0.3}_{-0.1}</td>
</tr>
<tr>
<td>Other bkg</td>
<td>18.4±1.3</td>
<td>4.3±0.3</td>
<td>0.7±0.1</td>
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<tr>
<td>$t\bar{t}$</td>
<td>29.5±1.6</td>
<td>28.2±1.6</td>
<td>6.9±0.5</td>
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<tr>
<td>Total expected</td>
<td>1280±44</td>
<td>75±5</td>
<td>10.1±0.8</td>
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<tr>
<td>Observed</td>
<td>1277</td>
<td>79</td>
<td>9</td>
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<tbody>
<tr>
<td><strong>ℓ + ≥ 4 jets</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$W+$jets</td>
<td>203±17</td>
<td>9.2±1.2</td>
<td>0.7±0.1</td>
</tr>
<tr>
<td>Multijet</td>
<td>65±9</td>
<td>4.1±1.1</td>
<td>0.0±0.4</td>
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<tr>
<td>Other bkg</td>
<td>2.9±0.4</td>
<td>1.2±0.2</td>
<td>0.21±0.01</td>
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<tr>
<td>$t\bar{t}$</td>
<td>32.5±3.0</td>
<td>36.3±3.3</td>
<td>11.4±1.4</td>
</tr>
<tr>
<td>Total expected</td>
<td>304±20</td>
<td>51±4</td>
<td>12.3±1.4</td>
</tr>
<tr>
<td>Observed</td>
<td>291</td>
<td>62</td>
<td>14</td>
</tr>
</tbody>
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