Search for Anomalous Heavy-Flavor Jet Production in Association With W Bosons at DØ

Wade Fisher
Princeton University

On behalf of the DØ Collaboration
Tevatron Run II

The collider has reached its design luminosity of $1.0 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$ !!!
The DØ Upgrade

- Forward Mini-drift chambers
- Central Scintillator
- Forward Scintillator
- Shielding
- New Solenoid, Tracking System
  - Si, ScFi, Preshower
  - + New Electronics, Trig, DAQ

✗ Muon coverage to |η|<2.0

✗ Silicon & Fiber Trackers
  ✗ allows for b-Tagging

Wade Fisher, Princeton University

DPF-2004  31 August 2004
Heavy-Flavor Jet Production at the Tevatron

× Inclusive W boson production contains a lot of physics

× W + heavy-flavor jets represents a more concentrated sample for many of these processes
  × Wbb, Top, Higgs / SUSY searches, Technicolor...

× Furthermore, W+heavy-flavor jets can be a (large) background for many analyses
  × Top, Higgs, SUSY, Technicolor...

× Our description of the data is improving
  × Alpgen MC normalized to MCFM cross sections provides for more accurate predictions
W+Heavy-Flavor Jets: The Search Process

1) Select $W \rightarrow e \nu$ and $W \rightarrow \mu \nu$ decays

2) b-Tag good jets using Secondary Vertex b-Tagging (SVT) and Soft Lepton b-Tagging (SLT)

3) Evaluate b-Tag overlaps, i.e., simultaneous SVT+SLT for any jet

Soft-Muon b-Tag

Secondary Vertex b-Tag

Doubly b-Tagged Jet
$W \rightarrow e \nu$ Selection: Electron & MET

- Require one isolated electron with a matching track
  - $p_T > 20$ GeV/c
  - $|\eta| < 1.1$
- Require the MET to be at least 20 GeV

Luminosity = 164 pb$^{-1}$
W→eν Selection: W Boson

Transverse W mass reconstruction requirements:

- $\Delta \phi(\text{electron,MET}) > \pi/8$
- $40 \text{ GeV/c}^2 < M_{WT} < 120 \text{ GeV/c}^2$

Luminosity = 164 pb$^{-1}$
$W \rightarrow \mu \nu$ Selection: Muon & MET

- Same MET selection as $W \rightarrow e\nu$
- MET > 20 GeV
- Require one isolated muon with a matching track
- $p_T > 20$ GeV/c, $|\eta| < 1.6$

Luminosity = 145 pb$^{-1}$
$W \rightarrow \mu \nu$ Selection: W Boson

- Transverse W mass reconstruction requirements:
  - $\Delta \phi(\text{muon}, \text{MET}) > \pi/8$
  - $40 \text{ GeV}/c^2 < M_{WT} < 120 \text{ GeV}/c^2$

Luminosity = 145 pb$^{-1}$
Jet Multiplicities Before b-Tagging

- Consider jets with
  - $p_T > 25$ GeV/c
  - $|\eta| < 2.5$
Secondary Vertexing

- Secondary Vertices are formed with tracks away from the PV
- Decay Length Significance (DLS) is the primary selection variable

\[ DLS = \frac{L_{xy}}{\sigma_{xy}} \]

Calorimeter
Energy Deposition
Jet Tracks

PV

Operating point for this analysis

Wade Fisher, Princeton University

DPF-2004 31 August 2004
Secondary Vertex b-Tagging

- Exclusive jet multiplicity for events with at least 1 SVT
Soft Muon b-Tagging

- Soft muon b-Tag is defined for muons with
  - $4 \text{ GeV}/c < p_T < 15 \text{ GeV}/c$
  - $|\eta_{\text{det}}| < 2.0$
  - Jets are tagged if the muon is within $\Delta R < 0.5$ to the jet

![Bar chart showing the number of jets with $p_T > 25$ GeV and at least one SLT tagged jet.]

DØ Run II Preliminary

Wade Fisher, Princeton University
DPF-2004 31 August 2004
Doubly-tagged Jet Events

- Doubly b-Tagged jets require b-tags with both algorithms
  - TIGHT SVT
  - SLT
- Exclusive number of jets in events with at least one doubly b-Tagged jet
Transverse W Mass for Tagged Events

**W → eν Selection**

*Transverse $M_W$ for events with at least one SVT or SLT provides a cross-check*
Limits on Anomalous Production

- In the absence of a specific model for new physics, we can set limits on anomalous production per exclusive jet bin
  - Based on doubly-tagged jet sample
- Limits are calculated as 95% Confidence Levels (CL) using the LEP method
  - Errors are folded into expectation via a gaussian distribution

<table>
<thead>
<tr>
<th>Source</th>
<th>W+1 jet</th>
<th>W+2 jets</th>
<th>W+3 jets</th>
<th>W+4 jets</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM Prediction</td>
<td>4.8±1.1</td>
<td>1.90±0.40</td>
<td>0.90±0.2</td>
<td>0.3±0.1</td>
</tr>
<tr>
<td>Data</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>95% CL Limit (Evts)</td>
<td>6.8</td>
<td>3.9</td>
<td>4.2</td>
<td>3</td>
</tr>
</tbody>
</table>
Limits on “SM-Like”
Anomalous Production

× Assuming any anomalous production would have the same topologies and efficiencies as SM processes, we can set cross section limits

× Top-like production: consider nJet = 2,3,4 bins
× Wbb-like production: consider nJet = 1,2 bins

<table>
<thead>
<tr>
<th>Source</th>
<th>W+1,2 jets</th>
<th>W+2,3,4 jets</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM Prediction</td>
<td>6.7±1.3</td>
<td>3.2±0.5</td>
</tr>
<tr>
<td>Data</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>95% CL Limit (Evts)</td>
<td>6.7</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Top-like Limit: 15.6 pb
Wbb-like Limit: 27.8 pb

Wade Fisher, Princeton University

DPF-2004 31 August 2004
Conclusions and Outlook

✗ Presented search results for anomalous heavy-flavor production in association with a W boson
✗ We find no evidence for physics beyond the SM prediction
✗ Used these results to set limits on anomalous heavy-flavor production

<table>
<thead>
<tr>
<th>Source</th>
<th>W+1,2 jets</th>
<th>W+2,3,4 jets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top-like Limit</td>
<td>-</td>
<td>15.6 pb</td>
</tr>
<tr>
<td>Wbb-like Limit</td>
<td>27.8 pb</td>
<td>-</td>
</tr>
</tbody>
</table>

✗ For scale, DØ Single-Top limit is 23 pb
✗ Expect improved results with increased data sample
In RunI, CDF observed an anomaly in their $W +$ doubly-tagged jet sample.
Comparison to the CDF Run I Result

- Care has been taken to achieve comparable purity levels
  - 4-Jet bin SVT $tt$ purity:
    - CDF: 68%
    - DØ: 71%
  - 4-Jet SLT $tt$ purity:
    - CDF: 42%
    - DØ: 67%
- But there are still efficiency differences

### Analysis differences

<table>
<thead>
<tr>
<th>Source</th>
<th>DØ</th>
<th>CDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>MET</td>
<td>25 GeV</td>
<td>20 GeV</td>
</tr>
<tr>
<td>$M_W$ Window</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Jet R</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Jet $E_T$</td>
<td>25 GeV</td>
<td>15 GeV</td>
</tr>
<tr>
<td>SVX Signif</td>
<td>0.7</td>
<td>0.3</td>
</tr>
<tr>
<td>SLT type</td>
<td>muon only</td>
<td>muon + em</td>
</tr>
<tr>
<td>SLT lepton $p_T$</td>
<td>4 GeV</td>
<td>2 GeV</td>
</tr>
</tbody>
</table>