Top Pair Production Cross-Section in the All-Hadronic Channel

Daniel Wicke, Fermilab on behalf of CDF and DØ

Outline

- Introduction
- Signal selection
- Background and efficiency determination
- Results
- Summary


Introduction

Top production

General signatures: $2b$-jets + missing $E_T$ + lepton(s)  
$2b$-jets + at least 4 jets

“dilepton and $l +$jets”

“all hadronic”

All hadronic channel

- Highest branching ratio: 44%
- Other quarks produced in the same process have many orders of magnitudes higher cross-section.

⇒ Overwhelming multijet background

The cross-section formula

$$\sigma_{t\bar{t}} = \frac{N - B}{\varepsilon \mathcal{L} \cdot \text{BR}}$$
**Signal Selection**

**Trigger**

CDF
4 calorimeter cluster of $E_T \geq 15$ GeV  
$H_T \geq 125$ GeV

DØ
4 Jets with $E_T > 12$ GeV  
[10 GeV]  
3 with $E_T > 15$ GeV  
[-]  
2 with of $E_T > 25$ GeV  
[20 GeV]  
$[H_T \geq 90$ GeV]

**Preselection**

CDF
4 or more jets of cone 0.4 with  
$p_T \geq 15$ GeV, $|\eta| < 3.0$, $z_{vtx} < 60$ cm  
no isolated high $p_T$ leptons

DØ
6 or more jets of cone 0.5 with  
$p_T \geq 15$ GeV, $|\eta| < 2.5$, $z_{vtx} < 60$ cm  
no isolated high $p_T$ leptons

**Luminosity**

CDF  
$165 \text{ pb}^{-1}$

DØ  
$162 \text{ pb}^{-1}$
Kinematic observables

1. Energy scale
   \( H_T, \sqrt{s} \)

2. Soft non-leading jets
   \( H_T^{3j}, E_{T4,5}, N_A^A \text{jets} \)

3. Event shape
   Aplanarity, Sphericity

4. Rapidity distribution
   Centrality, \( \langle \eta^2 \rangle \)

5. Specific top properties
   \( W^-\chi^2 \) (consistency of reconstructed \( W \)-masses with theo. value)
   \( t^-\chi^2 \) (consistency of \( t \)-masses with each other)
   \( M_{WW}, M_{tt}, M_{min}^{1,2}, M_{min}^{3,4} \)

Some of these are correlated
B-tagging

Both experiments use $b$-tagging through reconstruction of secondary vertices:

- Find track-jets
- Find secondary vertices within jets.
- Determine distance between secondary and primary vertex.

Both experiments check the significance of the displacement of the sec. vertices:

**CDF**
Accepts tags with significance > 3.

**DØ**
Accepts tags with significance > 7.
Final signal selection

CDF
Preselection plus 4 straight cuts:

\[ 6 \leq N_{\text{jets}} \leq 8 \]
\[ A + 0.0037H_T^{3j} \geq 0.85 \]
\[ C \geq 0.77 \]
\[ H_T \geq 320 \text{ GeV} \]

Counting secondary vertices ⇒ 326 b-Tags

DØ
3 artificial neural networks:

- NN0: Further preselection.
  Inputs: \( H_T, \sqrt{s}, N_{\text{jets}}^A, S, A \) and \( C \).
- One secondary vertex tag
- NN1: Kinematics.
  Inputs: as NN0 plus \( E_{T4,5}, \langle \eta^2 \rangle \)
  Result is fed into NN2

- NN2: Top properties:
  NN1 and rec. masses
  \( NN2 \geq 0.75 \)

Counting events: ⇒ 220 b-tagged events.
Background Description

• Tag Rate Functions (TRFs) parametrise probability to $b$-tag a jet.

• TRFs are measured after preselection (i.e. on background dominated sample)

  **CDF**
  uses only 4-jet events
  parametrises in $p_T$, $\eta$, 
  $\#$ tracks at primary vertex, 
  $N_{\text{tracks}}$ and Aplanarity.

  **DØ**
  uses all preselected events (after NN0)
  parametrises in $p_T$, $\eta$ and 4 $H_T$ bins.

• Replacing an actual $b$-tag with a weight computed from the TRFs
  simulates a $b$-tag as if the sample was all background.
Cross checks of TRFs

Both CDF and DØ prove that reweighted samples agree with tagged data:

<table>
<thead>
<tr>
<th>Jets</th>
<th>Tags</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 jets</td>
<td>0.06</td>
</tr>
<tr>
<td>5 jets</td>
<td>0.08</td>
</tr>
<tr>
<td>6 jets</td>
<td>0.10</td>
</tr>
<tr>
<td>7 jets</td>
<td>0.12</td>
</tr>
<tr>
<td>8 jets</td>
<td>0.14</td>
</tr>
</tbody>
</table>

CDF Run II preliminary, L=165 pb

Transverse Hadronic Energy

CDF
264.7 ± 17.2 background tags expected

DØ
186 ± 14.8 background events expected
**Selected Signal**

CDF Run II preliminary, $L=165$ pb$^{-1}$

<table>
<thead>
<tr>
<th>Tagged Jets</th>
<th>0</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
<th>100</th>
<th>120</th>
<th>140</th>
<th>160</th>
<th>180</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>4jets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5jets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6jets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7jets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8jets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Neural Network 2 output**

CDF Run II preliminary

- Integrated luminosity: 162 pb$^{-1}$
- Re-normalized background
- Vertex tagged data
- Expected $t\bar{t}$ contribution

CDF

$326 - 265 = 61$ surplus $b$-Tags.

DØ

$220 - 186 = 34$ surplus tagged Events.

Daniel Wicke, Top Pair Production Cross-Section in the All-Hadronic Channel, Selected Signal 28th August 2004
Signal Efficiencies

Signal efficiencies are obtained on $t\bar{t}$-simulation

<table>
<thead>
<tr>
<th>CDF</th>
<th>DØ</th>
</tr>
</thead>
<tbody>
<tr>
<td>kinematical select.</td>
<td>0.062 ± 0.012</td>
</tr>
<tr>
<td>trigger</td>
<td>1.00</td>
</tr>
<tr>
<td>mean # of $b$-tags</td>
<td>0.763 ± 0.065</td>
</tr>
<tr>
<td>Total</td>
<td>0.047</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DØ</th>
</tr>
</thead>
<tbody>
<tr>
<td>pre-selection</td>
</tr>
<tr>
<td>trigger</td>
</tr>
<tr>
<td>NN0 &gt; 0.05</td>
</tr>
<tr>
<td>$b$-Tag</td>
</tr>
<tr>
<td>NN2 &gt; 0.75</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Systematic uncertainties investigated include:

<table>
<thead>
<tr>
<th>CDF</th>
<th>DØ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator</td>
<td>±2.9%</td>
</tr>
<tr>
<td>ISR/FSR</td>
<td>±4.0%</td>
</tr>
<tr>
<td>p.d.f</td>
<td>±7.4%</td>
</tr>
<tr>
<td>Jet Energy Scale</td>
<td>±28.8%</td>
</tr>
<tr>
<td>DØ</td>
<td></td>
</tr>
<tr>
<td>Jet Identification</td>
<td>−9.8%</td>
</tr>
<tr>
<td>Jet Energy Scale</td>
<td>±28.2%</td>
</tr>
<tr>
<td>Top Mass ±5 GeV</td>
<td>−7.6% +5.9%</td>
</tr>
<tr>
<td>Trigger eff.</td>
<td>±4.0%</td>
</tr>
</tbody>
</table>
Results

CDF

DØ

\[ \sigma_{t\bar{t}} = 7.8 \pm 2.5^{+4.7}_{-2.3} \text{stat} \]

\[ \sigma_{t\bar{t}} = 7.7^{+3.4}_{-3.3} \text{stat}^{+4.7}_{-3.8} \text{syst} \pm 0.5 \text{lumi} \]

Dominating systematic uncertainties

- Efficiency: Jet Energy Scale: \( \sim 30\% \) on \( \varepsilon \).
- Background estimation from TRF: \( \sim 7\% \) on \( B \), \( \Rightarrow 30\% - 40\% \) in final result.

Daniel Wicke, Top Pair Production Cross-Section in the All-Hadronic Channel, Results 28th August 2004
Summary

- Top pair production cross-section presented by both CDF and DØ
  - Luminosity $\sim 160 \text{ pb}^{-1}$
  - Signal is extracted using kinematical properties and $b$-tagging.
  - Background determination is done from data using TRFs.
  - Signal efficiencies from MC.

- Dominating systematic uncertainties:
  - Jet energy scale
  - Background estimation

- CDF: $\sigma_{tt} = 7.8 \pm 2.5_{\text{stat}}^{+4.7}_{-2.3} \text{syst}$
  - DØ: $\sigma_{tt} = 7.7 \pm 3.4_{-3.3}^{+4.7} \text{stat} \pm 0.5 \text{lumi}$
CDF and DØ Run II Preliminary

σ (pb)

D0 dileptons
CDF l+track
CDF dilepton
D0 l+jets (topo)
CDF l+jets (kine)
CDF l+jets (kineNN)
D0 l+jets (soft µ)
CDF l+jets (soft µ)
D0 l+jets (CSIP)
D0 l+jets (SVT)
CDF l+jets (vtx tag)
CDF l+jets (vtx tag+kine)
D0 all jets
CDF all jets