Recent Top Quark Results at the D0

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On Behalf of the D0 Collaboration
Top Quark Production overview

- Top quark is produced at the tevatron through:
  - $qq$ annihilation (90%)
  - $gg$ fusion (10%)
- And decays predominantly into $b$ and $W$ (ll,jj)
- DØ recorded data set of 280 pb$^{-1}$
  - tt cross section is 30% higher in Run II than in Run I
- Work underway to measure:
  - tt cross section in all leptonic and all modes
  - Top mass to a higher precision
  - W helicity measurement
  - Observation of single top production
Dilepton Event Signature

- 2 high pt leptons
- $\geq 2$ jets
- Large $\not{E}_T$

Backgrounds:
- Physics
  - $WW \rightarrow e\mu, \mu\mu$
  - $Z \rightarrow \tau\tau \rightarrow e\mu, \mu\mu$
- Instrumental
  - $W + \text{jets}$ (jet fakes $e,\mu$)
  - QCD (2 jets fake $e,\mu$)
  - $Z \rightarrow ee$ and fake $\not{E}_T$
Background in the Dilepton channel

- $Z \rightarrow ee (\mu,\mu)$ is the largest background contribution to $ee$ and $\mu,\mu$ channels
- Remove $Z$ mass window
- Require high MET ($> 35$ GeV)
- $H_T > 120$ GeV
Top cross section in dilepton channel

Results from first 90 – 110 pb$^{-1}$

<table>
<thead>
<tr>
<th></th>
<th>ee</th>
<th>μμ</th>
<th>eμ</th>
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</thead>
<tbody>
<tr>
<td>Int. Lum (pb$^{-1}$)</td>
<td>107</td>
<td>90.4</td>
<td>97.7</td>
</tr>
<tr>
<td>Background</td>
<td>0.6±0.5</td>
<td>0.7±0.4</td>
<td>0.6±0.4</td>
</tr>
<tr>
<td>Expected signal</td>
<td>0.6±0.1</td>
<td>0.5±0.1</td>
<td>1.7±0.3</td>
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<tr>
<td>Signal+bkgd</td>
<td>1.2±0.5</td>
<td>1.2±0.5</td>
<td>2.3±0.5</td>
</tr>
</tbody>
</table>

Data: 2 0 3

Combined cross section from all three channels yields:

$$\sigma_{tt} = 8.7^{+6.4}_{-4.7} \text{ (stat)}^{+2.7}_{-2.0} \text{ (syst)} \pm 0.9 \text{ (lum)} \text{ pb}$$
Single lepton Channel

- Event selection:
  - 1 high $P_t$ isolated EM (Muon object)
  - High MET
  - $\geq4$ jets

Branching ratio is much higher than a dilepton channel but with larger background contribution.

- Two sources if the background
  - QCD events which fake an Electron or an isolated muon
  - $W$+jets events
Topological Analysis

- For background rejection a top event likelihood is constructed using 4 topological errors.
  - Jet Energy Scale systematic dominates earlier results
- Use topological variables that depend on
  - Angular quantities
    - sphericity
    - aplanarity
  - Ratios of energy-dependent quantities
    - $H'_T \bar{2}$
    - $K'_T \min$
**Likelihood fitting**

Number of $\bar{t}t$ events is extracted directly from the likelihood fit

- The likelihood shape for $tt$ has very weak mass dependence
- $tt$ shape is predicted by the MC at 175 GeV

<table>
<thead>
<tr>
<th>e+jets</th>
<th>$\mu$+jets</th>
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<tbody>
<tr>
<td>Inst Lum (pb$^{-1}$)</td>
<td>141.2</td>
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<tr>
<td>QCD</td>
<td>$14.1 \pm 1.2$</td>
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<td>W+jets</td>
<td>$94.6 \pm 15$</td>
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<td>Bkgnd</td>
<td>$108.7 \pm 15$</td>
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<tr>
<td>Observed</td>
<td>136</td>
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</table>

$$\sigma(tt) = 7.20^{+2.58}_{-2.39} \text{ (stat)} \ ^{+1.36}_{-1.34} \text{ (syst)} \pm 0.47 \text{ (lumi) pb}$$

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Lepton + jets kinematic distributions

pt of the first jet for EM in the CC

<table>
<thead>
<tr>
<th>entries</th>
<th>data</th>
<th>fitted ttbar</th>
<th>fitted W+jets</th>
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<td>RMS</td>
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missing ET for EM in the CC

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</table>

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**Single lepton with soft muon tagging**

- **Soft Lepton Tag**
  - In 40%, $b$ quarks decay semi-leptonically
    - These leptons have a softer $p_T$ spectrum than leptons from $W/Z$
    - They are not isolated
  - same preselection as topological analysis
  - $\geq 3$ jets
  - softer topological cut

- **e+jets (94 pb$^{-1}$):**
  - 7 observed events
  - Background $1.1 \pm 0.9$

- **$\mu$+jets (94 pb$^{-1}$):**
  - 8 observed events
  - Background $2.2 \pm 1.0$

$\sigma = 11.2 \pm 4.0 \text{ (stat)} \pm 1.3 \text{ (sys)} \pm 1.1 \text{ (lumi)}$

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Combined $\bar{t}t$ cross section from all channels

D0 Run II preliminary $\bar{t}t$ cross section result:

$$\sigma(\bar{t}t) = 7.20^{+2.58}_{-2.39} \text{ (stat)} \, ^{+1.36}_{-1.34} \text{ (syst)} \, \pm 0.47 \text{ (lumi) pb}$$
Preselection [*PRD 58 (1998), 052001*]
- Isolated lepton: $E_T > 20$ GeV,
- $|\eta_e| < 2, |\eta_\mu| < 1.7$
- Jets: $\geq 4$, $E_T > 15$ GeV, $|\eta| < 2$
- Missing $E_T > 20$ GeV
- $|E_T^{lep}| + |E_T| > 60$ GeV ; $|\eta_W| < 2$
- 91 events selected, 125 pb$^{-1}$

Run I DØ result (1998)
$m_t = 172.1 \pm 7.1$ GeV/c$^2$

Run I approach:
- Choose lowest $\chi^2$ solution from constrained kinematic fit $\rightarrow$ fitted mass
- Topological discriminant used to separate signal and background
- Mass estimate made with 2D fit in fitted mass and discriminant
• New Approach is to calculate per event probability to be a $\bar{t}t$ event

• Probability density

$$P(x, M_t) = \frac{1}{\sigma(x)} \int d\sigma(y, M_t) dq_1 dq_2 f(q_1) f(q_2) W(y,x)$$

Mass-dependent, $x$ : reconstructed 4-vectors

Differential Xsec (LO Matrix element + phase space)

PDF’s

Transfer function
Relating partonic Variables to Measured quantities

• Background probability
  • Main component $W+\text{jets}$ (85% of background)
  • $P_{\text{bkg}}$ calculated from leading order matrix element from VECBOS
  • QCD is not included in the Probability density matrix element
  • Only 4 jet events are considered

• Signal purity increased with cut on background probability: $P_{\text{bkg}} < 10^{-11}$.

• 22 events remain

• All jet-parton assignments considered
  • Sum probabilities of all possibilities (12 total)
Event probability: \[ P(x; c_1, c_2, M_t) = c_1 P_{t\bar{t}}(x; M_t) + c_2 P_{\text{bkgd}}(x) \]

- Likelihood formed, maximized to obtain \( M_t, c_1, c_2 \)

\[ M_t = 180.1 \pm 3.6 \text{ (stat)} \pm 3.9 \text{ (syst)} \text{ GeV/c}^2 = 180.1 \pm 5.3 \text{ GeV/c}^2 \]

- 12 signal, 10 background events
- Improvement in statistical uncertainty equivalent to 2.4 times more data
- Dominant systematic error from JES (3.3 GeV/c^2)
- The top decays before hadronization can occur
- Spin information transferred to daughters ($Wb$)
- SM: top decays via V-A current
  polarization for $M_t = 175$
  - 70% Longitudinal ($F_0$)
  - 30% Left-handed ($F_-$)
- Angular distribution of decay products in $W$ rest frame probes this mixture
- Same dataset, probability-based approach: allow $F_0$ to vary

$$F_0 = 0.56 \pm 0.31 \text{ (Statistical)} \pm 0.04 \text{ (Systematic)}$$
The future developments

- Near term (~ 280 pb)
  - New dilepton cross section results
  - B tagging using total sample
  - Top mass measurement using Run I original and matrix method approach
- Longer term
  - Top mass measurement with the 2 GeV precision
  - Observation of single top quark production
  - Detail study of production and decay properties
  - Cross section is all decay channels
  - Spin correlations
  - W polarization
  - Rare decays