Search for Production of Single Top Quarks in the Electron+Jets Channel at DØ

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(on behalf of the DØ Collaboration)

Plan of talk

- Introduction
  - Production of Single Top Quarks
  - Event Signature

- Single Top Analysis
  - Backgrounds
  - b-tagging Methods
  - Event Selection
  - Event Yields

- Results

- Conclusions and Outlook
**Electroweak Production of Single Top Quarks**

- **s-channel**
- **t-channel**
- **s+t channel**

- NLO cross section ($\sqrt{s}=1.96$ TeV): $0.88\text{pb} \pm 8\%$ $1.98\text{pb} \pm 11\%$

- Tevatron **Run I** limits: **DØ** : $< 17 \text{pb}$ $< 22 \text{pb}$
  (at 95% CL) **CDF** : $< 18 \text{pb}$ $< 13 \text{pb}$ $< 14 \text{pb}$

- **Run II**: higher cross sections, higher integrated luminosity,
  high b-tagging efficiency  - **Expect Discovery**!

- Discovery important in order to:
  - Measure CKM matrix element $V_{tb}$
  - Observe top-quark polarization
  - Discover new physics

- **Measure**
- **Observe**
- **Discover**
Single Top Event Signature

- One high-$E_T$ lepton (electron or muon),
- Missing transverse energy $\text{MET}$ (neutrino)
- $\geq 2 \text{ jets}$
  - s-channel: 2 b-quark jets
  - t-channel: 2 b-quark jets, 1 light quark jet
Backgrounds: Electron+Jets Channel

- W/Z + jets production (real-lepton)
  - Estimated using data
  - Wjj, Wcc, Wbb, Zjj, Zcc, Zbb, ...
  - WZ, WW, Z\(\tau\tau\) (negligible)

- Mis-reconstructed multi-jet events (fake-lepton)
  - Jet mis-identified as isolated electron
  - Estimated using background-dominated data
  - reverse “likelihood” cut for electron-ID

- Top-pair (tt) production
  - Lepton+jets, dilepton
  - Estimated from MC
b-tagging methods

- Use three different tagging algorithms to identify b-quark jets

• Muon-in-jet from B-meson decay
  ➔ Soft-Lepton Tag (SLT)

• Tracking-based Lifetime Taggers
  - B-meson has finite lifetime
  - Travels some distance from the vertex (~1mm) before decaying

  - Impact Parameter (IP) Significance
    \[ \frac{d}{\sigma(d)} \]
    Jet Lifetime IP Tag (JLIP)

  - Decay Length Significance
    \[ \frac{L_{xy}}{\sigma(L_{xy})} \]
    Secondary Vertex Tag (SVT)
**Data Sample and Event Selection: Electron+Jets channel**

- **Data sample**: 156-169 pb\(^{-1}\) of DØ Run II data

- **Preselections:**
  - One high-\(E_T\) electron (\(E_T > 15\) GeV), pseudorapidity |\(\eta^{\text{det}}\)\| < 1.1
  - \(\text{MET} > 15\) GeV
  - \(2 \leq \text{Njets} \leq 4\): \(E_T > 15\) GeV, |\(\eta^{\text{det}}\)\| < 3.4
  - Leading jet \(E_T > 25\) GeV, |\(\eta^{\text{det}}\)\| < 2.5
  - Also reject mis-reconstructed events: “triangle” cuts

- Reject events with muons in them (“orthogonal” electron and muon samples)

- \(\geq 1\) b-tagged jet (SLT, SVT, JLIP)

(SLT sample is orthogonal to the SVT and JLIP samples)
Event Yields: After Preselections

Yields (counts)

Jet multiplicity

SLT

Yields (counts/50 GeV)

H_T [GeV]

SVT

JLIP

Yields (counts/10 GeV)

M_T (W) [GeV]

Electron+Jets Channel

- Data
- fake-lepton
- W/Z + jets
- tt (lepton+jets)
- tt (dilepton)
- t-channel
- s-channel
Final Selection: Electron+Jets channel

Simple cut to reduce largest background (W/Z +jets)

- \( H_T \equiv E_T(\text{electron}) + \text{MET} + \sum_{i=1,2} E_T(\text{jet}_i) > 150 \text{ GeV} \)
Event Yields: After Final Selection

**Electron+Jets Channel**

- **Data**
- **fake-lepton**
- **W/Z + jets**
- **t\bar{t}**
- **t-channel**
- **s-channel**
## Event Yields: Electron+Jets channel

<table>
<thead>
<tr>
<th></th>
<th>SLT</th>
<th>SVT</th>
<th>JLIP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Signals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>s-channel</td>
<td>0.7 ± 0.1</td>
<td>1.8 ± 0.4</td>
<td>1.8 ± 0.4</td>
</tr>
<tr>
<td>t-channel</td>
<td>0.9 ± 0.2</td>
<td>3.0 ± 0.7</td>
<td>3.0 ± 0.7</td>
</tr>
</tbody>
</table>

| **Backgrounds**  |           |           |           |
| tt (lepton+jets and dileptons) | 9.7 ± 1.8 | 24.1 ± 4.7 | 24.5 ± 4.9 |
| W/Z +jets and fake-l | 25.7 ± 4.1 | 45.8 ± 8.9 | 62.2 ± 12.5 |

| **Sum of Backgrounds** | 35 ± 5 | 70 ± 10 | 87 ± 13 |

| **Observed**         | 54      | 63      | 78      |

### Systematic Uncertainties
- MC Signal acceptance: dominated by jet energy scale, trigger, and tagger modeling, 20%
- MC-based background yields: also includes normalization, 25%
- Data-based background yields: dominated by tagging probability estimate, 20%
Results: Limits for Single Top Production cross section

- Use **Bayesian** approach (with *flat* prior for single top cross section)
- Include systematic uncertainties and correlations (Multi-Variate Gaussian)
- Also use $C_{L_s}$ method for setting limits (different interpretation, but results similar)

**Observed/Expected limit at 95% CL** (Bayesian approach)

<table>
<thead>
<tr>
<th>Method</th>
<th>$\sigma_s$ (Obs/Exp)</th>
<th>$\sigma_t$ (Obs/Exp)</th>
<th>$\sigma_{s+t}$ (Obs/Exp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLT</td>
<td>&lt; 53/26 pb</td>
<td>&lt; 81/42 pb</td>
<td>&lt; 72/35 pb</td>
</tr>
<tr>
<td>SVT</td>
<td>&lt; 14/18 pb</td>
<td>&lt; 20/24 pb</td>
<td>&lt; 18/21 pb</td>
</tr>
<tr>
<td>JLIP</td>
<td>&lt; 16/20 pb</td>
<td>&lt; 22/27 pb</td>
<td>&lt; 20/24 pb</td>
</tr>
</tbody>
</table>

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**Graph:**

- **Title:** SVT Tagger
- **Axes:**
  - $\sigma$ (pb): 0 to 25
  - Posterior Prob. Density (pb\(^{-1}\)): 0.02 to 0.18
- **Legend:**
  - *s-channel*
  - *t-channel*
  - *s+t channel*

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Conclusions and Outlook

- First search for single top quark production in DØ Run II
  - Focus on understanding of data
  - Current sensitivity better than in Run I

- Work towards observation of single top
  - Improve detector understanding and background modeling
    - Reduce systematic uncertainties
  - Keep acceptance as high as possible
    - Improve selections, b-tagging
  - Employ advanced analysis techniques
    - Neural Networks for better background rejection
    - Limit setting using shapes of kinematic distributions
Backup Slides
Modeling of Signal and MC Backgrounds

Signal: Single Top Production
- COMPHEP (corrected to NLO), with
- PYTHIA: include underlying event, ISR/FSR, hadronization
- TAUOLA: decay tau leptons
- EVTGEN: decay B-hadrons
- $Q^2 = m_t^2$ (s-channel), $Q^2 = (m_t/2)^2$ (t-channel)
- Parton distribution functions (PDF): CTEQ6.1M

MC-based Backgrounds: Top-pair (tt) production
- LO ALPGEN, with
- PYTHIA: include underlying event, ISR/FSR, hadronization
- TAUOLA: decay tau leptons
- EVTGEN: decay B-hadrons
- cross section scaled to NLO
- $Q^2 = m_t^2$
- Parton distribution functions (PDF): CTEQ6M
Background Estimation

Preselected Sample

Tagged Sample
require at least one tag

Untagged Sample
=0 tags

scale to pre-tagged W+jets yield

apply Inclusive TRF

Final Data Sample

W+jets yield

multi-jet Sample
preselection cuts reverse electron likelihood cut

scale to pre-tagged mis-ID lepton yield

apply tagger

mis-ID lepton yield

MC Samples
preselection cuts

apply data/MC scale factors, trigger weight

scale to XS*lumi

apply tagger or flavor-dependent TRFs

MC yields