A Top Pair Resonance Search At DØ

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Tevatron Run II began on March 1st 2001.

The Tevatron collides protons and antiprotons at a center of mass energy of 1.96 TeV.

The predicted integrated luminosity by 2009 is between 4 and 8 fb\(^{-1}\).

The Tevatron delivered over 1 fb\(^{-1}\) (per experiment).

370 pb\(^{-1}\)
The DØ Detector
Introduction

The large mass of the top quark suggests it may play a special role in electroweak symmetry breaking. The Standard Model predicts non resonant top production. A significant bump would indicate a narrow resonance $\rightarrow$ new physics.

Top production studies serve in preparation for the LHC, where top production will be a large background for many new physics searches.

This search was done in the lepton + jets channel.
- the isolated lepton ($e/\mu$, possibly through an intermediate $\tau$) helps reduce multi jet background
- the large branching ratio yield good statistics

Top Pair Branching Fractions

- "alljets" 44%
- $\tau+\tau$ 1%
- $\tau+\mu$ 2%
- $\tau+\tau$ 2%
- $\tau+e$ 2%
- $\tau+\tau$ 1%
- $\mu+\mu$ 15%
- $\mu+e$ 15%
- $e+e$ 15%
- $e+\mu$ 15%
- $\mu+\tau$ 15%
- "dileptons" 15%
- "lepton+jets" 15%
**Event Selection**

**Main Signature**

- A lepton (e/µ) + jets trigger.
- A $p_T > 20$ GeV isolated lepton with $|\eta| < 1.1$ (e) or $|\eta| < 2.0$ (µ).
- At least 20 GeV of missing transverse energy ($MET$).
- Four or more $p_T > 15$ GeV jets with $|\eta| < 2.5$
- At least one jet is b-tagged by reconstructing a displaced secondary vertex.

**Additional Cuts**

- Central primary vertex location ($|z| < 60$ cm).
- A triangular cut in $\Delta \Phi(l, MET)$ vs $MET$
- A veto on a second high $p_T$ lepton.
- Kinematic fit converges
B-tagging

- B hadrons’ lifetime: $c\tau \sim 450$ $\mu$m
- B hadrons travel $L_{xy} \sim 3$ mm before decay

![Diagram of track selection and 3D secondary vertex reconstruction]

- **Track Selection**
  - (quality cuts, remove V0s)

- **3D secondary vertex reconstruction**

- $\frac{l}{\sigma_l} > 7$

- **Graph**
  - $p_T$ vs. Jet $p_T$ (GeV)
  - $D\bar{O}$
  - $b$-jet efficiency
  - $c$-jet efficiency
  - mis-tagging rate ($\times 10$)
The Main Backgrounds

**SM top pairs** \((l+\text{jets})\)
- Same signature → dominant background
- A lepton with high \(p_T\)
- A neutrino \(\rightarrow\) MET
- \(\geq 4\) jets

**W → lν + \(\geq 4\) jets**

**Multi jet events**
- Fake isolated lepton (often \(b\rightarrow lX\))
- Misreconstructed MET
Multi jet Background Estimation

The efficiencies of $\mu$-isolation & e-id are:

- Very different for real leptons and for multi jet events
- Well understood in the signal simulation

This makes them ideal for the matrix method:

\[
N_{\text{loose}} = N^{W+tt} + N^{QCD}
\]
\[
N_{\text{tight}} = \varepsilon_{W+tt} N^{W+tt} + \varepsilon_{QCD} N^{QCD}
\]

$\varepsilon_{W+tt} \approx 85\%$, $\varepsilon_{QCD} \approx 10-16\%$

Derived from a similar “untagged” data sample depleted in true leptons
W+jets Background Estimation

Flavor composition fractions
(for each jet multiplicity)

B-tagging efficiencies per jet, by flavor

Estimated contribution to the untagged sample

From simulation

Trigger effects

Estimated W+jets background

From data

B-tagging efficiencies per event
(for each jet multiplicity and flavor composition)
This procedure chooses the right permutation ~65% of the time.
Simulated a Z’-like X using PYTHIA:

- spin=1
- produced in $q\bar{q} \rightarrow X$

- Forced to decay to a top pair.
- $\Gamma_X = 0.012 M_X$

1. Two partons end up in one jet, and an additional gluon jet is picked up instead.
2. Many hard jets $\Rightarrow$ Inferior MET
3. PDFs enhance low mass production
# Systematic Uncertainties

Effects on the overall normalization of SM contributions.

<table>
<thead>
<tr>
<th>source</th>
<th>rel. syst. uncertainty (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\sigma^+$</td>
</tr>
<tr>
<td>Top quark mass (includes effect on $\sigma_{t\bar{t}}$)</td>
<td>+8.7</td>
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<tr>
<td>Signal subtraction from $W$+jets background estimate</td>
<td>+0.0</td>
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<tr>
<td>Jet reconstruction</td>
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<tr>
<td>Luminosity</td>
<td>+4.6</td>
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<tr>
<td>Theoretical uncertainty on $\sigma_{t\bar{t}}$</td>
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<tr>
<td>$W$+jets flavor composition</td>
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<tr>
<td>Jet energy calibration</td>
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<tr>
<td>$b$-tagging rate</td>
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<tr>
<td>MC-to-data correction factors</td>
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<tr>
<td>Theoretical uncertainty on $\sigma_{singletop}$</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>+13.2</strong></td>
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</tbody>
</table>
Observed Mass Distribution

DØ Run II Preliminary ($L = 370 \text{ pb}^{-1}$)

- data
- $\bar{t}t$
- W+jets
- multijet
- single top
- total systematic error

Used (NNLO) top pair cross section $6.77 \pm 0.42 \text{ pb}$

Number of events expected: $89.2^{+11.8}_{-13.3}$

Observed: 108

(in both channel combined)
Upper Limits

DØ Run II Preliminary (L = 370 pb⁻¹)

- prediction for topcolor Z'
  with $\Gamma_{Z'} = 1.2\% M_{Z'}$
- expected limit at 95% C.L.
- observed limit at 95% C.L.

Exclusion for the leptophobic Z' boson (part of a topcolor model) in Harris, Hill, Parke, hep-ph/9911288: $M_{Z'} > 680 GeV$
Conclusions

Performed a search for a narrow top pair resonance in the lepton + jets channel using 370 pb\(^{-1}\) of integrated luminosity.

No evidence for resonant top pair production.

Set a limit on a leptophobic Z': \( M_{Z'} > 680 GeV \)