Searches for $t\bar{t}$ Resonances at the Tevatron

Azeddine Kasmi
Baylor University
On behalf of the CDF and D0 Collaborations
ICHEP 2012, Melbourne, Australia

July 6, 2012
Table of Contents

1. Introduction
2. All Hadronic Channel
3. Lepton + Jets Channels
4. Conclusion
Introduction

- Top is the heaviest fundamental particle
  - In EWSB
  - In BSM scenarios
- Large radiative correction to the Higgs:
  - Need to cancel
  - New particles: Top partners (SUSY), Fermions (Little Higgs), Extra Dimensions
- How are $t\bar{t}$ pairs produced?
  - Only by SM QCD?
  - Or is there New Physics?
  - Are $t\bar{t}$ produced by massive resonances?
- At the Tevatron, we investigate these
pp\bar{p} collisions at 1.96 TeV
Peak luminosity $10^{34}$ cm$^2$s$^{-1}$
Weekly integrated luminosity $\sim 50$ pb$^{-1}$
$\sim 12$ fb$^{-1}$ delivered
($\sim 10$ fb$^{-1}$ on tape for each experiment)
The CDF and the D0 Detectors

- Muon systems
- EM and Had Calorimeters
- Solenoid
- Tracker
- Silicon Vertex Detector
All Hadronic Channel at CDF (2.8 fb\(^{-1}\))

- Advantages
  - Highest branching ratio
    - Most events are here
  - No missing information like neutrino
    - Better signal templates
  - Mass resolution is much improved over lepton+jets
  - Cross-check for a possible discovery
- Disadvantages
  - Large QCD background
  - More combinations
All Hadronic Results at CDF (2.8 fb$^{-1}$)

- The leptophobic model predicts a vector particle ($Z'$), which couples primarily to the third generation of quarks and has no significant couplings to leptons.
- Exclusion limit on leptophobic topcolor at 95% C.L.
  - $m_{Z'} < 805$ GeV/c$^2$
  - Width assumption, $\Gamma_{Z'} = 0.012 M_{Z'}$

Phys. Rev. D 84, 072003 (2011)
Lepton + Jets Channels at D0 (5.3 fb$^{-1}$)

- $W$ decays to an $e$ or $\mu$
- NN $b$ tagger to reduce background
- Reconstruct neutrino momentum by using measured $E_T$ and $W$ mass constraint for the lepton-neutrino pair

(a) exactly 3 jets
(b) at least 4 jets
Lepton + Jets Channels at D0 (5.3 fb$^{-1}$)

- Exclude leptophobic topcolor $Z'$ ($\Gamma_{Z'} = 0.012M_{Z'}$) at 95% C.L. below
  - 835 GeV/c$^2$ (observed)
  - 920 GeV/c$^2$ (expected)

Lepton + Jets Channels at CDF (4.8 fb$^{-1}$)

- For each event: apply $t\bar{t}$ hypothesis: observed event kinematics mapped to parton level using the Matrix Element for $t\bar{t}$ production and decay
- $L+J$ Backgrounds (treatment same as for $\sigma$ measurements)
  - $W+Jets$ (HF, LF) (get tag rate, etc)
  - QCD (data driven)
  - EWK (diboson, single top)

<table>
<thead>
<tr>
<th>component</th>
<th>4 jets</th>
<th>$\geq 5$ jets</th>
</tr>
</thead>
<tbody>
<tr>
<td>non-$W$</td>
<td>$46.1 \pm 35.7$</td>
<td>$15.7 \pm 12.2$</td>
</tr>
<tr>
<td>$Z+\text{light flavor}$</td>
<td>$6.4 \pm 0.5$</td>
<td>$1.6 \pm 0.1$</td>
</tr>
<tr>
<td>$W+\text{light flavor}$</td>
<td>$32.9 \pm 8.5$</td>
<td>$7.4 \pm 3.1$</td>
</tr>
<tr>
<td>$Wb\bar{b}$</td>
<td>$51.5 \pm 12.6$</td>
<td>$12.4 \pm 3.7$</td>
</tr>
<tr>
<td>$Wc\bar{c}$</td>
<td>$27.7 \pm 6.6$</td>
<td>$7.3 \pm 2.1$</td>
</tr>
<tr>
<td>$Wc\bar{c}$</td>
<td>$14.0 \pm 3.3$</td>
<td>$3.0 \pm 0.9$</td>
</tr>
<tr>
<td>single top</td>
<td>$8.9 \pm 0.4$</td>
<td>$1.4 \pm 0.0$</td>
</tr>
<tr>
<td>diboson</td>
<td>$9.1 \pm 0.6$</td>
<td>$2.4 \pm 0.1$</td>
</tr>
<tr>
<td>total non-$t\bar{t}$</td>
<td>$196.6 \pm 39.5$</td>
<td>$51.2 \pm 13.3$</td>
</tr>
<tr>
<td>SM $t\bar{t}$</td>
<td>$667.1 \pm 61.8$</td>
<td>$225.2 \pm 21.0$</td>
</tr>
</tbody>
</table>

Data: 996 370

$tt/non-tt:3.6$

Data/Bkg: 1.2
Lepton + Jets Channels at CDF (4.8 fb$^{-1}$)

95 CL limit on top-color-assisted technicolor $Z'$:

$m_{Z'} > 900 \text{ GeV}/c^2$ for $\Gamma_{Z'} = 0.012M_{Z'}$

Phys. Rev. D 84, 072004 (2011)
The chromophilic $Z'$ couples only to two gluons.

A dominant decay mode of $Z' \rightarrow q\bar{q}g$.

Cross section grows with $m_{Z'}$ for a fixed coupling.

We consider the decay mode:

- $Z' \rightarrow t\bar{t}g \rightarrow W^+bW^-\bar{b}g$
- One $W$ decays leptonically and the other hadronically
- Leptons include leptonic $\tau$ decays.
Chromophilic $Z'$ Resonance in Lepton + Jet at CDF

- Fit the most likely value of the sum of the $Z'$ cross section by performing a binned maximum-likelihood fit in $m_{t\bar{t}j}$
- Allow for systematic and statistical fluctuations
- No evidence for the presence of $Z'$ in $t\bar{t}j$ events, so we set upper limits on $Z'$ production at 95% C.L.
We set cross-section upper limits on the production of this chromophilic $Z'$ at 95% C.L. from 300 fb to 40 fb for $Z'$ masses ranging from 400 GeV/c$^2$ to 1000 GeV/c$^2$, respectively.
CDF and D0 reported a forward-backward asymmetry ($A_{FB}$) that is significantly larger than predicted by the SM.

Can be explained via models involving the production of a new heavy mediating particle $M$ that enhances $A_{FB}$.

Such new particles may also be singly produced in association with a $t$ ($\bar{t}$) and further decay to $\bar{t}$ ($t$) and an additional jet, $p\bar{p} \rightarrow M t(\bar{t}) \rightarrow \bar{t}j t(t\bar{t})$. 

$p\bar{p} \rightarrow M t(\bar{t}) \rightarrow \bar{t}j t(t\bar{t})$
Search For Top + Jet Resonances in Lepton + Jet at CDF

- We search for lepton + jet signature
- Detector signature $l + \nu + qq' + bb' + q$
- Exactly one $e$ or $\mu$ with $p_T > 20$ GeV
- At least 5 jets with $E_T > 20$ GeV and $|\eta| < 2.0$
- At least one $b$ tag
- $E_T \geq 20$ GeV
Search For Top + Jet Resonances in Lepton + Jet at CDF

- Data are consistent with the SM
- Set $\sigma$ limits from 0.61 pb to 0.02 pb for resonances ranging from 200 GeV/c$^2$ to 800 GeV/c$^2$
Conclusion

- Reported on $t\bar{t}$ resonant production results from the Tevatron
- No evidence for resonant production of $t\bar{t}$ and top+jets at the Tevatron
- Tevatron searches in some cases have better reach than LHC at low masses (below 1 TeV)
- The LHC will carry the torch to reach masses above 1 TeV