Top Properties and Searches for New Physics in Top Events at the Tevatron

Nathan Goldschmidt
University of Florida
on behalf of the CDF and DØ Collaborations

Recontres de Blois
July 18, 2010
Forward-backward asymmetry in $t\bar{t}$ @ CDF

- In leading order QCD, top production is symmetric; at NLO, top quark is repelled at high rapidities by soft Coulomb field of incoming light quark, anti-top is simultaneously attracted at low rapidity.

- MCFM, an NLO MC, predicts positive asymmetry at parton-level:
  - $A_{LAB} = 0.038 \pm 0.006$
  - $A_{tt\bar{t}} = 0.058 \pm 0.009$

$$A_{FB} = \frac{N(Y > 0) - N(Y < 0)}{N(Y > 0) + N(Y < 0)}$$
Forward-backward asymmetry in $t\bar{t}$ @ CDF

- Measure rapidity variables
- Subtract background events to extract signal
- Correct to parton-level via matrix unfold
- Calculate forward-backward asymmetry
  - inclusive
  - rapidity-dependent

\[
\begin{array}{|c|c|c|}
\hline
q & t_{\text{lep}} & t_{\text{had}} \\
\hline
+ & t & \bar{t} \\
- & \bar{t} & t \\
\hline
\end{array}
\]

\[-qY_{\text{had}} = Y_t = -Y_{\bar{t}}\]

\[q(Y_{\text{lep}} - Y_{\text{had}}) = q\Delta Y = Y_t - Y_{\bar{t}}\]
Forward-backward asymmetry in $t\bar{t}$ @ CDF

<table>
<thead>
<tr>
<th>LAB Frame $A_{FB}$</th>
<th>Inclusive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected</td>
<td>$0.150 \pm 0.050_{stat} \pm 0.024_{sys}$</td>
</tr>
<tr>
<td>MCFM Predicted</td>
<td>$0.038 \pm 0.006$</td>
</tr>
</tbody>
</table>
Forward-backward asymmetry in $t\bar{t}$ @ CDF

Reconstructed Top Rapidity Difference

Top Quark Rapidity Difference

<table>
<thead>
<tr>
<th>TTbar Frame $A_{FB}$</th>
<th>Inclusive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected</td>
<td>$0.158 \pm 0.072_{\text{stat}} \pm 0.017_{\text{sys}}$</td>
</tr>
<tr>
<td>MCFM Predicted</td>
<td>$0.058 \pm 0.009$</td>
</tr>
</tbody>
</table>
Forward-backward asymmetry in $\bar{t}t$ @ CDF

| $A_{FB}$             | Low Rapidity ($|\Delta y|<1$) | High Rapidity ($|\Delta y|>1$) |
|----------------------|-------------------------------|-------------------------------|
| Corrected            | $0.026 \pm 0.104_{stat} \pm 0.055_{sys}$ | $0.611 \pm 0.210_{stat} \pm 0.141_{sys}$ |
| MCFM Predicted       | $0.039 \pm 0.006$              | $0.123 \pm 0.018$             |
Spin correlations in $t\bar{t}$ @ CDF

- Decay width of the top quark is shorter than the spin decoherence time
- Spin information in V-A correlations in weak decay; leptons and d quarks are best to measure this
- Top pairs with the same spin are expected to dominate sample $\kappa \approx 0.40$ in helicity basis
- Seek to evaluate expected spin correlation in QCD
Spin correlations in $t\bar{t}$ @ CDF

- In lepton+jets channel, identify down quark as jet closest to b jet in $W$ rest frame.
- Measure cosine of lepton and down quark helicity angle.
  - $\cos \theta_{lep} \times \cos \theta_d$ gives a single variable to measure the helicity of the combined $t\bar{t}$ system.
- Create custom, polarized HERWIG templates for same helicity, opposite helicity, and background.
- Fit product of cosines to templates using binned likelihood fit.
Spin correlations in $t\bar{t}$ @ CDF

$\cos(\theta_I) \times \cos(\theta_d)$

CDF Run II preliminary $L=5.3 \text{ fb}^{-1}$

- Opposite Helicity
- Same Helicity
- Backgrounds
- Data

$\kappa: 0.48 \pm 0.48_{\text{stat}} \pm 0.22_{\text{sys}}$

In helicity basis: $\kappa = 0.48 \pm 0.48_{\text{stat}} \pm 0.22_{\text{sys}}$

In beam basis: $\kappa = 0.72 \pm 0.64_{\text{stat}} \pm 0.26_{\text{sys}}$
Search for nMSSM $H^+$ @ CDF

Motivation

▶ Search for $t \rightarrow H^+ b$, where $H^+ \rightarrow W^+ A$
▶ If $m_A < 2m_b$, $A \rightarrow \tau^+ \tau^-$ will dominate
▶ No strong limits on $A$ in this scenario
▶ c.f. arXiv:0807.2135

Selection

▶ Start with standard $t\bar{t}$ lepton+jets selection...
▶ $\geq 3$ jets, 1 $b$–tag, $H_T > 250$GeV
▶ Search for isolated track with $3 \leq p_T \leq 20$ GeV
▶ Dominant background from Underlying Event

arXiv:0905.3381
Search for nMSSM $H^+$ @ CDF

Underlying Event Modeling

- Many samples have identical UE $p_T$ spectra
- Jet–triggered data is used to model the UE $p_T$ spectrum
- This model is tested by measuring the $Z/\gamma^*$ cross–section
- Excellent agreement found with previous measurements
Search for nMSSM $H^+$ @ CDF

Results

- The data are consistent with the UE model
- But, no indication of signal
- Limits on $BR(t \to H^+ b)$ vs. $m_{H^+}$ are set for several values of $m_A$
Results

- For large \( \tan(\beta) \),
  \[ BR(H^+ \rightarrow \tau^+ \nu_\tau) \sim 1 \]
- Neural Net analysis to separate \( t\bar{t} \rightarrow H^+ bW^- \bar{b} \) from \( t\bar{t} \rightarrow W^+ bW^- \bar{b} \)
Results

- Limits on branching–ratio, $m_{H^+}$ vs. $\tan(\beta)$
Search for resonant $t\bar{t}$ production in the all–hadronic channel @ CDF

- Multijet background modeled using data.
- Event selection by Neural Net

CDF Run II preliminary, $L=2.8\,fb^{-1}$

![Graph showing $M_{tt}$ distribution with QCD and SM $t\bar{t}$ predictions, and CDF data, $N_{ev}=2086$.]

![Graph showing $\sigma \cdot BR(X^0 \rightarrow t\bar{t})$ vs. $M_{X^0}$ with expected and observed limits at 95% C.L., and expected limits at 1 and 2σ for a leptophobic $Z'$ with $\Gamma_{Z'}=1.2\% M_Z$.]
Search for resonant $t\bar{t}$ production in lepton+jets @ DØ

- Reconstruction simplified, robust
- 95 CL limit on top-color-assisted technicolor $Z'$: $m_{Z'} > 820$ GeV for $\Gamma_{Z'} = 0.012M_{Z'}$
Search for resonant $\bar{t}t$ production in lepton+jets @ CDF

- Full Matrix Element reconstruction
- 95 CL limit on top-color-assisted technicolor $Z'$: $m_{Z'} > 900$ GeV for $\Gamma_{Z'} = 0.012 M_{Z'}$
Search for $t' @ CDF$

- Search for $t' \rightarrow Wq$ in lepton+jet events
- $t'$ mass reconstructed using kinematic fit
- Fit to estimate signal cross-section in multidimensional space: $H_T$, $M_{rec}$, $N_{jet}$
Search for $t'$ @ CDF

- No statistically significant excess, it's really less than 2 sigma
- Events with high $M_{reco}$ appear to be clean lepton+jet events
Event Displays of high–$M_{reco}$ events

CDF Run II Preliminary

Run: 194323  Ht: 856.7 GeV  
Event: 9830702  Mreco: 449.7 GeV

CDF Run II Preliminary

Run: 192306  Ht: 635.2 GeV  
Event: 405574  Mreco: 521.9 GeV

Pt (mu): 148.8 GeV
Et: 200.2 GeV
Et: 37.9 GeV
Et: 217.0 GeV
MET: 88.0 GeV
Et: 154.9 GeV

Pt (mu): 218.6 GeV
Et: 210.2 GeV
Et: 43.2 GeV
Et: 65.1 GeV
MET: 57.4 GeV
Et: 40.7 GeV
Thank You