Measurements of Top Production and Decay at the Tevatron

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Production

\[ \sim 85 \% \]

\[ \sim 15 \% \]

Decay

\[ \sim 100 \% \]
Top Decay Channels

- Di-lepton ($W \rightarrow l\nu$, $W \rightarrow l\nu$)
- Lepton + Jets ($W \rightarrow l\nu$, $W \rightarrow qq$)
- All-hadronic ($W \rightarrow qq$, $W \rightarrow qq$)
This Talk

Properties
- Mass
- Charge
- Lifetime

Production
- Cross Section
- Asymmetry
- Resonant Production

Decay
- W Helicity
- Non SM Decay
- Top-like particles - 4th gen

Previous Talk
~ 6 fb$^{-1}$ delivered
~ 3 fb$^{-1}$ in current analysis
Top Production
Looking for Consistency

![Graph showing m_W vs. m_t with LEP2 and Tevatron (preliminary) and LEP1 and SLD data, with 68% CL confidence level.](Image1)

![Graph showing σ(pp -> t̄t) vs. Top Quark Mass (GeV/c^2) with different predictions from Moch & Uwer, Cacciari et al., and Kidonakis & Vogt, taken from arXiv:0807.2794, 0804.2800, and 0805.3844 (2008).](Image2)
Top Production
Looking for Consistency

- New production mechanisms can modify this picture - cross section, kinematics...
- Massive Gluons, Z' - remnants of some higher order symmetry breaking
Cross Section by b-jet Identification

- Essentially a counting measurement
- Performed in the lepton + jets channel
- Require events to have a b-jet identified through secondary vertex (b-tagging)
- Rely on data as much as possible to derive backgrounds
- Largest backgrounds QCD and W-boson associated with Heavy Flavor jets

\[
\sigma_{t\bar{t}} = \frac{N_{data} - N_{bkg}}{A \cdot \int \mathcal{L} \ dt}
\]
Cross Section by b-jet Identification

- Background estimate is calculated as a function of jet multiplicity
- Events with 1 or 2 jets are a control region
- Cross Section calculated from events with $\geq 3$ jets

$$\sigma_{tt} = 7.1 \pm 0.4_{\text{stat}} \pm 0.6_{\text{sys}} \pm 0.4_{\text{lum}} \text{ pb}$$

$$\frac{\Delta \sigma}{\sigma} = 11.6\%$$

@ $M_t = 175$ GeV/c$^2$
Cross Section by b-jet Identification

- Background estimate is calculated as a function of jet multiplicity.
- Events with 1 or 2 jets are a control region.
- Cross Section calculated from events with $\geq 3$ jets.

$\sigma_{t\bar{t}} = 7.1 \pm 0.4_{\text{stat}} \pm 0.6_{\text{sys}} \text{ pb}$ at $M_t = 175 \text{ GeV/c}^2$

Largest Systematics
- Correction on $W+HF$ Monte Carlo (4%)
- Correction on b-tagging in Monte Carlo (6%)
- Luminosity (6%)

$\frac{\Delta \sigma}{\sigma} = 11.6\%$
Top Cross Section using Event Kinematics

- Rely on identifying top events through kinematics as opposed to b-jet identification
- Feed distributions into Neural Net, trained to distinguish signal from background and fit templates to data
Top Cross Section using Event Kinematics

- Fit result yields cross section

$$\sigma_{t\bar{t}} = 7.0 \pm 0.4_{\text{stat}} \pm 0.4_{\text{sys}} \pm 0.4_{\text{lum}} \text{ pb}$$

@ $M_t = 175$ GeV/$c^2$

$$\frac{\Delta \sigma}{\sigma} = 10\%$$

- Topological approach does not rely on b-jet identification, therefore eliminating the last measurements larger systematics

- Largest systematics - Luminosity (6%) and Jet Energy Scale (3%)
Reducing the Luminosity Systematic

- Luminosity is the largest systematic (6%) for both cross section measurements
- Can employ a common technique in electroweak physics and measure the top cross section relative to the Z cross-section
- Z Cross section measured with same amount of data

\[ \sigma_{\gamma^*/Z} = 253.5 \pm 1.1_{\text{stat}} \pm 4.5_{\text{sys}} \pm 14.9_{\text{lum}} \text{ pb} \]

\[ \sigma_{\gamma^*/Z}^{\text{theory}} = 251.3 \pm 5.0_{\text{scales/pdf}} \text{ pb} \]

Top Cross Section

\[ \sigma_{t\bar{t}} = R \cdot \sigma_{Z}^{\text{theory}} \]

b-jet

\[ \sigma_{t\bar{t}} = 7.0 \pm 0.4_{\text{stat}} \pm 0.6_{\text{sys}} \pm 0.1_{\text{theory}} \text{ pb} \]

\[ \frac{\Delta \sigma}{\sigma} = 10\% \]

Kinematic

\[ \sigma_{t\bar{t}} = 6.9 \pm 0.4_{\text{stat}} \pm 0.4_{\text{sys}} \pm 0.1_{\text{theory}} \text{ pb} \]

\[ \frac{\Delta \sigma}{\sigma} = 8\% \]

Theory

\[ \sigma = 6.73^{+0.72}_{-0.63} \text{ pb} \]

@ \( M_t = 175 \text{ GeV/c}^2 \)
Good Agreement Across Channels & Experiment
Resonant Top Production

- Looking for $Z'$, Massive Gluon (new color octet)
- More direct search than cross section
- Search in mass spectrum of the $tt$ system
- Mass of the system fully reconstructed for each event
- Narrow resonance templates formed from Monte Carlo and fit to data
Resonant Top Production

- Fit to data performed across several mass points
- Using narrow width topcolor model for expected cross section
- $M_{Z'} > 760$ GeV at 95% CL

CDF Result: $M_{Z'} > 720$ GeV at 95% CL in 0.9 fb$^{-1}$
Top Decay

Looking for Consistency


- **Di-lepton** ($W \rightarrow l \nu$ $W \rightarrow l \nu$) with 12%
- **Lepton + Jets** ($W \rightarrow l \nu$ $W \rightarrow q\bar{q}$) with 44%
- **All-hadronic** ($W \rightarrow q\bar{q}$ $W \rightarrow q\bar{q}$) with 44%
Top Decay

Looking for Consistency

![Graph showing the cross-section of top quark (p + $\bar{p}$) in pb as a function of top quark mass (GeV/c^2) with different theories and data points.]

- **Di-lepton (W → lv  W → lv)**
- **Lepton + Jets (W → lv  W → qq)**
- **All-hadronic (W → qq  W → qq)**
Search for Charged Higgs

- Relative rates of cross sections across decay channels could be modified if top is decaying to charged Higgs

- Use events across three channels: lepton + jets, dilepton, and $\tau + \text{jets}$

- Consider two models: $H^+ \rightarrow \tau\nu$ and $H^+ \rightarrow cs$

- Compare cross sections in above three channels yields limit on models

- Limits placed on charged Higgs in pure leptophobic (MHDM) or tauonic models (MSSM >> $\tan\beta$)
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Search for $t\bar{t}H \rightarrow t\bar{t}b\bar{b}$

• Searching for Standard Model Higgs in association with top production

• $\sigma \cdot BR$ is very low, but interesting channel to search for deviations from SM

• Distinguish signal from background using:
  • Scalar sum of transverse energy - $H_T$
  • The number of jets
  • Track Parameters
  • The number of b-jets in the event (Neural Network Identification)
Search for $tt\bar{H} \rightarrow tt\bar{b}\bar{b}$

- No observed deviation from SM expectation
- Observed Limit at $M_H = 115$ GeV
  64 times larger than SM prediction
- Result contributes in CDF/D0 combined search
Search for Fourth Generation Top

- Search for heavy top (t') quark decaying to Wq final state
- 4th generation present in little Higgs and beautiful mirrors models
- Reconstruct mass of top from kinematic constraints
- Use reconstructed mass and scalar sum of transverse energy in the detector (H_T) to discriminate top from t'
Search for Fourth Generation Top

- Perform 2D Likelihood fit using the reconstructed mass and $H_T$

Exclude

$M_{t'} < 311 \text{ GeV at 95\% CL}$
No evidence for top decay to $H^+b$
No evidence for $ttH$ production
$M_{t'} < 311$ GeV at 95% CL

$\sigma_{tt} = 7.0 \pm 0.4_{stat} \pm 0.6_{sys} \pm 0.1_{theory}$ pb

$M_{Z'} > 760$ GeV at 95% CL

Visit the D0 & CDF public page for more results

http://www-d0.fnal.gov/Run2Physics/top_public_web_pages

http://www-cdf.fnal.gov/physics/new/top/top.html
On the Tevatron

8 weeks to get data
< 9 months to turn an analysis