Top pair production distributions at the Tevatron

—including Afb, differential cross sections—

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Top Quark Properties

- **Mass**
- **$m_t - m_\bar{t}$ difference**
- **Width**
- **Charge**

**Intrinsic**

**Decay**

- **Br($t \rightarrow Wb$)**
- **Br($t \rightarrow Zq$)**
- **$W$ helicity**

**Production**

- **$t\bar{t}$ Cross-section**
- **$t\bar{t}$ resonance**
- **Differential XS**
  - $d\sigma/p_T^t, d\sigma/M_{t\bar{t}}$
- **$t\bar{t}$ spin correlation**
- **$A_{FB}$ of $t\bar{t}$**

**Hyun Su Lee’s talk**

**R. Demina’s talk**

**This talk**
**$t\bar{t}$ Production at Tevatron**

- **$q\bar{q}$ annihilation**
  
  
  Dominant process at Tevatron

- **gluon fusion**

  10~20% contribution at Tevatron
  Dominant process at LHC

Tevatron is suitable to the study of $q\bar{q}$ annihilation process in $t\bar{t}$ production.

- Also interested in kinematical distributions, differential XS other than inclusive XS.
**$t\bar{t}$ Differential XS ($d\sigma / dp_T^t$)**

- $\ell + \geq 4$ jets channel (286 cand.)
- $t\bar{t}$ recons. by kinematical fitting
- Unfolding method to correct to parton level

\[
(N_{i}^{\text{Parton}}) = A^{-1}S^{-1}(N_{j}^{\text{Rec}} - N_{j}^{\text{Bkg}})
\]

$A_i$: Acceptance for $i$-th bin

$S_{ij}$: Response from $i$-th bin to $j$-th recons. bin

*Good agreement w/ NLO,NNLO*
$t\bar{t}$ Differential XS ($d\sigma/dM_{t\bar{t}}$)

- $\ell + \geq 4$ jets channel (650 cand.)
- $t\bar{t}$ recons. by kinematical fitting
- Unfolding method

No evidence beyond the SM

$\kappa/M_{Pl} > 0.16$ (95% CL) for $G \rightarrow t\bar{t}$ ($m_1 = 600\text{GeV}$) in RS model
$t\bar{t}$ F-B Asymmetry ($d\sigma / d\Delta y$)

$$\Delta y = y_t - y_{\bar{t}}$$

- $\ell + \geq 4$ jets channel (2653 cand.)
- $t\bar{t}$ recons. by kinematical fitting
- Unfolding method

- $A = 0.164 \pm 0.039 \pm 0.023$
  2.0\sigma away from NLO
- $A(\Delta y)$ has linear dep. on $\Delta y$
  Slope is larger than NLO pred. (2.2\sigma away)

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CDF

Recons. Level

$\ell + \text{jets}$

9.4fb$^{-1}$

Parton Level

Unfolding

$\Delta y$

Data

Pred.
$t\bar{t}$ F-B Asymmetry ($d^2\sigma/d\Delta y \cdot dM_{t\bar{t}}$)

$A(M_{t\bar{t}})$ has linear dependency on $M_{t\bar{t}}$
Slope is larger than NLO pred. ($2.4\sigma$ away)

Other AFB measurements at Tevatron

- $\Delta y$ dist. in D0 $\ell+\text{jets}$ and CDF dilepton also indicate larger asymmetry than expected (2~3$\sigma$)
- Lepton asymmetry ($\Delta \eta_{\ell\ell}$) in D0 dilepton is consistent with pred.

More detail will be given in R. Demina’s talk in plenary session tomorrow
Top Polarization and Correlations at $t\bar{t}$ production

Because top quark decays before losing polarization, $t/\bar{t}$ polarization and their correlations can be measured as angular distribution of decay products from $t\bar{t}$.

\[
\frac{1}{\sigma} \frac{d^2\sigma}{d\cos\theta_+ d\cos\theta_-} = 1 + C \cos\theta_+ \cos\theta_-
\]

More sensitive to $t\bar{t}$ production mechanism than other kinematic variables.

⇒ Might give a hint on $t\bar{t}$ F-B asymmetry.
Spin Correlation at CDF

- Dilepton channel (334 cand.)
- Extract $C_{\text{beam}}$ from reconstructed 2D ($\cos\theta_+, \cos\theta_-$) distribution

\[ C_{\text{beam}} = 0.04 \pm 0.56 \]

CDFnote 10719

- $\ell + \geq 4$ jets channel (725 cand.)
- up/down quark identification up-type is more energetic
- Extract $C_{\text{beam}}$ from $\cos\theta_+ \times \cos\theta_-$

\[ C_{\text{beam}} = 0.72 \pm 0.64 \pm 0.26 \]

CDFnote 10211

\( \Leftrightarrow \) SM pred.: $C_{\text{beam}} \sim 0.78$

Consistent with SM, but statistically limited...
Spin Correlation at DØ

- Dilepton (485 cand.) $\oplus \ell + \geq 4 \text{ jets (729 cand.)}$
- Matrix element method
  - Event probabilities on SM-correlation ME ($P_c$) and No-correlation ME ($P_u$)
  - Discriminant $R = P_c / (P_c + P_u)$

**Measured fraction of SM correlation** $f^{SM} = 0.85 \pm 0.29$

(f=1: SM, f=0: no correlation)

**Exclude the no-correlation hypo. at 99.84% CL (3.1σ)**

[Dilepton](image)

[Dilepton](image)
Top polarization in $t\bar{t}$ production

Top polarization along to helicity axis

Helicity basis

No evidence beyond the SM
Top polarization in $t\bar{t}$ production

Top polarization along to beamline axis

Beamline basis

No evidence beyond the SM
Summary

• Tevatron gives unique opportunity to study $q\bar{q} \rightarrow t\bar{t}$ production process for detail.
  • Kinematical distributions of $t\bar{t}$, $d\sigma/dX$ imply more information.
• $t\bar{t}$ AFB measurements at Tevatron suggest a contribution from new physics.
• Thanks to top quark short life-time, we can probe top quark polarization at $t\bar{t}$ production as well.
  • This might give more information on AFB.
Backup
Reconstructed $p_T(t\bar{t})$
Top/anti-top polarizations at $t\bar{t}$ production

Dominant process at Tevatron

Spin $1/2$, $J=1$, $J_z=\pm 1$

Helicity conservation

$tt\bar{t}$ has correlations in their polarizations

— in different way for $q\bar{q}$ and $gg$ processes —
Spin Correlation in $q\bar{q} \rightarrow t\bar{t}$ process

Top quark polarizations can be probed via lepton flight direction

$q\bar{q} \rightarrow t\bar{t}$ (near threshold)

$q\bar{q} \rightarrow t\bar{t}$ Herwig MC at parton level
Lepton asymmetry in $t\bar{t}$ events at Tevatron

- CDF dilepton
  - $A_{\text{raw}}(\Delta \eta) = 0.14 \pm 0.05$

- D0 dilepton
  - $A_{\text{raw}}(\Delta \eta) = 0.03 \pm 0.06$

- D0 $l+\text{jets}$
  - $A_{\text{raw}}(q \cdot \eta) = 0.14 \pm 0.04$