Measurement of $\sigma(t\bar{t})$ @ DØ using b-tagging

Florent CHEVALLIER
LPSC (Grenoble, FRANCE)

Introduction
- Motivations
- Signal & backgrounds

$\sigma(t\bar{t})$ measurement using b-tagging
- b-tagging algorithms
- Analyses overview

Results
Conclusion
Motivations for $\sigma(t\bar{t})$ studies

**Tests of QCD**
- *Production via strong interaction*
  \[ \sigma^{NLO}(t\bar{t}) = 6.77 \pm 0.42 \text{ pb} \ (m_{top}=175 \text{ GeV/c}^2) \]
  Dominant process at TeVatron: $q\bar{q} \rightarrow t\bar{t}$ (85%)
- Spin correlation studies

**Tests of EW & Higgs sector**
- *Probe top quark decays via $|V_{tb}|$ measurement*
  b-jet tagging methods assume $\text{BR}(t \rightarrow Wb)=1$;
  Topological method is free of this assumption
- *Probe W boson decays*
  Using dilepton to $l+\text{jets}$ cross sections ratio
- $\sigma(t\bar{t})$ sensitivity to $m_{top}$
  Provides indirect $m_{top}$ measurement

**New physics searches**
- *Exotic top decays*
  light $H^\pm$, stop, ...
- *New production diagrams*
  additional bosons, $t\bar{t}$ resonances, bound states, ...

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### Signal & backgrounds

#### Signal properties
- **Particle level**
  \[ \bar{t}t \rightarrow (Wb) (Wb) \rightarrow (lv b) (qq b) \quad l=e, \mu \]
- **Reconstructed level**
  - 1 high energy isolated lepton
  - High missing \( E_T \)
  - \( \geq 3 \) high energy jets
  - \( \geq 1 \) b-tagged jet

#### Backgrounds
- **With fake lepton**
  - QCD
- **With isolated lepton**
  - \( W + \text{jets} \)
  - \( Z + \text{jets} \)
  - Diboson : WW, WZ, ZZ
- **With top quarks**
  - Strong production : \( tt \rightarrow ll' \)
  - Electroweak production

#### Event preselection
- **Lepton & \( mE_T \)**
  - Isolated lepton \( |\eta^e|<1.1, \quad |\eta^\mu|<2, \quad p_T>20 \text{ GeV/c} \)
  - Veto against 2\(^{nd}\) isolated high energy lepton
  - \( mE_T>20 \text{ GeV} \)
  - Triangular cuts in \( (E_T, \Delta\Phi(\vec{E}_T, \vec{l})) \)
- **Jets**
  - \( \geq 3 \) jets, cone algorithm \( R=0.5 \)
  - Energetic jets, \( |\eta|<2.5 \)

#### Selection
- **b-tagging**
Why b-tagging?

- Discriminate $\bar{t}t$ signal from backgrounds
  - 2 central & high energy $b$-hadrons in $t\bar{t}$ decays
  - Few backgrounds with $b$ quarks
    - $S/B$ enhancement

$b$ quarks properties

- High mass
- Harder fragmentation than lighter quarks

- Weak decays: $b \rightarrow W c/u$
  - Long $b$-lifetime $\tau \sim 10^{-12}$s
  - $L_{xy} \sim$ several mm in the detector

Semileptonic decays

2 tagging methods used here

- Soft lepton tagger
  - $\geq 1 \mu$ in the jet
- Secondary vertex tagger (SVT)
  - $L_{xy}$ reconstruction
  - Leptons in jets

Higher vertex mass
- More tracks from the PV
- Wider jets

Tracks with large impact parameter
- Explicit secondary vertex reconstruction
- Leptons in jets
The SVT algorithm

Description
- **Reconstruct track-jets w.r.t PV**
  Good track selection & clustering into track-jets
- **Find secondary vertices for every track-jet**
  Create 2ndary vertices from tracks with $dca/\sigma_{dca} > 3.5$
  2ndary vertex selection : $\geq 2$ tracks & $|L_{xy}| > 7 \sigma_{L_{xy}}$
- **Tag calorimeter jets**
  $\geq 1$ secondary vertex within $\Delta R < 0.5$

b-tagging efficiency in data
- **Measured from a high $p_T^{rel}$ μ-in-jet enriched sample**
- **Uses positive-tagged jets ($L_{xy}>0$)**
- **MC-based corrections**
  Inclusive $b$ decays

Light jets mistag rate in data
- **Uses negative-tagged jets ($L_{xy}<0$)**
- **MC-based corrections**
  Long-lived particles
  Heavy flavour contamination
Analysis overview with Soft Lepton Tag

Sample composition estimation before tagging
- **QCD**
  Determined directly from data
- **W+jets, Z+jets**
  Absolute normalization from data
- **Other backgrounds**
  Rely on MC

Sample composition estimation after b-tagging
- **QCD**
  Determined directly from data
- **Other backgrounds**
  $\varepsilon^{\text{tag}}$ evaluated from MC according to jet flavour
  $\varepsilon^{\text{tag}}$ corrected with data

Cross-section extraction
- **Compute $N(bkg)$**
- **Compute cross-section**
  Standard method

$$\sigma(t\bar{t}) = \frac{N^{\text{observed}} - N^{bkg}}{L \cdot \varepsilon^{\text{trigger}} \cdot \varepsilon^{\text{selection}} \cdot \varepsilon \cdot B R}$$

**Control bins**

$L = 365 \text{pb}^{-1}, \sigma_{tt} = 7.7 \text{pb}$
Sample composition estimation before tagging
- **QCD**
  - Determined directly from data
- **W+jets**
  - Absolute normalization from data
  - Jet flavor composition from MC
- **Other backgrounds**
  - Rely on MC

Sample composition estimation after b-tagging
- **QCD**
  - Determined directly from data
- **Other backgrounds**
  - $\varepsilon_{tag} = f(\text{jet flavour})$
  - $\varepsilon_{tag}$ from MC & corrected with data

Cross-section extraction
- **Separate #jets, #b-tags, channels**
  - 8 different analyses
- **Compute cross-section**
  - Maximum likelihood fit

$$L = \text{Proba}(N_{\text{observed}}, N_{\text{predicted}}, \sigma(t\bar{t}) | \text{# jets, #b-tags, channel})$$

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APS 2006, Apr. 24th
**Results & systematics**

\[ SVT: \sigma(\bar{t}t)_{m_{top}=175\text{GeV/c}^2} = 8.1^{+1.3}_{-1.2} (\text{stat} + \text{syst}) \pm 0.5(\text{lumi}) \text{ pb} \]

\[ \Rightarrow \text{DØ's most precise measurement with } \mathcal{L} = 365 \text{ pb}^{-1} \]

\[ SLT: \sigma(\bar{t}t)_{m_{top}=175\text{GeV/c}^2} = 7.7 \pm 1.7(\text{stat}) \pm 1.2(\text{syst}) \pm 0.5(\text{lumi}) \text{ pb} \]

**Uncertainties on } \sigma(\bar{t}t) / SVT**

- **Statistics**: 11 %
- **Systematics**
  - W+jets estimation: 5.9 %
  - b-tag \(\varepsilon\) in data: 4.9 %
  - JES: 3.0 %
  - Jet reco*ID: 3.0 %
  - \(\mu\) preselection: 2.2 %
  - e preselection: 2.2 %
  - b-tag \(\varepsilon\) in MC: 2.0 %
  - Matrix method: 1.8 %

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⇒ DØ’s most precise measurement with $\mathcal{L} = 365 \text{ pb}^{-1}$

$SLT: \sigma(t\bar{t})_{m_{top}=175 GeV/c^2} = 7.7 \pm 1.7 (\text{stat}) \pm 1.2 (\text{syst}) \pm 0.5 (\text{lumi}) \text{ pb}$

Uncertainties on $\sigma(t\bar{t}) / SLT$

- **Statistics**: 22 %
- **Systematics**
  - Light jet b-tag $\varepsilon$: 12 %
  - $W+$jets estimation: 6 %
  - $Z+$jets estimation: 4 %
  - JES: 3 %
  - Jet reco*ID: 3 %
  - $\mu$ preselection: 2 %
  - e preselection: 2 %
  - Matrix method: 2 %
Conclusion

**tt cross-section measurement**
- *l+jets final states* (*e, μ* separately)
- *365 pb⁻¹ of DØ TeVatron Run II data*

**Results**

- *SVT:* $\sigma(t\bar{t})_{m_{top}=175 GeV/c^2} = 8.1^{+1.3}_{-1.2} (\text{stat + syst}) \pm 0.5 (\text{lumi}) \text{ pb}$
- *SLT:* $\sigma(t\bar{t})_{m_{top}=175 GeV/c^2} = 7.7 \pm 2.1 (\text{stat + syst}) \pm 0.5 (\text{lumi}) \text{ pb}$

  - Good agreement with SM expectations
  - Statistics limited results

**On-going l+jets analyses**

- *Different tt selection criteria*
- Secondary Vertex Tagger
- Soft Lepton Tagger
- Topological method
- *Optimizations in progress*

**New analyses**

- *Statistics x3*
- *Systematics reduced*
  - *New era of precision measurements*