Measurement of the Top Quark Pair Production Cross Section in Dilepton+Jets Final States Using Topological and Lifetime b Tagging Methods at DØ

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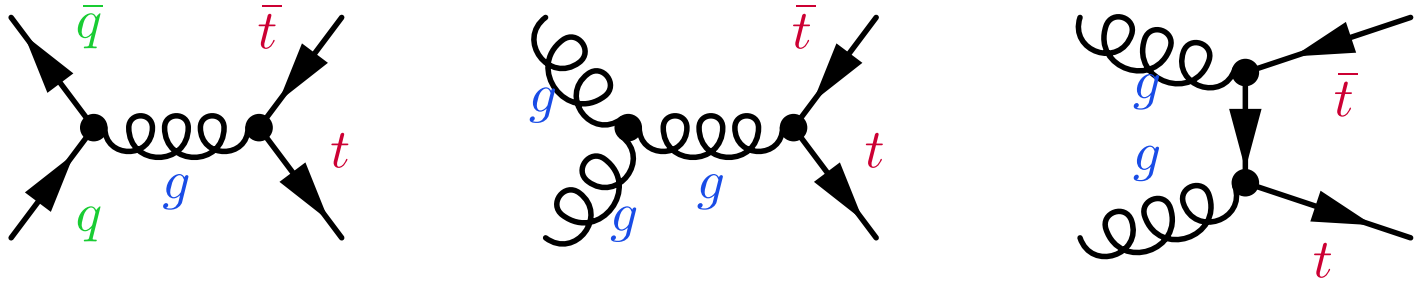
Overview:

1. Introduction.
2. Data sample and physics objects identification.
3. Topological $t\bar{t}$ cross section measurement:
   - event selection,
   - backgrounds,
   - results.
4. $t\bar{t}$ cross section measurement using lifetime b tagging:
   - secondary vertex b tagging algorithm,
   - b tagging performance,
   - results.
5. Conclusion.

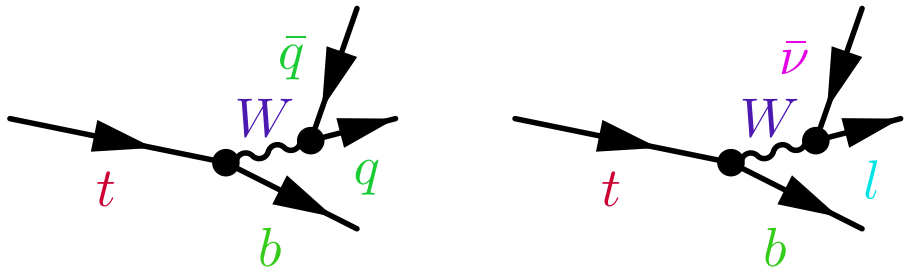
Introduction

$t\bar{t}$ pairs are produced at the Tevatron at $\sqrt{s} = 1.96\,\text{TeV}$ via $q\bar{q}$ annihilation (85%) or gluon fusion (15%):



Measurement of $t\bar{t}$ cross section is an important test of perturbative QCD.

Top quark decays almost always to Wb:

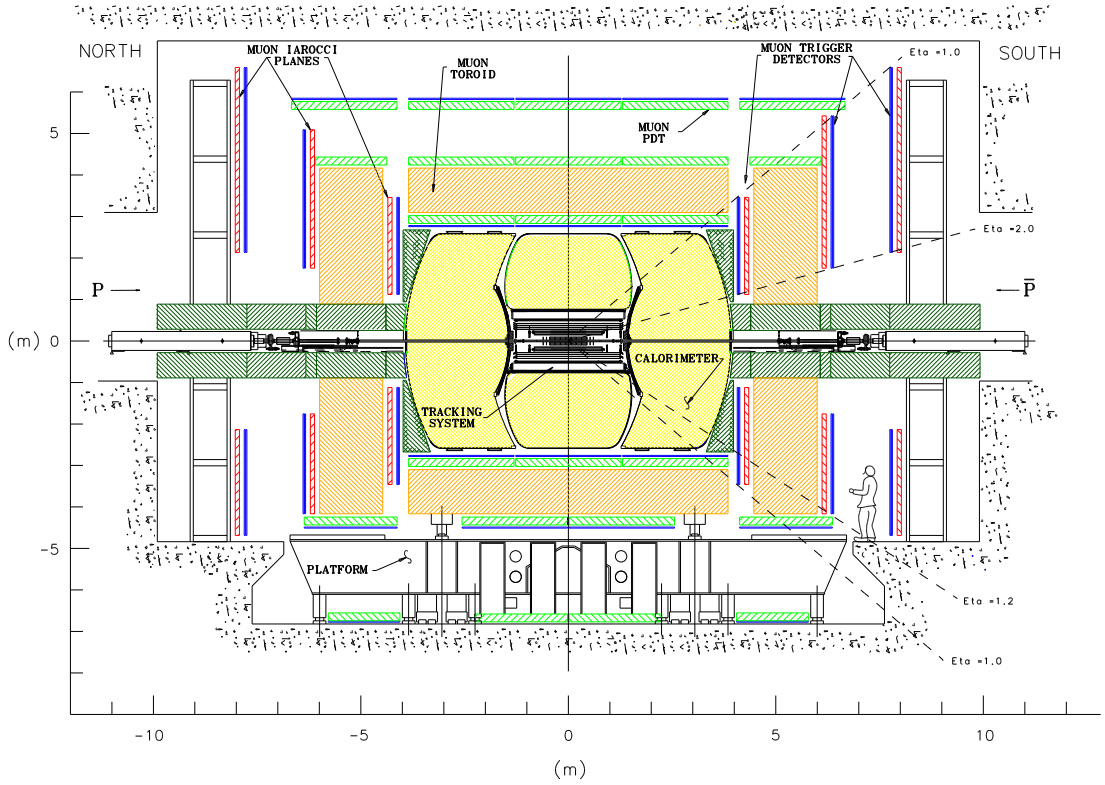


We show results of a topological analysis for the ee, $e\mu$, and $\mu\mu$ final states and a lifetime b tagging analysis for the $e\mu$ final state.

Run II DØ Detector

New in Run II:

- Central tracking system (silicon microstrip tracker, central fiber tracker, 2 T magnetic field).



- Trigger and readout system.
- Central muon scintillation counters and forward muon system.

Data Set and Object Identification

We use $\simeq$150 pb^{-1} of data collected between June 2002 and September 2003.

Electrons:

- Isolated EM clusters in the central ($|\eta| < 1.1$) and forward ($1.5 < |\eta| < 2.5$) calorimeter.
- Consistent shower shape and EM energy fraction.
- Matching central track.

Neutrinos:

- Inferred from the transverse momentum imbalance in the event.

Jets:

- Energy clusters in the calorimeter reconstructed with a cone algorithm.
- Cuts on longitudinal energy profile and energy fraction of leading cell to remove hot cells.

Muons:

- Inner muon layer track segment matched to outer.
- Matching central track.
- Scintillator timing cuts to reject cosmics.

Topological Analysis: Event Selection

- Electron trigger (ee and $e\mu$), muon trigger ($e\mu$ and $\mu\mu$).
- Primary vertex within 60 cm of the center of the detector.
- Two oppositely charged isolated leptons with matching tracks pointing to the primary vertex.
- $p_{\mathrm{T}}^{\mathrm{lepton}} > 15\,\mathrm{GeV}$ ($e\mu$ and $\mu\mu$), $p_{\mathrm{T}}^{\mathrm{lepton}} > 20\,\mathrm{GeV}$ (ee).
- Two jets with $p_{\mathrm{T}} > 20\,\mathrm{GeV}$.
- $\not\!\!E_{\mathrm{T}} > 25\,\mathrm{GeV}$ ($e\mu$), $\not\!\!E_{\mathrm{T}} > 35\,\mathrm{GeV}$ (ee and $\mu\mu$).
- M_{ll} outside the Z mass window for the ee and $\mu\mu$ channels.
- Scalar sum of p_{T} of leading lepton and jets $H_{\mathrm{T}}^{l} > 120\,\mathrm{GeV}$ ($\mu\mu$), $H_{\mathrm{T}}^{l} > 140\,\mathrm{GeV}$ ($e\mu$).

Topological Analysis: Backgrounds

Physics:

- $Z/\gamma^* \to ll$, $Z \to \tau\tau \to ll$,
- WW.

Estimated from Monte Carlo. Low contribution.

Instrumental:

- $\not\!\!E_{\rm T}$ in $Z/\gamma^* \to ll$ and QCD multijet events.
- Photons or jets which fragment to π^0 and acquire a nearby track identified as electrons.
- Non-isolated muons from jet fragmentation products or quark decay appear isolated.

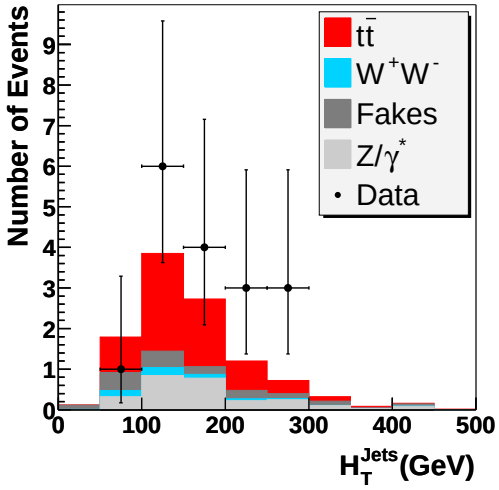
Estimated from Monte Carlo for $Z/\gamma^* \to \mu\mu$, the rest from data.

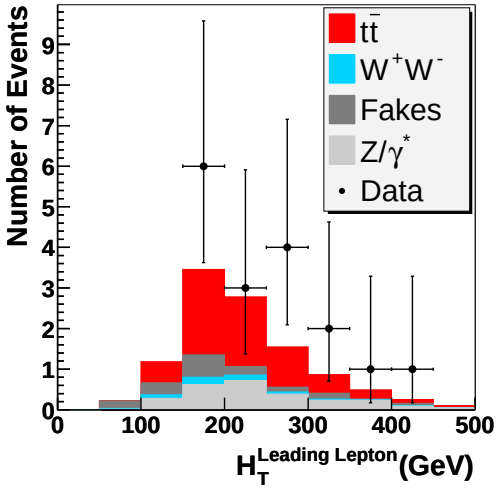
Topological Analysis: $t\bar{t}$ Event Yield

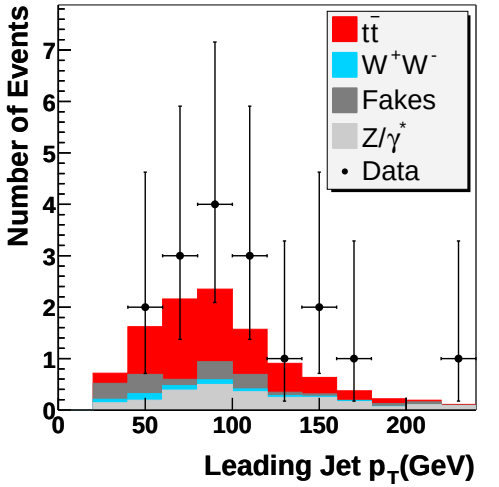
	ee	$\mu\mu$	$e\mu$	Combined
Z/γ^*	0.15 ± 0.10	2.04 ± 0.49	0.47 ± 0.17	2.66 ± 0.53
WW	0.14 ± 0.08	0.10 ± 0.04	0.29 ± 0.06	0.53 ± 0.11
Fakes	0.91 ± 0.30	0.46 ± 0.20	0.19 ± 0.06	1.56 ± 0.36
Total Backgr.	1.20 ± 0.33	2.61 ± 0.53	0.95 ± 0.19	4.76 ± 0.65
Expect. Signal	1.39 ± 0.19	0.83 ± 0.15	3.77 ± 0.44	5.99 ± 0.50
Expect. Total	2.59 ± 0.38	3.44 ± 0.55	4.73 ± 0.49	10.76 ± 0.83
Selected Events	5	4	8	17

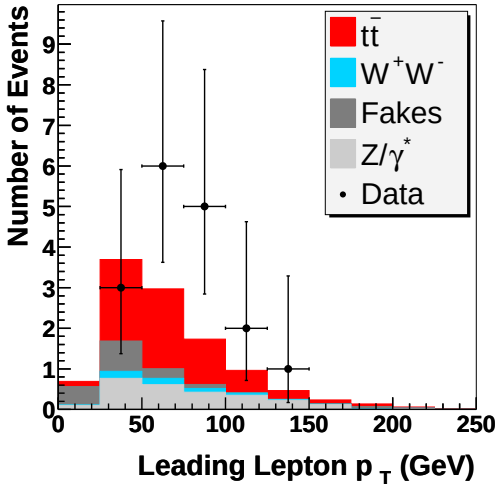
The expected signal yield assumes a 7 pb $t\bar{t}$ production cross section.

Topological Analysis: Kinematic Variables







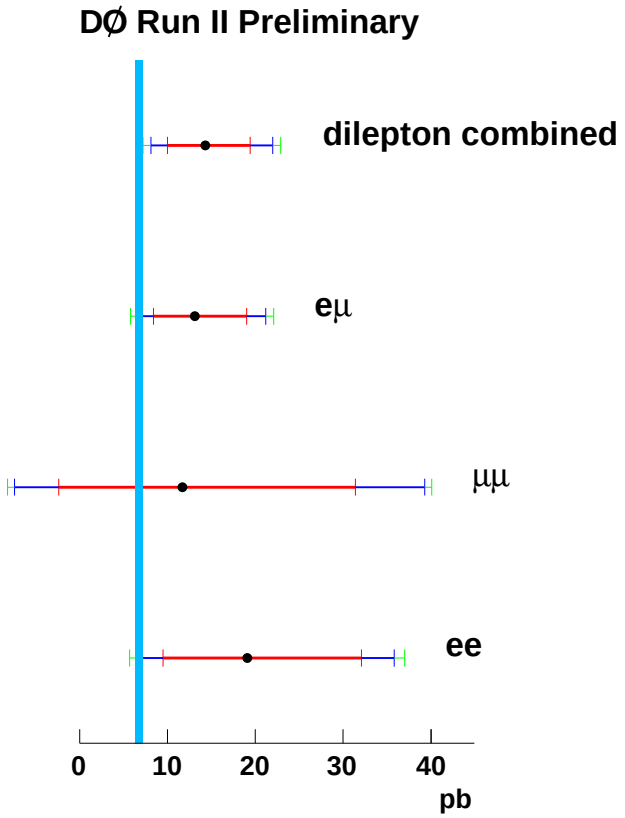


Topological Analysis: $t\bar{t}$ Cross Section

Measured by maximizing the product of likelihoods for each channel based on Poisson probability to observe a given number of events under the signal plus background hypothesis.

$$\sigma_{t\bar{t}} = 14.3^{+5.1}_{-4.3}\,(\text{stat})\;{}^{+2.6}_{-1.9}\,(\text{syst})\;\pm 0.9\,(\text{lumi})\,\text{pb}.$$

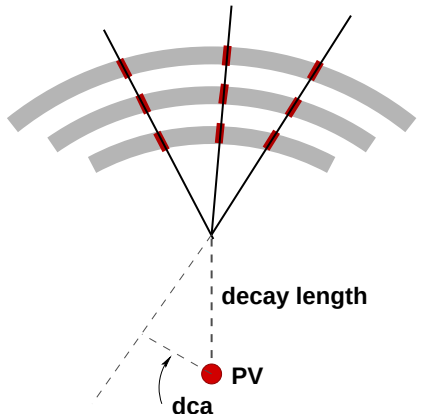
Dominant sources of systematic errors: jet energy scale and reconstruction.



Secondary Vertex (Lifetime) b Tagging Method

Use $e\mu$ final state: lowest background, largest branching fraction.

Require at least one reconstructed secondary vertex per event at a significant distance from the primary.



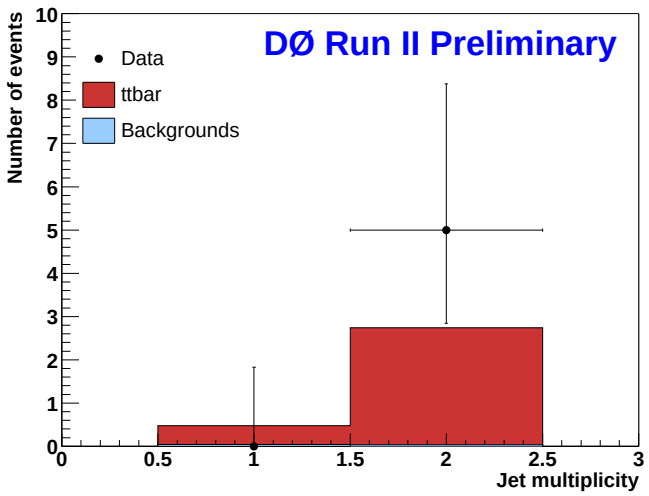
Powerful discriminant: $t\bar{t}$ events contain two b jets while jets in background events originate from light quarks and gluons.

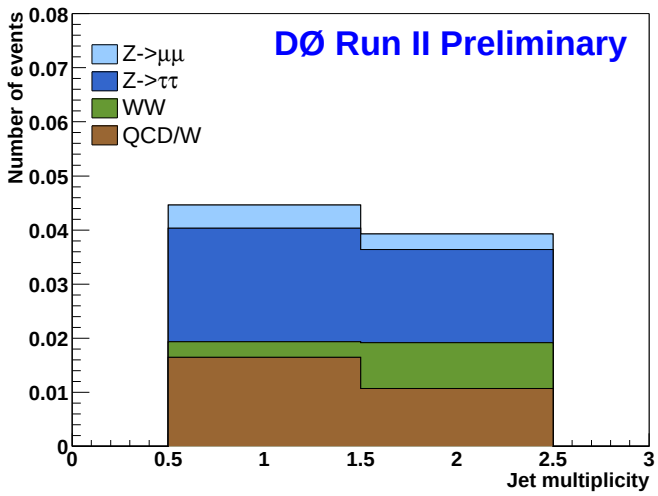
Event tagging probability, %:

Sample	$N_{\text{jets}} = 1$	$N_{\text{jets}} \geq 2$
$t\bar{t}$	38.0 ± 2.1	58.9 ± 1.6
WW	0.34 ± 0.06	1.8 ± 0.3
$Z \to \mu\mu, \tau\tau$	0.8 ± 0.2	2.9 ± 1.0
QCD, W+jets	1.6 ± 0.1	3.3 ± 0.5

b Tagged Signal and Background Event Yield

	Before tagging			After tagging	
	$N_{\text{jets}} = 0$	$N_{\text{jets}} = 1$	$N_{\text{jets}} \geq 2$	$N_{\text{jets}} = 1$	$N_{\text{jets}} \geq 2$
$t\bar{t}$:	0.052 ± 0.009	1.14 ± 0.04	4.58 ± 0.09	0.43 ± 0.03	2.70 ± 0.09
$S + B$:	13.2 ± 0.4	6.3 ± 0.3	6.1 ± 0.2	0.48 ± 0.03	2.74 ± 0.09
Observed:	13	7	8	0	5

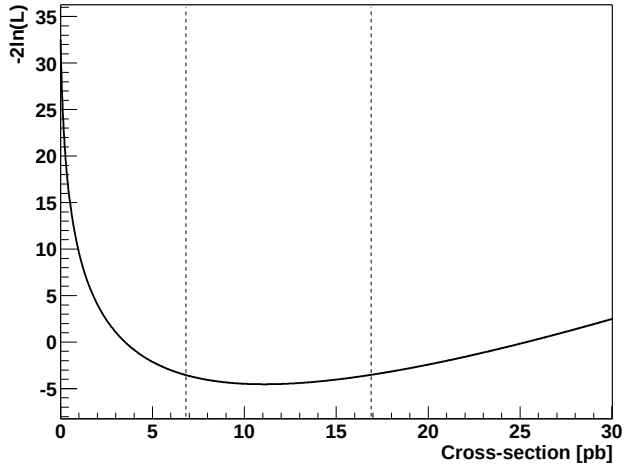




$t\bar{t}$ Cross Section with Lifetime b Tagging

The cross section is calculated by maximizing the product of likelihoods for the two jet multiplicity bins.

Likelihood function based on the Poisson probability:



$$\sigma_{t\bar{t}} = 11.1^{+5.8}_{-4.3}\,(\text{stat}) \pm 1.4\,(\text{syst}) \pm 0.7\,(\text{lumi})\,\text{pb}$$

Dominant sources of systematic errors: b tagging efficiency in data and jet energy scale.

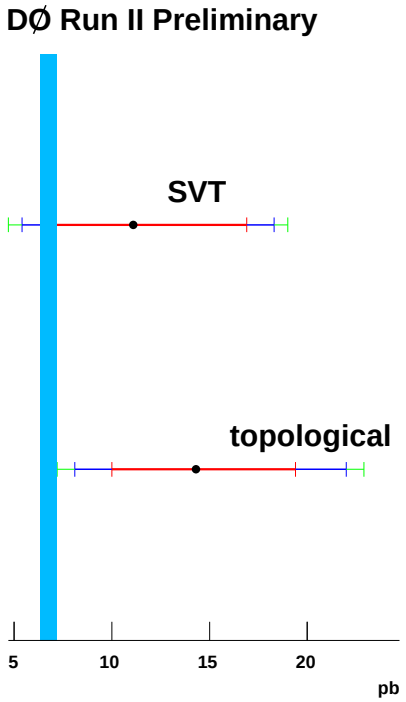
Summary

Combined topological measurement in the ee, $\mu\mu$, and $e\mu$ channels yields:

$\sigma_{t\bar{t}} = 14.3^{+5.1}_{-4.3}\,(\text{stat})^{+2.6}_{-1.9}\,(\text{syst}) \pm 0.9\,(\text{lumi})\,\text{pb}$

Lifetime b tagging measurement in the $e\mu$ channel yields:

$\sigma_{t\bar{t}} = 11.1^{+5.8}_{-4.3}\,(\text{stat}) \pm 1.4\,(\text{syst}) \pm 0.7\,(\text{lumi})\,\text{pb}$



- Both measurements are consistent with the perturbative QCD prediction of $\sigma_{t\bar{t}} = 6.77 \pm 0.42\,\text{pb}$.
- More data in the works...