# Top Pair Production at $\sqrt{s}$ = 2 TeV

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**Abstract.** This paper outlines recent measurements at the Fermilab Tevatron of the top quark pair production cross section. Several improvements to these analyses have been completed by the D0 and CDF collaborations. Results in several dilepton, single lepton and multijet channels are given for integrated luminosities of 311 - 370 pb$^{-1}$.

**Keywords:** top pair production cross section
**PACS:** 14.65.Ha

## INTRODUCTION

Top production is expected at the Tevatron to proceed strongly into top pairs. Higher order QCD calculations have been completed by two groups [1]. The current predicted cross section is 6.7±0.4 pb. Measurement of the top pair production cross section permits a unique test of these predictions. If there are three fermion generations, the expected decay probability of top to W plus b-quark is virtually 100%. The W decays into $l\nu$ or $q\overline{q}$ pairs. The two W decays result in dilepton, single lepton and all-jets final states. The b-quarks fragment, producing jets. The heavy flavor hadrons created have a long lifetime, so light final state hadrons will originate from a vertex that has traveled some distance from the event primary vertex. For the CDF and D0 detectors, precision Si vertex detectors identify b-jets by locating these vertices. Charged particle tracking in a magnetic field measures leptons. Electromagnetic and hadronic sampling calorimetry measures electrons, jets and missing $E_T$. And a muon system finds muons.

## DILEPTON FINAL STATES

The backgrounds to dilepton channels are rare, and come primarily from three different sources. Z/$\gamma^*$ can produce direct dilepton pairs to $ee$ and $\mu\mu$. In this case, missing $E_T$ must be faked by mismeasured jets or muons. Z/$\gamma^*$ can also produce dileptons by simultaneous leptonic decays of $\tau's$. Low $p_T$ neutrinos are produced which give rise to modest missing $E_T$. Diboson production, particularly through WW, can produce very similar leptonic signatures to top. If one lepton is faked, W plus jets can also be a background.

The CDF collaboration has observed some unexpected properties of their dilepton samples in Run 1 and Run 2 [2]. They have updated a parallel channel which relies on an implicit dilepton selection. Here, one well identified lepton ($e$ or $\mu$) is selected in conjunction with another isolated, high $p_T$ track. This analysis benefits from the added acceptance from not requiring lepton identification for a second lepton. In 360 pb$^{-1}$, 46 events are observed with $14 \pm 3.6$ background. The leading lepton $p_T$ is shown in Figure 1. The kinematics of these events do not suggest new physics. Cross section measurements are provided in Table 1.

D0 has performed an explicit reconstruction of the dilepton final state. They have a recently published result in 230 $pb^{-1}$ of data[3]. An update of this analysis in 370 $pb^{-1}$ of data garners 28 candidates with 6.8 events expected background. Figure 1 provides the missing $E_T$ distribution in the final event sample. Figure 1 also indicates the jet multiplicity of the dilepton sample with all other selections applied. These distributions are consistent with standard model effects.

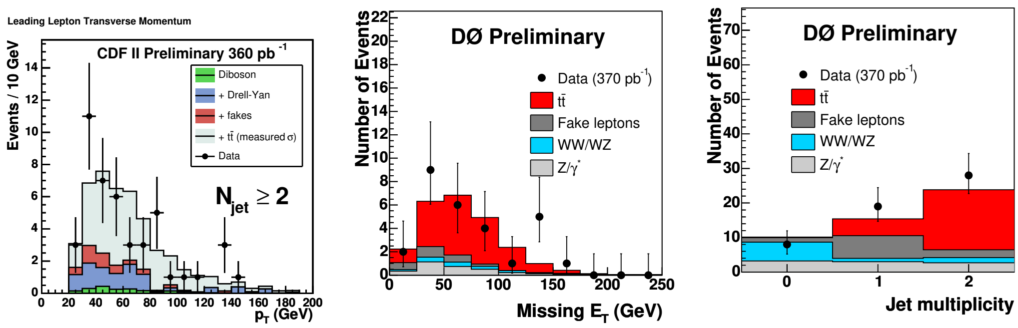


Figure 1: Leading lepton $p_T$ in CDF dilepton events (left). Event missing $E_T$ in D0 events (center), and jet multiplicity distribution (right).

## SINGLE LEPTON FINAL STATES

The primary background for single lepton channels arises from W plus jets production, as well as QCD multijet production where the lepton is faked. Recently, D0 has published an analysis of this channel using a kinematic likelihood selection in 230 $pb^{-1}$ of data [4]. Another approach to reducing the W background is to use secondary vertex tagging of b-jets. D0 employs a vertex reconstruction from tracks within a jet. If there is a vertex which lies significantly far from the event primary vertex given known tracking resolutions, then the jet is tagged as a b-jet. D0 has recently published its first measurement of the top cross section in single lepton channels using b-tagging with 230 $pb^{-1}$ of data [5]. This analysis has recently been updated in 370 $pb^{-1}$.

CDF has produced an expanded list of top cross section measurements in single lepton channels using b-tagging. Using two different secondary vertex algorithms having different efficiencies and background rates, they have produced cross section measurements which are quite consistent with one another. In another approach to b-tagging, CDF uses a knowledge of track resolutions to calculate a probability that tracks in a jet originate from an event primary vertex. Jets with low probability ($< 1\%$ and $< 5\%$ were tried) are tagged. The observed event yield is consistent between the two different selections.

**TABLE 1.** Recent cross section measurements at the Tevatron.

| channel | luminosity ($pb^{-1}$) | cross section (pb) |
|---|---|---|
| lepton+track (CDF) | 360 | $9.9 \pm 2.1(stat) \pm 1.3(sys) \pm 0.6(lum)$ |
| dilepton (D0) | 370 | $8.6^{+2.3}_{-2.0}(stat)^{+1.2}_{-1.0}(sys) \pm 0.6(lum)$ |
| lepton+ 2nd vertex (D0) | 370 | $8.1^{+1.3}_{-1.2}(stat+sys) \pm 0.5(lum)$ |
| lepton + 2nd vertex (CDF) | 318 | $8.9 \pm 0.9(stat)^{+1.7}_{-0.9}(sys)$ |
| lepton + heavy jet (CDF) | 318 | $8.9 \pm 1.0(stat) \pm 1.1(sys)$ |
| all-jets (D0) | 350 | $5.2^{+2.6}_{-2.5}(stat)^{+1.5}_{-1.0}(sys) \pm 0.3(lum)$ |
| all-jets (CDF) | 311 | $7.5^{+3.7}_{-2.8}(stat+sys)$ |
| jets + missing $E_T$ (CDF) | 311 | $5.9^{+1.8}_{-1.6}(stat+sys)$ |

# MULTI-JET FINAL STATES

For those top events in which both W's decay hadronically, one is faced with an enormous background from QCD multijet production. Tagging of b-jets is a necessity. In the traditional channel, where we expect six final quarks, D0 has a new result taken in 350 pb-1 of data. This analysis utilizes a neural network discriminant to isolate top from background. CDF has also measured the cross section in this final state channel. Another channel has been explored in 311 pb-1 of data by the CDF collaboration. In this analysis, high missing $E_T$ plus jets are required. This enhances the acceptance for the decay chain W$\rightarrow \tau\nu \rightarrow hadrons + \nu$.

# RESULTS

The results for the analyses outlined above are shown in Table 1. For both experiments, one of the largest systematic uncertainties comes from the calibration of jet energies. For single lepton b-tagging channels, substantial uncertainties arise from tagging efficiency uncertainty and background modeling.

The total integrated luminosity recorded by D0 and CDF is now well over 1 $fb^{-1}$ to tape. The ongoing analysis of this data will substantially reduce the statistical and systematic uncertainties for these measurements.

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