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Publication Date
2005-05-17

LBNL-57604
CDF/PUB/TOP/PUBLIC/7612
Version 1.1
May 17, 2005

TOP QUARK PAIR PRODUCTION AT THE TEVATRON [a]

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The measurement of the top quark pair production cross section in proton-antiproton collisions at $\sqrt{s} = 1.96$ TeV is a test of quantum chromodynamics and could potentially be sensitive to new physics beyond the standard model. I report on the latest $t\bar{t}$ cross section results from the CDF and DØ experiments in various final state topologies which arise from decays of top quark pairs.

1 Introduction to top quark production and decay

The physics of the top quark, the heaviest known fundamental particle, offers a new testing ground for the standard model, including quantum chromodynamics (QCD), as well as a new frontier for unexpected physics beyond the standard model. The top quark production measurements by the CDF and DØ experiments on the Tevatron collider at Fermilab are the first step towards exploiting this promising physics sector.

Top quark pair production in $p\bar{p}$ collisions at $\sqrt{s} = 1.96\,\mathrm{TeV}$ proceeds predominantly through the quark-antiquark annihilation (85%) and gluon fusion (15%) diagrams. The most recent QCD calculations of the cross section yield $6.7^{+0.9}_{-0.7}\,\mathrm{pb}$ for a $175\,\mathrm{GeV}/c^2$ top quark mass [1,2]. Each top quark decays immediately to a W boson and b quark, and the decays of the W bosons to quarks or leptons define the event signature of the top quark in the following three different final states:

[a] Contribution to the *Proceedings of the 40th Rencontres de Moriond: QCD and Hadronic Interactions*, La Thuile, Italy, Mar. 12-19, 2005.

dilepton, with 2 leptons and 2 jets; lepton plus jets, with 1 lepton and 4 jets; and all-jets, with 0 leptons and 6 jets. In each final state, 2 of the jets are b jets which can be tagged using heavy-flavor tagging algorithms based on identifying semileptonic b decays or tracks from b decays which do not originate from the primary event vertex.

2 Results from CDF and DØ experiments at the Tevatron

Both the CDF and DØ collaborations are pursuing measurements in all 3 final states using a variety of techniques. One challenge inherent in all measurements is the determination of the data sample composition. Knowledge of the sample composition is also important for future studies of top quark properties. The results presented here use collected data which represent integrated luminosities of $150 - 200\,\mathrm{pb}^{-1}$. All of the results estimate the number of $t\bar{t}$ events in the data sample and use the $t\bar{t}$ signal acceptance, determined using detailed detector simulation, to calculate a cross section.

2.1 Final states with two leptons plus jets

The dilepton sample is a small (5% branching fraction for e/μ analyses) but clean sample with backgrounds from Drell-Yan production and fake leptons. Analyses focus either on tight requirements to select an extremely clean sample (b-tagged $e + \mu$ channel) or loosened lepton identification (lepton + isolated track channel) in order to reduce statistical uncertainty [3].

2.2 Final states with one lepton plus jets

The lepton + jets signature benefits from high lepton trigger efficiency combined with large branching fraction (30% for e/μ plus jets). The dominant non-top backgrounds in the sample are W+jets production and non-W QCD events, but these backgrounds can be estimated by fitting kinematic distributions, e.g., the total transverse energy (H_T) in selected events [4]. Since the $t\bar{t}$ signal is expected to have 4 jets, a sample of events with lepton plus 2 jets is used as a control region for background checks.

The W+jets and non-W QCD backgrounds can be reduced by requiring at least one jet in the event be b-tagged, as expected from $t \to Wb$ decay. Even though the b-tagging requirement is only 50% efficient for $t\bar{t}$ events, approximately 98% of W+light flavor events are rejected. The remaining contribution due to W+heavy flavor production is estimated by calculating the heavy flavor fraction in W+jets events and applying this fraction to the observed data sample [5,6].

2.3 All-jet final state

The all-jets signature presents a challenge for triggering; one approach is to trigger on the total event energy and the number of high-E_T jets. Because of the large branching fraction (44% of $t\bar{t}$ events do not have leptonic W decays), this channel has the largest number of $t\bar{t}$ events.

The overwhelming background of QCD jet production is estimated in one of two ways. An artificial neural network can be employed to discriminate $t\bar{t}$ events from background based on kinematic variables which are most sensitive to high-mass objects like top quarks. These include total transverse energy, dijet masses and top quark masses. Alternatively, a tag rate matrix can be constructed from the control sample of 4-jet events (where there is no signal expected) and applied to the 6-jet sample.

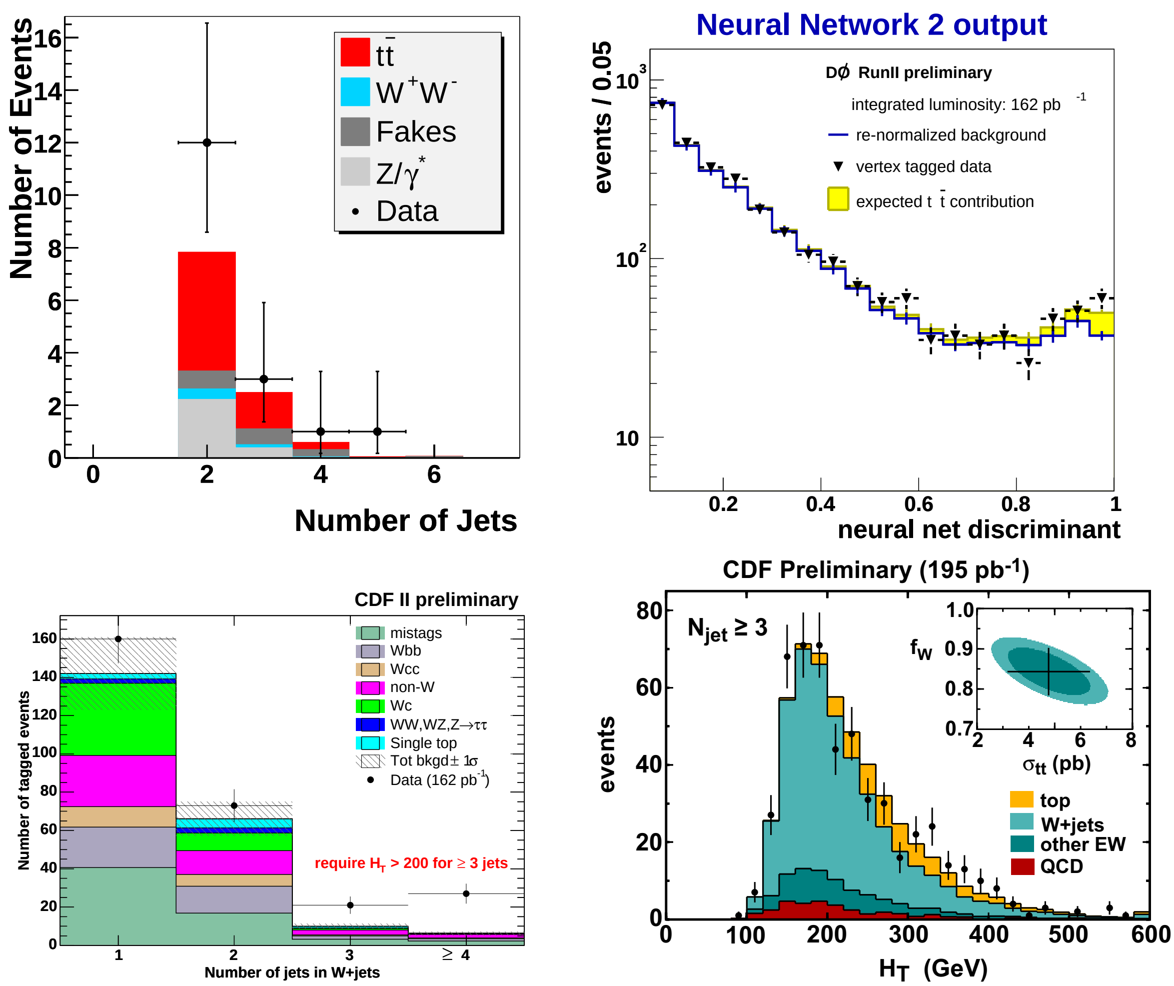

Figure 1: Top pair production cross section results from DØ dilepton jet-counting analysis (top left), DØ all-jets artificial neural network analysis (top right), CDF jet-counting lepton plus jets analysis (bottom left), and CDF H_T-fitting lepton plus jets analysis (bottom right).

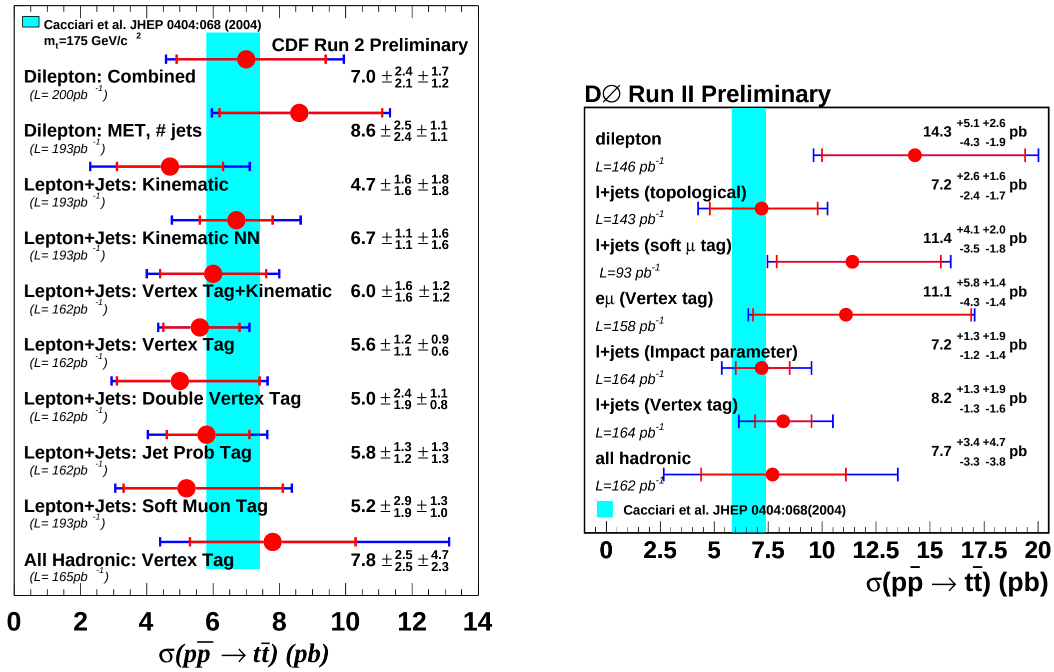

Figure 2: Summary of top pair production experimental results from CDF (left) and DØ (right) experiments. The blue band on both plots represents the NLO QCD theory calculation for a 175 GeV/c^2 top mass.

3 Summary of pair production cross section results

The summary of all results from CDF and DØ are displayed in Fig. 2. All of the measurements are consistent with each other and with the theory calculation, at least within the quoted errors. Selected experimental results at $\sqrt{s}$ = 1.8 GeV and 1.96 GeV are compared to the theory calculation at those two center-of-mass energies in Fig. 3. It is reasonable to expect that additional collected data and further understanding of the sample composition will reduce the uncertainties on all of these measurements.

Acknowledgments

It is a pleasure to thank the organizers for fostering the stimulating atmosphere of the conference. I must also acknowledge my CDF and DØ colleagues for their help in preparing these results.

This work was supported by the Director, Office of Science, Office of Basic Energy Sciences, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

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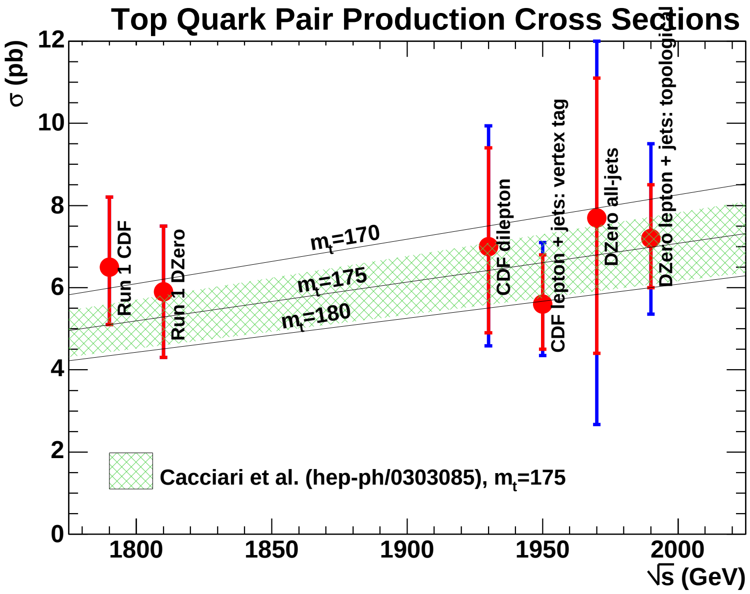

Figure 3: Comparison of selected results with NLO QCD calculations as a function of center-of-mass energy.

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