Fermi National Accelerator Laboratory

FERMILAB-Conf-96/118-E
CDF

Top Production at CDF

P. Azzi
For the CDF Collaboration

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

May 1996

Submitted to the *XXXIst Rencontres de Moriond, QCD and High Energy Hadronic Interactions*, Les Arcs, France, March 23-30, 1996

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

Disclaimer

CDF/PUB/TOP/PUBLIC/3679

TOP PRODUCTION AT CDF

P. Azzi
(for the CDF Collaboration)
I.N.F.N. Padova, Via Marzolo 8, I-35131 PADOVA, Italy

Abstract

We present the measurement of $t\bar{t}$ production cross section using $\mathcal{L} = 110\ pb^{-1}$ data sample of $p\bar{p}$ collisions at $\sqrt{s} = 1.8\ TeV$ collected with the Collider Detector at Fermilab (CDF). Combining the results from the channels with at least one W decaying into leptons (e or μ) plus jets we measure $\sigma_{t\bar{t}} = 7.5^{+1.9}_{-1.6}\ pb$.

We report the observation of $t\bar{t}$ production in the all hadronic decay channel using a kinematical selection and b identification techniques.

Finally we show preliminary evidence for $t\bar{t}$ production in the decay mode with one e or μ in the final state and an hadronically decaying τ.

1 Introduction

The first direct evidence for the *top* quark was presented by CDF in 1994[1] and has been confirmed by CDF and D0 in 1995[2, 3] using a larger data sample. Here we report the results obtained on a data sample of $\mathcal{L} = 109 \pm 7.2\ pb^{-1}$, corresponding to the full statistics collected between 1991 and 1995.

At the Tevatron collider, that provides $p\bar{p}$ collisions at $\sqrt{s} = 1.8\ TeV$, the dominant process for top production is $q\bar{q} \rightarrow t\bar{t}$ (90%). In the Standard Model the top decays almost 100% of the time (V_{tb}) in $t \rightarrow Wb$ and the classification of top events is based upon the decay mode of the W boson. We report results for the analysis of the following channels:

- dilepton, both W's decay leptonically (e or μ)
- single lepton plus jets, one W decays leptonically (e or μ) the other goes to $q\bar{q}'$
- all hadronic, both W's decays into quarks
- τ–dilepton, both W's decay into leptons, but one is required to be $W \rightarrow \tau\nu_\tau$ where the τ decays into hadrons.

2 Dilepton analysis

The event selection starts requiring two central and isolated leptons (e and μ only), oppositely charged, with $E_T \geq 20\ GeV$, a significant missing transverse energy to account for the undetected neutrinos ($\not{E}_T \geq 25\ GeV$), and two central and energetic jets ($E_T(jets) \geq 10\ GeV$). The contribution from $Z \rightarrow l^+l^-$ events is removed with a cut on the invariant mass of the lepton pair. Additional background rejection is obtained with a topological cut on the angular separation between the $\not{E}_T$ direction and the direction of the closest object, either a lepton or a jet when the $\not{E}_T \leq 50\ GeV$.

The dilepton candidates are 10 (fig.1): 7 $e\mu$, 2 $\mu\mu$[1] and 1 ee, well in agreement with the relative acceptances. The total background amounts to 2.1 ± 0.4 events and is dominated by Drell–Yan, $Z \rightarrow \tau\tau$ decays, fake leptons and di–boson events.

Looking *a posteriori* for the presence of b jets in the dilepton candidates we see that 4 events contain a jet that is b tagged. The total number of tagged jets in the 10 events candidate is 6 while from the background estimate we'd expect only 1 tag.

Using a total acceptance of $(0.77 \pm 0.08)\%$ evaluated for a $m_{top} = 175\ GeV/c^2$, we measure the cross section for $t\bar{t}$ production in this channel to be $\sigma_{t\bar{t}}(DIL) = 9.3^{+4.4}_{-3.4}\ pb$.

3 Lepton plus jets analysis

The event selection for the lepton plus jets analysis requires a single, high energy lepton (e or μ), significant $\not{E}_T$ ($\not{E}_T \geq 20\ GeV$) and at least three energetic jets ($E_T(jets) \geq 15\ GeV$) in the central region. Events satisfying the dilepton requirements are explicitily removed, as well as those events consistent with $Z \rightarrow l^+l^-$ decays.

In order to improve the rejection of the $W + jets$ background we require the presence of at least one b jet in the event. Two different techniques of b identification have been used.

The first one, SVX tagging, is based on the search for displaced vertices using the high spatial resolution of the CDF silicon vertex detector: its efficiency on $t\bar{t}$ events is 0.41 ± 0.04.

[1]Note than one of the $\mu\mu$ candidates is consistent with being a radiative Z decay.

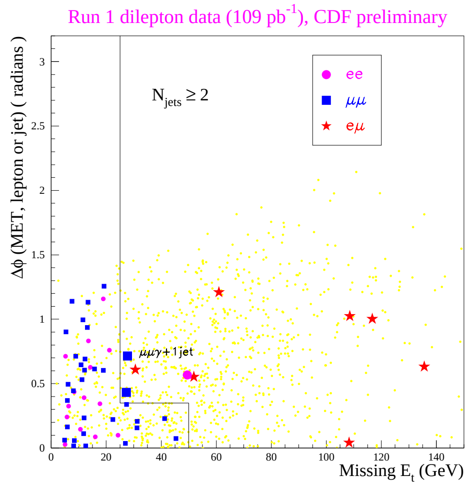

Figure 1: *Azimuthal angle between the* $\not\!\!E_T$ *and the nearest lepton or jet versus the* $\not\!\!E_T$ *for events with two leptons and two jets, and* $t\bar{t}$ *Monte Carlo for* $m_{top} = 175\ GeV/c^2$. *The line represent the* $\not\!\!ET$ *cut.*

Channel	$Acceptance(\%)$	N_{bkg}	Data	$\sigma_{t\bar{t}}(pb)$
DIL	0.77 ± 0.08	2.1 ± 0.4	10	$9.3^{+4.4}_{-3.4}$
SVX	3.52 ± 0.65	7.96 ± 1.37	34	$6.8^{+2.3}_{-1.8}$
SLT	1.73 ± 0.28	24.3 ± 3.5	40	$8.0^{+4.4}_{-3.6}$
DIL,SVX,SLT combined result				$7.5^{+1.9}_{-1.6}$
HAD	$\epsilon_{kin} = 9.9 \pm^{+3.0}_{-3.5}$, $\epsilon_{tag} = 47.2 \pm 4.5$	137.1 ± 11.3	192	$10.7^{+7.6}_{-4.0}$
τ-DIL	0.119 ± 0.014	1.96 ± 0.35	4	$15.6^{+18.6}_{-13.2}(stat)$

Table 1: *In this Table are summarized the results of the analysis in the different channels. The luminosity used is* $109.4 \pm 7.2\ pb^{-1}$. *All the acceptances are evaluated for* $m_{top} = 175\ GeV/c^2$.

The second one, called SLT, is based on the identification inside a jet of low p_T ("soft") leptons (e or μ) coming from the semileptonic b decays: its efficiency for having at least one tag in a $t\bar{t}$ event is 0.20 ± 0.02.

In fig.2 are represented the 42(44) observed tags for the SVX(SLT) tagging method as a function of the jet multiplicity of the event compared with the expectation from the background plus $t\bar{t}$ production.

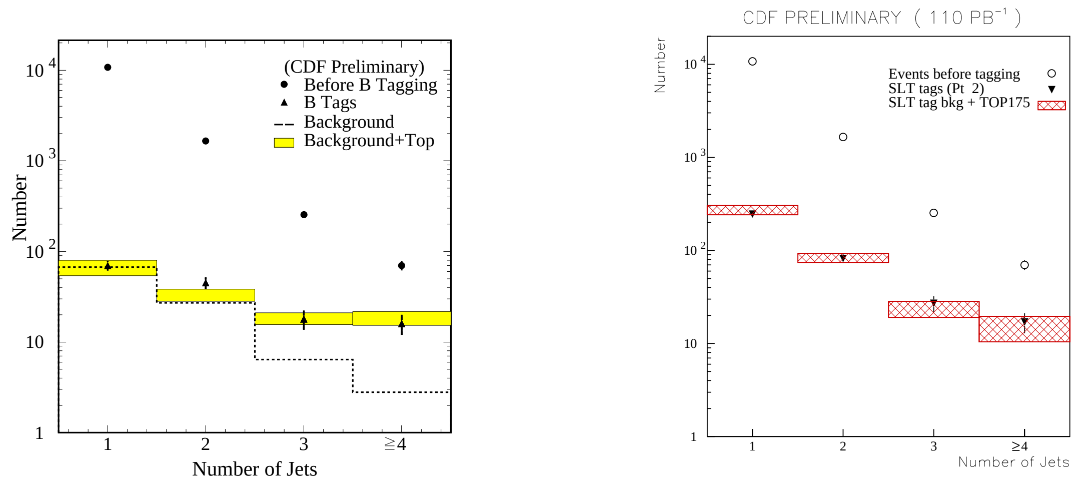

Figure 2: *Jet multiplicity distribution of SVX(left) and SLT(right) tagged jets observed in the lepton plus jets data compared with the sum of background and $t\bar{t}$ events contribution.*

The background in the SVX method amounts to 7.96 ± 1.37 events, were the biggest contribution come from by $Wb\bar{b}$ and $Wc\bar{c}$ (3.14 ± 0.76 events), fakes (2.34 ± 0.76 events) and $b\bar{b}$(2.15 ± 0.83 events). The observed events with at least one SVX tag are 34. Using a total acceptance of $(3.52 \pm 0.65)\%$ evaluated for a $m_{top} = 175\ GeV/c^2$, we measure the cross section for $t\bar{t}$ production in this channel to be $\sigma_{t\bar{t}}(SVX) = 6.8^{+2.3}_{-1.8}\ pb$.

In the SLT method we observe 40 events with at least one tag over a total background of 25.8 ± 3.7 events dominated by the contribution from fakes, $Wb\bar{b}$, $Wc\bar{c}$ and Drell–Yan. The total acceptance for this method is $(1.73 \pm 0.28)\%$ and the measured cross section is $\sigma_{t\bar{t}}(SLT) = 8.0^{+4.4}_{-3.6}\ pb$.

4 Combined cross section

In order to have a better statistical measurement of the $t\bar{t}$ production cross section the result from the dilepton and lepton plus jets channels are combined togheter, taking into account the correlations. For $m_{top} = 175\ GeV/c^2$ we obtain:

$$\sigma_{t\bar{t}}(DIL, SVX, SLT) = 7.5^{+1.9}_{-1.6}\ pb$$

In fig.3 is reported the CDF measurement compared with some of the most recent theoretical calculation [4, 5, 6].

The uncertainty is approximately equally divided between the statistical and the systematical contribution. Work is in progress to include also the measurement coming from the all hadronic channel (described below), that is correlated both in the acceptance and in the tagging efficiency with the SVX sample.

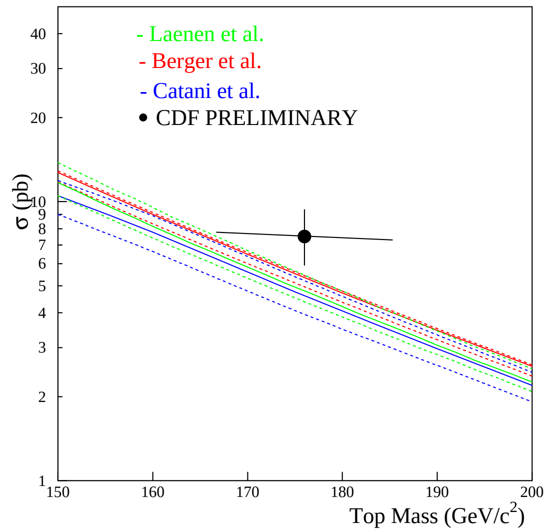

Figure 3: *CDF combined cross section compared with some of the most recent theoretical calculation*

5 All hadronic analysis

The search for top in the all hadronic final state is very challenging due to the presence of a huge QCD background, orders of magnitude bigger than the signal. The starting sample is made of 230,000 events and is obtained requiring at least four jets with $E_T \geq 15\ GeV$ and $|\eta| \geq 2$: at this level the S/B is about 1/1000. The analysis relies on a tight kinematical selection aimed to a strong background rejection while keeping a reasonable efficiency on the signal. The selection starts requiring a high jet multiplicity ($N(jets) \geq 5$) and a total transverse energy $\sum E_T \geq 300\ GeV$, "centrally" deposited in the detector ($\sum E_T/\sqrt{\hat{s}} \geq 0.75$). In addition the Aplanarity of the event has to satisfy the condition $Apl \geq -0.0025 \times \sum_3^N E_T + 0.54$, where $\sum_3^N E_T$ does not include the contribution from the 2 leading jets.

After the kinematical selection, the requirement of at least one SVX b-tag in the event provides the additional rejection power necessary to extract a signal. We observe 230 tagged jets over a background of 160.5 ± 10.4 coming almost totally from QCD heavy flavor production and mistags (fig.4). The probability that the number of tags observed is purely due to a background fluctuation is $\mathcal{P} = 1.5 \times 10^{-4}$ (3.6σ).

The number of events with at least one SVX tag is 192 with a background of 137.1 ± 11.3 events. Using the acceptance of the kinematical requirements for $m_{top} = 175\ GeV/c^2$, $(9.9^{+3.0}_{-3.5})\%$, and the b tagging efficiency in this channel, $(47.2 \pm 0.45)\%$, we measure the production cross section to be $\sigma_{t\bar{t}}(HAD) = 10.7^{+7.6}_{-4.0}\ pb$.

6 τ dilepton analysis

This is a dilepton analysis where one of the leptons in the final state is an e or μ, and the other one is a τ identified through its hadronic decay. For the τ identification we look for a narrow calorimeter cluster with a low multiplicity of charged tracks pointing to it. We require that $p_T^\tau \geq 15\ GeV/c$. The primary lepton is selected as in the dilepton case described above and there is an explicit removal of $Z \to l^+l^-$ events based on tracking and calorimeter information. We require also the presence of at least 2 jets with $E_T \geq 10\ GeV$. Additional

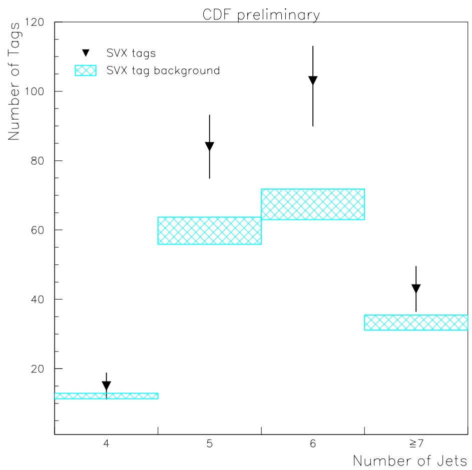

Figure 4: *SVX tagged jet distribution after the kinematical selection of the all hadronic analysis as a function of jet multiplicity compared with the expectation from the background.*

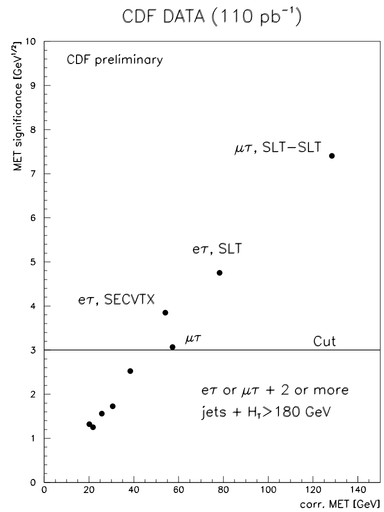

Figure 5: $\not{E}_T$ *versus* $\sigma_{\not{E}_T}$ *distribution for* τ*-dilepton events. The line represents the* $\sigma_{\not{E}_T}$ *cut.*

background rejection is obtained with a cut on $\mathcal{H}_T$ of the event, $\mathcal{H}_T \geq 180 GeV$ and on the $\sigma_{\not{E}_T}$, defined as $\sigma_{\not{E}_T} = \not{E}_T / \sum E_T$. The selection yelds 4 candidate events, shown in fig.5, with an expected background of 1.96 ± 0.35 events. Given the acceptance of $(0.119 \pm 0.014)\%$ for a $m_{top} = 175\ GeV/c^2$ we have a preliminary evaluation of the cross section of $\sigma_{t\bar{t}} = 15.6^{+18.6}_{-13.2}\ pb$ where the uncertainties are statistical only.

6.1 Kinematic distribution of the $t\bar{t}$ system

The measurement of the top mass is done on a subsample of the lepton plus jets data set with at least four jets, obtained lowering the E_T threshold on the fourth jet to 8 GeV. Before tagging there are 153 events in the sample, and we are left with 34 events with at least one SVX or SLT tag. The background of the tagged sample amounts to $6.4^{+2.1}_{-1.4}$ events. Each event is kinematically constrained to the $t\bar{t}$ hypotesis assuming that the tagged jet is one of the b partons. Based on the fit information we can study several properties of the $t\bar{t}$ system other than the mass (subject of a different talk). A preliminary comparison has been done between the *observed* quantities, biased by detector resolution, selection cuts and the fitting algorithm, with the corresponding Monte Carlo predictions. This is an important check of the consistency of the $t\bar{t}$ production properties with the Standard Model. Moreover effects of non-standard $t\bar{t}$ pair production can be seen in the $M(t\bar{t})$, $p_T(t\bar{t})$ and $p_T(t)$ distributions. The comparison is done for the pre-tagged, tagged and double tagged sample. As an example we show in fig.6 the distribution in the tagged sample of $p_T(t)$ and of $M(t\bar{t})$. No discrepancy with respect to the Standard Model predictions is observed in these and in all the other variables studied.

7 Conclusions

We reported the results obtained in 110 pb^{-1} of data collected with the CDF detector. After one year from the top quark discovery, the focus of CDF is aimed to a deeper understanding of its properties. We have updated the status of the data samples of the top analysis in the dilepton

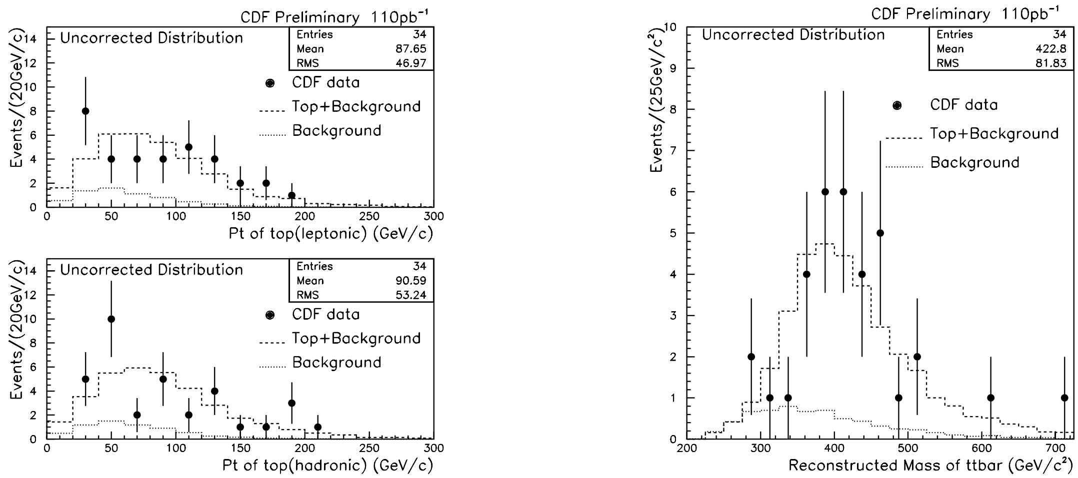

Figure 6: *Dsistribution of $p_T(t)$ (left) and $M(t\bar{t})$ (right) for the tagged mass sample.*

and single lepton channel, and measured their combined cross section: $\sigma_{t\bar{t}}(DIL, SVX, SLT) = 7.5^{+1.9}_{-1.6}$ pb.

We have presented evidence for $t\bar{t}$ production in the all hadronic channel. The cross section value measured in this channel is in agreement with $\sigma_{t\bar{t}}(DIL, SVX, SLT)$.

Finally we have presented a preliminary evidence for $t\bar{t}$ production in the τ-dilepton channel.

In order to gain a deeper understanding of top properties we have compared some kinematic distribution of the $t\bar{t}$ system with the Monte Carlo predictions. The results are still preliminary, but for the moment no discrepancy is seen between the data and the Monte Carlo.

References

[1] F. Abe *et al.* (CDF Collaboration), Phys. Rev. **D50**, 2966 (1994)

[2] F. Abe *et al.* (CDF Collaboration), Phys. Rev. Lett. **74**, 2626 (1995)

[3] S. Abachi *et al.* (D0 Collaboration), Phys. Rev. Lett. **74**, 2632 (1995)

[4] E. Laenen *et al.*, Nucl. Phys. **B321**, 254 (1994)

[5] E. Berger and H. Contopanagos, Phys. Lett. **B361**, 115 (1995)

[6] S. Catani *et al.*, CERN–TH/96-21, hep-ph/9602208 (1996)