RUN II CDF RESULTS IN THE TOP DILEPTON CHANNEL

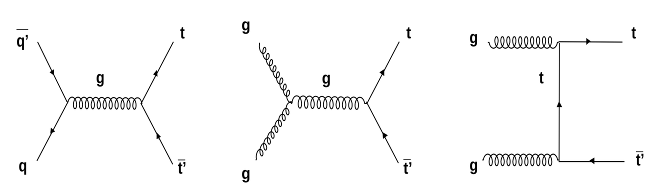
MIRCEA COCA
University of Rochester, NY, 14627, USA
For the CDF Collaboration

ABSTRACT

The $t\bar{t}$ dilepton decay channel ($t\bar{t} \rightarrow \ell^+\nu_\ell b \ell^- \bar{\nu}_\ell \bar{b}$) is of particular interest because measurements of the cross section and event kinematics can signal new physics if deviations from the SM predictions are observed. We present new preliminary measurements of top properties from dilepton final states in Run II. These measurements were made by the CDF experiment in proton antiproton collisions at a center-of-mass energy of 1.96 TeV at the Fermilab Tevatron. The results are compared to theoretical predictions and to previous measurements which used Tevatron Run I data.

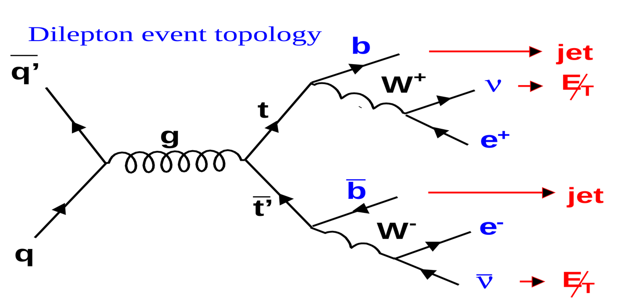
Production and Decay

At 1.96 TeV the top quark is mainly produced in pairs through the strong force.
Also top could be singly produced through the electroweak interaction. Single top production has not yet been observed.



	Run I	Run II	LHC
E_{CM}	$p\bar{p}$ 1.8 TeV	$p\bar{p}$ 1.96 TeV	pp 14 TeV
$\sigma_{t\bar{t}}$(pb)	5.0	6.7	800
qq (%)	90	85	5
gg (%)	10	15	95

The top quark decays almost exclusively into a W boson and a b quark.
A dilepton signature corresponds to both W's decaying leptonically.



The BR(W→ $\ell\nu$) = 1/9, where ℓ = e, μ or τ. Considering W's that decay to an electron or muon only, the dilepton channel accounts for only 5 % of the total $t\bar{t}$ events.
The dilepton yield is small, however the experimental signature allows a good separation of the signal from backgrounds.
We select a dilepton event by requiring:
- 2 energetic leptons (coming from W's)
- 2 energetic jets (a b quark hadronizes and is reconstructed as a jet)
- large transverse energy imbalance (or missing energy $\not{E}_T$, due to the neutrinos escaping the detector)
- large sum E_T of all the objects in the event, H_T (exploits the large m_{top}).

Dilepton Physics at CDF

The top quark was discovered in 1995 by CDF and DØ.
Many of its properties were determined using 109 pb^{-1} of data. The precision was statistically limited.
Below the previous measurements are summarized:

Top cross-section

The $t\bar{t}$ production cross section measurement tests the prediction of perturbative QCD and is sensitive to new physics beyond the SM.
A cross section is a simple counting experiment.

$$\sigma_{t\bar{t}} = \frac{N_{obs} - N_{bkg}}{A \cdot \int \mathcal{L}}. \quad (1)$$

In Run I CDF observed 9 events, with an expected background of 2.0±0.5 events; expected signal was 4 events .
We measured $\sigma_{t\bar{t}}$(ee,eμ,$\mu\mu$) = $8.4^{+4.5}_{-3.5}$ pb, compared to the theoretical prediction of (5.0 ± 1.0) pb.
We observed 7 eμ events with an expectation of 2.2 eμ events from top and 0.8± 0.2 eμ events from the SM background.
A few of the candidates had significantly higher lepton P_T and $\not{E}_T$ than expected from the SM.
Using 72 pb^{-1} of Run II data taken between March 2002 and January 2003, CDF has measured a top dilepton production cross section of 13.2 ± 5.9(stat) ± 1.5(syst) pb compared with the NLO theoretical calculation 6.7 ± 0.8 pb.

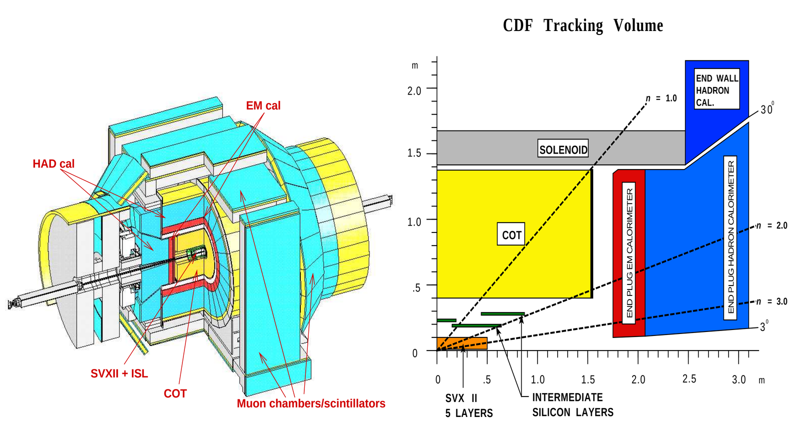
Source	Events (in 72 pb^{-1} - Run II)
Expected	2.8 ± 0.3
Data	5

Top mass

Precise measurements of the top mass together with W-boson mass provide an indirect constraint on the SM Higgs boson mass.
Using 9 Run I dilepton events CDF measured a top mass of 167.4±10.3±4.8 GeV compared with the combined Tevatron top mass 174.3 ± 5.1 GeV.
In Run II large dilepton samples will allow us to precisely measure top properties and look for new physics.

CDF Run II Detector

Since Run I the detector underwent major upgrades:
- A new tracking system made of three silicon detectors (L00, SVX and ISL) and a central drift chamber (COT).
- A new plug calorimeter and extended muon coverage allow CDF to extend the lepton identification in the forward regions between 1.0 < $|\eta|$ < 2.5 (η = -ln (tan (θ/2))).



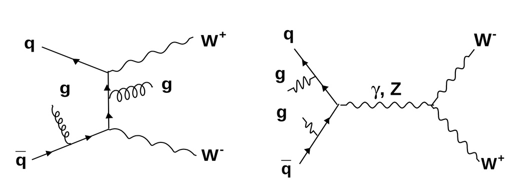
We make use of these new capabilities for the Summer 2003 cross section analysis.

Backgrounds

Physics Backgrounds

Diboson Production: $W^+W^-/W^{\pm}Z^0$+jets

$\sigma_{p\bar{p}\rightarrow W^+W^-}$ = 13.3 pb.
Requiring at least 2 jets highly reduces the cross section.
These events have softer H_T than dilepton events.

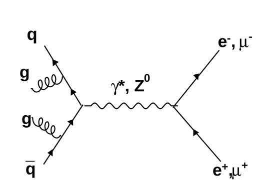


Drell Yan ($Z^0/\gamma* \rightarrow \tau^+\tau^-$) + jets

$\sigma_{p\bar{p}\rightarrow(Z^0\rightarrow\tau\tau)}$ = 250.2 pb.
These events have real, but low missing energy and $\not{E}_T$ tends to be very close to a lepton.
The ISR jets are softer than dilepton b-jets.

Instrumental Backgrounds

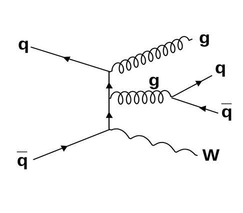
Drell Yan ($Z^0/\gamma* \rightarrow e^+e^-$, $\mu^+\mu^-$) + jets



These is no real $\not{E}_T$ in these events.
The most common way to have large $\not{E}_T$ is by mismeasuring the jets which end up in the detector cracks. Therefore, $\not{E}_T$ tends to be close to the mismeasured object which artificially creates it.

$W^{\pm}$+ multijets

$\sigma_{p\bar{p}\rightarrow(W\rightarrow\ell\nu)}$ = 2731.0 pb.
In this case a jet has to fake a lepton. The rate with which a jet fakes a lepton is very low ($O(10^{-4})$). Sometimes a heavy flavor quark decays semileptonically.
These events have real $\not{E}_T$.
The jets are typically softer than the top b-jets.



Summer 2003 Results

Di-lepton $\sigma_{t\bar{t}}$

Improvements to the analysis

Addition of the forward electrons in the dilepton analysis increases the acceptance by 30 %.
A new tracking algorithm (*Phoenix*) was developed for the forward region. It uses the plug calorimeter cluster energy and position and the event primary vertex to determine two possible helices. Then silicon hits are attached. The smallest χ^2 track is chosen.
The Phoenix algorithm allows reconstruction of the electron track and identification of its charge, thus reducing the backgrounds considerably.

Event Selection

- Two oppositely charged leptons (e or μ) with high P_T, at least one being isolated; the plug leptons are always isolated.
- Large $\not{E}_T$, not due to a mismeasured jet or lepton, is required.
- Dielectron and dimuon events with $M_{\ell\ell} \in$ (76, 106) GeV must pass tighter $\not{E}_T$ requirements.
- At least two jets with high E_T.
- Large H_T is required.

Top Dilepton Acceptance

CDF has increased the signal acceptance two times from the previous Run II measurement.
15 % of the produced top dilepton events pass the selection cuts.
Also 10 % of the acceptance comes from dilepton events with a τ which decays leptonically.
The estimated systematic uncertainty on the signal acceptance is 10 % and is mainly due to PDFs (7.7 %) and jet energy scale (5.6 %).
Inclusion of the forward electrons and relaxing the selection increases the backgrounds such that S/B = 2.2.

Results

The table below summarizes the expected and observed events in 126 pb^{-1} of data, taken from March 2002 until May 2003.

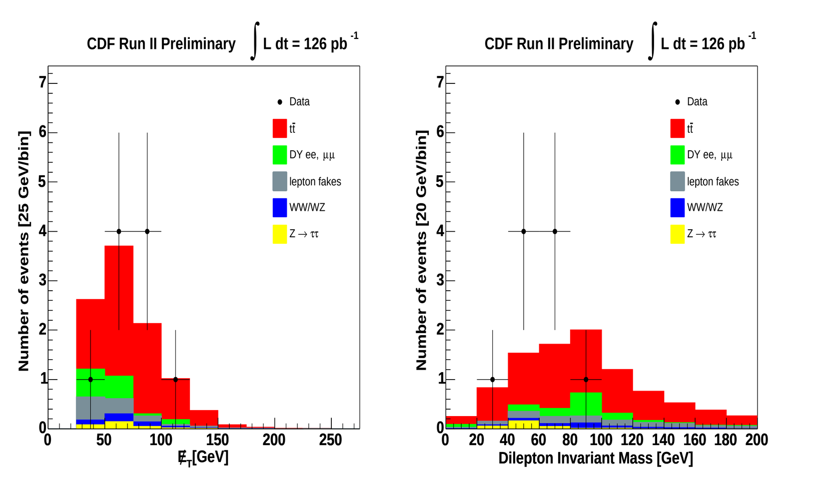
Source	Events per 126 pb^{-1} after all cuts			
	ee	$\mu\mu$	eμ	$\ell\ell$
WW/WZ	0.14 ± 0.06	0.09 ± 0.04	0.17 ± 0.07	0.40 ± 0.17
Drell-Yan	0.46 ± 0.29	0.73 ± 0.56	-	1.2 ± 0.7
Z → $\tau\tau$	0.07 ± 0.02	0.08 ± 0.03	0.17 ± 0.06	0.32 ± 0.11
Fakes	0.64 ± 0.21	0.02 ± 0.007	0.30 ± 0.10	0.95 ± 0.31
Total Background	1.31 ± 0.41	0.92 ± 0.29	0.64 ± 0.20	2.9 ± 0.9
$t\bar{t}$	1.54 ± 0.16	1.37 ± 0.15	3.36 ± 0.36	6.3 ± 0.7
SM Expectation	2.85 ± 0.44	2.29 ± 0.33	4.00 ± 0.41	9.2 ± 1.1
Data	2	3	5	10

Using the above numbers we measure

$$\sigma_{tt} = 7.6^{+3.8}_{-3.1}(\text{stat})\ ^{+1.5}_{-1.1}(\text{syst})\ \text{pb}$$

The additional background from light quark jets can be reduced by tagging the b-jets. Tagging algorithm (SECVTX) tries to resolve the secondary vertices separated by the event primary vertex by few millimeters.
Out of the 10 candidates, we expect 4 events to be b-tagged and see 6. One event is double-tagged.

Kinematic Distributions



Lepton+Isolated Track $\sigma_{t\bar{t}}$

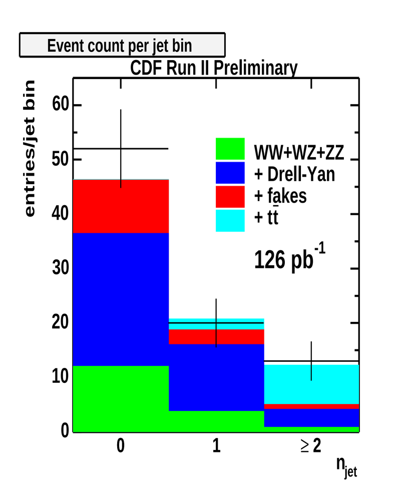
A second cross section performed by CDF requires a "good" central lepton and a second "isolated" track.
The analysis does not include forward electrons.
It opens the acceptance with looser lepton requirements, S/B = 1.4.
It has significant sensitivity to both hadronic and leptonic decays of τ (25 % of acceptance).

Event Selection

- One central isolated lepton (TCL) (e or μ) with large P_T and an isolated high-P_T track (TL).
- Large missing energy E_T .
- If $M_{TCL,TL} \in$ (76, 106) GeV, larger $\not{E}_T$ is required to reduce the Drell-Yan background.
- At least two jets with high-E_T.

Results

The number of events in different jet bins are plotted below for expected background and top dilepton signal. Most of the signal events have at least 2 jets and are used to measure the $t\bar{t}$ cross section. The uncertainties in the table are statistical only.



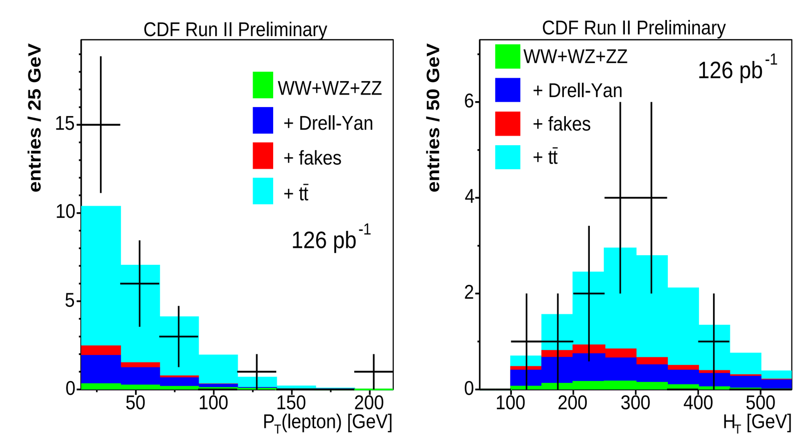
Source	njets >= 2
Signal	7.2 ± 0.2
WW	0.5 ± 0.1
WZ	0.2 ± 0.0
ZZ	0.1 ± 0.0
DY(ee)	1.6 ± 0.8
DY($\mu\mu$)	0.6 ± 0.3
DY($\tau\tau$)	1.2 ± 0.3
Fakes	0.9 ± 0.2
Total bck	5.1 ± 0.9
Total Expected	12.3 ± 0.9
Data	13

The measured cross section is

$$\sigma_{t\bar{t}} = 7.3 \pm 3.4(\text{stat}) \pm 1.7(\text{syst})\ \text{pb}$$

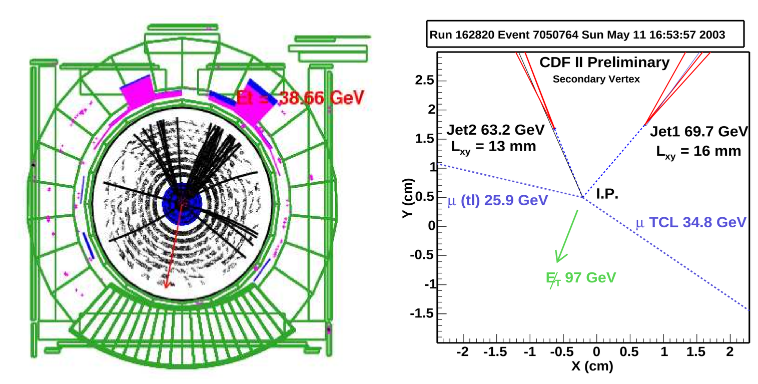
Of the 13 candidates there are 5 events with at least one SECVTX b-tag while the expectation was 4 events.
The two cross section measurements performed by CDF have 7 common candidates.

Kinematic Distributions Lepton+Track Analysis



A "golden" dilepton event

Events with b-jets tagged using the secondary vertex displacement represent a very clean subsample of dilepton events. Using a large such sample for the top mass measurement reduces significantly the uncertainties.
Left: a transverse view of the event; the tracking volume and calorimeters are shown.
Right: a zoomed view of the primary (I.P.) and secondary vertices (SECVTX). $\not{E}_T$ is represented by a green arrow. L_{xy} is the displacement between I.P. and SECVTX.



Top Mass Measurement in Dilepton Channel

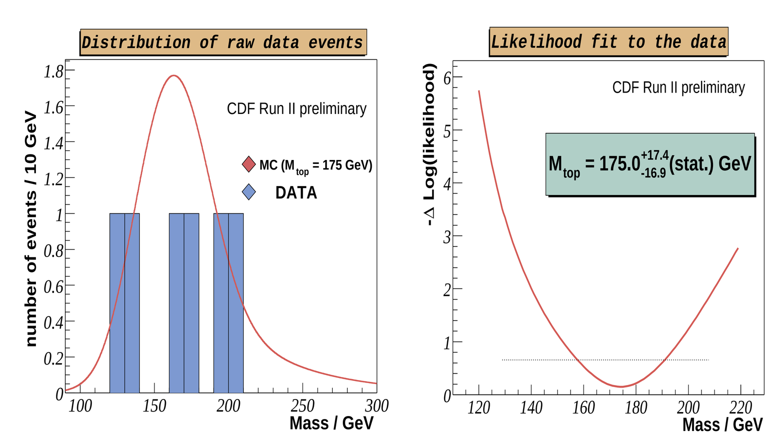
An event-by-event kinematic fit is performed.
Templates for different top masses and backgrounds are used in a likelihood to extract the top mass and the statistical uncertainty.

Event Selection

- A tighter selection than the one for the cross section is used.
- Two very energetic, oppositely charged, isolated leptons (e or μ) are required.
- Dielectrons and dimuons in the Z mass window are vetoed.
- Large $\not{E}_T$ and large H_T is required.

Results

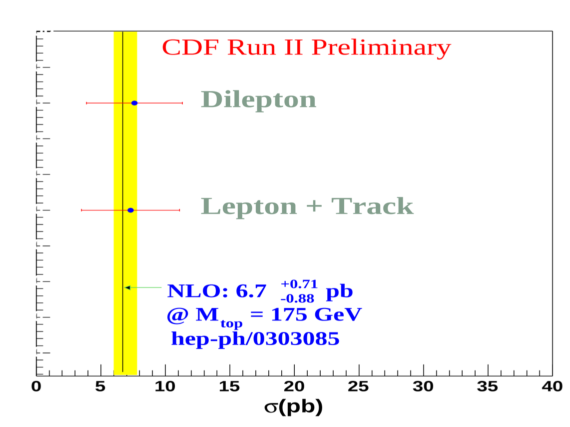
In 126 pb^{-1} of data, we observed 6 dilepton candidates, with 0.5 events expected to be background.



$$m_{top} = 170.2\ ^{+17.4}_{-16.9}\ \text{GeV}$$

Summary

Cross section measurements



Top Mass Measurement

$$m_{top} = 170.2\ ^{+17.4}_{-16.9}\ \text{GeV}$$

Acknowledgments

I would like to thank to CDF Top Group for their hard work and continuous help, in particular to Patrizia Azzi and Jaco Konigsberg and to my advisor, Paul Tipton.