CURRENT RESULTS FROM CDF ON W, Z, AND TOP

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Results based on data collected by the Collider Detector at Fermilab (CDF) during the Tevatron Collider run now in progress are presented. The results cover analyses of $W \rightarrow e\nu_e$ and $Z \rightarrow e^+e^-$, $\mu^+\mu^-$ event candidates, and discuss the status of the CDF top quark search. Preliminary results from studies of events containing a high E_T electron and muon or a high E_T electron plus ≥ 2 jets indicate that it is unlikely that the top quark mass is in the range $30 \leq M_{\text{top}} \leq 60 \text{ GeV}/c^2$ assuming Standard Model charged current decay.

1. INTRODUCTION

1.1. Summary of 1988-89 Tevatron Collider & CDF Operation

The current data taking run of the Collider Detector at Fermilab (CDF) began in June, 1988 and is expected to continue until June 1, 1989. As of March 31, 1989 data from 3.44 pb^{-1} integrated luminosity have been recorded. This far exceeds the initial goal of the run which was to collect an integrated luminosity of 1 pb^{-1} and it is now expected that a total integrated luminosity of $\sim 5 \text{ pb}^{-1}$ will be recorded by the end of the run. The luminosity delivered by the Tevatron has increased by over a factor of 20 from the 1987 run due to many improvements in Tevatron operation. These include more anti-protons from the accumulator, going from 3-on-3 to 6-on-6 bunch operation, improved main ring transmission and coalescing, reduced transverse emittance in the Tevatron, longer luminosity lifetime via reduced transverse emittance

growth, mini-beta operation in the B0 collision region, and reliability improvements to the Tevatron reducing the number of unintentional store aborts.

This paper presents preliminary results based on analyses of subsets of the full data sample collected to date. The integrated luminosity on which each analysis is based is given in the presentation of each particular result.

1.2 Summary Description of the CDF Detector

A schematic drawing of the CDF detector is shown in Fig. 1. The detector combines charged particle tracking in a 1.412 T magnetic field, fine-grained electromagnetic and hadronic calorimetry, and muon detection in the central as well as far forward and backward regions.¹

A vertex time projection chamber covering the polar angles, θ , of 3.5° to 176.5° provides a precision determination of the event vertex and is also used for track-calorimeter matching in the plug and forward calorimeters. Charged

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FIGURE 1
Schematic elevation view of half the CDF detector

particle momentum measurement with a resolution of $\delta p_T/p_T \leq 0.002 p_T$ (GeV/c) is provided in the pseudorapidity (η) region of ± 1.2 by a large drift chamber (CTC) located within the central solenoidal magnet.

The CDF calorimeters are all of the sampling type. They consist of a scintillator and lead electromagnetic calorimeter in the central region, $|\eta| < 1.1$, scintillator and iron hadronic calorimeters in the central region $|\eta| < 1.3$, gas sampling and lead electromagnetic calorimeters in the plug and forward regions of $1.1 < |\eta| < 4.2$, and gas sampling and iron hadronic calorimeters for $1.3 < |\eta| < 4.2$. The central electromagnetic calorimeter also provides shower position information with a resolution of a few millimeters via a proportional wire chamber embedded in the calorimeter at approximately shower maximum. Azimuthal position is given using the pulse height weighted centroid of the wire signals, while the induced signal on cath-

ode strips orthogonal to the wires provides a position measurement along the beam direction. The chamber is, hereafter, referred to as the central strip chamber. The calorimeter segmentation is $\Delta\eta \times \Delta\phi \sim 0.1 \times 15^\circ$ in the central region, and $\Delta\eta \times \Delta\phi \sim 0.1 \times 5^\circ$ in the plug and forward regions.

Muon detection is provided in the central region of $|\eta| < 0.65$, by drift chambers located behind the central hadronic calorimeter. In the far forward and backward regions ($2.0 < |\eta| < 3.6$) muons are tagged and reconstructed via a toroidal magnet instrumented with three planes of drift chambers.

The online trigger for the experiment is done in four levels of increasing computational ability. The Level 0 trigger signals an inelastic interaction from a crossing by using signals from scintillation counters located just before the forward and backward calorimeter systems. The Level 1 trigger uses minimal calorimeter and

track requirements such as transverse energy, E_T , summed over entire calorimeter systems or muon candidates from track stubs in the muon chambers. At Level 2, customized microprocessors provide detailed triggers using clustered E_T , high p_T tracks, and unbalanced (missing) E_T . Finally, at Level 3, a microprocessor farm analyzes fully readout events to form a mix of triggers that are completely programmable in software.

1.3 Summary of Physics Topics Discussed

The physics of most current interest from proton-antiproton colliders comes from events containing high E_T leptons. From the current CDF run, sufficient data will be collected to address several physics topics in this area. This includes $W^\pm \rightarrow e\nu_e$, $\mu\nu_\mu$, $\tau\nu_\tau$; $Z^0 \rightarrow e^+e^-$, $\mu^+\mu^-$, $\tau^+\tau^-$; and a search for evidence of top quark production with sensitivity to the decay channels t , $\bar{t} \rightarrow e + \mu + E_T$, $e + \text{jets} + E_T$, $\mu^+\mu^- + E_T$, $e^+e^- + E_T$. In Section 2, results from analysis of W events decaying via the electron channel are presented. Preliminary data on $Z^0 \rightarrow e^+e^-$, $\mu^+\mu^-$ are discussed in Section 3. Future goals in W and Z analysis are presented in Section 4. Finally, in Section 5, the status of the top search via the $e - \mu$ and $e + \text{jets}$ channels is presented.

2. $W \rightarrow e + \nu_e$ ANALYSIS

Candidate events for the $W \rightarrow e + \nu_e$ analysis were selected from a sample passing the online missing transverse energy, E_T , trigger. In Level 2, this requires the magnitude of the total E_T vector to be greater than 25 GeV/c and one or more calorimeter energy clusters with the highest transverse energy cluster in the central or plug calorimeter. In Level 3 of the trigger, the calorimetry is cleaned up to eliminate noisy channels or spurious signals, reclustering is performed and E_T is recomputed. Events are then accepted if they satisfy $E_T > 15$ GeV. A loose

cut is also made to eliminate mis-measured back-to-back dijet events.

Events satisfying the above trigger were processed offline and selected as W candidates with an electron in the central calorimeter if they met the following criteria:

- $E_T > 20$ GeV,
- presence of an electromagnetic cluster with $E_T > 15$ GeV, $|\eta| < 1.0$, and electromagnetic energy fraction $> 85\%$,
- $E_T/\sqrt{\Sigma E_T} > 2.4$,
- No cluster with $E_T > 5$ GeV within 30° of back-to-back with the electromagnetic cluster,
- $E/p < 2.0$.

This selection gave a total of 2000 central W candidates in a data sample representing 2.3 pb^{-1} of integrated luminosity. From this sample a set of "Golden Central W " events was selected for use in the central electromagnetic calorimeter calibration and in W mass determination. These events were required to satisfy the tighter restrictions of

- $E_T > 25$ GeV,
- a central electromagnetic cluster with $E_T > 25$ GeV,
- $E/p < 1.4$,
- no other energy cluster with $E_T > 7$ GeV (enhances selection of $W + 0$ jet events),
- having the "electron" within a fiducial area defined for the electromagnetic towers to reduce uncertainty in energy measurement from tower response mapping corrections.

These criteria produced a sample of 460 "Golden Central W 's".

The electron E_T versus E_T for the looser cut central W sample is shown in Fig. 2. The data

shown represent a 1.8 pb^{-1} subset of the event sample analyzed. The expected linear correlation of E_T^e and E_T for events with a W decaying to $e + \nu_e$ is apparent. Figure 3 shows histograms of electron quantities associated with the central strip chamber. These include CTC track matching with the azimuthal and z (beam direction) shower position measured by the chamber, and χ^2 distributions formed using the expected profile of electromagnetic showers at the location of the strip chamber. These variables are used in selecting an inclusive electron sample for the top quark search analysis. Our experience with the very clean W sample indicates that cuts on these variables select electrons with high efficiency and very good discrimination of background.

FIGURE 2
 E_T^e vs. E_T for $W \rightarrow e + \nu_e$ candidates selected with loose cuts described in text.

FIGURE 3
Strip chamber quantities for electrons from $W + e + \nu_e$ candidates. a) Position match of strip chamber shower centroid and extrapolated CTC track in azimuthal direction. b) Position match in z (beam) direction. c) χ^2 of lateral shower profile in wire (azimuthal) view. d) χ^2 in strip (beam) view.

The transverse mass, M_T^{ev} , defined by

$$M_T^{ev} \equiv \sqrt{2 E_T^e E_T^{\nu}(1 - \cos \Delta\phi^{ev})},$$

for the golden W events is shown in Fig. 4b and is qualitatively similar to the distribution in Fig. 4a produced by a sample of events generated using the ISAJET Monte Carlo² and processed through a CDF detector simulation routine.

FIGURE 4

Electron-neutrino transverse mass distribution for a) ISAJET Monte Carlo of $W + e + \nu_e$. b) Data. The plots are not relatively normalized and the Monte Carlo does not include $W + \tau\nu_\tau + e\nu_e \bar{\nu}_\tau\nu_\tau$ contributions.

As mentioned above, the golden W sample has been used to calibrate the energy scale of the central electromagnetic calorimeter. This is performed as a two step process. First, the momentum scale of the CTC was checked via a measurement of the ψ mass from reconstructed dimuon pairs. The mass distribution for a small

FIGURE 5

Opposite sign dimuon mass distribution for small subsample of data. Curve is a fit to Gaussian for ψ plus an exponentially falling background.

subset of the available data is shown in Fig. 5. The measured mass of $3108.5 \pm 3.5 \text{ MeV}/c^2$ agrees with the Particle Data Book value of $3096.9 \pm 0.1 \text{ MeV}/c^2$ to an accuracy of 0.4%. The calibration of the electromagnetic calorimeter is then verified by comparing the E/p distribution for the golden W events to a distribution produced by a Monte Carlo generated sample of $W + e + \nu_e$ that includes contributions from internal and external QED bremsstrahlung. This comparison is shown in Fig. 6. Here the data has the "best" set of corrections applied to E_T^e and p_T^e .

3. $Z^0 + 1^+1^-$ ANALYSIS

3.1. $Z^0 + e^+e^-$

$Z^0 + e^+e^-$ candidate events have been selected from an analysis of raw data tapes dedicated to selecting high invariant mass e^+e^- pairs. The selection was based only on quantities available from the online trigger and required,

E over P distribution

FIGURE 6

E/p distribution for golden W electrons compared to simulation with QED radiative corrections included.

- Two electromagnetic clusters each with $E_T > 10$ GeV and a hadronic- to-electromagnetic energy ratio of less than 10%,
- $m_{ee} > 50$ GeV/c² calculated using the cluster energies from the trigger,
- an associated trigger track with $p_T > 15$ GeV/c for clusters in the central calorimeter,
- verification via visual scanning by a physicist.

Again, a sample of "Golden Central Z" events was selected by requiring both electromagnetic clusters to have $|\eta| < 1.0$, $E/p < 1.4$, and to satisfy fiducial cuts on location within the electromagnetic calorimeter towers. The e^+e^- invariant mass for all selected events is shown as Fig. 7. As no energy corrections have been applied to the data, no attempt is made yet to extract an estimate of the Z^0 mass. A plot of the dielectron invariant mass for the golden Z sample as shown in Fig. 8 indicates that the observed width of the Z, while being consistent

with Standard Model expectations, is dominated by energy resolution of the calorimeter.

FIGURE 7

Invariant mass of e^+e^- pairs selected from analysis of 2.4 pb⁻¹ of raw data sample. A cut requiring $m_{ee} > 50$ GeV/c² has been made.

FIGURE 8

Dielectron invariant mass for "Golden Central Z" candidates. Curve is fit to Breit-Wigner resonance and has $\Gamma/2 = 1.8 \pm 0.5$ GeV/c².

3.2. $Z^0 \rightarrow \mu^+\mu^-$

The analysis of $Z^0 \rightarrow \mu^+\mu^-$ event candidates is still in a very preliminary stage. We present the current results here for the purpose of completeness. Events are selected requiring that at least one muon must satisfy the online muon trigger. This requires a CTC track match with a central muon chamber track stub and energy deposition in the central calorimeter consistent with a minimum ionizing particle. The second muon requires the presence of a high p_T track in the region $|\eta| < 1.2$ associated with a calorimetric energy deposition consistent with minimum ionization. Figure 9 shows the dimuon invariant mass for selected events from a data sample representing 1.3 pb^{-1} of integrated luminosity. A peak associated with Z^0 production is evident.

FIGURE 9

Opposite sign dimuon invariant mass distribution for $Z^0 \rightarrow \mu^+\mu^-$ candidates.

4. FUTURE W AND Z ANALYSIS

With the data collected from 5 pb^{-1} of integrated luminosity expected by the end of the current CDF run, we will obtain approximately 4300 $W \rightarrow e + \nu_e$ events with a central electron and 500 $Z^0 \rightarrow e^+e^-$ events. Events from the W

sample will be subjected to the tight cuts used to produce "Golden Central W's". From this sample of very clean W events, the mass of the W boson will be estimated by a fit to the $M_T^{e\nu}$ distribution. Likewise, a production analysis of e^+e^- events is now underway. Z^0 event candidates selected with tight cuts similar to those for the current "Golden Z" sample, will be used to provide a M_Z measurement. The central electromagnetic calorimeter energy scale calibration made using the E/P distribution from "Golden Central W's" along the inherent good energy resolution of the calorimeter ($\sigma_E/E = 13.5\%/\sqrt{E_T}$) should allow a high precision Z mass measurement. The $M_Z - M_W$ mass difference measurement thus made available provides a constraint on the top quark mass. This constraint arises due to dependence of radiative corrections to the mass difference on the top quark mass. The Higgs mass also enters into this radiative correction, but produces only a very small (and for CDF, unobservable) effect on the W - Z mass difference. Yet another constraint on the top quark mass is expected to be provided by the measurement of $\frac{\sigma \cdot B(W \rightarrow e + \nu)}{\sigma \cdot B(Z \rightarrow e^+ + e^-)}$ that will be possible with the large gauge boson sample expected.

In addition to the electron decay channels of the W, Z bosons, relatively large samples of decays to muon and tau channels are also anticipated. A τ lepton trigger has recently been added to the online trigger system and is expected to produce useful samples of $W \rightarrow \tau + \nu_\tau$ and $Z^0 \rightarrow \tau^+ + \tau^-$. These samples will allow checks of $e - \mu - \tau$ universality via measurements of $W \rightarrow l + \nu_l$ and $Z^0 \rightarrow l^+ + l^-$ cross sections. Finally, analysis of W, Z + jets events will provide information on the W, Z p_T spectra, α_s , and background in the t, $\bar{t} \rightarrow e + \text{jets}$ channel.

5. STATUS OF THE TOP QUARK SEARCH AT CDF

5.1. Introduction

At a proton-antiproton center-of-momentum energy of 1.8 TeV, the dominant production mechanism for top quarks, as indicated in Fig. 10, is via $gg \rightarrow t\bar{t}$. The top quark decays to a b quark plus a real or virtual W boson. Thus, the intermediate state of the pair production mechanism contains a b quark, an anti-b antiquark, and two W gauge bosons. Because of the large QCD multijet cross section, the top search at CDF is carried out requiring that one or both of the W's decay leptonically. The characteristic signatures for the processes are an energetic charged lepton, missing transverse energy associated with the undetected neutrino, and two

FIGURE 10

Top quark production cross section calculated by Altarelli et al. based on next to leading order calculation by Nason et al.⁴ Solid curves give expected range of direct $t\bar{t}$ production cross section. Stars are from an ISAJET Monte Carlo.

or more jets. The most advanced analyses to date are the $e + \mu + E_T$ and $e + \text{jets} + E_T$ channels. The analysis technique used is to restrict

the phase space of accepted events so as to exclude essentially all background leaving a small, but statistically observable, expected number of top quark events for a given mass range. The two analyses are treated separately below.

5.2. Search for $t, \bar{t} \rightarrow e + \mu + X$

The channel $t, \bar{t} \rightarrow e + \mu + X$ provides a cleaner signal than those channels requiring only a single semileptonic top quark decay, where $W + \text{multijet}$ production gives a large background contribution, or those with dileptons from the same family, which receive background contributions from Z^0 and Drell-Yan production of lepton pairs. The main backgrounds in the $e - \mu$ channel are from double leptonic decay of pair produced $b\bar{b}$, $Z^0 \rightarrow \tau^+\tau^- \rightarrow e + \mu$, and inclusive muon production accompanied by an asymmetric γ conversion. CDF has three Level 2 triggers sensitive to the $e - \mu$ channel: an $E_T > 12$ GeV central electron trigger; a $p_T > 9$ GeV/c central muon trigger requiring a track stub in the central muon chambers matching a CTC high p_T track; and a 5 GeV electron, 5 GeV/c muon trigger. Trigger studies indicate for full efficiency of all 3 triggers, offline analysis cuts requiring $E_T^e \geq 15$ GeV and $p_T^\mu \geq 12$ GeV/c are necessary.

Central electrons are identified using the strip chamber information discussed above in connection with Fig. 3, i.e. χ^2 distributions formed from expected wire and strip profiles for electrons; and strip chamber, CTC track matching. In addition, cuts are made requiring the hadronic-to-electromagnetic energy ratio in the calorimeter to be less than 5%, the ratio of measured calorimeter transverse energy to measured track transverse momentum, E_T/p_T be less than 1.4, and on a variable characterizing the distribution of energy within the calorimeter towers containing the electromagnetic cluster. The specific cuts made using strip chamber information are

- Strip chamber profile cuts:
 - χ^2 (wires) < 10
 - χ^2 (strips) < 10
- Strip chamber - CTC track matching:
 - $\Delta x(\text{azimuth}) < 3 \text{ cm}$
 - $\Delta z < 5 \text{ cm}$

From a Monte Carlo generated sample of $t, \bar{t}$ events with $m_{\text{top}} = 60 \text{ GeV}/c^2$ processed through the CDF detector simulation routine, we find 80% of the top quark events are accepted within the fiducial volume used for the analysis, and 65% of these events then pass the electron selection cuts above.

Muons in the central region of pseudorapidity, $|\eta| < 0.65$ are detected in the central muon drift chambers located outside of the central hadron calorimeter. These muons are selected offline with the following set of cuts:

- Track impact parameter at event vertex in $r - \phi$ plane < 0.5 cm
- $|z_{\text{vertex}} - z_{\text{track}}| < 5 \text{ cm}$
- Muon chamber - CTC track matching:
 - $\Delta x(\text{azimuth}) < 10 \text{ cm}$
 - $\Delta(\text{slope}) < 0.1$
- $E_T^{\text{em}} < 2 \text{ GeV}$
- $E_T^{\text{had}} < 6 \text{ GeV}$ } in tower containing muon

The last cut above is a loose minimum ionization requirement. The expected energy deposit for a minimum ionizing particle is 300 MeV in the electromagnetic calorimeter and 2 GeV in the hadronic calorimeter. We have extended our muon acceptance to the region, $0.65 < |\eta| < 1.2$ and identified central muons that miss the muon chambers by selecting high p_T CTC tracks that are consistent with a minimum ionizing particle. For this muon sample, fiducial cuts are applied to assure good calorimeter response. The other cuts applied are the same as those listed above

except that the CTC track - muon chamber matching is replaced with an isolation cut requiring that the transverse energy deposited in an annulus, $R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.13 - 0.4$, surrounding the track be less than 5 GeV. The top quark simulation with $M_{\text{top}} = 60 \text{ GeV}/c^2$ indicates that muons pass the chamber and calorimeter fiducial cuts with an efficiency of 80%, and are then selected by the muon quality cuts with a 75% efficiency.

Figure 11 shows scatter plots of E_T^e versus p_T^u for opposite sign leptons from the data, from a direct $b\bar{b}$ Monte Carlo simulation, from a direct $t\bar{t}$ Monte Carlo with $M_{\text{top}} = 40 \text{ GeV}/c^2$, and from a direct $t\bar{t}$ Monte Carlo with $M_{\text{top}} = 60 \text{ GeV}/c^2$. The plots have not been relatively normalized and the integrated luminosity of the sample is indicated for each plot. The experimental data are seen to resemble the b quark Monte Carlo distribution and are lacking the high E_T , high p_T events expected for t quark production. Figure 12 shows scatter plots of the minimum of E_T^e and p_T^u versus the $e - \mu$ azimuthal opening angle for the four different event samples. Again the experimental data distribution is similar to the b quark Monte Carlo. The mostly uniform population of the opening angle seen in the top quark Monte Carlo is not reproduced in the data.

A top quark signal region is defined for the current 2.5 pb^{-1} data sample by requiring $E_T^e > 15 \text{ GeV}$ and $p_T^u > 12 \text{ GeV}/c$. As one can see from Fig. 11, this leaves one experimental data event in the signal region. This event, however, has been identified as a muon plus an electron from a photon conversion. The photon conversion was flagged by the absence of a track associated with the electron in the vertex time projection chamber, and by the presence of a low mass oppositely charged track pair in the CTC. We, thus, observe no top quark event candidates in the

FIGURE 11

E_T^e vs. p_T^μ distributions for
a) 2.5 pb⁻¹ experimental data, b) 9.5 pb⁻¹ direct $b\bar{b}$ Monte Carlo,
c) 9.0 pb⁻¹ direct $t\bar{t}$ (40 GeV/c²) Monte Carlo, d) 59 pb⁻¹ direct $t\bar{t}$ (60 GeV/c²).

FIGURE 12

$\text{Min}(E_T^e, P_T^\mu)$ vs. $\Delta\phi^{e\mu}$ for a) data, b) $b\bar{b}$ Monte Carlo,
c) $M_{\text{top}} = 40 \text{ GeV}/c^2$, d) $M_{\text{top}} = 60 \text{ GeV}/c^2$.

Integrated luminosities are the same as Figure 11.

defined signal region. The number of events expected in the signal region is given in Table 1 for various top quark mass hypotheses. The number of expected events has been derived by the following procedure.

Table 1: Expected Number of Observed Top Events Estimated from Monte Carlo

M_{top} (GeV/c ²)	<u>30</u>	<u>40</u>	<u>50</u>	<u>70</u>
$\sigma \cdot B \cdot \epsilon$ (pb)	11	4.6	1.5	0.9
$N(e - \mu)$ in 2.5 pb ⁻¹	29	12	3.8	2.3
$N(e - \mu) + N(e\text{-MIP})$	49	20	6.5	3.9
Expected events after systematic derating	25	10	3.3	2.0

Top quark events are generated using a given mass hypothesis and processed through the CDF simulation package. The cross section for events with an electron plus a muon detected by the central muon chambers is calculated taking into account the branching ratio and lepton detection efficiencies. The number of such events expected for an integrated luminosity of 2.5 pb⁻¹ is calculated. Next this number of events is scaled up to account for the extra acceptance provided by the alternate muon signal from the high p_T minimum ionizing track criteria. Not all generated event samples have been analyzed with the high p_T minimum ionizing track criteria, so an estimate has been made of the increased acceptance from this selection. The acceptance for $M_{\text{top}} = 70$ GeV/c² is increased by a factor of 2.0 ± 0.3 , while for $M_{\text{top}} = 30$ GeV/c² the factor is 2.4 ± 0.7 . We have conservatively taken the factor one standard deviation below the estimated value and use a factor of 1.7 at all top quark mass hypotheses.

The numbers of events calculated by this procedure are subject to uncertainties from several sources of systematics. The theoretical cross section of Nason et al.⁴ used to derive the

expected observed cross section has an uncertainty of 30%. Monte Carlo simulations performed with varying event selection criteria give a 10% uncertainty in the acceptance. The p_T and η restrictions produce an additional 20% uncertainty, and, finally, there is 15% luminosity uncertainty. Again, to produce a conservative estimate of the expected number of events, we have taken the product of these uncertainties and derated the number of events by a factor of 1.97. The last line of Table 1 gives this final derated number of events. Since the analysis is considered preliminary and the sources of systematic errors are still under study, we do not quote an excluded mass region with a selected confidence level. However, assuming a conventional charged current decay for the top quark, the $e - \mu$ analysis indicates the top quark with a mass in the range $30 \leq M_{\text{top}} \leq 60$ GeV/c² is unlikely.

In the near future this "limit" will be made more quantitative as we add to the integrated luminosity of the data set, complete our efficiency studies, and complete the analysis of the electron plus high p_T minimum ionizing track Monte Carlo events.

5.3. Search for $t, \bar{t} \rightarrow e + \text{jets} + E_T$

The channel $t, \bar{t} \rightarrow e + \text{jets} + E_T$ has a much larger branching ratio than the $e - \mu$ decay channel and is, therefore, a potential source of a more readily detectable top quark production signal. Unfortunately, one must also contend with some large sources of background in this channel. At low electron p_T , $b, \bar{b}$ production becomes the dominant source of events, while at high p_T , the principal background is from $W + \text{jets}$.

Candidate top quark events were selected in the electron plus jets channel with electron selection criteria similar to that used for the $e - \mu$ analysis and a requirement of at least two jets in the pseudorapidity range $|\eta| < 2.0$, each with $E_T^{\text{jet}} > 10$ GeV. In addition, an explicit

isolation criterion was imposed on the electron to help reduce the $b\bar{b}$ background. This required that the transverse energy observed in the calorimeter towers surrounding the tower containing the electron candidate be less than 2 GeV. Monte Carlo studies have shown this to be a rather loose requirement for top quark production. Finally, the b quark background is reduced to a negligible level by requiring both E_T^e and E_T to be greater than 20 GeV.

The unbalanced (missing) transverse energy in the events selected by the above criteria is interpreted as the energy of the undetected neutrino in the semileptonic t quark decay. The $e - \nu$ transverse mass, $M_T^{e\nu}$, is then calculated according to the formula given in Section 2. The transverse mass distribution for the experimental data is shown in Fig. 13 along with the distributions from $W + \text{jets}$ and $M_{\text{top}} = 60 \text{ GeV}/c^2$ simulations. We note that the data distribution is qualitatively similar to the $W + \text{jets}$ Monte Carlo simulation distribution and shows no particular excess of events in the region below 60 GeV/c^2 where the peak of the simulated top quark signal lies. Extraction of a limit on the $t, \bar{t}$ production cross section from the transverse mass distribution is still in a very preliminary state. In particular, the efficiency of jet detection in the 10 - 20 GeV transverse energy range is being studied and checked using p_T balance in direct photon events. At present we take a conservative approach and use the number of data events observed in the transverse mass range of 10 - 60 GeV/c^2 with no background subtraction to place a limit on the production of top. The number of expected top events in this region is derated to account for uncertainties from the theoretical $t, \bar{t}$ production cross section, the electron selection efficiency, and the jet detection efficiency. While we don't think the analysis is yet complete enough to quote a limit with a statistical confidence level, we conclude that, based on the $e + \text{jet}$ analysis, a

FIGURE 13
Electron-neutrino transverse mass distribution for events with ≥ 2 jets with $E_T > 10 \text{ GeV}$. a) $M_{\text{top}} = 60 \text{ GeV}/c^2$ Monte Carlo. b) $W + 2$ jets Monte Carlo c) experimental data.

mark with mass between 45 and 60 GeV/c^2 is likely. This, as usual, assumes the conventional charged current decay for the top quark.

5.4. Expectations from the Top Search at CDF

We expect that studies of detection efficiencies and sources of systematic uncertainties for the top search will be completed in the near future. The completion of these studies will allow a statistically precise statement of a top mass limit should the lack of a signal persist. Analysis of the $e - \mu$ and $e + \text{jets}$ data should allow us to determine if the top mass is less than that of the W boson. If the top quark has a mass heavier than $-M_W + M_{\text{bottom}}$ but less than $\sim 100 \text{ GeV}/c^2$, then i) the W 's produced in the $t, \bar{t}$ decays are real and ii) we must content with a very difficult background from $W + \text{QCD}$

multijet production. We would expect that a combined analysis of all the leptonic top decay channels available to us would be required to address the question of a top quark in this mass region.

Finally, should the top mass exceed ~ 100 GeV/c², then detection at CDF might be possible in future runs in which we anticipate collecting a data sample from $O(100 \text{ pb}^{-1})$ of integrated luminosity. In addition, the detector is being upgraded with a silicon microvertex detector for the next run with which we should be able to tag b quarks associated with top decay. The higher integrated luminosity sensitivity and improved detection capability will allow us to cover, in the next few years, the entire mass range allowed for the top quark in the Standard Model.

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