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DØ

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For the DØ Collaboration

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ABSTRACT

We present preliminary results on the search for the top quark in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV by the DØ collaboration at the Fermilab Tevatron. The data presented correspond to an integrated luminosity of about 7.5 pb^{-1}. We have conducted searches in the electron-muon ($e\mu$) and the dielectron (ee) top decay channels. One $e\mu$ event was found. We obtain a lower limit on the top mass of 99 GeV/c^2 at 95% C.L.

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The existence of the top quark is required by the Standard Model (SM) to complete the three families. Up to now, direct searches have yielded a lower bound on the mass of the top quark of 91 GeV/c^2.[1] Precision measurements of electroweak parameters predict the mass of the top quark to be (152±17±21) GeV/c^2.[2] The first error is due to measurement errors, while the second arises from the uncertainity in the Higgs Mass, taken to be between 60 GeV/c^2 and 1 TeV/c^2. At the Tevatron, $t\bar{t}$ pair production via parton fusion is the dominant process for top quark creation. In the SM scenario, the top quark decays to a real W boson accompanied by a b quark, provided that the top quark is heavier than the W boson. Depending on the decay mode of the W, there are various signatures for the $t\bar{t}$ events. In this paper, we report on a search for top in the channels where both W's from a $t\bar{t}$ pair decay leptonically. Specifically, we have investigated the decay chains $t\bar{t} \rightarrow W^+ b W^- \bar{b} \rightarrow e\nu \mu\nu b\bar{b}$ and $t\bar{t} \rightarrow W^+ b W^- \bar{b} \rightarrow e\nu e\nu b\bar{b}$. The signature for these events is the presence of two isolated leptons with high transverse momentum (p_T), at least two jets from the hadronization of the accompanying b quarks and a significant missing transverse energy ($\not\!\!E_T$) due to the neutrinos from the decay of the W's. Although the branching fractions for these final states are fairly small, $B(t\bar{t} \rightarrow e\mu X) = 2.5\%$ and $B(t\bar{t} \rightarrow eeX) = 1.2\%$, they also have relatively small backgrounds.

The DØ detector[3] is ideal for detecting these events. Excellent electron identification is achieved due to the fine longitudinal and transverse segmentation of the uranium liquid argon calorimeter and the compact tracking system. The hermeticity of the calorimeter over the pseudorapidity range of $|\eta| \leq 4.5$ permits a precise determination of $\not\!\!E_T$ in the events. Muon detection is performed by three multilayer proportional drift tube chambers (PDT), one before and two behind magnetized iron toroids. Muon momentum is measured by the curvature of the muon track in the toroidal field.

The data presented here has been collected from August 1992 through March 1993 at the Tevatron. The integrated luminosities are 7.2 pb^{-1} and 7.5 pb^{-1} for the ee and $e\mu$ channels, respectively. For this search, the online triggers were designed to accept events with dileptons or combinations of single leptons, jets and $\not\!\!E_T$.

Offline electron identification begins with selection of calorimeter clusters with at least 90% of their total energy in the electromagnetic (EM) section. These candidates are subjected to a covariance matrix test,[4] which utilizes the correlations between the energy deposited in the EM calorimeter cells occupied by the electron shower. Electrons are required to be isolated by demanding that the energy deposited in the annular cone $0.2 < R < 0.4$, where $R = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$, be less than 20% of the EM energy contained in the smaller cone of $R < 0.2$ centered around the direction of the electron. A further optional requirement can be applied requiring that a track in the central tracking chambers (CD) points near the electron cluster. We identify muons as tracks in the PDTs. The energy deposited in the calorimeter along the muon track direction is required to be consistent with that expected of a minimum ionizing particle. We also demand a matching CD track. Finally, we check that the extrapolated muon track is consistent with an origin at the interaction vertex. A muon is considered isolated if the $\eta - \phi$ separation between the muon and the nearest jet, $R(\mu\text{-jet})$, is at least 0.5. We identify jets as an energy deposition in a cone of radius $R = 0.5$. The minimum measured E_T of a reconstructed jet is 8 GeV. At present we reject jets with more than 40% of their energy measured in the leakage detectors located between the cryostats of central and end calorimeters.

Event selection criteria are chosen to retain good efficiency for top quark decays while minimizing backgrounds. In the ee analysis, initial event candidates are selected by requiring two isolated electrons with $E_T > 15$ GeV, one of which is required to have a match with a CD track. Additionally, we require the presence of two jets with $E_T > 15$ and 13 GeV respectively in the event. Fig. 1 shows the distribution of the missing transverse energy ($\not\!\!E_T$) in the event versus the invariant mass of the electron pair ($M(ee)$) after the above selection cuts. For comparison, we present in Fig. 2, the corresponding distribution for $t\bar{t} \to ee$ Monte Carlo† (MC) events ($\int L dt = 2.7$ fb^{-1}, $M(t) = 140$ GeV/c^2). We eliminate dielectron events from decays of the Z by rejecting events with $M(ee)$ within $\pm$ 14 GeV/c^2 of the Z mass peak. Lastly, to discriminate against backgrounds from $Z \to \tau\tau$, $b\bar{b}$, diboson pairs (WW, WZ), leptons from Drell-Yan and QCD processes, we select events with $\not\!\!E_T > 20$ GeV. No events survive the above selection criteria.

For the top search in the $e\mu$ channel, one selects events with an isolated electron (no CD track match) with $E_T > 15$ GeV and an isolated muon with $p_T > 15$ GeV/c and $|\eta| < 1.7$. This channel is free from backgrounds arising from Drell-Yan processes. The isolation requirement suppresses backgrounds due to QCD multijet events. Radiative $W, Z \to \mu$ events are removed by demanding $R(e\text{-}\mu) > 0.25$. In Fig. 3 we plot the p_T of the

† All MC events used for the top search as well as for the background estimates are generated using the ISAJET[5] event generator and processed through a GEANT[6] detector simulation.

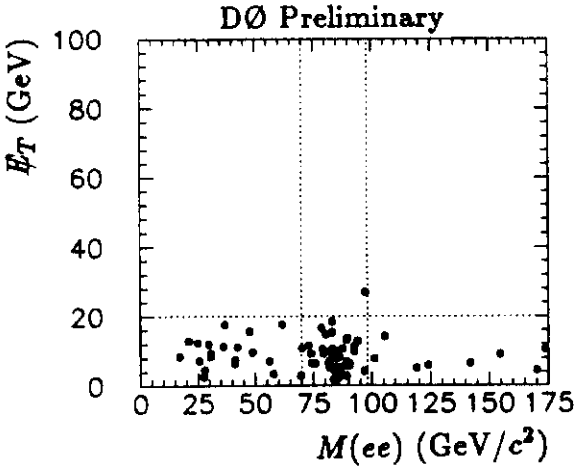

Fig. 1. $\not\!\!E_T$ vs. $M(ee)$ for DØ data.

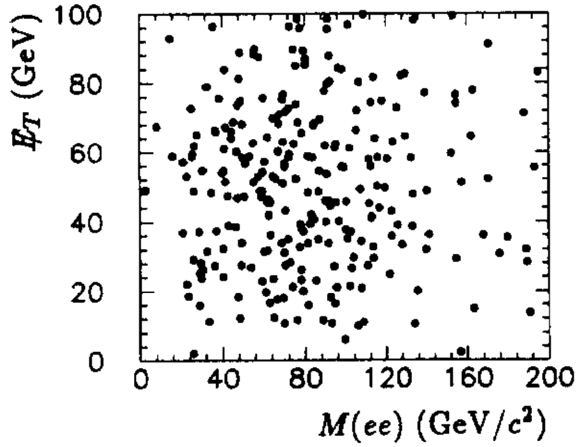

Fig. 2. $\not\!\!E_T$ vs. $M(ee)$ for $t\bar{t} \to ee$ MC.

muon versus the E_T of the electron for events passing these requirements, while the same quantities for a $t\bar{t} \to e\mu$ MC event sample ($\int L\,dt = 1.2$ $\mathbf{fb^{-1}}$, $M(t) = 120$ GeV) are plotted in Fig. 4. Again, background events due to $Z \to \tau\tau$, diboson pairs (WW, WZ), $Z \to b\bar{b}$ are rejected by demanding $\not\!\!E_T > 20$ GeV and at least two jets with $E_T > 15$ GeV and 13 GeV, respectively. Events in which the three body transverse mass $M_T(\mu\gamma\nu)$ is consistent with final state wide angle bremsstrahlung from $W \to \mu\nu$ decays are also rejected. One event with $E_T(e) \approx 97$ GeV and $p_T(\mu) \approx 100$ GeV survives the above selection criteria.

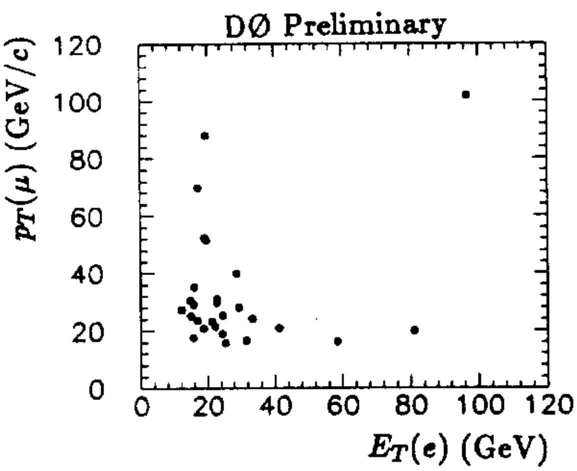

Fig. 3. $p_T(\mu)$ vs. E_T(e) for DØ data.

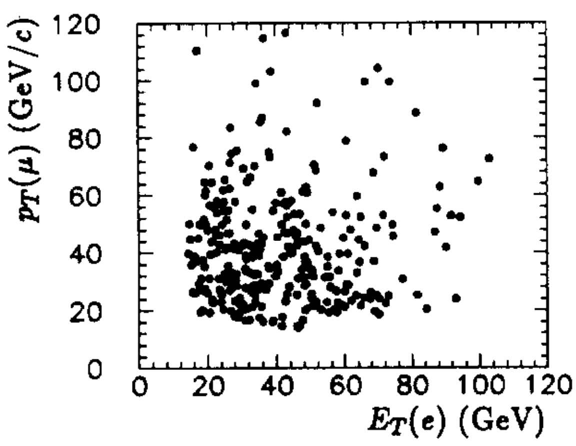

Fig. 4. $p_T(\mu)$ vs. E_T(e) for $t\bar{t} \to e\mu$ MC.

In order to determine the acceptance $\times$ efficiency for a signal from top quark decays for the kinematical and topological selection cuts used in the analyses, we generate $t\bar{t} \to ee$ and $e\mu$ events at four different top masses, $M(t) = 80$, 100, 120, and 140 GeV/c^2. Events are then processed through the DØ trigger simulator and DØ offline event reconstruction program. Application of the same selection criteria as those used for the data yields a top selection efficiency which varies between 9% (11%) and 26% (32%) as $M(t)$ varies between 80 and 140 GeV/c^2 for the $e\mu$ (ee) analyses. Relative systematic errors on the efficiencies are determined to be approximately 23% and 15% for the $e\mu$ and ee modes, respectively. Combining this with the top production cross section prediction[7] yields a signal estimate of 6.1 (3.7) and 1.0 (0.5) events over the same $M(t)$ range in the $e\mu$ (ee) channel.

Estimation of $e\mu$ and ee backgrounds from QCD multijets, $Z \rightarrow \tau\tau$, $Z \rightarrow b\bar{b}$, W+jets, WW, WZ and radiative $W(Z) \rightarrow \mu X$ is accomplished by generating MC events. Additionally, we have also considered instrumental backgrounds, e.g., due to mismeasured $\not{E}_T$, jets which are misidentified as electrons, muons from π/K in flight decays and cosmic ray muons. The rates for instrumental backgrounds are determined using multijet data as well as MC events. We find that major contributing sources are the W+jets and QCD multijet processes. Combining contributions from both physics and instrumental sources yields a background estimate of 0.65 events for the $e\mu$ and 0.22 for the ee mode.

With the observation of one event in the $e\mu$ channel, and with the background subtracted, we obtain an upper limit on the top production cross section at 95% confidence level as shown by the dotted curve in Fig. 5; the solid curve is the result without background subtraction. Comparing the limit curves to a theoretical cross section prediction[7] (dashed curve) leads to a lower limit on the mass of the top quark of 103 GeV/c^2 when background is subtracted, and to 99 GeV/c^2 without background subtraction.

The $e\mu$ event which passes all event selection criteria merits further discussion. The leptons in this event are well isolated and their transverse momenta are : $E_T(e) = (97\pm2)$ GeV, $p_T(\mu) = (110^{+\infty}_{-50})$ GeV/c ($>$ 43 GeV/c at 90% C.L.). The error on the muon momentum is approximately Gaussian in $1/p$ and $p_T(\mu)$ is 5σ above the 15 GeV/c event selection cut imposed on it. The $\not{E}_T$ measurement is strongly correlated with the measurement of $p_T(\mu)$. We measure $\not{E}_T = (74^{+\infty}_{-7})$ GeV. Its value cannot be below 67 GeV for any muon momentum. There are three additional jets in the event with E_T's of (30$\pm$5) GeV, (28$\pm$5) GeV and (14$\pm$2) GeV. The backgrounds described above are unlikely to produce events with such high p_T leptons. Therefore, it is interesting to examine this event under the hypothesis that it may be from $t\bar{t}$ production. Under this hypothesis, we extract the likely mass of the top quark from this event by extending the techniques used by Dalitz and Goldstein.[8] We find that if the two leading jets are interpreted as the b-jets, this event implies a lower limit on the top quark mass of 130 GeV/c^2 at 95% C.L.; the upper limit which is somewhat dependent on the details of resolution smearing and weighting functions is greater than 170 GeV/c^2.

To conclude, in a preliminary search for the top quark in the $t\bar{t} \rightarrow e\mu X$ and eeX decay modes, we observe one event in the $e\mu$ channel which is difficult to interpret from known backgrounds. We also set a 95% C.L. lower limit on mass of the top quark at 99 GeV/c^2.

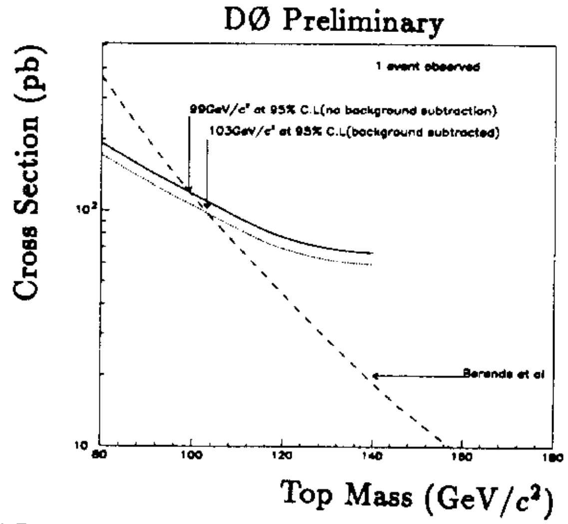

Fig. 5. 95% C.L. upper limit on top production cross section.

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