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DØ Results on Searches for the Top Quark

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Abstract

We have performed a search for creation of the top quark in $p\ \bar{p}$ collisions at $\sqrt{s} = 1.8$ GeV at Tevatron, Fermilab. $t\ \bar{t}$ production followed by top decay to $W + b$ quark is assumed. we have searched for the decay channels with both W's decaying leptonically, and with one W decay to an electron and the other to quarks. A preliminary report on the status of one interesting event is presented. By combining the results from the ee and $e\mu$ channels a lower top mass limit of 99 GeV on the 95% confidence level is obtained.

I. Introduction

A partner for the b quark is required by the Standard Model. Results of some indirect searches already indicate that the top quark should be heavy [1]. So far indications are that the top quark is more massive than the W boson [2]. In $p\bar{p}$ collisions at Tevatron energy of $\sqrt{s} = 1.8\ GeV$ top quarks are produced in pairs which subsequently decay to real W bosons and b quarks. The various decay modes of the W and the b will result in several distinct final states for the $t\bar{t}$ system. The final states with acceptable backgrounds are lepton plus jets and dilepton channels. The latter is the result of both W's decaying to leptons with the b quarks decaying into jets or additional leptons plus jets. The former is the result of hadronic decay of one of the W's while the other W decays leptonically. Again b quarks can produce additional jets or leptons in the event.

The D0 detector (described elsewhere [3]), is equipped with a 4π Uranium-Liquid Argon calorimeter system, as well as a vertex detector, central and forward tracking systems, transition radiation detector, and a large muon system. The hermiticity and excellent energy resolution of the D0 calorimeter and the full coverage of the muon detector translate into a sensitive device for the top search.

II. Analysis

A subset of the available data corresponding to ˜ 7.5 pb^{-1} is considered for this analysis. The appropriate triggers were selected from the Express line data which makes ˜ 10% of the total data logged to tape. The Express line data is the *OR* of many triggers which assures inclusion of data from all physics processes of interest. The final selected triggers are highly efficient for this search.

This analysis requires selection of high quality leptons. Below is a brief description of the lepton identification requirements used for this analysis.

a. *muon selection*
The η coverage for the acceptable muons was selected to be $|\eta| < 1.7$ due to our better understanding of muons in this region. Only high quality muons with good χ^2 of fit were selected. muons were required to have minimum ionizing trace in the calorimeter, and to be consistent with the primary vertex. Rejection of the cosmic rays was done by excluding events with back to back muons, or with tracks that possessed a MIP calorimeter trace in the opposite direction. A fiducial cut excluded muons from consideration if they passed through the thin part of the muon iron system.

b. *Electron selection*
The selection criteria for the electrons were primarily based on the information from the calorimeter. Clusters were selected with high electromagnetic (EM) energy ratio such that EM energy was at least 90% of the total energy in the cluster. Only isolated EM clusters were selected by requiring $E_{tot}(cone\ 0.4) - E_{EM}(cone\ 0.2)\ /\ E_{EM}(cone\ 0.2) < 0.2$. An Hmatrix

method was used to require shape cuts. A χ^2 cut where $\chi^2 = \sum_{ij}[x_i - < x_i >]\ H_{ij}\ [x_j - < x_j >]$ was used to choose EM clusters which conform with that of an actual EM shower. The Hmatrix was defined by $H_{ij}^{-1} =< (x_i - < x_i >)(x_j - < x_j >) >$.

2.1 *Search in ee channel*

The offline selection criteria for this channel requires two electromagnetic clusters with $E_t > 15\ GeV$ when at least one cluster has a matching Central Detector (CD) track match. Since top events contain neutrinos as a result of the decay of W's, a missing E_t ($\not\!\!E_t$) of at least 20 GeV is imposed. This cut is instrumental in rejecting QCD and D-Y events. To exclude the background from the Z events the region of the two-body mass spectrum occupied by the $Z \to ee$ ($70 < M_{ee} < 98\ GeV$) is also excluded. A minimum number of two jets with $E_t^{jet1} > 12.5\ GeV$ and $E_t^{jet2} > 10\ GeV$ is imposed to account for the jets produced as a result of the b quark decays. Additional jets may be produced from the b decays and from initial and final state radiations. Fig. 1 is a plot of the dilepton mass vs. $\not\!\!E_t$ from monte carlo generated top events with a mass of 120 GeV, and Fig. 2 shows the same plot for the real data. All cuts except mass and $\not\!\!E_t$ cuts are already imposed. It is evident that no candidate events appear in the region of interest for the real data of Fig. 2, while Fig. 1 shows a populated region for the monte carlo events.

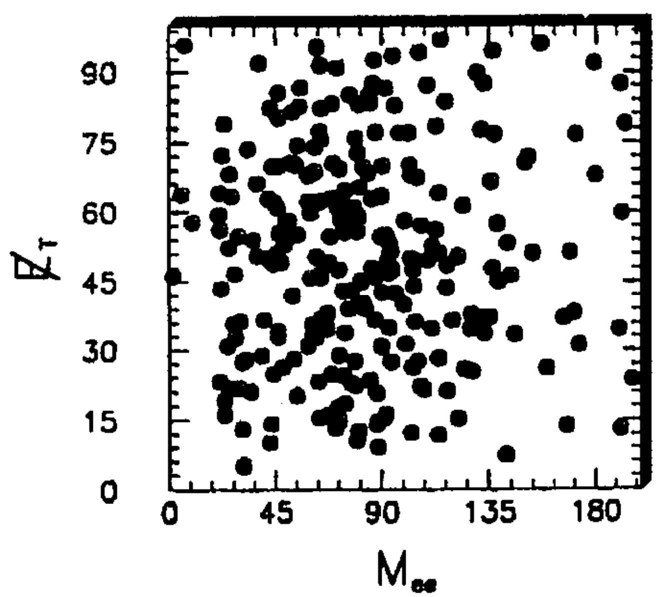

Fig. 1. M_{ee} *vs.* $\not\!\!E_t$ for Monte carlo with top mass of 120 GeV.

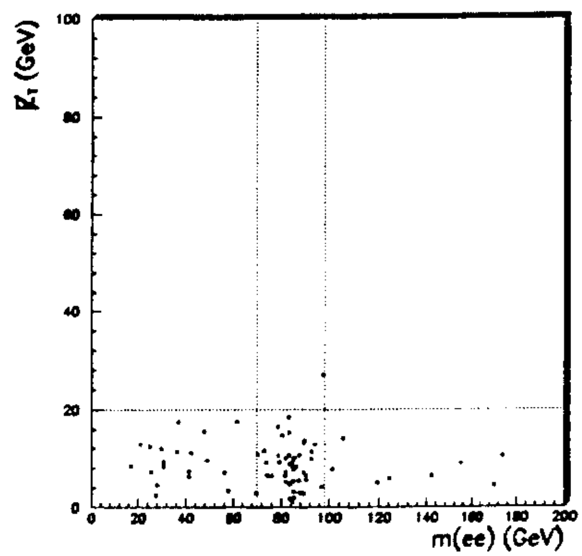

Fig. 2. M_{ee} *vs.* $\not\!\!E_t$ for real data.

2.2 *Search in $\mu\mu$ channel*

Due to a change in some triggers after collection of 3.7 pb^{-1} data the offline selection cuts for the second part were slightly different. For the first part, events with two high quality muons were selected. In addition it was required that P_t of both muons be greater than 15 GeV. To account for neutrinos a $\not\!\!E_t > 15\ GeV$ cut was imposed. Since the leptons from decay of the W's are highly isolated it was required that ΔR between each muon and the nearest jet be greater than 0.5, where $\Delta R = \sqrt{\delta\eta^2 + \delta\phi^2}$. Since the abundantly produced $Z \rightarrow \mu\mu$ events give back to back muons, it was required that $\delta\phi_{\mu\mu} < 160^o$. A minimum number of two jets was required with $E_t^{jet1} > 30\ GeV$ and $E_t^{jet2} > 20\ GeV$. For the second part of the data no $\not\!\!E_t$ cut was imposed and the requirement on the energy of the jets was reduced to $E_t^{jet1} > 12.5\ GeV$ and $E_t^{jet2} > 10\ GeV$. Two events survive the cuts. However due to the large number of background events from decay of the Z's the analysis of this channel is still being studied and the current results are not considered in the mass limit determination.

2.3 *Search in $e\mu$ channel*

The offline selection was designed to select events with high quality muon and electron with transverse energies of $E_t^e > 15\ GeV$ and $E_t^\mu > 15\ GeV$. To reject QCD events isolated muons were selected with ΔR between the muon and the nearest jet greater than 0.5. The requirement of $\not\!\!E_t > 20\ GeV$ was imposed to reduce the number of background events from $Z \rightarrow \tau\tau$ and QCD and D-Y processes. Muon bremsstrahlung events (from $W \rightarrow \mu\nu$ and $Z \rightarrow \mu\mu$) which could simulate an electron in the event were rejected by imposing mass cuts on the $\mu\nu\gamma$ system. Two jets were required to be present with $E_t^{jet1} > 12.5\ GeV$ and $E_t^{jet2} > 10\ GeV$. Figs. 3&4 show the events which survived the cuts before requiring two jets in the event. Only one event survived the final cuts (marked by an arrow in the Figures).

The preliminary details of the surviving $e\mu$ event are described in Tbl. 1. So far our studies of any possible background source cannot explain this event with any reasonable probability. The study of this event and the background sources are on going.

2.4 *Search in e + jets Channel*

Offline selection required the presence of an electron with $E_t^e > 20\ GeV$, and event $\not\!\!E_t > 20\ GeV$. To reduce QCD background with a jet faking an electron, events containing an electron with a back to back jet such that $\delta\phi(e - jet1) < 165^o$ were rejected. In this analysis we have required that a b quark be identified by its decay to a muon. This muon is normally very close to a jet as a result of the c quark (decay product of b). Therefore a soft muon with $P_t^\mu > 4\ GeV$ near a jet within $\Delta R < 0.7$ was required. One event survived the final cuts. The sources of background and the selection criteria imposed are currently being studied.

Tbl. 1. Kinematic parameters of the interesting event in the $e\mu$ channel.

object	$e\mu$ event (GeV)
E_t^{μ}	101 (> 43 90% CL)
E_t^{e}	97 ± 2
$\not{E}_t$	74 (> 66 95% CL)
E_t^{jet1}	30 ± 5
E_t^{jet2}	28 ± 5
E_t^{jet3}	13 ± 2.5

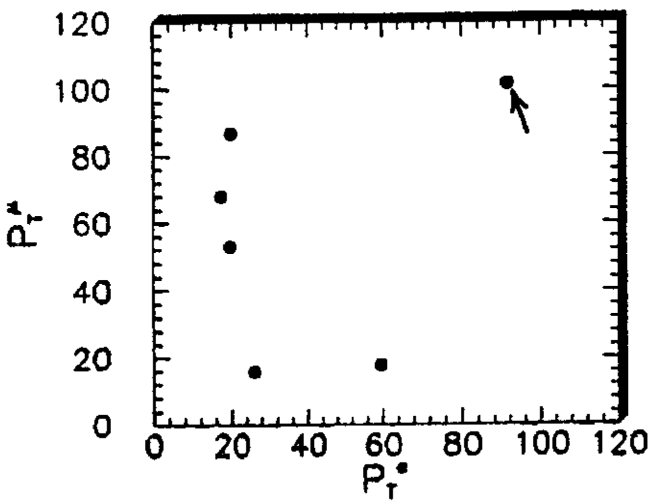

Fig. 3. P_t^e *vs.* P_t^{μ} for the $e\mu$ channel.

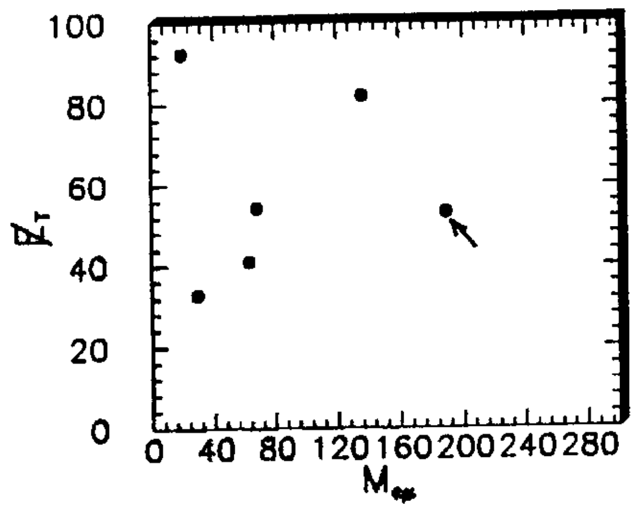

Fig. 4. Missing E_t *vs.* $M_{e\mu}$ for the $e\mu$ channel.

III. Background Studies

The estimates of the contamination from various background sources are currently available from some preliminary Monte carlo studies. Backgrounds appear due to physics processes combined with detector effects. The latter (instrumental background) are on one hand due to fluctuations in the calorimeter response which fake EM clusters from jets, and/or fake $\not{E}_t$'s, or due to punchthroughs and decay products of pions and kaons producing fakes or uninteresting muons.

These detector effects combined with processes such as QCD, $Z \rightarrow \tau\tau$, $Z \rightarrow b\bar{b}, c\bar{c} \rightarrow$ dileptons, W pairs, WZ, $W\gamma$ $W + jets \rightarrow$ dileptons, and Drell Yan processes decaying to $\tau\tau \rightarrow$ dileptons, ... etc, are the major sources of background for dilepton channels. $W + jets$ events are one of the main sources of contamination in lepton plus jets channel. Preliminary results from Monte carlo studies indicate that the expected number of background events to be 0.22 events in the ee channel, and 0.65 events in $e\mu$ channel. Background estimates for other channels are being calculated. Efforts to use data for estimation of background contamination is also underway.

IV. Combined Analysis Results

The one event that stands out in the $e\mu$ channel has been considered for a Dalitz type mass analysis [4]. The preliminary results point out that under the hypothesis that this event was a top decay, it would be consistent with a top mass between 130 and 170 GeV. (This analysis is done by taking into account the two leading jets only.)

The two ee and $e\mu$ channels are considered for calculation of the upper limit cross section and lower limit mass. The data curves appearing in Fig. 5 are the combined upperlimit cross sections at the 95% confidence level with and without background subtraction. The intercept of these curves and the theoretical calculation [5] are the lower mass limits. We obtain the preliminary values of 99 (103) GeV without (with) background subtraction. Careful studies of background estimates and choices of theoretical cross section calculations are under way.

V. Conclusions

In a subset of the data corresponding to ~ 7.5 pb^{-1} our preliminary search for creation of the top quark has not resulted in observing any definite signals. However an interesting event in the $e\mu$ channel has been observed that cannot be accounted for by our current understanding

130 to 170 GeV. The combined lower mass limit from ee and $e\mu$ channels gives a mass limit of 99 (103) without (with) background subtraction at the 95% confidence level. The analysis of the total 15.2 pb^{-1} of data collected in run 1a is underway and is expected to increase the mass sensitivity to about 120 GeV. It is also expected that the data which will be collected in run 1b in the next year period will give us a mass sensitivity of ~ 150 GeV.

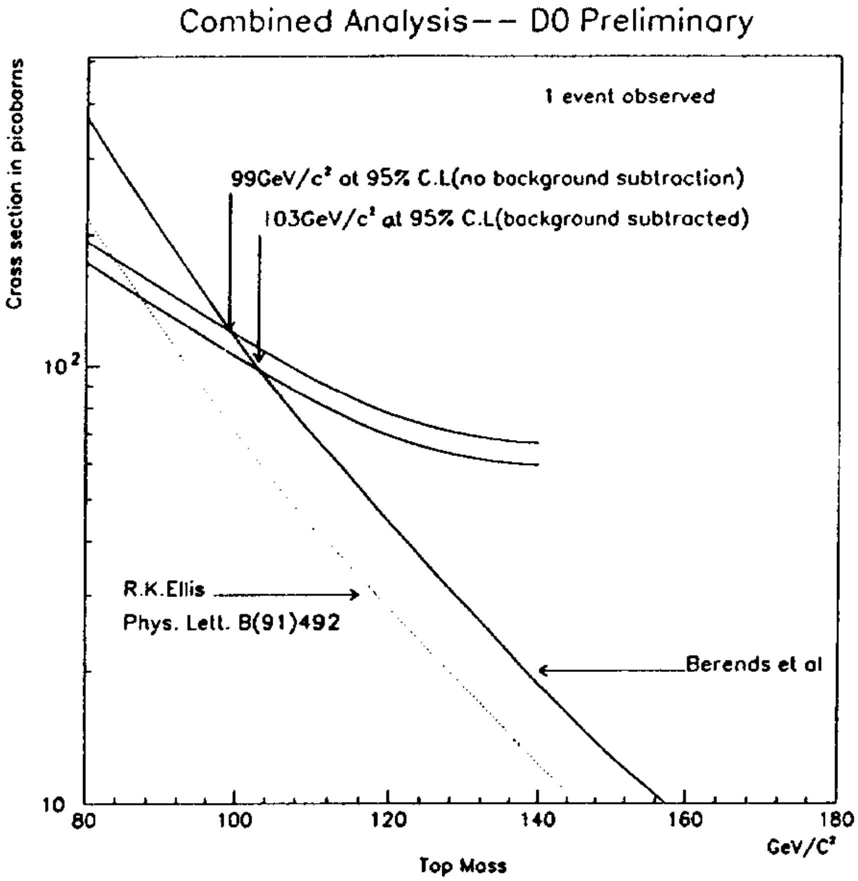

Fig. 5. Theoretical and upperlimit cross sections, used for extracting lower mass limits.

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