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ABSTRACT

Preliminary results from the search for the top quark and other new particles in $p\bar{p}$ collisions at $\sqrt{s}$ =1.8 TeV are reported. In a data sample corresponding to an integrated luminosity of about 7.5 pb^{-1}, one candidate event for top quark is found in the di-lepton channel. A lower limit for the mass of the top quark of 103 GeV/c^2 (99 GeV/c^2) is obtained at 95% confidence level with (without) background subtraction. Status of searches for other new particles that may arise from new phenomena beyond the standard model is summarized.

1. Introduction

The primary physics pursuits of the collider experiments at Fermilab have been to search for the top quark - the missing piece in the 3-generation standard model and to look for hints of new physics beyond the standard model. The existence of the top quark is expected not only for the theoretical consistency of the standard model, but is inferred from measurements of the isospin of the bottom (b) quark ($I_3(b)$=-1/2)[1] and from the absence of flavor-changing neutral currents[2]. From direct searches , a lower limit of 91 GeV/c^2 at 95% confidence level (C.L.) has been reported [3] for the mass of the top quark. Indirect constraints from precision measurements of electro-weak parameters predict the mass of the top quark to be $152 \pm 17 \pm 21\, GeV/c^2$ [4].

At the Tevatron, the top quarks are predominantly produced in pairs via parton-parton fusion [5, 6, 7]. Each top quark will subsequently decay into a real W and a b quark. The W can then decay either leptonically into a charged lepton and a neutrino or hadronically into a pair of quarks. Depending on the decay mode of the W, $t\bar{t}$ events can be classified into di-lepton, lepton+jets and all-jets categories. In this paper, we mainly report on the search for the top quark into ee and $e\mu$ decay channels which have branching fractions of $\frac{1}{81}$ and $\frac{2}{81}$ respectively. These channels are characterized by two central, isolated, high E_T leptons, a large missing E_T ($\not{E}_T$) in the event due to the two undetected neutrinos from W decays and two jets corresponding to the two b-quarks. We briefly summarize the status of search in the e+jets channel.

Status of search for first generation scalar leptoquarks decaying into leptons and jets and search for supersymmetric particles are also summarized.

[1] To be published in the Proceedings of the International Conference (V^{th} Blois Workshop) on Elastic and Diffractive Scattering (1993)

2. The DØ Detector

The DØ detector comprises of a central tracking system, a Uranium liquid-Argon calorimeter and a muon spectrometer. The DØ calorimeter[8], with its hermeticity, large angular coverage, fine longitudinal and transverse segmentation, sufficient depth for shower containment and e/π ~1, is an excellent device to detect electrons and jets. The measured energy resolutions are $(\sigma/E)^2 = (0.003)^2 + (0.157)^2/E + (0.29)^2/E^2$ for electrons and $(\sigma/E)^2 = (0.05)^2 + (0.50)^2/E + (0.30)^2/E^2$ for pions. The $\not\!\!E_T$ resolution of the calorimeter which is very important for top quark and other new particle searches, is excellent because of the hermeticity of the calorimeter and uniformity of the response. The muon system has coverage for $|\eta| \leq 3.2$ with muon momentum resolution of $\delta p/p = 0.2 + 0.01p$. The combined thickness(14λ to 19λ) of the calorimeter and the magnetic toroids of the muon system reduce the punch-through backgrounds to a negligible level.

3. Top Search

3.1. Di-lepton (ee and eμ) channels

The data for the ee and $e\mu$ analyses correspond to integrated luminosities of about 7.3 pb^{-1} and 7.5 pb^{-1} respectively. The errors on the integrated luminosities are about 12%. The on-line triggers for this data-set were designed to accept events with di-leptons or combinations of leptons, jets and $\not\!\!E_T$.

The electrons are identified off-line as calorimeter clusters with pattern of energy deposition conforming to that of an electromagnetic shower. This is tested by a covariance matrix χ^2 (< 200). The off-line event selection criteria for the ee channel analysis require two well identified, isolated electrons with $E_T > 15$ GeV, and at least one of the electrons having a corresponding track in the central detector (CD). This yields 1159 events. Fig. 1(a) shows a scatter plot of $\not\!\!E_T$ versus the di-electron invariant mass for 69 events with two such electrons and two jets with E_T greater than 12.5 GeV and 10 GeV. (Events with jets which deposit more than 40% of their energy in the Inter-Cryostat detector are also removed from the sample.) Figure 1(b) shows the $\not\!\!E_T$ versus the di-electron invariant mass for 140 GeV/c^2 mass top quark events from Monte Carlo($\int Ldt = 2840 pb^{-1}$), with the same cuts, for comparison. We further require $\not\!\!E_T$ to be greater than 20 GeV and reject $Z \rightarrow ee$ +jets background by removing events with di-electron invariant mass lying within 14 GeV/c^2 of the Z mass peak. No events survive all the off-line cuts.

In the $e\mu$ channel analysis, we start out with 77 events having one good electron and one good muon, both with $E_T > 15$ GeV. The electron identification cuts are same as for ee analysis. No CD track match is required for the electron. The muon is further required to have $|\eta| < 1.7$ and be at least 0.5 units away from the nearest jet in eta-phi space (for isolation). Fig. 2(a) shows a scatter plot of muon P_T versus electron E_T for the 27 events that pass these cuts. Corresponding plot for $t\bar{t} \rightarrow e\mu$ Monte Carlo events for top mass of 120 GeV/c^2 and $\int Ldt = 1420 pb^{-1}$ is shown in Fig. 2(b). The analysis also requires $\not\!\!E_T > 20$ GeV and 2 jets with

E_T greater than 12.5 GeV and 10 GeV, as in the case of ee analysis. These cuts are effective in rejecting $Z \rightarrow \tau\tau$, $Z \rightarrow b\bar{b}$ and W^+W^- background events (in both ee and $e\mu$ channels). To remove background from radiative $W \rightarrow \mu\nu$ events with muon bremsstrahlung, a cut is imposed on the $M_T(\mu\gamma\nu)$ and the separation between the two leptons is required to be greater than 0.25. One event survives all the off-line cuts.

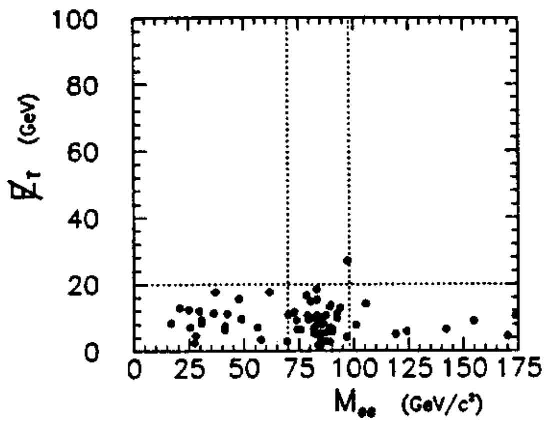

Fig. 1a. $\not{E}_T$ vs. M(ee) for DØ data

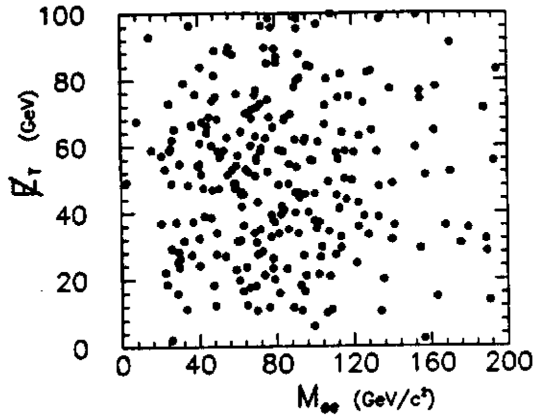

Fig. 1b. $\not{E}_T$ vs. M(ee) for $t\bar{t} \rightarrow ee$ MC

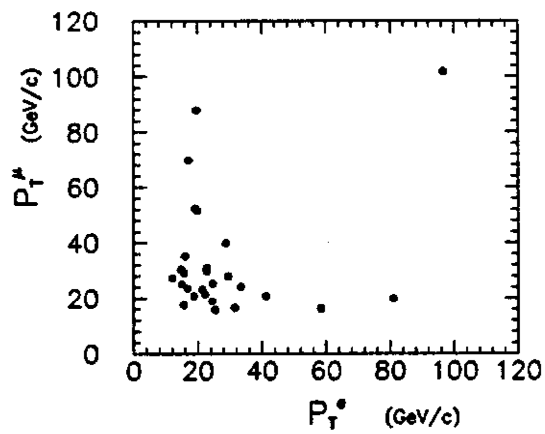

Fig. 2a. P_T^μ vs. P_T^e for DØ data

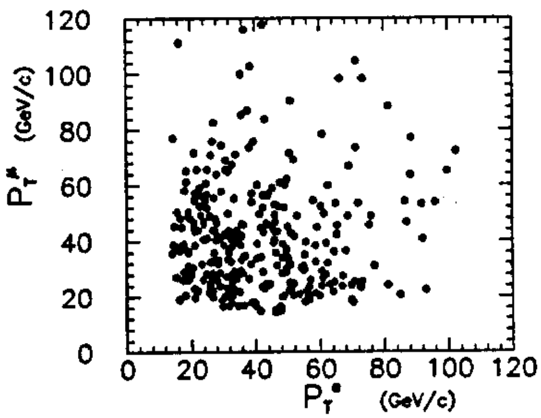

Fig. 2b. P_T^μ vs. P_T^e for $t\bar{t} \rightarrow e\mu$ MC

The $e\mu$ candidate event is a very clean event with well isolated and good quality leptons and three jets. The electron has E_T of 97 ± 2 GeV and muon P_T is $101^{+\infty}_{-50}$ GeV/c. The P_T of the muon is 5 sigma above the 15 GeV/c event selection cut. The $\not{E}_T$ is $74^{+\infty}_{-7}$ GeV. It is correlated with the muon momentum. However, its value cannot be smaller than 67 GeV for any muon momentum. Fig. 3(a) and (b) show R-Z and transverse view of this event respectively. Hypothesizing this event to be due $t\bar{t}$ production, an analysis similar to the one proposed by Dalitz et al[9], (assuming the two highest E_T jets are from b quarks and also using $\not{E}_T$ in the event), we find that the event is consistent with a top quark mass in the range of 130 to 170 GeV/c^2 at 90% C.L.

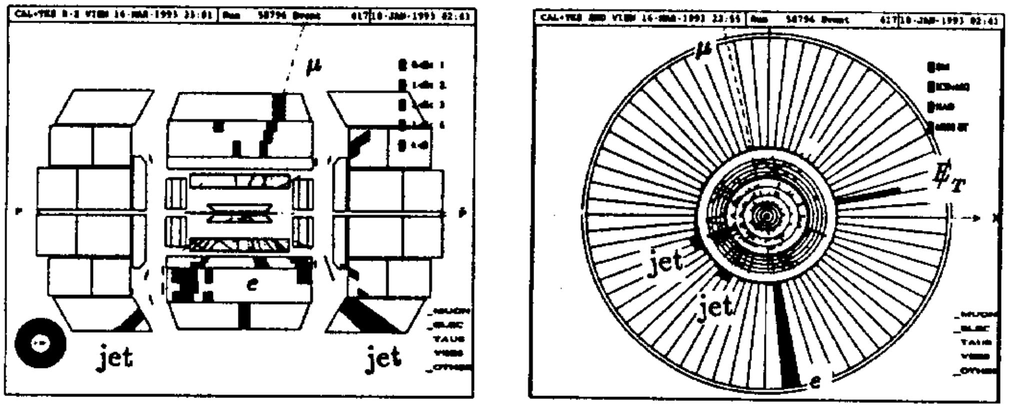

Fig. 3. The $e\mu$ candidate event in the DØ detector - a)R-Z view, b) End view

3.2. *Top Mass Limits*

We have used the analyses in the di-lepton channels ee and $e\mu$ to set a lower limit on the mass of the top quark. The final detection efficiencies (triggering and event-selection) for top in both ee and $e\mu$ decay channels have been studied as a function of top quark mass, using Monte Carlo. The efficiencies and the expected number of $t\bar{t}$ events using the predicted $t\bar{t}$ production cross-section[7] for different top masses are given in the table below.

Expected yields for $t\bar{t} \rightarrow ee$ and $e\mu$						
m_t (GeV)	σB_{ee} (pb)	ϵ_{ee} (%)	N_{ee}	$\sigma B_{e\mu}$ (pb)	$\epsilon_{e\mu}$ (%)	$N_{e\mu}$
80	4.6	11	3.7	9.1	9	6.1
100	1.3	18	1.7	2.5	15	2.8
120	0.5	28	1.0	1.0	22	1.7
140	0.2	32	0.5	0.5	26	1.0
	$\mathcal{L}$= 7.3 pb^{-1}			$\mathcal{L}$= 7.5 pb^{-1}		

To estimate the backgrounds in these channels, we have considered processes like $Z \rightarrow \tau\tau, Z \rightarrow b\bar{b}, W + Jets, WW, WZ$ and radiative $W(Z) \rightarrow \mu + X$. Instrumental backgrounds such as mis-identification of jets as electrons, mis-measurement of $\not E_T$, muons from π/K decays, punch-through and cosmic rays have also been considered. The total background is estimated to be 0.87±0.22 events (0.22 events in ee channel and 0.65 events in the $e\mu$ channel).

Fig. 4 shows the 95% C.L. upper limit for the $t\bar{t}$ production cross section we obtain by combining the ee and $e\mu$ channel analyses, with one event observed.

Using the cross-sections from Berends et al [7] we obtain a lower limit for the top quark mass of 103 GeV/c^2 (99 GeV/c^2) with (without) background subtraction.

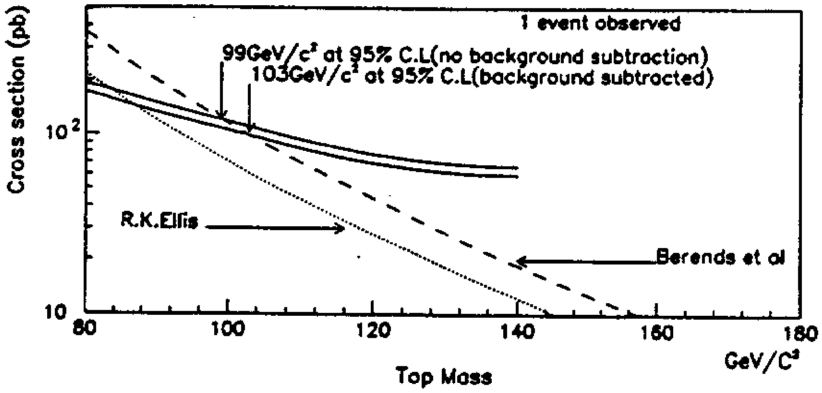

Fig. 4. 95% C.L. upper limit on the top production cross-section as a function of top mass. The dashed and dotted lines are theoretical predictions[6,7].

3.3. The e + jets channel

The event selection in this channel requires an isolated electron with $E_T > 20$ GeV and $\not{E}_T > 20$ GeV. The final efficiency for accepting $W \rightarrow e\nu$ events after these cuts is about 38%. To suppress QCD di-jet background, events with $d\phi(e-jet) > 165^\circ$ are rejected. If we then examine the number of events/pb^{-1} as a function of the number of jets for various jet E_T thresholds and compare to the prediction for W + multi-jet production (VECBOS Monte Carlo), we do not see any excess of events in the data for 3,4 or 5 jets. The jet multiplicity in e+jets events from data ($\int Ldt$ about 15pb^{-1}) for jet E_T thresholds of 15 GeV and 25 GeV are shown in Fig. 5, along with predictions from VECBOS (the bands show the uncertainty in the predictions for the two jet-E_T thresholds).

In order to improve the signal to background ratio in the e+jets channel, we are also investigating tagging of b quark jets by looking for muons in them.

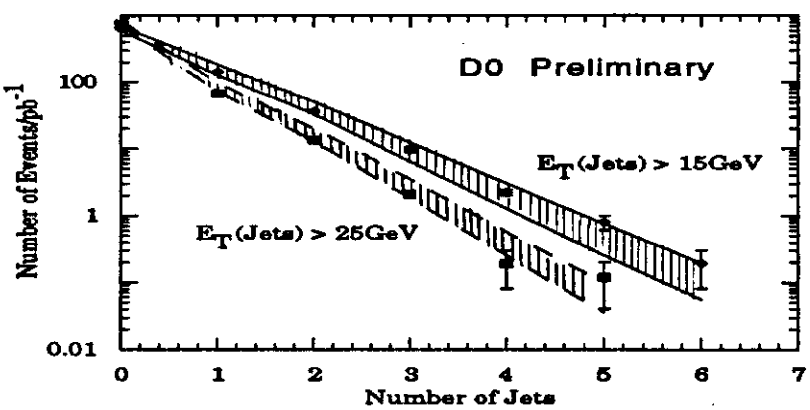

Fig. 5. Jet multiplicity in e+jets events for jet E_T thresholds of 15 GeV and 25 GeV. The bands are predictions for W+jets production from VECBOS.

4. New Particle Searches

Leptoquarks which carry both lepton quantum numbers and quark quantum numbers (fractional charge, baryon number and color) appear as elementary objects in unified theories with large groups (e.g., E(6) theories[10]) and as composite objects in composite and technicolor models[11]. In most models they are scalar particles. We have searched for first generation scalar leptoquarks that are pair-produced at the Tevatron, each one subsequently decaying into an electron or an electronic neutrino and a quark jet.

The integrated luminosity of the data used in this search is 7.5 pb^{-1}. We have searched in two channels[12]: a) 2 electrons + 2 jets and b) 1 electron + 2 jets + $\not{E}_T$. The electron identification cuts are very similar to those in the top quark search. The kinematic cuts applied were electron $E_T > 20$ GeV, jet $E_T > 20$ GeV and $\not{E}_T > 30$ GeV. In the di-electron plus 2 jets channel, events with di-electron invariant mass within 14 GeV/c^2 of the Z peak are rejected, while for electron + 2jets + $\not{E}_T$ channel $M_T(e\nu)$ is required to be greater than 95 GeV to reject QCD W + 2jets background. No events were found in either channels. For leptoquark mass of 100 GeV/c^2, the efficiency for the ee + 2 jets channel is determined to be 14 ± 1.8% and for $e\nu$ + 2 jets channel it is 6.2 ± 0.8%. By combining both channels, we can set a 95% C.L. lower limit on the leptoquark mass of 126 GeV/c^2 and 109 GeV/c^2 for 100% and 50% branching fraction into electron respectively.

Searches for evidence of various Supersymmetric particles are also being made at DØ . A grid search for squarks and gluinos[13] in the $(M_{\tilde q}, M_{\tilde g})$ plane has been made in events with multiple jets and high $\not{E}_T$. A preliminary analysis with a small data set rules out, at the 95% C.L., the existence of squarks and gluinos with $M_{\tilde q} = M_{\tilde g} = 100 GeV$. Search for $\tilde W, \tilde Z$ in 3 lepton channels where the expected search limits can be competitive with LEP II experiments are also underway. Searches for other new phenomena like compositeness (via large scalar E_T events), massive stable particles are also being pursued.

5. Conclusions

We have presented here preliminary results on the search for the top quark made using a partial data sample collected by the DØ collaboration during the 1992-93 run at the Fermilab collider. A candidate event is found in the $e\mu$ channel and by combined analysis of ee and $e\mu$ channels and using Berends et al[7] cross-section for top production, a lower limit of 103 GeV/c^2 (99 GeV/c^2) at 95% C.L. is obtained for the mass of the top quark, with (without) background subtraction. Search for the top quark in other channels are well underway. Search for first generation scalar leptoquarks yields a lower mass limit of 126 GeV/c^2 (109 GeV/c^2) for 100% (50%) branching fraction into electrons. Search for other new particles/phenomena are being pursued.

6. Acknowledgements

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