PROGRESS ON THE TOP SEARCH WITH CDF

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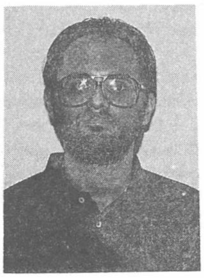

Abstract

At the time of this conference, a preliminary analysis of 10 pb^{-1} of data taken with the CDF detector during the 1992-1993 run at Fermilab had been performed. Various methods of searching for top quark decays are discussed, contrasting analysis of old CDF data and data taken with the upgraded detector. The analysis of events having two leptons (e or μ) in the final state yields a preliminary limit of $m_{top} > 108$ GeV (95% C.L.). Analyses of events having a single lepton in the final state, both using secondary vertex detection ability, and using the identification of secondary low-energy leptons, are described, as well as attempts to search for top quark decays in events containing no leptons.

1 Introduction

This is a report of preliminary results on the search for $p\bar{p} \rightarrow t\bar{t}X$ events in a sample obtained in the first half of the 1992-93 run of the Tevatron with CDF (Collider Detector at Fermilab). This sample comprises $\sim$ 10 pb^{-1} of $p\bar{p}$ data taken at $\sqrt{s} = 1.8$ TeV. Four search methods will be discussed: (1) search for events having two hard leptons (e or μ only), (2) search for events with a single hard lepton and a softer lepton, (3) search for events with a single hard lepton and evidence for a secondary vertex, and (4) searches using the kinematics of 6-jet events. Methods (2), (3), and (4) are presented as work in progress; a preliminary limit is presented using method (1).

The CDF detector has been described elsewhere [2]. The upgrade to the 1988-89 version of CDF relevant to these analyses is the addition of a silicon-strip microvertex detector (SVX) [3] which provides single track impact parameter resolution of $\sim 10\mu m$. Also added was extension of the muon detection coverage to pseudorapidities of $|\eta| < 1.0$ (was ~ 0.65); at the time of this writing, this new detector system was not used in the analyses presented here.

2 Dilepton search

The search method in the dilepton channel differs very little from the analysis done on the 1988-89 data; details of this analysis not given here may be found in Ref. [4].

2.1 Event selection

See the above reference for details of lepton identification; the basic requirement was that one of the leptons be well identified and within $|\eta| < 1.0$, while the identification requirements were loosened for the second lepton. The transverse momentum of both leptons (p_t^ℓ) was required to be > 20 GeV (was 15 for 1988-89 analysis). The azimuthal separation ($\Delta\phi$) between the leptons was required to be $< 160°$ for cosmic ray rejection. Z^0 decays were rejected in the ee and $\mu\mu$ cases by excluding pairs which had invariant mass M in the range $70 < M < 110$ GeV. Missing transverse energy ($\not{E}_t$) (after correcting for muons and jet energies) was required to be > 25 GeV (was 20). Lepton tracks were also required to be isolated from other tracks in the event (was a calorimeter isolation requirement). The combination of acceptance and efficiency of these criteria rises as the top mass increases: for $m_{top} = 120$ GeV, $A \times \epsilon \simeq 20\%$; for $m_{top} = 160$ GeV, $A \times \epsilon \simeq 30\%$. Including the 4/81 branching ratio to dileptons gives $A \times \epsilon \times B \sim 1 - 1.5\%$ over the range of interest.

Background predictions were in progress at the time of the conference; preliminary estimates were for ~ 3 events background in 10 pb^{-1} of data. The most significant sources considered were misidentified leptons, W-pair production, $Z^0 \rightarrow \ell^+\ell^-$, and $b\bar{b}$ events.

2.2 Dilepton data

In this analysis, data corresponding to $\mathcal{L} \sim 12$ pb^{-1} was scanned. Applying the lepton identification and p_t cuts to this data yielded 3 $e\mu$, 504 ee, and 249 $\mu\mu$ candidates. Of the $e\mu$ candidates, two events fail both the $\Delta\phi$ and $\not{E}_t$ criteria. The remaining event has $\not{E}_t \sim 140$ GeV, and $\Delta\phi \sim 20°$. Of the ee and $\mu\mu$ candidates, most are removed by the Z^0 mass requirement, and the rest are removed by the $\not{E}_t$ requirement. This leaves one event observed in all dilepton channels.

2.3 Limit on cross section

In order to set limits we compute

$$\sigma_{t\bar{t}} \leq \frac{N_{top}}{\mathcal{L}(A \times \epsilon \times \mathcal{B})}, \tag{1}$$

where N_{top} is the 95% C.L. upper limit on the number of events, $\mathcal{L} = 12$ pb^{-1} is the integrated luminosity, and the remaining term is acceptance times efficiency times branching ratio (discussed above). For these preliminary results, no background subtraction is performed in computing N_{top}, and a total systematic uncertainty of 15% is assumed (*c.f.* 13% in Ref. [4]). The results of Ref. [4] (*i.e.*, one event observed in $\mathcal{L} = 4.1$ pb^{-1}) are considered independent from the current data for the purpose of setting a limit.

The above information is summarized in Fig. 1, along with the old result of Ref. [4]. The predictions for the $t\bar{t}$ cross section are taken from Refs. [5, 6, 7], with the upper curve being the expected cross section (to order α_s^3) and the lower curve being a lower (theoretical) limit on the cross section. The intersection of this lower (more conservative) curve with the upper limit derived from the data gives the result: $m_{top} > 108$ GeV (95% C.L.).

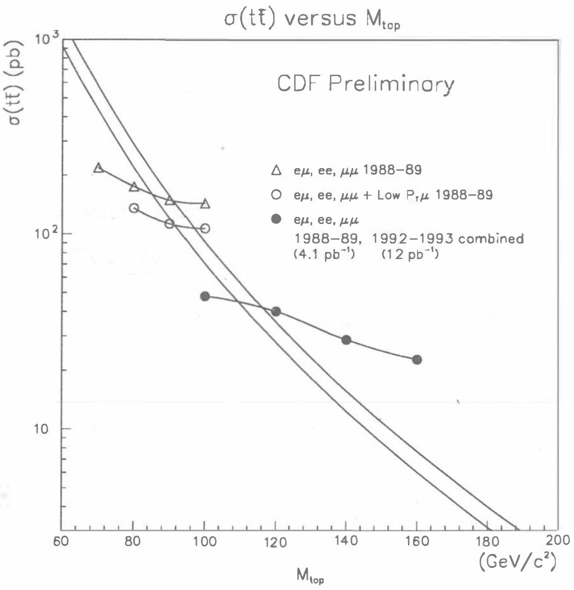

Figure 1: Total cross section for $t\bar{t}$ production versus top quark mass. Curves with symbols are the 95% C.L. upper limits from Ref. [4] and this analysis; smooth curves are theoretical predictions.

3 Single lepton searches (b-tagging)

Two general classes of search methods were used in events having a single hard lepton to find evidence for bottom quark jets: a search for an additional soft lepton (analysis similar to that in Ref. [4]), and a search for secondary vertices in jets. Event selection for both methods is similar, and will be described below.

3.1 Event selection

As in the dilepton events, selection began with general e and μ identification (see Ref. [4] for details). Also required was $p_t^\ell > 20$ GeV, and $\not{E}_t > 20$ GeV. A calorimeter isolation requirement was imposed on candidate tracks, and Z^0 rejection was performed by looking at the candidate track and other high-energy tracks in the event. The number of jets in each event was counted in different ways in the two analyses, and this will be described below.

3.2 Soft lepton selection

In order to be efficient for soft leptons down to 2 GeV, the lepton identification requirements were greatly loosened for this analysis. For muons, a track in the Central Tracking Chamber (CTC) was required to match with hits in at least three of the four layers in the central muon chamber (fake rate of $\simeq 0.75\%$ per track). For electrons, good profiles in the pre-shower and shower-max counters were required, with loose E/p and E_{HAD}/E_{EM} requirements (fake rate of $\simeq 0.5\%$ per track). Efficiency on Monte Carlo top events was seen to be around 20%, rising as the top mass increases.

3.3 Hard + soft lepton data

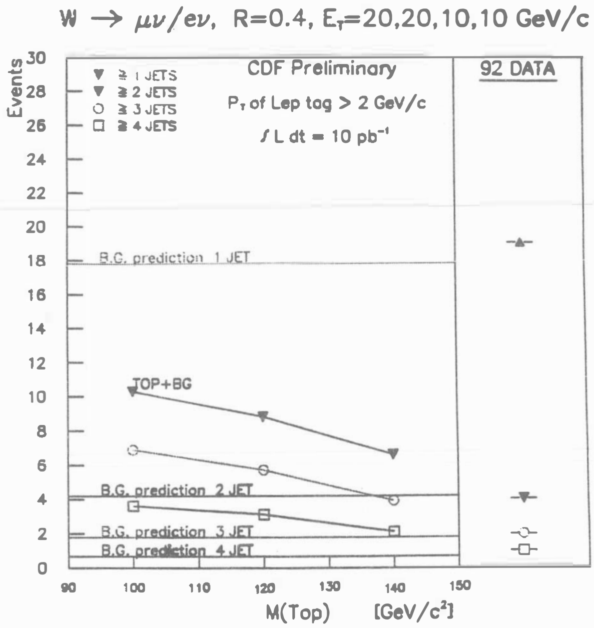

Figure 2: Left-hand side: Number of events expected versus top quark mass. Lines going across the page are the predicted background; lines falling across the page are Monte Carlo top plus background. Right-hand side: Number of events observed in 10 pb^{-1}.

This analysis looked at $\mathcal{L} \sim 10$ pb^{-1} of data. The right-hand side of Fig. 2 shows the number of events seen in the data having one, two, three, and four jets. Jets had to have $|eta| < 2.4$; the first two jets were required to have $E_t > 20$ GeV, while any third or fourth jet was required to have $E_T > 10$ GeV. The left-hand side of Fig. 2 shows the predicted background (using the fake rates per track noted above) and Monte Carlo top signal plus background. No excess over background is obvious; this analysis has not yet been used to set top mass limits.

3.4 Secondary vertex identification

A number of methods have been tried in order to use the information from the new SVX detector. The most promising method at the time of this conference was explicit reconstruction of secondary vertices using tracks with $p_t > 1$ GeV which were significantly displaced from the primary vertex. The efficiency of this method was determined from Monte Carlo and from inclusive lepton data (known to be enriched with heavy flavor content); the methods agreed quite well, both giving a tag rate of about

15% per jet. The false tagging rate was determined by looking at minimum bias data, and was about 0.5 – 1.0% per jet, rising slowly with the number of tracks in the jet.

3.5 Lepton + secondary vertex data

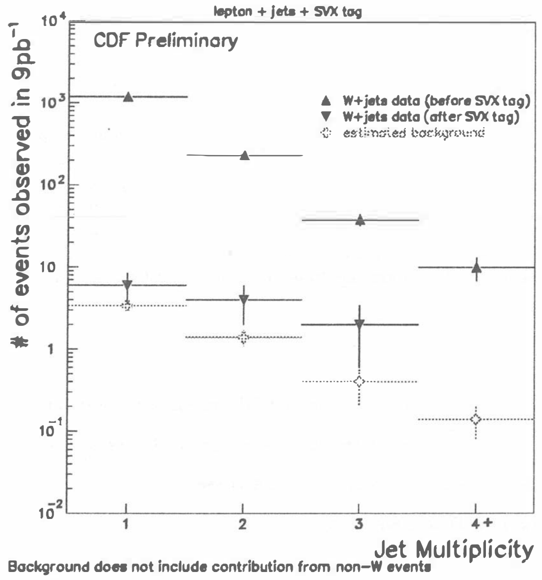

Figure 3: Number of events versus number of jets (jet counting described in text). Top set of points is number of events before the secondary vertex tag is applied; the middle set of points is the number of events after the tag is applied. The crosses are an estimate of the background due to mistagged jets.

This analysis scanned $\mathcal{L} \sim 9$ pb^{-1} of data, and the results are summarized in Fig. 3. In this plot, jets must have $E_t > 10$ GeV and be within $|\eta| < 2.0$. To determine the false-tagging background in this data, the false rate (obtained form minimum bias data) was determined as a function of track multiplicity and jet E_t; this rate was then applied to each jet in the hard lepton sample before the SVX tag was applied. Work continues in understanding backgrounds due to physical processes (*e.g.*, $Wb\bar{b}$ final states, $Z^0 \rightarrow \tau^+\tau^-$, *etc.*). Expected signal for three or more jets is about 2 events for $m_{top} = 120$ GeV, and about 0.8 events for $m_{top} = 160$ GeV in 9 pb^{-1}; with refinements the signal-to-background ratio should improve, and may be comparable with the dilepton analysis.

4 Six-jet search

Attempts are being made to extract a signal from QCD background in samples of six-jet events. One attempt discussed at this conference was a method which looks for secondary vertices. This method began with a "loose" set of jet cuts (requiring $\sum E_t > 150$ GeV and six jets of $E_t > 10$ GeV) which gave a signal to background ratio of $\sim 1/400$. The jet cuts were tightened (a $\sum E_t$ cut that scales with the number of jets, and requiring that the average $|\eta|$ of all the jets be < 1) to provide signal to background of $\sim 1/50$. Applying secondary-vertex finding similar to the method mentioned in the previous section yielded a signal to background ratio of $\sim 1/3$. Work continues to see if pursuit of this top decay mode will prove useful.

5 Summary

Progress on searching for the top quark at CDF during the first half of the present run has been presented. The result of the most mature analysis is that $m_{top} > 108$ GeV at the 95% confidence level. Work is in progress in understanding backgrounds and systematic errors in the single-lepton event searches. In the no-lepton events, signal to background ratios are still daunting, but work continues.

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References

[1] See D. Benjamin, these proceedings for a list of CDF collaborating institutions.

[2] See F. Abe *et al.*, Nucl. Instr. and Meth. A271 (1988) 387 and references therein.

[3] D. Amidei *et al.*, Nucl. Instr. and Meth. A289 (1990) 388.

[4] F. Abe *et al.*, Phys. Rev. D45 (1992) 3921.

[5] P. Nason, S. Dawson, and R.K. Ellis, Nucl. Phys. B303 (1988) 607.

[6] G. Altarelli *et al.*, Nucl. Phys. B308 (1988) 724.

[7] R.K. Ellis, Phys. Lett. B259 (1991) 492.