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in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV with the DØ Detector**

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**A SEARCH FOR $t\bar{t} \rightarrow lepton + \cancel{E}_T + jets$ SIGNATURE IN $p\bar{p}$ COLLISIONS
AT $\sqrt{s} = 1.8$ TeV WITH THE DØ DETECTOR**

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ABSTRACT

We report the results from a search for $t\bar{t}$ production in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV with the DØ detector at Fermilab in the final states consisting of one isolated high p_T lepton (e or μ), multiple jets and a substantial missing transverse energy (\cancel{E}_T), excluding the events that have μ -tagged jets. Two independent analysis approaches lead us to similar estimates for the cross-section. We see no conclusive evidence for top production in the 13.5 pb^{-1} of data taken during the 1992-1993 run of the Tevatron.

1. Introduction

According to the minimal Standard Model, a t quark should decay almost exclusively into a b quark and a real W boson. Our search focuses on the monoleptonic channels where one of the two W 's decays into $l\nu_l$ (" l " stands for an electron or a muon) while the other decays into $q_1\bar{q}_2$. The high mass of top drives the expectation values of the transverse momenta (p_T) of the final state partons pretty high, typically to $\frac{m_W}{2}$. In the detector, we expect to see an isolated high- p_T e or μ , a large \cancel{E}_T arising from the ν and about 4 high- E_T jets: two from the W decaying hadronically and the two b jets. The number of jets reconstructed is often larger due to initial or final state radiation and sometimes smaller due to jet merging. The total branching ratio of $t\bar{t}$ into such a final state is approximately 0.30. However, in this analysis, we reject any event that has a μ -tagged jet in order to avoid a possible overlap with another analysis that deals specifically with such events only. This results in a reduction in the effective branching ratio within the scope of our analysis to about 0.24.

Having established a new lower limit of 131 GeV (95% CL) from a previous analysis [1], our interest has since moved to the region above it. A vast improvement in our understanding of the detector performance and the background processes, combined with the shifting of the region of interest, has resulted in a significant modification in our analysis approaches. Here we present the new techniques and the results.

2. Signal and Backgrounds

Our signal can be viewed as a cascade production of $W + jets$ through high-mass resonance states. The dominant physical source of background for either channel

(e and μ) is the continuum QCD production of $W + jets$. We shall refer to this as the “ W background”. The complementary set, i.e. the “non- W background” is due to measurement fluctuations.

To model the kinematics of our signal, we use the ISAJET Monte Carlo [2]. The cross-sections necessary for the calculation of limits are taken from the NNLO calculations by Laenen *et al* [3]. For the calculation of backgrounds, we rely entirely on our own data except for one of our two analysis approaches where we employ the VECBOS parton generator [4] with ISAJET fragmentation to model the W -background. DØ GEANT is used for Monte Carlo detector simulation.

3. Event selection

We use very loose sets of requirements for triggering on the events of our interest online. The following offline event selection criteria help us improve the S/B ratio:

- $E_T(j) > E_T^{min}(j) = 15$ GeV. The leptons from W decay are expected to be fairly energetic. A cut $E_T(l) > E_T^{min}(l)$ helps reduce the non- W background. We use $E_T^{min}(e) = 20$ GeV and $p_T^{min}(\mu) = 15$ GeV.
- $|\eta(i)| < |\eta(i)|^{max}$ where “ i ” stands for e, μ, j . We use $|\eta(e)|^{max} = 2.0$, $|\eta(\mu)|^{max} = 1.7$ and $|\eta(j)|^{max} = 2.0$.
- The non- W backgrounds acquire lepton-id and \cancel{E}_T by statistical fluctuations. Therefore, we impose very tight lepton quality cuts and require $\cancel{E}_T > \cancel{E}_T^{min}$. For $e + jets$, $\cancel{E}_T^{min} = 25$ GeV; for $\mu + jets$, $\cancel{E}_T^{min} = 20$ GeV. For $\mu + jets$, we further require $\cancel{E}_{Tcal}^{min} = 20$ GeV where \cancel{E}_{Tcal}^{min} is the \cancel{E}_T measured by the calorimeter only.
- From a global point of view, the jets tend to be more isotropically distributed in the signal than in the backgrounds. In one of our two analysis approaches, we exploit this feature by requiring a minimum “spherical shape” of the events.

4. Analysis

We take two independent approaches to analyze our data:

A. Jet multiplicity analysis

In this approach, we assume the well-known exponential scaling law [5] to be valid for all non-resonant QCD multijet processes i.e.

$$\frac{\sigma(X + nj)}{\sigma(X + (n + 1)j)} = \rho \quad (1)$$

where ρ , a constant determined by α_s and $E_T^{min}(j)$, is independent of n (at least for $n < \sim 6$). Knowing the contribution of our signal to different values of n , we can make a fit to the observed data to estimate the amount of signal in it. Henceforth, whenever we talk about the number of jets, “ n_m ” will stand for the inclusive count, meaning “the number of events with m or more jets”. Figure 1a shows the multiplicity of jets in the W candidate events after subtracting the non- W backgrounds shown in Figure 1b (not to scale, see Figure caption) for two different values of $E_T^{min}(j)$. The exponential fits are made through the points n_2 and n_3 only .

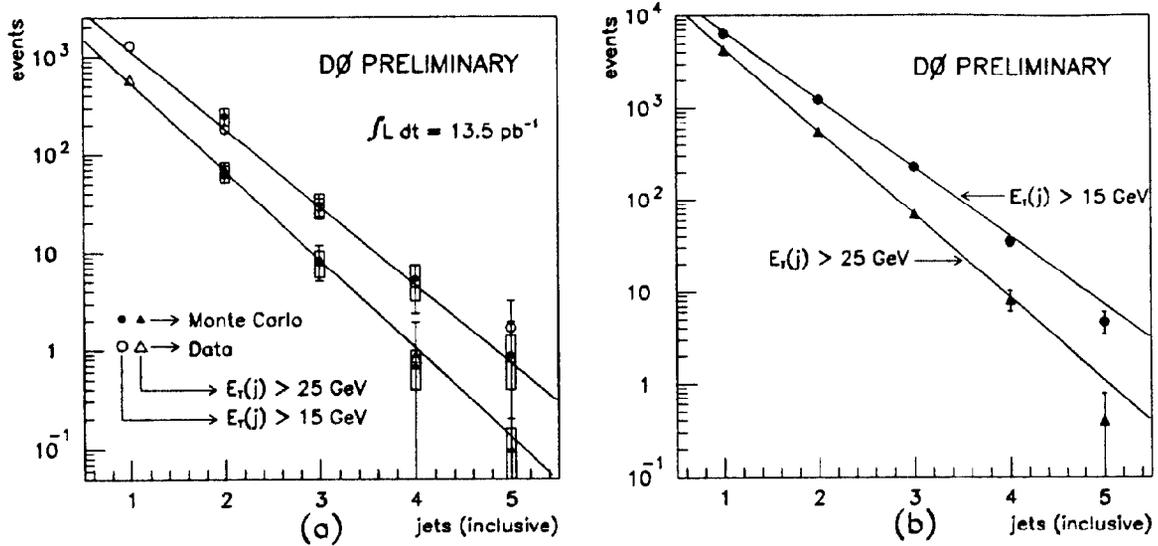


Fig. 1. Jet multiplicity distribution in the electron channel (a) W events: $DØ$ data and Monte Carlo (VECBOS); (b) non- W background corresponding to ~ 67 times our data sample.

m	n_m			
	data	non- W bkg.	W bkg.	$t\bar{t}$
1	1686	$142. \pm 20.$	$1656. \pm 96.$	5.7 ± 10.1
2	335	50.6 ± 7.1	278.8 ± 16.7	5.6 ± 9.9
3	57	10.3 ± 1.5	42.2 ± 7.1	4.5 ± 8.2
4	12	2.4 ± 0.4	6.6 ± 3.8	3.0 ± 4.6

Table 1. The inclusive jet multiplicities in $DØ$ data, estimated non- W background and the results of fitting for the W background and signal ($t\bar{t}$), e and μ channels combined

Let $n_{m\bar{t}}$ stand for the contribution of $t\bar{t}$ events to the n_m sample in our data. Then, if the background processes honor the scaling law, we have

$$n_m - n_{m\bar{t}} = \frac{(n_{m-1} - a_{(m-1),m} \cdot n_{m\bar{t}})^2}{n_{m-2} - a_{(m-2),m} \cdot n_{m\bar{t}}} \quad (2)$$

where $a_{k,l} \equiv n_{kl}/n_{ll}$ are ratios that we calculate using Monte Carlo. For $m = 4$, we can safely ignore the term containing $n_{m\bar{t}}^2$ whereby eq (3) yields the simple solution for $n_{4\bar{t}}$:

$$n_{4\bar{t}} = \frac{n_2 \cdot n_4 - n_3^2}{n_2 + a_{2,4} \cdot n_4 - 2a_{3,4} \cdot n_3} \quad (3)$$

Table 1 summarizes the results thus obtained. We find 12 events where we expect 9.0 ± 3.8 from background processes. The 3.0 ± 4.6 signal events translate to a cross-section obtained solely from the monoleptonic channels:

$$\sigma_{\bar{t}\bar{t}} = 6.4 \pm 9.8(\text{stat.}) \pm 4.0(\text{sys.}) \quad \text{pb} \quad (4)$$

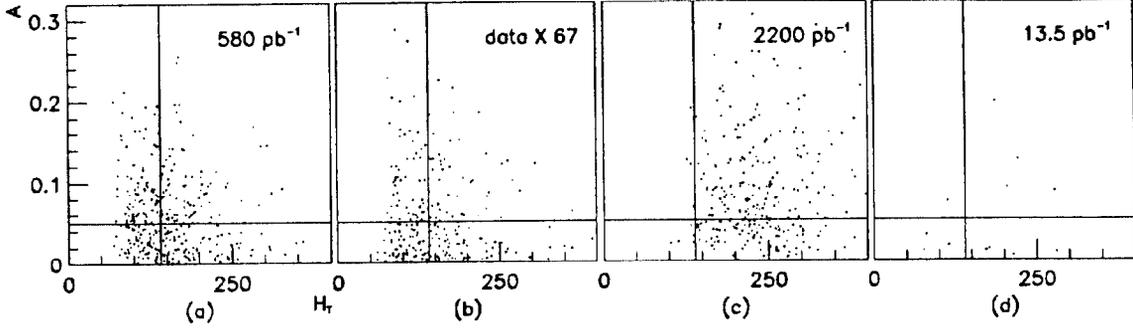


Fig. 2. A vs. H_T in $e/\mu + \cancel{E}_T + \geq 4jets$ events: (a) W background (VECBOS); (b) non- W background; (c) $t\bar{t}$ (ISAJET, $m_{top} = 180$ GeV); (d) $D\bar{0}$ data.

Quadrants \rightarrow	$A > A_0$	$A > A_0$	$A < A_0$	$A < A_0$
	$H_T > H_{T0}$	$H_T < H_{T0}$	$H_T < H_{T0}$	$H_T > H_{T0}$
Fractions \rightarrow	ϵ^1	ϵ^2	ϵ^3	ϵ^4
W bkg (VECBOS)	0.21 ± 0.03	0.27 ± 0.03	0.21 ± 0.03	0.31 ± 0.03
Non- W bkg	0.19 ± 0.04	0.25 ± 0.05	0.28 ± 0.05	0.28 ± 0.05
$t\bar{t}$ ($m_t = 180$ GeV)	0.60 ± 0.05	0.02 ± 0.01	0.02 ± 0.01	0.36 ± 0.04
Number of events \rightarrow	N^1	N^2	N^3	N^4
Data	4	1	3	4
Best fit	4.1	2.4	2.0	3.5
No $t\bar{t}$	2.4	3.2	2.9	3.5

Table 2. The split of backgrounds, signal ($t\bar{t}$), $D\bar{0}$ data and the results of fitting among the four quadrants of the A vs. H_T plane. The origin is at $A_0 = 0.05$, $H_{T0} = 140$ GeV

B. Event shape analysis

Here we examine the global characteristics such as the shape and the size of events which have at least 4 jets. To this end, we use a single variable called “Aplanarity” (A) [6], calculated using only the jets in an event, to quantify its shape. The higher the minimum one requires of A , which is bounded in the range $0 \leq A \leq 0.5$, the more spherical an event has to be in order to meet that requirement. We use H_T , defined as the scalar sum of the E_T ’s of all the jets in an event, to quantify its global size. Figure 2 shows the distribution of the backgrounds, signal and our data in the A vs. H_T plane. Table 2 shows the splits when we divide the plane into four quadrants with the origin at $A = 0.05$, $H_T = 140$ GeV. The origin was chosen so as to split the backgrounds more or less evenly among the four quadrants. This minimizes the statistical error in the procedure when, using Poisson distributions, we perform a maximum likelihood fit to the number of events observed in the four quadrants with respect to f , the unknown fraction of $t\bar{t}$ events in our sample. The results from the best fit, shown in the Table, corresponds to

$$f = 0.32 \pm 0.30 \quad (5)$$

This gives

$$N_{t\bar{t}} = 3.8 \pm 3.6(stat) \pm 1.5(sys) \quad (6)$$

which translates into

$$\sigma_{t\bar{t}} = 8.1 \pm 7.6(stat.) \pm 3.8(sys.) \quad pb \quad (7)$$

The last row in the Table shows the split expected if we force $f = 0$.

Finally, we apply the cuts $A > 0.05$, $H_T > 140$ GeV on the backgrounds. The two methods, A and B give independent estimates for the number of events to be expected from the background processes in the first quadrant of the A vs H_T plane which turn out to be very close:

$$N_B^A = \epsilon_W^1 \cdot N_W + \epsilon_{non-W}^1 \cdot N_{non-W} = 1.8 \pm 0.8 \pm 0.4 \quad (8)$$

and

$$N_B^B = \epsilon_B^1 \cdot (1 - f) \cdot N = 1.7 \pm 0.8 \pm 0.5 \quad (9)$$

Subtracting this background from the observed number of events (i.e. 4), we get yet another estimate for the cross-section:

$$\sigma_{t\bar{t}} = 7.5 \pm 7.3(stat.) \pm 3.3(sys.) \quad pb \quad (10)$$

This number is valid in the range $160 \text{ GeV} \leq m_{top} \leq 180 \text{ GeV}$. For $m_{top} = 140$ GeV, it would be $\sim 25\%$ higher.

5. Conclusions

Two independent ways of analyzing the *lepton + jets (sans μ -tag)* data collected from the first collider run of DØ in 1992-93 result in similar estimates for the $t\bar{t}$ production cross-section. Owing to the large branching ratio, the monoleptonic channels play a key role in the overall estimation of the cross-section that combines all the available channels. At this point, the uncertainties are dominated by statistical limitation. With the systematic uncertainties under control, we hope to be able to make a stronger statement based on a ~ 5 times larger set of data that is expected by the end of the ongoing run.

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