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Search for Production of Single Top Quarks in the Electron+Jets Channel at DØ

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We present a search for the electroweak production of single top quarks using 156-169 pb^{-1} of electron+jets data collected by the DØ detector, at $\sqrt{s} = 1.96$ TeV, at the Tevatron proton-antiproton collider at Fermilab. In the absence of any significant evidence for single top production we set upper limits on the cross section at 95% C.L., of 14 pb for s-channel, 20 pb for t-channel, and 18 pb for the combined $s + t$ channel.

1. Introduction

The top quark was discovered at the Tevatron, Fermilab, in 1995 [1] in pair production mode via strong interactions. The standard model also predicts the production of single top quarks via the electroweak exchange of a W boson. The dominant Feynman diagrams at the Tevatron for single top production are shown in Fig. 1. These represent the s-channel and the t-channel processes for which the total cross sections at the next to leading order are $0.88^{+0.07}_{-0.06}$ pb [2] and $1.98^{+0.23}_{-0.18}$ pb [3], respectively, at $\sqrt{s} = 1.96$ TeV, and for a top mass, $m_t = 175$ GeV.

Using Run I (1992-1996) Tevatron data at $\sqrt{s} = 1.8$ TeV, DØ set upper limits of 17 pb for the s-channel and 22 pb for the t-channel at 95% C.L using about 90 pb^{-1} of data. In Run II, a discovery of the electroweak top quark production is expected owing to significantly higher luminosity and much better b-quark identification. A measurement of the single top cross section would be useful in measuring directly the CKM matrix element, V_{tb}, in observing the polarization of the top quark, and in probing physics beyond the standard model.

We present here a first search for single top production in the Run II data at $\sqrt{s} = 1.96$ TeV, collected between August 2002 and September 2003 with the

Fig. 1. The dominant Feynman diagrams for s-channel (left) and t-channel (right) single top quark production.

upgraded DØ detector [4]. The analysis is done separately in the electron and the muon decay channels. We report here the results for the electron channel using 156-169 pb^{-1} of the electron+jets data depending on the b-tagging algorithm used.

2. Event Signature and Backgrounds

The final state signature of a single top quark event is characterized by the decay of the top quark (t$\rightarrow Wb$): one centrally produced high-p_T lepton, large missing transverse energy ($\not\!\!E_T$) from the neutrino, and one high-p_T central b-quark jet from the top decay. In addition there is an associated b-quark jet, and a light quark (t-channel). The dominant background is from W+jets and Z+jets events, in particular $Wb\bar{b}$ production. Additional backgrounds are from $t\bar{t}$ events both from lepton+jets and dilepton final states in which a jet or a lepton is not identified in the detector, and from QCD multi-jet events where one of the jets is mis-identified as a lepton. The backgrounds from multi-jet and W/Z+jets events are modeled using data; those from $t\bar{t}$ and the single top signal are estimated using Monte Carlo.

3. Event Selection and Yields

We apply very loose event selection in order to keep a high acceptance for single top events while reducing the background from multi-jet events. The event is required to contain exactly one isolated electron with $p_T > 15$ GeV and the pseudorapidity, $|\eta| < 1.1$, and between 2 and 4 jets with $p_T > 15$ GeV and $|\eta| < 3.4$. The leading jet must have $p_T > 25$ GeV and $|\eta| < 2.5$. At least one of the jets is required to contain a b-quark. We use three different tagging algorithms to identify the b-quark within a jet: the Soft Lepton Tag (SLT) and the tracking-based lifetime taggers – the Secondary Vertex Tag (SVT) and the Jet Lifetime Probability (JLIP) tag. To allow for a later combination of the SLT and lifetime tagger results, we exclude SLT events from the lifetime tagger analyses. Finally, we require the scalar sum of the transverse energies of the electron, two leading jets and missing energy ($H_T^{e\nu jj}$) to be greater than 150 GeV.

Figure 2 shows the jet multiplicity in exclusive multiplicity bins, and the transverse mass of the W boson. The observed number of events agrees well with the sum of the backgrounds within uncertainties. The dominant sources of uncertainties are from jet energy scale, and the modeling of the triggers and tagging, and vary between 20-25% for the different backgrounds and the signal.

4. Results

Since the observed number of events is consistent with the expectation from backgrounds, we set upper limits at 95% C.L. on the single top production cross section using Bayesian statistics [5]. A flat prior is used for the signal cross section, and a multivariate Gaussian prior for the signal acceptance times the integrated luminosity, and the background yields. A covariance matrix is used to describe the correlated uncertainties on these quantities. Table 1 shows the observed and the expected limits for the different taggers.

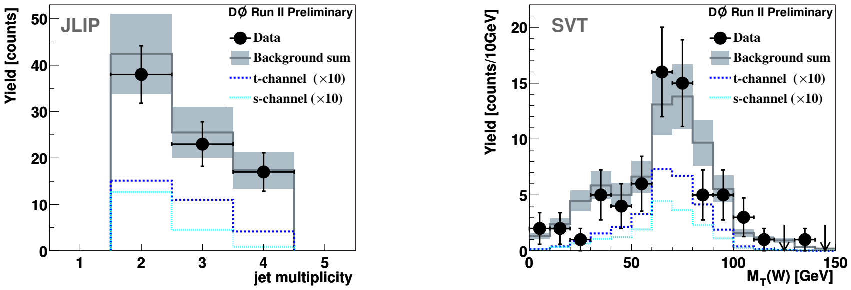

Fig. 2. Distributions of the number of good jets, and the transverse mass of the W boson for the electron channel, using different taggers.

Table 1. The 95% C.L. observed/expected upper limits (in pb) on the single top production cross sections in the electron decay channel.

Tagger	s-channel	t-channel	$s+t$ channel
SVT	14 / 18	20 / 24	18 / 21
JLIP	16 /20	22 / 27	20 / 24
SLT	53 / 26	81 / 42	72 / 35

5. Conclusions

We have shown preliminary results from the search for single top quark production using 156-169 pb^{-1} of DØ Run II data in the electron channel. These are 14 pb for s-channel, 20 pb for t-channel, and 18 pb for the combined $s+t$ channel, at 95% C.L., using the SVT tagger. For results in the muon channel and from the combined electron and muon analyses, see Ref. 6.

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