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MEASUREMENT OF THE $t\bar{t}$ PRODUCTION CROSS SECTION IN THE DILEPTON CHANNEL AT CDF

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We report a measurement of the $t\bar{t}$ production cross section using dilepton events with jets and missing transverse energy in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. Using 197 pb^{-1} of data recorded by the upgraded Collider Detector at Fermilab (CDF II), we use two complementary techniques to select candidate events. The combined result yields a $t\bar{t}$ production cross section of $7.0^{+2.4}_{-2.1}(\mathrm{stat})^{+1.6}_{-1.1}(\mathrm{syst})\pm 0.4(\mathrm{luminosity})$ pb which is consistent with the Standard Model.

Keywords: top quark; dilepton; cross-section.

1. Introduction

Since the discovery of the top quark [1], experimental attention has turned to the examination of its production and decay properties. Within the context of the Standard Model, theoretical calculations constrain the top quark production cross section with an uncertainty of less than 15% [2]. Furthermore, in the framework of the Standard Model, the top quark is expected to decay to a W boson and b quark nearly 100% of the time. The W boson subsequently decays to either a pair of quarks or a lepton-neutrino pair. Measuring the rate of the reaction $p\bar{p} \rightarrow t\bar{t} \rightarrow b\ell^+\nu_\ell\bar{b}\ell'^-\bar{\nu}_{\ell'}$ tests both the production and decay mechanisms of the top quark. A significant deviation from the Standard Model prediction would indicate either a novel production mechanism, *e.g.* the production and decay of a heavy resonance into $t\bar{t}$ pairs, or a novel decay mechanism, *e.g.* a decay into supersymmetric particles.

We describe a measurement of the $t\bar{t}$ cross section in the dilepton channel using data from Run II of the Tevatron taken with the upgraded Collider Detector at Fermilab (CDF II). The data sample corresponds to an integrated luminosity of 197 ± 12 pb^{-1}. The CDF II detector is described elsewhere [3].

2. Event Selection

We perform two complementary analyses. One, inspired by the technique used by CDF in Run I, requires that both leptons be specifically identified as either electrons or muons ("DIL" analysis). The other technique allows one of the leptons to be identified only as a high-p_T, isolated track ("LTRK" analysis), thereby significantly increasing the lepton detection efficiency with some increase in expected background events. The $b\ell^+\nu_\ell\bar{b}\ell'^-\bar{\nu}_{\ell'}$ events under study produce two high-p_T leptons, missing transverse energy ($\not\!\!E_T$) from the undetected neutrinos, and two jets from the hadronization of the b quarks. Additional jets are often produced by initial-state and final-state radiation. The dominant backgrounds to dilepton $t\bar{t}$ events are Drell-Yan ($q\bar{q} \to Z/\gamma^\star \to \ell^+\ell^-$) production, "fake" leptons in $W \to \ell\nu$ + jet events where a jet is falsely reconstructed as a lepton candidate, and diboson (WW, WZ, and ZZ) production.

As a baseline selection, both analyses require two oppositely charged lepton candidates with $E_T > 20$ GeV, $\not\!\!E_T > 25$ GeV and at least two jets. The DIL (LTRK) analysis counts jets with $E_T > 15$ (20) GeV detected in $|\eta| < 2.5$ (2.0). Further cuts are applied in order to reduce events with false $\not\!\!E_T$ and to veto on the Z region. The DIL analysis enhances its signal sensitivity by requiring that H_T, the scalar sum of the lepton p_T, jet E_T, and $\not\!\!E_T$, be greater than 200 GeV. A detailed description of the analyses is found elsewhere [4].

3. Results

The predicted and observed numbers of candidate events versus jet multiplicity is shown in Table 1. Good agreement is seen for the background-dominated zero and one jet events, establishing confidence in the background estimates. We measure the $t\bar{t}$ production cross section in the dilepton channel using events with two or more jets.

The products $a\times\epsilon\times BR(t\bar{t} \to b\ell^+\nu_\ell\bar{b}\ell'^-\bar{\nu}_{\ell'})$ are (0.62±0.09)% and (0.88±0.12)%, respectively. Hence, the measured cross sections, $(N_{\rm obs} - N_{\rm bkg})/(a \times \epsilon \times BR(t\bar{t} \to b\ell^+\nu_\ell\bar{b}\ell'^-\bar{\nu}_{\ell'})\times\int\mathcal{L}dt)$, are $8.4^{+3.2}_{-2.7}{}^{+1.5}_{-1.1}\pm0.5$ pb for the DIL and $7.0^{+2.7}_{-2.3}{}^{+1.5}_{-1.3}\pm0.4$ pb for the LTRK analysis, where the first two uncertainties are the statistical and systematic uncertainties, respectively, and the third arises from the luminosity uncertainty. We combine these results by dividing the analyses' expected signal and background into three disjoint regions (DIL-only, LTRK-only, and the overlap). Eleven events are shared between DIL and LTRK. Using the combined $a \times \epsilon \times BR(t\bar{t} \to b\ell^+\nu_\ell\bar{b}\ell'^-\bar{\nu}_{\ell'})$ of 1.03% and accounting for common systematic uncertainties, a joint Poisson likelihood is maximized yielding

$$\sigma_{t\bar{t}} = 7.0^{+2.4}_{-2.1}(\text{stat.})^{+1.6}_{-1.1}(\text{syst.}) \pm 0.4(\text{lum.})\text{ pb}$$

We looked at key kinematical distributions of the signal sample and find good agreement with the Standard Model, assuming a top mass of 175 GeV/c^2. For example, using events from the LTRK analysis, Figure 1 shows a distribution of the variable H_T, which is a good discriminant for top quark production over other processes. The $\not\!\!E_T$ distribution is also shown for the DIL analysis along with the lepton flavor composition of the candidate events.

Table 1. Expected physics backgrounds, fakes, and $t\bar{t}$ signal (assuming m_{top} = 175 GeV/c^2, σ=6.7 pb) for the two analyses. Luminosity uncertainties are not included.

	LTRK			DIL		
	$N_{\text{jet}} = 0$	$N_{\text{jet}} = 1$	$N_{\text{jet}} \geq 2$	$N_{\text{jet}} = 0$	$N_{\text{jet}} = 1$	$N_{\text{jet}} \geq 2$ ($H_T > 200$ GeV)
Diboson	21.8 ± 5.2	6.3 ± 1.5	1.2 ± 0.3	11.4 ± 3.3	3.2 ± 0.9	0.7 ± 0.2
Drell-Yan	26.5 ± 9.8	16.4 ± 6.0	4.2 ± 1.6	4.4 ± 1.9	2.9 ± 1.1	0.9 ± 0.5
Fakes	16.5 ± 2.4	5.0 ± 1.0	1.5 ± 0.5	3.0 ± 1.2	2.4 ± 1.0	1.1 ± 0.5
Total Bkgd	64.8 ± 11.3	27.7 ± 6.3	6.9 ± 1.7	18.8 ± 4.0	8.5 ± 1.8	2.7 ± 0.7
Expected $t\bar{t}$	0.3 ± 0.2	3.4 ± 0.6	11.5 ± 1.5	0.1 ± 0.0	1.3 ± 0.2	8.2 ± 1.1
Total	65.1 ± 11.3	31.1 ± 6.3	18.4 ± 2.3	18.9 ± 4.0	9.8 ± 1.9	10.9 ± 1.4
Observed	73	26	19	16	9	13

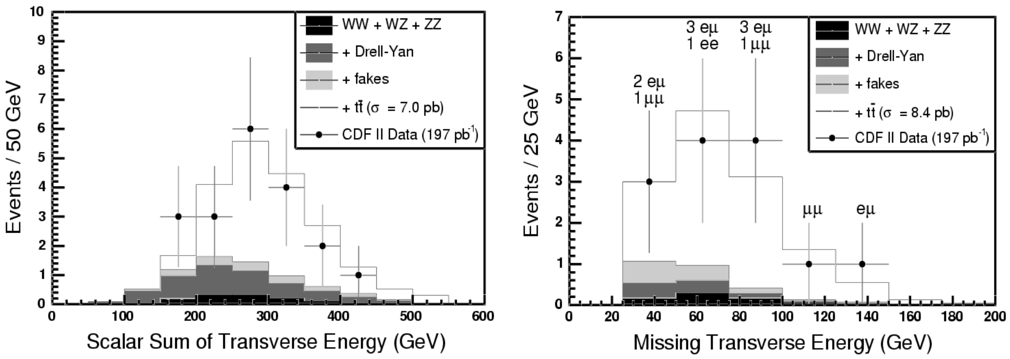

Fig. 1. Distribution of H_T (defined in text) for events from the LTRK analysis with at least two jets (left), and missing transverse energy for events from the DIL analysis with $H_T > 200$ GeV and at least two jets (right). The lepton flavor composition is also shown.

4. Conclusion

We observe good agreement between the data and the Standard Model prediction in event yield and key kinematic distributions for $t\bar{t}$ production in the dilepton channel. The measured cross section agrees well with the NLO Standard Model calculation.

References

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