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MEASUREMENT OF THE TOP QUARK PAIR PRODUCTION CROSS SECTION IN LEPTON+JETS FINAL STATES AT DØ USING A MULTIVARIATE TECHNIQUE

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A measurement of the $t\bar{t}$ production cross-section at $\sqrt{s} = 1.96$ TeV with the DØ detector at the Fermilab Tevatron, based on the application of a multivariate topological method is presented. The integrated luminosity corresponds to 143.9 pb^{-1} in the μ+jets and 141.2 pb^{-1} in the e+jets channel. The preliminary cross-section is measured to be $\sigma_{p\bar{p}\to t\bar{t}+X} = 7.2\,^{+2.6}_{-2.4}\,(\mathrm{stat})\,^{+1.6}_{-1.7}\,(\mathrm{syst})\,\pm 0.5\,(\mathrm{lumi})\,\mathrm{pb}$.

Keywords: Top quark; multivariate; cross section; DØ.

1. Introduction

In $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV at the Tevatron the top quark is expected to be dominantly produced via the strong interaction ($q\bar{q}$ annihilation (85%) and gluon fusion (15%)) in the Standard Model (SM).[1] The top quark decays subsequently to a W boson and a b quark nearly 100% of the time. The final states which are visible in the detector are fully determined by the W boson decay modes. In this analysis the combination of one W decaying to leptons and one to hadrons is considered, which signature is therefore one isolated, high p_T lepton, missing transverse energy ($\not\!\!E_T$) from a neutrino, and associated jets.

2. The Data Sample

The data sample used consists of data taken with the upgraded DØ detector in Tevatron's RunII during the period between April 2002 and September 2003. The data are collected with a lepton+jet trigger that requires a high transverse momentum lepton and a jet. The total integrated luminosity is 143.9 pb^{-1} for the μ+jets and 141.2 pb^{-1} for the e+jets channel. The total uncertainty on the integrated luminosity is estimated to be 6.5%.[2]

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3. The $t\bar{t}$ Event Selection

$t\bar{t}$ events are selected by reconstructing the decay products of the leptonically decaying W boson, an isolated lepton with high transverse momentum and a neutrino as $\not{E}_T$, and by requiring the presence of four or more jets in the event. The total acceptance $\times$ efficiency for $t\bar{t}$ events (ε) is measured in a combination of data and Monte Carlo. ε is measured in the $t\bar{t}$ simulation with respect to $t\bar{t} \to \ell\nu_\ell q\bar{q}'b\bar{b}$, where ℓ can be an electron, muon or tau, generated using Alpgen 1.2 see Ref. 3 for the hard scatter and PYTHIA 6.2 see Ref. 4 for subsequent generation of the remaining aspects of the events. Individual object identification efficiencies are scaled to the values measured in data. $\varepsilon = 4.7^{+0.5}_{-0.9}$ % for the μ+jets and $\varepsilon = 5.1^{+0.6}_{-0.8}$ % for the e+jets channel, where the errors include statistical and systematic effects.

4. Background

The dominant physics background to the $t\bar{t}$ signature arises from electroweak W boson production accompanied by four or more jets. Instrumental backgrounds for these channels originate primarily from QCD multijet processes where jets are misreconstructed resulting in fake leptons and fake $\not{E}_T$.

5. Cross Section Extraction Procedure

The $t\bar{t}$ events can be separated from the remaining background by combining topological and kinematical event information in a multivariate likelihood discriminant. The shape of the likelihood discriminant is compared to the signal and the background shapes which allows the extraction of the $t\bar{t}$ cross section.

Due to the large mass and the fact that the top-antitop pair is produced mainly at rest at Tevatron energies, $t\bar{t}$ is associated with energetic, central and isotropic events. The optimal variable (LD) is created from 4 kinematical varibales: sphericity, aplanarity, H'_{T2} (a measure for centrality) and K'_{Tmin} (a measure of the minimum jet p_T relative to another): $LD = \frac{\prod_i \mathcal{P}^i_{t\bar{t}}}{\prod_i \mathcal{P}^i_{t\bar{t}} + \prod_i \mathcal{P}^i_W}$, where $\mathcal{P}^i_{t\bar{t}}$ and $\mathcal{P}^i_W$ are the probabilities for the topological variable i to be $t\bar{t}$ or W+jets, repectively. This likelihood discriminant is constructed only from event shape variables and ratios of transverse energy variables, hence it has a reduced sensitivity to the dominant systematic uncertainty, originating from the jet energy scale.

The $t\bar{t}$ cross section is extracted by performing a binned likelihood fit to the discriminating variable (10 bins), where the most likely number of events from $t\bar{t}$, $N_t^{t\bar{t}}$, is given by maximizing $L(N_t^{t\bar{t}}, N_t^W, N_t^{QCD}) = \prod_{i=1}^{10} P(n_i^{obs}, \mu_i) \cdot P(N_{\ell-t}^{obs}, N_{\ell-t})$, where $N_t^{t\bar{t}}$, N_t^W and N_t^{QCD} are the number of $t\bar{t}$, W and QCD events and $P(n, \mu)$ generically denotes the Poisson probability density function for n observed events given an expectation of μ. The number of observed data events that populate the i-th bin is denoted by n_i^{obs}, the corresponding expected number of events is given by $\mu_i = P_i^{t\bar{t}} N_t^{t\bar{t}} + P_i^W N_t^W + P_i^{QCD} N_t^{QCD}$, where $P_i^{t\bar{t}}$, P_i^W, P_i^{QCD} are the corresponding probabilities for the three event classes. The sensitivity of the discriminating variable

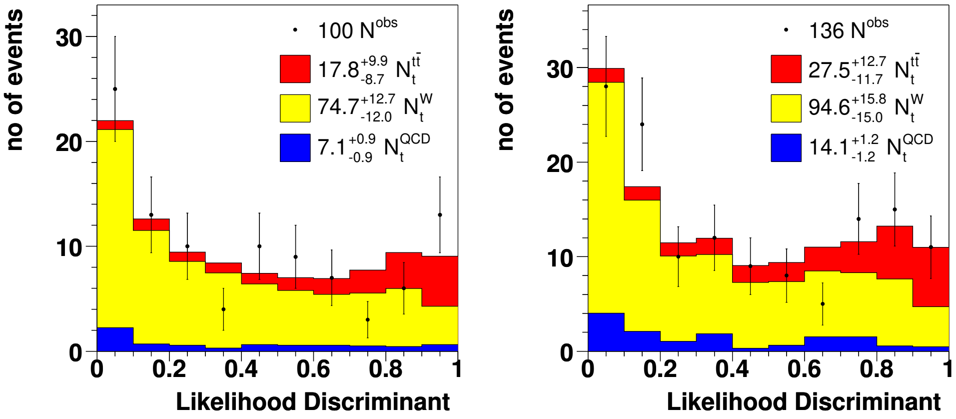

Fig. 1. Results of the topological likelihood fit showing data, fitted $t\bar{t}$, W and QCD in the μ+jets (left) and the e+jets channel (right), the corresponding number of events are given in the legend.

to distinguish QCD and non-QCD events is very small. Therefore an additional criterium is applied where the observed number of events which pass a *loose*, l, lepton identification criteria but not the final *tight*, t, criteria, $N^{obs}_{\ell-t}$, is compared with the corresponding expected one, $N_{\ell-t}$. The efficiencies for a *loose* lepton to pass also the *tight* criteria is different for leptons from $t\bar{t}$ or W events ($\sim 80-90\%$) and for (fake) leptons in QCD events ($\sim 8\%$), which is the origin of the discrimination power of this criterium between QCD and non-QCD.

6. Result

The $t\bar{t}$ production cross-section is given by $\sigma = \frac{N_t^{t\bar{t}}}{\mathcal{B}r\cdot\mathcal{L}\cdot\varepsilon}$. The topological likelihood fit is shown in Fig. 1 together with the relevant numbers for each channel, the $\mathcal{B}r = 43.5\%$ and the efficiencies were given in Sect. 3. The combined lepton+jets result of the $t\bar{t}$ production cross-section at $\sqrt{s}$ =1.96 TeV yields:

$$\sigma_{p\overline{p}\to t\overline{t}+X} = 7.2\,^{+2.6}_{-2.4}\,(\text{stat})\,^{+1.6}_{-1.7}\,(\text{syst})\;\pm 0.5\,(\text{lumi})\,\text{pb}\,. \tag{1}$$

The dominant systematic uncertainties originate from the jet energy scale, the jet identification and the W background modeling. See also Ref. 5 for more information.

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