Measurements of the $t\bar{t}$ Cross Section and the Top Quark Mass in the Hadronic τ + Jets Decay Channel at CDF

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We present the first exclusive observation of the $t\bar{t} \to$ hadronic τ + jets decay channel. Using these events from 1.96 TeV $p\bar{p}$ collisions at CDF, we measure the $t\bar{t}$ cross section as well as the top quark mass. Events require a single hadronic τ, large missing transverse energy, and exactly 4 jets of which at least one must be tagged as a b jet. The cross section measurement is extracted from a Poisson likelihood function based on the observed number of events and the predicted number of signal and background events for a given $t\bar{t}$ cross section. The mass is extracted from a likelihood fit based on per-event probabilities calculated from leading-order signal ($t\bar{t}$) and background (W+jets) matrix elements.

1. Introduction

We present the first exclusive observation of $t\bar{t} \to$ hadronic τ + jets events. With these events, we measure the $t\bar{t}$ production cross section in $\bar{p}p$ collisions at $\sqrt{s} = 1.96$ TeV with the CDF detector [1] at the Tevatron at Fermilab, as well as the first direct measurement of the top quark mass in τ + jets events. These measurements provide important tests of lepton universality and probe the top quark properties in a relatively unexplored channel which may be sensitive to new physics. Additionally, they are good examples of physics measurements performed with τ leptons in high jet multiplicity environments.

2. Selection and Background Estimation

This analysis uses a dataset with a total integrated luminosity of 2.2 fb^{-1} collected with the CDF detector between February 2002 and August 2007. The data is selected using a multi-jet trigger which requires at least four jets each with a calorimeter cluster with transverse energy (E_T, where transverse refers to being perpendicular to the beamline) > 15 GeV and a total sum E_T of all reconstructed jets > 175 GeV. To these events, we apply selection criteria which require 4 jets with $E_T > 20$ GeV, missing E_T ($\not\!\!E_{\rm T}$) > 20 GeV, and a hadronically decaying τ lepton with $E_T > 25$ GeV. Additionally, one of the 4 jets must be identified as coming from a b quark (b-tagging) [3]. Since our signal process gives a single τ lepton, we veto any event with an identified electron or muon. Hadronically decaying τ's appear as narrow jets with an odd number of charged tracks and low π^0 multiplicity. They are selected using similar requirements as described in [2], except we require both 1 and 3 prong τ's to have visible E_T of at least 25 GeV and a visible mass less than 1.8 GeV. We also place no explicit requirement on the transverse energy of the π^0's in the isolation region, but we do require that calorimeter energy in the isolation region be less than 10% of the τ energy.

2.1. Neural Network for QCD Multijets Removal

The dominant background for this analysis is high jet multiplicity QCD events with one of the jets faking the signature of a τ lepton. To further reduce the QCD multijets background, we developed an artificial neural network (NN) to distinguish between true $t\bar{t} \to \tau$ + jets events and QCD multijets events. First, we create a sample of QCD multijets from data by selecting events with a τ with no track isolation requirement. The NN is trained to distinguish between these selected QCD multijets events and $t\bar{t}$ events generated with the PYTHIA MC generator [4] where the τ decay is handled by the TAUOLA package [5] to properly account for the τ polarization. We use 8 variables to train the NN: $\not\!\!E_{\rm T}$, lead jet E_T, sum E_T of the jets and τ lepton, sum E_T of the two lowest E_T jets and the τ lepton, sum E_T of the two highest E_T jets, transverse momentum of the W which decays to a τ lepton, average η-moment of all jets not identified as coming from a b quark, and

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