CDF note 7179

A Measurement of BR($t \to \tau\nu q$)

The CDF Collaboration
URL http://www-cdf.fnal.gov

(Dated: August 9, 2004)

We measure the rate of top-anti-top events with a semi-leptonically decaying tau. We use 193.5 $\pm$ 12 pb^{-1} of data from $p\bar{p}$ collisions at a center-of-mass energy of 1.96 TeV from the upgraded Collider Detector at Fermilab. Our measurement is consistent with the Standard Model. We set a limit on an anomalous rate enhancement factor, $r_\tau < 5.0$ at 95% confidence.

Preliminary Results for Summer 2004 Conferences

I. INTRODUCTION

The Standard Model's heavy third generation particles, the top and bottom quarks, the tau and the tau neutrino are intriguing. The high energies required to produce the third generation particles, particularly in the case of the top quark, have resulted in the particles being the least studied in the Standard Model. Current measurements leave room for new physics in the interactions and decays of these particles[1][2][3]. The high masses of the particles give rise to the hope that studying them could help shed light on the origin of fermion masses[4][5].

The Tevatron at Fermilab, which collides protons and anti-protons at a center of mass energy of 1.96 TeV, is currently the only accelerator capable of producing top quarks. Top quarks decay to a W boson and a b quark about 100% of the time[6]. We look for $t\bar{t}$ events where one of the W bosons decays to an electron or muon and a neutrino, and the other W boson decays to a tau which then decays semileptonically to a tau neutrino plus hadrons. Semi-leptonic tau decays account for 64% of all tau decays. We do not look for taus decaying to electrons or muons because the leptonic tau decays are difficult to differentiate from prompt leptons.

We compare the rate we observe with our predicted rate as a test of the Standard Model. Many extensions to the Standard Model predict identical final states which could lead to an anomalous rate. For example the charged Higgs decay from $t\bar{t}$, $t\bar{t} \rightarrow H^{\pm}Wb\bar{b}$, $H^{\pm} \rightarrow \tau^{\pm}\nu_{\tau}$ [7] [8]. This analysis is a search for any such anomalous process that could show up in the final state as an enhanced (or suppressed) rate for tau leptons in top decay.

The CDF detector is described in detail in [9].

II. DATA SAMPLE & EVENT SELECTION

This analysis is based on an integrated luminosity of 193.5 pb^{-1} collected with the CDFII detector between March 2002 and January 2004. The data are collected with an inclusive lepton trigger that requires an electron or muon with E_T >18 GeV (P_T >18 GeV/c for the muon). From this inclusive lepton dataset we select events offline with a reconstructed isolated electron E_T (muon P_T) greater than 20 GeV. We also require

- $>$ 15 GeV tau lepton
- $>$ 20 GeV of missing transverse energy
- $\geq$ two jets:
  - one jet with $|\eta| < 2$, $E_T > 25$ GeV
  - an additional jet with $|\eta| < 2$, $E_T > 15$ GeV
- $>$ 205 GeV of H_T, where H_T is a summation of the energy of the physics objects (electrons, muons, taus, jets, and missing transverse energy) in the event
- opposite charge of primary lepton (electron or muon) and tau
- event must survive our Z Mass Veto, with a window of 65 GeV to 115 GeV, which is made only on events with angular distribution between the jets and missing transverse energy resembling signature of $Z \rightarrow \tau\tau$ events.

A. Geometric × Kinematic Acceptance

The total acceptance is measured in a combination of data and Monte Carlo. The geometric times kinematic acceptance of the basic tau dilepton event selection is measured using the PYTHIA Monte Carlo program [10]. The efficiency for identifying the isolated, high P_T lepton is scaled to the value measured in the data using the unbiased leg in Z-boson decays.

Our tau identification is sensitive to some calorimeter quantities that are difficult to model in the Monte Carlo simulation. We use PYTHIA Monte Carlo to generate $t\bar{t}$ events with the TAUOLA package [11] to correctly handle the tau polarization. We use Monte Carlo to calculate the tau ID efficiency for our acceptance as well as for several backgrounds so we measure a Monte Carlo to data normalization by comparing the physics process $W \rightarrow \tau\nu$ in 58 pb^{-1} of an independent data sample dominated by $W \rightarrow \tau\nu$ to what we predict with Monte Carlo. This physics process is our cleanest source of taus at CDF and allows us to measure the normalization to within 6%. We show the distribution of tracks in the data and Monte Carlo tau candidates in Figure 1 , where the electron background, the dominant background, has been added to the Monte Carlo so that it can be compared to the data. The tau P_T distributions are shown in Figure 2.

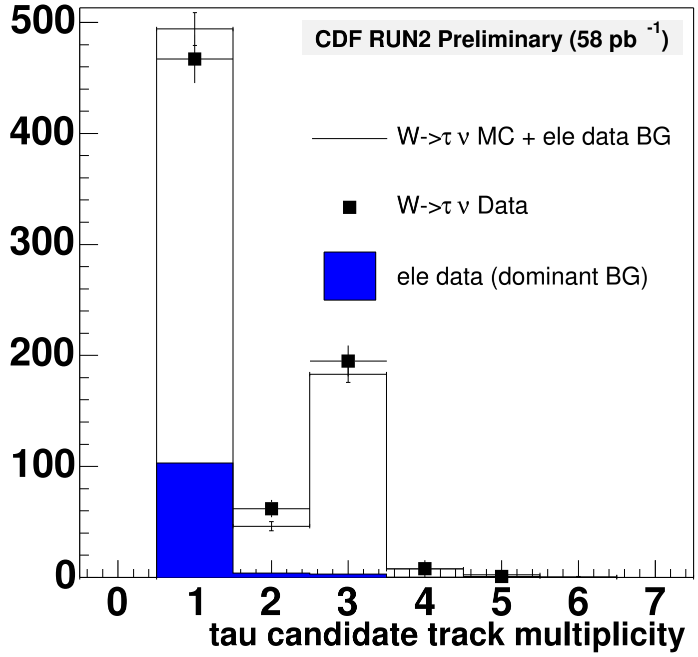

FIG. 1: The distribution of the number of tracks associated with taus in the a $W \to \tau\nu$ dominated data sample and Monte Carlo + electron background. This data sample is used in the analysis only as an independent data driven estimate of how well the Monte Carlo tau ID efficiency models the data.

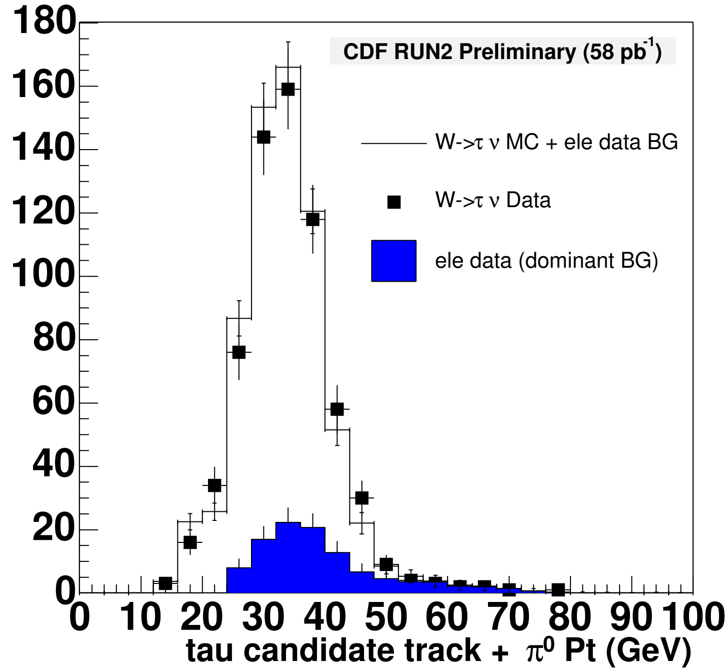

FIG. 2: The distribution of the tau P_T in a $W \to \tau\nu$ dominated data sample and Monte Carlo + electron background. This data sample is used in the analysis only as an independent data driven estimate of how well the Monte Carlo tau ID efficiency models the data.

Source	Systematic Uncertainty
Jet Corr/Energy Scale	±5.8%
Electron/Muon ID	±5%
Tau ID	± 6%
MC Generator	±7%
ISR	±7%
FSR	±7%
PDF	±1%
Total	16%

TABLE I: Summary of Systematics for Acceptance

The geometric times kinematic acceptance with both the electron and muon channel included is

$$0.00080 \pm 0.0005(\text{stat}) \pm 0.00014(\text{sys})$$

B. Systematic Uncertainties

We summarize the systematic uncertainty contributions in Table I.

III. BACKGROUNDS

Our dominant background is from W bosons produced in association with one or more jets where a jet passes all tau identification cuts to fake a tau. We calculate the rate of jets faking taus in four data samples as a function of jet E_T and calorimeter isolation. We apply the fake rate from the 50 GeV jet sample to loose tau candidates that pass the electron removal cut but fail final tau identification in order to determine the background from this source. Electrons faking taus provide another source of background primarily from $Z \to ee$ events. We measure the electron to tau fake rate using $Z \to ee$ events in the data and apply the rate to events with tau candidates that fail the electron removal cut. Muons faking taus provide the final non-tau background that we consider. Muons tend to deposit a small fraction of their energy in the calorimeter and so are reconstructed as taus less often than electrons. This background is primarily from $Z \to \mu\mu$ events and we determine it using $Z \to \mu\mu$ Monte Carlo after checking the modeling of our muon veto variable between the data and the Monte Carlo.

We also have backgrounds from processes that create real taus and can mimic our signal final state. The largest of these backgrounds is from $Z \to \tau\tau + jets$ events where one of the taus decays to an electron or muon and neutrinos and the other tau decays semi-leptonically to hadrons and a neutrino. This background was measured using the HERWIG Monte Carlo program [12]. The energy spectrum of the electron or muon will be softer in these events than in our signal events and the missing E_T spectrum will be much softer as the neutrinos from the tau decays have some tendency to be produced opposite each other partially canceling each other. Our H_T cut is therefore very effective in reducing this background (by about 40%) and our Z Mass Veto dramatically reduces the background by a factor of five.

The two other physics background processes we consider are WW and WZ produced in association with jets. The cross section * branching ratio of these are much lower than the $t\bar{t}$ cross section * branching ratio of our signal. Their levels are also significantly reduced by the H_T cut.

We show a summary of our backgrounds and expected signal in Table II.

	number of events expected
$\gamma^*/Z \to \tau\tau + jets$	0.26 ±0.06(stat) ±0.05(sys)
$j \to \tau$ fakes	0.75 ±0.12(stat) ±0.20(sys)
$e \to \tau$ fakes	0.08 ±0.03(stat) ±0.02(sys)
$Z \to \mu\mu$	0.05 ±0.03(stat)
WW	0.14 ±0.02(stat) ±0.03(sys)
WZ	0.02 ±0.02(stat)
Total expected background events	1.30 ±0.14(stat) ± 0.21(sys)
Signal exp from MC	1.03 ±0.06(stat) ±0.17(sys)

TABLE II: Summary of background and signal predictions in 193.5 pb^{-1}.

IV. RESULTS

We expect 2.3 events in 193.5 pb^{-1} and we observe 2 events, both in the e,tau channel. One of the events has a b-tagged jet, identified via a secondary vertex distinguishable from the primary vertex where the distance between the secondary vertex and primary vertex divided by the resolution is greater than 3. Slightly over 50% of $t\bar{t}$ events will have at least one b-tagged jet. A very small (less than 5%) fraction of background events are expected to have a b-tagged jet.

We measure the parameter r_τ where

$$r_\tau \equiv \frac{\mathrm{BR}(t \to b\tau\nu)}{\mathrm{BR}_{\mathrm{SM}}(t \to b\tau\nu)}.$$

We set an upper limit,

$$r_\tau < 5.0 \text{ at 95\% confidence level}$$

This measurement is consistent with the Standard Model prediction of $r_\tau = 1$.

A larger data sample and continued improvement to the purity and efficiency of τ identification will allow r_τ to be further constrained.

Acknowledgments

We thank the Fermilab staff and the technical staffs of the participating institutions for their vital contributions. This work was supported by the U.S. Department of Energy and National Science Foundation; the Italian Istituto Nazionale di Fisica Nucleare; the Ministry of Education, Culture, Sports, Science and Technology of Japan; the Natural Sciences and Engineering Research Council of Canada; the National Science Council of the Republic of China; the Swiss National Science Foundation; the A.P. Sloan Foundation; the Research Corporation; the Bundesministerium fuer Bildung und Forschung, Germany; the Korean Science and Engineering Foundation and the Korean Research Foundation; the Particle Physics and Astronomy Research Council and the Royal Society, UK; the Russian Foundation for Basic Research; the Comision Interministerial de Ciencia y Tecnologia, Spain; in part by the European Community's Human Potential Programme under contract HPRN-CT-20002, Probe for New Physics; and by the Research Fund of Istanbul University Project No. 1755/21122001.

[1] CDF Collaboration, F. Abe et al., Phys. Rev. Lett. 79, 3585 (1997).
[2] C. Yue, H. Zong, L. Liu, Mod. Phys. Lett. A18 2187-2194 (2003).
[3] T. Han, M.B. Magro, Phys. Lett. B 476, 79-86 (2000).
[4] J. Guasch, J. Sola, Phys. Lett. B416, 353-360 (1998).
[5] A. Rasin, Phys. Rev. D 57, 3977-3985 (1998).
[6] S. Eidelman et al., Phys. Lett, B 592, 1 (2004).
[7] V. Barger, R.J.N. Phillips, Phys. Rev. D 41 884 (1990).
[8] CDF Collaboration, T. Affolder et al., Phys. Rev. D 62, 012004(2000).

[9] F. Abe, et al., Nucl. Instrum. Methods Phys. Res. A **271**, 387 (1988); D. Amidei, et al., Nucl. Instum. Methods Phys. Res. A **350**, 73 (1994); F. Abe, et al., Phys. Rev. D **52**, 4784 (1995); P. Azzi, et al., Nucl. Instrum. Methods Phys. Res. A **360**, 137 (1995); The CDFII Detector Technical Design Report, Fermilab-Pub-96/390-E

[10] T. Sjostrand et al., High-Energy-Physics Event Generation with PYTHIA 6.1, Comput. Phys. Commun. **135**, 238 (2001).

[11] S. Jadach, et al., TAUOLA 2.5, CERN-TH-6793 (1992).

[12] G. Corcella et al., HERWIG 6: An Event Generator for Hadron Emission Reactions with Interfering Gluons (including supersymmetric processes), JHEP **01**, 10 (2001).