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P. Koehn
For the CDF Collaboration

The Ohio State University
Columbus, Ohio 43210

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

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Single Top and Top Properties at CDF

Phillip Koehn[1]
for the CDF Collaboration

[1] The Department of Physics, The Ohio State University, Columbus , OH 43210

Abstract

Recent CDF results with 110 pb^{-1} of data on top quark production and decay properties are presented. Limits are placed on single top quark production in the W^* and W-gluon channels. A measurement of the polarization of the intermediate W boson in top decay, a search for resonances in the mass of the $t\bar{t}$ system, and the transverse momentum of top quarks in $t\bar{t}$ events are presented.

1. Introduction

After the discovery of the top quark [1], next comes the task of studying its behaviour. This paper surveys recent CDF results beginning with two searches for single top, a measurement of the helicity of the W in top decays, a search for resonances in the mass of the $t\bar{t}$ system, and finally a measurement of the transverse momentum (P_T) of the top quark.

2. Single Top Production

At the Tevatron, top quarks are produced primarily by $t\bar{t}$ pair production via the strong interaction. However, single top is also expected to be produced at the Tevatron through the weak interaction. Shown in Figure 1 are the two dominant channels of single top production: W-gluon fusion and s-channel W^*. The theoretical prediction of the production cross section is 1.70 ± 0.30 pb[3] for W-gluon fusion, and 0.73 ± 0.10 pb[2] for s-channel W^*. A search for single top is important as its production cross section is a direct probe of the strength of the electroweak $(t - W - b)$ vertex, and is potentially sensitive to anomalous couplings.

The events in the search for single top occur in the W + jet data sample, and the selection criteria are as follows: a high P_T lepton(e or μ) with $P_T > 20$ GeV/c, high missing transverse energy ($\not\!\!E_T > 20$ GeV) to account for the undetected neutrino, and exactly two jets with $E_T > 15$ GeV and $|\eta| < 2$. The s-channel W^* search requires at least one b-tagged jet, while the W-gluon fusion process, exactly one b-tagged jet is required. The backgrounds for both search modes are from $t\bar{t}$ production and QCD W + jets processes with tagged jets: $Wb\bar{b}$, $Wc\bar{c}$, Wc, and W + 2 jets from

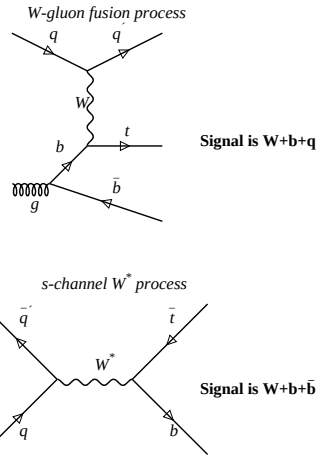

Figure 1. Two dominant processes for single top quark production at the Tevatron.

mistags. The mass of the top quark candidate is reconstructed with the four-momenta of the e or μ, ν and one of the jets, by taking the solution with the smaller absolute value for the neutrino P_Z from the W-mass constraint. The tagged jet is considered to be the b-jet from top. In the W-gluon fusion search, the reconstructed top quark mass must lie within 30 GeV of the measured top mass value.

In the W-gluon process, the charge (Q) of the top quark, obtained from the charge of the lepton, is correlated with the untagged (light quark) jet pseudorapidity (η). This correlation is not observed with QCD W + jets, $t\bar{t}$, and s-channel W^*. This distinctive event topology is exploited with a binned maximum likelihood fit made to the $Q \times \eta$ distribution (shown in Figure 2). No significant

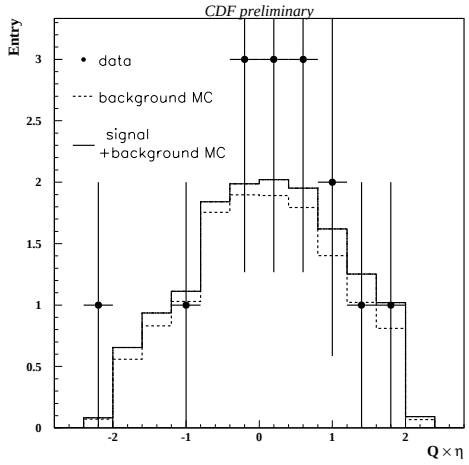

Figure 2. $Q \times \eta$ distribution for data, W-gluon signal and backgrounds.

excess above the Standard Model (SM) background prediction is observed. Therefore, an upper limit is set on the W-gluon fusion production cross section of 15.4 pb at 95% confidence level.

In s-channel W^* events, the $b(\bar{b})$-jet from the top (antitop) quark decay tends to point along the proton direction. So the jet with the largest forward (backward) η is defined as the $b(\bar{b})$-jet. from a top (antitop) decay. This assignment choice is correct 64% of the time. A binned maximum likelihood fit is performed with the reconstructed mass distribution(see Figure 3). Again, no significant excess above the SM background prediction is observed and an upper limit is set on the s-channel W^* production cross section of 15.8 pb at 95% confidence level.

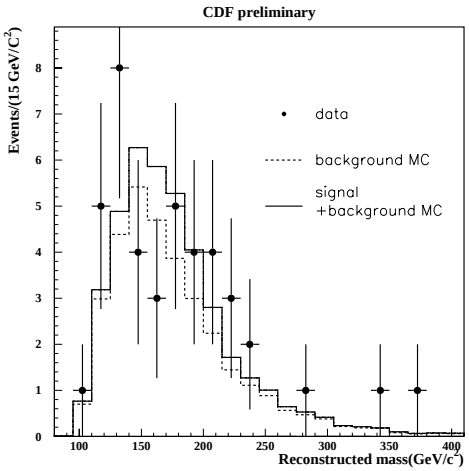

Figure 3. The reconstructed top quark mass distributions for data, W^*signal and backgrounds.

3. Helicity of W Bosons

For a top mass of 175 GeV/c^2, the SM predicts that 70% of the W bosons from top decay are longitudinally polarized, 30% are left handed, and none are right handed. Events in this analysis are taken from both the lepton+jets and dilepton channels. The P_T spectrum of leptons in the decay chain $t \to bW \to bl\nu$ in the lab frame is used to extract the fraction intermediate W's with a given polarization. This is done by performing an unbinned maximum likelihood fit of the lepton P_T distribution to the sum of the expectations for longitudinal and left-handed polarized W's, and background. Assuming a standard V-A weak decay, the contribution from right-handed polarized W's is assumed to be zero. Figure 4 shows the resulting fit.

A separate likelihood fit to the lepton P_T distribution is performed to search for a V+A weak decay component. This fit uses the sum of the expectations for right-handed and left-handed W's and background, while constraining the fraction of longitudinally polarized W's to be 0.70. The resulting fraction of right-handed polarized W's is determined to be 0.11 ± 0.15. Both results are consistent with SM predictions.

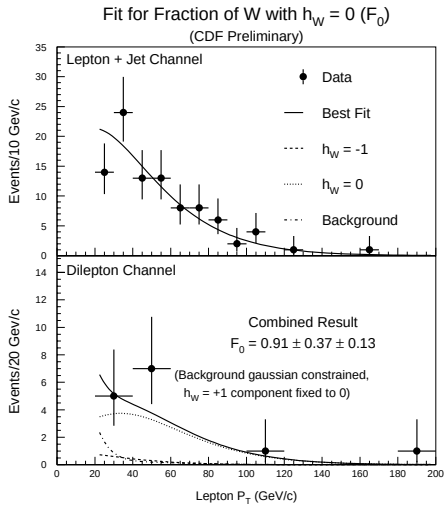

Figure 4. The transverse momentum distributions of leptons used to extract the fraction of longitudinally polarized W bosons produced in top quark decay.

4. Search for Resonances in the Mass of the $t\bar{t}$ System

A search for resonances in the mass of the $t\bar{t}$ system is motivated by beyond the SM theories such as Topcolor Assisted Technicolor [4] that predict the existence of heavy objects, Z' and topgluons, that decay to $t\bar{t}$ pairs ($X \rightarrow t\bar{t}$). This work follows CDF's top mass analysis in the lepton+jets mode, except that the top mass is constrained to 175 GeV/c^2. Using the parton-jet assignments returned by this constrained kinematic fit, the additional requirement is made that the unconstrained top masses reconstructed from the leptonic and hadronic sides of the event both be between 150 and 200 GeV/c^2. This technique reduces the number of parton-jet misassignments. A maximum likelihood fit is performed to the $M_{t\bar{t}}$ distribution, assuming the only sources present in the data are $X \rightarrow t\bar{t}$, SM $t\bar{t}$, and QCD W + *jets* background (described above). No significant excess above background is observed in the $M_{t\bar{t}}$ distribution. Figure 5 shows a comparison of the 95% confidence level upper limits, including systematic uncertainties, to the theoretical prediction of Z' decaying to $t\bar{t}$. The results indicate that the data excludes the existence of narrow $t\bar{t}$ resonances with masses less than 630 GeV/c^2.

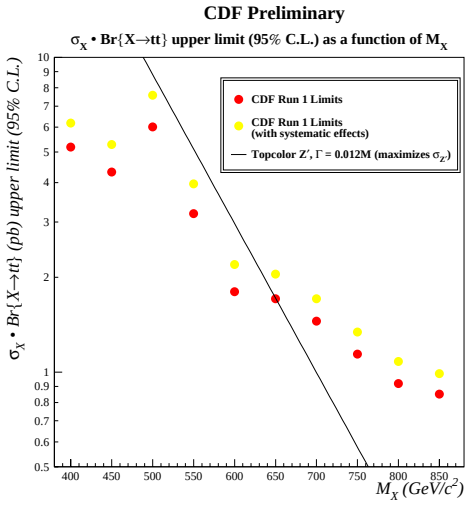

Figure 5. 95% C.L. upper limits as a function of $M_{t\bar{t}}$. Included for reference is the expected Topcolor Z' cross-sections for width = 1.2% of $M_{Z'}$. This particular width maximizes the predicted Topcolor Z' cross-section.

5. Top Quark P_T Spectrum

Models of anomalous top quark pair production predict deviations to the top quark P_T spectrum [5]. In this analysis, events in the lepton+jets channel are reconstructed with a kinematic fitter [6] that constrains the reconstructed top quark mass to its measured value. The top quark P_T distribution is measured with a likelihood technique that is designed to correct for experimental bias introduced by the kinematic fitter. Due to the correlations of the two top quarks in the event, the P_T is measured only from the hadronically decaying top quark. The observed fraction of top quarks produced in $t\bar{t}$ events binned in P_T are given in Table 5. The fraction of top quarks produced with a P_T in the range of 0 to 150 GeV/c is 0.72 $\pm$ 0.13 (stat) $\pm$0.06 (syst). At 95% C.L., the fraction of top quarks produced with a P_T in the range of 225 to 300 GeV/c is less than 0.114. These results are in agreement with the SM prediction.

Table 1. The fraction of top quarks produced in $t\bar{t}$ events within a binned P_T range.

P_T Bin	Measured Fraction of Top Quarks
$0 < P_T < 75$	$R_1 = 0.29^{+0.18}_{-0.18}(\text{stat})\ ^{+0.08}_{-0.08}$ (syst)
$75 < P_T < 150$	$R_2 = 0.42^{+0.18}_{-0.18}(\text{stat})\ ^{+0.05}_{-0.07}$ (syst)
$150 < P_T < 225$	$R_3 = 0.29^{+0.12}_{-0.10}(\text{stat})\ ^{+0.06}_{-0.05}$ (syst)
$225 < P_T < 300$	$R_4 = 0.000^{+0.035}_{-0.000}(\text{stat})\ ^{+0.019}_{-0.000}$ (syst)

6. Summary

Searches for single top production and measurements of top properties in the 110 pb^{-1} of data taken by CDF in Run I have been presented. The results are consistent with Standard Model expectations within the uncertainty of the measurements.

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