PROCEEDINGS OF SCIENCE

Top Cross Section and Standard Model Properties at CDF

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We present recent results on top quark pair production cross section in several final states as well as a spin correlations measurement and two W-helicity measurements from the CDF detector at the Tevatron $p\bar{p}$ collider operating at $\sqrt{s} = 1.96$ TeV. The most precise single $t\bar{t}$ cross section measurement, in the lepton+jets final state, using a Neural Network kinematic fit, yields a value of 6.8 $\pm$ 0.4 (stat) $\pm$ 0.4 (syst) $\pm$ 0.1 (theory) pb for a mass of 175 Gev/c^2, using 2.8 fb^{-1} of CDF data. This corresponds to a total uncertainty of 8%, similar to the uncertainties of the current best theoretical predictions. It is important to measure the $t\bar{t}$ cross section in as many different channels as possible as any significant discrepancy between them could be a sign of new physics. Two other $t\bar{t}$ cross section measurements are presented, all of which are in excellent agreement with the standard model predictions. A recent measurement of the spin spin correlations in the dilepton channel is presented which shows results that are compatible with the standard model predictions. Finally we present measurements of the helicity of the W-boson in top decays using two different methods as well as a combination of these results. Again the results are shown to be in good agreement with the standard model predictions.

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1. INTRODUCTION

The study of top quark pair production at the Tevatron is now entering the realm of precision physics. With 3 fb^{-1} of CDF data analysed, there are over 1200 reconstructed $t\bar{t}$ events in the lepton + jets channel. As the integrated luminosity increases, it is possible not only to make more precise measurements of the properties of the top quark but also to search for new physics through deviations from the expected behaviour.

2. TOP PAIR PRODUCTION CROSS SECTION

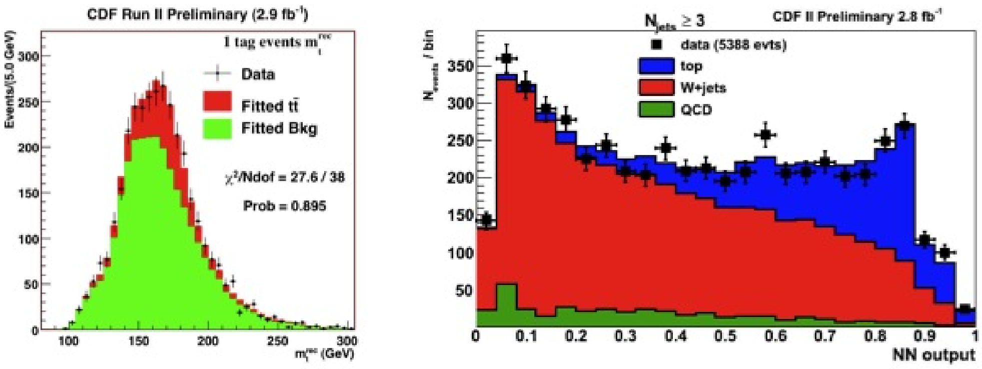

Figure 1: (left)Top mass distribution used to measure the $t\bar{t}$ cross section in the all hadronic channel, only the case of 1 heavy flavour tagged jet is shown here. The data is shown as black points and is compared to the output of the fit. The signal contribution is shown in red, the background in green. (right) Neural Network output distribution used to measure the $t\bar{t}$ cross section in the lepton+jets channel. The data is shown as black points and is compared to the output of the fit. The signal contribution is shown in blue, the W+jets background in red and the QCD in green.

Many new $t\bar{t}$ cross section measurements from CDF were presented at this conference. In the all hadronic channel, a result using an integrated luminosity of 2.9 fb^{-}1 was presented [1]. This result uses a likelihood fit to the reconstructed top mass and measured a top pair production cross section of $\sigma_{t\bar{t}}$ = 7.2 $\pm$ 0.5 (stat) $\pm$ 1.1 (syst) $\pm$ 0.4 (lumi) pb for an assumed top mass of 172.5 GeV/c^2. In this analysis the dominant systematics are the jet energy scale and the generator systematic that compares results from templates generated with PYTHIA and with HERWIG. These systematics are obtained by generating sets of pseudo-experiments with the shifted templates and fitting using the nominal ones. Figure 1 (left) shows the templates and fits for the case of exactly one heavy flavour tagged jet. In the lepton + jets channel, two new CDF measurements were shown that use an integrated luminosity of 2.8 fb^{-1} and assuming a top mass of 175 GeV/c^2. In both of these analyses, the same data sample is used to measure both the $t\bar{t}$ and the Z cross sections and then the ratio of the two cross sections is taken, thus essentially removing the common systematic uncertainties such as the luminosity measurement which was the dominant systematic. By multiplying this ratio by the theoretical Z cross section, one can obtain a measurement for the $t\bar{t}$ cross section with lower total uncertainty. The first analysis makes use of the enhanced signal to background fraction when at least one of the jets is required to have a heavy-flavor tag (using the displaced vertex tagger SecVtx) [2]. In this analysis, the data is used to constrain the backgrounds that cannot be predicted with great accuracy, such as W+jets. The value of the $t\bar{t}$ cross section is scanned until a minimum is found between the expected sum of the backgrounds plus signal and the observed number of data events. The observed cross section is $\sigma_{t\bar{t}}$ = 7.0 ± 0.4 (stat) ± 0.6 (syst) ± 0.1 (theory) pb. The other CDF analysis in the lepton + jets channel makes use of the difference in kinematic properties between the signal and background events [3]. This analysis relies on a fit to a Neural Network (NN) output that is based on inputs from seven kinematic quantities, most of them related to the characteristics of jets in the events. The distribution of the NN output is shown in Fig. 1 (right). The fitted cross section is $\sigma_{t\bar{t}}$ = 6.8 ± 0.4 (stat) ± 0.4 (syst) ± 0.1 (theory) pb.

3. SPIN CORRELATIONS

As the top quark does not hadronise before it decays, one can observe the original polarisation of top quark by looking at the kinematic distributions of its decay products. Spin-spin correlations in $t\bar{t}$ production can thus be observed through correlations between flight directions of the decay products. The correlation coefficient, κ, was extracted fom data, in the dilepton channel, from from multi-dimentional fits to angular distributions of the positive and negative lepton directions as well as the directions of the b-quarks on both sides [4]. A minimum unbinned likelihood fit is performed to extract the value of κ, that is expected to be around 0.8 at the Tevatron. Feldman-Cousins confidence levels are used to determine the uncertainties. CDF measures a value of $\kappa = 0.32^{+0.55}_{-0.78}$ assuming a top mass of 175 GeV/c^2, consistent with the standard model. This analysis is still statistics limited.

4. W HELICITY

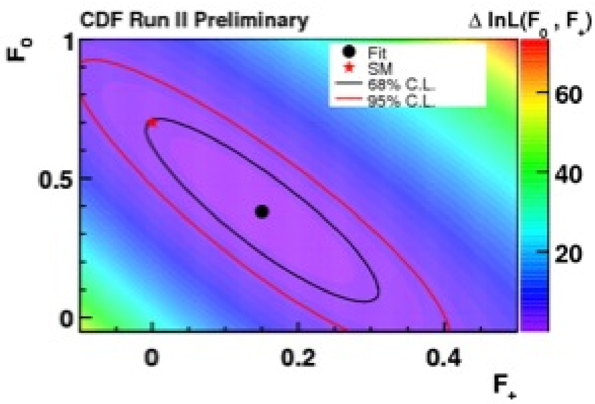

Figure 2: 2D fit of F_0 and F_+ W-helicity fractions for one of the CDF analyses. The contours show the confidence intervals.

The decay products of the top quark preserve the helicity content of the underlying weak interaction. Measuring the helicity of the W-bosons from top decay probe the V-A structure of the weak interactions; thus measuring helicity fractions different from the standard model expectations would be a sure sign of new physics. We measured the angle between the direction of the charged lepton in the W-boson rest frame and the direction of the W-boson in the top quark rest frame; it is thus necessary to reconstruct the four-vectors of the top quark, the W-boson and the charged lepton. Two separate CDF analyses use two different methods to reconstruct this angle; the results are then combined [5]. Various types of fits are carried out. The first two constrain one of the parameters to the standard model value and fit the other, while the third simultaneously fits both F_0 and F_+. The results from the two-parameter fit for one of the analyses is shown in Fig. 2. For a top mass of 175 GeV/c^2, the combination of the simultaneous fit to both parameters gives $F_0 = 0.66 \pm 0.16(stat) \pm 0.05(sys)$ and $F_+ = -0.03 \pm 0.06(stat) \pm 0.03(sys)$, in excellent agreement with the standard model.

References

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[5] T. Aaltonen *et al.* (CDF Collaboration), Phys. Let. B. 674, p160.