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TOP PHYSICS AT CDF

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The top quark is the most massive fundamental particle observed so far, and the study of its properties is interesting for several reasons ranging from its possible special role in electroweak symmetry breaking to its sensitivity to physics beyond the Standard Model (SM). This article will focus on the latest top physics results from CDF based on 320-750 pb^{-1} of $p\bar{p}$ collision data at $\sqrt{s} = 1.96$ TeV. The $t\bar{t}$ cross section and the top mass have been measured in different decay channels and using different methods. We have also searched for massive $t\bar{t}$ resonances.

1. Introduction: top at CDF

The CDF detector, upgraded [1] for Run II of the Tevatron, has recorded $\approx$1.2 fb^{-1} of $p\bar{p}$ collision data at $\sqrt{s} = 1.96$ TeV. At the Tevatron, top is produced predominantly in $t\bar{t}$ pairs through the strong interaction by quark-antiquark annihilation (85%) or by gluon gluon fusion (15%).

In the SM, top decays almost 100% of the times to Wb. Therefore, the final state of a $t\bar{t}$ event is given by the decay mode of the W bosons. Events where both Ws decay to e or μ are called "dilepton" events. This mode is relatively clean, with a S/N of about 1.5 to 3.5, but it has a low branching ratio ($\sim$5%) due to the small leptonic branching fraction of W. Events in which one W decays to e or μ and the other decays to quarks are called "lepton+jets" events. This decay channel has a higher branching ratio ($\sim$30%), but it has worse S/N (0.3 to 3). Finally, events in which both Ws decay to quarks are called "all hadronic" events. This channel has the largest branching ratio ($\sim$44%) but is also the one with more backgrounds.

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2. Top Cross-Section

The measurement of the $t\bar{t}$ production cross section in the different decay modes and with different methods is a great tool to look for new physics.

In the lepton+jets decay mode several cross section measurements have been performed. The basic event selection requires one identified lepton, large missing transverse energy and 3 or more energetic jets. Counting analyses require at least one of the jets to be tagged as a b-jet in order to further reduce the otherwise dominant W+jets and QCD backgrounds.

The most precise determination of the $t\bar{t}$ cross section at CDF uses ≈695 pb^{-1} of lepton+jets events and requires at least one jet to be b-tagged by a secondary vertex [4] algorithm, which looks at tracks associated to the jet. The resulting cross section is

$$\sigma_{t\bar{t}} = 8.2 \pm 0.6(\text{stat}) \pm 1.0(\text{sys}) \text{ pb } (\text{m}_\text{t} = 175 \text{ GeV}).$$

There is another measurement that uses ≈318 pb^{-1} and applies the same event selection but uses the Jet Probability [5] tagging algorithm in order to identify b-jets. The obtained cross section in this case is

$$\sigma_{t\bar{t}} = 8.9 \pm 1.0(\text{stat}) \pm 1.1(\text{sys}) \text{ pb } (\text{m}_\text{t} = 178 \text{ GeV}).$$

In both cases, 6% luminosity uncertainty is included in the systematic uncertainty. Figure 1 left (right) shows the distribution of the b-tagged events, $t\bar{t}$ signal and the predicted background rates as a function of jet multiplicity for the Secondary Vertex (Jet Probability) analysis.

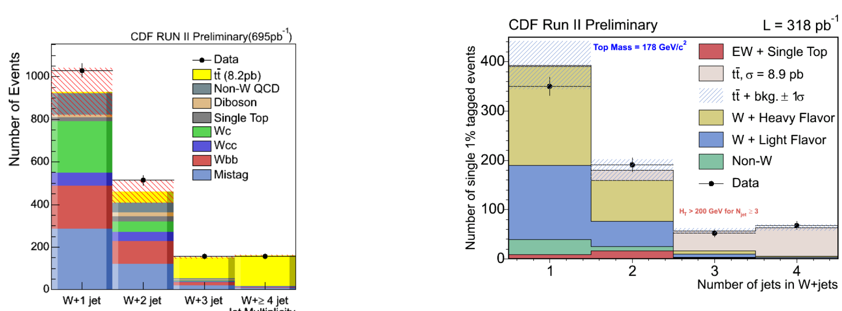

Figure 1. Left (right): b-tagged lepton+jets events, $t\bar{t}$ signal and expected background as a function of jet multiplicity for the Secondary Vertex (Jet Probability) analysis.

Other analyses in the lepton+jets channel do not use b-tagging. Instead, they make use of kinematic information in the $t\bar{t}$ candidate events. A neural net (NN), which includes information from seven different kinematic distributions, is built to separate top signal from the background. The performance of the NN is shown in Fig. 2 (left). The NN analysis uses $\approx$760 pb^{-1} and observes 325 (pretag) $t\bar{t}$ events from the fit. The measured cross section is

$$\sigma_{t\bar{t}} = 6.0 \pm 0.6(\mathrm{stat}) \pm 0.9(\mathrm{sys})\ \mathrm{pb}\ (\mathrm{m_t} = 175\ \mathrm{GeV}).$$

In the dilepton channel, the basic event selection requires two identified leptons (e or μ), large missing transverse energy and 2 or more energetic jets. Figure 2 (right) shows the distribution of candidate events, $t\bar{t}$ signal and the predicted background rates as a function of jet multiplicity for this analysis. The resulting cross section is

$$\sigma_{t\bar{t}} = 8.3 \pm 1.5(\mathrm{stat}) \pm 1.0(\mathrm{sys}) \pm 0.5(\mathrm{lum})\ \mathrm{pb}\ (\mathrm{m_t} = 175\ \mathrm{GeV}).$$

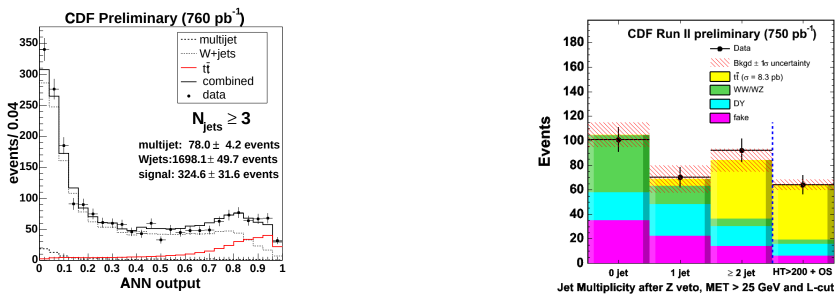

Figure 2. Left: NN output distributions for data, top and background. Signal and background distributions are fit to the data to determine the $t\bar{t}$ fraction. Right: number of dilepton events, $t\bar{t}$ signal and estimated background as a function of jet multiplicity.

Several other measurements of the cross section have been performed being all consistent with each other and with the theoretical prediction [2] $\sigma_{t\bar{t}}^{\mathrm{th}} = 6.7^{+0.7}_{-0.9}$ pb for $m_t = 175$ GeV.

3. Top Mass

The top mass is a fundamental parameter of the SM since it is a dominant parameter in higher order radiative corrections to other SM observables. In particular, an accurate determination of the top mass, combined with precision electroweak measurements, helps to constrain the mass of the elusive SM Higgs.

Top mass measurements are difficult for several reasons: there are many jet-parton possible assignments; in the dilepton channel, the undetected neutrinos cause the event kinematics to be under-constrained; and the jet energies must be known with high accuracy. The dominant systematic uncertainty for all top mass measurements is the jet energy determination.

In the lepton+jets channel, the top mass has been measured using "template" analyses, in which a value for the top mass is reconstructed for each event, with ≈680 pb^{-1} of data. The resulting m_t distribution is then compared to Monte Carlo m_t templates simulated at various top masses (shown in Fig. 3 left). Since reconstructed top mass is sensitive to the Jet Energy Scale, JES, m_t is determined by a simultaneous fit of the templates to the observed distribution, as a function of m_t and Δ_{JES} using $W \to jj$ decays. Figure 3 (right) shows the result of the fit. The obtained top mass is

$$m_t = 173.4 \pm 2.5(\text{stat} + \text{JES}) \pm 1.3(\text{sys}) \text{ GeV}.$$

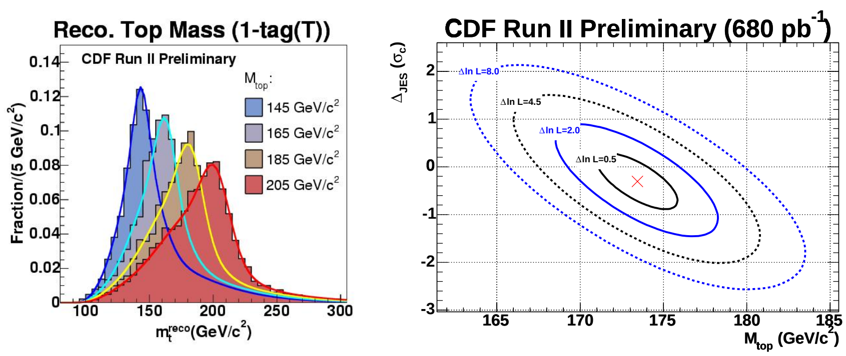

Figure 3. Left: Monte Carlo m_t templates. Right: result of the fit of the templates to the observed distribution, as a function of m_t and Δ_{JES} using $W \to jj$ decays.

In the dilepton channel, the top mass has been measured using a "matrix element" technique with ≈750 pb^{-1} of data. The reconstructed top mass for each event is obtained convoluting matrix elements with resolution functions. The top mass is determined to be

$$m_t = 164.5 \pm 4.5(\text{stat}) \pm 3.1(\text{sys}) \text{ GeV}.$$

Other measurement that does not need full event reconstruction has been developed. This analysis, with ≈695 pb^{-1}, makes use of the correlation between the top mass and the decay length of the b hadrons from the top decay. Although is a statistically limited method, it has the advantage that does not depend on the JES. The measured top mass is

$$m_t = 183.9^{+15.7}_{-13.9}(\text{stat}) \pm 5.6(\text{sys}) \text{ GeV}.$$

4. Search for $t\bar{t}$ Resonances

If we move beyond the SM, $t\bar{t}$ can also be produced via an unknown heavy resonant state, or through some other process such as Topcolor-Assisted Technicolor [3]. CDF has performed a search for a heavy resonance decaying into $t\bar{t}$ in the lepton+jets channel using $\approx$680 pb^{-1} of data. No evidence has been observed. Upper limits have been set on the production cross section at the 95% CL. For one leptophobic topcolor production mechanism we exclude masses up to 725 GeV.

5. Conclusions

Top physics program at CDF is very rich. No evidence of non-SM top quark has been found so far. The $t\bar{t}$ production cross section has been measured in different top decay channels and using different techniques. The top mass has also been measured using different samples and techniques achieving a total uncertainty of $\sim$2 GeV. We expect to have more precise measurements by this summer, with 1 fb^{-1} of data.

Acknowledgments

The results shown here represent the work of many people. I thank my CDF colleagues for their efforts to carry out these challenging physics analyses. I thank the conference organizers for a very nice week of physics. Finally, I thank the colleagues of my research institution, IFCA, for all their help.

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