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LATEST TOP RESULTS FROM CDF

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The top quark is a relatively young particle which can still be produced only at the Tevatron $p\bar{p}$ collider. The study of its properties provides stringent tests of many Standard Model predictions; moerover, thanks to its huge mass, the top quark is a probe to the highest achievable mass scale. This document will cover some of the most recent results obtained analyzing up to $1\,\mathrm{fb}^{-1}$ of data collected by the CDF detector.

1. Introduction

The top quark was first dicovered[1] in 1995 by the CDF[2] and D0 collaborations analyzing few tens of pb^{-1} of data from $p\bar{p}$ collisions at the Tevatron collider. The two detectors went back to operations in 2001; since then about $2.0\,\mathrm{fb}^{-1}$ of data were collected and up to $1.0\,\mathrm{fb}^{-1}$ analyzed. With more than 10 times the statistics needed for the discovery, top physics is now mature for a broad range of explorations. At the Tevatron center-of-mass energy of 1.96 TeV, the top quark is produced mostly in pairs with a theoretical cross section[3] of 6.7 pb assuming a top quark mass of $175\,\mathrm{GeV/c}^2$. Due to its very large mass, according to the Standard Model (SM) it decays before hadronizing into a W boson and a b quark almost 100% of the times. At CDF, $t\bar{t}$ events are classified into four non-overlapping samples according to the final states signatures. These are characterized by differing Branching Ratios (BR) and background amount and composition:

(1) **Lepton+jets** - This sample contains events where one W decays leptonically and the other decays hadronically; it is characterized

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by large BR(∼30%) and moderate background, mostly coming from production of W plus jets.

(2) **All-jets** - Here both W's decay hadronically. This channel has the largest BR(∼44%) but also a very large background from QCD multijet production.

(3) **Dilepton** - This is the cleanest sample, having a modest background coming from Drell-Yan dilepton production or dibosons, but on the other hand the smallest BR(∼5%).

(4) $\not\!\!E_T$**+jets** - This channel is peculiar to CDF and collects a large number of leptonic events, while being orthogonal to the others. Here the background comes mostly from QCD multijet production and W's produced in association with jets.

Most analysis are performed in the lepton+jets channel because of its good balance between BR and signal purity. In some cases the top properties measurements performed in different channels are combined to reduce the overall uncertainty.

2. Cross section measurements

The measurement of the $t\bar{t}$ production cross section provides a test of QCD calculation and any discrepancy from the theoretical expectation could hint to production or decay mechanisms not predicted by the SM. The most precise measurement is performed in the lepton+jets channel with $695\,\mathrm{pb}^{-1}$, counting events passing selection cuts and requiring at least one jet to be identified as coming from a b-quark by a b tagging algorithm; the measured cross section corresponds to:

$$\sigma_{t\bar{t}} = 8.2 \pm 0.6(stat.) \pm 1.0(syst.)\,\mathrm{pb}\,. \qquad (1)$$

A more recent measurement comes from the analysis of the all-hadronic channel, where for the first time at CDF a neural network is used to achieve a considerable background reduction, i.e. from about 1/1000 to ∼1/2. The measured cross section amounts to

$$\sigma_{t\bar{t}} = 8.3 \pm 1.0(stat.)^{+2.1}_{-1.6}(syst.)\,\mathrm{pb}\,, \qquad (2)$$

the uncertainty on this result being dominated by the Jet Energy Scale (JES) systematics. Overall, the measurements performed in all four samples are in good agreement with each other and with the theoretical prediction.

3. Top quark mass measurement

The top quark mass, M_{top}, is probably the most important parameter to be measured in the top sector. Due to the top quark contribution to radiative corrections, together with the W boson mass it provides a constraint on the Higgs boson mass. There are two main classes of methods to extract the mass: the Template Method and the Matrix Element (ME) method. The JES is the main source of systematics in each channel. To increase precision both methods now employ an *in situ* calibration of the JES; this has the noticeable advantage of reducing the JES uncertainty with the collected luminosity. The Template Method consists in choosing a variable which is strongly correlated with the observable one wants to measure, and building distributions (templates) of this variable for simulated signal events (with different assumptions) and background events. The variable used to measure the M_{top} is a reconstructed invariant mass; the light quark dijet mass is chosen to simultaneously measure the JES. The Matrix Element aims to put all the available informations calculating a probability for the event to come from signal or background according to the theory predictions for the final state kinematics. Transfer functions are needed in order to convert reconstructed objects into kinematical tree-level quantities. For both techniques a likelihood will compare the data to the signal and background and its maximization will provide us the measured values.

The most precise measurement is performed using the ME in the semileptonic channel to simultaneously measure M_{top} and JES. The measured value amounts to:

$$M_{top} = 170.9 \pm 1.6(stat.) \pm 1.4(JES) \pm 1.4(syst.)\,\mathrm{GeV/c}^2\,. \tag{3}$$

There is an interesting trend in top mass analysis, consisting in the increasing precision achieved in the all-hadronic channel: thanks to the novel neural network approach it is now possible to extract the signal with high efficiency and purity; moreover, the hadronically decaying W's allow an *in situ* JES calibration as done in the lepton+jets case. Thanks to these two tools the all-hadronic top quark mass measurement is now the second most precise at CDF. Two different results are presented here: the first one, obtained using the Template Method after selecting events with a neural network, but without *in situ* JES calibration, gives:

$$M_{top} = 174.0 \pm 2.2(stat.) \pm 4.5(JES) \pm 1.5(syst.)\,\mathrm{GeV/c}^2\,. \tag{4}$$

The second employs a simpler selection and a mixed technique to extract the mass: a template is built out of the probability given by the matrix element computation, and a dijet mass is used to measure the JES; this result is now the most precise in this channel and corresponds to

$$M_{top} = 171.1 \pm 2.8(stat.) \pm 2.4(JES) \pm 2.1(syst.)\,\mathrm{GeV/c}^2\,. \tag{5}$$

The best measurement in each channel is then combined to give the very precise CDF average value of

$$M_{top} = 170.9 \pm 2.4(stat. + syst.)\,\mathrm{GeV/c}^2. \tag{6}$$

4. Other top properties

Semileptonic $t\bar{t}$ events are the best candidates to test SM predictions and non-SM particle production in the top sector; some of these analysis are presented here. According to the SM the W boson is produced 70% of the time with longitudinal helicity, and the rest with left-handed helicity. Right handed helicity is forbidden by the theory. A template method is used, the template variable being $cos\theta^*$, the cosine of the decay angle between the momentum of the charged lepton in the W boson rest frame and the W momentum in the top quark rest frame, which is highly sensitive to the W helicity. In order to determine the $cos\theta^*$ distribution in the data, the kinematics of the $t\bar{t}$ events are fully reconstructed. A likelihood fit gives

$$F^0 = \ \ 0.59 \pm 0.12(stat.)^{+0.07}_{-0.06}(syst.) \tag{7}$$

$$F^+ = -0.03 \pm 0.06(stat.)^{+0.04}_{-0.03}(syst.)\,, \tag{8}$$

which is well consistent with the Standard Model. Production mechanism is also tested using $t\bar{t}$ events. Having estabilished that the average number of low-P_T tracks is proportional to the gluon content of a sample, a template method is used to fit the data to a gluon-rich and a gluon-deprived track multiplicity distribution to measure the fraction of events produced through gluon-gluon fusion to be

$$\sigma(gg \to t\bar{t})/\sigma(p\bar{p} \to t\bar{t}) = 0.01 \pm 0.16(stat.) \pm 0.07(syst.)\,. \tag{9}$$

A recent analysis searches for non-SM production of heavy boson X^0 decaying to $t\bar{t}$ pairs. After fully reconstructing the events, the $t\bar{t}$ invariant mass distribution is scanned for possible peaks due to resonant production; choosing X^0 masses in the range 450-900 GeV/c^2, limits can be set to the product of the cross section times the branching ratio to top pairs. This limit amounts to $\sigma \times BR(X^0 \to t\bar{t}) < 0.8\,\mathrm{pb}$ at 95% confidence level for a X^0 mass greater than 600 GeV/c^2.

Finally, there are currently three analysis aiming to reveal the single top production which the SM predicts to have the very low cross section of 2.9 pb [4]. The most precise of these analysis uses a refined event selection and the knowledge of the matrix element of the process to measure

$$\sigma_t = 2.7^{+1.5}_{-1.3}\,\mathrm{pb} \tag{10}$$

with a statistical significance of $2.3\,\sigma$, thus giving no evidence yet.

5. Conclusions

The top program at the CDF experiment is very broad and aims to delineate the picture of this relatively young particle. The most important top parameter, M_{top}, is now measured with an unprecedented precision, i.e. 1.4% of the measured value. The main systematic uncertainty is reduced by calibrating *in situ* the jet energy scale, so that the mass measurement uncertainty is statistic dominated, and the same holds true for many other property measurements. Morever, the possibility to find an evidence of singly produced top quarks is now at hand. The Tevatron has already collected twice the data used here which once analzyed will provide answer to many questions while surprises can still come out.

Acknowledgments

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