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Measurements of the top quark pair cross section at DØ

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We present the most recent measurements of the top quark pair production cross section in proton antiproton collisions at $\sqrt{s} = 1.96$ TeV. These measurements are based on up to 5.3 fb^{-1} of data collected by the DØ experiment.

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1. Introduction

At the Tevatron, the top quark is mainly produced by pairs via strong interaction. In the Standard Model (SM), the top decays into a W boson and a b quark with a probability close to 100%. The final states are consequently defined by the decays of the two W bosons and are classified as *lepton+jets, dilepton* and *all hadronic* final states. Measuring the top pair cross section allows to test the Standard Model by comparing the measurements with the different NLO QCD calculations and to extract the top quark mass. The comparison between the different channels allows to probe new physics. The $t\bar{t}$ cross section is measured using the following formula:

$$\sigma_{t\bar{t}} = \frac{N_{observed} - N_{background}}{\varepsilon(m_t)L} \tag{1.1}$$

where $N_{observed}$ and $N_{background}$ are the number of data events observed after selection and the predicted number of background events. $N_{observed} - N_{background}$ can be evaluated either by counting or by fitting discriminating variables. L is the analyzed luminosity and $\varepsilon(m_t)$ is the signal selection efficiency evaluated using the simulation.

2. Lepton+jets final state

In the lepton+jets final state one W boson decays to a lepton (electron or muon) and the other W boson to jets. The signature for $t\bar{t}$ events is one high p_T isolated lepton, large missing transerve energy and four jets including two jets from b quarks. The main backgrounds come from W+jets events which is simulated but normalized to data before b-tagging and from multijets events where one jet fakes an isolated lepton. Two approaches have been used to measure the cross section: a fit to a likelihood discriminant using kinematic variables (invariant masses, sphericity, aplanarity...) and the use of b-tagging based on a neural network combining different b tagging algorithms using variables caracteristic of b quarks (vertex masses, vertex decay length significance...).

The combination of the two measurements leads to the value presented on Figure 4 [1]. The main systematic uncertainty comes from b-tagging efficiency and fake rate for the b-tag method and from selection efficiency for the likelihood method.

The top pair production cross section can also be evaluated simultaneously with the ratio R of top quark branching fractions defined as:

$$R = \frac{\mathscr{B}(t \to Wb)}{\mathscr{B}(t \to Wq)} = \frac{|V_{tb}^2|}{|V_{tb}^2| + |V_{ts}^2| + |V_{td}^2|}. \tag{2.1}$$

The SM prediction is $R \simeq 1$. This value is assumed for the standard cross section measurement. D0 performed the measurement and finds: $R = 0.97^{+0.09}_{-0.08}$ (stat+sys) and $\sigma_{t\bar{t}} = 8.18^{+0.90}_{-0.84}$ (stat+sys) $\pm$ 0.50 (lumi) pb [2]. This values are in good agreement with SM expectations.

A measurement of the inclusive differential cross section binned in top quark p_T has also been performed [3]. After substraction of the background and removal of resolution effects, the experimental distribution (see Figure 1) shows good agreement with the different theoretical calculations. The disagreement with Pythia [4] and Alpgen [5] expectations is due to normalization and not shape difference.

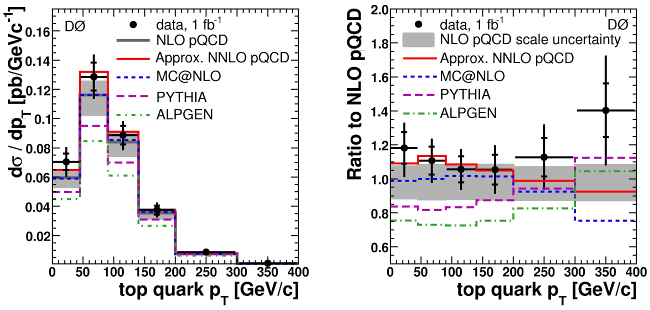

Figure 1: Inclusive $d\sigma/dp_T$ for $t\bar{t}$ production in lepton+jets channel compared with theoretical expectations and event generators [3].

3. Dilepton final state

In the dilepton final state the two W bosons decay to a lepton (electron or muon). The signature for $t\bar{t}$ events is two high p_T isolated leptons, large missing transerve energy and two jets from b quarks. The main background comes from Drell-Yan production. This background and the diboson background are simulated and normalized with NLO or NNLO theoretical cross sections. W+jets events can also be a background when a jet fakes a lepton: this contamination is evaluated from the data. In the three channels (ee, $\mu\mu$, $e\mu$), a topological approach has been used. To suppress the large Drell Yan background in the ee and $\mu\mu$ channels a multivariate discriminant (BDT) has been used.

The combined result for the three channels is showed on Figure 4 [6]. This result is systematically limited: the main systematics uncertainties come from electron identification for the ee channel, trigger efficiency determination for the $e\mu$ channel and MC background normalization for the $\mu\mu$ channel.

4. τ+lepton final state

In the τ+lepton final state one W boson decays to a lepton (electron or muon) and the second W boson decays to a τ lepton then decays hadronically (events where the τ is decaying leptonically are analyzed as part of the dilepton). The signature for $t\bar{t}$ events is one high p_T isolated lepton, one τ lepton, large missing transerve energy and two jets from b quarks. The τ lepton identification is challenging. The DØ collaboration uses neural networks based on isolation, energy profiles, track/calorimeter correlation... The physical backgrounds (Drell Yan and diboson) are identical to the dilepton channel. The W($\to l\nu$)+jets background is determined using both data and MC. The cross section measurement is showed on Figure 4 [7]. The dominant systematic uncertainty comes from MC background statistics.

Using the τ+lepton measurement, ratios of cross sections in different final states have been evaluated: they can be sensitive to non SM top decay (for instance the decay $t \to H^+b$ for light enough Higgs boson mass can compete with the SM decay $t \to W^+b$) [7]:

$$R^{ll/lj} = \sigma_{t\bar{t}}^{ll}/\sigma_{t\bar{t}}^{lj} = 0.86^{+0.19}_{-0.17} \quad R^{\tau l/ll+lj} = \sigma_{t\bar{t}}^{\tau l}/\sigma_{t\bar{t}}^{ll+lj} = 0.97^{+0.32}_{-0.29}. \tag{4.1}$$

These results are consistent with the SM expectations. Limits on $B(t \to H^+ b)$ for tauonic and leptophobic decaying H^+ in MSSM models can be consequently derived (see Figure 2).

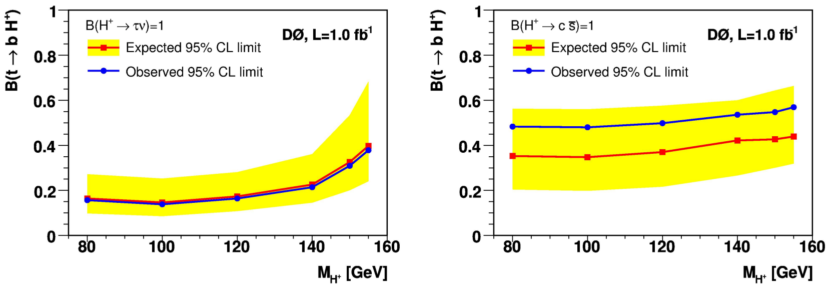

Figure 2: Upper limits on $B(t \to H^+ b)$ for tauonic (left) and leptophobic (right) H^+ decays [7].

5. All hadronic final state

In the all hadronic final state both W bosons decays to jets. The signature for $t\bar{t}$ events is six high p_T jets including two jets from b quarks and no lepton. In this channel, the background is dominated by multijet events. This large background can not be modeled by Monte Carlo: data have to be used. This model is based on 5-jets events with topology identical to 6-jet events: the lowest p_T jet from the 6-jet event is added to the 5-jet event to construct a 6-jet event. The method has been checked by constructing 5-jet events and comparing them to data (see Figure 3): the agreement is good.

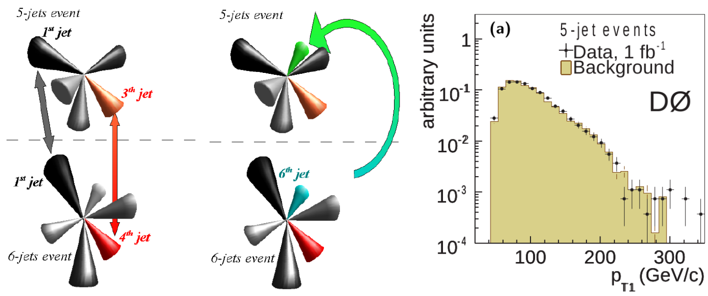

Figure 3: Construction of the background sample.

Since the signal over background ratio is still low after selection, we use a likelihood discriminant based on topological observables (rapidity difference between jets, centrality,...) to further separate signal from background. The result is showed on Figure 4 [9]. The dominant systematic uncertainties come from background model and jet energy calibration.

6. Extraction of the top quark mass from cross section measurement

The top quark mass can be extracted from the combined dilepton, lepton+jets and τ+lepton channel. This mass relies less on Monte Carlo simulations than direct measurements. For this extraction, a likelihood is built combining experimental and theoretical uncertainties. The result of

this extraction using the approximate NNLO theoretical calculation from [10] is :
$m_t = 169.1^{+5.9}_{-5.2}$ GeV [8], which is in good agreement with the world average mass :
$m_t = 173.1 \pm 1.3$ GeV [11].

7. Conclusion

The DØ collaboration has measured the top quark pair production in all channels (see Figure 4). All these measurements are in good agreement with the SM and with each other: there is no sign of new physics. Most of these measurements are now systematically limited: a work on improving the systematic uncertainties is now important to further improve the precision of the measurements.

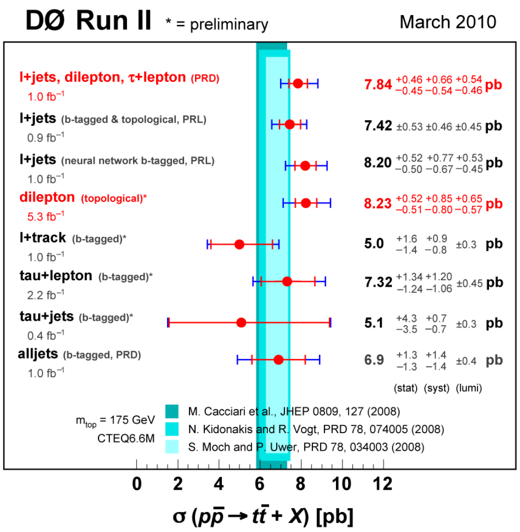

Figure 4: Summary of D0 top pair cross section measurements.

References

[1] *V.M. Abazov et al.*, PRL 100, 192004 (2008).

[2] *V.M. Abazov et al.*, PRL 100, 192003 (2008).

[3] *V.M. Abazov et al.*, arXiv: 1001.1900v1.

[4] `http://home.thep.lu.se/~torbjorn/Pythia.html`

[5] `http://mlm.home.cern.ch/mlm/alpgen/`

[6] *V.M. Abazov et al.*, DØ Note 6038 CONF.

[7] *V.M. Abazov et al.*, DØ Note 5607 CONF.

[8] *V.M. Abazov et al.*, PRD 80, 071102 (2009).

[9] *V.M. Abazov et al.*, FERMILAB-PUB-09-592-E (2009).

[10] *S.Moch and P.Uwer*, PRD 78, 0304003 (2008).

[11] *The Tevatron Electroweak Working Group*, arXiv:0903.2503 (2009).