Top quark cross section measurements with CMS

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1 Introduction

Measurement of the top quark production pair cross-section at the Large Hadron Collider (LHC) is important for many reasons. It probes the dynamics of heavy particle production at a new energy region. New physics can manifest itself in the production dynamics of top quarks. Understanding of top quark production paves the way toward precision measurements of top quark properties.

Within the Standard Model, the top quark decays predominantly to a W boson and a b quark. Depending on the subsequent decays of the W bosons, top quark pairs may decay into final states with zero, one, or two charged leptons from the decays of the W bosons. They are known as 'all hadronic', 'lepton+jets', and 'dilepton' channel, respectively.

The CMS Collaboration [1] has measured the production cross-section of top quark pairs in pp collisions at center-of-mass energy of 7 TeV. We present three measurements: one in dilepton channel, one in lepton+jets channel without explicit identification of jets from b quark, and one in lepton+jets channel with explicit identification of jets from b quark.

The MadGraph event generator is used to model $\mathrm{t\bar{t}}$ signal production, as well as background from W+jets, Z/γ+jets, and single top productions. The CMS detector is required to be in good operational condition during the period of data recording. The amount of data recorded after this requirement is 36 ± 4 pb^{-1}.

2 Cross section in the dilepton channel

In the dilepton channel, events are collected using lepton triggers which require the presence of either a muon, or one or two electrons. The main background in this channel comes from Z/γ+jets events, which is normalised in the region where the invariant mass of the dilepton pair is between 76 GeV/c^2 and 106 GeV/c^2. Jets from b quark decay are identified, but not explicitly required in the event selection.

The selected event sample is divided into subsamples with one and two or more jets for each specific decay modes, a total of six channels. The sample with at least one jet from b quark, is divided into subsamples of specific decay modes. The top quark pair production cross-section is measured in all nine channels and then combined using the BLUE method [2]. The top quark pair production cross-section is measured to be $\sigma_{t\bar{t}} = 168 \pm 18(\text{stat.}) \pm 14(\text{syst.}) \pm 7(\text{lumi})$ [3]. The principal source of systematic uncertainty is lepton identification, factorization scale, and b jet identification.

3 Cross section in the lepton+jets channel

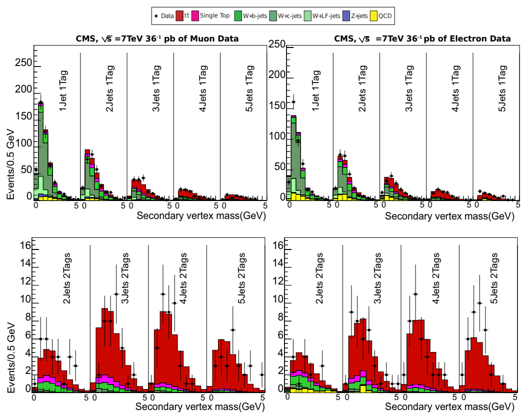

Figure 1: The simultaneous fit over electron+jets and muon+jets sample, with one and two or more b jets.

In the lepton+jets channel, events are collected using single lepton triggers. The particle flow algorithm [4] is used to reconstruct jets and missing transverse energy in order to obtain the best energy resolution.

The measurement without b quark identification uses the difference in kinematic properties between top quark pair events and background events. The event samples are divided into subsamples of three jets and four or more jets. In the three-jet subsample, missing transverse energy is used as discriminating variable. In the four or more jets subsample, the quantity M3 is used as discriminating variable, where M3 is the invariant mass of the three jet combination which has the highest vectorial sum of transverse momentum. Monte Carlo simulations are used to obtain templates of signal and background, with the exception of the template for background from QCD, which is derived using a data-driven method. The output from a simultaneous fit over all subsamples is used as the estimator in the Neyman construction with 50,000 pseudo experiments. The top quark pair production cross-section is measured to be $\sigma_{\mathrm{t\bar{t}}} = 173^{+39}_{-32}(\mathrm{stat.} + \mathrm{syst.}) \pm 7(\mathrm{lumi})$ [5]. The principal source of systematic uncertainty is jet energy scale.

The measurement with b quark identification uses events that have one or more jets, one of which must be identified to come from b quark. This measurement uses a novel method which fits two variables simultaneously: one variable discriminates between events with and without heavy flavor content, and one variable discriminates between events with and without high jet multiplicity. This methods alleviate the difficulties with normalization of W+heavy flavor events which often are not modeled precisely.

A simultaneous fit of the secondary vertex mass of the leading b jet over samples with different jet multiplicity is then used to extract the amount of signal and background events. Figure 1 shows the results of this simultaneous fit. Most of the systematic uncertainties are included as nuisance parameters in the fit. This method yields the most precise results among the three measurements presented. The top quark pair production cross-section is measured to be $\sigma_{\mathrm{t\bar{t}}} = 150 \pm 9(\mathrm{stat.}) \pm 17(\mathrm{cyst.}) \pm 6(\mathrm{lumi})$ [6]. The principal source of systematic uncertainty is jet energy scale, b jet identification, and factorization scale.

4 Combined cross-section

A combination of measurements in the dilepton channel and in the lepton+jets channel with b jet identification is performed using a profile likelihood method. The method is validated using pseudo-experiments, from which an underestimation of the total uncertainty is discovered and corrected. In the combination, the top quark pair production cross-section is measured to be $\sigma_{\mathrm{t\bar{t}}} = 154 \pm 17(\mathrm{stat.} + \mathrm{syst.}) \pm 6(\mathrm{lumi})$ [6].

Figure 2 shows the results of all three measurements and the combined result, as well as a comparison of the CMS and Tevatron results. Our results agree with theoretical calculation at NLO and approximate NNLO.

References

[1] S. Chatrchyan *et al.* [CMS Collaboration], "The CMS experiment at the CERN LHC," JINST **3** (2008) S08004.

[2] L. Lyons, D. Gibaut and P. Clifford, "How to combine correlated estimates of a single physical quantity," Nucl. Instrum. Meth. A **270** (1988) 110.

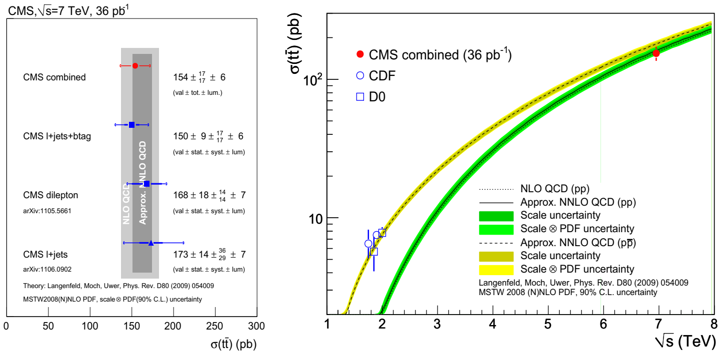

Figure 2: Left: Summary of CMS measurements of top quark pair production cross-section on 2010 LHC data. Right: Summary of measured top quark pair production cross-section from CMS and Tevatron experiments.

[3] S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the $t\bar{t}$ production cross section and the top quark mass in the dilepton channel in pp collisions at $\sqrt{(s)} = 7$ TeV," JHEP **1107** (2011) 049 [arXiv:1105.5661 [hep-ex]].

[4] CMS Collaboration, "Commissioning of the Particle-Flow Reconstruction in Minimum-Bias and Jet Events from pp collisions at 7 TeV", **CMS-PAS-PFT-10-002**, 2010.

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[6] S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the $t\bar{t}$ Production Cross Section in pp Collisions at 7 TeV in Lepton + Jets Events Using b-quark Jet Identification," arXiv:1108.3773 [hep-ex].