

# Measurement of the $t\bar{t}$ production cross section in the dilepton channel in proton-proton collisions at $\sqrt{s} = 8$ TeV with the CMS experiment

Jan Kieseler for the CMS Collaboration

Deutsches Elektronen-Synchrotron (DESY), Notkestraße 85, 22607 Hamburg, Germany

E-mail: [jan.kieseler@desy.de](mailto:jan.kieseler@desy.de)

**Abstract.** The cross section for top quark pair production is measured in proton-proton collisions at  $\sqrt{s} = 8$  TeV in a data sample corresponding to  $2.4 \text{ fb}^{-1}$  of integrated luminosity collected by the CMS experiment in 2012. The measurement is performed with events with two leptons (electrons or muons), as well as with identified b-quark jets in the final state. The combined measured cross section is  $\sigma_{t\bar{t}} = 227 \pm 3 \text{ (stat.)} \pm 11 \text{ (syst.)} \pm 10 \text{ (lumi.) pb}$ , in agreement with theoretical predictions.

## 1. Introduction

A precise measurement of the  $t\bar{t}$  production cross section in proton-proton (pp) collisions at the Large Hadron Collider (LHC) offers a benchmark for the production mechanism of other processes also dominated by gluon-gluon fusion. Moreover, it can be used to validate calculations in quantum chromodynamics or to provide constraints on parton distribution functions. An accurate understanding of the  $t\bar{t}$  production and decay is also crucial for searches for new physics processes that show a similar event topology.

Here, the measurement [1] of the  $t\bar{t}$  production cross section in pp collisions at  $\sqrt{s} = 8$  TeV with the CMS experiment [2] is described. It is performed in the dileptonic decay mode using data corresponding to an integrated luminosity of  $2.4 \text{ fb}^{-1}$  delivered by the LHC in 2012 and compared to standard model predictions at approximate next-to-next-to-leading order (NNLO).

## 2. Event Selection and Simulation

The event selection is based on the decay topology of the  $t\bar{t}$  pair in the dilepton channel, where both  $W$ -bosons from the decay  $t\bar{t} \rightarrow W^+W^-b\bar{b}$  subsequently decay to a lepton and a neutrino. Therefore, dilepton triggers are used. These are based on the presence of two high transverse momentum ( $p_T$ ) leptons, in particular electrons or muons.

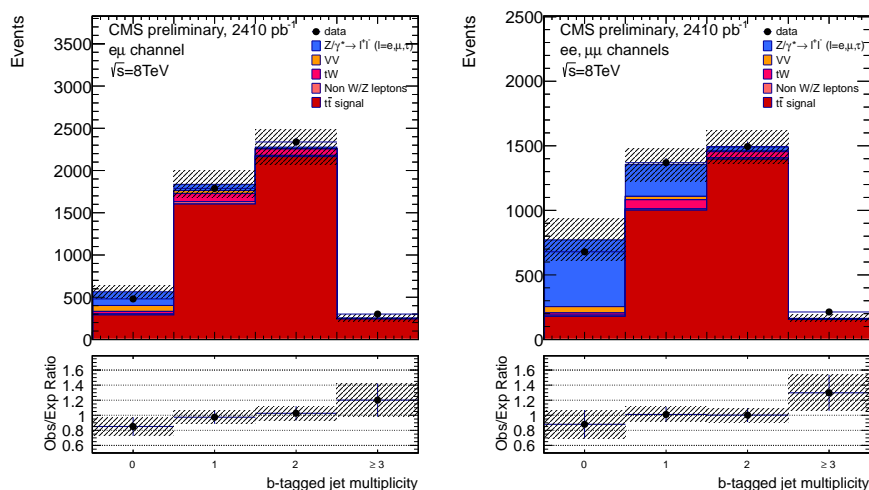
Proton-proton collision events are selected with at least two oppositely charged isolated leptons and two jets of which one is identified as a b-jet. The leptons are required to have  $p_T > 20$  GeV and a pseudorapidity  $|\eta| < 2.5$  ( $e$ ) or  $|\eta| < 2.4$  ( $\mu$ ). Jets are selected with  $p_T > 30$  GeV and  $|\eta| < 2.5$ . Jets originating from the b-quarks are identified using combined secondary vertex and track-based lifetime information. Events with heavy flavor resonance decays with a dilepton mass  $M_{ll} < 20$  GeV are removed in all channels. Contributions from Z production in the  $e^+e^-$  and  $\mu^+\mu^-$  decay modes are further reduced by requiring  $M_{ll}$  to be



outside a Z mass window of  $91 \pm 15$  GeV and  $\cancel{E}_T > 40$  GeV. Figure 1 shows the multiplicity of b-tagged jets after applying the aforementioned selection.

The simulation of signal and background events is performed using Monte Carlo (MC) event generators. The signal events are modeled by MADGRAPH. The background contributions from Drell-Yan (DY) production, W+jets events and WW processes are generated with MADGRAPH, WZ and ZZ contributions with PYTHIA, and the single top-quark background with POWHEG. In all cases, the subsequent hadronization and parton showering are simulated with PYTHIA.

Among all of the simulated background contributions, only those from single-top-quark production and diboson (VV, where V=W or Z) are used to estimate the absolute number of background events. The remaining background events are estimated using data-based methods.



**Figure 1.** Multiplicity of b-tagged jets after the full event selection except the b-tag requirement for the  $e^\pm\mu^\mp$  (left) and the summed  $e^+e^-$  and  $\mu^+\mu^-$  channels (right). The corresponding data-to-simulation ratios are also shown.

### 3. Background Determination

DY processes are the dominant background in the  $e^+e^-$  and  $\mu^+\mu^-$  final states. Their contribution is estimated using the Z invariant mass interval as a control region to rescale the DY contamination in the signal region. The contribution of non-DY background in the control region is subtracted using the  $e^\pm\mu^\mp$  channel taking into account the corresponding lepton efficiencies. The DY background in the  $e^\pm\mu^\mp$  final state is mainly dominated by Z processes with subsequent  $\tau$  decays. Here, the DY contribution is estimated by fitting the dilepton invariant mass distribution in data taking into account the remaining backgrounds.

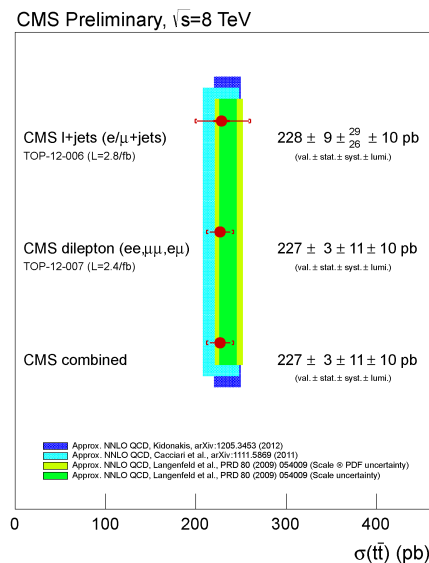
The contamination from events with non-W/Z leptons is extrapolated from an estimate at 7 TeV with a data-based method by comparing the yields of opposite-sign ( $N_{OS}$ ) and same-sign ( $N_{SS}$ ) dilepton events. The ratio  $R_{OS/SS}$  of these yields is assumed to be independent of the center-of-mass energy. Thus, the number of background events with non-W/Z leptons can be estimated by counting the number of same-sign dilepton events at 8 TeV as

$$N_{OS}(8 \text{ TeV}) = N_{SS}(8 \text{ TeV}) \cdot R_{OS/SS}(7 \text{ TeV}).$$

#### 4. Cross Section Determination

The  $t\bar{t}$  production cross section  $\sigma_{t\bar{t}}$  is determined by a cut-and-count approach in each dilepton channel separately. The combination of all three channels, using the BLUE method, results in a cross section of  $\sigma_{t\bar{t}} = 227 \pm 3$  (stat.)  $\pm 11$  (syst.)  $\pm 10$  (lumi) pb. The dominant systematic uncertainties contributing to the combined measurement come from the jet energy scale (2.5%), the trigger and lepton efficiencies (1.8%), the jet energy resolution (1.7%), the branching ratios (1.7%), and the determination of the non-W/Z background (1.4%).

The measured  $t\bar{t}$  cross section is combined with the corresponding measurement [3] in the lepton plus jets channel ( $l$ +jets) and compared to different theory predictions, see Figure 2.



**Figure 2.** The  $t\bar{t}$  cross section measurements using different decay modes,  $l$ + jets and dilepton, and their combination. The vertical band shows different theory predictions at approximate NNLO.

#### 5. Summary

CMS has performed a measurement of the  $t\bar{t}$  cross section in the dilepton final states using event candidates containing two opposite sign leptons, two jets, and requiring the presence of missing transverse energy. To further disentangle signal and background, b-tagging information is used as an additional selection requirement on at least one of the jets. The DY contribution is estimated from data as well as the non-W/Z contribution. For a top-quark mass of 172.5 GeV, the  $t\bar{t}$  cross section is measured to be  $\sigma_{t\bar{t}} = 227 \pm 3$  (stat.)  $\pm 11$  (syst.)  $\pm 10$  (lumi) pb, in agreement with standard model predictions.

#### References

- [1] The CMS Collaboration, *Measurement of the  $t\bar{t}$  production cross section in the dilepton channel in pp collisions at  $\sqrt{s} = 8$  TeV*, PAS-TOP-12-007 (2012)
- [2] The CMS Collaboration, *The CMS experiment at the CERN LHC*, JINST 03 (2008) S08004
- [3] The CMS Collaboration, *Top pair cross section in  $e/\mu$ +jets at 8 TeV*, PAS-TOP-12-006 (2012)