PROCEEDINGS OF SCIENCE

Measurement of the top quark pair production cross section at 13 TeV with the CMS detector

Till Arndt[*†]
Deutsches Elektronen-Synchrotron Hamburg and Zeuthen (DE)
E-mail: till.michael.arndt@cern.ch

Since the discovery of the top quark in 1995 at the Fermilab Tevatron collider, the $t\bar{t}$ production cross section has been measured with ever higher precision. By now, no deviation from the standard model has been found. The LHC restarts around mid 2015, and it enables us to measure $t\bar{t}$ production at a previously unreached energy of 13 TeV. In this presentation, the very first $t\bar{t}$ cross section measurement from CMS using the electron-muon final state is discussed. Moreover, detector related efficiencies are outlined and the measurement is compared to theory predictions.

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*Speaker.
†A footnote may follow.

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1. Introduction

The study of top-quark production is an important check of the Standard Model (SM) predictions, and may possibly shed light on anomalous processes. At the LHC top quarks are predominantly produced in pairs and these proceedings are concerned with the first measurement of the top-quark pair production cross section at a center-of-mass energy $\sqrt{s} = 13$ TeV. The described measurement serves as an important test of the SM at a previously unreached center-of-mass energy and it has the potential to discover first hints of possible Beyond-Standard-Model (BSM) contributions to top-quark pair production.

The main goal of the presented analysis is to provide a robust measurement of the top-quark pair-production cross section and for this reason the cut-and-count approach is chosen as a well established measurement strategy.

The final result for the $t\bar{t}$ cross section is computed as:

$$\sigma(t\bar{t}) = \frac{N_{\text{Data}} - N_{\text{Bkg}}}{A \cdot \varepsilon \cdot \text{BR} \cdot \int \mathscr{L}}. \tag{1.1}$$

Here the efficiency ε and the acceptance A are determined from simulation and cross checked from data where possible. The number of events in data N_{Data} is measured and determination of the number of background events N_{Bkg} is described below. The branching ratio BR is taken from the theory prediction and $\int \mathscr{L}$ denotes the integrated luminosity used in the analysis.

2. Analysis Setup

The presented analysis uses an integrated luminosity of $\int \mathscr{L} = 42$ pb^{-1} taken in June 2015 with the CMS detector.

Events in data and simulation are selected if they include an opposite sign muon-electron pair with an invariant mass of $m_{ll} > 20$ GeV where the leptons have transverse momenta $p_T > 20$ GeV and pseudo rapidities $|\eta| < 2.4$. Collision events have been recorded using a dilepton trigger. After the dilepton selection step, events are additionally required to include two jets with transverse momenta $p_T > 30$ GeV and pseudo rapidities $|\eta| < 2.4$ to be considered for the final cross section measurement.

Figure 1 shows consistency between data and simulation. It also shows that the final selection of two more jets is dominated by $t\bar{t}$ events. A detailed breakdown of the event yields is given in Table 1.

Figure 2 shows similar agreement between data and simulation after the complete event selection. The two distributions are sensitive to possible BSM scenarios: the invariant mass distribution of the two leptons is sensitive to a resonance whereas the angle between the leptons is sensitive to non-SM spin correlations. No deviations are found within the statistical uncertainty of the data.

The backgrounds are normalized to the amount of data using the theory predictions for their cross sections and the luminosity in data. The diboson and single-top backgrounds are taken from simulation, whereas the normalization for Drell-Yan and non-W/Z leptons backgrounds are determined with data-driven methods: The contribution from Drell-Yan is normalized to the Z-peak in data and the Non-W/Z contribution is obtained from a same-sign control region in data while using a scale factor to the opposite sign signal region obtained from simulation.

PoS(TOP2015)026

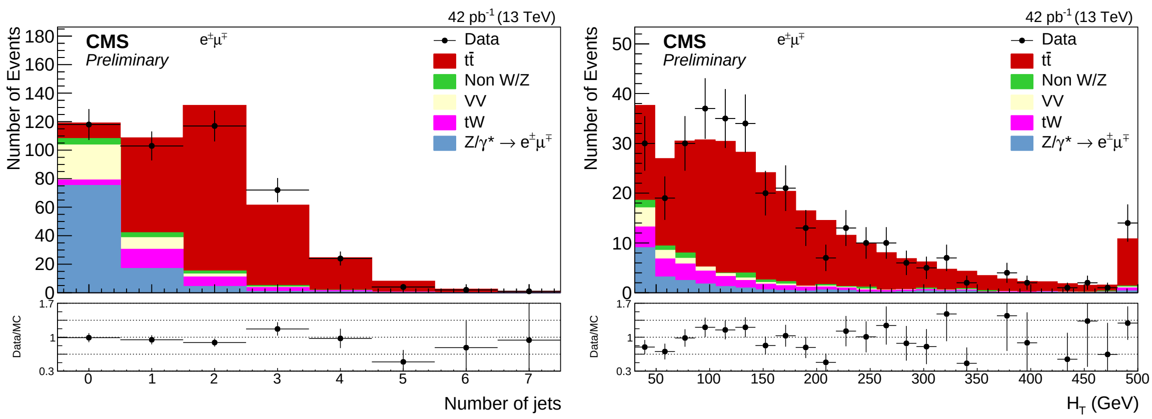

Figure 1: The jet multiplicity (a) and H_T (b) distributions for events with an oppositely charged e-μ pair. The last bin contains overflow events and the ratio between data and simulation is shown below the distributions [1].

Source	Number of events $e^{\pm}\mu^{\mp}$
Drell–Yan	6.4 ± 1.2
Non-W/Z leptons	8.5 ± 4.3
Single top quark	10.6 ± 3.4
VV	2.6 ± 0.9
Total background	28.1 ± 5.7
$t\bar{t}$ dilepton signal	207 ± 16
Data	220

Table 1: Number of dilepton events obtained after the full selection. The uncertainties correspond to the statistical and systematic components added in quadrature. [1]

3. Systematic Uncertainties

A systematic uncertainty (without luminosity uncertainty) of 8.0 %, a luminosity uncertainty of 12 % and a statistical uncertainty of 7.7 % on the $t\bar{t}$ cross section are determined in the measurement. In order to obtain the total uncertainty all contributions are added in quadrature.

The dominant systematic uncertainties are due to integrated luminosity (12 %), the trigger efficiencies (5 %) and lepton identification (4.3 %). All of these three uncertainties are expected to be reduced significantly by the end of LHC Run II.

4. Result

For the assumption of a top mass of $m_t = 172.5$ GeV the $t\bar{t}$production cross section is measured as $\sigma(t\bar{t}) = 772 \pm 60(\text{stat.}) \pm 62(\text{syst.}) \pm 93(\text{lumi.})$ pb. As shown in Figure 3 this result is in agreement with the theory prediction as well as the CMS measurement in the semi-leptonic $t\bar{t}$ decay channel.

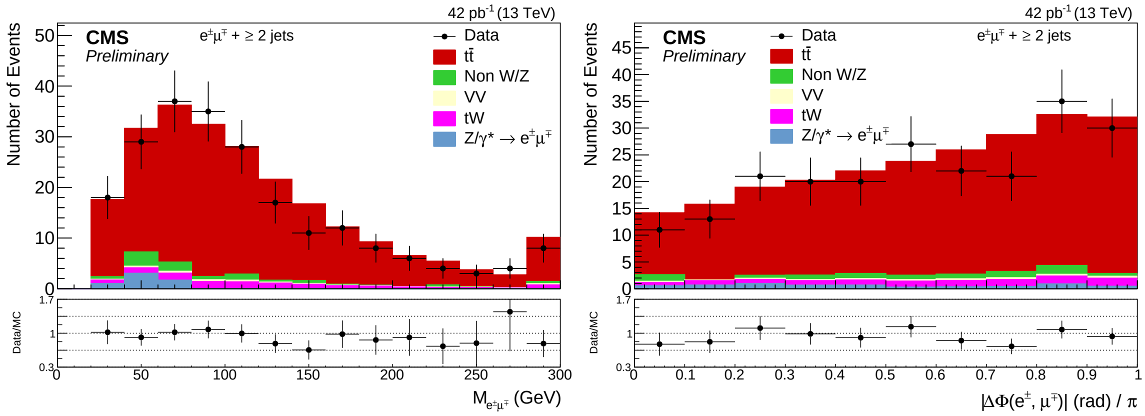

Figure 2: The invariant mass of the dilepton system (a) and the azimuthal opening angle between the two leptons (b) for events with an oppositely charged e-μ pair and two additional jets. The last bin contains overflow events and the ratio between data and simulation is shown below the distributions [1].

In conclusion the measured cross section agrees with the SM prediction and no hints for new physics are observed. The statistical and systematic uncertainties are expected to improve significantly with more data from LHC run-II.

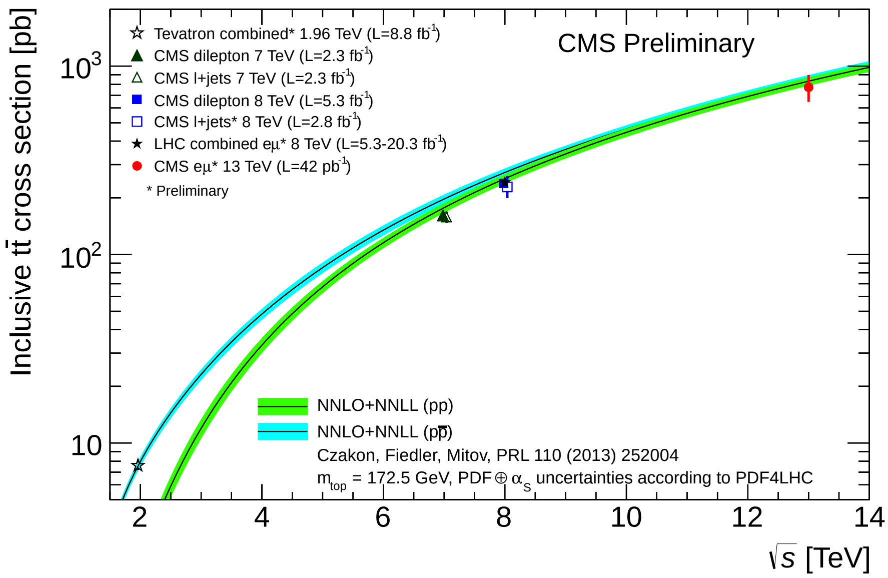

Figure 3: Summary of top-quark pair production cross section measurements in comparison with the theory prediction as a function of the center-of-mass energy. [1]

References

[1] The CMS Collaboration, "*Measurement of the top quark pair production cross section in proton-proton collisions at sqrt(s)=13 TeV with the CMS detector*", CMS PAS TOP-15-003