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Measurement of the inclusive top-pair production cross section at $\sqrt{s} = 13$ TeV with the CMS detector in the dilepton final state.

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The inclusive cross section for top-quark pair production is measured in proton-proton collisions at a centre-of-mass energy of 13 TeV with the CMS experiment at the LHC. The measurement is performed with events containing an opposite charge electron-muon pair and at least 2 jets, one of which is identified as a b-jet. Background estimates are obtained using data driven techniques as much as possible and a event counting is used for the final measurement.

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1. Introduction and motivation

The measurement of the top-antitop ($t\bar{t}$) production cross section provides an excelent test for the predictions of quantum chromodynamics (QCD). Precision measurements of this cross sections allow for a test of his energy dependence as predicted by QCD; they can also place constrains on the parton distribution functions (PDFs), the value of top-quark pole mass and plenty of parameters in physical scenarios beyond the Standard Model.

The $t\bar{t}$ production cross section at $\sqrt{s} = 13$ TeV was first measured by CMS with the early data taken [1] and now a precision measurement using a luminosity of 2.2 fb^{-1}, collected by CMS in 2015 during the Run2 is presented [2]. The value of the cross section is extracted using an event-counting methon and calculated with the next formula:

$$\sigma_{t\bar{t}} = \frac{N_{data} - N_{bkg}}{\int \mathscr{L} dt \cdot \mathscr{A}},$$

where N_{data} is the number of events observed in data after the selection, N_{bkg} is the expected number of background events and $\mathscr{A}$ is the total acceptance of the selection.

2. Event Selection

In the Standard Model (SM) top-quarks are mostly produced in $t\bar{t}$ pairs. These quarks mostly decay into a b-quark and a W boson. We will consider final states where both W bosons decay leptonicaly, having in the final state one opposite-charge electron-muon pair. All particles are reconstructed using the particle flow (OF) algorithm [3] . Both the electron and the muon are required to have a p_{T} of at least 20 GeV and $|\eta| < 2.4$ and they must be isolated.

The selected dilepton pair must reconstruct an invariant mass greated than 20 GeV. Also, selected events must have at least two reconstracted jets. Jets are reconstructed from PF candidates, using an anti-k_t clustering algorithm with a distance parameter of 0.4. Also, selected jets must have a p_{T} of at least 30 GeV and $|\eta| < 2.4$.

Furthermore, as the final state contains two b-quarks, selected events must have at least one b-tagged jet (b-jet). This requirement reduces the backgroud contamination from DY and W+Jets production. Jets are identified as b-jets using the combined secondary vertex algorithm [4] with an operating point which yields an identification efficiency of 67% and a misidentification probability of about 1%.

3. Background determination

Background events are mostly produced from single top (tW) process, DY production or VV production. The DY event yield is estimated from data using the $R_{out/in}$ method, where events with same-flavour leptons are used to calculate a data-to-MC factor, estimated using the number of events in data within a 15 GeV window around the Z boson mass and extrapolating outside the window. The scale factor obtained to normalize the MC simulation is of 0.92 ± 0.05.

Other background sources, such as $t\bar{t}$ in the lepton + jets final state or W+jets production can contaminate the signal if a jet is incorrectly reconstructed as a lepton, or a lepton is incorrectly identified as being isolated. These events are grouped into a "NonW/Z leptons" category. This instrumental background is estimated using events in a same-sign region in data, with the standard selection but the electron and the muon must have a charge with same sign.

Other backgounds are estimated from MC. The estimated yields can be found in Table 1.

Source	Number of $e^{\pm}\mu^{\mp}$ events
Drell–Yan	46 ± 5 ± 7
Non-W/Z leptons	101 ± 8 ± 30
Single top quark	464 ± 6 ± 145
VV	15 ± 2 ± 5
$t\bar{t}\,V$	31 ± 1 ± 10
Total background	657 ± 11 ± 148
$t\bar{t}$ signal	10197 ± 14 ± 445
Data	10368

Table 1: Number of events obtained after applying the full selection for $t\bar{t}$ and background estimates and data. The uncertainties correspond to statistical and systematic components.

4. Systematic uncertainties

The measurement of the cross section is affected by systematic uncertainties originated from several sources. These uncertainties are sumarized in Table 2.

Some of the most important experimental systematic uncertainties are given by the uncertainty in the trigger efficiency scale factor (SF) applied to simulation to correct for differences with respect to data, which is 1.1%, or the uncertainty in the SF applied to correct the electron (muon) identification efficiency, that is found to be about 1.8% (1.5%). The measurement is also afected by the uncertainty in the jet energy scale (JES) which is estimated by comparing the change in the number of simulated $t\bar{t}$ events after varying the jet momenta within JES uncertainties (2.1%).

The largest of the modelling uncertainties is given by the NLO generator (2.1%), comparing the prediction for the number of signal events from the nominal POWHEG sample and from a sample generated with MC@NLO. The uncertainty in the background estimation is dominated by de uncertainty on single top modelling (1.5%).

5. Results

The measured cross section is:

$$\sigma_{t\bar{t}} = 792 \pm 8\ (stat) \pm 37\ (syst) \pm 21\ (lumi)\ pb,$$

which is consistent with the SM prediction of $\sigma_{t\bar{t}} = 832^{+40}_{-46}$ pb for a top quark mass of 172.5 GeV.

Source	$\Delta\sigma_{t\bar{t}}$ (pb)	$\Delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}}$ (%)
Trigger efficiencies	9.7	1.2
Lepton efficiencies	18.3	2.3
Lepton energy scale	<1	≤ 0.1
Jet energy scale	16.9	2.1
Jet energy resolution	0.8	0.1
b tagging	10.6	1.3
Mistagging	<1	≤ 0.1
Pileup	1.4	0.2
μ_F and μ_R scales	<1	≤ 0.1
$t\bar{t}$ NLO generator	16.8	2.1
$t\bar{t}$ hadronization	5.9	0.7
Parton shower scale	6.3	0.8
PDF	4.8	0.6
Single top quark	11.8	1.5
VV	<1	≤ 0.1
Drell–Yan	<1	≤ 0.1
Non-W/Z leptons	2.5	0.3
$t\bar{t}V$	<1	≤ 0.1
Total systematic (no integrated luminosity)	36.8	4.6
Integrated luminosity	21.4	2.7
Statistical	8.3	1.0
Total	43.4	5.5

Table 2: Summary of the individual contributions to the uncertainty in the $\sigma_{t\bar{t}}$ measurement. The first and second uncertainty corresponds to the total and relative component, respectively.

References

[1] CMS Collaboration, "*Measurement of the top quark pair production cross section in proton-proton collisions at* $\sqrt{s} = 13$ *TeV*, *Phys. Rev. Lett.*" **116** (2016) 052002, doi:10.1103/PhysRevLett.116.052002, arXiv:1510.05302.

[2] CMS Collaboration, "*Measurement of the* $t\bar{t}$ *production cross section using events in the* $e\mu$ *final state in pp collisions at* $\sqrt{s} = 13$ *TeV*", submited to *Eur. Phys. J. C.*, arxiv:1611.04040

[3] CMS Collaboration, "*Commissioning of the Particle-flow Event Reconstruction with the first LHC collisions recorded in the CMS detector*", CMS Physics Analysis Summary CMS-PAS-PFT-10-001, 2010.

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