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Inclusive $t\bar{t}$ production cross section at $\sqrt{s}$ = 5.02 TeV in CMS

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The top quark pair production cross section is measured in proton-proton collisions at a centre-of-mass energy of 5.02 TeV. The data collected in 2017 by the CMS experiment at the LHC corresponding to an integrated luminosity of 304 pb^{-1} are analysed. The measurement is performed using events with one electron and one muon of opposite sign, and at least two jets. The measured cross section is found to be 60.3 ± 5.0 (stat) ± 2.8 (syst) ± 0.9 (lumi) pb. To reduce the statistical uncertainty, a combination with the result in the ℓ + jets channel, based on 27.4 pb^{-1} of data collected in 2015 at the same centre-of-mass energy, is then performed, obtaining a value of 62.6 ± 4.1 (stat) ± 3.0 (syst+lumi) pb, with a total uncertainty of 7.9%, in agreement with the standard model.

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1. Introduction

The top quark is the heaviest particle of the standard model (SM). The study of its properties and production modes is one of the core elements of the LHC physics programme. At the LHC, top quarks are mainly produced in pairs ($\mathrm{t\bar{t}}$ process).

In this document, a measurement of the $\mathrm{t\bar{t}}$ production cross section in pp collisions at 5.02 TeV centre-of-mass energy is presented. The analysis is performed using data recorded with the CMS detector [1] in 2017 corresponding to an integrated luminosity of 304 pb^{-1}. The cross section is extracted performing a counting experiment and using events with two opposite-sign different-flavour leptons ($\mathrm{e}^{\pm}\mu^{\mp}$ channel) and at least two jets. This result is combined with the measured cross section from the ℓ + jets channel based on 27.4 pb^{-1} of data collected in 2015 at 5.02 TeV [2].

2. Methodology

Events are selected online using a two-tiered trigger system. The first level (L1) is composed of a farm of custom hardware processors that select events at a rate of 100 kHz. The second level is known as the high-level-trigger (HLT), and runs an optimised version of the full event reconstruction for fast processing. It reduces the event rate down to 1 kHz which is possible to store. Events passing at least one of the single lepton triggers with transverse momentum (p_{T}) thresholds greater than 12 (17) GeV in the case of muons (electrons) are considered.

Several selection criteria are considered for the objects present in the analysis. Reconstructed electrons must satisfy $p_{\mathrm{T}} > 10$ GeV and $|\eta| < 2.5$, muons $p_{\mathrm{T}} > 10$ GeV and $|\eta| < 2.4$ and jets $p_{\mathrm{T}} > 25$ GeV and $|\eta| < 2.4$. Leptons must be consistent with originating from the primary vertex. The primary vertex is defined as the vertex with the highest sum of p_{T}^2 of all the particles coming from it. Finally, non-isolated electrons and muons are vetoed.

Events with one electron and one muon of opposite charge and with two or more jets in the final state are selected. The leading lepton is required to have $p_{\mathrm{T}} > 20$ GeV to ensure successful trigger reconstruction. In addition, events must have a dilepton invariant mass above 20 GeV. This reduces backgrounds from low mass resonances and from photon conversions.

After the event selection, the cross section is measured by performing a counting experiment subtracting background from data. The main background events arise from tW, Drell-Yan (DY) and VV processes, where V refers to the vector bosons $\mathrm{W}^{\pm}$ and Z^0. The tW and VV contributions are estimated from simulation and the DY events from data using the $R_{\mathrm{out/in}}$ method [3]. Other residual background sources, such as semileptonic $\mathrm{t\bar{t}}$ or W + jets events, may contaminate the signal when a jet is misreconstructed as a lepton, or contains a lepton from a hadron decay. These events are grouped into the nonprompt lepton category, and its contribution is estimated from simulation.

In Fig. 1, distributions of the p_{T} of the two leptons in the event, the p_{T} of the leading jet and the jet multiplicity of the selected events are presented. The contributions of each process are stacked to compare them with the experimental data points. At the bottom of each figure, the ratio between data and the prediction is presented. In general, good agreement is observed.

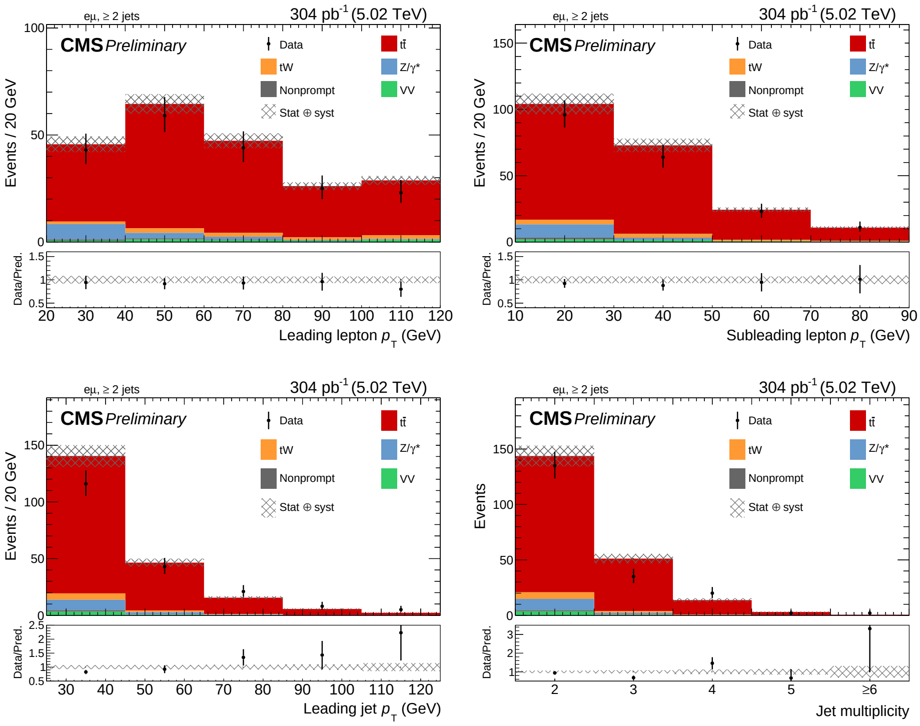

Figure 1: Leading lepton p_T (top-left), sub-leading lepton p_T (top-right), leading jet p_T (bottom-left) and jet multiplicity (bottom-right) in the selected events. The hatcheds band corresponds to systematic and statistical uncertainties [4].

3. Results

The inclusive cross section of $\mathrm{t\bar{t}}$ is obtained using

$$\sigma_{\mathrm{t\bar{t}}} = \frac{N_{\mathrm{obs}} - N_{\mathrm{bkg}}}{\varepsilon \mathcal{A} \mathcal{B} \mathcal{L}}. \tag{1}$$

Where N_{obs} is the number of observed events; N_{bkg} is the number of estimated background events; $\mathcal{L}$ is the integrated luminosity, $\mathcal{B}$ is the branching fraction of W boson pair to $\mathrm{e}^{\pm}\mu^{\mp}$ of 3.194%, $\mathcal{A}$ is the total acceptance defined as the fraction of all $\mathrm{t\bar{t}} \rightarrow \mathrm{e}^{\pm}\mu^{\mp}$ events fulfilling the aforementioned selection criteria, and ε is the event selection efficiency.

The measurement of $\sigma_{\mathrm{t\bar{t}}}$ is affected by sources of systematic uncertainty that originate from detector effects or from the modelling of the processes. The effect of each systematic uncertainty on $\sigma_{\mathrm{t\bar{t}}}$ is evaluated by repeating the measurement with dedicated simulation samples with different settings (modelling uncertainty) or with variations of the input parameters by $\pm 1\sigma$ (experimental uncertainty). The total uncertainty is calculated by adding the effects of all the individual systematic components in quadrature, assuming they are independent.

The measured inclusive cross section for a top quark mass of 172.5 GeV is

$$\sigma_{\mathrm{t\bar{t}}} = 60.3 \pm 5.0(\mathrm{stat}) \pm 2.8(\mathrm{syst}) \pm 0.9(\mathrm{lumi})\ \mathrm{pb} = 60.3 \pm 5.5(\mathrm{tot})\ \mathrm{pb}. \tag{2}$$

To reduce the statistical limitation, a combination with the ℓ + jets channel of Ref. [2] is performed using the Best Linear Unbiased Estimator (BLUE) [5, 6]. The resulting cross section is

$$\sigma_{t\bar{t}} = 62.6 \pm 4.1(\text{stat}) \pm 3.0(\text{syst+lumi})\ \text{pb} = 62.6 \pm 5.0(\text{tot})\ \text{pb}, \tag{3}$$

which represents an improvement from a total uncertainty of 13% from [2] to 7.9%. Also, this result is in agreement with the SM prediction

$$\sigma_{t\bar{t}}^{SM} = 66.8 \pm^{1.9}_{2.3} (\text{scale}) \pm 1.7(\text{PDF}) \pm^{1.4}_{1.3} (\alpha_S(m_Z))\ \text{pb}, \tag{4}$$

at NNLO in QCD including soft-gluon resummation at NNLL.

Figure 2 presents a summary of CMS measurements of $\sigma_{t\bar{t}}$ in pp collisions at different $\sqrt{s}$ in the ℓ + jets and dilepton channels, compared to the NNLO+NNLL prediction using the NNPDF3.0 NNLO PDF set with $\alpha_S(m_Z) = 0.118$ and $m_t = 172.5$ GeV. In the inset, the results from this analysis at $\sqrt{s} = 5.02$ TeV are also compared to the predictions from the MMHT14, CT14, and ABMP16 NNLO PDF sets, with the latter using $\alpha_S(m_Z) = 0.115$ and $m_t = 170.4$ GeV.

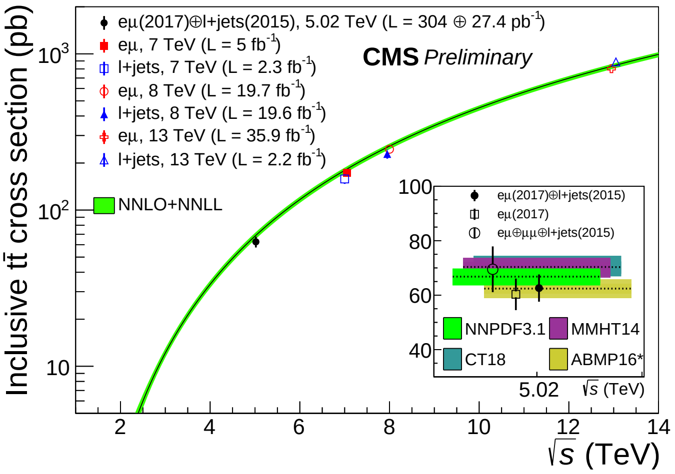

Figure 2: Summary of CMS measurements of $\sigma_{t\bar{t}}$ in pp collisions at different $\sqrt{s}$, compared to the NNLO+NNLL prediction using the NNPDF3.0 NNLO PDF set with $\alpha_S(m_Z) = 0.118$ and $m_t = 172.5$ GeV. The vertical bars and bands represent the total uncertainties in the data and in the predictions respectively [4].

4. Conclusions

A measurement of the top quark pair production cross section at a centre-of-mass energy of 5.02 TeV is presented for events with one electron and one muon of opposite sign, and at least two jets, using proton-proton collisions collected by the CMS experiment in 2017 and corresponding to an integrated luminosity of 304 pb^{-1}. The measured cross section is found to be $\sigma_{t\bar{t}} = 60.3 \pm 5.0(\text{stat}) \pm 2.8(\text{syst}) \pm 0.9(\text{lumi})$ pb. This measurement is statistically limited due to the small data sample. To reduce the statistical uncertainty in the result, a combination with the ℓ + jets result of Ref. [2] using a data set collected in 2015 corresponding to a luminosity of 27.4 pb^{-1} is performed, obtaining a measurement of $\sigma_{t\bar{t}} = 62.6 \pm 4.1(\text{stat}) \pm 3.0(\text{syst+lumi})$ pb, with a total uncertainty of 7.9%, in agreement with the prediction from the SM.

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