PROCEEDINGS OF SCIENCE

Recent $t\bar{t}$ and single top inclusive cross sections results in CMS

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Latest results on inclusive top quark pair and single top quark production cross sections are presented using proton-proton collision data collected by CMS. The single top quark analyses investigate separately the production of top quarks via t-channel exchange, and via associated production with a W boson (tW).

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1. Introduction

The top quark cross section measurements are crucial to test Standard Model (SM) predictions. Furthermore, due to the high production rate of top quarks in the LHC, these processes are main backgrounds in plenty of searches for new particles and measurements of rare SM processes.

In this document, the latest $t\bar{t}$ and single top cross section measurements by CMS [1] are presented. The full 2016 dataset, corresponding to a luminosity of $35.9\,\mathrm{fb}^{-1}$, is used in all the analyses.

2. Inclusive $t\bar{t}$ cross section

A precise mesasurement of the $t\bar{t}$ inclusive cross section has been performed using dilepton events [2]. The events are categorized according to the number of jets and b-tag and several distributions, such as the transverse momentum of jets, are fitted to the data in the different categories in order to constrain uncertainties and extract the signal cross section.

Assuming a top quark mass in the simulation of $m_t^{MC} = 172.5\,\mathrm{GeV}$, the cross section was measured in the visible region and then extrapolated to the full phase space, obtaining a value of $\sigma_{t\bar{t}} = 803 \pm 2\ \mathrm{(stat)} \pm 25\ \mathrm{(syst)} \pm 20\ \mathrm{(lumi)}$. The measurement is in agreement with the theoretical next-to-next-to-leading order QCD prediction.

The measurement is repeated including m_t^{MC} in the fit, as an additional free parameter. In this case, the fit includes some distributions sensitive to the top quark mass, such as the minimum invariant mass reconstructed with a b-tagged jet and a lepton. A $t\bar{t}$ cross section of $\sigma_{t\bar{t}} = 815 \pm 2\ \mathrm{(stat)} \pm 29\ \mathrm{(syst)} \pm 20\ \mathrm{(lumi)}$ is obtained, with a mass of the top quark MC mass of $m_t^{MC} = 172.33 \pm 0.14\ \mathrm{(stat)}\ ^{+0.66}_{-0.72}\ \mathrm{(syst)}\ \mathrm{GeV}$.

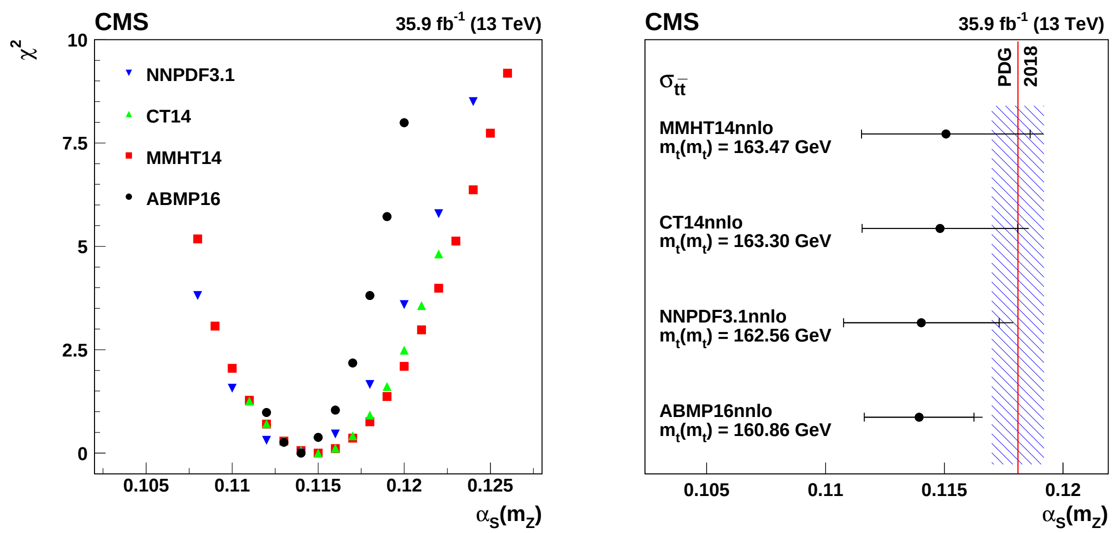

Figure 1: χ^2 value as a function of $\alpha_s(m_Z)$obtained from the comparison of the measured $\sigma_{t\bar{t}}$ value with the NNLO prediction using different PDFs (left) and the measured value of $\alpha_s(m_Z)$with their uncertainties, for different PDFs, and the comparison with the world-average $\alpha_s(m_Z)$value [2].

Furthermore, the value of $\sigma_{t\bar{t}}$ obtained in the simultaneous fit is used to extract the values of the top quark pole mass and the strong coupling constant. The measured values are compared with predictions using different PDF sets, as shown in figure 1.

This $t\bar{t}$ precision measurement improves previous results at $\sqrt{s} = 13$ TeV by the CMS Collaboration, reaching an uncertainty smaller than the best theoretical predictions.

3. Inclusive tW cross section

The tW cross section is measured using events with an opposite-sign electron-muon pair and jets [3]. The events are further categorized according to the number of jets and b-tagged jets, as shown in figure 2.

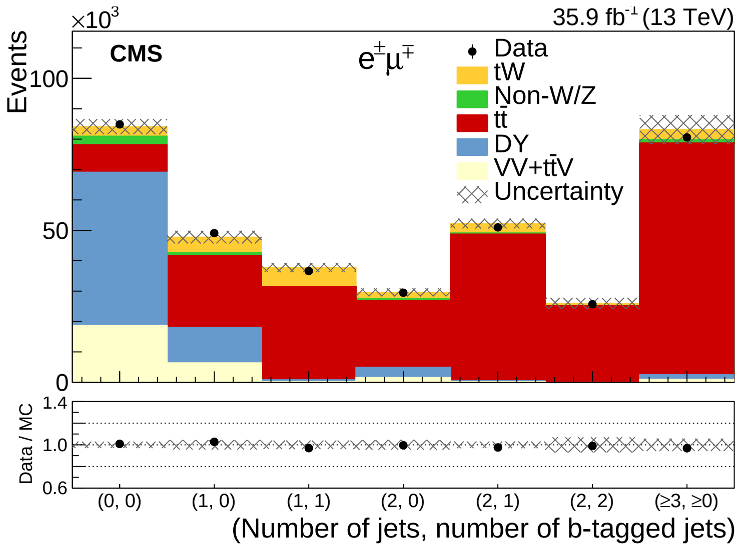

Figure 2: Jet and b-tagged jet multiplicity for observed and predicted events containing an opposite-sign eμ pair [3].

A boosted decision tree is used to discriminate between tW and $t\bar{t}$ events, using events with one b-tagged jets and events with two jets, one of which is b-tagged. The output BDT distributions and the distribution of the transverse momentum of the subleading jet for events with two b-tagged jets are used to extract the signal cross section performing a maximum likelyhood fit. The uncertainties are taken as nuisance parameters within the fit and their value is constrained. The distribution of the BDT output for events with exactly one b-tagged jet is shown in figure 3.

This measurement is affected by experimental and modeling uncertainties affecting both signal acceptance and $t\bar{t}$ prediction. The most relevant sources of uncertainties are lepton and trigger efficiencies, jet energy scale and $t\bar{t}$ normalization, each of them of the order of 3%. The extrapolation uncertainty from the visible region to the full phase space is also of the order of 3%.

The measured cross section is 63.1 ± 1.8 (stat) ± 6.4 (syst) ± 2.1 (lumi) pb, in agreement with the SM and with a improved uncertainty, of 11%, with respect to previous results.

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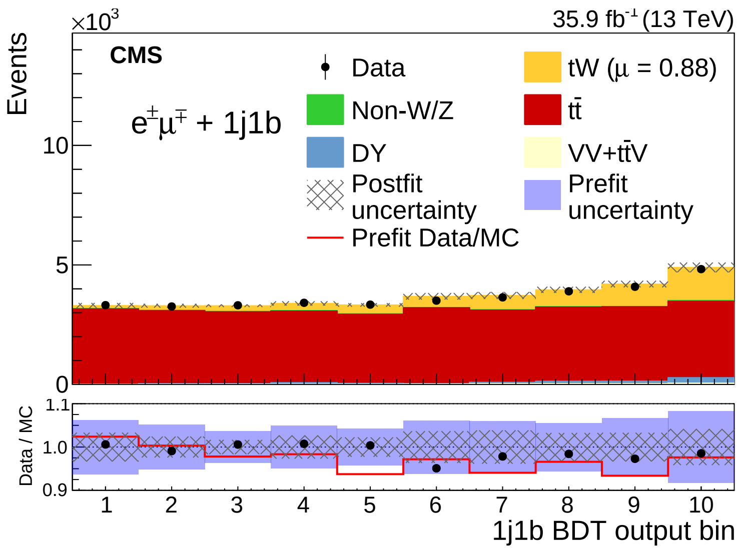

Figure 3: Postfit distribution of the BDT output for eμ data and MC events with exactly one b-tagged jet [3].

4. Inclusive t-channel cross section

The single top t-channel cross section is measured using events with one electron or one muon and multiple jets in the final state [4]. Events are categorized according to the flavour of the lepton and the jet and b-tag multiplicities, as shown in figure 4. A boosted decision tree is used to separate signal event in each category from $t\bar{t}$ background events.

The measured cross section are 136 ± 1 (stat) ± 22 (syst) pb for the production of single top quarks and 82 ± 1 (stat) ± 14 (syst) pb for the production of single top antiquarks. The combined result is used to calculate the value of the Cabibbo-Kobayashi-Maskawa matrix element $|fLV_{\text{tb}}| = 1.00 \pm 0.08$ (exp) ± 0.02 (theo) , including anomalous from factor fLV.

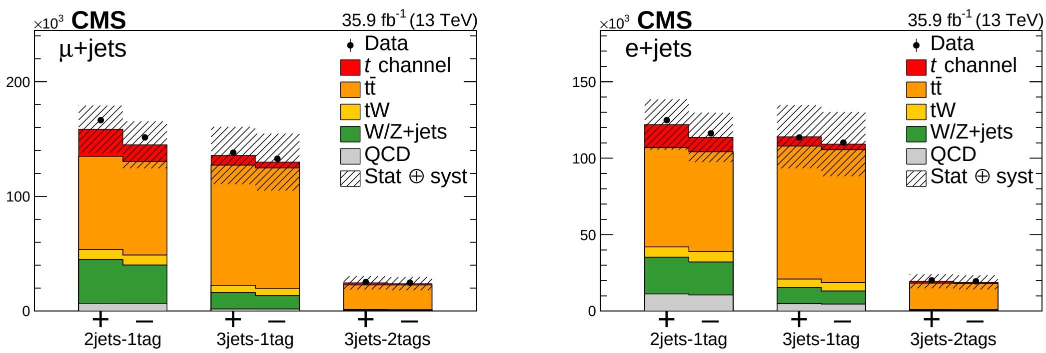

Figure 4: Event yields for the relevant processes in all categories after applying the full event selection in the different categories used in the analysis [4].

The ratio of the measured cross sections of the two processes is $R_{\text{t-ch}} = 1.66 \pm 0.02$ (stat) $\pm$

0.05syst. This ratio is compared to recent predictions using different parton distribution functions (PDFs) to describe the proton structure. Good agreement with most PDF sets is found within the uncertainties.

The uncertainty in the measurement of the t-channel production cross section is limited by the systematic uncertainties in the modeling of the signal process, while most of these uncertainties partially cancel out in the measurement of the ratio between cross sections. The precision on the measurement of $R_{\mathrm{t-ch}}$ is significantly improved with respect to the results of previous measurements.

References

[1] CMS Collaboration, "The CMS experiment at the CERN LHC", JINST 3 (2008) S08004, doi:10.1088/1748-0221/3/08/S08004.

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[3] CMS Collaboration, Measurement of the production cross section for single top quarks in association with W bosons in proton-proton collisions at $\sqrt{s} = 13$ TeV, JHEP 10 (2018) 117.

[4] CMS Collaboration, Measurement of the single top quark and antiquark production cross sections in the t-channel and their ratio in proton-proton collisions at $\sqrt{s} = 13$ TeV, arXiv:1812.10514 . Submitted to Phys. Lett. B.