PROCEEDINGS OF SCIENCE

Measurement of the t-channel single-top quark production cross section at 13 TeV with the CMS detector

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The electroweak production of single-top quarks in the t-channel can be affected by any deviation from the Standard Model, it is therefore an excellent opportunity to search for new physics. In this talk the recent cross section measurement of the CMS collaboration is presented with the first data from the LHC Run II at a center-of-mass energy of 13 TeV. The cross section is extracted using a binned maximum likelihood fit to the pseudorapidity distribution of the characteristic forward jet in events containing one isolated muon in the final state.

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In contrast to the top quark pair production, single top quarks are produced via the electroweak interaction. Hence, the cross section for this process is smaller compared to the pair production, which is realized via gluons of the strong interaction. However, the process is highly sensitive to new physics like FCNC or new particles.
It is possible to produce single top quarks via three different processes in the standard model: t-channel, s-channel (where t and s are referring to the Mandelstam variables) and the tW associated production. The t-channel is the dominate production mode with a fraction of about 80% at a center-of-mass energy of $\sqrt{s} = 13\,\mathrm{TeV}$.
The leading order Feynman diagram of the t-channel single top quark production is shown in Figure 1. A light flavored quark and a gluon, which splits into a pair of bottom quarks, are present

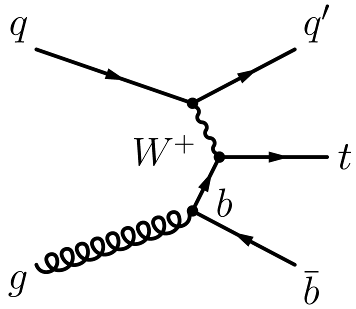

Figure 1: Feynman diagram of the t-channel single top quark production.

in the initial state. The light flavored quark can emit a W boson which produces a single top quark together with one of the bottom quarks. The software `Hathor` [1] was used to calculate the theoretical cross section of this channel for proton-proton collisions:

$$\sigma_{t-\mathrm{ch.}}^{\mathrm{theo.}} = 216.99^{+6.62}_{-4.64}\,(\mathrm{scale}) \pm 6.16\,(\mathrm{PDF})\,\mathrm{pb}. \tag{1}$$

The analyzed dataset consists of events recorded at the 50 ns Run II of the Large Hadron Collider (LHC) in Summer 2015, corresponding to an integrated luminosity of $L = 41$ pb^{-1}. The top quark decays in almost all cases into a W boson and a bottom quark. Thus, the top quark decay is characterized by the following decay of the W boson. The analysis focuses only on leptonically decaying top quarks, since the hadronic case suffers from large background.
Events are selected which contain exactly one muon from the decay of the W boson, passing various kinematic and isolation criteria. The neutrino escapes without interacting with the detector material, but the transverse component of the momentum can be extrapolated by balancing all reconstructed objects in the transverse plane. The longitudinal component is calculated by constraining the W boson mass to $m_{\mathrm{W}} = 80.4\,\mathrm{GeV}$. Jets clustered with the anti-k_{t} algorithm are used to reconstruct the hadronized quarks from the final state. A multivariate discriminator, called b-tagging, is used to determine the probability that a jet originates from a bottom quark or a light flavored quark/gluon. Different categories are defined by the number of jets M and the number of b-tagged jets N in an event, in the following abbreviated as MjNt region.
The best signal-to-background ratio is achieved in the 2j1t region and the 3j2t region is defined to constrain the contribution of the dominating background from top quark pair production, as the

Process	SR	SB
$t\bar{t}$ & tW	157 ± 1	71.7 ± 0.4
W/Z+jets	40 ± 4	47 ± 4
QCD	10 ± 5	2 ± 1
t-channel	33 ± 1	7.2 ± 0.3
Total expected	240 ± 6	128 ± 4
Data	252	127

Table 1: Event yields in the 2j1t region for the signal region (SR) and the sideband (SB), defined by the reconstructed to quark mass. The QCD background is derived from data, the other predictions are derived from Monte Carlo

second bottom quark from the initial gluon splitting often fails the detector acceptance. To further increase the ratio of signal events, the 2j1t region is divided into a signal region (SR), where the reconstructed top mass is above 130 GeV and below 225 GeV, and a sideband (SB). The top quark is reconstructed by adding the four-vector of the b-tagged jet and the W boson. An additional cut of 50 GeV on the transverse mass of the W boson is applied to reduce the contribution from QCD multi-jet events.
The yield and shape of the QCD background is determined from a data-driven estimation. A fit to the full transverse mass distribution of the W boson is performed with QCD-enriched anti-isolated data and then extrapolated to the signal enriched phase space. The W+jets, especially W boson with additional heavy flavor, background is independent of the reconstructed top quark mass and the modeling is therefore validated in the 2j1t SB. Table 1 shows the event yields in 2j1t region for the SR and the SB. The cross section is then derived from a simultaneous maximum likelihood fit in the 2j1t SR and the 3j2t region to the absolute pseudorapidity of the non-tagged jet. Both fitted distributions are shown in Figure 2. The distribution of the reconstructed top quark mass in the

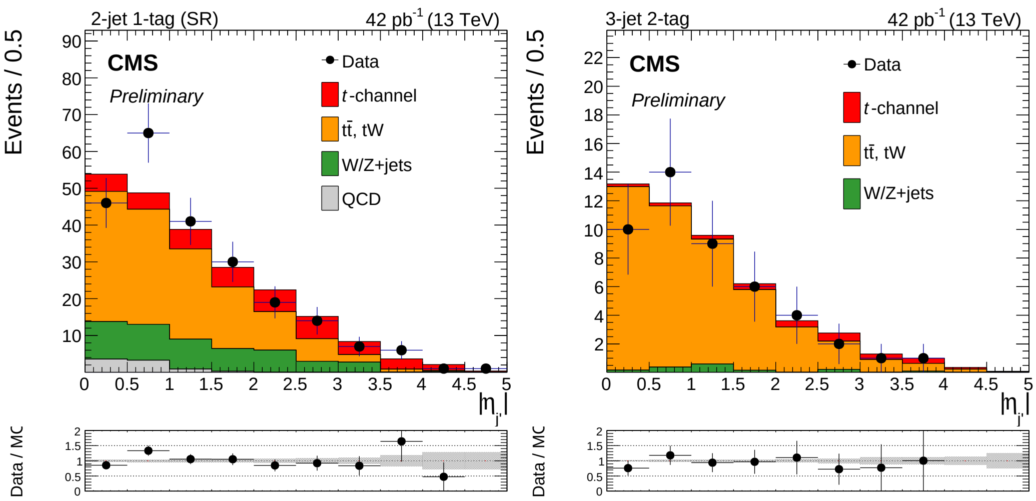

Figure 2: Fitted distributions of the pseudorapidity of the light flavored jet in the 2j1t signal region (left) and the 3j2t region (right).

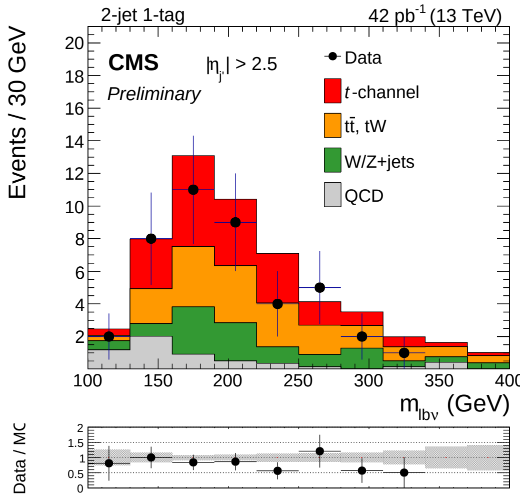

Figure 3: Distribution of the reconstructed top quark mass after applying an additional cut on the pseudorapidity of the light flavored jet of $|\eta_{\mathrm{j'}}| > 2.5$ in the entire 2j1t region.

entire 2j1t region is shown in Figure 3, which only uses events from the tail of the pseudorapidity distribution ($|\eta| > 2.5$). A good agreement between data and simulation is observed within the uncertainties.

Various sources of systematic uncertainties affect the result of the measured cross section. To estimate these uncertainties the fit is repeated with distributions that have been shifted by $\pm$ one standard deviation of the specific systematic uncertainty. The total systematic uncertainty is 19%, where the jet energy scale, b-tagging and parton density function are the most dominant contributions in descending order. An uncertainty of 12% on the value of the integrated luminosity is assumed and the amount of data corresponds to an statistical uncertainty of 36%. All together, the cross section is measured to be

$$\sigma_{t-\mathrm{ch.}}^{\mathrm{exp.}} = 274 \pm 98\,(\mathrm{stat.}) \pm 52\,(\mathrm{syst.}) \pm 33\,(\mathrm{lumi.})\,\mathrm{pb}\,, \tag{2}$$

which is in agreement with the predictions from the Standard Model. Assuming that the elements $|V_{\mathrm{td}}|$ and $|V_{\mathrm{ts}}|$ of the Cabibbo-Kobayashi-Maskawa matrix are much smaller than $|V_{\mathrm{tb}}|$, the latter one can be calculated as the square root of the cross section ratio:

$$|V_{\mathrm{tb}}| = 1.12 \pm 0.24\,(\mathrm{exp.}) \pm 0.02\,(\mathrm{theo.}). \tag{3}$$

A more detailed description of the analysis is available in Ref. [2].

References

[1] M. Aliev, H. Lacker, U. Langenfeld, S. Moch, P. Uwer and M. Wiedermann, "HATHOR: HAdronic Top and Heavy quarks crOss section calculatoR," Comput. Phys. Commun. **182**, 1034 (2011) [arXiv:1007.1327 [hep-ph]].

[2] CMS Collaboration, *Measurement of the t-channel single top-quark cross section at 13 TeV*, CMS-PAS-TOP-15-004, Geneva 2015, http://cds.cern.ch/record/2052187