Measurement of the top quark pair production cross section at 7 TeV in the all-hadronic channel

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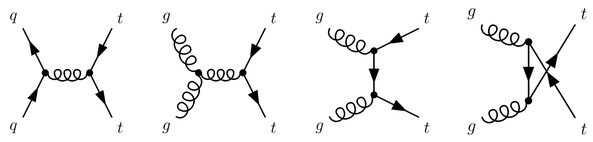
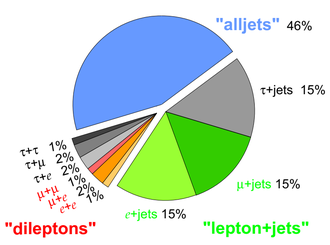
The first measurement of the top quark pair production cross section in the fully hadronic decay channel at a center-of-mass energy of 7 TeV is presented. The measurement has been performed using an integrated luminosity of 1.09 fb^{-1}, collected with the CMS detector. The cross section is determined from an unbinned maximum likelihood fit to the reconstructed top quark mass. The reconstruction of ttbar candidates is performed after a cut-based event selection using a kinematic fit. A data-driven technique is used to estimate the dominant background from QCD multijet production. The cross section measurement yields σ(ttbar)=136±20(stat.)±40(sys.)±8(lumi.) pb. This result is consistent with measurements in other decay channels and with the Standard Model prediction.

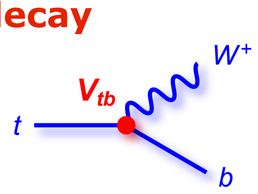
Top pair production and decay



Top Pair Branching Fractions

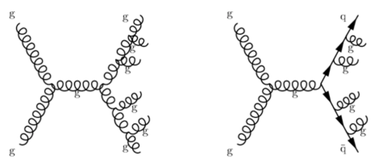


qq annihilation dominant at Tevatron.
gluon-gluon fusion dominant at LHC.



The top quark decays almost exclusively in a W boson and a b quark. V_{tb}~1.

The all-hadronic channel has the highest branching fraction.
It's also the one with the largest background.



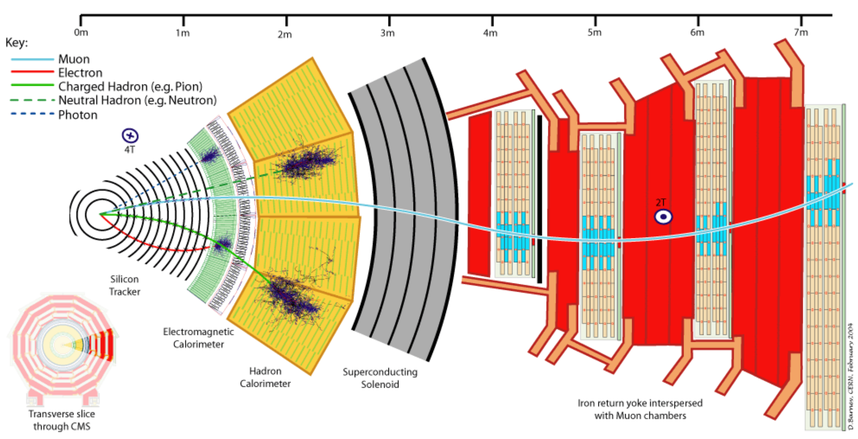
The topology of the final state is 6 jets without missing energy. QCD multi-jet production cross section is much larger.

Trigger strategy

The triggers designed to collect this signal require 5 or 6 jets with different thresholds.
Jets are reconstructed with the Calorimeter information only. The algorithm used is AntiKt with R=0.5
The thresholds applied are:
- 5 jets with p_T>40 GeV/c
- 4 jets with p_T>50 GeV/c
for the trigger at low luminosity. An additional requirement of
- 6 jets p_T>30 GeV/c
for the trigger at higher luminosity.
With these 2 triggers 2.5 M events have been collected in 1.09 fb^{-1}.

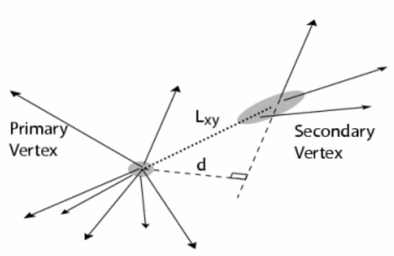
Event reconstruction and selection

The jets are reconstructed using the PF reconstruction technique. This allows the identification and reconstruction of all leptons, photons and hadrons in the event, by combining the informations from all the CMS subdetectors.



The basic event selection is driven by the trigger requirements.
Jets are reconstructed with the antiKt algorithm (R=0.5) and the followings p_T requirements:
- 6 jets p_T>40 GeV/c
- 5 jets p_T>50 GeV/c
- 4 jets p_T>60 GeV/c
These are set to stay (nearly) on the plateau of the trigger turn-on curves and minimize the impact of the trigger related systematics.

Jets coming from the decay of a b quark are identified using a *b-tagging algorithm* based on the presence of a *secondary vertex* in the event.
At least 2 b-tagged jets are required.



Kinematic reconstruction

A kinematic fit (least squares) is applied to the selected events.
A χ^2 is calculated and minimized:

$$\chi^2 = \sum_i \sum_j \frac{\left(i_{j,rec} - i_{j,fit}\right)^2}{\sigma^2_{i_j}} + \sum_c \lambda_c d_c \text{ with } i = E_t, \eta, \varphi \text{ and } j = jets$$

The minimization procedure is repeated for each jet combination, using the information from the b-tagging.
A cut on the χ^2 is applied to further imporve the purity of the selected sample.

Selection step	Events	Signal fraction
At least 6 jets	248,109	2%
At least two b-tags	6,905	17%
Kinematic Fit	1,620	32%

The signal fraction improves a lot after the full selection. But the background amount is still very high, it needs to be estimated from data themselves.

Background estimation

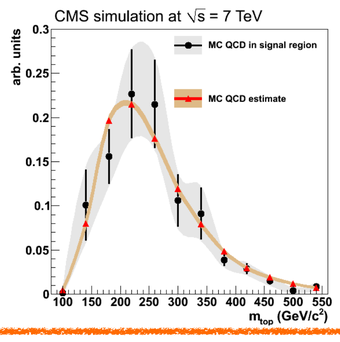
The amount of background in the selected sample is estimated from data. Events are selected with exactly 0 b-tagged jets. The signal contribution in this region of the phase space is around 1%.
A parametrization is applied to account for the different kinematics via the scale factor:

$$R(p_T, |\eta|) = \frac{N\left(p_T, |\eta|, d_B\,(\text{SSVHP}) > 2.0\right)}{N\left(p_T, |\eta|, d_B\,(\text{SSVHP}) \leq 2.0\right)}$$

$$w = R(p_T^b, |\eta^b|) \times R(p_T^{\bar{b}}, |\eta^{\bar{b}}|)$$

Events are reweighted and the kinematic fit is applied in the same way as for the b-tagged events.

The estimation method is validated by comparing with the simulation the distribution of the variable m_{top}.



Signal extraction and cross section measurement

The inclusive cross section is taken from a fit to the top mass.
The main sources of systematic uncertainty are b-tag and JES.

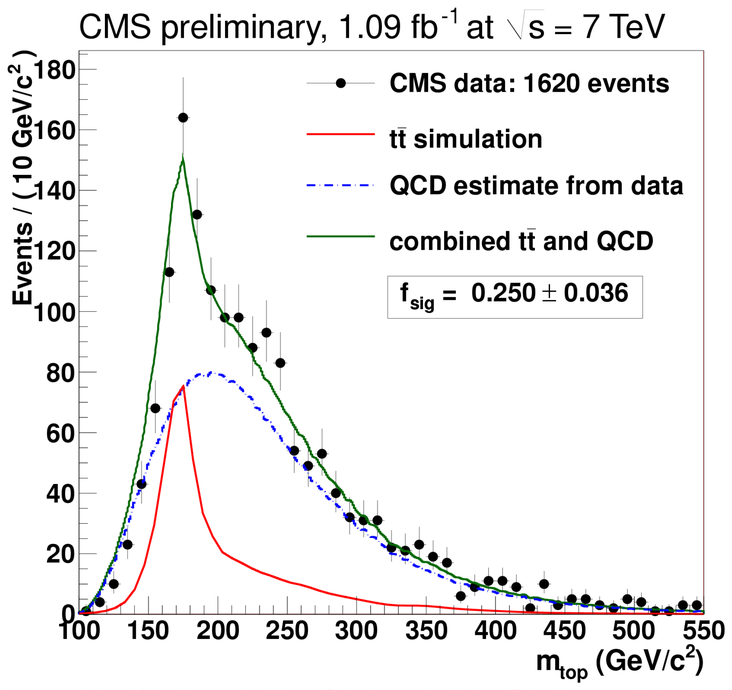
$$\sigma_{t\bar{t}} = \frac{f_{sig} \cdot N}{\epsilon \cdot \delta_\epsilon^{\text{b-tag}} \cdot \delta_\epsilon^{\text{trigger}} \cdot L_{int}}$$

f_{sig}: fraction of events from the fit
N: number of events seen in data
ε: ttbar selection efficiency
$\delta_\epsilon^{b\text{-}tag}$: scale factor for b-tag
$\delta_\epsilon^{trigger}$: scale factor for trigger
L_{int}: integrated luminosity

Source	Relative Uncertainty (%)
B-Tagging	15.7
Jet Energy Scale	13.5
Background	12.2
Q^2 Scale	8.7
Tune	8.1
ISR/FSR	5.6
Top Quark Mass	5.3
Parton Shower Matching	5.2
Jet Energy Resolution	4.8
Trigger	4.5
Pile-Up	0.6
Systematic	29.1
Statistical	14.3
Luminosity	6.0
Total Uncertainty	33.0

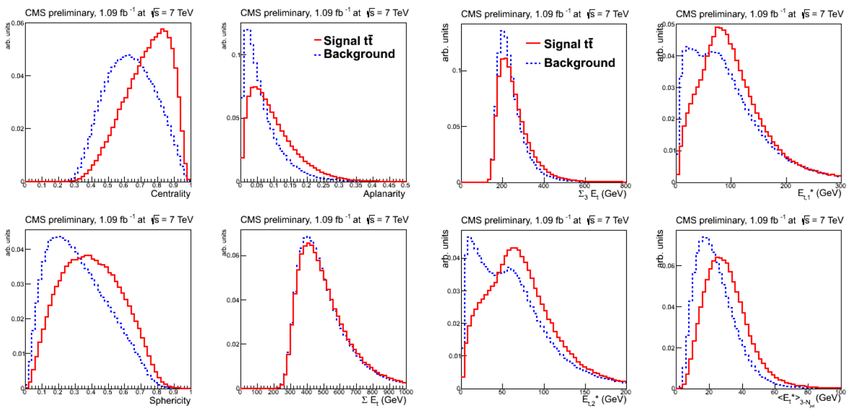
Final result compatible with the theoretical calculation and the other measurements in lepton+jets and dilepton channels.

$$\sigma_{t\bar{t}} = 136 \pm 20\,(\text{stat.}) \pm 40\,(\text{sys.}) \pm 8\,(\text{lumi.})\ \text{pb}$$



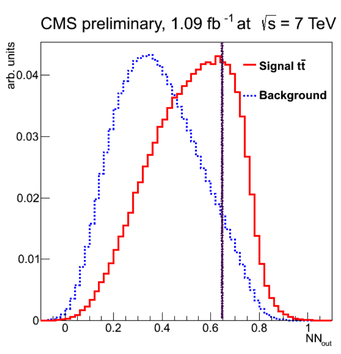
Cross check with a NN based analysis

A Neural Network analysis has also been developed to have an indipendent measurement of the inclusive cross section.
The jets selection is the same as for the main analysis. In addition to this also the kinematical properties of the ttbar event are exploited.



8 variables are combined via a Neural Network and the optimal cut is applied on the NN output.

A requirement of at least 2 b-tagged jets is also applied.

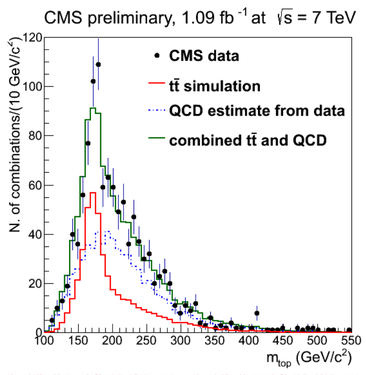


The background is estimated from data, taking the events with 4 or 5 jets that don't pass the NN cut.
The probability of jets having 2 loose b-tags to also have 2 medium b-tags is parametrized and a weight is extracted.

$$w = \sum_{jLjL} R_{LL}^{MM}(\langle p_T \rangle,\ \langle |\eta| \rangle,\ \Delta R)$$

A kinematic fit is used to reconstruct the event and a cut on the χ^2 is applied. A cut on ΔR between the b-tagged jets is also applied to reduce the gluon splitting contribution.
Templates are extracted from the simulation (signal) and from the background (data).
Finally a binned maximum likelihood fit is performed and the inclusive cross section is extracted.

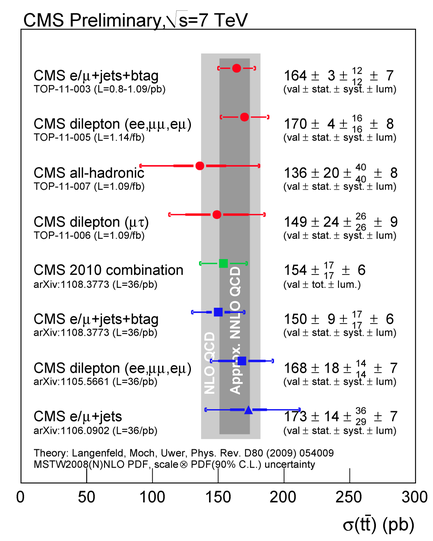
$$\sigma_{t\bar{t}} = 157 \pm 30\,(\text{stat.}) \pm 47\,(\text{sys.}) \pm 9\,(\text{lumi.})\ \text{pb}$$



Source	Relative uncertainty (%)
Background	-
JES	7.3
b-tagging	19.7
Trigger efficiency	4.5
ISR/FSR	12.5
JER	5.3
Top quark mass	2.4
Pile-up	1.3
Q^2 scale	13.5
Parton matching	4.8
Tune	5.1
Total	29.8
Luminosity	6

Summary

The inclusive ttbar production cross section has been measured also in the full hadronic channel, for the first time at the LHC.
2 measurements have been independently performed and they are in agreement between each other and with the same measurement in the other channels.
The measurements are also in agreement with the theoretical predictions.



Reference

TOP-11-007 Measurement of the ttbar production cross section in the fully hadronic decay channel in pp collisions at √s=7 TeV