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Measurement of the top-quark pair production cross section in the semi-leptonic channels at $\sqrt{s} = 7\,\mathrm{TeV}$ with the CMS experiment

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Summary. — A measurement of the top-quark pair production cross section is presented using between 0.8 and 1.1 fb^{-1} of data recorded by the CMS experiment at the Large Hadron Collider at a center-of-mass energy of 7 TeV. The cross section measurement is performed in the semi-leptonic final state with events containing one lepton, either a muon or an electron, missing transverse energy and jets. The cross section measurement yields $164.4 \pm 2.8(\mathrm{stat.}) \pm 11.9(\mathrm{syst.}) \pm 7.4(\mathrm{lum.})$ pb which is consistent with higher order QCD calculations.

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1. – Introduction

The approximate next-to-next-to-leading-order top-quark pair production cross section has been calculated as $\sigma_{t\bar{t}} = 163\,\mathrm{pb}$ for a top quark mass of 173 GeV [1]. This analysis [2] aims to provide a measurement of the top quark pair production cross section at $\sqrt{s} = 7\,\mathrm{TeV}$ using b-quark jet identification techniques at the CMS experiment [3]. The top quark decays almost exclusively to a W-boson and a bottom quark. This measurement focuses on the semi-leptonic top quark pair decay channels where one W-boson decays to quarks and the other decays to a neutrino and a charged lepton, either a muon or an electron.

2. – Event selection

Selected events contain exactly one isolated electron with a transverse momentum $p_T > 45\,\mathrm{GeV}$ and within the pseudo-rapidity range of $\eta < |2.5|$, or exactly one muon with $p_T > 35\,\mathrm{GeV}$ and $\eta < |2.1|$. A selected event must have a measured missing transverse energy $\not{E}_T > 30\,(20)\,\mathrm{GeV}$ for the electron (muon) channel. Requiring exactly one lepton suppresses dilepton events from top quark pair decay and Z-boson decay. A lepton isolation requirement removes QCD multi-jet background events. Jets are selected with $p_T > 30\,\mathrm{GeV}$ and $\eta < |2.5|$. W+jets events dominate the sample for low

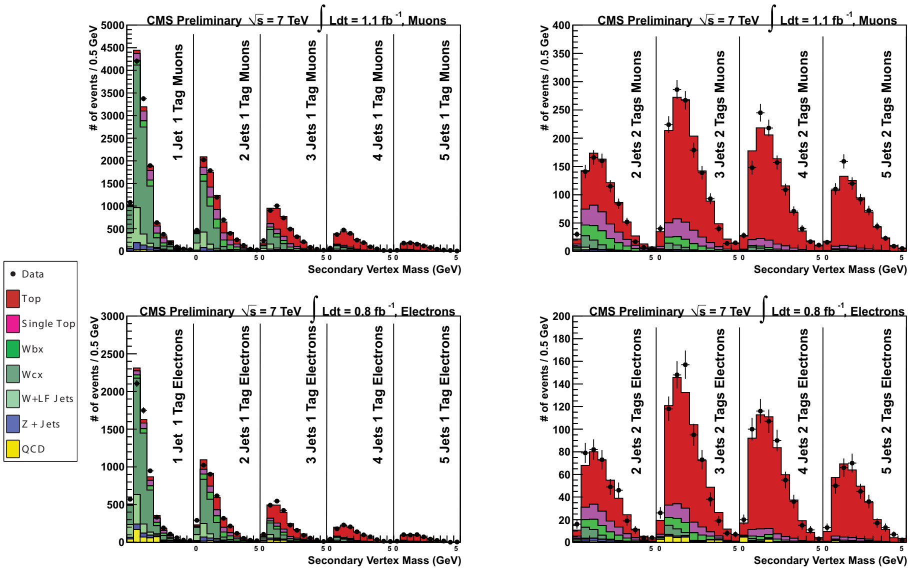

Fig. 1. – Secondary vertex mass distributions for each jet multiplicity and number of b-tagged jets combination used for the combined likelihood fit in the muon and electron channels.

jet multiplicities while semi-leptonically decaying top quark pairs dominate at high jet multiplicities. W+jets events containing light flavour jets are separated from $t\bar{t}$ events by requiring jets from the hadronisation of a b-quark. These jets are identified using a displaced secondary vertex b-tagging algorithm.

3. – Data-driven background estimation

The normalisation of the QCD multi-jet background is determined using a maximum-likelihood fit to the $\not{E}_T$ distribution in data. In the muon channel the secondary vertex mass shape for the QCD background is derived from data by applying an inverse lepton isolation requirement. The template is then corrected based on the simulation to take into account correlations between $\not{E}_T$ and lepton isolation. In the electron channel the non-isolated sideband regions do not accurately represent the shape of the $\not{E}_T$ distribution. Therefore, a template based on QCD multi-jet simulation is used for the cross section extraction.

4. – Cross section extraction

The cross section is extracted using a binned maximum-likelihood fit to the secondary vertex mass distribution for different jet multiplicities $(1, 2, 3, 4, \geq 5)$ and number of b-tagged jets $(1, \geq 2)$, as shown in fig. 1. The template shapes for the $t\bar{t}$ signal and the W+jets, Z+jets and single top background are taken from simulation. The QCD multi-jet background template is derived as described in sect. **3**. The b-jet, c-jet and light flavour components of the W/Z+jets background may float independently in the fit, allowing the normalisation of each component to be extracted. The systematic effects which are expected to have the largest impact on the cross section uncertainty are

TABLE I. – *Summary of the systematic uncertainties estimated in the muon, electron, and combined muon and electron cross section measurements.*

Source	Muon Analysis	Electron Analysis	Combined Analysis
Quantity	Uncertainty (%)		
Lepton ID/reco/trigger	3.4	3	3.4
Met resolution due to unclustered energy	< 1	< 1	< 1
$t\bar{t}$ + jets Q^2 scale	2	2	2
ISR/FSR	2	2	2
ME to PS matching	2	2	2
Pile-up	2.5	2.6	2.6
PDF	3.4	3.4	3.4
Profile Likelihood Parameter	Uncertainty (%)		
Jet energy scale and resolution	4.2	4.2	3.1
b-tag efficiency	3.3	3.4	2.4
W+jets Q^2 scale	0.9	0.8	0.7
Combined	7.8	7.8	7.3

treated as nuisance parameters in the profile likelihood fit. The jet and b-tag multiplicity distributions are sensitive to the jet energy scale and b-tag efficiency respectively. Therefore, the fit provides an *in situ* measurement of the b-tagging and jet energy scale uncertainties.

5. – Systematic uncertainties

The effect of theoretical uncertainties in the signal modeling on the measured cross section are taken as systematic uncertainties in table I. The uncertainty on the lepton trigger, reconstruction and identification efficiencies are estimated using events where a Z-boson decays to two leptons. The uncertainty due to the overall luminosity determination is 4.5%. The b-tagging scale factor is measured as $97 \pm 1\%$ and a jet energy scale factor of $99 \pm 2\%$ is measured. A cross section scale factor of 1.2 ± 0.3 is found for the W+b-jets contribution. A scale factor of 1.7 ± 0.1 is measured for the W+c-jets contribution.

6. – Conclusion

In the electron channel the cross section is measured as

$$\sigma_{t\bar{t}} = 163.0 \pm 4.4(\text{stat.}) \pm 12.7(\text{syst.}) \pm 7.3(\text{lum.})\ \text{pb.}$$

In the muon channel the measured cross section is

$$\sigma_{t\bar{t}} = 163.2 \pm 3.4(\text{stat.}) \pm 12.7(\text{syst.}) \pm 7.3(\text{lum.})\ \text{pb.}$$

The combined measurement of the top quark pair production cross section in the semi-leptonic electron and muon channels yields

$$\sigma_{t\bar{t}} = 164.4 \pm 2.8(\text{stat.}) \pm 11.9(\text{syst.}) \pm 7.4(\text{lum.})\ \text{pb}.$$

The separate measurements in the two lepton channels agree within uncertainties and are consistent with the predicted NNLO top quark pair production cross section.

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