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Study of the single top production in the t-channel with the CMS experiment at the LHC

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Summary. — We present a measurement of the inclusive single top t-channel production cross section in proton-proton collisions at the LHC, using data collected with the CMS experiment in 2011 and 2012 at a centre-of-mass energy of 7 TeV and 8 TeV, respectively. The 7 TeV analysis makes use of two different and complementary approaches. The first is a template fit analysis using background estimates determined from control samples in data. The second is based on multivariate techniques that probe the compatibility of the candidate events with the signal. The update of the template fit analysis with 8 TeV data is also presented together with the measurement of the t-channel single top quark and anti-quark production ratio. The cross section measurements are also used to determine the CKM matrix element $|V_{\mathrm{tb}}|$.

PACS 14.65.Ha – Top quarks.
PACS 13.60.Hb – Total and inclusive cross sections (including deep-inelastic processes).

1. – Introduction

Among the three different single top electroweak production modes, the t-channel is the one with higher production cross section at the LHC, and which presents the most striking final state topology. The typical signature expected for such events comprises one forward jet recoiling against the heavy top quark and one central b-jet coming from top decay. As in past analyses [1], only the leptonic decays of the W boson are considered, so one isolated charged lepton and missing energy are present as well in the final state.

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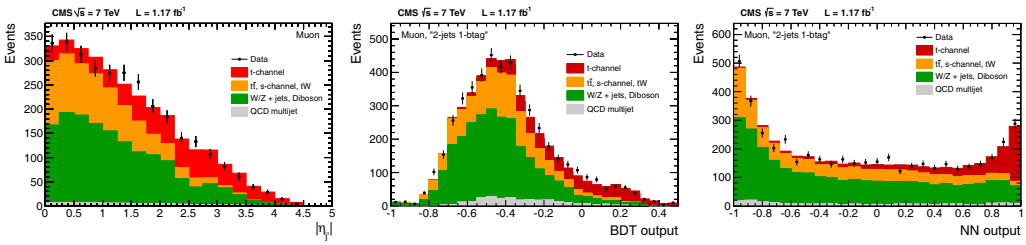

Fig. 1. – Results of the fit to $|\eta_{j'}|$ (left) and measured distributions of the classifier outputs, BDT (centre) and NN (right). Muon decay channel.

2. – Inclusive cross section at 7 TeV

Analysing 1.17 (muon channel) and 1.56 fb^{-1} (electron channel) of data collected by CMS [2] in 2011 at 7 TeV, two approaches have been adopted for the t-channel production cross section measurement. One approach is based on a fit of the characteristic pseudorapidity distribution of the light quark recoiling against the single top quark ($|\eta_{j'}|$), exploiting the reconstructed top quark mass with background determination from data. The other is based on two multivariate discriminators, a Neural Network and Boosted Decision Trees. The multivariate analyses reduce the impact of systematic uncertainties by simultaneously analysing different phase space regions. Figure 1 shows the $|\eta_{j'}|$ and the classifier output distributions for data and simulation, in the muon channel.

Since results are all consistent within uncertainties, the three analyses have been combined with BLUE method [3]. The single top t-channel production cross section [4] and the CKM matrix element $|V_{\text{tb}}|$ obtained are

$$\sigma_{t\text{-ch.}} = 67.2 \pm 6.1\,\text{pb} = 67.2 \pm 3.7(\text{stat.}) \pm 3.0(\text{syst.}) \pm 3.5(\text{theor.}) \pm 1.5(\text{lum.})\text{pb},$$
$$|f_{LV} V_{\text{tb}}| = \sqrt{\sigma_{t\text{-ch.}}/\sigma^{\text{th}}_{t\text{-ch.}}} = 1.020 \pm 0.046(\text{meas.}) \pm 0.017(\text{theor.}),$$

assuming $|V_{\text{td}}|$ and $|V_{\text{ts}}| \ll |V_{\text{tb}}|$, allowing for the presence of a possible anomalous form factor f_{LV} [5] and where $\sigma^{\text{th}}_{t\text{-ch.}}$ is the SM prediction calculated assuming $|V_{\text{tb}}| = 1$.

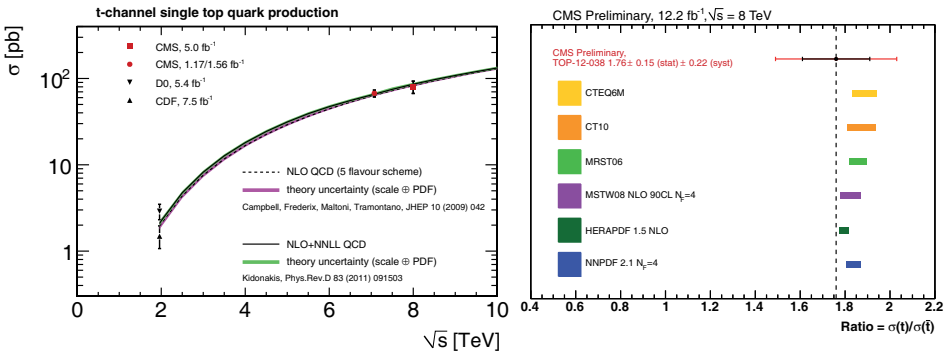

Fig. 2. – Left: single top t-channel cross section as function of the centre-of-mass energy. Right: comparison of the measured $R_{t\text{-ch.}}$ with the prediction obtained using different PDF sets.

3. – Inclusive cross section and charge ratio at 8 TeV

The update of the 7 TeV cross section measurement to the 2012 data at 8 TeV has been presented for the template fit analysis in the muon channel only [6] with $5.0\,\text{fb}^{-1}$. With an analysis strategy based on W+jets and $t\bar{t}$ backgrounds estimation from control samples in data, it has been measured $\sigma_{t\text{-ch.}} = 80.1 \pm 13.0\,\text{pb} = 80.1 \pm 5.7(\text{stat.}) \pm 9.0(\text{syst.}) \pm 6.3(\text{theor.}) \pm 4.0(\text{lumi.})\text{pb}$ and $|f_{LV}\,V_{\text{tb}}| = 0.96 \pm 0.08(\text{meas.}) \pm 0.02(\text{theor.})$.

A peculiar feature of the t-channel process in pp collisions is the asymmetry in the production of top quarks and anti-quarks. It directly comes from the greater contribution of the parton distribution function of the u quarks with respect to that of the d quarks in the protons. A measure of this asymmetry is interesting because it provides a handle to constrain different parton distribution functions models and it is sensitive to physics beyond standard model (anomalous tWb couplings and Flavour Changing Neutral Current processes). The analysis performed on $12.2\,\text{fb}^{-1}$ of 2012 data is based on a fit to the pseudorapidity distribution of the recoil jet separated by lepton charge (which reflects the top quark charge) [7]. The ratio of the single top quark and anti-quark cross sections in the t-channel is measured to be $R_{t\text{-ch.}} = 1.76 \pm 0.15(\text{stat.}) \pm 0.22(\text{syst.})$ in agreement with the standard model prediction [8].

Figure 2 shows a summary of the results presented here: the 7 TeV and 8 TeV cross section measurements and charge ratio compared to the theoretical predictions.

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