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Measurement of the single top quark cross section in 0.70 fb^{-1} of pp collisions with the ATLAS detector

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Summary. — We present the single-top production results carried out with 0.70 fb^{-1} of integrated luminosity collected by the ATLAS detector during the 2011 LHC run at 7 TeV center of mass. The t-channel production cross section in the lepton+jets final state and the Wt production cross section in the dilepton final state are measured. An upper limit on the s-channel production cross section at 95% CL is set.

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The ATLAS detector [1] is a multi-porpuse particle physics detector at the Large Hadron Collider (LHC) at CERN. It is optimized to record information coming from proton-proton collisions happening in the center of the detector. Single top-quark production proceeds through three different mechanisms, resulting in distinct final states. These three mechanisms are presented in fig. 1: the t-channel exchange of a W boson [2], the associated production of a top quark and a W boson (Wt-channel) [3], and the s-channel production [4]. The main contribution comes from t-channel with a production cross section of $64.57^{+3.32}_{-2.62}$ pb, compared the production cross sections of Wt-channel of $15.74^{+1.34}_{-1.36}$ pb and the s-channel $4.63^{+0.29}_{-0.27}$ pb all corresponding a 7 TeV.

For the t-channel analysis, events are selected with one isolated lepton (electron or muon) with $p_T > 25$ GeV, missing transverse energy ($\not{E}_T > 25$ GeV), and two or three jets with $p_T > 25$ GeV and $|\eta_{jet}| < 4.5$, one of them identified as a b-jet. Jets containing b-quarks are tagged by reconstructing secondary vertices from the tracks associated with each jet and requiring a minimum signed decay length significance of the secondary vertices relative to the primary vertex. The chosen working point corresponds to a b-tagging efficiency of 50% and a light quark jet rejection factor of around 270, as measured in simulated top pair events.

For the s-channel analysis, the selection is very similar to the t-channel selection except that only two jets were selected, the requirement on the η of the jets is much

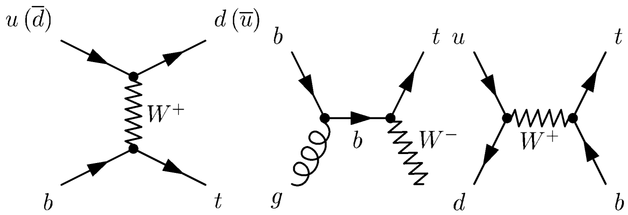

Fig. 1. – Leading-order diagrams corresponding to the three single top production mechanisms: t-channel (left), Wt-channel (middle), and s-channel (right).

tighter ($|\eta_{jet}| < 2.5$), and both jets could be identified as a b-jet. The same b-tagging working point is used in this case.

The background contribution for both analyses consists of multijets, W+jets and top quark pair events, with smaller contributions from Z+jets and diboson events. We normalize the electroweak Z+jets, WW, WZ and ZZ, the $t\bar{t}$ and the Wt and t-channel single top background contributions to their theory predictions and the shape of the distributions is taken from the Monte Carlo (MC) simulated events. Since the multijets background is difficult to model precisely, its contribution is reduced with a dedicated triangular cut, $m_T(W)$(1) $> 60\,\mathrm{GeV} - \not{E}_T$, where $m_T(W)$ is the lepton-$\not{E}_T$ transverse mass. The multijets background normalization is estimated using a binned likelihood fit to the $\not{E}_T$ distribution. The shape of the multijets background in this fit is taken from the jet-electron sample, which requires a jet with a similar detector signature as an electron. This jet must have $p_T > 25\,\mathrm{GeV}$, the same acceptance in η as the signal electron and 80–95% of its energy deposited in the electromagnetic section of the calorimeter. The jet must also contain at least four tracks, thus reducing the contribution from converted photons. The fit is performed separately in the pretag, 1-tag and 2-tag samples, after applying all selection cuts, including the triangular cut, but leaving out the $\not{E}_T$ cut. The result of the likelihood fit in the muon channel is shown in fig. 2. A systematic uncertainty of 50% is assigned to the multijets normalization. The distributions for the W+jets background are taken from Monte Carlo samples, while the overall normalization and the flavor composition are derived from data. The number of W+jets events in the data is taken as the difference between the observed data counts and the number of events estimated for non-W+jets backgrounds in each jet multiplicity bin. The overall W+jets normalization factor is the ratio of the number of W+jets events in the data over the number of W+jets events in MC. The flavor composition of the W+jets background is estimated from samples obtained from: the 1-jet 1-tag sample and the 2-jet pretag and 2-jet 1-tag samples. Scale factors for each of the individual W+jets flavor samples are obtained such that the W+jets event yields in the two-jet samples agree with the data W+jets event yields. Systematic uncertainties and their correlations are included in the evaluation of these scale factors.

Events used for the Wt dilepton analysis contain two isolated leptons (electrons or muons) with $p_T > 25\,\mathrm{GeV}$, missing transverse energy, $\not{E}_T > 50\,\mathrm{GeV}$, and at least one jet

(1) Defined as $\sqrt{2p_T^l p_T^\nu(1-\cos(\phi^l-\phi^\nu))}$, with l and ν the lepton and the neutrino, respectively, coming from W decay, where the measured missing E_T vector provides the neutrino information.

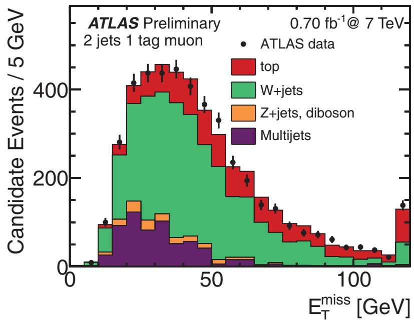

Fig. 2. – E_T^{miss} distribution for the 2-jet tag sample in the muon channel.

with $p_T > 25\,\text{GeV}$. Some other requirements has been included to optimize the signal region like a Z mass window cut: $|m_{l1,l2} - m_Z| > 10\,\text{GeV}$ or a $Z \to \tau\tau$ rejection ($Z \to \tau\tau$ veto: $\Delta\phi(l_1, E_T^{miss}) + \Delta\phi(l_2, E_T^{miss}) > 2.5$). The analysis uses three lepton categories two electrons (ee), two muons ($\mu\mu$) and one electron and one muon ($e\mu$), the categories are exclusive samples. Z mass veto is only applied to the ee and $\mu\mu$ samples, while $Z \to \tau\tau$ veto is applied to all three final states. The background model consists of top quark pair, drell-yan, diboson, and multijets events as shown on the jet multiplicity distribution for all lepton categories combined in fig. 3.

Finally, the three results quoted on this paper are estimated using a cut-based approach and an integrated luminosity of 0.70 fb^{-1}. We measure the t-channel production cross section obtaining a result of $\sigma_t = 90 \pm 9(\text{stat})^{+31}_{-20}(\text{syst})\,\text{pb}$ [5]. This result is consistent with the Standard Model (SM) expectation. We also perform a t-channel cross section measurement using a neural network [6]; result which is as well consistent with the SM expectation. For the cut-based analysis the b-tagging uncertainty is the largest systematic uncertainty.

The Wt dilepton cross section is measured obtaining a result of $\sigma_{Wt} = 14.4^{+5.3}_{-5.1}(\text{stat})$ $^{+9.7}_{9.4}(\text{syst})\,\text{pb}$ [7], that corresponds with a 1.2σ significance. The uncertainties related to

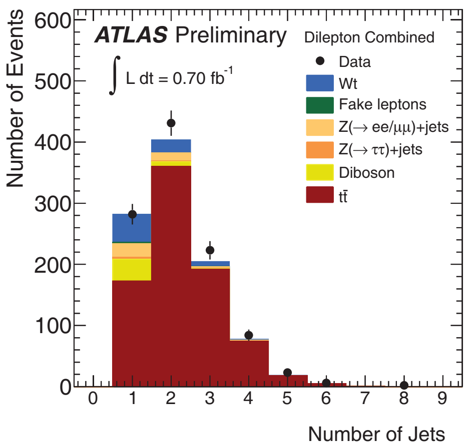

Fig. 3. – Jet multiplicity distribution for the preselected sample with all channels combined.

jet energy scale, jet energy reconstruction efficiency and jet energy resolution are the largest systematic uncertainties in this measurement.

On the s-channel analysis, after the final selection, 296 data events are observed compared with a prediction of 285. The predicted signal purity is 6%. We set an upper limit on the s-channel production cross section of 26.5 pb at 95% CL [8], five times higher than the SM prediction. The main source of systematic uncertainties is the data and MC statistics.

In summary, work is already in progress to update these results including new approaches and the data collected by the ATLAS detector during the 2011 LHC run. These analyses will also benefit from improving the systematic uncertainties since they are all systematics dominated. These results are already competitive with the Tevatron [9, 10] results.

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