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Reconstruction of Single-Top Events in the Semi-Leptonic t-Channel at $\sqrt{s} = 7\,\mathrm{TeV}$

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The electroweak production of single top quarks is of great interest for many aspects in and beyond the standard model. The reconstruction of such events is a demanding task and requires sophisticated analysis methods in order to achieve a good background suppression. At ATLAS, a simple cut-based analysis as well as more complex methods are used for the reconstruction of single-top *t*-channel events. All of them are based on the selection of events containing an isolated high-p_{t} electron or muon, jets and missing transverse energy. The different methods are described in detail and the results of their application to pp collision data recorded with the ATLAS detector in 2011 at a centre-of-mass energy of $\sqrt{s} = 7\,\mathrm{TeV}$ are presented using an integrated luminosity of $\int \mathcal{L}\mathrm{d}t = 0.70\,\mathrm{fb}^{-1}$.

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1. Introduction

The electroweak production of top-quarks was observed for the first time by the CDF and DØ collaborations in $p\bar{p}$ collisions. Recently CMS [1] and ATLAS [2, 3] reported first measurements of the single-top production cross-section at the LHC for the t-channel. These provide direct access to the Wtb coupling and allow to measure the CKM element V_{tb} directly. The single-top final state is sensitive to models of new physics like anomalous couplings, 4^{th} generation quarks or FCNC [4].

2. Event Selection

The final state of single-top t-channel events at ATLAS are characterized by an isolated high-p_{t} lepton (either electron or muon), at least one high-p_{t} jet (one of them b-tagged) and a certain amount of missing transverse energy. Electrons with a transverse energy, E_{t}, larger than 25 GeV and a pseudo-rapidity η in the range $|\eta|<2.47$ were selected. For muons a transverse momentum of $p_{\mathrm{t}}>25$ GeV and $|\eta|<2.5$ were required. Jets were reconstructed using the anti-k_{t} algorithm with a jet-size of 0.4 and requiring a transverse momentum of $p_{\mathrm{t}}>25$ GeV, and $|\eta|<4.5$. The b-tagging applied was chosen to achieve a tagging effiency of 50%. Jets overlapping with an electron within a distance of $\sqrt{\Delta\eta^2+\Delta\varphi^2}<0.2$ were removed. For the suppression of QCD mulit-jet events a missing transvere energy, $\not{E}_{\mathrm{t}}$, of at least 25 GeV and a reconstructed transverse W boson mass of $M_{\mathrm{t}}(\mathrm{W})>60\ \mathrm{GeV}-\not{E}_{\mathrm{t}}$ were required.

3. Cut-Based Analysis

In addition to the event selection, here a reconstructed top-quark mass of $150<M_{\ell\nu\mathrm{b}}<190$ GeV, a total transverse energy of the final state $\sum E_{\mathrm{t}}>210$ GeV and an azimuthal difference between the b-tagged and the untagged second leading jet of $\Delta\eta(\text{b-jet1, u-jet1})>1.0$ with a pseudo-rapidity of the untagged jet of $|\eta(1-\text{jet})|>2.0$ were required. The results of this analysis are listed in Tab. 1 for 2-jet and 3-jet events for real data as well as for the signal Monte Carlo events and the backgrounds, separated for positively and negatively charged leptons.

	Cut-based 2-jets		Cut-based 3-jets	
	Leptons+	Leptons-	Leptons+	Leptons-
t-channel	51.8±16.4	23.7±6.5	33.0±7.0	16.3±4.8
s-channel	0.9±0.2	0.6±0.2	0.3±0.1	0.3±0.1
Wt	1.1±0.5	0.6±0.7	1.5±0.6	1.5±1.2
$t\bar{t}$	7.1±3.2	7.2±2.9	26.8±8.0	25.0±7.6
W+jets	3.7±1.7	2.6±1.2	2.1±1.5	2.1±1.4
Wc+jets	18.3±3.8	11.7±3.4	7.8±3.0	6.5±2.6
W$b\bar{b}$+jets	7.7±5.9	2.5±2.5	6.2±5.2	2.9±2.4
W$c\bar{c}$+jets	3.1±2.4	1.3±1.0	3.6±2.8	1.7±1.4
Diboson	0.1±0.1	0.1±0.1	0.2±0.2	0.1±0.1
Z+jets	0.2±0.4	0.1±0.2	1.0±1.0	1.5±1.3
QCD	<0.1	<0.1	<0.1	<0.1
TOTAL Exp	94.1±18.4	50.2±8.5	82.6±12.7	57.9±10.1
S/B	1.23	0.89	0.67	0.39
DATA	118	68	74	60

Table 1: Event yields of the cut-based analysis for 2-jet and 3-jet events [2].

4. Neural Network Analysis

A three-layer feed-forward neural network with a complex preprocessing (NeuroBayes®) was used [5]. The net consisted of 13 input nodes, 33 hidden nodes and a single output node. The signal yield was extracted by performing a maxium likelihood fit to the discriminant output variable for real data and Monte Carlo templates. The input variables were the same as for the cut-based analysis plus 9 additional ones. This analysis was performed for 2-jet events only. Its results are shown in Tab. 2.

Source	yield after NN fit
t-channel	900 ± 60
s-channel	52 ± 5
Wt	165 ± 16
$t\bar{t}$	770 ± 64
W+jets	545 ± 173
Wc+jets	1480 ± 400
$Wb\bar{b}/c\bar{c}$+jets	2130 ± 420
Diboson	79 ± 4
Z+jets	139 ± 78
Multijets	700 ± 250
TOTAL Exp	6950 ± 880
DATA	6953

Table 2: Event yields of the neural network analysis [2].

5. Background Estimate

The backgrounds for top-pair production, Z+jets, di-boson and single-top (Wt and s-channel) events were normalised to the prediction while the mutli-jet normalisation was obtained by a template fit of the $\not{E}_t$ distribution to real data. The W+jets overall normalisation and flavour composition were estimated from real data as well.

6. Systematics

The main systematic uncertainties of both analyses are summarised in Tab. 3. Both analyses suffer mostly from the residual differences between data and simulation (object modelling), in particular the jet energy scale. Another large contribution arises from the choice of Monte Carlo generators and PDFs for signal and background mostly due to the imperfect modelling of the radiation of additional gluons.

			DATA statistics	MC statistics	Object modelling	Generators & PDF	Bkg. normalization	Luminosity	All systematics	Total
$\Delta\sigma/\sigma$ [%]	c.b.	▲	+13	+6	+23	+25	+10	+7	+41	+44
		▼	-13	-6	-14	-22	-10	-6	-27	-30
	NN	▲	+10	+7	+36	+19	+3	+5	+44	+45
		▼	-10	-7	-25	-17	-3	-5	-34	-34

Table 3: Relative change in the single-top cross-section for different systematic effects for both the cut-based (c.b.) as well as the neural network analysis (NN). Upward (▲) and downward variations (▼) are shown separately [2].

7. Results

ATLAS has measured the following cross-sections for single-top production in pp collisions at a centre-of-mass energy of $\sqrt{s} = 7\,\text{TeV}$ using an integrated luminosity of $\int \mathcal{L} dt = 0.70\,\text{fb}^{-1}$:

- Cut-based: 2/3-jet $\sigma_t = 90^{+9}_{-9}(\text{stat})^{+31}_{-20}(\text{syst})\,\text{pb} \quad = 90^{+32}_{-22}\,\text{pb}$
  expected $\sigma_t^{\text{exp}} = 65^{+28}_{-19}\,\text{pb}$
- Neural network: 2-jet $\sigma_t = 105^{+7}_{-7}(\text{stat})^{+36}_{-30}(\text{syst})\,\text{pb} \quad = 105^{+37}_{-31}\,\text{pb}$
  expected $\sigma_t^{\text{exp}} = 65^{+29}_{-22}\,\text{pb}$

References

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