First measurement of Single Top production in the tW-channel in pp collisions

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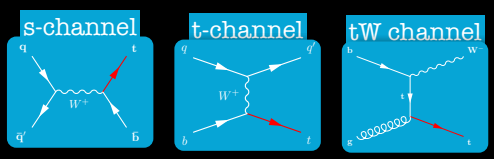
Single Top at the LHC

Single Top production at the LHC proceeds via weak interaction in 3 production channels:



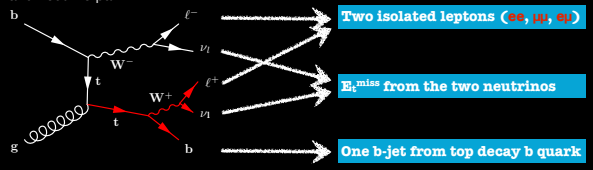
This analysis studied the production of a single top in association with a W boson (tW), a process for which evidence was observed by both ATLAS [1] and CMS [2] in the LHC 7TeV data. The results presented here are obtained from **8TeV** center of mass energy proton-proton collisions, recorded by the CMS experiment, for a total luminosity of **12.2 fb^{-1}**.

Cross sections (pb)	s-channel	t-channel	tW channel	top pairs
Tevatron: ppbar@1.96TeV	1.05	2.08	0.22*	7.08
LHC: pp @ 7 TeV	4.56	65.9	15.6	163
LHC: pp @ 8 TeV	5.55	87.2	**22.2**	**234**

N. Kidonakis arXiv:1205.3453v1 (2012)

Event Selection

Top quarks almost always decay into a b quark and a W boson. This analysis considers the tW final state in which both the associated W boson and the W boson produced by the single top, decay in a lepton and neutrino pair.



The main background is top pair decays, where one of the b quark jets is either too soft, or not reconstructed. The second most important is Z+jets, the other backgrounds are easily removed.

- Electrons:
  - $p_T > 20$ GeV, $|\eta| < 2.5$
  - IP < 0.04 cm from beam spot
  - RelIso < 0.15 in a cone of $\Delta R < 0.3$
- Muons:
  - $p_T > 20$ GeV, $|\eta| < 2.4$
  - RelIso < 0.20 in a cone of $\Delta R < 0.4$
- Jets:
  - Anti-k_t algorithm,
  - $p_T > 30$ GeV, $|\eta| < 2.4$
  - Combined Secondary Vertex tagging

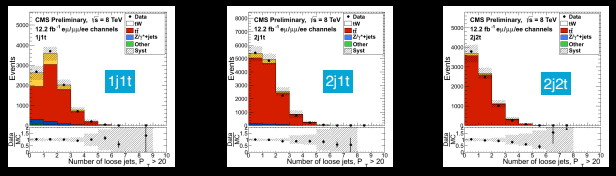
- Event Selection:
  - Exactly 2 oppositely charged leptons
  - $m_{ll} > 20$GeV
  - for ee, μμ channels:
    - Z-mass veto: 81< m_{ll} <101 GeV
    - $E_T^{miss} > 50$ GeV
- Signal and control regions:
  - Based on jet multiplicity and b-tagging
  - Signal: 1jet1b-tag (**1j1t**)
  - Top pair control regions:
    - 2 jets, 1 b-tag (**2j1t**)
    - 2 jets, 2 b-tags (**2j2t**)

Multivariate Analysis

After event selection, a Boosted Decision Tree (BDT) is used to discriminate tW from top pairs using the following kinematic input variables.

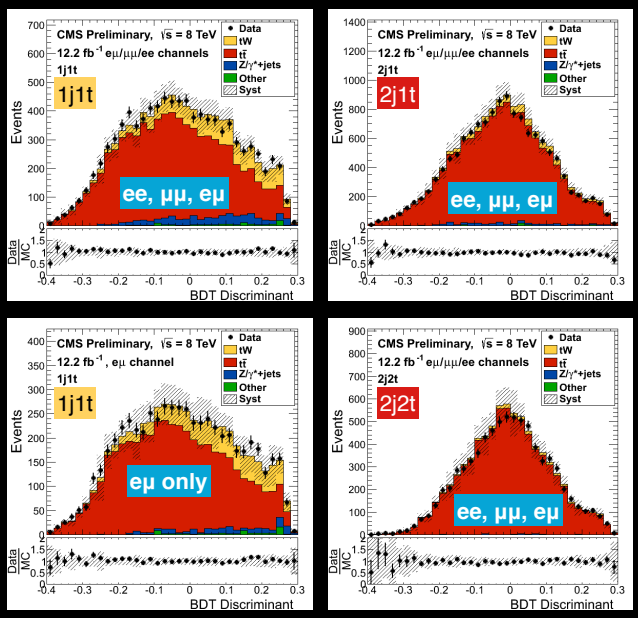
The BDT is trained on 200k signal (tW) and background (top pair) MC events from exclusive dilepton sample.
Adaptive boosting method is used with 400 trees.
Input variables were selected based on discriminating power and data/MC agreement in the control regions.

Variable	Description
Nloosejets	Number of loose jets, $p_T > 20$ GeV, $\|\eta\| < 4.9$
NlosejetsCentral	Number of loose jets, $p_T > 20$ GeV, $\|\eta\| < 2.4$
NbtaggedLoosejets	Number of loose jets, $p_T > 20$ GeV, CSVM btagged
$p_{T,sys}$	Vector sum of p_T of leptons, jet, and E_T^{miss}
H_T	Scalar sum of p_T of leptons, jet, and E_T^{miss}
Jet p_T	p_T of the leading, tight, b-tagged jet
Loose jet p_T	p_T of leading loose jet, defined as 0 for events with no loose jet present
$p_{T,sys}/H_T$	Ratio of $p_{T,sys}$ to H_T for the event
Msys	Invariant mass of the combination of the leptons, jet, and E_T^{miss}
centralityJLL	Centrality of jet and leptons
$H_{T,leptons}/H_T$	Ratio of scalar sum of p_T of the leptons to the H_T of full system
p_T-jll	Vector sum of p_T of jet and leptons
E_T^{miss}	Missing transverse energy in the event



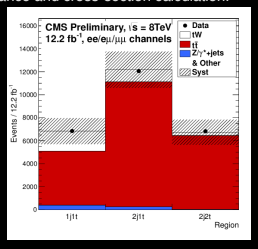
Analysis Strategy

The BDT discriminant is calculated for each event and signal-like events have higher values, while background-like events tend to have lower values.



A likelihood fit to the BDT discriminant distribution is carried out to estimate the significance (using pseudo-experiments) and cross-section (profile likelihood) of the tW process. The fit is performed simultaneously in all three channels and across the signal and control regions. Templates for the shape of signal and backgrounds are taken from simulation,
Systematic uncertainties are taken into account in the fit as nuisance parameters. Shape/rate changes (+/- 1σ variations) to the templates are used to estimate them. Theory shape uncertainties are externalized and treated conservatively in both the significance and cross-section calculation.

Two cross-check analyses have been carried out using the same base event selection, with the addition of a veto on events with extra b-tagged jets with low momentum and, for the eμ channel only, a cut on the H_t variable (scalar sum of p_t of the leptons, of the jet and missing transverse energy).
The same signal and control regions based on jet multiplicity and b-tagging are defined and in one case the number of events in each region is used to extract the signal, in the other a fit to the P_t^{sys} variable is performed.



Results

An excess over the background-only hypothesis is **observed** with a **significance of 6.0σ**, compatible with the **expected significance of 5.4$^{+1.5}_{-1.4}$ σ** from simulation.

The tW cross-section is measured to be **23.4$^{+5.5}_{-5.4}$ pb**, in agreement with the standard model prediction of 22.2 +-0.6 +-1.4 pb [3].
An estimate of the CKM matrix element $|V_{tb}|$ is extracted under the assumption that $|V_{tb}|$ is much larger than $|V_{td}|$ and $|V_{ts}|$:

$$|V_{tb}| = \sqrt{\frac{\sigma_{tW}}{\sigma_{tW}^{th}}} = 1.03 \pm 0.12(exp.) \pm 0.04(th.)$$

Both cut and count and P_t^{sys} cross-check analyses results are compatible with the BDT one. The observed significances are respectively 3.6σ and 4.0σ (with 2.8σ and 3.2σ expected). The cross-sections are respectively 34$^{+9}_{-9}$ pb and 24$^{+9}_{-9}$ pb.

References

The results of this analysis will be available shortly on the CERN document server as CMS PAS TOP-12-040.

[1] Phys. Lett. B 716 (2012) 142
[2] Phys. Rev. Lett. 110, 022003 (2013)
[3] N. Kidonakis arxiv.org/pdf/1205.3453v1 (2012)

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