Measurement of the top quark pair production cross section in dilepton final states with ATLAS

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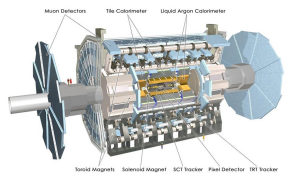
INTRODUCTION

The measurement of the top pair production cross section is a sensitive test of perturbative QCD and the Standard Model (SM) description of top-quark decay. A measured cross section that differs significantly from the SM prediction of 165^{+11}_{-16} pb (at $\sqrt{s} = 7$ TeV and m_t=172.5 GeV) can be a sign of new physics in either the production, or the decay. Furthermore, top pair production cross section measurement augments our understanding of top events as major background in many searches for physics beyond the SM, and in searches for SM Higgs boson.

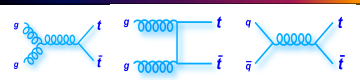
THE ATLAS DETECTOR



Data Collection 2011

- p-p collisions at $\sqrt{s} = 7$ TeV
- Peak Luminosity 1.25×10^{33} cm^{-2} s^{-1}
- Average number of interactions per bunch crossing $\langle\mu\rangle = 5.6$
- Single lepton triggers ~ 690 pb^{-1}
  E^e_T=20 GeV, P^μ_T =18 GeV
- Luminosity Uncertainty 3.7 %

TOP PRODUCTION & DECAY



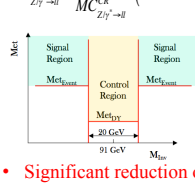
- Dominant mechanism at LHC is gluon-gluon fusion with additional contribution from qq-annihilation
- Focus on final state (FS) with both W decaying into a pair of lepton and neutrino
- FS characterized with clean signature and relatively small branching fraction of ~6.5%

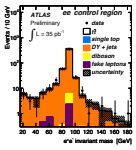
BACKGROUNDS

Drell-Yan Estimate Normalized to Data

- Dominant background for same flavor lepton channels
- Minimal total uncertainty on DY estimate is crucial to maximize measurement sensitivity

$$N^{SR}_{Z/\gamma^* \to ll} = \frac{MC^{SR}_{Z/\gamma^* \to ll}}{MC^{CR}_{Z/\gamma^* \to ll}} \cdot \left(Data^{CR} - MC^{CR}_{other}\right)$$



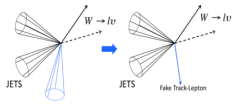


- Significant reduction on systematic uncertainty

	Pretag		B-tag	
Channel	ee	$\mu\mu$	ee	$\mu\mu$
$Z/\gamma^* \to ee/\mu\mu$+jets	$3.8^{+2.5}_{-1.2}$	14.8 ± 4.7	$9.3^{+3.7}_{-1.9}$	$19.1^{+2.4}_{-1.6}$

Fakes from Matrix Method

$$\begin{bmatrix} N_{TT} \\ N_{TL} \\ N_{LT} \\ N_{LL} \end{bmatrix} = M \times \begin{bmatrix} N_{RR} \\ N_{RF} \\ N_{FR} \\ N_{FF} \end{bmatrix}$$



	Pretag			B-tag		
Channel	ee	$\mu\mu$	$e\mu$	ee	$\mu\mu$	$e\mu$
Fakes	3.1 ± 2.2	$0.3^{+0.5}_{-0.3}$	44 ± 24	4.9 ± 3.1	1.0 ± 0.8	19 ± 12

Remaining Backgrounds taken from MC

	Pretag			B-tag		
Channel	ee	$\mu\mu$	$e\mu$	ee	$\mu\mu$	$e\mu$
$Z/\gamma^* \to \tau\tau$+jets	5.2 ± 2.6	11.2 ± 4.8	43 ± 16	$1.6^{+1.1}_{-0.9}$	$7.0^{+2.8}_{-3.2}$	$9.1^{+3.8}_{-3.9}$
Wt	6.6 ± 1.2	16.2 ± 2.0	40.9 ± 5.6	$6.8^{+1.3}_{-1.2}$	$15.4^{+2.5}_{-2.4}$	$30.8^{+4.5}_{-4.5}$
WW/WZ/ZZ	5.6 ± 1.0	8.2 ± 1.2	30.9 ± 4.6	2.1 ± 0.8	$2.7^{+0.9}_{-0.6}$	$8.7^{+1.5}_{-1.3}$

ANALYSIS OBJECT SELECTION

Electrons

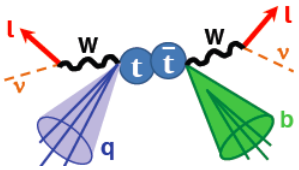
- Isolated EM Calo cluster with stringent quaity requirement
- $E_T > 25$ GeV
- Exclude $1.37 < |\eta| < 1.52$ region
- Exclude dead region (~1%)

Muons

- Track segments from Muon Spec. that are matched to tracks from Inner Det. and refitted
- Both calorimeter and tracker isolation
- $P_T > 20$ GeV & $|\eta| < 2.5$

E_T^{MISS}

- Vector sum of calo cell energy depositions
- Corrected for identified objects consistent with those used in the analysis



Event Cleaning

- Good Run Conditions
- Primary vertex with at least 5 tracks
- Bad jet veto
- Non collision event veto
- Good Liquid Argon conditions

Jets

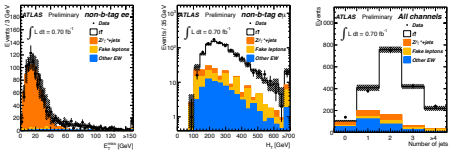
- Topological clusters
- Anti-k_t algorithm (R=0.4)
- MC-based calibration
- $P_T > 25$ GeV & $|\eta| < 2.5$
- Corrected P_T for pile-up effects

B-Jets

- All nominal jet identification requirements
- Likelihood ratio as tagging algorithm

ANALYSIS WITHOUT B-TAGGING

- A pair of opposite-sign leptons & at least 2 jets
- $ee/\mu\mu$: $|m_{ll}-m_Z| > 10$ GeV, $m_{ll} > 15$ GeV, $E_T^{MISS} > 60$ GeV
- $e\mu$: $H_T = \Sigma(P_T^{Lep} + P_T^{Jet}) > 130$ GeV



Main systematics

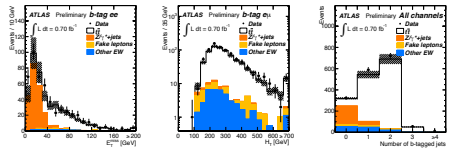
- Lepton ident. (2.7 %)
- Jet energy scale (6 %)
- Gener., I/FSR (2.5%)

Channel	ee	$\mu\mu$	$e\mu$
Total Bkg.	$24.3^{+5.4}_{-4.7}$	50.8 ± 8.4	158 ± 34
Expected $t\bar{t}$	135 ± 17	252^{+23}_{-28}	753 ± 61
Data Obs.	165	287	962

$$171 \pm 6(\text{stat})^{+16}_{-14}(\text{syst}) \pm 8(\text{lum})\ \text{pb}$$

ANALYSIS WITH B-TAGGING

- A pair of opposite-sign leptons & at least 1b-tagged jets
- $ee/\mu\mu$: $|m_{ll}-m_Z| > 10$ GeV, $m_{ll} > 15$ GeV, $E_T^{MISS} > 40$ GeV
- $e\mu$: $H_T = \Sigma(P_T^{Lep} + P_T^{Jet}) > 140$ GeV



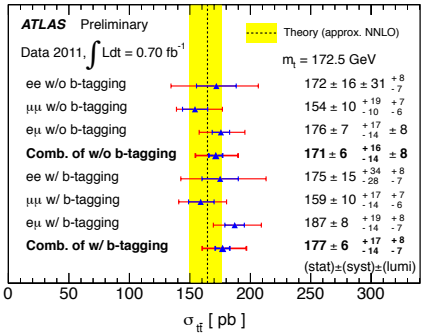
Main systematics

- Jet energy scale (5.3 %)
- B-tag efficiency (4.5%)
- PDF (2.7%)

Channel	ee	$\mu\mu$	$e\mu$
Total Bkg.	$24.7^{+5.2}_{-4.0}$	$45.2^{+4.6}_{-4.4}$	68 ± 14
Expected $t\bar{t}$	167^{+21}_{-22}	314^{+30}_{-38}	666^{+62}_{-77}
Data Obs.	202	349	823

$$177 \pm 6(\text{stat})^{+17}_{-14}(\text{syst})^{+8}_{-7}(\text{lum})\ \text{pb}$$

SUMMARY



Measurement of top pair production cross section

- Used robust cut and count method to measure the cross section in dilepton final state

$$\sigma = \frac{N_{Observed} - N_{Expected}}{A \cdot \varepsilon \cdot \int L\,dt} \pm \Delta\sigma_{stat} \pm \Delta\sigma_{syst} \pm \Delta\sigma_{lum}$$

- Analysis with and without B-Tagging
- Data-Driven estimation for DrellYan and fake backgrounds
- Detailed studies of systematic uncertainties
- Measurements are consistent with SM prediction
- Published results are available at:

ATLAS-CONF-2011-100

Combined measurement

- Combine 2010 single-leptonic result (35 pb^{-1}) with 2011 dilepton result (690 pb^{-1}) to produce the combined measurement

$$176 \pm 5(\text{stat}) \pm 10(\text{syst}) \pm 7(\text{lum})\ \text{pb}$$