Measurement of the top quark pair production cross section with ATLAS in *pp* collisions at $\sqrt{s}$ = 7 TeV in the single-lepton channel using semileptonic *b* decays[1]

L. Cerrito, **J.D. Morris**, G.Snidero, G. Salamanna : Queen Mary University of London
V. Boisvert, M. Rose, N. Cooper-Smith, J. Blanco : Royal Holloway University of London

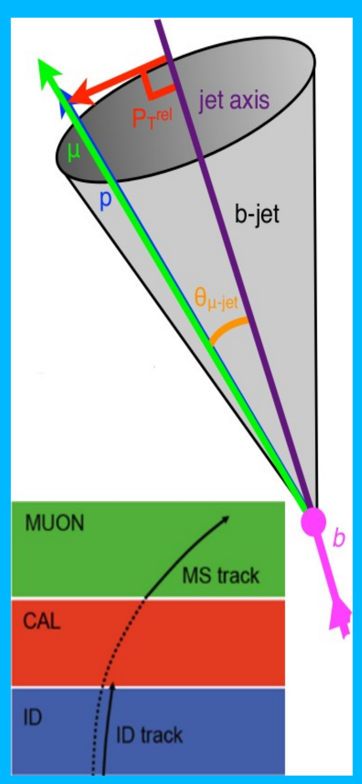
The cross section for top quark pair production in *pp* collisions at $\sqrt{s}$ = 7 TeV is measured using data recorded with the ATLAS detector at the Large Hadron Collider with a data sample corresponding to 4.66 fb^{-1} of integrated luminosity. Semileptonic *b* decays are identified by a lower momentum muon inside a jet, leading to substantially different sources of systematic uncertainty compared with other measurements. The top quark pair production cross section is measured to be:

$$\sigma_{t\bar{t}} = 165 \pm 2(\text{stat.}) \pm 17(\text{syst.}) \pm 3(\text{lumi.})\ \text{pb}$$

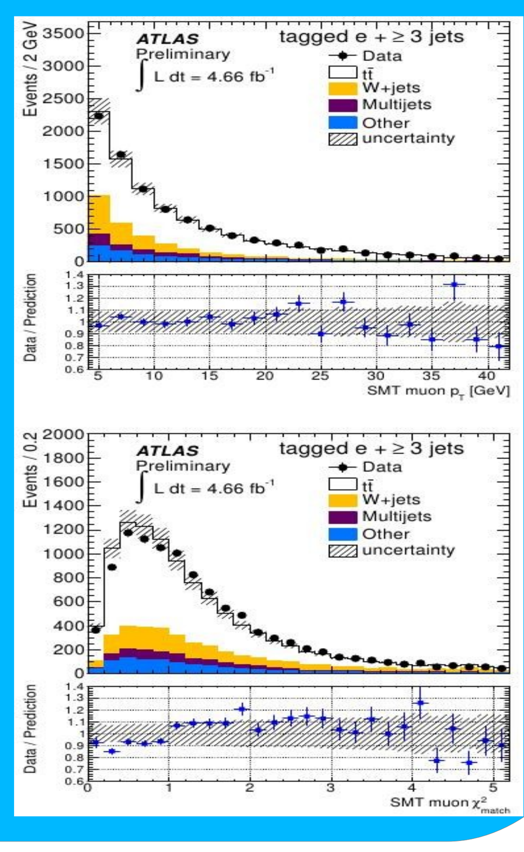
In agreement with a theoretical prediction of 167 ± 18 pb[2,3] based on perturbative QCD and with other measurements which used different techniques or decay channels[4,5,6].

This tagging algorithm has by far the lowest systematic uncertainties of any on ATLAS

Soft Muon Tagger (SMT)



- Match χ^2 based jet tagger
- Branching ratio $b \to \mu X \approx 20\%$
  - Tag *b*-jets if they contain a muon
- Muon requirements:
  - Good ATLAS muon
  - ΔR(jet,μ) < 0.5, |d0| < 3mm, |z0sin(θ)| < 3mm
  - p_T > 4 GeV, |η| < 2.5
  - N(tracks in jet) > 3, χ^2 / d.o.f < 3.2
- Match χ^2 :
  - Quality of match between inner detector and muon spectrometer
  - Built with 5 track parameters
- Systematics uncorrelated with lifetime based taggers
- Systematics smaller than lifetime based taggers



$b \to \mu X$ Branching Ratio Re-weighting

- Important that MC simulation accurately reproduces rates of soft muons from semileptonic *b/c* decays
- Pythia and Herwig rates are different from those listed by the PDG[7]
- Each soft muon in the simulation is re-weighted accordingly

Source	PDG	Herwig	PDG/Herwig	Pythia	PDG/ Pythia
$b \to \mu$	0.1095 ± 0.0029	0.0957 ± 0.0003	1.14 ± 0.03	0.1001 ± 0.0003	1.09 ± 0.03
$b \to \tau \to \mu$	0.0042 ± 0.0004	0.0070 ± 0.0002	0.60 ± 0.06	0.0067 ± 0.0001	0.62 ± 0.06
$b \to c \to \mu^+$	0.0802 ± 0.0019	0.0824 ± 0.0002	0.97 ± 0.02	0.0889 ± 0.0003	0.90 ± 0.02
$b \to \bar{c} \to \mu^-$	0.0160 ± 0.0050	0.0251 ± 0.0002	0.64 ± 0.20	0.0266 ± 0.0002	0.60 ± 0.19
$c \to \mu\,(W \to cs)$	0.0820 ± 0.0050	0.0854 ± 0.0006	0.96 ± 0.06	0.1053 ± 0.0007	0.78 ± 0.05

Data-Driven Background Estimation

W+Jets background estimation

- Important background – Events contain a real lepton and E_t^{miss}
- Uncertainty on relative contribution from heavy and light flavoured jets
- Overall normalisation determined by *W* charge asymmetry method[8]
  - The ratio of positively and negatively charged *W* bosons suffers from a small theoretical uncertainty
  - Cross check performed using the Berends-Giele[9] scaling method is found to be consistant
- Determine relative contributions in pre-tag sample and a tagging rate for each flavour
  - Leads to estimate for the SMT tagged sample that is used in the cross-section calculation

	e+jets			μ+jets		
Flavour	W_{pretag}	R_{tag}	W_{tag}	W_{pretag}	R_{tag}	W_{tag}
bb	4400 ± 1800	0.108 ± 0.007	480 ± 200	7700 ± 2800	0.094 ± 0.005	720 ± 260
cc	8300 ± 3400	0.044 ± 0.003	360 ± 150	14700 ± 5300	0.040 ± 0.003	590± 210
c	7000 ± 4000	0.045 ± 0.004	290 ± 170	16700 ± 7200	0.043 ± 0.003	710 ± 310
Light	40000 ± 6000	0.013 ± 0.002	500 ± 110	78000 ± 11000	0.011 ± 0.001	860 ± 170
Total	60000 ± 5000		1630 ± 330	117000 ± 9000		2900 ± 500

Mulitjet background estimation

- An important background that is determined using the data-driven matrix method[10] technique
- Events with electrons come mainly from photon conversions and jets with high EM fractions
- Events with muons come from the semileptonic decay of heavy (*b/c*) quarks, the decay in flight of pions and kaons and from "punch-through" hadrons that are not fully absorbed within the hadronic calorimeter and are observed in the muon spectrometer
- Multijet estimates are obtained by considering control regions close to the signal region and obtaining a SMT tagging rate, as listed in the table below. The final yields are given at the bottom of this poster.

e+jets Multijet control region	SMT tagging rate (%)	μ+jets Multijet control region	SMT tagging rate (%)
A (Low-E_T^{miss}, non-isolated *e*)	3.8±0.1	Inverted isolation	5.7±0.1
B (High-E_T^{miss}, non-isolated *e*)	5.1±0.4	Inverted triangular cut	4.0±0.5
C (Low-E_T^{miss}, isolated *e*)	2.5±1.3		
Unweighted average	3.8±1.3	Unweighted average	4.9±0.8

Event Selection

Data taken with the ATLAS detector in 2011 using *pp* collisions at $\sqrt{s}$=7 TeV
Total integrated luminosity of 4.66 fb^{-1}

Events are selected that pass a Good Run List criteria with:

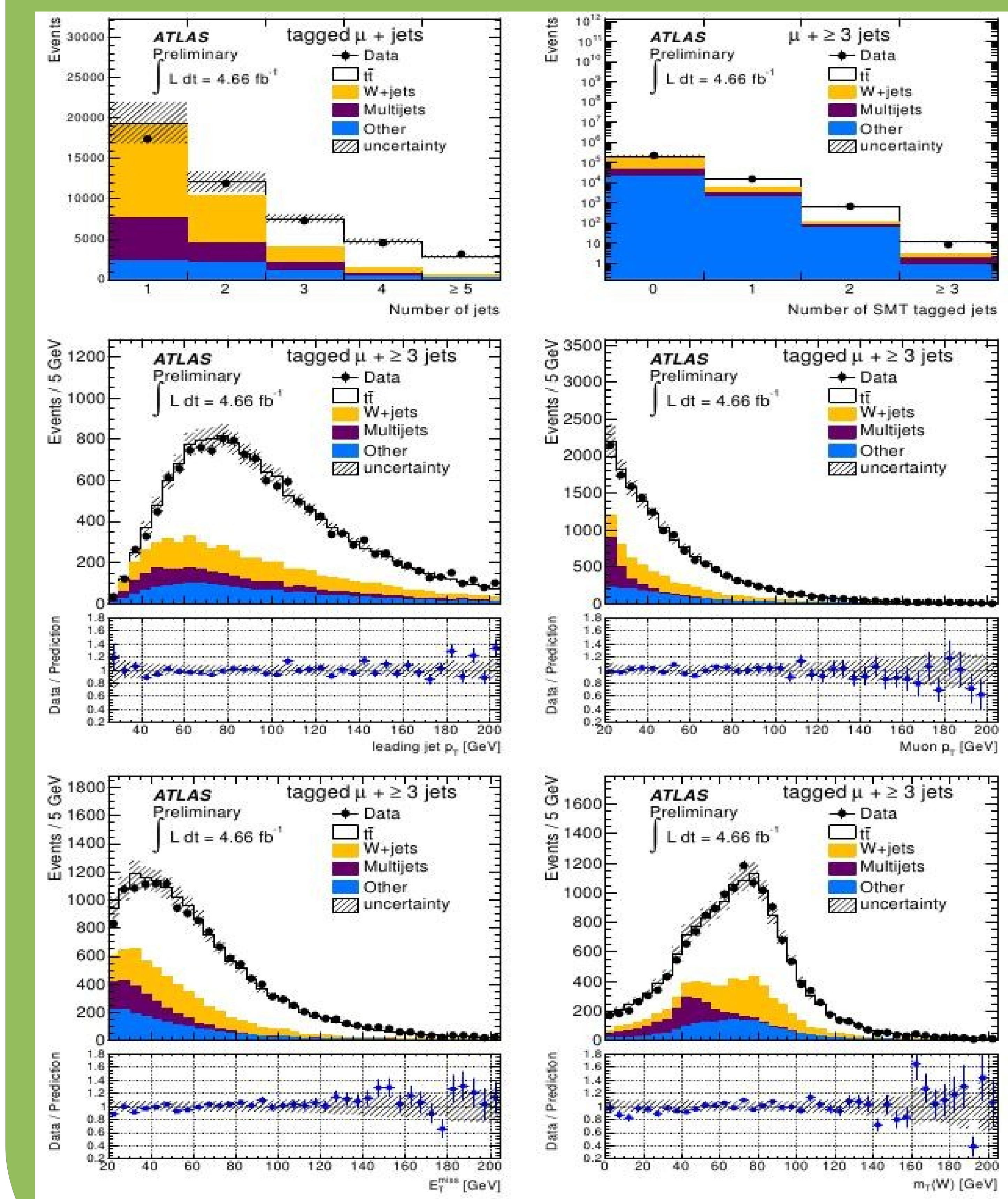
- At least 3 Anti-k_T jets (recombination parameter = 0.4) with:
  - Jet p_T > 25 GeV, |η| < 2.5
  - At least 1 jet tagged by the SMT algorithm

Electron Channel

- Electron trigger
- Single good ATLAS electron with:
  - p_T > 25 GeV
  - |η|<2.47, veto 1.37≤|η|≤1.52
- E_t^{miss} > 30 GeV
- $m_T(W)$ > 30 GeV

Muon Channel

- Muon trigger
- Single good ATLAS muon with:
  - p_T > 20 GeV, |η|<2.5
- E_t^{miss} + > $m_T(W)$ > 60 GeV
- Invariant Mass ($\mu_{analysis}$,μ_{SMT}) = $M_{\mu\mu}$
  - Veto 8 ≤ $M_{\mu\mu}$ ≤ 11 GeV : Exclude Υ
  - Veto 80 ≤ $M_{\mu\mu}$ ≤ 100 GeV : Exclude Z



Sample	Pretag	Tagged
Data(4.66 fb^{-1})	351742	24105
$t\bar{t}$ MC	84000±2060	15060±590
W+jets DD	176500±10750	4520±600
Multijet DD	43200±9700	1930±470
Z+jets MC	21400^{+3470}_{-2130}	1050^{+145}_{-105}
Single Top MC	11430±680	1630±100
DiBoson MC	3220^{+410}_{-350}	100±15
$t\bar{t}$ MC + Backgrounds	340000± 15000	24300±980
Measured $t\bar{t}$		14900±800
Selection Efficiency (%)		3.57 ± 0.03

$$\sigma_{t\bar{t}} = 165 \pm 2(\text{stat.}) \pm 17(\text{syst.}) \pm 3(\text{lumi.})\ \text{pb}$$

Source	Relative cross section uncertainty [%]
Statistical Uncertainty	±1.0
Object selection	
Lepton energy resolution	+0.2 /-0.1
Lepton reco, ID, trigger	+1.7 /-1.8
Jet energy scale	+3.5 /-3.8
Jet energy resolution	±0.2
Jet reconstruction efficiency	±0.06
Jet vertex fraction	+1.2 /-1.4
E_T^{miss} uncertainty	±0.07
SMT muon reco, ID	±1.3
SMT muon χ^2_{match} efficiency	±0.6
Background estimates	
Multijet normalisation	± 4.4
W+jet normalisation	± 5.5
Other bkg normalisation	± 0.1
Other bkg systematics	+2.2 /-1.8
Signal simulation	
$b \to \mu X$ Branching ratio	+2.9 /-3.1
ISR/FSR	± 1.5
PDF	± 3.1
NLO generator	± 3.2
Parton shower	± 2.2
Total systematics	±10.5
Integrated luminosity	± 1.8

[1] ATLAS-CONF-TOPQ-2861
[2] arXiv : 1111.5869 [hep-ph]
[3] arXiv : 1112.5675 [hep-ph]
[4] ATLAS-CONF-2011-121
[5] ATLAS-CONF-2012-024
[6] CMS-PAS-TOP-11-003
[7] Phys. Rev. **D86** (2012) 010001
[8] Eur. Phys. J. **C72** (2012) 2039
[9] Nucl. Phys. **B 357(1)** (1991), 32
[10] Eur. Phys. J. **C71** (2011) 1577