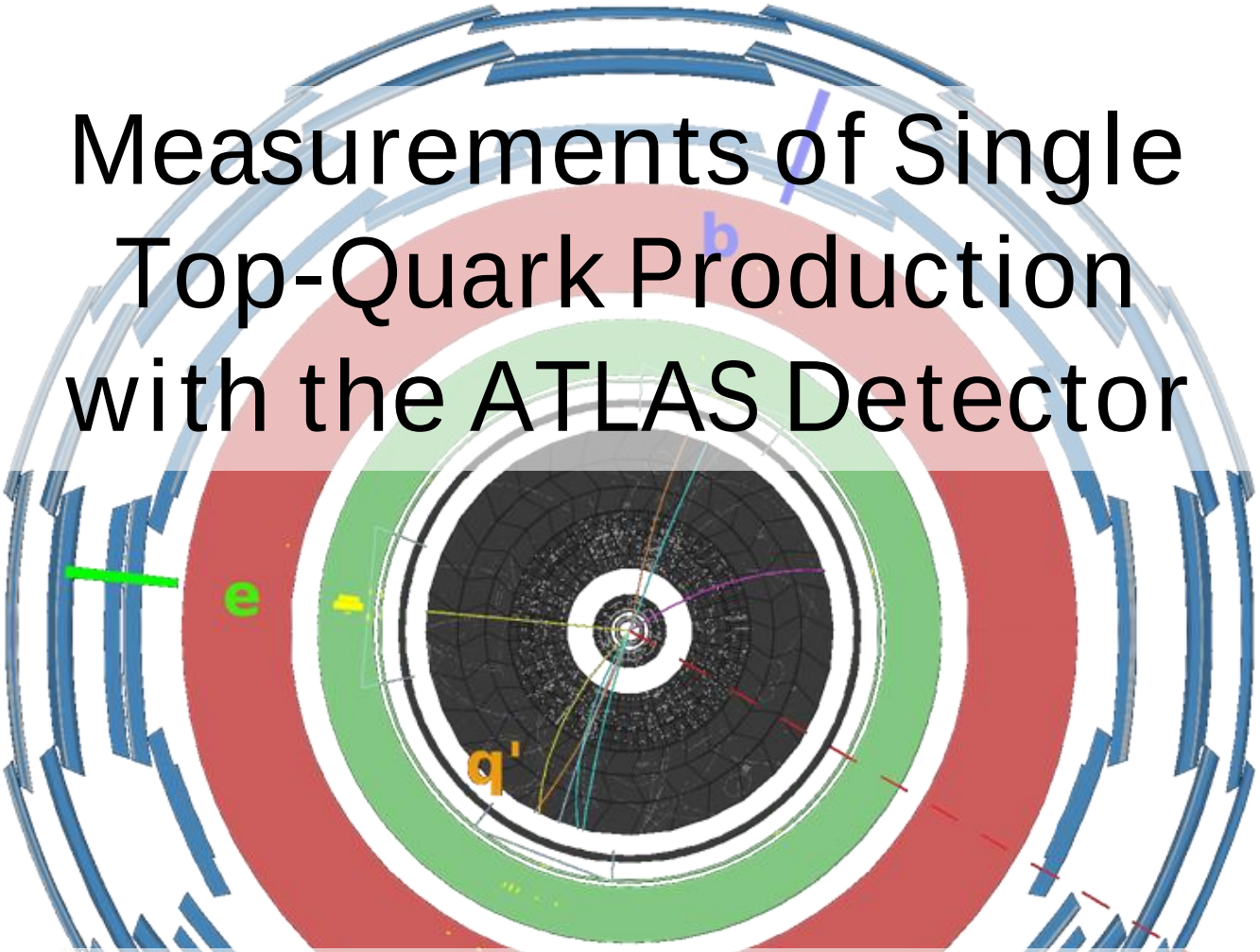
Measurements of Single Top-Quark Production with the ATLAS Detector



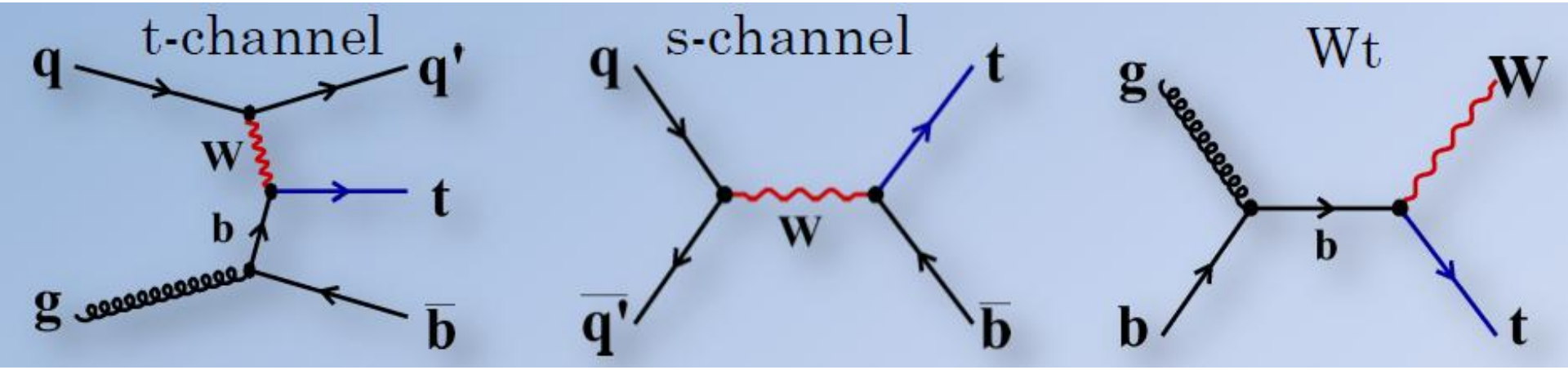
Philipp Sturm
On behalf of the ATLAS collaboration

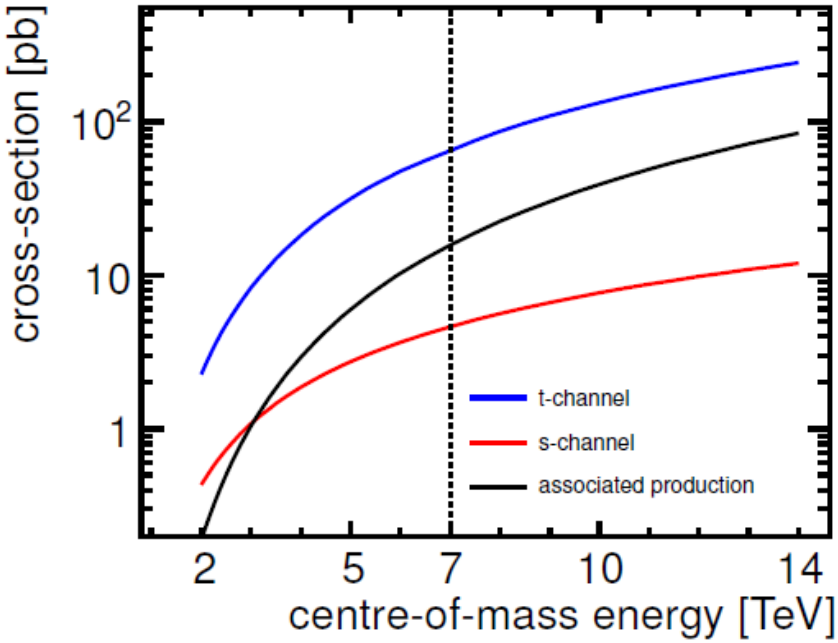
ICHEP - Melbourne
05.07.2012

BERGISCHE UNIVERSITÄT WUPPERTAL

PHYSICS AT THE TERA SCALE
Helmholtz Alliance

Single Top-Quark Production Mechanism





t-channel	$64.6^{+2.7}_{-2.0}$ pb
Wt	15.7 ± 1.1 pb
s-channel	4.6 ± 0.2 pb

$M_t = 172.5$ GeV

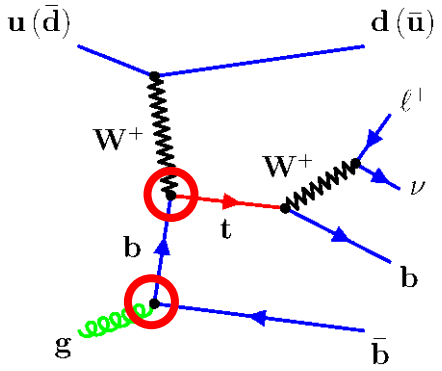
Calculations by N. Kidonakis:
Phys.Rev.D83 (2011) 091503, Phys.Rev.D82 (2010) 054018,2010,
Phys.Rev.D81 (2010) 054028
at NLO + NNLL resummation ($NNLO_{approx}$)

Motivation

Test of the SM prediction

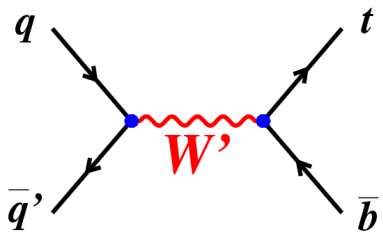
- Establish the different channels separately
- Cross-section $\propto |V_{tb}|^2$

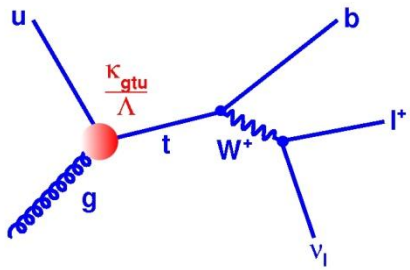
  → Test of the unitarity of the CKM-matrix
- $R_t = \sigma(t)/\sigma(\bar{t})$ is senstitive to the u/d-Quark PDF
- Test of the b-quark PDF



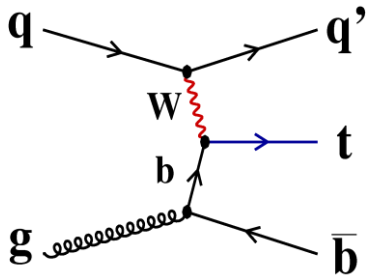
Search for non-SM phenomena

- W-t-b vertex modifications
- Fourth quark generation
- W′ or H^+ (s-channel signature, TR4 B. Gonzalez)
- FCNC: ug → t (TR4 M. Cristinziani)





t-Channel Analysis



Charged lepton:

- Isolated electron or muon
- p_T > 25 GeV

Missing transverse momentum:

- E_T^{miss}> 25 GeV

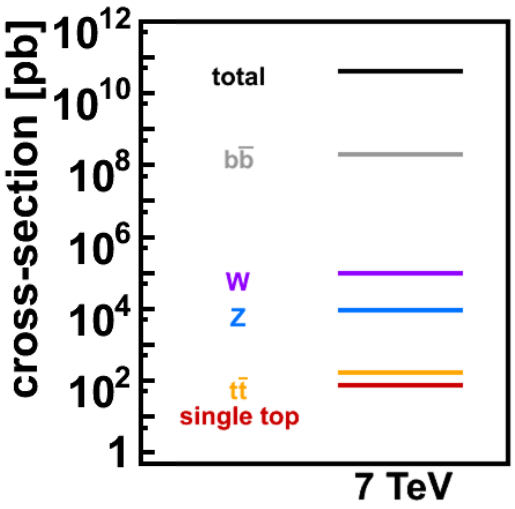
Jets:

- Anti-k_T algorithm (0.4)
- 2 or 3 jets
- p_T > 25 GeV, $|\eta|$<4.5
- One b-tagged jet

Veto against QCD multi-jet events

Analysis of 1.04 fb^{-1} of the 2011 dataset at $\sqrt{s}$ = 7 TeV

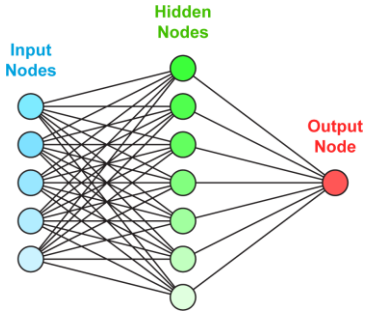
Signal and background modelling

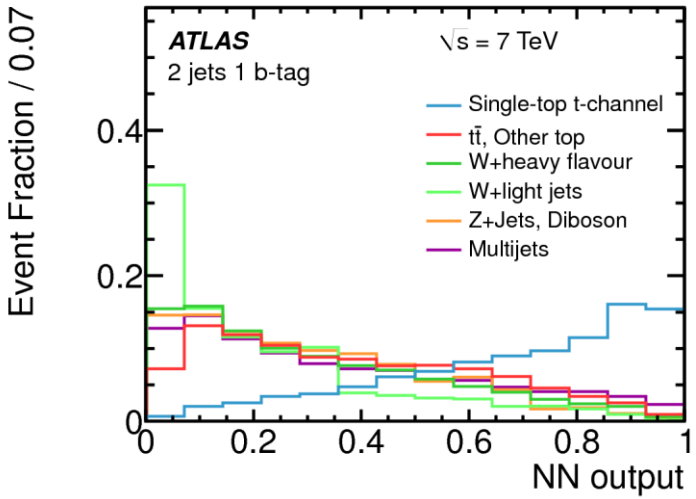


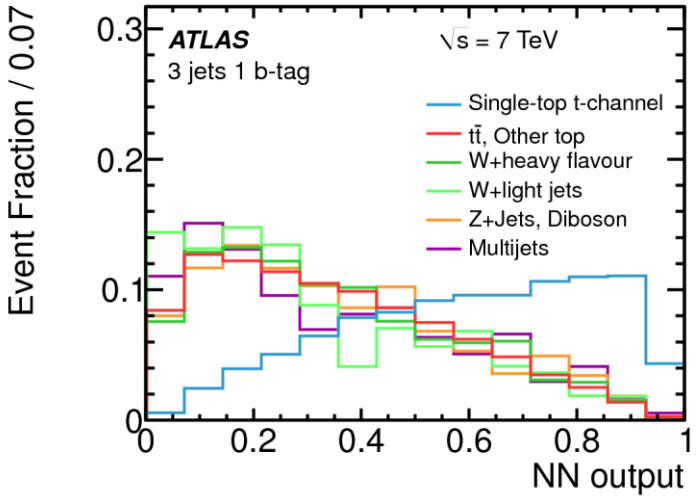
- W/Z+Jets, Top, Diboson from MC simulation
- QCD-multijet background with the data-driven JetElectron model and Fit of the E_T^{miss}-distribution

t-Channel Cross-Section with 1 fb^{-1}

2-jet variables	3-jet variables
$m(\ell\nu b)$	$m(j_1 j_2)$
$\|\eta(j_u)\|$	$m(\ell\nu b)$
$E_T(j_u)$	$\|\Delta\eta(j_1, j_3)\|$
$\|\Delta\eta(b, W)\|$	$\|\Delta\eta(j_2, j_3)\|$
$\|\Delta\eta(j_u, b)\|$	$m_T(W)$
$p_T(\ell)$	$H_T(\ell, \text{jets}, E_T^{\text{miss}})$
$H_T(\ell, \text{jets}, E_T^{\text{miss}})$	$\|\Delta\eta(\ell, b)\|$
$m_T(W)$	$\|\Delta\eta(j_1, j_2)\|$
$\eta(\ell)$	$p_T(\ell)$
$m(b)$	$\eta(\ell)$
E_T^{miss}	$m(b)$
$m(j_u b)$	$m(j_1 j_3)$
	$\|\Delta\eta(b, W)\|$
	$\cos\theta^*$
	E_T^{miss}
	$\|\Delta\eta(\ell, j_3)\|$
	$\|\Delta\eta(\ell, j_2)\|$
	$m(j_1 j_2 j_3)$

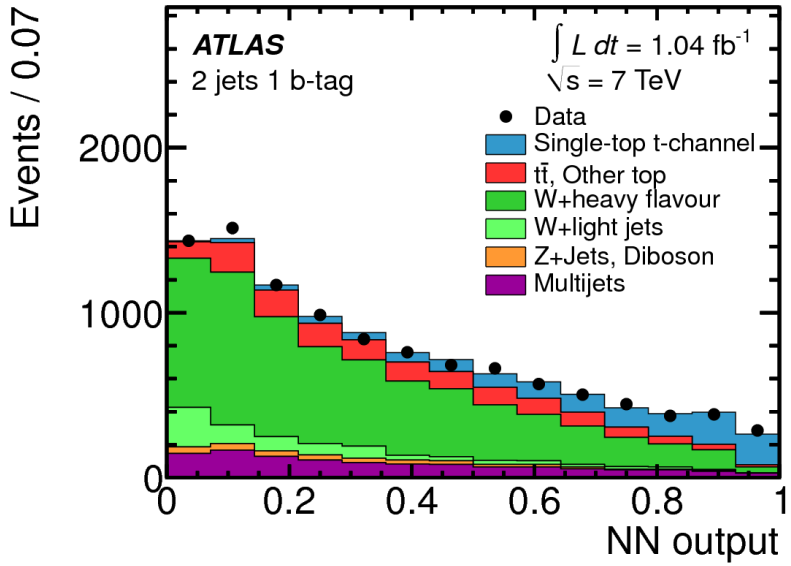


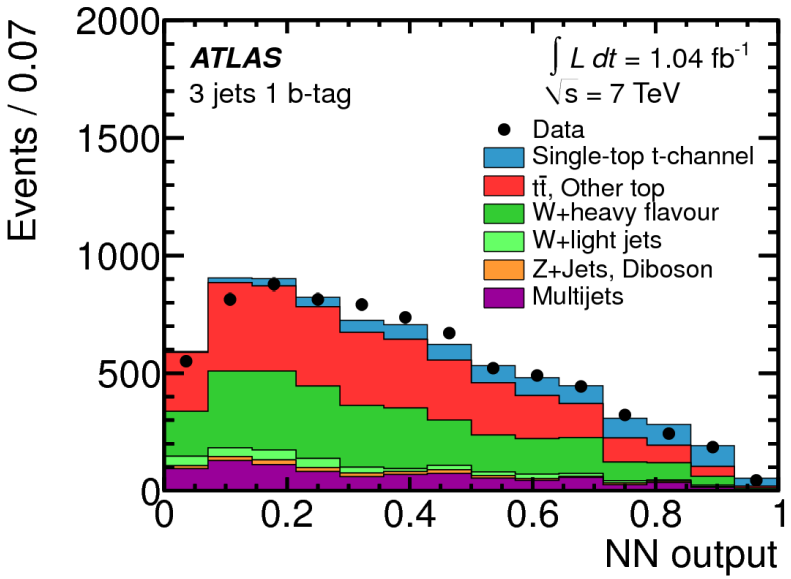


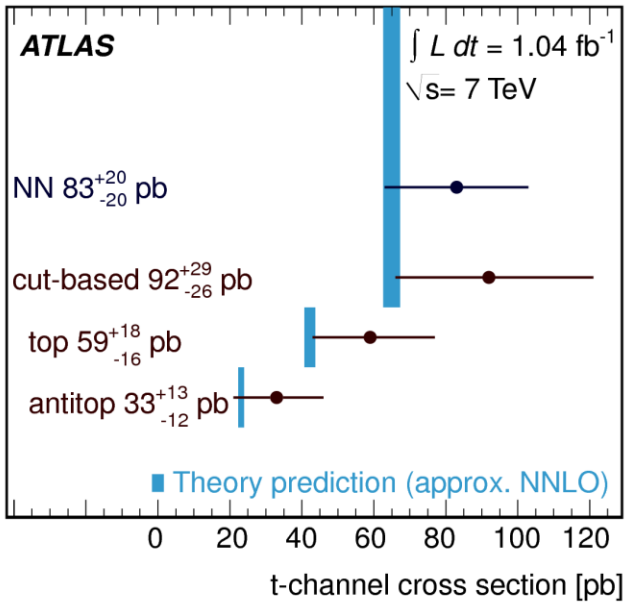


- Neural Network (NeuroBayes) discriminant
- Separate NNs for the two and three jet dataset
- Cross-section measurement:
  - Maximum likelihood fit using the full NN output distribution
  - Simultaneous determination of the signal rate and background rates

t-Channel Cross-Section with 1 fb^{-1}







- Total relative uncertainty 24%
- Main Systematics:
  - B-tagging efficiency 13%
  - ISR/FSR 14%
- Significance: 7.2σ
- Cut-based analysis as a cross-check

arXiv:1205.3130
Submitted to: Physics Letters B

t-channel Cross-Section Ratio with 5fb^{-1}

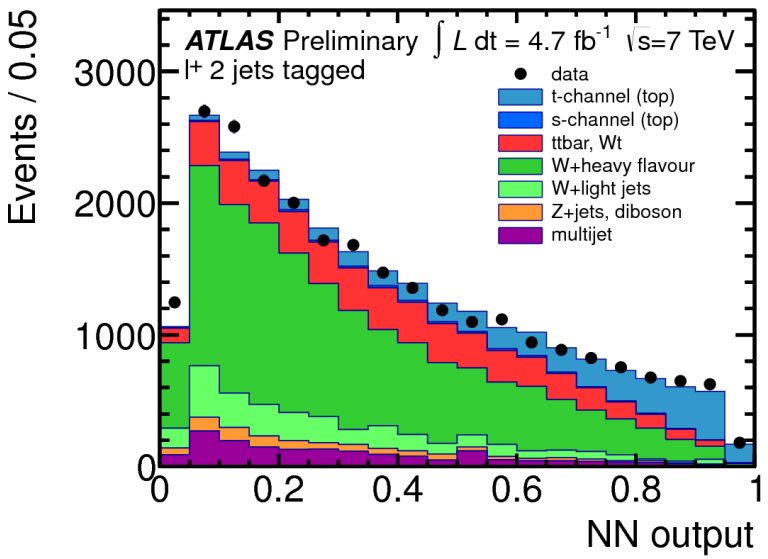
- Flavour of the incoming light-quark defines the top-quark charge
- Measure $R_t \equiv \sigma_t(t)/\sigma_t(\bar{t})$ to constrain the light quark PDF in the momentum fraction range of 0.02 < x < 0.5
- Separate neural networks for top/anti-top production to measure R_t

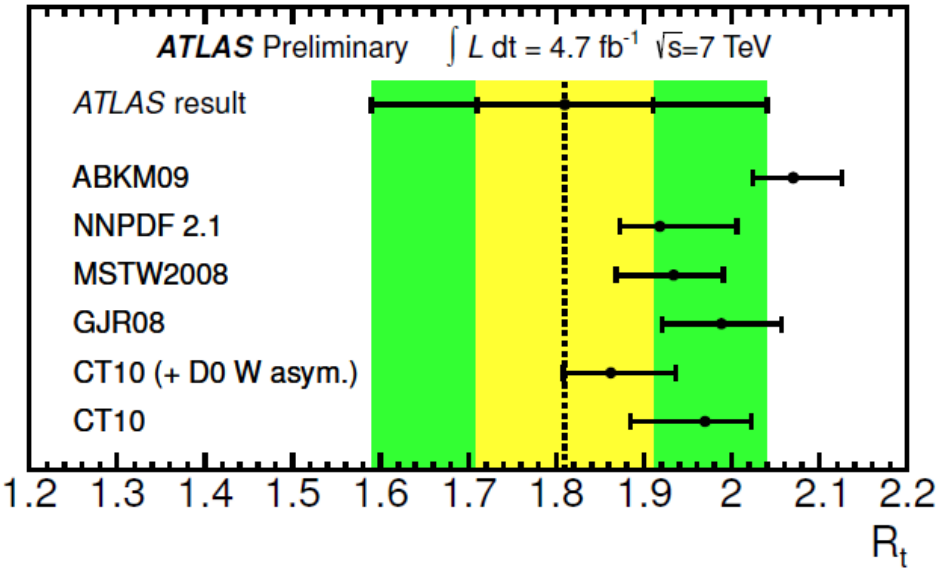
Result:

$$\sigma_t(t) = 53.2 \pm 10.8\,\text{pb}$$
$$\sigma_t(\bar{t}) = 29.5^{+7.4}_{-7.5}\,\text{pb}$$
$$R_t = 1.81^{+0.23}_{-0.22}.$$

Main Systematics:

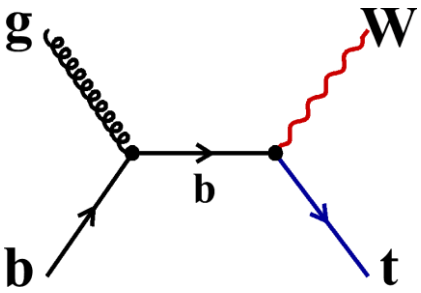
- σ: JES 20% →R_T 4%
- R_t: stat 6%, BG Norm 4%





ATLAS-CONF-2012-056

Wt-Channel Analysis



Charged lepton:

- Opposite sign di-lepton: ee, eμ, μμ
- Isolated electron or muon
- $p_T > 25$ GeV

Missing transverse momentum:

- $E_T^{miss} > 50$ GeV

Jets:

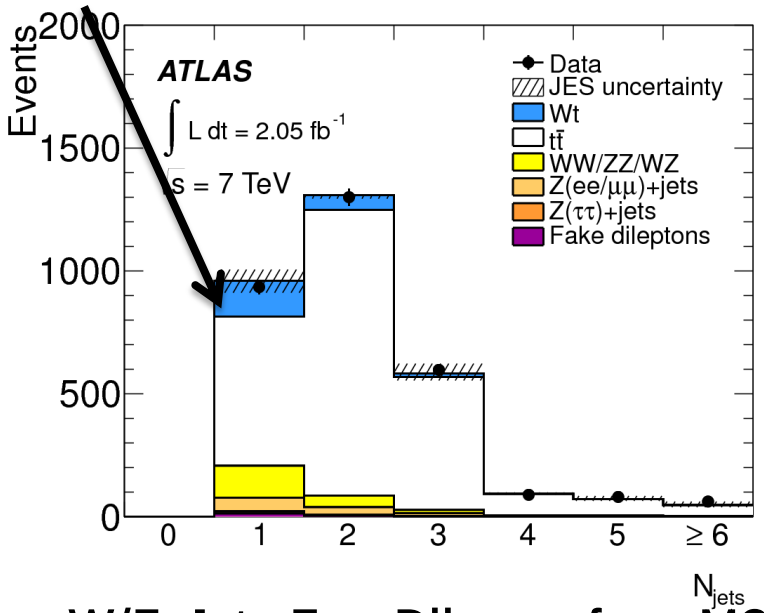
- Anti-k_T algorithm (0.4)
- 1, 2 and 3+ jets
- $E_T > 30$ GeV, $|\eta| < 2.5$
- No b-tagging

Z-Veto: Z-mass window, triangular cut

Analysis of 2.05 fb^{-1} of the 2011 dataset at $\sqrt{s}$ = 7 TeV

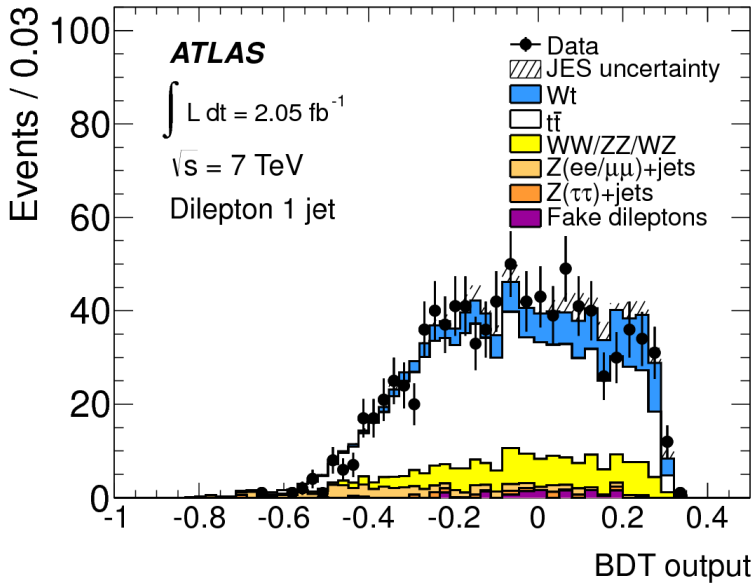
Signal and background modelling

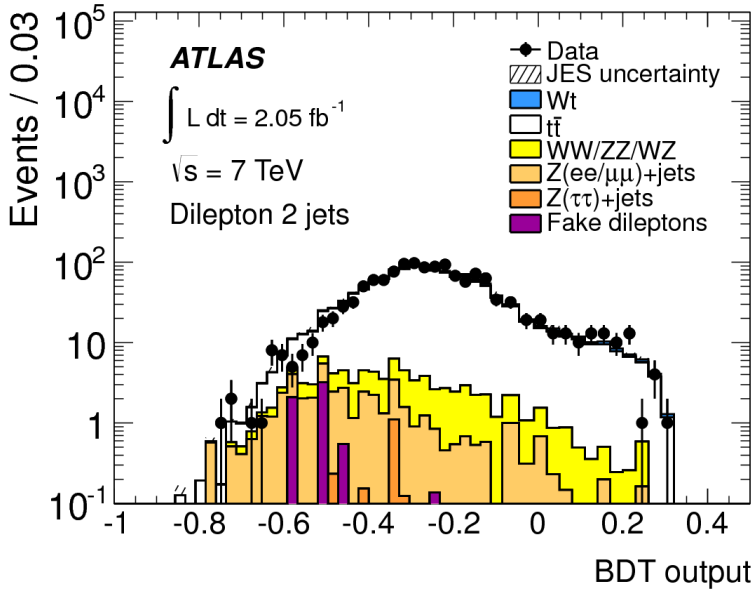
~150 signal events expected



- **W/Z+Jets, Top, Diboson from MC simulation**
- **Z+jets normalisation from data driven ABCDEF method**

Wt Cross-Section with 2.05 fb^{-1}





- Uses 2.05 fb^{-1} of 2011 data set
- Boosted decision tree based discriminant
  - 1 jet dataset is the signal region
  - 2/3 jet dataset as control regions to constrain the background rates
- Cross-section measurement:
  - Simultaneous determination of the signal rate and background rates from the sidebands

Wt Cross-Section with 2.05 fb^{-1}

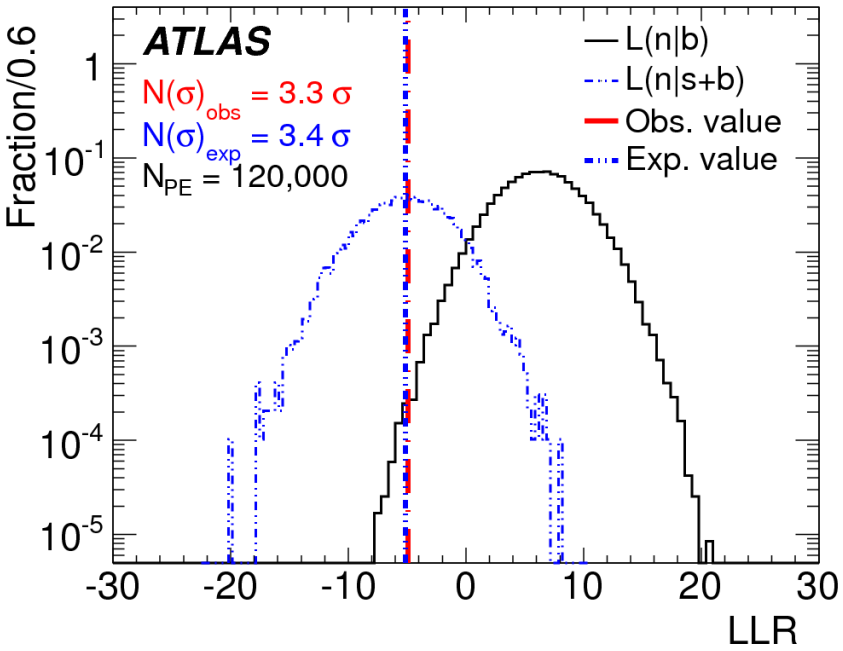
Cross-section measurement:

$$\sigma_{Wt} = 16.8 \pm 2.9\,(\text{stat}) \pm 4.9\,(\text{syst})\ \text{pb}$$

- Relative uncertainty. 33%

Main Systematics:

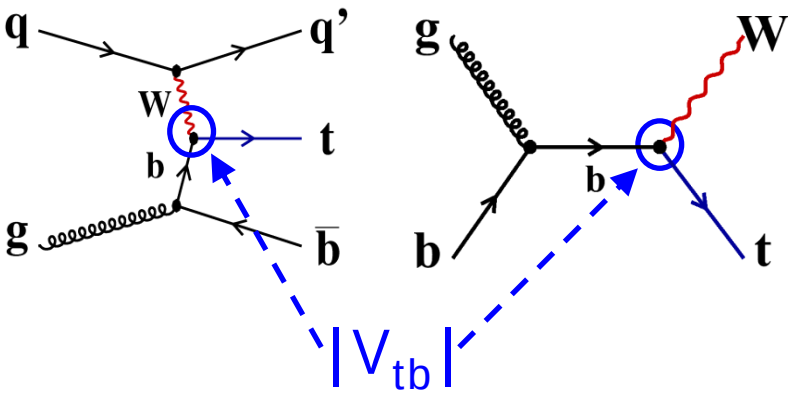
- Data Statistics 17%
- JES 14%
- Genertator 12%
- Parton Shower 14%



Evidence for Wt-production with an observed significance of 3.3σ

arXiv:1205.5764
Sumitted to: Physics Letters B

Measurement of $|V_{tb}|$



- Cross-section result to measure $|V_{tb}|$
- Assume Standard Model (V-A) coupling
- For the t-channel: $|V_{tb}| >> |V_{ts}|, |V_{td}|$ (Consistent with BR(t →Wb) measurements)

$$|V_{tb,meas}|^2 = \frac{\sigma_{meas}}{\sigma_{SM}} \cdot |V_{tb,SM}|^2$$

Channel	Dataset	$\|V_{tb}\|$	rel. exp. precision
t-channel	1.04 fb^{-1}	$1.13\ ^{+0.14}_{-0.13}$ (exp. + theo.)	12%
Wt	2.05 fb^{-1}	$1.03\ ^{+0.16}_{-0.19}$ (exp. + theo.)	17%

Measurements of Single Top-Quark Production

- t-channel analysis:
  - Cross-section measurement:

$$\sigma^{t-\text{channel}}_{\text{observed}} = 83 \pm 20\,\text{pb}$$

  - Top/anti-top cross-section ratio:

$$R_t = 1.81^{+0.23}_{-0.22}.$$

- Evidence for Associated Production
  - Cross-section measurement:

$$\sigma_{Wt} = 16.8 \pm 2.9\,(\text{stat}) \pm 4.9\,(\text{syst})\,\text{pb}$$

  - Observed significance of 3.3σ