TOP QUARK PRODUCTION IN ATLAS

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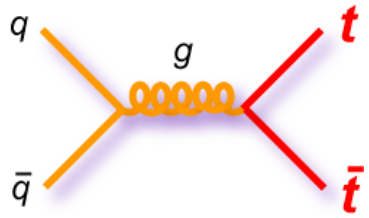
On behalf of the ATLAS Collaboration

Deep Inelastic Scattering 2013

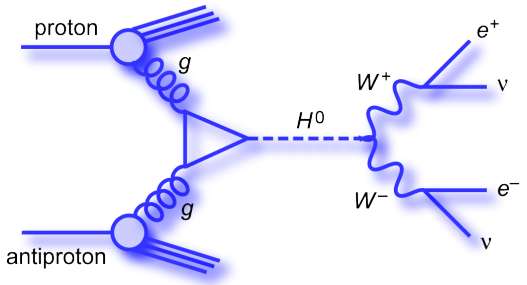
Top pair production

- Why is it interesting?
  - Precision measurement of cross section, branching ratio, polarization could indicate presence of new physics
  - Background to searches for new physics beyond the SM and Higgs boson production
- Direct Search for new physics:
  - Higgs associated production: $t\bar{t}H(H \to b\bar{b})$
  - Beyond Standard Model particles: *Z'* resonances, Kaluza-Klein gluon, stop production
- Detector Calibration
  - Top quark presents a striking signature: possibility of identifying pure samples of electrons, muons, *b*-jets

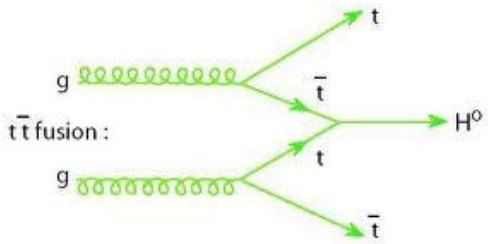
Top pair production



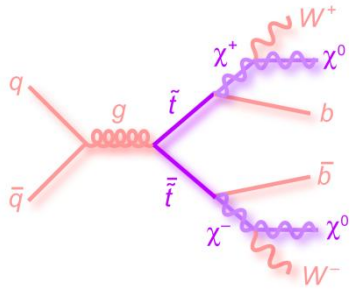
Background for Higgs boson production



Higgs associated production



Stop search

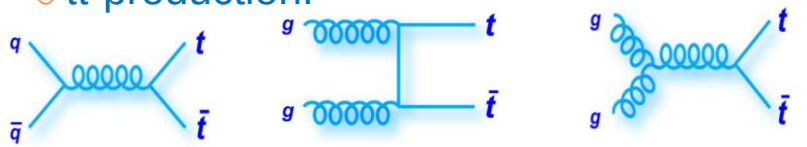


Top pair production

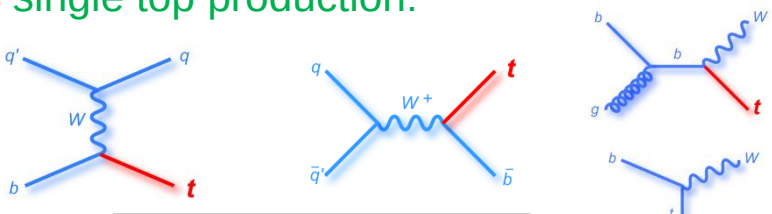
- In proton-proton collision, top quark can be produced in pairs or singly
  - Top pairs are produced through gluon-gluon fusion and quark-quark annihilation (85%/15% @ √7 TeV) → QCD production
  - Single top is produced with an extra quark in the *t*- and *s*-channel diagrams or with a W boson, in the *Wt* diagram → EW production
- In the SM, the top quark decay into W boson and *b*-quarks almost 100% of the time
  - The W boson decays subsequently into
    - Lepton-neutrino (~33%)
    - Di-quark (~67%)
  - $t\bar{t}$ pair decays
    - lepton (e/μ) + jets (including τ to lepton decays) ~ 34.3%
    - dilepton (ee, $\mu\mu$, $e\mu$) ~ 6.4%
    - τ_{had} + jets ~ 9.8%
    - τ_{had} + lepton (e, μ, τ to e, μ) ~ 3.7%
    - all hadronic ~ 45.7%

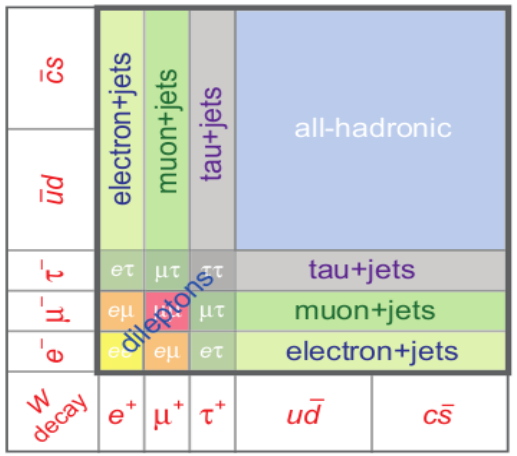
NNLO+NNLL cross section for m_t =173 GeV[arXiv:1303.6254]		
	@ √s = 7TeV (pb)	@ √s = 8TeV (pb)
$t\bar{t}$	$172.0^{+4.4}_{-5.8}{}^{+4.7}_{-4.8}$	$245.8^{+6.2}_{-8.4}{}^{+6.2}_{-6.4}$
Approx. NNLO cross section for m_t = 173 GeV [arXiv: 1210.7813]		
t-channel	$65.9^{+2.1}_{-0.7}{}^{+1.5}_{-1.7}$	$87.2^{+2.8}_{-1.0}{}^{+2.0}_{-2.2}$
s-channel	$4.56 \pm 0.07^{+0.18}_{-0.17}$	5.55 ± 0.08 ± 0.21
Wt-channel	15.6 ± 0.4 ± 1.1	22.2 ± 0.6 ± 1.4

- $t\bar{t}$ production:



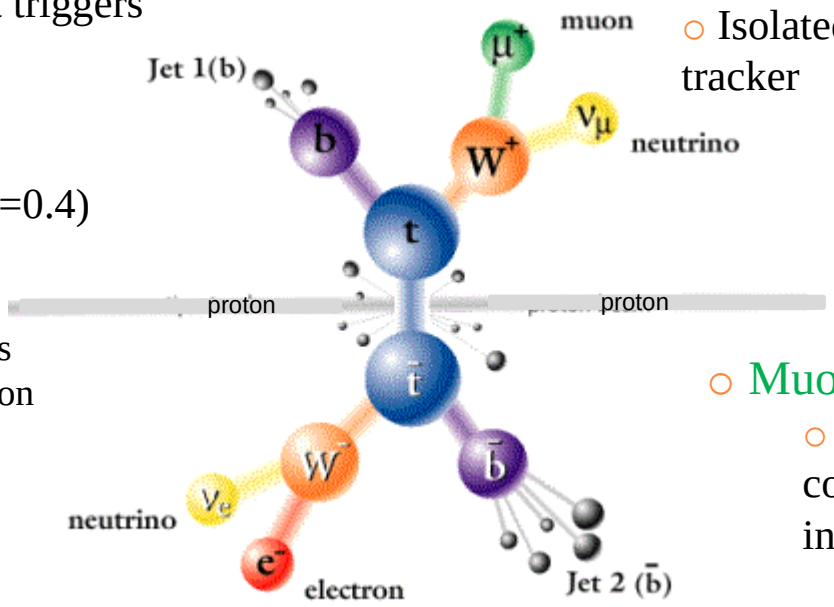
- single top production:





Object reconstruction

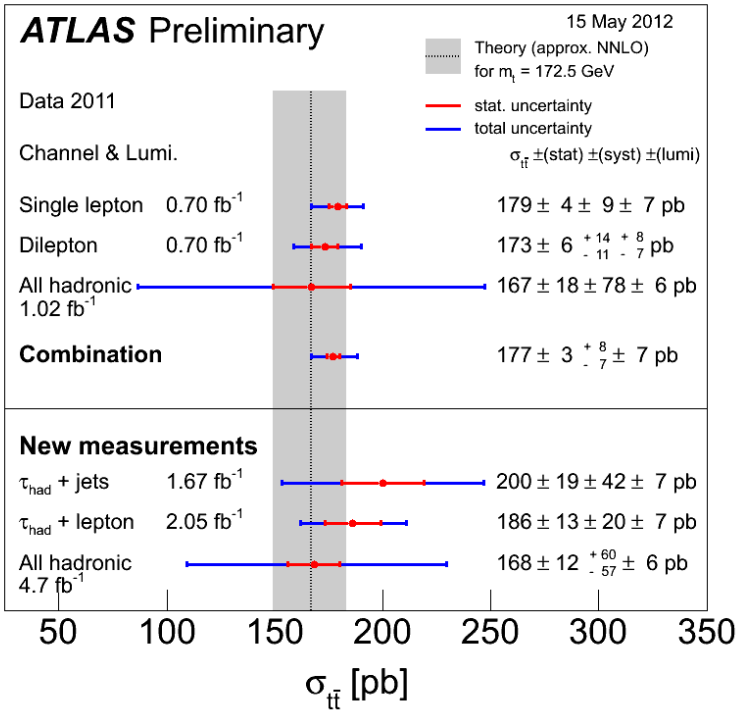
- Trigger:
  - Based on single lepton high p_T
  - Multi jets trigger, *b*-jet triggers
- Jets:
  - Anti k_T –algorithm (R =0.4)
  - Jet energy calibration
    - η and p_T dependent correction with factors derived from simulation and validated on data



- Electron:
  - Reconstructed offline using a cluster based algorithm
    - $|\eta| < 2.5$ $p_T > 25$ GeV
      - excluding $1.37 < |\eta| < 1.52$
  - Matched track and EM cluster
  - Isolated in calorimeter and tracker
- Muon:
  - Reconstructed by combining track segments in the ID and MS
    - $|\eta| < 2.5$ $p_T > 20$ GeV
  - Isolated in calorimeter and tracker
- *b*-tagging:
  - long lifetime of B-hadrons
  - multivariate discriminant based on impact parameter, secondary vertex, fragmentation proprieties, resonance mass
- E_T^{miss} :
  - Vector sum of transverse momenta of the reconstructed objects as well as transverse energy in calorimeter

Top pair production @ √s = 7 TeV

- Top pair production cross section measurement in the e/μ+jets, dilepton final and all hadronic channels will be shown
- Combination is driven by the high precision measurement with e/μ in the final state
  - ATLAS-CONF-2012-024
- Measurements dominated by the systematic uncertainties



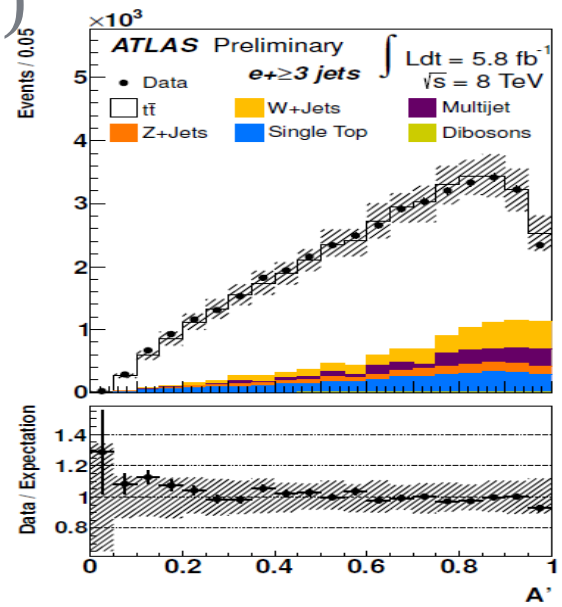
Results compared with the Standard Model prediction

Lepton + jets cross section ($\sqrt{s}$ = 8 TeV)

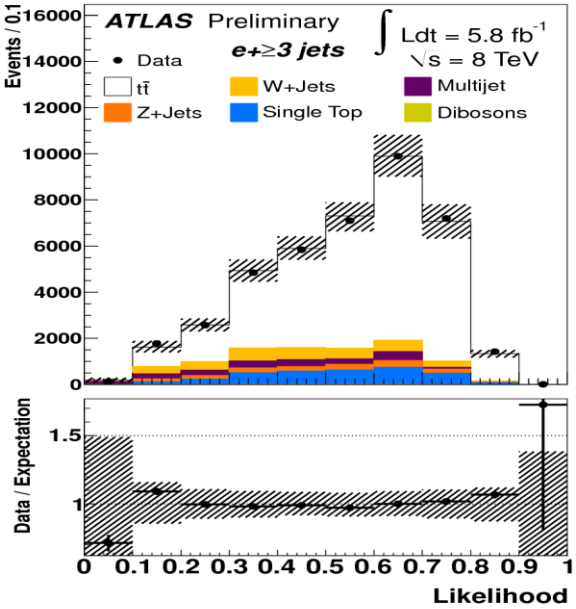
- Signature: e/μ + E_T^{miss} + jets
- To suppress QCD multi-jets background
  - Lepton p_T > 40 GeV
  - E_T^{miss} > 35 (25) GeV for $e(\mu)$-channel
  - $m_T(W)$ > 25 GeV ($m_T(W)$ + E_T^{miss} > 60 GeV) for $e(\mu)$-channel
- Background:
  - W+jets: shape from Alpgen MC, normalization from the fit
  - Top quark, di-boson, Z+jets: rely on MC
  - QCD multi-jets: matrix method on data
- Extraction of $t\bar{t}$ events fraction:
  - Construct a likelihood discrimination function using two kinematic variables: lepton pseudorapidity and aplanarity
    - Aplanarity → $t\bar{t}$ events are more isotropic than W+jets events
  - Likelihood ratio discriminant is defined as the ratio of the signal to the sum of signal and background likelihood
- Cross section is estimated by performing a likelihood fit to discriminant observed in data using the signal and all background templates

σ_{tt} = 241 ± 2 (stat.) ± 31 (syst.) ± 9 (lumi.) pb

ATLAS-CONF-2012-149



Aplanarity in e+jets channel



Fit to the likelihood discriminant distribution in e+jets channel

Lepton + jets cross section with a semi-leptonic *b*-decay ($\sqrt{s}$ = 7 TeV)

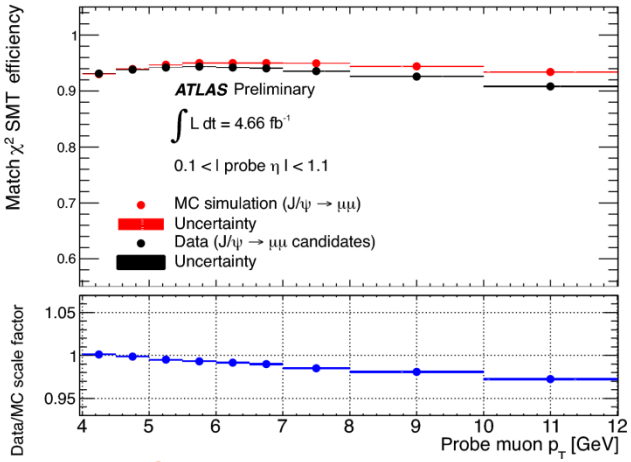
- Signature: e/μ + E_T^{miss} + jets
- Soft Muon Tagging (SMT) algorithm based on the presence of a reconstructed μ within a jet
  - BR(b → μ X) ~ 20%
    - 36 % of $t\bar{t}$ events contain at least one *b*-jet that decays semi-muonically
  - The quality of the match between ID and MS tracks of the μ (χ^2_{match}) discriminates heavy flavour jets from light ones
    - $\chi^2_{match} < 3.2$ → $eff_{b\text{-jets}}$ ~10% and $rejection_{light}$ ~ 200 per jet
- Cross is determined by cut-and-count method

$$\sigma_{t\bar{t}} = \frac{N_{data} - N_{bkg}}{\int L dt \cdot \varepsilon \cdot BR_{noFullHad}}$$

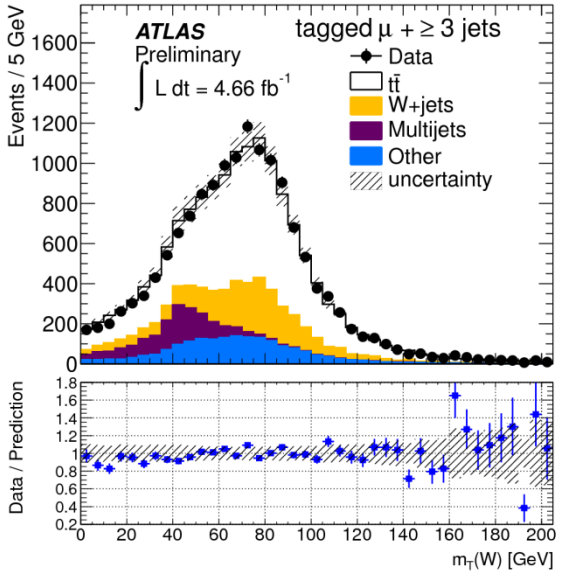
σ_{tt} = 165 ± 2 (stat.) ± 17 (syst.) ± 3 (lumi.) pb

- Main systematic uncertainties
  - Background normalization, generator, jet energy scale and BR(b → μ X)

ATLAS-CONF-2012-131



SMT χ^2_{match} efficiencies w.r.t. the p_T of the muon



Transverse mass of the W in the μ+jets channel with at least three jets and at least one SMT tagged jet

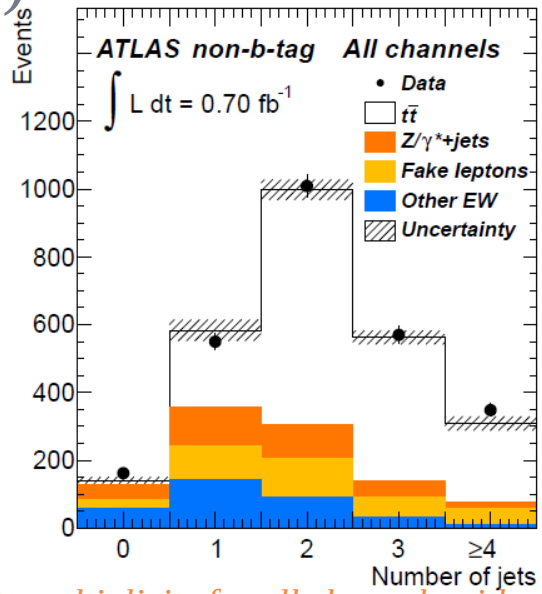
Dilepton cross section ($\sqrt{s}$ = 7 TeV)

JHEP 1205 (2012) 059

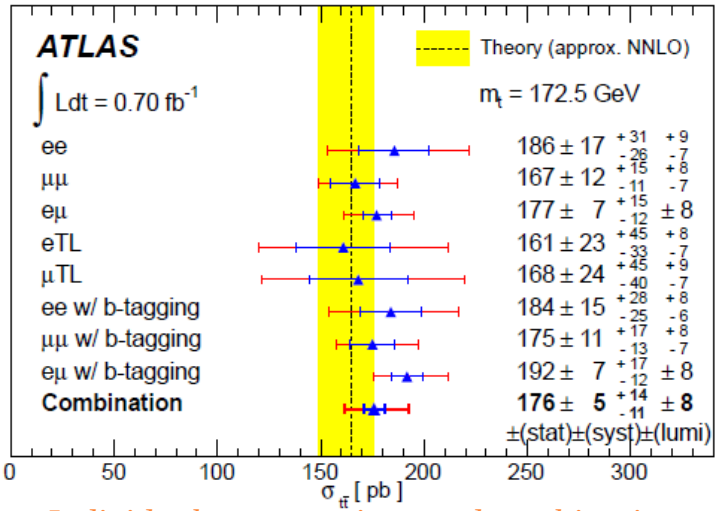
- Signature:
  - two isolated oppositely charged lepton (*ee*, $\mu\mu$, μe) or one lepton & one opposite charge track (μTL, *eTL*) + E_T^{miss} + at least 2 high p_T jets
- To reject background from vector-meson decays: $m_{ll} > 15$ GeV
- In *ee*/$\mu\mu$ channel $E_T^{miss} > 60$ GeV and $|m_{ll} - m_Z| < 10$ GeV → suppress Z/γ^*+jets and multi-jets
- In $e\mu$ channel: $H_T > 130$ GeV
- Three samples
  - "non b-tag": no *b*-tag jets
  - "b-tag": at least one *b*-tag jet
    - Relaxed cut on E_T^{miss} : $E_T^{miss} > 40$ GeV
  - lepton+track
    - In order to maximize acceptance for leptons
- Cross section is determined by cut-and-count method in each channel, and they are combined with profile likelihood technique

σ_{tt} = 165 ± 2 (stat.) ± 17 (syst.) ± 3 (lumi) pb

- Dominant systematic uncertainties
  - Generator, Jet energy scale, lepton-related uncertainties



Jets multiplicity for all channels without the b-tagging requirement

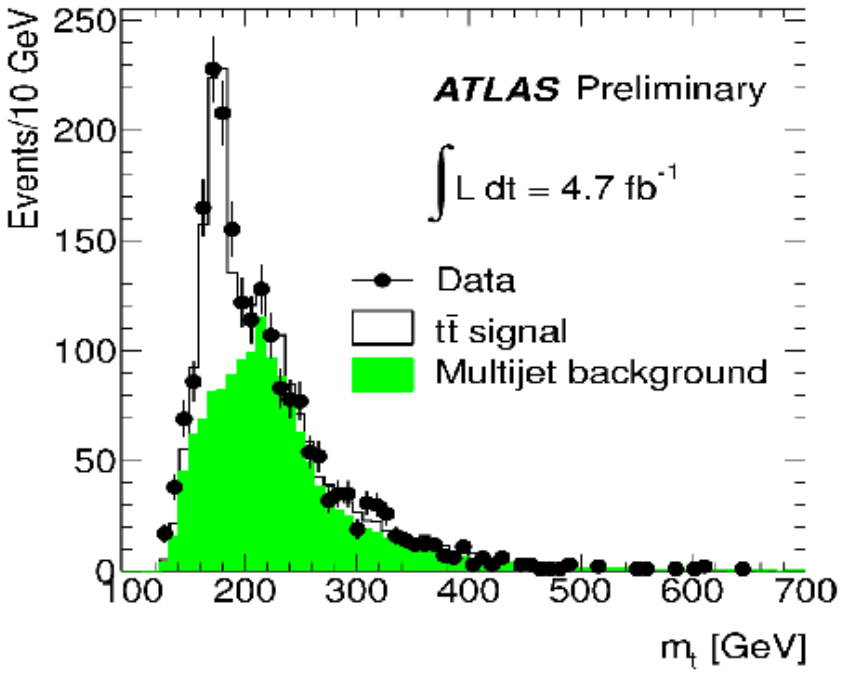


Individual cross sections and combination of non b-tagged and exclusive b-tagged channels

$t\bar{t}$ all hadronic cross section measurement ($\sqrt{s}$ = 7 TeV)

ATLAS-CONF-2012-031

- Signature: no lepton, no E_T^{miss} , at least 6 jets, two *b*-tagged jets
- Isolation cut on the jets: $\Delta R_{jj} > 0.6$
- $t\bar{t}$ topology reconstructed by a kinematic likelihood fit
  - W mass and width set to known values
  - Top mass: free parameter
    - Top and anti-top masses should be equal
- Multi jet background: data-driven
  - Shape estimate in a sample without *b*-tagging requirement
- Cross section extracted using a unbinned likelihood fit to top mass reconstructed by the kinematic fit



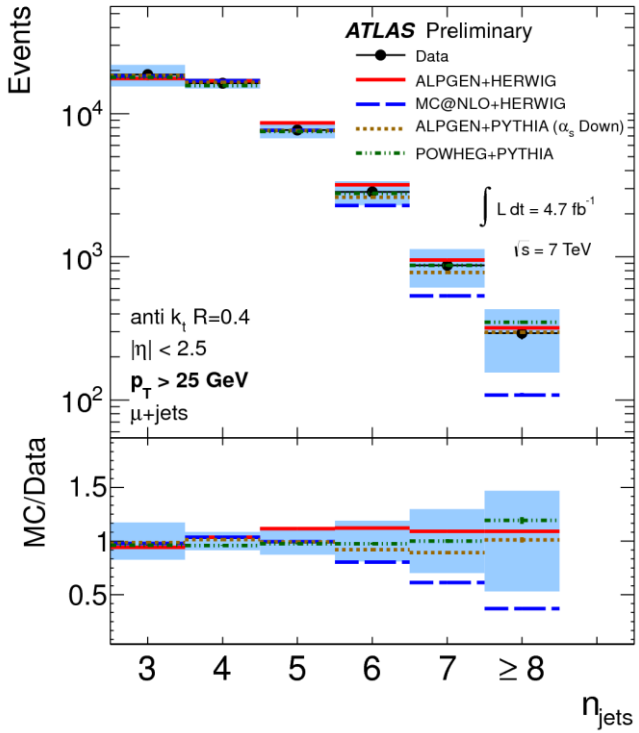
- Dominant systematic uncertainties:
  - Jet energy scale, *b*-tagging and ISR/FSR

$\sigma_{tt} = 168 \pm 12\ (stat.)_{-57}^{+60}(syst.) \pm 7\ (lumi.)$ pb

Jet Multiplicity in $t\bar{t}$ events($\sqrt{s}$ = 7 TeV)

ATLAS-CONF-2012-155

- Useful to constrain models of initial and final state radiation (ISR/FSR) and also provides a test of perturbative QCD
- Signature: lepton + jets + E_T^{miss}
- Strategy: Count the number of jets produced in the events with different jet p_T thresholds: 25 GeV, 40 GeV, 60 GeV and 80 GeV
- Same event selection applied to reconstructed and particle-level objects



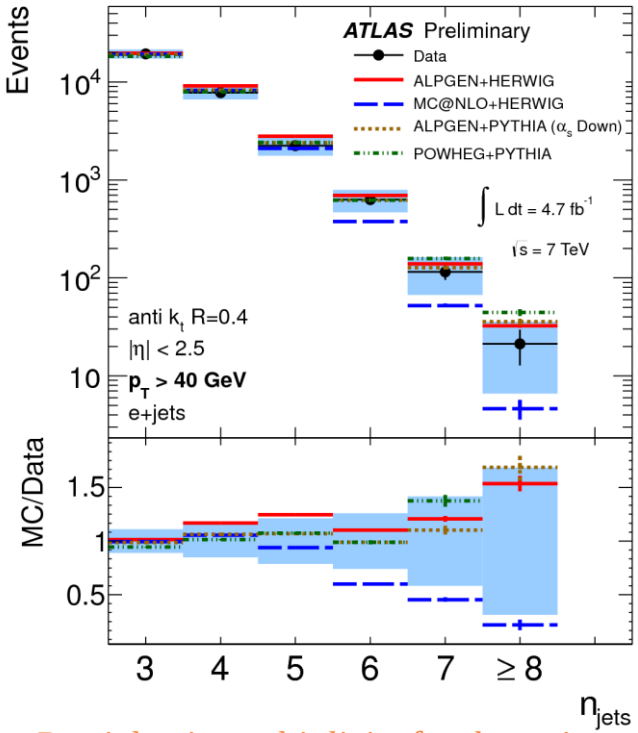
Particle– jet multiplicity for the mu+jets channel and jet p_T > 25 GeV

- Jet multiplicity corrected back to the particle-level within the selected kinematic range
  - The unfolding procedure takes into account the detector efficiencies, resolution and biases

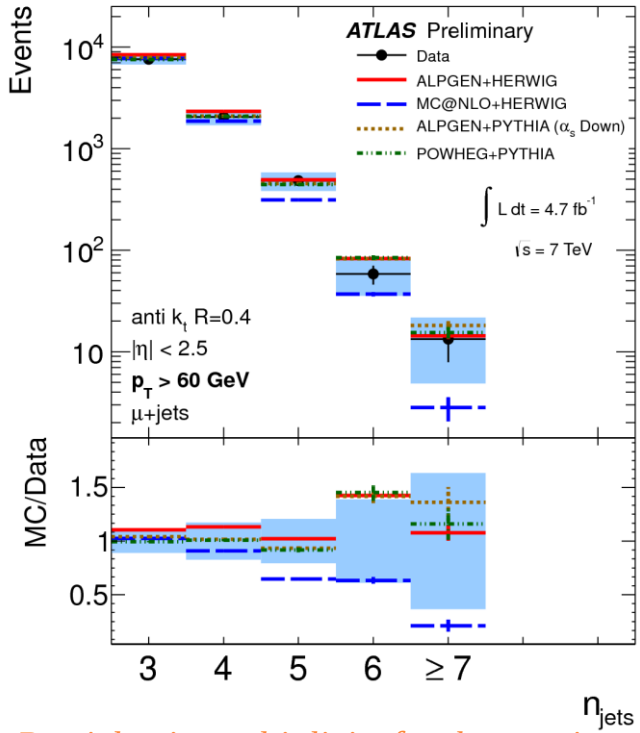
Jet Multiplicity in $t\bar{t}$ events($\sqrt{s}$ = 7 TeV)

ATLAS-CONF-2012-155

- Measurement limited by systematic uncertainties: background modeling, jet energy scale
- MC@NLO+HERWIG underestimate the events with ≥ 6 jets with p_T > 25 GeV and at low N_{jets} for high p_T
  - MC@NLO → too soft
- POWHEG+PYTHIA, ALPGEN+HERWIG and ALPGEN+PYTHIA with α_s –down variation are consistent with data in all jet bins



Particle– jet multiplicity for the e+jets channel and jet p_T > 40 GeV

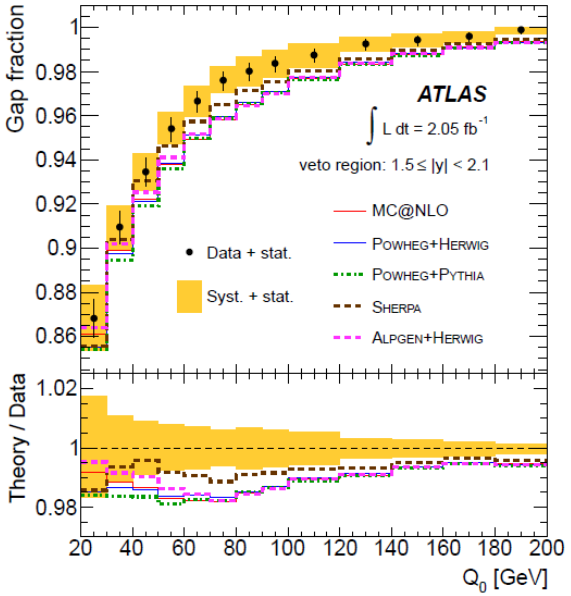


Particle– jet multiplicity for the mu+jets channel and jet p_T > 60 GeV

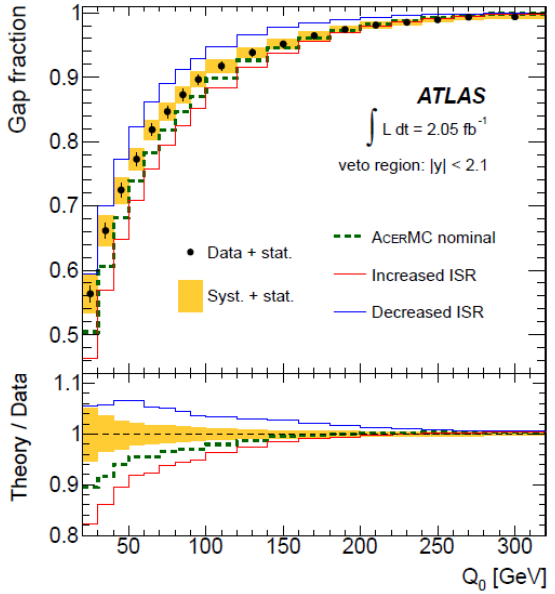
Jet Veto Gap Fraction ($\sqrt{s}$ = 7 TeV)

- Motivation: constrain the uncertainties arising from theoretical description of q/g radiation in simulation
- Analysis performed in dilepton channel
- Jet veto → quantify the jet activity coming from q/g radiation with ttbar system
- Gap fraction $f(Q_0) = \frac{\sigma(Q_0)}{\sigma}$, $f(Qsum) = \frac{\sigma(Qsum)}{\sigma}$
  - σ: total cross section for $t\bar{t}$ events
  - $\sigma(Q_0)$: cross section for $t\bar{t}$ events without additional jets with $p_T > Q_0$ in the central region
    - Estimated as a function of Q_0 (transverse momentum of one additional jet) or Q_{sum} (scalar transverse momentum sum of additional jets)
- Data compared with MC@NLO, POWHEG, ALPGEN, SHERPA
  - Simulation predicts too much jet activity in the most forward rapidity interval (1.5<|η|<2.1)
  - Data compared to the ACERMC+PYTHIA ISR/FSR predictions
    - Data allows for a reduction on the parameter variation used to estimate ISR/FSR uncertaities

Eur. Phys. J C72 (2012) 2043



Gap fraction as a function of Q_0

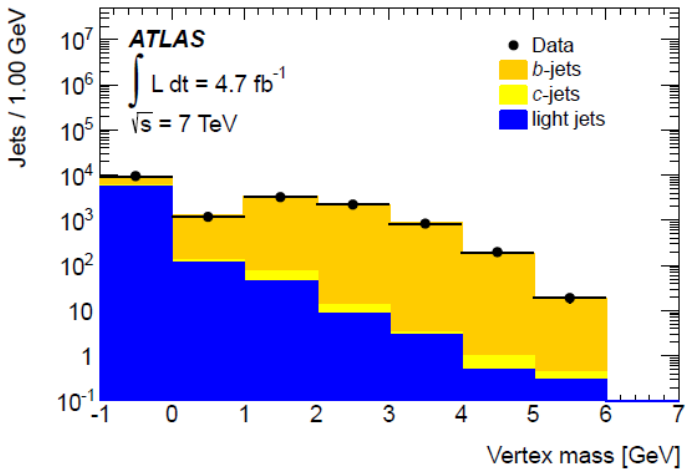


Gap fraction as a function of Q_0

$t\bar{t}$ + heavy flavor quarks ($\sqrt{s}$ = 7 TeV)

NEW: To be submitted to Phys. R. D

- Motivation: $t\bar{t}+b/c+X$ events are main background to $t\bar{t}H(H \to b\bar{b})$
  - $c\bar{c}/b\bar{b}$ are produced in association with top via gluon splitting from ISR/FSR
- Signature: two opposite sign leptons + E_T^{miss} + at least two jets
  - $t\bar{t}$+HF: at least 3 *b*-tagged jets
  - $t\bar{t}$+jets: at least 2 *b*-tagged jets (at least 3 jets)
- Background:
  - Di-boson, Z+jets, single top: rely on simulation
  - fake leptons: data-driven from same sign lepton sample
  - *b*-tag jets from mistagged LH jets:
    - $t\bar{t}$+jets: MC simulation
    - $t\bar{t}$+HF: fit to the vertex mass of b-tagged jets



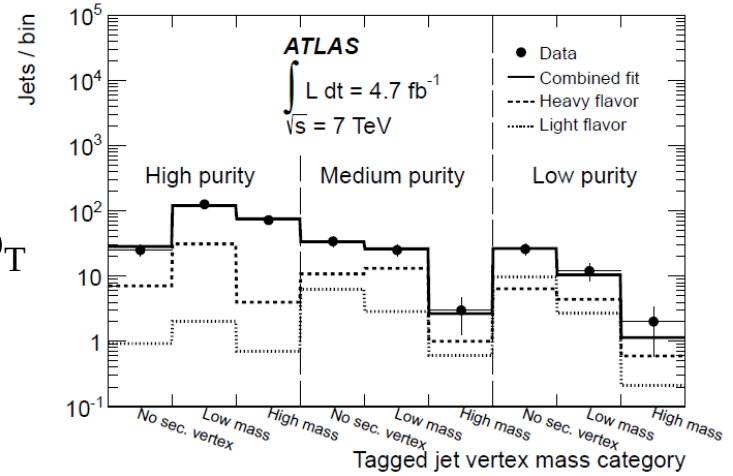
Vertex mass for b-tagged jets

- Strategy: quote the R_{HF} ratio between the $t\bar{t}$+HF cross section and $t\bar{t}$+jets one in a fiducial volume
  - $$R_{HF} = \frac{\sigma_{fid}^{(t\bar{t}+HF)}}{\sigma_{fid}^{(t\bar{t}+j)}} \Rightarrow \sigma_{fid}^{(t\bar{t}+X)} = \frac{N_X}{\int Ldt \cdot \varepsilon}$$
    - N_X : the number of additional *b*-tagged jets for the $t\bar{t}$+HF selection; number of selected dilepton events for the $t\bar{t}$+jets selection
    - Fiducial volume: two leptons from top decay with p_T >25(20) GeV for e(μ) and |η|<2.5 and at least 3 (2) *b*-jets for $t\bar{t}$ + HF ($t\bar{t}$ + jets) and at least 3 jets for $t\bar{t}$ +HF

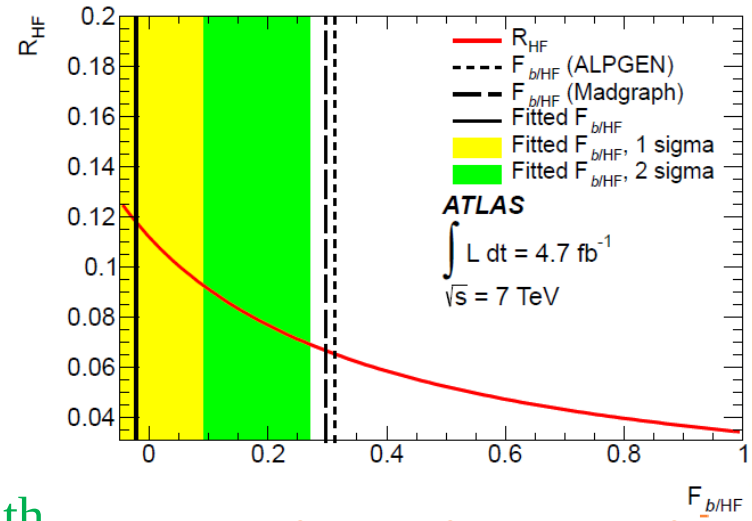
$t\bar{t}$ + heavy flavor quarks ($\sqrt{s}$ = 7 TeV)

NEW: To be submitted to Phys. R. D

- Fraction of HF jets extracted by a binned maximum likelihood template fit on the vertex mass distribution
  - To increase the sensitivity → 2D p.d.f . (p_T – vertex mass)
  - Three exclusive bins of *b*-jet purity: $\varepsilon_{b\text{-tag}}$ = 60%, 60% to 70%, 70% to 75%
    - To differentiate between *b*'s, light flavor and *c*'s
- σ_{HF} ($t\bar{t}$+HF)= 0.18 ± 0.03(stat.) pb
- σ_{HF} ($t\bar{t}$+jets)= 2.55 ± 0.07(stat.) pb
- R_{HF} = [7.1 ± 1.3(stat.)$_{-2.0}^{+5.3}$ (syst.)] %
  - Dominant uncertainty: fiducial flavor composition
- Result consistent at 1.4σ level with LO SM prediction from ALPGEN and at 0.6σ level with approx. NLO result from POWHEG



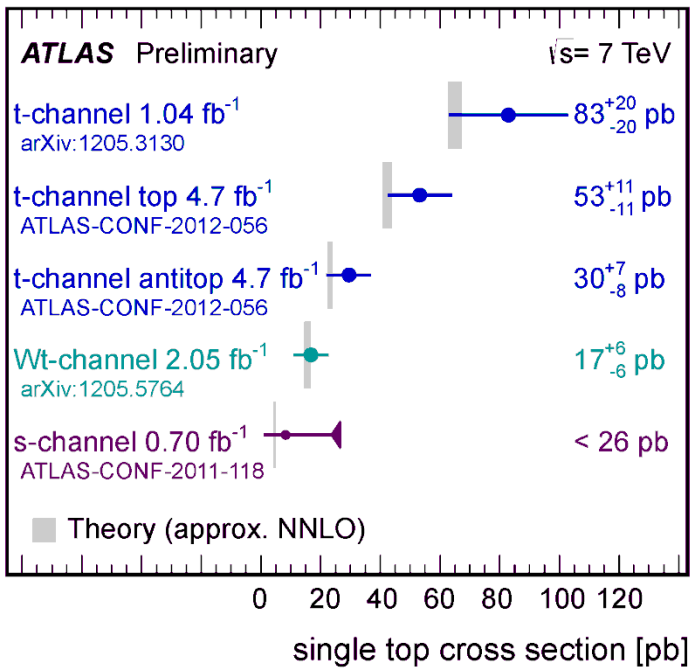
Template fit results to vertex mass

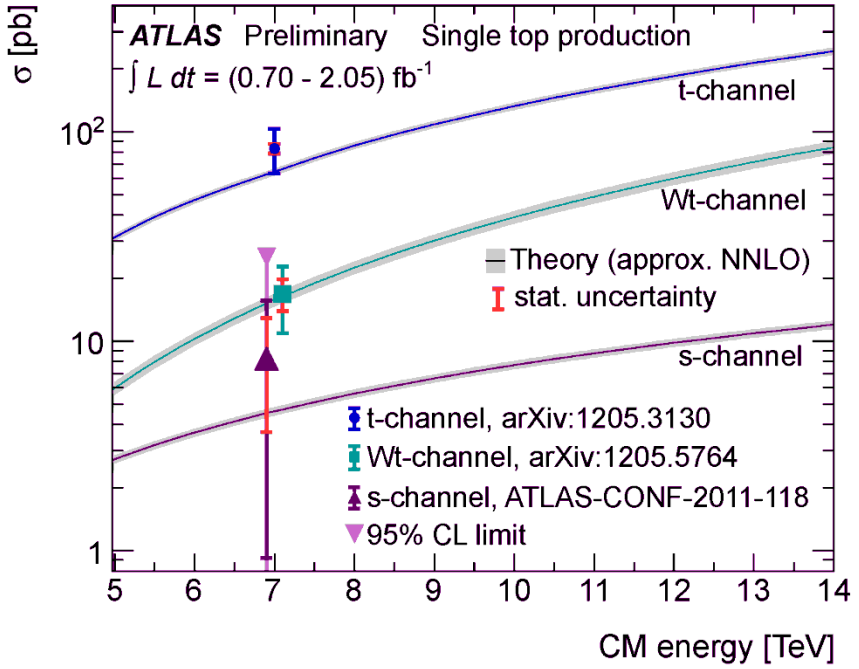


R_{HF} as a function of $F_{b/HF}$, ratio of $t\bar{t}$ events with additional b-quarks to $t\bar{t}$ events with additional c- or b-quarks

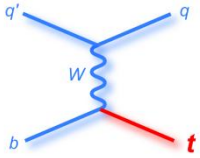
Single top quark production

- Single tops are produced in *t*-, *Wt*-, *s*- channel
- ATLAS has:
  - Observed the *t*-channel
  - Evidence for *Wt*- channel in dilepton mode @ $\sqrt{s}$ =7 TeV
  - Upper limits in *s*-channel



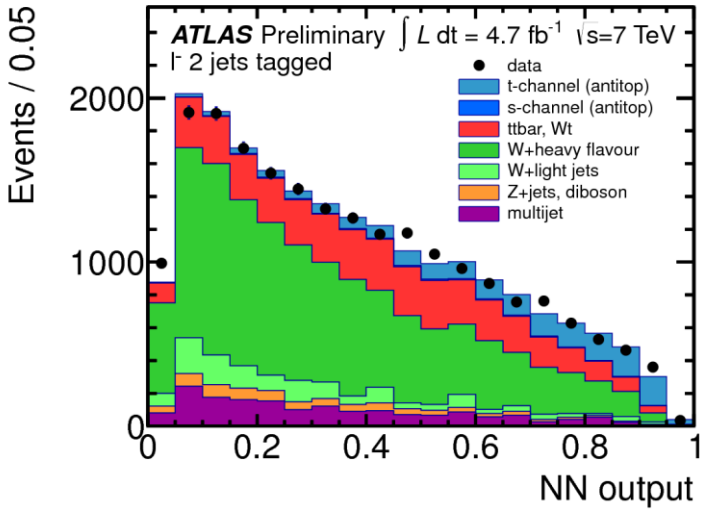


Single Top Production: *t*-channel ($\sqrt{s}$ = 7 TeV)

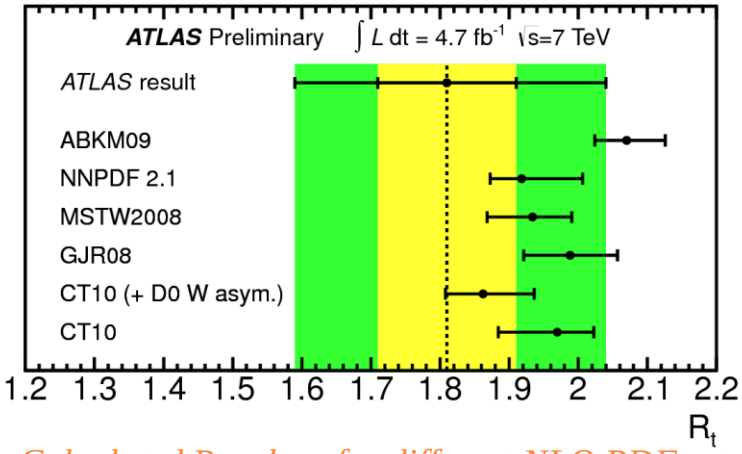


ATLAS-CONF-2012-056

- Measurement of single top and single anti-top production (u or d quark induced)
  - measurements sensitive to the PDFs of the u/d- quarks
- 2 channels for each charge lepton: 2 or 3 jets, with 1 b-tagged jets
- To reduce QCD multi-jets → E_T^{miss} >30 GeV, m_T (W)> 30 GeV
- Signal and background separeted by a NN discriminant
- Extract the R_t (cross section ratio) perform a binned maximum likelihood fit on NN output distribution
  - Background normalization from fit, constrained with theoretical uncertainties or uncertainties from DD methods
- σ_{top} = 53.2 ± 1.7 (stat.) ± 10.6 (syst.) pb
- $\sigma_{anti\text{-}top}$ = 29.5 ± 1.5 (stat.) ± 7.3 (syst.) pb
- R_t = 1.81 ± 0.10 (stat.)$_{-0.20}^{+0.21}$ (syst.) pb
- Dominant systematic uncertainties for the ratio: Jet energy scale, *b*-tagging and background normalization
- The analysis, performed with 1.04 fb^{-1}, gives a results on the coupling at the W-t-b vertex
  - $|V_{tb}|$ = 1.13$_{-0.13}^{+0.14}$ and the 95% CL lower limit on CKM matrix element is 0.75
  - Phys. Lett. B 717 (2012) 330-350



NN output distribution normalized to the fit result in 2-jets tagged l-

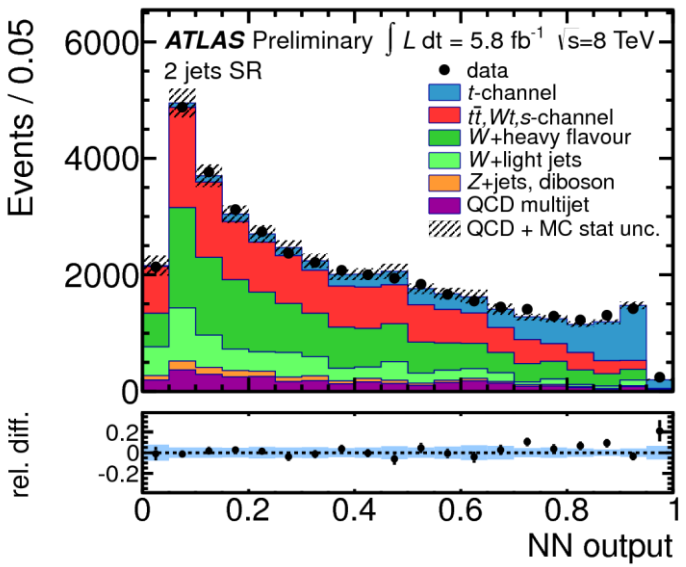


Calculated R_t values for different NLO PDF sets

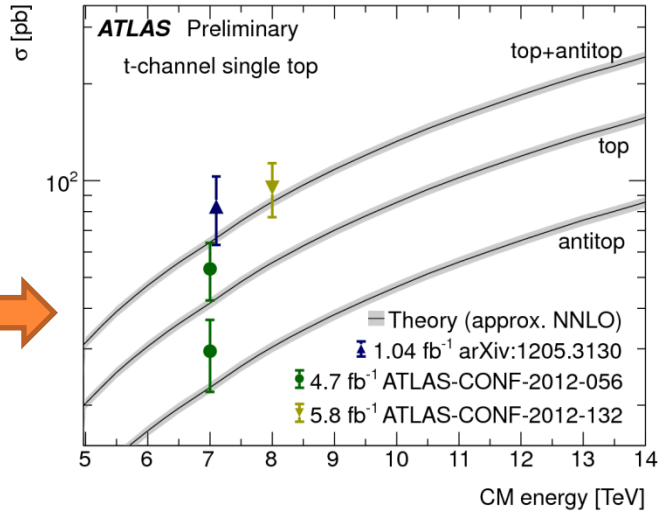
Single Top Production: *t*-channel ($\sqrt{s}$ = 8 TeV)

ATLAS-CONF-2012-132

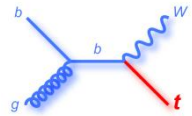
- Similar selection implemented in 2011 data analysis
- NN trained on 11 kinematic variables
- σ_t = 95 ± 2(stat.) ± 18(syst.) pb
  - Dominant systematic uncertainties: ISR/FSR, *b*-tagging and jet energy scale
- Coupling at the W-t-b vertex is $|V_{tb}| = 1.04^{+0.10}_{-0.11}$
- 95% C.L. lower limit on the CKM matrix element $|V_{tb}|$ is 0.80
- Results for the cross section @ $\sqrt{s}$ =7 TeV and $\sqrt{s}$ =8 TeV compared to the SM prediction



NN output distribution for the two-jets sample in the signal region

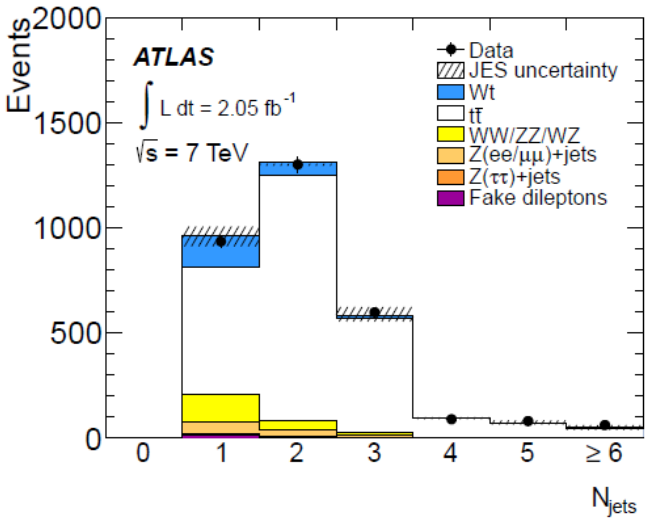


Single Top Production: *Wt*-channel ($\sqrt{s}$ = 7 TeV)

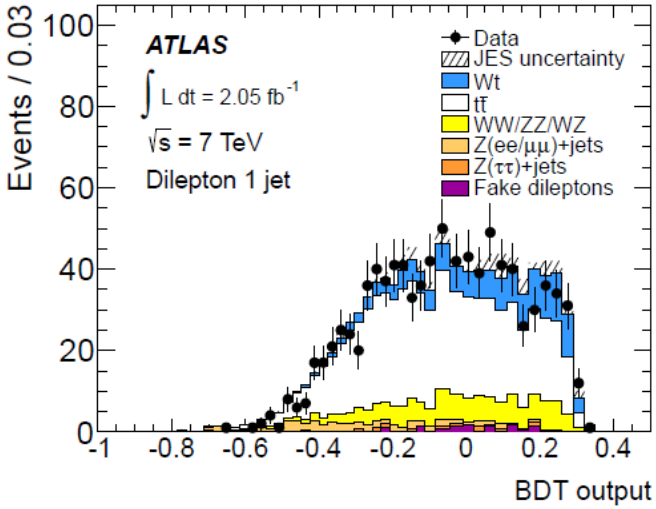


arXiv:1205.5764

- Signature: 2 lepton+ jets + E_T^{miss}
- No *b*-tagging is used
- In *ee/μμ* channel m_{ll} 10 GeV way from m_Z → suppress contamination from Z
- $\Delta\varphi(l_1, E_T^{miss}) + \Delta\varphi(l_2, E_T^{miss}) > 2.5$ → suppress $Z \rightarrow \tau\tau$
- BDT used to discriminate Wt-channel and top pairs
  - Most discriminant variable: p_T system
- A likelihood fit performed on the BDT output to extract the cross section
- σ_{Wt} = 16.8 ± 2.9(stat.) ± 4.9(syst.) pb
  - Ensemble tests performed on pseudo-experiments
  - Observed significance is 3.3 σ for an expected sensitive of 3.4 σ
- Determination of $|V_{tb}| = 1.03^{+0.16}_{-0.19}$
- Dominant systematic uncertainties: Jet energy scale, parton shower and generator



N_{jets} with p_T >30 GeV and $|\eta|$<2.5



BDT_{output} in 1-jets caterories

Summary

- High precision inclusive cross section measurements are in agreement with theoretical prediction
- Large data samples allow possibility to probe radiation in top events
- Single top cross section measurement are performed in t- and Wt channel and the coupling strength at the W-t-b vertex is determined in both channel
- More information on the analyses are available at the following link
  - https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults
- Most of the analysis are updating the results using the approximately 20 fb^{-1} of data collected in 2012
  - More results soon!!

Thanks for your attention!

Top quark analyses

- $t\bar{t}$ cross section measurements
  - e/μ+ jets inclusive: [ATLAS-CONF-2011-121] [ATLAS-CONF-2012-149]
  - e/μ+ jets cross section using SMT [ATLAS-CONF-2012-131]
  - ee, $e\mu$, $\mu\mu$ [JHEP 1205 (2012) 059]
  - $t\bar{t}$ all hadronic cross section [ATLAS-CONF-2012-031]
  - Jet multiplicity in lepton+jets decay [ATLAS-CONF-2012-155]
  - Jet veto gap fraction [Eur. Phys. J. C72 (2012) 2043]
- Single top cross section measurements
  - *t*-channel [ATLAS-CONF-2012-056] [ATLAS-2012-132][Phys. Lett. B 717 (2012) 330-350]
  - Evidence for *Wt*-channel [Phys. Lett. B 716 (2012) 142.159] [arXiv:1205.5764]
- Not mentioned in the talk
  - Relative differential cross sections [Eur. Phys. J.C (2013) 73:2261]
  - τ+ jets [Eur. Phys. J. C 73 (2013) 2328]
  - τ+e/μ+ jets [Phys. Lett B717(2012) 89-108]
  - Search for CP violation in single top [ATLAS-CONF-2013-032]
  - *b** search/single top *Wt* final state [Phys. Lett. B 721 (2013) 171-189]
  - Search for *tb* resonances [Phys. Rev. Lett. 109 (2012) 081801]
  - *s*-channel search [ATLAS-CONF-2011-118]
  - Single top FCNC search [arXiv:1203.0529]

Back-Up

ATLAS Detector

Inner Detector (|η|<2.5):

- Si-pixel, Semiconductor Tracker, Transition radiation Tracker
- Tracking and vertexing,e/π separation
- $\sigma(p_T)/p_T$ ~ 0.038% pT (GeV) + 1.5%

HAD calorimeter (|η|<2.5):

- Fe/scintillator tiles (central)
- Cu/W LAr (fwd)
- Trigger, jets and Etmiss
- $\sigma(E)/E \sim 50\%/\sqrt{E} + 3\%$ (central)
- $\sigma(E)/E \sim 100\%/\sqrt{E} + 10\%$ (fwd)

Muon spectrometer (|η|<2.7):

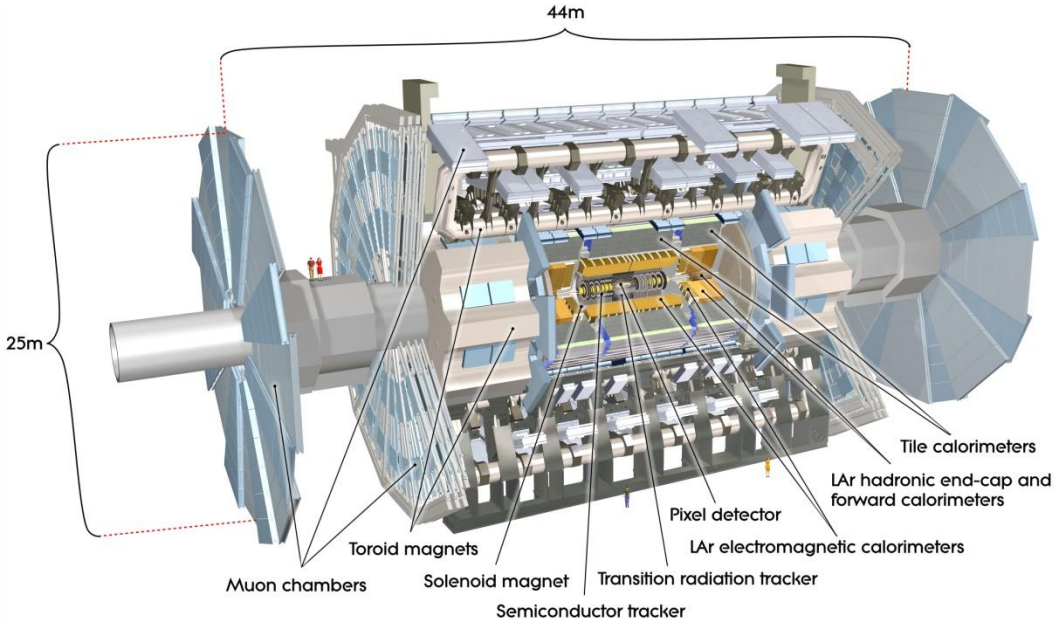
- Air cores toroids with gas-based chambers.
- Trigger and measurement.
- Momentum resolution <10% up to E_μ ~1 TeV

Trigger:

- first level: hardware
- second and third level: ~400 Hz output

EM calorimeter (|η|<3.2):

- Pb/Lar accordion
- Trigger, e/γ reco and ID
- $\sigma(E)/E \sim 10\%/\sqrt{E} + 0.7\%$

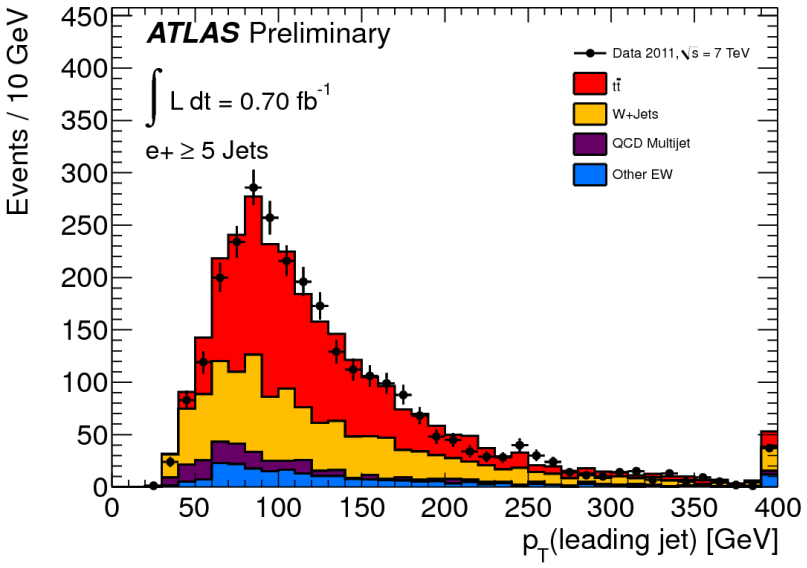


- Pseudorapidity (η) is define as $-\ln\left(\tan\frac{\theta}{2}\right)$
  - θ is the polar angle, measured from z-axis (beam direction)

Lepton + jets cross section ($\sqrt{s}$ = 7 TeV)

- Signature: e/μ, E_T^{miss} , jets
- To suppress QCD multi-jets background
  - + E_T^{miss} > 35 (25) GeV for e(μ)-channel
  - $m_T(W)$ > 25 GeV ($m_T(W)$ + E_T^{miss} > 60 GeV) for e(μ)-channel
- Background:
  - W+jets: shape from Alpgen MC, normalization from data-driven estimation based on charge asymmetry of W boson production
  - Top quark, di-boson, Z+jets: rely on MC
  - QCD multi-jets: matrix method on data
- Extraction of $t\bar{t}$ events fraction:
  - Construct a likelihood discrimination function using the pseudorapidity of the lepton, leading jet p_T , aplanarity *A*, $H_{T,3p}$ (ratio of transverse to longitudinal momenta)
    - Aplanarity is defined as 1.5 times the smallest eigenvalue of the momentum tensor calculated using the momenta of all jets and the lepton

ATLAS-CONF-2011-121



leading jet p_T in e+jets channel in the N_{jet} > 4 bin

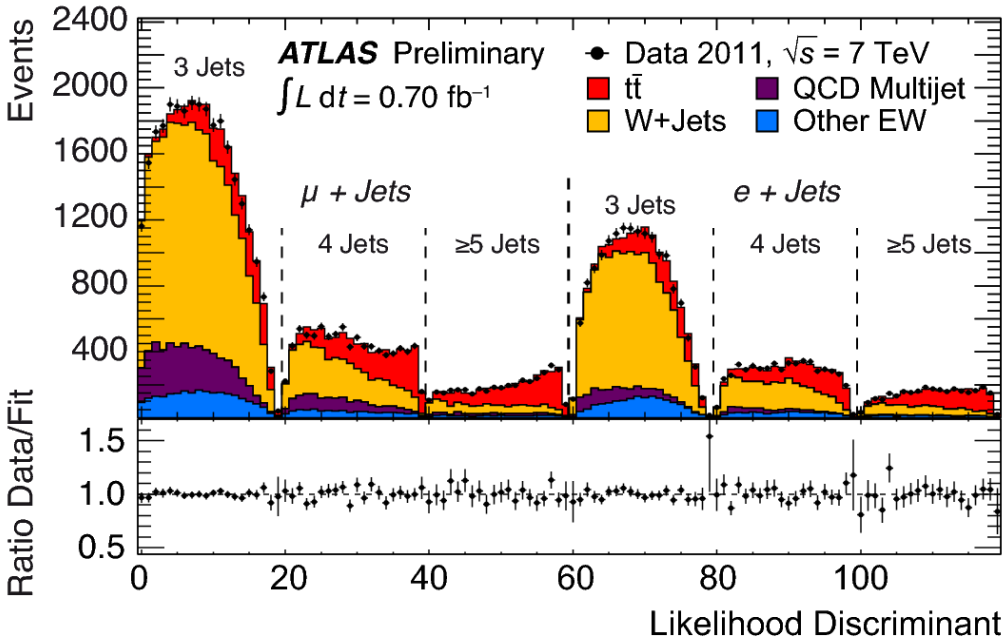
- Data/MC agreement checked in signal (≥3jets) region and in control region (=2 jets)
- Information from 3, 4, ≥ 5 jet bins are used to extract the cross section

Lepton + jets cross section ($\sqrt{s}$ = 7 TeV)

ATLAS-CONF-2011-121

- The $t\bar{t}$ cross section is estimated by performing a maximum likelihood fit to discriminant observed in data using the signal and all background templates
- The measured cross section is:

  σ_{tt} = 179.0 ± 3.9 (stat.) ± 9.0 (syst.) ±6.6 (lumi.)
- The systematic uncertainties are included in the fit via nuisance parameters



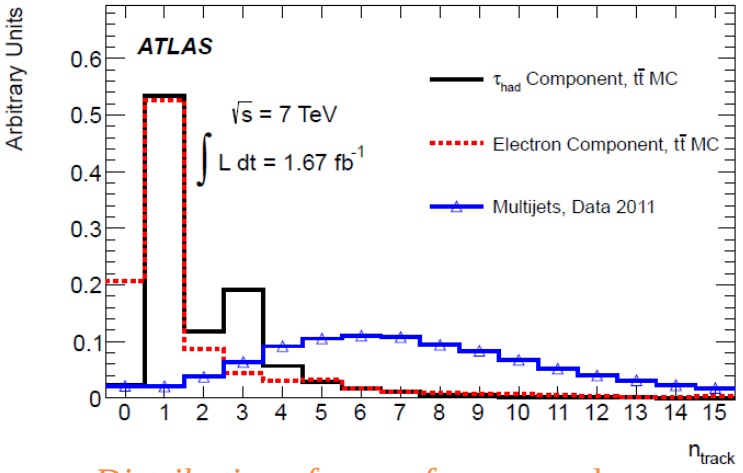
- Main systematic uncertainties
  - Generator syst. 3%
  - Jet energy scale 2.4%
- Result is in a good agreement with the approximate NNLO theoretical prediction

τ_{had} + jets Analysis ($\sqrt{s}$ =7 TeV)

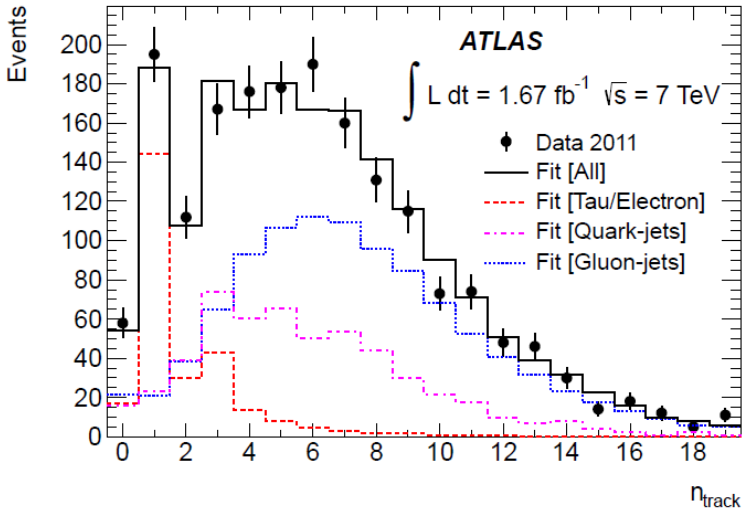
Eur. Phys. J.C73 (2013) 2328

- Difficult final state to reconstruct, suffers from large background
- Events collected with a *b*-jet trigger:
  - 4 jets of which 2 *b*-tagged jets
- To reduce all hadronic $t\bar{t}$ decay and multi jets background → E_T^{miss} /(0.5 *$\sqrt{\sum E_T}$) > 8
- τ lepton decays hadronically 65% of the time
  - Signature: calorimeter energy deposition matched with 1/3 charged tracks
  - Use the sum of the tracks to separate τ candidate from quark/gluon jets
- Extended binned likelihood fit to templates used to extract the number of τ+jets & *e*+jets events

  σ_{tt} = 194 ± 18 (stat.) ± 46 (syst.) pb
- Uncertainties are dominated by the ISR/FSR, generator modeling and *b*-tagging efficiency



Distribution of n_{track} *for* τ_{had} and electron for MC tt events, for jets in multijets events in data



n_{track} *for* τ_{had} candidates

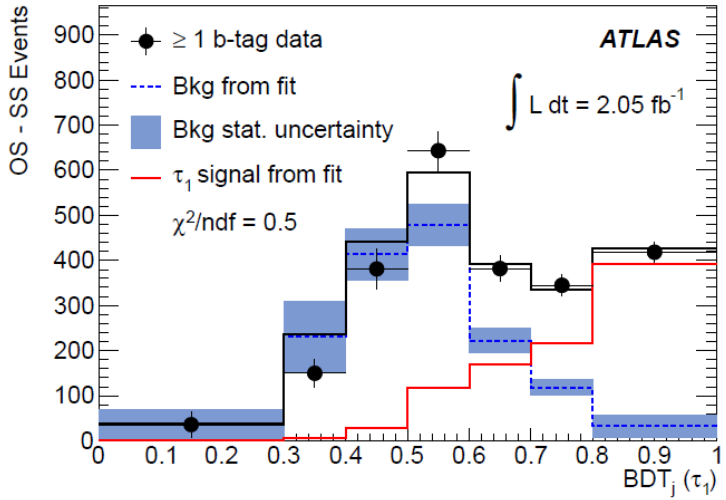
τ + e/μ + jets ANALYSIS ($\sqrt{s} = 7TeV$)

Phys. Lett B717(2012) 89-108

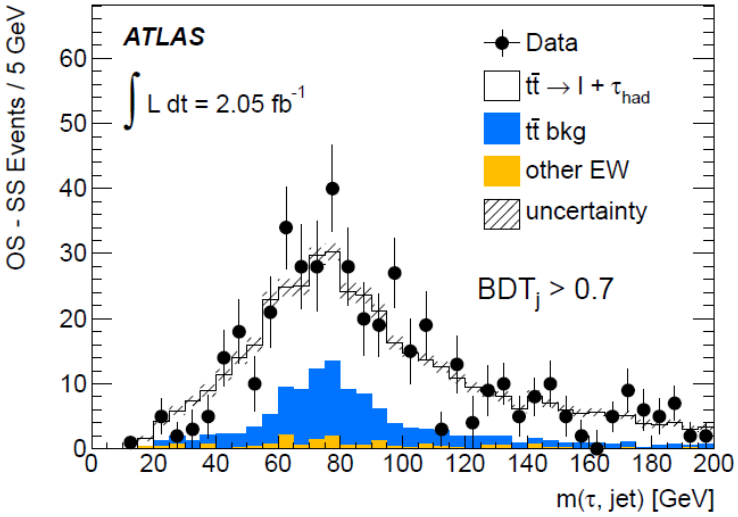
- τ identification performed with a multivariate discriminants (BDT)
  - BDT_e trained to separate τ candidate from fake τ from electrons
  - BDT_j used to separate τ leptons in τ candidates with one or more tracks from such jets
- Events divided in two channels depending on the lepton charges
  - Same sign (SS): almost pure background
  - Opposite sign (OS): contain real τ leptons
- Background template extracted in the 0 *b*-tagged sample
- Cross section is derived from template fit to the number of observed (OS-SS) signal events in the ≥ 1 *b*-tag sample
  - Signal template derived from MC simulation

$\sigma = 186 \pm 13(stat.) \pm 20(syst.) \pm 7(lumi)$ pb

- Dominant systematic uncertainties:
  - *b*-tagging, ISR/FSR



BDT (OS-SS) distribution of $l+\tau$ in the ≥ 1 b-tagged sample

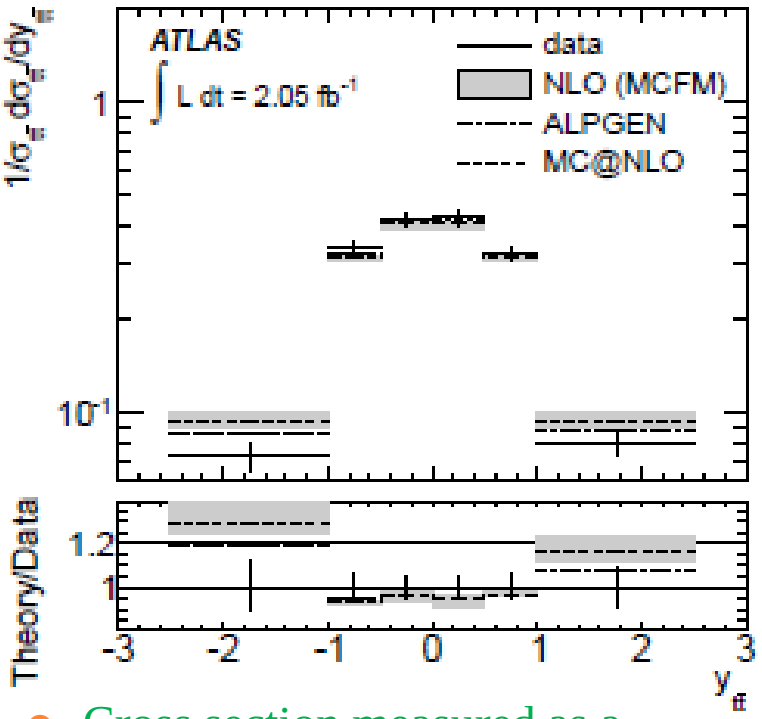


OS-SS invariant mass of jet and τ candidate in the ≥ 1 b-tagged sample

Relative differential measurement ($\sqrt{s}$ = 7 TeV)

Eur. Phys.J.C(2013) 73:2261

- Signature: lepton+ jets+ E_T^{miss}
  - at least one *b*-tagged jet
- Background:
  - W+jets, fake lepton
  - EW background estimate from simulation
    - Diboson, Z+jets and single top
- $t\bar{t}$ topology reconstruction performed using a likelihood fit of the measurement objects to a LO representation of the $t\bar{t}$ system
  - Cut on the kinematical likelihood function to select events which are consistent with $t\bar{t}$ hypothesis
- Use migration matrices to 'unfold' the results to truth parton-level
  - Cross section extraction:
    - Subtracting background B_i, correcting bin migration M^{-1}, acceptance A_i and dividing by the luminosity L
    - $$\sigma_j = \frac{\sum_i (M^{-1})_{ji}(N_i - B_i)}{A_j L}$$

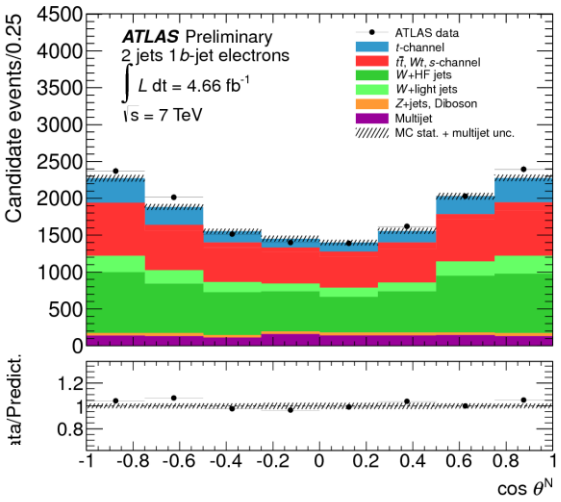


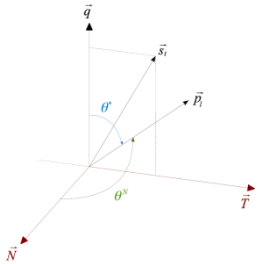
- Cross section measured as a function of observable sensitive to QCD prediction mass, p_T, rapidity y of $t\bar{t}$ system
- Measurement uncertainties range between 10% and 20%
  - dominated by systematics
- No deviation from SM expectation

CP violation in single top quark events ($\sqrt{s}$ = 7 TeV)

- Motivation: measure the forward-backward asymmetry A_{FB}^{N} to probe the anomalous coupling g_R
  - SM prediction : g_R = (-7.17-1.23i) x 10^{-3}
- Signature: one lepton + E_T^{miss} + two jets (1 b-tag)
- To compute θ^N → reconstruct the four vector of top quark and W boson
- To separate signal and background
  - Light jets in $|\eta|>2$, $H_T > 210$ GeV, 150 GeV < m_t <190 GeV, $\Delta\eta$(light-jet, b-jets)>1
- A_{FB}^{N} computed from θ^N distribution
  - Two-bin distribution to avoid problems due to the statistics
- *cos* θ^N distribution is distorted to detector effects → unfolded to parton
- A_{FB}^{N} = 0.031 ± 0.065 (stat.) $^{+0.029}_{-0.031}$ (syst.)
  - First experimental limit of [-0.20,0.30] on imaginary part of g_R at 95% CL

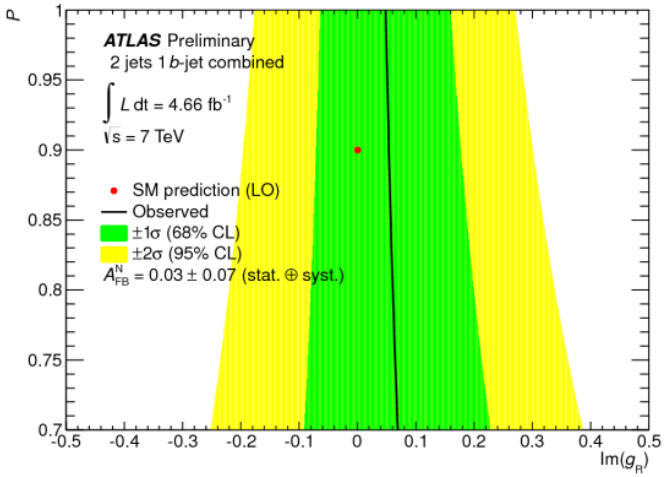
ATLAS-CONF-2013-032





cosθ^N distribution for e-channel

- *θ^N : angle between the lepton in the W boson rest frame and the direction N = s_t x q ; s_t = spin direction ,q =W boson direction in top quark frame*



Constraints in the top quark polarization versus imag g_R plane from A_{FB}^{N}