Top quark production in the ATLAS detector of the LHC

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on behalf of the ATLAS Collaboration

HEP2013

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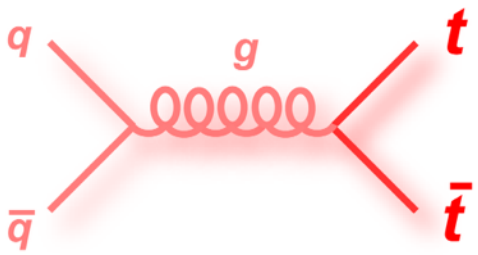
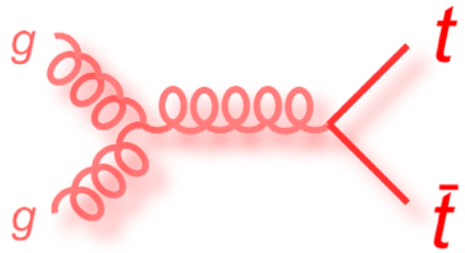
Top quark pair production

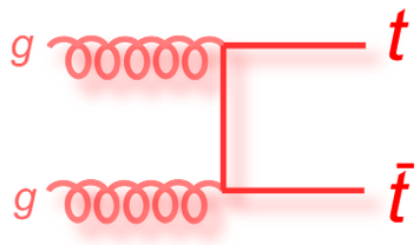
Single-top production

Top quark pair production and decay

- **Production**

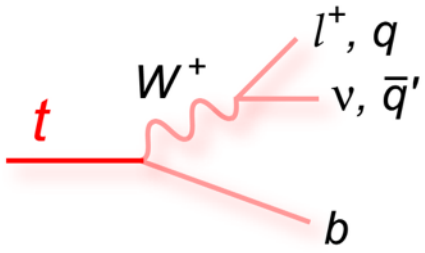






gg fusion ~87% @ LHC 8 TeV

- **Decay**



BR(t→Wb) almost 100%

Top Pair Decay Channels

W decay	e^+	μ^+	τ^+	$u\bar{d}$	$c\bar{s}$
$e^-\bar{\nu}_e$	ee	eμ	eτ	electron+jets	
$\mu^-\bar{\nu}_\mu$	eμ	μμ	μτ	muon+jets	
$\tau^-\bar{\nu}_\tau$	eτ	μτ	ττ	tau+jets	
$\bar{u}d$	electron+jets	muon+jets	tau+jets	all-hadronic	
$\bar{c}s$					

dileptons

- **All hadronic** large sample
  Large background
- **Single lepton** medium sample
  Manageable background
- **Dilepton** smaller sample
  Clean signature

- Using ~all measurable objects
  e, μ, (b-)jets, missing E_T, τ...

Top quark pair production cross section

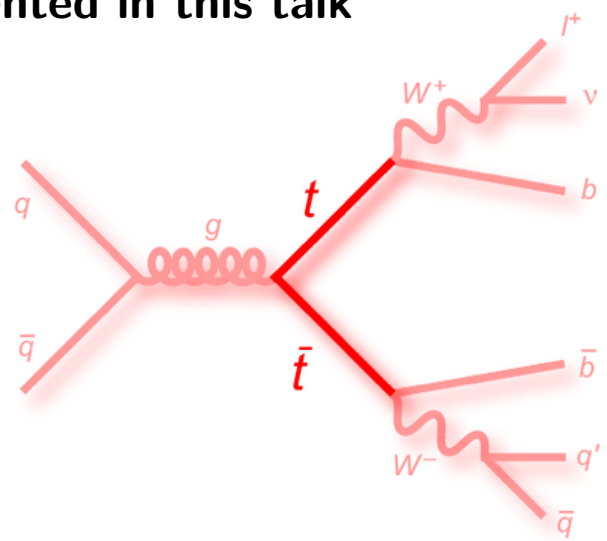
- **Motivations**:
  - Precise **tests of pQCD**

    Comparison with recent theoretical calculations at NNLO + NNLL arXiv:1303.6254

for $m_t = 172.5$ GeV $\quad \sigma_{t\bar{t}}(\sqrt{s} = 7\,\text{TeV}) = 177.3^{+10.1}_{-10.8}\,\text{pb}$, $\sigma_{t\bar{t}}(\sqrt{s} = 8\,\text{TeV}) = 252.9^{+13.3}_{-14.5}\,\text{pb}$

  - **Significant background** for various analyses/searches ($H \to bb$, VLQ, stop)
  - Indirect sensitivity to **new physics**
  - Constraints on **PDF modeling and α_s** with differential measurements

- Measurements done in many decay channels, **four presented in this talk**
  - Inclusive cross section
    - Single lepton @ 8 TeV
    - Dilepton @ 8 TeV
  - Differential cross section (single lepton)
    - $\sigma_{t\bar{t}}(p_T(t)), \sigma_{t\bar{t}}(m_{t\bar{t}}), \sigma_{t\bar{t}}(y_{t\bar{t}})$ @ 7 TeV
    - $\sigma_{t\bar{t}}(n_{jets})$ @ 7 TeV



Single lepton channel

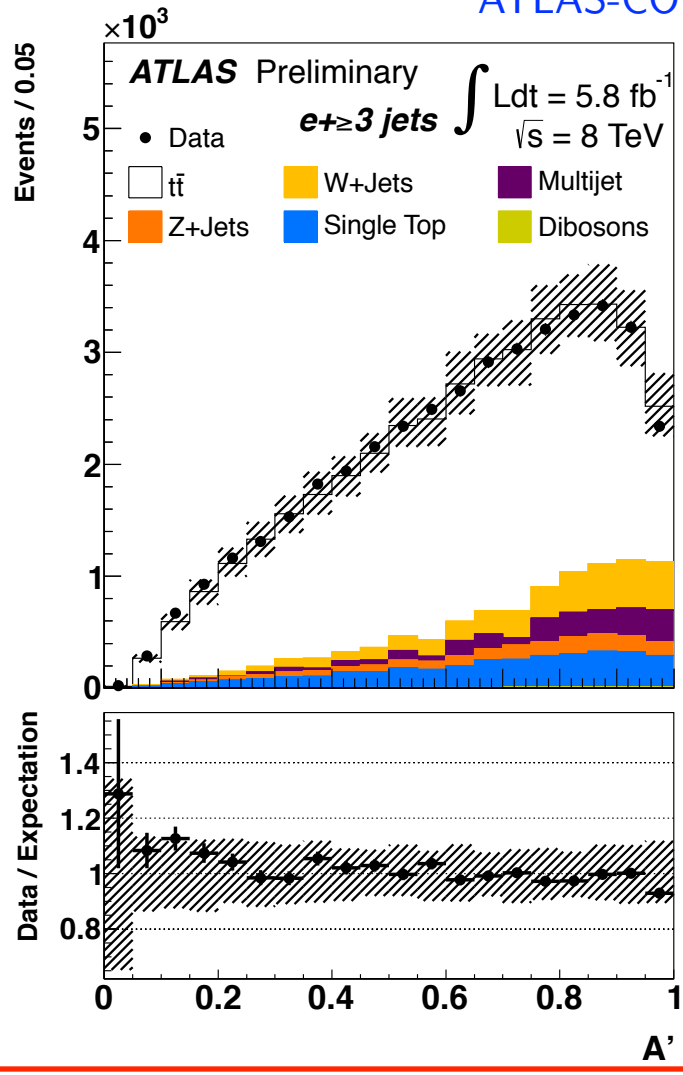
Inclusive top quark pair cross section

Single lepton channel @ 8 TeV (5.8 fb^{-1})

ATLAS-CONF-2012-149

- **Selection**
  - 1 isolated e/μ $p_T > 40$ GeV, $|\eta| < 2.5$
  - > 3 jets with $p_T > 25$ GeV, $|\eta| < 2.5$ with at least 1 b-tagged
  - e+jets: $E_T^{miss} > 30$ GeV, $m_T(W) > 30$ GeV
  - μ+jets: $E_T^{miss} > 20$ GeV, $m_T(W) + E_T^{miss} > 60$ GeV

- **Analysis**
  - Measurement using a **likelihood discriminant template fit**
  - Discriminant variables: **$\eta_{e,\mu}$, aplanarity (A')**
  - **Data driven** W+jets (normalisation) and multijet background



- **Results**
  - Main systematics: Signal modeling (11%) and jet uncertainties (5-6%)

$$\sigma_{t\bar{t}} = 241 \pm 2\,(\text{stat.}) \pm 31\,(\text{syst.}) \pm 9\,(\text{lumi})\ \text{pb}$$

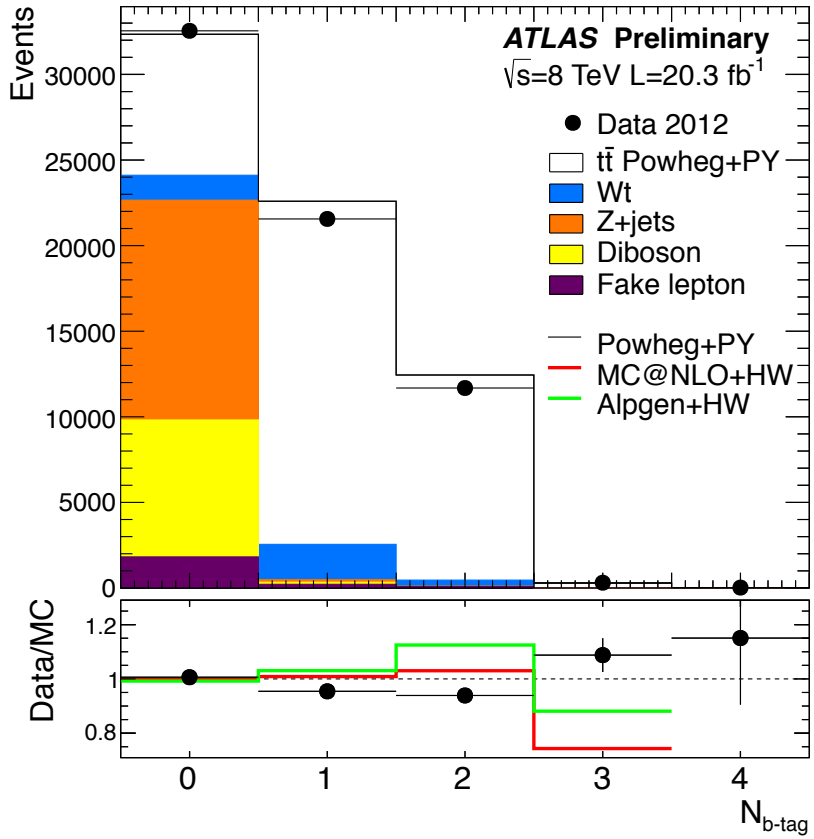
consistent with theory

Dilepton channel @ 8 TeV (20.3 fb^{-1})

ATLAS-CONF-2013-097

- **Selection** (eμ+jets)
  - Exactly 1 eμ pair with opposite sign each isolated
  - 1 or 2 b-tagged jets
  - $p_T > 25$ GeV, $|\eta| < 2.5$ for all objects
  - Very pure signal selection

- **Analysis**
  - tt event counting in samples with exactly **one and two b-tagged jets**
  - Simultaneous estimation of $\boldsymbol{\sigma_{tt}}$ and the **efficiency to reconstruct and b-tag jets** $\rightarrow$ reduced jet and modeling uncertainties
  - Fake lepton estimation using data and MC



- **Results**
  - Main systematics: luminosity (3.1%), beam energy (1.7%),signal modeling (1.5%), electron ID (1.4%)

$$\sigma_{t\bar{t}} = 237.7 \pm 1.7\,(\text{stat.}) \pm 7.4\,(\text{syst.}) \pm 7.4\,(\text{lumi}) \pm 4.0\,(\text{beam energy})\ \text{pb}$$

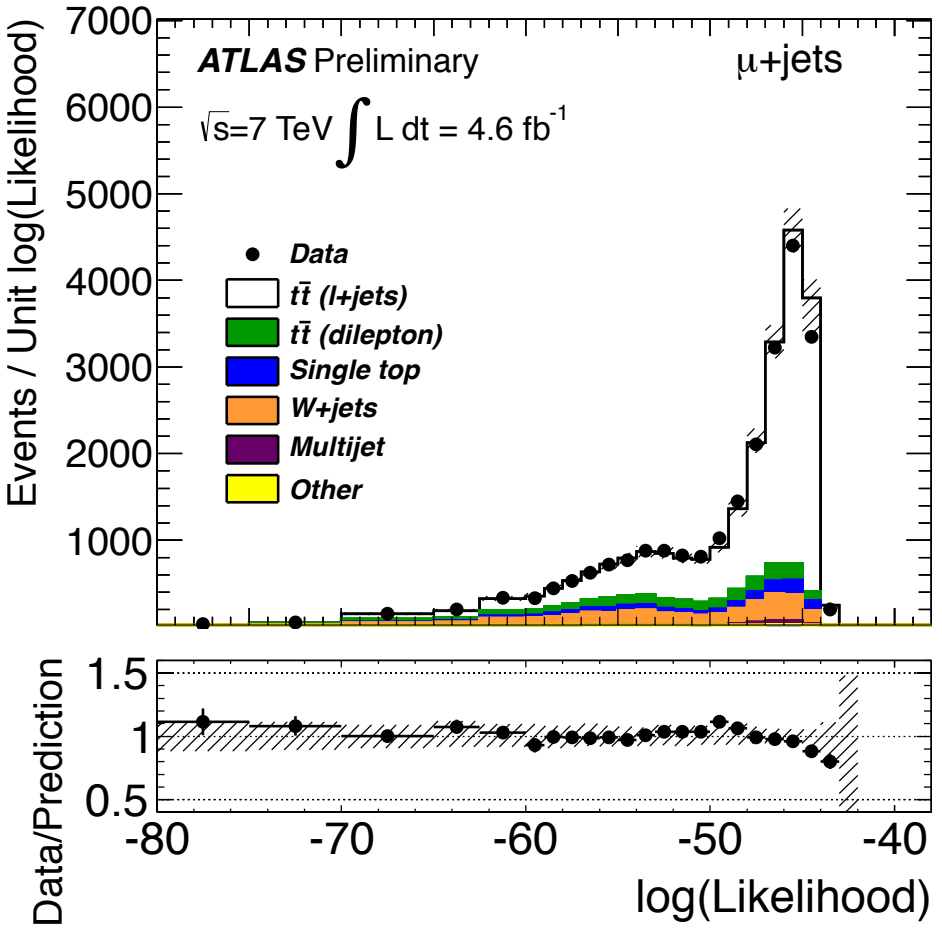
consistent with theory

Differential top quark pair cross section

$d\sigma_{tt}/dX$ @ 7 TeV (4.6 fb^{-1})

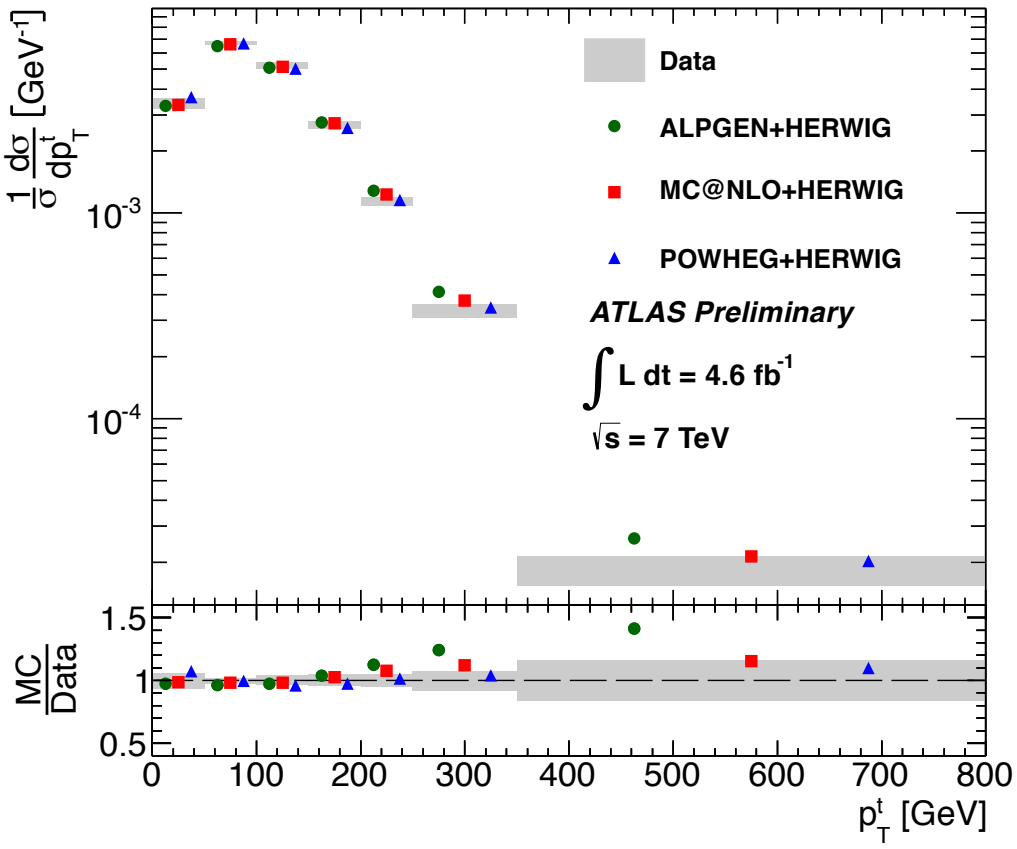
ATLAS-CONF-2013-099

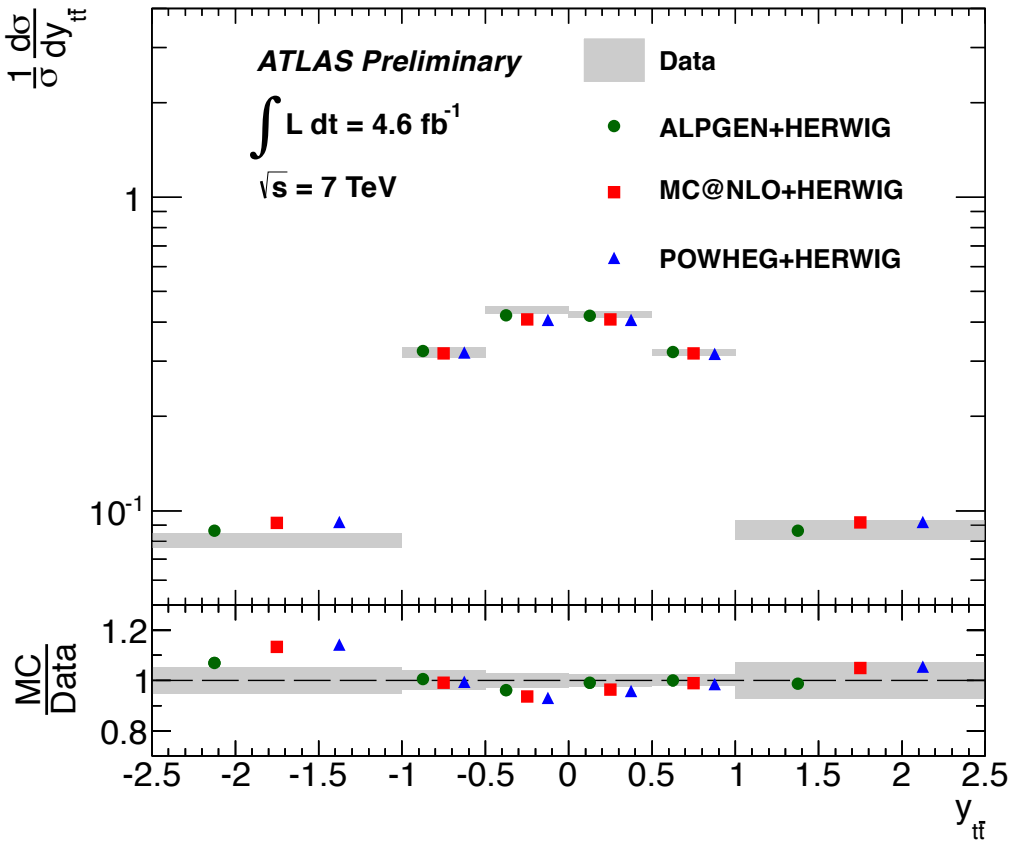
- **Lepton+jets selection**
- Measurement in bins of p_T^t, m_{tt}, y_{tt} and p_T^{tt}
- tt kinematics reconstructed using a **maximum likelihood fit** to the reconstructed objects
  - Relates measured objects to the parton level tt decay
  - Maximisation performed for each jet combination
- Reconstructed variables are **unfolded** after background subtraction
  - Correction for detector effects and acceptance through a migration matrix derived from simulation



$d\sigma_{tt}/dX$ and MC generators

ATLAS-CONF-2013-099

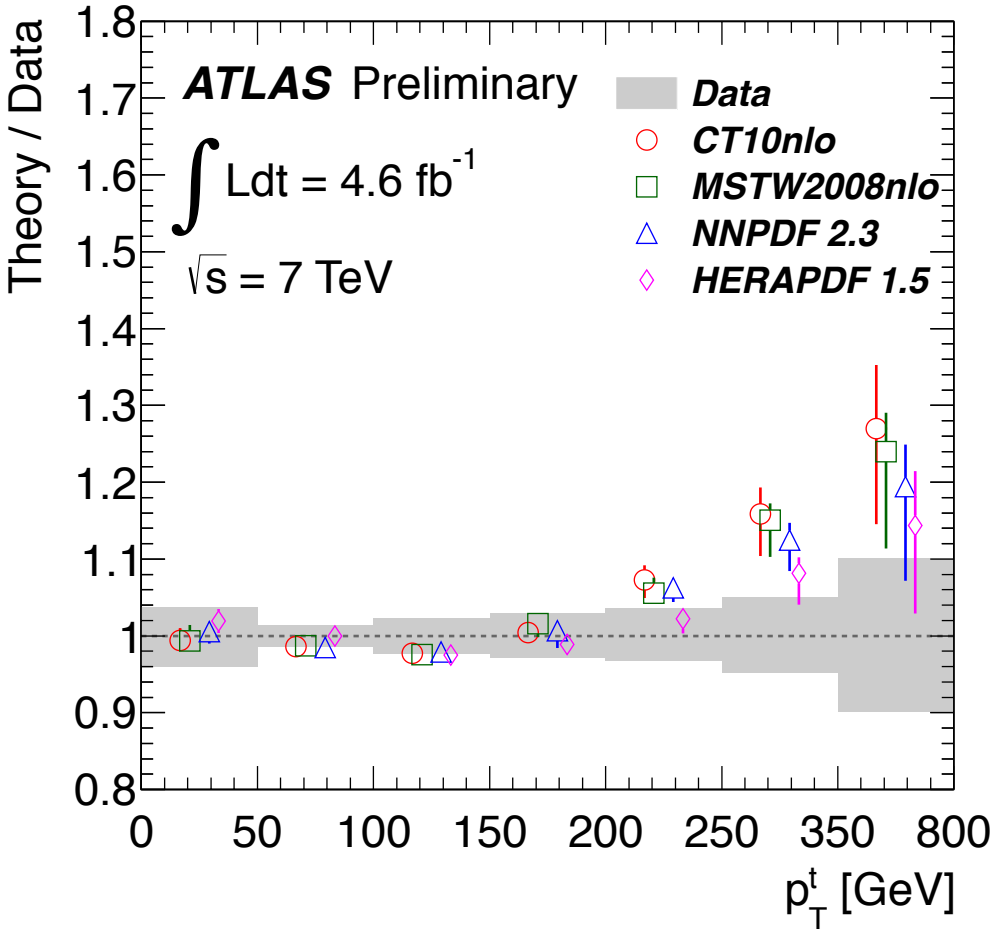


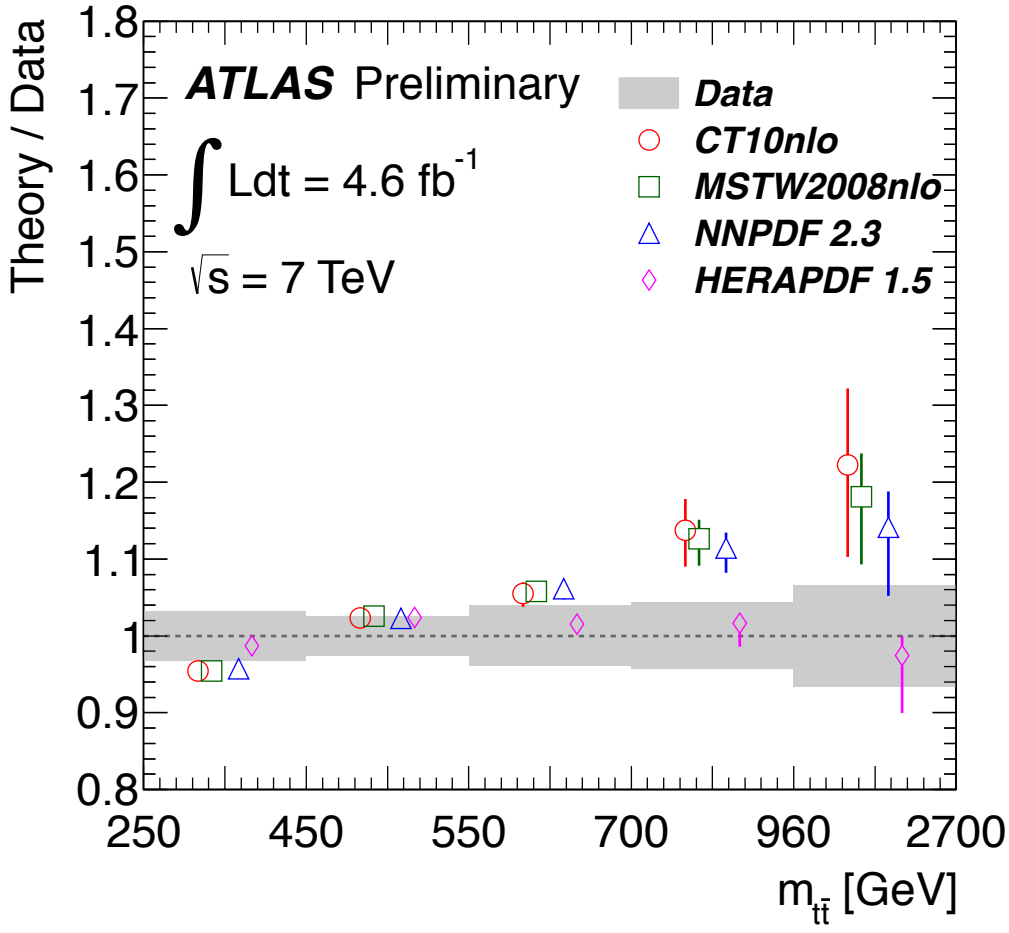


- Comparison with ALPGEN, MC@NLO and POWHEG
- p_T^t: softer measured spectrum above 200 GeV
  - Best data description by POWHEG+HERWIG
- y_{tt}: overestimation by MC@NLO and POWHEG for $y < -1$, underestimation for $|y| < 0.5$
  - Best data description by ALPGEN+HERWIG

$d\sigma_{tt}/dX$ and PDF sets

ATLAS-CONF-2013-099





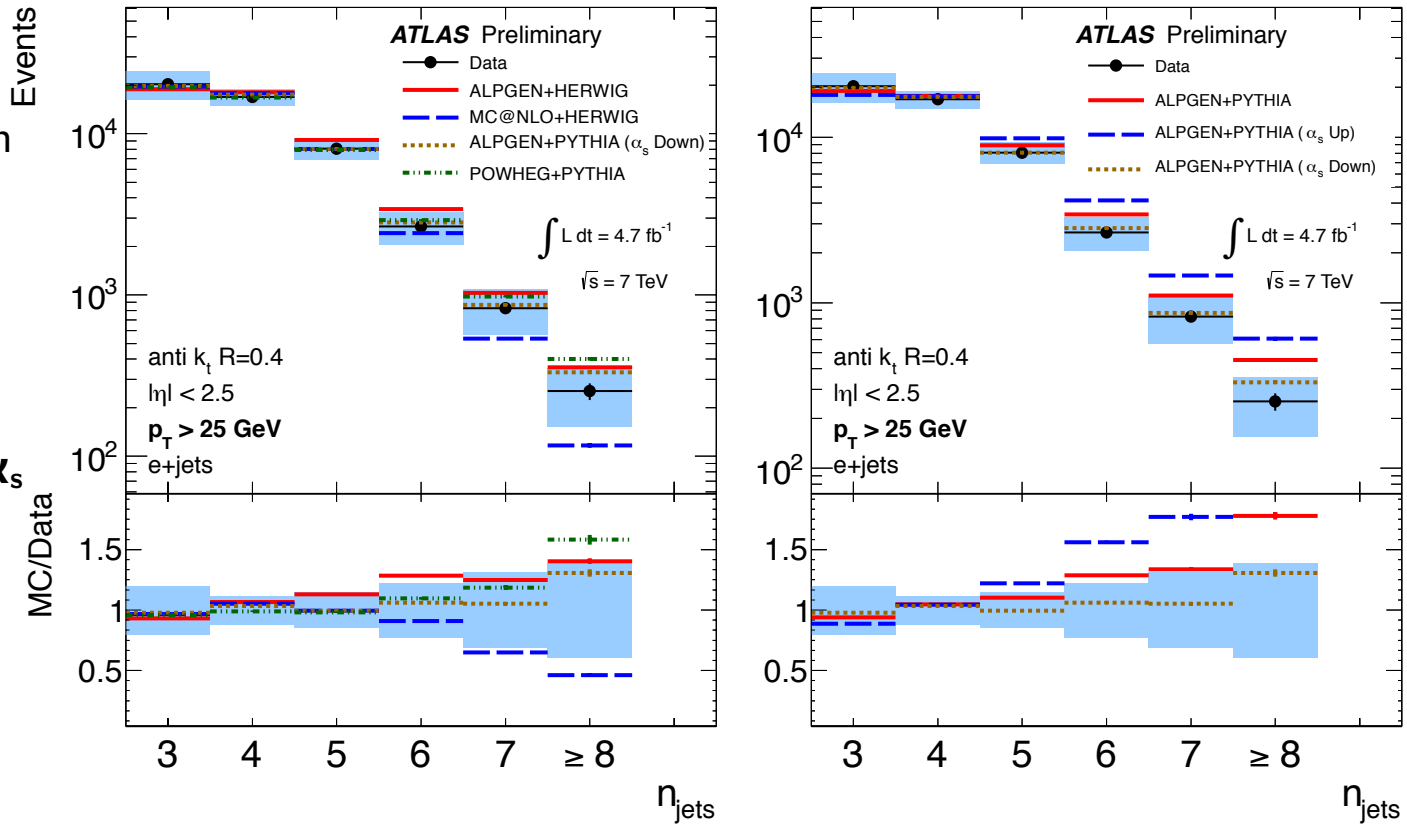
- Comparison with CT10, MSTW2008, NNPDF and HERAPDF
  - From NLO theory calculation
- **p_T^t**: Certain tension at high p_T for all predictions, need more data to gain significance
- **m_{tt}**: Best data description by HERAPDF, deviation at high m_{tt} for others

σ_{tt} vs jet multiplicity @ 7 TeV (4.6 fb^{-1})

ATLAS-CONF-2012-155

- Jet multiplicity in tt events for different p_T thresholds (25, 40, 60, 80 GeV)
- Corrected for all detector effects within acceptance
- Comparison of data with ALPGEN+HERWIG, MC@NLO+HERWIG, ALPGEN+PYTHIA and POWHEG+PYTHIA

- MC@NLO predicts fewer jets than measured spectra
  - Other generator predictions consistent with data
- **Sensitive to scale settings of α_s**
  - Best data compatibility: ALPGEN+PYTHIA with α_s down variation



σ_{tt} vs jet multiplicity @ 7 TeV (4.6 fb^{-1})

ATLAS-CONF-2012-155

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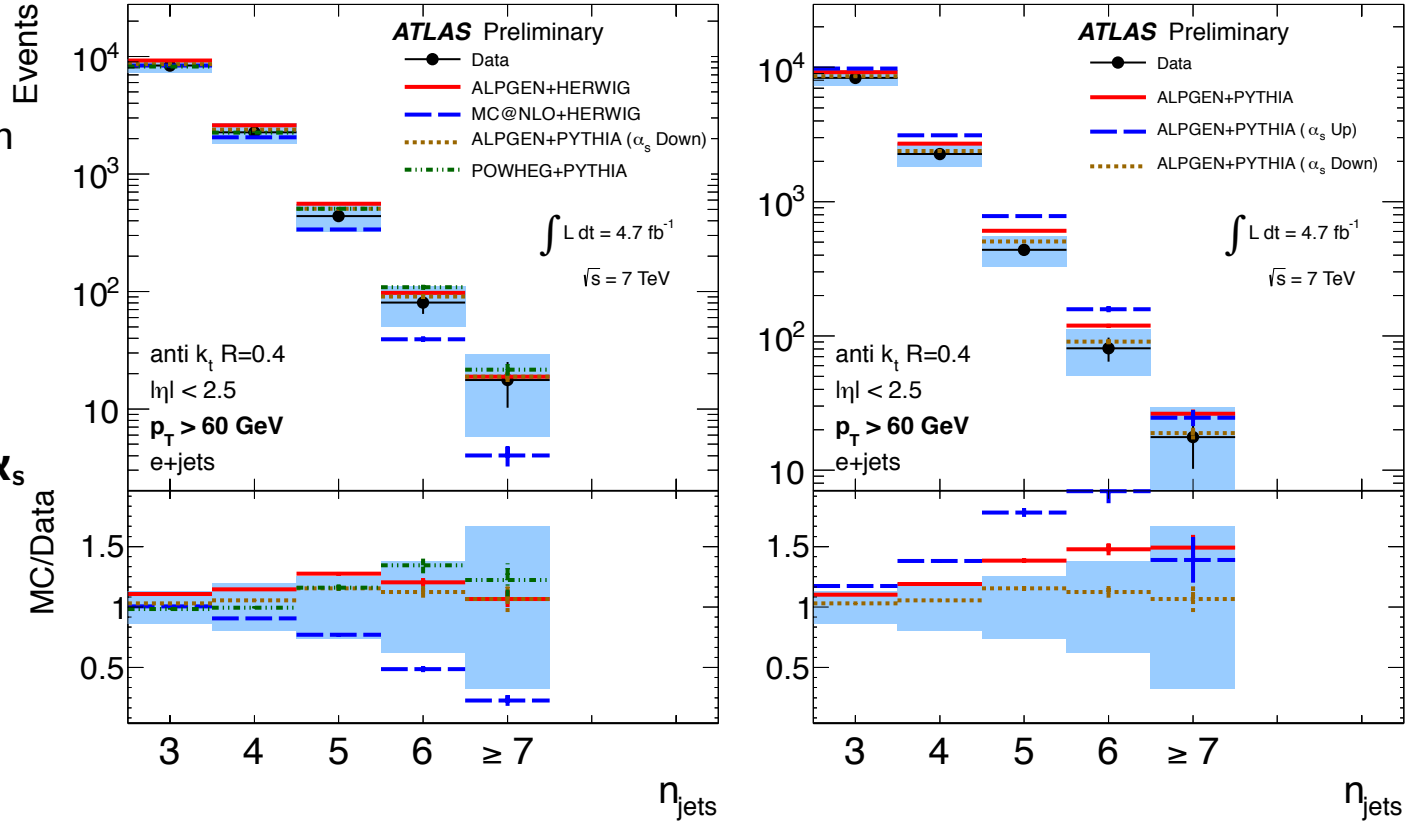
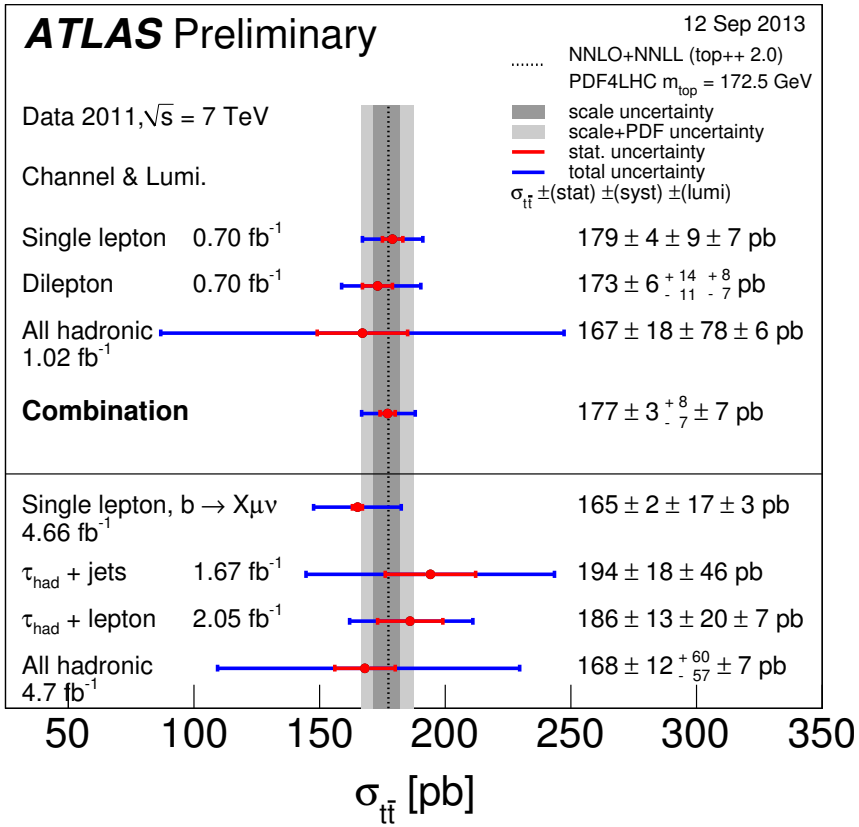
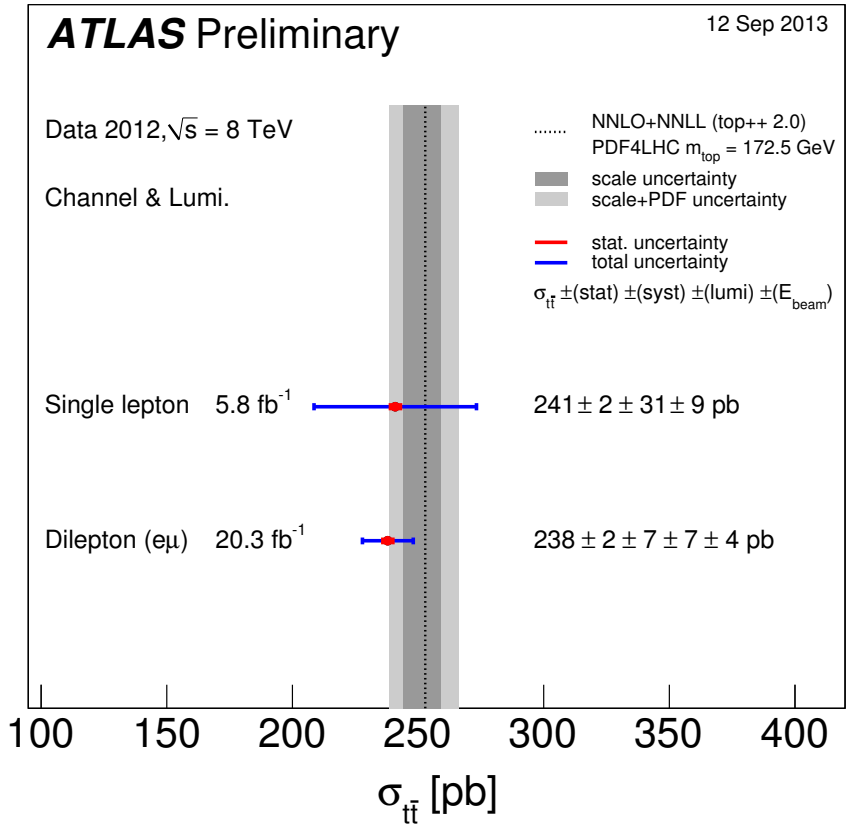


Top quark pair cross section summary





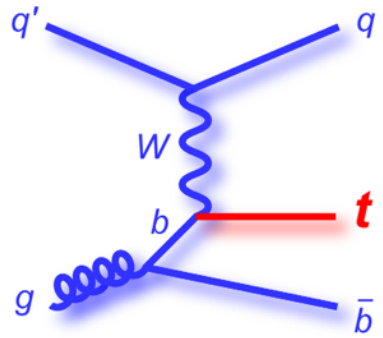
- **Inclusive**
  - Broad range of measurements
  - Major channels covered @ 7 TeV
  - First measurements @ 8 TeV in semileptonic and dileptonic channel
- **Differential**
  - Very important measurements to constraint SM modeling differences
  - Done in fiducial range to avoid large extrapolations

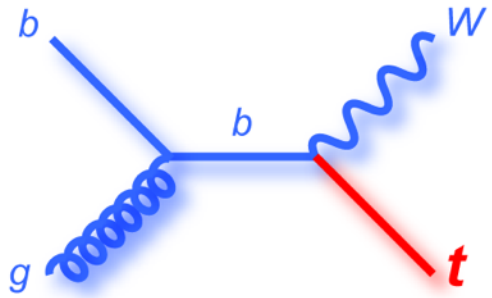
All results consistent with SM expectations

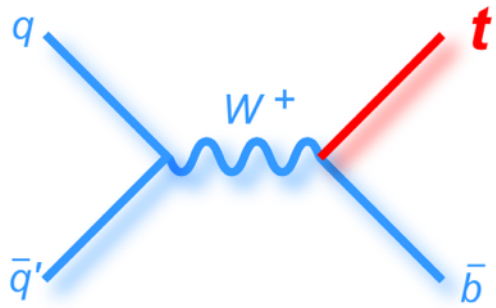
Top quark pair production

Single top production

Single top quark production







t-channel

approx. NNLO

$\sigma_t(7\,\text{TeV}) = 64.6^{+2.7}_{-2.0}\,\text{pb}$

$\sigma_t(8\,\text{TeV}) = 87.8^{+3.4}_{-1.9}\,\text{pb}$

Discovered at Tevatron

Wt channel

$\sigma_{Wt}(7\,\text{TeV}) = 15.7 \pm 1.1\,\text{pb}$

$\sigma_{Wt}(8\,\text{TeV}) = 22.4 \pm 1.5\,\text{pb}$

Observed at LHC

s-channel

$\sigma_s(7\,\text{TeV}) = 4.6 \pm 0.2\,\text{pb}$

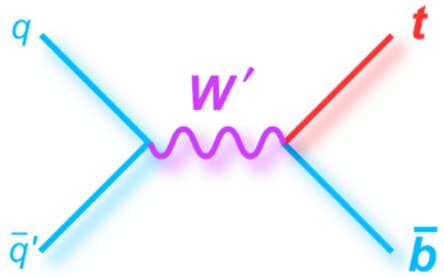
$\sigma_s(8\,\text{TeV}) = 5.6 \pm 0.2\,\text{pb}$

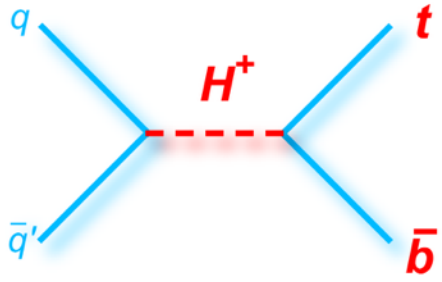
Evidence at Tevatron

Motivations

- **Test of SM**
- **Probe W-t-b vertex**
  - Constraint on $|V_{tb}|$
  - Search for modified couplings
  - Anomalous polarisation

- PDF constraints
  - **u/d ratio**, b quark
- Direct sensitivity to new physics
  - FCNC
  - Excited quarks (b*)
  - Charged higgs (H^+)
  - W' covered in Madalina's talk





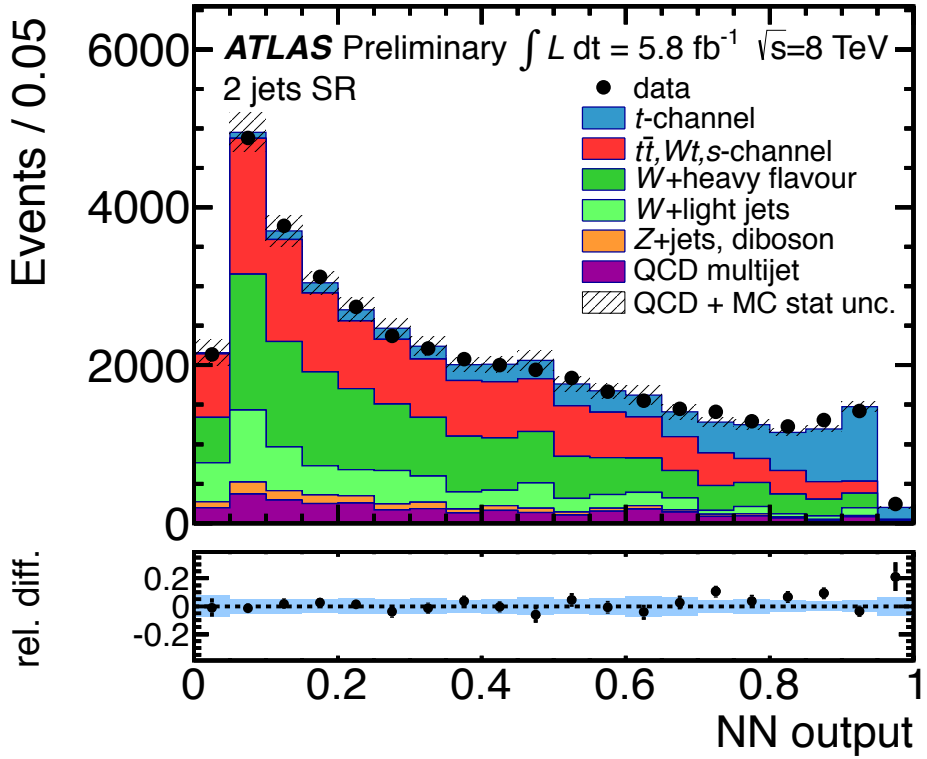
results presented in this talk

Single top quark cross section measurements

t-channel @ 8 TeV (5.8 fb^{-1})

ATLAS-CONF-2012-132

- **Selection**
  - W leptonic decay
  - 1 isolated lepton $p_T > 25$ GeV
  - 2 or 3 jets $|\eta| < 4.5$, $p_T > 30$ GeV
  - 1 b-tagged jet
  - $E_T^{miss} > 30$ GeV, $m_T(W) > 50$ GeV
- **Analysis**
  - Use of a **NN** for signal/background discrimination
  - Measurement from **maximum likelihood fit** to NN distributions
  - **Data driven** multijet and W+jets background estimations
  - Other background estimated from simulation
- **Results**
  - Main systematics: ISR/FSR (9.1%), b-tagging efficiency (8.5%) and jet energy scale (7.7%)



$$\sigma_t = 95 \pm 2\,(\text{stat.}) \pm 18\,(\text{syst.})\,\text{pb}$$

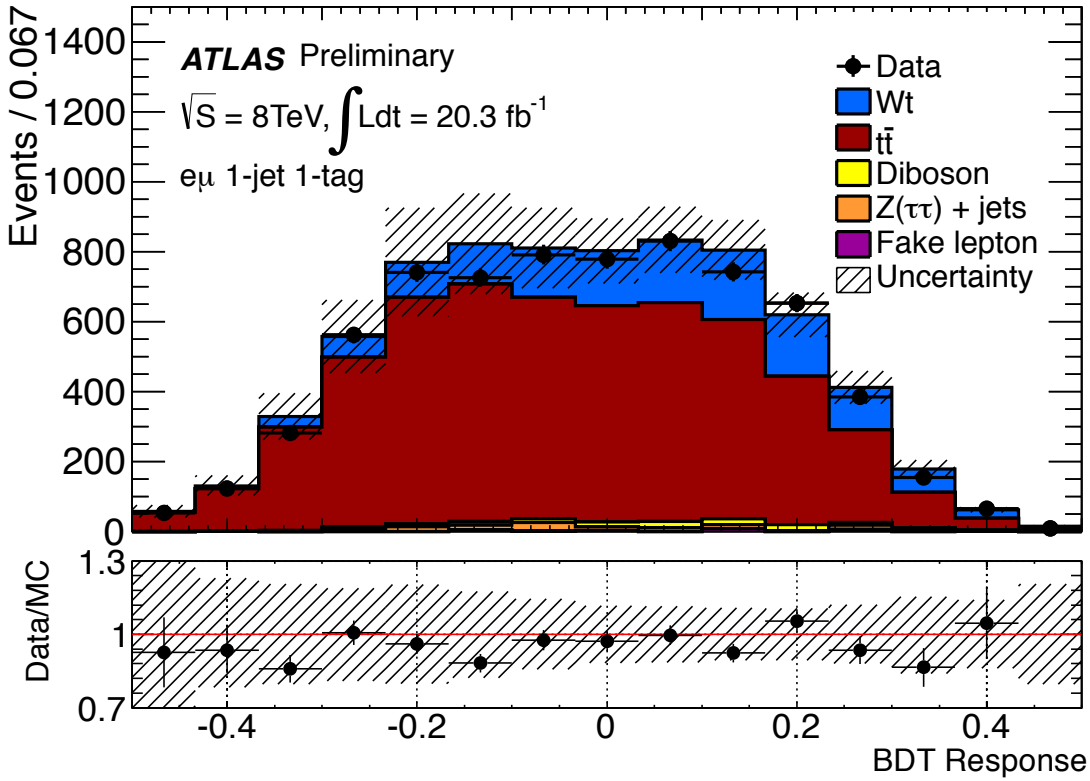
consistent with theory

Wt channel @ 8 TeV (20.3 fb^{-1})

ATLAS-CONF-2013-100

- **Selection**
  - Leptonic W decays, eμ channel
  - Two isolated leptons $p_T > 25$ GeV of opposite charge
  - 1 or 2 jets $p_T > 30$ GeV, $|\eta| < 2.5$ with 1 b-tagged

- **Analysis**
  - Background discrimination using Boosted Decision Trees (BDT) in 1 and 2 jet samples
  - Measurement using a **maximum likelihood fit on BDT distributions**
  - Data driven fakes estimation



- **Results**
  - Main systematics: jet energy scale, b-tagging (~9%) and generator

$$\sigma_{Wt} = 27.2 \pm 2.8\,(\text{stat.}) \pm 5.4\,(\text{syst.})\ \text{pb}$$

Significance: **4.2σ** (exp. 4.0σ)

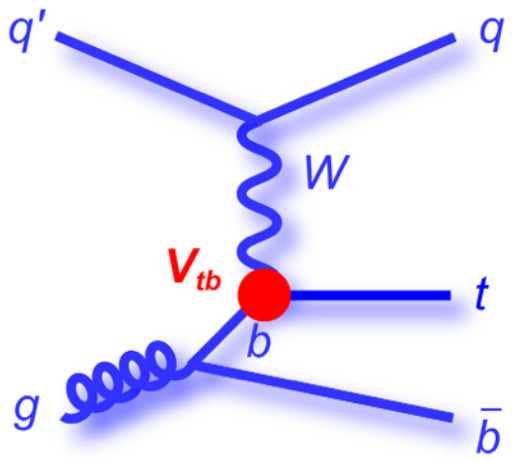
Direct $|V_{tb}|$ measurement (t and Wt channel)

ATLAS-CONF-2012-132 - ATLAS-CONF-2013-100

- Cross section proportional to $|V_{tb} \cdot f|^2$
  - with f a coupling (=1 in SM)

- **Measurement**

$$|V_{tb} \cdot f|^2 = \frac{\sigma_t^{exp}}{\sigma_t^{th}}$$



- Independent of N_{quark} generation and CKM unitarity

- **Assumptions**
  - Left handed SM-like W-t-b interaction
  - $|V_{tb}| >> |V_{td}|, |V_{ts}|$

Results (8TeV)

t-channel

$$|V_{tb} \cdot f| = 1.04^{+0.10}_{-0.11}$$
$$> 0.80 \ (95\% \text{ CL})$$

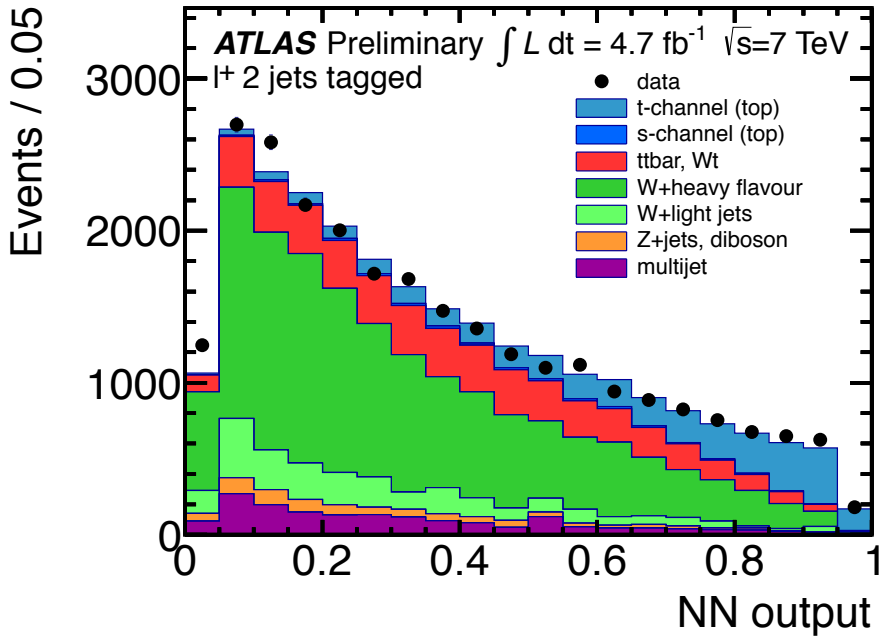
Wt

$$|V_{tb} \cdot f| = 1.10 \pm 0.12$$
$$> 0.72 \ (95\% \text{ CL})$$

Top/antitop cross section ratio (R_t) @ 7 TeV (4.7 fb^{-1})

ATLAS-CONF-2012-056

- $R_t = \sigma_{top}/\sigma_{antitop}$ sensitive to u/d quark PDF ratio
- Similar W leptonic decay selection
- **Analysis**
  - Similar to inclusive cross section measurement
  - Separate NN **depending on the lepton charge**
- **Results**
  - Main systematics: ISR/FSR (4.2%), QCD background normalisation (~3.8%), jet energy scale (3.7%)

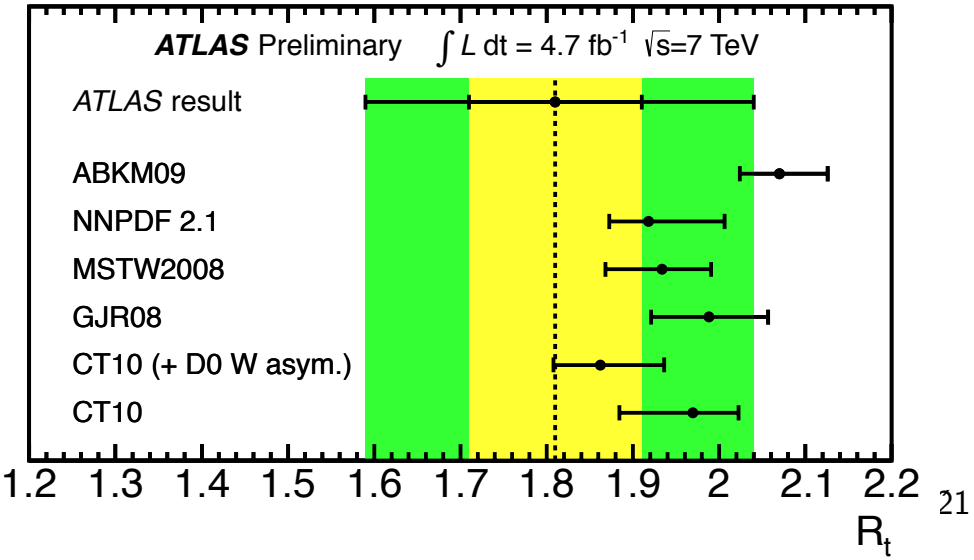


$R_t = 1.81 \pm 0.10\,(\text{stat.}) \pm 0.21\,(\text{syst.})$

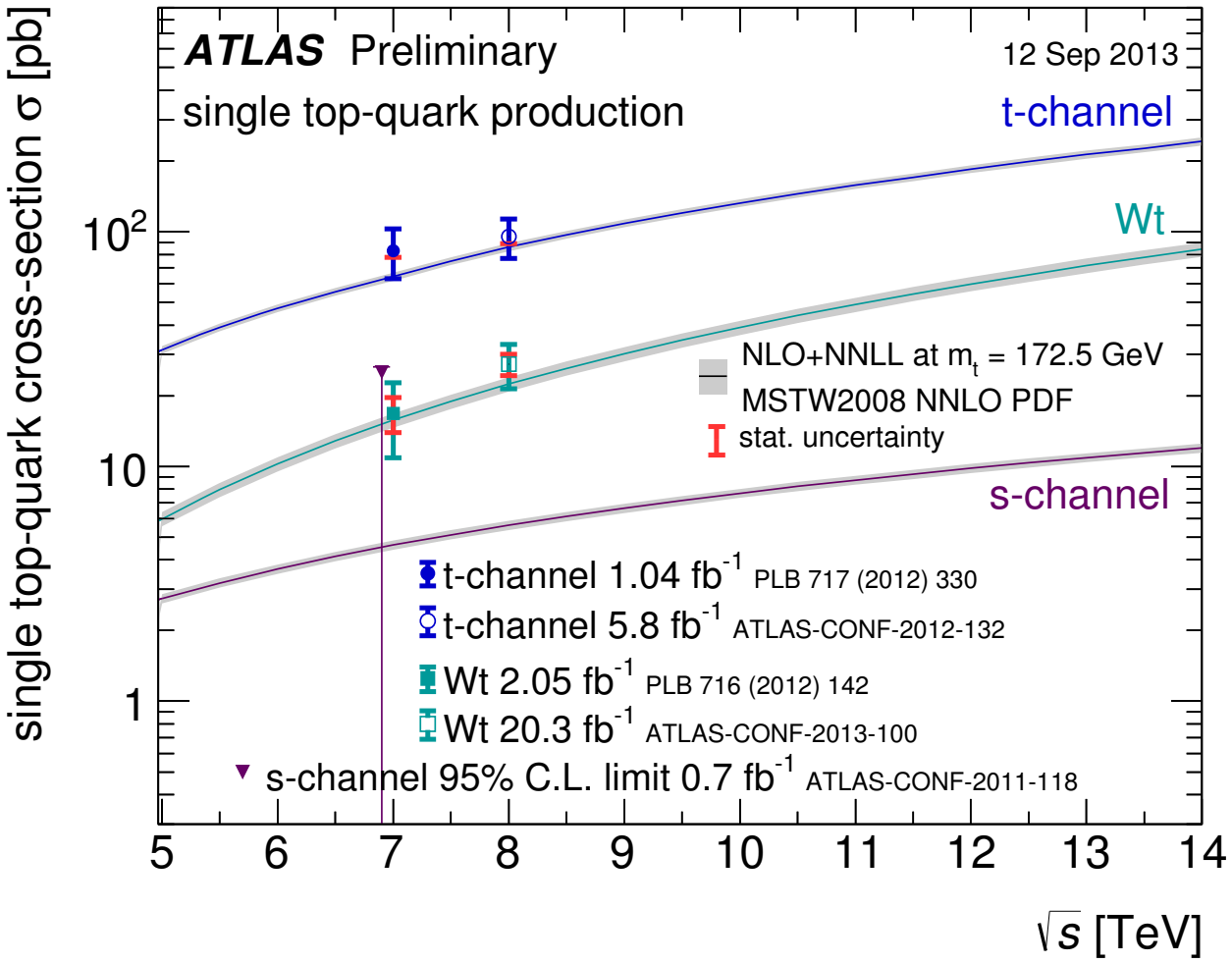
$\sigma_t(t) = 53.2 \pm 1.7\,(\text{stat.}) \pm 10.6\,(\text{syst.})$ pb

$\sigma_t(\bar{t}) = 29.5 \pm 1.5\,(\text{stat.}) \pm 7.3\,(\text{syst.})$ pb

agreement with predictions using various PDF sets



Single top quark production summary



- **Many results in the single top quark sector**
- Presented here:
  - **t-channel** cross section @ 8 TeV
    - **Combination with CMS**

$\sigma_t = 85 \pm 4\,(\text{stat.}) \pm 11\,(\text{syst.}) \pm 3\,(\text{lumi})\ \text{pb}$

ATLAS-CONF-2013-098

  - **Wt channel** cross section @ 8 TeV
    - **4.2σ evidence**
  - Direct measurement of $|V_{tb}|$
  - Cross section ratio in t-channel
    → sensitive to u/d PDFs

All results consistent with SM expectations

Summary and outlook

- All top quark production cross section measurements are **consistent with SM expectations**
- Differential cross section measurements important to constraint SM modeling differences
  - Current measurements **start to be discriminating**
- More measurements coming @ 8 TeV

All public results from the ATLAS top physics working group here
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults

Many new results ahead!

THANK YOU

BACKUP

Dilepton channel @ 8 TeV (20.3 fb^{-1})

ATLAS-CONF-2013-097

- **Cross section** and **b-tag/jet reconstruction efficiency** extracted from event counts in 1 and 2 b-tagged jets samples

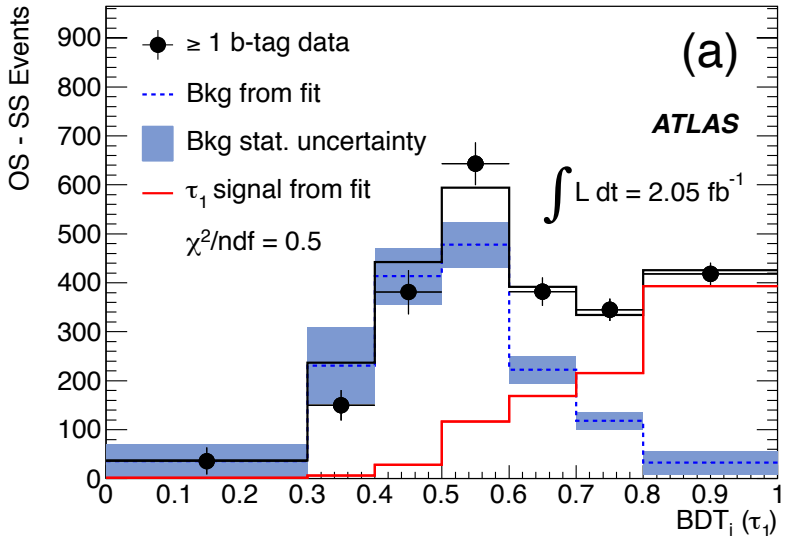
$$N_1 = L\sigma_{t\bar{t}}\epsilon_{e\mu}2\epsilon_b(1 - C_b\epsilon_b) + N_1^{bkg}$$
$$N_2 = L\sigma_{t\bar{t}}\epsilon_{e\mu}2C_b\epsilon_b^2 + N_2^{bkg}$$

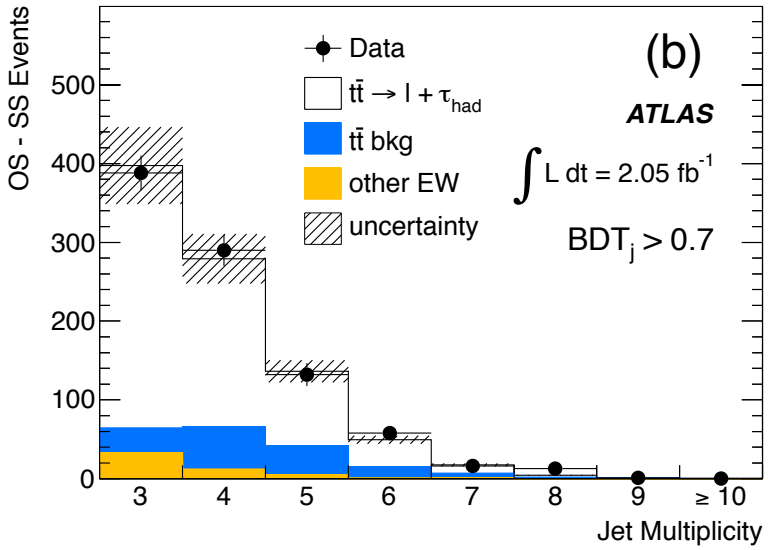
- with:
  - L: integrated luminosity
  - σ_{tt}: cross section
  - $\varepsilon_{e\mu}$: efficiency to pass eμ preselection
  - ε_b: Probability for a jet from $t \to Wq$ to be within acceptance, reconstructed as a jet and b-tagged
  - C_b: correlations between two b-tagged jets
  - N^{bkg}: number of background events

τ+lepton channel @ 7 TeV (2.1 fb^{-1})

arXiv:1205.2067

- Cross section measurement with τ decaying hadronically
- Sensitive to non SM processes $t \to bH^+ \to b\tau^+\nu_\tau$
- **τ reconstruction and ID**
  - 1-3 associated tracks $p_T > 1$ GeV
    $20 < E_T < 100$ GeV, $|\eta| < 2.3$
  - Discrimination between τ and misidentified electron and jets using **boosted decision trees** (BDT)
    ID variables from tracking and calorimeter
- **Analysis**
  - Estimation on **opposite sign - same sign distribution** to suppress fake τ from gluon jets and multijet background
  - **χ2 fits** to the OS-SS BDT distributions on events with at least one b-jet
  - Signal templates from MC, background templates from 0 b-jet sample
- **Results**
  - Main systematics: b-tagging, ISR/FSR, τ-ID





$$\sigma_{t\bar{t}} = 186 \pm 13\,(\text{stat.}) \pm 20\,(\text{syst.}) \pm 7\,(\text{lumi})\ \text{pb}$$

consistent with $\sigma_{t\bar{t}}^{\text{NNLO+NNLL}} = 177.3^{+10.1}_{-10.8}$ pb

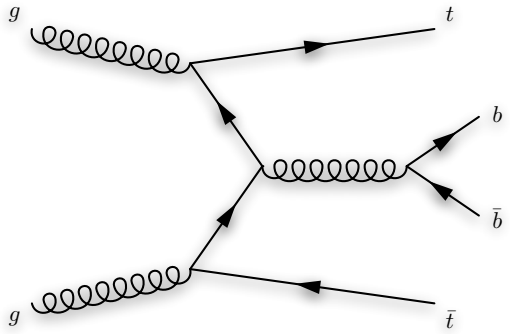
$t\bar{t}$ + heavy flavor @ 7 TeV (4.7 fb^{-1})

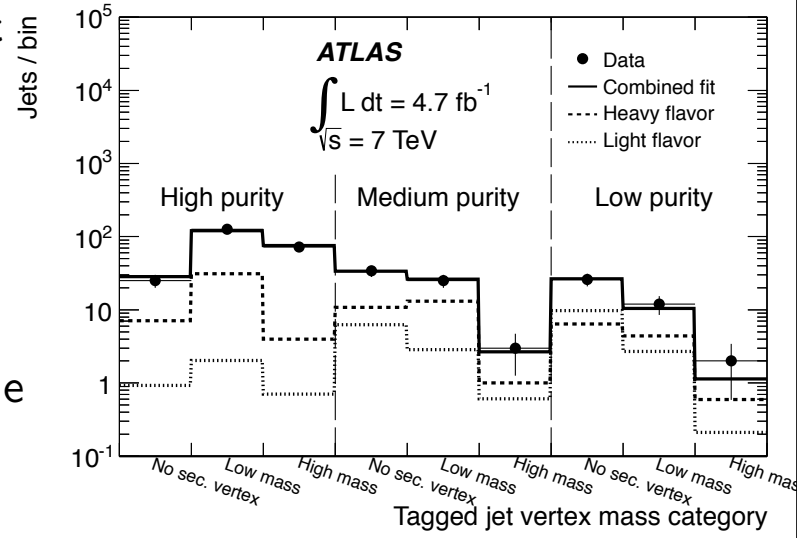
arXiv:1304.6386

- Main irreducible background to $t\bar{t} + H$ with $H \to b\bar{b}$
- Measurement of ratio R_{HF} to reduce systematic uncertainties

$$R_{HF} = \frac{\sigma_{fid}(t\bar{t} + HF)}{\sigma_{fid}(t\bar{t} + j)} \qquad HF = b,c \quad j = \text{any flavor}$$

- Both σ_{fid} measured in a **kinematic fiducial region** within the detector acceptance
- Nominal tt dilepton selection with a **third jet requirement** $\to$ b-tagged for σ_{fid} (tt +HF)
- Main background for tt + HF is tt + jet with misidentified light jet
- Binned maximum likelihood fit to secondary vertex mass distribution to estimate heavy and light flavor content of the additional b-tagged jets





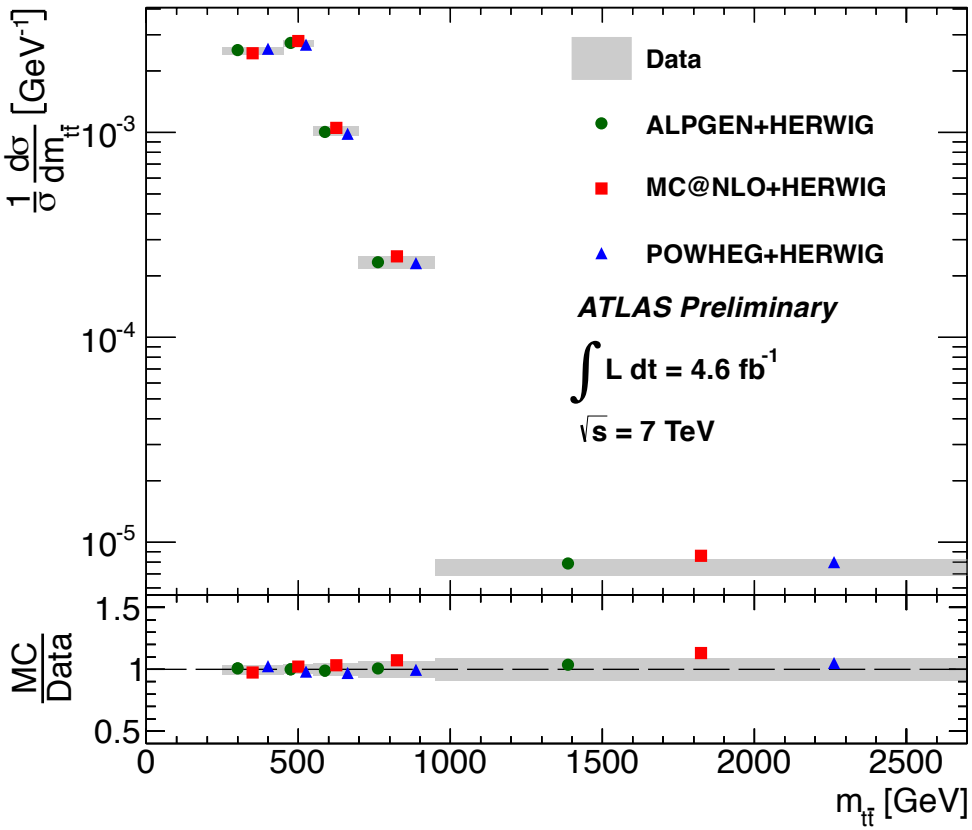
- **Results**
  - Main systematics: fiducial flavor composition (+69%), c-jets tagging efficiency (~21%)

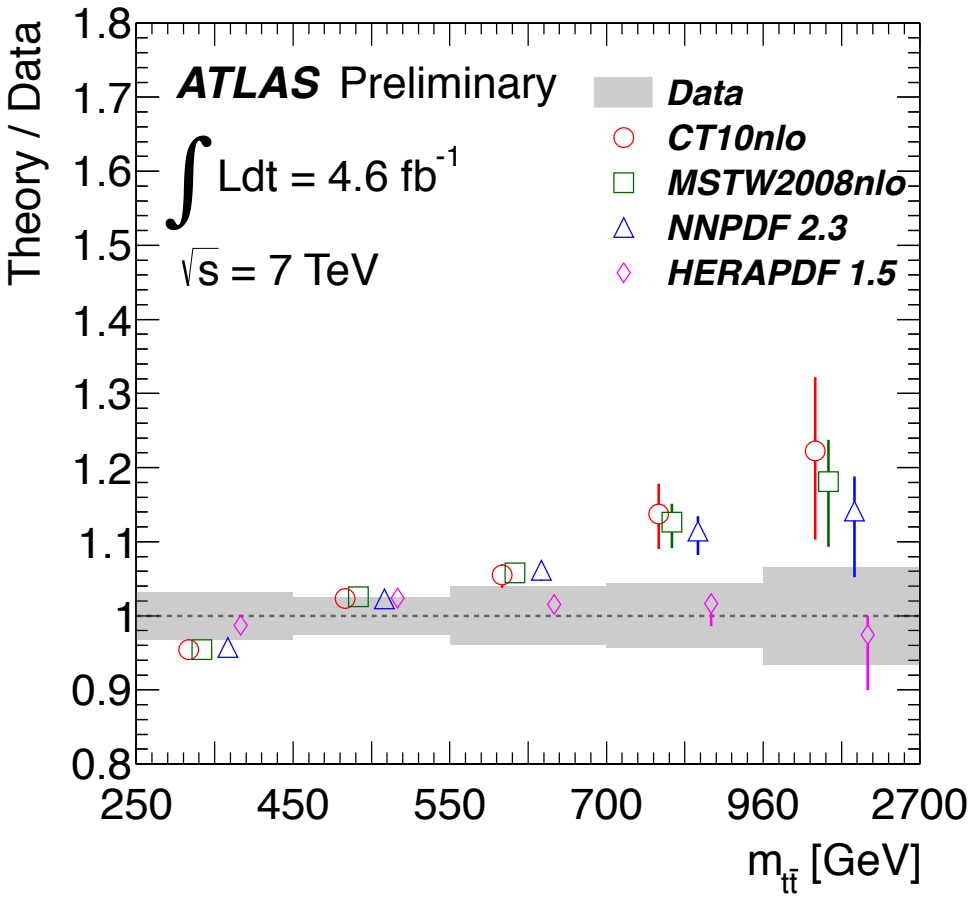
$$R_{HF} = [7.1 \pm 1.3\,(\text{stat.})\,^{+5.3}_{-2.0}\,(\text{syst.})]\%$$

prediction ALPGEN+HERWIG (LO): $R_{HF} = [3.4 \pm 1.1]\%$

$d\sigma_{tt}/dm_{tt}$

ATLAS-CONF-2013-099

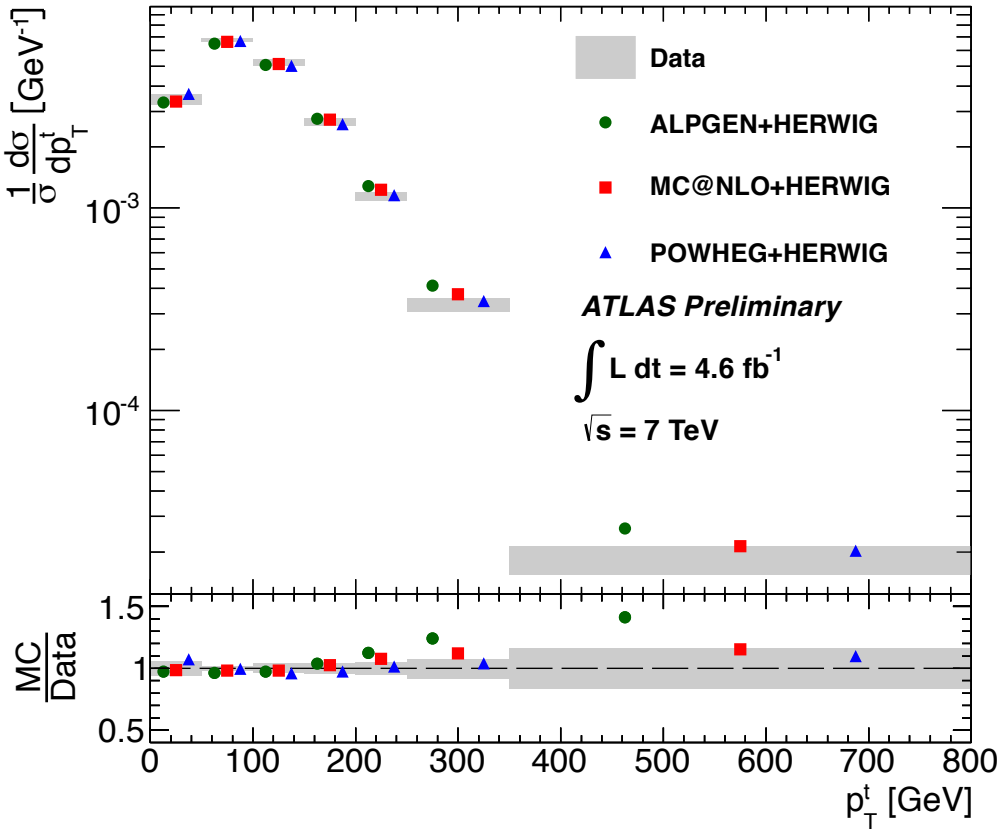


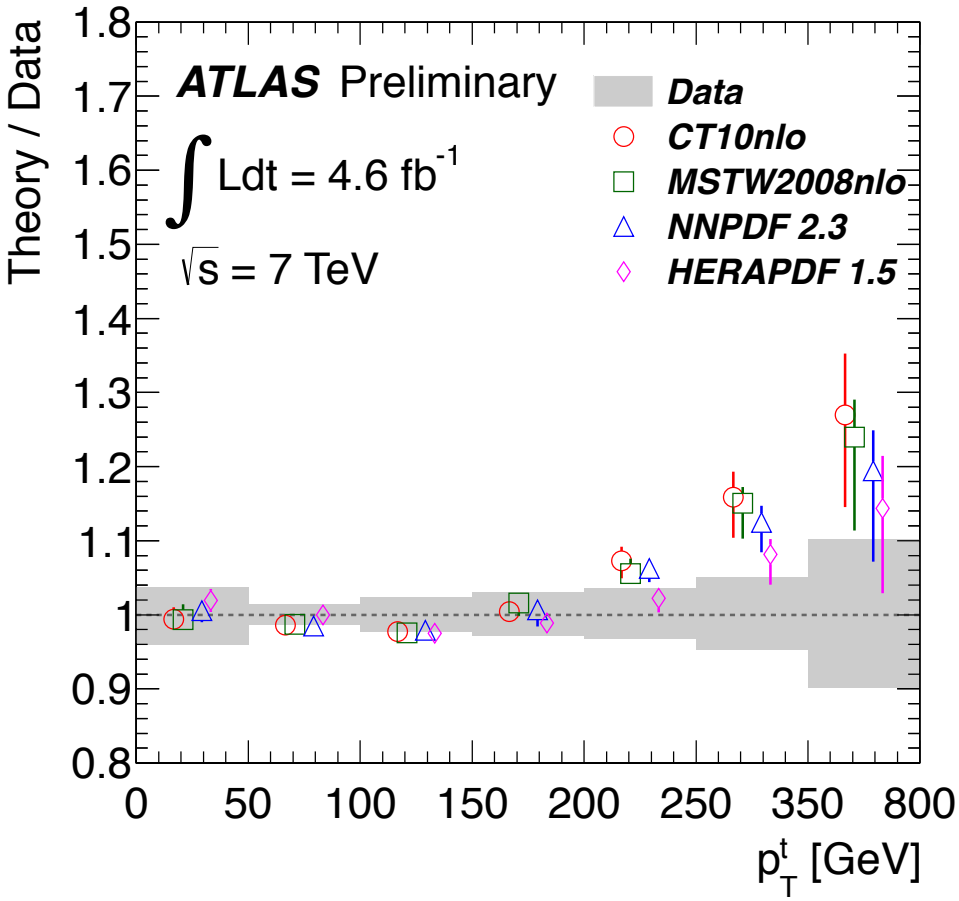


- **Generator**: good data/MC agreement
- **PDF**: best data description by HERAPDF, deviation at high m_{tt} for others

$d\sigma_{tt}/dp_T^t$

ATLAS-CONF-2013-099

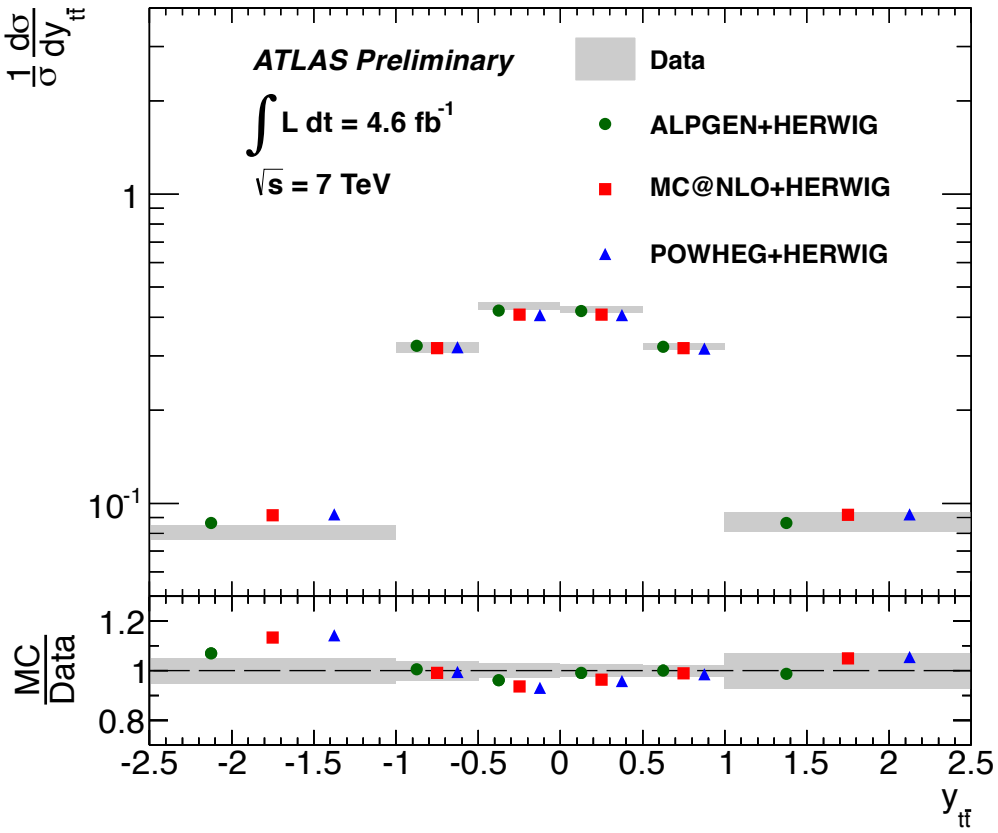


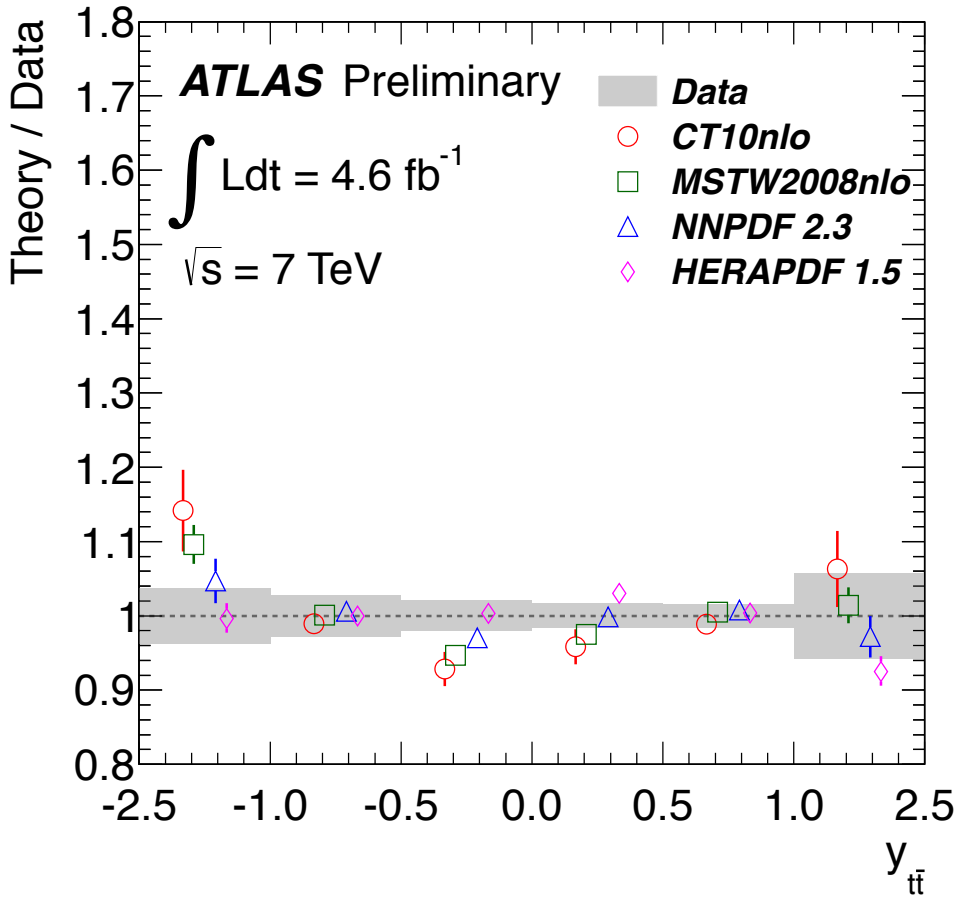


- **Generator**: softer measured spectrum above 200 GeV
  - Best data description by POWHEG+HERWIG
- **PDF**: certain tension at high p_T for all predictions

$d\sigma_{tt}/dy_{tt}$

ATLAS-CONF-2013-099

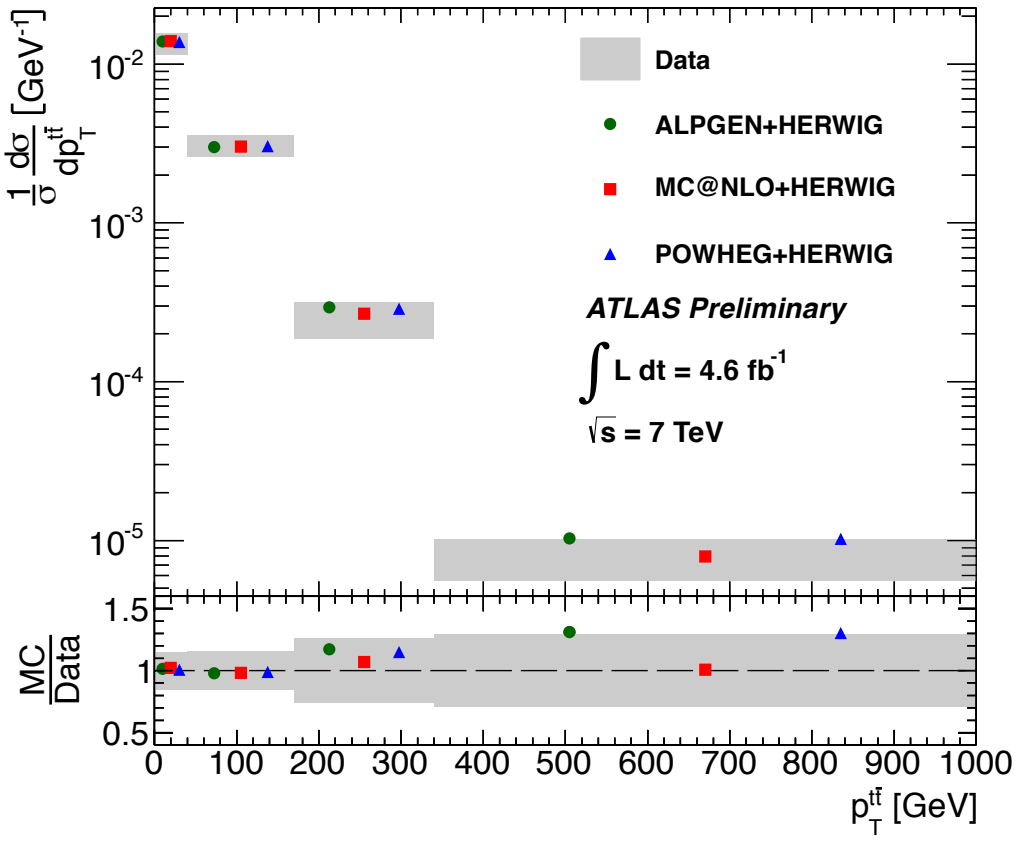


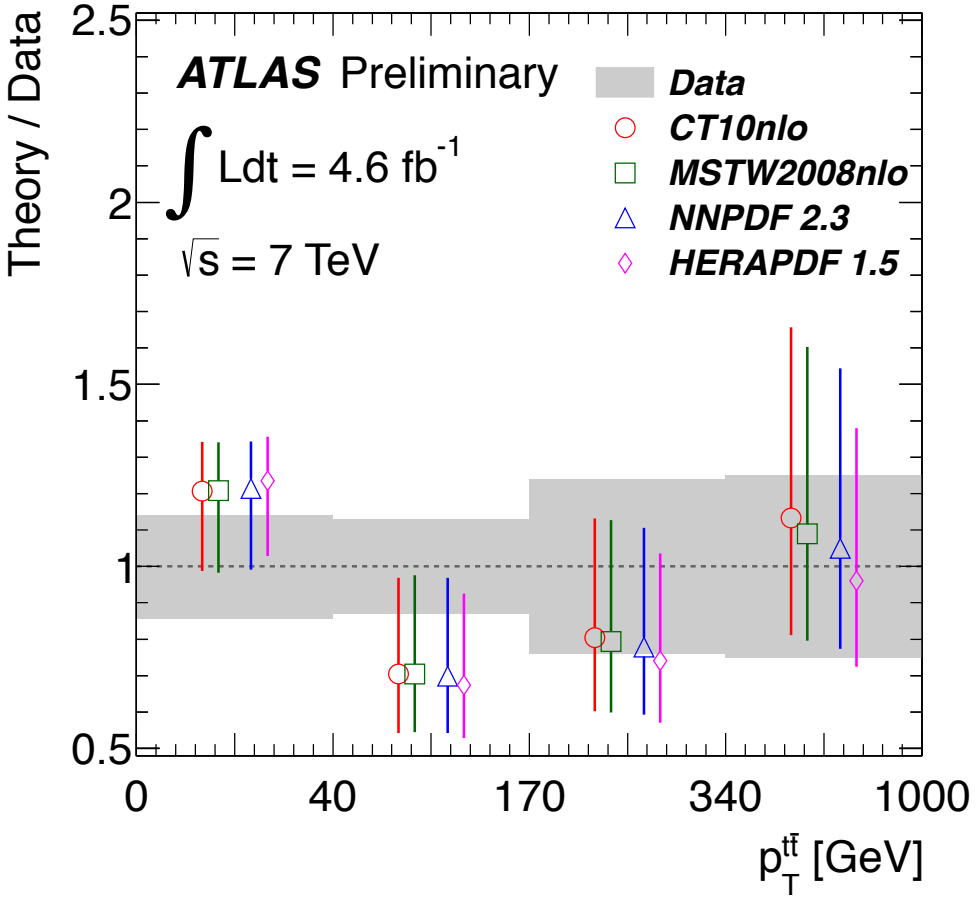


- **Generator**: overestimation by MC@NLO and POWHEG for $y < -1$, underestimation for $|y| < 0.5$
  - Best data description by ALPGEN+HERWIG
- **PDF**: better agreement for NNPDF and HERAPDF

$d\sigma_{tt}/dp_T^{tt}$

ATLAS-CONF-2013-099

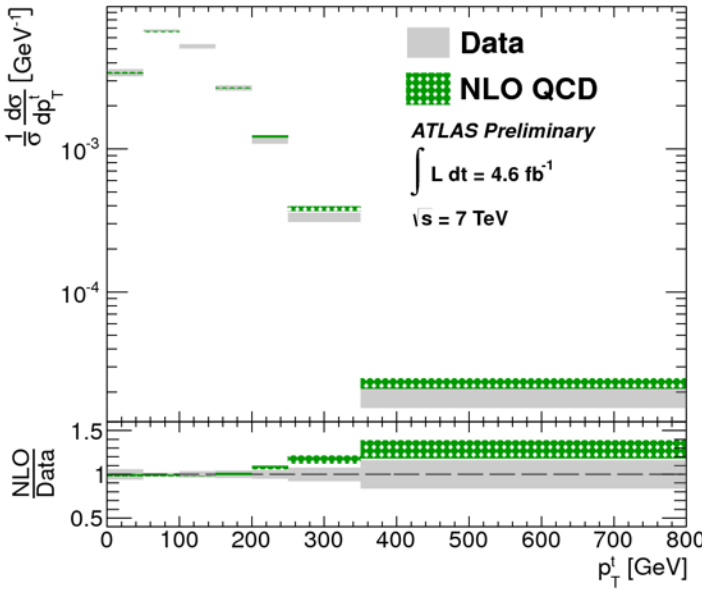


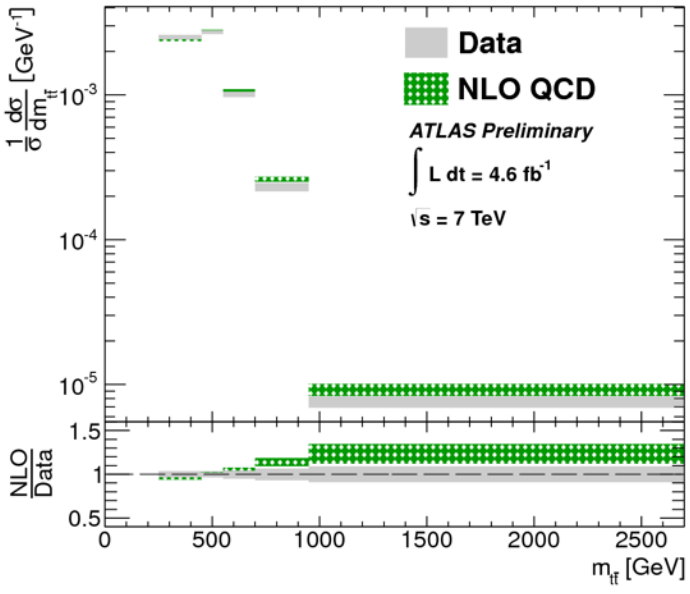


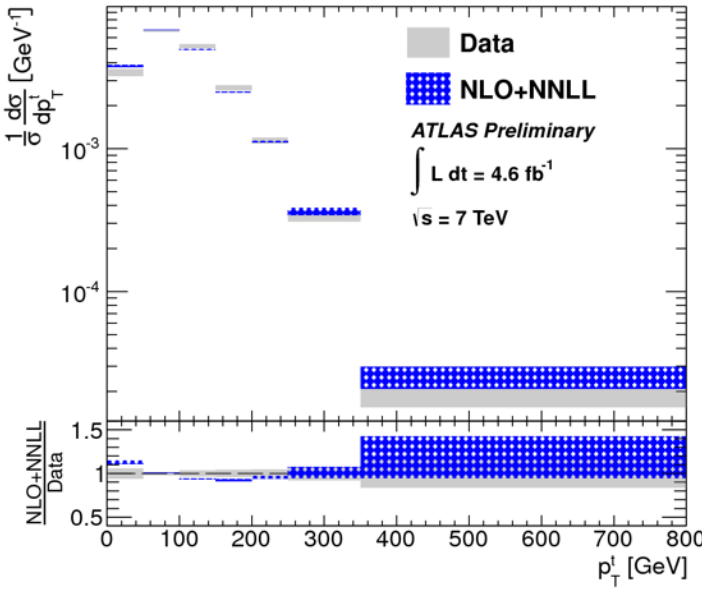
- Compatility MC/data and PDF/data within uncertainties

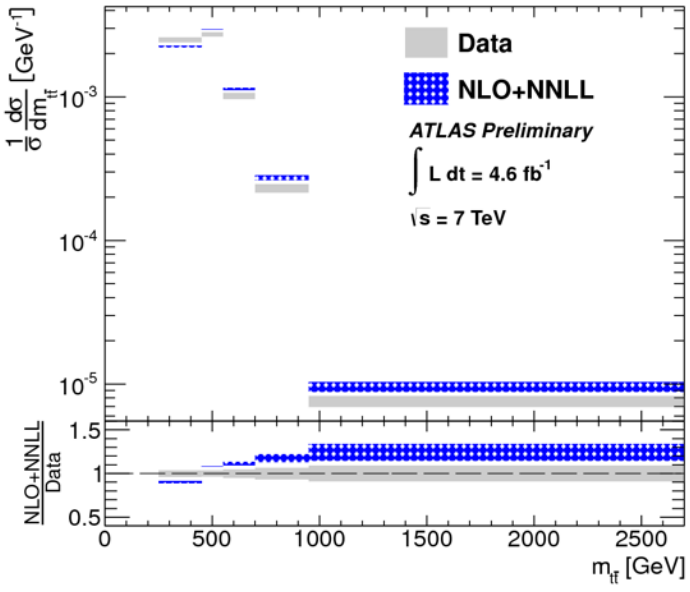
$d\sigma_{tt}/dX$ and QCD calculations

ATLAS-CONF-2013-099





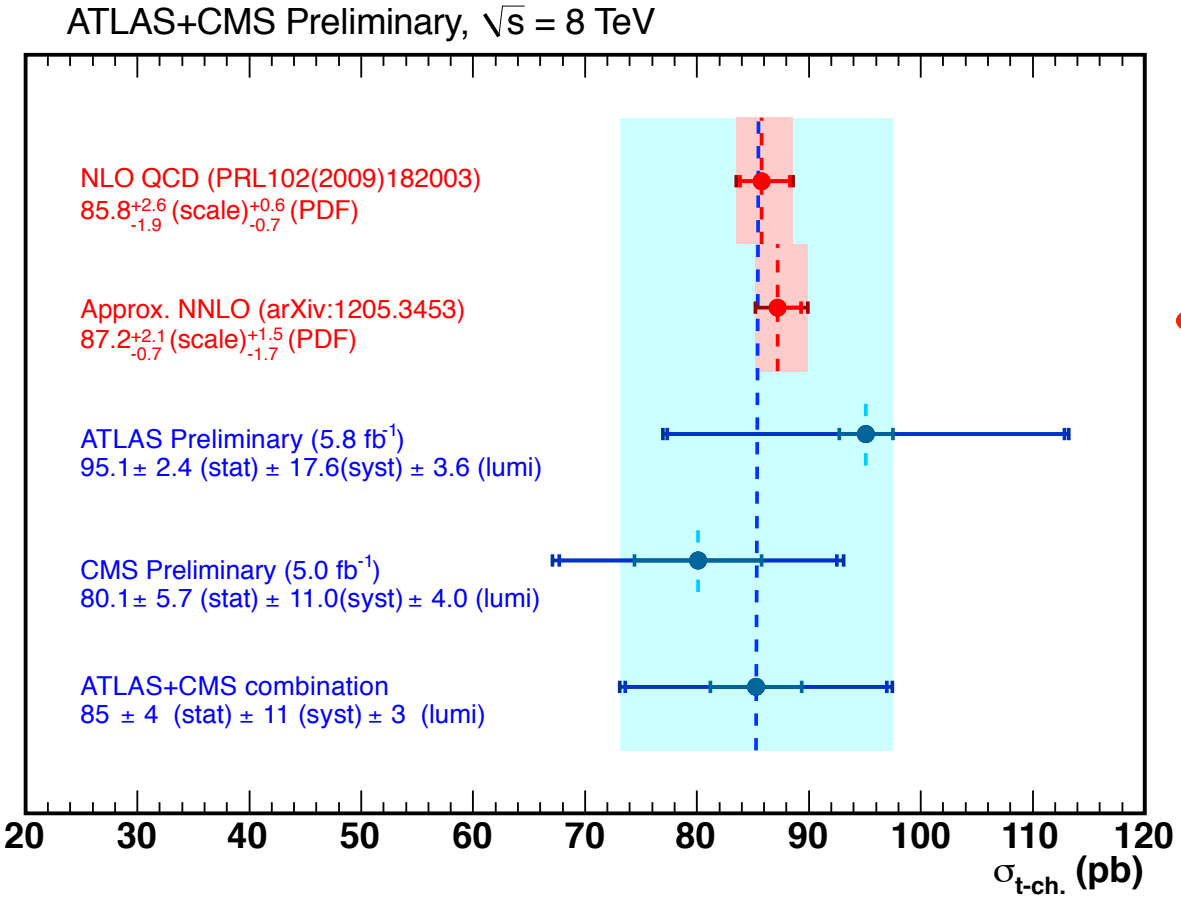




- Comparison with MCFM (NLO QCD) and NLO+NNLL
- Predictions do not include parton showering
- p_T^t: Data a bit softer than both predictions
- m_{tt}: Spectrum falls more quickly than both predictions $\rightarrow$ better agreement with NLO QCD

t-channel LHC combination

- Combination using **best linear unbiased estimator** (BLUE)
  - Consider individual contributions to systematic uncertainties and their correlations



Source	Uncertainty (pb)
Statistics	4.1
Luminosity	3.4
Simulation and modelling	7.7
Jets	4.5
Backgrounds	3.2
Detector modelling	5.5
Total systematics (excl. lumi)	11.0
Total systematics (incl. lumi)	11.5
Total uncertainty	12.2

$$\sigma_t = 85 \pm 4\,(\text{stat.}) \pm 11\,(\text{syst.}) \pm 3\,(\text{lumi})\ \text{pb}$$

Wt channel @ 8 TeV - BDT variables

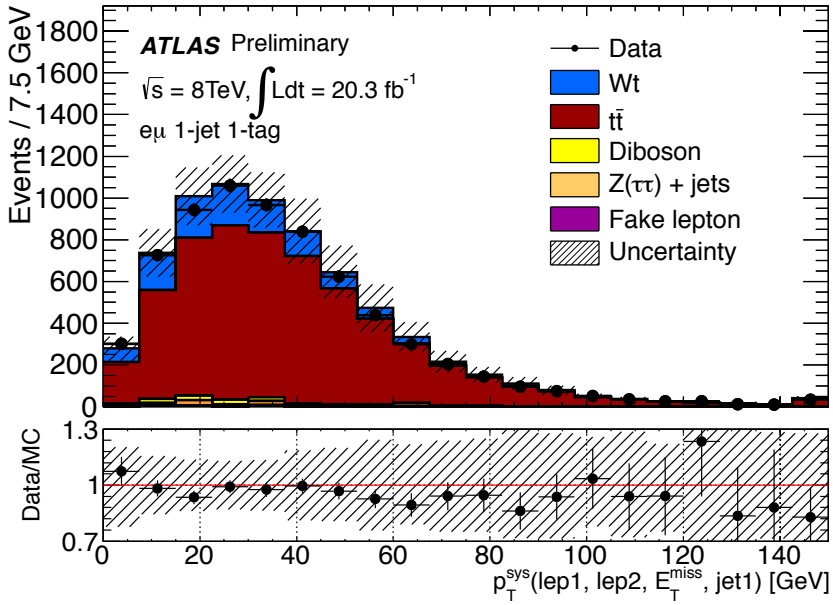
ATLAS-CONF-2013-100

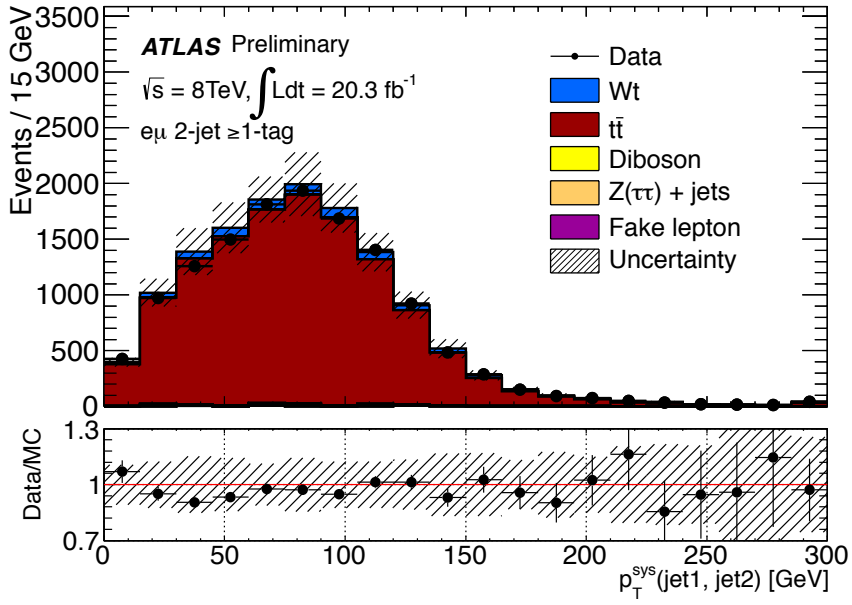
1-jet sample

Variable
p_T^{sys} variables
p_T^{sys} (lep1,lep2,E_T^{miss},jet1)
p_T^{sys} (lep1,lep2,jet1)
p_T-related variables
Δp_T ((lep1,lep2),(E_T^{miss},jet1))
Δp_T (lep1,E_T^{miss})
$\sum E_T$
H_T (lep1,lep2,E_T^{miss},jet1)
Angular correlations
$\Delta\phi$ ((lep1,lep2),jet1)
ΔR ((lep1,lep2),jet1)
$\Delta\phi$ (lep1,jet1)
$\Delta\phi$ (E_T^{miss},jet1)
Centrality (lep1,lep2)
Thrust
η (lep1,lep2)
m or m_T variables
m_T (lep2,E_T^{miss})
m (lep1,lep2,jet1)
m (lep1,jet1)
Object kinematics
E_T^{miss}
E_T (jet1)
η (lep2)

2-jet sample

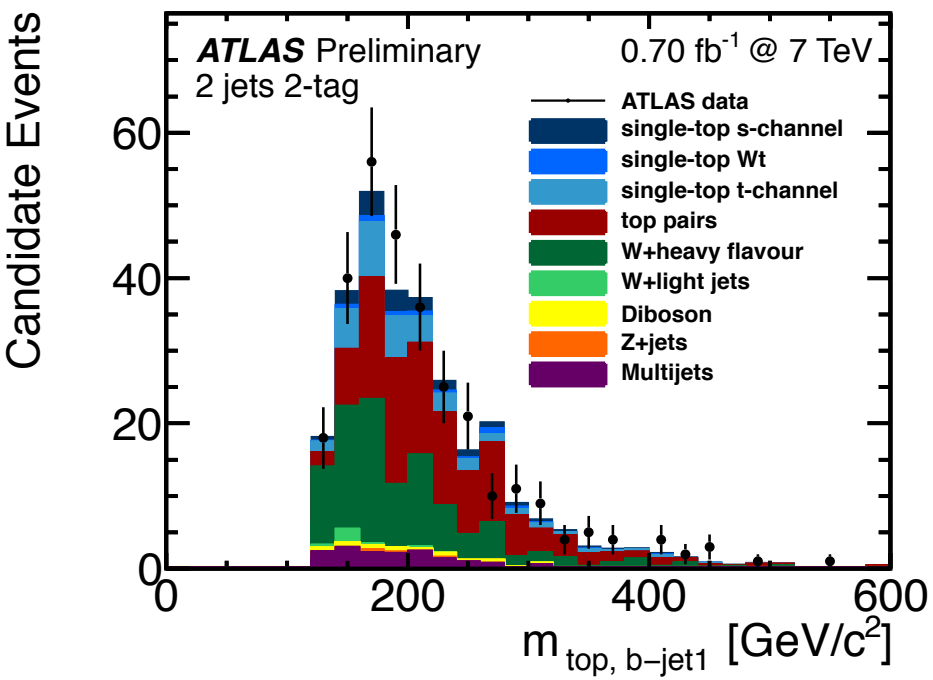
Variable
p_T^{sys} variables
p_T^{sys} (jet1,jet2)
p_T^{sys} (lep1,lep2)
p_T^{sys} (lep1,lep2,E_T^{miss},jet1)
p_T^{sys} (lep1,E_T^{miss},jet2)
p_T-related variables
Δp_T ((lep1,lep2),(E_T^{miss},jet1))
Δp_T (jet1,E_T^{miss})
Angular correlations
$\Delta\phi$((lep1,lep2),(E_T^{miss},jet1))
$\Delta\phi_{MAX}$ (lep,jet1)
ΔR ((lep1,jet2)
Centrality (lep2,jet1,jet2)
η (lep1,jet2)
m variables
m (lep1,jet2)
m (lep1,jet1)
m (lep2,jet1)
m (lep2,jet2)
Object kinematics
E_T^{miss}
E_T (jet1)
E (lep1)
E (jet2)

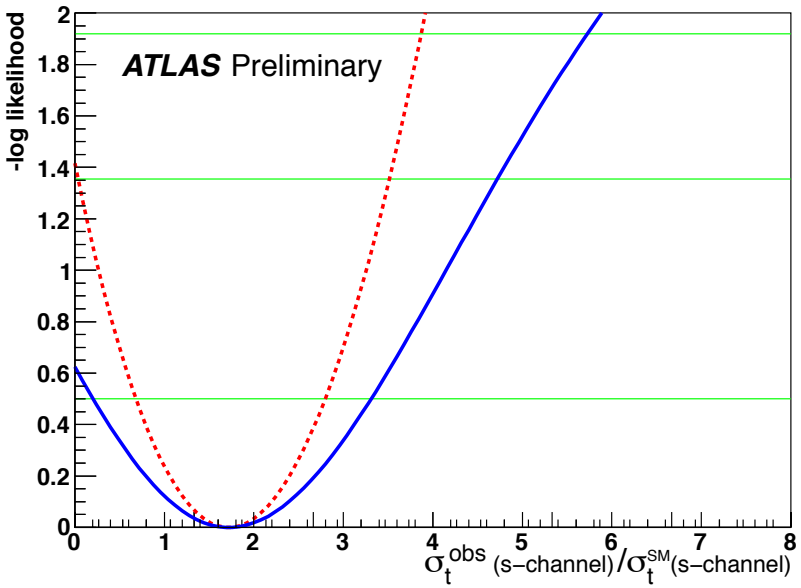


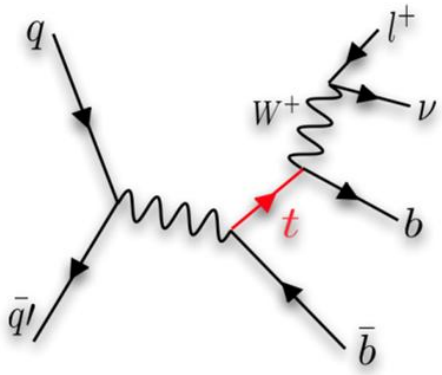


s-channel @ 7 TeV (0.7 fb^{-1})

ATLAS-CONF-2011-118







Preselection

1 isolated lepton $p_T > 25$ GeV

2 b-tagged jets $p_T > 25$ GeV

$E_T^{miss} > 25$ GeV

$m_T(W) > 60$ GeV - E_T^{miss}

- **Analysis**
  - **Cut based** signal extraction
  - **Data driven** W+jets (normalisation) and multijet background
  - Main backgrounds: tt and W+jets
- **Results**
  - After selection: Expected signal: 16 ± 6
    Data total: 296
  - Limited by statistics

$\sigma_s < 26.5$ pb (20.5 exp) @ 95% CL

$\sigma_s^{NLO+NNLL} = 4.6 \pm 0.3$ pb

Single top FCNC production @ 8 TeV (14.2 fb^{-1})

ATLAS-CONF-2013-063

- FCNC in top decay B(t → qV) with V = H,Z,γ,g
- Highly suppressed by SM
  - Can be enhanced in some BSM models (B~10^{-5}-10^{-3})
- t → qg difficult due to large QCD background
- Better sensitivity with qg → t → bW(→lυ)
- **Selection**

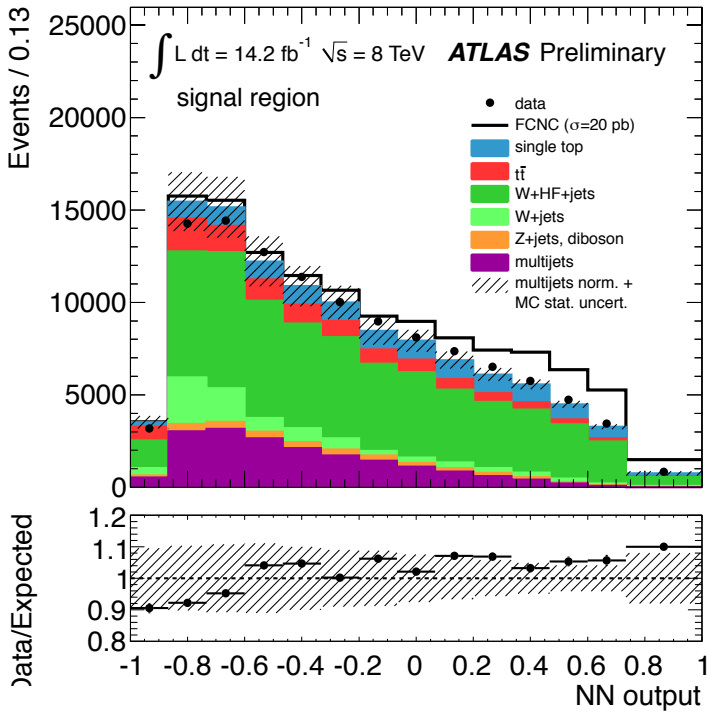
  1 isolated lepton , 1 b-tagged jet

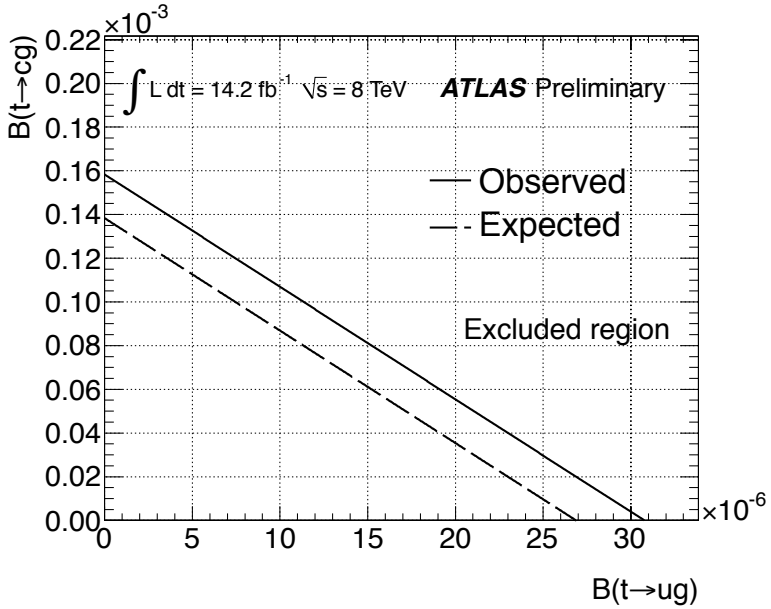
  $E_T^{miss} > 30$ GeV , $m_T(W) > 50$ GeV
- **Analysis**
  - Binned likelihood **fit to NN distribution**
  - Signal region: tight b-tag
  - Control region: looser b-tag (more W+jets)
  - Data driven multijet normalisation
- **Results**
  - **No excess observed**

$\sigma_{FCNC} < 2.5$ pb @ 95% CL (2.2 exp.)

$B(t \to ug) < 3.1 \cdot 10^{-5}$ if $B(t \to cg) = 0$

$B(t \to cg) < 1.6 \cdot 10^{-4}$ if $B(t \to ug) = 0$

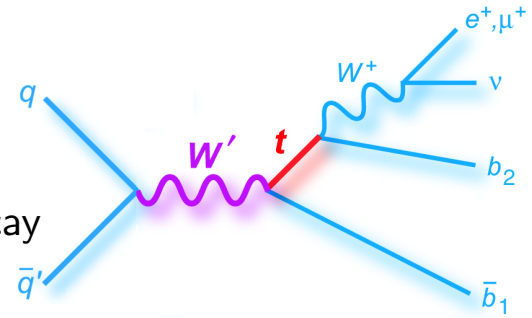




W' → tb @ 8 TeV (14.3 fb^{-1})

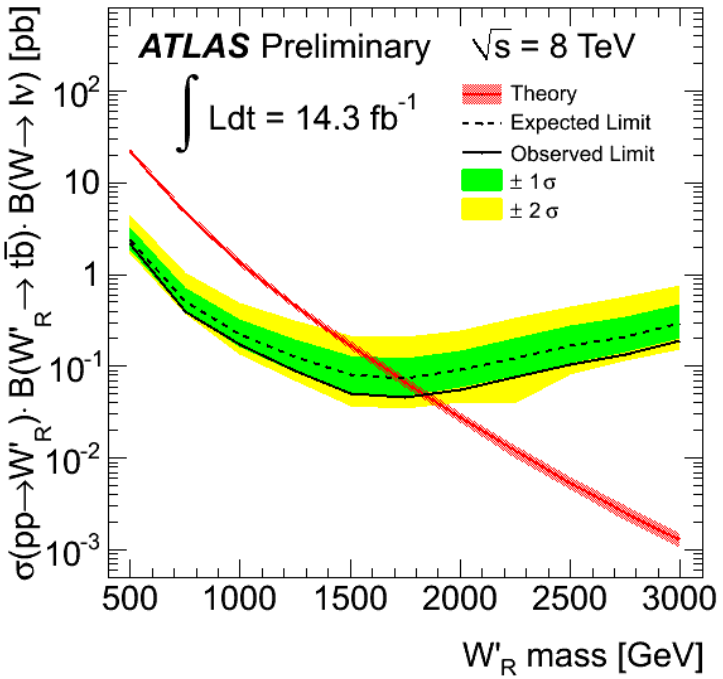
ATLAS-CONF-2013-050

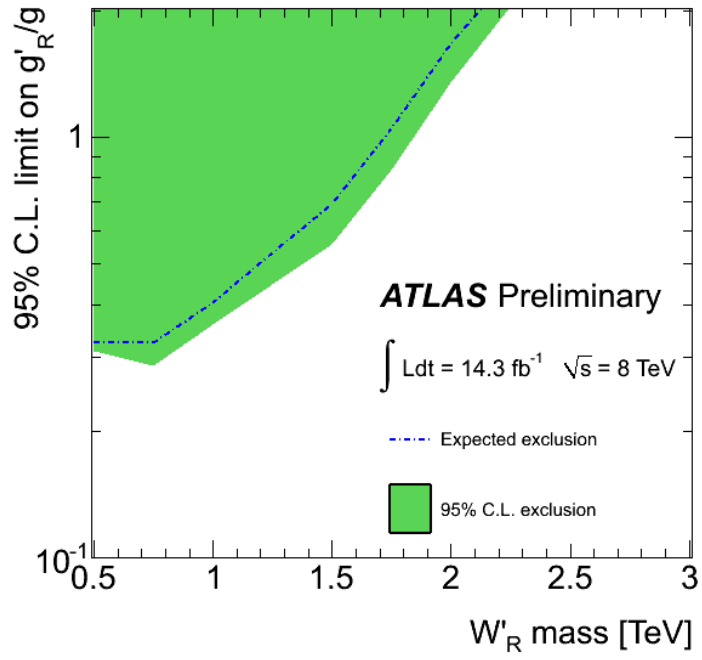
- **Motivations**
  - W' bosons introduced by many BSM approaches (KK excitations, L/R models...)
  - **W' → tb specificities**
    - **Explore more models** than leptonic decay



Selection with W leptonic decay

- Search using a **model independent approach**
  - Effective left-right model





Analysis

- Fit on **BDT distributions**
- **Data driven** multijet and W+jets normalisations
- Hypothesis testing using CL_s

Results

- **No excess observed**
- 95% CL exclusion limits on
  - $W'_{L/R}$ cross section
  - $g'_{L/R}/g$ coupling ratios
- Exclusion limits on W' mass

$$m_{W'_L} < 1.74\ \text{TeV}$$
$$m_{W'_R} < 1.84\ \text{TeV}$$

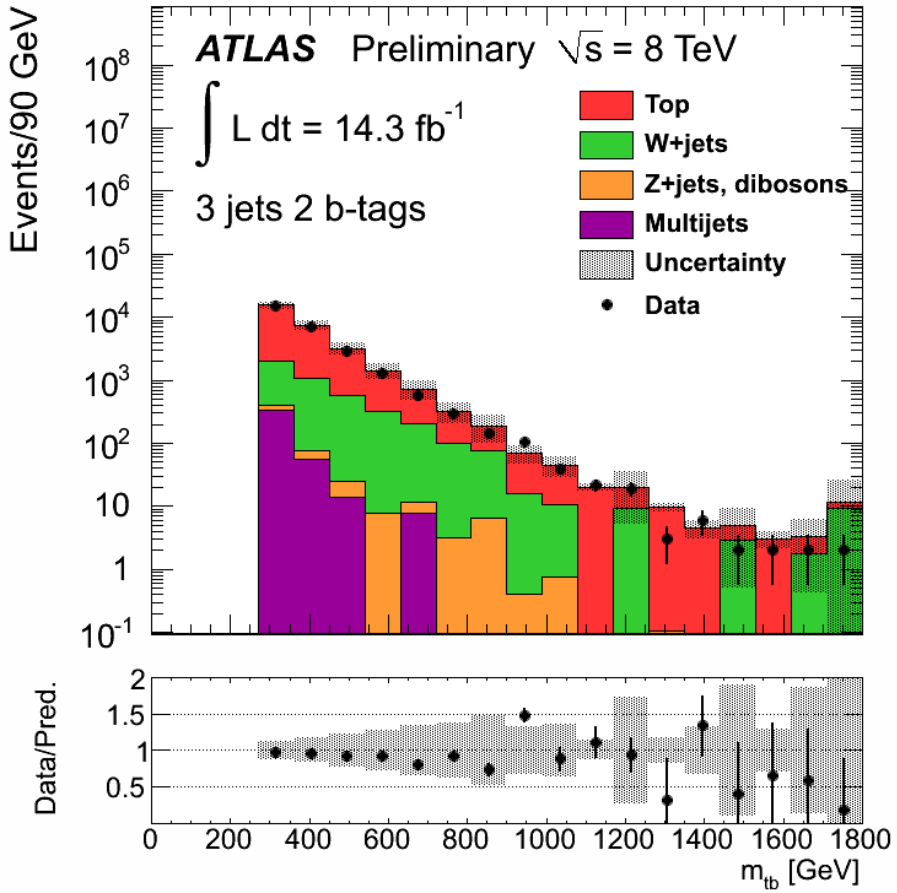
exp. $m_{W'_L} < 1.56$ TeV, $m_{W'_R} < 1.72$ TeV

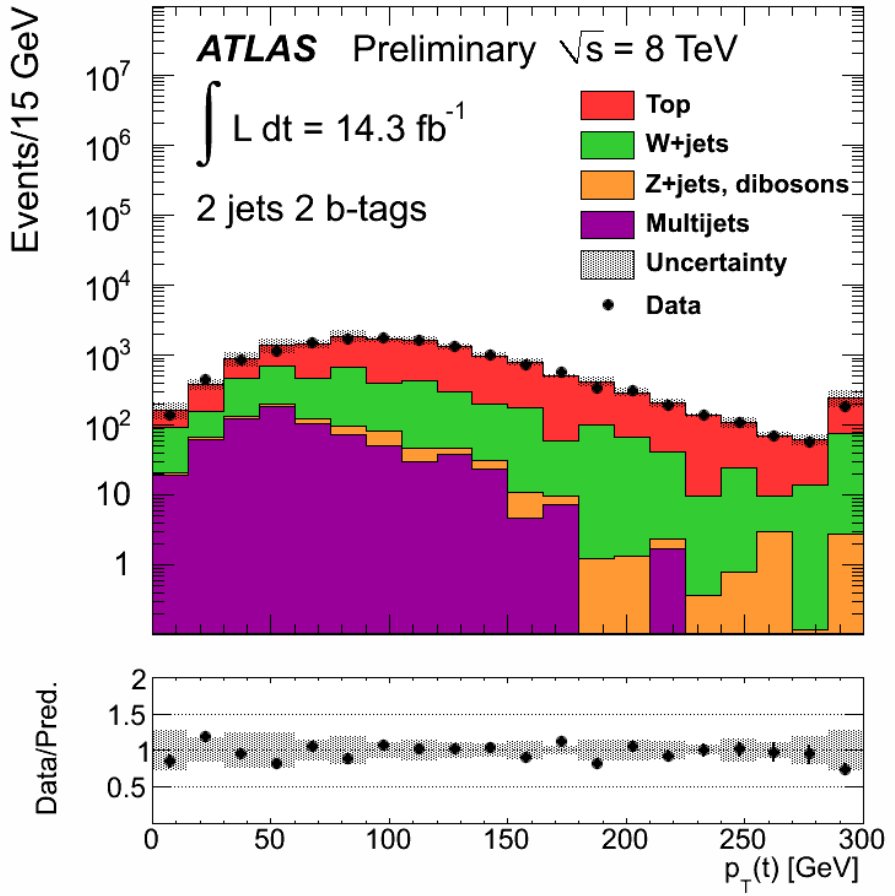
W' → tb @ 8 TeV - BDT variables

ATLAS-CONF-2013-050

- **2-jets sample**: 14 variables
  - Most discriminating: $\mathbf{m_{tb}}$, $\mathbf{p_T(t)}$ and $\mathbf{\Delta R(l, b_2)}$

- **3-jets sample**: 13 variables
  - Most discriminating: $\mathbf{m_{tb}}$, $\mathbf{p_T(t)}$ and **sphericity**





More results

- More references (non exhaustive list)

  - **Top quark pair production**
    - Single lepton @ 7 TeV ATLAS-CONF-2011-121
    - Dilepton @ 7 TeV ATLAS-CONF-2013-077
    - All hadronic @ 7 TeV ATLAS-CONF-2012-031
    - τ + jets @ 7 TeV ATLAS-CONF-2012-032
    - Gap fraction @ 7 TeV 1205.5015
    - tt resonances with boosted tops @ 7 TeV 1207.2409
  - **Single top quark production**
    - t-channel @ 7 TeV 1205.3130
    - Wt channel @ 7 TeV 1205.5764
    - Single b* production @ 7 TeV 1301.1583
    - FCNC @ 8 TeV ATLAS-CONF-2013-063
    - . . .

All public results from the ATLAS top physics working group here

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults