# Top Physics at ATLAS
## Recent measurements

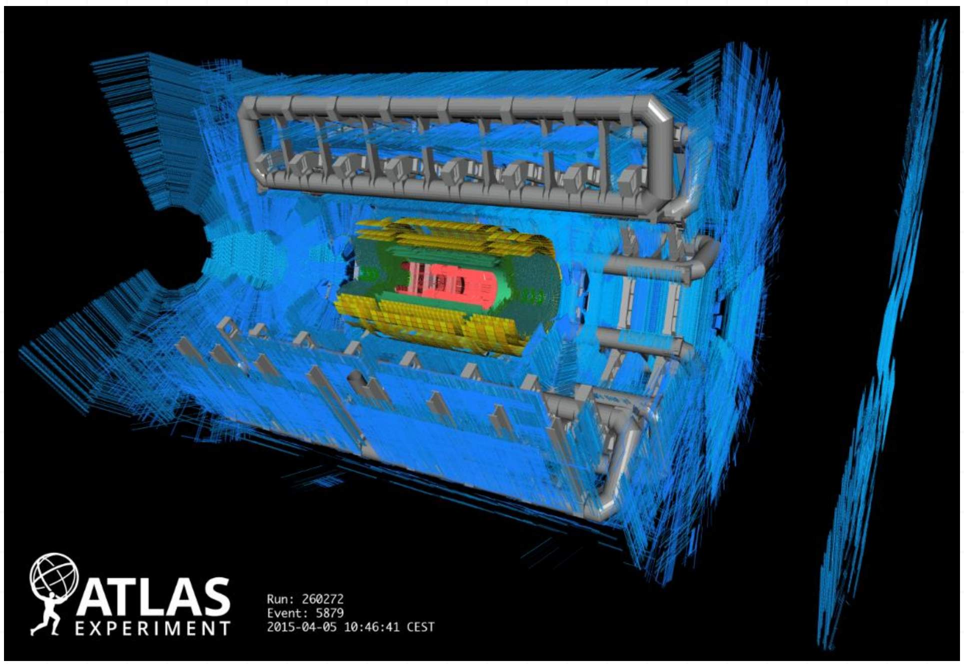
Marino Romano
INFN & University - Bologna

**IFAE 2015**
Università di Roma
Tor Vergata
8-10 Aprile 2015

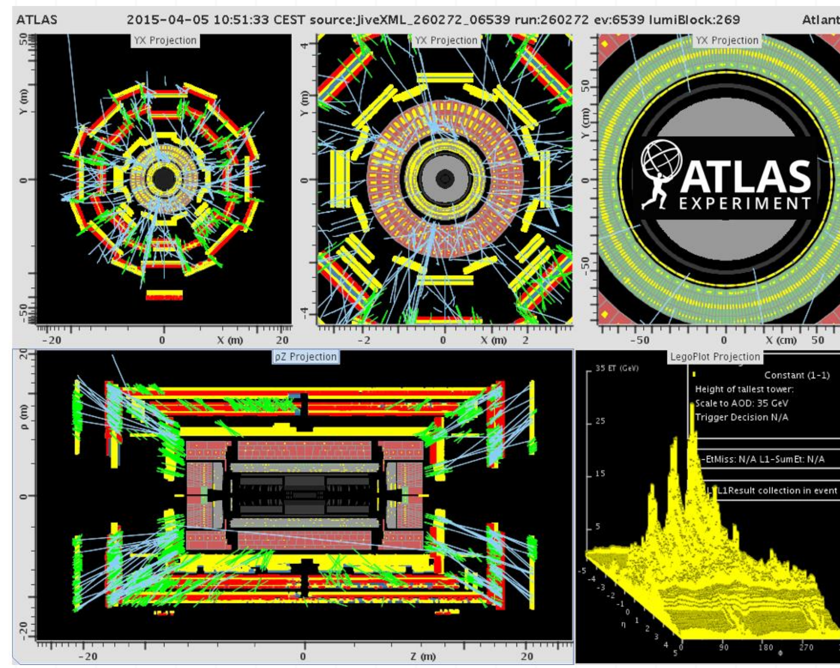
# Beam splash events @ ATLAS

- First beam splash events recorded by ATLAS on Sunday April the 5th
- (Re)comissioning of LHC and ATLAS *with beams* has finally started!
- Hopefully we'll get first collisions @ 13 TeV before the summer

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/EventDisplayRun2Start

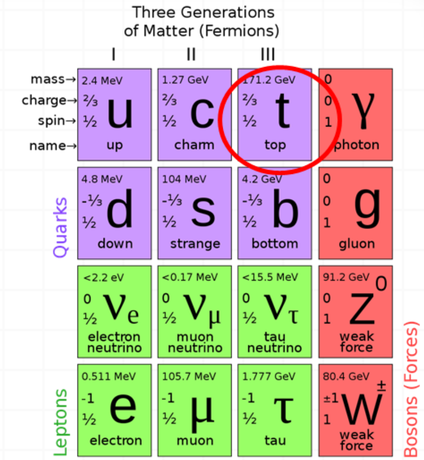



Event 5879, Run 260272




Event 6539, Run 260272

# Top quark physics




- Top quark basics:
  - Mass: 173.21 ± 0.51 ± 0.71 GeV (PDG, Chin. Phys. C, **38**, 090001 (2014))
  - Decays: charged current weak decays in $t \rightarrow Wb$
- Why study top quark physics?
  - Yukawa coupling with the Higgs ~1→Important role in the EWSB
  - Life-time shorter than hadronization time →Unique possibility to observe a 'bare' quark
  - Precise tests of the Standard Model and verification of pQCD
  - Privileged window to search for new physics

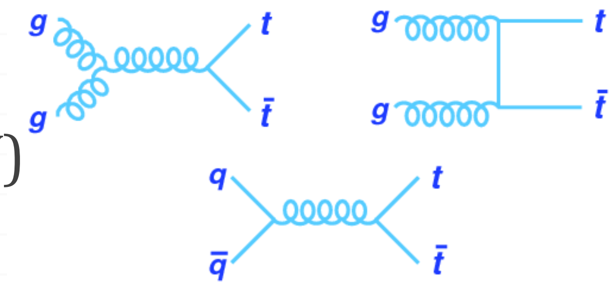
# Top cross section measurements

- $t\bar{t}$: inclusive and differential
- Single top
- $t\bar{t} + \gamma$ associate production

# Top pair production and decays

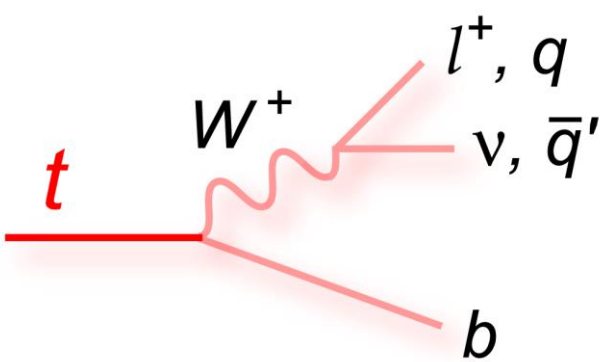
## Production mechanisms at LHC

- Gluon-gluon fusion (~85% @ 7 TeV)
- Quark-antiquark annihilation




## Decays

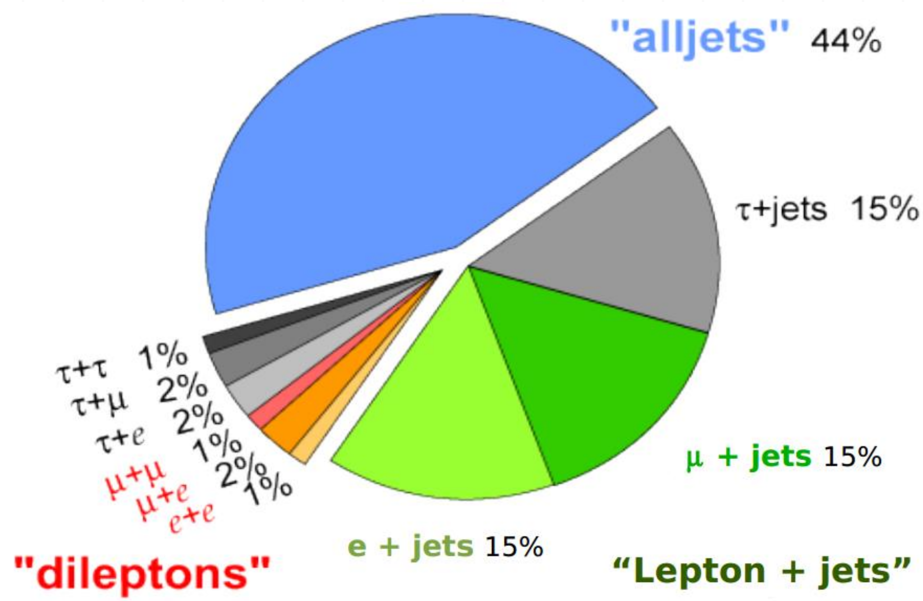
- $t \to Wb (\sim 100\%)$




$W \to l\nu_l \sim 33\%$

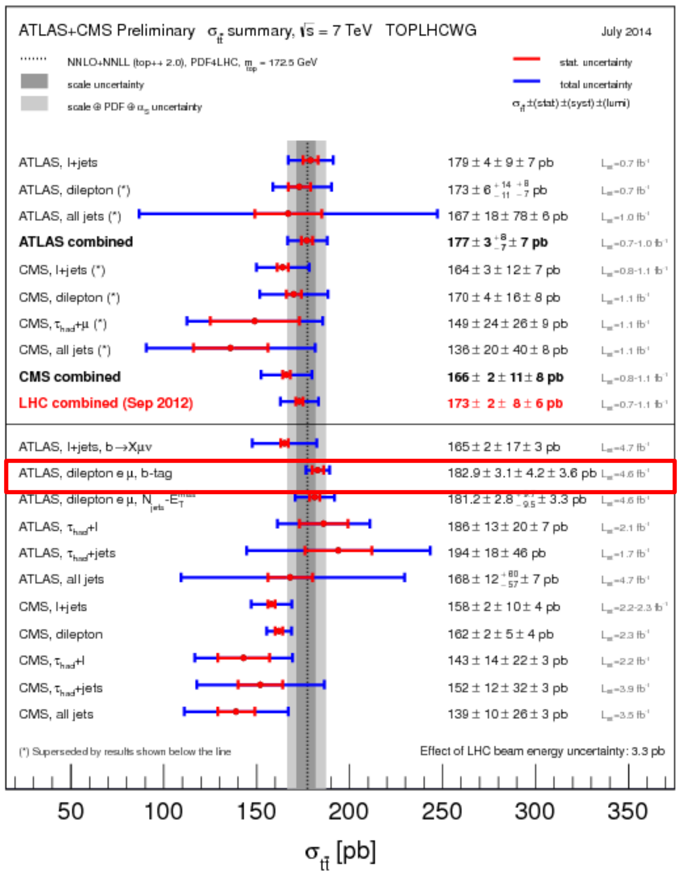
$W \to q\bar{q}' \sim 66\%$

## Top pair final states

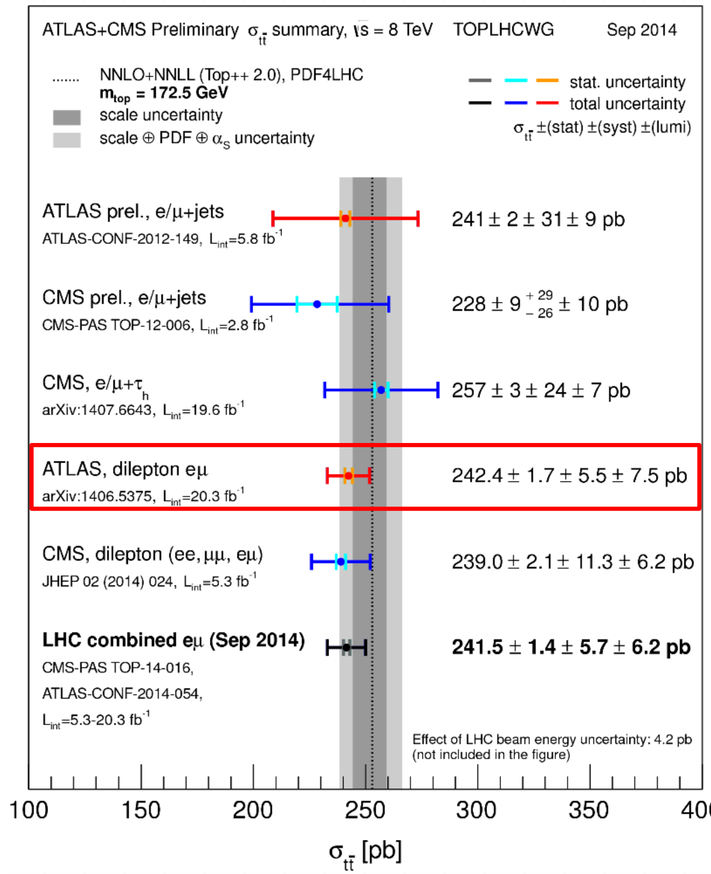


# $t\bar{t}$ inclusive cross section: summary

$\sigma(t\bar{t})$ @ $\sqrt{s} = 7$ TeV




$\sigma(t\bar{t})$ @ $\sqrt{s} = 8$ TeV




Good agreeement of all measurements with SM predictions

Experimental uncertainties already comparable with theoretical ones

Dilepton $e\mu$ measurement is the most precise measurement to date

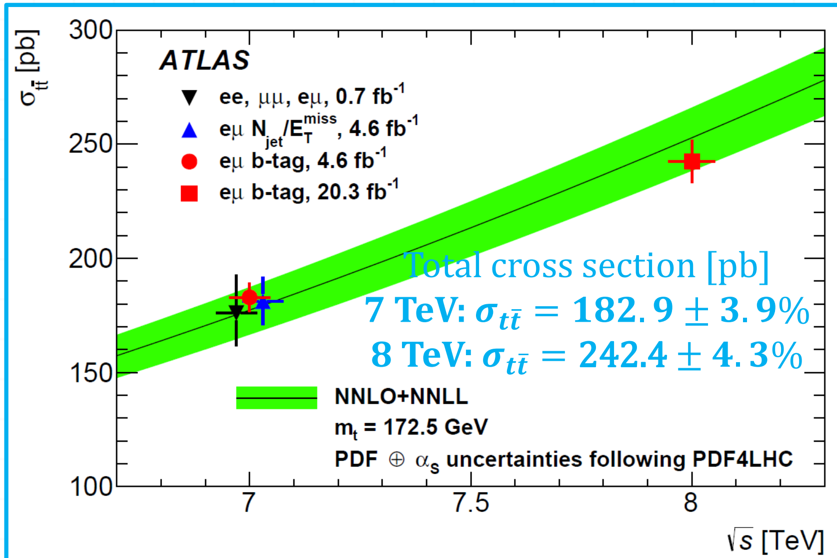
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/TOP/

# $t\bar{t}$ inclusive cross section $e\mu$ channel

**EPJC 74 (2014) 3109**

$\sqrt{s} = 7$ TeV, $\int Ldt = 4.6$ fb$^{-1}$
$\sqrt{s} = 8$ TeV, $\int Ldt = 20.3$ fb$^{-1}$

- Simultaneous fit of the total and fiducial $t\bar{t}$ production cross section, b-jet reconstruction and tagging efficiency in 1- and 2-btag samples
  - Significant reduction of major (btag) systematics
- Fiducial phase space: less MC generator dependent
  - No extrapolation to the full phase space




Total cross section [pb]
**7 TeV: $\sigma_{t\bar{t}} = 182.9 \pm 3.9\%$**
**8 TeV: $\sigma_{t\bar{t}} = 242.4 \pm 4.3\%$**

NNLO+NNLL predictions
7 TeV: $\sigma_{tt}^{th} = 177.3 \pm 9^{+4.6}_{-6.0}$ pb
8 TeV: $\sigma_{tt}^{th} = 252.9 \pm 11.7^{+6.4}_{-6.0}$ pb

Fiducial cross section
**7 TeV: $\sigma_{t\bar{t}} = 2.615$ pb $\pm 3.8\%$**
**8 TeV: $\sigma_{t\bar{t}} = 3.448$ pb $\pm 4.1\%$**

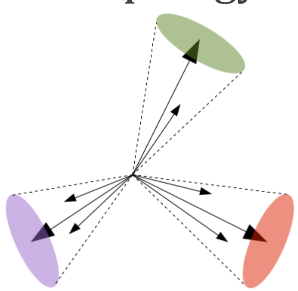
# Top pairs differential cross section measurements in ATLAS

Total $\sigma_{t\bar{t}}$ measurements show very good agreement with the SM

- New physics phenomena can still affect the *shape* of $\sigma_{t\bar{t}}$

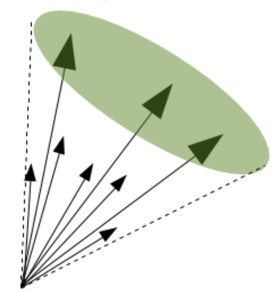
Top reconstruction strategies

'Resolved' topology



- Optimized for low-pt (< 300 GeV) top quarks
- Top-quark decay products are well separated and can be recostructed individually
- Top-antitop kinematic evaluated from the reconstructed decay products

'Boosted' topology



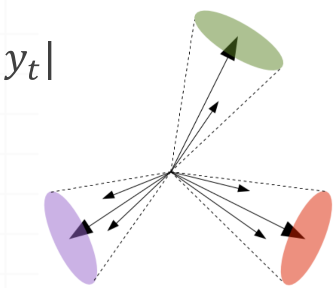
- Optimized of high-pt (> 300 GeV) top quarks
- Top quark decay products are not isolated
- Hadronically decaying top quark is reconstructed in a single large radius jet

# Top pair differential cross section

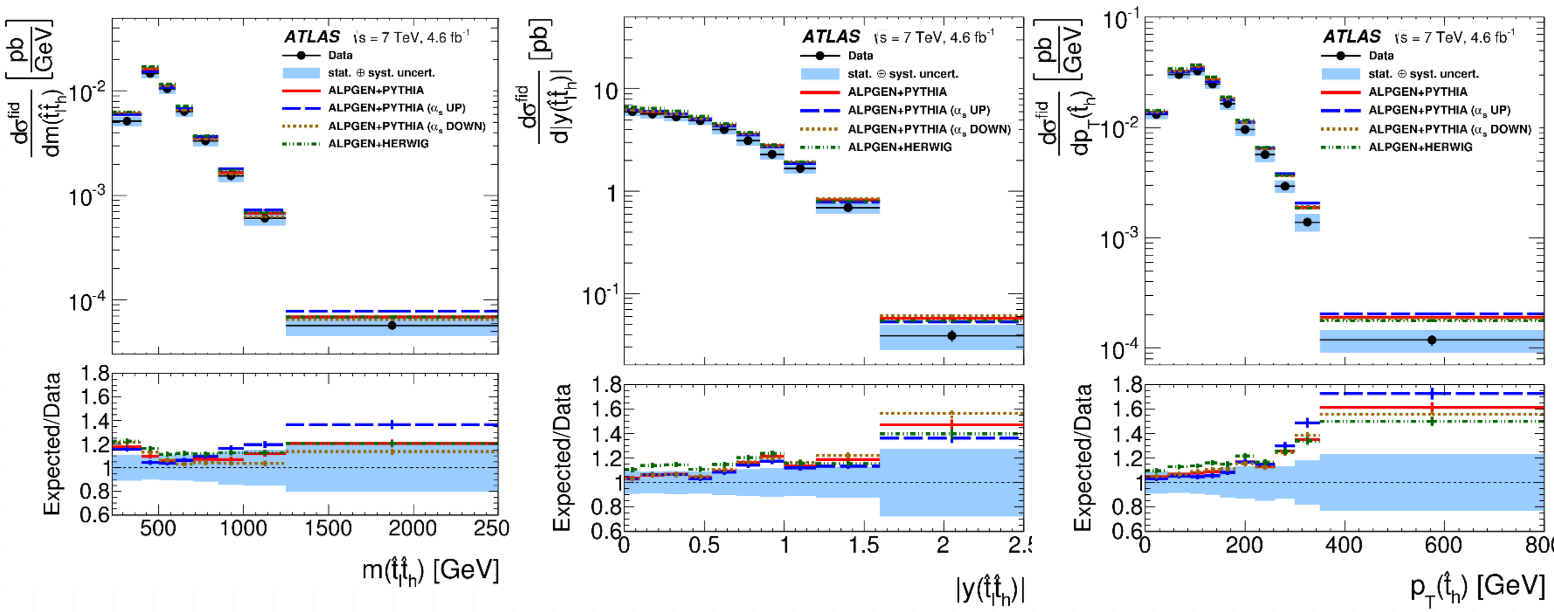
**arXiv:1502.05923, Submitted to JHEP**

$\sqrt{s} = 7\text{ TeV}, \int Ldt = 4.06\text{ fb}^{-1}$

- Top-antitop differential cross section $\left(\frac{d\sigma}{dX}\right)$ where $X = m_{t\bar{t}}, p_{\mathrm{T},t\bar{t}}, |y_{t\bar{t}}|, p_{T,t}$ and $|y_t|$
  - *Fiducial* measurement: pseudo top ($\hat{t}$) observables instead of parton tops
- Cut-based analysis in the $l$+jets channel
- Final fiducial level measurement extracted via unfolding methods



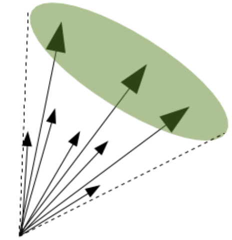
- General trend of data being softer in $p_{T,t}$ above 200 GeV
- Same behavior is observed by the boosted analysis



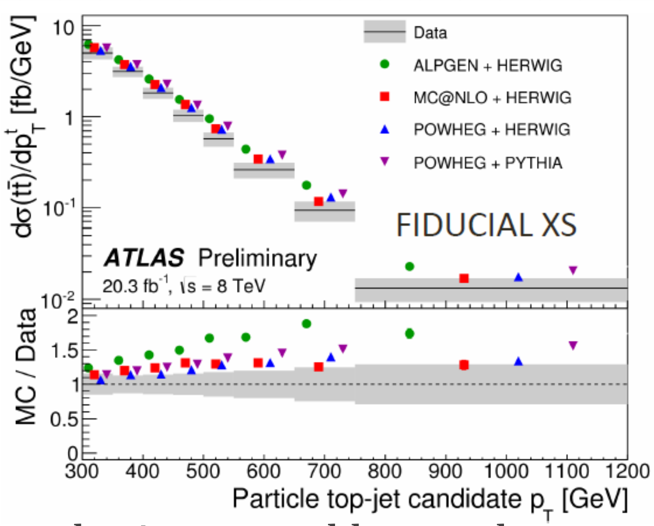
# $t\bar{t}$ differential cross section: boosted tops

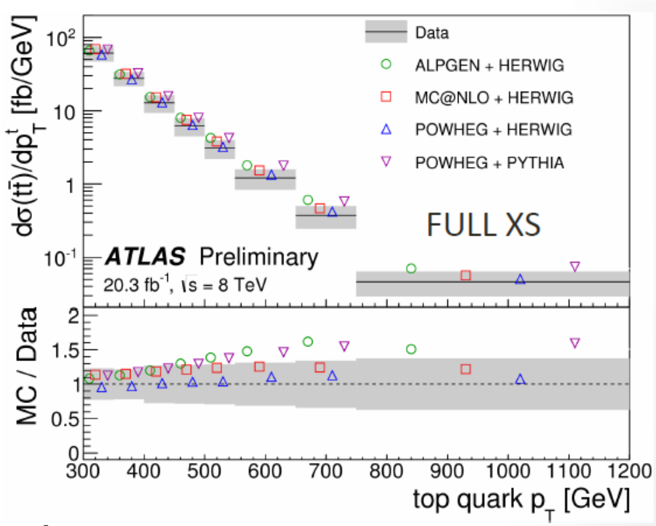
**ATLAS-CONF-2014-057**

$\sqrt{s} = 8$ TeV, $\int Ldt = 20.3$ fb$^{-1}$



- First measurement of high-$p_T$ (boosted) top cross section
- Semi-leptonic ($e/\mu$) channel with $p_T(t_{had}) > 300$ GeV
  - Boosted hadronic top defined as a single large-$R$ jet
- Fiducial (particle pseudo tops) and total (parton tops) phase space measurements



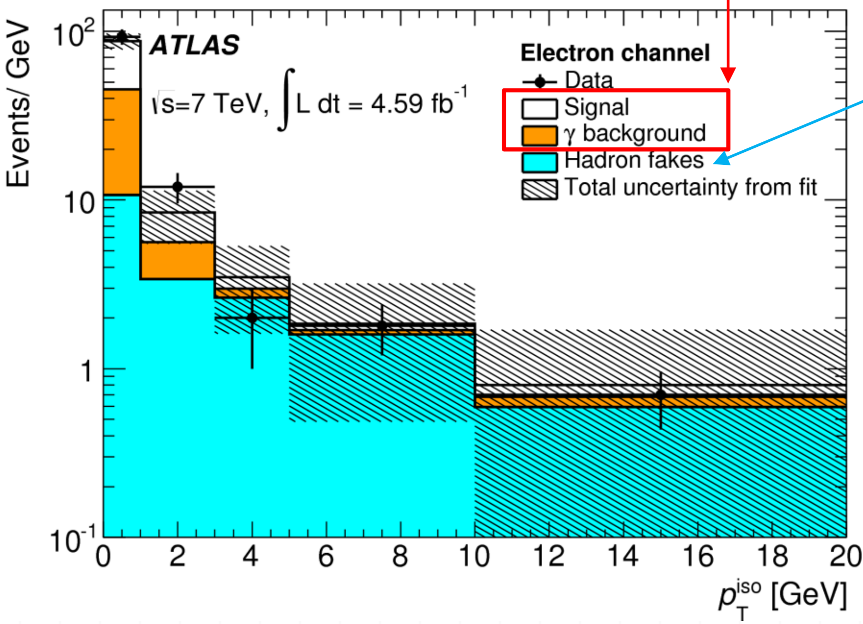

- Measured $\sigma$ in general lower than predictions
  - Discrepancy tends to increase at high $p_T$
- See Lorenzo Massa's poster for further details

# $t\bar{t} + \gamma$ inclusive cross section

**arXiv:1502.00586, Accepted by PRD**

$\sqrt{s} = 7\text{ TeV}, \int Ldt = 4.6\text{ fb}^{-1}$

- Measurement in the lepton+jet channel
  - 1 lepton $(e/\mu), \geq 4jets(\geq 1btag), E_T^{miss}, 1\gamma$
- Inclusive *fiducial* cross section extracted via binned template likelihood fit
  - Template: $p_T^{iso}$ ($\sum p_T^{track}$ with $\Delta R(track, \gamma) < 0.2$)
  - Templates built for prompt photons (signal&bkg) and bkg non-prompt photons sources



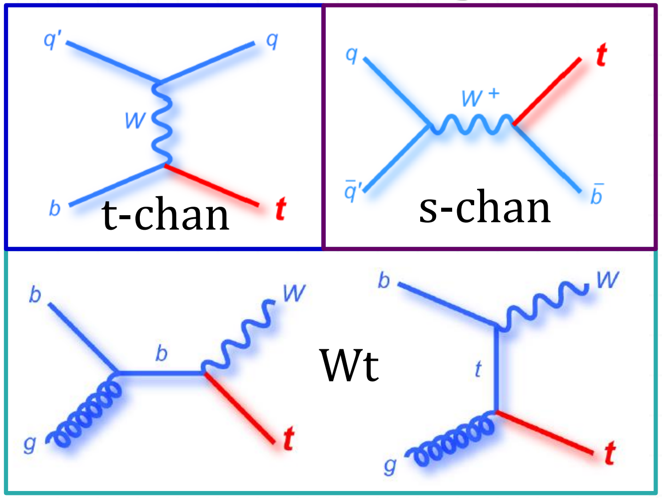

$\boldsymbol{\sigma_{tt\gamma}(\sqrt{s} = 7\text{ TeV}) \times BR = 63^{19}_{-16}\text{ fb}}$

**$5\sigma$** significance

$\sigma^{th}_{tt\gamma}(\sqrt{s} = 7\text{ TeV}) = 48 \pm 10\text{ fb}$

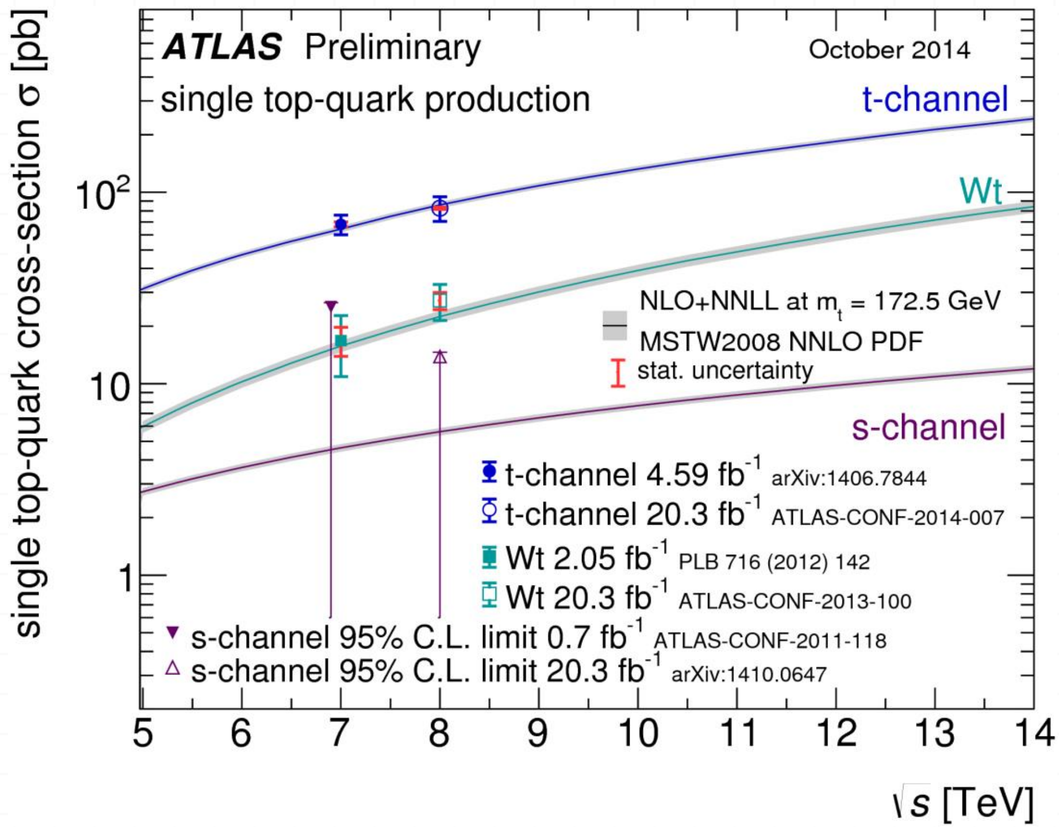
(Prediction from MadGraph and WHIZARD)

# Single top cross section




Cross section summary @ Run I

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/TOP/




Measurements at 7 TeV:

- Cross section for all channels
  - *Wt* measured for the first time ($> 5\sigma$ level)
  - Upper limit for the s-channel
- Top/antitop t-channel ratio ($R_t$)

$$R_t = \frac{\sigma_{ub \to td}}{\sigma_{d\bar{b} \to \bar{t}d}}$$

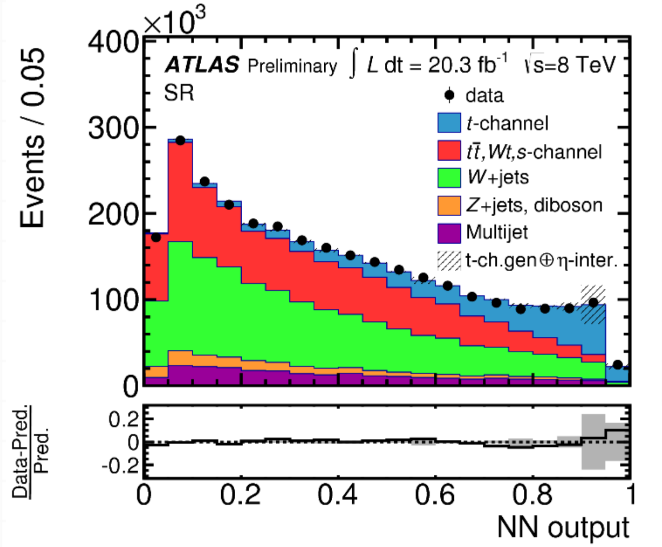
Measurements at 8 TeV:

- Cross section in t- and Wt-channel
- Upper limit in s-channel

# Single top *t*-channel cross section

**ATLAS-CONF-2014-007**

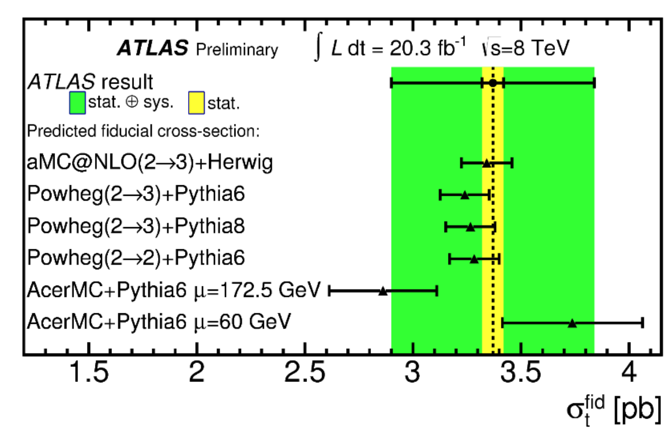
$\sqrt{s} = 8$ TeV, $\int Ldt = 20.3$ fb$^{-1}$




- A multivariate Neural Network (NN) discriminant trained with the 14 most-sensitive variables
  - Contributions from signal and background evaluated via MC
- Lepton + 2 jets channel, 1-btag
- $\boldsymbol{\sigma_{t-chan}}$ extracted via a maximum-likelihood fit of the NN output in the data
- Total and fiducial phase space measurements

$$\boldsymbol{\sigma_{t-chan}(\sqrt{s} = 8\ \text{TeV}) = 82.6 \pm 11.8\ \text{pb}}$$
(aMC@NLO)
$$\sigma_{t-chan}^{aNNLO}(\sqrt{s} = 8\ \text{TeV}) = 87.8^{+3.4}_{-1.9}\ \text{pb}$$

$$\boldsymbol{\sigma_{t-chan}(\sqrt{s} = 8\ \text{TeV}) = 3.4 \pm 0.5\ \text{pb}}$$



# Top properties measurements

- Top mass
- $t\bar{t}$ charge asymmetry
- $t\bar{t}$ spin correlation

# Top quark mass in Run I

Top mass summary

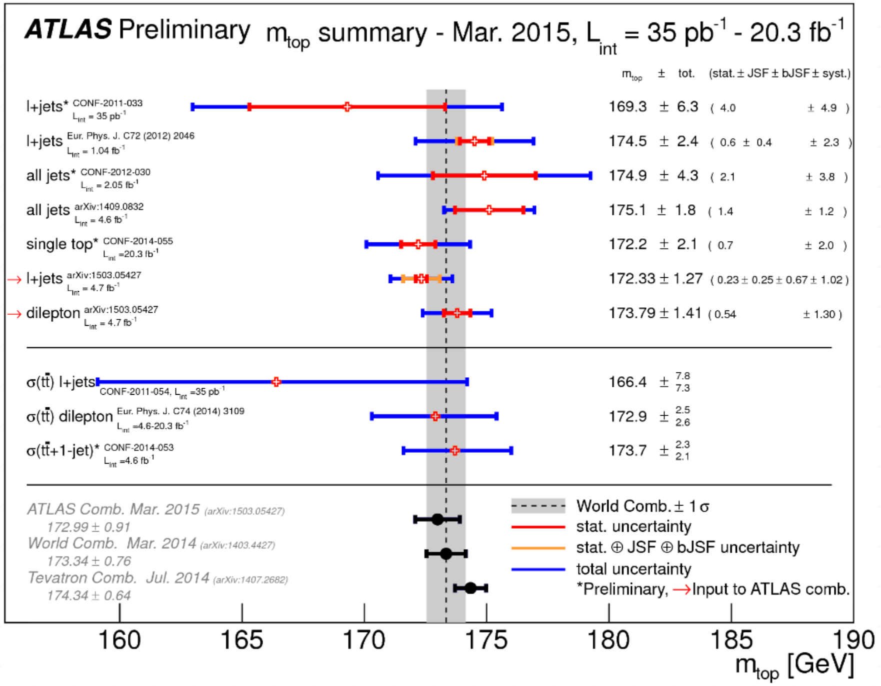
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/TOP/

Most precise measurement by ATLAS:

$m_t = 172.99 \pm 0.48 \pm 0.78$ GeV

arXiv:1503.05427

l+jets and dilepton channels, $\int Ldt$ =4.7fb$^{-1}$




Precision on $m_t$ measurement at LHC is constantly improving and getting closer to the precision achieved at Tevatron

# Top quark mass

**Most precise measurement in ATLAS**

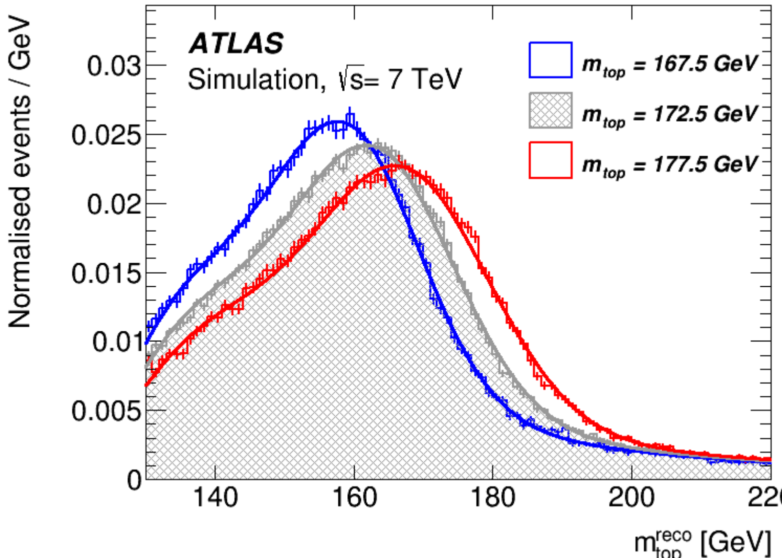
**arXiv:1503.05427, Submitted to EPJC**

$\sqrt{s} = 7$ TeV, $\int Ldt = 4.6$ fb$^{-1}$

- *3D template fit* in the lepton+jets channel
  - $m_t$, global jet energy scale factor (JSF) and bJet energy scale factor (bJSF)
- 1D template fit in dilepton channel
- Templates: $m_{t,reco}$, $m_{lb,reco}$, $m_{W,reco}$ and $R_{lb}^{reco}$ (ratio of the sum of the $p_T$ of the bjets from the top and light jets from the W)
  - Templates built by varying the fit parameters in Monte Carlo

☑ (green) = linear dependency for signal and bg
☑ (black) = linear dependency but not fitted
✓ = linear dependency for signal only

| | $m_t$ | JSF | bJSF |
|---|---|---|---|
| $m_{t,reco}$ | ✓ | ☑ (green) | ☑ (green) |
| $m_{W,reco}$ | | ☑ (green) | |
| $R_{lb}^{reco}$ | ✓ | | ☑ (green) |
| $m_{lb,reco}$ | ✓ | ☑ (black) | ☑ (black) |




- Probability density functions for each parameter evaluated by fitting each template distribution for signal and background

# Top quark mass

**arXiv:1503.05427, Submitted to EPJC**

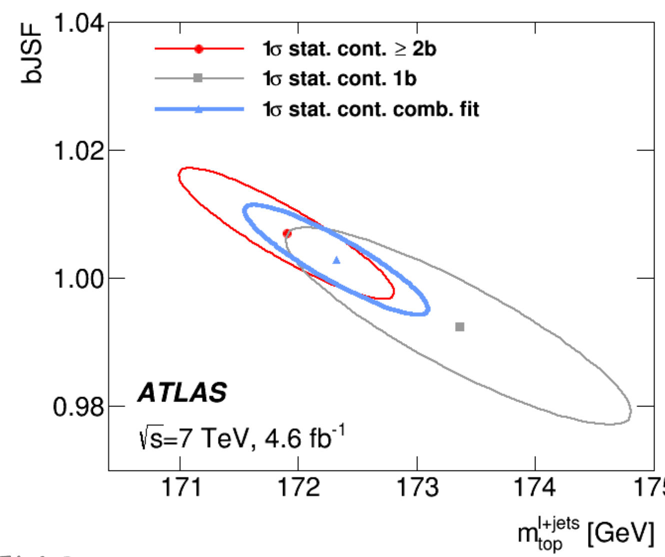
$\sqrt{s} = 7$ TeV, $\int Ldt = 4.6$ fb$^{-1}$

- $t\bar{t}$ kinematics reconstructed by a fit maximizing an event likelihood→ $m_{t,reco}$, $m_{W,reco}$ and $R_{lb}^{reco}$
  - $m_t$ is not fixed in the fit
- Signal and background PDFs are used in an unbinned likelihood fit to the data for all events separately for 1 and 2+ btag samples:

$$L(m_{t,reco}, m_{W,reco}, R_{lb}^{reco} | m_t, JSF, bJSF, n_{bkg}), \text{ l+jets}$$

$$L(m_{lb,reco} | m_t, n_{bkg}), \text{ dilepton}$$

- Results in the 1 btag and 2 btag samples are in good agreement
- First time implementation of an $m_t$ measurement with simultaneous constraint on $m_t$, JES and bJSF
- Single and di-lepton results are combined using BLUE



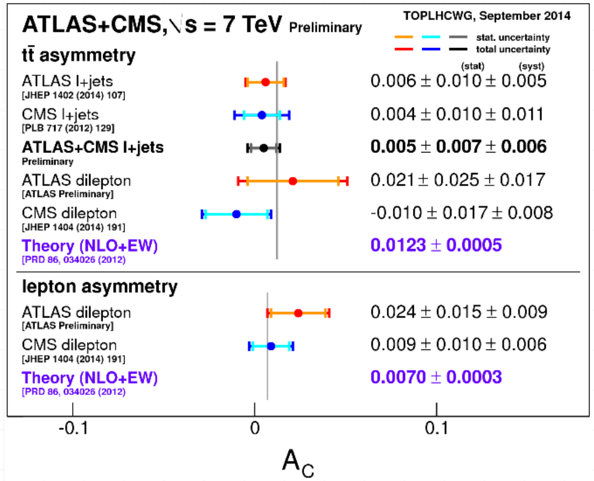

$$\boxed{m_t^{comb} = 172.99 \pm 0.48(stat) \pm 0.78(syst)}$$

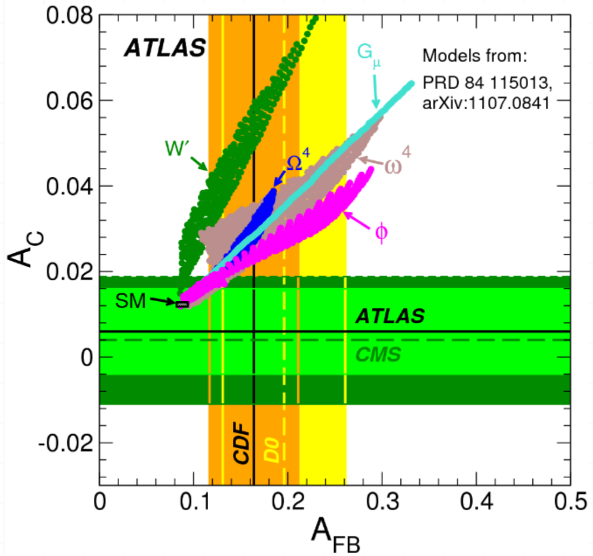
# $t\bar{t}$ charge asymmetry in Run I

$$A_C = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)} \qquad \Delta|y| = |y_t| - |y_{\bar{t}}| \qquad \Delta|y| = |y_{l^+}| - |y_{l^-}|$$

$$A_{FB} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)} \qquad \Delta y = y_t - y_{\bar{t}}$$

- $A_{FB}$ measured at Tevatron
  - Not a “good” observable at LHC
- $A_C$ Extensively measured @ 7 TeV
- All results obtained after unfolding to parton level
  - Dilepton channel (submitted to JHEP)
    - Simultaneous measurement of $A_C(tt)$ and $A_C(ll)$
  - Single lepton channel (JHEP02(2014)107)
  - Combination with CMS (ATLAS-CONF-2014-012)
- Results in agreement with SM predictions



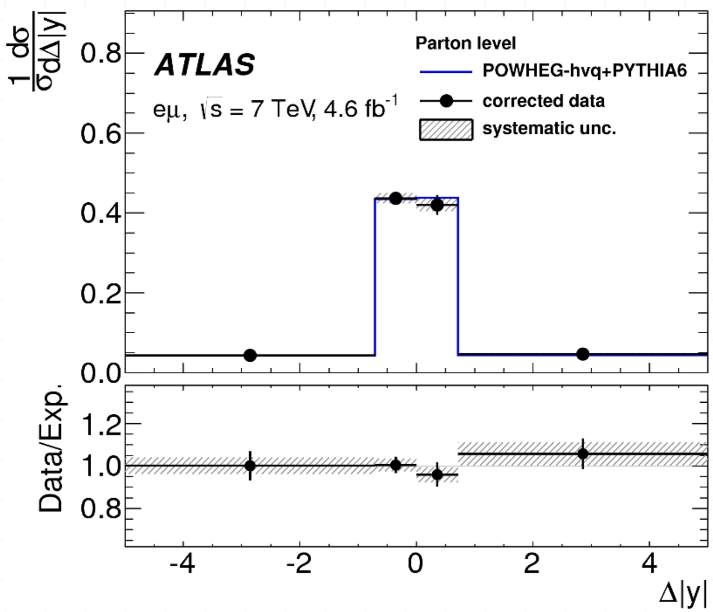



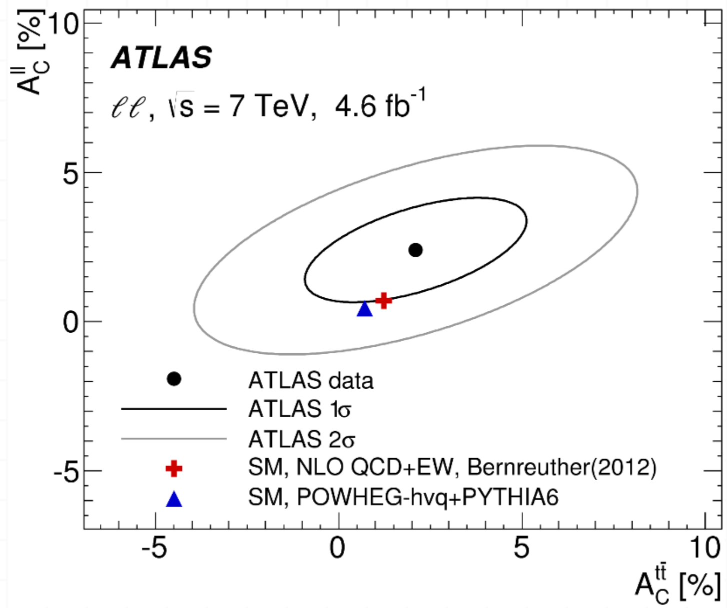
# $t\bar{t}$ charge asymmetry in $l^+l^-$ channel

**arXiv:1501.07383, Submitted to JHEP**

$\sqrt{s} = 7$ TeV, $\int Ldt = 4.6$ fb$^{-1}$

- Dilepton channel allows lepton-based asymmetry
  - No dependence on top reco algorithms
- Unfolding procedures to correct reco $\Delta|y|$ spectra for detector response and acceptance

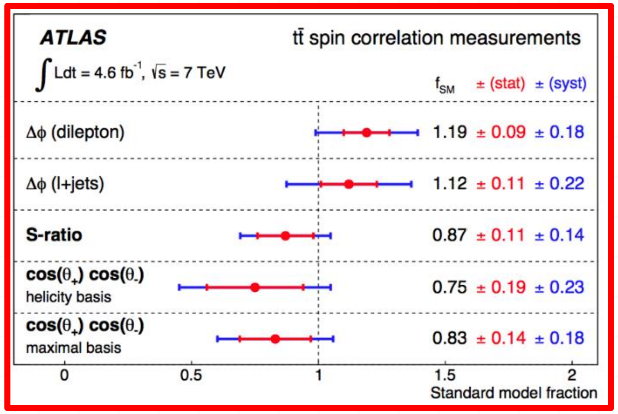


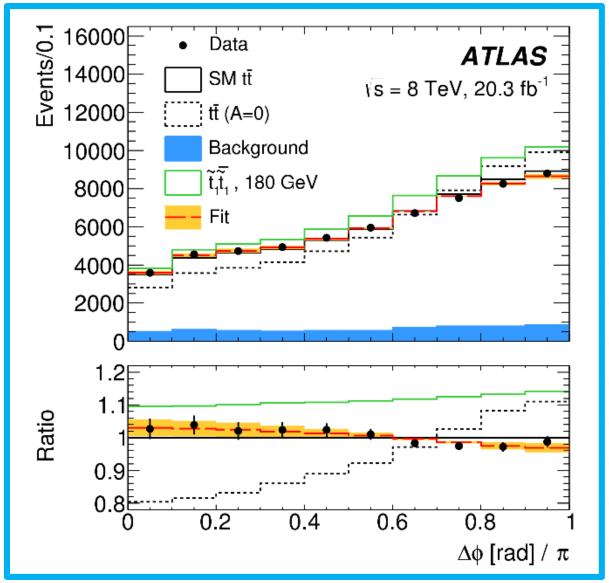

$$A_C^{ll} = 0.024 \pm 0.015 \pm 0.009$$
$$A_C^{tt} = 0.021 \pm 0.025 \pm 0.017$$

# Spin correlation measurements

$$A = \frac{N(\uparrow\uparrow)+N(\downarrow\downarrow)-N(\uparrow\downarrow)-N(\downarrow\uparrow)}{N(\uparrow\uparrow)+N(\downarrow\downarrow)+N(\uparrow\downarrow)+N(\downarrow\uparrow)} \quad A^{SM}_{helicity} = 0.38 \pm 0.04$$




- **7 TeV analysis:** Phys. Rev. D. 90, 112016 (2014)
  - Four observables used to extract the spin correlation from a binned likelihood fit of $f_{SM}$ where
    $$A_{measured} = f_{SM} A^{th}_{SM}$$
  - $\Delta\phi(ll)$ shows highest sensitivity




- **8 TeV analysis**: arXiv:1412.4742, submitted to PRL
  - Spin correlation extracted via a template fit on $\Delta\phi(ll)$ distribution
    $$f_{SM} = 1.20 \pm 0.05(stat) \pm 0.13(syst)$$
  - Most precise measurement to date
  - See Paolo Dondero's poster for stop exclusion from $t\bar{t}$ spin correlation

# Summary

- Top quark measurements have provided stringent tests of SM
- Top quark pair production
  - Inclusive cross-section measured with 4% accuracy (and it gets better after combinations!)
  - Differential cross sections: resolved and boosted topologies, parton and particle level
  - Spin correlation, charge asymmetry measurements
  - SM predictions in general good agreement with data
- Top quark mass
  - World combination reaches uncertainty of ~0.8 GeV!
- Top quark measurements have started to probe for new physics
  - Stop exclusion from cross section and spin correlation (see Paolo Dondero's poster)
- Stay tuned for new results with early data in Run II at 13 TeV, as well as for more refined studies from Run I!

# Backup

# Common object definitions

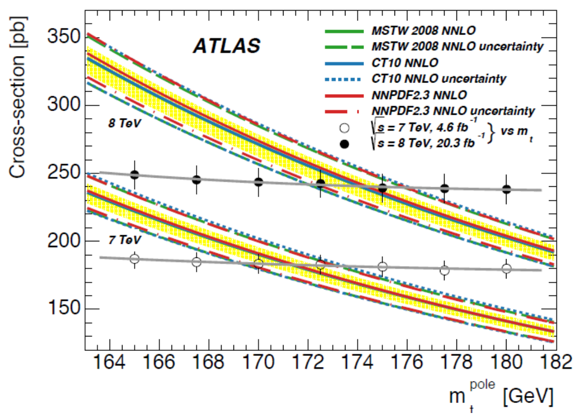
- Details can vary among the different analyses
- Jets:
  - Reconstructed from topological clusters using the anti-kt algorithm ($R = 0.4$)
  - $p_{\mathrm{T}}$> 25 GeV, $|\eta|$ <2.5
- B-tagging via a Neural network based algorithm (MV1) with average efficiency of 70% and light jet rejection factor $\sim$140
- Electrons:
  - EM cluster with track matched
  - Isolation in tracker and calorimeter
  - $E_{\mathrm{T}}$ > 25 GeV, $|\eta|$<1.37 or 1.52 < $|\eta|$ <2.47
- Muons:
  - Tracks in inner detector and muon spectrometer
  - Isolation in tracker and calorimeter
  - $p_{\mathrm{T}} > 20$ GeV, $|\eta|$ <2.5
- Missing transverse energy
  - Vector sum of energy deposits in calorimeters, with corrections based on the associated reconstructed object

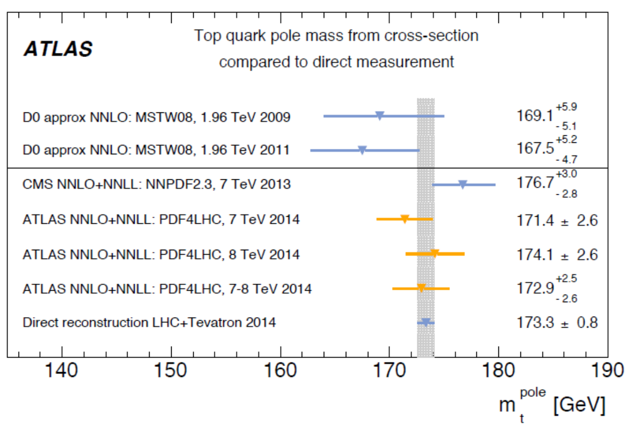
# $t\bar{t}$ inclusive cross section $e\mu$ channel

**EPJC 74 (2014) 3109**

## Strong dependence of $\sigma_{tt}$ on top mass

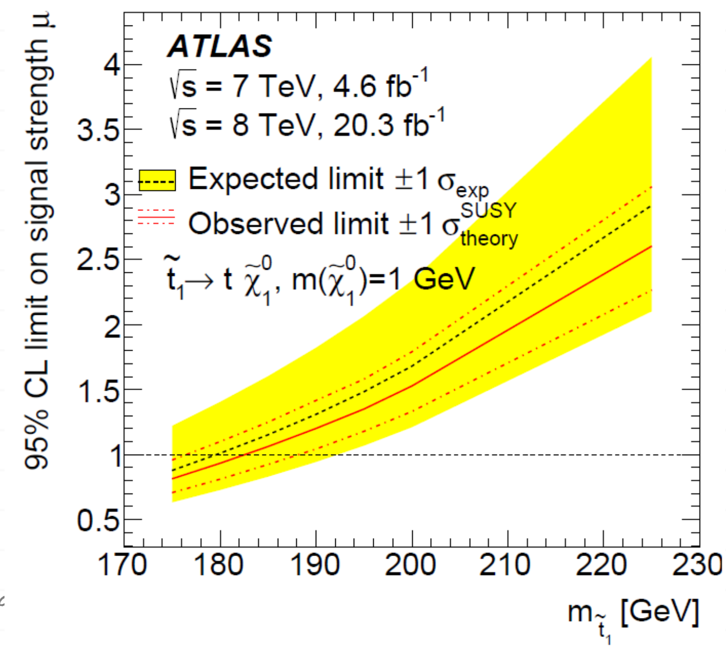
- Extraction of top mass via the maximization of a Baysian likelihood function




## Constraints on stop pair production

- $R$-parity conserving SUSY extension of SM with $\tilde{t}_1 \to t\tilde{\chi}_1^0$ (BR = 100%)
- Fit $\sigma_{\tilde{t}_1\tilde{t}_2}$ to the $\sigma_{tt}^{meas} - \sigma_{tt}^{th}$ difference
- 95% CL exclusion of stop with $m_t < m_{\tilde{t}_1} < 177$ GeV



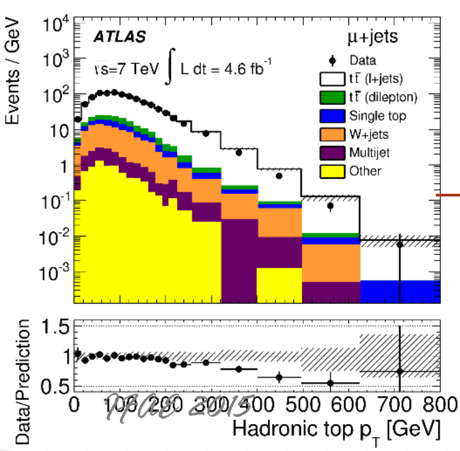
# Top pair differential cross section

**Phys. Rev. D 90, 072004**

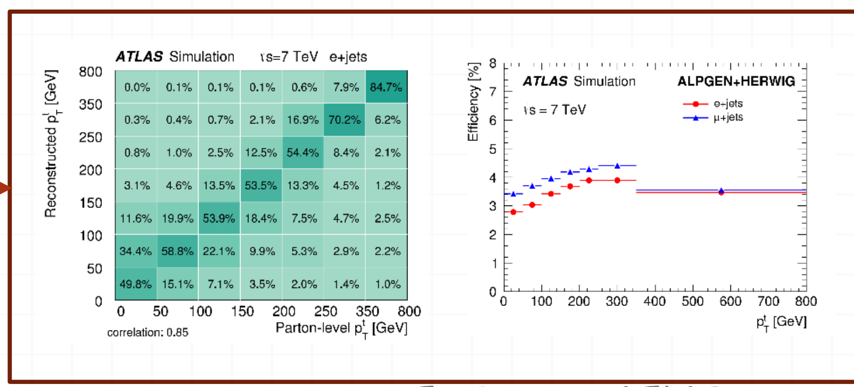
$\sqrt{s} = 7\text{ TeV}, \int Ldt = 4.06\text{ fb}^{-1}$

- Total $\sigma_{t\bar{t}}$ measurements show very good agreement with the SM
  - New physics phenomena can still affect the *shape* of $\sigma_{t\bar{t}}$
- Top-antitop relative differential cross section $\left(\frac{1}{\sigma}\frac{d\sigma}{dX}\right)$ where $X = m_{t\bar{t}}, p_{\mathrm{T},t\bar{t}}, |Y_{t\bar{t}}|$ and $p_{T,t}$
  - *Relative* measurement more precise than the *absolute* →cancellation of correlated systematics
- Cut-based analysis in the *l*+jets channel
- $t\bar{t}$ system reconstructed via a kinematic likelihood fit.
- Final parton level measurement extracted via unfolding methods

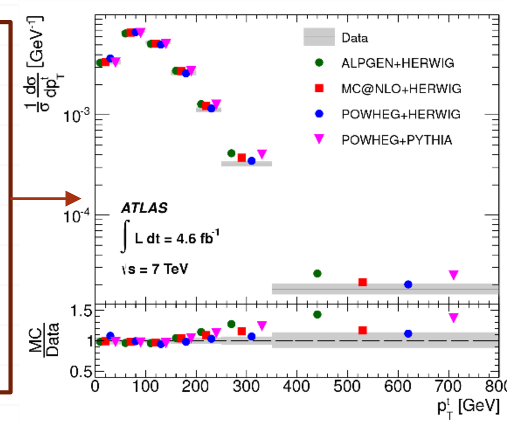
Reco spectrum




Resolution & efficiency corrections




Parton level measurement



# Results: comparison with generators

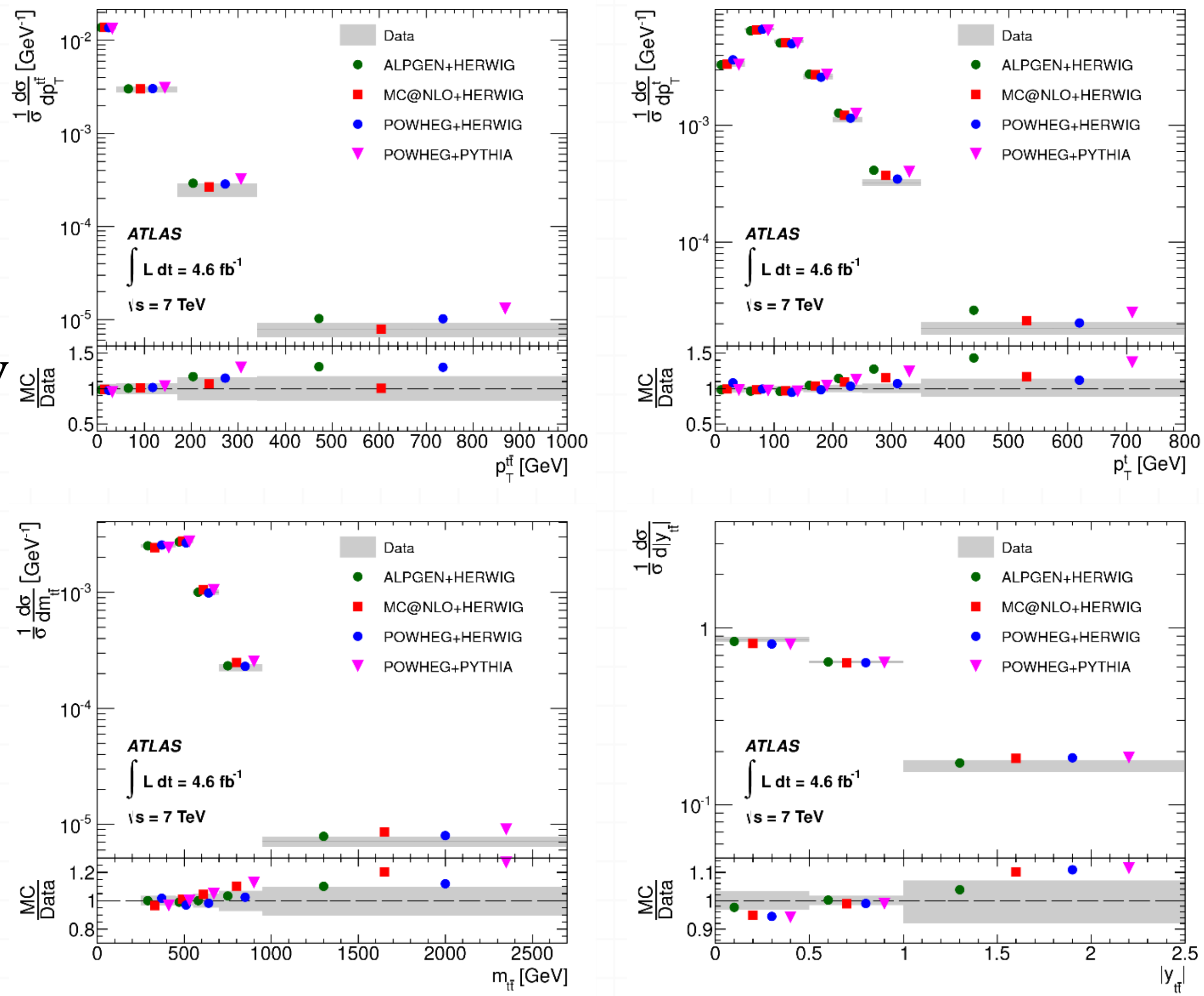
**Phys. Rev. D 90, 072004**

$\sqrt{s} = 7 \text{ TeV}, \int Ldt = 4.06 \text{ fb}^{-1}$

Electron and muon channel combination via the Asymmetric Iterative BLUE (AIB)

MC generators: Alpgen, PowHeg and Mc@Nlo interfaced with Herwig+Jimmy and PowHeg+Pythia

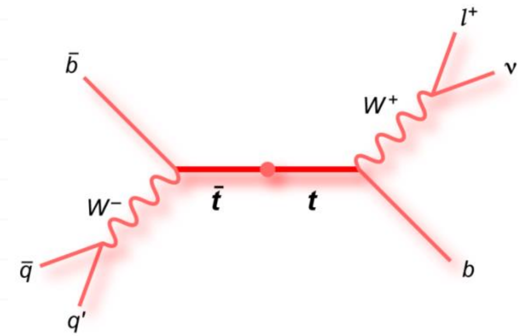
- General trend of data being softer in $p_{T,t}$ above 200 GeV
- All four MC generators well describe the shape of $m_{t\bar{t}}$ and $p_{T,t\bar{t}}$
- Alpgen gives the best prediction of the $|y_{t\bar{t}}|$



# Reconstruction of the $tt$ system via kinematic likelihood fit

- The tt system reconstruction is performed trough a kinematic fit using a maximum likelihood approach

$$\begin{aligned}\mathcal{L} \; = \; & \mathcal{B}\left(\widetilde{E}_{p,1}, \widetilde{E}_{p,2} | m_W, \Gamma_W\right) \cdot \mathcal{B}\left(\widetilde{E}_{l}, \widetilde{E}_{\nu} | m_W, \Gamma_W\right) \cdot \\ \cdot \; & \mathcal{B}\left(\widetilde{E}_{p,1}, \widetilde{E}_{p,2}, \widetilde{E}_{p,3} | m_t, \Gamma_t\right) \cdot \mathcal{B}\left(\widetilde{E}_{l}, \widetilde{E}_{\nu}, \widetilde{E}_{p,4} | m_t, \Gamma_t\right) \cdot \\ \cdot \; & \mathcal{W}\left(\widehat{E}_x^{miss} | \tilde{p}_{x,\nu}\right) \cdot \mathcal{W}\left(\widehat{E}_y^{miss} | \tilde{p}_{y,\nu}\right) \cdot \mathcal{W}\left(\widehat{E}_{lep} | \widetilde{E}_{lep}\right) \cdot \\ \cdot \; & \prod_{i=1}^{4} \mathcal{W}\left(\widehat{E}_{jet,i} | \widetilde{E}_{p,i}\right) \cdot P\left(b \text{ tag} \mid \text{quark}\right),\end{aligned}$$




- The likelihood assesses the compatibility of the event with a typical ttbar pair
- The algorithm is fed with the 4 or 5 reconstructed highest-pt jets (and their b-tag info), the lepton and the $E_T^{miss}$
- The output is the permutation of the four jets, lepton and $E_T^{miss}$ that maximizes the likelihood

# From the detector-level spectra to the cross section measurement

The 'detector-level' spectra are linked to the 'parton level'cross section $\sigma_j$ via

$$N_i = \sum_j M_{ij} \epsilon_j \sigma_j \beta L + B_i$$

Where

- $N_i$ is the number of observed data events in the bin j.
- L is the luminosity
- $B_i$ is the number of background events in the bin i.
- $\beta$ is the branching ratio
- $M_{ij}$ is the 'migration matrix'
- $\epsilon_j$ is the efficiency of the selection

# $t\bar{t}$ + jets differential cross section

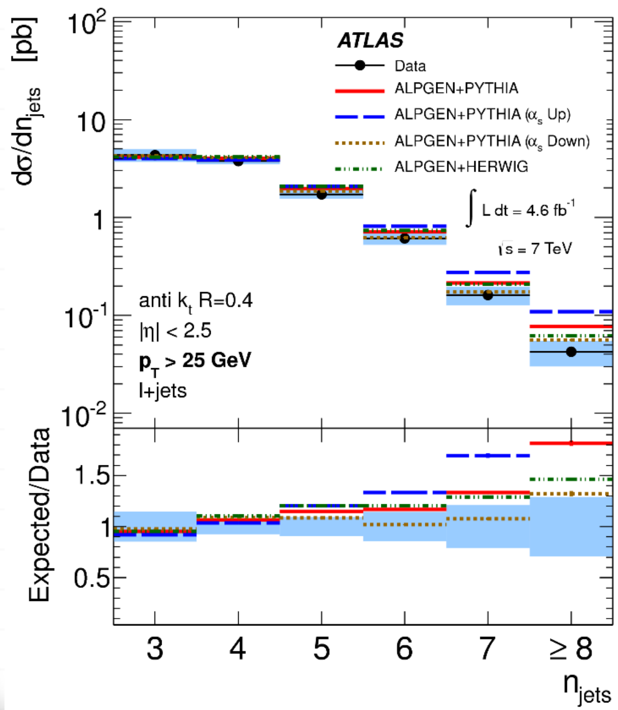
**JHEP 01(2015)020**

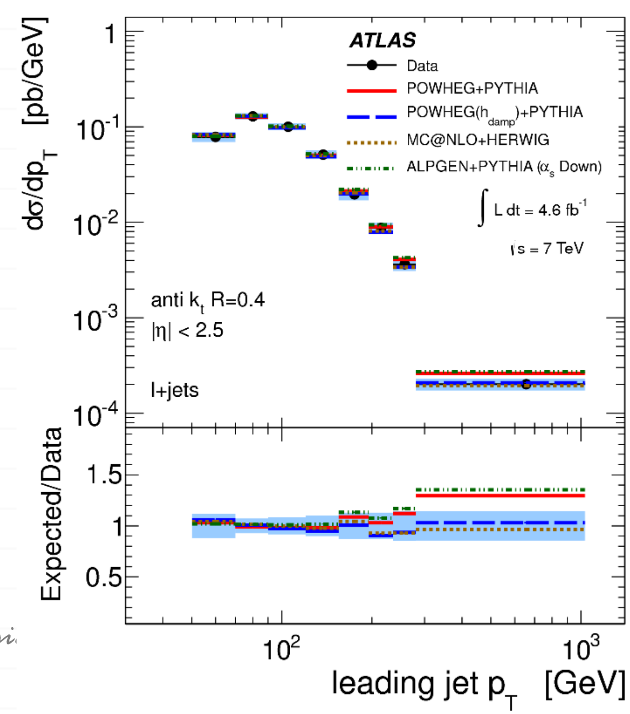
$\sqrt{s} = 7$ TeV, $\int Ldt = 4.6\text{fb}^{-1}$

- Cut-based analysis in the *l*+jets channel
- *Particle level* measurement
- Limited by systematic uncertainties, background modelling (for $n_{jets} < 4$) and jet energy scale ($n_{jets} \geq 4$)

$\frac{d\sigma_{tt}}{dN_{jets}}$: sensitive to hard emissions in QCD bremsstrahlung processes.

$\frac{d\sigma_{tt}}{dp_{t,jet}}$: sensitive to the modelling of higher-order QCD effects in MC

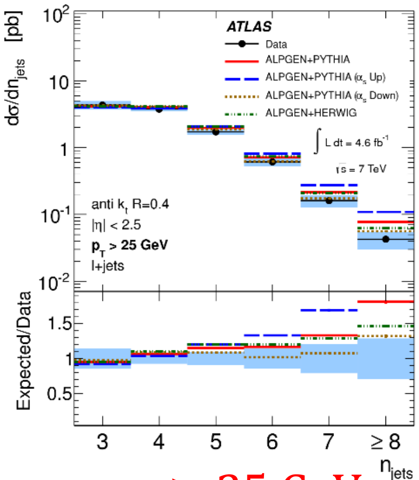


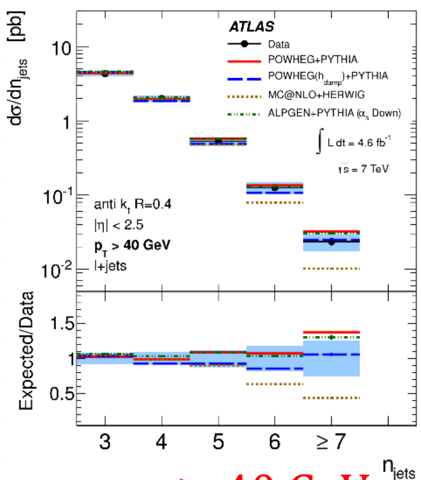
# Jet multiplicity in top–anti-top final states

- Useful to constrain models of initial and final state radiation (ISR/FSR)
- Provides a test of perturbative QCD
- Single-lepton channel
  - Four jet $p_T$ thresholds: (25, 40, 60, and 80 GeV)
- Results are corrected for all detector effects through unfolding
  - Reconstructed level → particle level
- Measurement is limited by systematic uncertainties,
  - background modelling (at lower jet multiplicities)
  - jet energy scale (at higher jet multiplicities)

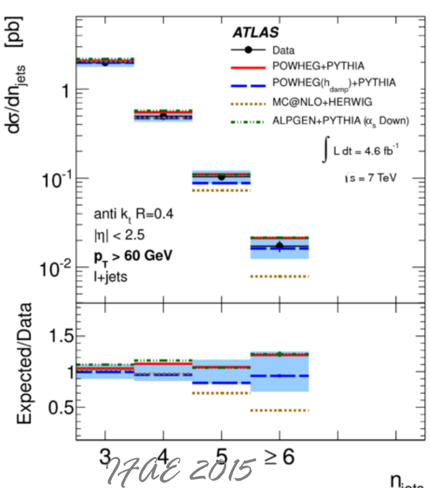
# Jet multiplicity in top–anti-top final states



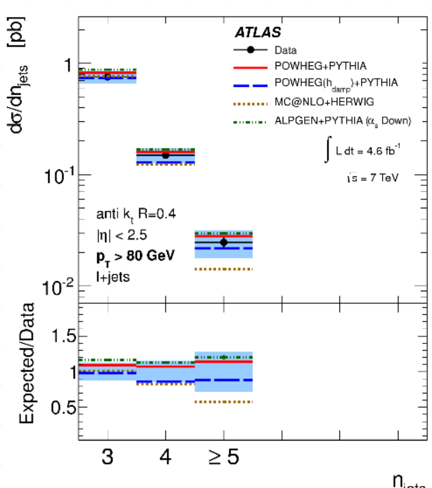

$p_T > 25$ GeV




$p_T > 40$ GeV




$p_T > 60$ GeV




$p_T > 80$ GeV

- MC@NLO modelling predicts a lower jet multiplicity spectrum and softer jets
- Predictions from ALPGEN + HERWIG or PYTHIA and POWHEG + PYTHIA are consistent with the data

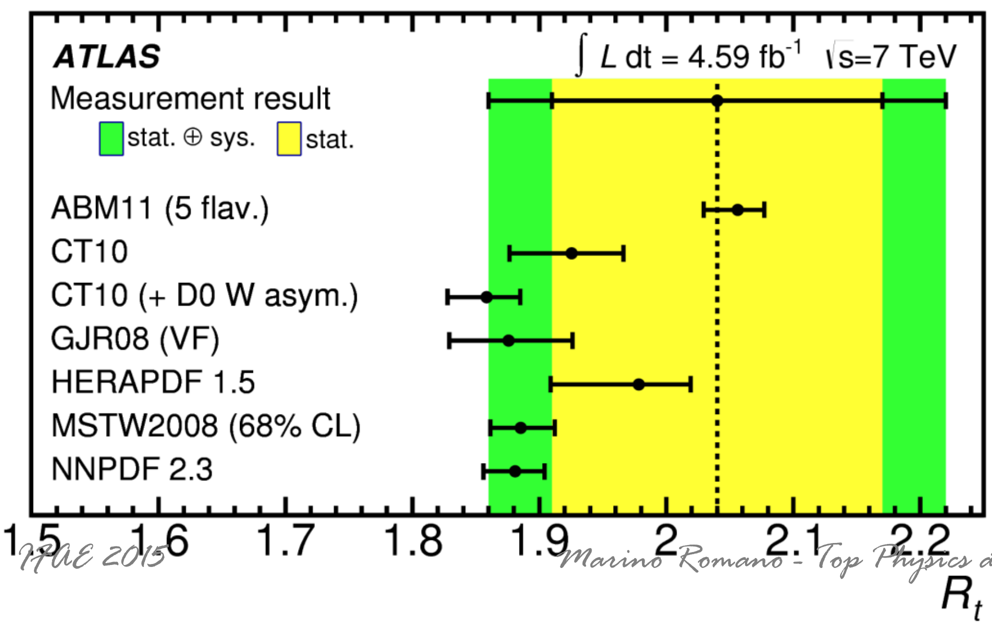
# Single top/antitop t-chan ratio

$$R_t = \frac{\sigma_{ub\to td}}{\sigma_{d\bar{b}\to\bar{t}d}}$$

**Phys. Rev. D. 90, 112006 (2014)**

$\sqrt{s} = 7$ TeV, $\int Ldt = 4.7$ fb$^{-1}$

- Very sensitive to the ratio of the PDF of the valence quark in the high *x* regime
  - Smaller uncertainties because of error cancelations
- Sensitive to new physics effects
- Same analysis technique used in the $\sigma_{tchan}$ measurement




The measurement is in agreement with the predictions from different PDF sets and is dominated by systematic uncertainties

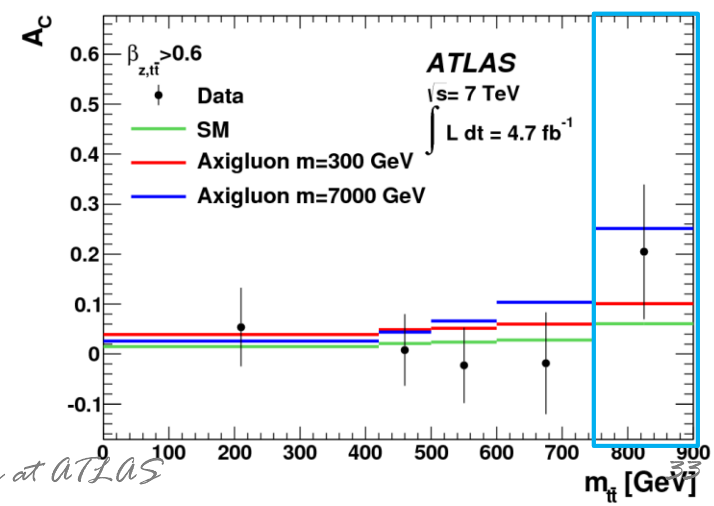
# Tt charge asymmetry in Run II

- Interest shown for boosted analyses
  - Combinations with resolved analyses could improve the precision
- $A_C$ at high $m_{tt}$ particularly sensitive to new physics
- Run II ideal environment for boosted analyses
  - Expected 7x more boosted tops ($m_{tt}$>1TeV) with 5/fb

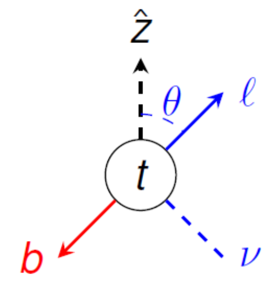
Interest shown also for $A_C(tl)$ with a high $p_T$ hadronically decaying top (arXiv:1401.2443)

$$A_C^{tl} = \frac{N(\Delta|y|^{tl} > 0) - N(\Delta|y|^{tl} < 0)}{N(\Delta|y|^{tl} > 0) + N(\Delta|y|^{tl} < 0)}$$

No ambiguity due to the z-component of the neutrino



# Spin correlation observables

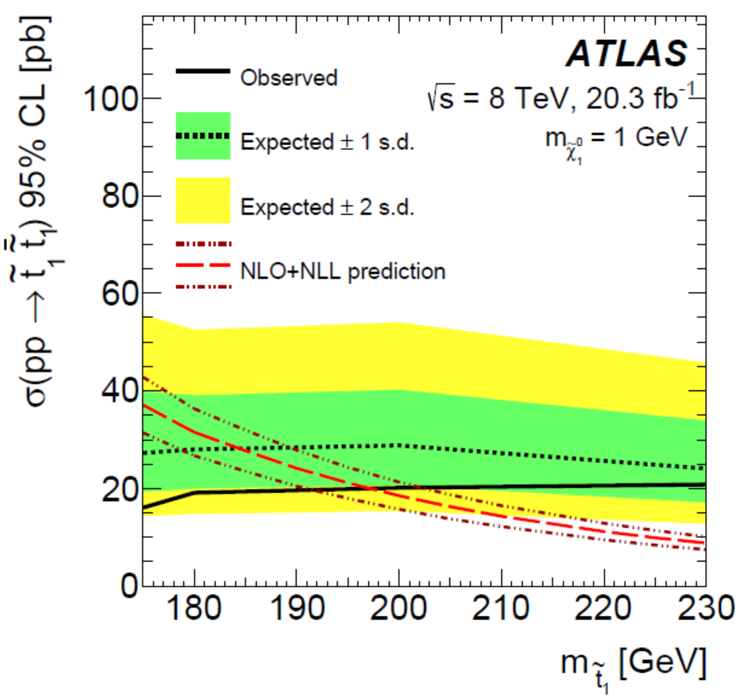


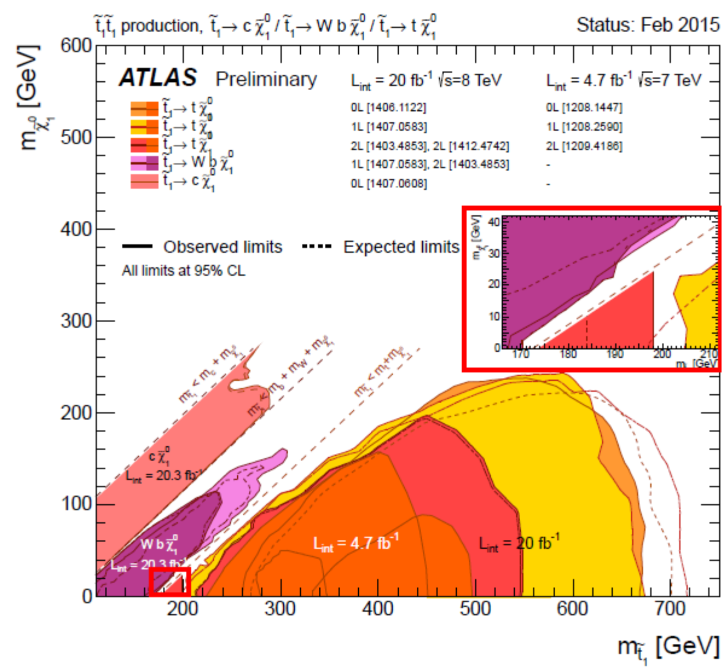

- Angular distributions of daughter pairs
  - $\frac{d\sigma}{dcos\theta_1 dcos\theta_2} \sim 1 - \boldsymbol{A}\alpha_1\alpha_2 cos\theta_1 cos\theta_2$
  - Elicity basis: top rest frame
  - Maximal basis: event-by-event axis that maximize correlation for $gg$ fusion
- S-ratio
  - Ratio of matrix elements of like-helicity gluon fusion with spin correlation to without correlation

$$S = \frac{(|M|^2_{RR} + |M|^2_{LL})_{corr}}{(|M|^2_{RR} + |M|^2_{LL})_{uncorr}}$$
$$= \frac{m_t^2[(t \cdot l^+)(t \cdot l^-) + (\bar{t} \cdot l^+) - m_t^2(l^+ \cdot l^-)]}{(t \cdot l^+)(\bar{t} \cdot l^-)(t \cdot \bar{t})}$$

# Spin correlation: stop exclusion

- $t\bar{t}$ spin correlation is sensitive to SUSY processes $\tilde{t}\bar{\tilde{t}} \rightarrow t\bar{t}\tilde{\chi}^0\,\tilde{\chi}^0$
- Limits on stop production can be set by measuring $t\bar{t}$ spin correlation



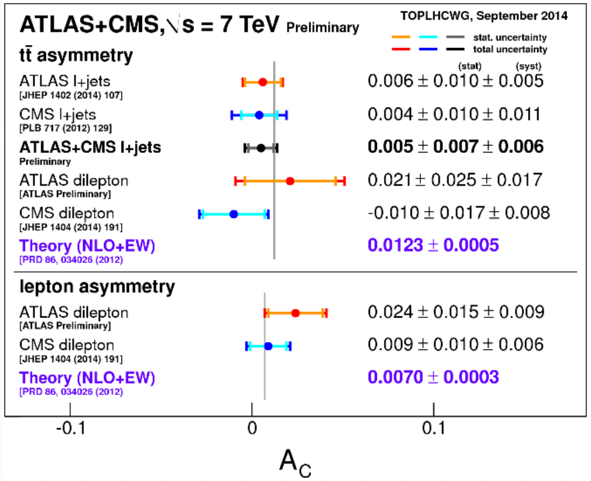




ATLAS SUSY summary plot on atlas.web.cern.ch

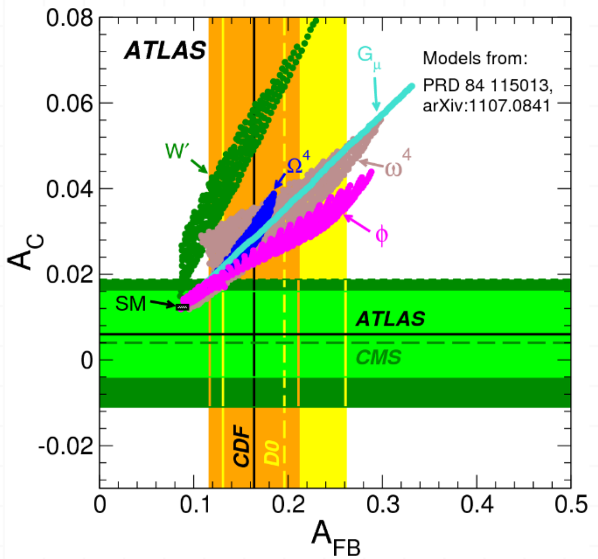
# $t\bar{t}$ charge asymmetry in Run I

$$A_C^{tt} = \frac{N(\Delta|y|>0) - N(\Delta|y|<0)}{N(\Delta|y|>0) + N(\Delta|y|<0)} \qquad \Delta|y| = |y_t| - |y_{\bar{t}}|$$

$$A_C^{ll} = \frac{N(\Delta|y|>0) - N(\Delta|y|<0)}{N(\Delta|y|>0) + N(\Delta|y|<0)} \qquad \Delta|y| = |y_{l^+}| - |y_{l^-}|$$




- Extensively measured @ 7 TeV
- All results obtained after unfolding to parton level
  - Dilepton channel (submitted to JHEP)
    - Simultaneous measurement of $A_C(tt)$ and $A_C(ll)$
  - Single lepton channel (JHEP02(2014)107)
  - Combination with CMS (ATLAS-CONF-2014-012)
- Results in agreement with SM predictions
  - To understand the discrepancies in $A_{FB}$ @ Tevatron



# Summary

- Physics of the top quark can answer fundamental questions.
- So far all results agree with SM predictions
  - Most of the measurements are limited by systematics.
- Top analyses in ATLAS presented in this talk
  - Top pair cross section (total, differential and associate production)
  - Top-quark mass measurement
  - Top-antitop charge asymmetry
  - Top-antitop spin correlation
  - Additional results can be found at the ATLAS public page https://twiki.cern.ch/twiki/bin/view/AtlasPublic/
- Stay tuned for new results with early data in Run II at 13 TeV, as well as for more refined studies from Run I!