Recent Top Quark Measurements at the LHC in ATLAS

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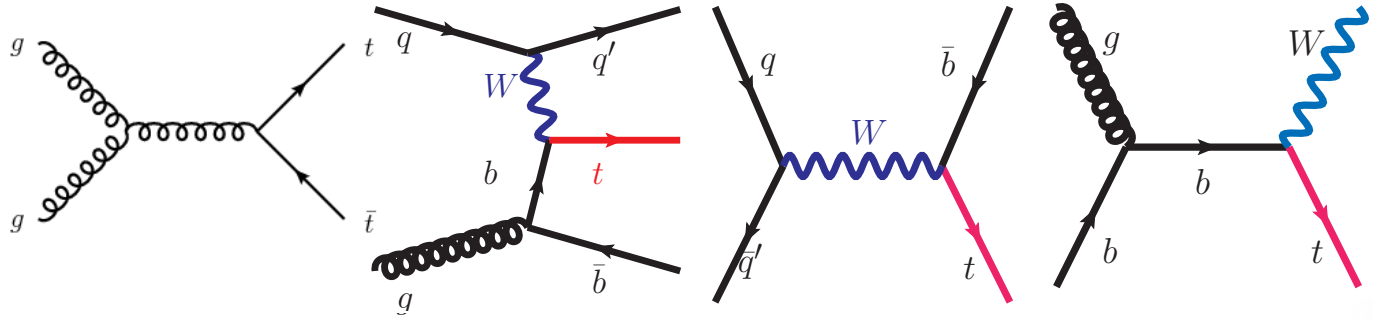
Introduction – The Top Quark

- The top quark is the heaviest known fundamental particle
  - World combination 2014 of Tevatron and LHC:
    - m_t = 173.34 ± 0.27 (stat) ± 0.71 (syst) GeV (arxiv:1403.4427v1)
    - Around the electro-weak scale
- The top quark decays **before** hadronization
  - $\Gamma_t \sim 4*10^{-25}s << \Gamma_{QCD} \sim 28*10^{-25}s$
  - Its properties are transferred to the decay products
- The top quark is a perfect candidate for precision tests of the Standard Model and searches for new physics
- The top quark also controls Higgs-Boson production
  - Determination of “top-higgs coupling” very important

Top Quark Production and Decay

- As tT pairs via strong interaction in gluon – gluon fusion (85%)
  - But also quark-gluon fusion and quark-antiquark annihilation
- As single top quarks via electro-weak interaction

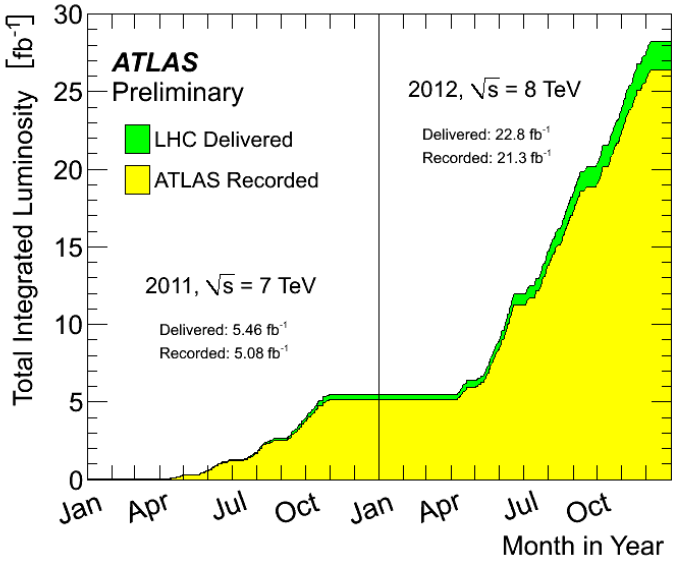


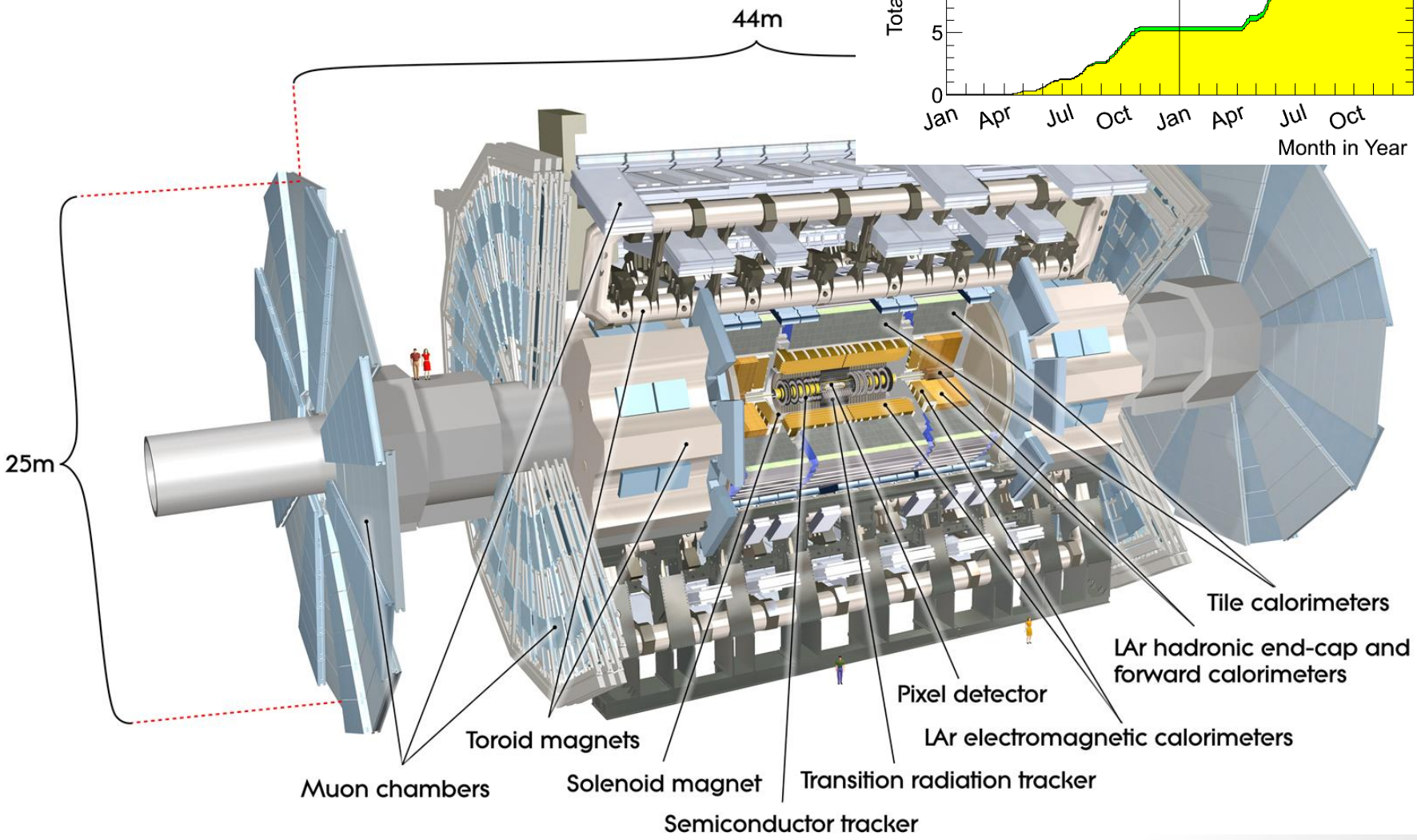
σ_{Theory} [pb]	tT	t-channel	s-channel	Wt-channel
Tevatron 1.96 TeV	7.35	2.3	1.1	0.2
LHC 7 TeV	177.3±9.0	64.6±2.4	4.6±0.2	15.7±1.1
LHC 8 TeV	252.9±11.7	87.8±3.4	5.6±0.3	22.4±1.5

- Decay almost exclusively into W boson and bottom quark
  - Decay of the two W bosons defines decay modes of tT as
  - semi-leptonic (45%), di-leptonic (9%) or fully hadronic (46%)

The ATLAS Detector

- Data in 2011 (7 TeV) and 2012 (8 TeV)

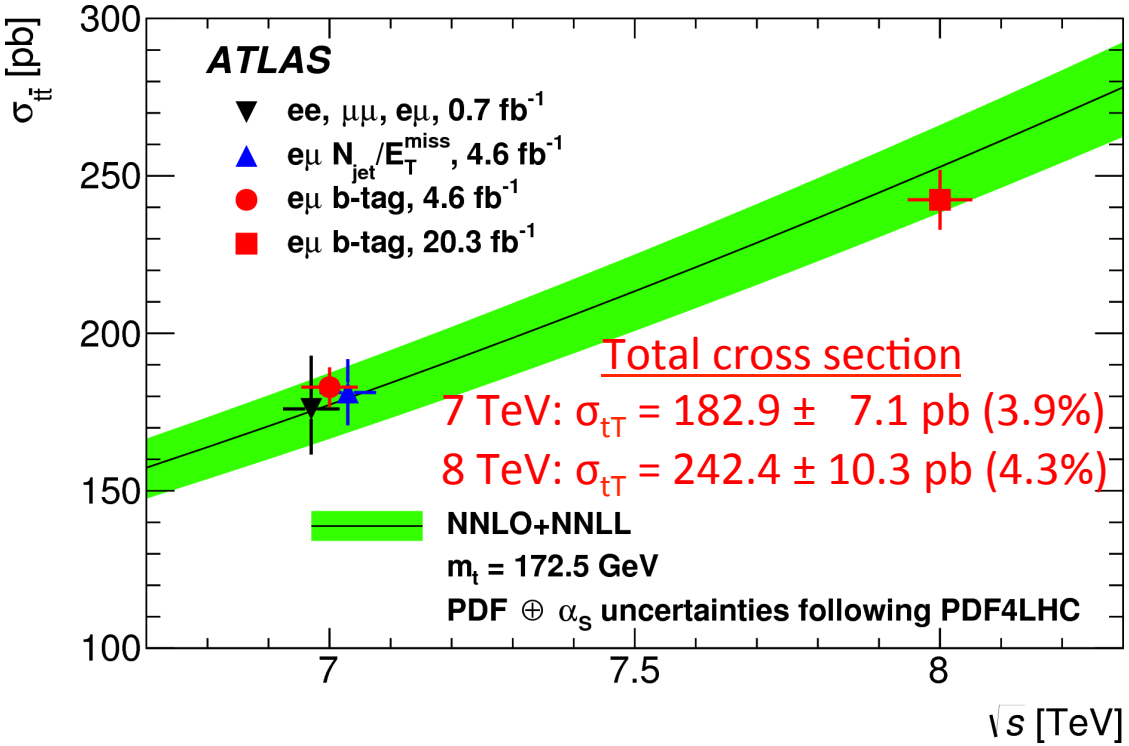




EPJC 74 (2014) 3109

Top Quark Pair Production XS

- Use di-leptonic decay channel (eμ) to measure total and fiducial production cross sections at √s = 7 and 8 TeV
- Determine σ_{tT} and b-jet reco and tagging efficiency together
  - Reduces systematics related to jet energy scale and b-tagging
- Fiducial XS: expected to be less MC generator dependent
  - no extrapolation to full phase space



Standard Model prediction in good agreement with data!

Fiducial cross section
(lepton p_T > 25 GeV, $|\eta|$ < 2.5)
7 TeV: σ_{tT} = 2.615 pb ± 3.8%
8 TeV: σ_{tT} = 3.448 pb ± 4.1%

Reduction mostly in PDF and tT modeling uncertainties.

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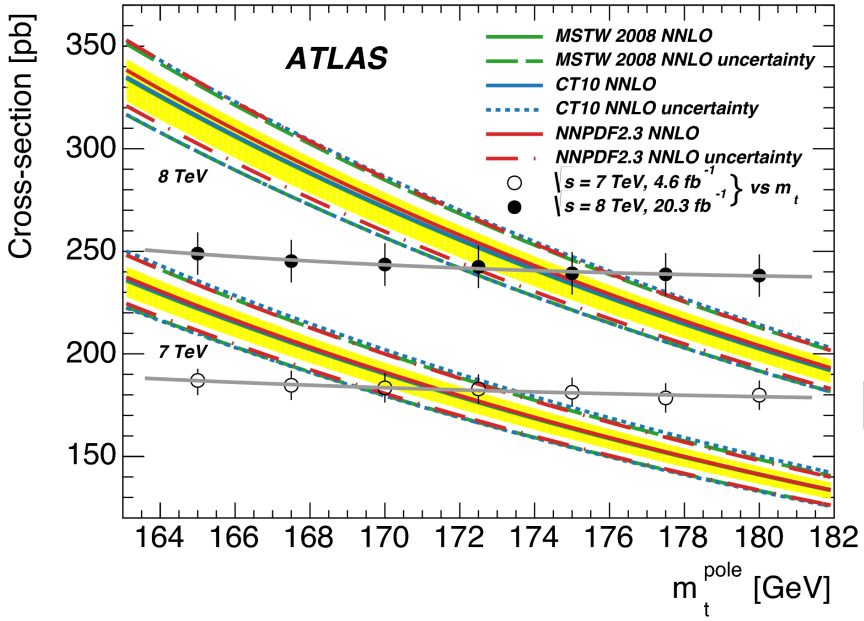
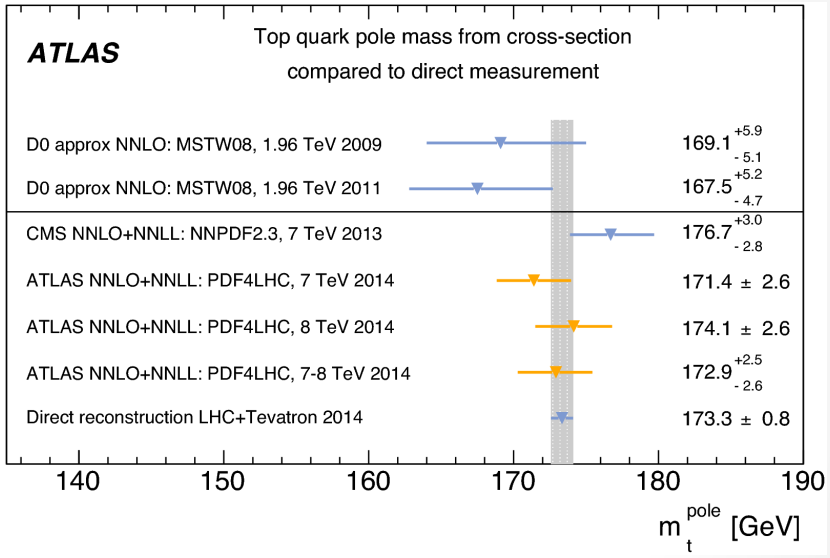
Top Quark Pair Production XS

- Inclusive cross section depends on pole mass $\sigma_{tT}(m_t)$
  - Extract pole mass and compare to kinematic measurements



Good agreement between measurements:



- Supersymmetry, set limit on mass of stop quark
  - Assume decay $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$ and fit cross section of stop pair production to difference $\sigma_{tT}^{measured}$ and σ_{tT}^{theory}
  - Limit: No stop with $m_{top} < m_{stop} < 177$ GeV @ 95% CL

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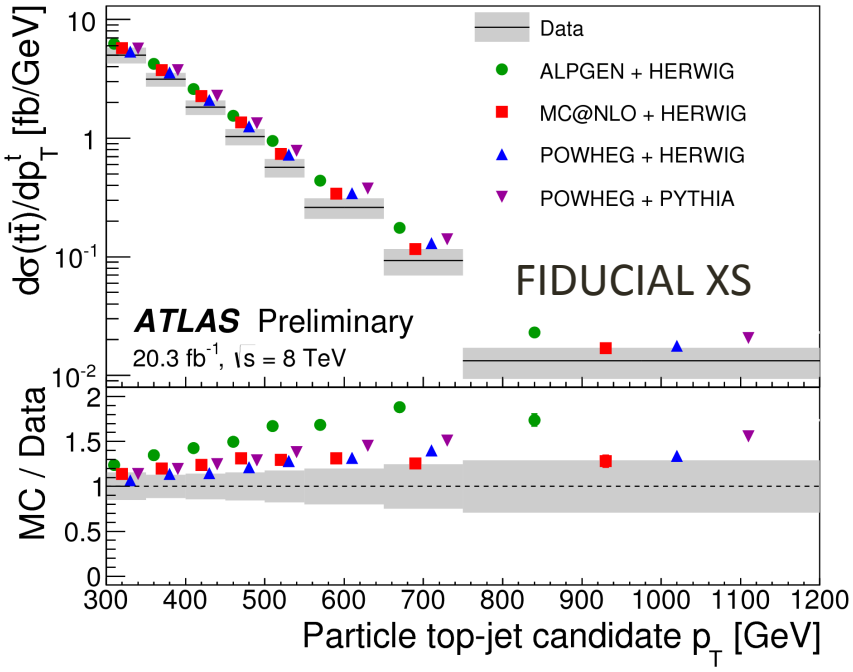
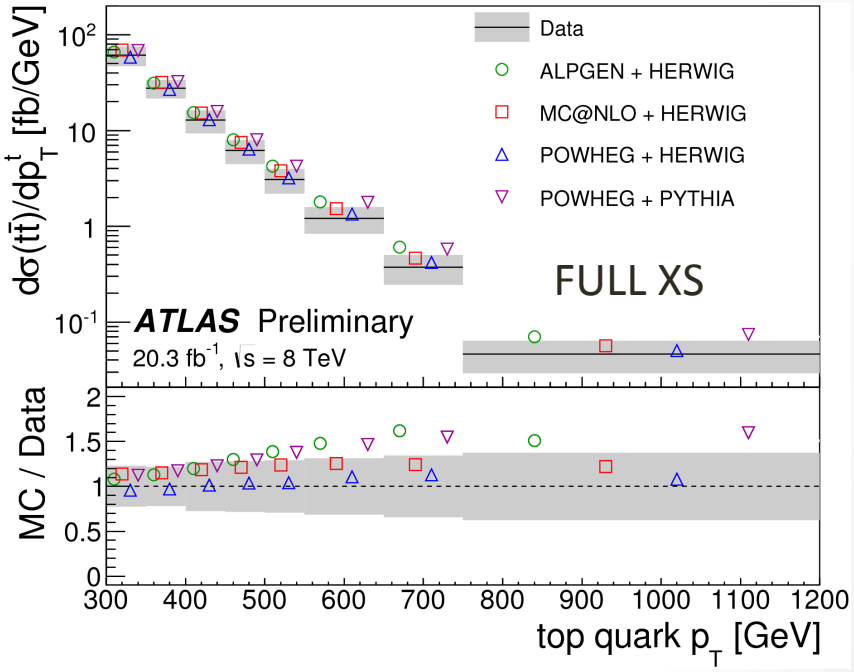
Differential XS of Boosted Top @ 8 TeV

ATLAS-CONF-2014-057

- Semi-leptonic tT channel with hadronic top p_T > 300 GeV
  - First time differential XS up to TeV of hadronic top p_T
  - Boosted top is reconstructed as single large radius jet
- Measure fiducial (particle-level) and full (parton-level) XS





- Measured cross section in general lower than predictions
  - Discrepancy increases with top quark p_T

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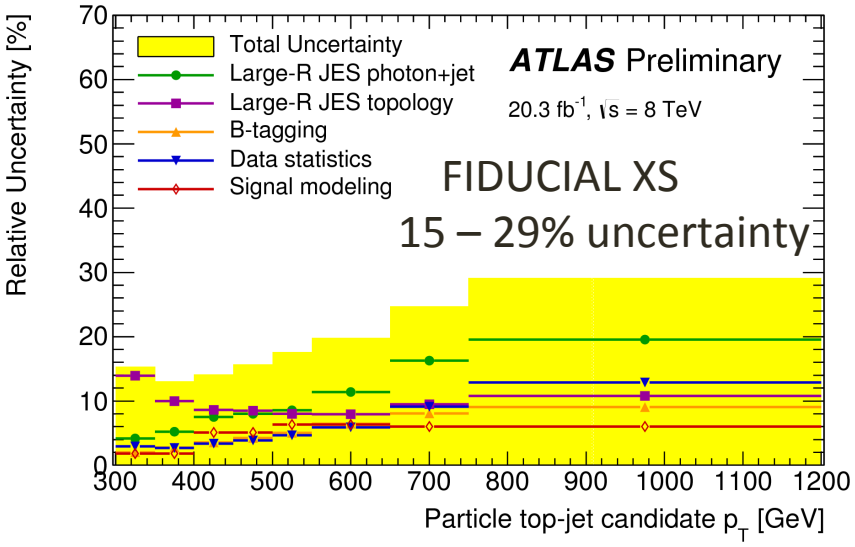
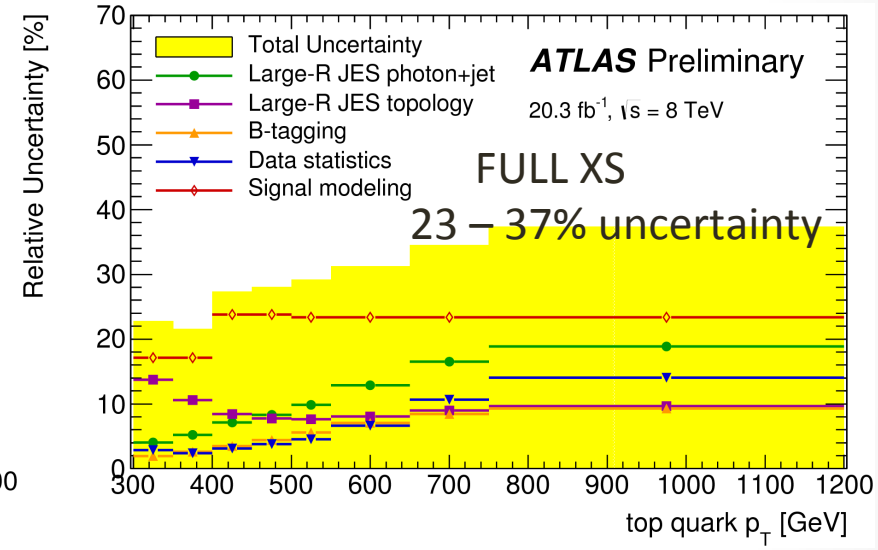
Differential XS of Boosted Top @ 8 TeV

ATLAS-CONF-2014-057

- smaller theoretical uncertainties for fiducial measurement expected
- Comparison of systematic uncertainties

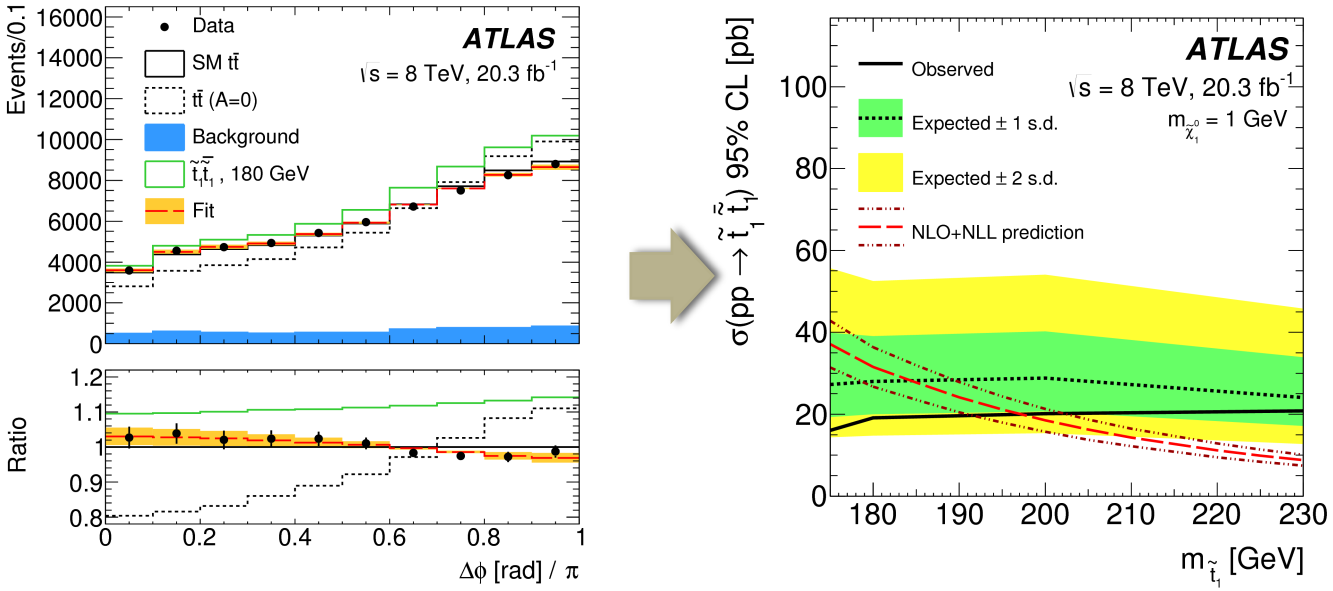




- Systematic uncertainties related to MC generators (signal modeling) largely reduced in fiducial measurement
  - Stringent test of MC generators

Spin Correlation in tT @ 8 TeV

- Orientation of spin of top quarks is transferred to decay products
- Study tT di-leptonic events and extract spin-correlation strength $A_{Helicity}$ from angle between two leptons
- SM prediction 0.31 ± 0.005 in agreement with data 0.38 ± 0.04



CERN-PH-EP-2014-257
Submitted to PRL

- SUSY: stop quark has spin 0 -> $A_{Helicity} = 0$
  - Extract limit on m_{stop} by fit to measured $A_{Helicity}$
  - No stop within $m_{top} < m_{stop} < 191$ GeV @ 95% CL

Charge Asymmetry of tT (and leptons)

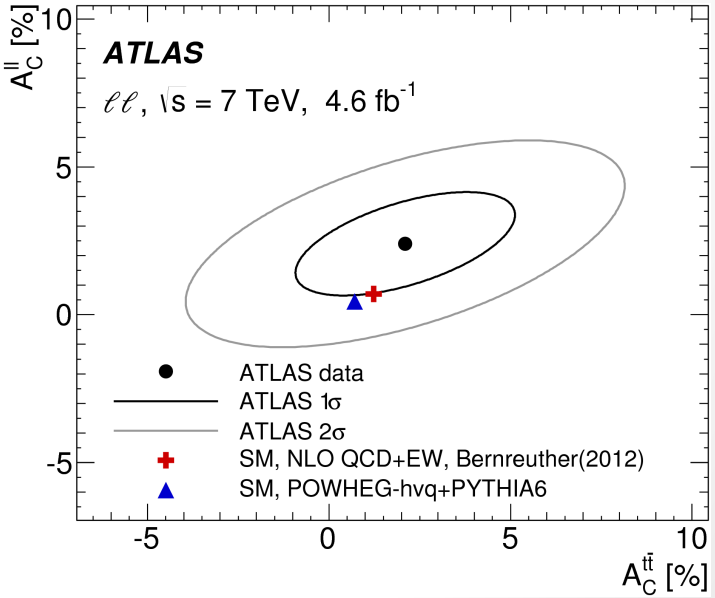
- SM predicts a charge asymmetry $A_C^{t\bar{t}} = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$ at next to leading order
  - Only in tT produced via qQ or qg fusion (small contribution)
  - Much more pronounced at pP collider (Tevatron) where qQ annihilation is the dominant production process

$$\Delta|y| = |y_t| - |y_{\bar{t}}|$$

- Stringent test of the Standard Model and MC generators
- Look at di-lepton decay channel (no taus) @ 7 TeV and also study angles between leptons (not only between top quarks)
- SM predictions in good agreement with data
- Results:

$$A_C^{\ell\ell} = 0.024 \pm 0.015\ (\text{stat.}) \pm 0.009\ (\text{syst.})$$

$$A_C^{t\bar{t}} = 0.021 \pm 0.025\ (\text{stat.}) \pm 0.017\ (\text{syst.})$$

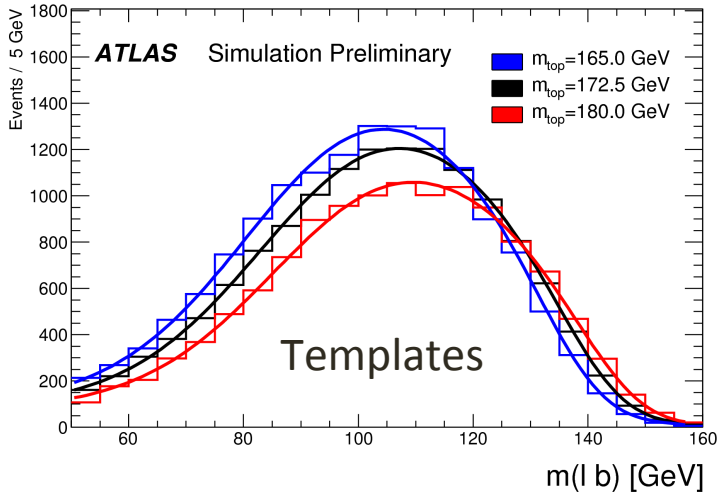


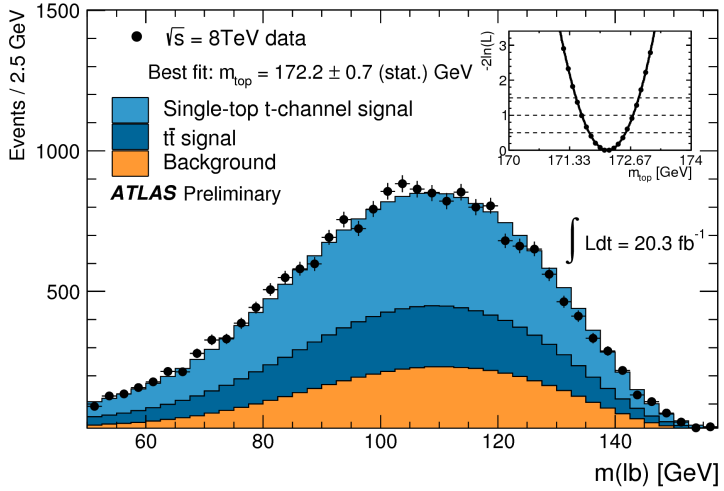
CERN-PH-EP-2014-233
Submitted to JHEP

Top Quark Mass in Single Top @ 8 TeV

ATLAS-CONF-2014-055

- First measurement of top quark mass in single top t-channel
- Look at events where W decays to eν or μν
  - Final state with 1 lepton, missing E_T, 1 jet, 1 b-quark jet
  - Largest systematic: jet energy scale (1.5 GeV)
- Reduce background to below 30% by use of neural network
- Extract top quark mass by 1D template fit
  - Estimator: invariant mass of lepton and b-jet



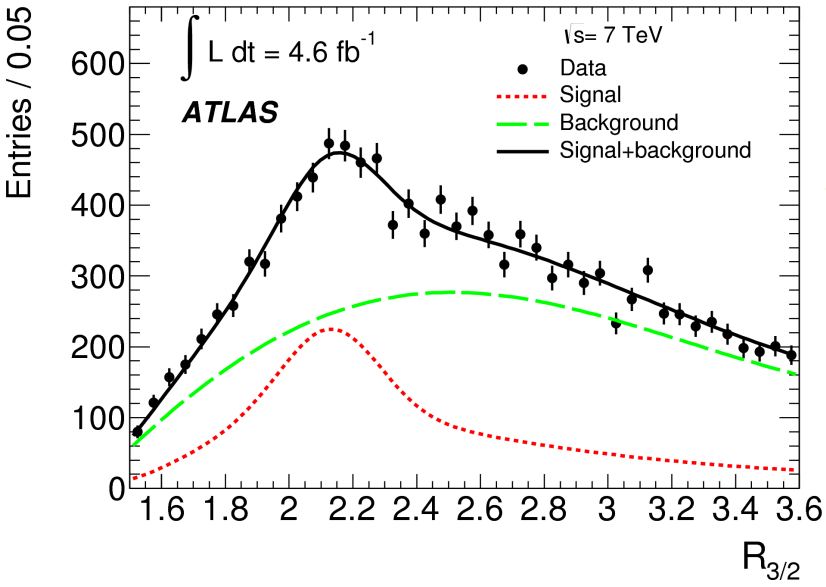


- Best fit: m_{top} = 172.2 ± 0.7 (stat.) ± 2.0 (syst.) GeV

Top Quark Mass in fully hadronic tT @ 7 TeV

- Fully hadronic decay channel has large BR (46%) but no leptons
  - Large QCD multi-jet background expected
- Use template fit with R_{32} estimators for m_{top}
  - R_{32}: ratio of 3 to 2 jet masses (jets from top and W)
  - Expected to be less sensitive to jet energy scale uncertainty
- Large QCD background modelled by data driven matrix element method ("ABCD" method)

CERN-PH-EP-2014-208
Submitted to EPJC



- Final fit with Gauss+Landau:

$$m_t = 175.1 \pm 1.4\ (\text{stat.}) \pm 1.2\ (\text{syst.})\ \text{GeV}$$

- Largest systematics:
  - Jet Energy Scale (JES): 0.51 GeV
  - bJES (b quark): 0.62 GeV

Conclusion

- Top quark measurements have provided stringent tests of SM
- Top quark pair production
  - Cross-section measured with 4% accuracy (individual!)
  - Spin correlation, charge asymmetry measurements: SM predictions in good agreement with data
- Top quark mass
  - World combination reaches uncertainty of ~0.8 GeV!
  - Precision now limited by systematic uncertainties (theory, exp.)
  - Top quark measurement also in “more difficult” channels (tT full hadronic, single top t-channel) quite precise
- Top quark measurements have started to probe for new physics
  - Shown in this talk: cross section and spin correlation measurements set limits on the mass of a possible stop quark