ATLAS Top Quark Results

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On behalf of the ATLAS Collaboration
SUSY 2017: Mumbai

Top Physics at LHC

- The top is the heaviest known elementary particle **~175 GeV**
- Its large mass is a fundamental parameter in SM: largest coupling to the Higgs boson
- Due its very short lifetime, the top-quark decays before hadronizing
  $t \rightarrow Wb$ **$\sim 10^{-24}$s**: allows the study of properties of the quark
- Large cross section:

σ_{tt} = 830 pb @ 13TeV (~ 500 tt pairs/min,~ 30 million tt in 36fb^{-1})

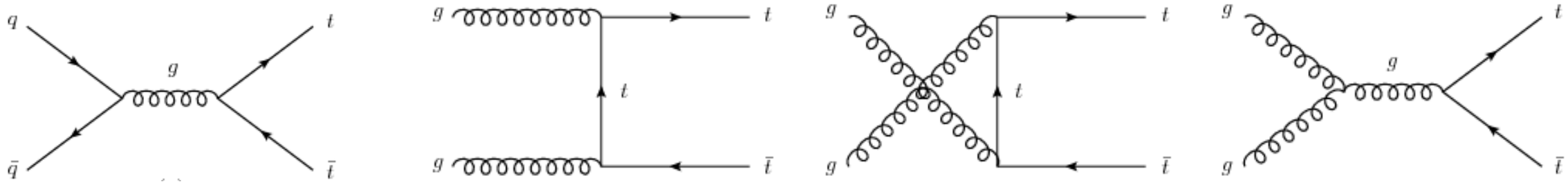
These unique properties of the top quark gives rise to a wide variety of interesting physics analysis:

- Tests of the SM
  - Properties of quark
  - pQCD in top quark pair productions
  - EW interaction in single top quark productions

- Sensitive to beyond SM physics
- Important background to new physics searches

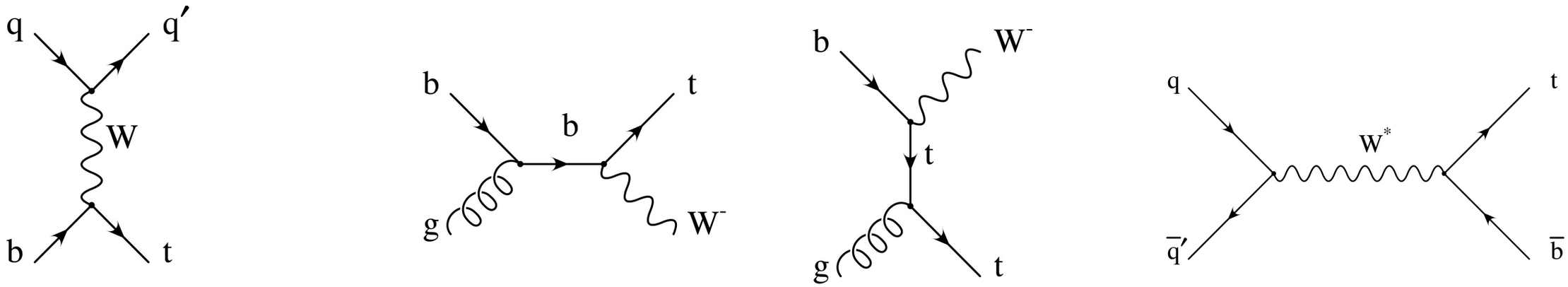
Top Quark Production at LHC

Top-Pair production via strong interaction



830 pb @ 13TeV

Single-top quark production via weak interaction



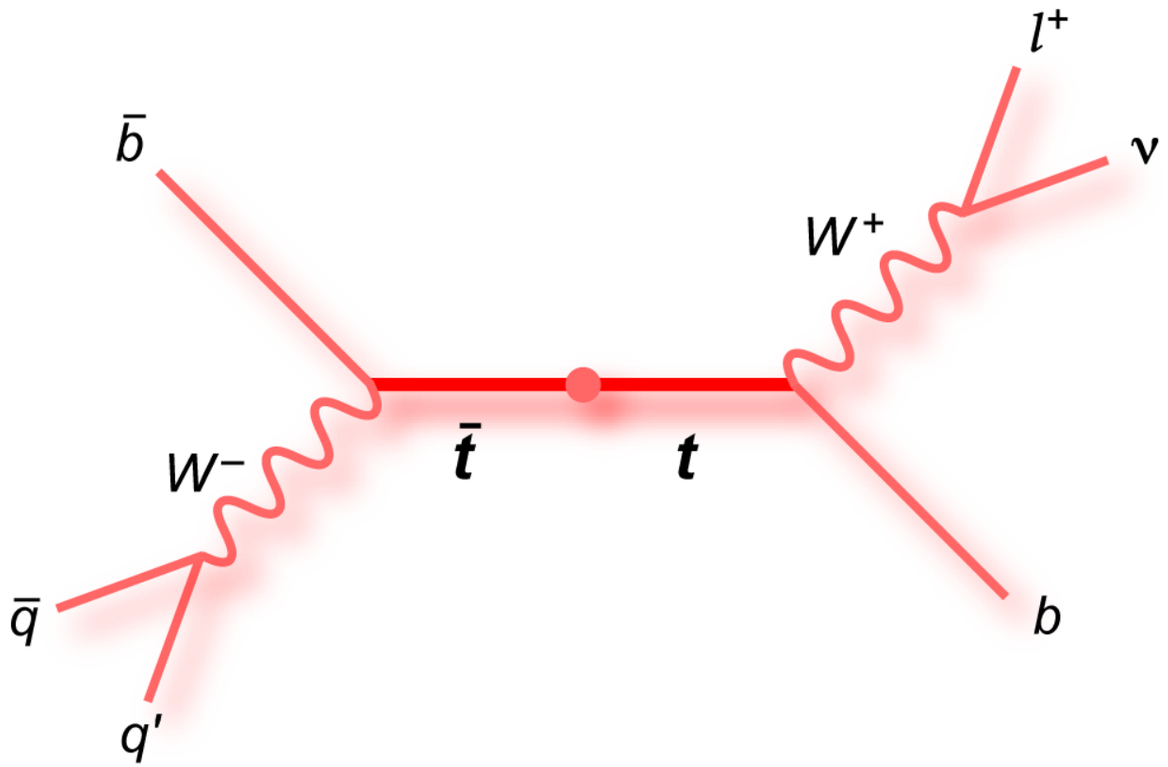
t-channel
210 pb @ 13 TeV

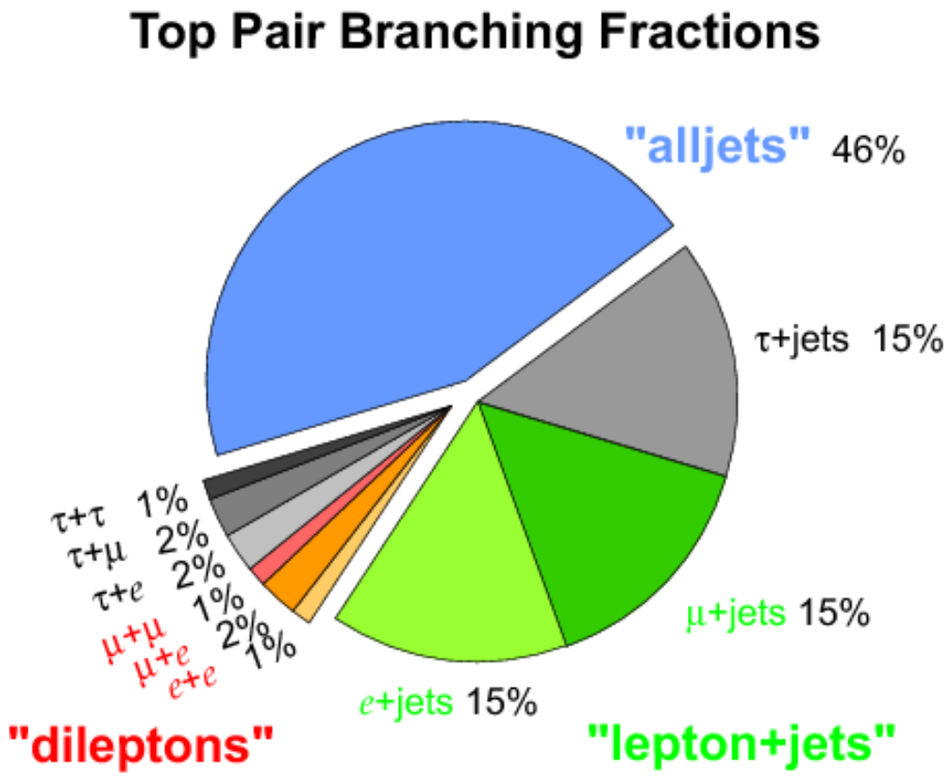
Wt-channel
72 pb @ 13 TeV

s-channel
11 pb @ 13 TeV

Top quark Decay

- In SM, top quarks decay to Wb ~99.8% of the time
- Decay signatures of top pairs are categorised according to decay of the two Ws: leptonically or hadronically





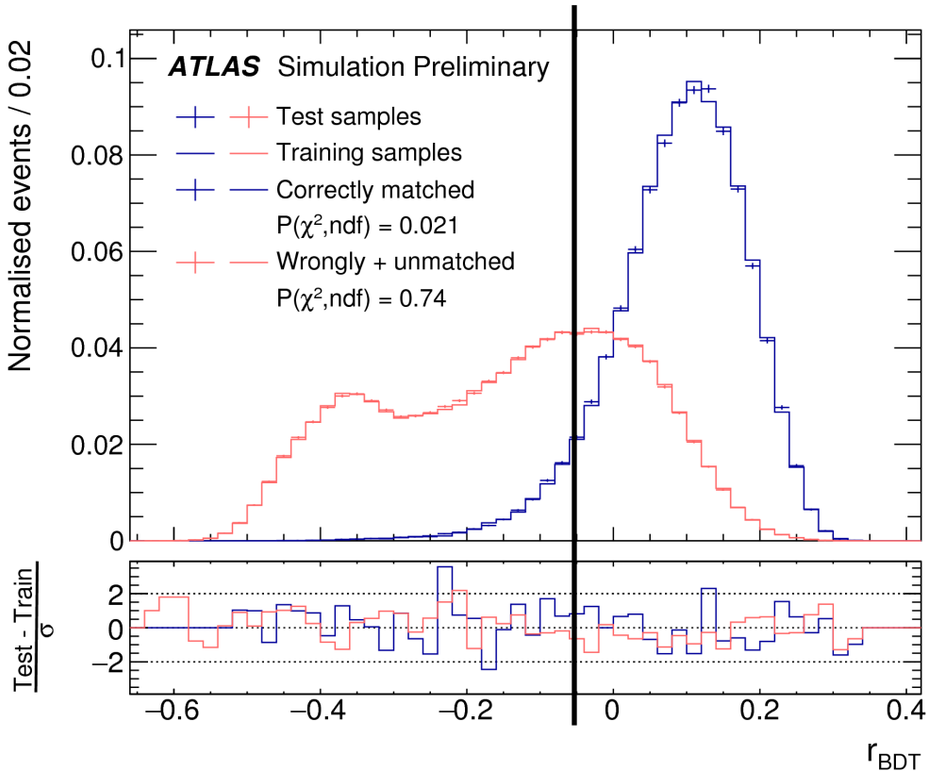
- All-hadronic: both Ws decay hadronically
- ℓ+jets: one leptonically and one hadronically
- dilepton: both leptonically

Results at 7 and 8 TeV

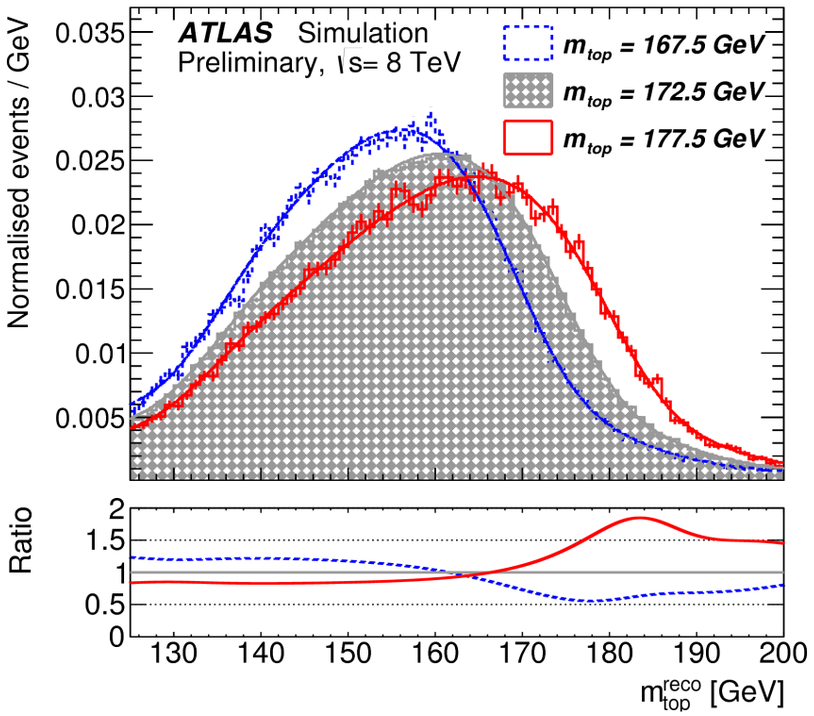
Precision measurements exploiting a well-understood dataset

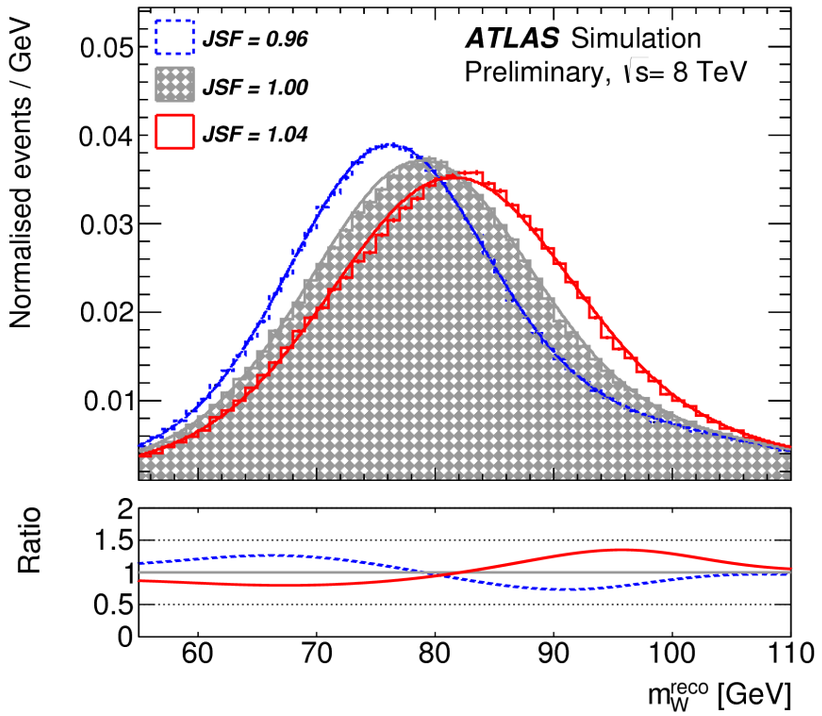
- Top mass measurement: ATLAS-CONF-2017-071
- Top Decay width: arXiv:1709.04207
- tt charge asymmetry ATLAS+CMS combination: arXiv:1709.05327

Top Mass Measurement



- Lepton+jets channel using data taken at 8TeV
- 1 e/μ + 4 jets (2 b-tagged)
- Train a BDT to distinguish correctly/incorrectly assigned configurations of reconstructed objects
- Cut on BDT output at -0.05
- 3D template fit technique to extract m_{top}, jet energy scale factor (JSF) and b-to -light jet energy scale factor (bJSF)



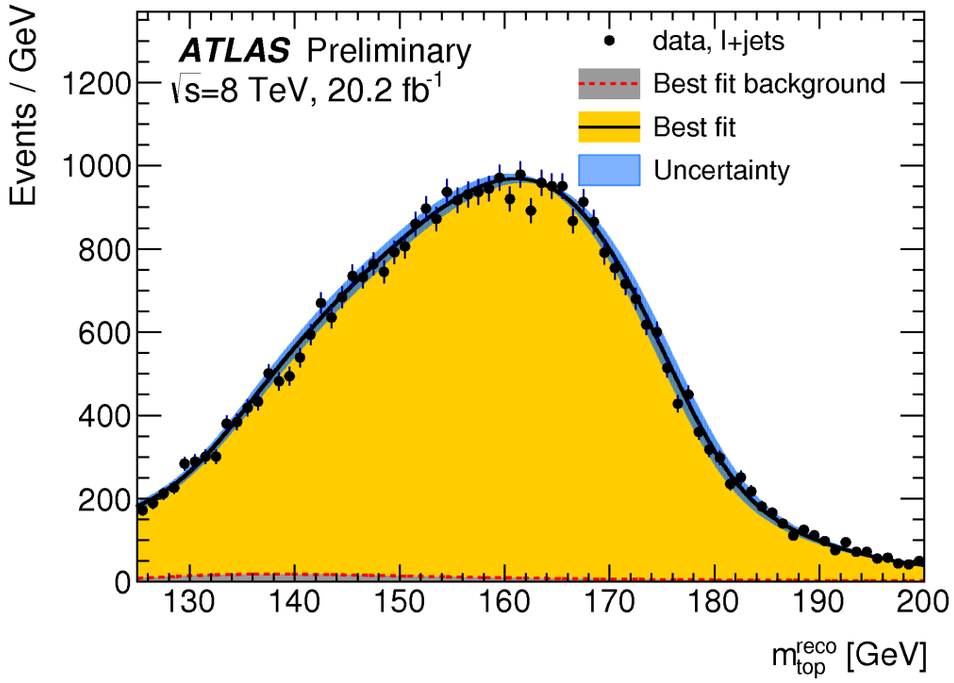


- Construct templates of:
  - m_{top}^{reco}
  - m_W^{reco}

$$R_{bq}^{\text{reco}} = \frac{p_{\text{T}}^{b_{\text{had}}} + p_{\text{T}}^{b_{\text{lep}}}}{p_{\text{T}}^{q_1} + p_{\text{T}}^{q_2}}$$

ATLAS-CONF-2017-071

Top Mass Measurement

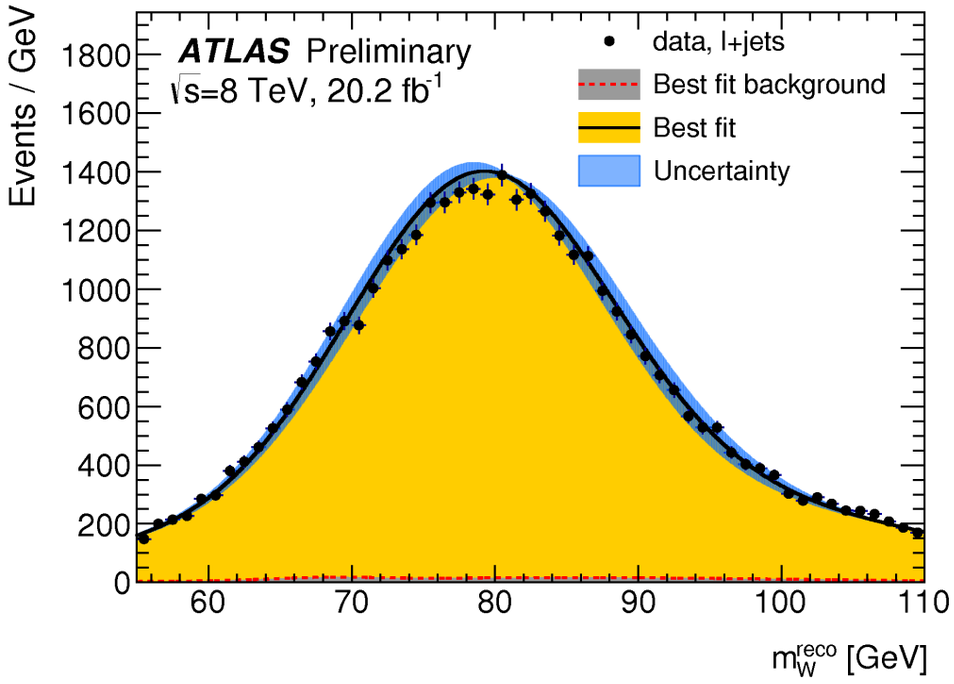


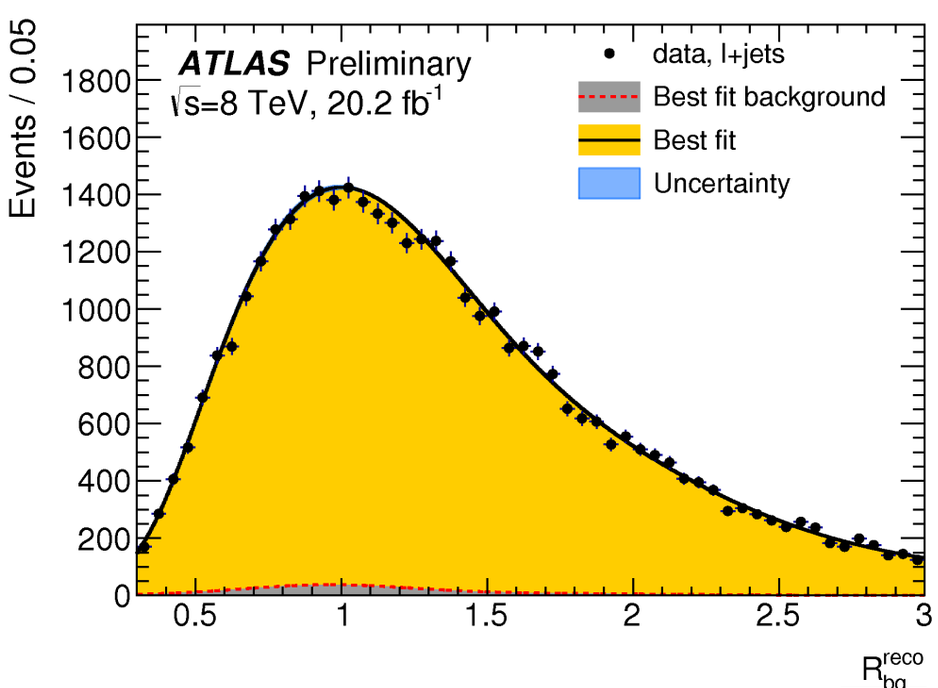
ATLAS-CONF-2017-071

- Fit to data of the 3 variables yields:

  m_{top} = 172.08 ± 0.39 (stat) ± 0.82 (syst) GeV

- 29% improvement with respect to 7TeV
- Systematic uncertainty mainly due to JES, b-tag, MC modelling





Top Mass Measurement

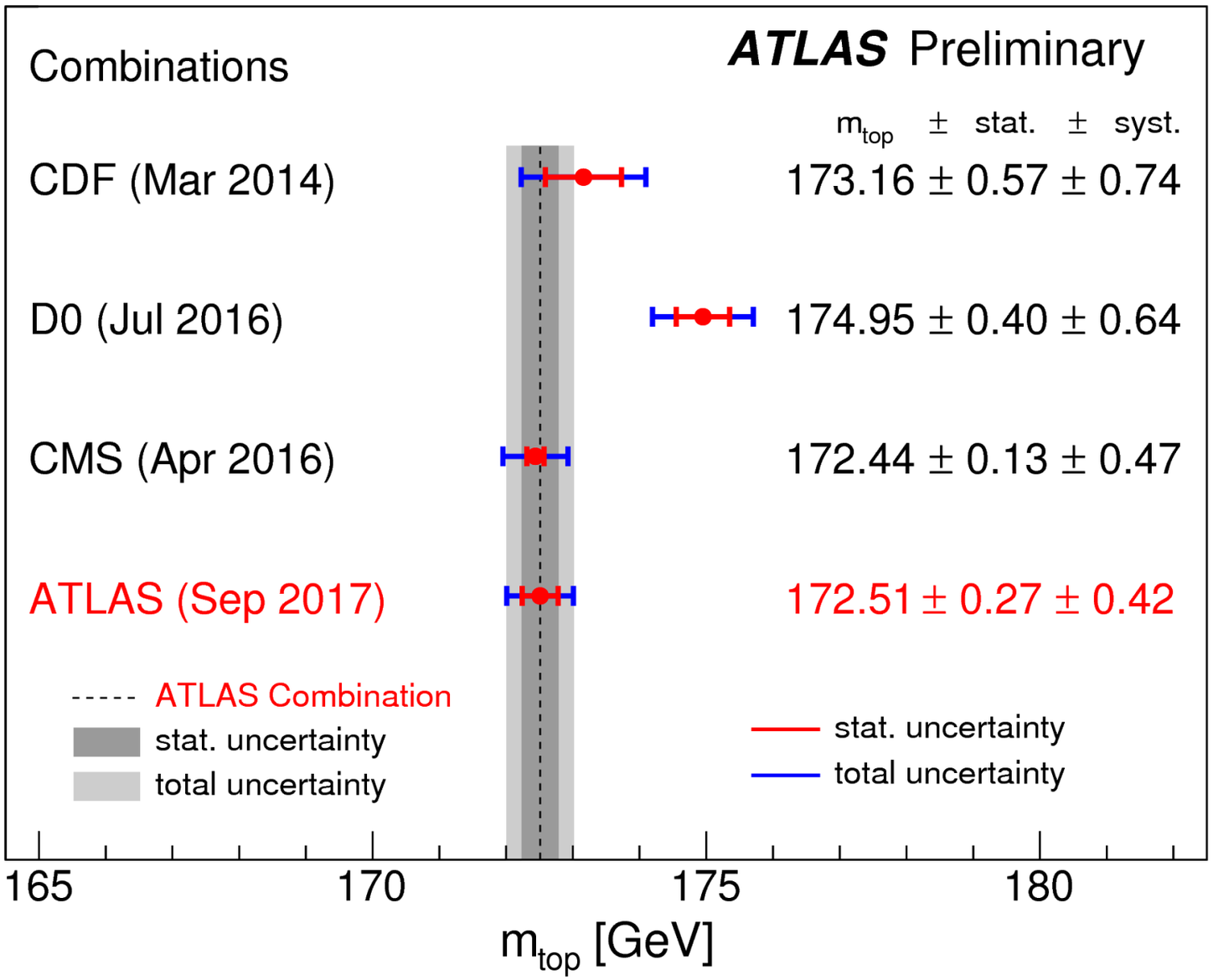
ATLAS-CONF-2017-071

Combination of this result with:

- Dilepton and Lepton+jets channels at 7TeV
  Eur. Phys. J. C 75 (2015) 330

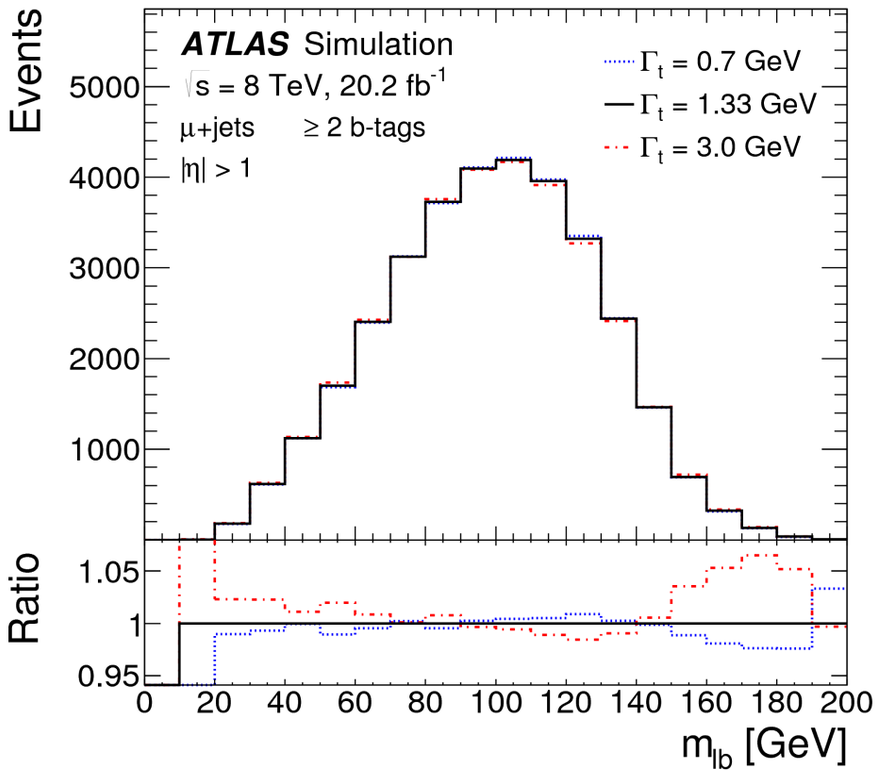
- Dilepton channel at 8TeV
  PLB 761 (2016) 350

The resulting combined values of m_{top} from the two LHC experiments are close and have similar total uncertainties.



Top decay width

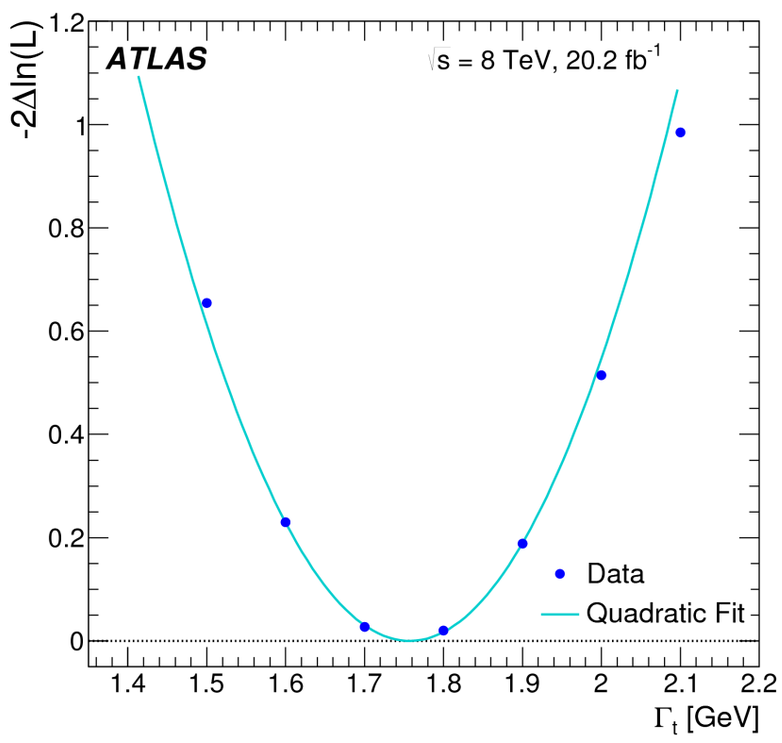
arXiv:1709.04207



- Lepton+jets channel using data taken at 8TeV
- 1 e/μ + 4 jets (1 b-tagged)
- Reconstruction: kinematic likelihood fit (using b-tagging information)
- Events split into 8 regions
- Perform template fit using m_{lb} for the leptonic top decay and $\Delta R_{min}(b,q)$ (b-jet and closest light jet) for the hadronic decay

$$\Gamma_t = 1.76 \pm 0.33\ (\text{stat.}) \pm {}^{0.79}_{0.68}\ (\text{syst.})\ \text{GeV}$$

- Consistent with SM Γ_t ~1.32 GeV
- First direct top width measurement in ATLAS
- Dominant systematics: JES, JER and signal modelling

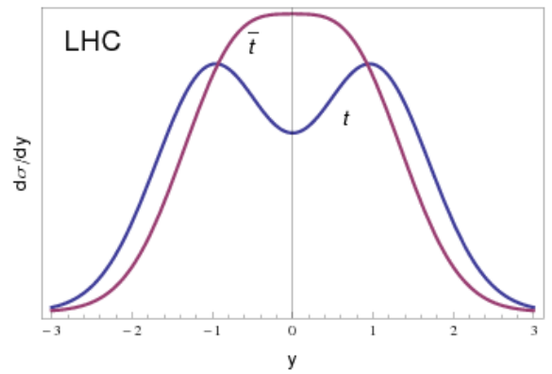


tt charge asymmetry combination

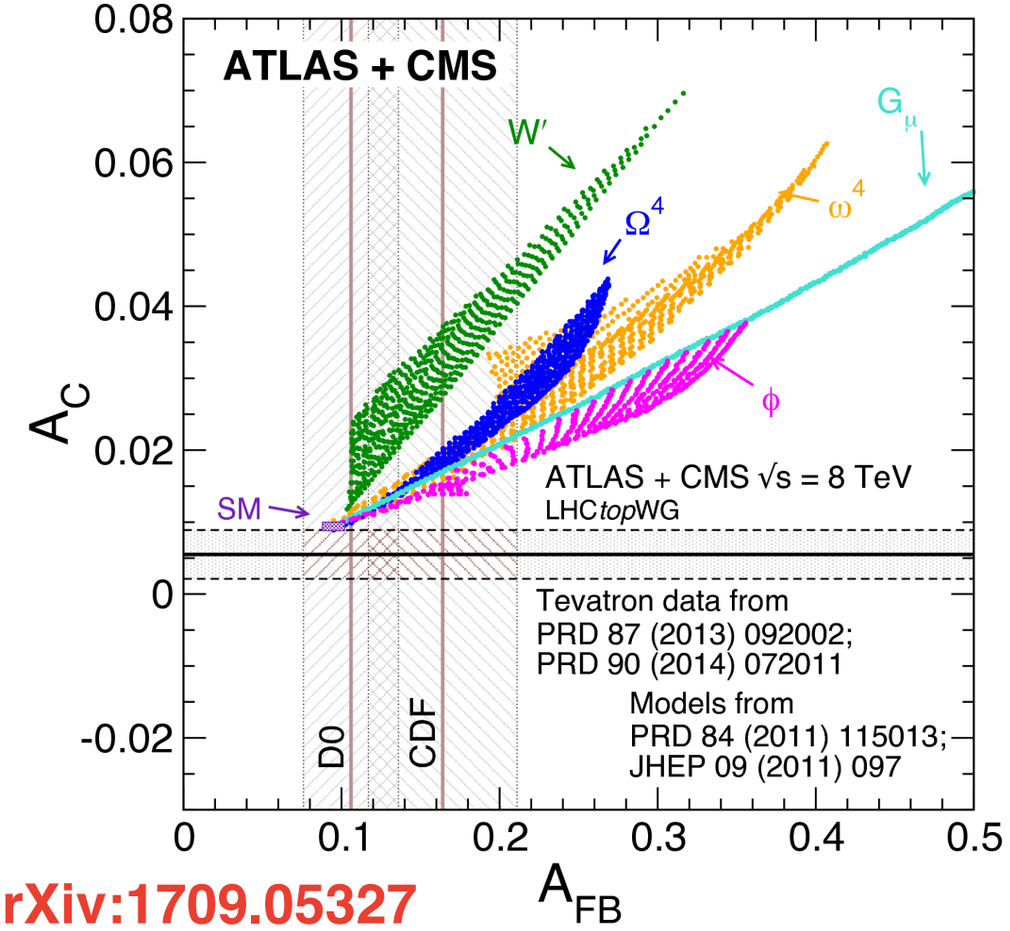
- Larger average momentum fraction of quarks vs anti-quarks leads to an excess of top quarks produced in the forward direction
- LHC has symmetric initial state
- Asymmetry very small in SM: but enhanced in NP

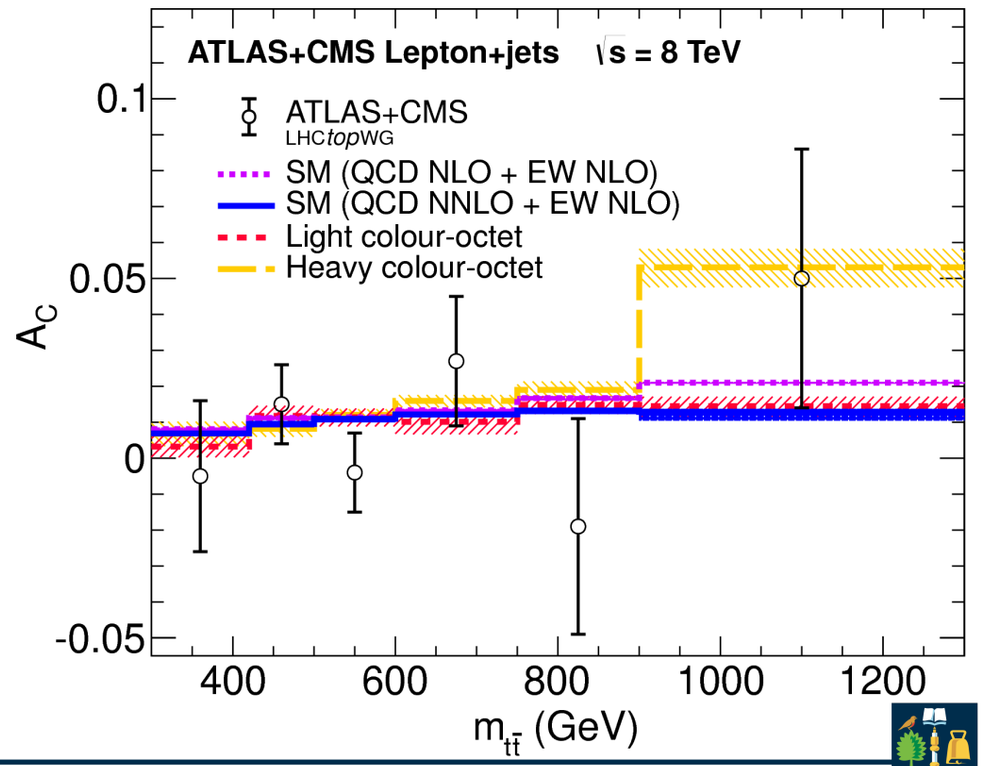
$$A_C = \frac{N^{\Delta|y|>0} - N^{\Delta|y|<0}}{N^{\Delta|y|>0} + N^{\Delta|y|<0}}$$

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



- Combination of ATLAS and CMS inclusive and differential measurements
- lepton+jets signature
- Inclusive charge asymmetry and as a function of tt invariant mass are consistent with SM predictions





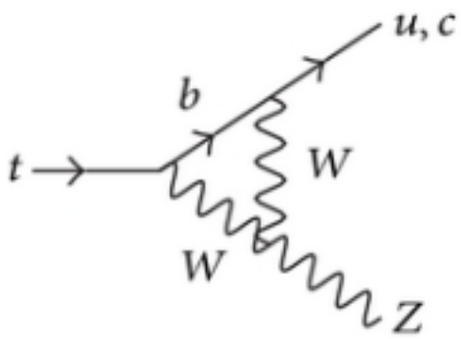
arXiv:1709.05327

Results at 13 TeV

Extending the reach to study rarer processes

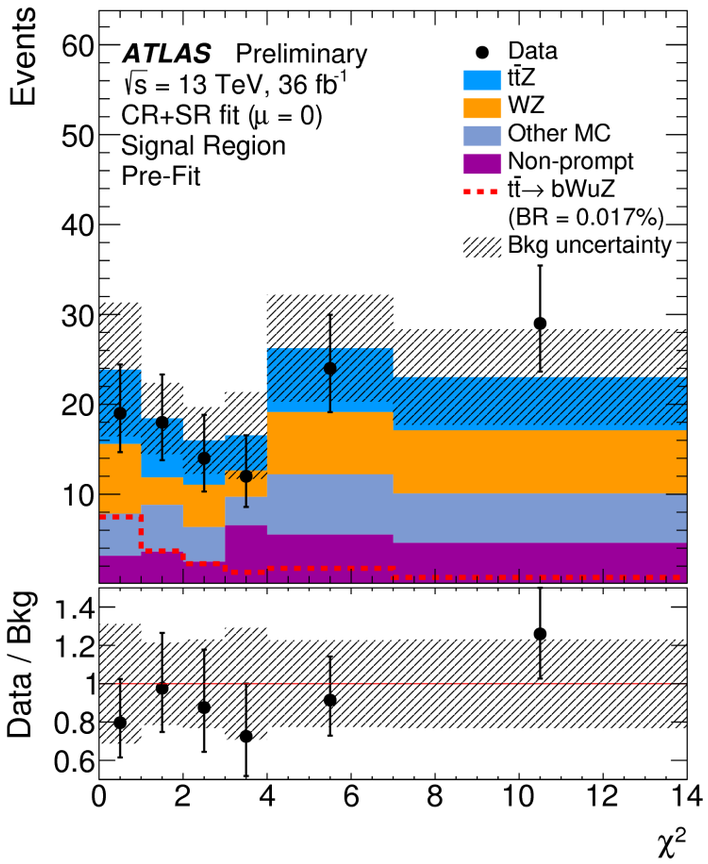
- Search for FCNC t→qZ decays: ATLAS-CONF-2017-070
- All-hadronic tt cross section at high-pT: ATLAS-CONF-2016-100
- Associated Single Top Production: arXiv:1710.03659

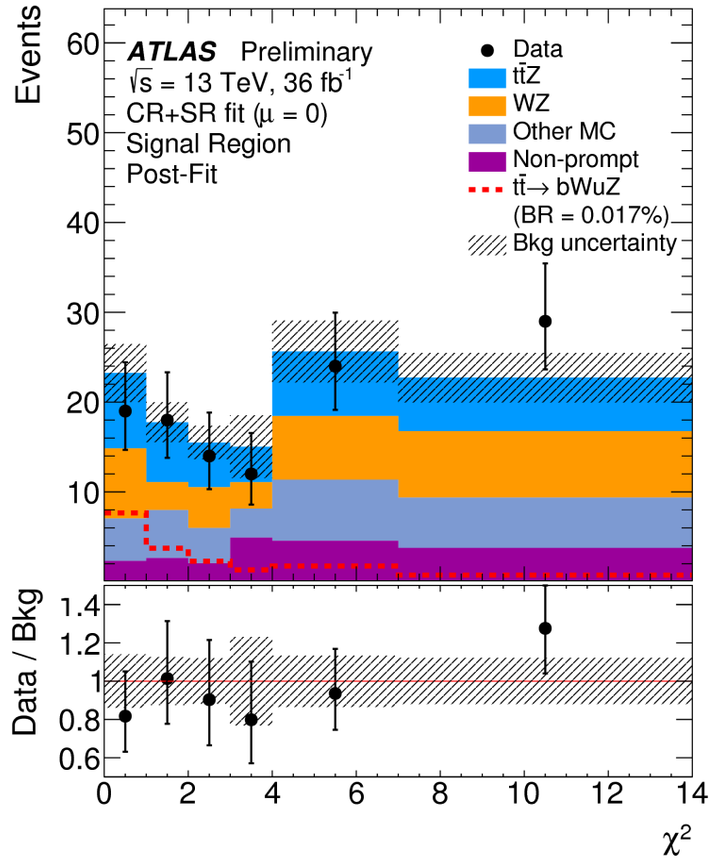
Search for FCNC $t \to qZ$ decays



Model:	SM	QS	2HDM	FC 2HDM	MSSM	$\not{R}$ SUSY	RS	EMF
BR($t \to qZ$):	10^{-14}	10^{-4}	10^{-6}	10^{-10}	10^{-7}	10^{-6}	10^{-5}	10^{-6}

- Search performed in channel where
  - one top decays to bW
  - other t→qZ through FCNC
- 3 isolated charged leptons + ≥ 2 jets (1 b-tagged)
- Minimize χ^2 for reconstruction of the final state
- Combined fit in CRs and SR





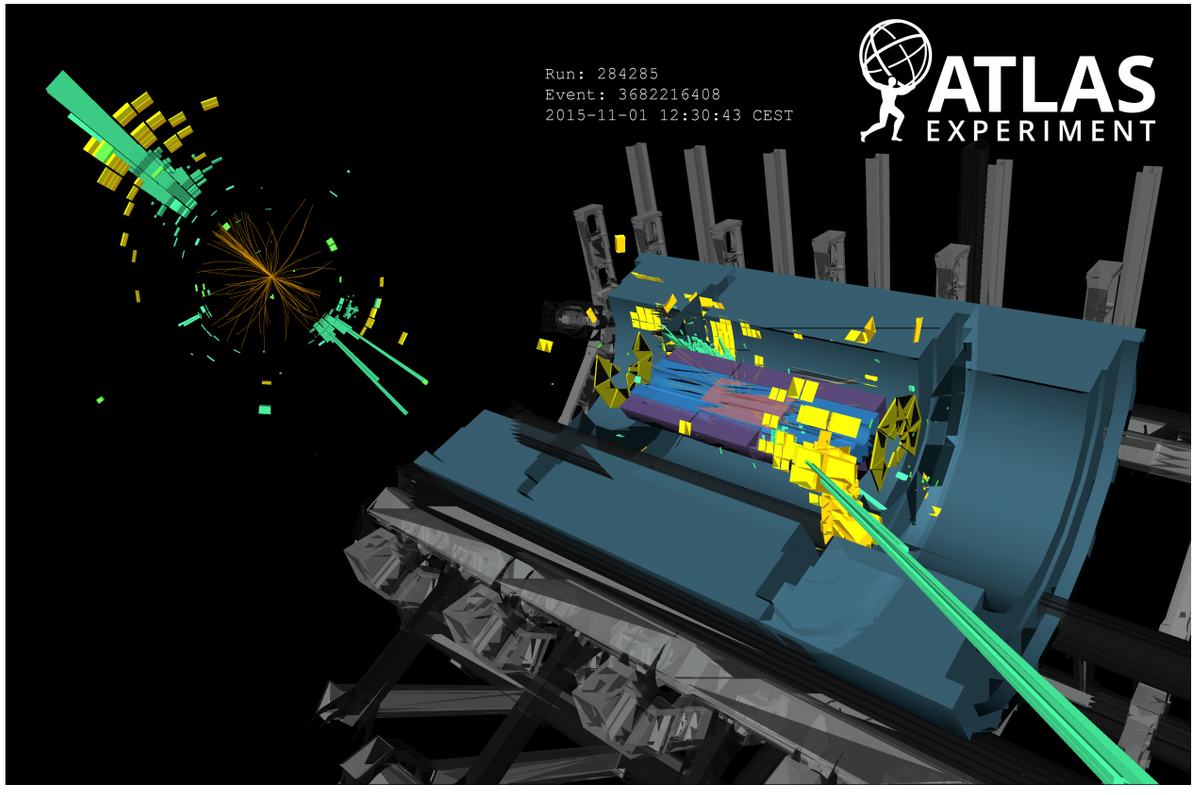
	BR($t \to uZ$)	BR($t \to cZ$)
Observed	1.7×10^{-4}	2.3×10^{-4}
Expected -1σ	1.7×10^{-4}	2.2×10^{-4}
Expected	2.4×10^{-4}	3.2×10^{-4}
Expected $+1\sigma$	3.5×10^{-4}	4.6×10^{-4}

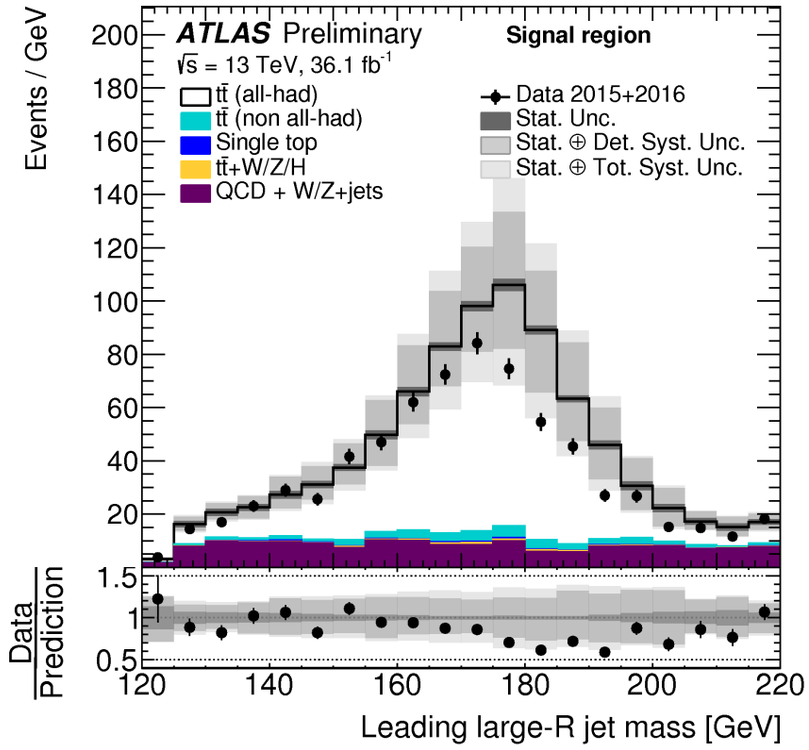
- Data are consistent with SM
- Constitutes the most stringent limits on this process to date

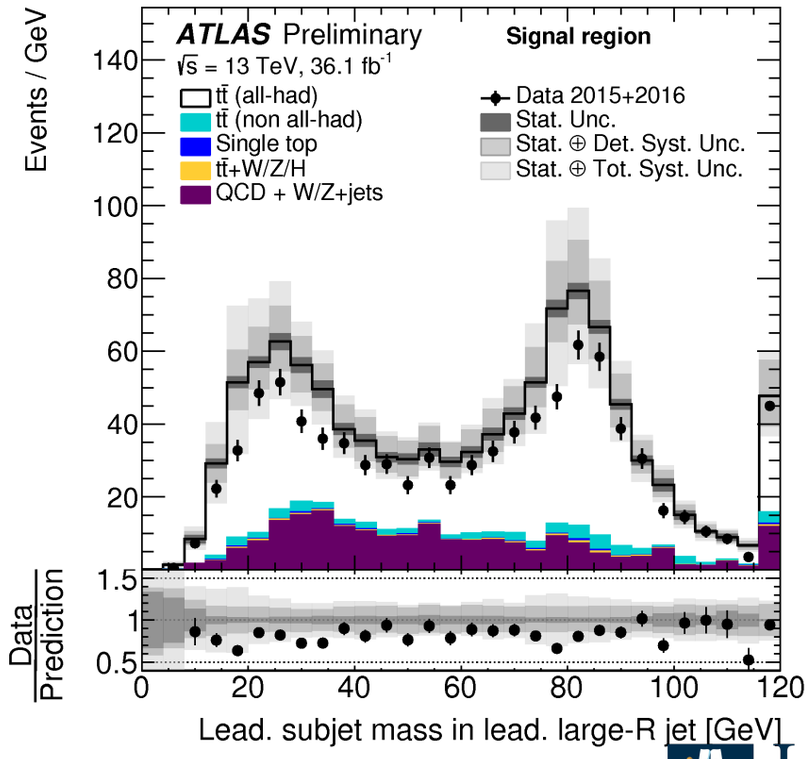
ATLAS-CONF-2017-070

tt cross section (all-hadronic)

- Boosted top quark pairs: R=1.0 jets
- Top candidates: p_T > 500GeV, 350GeV
- Top-tagger with cuts depending on calibrated jet mass and n-subjettiness
- Enhance top purity by requiring 1 small b-tagged jet associated with each candidate
- Uses 36fb^{-1} data from 2015+2016



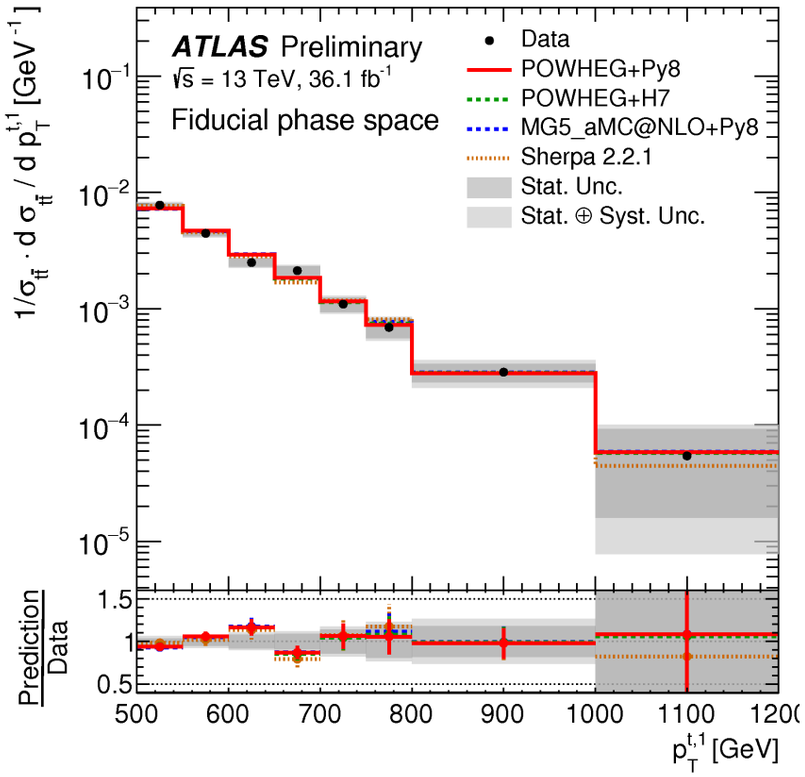


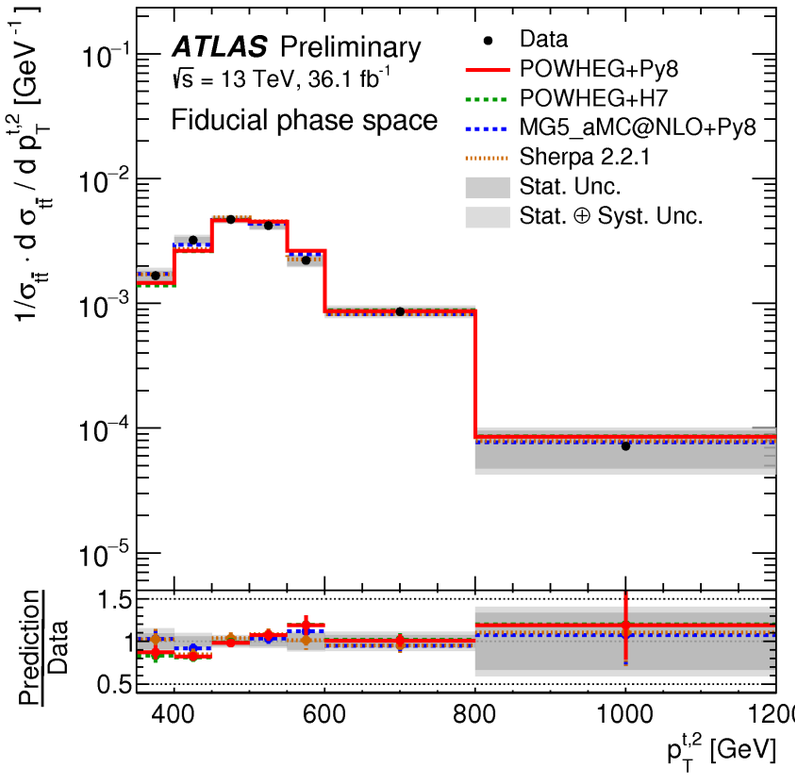


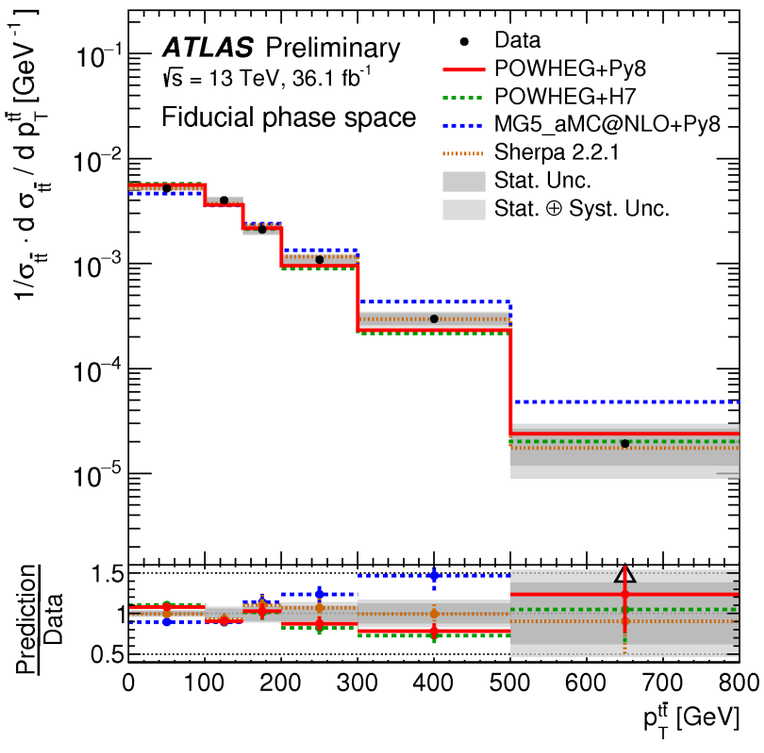
ATLAS-CONF-2016-100

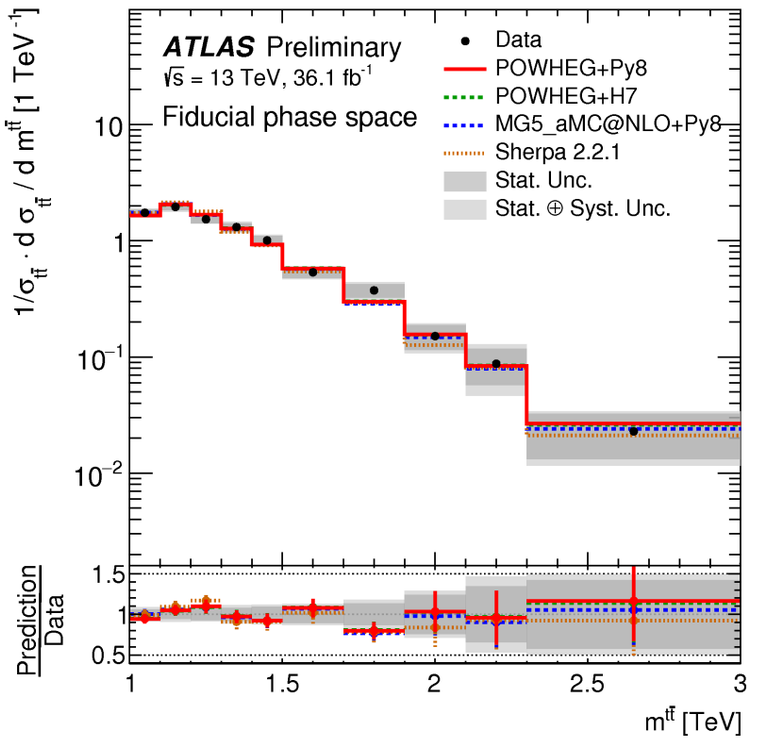
tt cross section (all-hadronic)

- Kinematic distributions are unfolded to recover the differential cross-sections
- Compared with SM predictions







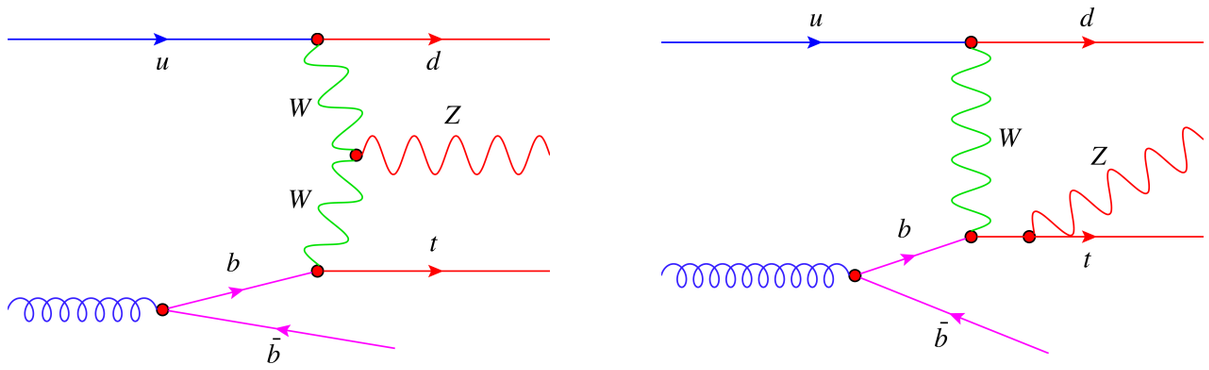


Measured cross section:

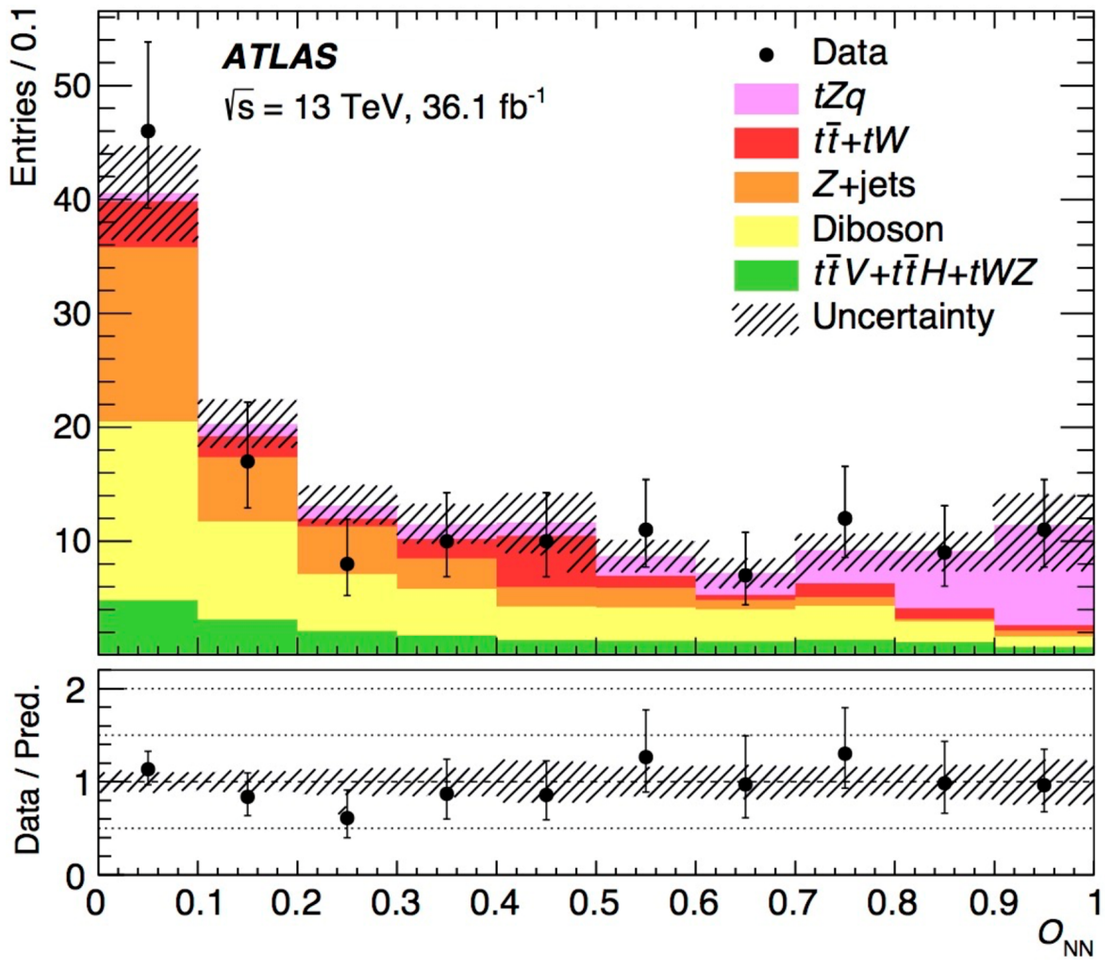
292 ± 7 (stat) ± 76 (syst) fb

All predictions are above the measured cross-section by ~30%, in agreement to within ~1σ

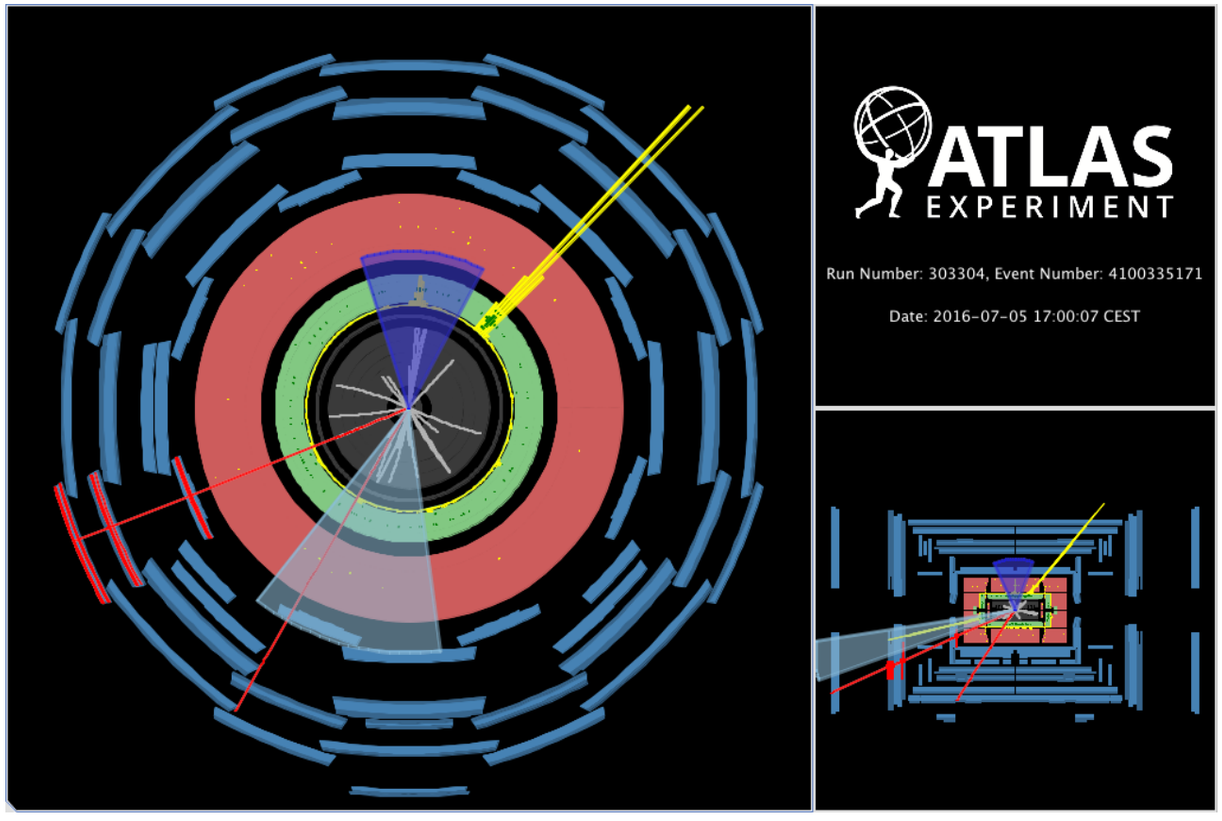
Associated Single Top Production



arXiv:1710.03659



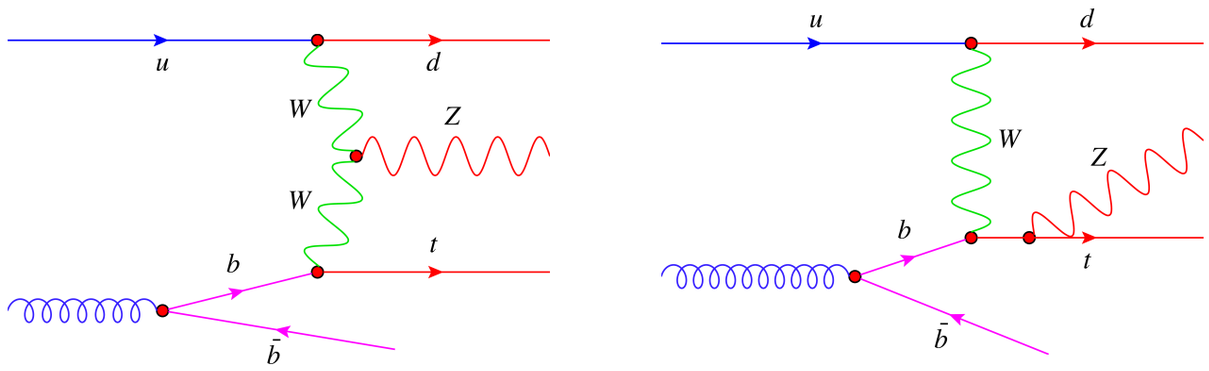
- Select events with 3 leptons and two jets (1 b-tagged)



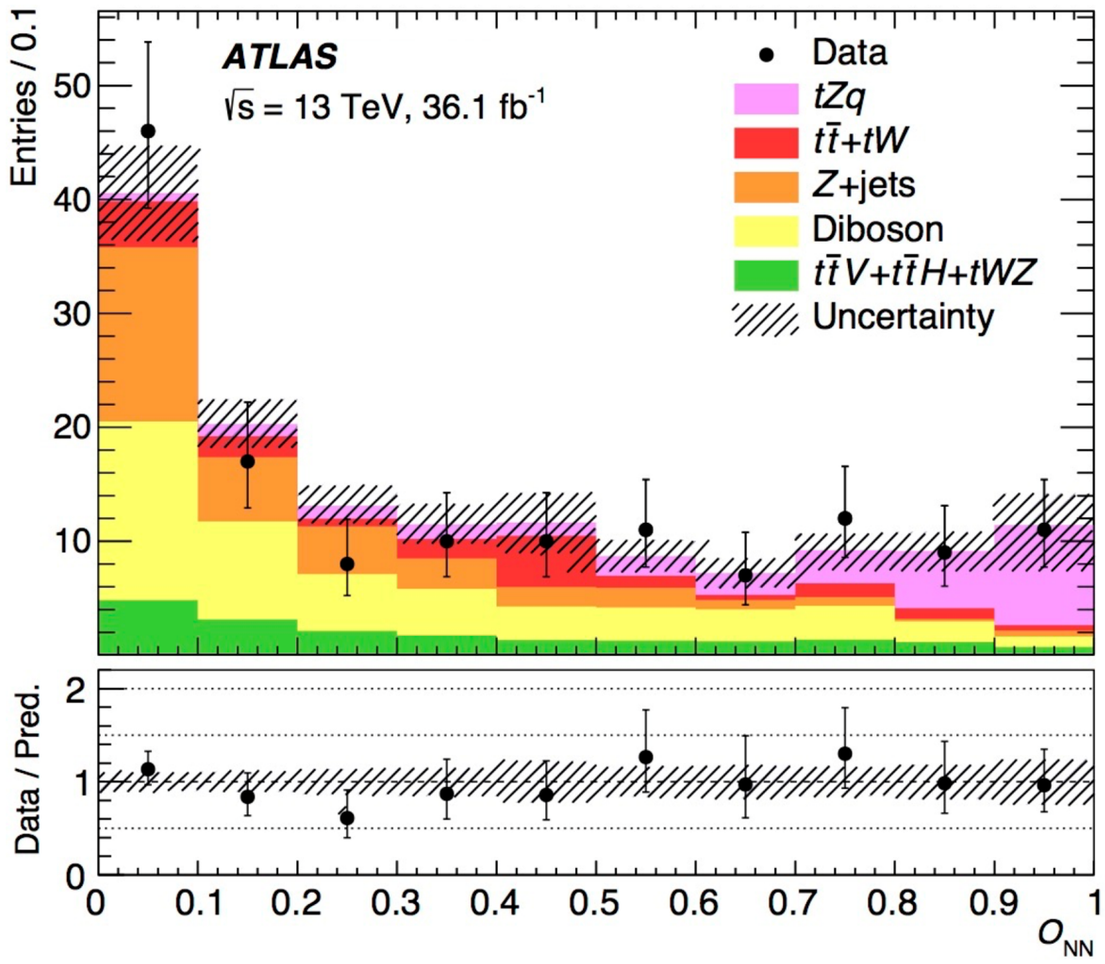
Evidence for signal obtained with a measured (expected) significance of 4.2σ (5.4σ)

Measured cross section:
600 ± 170 (stat) ± 140 (syst) fb

Associated Single Top Production



arXiv:1710.03659



- Select events with 3 leptons and two jets (1 b-tagged)
- Major backgrounds:
  - diboson
  - tt, Z+jets: through fake leptons
  - Determined from combination of MC and DD methods
- Use a neural network to improve background rejection and extract signal

predicted cross section: 800 ± $^{6.1}_{7.4}$ fb

Evidence for signal obtained with a measured (expected) significance of 4.2σ (5.4σ)

Measured cross section:
600 ± 170 (stat) ± 140 (syst) fb

Conclusion

- Comprehensive program at ATLAS to measure and understand the production of $t\bar{t}$ and single top

- Precise measurements of the top quark mass and properties may provide insights on the underlying mechanism for EWSB and the role the top quark plays in it

- Using newest data to probe rarer processes:
  - Search for FCNC $t \rightarrow qZ$ decays
  - Using high branching ratio of all-hadronic to study high-pT tt cross section
  - First evidence of tZq process shown

- All measurements consistent with SM predictions

Thank you for listening!

BACK UP