MANCHESTER 1824
The University of Manchester

Top-quark cross-section results at the LHC

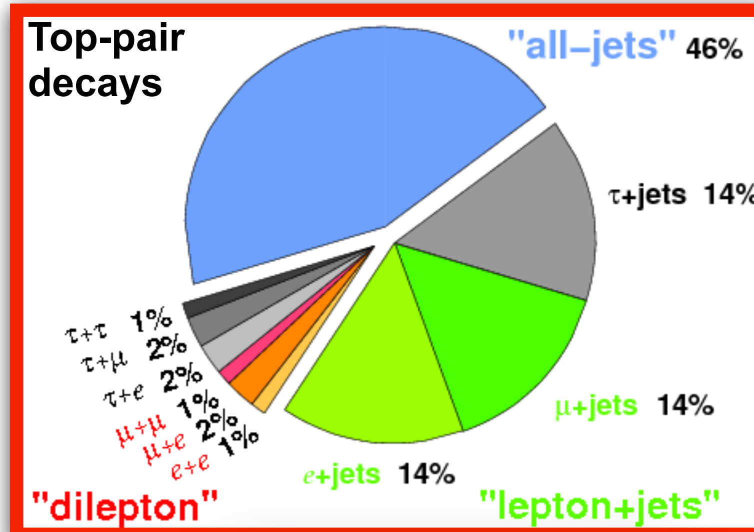
Ian Connelly
on behalf of the ATLAS and CMS Collaborations

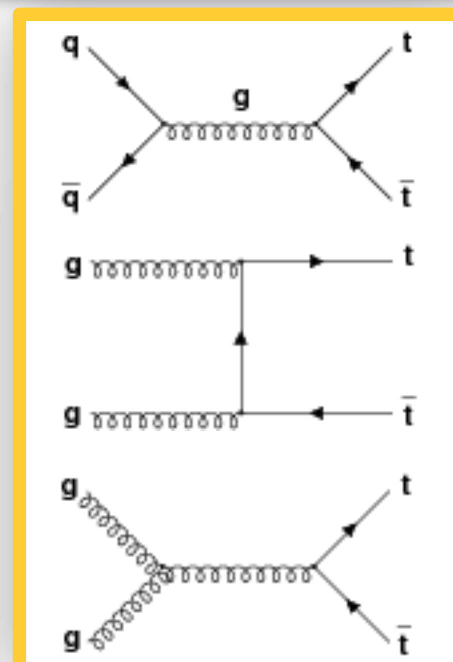
SM@LHC, Berlin, April 2018

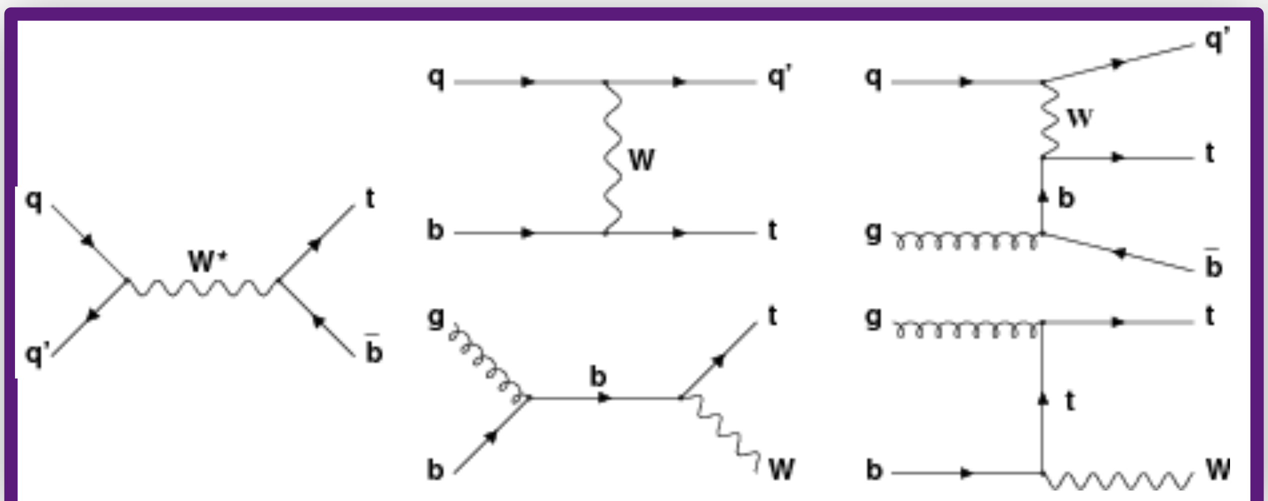
Why study top quark production?

MANCHESTER 1824
The University of Manchester

- The most **massive** fundamental particle
- Largest coupling to the Higgs boson
- Many final state signatures
  - Background to searches
- Provides a powerful test of the Standard Model
  - **t→Wb** ∴ signatures from W decays
  - Strong and **electroweak** production





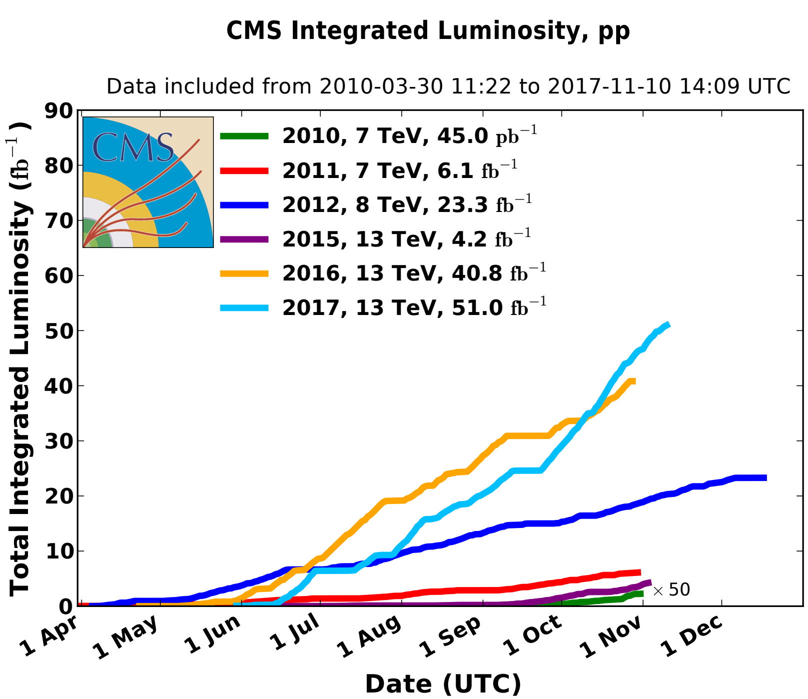


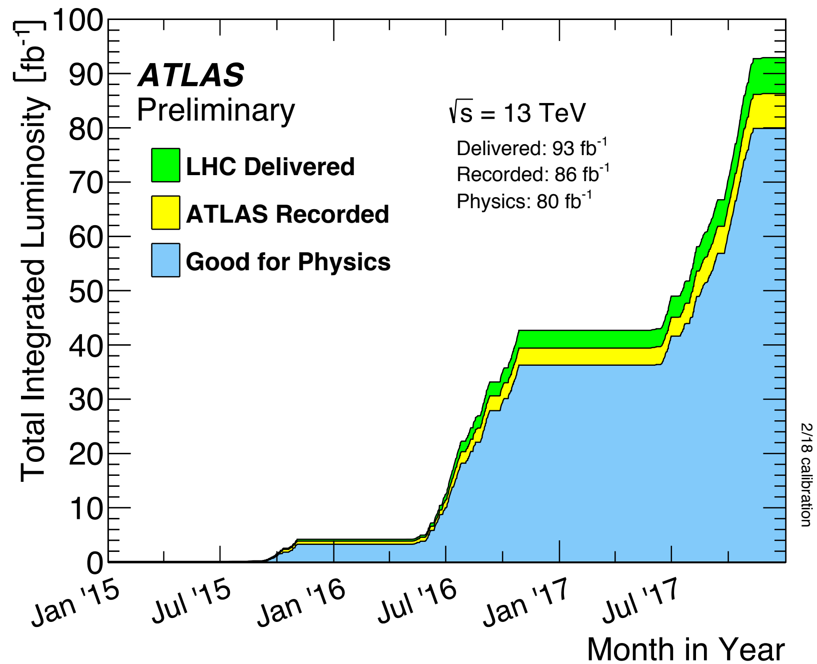
Top quark production @ LHC

MANCHESTER 1824
The University of Manchester

- The LHC is a top factory!
- Delivered ~80M top-pair events to each experiment at 13 TeV
- Huge dataset to analyse

Run 2 Data Taking Year	Cumulative Top-Pair Events	Cumulative Single-Top Events
2015	3.5M	1.2M
2016	34M	13M
2017	80M	29M





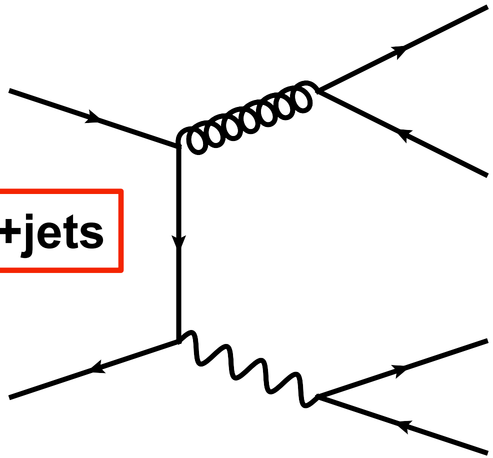
Background Processes

MANCHESTER 1824
The University of Manchester

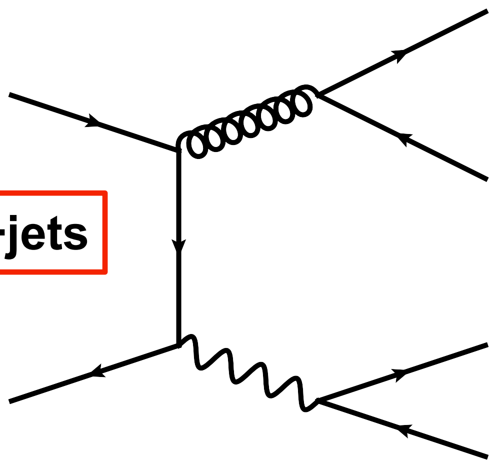
top-pair

single-top (t, s, Wt)

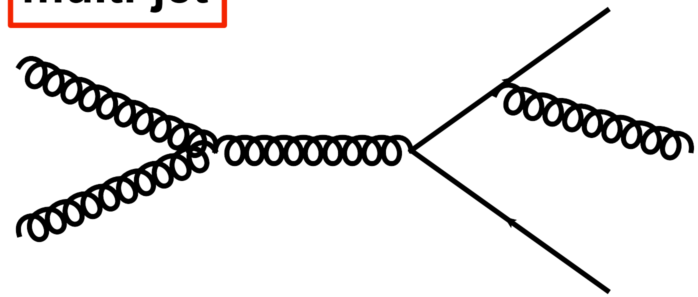
W+jets



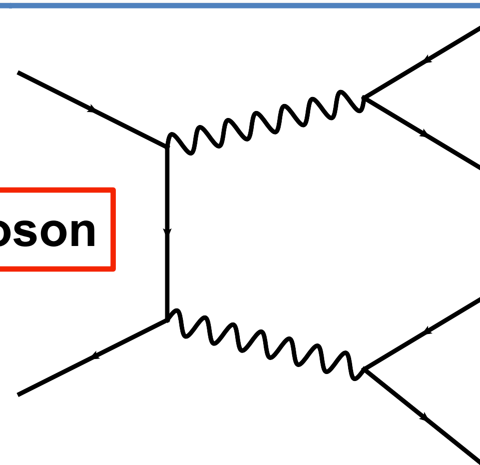
Z+jets



multi-jet



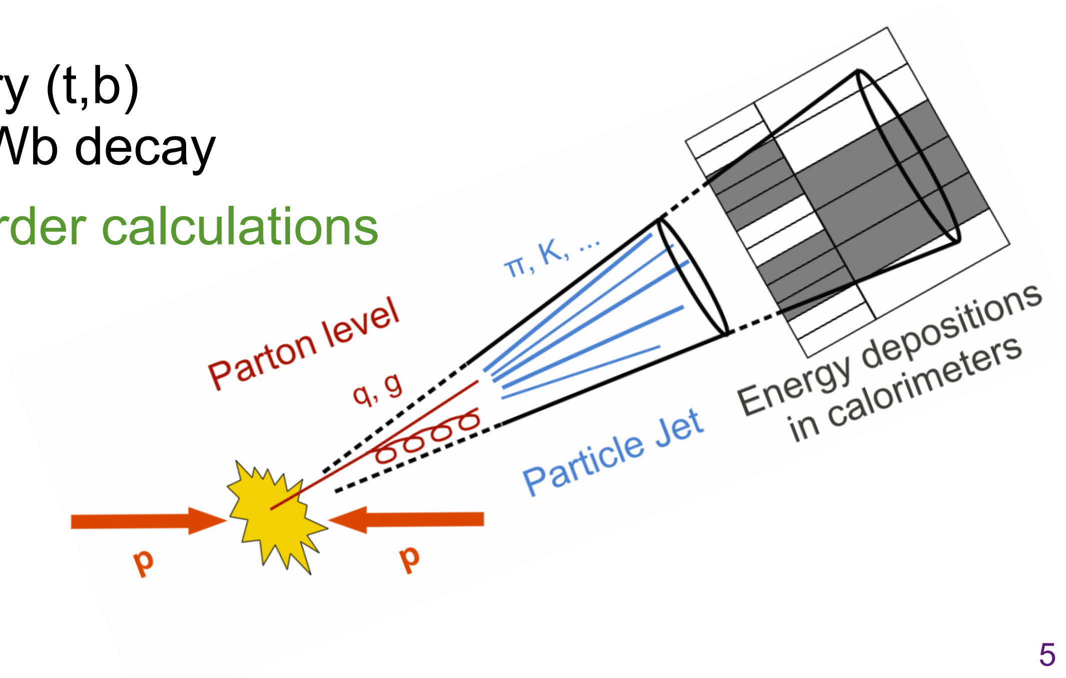
diboson



Cross-section measurements

MANCHESTER
1824
The University of Manchester

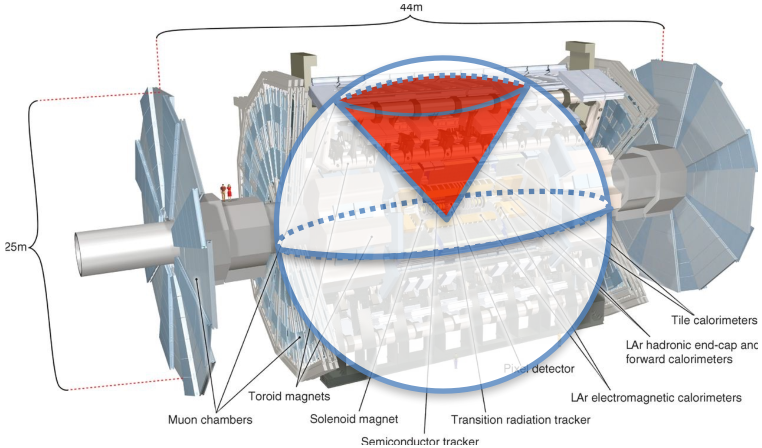
- **Detector level**
  - Select events corresponding to final state signature using reconstructed objects
- **Particle level**
  - Jets constructed from stable particles, dressed leptons, etc
  - Apply ~same selection with these objects
  - Can be used to improve top modelling
- **Parton level**
  - Typically quarks in MC history (t,b) after QCD radiation, before Wb decay
  - Easier to compare to fixed-order calculations



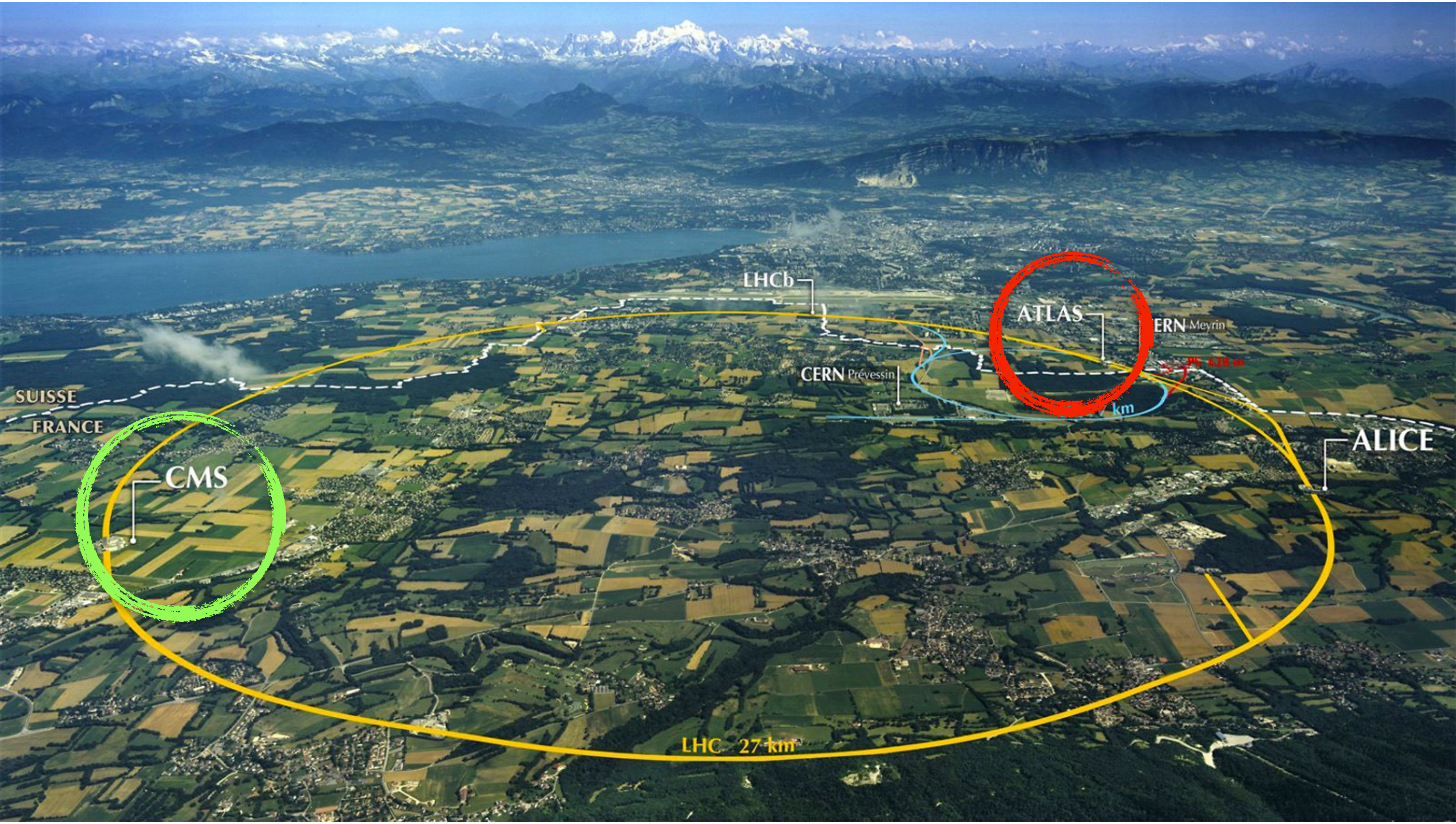
Cross-section measurements

MANCHESTER 1824 The University of Manchester

- **Fiducial cross-section**
  - Extract number of observed events by subtracting background estimate
  - Correct total number of events by selection efficiency
  - Less model dependent, smaller extrapolations
- **Total cross-section**
  - Correct fiducial cross-section by the fiducial acceptance and branching fractions
  - Remove channel and selection dependence
  - Easy and broad interpretation



The experiments



Inclusive cross-sections

Inclusive - σ_{tt}

8 TeV [20.2 fb^{-1}] lepton + jets

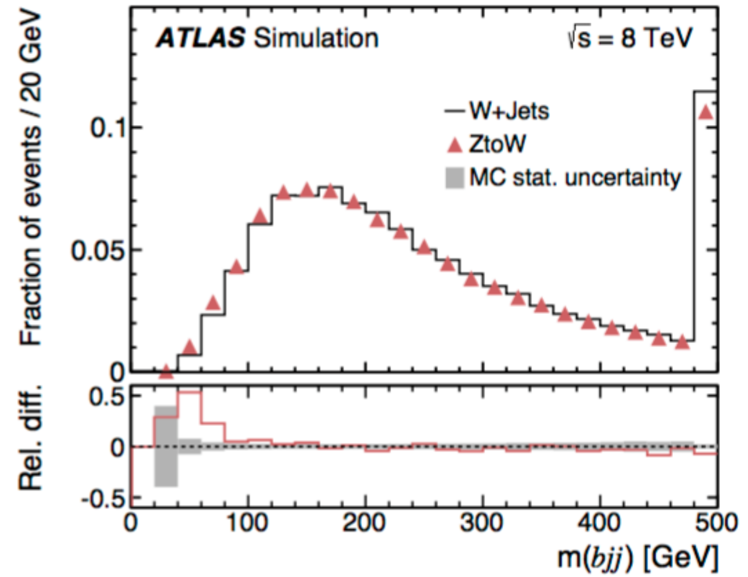
ATLAS EXPERIMENT

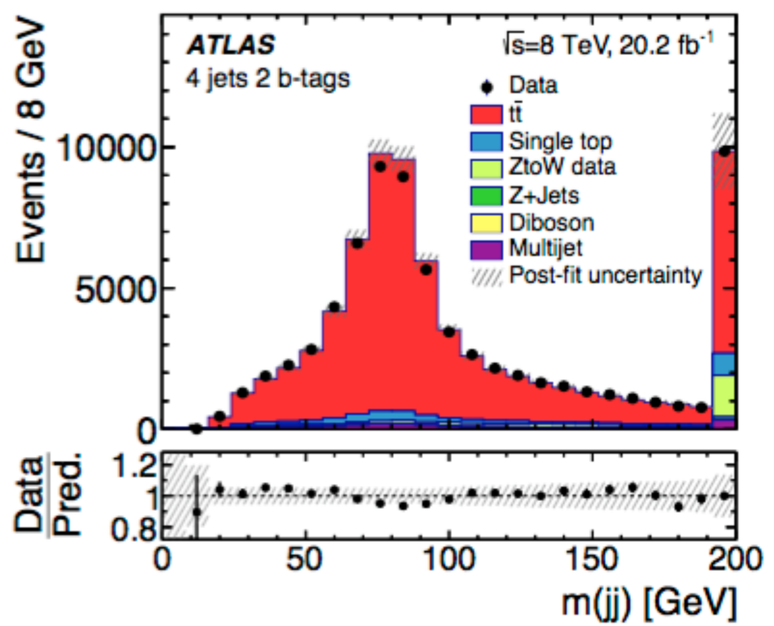
MANCHESTER 1824 The University of Manchester

- **Lepton+jets measurement**
  - Enhance fraction of leptonic W-decays

$$m_{\mathrm{T}}(W) = \sqrt{2p_{\mathrm{T}}(\ell) \cdot E_{\mathrm{T}}^{\mathrm{miss}} \left[1 - \cos\left(\Delta\phi\left(\vec{\ell}, \vec{E}_{\mathrm{T}}^{\mathrm{miss}}\right)\right)\right]} \; > \; 30\,\mathrm{GeV},$$

  - Z+jets data events used to model W+jets
- **Binned maximum-$\mathscr{L}$ fit with three regions**
  - Separate signal and background (NN)
  - Control W+jets background (β^{tt}, β^{W_i})
  - Fit b-tagging and JES uncertainties
- **Dominant uncertainties**
  - Top modelling, JES, lepton ID/trigger, lumi
    - Range from 1-3%





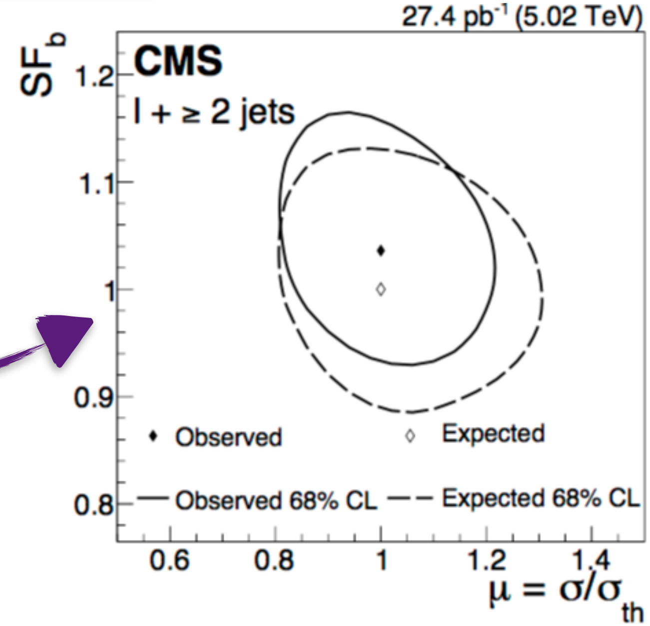
$\sigma_{fid}(tt) = 48.8 \pm 0.1 \pm 2.0 \pm 0.9$ pb
$\sigma_{inc}(tt) = 248.3 \pm 0.7 \pm 13.4 \pm 4.7$ pb

arXiv:1712.06857

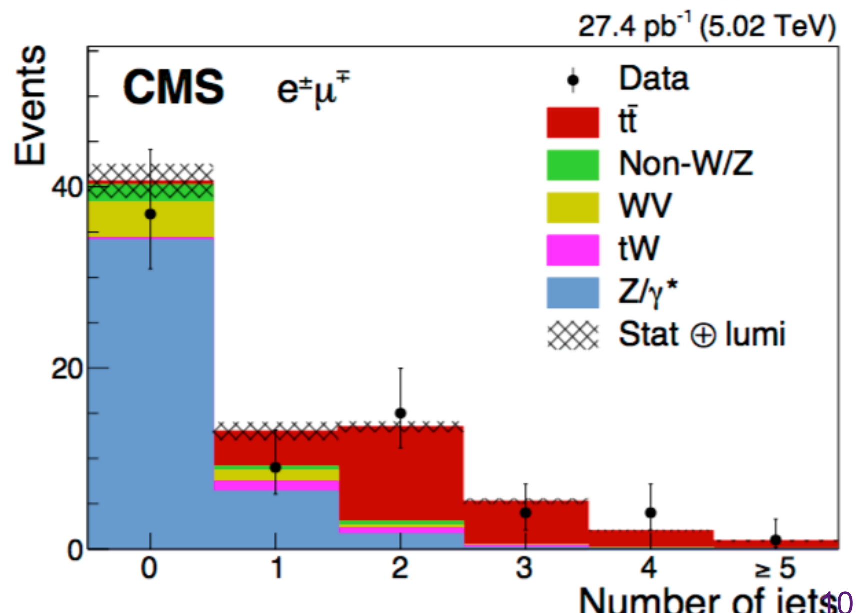
Inclusive - σ_{tt}

5.02 TeV [27.4 pb^{-1}]
≥ 1 lepton

- **Select events with ≥ 1 lepton and ≥ 2 b-jets**
  - Separate b-jet multiplicity to control backgrounds (W/Z+jets, QCD)
  - Data-driven QCD and Z+jets normalisation
- **Profiled likelihood fit in lepton+jets channel**
  - Fit cross-section and b-tagging scale factor simultaneously
- **Event counting in dilepton channel**
  - Split into eμ and μμ channels
- **Statistical and systematic uncertainties comparable**
  - Cross-sections measured in fiducial region and extrapolated to inclusive phase-space
  - Combined using BLUE



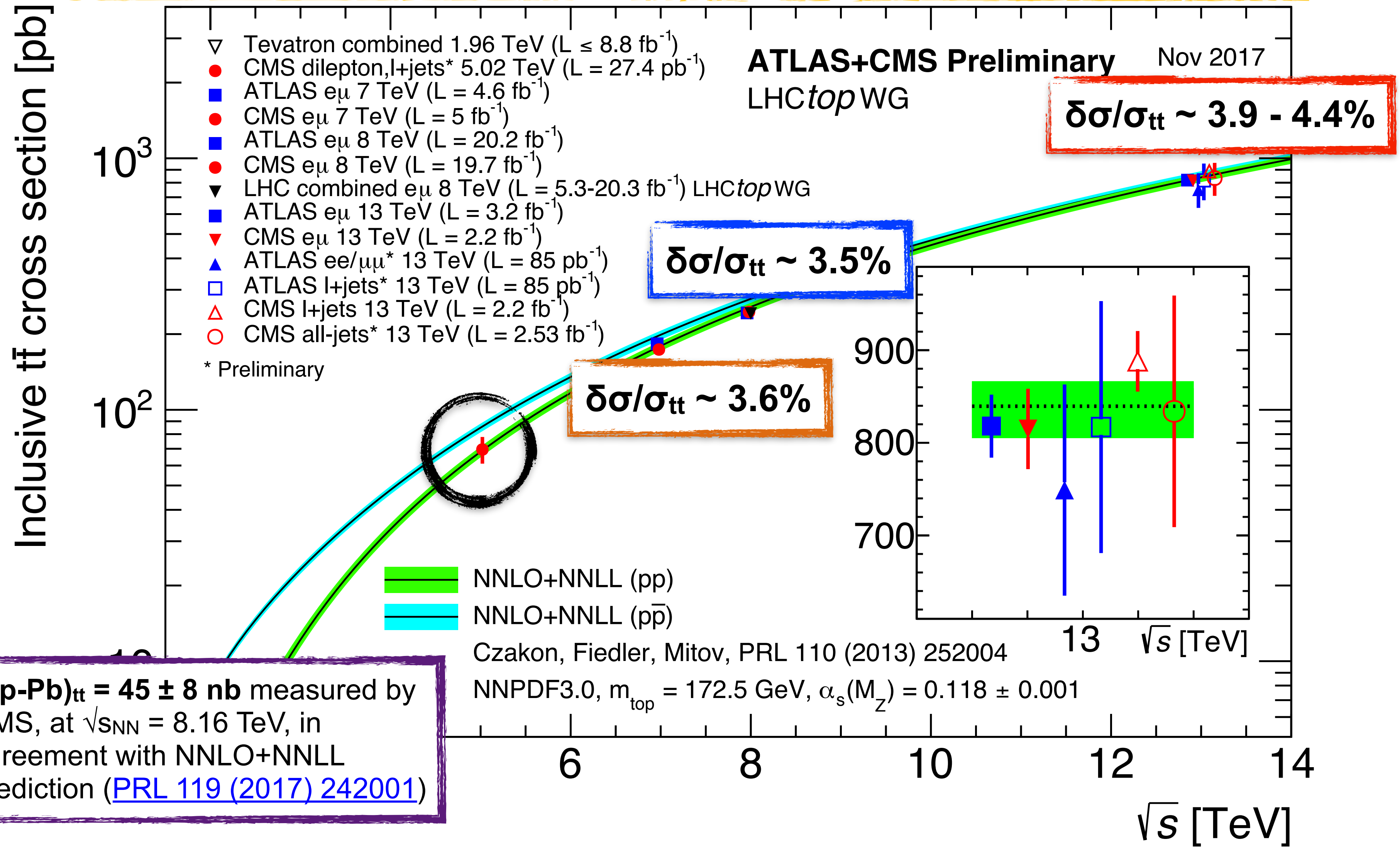
$\sigma_{inc}(tt)$ = 69.5 ± 8.4 pb



arXiv:1711.03143

Inclusive - $\sigma_{tt}(\sqrt{s})$

Measured at all LHC energies and dependence with √s is well understood

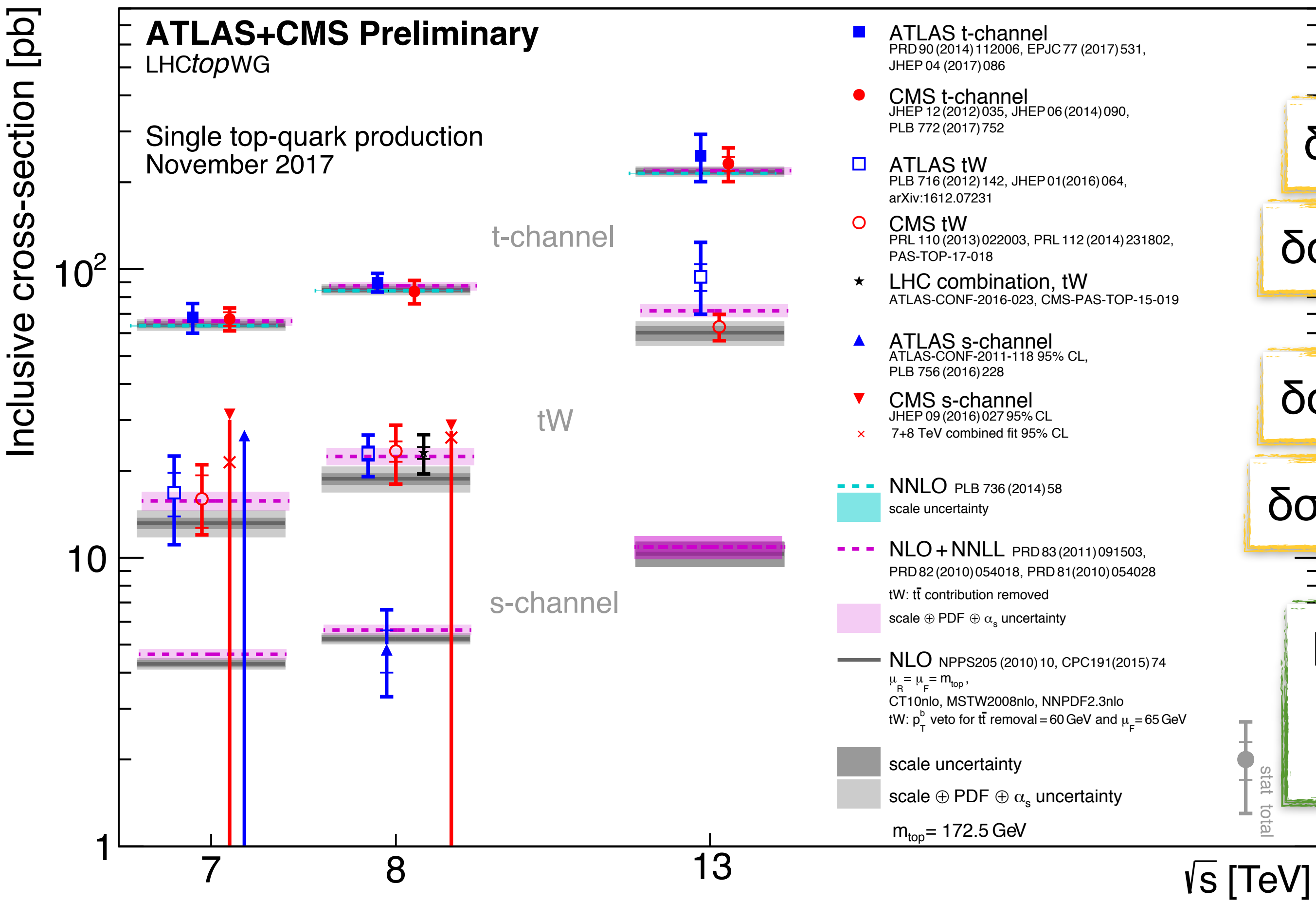


$\sigma(p\text{-}Pb)_{tt}$ = 45 ± 8 nb measured by CMS, at $\sqrt{s_{NN}}$ = 8.16 TeV, in agreement with NNLO+NNLL prediction (PRL 119 (2017) 242001)

Summary plots

Inclusive - $\sigma_t(\sqrt{s})$

Measurements dominated by **systematic** uncertainties
Good agreement with high precision theoretical predictions



$\delta\sigma/\sigma_{t\text{-chan}}$ (8 TeV) ~ 9%

$\delta\sigma/\sigma_{t\text{-chan}}$ (13 TeV) ~ 20%

$\delta\sigma/\sigma_{tW\text{-chan}}$ (8 TeV) ~ 16%

$\delta\sigma/\sigma_{tW\text{-chan}}$ (13 TeV) ~ 31%

Evidence of s-channel production at the LHC at 8 TeV

Summary plots

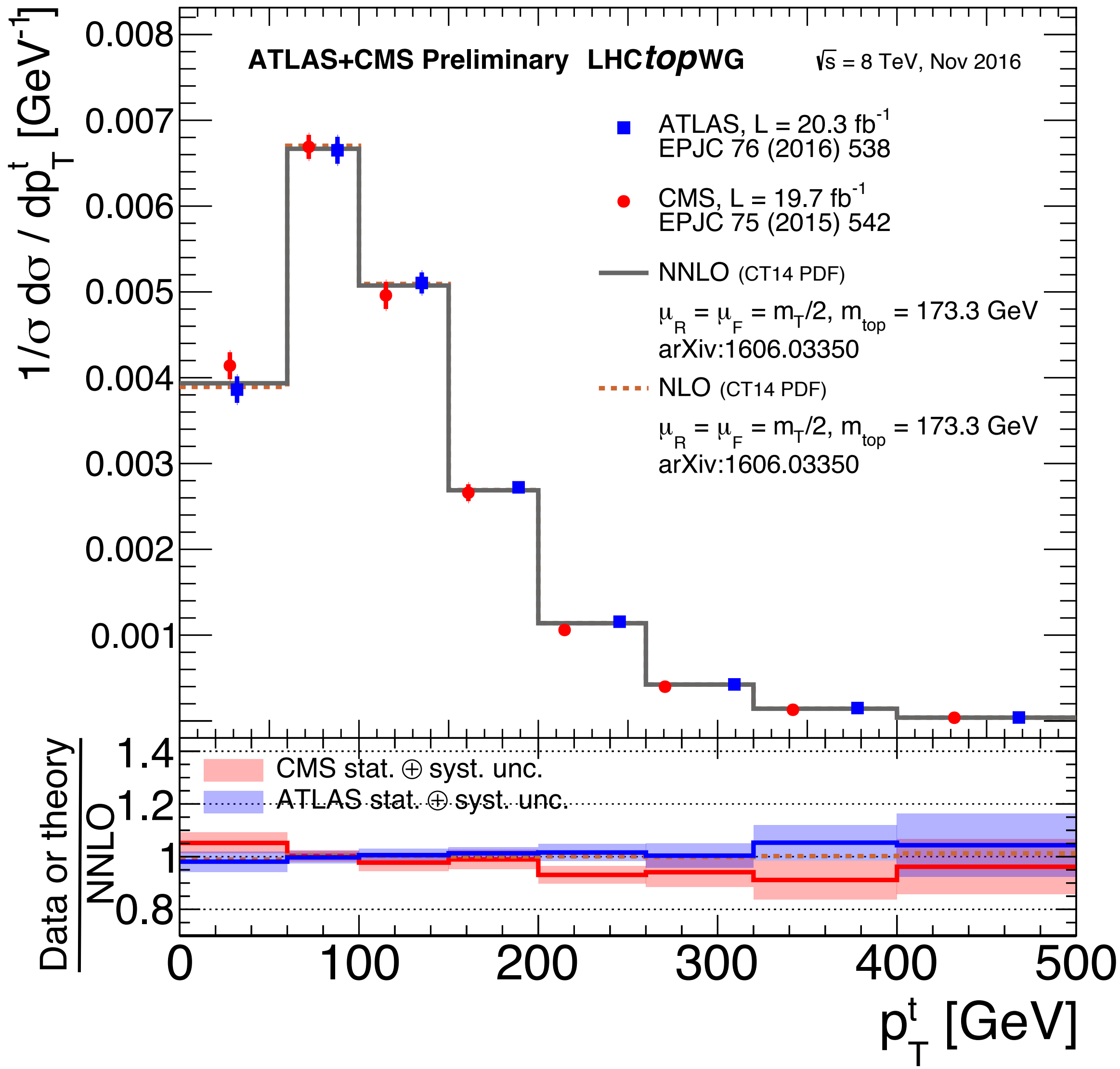
Differential cross-sections

Top p_T discrepancy

Generally accepted that current NLO generators are not modelling top kinematics particularly well

In particular, top p_T has shown to be poorly modelling between different generators

Double differential measurements can provide insight into where the dominant mismodelling may originate.

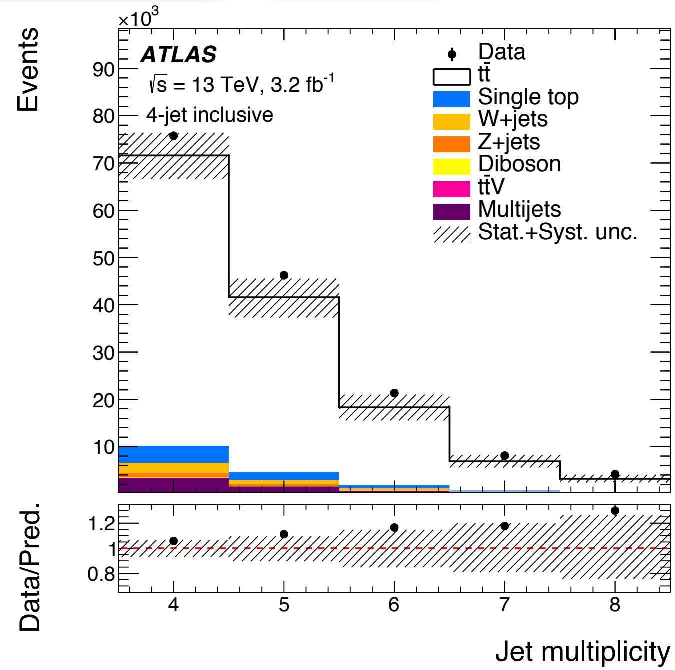


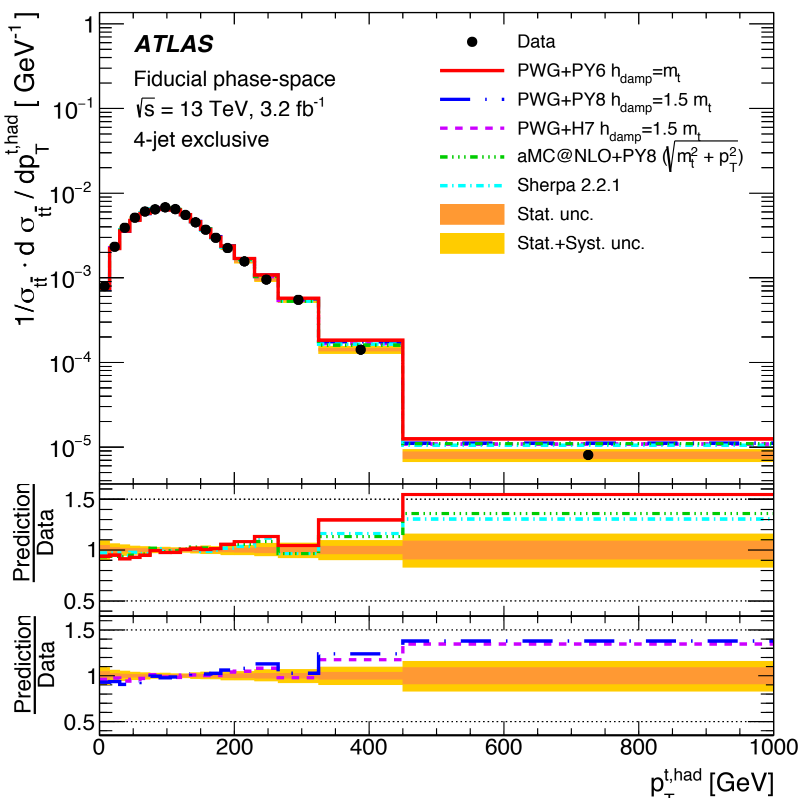
[Summary plots]

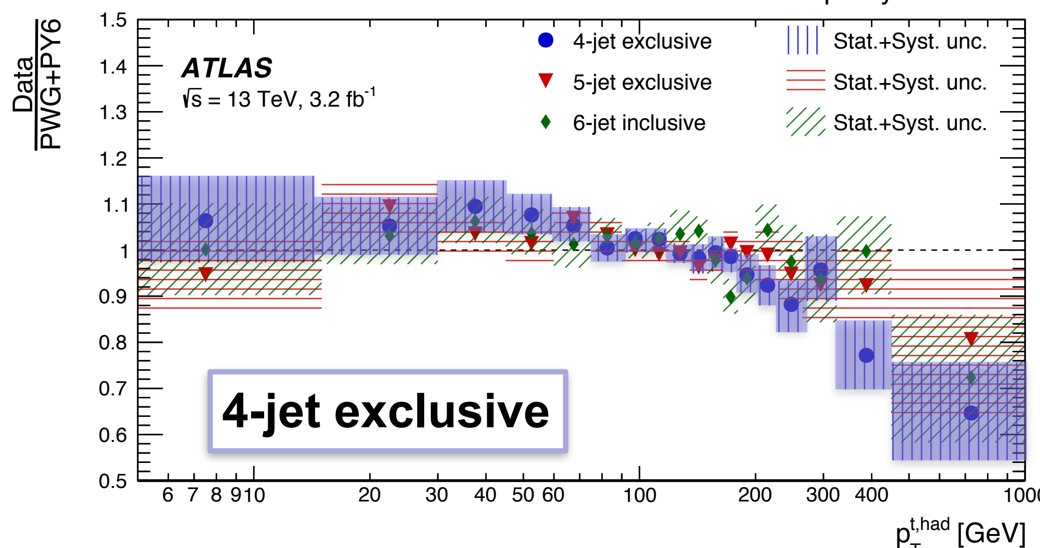
Differential - $\sigma_{tt+jets}$

13 TeV [3.2 fb^{-1}] lepton + jets

- **Differential in bins of jet multiplicity**
  - Particle level measurements
  - Slope in 4-jet exclusive where modelling is dominated by NLO matrix elements





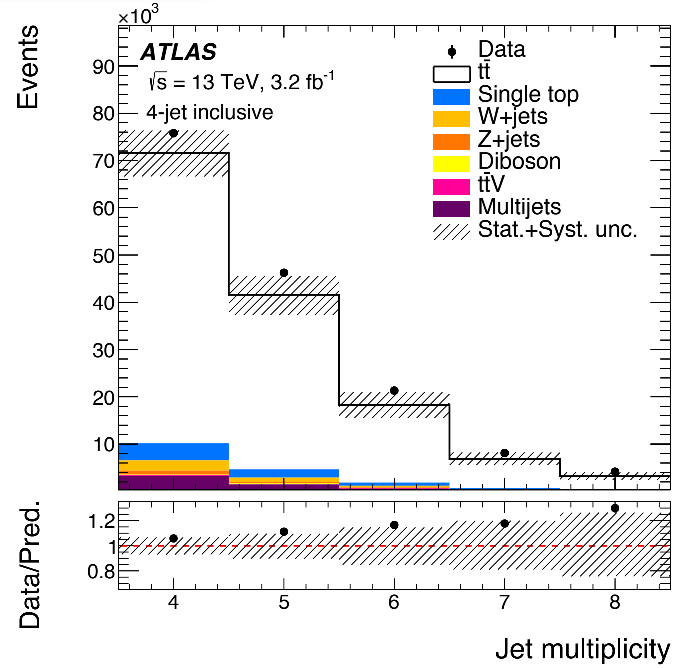


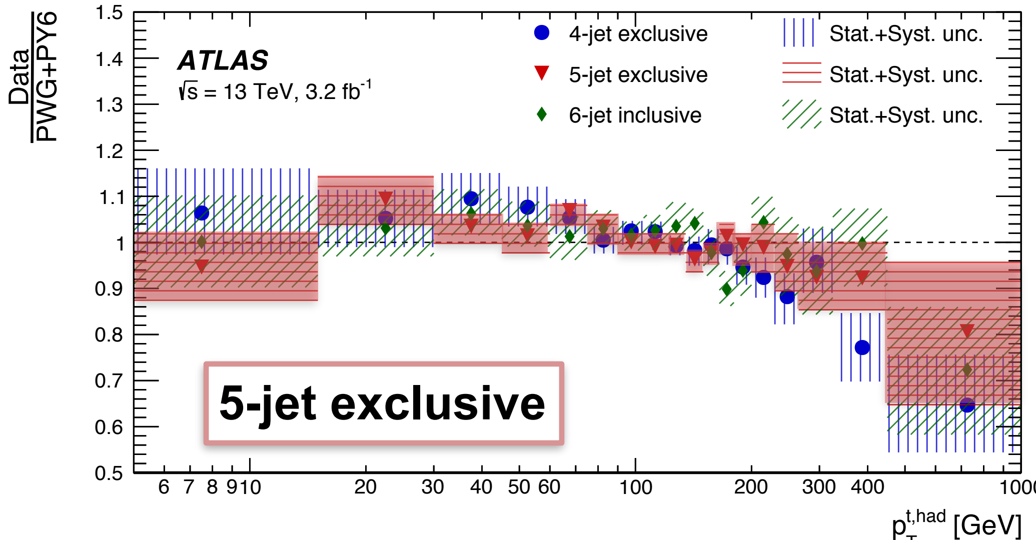
[arXiv:1802.06572](https://arxiv.org/abs/1802.06572)

Differential - $\sigma_{tt+jets}$

13 TeV [3.2 fb^{-1}]
lepton + jets

- **Differential in bins of jet multiplicity**
  - Particle level measurements
  - Less pronounced slope in 5-jet exclusive, where modelling starts to have some parton shower dependence



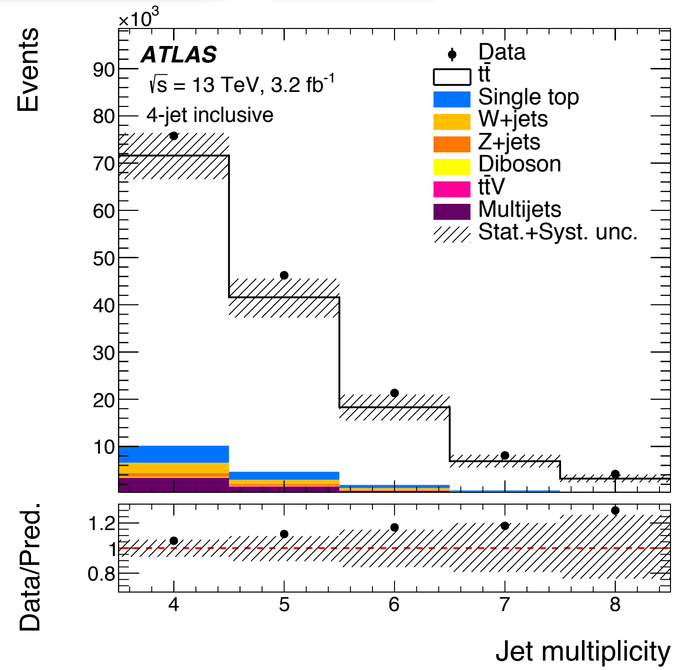


arXiv:1802.06572

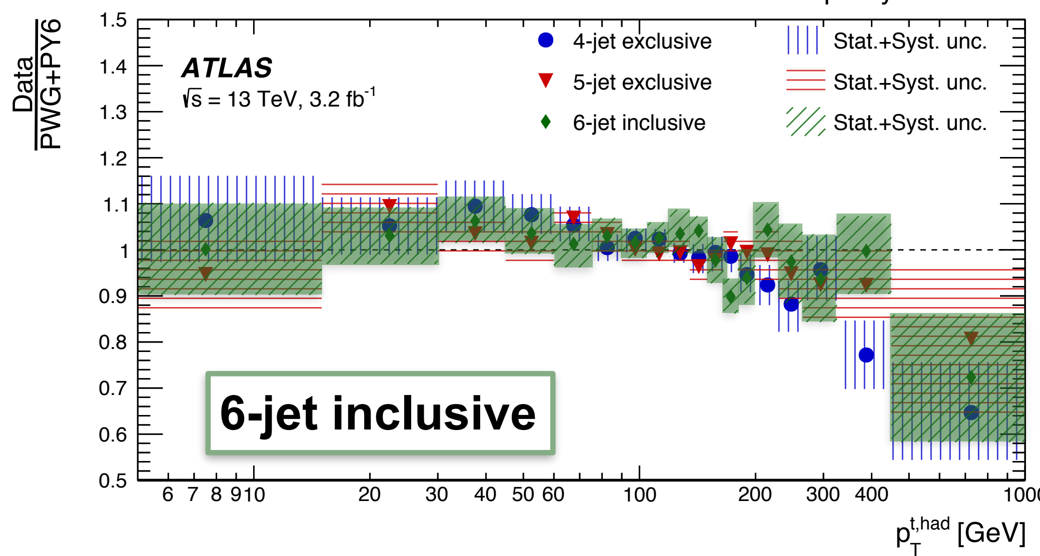
Differential - $\sigma_{tt+jets}$

13 TeV [3.2 fb^{-1}]
lepton + jets

- **Differential in bins of jet multiplicity**
  - Particle level measurements
  - Slope in 6-jet inclusive almost flat (except last bin), where the modelling is dominated by parton shower
  - Could be result of tuning



Interesting as NLO generators should be providing NLO precision on top pT



[arXiv:1802.06572](https://arxiv.org/abs/1802.06572)

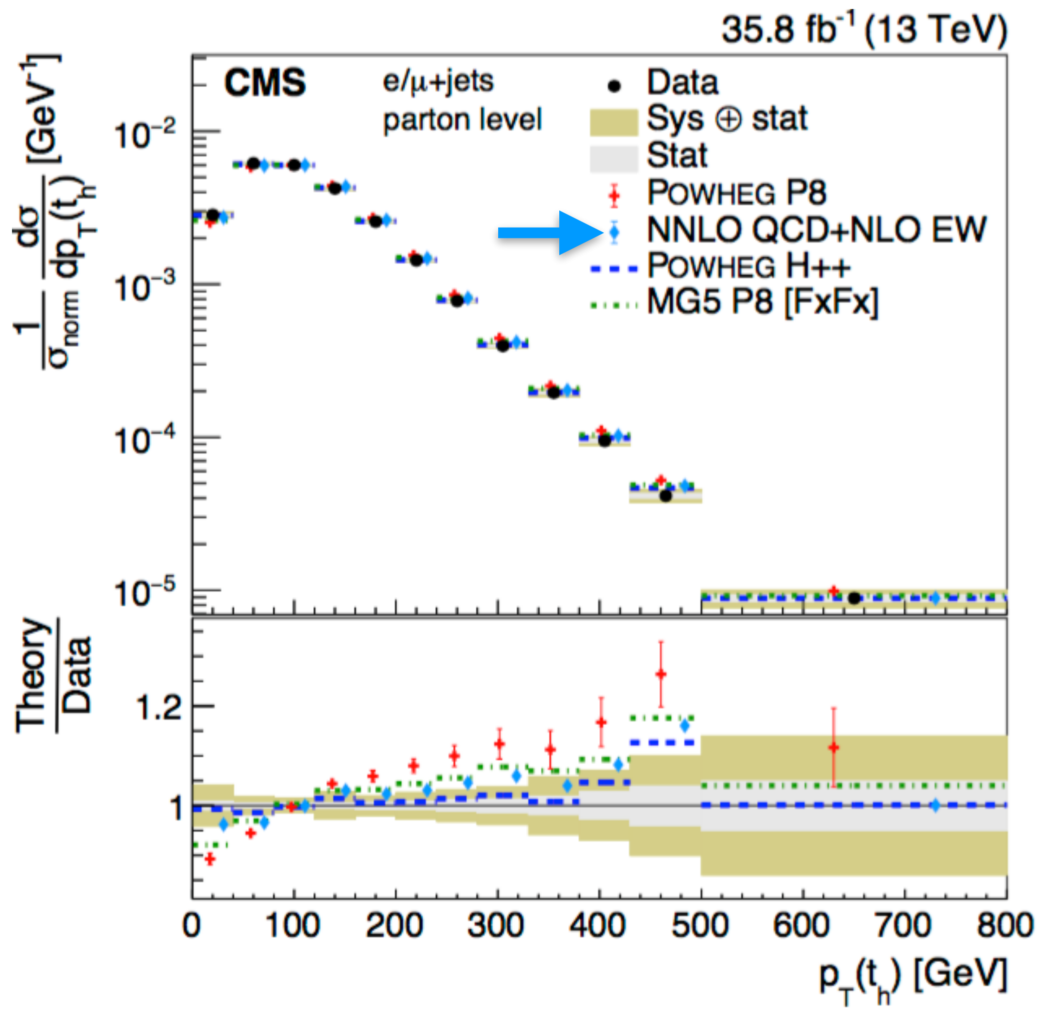
Differential - $\sigma_{tt+jets}$

13 TeV [35.8 fb^{-1}] lepton + jets

MANCHESTER 1824
The University of Manchester

- **Single and double-differential cross-sections**
  - Parton and particle level measurements
  - First comparison with **NNLO(QCD)+NLO(EW)**
  - Shows a slightly harder p_T spectrum than data, but good agreement within the errors
  - Double differential results

Distribution	χ^2/dof	p-value	χ^2/dof	p-value	χ^2/dof	p-value
	POWHEG+P8 with unc.		POWHEG+P8		NNLO QCD+NLO EW	
$p_T(t_h)$	16.1/11	0.138	22.9/11	0.018	4.99/11	0.932



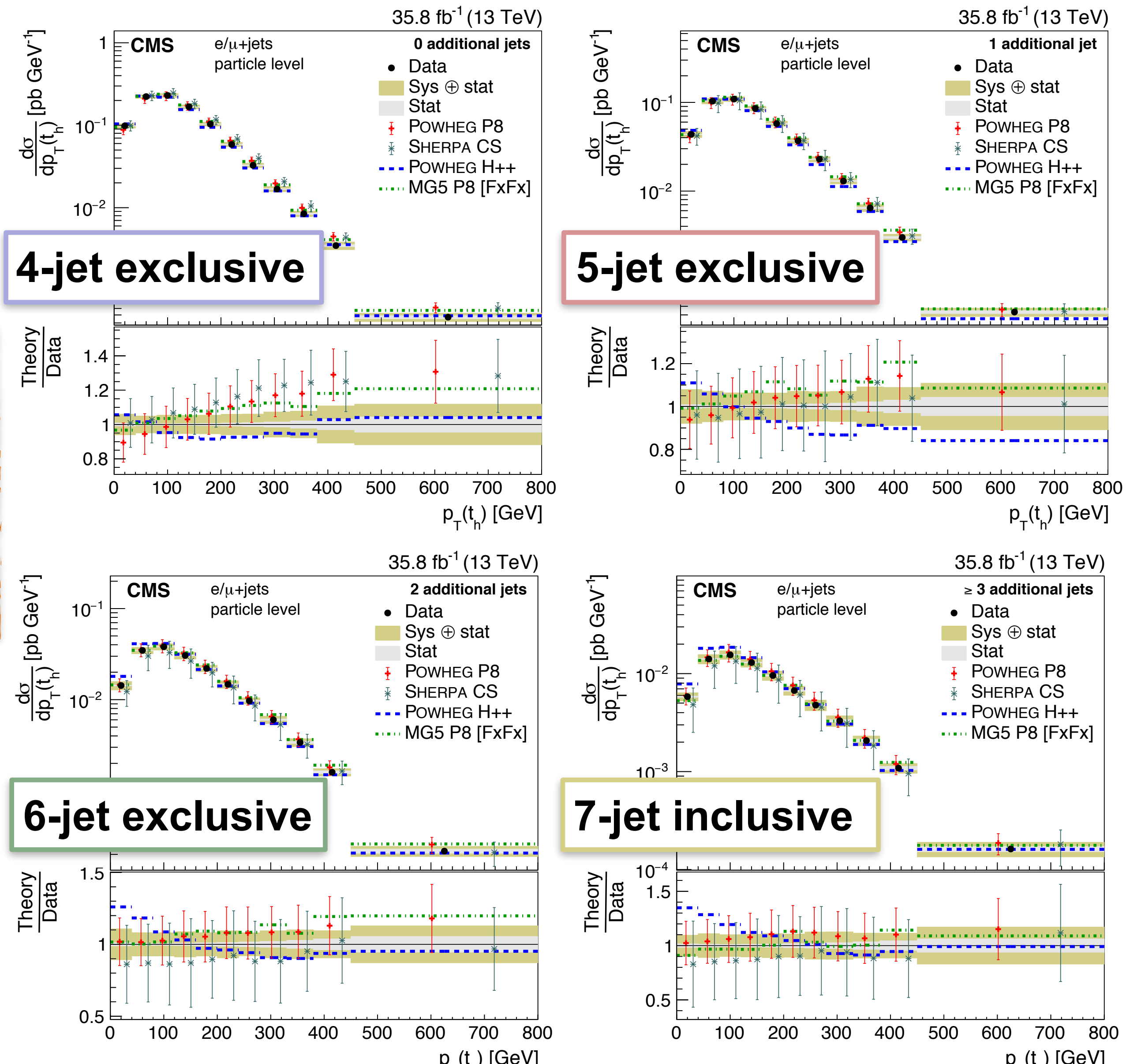
vs.	$p_T(t_h)$	y(tt)	M(tt)	N_{Jets}
$y(t_h)$	x			
M(tt)		x		x
$p_T(t_h)$			x	x
p_T(tt)				x

arXiv:1803.08856

Differential - $\sigma_{tt+jets}$

13 TeV [35.8 fb^{-1}]
lepton + jets

The University of Manchester



Behaviour of top p_T across jet multiplicities appears consistent between ATLAS and CMS

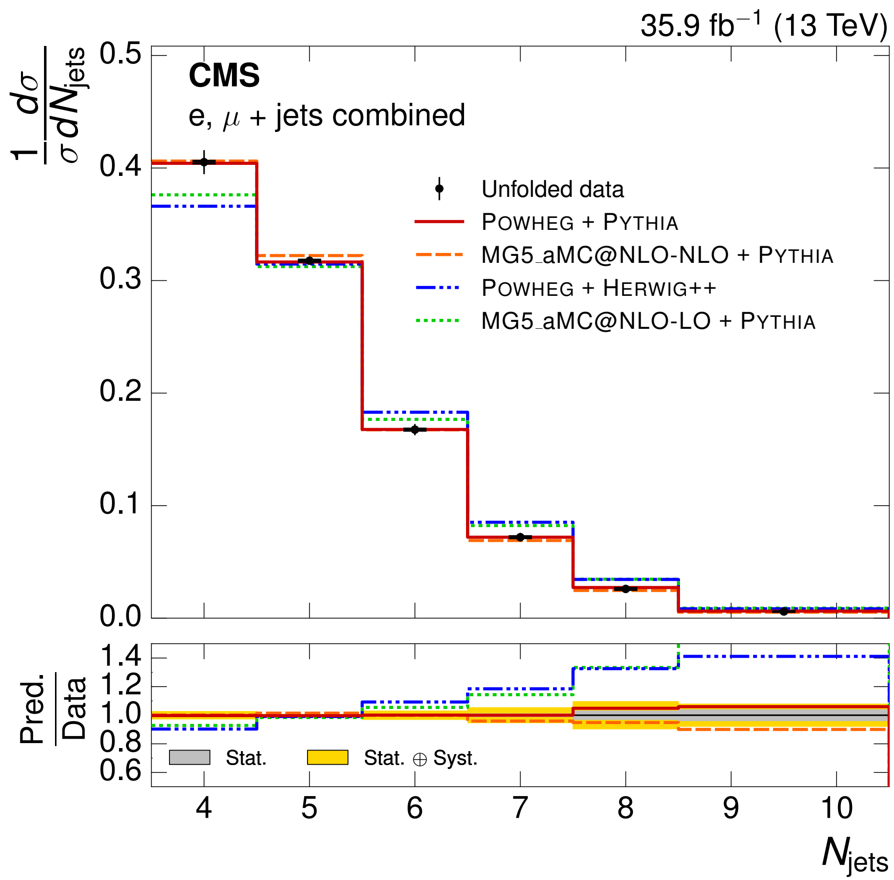
NB: Ratio is inverted compared to ATLAS

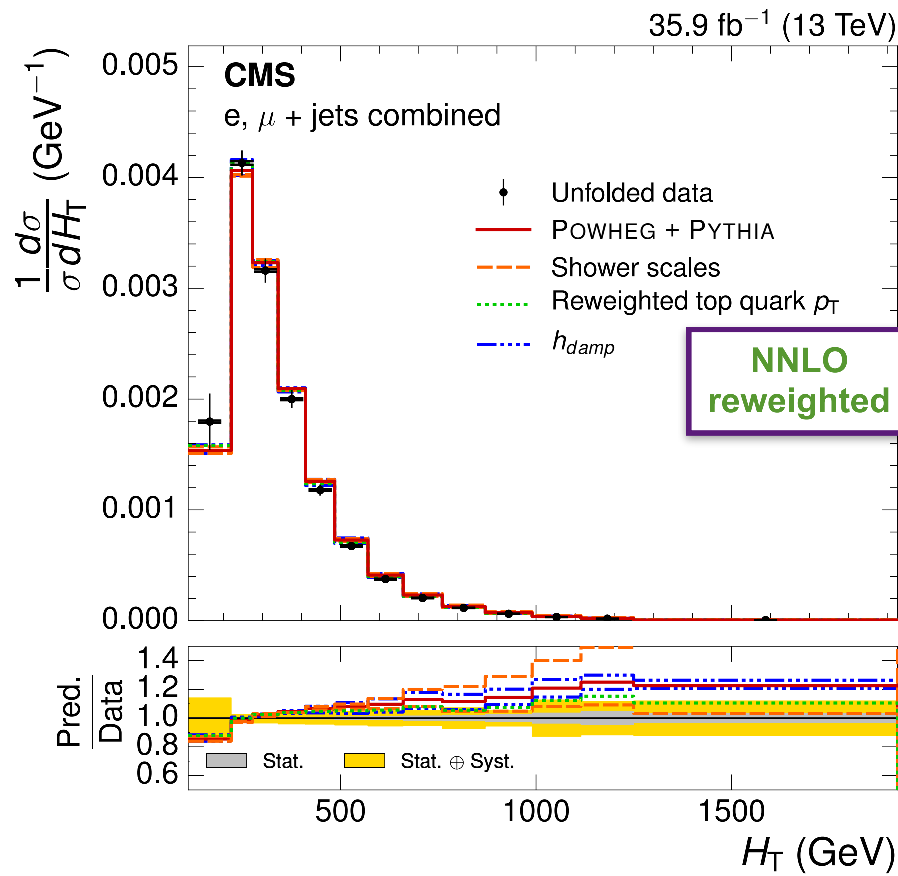
arXiv:1803.08856

Differential - $\sigma_{tt+jets}$

13 TeV [35.9 fb^{-1}] lepton + jets

- **Kinematic event variables**
  - Particle level measurements
  - No top-reconstruction required





Differential - σ_{tt}

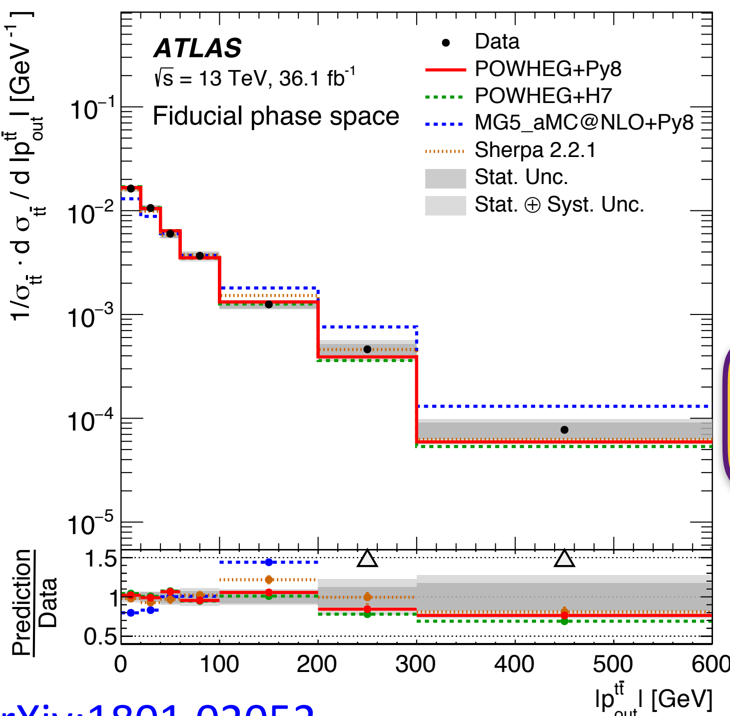
13 TeV [36.1 fb^{-1}] all-hadronic

- **Boosted regime**
  $p_T(top_1; top_2) > 500; 350$ GeV
  - Particle and parton level results
  - Top decay products collimated into large-R jets
  - Top-tagging @ 50% efficiency (m_j, τ_{32})
  - Data-driven background estimate

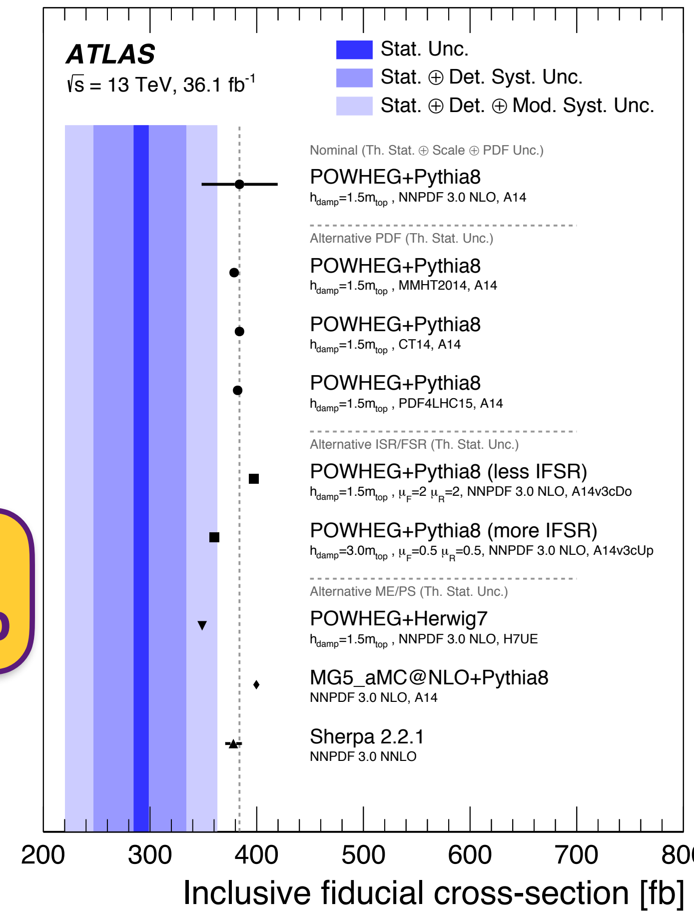
> 15% events with >= 1 top

2nd large-R jet				
1t1b	J (7.6%)	K (21%)	L (42%)	S
0t1b	B (2.2%)	D (5.8%)	H (13%)	N (47%)
1t0b	E (0.7%)	F (2.4%)	G (6.4%)	M (30%)
0t0b	A (0.2%)	C (0.8%)	I (2.2%)	O (11%)
	0t0b	1t0b	0t1b	1t1b

Leading large-R jet



$\sigma_{fid}(tt)$ = 292 ± 7 ± 76 fb

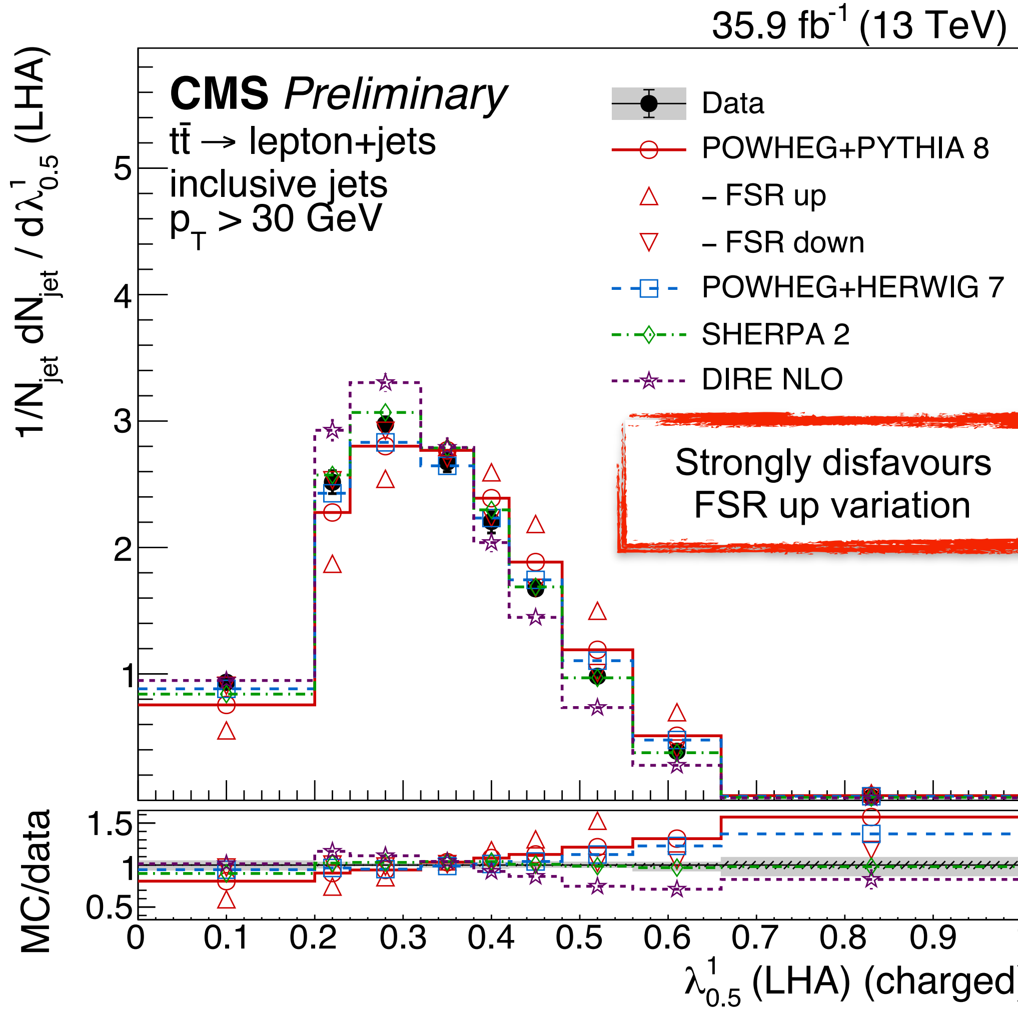


arXiv:1801.02052

Differential - Jet Shapes

13 TeV [36.1 fb^{-1}] lepton+jets

- **Particle level measurements**
  - Partial tt reconstruction
  - Measurements using inclusive jets and splitting by flavour
  - Range of models tested
- **Jet shape variables are sensitive to generator parameters**
  - Angularity
  - Eccentricity
  - N-subjettiness
  - Soft-drop observables
  - Energy correlation functions



Strongly disfavours FSR up variation

“Les Houches angularity”

CMS-PAS-TOP-17-013

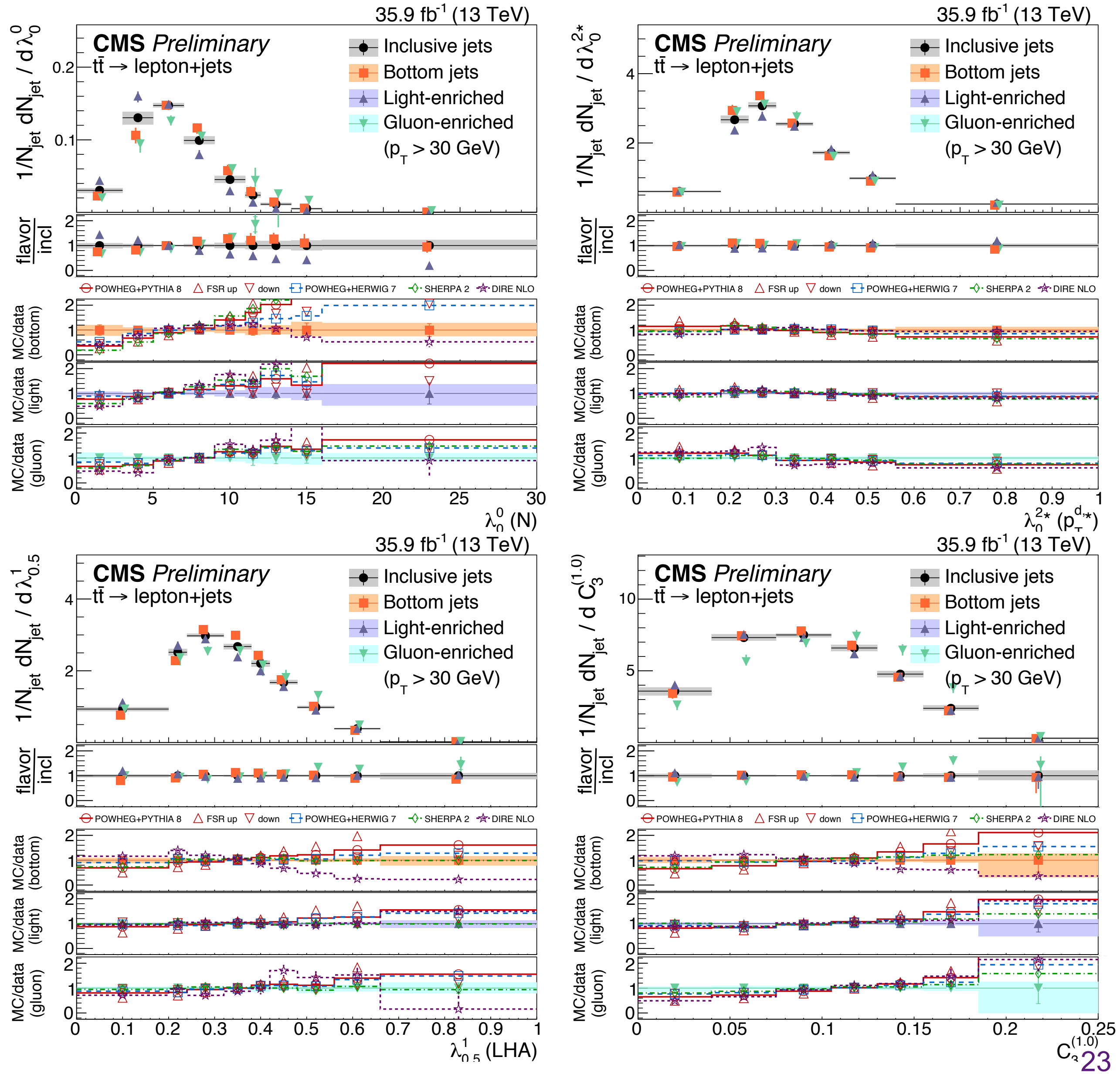
Differential - Jet Shapes

13 TeV [36.1 fb^{-1}]
lepton+jets

The University of Manchester

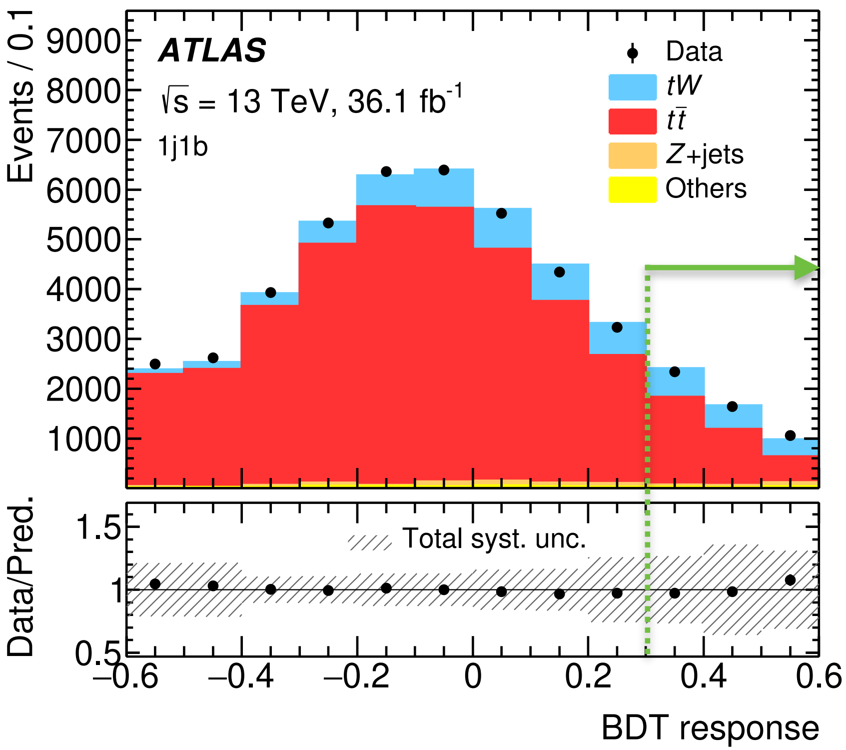
Variables shown are relevant for quark/ gluon discrimination

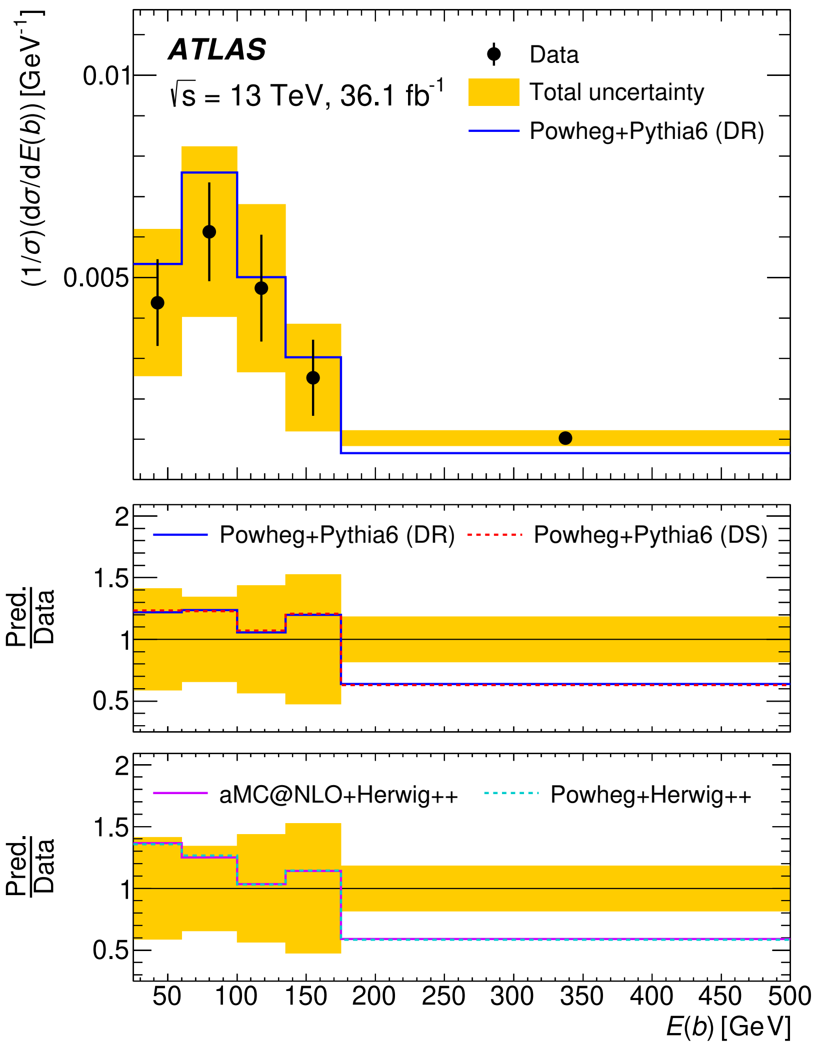
Different responses can be observed and guide future flavour-specific tunings



CMS-PAS-TOP-17-013

- **Particle level measurement**
  - Analysis designed to reduce sensitivity to tt-Wt interference
  - BDT trained to separate tt and Wt
  - No discrepancy in prediction using DR and DS schemes





Summary

MANCHESTER 1824
The University of Manchester

- **Many results from both ATLAS and CMS in Run 2**
  - Shown here just a handful of the most recent ones
- **Wide range of inclusive single-top and top-pair measurements**
  - Very good agreement with high precision predictions across LHC energies
- **Entered the era of precision measurements of top kinematics**
  - Further investigating discrepancies in top modelling
  - Double-differential measurements becoming more prolific
  - Probing phase-space relevant for searches where top-production is a key background
  - Testing higher order corrections (e.g. NNLO(QCD) + NLO(EW))
  - Start to investigate single-top differential properties

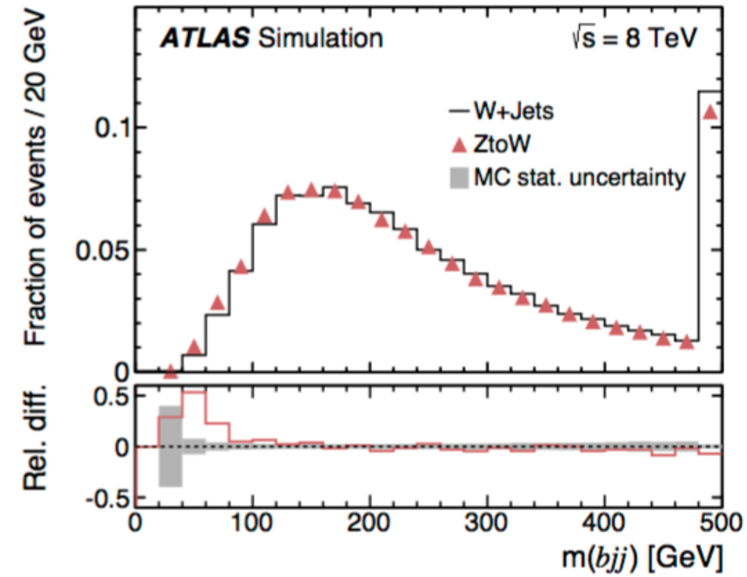
Backup

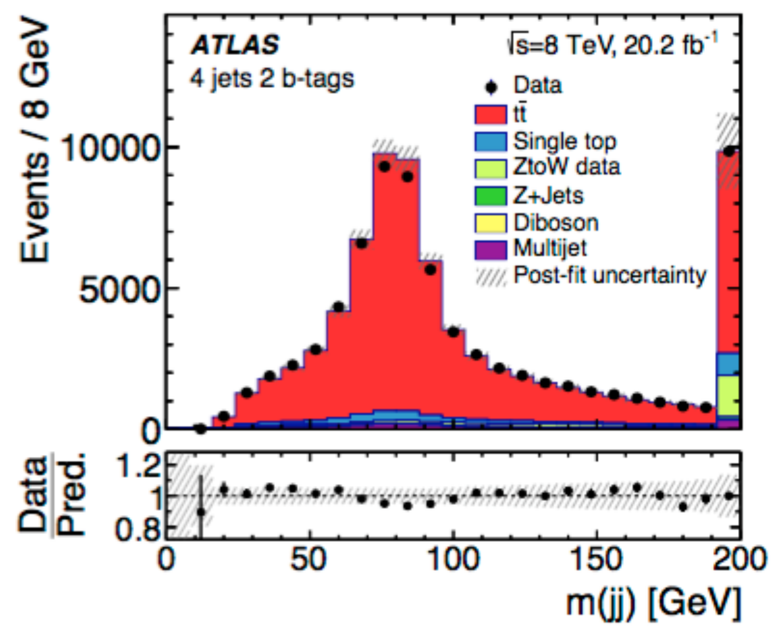
Inclusive - σ_{tt}

8 TeV [20.2 fb^{-1}]
lepton + jets

- **Improved lepton+jets measurement**
  - Reduce jet uncertainties by targeting leptonic W-decay
  - 1 lepton (e,μ) + ≥ 4 jets
  - $m_T(W) \geq 30$ GeV and E_T-miss ≥ 25 GeV
  - W+jets shape corrected to Z+jets in data
  - Non-prompt lepton normalised to E_T-miss distribution
- **Binned maximum-$\mathscr{L}$ fit with three regions**
  - Separate signal and background (NN)
  - Control W+jets background (β^{tt}, β^{W_i})
  - Fit b-tagging and JES uncertainties

$\sigma_{fid}(tt) = 48.8 \pm 0.1 \pm 2.0 \pm 0.9$ pb
$\sigma_{inc}(tt) = 248.3 \pm 0.7 \pm 13.4 \pm 4.7$ pb





arXiv:1712.06857

Inclusive - σ_{tt}

8 TeV [20.2 fb^{-1}]
lepton + jets

ATLAS EXPERIMENT

MANCHESTER 1824
The University of Manchester

Table 4: Breakdown of relative uncertainties in the measured inclusive and fiducial $t\bar{t}$ cross-sections. The total uncertainties contain all considered uncertainties.

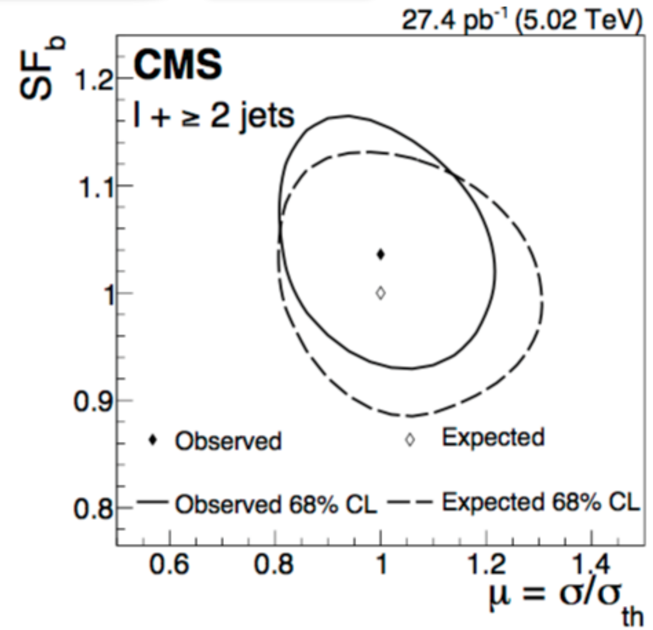
Source	$\frac{\Delta\sigma_{\text{inc}}}{\sigma_{\text{inc}}}$ [%]	$\frac{\Delta\sigma_{\text{fid}}}{\sigma_{\text{fid}}}$ [%]
Statistical uncertainty	0.3	0.3
Physics object modelling		
Jet energy scale	1.1	1.1
Jet energy resolution	0.1	0.1
Jet reconstruction efficiency	<0.1	<0.1
$E_{\text{T}}^{\text{miss}}$ scale	0.1	0.1
$E_{\text{T}}^{\text{miss}}$ resolution	<0.1	<0.1
Muon momentum scale	<0.1	<0.1
Muon momentum resolution	<0.1	<0.1
Electron energy scale	0.1	0.1
Electron energy resolution	<0.1	<0.1
Lepton identification	1.4	1.4
Lepton reconstruction	0.3	0.3
Lepton trigger	1.3	1.3
b-tagging efficiency	0.3	0.3
c-tagging efficiency	0.5	0.5
Mistag rate	0.3	0.3
Signal Monte Carlo modelling and parton distribution functions		
NLO matching	1.1	0.9
Scale variations	2.2	1.0
Parton shower	1.3	0.9
PDF	3.0	0.1
Background normalisation for non-fitted backgrounds		
Single top	0.3	0.3
Z+jets	0.2	0.2
Diboson	0.1	0.1
Background modelling		
$Z$to$W$ modelling	1.1	1.1
Multijet	0.6	0.6
Luminosity	1.9	1.9
Total (syst.)	5.7	4.5
Total (syst.+stat.)	5.7	4.5

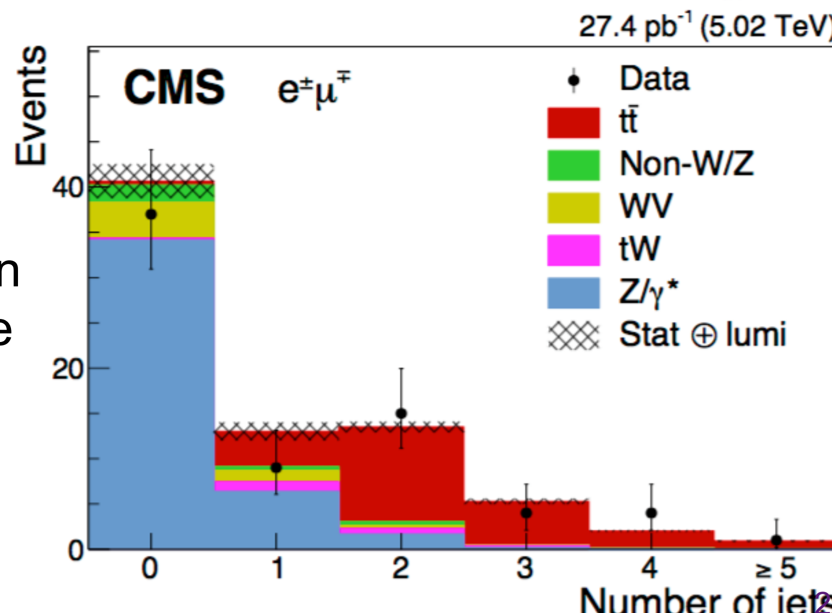
arXiv:1712.06857

Inclusive - σ_{tt}

5.02 TeV [27.4 pb^{-1}]
≥ 1 lepton

- **Select events with ≥ 1 lepton and ≥ 2 b-jets**
  - Separate b-jet multiplicity to control backgrounds (W/Z+jets, QCD)
  - Data-driven QCD and Z+jets normalisation
- **Profiled likelihood fit in lepton+jets channel**
  - Fit cross-section and b-tagging scale factor simultaneously
  - Include uncertainties as nuisance parameters
- **Event counting in dilepton channel**
  - Split into eμ and μμ channels
- **Statistical and systematic uncertainties comparable**
  - Cross-sections measured in fiducial region and extrapolated to inclusive phase-space
  - Combined using BLUE

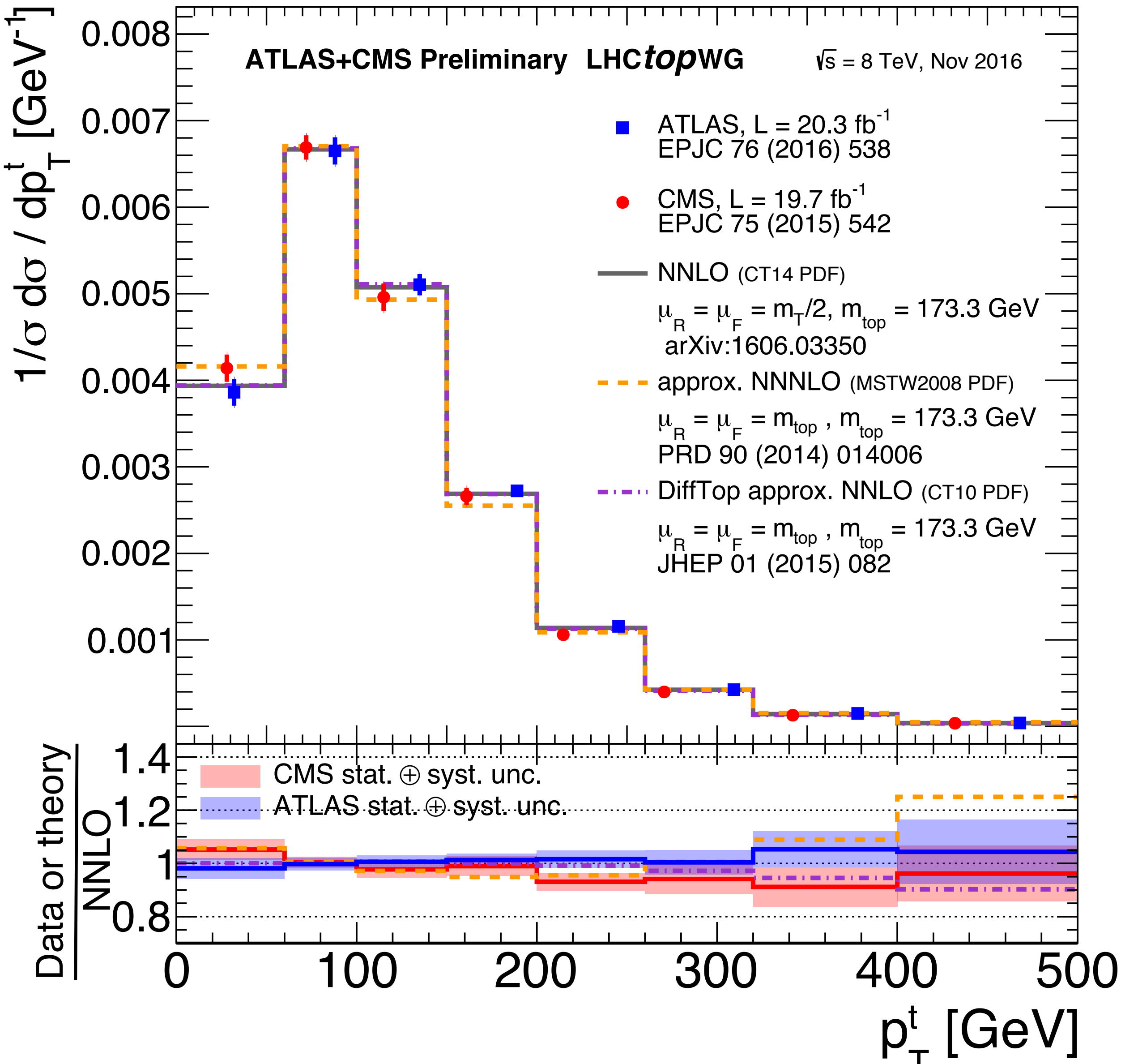




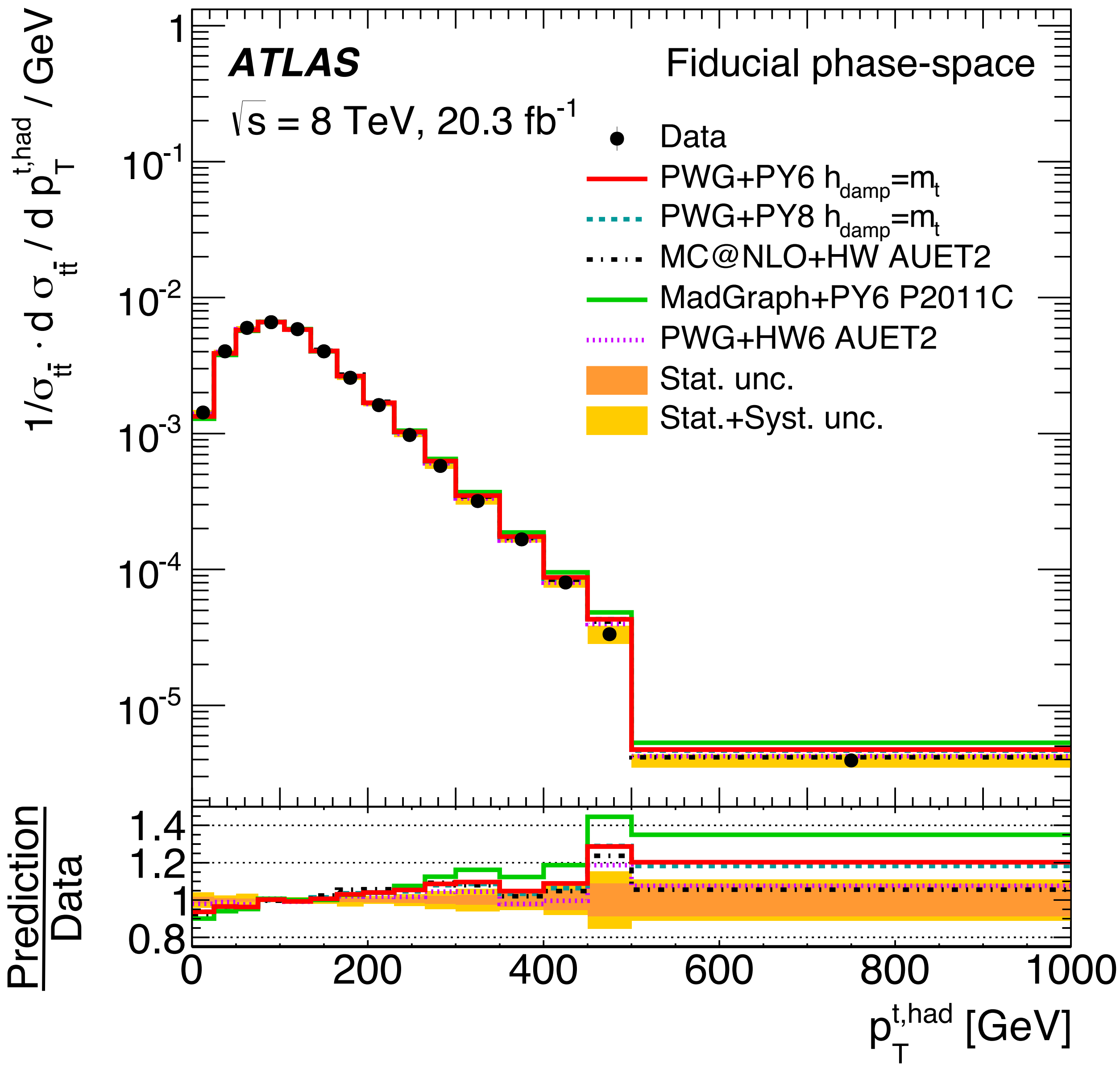
$\sigma_{inc}(tt)$ = 69.5 ± 8.4 pb

arXiv:1711.03143

Top p_T discrepancy



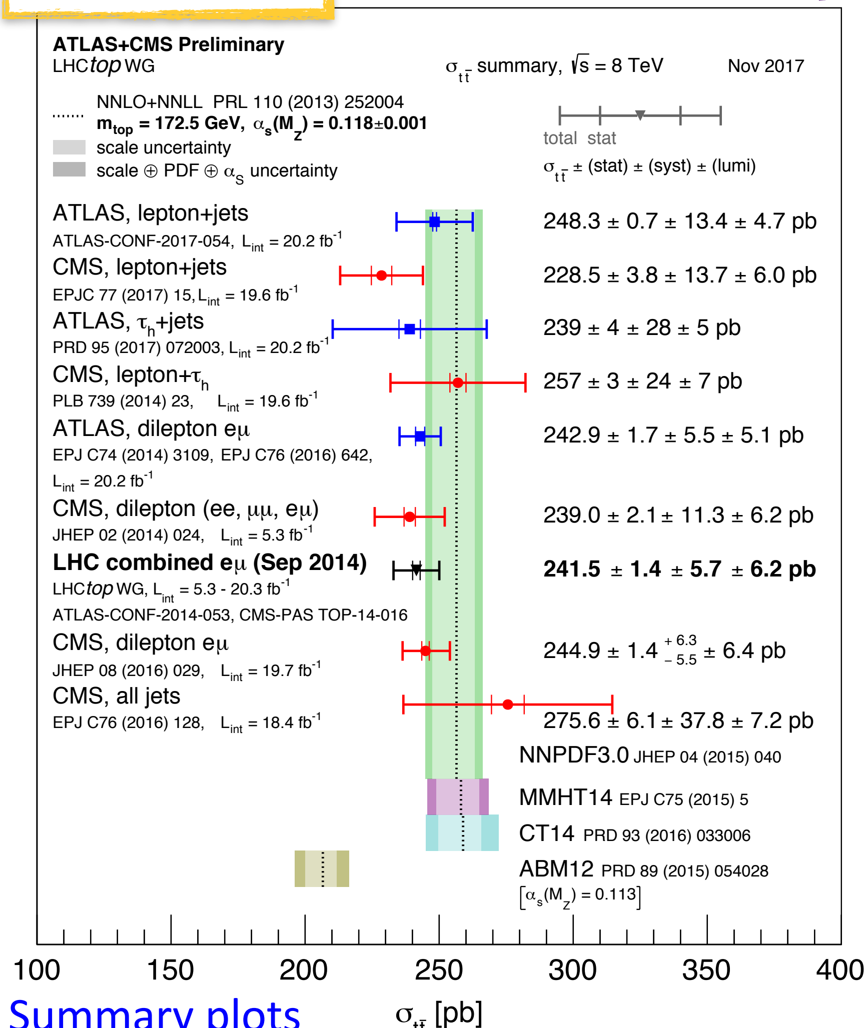
Top p_T discrepancy



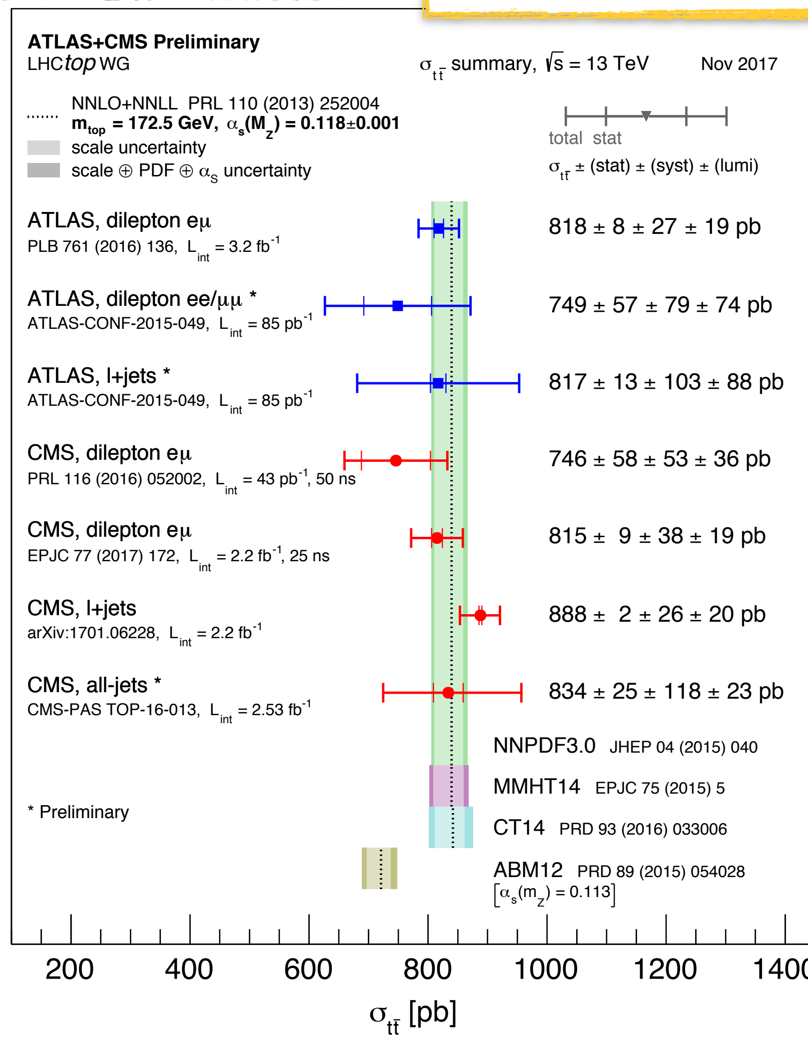
Inclusive - $\sigma_{tt}(\sqrt{s})$

Measurements at **8 and 13 TeV** dominated by systematic uncertainties
Good agreement with NNLO+NNLL prediction

$\delta\sigma/\sigma_{tt}$ ~ 3.5%



$\delta\sigma/\sigma_{tt}$ ~ 3.9 - 4.4%

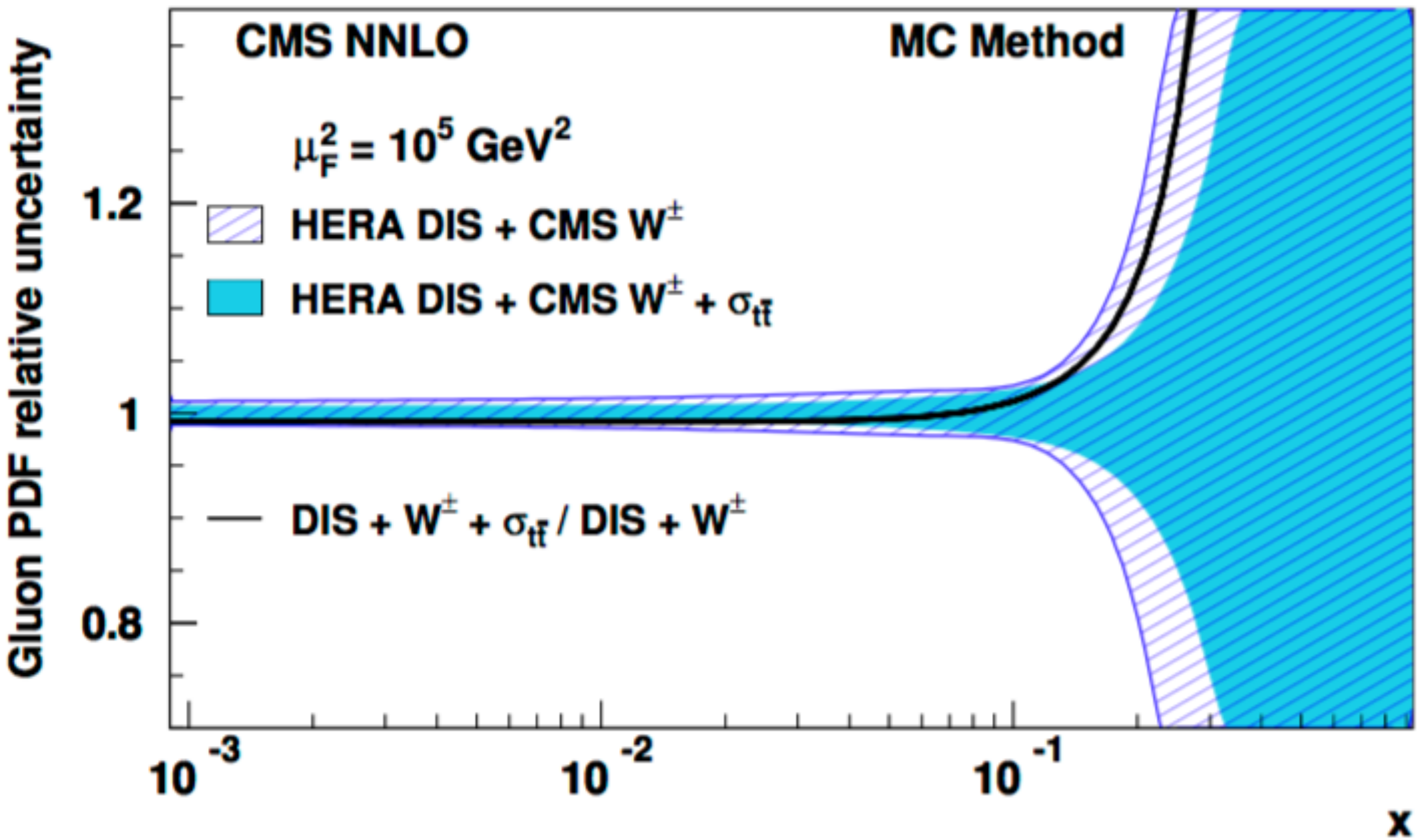


Summary plots

Backup

5.02 TeV [27.4 pb^{-1}]
≥ 1 lepton

- **Measuring the cross-section at a new centre-of-mass energy**
  - Provides new data at high values of Bjorken-x
  - Study of the proton PDFs shows a modest improvement in gluon uncertainties for $x > 10^{-1}$



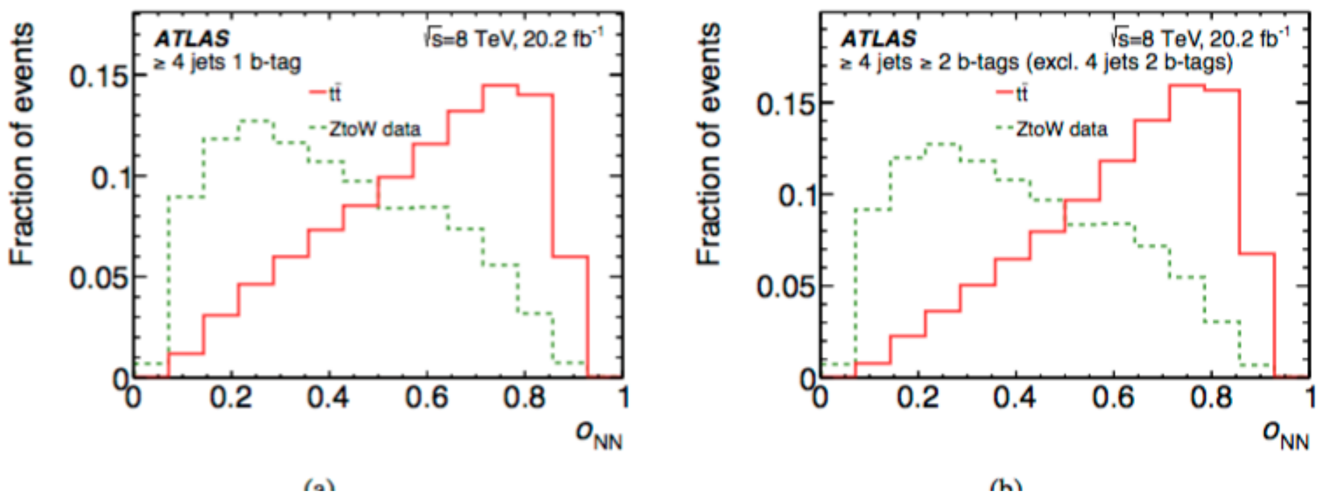
arXiv:1711.03143

Backup

8 TeV [20.2 fb^{-1}] lepton + jets

Table 2: List of the seven input variables of the NN, ordered by their discriminating power.

Variable	Definition
m_{12}	The smallest invariant mass between jet pairs.
$\cos(\theta^*)_{bjj}$	Cosine of the angle between the hadronic top-quark momentum and the beam direction in the $t\bar{t}$ rest frame.
$m(\ell\nu b)$	Mass of the reconstructed semileptonically decaying top quark.
A	Aplanarity, as defined in Eq. (2)
$m(bjj)$	Mass of the reconstructed hadronically decaying top quark.
$m_{\ell 1}$	The smallest invariant mass between the charged lepton and a jet.
m_{23}	The second smallest invariant mass between jet pairs.

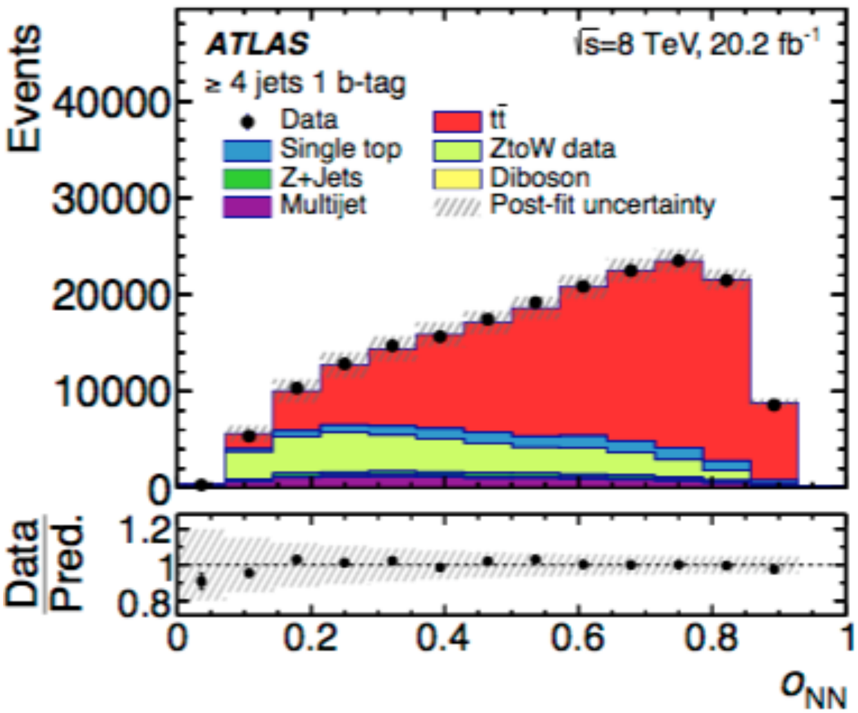


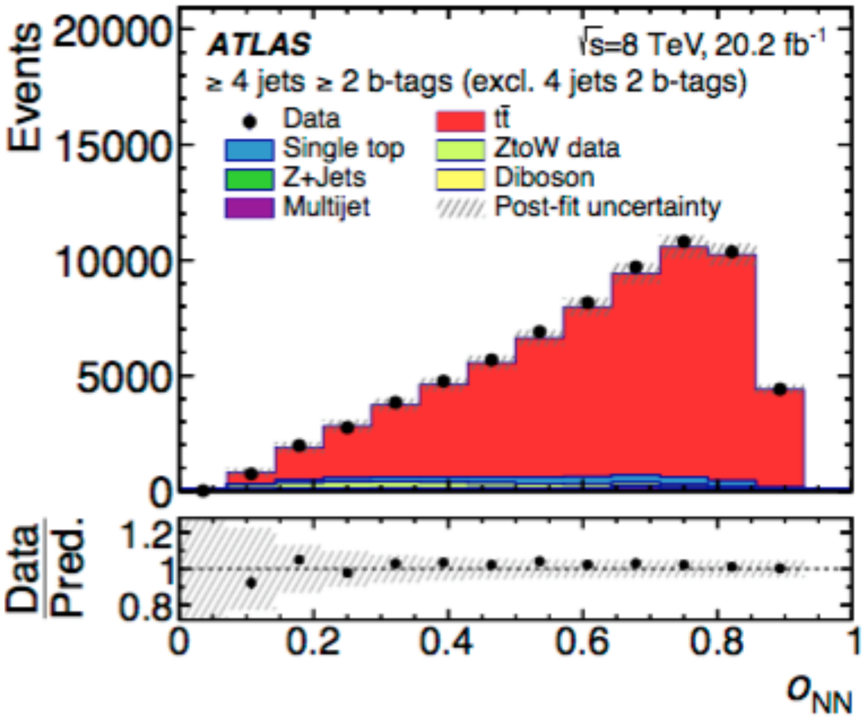
arXiv:1712.06857

Backup

8 TeV [20.2 fb^{-1}] lepton + jets

- **Neural network output**





arXiv:1712.06857

Differential - $\sigma_{tt+jets}$

13 TeV [35.8 fb^{-1}]
lepton + jets

CMS

MANCHESTER 1824
The University of Manchester

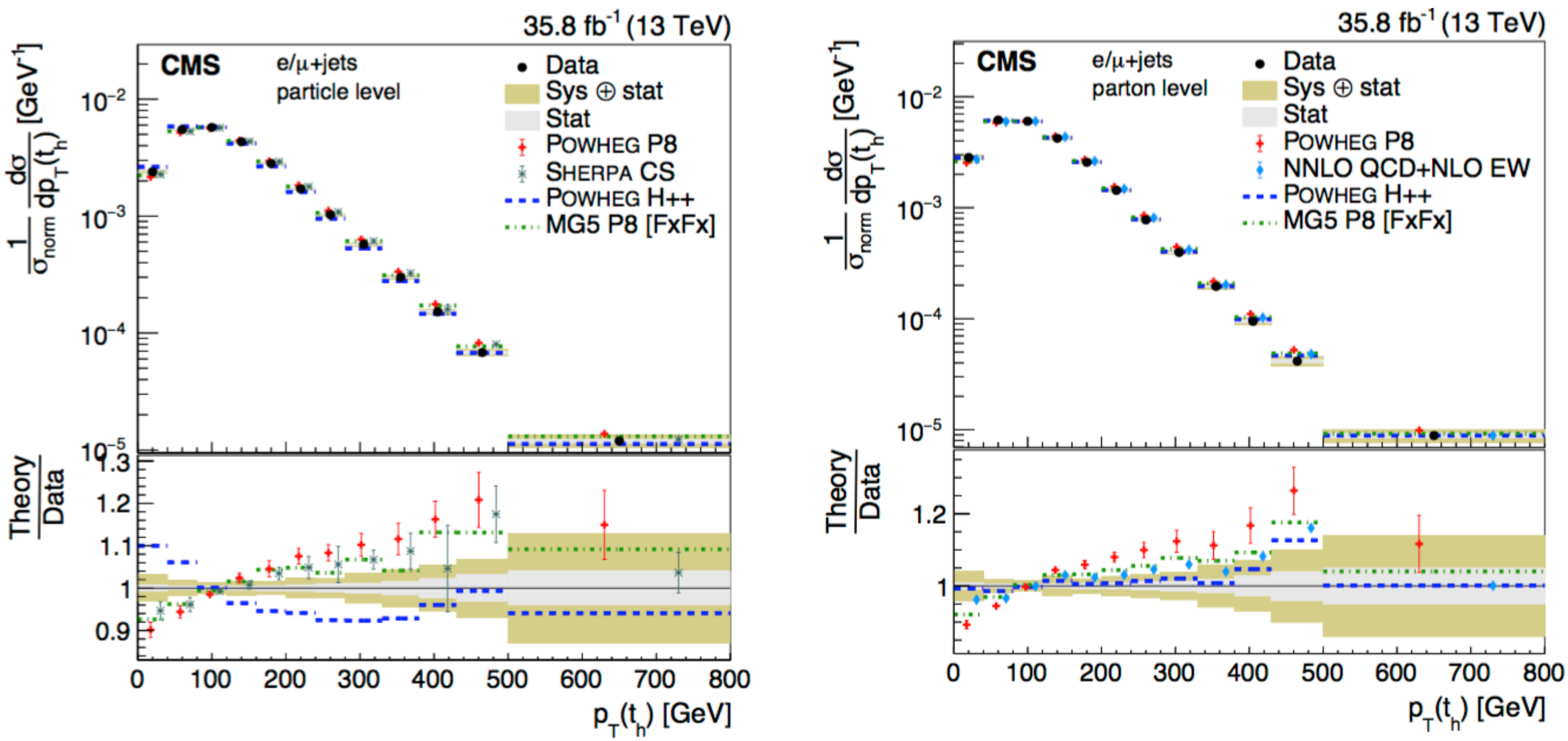
Table 2: Comparison between the measured normalized differential cross sections at the parton level and the predictions of POWHEG combined with PYTHIA8 (P8) or HERWIG++ (H++), the multiparton simulation MG5_aMC@NLO FxFx, and the NNLO QCD+NLO EW calculations. The compatibility with the POWHEG+PYTHIA8 prediction is also calculated including its theoretical uncertainties (with unc.), while those are not taken into account for the other comparisons. The results of the χ^2 tests are listed, together with the numbers of degrees of freedom (dof) and the corresponding p-values.

Distribution	χ^2/dof	p-value	χ^2/dof	p-value	χ^2/dof	p-value
	POWHEG+P8 with unc.		POWHEG+P8		NNLO QCD+NLO EW	
$p_T(t_{high})$	18.4/11	0.073	24.4/11	0.011		
$p_T(t_{low})$	16.6/11	0.120	40.0/11	<0.01		
$p_T(t_h)$	16.1/11	0.138	22.9/11	0.018	4.99/11	0.932
$\|y(t_h)\|$	1.25/10	1.000	1.33/10	0.999	2.23/10	0.994
$p_T(t_\ell)$	23.6/11	0.014	33.0/11	<0.01	8.67/11	0.652
$\|y(t_\ell)\|$	2.03/10	0.996	2.29/10	0.994	8.18/10	0.611
$M(t\bar{t})$	7.78/9	0.556	11.3/9	0.259	24.4/9	<0.01
$p_T(t\bar{t})$	5.52/7	0.597	40.9/7	<0.01		
$\|y(t\bar{t})\|$	3.89/9	0.919	5.36/9	0.802	9.29/9	0.411
$\|y(t_h)\|$ vs. $p_T(t_h)$	22.7/43	0.995	38.8/43	0.654		
$M(t\bar{t})$ vs. $\|y(t\bar{t})\|$	20.2/34	0.970	33.2/34	0.507		
$p_T(t_h)$ vs. $M(t\bar{t})$	34.4/31	0.309	57.4/31	<0.01		
	POWHEG+H++		MG5_aMC@NLO+P8 FxFx		—	
$p_T(t_{high})$	4.10/11	0.967	13.2/11	0.283		
$p_T(t_{low})$	17.4/11	0.096	11.9/11	0.370		
$p_T(t_h)$	3.61/11	0.980	9.95/11	0.535		
$\|y(t_h)\|$	1.63/10	0.998	1.11/10	1.000		
$p_T(t_\ell)$	8.36/11	0.680	16.4/11	0.128		
$\|y(t_\ell)\|$	1.57/10	0.999	2.48/10	0.991		
$M(t\bar{t})$	3.57/9	0.937	7.61/9	0.574		
$p_T(t\bar{t})$	43.4/7	<0.01	20.5/7	<0.01		
$\|y(t\bar{t})\|$	5.94/9	0.746	4.65/9	0.864		
$\|y(t_h)\|$ vs. $p_T(t_h)$	32.6/43	0.877	27.8/43	0.965		
$M(t\bar{t})$ vs. $\|y(t\bar{t})\|$	27.2/34	0.788	40.2/34	0.214		
$p_T(t_h)$ vs. $M(t\bar{t})$	67.9/31	<0.01	77.9/31	<0.01		

arXiv:1803.08856

Powheg Herwig++ and NNLO+NLO

MANCHESTER
1824
The University of Manchester



Differential - σ_{tt}

13 TeV [36.1 fb^{-1}]
all-hadronic

ATLAS EXPERIMENT

MANCHESTER 1824
The University of Manchester

- **Boosted regime**
  $p_T(top_1; top_2) > 500; 350$ GeV
  - Top decay products collimated into large-R jets
  - Top-tagging requirement @ 50% efficiency (m_{jj}, τ_{32})

> 15% events with >= 1 top

2nd large-R jet				
1t1b	J (7.6%)	K (21%)	L (42%)	S
0t1b	B (2.2%)	D (5.8%)	H (13%)	N (47%)
1t0b	E (0.7%)	F (2.4%)	G (6.4%)	M (30%)
0t0b	A (0.2%)	C (0.8%)	I (2.2%)	O (11%)
	0t0b	1t0b	0t1b	1t1b

Leading large-R jet

This "ABCD" estimate assumes that the mistagging rate of the leading jet does not depend on how the second-leading jet is tagged. This assumption is avoided by measuring the correlations in background-dominated regions, e.g. comparing the ratio of the numbers of events in regions F and E (giving the leading jet top-tagging rate when the second-leading jet is top-tagged) with the ratios of events in regions C and A (giving the leading jet top-tagging rate when the second leading jet is not top-tagged). This results in a refined data-driven estimate of the size of the multijet background given by

$$S = \frac{J \times O}{A} \cdot \frac{D \times A}{B \times C} \cdot \frac{G \times A}{E \times I} \cdot \frac{F \times A}{E \times C} \cdot \frac{H \times A}{B \times I},$$

$$= \frac{J \times O \times H \times F \times D \times G \times A^3}{(B \times E \times C \times I)^2}, \qquad (1)$$

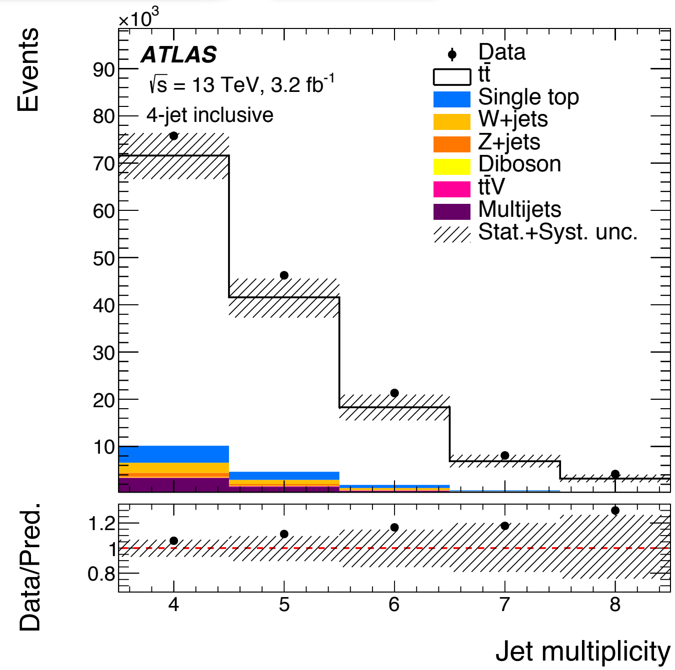
Differential - $\sigma_{tt+jets}$

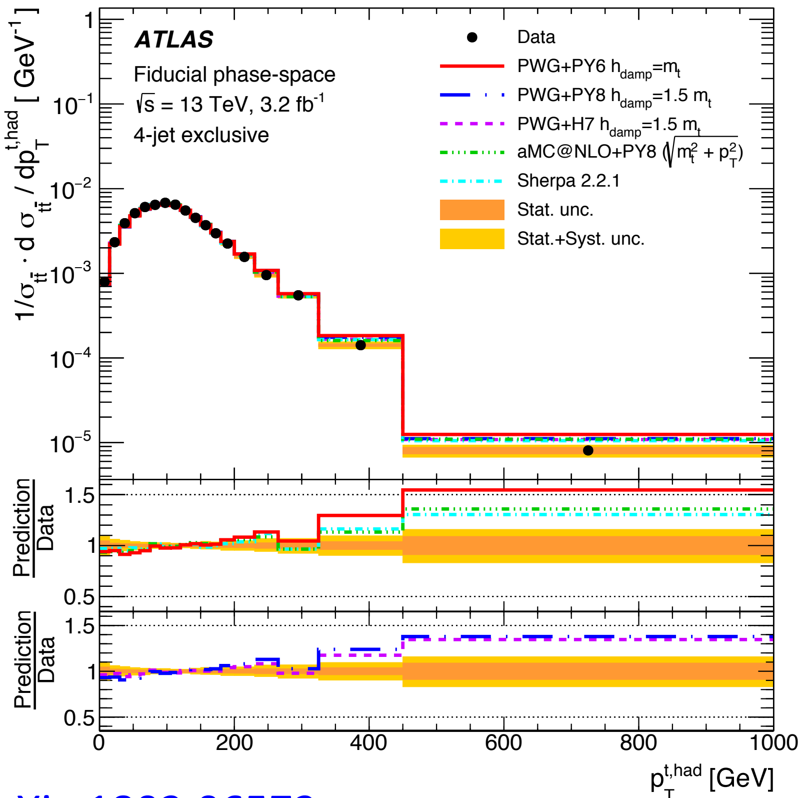
13 TeV [3.2 fb^{-1}] lepton + jets

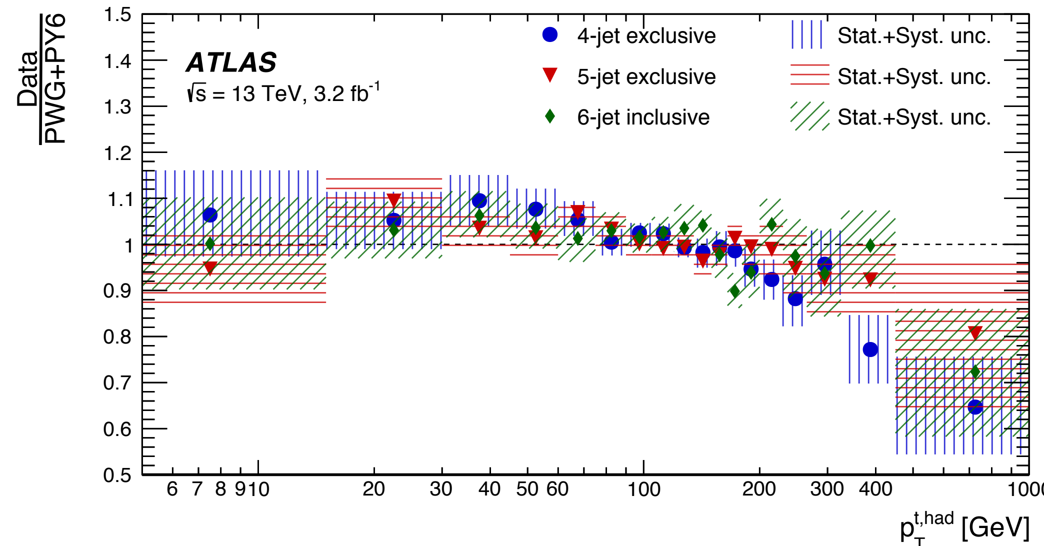
ATLAS EXPERIMENT

MANCHESTER 1824 The University of Manchester

- **Differential in bins of jet multiplicity**
  - Particle level measurements
  - Slope visible in p_T(t,had) for all jet multiplicities
  - Large uncertainty for ≥ 6 jets







arXiv:1802.06572

Differential - σ_{tt}

13 TeV [36.1 fb^{-1}]
lepton+jets

CMS

MANCHESTER
1824
The University of Manchester

Radiation uncertainty samples used to determine uncertainty are separate to the radHi/Lo samples overlaid on the unfolded measurements. The radHi/Lo samples vary the shower alpha_s value according to the scale variation, but do not touch hdamp.

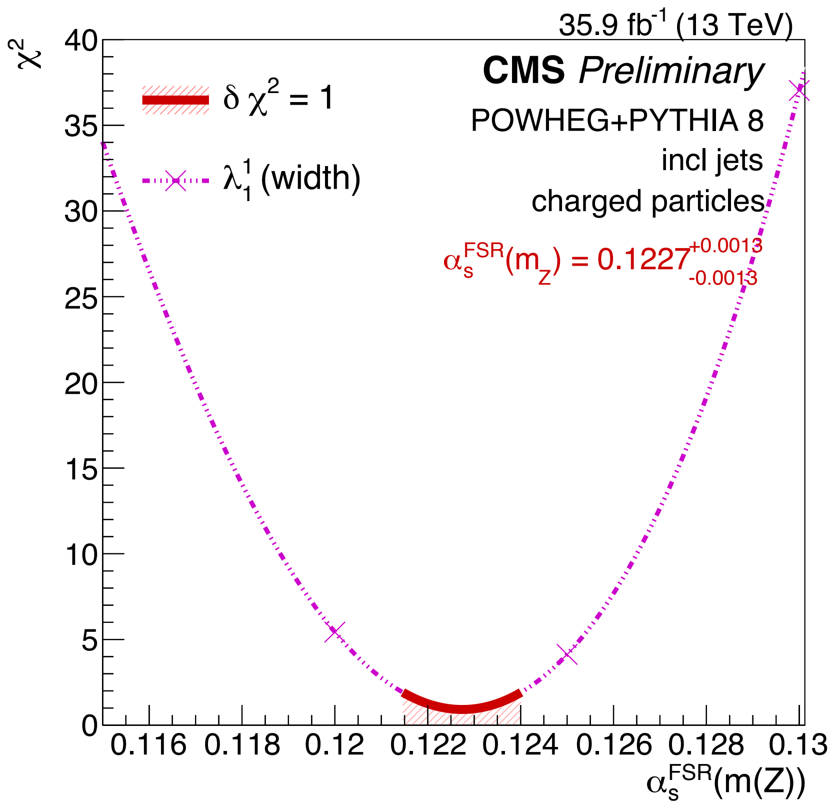
The uncertainties on the modeling of the $t\bar{t}$ signal are estimated by using migration matrices derived from samples with the following variations. The renormalization and factorization scales in the matrix-element calculation are varied by factors of 0.5 and 2.0 using weights. The scales for initial- and final-state radiation in the parton shower are varied independently by factors of 0.5 and 2.0 with respect to their default values. The "hdamp" parameter regulating the real emissions in POWHEG is varied from its central value of $1.58 \times m_t$ using samples with hdamp set to $0.99 \times m_t$ and $2.24 \times m_t$. Additional samples are generated with the underlying event tune varied within its uncertainties. For estimating the uncertainty due to color reconnection, the default MPI-based, QCD-inspired [75], and gluon-move [76] models are compared with and without early resonance decays. An additional sample is generated using POWHEG +HERWIG++ for testing an alternative model of parton shower, hadronization, underlying event, and color reconnection. The b fragmentation function is varied to cover e^+e^- data at the Z pole [4, 9, 77, 78] with the Bowler–Lund [41] and the Peterson [79] parametrizations. Semileptonic branching ratios of B hadrons are varied within their measured values [80]. The top quark mass is measured by CMS with an uncertainty of ± 0.49 GeV [81], but samples in this analysis are generated with ± 1 GeV in order to conservatively estimate its impact on the jet substructure measurements. The transverse momentum distribution of the top quark was not found to be in agreement with NLO predictions by recent CMS measurements at $\sqrt{s} = 13$ TeV [82, 83]. The full data-MC difference in the top quark p_T distribution is taken as an uncertainty. The effects of the most important systematic uncertainties are shown in Appendix A.

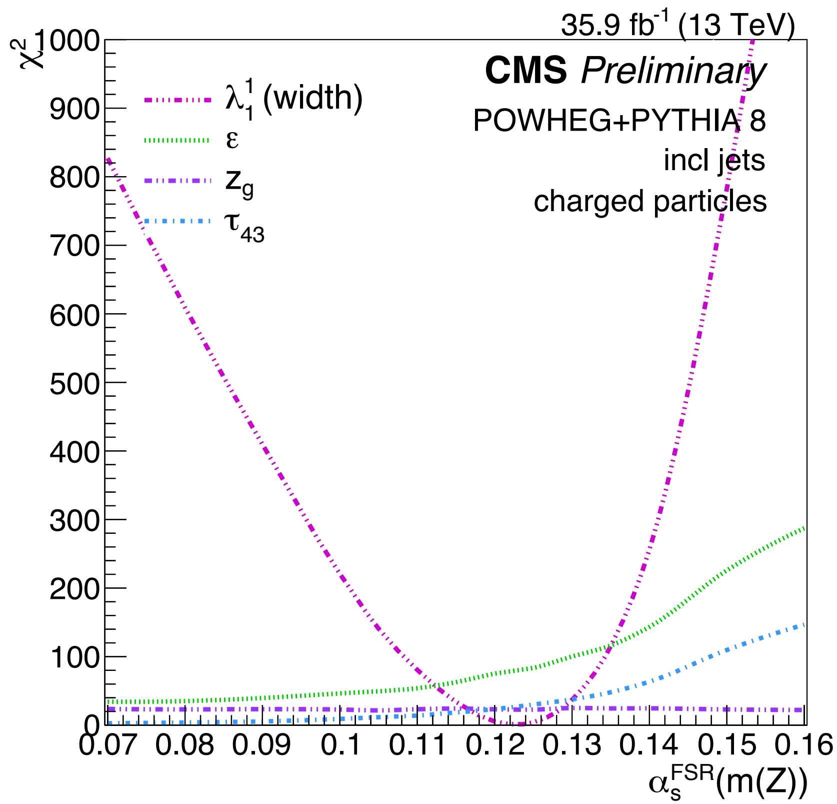
Differential - σ_{tt}

13 TeV [36.1 fb^{-1}]
lepton+jets

Generally, data shows a preference for a lower alpha_s than generators provide by default.

Pythia8 specific scan of alpha_s was made using X2 fit.





Wt (dilepton)

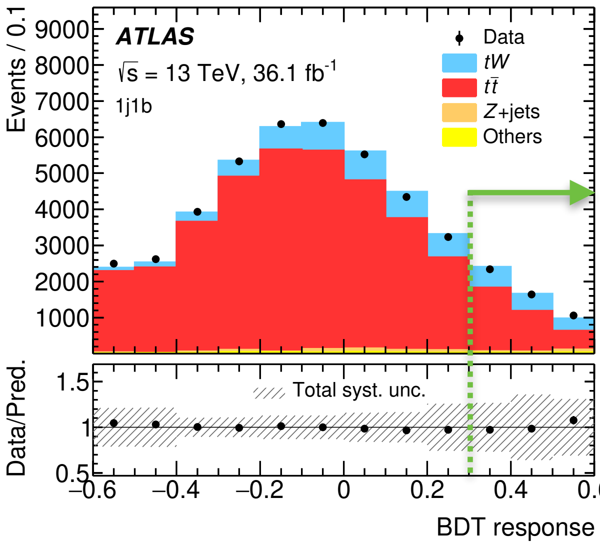
13 TeV [36.1 fb^{-1}]

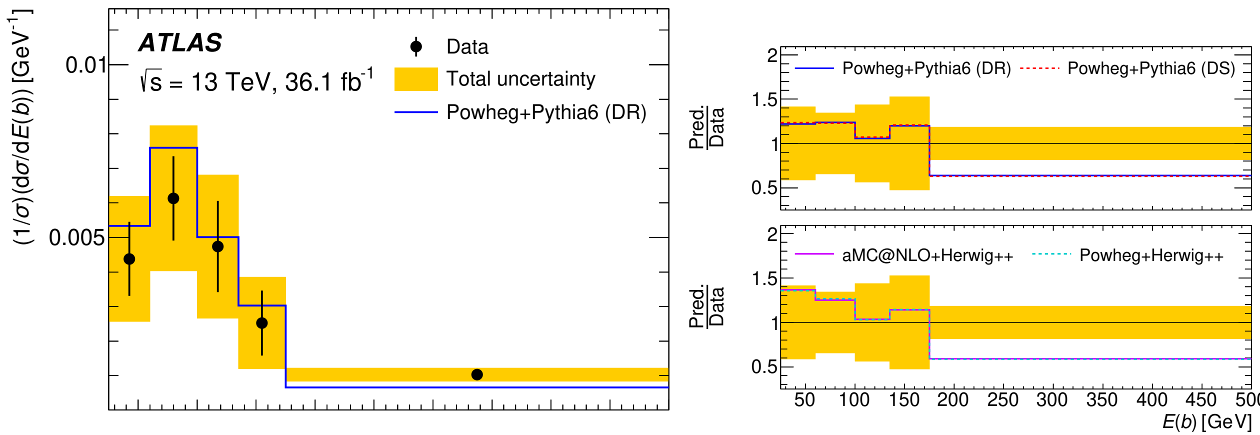
13 TeV [35.9 fb^{-1}]

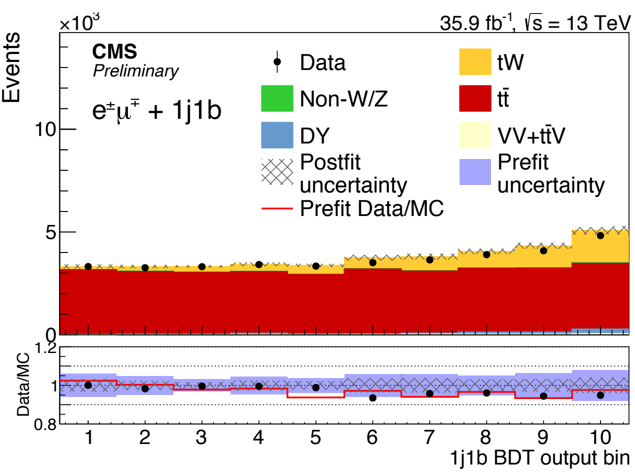
ATLAS EXPERIMENT

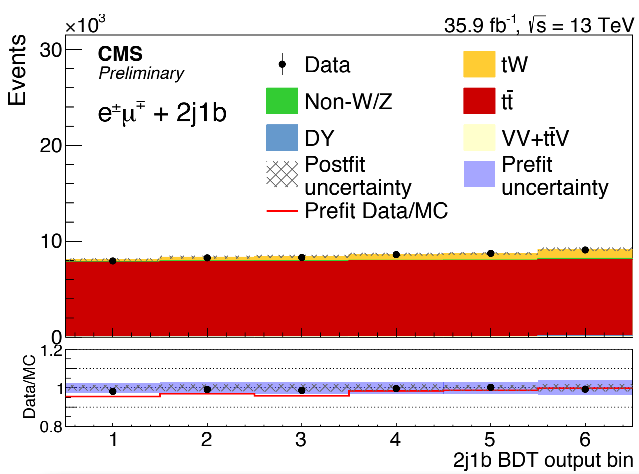
CMS

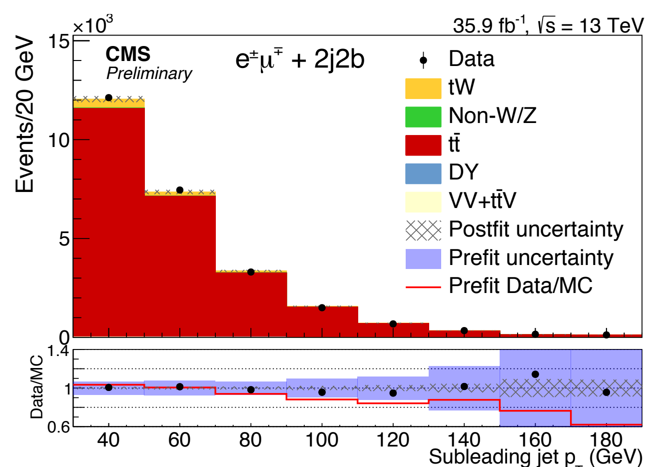
MANCHESTER 1824
The University of Manchester











μ = 0.88 ± 0.02 ± 0.08 ± 0.03

σ_{inc}(tW) = 63.1 ± 1.8 ± 6.0 ± 2.1 pb