ALL-HADRONIC RESOLVED DIFFERENTIAL TTBAR CROSS-SECTION MEASUREMENTS

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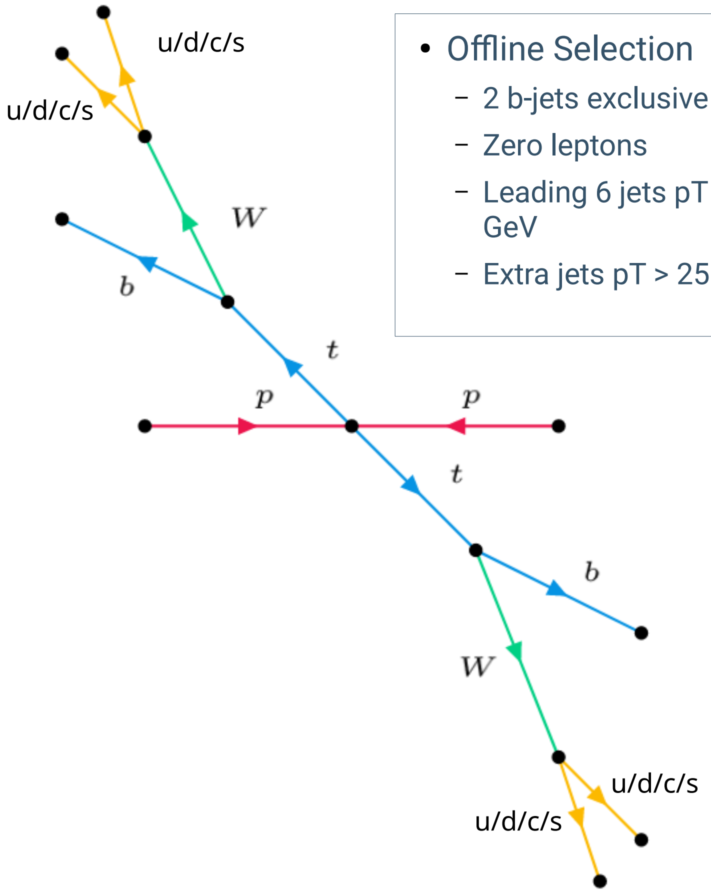
on behalf of the ATLAS collaboration

OVERVIEW OF THE ANALYSIS

- Channel with the largest BR ~ 46%
- Full kinematic reconstruction of both tops
- Study correlations between additional jet radiation and top (system) kinematics
  - New observables to describe the kinematics of the extra-jets
  - Studying the parameter related to the additional jets emission in the MC generators
- Helpful for searches where ttbar+jet is a major background
  - Reduce modelling systematic
- Particle level results
  - Rivet routine used for MC studies
- Parton level results
  - Unfolded results available as input for measurement of top pole mass and PDF fit
- Total and differential cross-section
  - Absolute and normalised
  - Fiducial and full phase-space

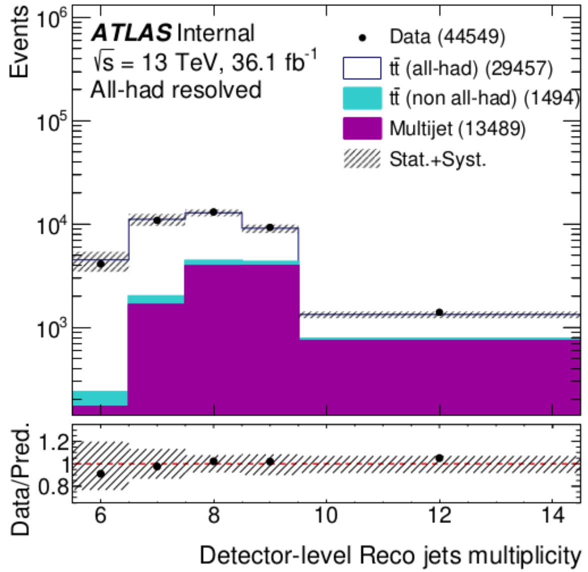


- Offline Selection
  - 2 b-jets exclusive (70%)
  - Zero leptons
  - Leading 6 jets pT > 55 GeV
  - Extra jets pT > 25 GeV

ANALYSIS STRATEGY

- Fiducial phase space at particle level
  - Analogous to detector level selection
- Full phase-space at parton level
- System reconstruction performed selecting the combination that minimises the χ^2
  - χ^2 computed for all possible permutations and the permutation with the smallest value is selected
  - Jet assignment based on W mass constraint and top anti-top mass agreement
    - Sigma values extracted from mass distributions in simulated MC events
  - Particle level efficiency ~ 85% in 6 jets exclusive region, 60-75% in 7-9 jets region
  - Parton level efficiency ~ 75% in 6 jets exclusive, ~ 65% in 7 jets exclusive, ~45-60% in 8-9 jets regions

- Multi-jet background
  - Dominant background component
  - Data driven ABCD method
    - (see extra for more details)
  - Negligible contamination for Njets == 6
- Unfolding
  - D'Agostini iterative, four iterations



CHI2 RECONSTRUCTION

$$\chi^2 = \frac{(m_{b_1 j_1 j_2} - m_{b_2 j_3 j_4})^2}{2\sigma_t^2} + \frac{(m_{j_1 j_2} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_3 j_4} - m_W)^2}{\sigma_W^2}$$

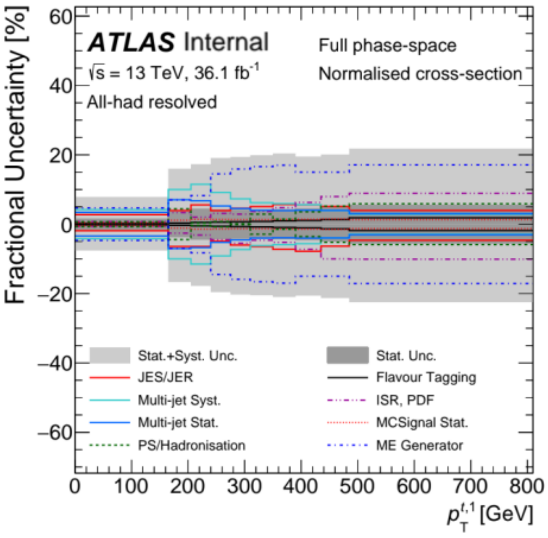
UNCERTAINTIES

SUMMARY ON INCLUSIVE XS

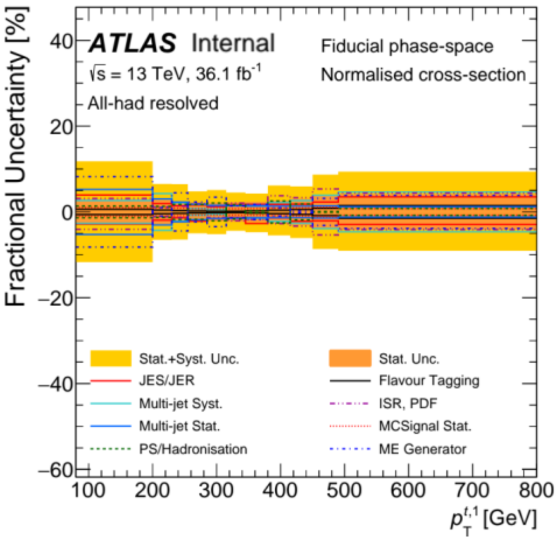
Source	Uncertainty [%]	
	Particle level	Parton level
PS/hadronisation	8.2	7.9
Multi-jet syst.	7.7	7.7
JES/JER	6.7	6.7
ISR, PDF	3.3	3.5
ME generator	2.4	5.3
Flavour tagging	2.2	2.2
Luminosity	2.1	2.1
Multi-jet stat.	0.6	0.6
MC signal stat.	0.3	0.3
Stat. unc.	0.7	0.7
Stat.+syst. unc.	14	15

- Relative uncertainties on the inclusive cross-section
- PS/hadronisation dominant followed by multi-jet background and JES/JER

PARTON LEVEL



PARTICLE LEVEL

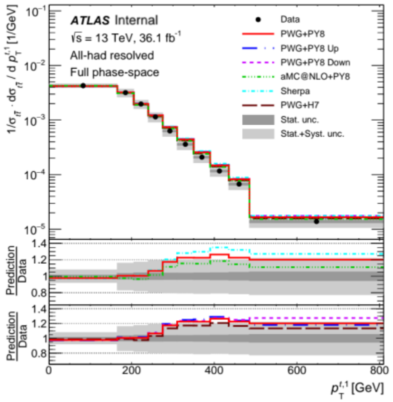


- Normalised fractional uncertainties
- Dominant systematics: JES/JER and modelling
- Multi-jet background systematic relevant only in low statistics regions

RESULTS – 1D

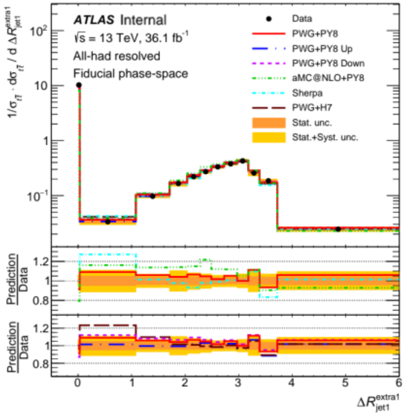
- Leading top p_T shown here as example
- Summary of the 1D measurements
  - Angular distributions are well modelled
  - Transverse momentum distributions between tops, decay products and FSR are poorly described by MC
  - MC modelling cannot simultaneously get the top p_T and the $t\bar{t}$ p_T correct
- Highlight feature of extra jet radiation
  - ΔR between leading jet and leading extra jet
  - Peak at 0 is where the leading jet is from an ISR emission
  - Significant mismodelling for Shrepa, aMC@NLO+Pythia8, Powhet+Herwig7
  - Underestimate how frequently the leading jet comes from a top

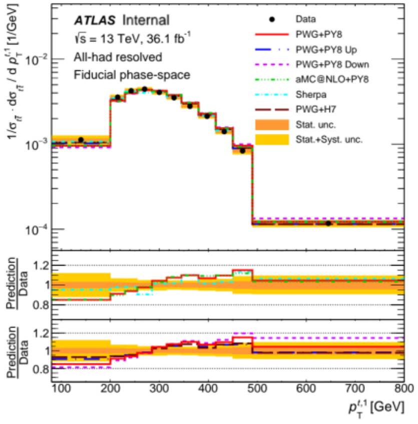
Leading top p_T



PARTON

ΔR between leading jet and leading extra jet

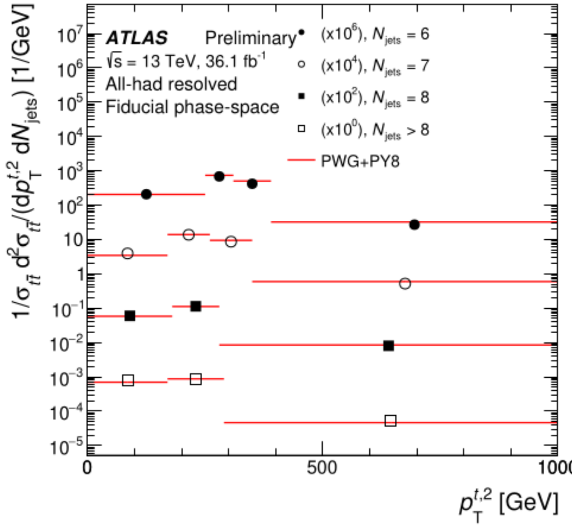




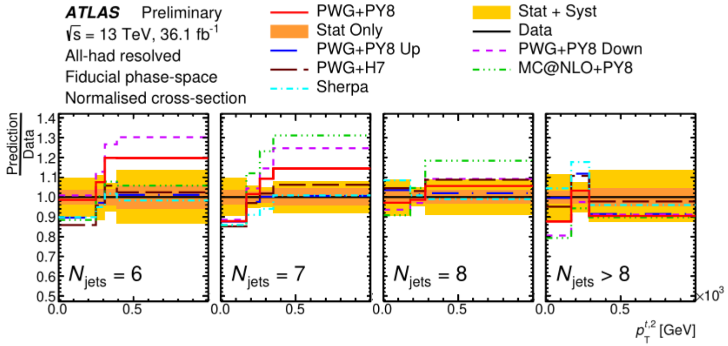
PARTICLE

RESULTS – 2D

- Chi2 and p-value agreement between MC prediction and data
  - Evaluated using the full covariance matrix due to data statistics and systematic uncertainties
  - No MC prediction is compatible with data in all 2D distribution



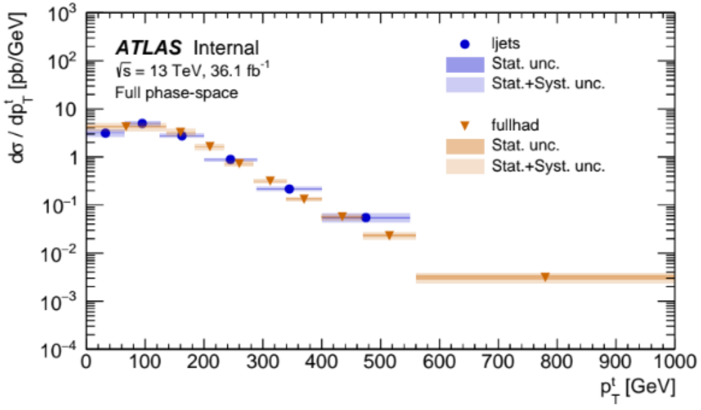
Observable	PWG+PY8		PWG+PY8 Var. Up		PWG+PY8 Var. Down		aMC@NLO+PY8		Sherpa		PWG+H7	
	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value
$\Delta\phi^{t\bar{t}}$ vs N_{jets}	29.8/11	<0.01	24.1/11	0.01	57.0/11	<0.01	140.0/11	<0.01	16.9/11	0.11	24.0/11	0.01
$\lvert P_{\text{cross}}\rvert$ vs N_{jets}	14.0/12	0.30	5.7/12	0.93	30.3/12	<0.01	50.7/12	<0.01	16.7/12	0.16	8.0/12	0.78
$\lvert P_{\text{out}}^{t,1}\rvert$ vs N_{jets}	53.5/13	<0.01	35.4/13	<0.01	86.3/13	<0.01	112.0/13	<0.01	28.2/13	<0.01	26.3/13	0.02
$\lvert y^{t\bar{t}}\rvert$ vs $m^{t\bar{t}}$	41.4/23	0.01	27.1/23	0.25	52.9/23	<0.01	45.3/23	<0.01	32.3/23	0.09	26.8/23	0.27
$p_{\text{T}}^{t,1}$ vs N_{jets}	28.2/18	0.06	25.4/18	0.12	45.4/18	<0.01	70.7/18	<0.01	44.8/18	<0.01	28.2/18	0.06
$p_{\text{T}}^{t,1}$ vs $m^{t\bar{t}}$	31.9/10	<0.01	16.8/10	0.08	48.1/10	<0.01	46.6/10	<0.01	11.5/10	0.32	15.3/10	0.12
$p_{\text{T}}^{t,1}$ vs $p_{\text{T}}^{t,2}$	17.6/11	0.09	21.8/11	0.03	27.3/11	<0.01	38.3/11	<0.01	28.9/11	<0.01	10.4/11	0.49
$p_{\text{T}}^{t,2}$ vs N_{jets}	25.5/13	0.02	14.9/13	0.32	47.7/13	<0.01	108.0/13	<0.01	19.5/13	0.11	23.4/13	0.04
$p_{\text{T}}^{t,2}$ vs $m^{t\bar{t}}$	21.2/11	0.03	6.2/11	0.86	40.1/11	<0.01	35.9/11	<0.01	9.3/11	0.59	8.3/11	0.69
$p_{\text{T}}^{t\bar{t}}$ vs N_{jets}	28.9/10	<0.01	16.2/10	0.09	56.3/10	<0.01	149.0/10	<0.01	21.5/10	0.02	12.0/10	0.28
$p_{\text{T}}^{t\bar{t}}$ vs $m^{t\bar{t}}$	25.4/10	<0.01	43.0/10	<0.01	33.7/10	<0.01	33.5/10	<0.01	26.9/10	<0.01	14.0/10	0.17



COMPARISON RESULTS

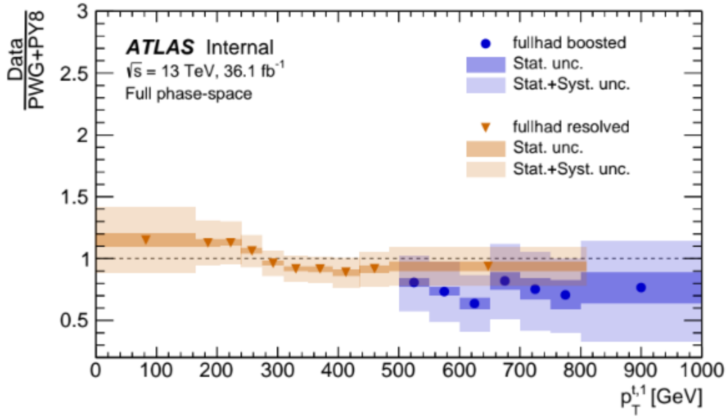
ALL-HADRONIC wrt L+JETS

- Same phase space and object definition at parton level
- Consistent in the overlap region
- Complementary bin resolutions between the two channels

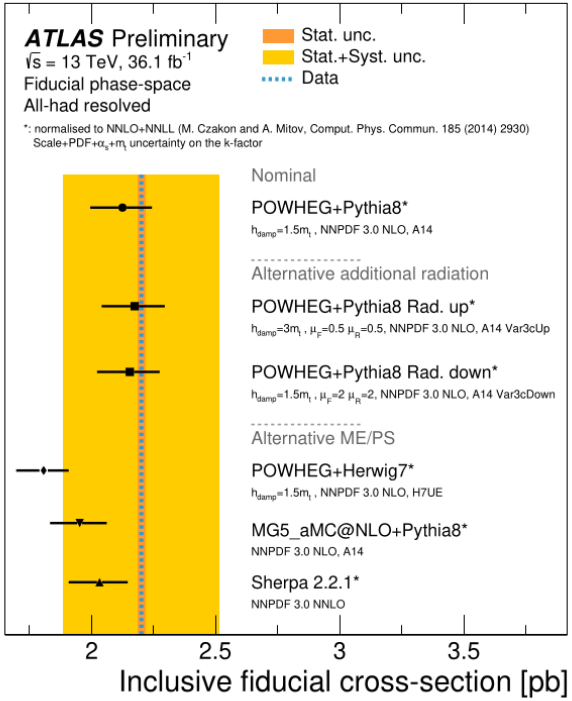


ALL-HADRONIC wrt BOOSTED

- Direct comparison not possible
  - Fiducial vs. full phase-space
- Ratio consistent in the overlap region



TOTAL CROSS-SECTION



- Powheg+Herwig7 has the largest discrepancy from total XS
  - On the other hand it has the best description for differential distributions

l+jets and boosted paper: https://link.springer.com/article/10.1140/epjc/s10052-019-7525-6

SUMMARY

- Comprehensive cross-section measurement
  - Single- and double-differential
  - Absolute and normalised
  - Particle and parton levels
- Several kinematic variables
  - Additional novel variables to study top associated jet radiation
- Data driven background estimate strategy
- Results sensitive to different aspects of MC
  - Improve top-quark MC modelling
  - Check out Simone Amoros's talk which presents new MC studies using our Rivet routine
    - https://conference.ippp.dur.ac.uk/event/891/contributions/4891/
- Parton level results can be used for PDF and top pole mass extraction

JHEP PAPER

https://arxiv.org/abs/2006.09274

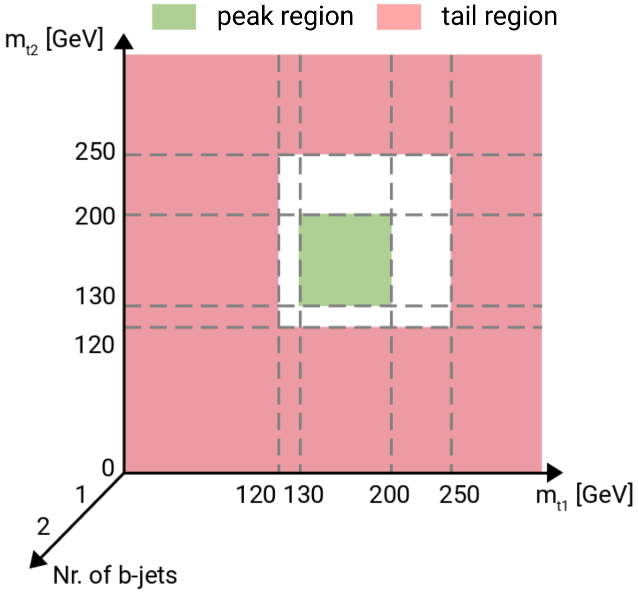
EXTRA

BACKGROUND ESTIMATE

- Data driven ABCD method
  - estimated bin-by-bin for all observables
- Discriminant variables
  - Nr. of b-jets
  - Combination of top masses
- Nominal estimate
  - A_1, B_1, C, D
  - Using the 1 b-tagged region
- Alternate estimate for uncertainty
  - A_0, B_0, C, D
  - Using the 0 b-tagged region
- Gap between SR and CR region
  - White area in the chart
  - Significant reduction of the signal contamination

mass region	condition
$(m_{t1}, m_{t2}) \in$ tail	if at least one top with $m_t < 120$ GeV or $m_t > 250$ GeV
$(m_{t1}, m_{t2}) \in$ peak	if both top have 130 GeV $< m_t <$ 200 GeV

Table 4: Definition of the mass region based on the m_t of the two top quarks.



	tail	peak
$N_{\text{b-jets}} = 0$	A_0	B_0
$N_{\text{b-jets}} = 1$	A_1	B_1
$N_{\text{b-jets}} = 2$	C	D

D: signal region

A_1, B_1: QCD Estimate

A_0, B_0: Used for uncertainty

$$D(X) = \frac{B_1(X) \cdot C(X)}{A_1(X)}$$

$$D'(X) = \frac{B_0(X) \cdot C(X)}{A_0(X)}$$

$$\Delta D = D' - D$$