Top quark pair production cross-section in ATLAS

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Results shown today

Latest results from the ATLAS EXPERIMENT Collaboration:

1.) Measurement of the inclusive top quark pair production cross-section at $\sqrt{s}$=5.02 TeV in the single-lepton and dilepton final states.

New result for LHCP 2022!
ATLAS-CONF-2022-031

2.) Full Run-2 differential top quark pair cross-section measurements using boosted top quarks in the all-hadronic final state.

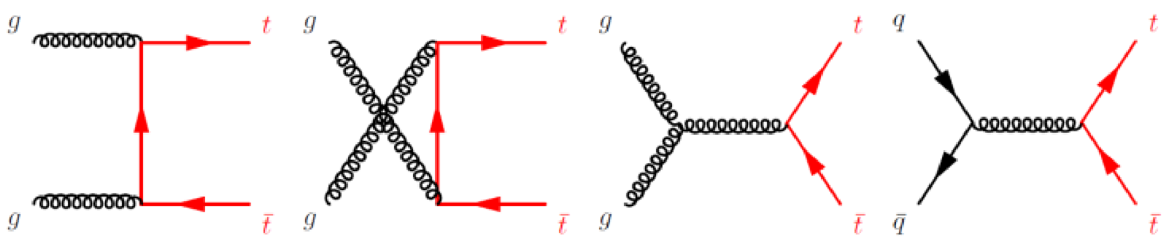
arXiv:2205.02817 (May. 2022)
submitted to JHEP
superseed ATLAS-CONF-2021-050

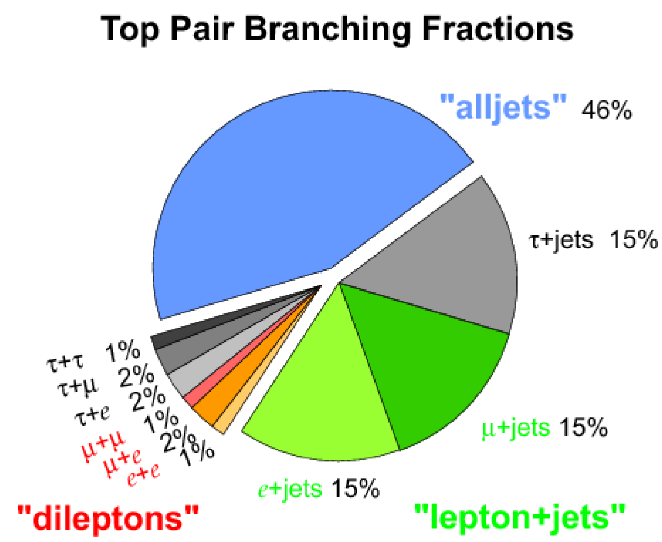
3.) Full Run-2 differential cross-sections using boosted top quark pair events in the lepton+jets channel at $\sqrt{s}$ = 13 TeV.

arXiv:2202.12134 (Feb. 2022)
accepted in JHEP
superseed ATLAS-CONF-2021-031

Top quark production and decay

- Top quark pair (ttbar) production governed by **strong** interaction:

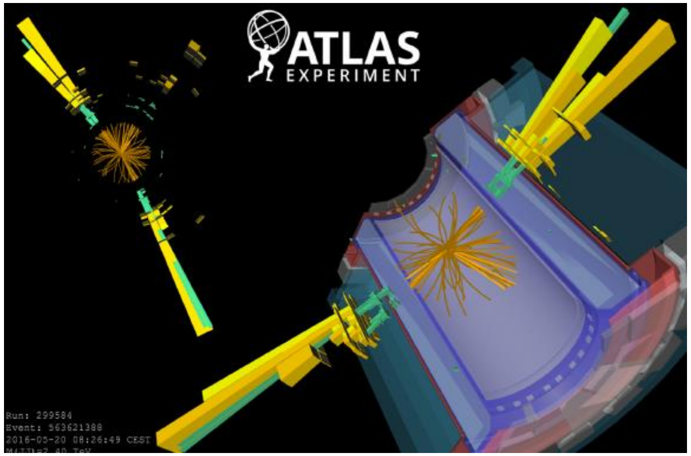




- Final state topology is given W-boson decays:

  $W \rightarrow l\nu$ (~ 30%) / qq' (~ 70%)

Resolved or **boosted** topologies:



Inclusive ttbar cross-section measurement

Inclusive σ(tt): a standard candle at LHC, allows us to test QCD predictions and constrain parameters such as top mass, α_S and PDFs

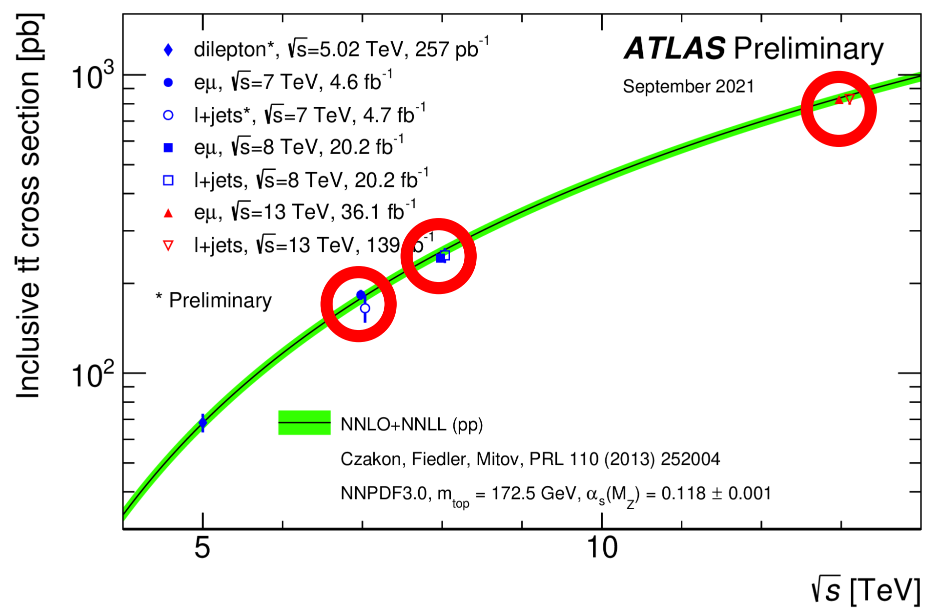
- Theory (NNLO+NNLL) predictions with **5.0% - 7.5%** precision
- ATLAS precision measurements:

~**4%** (eμ channel) and ~**6%** (l+jets) at 7 TeV and 8 TeV

2.4% (eμ) and **4.6%** (l+jets) at 13 TeV

- Usually dominated by luminosity uncert. (dilep) and modelling (l+jets)

Inclusive cross-section



ATL-PHYS-PUB-2021-014

Channel	$\sqrt{s}$ [TeV]	$\int \mathcal{L}\,dt$ [fb^{-1}]	$\sigma_{t\bar{t}}$ [pb]	Reference
Dilepton	5	0.257	66.0 ± 4.9	[2]
$e\mu$	7	4.6	183 ± 7	[3]
ℓ+jets	7	4.7	165 ± 17	[4]
$e\mu$	8	20.2	242 ± 9	[3]
ℓ+jets	8	20.2	248 ± 14	[5]
$e\mu$	13	36.1	826.4 ± 19.9	[6]
ℓ+jets	13	139	830 ± 39	[7]

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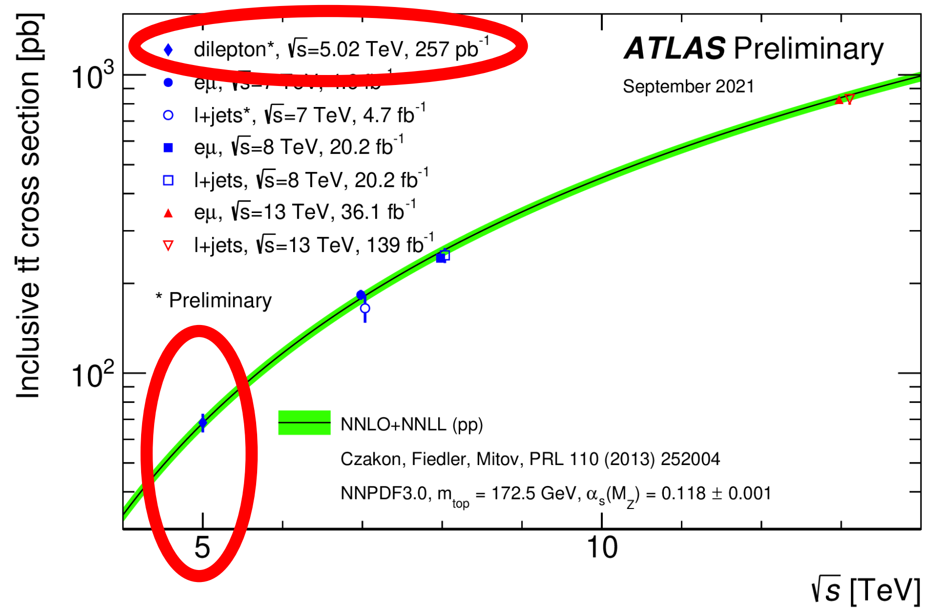
2.4% (eμ) and **4.7%** (l+jets) at 13 TeV

- Usually dominated by luminosity uncert. (dilep) and modelling (l+jets)
- Preliminary dilepton channel (eμ, ee, μμ) at √s=5.02 TeV, observing: σ(tt) = 66.0 ± 4.9 pb (**7.5%** precision)

Inclusive cross-section



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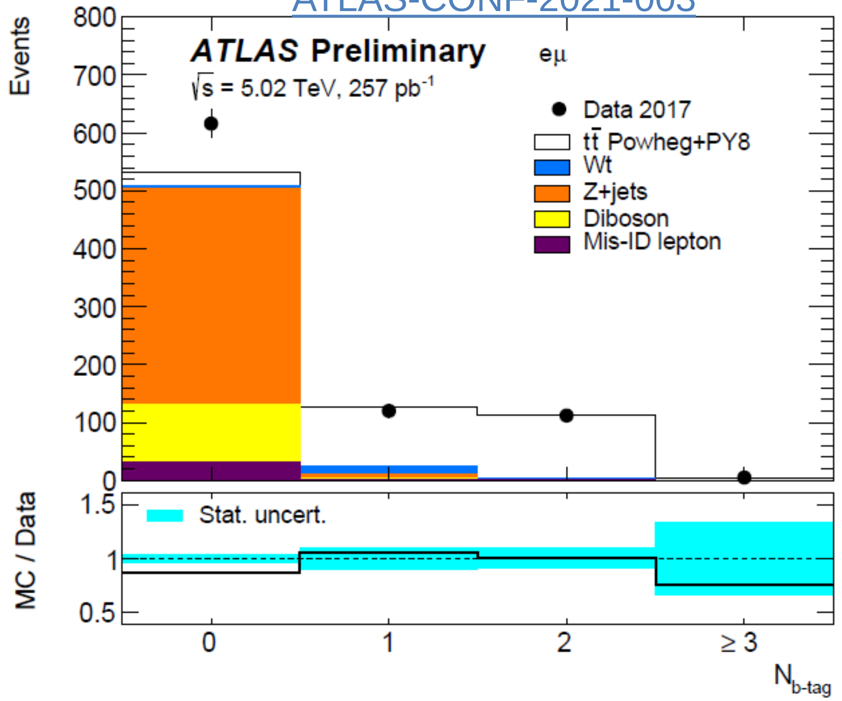
Inclusive ttbar cross-section at √s=5.02 TeV

- 257 pb^{-1} of data collected by ATLAS in November 2017 at √s = 5.02 TeV
  - low-μ environment (data levelled to <μ>≈2)
- Dilepton channel (ATLAS-CONF-2021-003 released in 2021) using the standard double-tagging formalism in opposite-flavour dilepton events (extended to same-flavour ee, μμ channels):

$$N_1^{e\mu} = L\sigma_{t\bar{t}}\,\epsilon_{e\mu} 2\epsilon_b^{e\mu}(1 - C_b^{e\mu}\epsilon_b^{e\mu}) + \sum_{k=\mathrm{bkg}} s_1^k N_1^{e\mu,k}$$

$$N_2^{e\mu} = L\sigma_{t\bar{t}}\,\epsilon_{e\mu} C_b^{e\mu}(\epsilon_b^{e\mu})^2 + \sum_{k=\mathrm{bkg}} s_2^k N_2^{e\mu,k}$$

ATLAS-CONF-2021-003



New inclusive ttbar cross-section at √s=5.02 TeV

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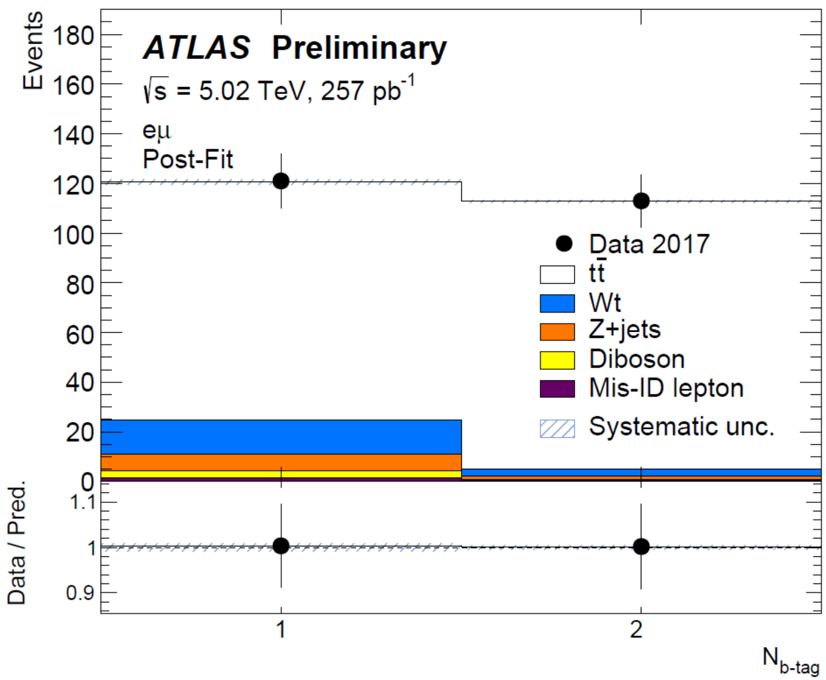
New result for LHCP 2022!

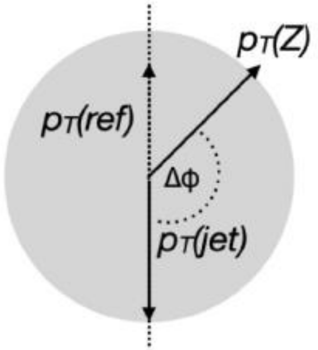
- in-situ JES/JER **calibration** at √s = 5.02 TeV
- addition of new **single-lepton** channel
- **combination** with the dilepton channel

ATLAS-CONF-2022-031



New inclusive ttbar cross-section at √s=5.02 TeV

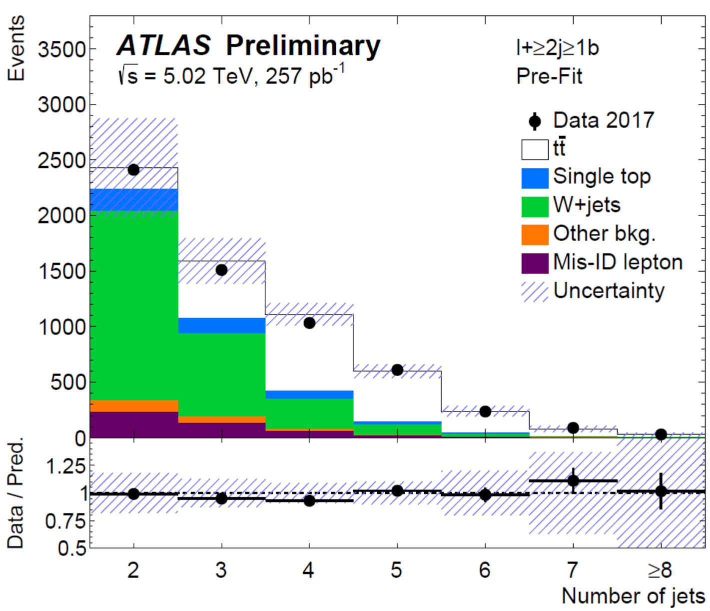
- In-situ correction derived using the Z+jet balance technique due lower noise thresholds during 5.02 data-taking (~ 2-8%)
  - ✓ Dilepton channel re-analysed, not sensitive to JES/JER, minor change: σ(ttbar) = 66.0 ± 4.9 pb → 65.7 ± 4.9 pb

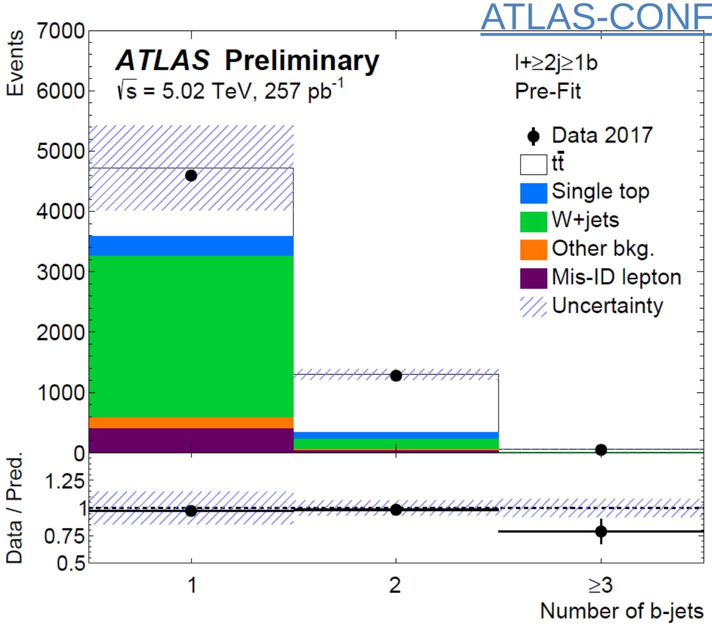


$p_T^{ref} = p_T(Z) * |\cos \Delta\varphi(Z, j_1)|$

- **New channel added: single-lepton**
  - ≥2 jets, 1 or 2 b-jets with pT > 20 GeV, and MET/mTW cuts > 30 GeV
  - MC for W/Z+jets, single top, diboson; data-driven mis-identified leptons

ATLAS-CONF-2022-031





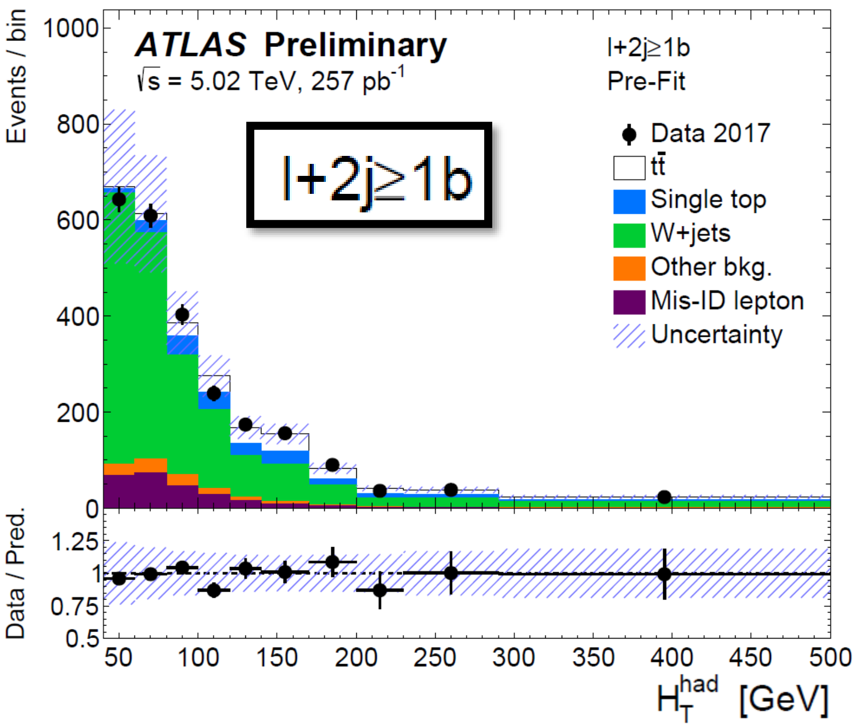
New inclusive ttbar cross-section at √s=5.02 TeV

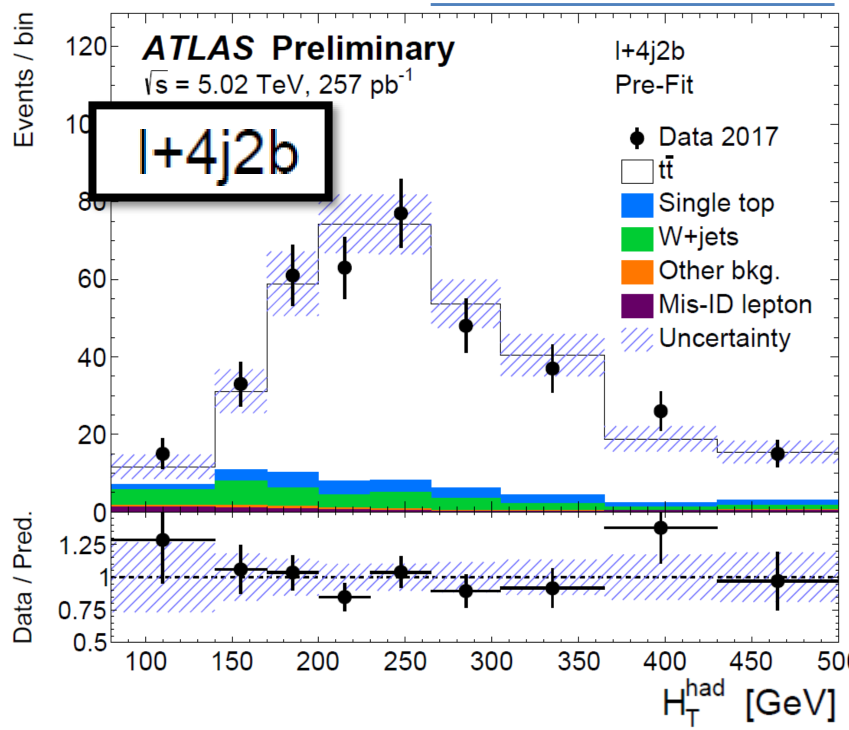
- Divide into six regions based on # of jets and b-jets

✓ Excellent pre-fit agreement of rates and shapes in all regions

Region name	Jet multiplicity	b-jet multiplicity
ℓ+2j≥1b	2	≥ 1
ℓ+3j 1b	3	1
ℓ+3j 2b	3	2
ℓ+≥4j 1b	≥ 4	1
ℓ+4j 2b	4	2
ℓ+≥5j 2b	≥ 5	2

ATLAS-CONF-2022-031



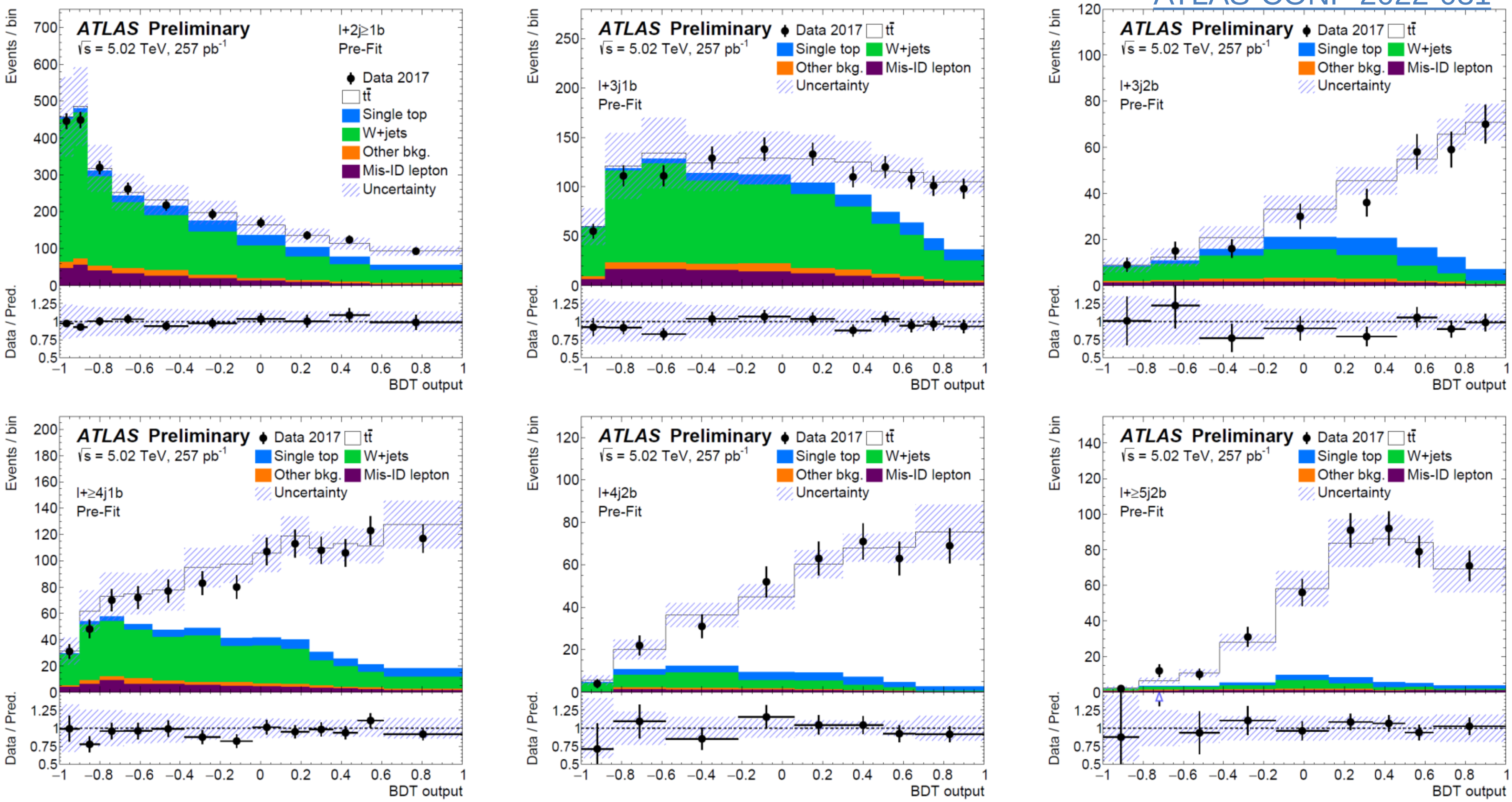


New inclusive ttbar cross-section at √s=5.02 TeV

- 2 boosted-decision trees using six input variables each trained to separate signal from background (mainly W+jets and single top)

✓ Good agreement is found in the shapes of the BDT outputs in each region

ATLAS-CONF-2022-031



New inclusive ttbar cross-section at $\sqrt{s}$=5.02 TeV

Category	$\delta\sigma_{t\bar{t}}$ [%] Dilepton	Single lepton
$t\bar{t}$ generator†	1.2	1.0
$t\bar{t}$ hadronisation*,†	0.3	0.9
$t\bar{t}$ h_{damp} and scale variations†	1.0	1.1
$t\bar{t}$ parton-distribution functions†	0.2	0.2
Single-top background	1.1	0.8
W/Z+jets background*	0.8	2.4
Diboson background	0.3	0.1
Misidentified leptons*	0.7	0.3
Electron identification/isolation	0.8	1.2
Electron energy scale/resolution	0.1	0.1
Muon identification/isolation	0.6	0.2
Muon momentum scale/resolution	0.1	0.1
Lepton-trigger efficiency	0.2	0.9
Jet-energy scale/resolution	0.1	1.1
$\sqrt{s}$ = 5.02 TeV JES correction	0.1	0.6
Jet-vertex tagging	<0.1	0.2
Flavour tagging	0.1	1.1
$E_{\text{T}}^{\text{miss}}$	0.1	0.4
Simulation statistical uncertainty*	0.2	0.6
Data statistical uncertainty*	6.8	1.3
Total systematic uncertainty	3.1	4.2
Integrated luminosity	1.8	1.6
Beam energy	0.3	0.3
Total uncertainty	7.5	4.5

- Largest uncertainties: luminosity (1.6%), signal and background modelling, object reconstruction

New inclusive ttbar cross-section at √s=5.02 TeV

Category	$\delta\sigma_{t\bar{t}}$ [%] Dilepton	Single lepton	Combination
$t\bar{t}$ generator†	1.2	1.0	0.8
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$t\bar{t}$ parton-distribution functions†	0.2	0.2	0.2
Single-top background	1.1	0.8	0.6
W/Z+jets background*	0.8	2.4	1.8
Diboson background	0.3	0.1	< 0.1
Misidentified leptons*	0.7	0.3	0.3
Electron identification/isolation	0.8	1.2	0.8
Electron energy scale/resolution	0.1	0.1	< 0.1
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Lepton-trigger efficiency	0.2	0.9	0.7
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$\sqrt{s}$ = 5.02 TeV JES correction	0.1	0.6	0.5
Jet-vertex tagging	< 0.1	0.2	0.2
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Integrated luminosity	1.8	1.6	1.6
Beam energy	0.3	0.3	0.3
Total uncertainty	7.5	4.5	3.9

- Largest uncertainties: luminosity (1.6%), signal and background modelling, object reconstruction

- **Combination** of a cut-and-count dilepton result with a binned PLL fit in single-lepton channel:
  - ✓ Using Convino tool (Eur. Phys. J. C(2017) 77 792)
  - ✓ Post-fit uncertainty correlations accounted for in the combination

New inclusive ttbar cross-section at √s=5.02 TeV

- Observed production cross-section in the **dilepton channel:**

$$\sigma_{t\bar{t}} = 65.7 \pm 4.5\,(\text{stat.}) \;\; \pm 1.6\,(\text{syst.}) \;\; \pm 1.2\,(\text{lumi.}) \;\; \pm 0.2\,(\text{beam})\ \text{pb}$$

(7.5% precision)

- Observed production cross-section in the **single-lepton channel:**

$$\sigma_{t\bar{t}} = 68.2 \pm 0.9\,(\text{stat.}) \;\; \pm 2.9\,(\text{syst.}) \;\; \pm 1.1\,(\text{lumi.}) \;\; \pm 0.2\,(\text{beam})\ \text{pb}$$

(4.5% precision)

- **Combination** of the dilepton and single-lepton measurements:

$$\sigma_{t\bar{t}} = 67.5 \pm 0.9(\text{stat.}) \pm 2.3(\text{syst.}) \pm 1.1(\text{lumi.}) \pm 0.2(\text{beam})\ \text{pb}$$

(3.9% precision)

- Results are consistent with the NNLO+NNLL QCD prediction of 68.2 ± 5.2 pb, calculated with Top++, and exceed the relative precision of theoretical calculations

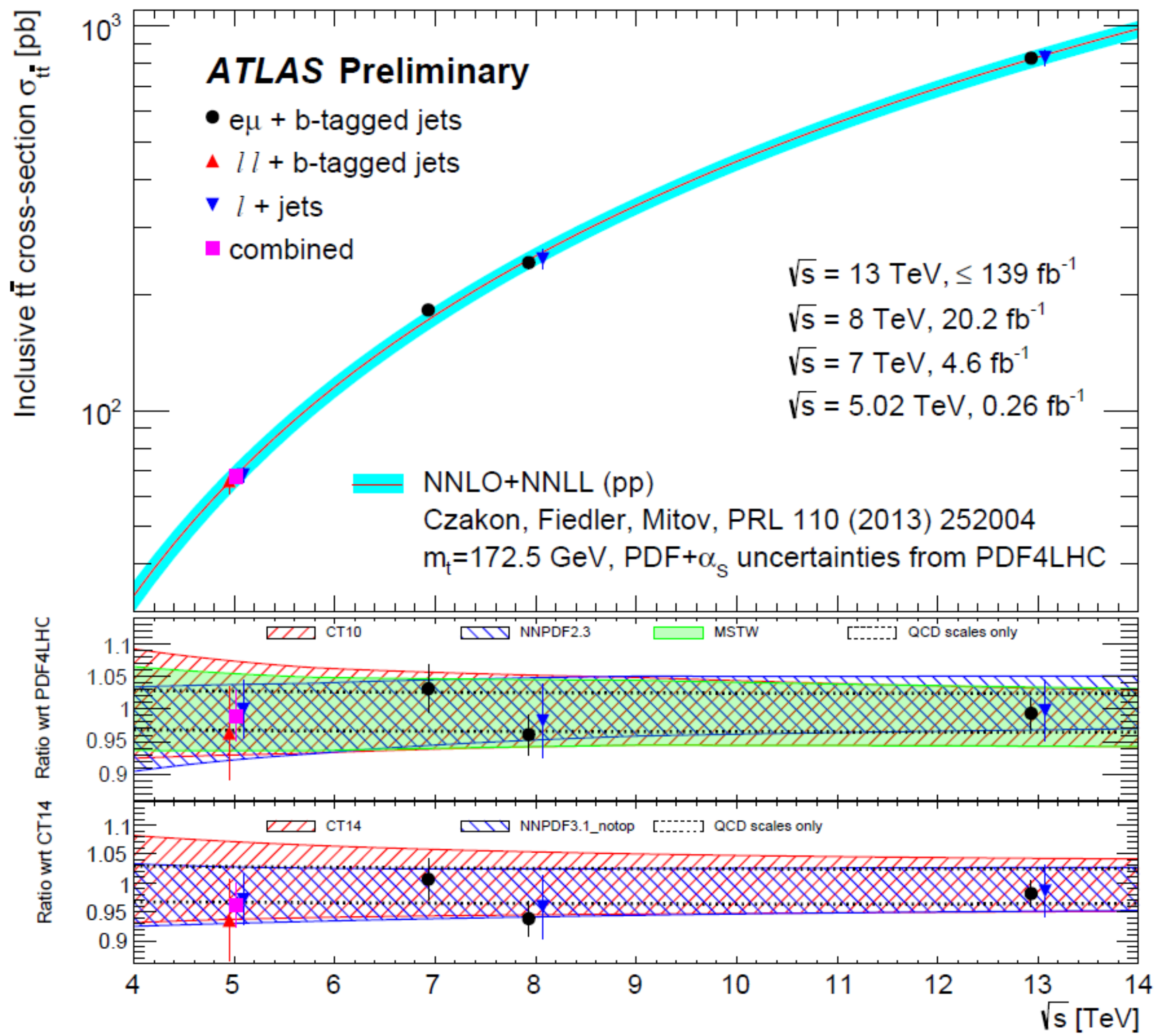
New inclusive ttbar cross-section at √s=5.02 TeV

- **Most precise** single-lepton result in ATLAS, slightly more precise than 13 TeV using ~500 more data [Phys. Lett. B 810 (2020) 135797]

- 5.02 TeV result from CMS [JHEP 04 (2022) 144] combined single-lepton result using 2015 data (27.4 pb^{-1}) and dilepton using 2017 data (304 pb^{-1}) with 8% precision: σ(tt) = 63.0 ± 5.1 pb

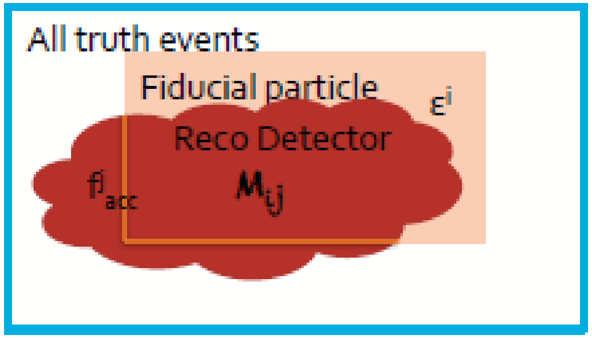
- Consistent with CMS, total uncertainty **reduced** by almost a **factor of two**

ATLAS-CONF-2022-031



Differential ttbar cross-section measurements

- Extensions to the SM may modify differential cross-sections in ways that an inclusive cross-section measurement is not sensitive to
    - i.e. distort the top-quark p_T distribution

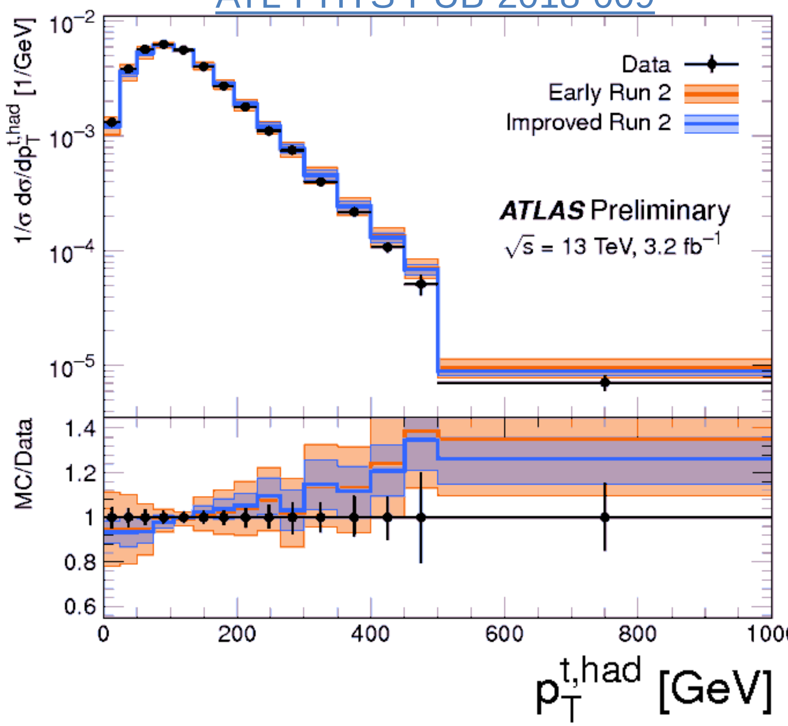


- Test global properties of ttbar events at parton-level and particle-level

- Used to improve MC generators modelling

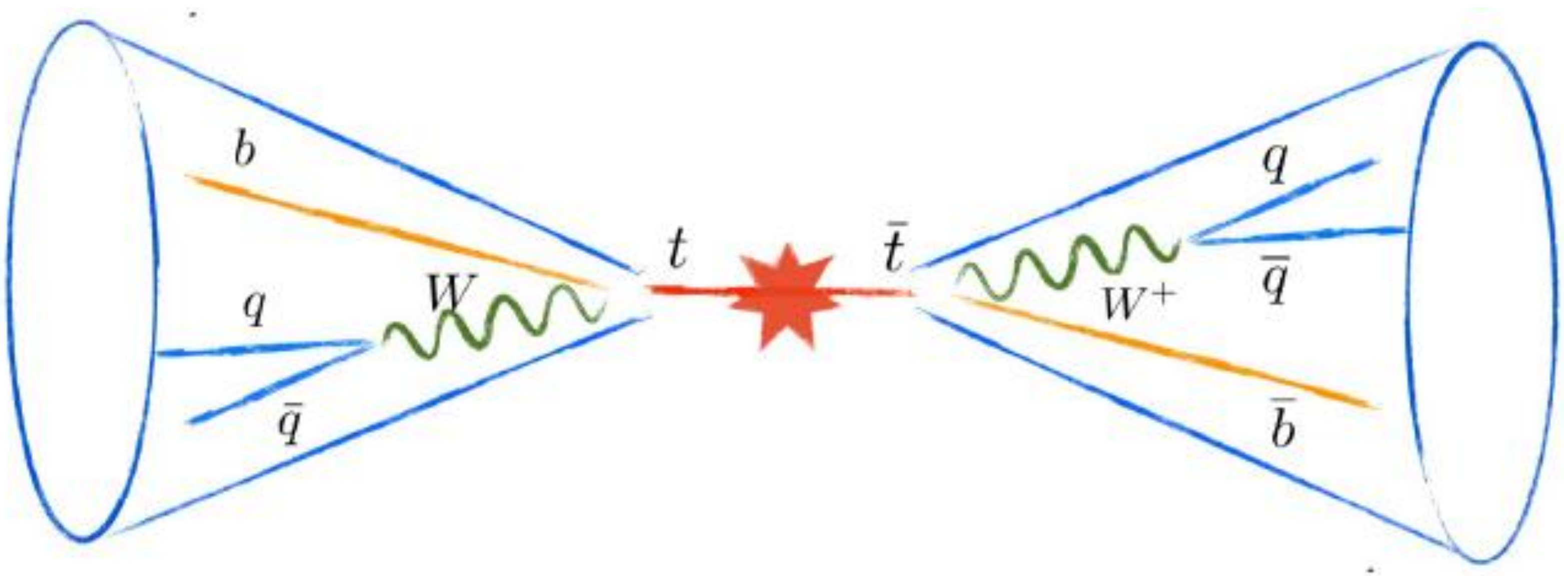
Early Run 2 ⇒ Improved Run 2

ATL-PHYS-PUB-2018-009



Differential ttbar in boosted all-hadronic events

arXiv:2205.02817



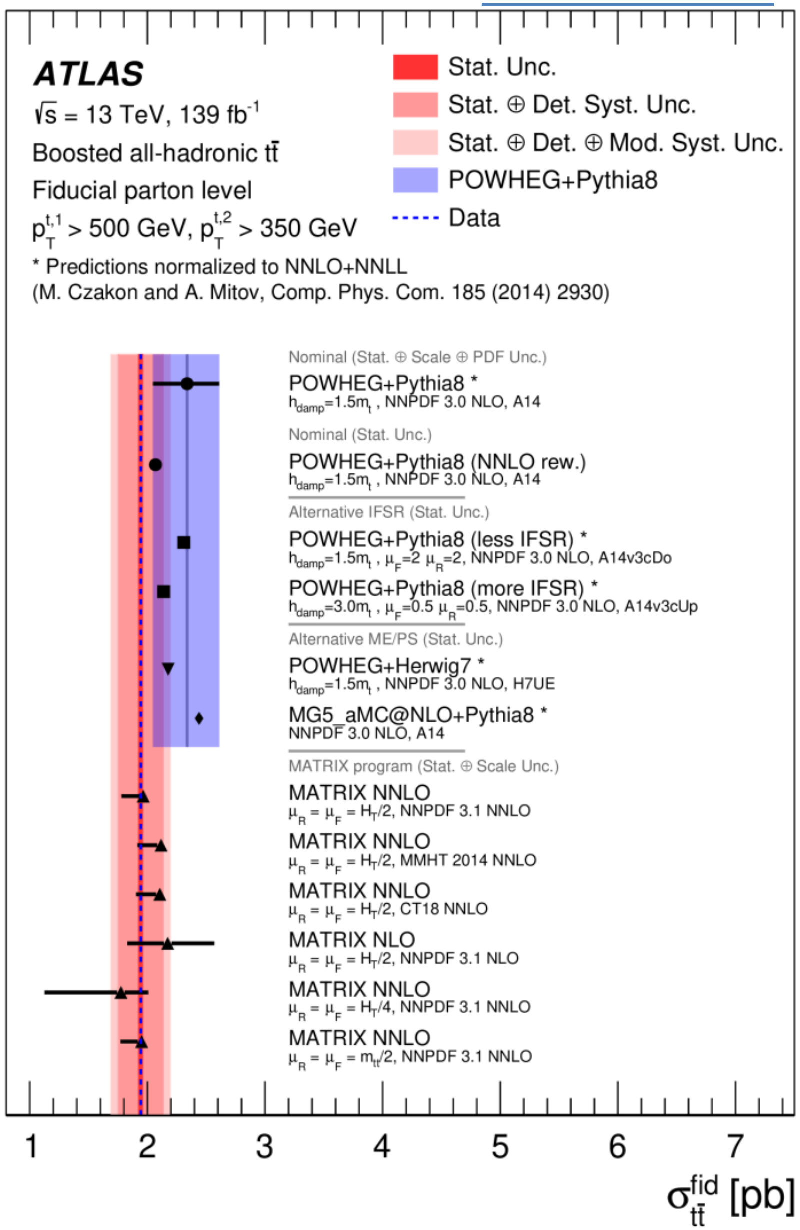
Differential ttbar in boosted all-hadronic events

- 2 high-p_T large-R DNN top-tagged jets
  - ✓ Data-driven multijet background
- Unfolding performed using Iterative Bayesian Unfolding (RooUnfold) at particle- and parton-level.
- Inclusive parton-level fiducial phase-space with 13% precision:

$\sigma(tt) = 1.94 \pm 0.02\ (stat) \pm 0.25\ (syst)$ pb

- Powheg+Pythia 8 MC predictions 20% larger, consistent within the theo. uncert.
- Better agreement for the NNLO Matrix predictions

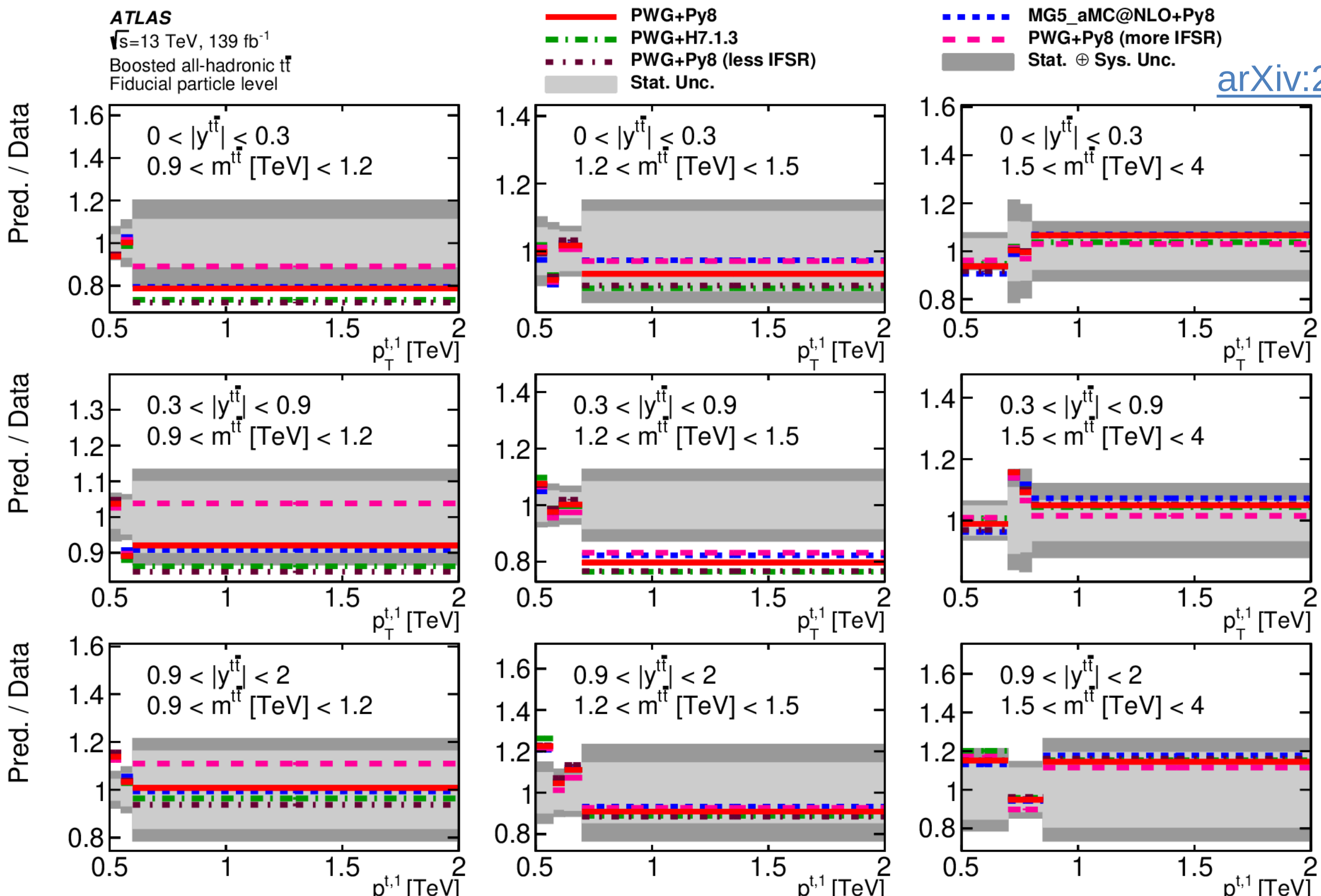
arXiv:2205.02817



Differential ttbar in boosted all-hadronic events

- Triple-differential cross-section in y^{tt}, m^{tt} and $p_T^{t,1}$ exhibit a precision of 10-20% and are in agreement with several NLO+PS predictions for most of the observables.

arXiv:2205.02817

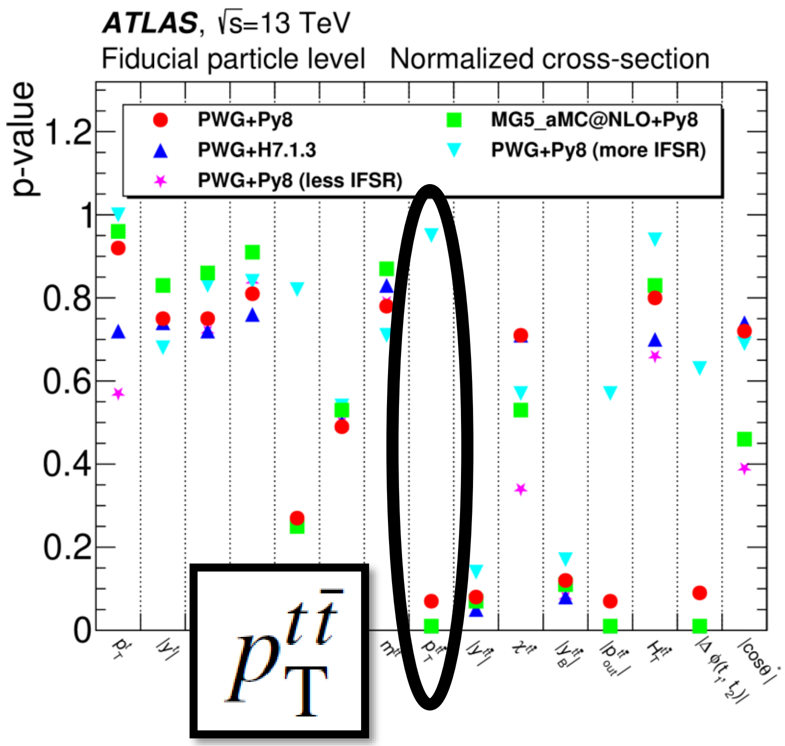


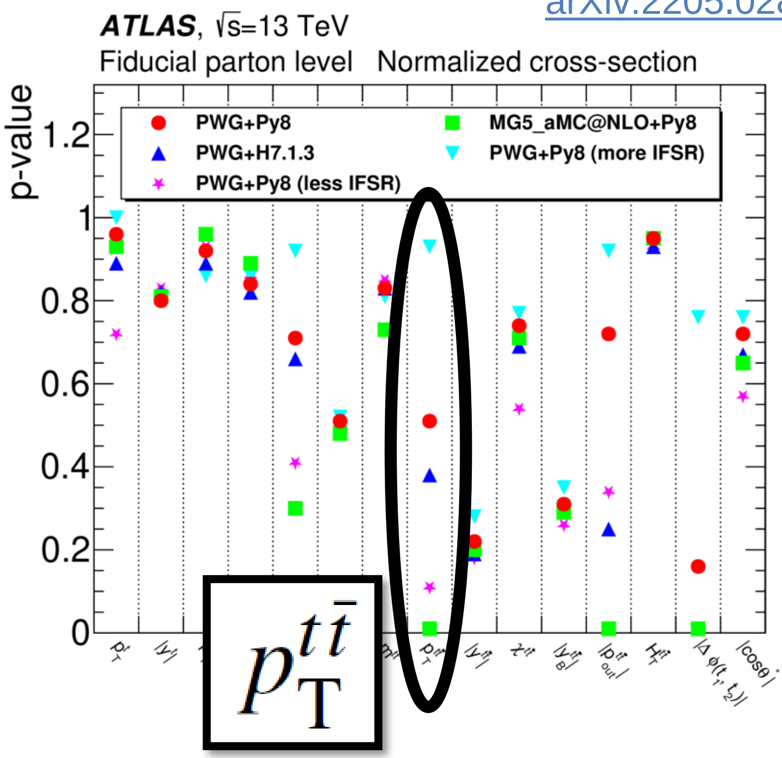
leading top-quark jet $p_T^{t,1}$

Differential ttbar in boosted all-hadronic events

- Most precise differential cross-sections in the boosted ttbar all-hadronic final state, uncertainty reduced by a 2x (and up to 5x) compared to previous ATLAS results [Phys. Rev. D 98, 012003 (2018)]

arXiv:2205.02817

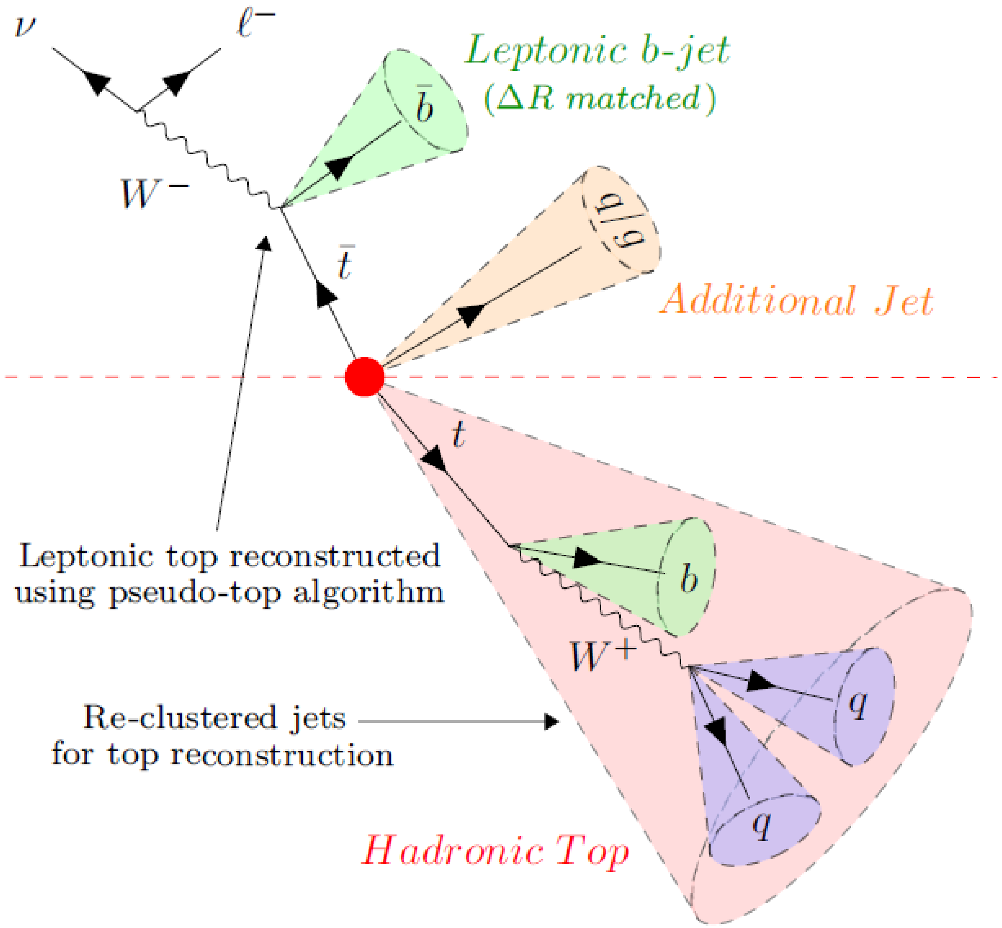




- p-values: deficit of radiation in MC prediction, not evident in the parton-level comparisons: arise due to PS/hadronisation or ISR/FSR

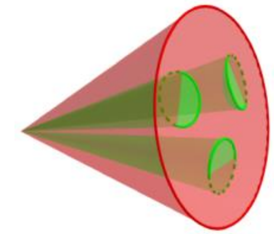
Differential ttbar in boosted single-lepton events

arXiv:2202.12134

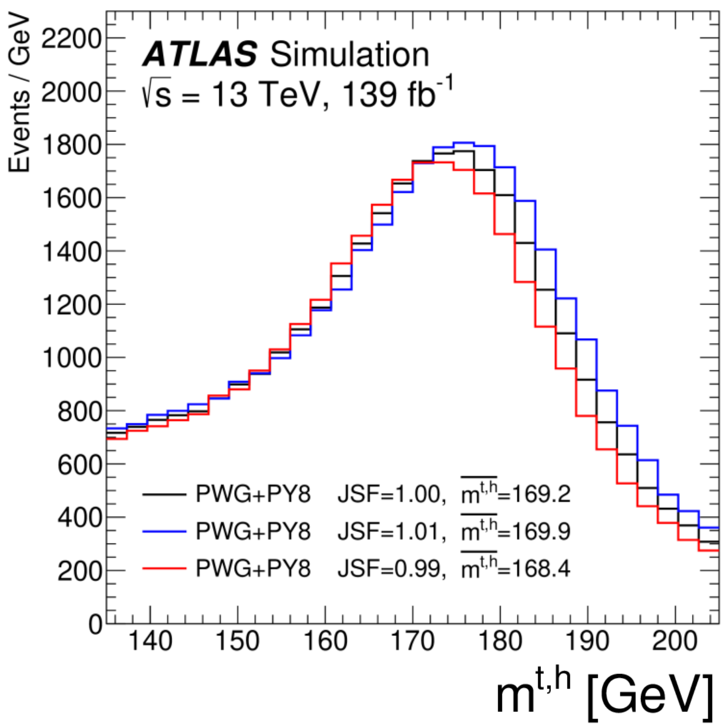


Differential ttbar in boosted single-lepton events

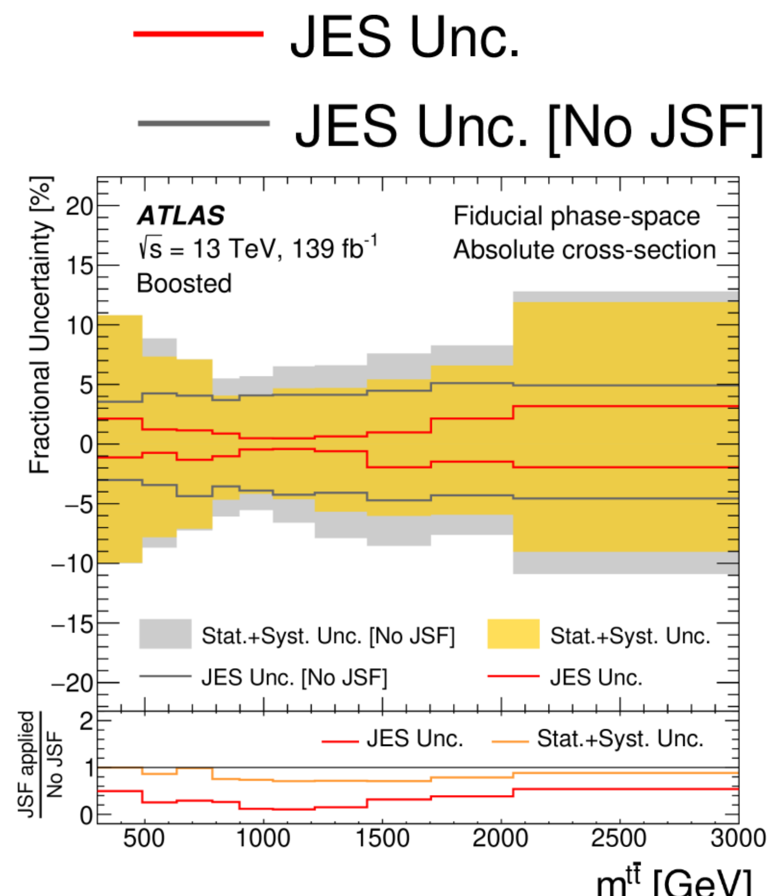
- One hadronically decaying boosted top quark and one leptonic decay
- Reclustered large-R jet used as a proxy for top quark
  - ✓ mass depends on the energy-scale of its small-R sub-jets



- The overall JES difference between data and simulation for small-R jets is parameterised with a jet energy scale factor (JSF)



Reduction:
4.2% to 0.7%



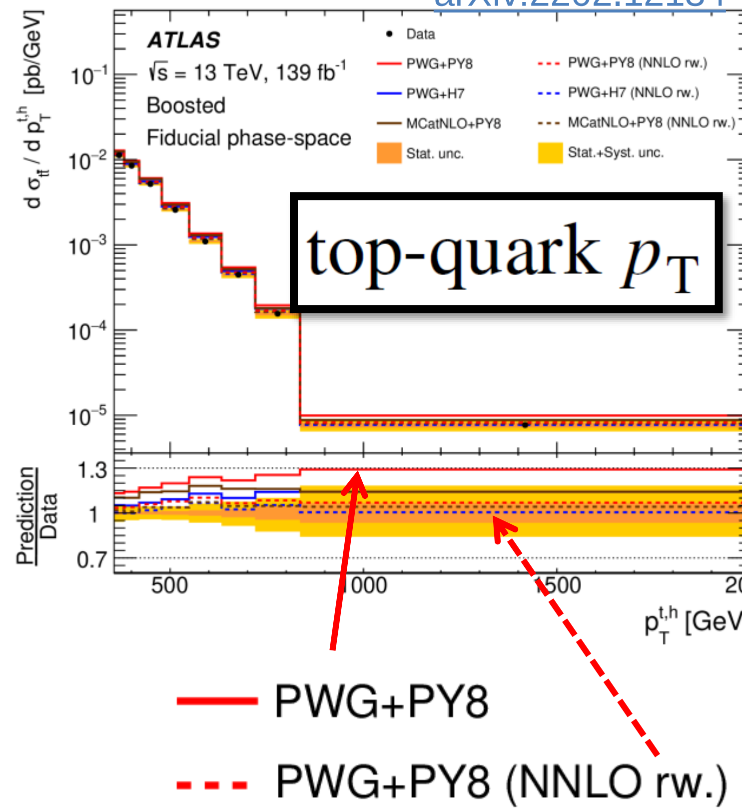
arXiv:2202.12134

Differential ttbar in boosted single-lepton events

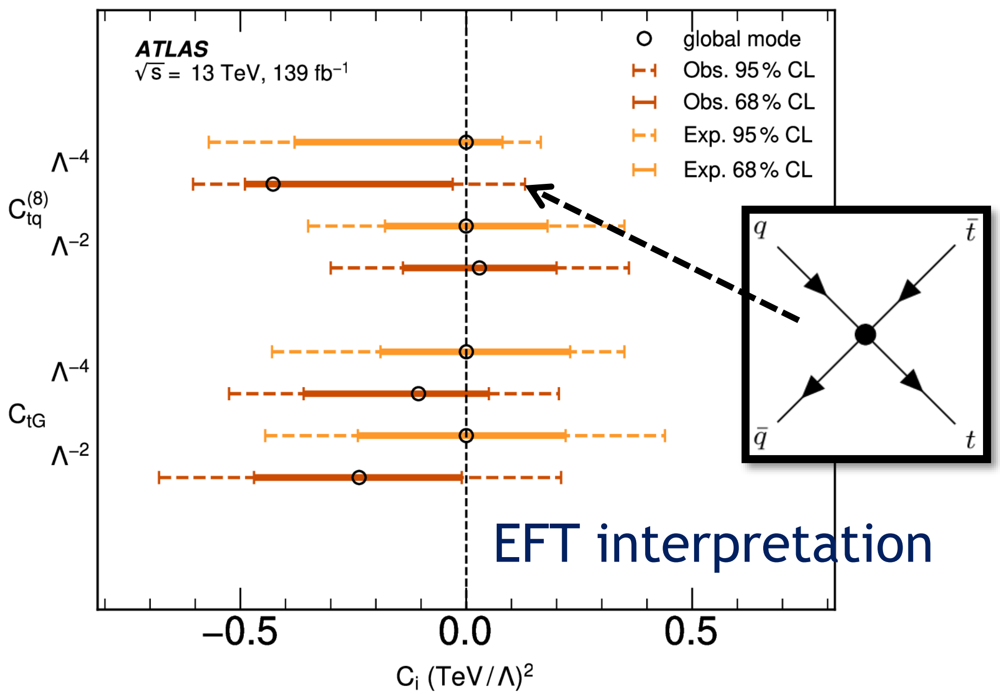
- Top quark kinematics and radiation probed in fiducial (particle) phase space.
  - ✓ ~50% more precise as previous ATLAS result [Eur. Phys. J. C 79 (2019) 2018] and CMS boosted result [Phys. Rev. D 103, 052008 (2021)]

➢ No single NLO+PS MC generators is able to describe all variables!

arXiv:2202.12134



- 3D-iterative MC reweighting [arXiv:2105.03977] to NNLO in QCD and NLO EW prediction leads to better agreement.



Differential ttbar in boosted single-lepton events

- Inclusive particle-level fiducial cross-section with 4.2% precision:

$\sigma(tt)$ = 1.267 ± 0.005 (stat) ± 0.053 (syst) pb

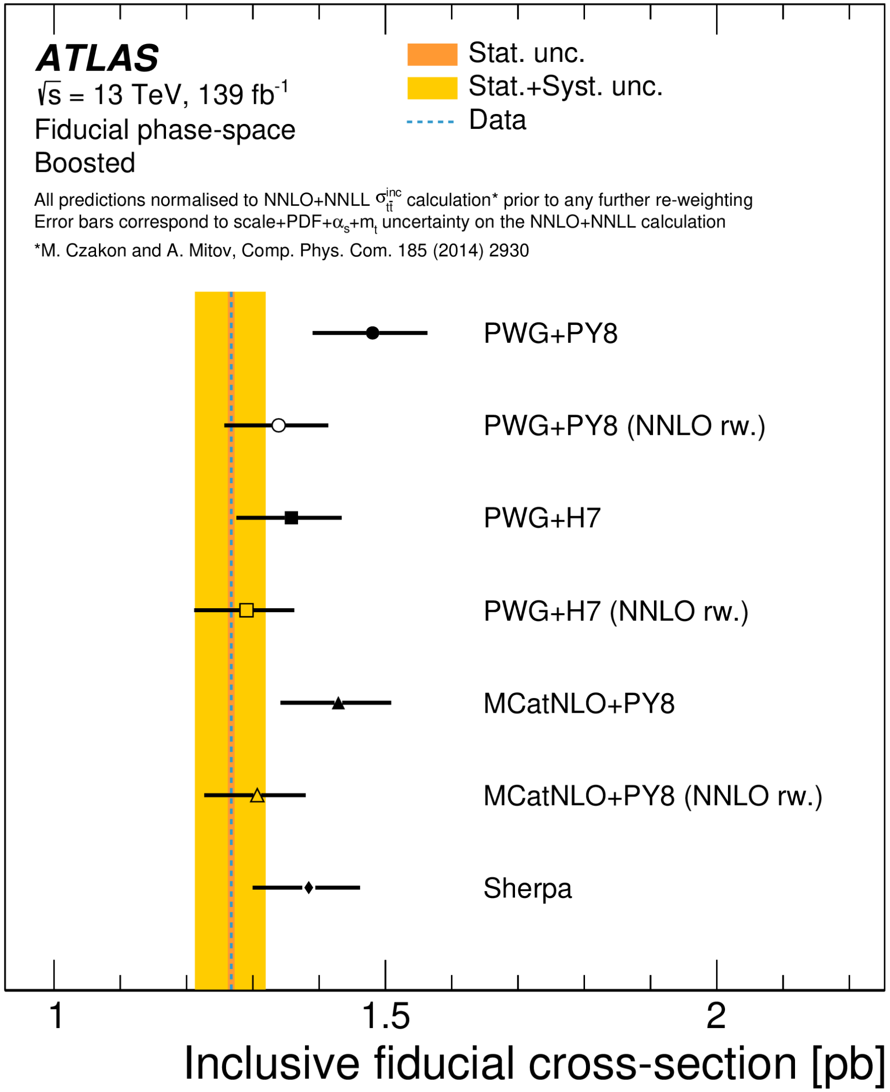
✓ Exceeds the relative precision of NNLO+NNLL calculations

✓ Same level of precision as in the resolved topologies!

- All MC predictions higher than data, ~2 std. dev. above data

- Significantly better agreement is seen after reweighting the MC simulations to the differential NNLO predictions

arXiv:2202.12134



Conclusions

- The Run 2 data set of ATLAS continues to be a fruitful resource for high precision and innovative measurements.
- New measurement released for LHCP2022 of the ttbar production cross-section at 5.02 TeV in single-lepton and dilepton channels:
  - ✓ Optimisation of the analysis strategy, MVA, uncertainties and PLL fit in the single-lepton channel to achieve a high precision result.
  - ✓ Extension of the established dilepton eμ+b-tag method to include SF ee and μμ channels; combination keeping post-fit correlations
- Comprehensive measurements of differential cross-sections in boosted regimes in single-lepton and all-hadronic final states:
  - ✓ input for tuning of MC generators, basis for EFT interpretations
  - ✓ NNLO fixed-order computations provide significant improvement
- Looking forward for new inclusive and differential results at Run 3!

BACK-UP

Public links to ATLAS results

- **Measurement of the inclusive ttbar production cross-section at √s=5.02 TeV in the single-lepton and dilepton final states.**

CDS: https://cds.cern.ch/record/2809724

Public webpage: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2022-031/

- **Measurements of differential cross-sections in top-quark pair events with a high transverse momentum top quark and limits on beyond the Standard Model contributions to top-quark pair production with the ATLAS detector at √s=13 TeV**

CDS: https://cds.cern.ch/record/2802296

Public webpage: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/TOPQ-2019-23/

- **Differential tt cross-section measurements using boosted top quarks in the all-hadronic final state with 139/fb of ATLAS data**

CDS: http://cds.cern.ch/record/2808775

Public webpage: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/TOPQ-2018-11/

CMS Collaboration results at $\sqrt{s}$=5.02 TeV

JHEP 04 (2022) 144

CMS dilepton (eμ) channel using 304 pb^{-1} of data at 5.02 TeV

Source	$\Delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}}$ (%)
Electron efficiency	1.6
Muon efficiency	0.6
Trigger efficiency	1.3
JES	2.2
JER	1.2
L1 prefiring	1.4
μ_R, μ_F scales	0.2
Final-state radiation	1.1
Initial-state radiation	< 0.1
h_{damp}	1.0
PDF$\oplus\alpha_S(m_Z)$	0.3
Underlying event tune	0.7
tW	1.0
Nonprompt leptons	0.4
Drell-Yan	1.8
VV	0.8
Total systematic uncertainty	4.3
Integrated luminosity	1.9
Statistical uncertainty	8.2

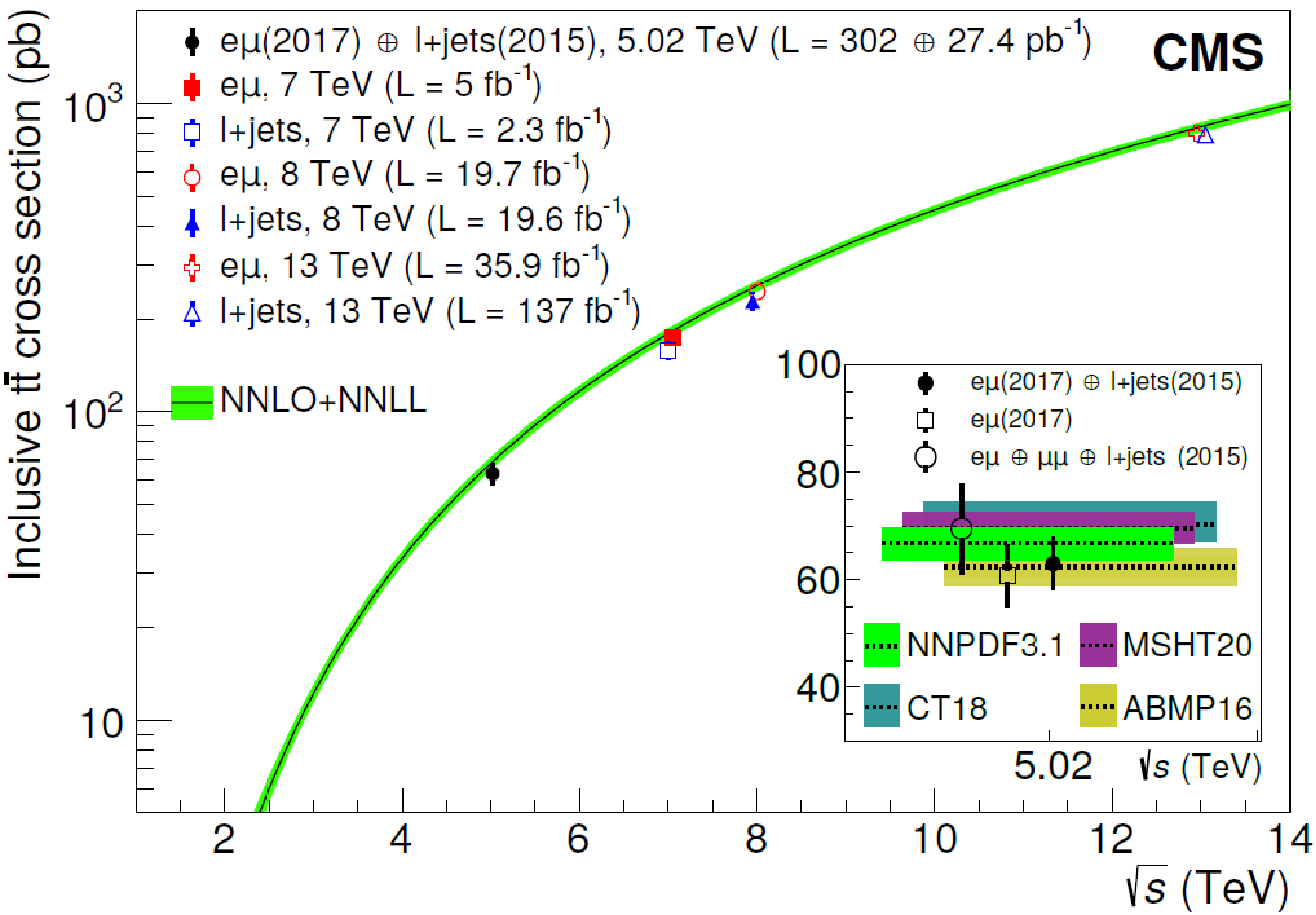
JHEP 03 (2018) 115

CMS l+jets channel using 27.4 pb^{-1} of data at 5.02 TeV

Source	$\Delta\mu/\mu$	
	Distr.	Count
Statistical uncertainty	0.095	0.100
Experimental systematic uncertainty	0.085	0.160
Individual experimental uncertainties		
W+jets background	0.035	0.025
QCD multijet background	0.024	0.044
Other background	0.013	0.013
Jet energy scale	0.030	0.031
Jet energy resolution	0.006	0.023
b tagging	0.034	0.045
Electron efficiency	0.011	0.028
Muon efficiency	0.017	0.022
Theoretical uncertainties		
Hadronization model of $t\bar{t}$ signal	0.028	0.069
μ_R, μ_F scales of $t\bar{t}$ signal (PS)	0.044	0.115
μ_R, μ_F scales of $t\bar{t}$ signal (ME)	<0.010	<0.010
Total uncertainty	0.127	0.189

CMS Collaboration results at √s=5.02 TeV

JHEP 04 (2022) 144



Comparison with ATLAS single-lepton 13 TeV result

Phys. Lett. B 810 (2020) 135797

ATLAS l+jets channel using 139 fb^{-1} of data at 13 TeV

Category	$\frac{\Delta\sigma_{inc}}{\sigma_{inc}}$ [%]
Signal modelling	
$t\bar{t}$ shower/hadronisation	±2.9
$t\bar{t}$ scale variations	±2.0
Top p_T NNLO reweighting	±1.1
$t\bar{t}$ h_{damp}	±1.4
$t\bar{t}$ PDF	±1.5
Background modelling	
MC background modelling	±2.0
Multijet background	±0.6
Detector modelling	
Jet reconstruction	±2.6
Luminosity	±1.7
Flavour tagging	±1.3
E_T^{miss} + pile-up	±0.3
Muon reconstruction	±0.5
Electron reconstruction	±0.6
Simulation stat. uncertainty	±0.7
Total systematic uncertainty	±4.6
Data statistical uncertainty	±0.05
Total uncertainty	±4.6

ATLAS-CONF-2022-031

ATLAS l+jets channel using 257 pb^{-1} of data at 5.02 TeV

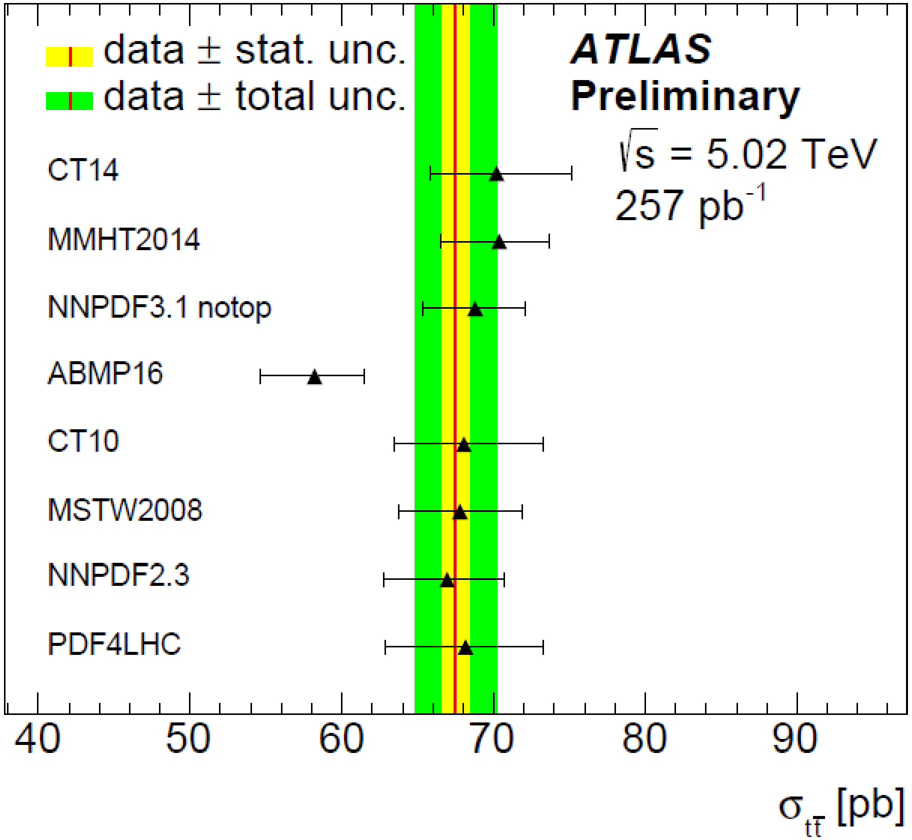
Category	$\delta\sigma_{t\bar{t}}$ [%] Single lepton
$t\bar{t}$ generator†	1.0
$t\bar{t}$ parton-shower/hadronisation*,†	0.9
$t\bar{t}$ h_{damp} and scale variations†	1.1
$t\bar{t}$ parton-distribution functions†	0.2
Single-top background	0.8
W/Z+jets background*	2.4
Diboson background	0.1
Misidentified leptons*	0.3
Electron identification/isolation	1.2
Electron energy scale/resolution	0.1
Muon identification/isolation	0.2
Muon momentum scale/resolution	0.1
Lepton-trigger efficiency	0.9
Jet-energy scale/resolution	1.1
$\sqrt{s}$ = 5.02 TeV JES correction	0.6
Jet-vertex tagging	0.2
Flavour tagging	1.1
E_T^{miss}	0.4
Simulation statistical uncertainty*	0.6
Data statistical uncertainty*	1.3
Total systematic uncertainty	4.2
Integrated luminosity	1.6
Beam energy	0.3
Total uncertainty	4.5

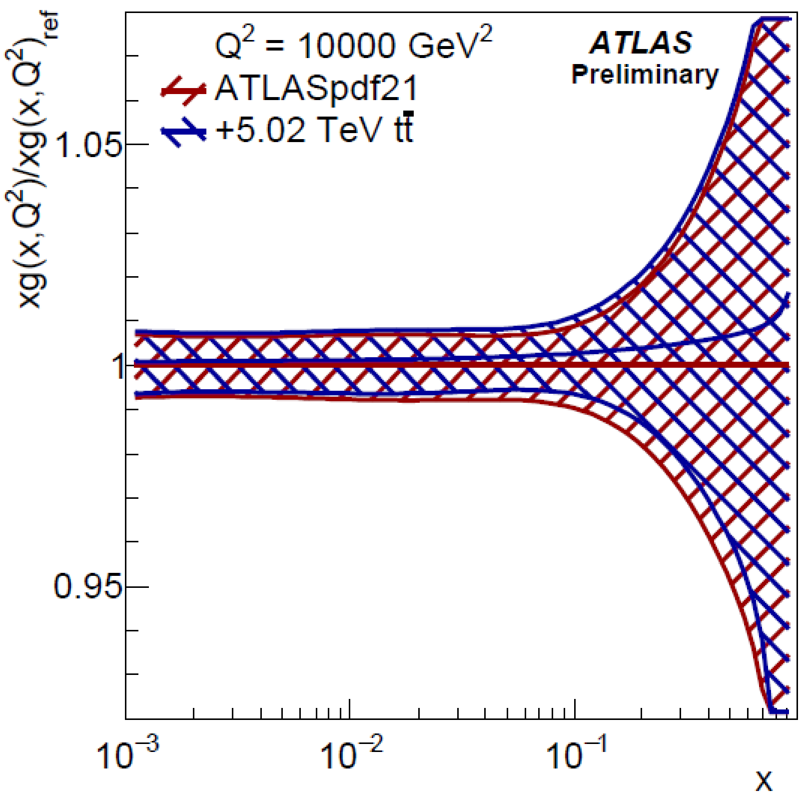
PDF studies with the new result at 5.02 TeV

- The measured value is compatible with the predictions of several PDFs considered, except ABMP16 (expected since has softer gluon PDF and predicts lower cross-section)

- Addition of new data shows a 5% reduction in the gluon PDF uncert. in the region of Bjorken-x of 0.1

ATLAS-CONF-2022-031





Differential ttbar in boosted all-hadronic events

- Unfolding performed using Iterative Bayesian Unfolding

arXiv:2205.02817

$$\frac{d\sigma^{\text{fid}}}{dX^i} \equiv \frac{1}{\int \mathcal{L}\, dt \cdot \Delta X^i} \cdot \frac{1}{\epsilon^i_{\text{eff}}} \cdot \sum_j \mathcal{M}^{-1}_{ij} \cdot f^j_{\text{acc}} \cdot \left(N^j_{\text{reco}} - N^j_{\text{bg}}\right)$$

Fiducial efficiency

Correct for bin-by-bin migrations

Acceptance correction

Observable	PWG+Py8 NNPDF30 A14		MG5_aMC@NLO+Py8 NNPDF30 UE-EE-5		PWG+H7.1.3 NNPDF30 A14		PWG+Py8 (more IFSR) NNPDF30 A14		PWG+Py8 (less IFSR) NNPDF30 A14	
	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
p_T^t	3.9/9	0.92	3.1/9	0.96	6.2/9	0.72	1.2/9	1.00	7.7/9	0.57
$\lvert y^t\rvert$	6.8/10	0.75	5.8/10	0.83	6.8/10	0.74	7.5/10	0.68	5.9/10	0.83
$p_T^{t,1}$	5.1/8	0.75	3.9/8	0.86	5.3/8	0.72	4.3/8	0.83	5.3/8	0.72
$\lvert y^{t,1}\rvert$	6.1/10	0.81	4.7/10	0.91	6.7/10	0.76	5.7/10	0.84	5.6/10	0.84
$p_T^{t,2}$	9.9/8	0.27	10.2/8	0.25	13.9/8	0.08	4.4/8	0.82	16.0/8	0.04
$\lvert y^{t,2}\rvert$	9.4/10	0.49	9.0/10	0.53	9.4/10	0.50	8.9/10	0.54	9.3/10	0.50
$m^{t\bar{t}}$	8.1/12	0.78	6.9/12	0.87	7.4/12	0.83	8.9/12	0.71	7.9/12	0.79
$p_T^{t\bar{t}}$	14.3/8	0.07	35.2/8	< 0.01	24.5/8	< 0.01	2.7/8	0.95	33.5/8	< 0.01
$\lvert y^{t\bar{t}}\rvert$	16.7/10	0.08	17.3/10	0.07	18.1/10	0.05	14.8/10	0.14	17.9/10	0.06
$\chi^{t\bar{t}}$	8.0/11	0.71	10.0/11	0.53	8.1/11	0.71	9.5/11	0.57	12.4/11	0.34
$\lvert y_B^{t\bar{t}}\rvert$	15.3/10	0.12	15.7/10	0.11	16.6/10	0.08	14.1/10	0.17	16.6/10	0.08
$\lvert p_{\text{out}}^{t\bar{t}}\rvert$	17.1/10	0.07	53.6/10	< 0.01	30.9/10	< 0.01	8.6/10	0.57	32.7/10	< 0.01
$H_T^{t\bar{t}}$	5.4/9	0.80	5.0/9	0.83	6.4/9	0.70	3.6/9	0.94	6.8/9	0.66
$\lvert\Delta\phi(t_1, t_2)\rvert$	12.2/7	0.09	73.4/7	< 0.01	23.6/7	< 0.01	5.3/7	0.63	28.5/7	< 0.01
$\lvert\cos\theta^\star\rvert$	7.0/10	0.72	9.8/10	0.46	6.8/10	0.74	7.4/10	0.69	10.5/10	0.39
$p_T^{t,1} \otimes p_T^{t,2}$	27.1/15	0.03	27.0/15	0.03	36.7/15	< 0.01	12.0/15	0.68	41.0/15	< 0.01
$\lvert y^{t,1}\rvert \otimes \lvert y^{t,2}\rvert$	11.6/19	0.90	9.8/19	0.96	12.0/19	0.88	14.3/19	0.77	9.7/19	0.96
$\lvert y^{t,1}\rvert \otimes p_T^{t,1}$	8.5/15	0.90	7.6/15	0.94	9.4/15	0.85	9.5/15	0.85	8.4/15	0.91
$\lvert y^{t,2}\rvert \otimes p_T^{t,2}$	15.9/20	0.72	17.1/20	0.65	19.5/20	0.49	10.8/20	0.95	20.7/20	0.41
$p_T^{t,1} \otimes p_T^{t\bar{t}}$	16.1/15	0.37	12.6/15	0.63	26.7/15	0.03	7.3/15	0.95	30.7/15	< 0.01
$p_T^{t,1} \otimes m^{t\bar{t}}$	23.1/18	0.19	21.9/18	0.24	26.7/18	0.08	13.8/18	0.74	30.5/18	0.03
$\lvert y^{t\bar{t}}\rvert \otimes p_T^{t,1}$	14.4/15	0.50	14.5/15	0.49	15.0/15	0.45	12.8/15	0.62	15.6/15	0.41
$\lvert y^{t\bar{t}}\rvert \otimes \lvert y^{t,1}\rvert$	14.7/15	0.47	18.0/15	0.26	15.6/15	0.41	11.6/15	0.71	19.1/15	0.21
$\lvert y^{t,1}\rvert \otimes m^{t\bar{t}}$	20.0/19	0.40	20.1/19	0.39	20.0/19	0.39	19.5/19	0.42	20.3/19	0.38
$\lvert y^{t\bar{t}}\rvert \otimes m^{t\bar{t}}$	12.5/18	0.82	12.1/18	0.84	13.2/18	0.78	12.5/18	0.82	12.9/18	0.80
$p_T^{t\bar{t}} \otimes m^{t\bar{t}}$	20.2/18	0.32	17.9/18	0.46	30.9/18	0.03	9.4/18	0.95	35.2/18	< 0.01
$\lvert y^{t\bar{t}}\rvert \otimes p_T^{t\bar{t}}$	19.1/15	0.21	14.5/15	0.49	29.4/15	0.01	12.2/15	0.66	33.4/15	< 0.01
$\lvert y^{t\bar{t}}\rvert \otimes m^{t\bar{t}} \otimes p_T^{t,1}$	21.9/31	0.88	24.1/31	0.81	24.6/31	0.79	18.0/31	0.97	26.9/31	0.68

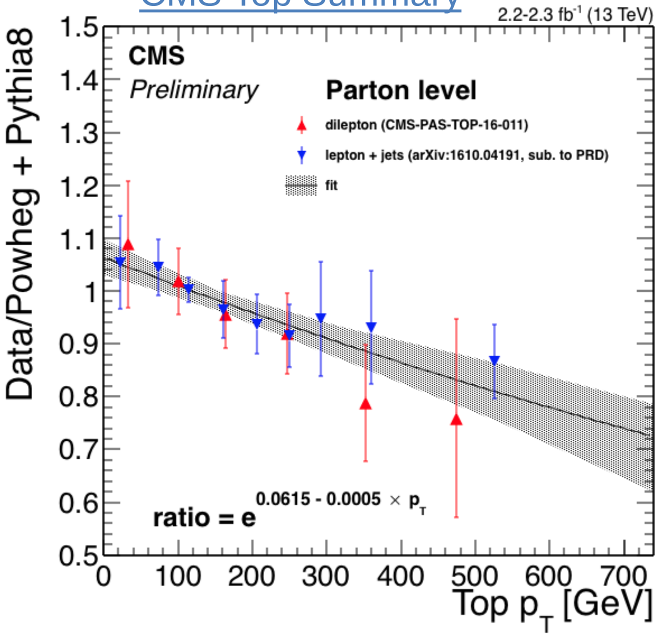
Differential ttbar in boosted single-lepton events

arXiv:2202.12134

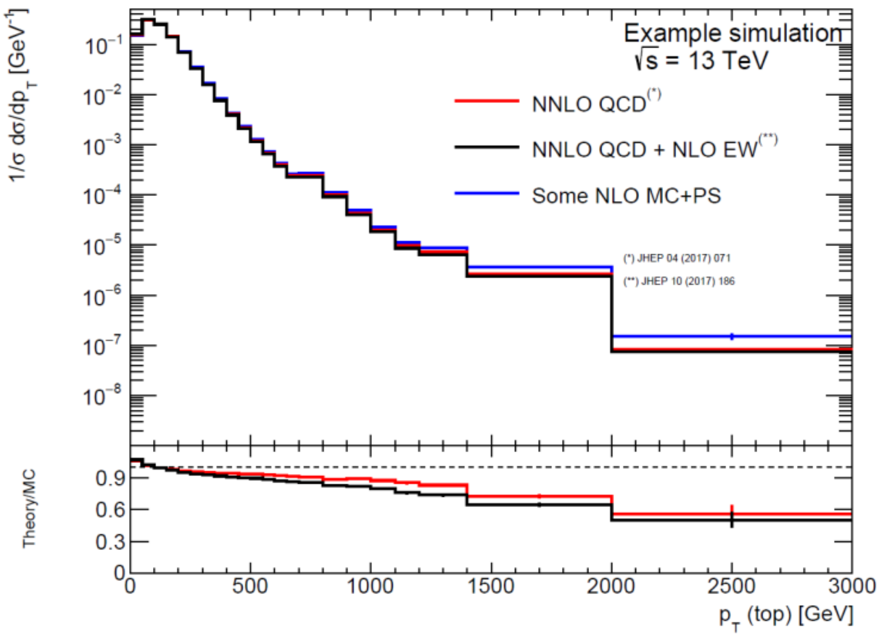
Observable	PWG+PY8		PWG+PY8(NNLO WEIGHT)		MC@NLO+PY8		MC@NLO+PY8(NNLO WEIGHT)		PWG+H7		PWG+H7(NNLO WEIGHT)	
	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value
$p_T^{t,h}$	26/8	<0.01	5/8	0.79	18/8	0.03	4/8	0.85	7/8	0.56	3/8	0.94
$p_T^{t,\ell}$	78/8	<0.01	28/8	<0.01	144/8	<0.01	10/8	0.27	43/8	<0.01	18/8	0.02
$p_T^{t\bar{t}}$	162/7	<0.01	46/7	<0.01	171/7	<0.01	22/7	<0.01	122/7	<0.01	39/7	<0.01
$H_T^{t\bar{t}+\text{jets}}$	36/7	<0.01	7/7	0.42	17/7	0.02	23/7	<0.01	21/7	<0.01	12/7	0.10
$H_T^{t\bar{t}}$	86/10	<0.01	37/10	<0.01	110/10	<0.01	16/10	0.10	47/10	<0.01	28/10	<0.01
$\|y^{t,h}\|$	47/17	<0.01	27/17	0.06	37/17	<0.01	23/17	0.15	30/17	0.03	26/17	0.07
$\|y^{t,\ell}\|$	40/14	<0.01	17/14	0.26	29/14	0.01	12/14	0.58	28/14	0.01	19/14	0.16
$\|y^{t\bar{t}}\|$	30/10	<0.01	8/10	0.58	23/10	0.01	6/10	0.81	14/10	0.19	7/10	0.74
$m^{t\bar{t}}$	52/10	<0.01	24/10	<0.01	81/10	<0.01	7/10	0.74	29/10	<0.01	22/10	0.02
$p_T^{j,1}$	115/15	<0.01	38/15	<0.01	413/15	<0.01	194/15	<0.01	143/15	<0.01	69/15	<0.01
$p_T^{j,2}$	46/9	<0.01	19/9	0.02	25/9	<0.01	74/9	<0.01	42/9	<0.01	29/9	<0.01
N^j	32/5	<0.01	12/5	0.03	76/5	<0.01	78/5	<0.01	57/5	<0.01	62/5	<0.01
$\Delta\phi(j_1, t_h)$	17/9	0.05	8/9	0.53	150/9	<0.01	80/9	<0.01	42/9	<0.01	30/9	<0.01
$\Delta\phi(j_2, t_h)$	8/9	0.56	5/9	0.84	8/9	0.57	25/9	<0.01	85/9	<0.01	76/9	<0.01
$\Delta\phi(b_\ell, t_h)$	95/13	<0.01	34/13	<0.01	145/13	<0.01	16/13	0.23	52/13	<0.01	25/13	0.02
$\Delta\phi(t_h, t_\ell)$	111/5	<0.01	36/5	<0.01	134/5	<0.01	82/5	<0.01	90/5	<0.01	36/5	<0.01
$\Delta\phi(j_1, j_2)$	24/11	0.01	16/11	0.13	31/11	<0.01	69/11	<0.01	237/11	<0.01	215/11	<0.01
$m(j_1, t_h)$	50/12	<0.01	20/12	0.06	221/12	<0.01	48/12	<0.01	41/12	<0.01	19/12	0.08
$p_T^{j,1}$ vs N^j	355/21	<0.01	205/21	<0.01	633/21	<0.01	316/21	<0.01	263/21	<0.01	159/21	<0.01
$p_T^{j,1}$ vs $p_T^{t,h}$	115/17	<0.01	53/17	<0.01	383/17	<0.01	152/17	<0.01	121/17	<0.01	74/17	<0.01
$\Delta\phi(j_1, t_h)$ vs $p_T^{t,h}$	69/21	<0.01	43/21	<0.01	427/21	<0.01	223/21	<0.01	78/21	<0.01	60/21	<0.01
$\Delta\phi(j_1, t_h)$ vs N^j	109/19	<0.01	64/19	<0.01	545/19	<0.01	250/19	<0.01	85/19	<0.01	60/19	<0.01

Iterative reweighting of ttbar MC to theory predictions

CMS Top Summary



arXiv:2105.03977



- General trend of the NLO predictions to overestimate the data at high pT(top)
- ATLAS and CMS reweight parton-level kinematics (usually top and anti-top pT) to the best available fixed-order prediction (NNLO QCD + NLO EW)
- Proposal in arXiv:2105.03977 : reweight the different distributions iteratively and repeat the procedure recursively (3 x 3) – gives MC prediction that matches both top pT, ttbar pT and ttbar mass NNLO predictions