

# ATLAS+CMS Common MC

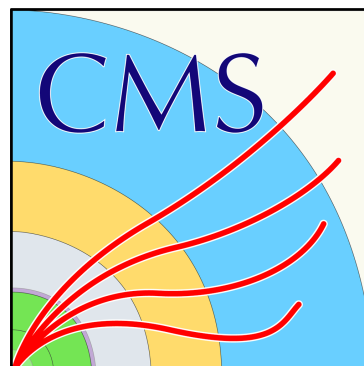
Open LHCTopWG meeting Nov 11, 2022

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LHCTopWG

On behalf of the ATLAS and CMS Collaborations



# Overview

- ATLAS and CMS both use Powheg+Pythia for the nominal ttbar sample
  - POWHEG-BOX(hvq)+Pythia8
- Effort in LHCTopWG to compare the two samples and produce a common Powheg+Pythia sample
- Goals:
  - Compare ATLAS and CMS settings and distributions for Powheg+Pythia
  - Produce settings and samples that can be used by both collaborations
  - Helps understand correlations and differences between experiments in measurements
  - Helps understand where both see similar trends in data
  - Could be used as baseline prediction
  - Share resources (through LHCTopWG) for event generation
- Also produce common Sherpa settings and samples
  - Same version and settings used in both experiments

# Common MC timeline

- 2019, Public plots: Compare ATLAS and CMS distributions
  - <https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CommonSamplesPlots>
- 2021-05, PW+PY common settings v0.1:
  - <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2021-016/>
  - Compare ATLAS and CMS PW+PY settings
  - Propose PW+PY settings that are not ATLAS, not CMS
  - First version, not suitable for physics analysis
  - Great technical achievement!
- 2022: Common PW+PY settings v2 - **New!**
  - Sensible physics settings that agree well with data
  - Setups that can run in both ATLAS and CMS simulation frameworks
- 2022: Common Sherpa settings v1 - **New!**
  - Sensible physics settings that agree well with data
  - Setups that can run in both ATLAS and CMS simulation frameworks

# Common MC PW+PY and Sherpa

- Goals for version 2 of common PW+PY builds on v0.1
  - Produce reasonable physics distributions
  - Compare to unfolded data by ATLAS and CMS
  - Settings chosen by ATLAS and CMS and theory experts to agree with data, but not reproduce ATLAS or CMS settings
  - Shared resources and shared LHE files used to produce samples
- Version 1 of common Sherpa builds on individual efforts
  - Current version and settings for Sherpa used by ATLAS
  - First Sherpa top-pair sample in CMS
- Presented here: Compare common samples (PW+PY and Sherpa) with default PW+PY and with data
  - Produce common MC in ATLAS and CMS simulation frameworks
  - Distributions agree for common MC when produced by ATLAS and CMS (not shown, but will be in the full note)
  - Compare to ATLAS and CMS data using existing Rivet routines

# Common MC settings v2 comparison

- Compare PW+PY v2 to v0.1 and to ATLAS and CMS default settings
- Main difference is shower tune (Monash-CMW) and corresponding parameters

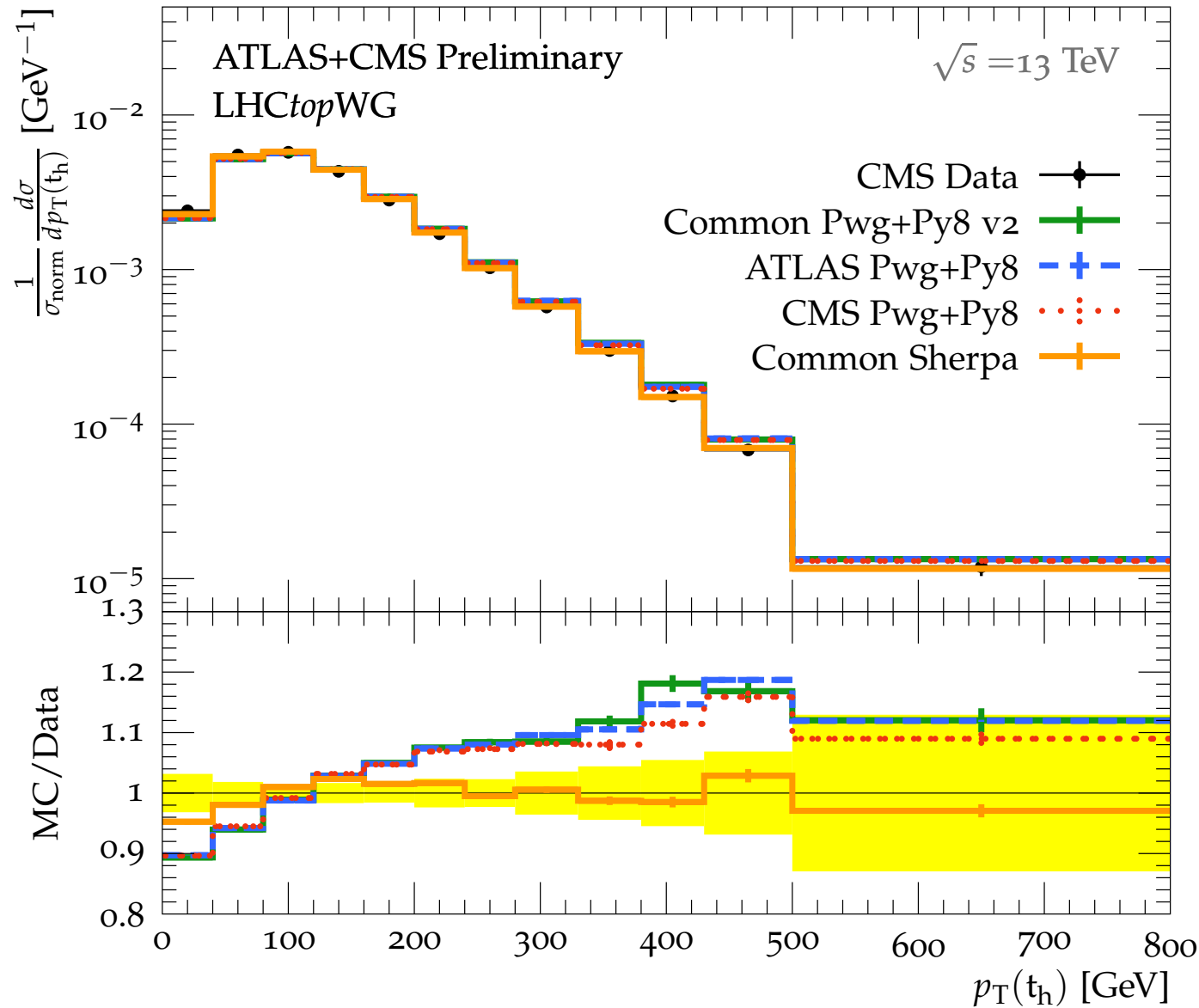
Setting name	Setting description	CMS default	ATLAS default	Common Pwg+Py8 v0.1	Common Pwg+Py8 v2
<b>POWHEG</b>					
qmass	top-quark mass [GeV]	172.5	172.5	172.5	172.5
twidth	top-quark width [GeV]	1.31	1.32	1.315	1.311
hdamp	first emission damping parameter [GeV]	237.8775	258.75	250	250
wmass	$W^\pm$ mass [GeV]	80.4	80.3999	80.4	80.4
wwidth	$W^\pm$ width [GeV]	2.141	2.085	2.11	2.085
bmass	$b$ -quark mass [GeV]	4.8	4.95	4.875	5.06
<b>PYTHIA 8</b>					
	PYTHIA 8 version	v240	v230	v240 (CMS) v244 (ATLAS)	v240 (CMS) v244 (ATLAS)
	Tune	CP5	A14	Monash	Monash-CMW
PDF:pSet	LHAPDF6 parton densities to be used for proton beams	NNPDF31_nnlo _as_0118	NNPDF23_lo _as_0130_qed	NNPDF23_lo _as_0130_qed	NNPDF23_lo _as_0130_qed
TimeShower:alphaSvalue	Value of $\alpha_s$ at $Z$ mass scale for Final State Radiation	0.118	0.127	0.1365	0.118
SpaceShower:alphaSvalue	Value of $\alpha_s$ at $Z$ mass scale for Initial State Radiation	0.118	0.127	0.1365	0.118
MPI:alphaSvalue	Value of $\alpha_s$ at $Z$ mass scale for Multi-Parton Interaction	0.118	0.126	0.130	0.130
MPI:pT0ref	Reference $p_T$ scale for regularizing soft QCD emissions	1.41	2.09	2.28	2.28
ColourReconnection:range	Parameter controlling colour reconnection probability	5.176	1.71	1.80	1.80

# Common Sherpa MC

- Default settings (with ATLAS changes) work very well

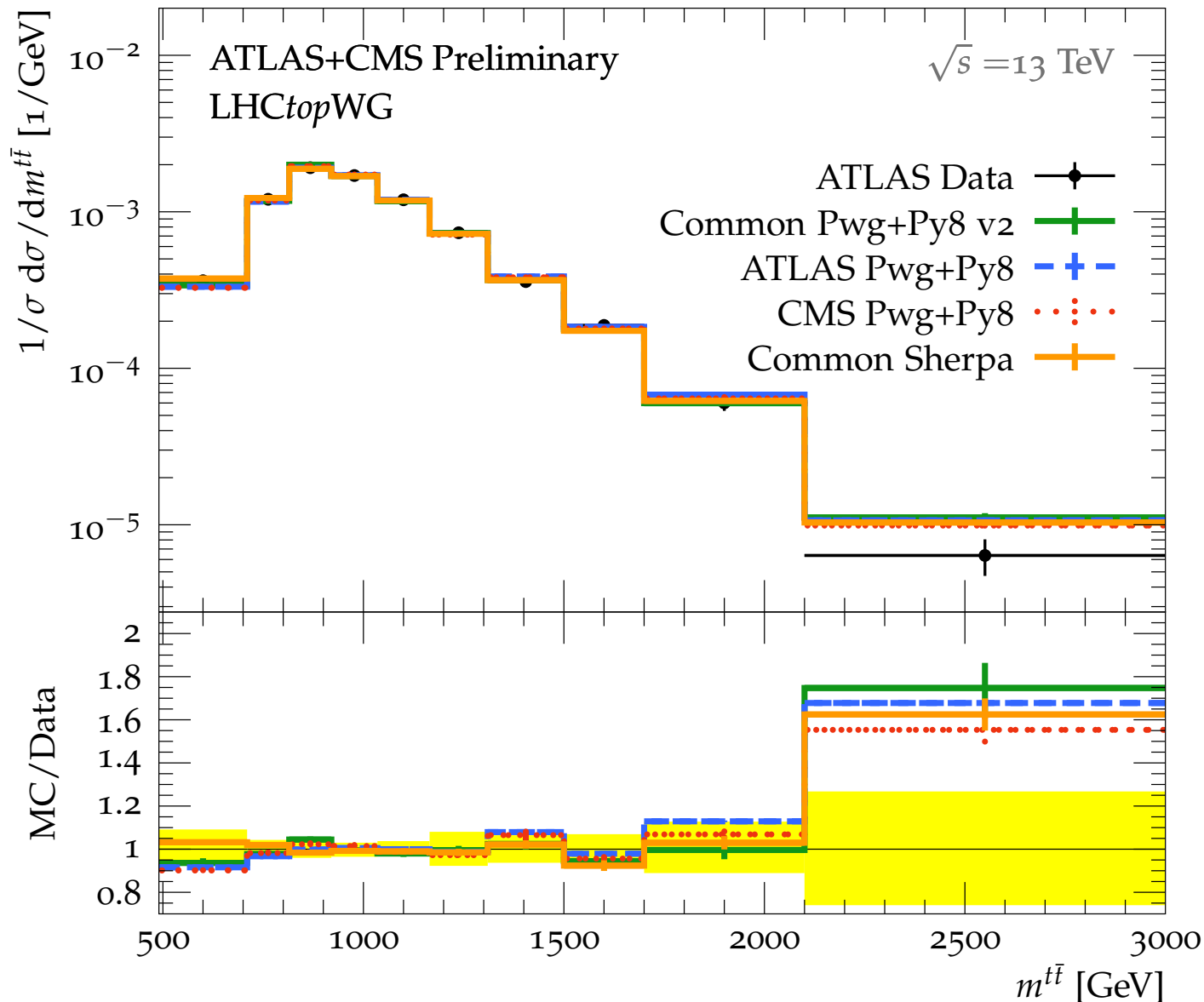
Setting name	Setting description	Common Sherpa v1
MASS[6]	top-quark mass [GeV]	172.5
HDH_WIDTH	top-quark width [GeV]	1.32
QCUT	CKKW merging cut [GeV]	30
MASS[24]	$W$ boson mass [GeV]	80.399
WIDTH[24]	$W$ boson width [GeV]	2.085
MASS[5]	$b$ -quark mass [GeV]	4.8
PDF	PDF set to be used for proton beams	NNPDF30_nnlo
USE_PDF_ALPHAS	Whether to use the $\alpha_s$ evolution provided in LHAPDF	1
AlphaS	Value of $\alpha_s$	0.118
CSS_EVOLUTION_SCHEME	Choice of evolution variable in the shower	30, modified $p_T$ order incl. $m_{\text{parton}}$ for $g \rightarrow qq$

# Transverse momentum of top



- CMS lepton+jets unfolded data (PRD 97, 112003 (2018), [arXiv:1803.08856](https://arxiv.org/abs/1803.08856))
- Similar trend for PW+PY in all unfolded top  $p_T$  distribution
  - Consistent with what we have seen before

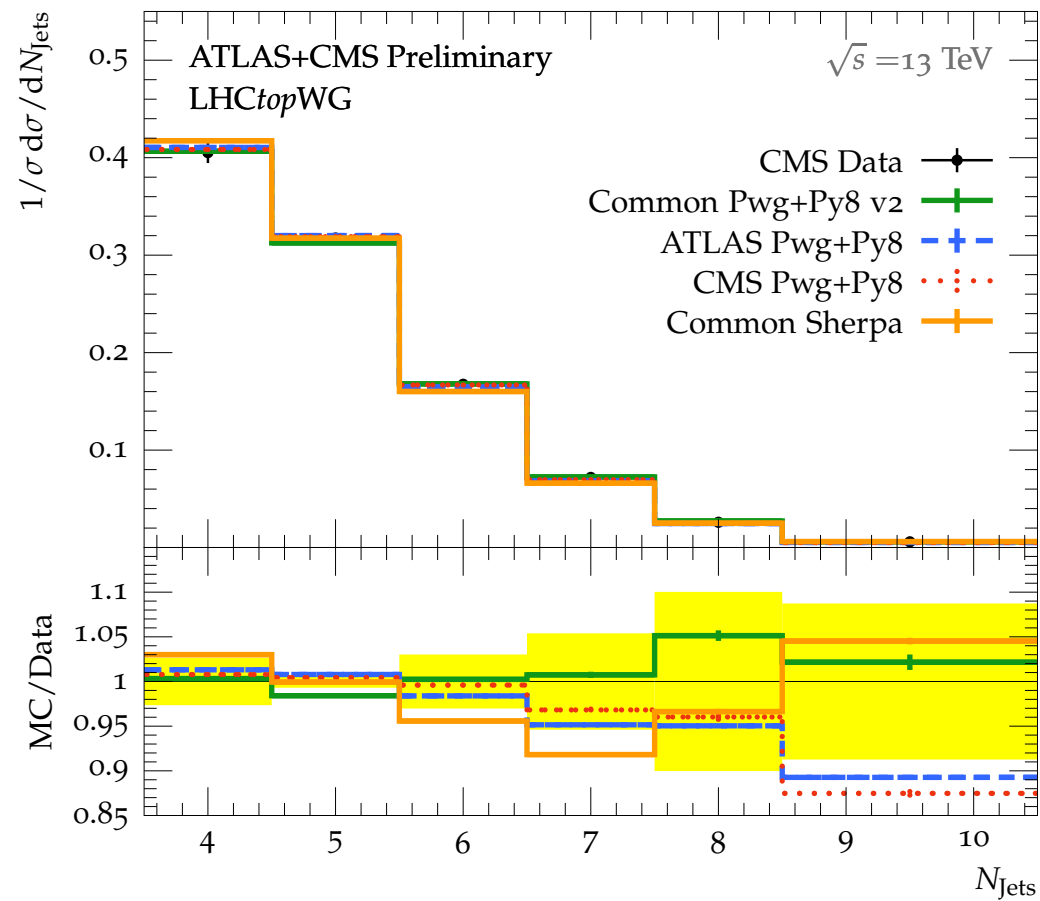
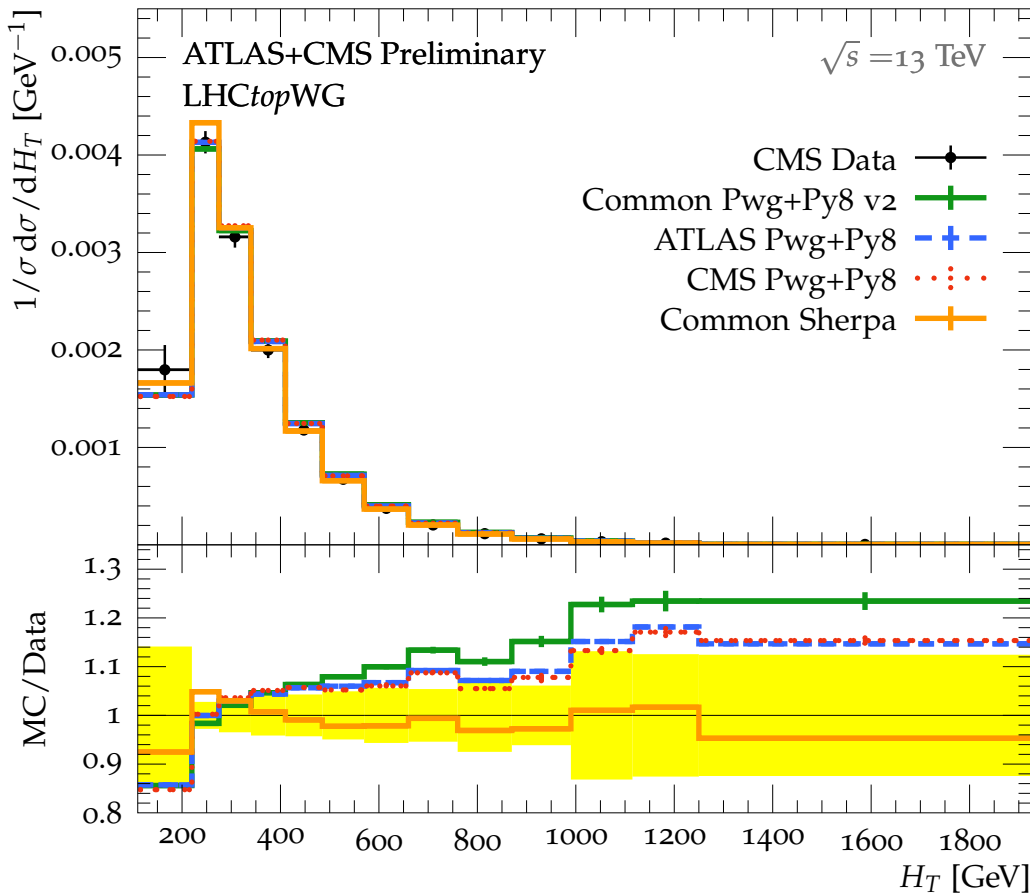
# Mass of top-pair system



- ATLAS lepton+jets boosted events (EPJ C 79 (2019) 2018, [arXiv:1908.07305](https://arxiv.org/abs/1908.07305))
  - Very good agreement up to 2 TeV

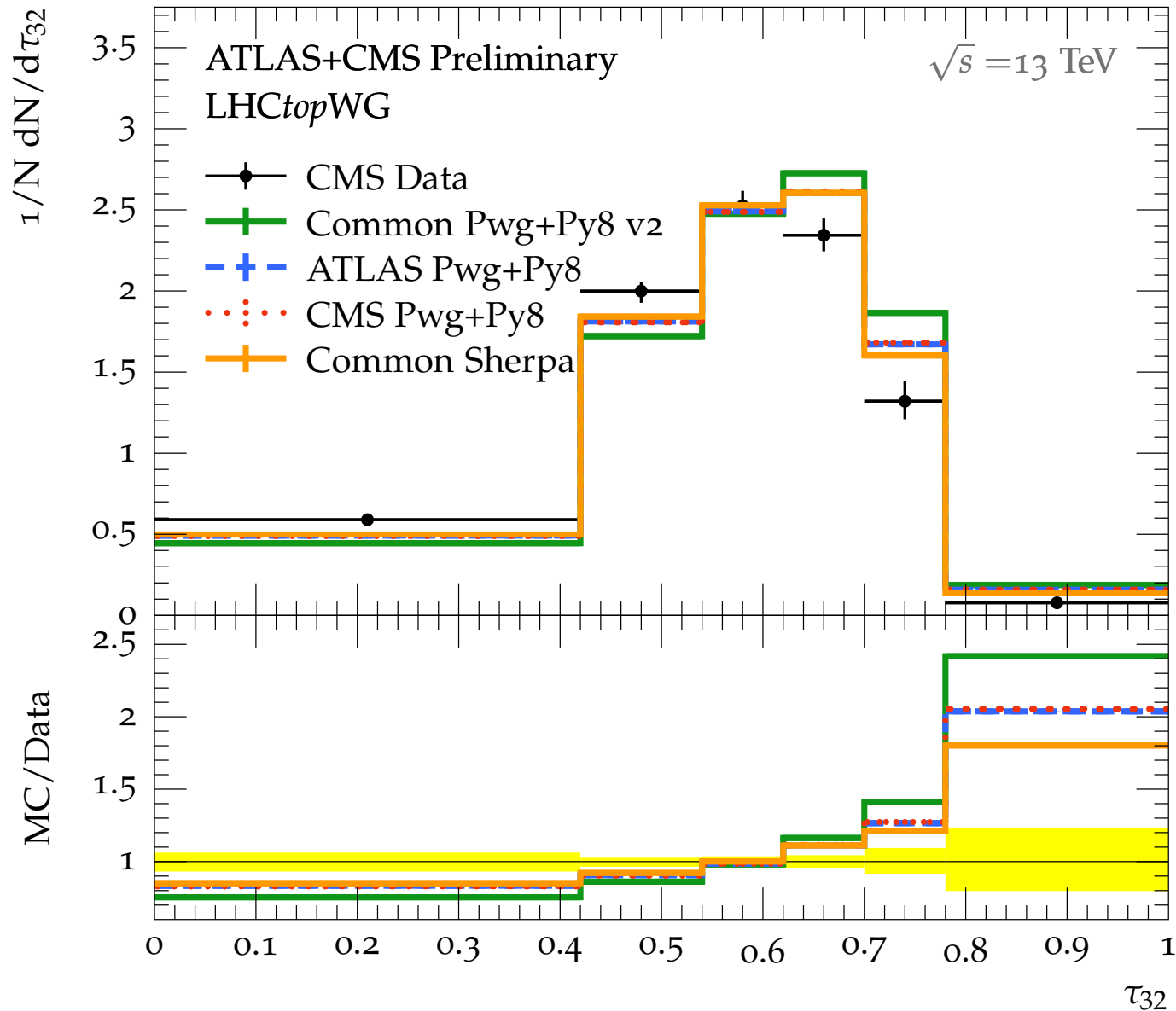


# $H_T$ and number of jets



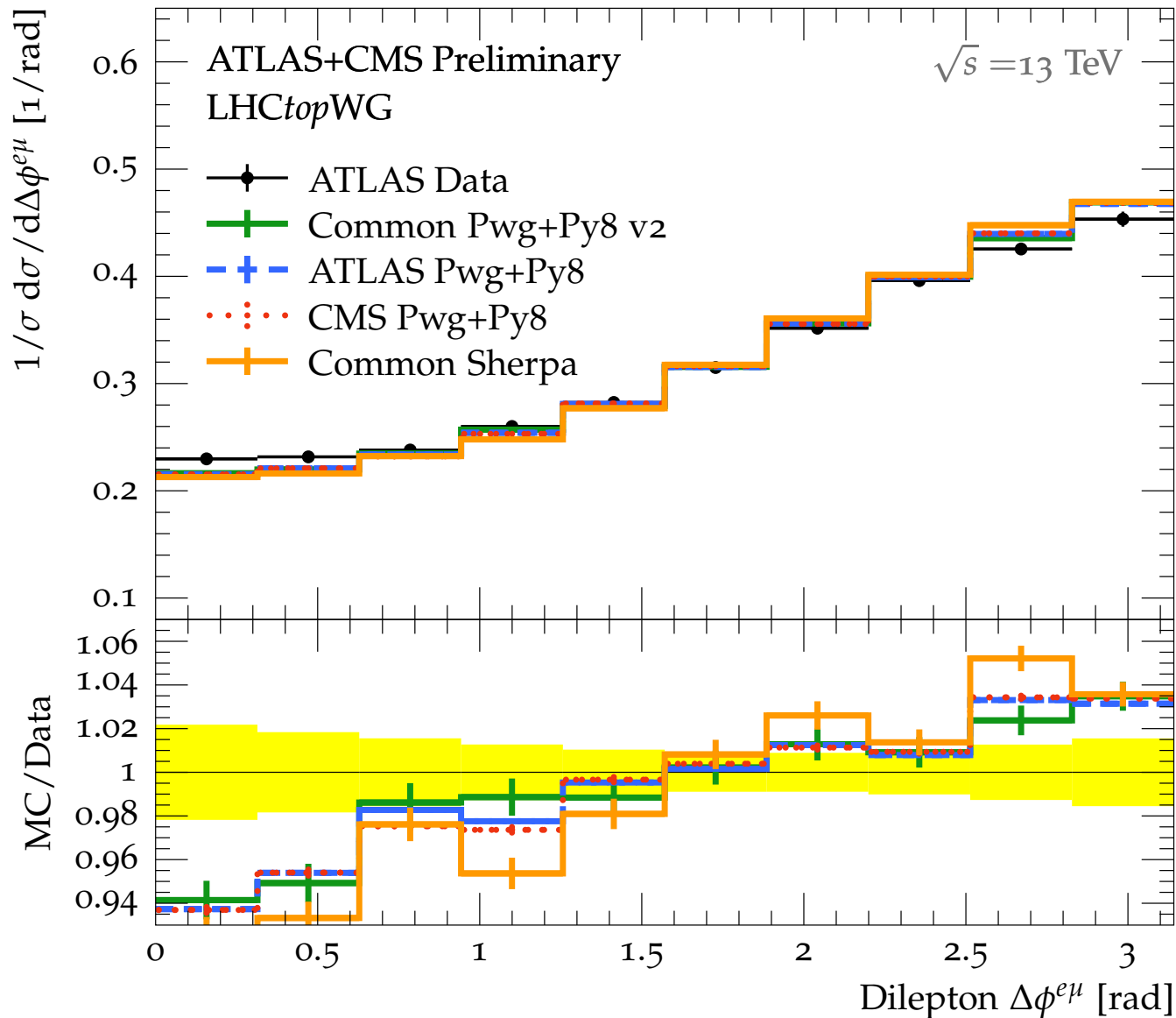
- CMS lepton+jets events (JHEP 06 (2018) 002, [arXiv:1803.03991](https://arxiv.org/abs/1803.03991))
- Much better agreement now than for PW+PY v0.1
- Common Sherpa is best at reproducing  $H_T$
- Common PW+PY is best at reproducing  $N_{\text{jets}}$

# Jet substructure



- CMS lepton+jets events (PRD 98, 092014 (2018), [arXiv:1808.07340](https://arxiv.org/abs/1808.07340))
- Clear trend in all generators visible in the ratio

# Dilepton DeltaPhi



- ATLAS dilepton events (EPJ C 80 (2020) 528, [arXiv:1910.08819](https://arxiv.org/abs/1910.08819))
  - Not the spin correlation analysis, small differences in the selection
- All generators show the same trend

# Conclusions/Outlook

- Common Powheg+Pythia8 v2 is ready
  - Settings for Powheg+Pythia8 that give agreement with ATLAS and CMS nominal settings and with data
  - Monash-based tune with consistent, lower  $\alpha_s$
- Common Sherpa v1 is ready
- Public note (link here)
  - Plots and highlight settings
- Full note with details is in progress
  - Parton-level and particle-level comparisons
  - All decay channels
  - More kinematics, underlying event, shower variables in top pair events
- Settings are defined, LHE samples exist, everyone can (should) add common MC curves to their top pair distributions