Common MC update

LHCtopWG open meeting

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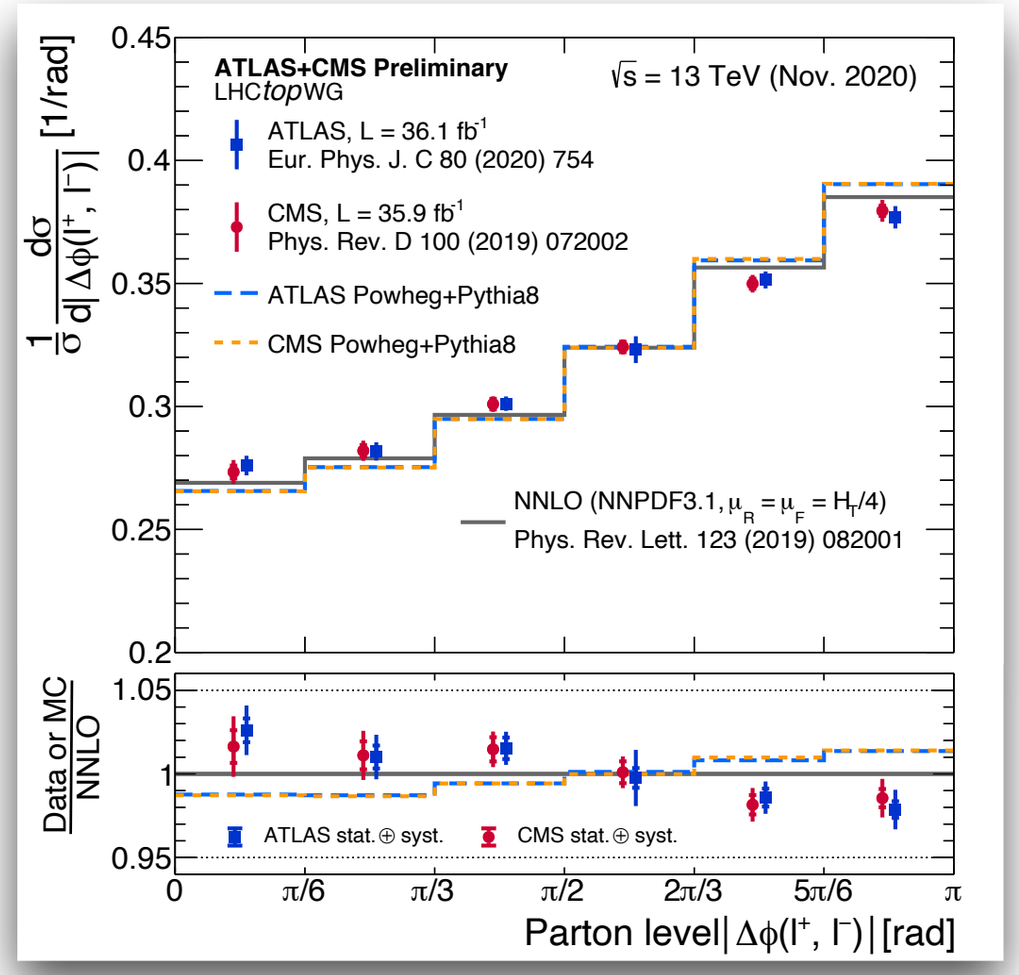
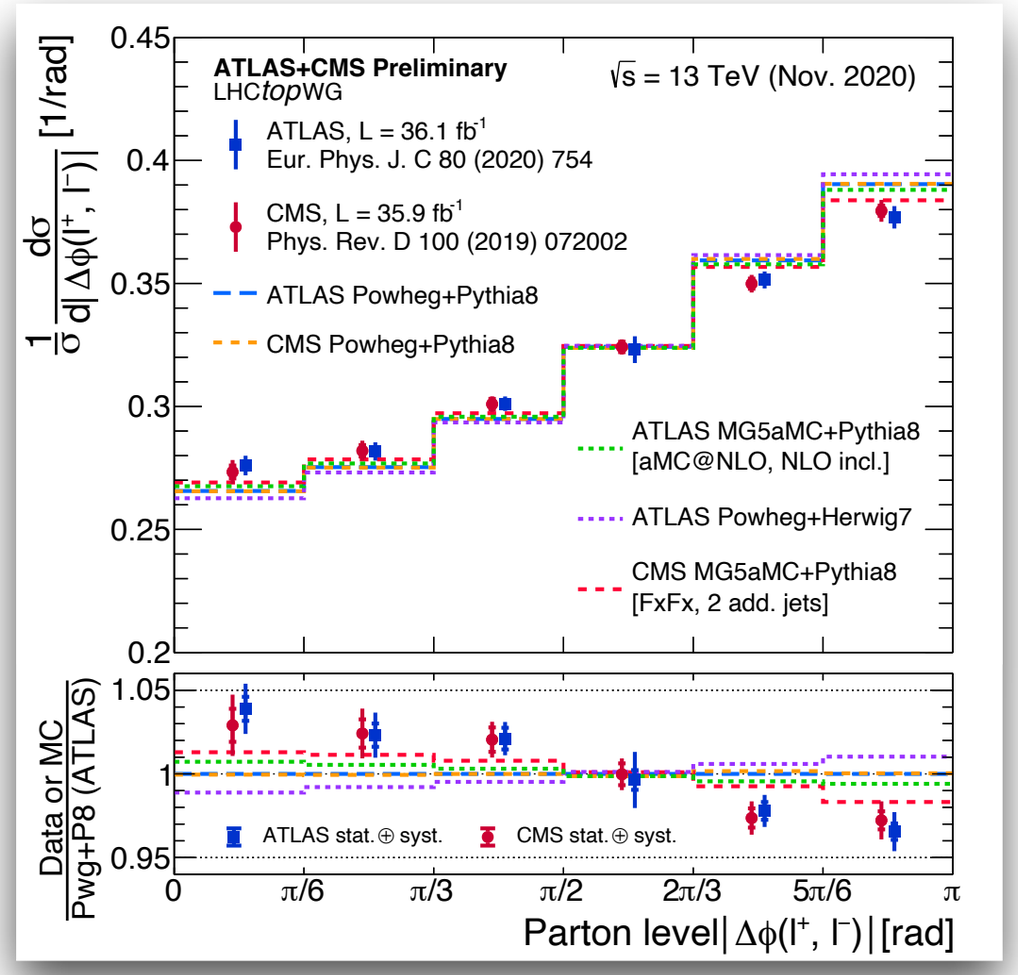
Introduction

- Production of **common top-quark MC samples** for ATLAS and CMS:
  - document settings used in ATLAS and CMS default generator (Powheg+Pythia)
  - compare different ATLAS/CMS generator+parton shower settings
  - generate common Powheg+Pythia MC sample and document corresponding settings
- **Updated study** w.r.t. “old” one:
  - updated software releases to be consistent with Run2 analyses
  - updated RIVET routine used by both ATLAS and CMS
  - updated settings used by both experiments

Motivation

- Understand similarities and differences between ATLAS and CMS ttbar MC samples
  - can be crucial to **reduce modeling systematics** in analysis combination
- Save computing resources by sharing them between experiments
- Benchmark for future ATLAS-CMS comparisons and combinations
  - baseline prediction for $|\Delta\phi_{\ell\ell}|$ combination (first comparison @13 TeV, plots available here)





Comparison of settings

- Both experiments use POWHEG-BoxV2 with slightly different settings

- Both experiments use Pythia8 with few different settings for showering + hadronization:
  - dedicated tune for each experiment:
    - ATLAS: A14
    - CMS: CP5
  - different PDF sets:
    - ATLAS: NNPDF 2.3 Leading Order
    - CMS: NNPDF 3.1 Next-to-Next-to-Leading Order
    - different values and orders of running α_s
  - EvtGen only used by ATLAS for the decay of heavy flavour particles

- Comparison of generated samples:
  - running each experiment's settings in the other experiment's software framework

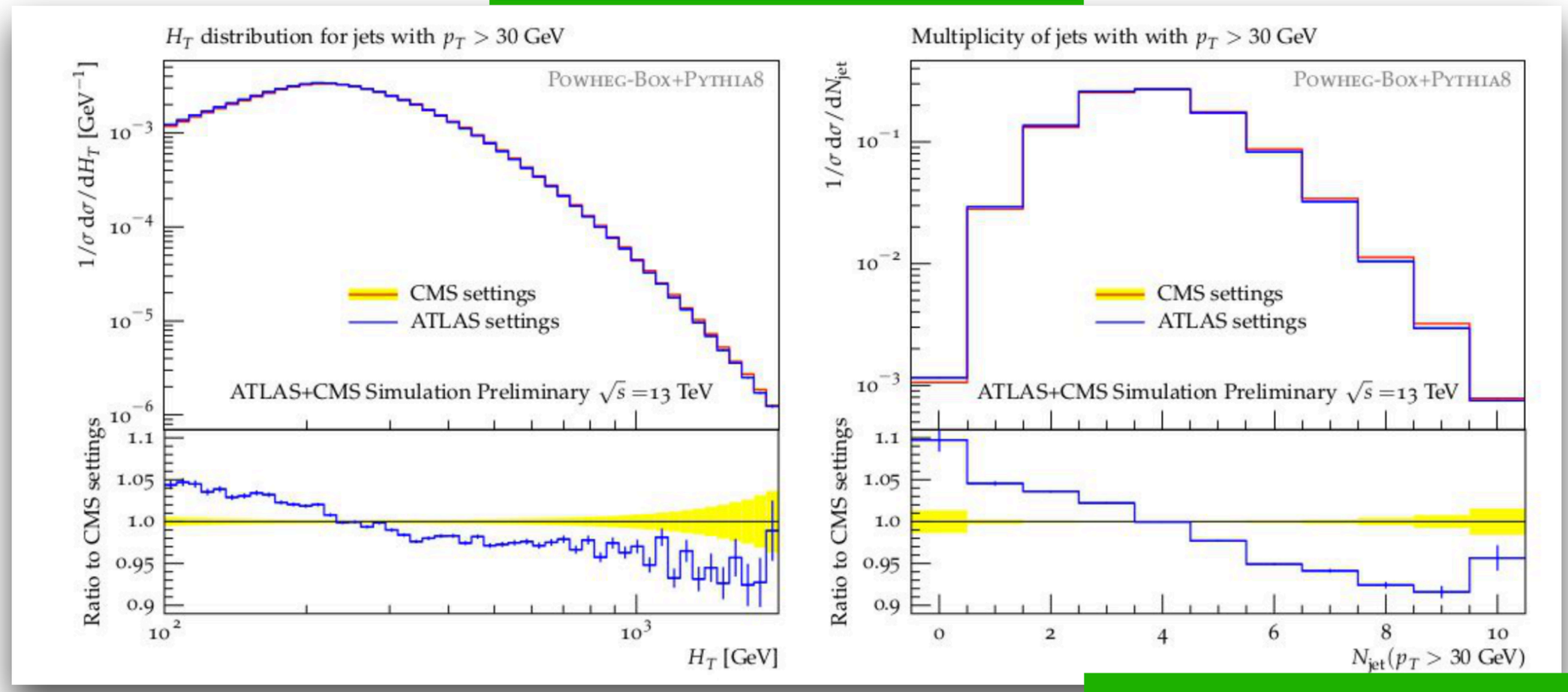
ATLAS and CMS settings checked and used in both softwares

Nominal samples

- Old NLO ttbar MC comparisons plots already available in twiki
- Both ATLAS and CMS statistically independent samples produced with:
  - old software releases
  - "MC_TTBAR" Rivet routine from Rivet 2.5.4
  - Powheg-Box v2 matched with Pythia8 v8.230
- Clear trends observed in jets distributions
  - softer spectrum with ATLAS settings

Basic selection in l+jets channel:
⩾ 1 charged lepton with $p_T > 30$ GeV
MET > 30 GeV
⩾ 4 anti-kT R = 0.6 jets with $p_T > 30$ GeV
…

nominal ATLAS and CMS settings



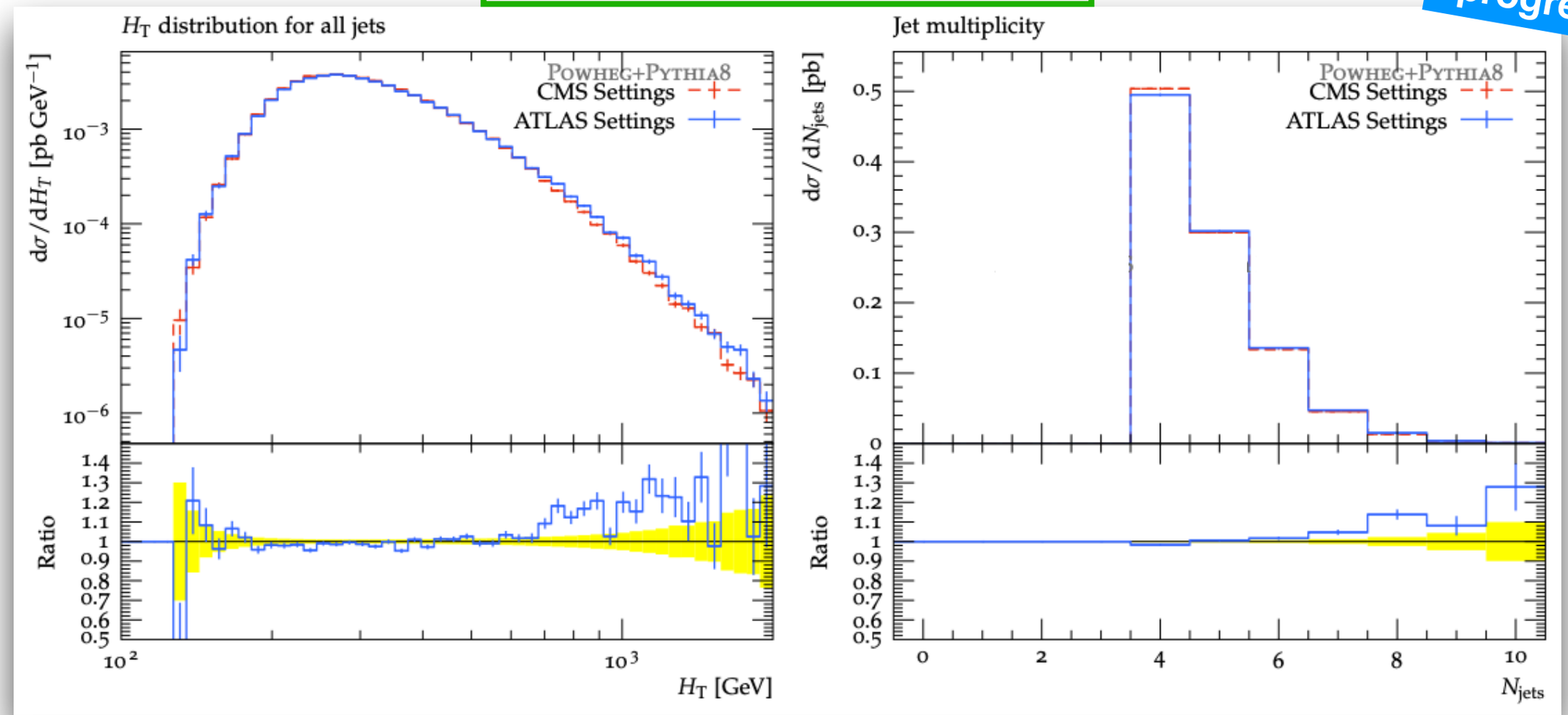
First ATLAS and CMS samples produced in both experiments

New ATLAS samples

- Both ATLAS and CMS statistically independent samples produced with:
  - new ATLAS software release (R21)
  - new "MC_TTBAR" Rivet routine from Rivet v3.0.1 updated with multiple lepton multiplicities and slightly different selection
  - same Powheg release (Powheg Box v2)
  - new Pythia version (v8.230 → **v8.244**)
- Previous trends in jets distributions seem **reversed**

nominal ATLAS and CMS settings

Work in progress



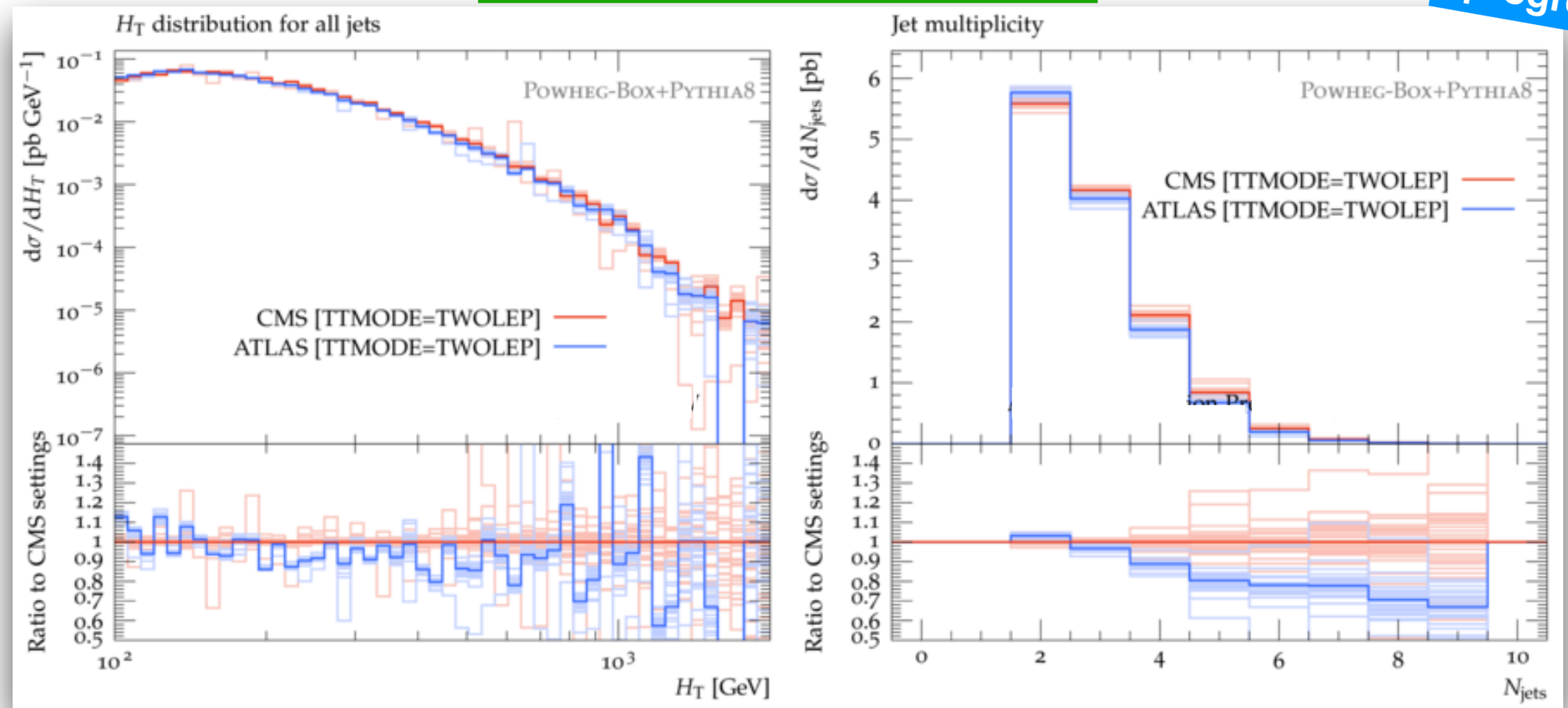
Different behavior in new ATLAS samples

New CMS samples

- Both ATLAS and CMS statistically independent samples produced with:
  - new CMS software release (CMSSW_11_0_1)
  - new "MC_TTBAR" Rivet routine from Rivet v3.0.1 updated with multiple lepton multiplicities and slightly different selection
  - same Powheg release (Powheg Box v2)
  - new Pythia version (v8.230 → **v8.243**)
- Previous trends in jets distributions seem **confirmed**

nominal ATLAS and CMS settings

Work in progress



New CMS samples agree with old ones

ATLAS: old vs new release

- Differences between ATLAS samples produced in old and new software release for same (old) routine:

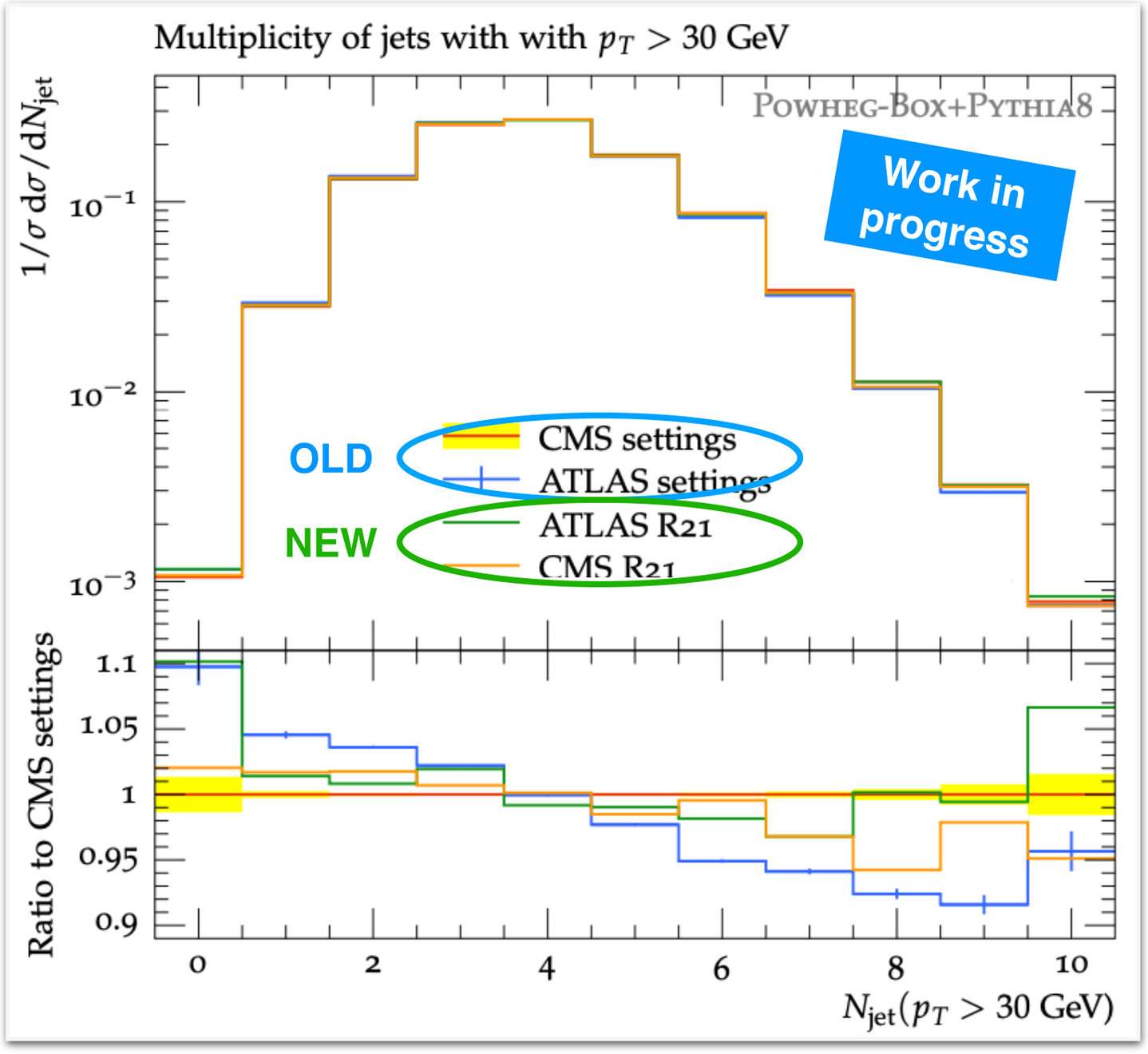
- Same Powheg release but few Powheg settings different

- Pythia v8.230 vs Pythia v8.244
  - UE tune different in new Pythia version but small difference (< 5%) → it shouldn't affect high-pT top samples

- Investigation of different behaviour:
  - test on Rivet versions
  - test on different weights generated with sample
  - test on setup

Tests ongoing to understand trend in new ATLAS samples

Old vs New with old Rivet routine



CMS: old vs new release

- Same Powheg and Pythia settings:
  - no change between Run2 ReReco (Pythia v8.226 + v8.230) and Legacy ReReco (Pythia v8.240) processing of data
  - no change before Run3

- New Pythia version:
  - bug in Pythia v8.243 related to ttbar → solved in new versions
  - Pythia v8.244 not available in CMSSW → no common version between experiments

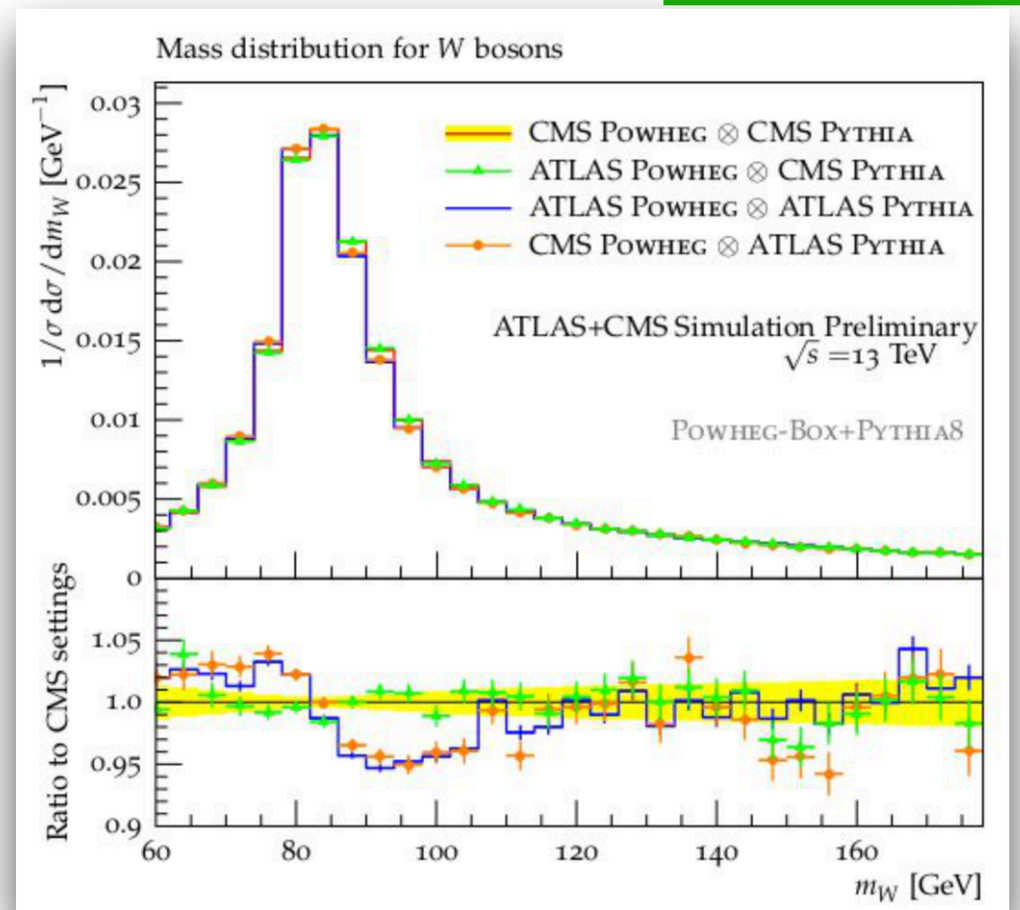
- Now trying with Pythia **v8.240**:
  - version **used for Run2 analyses in CMS**

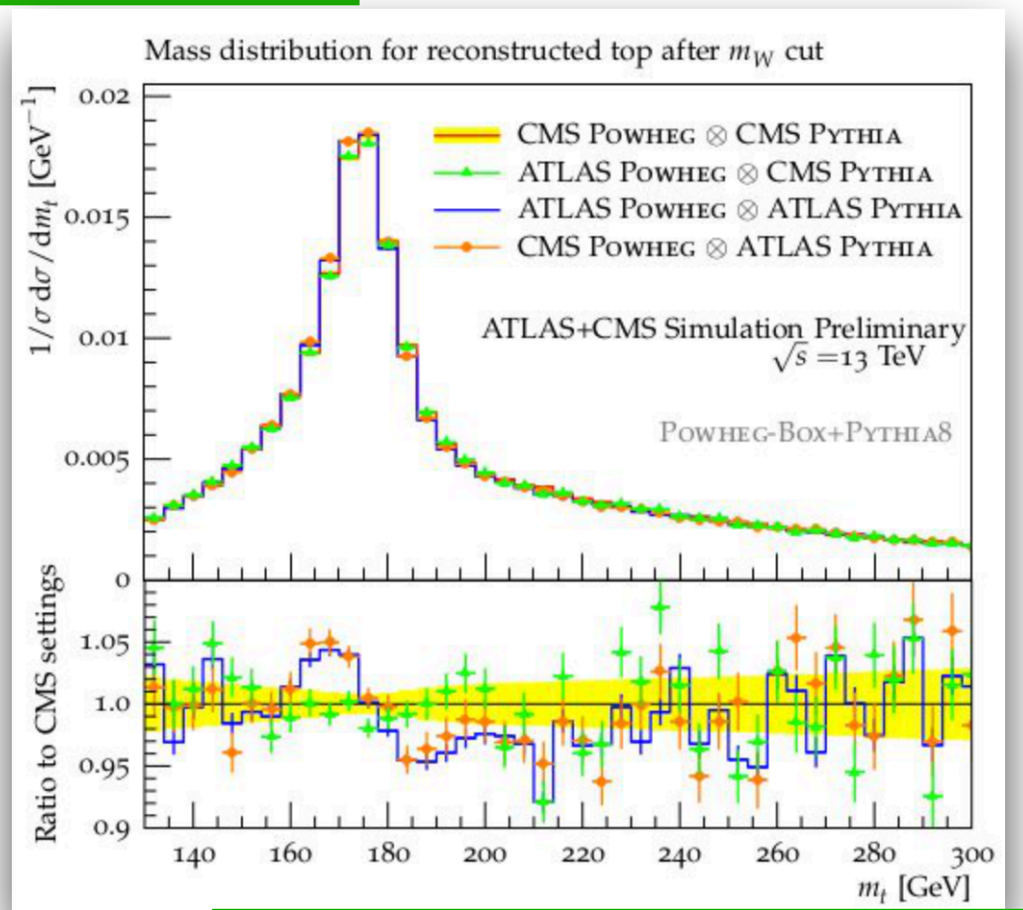
Updating new CMS samples to Run2 analyses setup

Comparison of generators

- Compare different ATLAS/CMS Powheg and Pythia settings to investigate sources of differences in distributions
- Old “mixed” plots already available in twiki
- Good agreement between samples with same shower + hadronization settings
  - differences driven by Pythia settings
  - minimal impact of different POWHEG settings
- Trends also confirmed by samples produced with new CMS software release

mixing of ATLAS and CMS settings



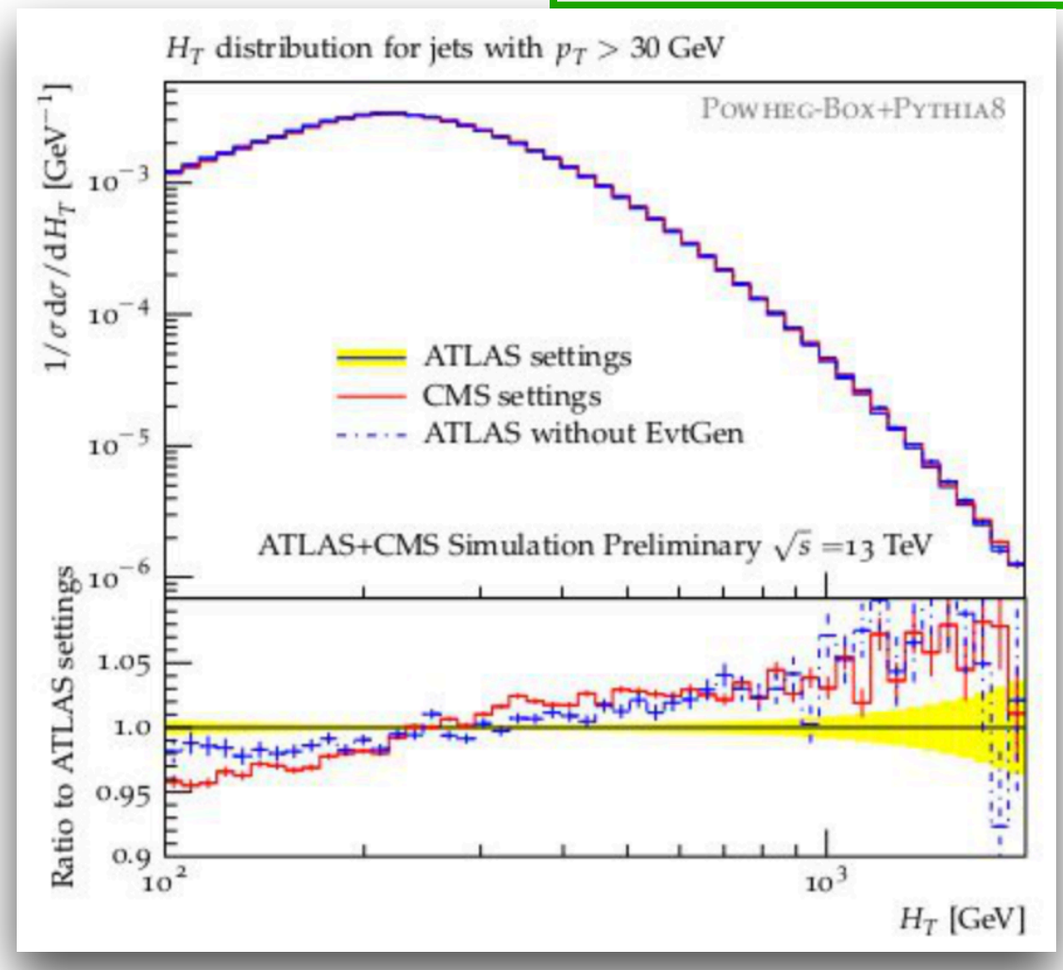


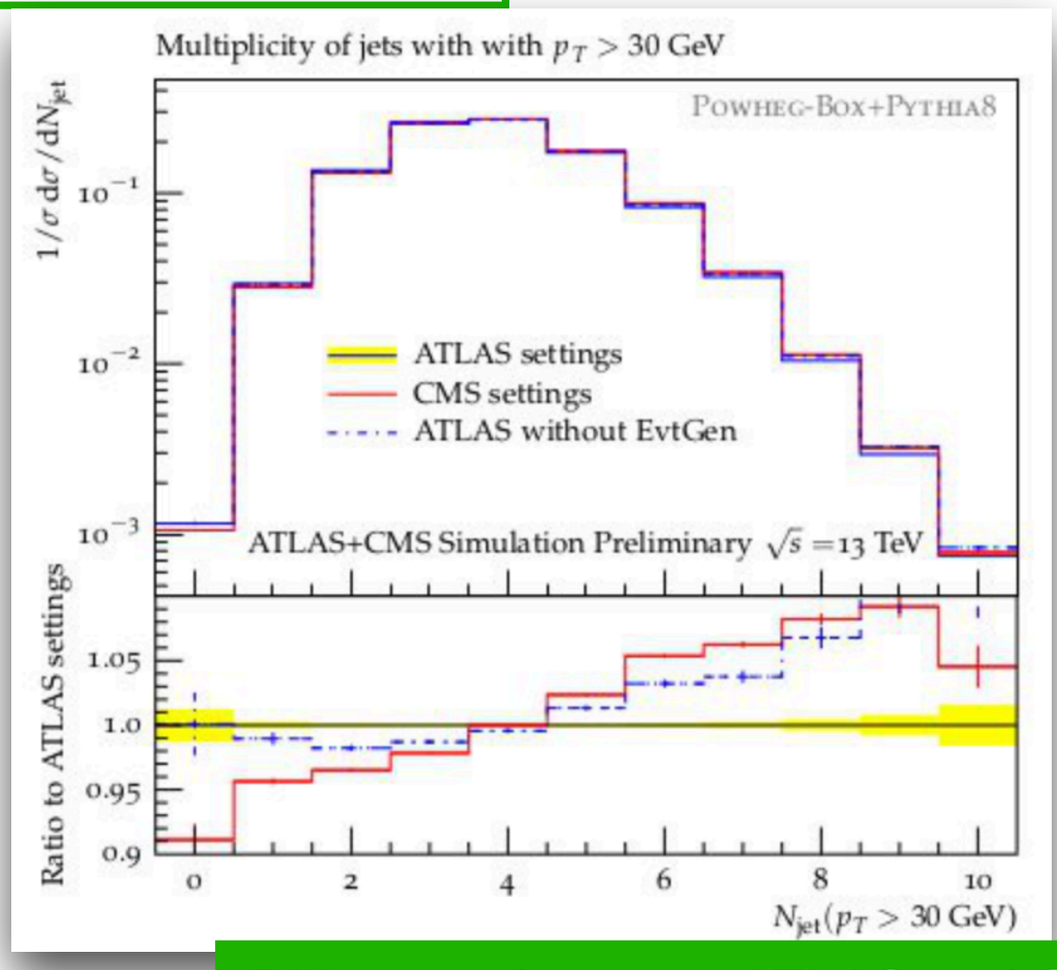
Samples with same shower+hadron. settings have similar trends

Impact of EvtGen

- Old comparison plots w/o EvtGen already available in twiki:
  - differences in jet distributions impacted by EvtGen
  - no clear impact on angular distributions
  - no significant impact on mass distributions → coming from Pythia settings

ATLAS w/o EvtGen and CMS nominal settings





Difference between ATLAS and CMS not fully explained by EvtGen
→ won't be used in common sample

Next steps

- Compare Powheg v2 vs Powheg v1 to check its stability

- **Common sample**:
  - decision on common settings (e.g. take “average” of both experiments settings; produce 2 statistically independent samples of the same size with the same settings in ATLAS and CMS releases, then produce 1 sample with half events from ATLAS and half events from CMS; …)
  - sample production → to be used in $\Delta\phi$ combination

- **Data-MC comparison**:
  - use Rivet routines for available analyses
  - include “Spin Correlation” Rivet routine

- Previous and current studies being documented in a **PUB note**:
  - MC comparisons plots for samples produced with old release updated with new comparison plots
  - documentation of ATLAS and CMS default settings + proposal of settings for common sample

Goal: have public document with new results and common sample proposal as soon as possible

Summary

- ATLAS and CMS nominal ttbar simulation samples produced in both experiments
- Settings documented and first nominal and mixed samples compared
- New ATLAS and CMS samples compared to old ones:
  - trend in jet distributions consistent when processed with old and new CMS release
  - different behaviour seen when processed with old and new ATLAS release
- **Next steps**:
  - understand new trends in ATLAS samples
  - produce new CMS samples with standard Run2 setup
  - finalise public note with new MC plots and common settings proposal
  - work on common sample
  - add data-MC comparisons with new samples

BACKUP

Powheg settings

Setting Name	Setting description	CMS default	ATLAS default
qmass	top-quark mass [GeV]	172.5	172.5
twidth	top-quark width [GeV]	1.31	1.32
hdamp	first emission damping parameter [GeV]	237.8775	258.75
wmass	$W^{\pm}$ mass [GeV]	80.4	80.3999
wwidth	$W^{\pm}$ width [GeV]	2.141	2.085
bmass	b-quark mass [GeV]	4.8	4.95
cmass	c-quark mass [GeV]	1.5	1.55
smass	s-quark mass [GeV]	0.2	0.5
dmass	d-quark mass [GeV]	0.1	0.32
umass	u-quark mass [GeV]	0.1	0.32
taumass	τ mass [GeV]	1.777	1.777
mumass	μ mass [GeV]	0.1057	0.1057
emass	e mass [GeV]	0.00051	0.00051
elbranchin	W-boson electronic branching fraction	0.108	0.1082
sin2cabibbo	quark mixing angle	0.051	0.051

Pythia settings

Setting Name	Setting description	CMS default	ATLAS default	Pythia8 default
POWHEG	Parameters for matching to POWHEG matrix element calculations			
pTdef	Flag for hardness criterion (POWHEG vs PYTHIA)	1	2	0
emitted	Flag for defining emissions	0	0	0
pTemt	Flag for which partons are used to define POWHEG hardness criteria	0	0	0
pThard	Flag for how to calculate POWHEG hardness criteria	0	0	0
vetoCount	How many emissions vetoed showers checks after first allowed emission	100	3	3
nFinal	Number of outgoing particles for born level process	2	2	2
veto	Flag for vetoed or unvetoed showers	1	1	0
MPIveto	Flag for applying veto to Multi Parton Interactions	NA	0	0
TimeShower	Final State Radiation Parameters			
mMaxGamma	Maximum invariant mass for $\gamma \to f\bar{f}$	1.0	NA	10
alphaSorder	Order of running for α_s	2	NA	1
alphaSvalue	Value of α_s at Z mass scale	0.118	0.127	0.1365
pTmaxMatch	Flag for setting maximum shower scale algorithm	2	2	1
SpaceShower	Initial State Radiation Parameters			
alphaSorder	Order of running for α_s	2	NA	1
alphaSvalue	Value of α_s at Z mass scale	0.118	0.127	0.1365
pTmaxMatch	Flag for setting maximum shower scale algorithm	2	2	0
rapidityOrder	Force emissions to be ordered in rapidity	on	on	on
rapidtyOrderMPI	Force emissions in secondary scatterings to be ordered in rapidity	NA	on	on
pT0Ref	Reference p_T scale for regularizing soft QCD emissions	NA	1.56	2
pTmaxFudge	Multiplication factor for pTMaxMatch in some instances	NA	0.91	1
pTdampFudge	Multiplication factor for pTDamping scale for high-p_T emissions	NA	1.05	1
MPI	Multi-Parton Interaction Parameters			
alphaSorder	Order of running for α_s	2	NA	1
alphaSvalue	Value of α_s at Z mass scale	0.118	0.126	0.130
ecmPow	Exponent control kinematic dependence of pT0	0.03344	NA	0.215
bprofile	impact parameter profile choice flag for hadron beams	2	NA	3
coreRadius	Inner radius of core when using bprofile $= 2$	0.7634	NA	0.4
coreFraction	Matter content fraction of core when using bprofile $= 2$	0.63	NA	0.5
pT0ref	Reference p_T scale for regularizing soft QCD emissions	1.41	2.09	2.28
BeamRemnants				
primordialKThard	Parameter controlling k_T of beam remnant initiators	NA	1.88	1.8
ColourReconnection				
range	Parameter controlling colour reconnection probability	5.176	1.71	1.8
ParticleDecays	Particle Decay Settings			
limitTau0	Only decay particles with lifetimes below $\tau_{0,max}$	on	on	off
tau0Max	$\tau_{0,max}$	10	10	10
allowPhotonRadiation	Allow photon radiation in decays to lepton pairs	on	NA	off

NA values = default Pythia8 values

ATLAS new Powheg settings

	ATLAS old	ATLAS new	CMS
bornktmin	-1 (0)	5.0	
bottomthr	-1 (4.95)	4.95	
bottomthrpdf	-1 (4.95)	4.95	
charmthr	-1 (1.55)	1.55	
charmthrpdf	-1 (1.55)	1.55	
compress_lhe	-	-1	
compress_upb	-	-1	
minlo	-1	0	
itmx1	5	1	5
itmx2	5	8	5
iupperfsr	2	-1	
iupperisr	1	-1	
lhrwgt_descr	'nominal'	-	
lhrwgt_group_combine	'none'	-	
lhrwgt_group_name	'nominal'	-	
max_io_bufsize	-	-1	
maxseeds	-	-1	
mintupbratlim	-	-1	
mintupbxless	-	-1	
ncall1	10000	500	10000
ncall2	100000	50000	100000
ncallfrominput	-1	1	
nubound	100000	800000	100000
rwl_add	-	0	
rwl_file	-	''	
rwl_format_rwgt	-	1	
rwl_group_events	-	1000	
ubexcess_correct	-	1	
xupbound	2	10	2

"-1" means Powheg default (in brackets)

"-" means it does not exist in that release (most of these are ATLAS specific for steering systematics)

CMS values not specified are default ones

Data-MC comparisons

- Available analyses Rivet routines to compare MC to data:

```
‘ATLAS_2017_I1495243', # tt+j
 'ATLAS_2016_I1468168', # dilepton early xs
 'ATLAS_2017_I1614149', # 3fb ljets differential  (resolved + boosted)
 'ATLAS_2018_I1646686', # allhad differential (boosted)
 'ATLAS_2018_I1656578', # 3fb ljets njets
 'ATLAS_2018_I1705857', # ttbb
 'ATLAS_2019_I1724098:MODE=TW', # JSS analysis

 'CMS_2016_I1491950', # 3fb ljets differential
 'CMS_2018_I1662081', # event kinematics differential (ljets)
 'CMS_2018_I1663958', # 36fb ljets differential
 'CMS_2018_I1690148', # jss
```

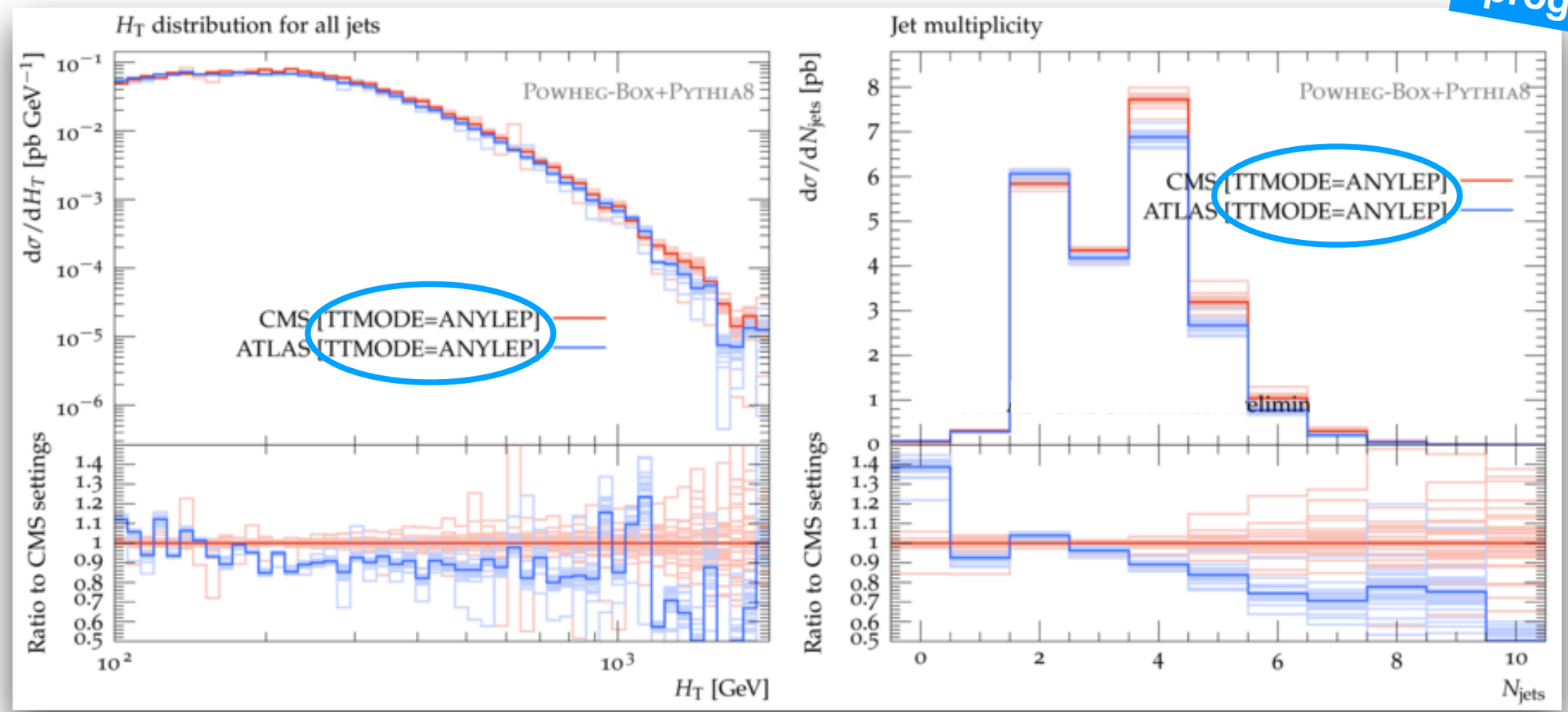
New CMS samples

- New samples (with 100k events) produced with new CMS software release:
  - new "MC_TTBAR" Rivet routine
  - same Powheg release (Powheg Box v2)
  - new Pythia version (v8.243)
  - new Rivet version (v3.0.1)
- Previous trends in jets distributions seem confirmed

1 lepton with pT > 30 GeV
MET > 30 GeV
4 R = 0.6 jets with pT > 30 GeV

nominal ATLAS and CMS settings

Work in progress



Mandate

- Document settings used in ATLAS and CMS default generator (Powheg+Pythia) to go along with the plots that are already public
- Show, document and compare different generator combinations (generator+parton shower for ATLAS/CMS)
- Create a common Powheg+Pythia MC sample and document the corresponding settings
- Produce plots at parton level and particle level
- Use common MC as a baseline prediction for $|\Delta\phi_{\ell\ell}|$ (angle between leptons in transverse plane) combination