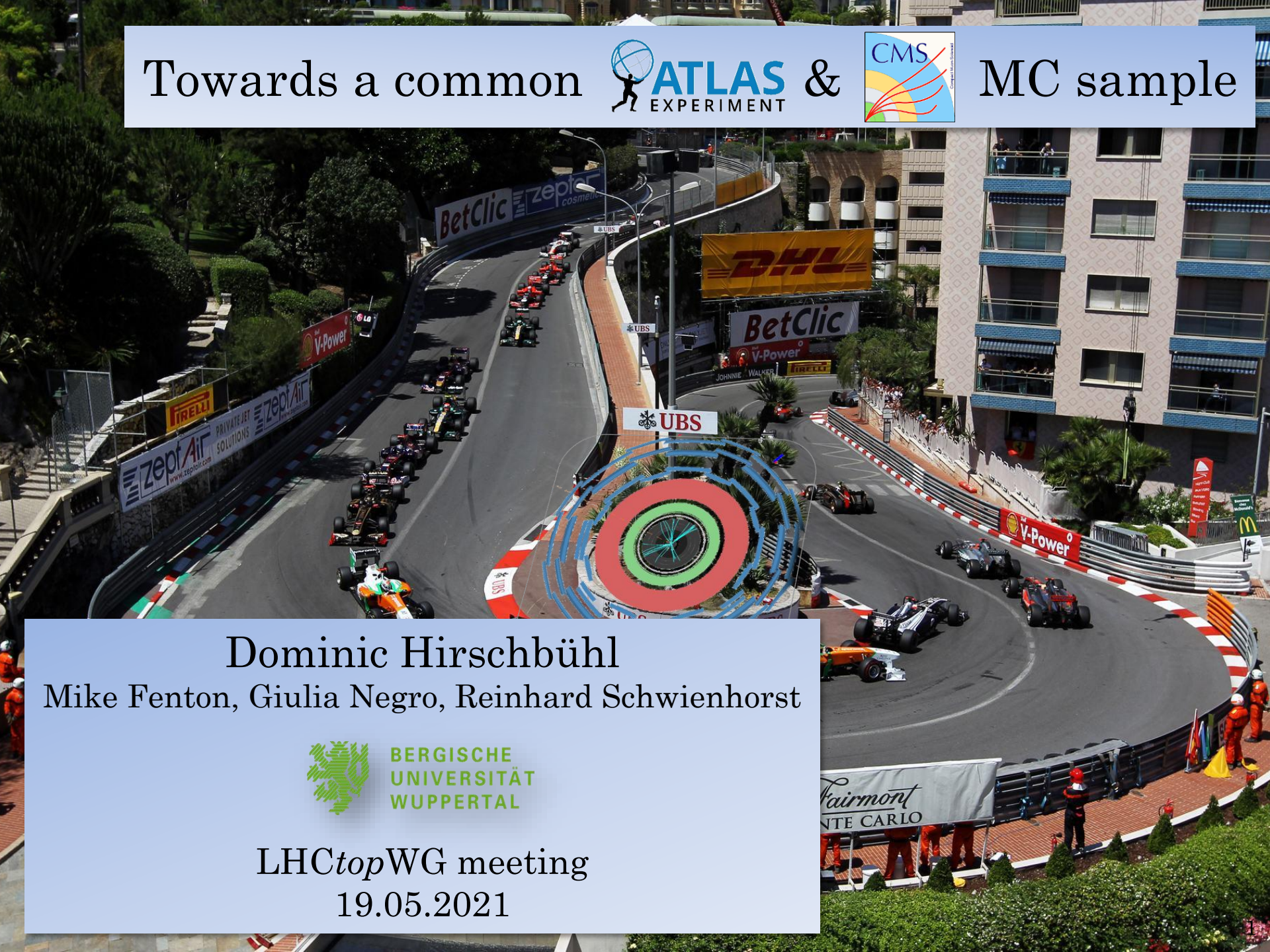
Towards a common ATLAS & CMS MC sample



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Motivation

Currently ATLAS and CMS are using different nominal $t\bar{t}$ samples

A $t\bar{t}$ sample using common settings would make combinations and comparisons easier

- Helps to understand correlations of systematic uncertainties
- Understanding of trends in similar analyses with slightly different selections or binnings

Remove differences in top quark mass measurements

- Differences in color reconnection models
- Differences in parton shower / soft physics settings

First step towards sharing resources, for this and future generators

Plots and tables are documented in:
ATL-PHYS-PUB-2021-xxx
CMS-Note XYZ

Current status

Main $t\bar{t}$ sample: POWHEG-BOX (hvq) + Pythia8

- That's almost the only point which is common
- Many parameters are different:
  Powheg revision & settings, Pythia8 version & settings, usage of EvtGen etc.

Main Powheg and Pythia8 parameters

Setting name	Setting description	CMS default	ATLAS default
POWHEG-BOX			
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
PYTHIA 8			
	PYTHIA 8 version	v240	v230
	Tune	CP5	A14
PDF:pSet	LHAPDF6 parton densities to be used for proton beams	NNPDF31_nnlo_as_0118	NNPDF23_lo_as_0130_qed
TimeShower:alphaSvalue	Value of α_s at Z mass scale for Final State Radiation	0.118	0.127
SpaceShower:alphaSvalue	Value of α_s at Z mass scale for Initial State Radiation	0.118	0.127
MPI:alphaSvalue	Value of α_s at Z mass scale for Multi-Parton Interaction	0.118	0.126
MPI:pT0ref	Reference p_T scale for regularizing soft QCD emissions	1.41	2.09
ColourReconnection:range	Parameter controlling colour reconnection probability	5.176	1.71

Common settings

First step towards a $t\bar{t}$ sample with common settings (v0.1)

- To avoid lengthy discussion we used a “democratic” setup:
  - Tune: Monash (basis of both ATLAS and CMS tunes)
  - Averaged all physical parameters (which don’t come from the tune)
  - Technical parameters are mainly chosen from ATLAS

Setting name	Setting description	CMS default	ATLAS default	Common Proposal
POWHEG-BOX				
qmass	top-quark mass [GeV]	172.5	172.5	172.5
twidth	top-quark width [GeV]	1.31	1.32	1.315
hdamp	first emission damping parameter [GeV]	237.8775	258.75	250
wmass	$W^{\pm}$ mass [GeV]	80.4	80.3999	80.4
wwidth	$W^{\pm}$ width [GeV]	2.141	2.085	2.11
bmass	b-quark mass [GeV]	4.8	4.95	4.875
PYTHIA 8				
	PYTHIA 8 version	v240	v230	v240 (CMS) v244 (ATLAS)
	Tune	CP5	A14	Monash
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
TimeShower:alphaSvalue	Value of α_s at Z mass scale for Final State Radiation	0.118	0.127	0.1365
SpaceShower:alphaSvalue	Value of α_s at Z mass scale for Initial State Radiation	0.118	0.127	0.1365
MPI:alphaSvalue	Value of α_s at Z mass scale for Multi-Parton Interaction	0.118	0.126	0.130
MPI:pT0ref	Reference p_T scale for regularizing soft QCD emissions	1.41	2.09	2.28
ColourReconnection:range	Parameter controlling colour reconnection probability	5.176	1.71	1.80

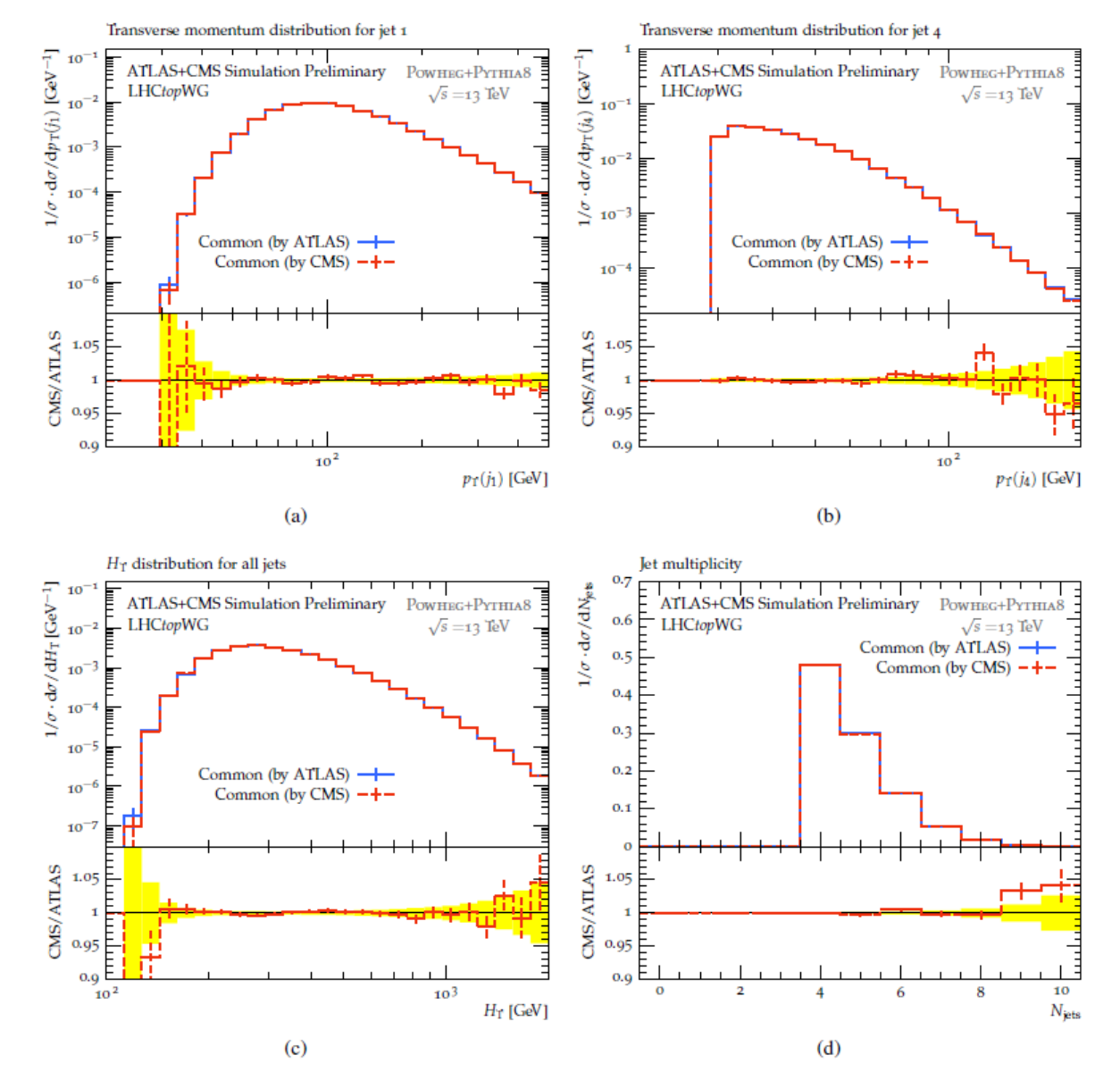
Common sample

Technical setup of the production

- Samples are produced separately in the respective frameworks
- Used agreed settings – exchange through simple text files
  → converted them to corresponding config files.
- Since not all Pythia versions are available in the respective frameworks different versions are used
  → Checked before, that all Pythia versions 8.230, 8.24x leading to identical results
- Produced 10M inclusive events each
- Plots are produced with Rivet v3.1.2 and the MC_TTBAR routine (onelep mode)

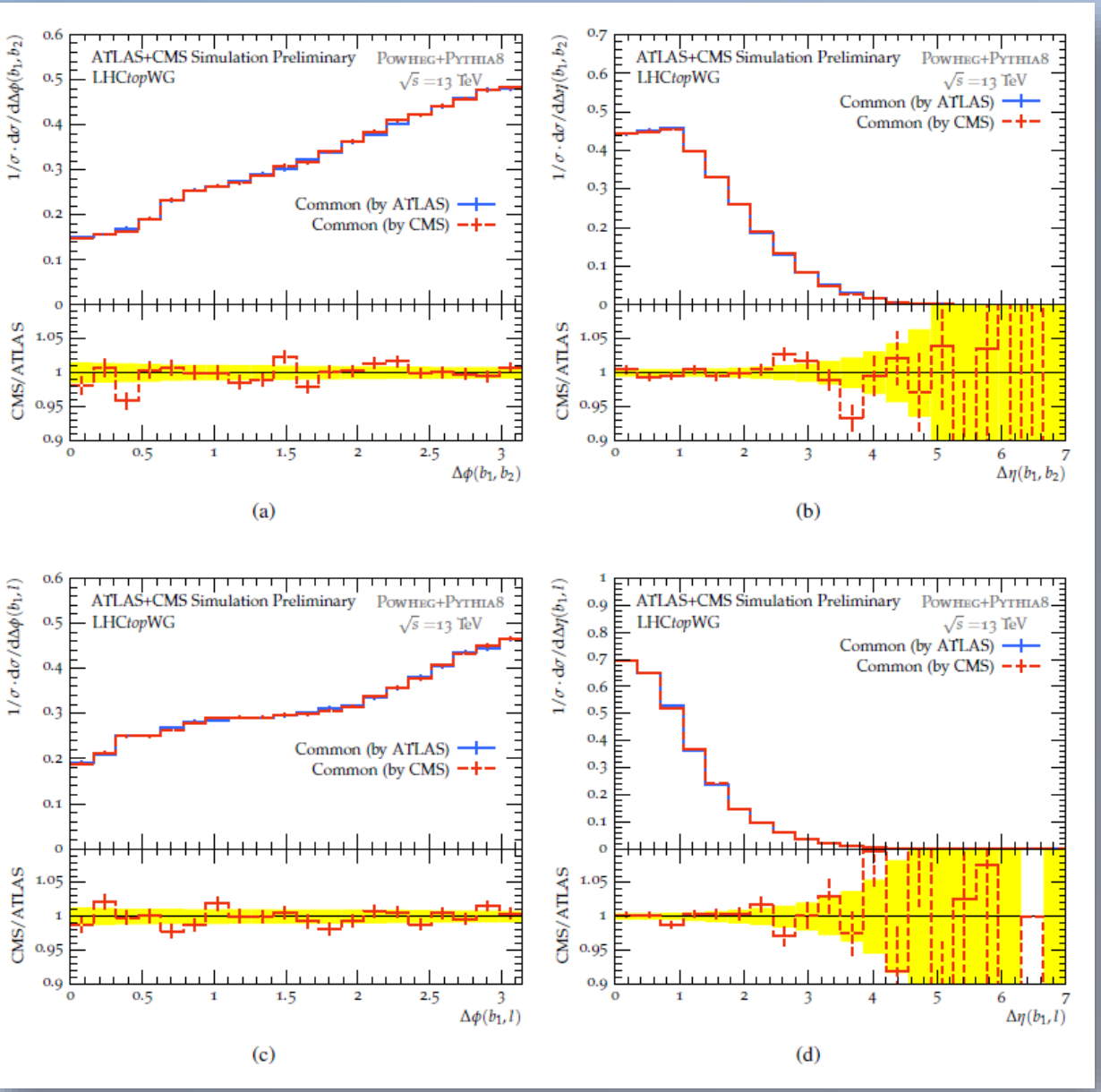
Note: We don't expect identical events, but the overall sample should agree

Validation of samples using common settings



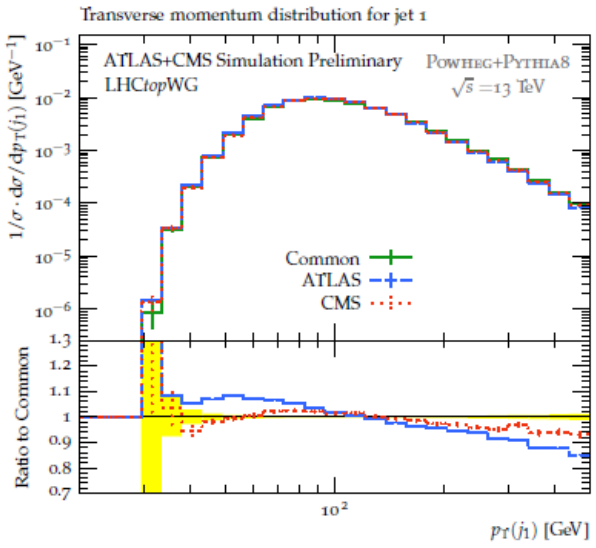
Perfect agreement within produced statistics

Validation of samples using common settings

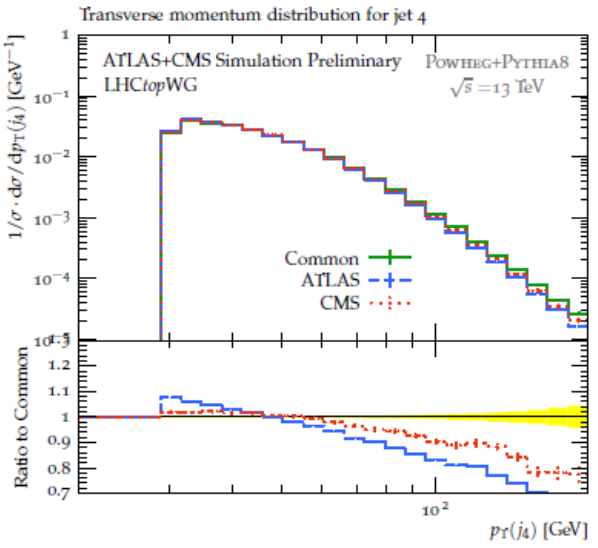


Perfect agreement within produced statistics

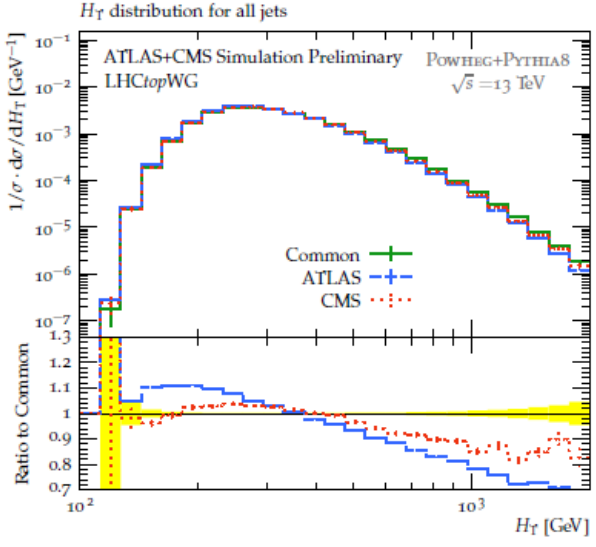
ATLAS/CMS vs Common settings



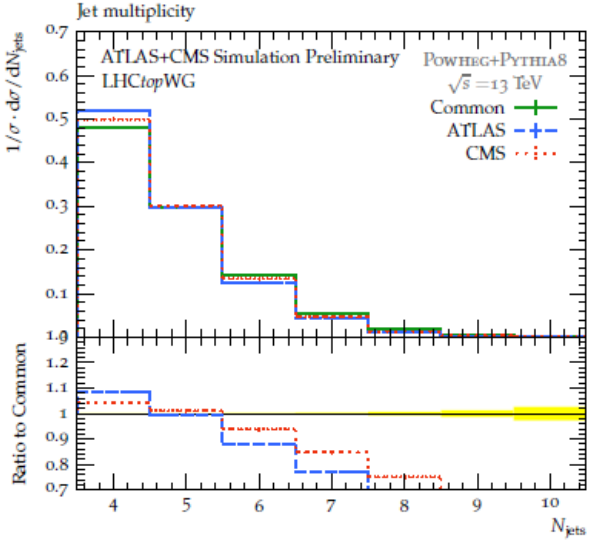
(a)



(b)



(c)



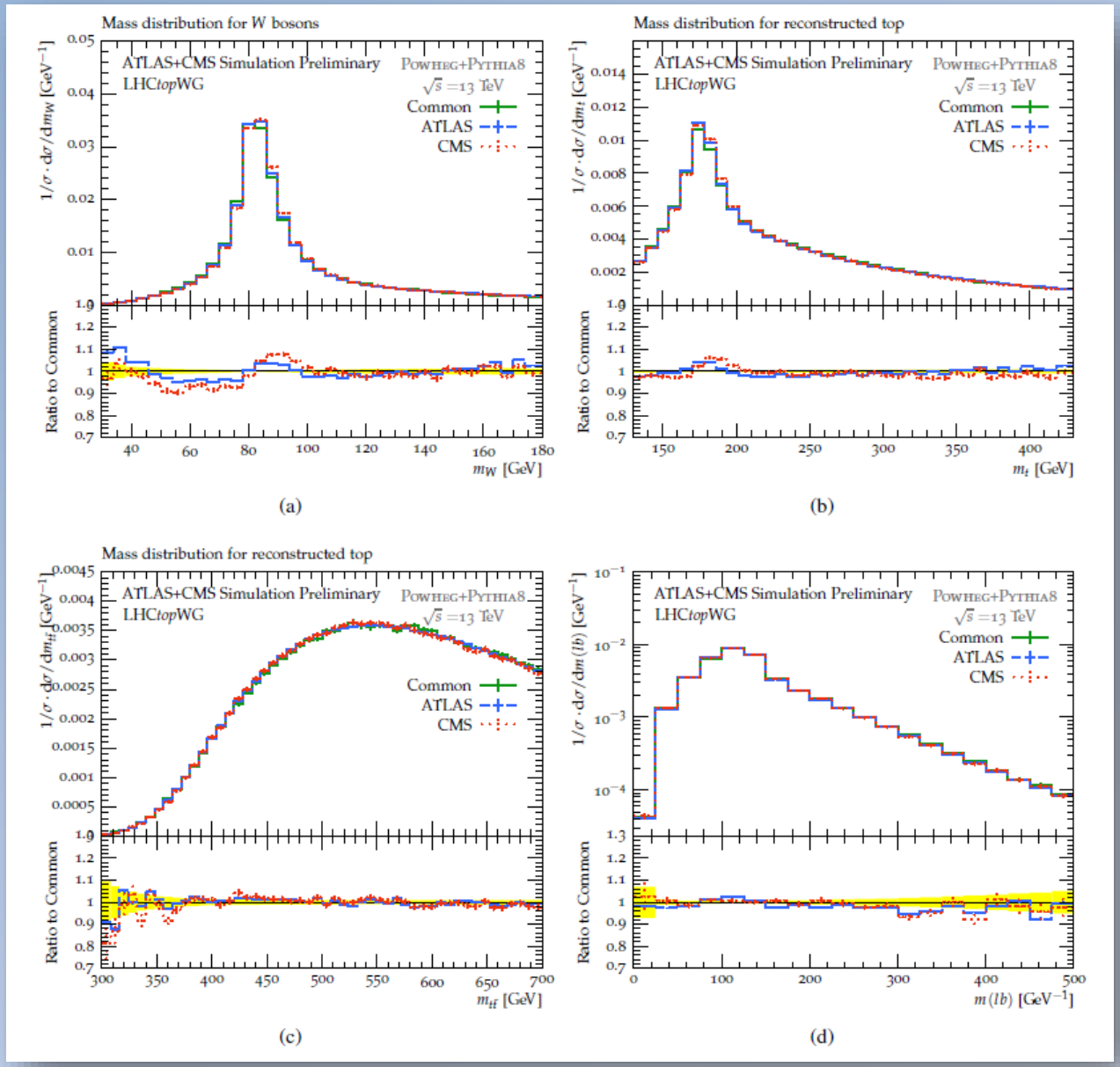
(d)

Difference between Common sample and ATLAS/CMS mainly due to different α_s of the tune

ATLAS and CMS are tuned to their experimental results

Note:
These common settings are not optimized/tuned, but mainly aimed at providing input for technical validation

ATLAS/CMS vs Common settings



Note the difference in the reconstructed W boson and top quark masses!

Using a simple Gaussian fit around the peak:

Common vs. ATLAS:
0.2 ± 0.1 GeV

Common vs. CMS:
0.4 ± 0.1 GeV

Conclusion / Outlook

First successfully produced MC sample with common settings (v0.1)

- Key point: Exchanged the full list of Powheg and Pythia8 parameters between the experiments
- Produced separate samples in separate frameworks
  → Distributions are in perfect agreement within statistical uncertainties

Next steps

- Agree on a more tuned set of parameters resulting in closer distributions to tuned ones
- Prepare a common LHE sample
- Establish common sample to be added to all published differential distributions

Ultimate goal

- Real common sample – using identical events
- Common Pythia8 tuning using ATLAS and CMS data
- Sharing of resources and of prescriptions, for nominal and systematic uncertainties

POWHEG-BOX settings

Setting name	Setting description	CMS default	ATLAS default	Common Proposal
	POWHEG-BOX V2 svn revision	3728	3026	3728 (CMS) 3026 (ATLAS)
qmass	top-quark mass [GeV]	172.5	172.5	172.5
twidth	top-quark width [GeV]	1.31	1.32	1.315
hdamp	first emission damping parameter [GeV]	237.8775	258.75	250
wmass	$W^{\pm}$ mass [GeV]	80.4	80.3999	80.4
wwidth	$W^{\pm}$ width [GeV]	2.141	2.085	2.11
bmass	b-quark mass [GeV]	4.8	4.95	4.875
cmass	c-quark mass [GeV]	1.5	1.55	1.525
smass	s-quark mass [GeV]	0.2	0.5	0.35
dmass	d-quark mass [GeV]	0.1	0.32	0.21
umass	u-quark mass [GeV]	0.1	0.32	0.21
taumass	τ mass [GeV]	1.777	1.777	1.777
mumass	μ mass [GeV]	0.1057	0.1057	0.1057
emass	e mass [GeV]	0.00051	0.00051	0.00051
elbranching	W-boson electronic branching fraction	0.108	0.1082	0.1081
sin2cabibbo	quark mixing angle	0.051	0.051	0.051

Table 1: POWHEG-BOX settings used in the ATLAS and CMS default Monte Carlo event generation setups for $t\bar{t}$ production and proposal for Common Settings.

POWHEG-BOX settings

Setting name	Setting description	CMS default	ATLAS default	Common Proposal
bmass_lhe	b-quark mass in GeV (for momentum reshuffling)	(5.0)	4.95	4.875
cmass_lhe	c-quark mass in GeV (for momentum reshuffling)	(1.5)	1.55	1.525
fastbtlbound	use fast btilde bound	(1)	1	1
ptsqmin	minimum pT in GeV for generating gluon emission off light quarks	(0.8)	0.8	0.8
ubexcess_correct	whether to correct for upper bound violations in btilde/remnant generation	(1)	1	1
withnegweights	allow negative weights	(1)	1	1
lhans1/lhans2	LHA pdfs	306000	260000	260000
ncall1	number of calls for initializing the integration grid	10000	500	500
itmx1	number of iterations for initializing the integration grid	5	1	1
ncall2	number of calls for computing the integral and finding upper bound	100000	50000	50000
itmx2	number of iterations for computing the integral and finding upper bound	5	8	8
nubound	number of calls to setup upper bounds for radiation	100000	800000	800000
xupbound	increase upper bound for radiation generation	2	10	10

Table 2: Additional POWHEG-BOX settings used in the ATLAS and CMS default Monte Carlo event generation setups for $t\bar{t}$ production and proposal for Common Settings. Entries where the default POWHEG-BOX value is being used are indicated in parentheses.

PYTHIA8 settings

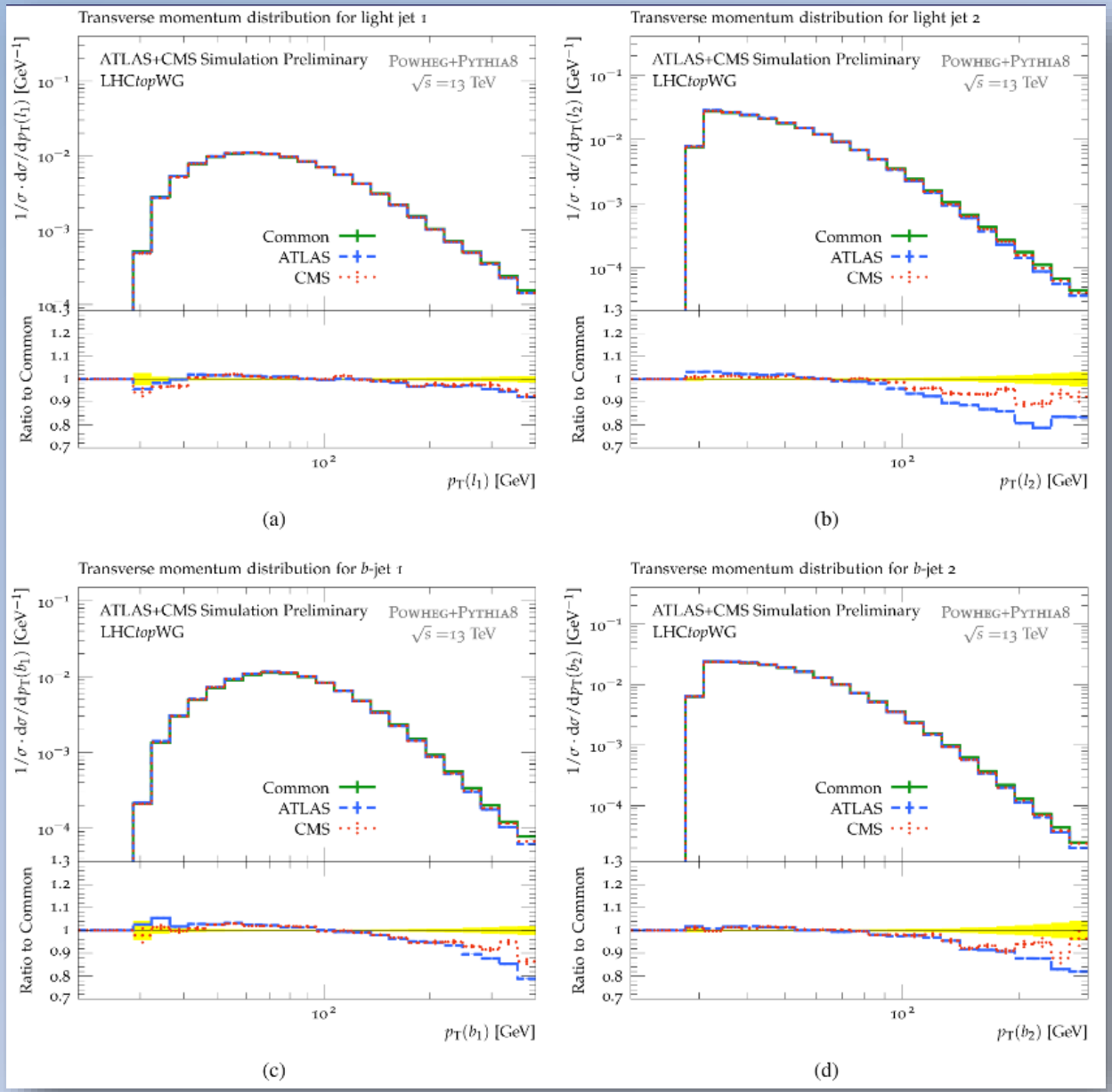
Setting name	Setting description	CMS default	ATLAS default	Common proposal
	PYTHIA 8 version	v240	v230	v240 (CMS) v244 (ATLAS)
POWHEG	Interface parameters in PYTHIA for matching to POWHEG			
pTdef	Flag for hardness criterion (POWHEG vs PYTHIA)	1	2	1
emitted	Flag for defining emissions	0	0	0
pTemt	Flag 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	50
nFinal	Number of outgoing particles for born level process	2	2	2
veto	Flag for vetoed or unvetoed showers	1	1	1
MPIveto	Flag for applying veto to Multi Parton Interactions	(0)	0	0
TimeShower	Final State Radiation Parameters			
mMaxGamma	Maximum invariant mass for $\gamma \to f\bar{f}$	1.0	(10)	10
alphaSorder	Order of running for α_s	2	(1)	1
alphaSvalue	Value of α_s at Z mass scale	0.118	0.127	0.13650
pTmaxMatch	Flag for setting maximum shower scale algorithm	2	2	2
SpaceShower	Initial State Radiation Parameters			
alphaSorder	Order of running for α_s	2	(1)	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	2
rapidityOrder	Force emissions to be ordered in rapidity	on	on	on
rapidityOrderMPI	Force emissions in secondary scatterings to be ordered in rapidity	(on)	on	on
pT0Ref	Reference p_T scale for regularizing soft QCD emissions	(2)	1.56	2
MPI	Multi-Parton Interaction Parameters			
alphaSorder	Order of running for α_s	2	(1)	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	(0.215)	0.215
bprofile	impact parameter profile choice flag for hadron beams	2	(3)	3
coreRadius	Inner radius of core when using bprofile = 2	0.7634	(0.4)	0.4
coreFraction	Matter content fraction of core when using bprofile = 2	0.63	(0.5)	0.5
pT0ref	Reference p_T scale for regularizing soft QCD emissions	1.41	2.09	2.28
BeamRemnants	Parameters for all partons extracted from a beam			
primordialKThard	Parameter controlling k_T of beam remnant initiators in hard-interations	(1.8)	1.88	1.8
ColourReconnection	Colour Reconnection Parameters			
range	Parameter controlling colour reconnection probability	5.176	1.71	1.80
ParticleDecays	Particle Decay Settings			
allowPhotonRadiation	Allow photon radiation in decays to lepton pairs	on	(off)	off

Table 3: PYTHIA8 settings used in the ATLAS and CMS default Monte Carlo event generation setups for $t\bar{t}$ production and proposal for Common Settings. Entries where the default PYTHIA8 value (from v240 in CMS and from v230 in ATLAS) is being used are indicated in parentheses.

PYTHIA8 settings

Setting name	Setting description	CMS default	ATLAS default	Common proposal
Check	Parameters for Error Checking			
epTolErr	Maximum allowed summed deviation of different values	0.01	0.0001	0.0001
Tune	Tune Settings			
	Tune	CP5	A14	Monash
preferLHAPDF	LHAPDF package to obtain PDF values	2	1	1
pp	Choice of tune to $pp/p\bar{p}$ data	14	14	14
ee	Choice of tune to e^+e^- data	7	7	7
SigmaTotal	Parameters for Total Cross Sections			
zeroAXB	Flag to switch off central diffraction	off	on	on
mode	Mode	0	1	1
sigmaEl	Elastic cross section (in mb)	21.89	25.00	25.00
sigmaTot	Total cross section (in mb)	100.309	100.000	100.000
PDF	Parameters for PDF selection			
pSet	Parton densities to be used for proton beams	LHAPDF6:NNPDF31 _nnlo_as_0118	LHAPDF6:NNPDF23 _lo_as_0130_qed	LHAPDF6:NNPDF23 _lo_as_0130_qed
StandardModel	Standard Model Parameters			
sin2thetaW	Weak mixing angle	(0.23120)	(0.23113)	0.23113
sin2thetaWbar	Weak mixing angle for fermions vector couplings to Z^0	(0.23150)	(0.23146)	0.23146

More comparisions



More comparisions