Studies of Top Quark Monte Carlo Modelling with the ATLAS Detector

MPI@LHC, Shimla, 12th December 2017

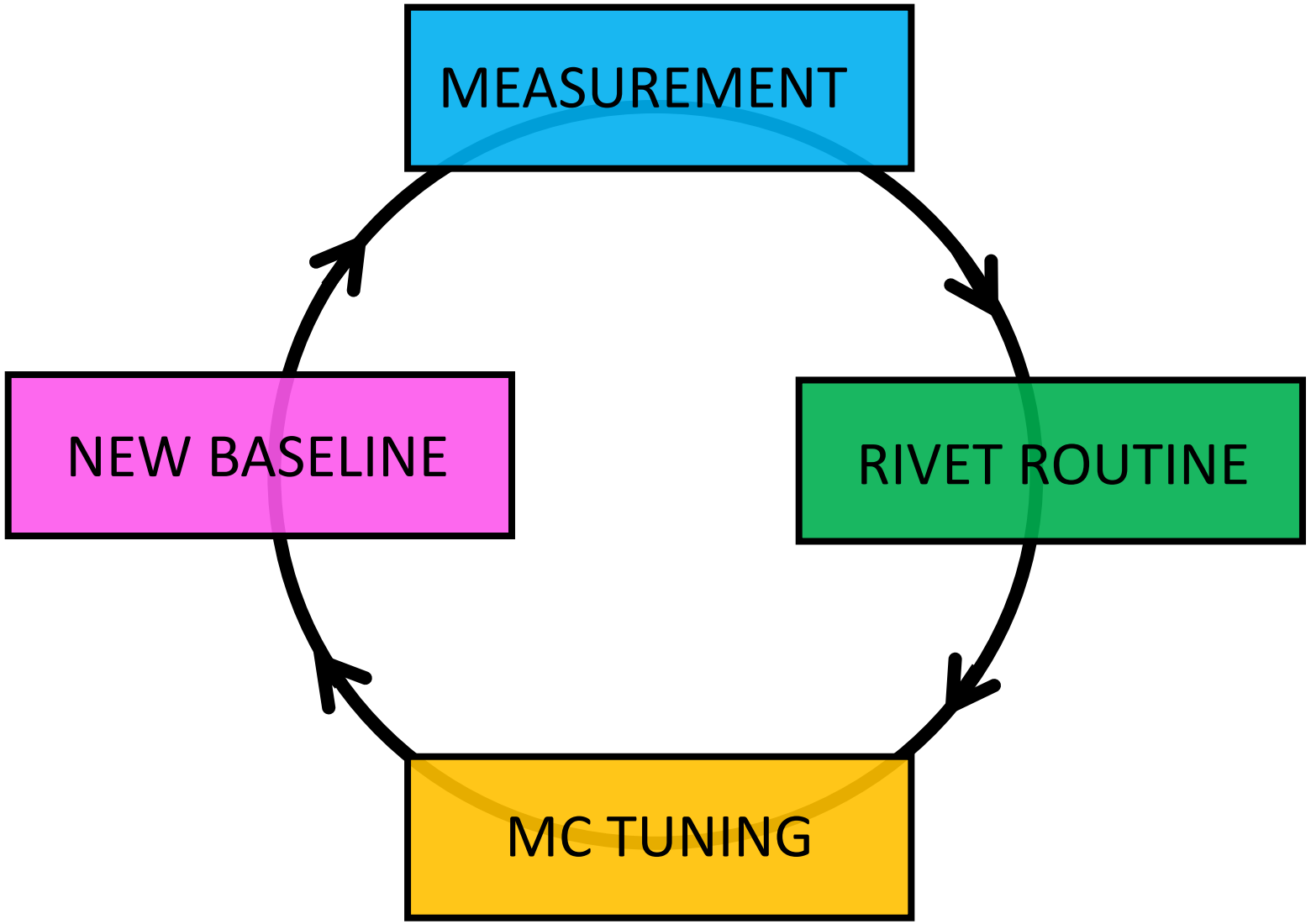
Lily Asquith for the ATLAS collaboration

ATLAS EXPERIMENT

THE ROYAL SOCIETY

UNIVERSITY OF SUSSEX

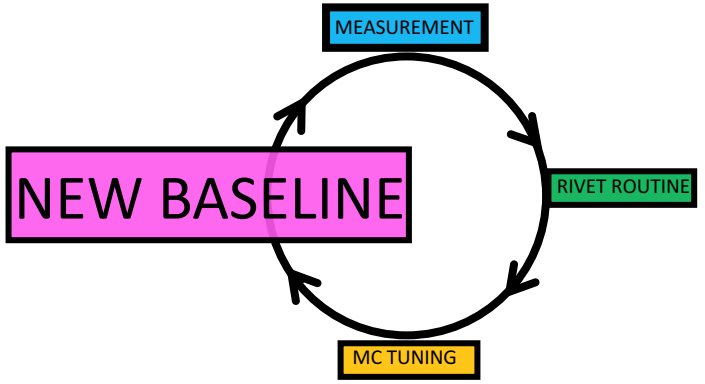
Monte Carlo Modeling Cycle



A huge amount of work has been done in determining the current baseline generator setup used by ATLAS for $t\bar{t}$.

This talk focuses on 13 TeV $t\bar{t}$ measurements using the latest baseline, and discusses ongoing work for the next cycle.

Baseline Setup



Current: Powheg + Pythia8 with A14 tune (based on 7 TeV data)

(*Pythia8 models soft radiation better than Pythia6*)

Monte Carlo Choices:

⚀ PDF
- ★ **NNPDF3.0NLO**
- ⚙ NNPDF2.3LO
- ⚙ CT10, CT10f4
- ⚙ PDF4LHC15

⚁ Matrix Element
- ★ **Powheg BOX (v2 r3026)**
- ⚙ MG5_aMC@NLO (2.2.3.p1)
- ⚙ Sherpa (2.2.1)

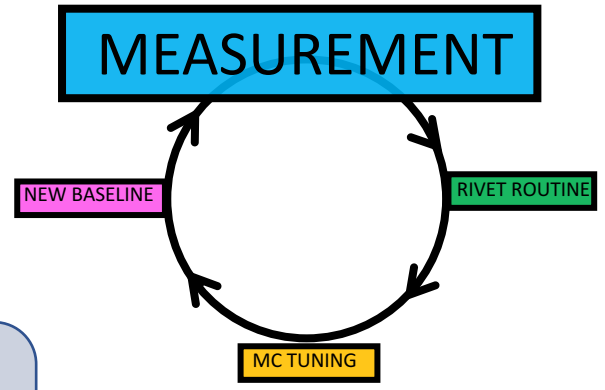
⚂ Parton Shower
- ★ **Pythia8.186 (A14)**
- ⚙ Pythia6.427 (Perugia 2012c)
- ⚙ Herwig7 (H7UE)
- ⚙ Herwig++ 2.7.1 (UE-EE-5)
- ⚙ Sherpa (author tune)

⚃ Afterburner
- ★ **EvtGen (1.2.0)**

Baseline choice **must** allow consistent set of uncertainties.

See Backup slides 2 and 3 for full details of generator/PDF/PS/tune versions

13 TeV ATLAS Measurements



Measurement of jet activity produced in top-quark events with an electron, a muon and two b-tagged jets in the final state in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

arXiv:1610.09978
TOPQ-2015-17
(**Eur. Phys. J. C77 (2017) 220**)

(May 2017)

Measurements of top-quark pair differential cross-sections in the lepton+jets channel in pp collisions at $\sqrt{s} = 13$ TeV using the ATLAS detector

arXiv:1708.00727
TOPQ-2016-01
(**JHEP 11 (2017) 191**)

(August 2017)

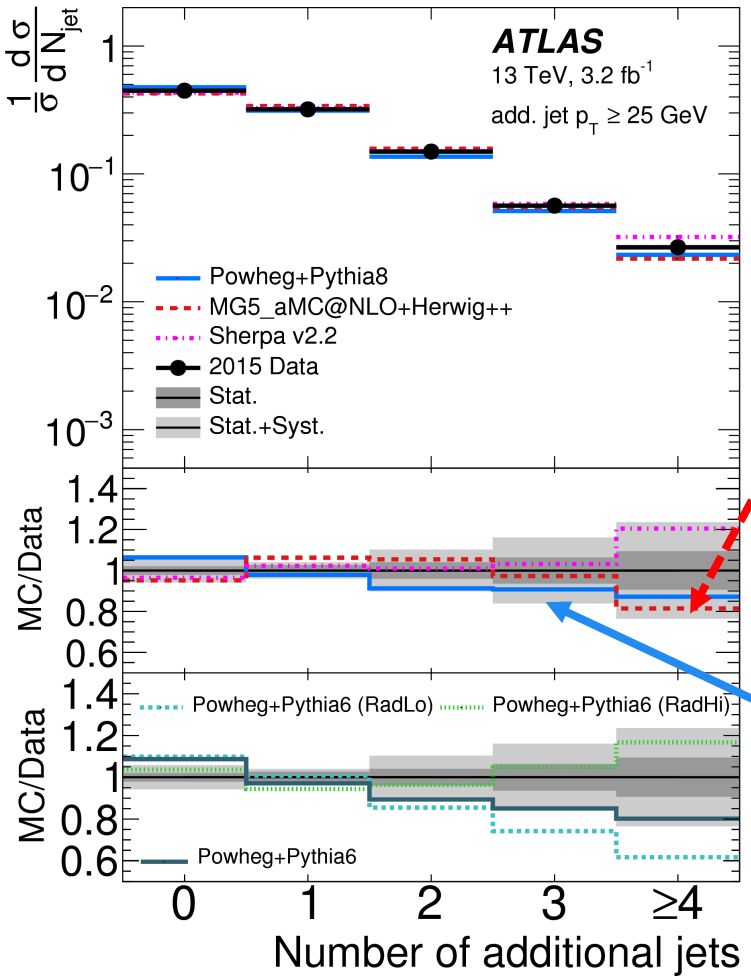
Measurement of colour flow using jet-pull observables in $t\bar{t}$ events with the ATLAS experiment at $\sqrt{s} = 13$ TeV

ATLAS-CONF-2017-069

(September 2017)

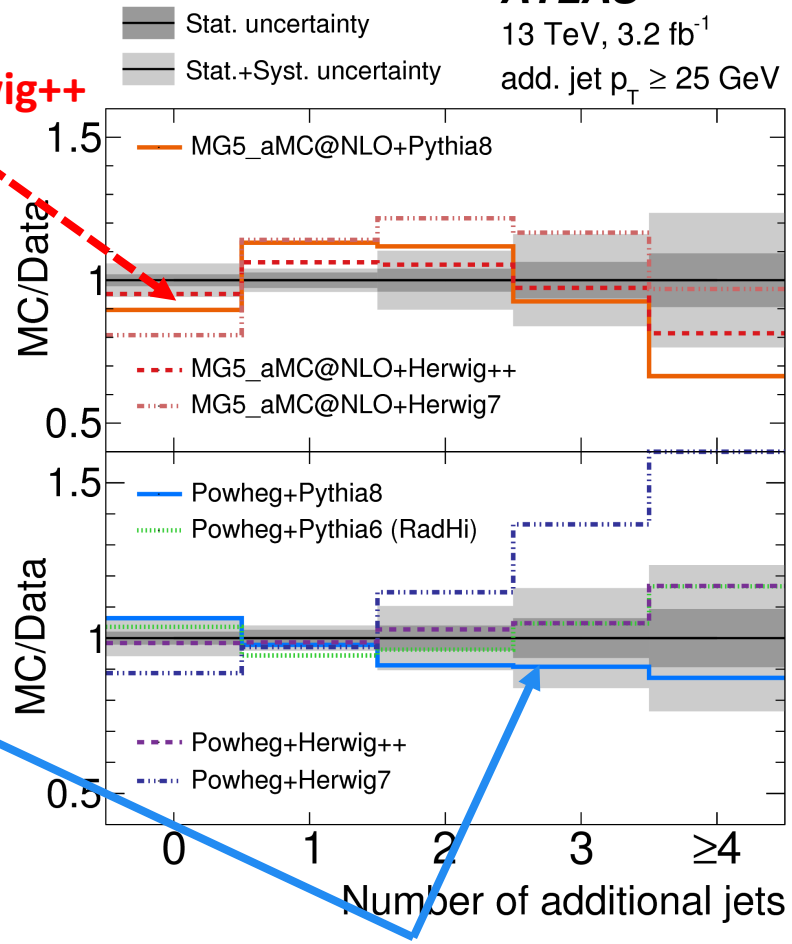
Jet Multiplicity

arXiv:1610.09978

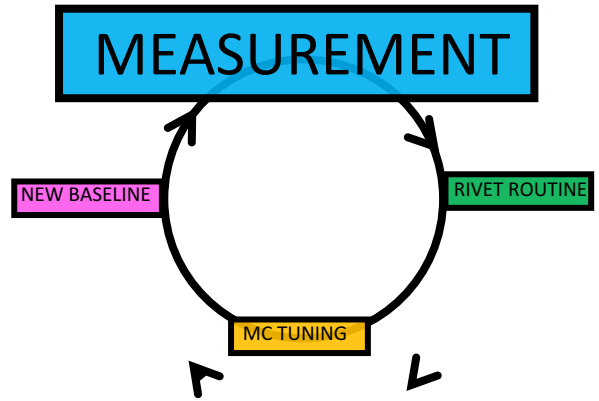


Pythia6 uses hdamp=m_t

MG5+Herwig++



Baseline Powheg+Pythia8



MG5_aMC@NLO : Vary PS only

Pythia8

Herwig++

Herwig7

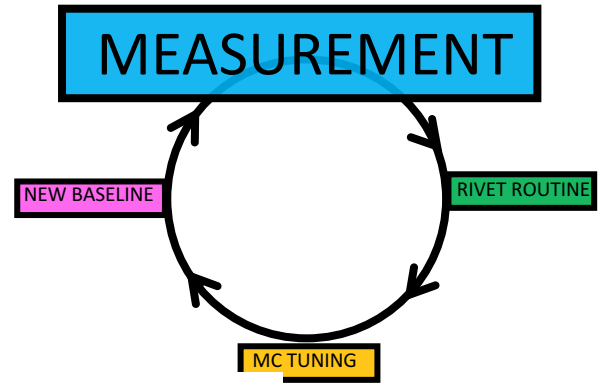
Powheg : Vary PS only

Pythia8

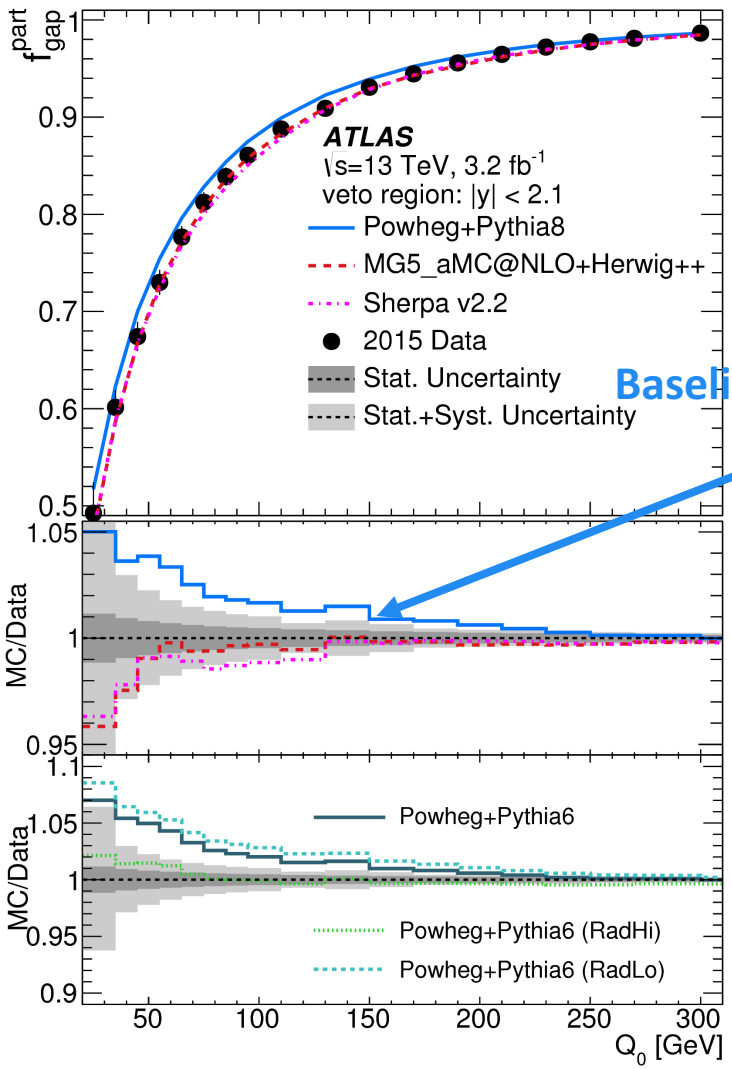
Herwig++

Herwig7

Jet Fraction in |y|<2.1 above Q_0

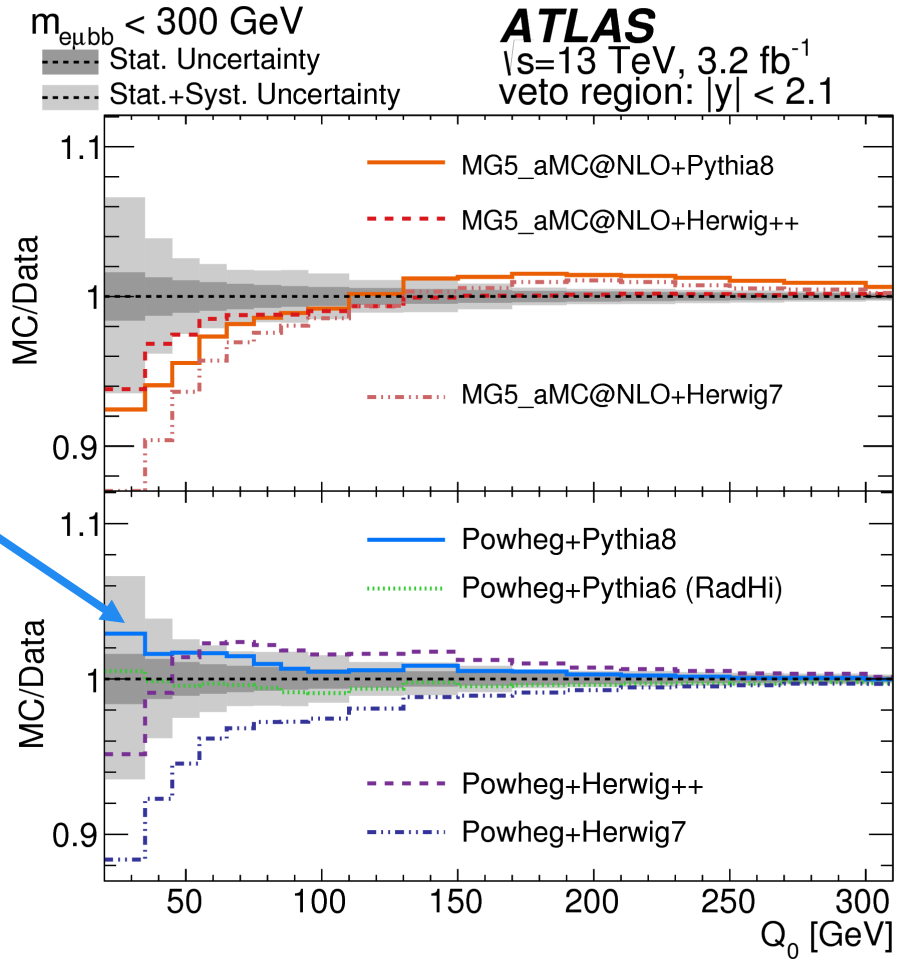


arXiv:1610.09978

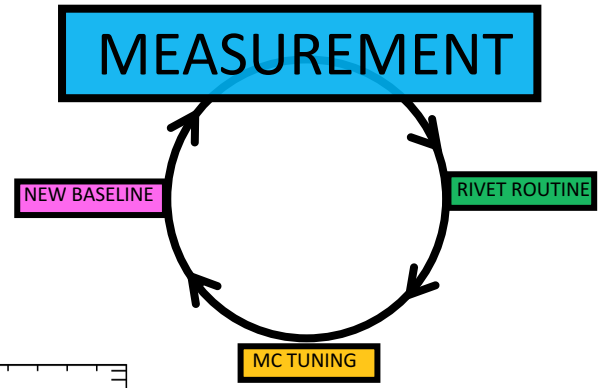


f_{gap} =1 : no additional jets

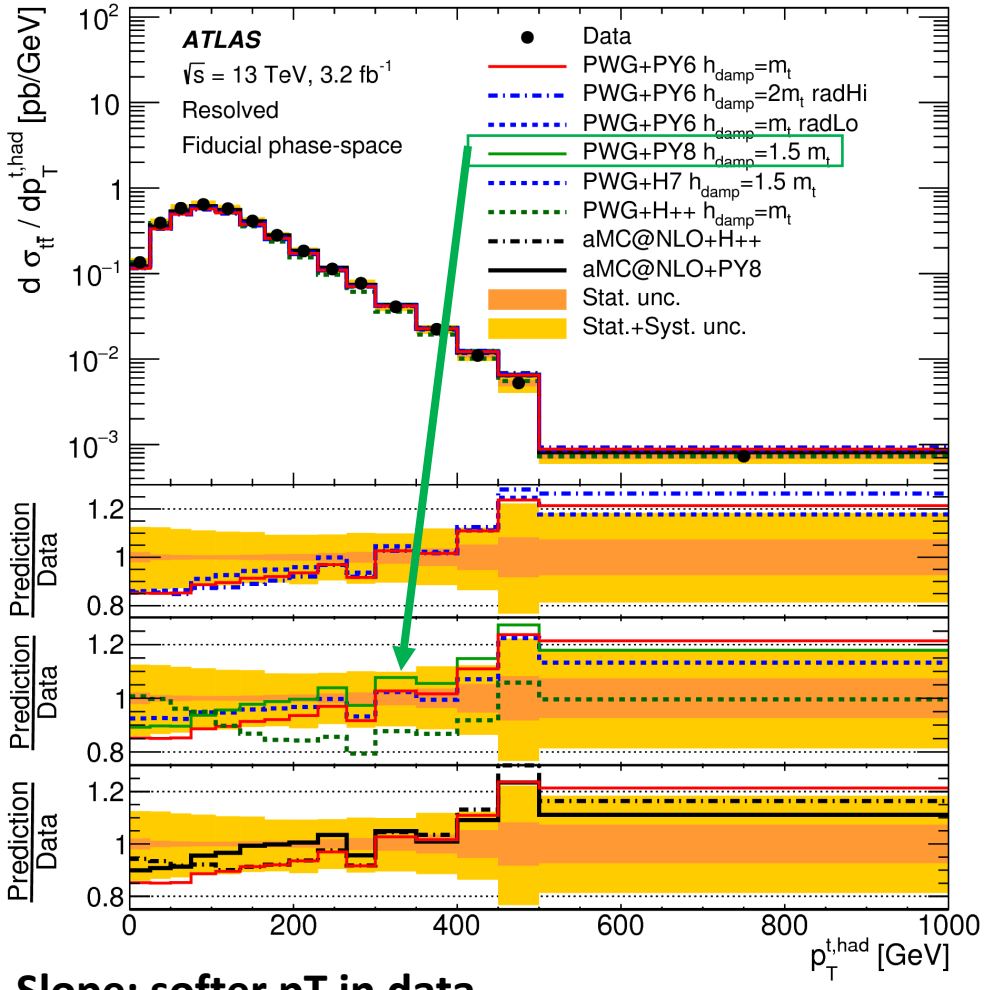
Baseline Powheg+Pythia8

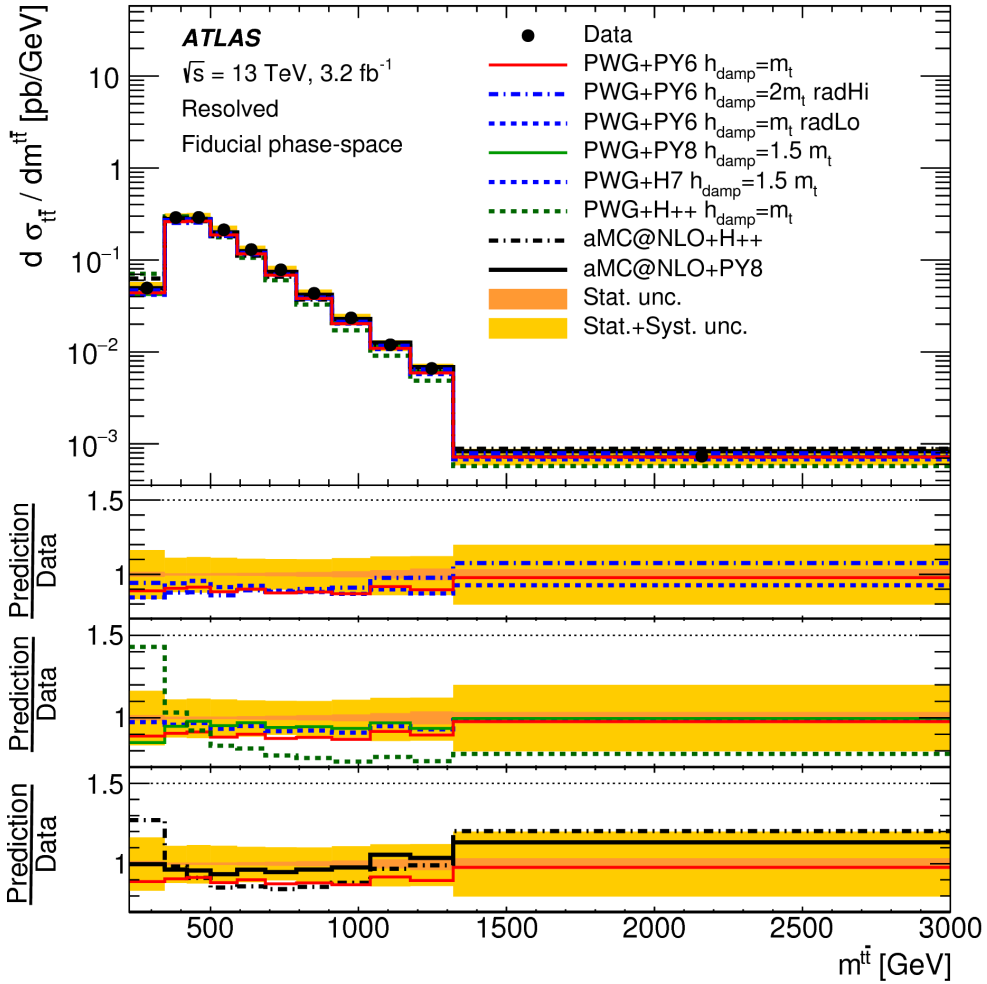


Had Top p_T and $mt\bar{t}$



arXiv:1708.00727





Slope: softer pT in data

Jet pull angle

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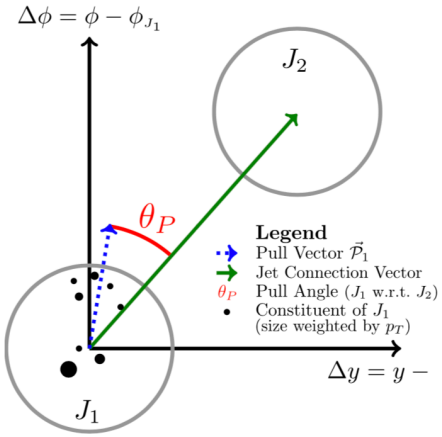
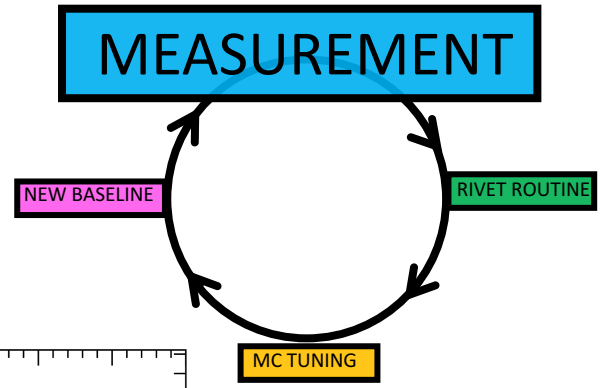
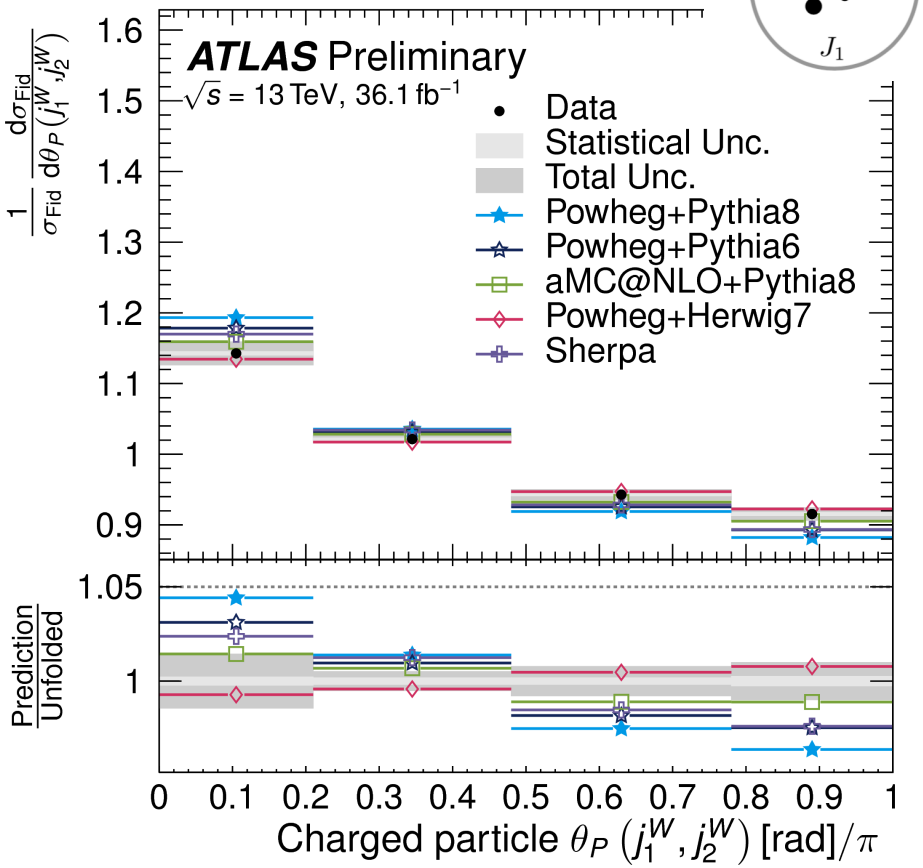
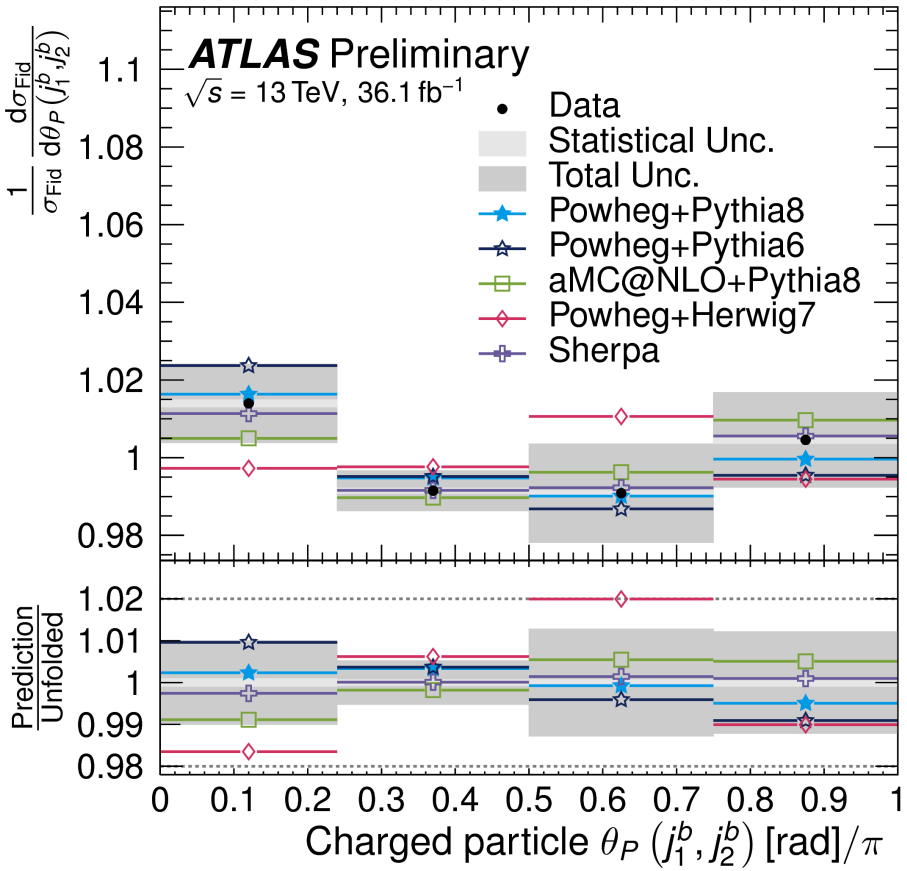




Between W daughters



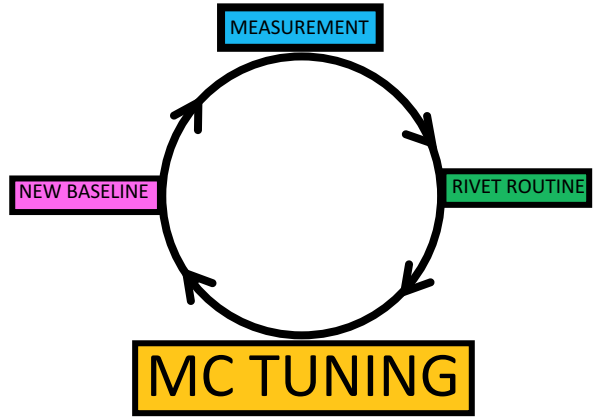
Between b-jets



Baseline Powheg+Pythia8 gives *worst* description of θ variable for W daughters.

No generator describes all distributions.

Tuning with 13 TeV data



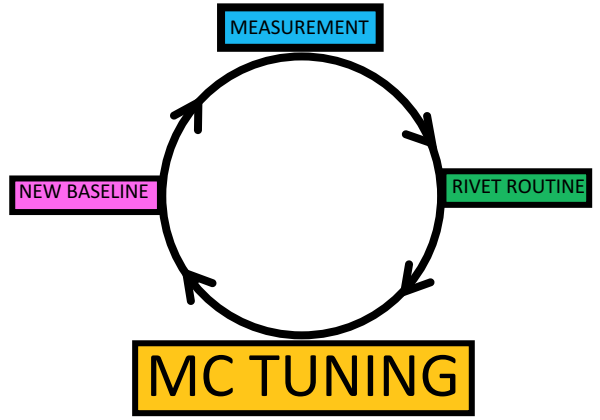
Studies on top-quark Monte Carlo modelling with Sherpa and MG5_aMC@NLO — ATL-PHYS-PUB-2017-007 *(May 2017)*

Studies on top-quark Monte Carlo modelling for Top2016 — ATL-PHYS-PUB-2016-020 *(October 2017)*

A study of different colour reconnection settings for Pythia8 generator using underlying event observables — **ATL-PHYS-PUB-2017-008** *(May 2017)* → Deepak's talk

Full list of PUB notes: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/MCPublicResults

Radiation and Scale Variations

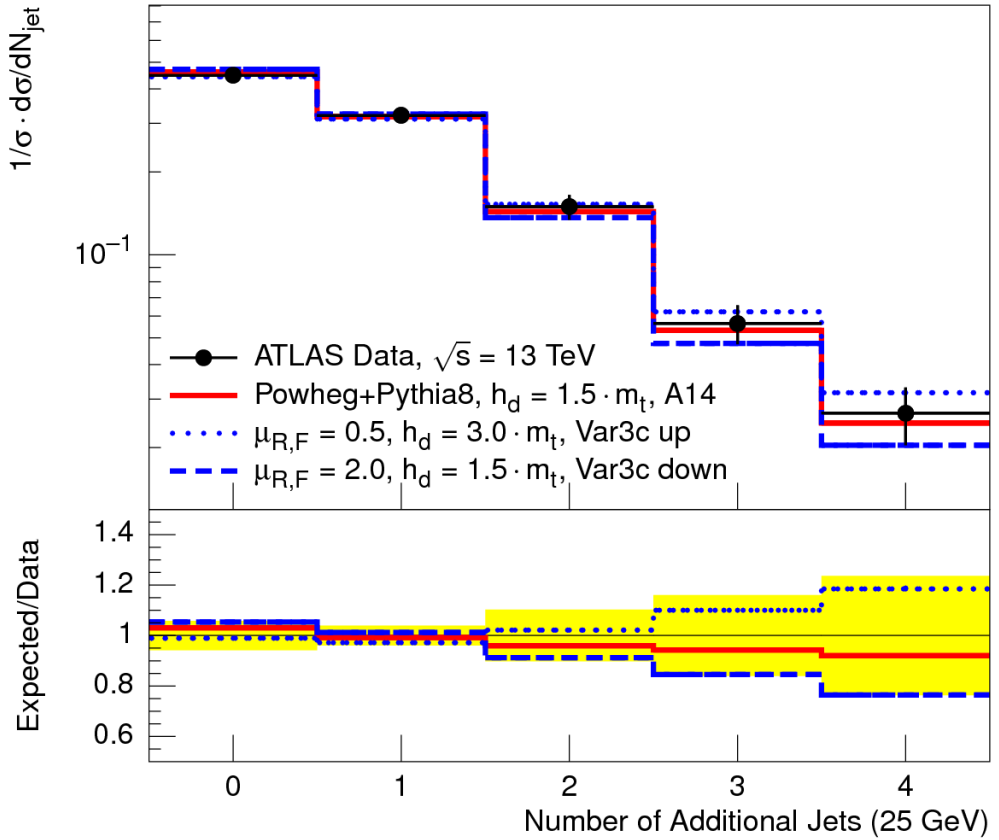


ATL-PHYS-PUB-2017-007

Vary simultaneously:

hdamp {1.5 - 3 mtop} (1.5mtop) α_s {0.115 – 0.140}(0.127) and $\mu_{F,R}$ {0.5,2.0}

Source	ATLAS
Radiation/scale	Simultaneous $\mu_{R,F}$, h_{damp}, α_S^{ISR} variations
Shower/ Hadronisation/ Fragmentation	Pythia8 vs Herwig7
ME Generator	Powheg vs MG5_aMC@NLO
Non-pertubative	A14 tune variations



Emyr Clement, LHCTopWG, Nov 17

Variations performed to bracket uncertainties

Parton Shower Variations

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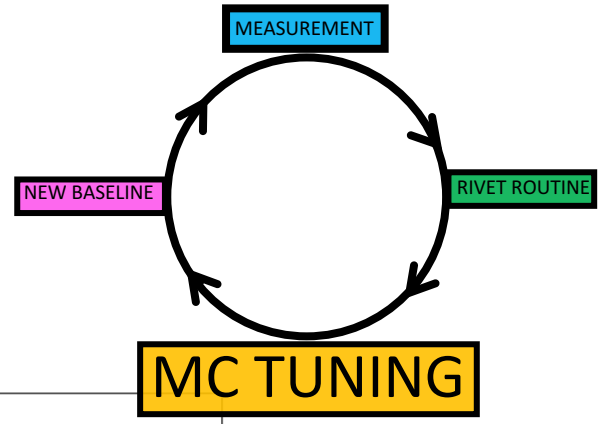
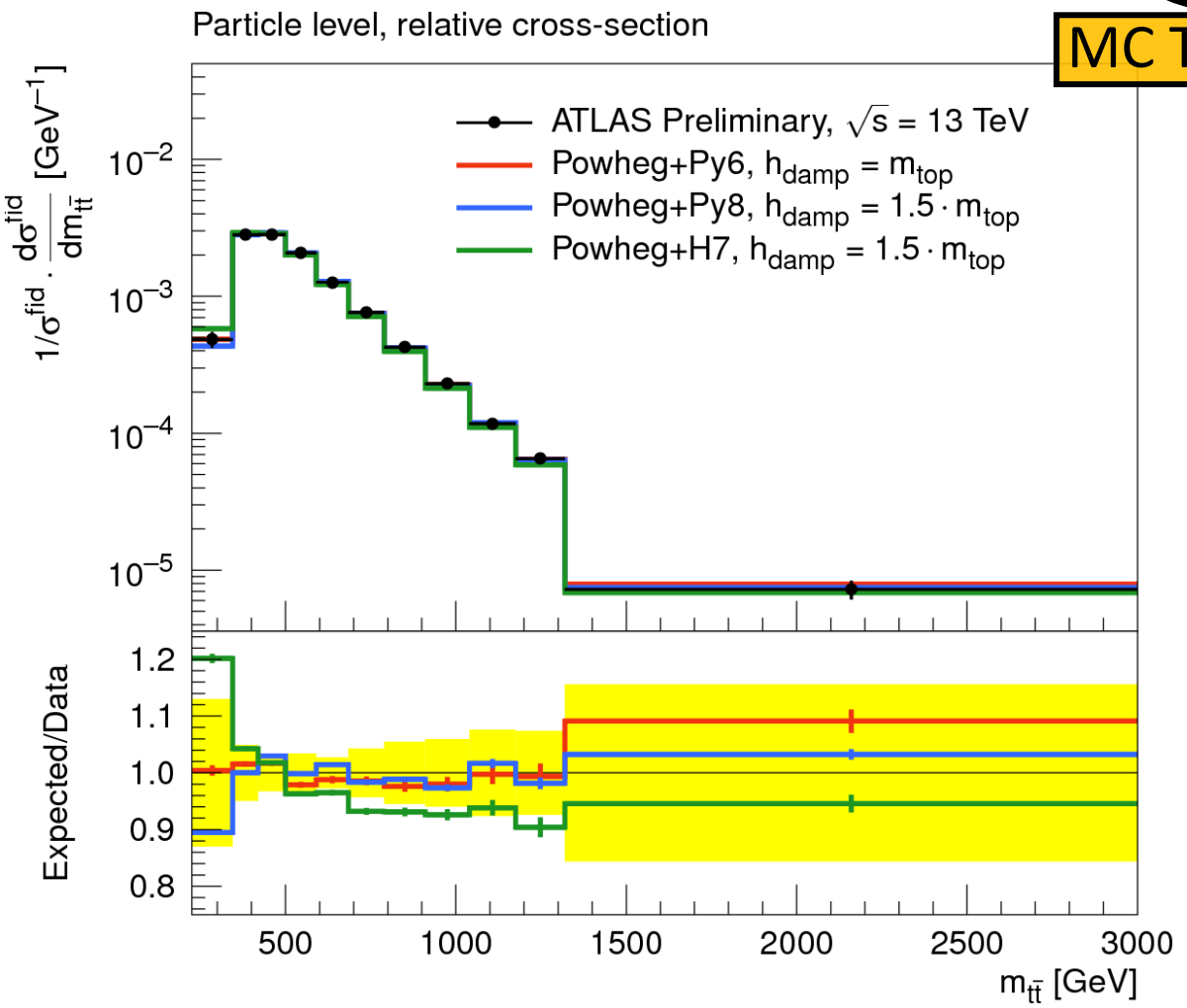
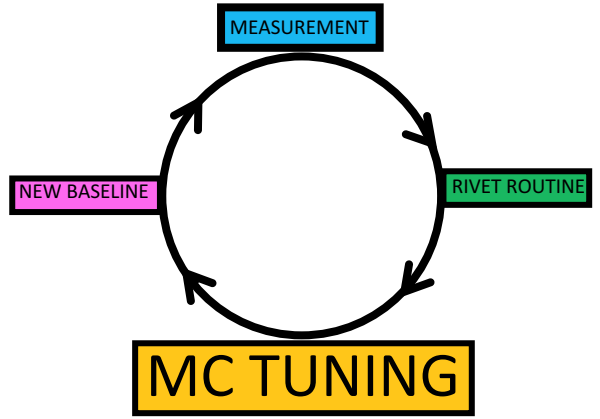


Source	ATLAS
Radiation/scale	Simultaneous $\mu_{R,F}$, h_{damp}, α_S^{ISR} variations
Shower/ Hadronisation/ Fragmentation	Pythia8 vs Herwig7
ME Generator	Powheg vs MG5_aMC@NLO
Non-pertubative	A14 tune variations

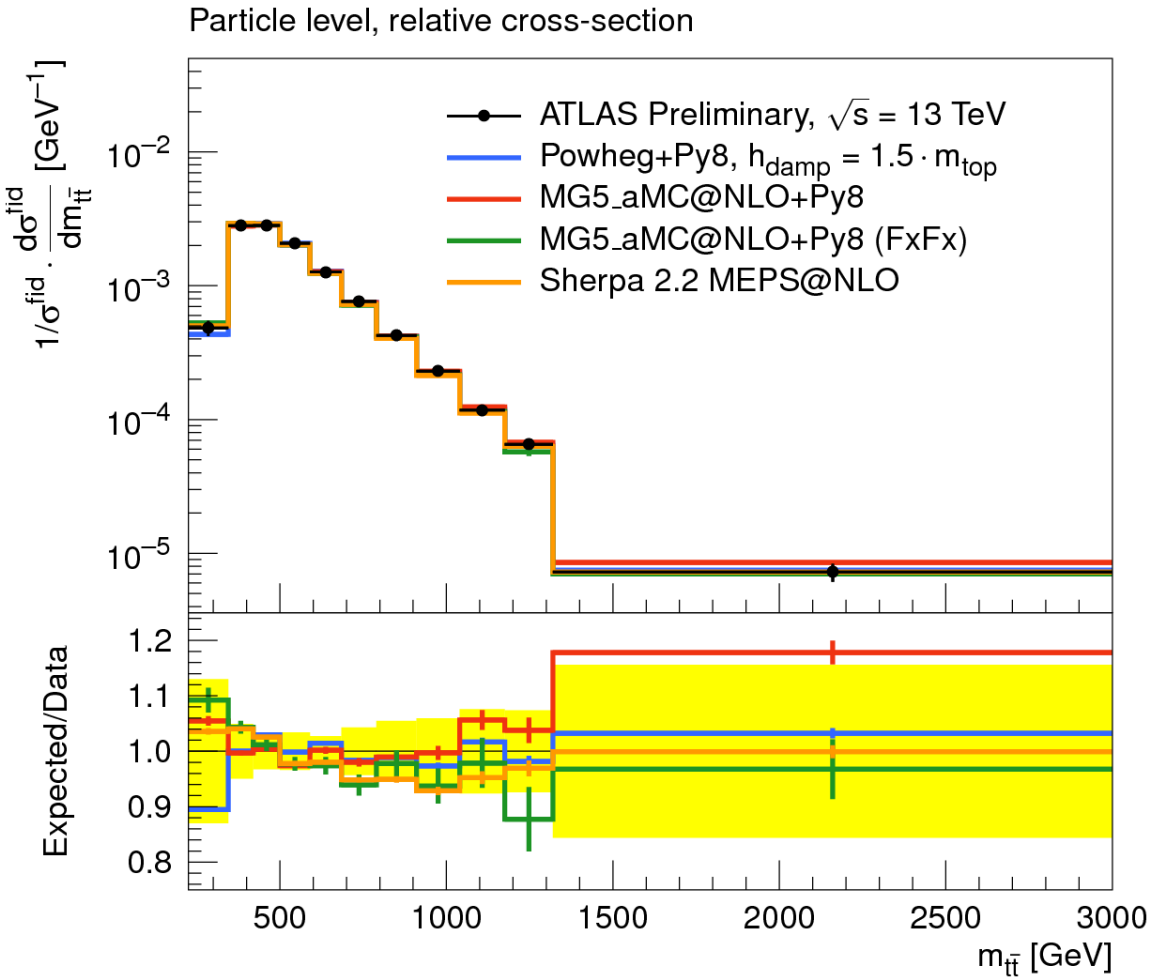


Matrix Element Variations

ATL-PHYS-PUB-2016-020



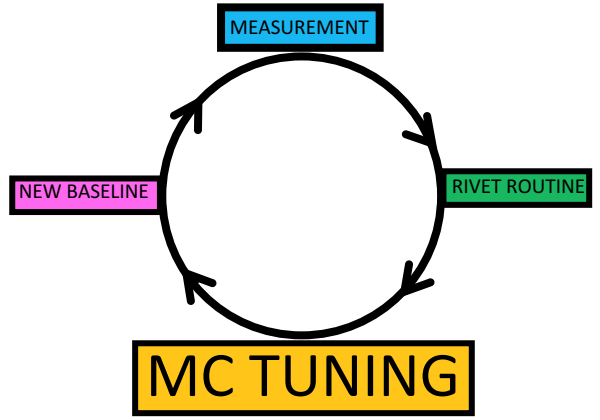
Source	ATLAS
Radiation/scale	Simultaneous $\mu_{R,F}$, h_{damp}, α_S^{ISR} variations
Shower/ Hadronisation/ Fragmentation	Pythia8 vs Herwig7
ME Generator	Powheg vs MG5_aMC@NLO
Non-pertubative	A14 tune variations



Fairly consistent

Tune Variations

ATL-PHYS-PUB-2017-008

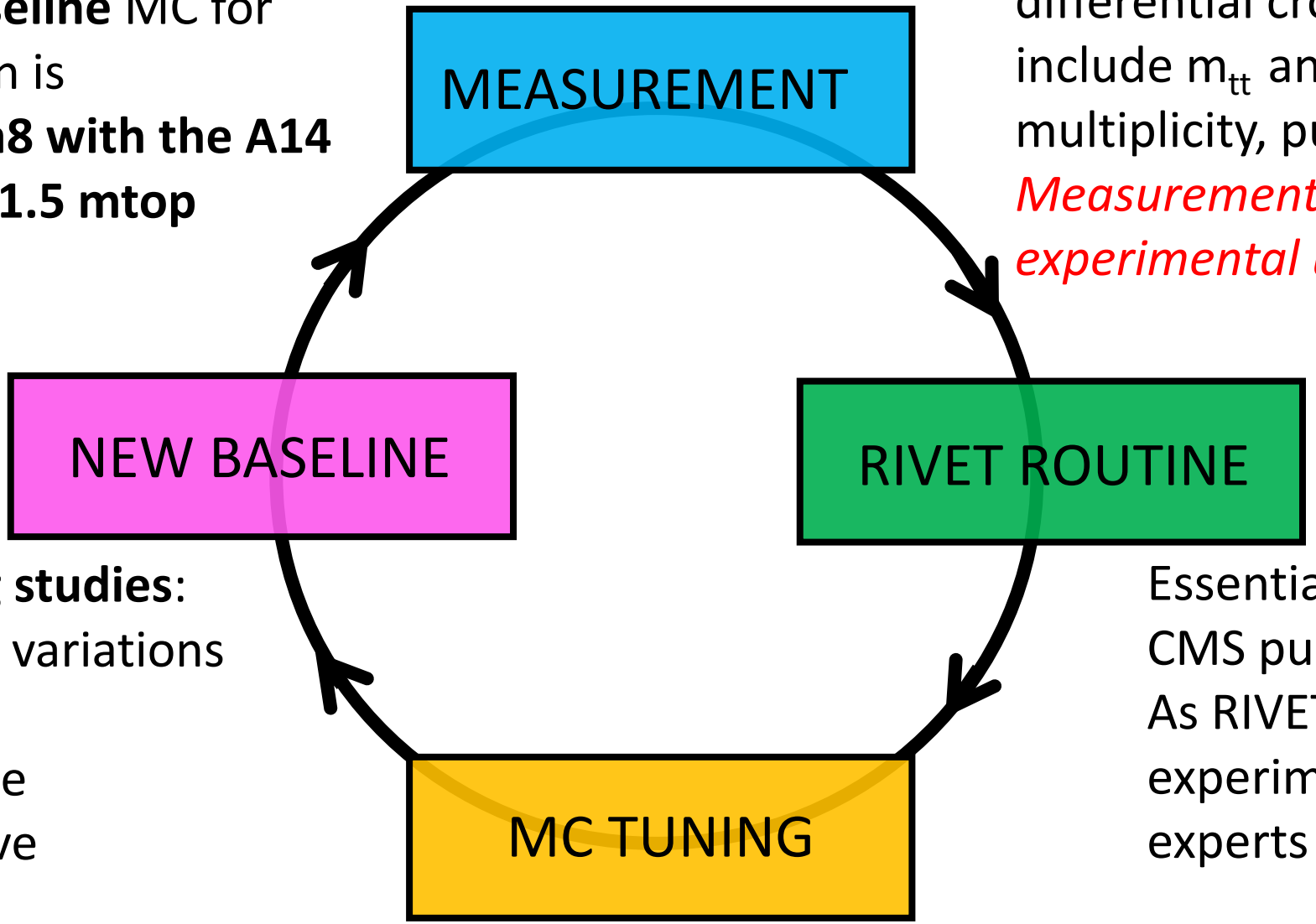


Source	ATLAS
Radiation/scale	Simultaneous $\mu_{R,F}$, h_{damp}, α_S^{ISR} variations
Shower/ Hadronisation/ Fragmentation	Pythia8 vs Herwig7
ME Generator	Powheg vs MG5_aMC@NLO
Non-pertubative	A14 tune variations

Deepak's talk, next!

Summary

The current **baseline** MC for ttbar production is **Powheg+Pythia8 with the A14 tune, hdamp = 1.5 mtop**



13 TeV data : unfolded differential cross-sections, vars include m_{tt} and p_T^{tt},$p_T^{t,had}$, jet multiplicity, pull angle, etc.
Measurements often limited by experimental uncertainties.

Ongoing **tuning studies**:
Matrix Element variations
Parton Shower
Radiation / Scale
Non Perturbative

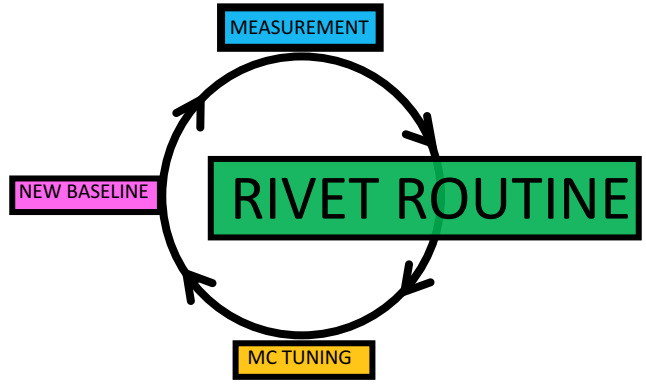
Essential that ATLAS and CMS publish unfolded data As RIVET routines – for experimentalists and MC experts for tuning.

Here's to the next baseline!

...thank you for your attention.

ADDITIONAL MATERIAL

Rivet



http://rivet.hepforge.org/analyses

7 TeV results:

- Jet veto measurement (arXiv:1203.5015)
- Jet shapes in ttbar events (arXiv:1307.5749)
- ttbar+jets (arXiv:1407.0891)
- Differential ttbar cross-section, particle-level variables (arXiv:1502.05923)

8 TeV results:

- Colour flow measurement (arXiv:1506.05629)
- Differential ttbar cross-section of highly boosted top quarks as a function of top pT (arXiv:1510.03818).
- Fiducial cross-sections for ttbar production with one or two additional b-jets (arXiv:1508.06868).
- Measurement of the production cross-section of a single top quark in association with a W boson (arXiv:1510.03752).
- Measurements of top-quark pair differential cross-sections in the lepton+jets channel (arXiv:1511.04716)

BACKUP 1/3

ATLAS-CONF-2017-069

Process	Generator	Type	Version	PDF	Tune[2]
$t\bar{t}$	POWHEG-BOX v2 [13–15] +PYTHIA 8 [17]	NLO ME +LO PS	r3026 v8.186	NNPDF 3.0 [16] NNPDF 2.3 [18]	– A14 / A14.v1† / A14.v3c† [19]
Single top	POWHEG-BOX v1 +PYTHIA 6 [21]	NLO ME +LO PS	r2819 v6.425	CT10 [20] CTEQ6L1 [22]	– PERUGIA 2012C [23]
WW, WZ, ZZ	SHERPA [24–26]	LO/NLO multileg ME+PS	v2.1.1	CT10	Default
W/Z + jets	SHERPA	LO/NLO multileg ME+PS	v2.2.1	NNPDF 3.0	Default
$t\bar{t}W/Z$	MG5_aMC@NLO [27] +PYTHIA 8	NLO ME +LO PS	v2.3.3 v8.210	NNPDF 3.0 NNPDF 2.3	– A14
$t\bar{t}H$	MG5_aMC@NLO +PYTHIA 8	NLO ME +LO PS	v2.2.3.p4 v8.210	NNPDF 3.0 NNPDF 2.3	– A14
$t\bar{t}^{\dagger}$	POWHEG-BOX v2 +HERWIG 7 [28]	NLO ME +LO PS	r3026 v7.0.1.a	NNPDF 3.0 MMHT 2014 [29]	– H7UE
$t\bar{t}^{\dagger}$	MG5_aMC@NLO +PYTHIA 8	NLO ME +LO PS	v2.3.3.p1 v8.112	NNPDF 3.0 NNPDF 2.3	– A14
$t\bar{t}^{\star}$	POWHEG-BOX v2 +PYTHIA 6	NLO ME +LO PS	r2819 v6.428	CT10 CTEQ6L1	– PERUGIA 2012
$t\bar{t}^{\star}$	SHERPA	LO/NLO multileg ME+PS	v2.2.1	NNPDF 3.0 NNLO	–

NOMINAL

VARIATIONS

BACKUP 2/3

JHEP 11 (2017) 191

Physics process	Event generator	Cross-section normalisation	PDF set for hard process	Parton shower	Tune
$t\bar{t}$ Nominal	POWHEG-BOX v2	NNLO+NNLL	CT10	PYTHIA 6.428	Perugia2012
$t\bar{t}$ PS syst.	POWHEG-BOX v2	NNLO+NNLL	CT10	HERWIG++v2.7.1	UE-EE-5
$t\bar{t}$ ME syst.	MADGRAPH5_aMC@NLO	NNLO+NNLL	CT10	HERWIG++v2.7.1	UE-EE-5
$t\bar{t}$ rad. syst.	POWHEG-BOX v2	NNLO+NNLL	CT10	PYTHIA 6.428	'radHi/Lo'
Extra $t\bar{t}$ model	POWHEG-BOX v2	NNLO+NNLL	NNPDF3.0NLO	PYTHIA 8.210	A14
Extra $t\bar{t}$ model	POWHEG-BOX v2	NNLO+NNLL	NNPDF3.0NLO	HERWIG v7.0.1	H7-UE-MMHT
Extra $t\bar{t}$ model	MADGRAPH5_aMC@NLO	NNLO+NNLL	NNPDF3.0NLO	PYTHIA 8.210	A14
Single top t-channel	POWHEG-BOX v1	NLO	CT10f4	PYTHIA 6.428	Perugia2012
Single top s-channel	POWHEG-BOX v2	NLO	CT10	PYTHIA 6.428	Perugia2012
Single top Wt-channel	POWHEG-BOX v2	NLO+NNLL	CT10	PYTHIA 6.428	Perugia2012
$t\bar{t}+W/Z/WW$	MADGRAPH5_aMC@NLO	NLO	NNPDF2.3LO	PYTHIA 8.186	A14
$W(\rightarrow \ell\nu)$+ jets	SHERPA v2.1.1	NNLO	CT10	SHERPA	SHERPA
$Z(\rightarrow \ell\bar{\ell})$+ jets	SHERPA v2.1.1	NNLO	CT10	SHERPA	SHERPA
WW, WZ, ZZ	SHERPA v2.1.1	NLO	CT10	SHERPA	SHERPA

BACKUP 3/3