Review of ATLAS JES uncertainties related to MC modelling

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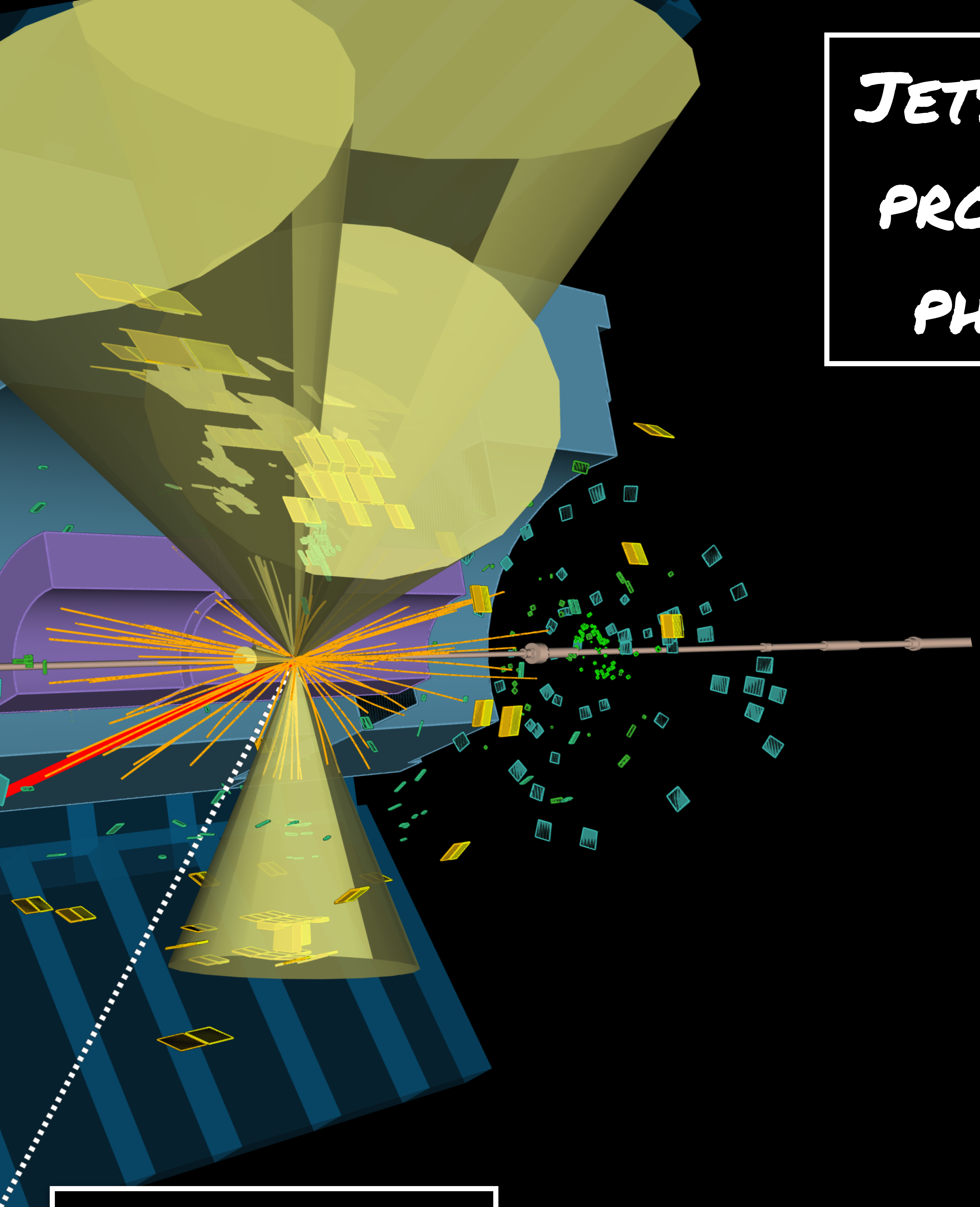
Les Houches PhysTeV 2023 SM Session

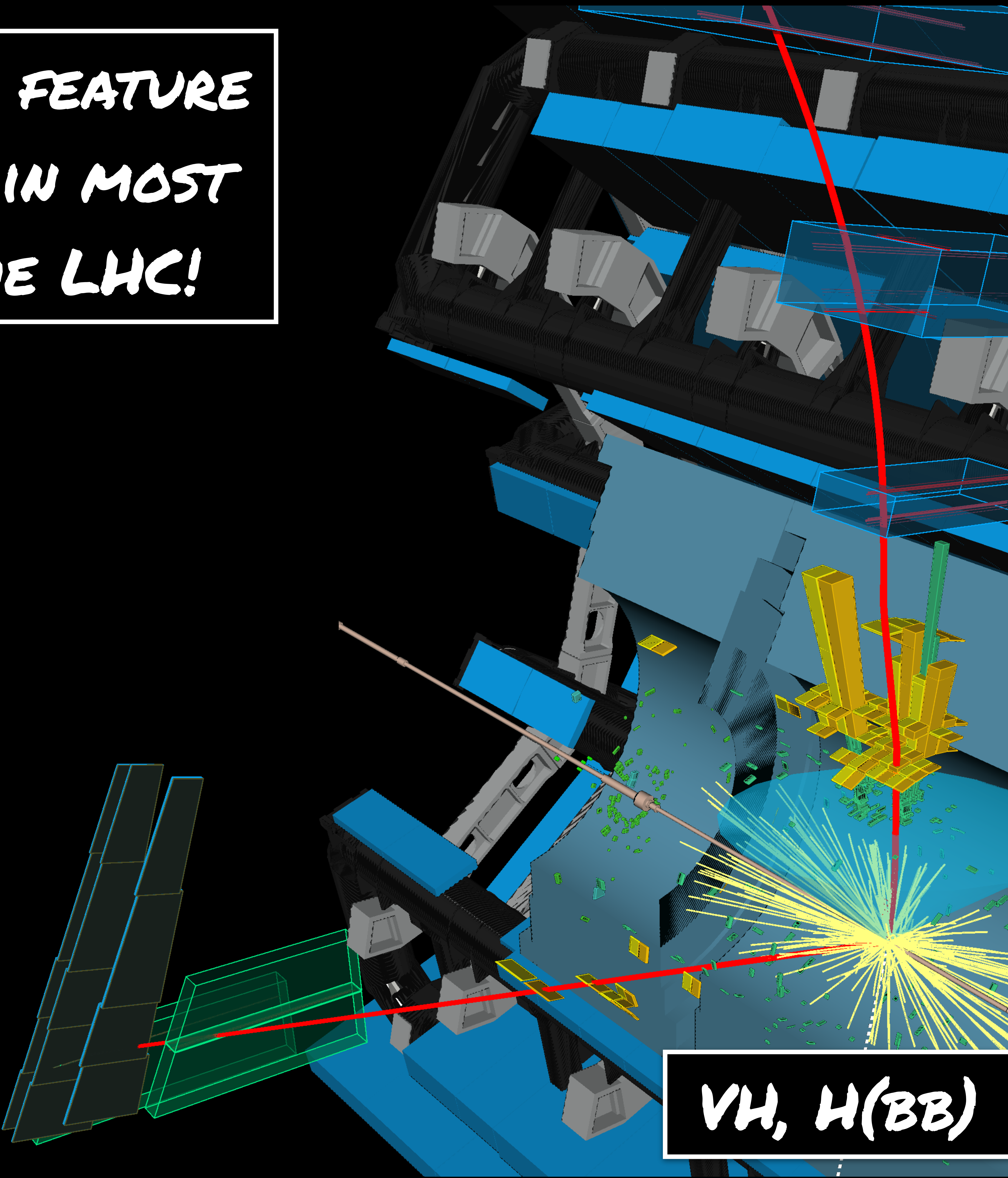
The University of Manchester

Jets and QCD feature prominently in most physics @ the LHC!



Top mass m_T

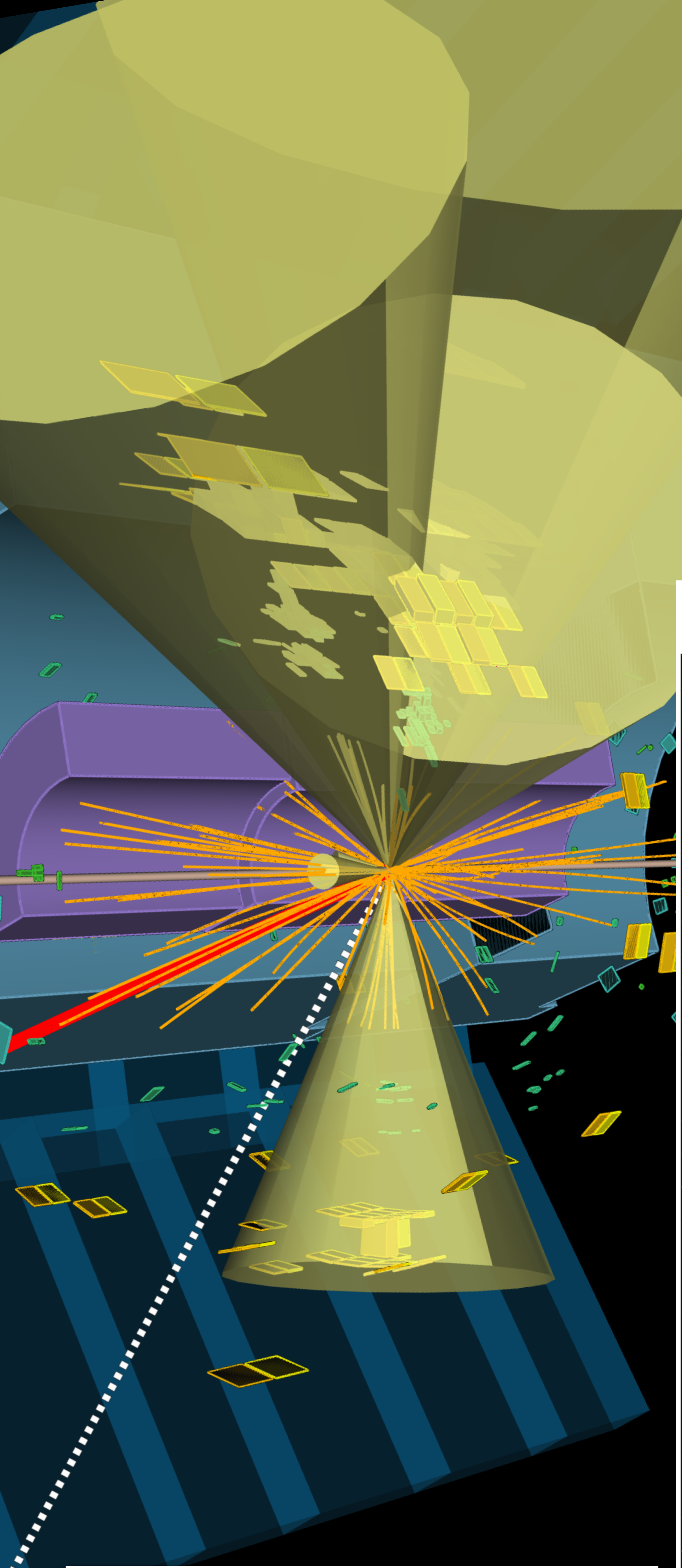
ATLAS, EPJC 79 (2019) 290



VH, H(bb)

ATLAS, PLB 816 (2021) 136204

Jets and QCD feature prominently in most physics @ the LHC!



		$\sqrt{s} = 8$ TeV $m_{top}^{\ell+jets}$ [GeV]
k	Results ($i = 0\ldots,5$)	172.08
0	Statistics	0.39
	– *Stat. comp.* (m_{top})	0.11
	– *Stat. comp.* (JSF)	0.11
	– *Stat. comp.* (bJSF)	0.35
1	Method	0.13 ± 0.11
2	Signal Monte Carlo generator	0.16 ± 0.17
3	Hadronization	0.15 ± 0.10
4	Initial- and final-state QCD radiation	0.08 ± 0.11
5	Underlying event	0.08 ± 0.15
6	Colour reconnection	0.19 ± 0.15
7	Parton distribution function	0.09 ± 0.00
8	Background normalization	0.08 ± 0.00
9	W/Z+jets shape	0.11 ± 0.00
10	Fake leptons shape	0
11	Data-driven all-jets background	
12	Jet energy scale	0.54 ± 0.02
13	Relative b-to-light-jet energy scale	0.03 ± 0.01
14	Jet energy resolution	0.20 ± 0.04
15	Jet reconstruction efficiency	0.02 ± 0.01
16	Jet vertex fraction	0.09 ± 0.01
17	b-tagging	0.38 ± 0.00
18	Leptons	0.16 ± 0.01
19	Missing transverse momentum	0.05 ± 0.01
20	Pile-up	0.15 ± 0.01
21	All-jets trigger	
22	Fast vs. full simulation	
	Total systematic uncertainty	0.82 ± 0.06
	Total	0.91 ± 0.06

Modelling various aspects of QCD…

JES → Modelling here!

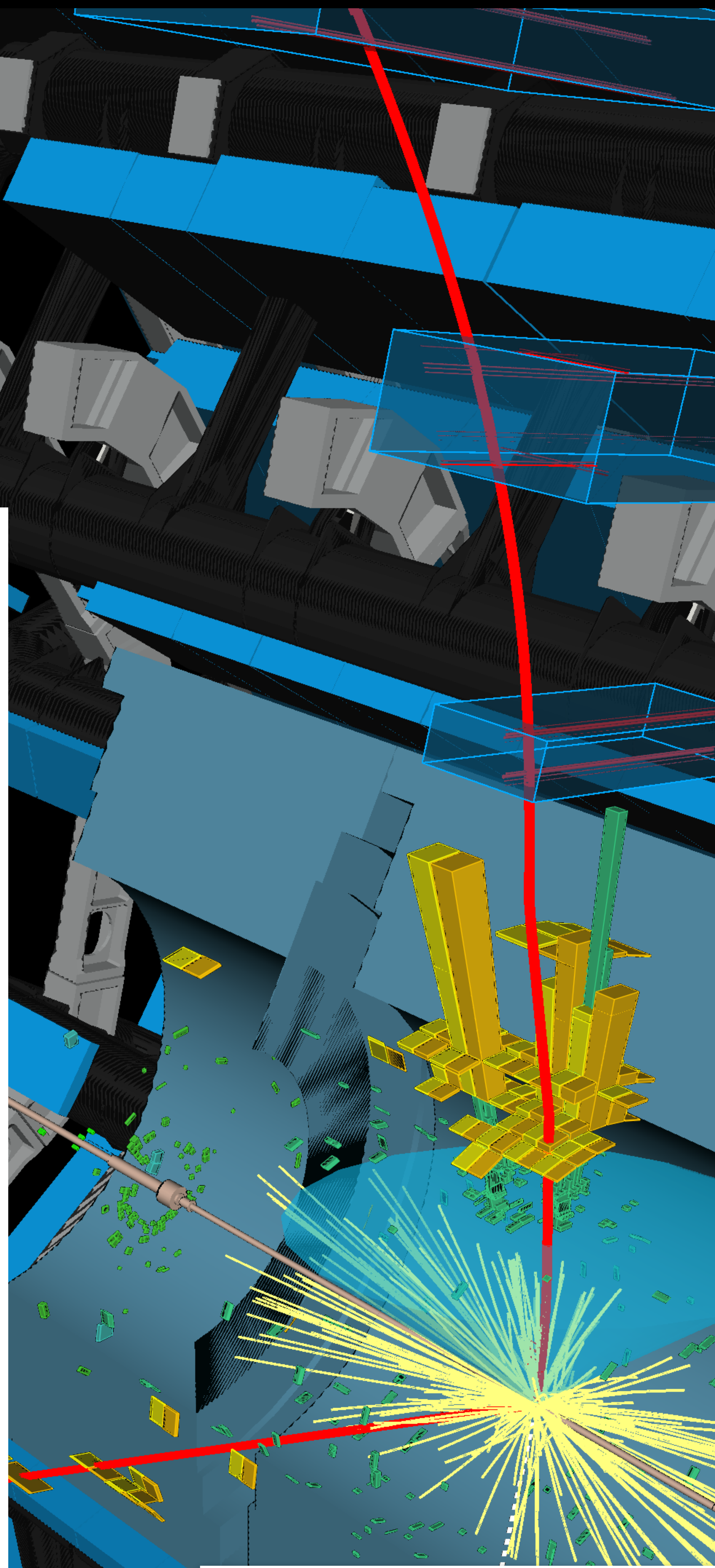
Top mass m_T

ATLAS, EPJC 79 (2019) 290

JMR modelling

Parton shower

Source of uncertainty		Avg. impact
Total		0.372
Statistical		0.283
Systematic		0.240
Experimental uncertainties		
Small-R jets		0.038
Large-R jets		0.133
E_T^{miss}		0.007
Leptons		0.010
b-tagging	b-jets	0.016
	c-jets	0.011
	light-flavour jets	0.008
	extrapolation	0.004
Pile-up		0.001
Luminosity		0.013
Theoretical and modelling uncertainties		
Signal		0.038
Backgrounds		0.100
↪ Z + jets		0.048
↪ W + jets		0.058
↪ $t\bar{t}$		0.035
↪ Single top quark		0.027
↪ Diboson		0.032
↪ Multijet		0.009
MC statistical		0.092



VH, H(bb)

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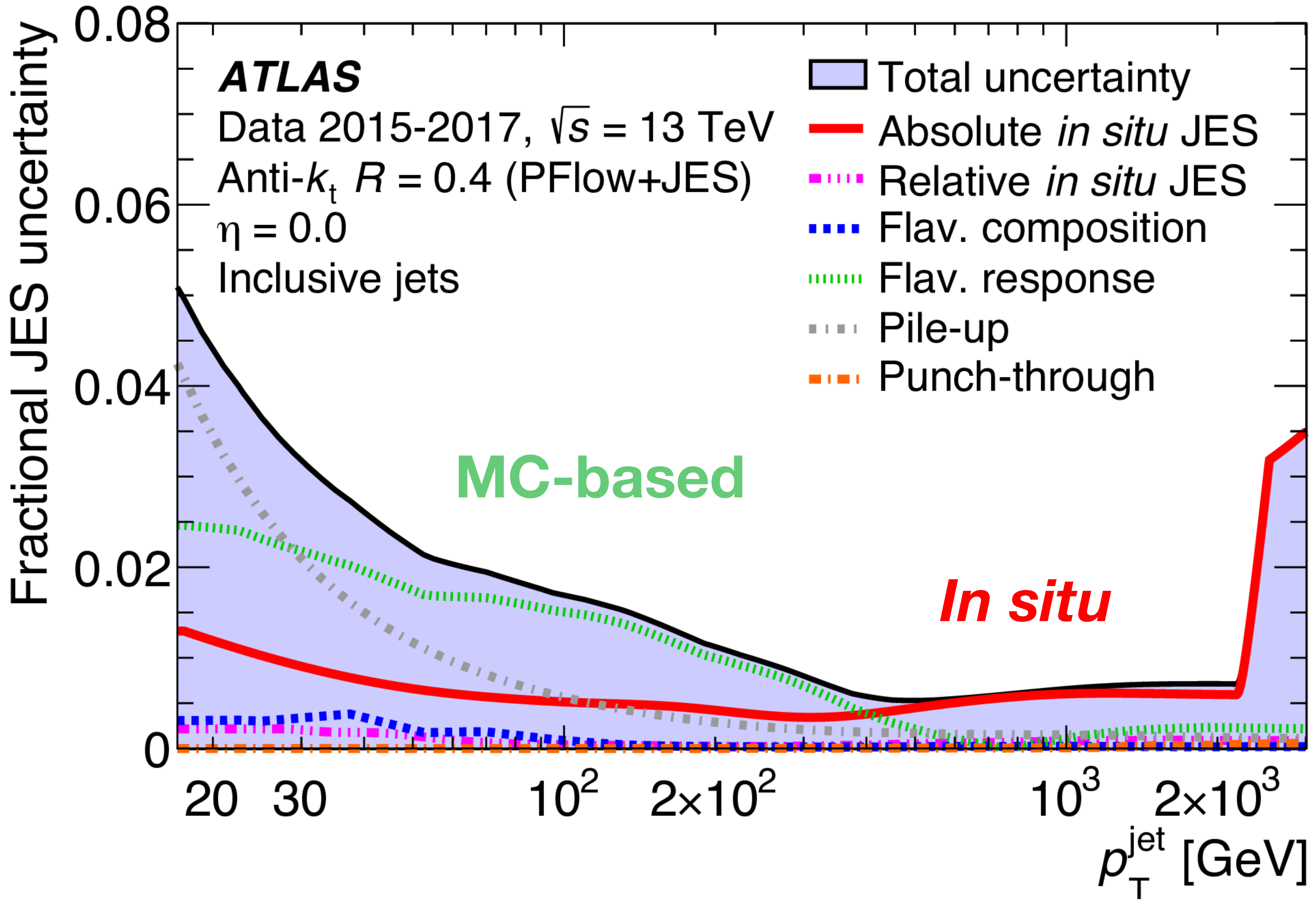
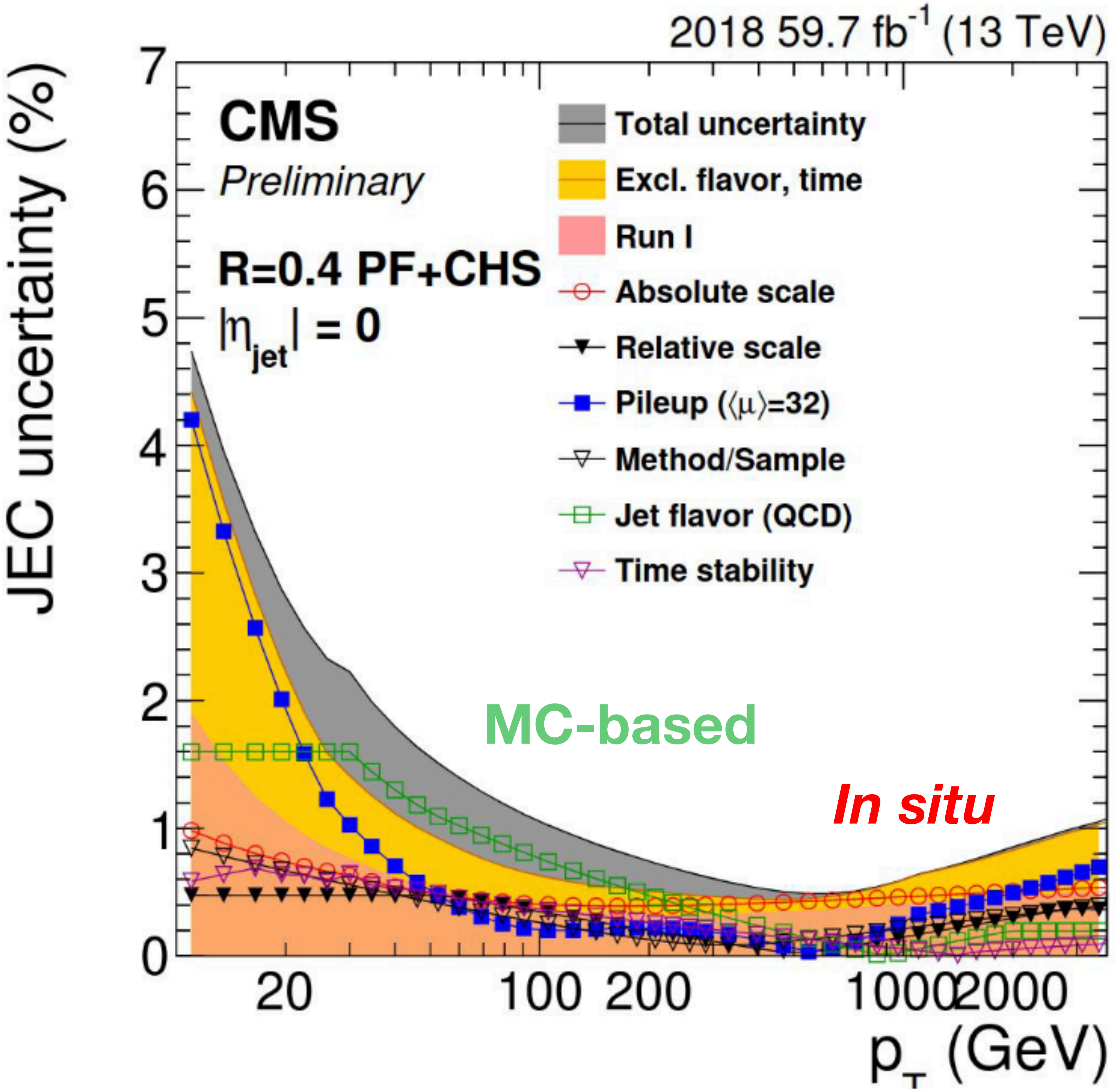
Jet Energy Scale (JES)



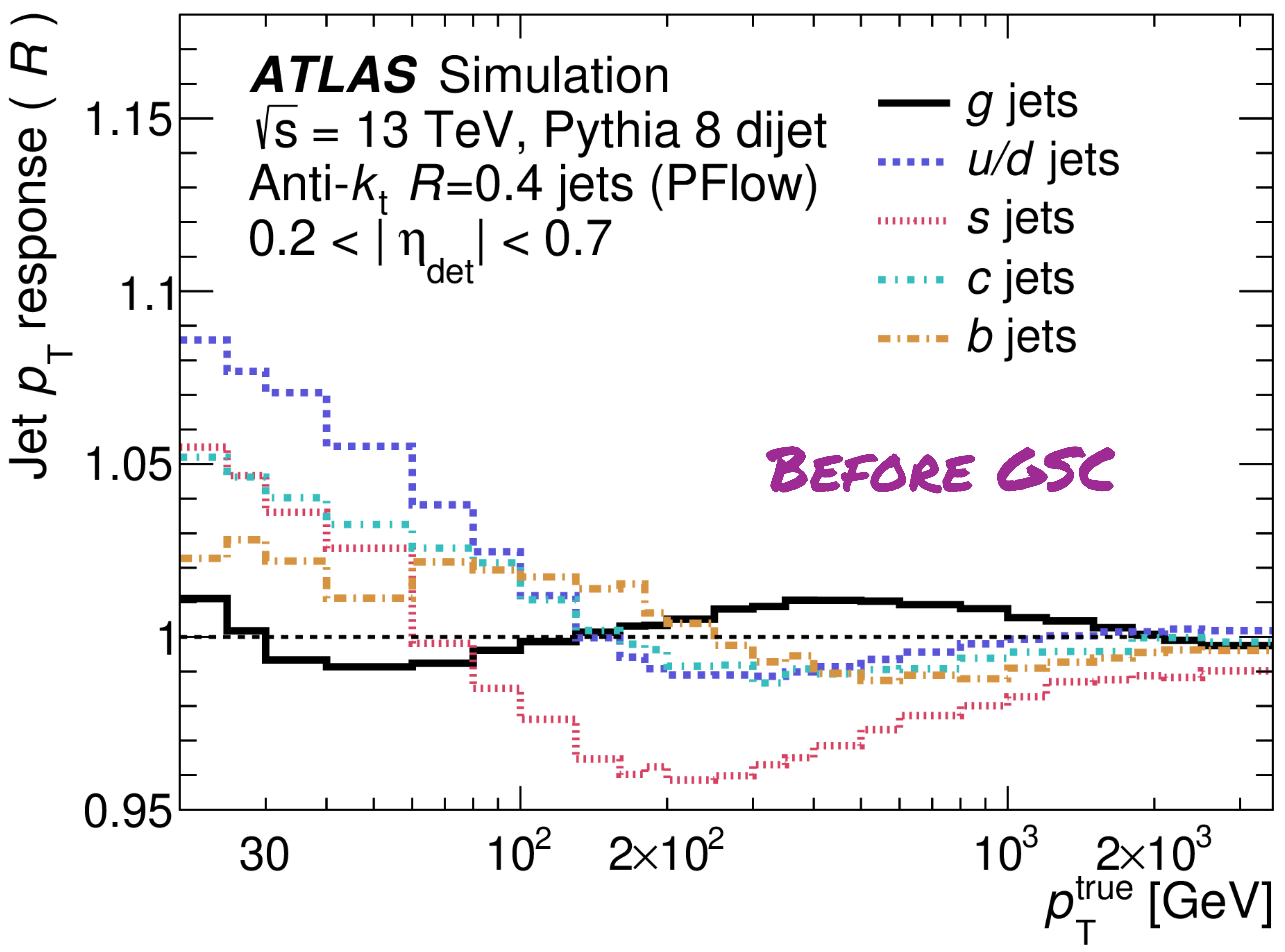


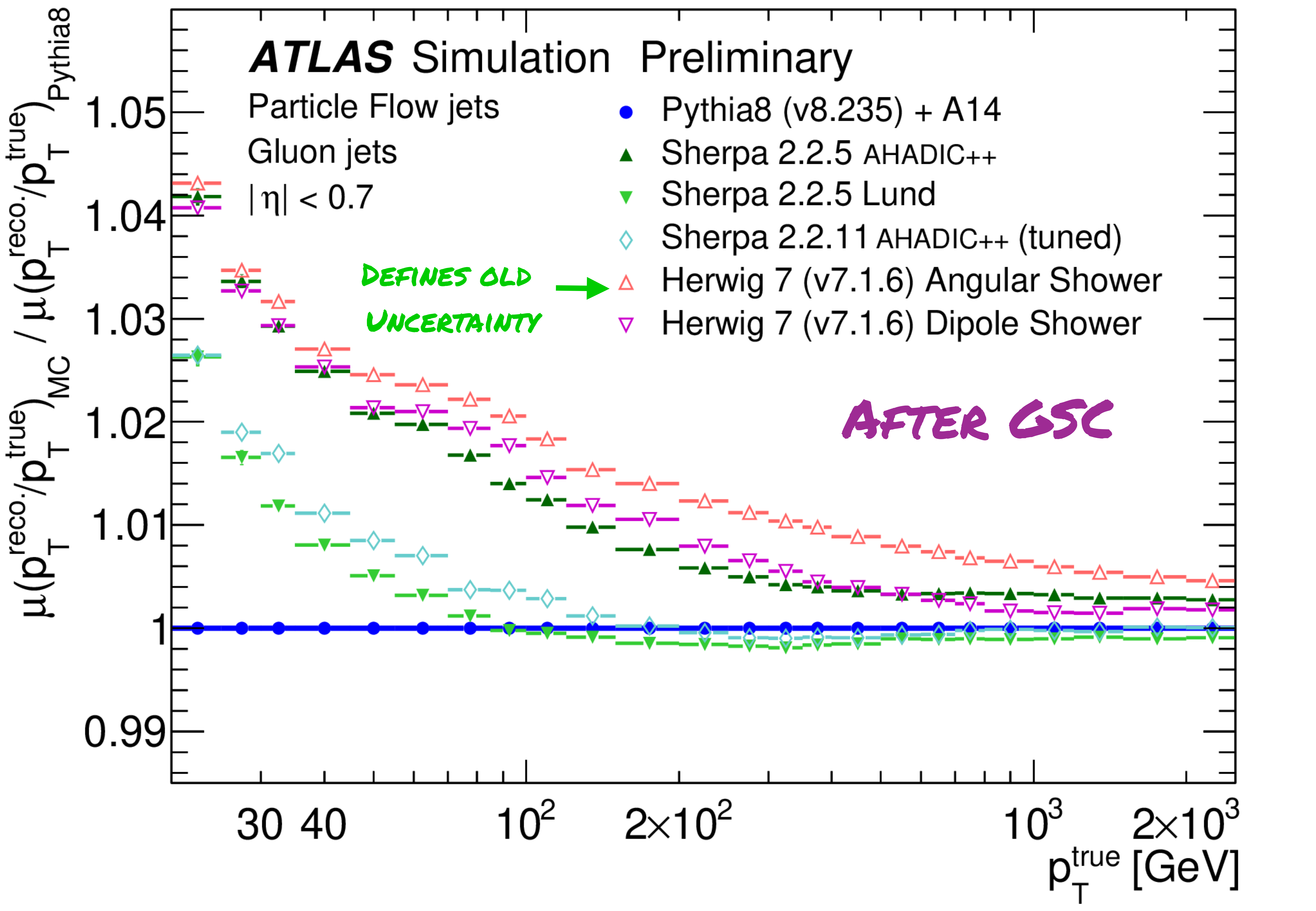
MC-based

JES Flavour Response

ATLAS ATL-PHYS-PUB-2022-021

ATLAS 2303.17312 (new!)





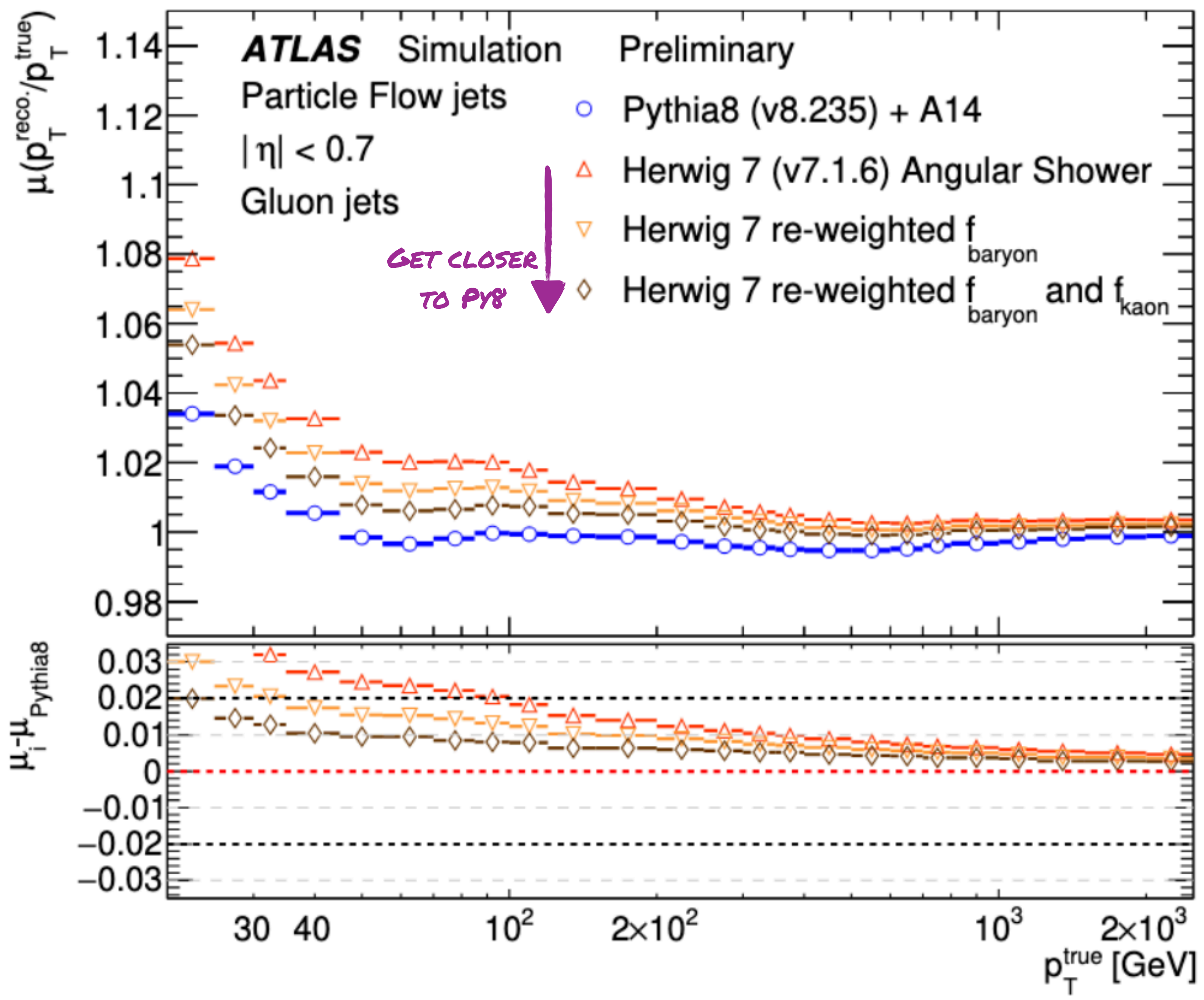
"Difference in gluon jet response between Pythia8 + other MC"

MC-based

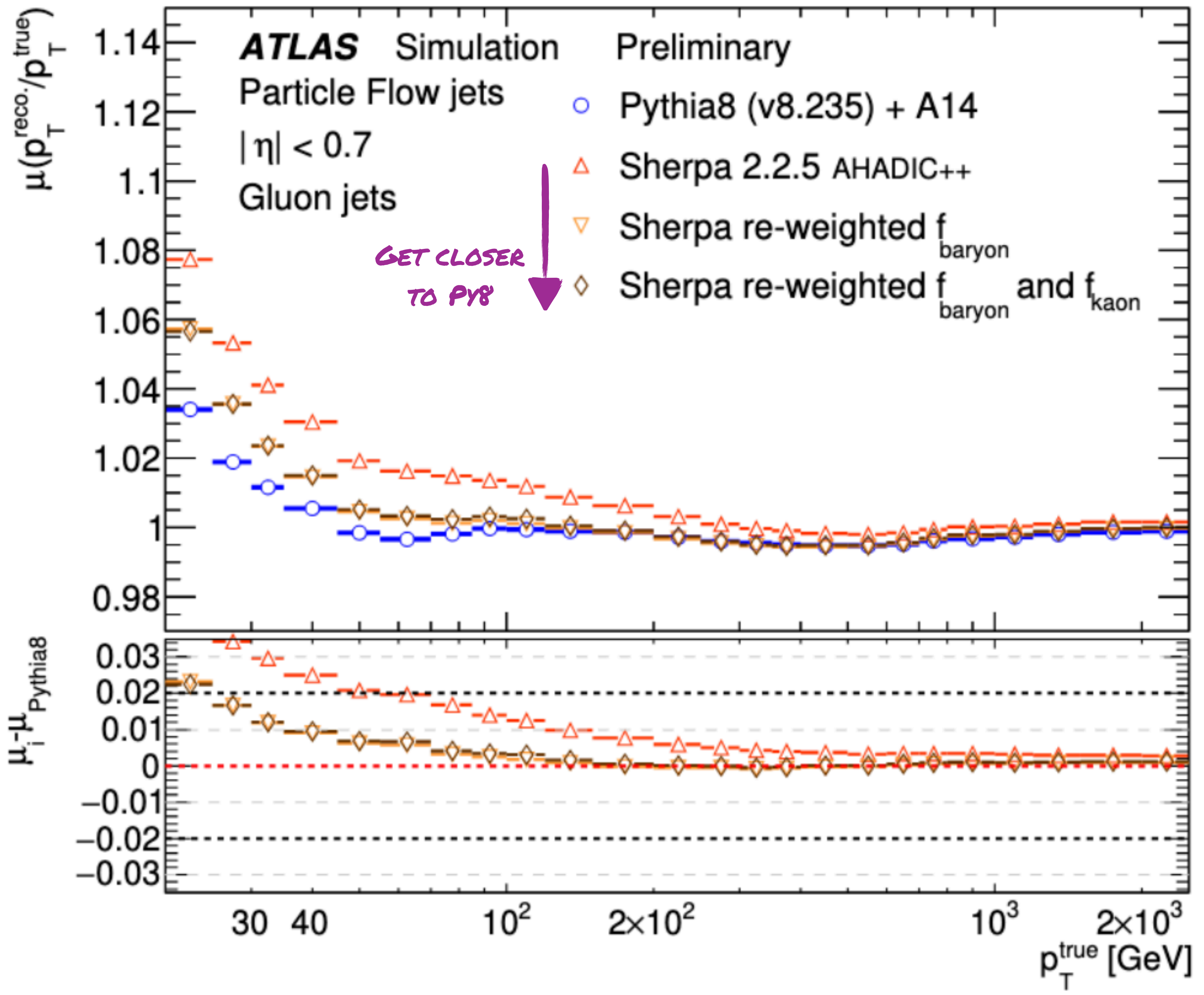
JES Flavour Response

ATLAS ATL-PHYS-PUB-2022-021

PYTHIA V8.235 VS. HERWIG V7.1.6



PYTHIA V8.235 VS. SHERPA 2.2.5



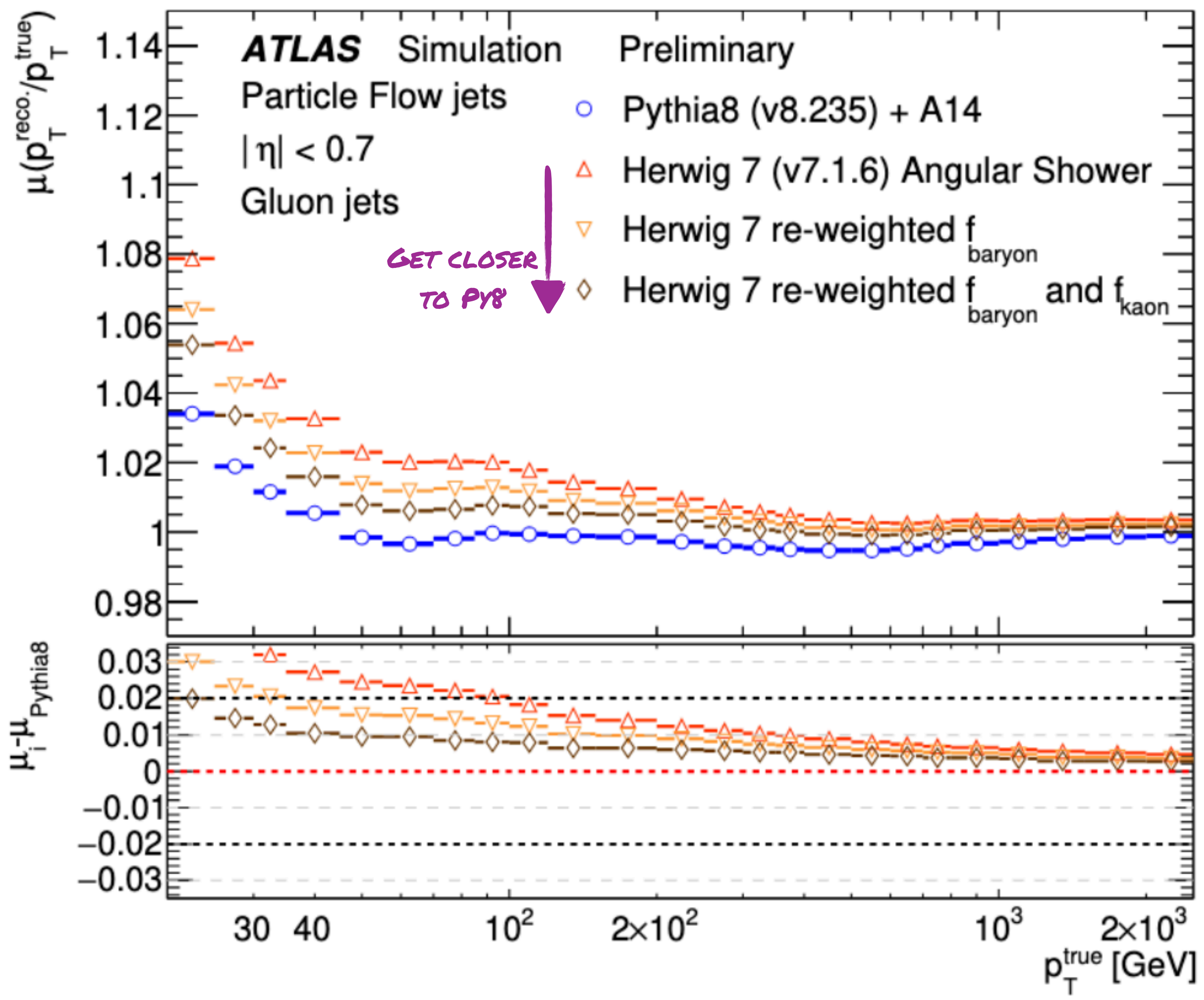
By re-weighting the **baryon and kaon fractions** within Herwig and Sherpa jets to match Pythia, the jet response in all generators can be made closer.

MC-based

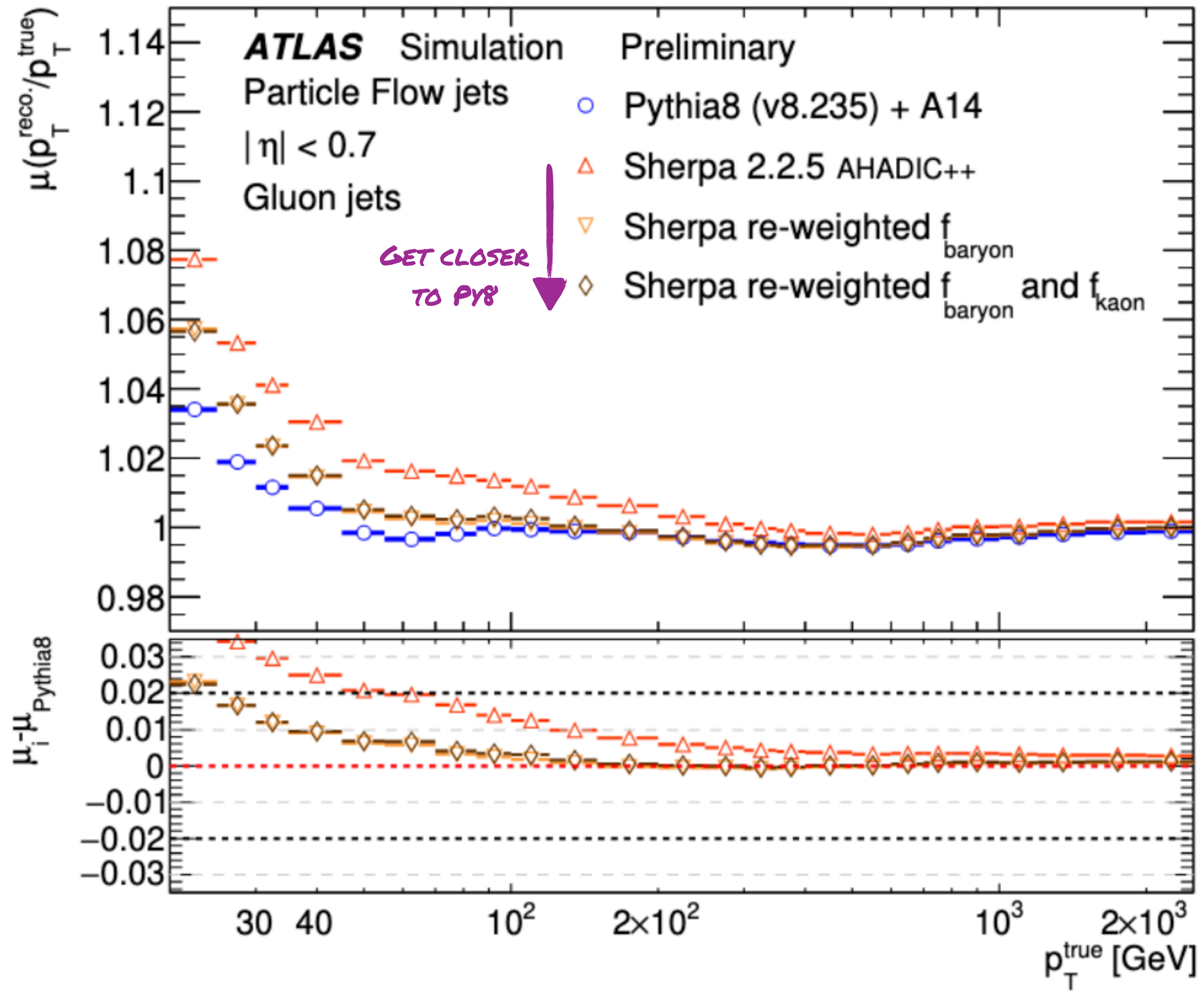
JES Flavour Response

ATLAS ATL-PHYS-PUB-2022-021

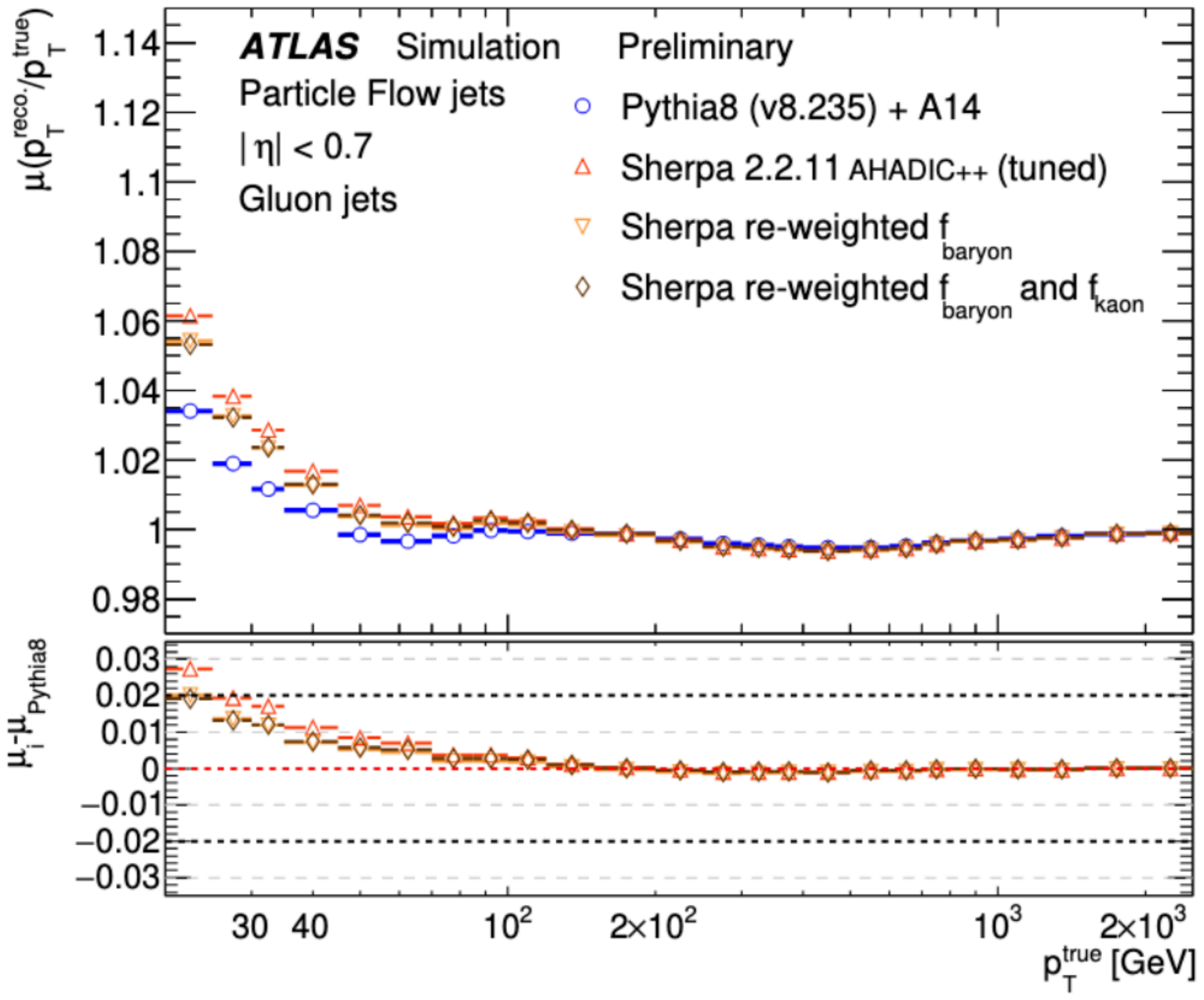
Pythia v8.235 vs. Herwig v7.1.6



Pythia v8.235 vs. Sherpa 2.2.5



Pythia v8.235 vs. Re-tuned Sherpa 2.2.5

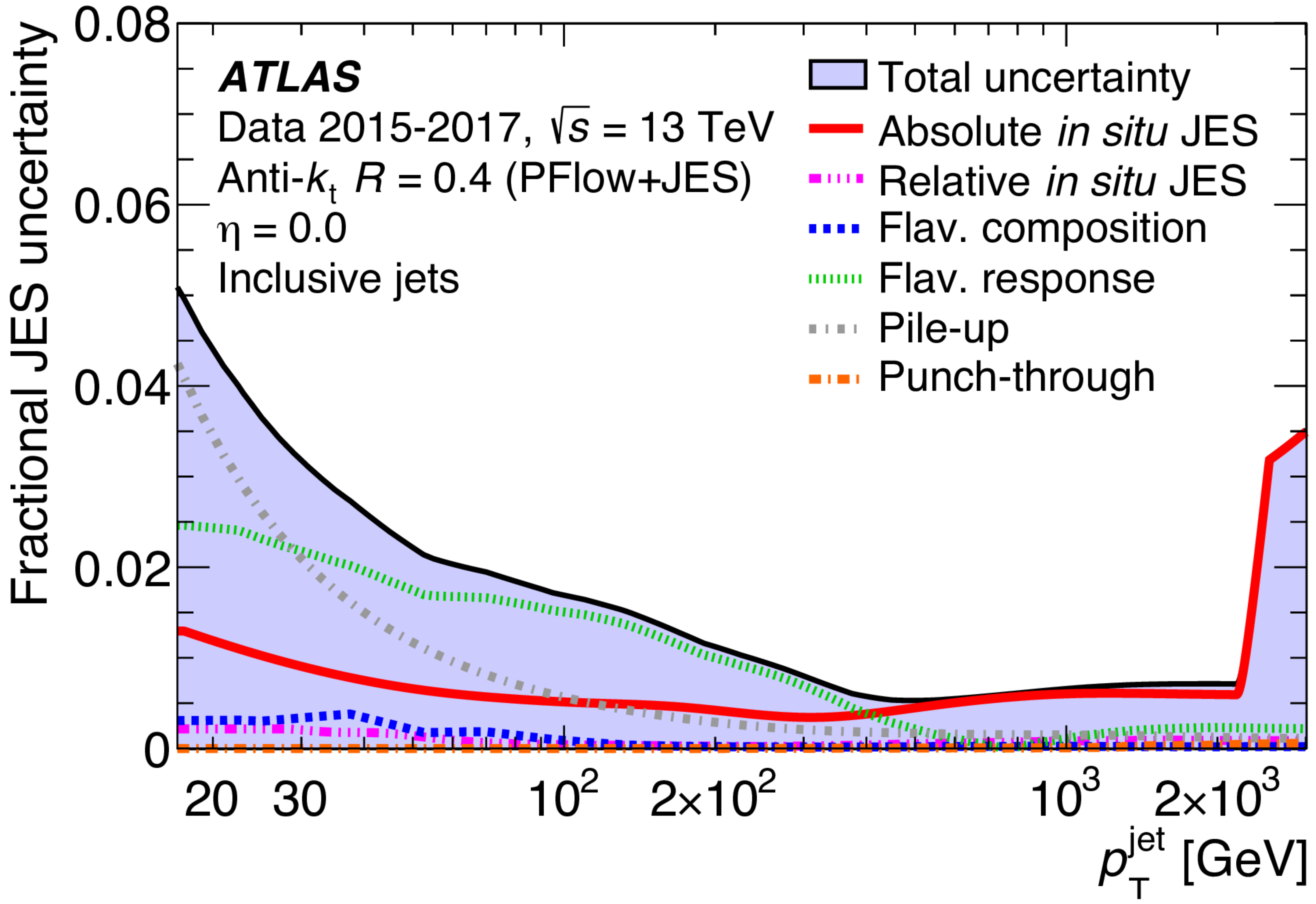


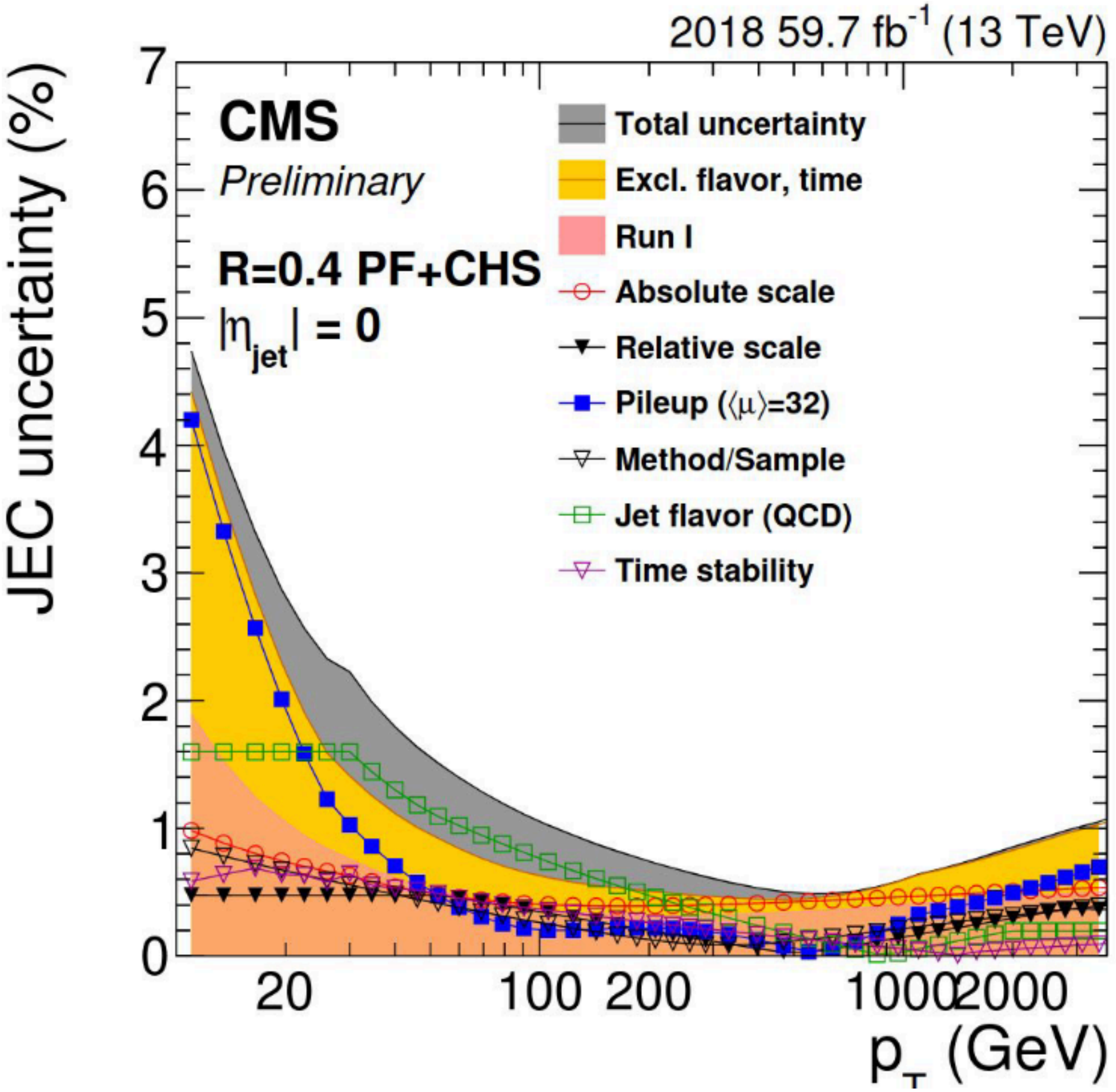
By re-weighting the **baryon and kaon fractions** within Herwig and Sherpa jets to match Pythia, the jet response in all generators can be made closer.

Sherpa can also brought to Pythia out-of-the-box by re-tuning to LEP data!

MC-based

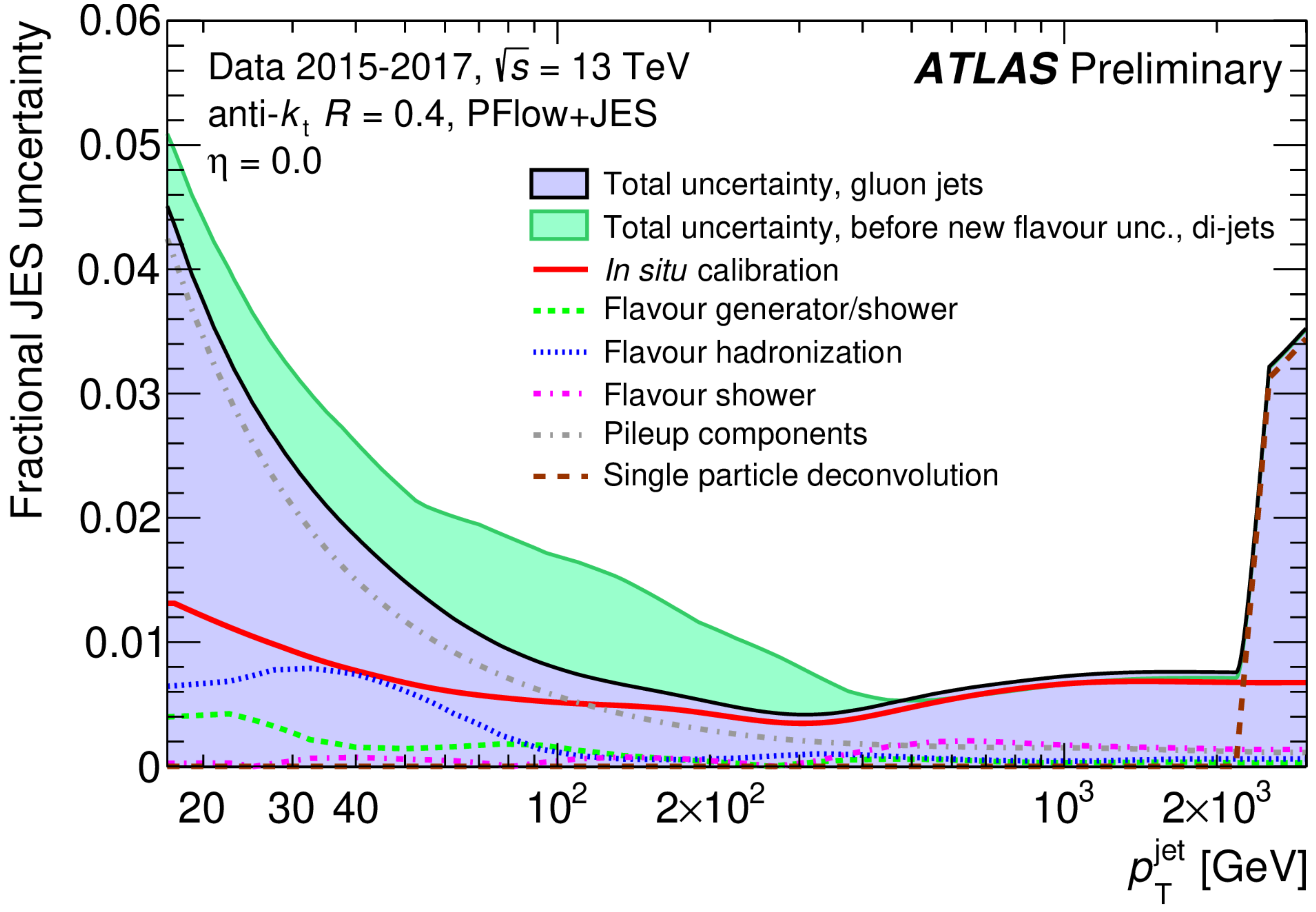
JES Flavour Response

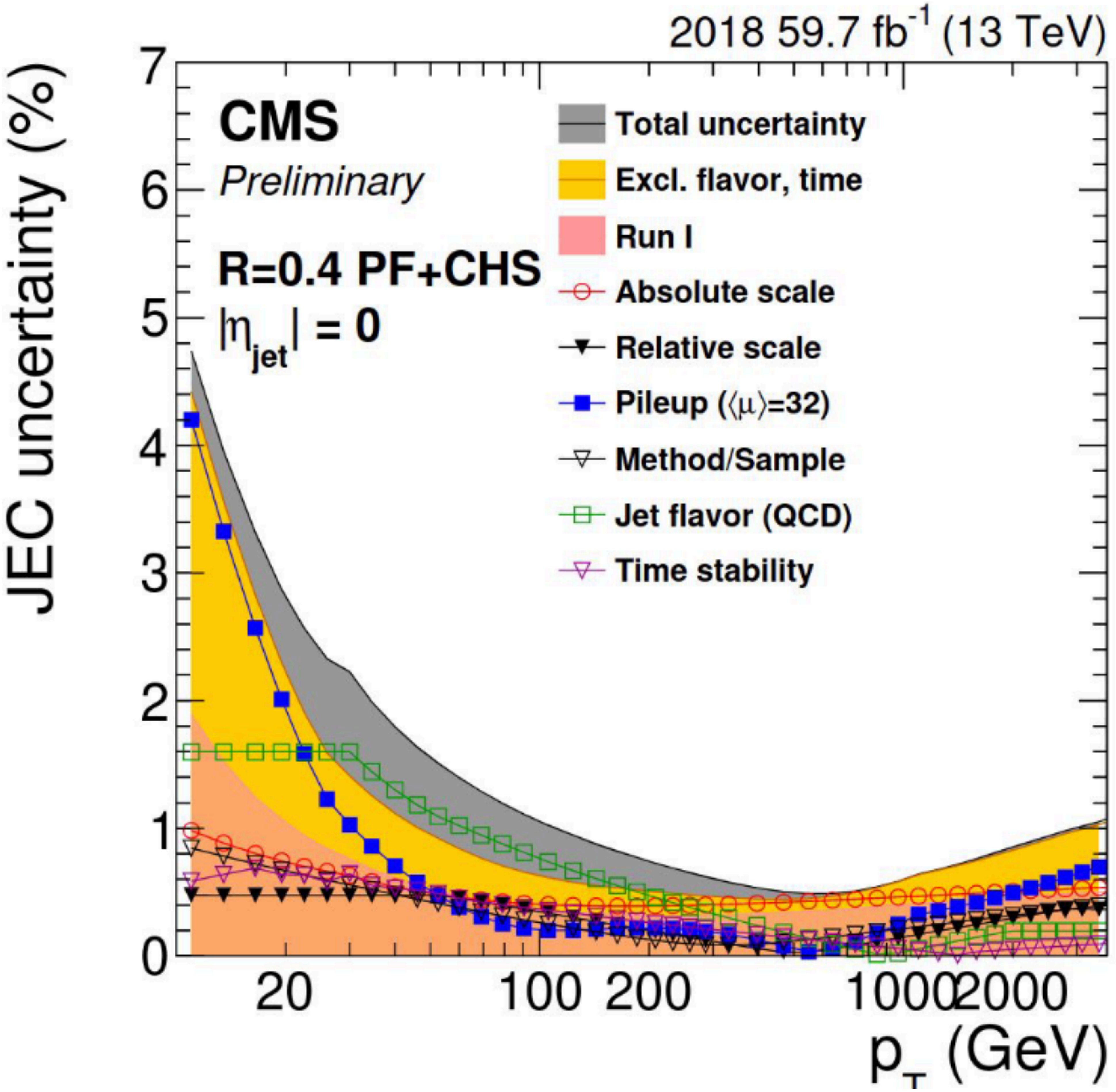




JES Flavour Response

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/JETM-2022-005/





JES Flavour Response

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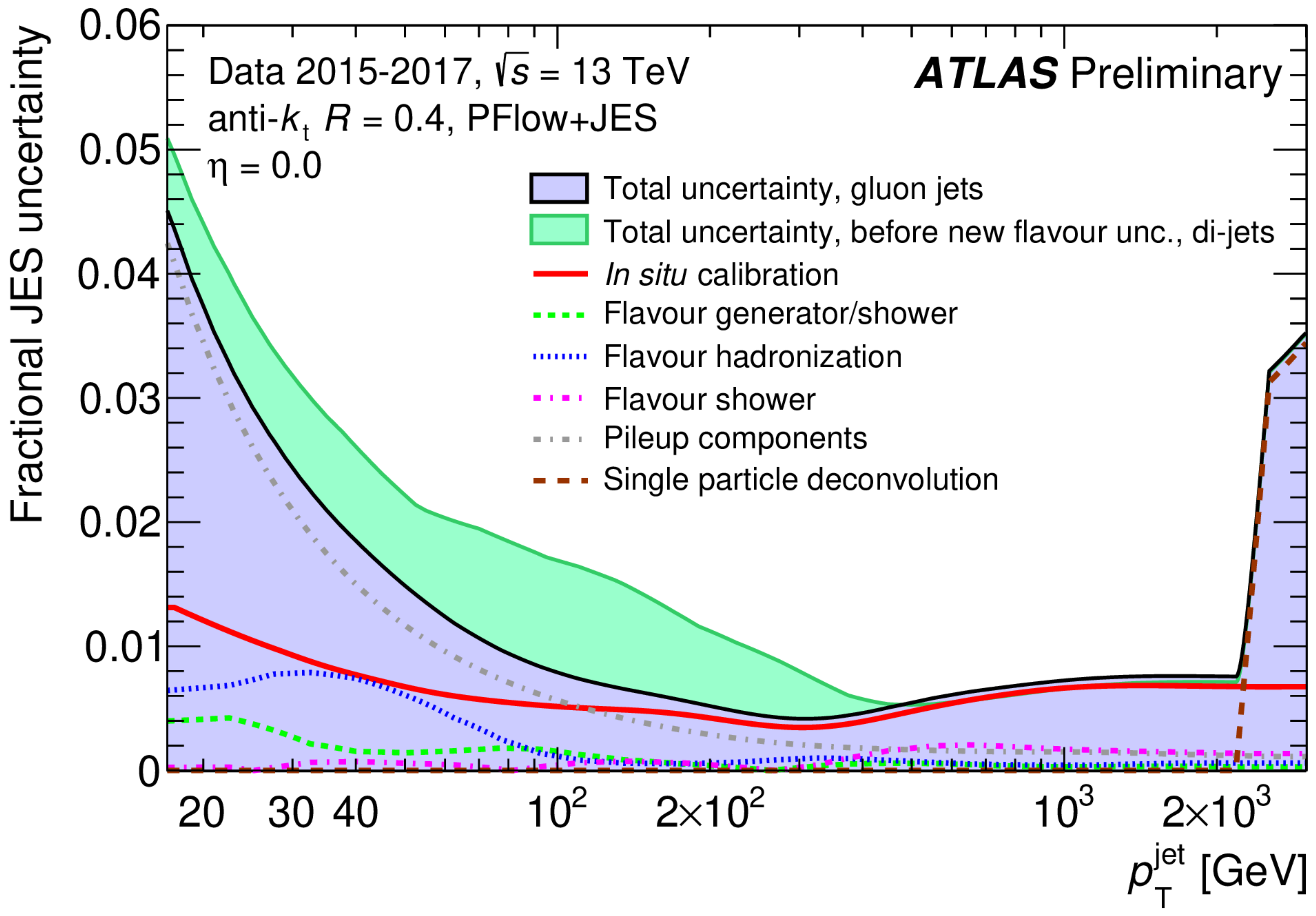


Flavour generator/shower

Pythia8 [1] *vs*.
Sherpa v2.2.5 w/ Lund hadronisation (Pythia 6) [2][3]

Flavour hadronization

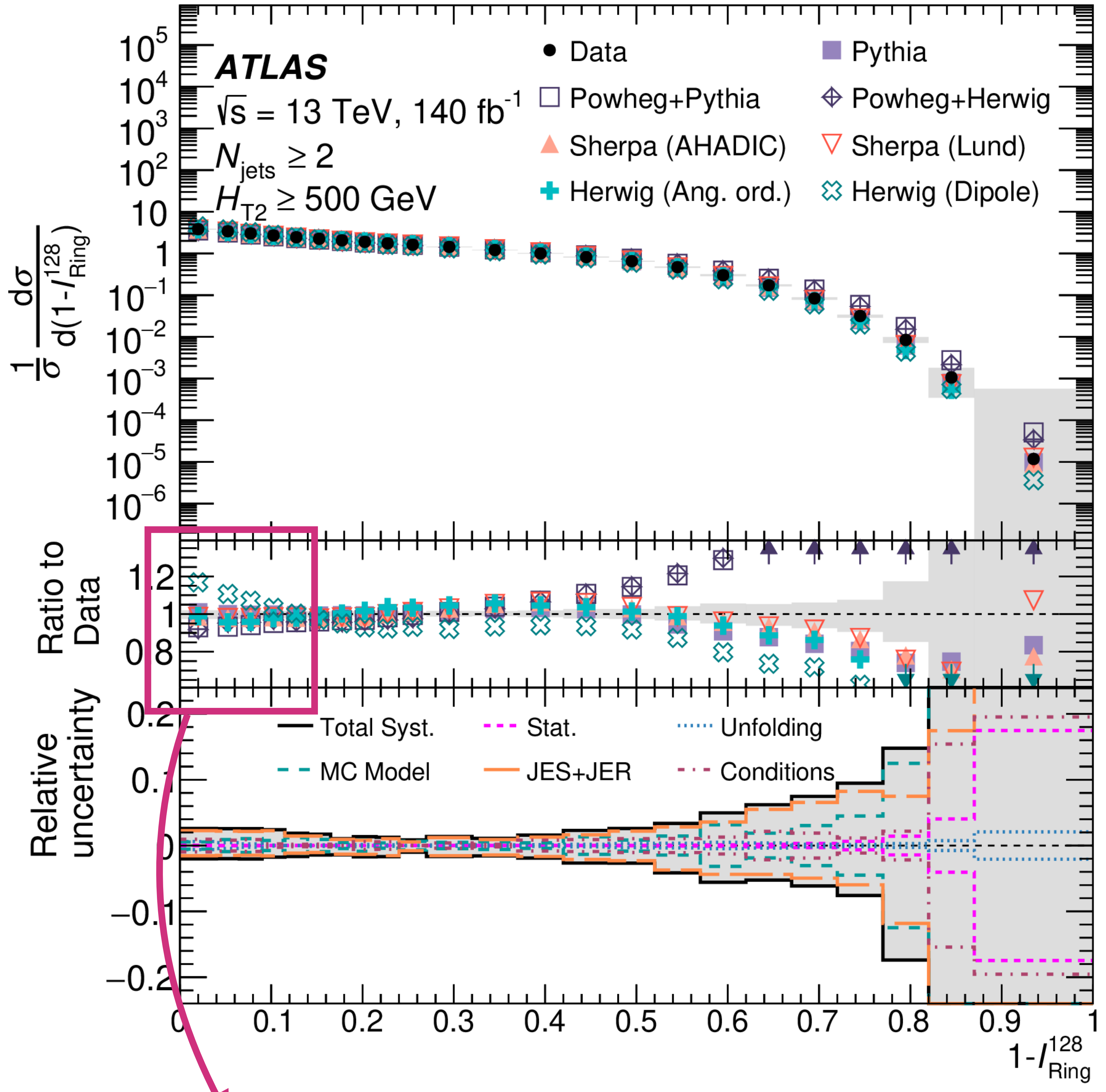
Sherpa v.2.2.11w/ AHADIC cluster hadronisation [2][4] (new tune [5]) *vs*.
Sherpa v2.2.5 w/ Lund hadronisation (Pythia 6)

Flavour shower

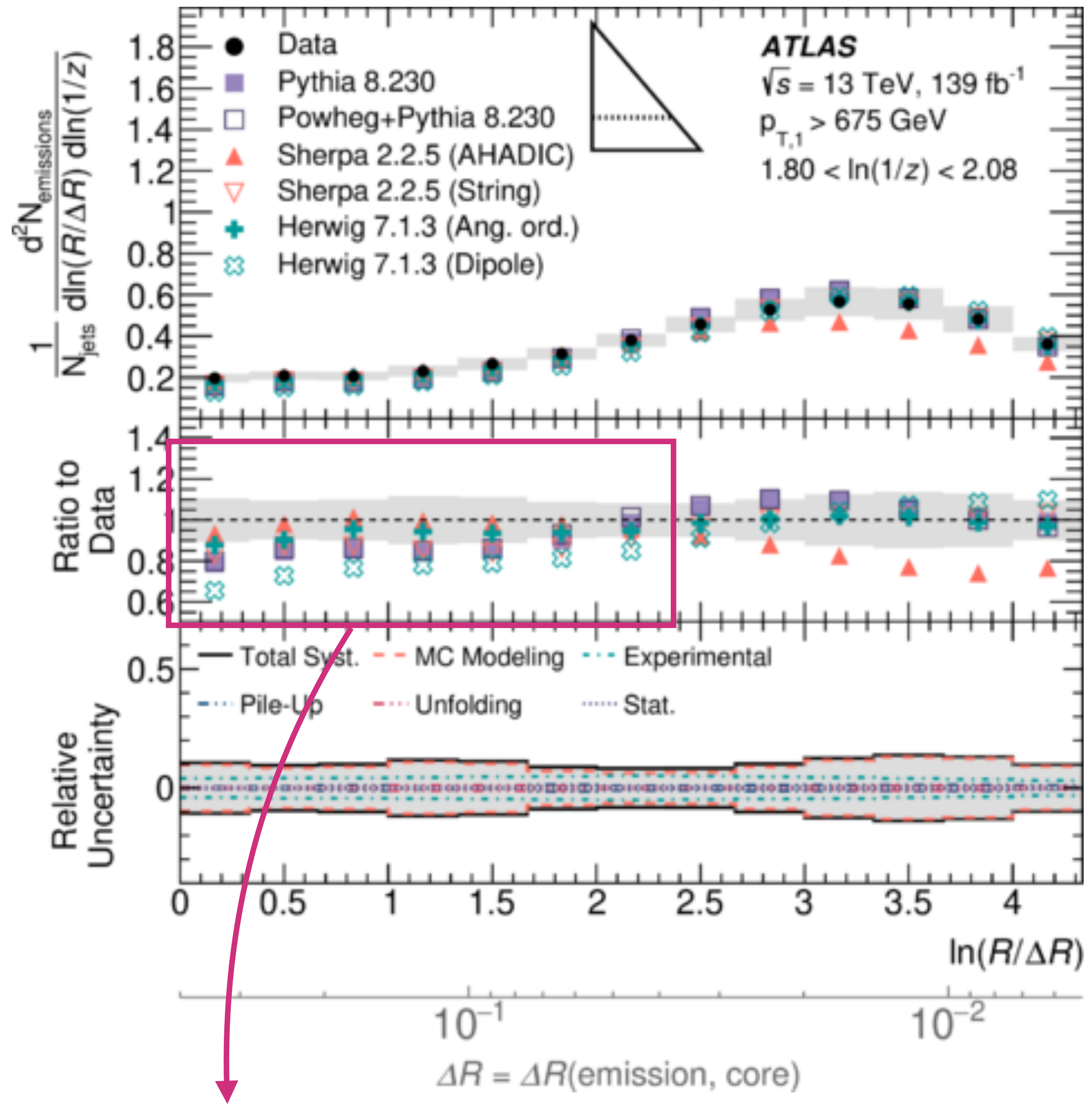
Herwig7 angular parton shower [6][7] *vs*.
Herwig7 dipole parton shower [6][8] shower models

Aside: H7 dipole PS?

ATLAS 2004.03540, 2305.16930 (new!)



Dijet-like region of event shapes

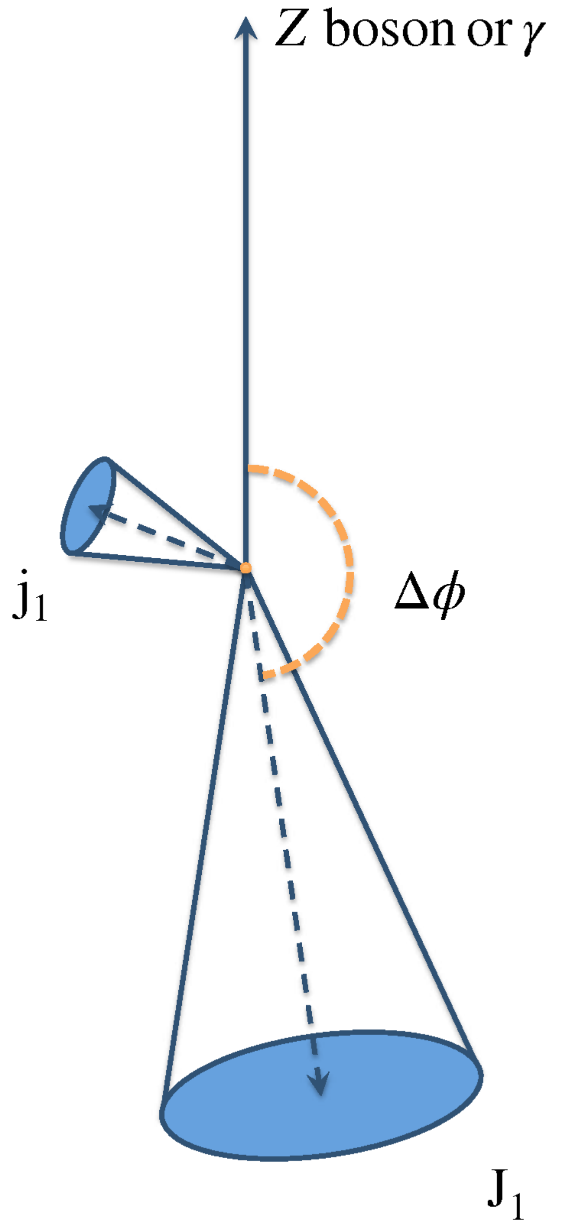


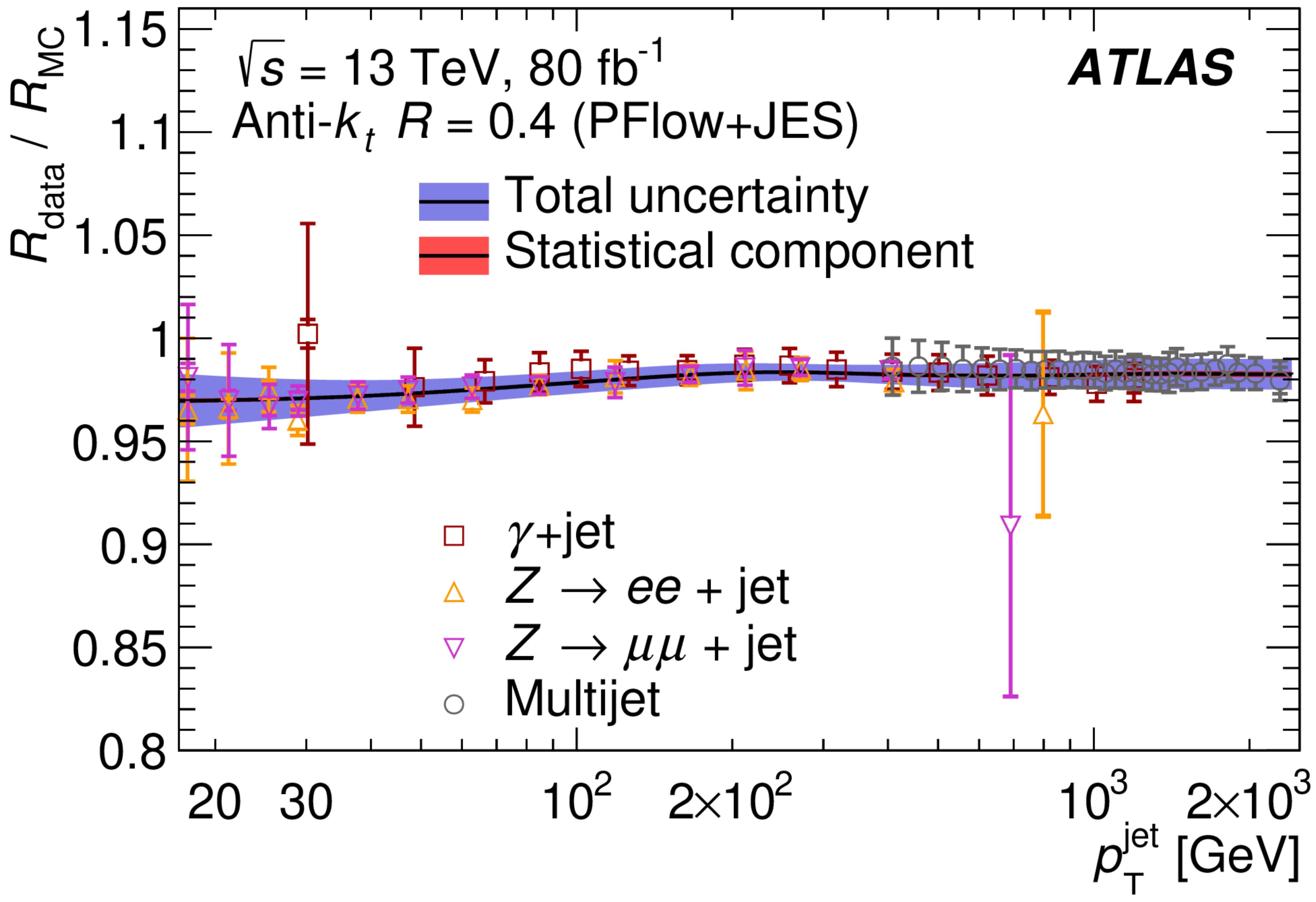
Perturbative emissions within jets (Lund jet plane)

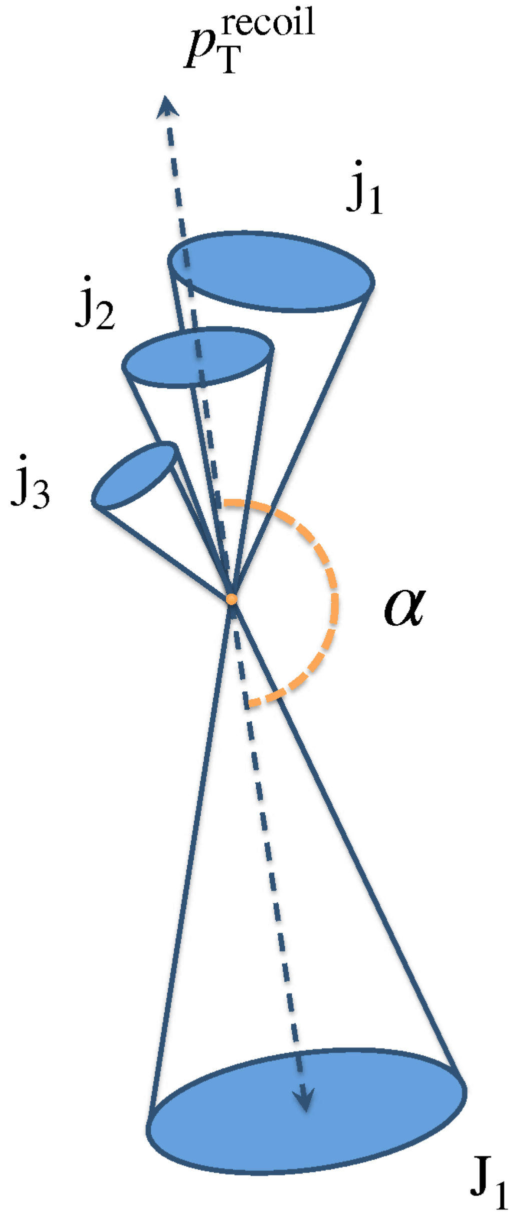
JES Flavour Response

ATLAS ATL-PHYS-PUB-2022-021

It also motivates the measurement of these quantities in LHC data to enable such tuning, as well as careful comparison to the LEP e^+e^- data. While ATLAS does have the ability to identify protons and $K^{\pm}$ at very low momenta [56] it is not designed for measurements in the p_{T} range of particles in jets at LHC. However, the ALICE detector is capable of good particle identification [57] and has already published spectra of identified particles in minimum bias collisions [58] and therefore precise measurements of the baryon and kaon energy fractions of jets are feasible. Such a measurement could have a significant impact on precision measurement of the LHC physics program.





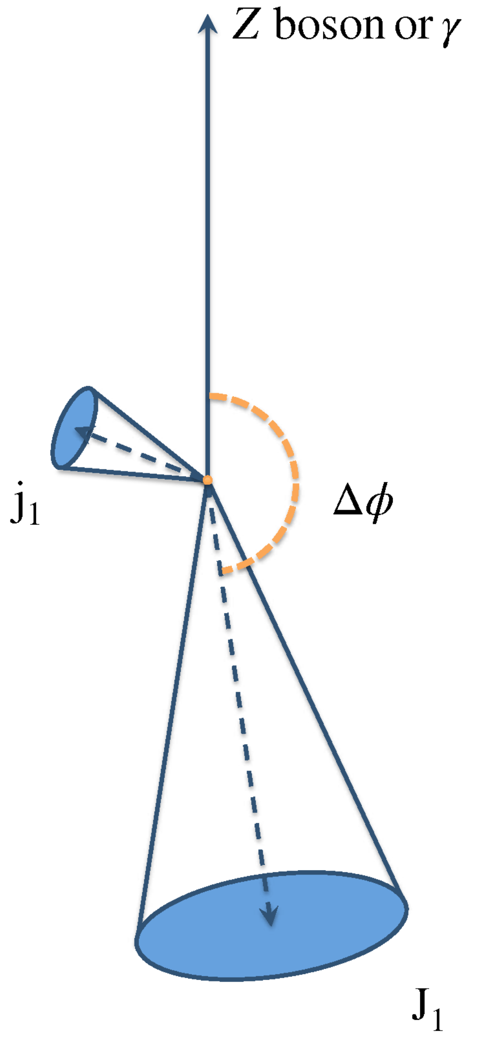


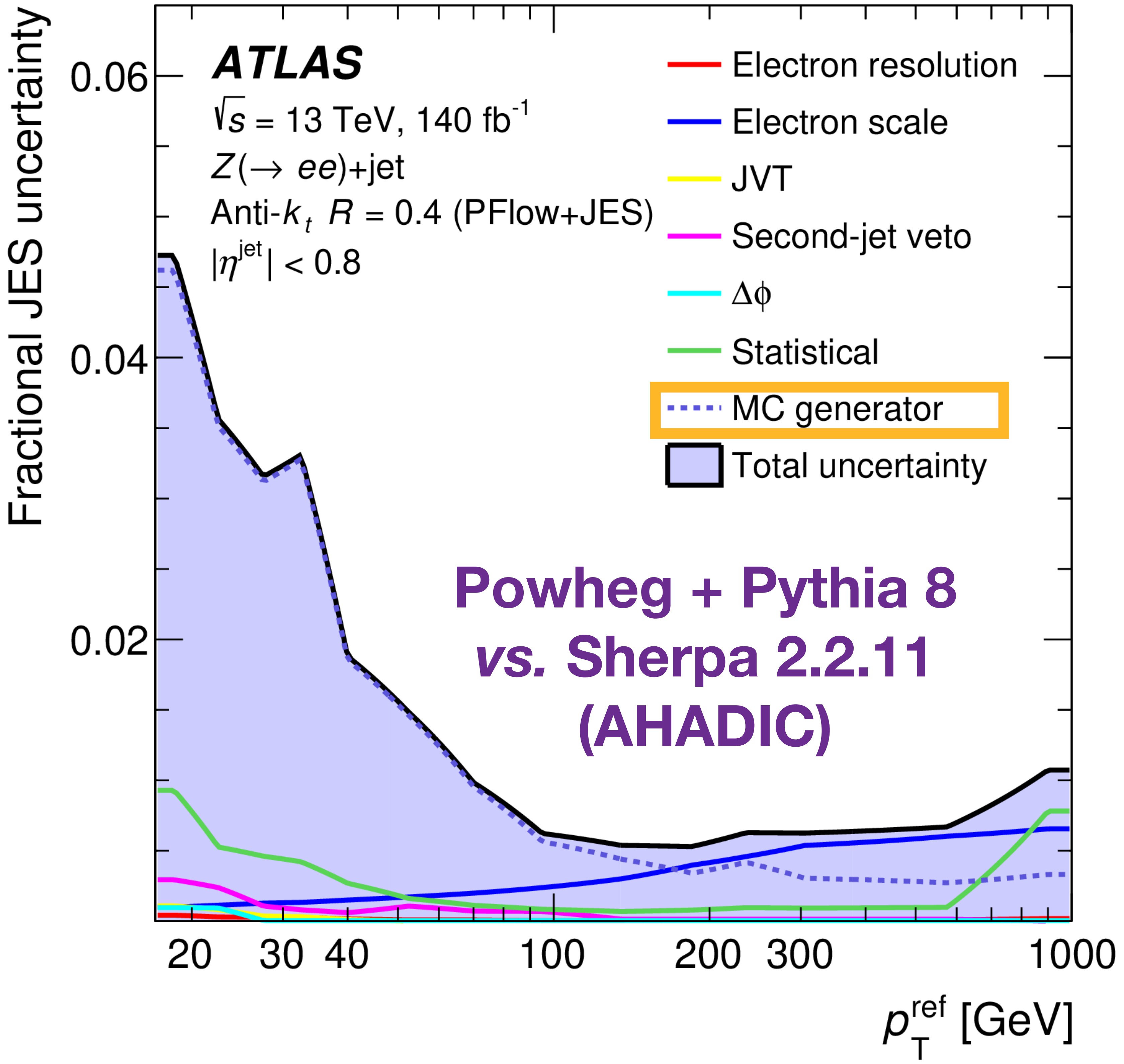
- Experimentalists at the LHC **work hard to calibrate the jet energy scale (JES)** using *in situ* balance measurements in different topologies…

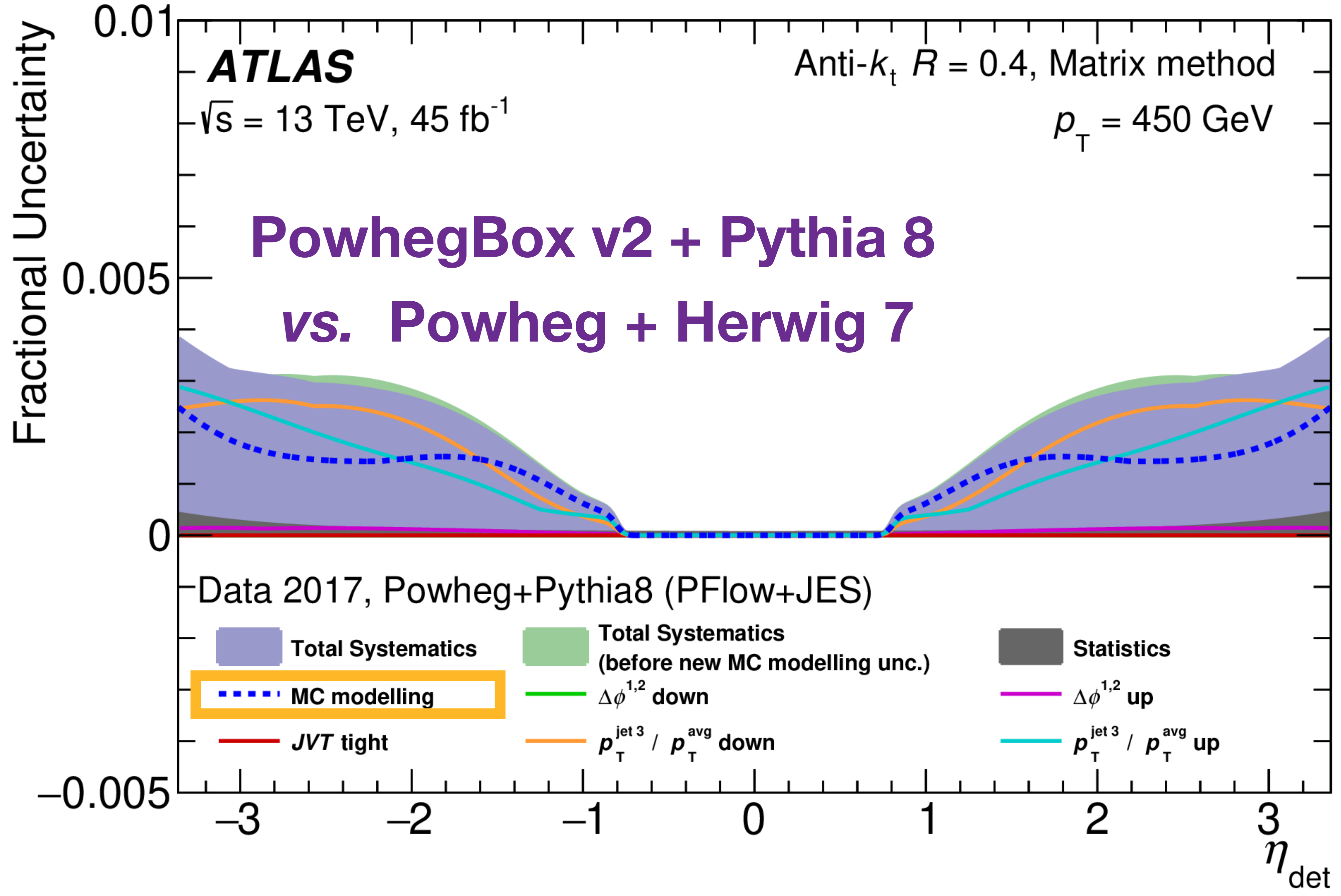
ATLAS JES **Run 2:** EPJC 81 (2021) 689 **Run 3 (brand new!)**: 2303.17312

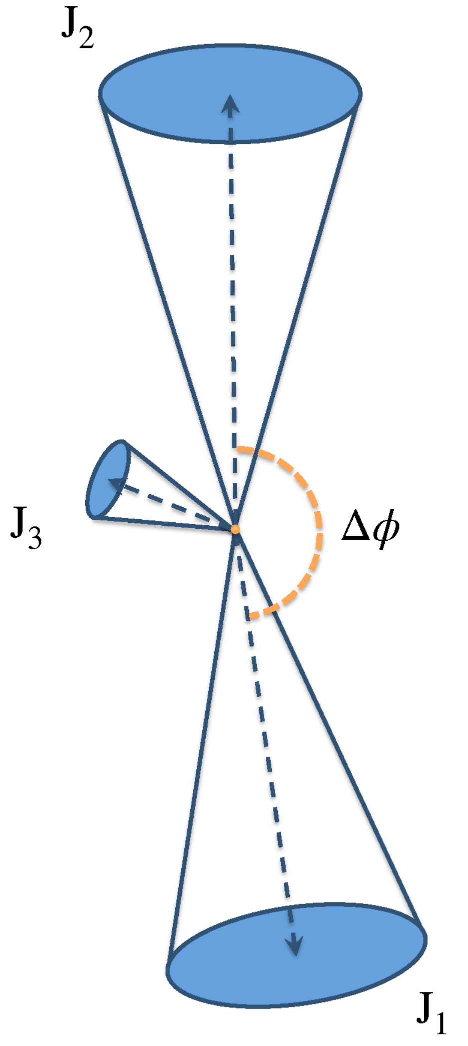
ATLAS Jet Energy Scale

ATLAS, 2303.17312 (brand new!)



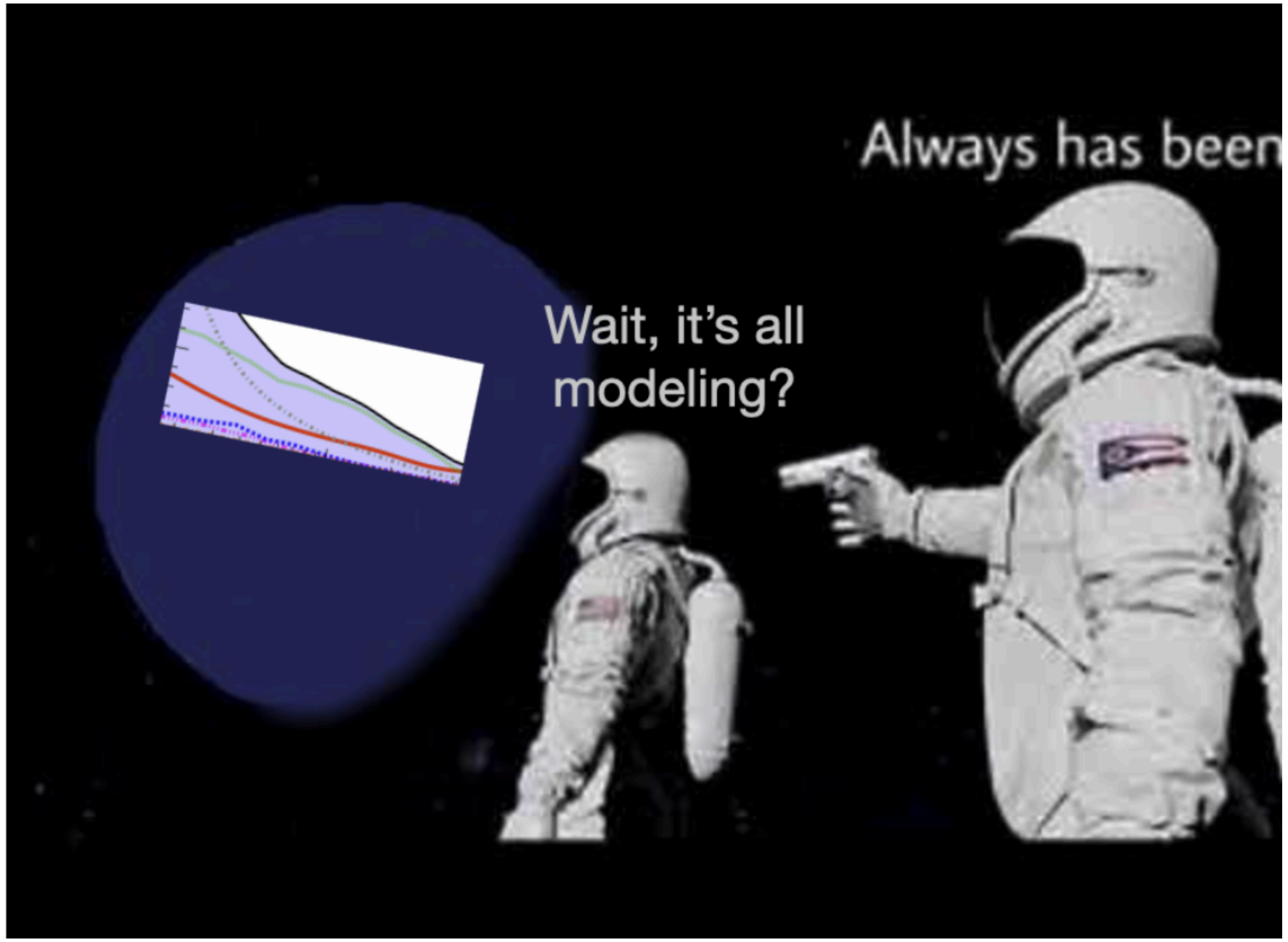






- With our latest techniques, the *in situ* JES uncertainty is driven by **the choice of nominal MC model** in many places…
  - Need to cover extrapolation between MC-based JES calibration & main samples for physics analysis: **long duty cycle of MC generator setups.**

Summary of Modelling Uncertainties in Jet Calibrations




Thanks for Listening!

JES NPs — Overview (ATLAS Run 2)

Simulation-based

Area Subtraction +Pile-up residual

Pileup_OffsetMu
Pileup_OffsetNPV
Pileup_PtTerm
Pileup_RhoTopology

MC JES

GSC

Flavor_Composition
Flavor_Response

Purple : Categorized as "Modelling" in JES Config

Green : defined by MC comparisons

In situ techniques

Relative JES

Eta Intercalibration

EtaIntercalibration_TotalSyst
EtaIntercalibration_NonClosure_highE
EtaIntercalibration_NonClosure_negEta
EtaIntercalibration_NonClosure_posEta

+531 Statistical

Absolute JES

Z+jet balance (MPF)

Zjet_ElecESZee
Zjet_ElecEsmear
Zjet_Jvt
Zjet_ShowerTopology
Zjet_MC
Zjet_MuScale
Zjet_MuSmearID
Zjet_MuSmearMS
Zjet_MuSagittaRes
Zjet_MuSagittaRho
Zjet_Veto
Zjet_dPhi
+28 Statistical

γ+jet balance (MPF)

Gjet_GamESZee
Gjet_GamEsmear
Gjet_Generator
Gjet_Jvt
Gjet_ShowerTopology
Gjet_Purity
Gjet_Veto
Gjet_dPhi

+16 Statistical

Multijet balance

MJB_Alpha
MJB_Beta
MJB_Fragmentation
MJB_JVT
MJB_Asym
MJB_Threshold
+28 Statistical
+ Propagated NPs

JER

Dijet JER

JER_DataVsMC_MCTYPE
JER_dijet_closure
JER_dijet_jesnp1-3
JER_dijet_jv
JER_dijet_mcgenerator
JER_dijet_pt3dphi
JER_dijet_stat1-12

JER Noise Term

JER_N_constscale_noise_up
JER_N_fit_conversion_hist_variation
JER_N_fit_error_up
JER_N_fitrange_high_up
JER_N_mc_non_closure_variation
JER_N_no_pu_N_fit_instability_variation
JER_N_no_pu_N_unc_up
(All w/ central & forward)

High-pT

Punch-through

PunchThrough_MCTYPE

Other: E/p & b-JES

SingleParticle_HighPt

BJES_Response

n.b. propagated NPs through MJB omitted