LHC Run 2 jet performance in ATLAS

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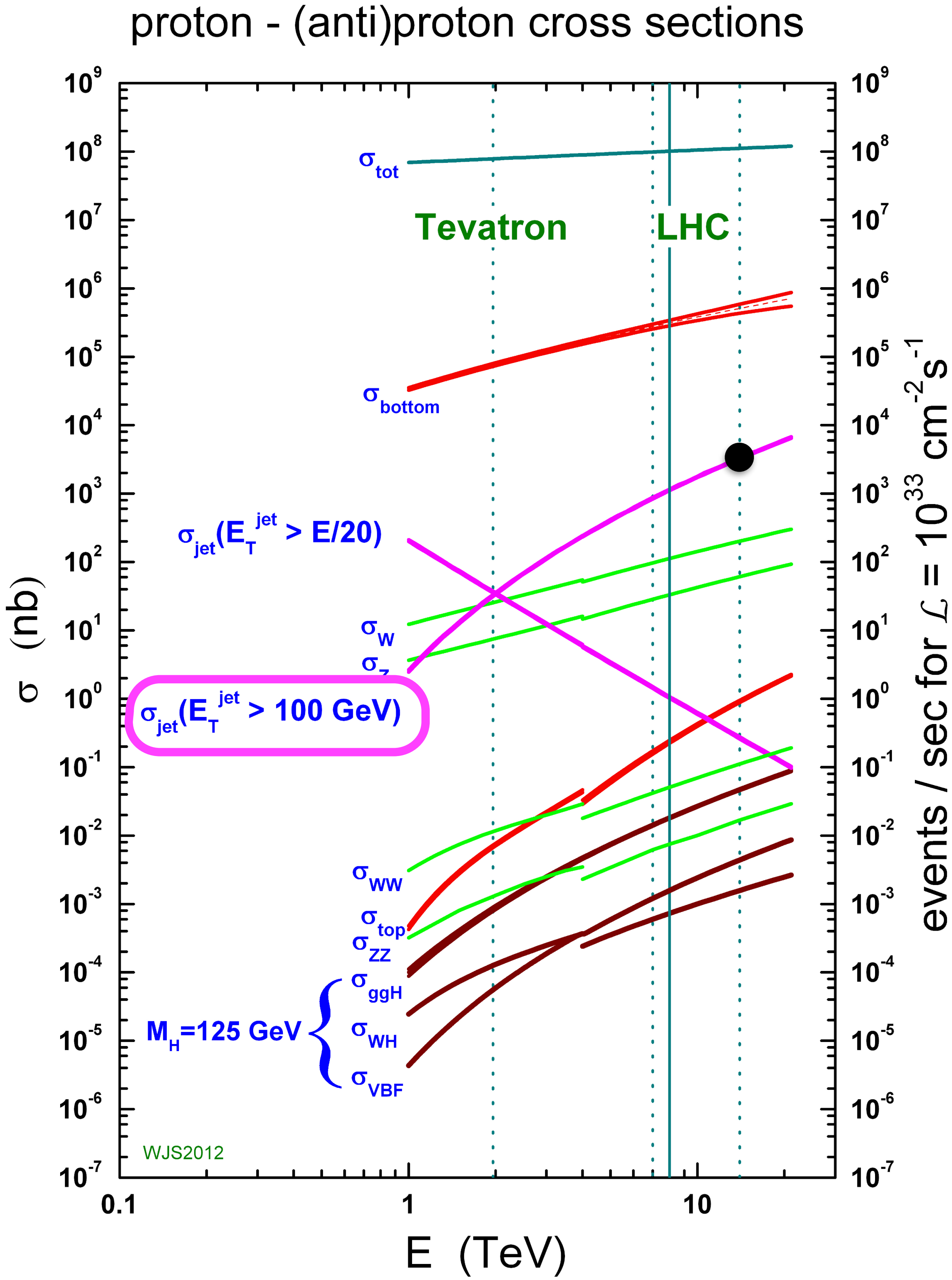
on behalf of the ATLAS collaboration

Outlook

- ★ : EPS 2015
- ★ : Boost 2015

- **Run 1 jet performance studies, applicable to Run 2**
  - Summary of **jet calibration** in ATLAS
    - **Global sequential calibration**
  - A new method to **reduce** jet energy scale (**JES**) **uncertainty components** New
  - **Jet energy resolution** (JER) measurement in data New
    - Novel study to measure JER noise term in data
  - New technique for **rejecting forward pileup jets** New
- **Run 2 jet studies**
  - Data Vs MC comparison of **jet calibration inputs** New
  - **Jet cleaning** in Run 2 New
  - How to **calibrate jets** in early Run 2 before having enough statistics for in-situ measurements at **13 TeV**? New
- A **Run 2 physics analysis result** where jet performance is critical New

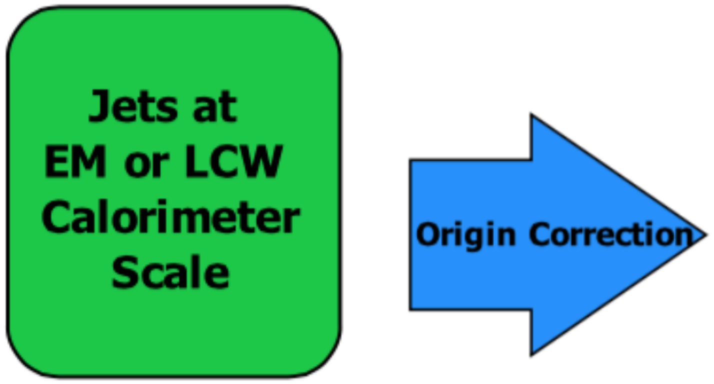
Introduction



- Energetic jets in LHC *pp* collisions are produced abundantly
  - Signal, pQCD prediction
  - Significant background to other analyses
- **Anti-k$_T$** , **C/A** algorithms to create jets from **calorimeter 3D topological clusters** in several cone sizes using two energy scales
  - **EM:** Electromagnetic detector scale
  - **LCW:** Local cluster weighting scale
    - Deposits classified as being either electromagnetic or hadronic using shower shape variables
- Raw **calorimeter signals** need to be calibrated to the jet calibration reference scale: **truth jet** (**particle jet**)

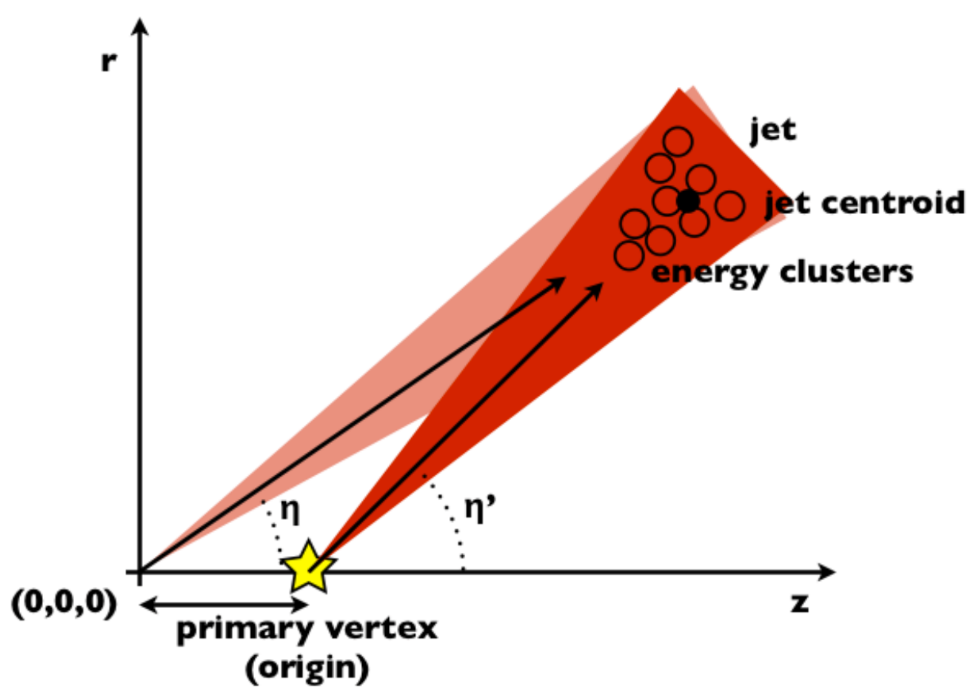
Jet energy calibration sequence

Jet calibration chain

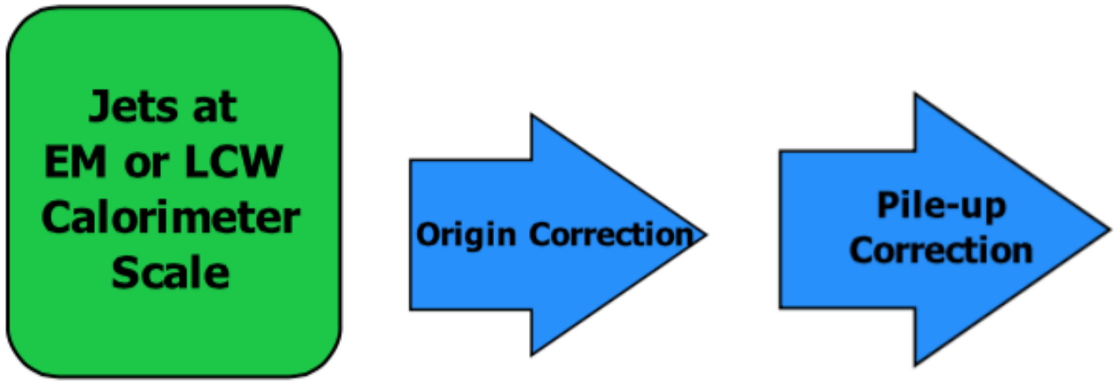


- Start from input EM or LCW jets

- **Origin correction:** to account for the hard scattering primary vertex. Changes the jet direction



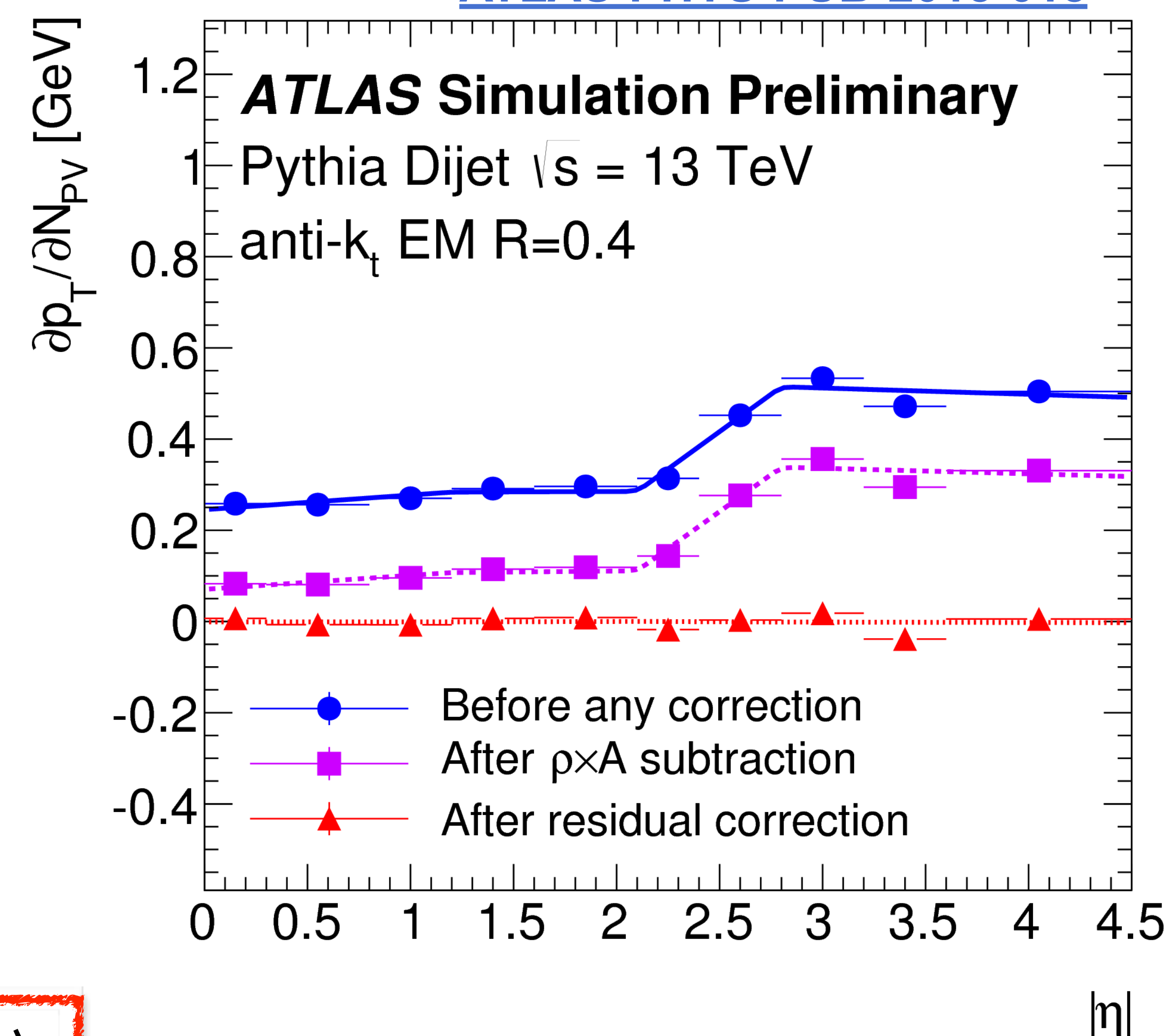
Jet calibration chain



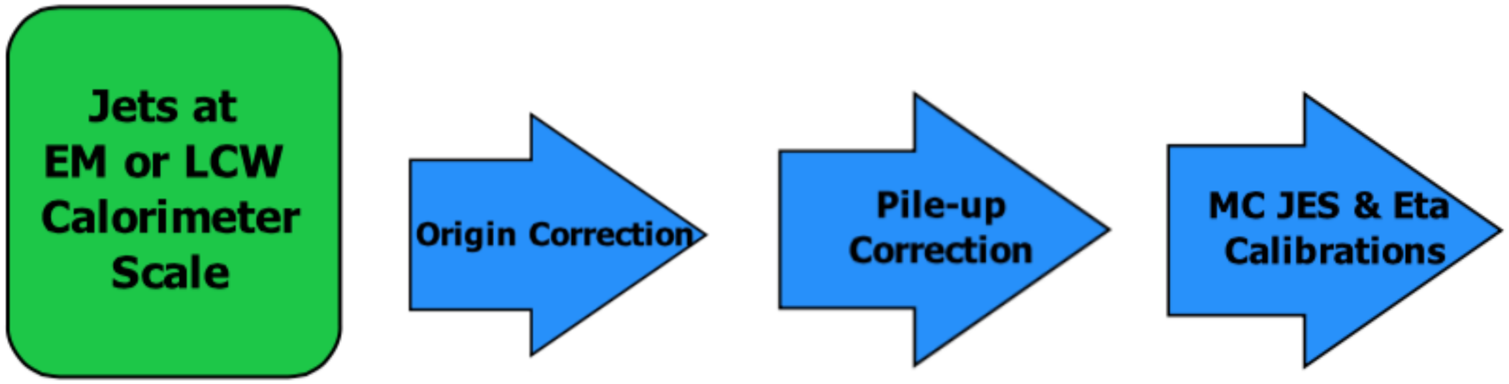
- Start from input EM or LCW jets
  - **Origin correction:** to account for the hard scattering primary vertex. Changes the jet direction
  - **Jet area and residual pileup corrections** to decrease pile-up contamination

$$p_T^{corr} = p_T - \rho A_T - \alpha(N_{PV} - 1) - \beta\langle\mu\rangle$$

ATLAS-PHYS-PUB-2015-015



Jet calibration chain



- Start from input EM or LCW jets

- **Origin correction:** to account for the hard scattering primary vertex. Changes the jet direction
- **Jet area and residual pileup corrections** to decrease pile-up contamination
- **MC JES:** Calibrates the jet energy and pseudo rapidity to the reference scale

Jet calibration chain

ATLAS-CONF-2015-002

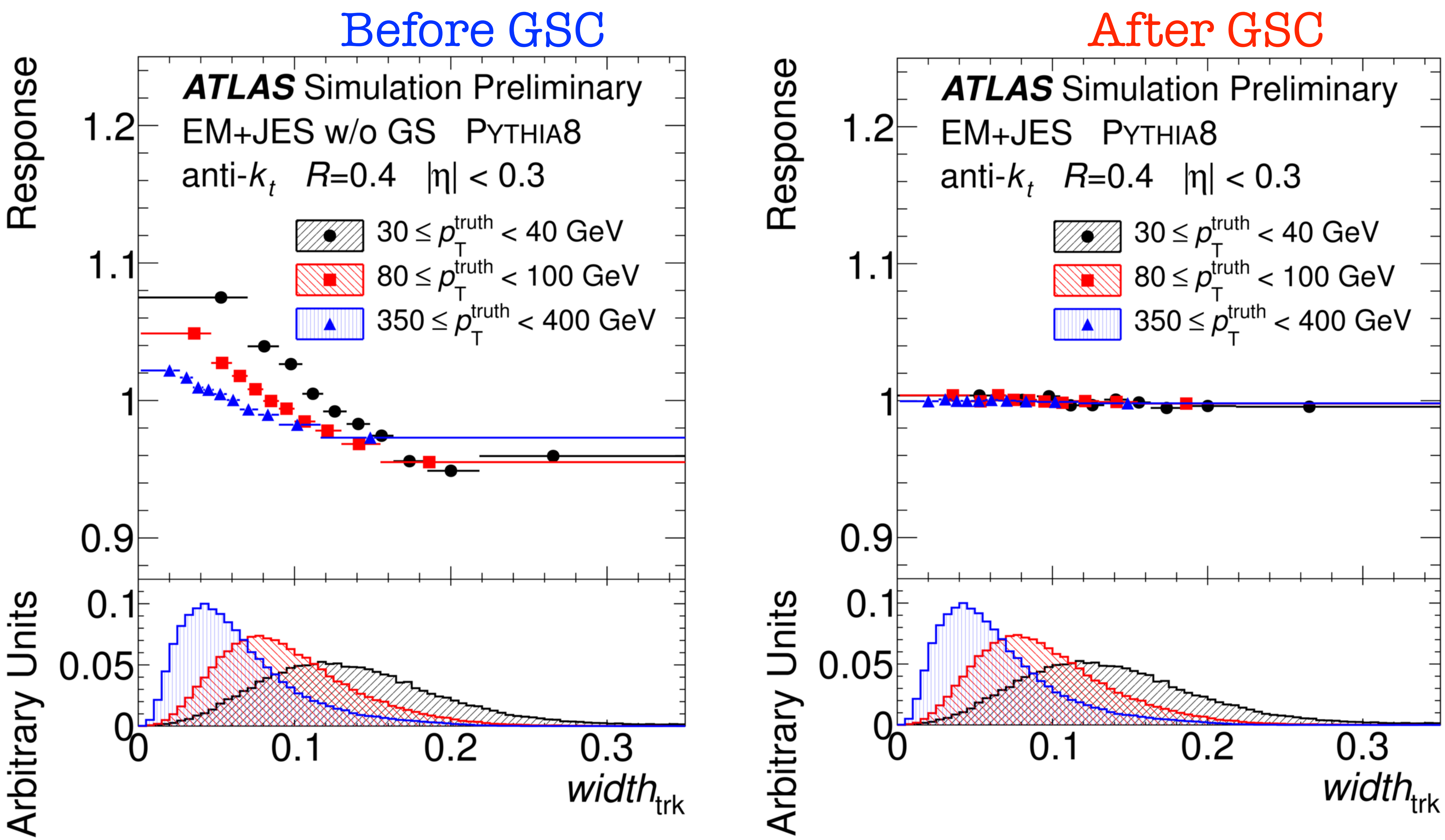
- **Global sequential calibration (GSC)**: to **reduce** fluctuation **effects**
  - ✦ Use jet-by-jet information to correct the response of each jet individually
- MC JES (one step before) corrects jets to particle level reference on **average**
- GSC variables
  - Longitudinal structure of the **energy depositions** within the calorimeters
  - **Track information** associated to the jet
  - Information related to the activity in the muon chamber behind a jet (**muon segments**)

$\|\eta\|$ region	Correction 1	Correction 2	Correction 3	Correction 4	Correction 5
$[0, 1.7]$	f_{Tile0}	f_{LAr3}	n_{trk}	$width_{\mathrm{trk}}$	N_{segments}
$[1.7, 2.5]$		f_{LAr3}	n_{trk}	$width_{\mathrm{trk}}$	N_{segments}
$[2.5, 2.7]$		f_{LAr3}			N_{segments}
$[2.7, 3.5]$		f_{LAr3}			

Global Sequential Calibration

ATLAS-CONF-2015-002

- Derived using MC, parametrised in p_T and η



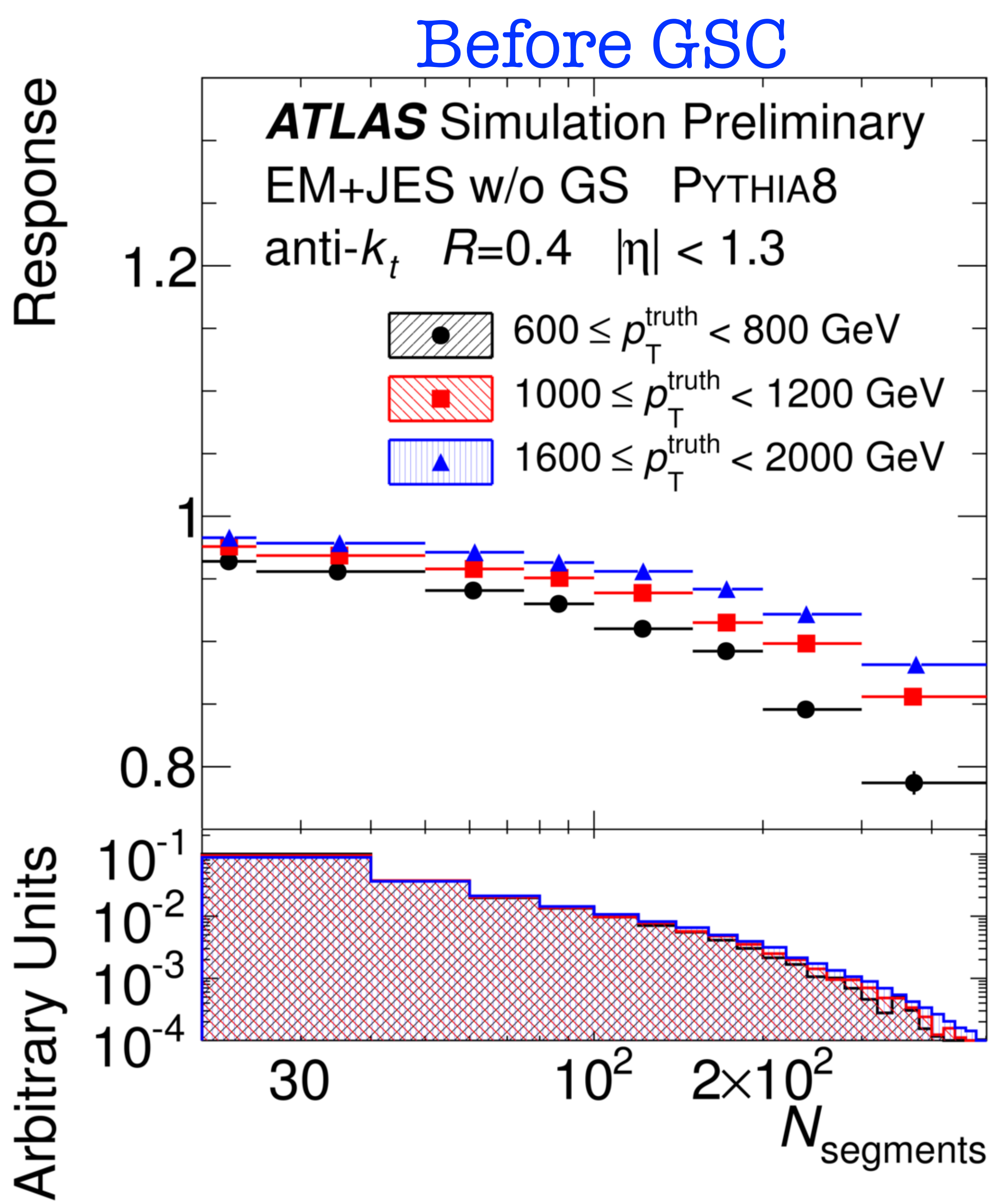
$$width_{trk} = \frac{\sum_i p_T^i \Delta R(i, \text{jet})}{\sum_i p_T^i},$$ average distance between tracks associated to jets and jet axis

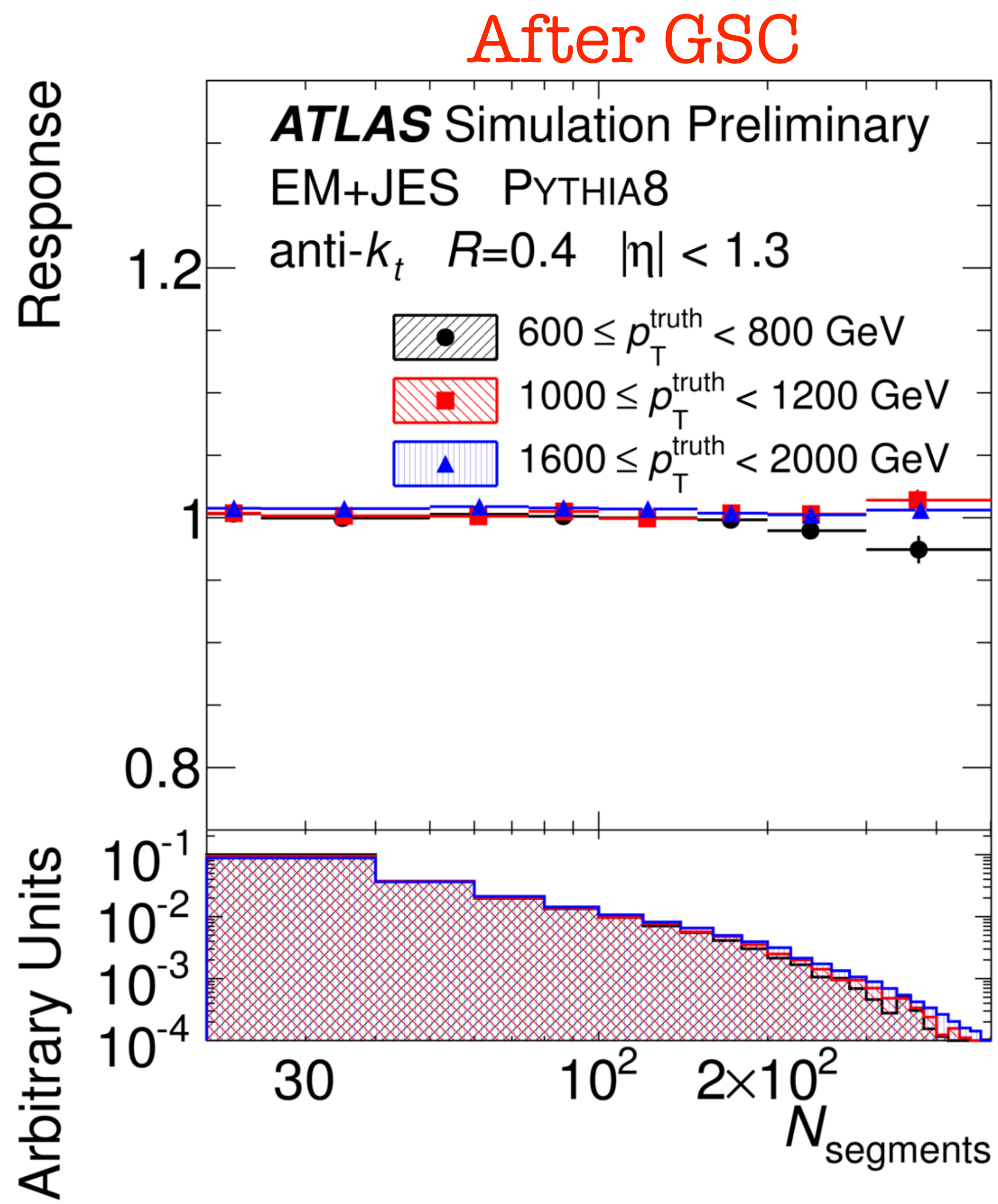
- GSC corrects response significantly

Global Sequential Calibration

ATLAS-CONF-2015-002

- Derived using MC, parametrised in p_T and η
- GSC validated using di-jet data events

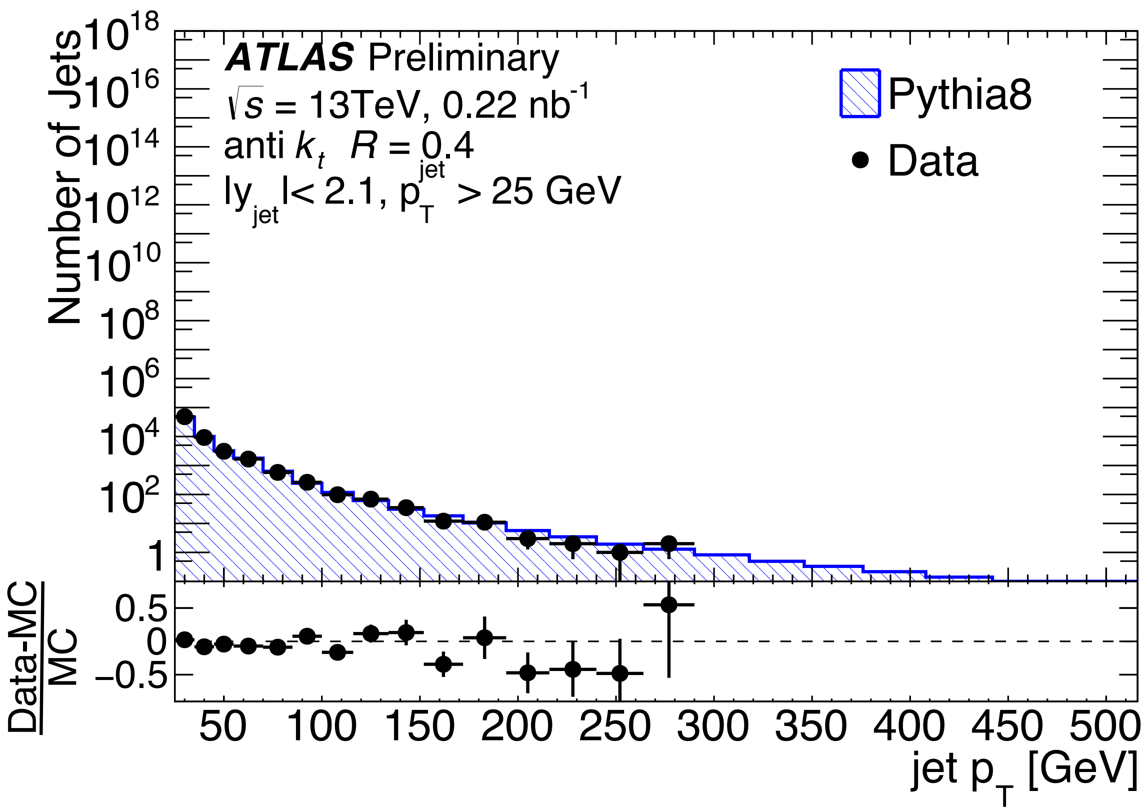


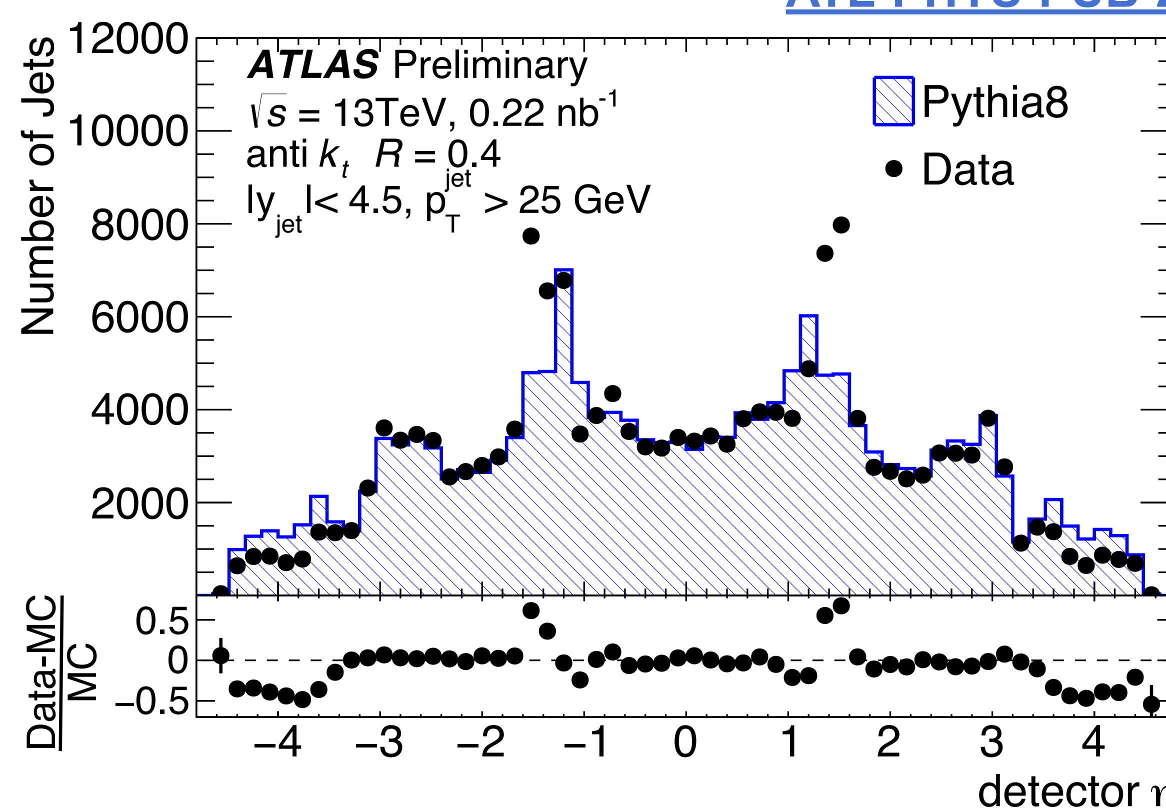


➡ **Need to validate all these quantities in Run 2**

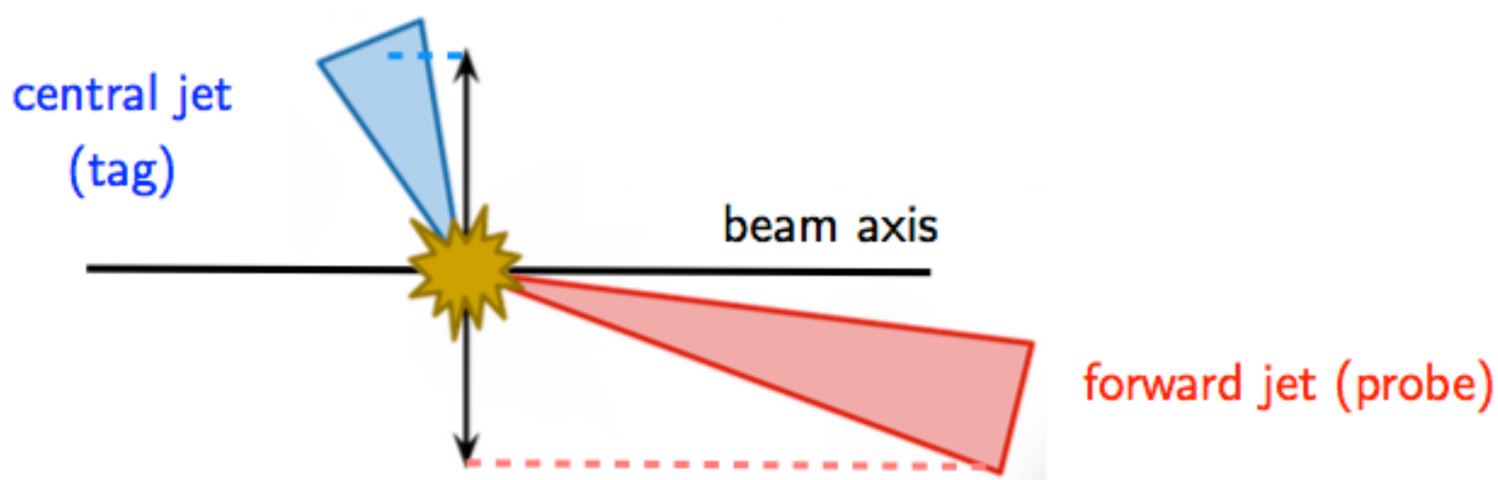
Jet kinematic distributions @ Run 2

ATL-PHYS-PUB-2015-036





- **MC simulation** typically describes the the **data** to within about **10%**
- **$|\eta|$ ~ 1.4** and **$3.1 < |\eta| < 4.9$**, 50% deviation
- More adequate calibration for forward region is needed: perform **η inter-calibration** in dijet events to **correct η dependence of jet response**



Topocluster energies @ Run 2

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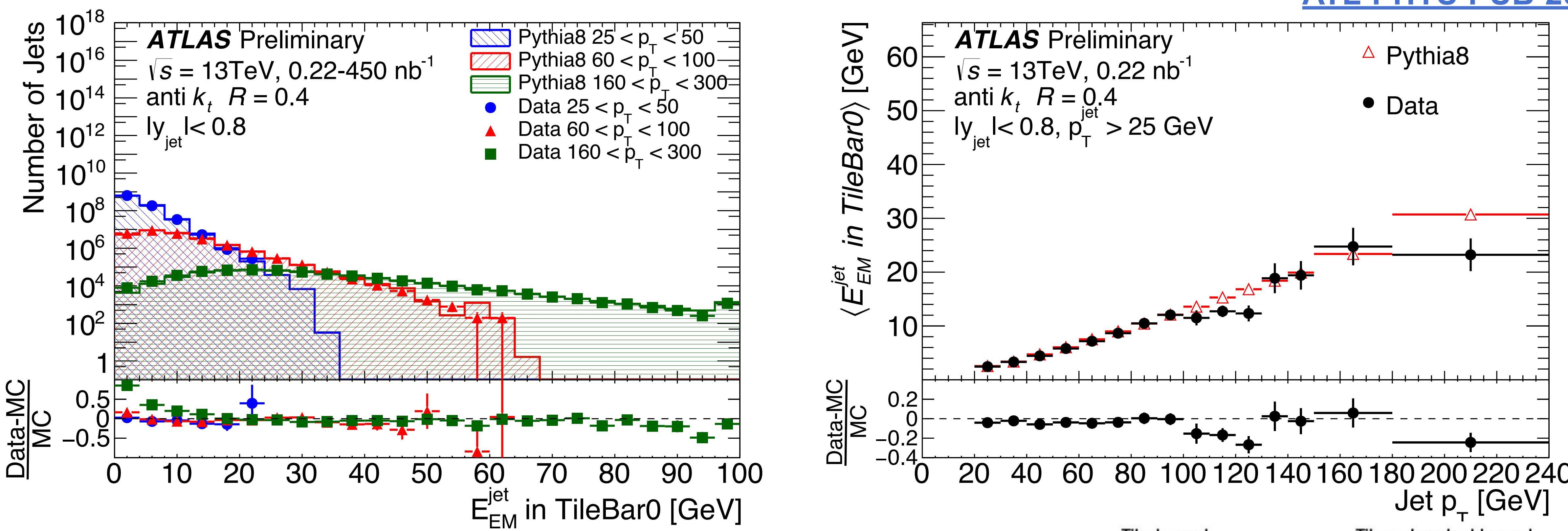
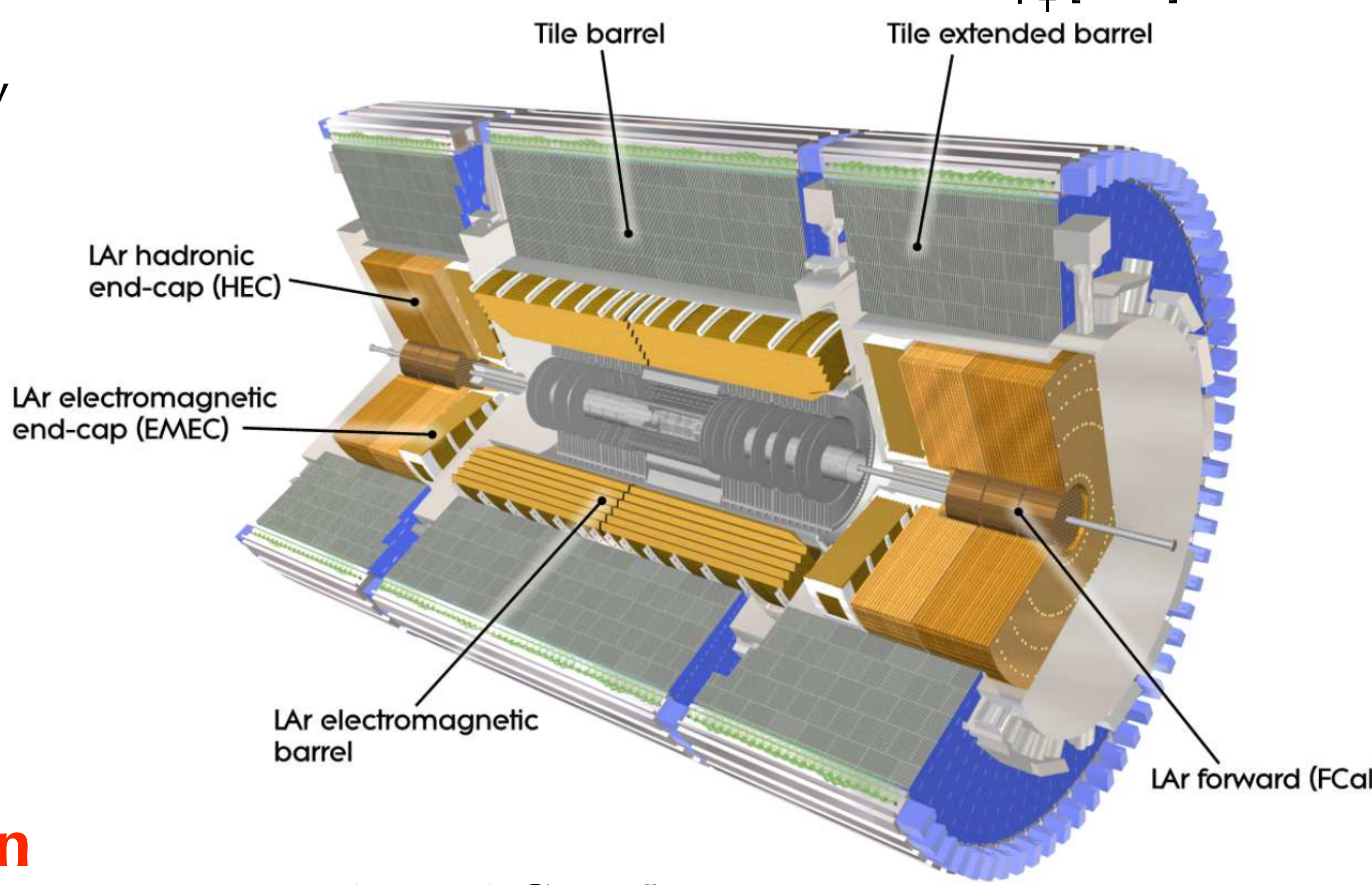


- Mean **energy ratios** **well described** by simulation
- **TileBar0**: Energy in the first layer of hadronic calorimeter (first layer outside the LAr cryostat): **very good description**
  - Decent understanding of the **longitudinal jet energy profile**, **appropriate dead material description**



ATLAS calorimeters

Track, muon properties @ Run 2

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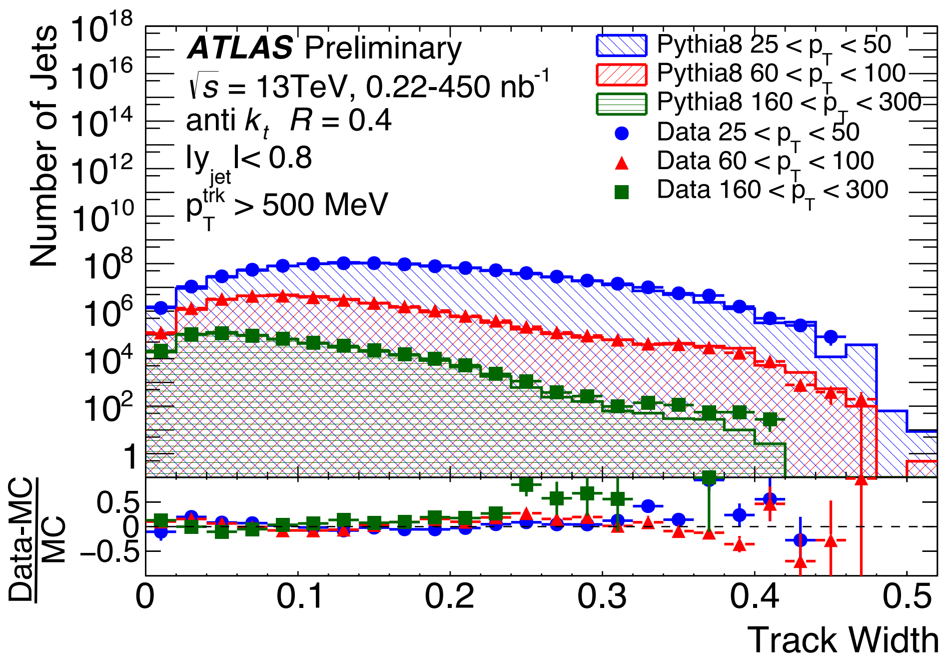
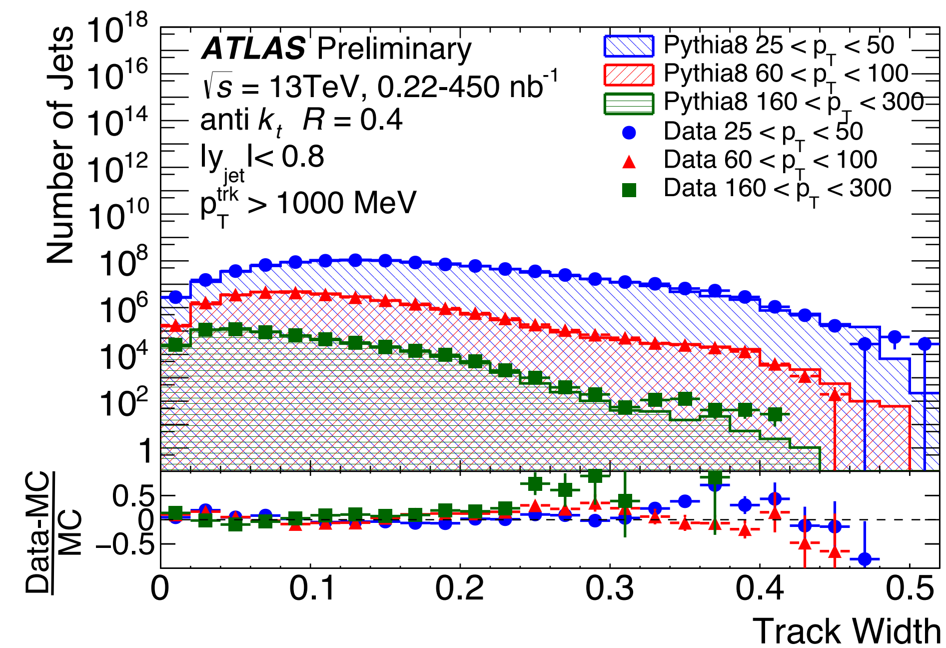
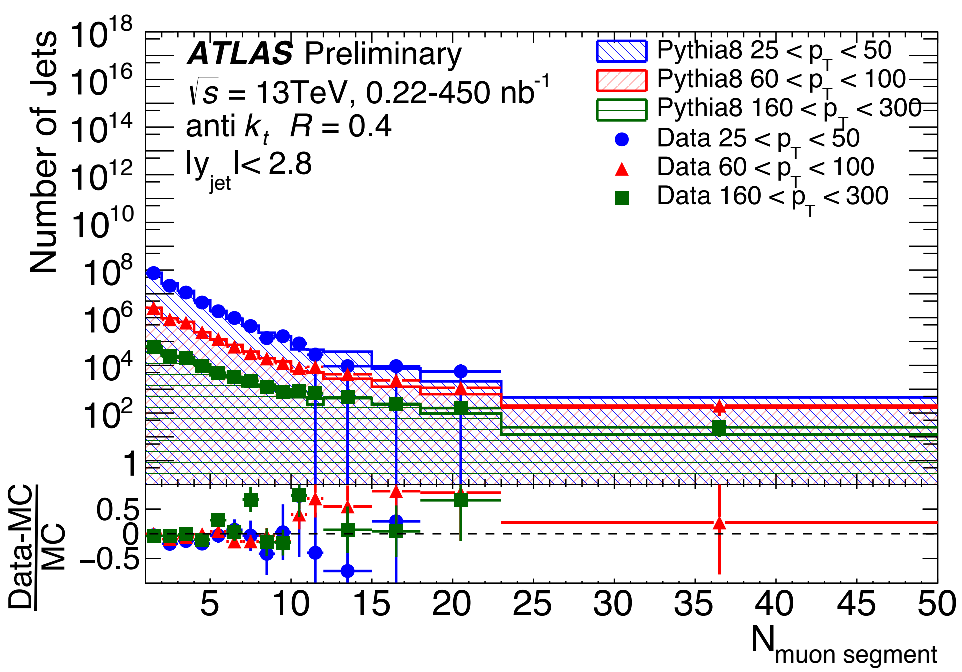
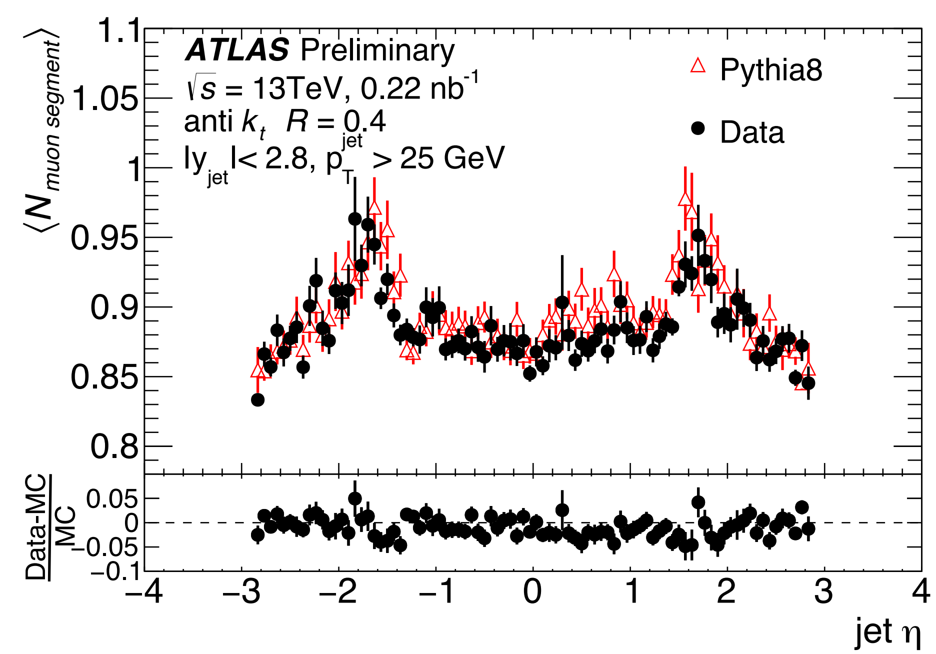






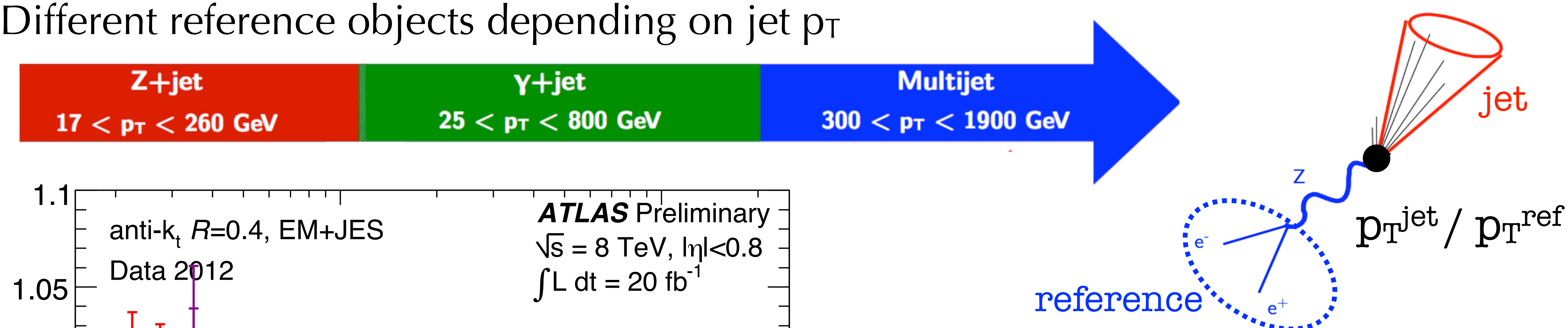


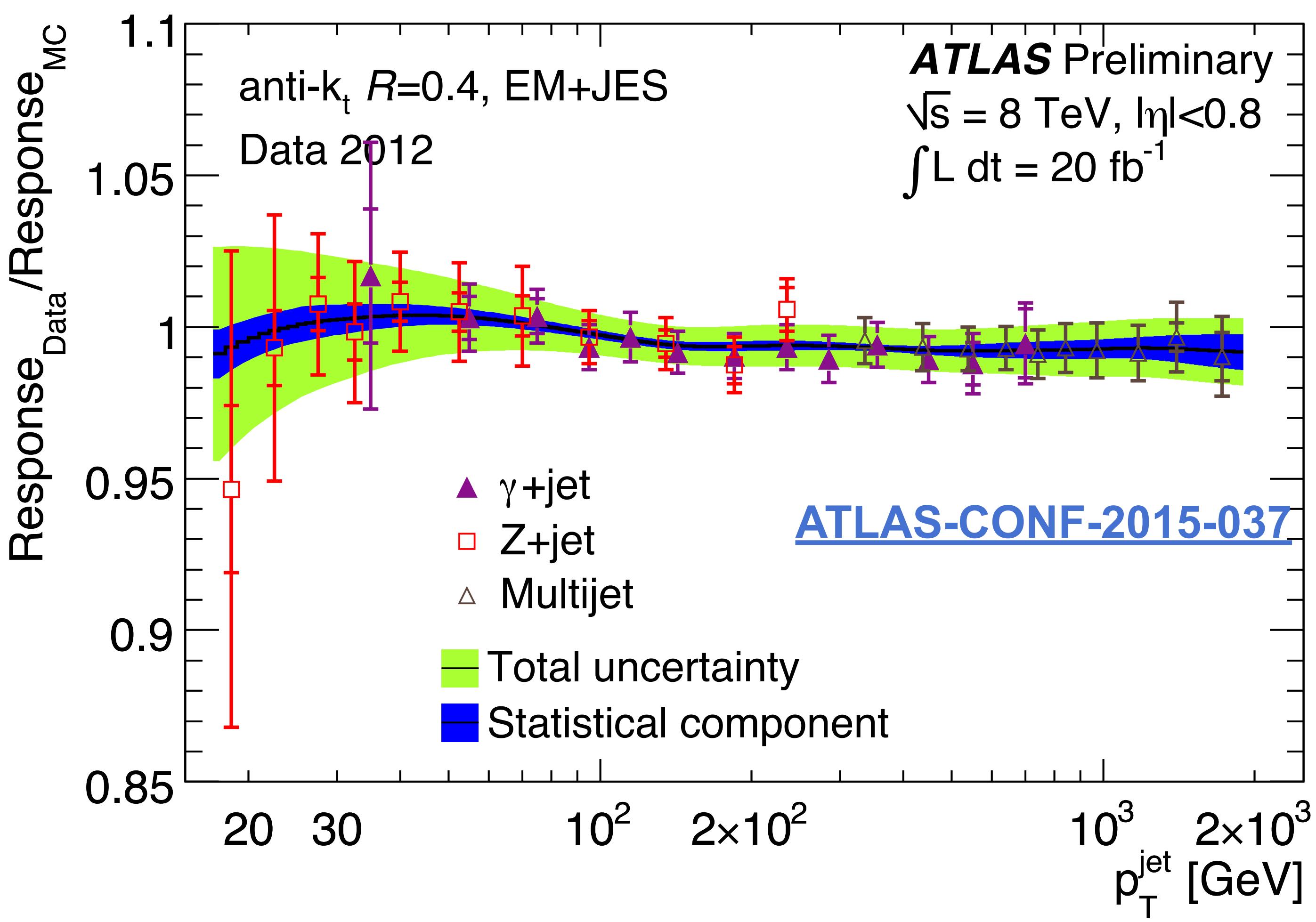
➡ <u>**Overall good agreement between data and simulation**</u>

➡ These checks **build confidence** towards **Run 2 jet reconstruction** and **good performance**

In-situ corrections

- **In-situ** measurement using a **well-calibrated** object as a **reference**, recoiling against **jet**
- Different reference objects depending on jet p_T



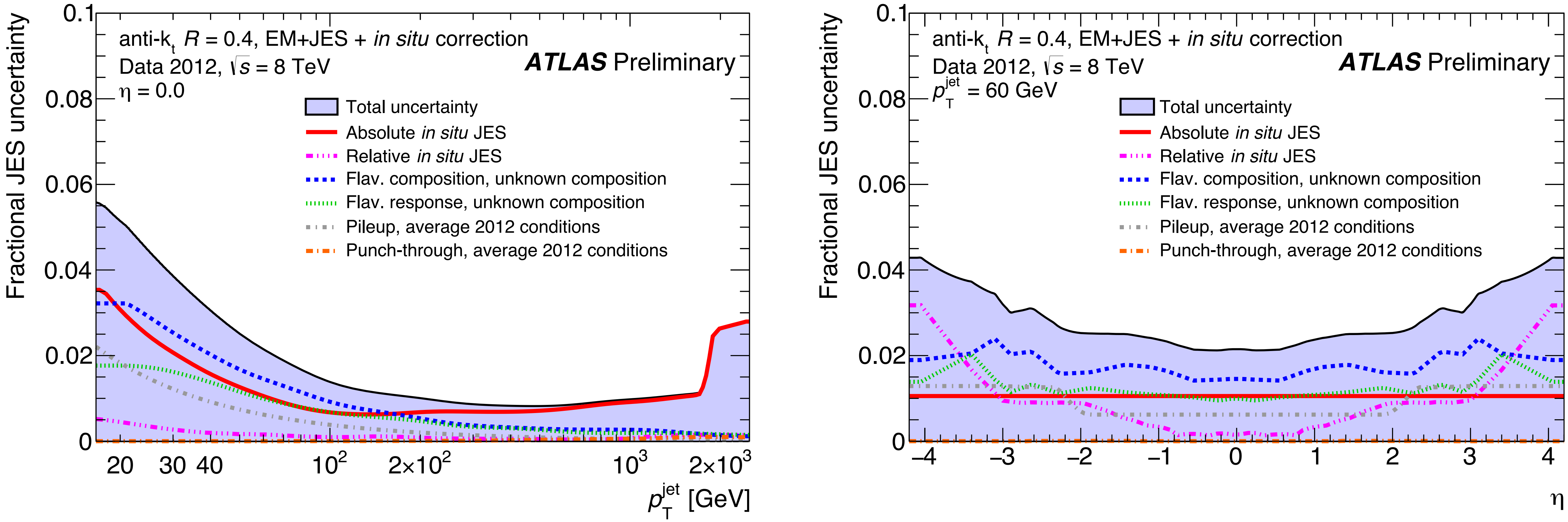


- In-situ calibration: **p_T global fit** of **3 in-situ measurements**, binned in **η**
  - γ+jet / Z+jet / Multijet
- All in-situ systematic **uncertainties** propagated to **final in-situ combination**

Jet energy scale
and its uncertainties

JES uncertainties in Run 1

ATLAS-CONF-2015-037

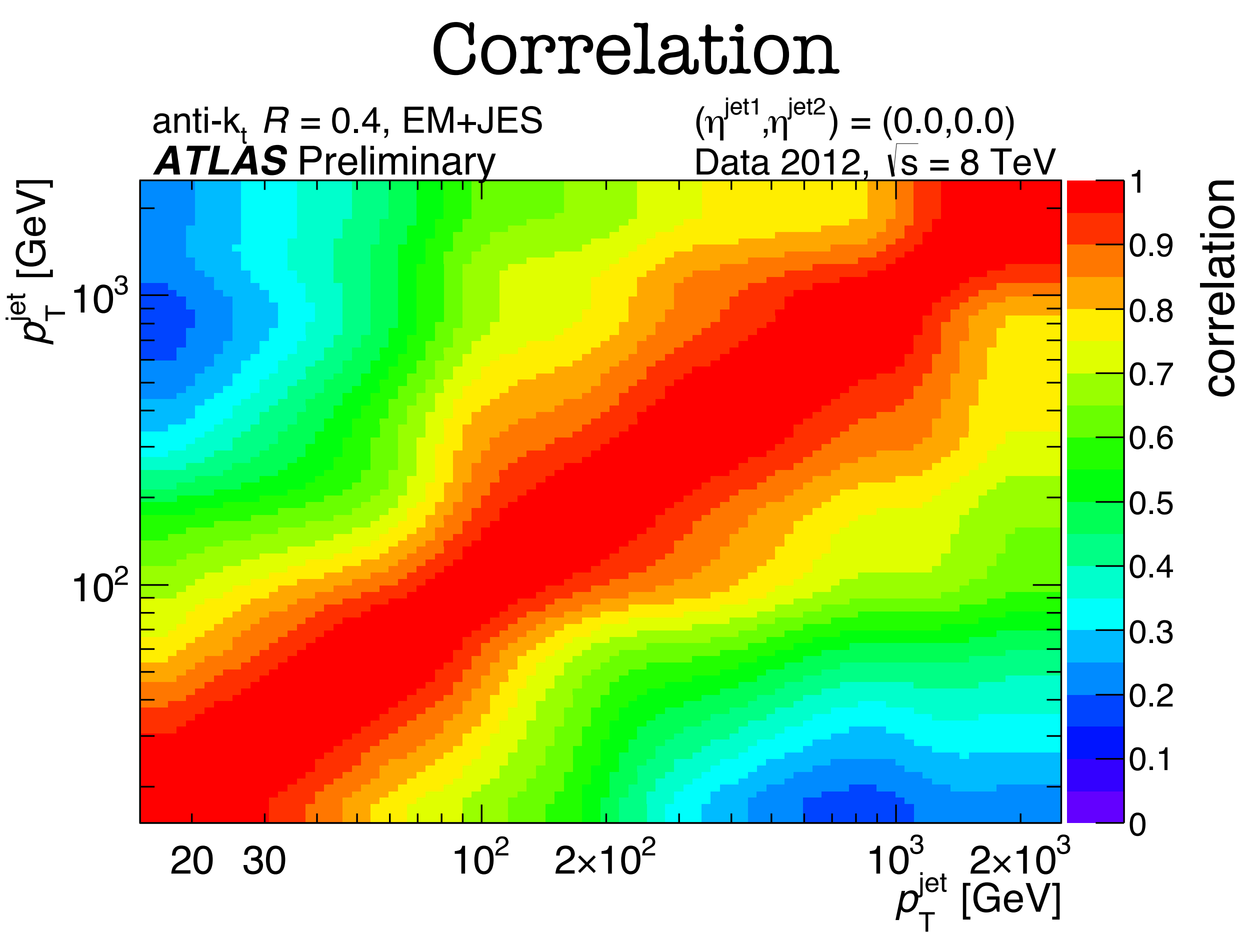


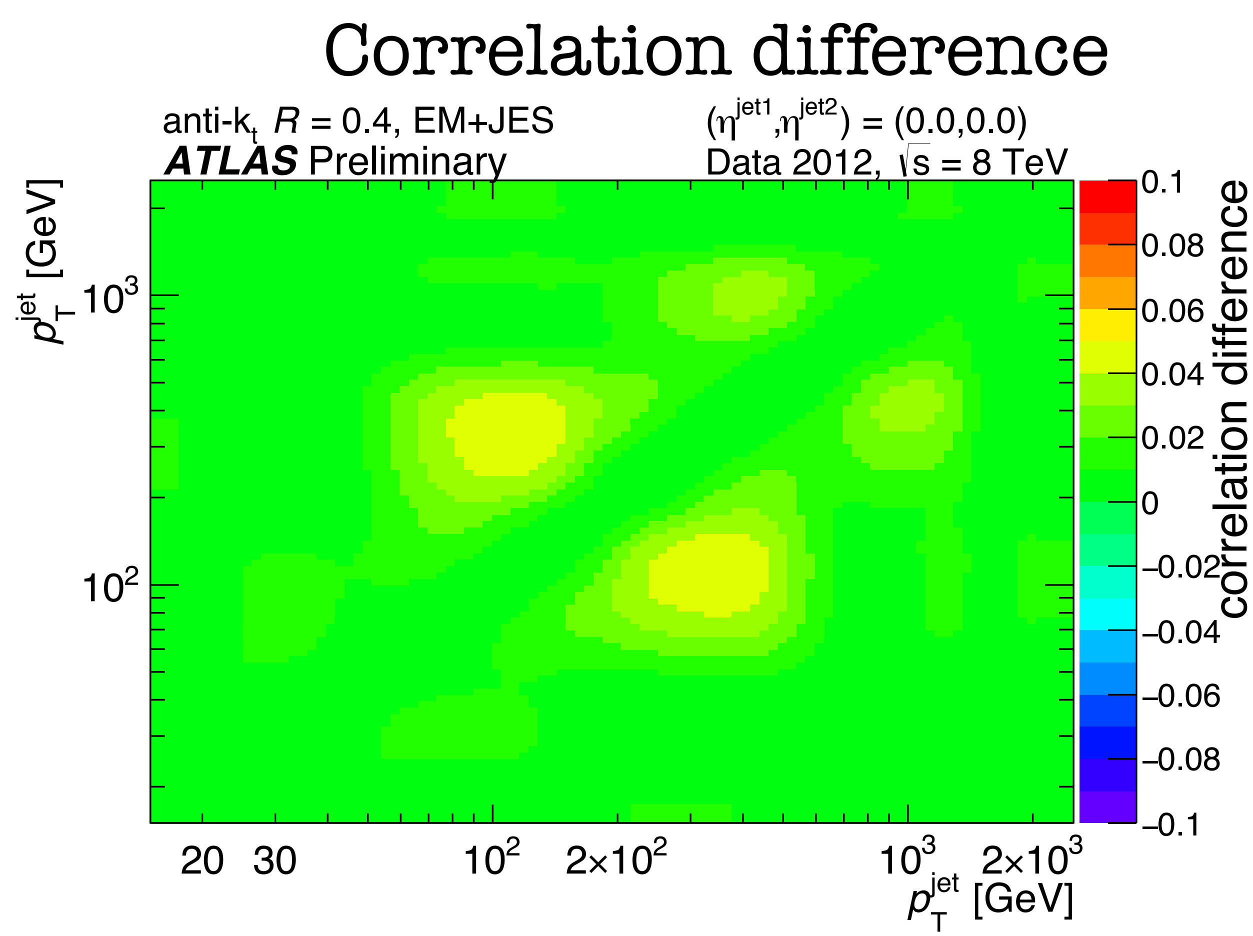
- Final JES uncertainties **O(60)**, a combination of **in-situ components** and components **estimated upstream in calibration chain**
  - O(20) systematics from in-situ
  - O(30) statistical sources from in-situ
  - O(10) from pileup, punch-through, flavor dependence

JES uncertainty components reduction

ATLAS-CONF-2015-037

- O(60) number of nuisance parameters (NPS) can be reduced performing an **eigenvector reduction**
  - ✦ **Covariance matrix diagonalization**
  - ✦ Most important eigenvectors are kept and others are combined
  - ✦ **Correlation** information is **preserved** and number of NPs reduced to **O(20)**



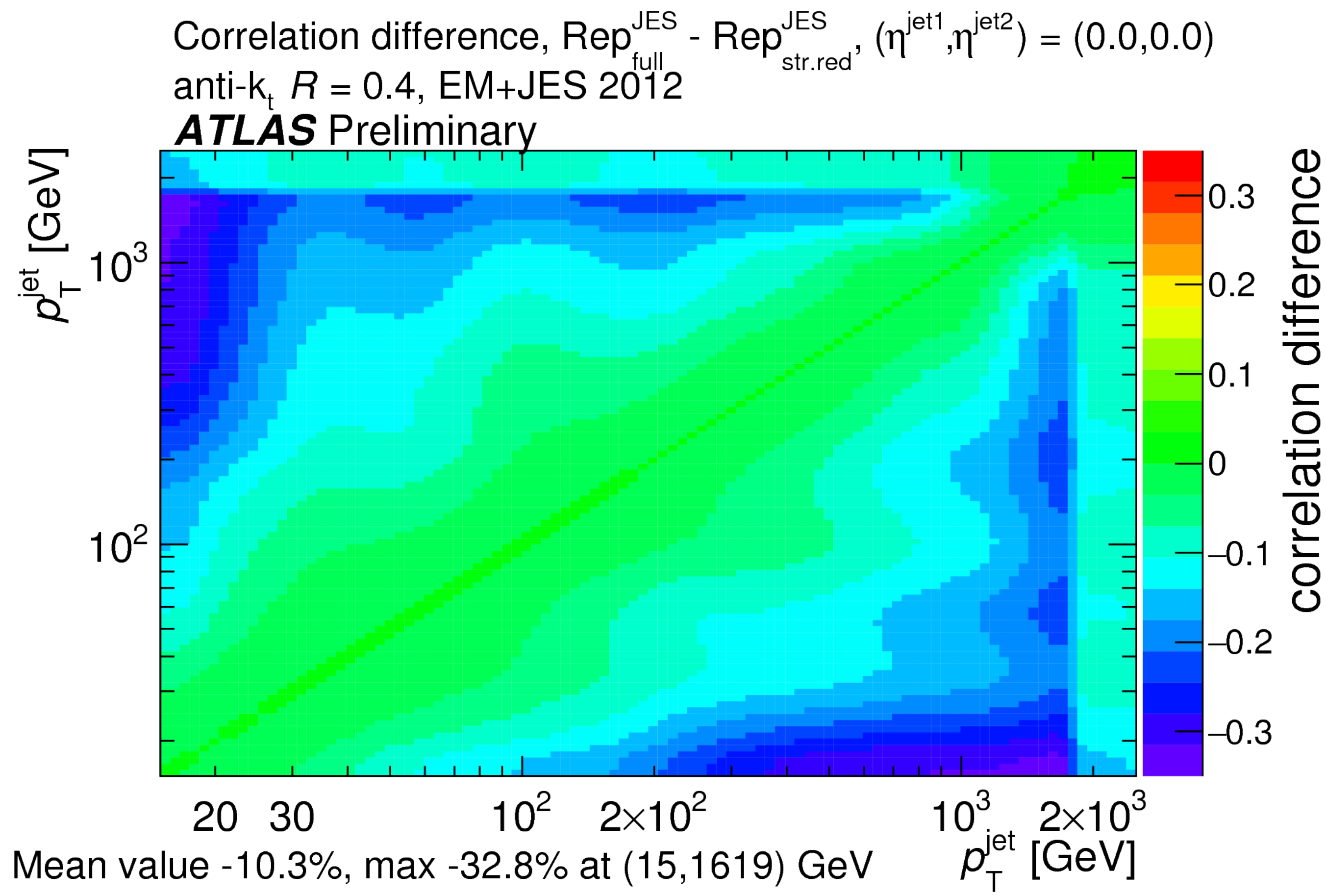


JES NPs strong reduction

ATL-PHYS-PUB-2015-014

- Many searches are **not sensitive** to **JES uncertainties**
- Having **O(60)** or even **O(20)** JES uncertainty components is a **burden**
- **Strong reduction** performed leading to **O(3)** with some **loss of correlations** in specific regions of phase space

Correlation difference



Mean value -10.3%, max -32.8% at (15,1619) GeV

➡ **Repeat** the full **procedure** with different **assumptions**

- ➡ **Combining components** in a way that **different kinematic regions** become better or worse representations of the **full matrix**

➡ End up with **4 sets of 3 NPs** to describe **full correlations**

Jet energy resolution and its uncertainties

Jet energy resolution (JER)

ATLAS-CONF-2015-037

- Jet energy resolution:

noise term (N), stochastic term (S), constant (C)

$$\frac{\sigma_{p_T}}{p_T} = \frac{N}{p_T} \oplus \frac{S}{\sqrt{p_T}} \oplus C$$

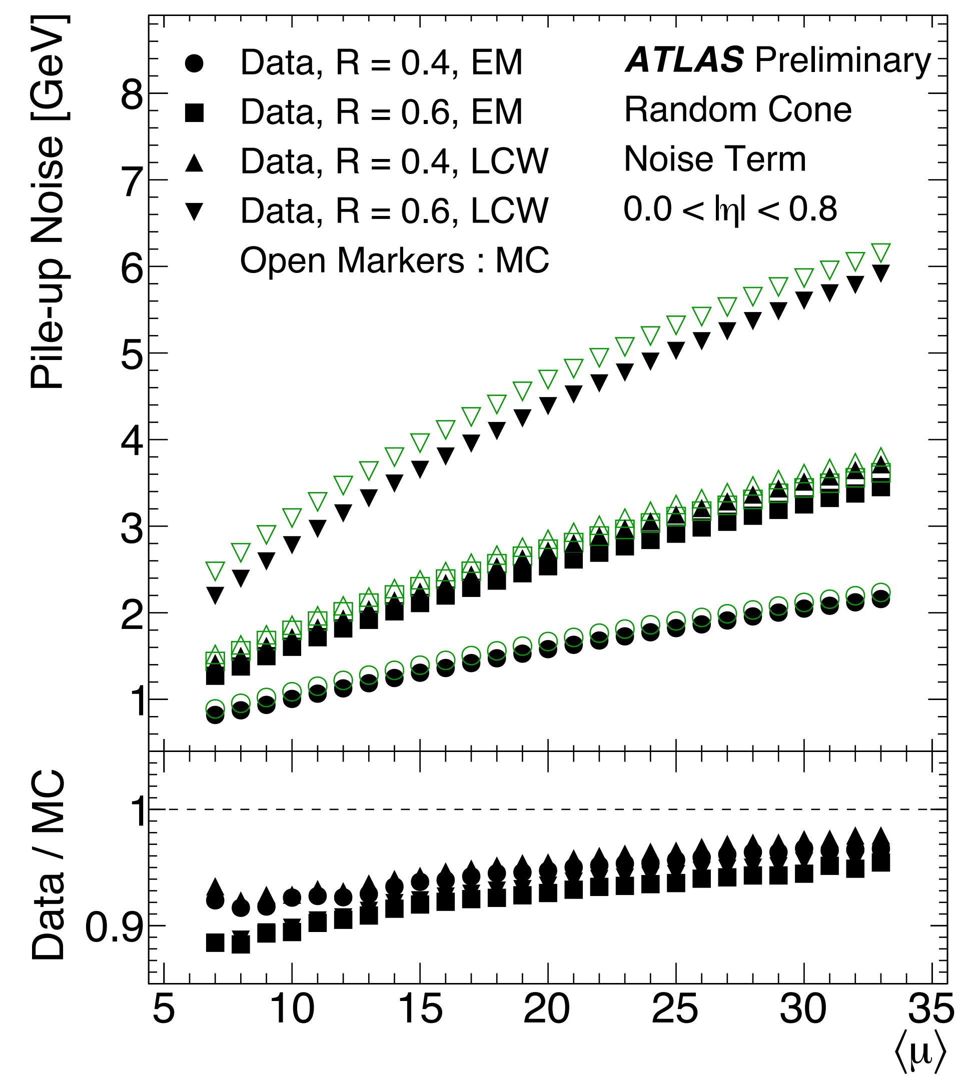
- **Extract the N, S, C terms** from in-situ **data measurements** for the first time!

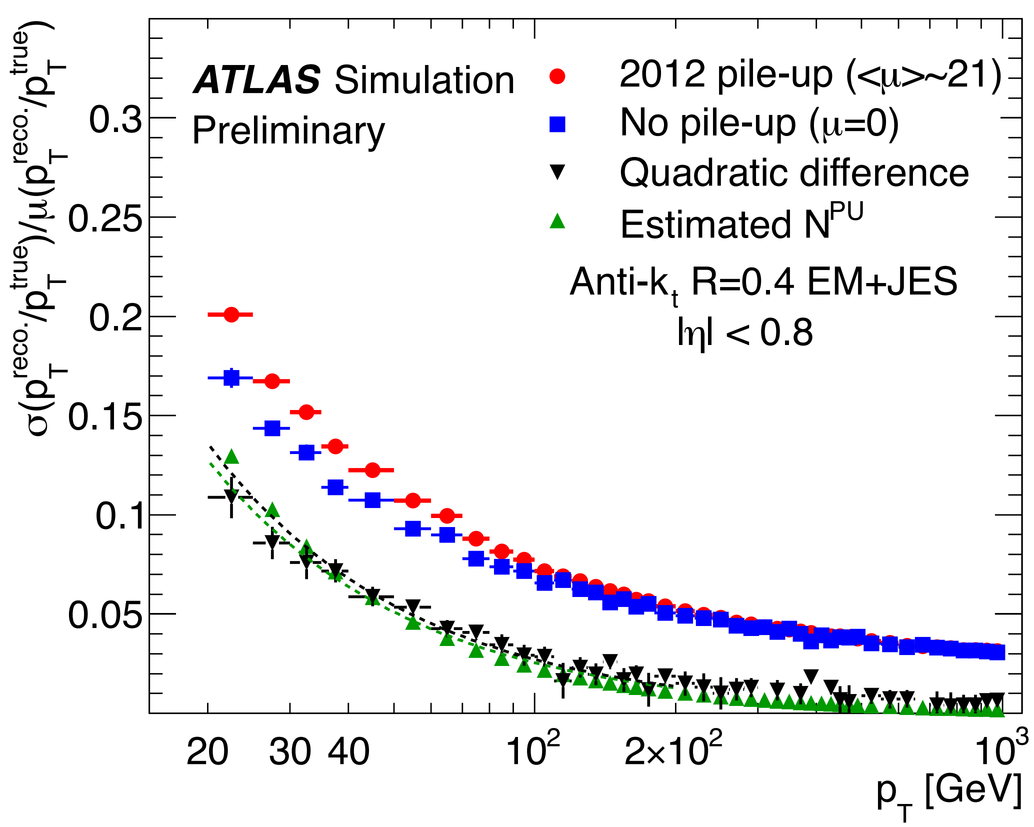
➡ Particularly important to **constrain** the **noise term**

➡ **Noise** is a **significant** component of the JER at **low p_T** (calorimeter electronics & pile-up)

➡ Extract noise term by combining two methods:

- ✦ **"Random cones"** in zero bias data ⟶
- ✦ Measure fluctuations of the event energy density ρ





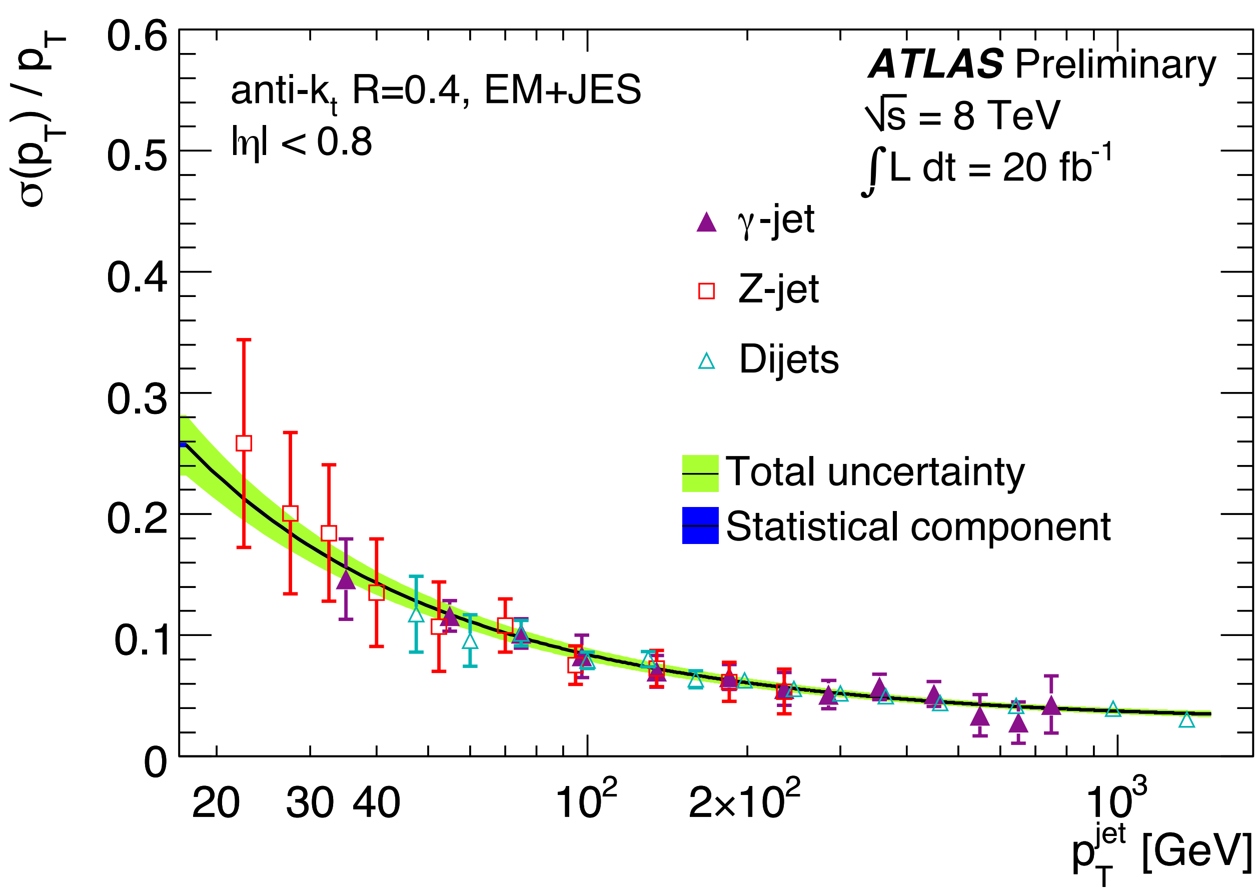
Jet energy resolution (JER)

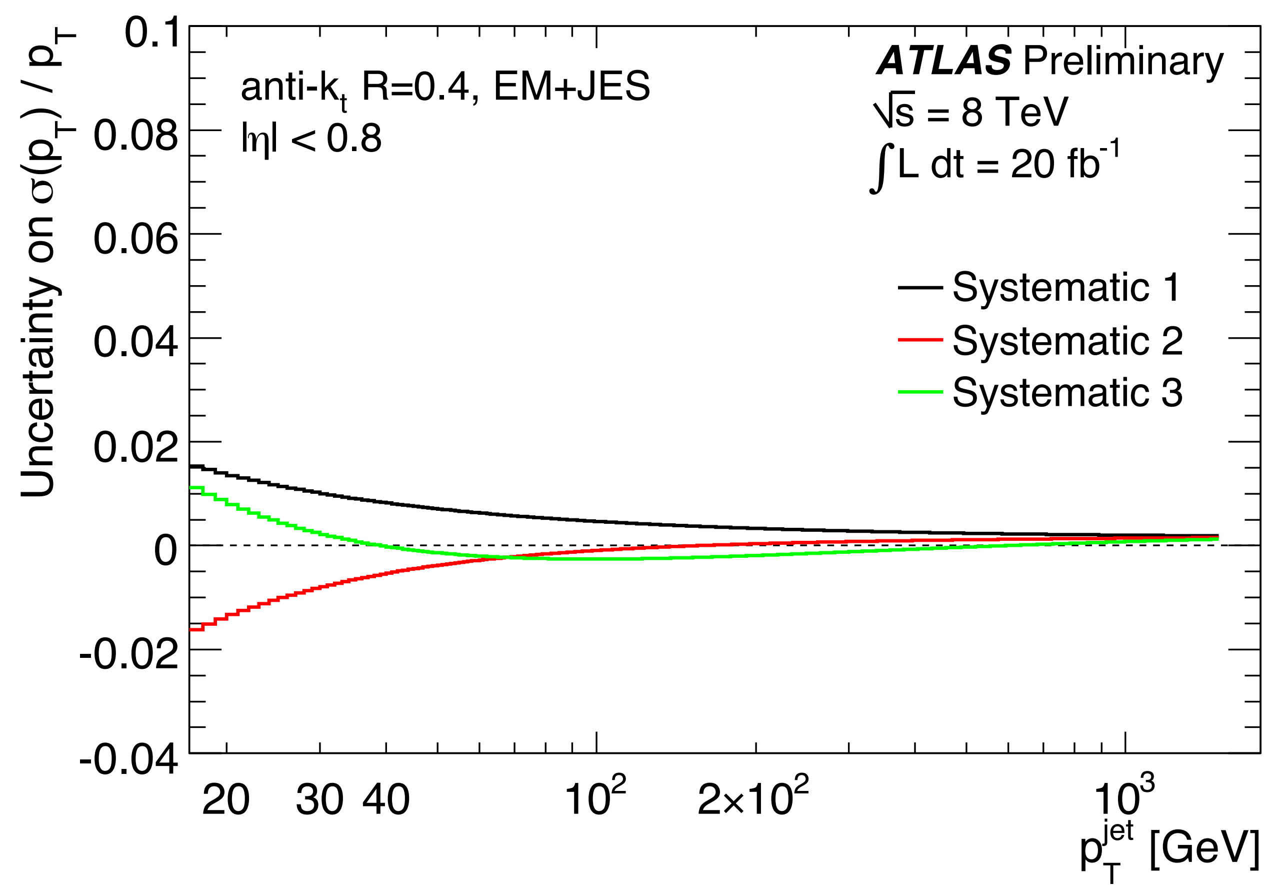
ATLAS-CONF-2015-037

- Measure jet resolution combining Run1 in-situ γ+jet, Z+jet and dijet by performing a p_T global fit, similarly to what is done for the JES

➡ **Additional constraint on noise term improves the uncertainty on low p_T**

- JER uncertainties by propagating the individual in-situ and noise constraint uncertainties
  - ✦ Covariance matrix diagonalization to reduce the number of NPs to 3, **preserving the correlations information**



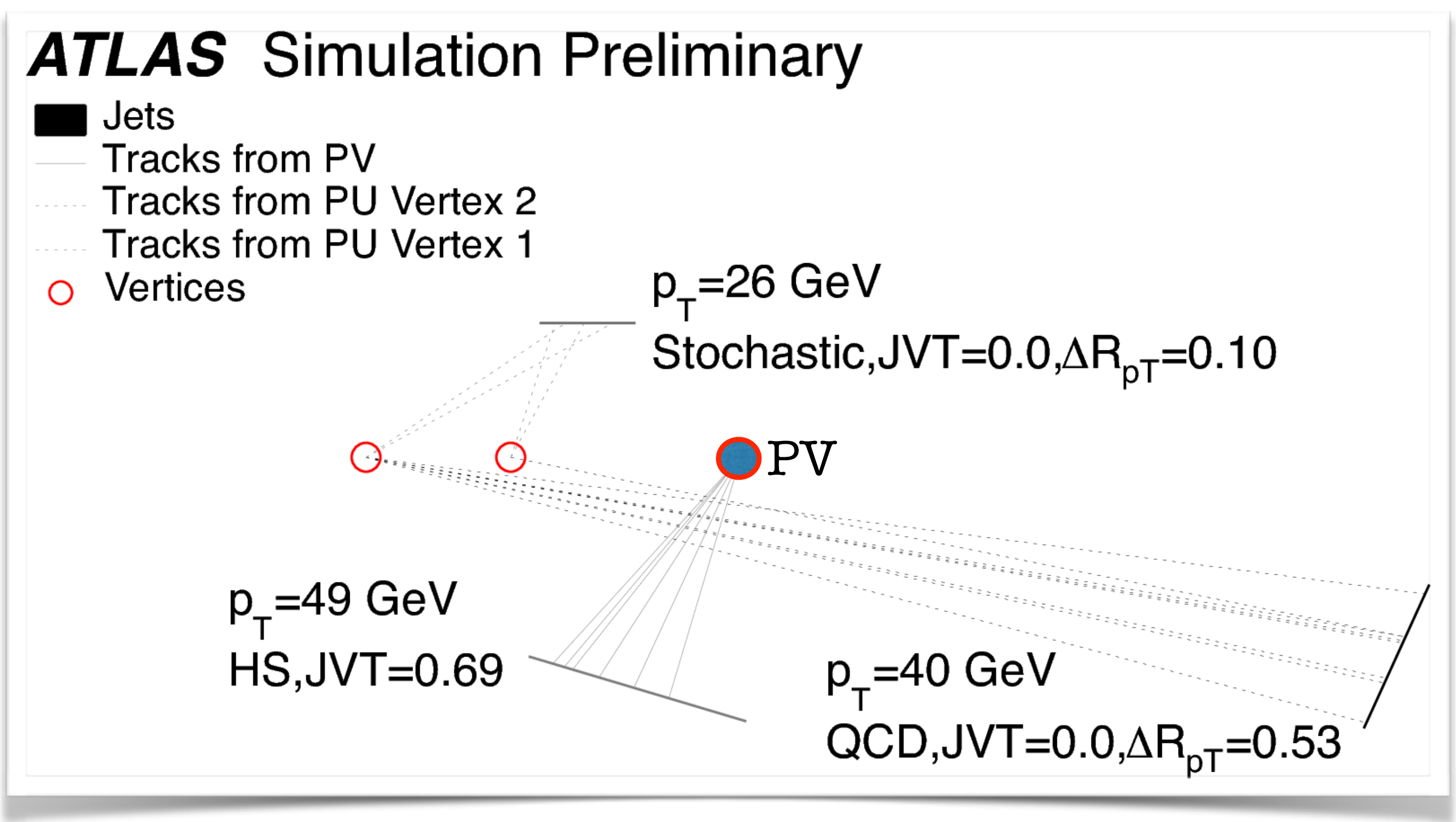


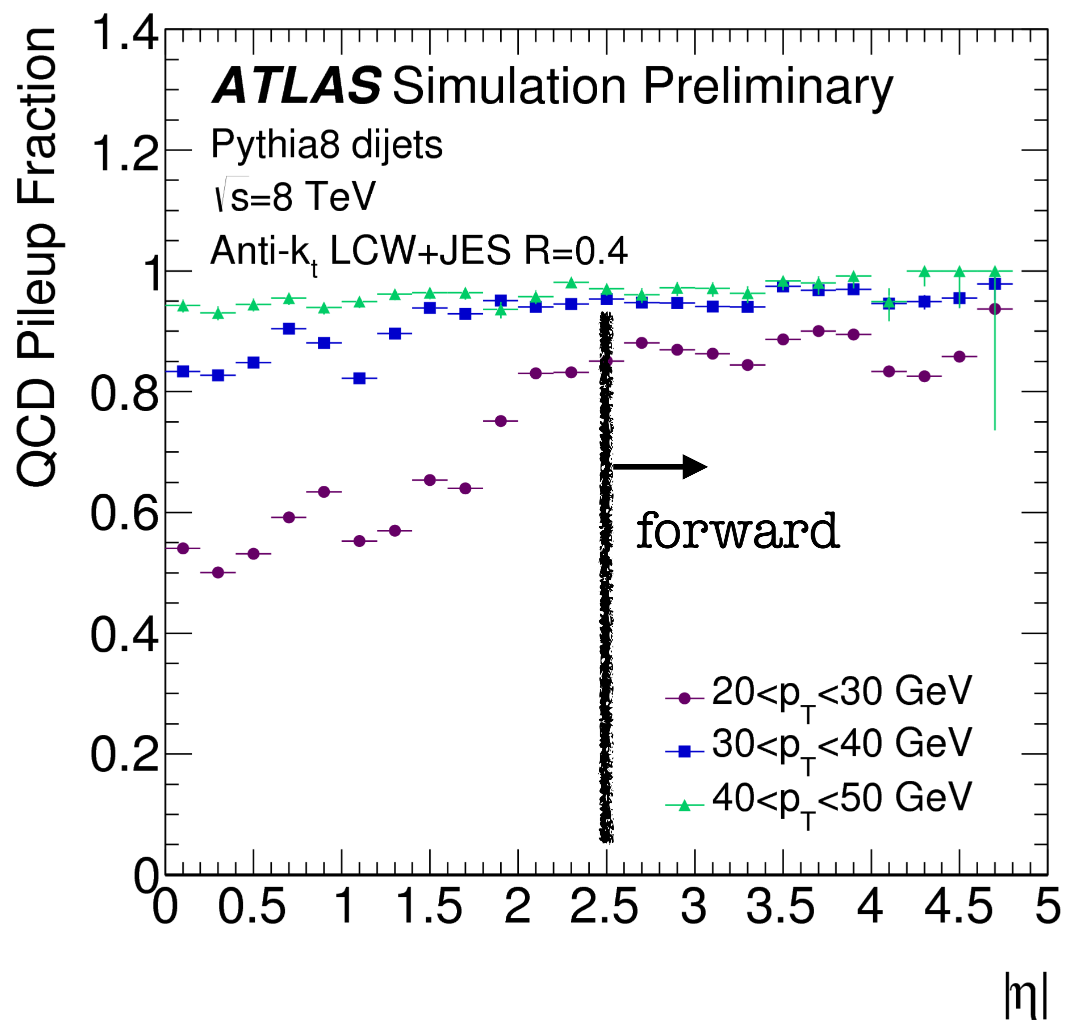
A novel technique to reduce forwards pileup jets

Forward jet vertex tagging

ATL-PHYS-PUB-2015-034

- Problem: **hard to deal** with pileup jet **outside the tracker coverage** $|\eta|>2.5$
- Idea: **exploit** the **correlation** between **central** and **forward** jets originating from **QCD pileup interactions**
  - ✦ Discriminate between stochastic and QCD pileup jets in the central region using tracking information



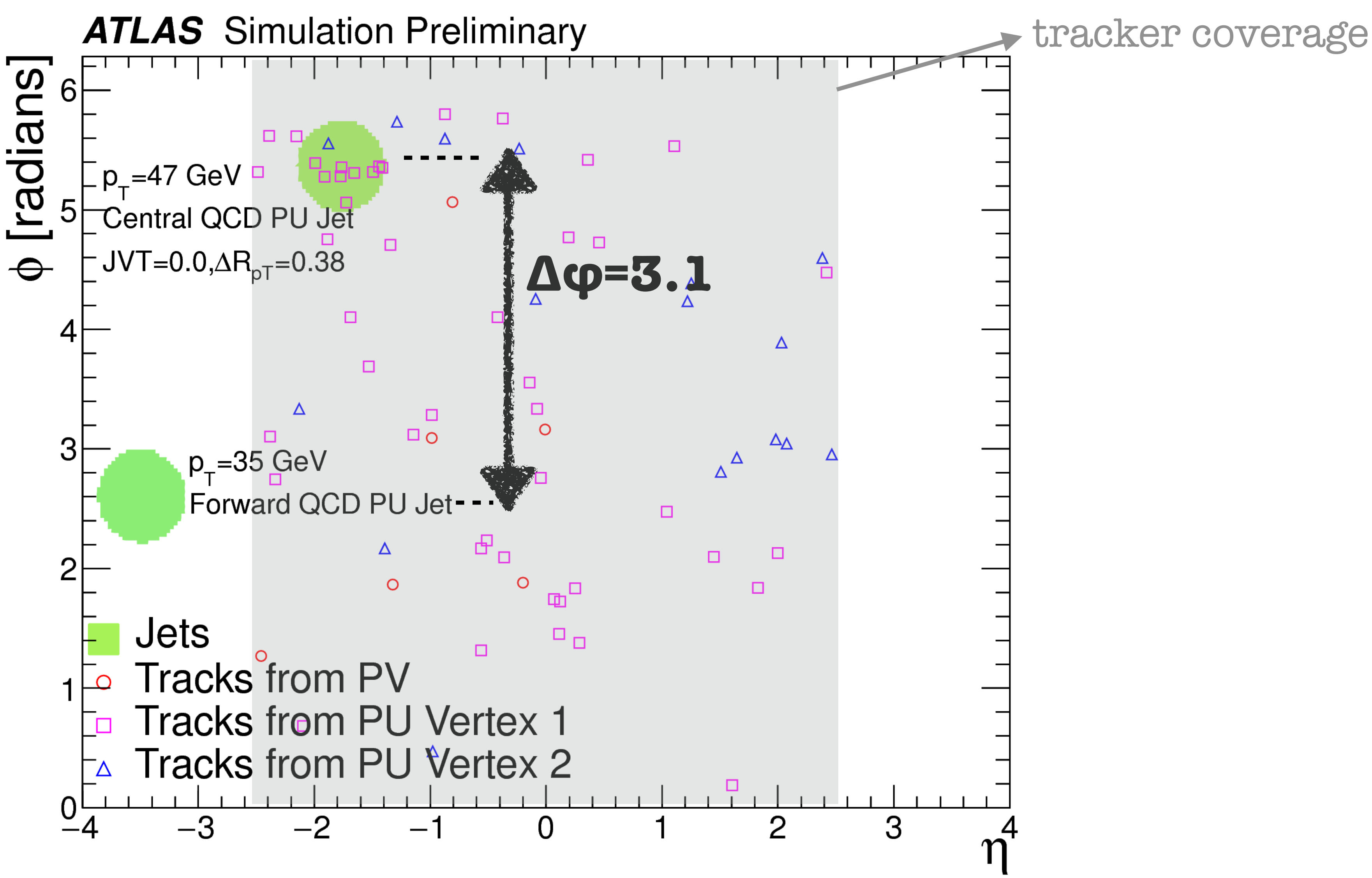


- **Biggest fraction** of pileup jets is of **QCD origin**

Forward jet vertex tagging

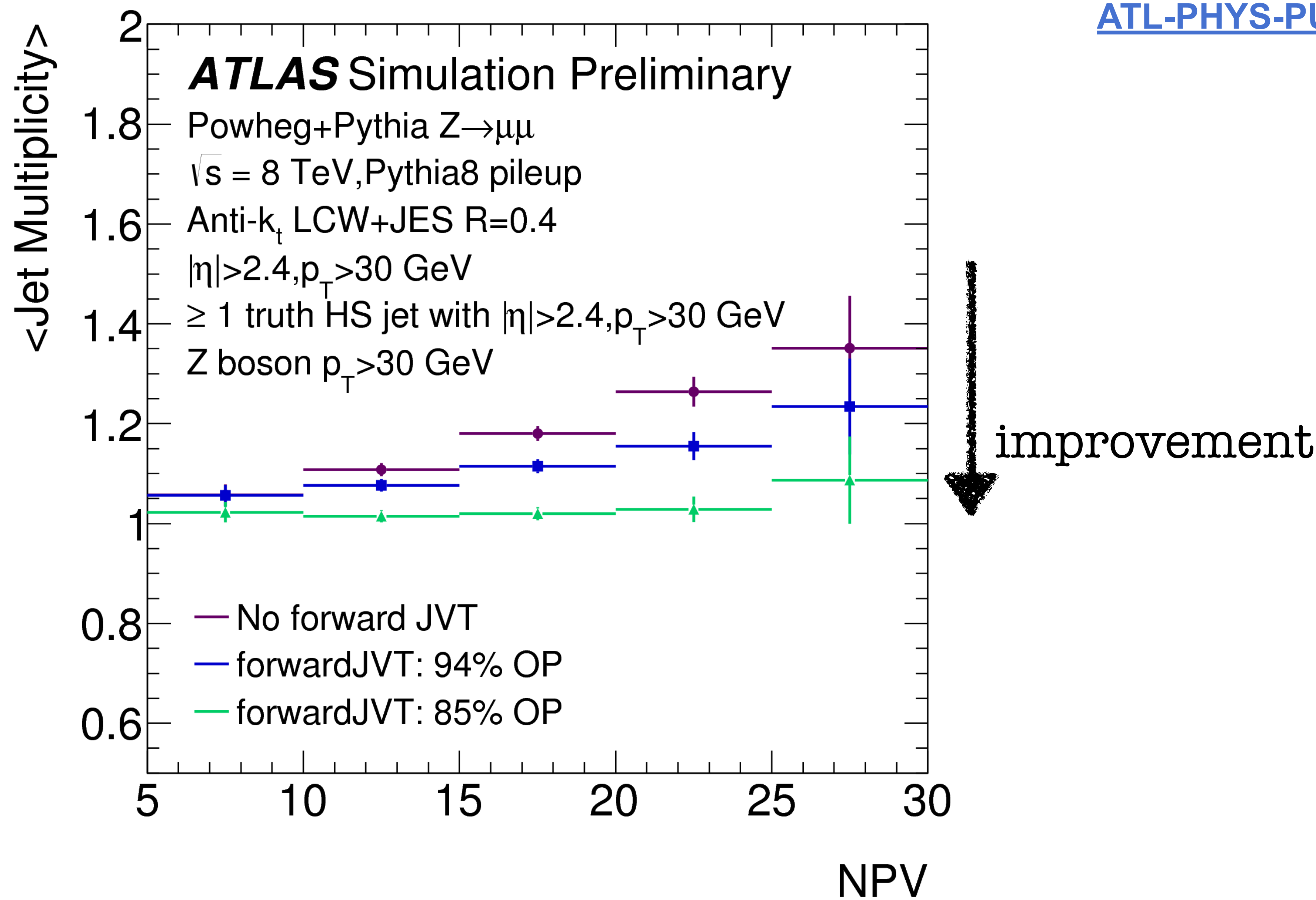
ATL-PHYS-PUB-2015-034

- Problem: **hard to deal** with pileup jet **outside the tracker coverage** $|\eta|>2.5$
- Idea: **exploit** the **correlation** between **central** and **forward** jets originating from **QCD pileup interactions**
  - ✦ Discriminate between stochastic and QCD pileup jets in the central region using tracking information
  - ✦ **QCD pileup jets are mostly produced in pairs and back to back.**



Remove pileup forwards jets

ATL-PHYS-PUB-2015-034



- Forward JVT cut hard-scatter efficiency provided for two working points
  - ✦ **Removes** the dependence of **jet multiplicity** on the **N_{PV} for jets p_T>30 GeV**
- **New capability for pileup suppression at the LHC**
- Identification and removal of pileup jets outside the tracker acceptance

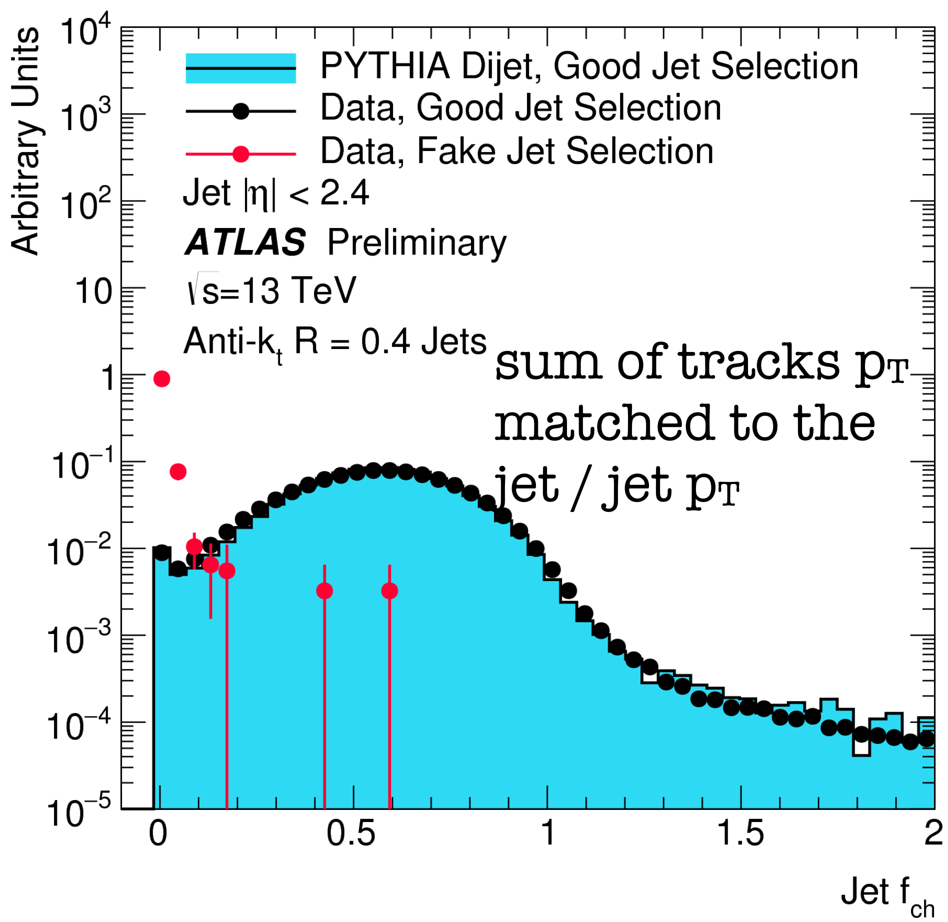
➡ **Broad impact on all VBF physics analysis**

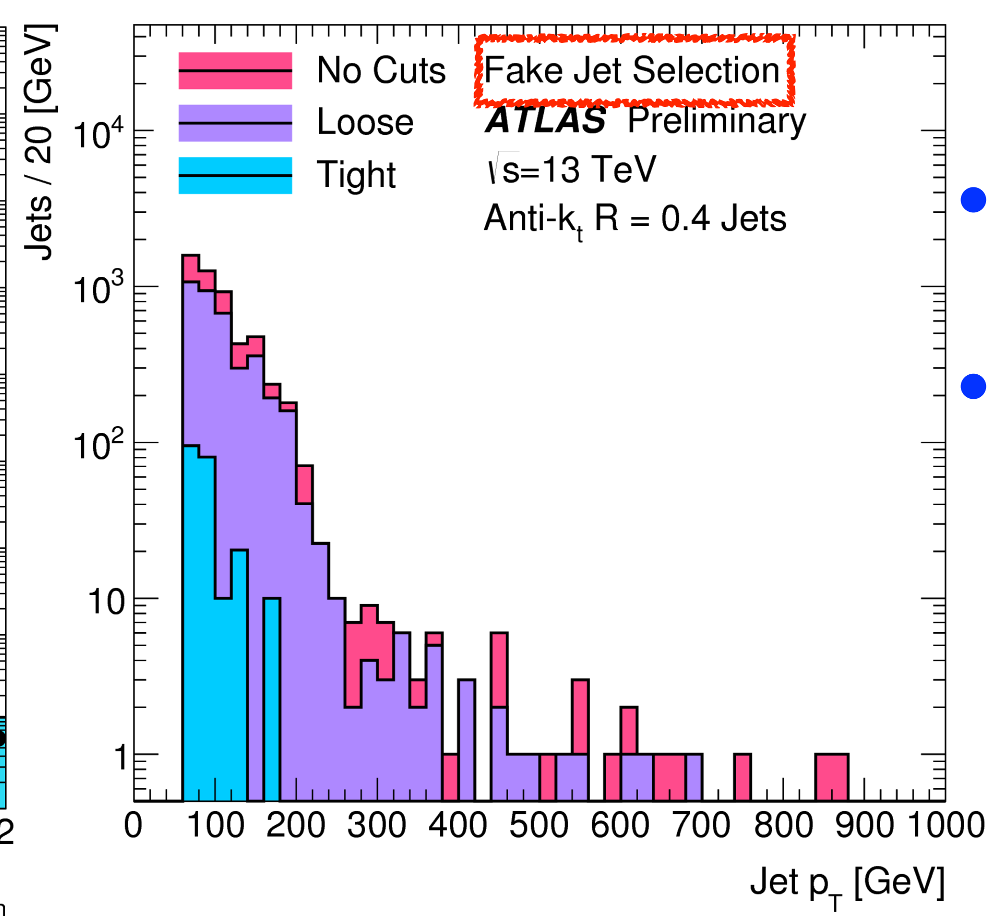
Early Run 2 results

Jet cleaning @ 13 TeV

ATLAS-CONF-2015-029

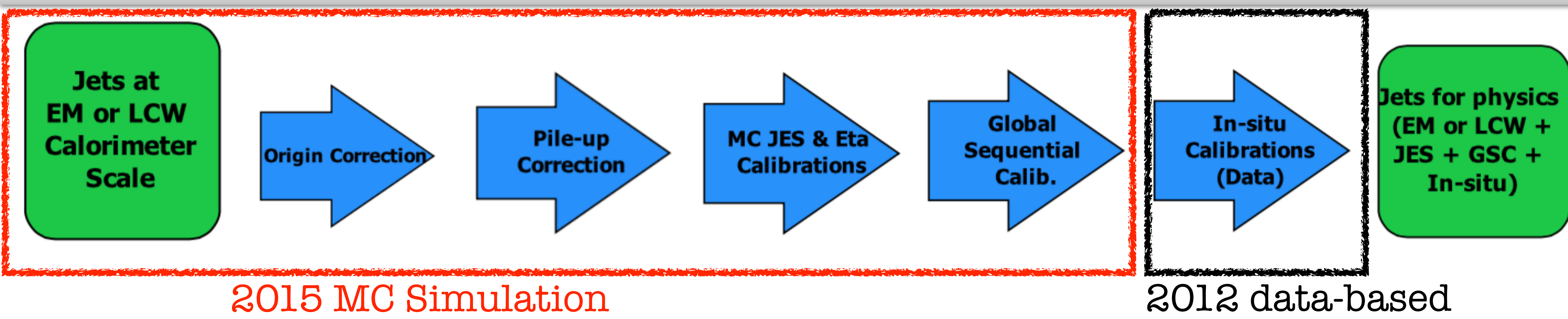
- **Jets** in pp collisions must be **distinguished** from **fake jets** originating from **non collision sources**
  - ✦ Beam induced background / cosmic-ray showers / calorimeter noise
- Use enriched samples of **good jets** and **fake jets**
- Jet cleaning discriminating variables
  - ✦ Discriminating calorimeter noise
  - ✦ Energy ratios, tracking information
  - ➡ Jet quality selection to define a **loose** and a **tight** jet cleaning





- **Loose** selection efficiency: **>99.5 %**
- **Tight** selection efficiency: **>95% , >99% if jet p_T>100 GeV**

Jet calibration for Run2



ATLAS-PHYS-PUB-2015-015

- The idea is to be **based on** the **Run-I knowledge**
- Use the **2012** in-situ (Z/gamma+jet, Multijet balance)
- In-situ are applied to data only, and **derived wrt to 2012 simulation**
- Need to **apply** a **correction/uncertainty** based on **2012→2015 simulation changes** to **maintain** the **applicability** of the 2012 in-situ corrections to **2015 data**
  - *Detector:* IBL - added material because of IBL services, mainly in the forward region
  - *Beam conditions:* 8→13 TeV (flavor comp., underlying event); 50→25 ns (pile-up)
  - *LAr and Tile calorimeter energy reconstruction updates*
  - *Topological clustering algorithm updates*
  - *Tracking reconstruction updates (IBL)*
  - *Geant4 detector simulation updates*

Jet energy related uncertainties in Run2

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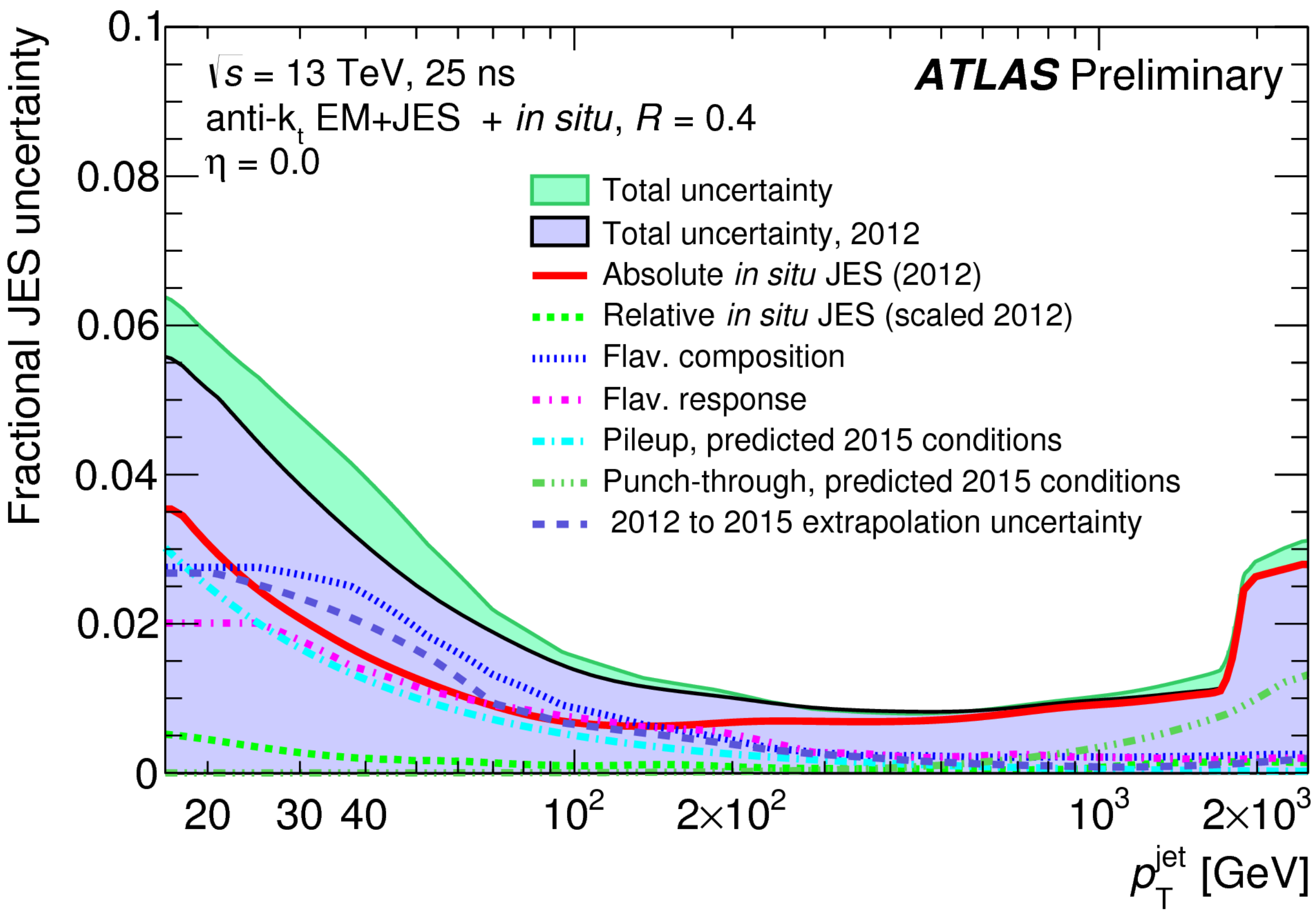
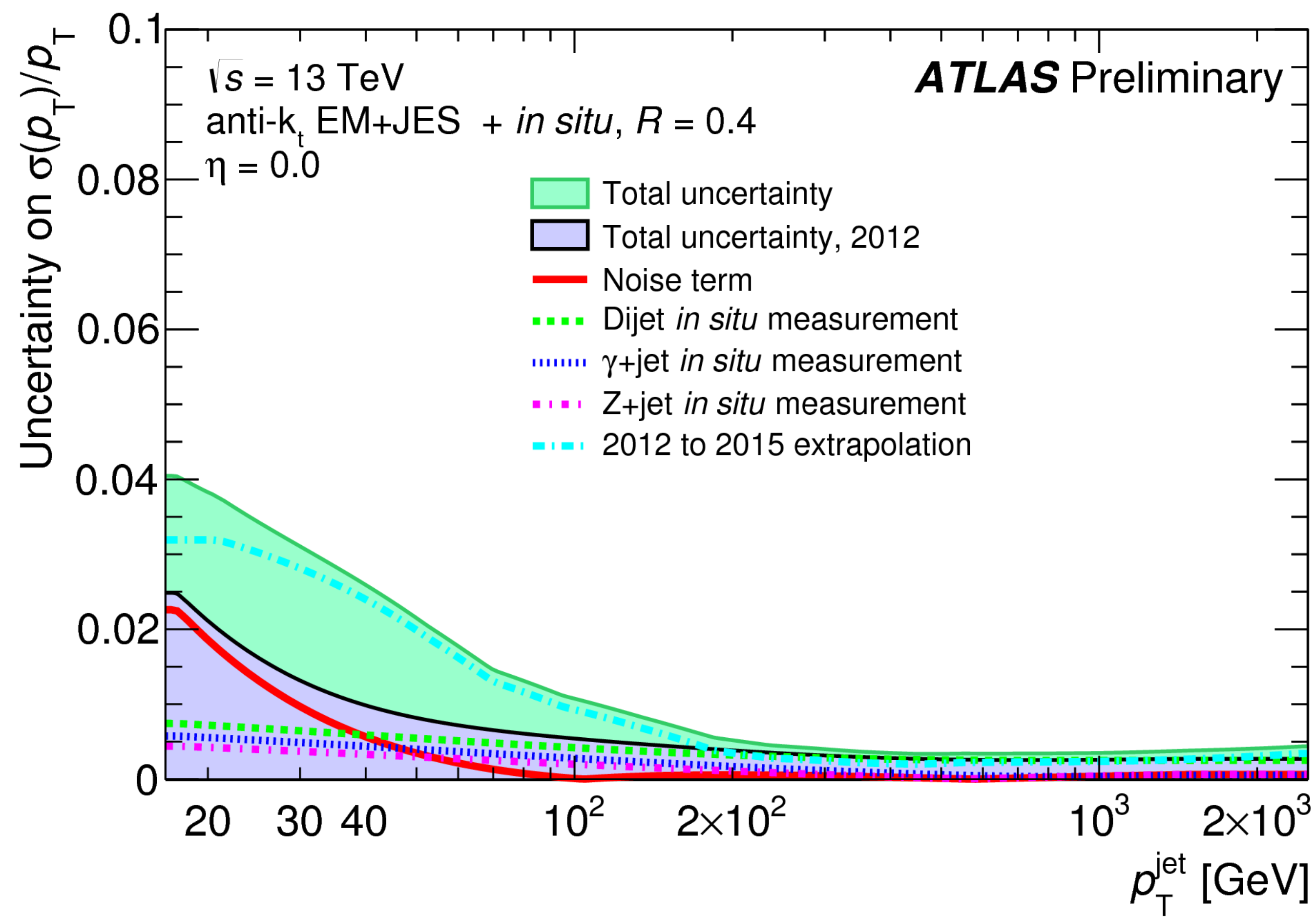
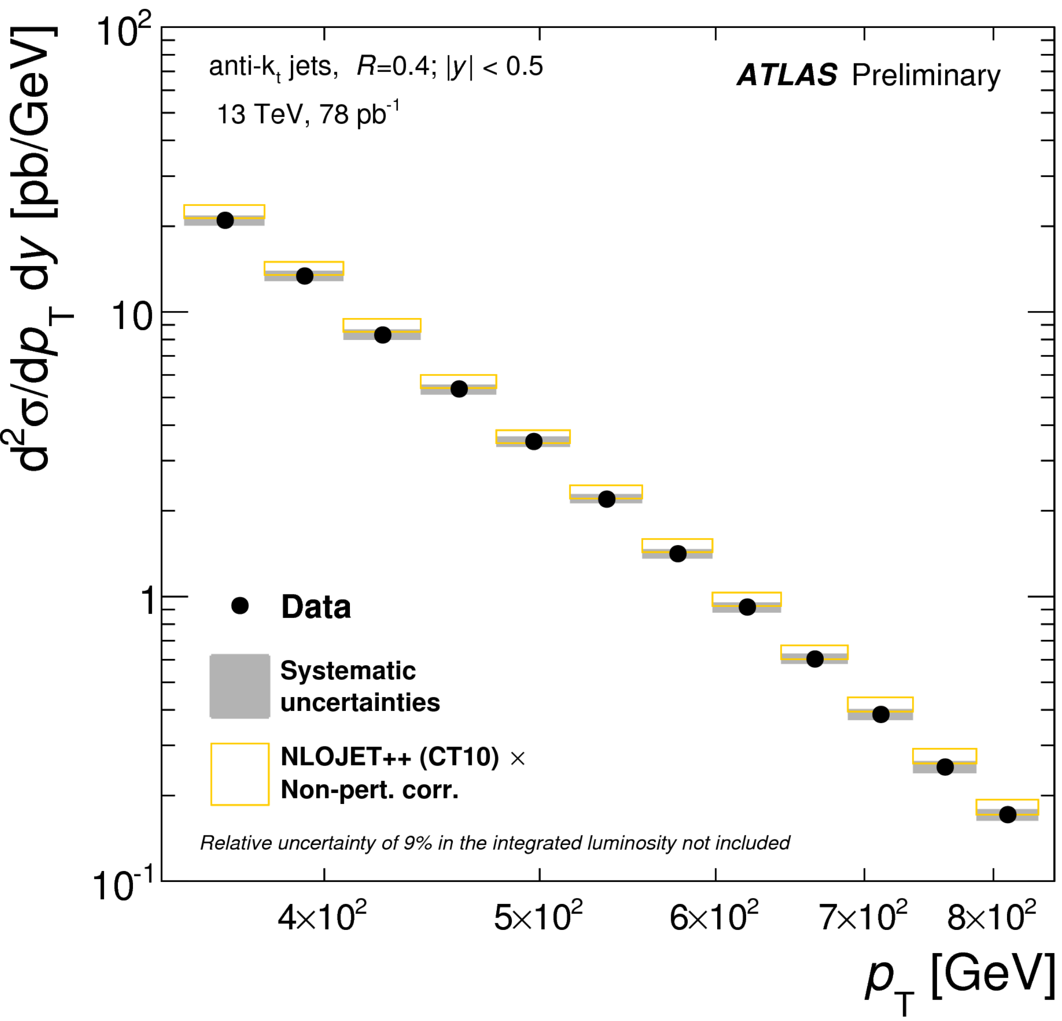


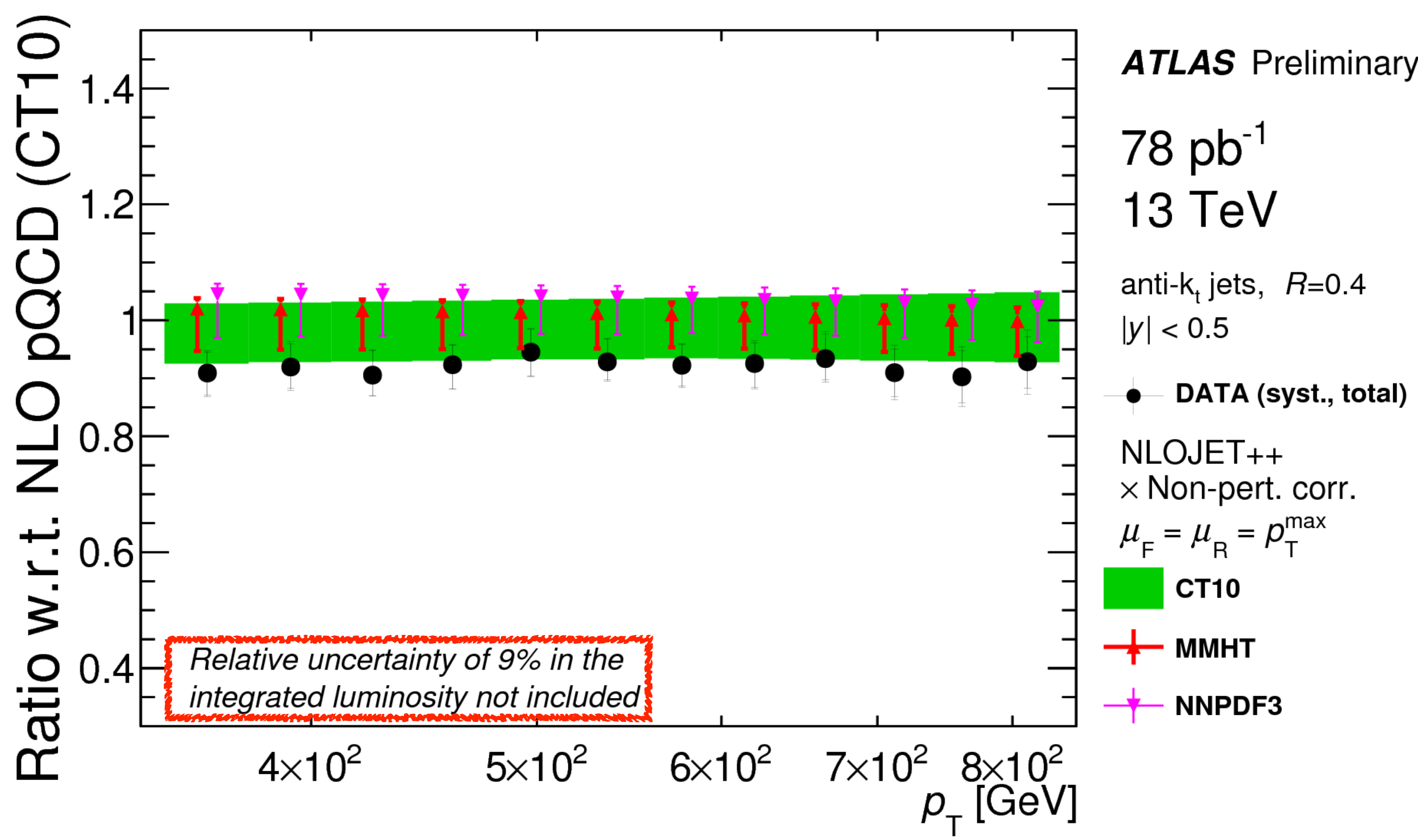


- **~3%** additional uncertainty **with respect to Run 1** originating from the 2012 to 2015 conditions extrapolation uncertainty, **quickly falling with p_T**
  - **Negligible** for jet **p_T > 200 GeV**

First inclusive jet x-section in Run 2

- **Run 2 jet performance in physics analysis action!** ATLAS-CONF-2015-034
- **Inclusive jets cross-section** measurement using the **first 13 TeV data**
  - ✦ $350 < pT < 840$ GeV and $|y_{jet}|<0.5$
  - ✦ Single jet trigger, fully efficient above 300 GeV
  - ✦ Dominant systematic: jet energy scale





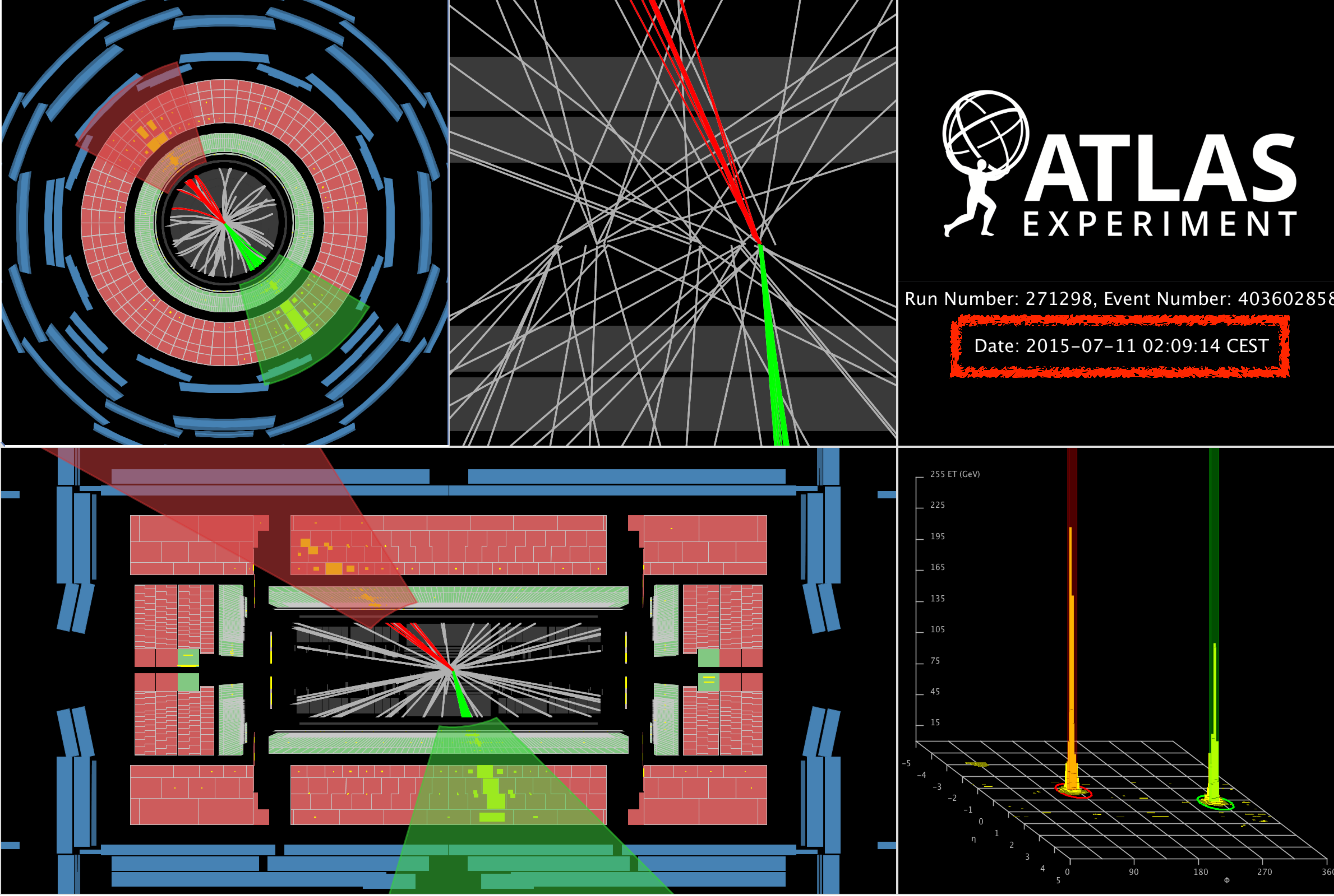
NLO QCD predictions are consistent with the measured cross sections

Conclusions

- **Run 1 jet performance paves the way towards Run 2**
  - **Global Sequential Calibration** to improve MC JES and flavour uncertainty
  - **Strong reduction** of JES uncertainties nuisance parameters
  - **JER** measured in data
    - Measure noise term with data
    - Combine 3 in-situ measurements
  - New approach to **tag** and **reject forward pileup jets**

- **Run 2 jets (being) studied and (being) validated**
  - **Performance reasonably understood in a very short time scale**
  - More robust checks and complete jet performance studies will be done as we will be collecting more data in Run 2

➡ **ATLAS Run 2 jets ready for ambitious physics program**



– Jet-1 p_T = 1.47 TeV, Jet-2 p_T = 1.40 TeV, m_{jj} = 3.25 TeV

References

- Run1
  - GSC: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2015-002/
  - JES/JER: ATLAS-CONF-2015-037 https://twiki.cern.ch/twiki/bin/view/AtlasPublic/JetEtmissPublicResults
  - Dijet/Multijet: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2015-017/
  - Forward jets pileup suppression: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2015-034/

- Run2
  - Jet inputs: ATL-PHYS-PUB-2015-036 https://twiki.cern.ch/twiki/bin/view/AtlasPublic/JetEtmissPublicResults
  - Jet cleaning : http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2015-029/
  - JES/JER : http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2015-015/

- JES uncertainty nuisance parameter reduction
  - http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2015-014/

- **All Jet/E_T^{miss} related ATLAS public results in one twiki**

Back-up

Forward pileup rejection

Remove pileup forwards jets

$$\text{corrJVF} = \frac{\sum_k p_T^{\text{trk}_k}(\text{PV}_0)}{\sum_l p_T^{\text{trk}_l}(\text{PV}_0) + \frac{\sum_{m\geq 1}\sum_l p_T^{\text{trk}_l}(\text{PV}_m)}{(k \cdot n_{\text{trk}}^{\text{PU}})}}.$$

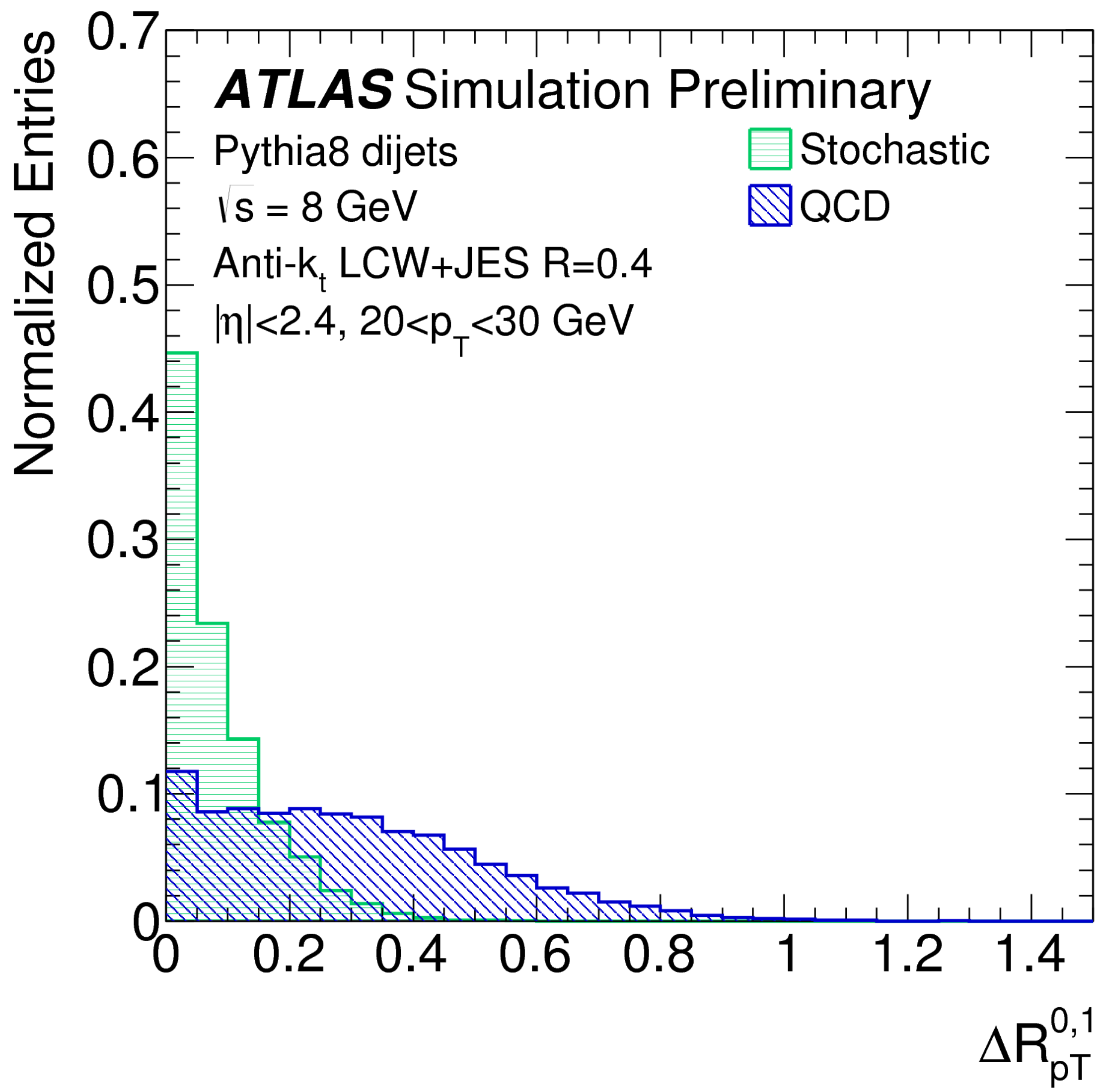
$$R_{\text{pT}} = \frac{\sum_k p_T^{\text{trk}_k}(\text{PV}_0)}{p_T^{\text{jet}}}$$

The variable **R**pT is defined as the scalar **p**T sum of the tracks that are associated with the jet and originate from the hard-scatter vertex divided by the fully calibrated jet **p**T, which includes pileup subtraction:

QCD jets, where the particles in the jet come from a single pileup interaction,

stochastic jets, that combine particles from different vertices in the high density particle flow.

Forward jet vertex tagging



$$R_{\mathrm{pT}} = \frac{\sum_k p_{\mathrm{T}}^{\mathrm{trk}_k}(\mathrm{PV}_0)}{p_{\mathrm{T}}^{\mathrm{jet}}}$$

Remove HS central jets
JVT < 0.05

↓

Remove stochastic PU central jets with ΔR_{pT}

↓

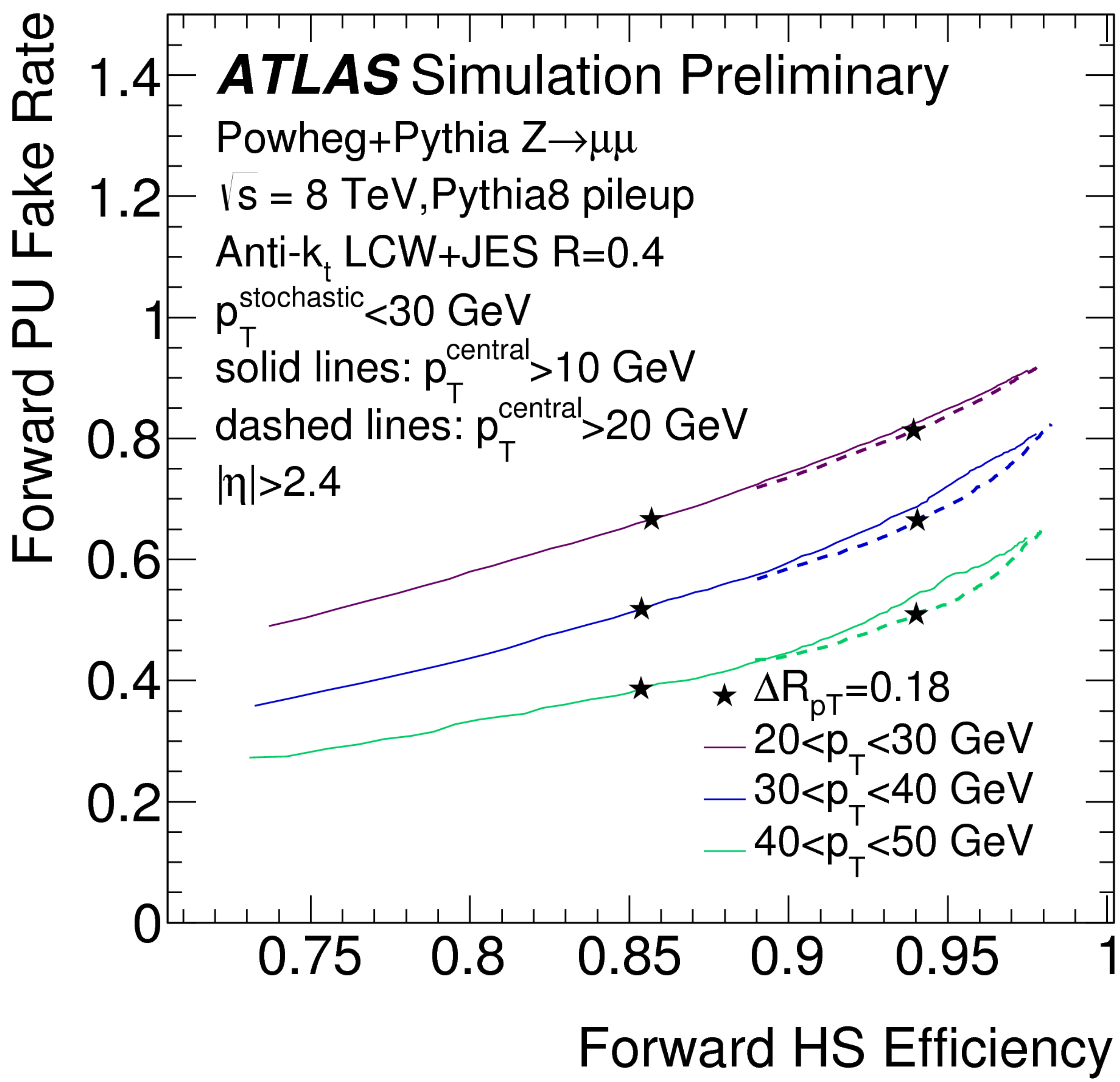
Match forward jets to back-to-back PU QCD central jets with $|\Delta\varphi| > \pi - 1$

↓

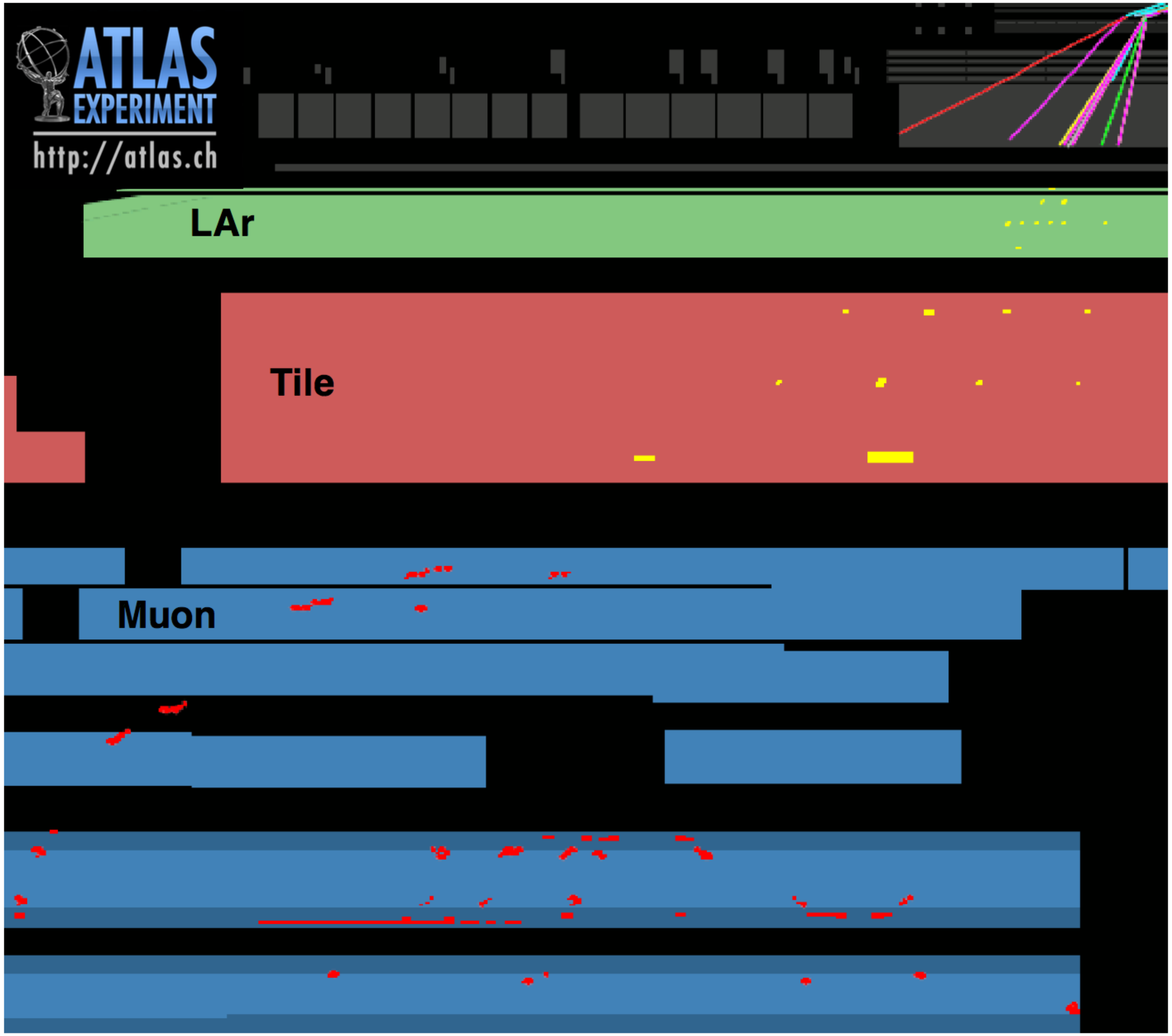
Remove forward jets matched to central jet.

Remove pileup forwards jets

- Forward JVT cut hard-scatter efficiency of 85 (94)% , if $p_T^{central}$>10 (20) GeV
- fJVT removes the dependence of jet multiplicity on the N_{PV} for jets p_T>30 GeV



GSC



GSC variables

ATLAS-CONF-2015-002

$$f_{\mathrm{layer}} = \frac{E_{\mathrm{EM}}^{\mathrm{layer}}}{E_{\mathrm{EM}}^{\mathrm{jet}}}$$

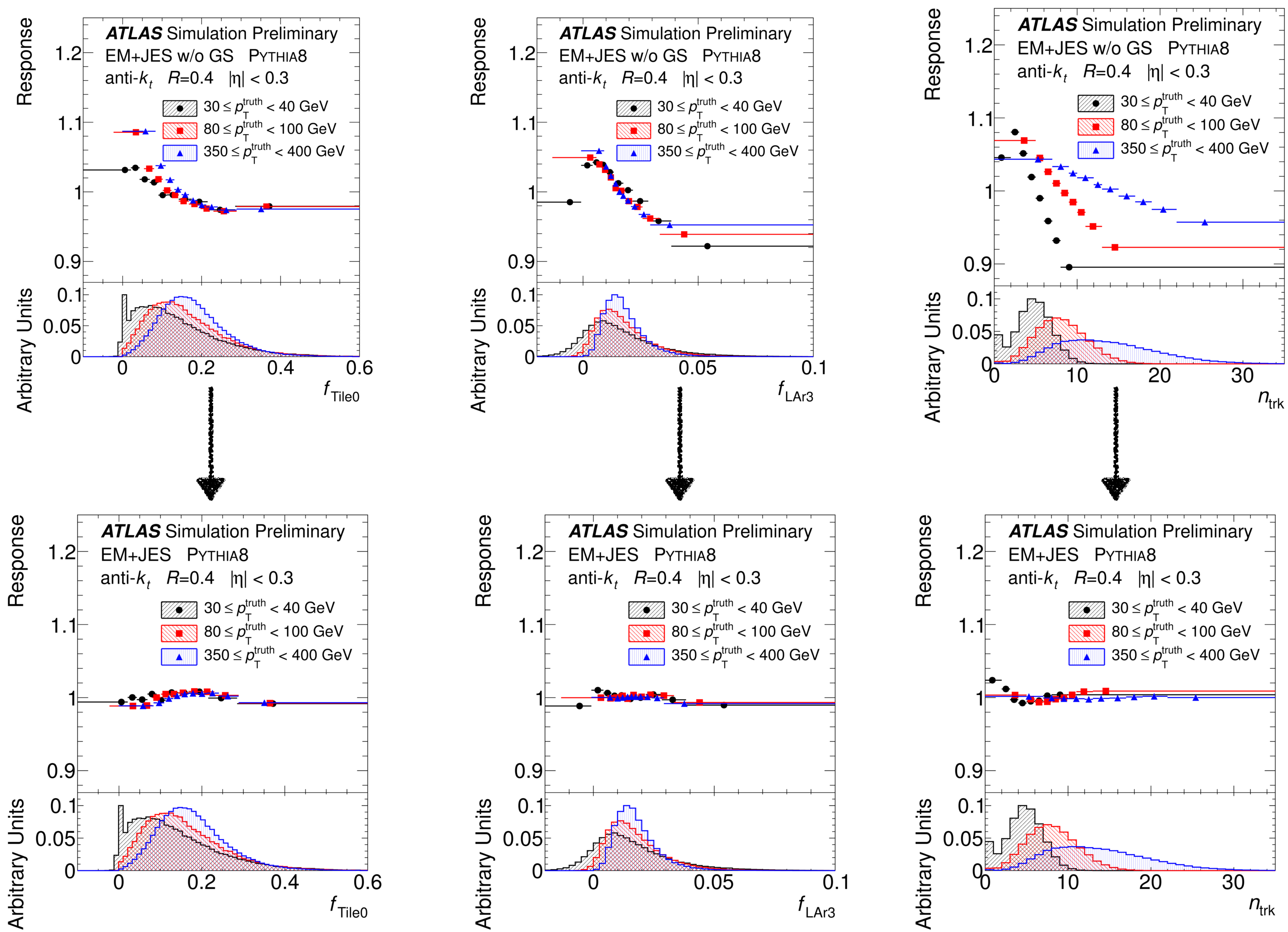
Close to a transition region between calorimeter modules, the transverse extension or width of a jet is correlated to how many particles of the jet hit the poorly instrumented transition region.

$$width_{\mathrm{trk}} = \frac{\sum_{\mathrm{i}} p_{\mathrm{T}}^{i} \Delta R(i,\mathrm{jet})}{\sum_{\mathrm{i}} p_{\mathrm{T}}^{i}}$$

average distance between the tracks associated to the jet and the calorimeter jet axis, weighted by the track **p**T

GSC variables

ATLAS-CONF-2015-002

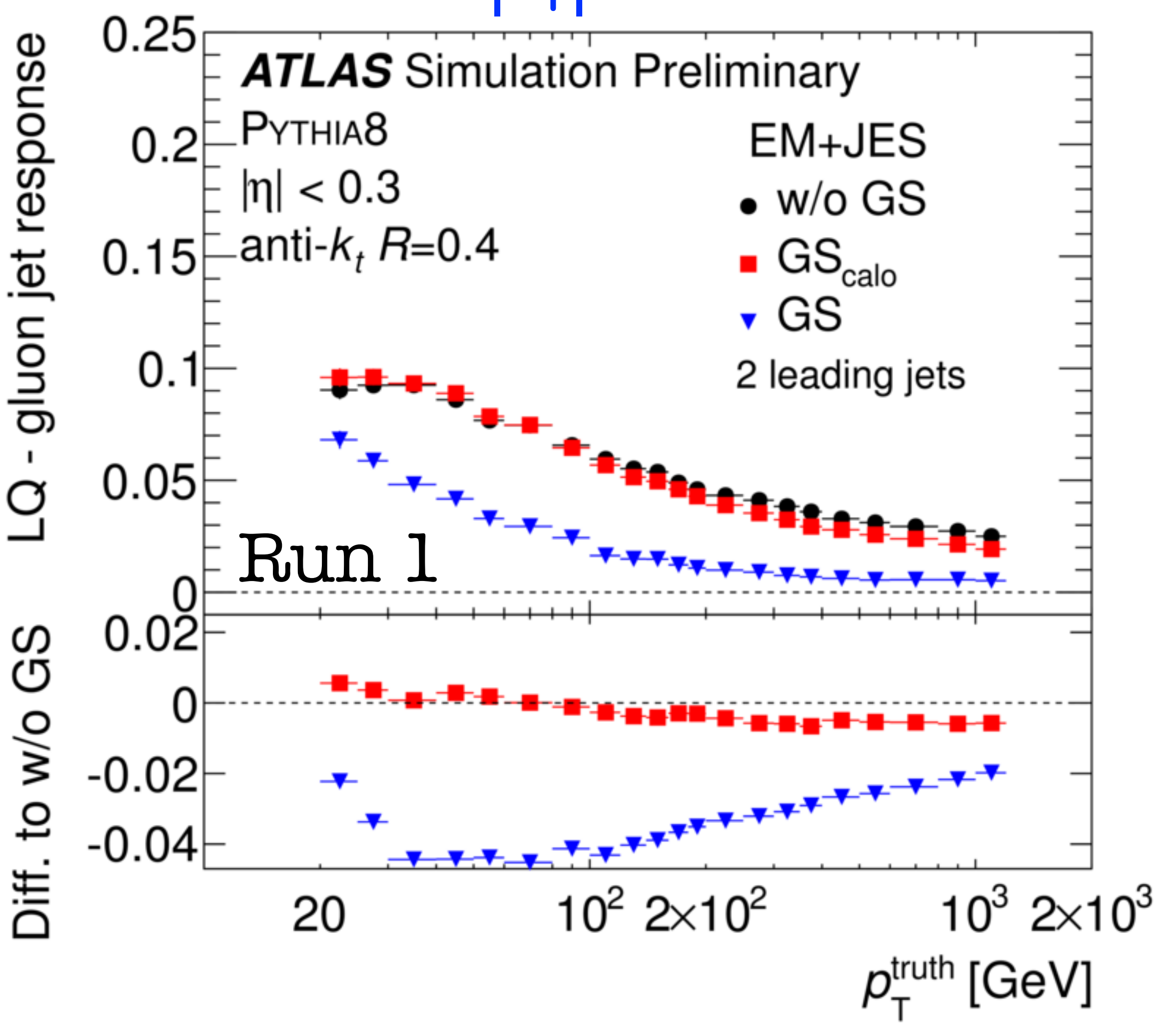


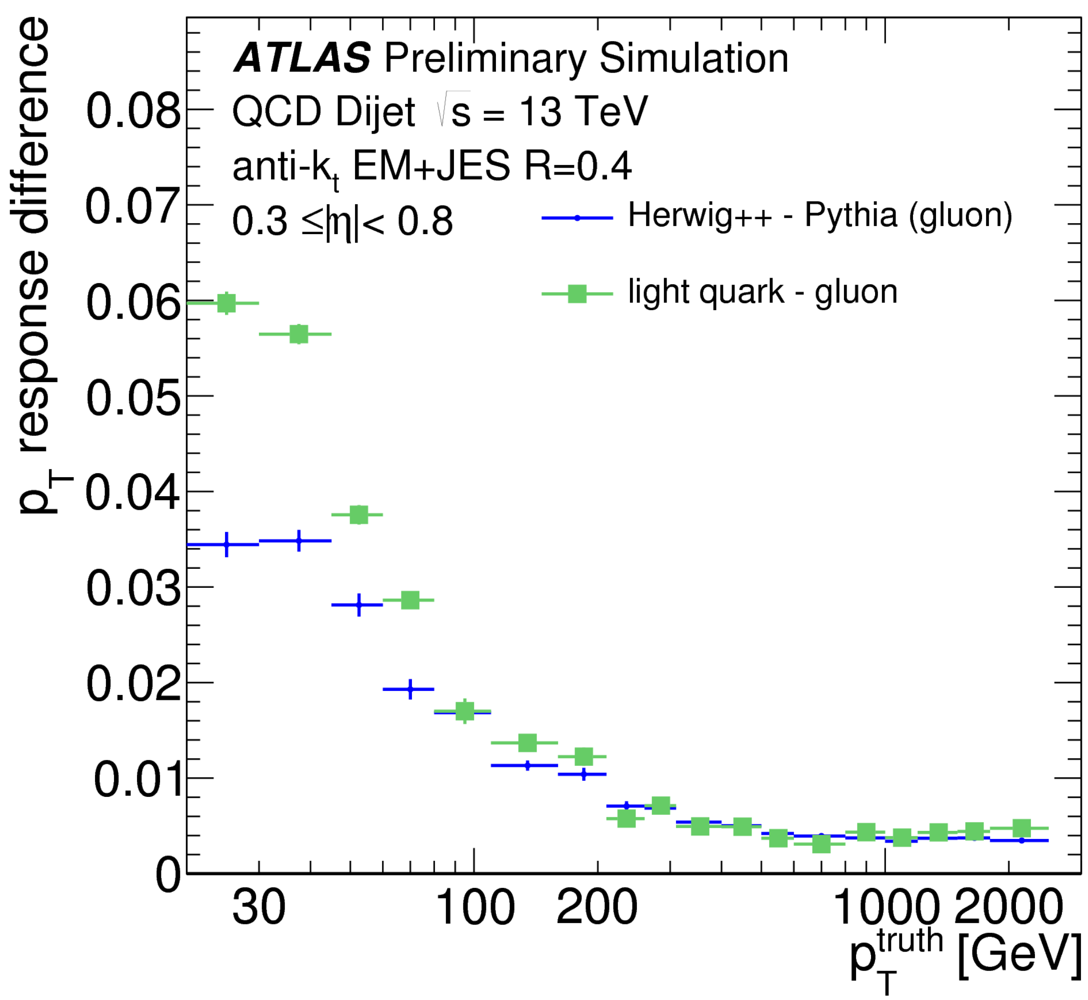
Global Sequential Calibration

ATLAS-CONF-2015-002

- GSC significantly improves jet flavour response, and consequently the related uncertainty
- Tracking variables discrimination power with respect to jet flavour

|η| < 0.3

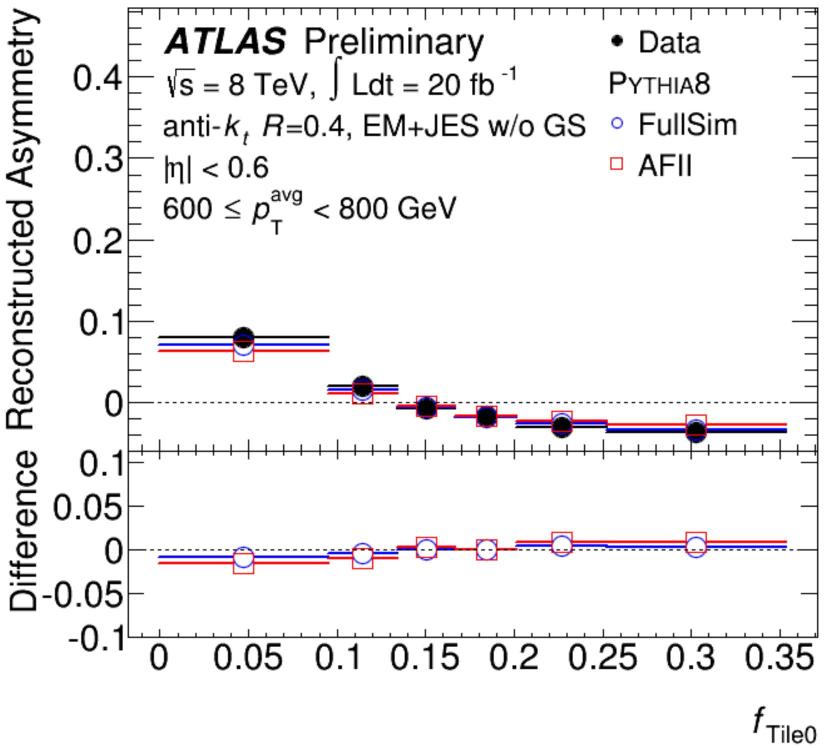


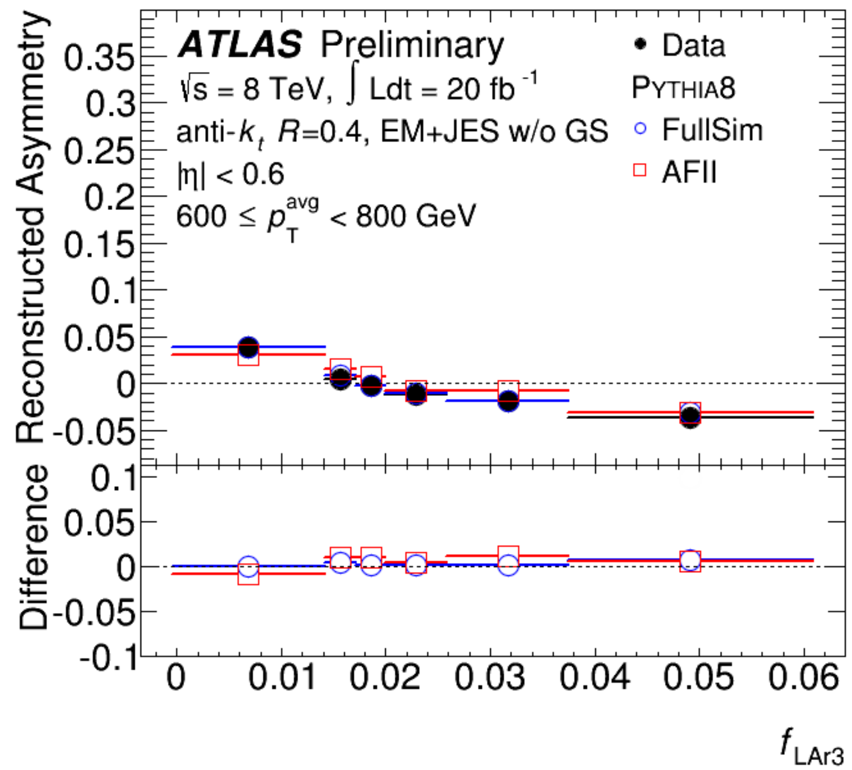


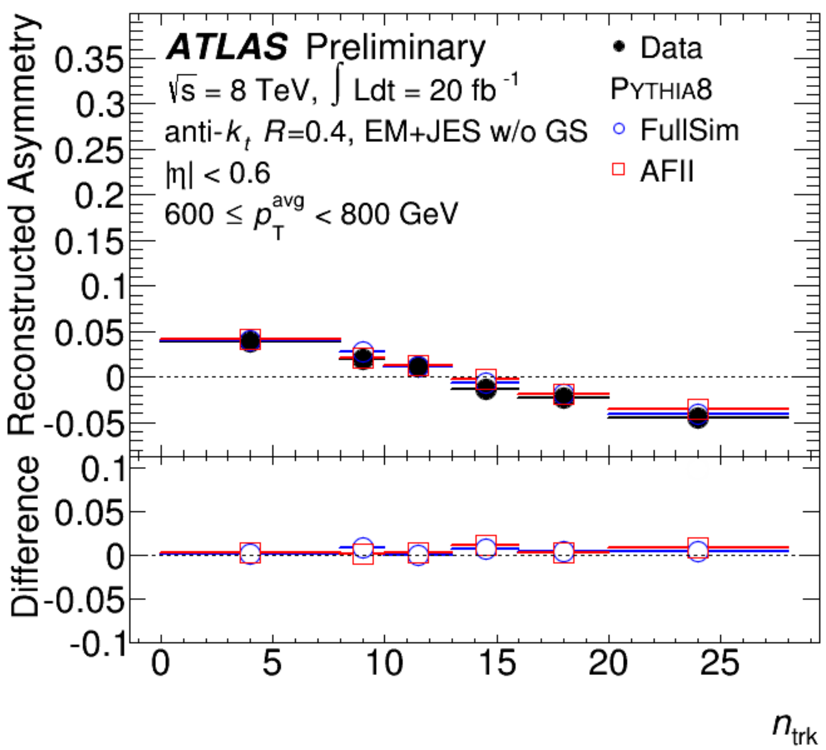
➡ **Need to validate all these quantities in Run 2**

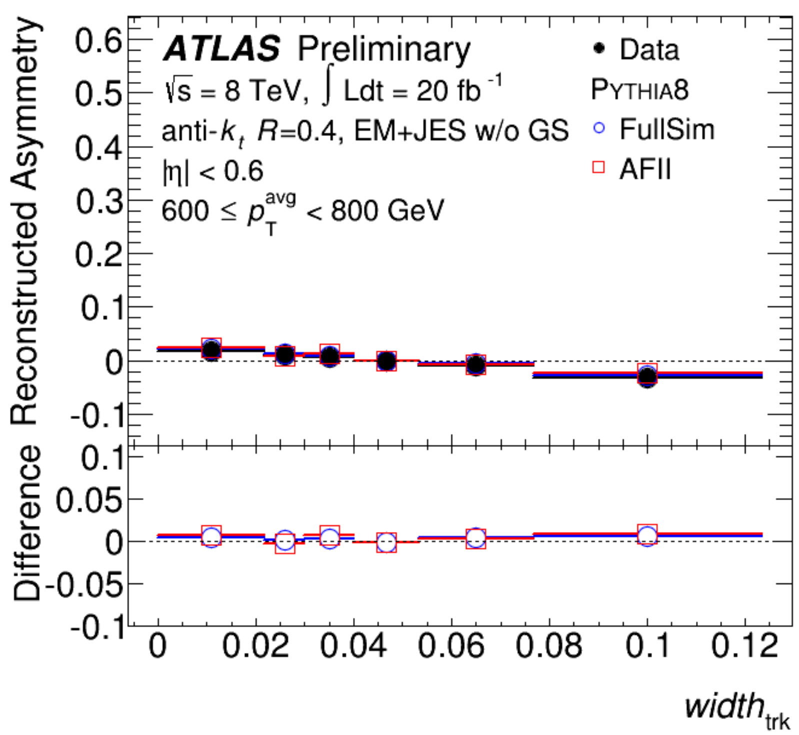
GSC validation

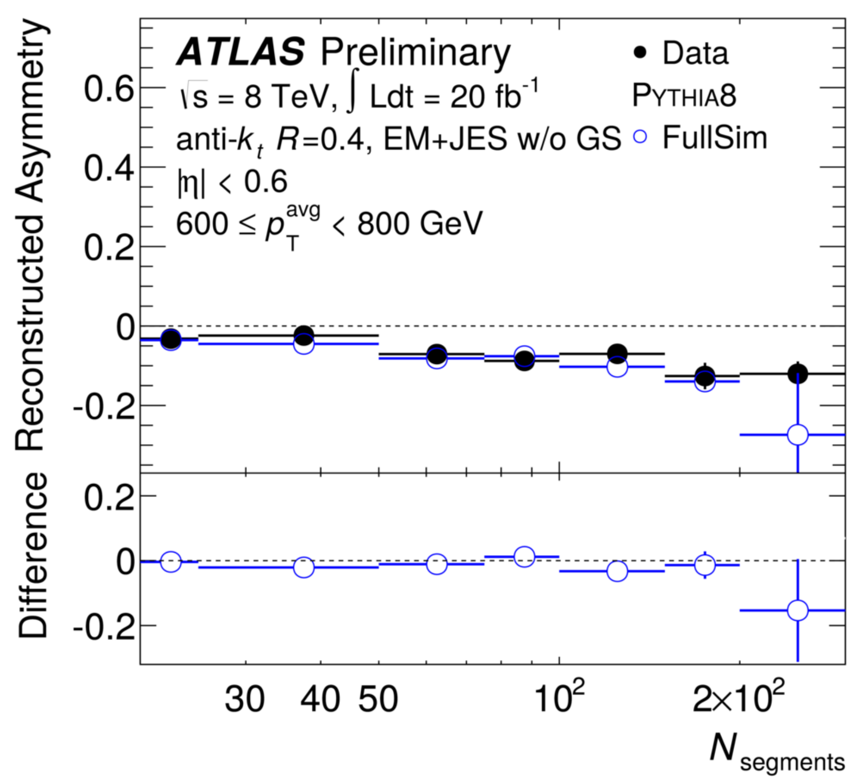
ATLAS-CONF-2015-002







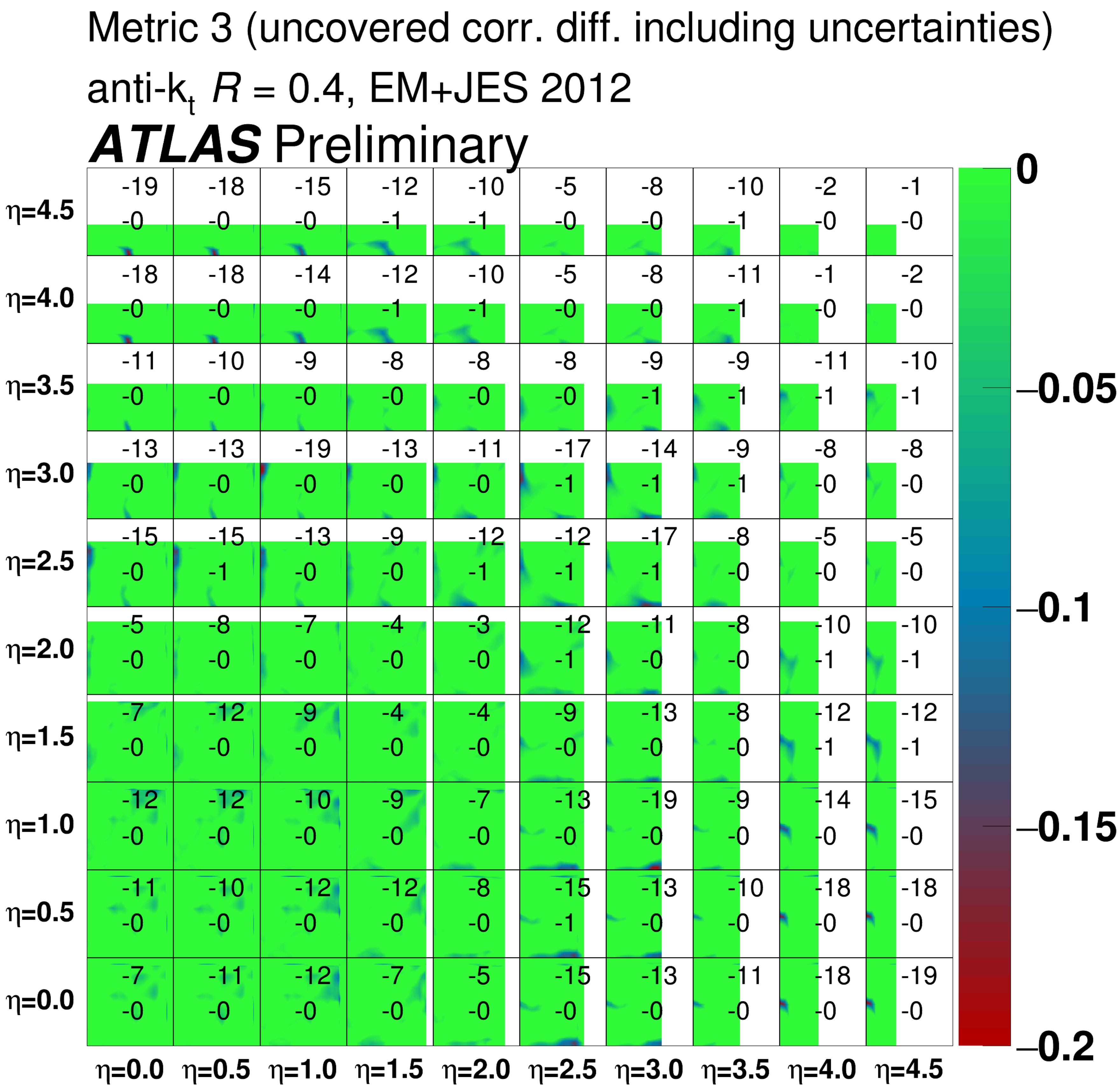




Strong NP reduction

Strong NP reduction

ATL-PHYS-PUB-2015-014

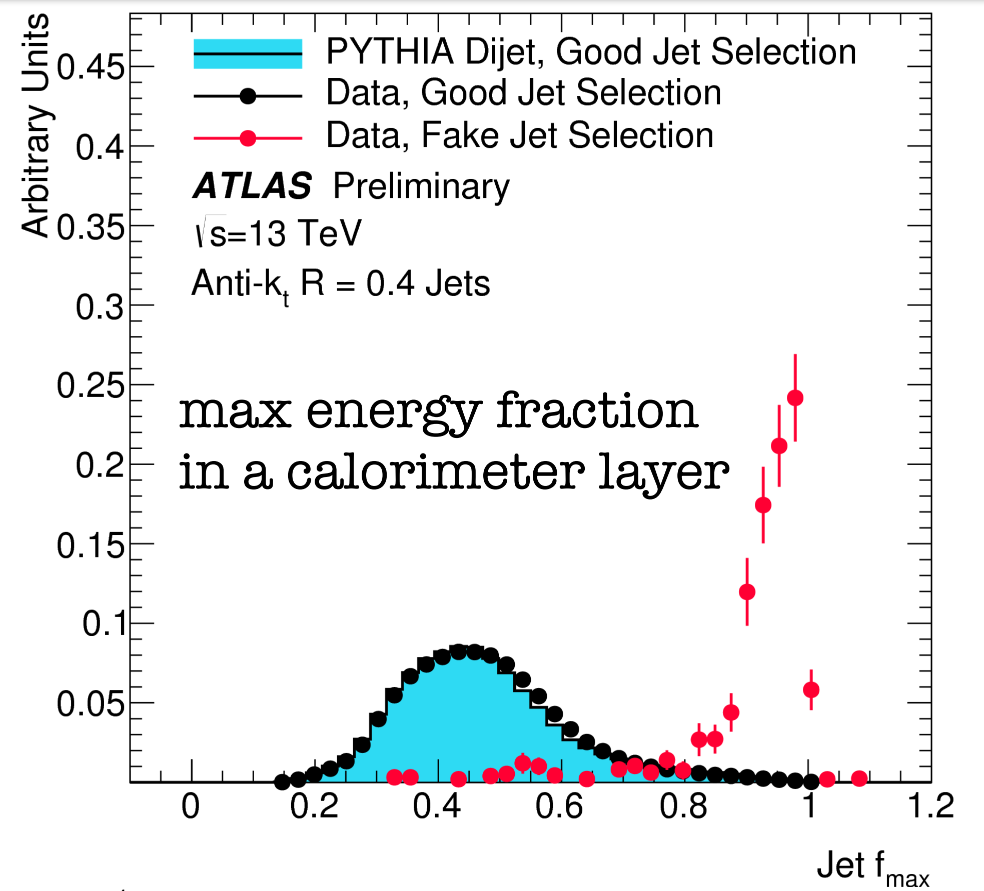


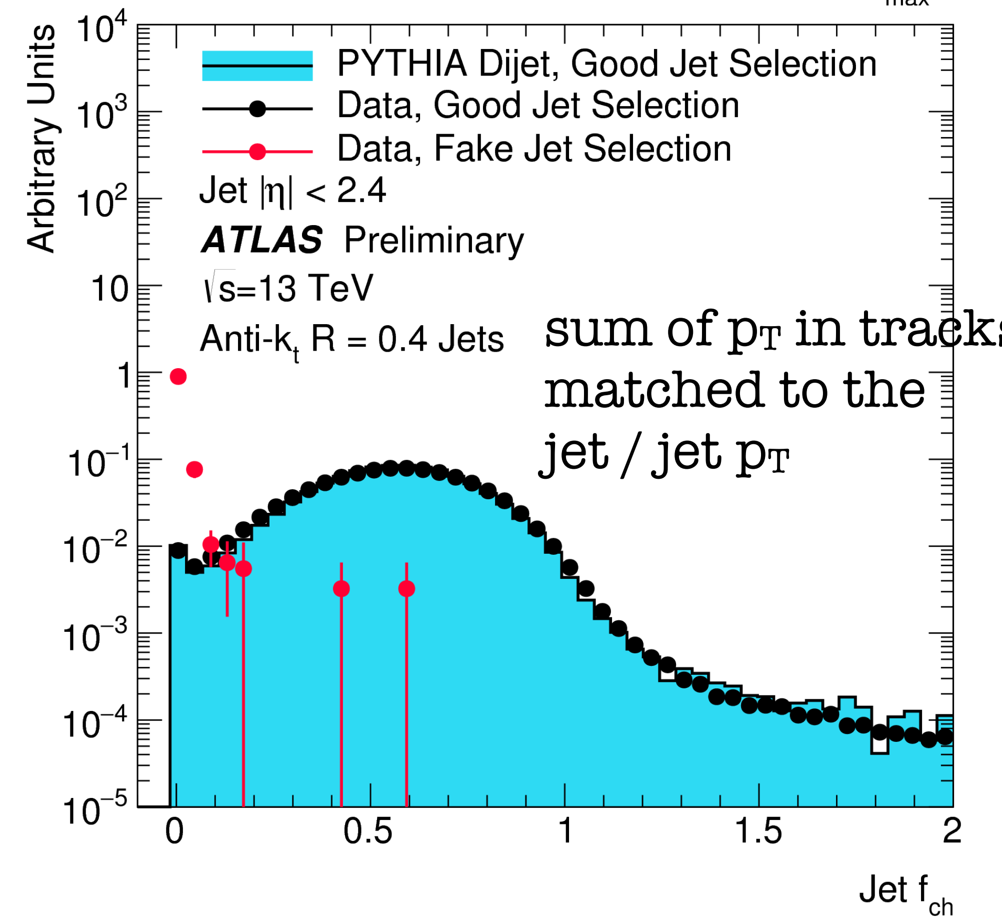
Jet cleaning

Jet cleaning @ 13 TeV

ATLAS-CONF-2015-029

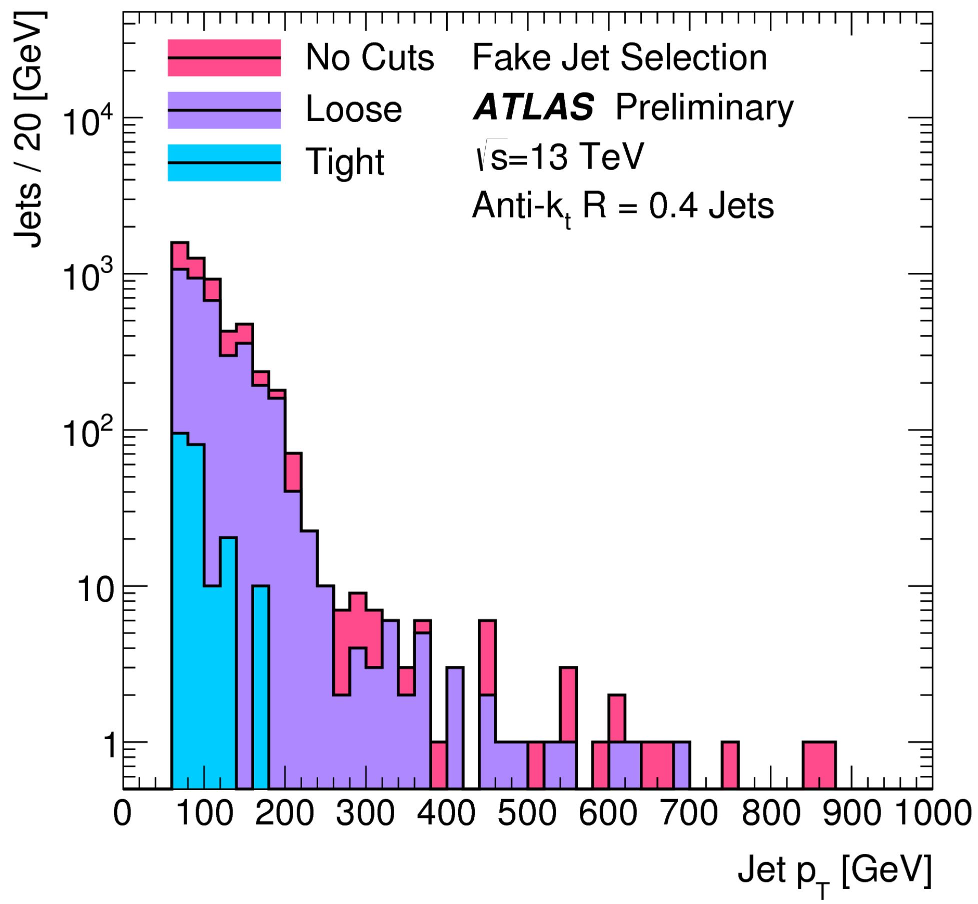
- Jets in pp collisions must be distinguished from fake jets originating from non collision sources
  - ✦ Beam induced background / cosmic-ray showers / calorimeter noise
- Use enriched samples of **good jets**
  - ✦ At least two jets with $p_T > 70$ GeV
  - ✦ $|\Delta\varphi_{jet1,jet2}| > 3.0$
  - ✦ $|p_T^{jet1} - p_T^{jet2}| / |p_T^{jet1} + p_T^{jet2}| < 0.3$
- Use enriched samples of **fake jets**
  - ✦ At least two jets with $p_T > 70$ GeV
  - ✦ Unbalanced Transverse Momentum: $-\Sigma_{jets}\vec{p_T} > 70$ GeV
  - ✦ $|\Delta\varphi_{jet1,UTM}| > 3.0$
  - ✦ Out-of-time $|t_{jet1}| > 6$ns
- Jet cleaning discriminating variables
  - ✦ Discriminating calorimeter noise
  - ✦ Energy ratios, Track based
  - ➡ Jet quality selection to define a **loose** and a **tight** jet cleaning

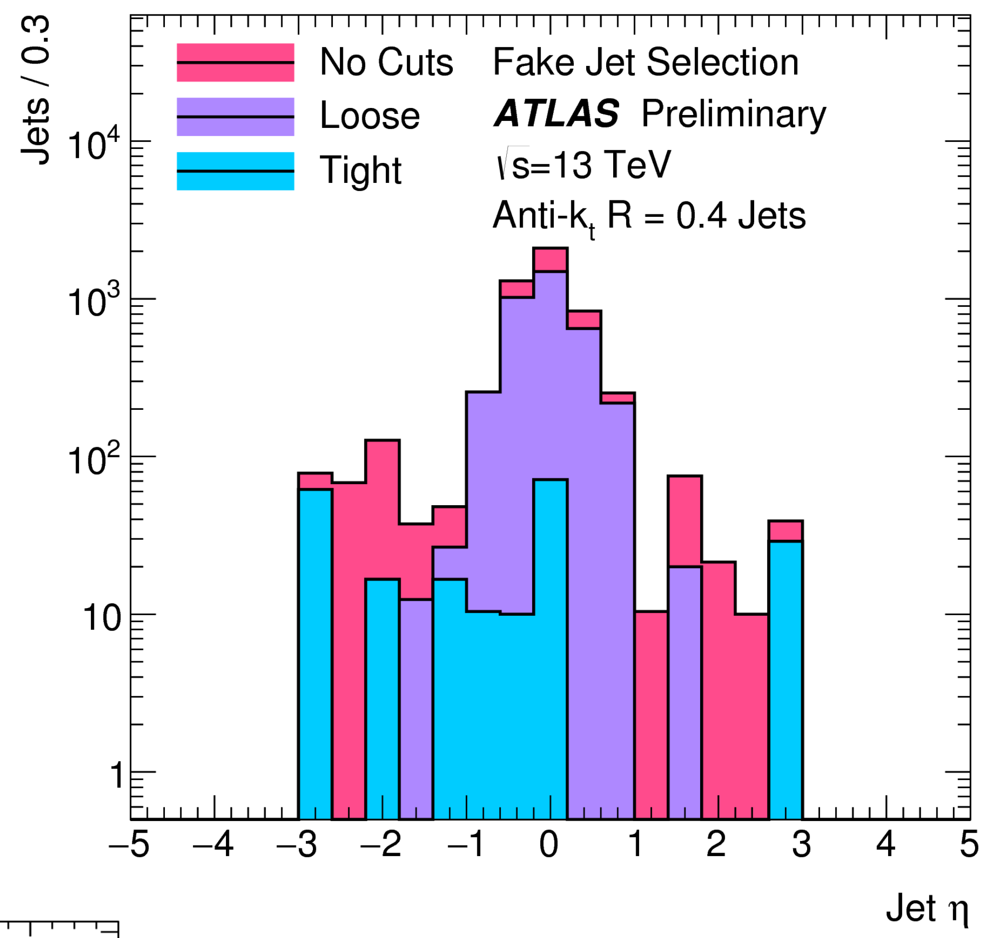




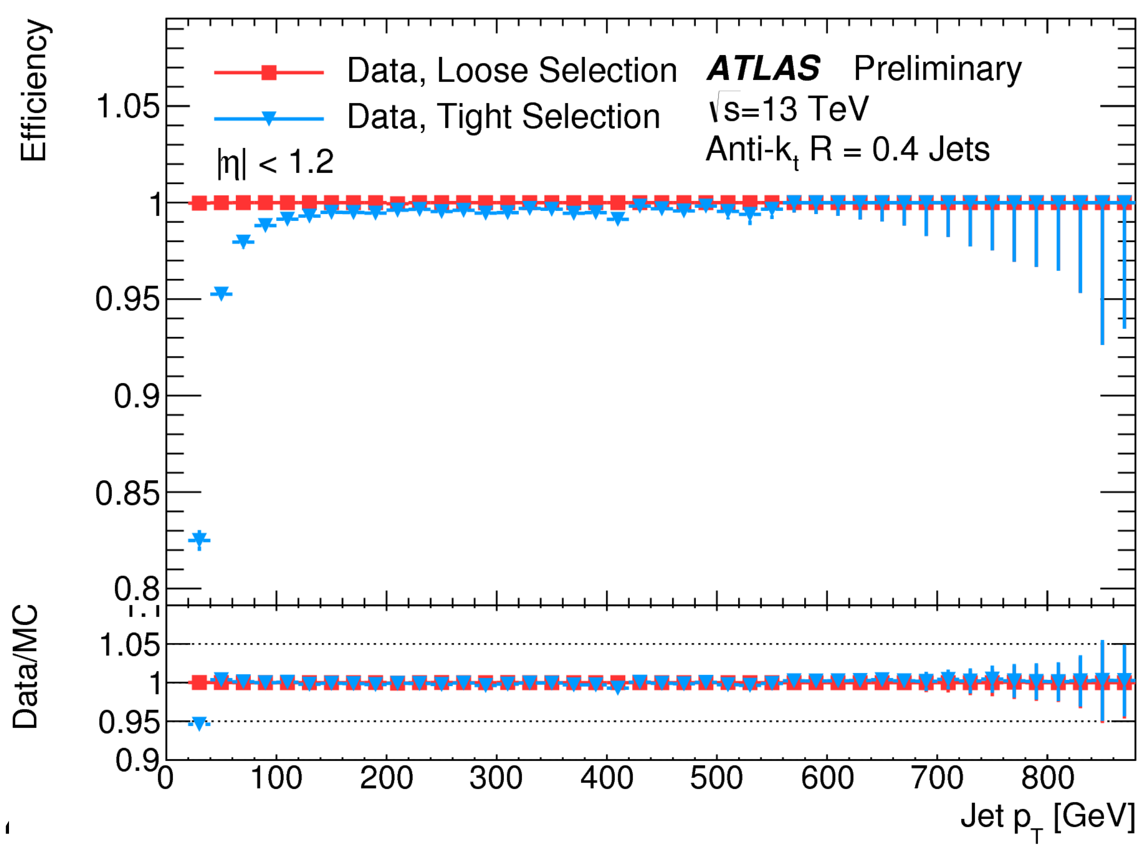
Jet cleaning performance

ATLAS-CONF-2015-029





- Cleaning cuts very efficient in rejecting most of fake jets



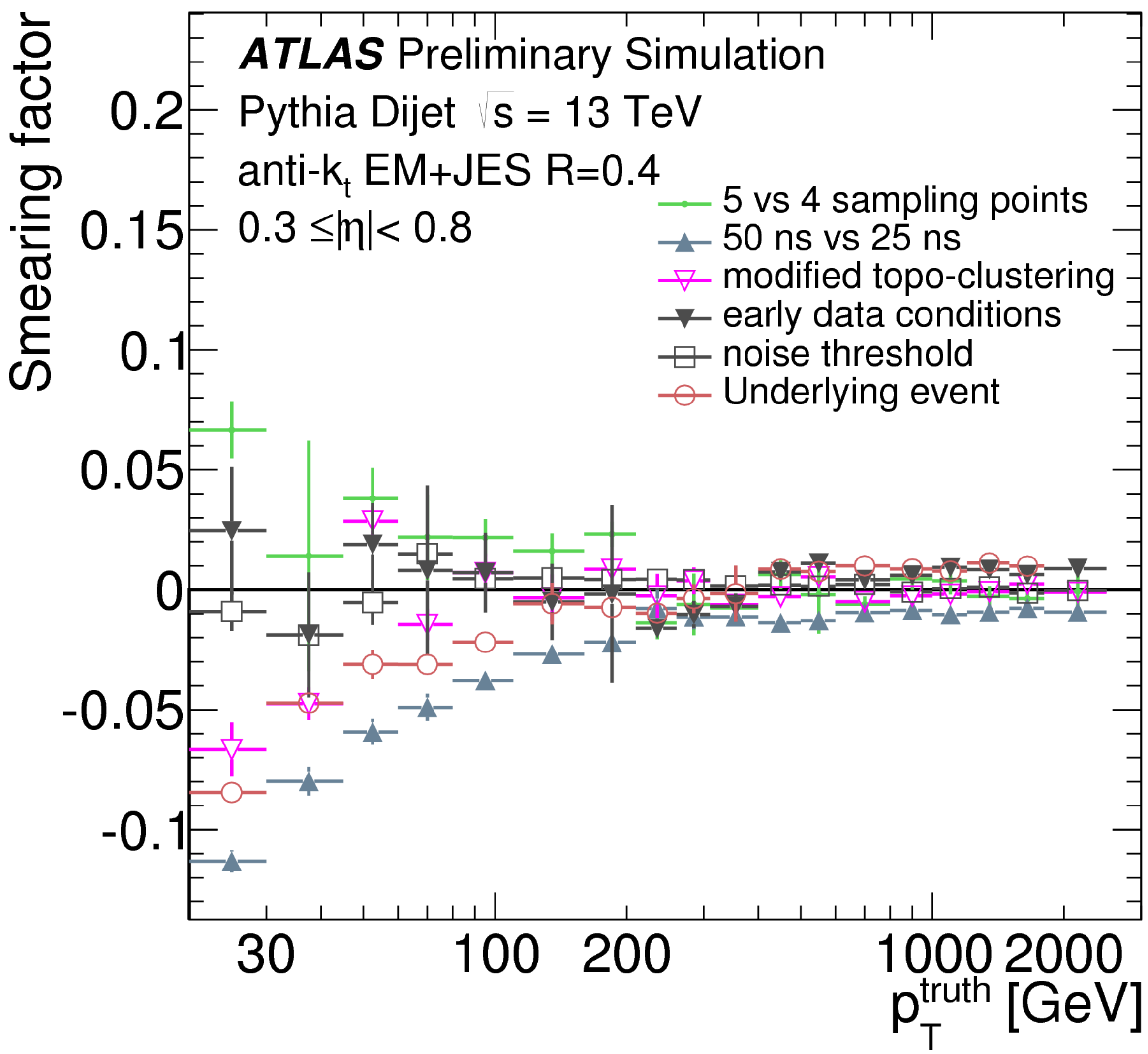
- Loose selection efficiency
  - >99.5 %
- Tight selection efficiency
  - >95% , >99% if jet p_T > 100 GeV
  - Larger rejection of fake jets wrt tight selection
  - Specific for analyses that are sensitive to non-collision backgrounds

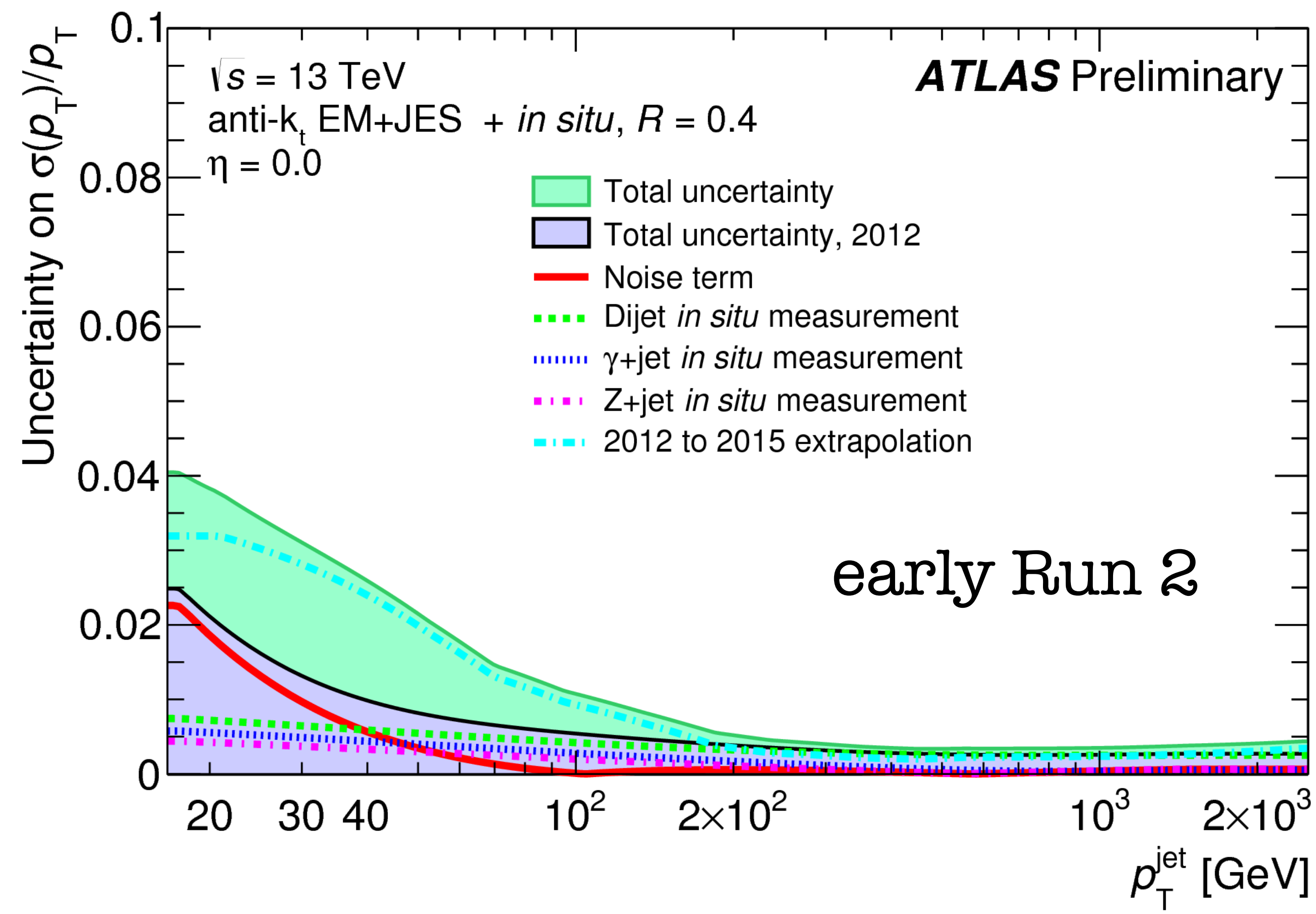
JES / JER

Jet energy resolution in early Run2

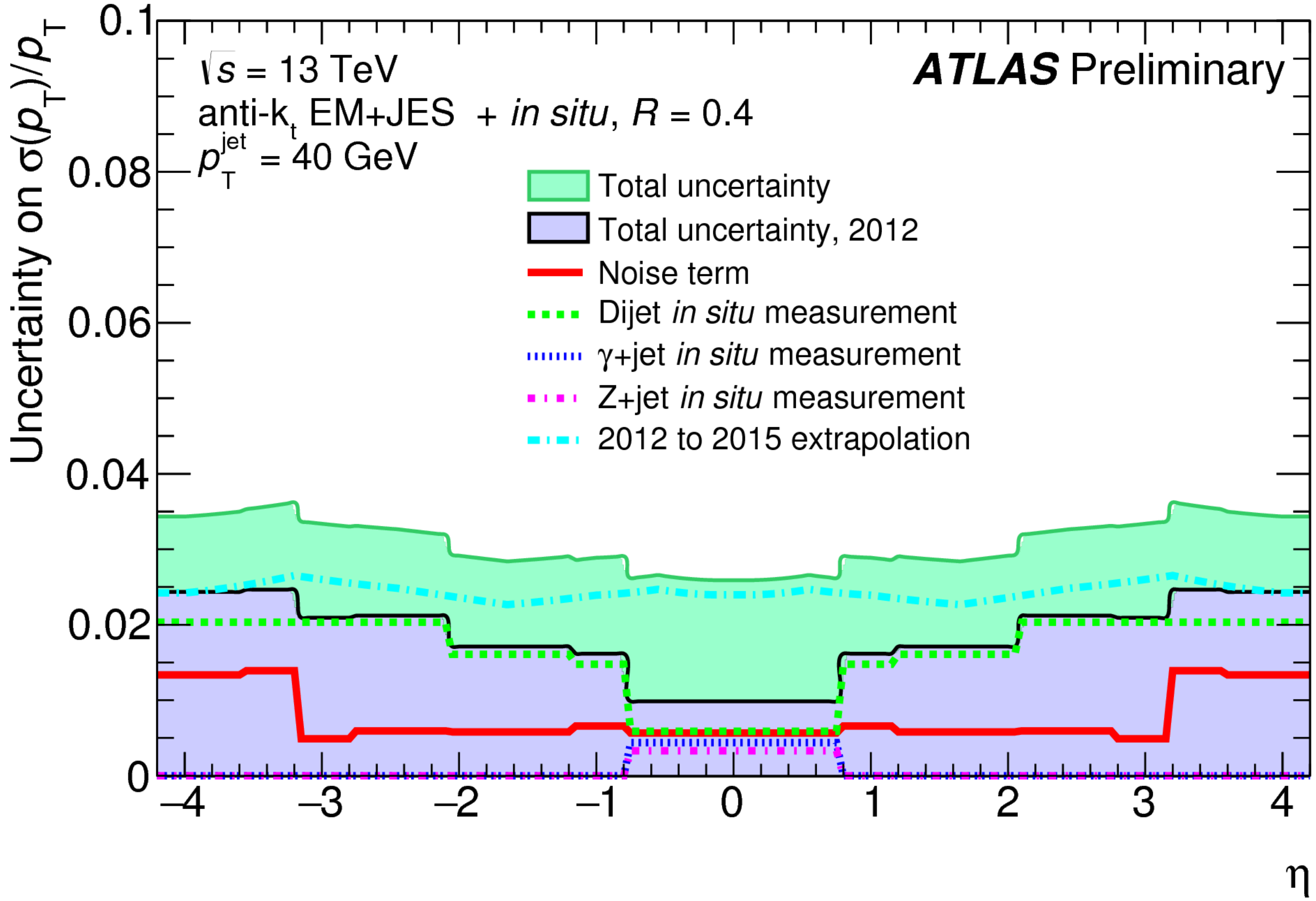
ATL-PHYS-PUB-2015-015

- Assume the same jet energy resolution as in Run1
- Jet energy resolution uncertainty estimated similarly to JES uncertainty
- 2012 → 2015 conditions extrapolation to jet energy resolution





Jet energy resolution in early Run2



Jet energy resolution

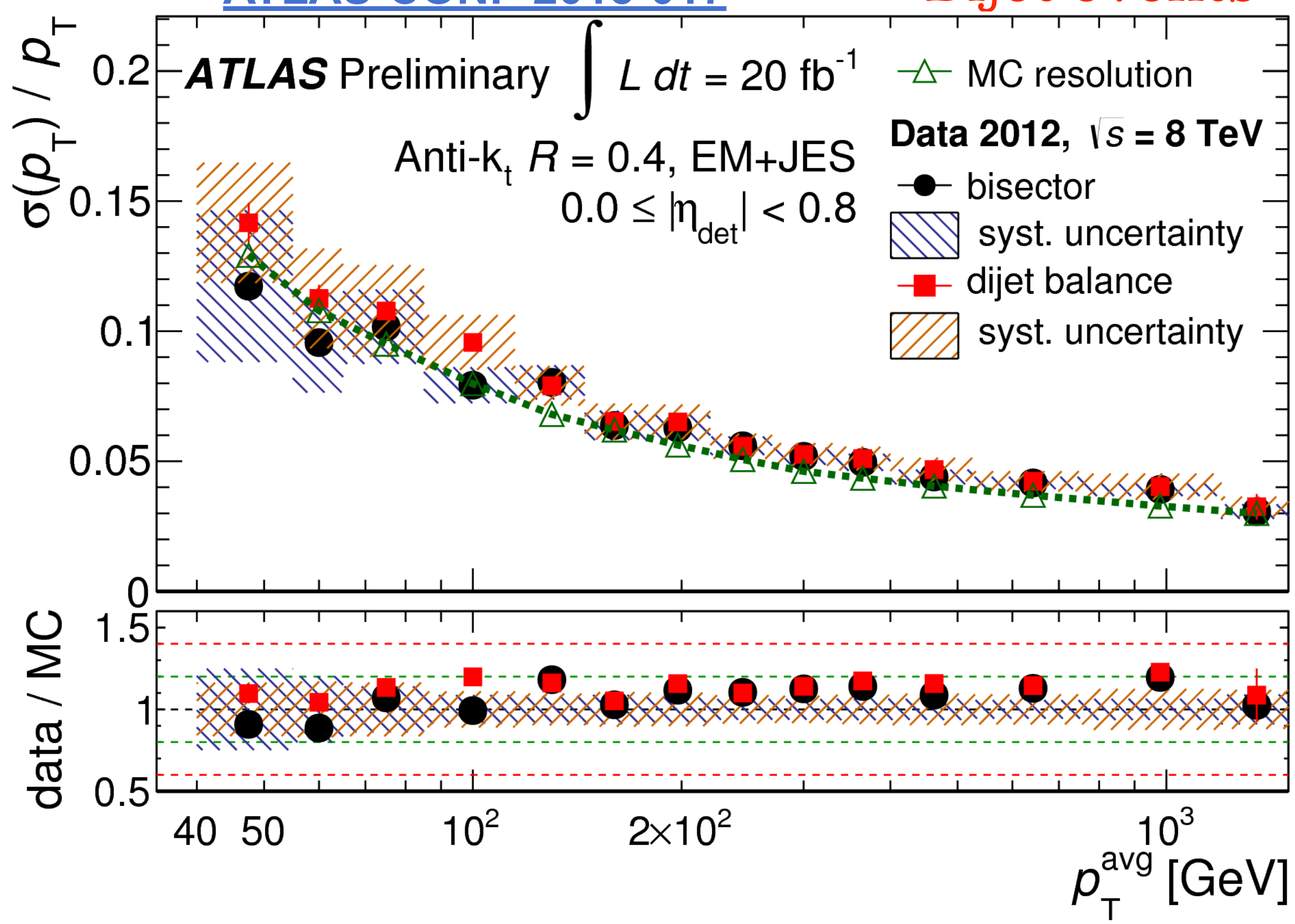
- Jet energy resolution:

$$\frac{\sigma_{p_T}}{p_T} = \frac{N}{p_T} \oplus \frac{S}{\sqrt{p_T}} \oplus C$$

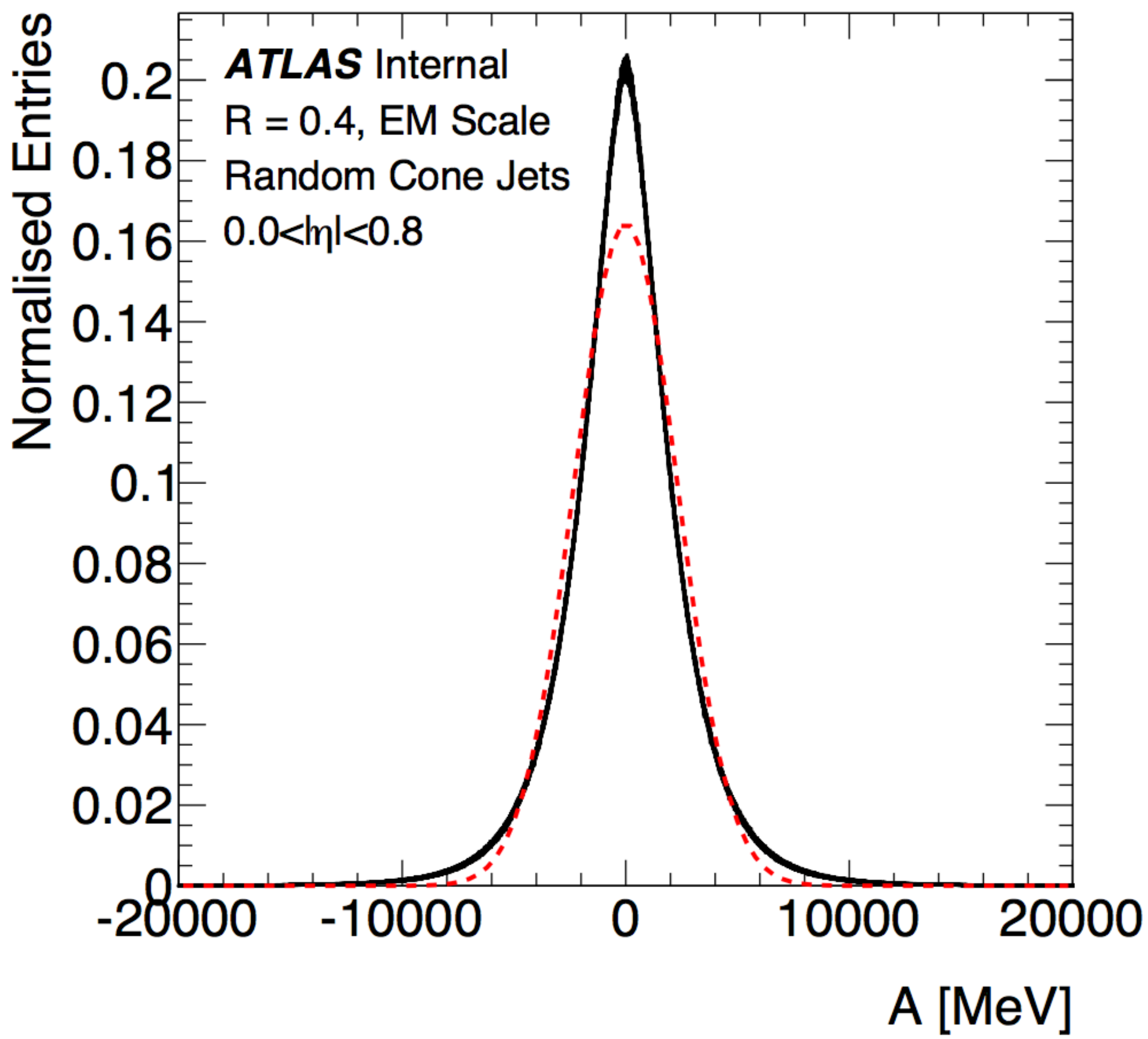
noise term (N), stochastic term (S), constant (C)

- Plan to combine the three γ+jet, Z+jet and dijet in-situ measurements similarly to what is done for the JES
- In high p_T JER is driven from dijet analysis with a precision of 3-12%

ATLAS-CONF-2015-017 Dijet events



Jet energy resolution noise

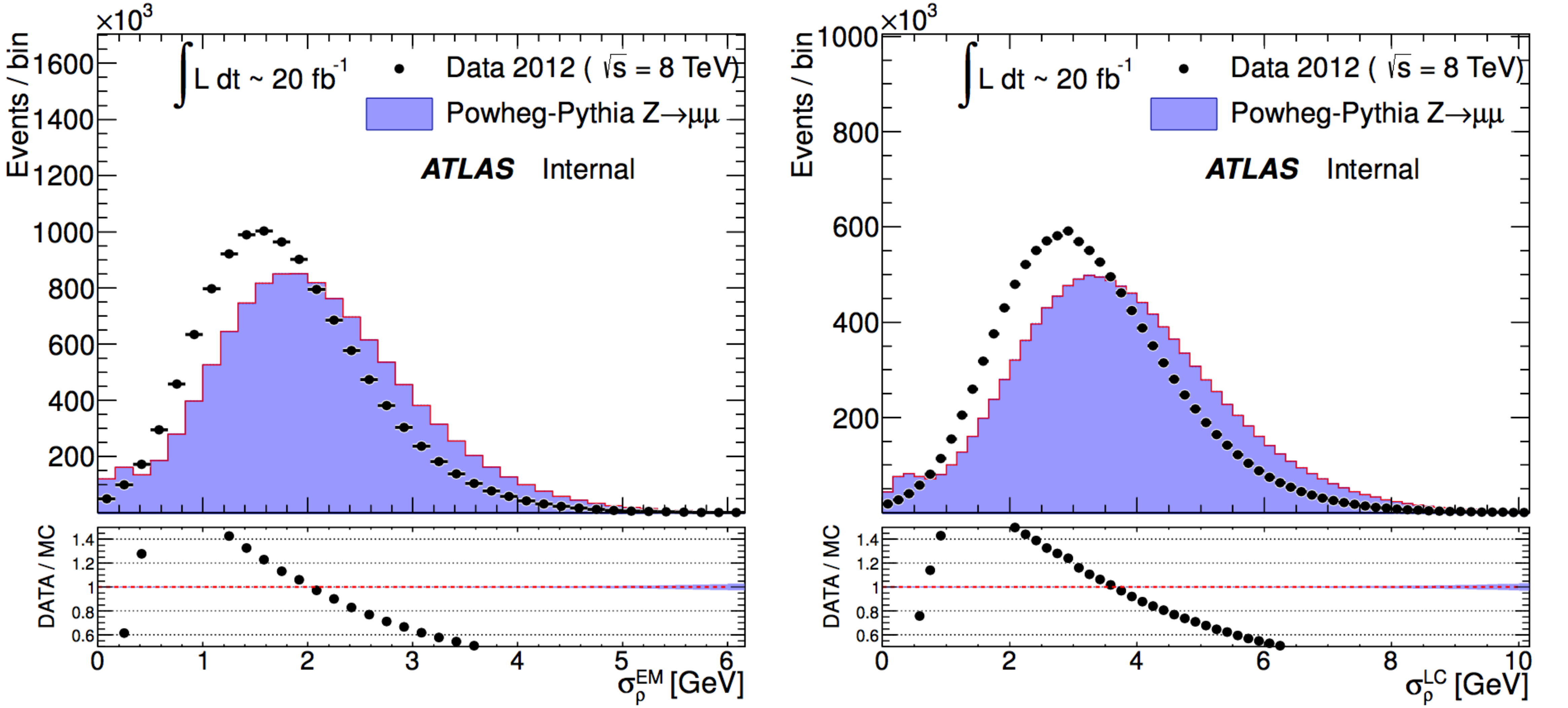


- Due to the Poisson nature of the pile-up energy deposits, the 68% confidence interval is used to define the width

- This gives the fluctuations on two jets so this value, is scaled down by sqrt(2) to give the noise term at the constituent scale for a given jet

- The first method uses "random cones" in zero bias data
- A randomly selected direction in (η,φ) is chosen and all clusters within R are combined to form a "cone"
- A second cone is projected back-to-back in φ and with another random η
- The balance of these cones is then exploited to give a measurement of the fluctuations in the cones
- The resultant distribution is non-gaussian and so, the 68% confidence interval is used to define the width

Jet energy resolution noise



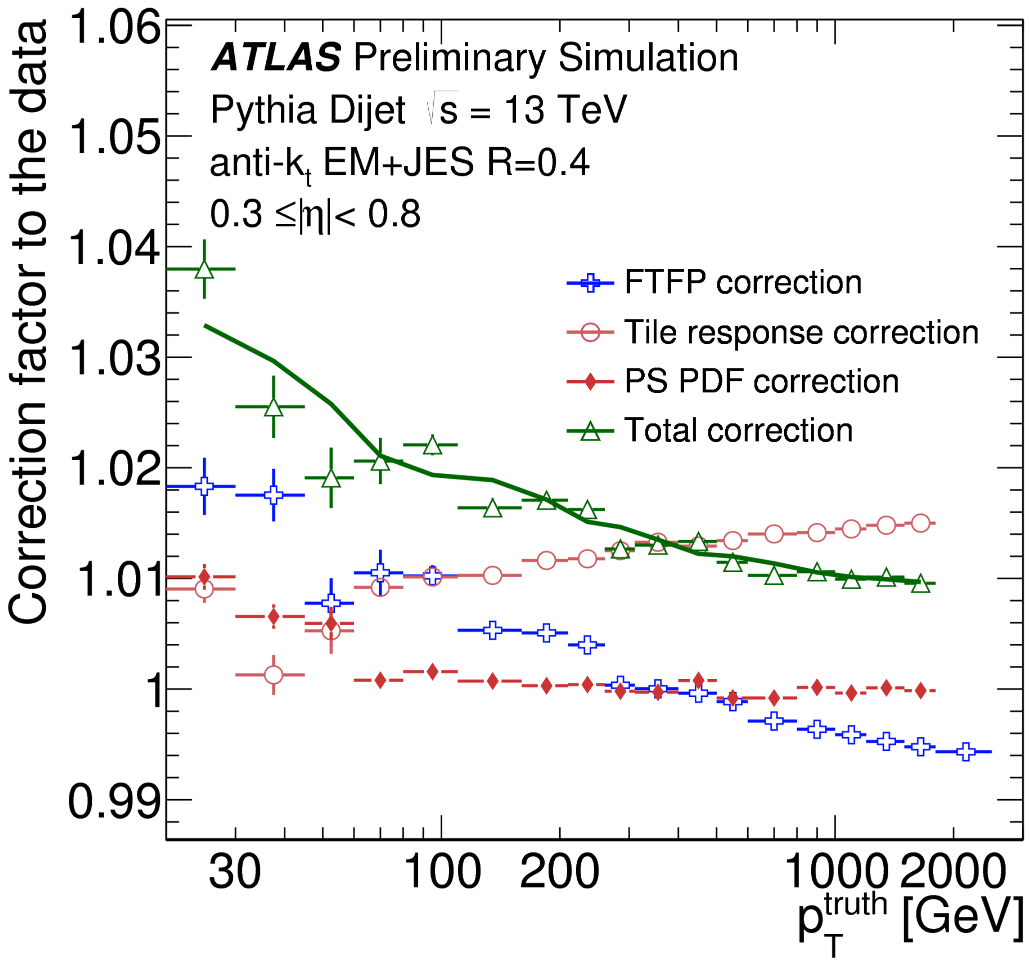
- A second method is used to derive the magnitude of pile-up fluctuations in the central region of the detector
- This uses the fluctuations of the event energy density event-by-event
- These fluctuations can be related to the pile-up fluctuations in jets

Jet energy resolution

EM+JES $R = 0.4$			EM+JES $R = 0.6$		
N	S	C	N	S	C
$\|\eta\| < 0.8$					
3.33 ± 0.63	0.71 ± 0.07	0.030 ± 0.003	4.34 ± 0.93	0.67 ± 0.08	0.030 ± 0.003
$0.8 < \|\eta\| < 1.2$					
3.04 ± 0.70	0.69 ± 0.13	0.036 ± 0.003	4.06 ± 0.93	0.76 ± 0.10	0.031 ± 0.003
$1.2 < \|\eta\| < 2.1$					
3.34 ± 0.80	0.61 ± 0.16	0.044 ± 0.008	3.96 ± 0.91	0.56 ± 0.14	0.042 ± 0.007
$2.1 < \|\eta\| < 2.8$					
2.9 ± 1.0	0.46 ± 0.30	0.053 ± 0.011	3.41 ± 0.84	0.48 ± 0.27	0.049 ± 0.012

LCW+JES $R = 0.4$			LCW+JES $R = 0.6$		
N	S	C	N	S	C
$\|\eta\| < 0.8$					
4.12 ± 0.74	0.74 ± 0.10	0.023 ± 0.003	5.50 ± 0.99	0.66 ± 0.12	0.026 ± 0.004
$0.8 < \|\eta\| < 1.2$					
3.66 ± 0.75	0.64 ± 0.13	0.039 ± 0.009	5.40 ± 0.98	0.78 ± 0.15	0.032 ± 0.005
$1.2 < \|\eta\| < 2.1$					
4.27 ± 0.75	0.58 ± 0.15	0.034 ± 0.007	5.7 ± 1.0	0.62 ± 0.16	0.031 ± 0.006
$2.1 < \|\eta\| < 2.8$					
3.38 ± 0.65	0.26 ± 0.36	0.050 ± 0.010	5.2 ± 1.0	0.51 ± 0.38	0.028 ± 0.019

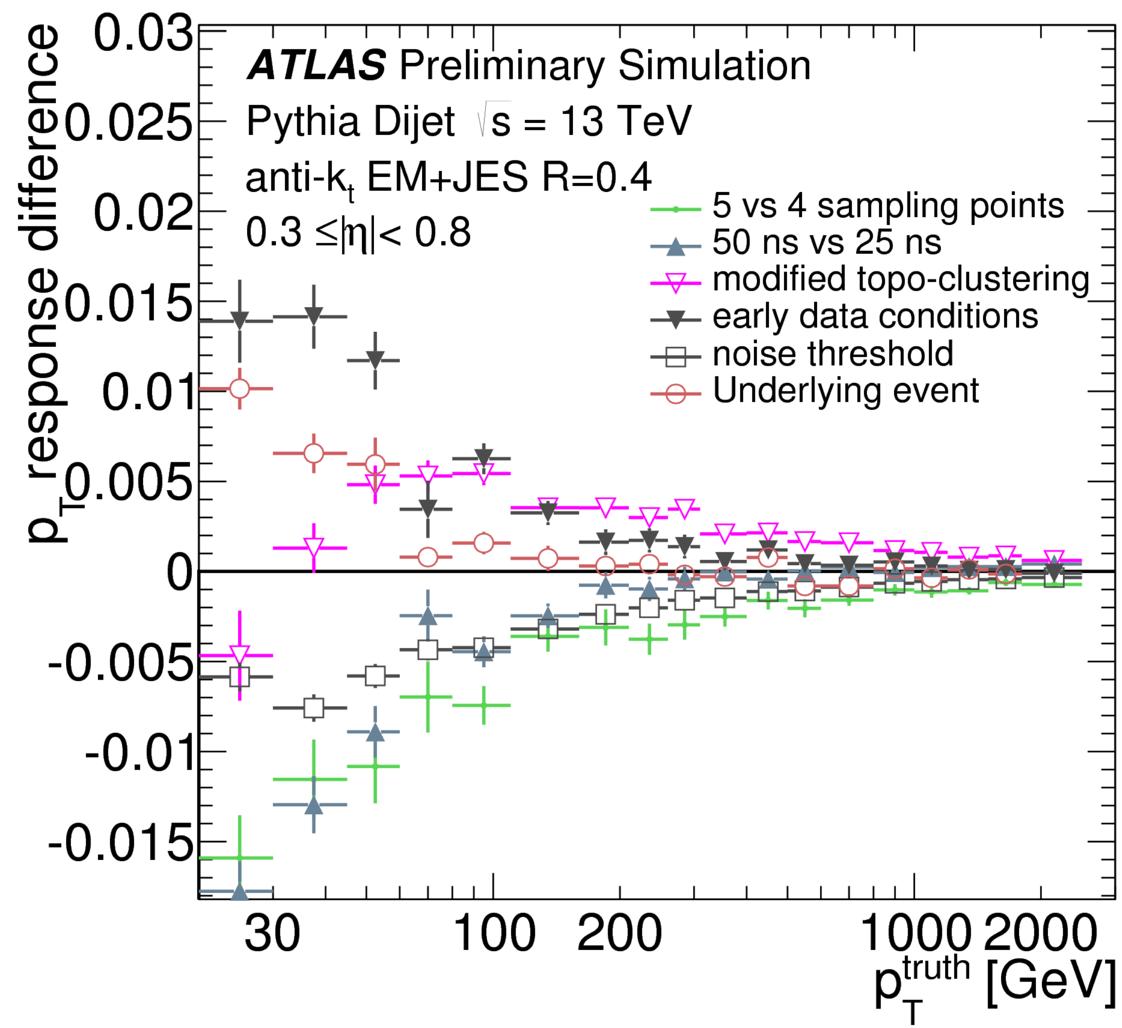
2012 to 2015



ATLAS-PHYS-PUB-2015-015

$$f_{2015} = \frac{R_{\text{new tune}}}{R_{\text{old tune}}} \times \frac{R_{\text{new tile sim}}}{R_{\text{old tile sim}}} \times \frac{R_{\text{FTFP}}}{R_{\text{QGSP}}} \times f_{2012}$$

- Correction incorporating change in MC tune, updates on Tile calorimeter energy and on Geant4 physics list update
- 3% effect, falling with increasing p_T

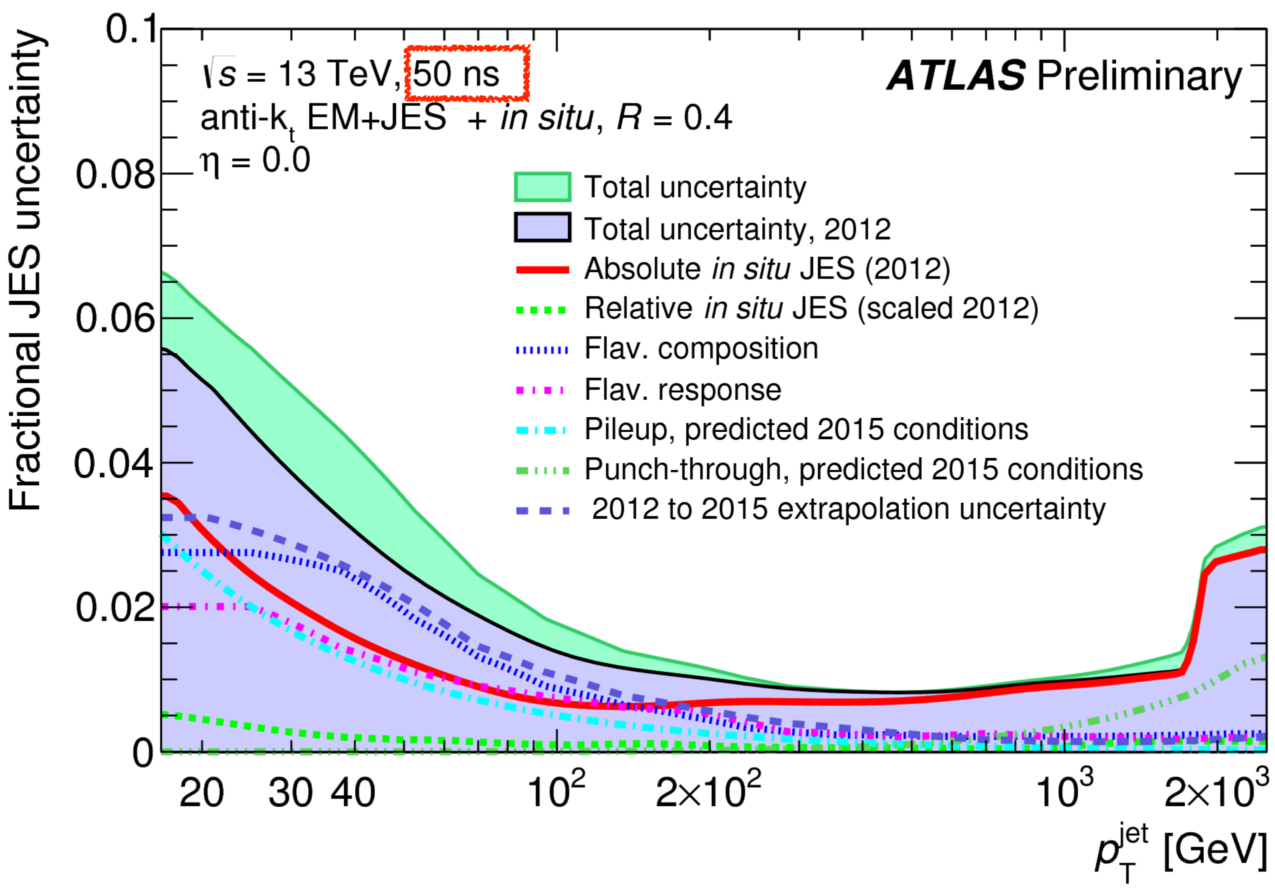


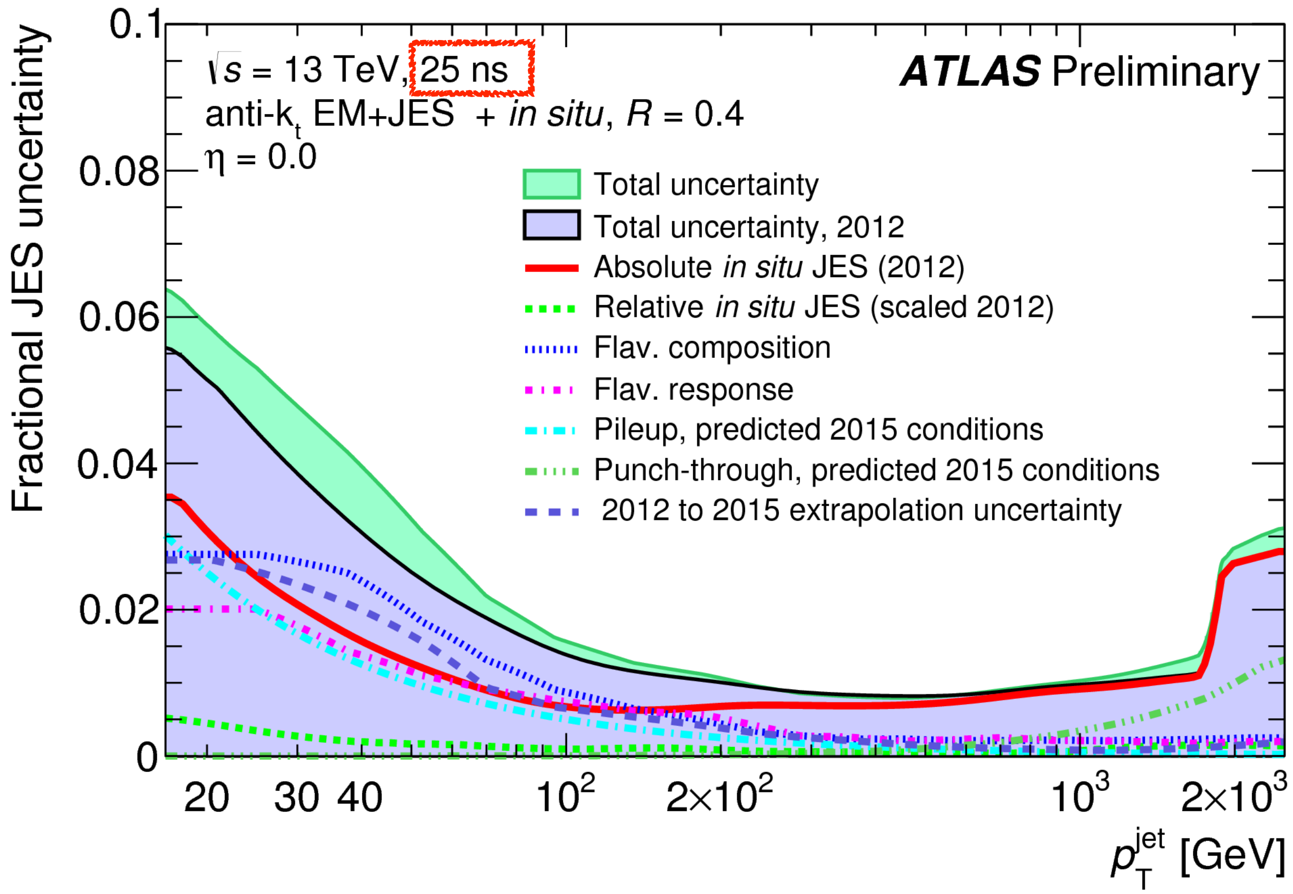
- Relative change in jet energy scale by looking at the response difference based on the 2012→2015 conditions
- Negligible for jet p_T>200 GeV

JES uncertainties in early Run 2

ATLAS-PHYS-PUB-2015-015

- ~3% additional uncertainty with respect to Run 1 originating from the 2012 to 2015 conditions extrapolation uncertainty, quickly falling with p_T
  - Negligible for jet p_T > 200 GeV
- Uncertainties available for both Run 2, 50ns (July 2015) and 25ns (August and onwards) datasets

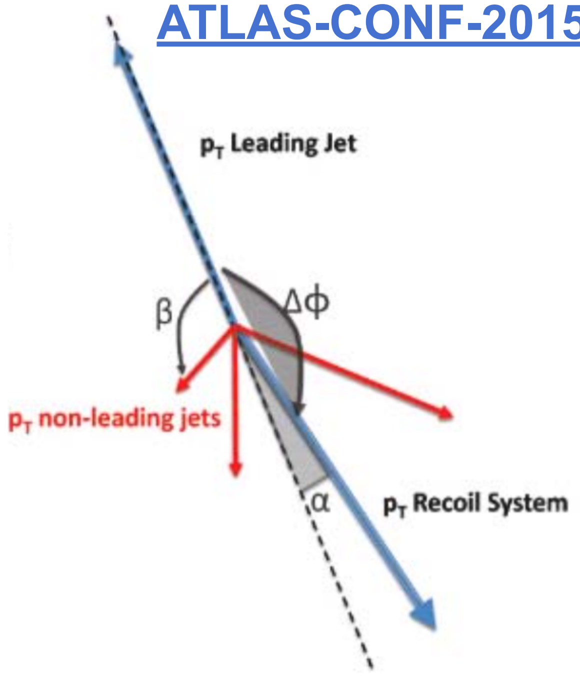


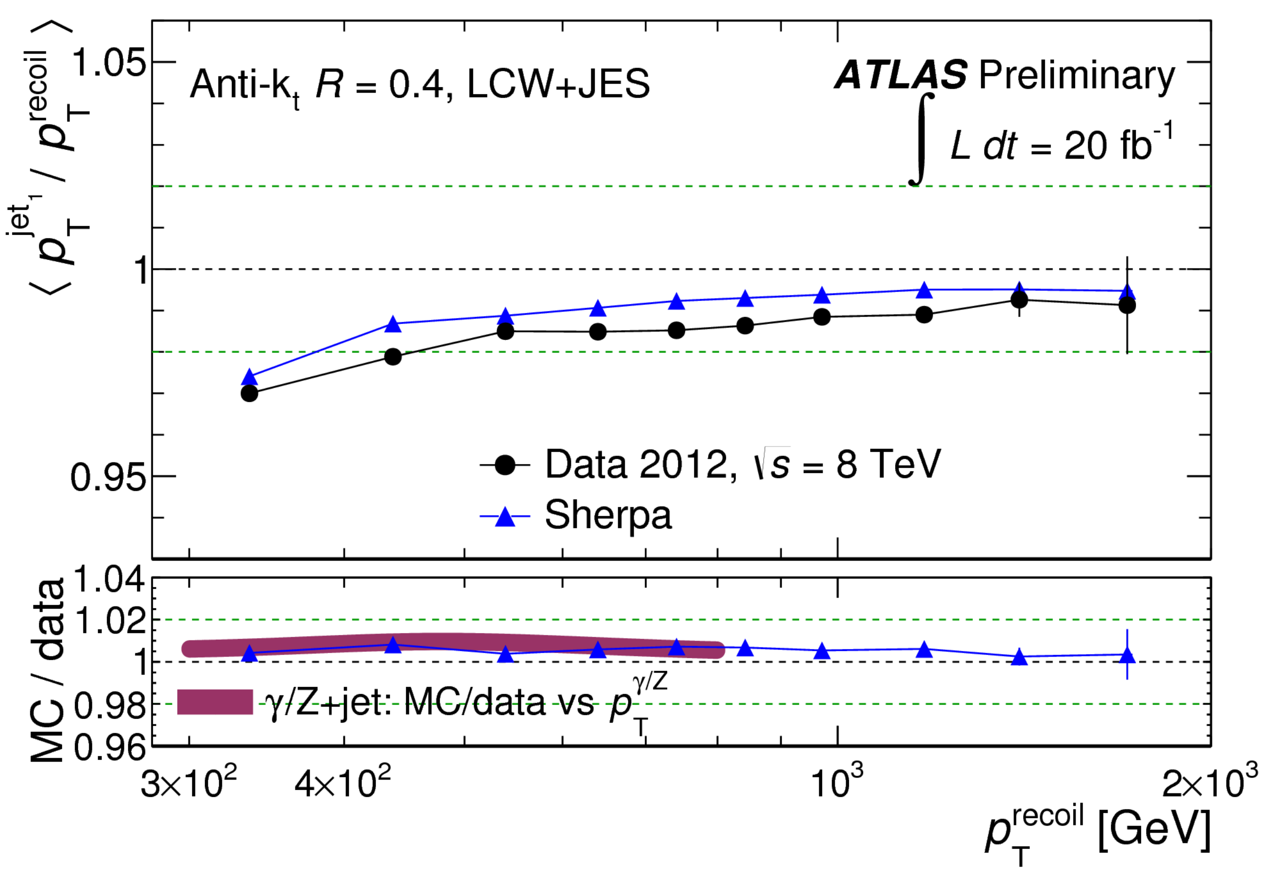


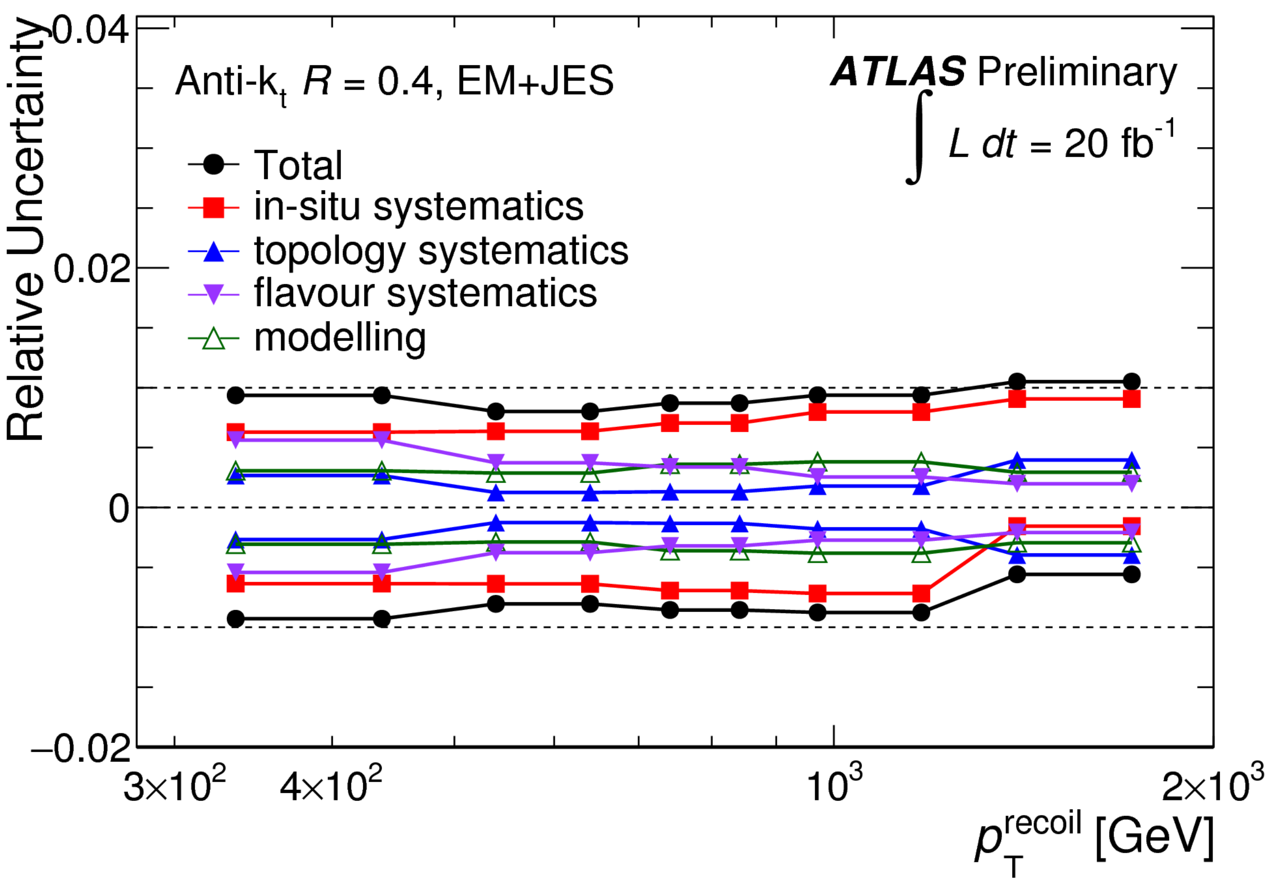
Multi-jet balance

ATLAS-CONF-2015-017

- Multi-jet balance (MJB), when the highest-p_T jet is produced back-to-back with a recoil system of low p_T jets
- $R_{MJB} = \frac{p_T^{leading}}{p_T^{recoil}}$
- R_{MJB} measured both in Data and MC
- Systematics
  - ✦ In-situ systematics / Event selection criteria / Flavour related systematics / MC modelling by comparing different MC generators





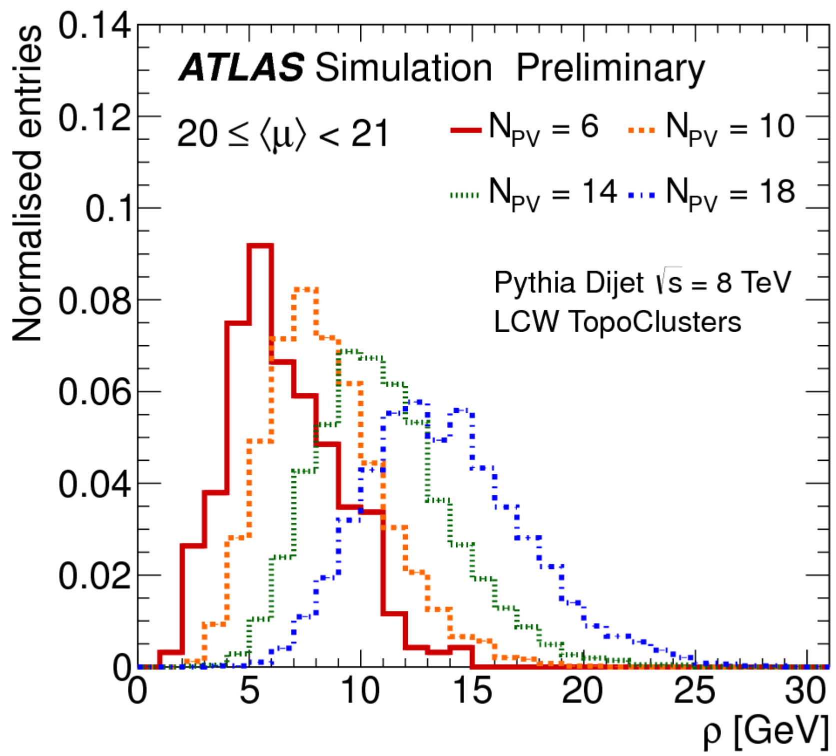


Correcting pile-up

Jet area correction — **Residual correction (MC-based)**

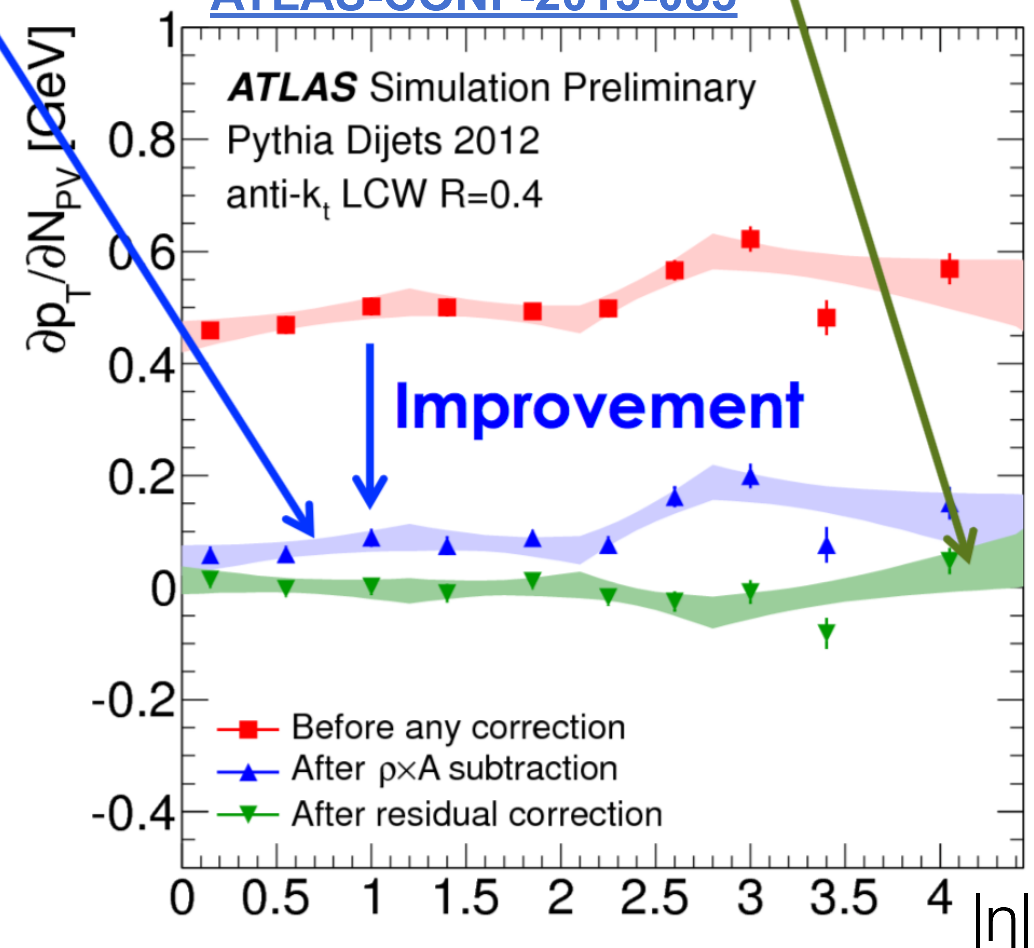
$$p_T^{corr} = p_T - \rho A_T - \alpha(N_{PV} - 1) - \beta\langle\mu\rangle$$

- **Median p_T density, ρ:** Event-by-event pile-up activity



- **Jet Area, A_T:** Jet-by-jet pile-up sensitivity
- **Residual correction**
  - ✦ Takes into account topology/threshold effects, and out-of-time pileup effects

ATLAS-CONF-2013-083



- 4 systematic uncertainties
  - ✦ p_T dependence of residual correction: in MC
  - ✦ Uncertainty on the two coefficients α,β: estimated in data
  - ✦ ρ modelling: Evaluated in data, in different topologies