Particle flow current status

Regina Moles-Valls

V Single Top Workshop

12-15 December 2016
IFIC - Valencia

Outline

- Introduction to Particle Flow
  - How does it work in general?
- Particle Flow performance studies at 8 TeV
- Jet recommendations: status and plans
- Quick look at top samples with Particle Flow jets
- Systematic uncertainties (but not for PFlow jets)

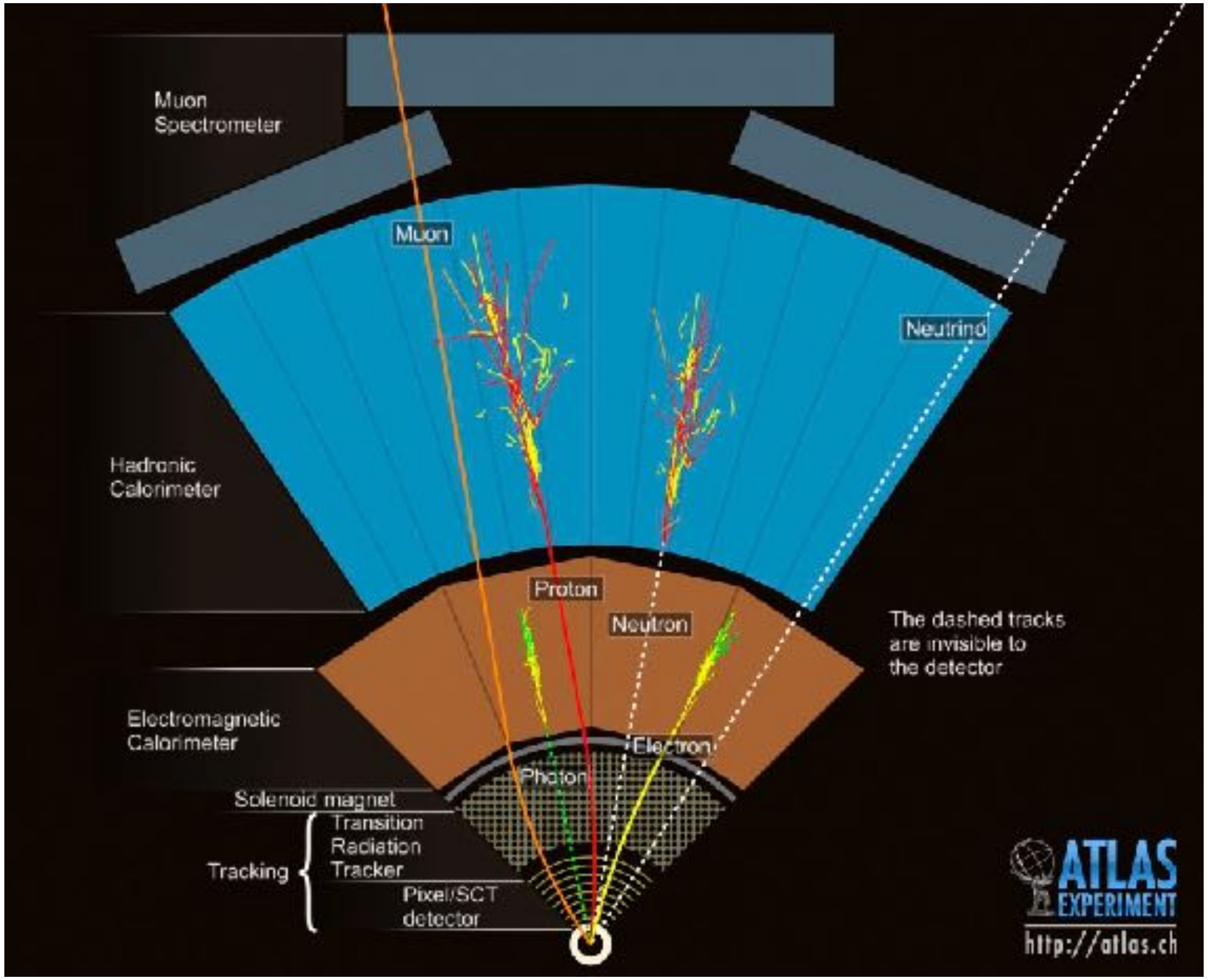
Introduction to Particle Flow

Particle Flow algorithms try to follow the path of the particles through the detector.

Main goal is to improve the energy resolution of the hadronic objects

How to do it? combining the information from different sub-detectors

➡ Emphasise the role of the tracker in jet physics.



Why Particle Flow in ATLAS?

- Reasons for using Particle Flow in ATLAS:

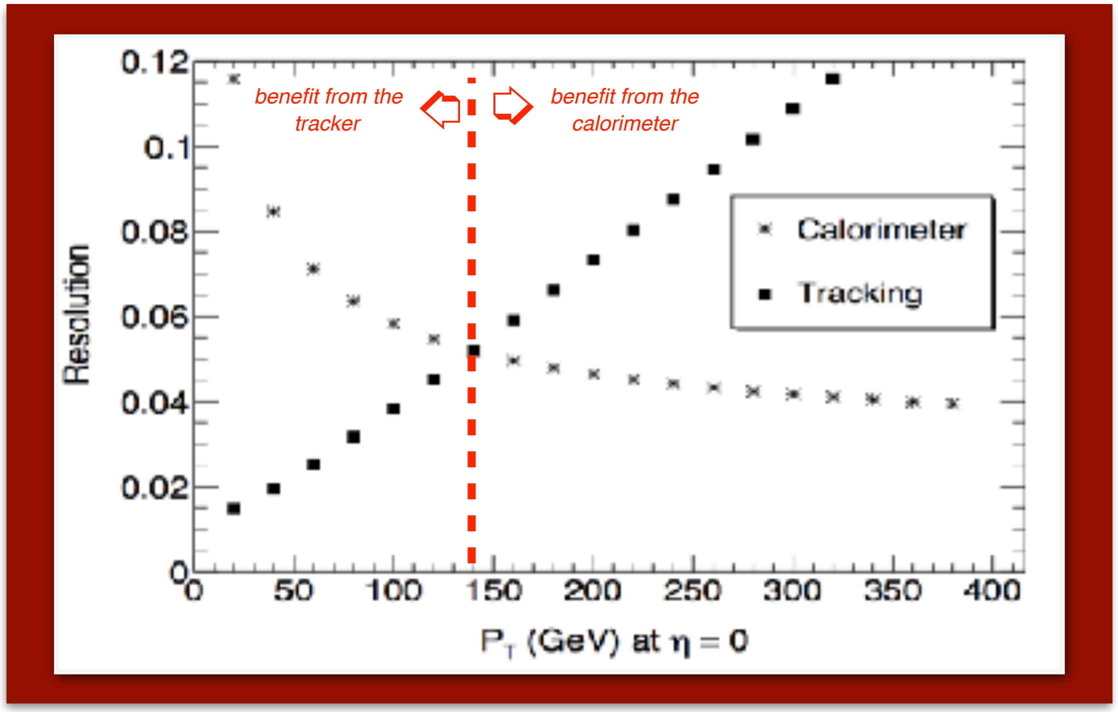
ID tracker

- Tracker resolution significantly better than Calo resolution at low p_T
- Particles that don't create a topocluster (low E) are accessible by the ID
- Better angular resolution of the tracker for single particles
- The vertex information can be used to mitigate the pileup contribution

Calorimeter

- Calorimeter's ability to reconstruct neutral particles
- Better energy resolution at high p_T

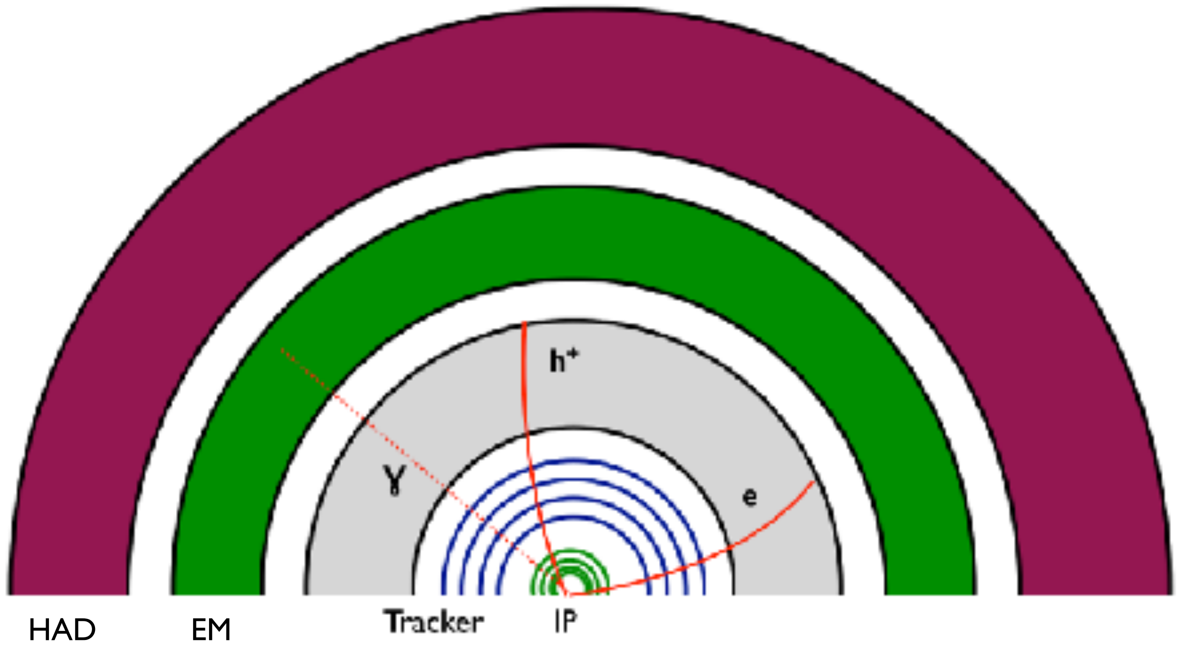
Particle Flow algorithm uses a combination of both, tracking and calorimeter information



Introduction: Particle Flow principle

How does Particle Flow work?

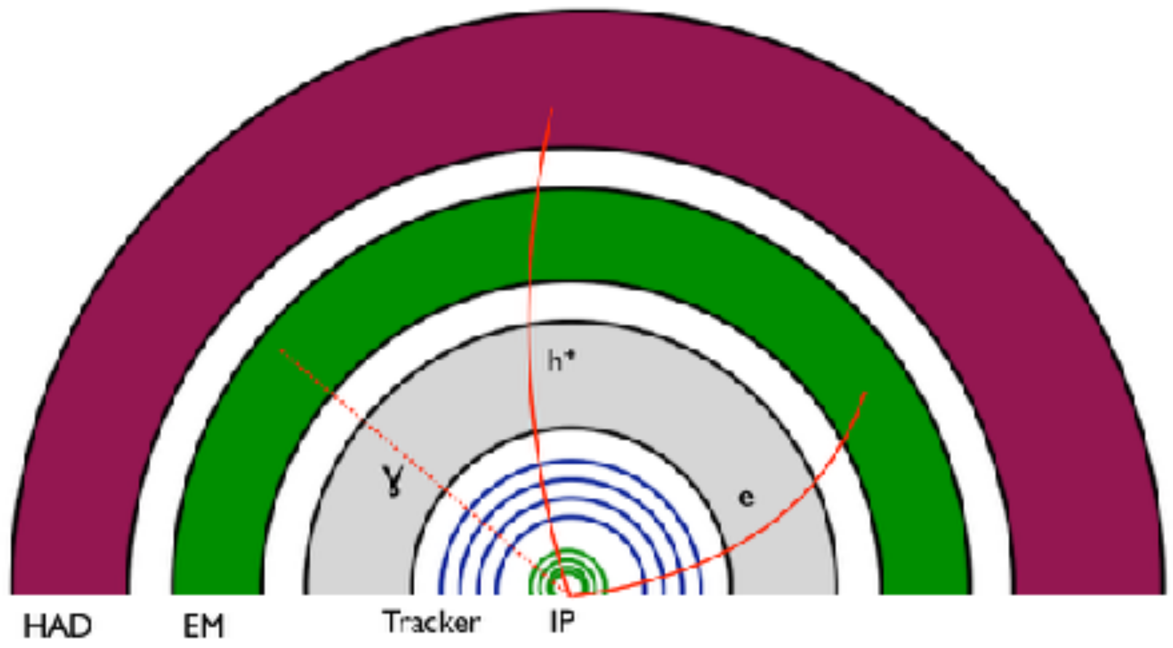
- Track reconstruction in the ID



Introduction: Particle Flow principle

How does Particle Flow work?

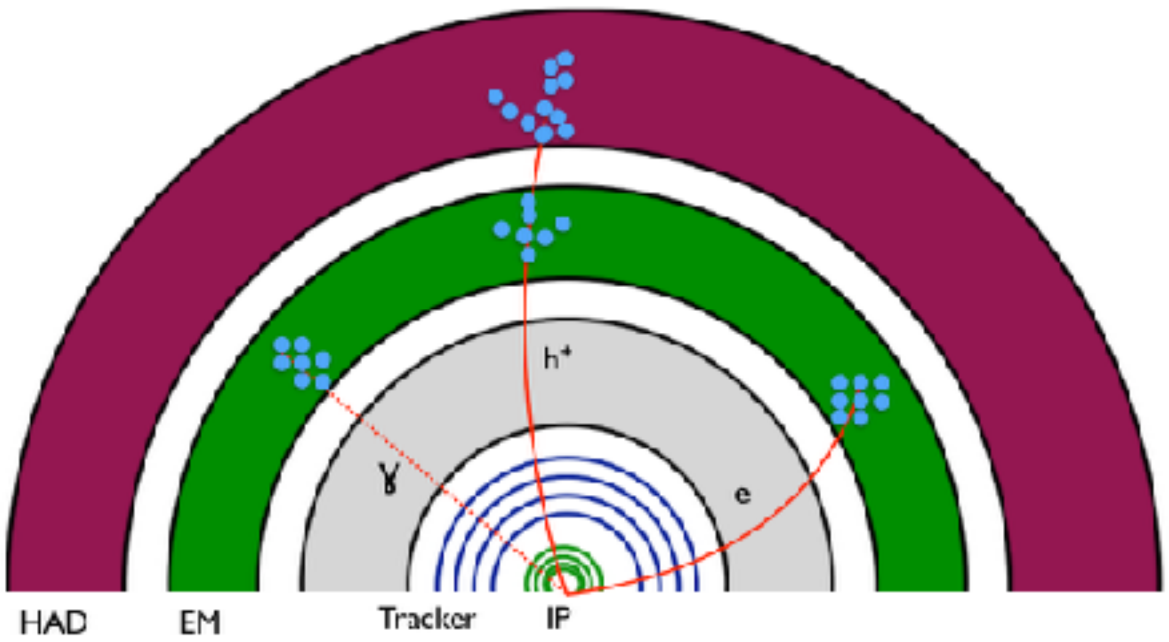
- Track reconstruction in the ID
- Extrapolate the tracks to the Calorimeter



Introduction: Particle Flow principle

How does Particle Flow work?

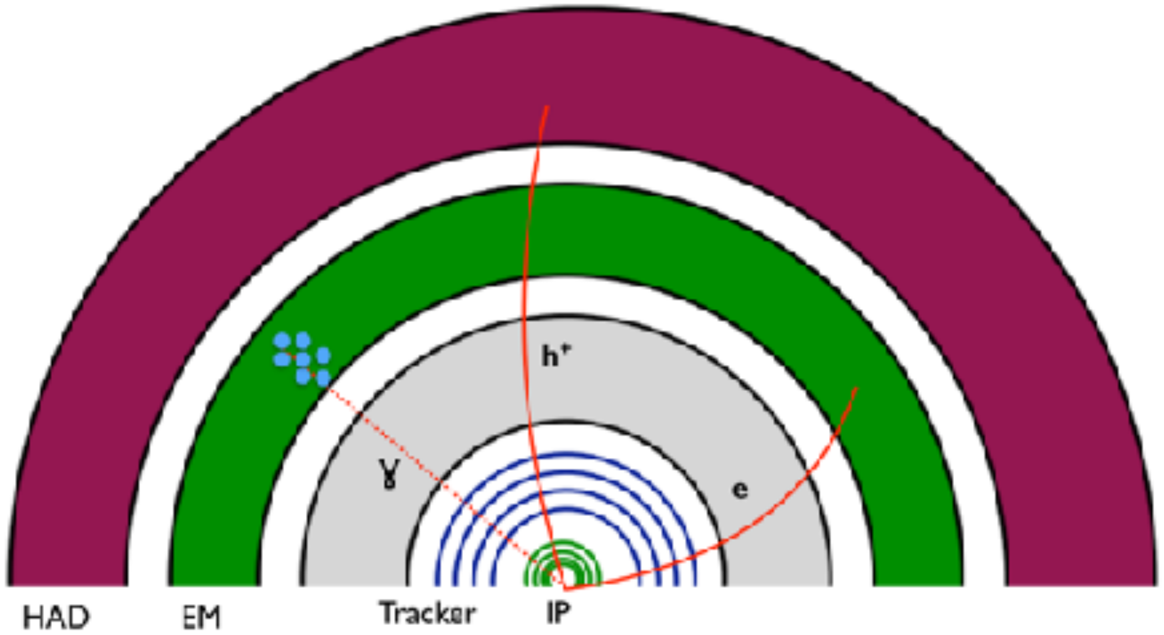
- Track reconstruction in the ID
- Extrapolate the tracks to the Calorimeter
- Match the tracks to the clusters



Introduction: Particle Flow principle

How does Particle Flow work?

- Track reconstruction in the ID
- Extrapolate the tracks to the Calorimeter
- Match the tracks to the clusters
- Remove clusters from charge particles
- Finally keep:
  - <u>tracks</u> (charged particles) and
  - <u>clusters</u> (neutral particles)



Introduction: Particle Flow principle

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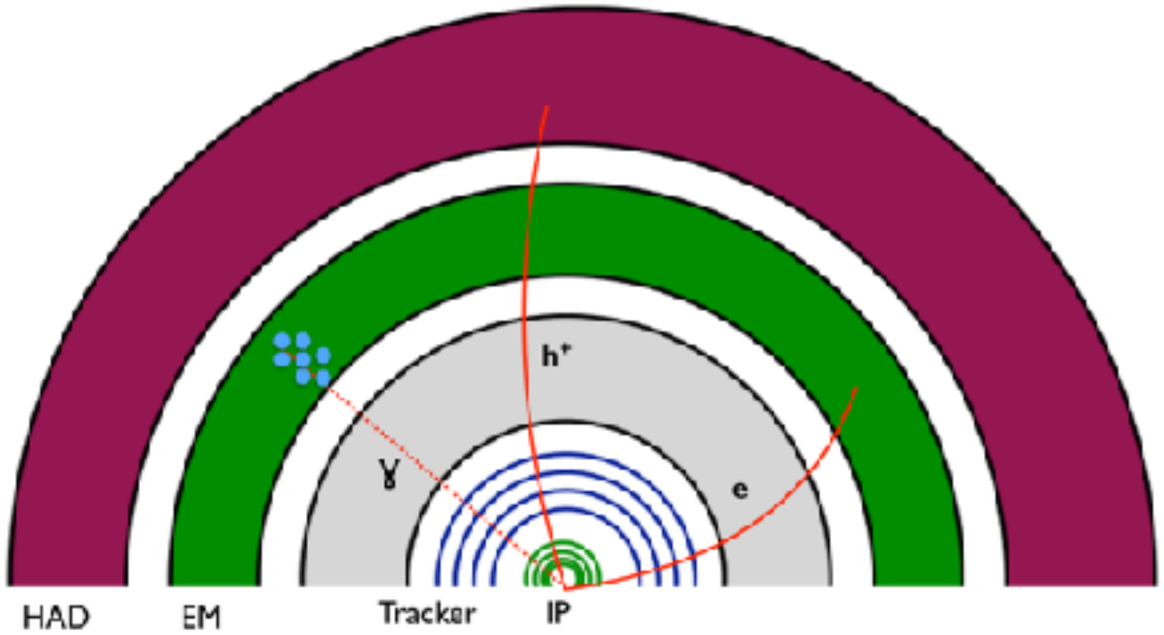
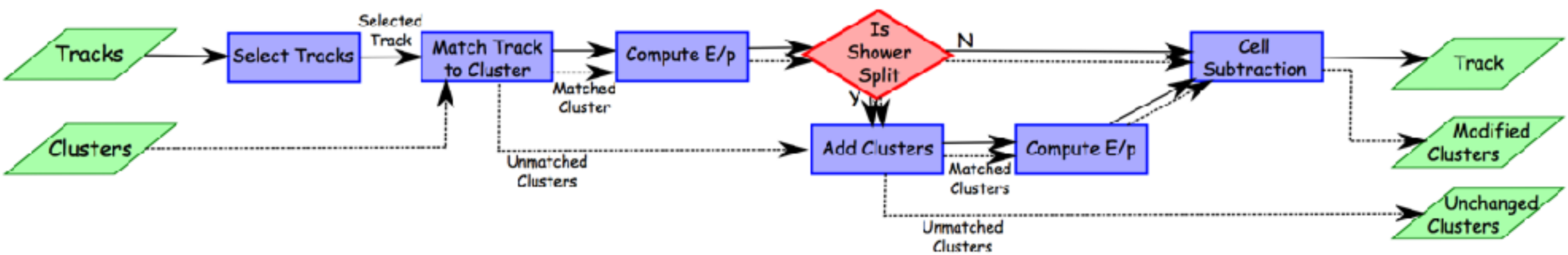
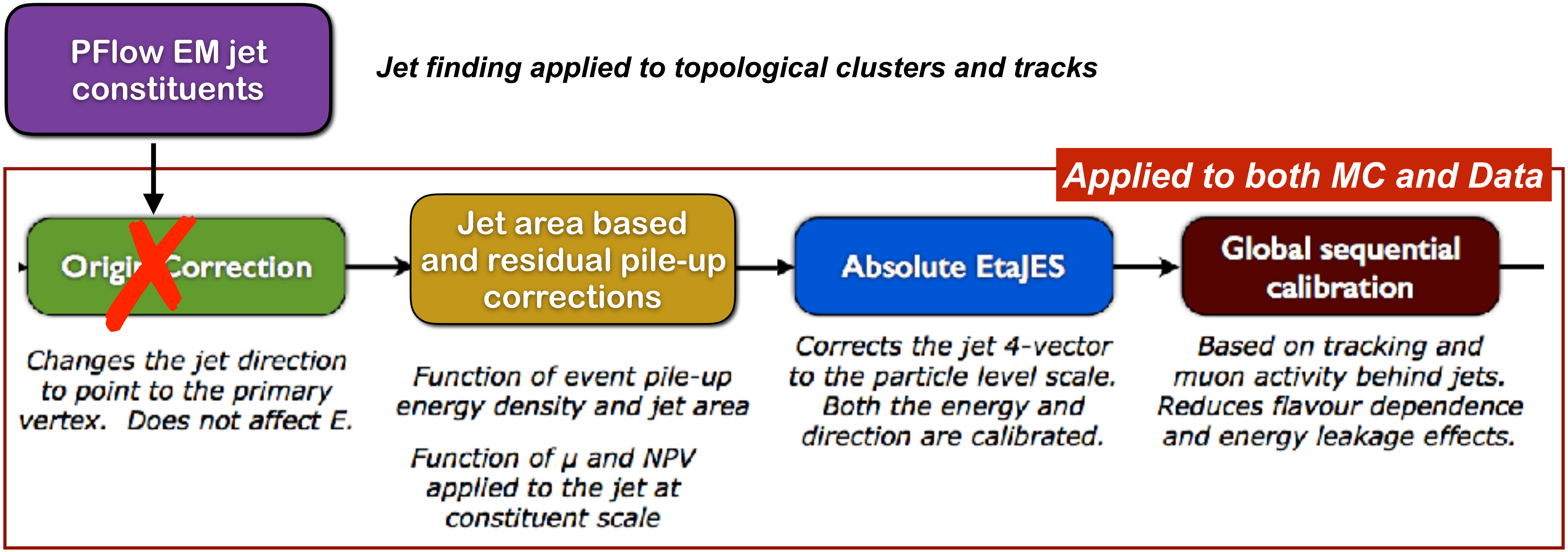
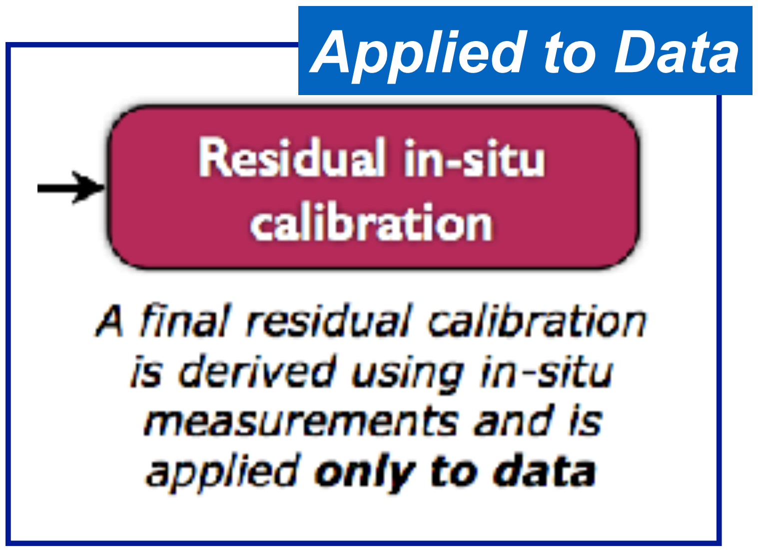


eflowRec algorithm in ATLAS



ATLAS jet calibration





Calibration chain:

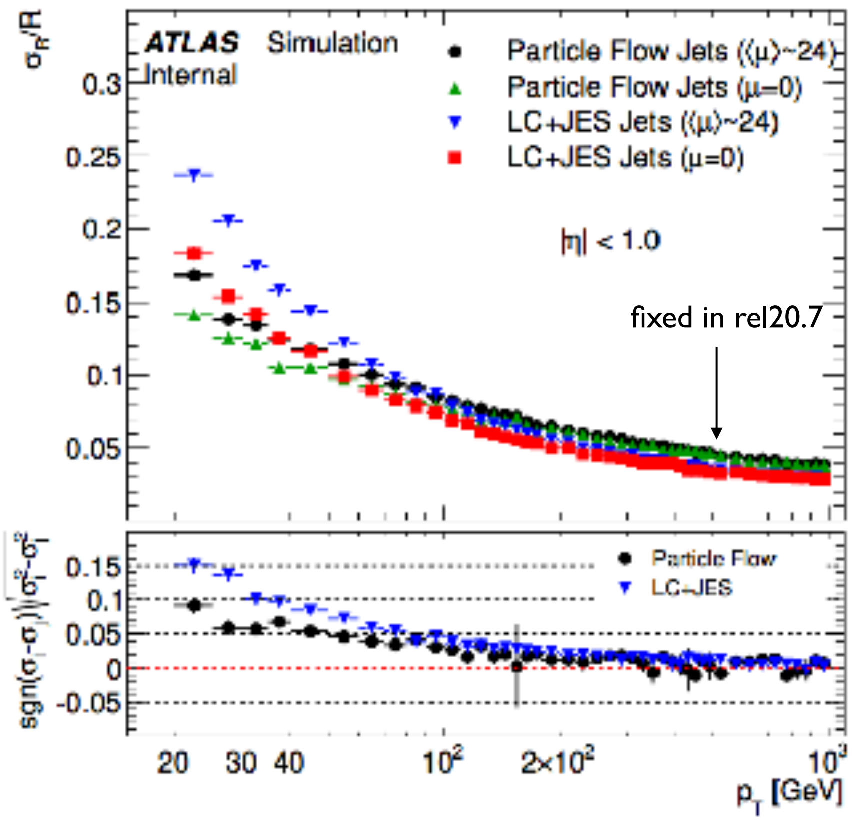
- Slightly different steps depending on the jet collection.
- MC studies to infer the missed energy in the jets using the jet response: $R=p_T^{jet}/p_T^{truth}$.
- In-situ studies provide an additional correction to take into account data-MC differences as well as part of JES (R^{data}/R^{MC}).

Particle flow performance studies

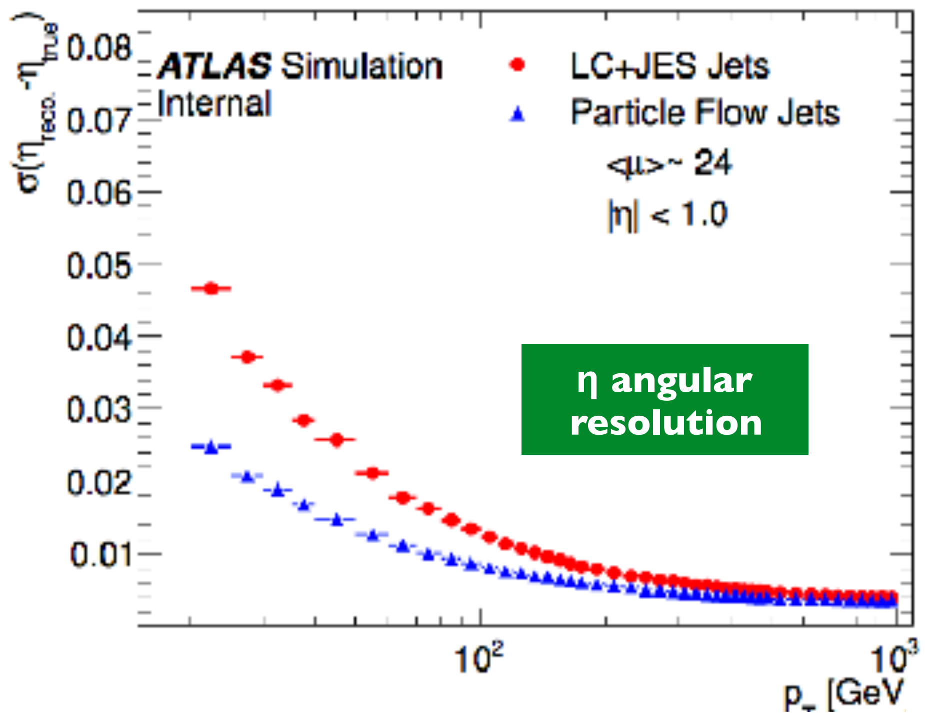
Paper link: PFlowPaper

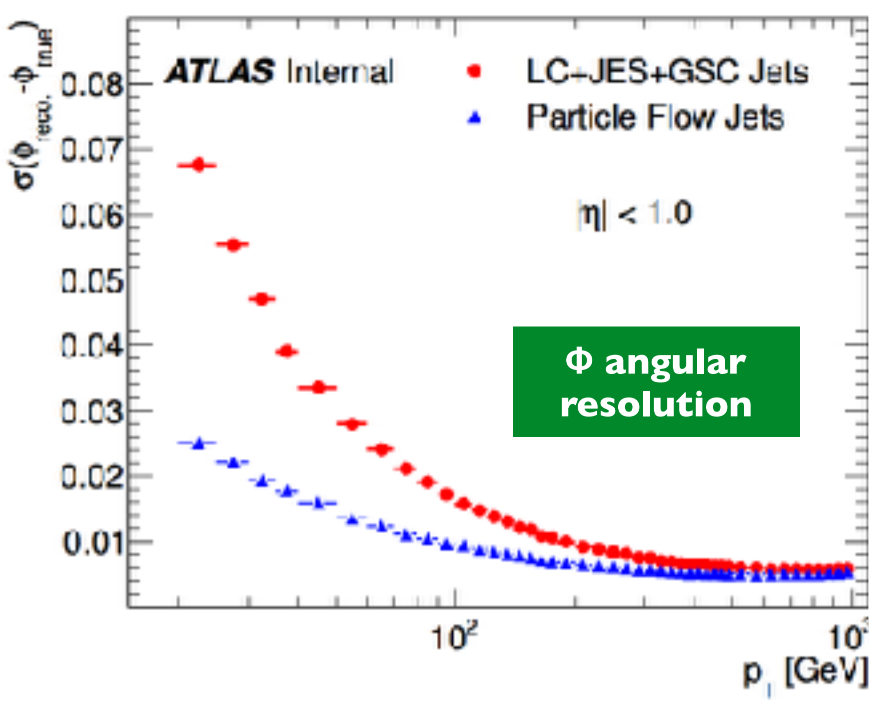
$\sqrt{s}$ = 8 TeV

Jet P_T resolution

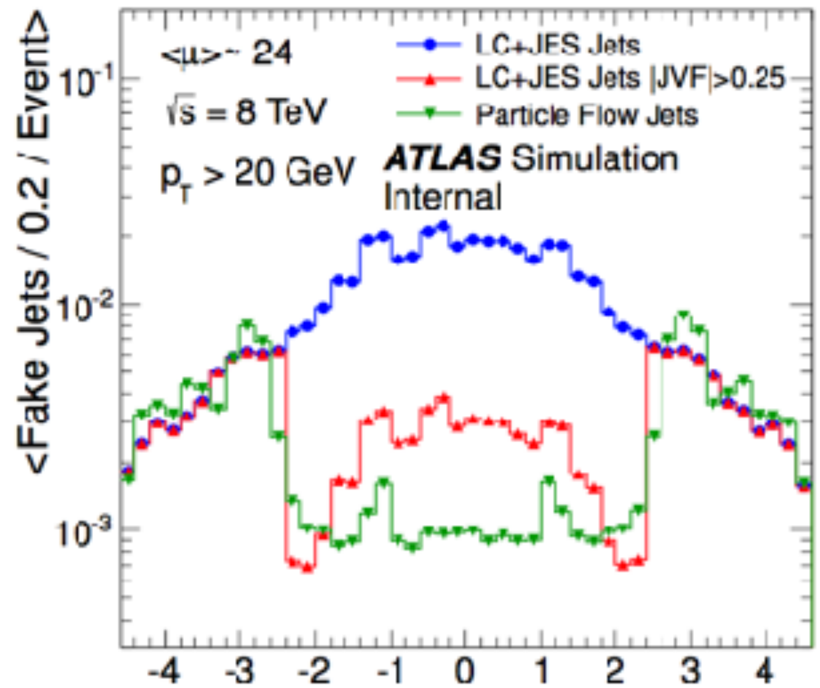


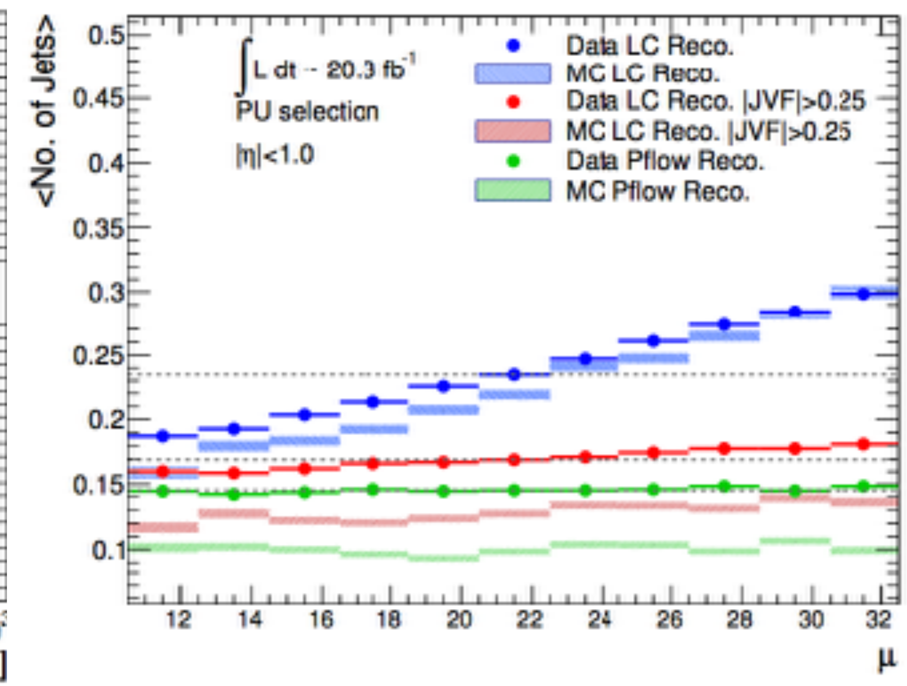
Jet angular resolution





Pile-up rejection





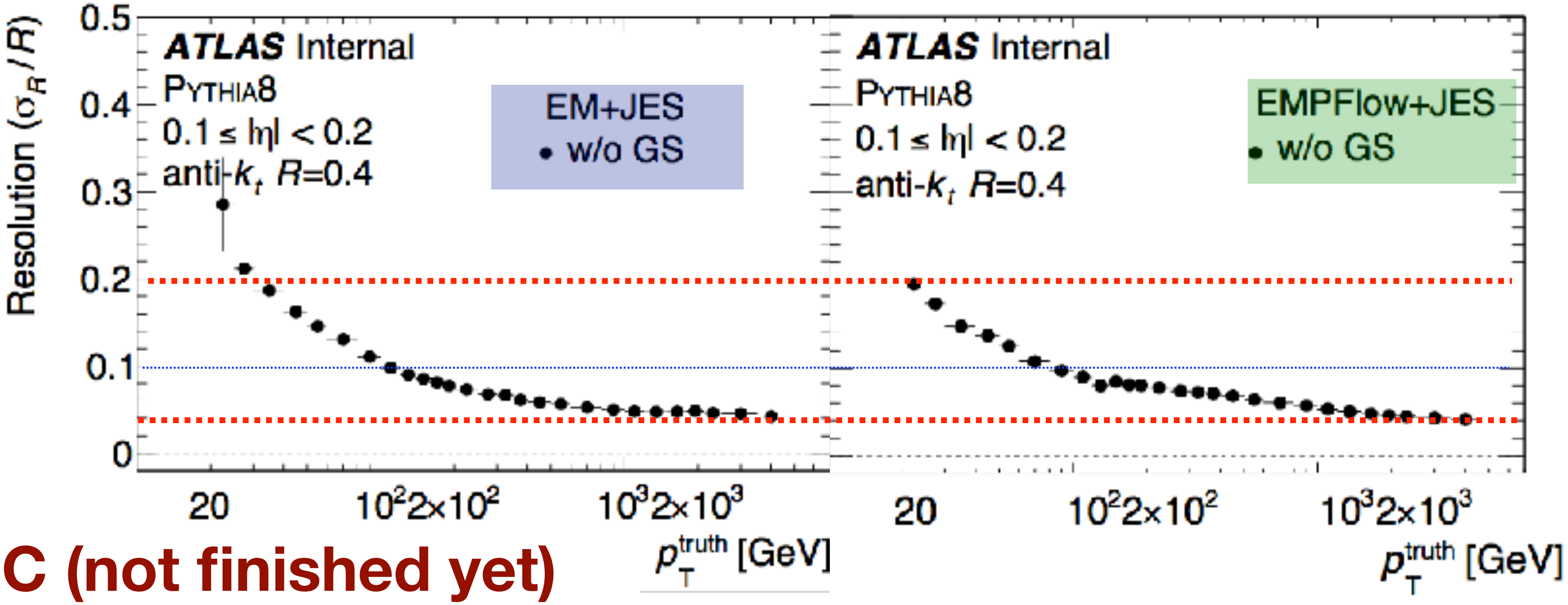
PFlow jet calibration current status

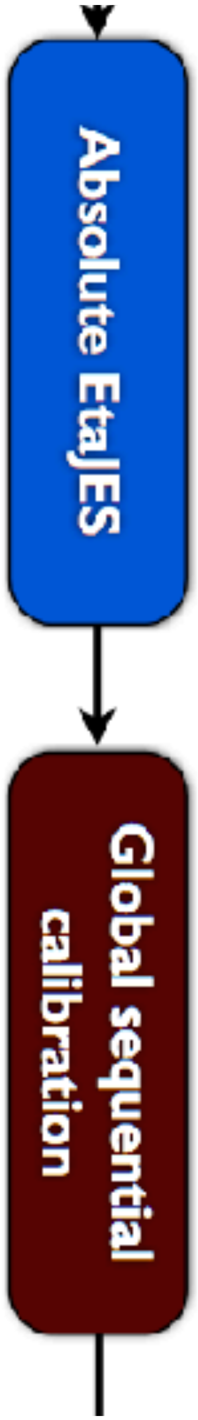
Unfortunately, final recommendations have been delayed until January due to problems with MC calibration … but working to get them asap, hopefully by January!

First calibration for PFlow jets ongoing:

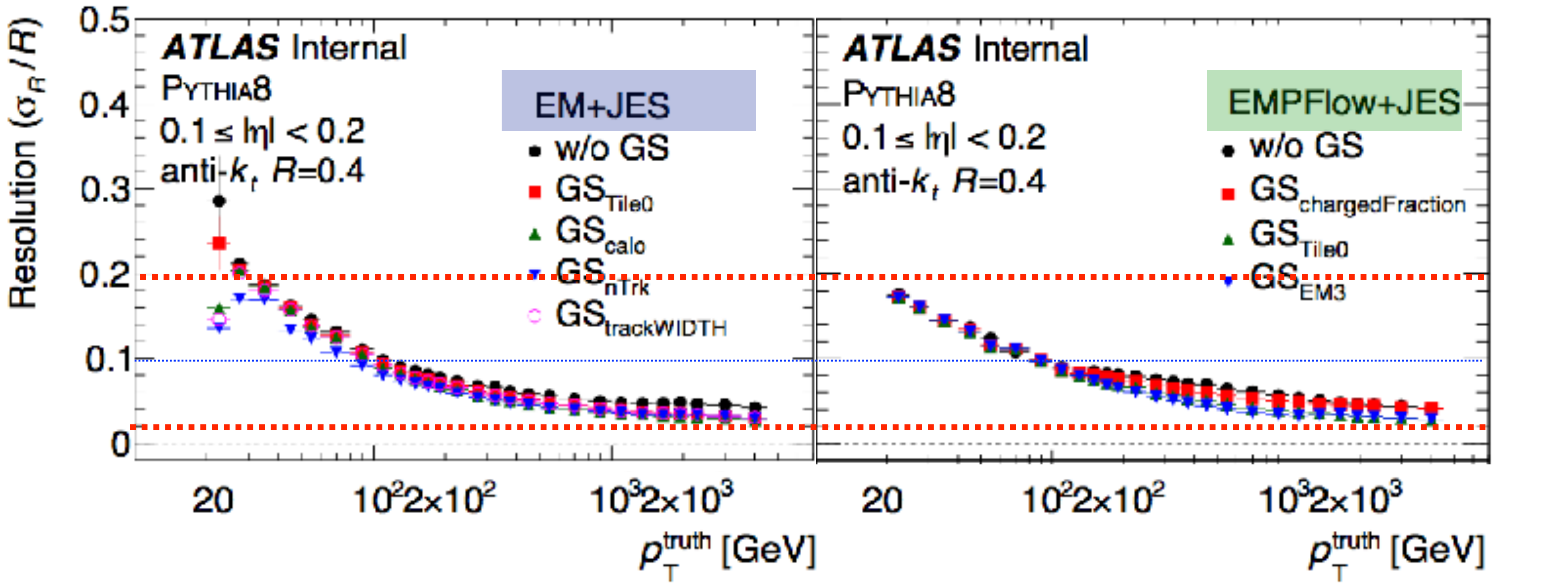
2016 data

JES MC calibration





GSC (not finished yet)



First calibration for PFlow jets ongoing:

2016 data

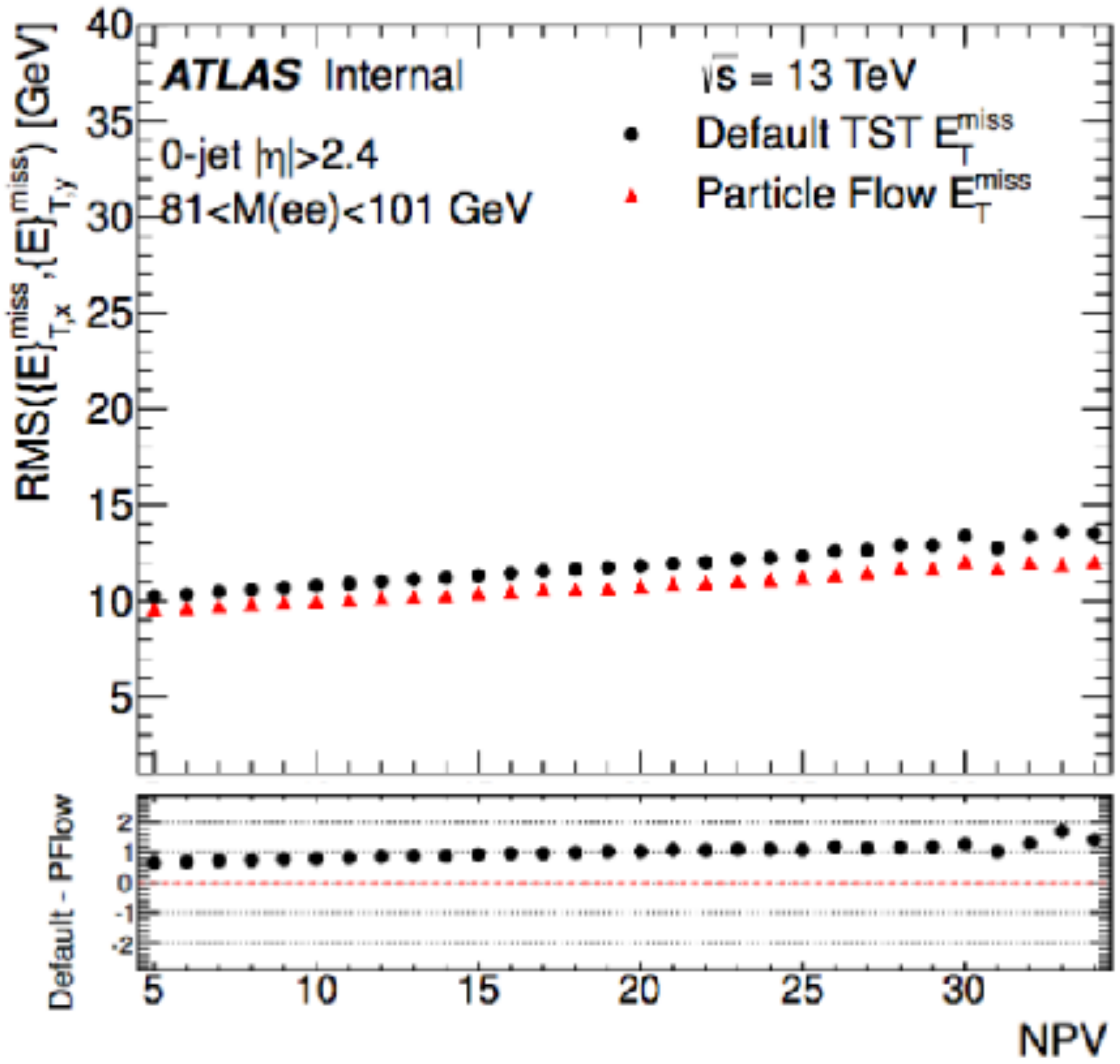
PFlow calibration status:

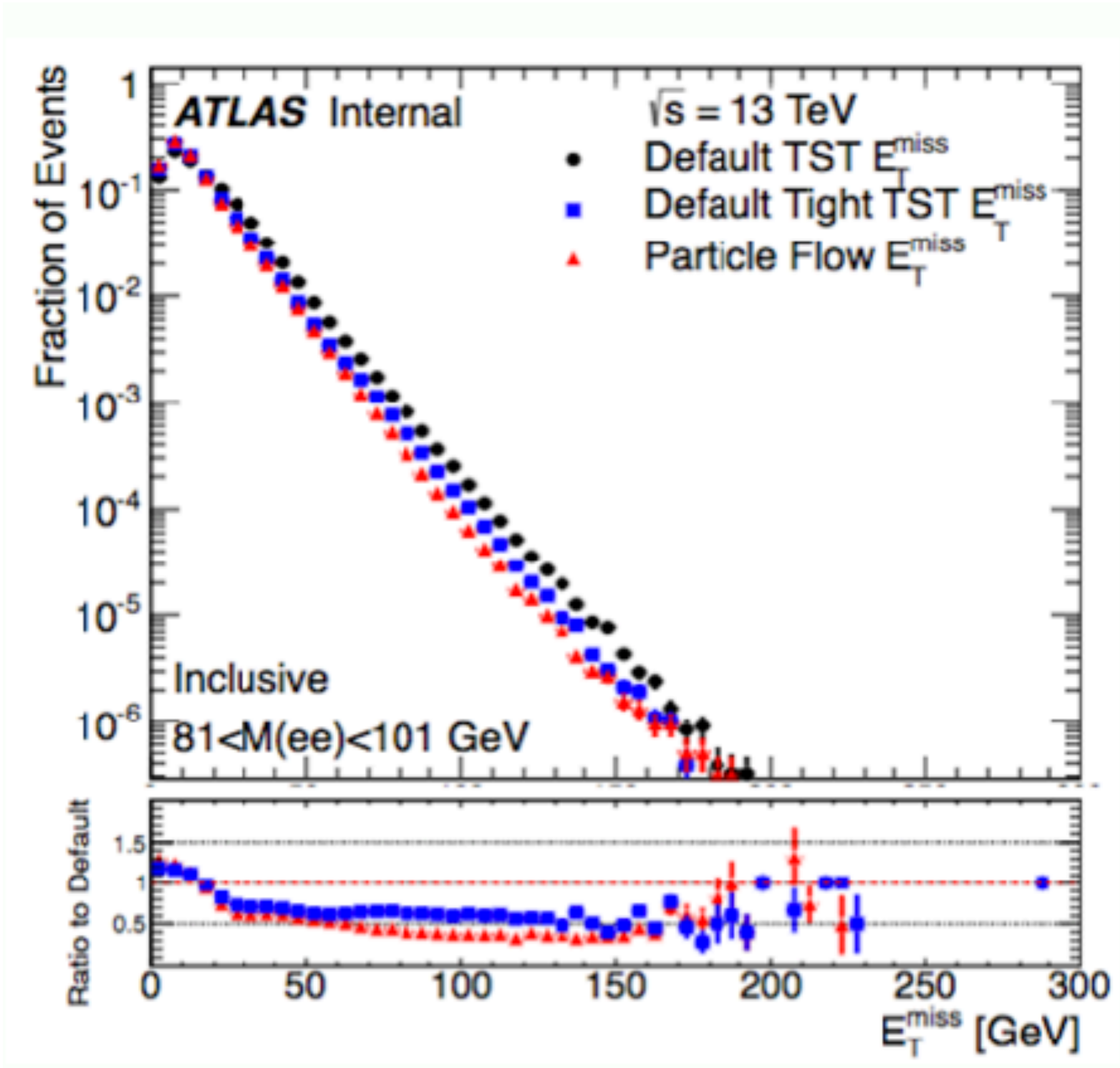
- JES finished:
  - Included in `JetCalibTools-00-04-68` or later
  - https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/ApplyJetCalibration2016
- GSC almost ready:
  - Punch-through not available but not essential for PFlow
  - Preliminary tag available for testing
- In-situ measurements prepared to start (waiting for the final MC calibration)
- Uncertainties are not evaluated yet

MET studies using PFlow jets:

2016 data

- **PFlow MET** studies ongoing:
  - Stable with pileup (left)
  - Reduction of the tails in Z→ee compared with TST MET (right)





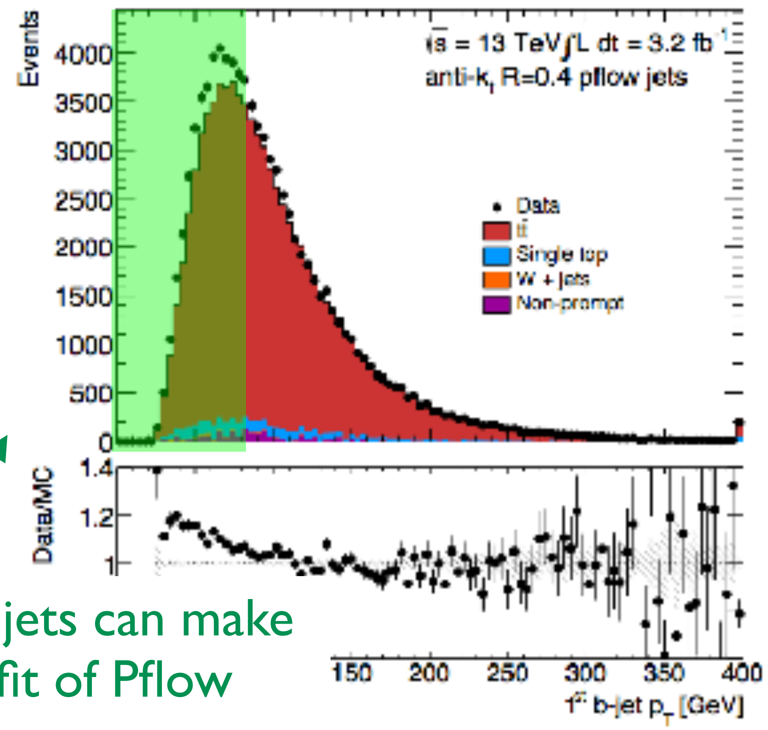
A first look to pflow jets with top samples ...

Look at PFlow jets in ttbar events

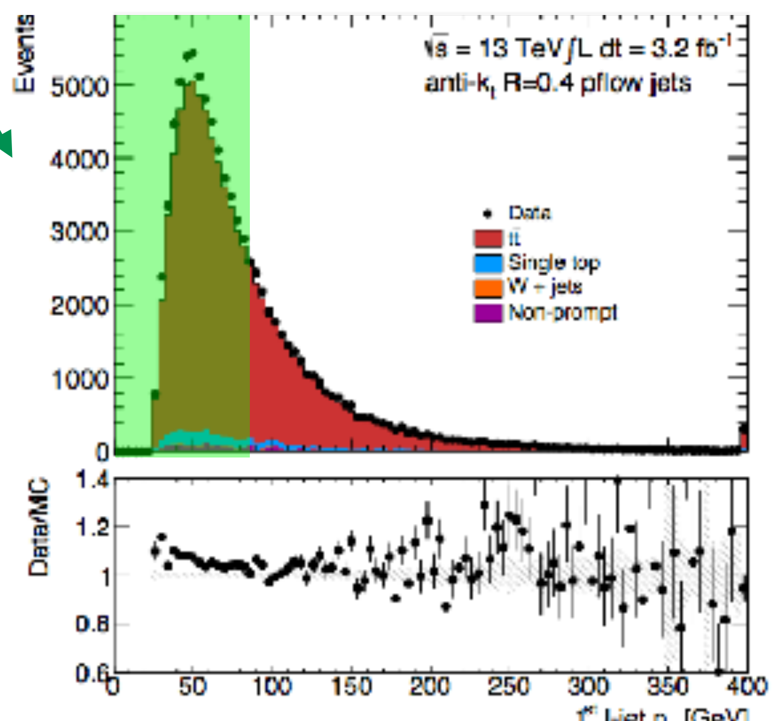
P. Falke (master thesis)

2015 data

- ttbar TOPQ1 derivation
  (mc15_13TeV.410000.PowhegPythiaEvtGen_P2012_ttbar_hdamp172p5_nonallhad.merge.DAOD_TOPQ1.e3698_s2608_s2183_r7267_r6282_p2460)
  - l+jets selection implemented



These jets can make profit of Pflow



Jet angular resolution

b- tagged jets **light-jets**

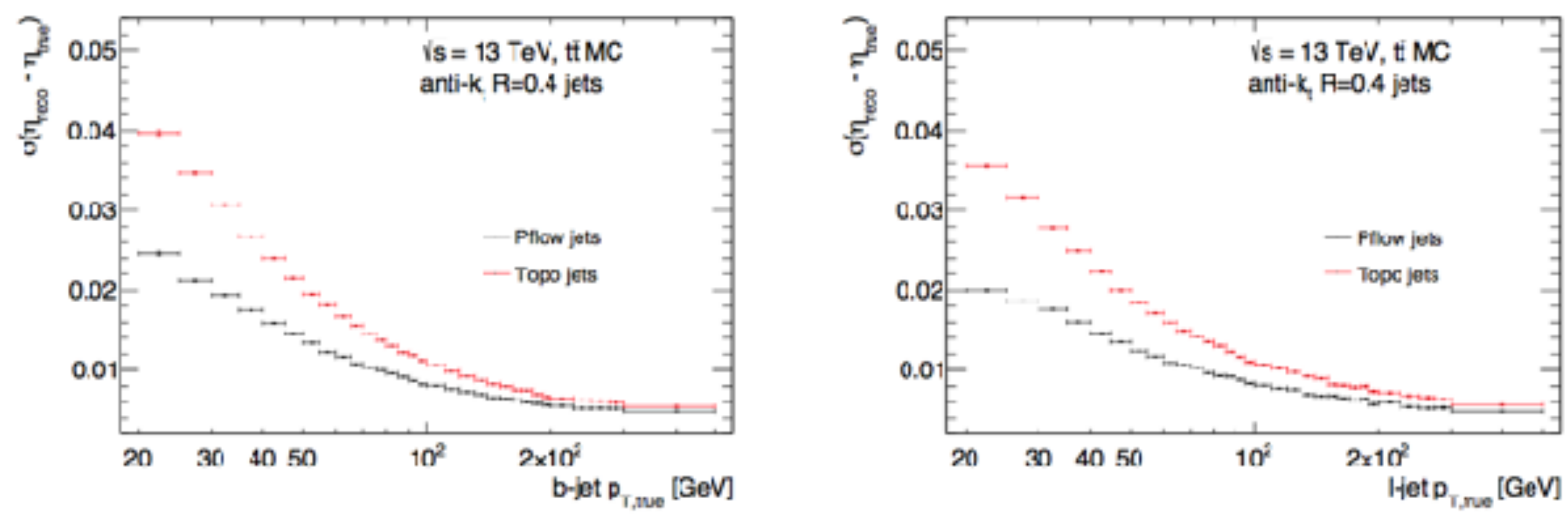


Figure 8.4: Width of the $\eta_{\text{reco}} - \eta_{\text{truth}}$ distribution for b-jets (left) and l-jets (right) depending on $p_{\text{T,truth}}$.

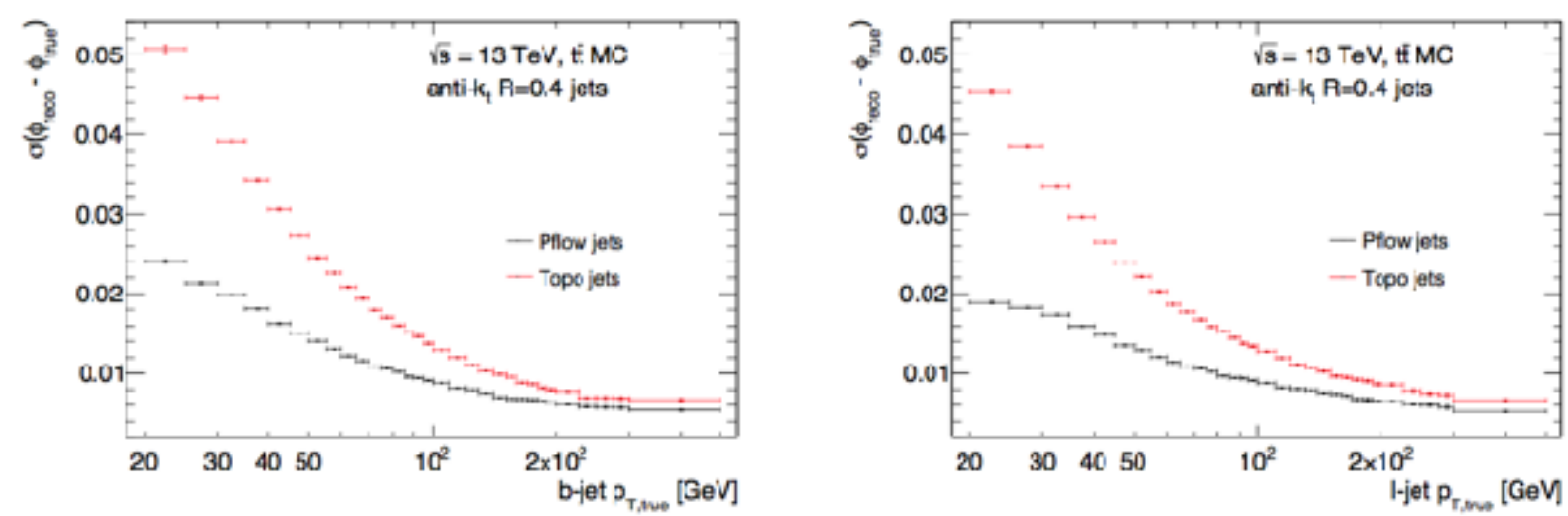


Figure 8.5: Width of the $\phi_{\text{reco}} - \phi_{\text{truth}}$ distribution for b-jets (left) and l-jets (right) depending on $p_{\text{T,truth}}$.

Look at PFlow jets in ttbar events

P. Falke (master thesis)

2015 data

W mass: m(Wₕ) | **top mass: m(tₕ)**

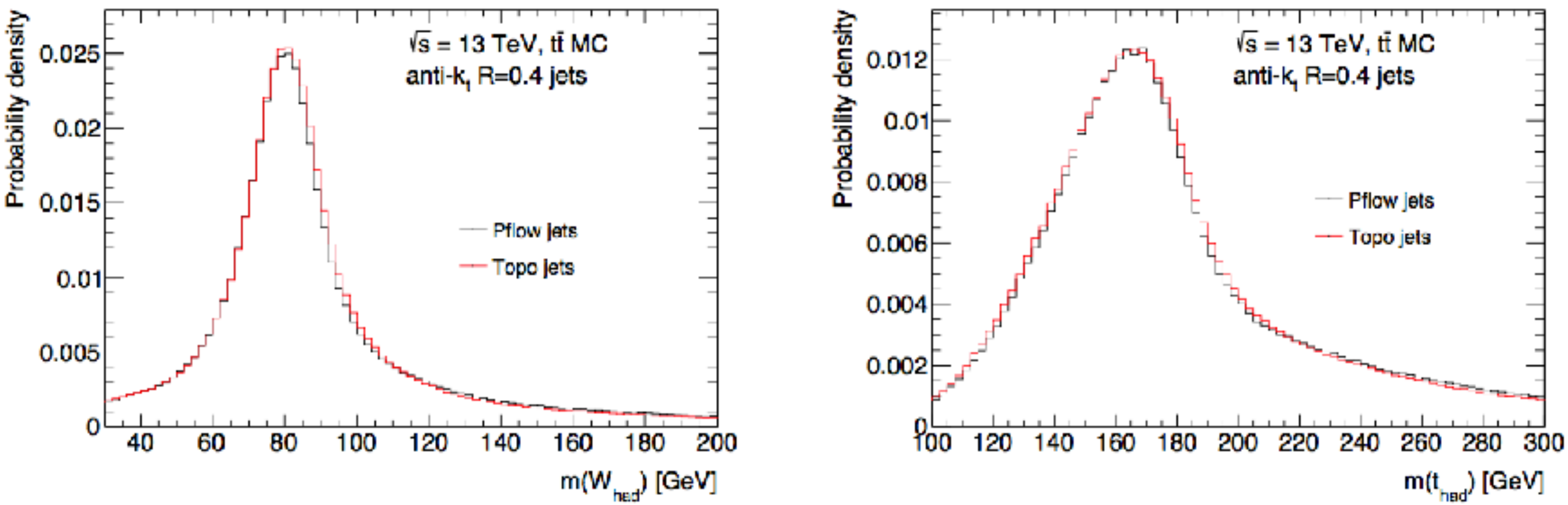


Figure 8.6: Comparison of the normalised $m(W_{\text{had}})$ (left) and $m(t_{\text{had}})$ (right) distributions for pflow and topo jets.

The mass peak resolution (σ_{Novo}/μ_{Novo}) improves a factor 4% in PFlow jets compared with EMTopo

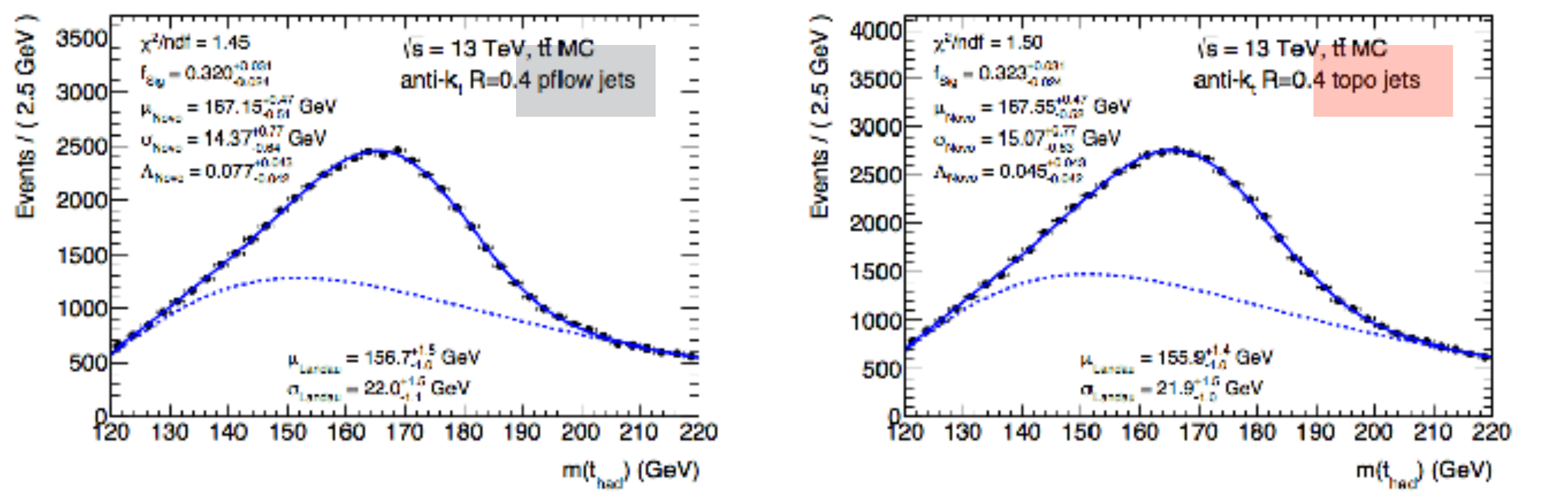


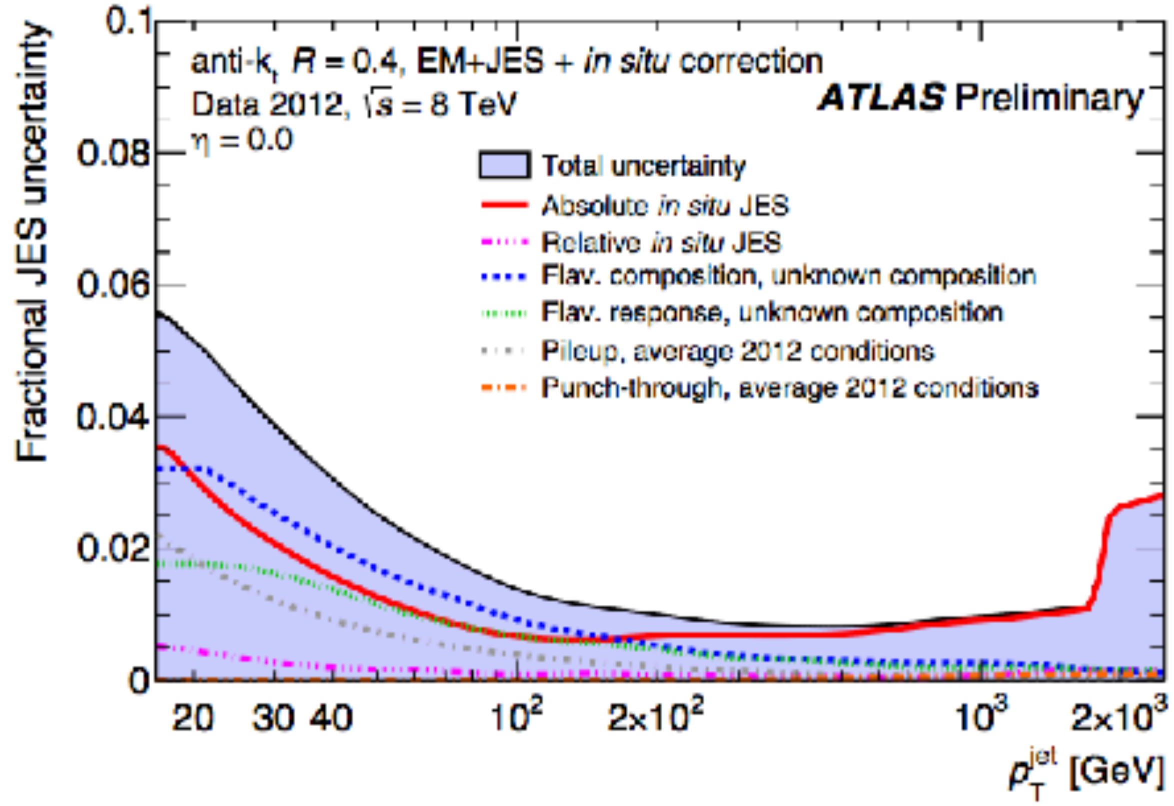
Figure 8.8: Fit to the $m(t_{\text{had}})$ distribution using all events, independent of their truth match category, for pflow jets (left) and topo jets (right).

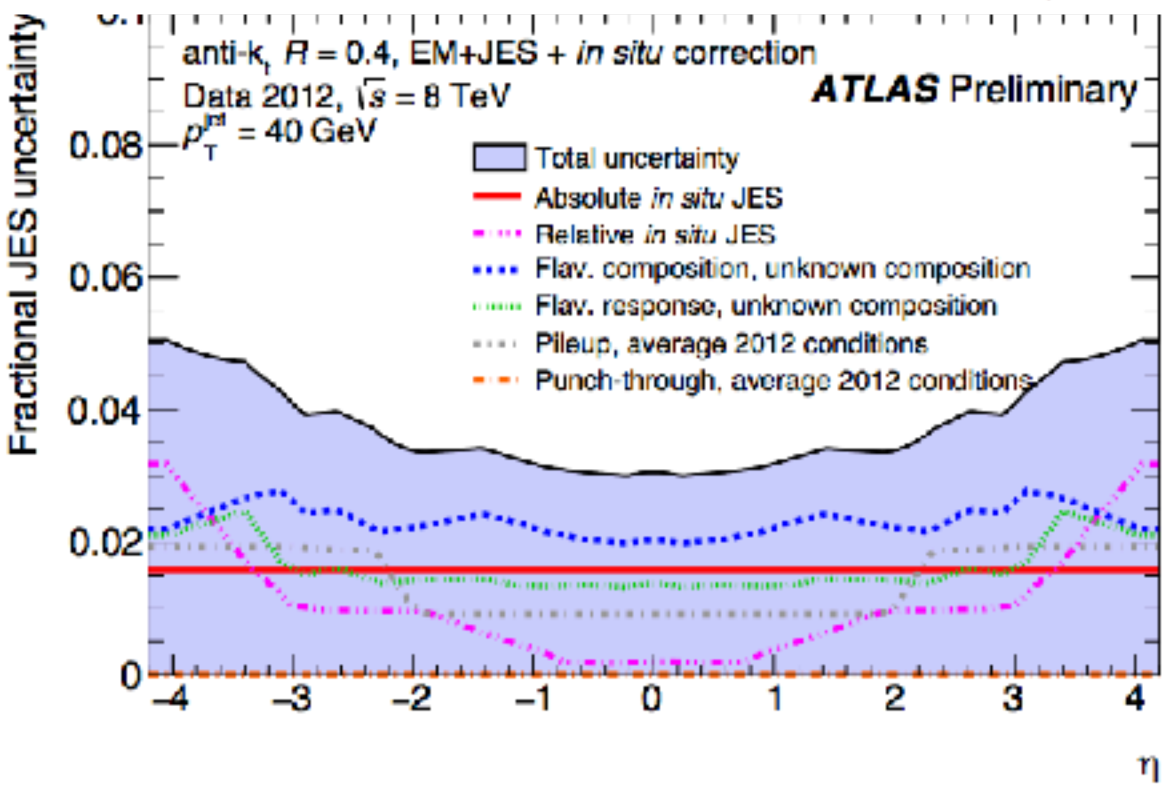
Systematic uncertainties

Unfortunately not for PFlow jets but available for other jet collections

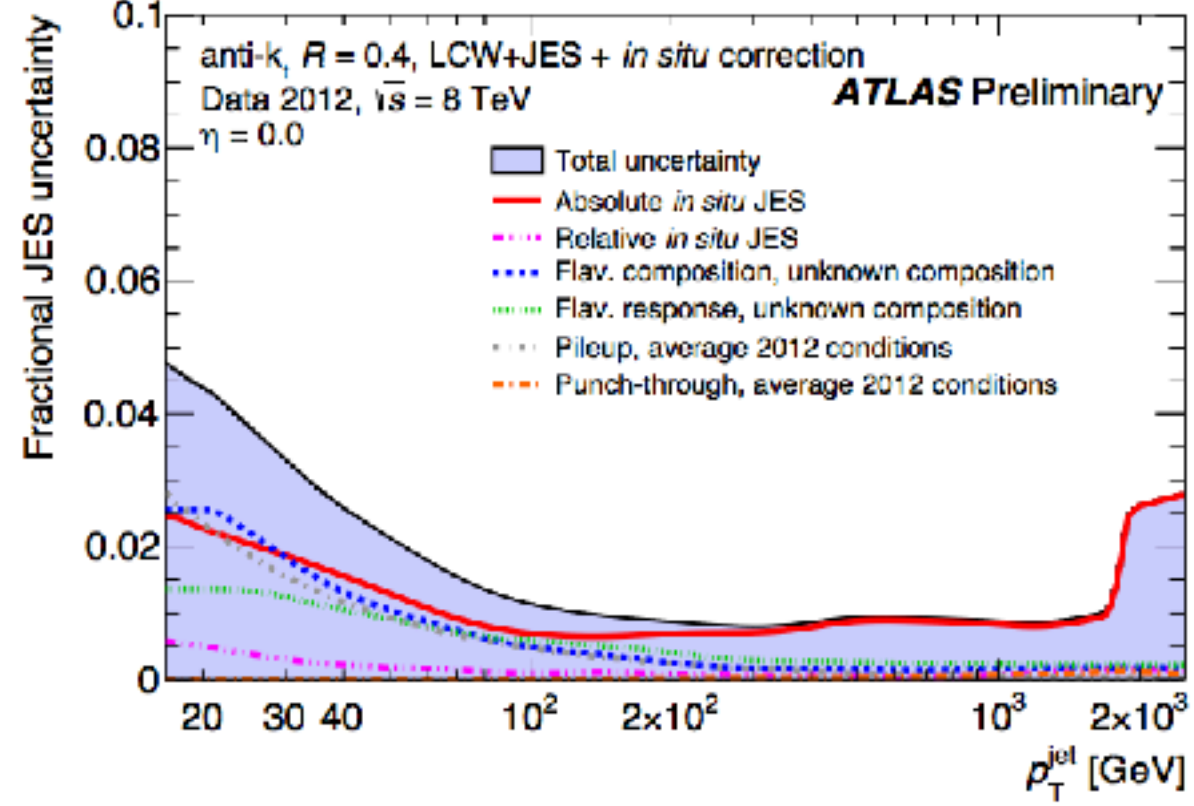
Systematic uncertainties at 8 TeV

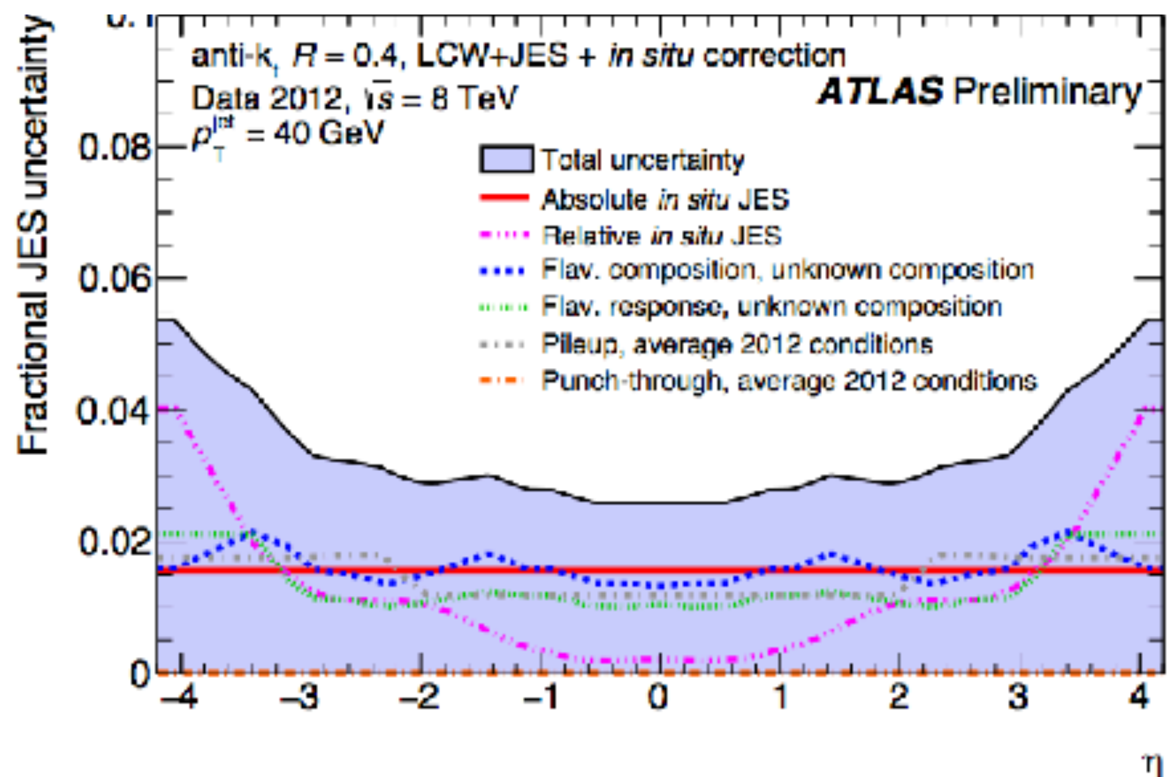
EM+JES





LC+JES

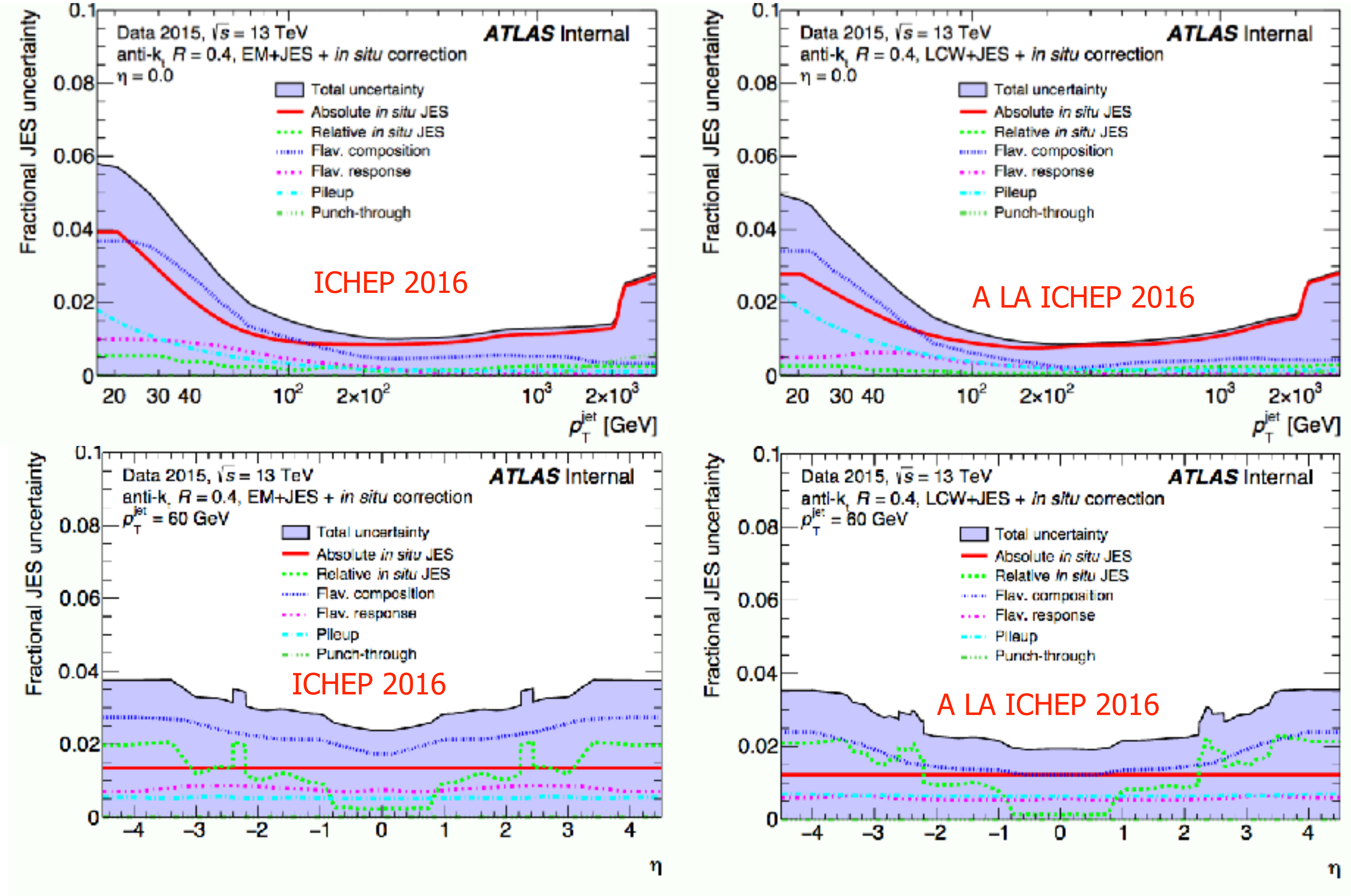




Systematic uncertainties at 13 TeV (Current recommendations)

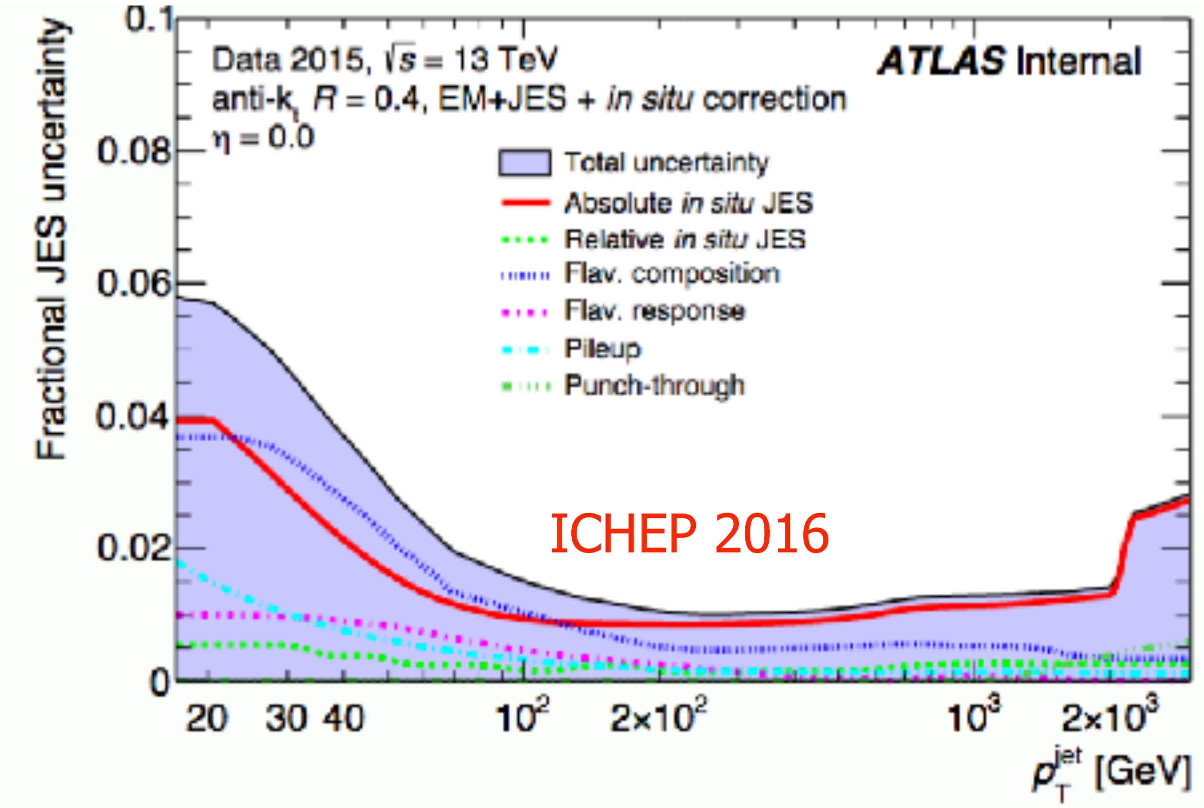
EM+JES

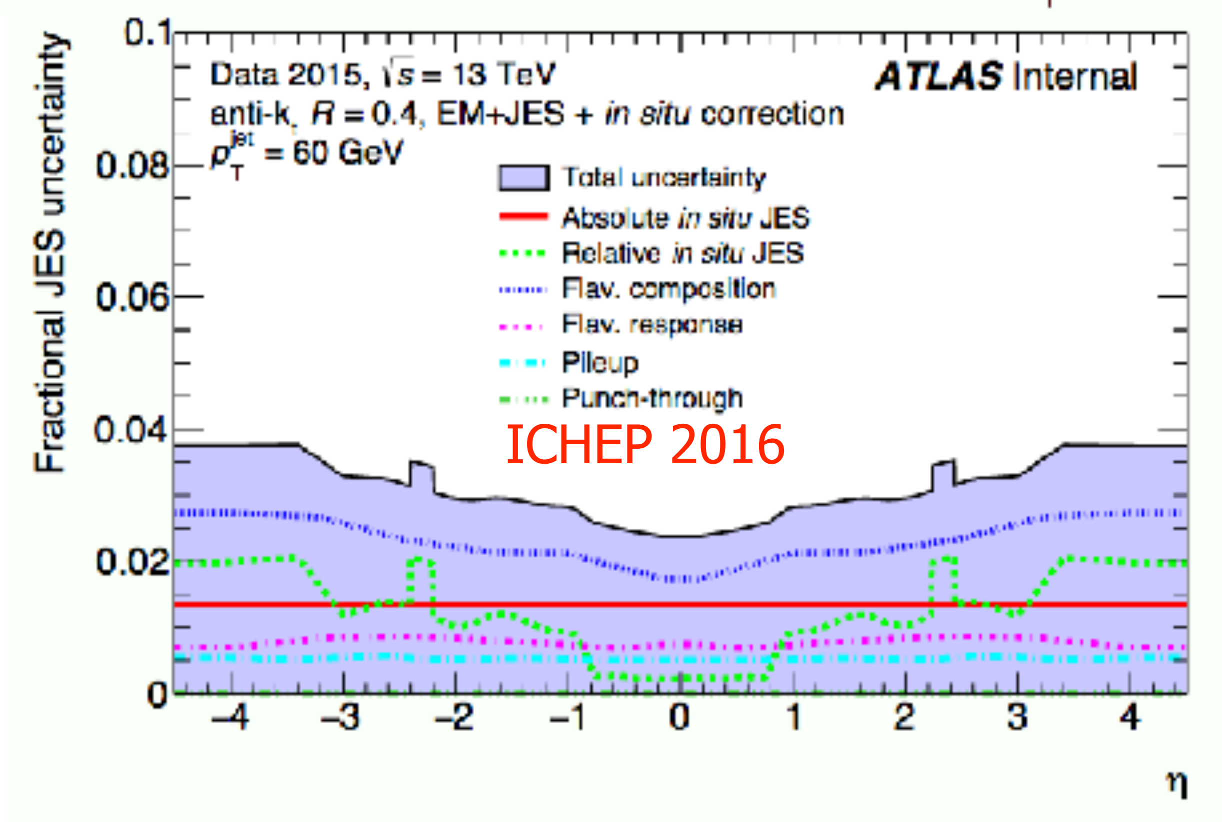
LC+JES



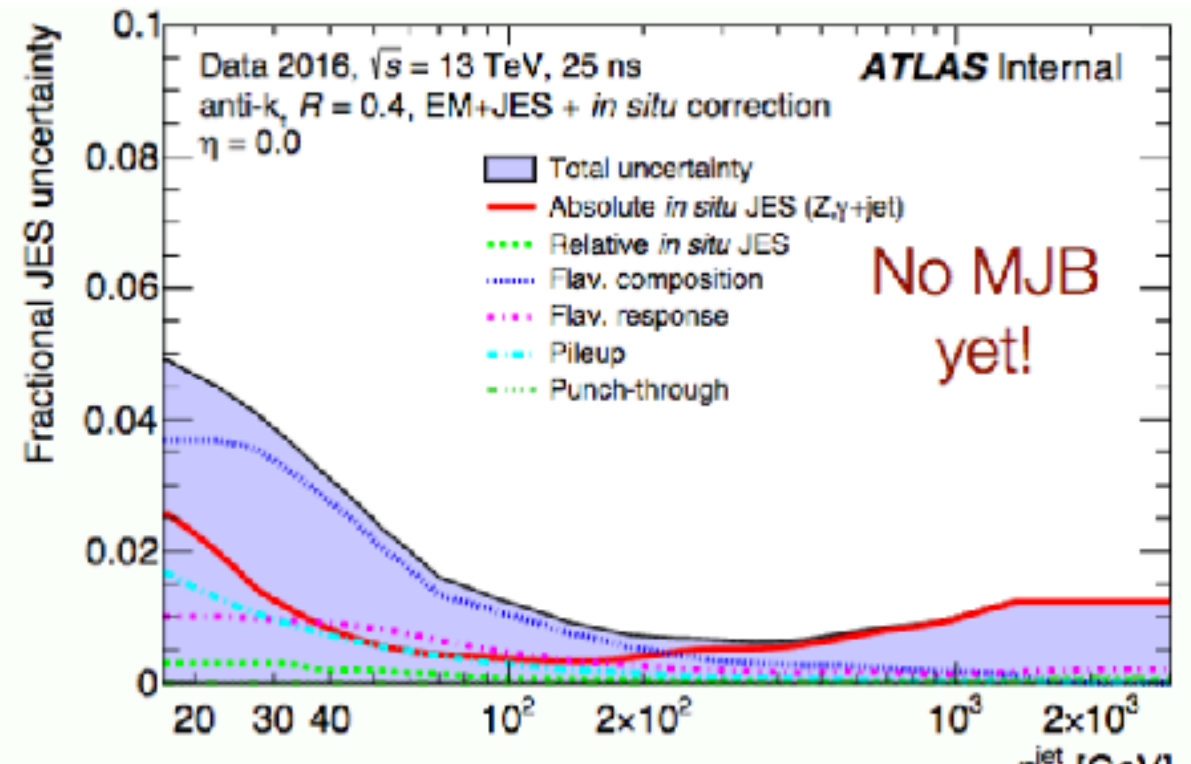
Systematic uncertainties at 13 TeV (EM+JES)

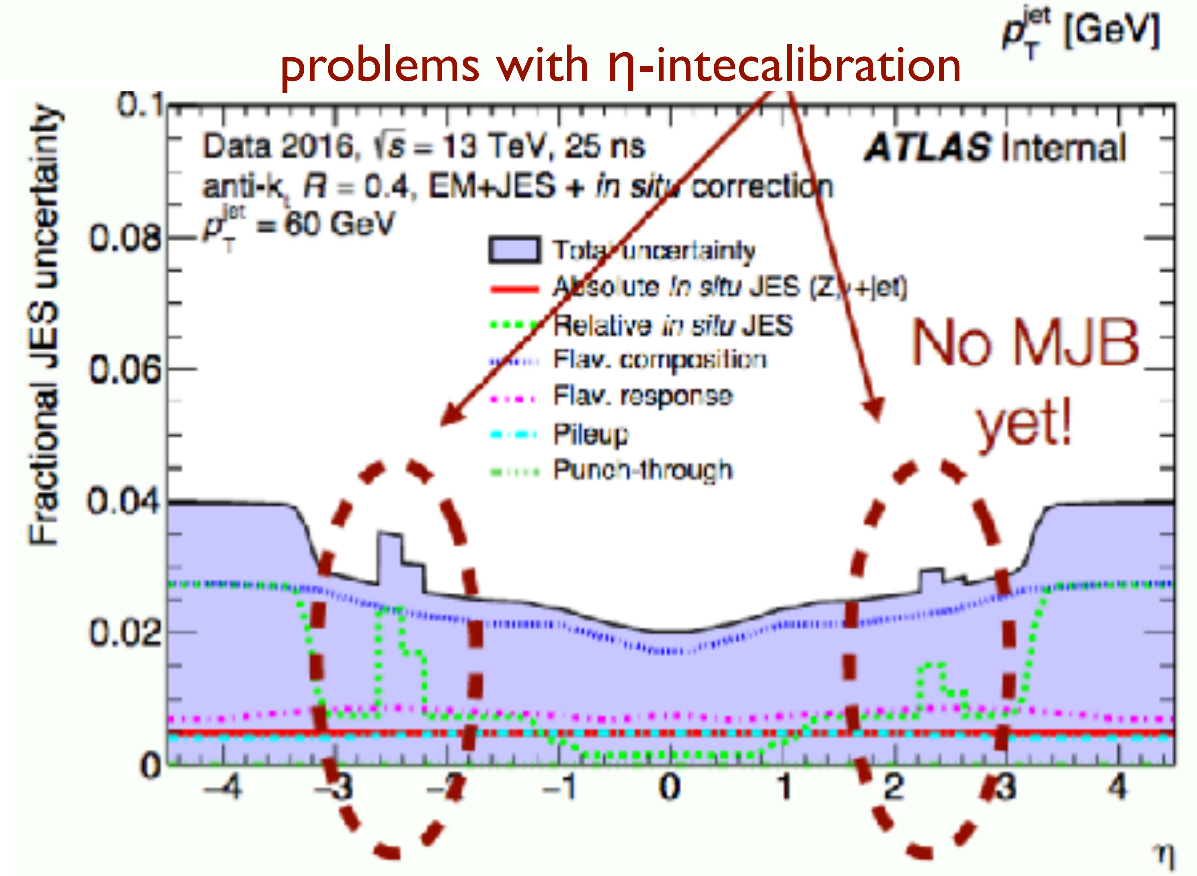
EM+JES (CURRENT)





EM+JES (PRELIMINARY)



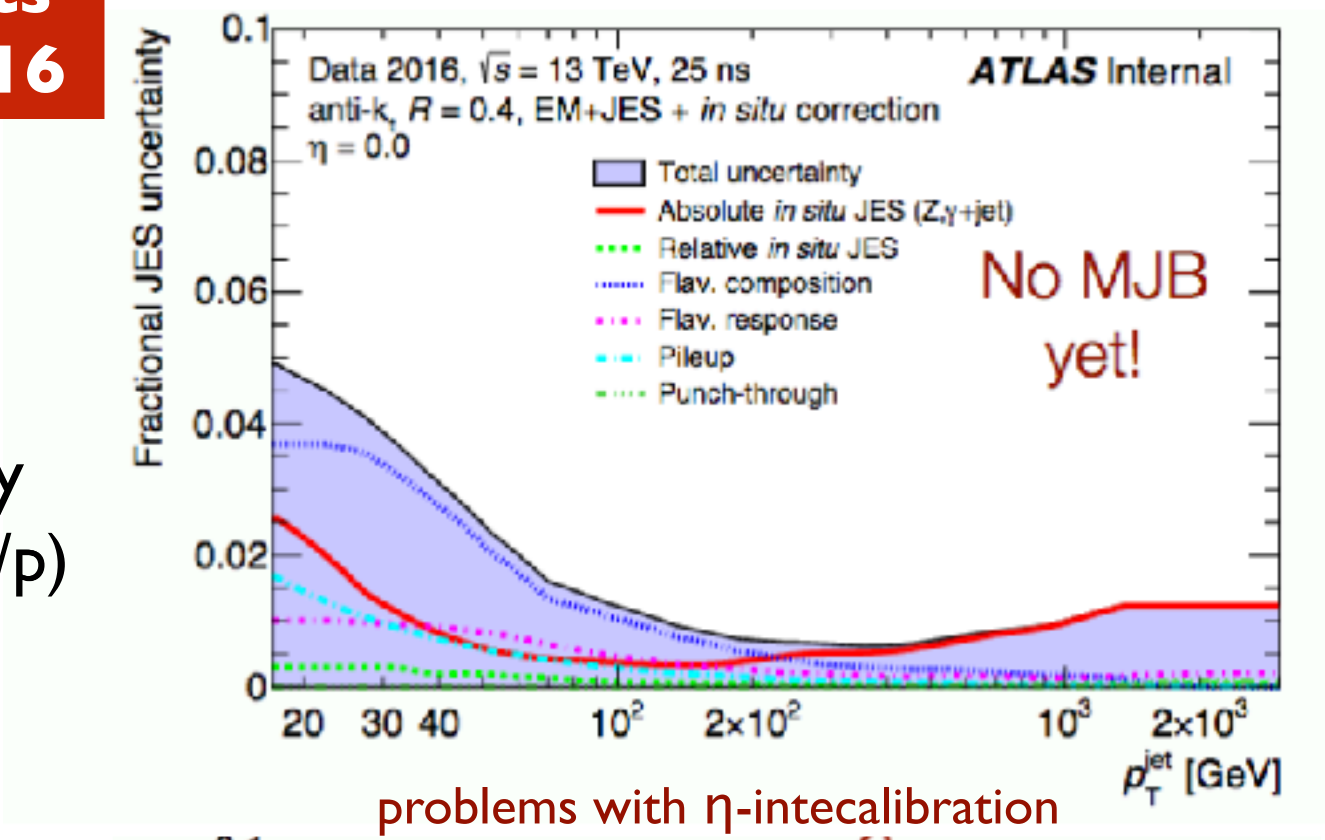


Systematic uncertainties at 13 TeV (EM+JES)

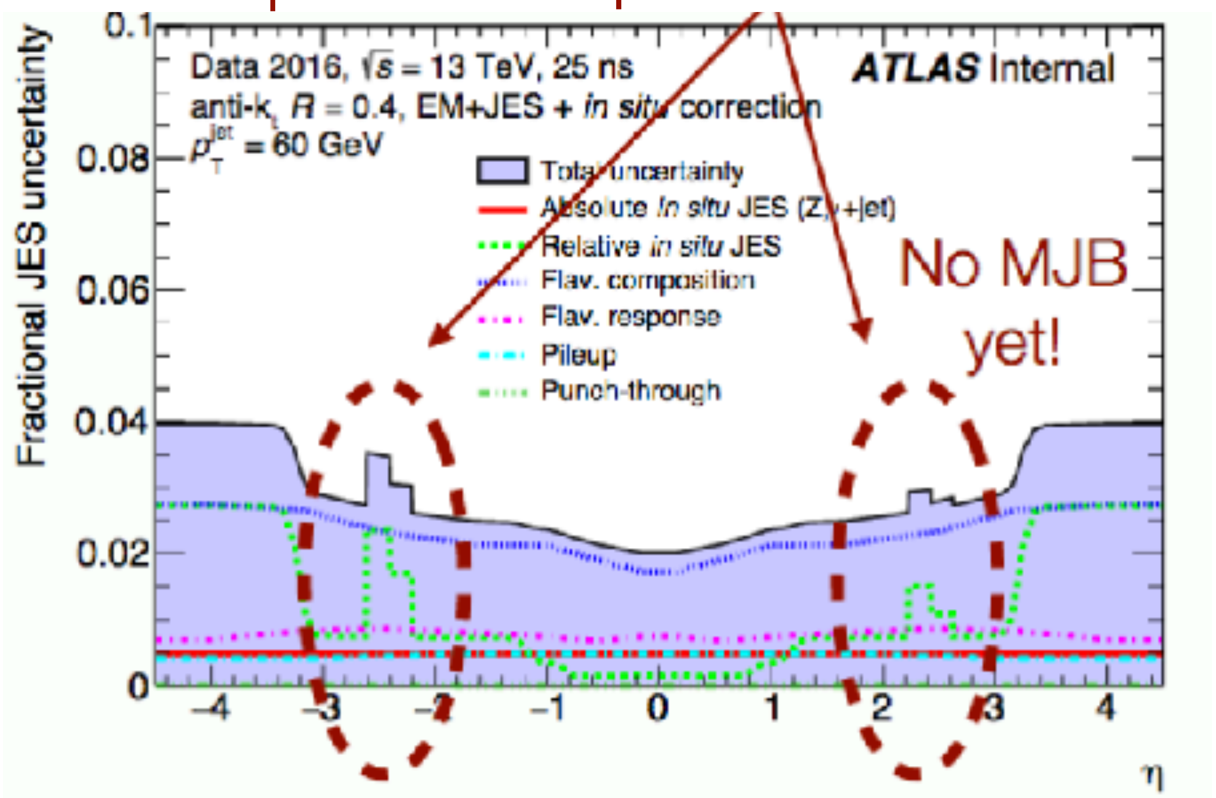
Moriond-17 version improvements at low and high p_T wrt to ICHEP-16

- Without two highest-p_T effects:
  - No MJB
  - No High-p_T single pions uncertainty (Improvements expected from new E/p)
- Reduction of in-situ uncertainties:
  - Improve out-of-cone uncertainty
  - New sherpa 2.2 samples
  - Higher statistics
- Main systematic **Flavour uncertainty**
  - Can be reduced by top group deriving the correct quark-gluon composition

EM+JES (PRELIMINARY)



problems with η-intecalibration



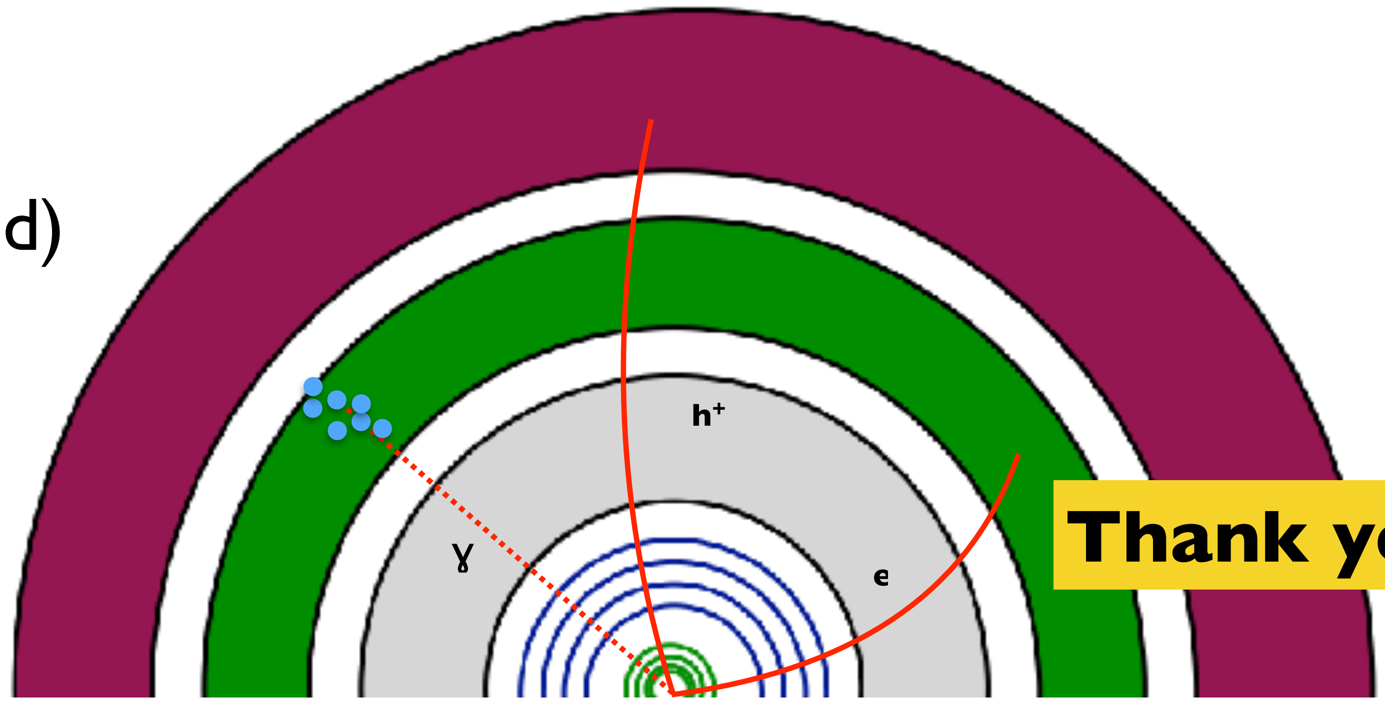
Summary

- Performance studies have demonstrated advantages for the particle-flow jets:
  - Better jet momentum resolution at low p_T and comparable above ~80 GeV
  - Better angular determination (in η and Φ)
  - Reduction and stability of/with pile-up and improvements in E_T^{miss}

- Many (single)-top analysis can make profit of using PFlow jets.
- Not urgent but it would be nice to include them in SingleTop ntuples
  - Study the impact in top analyses
  - Provide feedback to JetETMiss
  - Papers with PFlow for summer conferences

- Systematics:
  - Not ready yet for PFlow but
  - EMTopo improvements (Moriond)
  - LCTopo will come soon

It is time for starting having a look at **particle-flow** in **top physics**!



Thank you

Backup

PFlow in Top xAOD

- PFlow collection available in the primary xAOD
- DerivationFramework (00-02-78)
  - **AntiKt4EMPFlowJets** (1% of the total size in the slimmed xAOD)
    DerivationFramework/DerivationFrameworkCore/trunk/python/AntiKt4EMPFlowJetsCPContent.py
  - **MET_AntiKt4EMPFlow**
    DerivationFrameworkCore/trunk/python/MET_Reference_AntiKt4EMTopoCPContent.py
  - **BTagging_AntiKt4EMPFlow**
    DerivationFrameworkCore/trunk/python/BTagging_AntiKt4EMTopoCPContent.py

- AnalysisTop
  - Apply the right calibration for running PFlow jet collection:
    - JES_MC15Prerecommendation_PFlow_July2015.config
  - No b-tagging SF applied (not available yet)
  - Turn off the jet uncertainties (not available yet)
  - JetCleaning variables not included in the derivation (should use AntiKt4EMTopJets)

from Dimitris (top mass workshop)

JES uncertainties breakdown

- 8 TeV lepton+jets analysis, analysis ongoing

most likely, includes “customised” jet flavour composition → JES flavor

JES Component	Uncertainty
JES stat	0.1344
JES model	0.4068
JES det	0.0959
JES mix	0.0895
JES eta	0.0328
JES pileup	0.2242
JES flavor	0.2566
JES puncht	0.0479
tot JES unc	0.5660
bJES	0.0242
Total	0.5770

Name	Description	Category
Z+jet		
e E-scale material	Material uncertainty on electron energy scale	det.
e E-scale presampler	Presampler uncertainty on electron energy scale	det.
e E-scale baseline	Baseline uncertainty on electron energy scale	mixed
e E-scale smearing	Uncertainty on electron energy smearing	mixed
μ E-scale baseline	Baseline uncertainty on muon energy scale	det.
μ E-scale smearing ID	Uncertainty on muon ID momentum smearing	det.
μ E-scale smearing MS	Uncertainty on muon MS momentum smearing	det.
MC generator	Difference between MC generators	model
JVF	JVF choice	mixed
$\Delta\phi$	Extrapolation in $\Delta\phi$	model
Out-of-cone	Contribution of particles outside the jet cone	model
Sub-leading jet veto	Variation in sub-leading jet veto	model
Statistical components	Statistical uncertainty	stat./meth.
γ+jet		
γ E-scale material	Material uncertainty on photon energy scale	det.
γ E-scale presampler	Presampler uncertainty on photon energy scale	det.
γ E-scale baseline	Baseline uncertainty on photon energy scale	det.
γ E-scale smearing	Uncertainty on photon energy smearing	det.
MC generator	Difference between MC generators	model
$\Delta\phi$	Extrapolation in $\Delta\phi$	model
Out-of-cone	Contribution of particles outside the jet cone	model
Sub-leading jet veto	Variation in sub-leading jet veto	model
Photon purity	Purity of sample in γ+jets	det.
Statistical components	Statistical uncertainty	stat./meth.
Multijet balance		
α selection	Angle between leading jet and recoil system	model
β selection	Angle between leading et and closest sub-leading jet	model
MC generator	Difference between MC generators (fragmentation)	mixed
p_T asymmetry selection	Asymmetry selection between leading and sub-leading jet	model
Jet p_T threshold	Jet p_T threshold	mixed
Statistical components	Statistical uncertainty	stat./meth.

Table 6: Summary of the uncertainty components propagated through to the combination of *in situ* jet energy scale measurements from Z+jet, γ+jet and multi-jet balance studies. These are discussed in more detail in Sections 7 and 8.

11

PFlow MET

from Kate (Jamboree)

PFlow MET studies

- Default selection:
- - 20<pT<60 GeV && |eta|<2.4 && Jvt>0.64
- + pT>60 GeV && |eta|<2.4
- + pT>20 GeV && |eta|>2.4
- Default Tight selection:
- - 20<pT<60 GeV && |eta|<2.4 && Jvt>0.64
- + pT>60 GeV && |eta|<2.4
- + pT>30 GeV && |eta|>2.4
- Particle Flow selection:
- - 20<pT<60 GeV && |eta|<2.4 && Jvt>0.2
- + pT>60 GeV && |eta|<2.4
- + pT>30 GeV && |eta|>2.4

Two E_T^{miss} variants depending on the Soft Term:

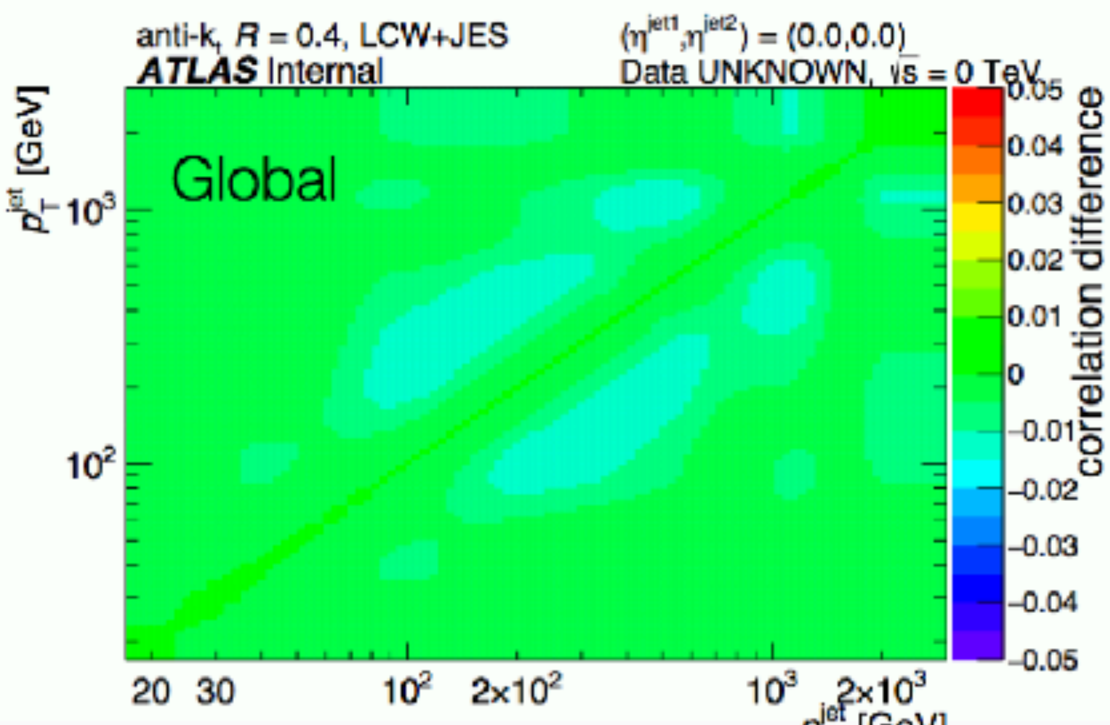
- Track Soft Term => ***TST E_T^{miss}***
  - Fully calibrated physics objects
  - Core tracks coming from the primary vertex unassociated to physics objects
  - Tracks belonging to jets between 7 and 20 GeV with JVT cut
    - ⇒ **Pile-up suppressed**
    - ⇒ **Neutrals in Soft Term are lost**
    - ⇒ **Limited Tracker acceptance**
- Calorimeter Soft Term => ***CST E_T^{miss}***
  - Fully calibrated physics objects
  - Core clusters
  - Clusters belonging to jets between 7 and 20 GeV, no JVT cut
    - ⇒ **Non Pile-up suppressed**
    - ⇒ **Neutrals in Soft Term are kept**
    - ⇒ **Full calorimeter acceptance**

Global and category reductions

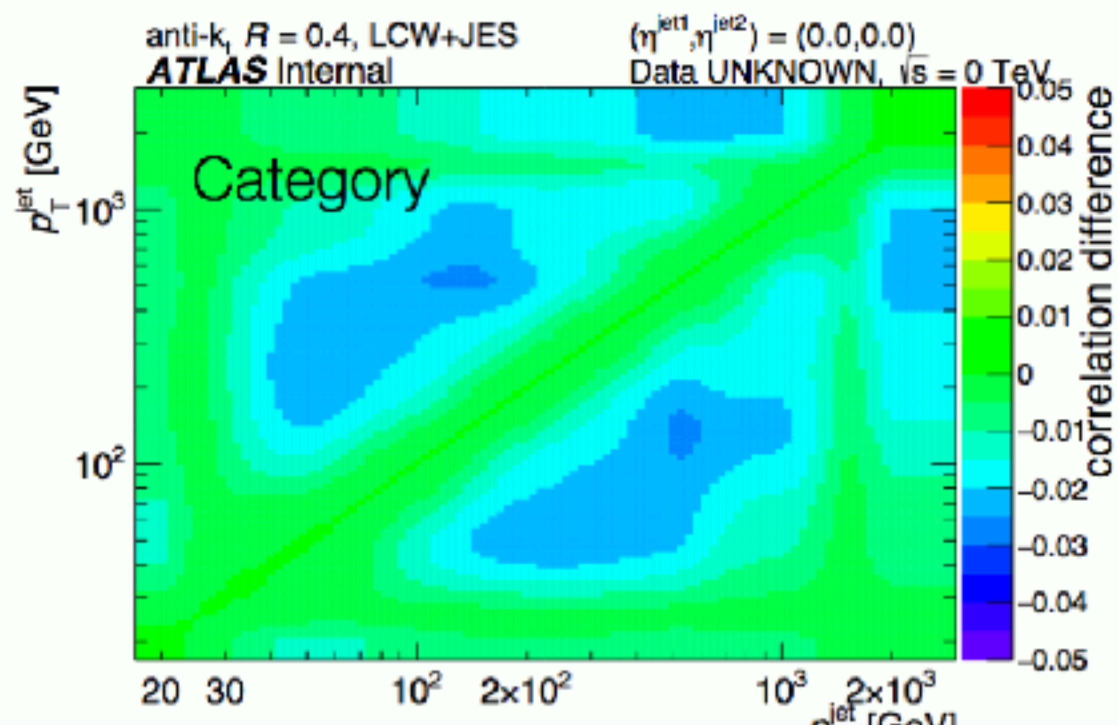
K.Pachal's slides

Global and category reductions

- 19-parameter and 25-parameter uncertainty reductions also ready, using the same config files which specify the EM reductions. Maximum correlation loss is 1.5% in the global reduction and 2.6% in the category reduction (both smaller than corresponding EM reductions)
- Strongly reduced uncertainties not yet available for LC jets, but we think also non-critical for primary users. Will follow in the next ~week. Strongly reduced configs in the tag contain only EM recommendations.



Mean value -0.4%, max -1.5% at (478,1094) GeV



Mean value -1.1%, max -2.6% at (131,530) GeV

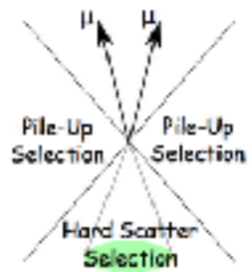
7

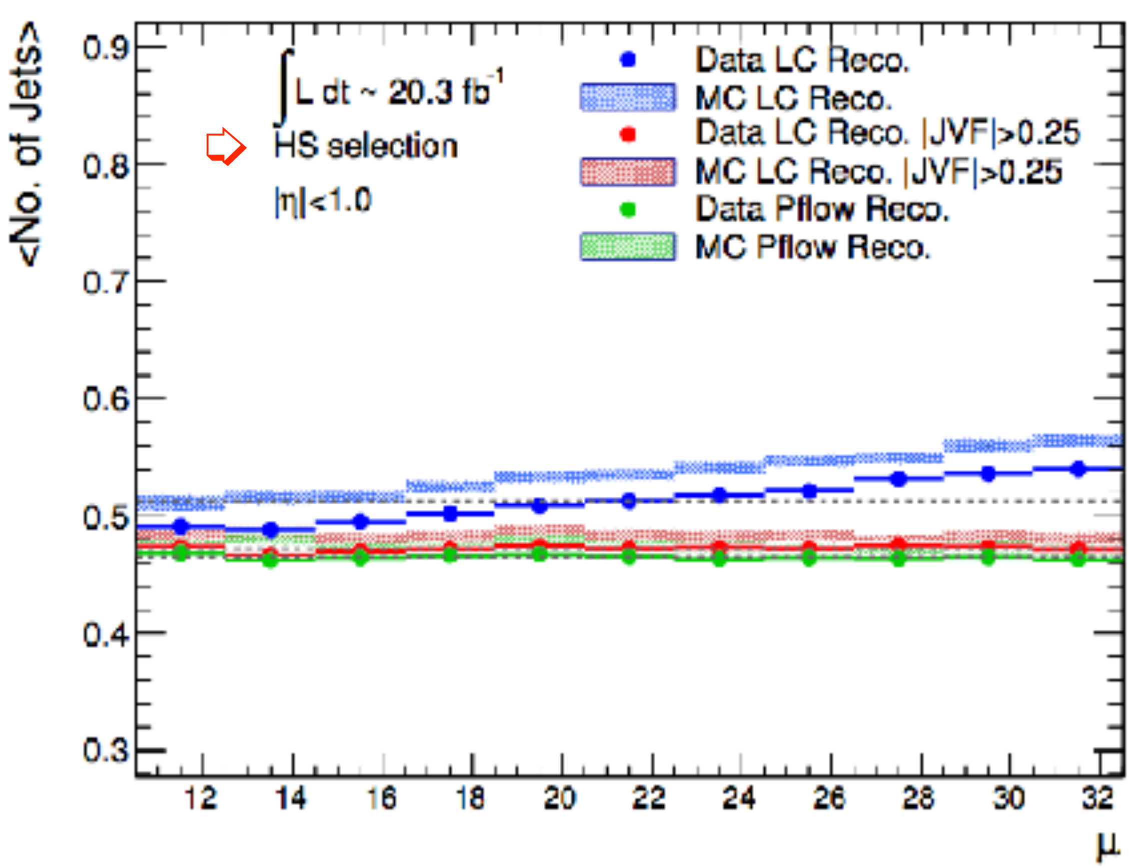
Particle flow performance studies

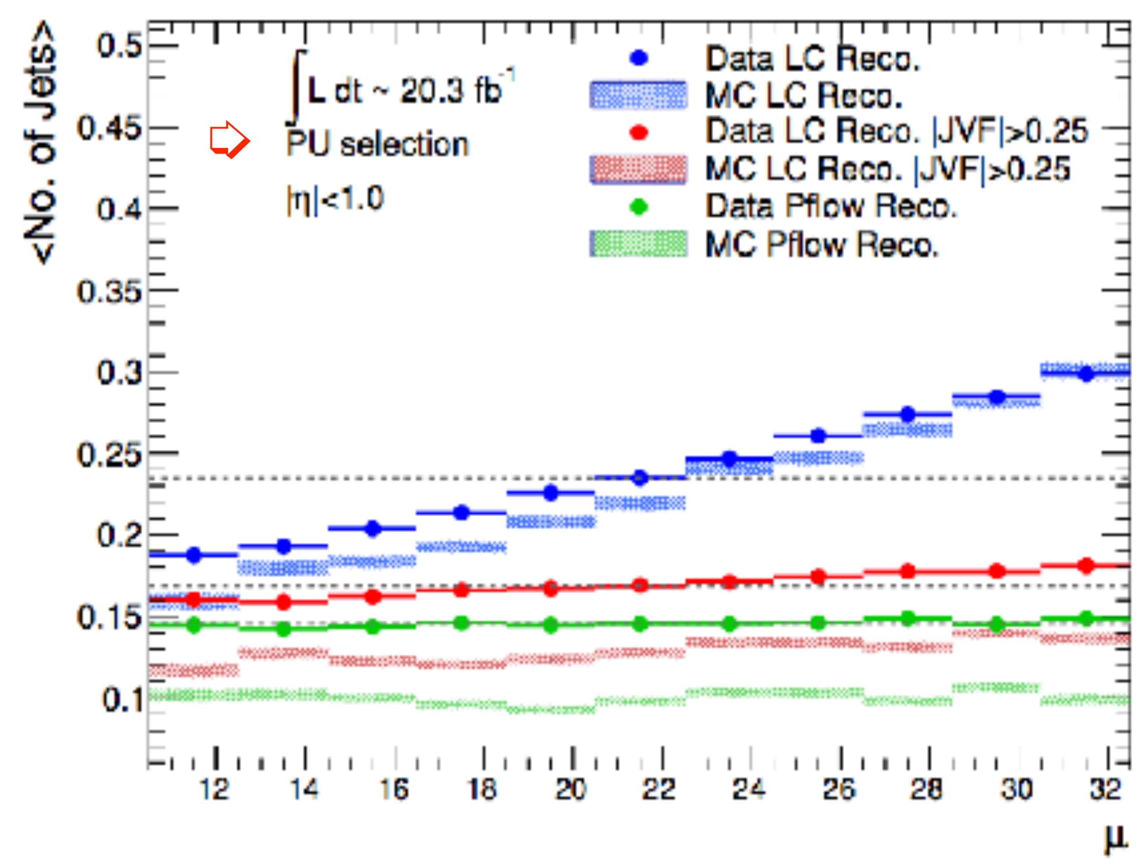
$\sqrt{s}$ = 8 TeV

Pile-up

- Average number of particle flow jets originating form pile-up is much suppressed.
- Average number of particle flow jets is stable as a function of pile-up.
- **Particle flow** jets behaviour flatter than the **LC** and **LC+JVF** jets
    - Hard scatter (HS) selection
    - Pileup (PI) selection







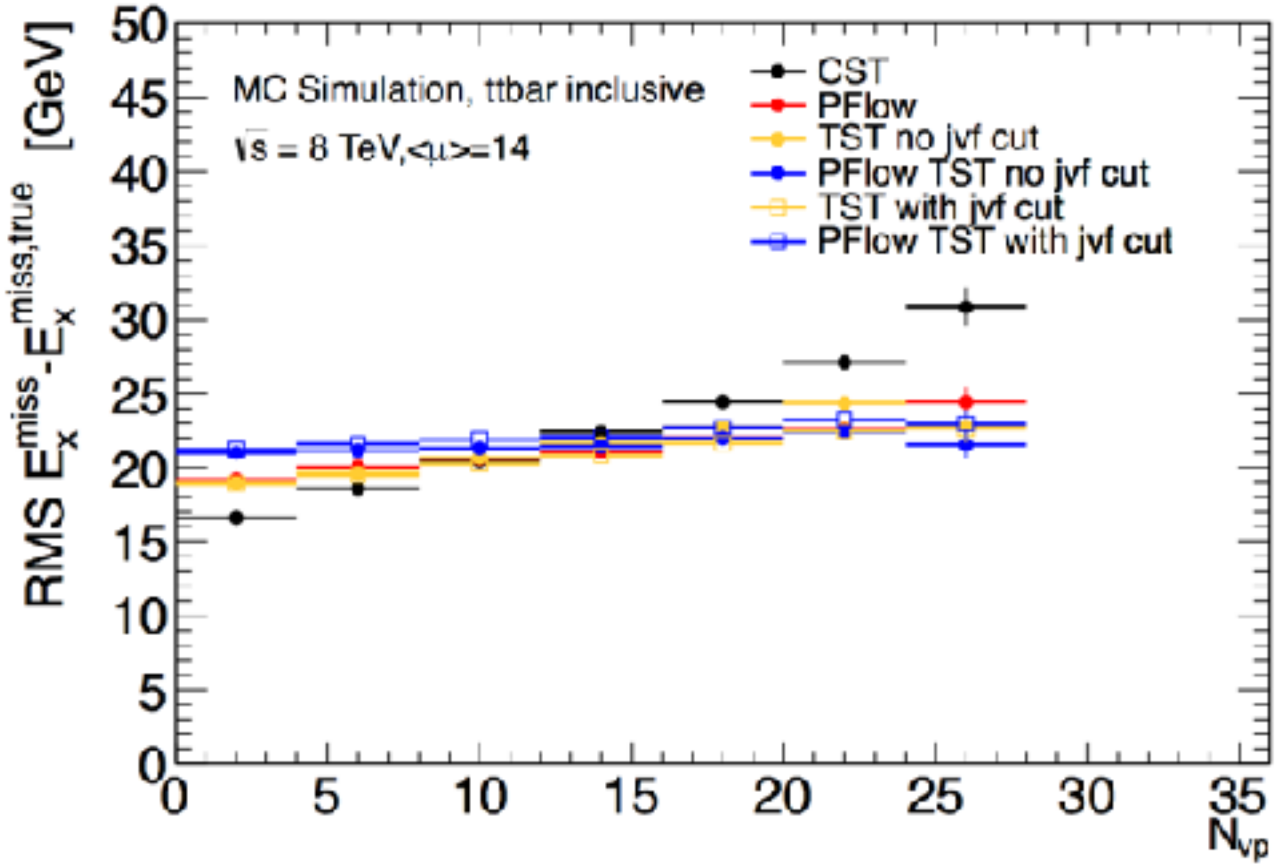
Particle flow performance studies

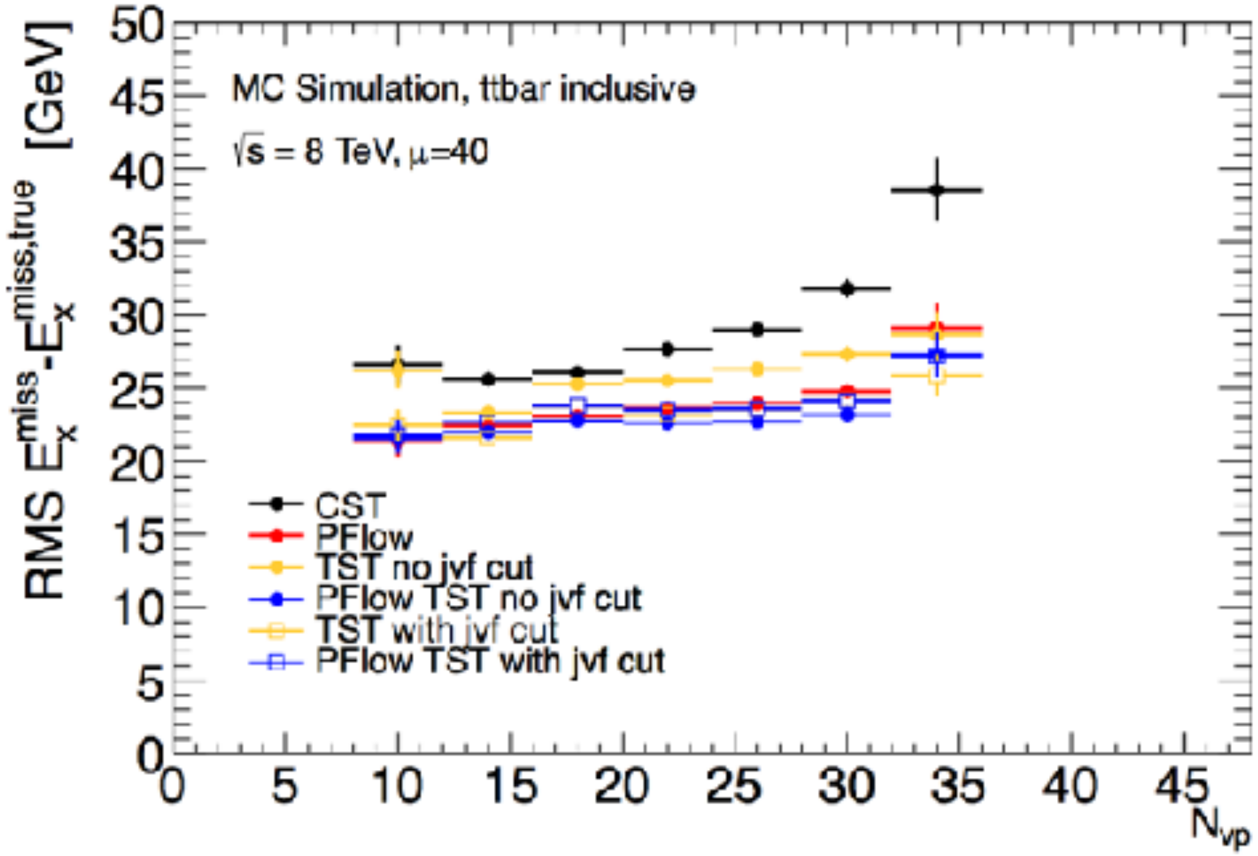
$\sqrt{s}$ = 8 TeV

E_T^{miss}

$$E_{x,y}^{\text{miss}} = -\left(\Sigma E_{x,y}^{\text{particle flow jets}} + \Sigma p_{x,y}^{e} + \Sigma p_{x,y}^{\gamma} + \Sigma p_{x,y}^{\mu} + \Sigma p_{x,y}^{\text{trk, unassociated}} + \Sigma E_{x,y}^{\text{clu, unassociated}}\right)$$

- ttbar MC events with high and low pileup conditions
  - **PFlow**
  - **CST** (cluster soft term)
  - **TST** (track soft term)
  - **PFlow TST** (PFlow track soft term)



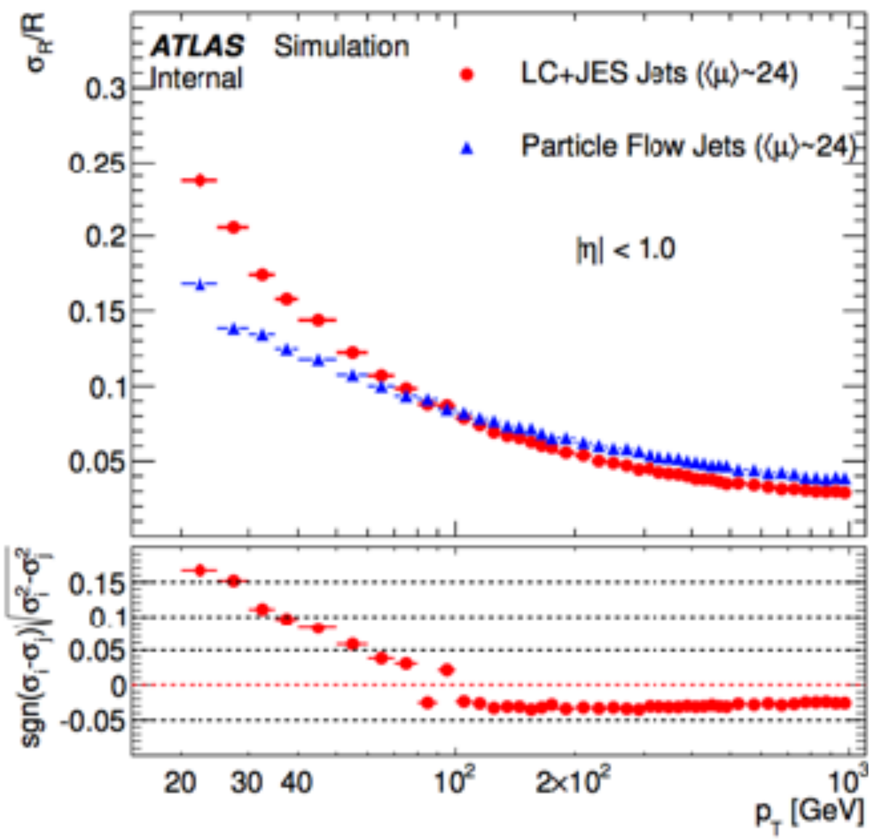


Particle flow performance studies

Paper link: PFlowPaper

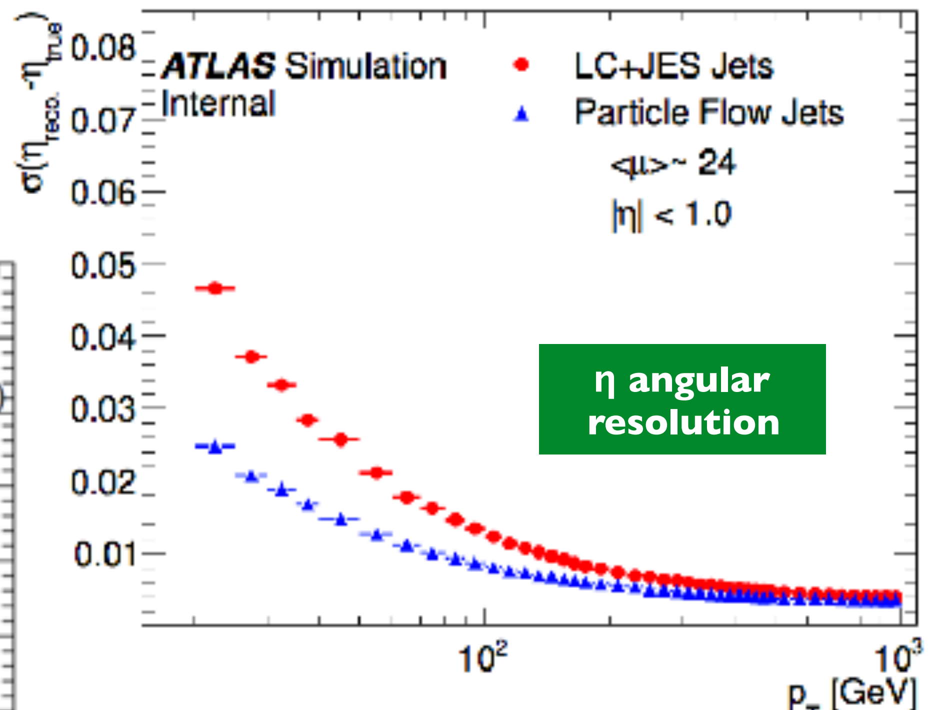
$\sqrt{s}$ = 8 TeV

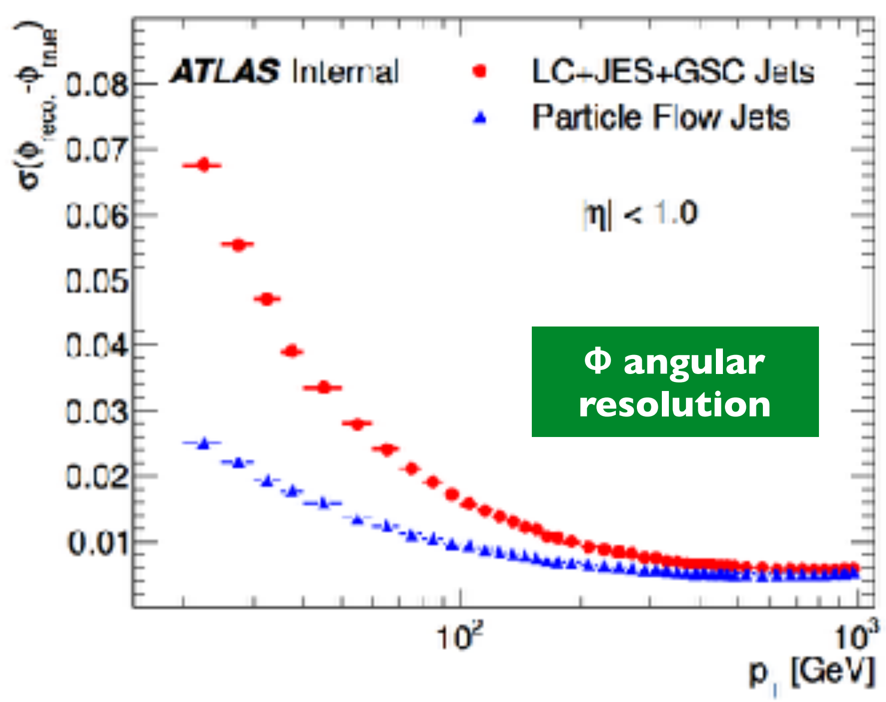
Jet P_T resolution



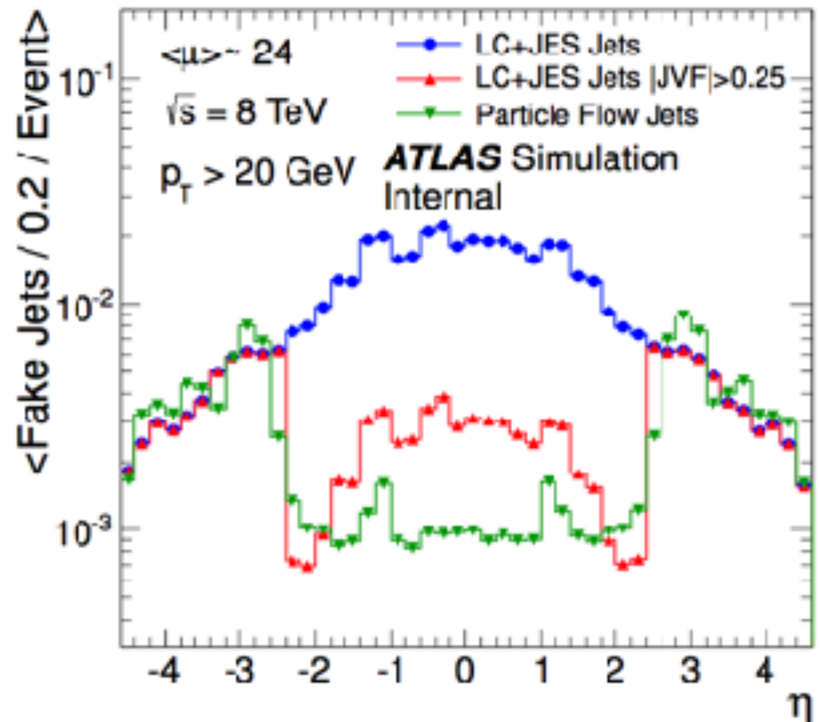
- Most significant improvements at low p_T and central η region
- Resolution at high p_T is a bit worse
  - It will be fixed in Rel 20.7

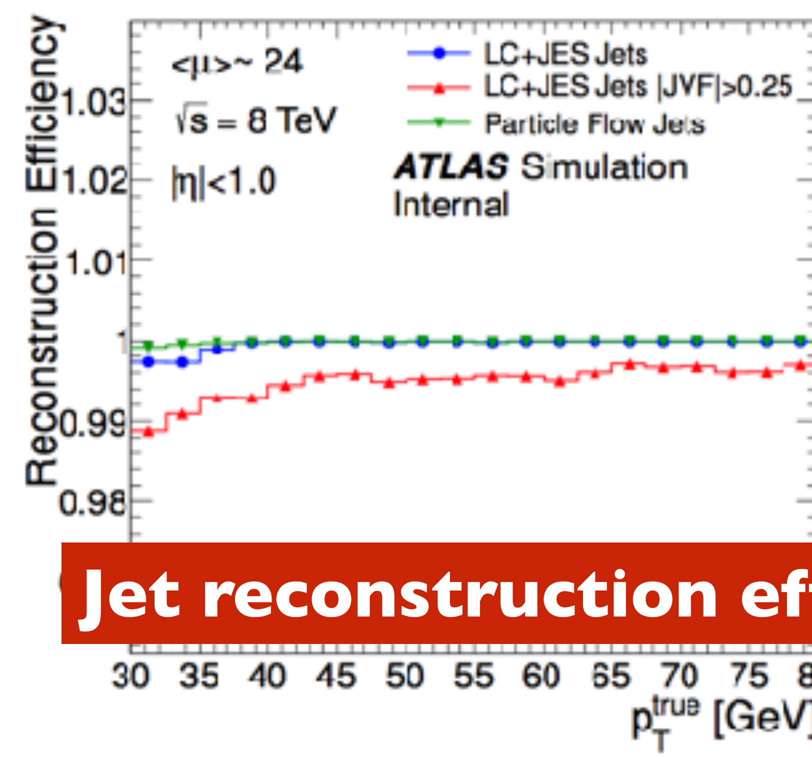
Jet angular resolution





Pile-up rejection





Jet reconstruction eff.

Global Sequential Correction steps

EM jets:

1. f_{ch}: jet charged fraction
2. f_{Tile0}: jet energy fraction in the Tile0 layer
3. f_{LAr3}: jet energy fraction in the EM3 layer
4. n_{trk}: number of tracks associated to the jet
5. $width_{trk}$: average angular spread of tracks around jet, weighted by track p_{T}
6. $N_{segments}$: number of muon segments behind the jet

- Each jet property leads to an improvement of:
  - f_{Tile0} and f_{LAr3} $\rightarrow$ jet energy resolution
  - n_{trk} and $width_{trk}$ $\rightarrow$ flavour response difference LQ and gluon jets
  - $N_{segments}$ $\rightarrow$ very high p_{T} jets entering in the muon spectrometer

p-flow jets:

1. f_{ch}: jet charged fraction
2. f_{Tile0}: jet energy fraction in the Tile0 layer
3. f_{LAr3}: jet energy fraction in the EM3 layer
4. n_{trk}: number of tracks associated to the jet
5. $width_{trk}$: average angular spread of tracks around jet, weighted by track p_{T}
6. $N_{segments}$: number of muon segments behind the jet

   $\rightarrow$ $N_{segments}$ not implemented yet due to technical issues

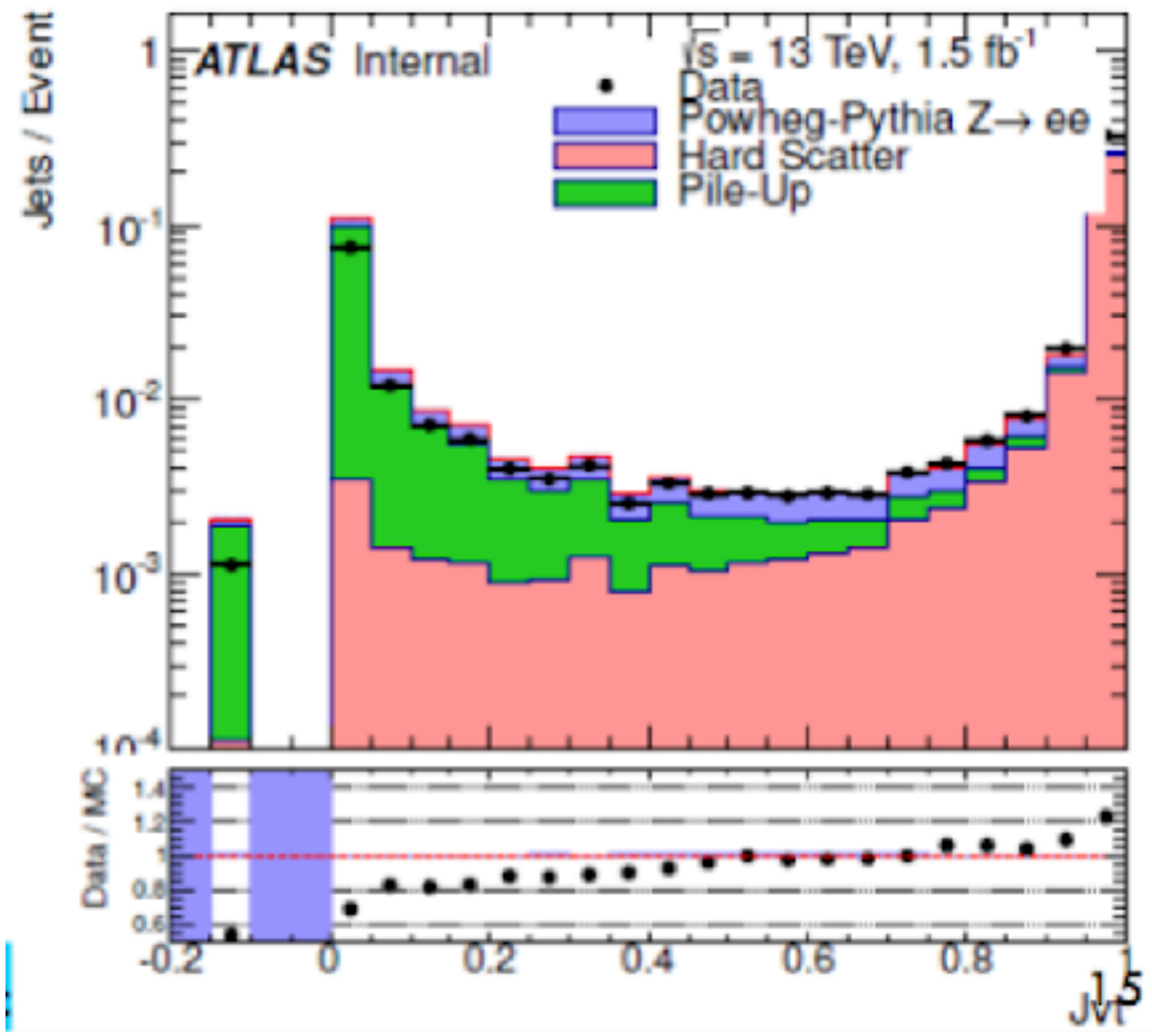
- Each jet property leads to an improvement of:
  - f_{Tile0} and f_{LAr3} $\rightarrow$ jet energy resolution
  - n_{trk} and $width_{trk}$ $\rightarrow$ flavour response difference LQ and gluon jets
  - $N_{segments}$ $\rightarrow$ very high p_{T} jets entering in the muon spectrometer

JVT studies using PFlow jets:

2016 data

- First look at **JVT** with PFlow jets:
  - A small fraction of PU jets remains
  - Further reduction by a factor > 5 using a cut at 0.1with 1% inefficiency for HS jets

Chris



Current recommendations based on EMTopo

Working Point	JVT Cut	Average efficiency
Loose	0.11	97%
Default	0.59	92%
Tight	0.91	85%