Research progress and plans

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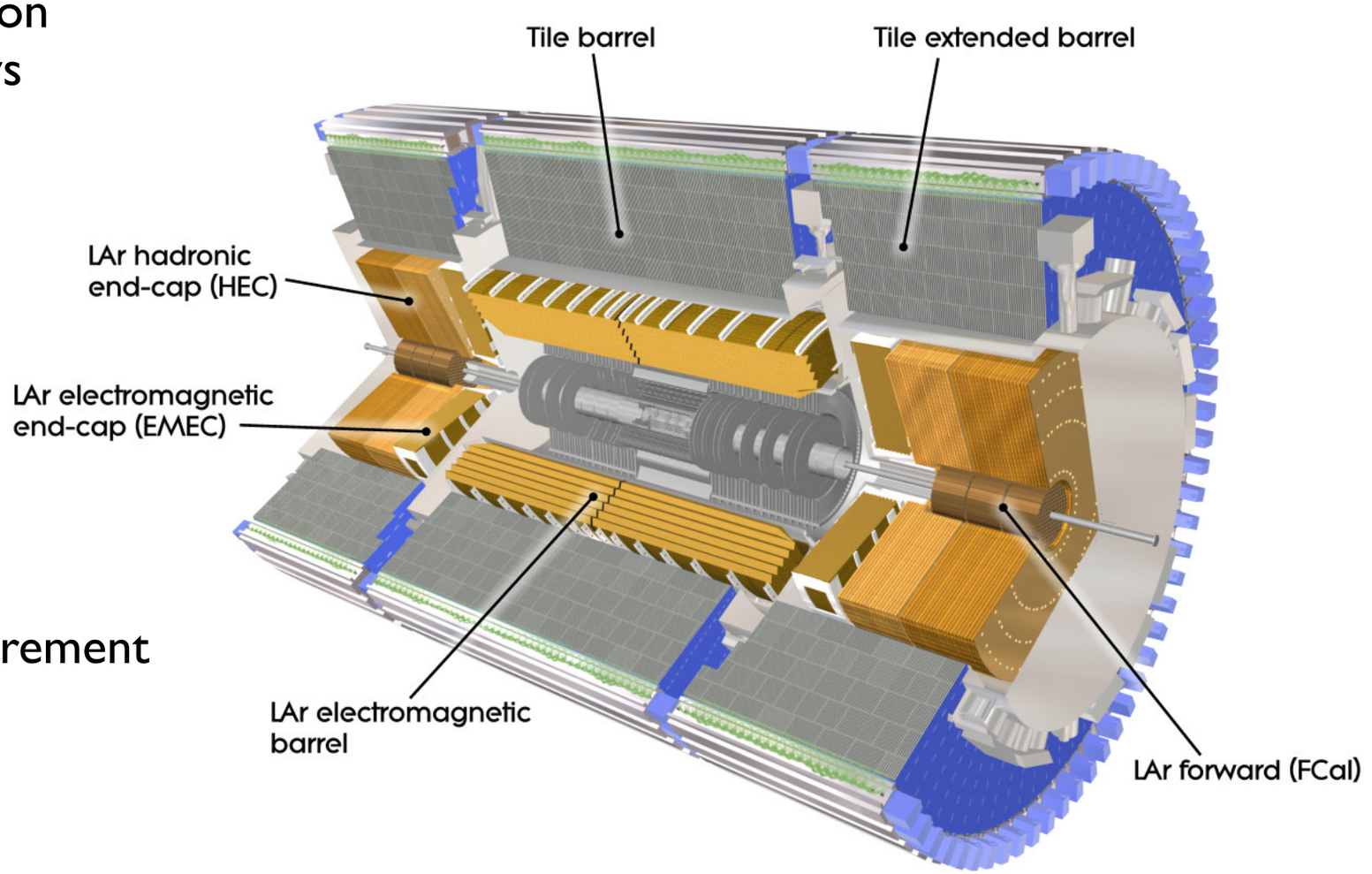
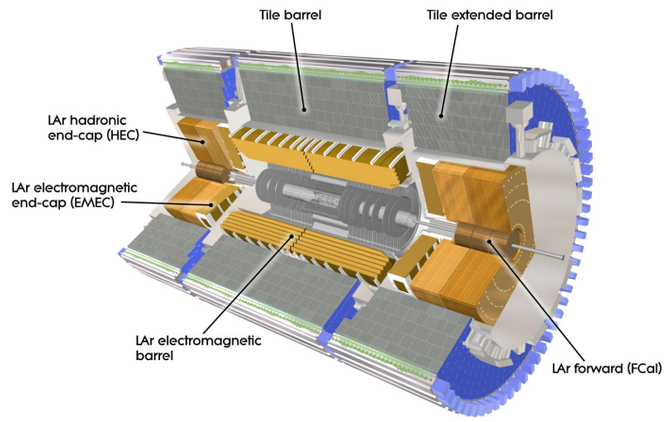
CERN-KEK Committee, 5th meeting

Outline

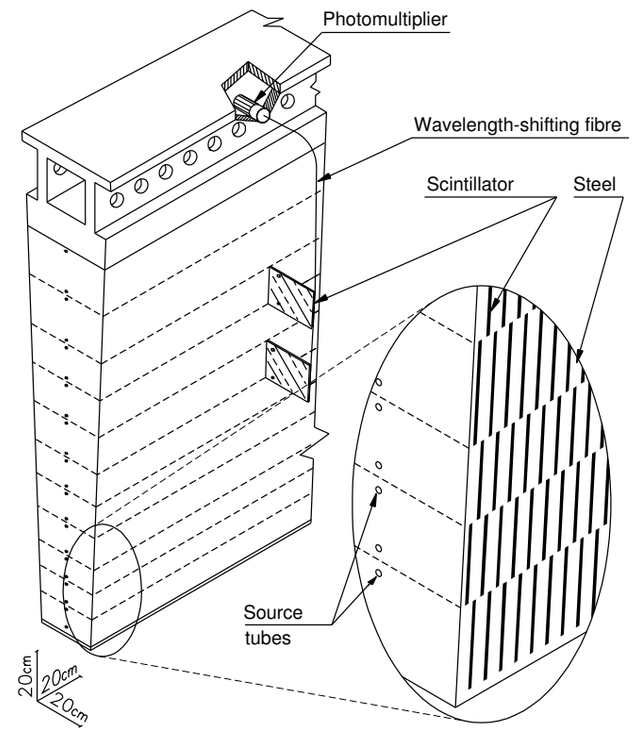
- Work progress
  - 10.2008 - 3.2010
    - ATLAS TileCal EM scale calibration
      - performance using cosmic rays
  - 4.2010 - now
    - Jet performance study
      - Cleaning
      - Data preparation with new calibration
      - Jet energy scale uncertainty
      - Pile-up
    - Jet inclusive cross section measurement
- Summary and future plans

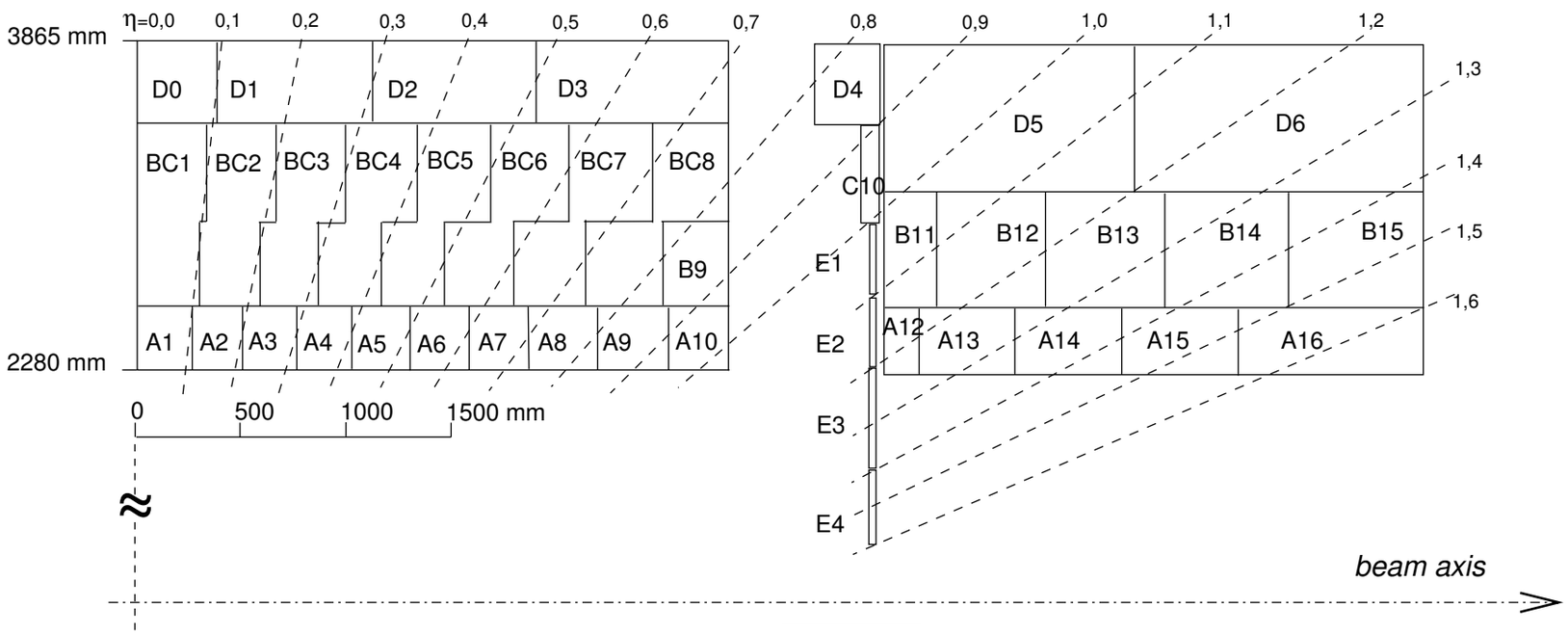


ATLAS Tile Calorimeter



- Hadronic calorimeter
  - Flat iron absorbers + scintillator tiles
  - $|\eta| < 1.7$
    - Long Barrel: $|\eta| < 1.0$
    - Extended Barrel: $0.8 < |\eta| < 1.7$
- Goal
  - $\sigma E/E$ (jet) = ~50%/$\sqrt{E} \oplus 3\%$ (TDR)
  - Jet energy scale uncertainly: 1-2%
- Geometry
  - Length
    - LB: 5.8m, EB: 2.6m
  - Radius
  - Inner: 2.28m, Outer: 4.25m
    - 7.4λ
- Granularity
  - 64 modules in each barrel
    - $\Delta\varphi$ ~ 0.1 rad
  - 3 layers
    - A, BC, D: "Cells"
  - "Tower"
    - $\Delta\eta$ = 0.1 for A and BC cells
      0.2 for D cells
  - ~5000 cells



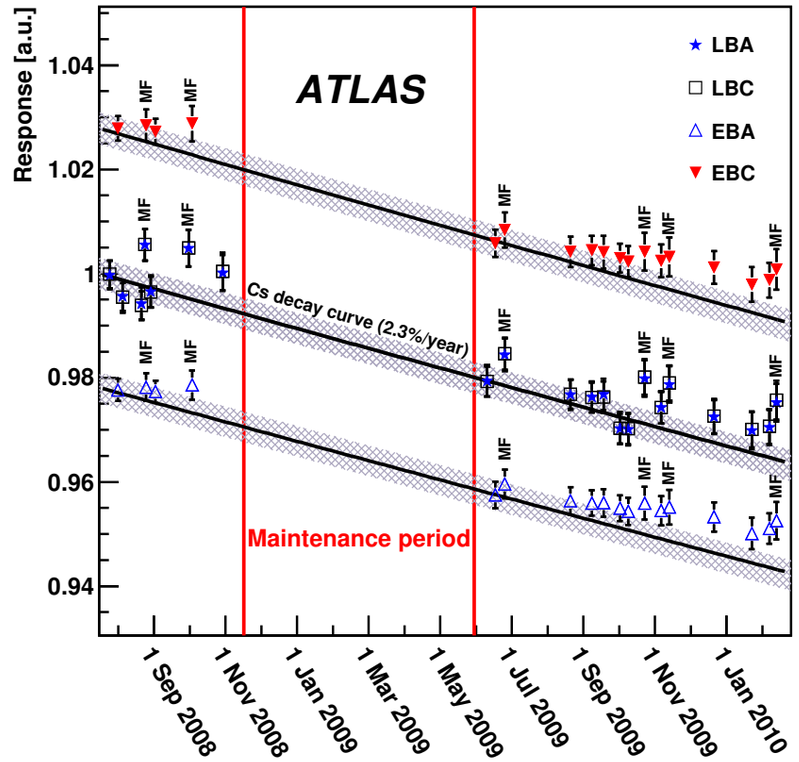


TileCal EM calibration

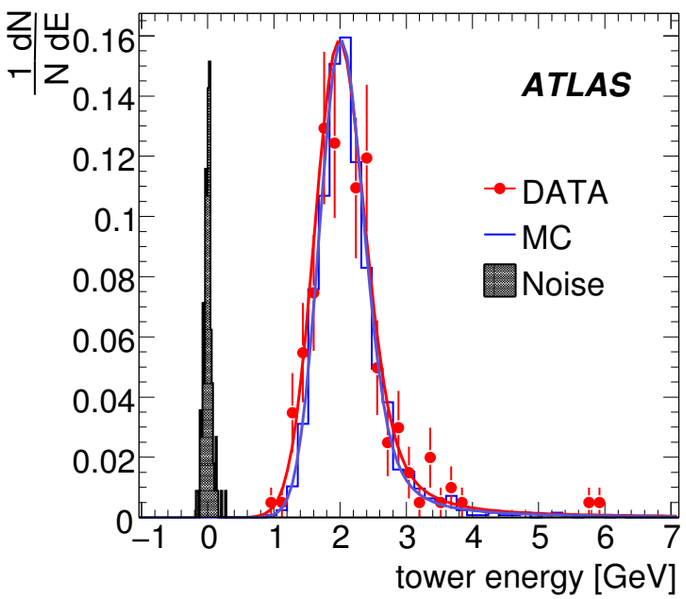
- EM calibration
  - Basic calibration/monitoring method
    - Cs system
      - works well
      - correction from decay curve

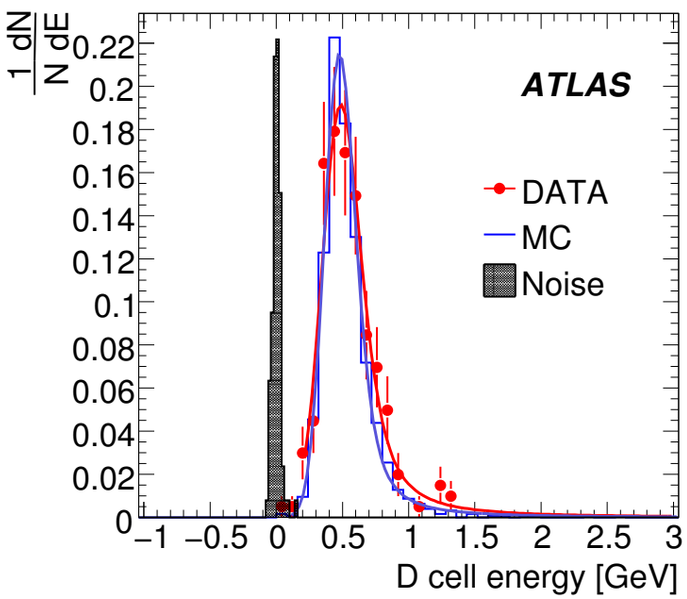
- Validation with cosmic rays
  - dE/dx from mean value provide well-defined signal in data/MC comparisons

- response compared to noise
  - with the Landau⊗Gauss peak position
    - S/N = 29 for total response
    - S/N = 16 for D-cells



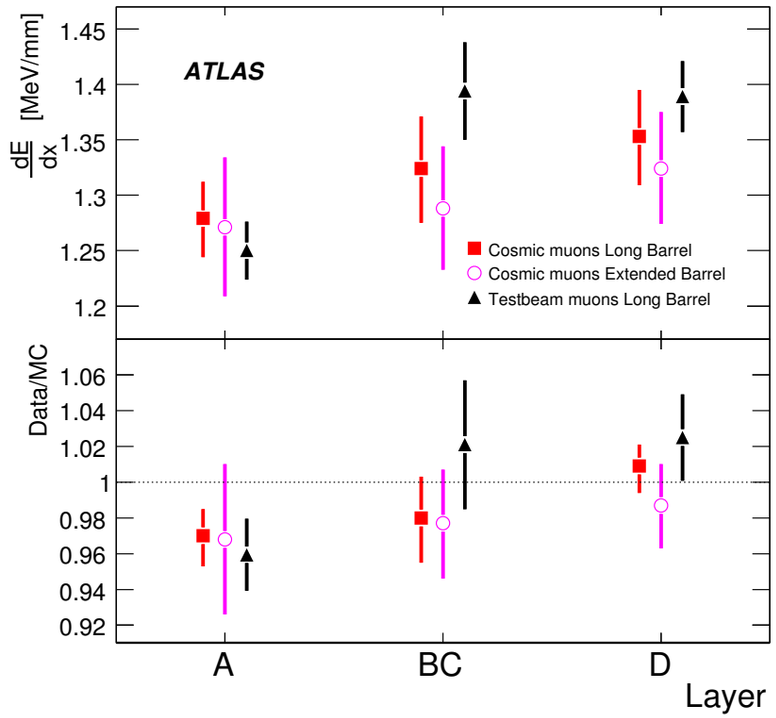
Time dependence of Cs signal





Results on the TileCal's "readiness"

- TileCal EM calibration
  - Validated in cosmic rays measurement
  - Comparison with the TestBeam result
  - Results
    - Truncated mean & Landau distribution
      - dE/dx ~ 1.3 MeV/mm
    - Energy scale uncertainty
      - Long Barrel (LB, central region) : 2-4%
      - Extended Barrel (EB, outer region) : 3-4%



- Results published
  - "Readiness of the ATLAS Tile Calorimeter for LHC collisions"
    - arXiv:1007.5423, CERN-PH-EP-2010-024

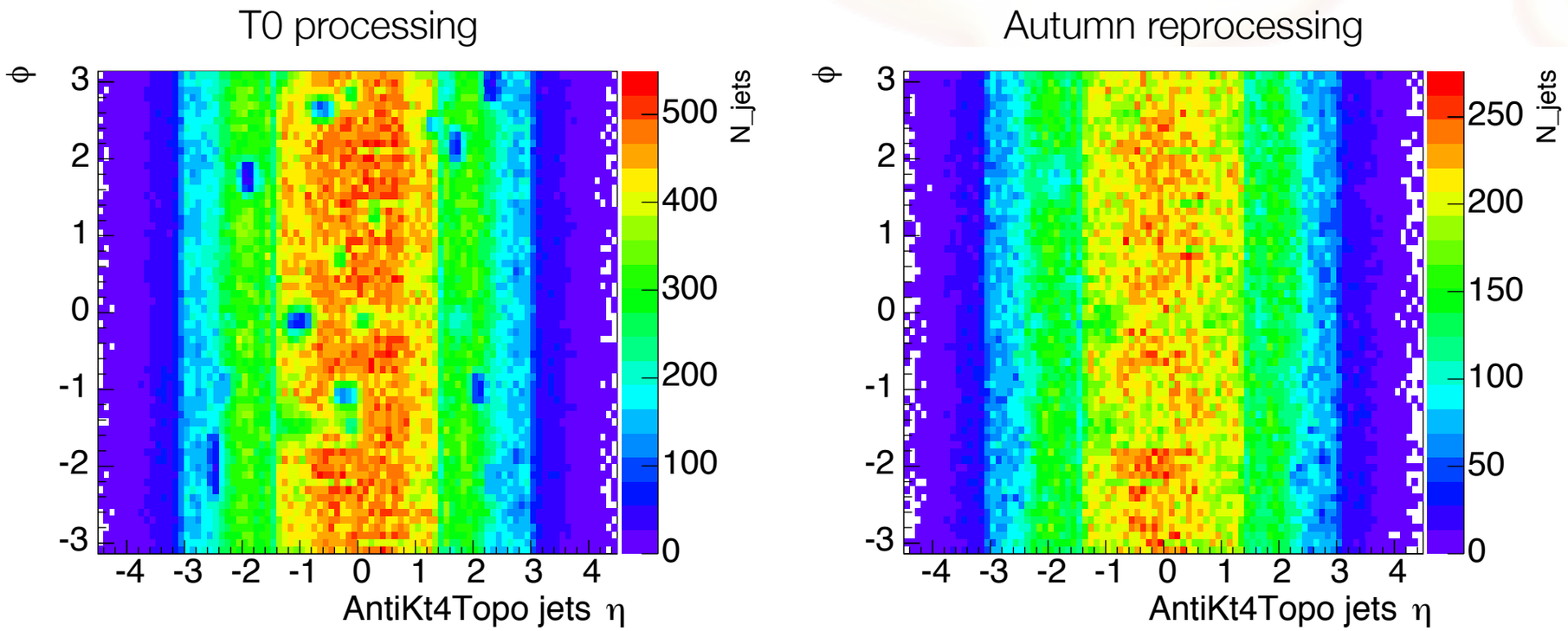
Radial layer		A	BC	D
Cosmic muons, LB	Data	$1.28^{+0.03}_{-0.04}$	1.32 ± 0.05	1.35 ± 0.04
	MC	1.32 ± 0.04	1.35 ± 0.05	1.34 ± 0.04
	Data/MC	$0.97^{+0.01}_{-0.02}$	0.98 ± 0.02	1.01 ± 0.01
Cosmic muons, EB	Data	1.27 ± 0.06	1.29 ± 0.06	1.32 ± 0.05
	MC	1.31 ± 0.03	1.32 ± 0.06	1.34 ± 0.05
	Data/MC	0.97 ± 0.04	0.98 ± 0.03	0.99 ± 0.02
Testbeam, LB	Data	1.25 ± 0.03	1.39 ± 0.04	1.39 ± 0.03
	MC	1.30 ± 0.02	1.37 ± 0.03	1.36 ± 0.02
	Data/MC	0.96 ± 0.02	1.02 ± 0.04	1.02 ± 0.02
Double ratio $\frac{(\text{Data/MC})_{\text{Cosmic muons, LB}}}{(\text{Data/MC})_{\text{TB, LB}}}$		1.01 ± 0.03	0.96 ± 0.04	0.98 ± 0.03

Recent improvements in the calorimeters

- New features
  - Dead calorimeter read-out correction in LAr
    - to recover the energy by L1 Trigger read-out
  - LAr HV Moment
    - to clean up events with large HV correction
  - Tile Noise Filter
    - to unfold the coherent noise in TileCal
  - Offset correction from pile-up
    - to subtract the energy from another PV

- Prepared a special test sample !!
  - obtained much experience and feedback ***before*** the Autumn reprocessing

✓ Need to check the effect for the jet Pt scale from the Bad/Dead regions



Data preparation work

- In charge of production and maintenance of Jet/EtMiss & Jet physics D3PD

- Current analysis scheme
  - Produce ESD/AOD → D3PD
    - D3PD contains a few flat ntuples for
      - run information
      - track/cluster, electron/photon/muon/tau, jet/MissingET
      - trigger information
      - Luminosity information
        - ✓ Useful, and easy to look at

- "NTUP_JETMET" D3PD
  - used by
    - Jet/EtMiss combined performance group
      - many jet calibration studies
      - MissingET studies
    - SM QCD jet physics group
      - Inclusive jet cross section measurement
    - Exotic physics group
      - Black-hole search
      - Contact interaction

- D3PD production
  - Current data size is already too large for personal grid usage...
  - To use the central production system, we need
    - special analysis package release
      - installation into the grid
    - production-tag creation
      - ✓ We appreciate big help by the production group!!

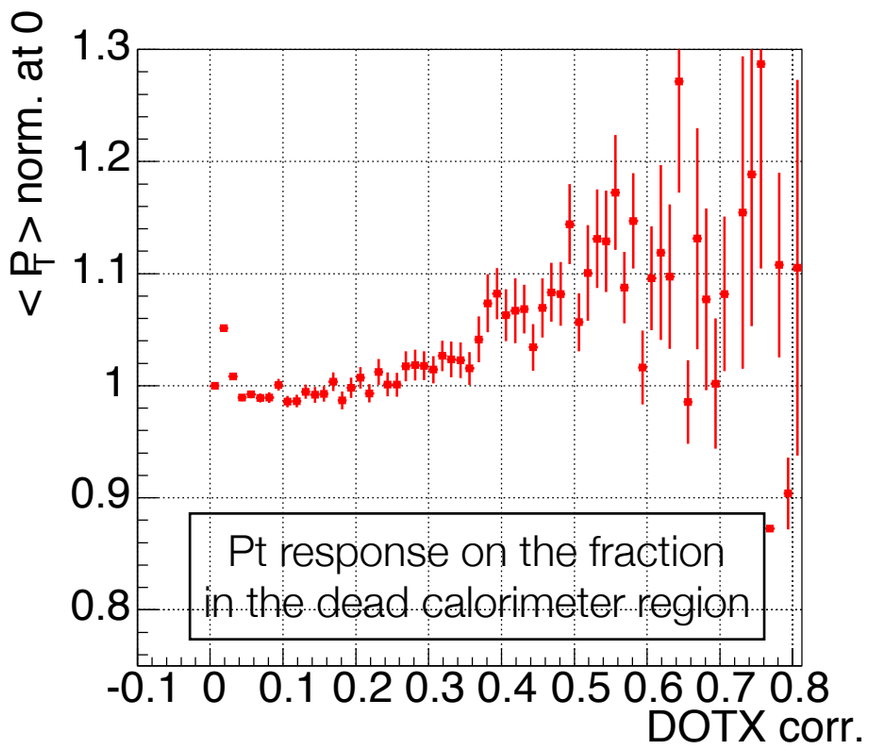
- Jet/EtMiss group disk management
  - Current D3PD size for the full 2010 data : more than 35TB...
    - need careful monitoring and management for production of data sample replicas in the grid sites

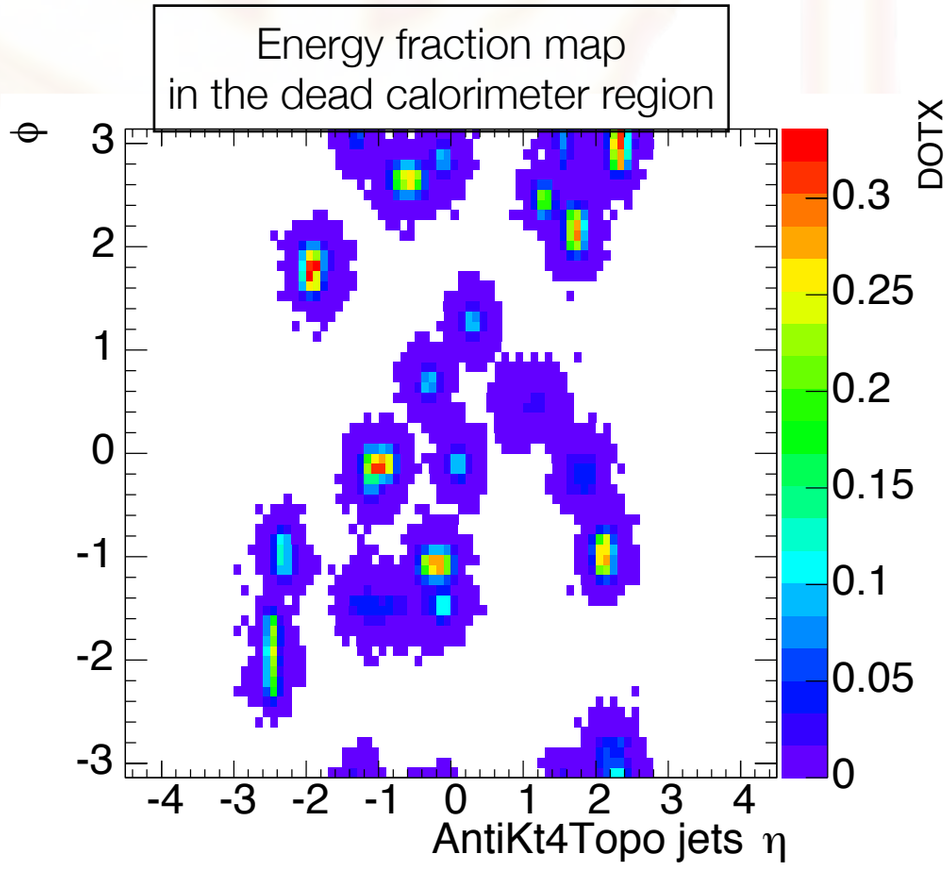
✓ We are ready for the winter conf. analyses !!

Jets in bad calorimeter region

- Measurement of Jet Pt response dependence
  - on the energy fraction of the jets in the "bad" region in the calorimeter
    - ✓ called "ugly" jets
    - correction for missing calo readout by the trigger read-out
      - over-correction seen
    - Some regions suffer from low HV

- We can define the fiducial region of the calorimeter using dedicated variables given fraction of energy in bad regions to the total jet energy

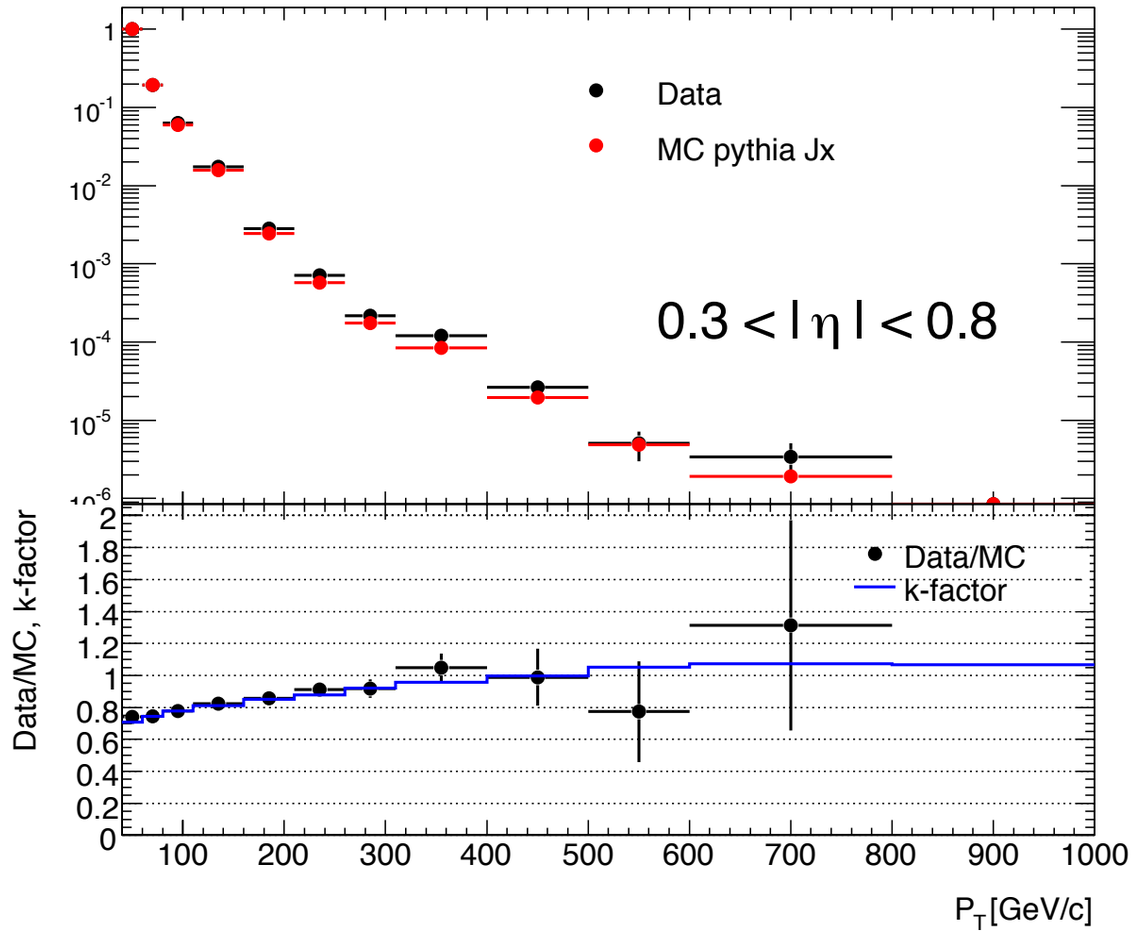




Inclusive Jet Pt distribution

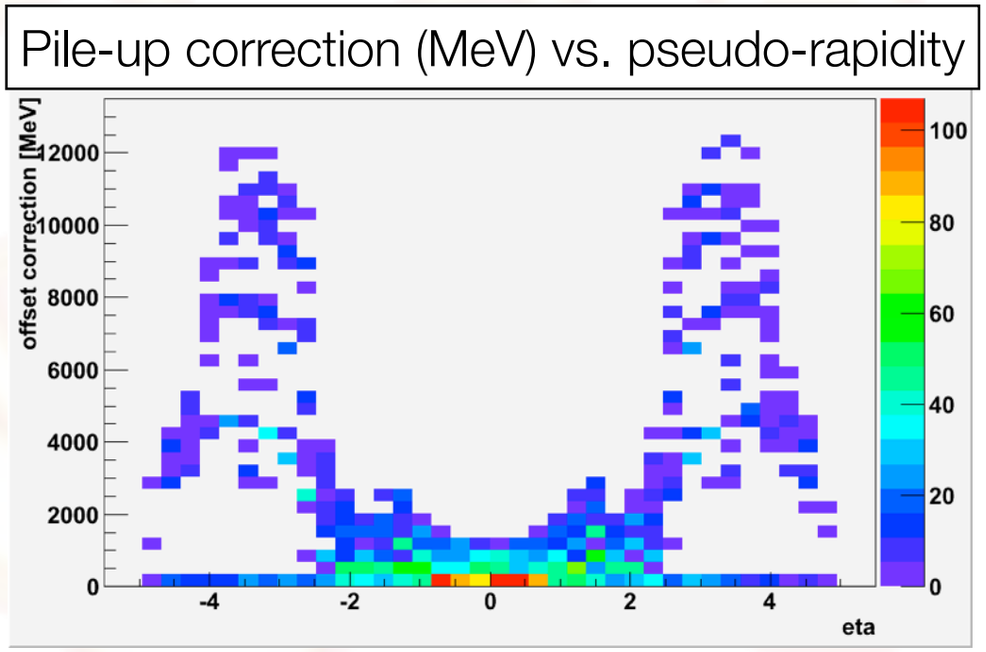
- Current Data and MC comparison
  - Pt in Data is harder than MC
    - MC: Pythia Leading order (LO) generator

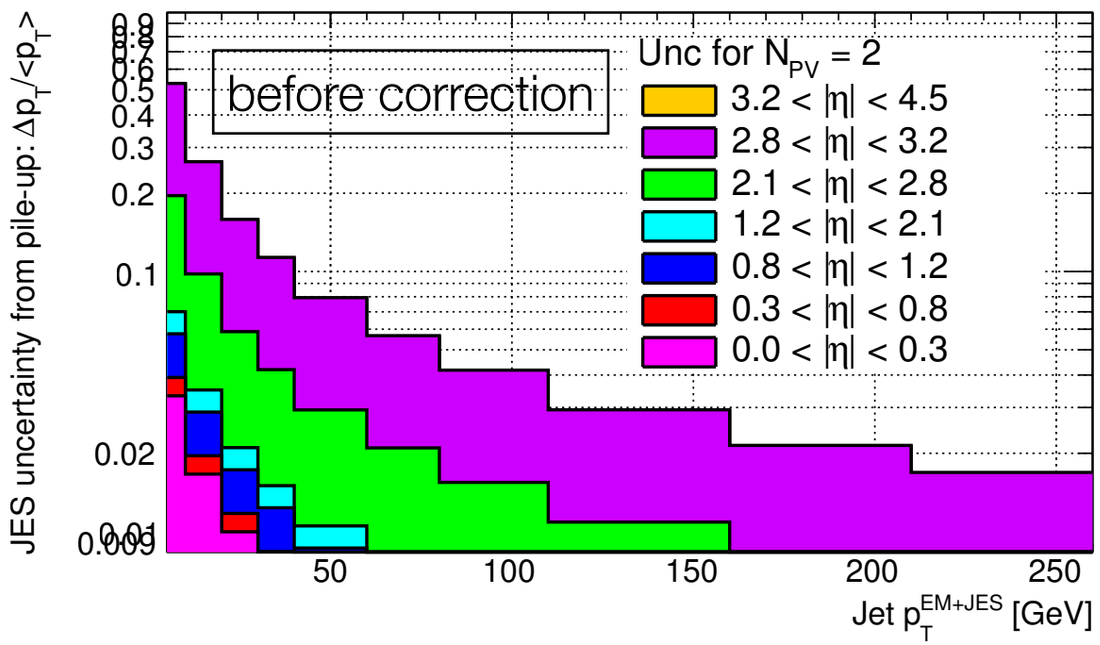
- To solve disagreement due to the LO-PDF in Pythia
  - simple calculation
    - k-factor = $$\frac{\text{ME-LO} \otimes \text{PDF-LO}}{\text{ME-LO} \otimes \text{PDF-NLO}}$$
  - good agreement with the data/MC ratio
    - PDF choice is driving current Data/MC difference
      - LO-PDF has higher gluon density than NLO-PDF (since less splitting q→gq)

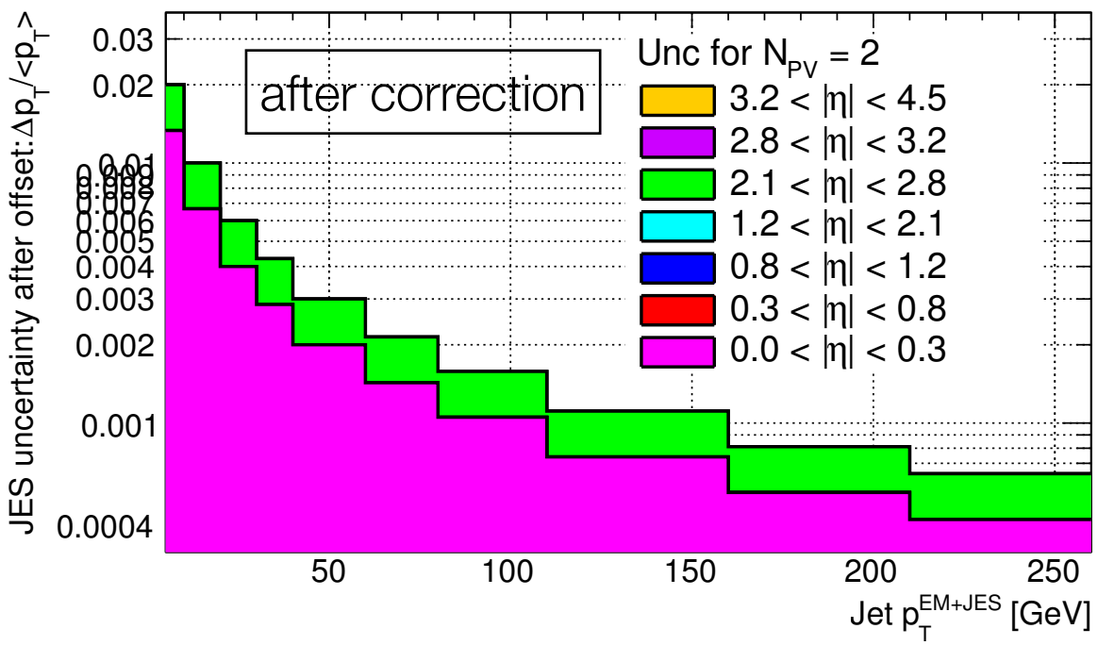


Pile-up study

- Additional collision of protons in the same bunch add energy to the jets : Pile-up
  - need correction to subtract the "offset" by pile-up
    - applied in the new release of analysis software
    - significant improvement in the forward region
      - up to 1% uncertainty will be quoted
- One problem found...
  - The offset correction is calculated with the number of towers
    - a mean number of towers used for the jets with clusters
      - large fluctuation in the transition region between HEC - FCAL
        - ✓ (Pt - Offset) can be negative !!
        - ✓ Need one additional cleaning cut: E > 0







Summary

- Progress
  - TileCal EM calibration
    - showed good performance in the measurements for energy loss by muons from cosmic rays
      - 4% uncertainty on EM scale energy achieved
        - ✓ published
  - Jet performance
    - Several new correction techniques in the bad region of calorimeter tested with the special sample
    - New D3PD sample prepared
    - Study of Pt response in the bad calorimeter region
    - Pile-up contribution tested

- Future plan
  - Towards a better jet energy scale uncertainty
    - Continue the "ugly" jets study
    - Quantify uncertainty from the pile-up correction effect
      - part of a new JES with the release 16 sample soon
  - Measure the Jet Inclusive cross section with the better JES uncertainty using full 2010 dataset

Backup

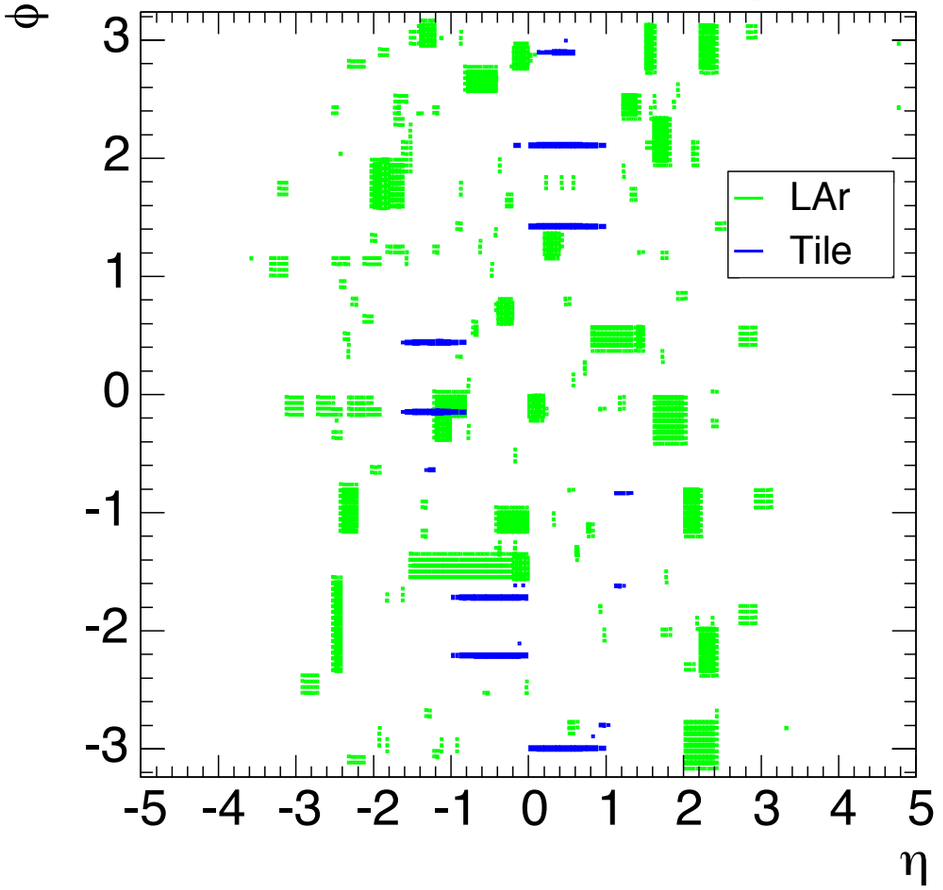
Bad regions in the calorimeters

- Dead LAr modules
  - big energy loss due to the dead 2nd layers
  - energy recovery
    - DOTX correction
- Dead Tile modules
  - energy recovery
    - Cell energy interpolation correction

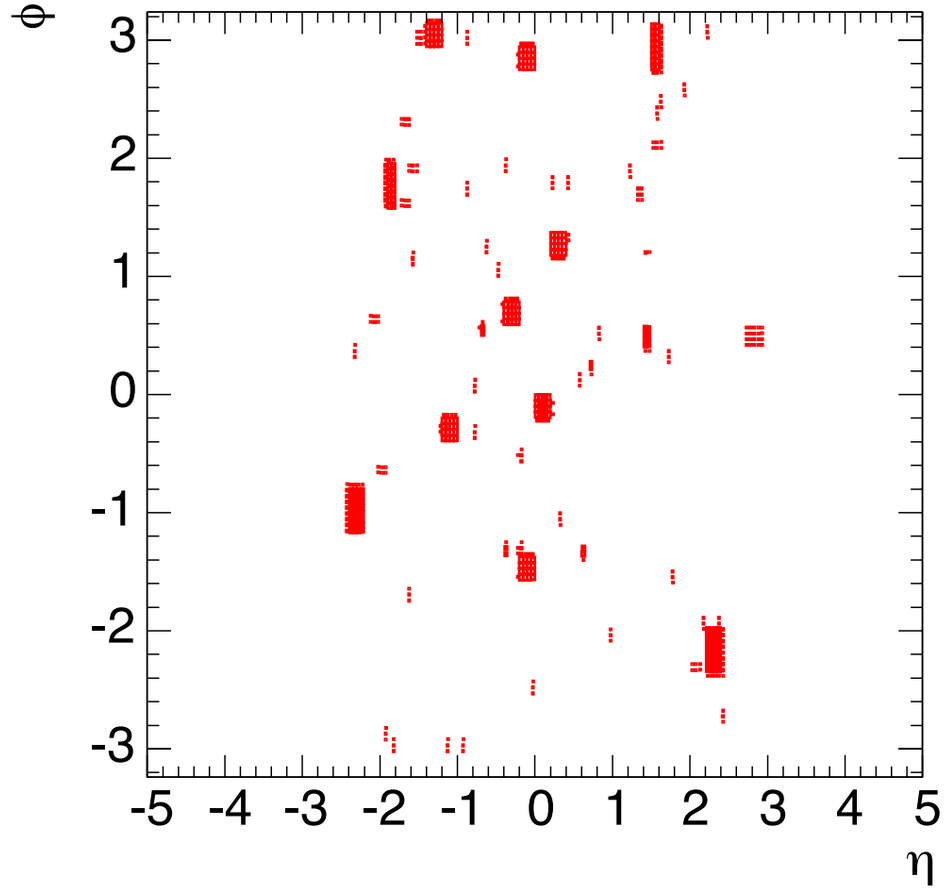
- LAr Bad HV region
  - LAr with reduced HV
  - not a correction

- "Ugly" jets
  - true jets but affected by the bad calorimeter region

all the dead calorimeter regions

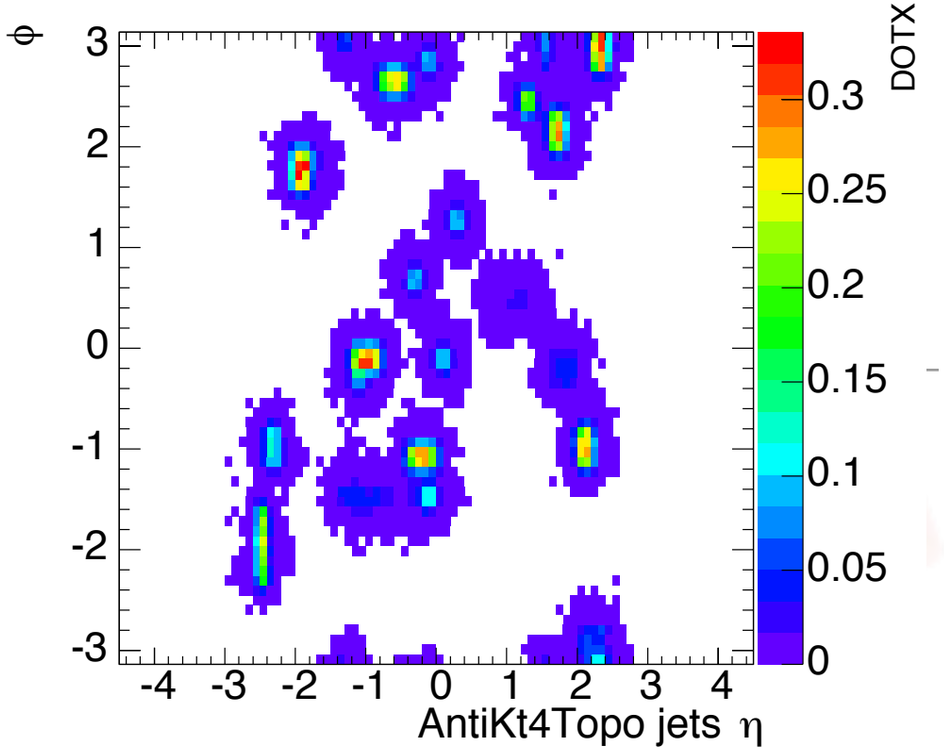


dead LAr 2nd layer

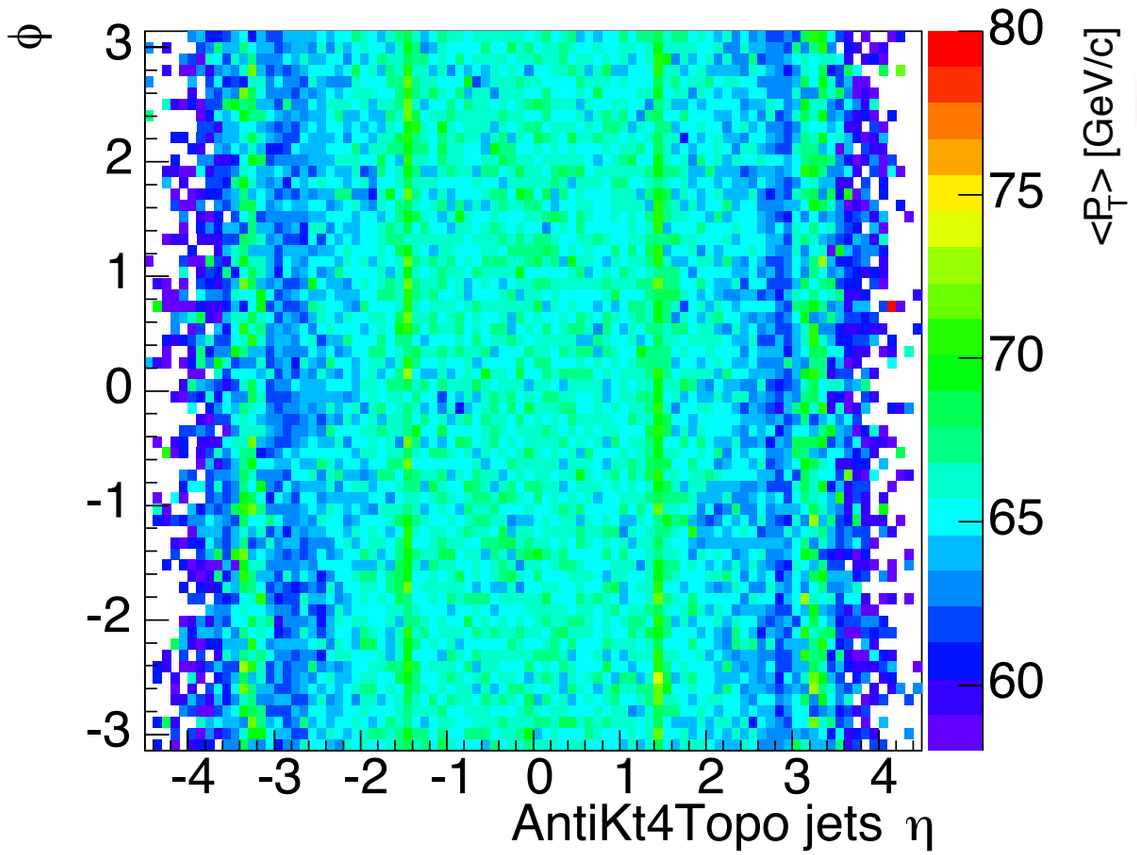


Effect by DOTX: $P_\perp$

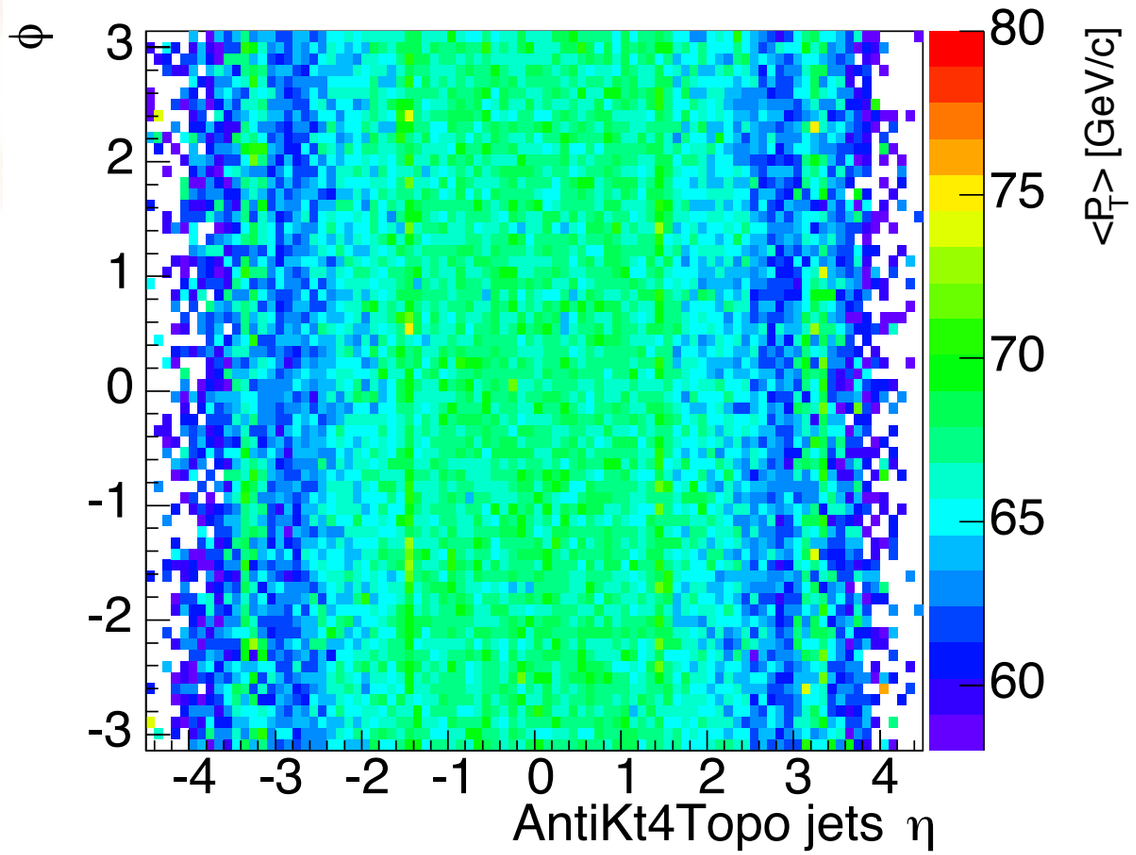
- jet Pt recovered
  - no hole in dOTx region
  - flat Pt distribution in barrel region



f2xx: old

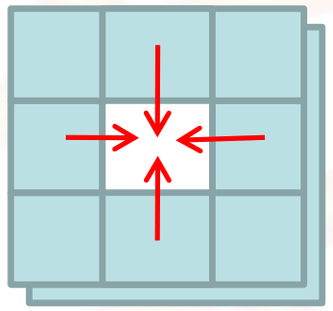


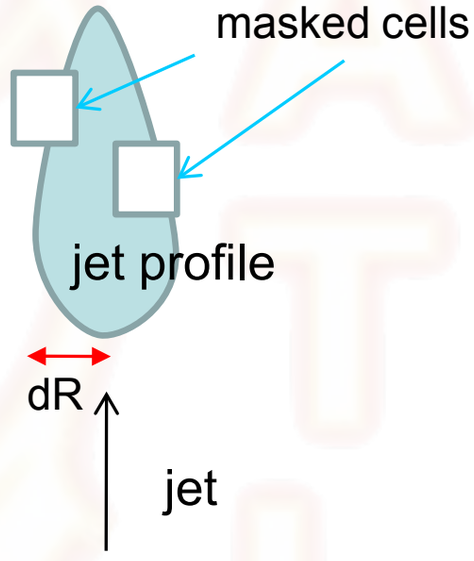
r1647: new



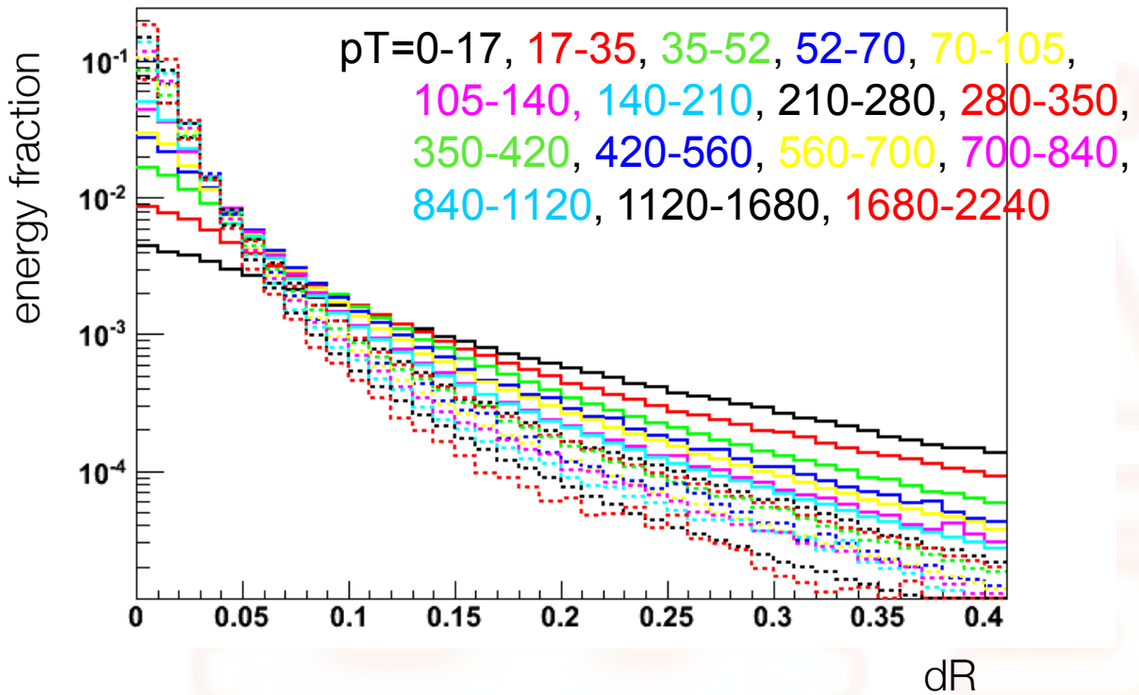
Other correction methods

- for the bad regions
  - Cell level correction
    - extrapolation from the neighboring cells
      - applied in the EM energy





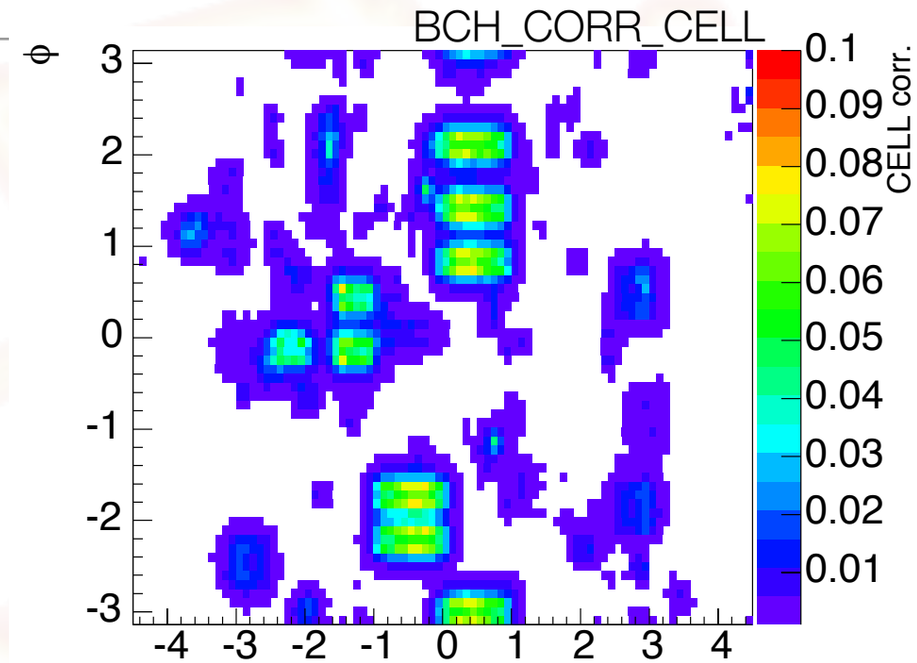
  - Jet level correction
    - function between energy dispersion vs. dR
      - not applied to the energy

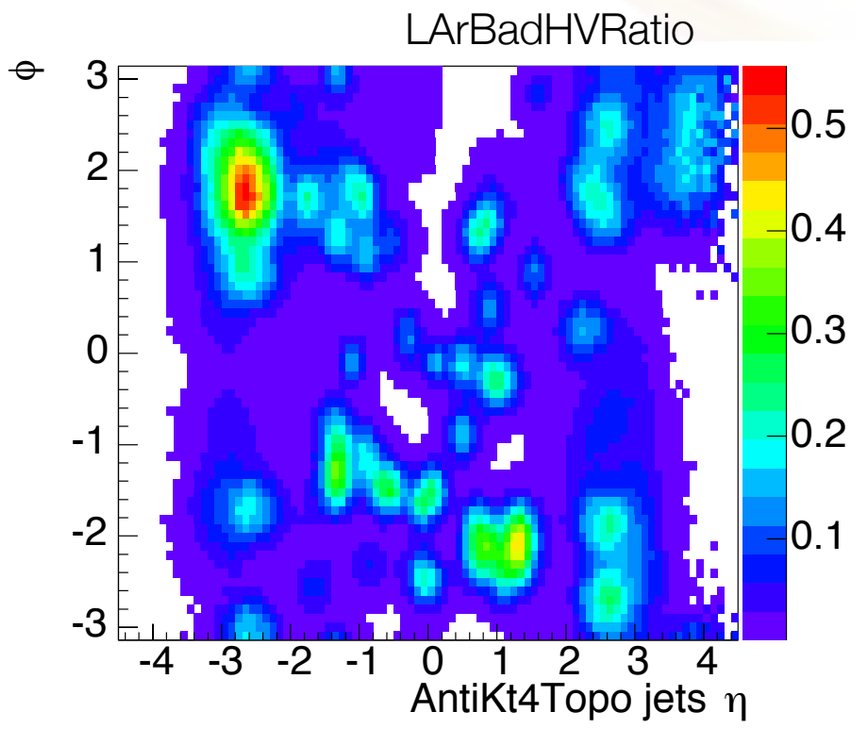


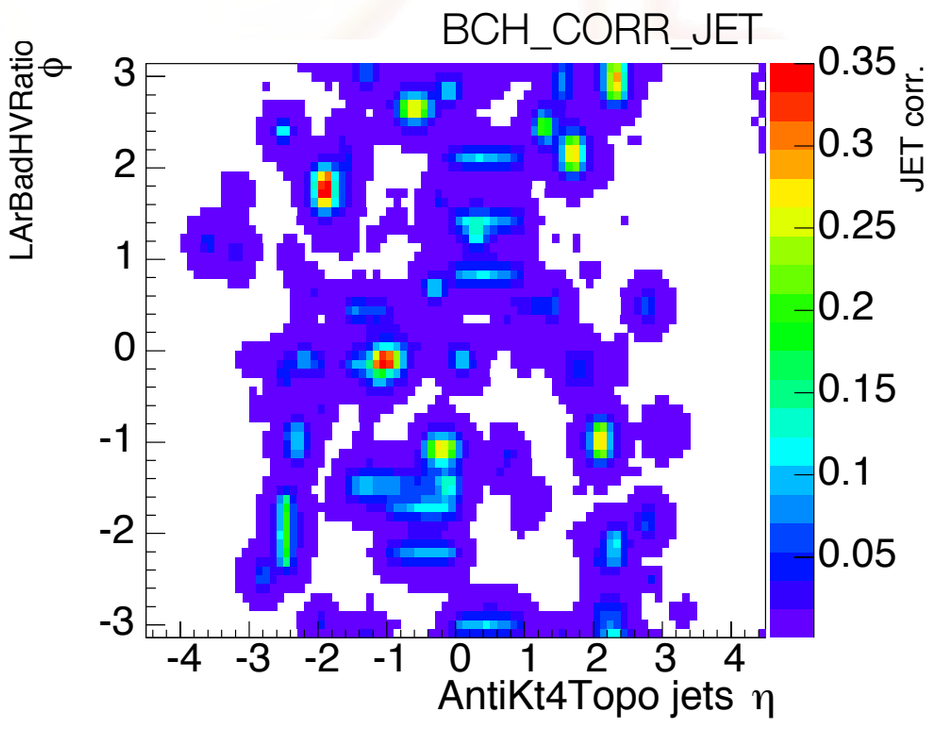
Parameters for the bad region

- BCH_CORR_* , LArBadHVRatio
  - EM scale energy ratio in the bad regions
- η-Φ map of correction factors
  - energy fraction in the bad region in the EM scale for each jet
- CELL correction is mainly applied to the dead TileCal modules

r1647 (Autumn reprocessing)



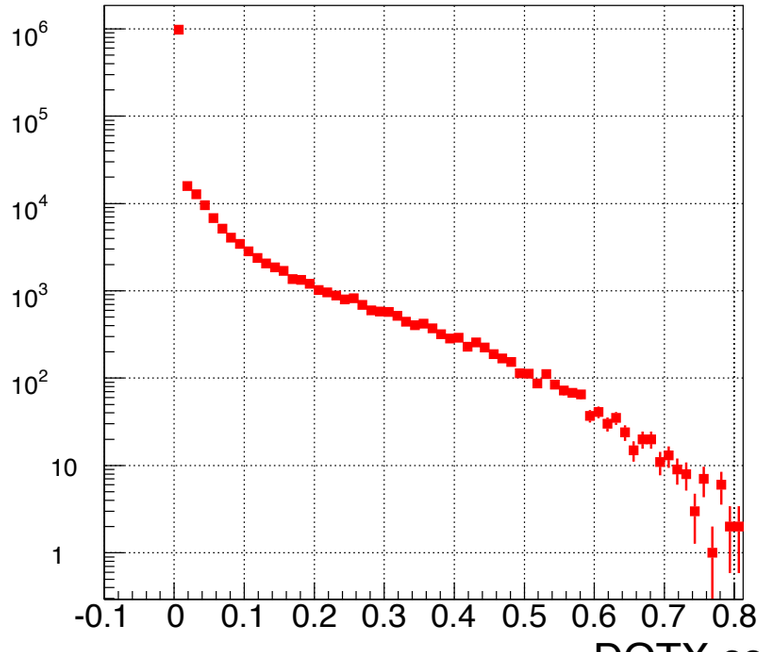


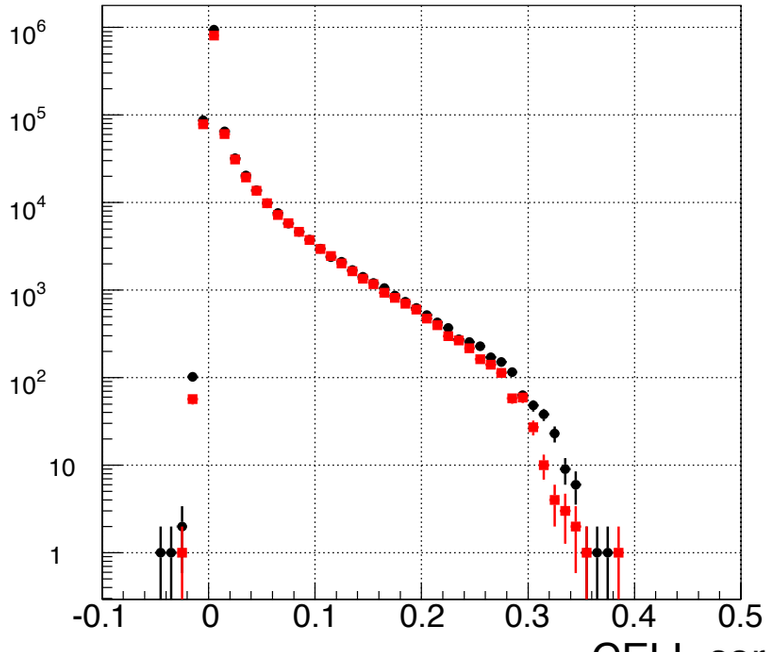


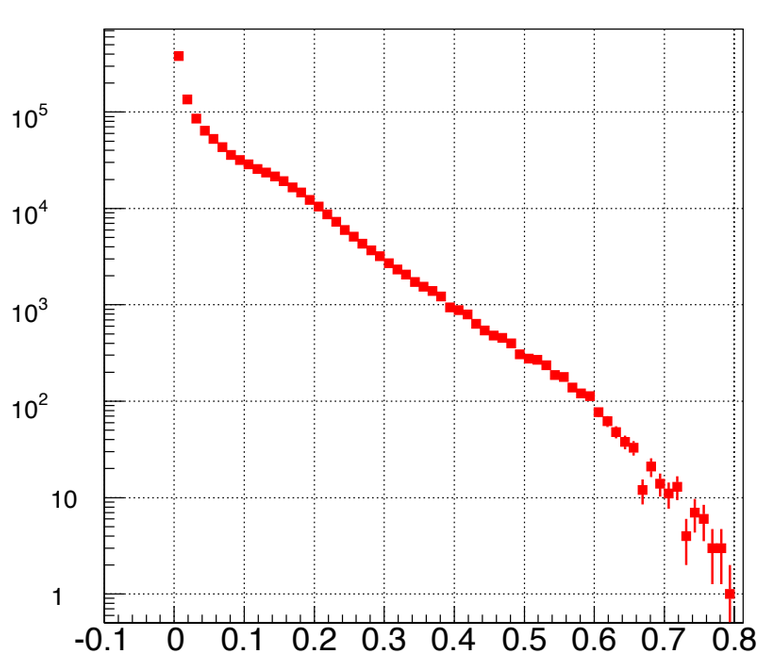
Correction factors

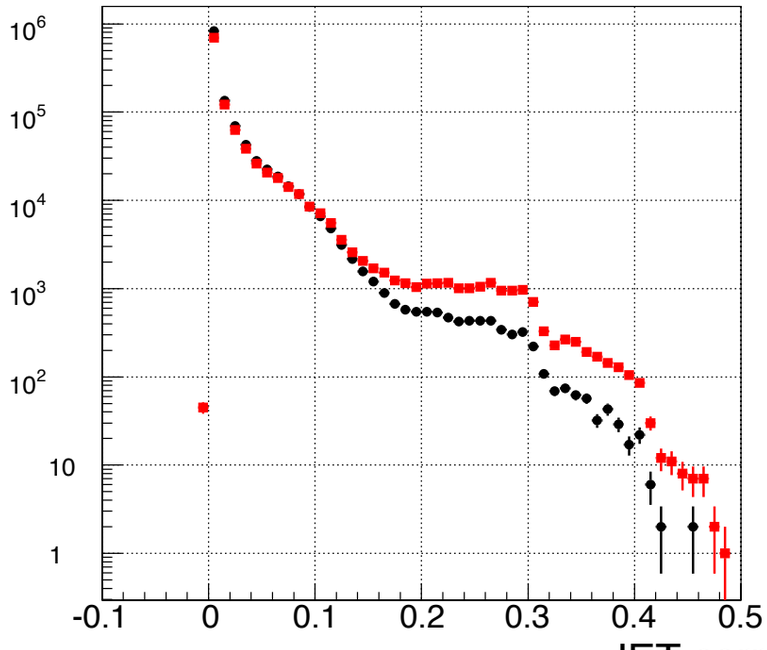
●: old w/o DOTX
■: new w/ DOTX

- DiRegion
  - $|\eta| < 2.8$





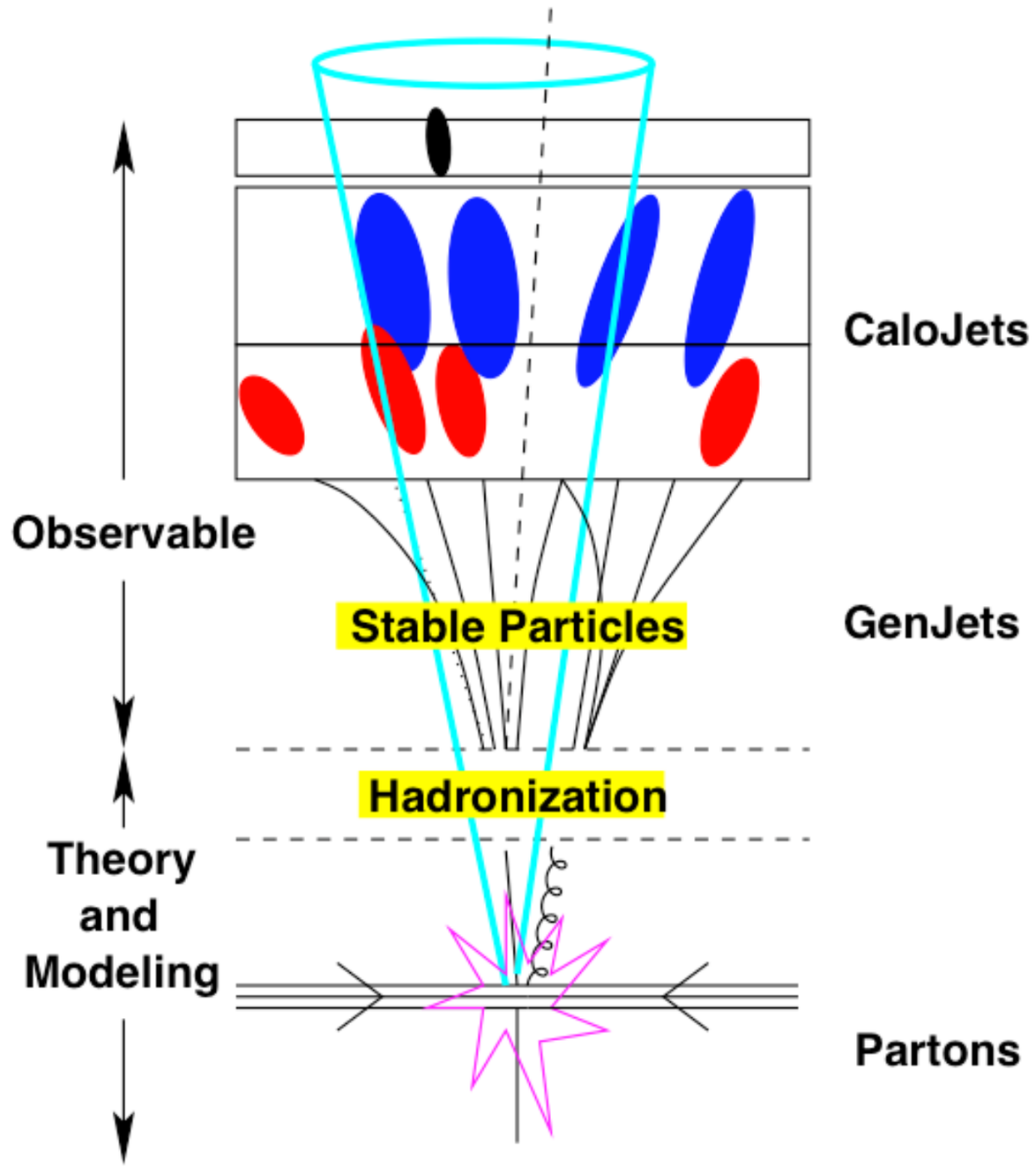




What are Jets ?

- Collimated bunches of stable hadrons
  - originating from partons (quarks & gluons) after fragmentation/hadronization

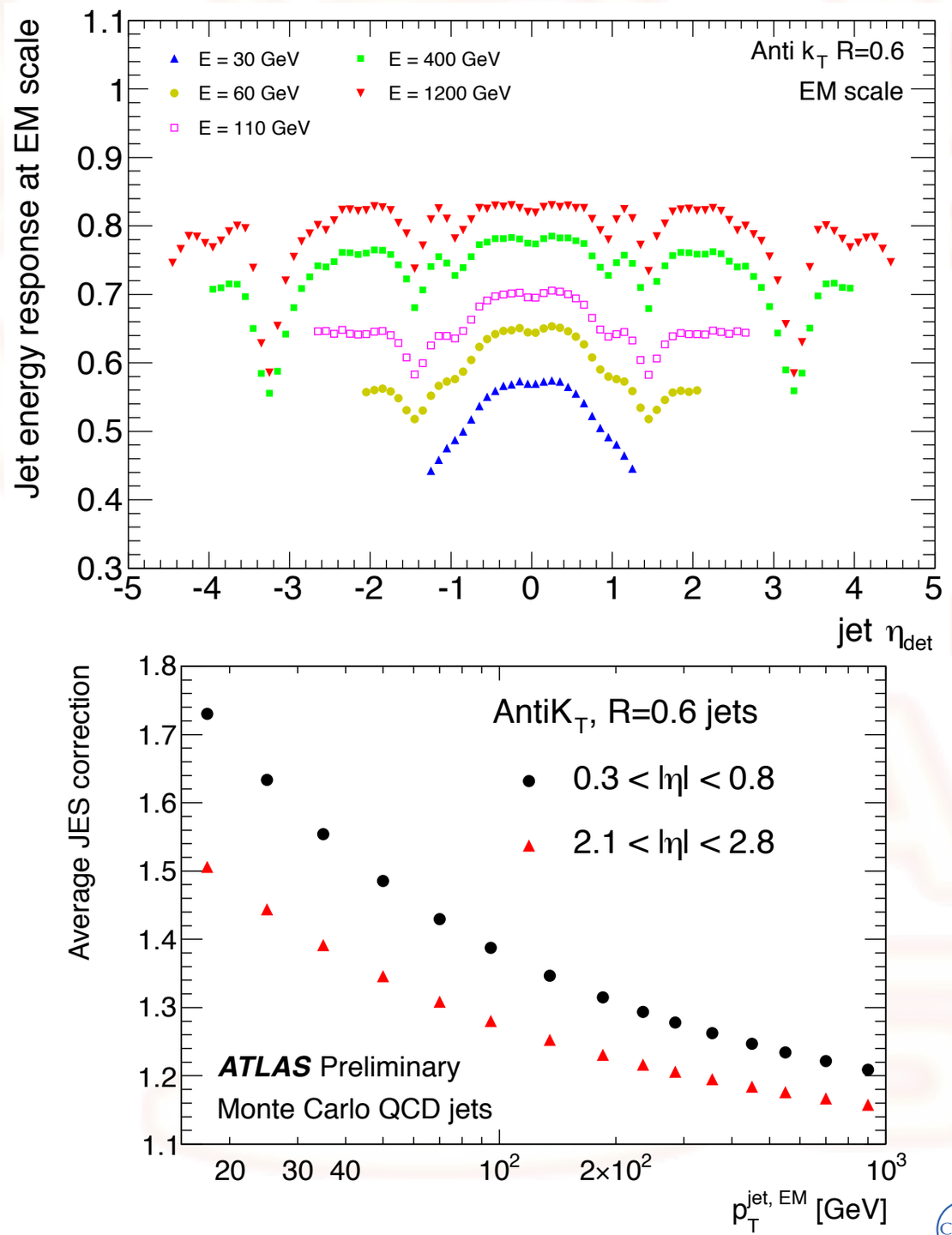
- Difficulty in the jet measurement
  - need to understand every stage
    - Prediction by theory
      - parton distribution
        - ✓ quark/gluon
      - hadronization
    - Jet Finding
      - approximate attempts to reverse-engineer the quantum mechanical processes of hadronization
    - Calorimeter response
      - in the EM scale
      - to hadrons



Jet calibration schemes

- Jet Energy (re-)Scale : a.k.a. Numerical Inversion(NI)
  - "Truth" jets
    - obtained by applying the jet reconstruction algorithm to the hadrons in MC
  - An energy scale applied to the reconstructed jet energy in order to adjust it to the "truth" jet scale
    - NI(JES) = E_{True} / E_{Reco}
      - e.g.) EM+JES
        - ✓ Jet reconstruction in the EM scale and NI for the final scale

- Cell weighting
  - EM
    - no weight, default
  - Global Cell Weighting (GCW, old H1)
    - Fit cell weight based on the energy density minimising resolution of reconstructed jets
  - Local Cell Weighting (LCW)
    - calculate corrections to single $\pi^{\pm}$ from MC to each TopoCluster
      - i.e.) simple particle ID
        - ✓ EM like: ~1, $\pi^{\pm}$ like: 1.3-1.6
  - JES for GCW/LC would be smaller

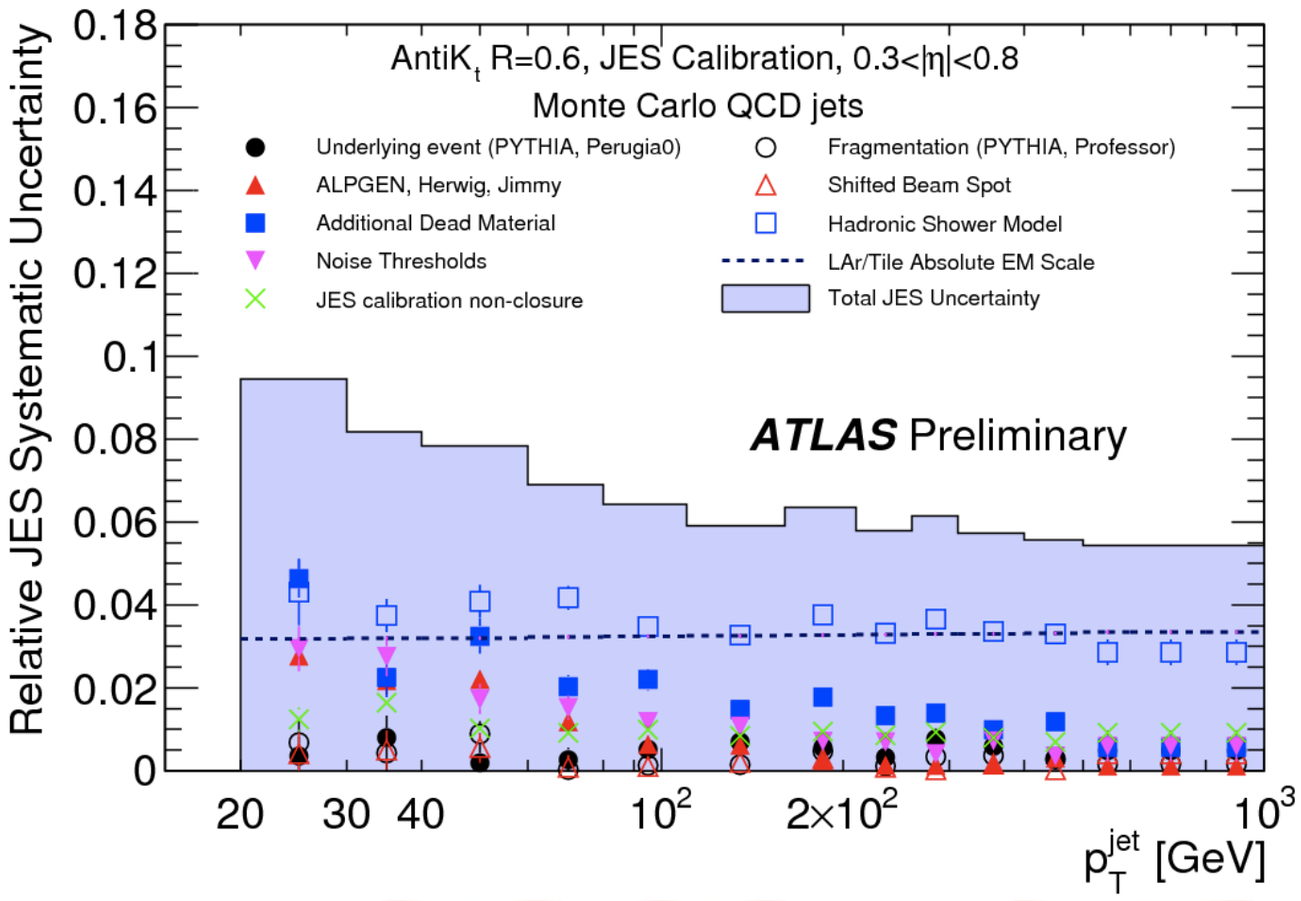


Jet Energy Scale Uncertainty

- Important parameter
  - for the sensitivity/systematic uncertainty in the physics analyses

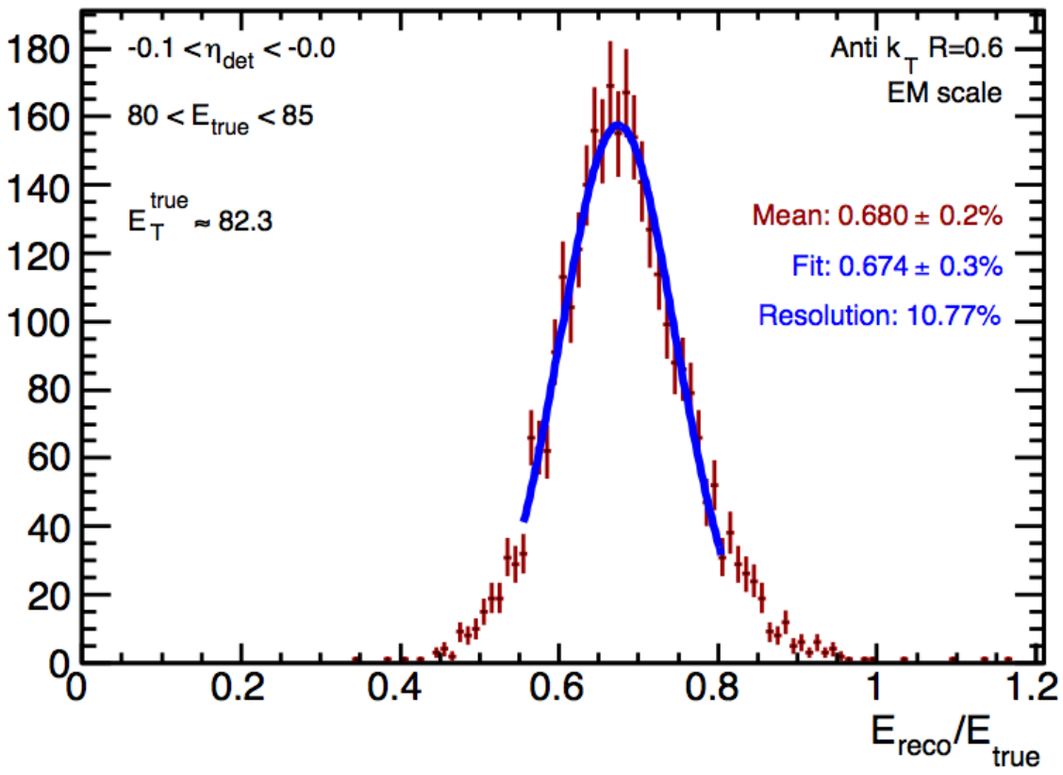
- JES uncertainty in the EM+JES jets for ICHEP
  - 10% at Pt>20GeV
  - 7% at Pt>60GeV
  - Source
    - EM Scale: 3%
    - Noise: 3%
    - Hadronic shower model: 4%
    - Shape/Fragmentation: 3% (low Pt)
    - Non-closure: 1-2 %
      - added linearly

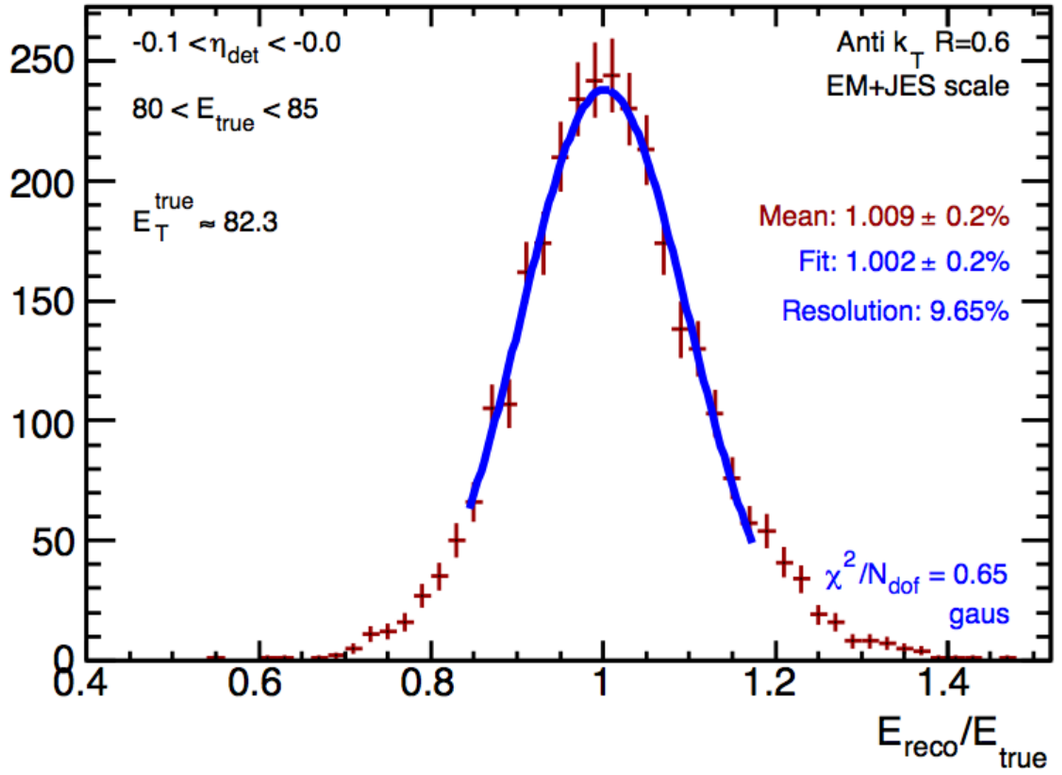
- Report on the recent Improvements
  - EM scale
  - Closure
  - Noise
  - Pile-up
- New method based on the single particle E/p measurement



MC-derived calibration

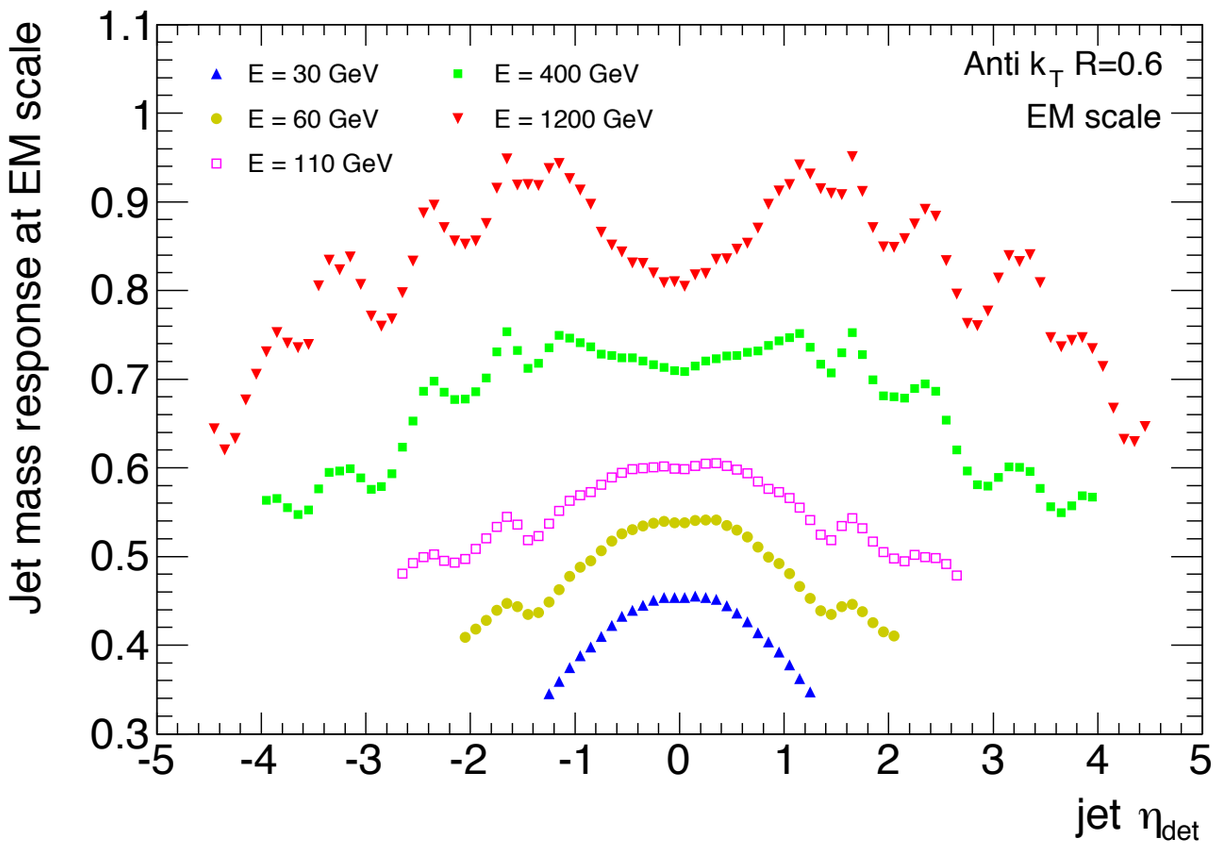
- Numerical Inversion using the jet energy

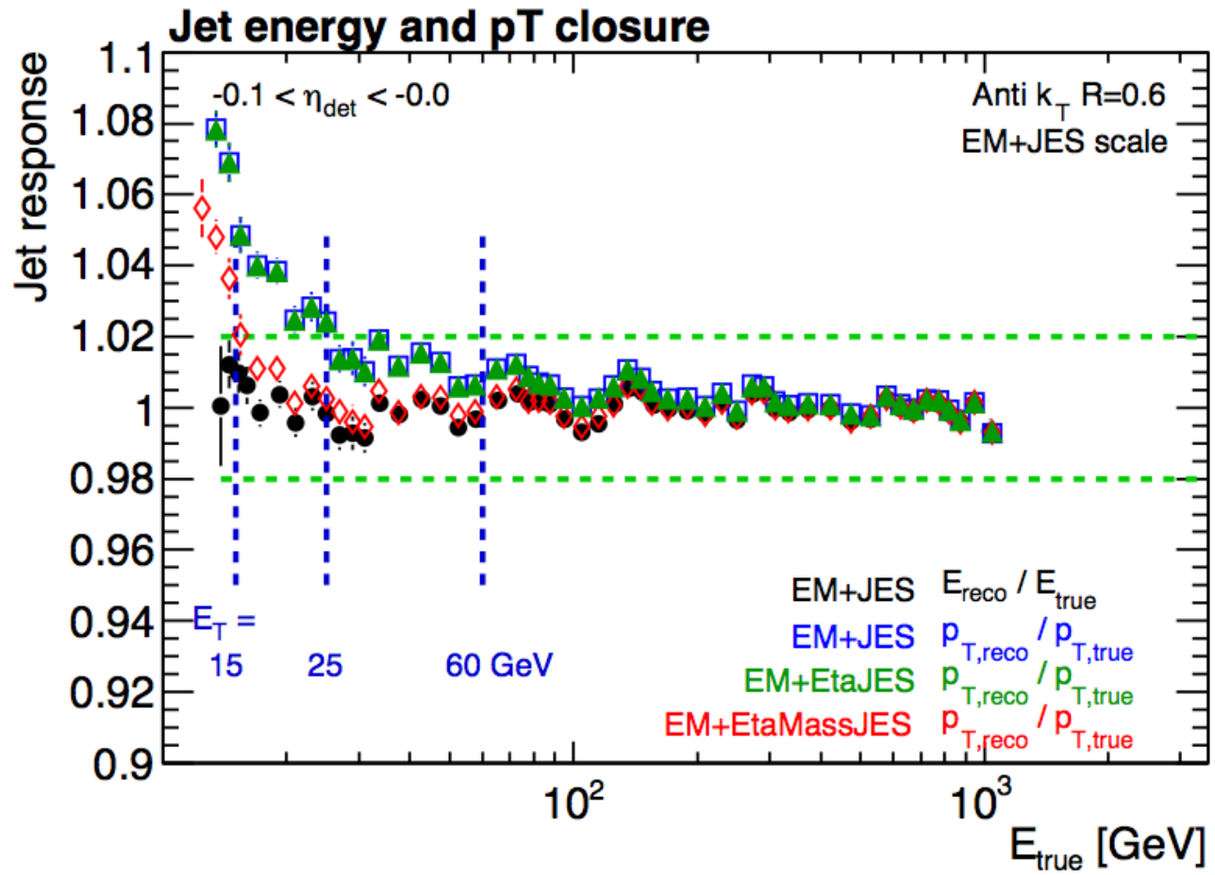




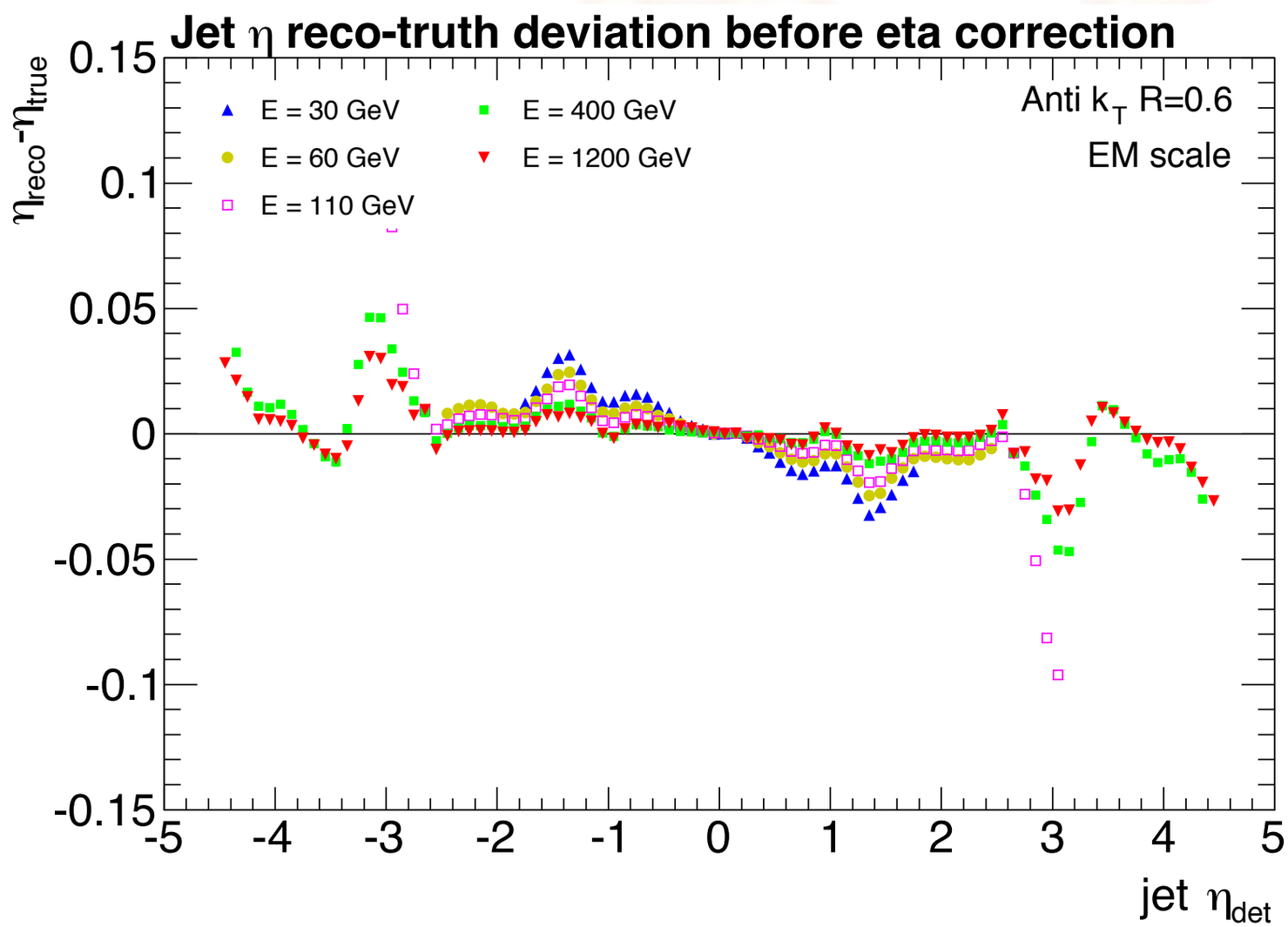
Jet mass correction in JES

- m_{Reco} / m_{True}
  - measured in the same way as energy response





JES Eta correction



Heavy Ion sample

- NTUP_JETMET compatible D3PD prepared for HI data
  - events with jet_Et[0]>100GeV, Et[1]>25GeV
  - ~1650 events
- Added variables
  - Jets
    - Tower (not TopoTower)
    - R=0.2
    - SisCone
  - MET based on Tower jets
- Helped Jet/MET studies for the first result !!