Commissioning of the ATLAS calorimeters with perspective on early physics

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On behalf of ATLAS collaboration

Berkeley Workshop on Physics
Opportunities with early LHC Data.
Wednesday 6th of May 2009

Outline

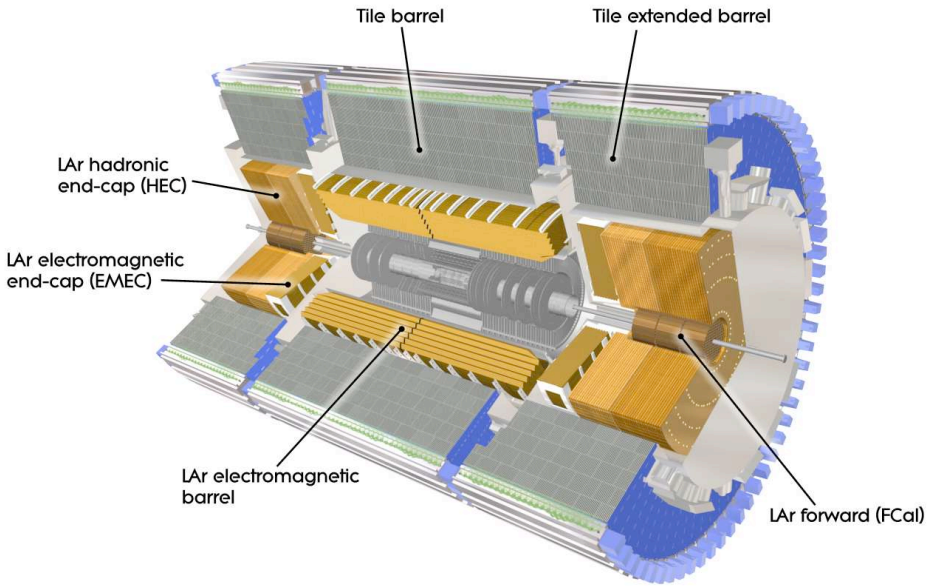
- Calorimeter Introduction & Electronic noise

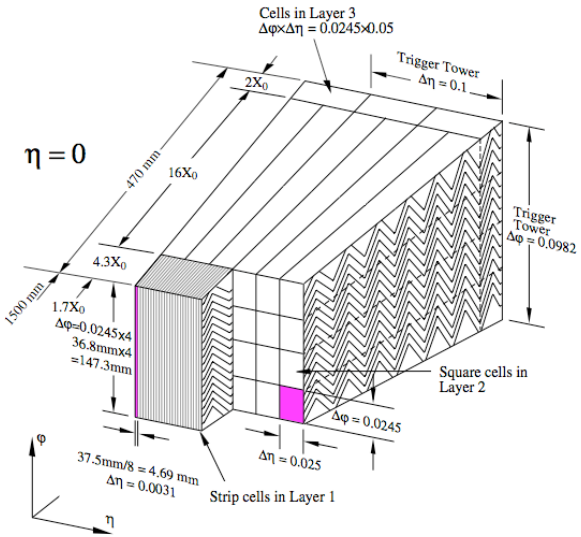
- Cosmics data taking
  - September/October 2008 (just after LHC incident )
  - Smooth running with most of ATLAS detector partitions ON
  - Data reprocessed during Christmas 2008
  - Calorimeter Bad channel status: 1.0% problematic , 0.1% masked

- I. Calo commissioning through E_T^{miss} studies on random triggers

- II. High energy cosmic muon jet studies.

ATLAS Calorimeters





LAr EM barrel module

- Complete azimuthal symmetry, Coverage $|\eta|<4.9$

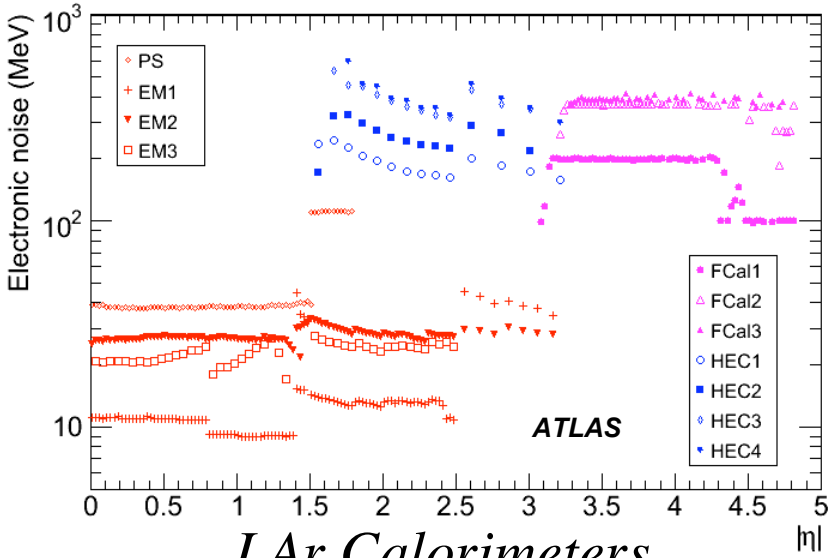
Electromagnetic Calorimeter

- Pb-LAr accordion geometry
- 3 longitudinal samplings
- Presampler detector
  - Thin LAr layer $|\eta|<1.8$ for dead matter corrections
- **170k** channels

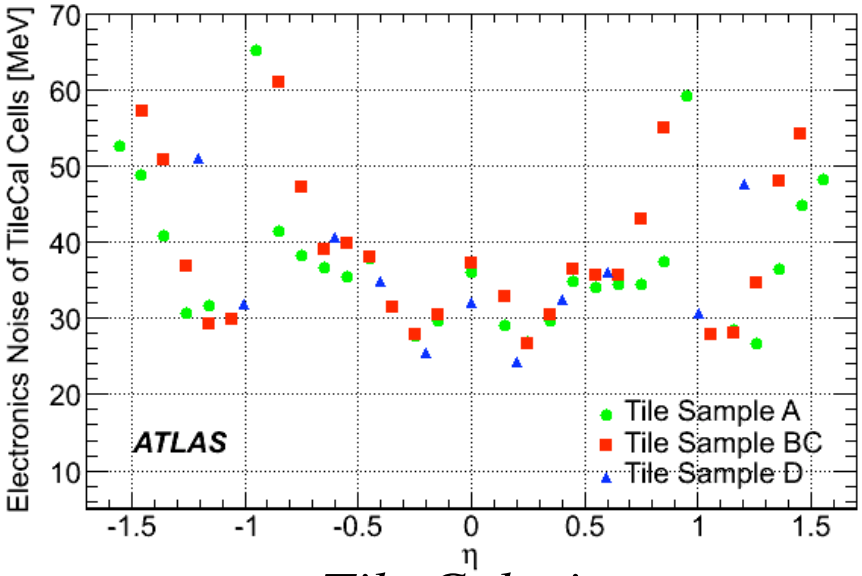
Hadronic Calorimeter

- Barrel : iron - scintillator tiles (3 longitudinal samplings)
- EndCap/Forward: Cu/W-LAr (4/3 longitudinal samplings)
- **20k** channels

Noise in ATLAS calorimeters



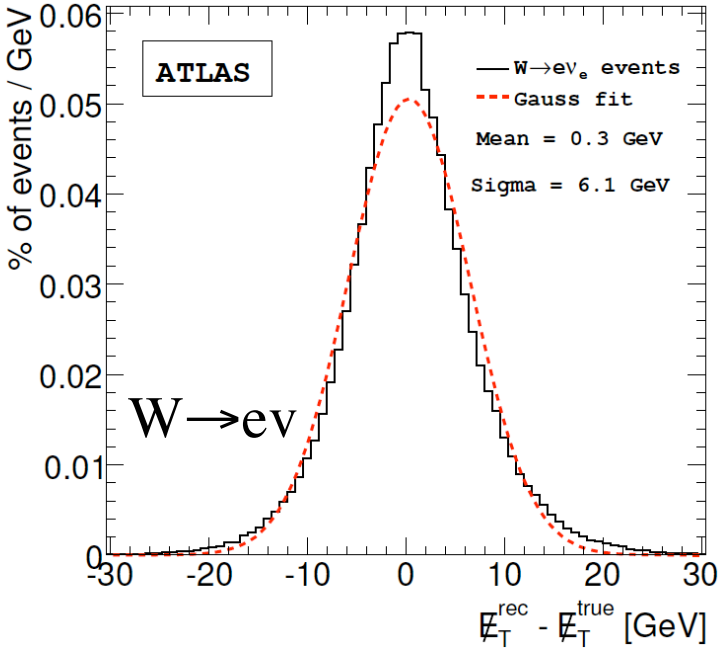
LAr Calorimeters

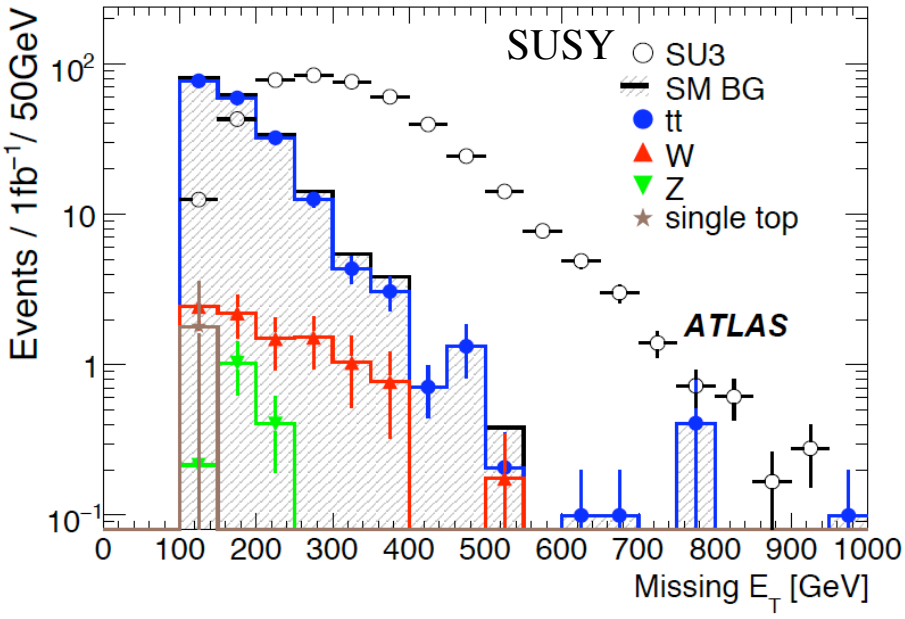


Tile Calorimeters

- **190k** readout channels of ATLAS calorimeters: electronic noise which contributes significantly E_T^{miss}/*Jet* studies
- Electronic noise
  - Measured in random trigger of a cosmic run September 2008
- Electronic noise variation
  - LAr EM : 10-100 MeV
  - LAr Had : 100-600 MeV
  - Tile Had : 20-70 MeV

LHC physics motivation (E_T^{miss} examples)





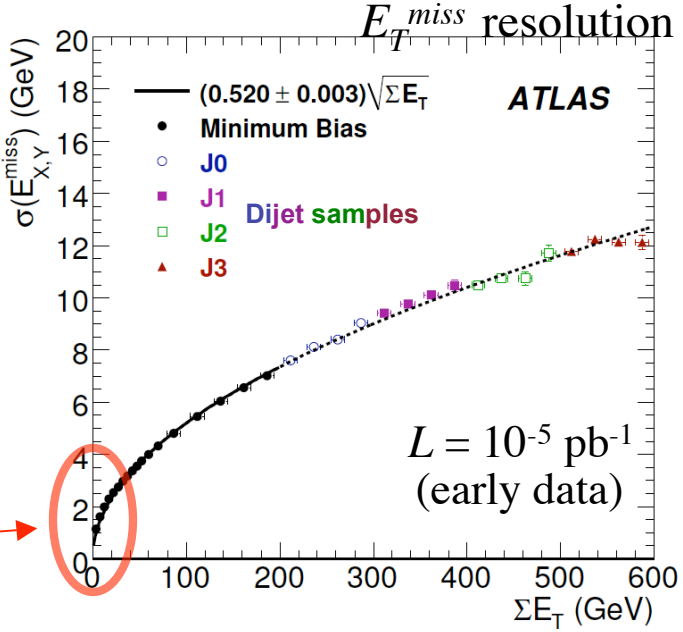
arXiv:0901.0512 ; CERN-OPEN-2008-020

- SM W→eν
  - E_T^{miss} performance reflected when reconstructing a leptonic W boson despite the presence of neutrino
- Numerous similar examples with significant E_T^{miss} : tt-bar production, Z→ττ, VBF H→ττ,
- SUSY
  - Clear excesses will be observed in high E_T^{miss} values

I. E_T^{miss} measurements with random triggers

- Motivation
  - Understand electronic noise in ATLAS Calorimeters
  - Allow us to start E_T^{miss} Calorimeter commissioning

Random triggers, or "empty events": Only contribution, electronic noise. Region of following E_T^{miss} study results

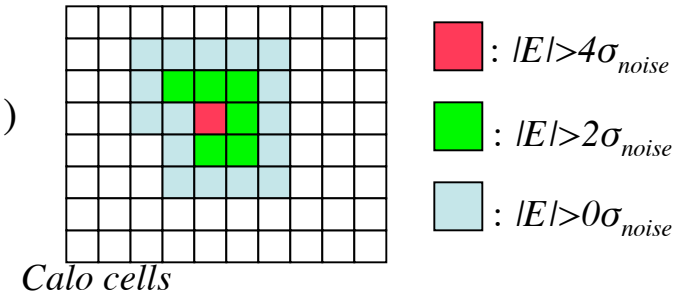


arXiv:0901.0512 ; CERN-OPEN-2008-020

  - Calorimeter global variable that combines all different sub-calorimeter systems (LAr - Tile)

E_T^{miss} Introduction

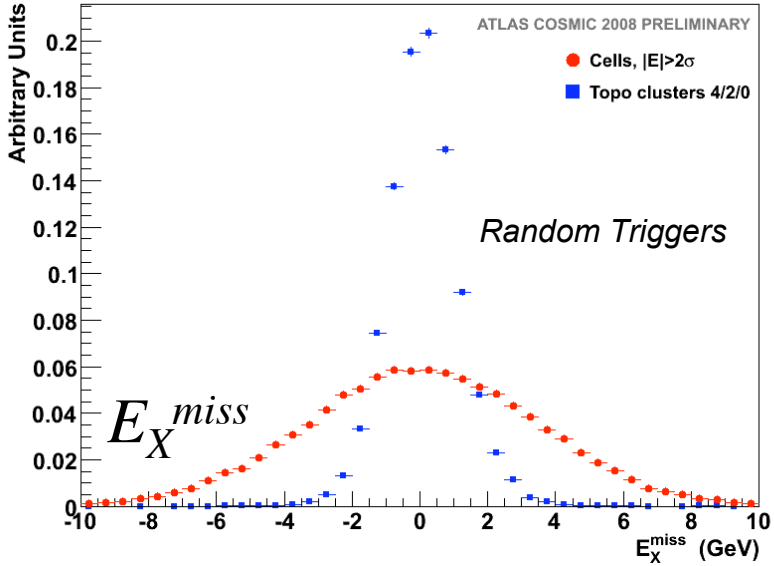
- $\not\!\!E_{x,y}^{Final} = \not\!\!E_{x,y}^{Calo} + \not\!\!E_{x,y}^{Muon} + corrections(dead\ matter)$
- Goal : Estimate Calorimeter E_T^{miss} performance on empty events, using default EM energy scale
  - $E_X^{miss} = -\sum E \cdot \sin\theta \cdot \cos\phi$
  - $E_Y^{miss} = -\sum E \cdot \sin\theta \cdot \sin\phi$
  - $\sum E_T = \sum E \cdot \sin\theta$
  - $E_T^{miss} = \sqrt{(E_X^{miss})^2 + (E_y^{miss})^2}$ (E_T^{miss}: *variable used in physics analysis's*)
- Before measuring E_T^{miss} , noise should be suppressed. Two methods used in ATLAS that define **two kinds of E_T^{miss} quantities** :
  - **Cell Based E_T^{miss} : $|E|>2\sigma_{noise}$** , robust method used for first data
  - **Topo Cluster Based E_T^{miss} :official ATLAS E_T^{miss}** based on **3D** topological clusters
    - Cell seed with $|E|>4\sigma_{noise}$
    - Neighbour cells with $|E|>2\sigma_{noise}$
    - Final cluster layer with all neighbour cells ($|E|>0\sigma_{noise}$)
- An excellent understanding and thus description of noise becomes an issue of crucial importance

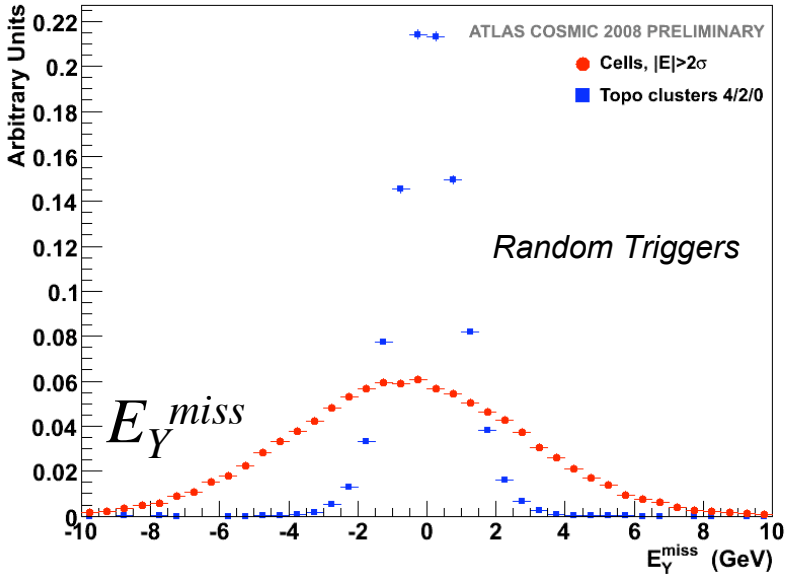


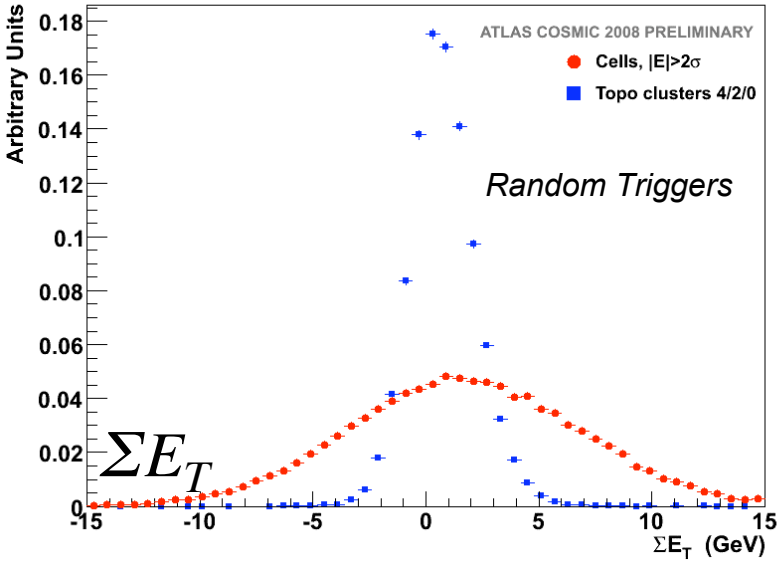
2D example of a topological cluster

E_X^{miss} , E_Y^{miss} , ΣE_T

- Results based on random stream of a combined cosmic run of October 2008 (50k events)

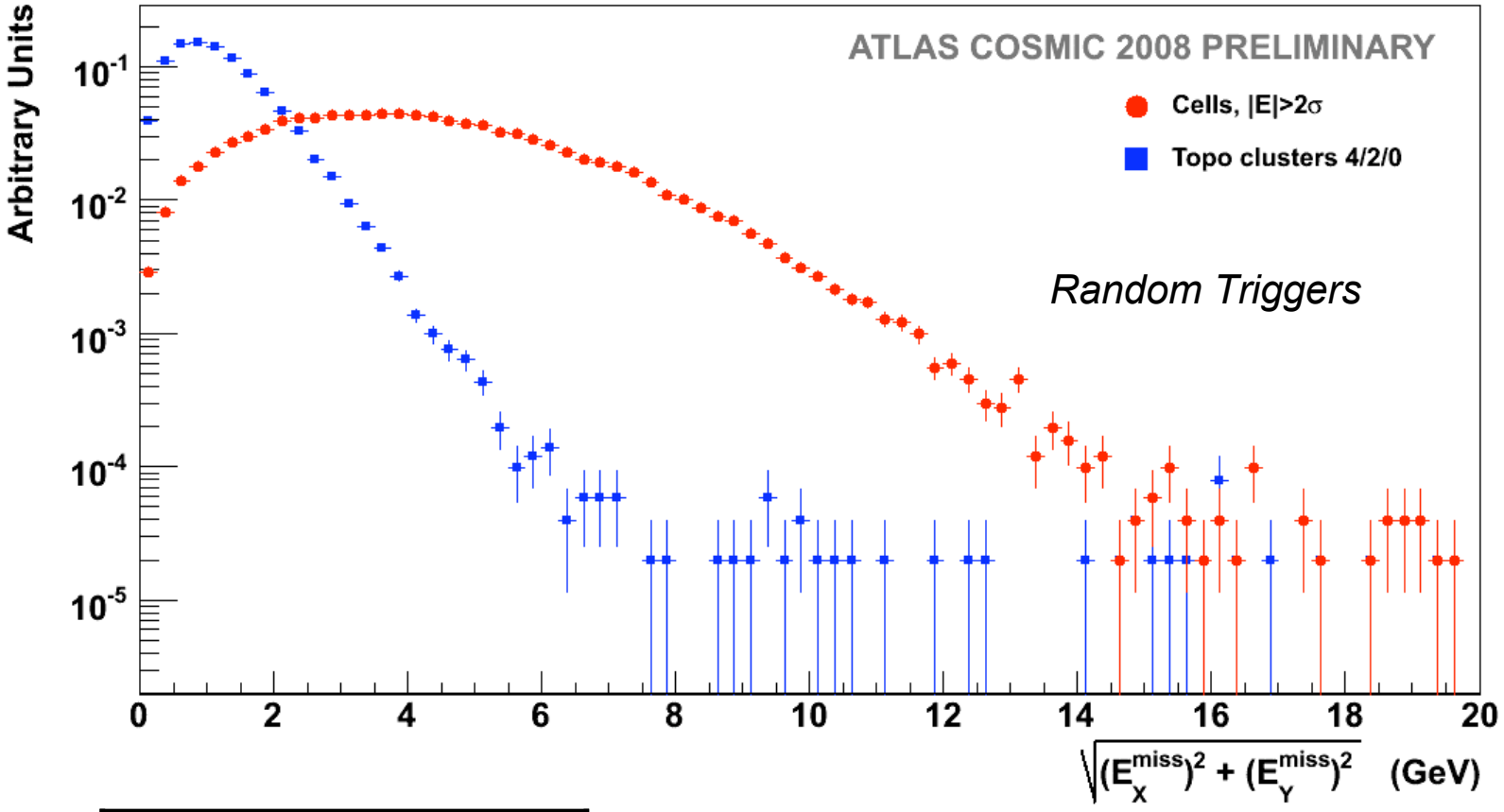






- Good Gaussian shape and almost centred at zero
- Topoclusters: better noise suppression thus, better resolution
- Similar studies showed a remarkably good stability in a time period of 6 weeks of data taking

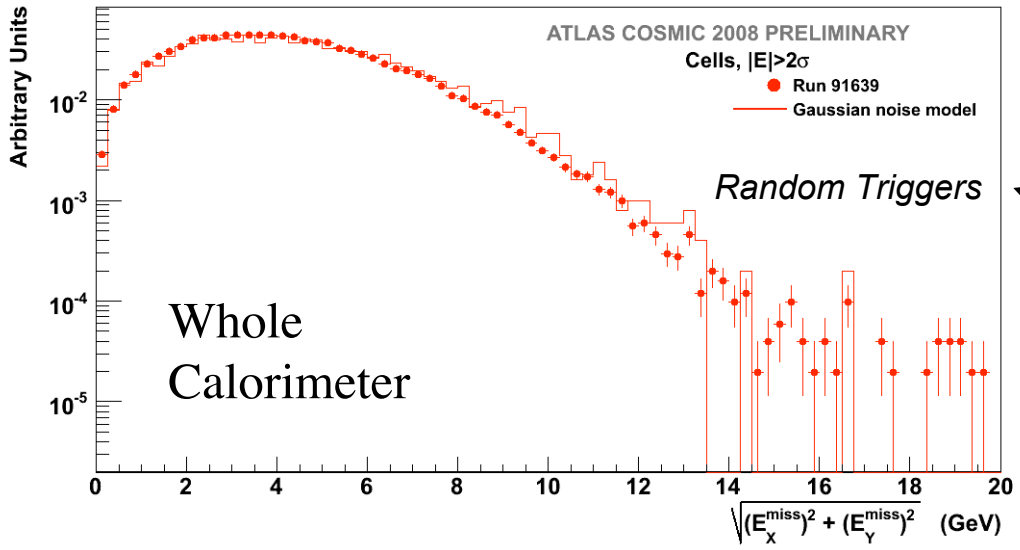
E_T^{miss}

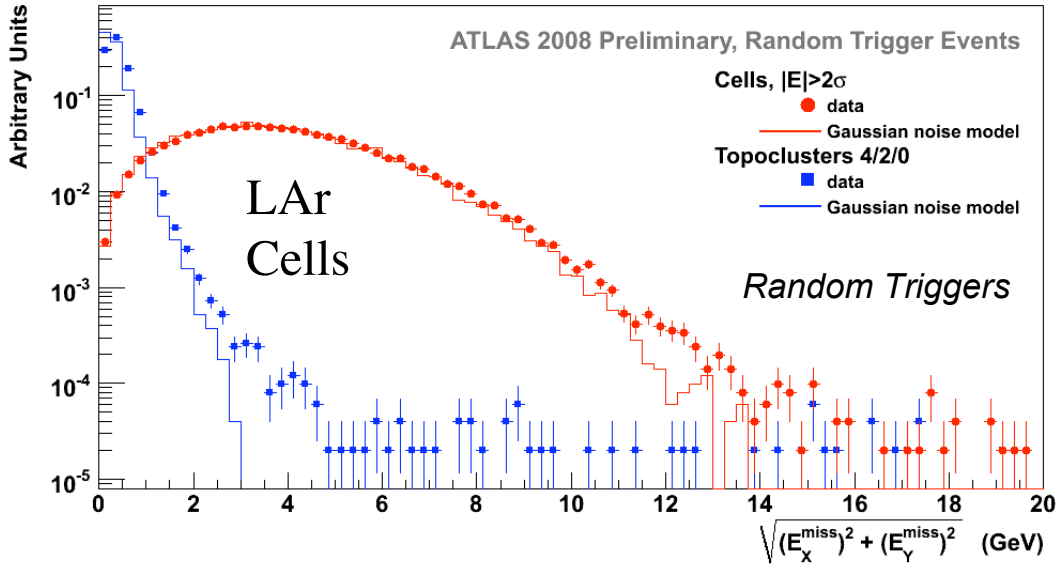


E_T^{miss}	Mean (GeV)	RMS (GeV)
Cells, $\|E\|>2\sigma$	4.29	2.28
Topo clusters	1.22	0.74

- Tails in E_T^{miss} understood
  - Due to coherent noise in a region of EM Presampler
  - **Fixed now in the hardware**
- This study revealed this Presampler feature:
  - Excellent example of Calorimeter Commissioning before collision data

E_T^{miss} results compared to MC





- **Gaussian noise model**: Toy MC based on a Gaussian distribution in a cell by cell basis
- **Whole Calorimeter**:
  - Very good agreement between data and toy MC for **Cell based** case
- **LAr Calorimeter contribution**:
  - Very good agreement between data and toy MC for **both Cell based** and **Topocluster** based.
  - **Tile Calorimeter**:
  - Some discrepancy in topoclusters due to Non-Gaussian Noise in Tile Calorimeter.

Calo commissioning example

Tile noise non-Gaussian behaviour and its influence to Topoclusters:
Noise modelling in progress

II. Jets from high energy cosmic muons

Highly energetic cosmic rays

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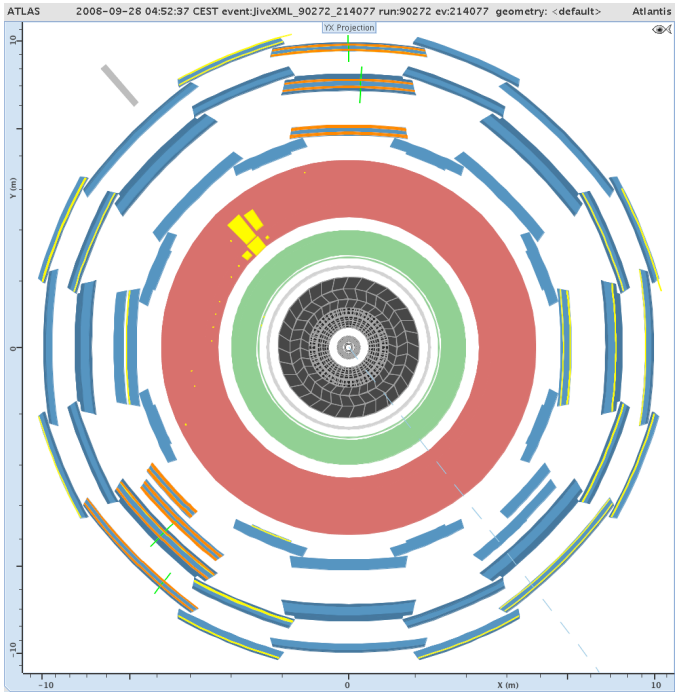

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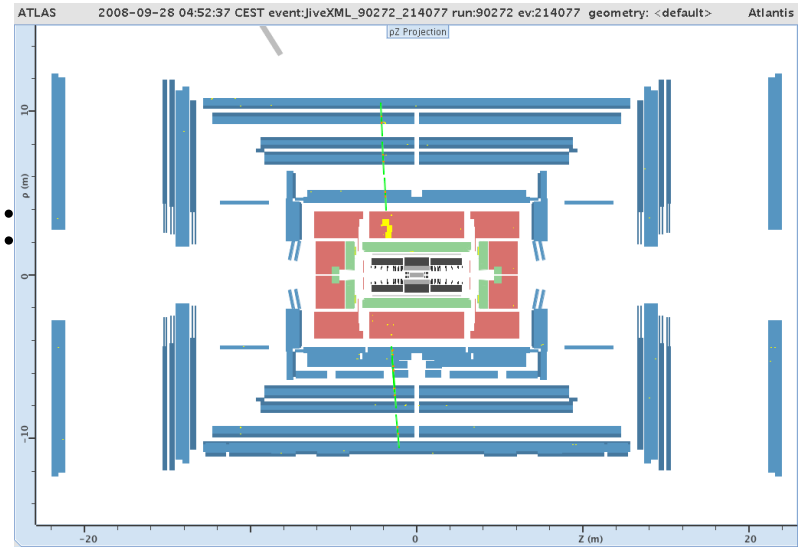
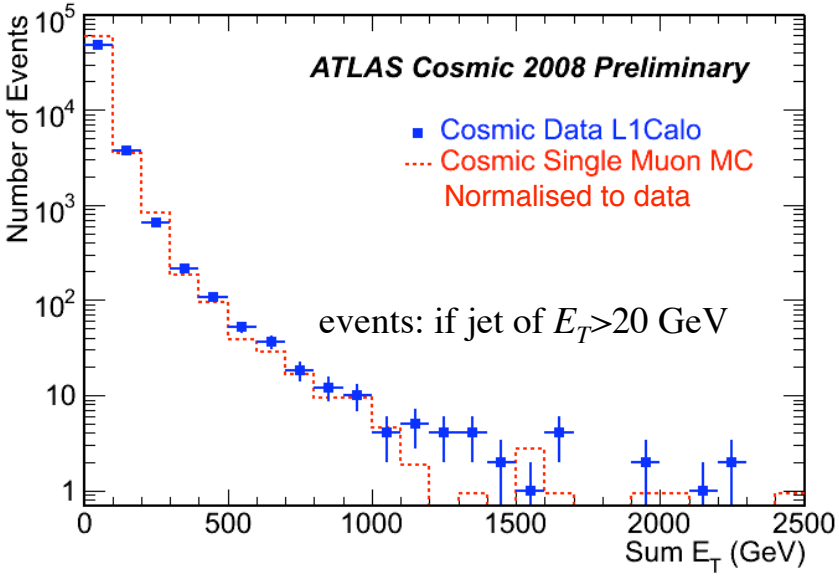


- Cosmic data triggered by **L1Calo** (large energy deposit in ATLAS Calorimeter)
- Cosmic run from September 2008
- **Monte Carlo** produced simulating the cosmic muon flux at ground level

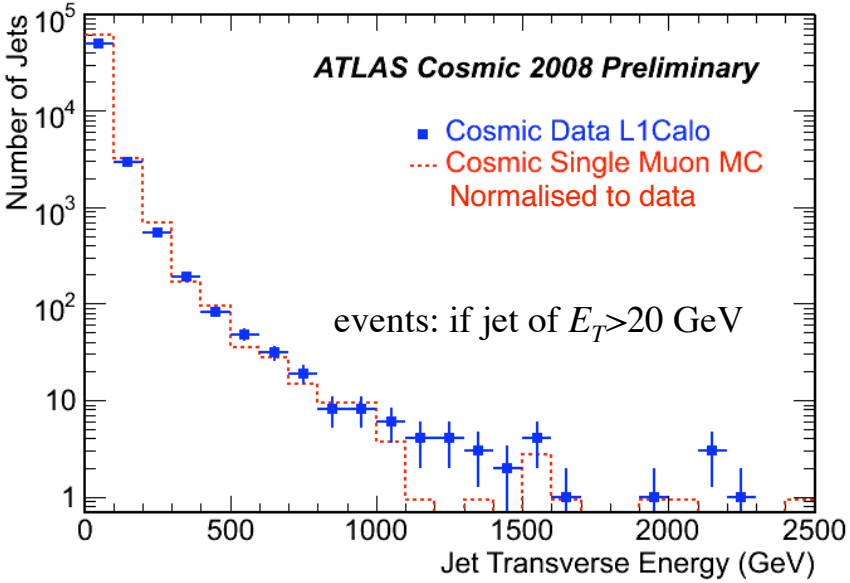
  (*A. Dar, Phys. Rev. Letters 51, 227 (1983)*)
  - Only single muons are considered (no air showers)
  - No simulation of trigger is considered
  - Normalised to data

- Green line : muon track
- Yellow boxes : energy deposits in Tile Cal
- Dotted line : E_T^{miss} direction

High energy events



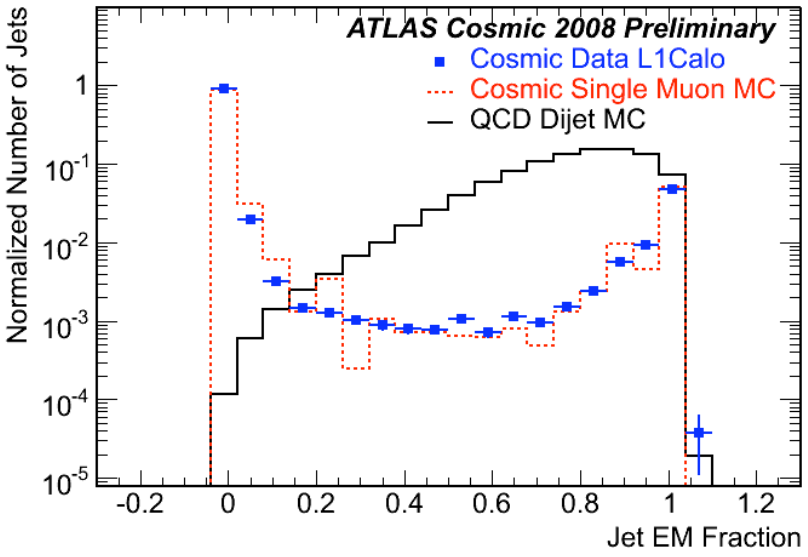
- Sum E_T : Total scalar sum of E_T , cells with |E|>2σ in the Calorimeter

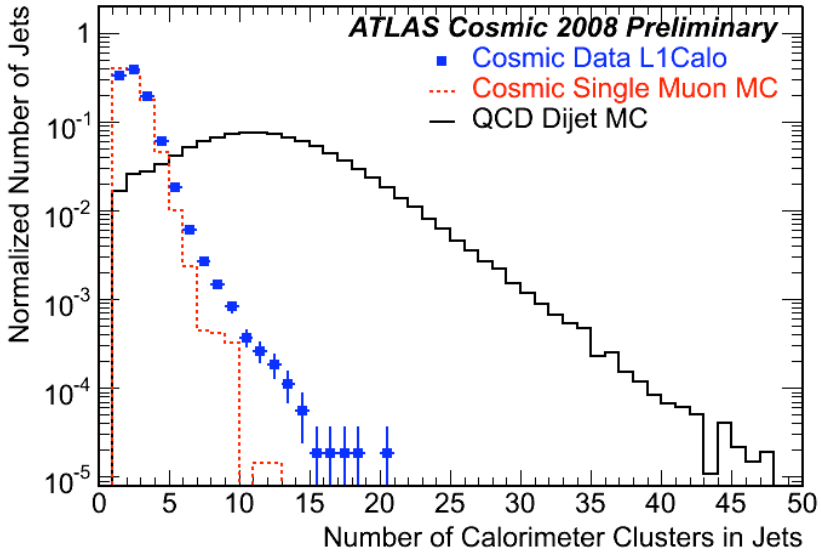


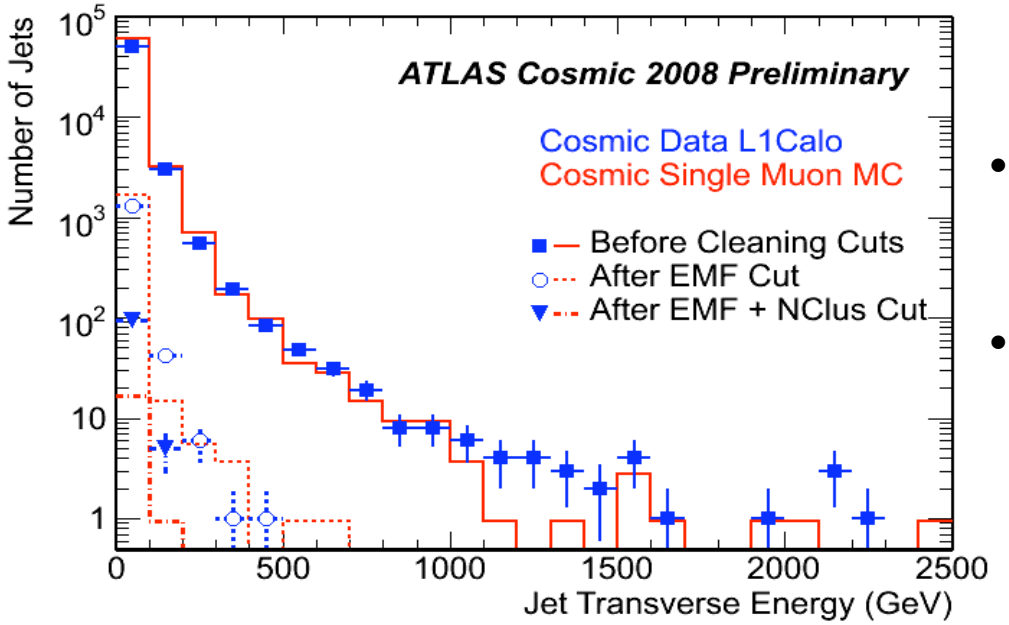
- TopoCluster **jets** of cone 0.4

- **Cosmic muons can cause large energy deposits in Calo ⇒ Jets**
- **Good agreement between data and MC**

Jet cleaning cuts





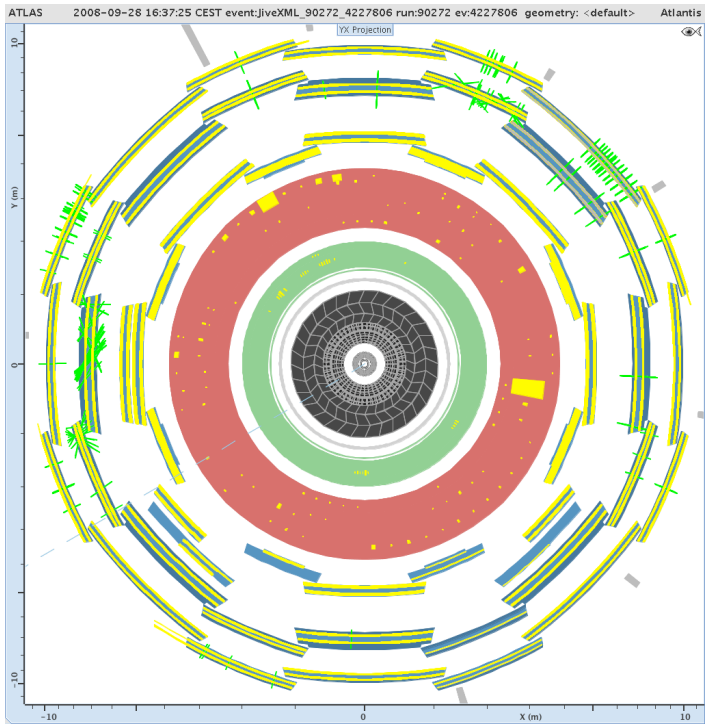


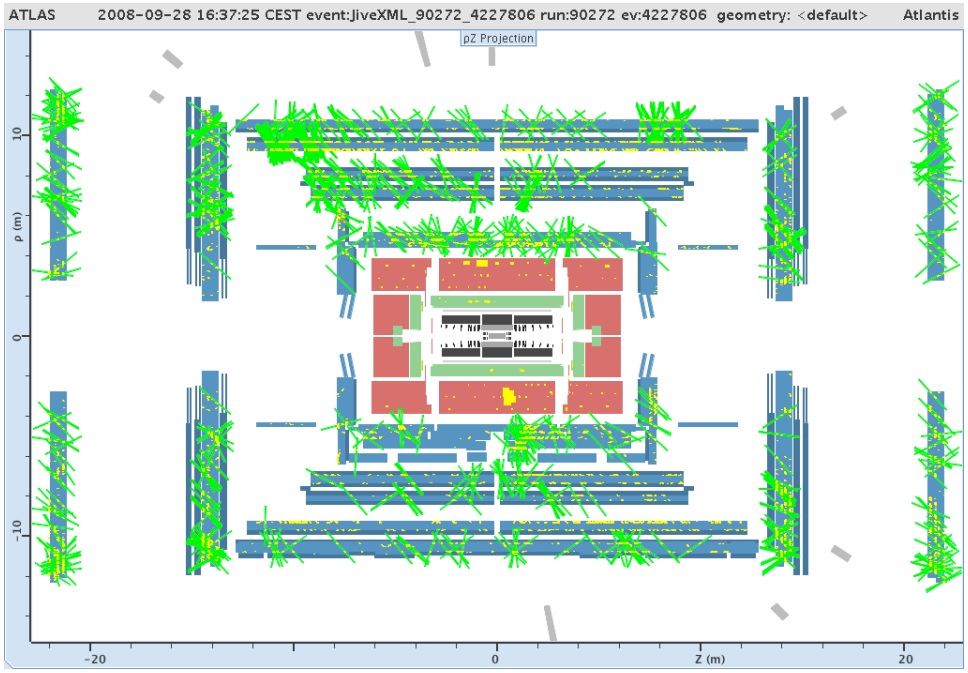
- Cosmic jets could fake QCD jets during normal (collision) data taking
- Cleaning cuts to suppress cosmic jets
  - Jet EM fraction
  - Jet Clusters multiplicity
- When applying both cuts
  - Very good cosmic jets rejection achieved
  - But performance can change when cosmic overlap with collision events

Conclusions

- LHC is about to start this fall: ATLAS Calorimeter system (190k cells) commissioning already reasonably understood
  - Some Calorimeters features have been spotted
  - Few bad channels masked
  - Good description of noise with a Gaussian model
  - High energy cosmics:
    - Shape of $\mathrm{SumE_T}$ and jet E_T well described by MC simulated single muons
    - Jet cleaning variables show good rejection power

Back-up

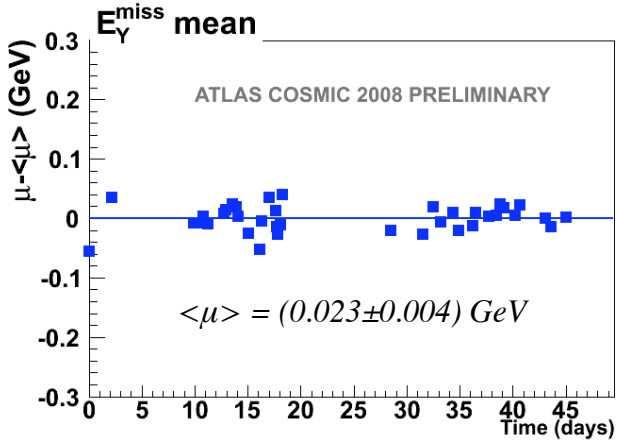


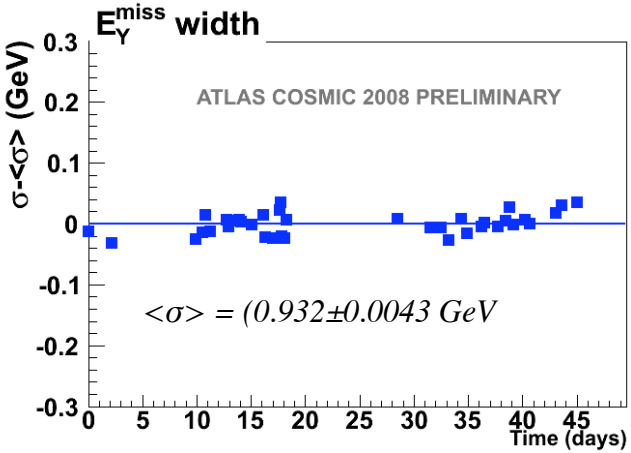


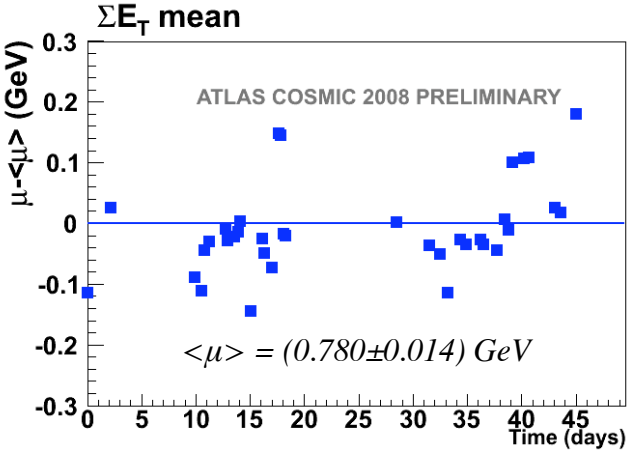
Air Shower Event

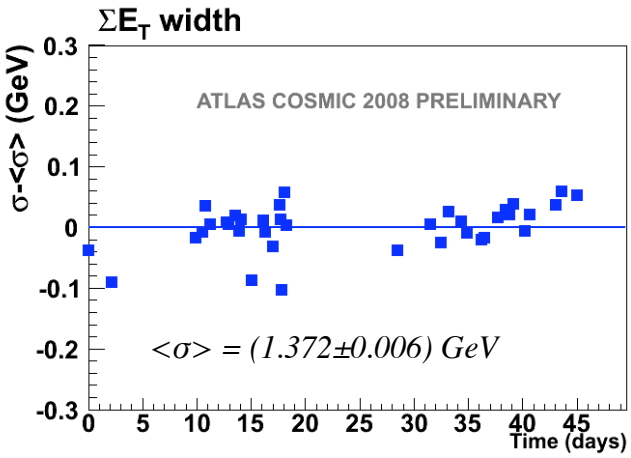
Time stability in Topo cluster E_T^{miss}

- Information in random triggers taken from 35 different cosmic/single beam runs starting from September 2008
- t=0 : First run at 10th September 2008: duration 6 weeks



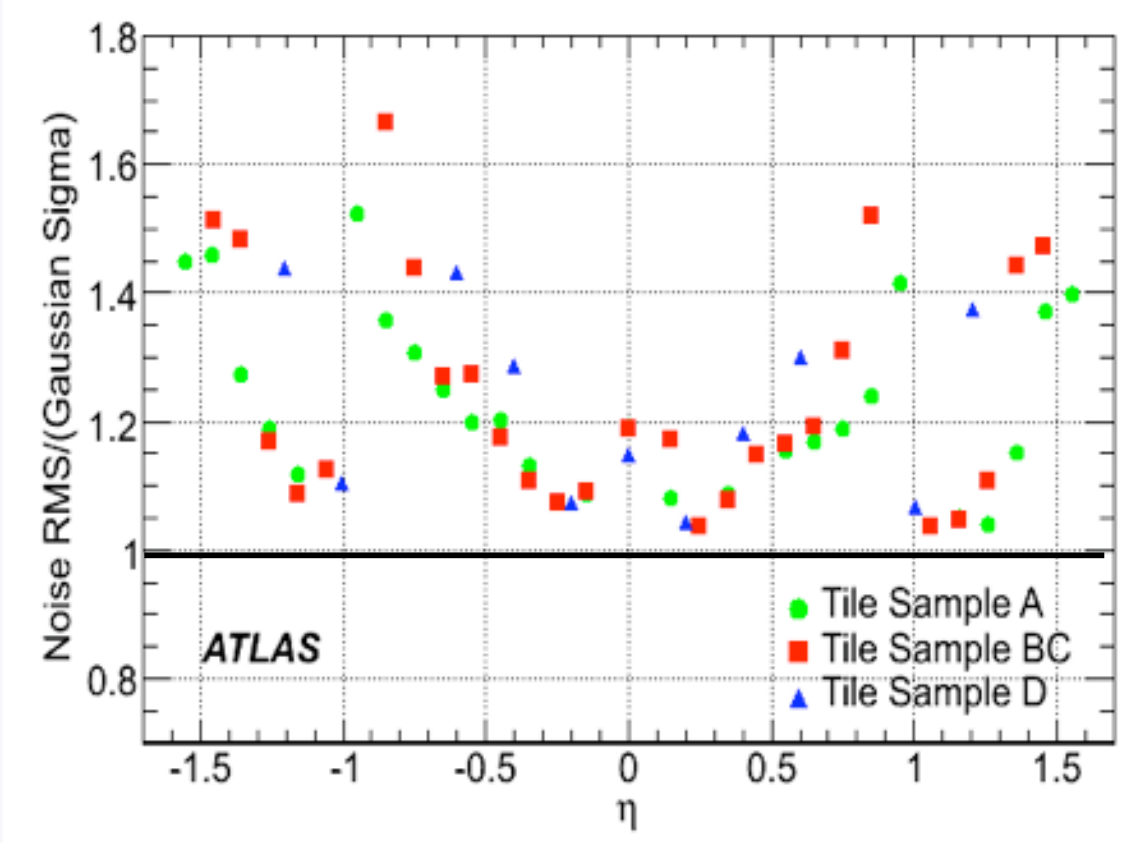






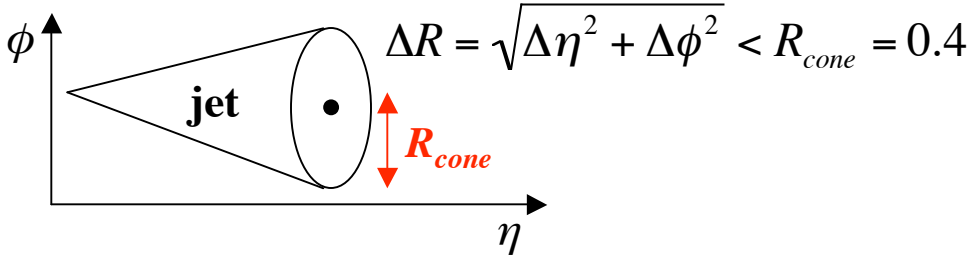
- **Very good stability within 45 days, all plots made using one fixed data base**

Tile NonGaussian Noise

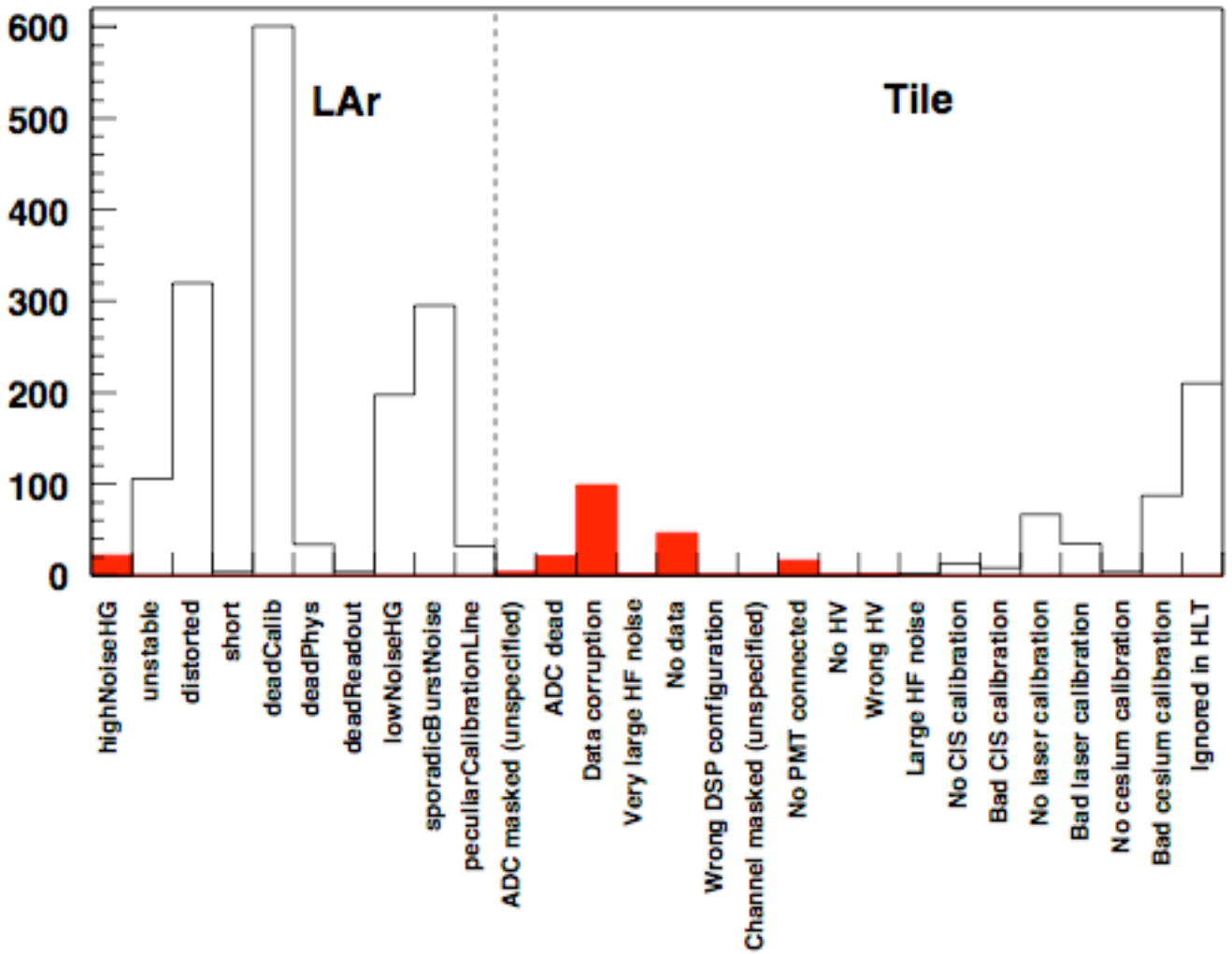


Jets cone 0.4

- TopoCluster **jets** of cone 0.4



Problematic Cells



End-cap cryostat