Les Premières Données dans ATLAS et le Calorimètre à Argon Liquide

Des muons cosmiques aux premières collisions

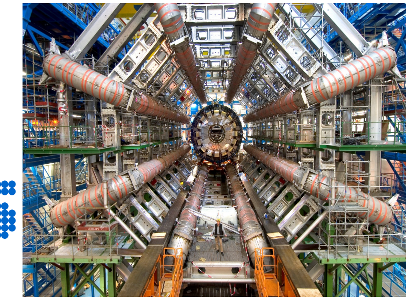
S. Laplace, P. Iengo
Pour le groupe ATLAS-LAPP

Plan:

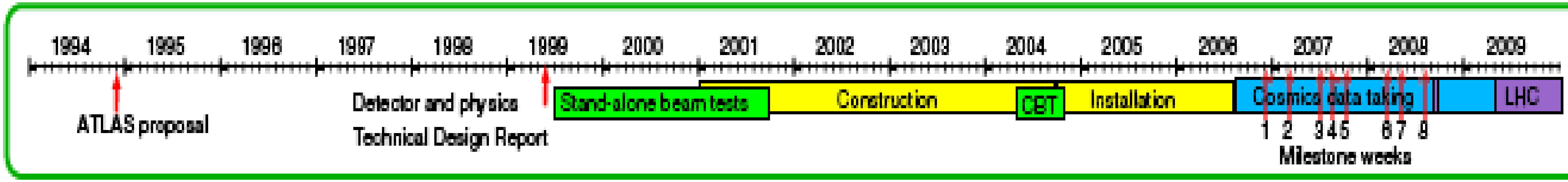
- Introduction
- Commissioning du calo Lar (muons+beam splashes)
- Résultats des premières collisions

Remarque: le logo signifie que le LAPP a contribué à l'analyse montrée

ATLAS In-Situ Commissioning Steps

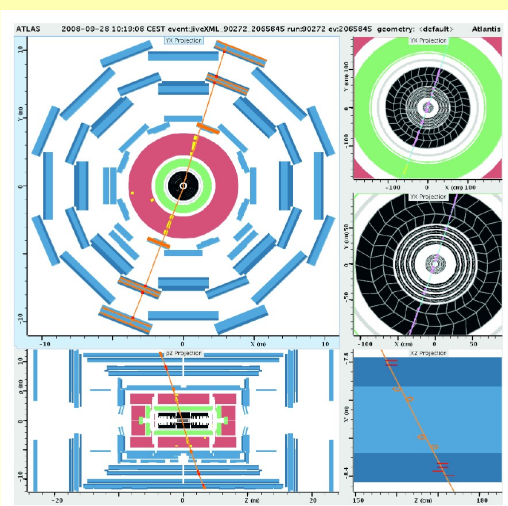


- In situ commissioning of ATLAS detectors ongoing since 4 years:



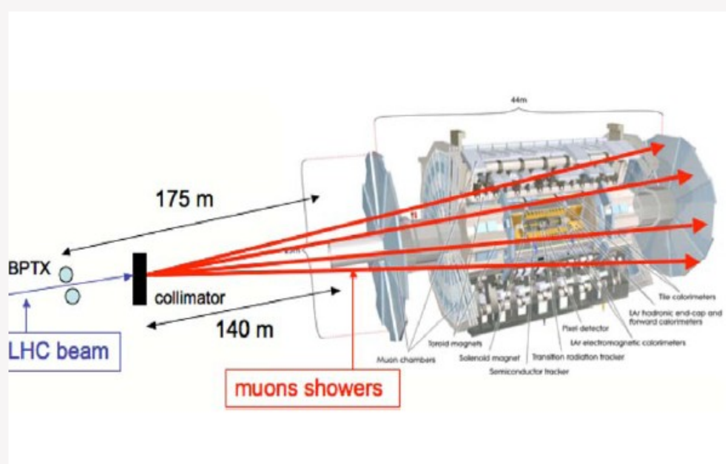
Cosmic muons (since 2006)

Muon: Minimum Ionizing Particle (MIP) in LAr calorimeter



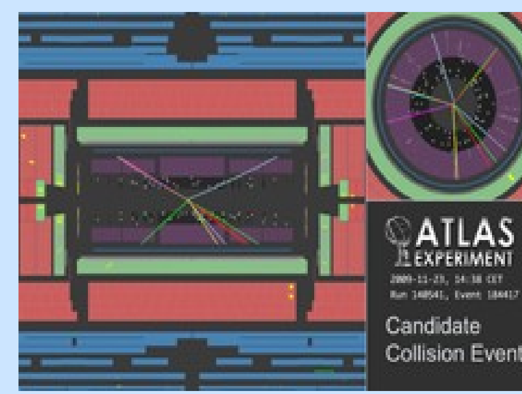
First LHC Beams (Sept. 10-12, 2008)

Very large energy deposited in most of LAr cells !



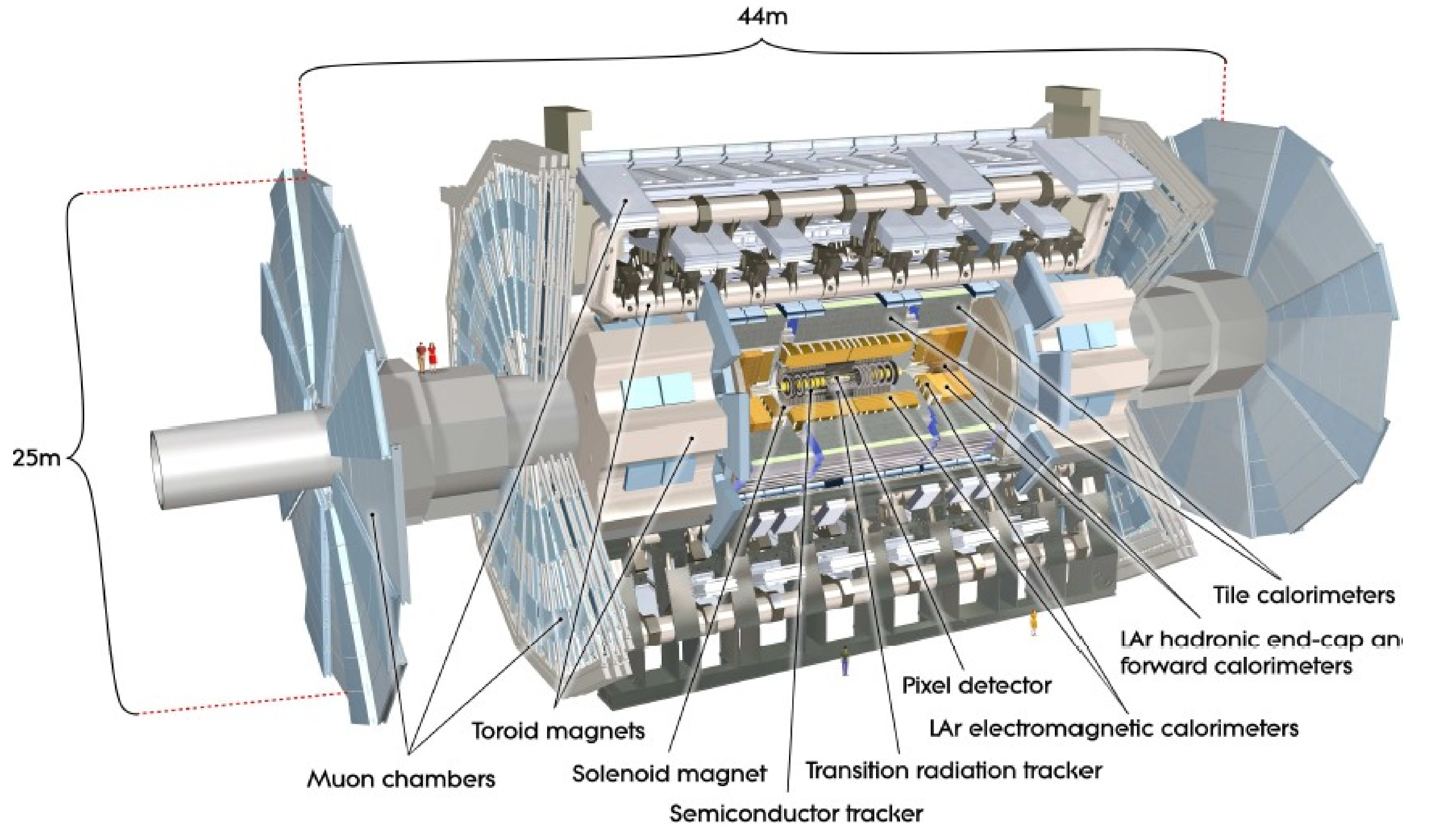
First Collisions (Nov. 23, 2009)

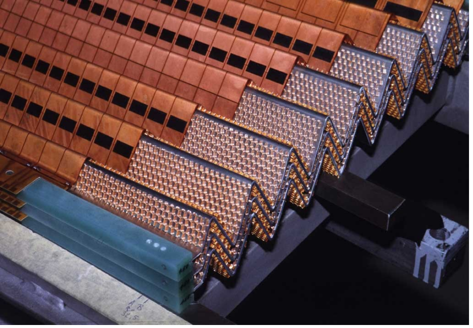
Real events !



Detector component	Required resolution	η coverage	
		Measurement	Trigger
Tracking	$\sigma_{p_T}/p_T = 0.05\%\ p_T \oplus 1\%$	± 2.5	
EM calorimetry	$\sigma_E/E = 10\%/\sqrt{E} \oplus 0.7\%$	± 3.2	± 2.5
Hadronic calorimetry (jets)			
barrel and end-cap	$\sigma_E/E = 50\%/\sqrt{E} \oplus 3\%$	± 3.2	± 3.2
forward	$\sigma_E/E = 100\%/\sqrt{E} \oplus 10\%$	$3.1 < \lvert\eta\rvert < 4.9$	$3.1 < \lvert\eta\rvert < 4.9$
Muon spectrometer	σ_{p_T}/p_T=10% at $p_T = 1$ TeV	± 2.7	± 2.4

ATLAS

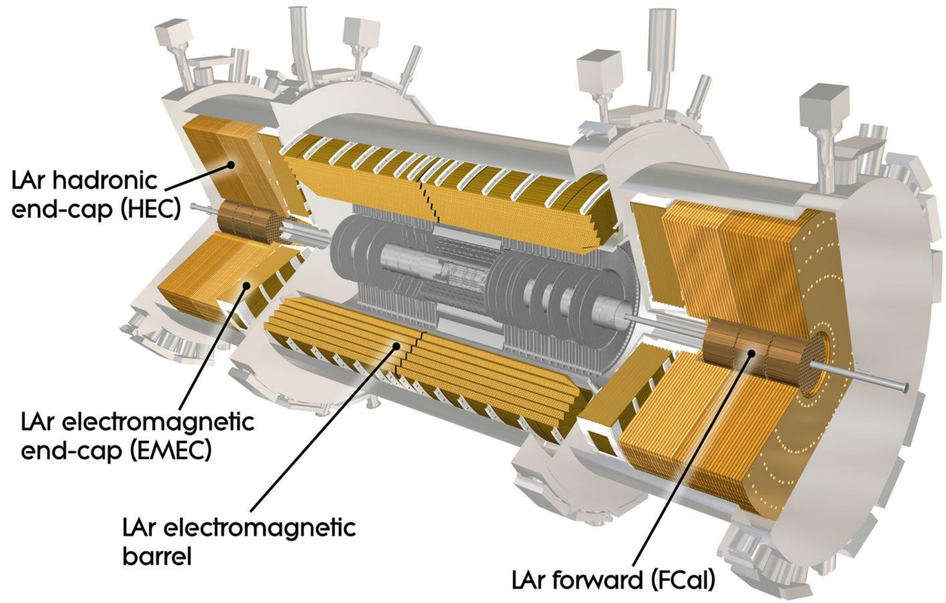




Introduction to the ATLAS LAr Calorimeter (1/3)

- Sampling calorimeters: Lar+Pb/Cu/W
- Standard barrel/endcap structure:

- barrel (|η|<1.4): electromagnetic (EM)
- endcap (|η|<4.9): EM+ hadronic (HAD) + forward (FCAL)
- presampler up to |η|=1.8

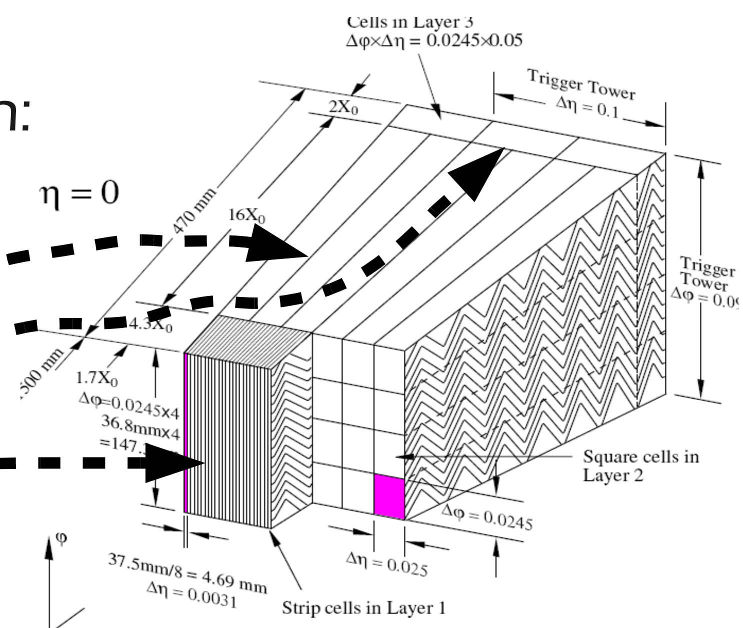


- Segmentation: lateral (eta,phi) but also in depth:
  - (Pre-Sampler)
  - Strips
  - Middle
  - Back
- Energy resolution:

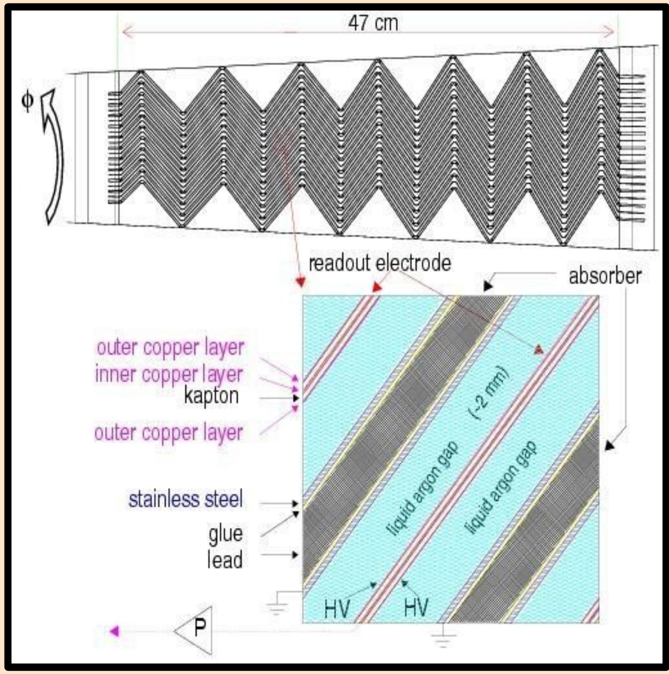
$\sigma/E \sim 10\%/\sqrt{E} \oplus 0.7\%$ (EM)

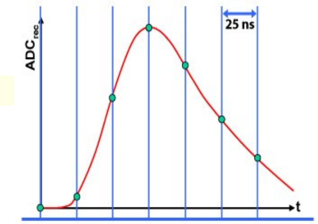
$\sigma/E \sim 50\%/\sqrt{E} \oplus 3\%$ (HAD)

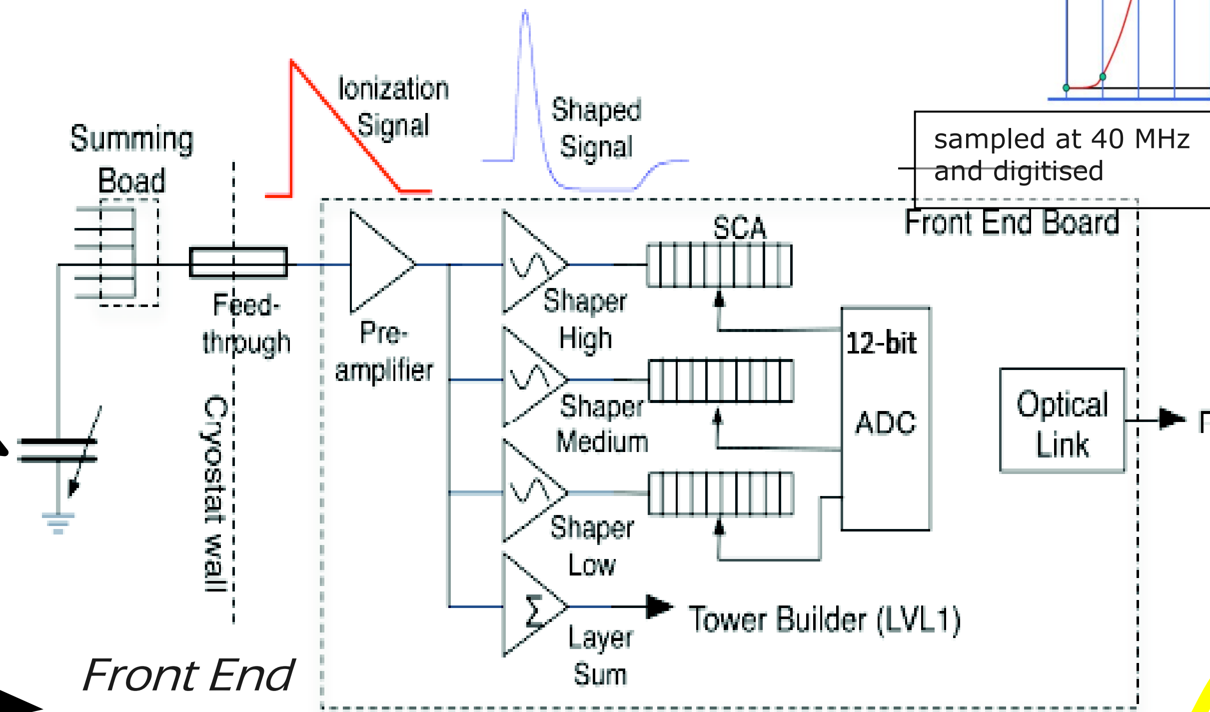
$\sigma/E \sim 100\%/\sqrt{E} \oplus 10\%$ (FCAL)



Introduction to the ATLAS LAr Calorimeter [2/3]







Calorimeter

Front End Electronics

Back End Electronics

Phys/Cal Difference

ADC to DAC (Ramps)

Pulse Samples

$$E_{\text{cell}} = F_{\mu\text{A}\rightarrow\text{MeV}} \cdot F_{DAC\rightarrow\mu\text{A}} \cdot \frac{1}{\frac{\text{M}_{\text{phys}}}{\text{M}_{\text{cali}}}} \cdot R \left[\sum_{j=1}^{N_{\text{samples}}} a_j \left(s_j - p \right) \right]$$

Energy

Energy Conversion

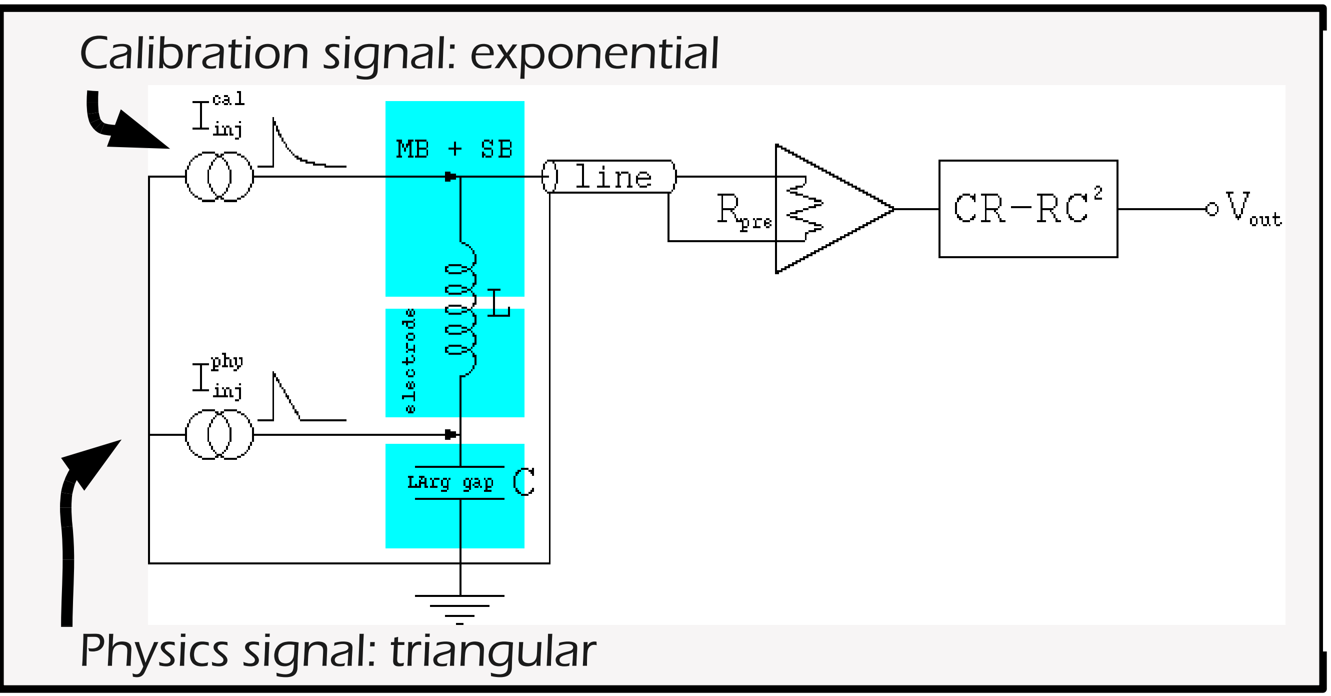
Calibration board

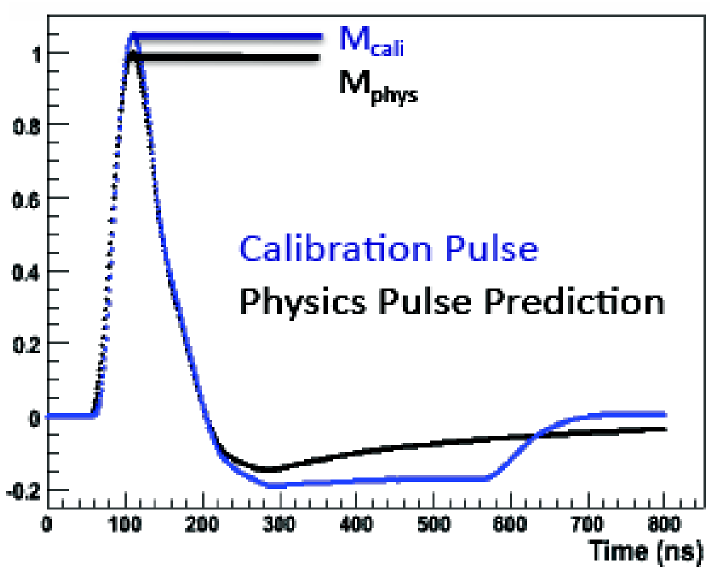
Optimal Filtering Coefficients

Pedestals

Introduction to the ATLAS LAr Calorimeter (3/3): The Calibration System

- Used to compute several electronics-related constants, including optimal filtering coefficients
- Calibration and physics pulse are different due to different injected signal and injection points: methods exist to predict physics pulses from calibration pulse



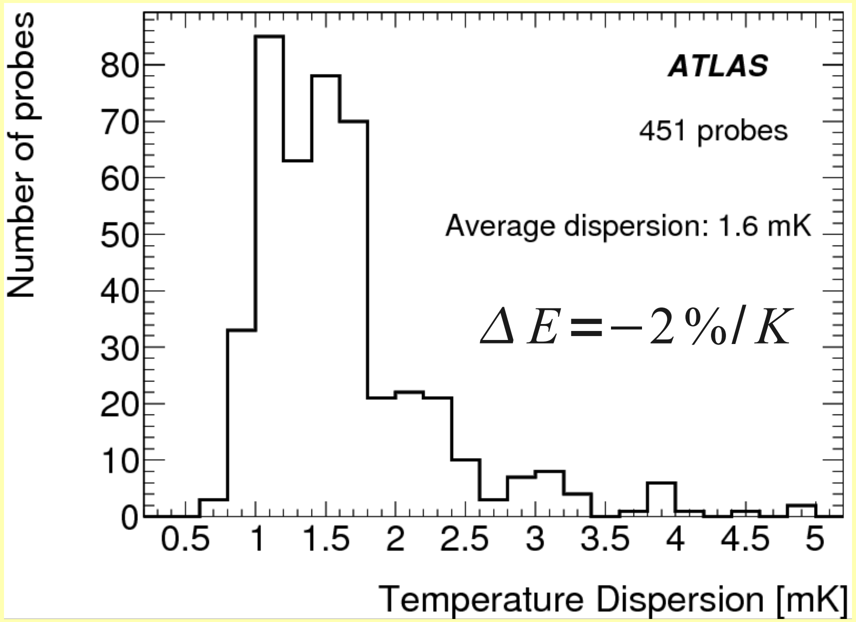


ATLAS Status

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.9%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.2%
LAr EM Calorimeter	170 k	98.8%
Tile calorimeter	9800	99.2%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.4%
RPC Barrel Muon Trigger	370 k	98.5%
TGC Endcap Muon Trigger	320 k	99.4%
LVL1 Calo trigger	7160	99.8%

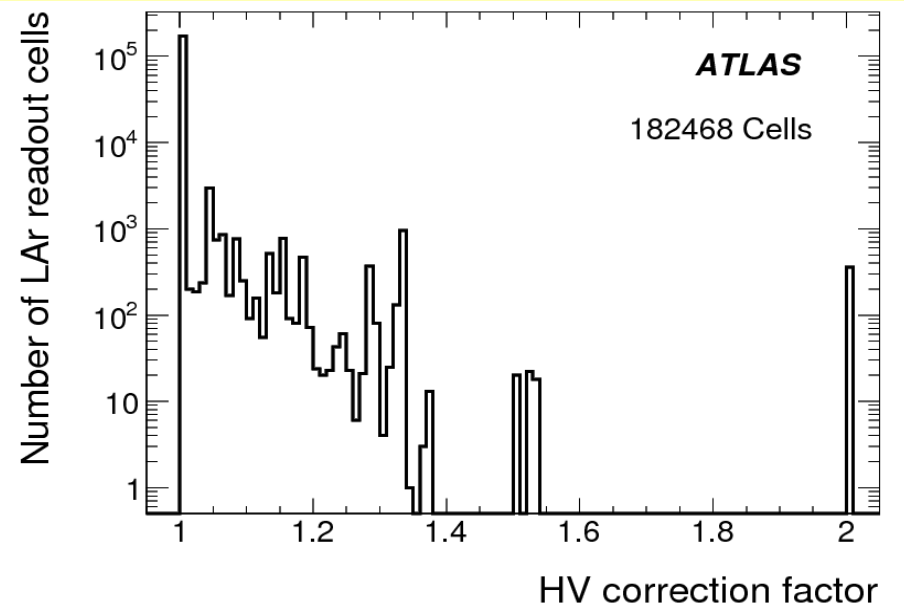
Calorimeter Status

LAr temperature



Typical cryostat uniformity: 70-80 mK
[requirement < 100 mK → c<0.2%]

High-Voltage



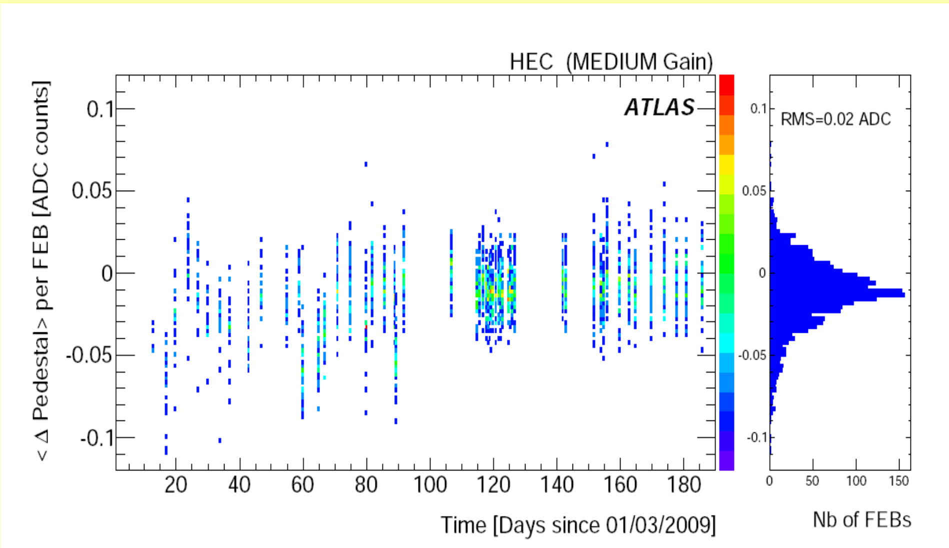
Nominal HV cells: 93.9%
No dead HV region (corrections)

LAr Readout status (as of end of Sept. 2009:

- 98.7% cells used in reconstruction
- 1.3% remaining:
  - 1.2% (19) inactive FEBs (dead OTx) → Can recover energy for jet/ETmiss using trigger tower energy
  - 0.1% of problematic cells:
    - 0.02% dead
    - 0.03% permanently noisy
    - 0.07% sporadically noisy

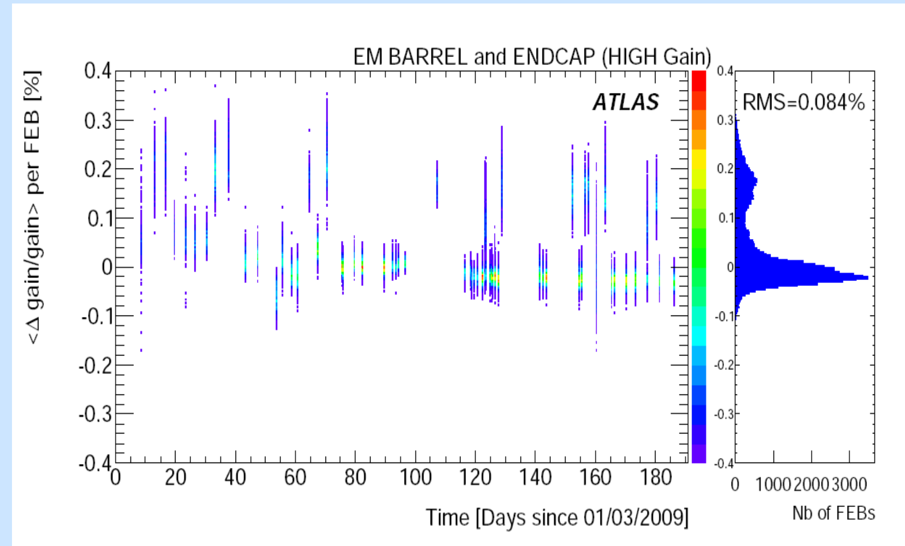
Calibration Constants Stability

Pedestal



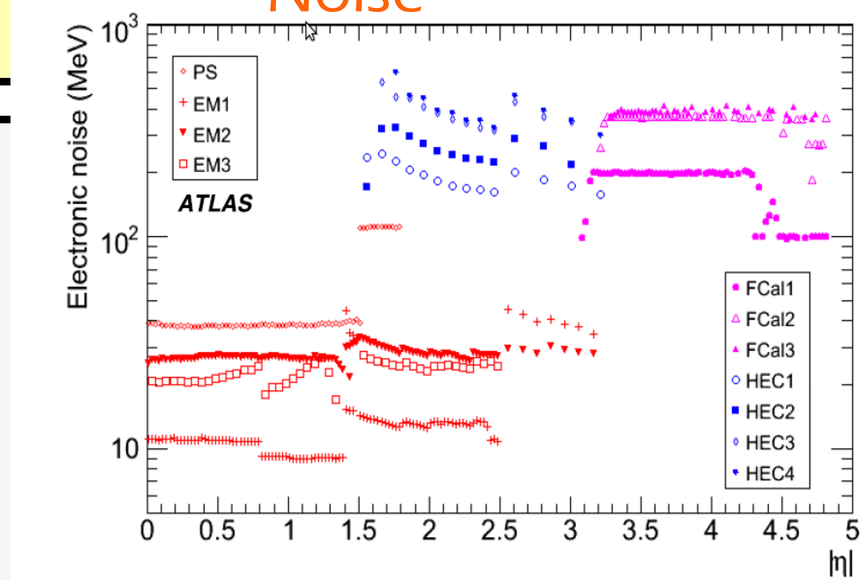
Pedestal variations << numerical precision on E

Ramp



Ramp variations <0.3% and corrected after each run

Noise



- Noise variations negligible
- Coherent noise = 2% (< requirement= 5%)

Calorimeter Readiness for LHC Collisions

Results from random triggers, cosmics muons and first beams:

- Timing Alignment
- dE/dx in calo
- Ionization pulse shapes
- Ion drift time measurement (dedicated paper in prep.)
- Missing Transverse Energy
- Calorimeter Uniformity

All these results are (almost) published in EPJC: FIRST ATLAS paper !

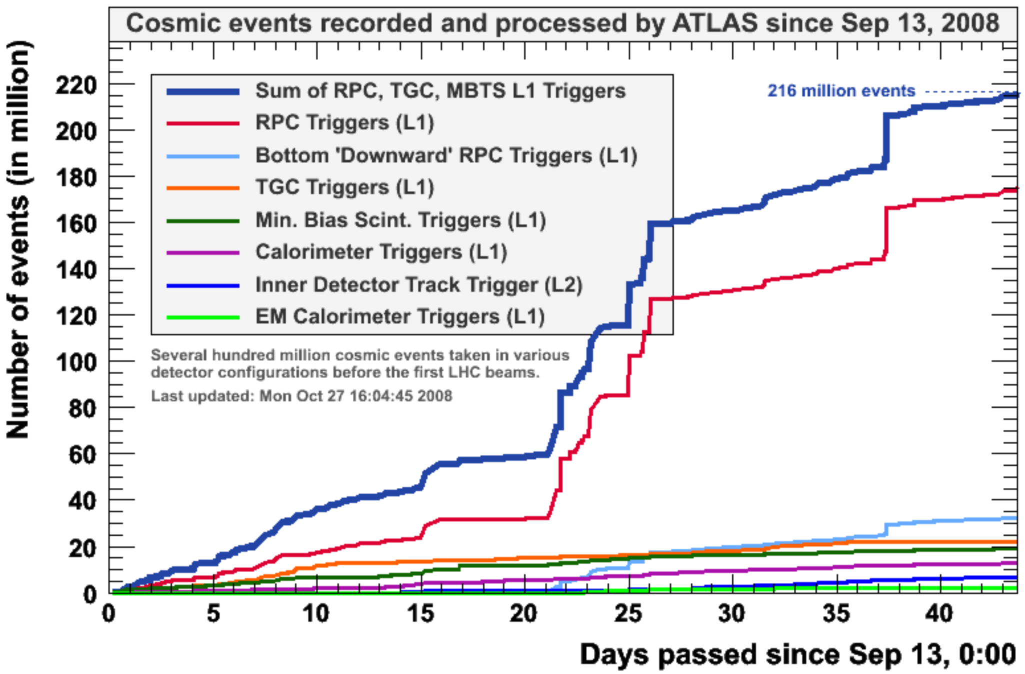
EPJ manuscript No.
(will be inserted by the editor)

Readiness of the ATLAS Liquid Argon Calorimeter for LHC Collisions

arXiv:0912.2642

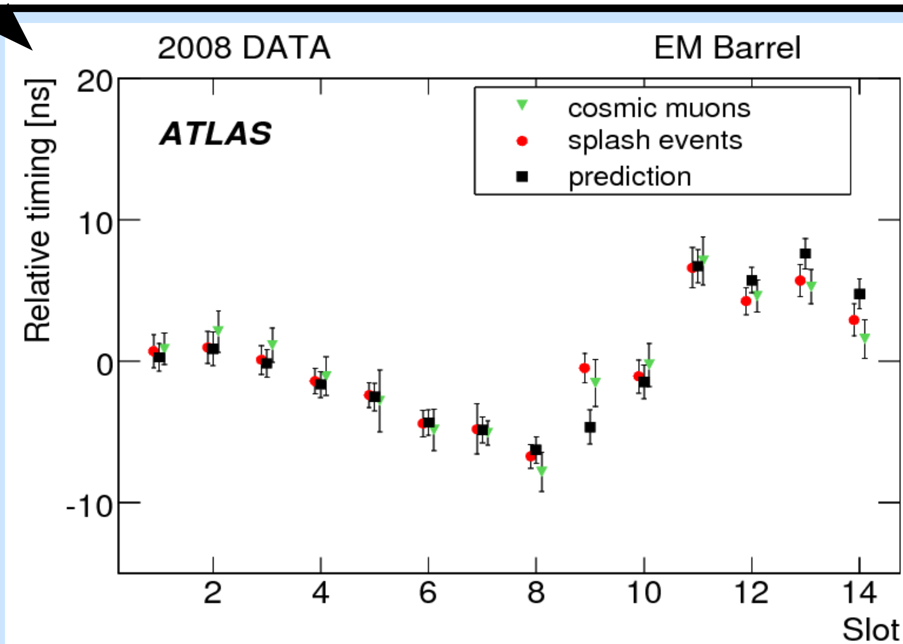
Cosmic Data Taking

- Long cosmic runs in September-october 2008 and june-july 2009: more than 300 million events were recorded (>500 TB of data)
- Triggers used for studies preented here:
  - L1: muon chambers, L1Calo
  - L2: inner detector tracks

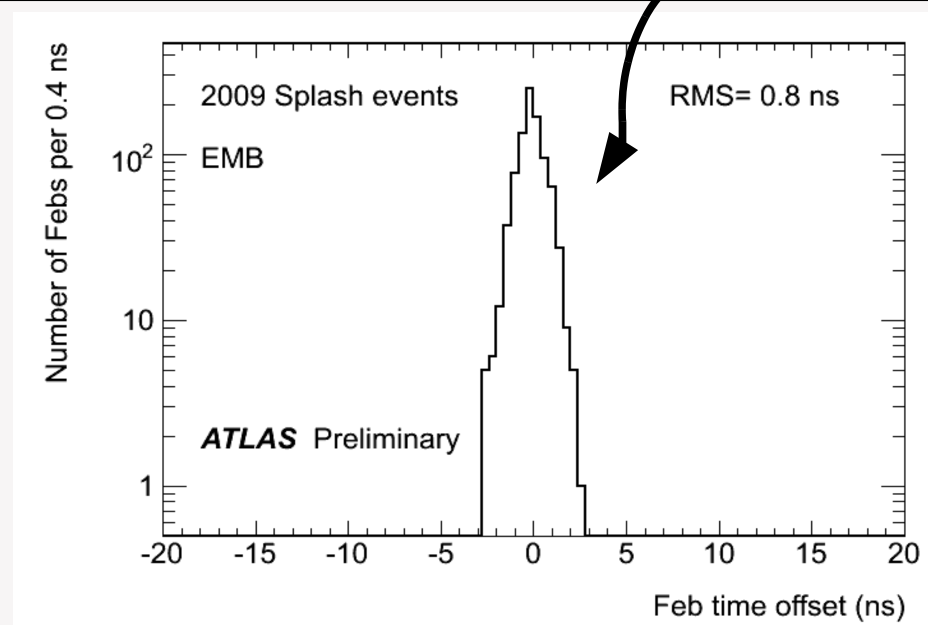


Timing Alignment

- Predicted (=calibration) versus measured (=physics) timing:
  - Measurement: time obtained from Optimal Filtering algorithm + time of flight correction
  - Prediction: calibration pulse + readout path
- Adjustable delay per Front End Board (FEB): obtain values for first collisions



Agreement with prediction better than ± 2ns

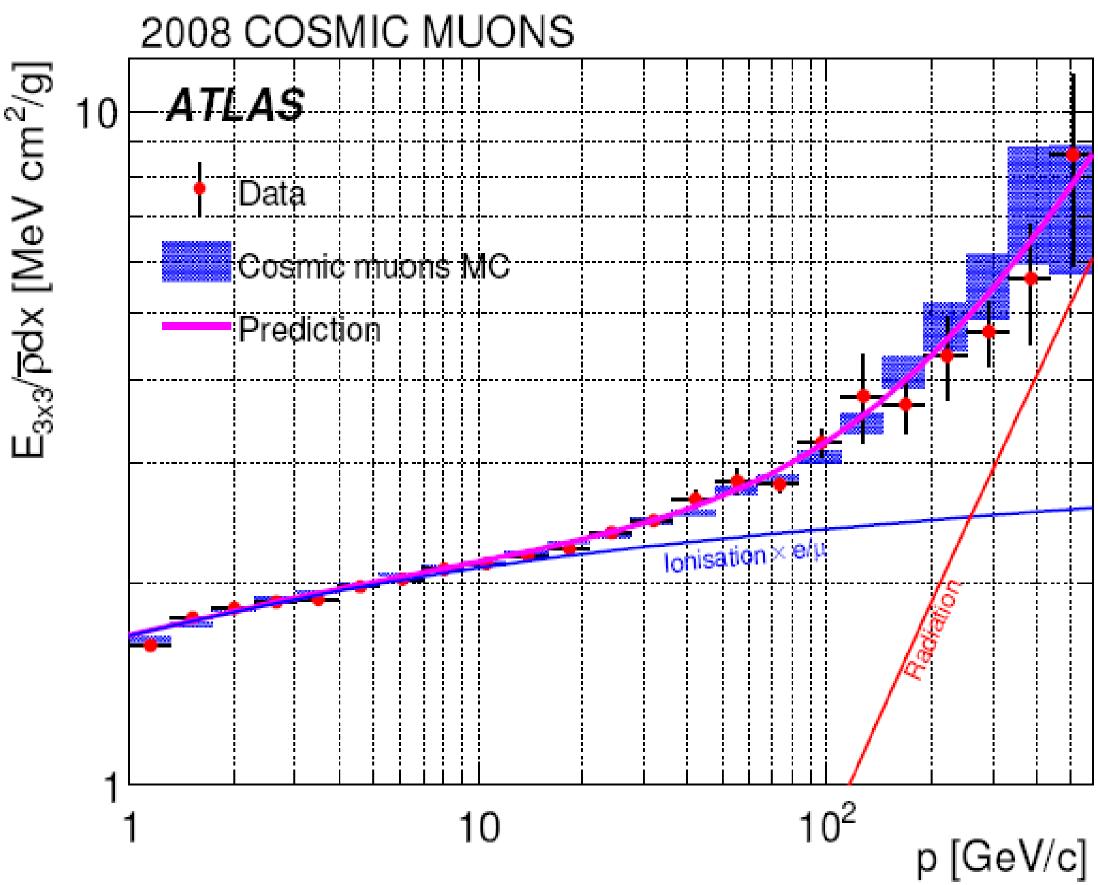


Timing first first beam 2009 better than 1ns !

Cosmic Muons

dE/dx in the EM Barrel

- Mean energy deposit per unit length as a function of the incoming muon momentum:



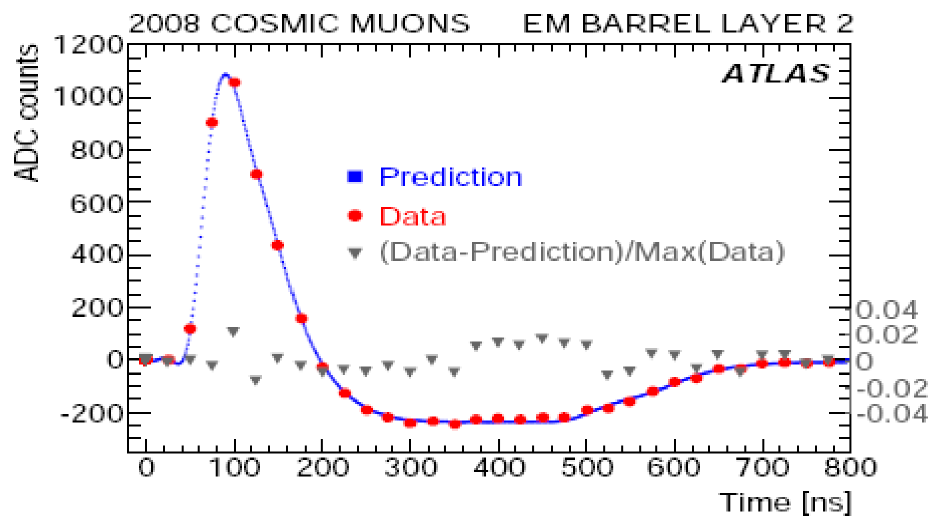
$$\frac{dE}{\rho\, dx} = \frac{E_{3x3}}{\bar{\rho}\, L}$$

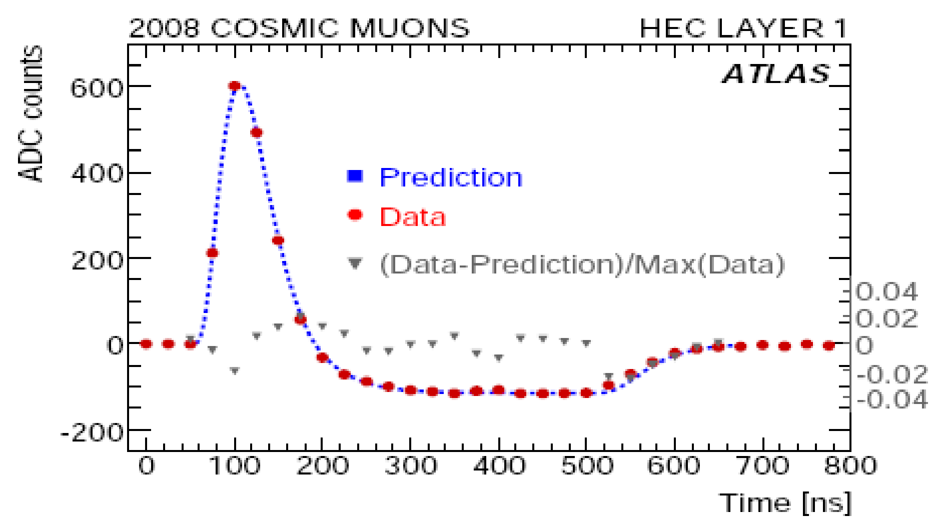
- **E33** = energy measured in a 3x3 clusters (middle layer) taking into account sampling fraction
- **Mean density**: rho=4.01 g/cm3 from "equivalent" molecule for calo: $Pb_{30}Ar_{56}Fe_{24}C_{21}H_{41}$

→ Data and MC agree very well
→ Also agree with theoretical energy loss from PDG

Cosmic Muons

Ionization Pulse Shapes [1/2]





Main ingredient to compute optimal filtering coefficients: need to be precisely known !

- Prediction using calibration pulses + cell modeled as resonant RLC circuit
- Measurement using 32-sample samples of radiating cosmic muons

→ agreement at the 1-2% level

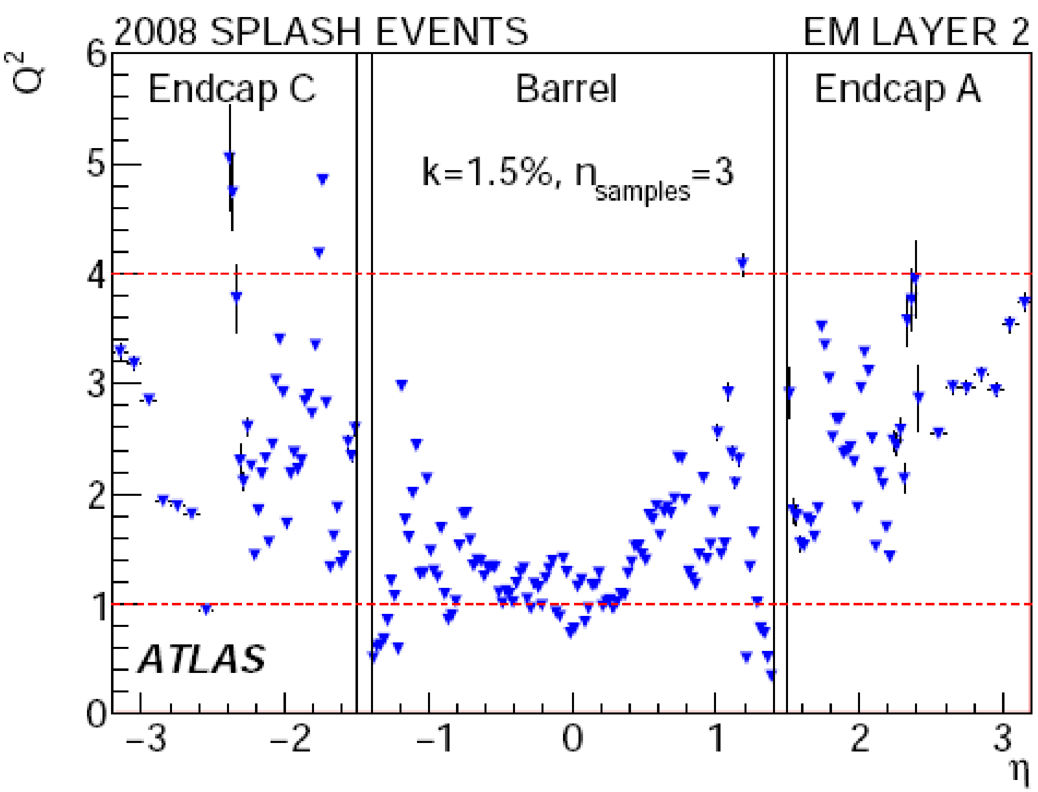
First Beams

Ionization Pulse Shapes (2/2)

- More quantitative conclusion on signal prediction accuracy obtained by looking at following quality estimator:

$$Q^2 = \frac{1}{N_{dof}} \sum_{j=1}^{N_{samples}} \frac{\left(s_j - A g_j^{phys}\right)^2}{\sigma_{noise}^2 + (kA)^2}$$

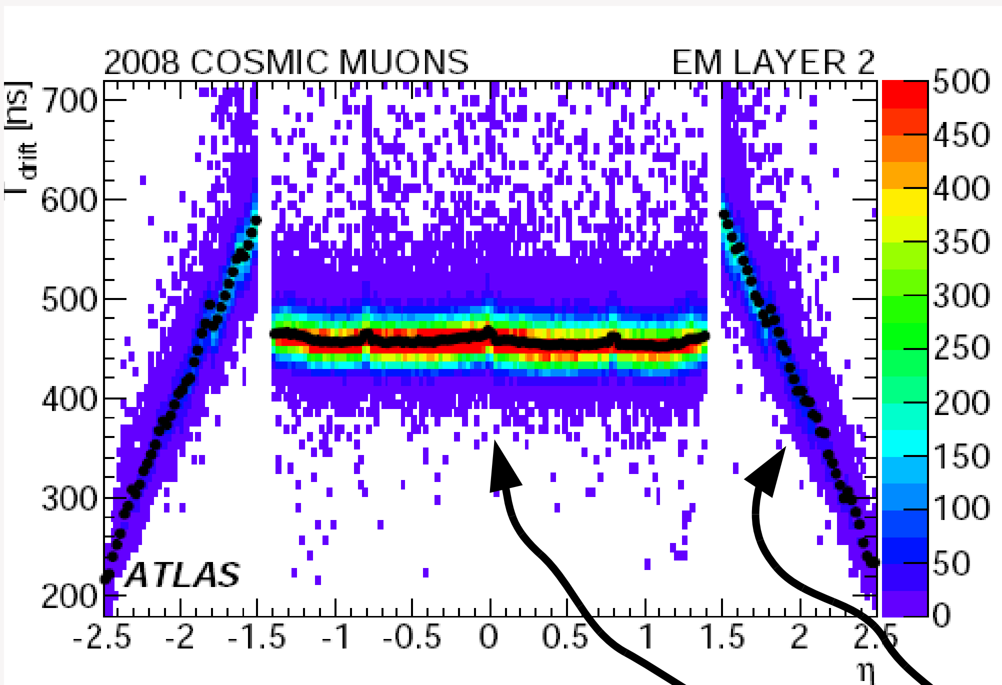
- Factor "k" quantifies the relative accuracy on the amplitude:
  - Barrel: k = 1.4%
  - Endcap: k = 2.6%
- Similar to testbeam result where contrib. to constant term due to signal prediction was 0.25%



Ionization Drift Time

Drift time extracted from fit to the measured pulse

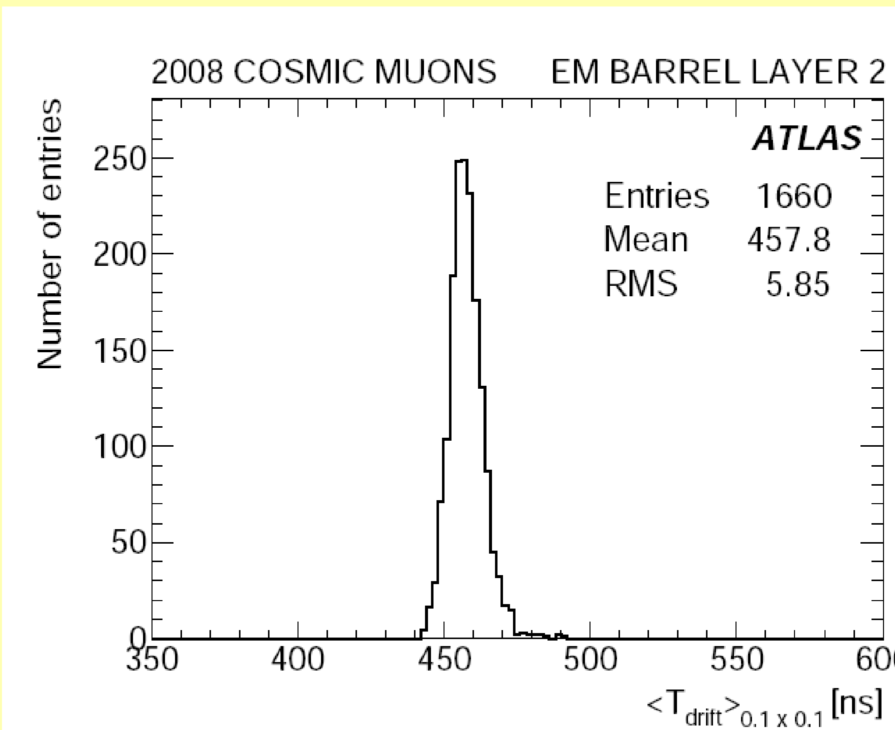
(undershoot region)



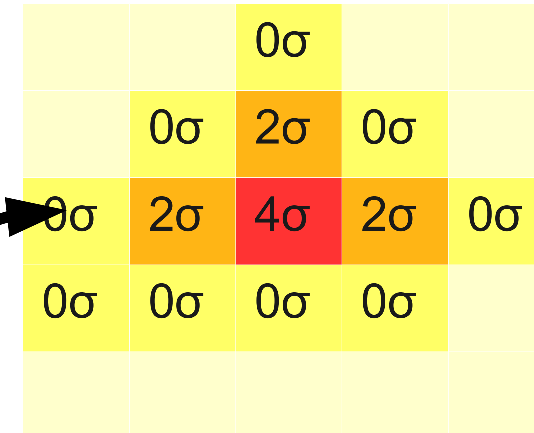
$$T_{drift} = \frac{\omega_{gap}^{\alpha+1}}{V^{\alpha}}$$

Constant field in barrel
Varying field in endcap

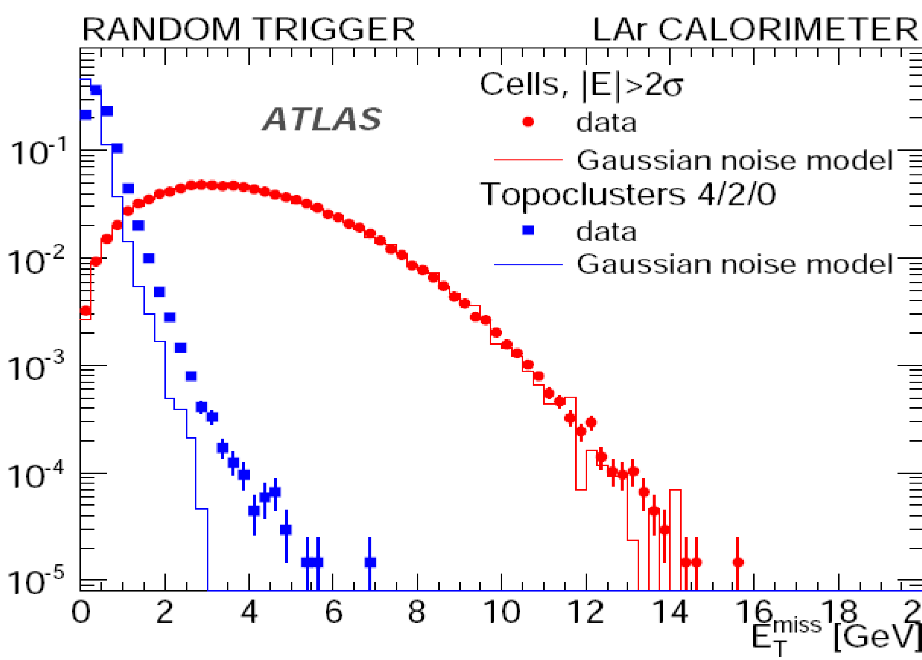
Drift time variations linked to intrinsic calorimeter uniformity:
RMS/mean = 0.29 +- 0.01%
→ upper bound on corresponding constant term
(at construction: 0.16%)

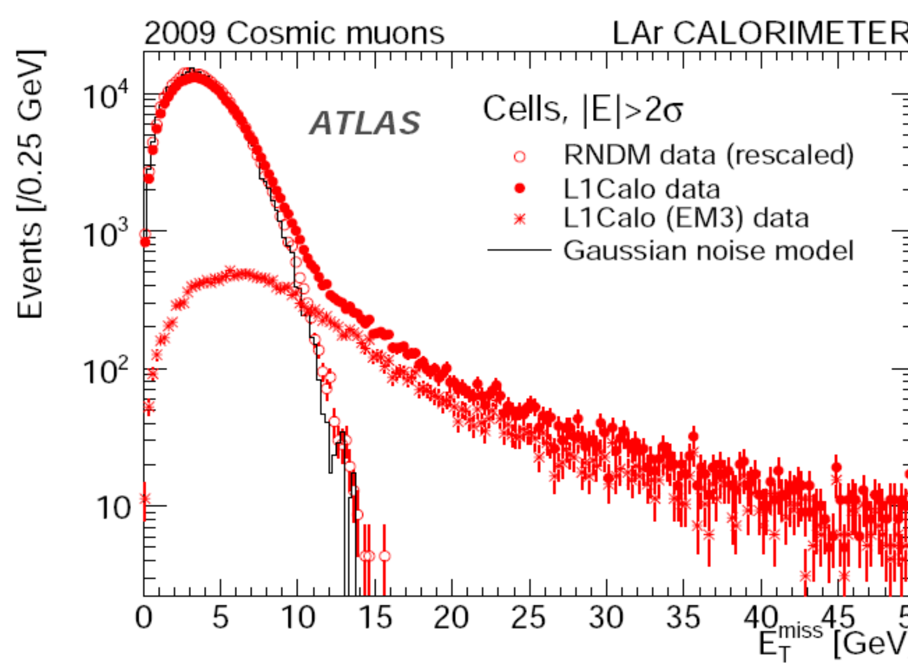


Missing Transverse Energy



- Two noise-suppression methods to compute ETmiss:
  - All cells with |E|>2 sigmas_noise
  - Topological clusters "4-2-0"
- Noisy cells are masked
- ETmiss measured in random events, and L1Calo triggered events:





Cosmic Muons

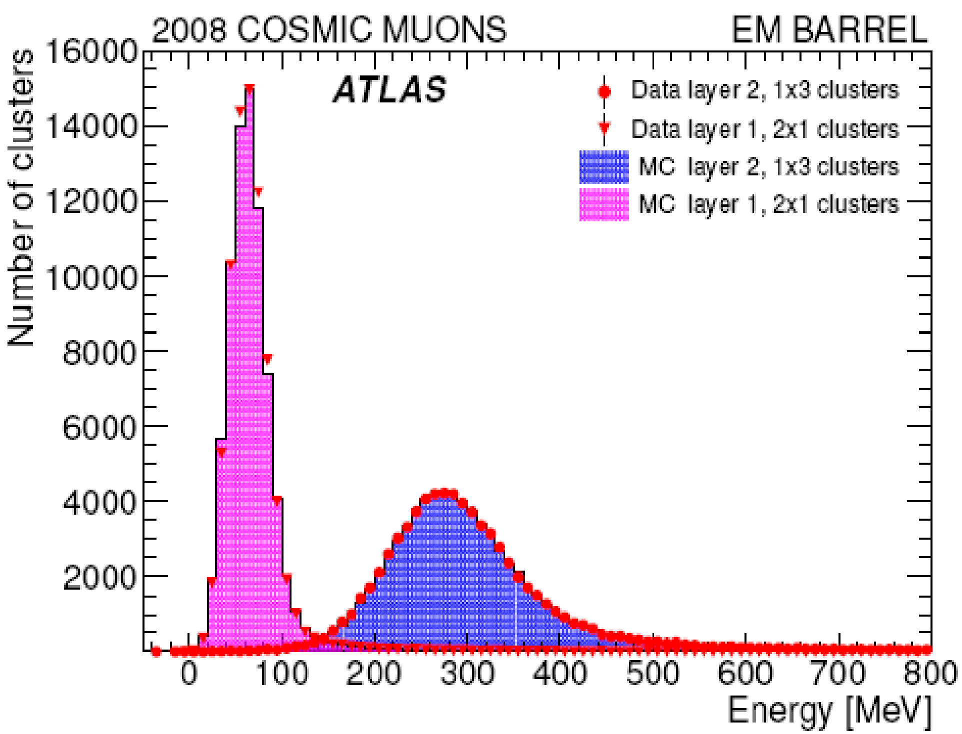
Calorimeter Uniformity: Introduction

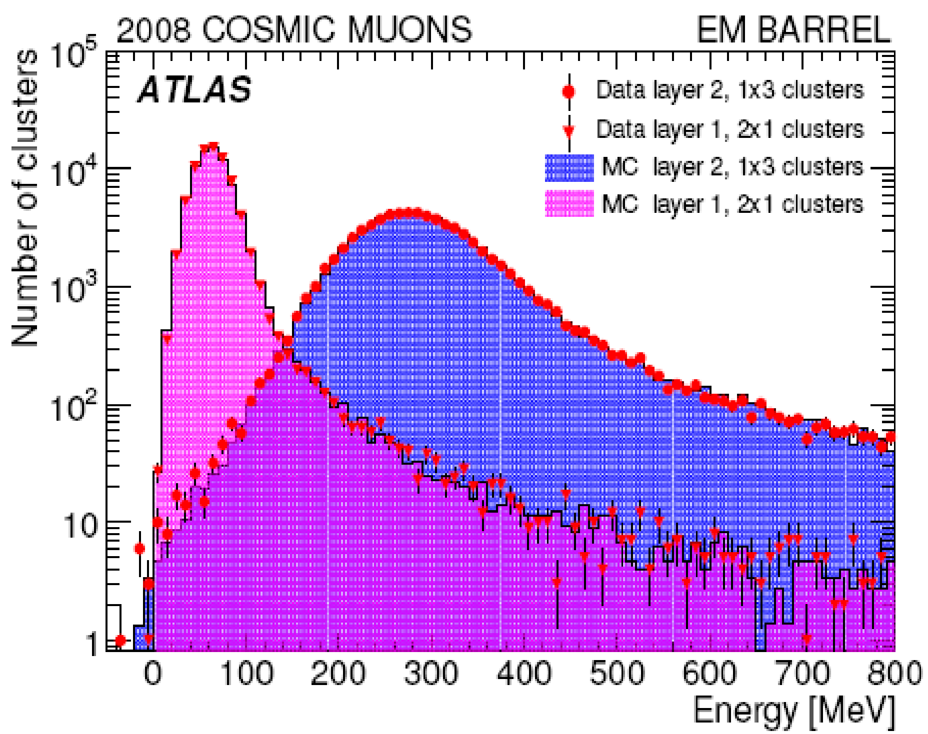
- Cosmic muons used to probe calorimeter uniformity response:
  - Deposited energy proportional to LAr crossed (cell depth) → uniformity measured by comparing with MC prediction
  - Muons not sensitive to material as electrons, but allow to measure uniformity cell-by-cell
- Muon energy reconstruction:
  - Use muon track to seed calo cluster search
  - Deposited energy in calo reconstructed using 1x3 (middle) and 2x1 (strips) clusters
  - Projectivity/centrality cuts allow to reduce biases

Cosmic Muons

Calorimeter Uniformity: Energy Lineshapes

- Agreement between data and MC lineshapes is very good
- Global energy scale agrees between MC and data at the 1-2% level: Impressive !
- Lineshapes are fitted with Landau convoluted with Gaussian:
  → Landau Most Probably Value (MPV) estimates the muon deposited energy

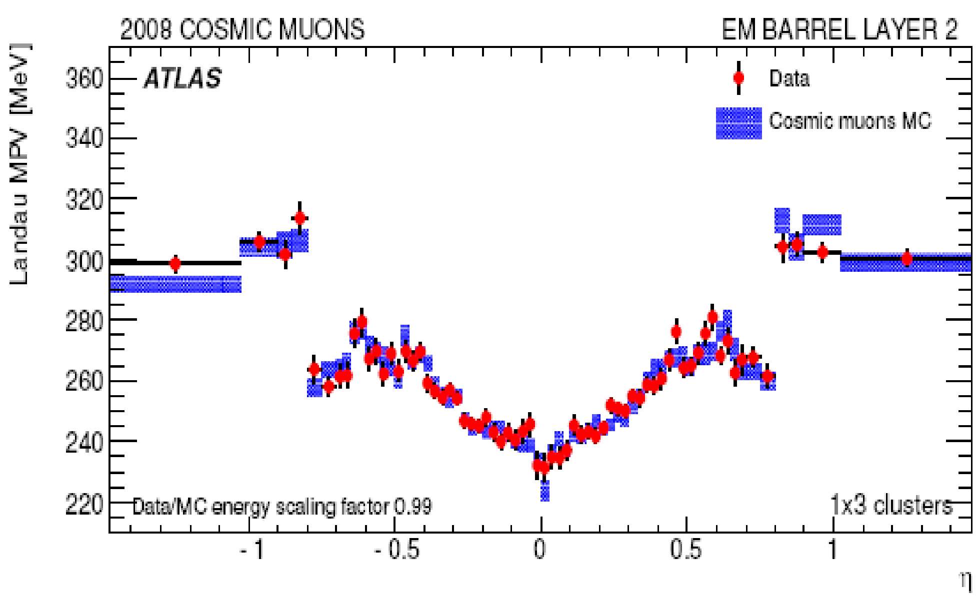


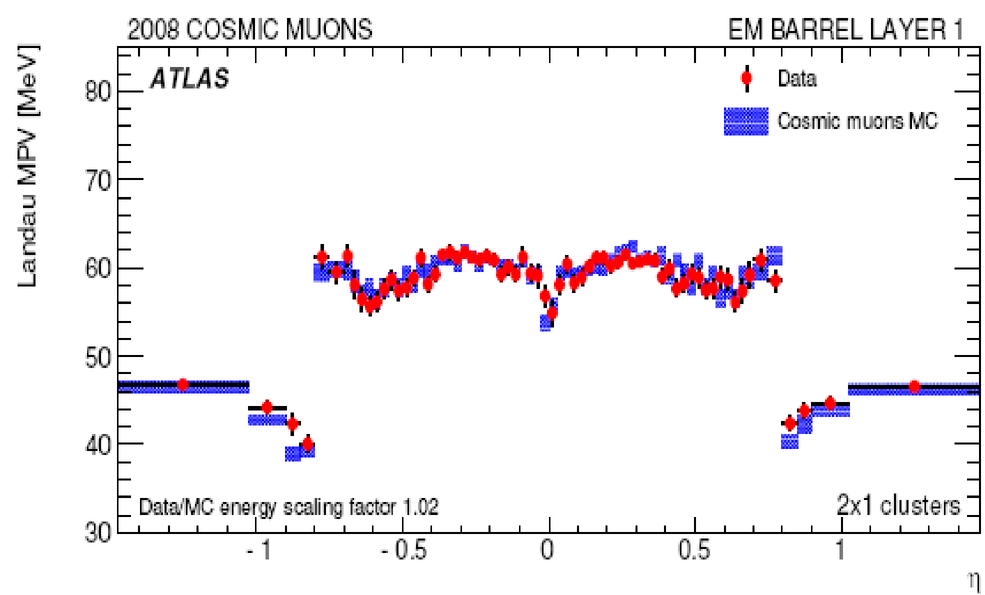


Cosmic Muons

Calorimeter Uniformity: MPVs versus eta

- Limited statistics → natural choice to group cells along phi
- Look at Landau MPV along eta for data and MC:
  - Layer 2: typical V-shape due to cell depth variation+ transition at eta=0.8 (lead thickness)
  - Layer 1: flat + transition at eta=0.8





Cosmic Muons

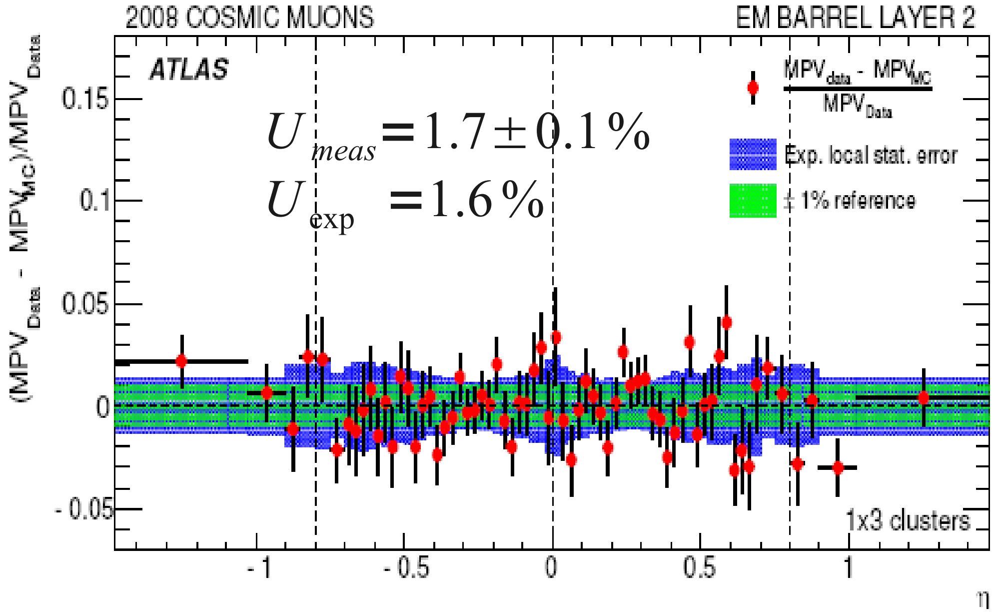
Calorimeter Uniformity

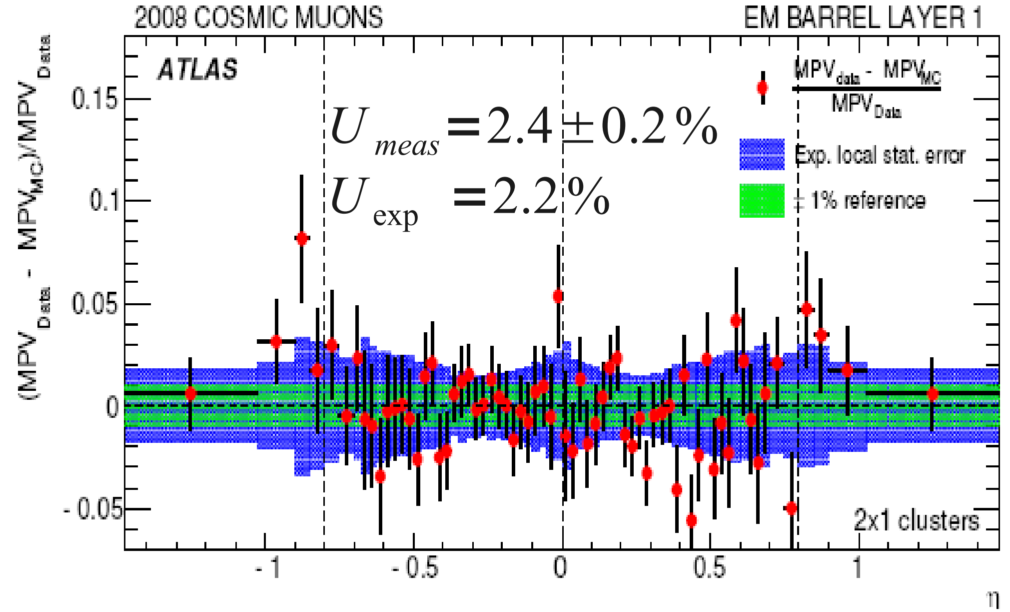
- Measured uniformity (RMS of normalized difference in data and MC MPV):

$$U_{meas} = \sqrt{\sum_{i=1}^{N_{bins}} \left(U_{i,meas} - \langle U_{i,meas} \rangle\right)^2 / N_{bins}} \quad \text{with} \quad U_{i,mean} = \frac{MPV_{i,Data} - MPV_{i,MC}}{MPV_{i,Data}}$$

- To be compared with expected uniformity (fluctuations due to noise, ...):

$$U_{exp} = \sqrt{U_{i,Data}^2 + U_{i,MC}^2} \quad \text{with} \quad U_{i,Data(MC)} = \sqrt{\sum_{i=1}^{N_{bins}} \left(\frac{\sigma\left(MPV_{i,Data(MC)}\right)}{MPV_{i,Data(MC)}}\right)^2}$$





Limits at 95% CL on non-uniformities: 1.1% in middle layer, 1.7% in first layer

Conclusions

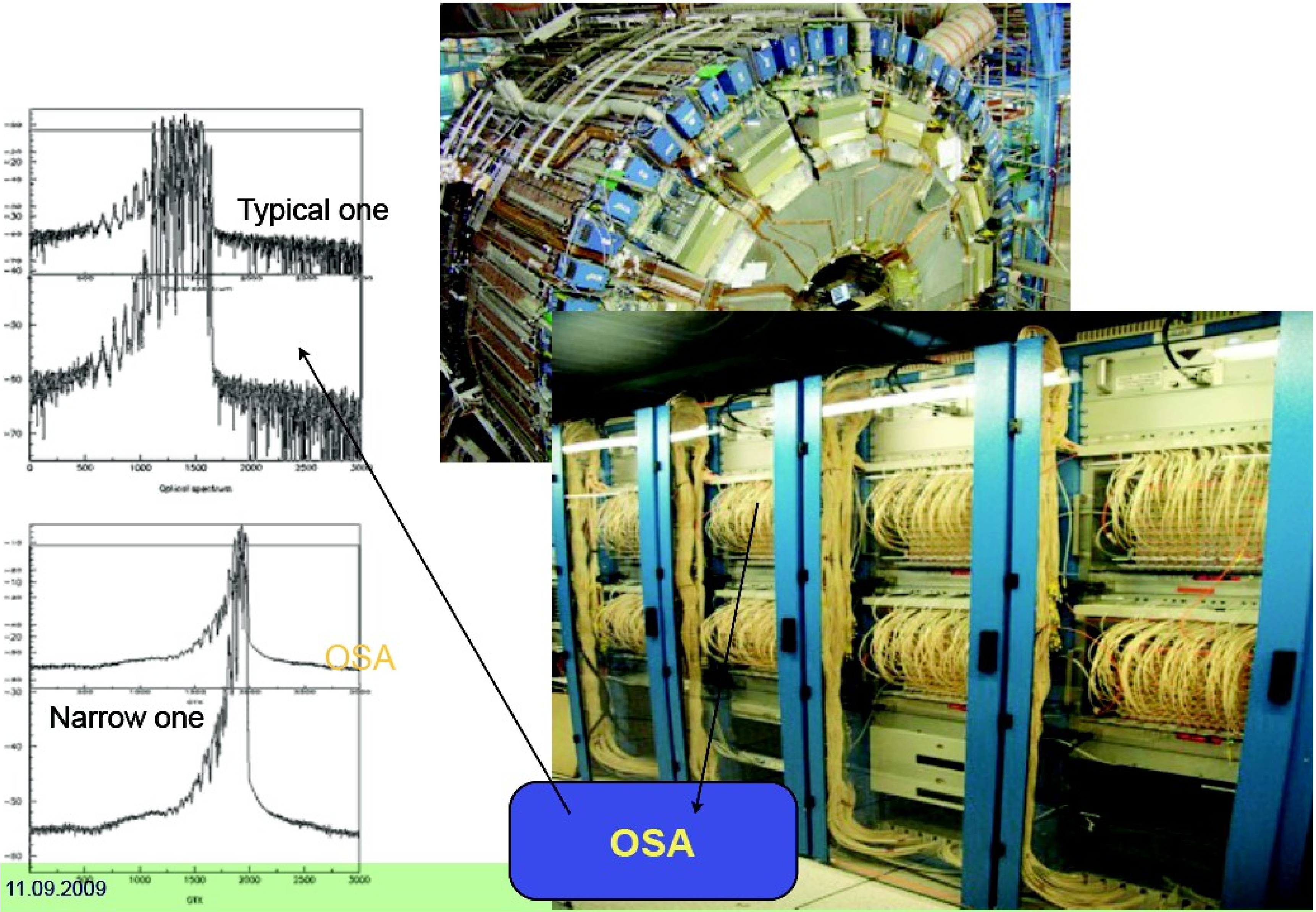
- LAr calorimeter was in very good shape for first collisions:

→ Paolo

Backup

Dying Otx (1/2)

Optical Spectrum: an indicator of End of Life?



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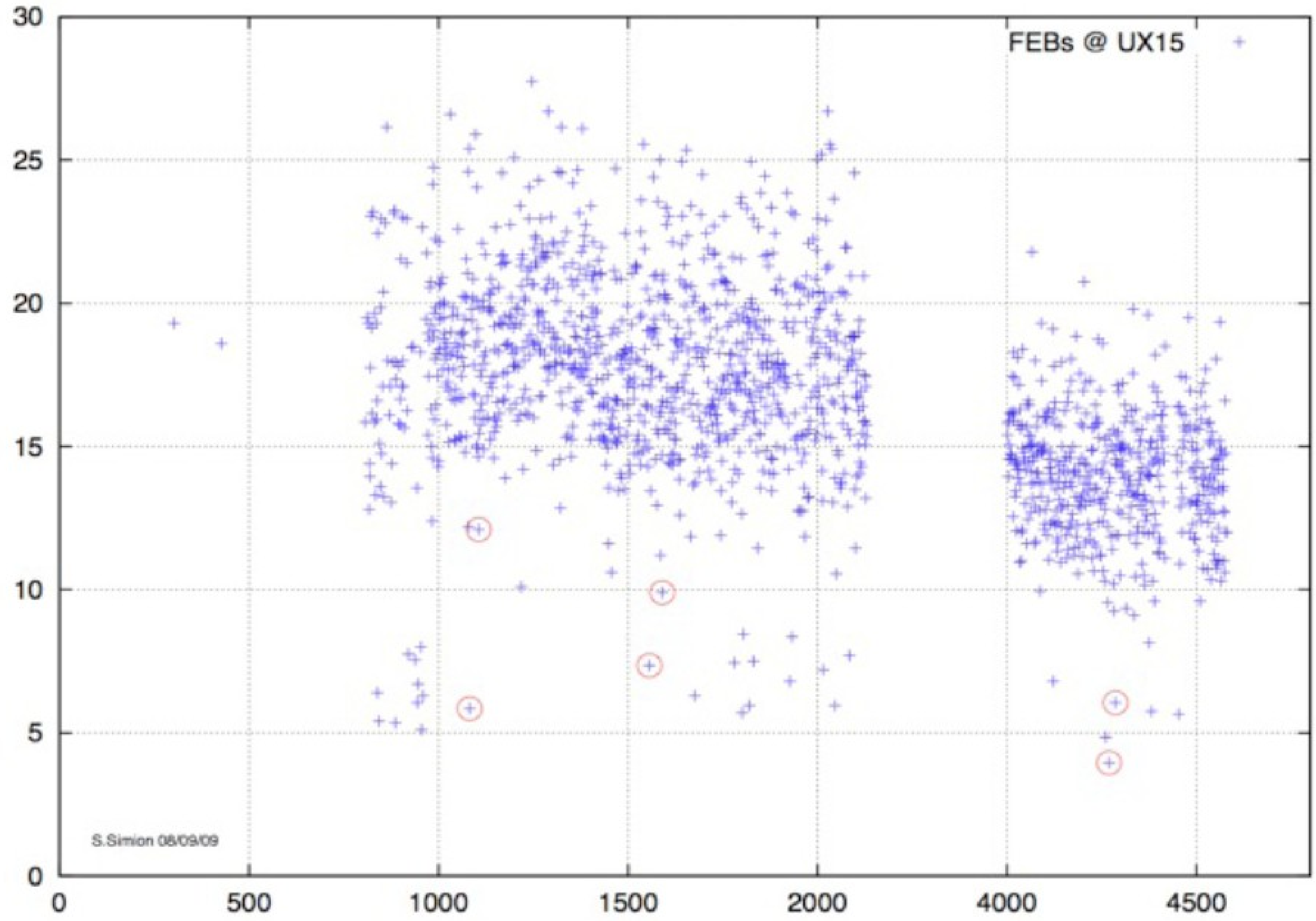
Dying Otx [2/2]

Results: OSwidth vs OTx serial number



The six which died after the measurement was performed

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