For Calor2010 conference @ IHEP - Beijing - China

Commissioning of the ATLAS Tile Hadronic Calorimeter with cosmic muons, single beams and first collisions

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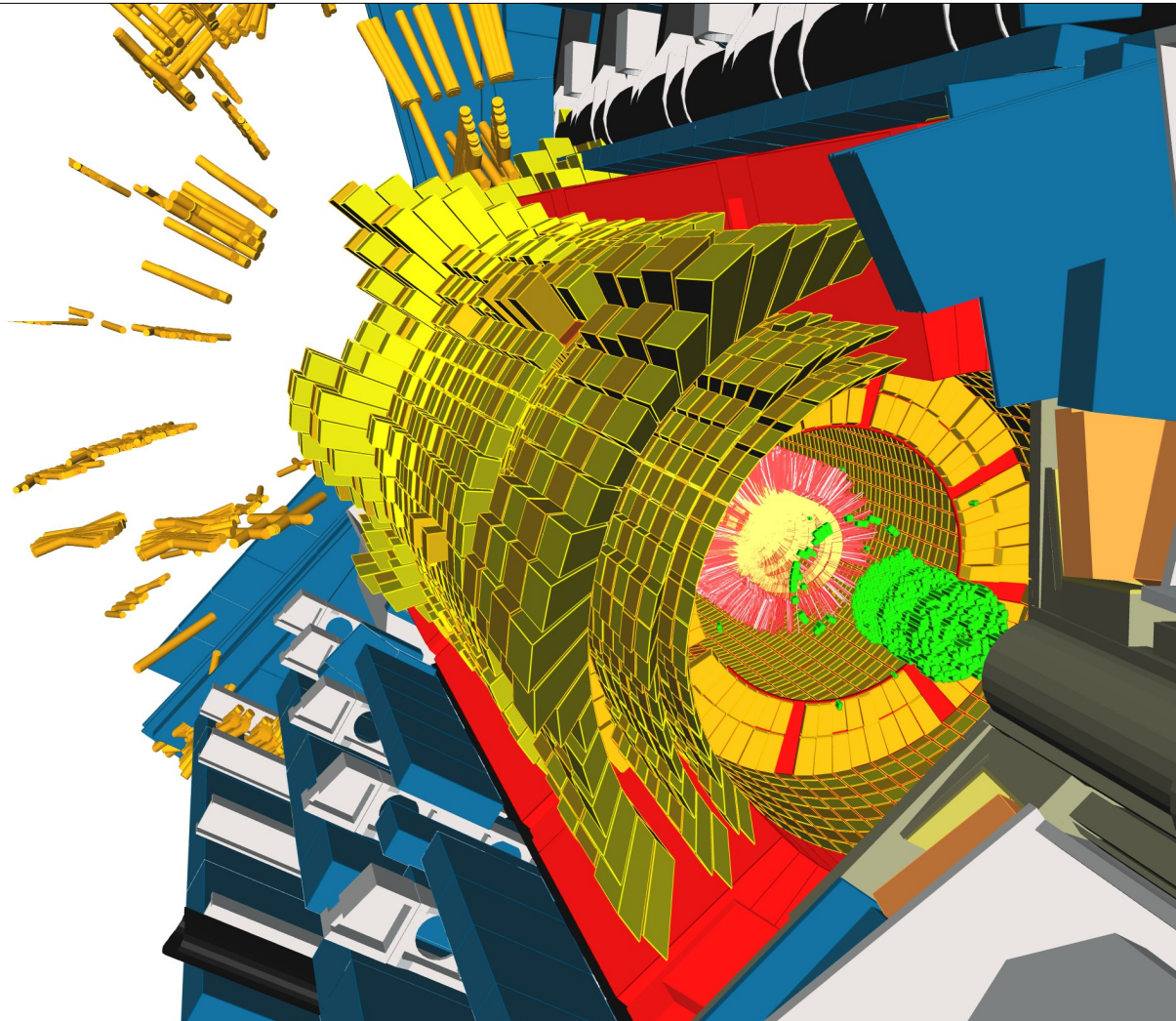


Outline

1) Tile Calorimeter in the ATLAS detector
2) Cosmic muons analysis: EM scale and uniformity
3) Timing calibration with single beam and cosmics
4) Performance with collisions

Other 2 talks on Tile calorimeter:

- M. Simonyan - Hadron response and shower development in the ATLAS calorimeters
- G. Usai - Implementation and performance of the signalreconstruction in the ATLAS Hadronic Tile Calorimeter

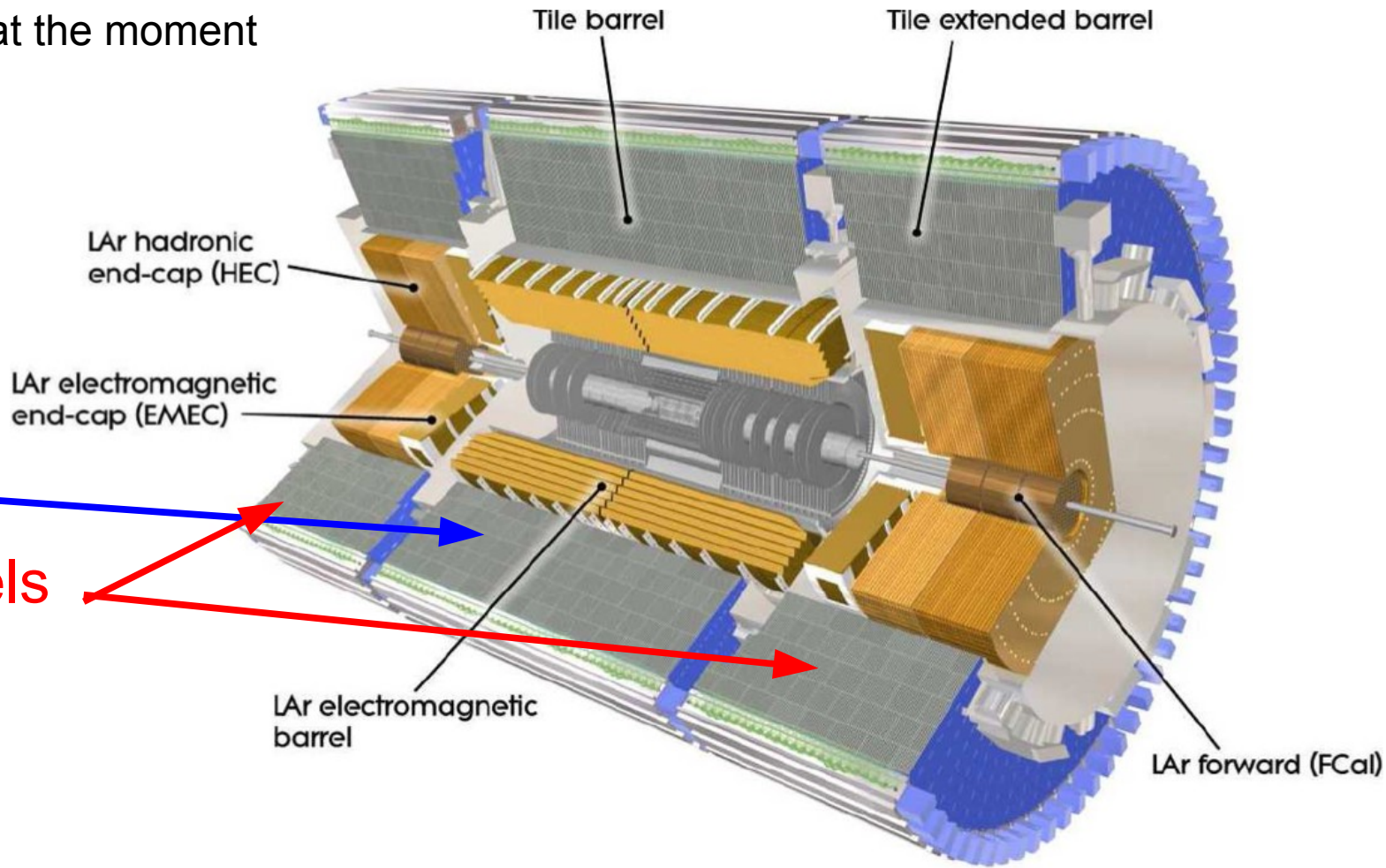
Atlas Tile Hadronic Calorimeter

- Is the central hadronic calorimeter of ATLAS
- Coverage |η|<1.7
- Iron and plastic tile scintillators + WLS fibres + PMTs
- Granularity Δη x ΔΦ = 0.1 x 0.1
- Radial segmentation in 3 layers
- ~10000 channels for ~5000 cells (double readout)
- 97.3% operational at the moment

$$\frac{\sigma}{E} = \frac{(52.9\pm0.9)\%}{\sqrt{E_{beam}}} \oplus (5.7\pm0.2)\%$$

For πs

e/h = 1.3



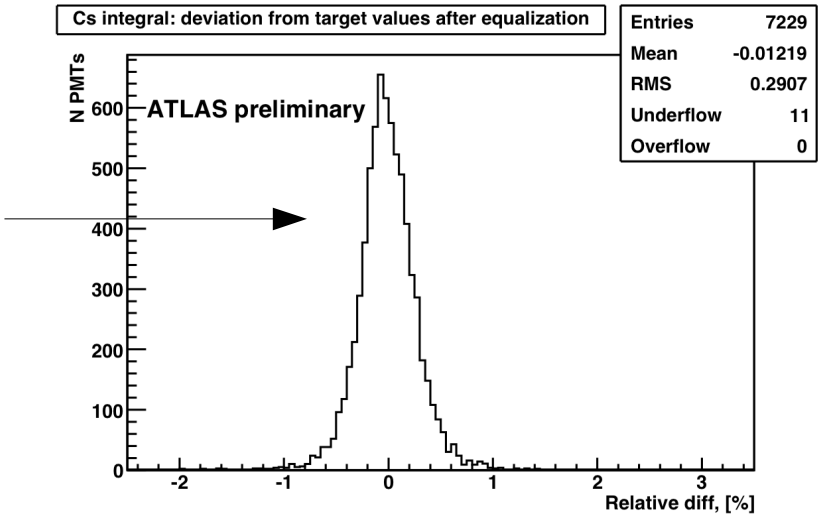
Long Barrel

Extended Barrels

Atlas Tile Hadronic Calorimeter

- EM scale calibration:

➔ Set with a beam of electrons on 11% of the modules and propagated to all the others with the calibration systems.

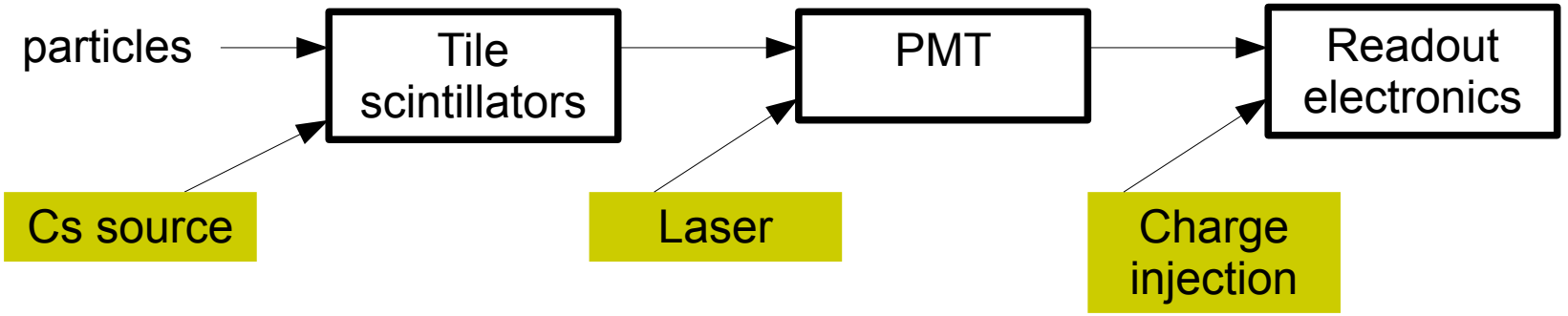


- 3 calibration systems:

➔ ^{137}**Cesium:** allow to equalize cell response (precision 0.3%)

➔ **Laser**: Monitor the PMT gain, and the timing of the channels

➔ **Charge injection**: ADC counts to pC monitoring

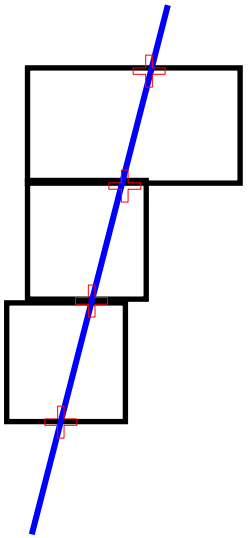


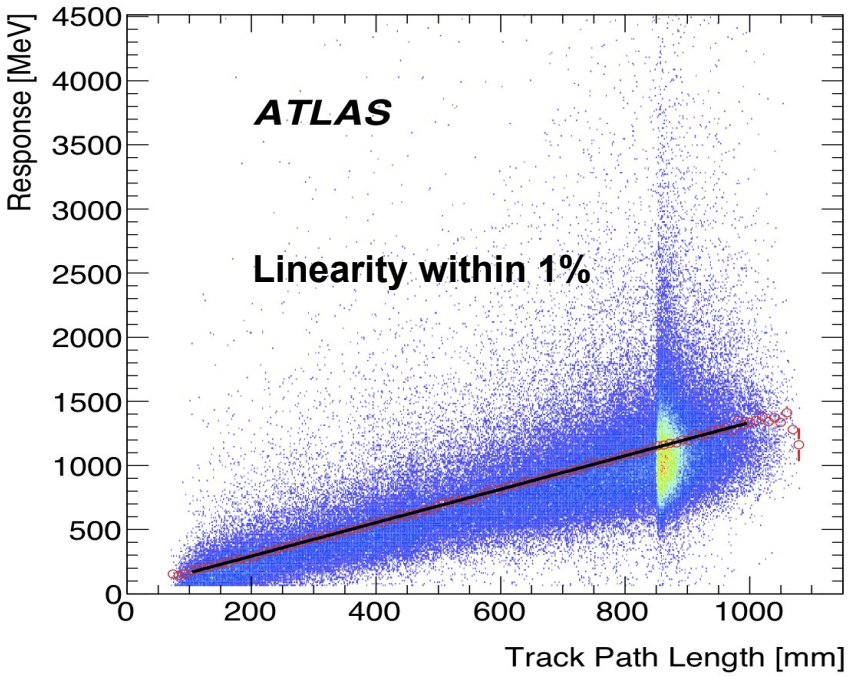
- We used cosmics in the cavern to validate the EM scale set at test beam

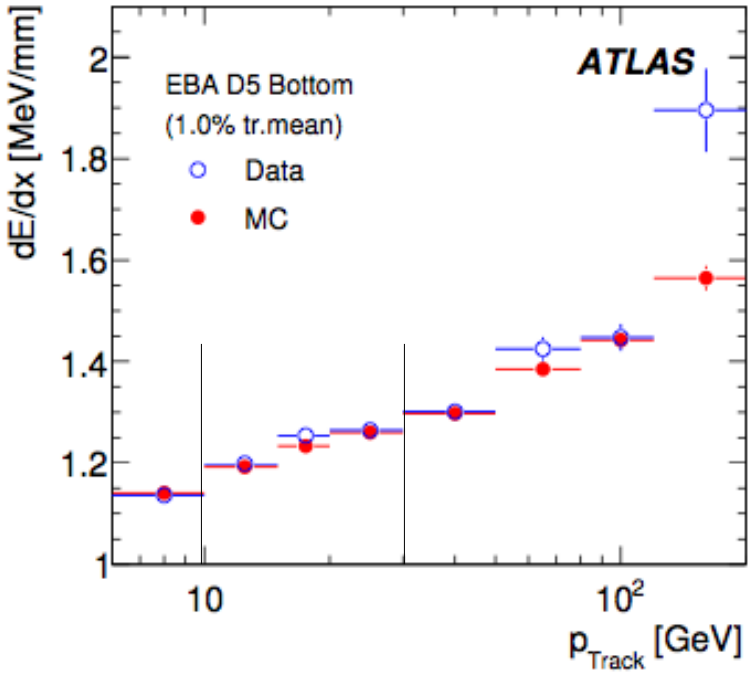
Commissioning with cosmic muons

Cosmic muons analysis

- Muons tracks are reconstructed in the Inner Detector and extrapolated at the calorimeter layers (3 longitudinal layers).
- Selected muons with: 10GeV < p_{muon} < 30GeV
- Muon paths in every crossed cell are computed.
- Study the response of the calorimeter and compare it with MC, using the mean dE/dx without the 1% of the events with the higher values (truncated mean)

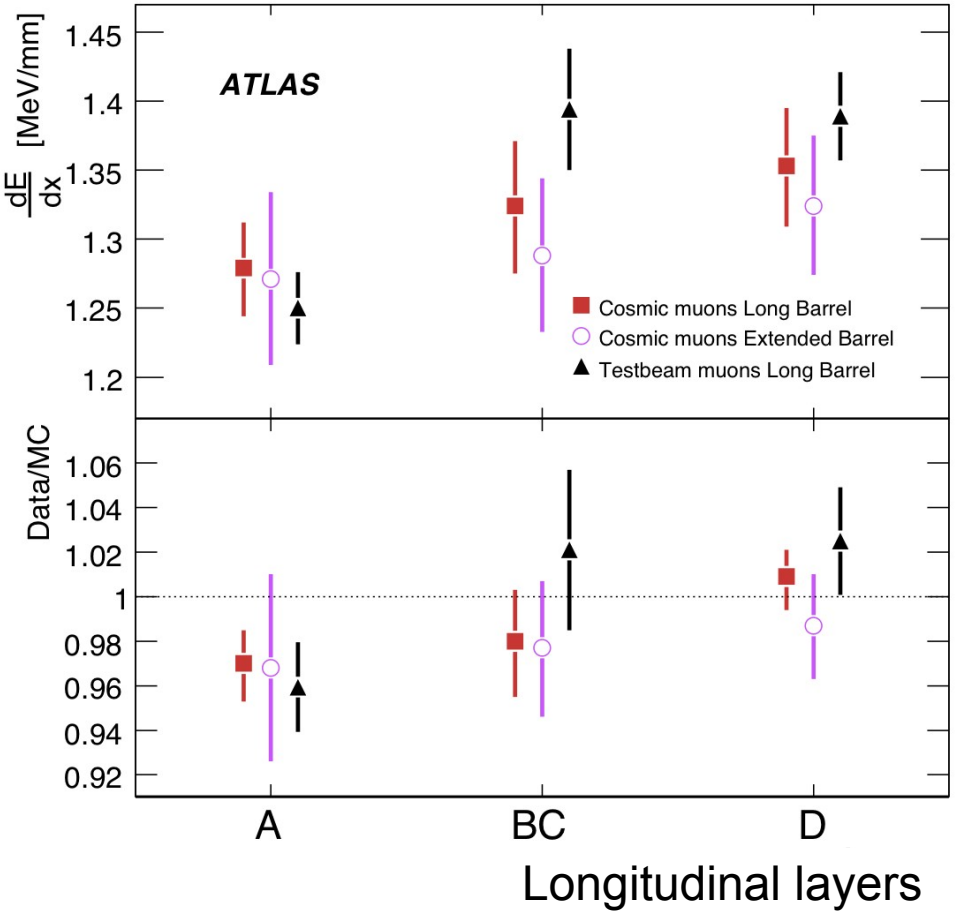






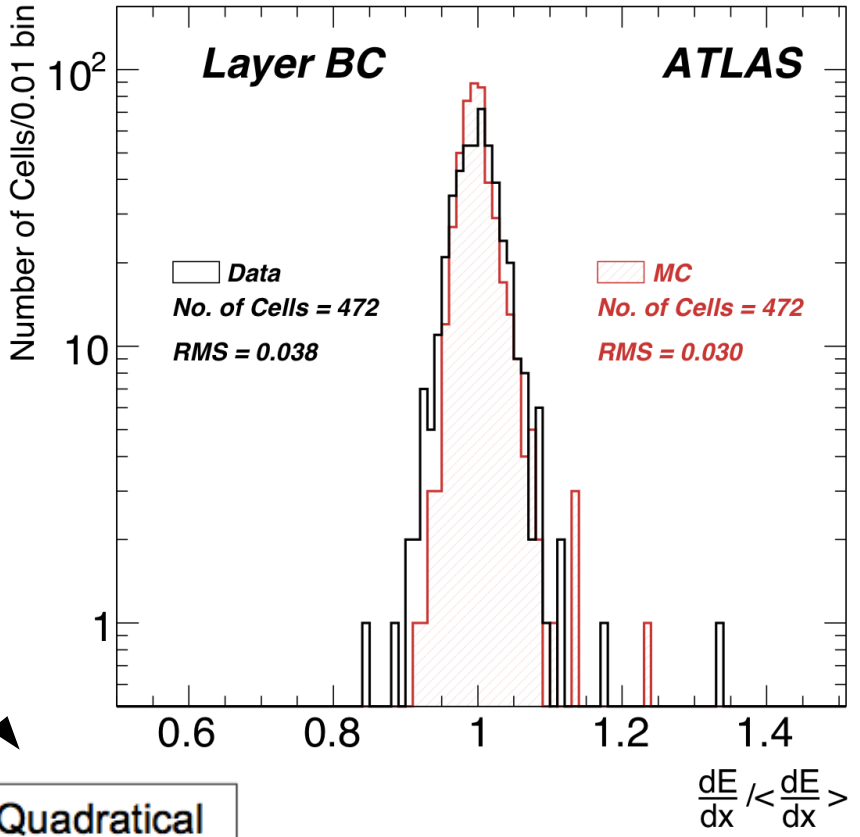
Validation of EM scale with cosmics

- dE/dx in the various longitudinal layers in cavern and test beam is compared with MC
- Systematic uncertainties ~3-6% depending on the layer (more in backup slides).
- Good agreement between data and MC in test beam and cavern.
- EM scale validated with cosmics with the precision of 3%



Response uniformity

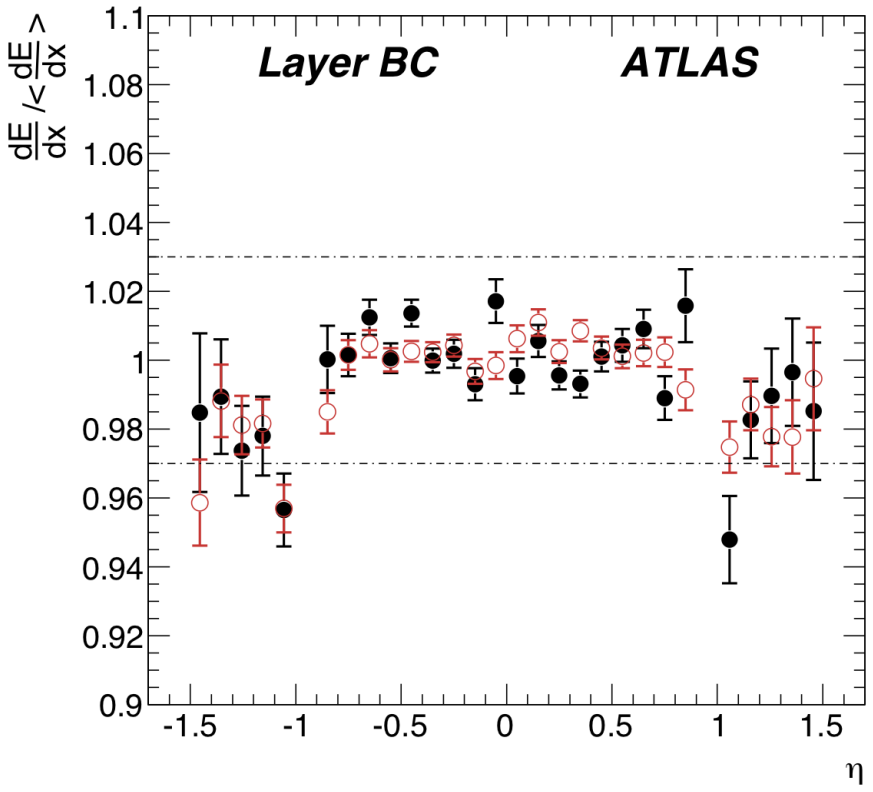
- The spread seen in MC shows the limitation of the method (~ 2-3%).
- With a quadratical subtraction data – MC we get the cells uniformity (~ 2-3%), well below 10% (construction target)

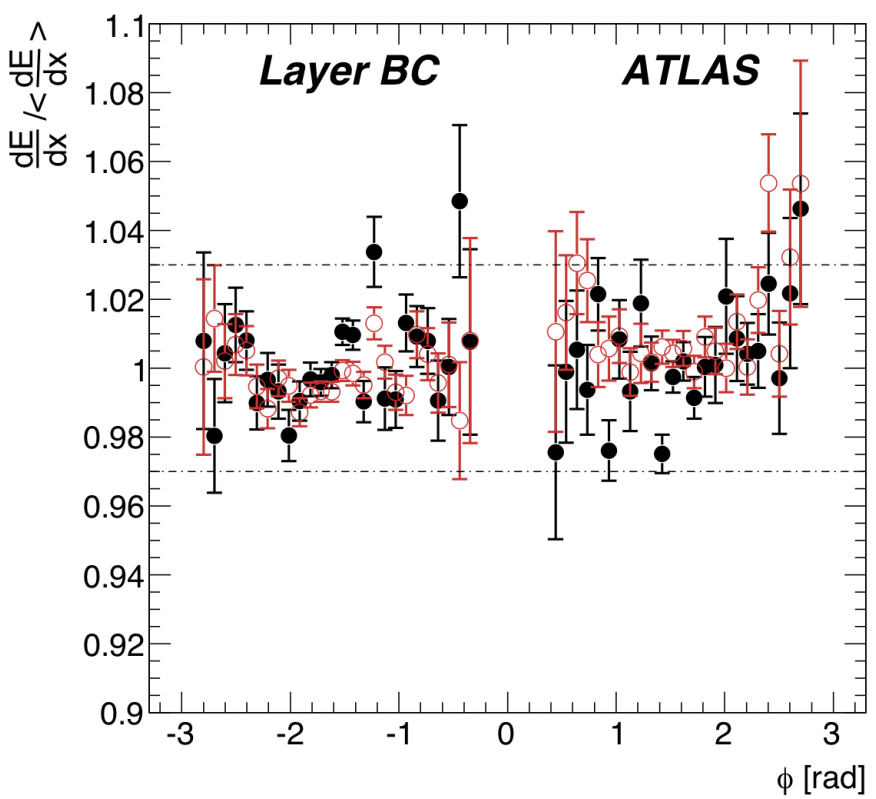


Radial layer	Number of cells	Fraction of cells	RMS data (%)	RMS MC (%)	Quadratical subtraction
A	400	21%	4.6	3.1	3.4
BC	472	25%	3.8	3.0	2.3
D	323	39%	3.9	2.4	3.0

Response uniformity

- Good uniformity in η and Φ (1.5-3%), within the systematic uncertainty of the method (~3-6%).
- The absence of data at Φ ~ 0,±π corresponds to a lack of "horizontal muons".

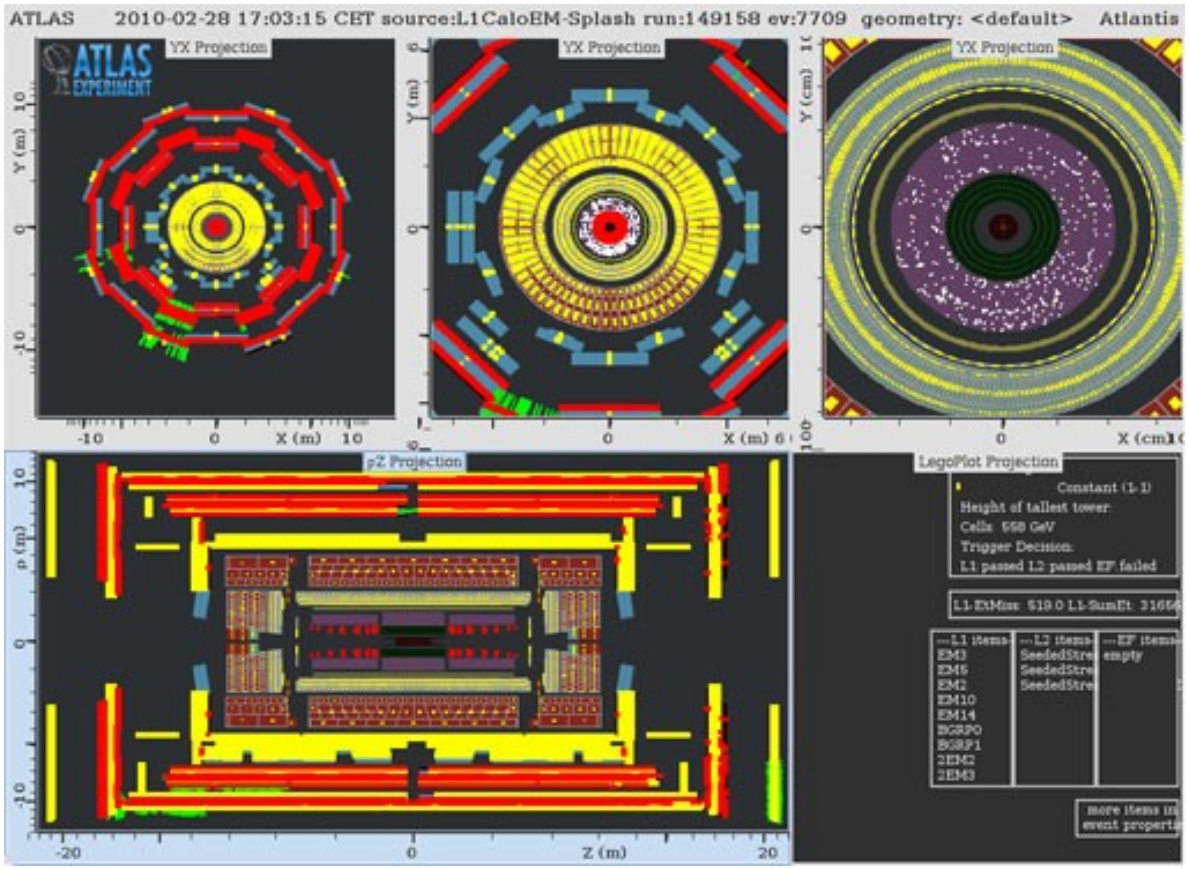


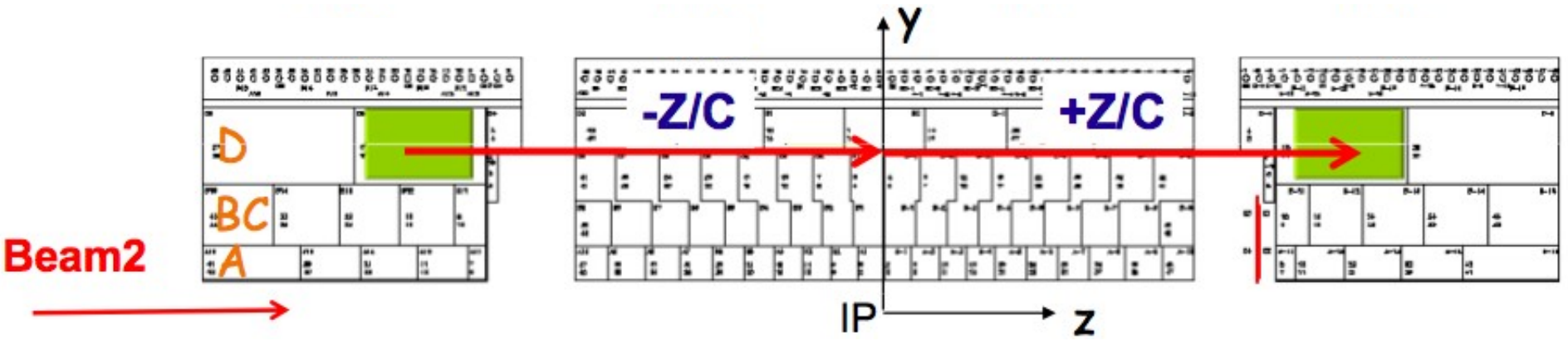


Timing calibration with single beam and cosmics

Splash events

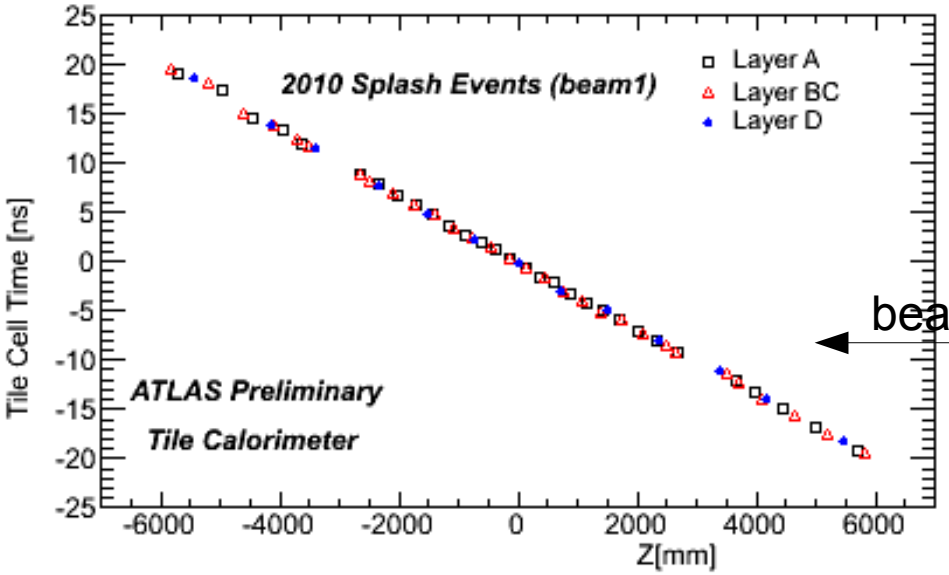
- In a splash event the beam hit a completely closed collimator 140 m far from the center of ATLAS.
- ~10^5 particles (mostly muons) pass through TileCal leaving ~10^3 TeV of energy.





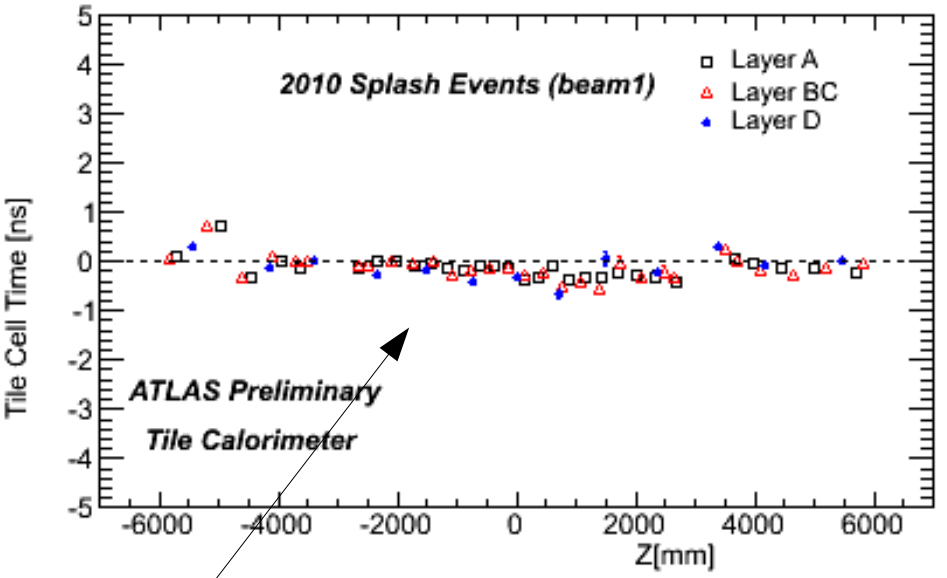
Time calibration with splashes - 2010

Before TOF correction

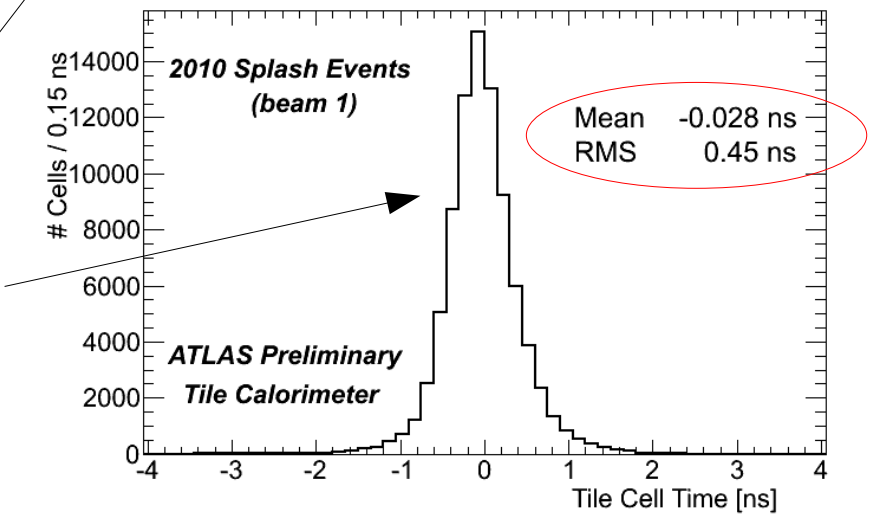


beam

After TOF correction



- Cell times are corrected for the Time Of Flight (TOF) of the particles through the 12 m calorimeter
- Very good intercalibration in all the calorimeter cells.
- Time intercalibration with splash events within 450ps (~3% of the cells removed)



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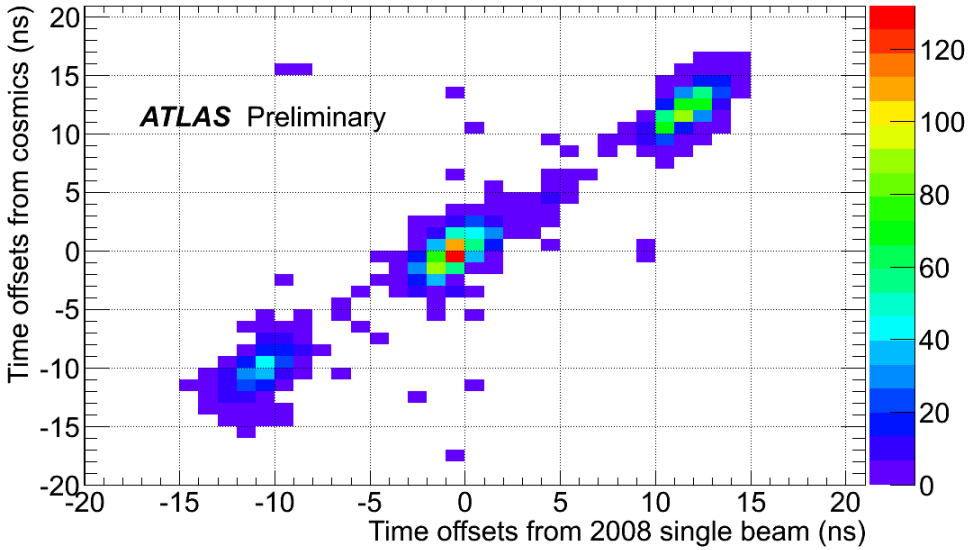
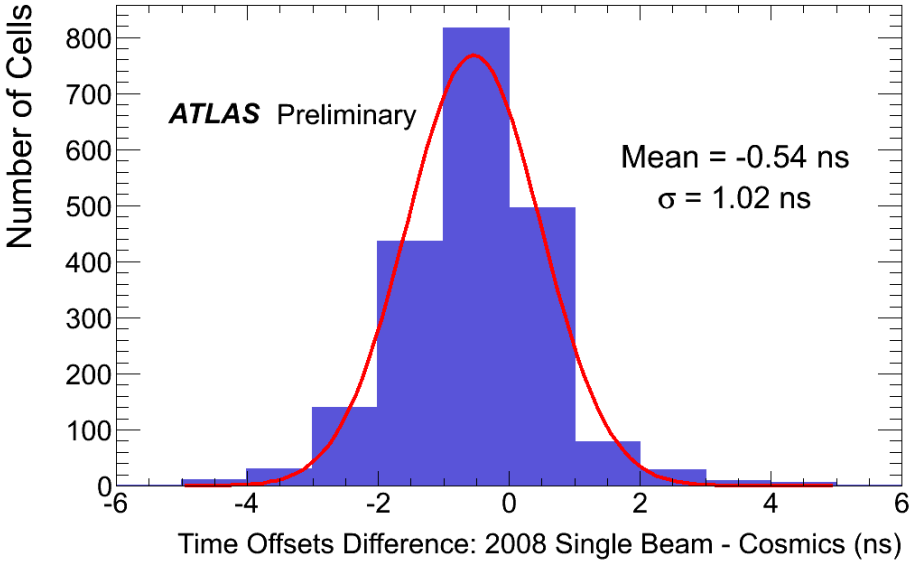
Time validation with cosmics

- Time intercalibration tested with cosmics
- The relative timing between cells was compatible with the one found in 2008 splashes

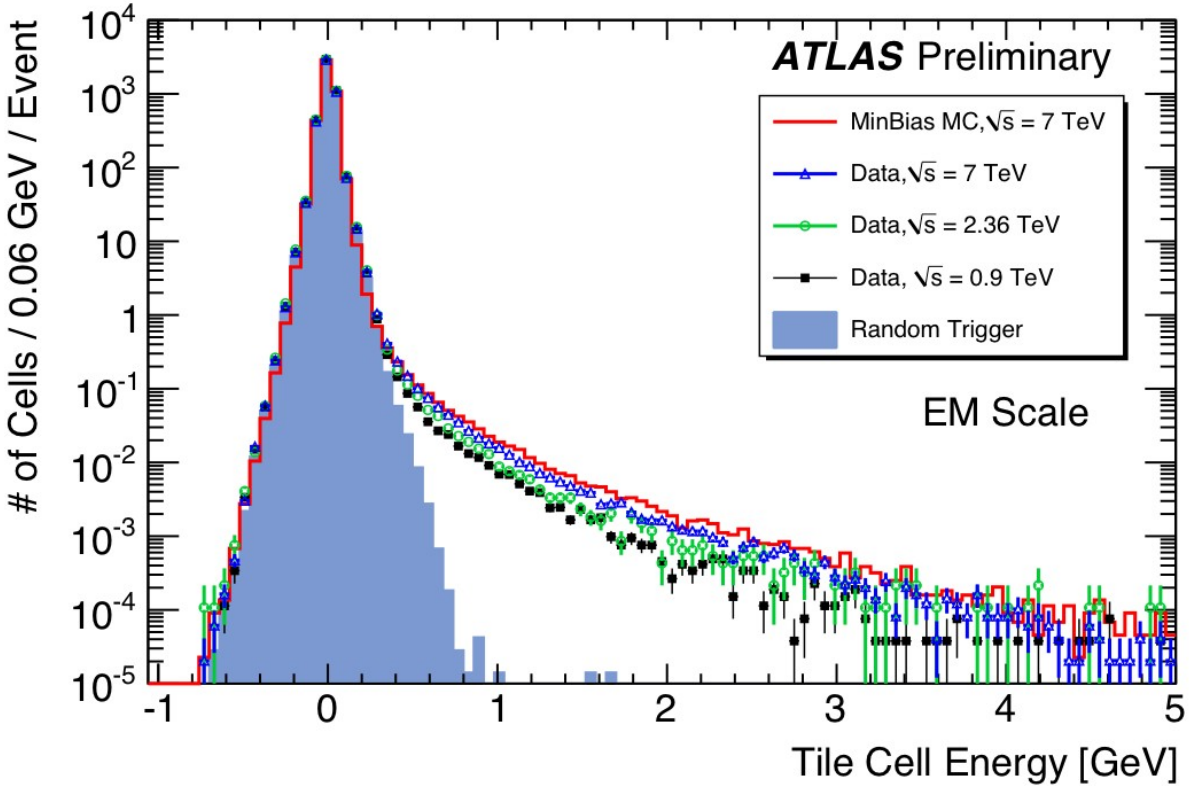




Collision events

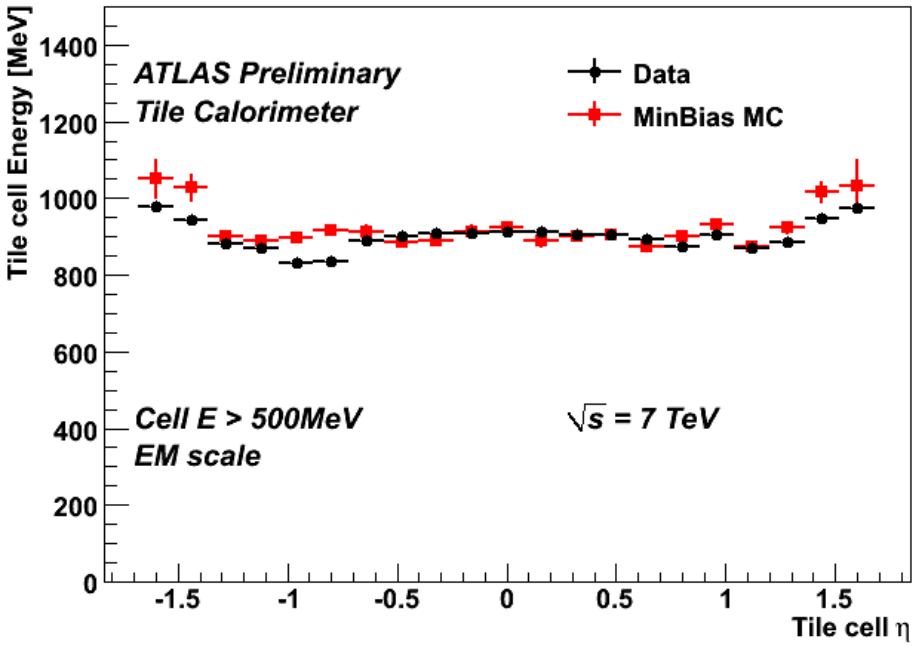
Cell response in collision data

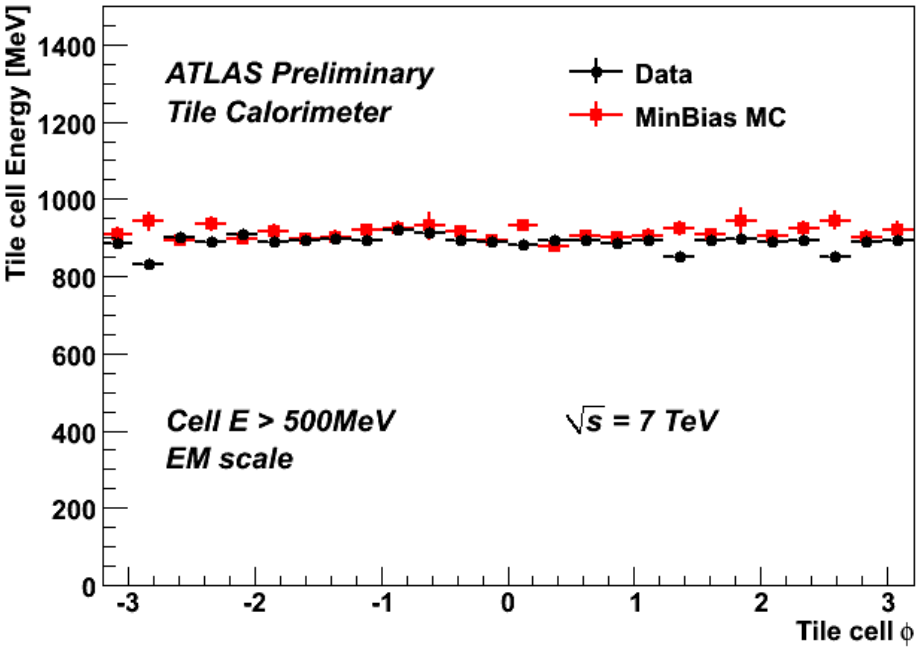
- From November 2009 LHC delivered collisions at √s=0.9 TeV, 2.36 TeV and 7 TeV
- The cell energy spectrum in the 0.9TeV , 2.36TeV and 7TeV collisions, compared with MC and noise (random triggered events).
- Good data/MC description in 9 orders of magnitude for noise and energy deposits



Response vs η and Φ

- Energies are considered at EM scale.
- The energy response is:
  - at the same level of the MC
  - uniform in Φ
  - follows the shape of the MC in η

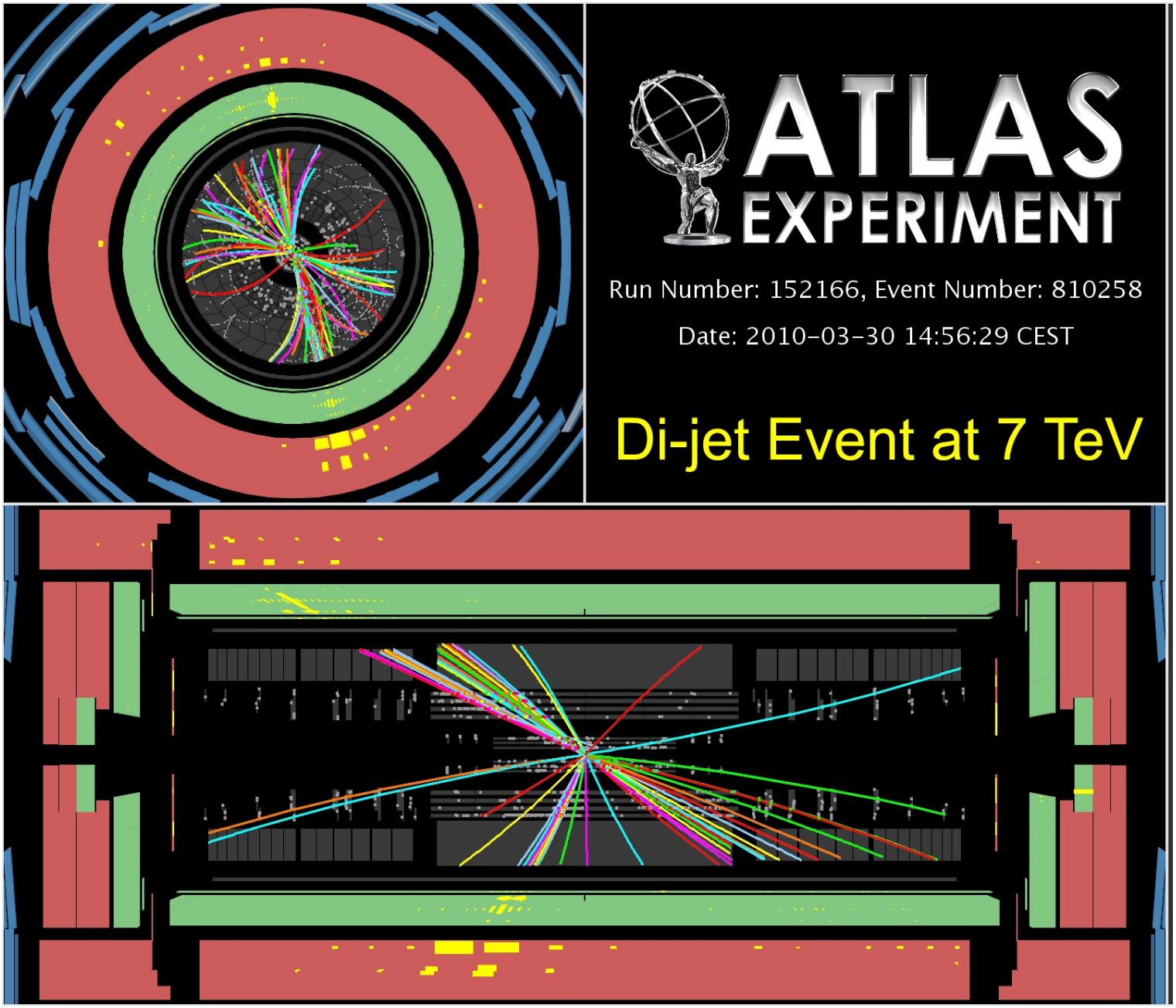




Conclusions

- TileCal participates in 7 TeV collisions with detector 97.3% operational.
- Individual calibration systems (Cs, Laser, Charge Injection) within design requirements, showing stability well below 1%.
- Performance with cosmic muons:
  - Good match of dE/dx between cosmics and testbeam
  - Cells uniformity at 2-3% within each layer
- Single beam allowed to finish the cells synchronization and results show a very good understanding of the detector timing.
- In first collision data we find a good agreement between data and MC and good response uniformity.

- TileCal is in good shape and ready for new more collisions.

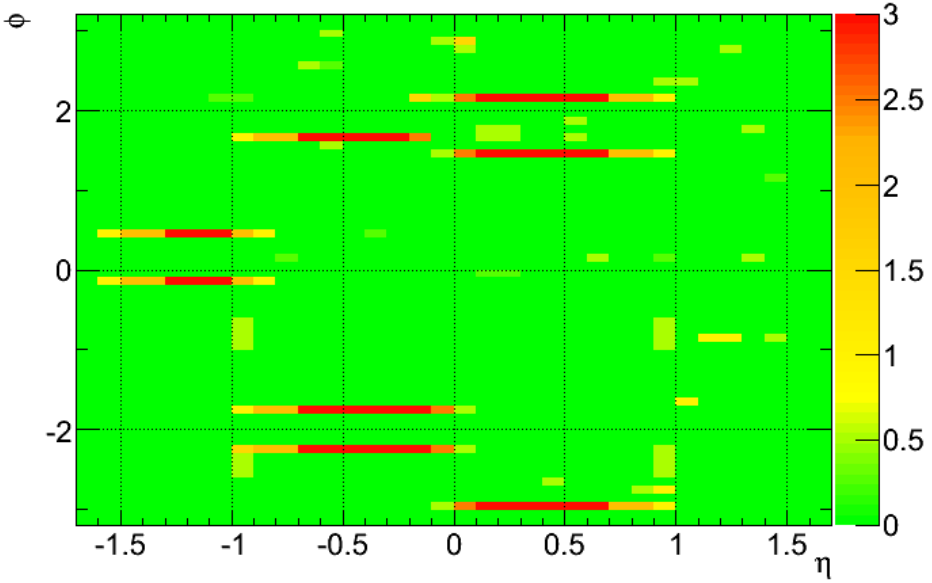

ATLAS
EXPERIMENT
Run Number: 152166, Event Number: 810258
Date: 2010-03-30 14:56:29 CEST
Di-jet Event at 7 TeV

Backup slides

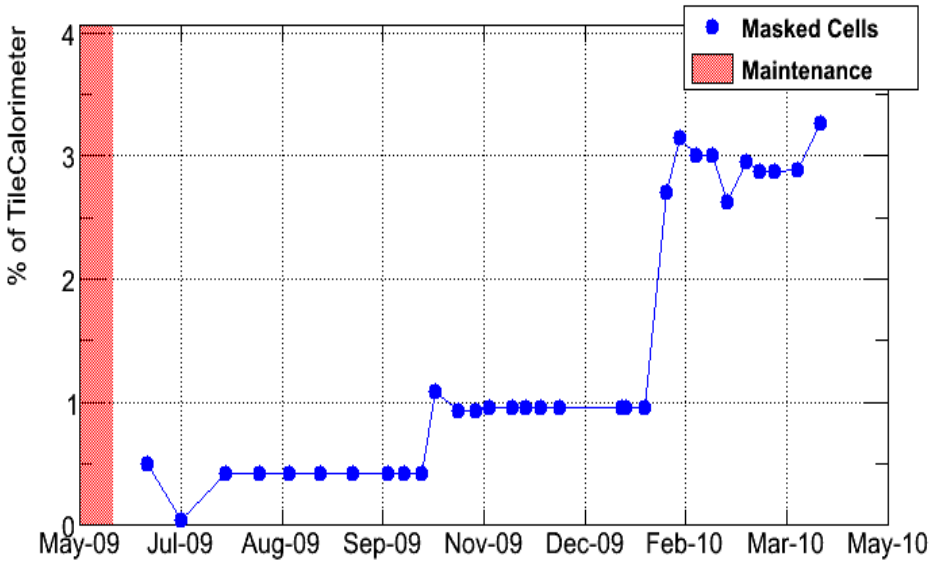
Detector Status (April 2010)

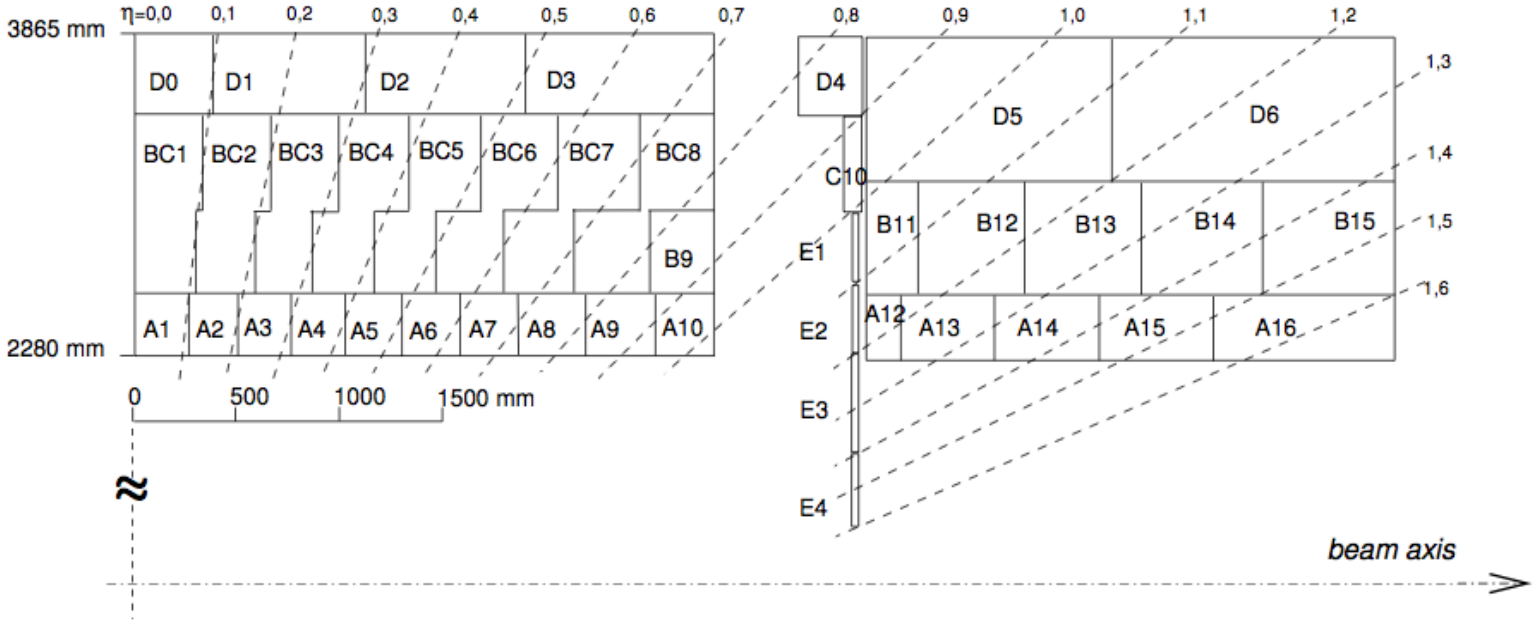
- 7 modules over 264 are off (mostly for LV power supplies problems)
- The effects of up to 9 modules off on jet and MET resolution is negligible (seen with a detailed study)
- During the data taking for 7TeV collisions (started on March the 30th) ~3% of the cells is off or masked.

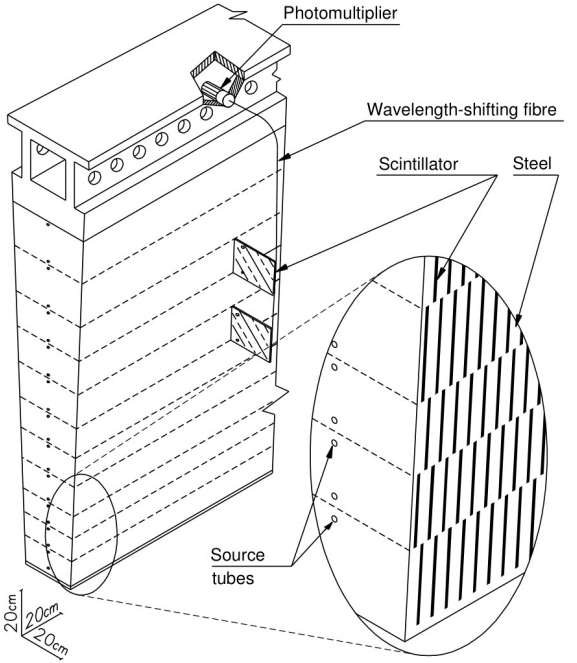
Number of masked cells (in April the 12th)



Percentage of masked cells vs time

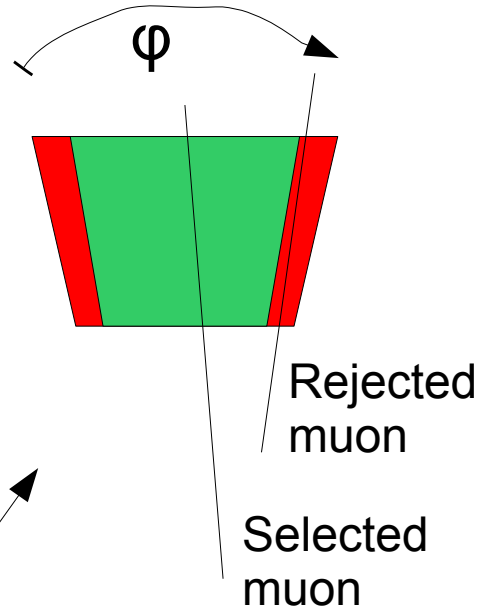


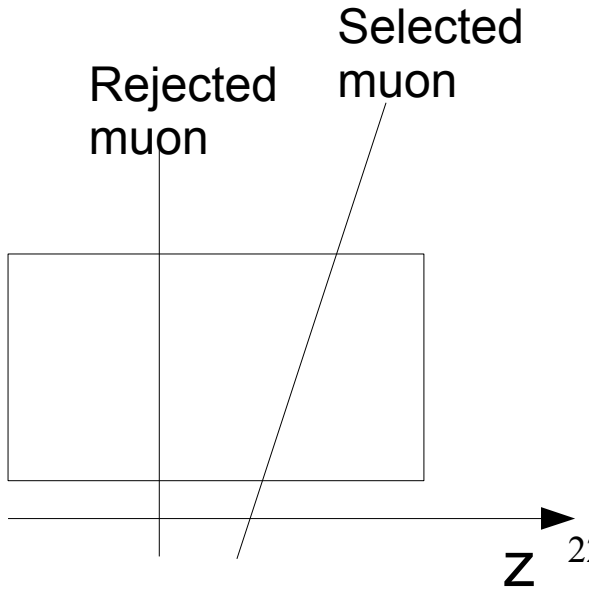

3865 mm
2280 mm
η=0,0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1,0
1,1
1,2
1,3
1,4
1,5
1,6
D0
D1
D2
D3
D4
D5
D6
BC1
BC2
BC3
BC4
BC5
BC6
BC7
BC8
B9
C10
B11
B12
B13
B14
B15
E1
E2
E3
E4
A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A12
A13
A14
A15
A16
0
500
1000
1500 mm
beam axis


Photomultiplier
Wavelength-shifting fibre
Scintillator
Steel
Source
tubes
20cm
20cm
20cm

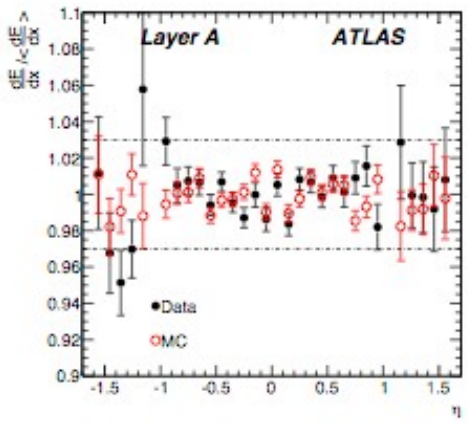
Selection

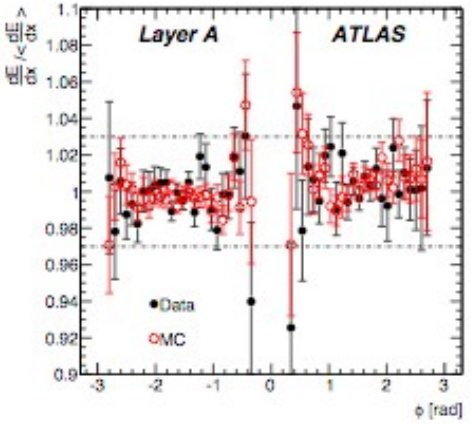
- One track reconstructed in the inner detector
- Tracks with at least 7 hits in SCT and Pixel
- Muon momentum between 10 and 30 GeV (in order to riduce radiative loses and multiple scattering effects)
- The muons passing in the borders in phi of the cells are rejected. We take a fiducial volume in phi of 0.09 (the total phi of a cell is 0.098)
- The Z coordinates of the entrance and exit point of a muon in a cell, must be different of at least 3 cm (@1.5 periods)
- Energy in the cell > 0
- Dead cells and dead modules are removed

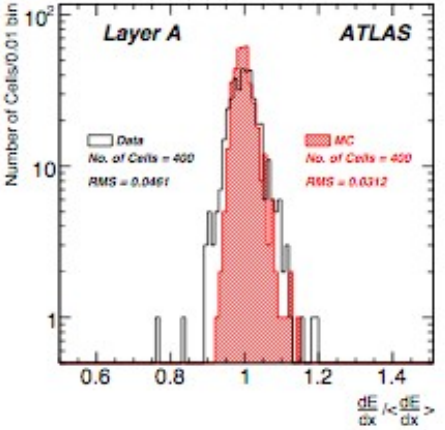


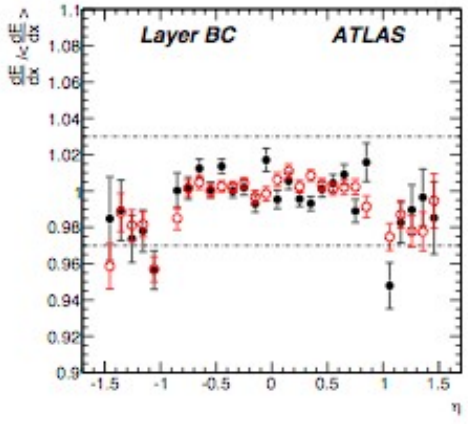


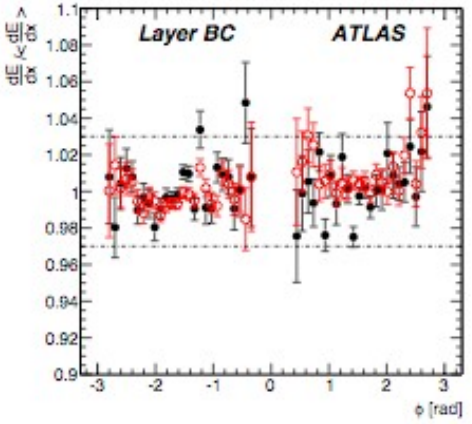
Cosmics analysis: uniformity for all layers

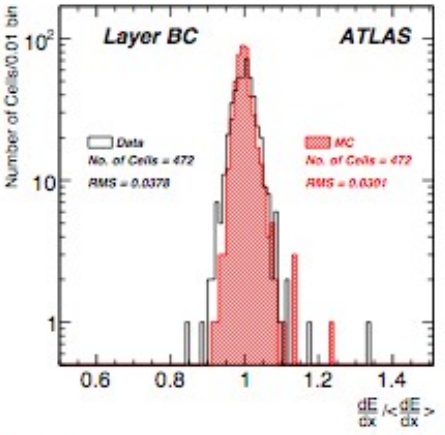


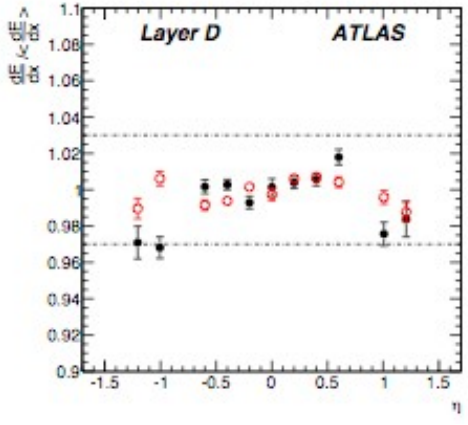


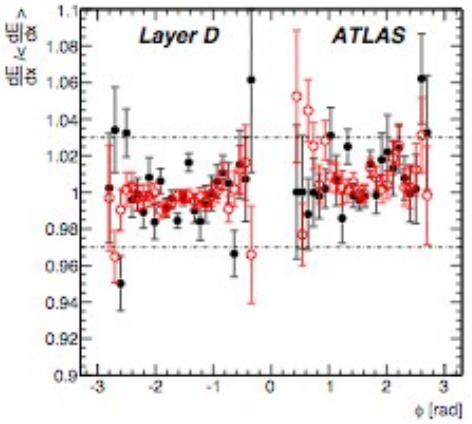


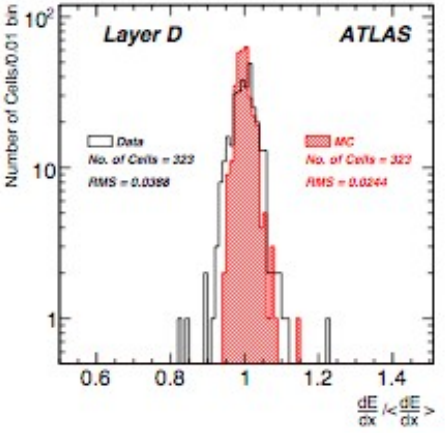












Cosmic Analysis + testbeam results

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

Cosmics analysis: systematic uncertainties

Various sources of systematic uncertainties were studied: truncation, momentum dependence, noise, trigger and event topology...

For every contribution, the associated parameter was varied in the given range and the systematic uncertainty contribution was evaluated as a half of the difference between the maximum and minimum resulting truncated mean

Systematic Uncertainties [MeV/mm] for Data and MC							
Uncertainty source		Long Barrel			Extended Barrel		
		A	BC	D	A	B	D
Path	Data	±0.015	±0.029	±0.019	±0.048	±0.031	±0.016
	MC	±0.006	±0.009	±0.013	±0.014	±0.015	±0.022
	Data/MC ratio	±0.007	±0.016	±0.009	±0.034	±0.022	±0.018
Momentum	Data	±0.023	±0.032	±0.033	±0.035	±0.042	±0.044
	MC	±0.032	±0.042	±0.035	±0.020	±0.042	±0.044
	Data/MC ratio	±0.009	±0.007	±0.004	±0.023	±0.004	±0.010
Noise	Data	±0.007	±0.002	±0.002	±0.009	±0.004	±0.003
	MC	±0.004	±0.002	±0.003	±0.003	±0.002	±0.002
	Data/MC ratio	±0.002	±0.000	±0.001	±0.005	±0.001	±0.000
Truncation	Data	±0.014	±0.014	±0.014	±0.014	±0.014	±0.014
	MC	±0.014	±0.014	±0.014	±0.014	±0.014	±0.014
	Data/MC ratio	±0.004	±0.005	±0.005	±0.003	±0.001	±0.001
Top/Bottom	Data	±0.006	±0.006	±0.011	±0.008	±0.010	±0.008
	MC	±0.015	±0.014	±0.014	±0.016	±0.037	±0.006
	Data/MC ratio	±0.006	±0.014	±0.003	±0.006	±0.019	±0.010
Global EM scale	Data	+0.005 −0.013	+0.005 −0.013	+0.005 −0.014	+0.000 −0.008	+0.000 −0.008	+0.000 −0.008
	MC	–	–	–	–	–	–
	Data/MC ratio	+0.004 −0.010	+0.004 −0.010	+0.004 −0.010	+0.000 −0.006	+0.000 −0.006	+0.000 −0.006
Total	Data	+0.033 −0.035	+0.046 −0.048	+0.042 −0.043	+0.062 −0.063	+0.055 −0.056	+0.050 −0.051
	MC	±0.039	±0.047	±0.042	±0.033	±0.060	±0.052
	Data/MC ratio	+0.014 −0.016	+0.032 −0.034	+0.011 −0.014	+0.042 −0.042	+0.029 −0.030	+0.023 −0.024

Table 5: The individual contributions to the systematic uncertainty of the truncated mean dE/dx in cosmic muon Data and Monte Carlo. Analyses were performed with the ID-track method.

Splash events and time calibration

$$\text{measured } T_{\text{collision}} = T_{\text{trigger}} + \text{TOF-z} + T_{\text{fibers}} + T_{\text{residual}}$$

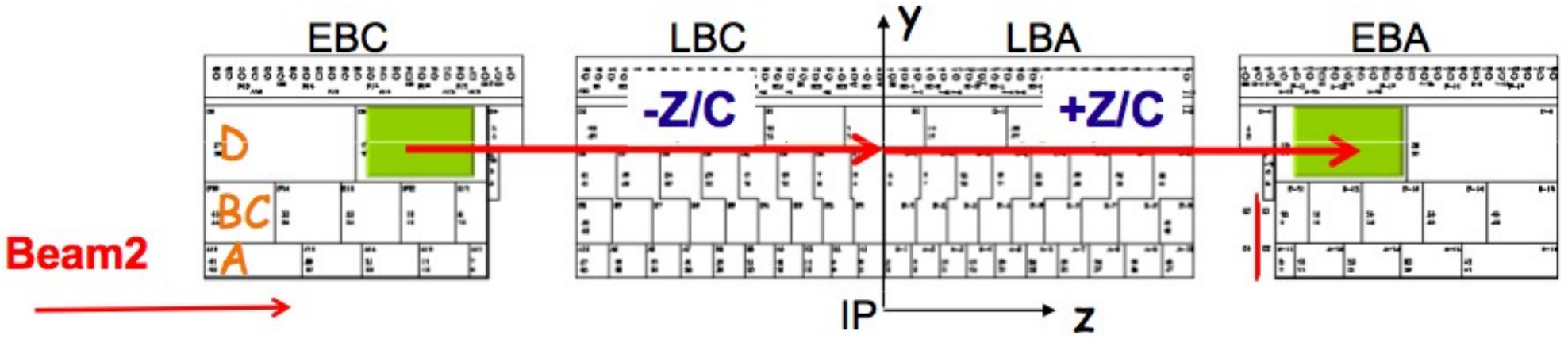
$$\text{measured } T_{\text{splash}} = T_{\text{trigger}} + \text{TOF-IP} + T_{\text{fibers}} + T_{\text{residual}}$$

Difference between trigger and TileCal readouts

TOF from the Interaction point or for the Z displacement

Delay due to the length of the optical fiber between cells and PMTs

Dependent on the channel



Time calibration with splashes - 2008

- Cell times are corrected for the Time Of Flight (TOF) of the particles through the calorimeter
- The results showed a miscalibration of ~10/20 ns between the partitions.
- Corrections were retrieved in order to have the channels intercalibrated.

beam