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Results from ATLAS Calorimeter Combined Test Beam

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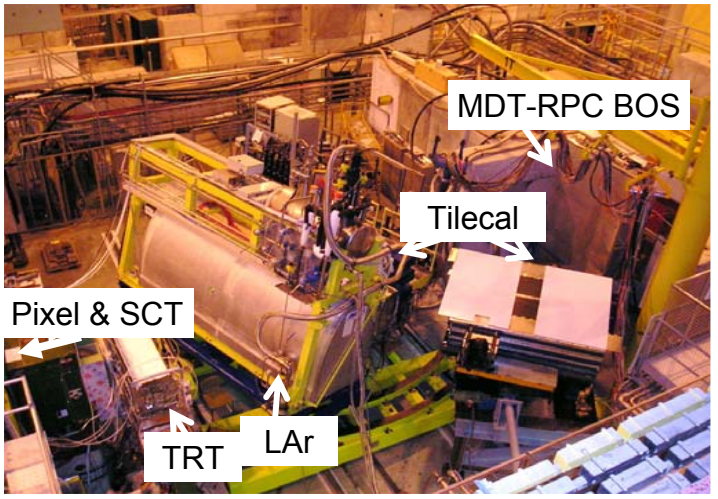
(on behalf of the Calorimeter Combined Test Beam Team)

ATLAS

2004 Combined Test Beam

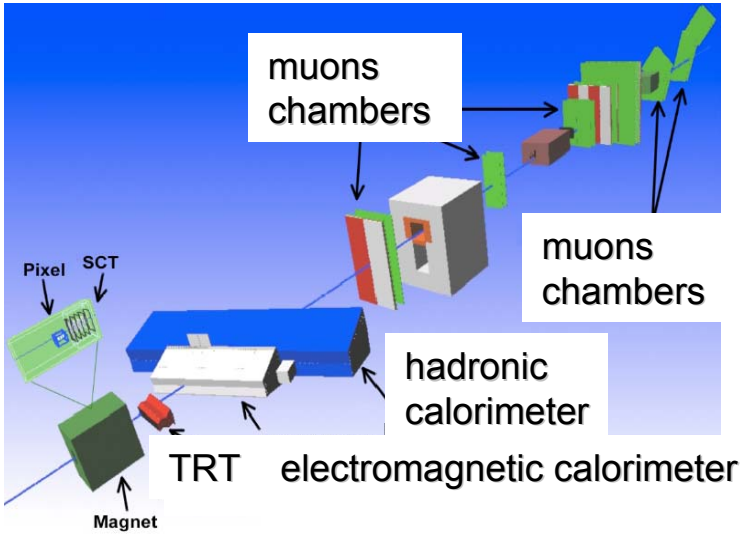
Combined Test Beam :

- Full central **slice** of ATLAS
- Configuration **very close** to ATLAS
- **90 millions** of events : e, π, μ,γ,p
- Energy between **1** and **350 GeV**



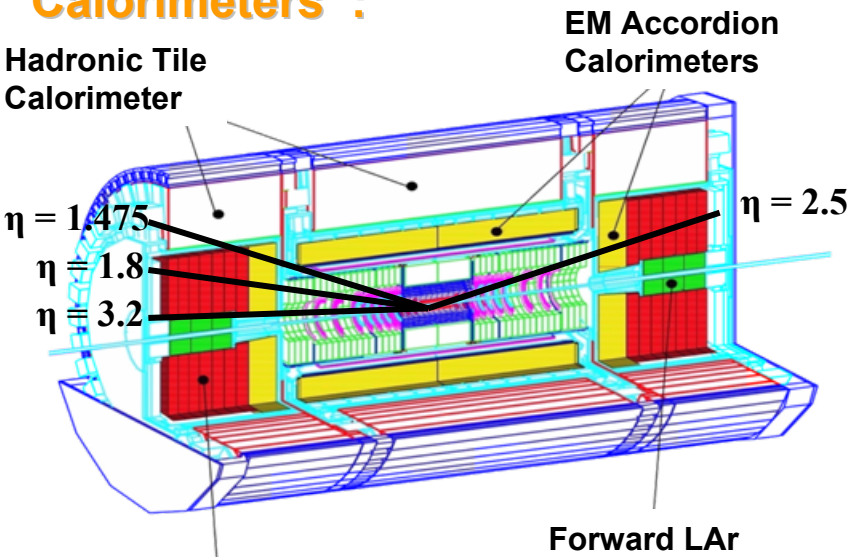
Goals:

- Study of individual **detector performance** (efficiency, resolutions, noise)
- **Combined** performance (material effects, particle ID, photon conversions)
- **Validate** the modelisation of the **Monte Carlo**
- **Common** ATLAS software used to analyze the data



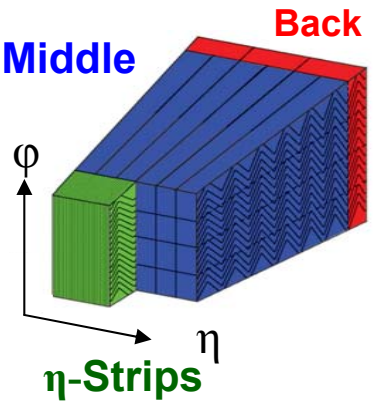
ATLAS Calorimetry

Calorimeters :



- Electromagnetic Barrel : (in $|\eta|<1.475$)
  $\sigma_E/E = 10\%/\sqrt{E(GeV)} \oplus 0.245/E(GeV) \oplus 0.7\%$
  (low luminosity)

Layer	Granularity ($\Delta\eta x \Delta\varphi$)
Presampler	0.025 x 0.1
Strips	0.003 x 0.1
Middle	0.025 x 0.025
Back	0.05 x 0.025



- Hadronic Barrel : (in $|\eta|<1.7$)
  $\sigma_E/E = 50\%/\sqrt{E(GeV)} \oplus 3.0\ \%$

Layer	Granularity ($\Delta\eta x \Delta\varphi$)
Tile0	0.1 x 0.1
Tile1	0.1 x 0.1
Tile2	0.2 x 0.1

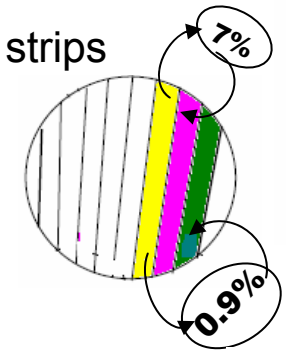
LAr Energy Reconstruction

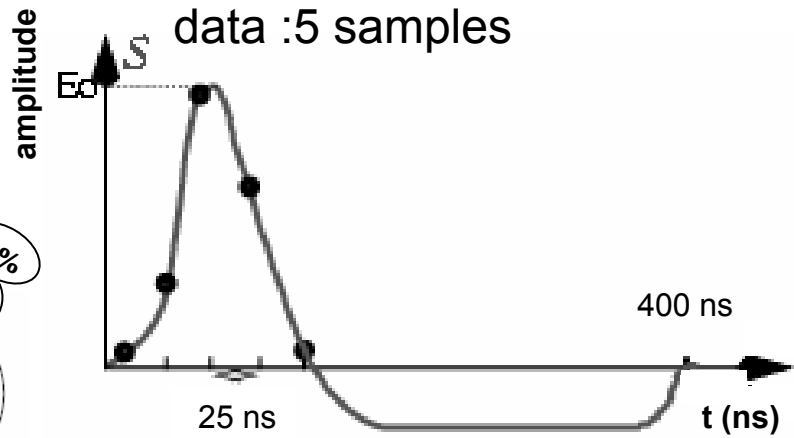
LAr Energy reconstruction :

- **Energy** : $E = F\sum_{i=1}^{5} a_i(ADC_i - P)$
- **Electronic** calibration :
  a = **Optimal Filtering Coefficients**
  F = **ADC→MeV**
  P = **pedestal**

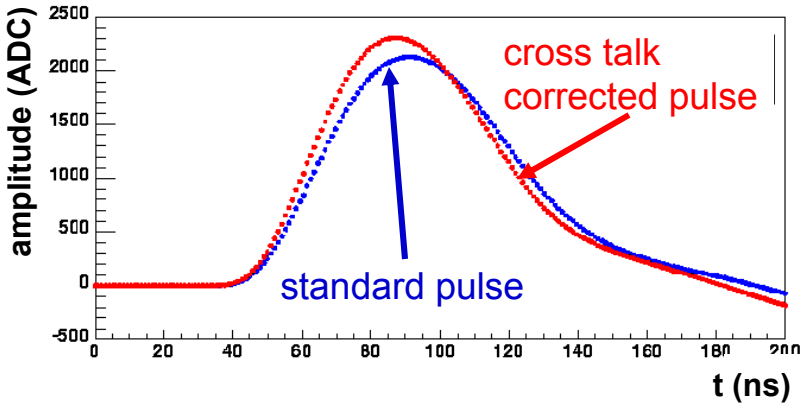
Strips cross talk corrections :

- Signal in **one strip** gets distributed into **neighboring strips** due to **cross talk**
- During **calibration runs** the signal of the neighboring cells **needs to be added** to the pulsed cell
- Electronic calibration constant **corrected** for the cross-talk





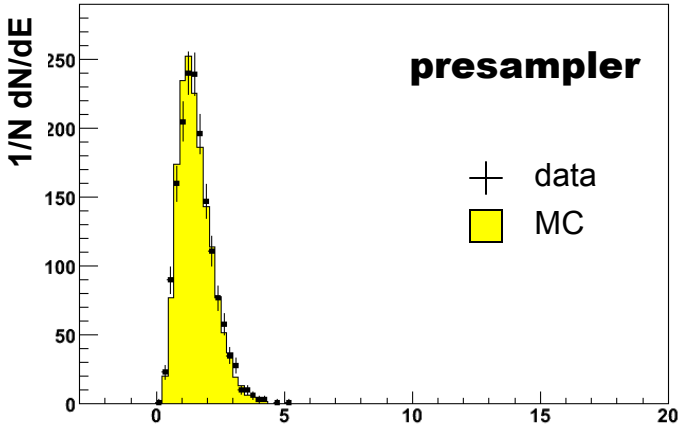
electronic calibration pulse

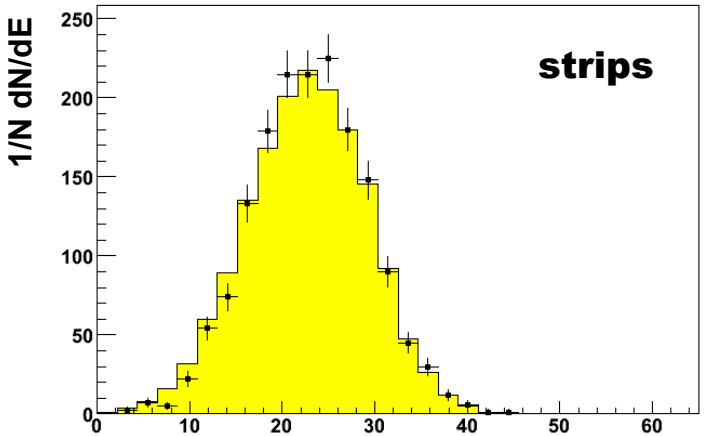


These corrections have been developed for the test beam, implemented into our common software and will be used in ATLAS

Monte Carlo/Data (High Energies)

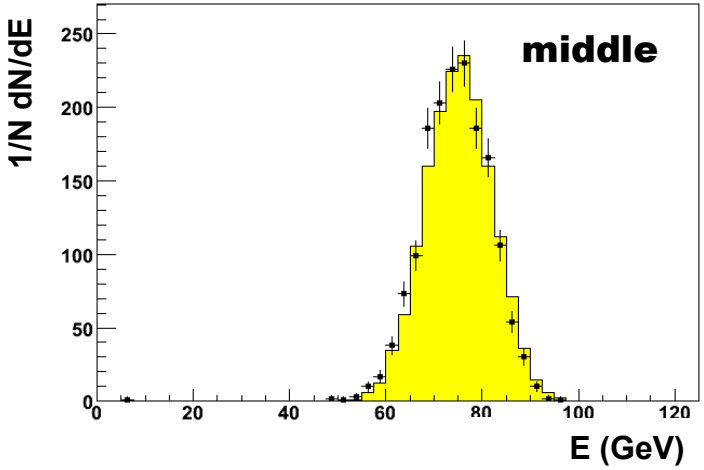
Electrons at 100 GeV, good agreement for all energies :

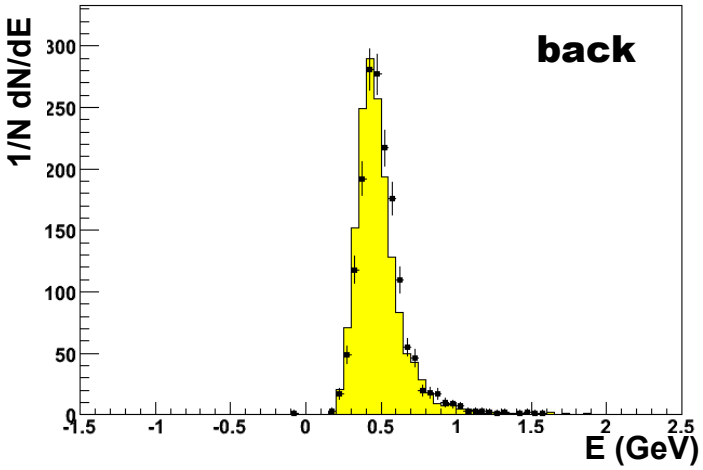




100 GeV

$\Delta\eta \times \Delta\varphi$=3x3 **fixed window** cluster



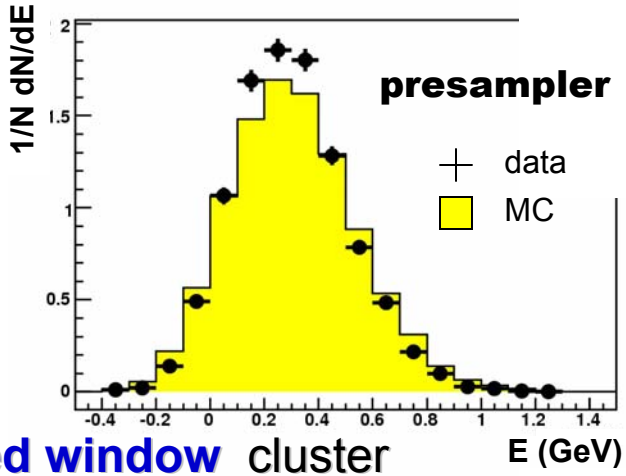


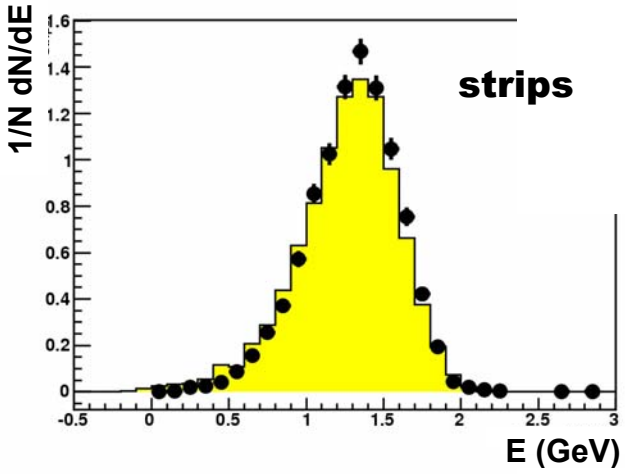
Monte Carlo/Data (Low Energies)

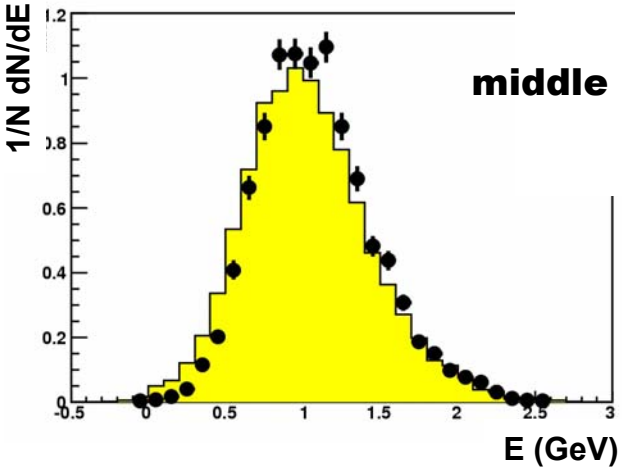
Electrons at 3 GeV, similar good agreement for other very low energies :

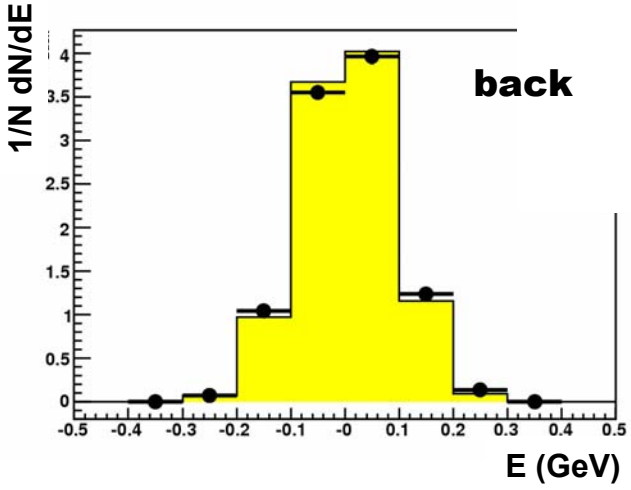
3 GeV

$\Delta\eta \times \Delta\varphi = 5 \times 5$ **fixed window** cluster







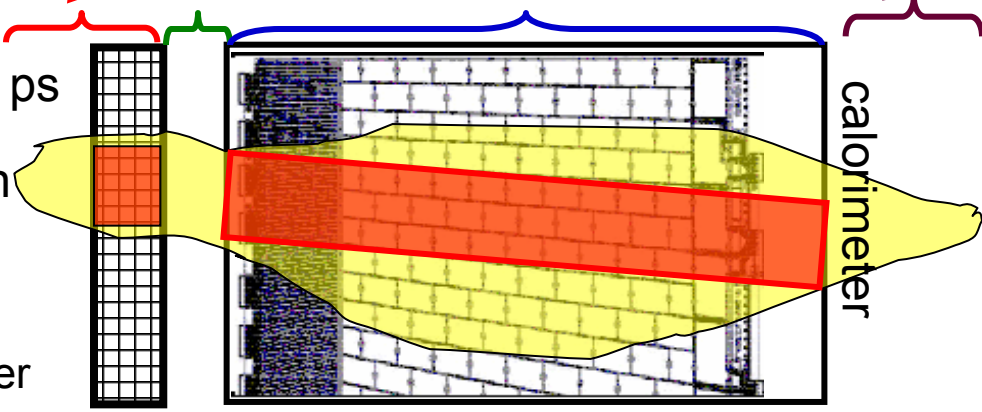


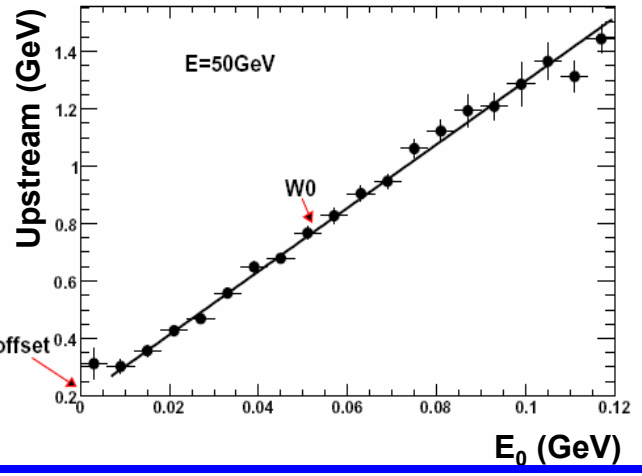
Calibration

Based on calibration hits (simulation) :

$$E_{\text{particle}} = \text{offset} + W_0 E_0 + W_{01}\sqrt{E_0 E_1} + \lambda E_{acc} + W_3 E_3$$

- **Offset**: electrons (not reaching the calorimeter) energy lost by ionization
- **W_0** : an equivalent sampling fraction factor for the presampler
- **W_{01}** : "sqrt term" factor to correct for the energy lost between ps-calorimeter
- λ : accordion factor = out of cluster and sampling fraction correction
- **W_3**: back weight





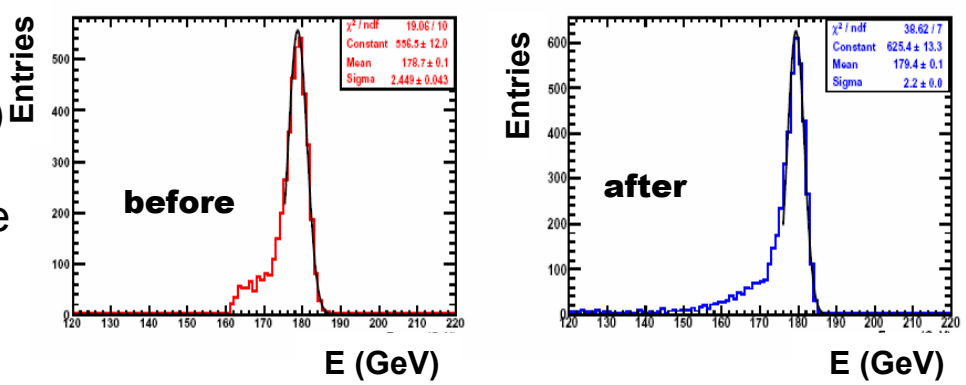
Weights depend on η and **energy**

Corrections

Cell level :

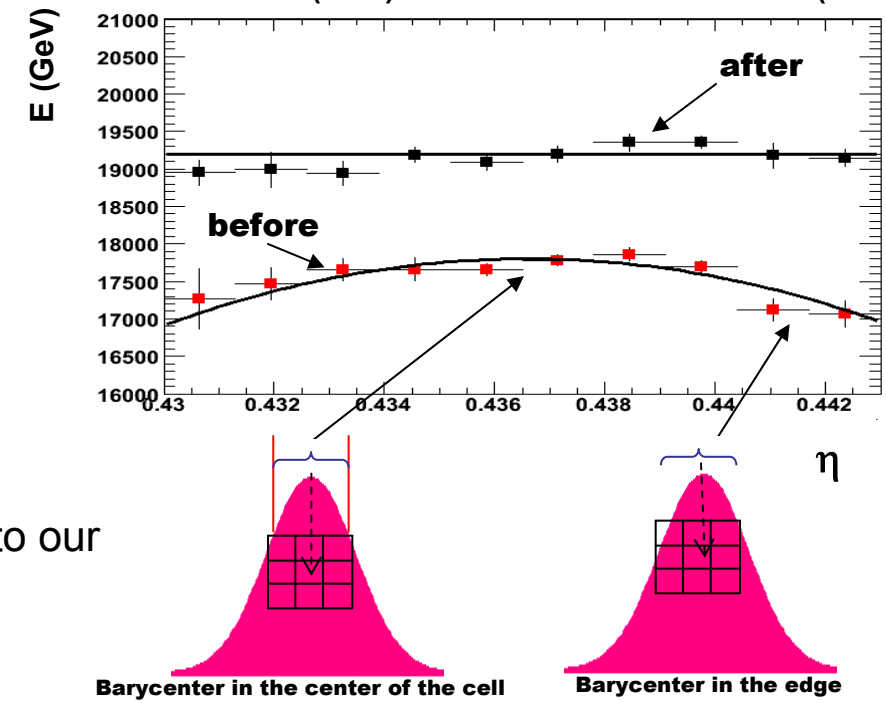
- **HV** corrections (lower HV, dead HV sectors)
- Correction applied **event by event** using the shower shape

With High Voltage correction



Cluster level :

- **S-shape** in the middle layer (η)
- **S-shape** in the strips (η)
- **Out of cone** (including sampling fraction)
- **Energy** modulation along : η, φ



All these **corrections** have been implemented into our **common software** and have been **tested** with **combined test beam data**

LAr Standalone High Energy Results

Energy resolution :

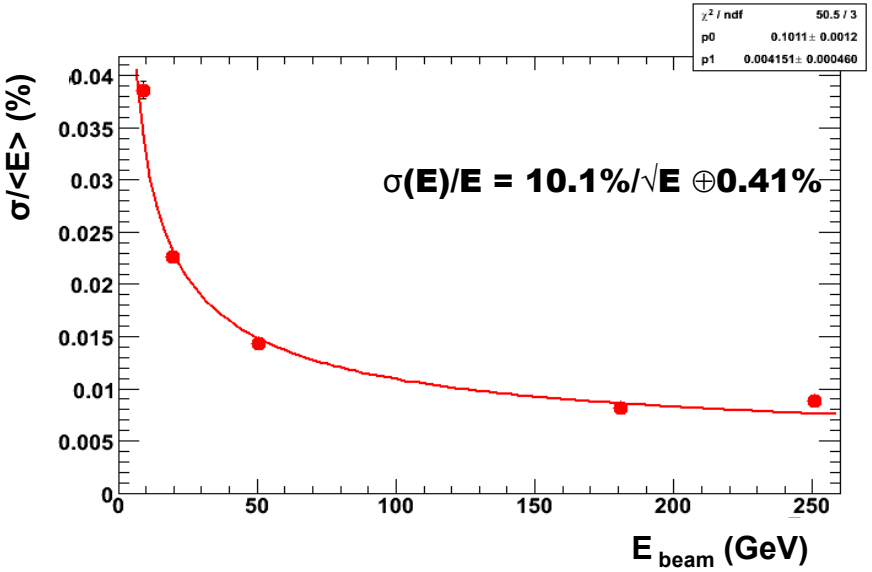
- Substracted **electronics noise** (~200 MeV)
- Local constant term : **0.41 %**
- Sampling term : **10.1 %**

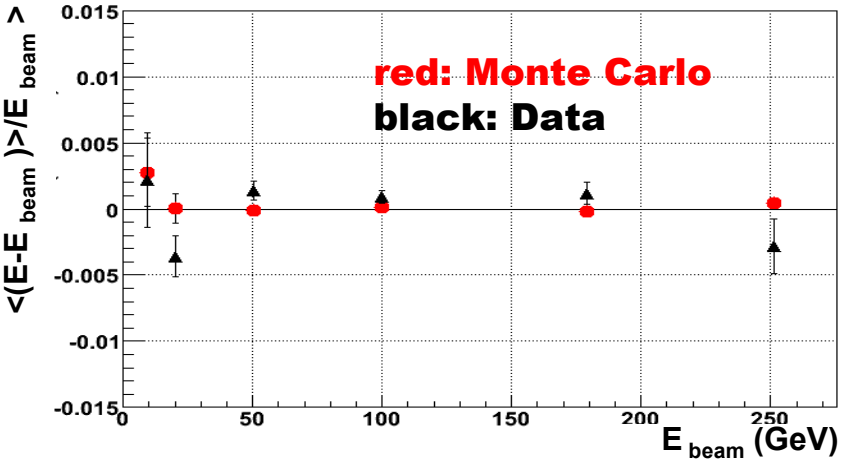
Uniformity response :

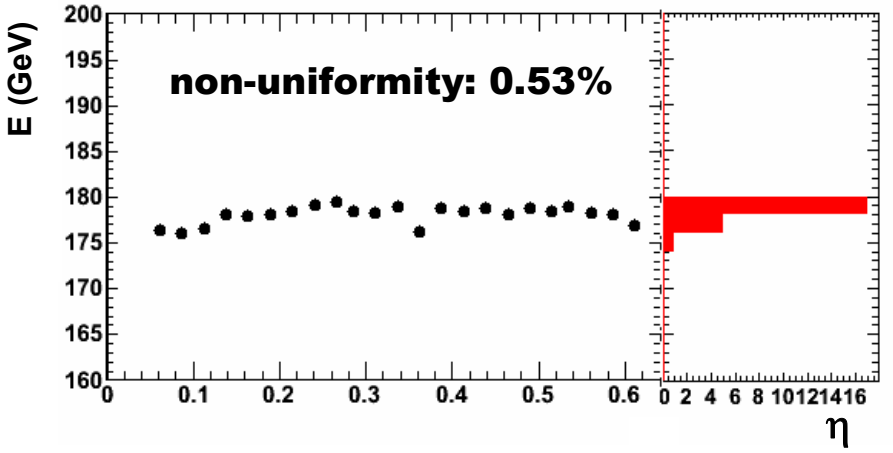
- Electron at **180 GeV** : eta scan η=[0.03,0.6]
- Non-uniformity : **0.53 %**

Global constant term: ~0.7%

Linearity better than 0.2%







Very Low Energy Electrons MC Study

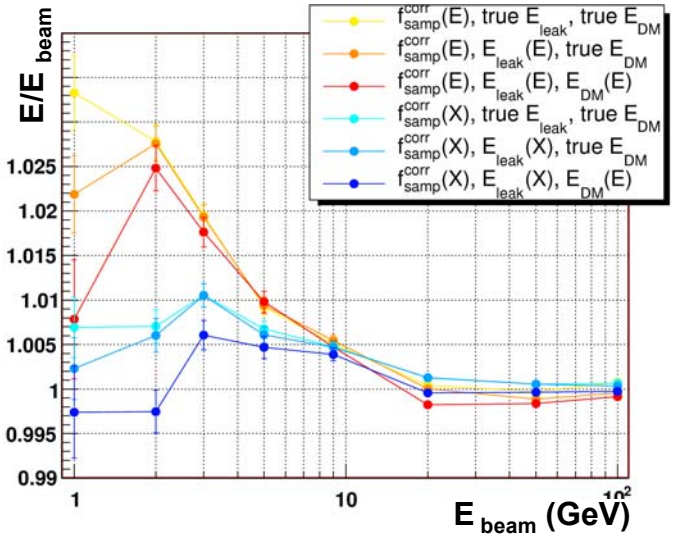
The accordion factor :

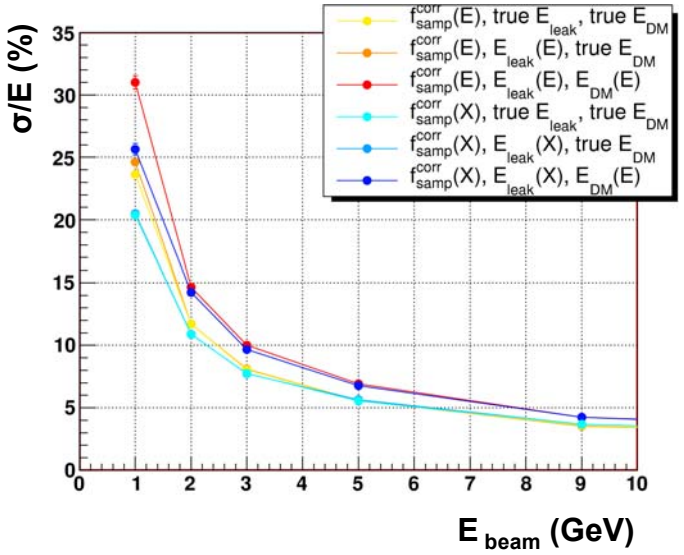
- corrects for the sampling fraction and compensates for out of cluster energy (lateral leakage)
- Parametrization as function of energy/ shower depth

MC study shows that a pure energy parametrization of the calibration constants leads to an over-estimation of energies below 10 GeV

Sampling fraction corrections taking into account the shower depth (and using 5x5 clusters) perform better

Next steps: Apply this modified calibration scheme to combined test beam data

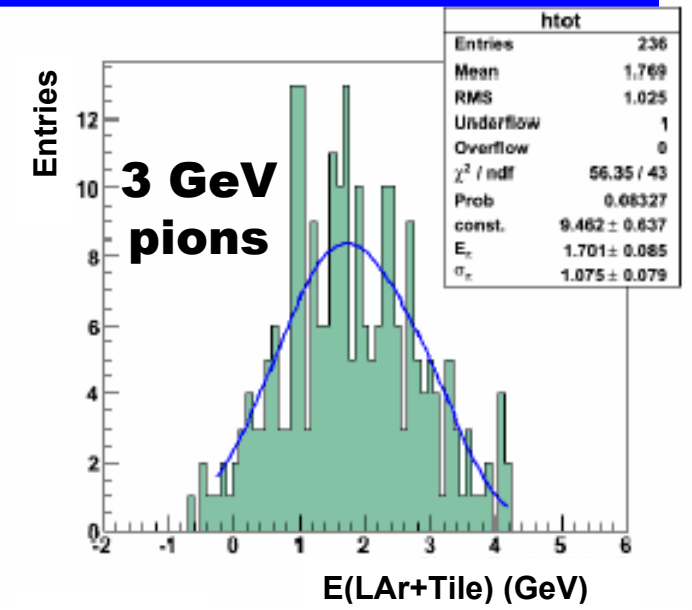


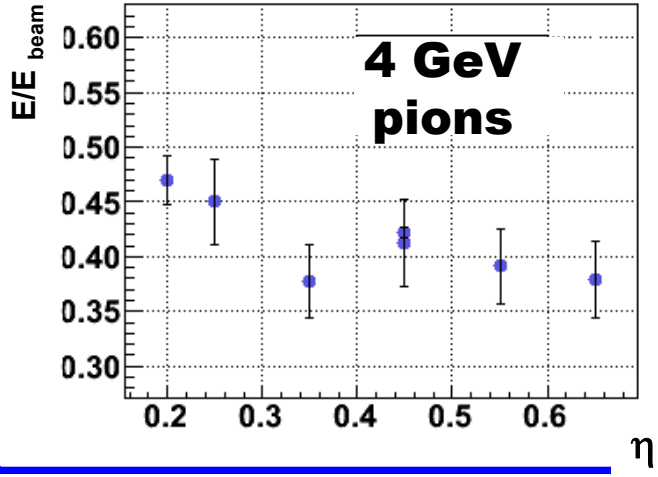


Very Low Energy Pions Data Analysis

Very Low Energy Pions :

- Systematic pion analysis being done, determination of purity of pion sample (few percents electron contamination)
- The electrons were rejected using TRT and Cherenkov counter
- Pions were rejected requiring a small signal in the third sample of TileCal ED < 150 MeV
- Pions response fitted using a double gaussian function one for the e and the other for π
- Fully constrained gaussian for e (shape and integral)
- Muon contamination negligible (around 0.5% muon contamination)
- The errors include systematic errors due to pedestal subtraction, electron contamination and beam uncertainties. The statistical errors dominate





Conclusions & Outlook

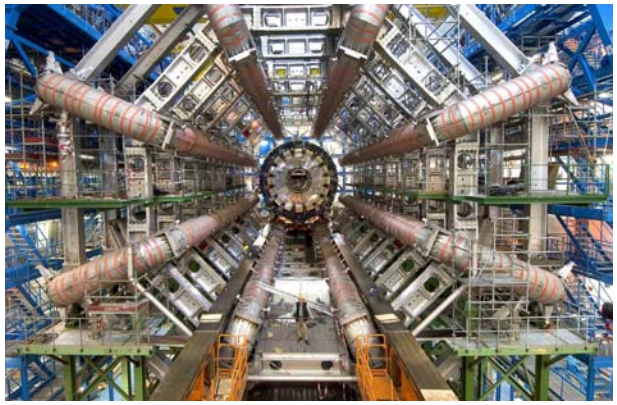
- For the first time, all ATLAS sub-detectors integrated and ran together with common DAQ, “final” electronics, slow-control, etc
- Gained lot of global operation experience during ~ 6 month run
- Common ATLAS software used to analyze the data
- The LAr calorimeter data is very well described by the MC. Results from the combined test beam meet the ATLAS requirements and are in agreement with previous test beam results.
- New interesting results from Very Low Energy analyses
- Ongoing work on the Very Low Energy electrons and pions analyses and on combined studies together with the Inner Detector and TileCal (E/p, photon conversions, pions)

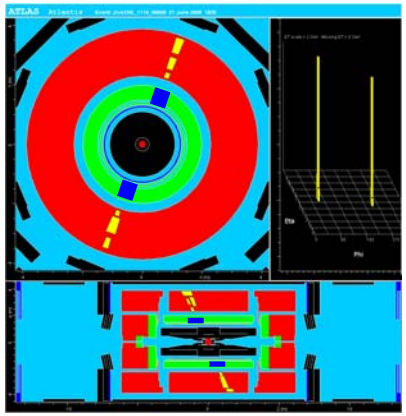
The Road to Physics

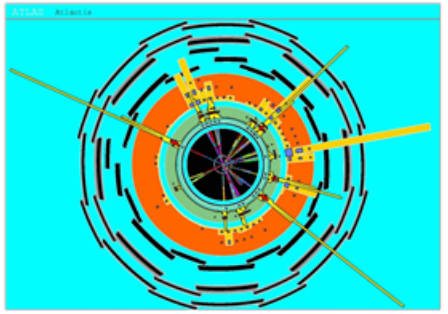
Test beam
(1% of ATLAS)

Subdetector Installation,
Cosmic Ray Commissioning

First LHC
collisions



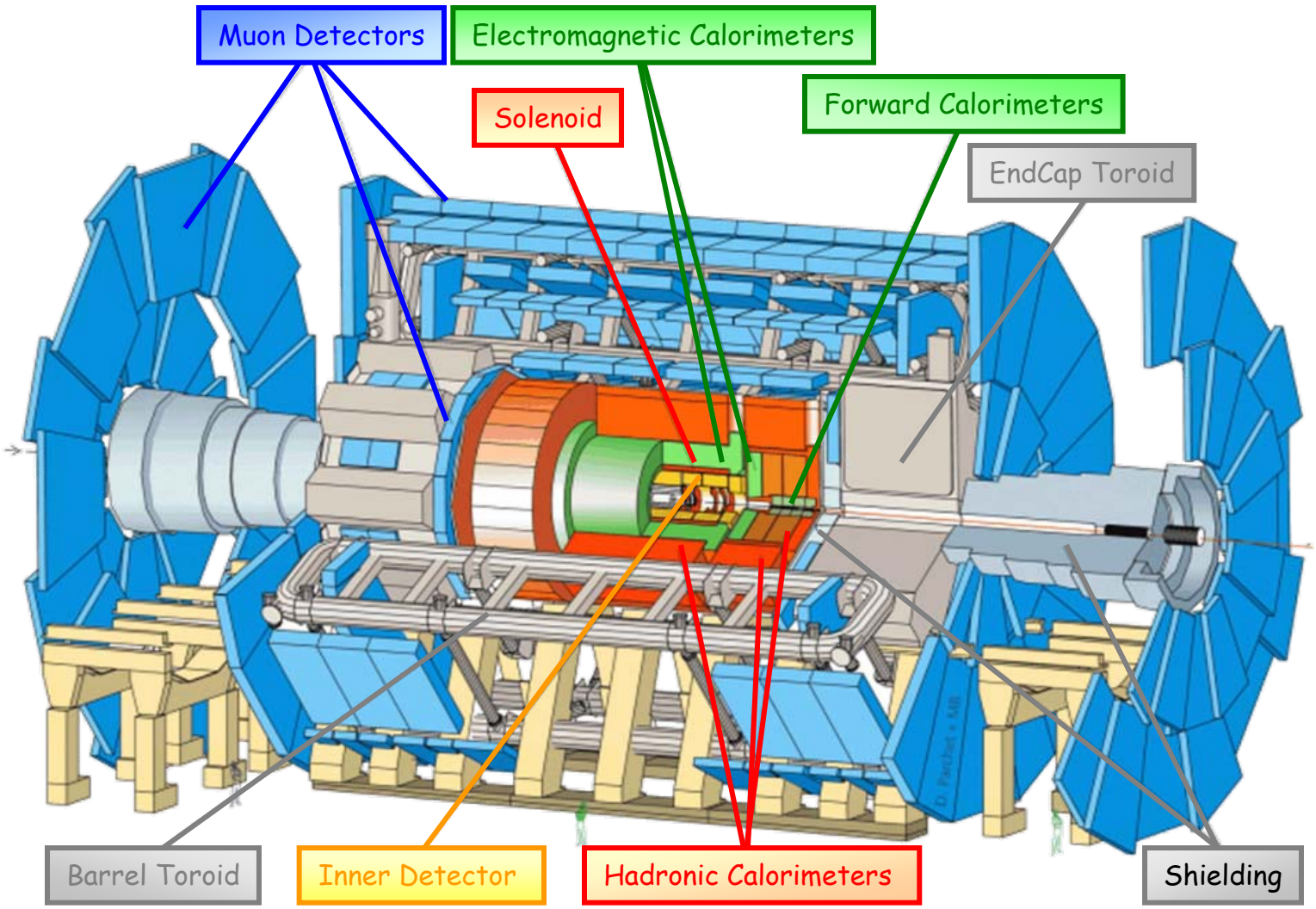




2005 2006 2007 2008

Back-up Slides

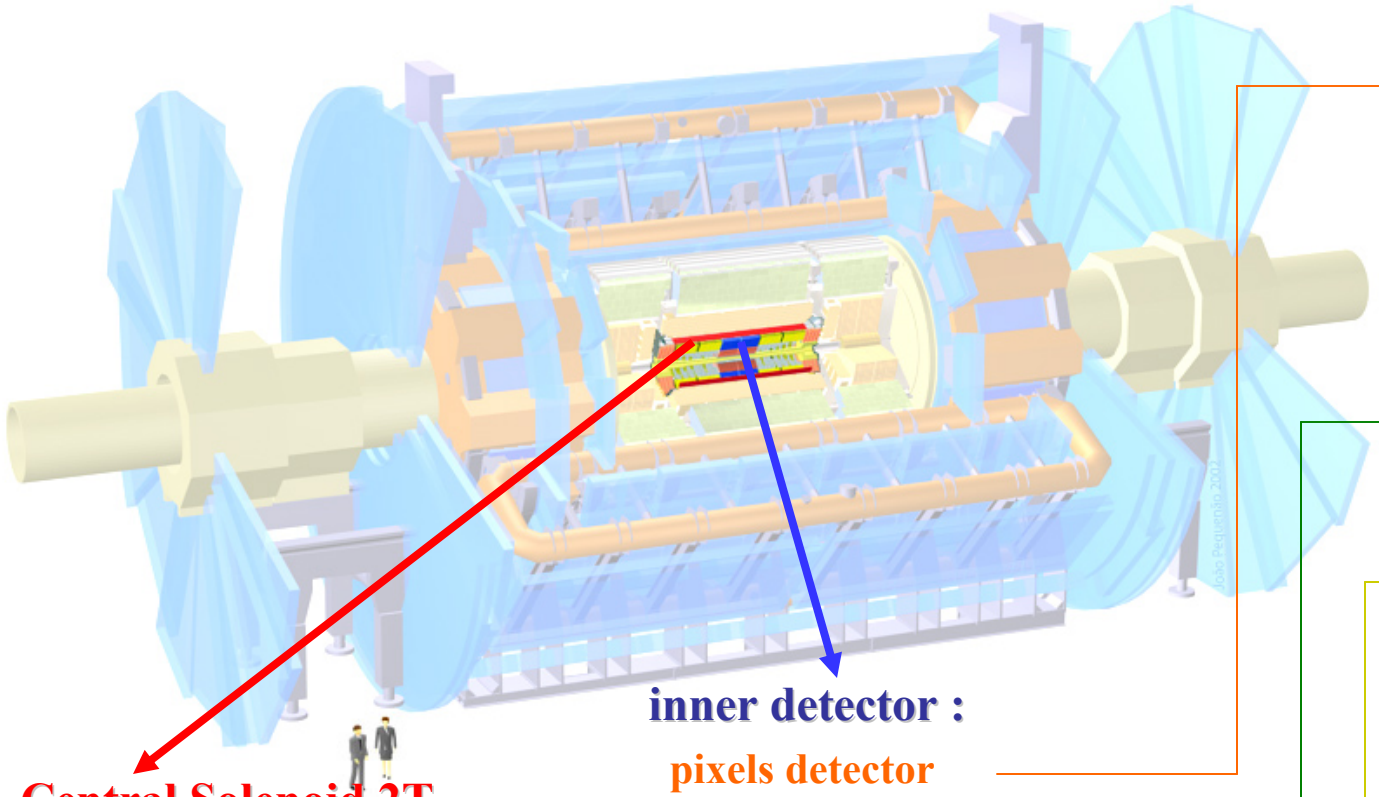
ATLAS layout

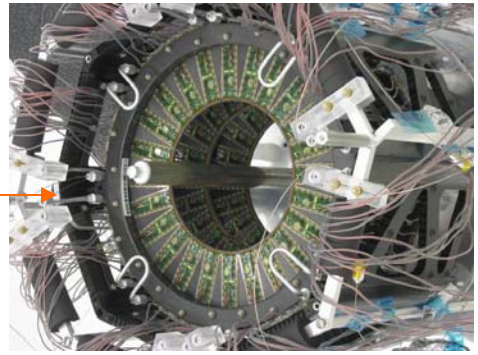


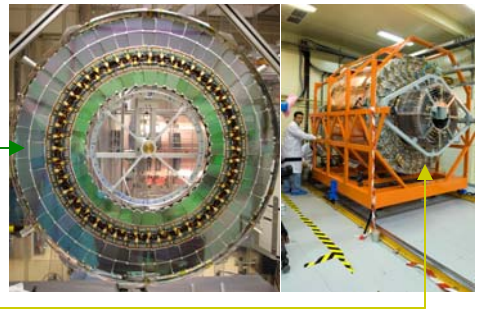
Inner Detector

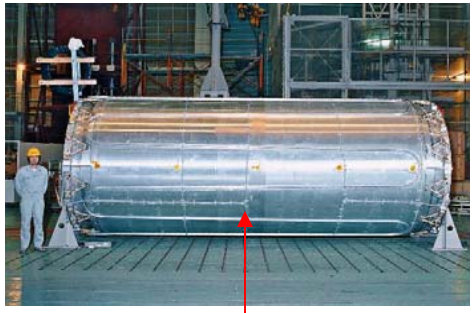
- **Impulsion resolution :**

  $\sigma(p)/p = 0.05\ \%\ p\ (GeV) \oplus 1\%$ for $|\eta|<2.5$









inner detector :

pixels detector

SCT (Semi-Conductor Tracker)

TRT (Transition Radiation Tracker)

Central Solenoid 2T

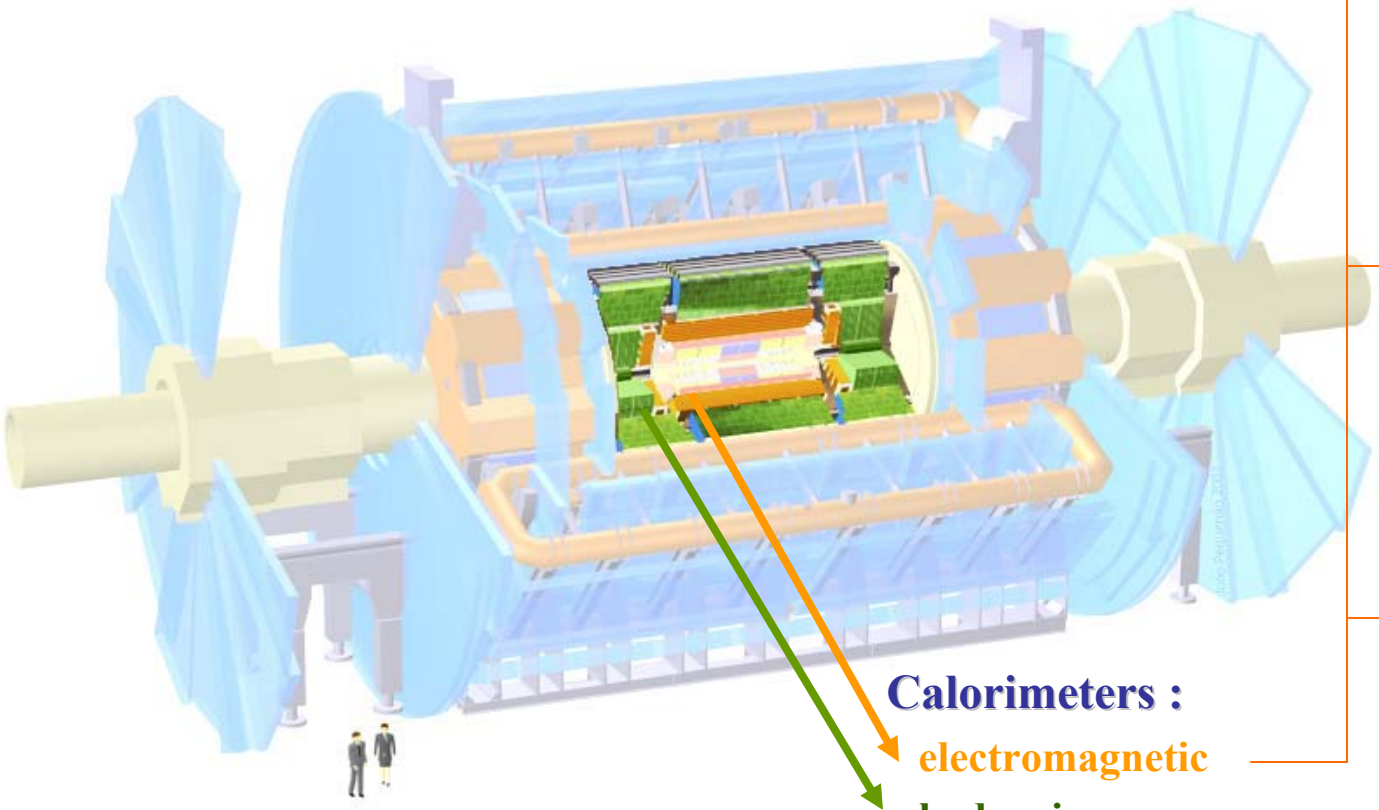
Calorimeters

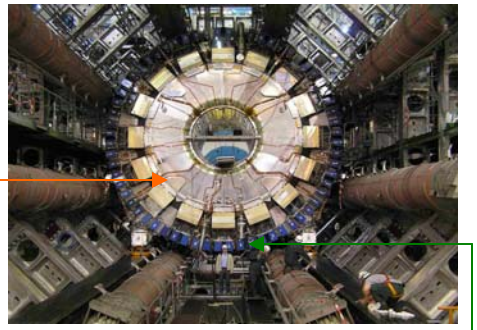
- **Energy resolution (GeV) :**

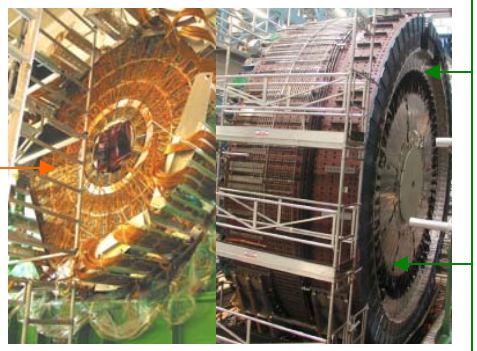
  electromagnetic : $\sigma(E)/E = 10\%/\sqrt{E} \oplus 0.3/E \oplus 0.7\%$ for $|\eta|<3.2$

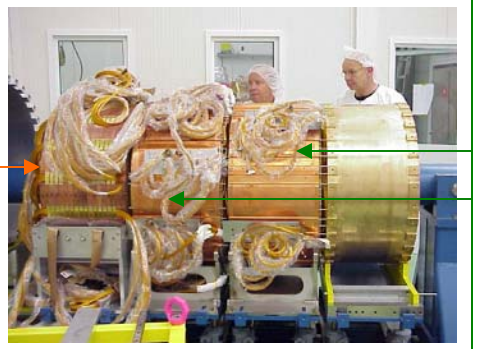
  hadronic : $\sigma(E)/E = 50\%/\sqrt{E} \oplus 3\%$ for $|\eta|<3$

  : $\sigma(E)/E = 100\%/\sqrt{E} \oplus 5\%$ for $3<|\eta|<5$









Calorimeters :

electromagnetic

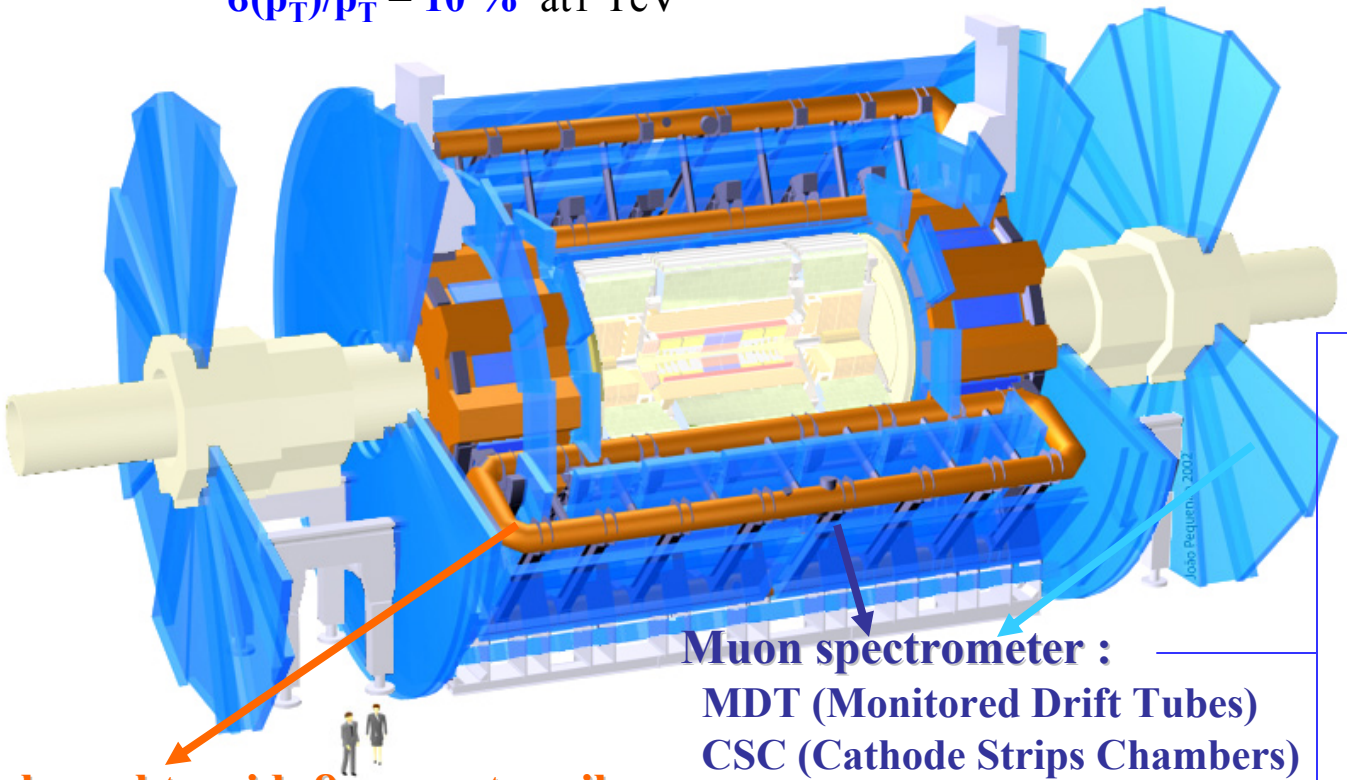
hadronic

Muon Spectrometer

- **Impulsion resolution :**

  $\sigma(p_T)/p_T < 3\%$ for $10<p_T<250$ GeV and for $|\eta|<2.7$

  $\sigma(p_T)/p_T = 10\%$ at1 TeV



barrel toroid: 8 separate coils

and 2 end-cap toroids

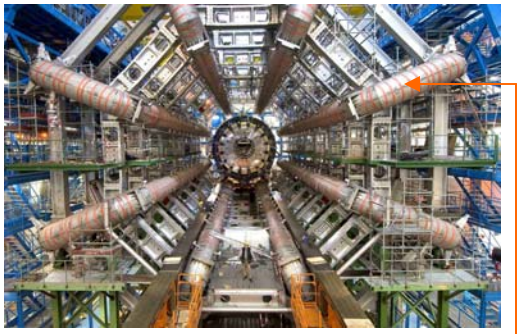
Muon spectrometer :

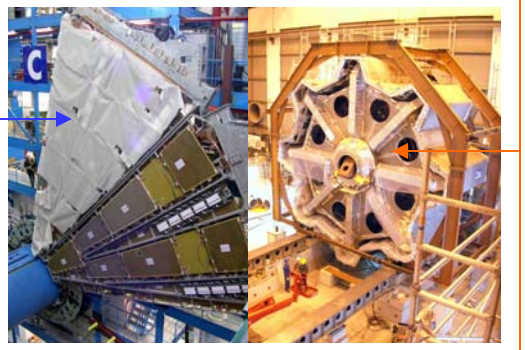
MDT (Monitored Drift Tubes)

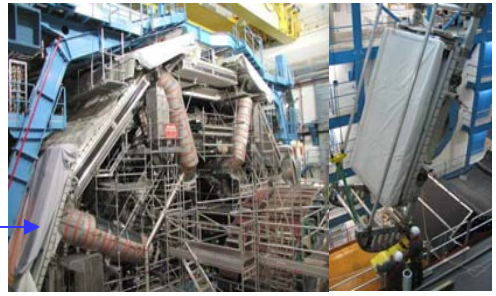
CSC (Cathode Strips Chambers)

RPC (Resistive Plate Chambers)

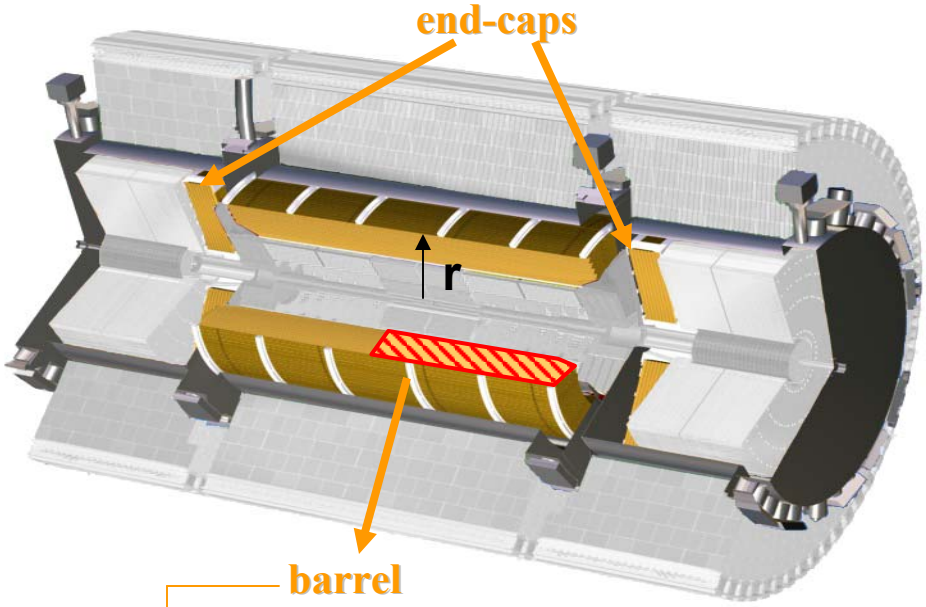
TGC (Thin Gap Chambers)

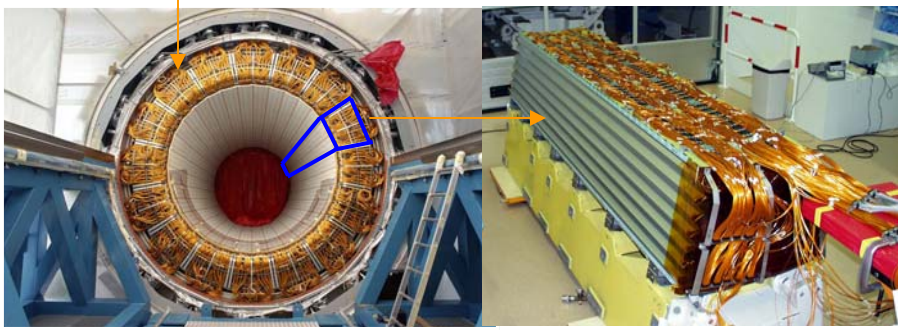






Electromagnetic Calorimeter (LArg)





caracteristics :

- **sampling calorimeter**
  lead/LArg
- **liquid argon (90 K) :**
  stable
- **acceptance :**
  |η|<1.475 for the barrel
  1.375<|η|<3.2 for the end-caps
- **accordeon-shaped' geometry**

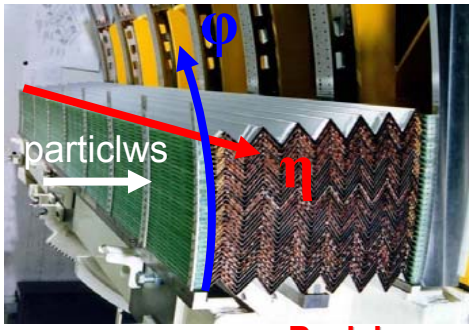
barrel :

- **depth (fonctions of r) :**
  25 to 34 X_0 lenghts of radiation
- **2 half barrels**
  z<0 and **z>0**
- **1 hafl barrel :**
  16 modules

Principle and Segmentation

principle :

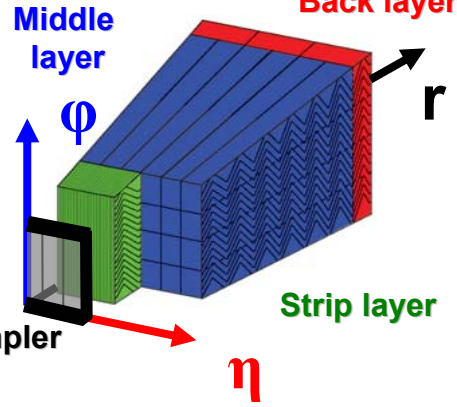
- **development of the shower :** **lead** absorbers : X_0=0.56 cm
- **ionisation of LAr :** **electrons** of ionisation
- **signal :** collected by the **centrale layer** of the **electrod**

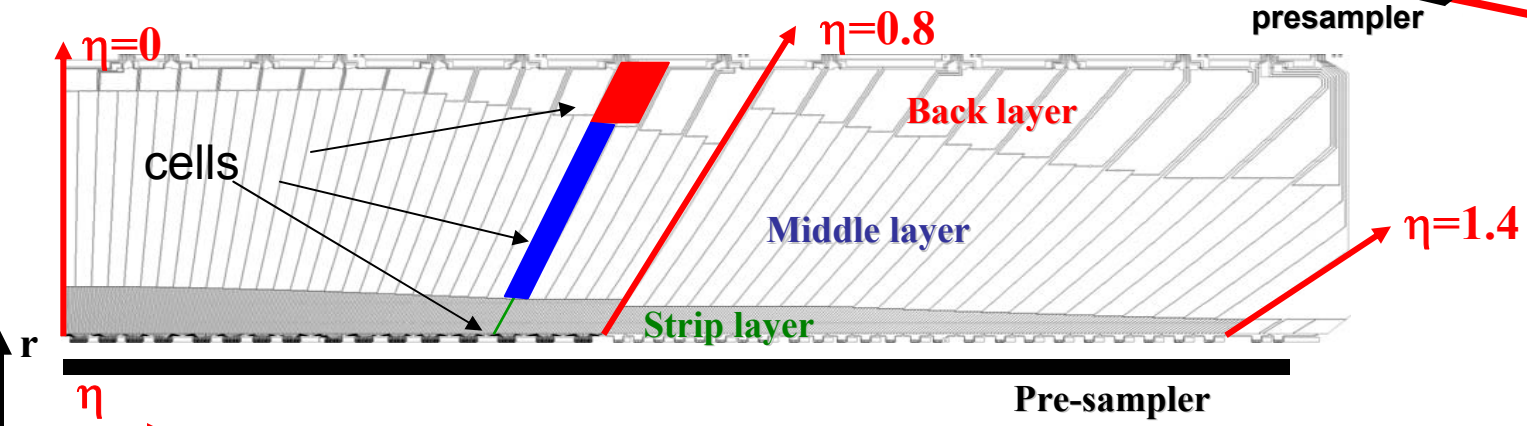


segmentation :

- **layer** **granularity** ($\Delta\eta\times\Delta\varphi$) **depth**

pre-sampler	0.025 x 0.1	1-2 X_0
strip	0.003 x 0.1	3-5 X_0
middle	0.025 x 0.025	15-18 X_0
back	0.05 x 0.025	1-8 X_0



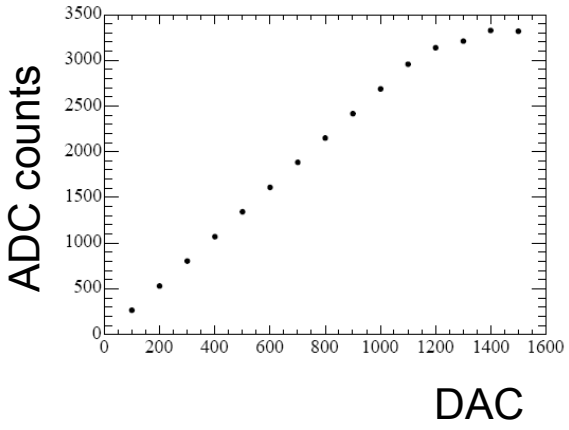


Reconstruction of the energy

reconstruction of the energy for a cell :

- Use of **Optimal Filtering Coefficients** :

$$E(MeV) = f_{DAC\rightarrow\mu A} \cdot f_{\mu A\rightarrow MeV} \cdot \frac{M_{physic}}{M_{calibration}} \cdot P(ADC_{pic})_{(ADC\rightarrow DAC)}$$



calculate

extraction from Monte Carlo + test beam

Ratio of maximums :
$g_{physique}$ over $g_{calibration}$

calibration

$$P(ADC)_{(ADC\rightarrow DAC)} = R_0 + R_1.ADC + R_2.ADC^2$$

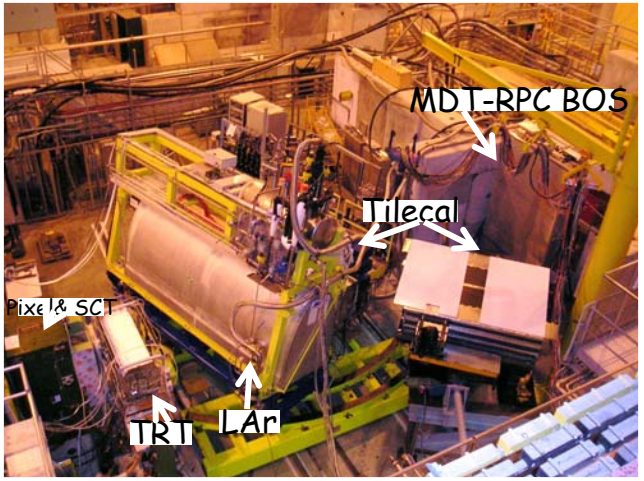
$$ADC_{pic} = \sum_{i=1}^{N\ sample} a_i \cdot (\text{sample[i]} - \text{pedestal})$$

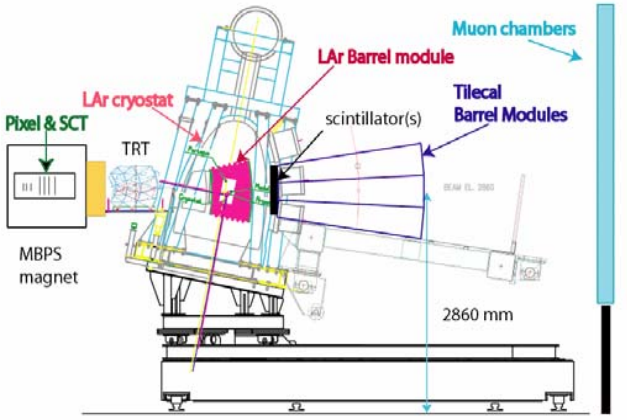
Optimal Filtering Coefficients

2004 Combined Test Beam

2004 Combined Test Beam :

- Configuration very close to **ATLAS**
- Full central **slice** of ATLAS:
  - MBPS **magnet** with horizontal field (1.4T)
  - 3x2 **pixel** and **4 SCT** planes
  - **TRT**
  - **LAr** barrel module
  - 3 **TILE** Calo. Modules
  - **Muon** chambers
- **Read-out/DAQ/software** as in ATLAS
- Beams: **e,γ, π, p, μ** (from 1 to 350 GeV)

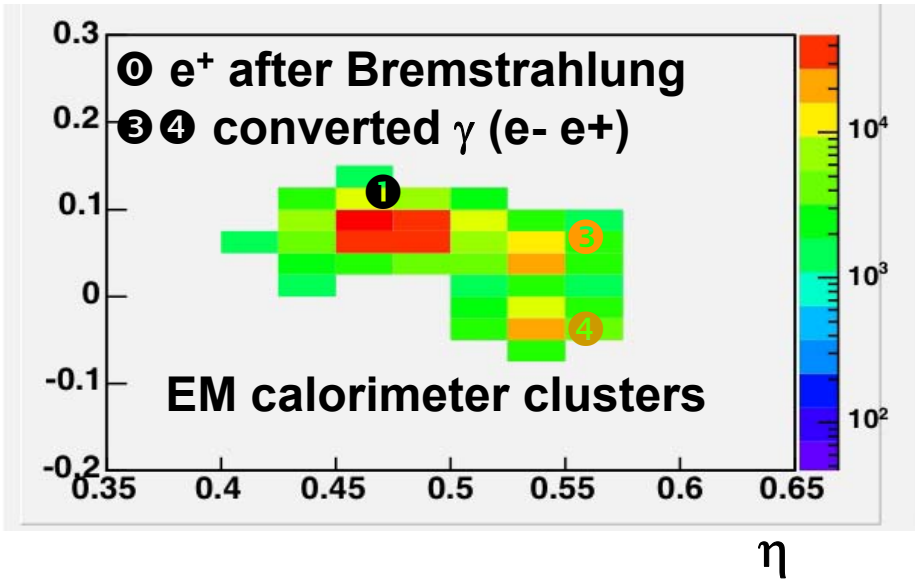


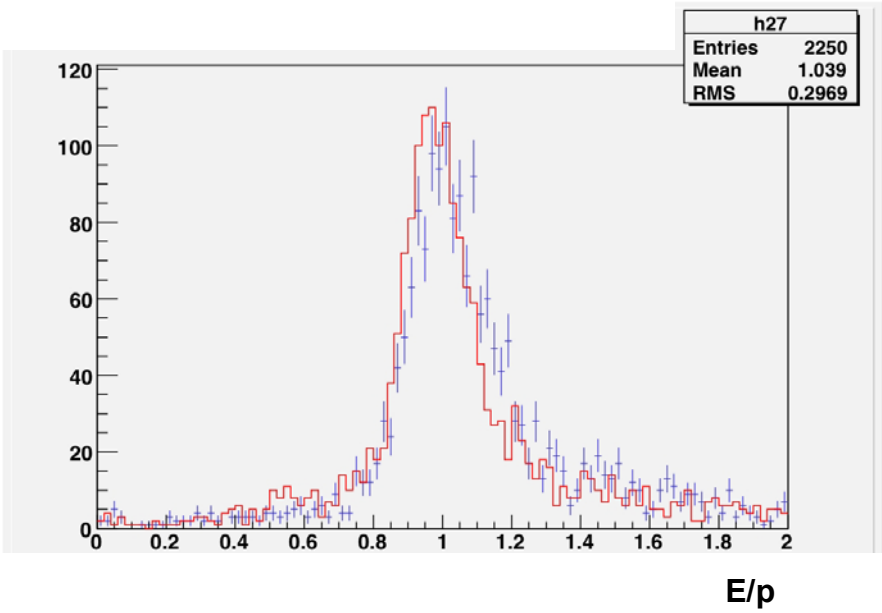


Converted photons

Converted photons :

- Back tracking γ to conversion point
- Needs more efficiency studies (on going)

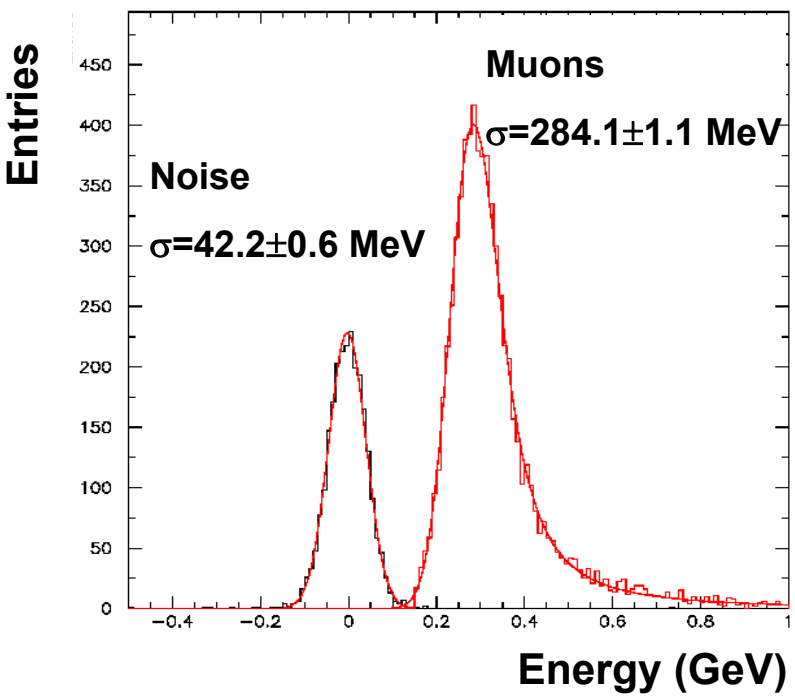


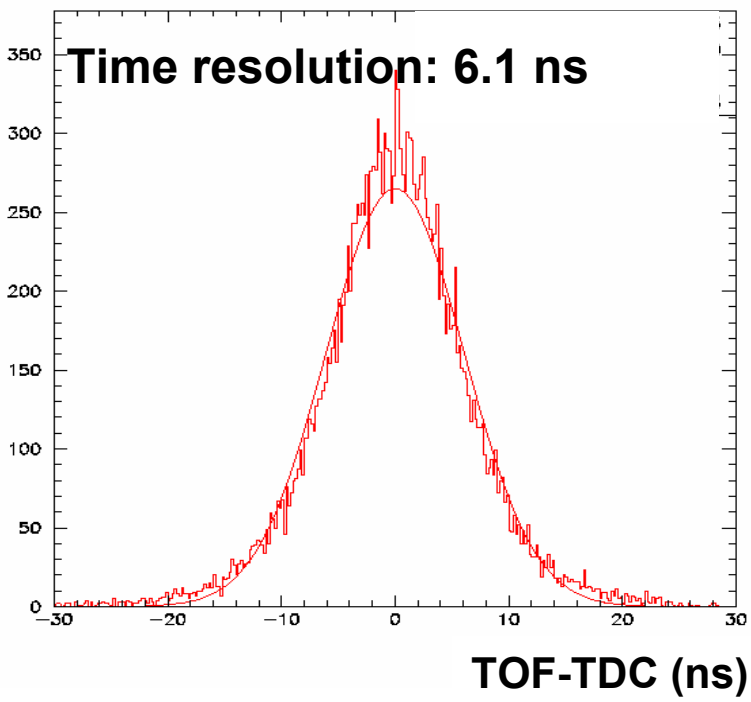


Response to Muons (EM)

Response to Muons (EM) :

- Noise goes like $\approx \Delta\eta \times \Delta\varphi$,
- Signal goes like sampling depth $\Rightarrow$ Most favourable S/N : Middle layer





Muons at 6σ from noise

With 100 µ/cell: check physics timing to 0.6 ns for Commissioning with cosmics