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The ATLAS Liquid Argon Calorimeter at the LHC

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on behalf of the ATLAS Liquid Argon Calorimeter Group

Outline

- Introduction
  - the LAr Calorimeter of the ATLAS detector
- Electronic calibration
  - energy reconstruction
- Results with cosmic muons
  - signal shape
  - uniformity of response
- Results with single beam and splash events
  - timing
- First collisions!
- Conclusions

The ATLAS experiment

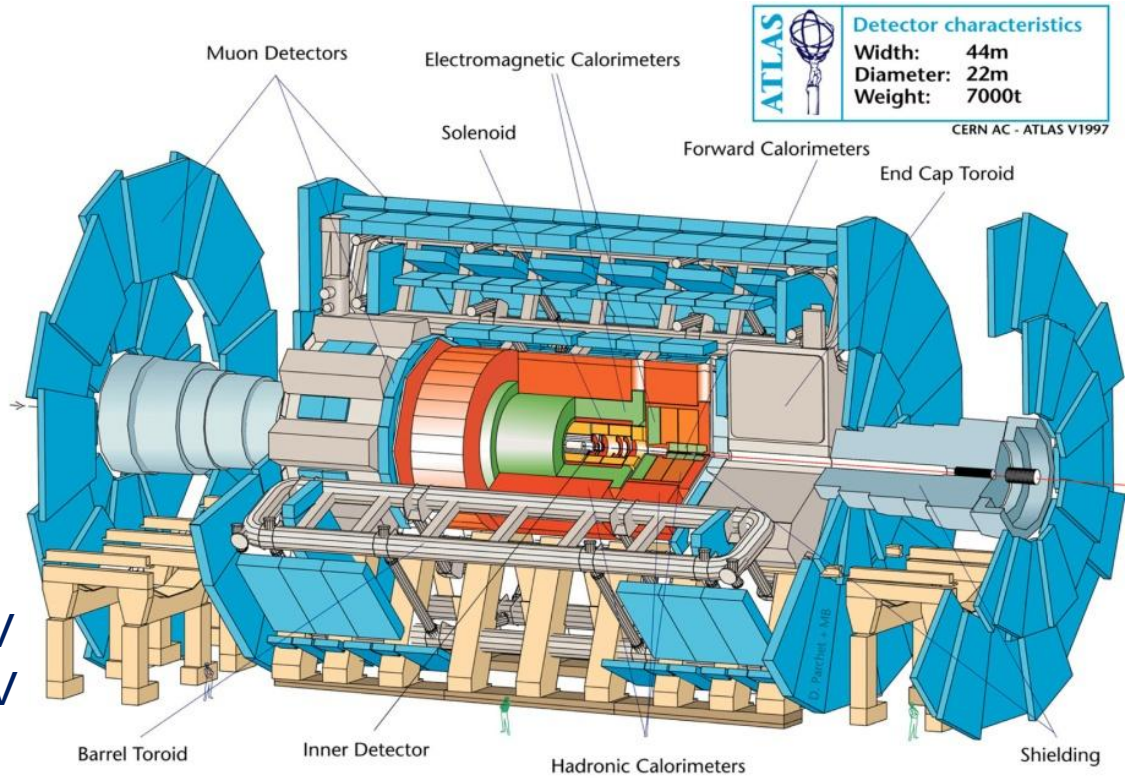
- 1992 Letter of Intention
- 1997 start of construction

- until 2004: test beam

- 2008: installed in the tunnel
- until today: cosmic runs

- fall 2008 and 2009
✓ beam in LHC
✓ splash events

- 23/11/09 first collision at 900 GeV
- 08/12/09 first collision at 2.36 TeV



Physics analysis:

Higgs : H→ γγ, H→ 4l
SUSY (+exotics): missing E_T
SM signatures : Z and W
(leptons and missing E_T)

Hadronic environment:

p-p collisions every 25 ns, nominal E of 14 TeV
➢ high interaction rates and high radiation

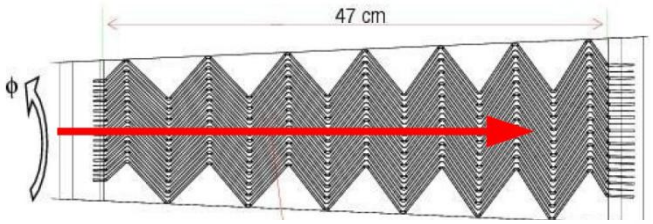
Requires very good calorimetry!

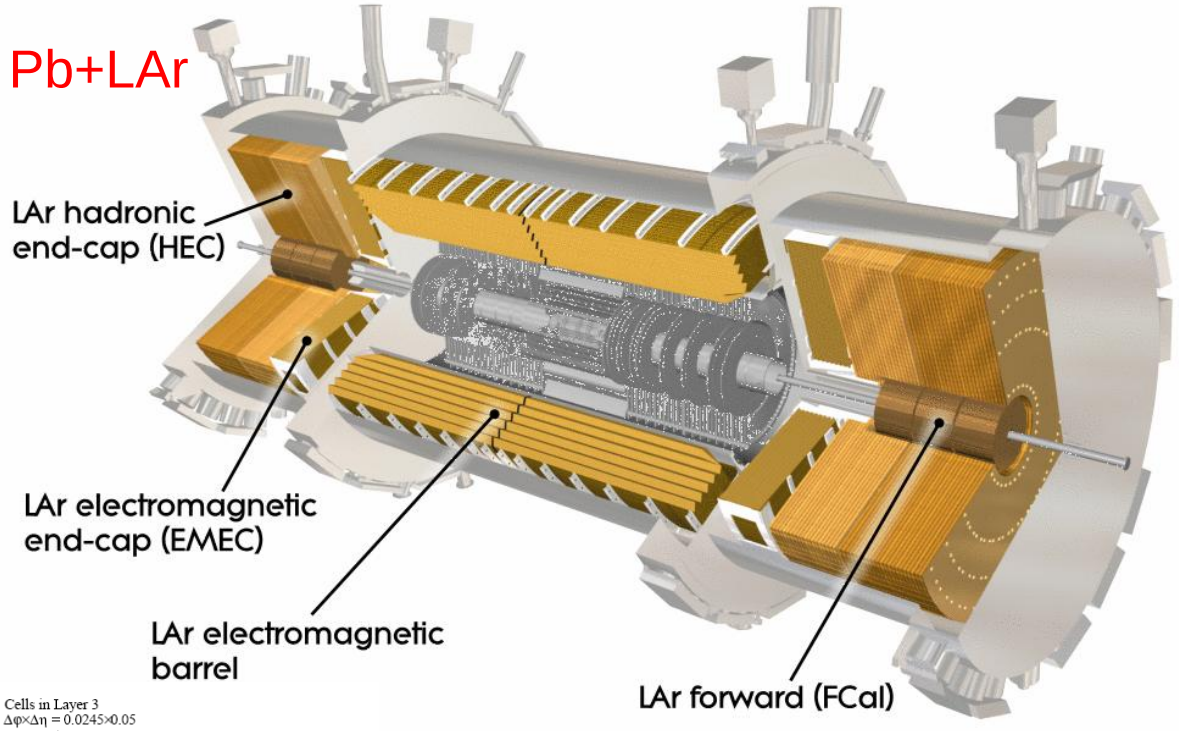
- energy resolution
- coverage in η and φ
- missing E_T reconstruction
- accurate time measurement

(eventual new, long-lived particles)

The ATLAS LAr Calorimeter

Electromagnetic calorimeter Pb+LAr





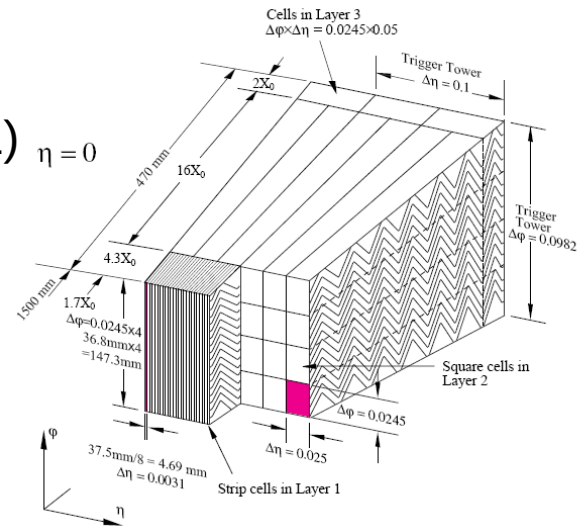
Complete φ coverage
Pseudo-rapidity |η| < 3.2

3 longitudinal layers

strips: 4.3 Xo
(Δη×Δφ=0.003×0.1)

middle: 16 Xo
back: 2 Xo

+presampler
at |η| <1.8



Energy resolution:

$$\frac{\Delta E}{E} = \frac{10\%}{\sqrt{E(GeV)}} \oplus 0.7\%$$

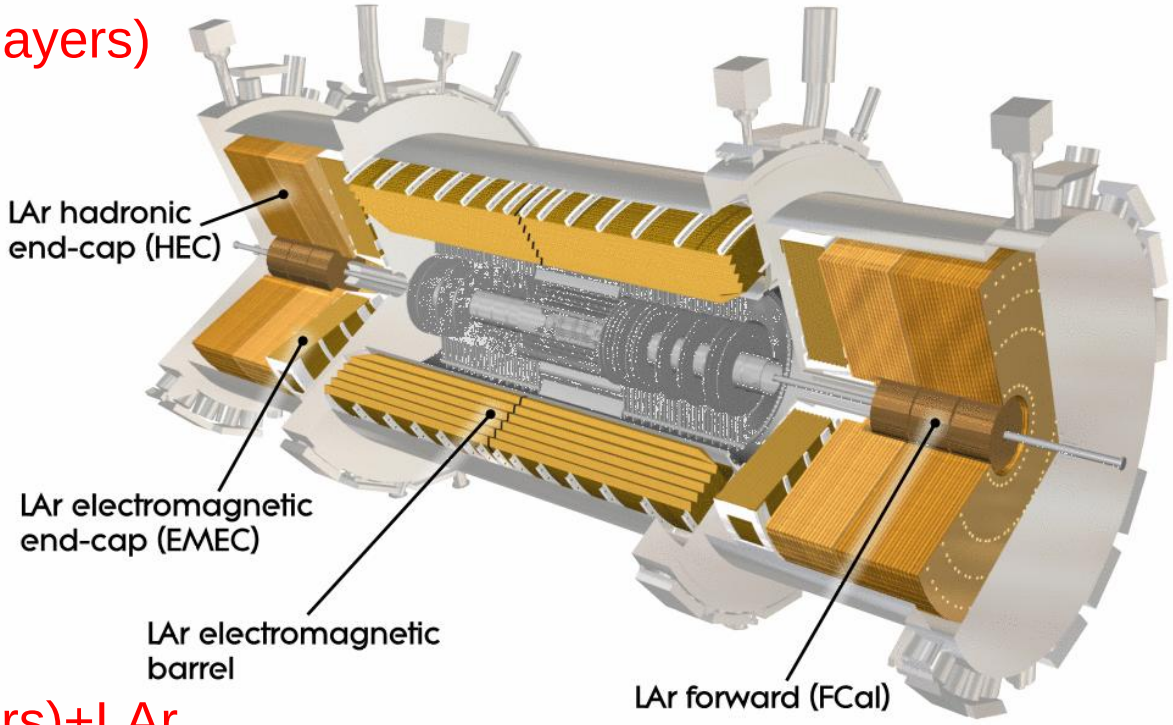
The ATLAS LAr Calorimeter

Hadronic endcap Cu+LAr (4 layers)

Coverage 1.5<|η|<3.2

Energy resolution

$$\frac{\Delta E}{E} = \frac{50\%}{\sqrt{E(GeV)}} \oplus 3\%$$



Forward calorimeter:
Cu(em-1 layer)/W(had-2 layers)+LAr

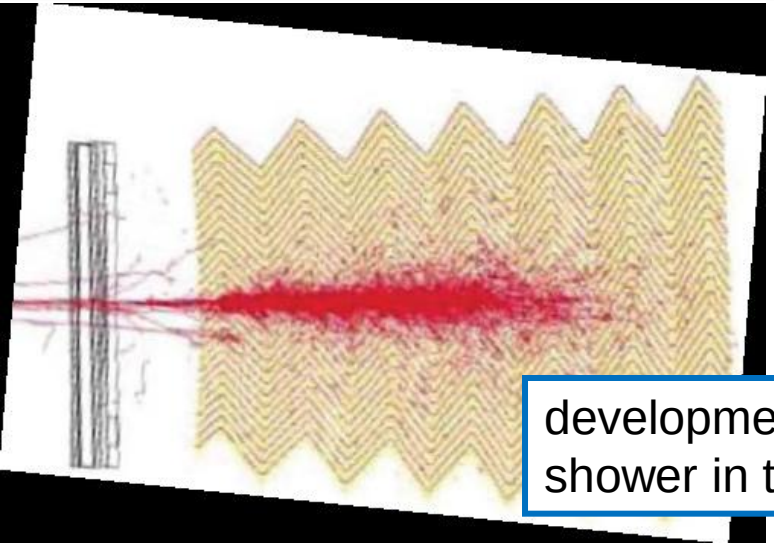
Coverage 3.1<|η|<4.9

Hadronic energy resolution

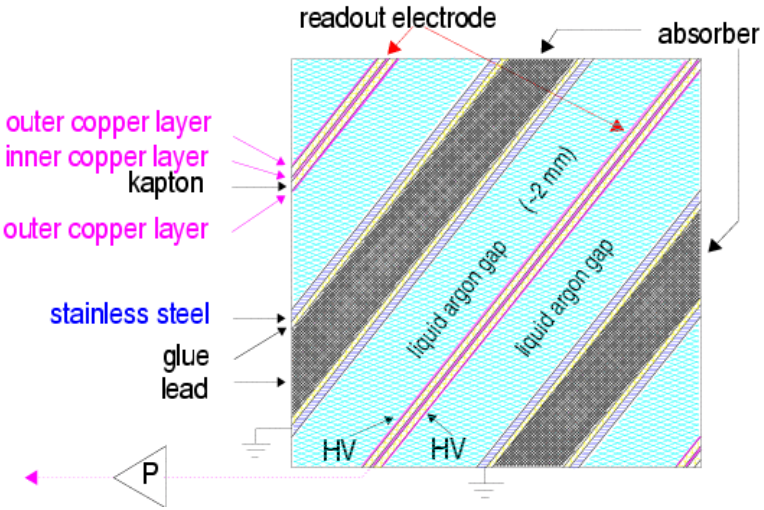
$$\frac{\Delta E}{E} = \frac{100\%}{\sqrt{E(GeV)}} \oplus 10\%$$

in total:182468 LAr channels
common readout system
✓98.7 % are used
✓94 % with nominal HV

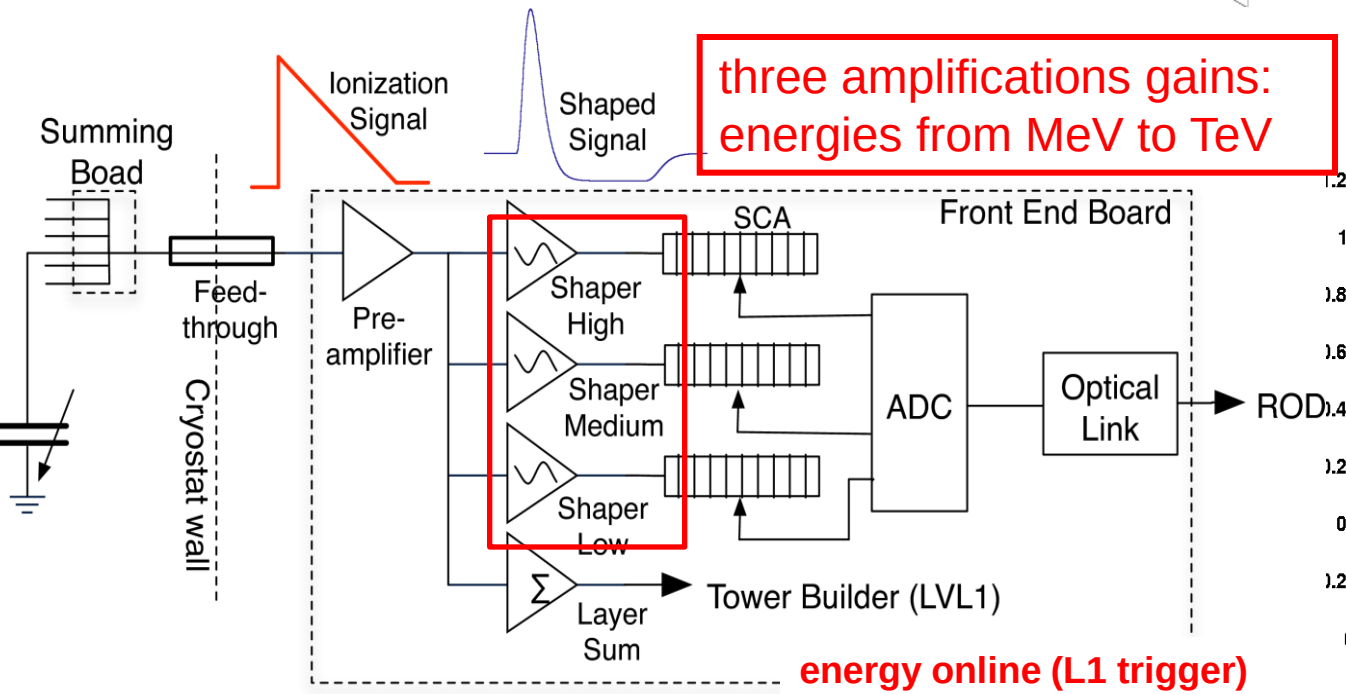
Ionization and calibration signal

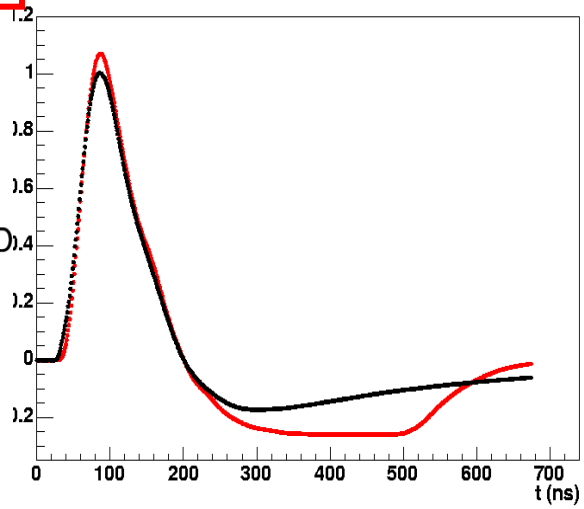


development of a shower in the absorber



three amplifications gains: energies from MeV to TeV





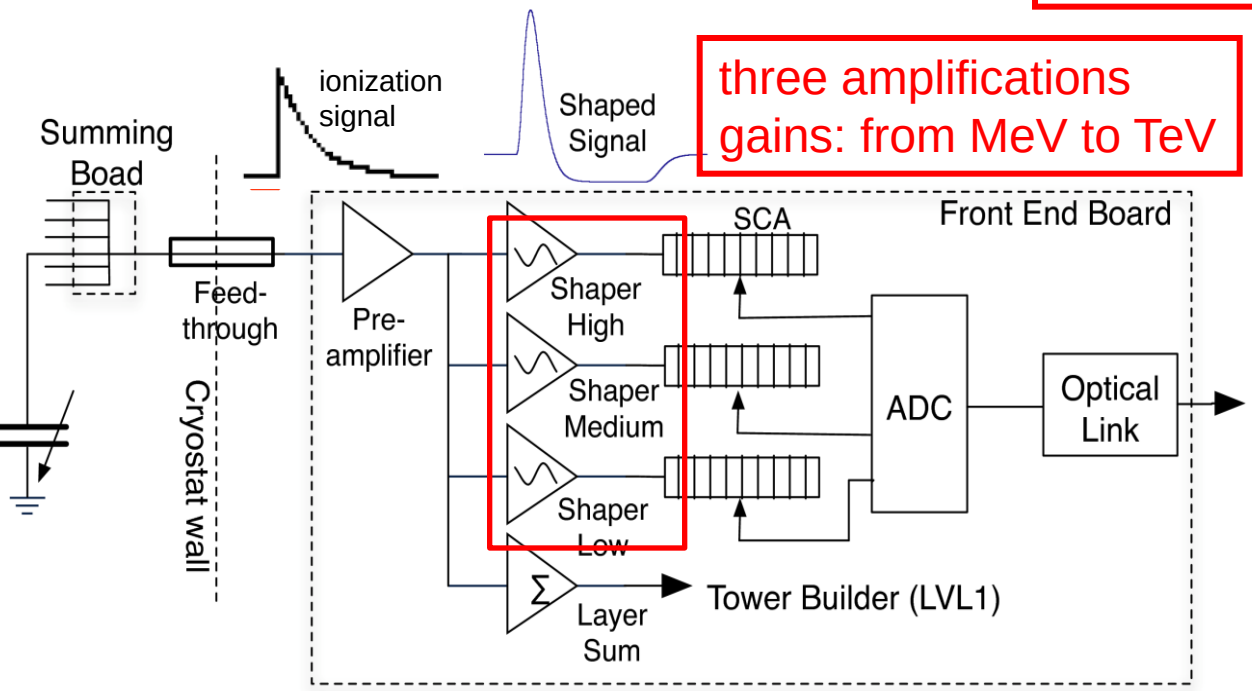
energy online (L1 trigger)

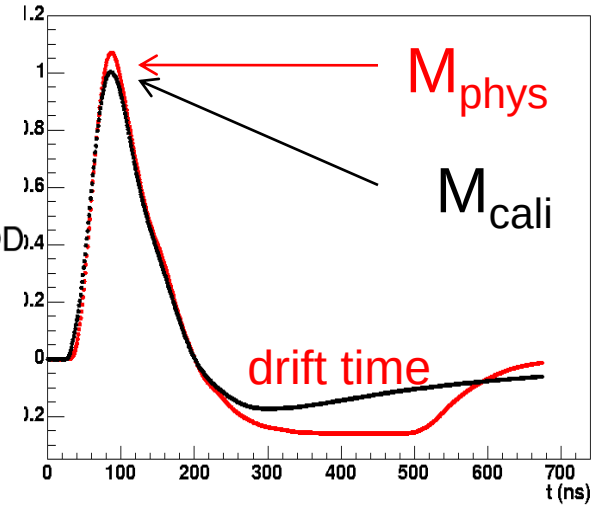
Ionization and calibration signal

For calibration runs:

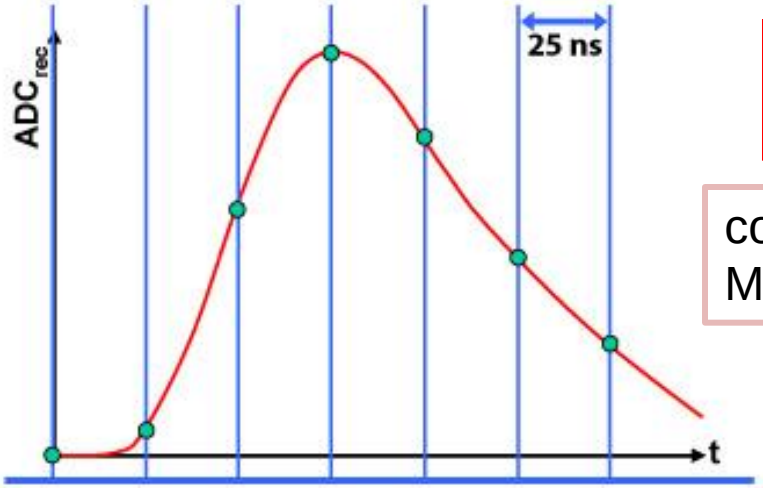
a known exponential current is injected and then amplified, shaped and read

Ionization and calibration pulses don't have the same shape





Energy reconstruction



5 (or more) amplitude measurements spaced by 25 ns

correction for Mphys≠Mcali

ADC to DAC (Ramps)

Pulse Samples

$$E_{\text{cell}} = F_{\mu A \to MeV} \cdot F_{DAC \to \mu A} \cdot \frac{1}{\frac{M_{phys}}{M_{cali}}} \sum_{i=1}^{M_{ramps}} R_i \left[\sum_{j=1}^{N_{samples}} a_j \left(s_j - p \right) \right]^i$$

Cell energy

Sampling fraction

Calibration board

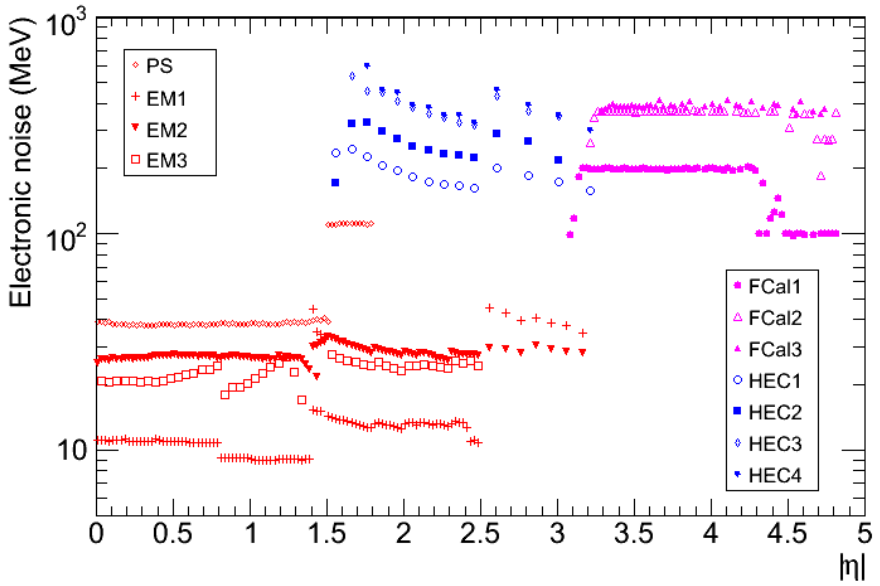
Optimal Filtering Coefficients

Pedestals

Regular electronic calibration runs (in every fill in when running)

- pedestal and noise measurement
- delay runs for the detailed pulse shape
- ramp runs to measure the gain (ADC to DAC)

Electronic calibration

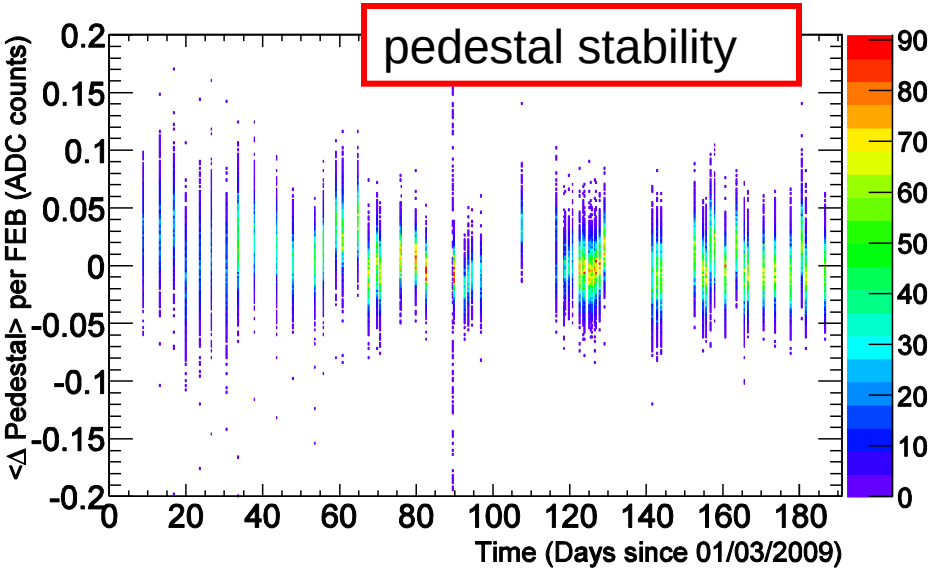


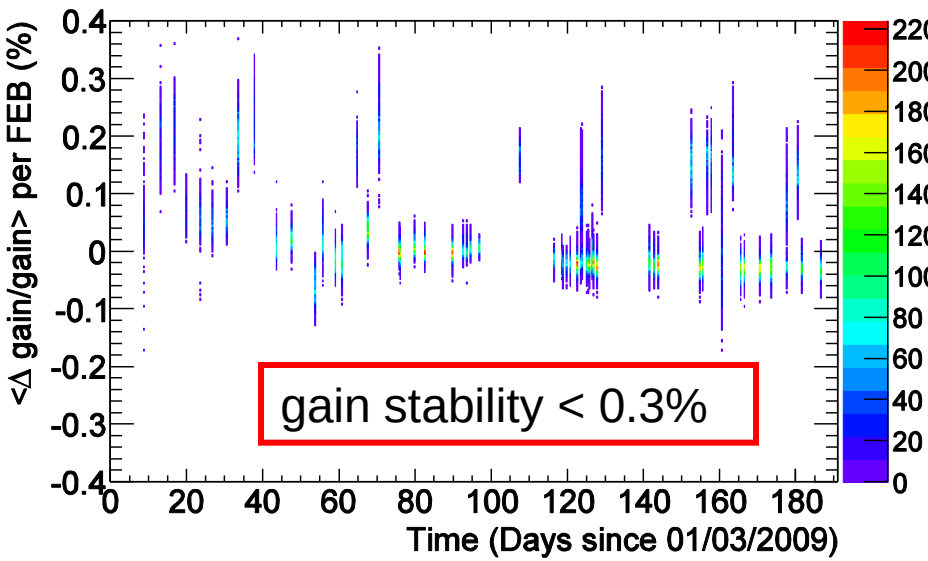
low and very stable noise

- The calibration constants are stored in a data base and used for the energy reconstruction
- They are updated in every calibration run if needed

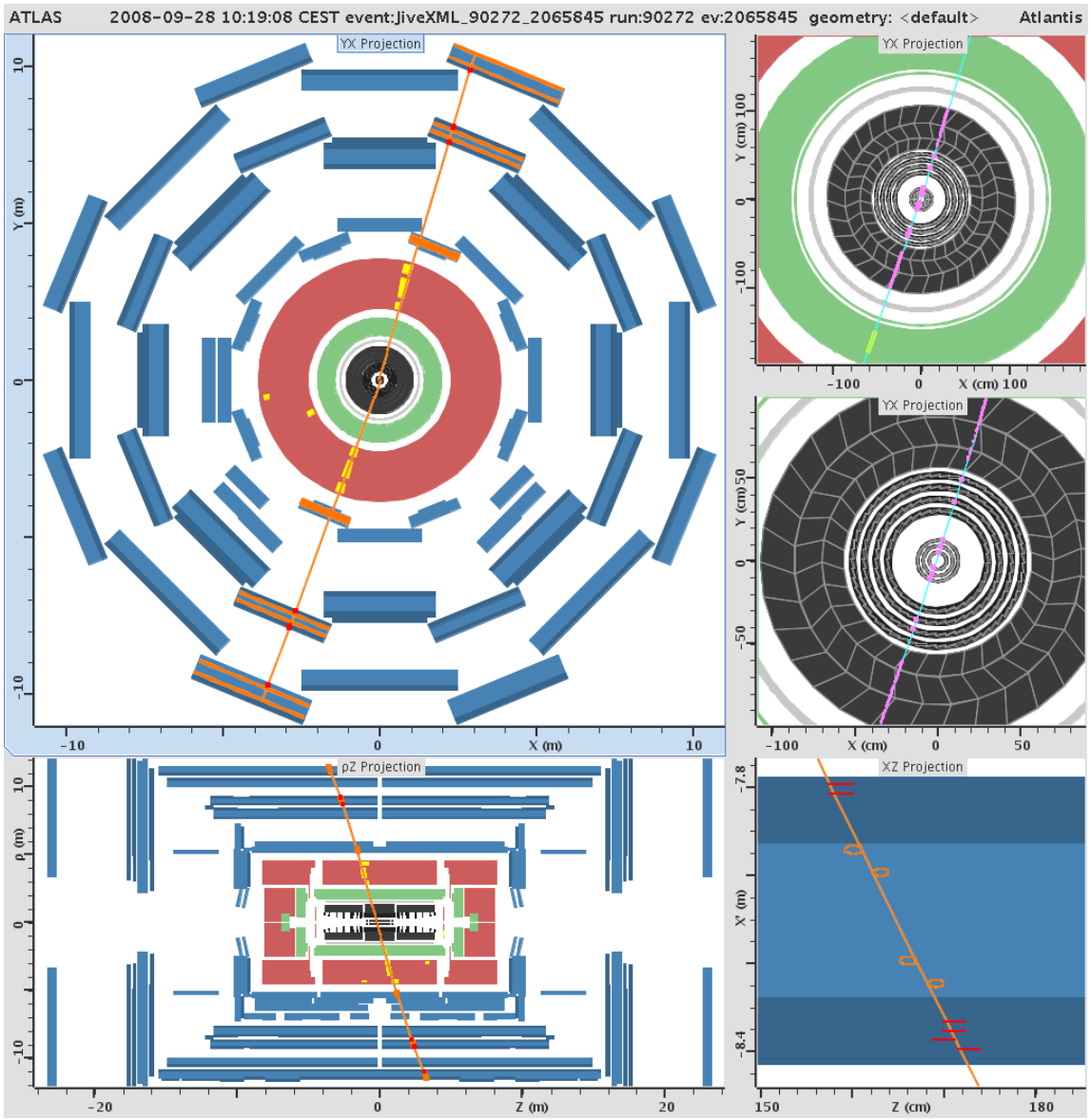
Stability of the calibration constants

pedestal stability





Cosmic data taking

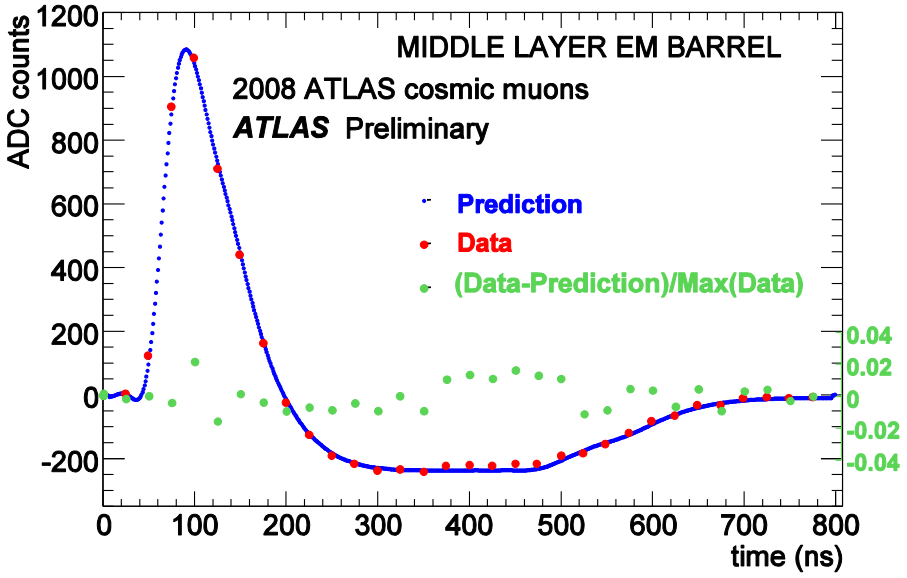


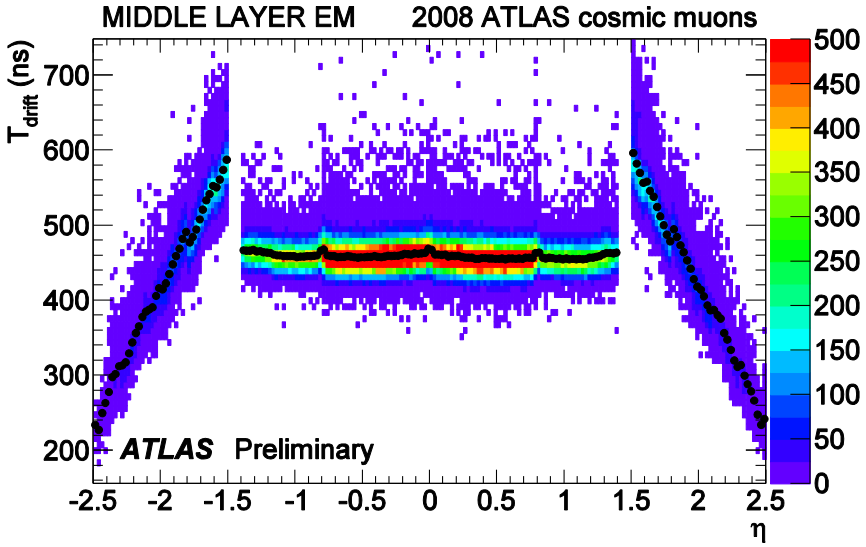
Cosmic muons

September-October 2008
June-July 2009

300 million events recorded

Study of the signal shape





Signal of cosmic muons:

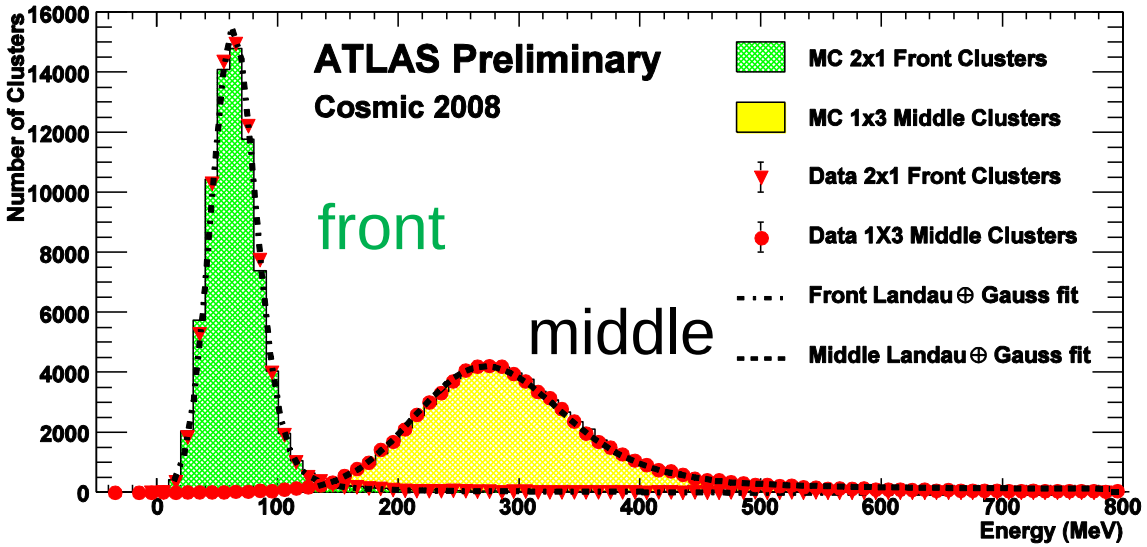
shape very well predicted by the electronic calibration procedure
(residuals < 2%)

Drift time extraction
depend on HV and gap size

electromagnetic barrel (constant)
➢ gap size variations (constant HV)
(contribution to E ct term: 0.29 %)

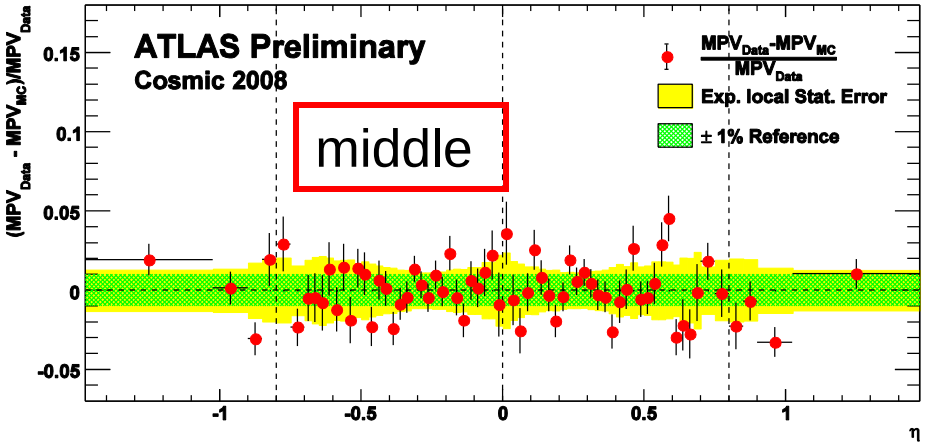
endcaps: varying gap size
(contribution to E ct term: 0.53%)

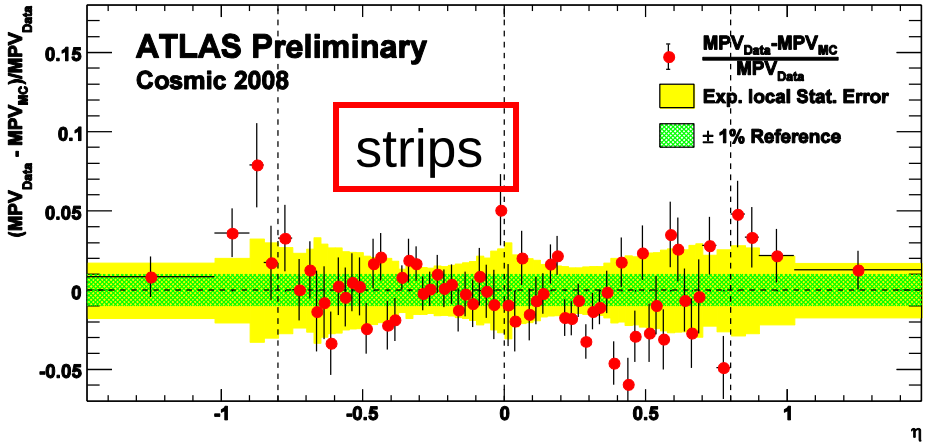
Uniformity with cosmic muons



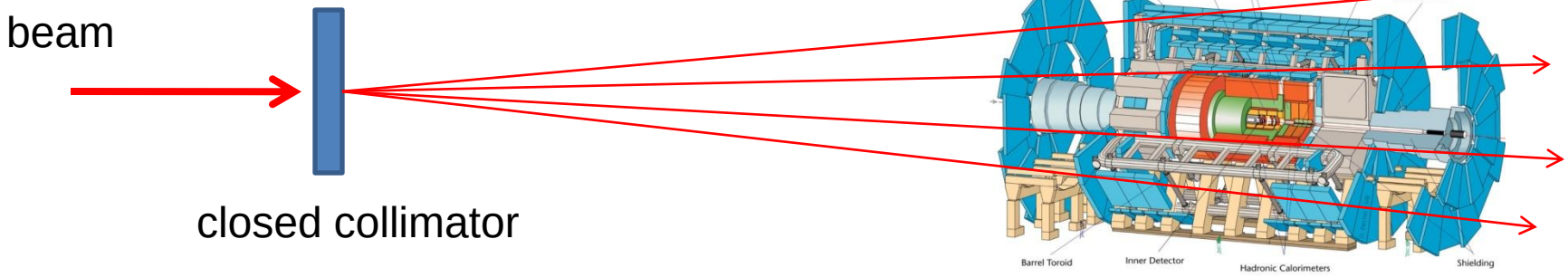
Projective muons leave a very clear signal in the LAr

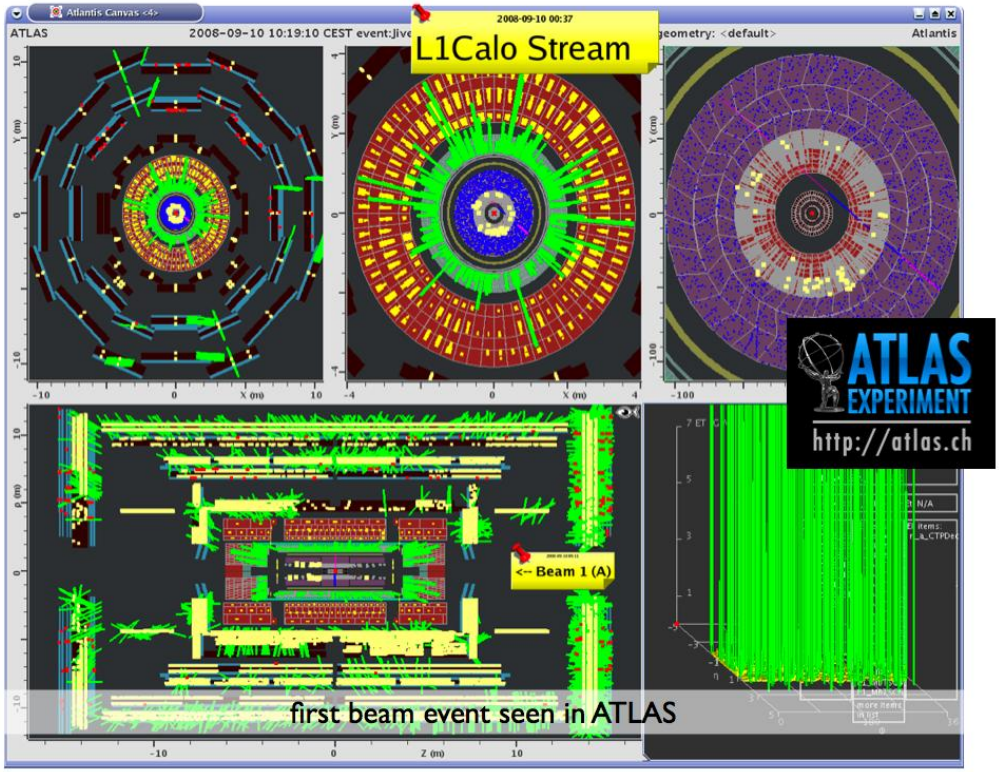
- study of the uniformity: at 1% level





LHC single beam



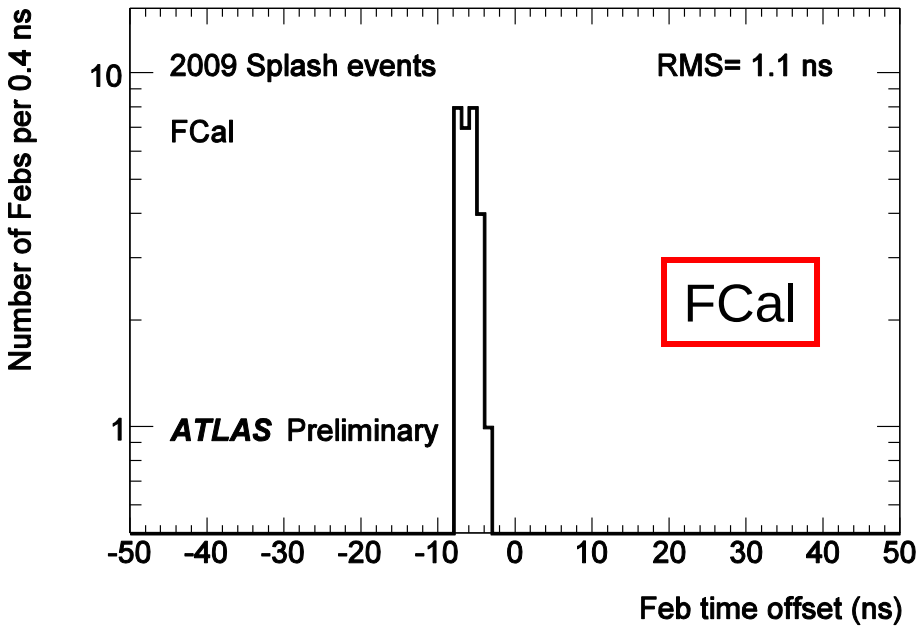


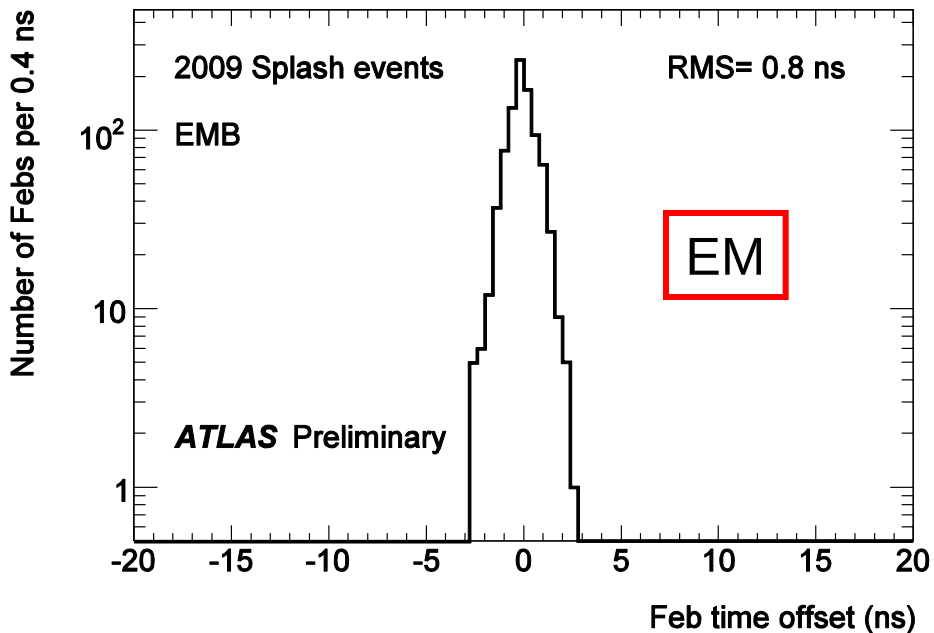
splash events using the September 2008 and November 2009 single beam data taking

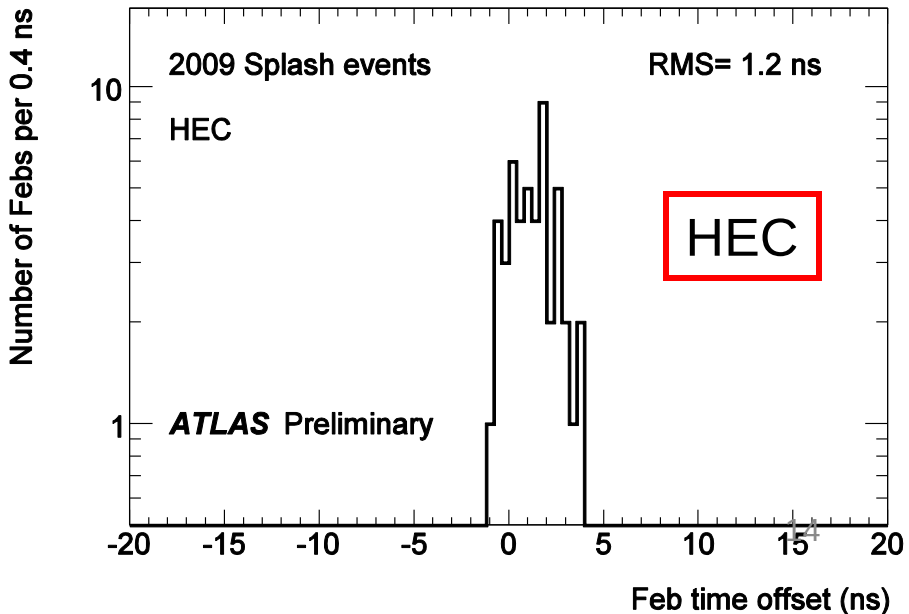
LAr Timing

Relative time per Front End Board

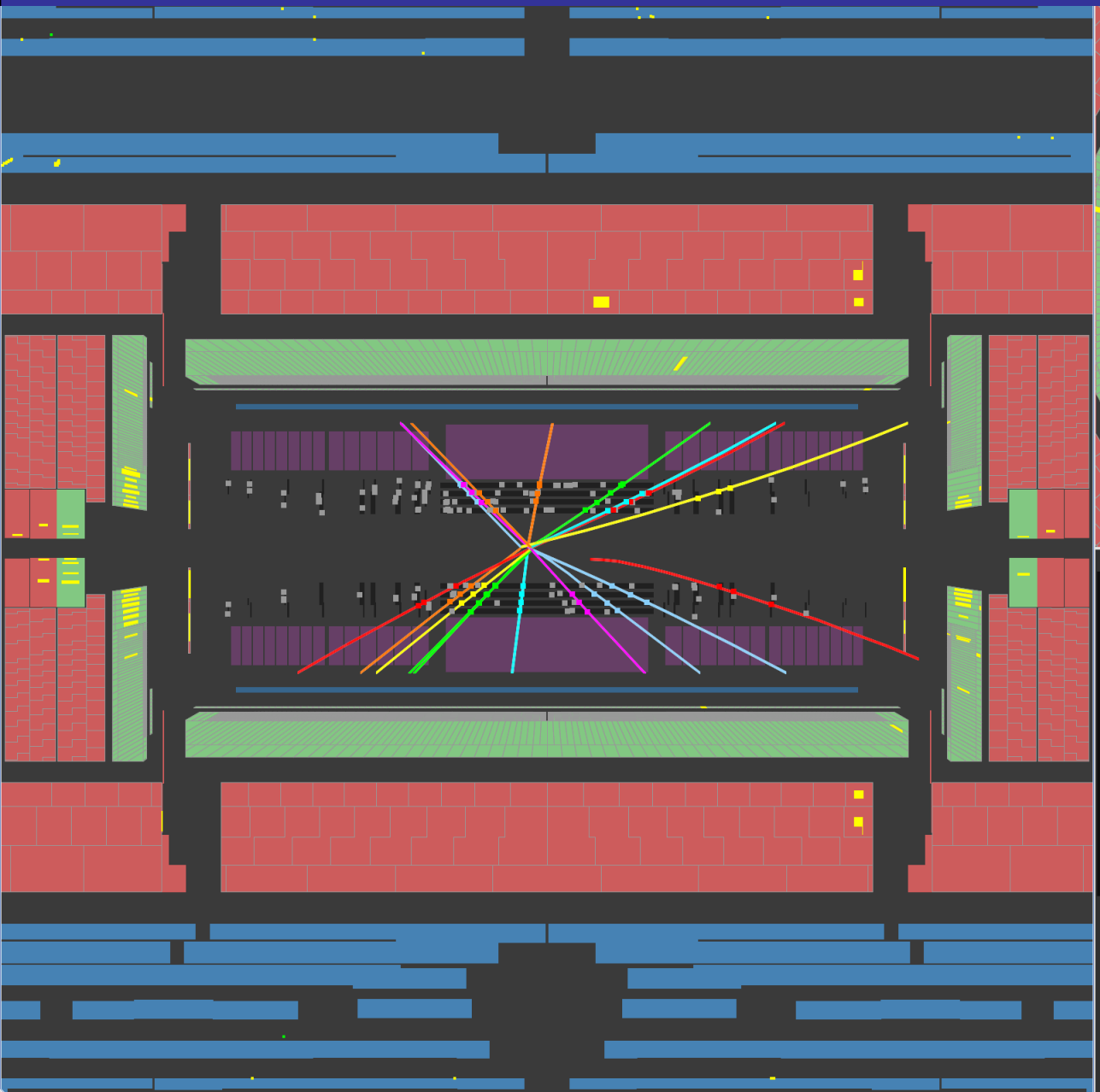
~1 ns accuracy for every sub detector

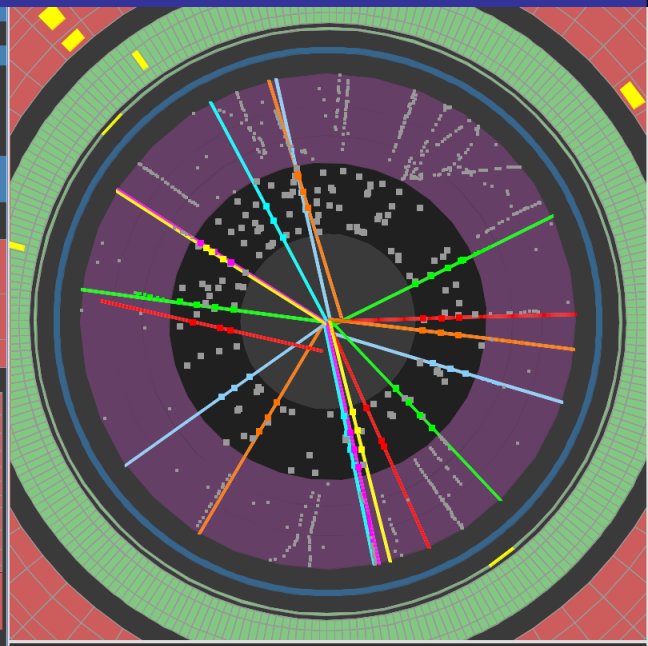






First observed collision





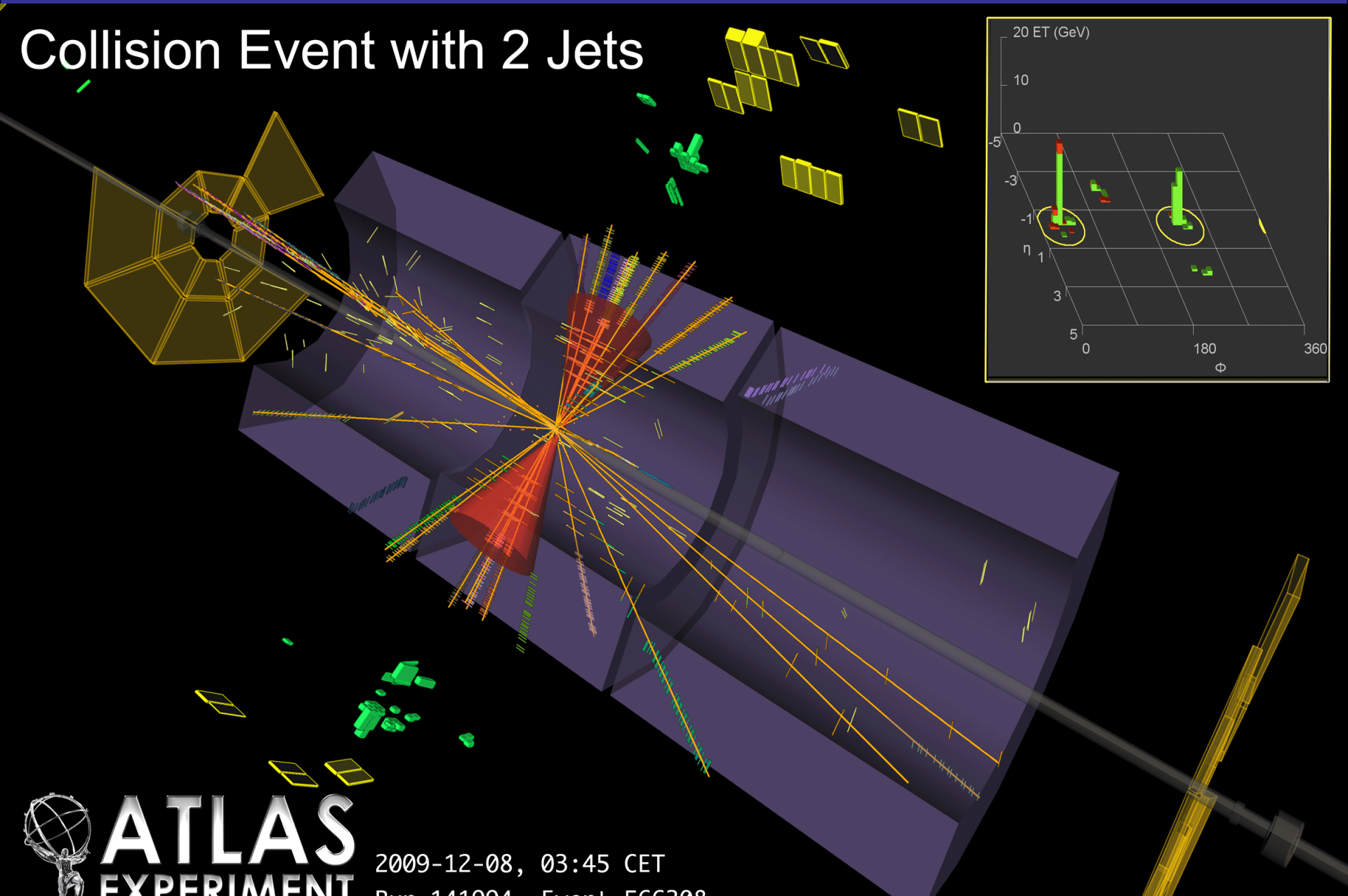
ATLAS EXPERIMENT

2009-11-23, 14:22 CET

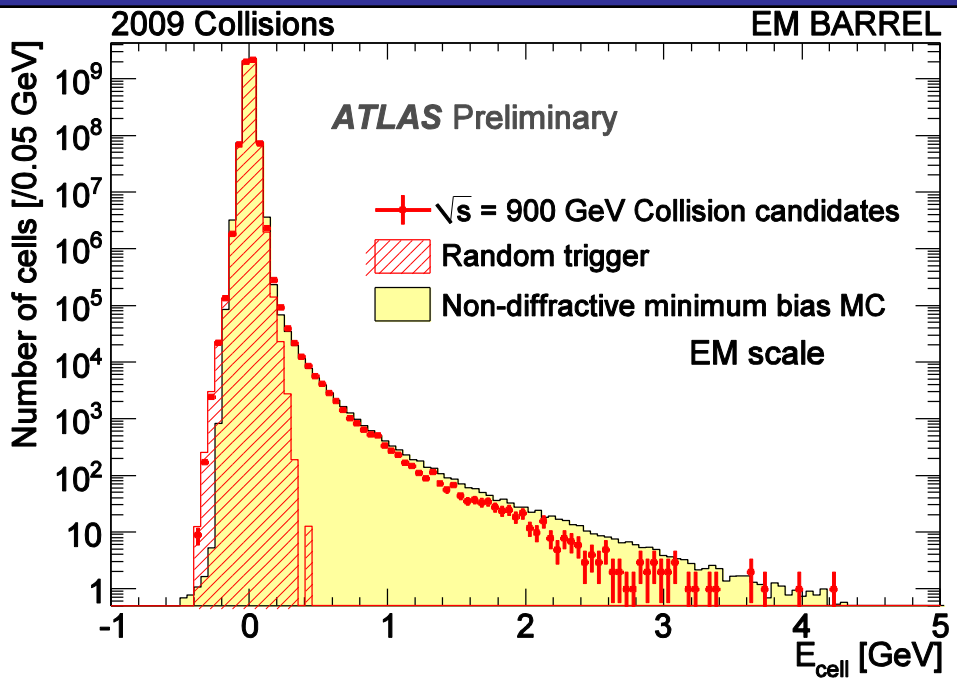
Run 140541, Event 171897

Candidate Collision Event

Collision event with 2 jets

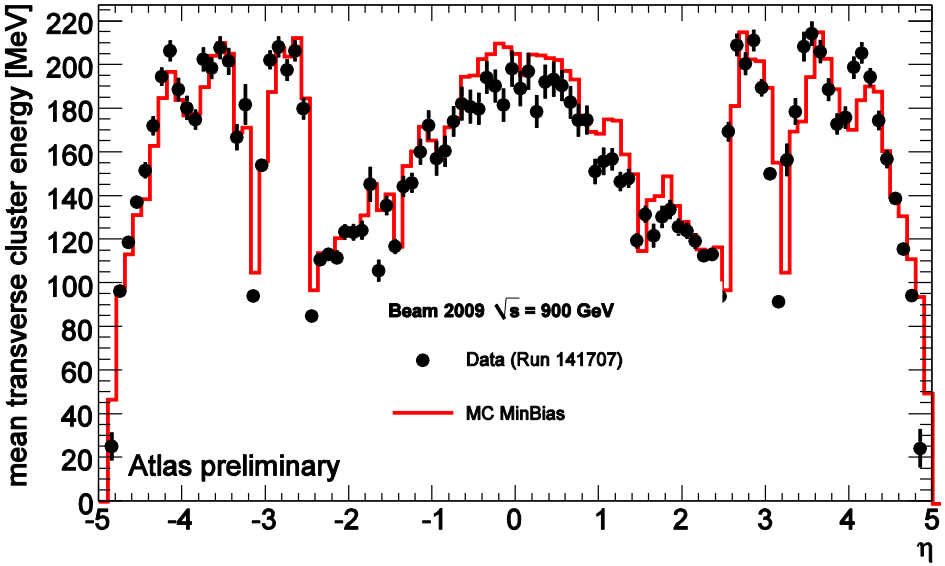


Energy in the LAr cells



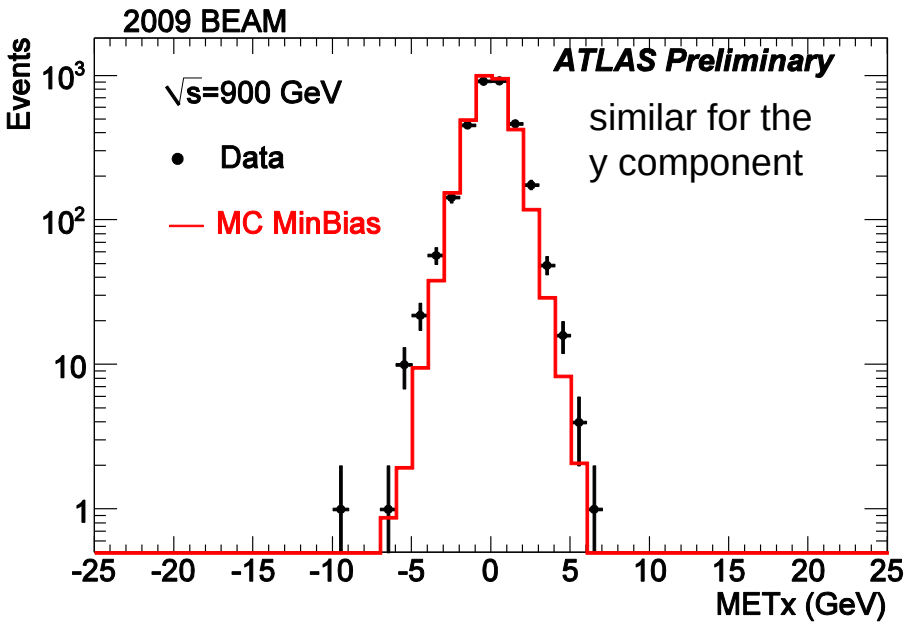
Collision energy in the LAr wrt random trigger energy

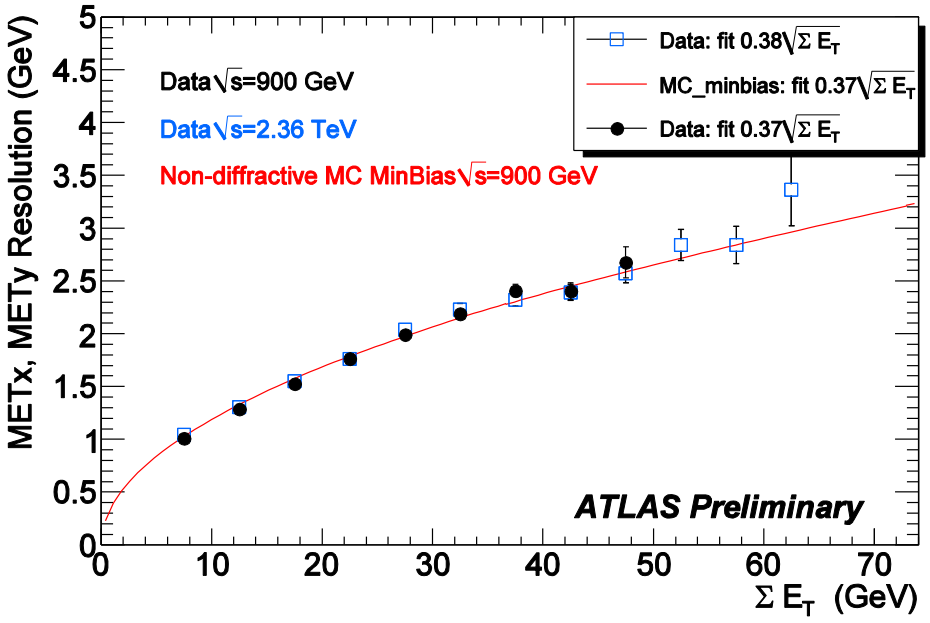
Good data-MC agreement



average E_T value all over the LAr calorimeter in collisions
cluster seeded by cells with E>4σ

Missing E_T reconstruction





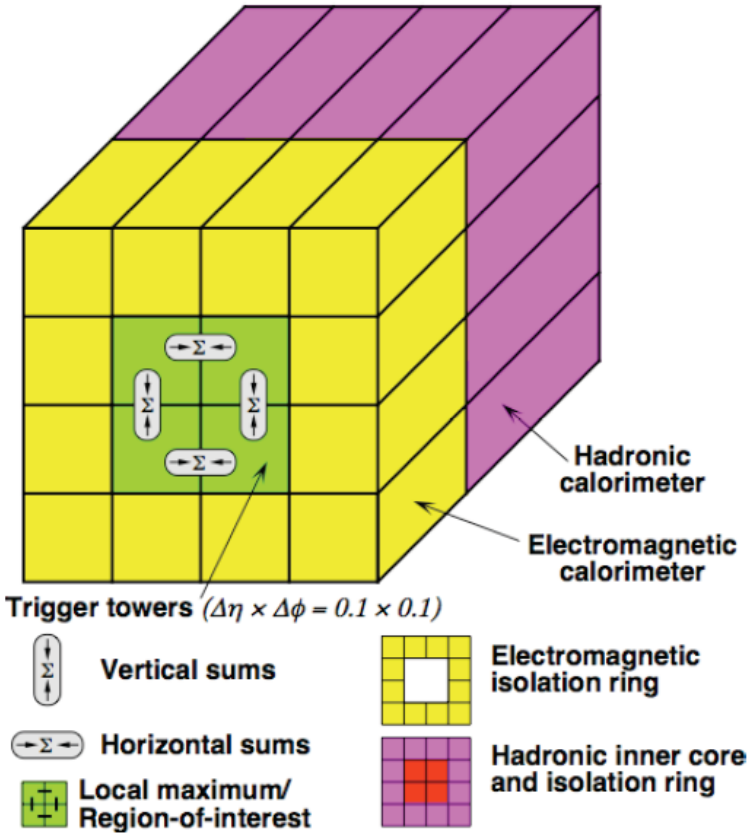
- Use of the complete calorimeter coverage (|η|<4.9)
- Take into account only cells in clusters (noise suppression)

For the moment: (next steps)

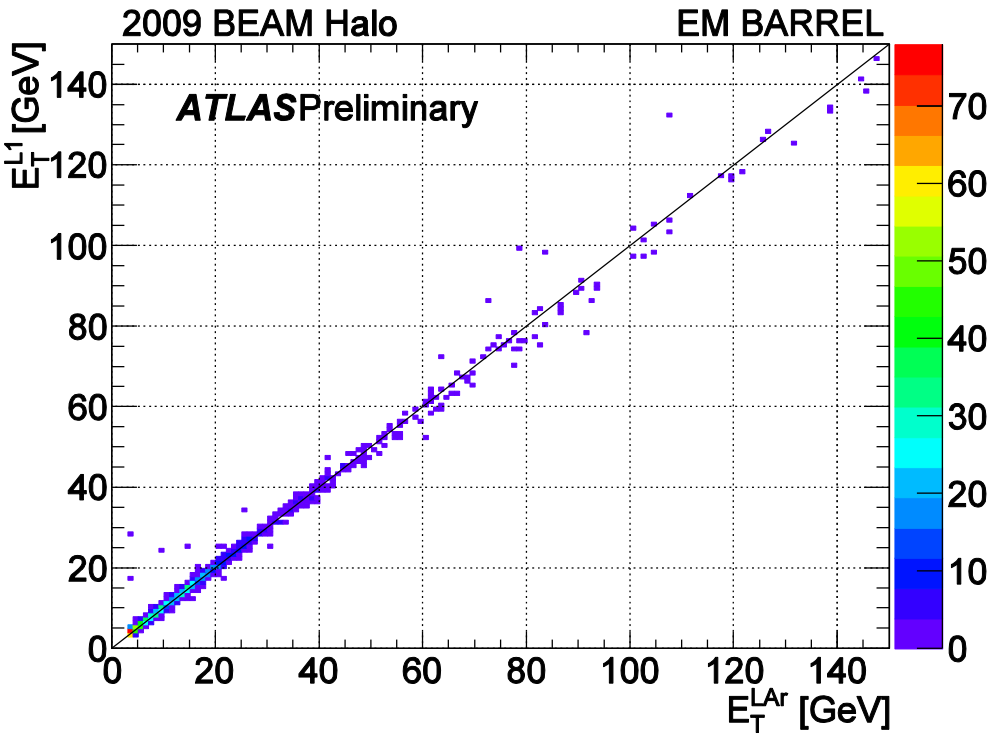
- no dedicated calibration for different final state objects (electron/photon/jet)
- no specific hadronic calibration

Good agreement between data and MC

Level 1 calorimeter trigger



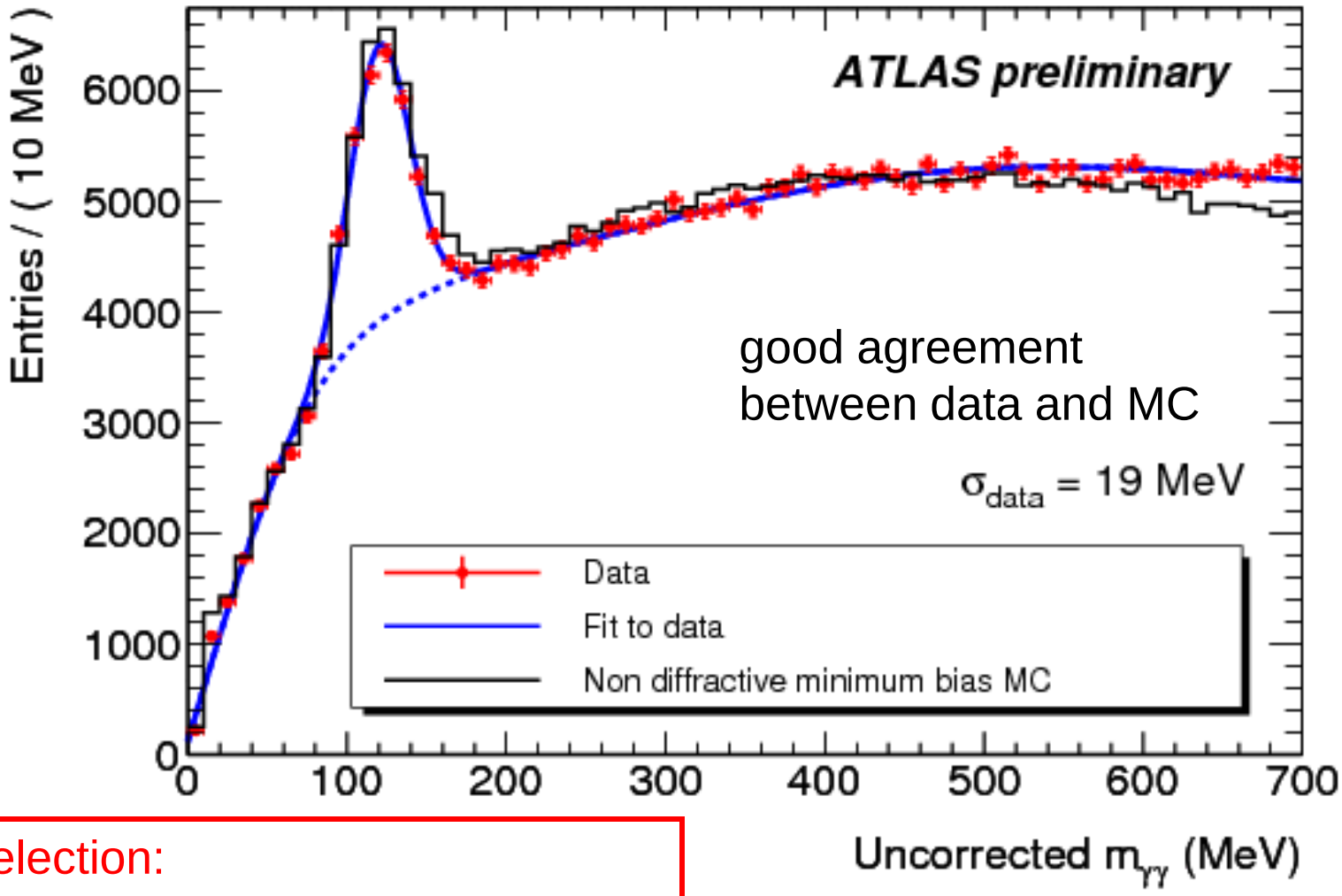
- LVL 1 calorimeter trigger
- energy sum of cells belonging to a trigger tower reconstructed online
- tower size: Δη x Δφ = 0.1 x 0.1



- Correlation with the offl reconstructed energy in 0.1x0.1

- E_T(L1) resolution < 5% for E>10 GeV

π^0 observation



π^0 selection:

- E_T (cluster) > 300 MeV
- E_T (π^0 candidates) > 900 MeV
- shower shape cut

no corrections for dead material

Conclusion

- The ATLAS LAr Calorimeter is completely installed since 2008

- Commissioning and calibration campaigns have been continuous

- It has been studied and tested using

-test beam (until 2005)
-cosmics (since 2008)
-splash events (fall 2008 and 2009)
-collisions (since November 2009)

- The LAr performance is excellent and very close to expected

Ready for the coming longer data taking !