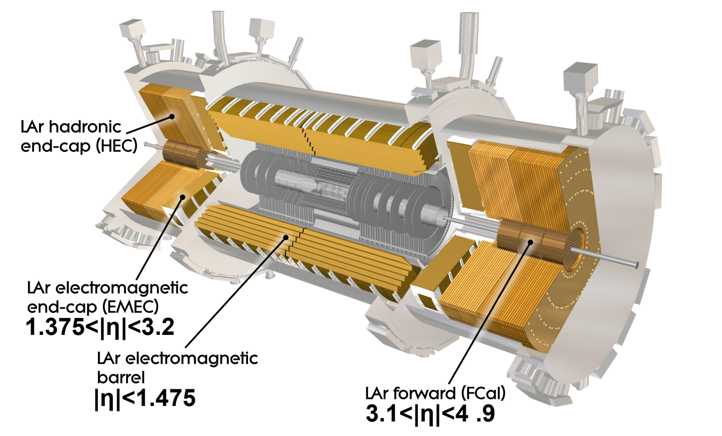
EPS Poster Session - Stockholm, 18-24th July 2013

Operation and performance of the ATLAS liquid argon electromagnetic calorimeters

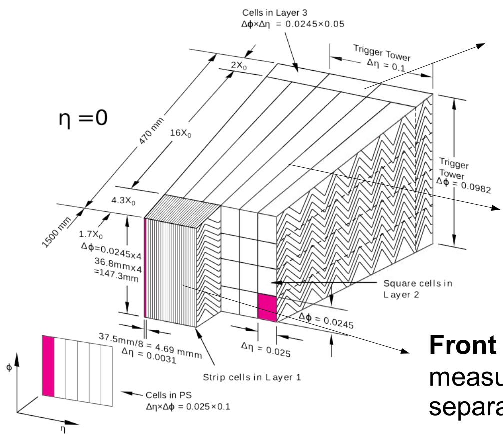
The electromagnetic calorimeter is a key component for the achievement of the ATLAS physics goals. It must provide an excellent energy resolution in a vast domain (1 GeV – several TeV) as well as great abilities for electron and photon identification. This poster presents the performances reached in the first 3 years of data taking at the LHC.



Sampling calorimeter : lead absorbers + liquid argon as ionized medium

Accordion structure : excellent uniformity in φ

Segmentation in precision region (|η|<2.5) :



Back : correct for shower energy leakage beyond calorimeter

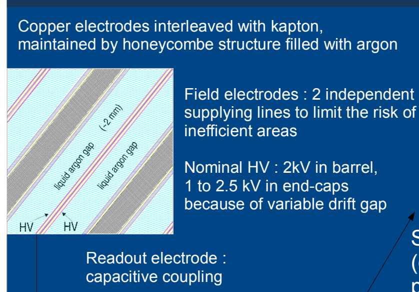
Middle : collect most of shower energy, φ measurement

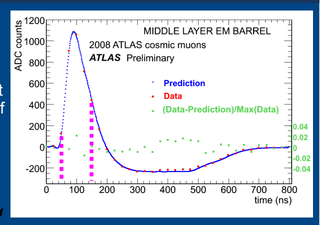
Front : precise η measurement, γ-π^0 separation

Presampler (|η|<1.8) : flat, no absorber control energy losses before calorimeter

~173k readout channels, 50% front, 30% middle

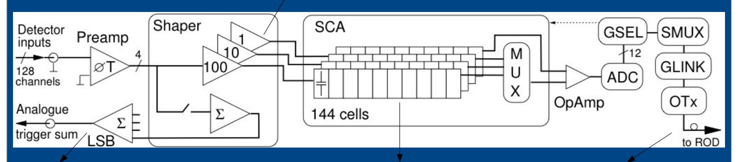
Readout and energy reconstruction





Shaping to reduce signal duration (drift time ~450 ns), out-of-time pile-up effect, and total noise

Front End Board : fast readout mounted on cryostat, 128 channels/board, 1524 boards

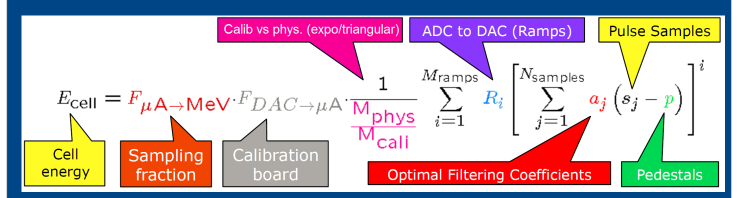


Build trigger towers L1 decision in 2 µs

40 MHz sampling 2.5 µs buffer

Optical link to back-end

Calibration up to 32 samples/event, **data-taking** 5 samples → limited by L1 rate (75 kHz) and bandwidth



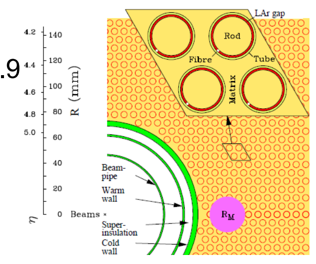
Optimal Filtering Coefficients extracted from calibration

Forward calorimeter 3.1<|η|<4.9

High particles flux → specific structure

Cylindric electrodes in copper matrix

Reduced gap size 269 µm

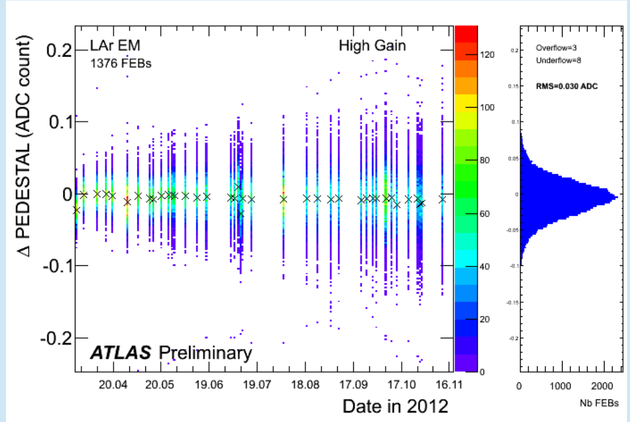


Stability during operation

Electronic calibration performed daily by injecting calibration signal, checking :

– Pedestal and noise (no signal)
– Gain
– Shape → recompute OFCs (weekly)

Stability of pedestals over 2012, all channels:

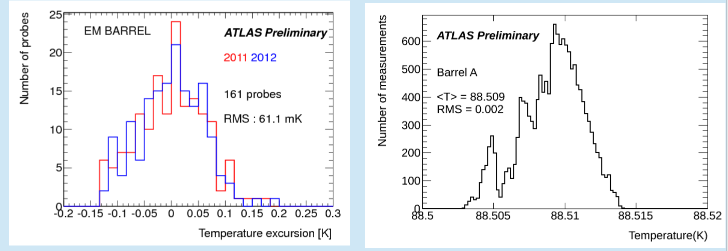


Very stable **~0.03 ADC**, gain **0.005-0.03%**

Temperature homogeneity and uniformity

508 monitoring probes in various locations

-2%/K change of energy scale (drift speed)
→ excursions must be kept below 100 mK

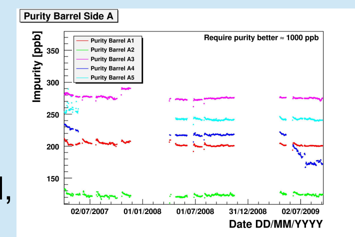


Uniformity **~60 mK**, very small excursions → no degradation of energy resolution

Liquid argon purity

Impurity level must be kept below 1000 ppb

Achieve **200 ppb** in barrel, **140 ppb** in end-caps



Data taking efficiency

ATLAS online recording efficiency : >94% for 2011+2012 → EM calorimeter contribution negligible

Data quality: fraction of recorded data good for physics

Total EM calo DQ losses in 2012 : 0.88% recorded data → used previous years experience (2011 inefficiency 3.3%)

Operational EM calo fraction: 99.9% of channels

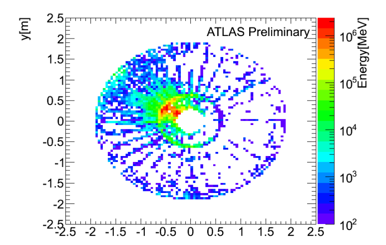
Trips of HV supply modules responsible for **0.46%** → very noisy environnement, unknown HV on electrodes

Reduced wrt 2011 losses (1%) thanks to new HV modules tolerating temporary current overload, avoiding HV trip

Quality factor very valuable tool to spot cell noise

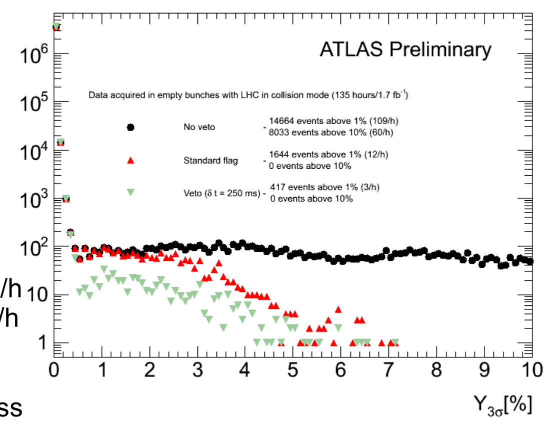
$$Q^2 = \frac{1}{nDoF}\sum_{i=1}^{n_{samples}}\frac{(A_i^{data}-A_i^{pred})^2}{\sigma_{noise}^2+\sigma_{pred}^2}$$

Comparing sampled signal and ref. shapes



Bursts of coherent noise, mostly in end-caps, with recurrent structure
– only seen in presence of collisions
– very short duration (typically 5µs)
– frequent at high luminosity, ~1/min

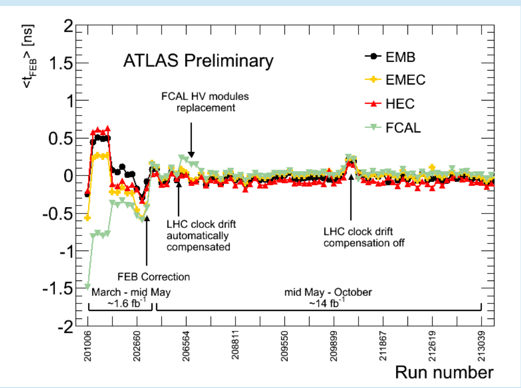
Left : end-cap cell energies in interbunch trains



Identified by fraction of cells with energy above 3σ (empty bunches) →109/h
Improved by rejecting events with many cells with bad quality factor → 12/h
Fully cleaned by time window veto (±250 ms) around candidates → 3/h
Corresponding loss on 2012 data : **~0.2%**
Early identification less efficient in 2011, noise bursts caused 1.2% data loss

Timing

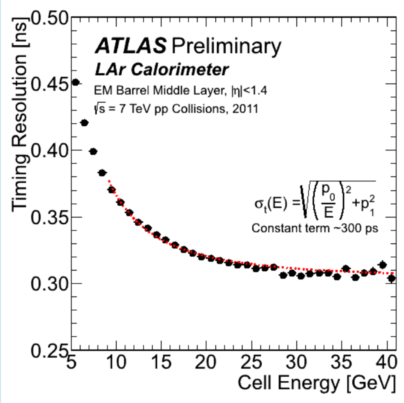
Signal timing obtained from sampled shape with different set of OFCs



FEBs aligned at O(100 ps), to be compared with nominal bunch crossing period of 25 ns

Object level (electron) **~300 ps**, including 220 ps beam spread

Application : noise cleaning (e.g. cosmics), long-lived particles



Electron and photon reconstruction

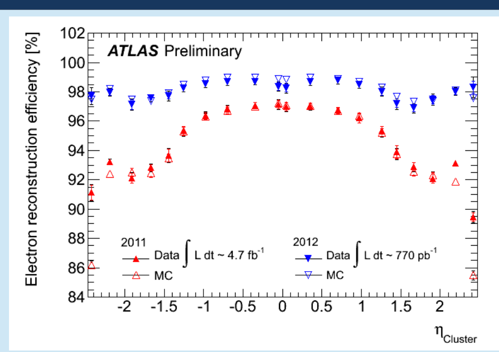
Pre-clusters 3×5 middle cells, local E_T maximum, E_T>2.5 GeV

Track found in Δη×Δφ=0.05×0.1→ **electron**
final cluster 3×7 (barrel) or 5×5 (end-cap)

No track → **unconverted photon**
final cluster 3×5 (barrel) or 5×5 (end-cap)

Track + conversion vertex → **converted photon**
same cluster as electron

2012 : refitted tracks with Brehmsstrahlung emission model → improved efficiency, especially low E_T / high η



Energy calibration for electrons and photons

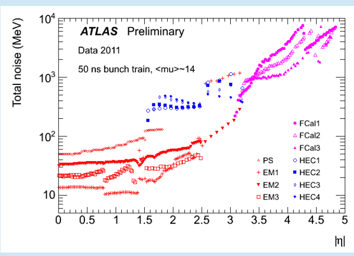
Calorimeter energy resolution:

$$\sigma/E_T = a/\sqrt{E_T} \oplus b/E_T \oplus c$$

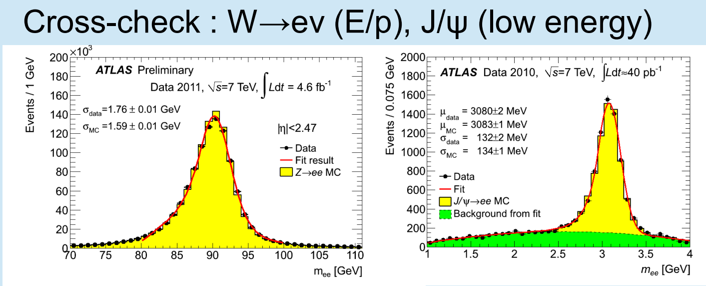
a stochastic term **~10%**
Shower particles stopped in absorber

b noise, negligible at high E_T
Electronic (preamplifiers) + pile-up

c constant term, design **0.7%**
Inhomogeneities in cell geometry, or temperature, material in front of calorimeter, local mis-calibration



Absolute energy scale determined *in situ* from reconstructed Z→ee invariant mass
Cross-check : W→eν (E/p), J/ψ (low energy)



Scale corrections **~2%** barrel, **~4%** end-caps

Cluster calibration corrects for fine geometry effects and accounts for various losses :

$E = E_{front}$ Material in front of calorimeter

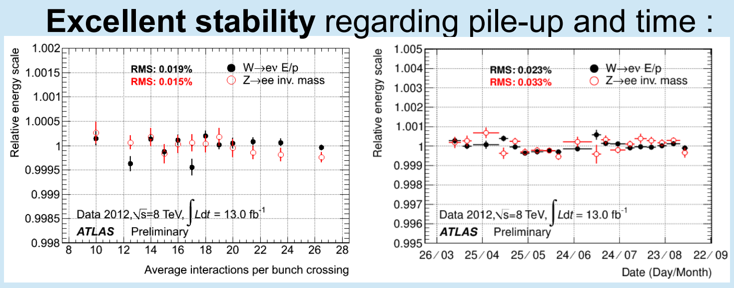
$+ E_{calo}$ Cluster + out-of-cluster

$+ E_{back}$ Longitudinal leak in hadronic calorimeter

Contributions parametrized by functions of η, longitudinal barycenter, and fraction of energy in presampler
Simulation used to tune parametrization, using dedicated samples recording energy deposits in all passive detector material

Angular resolution(design): Δη~**3 10^{-4}**, Δφ~**1mrad**

Excellent stability regarding pile-up and time :



Energy resolution also measured from Z peak

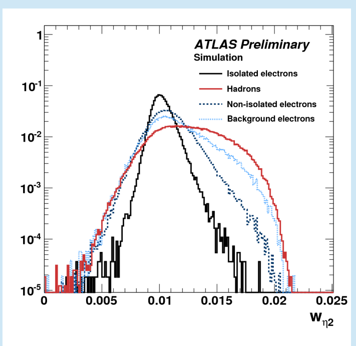
Subsystem	η-range	Effective constant term, c_{data}
EMB	$\lvert\eta\rvert < 1.37$	$1.2\% \pm 0.1\%(\text{stat})^{+0.5\%}_{-0.6\%}(\text{syst})$
EMEC-OW	$1.52 < \lvert\eta\rvert < 2.47$	$1.8\% \pm 0.2\%(\text{stat}) \pm 0.4\%(\text{syst})$
EMEC-IW	$2.5 < \lvert\eta\rvert < 3.2$	$3.3\% \pm 0.2\%(\text{stat}) \pm 1.1\%(\text{syst})$
FCal	$3.2 < \lvert\eta\rvert < 4.9$	$2.5\% \pm 0.4\%(\text{stat})^{+1.0\%}_{-1.5\%}(\text{syst})$

Future gains by improved material mapping

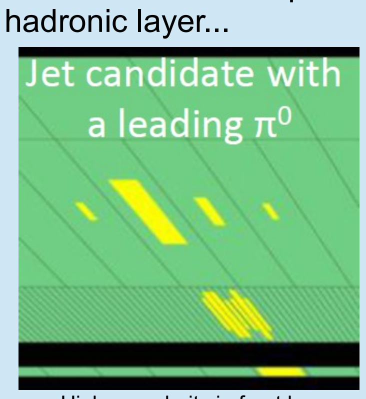
Electron and photon identification

EM calorimeter crucial for particle identification

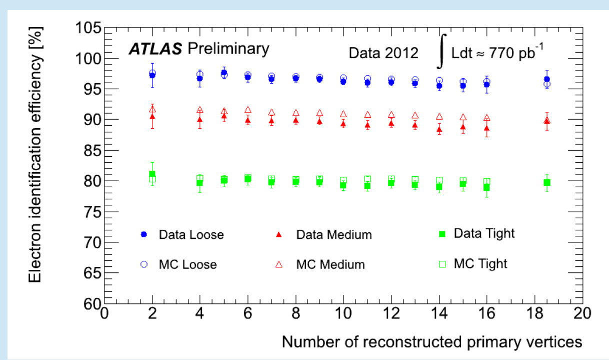
Discriminant variables built on shower shape : lateral width, leakage in hadronic layer...



Shower width in middle layer

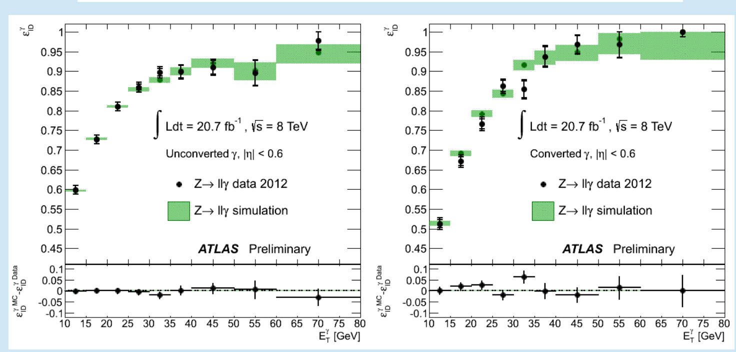


High granularity in front layer allowing resolution of π^0→γγ



Electron ID further makes use of track quality, track-cluster matching, transition radiation with TR tracker...

Efficient electron ID also in 2.5<|η|<4.9

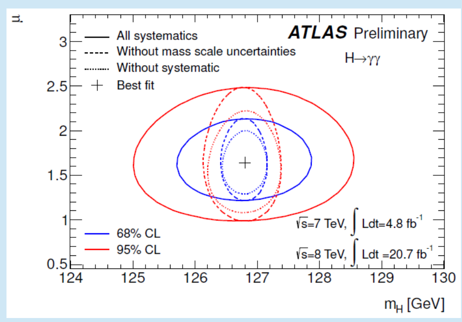


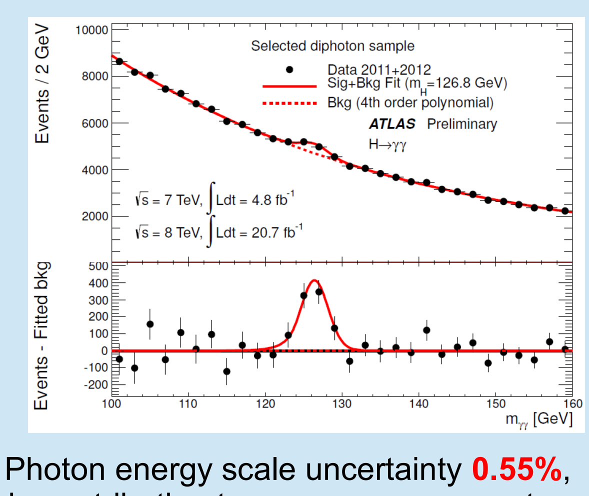
Implication in Higgs boson mass measurement

Particularly important in H→γγ search :

– **Large background** (jj+γj) requires excellent photon ID

– **Narrow** invariant mass resonance needed to disentangle signal from continuous irreducible background
→ excellent energy resolution
→ excellent angular resolution, achieved in particular by vertex pointing with front and middle layer cluster barycenters





→ Photon energy scale uncertainty **0.55%**, main contribution to mass measurement

→ negligible vertex contribution to invariant mass resolution (overall 1.7 GeV)

H→4e requires high efficiency electron ID, and good energy resolution

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