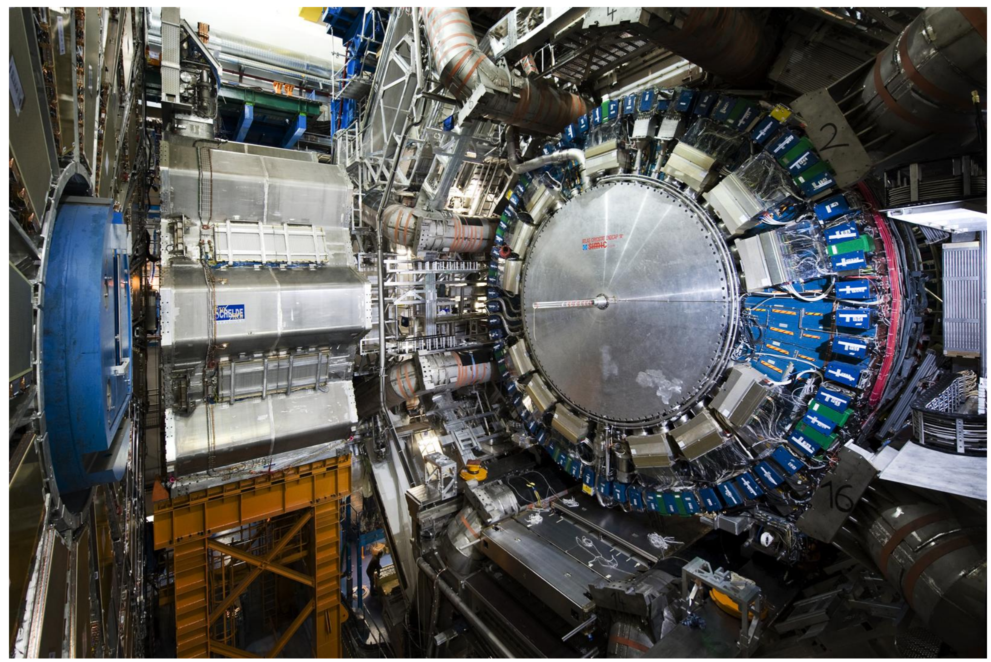
The ATLAS Calorimeter

Dresden — 4th Annual Workshop of the Helmholtz Alliance "Physics at the Terascale" — 1-3 Dec. 2010

- LHC and ATLAS
- ATLAS Calorimeters
- Status and Performance
- Upgrade
- Conclusions



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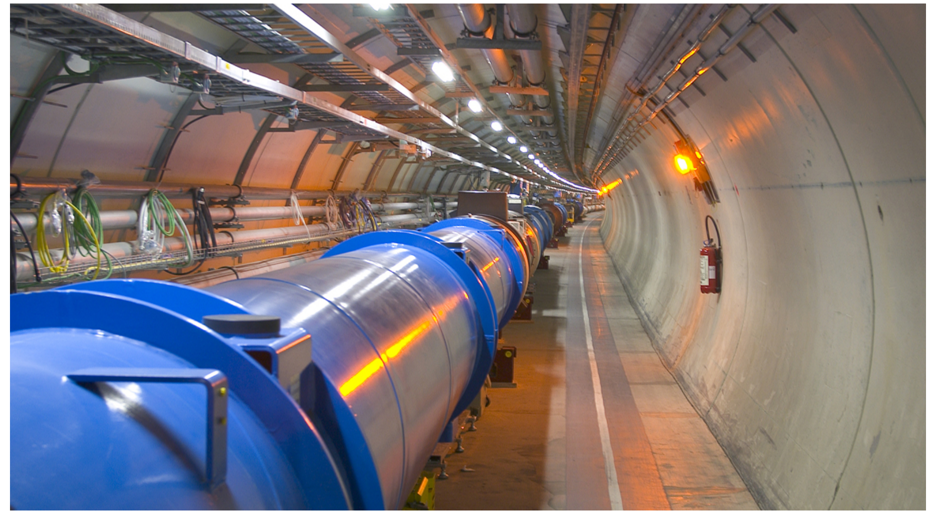
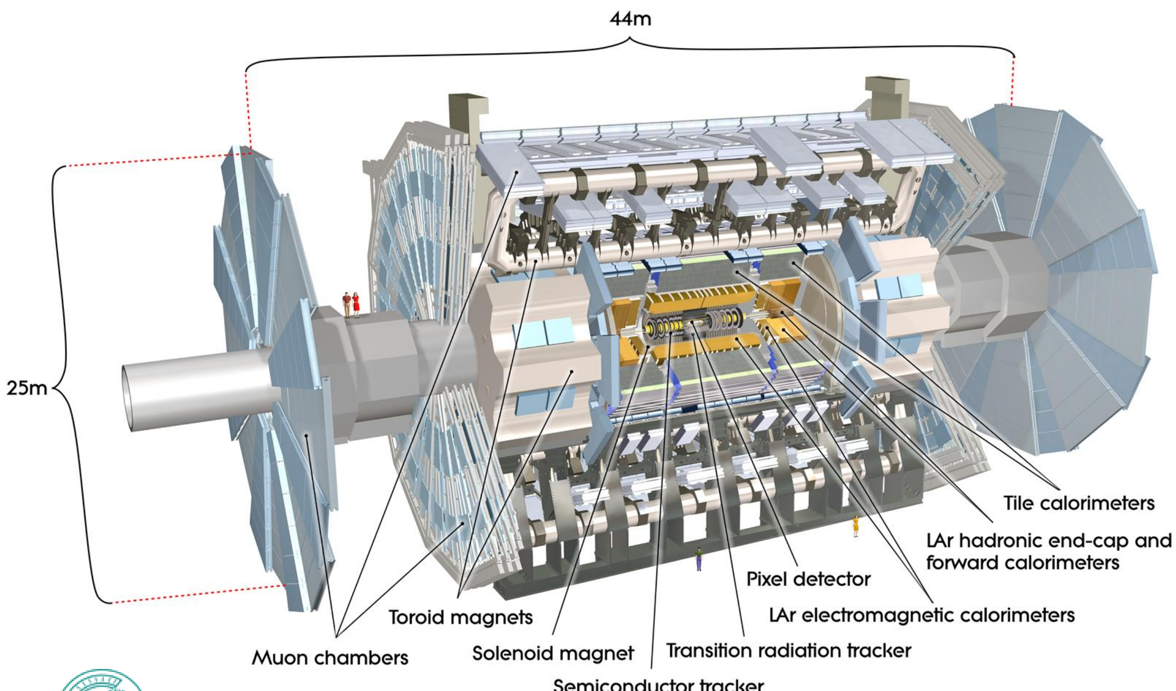
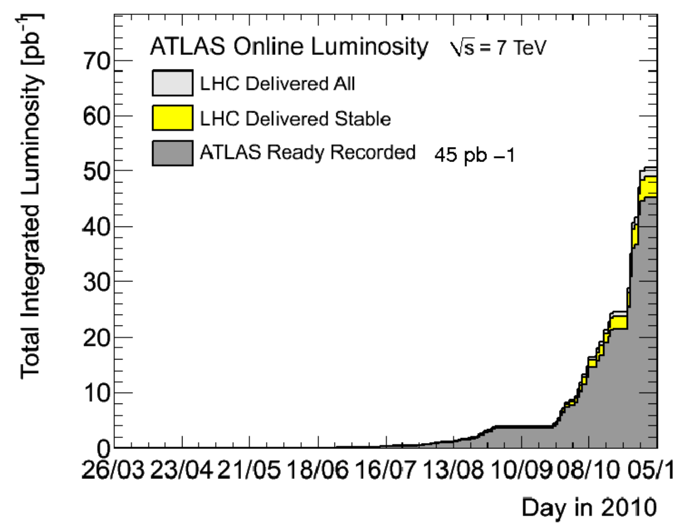
LHC and ATLAS

- The **Large Hadron Collider (LHC)** at CERN is operating and taking data:
  - In Dec. 2009, pp collision at $\sqrt{s} = 0.9\,\text{TeV}$ & $2.36\,\text{TeV}$
  - From March till Nov. 2010, pp collision at $\sqrt{s} = 7\,\text{TeV}$
  - From Nov. till Dec. 2010, Pb Pb collision $\sqrt{s_{NN}} = 2.76\,\text{TeV}$



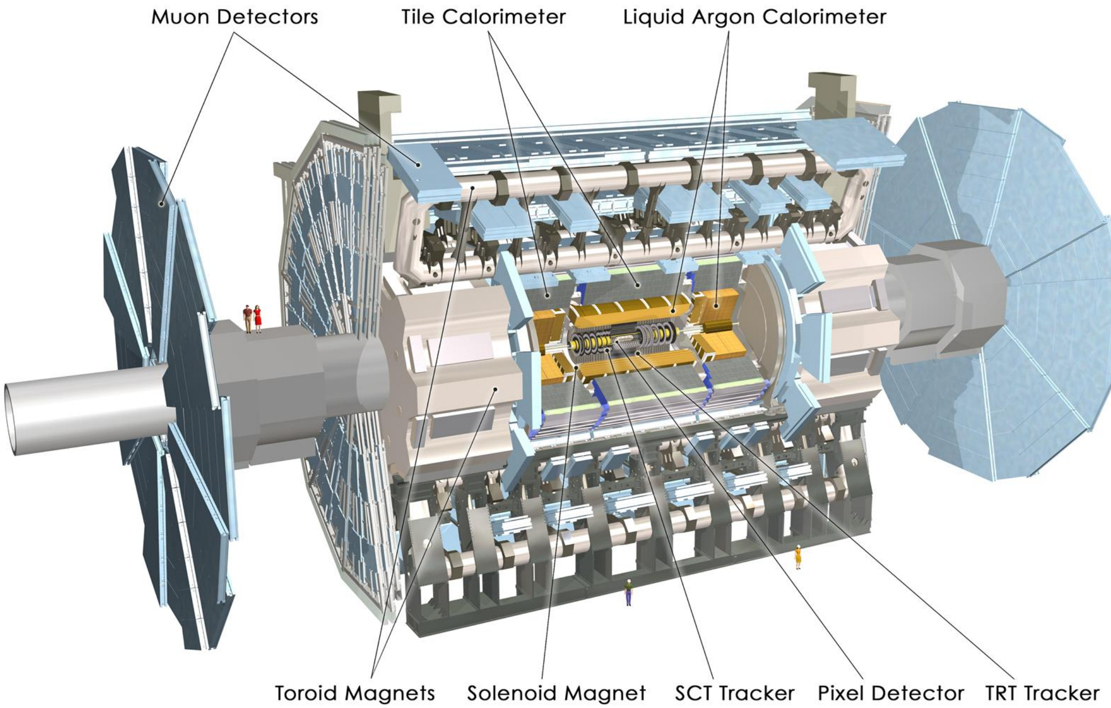
- **ATLAS: A Toroidal LHC ApparatuS**





The ATLAS Calorimeter

- With the LHC running at high luminosity the ATLAS calorimeters will play a key role in many physics measurements
- They are required to perform accurate measurements of e, γ, τ, jets, and missing E_T
- To minimize the impact of the pile-up on the physics performance it is required to have "fast" calorimeter response (< 50 ns) and fine granularity
- High radiation resistance for a period of at least 10 years

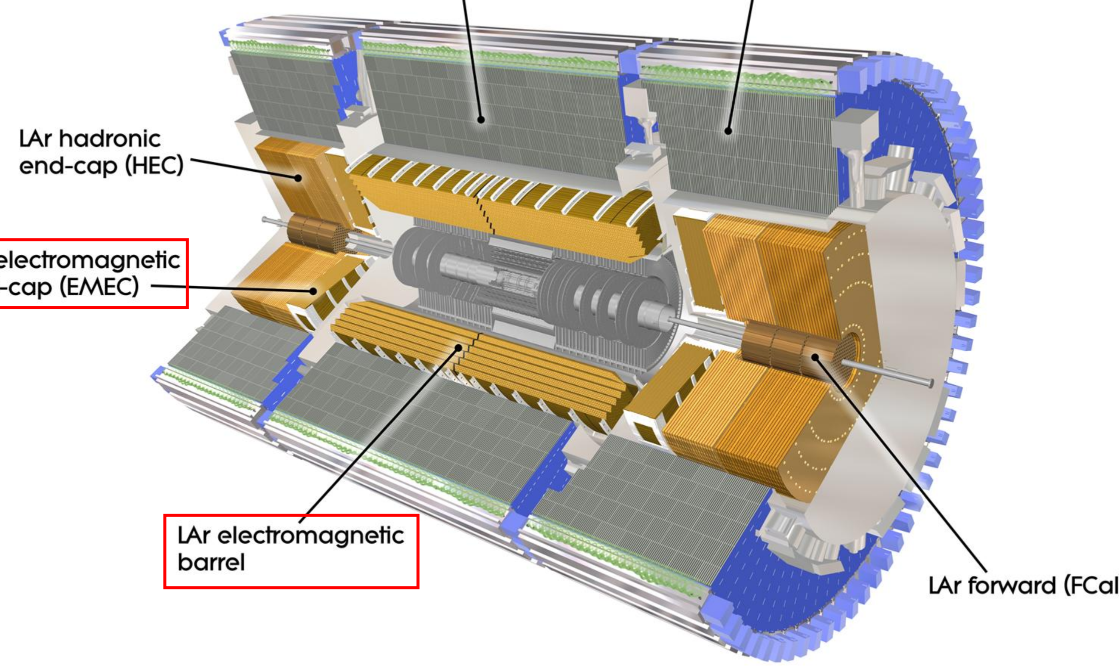


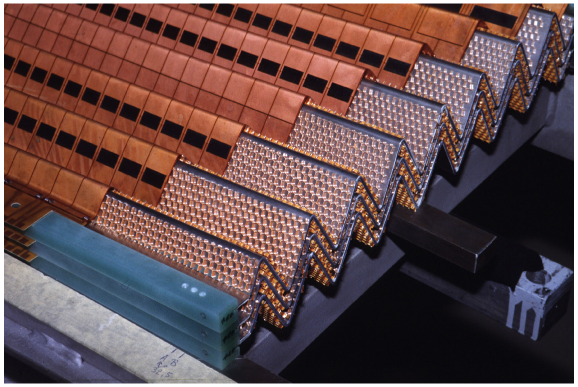
The ATLAS calorimetry consists of

- LAr Electromagnetic calorimeter (EM)
- LAr Hadronic end-cap calorimeter (HEC)
- LAr Forward calorimeter (FCAL)
- Barrel hadronic calorimeter (TileCal)

LAr Electromagnetic Calorimeters: EM

- The **LAr EM** is a Pb/LAr sampling calorimeter with accordion geometry
- Coverage $|\eta| < 3.2$
- It consists of:
  - 1 LAr EM Barrel (EMB): $|\eta| < 1.475$
  - 2 LAr EM End-Caps (EMECA, EMECC): $1.375 < |\eta| < 3.2$
  - A presampler PS: $|\eta| < 1.8$
  - 173312 readout channels
  - **$98.5\,\%$ channels operational**
  - Design resolution: $\sigma(E)/E = 10\%/\sqrt{E(GeV)} \oplus 0.7\%$

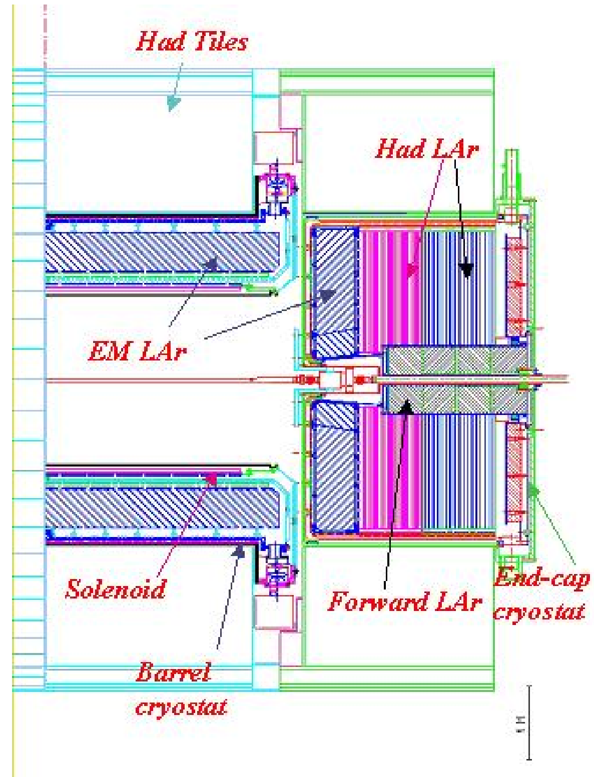




LAr HEC and FCAL Calorimeters

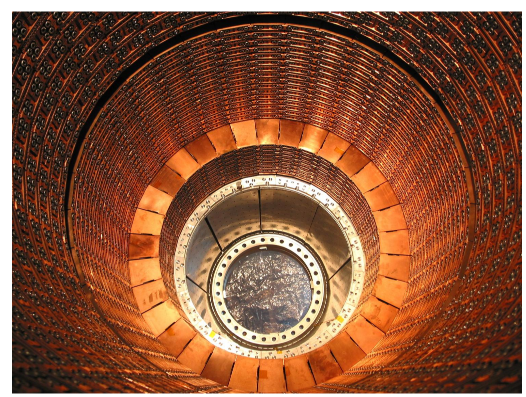
- The **LAr HEC** is a Cu/LAr sampling calorimeter with 4 longitudinal samplings
- Coverage: $1.5 < |\eta| < 3.2$
- It consists of:
  - 2 end-caps: HECA, HECC
  - 4 wheels, 4×32 modules
  - 5632 readout channels
  - 99.9% **operational**
  - $\Delta\eta \times \Delta\phi$ of 0.1×0.1 and 0.2×0.2 for $\eta > 2.5$
  - Cold electronics
  - Design resolution:

    $\sigma(\mathrm{E})/\mathrm{E} = 50\%/\sqrt{\mathrm{E(GeV)}} \oplus 3\%$



- The **LAr FCAL** is a Cu/W-LAr sampling calorimeter
- Coverage: $3.1 < |\eta| < 4.9$
  - 3524 readout channels
  - 100% **operational**
  - Design resolution:

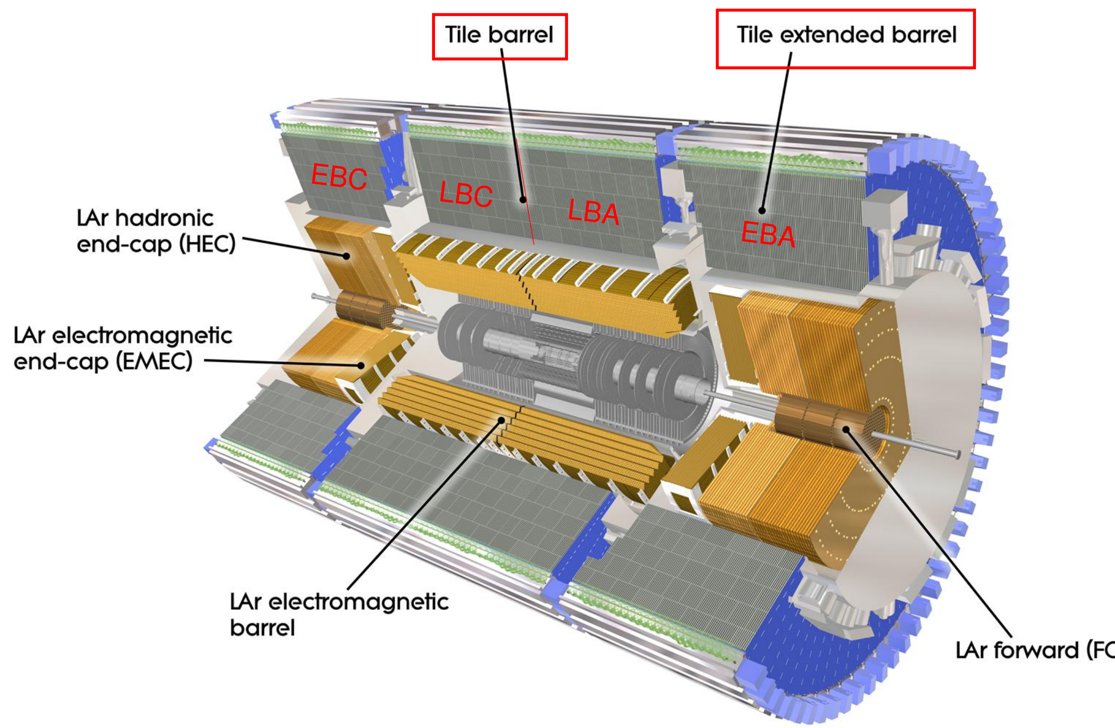
    $\sigma(\mathrm{E})/\mathrm{E} = 100\%/\sqrt{\mathrm{E(GeV)}} \oplus 7\%$



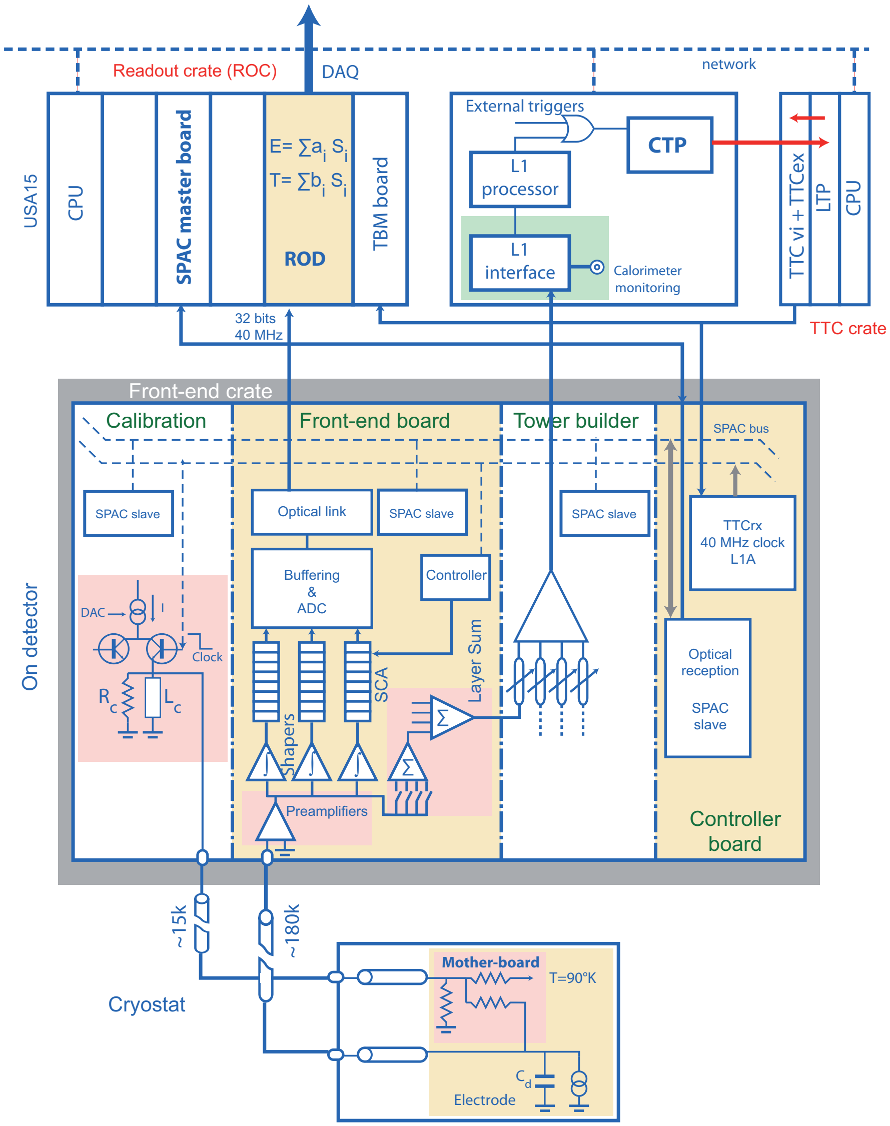
The Barrel Hadronic Calorimeter

- The **Atlas TileCal** is a sampling calorimeter using iron/plastic scintillators tiles
- Light transported through wavelength shifting optical fibers to photomultipliers
- Coverage $|\eta| < 1.7$
- It consists of:
  - 2 long barrel partitions: LBA, LBC
  - 2 extended barrel partitions: EBA, EBC
  - Total 4×64 modules in ϕ
  - Granularity $\Delta\eta \times \Delta\phi$ of 0.1×0.1 and 0.2×0.1 in last radial layer
  - Total 5182 cells
  - **97.1% cell operational**
  - 256 front-end electronics: Super Drawers (SD)
  - 256 Low Voltage PS
  - Design resolution:

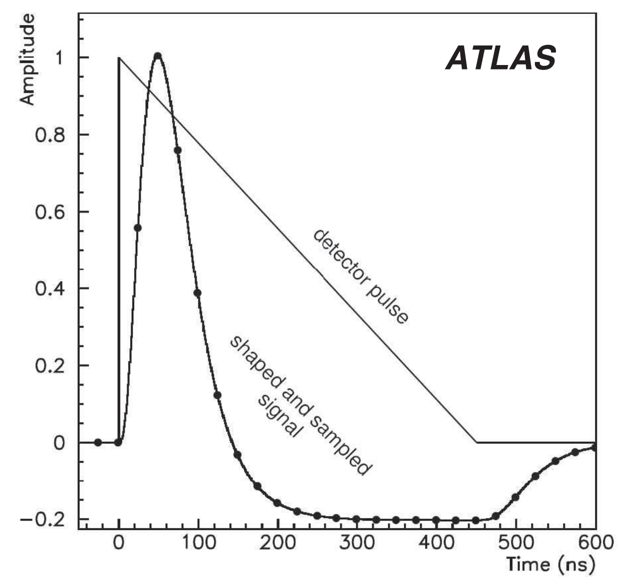
$$\sigma(E)/E = 50\%/\sqrt{E(GeV)} \oplus 3\%$$



LAr Signal Reconstruction



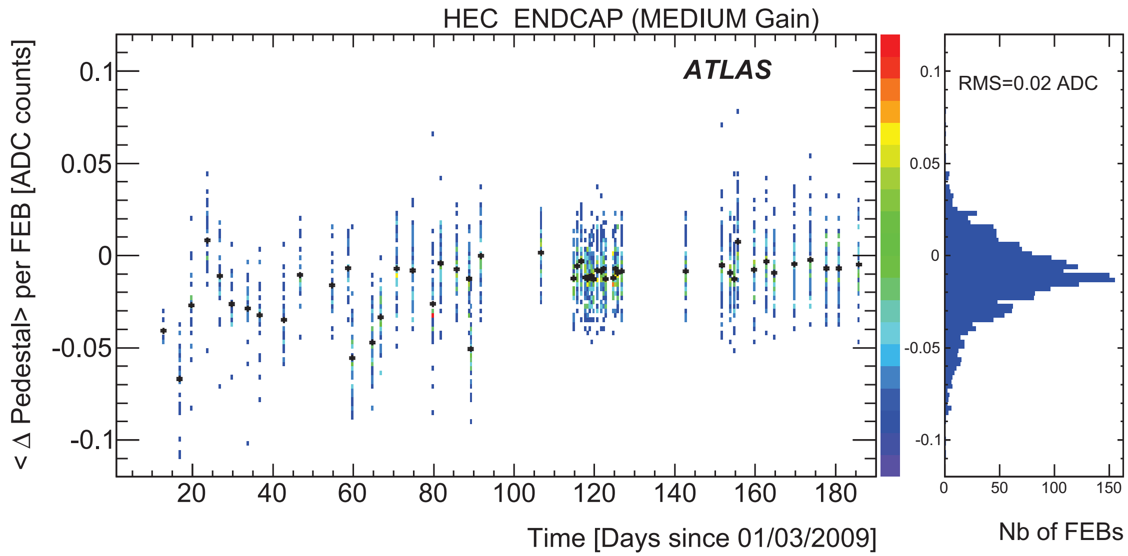
- **FEB:** signal amplification and shaping (except HEC) at 40 MHz (shortly stored) and digitized if event passed L1 trigger decision
- **ROD:** cell energy reconstruction using Optimal Filtering (OF) algorithm

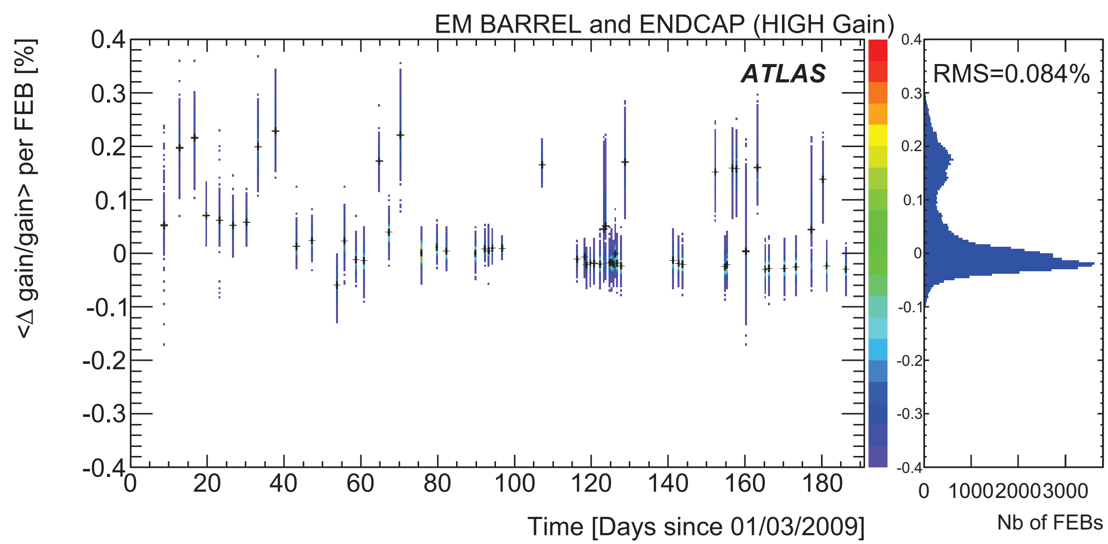


Shaped signal, digitized. Sampled at 40MHz

LAr Calibration Stability

- The stability of the properties of each readout channel (pedestal, gain, noise) essential for the calorimeter
  - Calibration runs are taken every LHC fill
  - Calibration constants are updated every a few weeks
  - Stability of the constants are monitored for long periods
- Pedestal: < 0.03ADC count for all calorimeters
- Gains: < 0.1 for all calorimeters
- **Robust calibration procedure**
- **Good electronic stability**

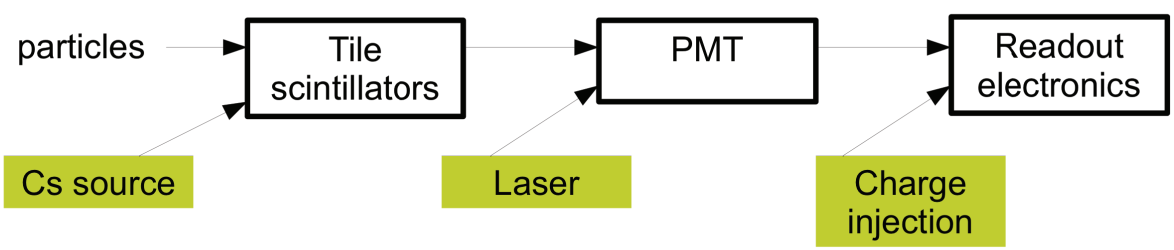




arXiv:0912.2642v4 [physics.ins-det]

TileCal Calibration

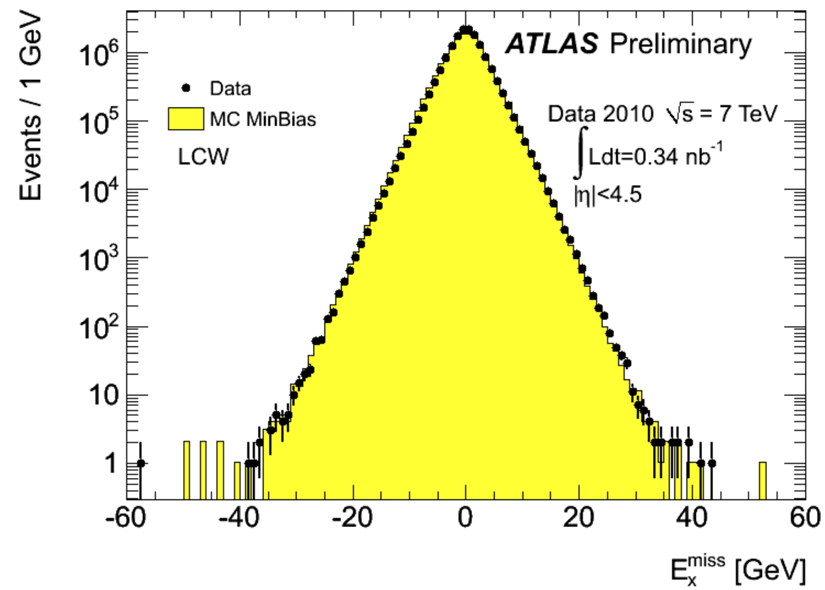
- EM scale calibration:
  - Set with a beam of electrons on 11% of the modules and propagated to all the others with the calibration systems
- 3 calibration systems:
  - ^{137}**Cesium** : allow to equalize cell response (precision 0.3%)
  - **Laser** : Monitor the PMT gain, and the timing of channels
  - **Charge injection** : ADC counts to pC monitoring, stability in time better than 0.1%
  - Used cosmics in the cavern to validate the EM scale set at test beam
- Each calibration proved stability well below 1%

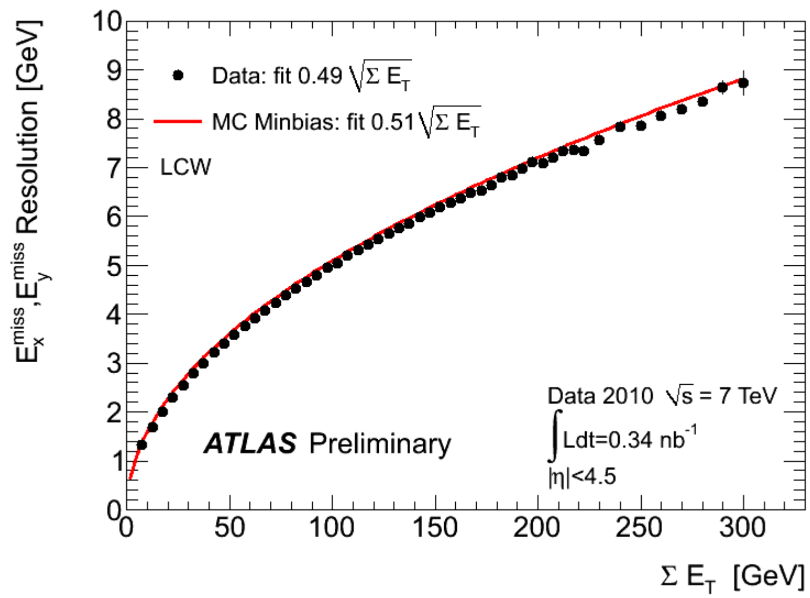


arXiv:1007.5423v2 [physics.ins-det]

Missing E_T

- Signature of W bosons are νs "escaping" detection
- Missing transverse momentum (E_T^{miss}) , very sensitive to
  - Calorimeter performance: dead and noisy channels, mis-calibration
  - non-collision background
- **No tails observed in data after "cleaning" and calibration"**
- **Resolution as expected from MC**

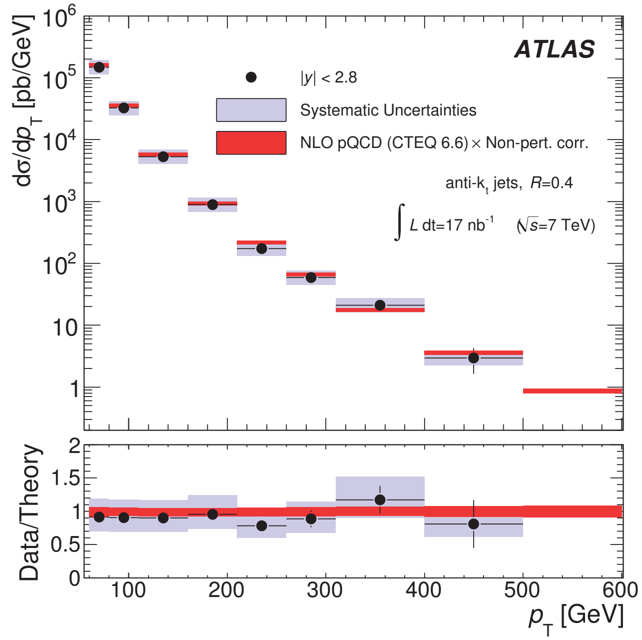




See: ATLAS-CONF-2010-057

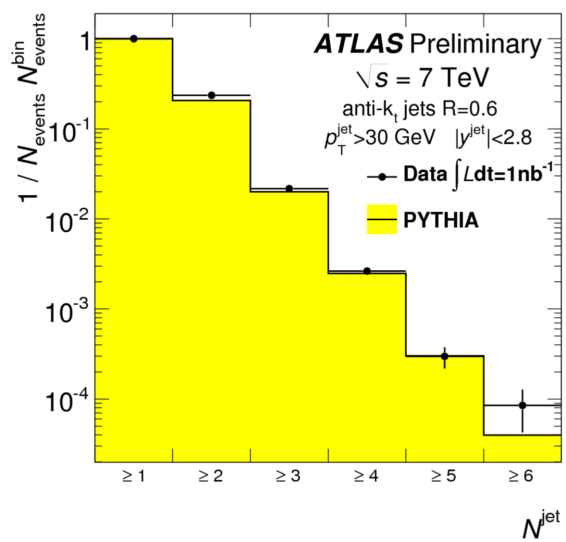
Jet Physics

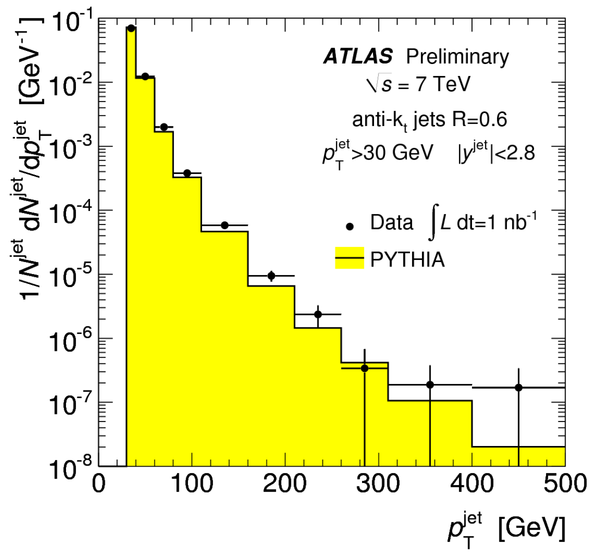
- Jet cross-section is well described over 5 orders of magnitude.
    - Uncertainty is 30 – 40%
    - Dominated by Jet Energy Scale (known at 7%, final aim is to achieve 1%)



See: arXiv:1009.5908v2 [hep-ex]

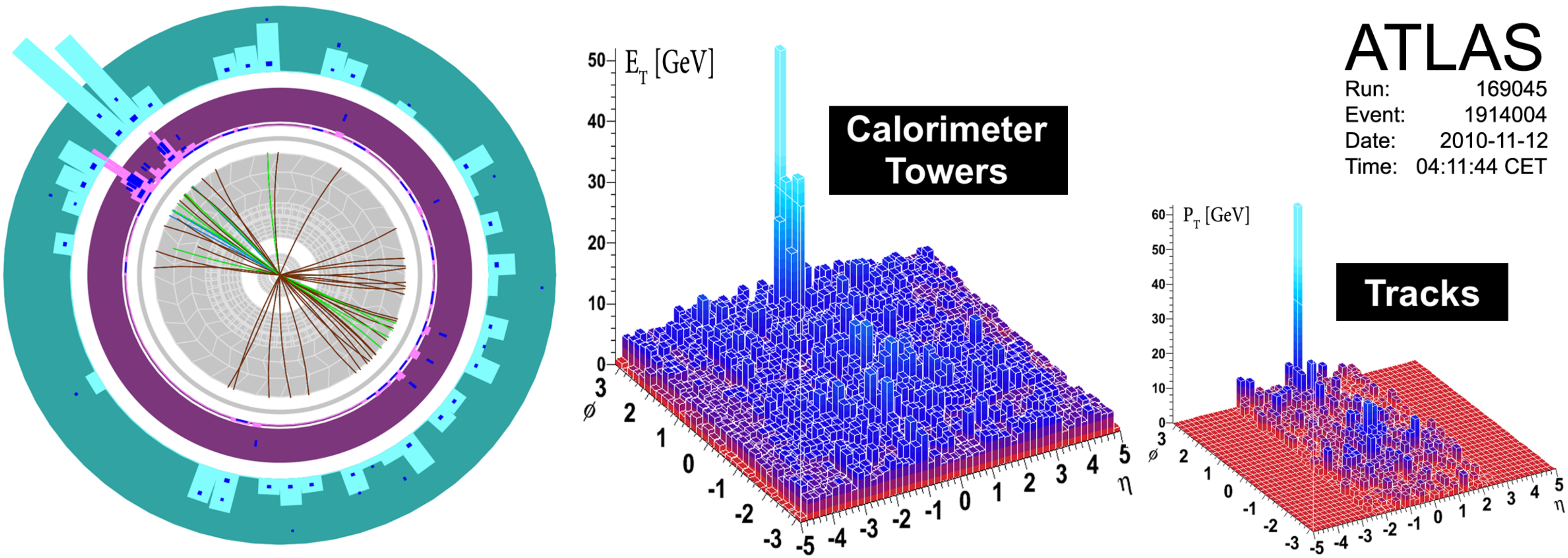
- **Accessing very high energy jet multiplicity regions**





ATLAS-CONF-2010-043

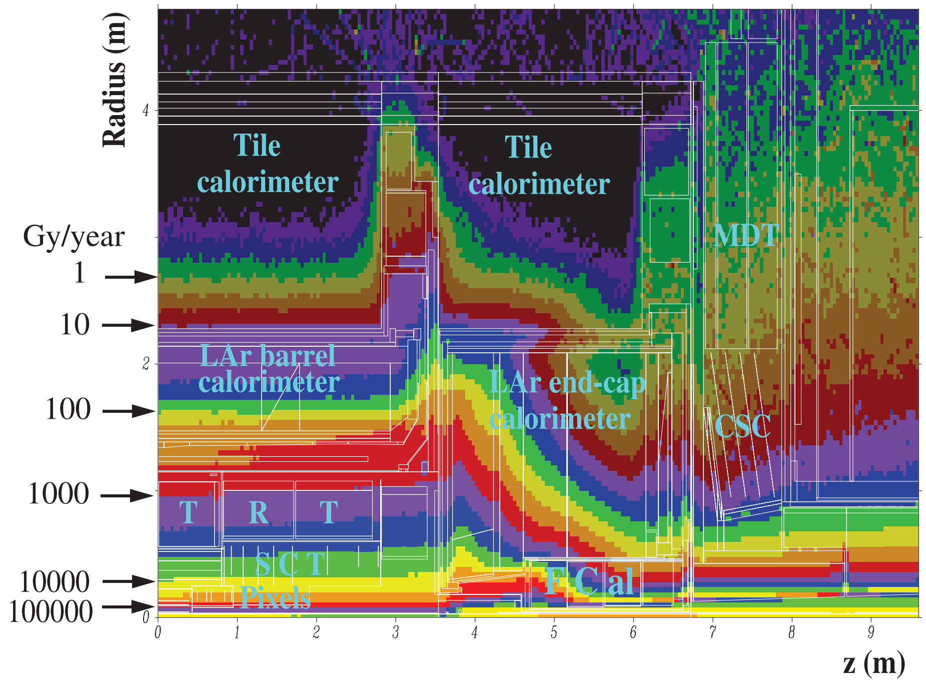
Dijet Asymmetry



Event display of a highly asymmetric dijet event in lead ions collisions at LHC. One jet with $E_T > 100\,\mathrm{GeV}$, no evident recoiling jet, no significant missing E_T , and high energy calorimeter cell deposits distributed over a wide azimutal region.

arXiv:1011.6182v1 [hep-ex]

Calorimetry Upgrade for sLHC



Total ionising dose per year calculated by the GCALOR software package

- FCal upgrade:
  - For instantaneous luminosities above $10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$: ion build-up, space-charge effects, high voltage drops leading to inefficient charge collection, etc. etc. these are all the causes of the FCal degradation
- LAr (EM+HEC) and TileCal upgrade:
  - Readout electronics, e.g. the cold electronics for the HEC need to be replaced
- **LoI in preparation**

Conclusions

- The ATLAS Calorimeter is acquiring data efficiently
- Its good performance has a key role in many ATLAS physics results already published or in preparation
- This is the result of a long effort of many people