Performance of the ATLAS hadronic Tile calorimeter

P. Bartoš on behalf of the ATLAS collaboration

Comenius University

**Tile calorimeter**
- The Tile Calorimeter (TileCal) is the central (|y| < 1.7) hadronic sampling calorimeter.
- Energy reconstruction of hadrons, jets, tau-particles and missing transverse energy.
- Around 10000 channels (two per cell) measuring energies ranging from ~30 MeV to ~2 TeV.
- Longitudinal segmentation – 3 radial layers (7.4Kx in total).
- Transverse granularity (Δx x Δy) = (0.1 x 0.1); in the last layer (0.2 x 0.1).
- Light is transmitted to photomultiplier tubes (PMTs) where the analysis signals are amplified, shaped and digitized every 25 ns.

**CIS calibration**
- Charge injection (CIS): determines conversion from ADC counts to pC by comparing known injected charge with the response of the electronics.
- Laser system: monitors the PMTs and downstream electronics by sending well-calibrated light pulses into PMTs.
- Cesium system: circulates a radioactive source through all cells to equalize their response, monitors scintillators and PMTs.

**Calibration chain**
- Energy response of the calorimeter is checked in events with isolated muons (cosmic, or W → μν) and isolated charged hadrons.
- Isolated charge hadrons: signal compatible with a minimum ionizing particle; response characterized with E/p ratio and momentum of the particle (track) precisely measured by inner detector. E = energy in 3D cluster around the extrapolated track.
- The largest disagreement is 18% for 9 < p < 10 GeV.

**Calorimeter performance**
- The energy response of the calorimeter is checked in events with isolated muons (cosmic, or W → μν) and isolated charged hadrons.
- Isolated muons:
  - uses ratio of deposited energy to the length travelled by the muon in a cell: AE/Δx
  - ratio (AE/Δx)_iso / (AE/Δx)_μ shown (left plot) for each radial layer
  - good consistency: electromagnetic scale was uniformed and stable over Run 1.
- Isolated charge hadrons:
  - similar obtained from muons
  - run-to-run corrections applied
  - resolution obtained with 50 ns bunch-spacing data (lower out-of-time pile-up)
  - resolution better than 1 ns for E_{vis} > 4 GeV

**Time calibration and resolution**
- The time calibration is important for the energy reconstruction; aims to set the phase in each channel so that a particle from the interaction point gives signal with measured time equal to zero.
  - Time calibration obtained with jets:
    - similar obtained from muons
    - run-to-run corrections applied
    - resolution obtained for Long Barrel, slightly worse in Extended Barrel (larger cells)
    - same resolution obtained with 50 ns bunch-spacing data (lower out-of-time pile-up)
    - resolution better than 1 ns for E_{vis} > 4 GeV.

**Detector status**
- Masked channels are faulty and not used for reconstruction.
- The ADC → pC conversion factor stable over time.
  - Laser calibration: The Run 2 laser system is more stable (stability <1%).
  - Laser system: monitors the PMTs and downstream electronics by sending well-calibrated light pulses into PMTs.
  - Cesium system: circulates a radioactive source through all cells to equalize their response, monitors scintillators and PMTs.
- The ADC → pC conversion factor stable over time.

**Calibration chain**
- Energy response of the calorimeter is checked in events with isolated muons (cosmic, or W → μν) and isolated charged hadrons.
- Isolated muons:
  - uses ratio of deposited energy to the length travelled by the muon in a cell: AE/Δx
  - ratio (AE/Δx)_iso / (AE/Δx)_μ shown (left plot) for each radial layer
  - good consistency: electromagnetic scale was uniformed and stable over Run 1.
- Isolated charge hadrons:
  - signal compatible with a minimum ionizing particle; response characterized with E/p ratio and momentum of the particle (track) precisely measured by inner detector.
  - E = energy in 3D cluster around the extrapolated track.
- The largest disagreement is 18% for 9 < p < 10 GeV.

**Time calibration and resolution**
- The time calibration is important for the energy reconstruction; aims to set the phase in each channel so that a particle from the interaction point gives signal with measured time equal to zero.
  - Time calibration obtained with jets:
    - similar obtained from muons
    - run-to-run corrections applied
    - resolution obtained for Long Barrel, slightly worse in Extended Barrel (larger cells)
    - same resolution obtained with 50 ns bunch-spacing data (lower out-of-time pile-up)
    - resolution better than 1 ns for E_{vis} > 4 GeV.

**CIS calibration**
- Calibration chain
  - Energy [GeV] = ADC × C_{ADC} × pC × C_{low} × C_{Cs} × C_{pC/GeV}
  - A[ADC] = amplitude of the signal measured by channel
  - C_{pC/GeV} = global electromagnetic scale; set using 11% of modules in a test beam of electrons (C_{pC/GeV}=1.05pC/GeV)
  - Charge injection (CIS): determines conversion from ADC counts to pC by comparing known injected charge with the response of the electronics.
  - Laser system: monitors the PMTs and downstream electronics by sending well-calibrated light pulses into PMTs.
  - Cesium system: circulates a radioactive source through all cells to equalize their response, monitors scintillators and PMTs.
- The ADC → pC conversion factor stable over time.
- The Run 2 laser system is more stable (stability <1%).
- Laser system: monitors the PMTs and downstream electronics by sending well-calibrated light pulses into PMTs.
- Cesium system: circulates a radioactive source through all cells to equalize their response, monitors scintillators and PMTs.
- The ADC → pC conversion factor stable over time.
- The Run 2 laser system is more stable (stability <1%).

**LHCP 2016, June 13 – 18, Lund, Sweden**