Response of single isolated hadrons in the ATLAS calorimeter

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The ATLAS Detector

Large collider detector built for LHC at CERN
Pixel, strip and transition radiation tracking sub-systems in a 2T magnetic field with coverage $|\eta| < 2.5$.

Transverse momentum resolution $\sigma_{P_T}/P_T = 0.05\%P_T(\text{GeV}) \pm 1\%$. 

ATLAS Tracking
In the central region:
lead-liquid argon (LAr) and iron-scintillator sampling calorimeters
energy resolution for hadrons and jets \( \sigma_E/E = 50%/\sqrt{E}(\text{GeV}) \pm 3\% \)

In the forward region:
copper and tungsten as passive materials with liquid argon technology
Method Description

- Select isolated tracks.
- Measure momentum with tracking detectors.
- Sum up energy deposition in the calorimeter around the track.
- The purpose of the study is to understand calorimeter response using track measurements as a reference.

- The results are based on one million proton-proton collision events collected in December 2009 at 900 GeV center-of-mass energy.
- Simulated events are generated using Pythia and detector simulation is based on Geant4 with QGSP_BERT physics list.
Event and Track Selection

- Minimum bias trigger.
- Reconstructed vertex with at least 2 associated tracks.
- Transverse momentum $P_T > 500$ MeV.
- Track quality requirements.
- Requirements on transverse and longitudinal impact parameters with respect to the primary vertex.
- Isolation requirement: no other track within
  \[ \Delta R_{ij} = \sqrt{(\eta_{EM2}^i - \eta_{EM2}^j)^2 + (\phi_{EM2}^i - \phi_{EM2}^j)^2} > 0.4 \] in the extrapolated position in the electromagnetic calorimeter.
Energy Clustering

- Find calorimeter cells with $|E_{cell}| > 4\sigma_{noise}$ of noise.
- Include all neighboring cells $|E_{cell}| > 2\sigma_{noise}$.
- Finally add all cells surrounding the resulting cluster.
- The layer energy is used if
  \[ \sqrt{(\eta_{tr}^{kj} - \eta_{cl}^{ij})^2 + (\phi_{tr}^{kj} - \phi_{cl}^{ij})^2} < R_{coll}. \]
- The energy of layers is summed $E = \sum E_j$.

$R_{coll} = 0.2$ is chosen as compromise between shower containment and background contribution due to neutral particles.

The energy is at electromagnetic energy scale, i.e. no correction for non-compensation or dead material energy losses.
The peak 0 corresponds to tracks with no matching cluster.

Define probability of calorimeter response being compatible with zero as a fraction of events with $E/P < \sigma$ where $\sigma$ corresponds to the bin in the negative side with $\sqrt{e}$ times fewer events compared to $E/P = 0$. 

$2.8 \, \text{GeV} < P < 3.6 \, \text{GeV}$
$1.9 < |\eta| < 2.3$
Good agreement between data and MC.
Demonstrates the good description of material before the calorimeter and of the noise.
The overall agreement between data and MC is within 5% except for the $1.5 < |\eta| < 1.8$ region corresponding to transition between barrel and end-cap EM calorimeter.
Pseudo-rapidity Dependency

Good agreement between data and MC except $|\eta| = 1.7$ region corresponding to transition region between barrel and end-cap EM calorimeter.
The ATLAS detector is fully operational.

Good description of dead material before the calorimeter and of the noise.

Hadronic response in calorimeter is described by MC simulation within 5% for single isolated hadrons with $|\eta| < 2.3$.

The results are used in estimation of jet energy scale uncertainties in ATLAS.
More information can be found in \textit{ATLAS-CONF-2010-017}
Track Pseudo-rapidity and Transverse Momentum

$1/N_{ev} \cdot dN_{ch} / d\eta$

$p_T > 500$ MeV, $|\eta| < 2.5$, $n_{ch} \geq 1$

ATLAS
$\sqrt{s} = 900$ GeV

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Noise in Calorimeter

Noise level as a function of pseudo-rapidity

Cell energy distribution

Good description of noise in the calorimeter