Response of single isolated hadrons in the ATLAS calorimeter and comparison to Geant4 simulation

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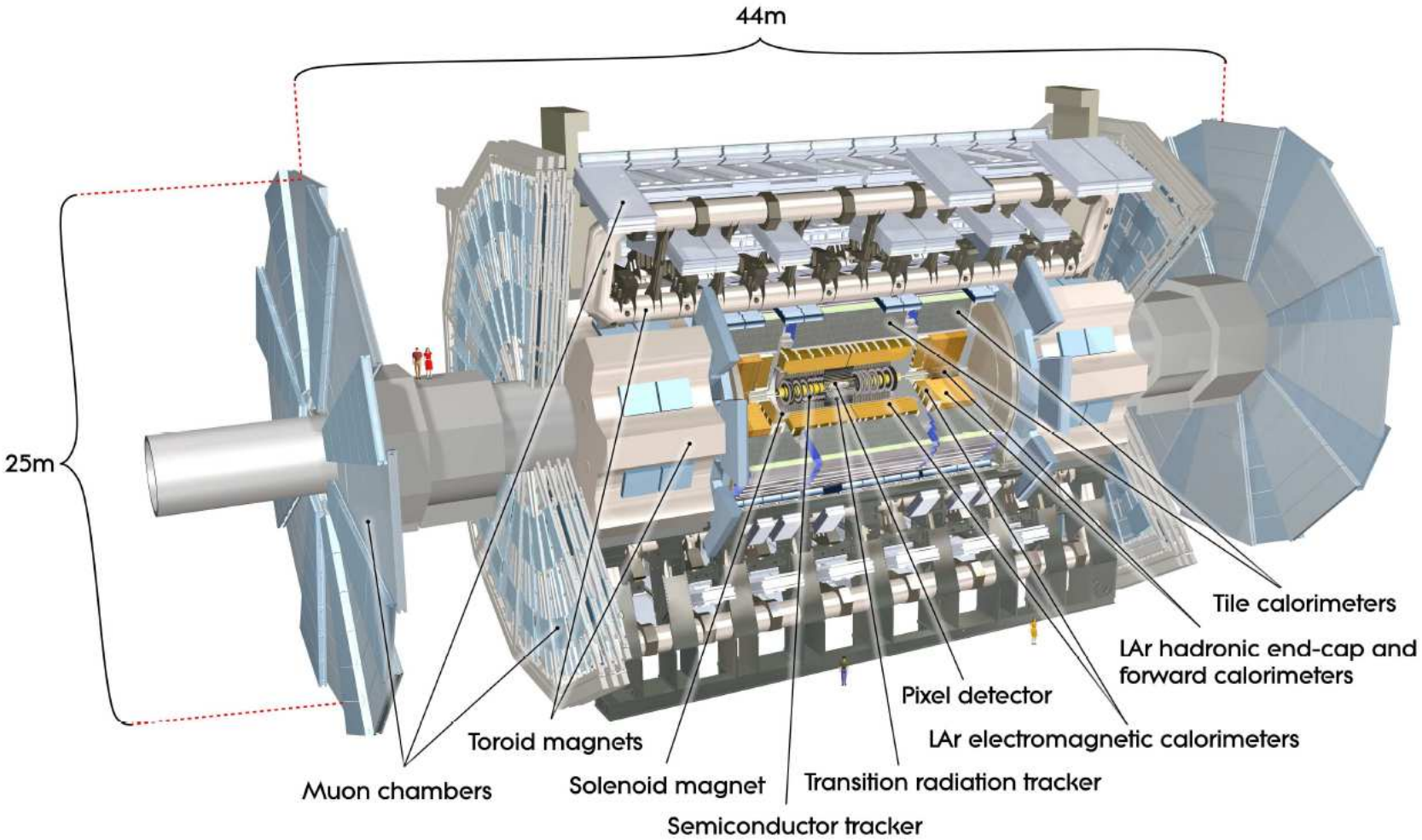
LCG Physics Validation meeting

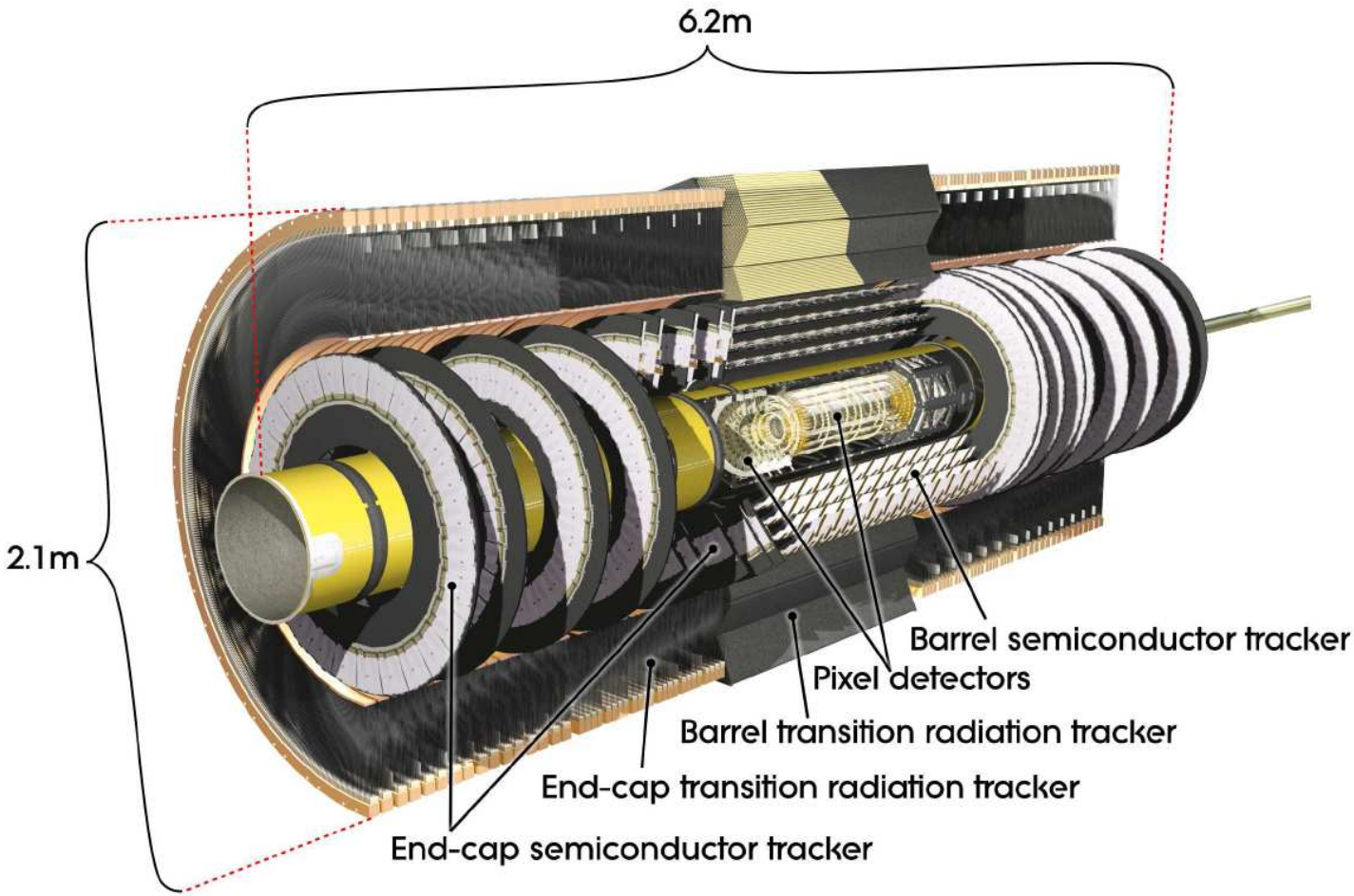
Outline

The ATLAS Detector

Large collider detector built for LHC at CERN

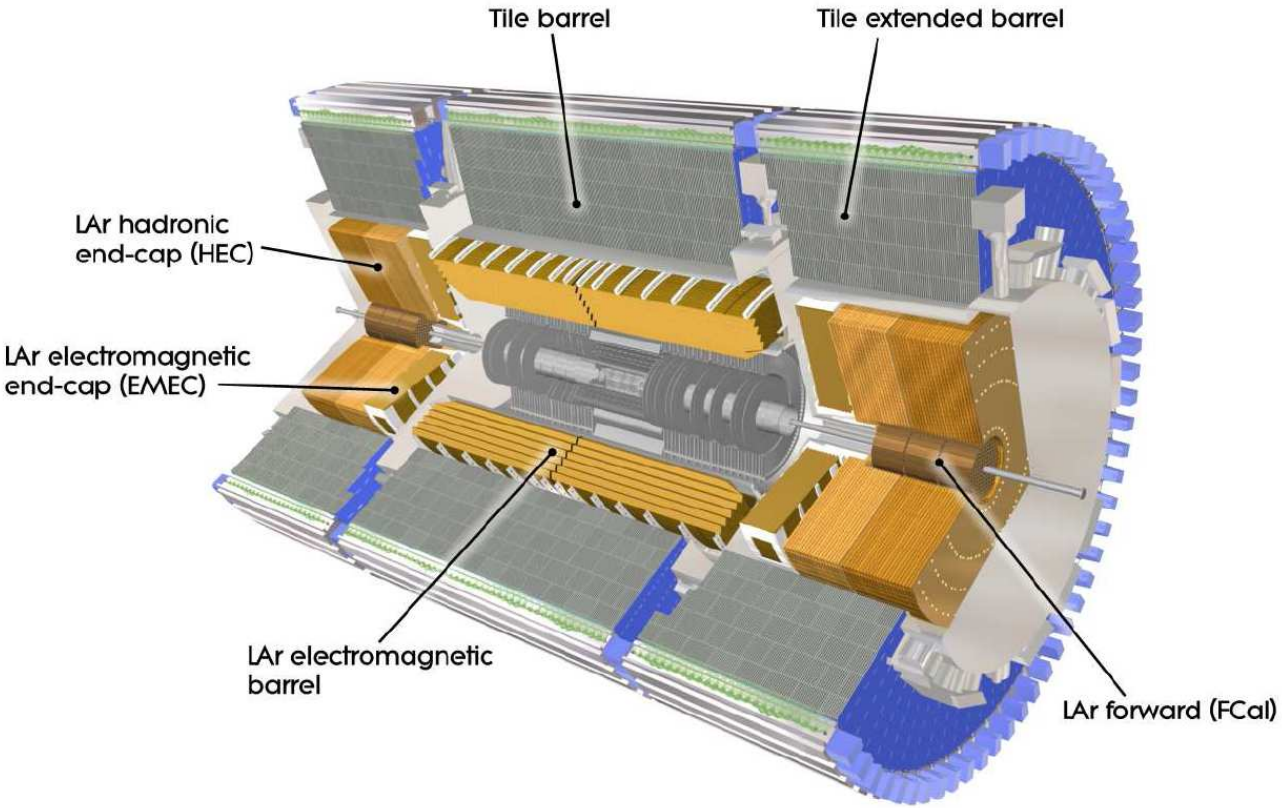


ATLAS Tracking



Pixel, strip and transition radiation tracking sub-systems in a 2T magnetic field with coverage $|\eta| < 2.5$.
Transverse momentum resolution $\sigma_{P_T}/P_T = 0.05\% P_T(GeV) \oplus 1\%$.

ATLAS Calorimeters



In the central region:

lead-liquid argon (LAr) and iron-scintillator sampling calorimeters

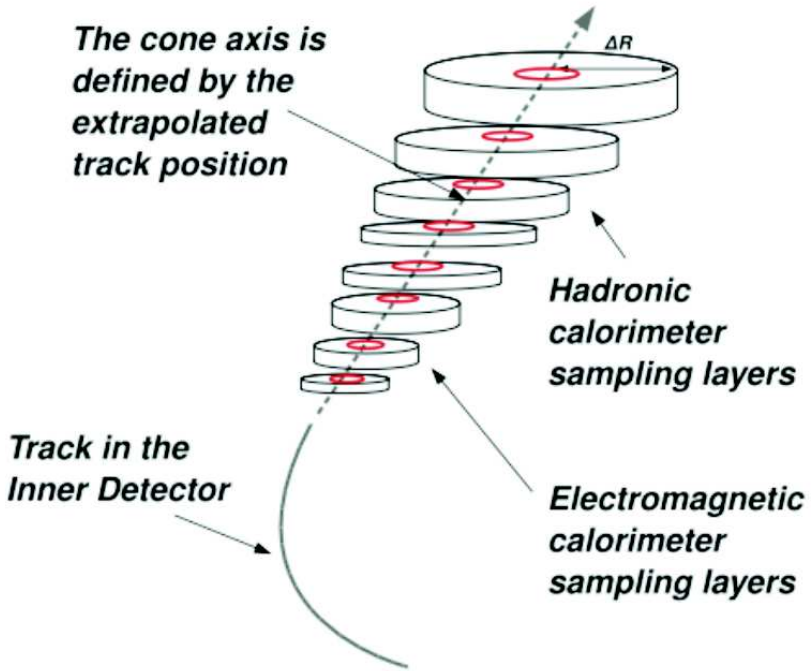
energy resolution for hadrons and jets $\sigma_E/E = 50\%/\sqrt{E(GeV)} \oplus 3\%$

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.



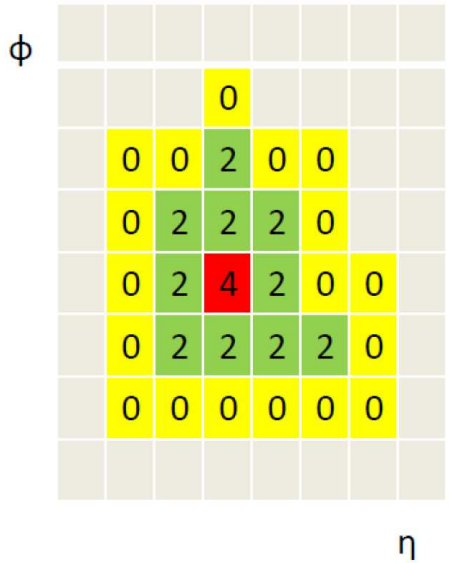
- The results are based on one million proton-proton collision events collected in December 2009 at 900 GeV center-of-mass energy.
- Simulated events are generated using Pythia and detector simulation is based on Geant4 with QGSP_BERT physics list.

Event and Track Selection

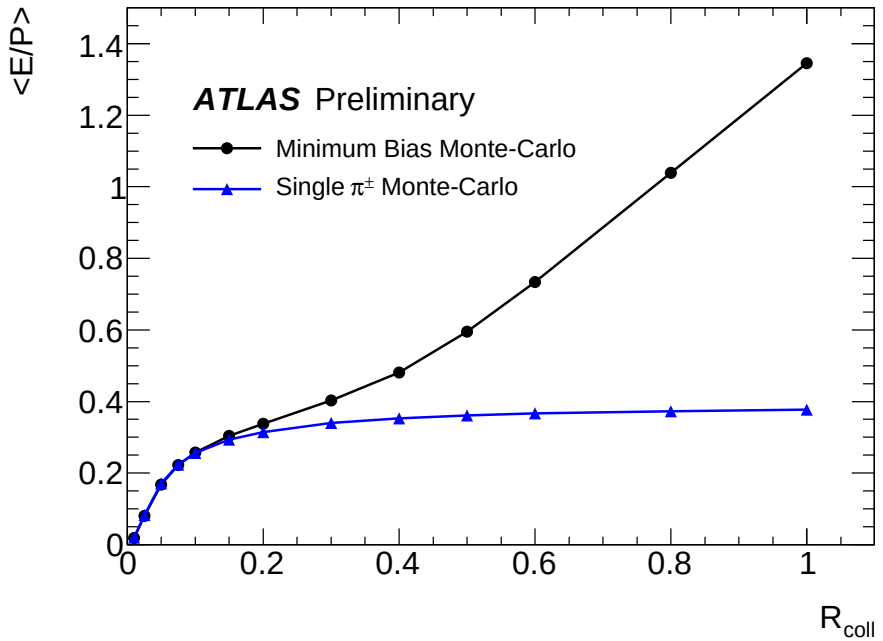
- Minimum bias trigger.
- Reconstructed vertex with at least 2 associated tracks.
- Transverse momentum $P_T > 500$ MeV.
- Track quality requirements.
- Requirements on transverse and longitudinal impact parameters with respect to the primary vertex.
- Isolation requirement: no other track within $\Delta R_{ij} = \sqrt{(\eta^i_{EM2} - \eta^j_{EM2})^2 + (\phi^i_{EM2} - \phi^j_{EM2})^2} > 0.4$ 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.

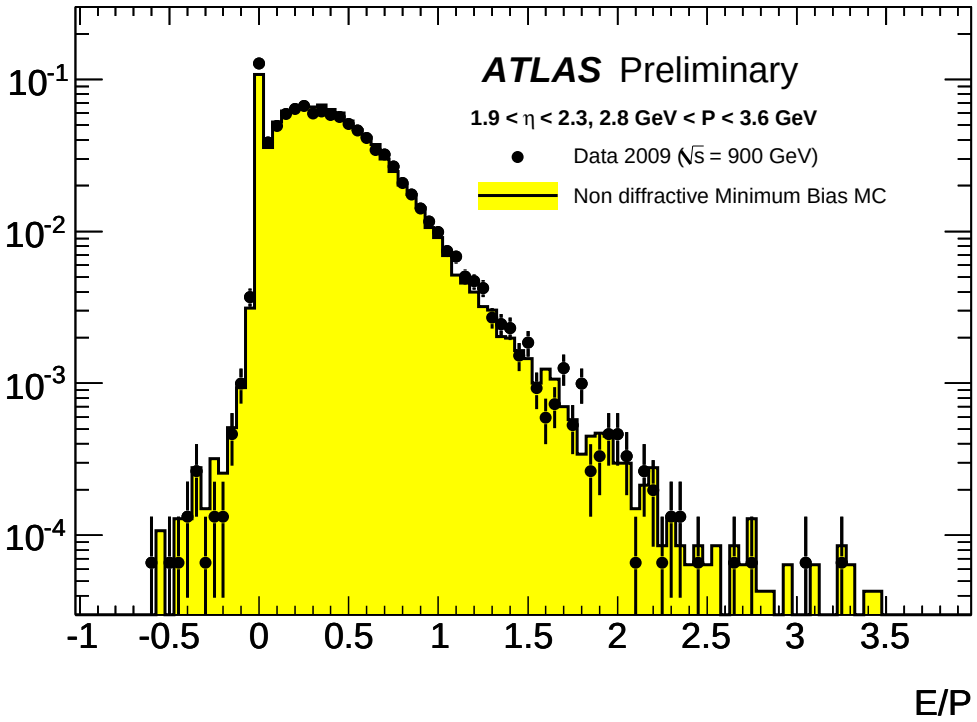


E/P Distribution

- The peak 0 corresponds to tracks with no matching cluster.

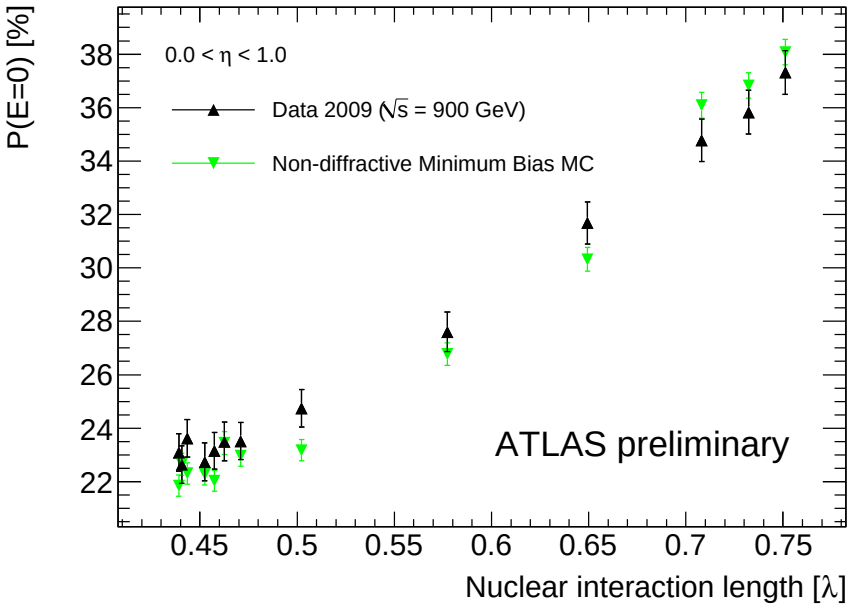
Define probability of calorimeter response being compatible with zero as a fraction of events with E/P < σ where σ corresponds to the bin in the negative side with $\sqrt{e}$ times fewer events compared to $E/P = 0$.

2.8 GeV < P < 3.6 GeV
1.9 < $|\eta|$ < 2.3

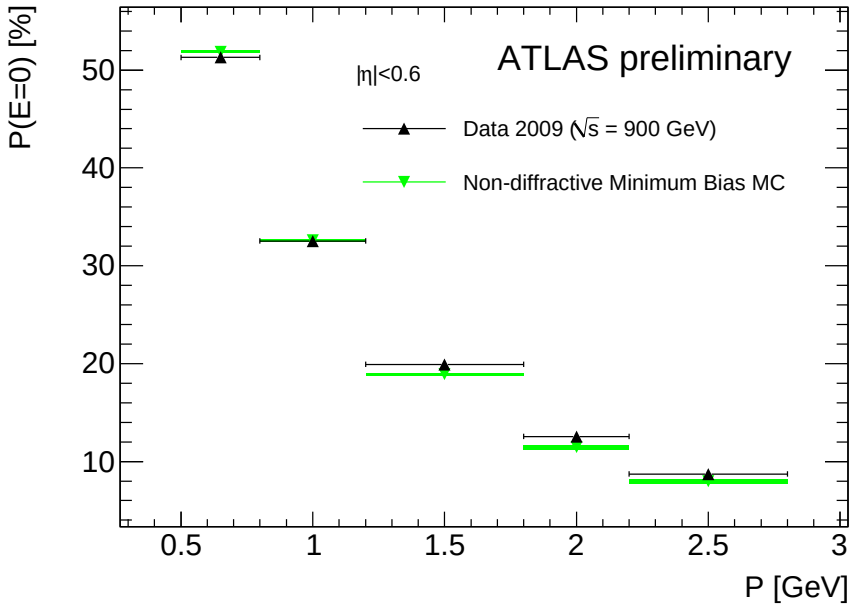


Probability of No Energy in Calorimeter

P(E=0) as a function of material depth in front of calorimeter



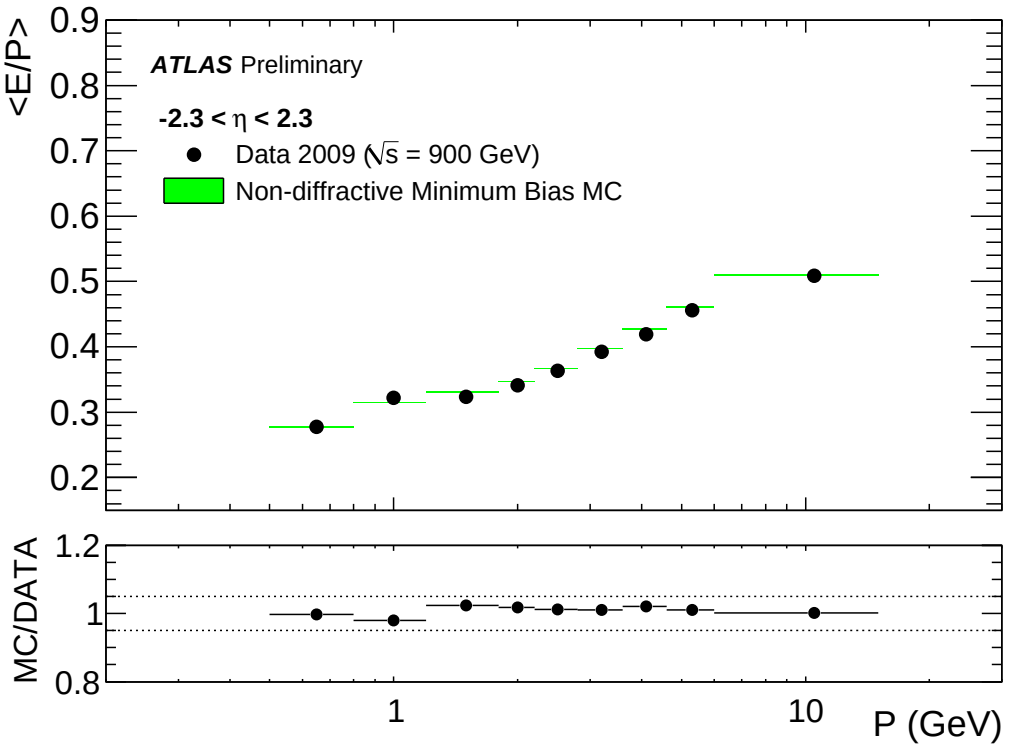
P(E=0) as a function of track momentum



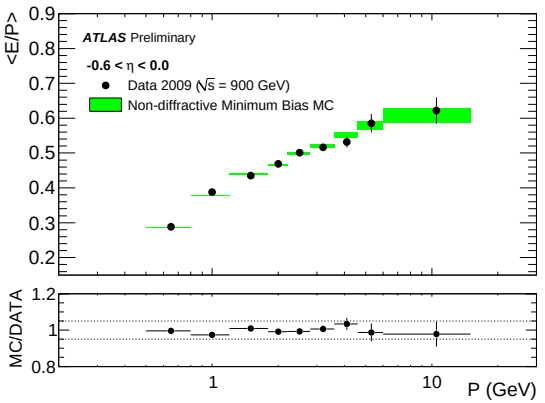
- Good agreement between data and MC.
- Demonstrates the good description of material before the calorimeter and of the noise.

Momentum Dependence

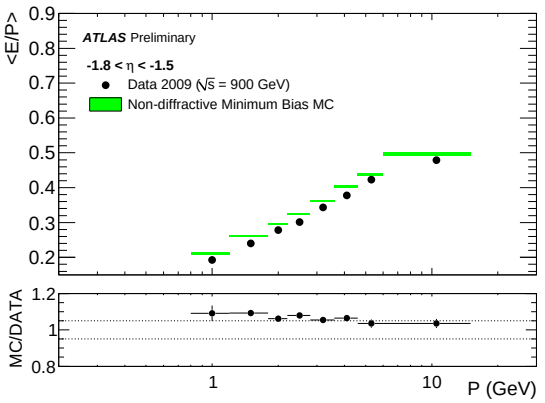
-2.3 < η < 2.3



-0.5 < η < 0.0



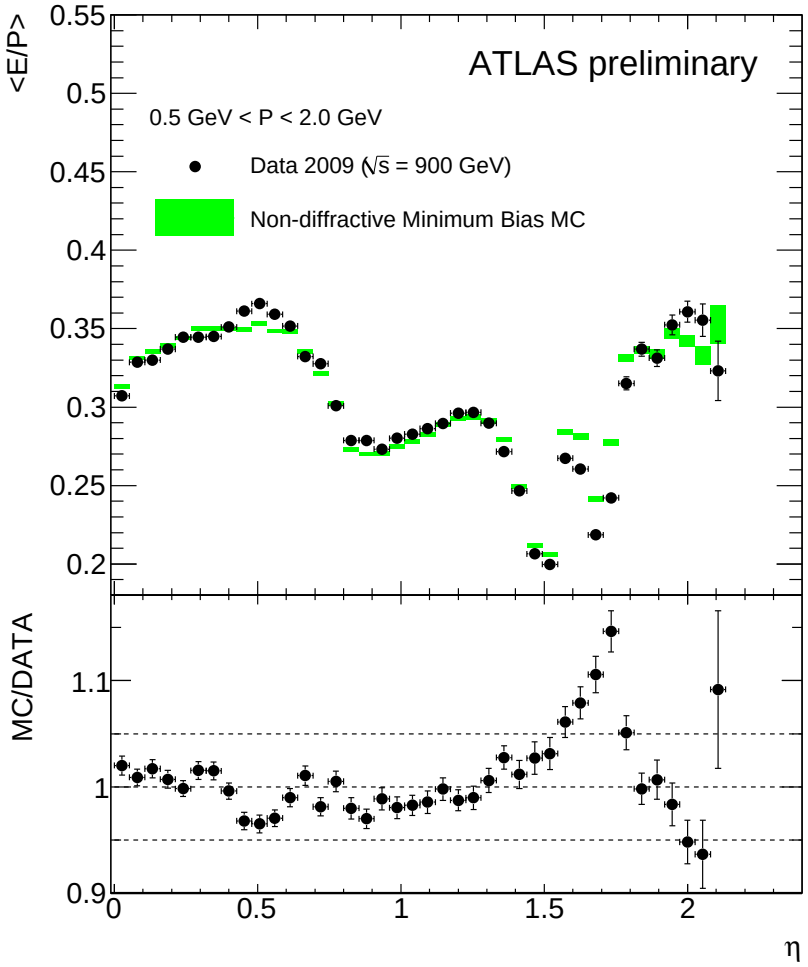
-1.8 < η < -1.5



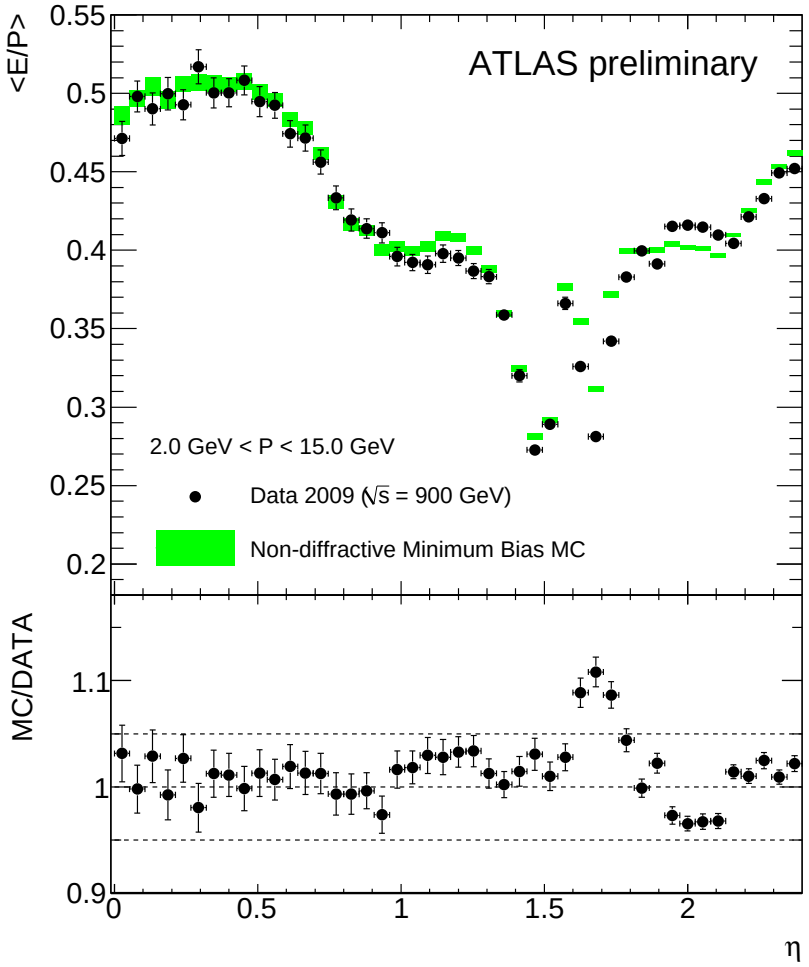
The overall agreement between data and MC is within 5% except for the 1.5 < $|\eta|$ < 1.8 region corresponding to transition between barrel and end-cap EM calorimeter.

Pseudo-rapidity Dependency

0.5 GeV < P < 2.0 GeV



2.0 GeV < P < 15.0 GeV



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

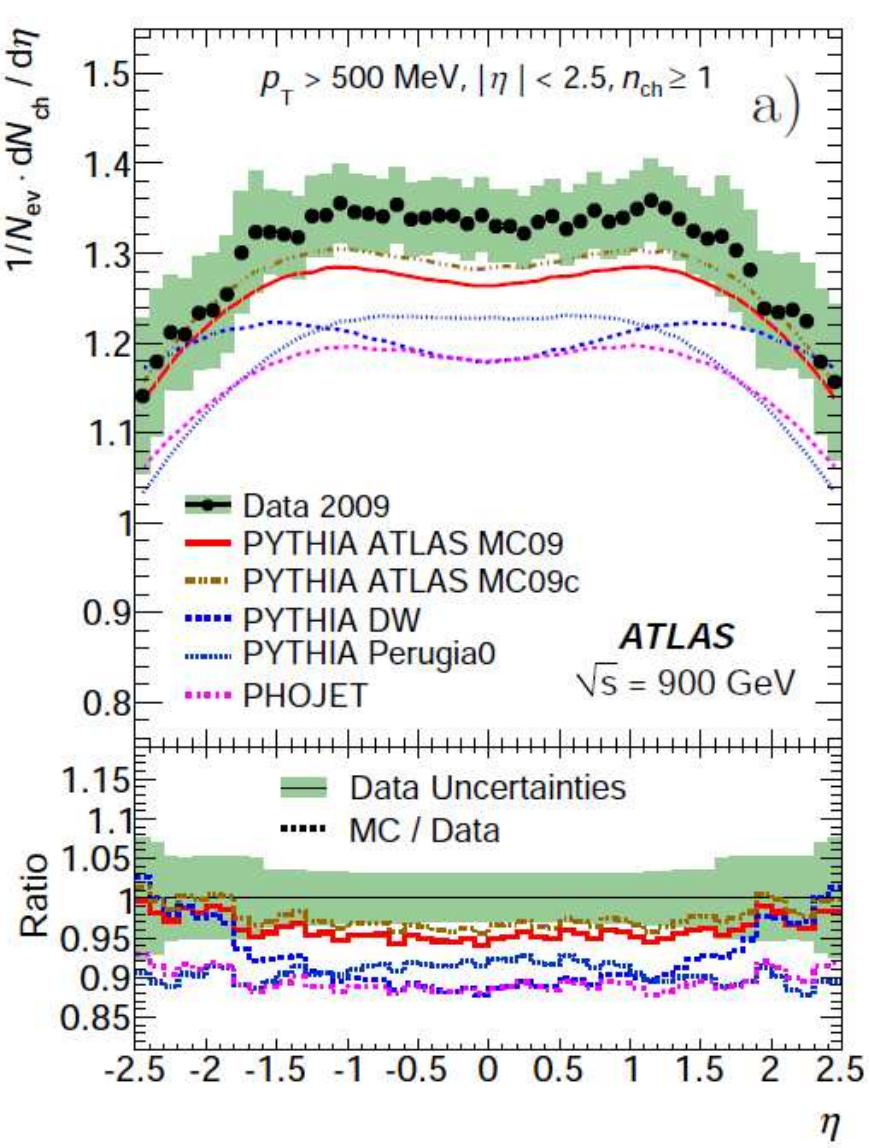
Conclusion

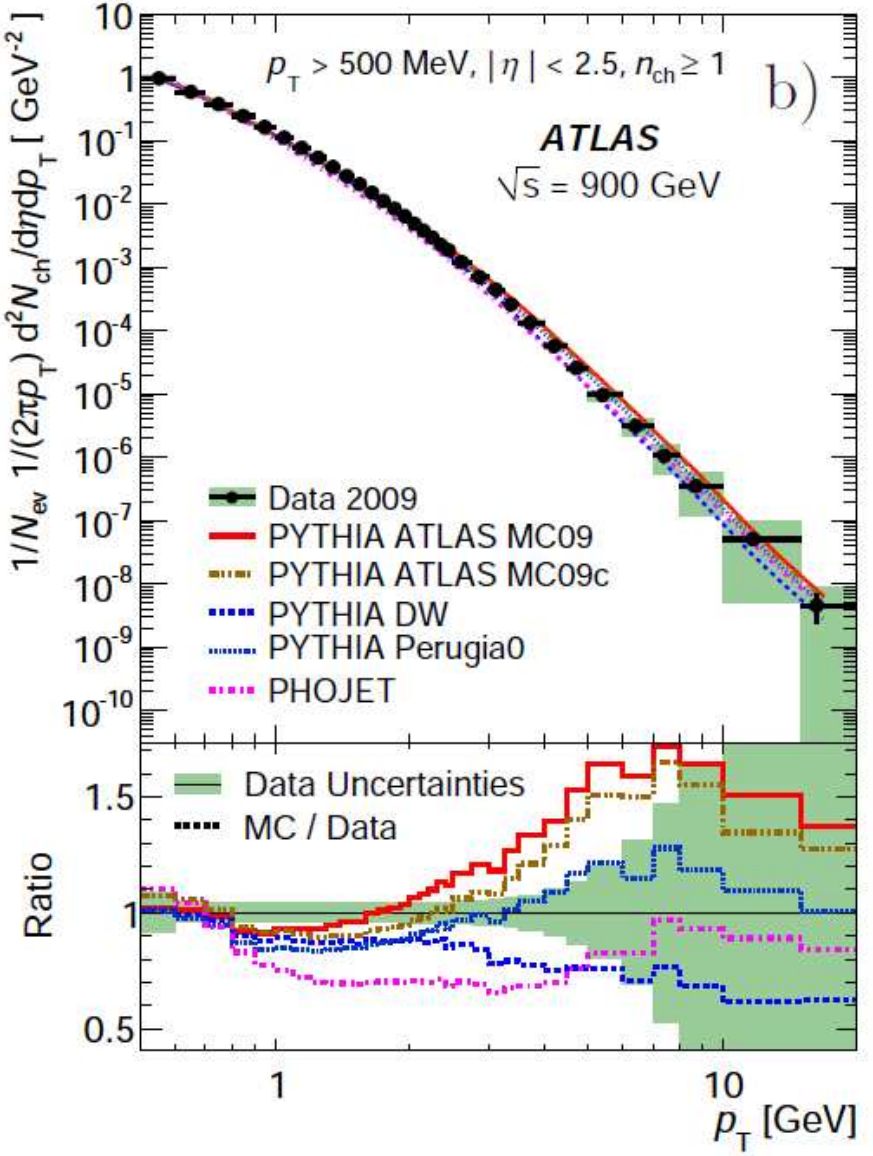
- The ATLAS detector is fully operational.
- Good description of dead material before the calorimeter and of the noise.
- Hadronic response in calorimeter is described by MC simulation within 5% for single isolated hadrons with $|\eta| < 2.3$.
- The results are used in estimation of jet energy scale uncertainties in ATLAS.

Backup

More information can be found in *ATLAS-CONF-2010-017*

Track Pseudo-rapidity and Transverse Momentum





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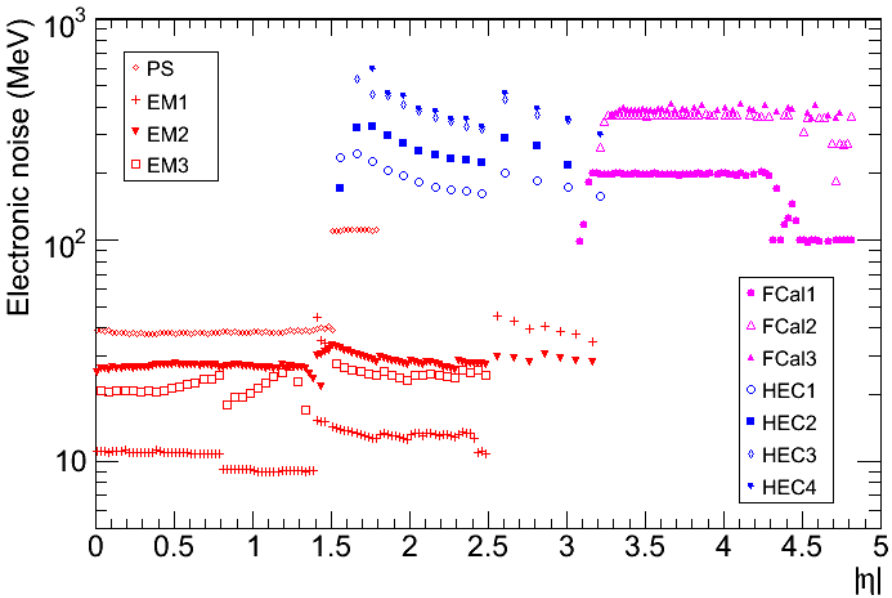
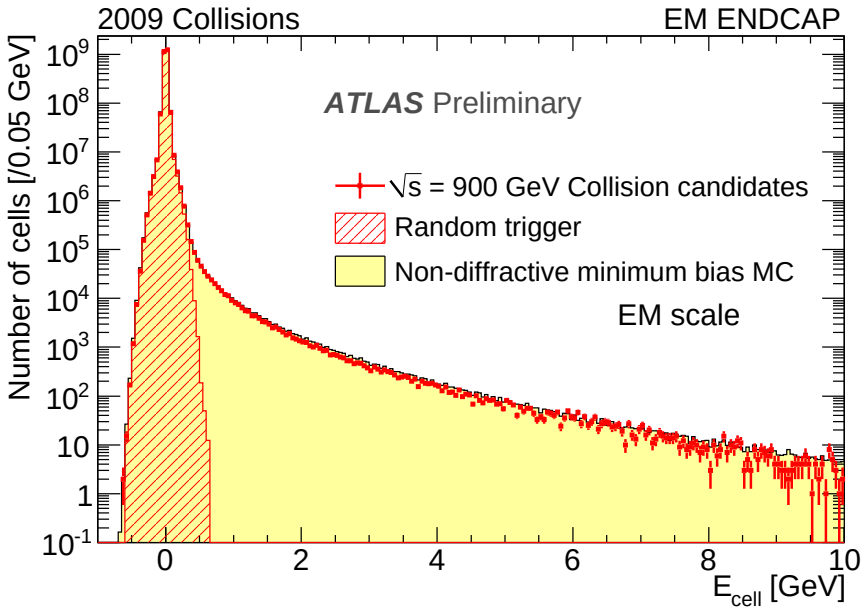
Noise in Calorimeter

Noise level as a function of pseudo-rapidity



Cell energy distribution



Good description of noise in the calorimeter