Lateral Profiles of Hadron-Induced Showers in the AHCAL

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Overview

Purpose of Analysis

- **Lateral** shower profiles have two components: **an electromagnetic core** (from π^0), and **a non-electromagnetic halo** (mainly non-relativistic shower particles)
- Do we see this in our AHCAL?

Analysis Procedure

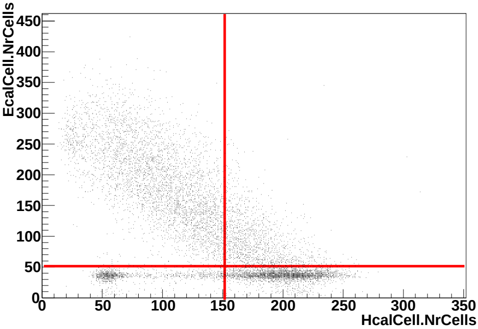
- Calculate trajectory of impinging track through the AHCAL
  $\Rightarrow$ use tracking information from **drift chambers**
- For correct track projection through calorimeter, **align** the calorimeter to chambers
  $\Rightarrow$ use hadronic shower center of gravity in calorimeter for alignment
- Radial development of shower energy deposition along AHCAL calculated with respect to the reconstructed track trajectory
  $\Rightarrow$ for each calorimeter cell, calculate radial coordinate:

$$\rho_{cell} = \sqrt{(x_{cell} - x_{track})^2 + (y_{cell} - y_{track})^2}$$

- Variables of interest:
  mean energy sum / mean energy density as a function of ρ

Data Selection

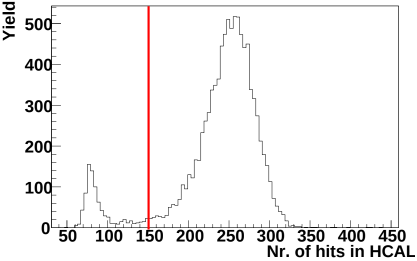
- π^- beam data from **CERN 2007** period; combined ECAL/HCAL/TCMT data taking (no energy deposited in TCMT used so far)
- Distributions shown for run 330327 (18 GeV π^-),
- Trigger selection: BEAM (SPILL + scintillator coincidence) & SPILL data (skip calibration/pedestal data)
- Discard events with showers already starting in ECAL: $N_{ECAL\ hits} < 50$



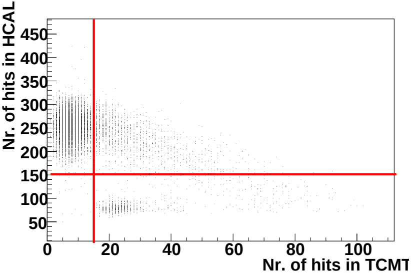
Data Selection - continued

- Noise reduced by AHCAL energy cut: $E_{AHCAL} > 0.5$ MIPs

- Discard MIP-type events in HCAL: $N_{AHCAL\ hits} > 150$



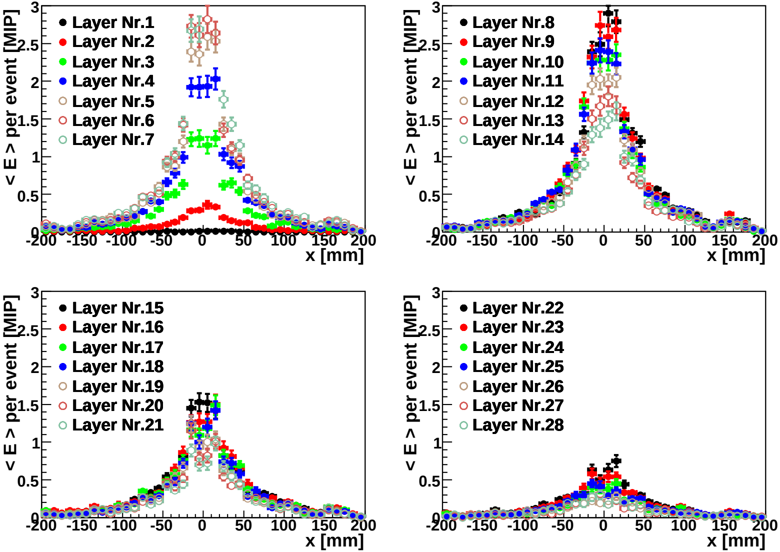
- Discard events showering in TCMT: $N_{TCMT\ hits} < 15$



Software Framework

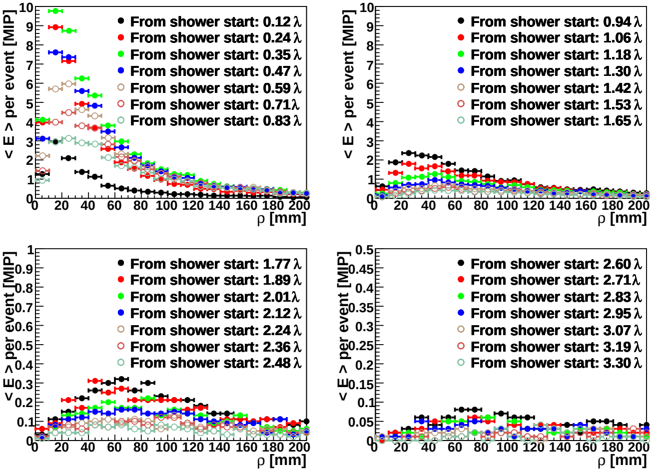
- Latest reconstruction software used to produce lcio files for reconstructed data
- 'Old' code used for track reconstruction (issues with *TBTrack*)

- Mean energy as a function of $\boxed{x = x_{HCAL\ cell} - x_{track}}$ for 18 GeV π^-
- Profiles scale with distance from calorimeter start



Radial Profiles of Mean Energy

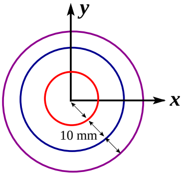
- Thanks to the high longitudinal granularity of the AHCAL we can investigate the shower development accurately **for different depths from shower start**
- Mean energy as a function of radius ρ for 18 GeV π^-

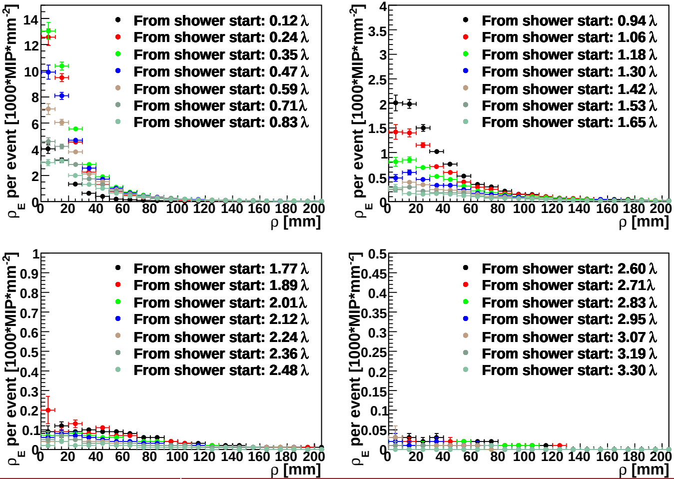


- Largest energy deposition in first lambdas
- Maximum of mean energy moves outwards with increasing λ_I
- Possibly, two slopes visible in the profiles $\Rightarrow$ different contributions in hadron showers?

- Mean energy density as a function of radius ρ, **for different depths from shower start**
- Maximum of energy density at shower center

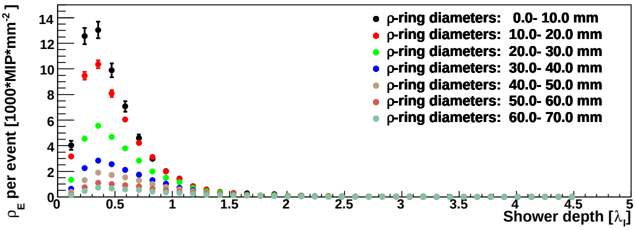
- Look for energy deposited in rings
- Calculate energy density = energy/area of the ring

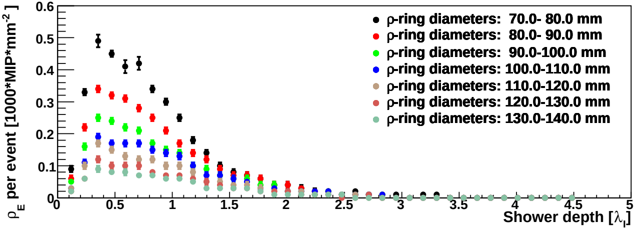




Lateral Scan of Longitudinal Shower Development

- Mean energy density as a function of shower depth

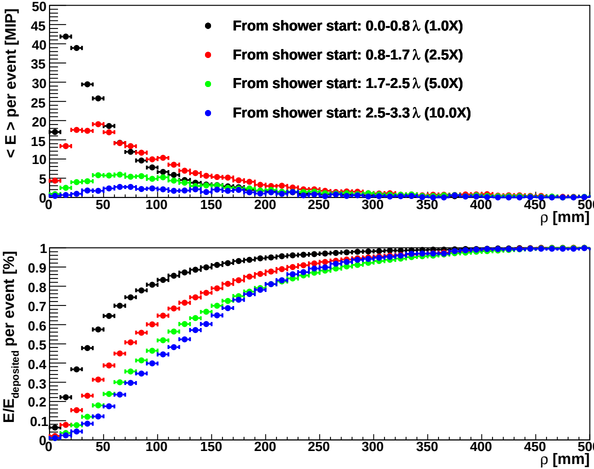




- Strongest longitudinal development observed in the centre of the shower
- Dips observed - to be investigated

Profile Evolution During Showering

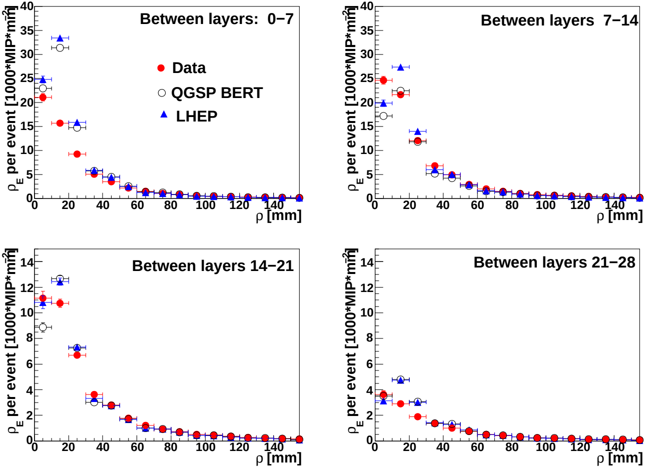
- Mean energy as a function of radius ρ



- Core appears to decay faster than shower halo
- The fractional energy deposition can be investigated

Energy Density: Data vs Monte Carlo

- The only way to trust Monte Carlo simulations is to validate them with data
- First look at MC: two physics lists, QGSP-BERT and LHEP (Birks law and time cut included)
- No tracking code used for MC, just simple fitting of hits from drift chamber
- Only basic cuts applied in MC



- Core shape different in MC (reasons under investigation)
- Shower tails well described in both investigated models
- The tools necessary for a deeper MC investigation are ready and running

Conclusions: Data

- Analysis of transverse profile well ongoing; done with respect to calorimeter and to shower start
- Several observables investigated: radial profile of mean energy and energy density, lateral scan of longitudinal shower development, fractional energy profiles
- Remaining sources of measurement bias:
  - possible remaining MIP contamination ?
  - systematic uncertainties (due to alignment procedure, etc)

Conclusions: Monte Carlo

- First very preliminary look into MC distributions

Overview

- Improve the cleaning of the data sample and include information from TCMT
- Work towards data-Monte Carlo agreement (several things to be checked: does the beam hit the same tiles in HCAL in both cases, etc)
- Study effect of finite tile size with Monte Carlo
- Lateral profile of fractional energy (Moliere radius)
- Extract different contributions in the shower development
- Need working (and understood) *TBTrack* code for both data and Monte Carlo

BACK-UP SLIDES

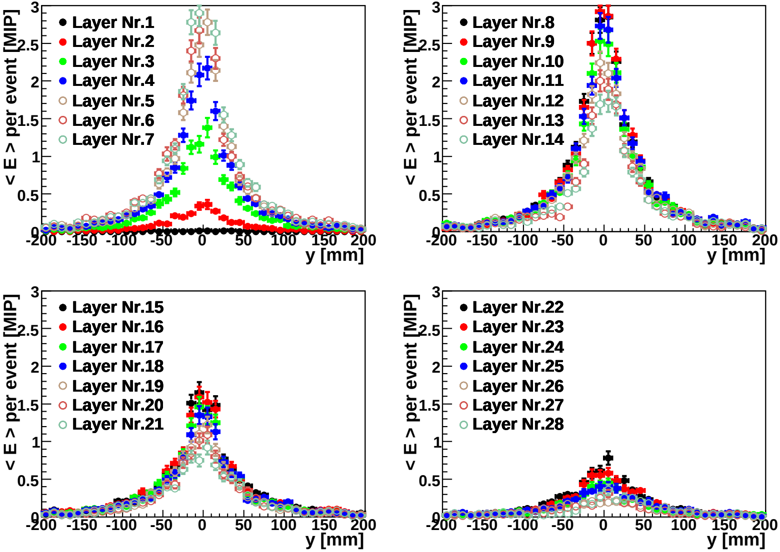
Selected Runs

- Combined ECAL/HCAL/TCMT data taking

Run number	Energy [GeV]
330325	25
330326	20
330327	18
330328	15
330332	10
330308	8
330390	40
330391	50
330392	80

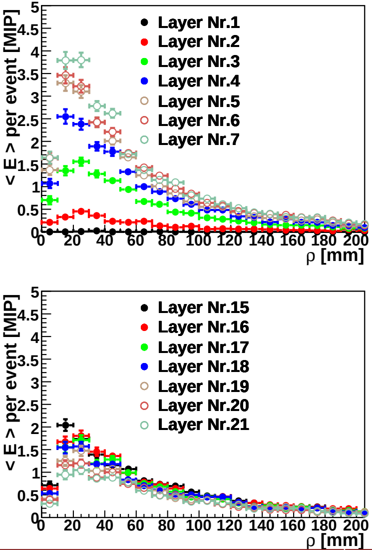
y-Profile of Mean Energy

- Mean energy as a function of $y = y_{HCAL\ cell} - y_{track}$ for 18 GeV π^-

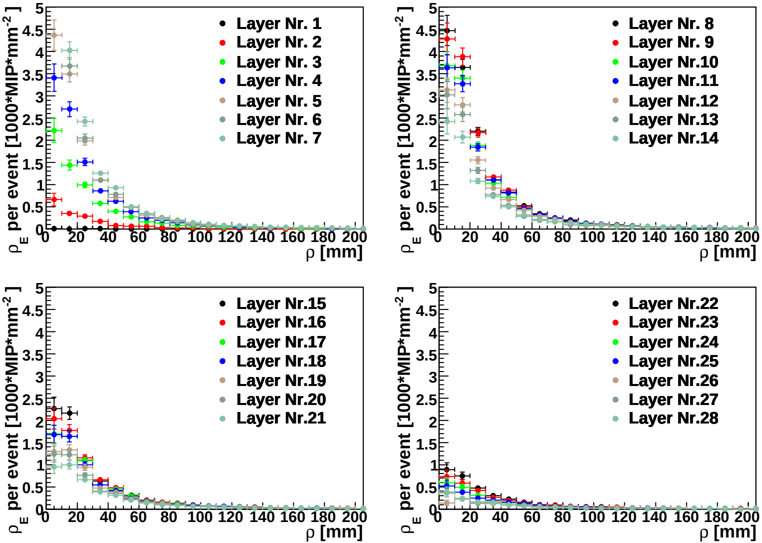


Radial Profiles of Mean Energy

- Mean energy as a function of radius ρ for 18 GeV π^-, **in different calorimeter layers**



- Mean energy density as a function of radius ρ, **for different calorimeter layers**



Lateral Scan of Longitudinal Shower Development

- Mean energy density as a function of calorimeter layer number