Validation of the ATLAS Hadronic Calibration with LAr End-Cap Beam Tests data

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Calor 2008
Pavia, 26 - 30 May 2008

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on behalf of the ATLAS LAr End-Cap Group: Canada, China, France, Germany, Russia, Slovakia, Spain, U.S.A.
In this talk I will present the initial studies done to validate the MC simulation using the full ATLAS hadronic calibration procedure (see talk from G. Pospelov) with the EMEC-HEC-FCal beam tests data.

The data shown are $\pi$'s obtained in the H6 2004 combined beam tests (see talk from P. Strizenec). They correspond to an ATLAS region $2.5 < |\eta| < 4.0$, and cover a energy range $40 \leq E \leq 200\text{GeV}$.

The MC simulation used in this analysis consists $\pi$'s obtained using Geant 4 8.3 QGSP EMV.

To preliminary compare the MC with the beam tests data, the full ATLAS Geant 4 MC has been restricted so to approximately describe the beam tests area.

Results are presented for data taken at point D (EMEC-HEC) and at point H (FCal), see red circles in the right figure.
Hadronic Calib. Performance: $\pi$s at Point D

- Plots show the total reconstructed energy over the nominal beam energy for 60 GeV$\pi$ and 200 GeV$\pi$ at Point D for EM-scale (red); weighted (green); weighted + OOC (blue); weighted + OOC + DM (black)

- Data point D: 60 GeV$\pi$
  - Mean improves in every step:
    after em $= 0.684$, after weight $= 0.780$, after ooc $= 0.844$, after dm $= 0.943$
  - Resolution remains about constant: after em $= 16.27\%$, after weight $= 16.41\%$, after ooc $= 15.7\%$, after dm $= 15.63\%$
  - Final deviation from $E_{\text{reco}}/E_{\pi} = 1$ is 5.7%

- Data point D: 200 GeV$\pi$
  - Mean improves in every step
    after em $= 0.756$, after weight $= 0.869$, after ooc $= 0.906$, after dm $= 0.993$
  - Resolution improves in every step after em $= 12.61\%$, after weight $= 11.09\%$, after ooc $= 10.91\%$, after dm $= 10.39\%$
  - Final deviation from the $E_{\text{reco}}/E_{\pi} = 1$ is $\approx 0.7\%$
Plots show the linearity and the resolution for $40 \text{ GeV} \leq \pi \leq 200 \text{ GeV}$, data and MC, at Point D. Full (open) red circles are data (MC) at EM-scale. Full (open) black triangles are data (MC) after weighting + OOC + DM corrections.

**Linearity at point D:**
- There is a difference between data ($\pi$) and MC at 40 and 60 GeV. At higher energies the calibrated data are in fairly good agreement with the MC.

**Resolution at point D:**
- The MC gives an overall better resolution than the data, both at EM-scale and after calibration corrections.

We know the noise in the data is higher than in the MC. We also know that the lateral shower shape of Geant 4 QGSP doesn’t describe data.
Energy Density Moment at Points D and H

Points show the energy density cluster moment: \( \log_{10} \left( \frac{\sum_{\text{cells}} \frac{E_{\text{cell}}}{V_{\text{cell}}} \times E_{\text{cell}}}{\sum_{\text{cells}} E_{\text{cell}}} \right) \) for 200 GeVπ at Point D (left plot) and H (right plot).

At both points D and H the MC has slightly higher energy density than the data, we can say it reasonable describes the data.

The energy density moment is used in the calibration procedure for separation of hadronic from electromagnetic showers.

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Second Radial Moment at Points D and H

- Plots below show the sqrt of the second radial moment (lateral spread) for 200 GeV π at points D (left plot) and H (right plot).

- Even though there is a shift to the right, at point H the MC describes the data. At point D the MC fails to describe the data.

- The shower model used in MC physics list doesn’t describe the data well.
Outlook

- We have started to validate the ATLAS Hadronic Calibration procedure using the LAr End-Cap Beam Tests data.
- In the studies shown in this presentation we see that the MC Geant 4 8.3 QGSP EMV has problems to describe the data.
- We need and we are working to have a proper beam tests MC simulation.
- Once a test-beam MC simulation is available, further improvements for the hadronic calibration procedure (EM-scale, weighting, OOC and dead material correction) can be done.
- These are the first validation results with LAr end-cap beam tests data obtained so far.
BACKUP SLIDES
Hadronic Calib. Performance: $\pi$ s at Point H

- Plots below show $E_{\text{reco}}/E_\pi$ for $\pi$ in Point H for EM-scale (red); weighted (green); weighted + OOC (blue); weighted + OOC + DM (black).

- Data point H: 60 GeV$_{\pi}$
  - Mean improves in every step, the resolution becomes worse
  - Final deviation from $E_{\text{reco}}/E_\pi = 1$ is 6.03%

- Data point H: 200 GeV$_{\pi}$
  - Mean and resolution improve in every step of the corrections
  - Final deviation from the $E_{\text{reco}}/E_\pi = 1$ is $\approx$ 7.21%
Linearity and Resolution at Point H

- Plots show the linearity and the resolution for data and MC at Point H. Full (open) red circles are data (MC) at EM-scale. Full (open) black triangles are data (MC) after weighting + OOC + DM corrections.

- **Linearity at point H:**
  - The calibrated data (for $E > 40$ GeV) show a fairly good agreement with the MC.

- **Resolution at point H:**
  - In the low energy region the data have a better resolution than the MC. In the higher energy bins the MC performs better. The dead material correction are problematic in this region for both data and MC.