Validation of Geant4 hadronic models using AHCAL data

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- Validation of hadronic shower models
  - Energy resolution, compensation
  - Longitudinal profiles
  - Particle flow with CALICE data
- Summary

Motivation

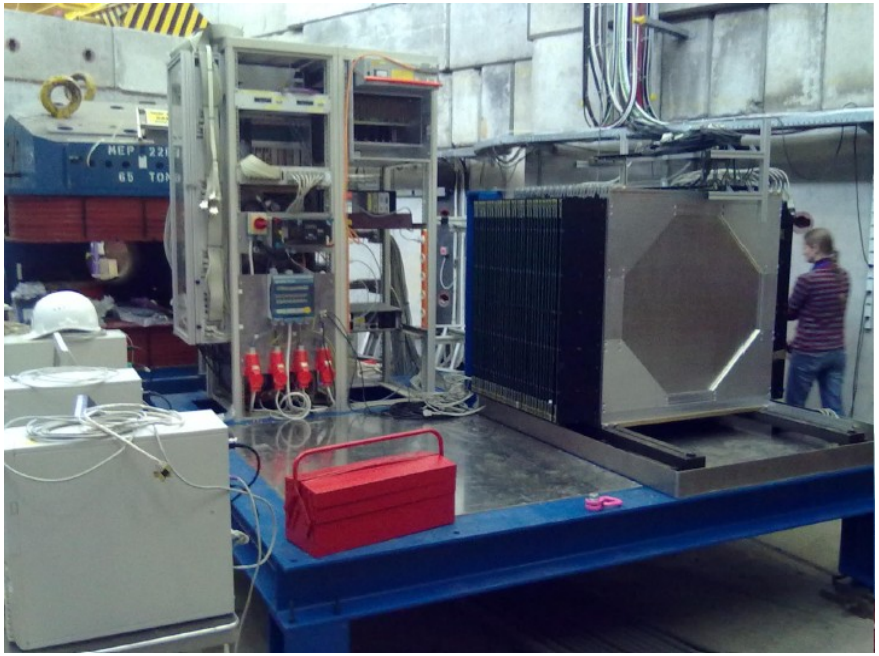
Physics goal: Separation of hadronic W, Z decays

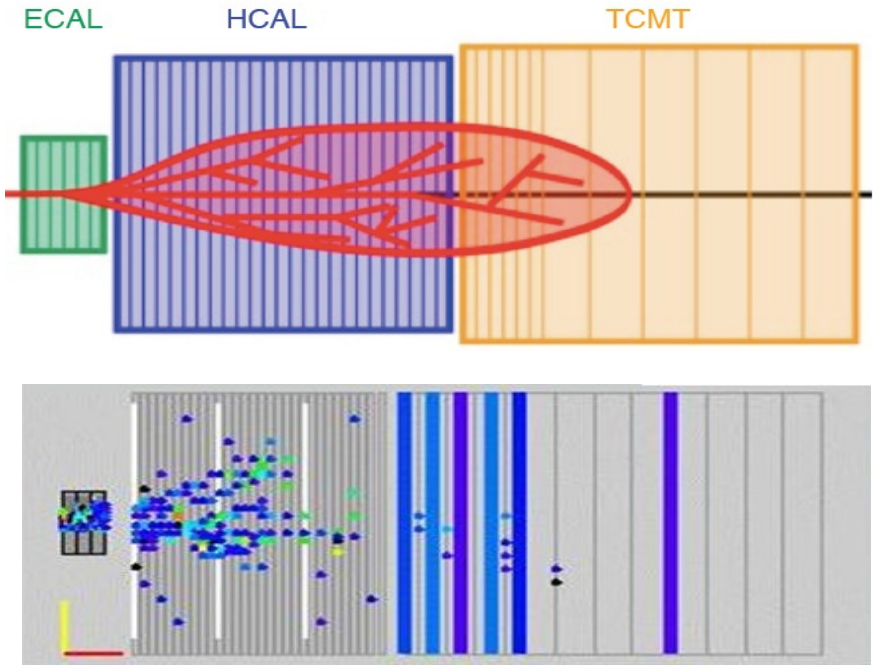
→ Jet energy resolution: ΔE/E = 30%/sqrt(E)

→ Particle Flow: Detect each particle in a jet, high granularity required

Intermediate task: Understand test beam data and validate MC models

(Data presented here from CERN 2007 test beam campaign (8-100 GeV pions))

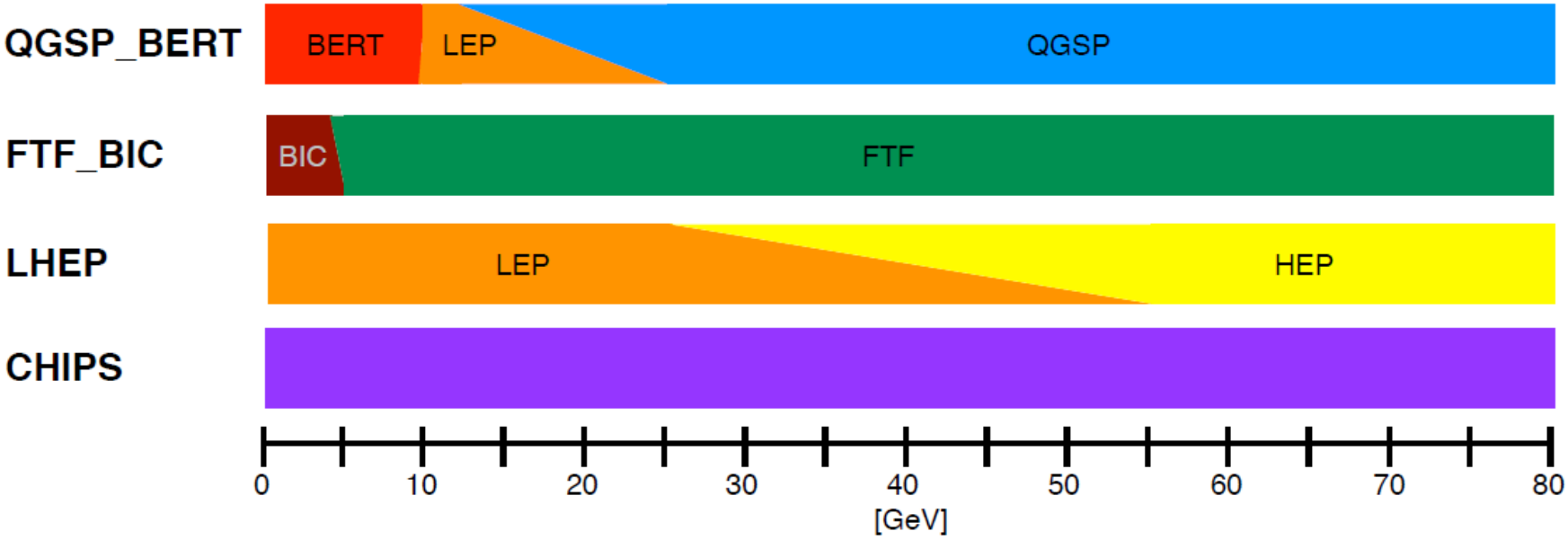




MC simulations

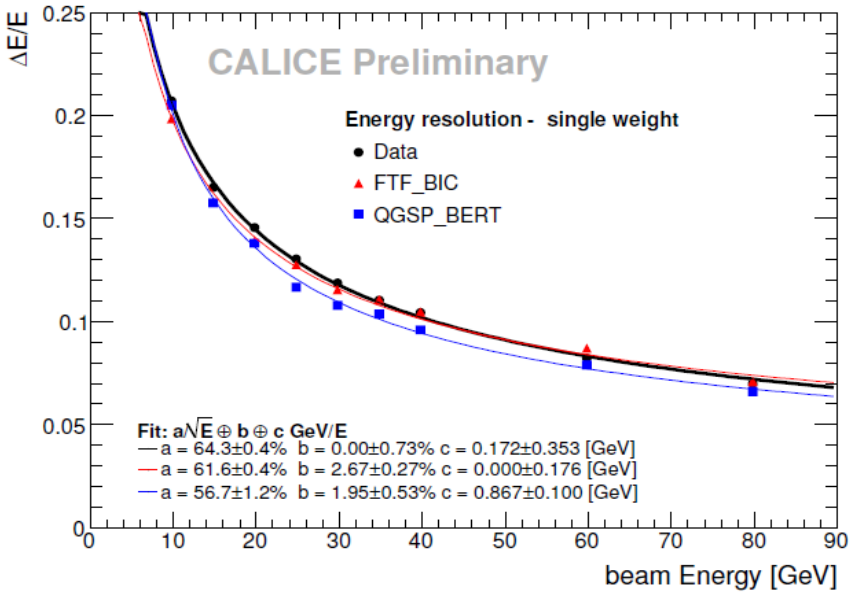
- **Mokka:** Geant4 application able to simulate full ILD detector and TB setup
- Geant4 simulation organized in physics lists combining several models valid at different energies

  → Unphysical steps between model validity ranges
- Develop physics lists without LHEP as stop gap
- Develop models for full energy range



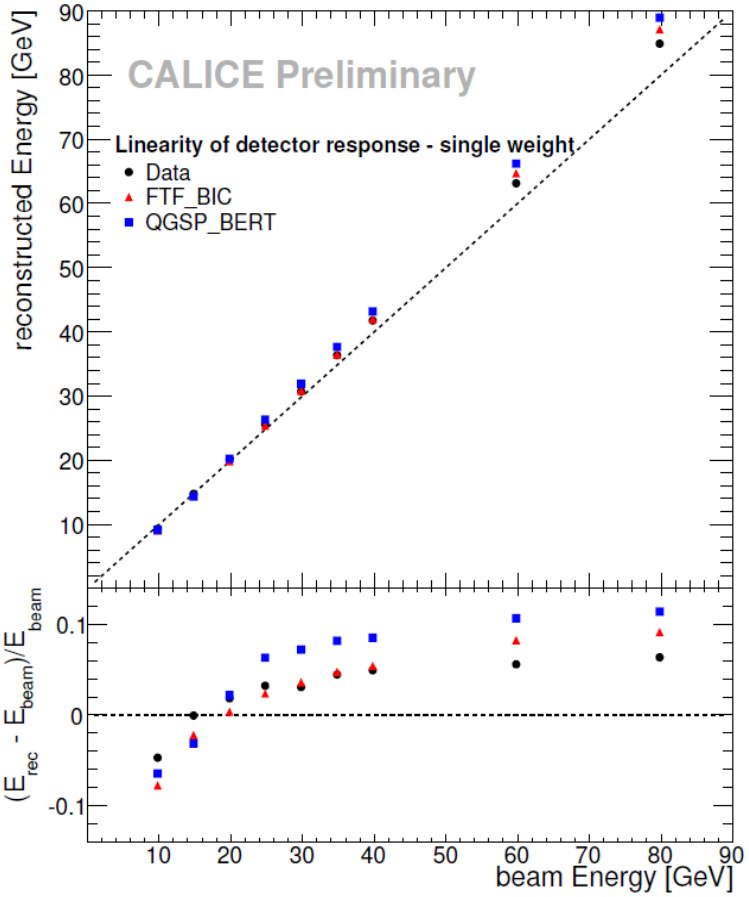
Energy resolution

- First look at energy scale to validate calibration and simulation
- For data presented here clustering algorithm has been used (only showers that start in AHCAL)
- Energy resolution for single weight 0.03 GeV/MIP (from 15 GeV pion run)



- Non-linear response due to energy dependent em fraction

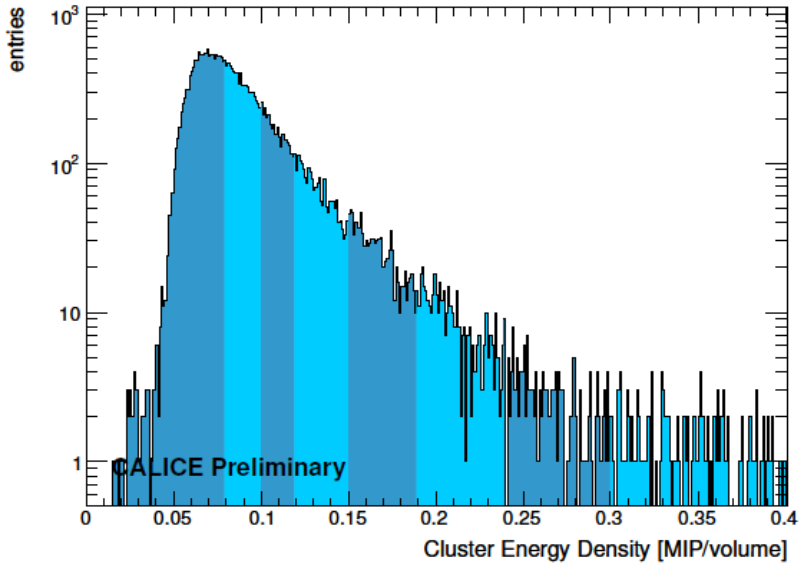
→ Compensation necessary

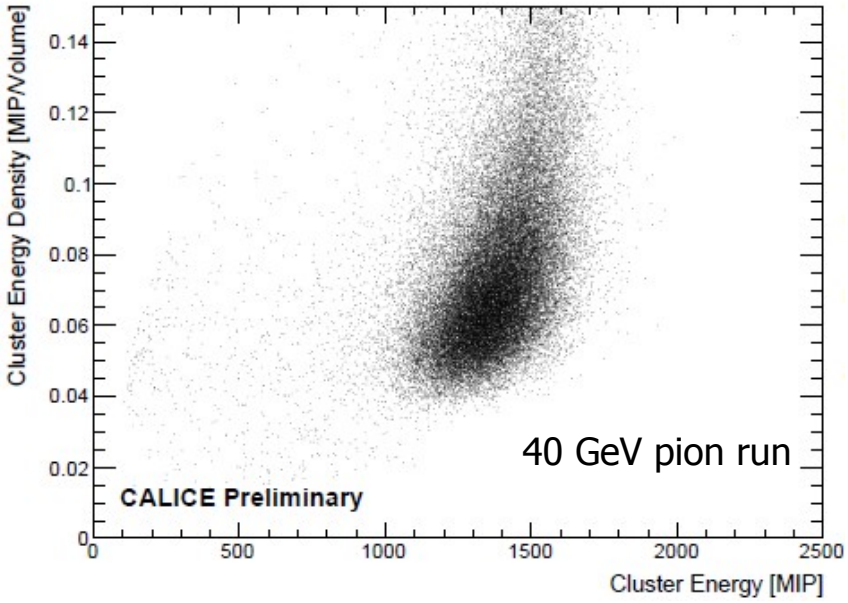


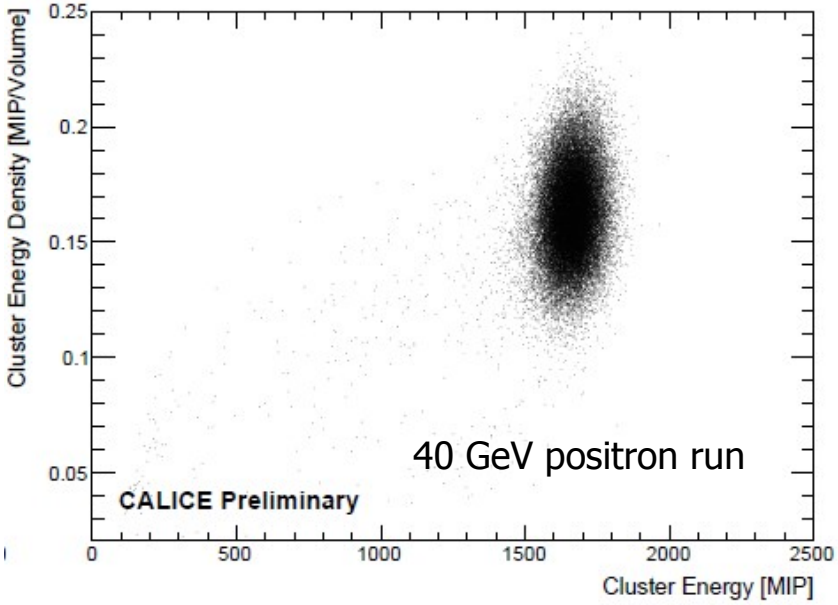
Energy resolution – Compensation

- Electromagnetic showers much denser than hadronic showers
- Electromagnetic fraction increases with increasing beam energy

  → Determine weights as function of energy and energy density (8 bins)





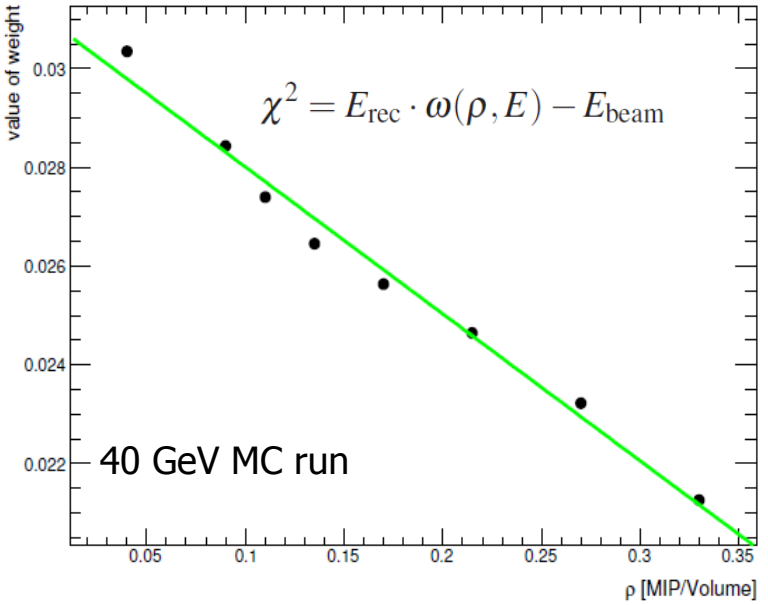


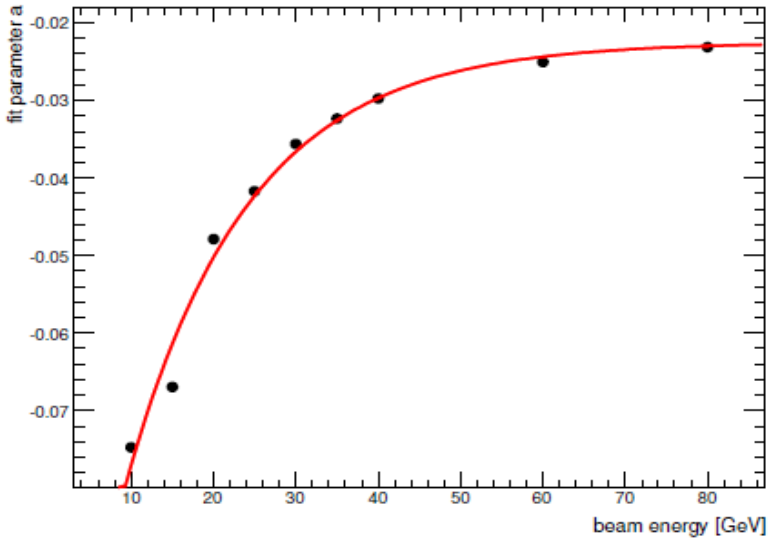
Energy resolution – Compensation

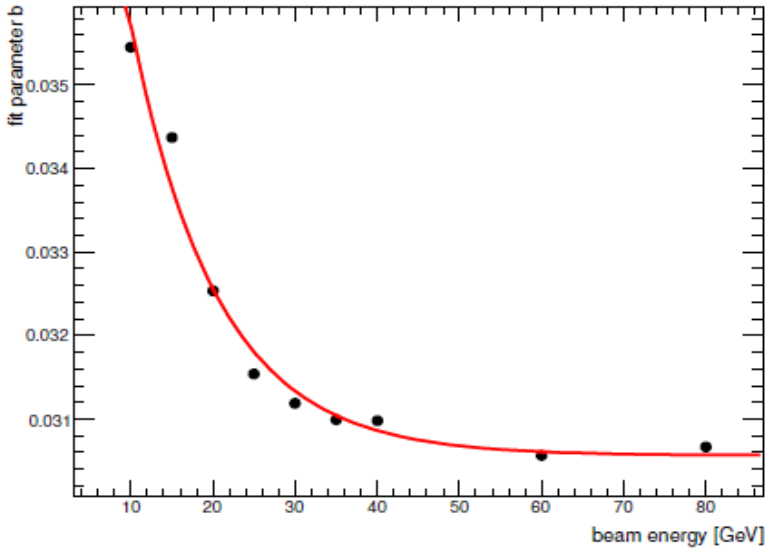
- Calculate weights via x^2 minimization

  → Construct calibration curve from different beam energies

→ Apply energy and density dependent weight to each event

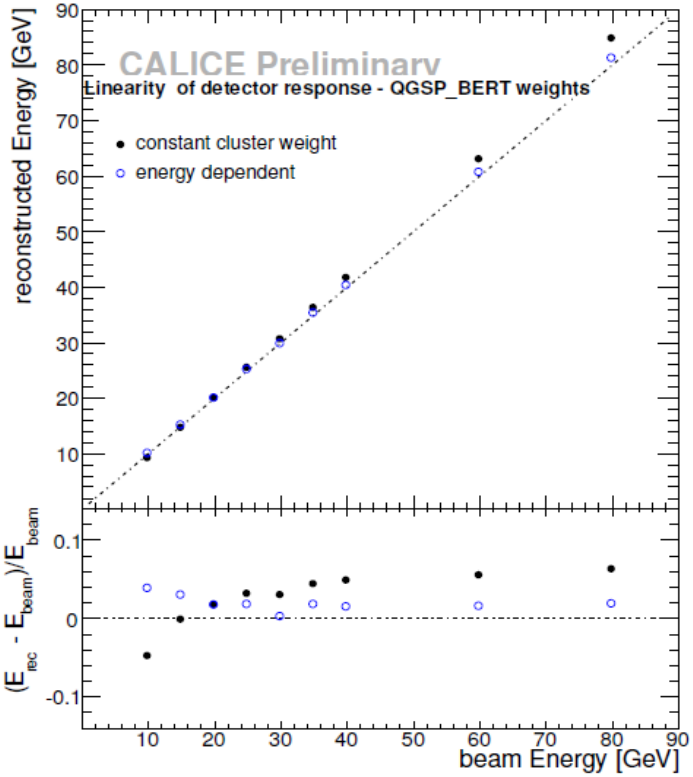


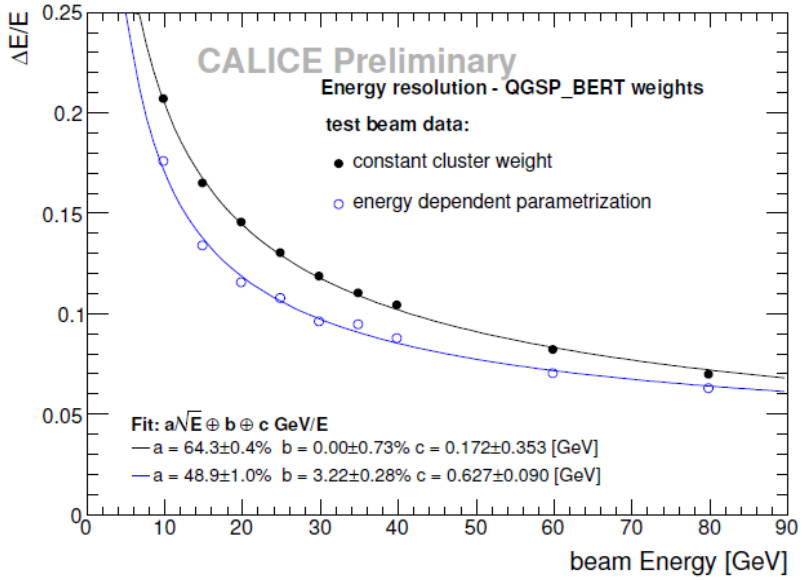


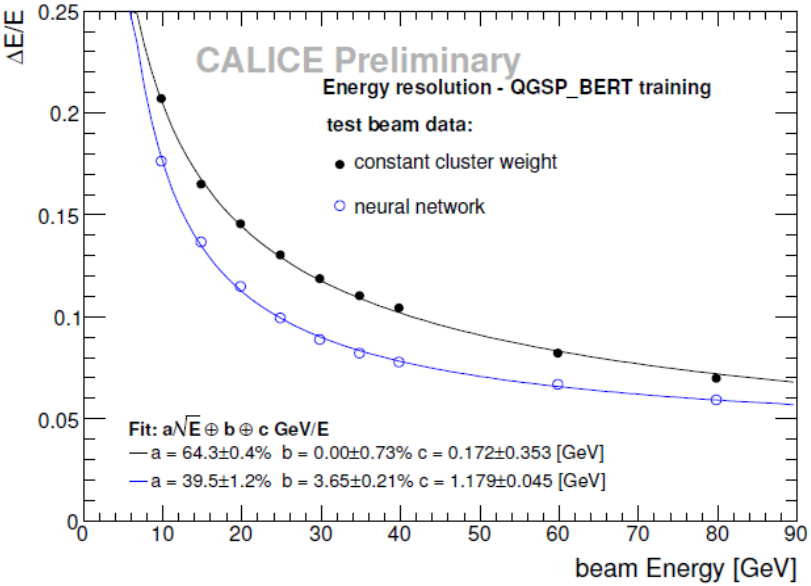


Energy resolution – Compensation

- Application of weights determined from MC data significantly improves resolution and linearity
- Neural net method further improves resolution and linearity





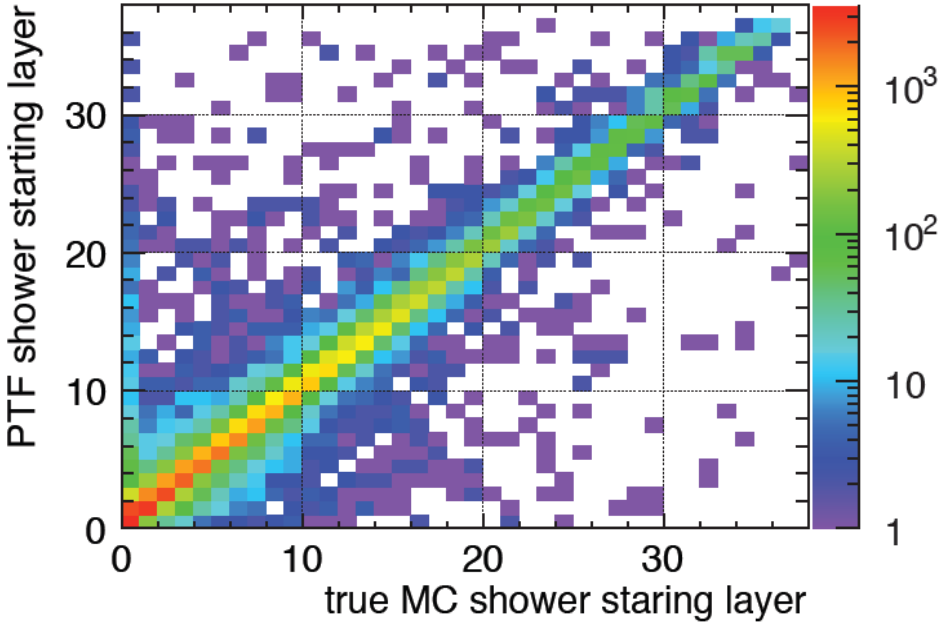


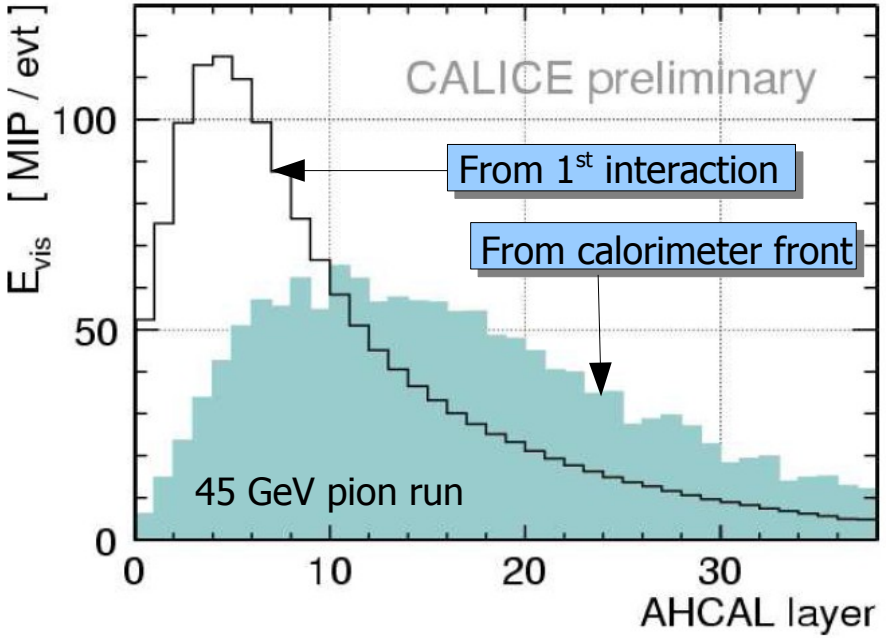
Spatial shower information

- Not only energy information can be used to check MC models, but also the spatial shower development information
- Exploit high granularity to measure shower starting point (Primary Track Finder)

  → Deconvolution of measured longitudinal development from starting point

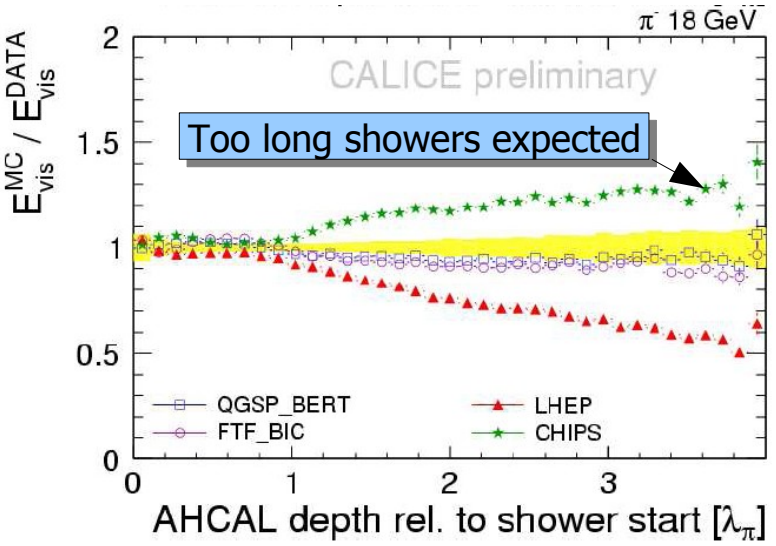
  → Measurement of effective nuclear interaction length in AHCAL material

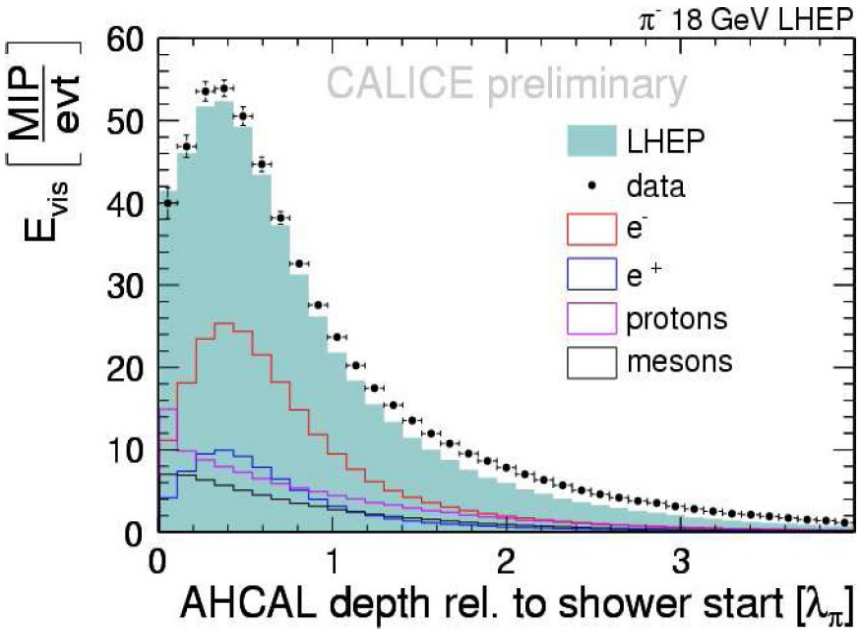


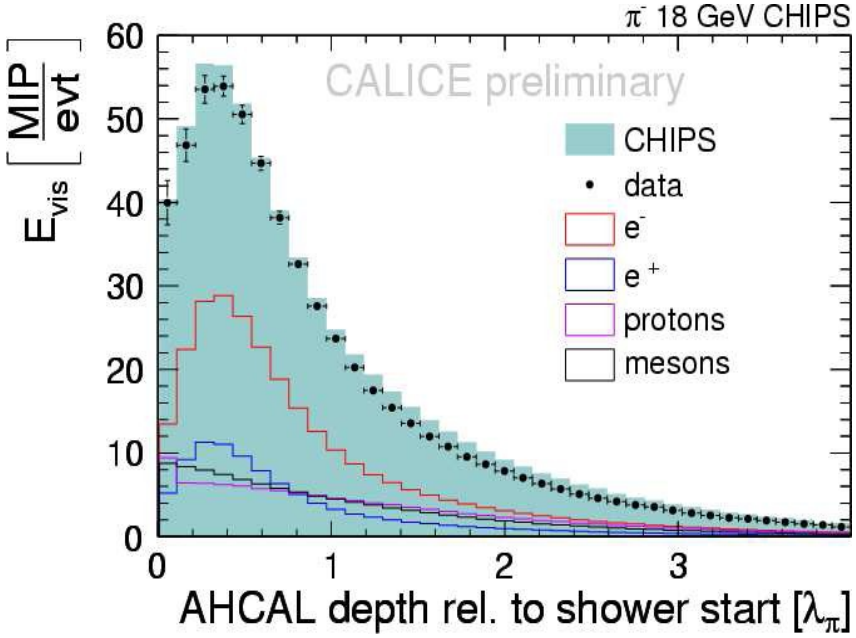


Longitudinal shower profile – 18 GeV

- True longitudinal shower profile can be compared to MC (errors from PTF only)
- Position of shower maximum well simulated
- Differences in shower length and deposited energy in maximum (too high/low em component?)

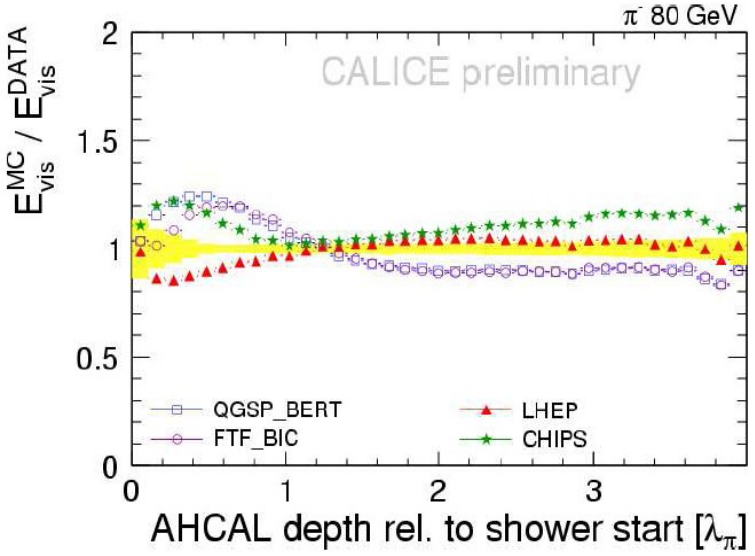


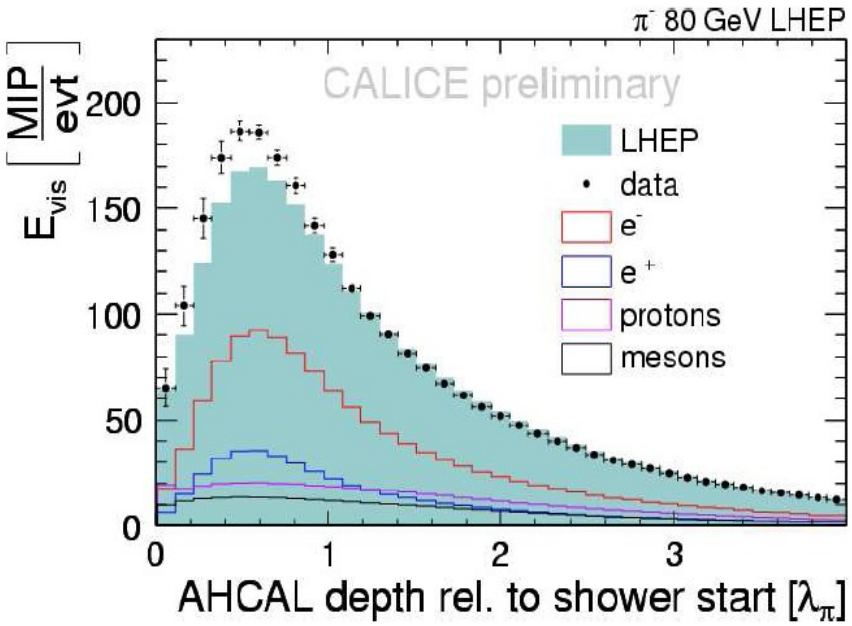


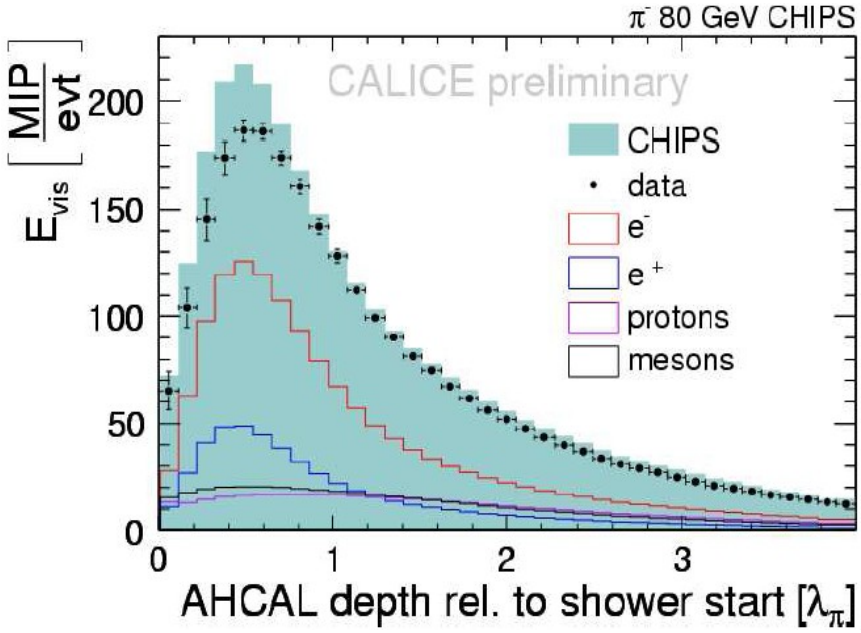


Longitudinal shower profile – 80 GeV

- True longitudinal shower profile can be compared to MC (errors from PTF only)
- Position of shower maximum well simulated
- Differences in shower length and deposited energy in maximum (too high/low em component?)

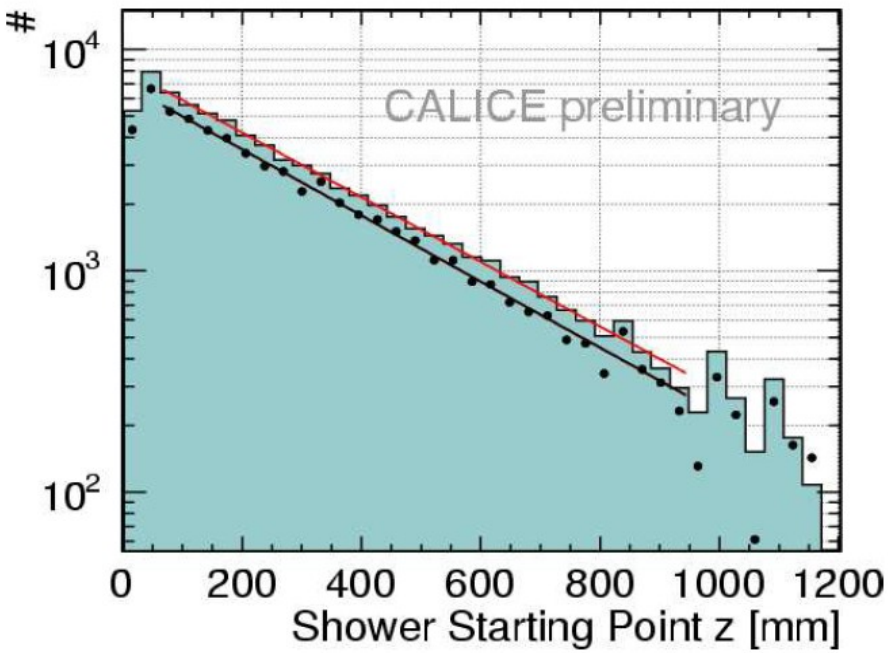


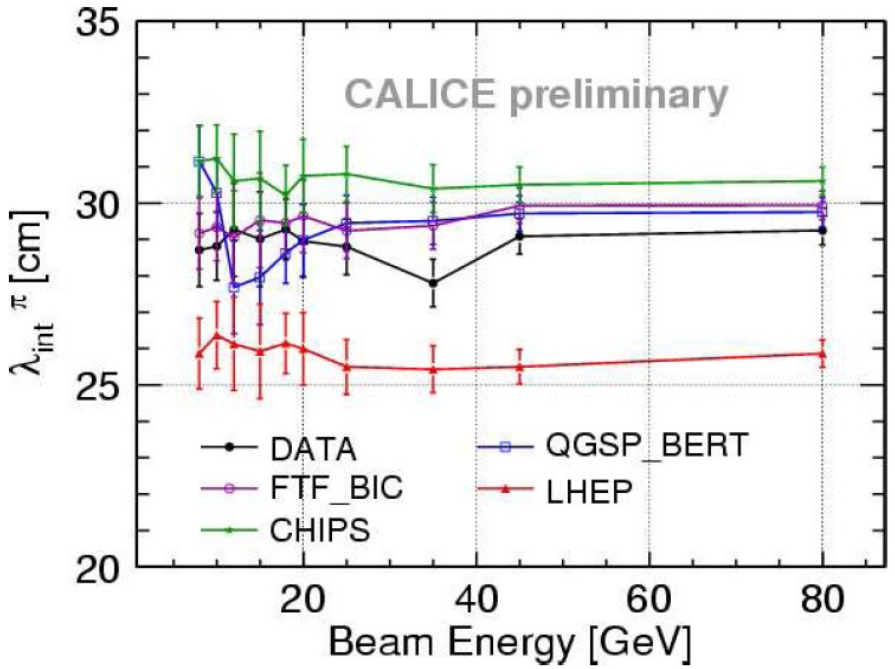




Nuclear interaction length

- Nuclear interaction length can directly be measured from shower start
  → Fit exponential to distribution of shower start
  → Test of cross section implemented in Geant4 physics lists
- FTF_BIC agrees with data, for QGSP_BERT transition region visible
- LHEP and CHIPS have different lambda (expected due to different cross sections)

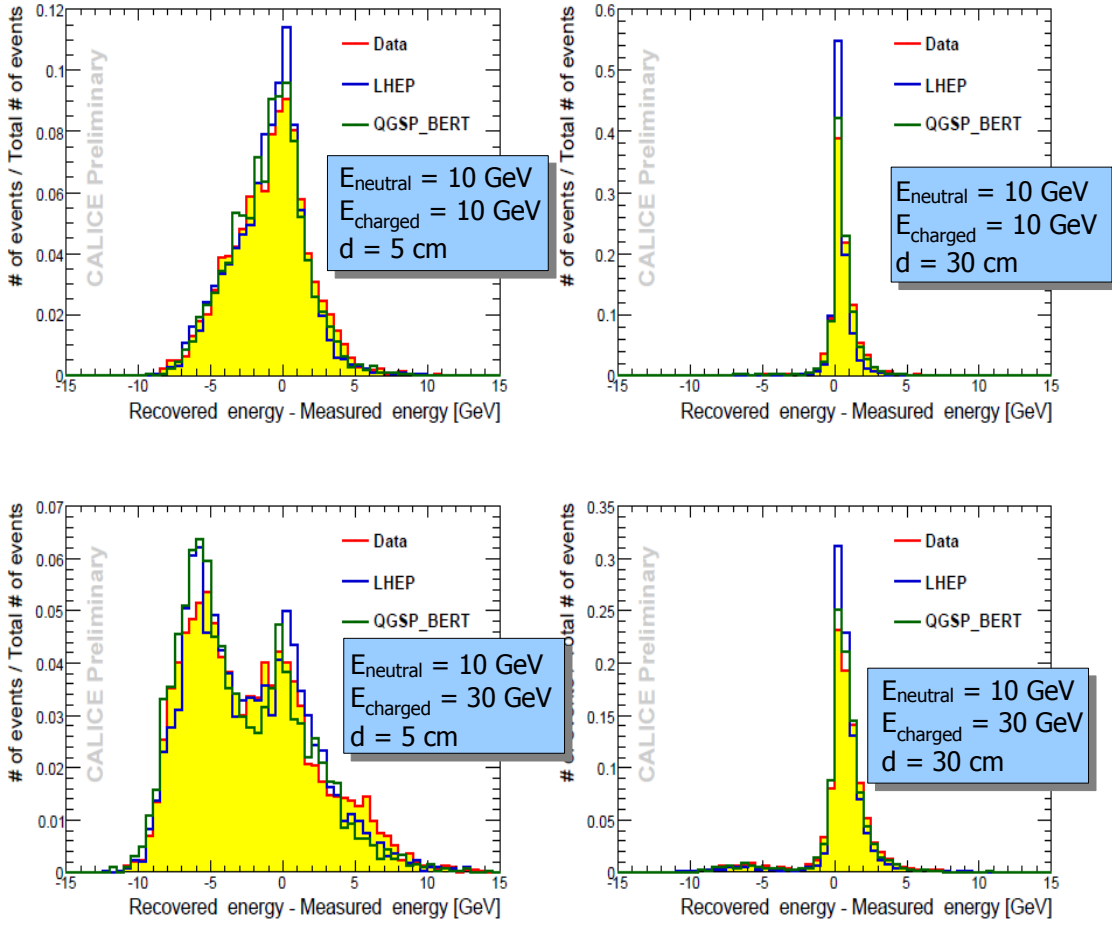




Particle Flow

Test MC models with important particle flow analysis

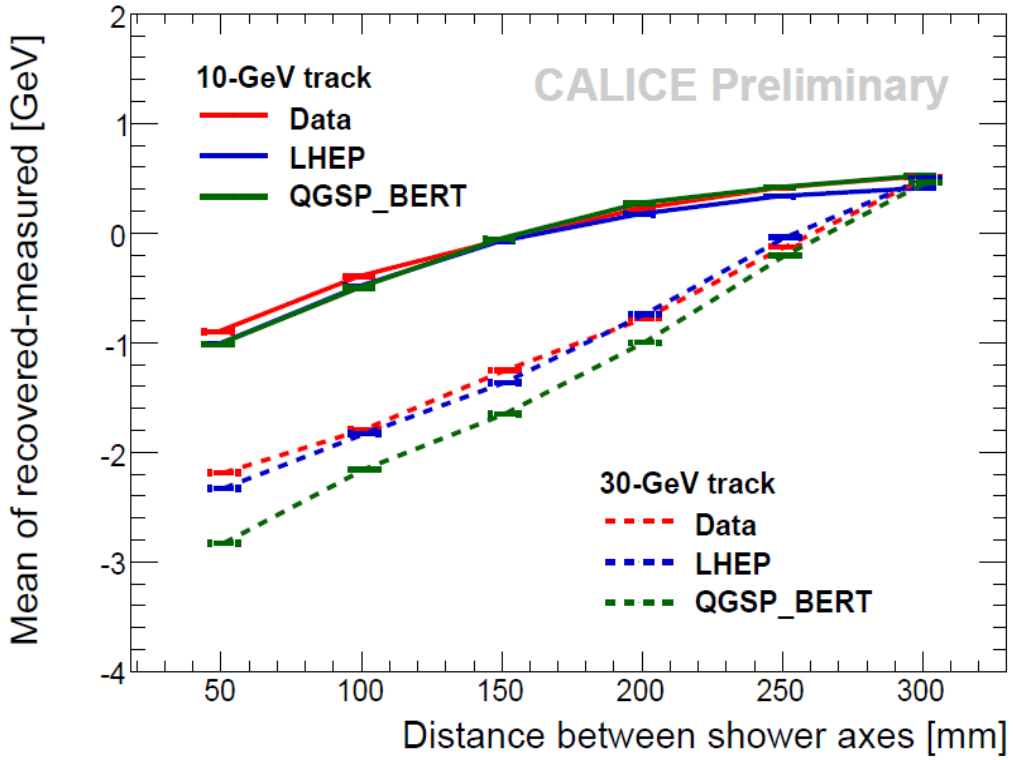
- **Method:**
  - Take 2 pion events and map them to ILD geometry
  - Assume one is neutral
  - Vary distance between the 2 pions and test how well the energy of neutral pion is reconstructed



Particle Flow

- Confusion depends on radial distance between showers (overlap) and their energy

→ Good agreement between data and MC



Summary

- High granularity of the CALICE AHCAL offers unique possibility to investigate hadronic showers
- MC application shown for different aspects of data analysis
  - Energy resolution, compensation
  - Spatial shower information
  - Application of particle flow algorithm
- Active collaboration with Geant4 people

Monte Carlo Energy Correction