Simulation of 96 Test Beam Setup with Geant4

Outline

- Test Beam Setup
- Simulation
- Energy Measurement
- Comparison for HCal alone data
- Comparison for ECal + HCal data

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Test Beam Setup

The test beam detector module has two components:

- Hadron calorimeter with alternate layers of absorber and plastic scintillator

  28 scintillator plates mostly of 4 mm thickness with absorber of varying thickness in-between

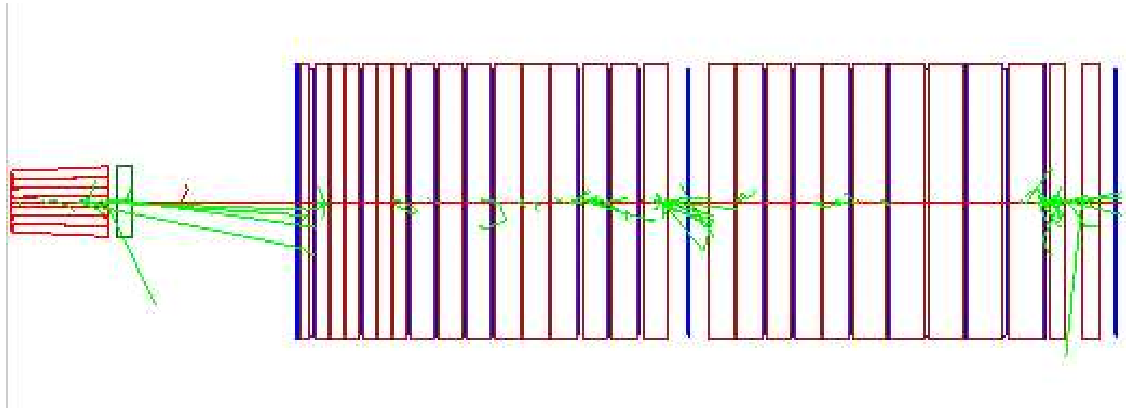
- Electromagnetic calorimeter consisting of 49 lead tungstate crystals.

Data taking conditions:

- Each scintillator layer is read out independently using PMT and the crystals are equipped with APD
- Data are taken with three geometrical configuration: with, without and inverted ECal in front
- Use electron and π beams of energy between 10 and 300 GeV (+ 225 GeV μ beam for calibration)
- Magnetic field between 0 and 3 Tesla with direction parallel to the face of the scintillator plates - (HCal Barrel configuration)

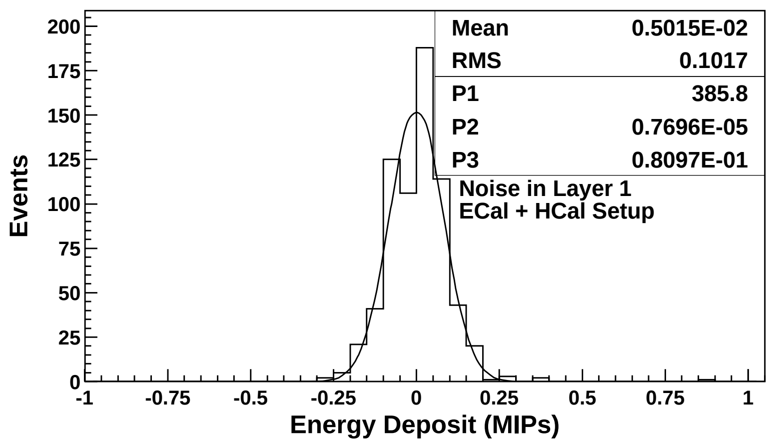
Simulation

- Use GEANT 4.5.2.p02 with the Test Beam description given as one of the advance examples

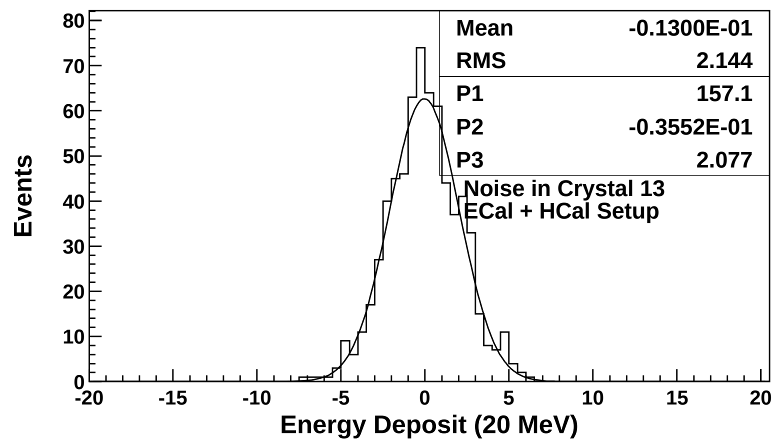


- The absorber layers are made of a special type of Brass (not Copper) of substantial lower density (interaction length)
- All Monte Carlo event samples are regenerated with the new setup definition and using the physics list of version PACK 2.3:
  - LHEP version 3.6
  - QGSP version 2.7
  - QGSC version 2.8
  - FTFP version 2.7

- Cutoff of 700 μm used on range of particles
- Also generate event samples using GEANT 3.21 with GHEISHA package to simulate hadron showers. Choose 100 KeV cutoffs for photon, electron, charged hadrons and 10 KeV cutoff for neutrons
- Simulate inhomogeneity in light collection in the crystals along its length using the efficiency curve
- Noise studied from data and added to individual channels



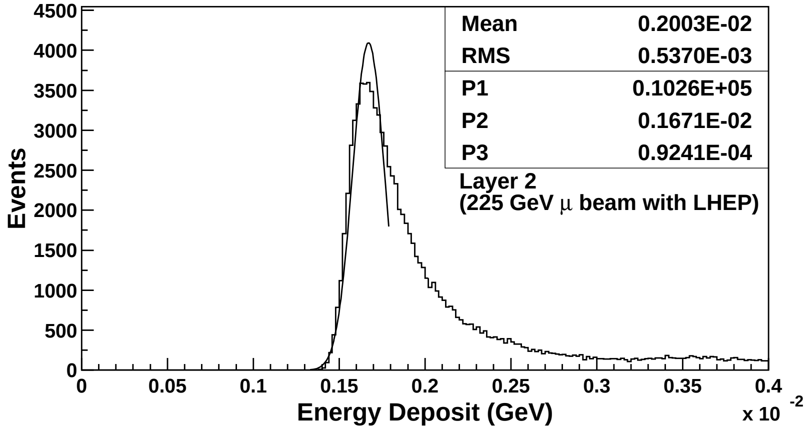
HCal

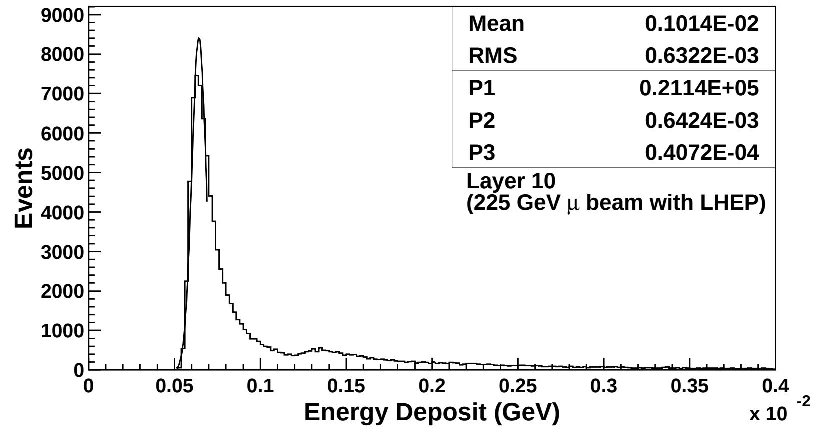


ECal

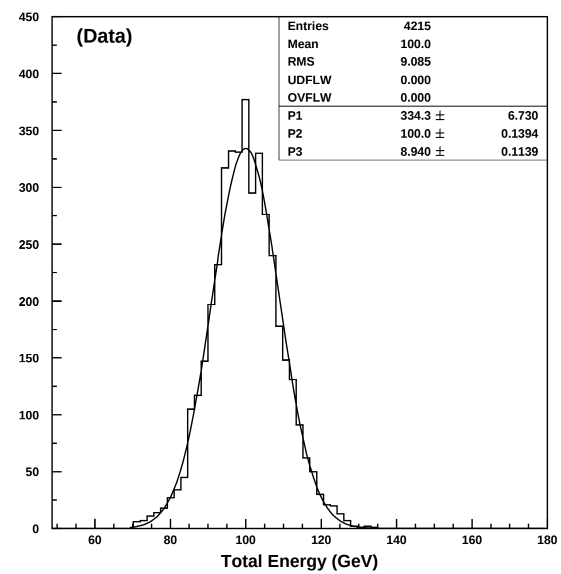
Energy Measurement

Calibrate each channel using μ sample (for data as well as simulation)

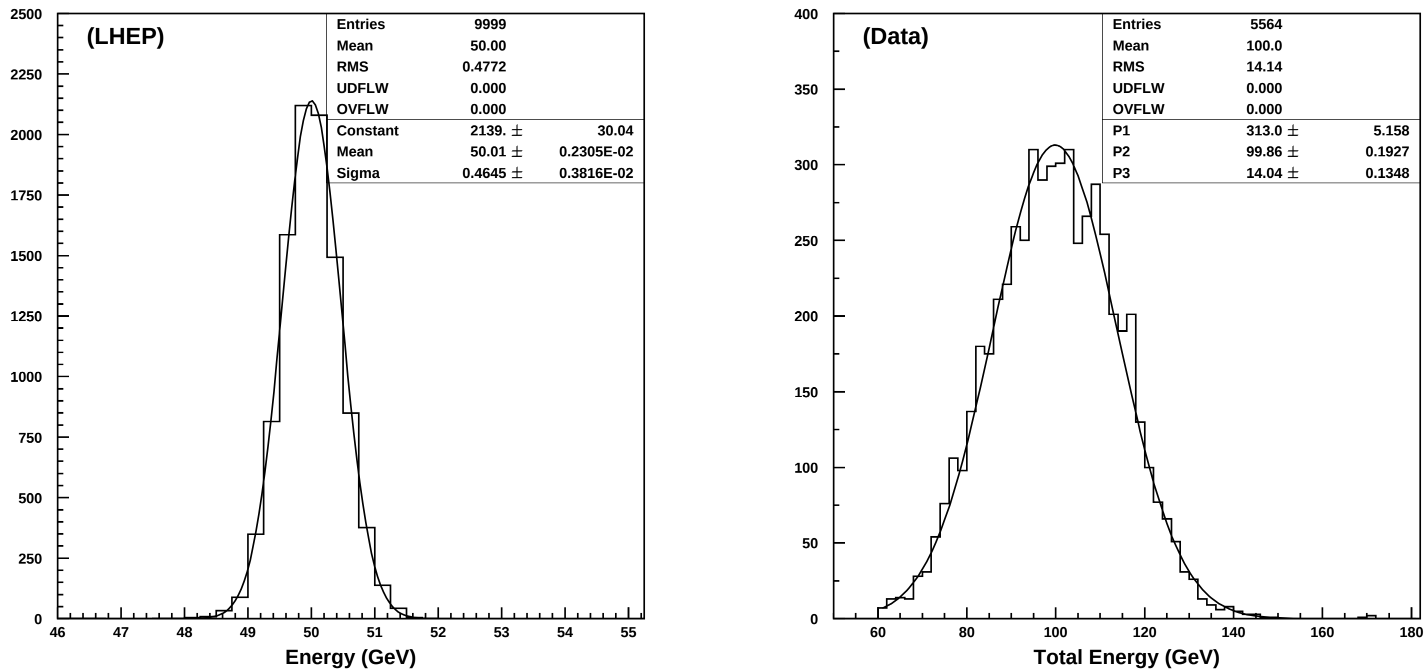




- For a configuration with HCal alone:
  - Convert energy deposits in terms of MIPs
  - Weigh the energy deposit in each layer by the absorber thickness in front
  - Normalise to beam energy using 100 GeV pion data



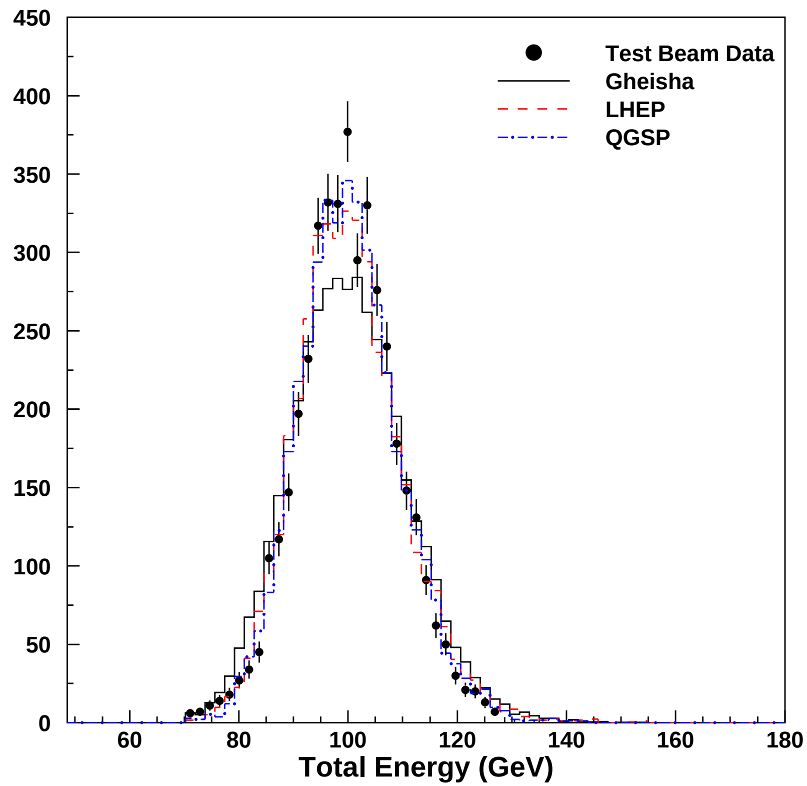
- For a configuration with ECal and HCal together:
  - Fix the scale of the electromagnetic calorimeter using electron data at high energies



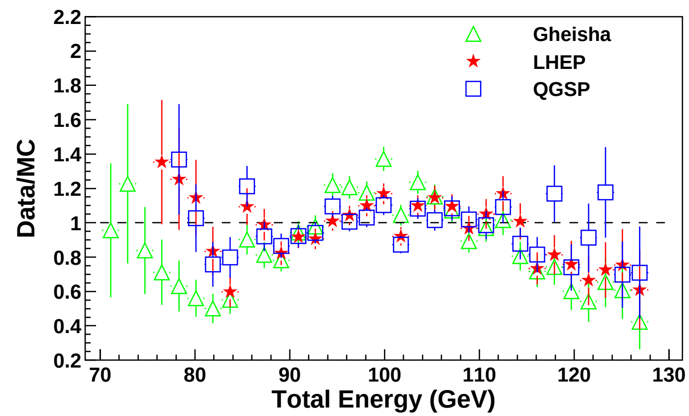
  - Calibrate the energy deposit in the hadron calorimeter using the same method as before and normalise the hadron calorimeter scale with 100 GeV pion data

HCal alone data

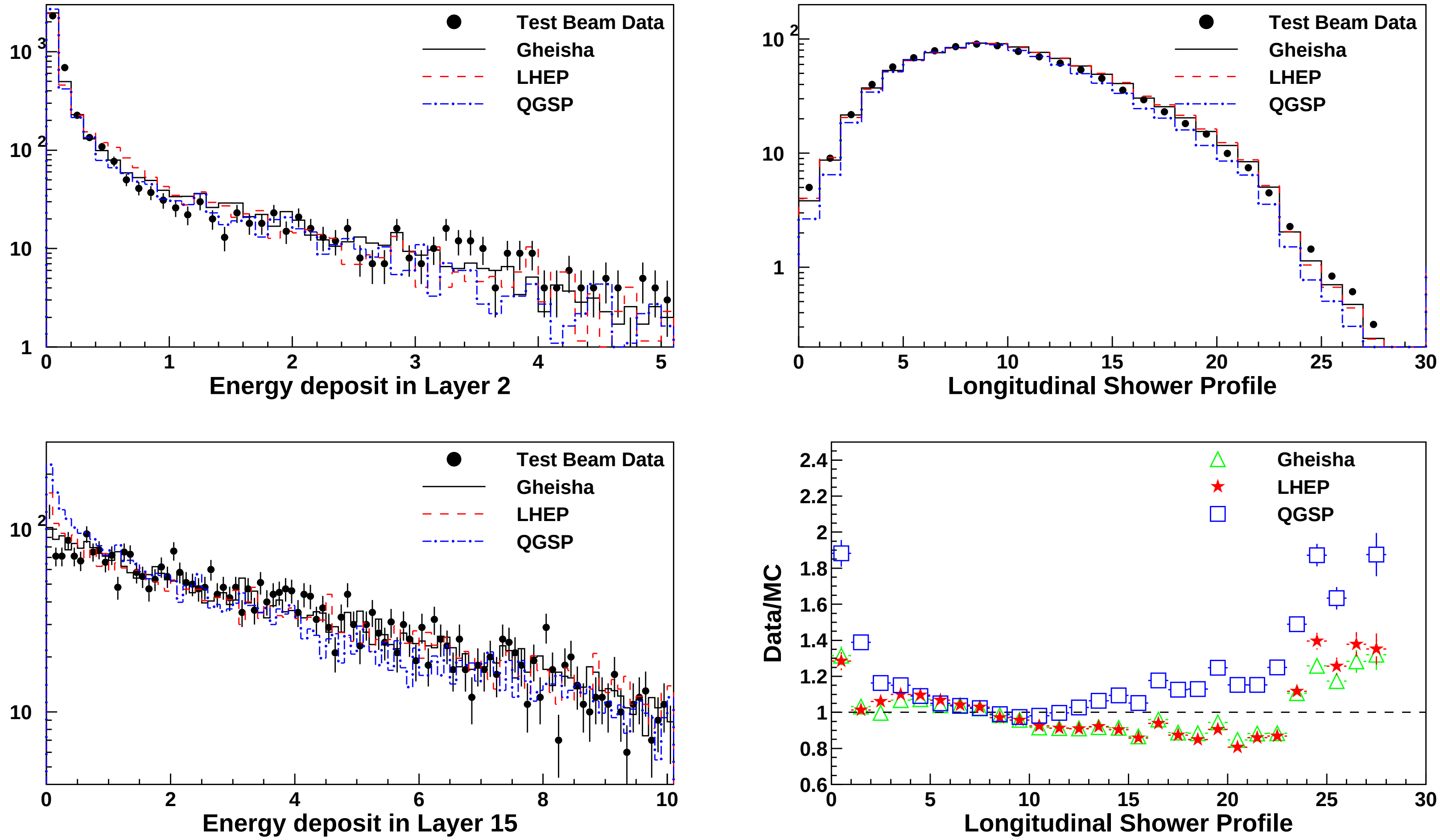
100 GeV π sample has been used to obtain the energy scale factor



	σ (GeV)	RMS (GeV)
Data	9.2±0.1	9.4±0.1
LHEP	9.8±0.1	10.3±0.1
QGSP	9.2±0.1	9.5±0.1
Gheisha	10.2±0.1	11.0±0.1

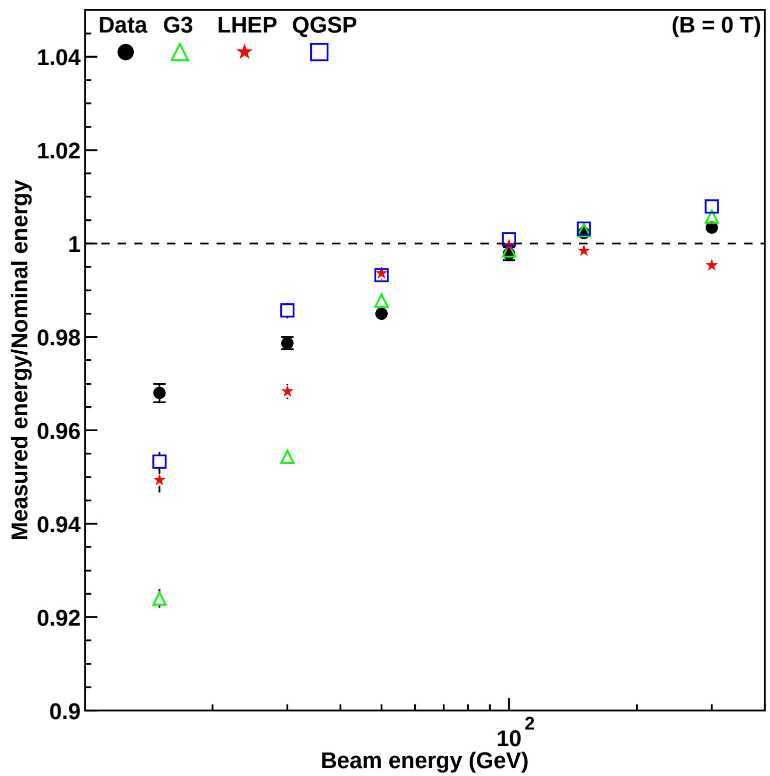


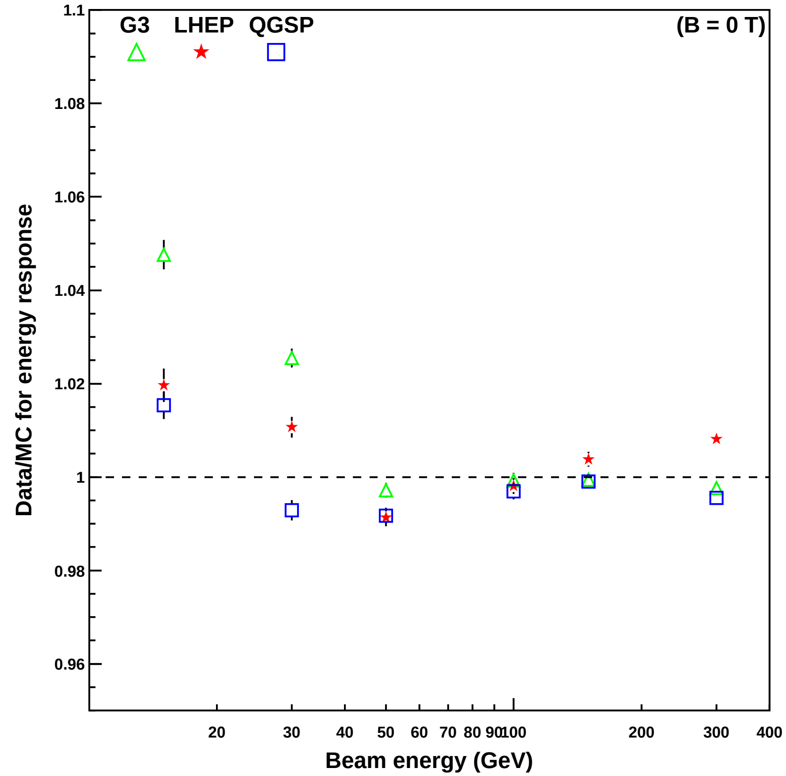
Geant4 models (particularly QGSP) provide good description of energy resolution



For longitudinal shower profile, data lie between predictions from LHEP and QGSP

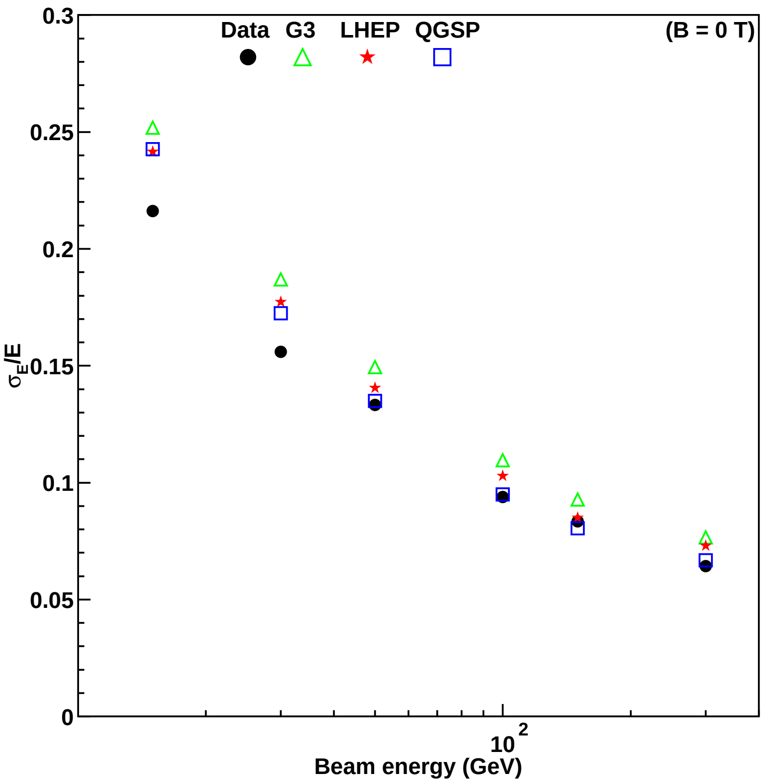
Energy response:

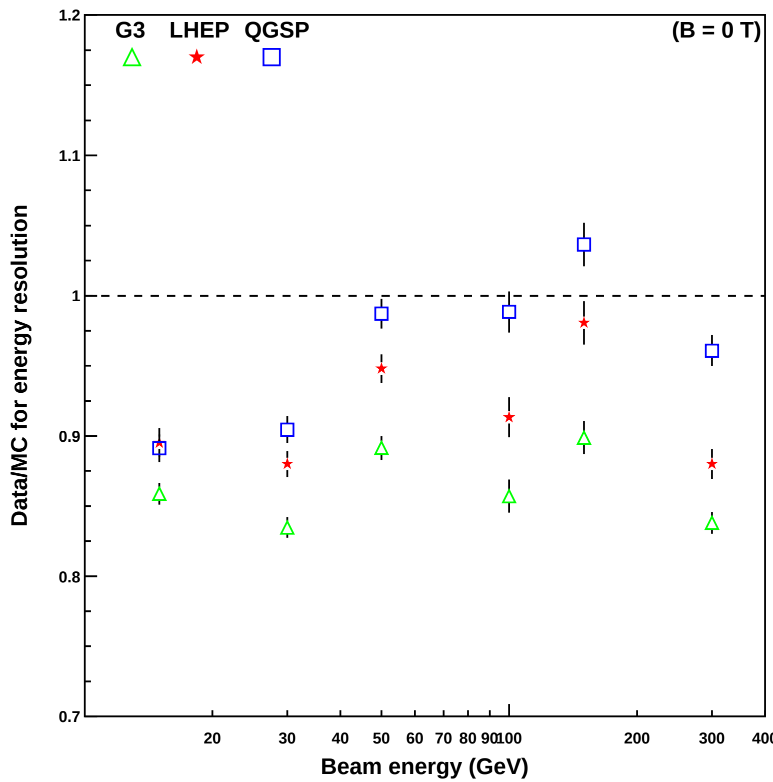




- Nonlinearity in the energy response is reasonably described by different Geant4 models

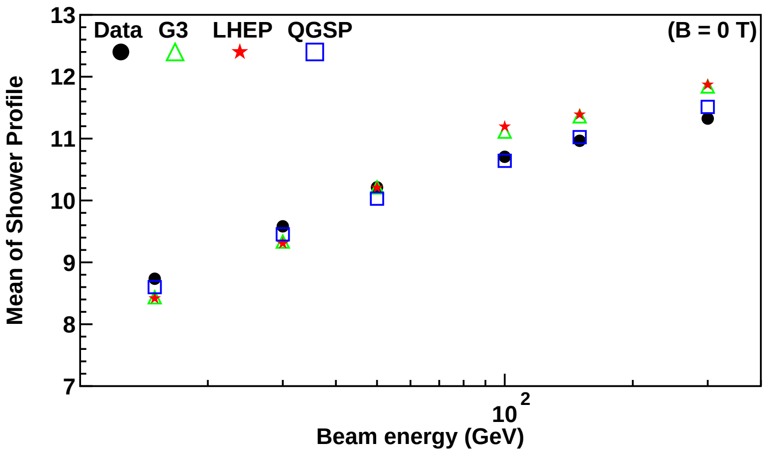
Energy resolution:

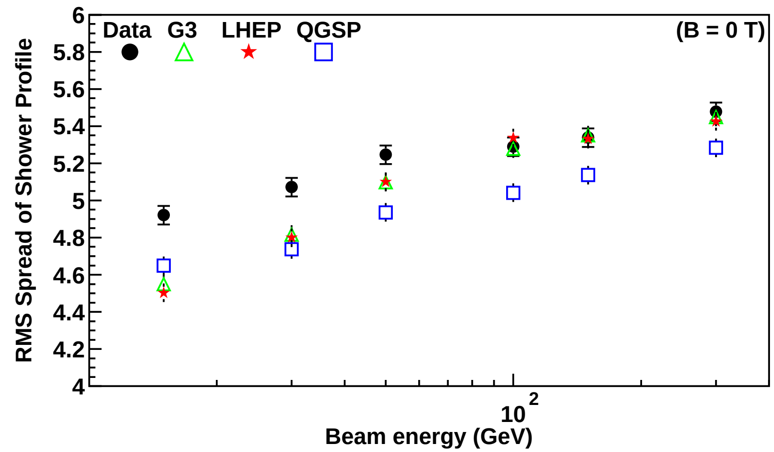




- ❑ Energy resolution at high energy is well explained by QGSP model

Longitudinal shower profile:

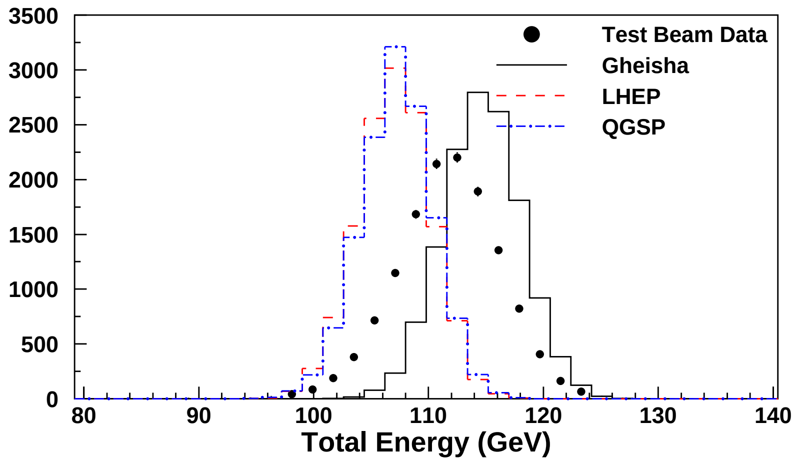




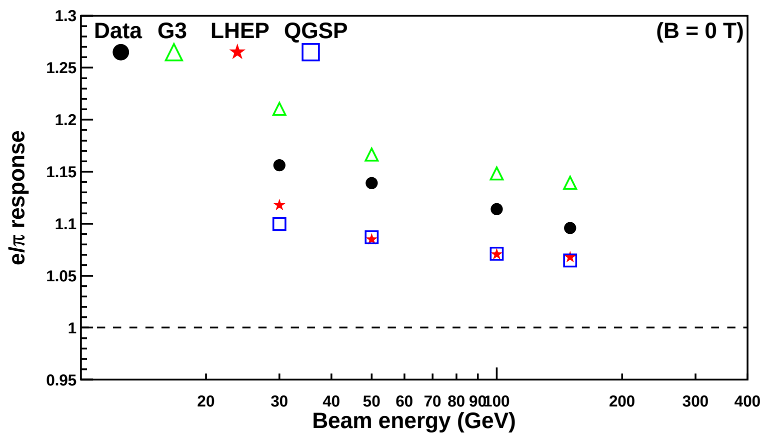
- Mean of the shower profile distributions increases logarithmically with energy for data as well as for MC models
- Mean for the data agrees better with microscopic models at high energy
- Width in the shower profile spectrum is much larger in the data at low energies and there is a good agreement between data and parametrised models at higher energies

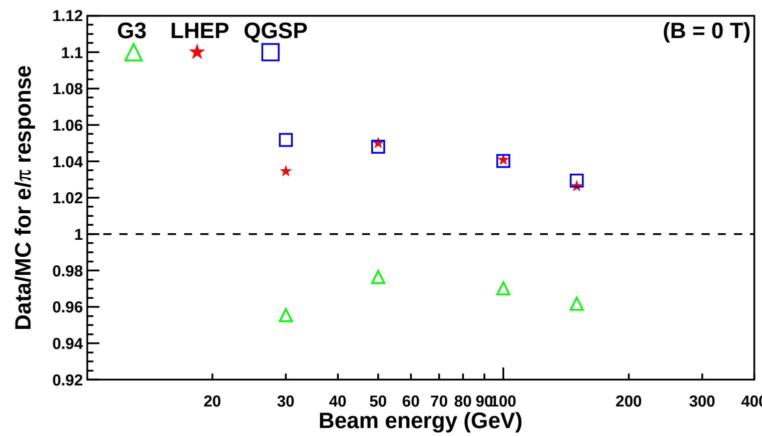
e/h:

Measure electron energy with the same scale factor as for $\pi \Rightarrow e/\pi$ ratio



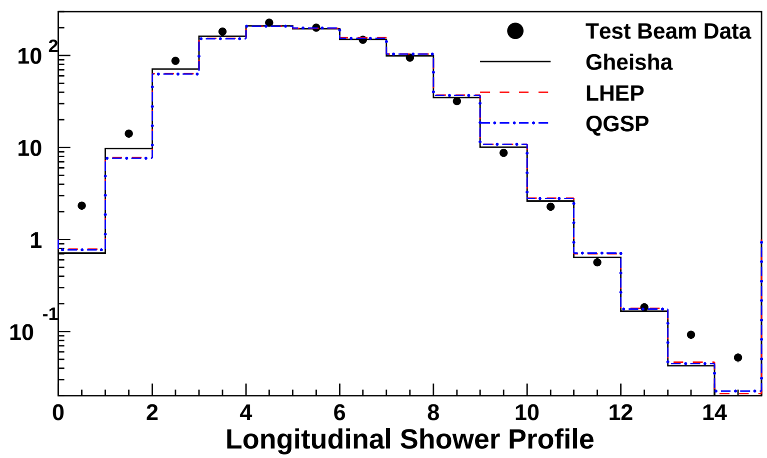
	at 100 GeV	at 50 GeV
Data	1.112±0.001	1.122±0.001
LHEP	1.070±0.001	1.078±0.001
QGSP	1.072±0.001	1.080±0.001
Geant3	1.147±0.001	1.152±0.001

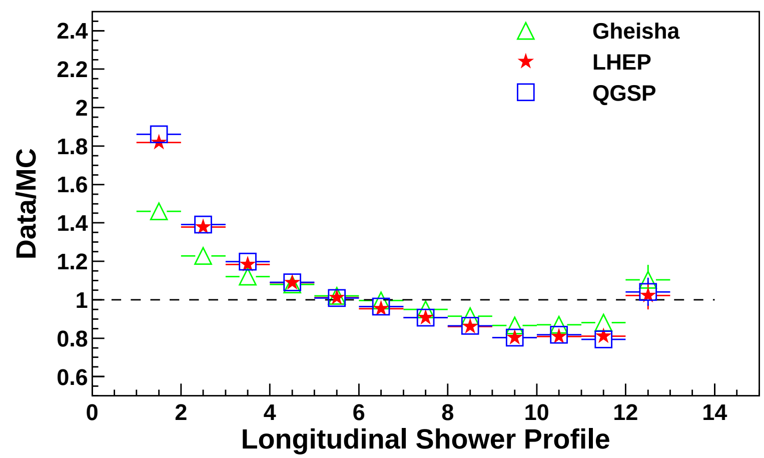




- e/h ratio in HCal is $\sim$ 3% higher in Geant3 while it is $\sim$ 4% smaller in the different models of Geant4
- Use a parametrisation for $F(\pi^0)$ to estimate e/h response of the setup

	(Wigmans)	(Gabriel)
Data	1.27±0.05	1.33±0.05
LHEP	1.17±0.01	1.20±0.01
QGSP	1.16±0.01	1.19±0.01
Geant3	1.36±0.01	1.44±0.01



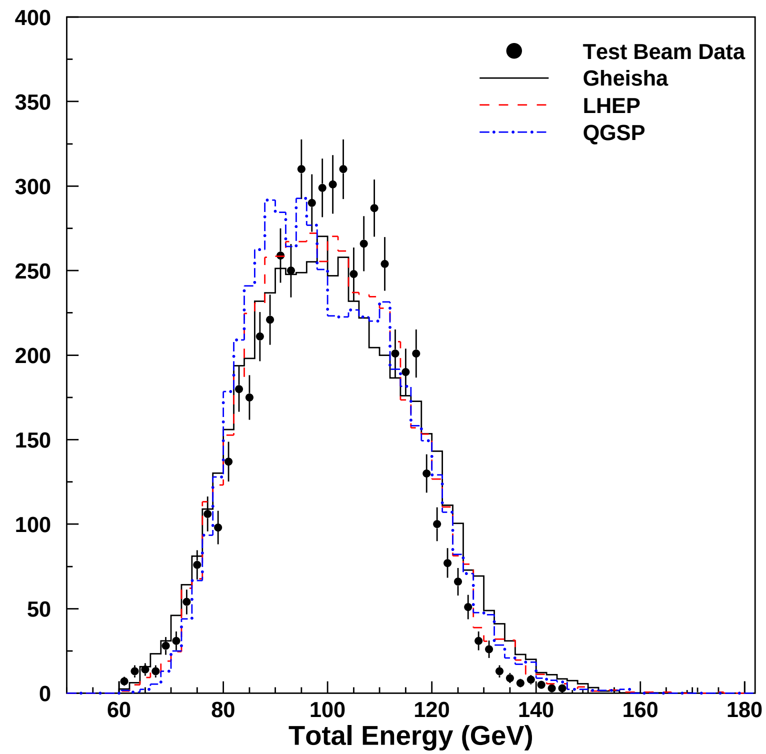


- More energy deposit in layers 1 and 2 in case of real data
- Longer tails in the shower in case of real data

ECal + HCal data

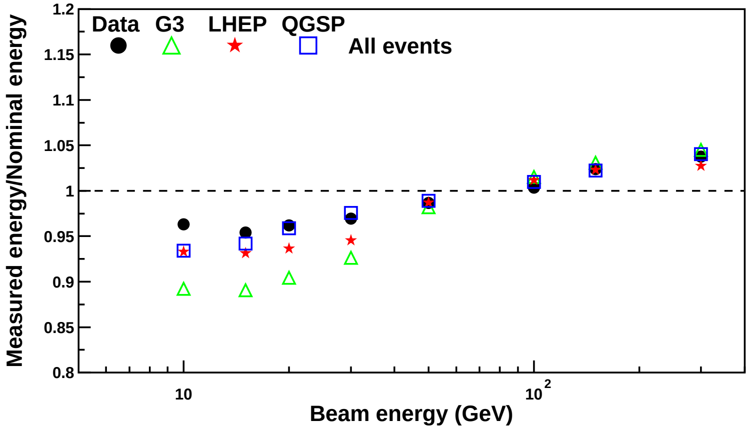
With 100 GeV π^- in the combined setup

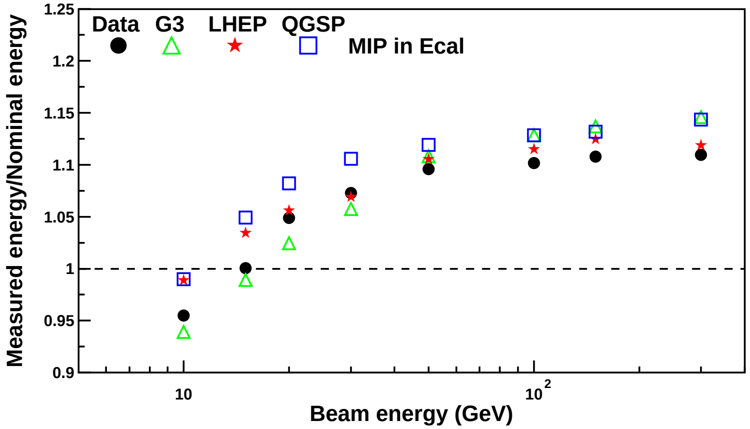
	σ (GeV)	RMS (GeV)
Data	14.2±0.1	14.2±0.1
LHEP	14.8±0.1	15.2±0.1
QGSP	14.4±0.1	15.2±0.1
Geant3	16.1±0.1	16.2±0.1

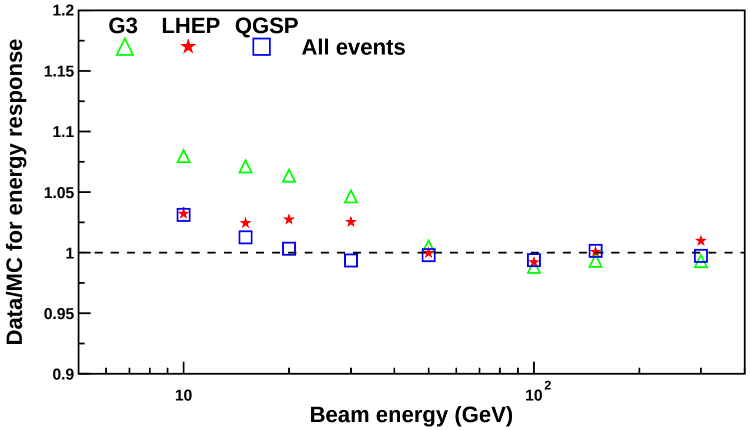


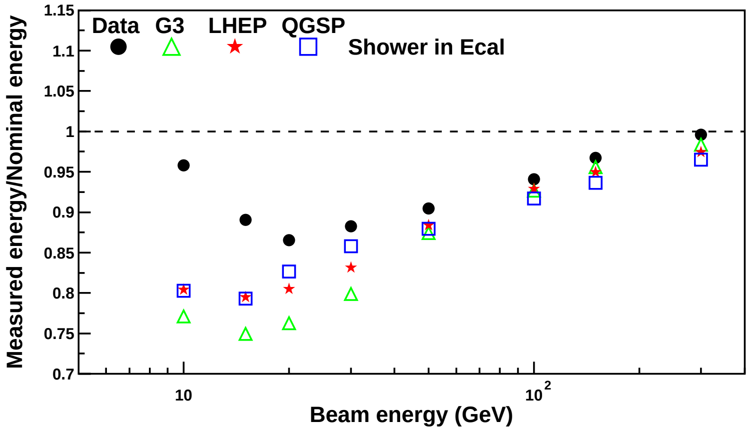
Worsening in resolution is due to non-matching e/h between ECal and HCal

Energy response:



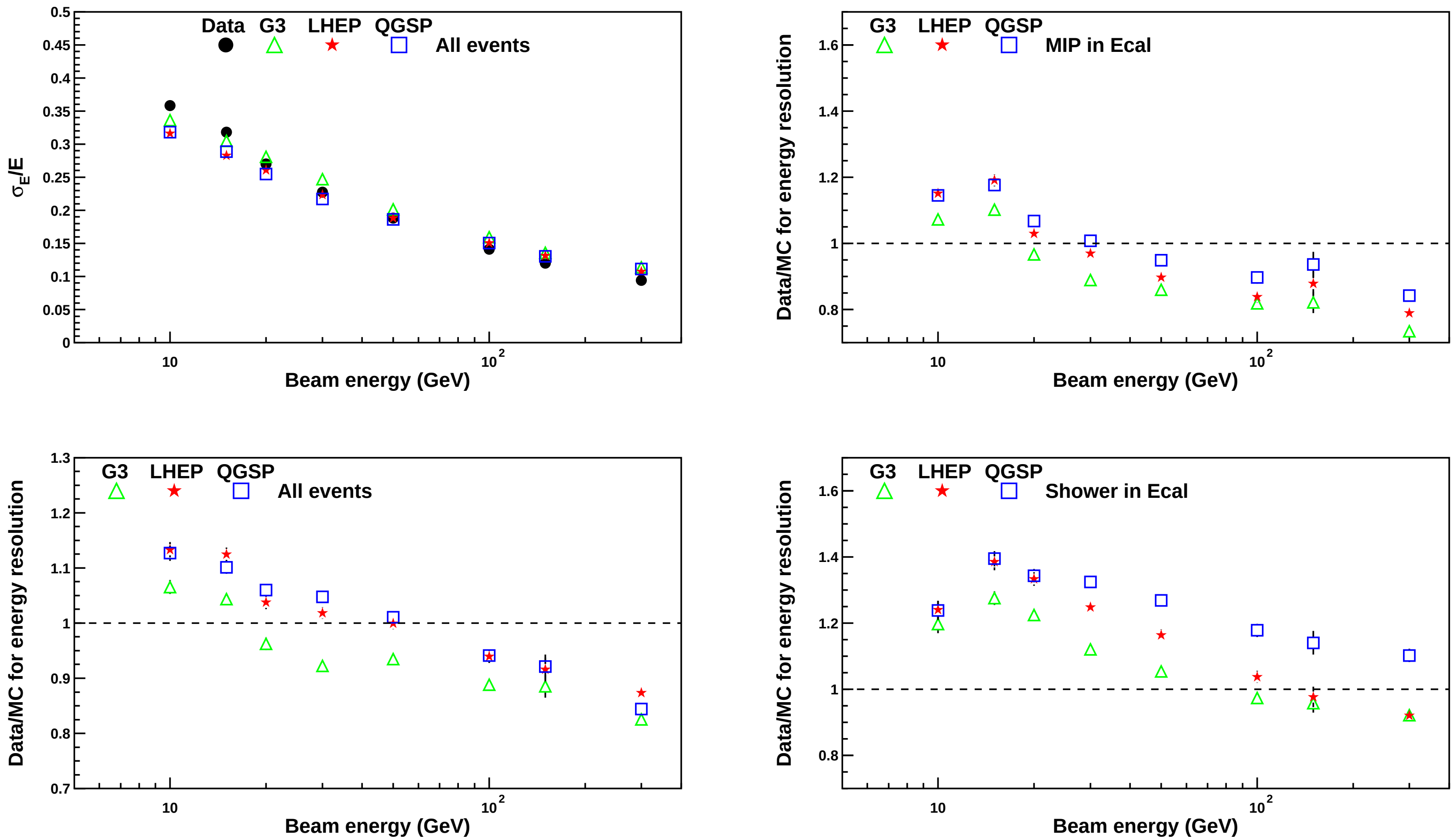






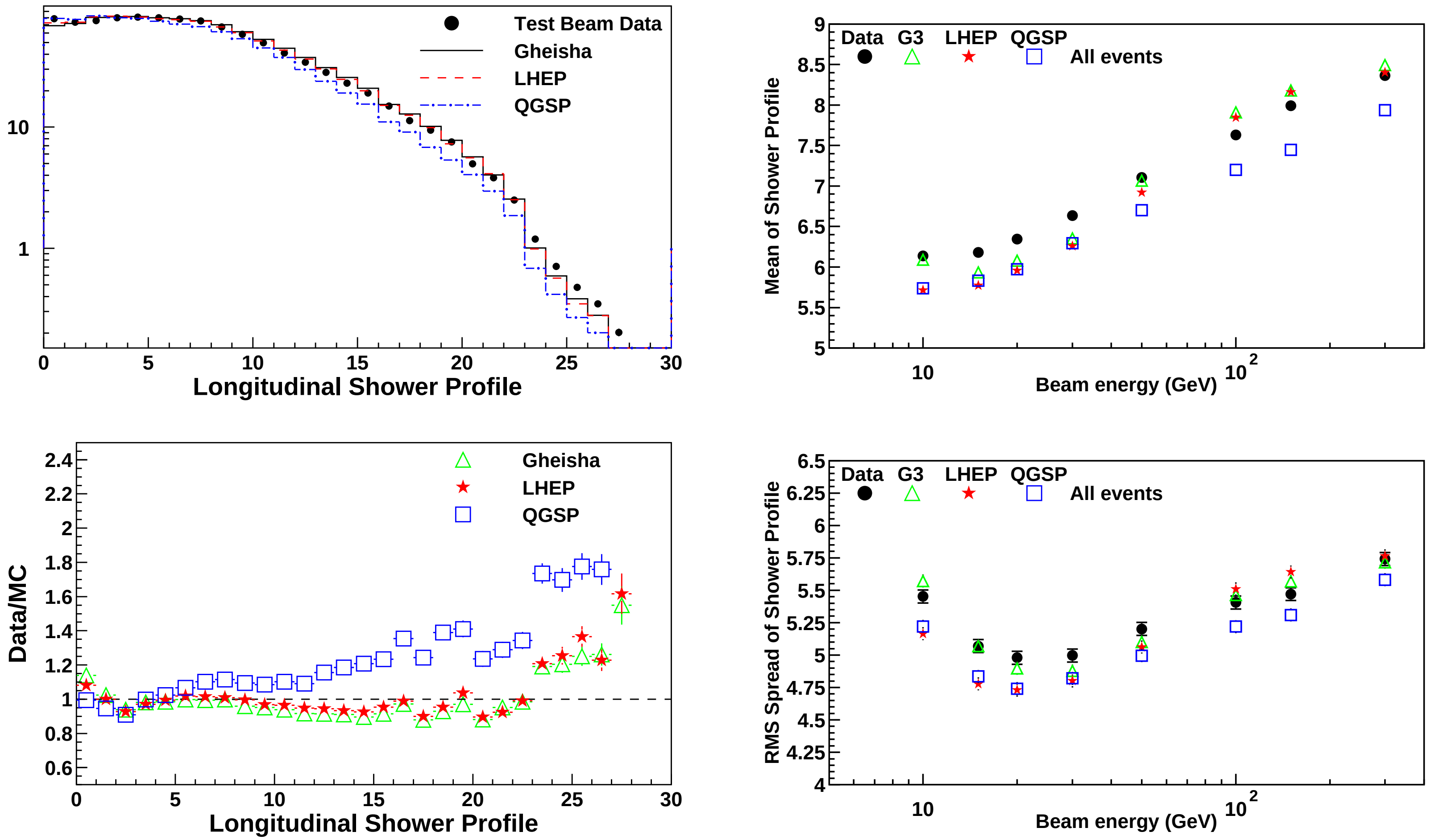
- Non-linearity in response is reasonably reproduced by the models
- Larger discrepancy is in the sample which starts showering in ECal

Energy resolution:



- Energy resolution is described within 10%
- Discrepancy is larger in the sample which starts showering in ECal

Longitudinal shower profile:



- ❑ Difference between data and Monte Carlo reduces at higher energies
- ❑ Parametrised models are in better agreement