Simulation of 96 Test Beam Setup with Geant4

Outline

- Test Beam Setup
- Changes since October Analysis
- Comparison of HCAL alone data
- Comparison of ECAL + HCAL data
- Outlook

Sunanda Banerjee
CERN/TIFR

December 3, 2003

Test Beam Setup

The test beam detector module has two components:

- Hadron calorimeter with alternate layers of copper 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:

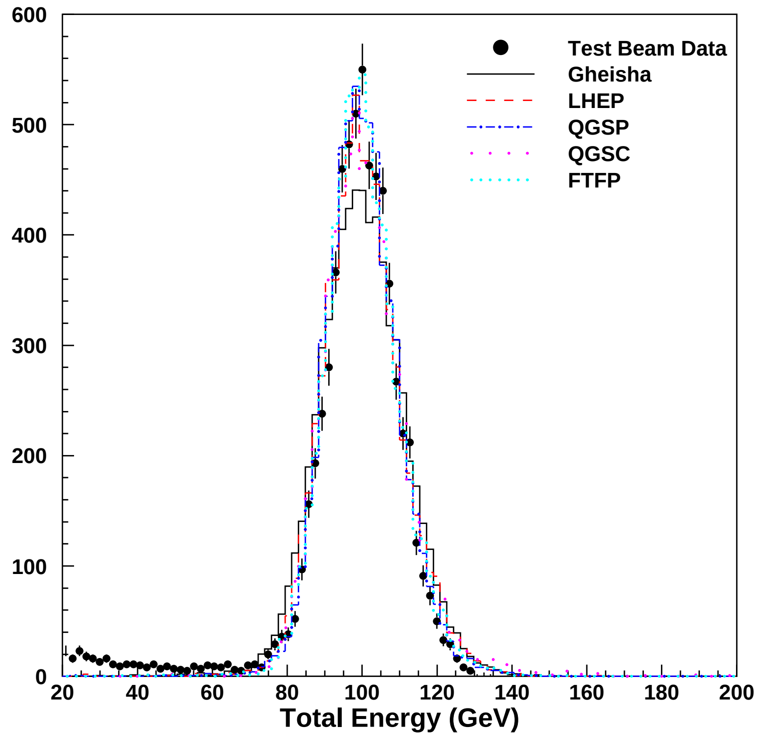
- Each scintillator layer is read out independently using PMT and the crystals are equipped with APD
- Data are taken with three geometrical configuration: with, without and inverted ECAL in front
- Use electron and π beams of energy between 10 and 300 GeV ($+$ 225 GeV μ beam for calibration)
- Magnetic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

Changes with respect to Last Analysis

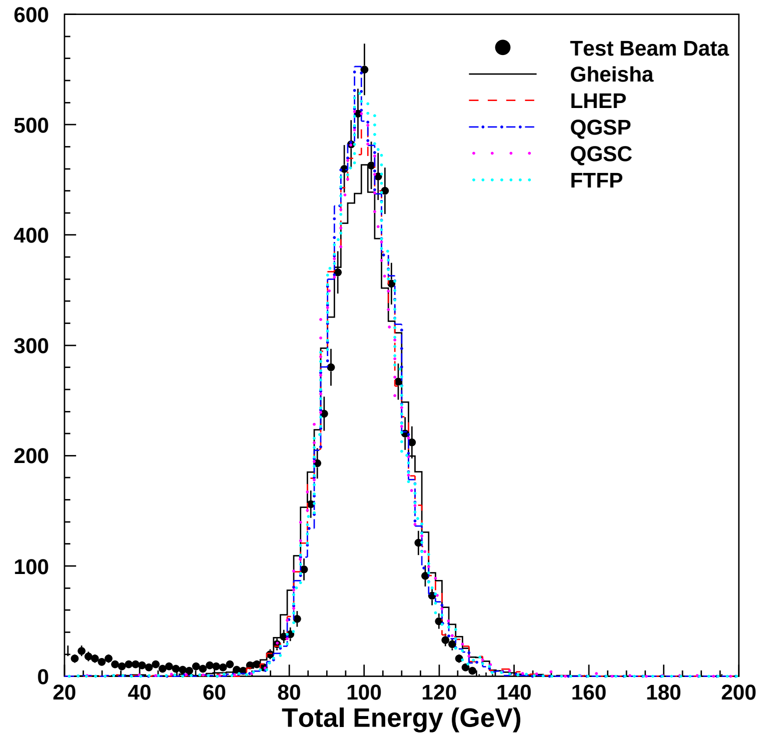
- Use Geant4 version geant4-05-02-patch-02 dated October 3, 2003
- Use of new physics list with the PACK 2.3 version of the packaging system:
  - LHEP version 3.6
  - QGSP version 2.7
  - QGSC version 2.8
  - FTFP version 2.7
- Use G4ClassicalRK4 instead of G4SimpleRunge as field integrator with precision values for stepping, intersection and chord finding set at small values ($\sim 1\ \mu$m)
- Correct for inhomogeneity in light collection in the crystals along its length
- Use of coherent set of calibration constants for the field on data (and Monte Carlo)
- Study more beam energy data sets with HCAL alone setup and also with more than one B-field values

HCAL alone Setup

Total energy measurement for 100 GeV π in HCAL alone setup

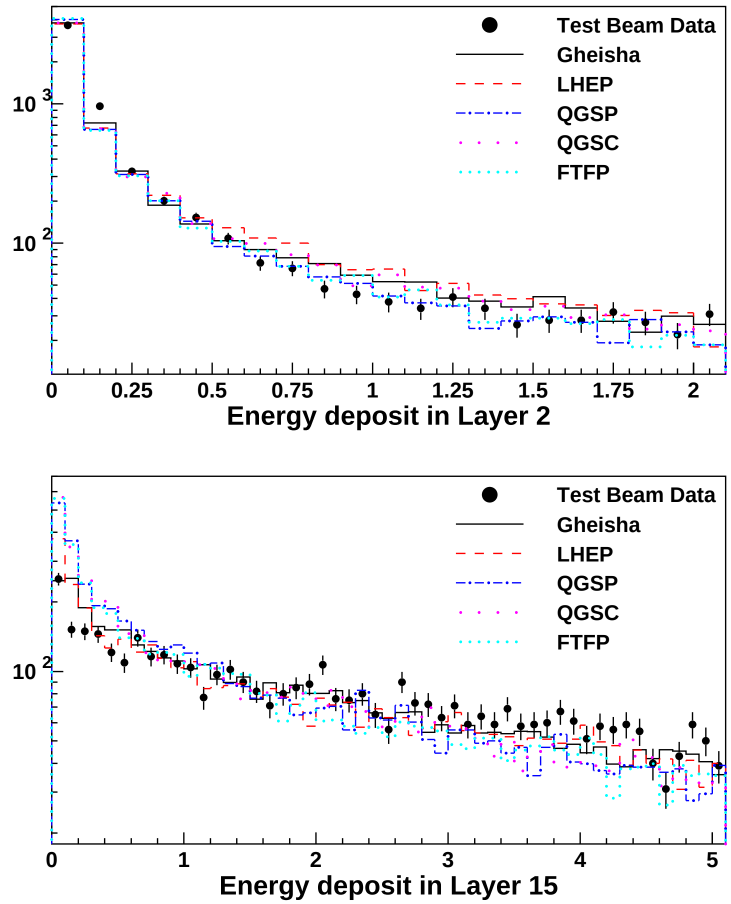


Physics List as in OSCAR 240

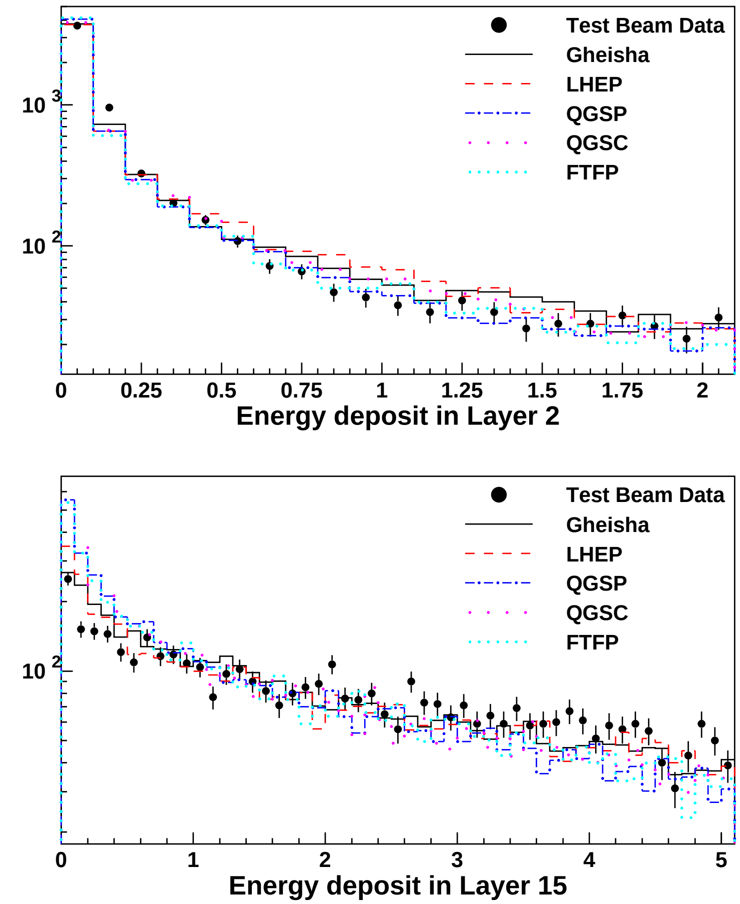


Physics Lists in Pack23

Energy deposit in different layers for 100 GeV π in HCAL alone setup

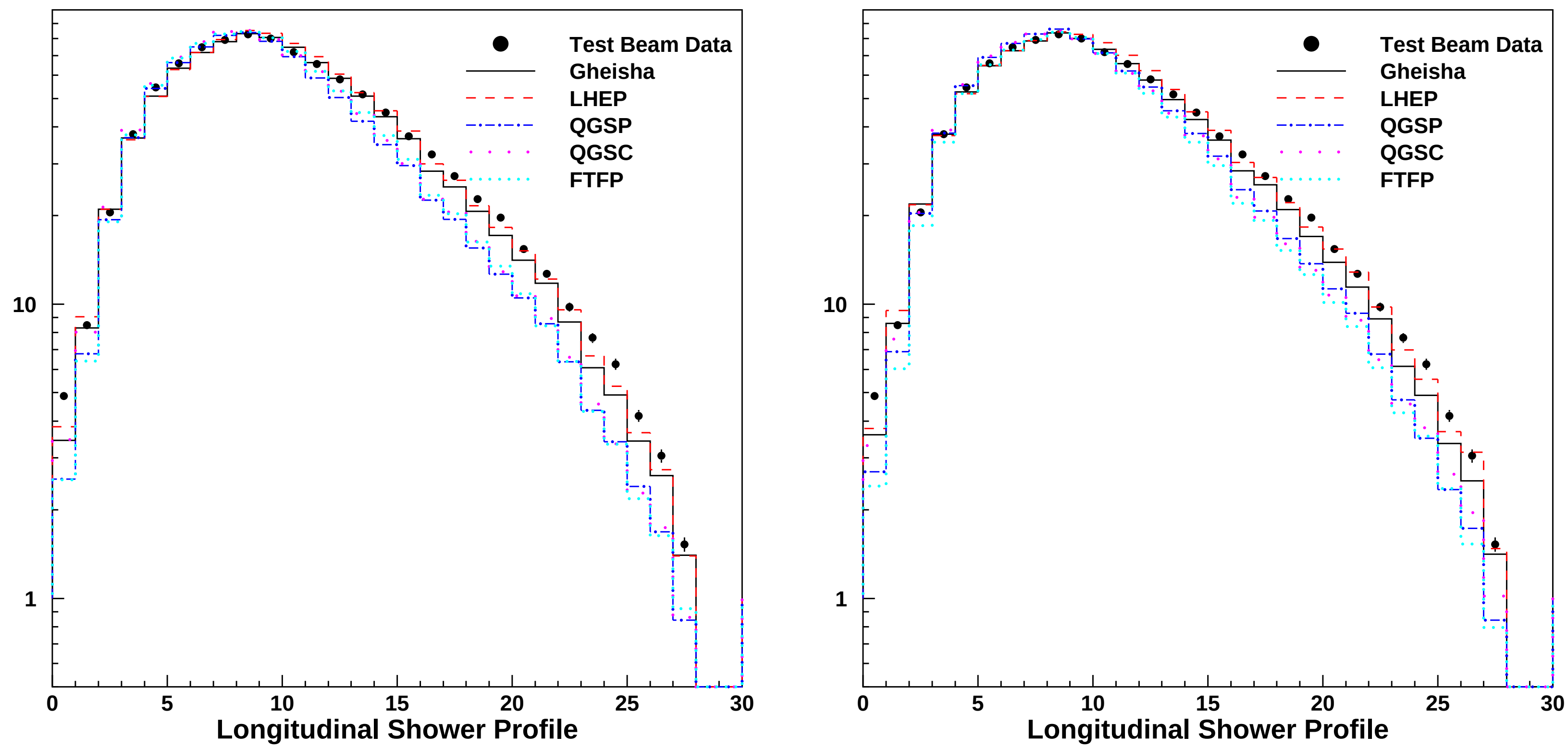


Physics List as in OSCAR 240



Physics Lists in Pack23

Longitudinal shower profile for 100 GeV π in HCAL alone setup



Physics List as in OSCAR 240

Physics Lists in Pack23

Energy Resolution in GeV

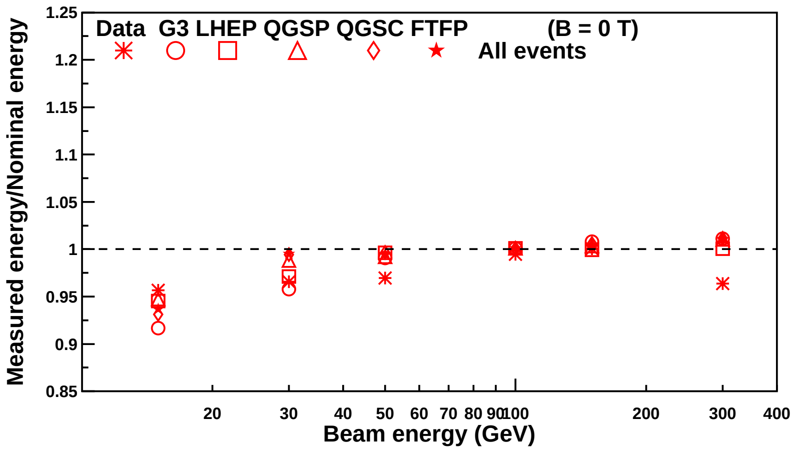
	Old	New
Data	10.3±0.1	10.3±0.1
LHEP	10.6±0.1	10.6±0.1
QGSP	9.8±0.1	9.8±0.1
QGSC	11.7±0.1	11.2±0.1
FTFP	9.9±0.1	9.9±0.1
Geant3	11.3±0.1	11.3±0.1

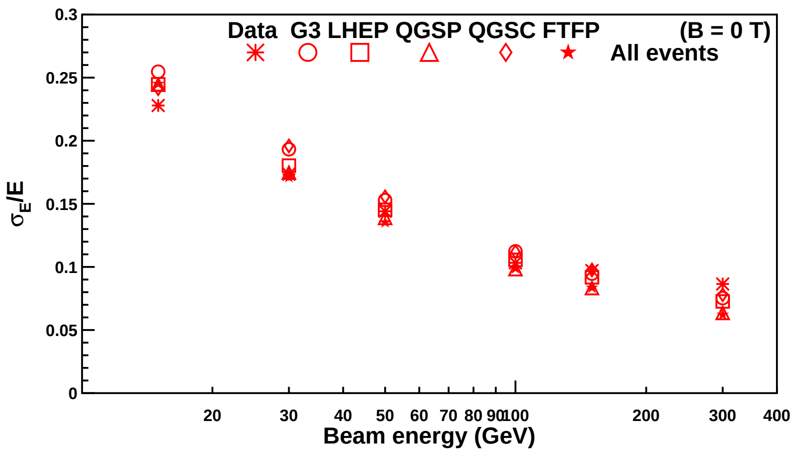
⇒ no appreciable change

From the longitudinal shower profile distribution:

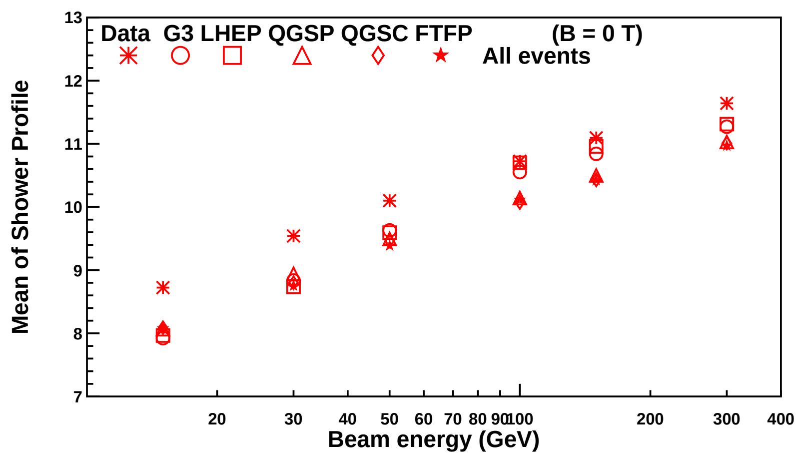
	Mean		RMS	
	Old	New	Old	New
Data	10.72±0.05	10.72±0.05	5.28±0.05	5.28±0.05
LHEP	10.69±0.05	10.70±0.05	5.13±0.05	5.16±0.05
QGSP	10.07±0.05	10.14±0.05	4.86±0.05	4.88±0.05
QGSC	10.02±0.05	10.07±0.05	4.86±0.05	4.89±0.05
FTFP	10.10±0.05	10.11±0.05	4.83±0.05	4.80±0.05
Geant3	10.55±0.05	10.55±0.05	5.13±0.05	5.13±0.05

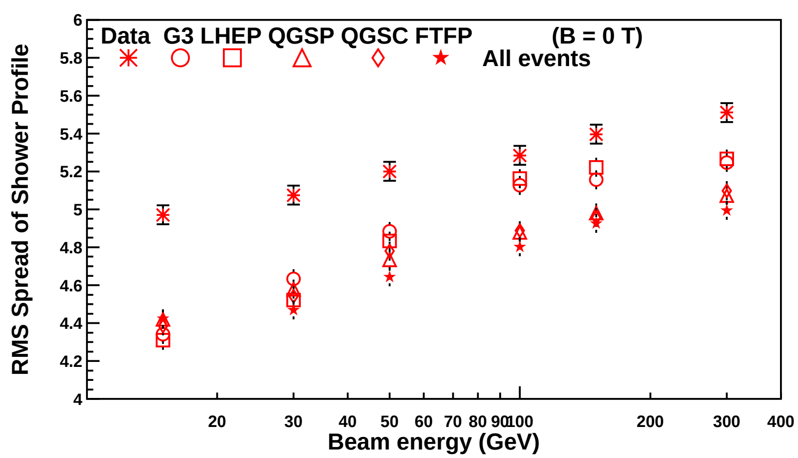
⇒ the changes are not adequate



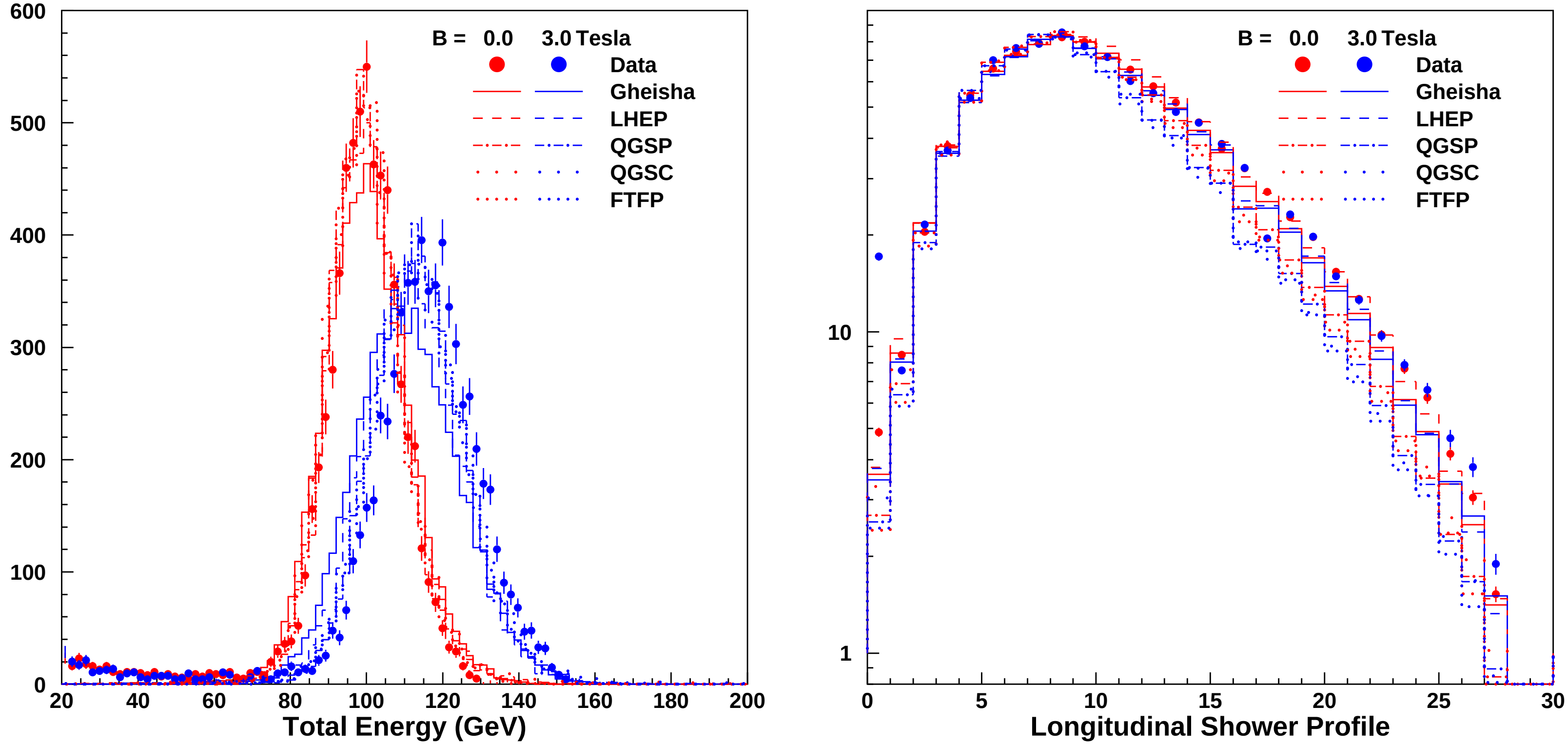


- Nonlinearity in the energy response is reasonably described by different models
- Calibration for the 300 GeV data may be of suspect
- Energy dependence of energy resolution is explained within systematics of the data
- Monte Carlo models show larger non-Gaussian tails than in the data at lower beam energies



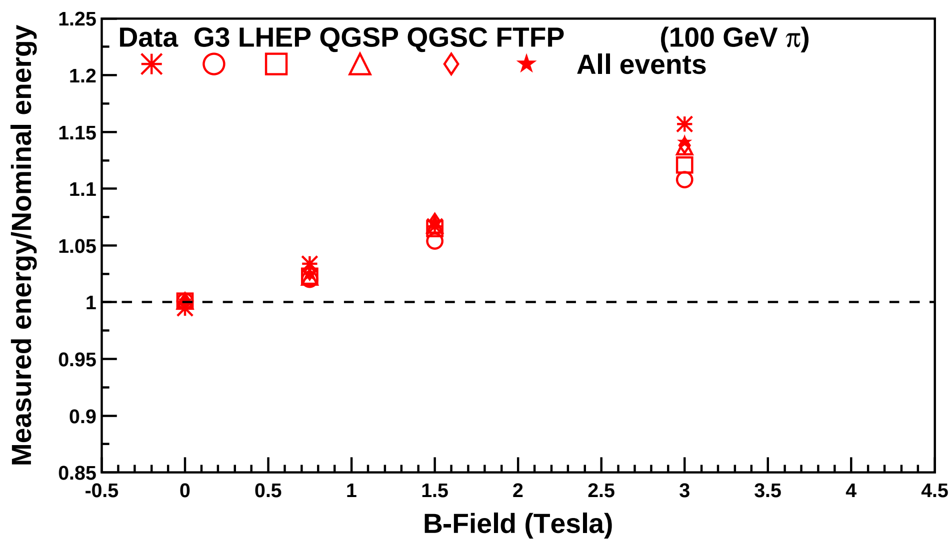


- Mean of the shower profile distributions increases logarithmically with energy for data as well as some MC models
- Slopes are similar but there is an offset. LHEP/G3 show change in slope at high energies
- Width in the shower profile spectrum is much larger in the data and the difference decreases somewhat at higherenergies



- 3 Tesla B-field results increase in response in the HCAL with substantial gain in layers 5-11
- Simulation models also predict an increase in the response

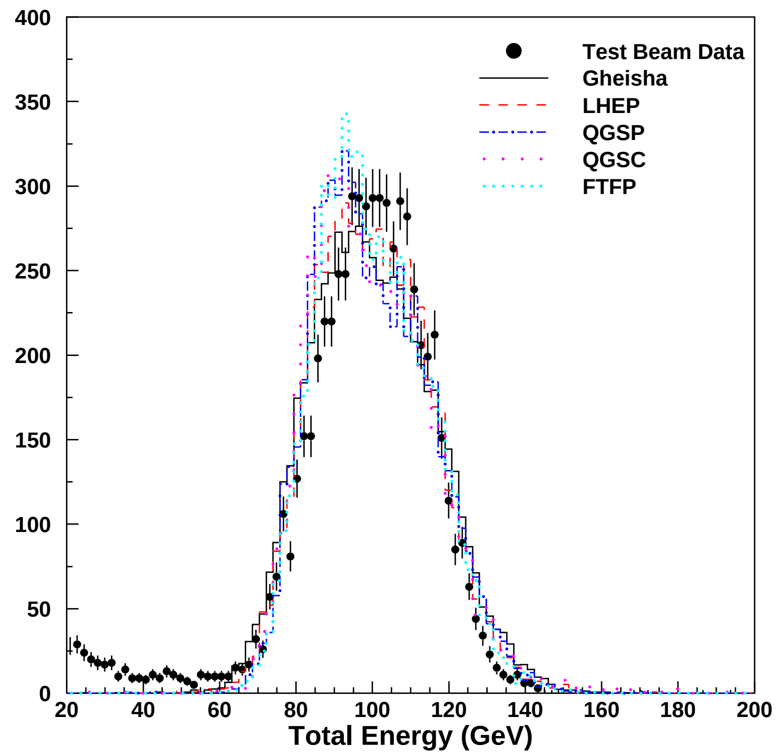
	Measured energy of 100 Gev π		
	B = 0.75T	B = 1.50T	B = 3.00T
Data	103.4±0.1	106.7±0.1	115.7±0.2
LHEP	102.3±0.1	106.5±0.1	112.1±0.2
QGSP	102.2±0.1	106.8±0.1	113.7±0.2
QGSC	102.7±0.1	107.1±0.1	113.8±0.2
FTFP	102.5±0.1	107.0±0.1	114.1±0.2
Geant3	102.0±0.1	105.4±0.1	110.8±0.2



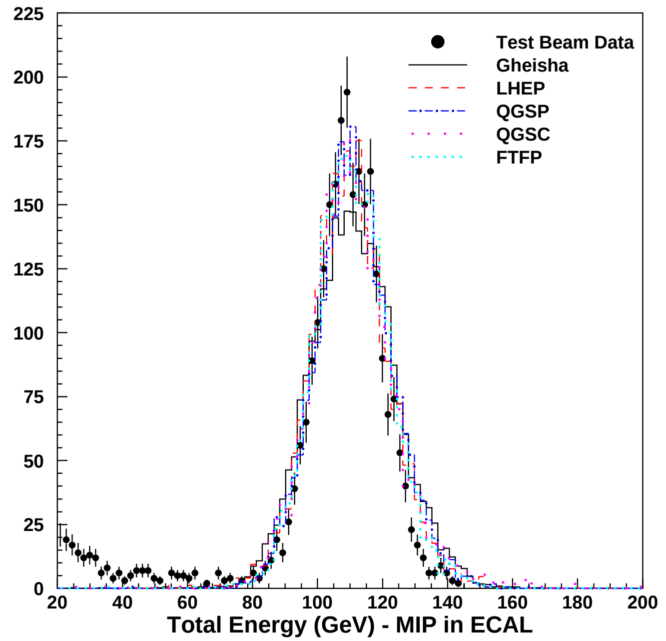
ECAL + HCAL data

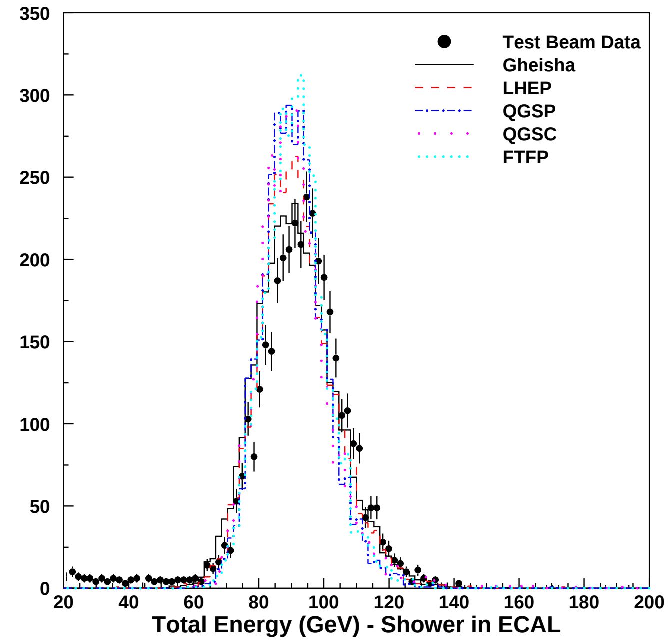
With 100 GeV π^- in the combined setup

	Peak (GeV)	σ (GeV)
Data	100.1±0.2	14.4±0.2
LHEP	100.0±0.2	14.3±0.1
QGSP	100.0±0.2	13.9±0.1
QGSC	100.1±0.2	13.7±0.2
FTFP	100.0±0.2	13.4±0.2
Geant3	100.0±0.2	15.1±0.1



Worsening in resolution is due to non-matching e/h between ECAL and HCAL

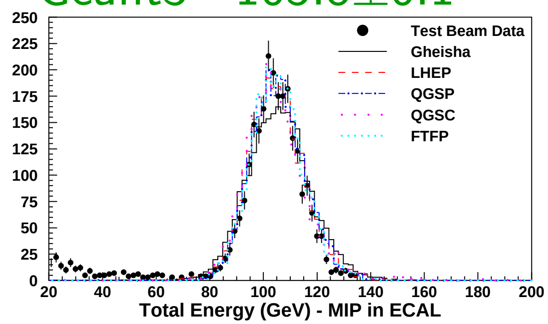


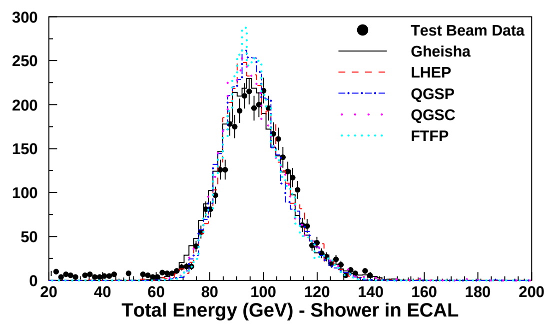


	MIP in ECAL		Shower in ECAL	
	Peak (GeV)	σ (GeV)	Peak (GeV)	σ (GeV)
Data	109.6±0.2	9.8±0.2	93.6±0.2	12.0±0.2
LHEP	110.3±0.2	11.2±0.2	91.8±0.2	11.4±0.2
QGSP	111.5±0.2	11.2±0.2	90.9±0.1	9.5±0.1
QGSC	111.2±0.2	11.0±0.2	91.3±0.1	10.2±0.1
FTFP	110.7±0.2	10.9±0.2	91.5±0.1	9.5±0.1
Geant3	111.0±0.2	12.4±0.2	91.5±0.1	12.5±0.1

Re-weighting layer 1 moves the peaks of the two samples closer

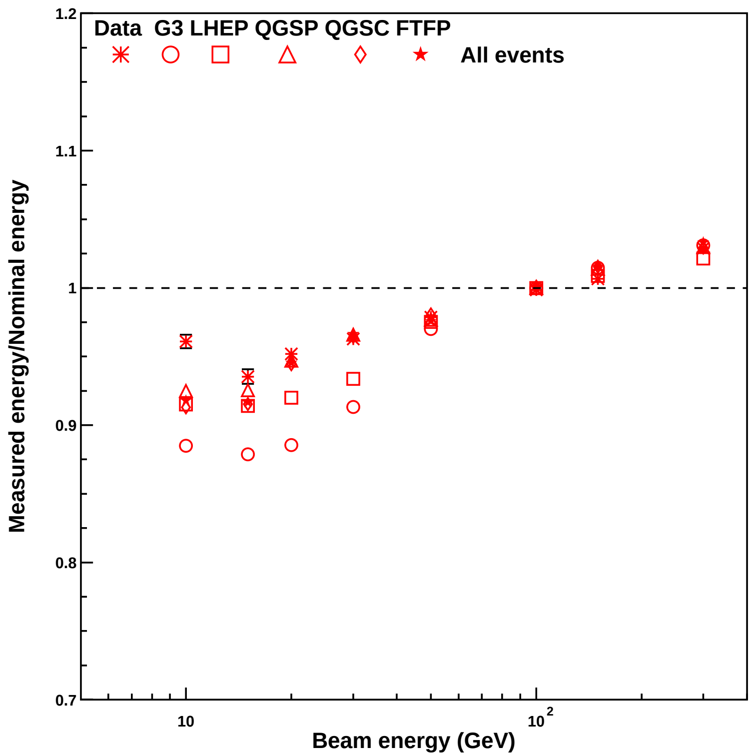
	MIP in ECAL		Shower in ECAL	
	Peak (GeV)	σ (GeV)	Peak (GeV)	σ (GeV)
Data	104.5±0.2	9.1±0.1	97.3±0.2	12.1±0.2
LHEP	104.9±0.2	9.7±0.1	96.9±0.2	11.5±0.1
QGSP	105.4±0.2	9.6±0.1	96.5±0.2	11.0±0.1
QGSC	104.8±0.2	9.7±0.1	96.9±0.2	11.3±0.2
FTFP	105.3±0.1	9.2±0.1	96.6±0.2	10.6±0.1
Geant3	105.8±0.1	11.2±0.1	96.4±0.1	12.7±0.1

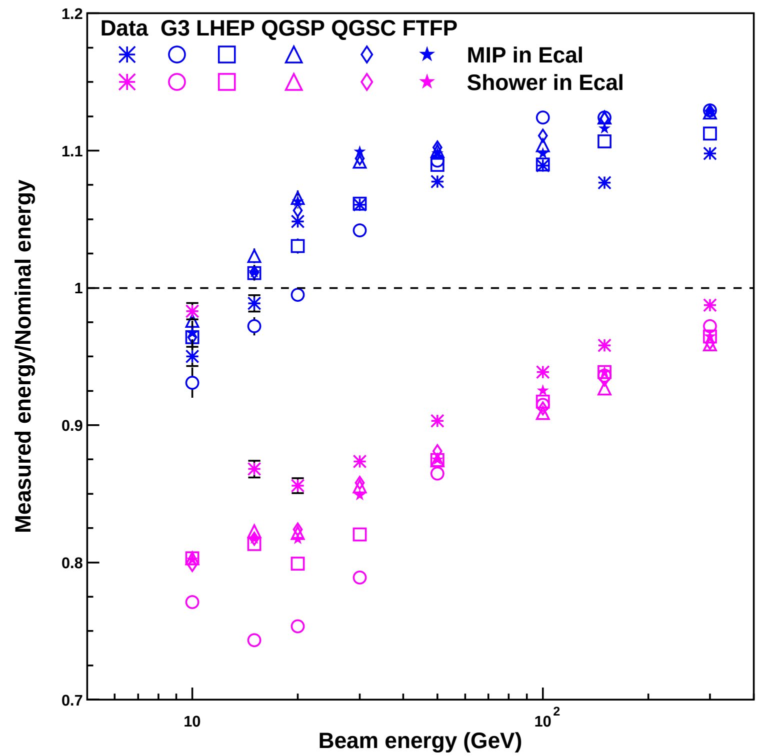




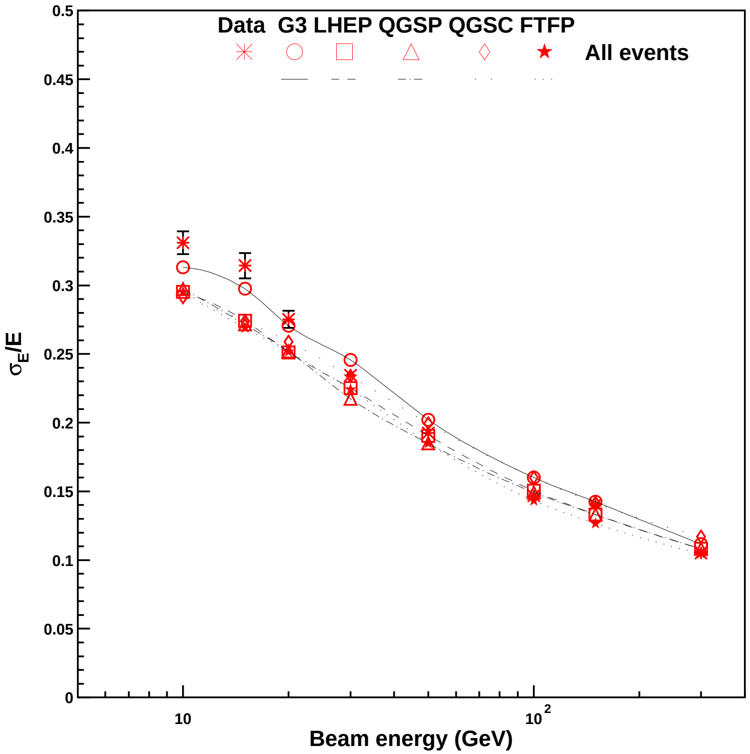
This improves the overall resolution

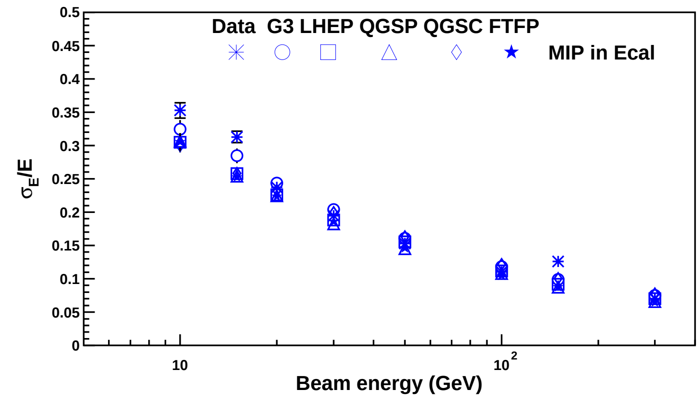
	σ (GeV)
Data	11.8±0.1
LHEP	11.7±0.1
QGSP	11.4±0.1
QGSC	11.4±0.1
FTFP	11.2±0.1
Geant3	12.8±0.1

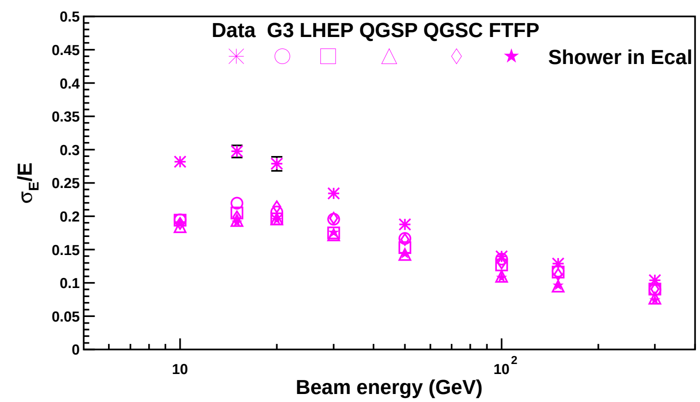




- Non-linearity in the response with energy is reasonably well reproduced by the different models inside Geant4
- The remaining discrepency is there in the sample which starts showering in the electromagnetic calorimeter







- Energy resolution is well described at high energies
- The discrepancy at lower energies is more in the sample which starts showering in ECAL

Outlook

➢ Energy response and resolution look reasonable and so is the increase in response due to B-field

➢ Try to understand the discrepency in the longitudinal shower profile (HPW)

➢ Look at data with different beam energies for electrons and pions in the HCAL alone setup to get a better understanding of e/h ratio

➢ Look into more samples with magnetic field on (at other beam energies)

➢ Complete the work at the earliest possible time