Simulation of HCAL Testbeam Setup of CMS in GEANT4

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CMS

Introduction

CMS Calorimeter Description

- Electromagnetic part
  - 23 cm long PbWO4 crystals
  - Tower Structure
  - 25.8 radiation lengths
    ($\sim$ 1.1 interaction length)
- Hadronic part
  - Sampling Calorimeter - Scintillator/Brass sandwich
  - $\sim$ 11 interaction lengths over large η range
  - light collection using optical fibres

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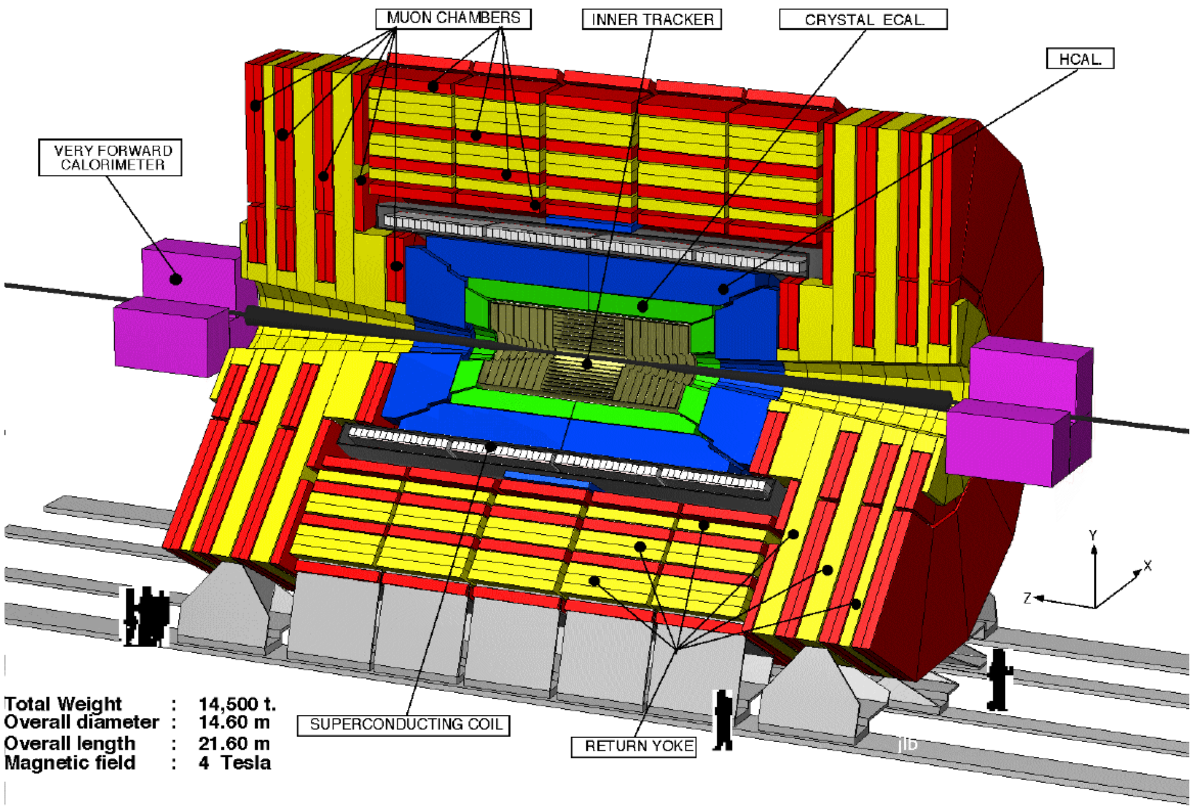
CMS Detector



Hadron Calorimeter Barrel and Endcap cover $|\eta| < 3.0$

Forward part covers $3.0 < |\eta| < 5.0$

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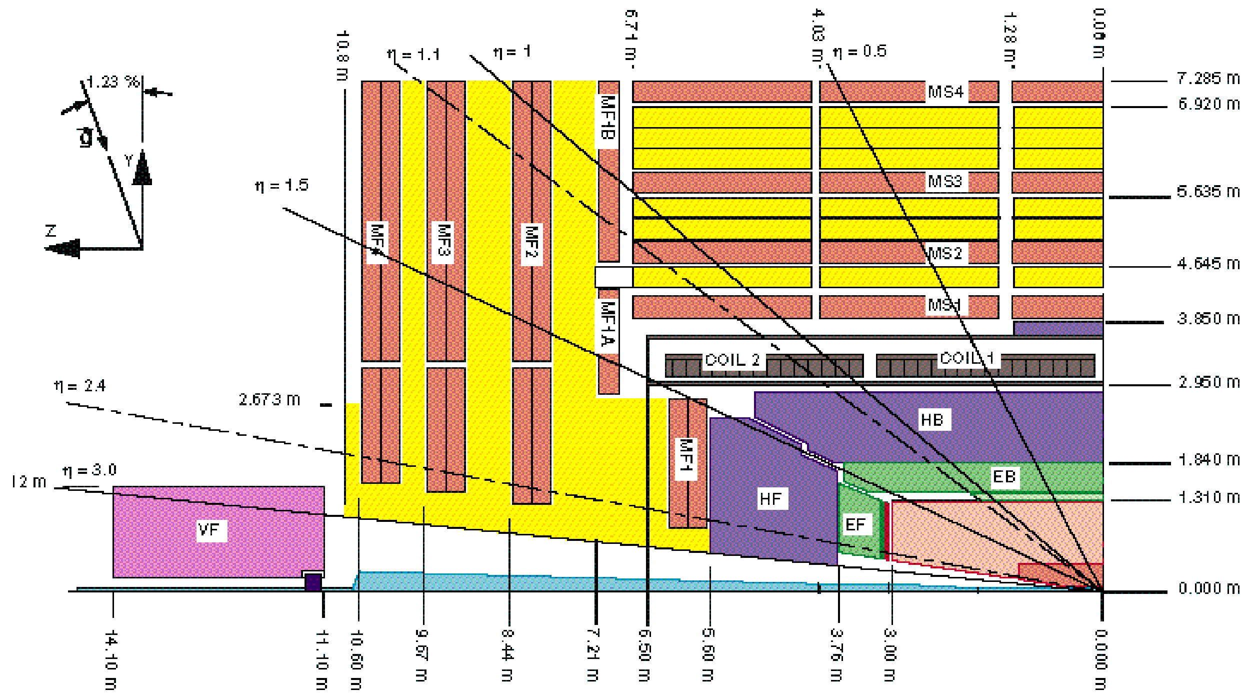
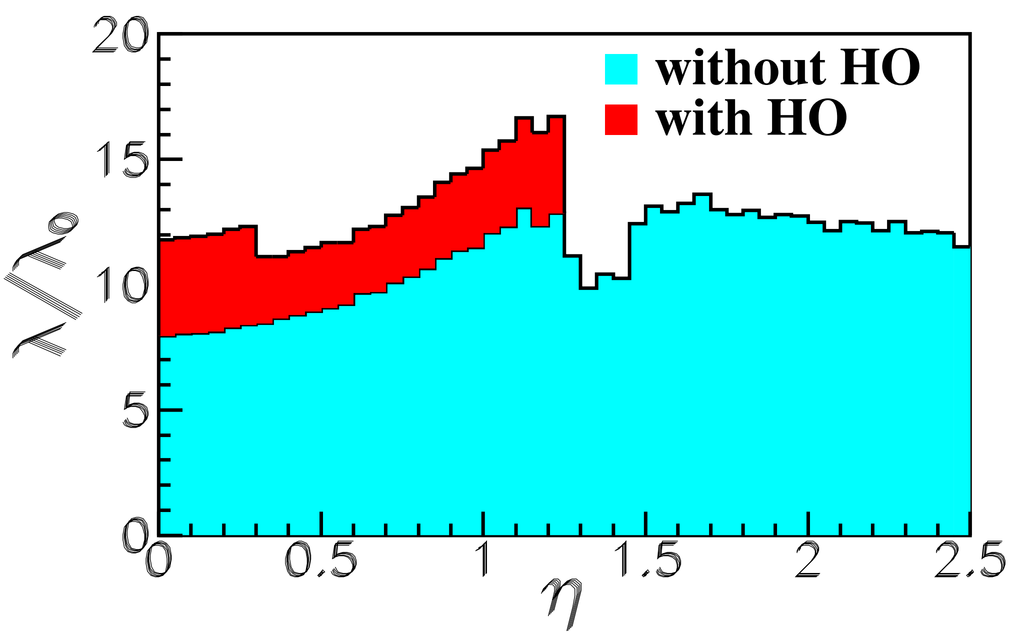
CMS Detector, X-Z view





η coverage in interaction lengths

1996 Testbeam Setup for CMS HCAL

A test module of copper absorber plates with scintillator tile sampling was exposed to hadrons, electrons and muons.

28 scintillator plates were used with absorber of varying thickness inbetween.

Response of the Calorimeter was studied as a function of:

- Magnetic field: effect on scintillator
- Absorber thickness: optimization of resolution versus containment
- Absorber depth: energy containment
- Electromagnetic Calorimeter contribution: e/π effects

A prototype lead tungstate crystal electromagnetic calorimeter used.

Direction of magnetic field was parallel to the face of the scintillator plates - HCAL Barrel configuration.

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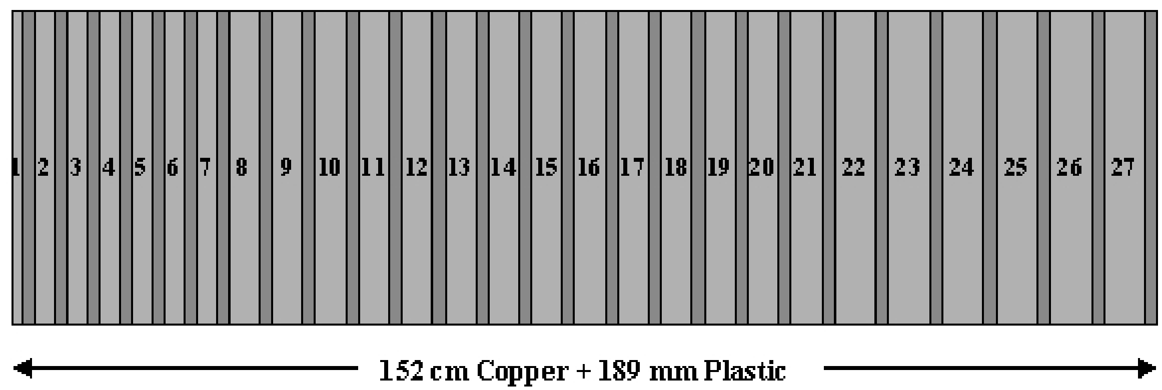
HCAL (H2 1996) Test-Beam Setup



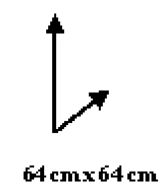
Layer 1 : 2 cm Copper

Layers 2 to 7 : 3 cm Copper

Layers 8 to 21: 6 cm Copper

Layers 22 to 27: 8 cm Copper

Scintillators: 2 mm passive Plastic
4 mm active Plastic
1 mm passive Plastic



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Description of Data

1996 Testbeam:

- Energies:
  - 225 GeV muons (for calibration)
  - 10 to 300 GeV pions
  - 10 to 300 GeV electrons
- Magnetic Field:
  - 0, 1.5, 2, 3 tesla
    (parallel to the face of scintillator)
- Configuration:
  - Only HCAL
  - ECAL + HCAL

$\sim$ 5000 events were taken for each setup

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GEANT3 Setup

Data was generated with GEANT 3.21, GHEISHA package was used to simulate hadronic showers.

- Energies:
  - 200 GeV muons
  - 10 to 300 GeV pions
  - 10 to 300 GeV electrons
- Magnetic Field:
  - 0, 3 tesla
    (parallel to the face of scintillator)
- Configuration:
  - Only HCAL
  - ECAL + HCAL

Statistics: 5000 events for each case were generated.

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GEANT4 setup

Data was generated with GEANT 4.1.1,
a cutoff of 2 mm was used on range of particles.

- Energies:
  - 200 GeV muons
  - 10 to 100 GeV pions
  - 10 to 100 GeV electrons
- Magnetic Field:
  - 0 tesla
- Configuration:
  - Only HCAL
  - ECAL + HCAL

Statistics: $\sim$ 2000 events for each case were generated.

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Energy Calculation

Energy was calculated using the same algorithm for Testbeam data and Simulated data.

Total Energy = ECAL + $w_1.H_1$ + $w_2.H_2$ + $w_3.H_3$

H_1= Energy deposited in the first layer of HCAL (Compensates for high e/π of ECAL)

H_2= $\Sigma_{i=2}^{i=18}$ (Energy deposit in layer i) (simulates Hadron Barrel calorimeter in CMS)

H_3= $\Sigma_{i=19}^{i=28}$ (Energy deposit in layer i) (simulates energy leakage)

w_1, w_2, w_3 are weights assigned to the energy values to improve resolution.

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Determination of w_1, w_2, w_3

- w_2 and w_3 are evaluated by minimizing energy resolution (σ of energy distribution) for 100 GeV pions
  (Using data without ECAL in front)
- w_1 is evaluated using data where both ECAL and HCAL are present. The value of w_1 is adjusted so that the mean value of the energy distribution becomes the same as the energy of the incident beam

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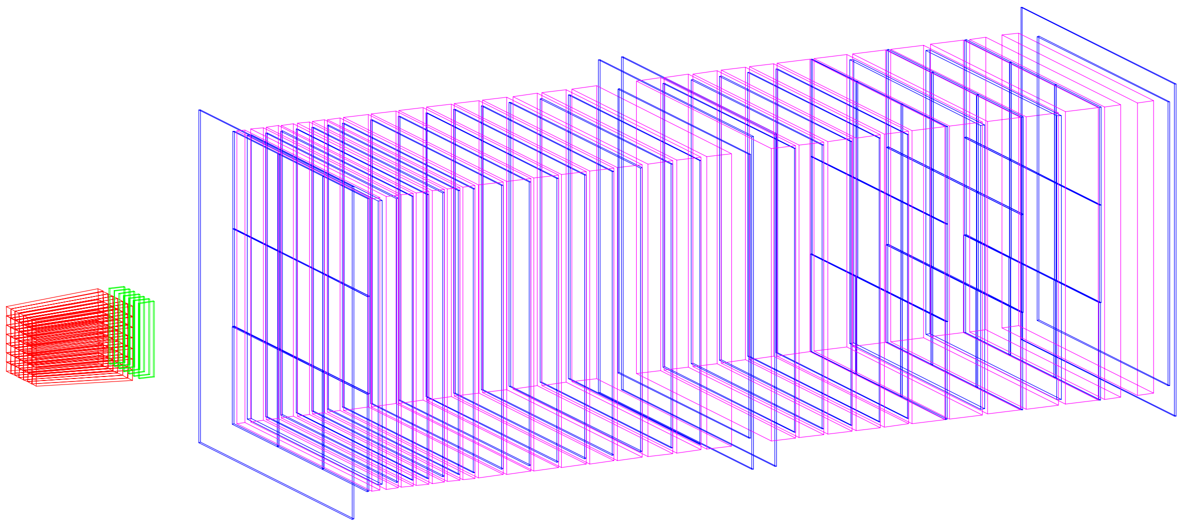
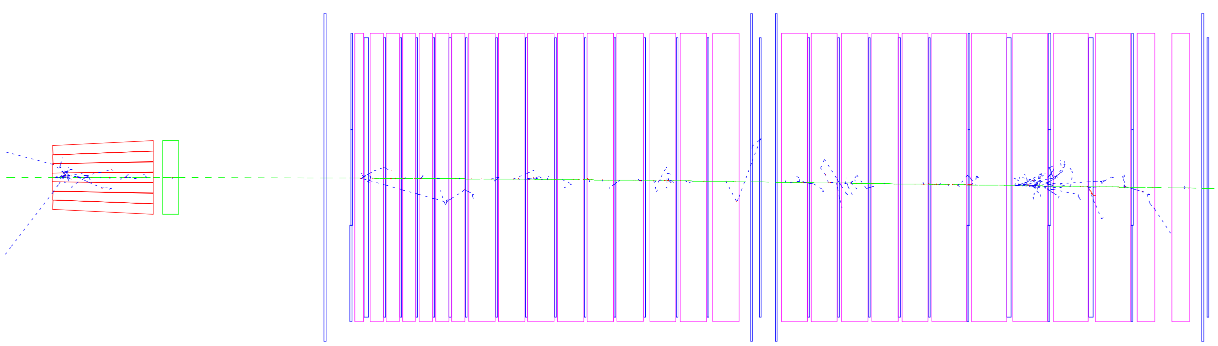
Detector Geometry, GEANT3



CMS HCAL 1996 testbeam geometry



A muon passing through the detector

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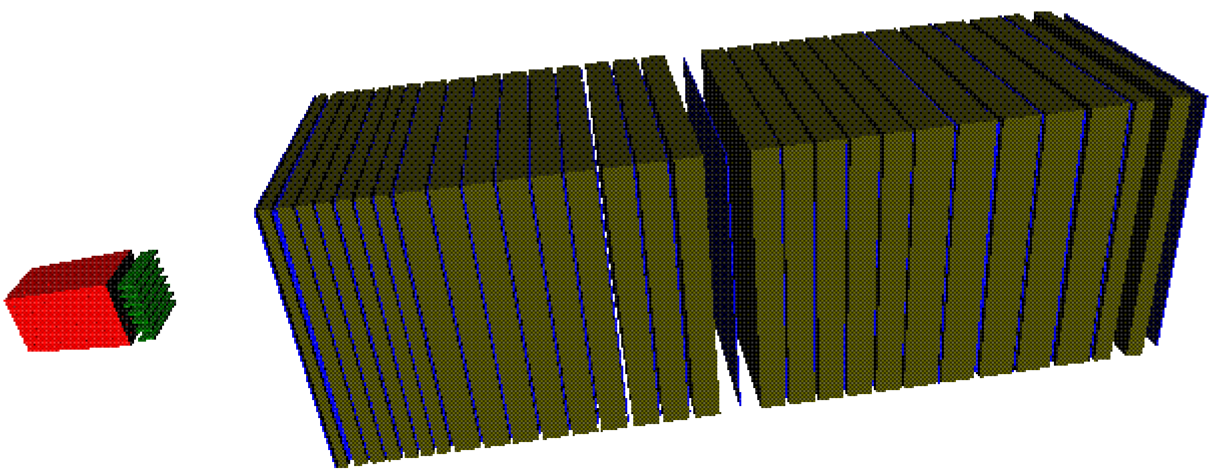
Detector Geometry, GEANT4



CMS HCAL 1996 testbeam geometry

ECAL with electronics at the back followed by HCAL

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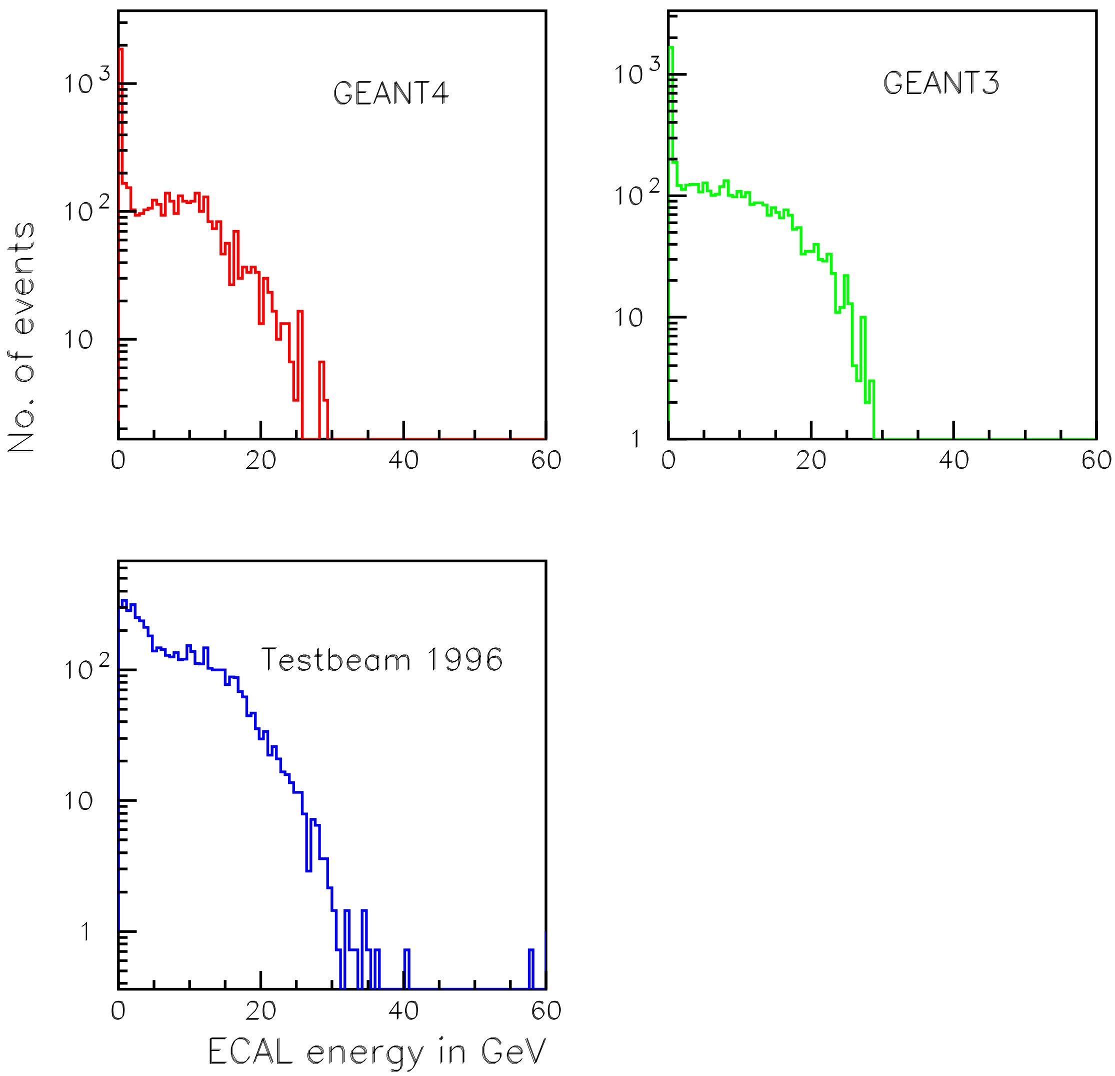
Energy in ECAL



Energy distribution in ECAL for a 30 GeV π

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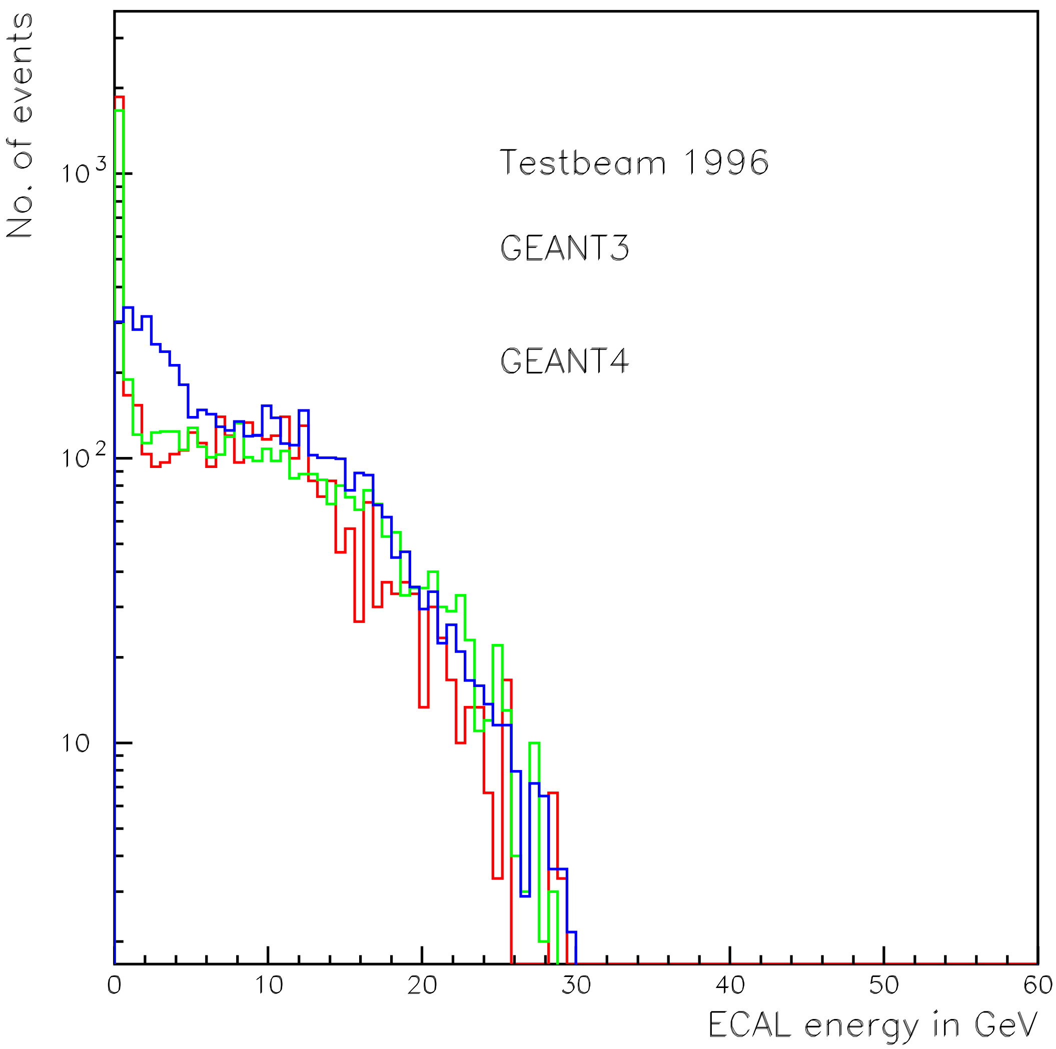
30 GeV pion energy in ECAL



– GEANT4, – GEANT3, – Testbeam

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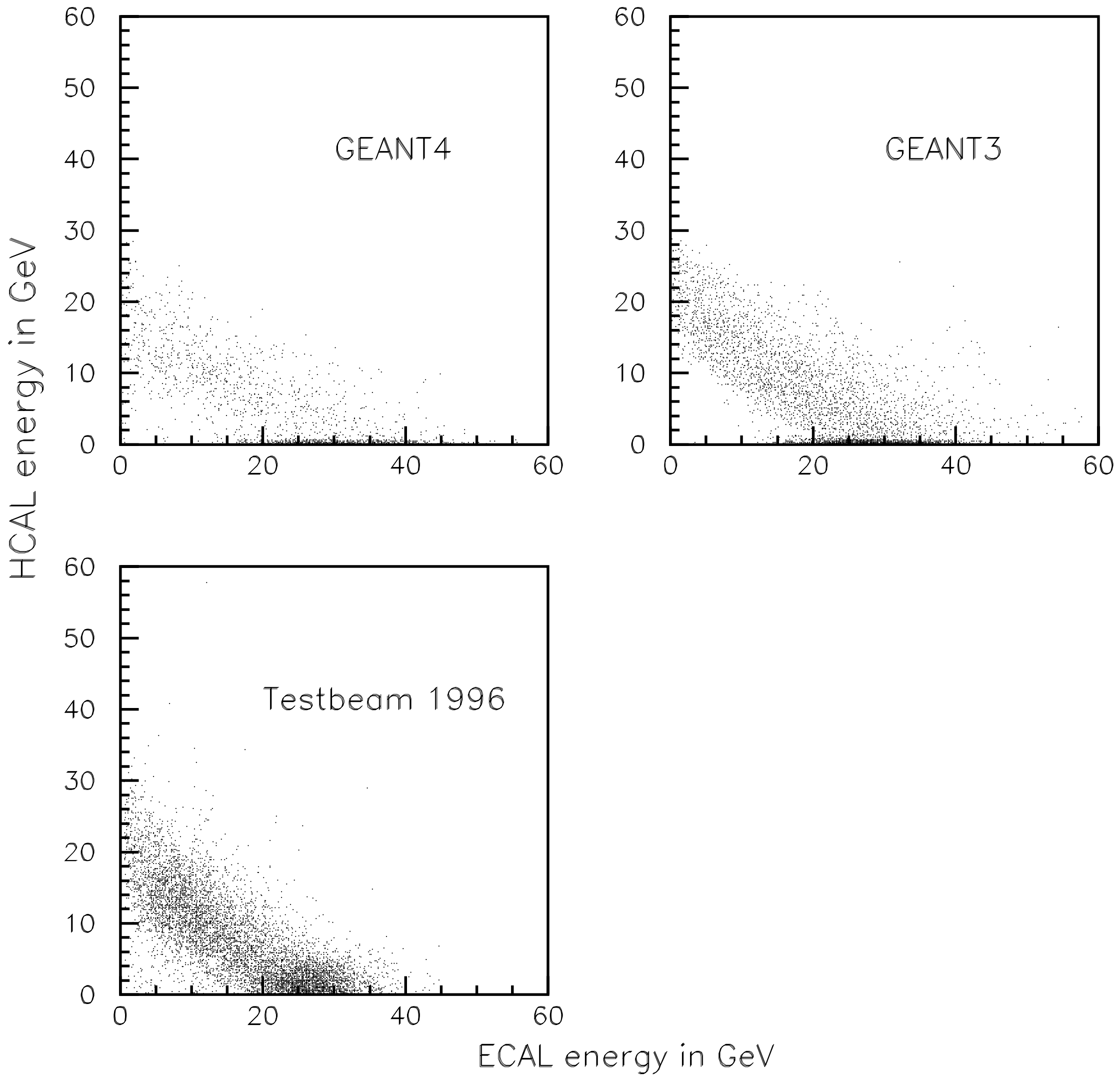
ECAL vs. HCAL



Comparison of energy in ECAL with energy in HCAL for 30 GeV pions

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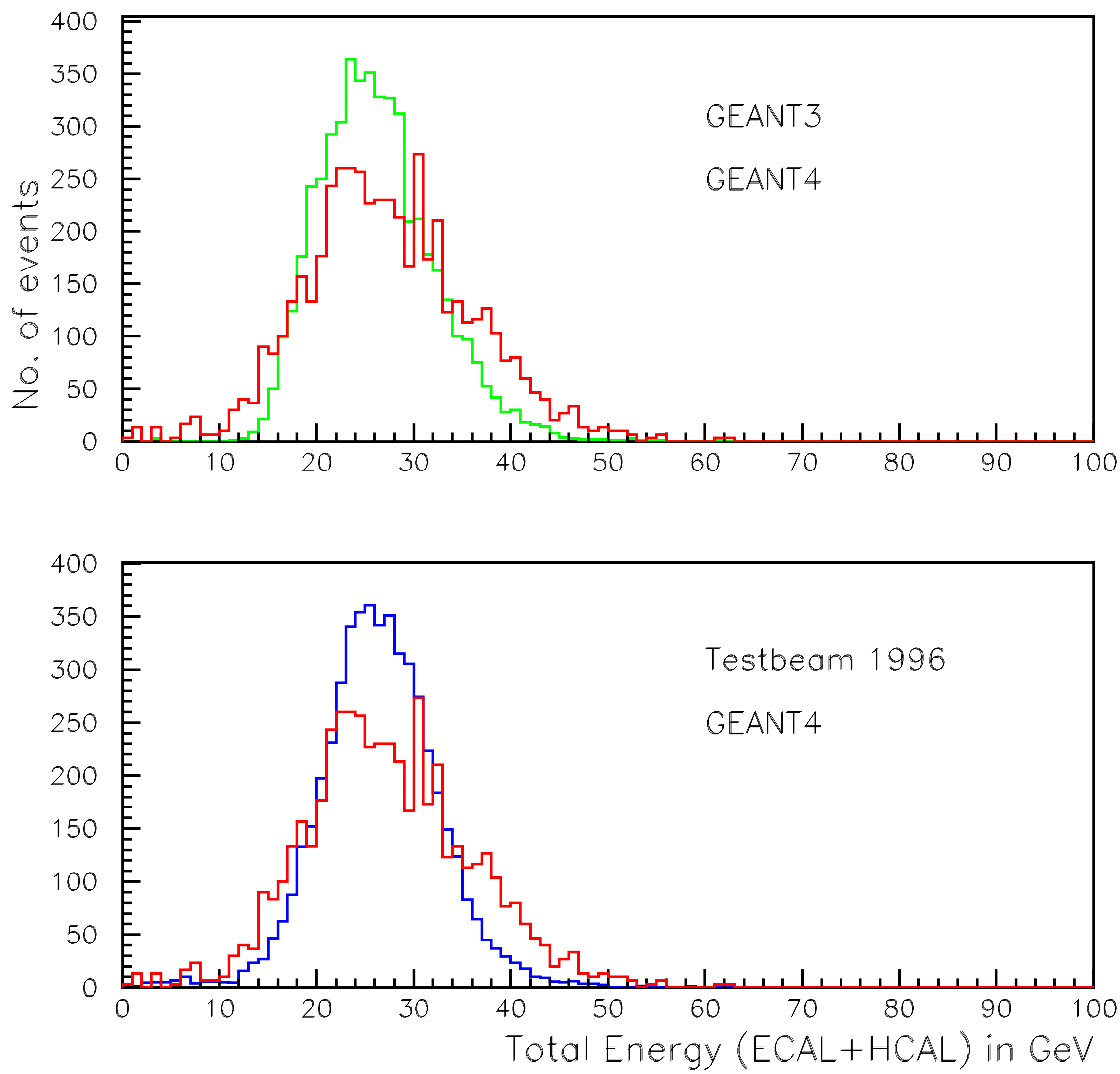
Total Energy



Total energy (ECAL+ weighted HCAL) for 30 GeV pions,

— GEANT4, — GEANT3, — Testbeam

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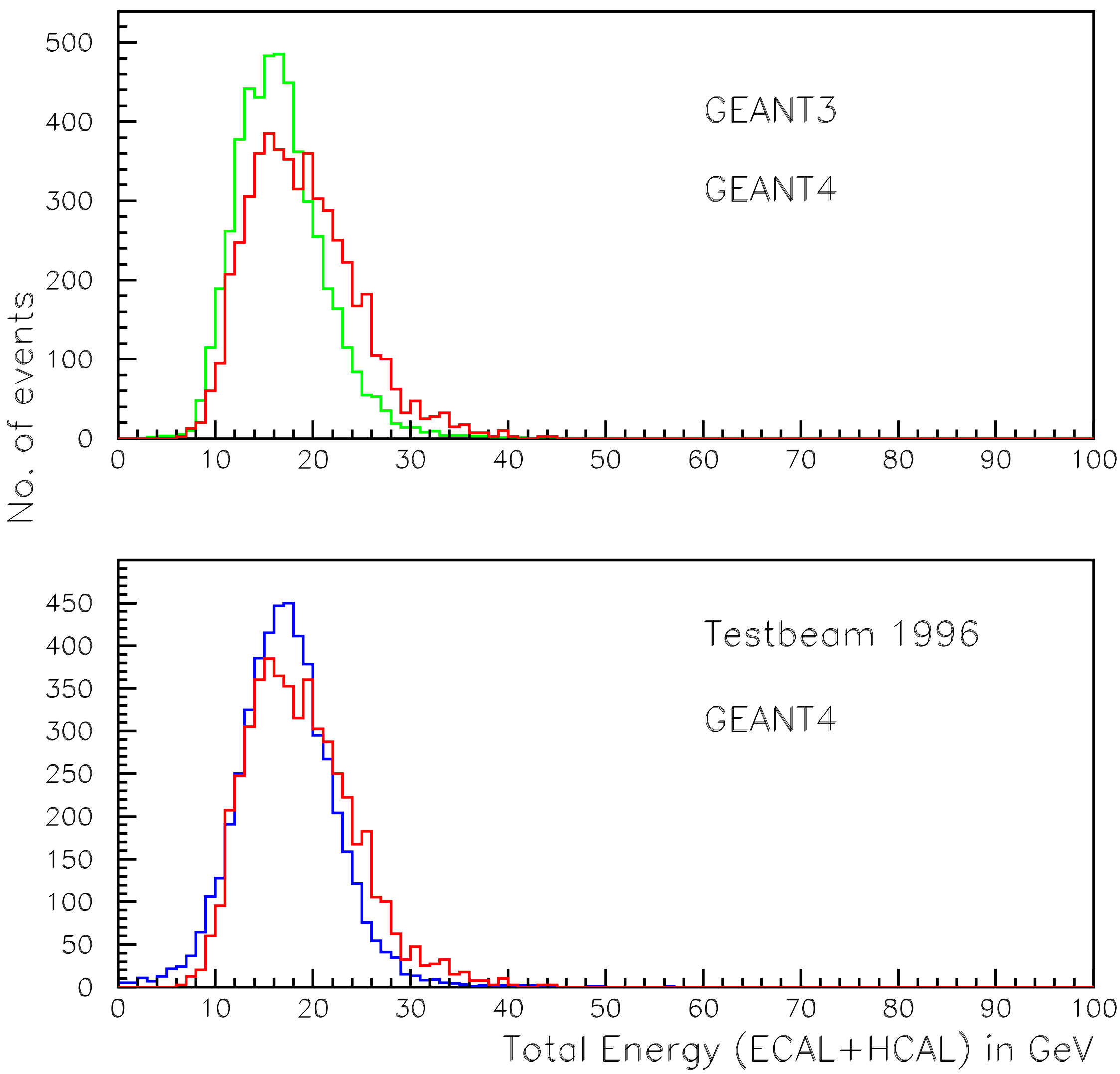
Total Energy

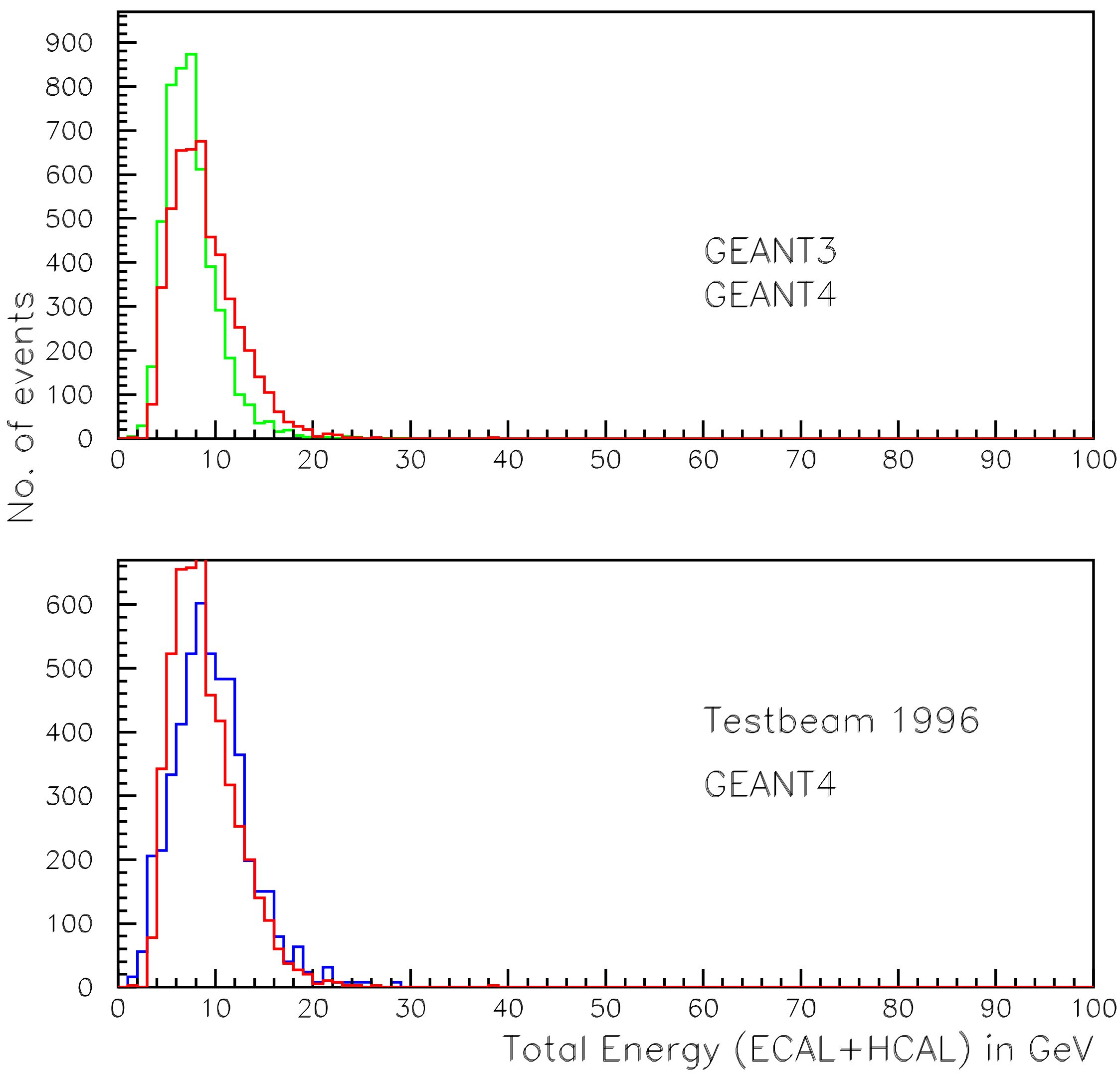


Total energy (ECAL+ weighted HCAL) for 20 GeV pions,

– GEANT4, – GEANT3, – Testbeam

CMS

Total Energy

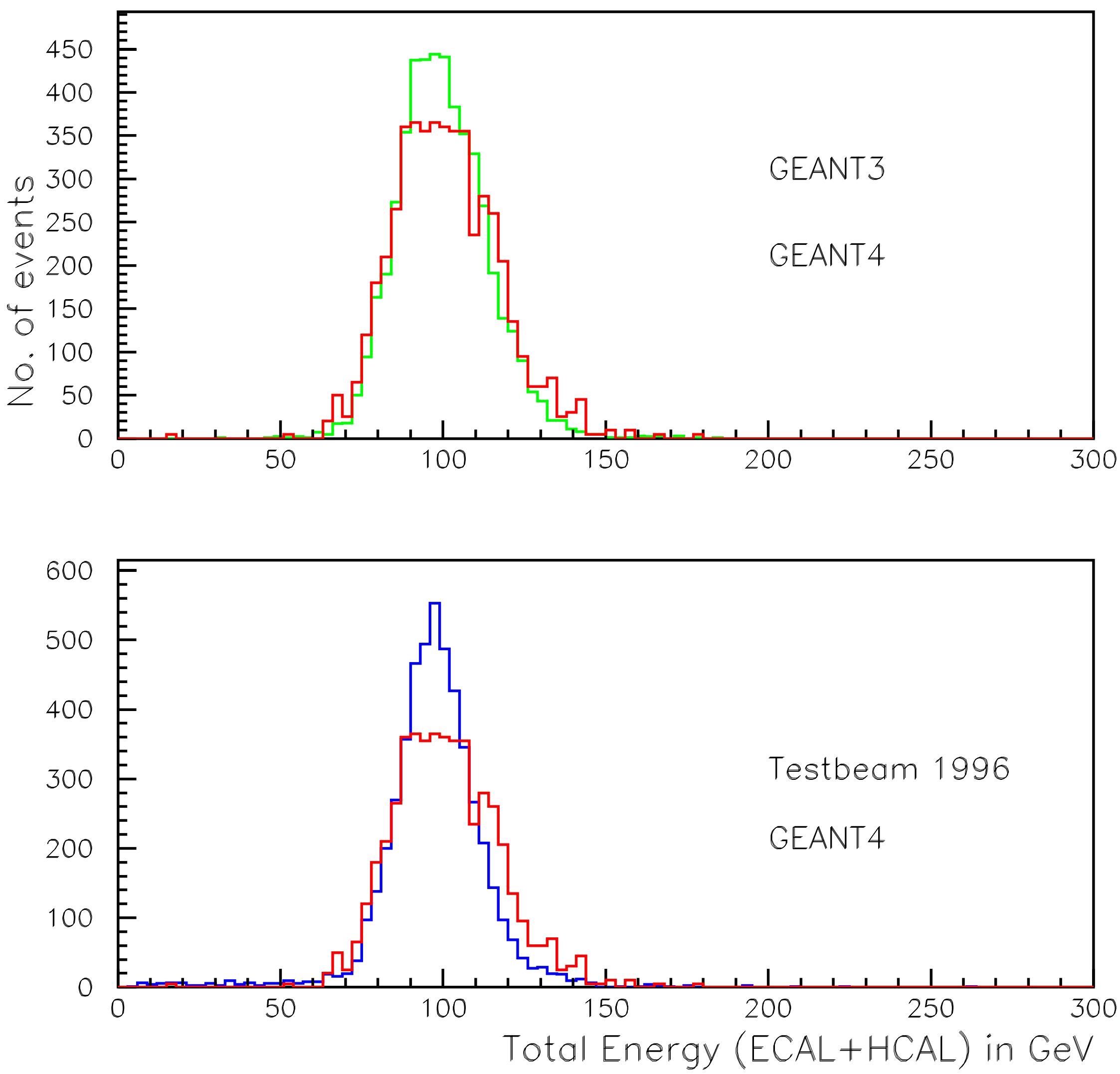


Total energy (ECAL+ weighted HCAL) for 10 GeV pions,

– GEANT4, – GEANT3, – Testbeam

CMS

Total Energy



Total energy (ECAL+ weighted HCAL) for 100 GeV pions,

— GEANT4, — GEANT3, — Testbeam

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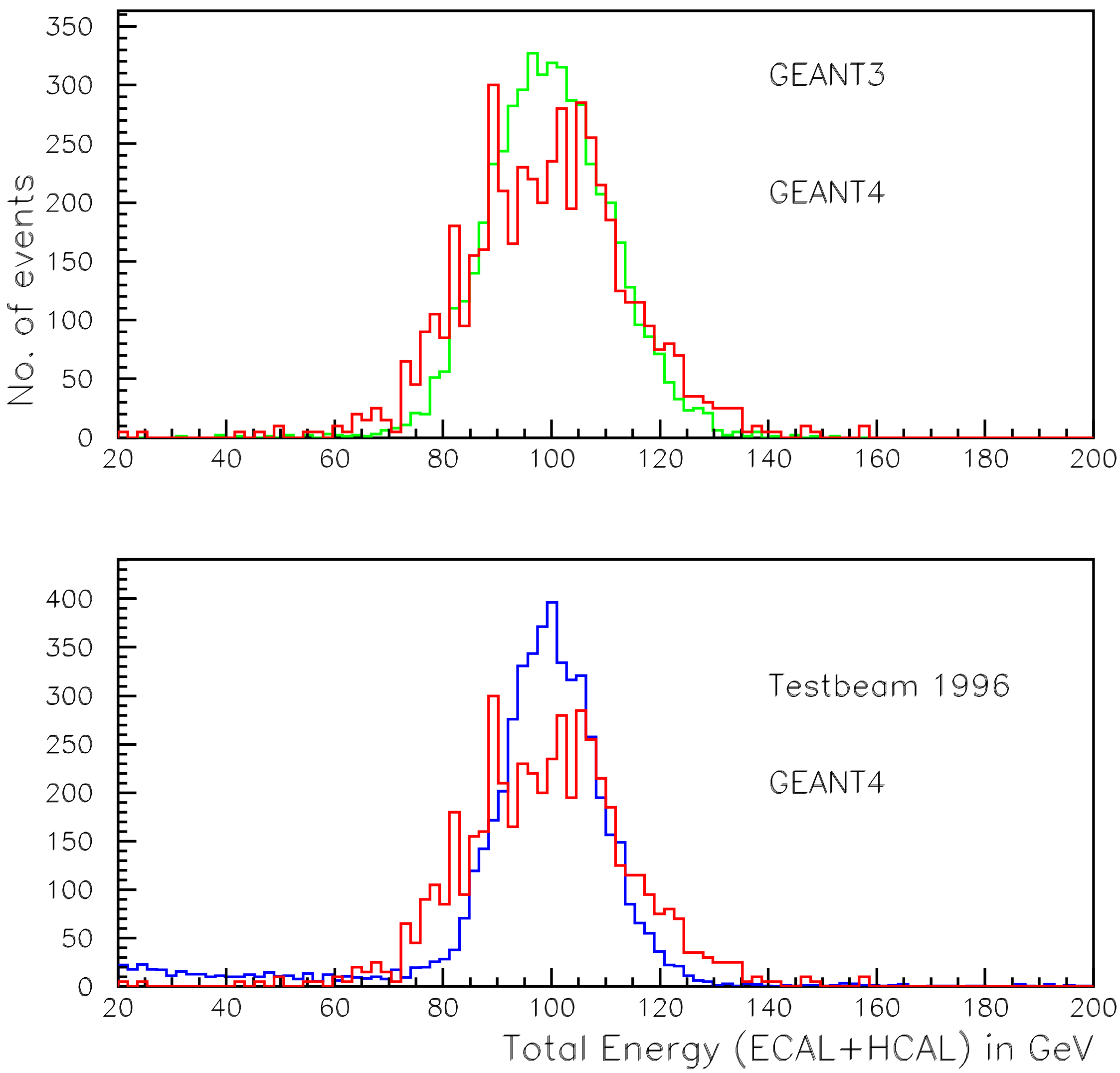
Total Energy, no ECAL



Total energy (HCAL) for 100 GeV pions,

— GEANT4, — GEANT3, — Testbeam

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Conclusions

- Still a long way to go
- HCAL shower profile for hadrons is under study
- HCAL response to muons and electrons is under study
- Effect of magnetic field on performance of HCAL is under study

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