Hadron particle detection
(with CMS detector)

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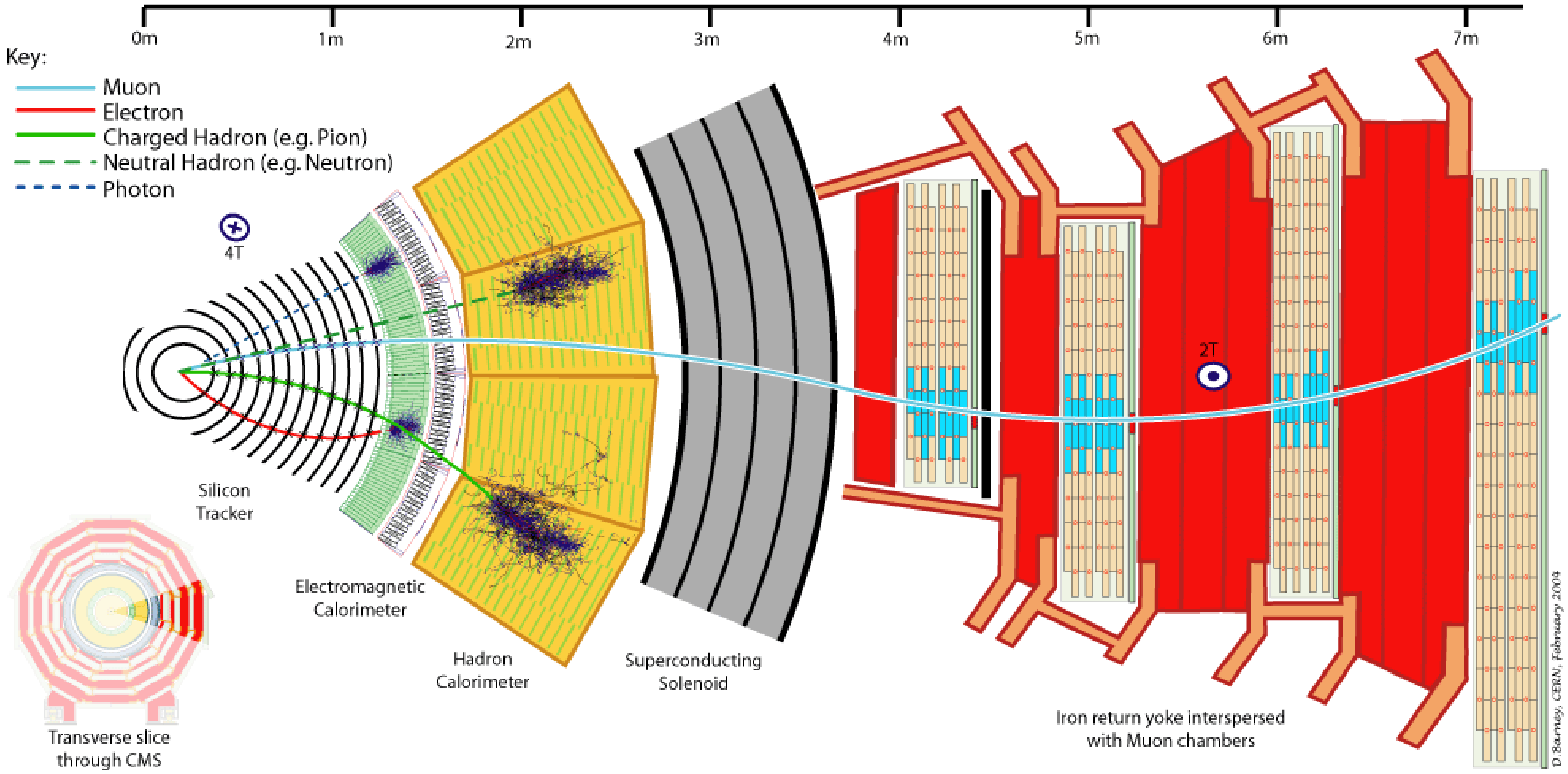
Outline

- Hadron Calorimetry: Measuring the energy of a hadron
- CMS detector and its calorimetric systems
- TestBeam Measurements
- MonteCarlo Simulation and comparison to TestBeam

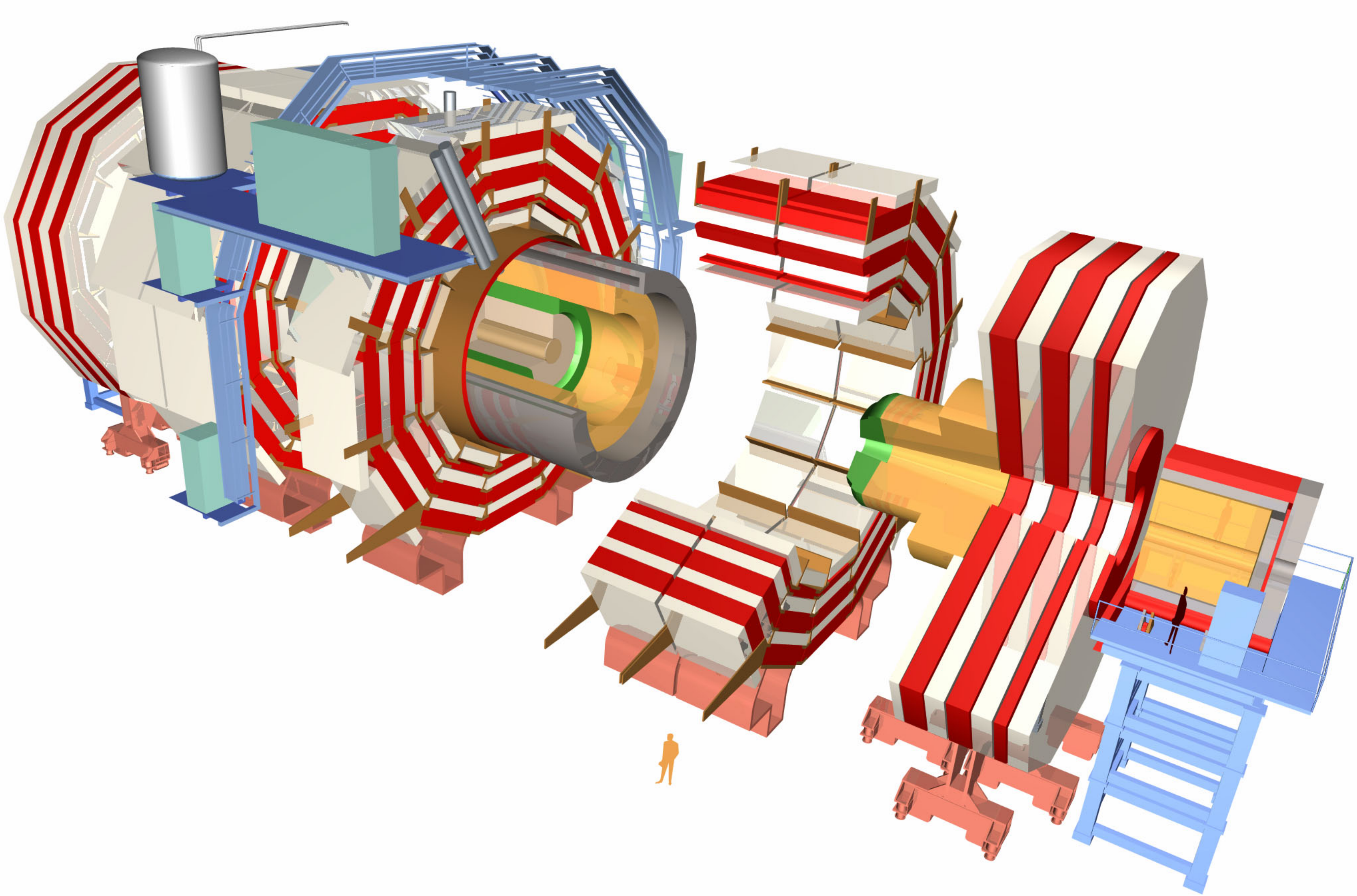

0m
1m
2m
3m
4m
5m
6m
7m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
Transverse slice through CMS
D.Barney, CERN, February 2004

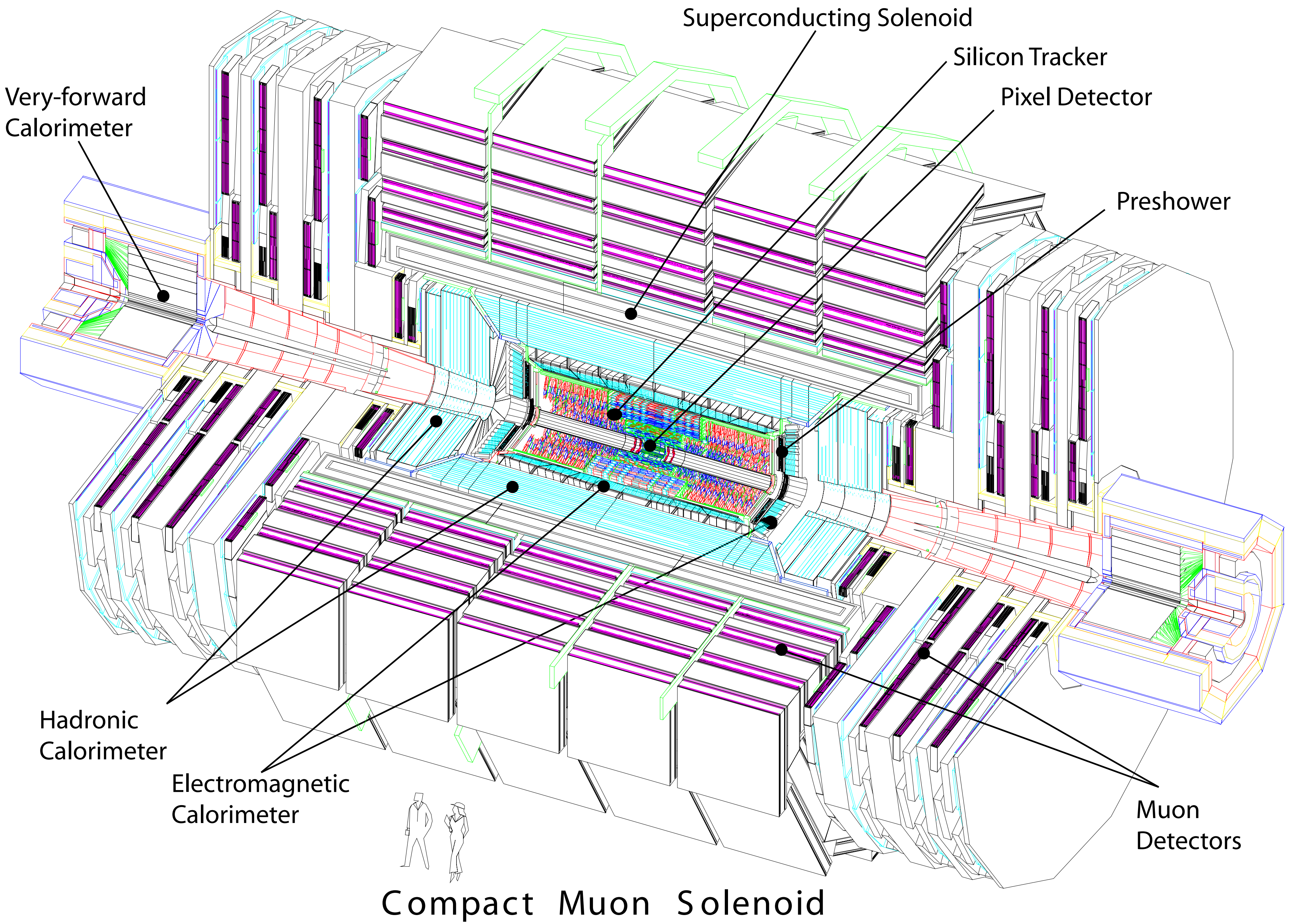
Function of Calorimeters:

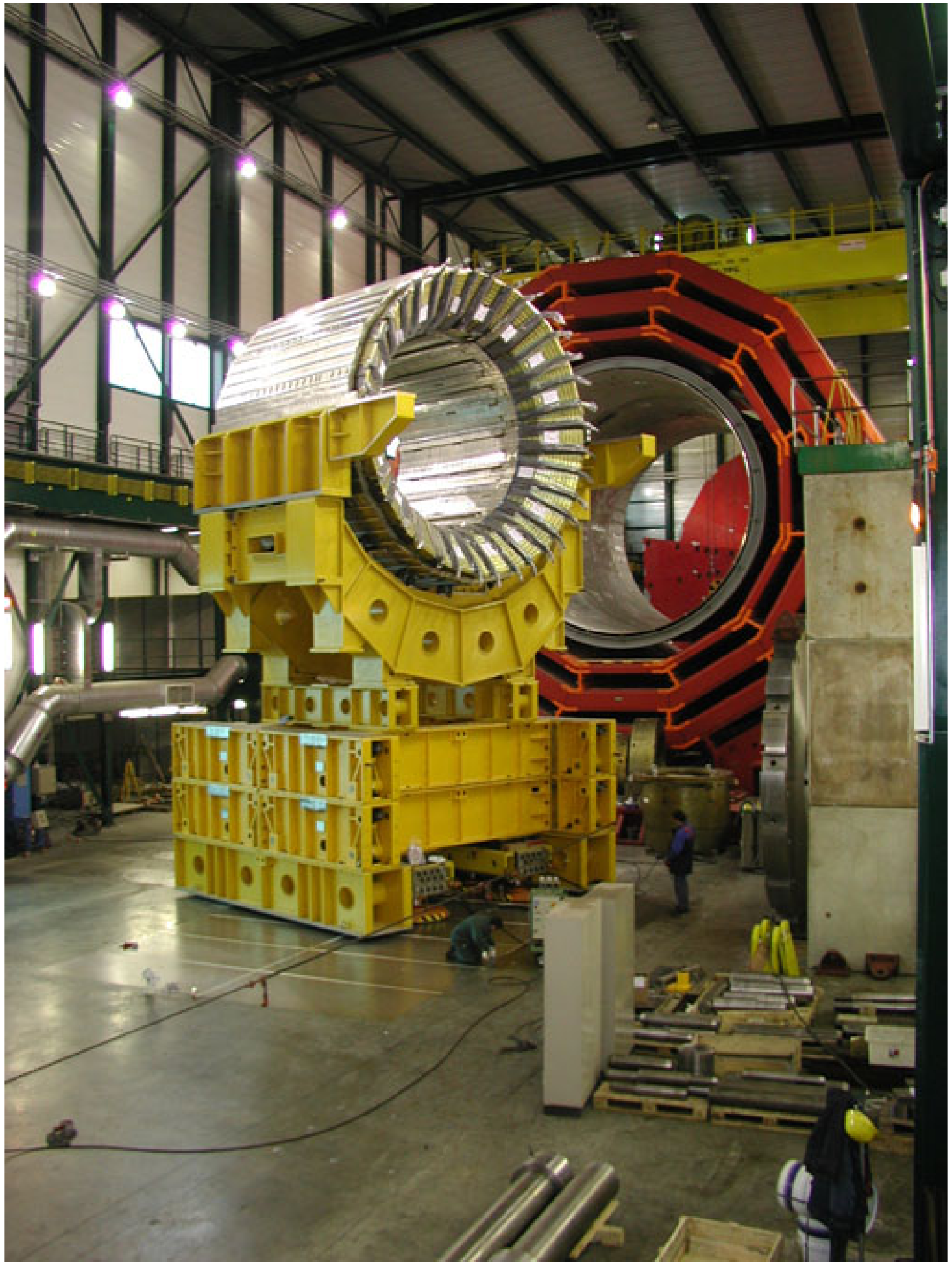
- Measure the energy of a hadron (in most cases - jets of hadrons)
- Provide hermeticity, so that missing energy can be measured

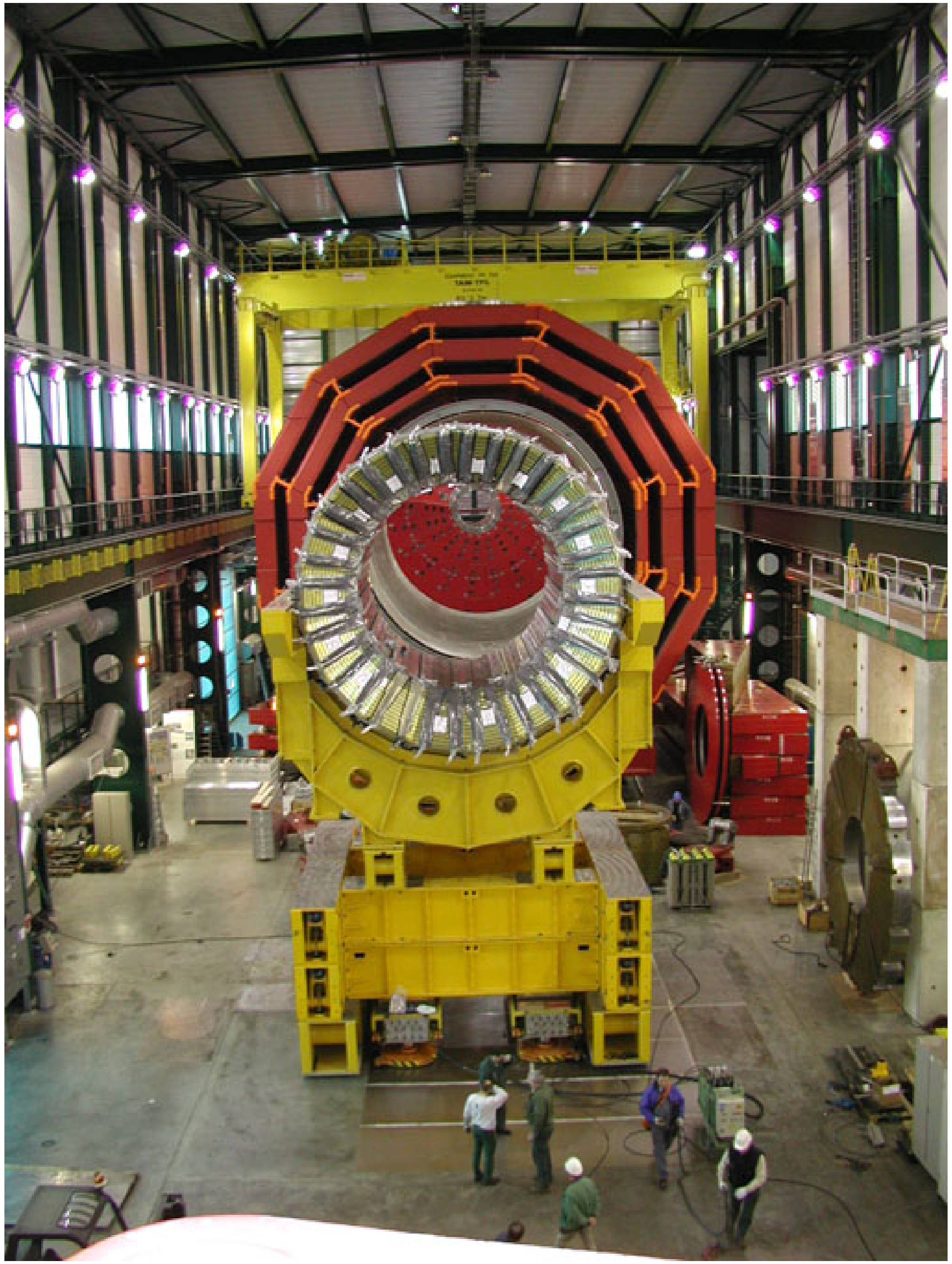
Depending on their function and application, calorimeters can be of various kinds:

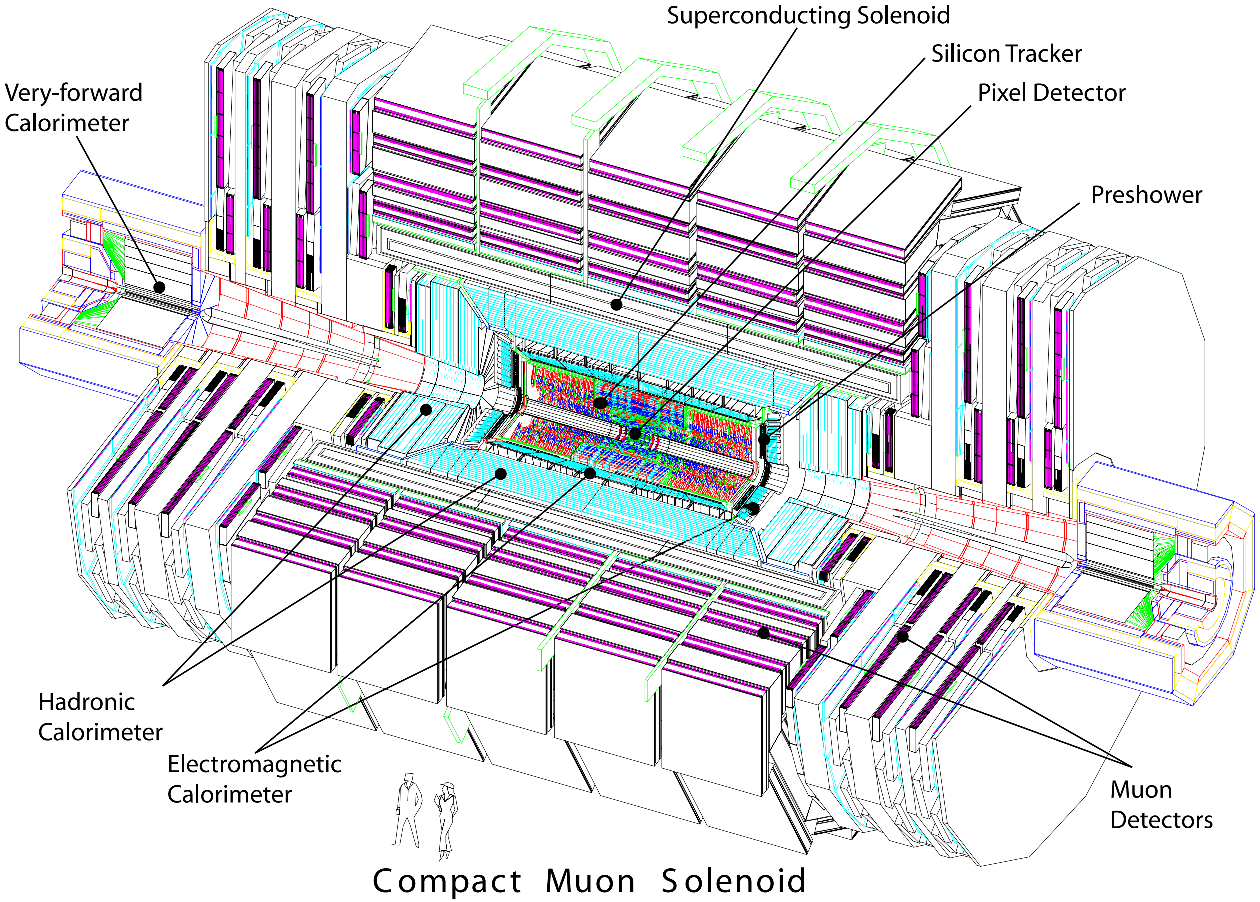
- Homogenious vs. Sampling (structure)
- Solid vs. Liquid (medium)
- Scintillating vs. Cherenkov (signal)
- Compensating vs. Non-compensating (performance)



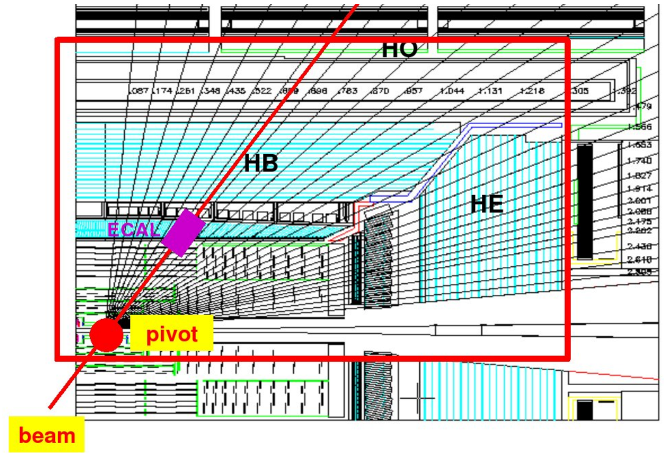

Superconducting Solenoid
Silicon Tracker
Pixel Detector
Very-forward Calorimeter
Preshower
Hadronic Calorimeter
Electromagnetic Calorimeter
Muon Detectors
Compact Muon Solenoid







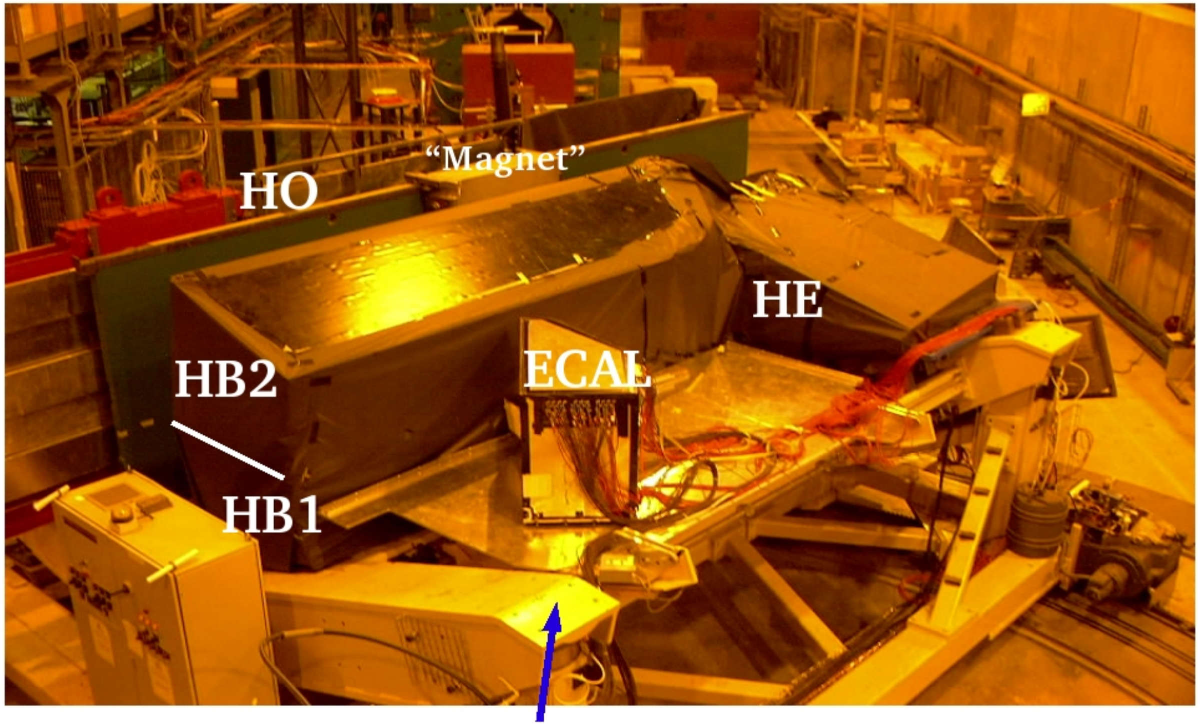
HCAL = Hadronic Calorimeter
ECAL = Electromagnetic Calorimeter
HB = HCAL Barrel
HE = HCAL EndCap
HO = HCAL Outer



Calorimetric systems present on the Testbeam 2004 table.

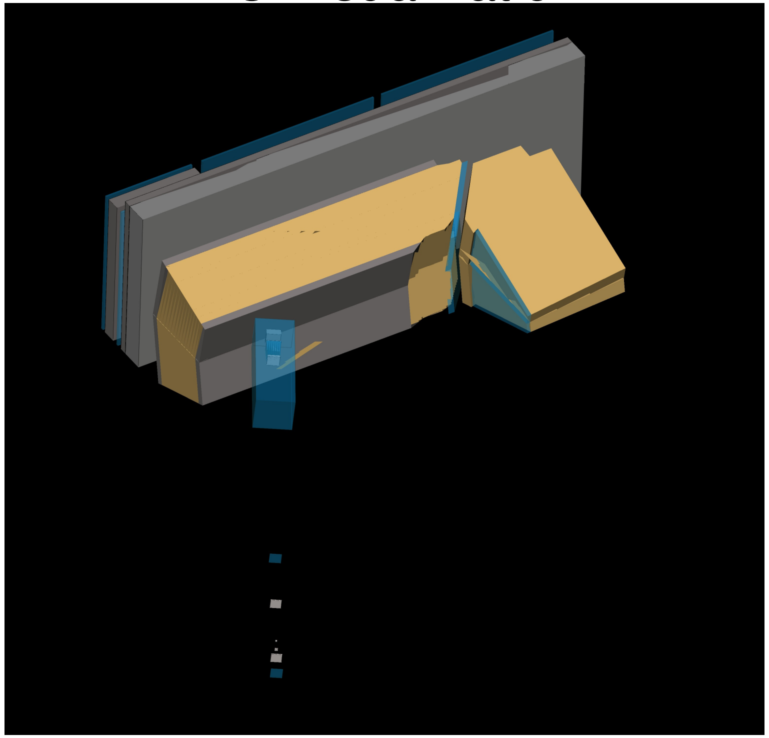
Pivot point corresponds to interaction point in CMS. ECAL is a matrix of 7x7 prototype crystals.
HCAL Barrel modules are production wedges readout with real front-end electronics.

Photo of testbeam area



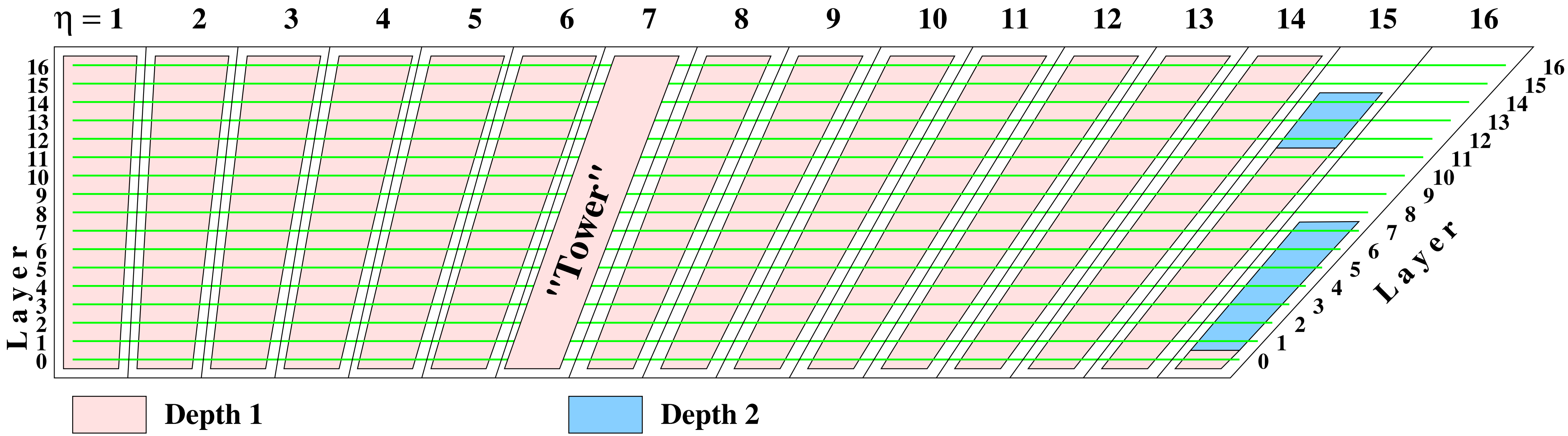
Beam from SPS.

MC Visualization

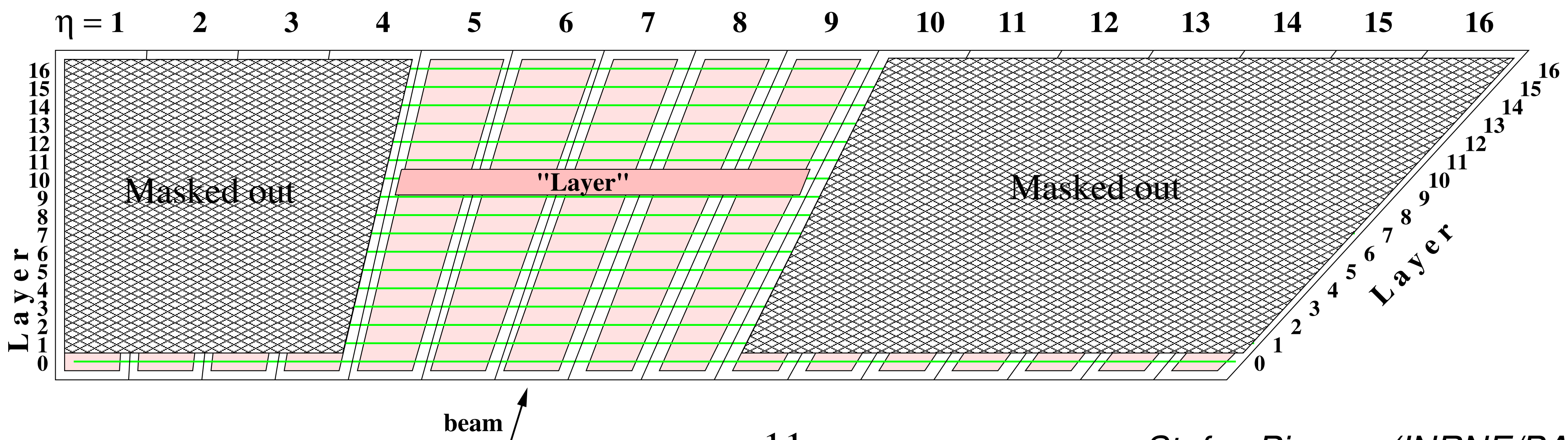


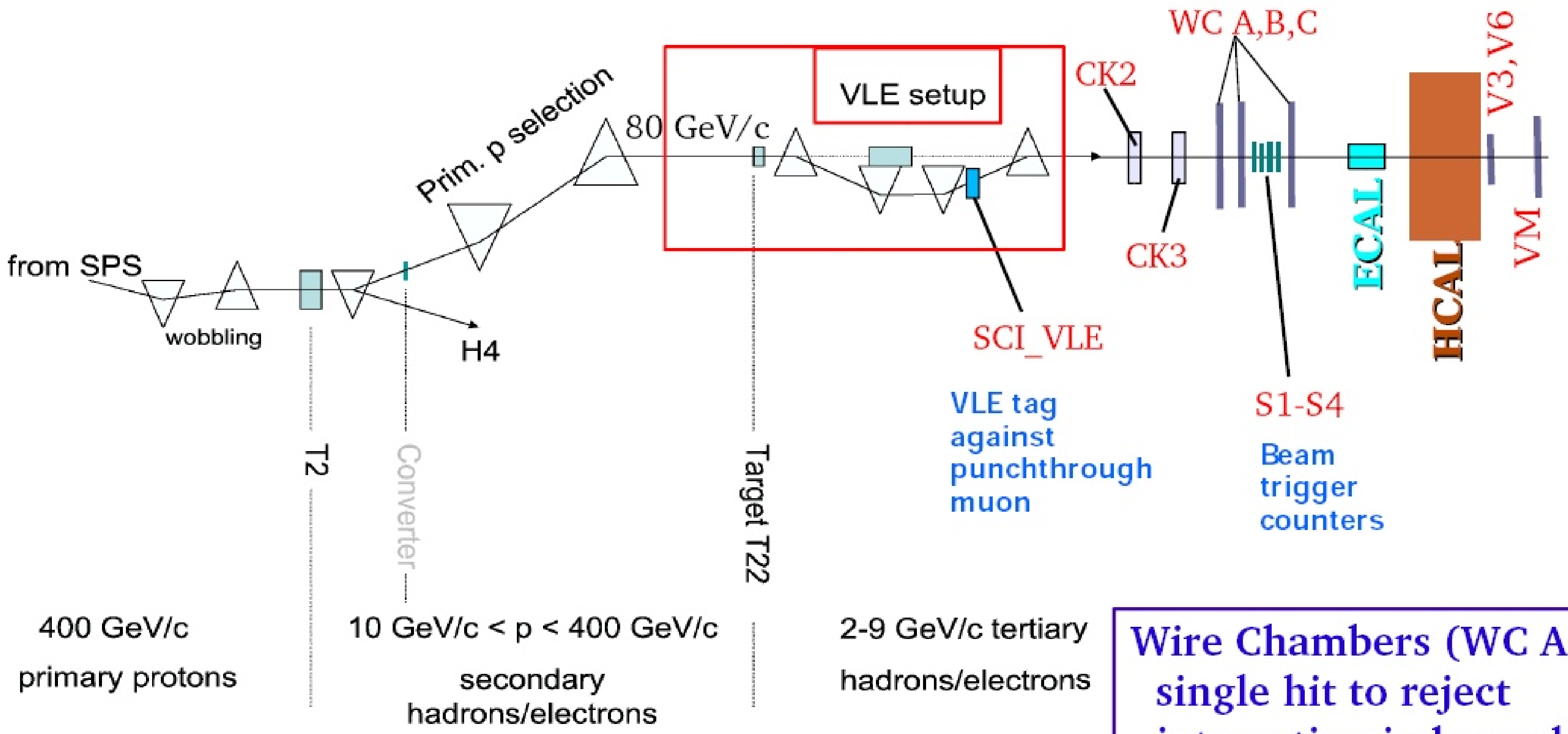
Moving table allows beam to be sent into arbitrary eta/phi tower of HCAL.
ECAL crystals always stay in the beam.

HB1: tower−wise readout – normal, as in CMS



HB2: Layer−wise readout – for longitudinal shower profile studies





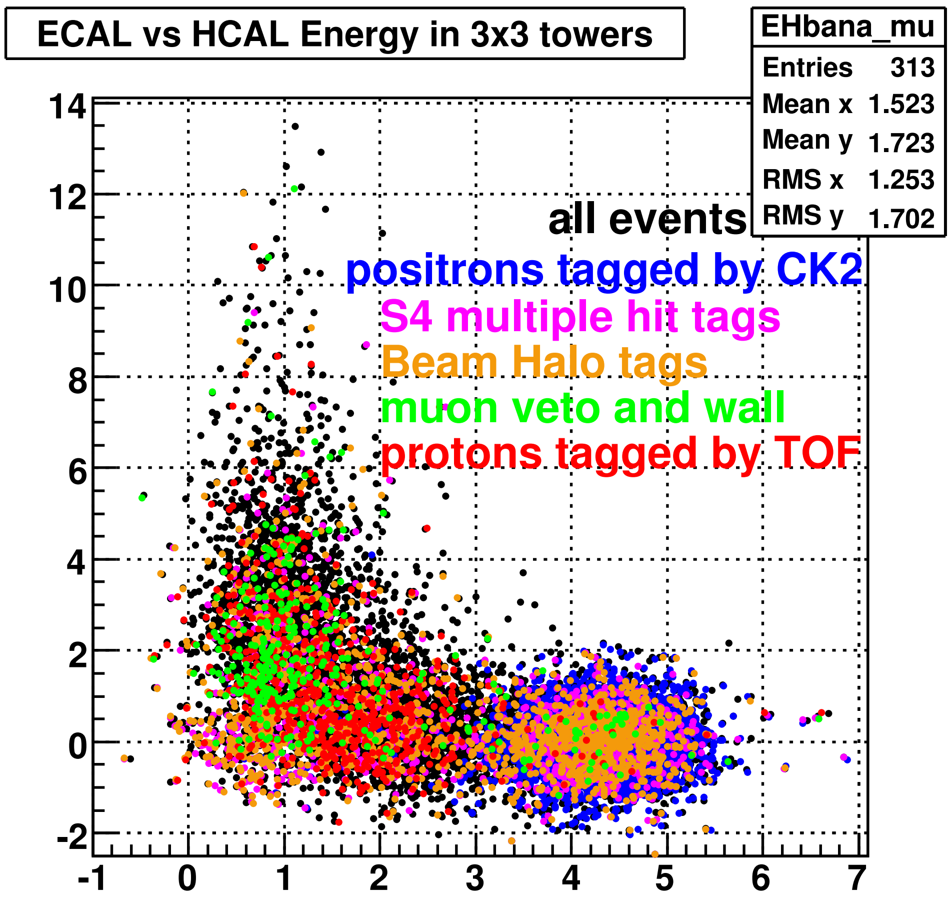
Wire Chambers (WC A,B,C):
single hit to reject
interaction in beam line

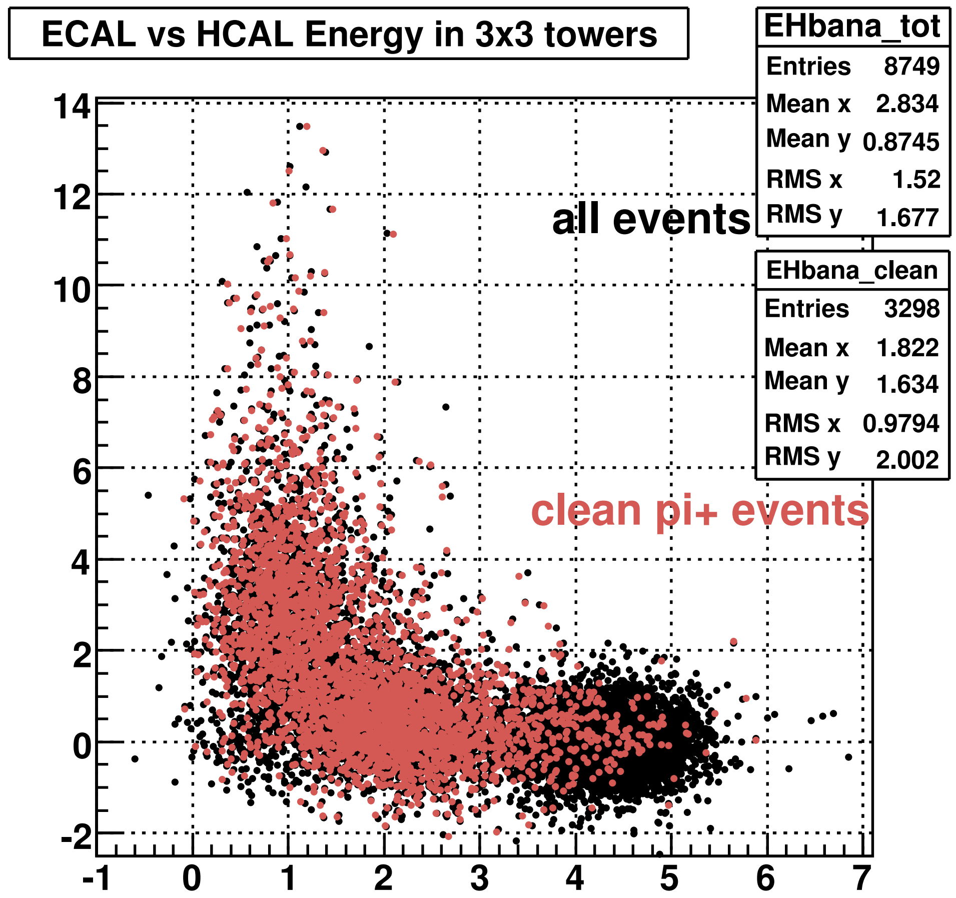
Available beam tunes:
- pions 2-300 GeV
- muons 80/150 GeV
- electrons 9-100 GeV

P-ID:
- Cerenkov counter (CK2) - electron
- Cerenkov counter (CK3) - pion / kaon / proton
- Scintillators (V3, V6, VM) – muon tagging

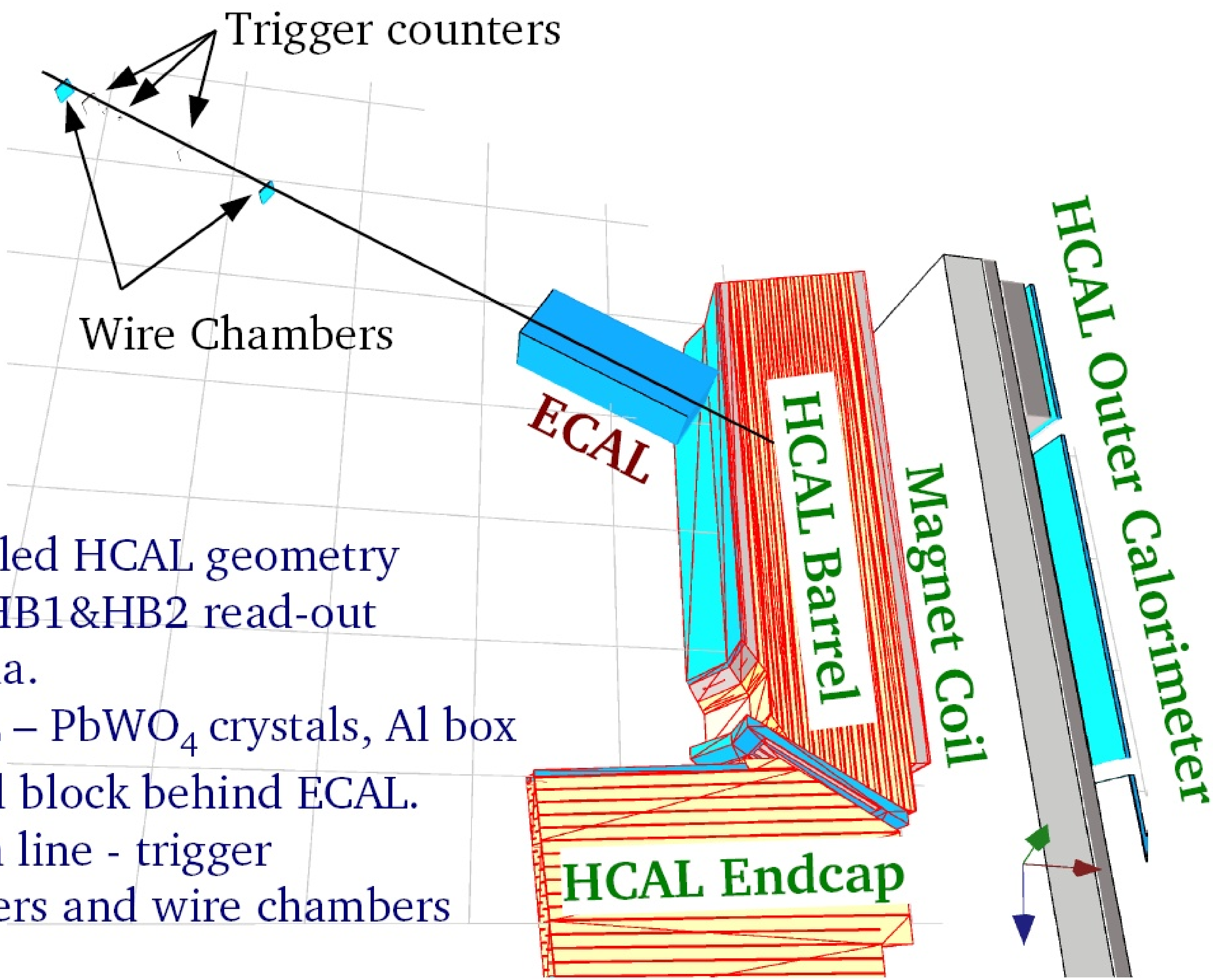
Example of beam clean-up possible in TB2006

Run#29665: 5GeV pi+





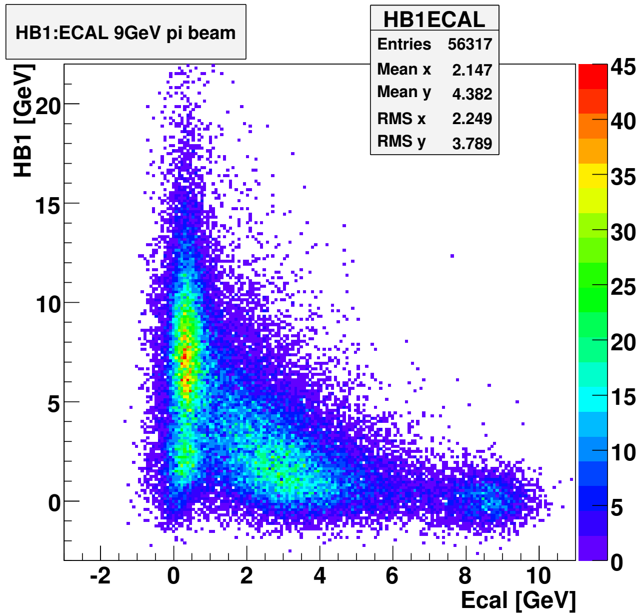
All simulations done with Geant4 toolkit



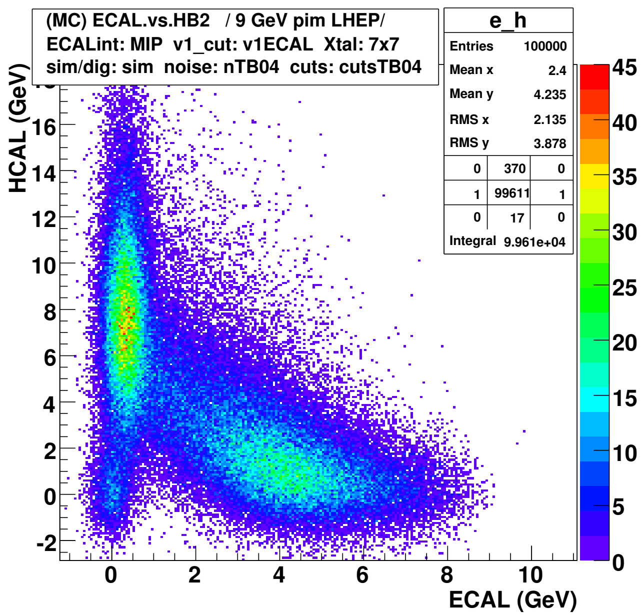
- Detailed HCAL geometry with HB1&HB2 read-out schema.
- ECAL – $PbWO_4$ crystals, Al box and Al block behind ECAL.
- Beam line - trigger counters and wire chambers

HCAL signal vs. ECAL signal - the ”banana” plot

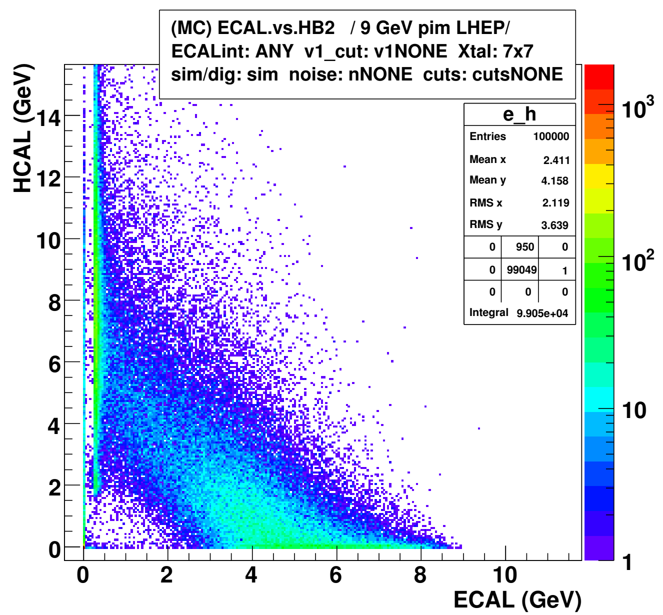
TestBeam data



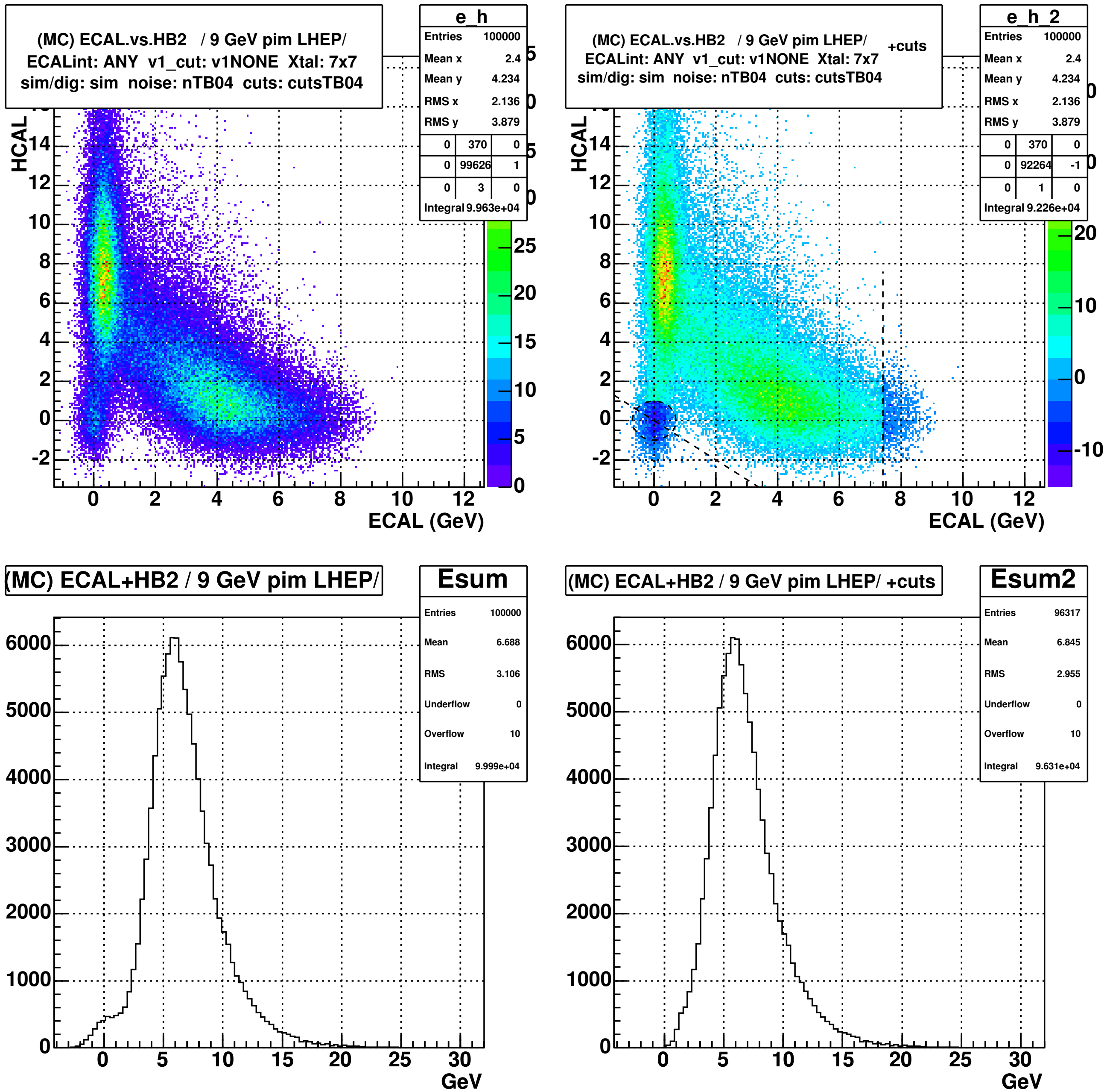
G4.6.2_p2 MC with noise



G4.6.2_p2 MC w/o noise

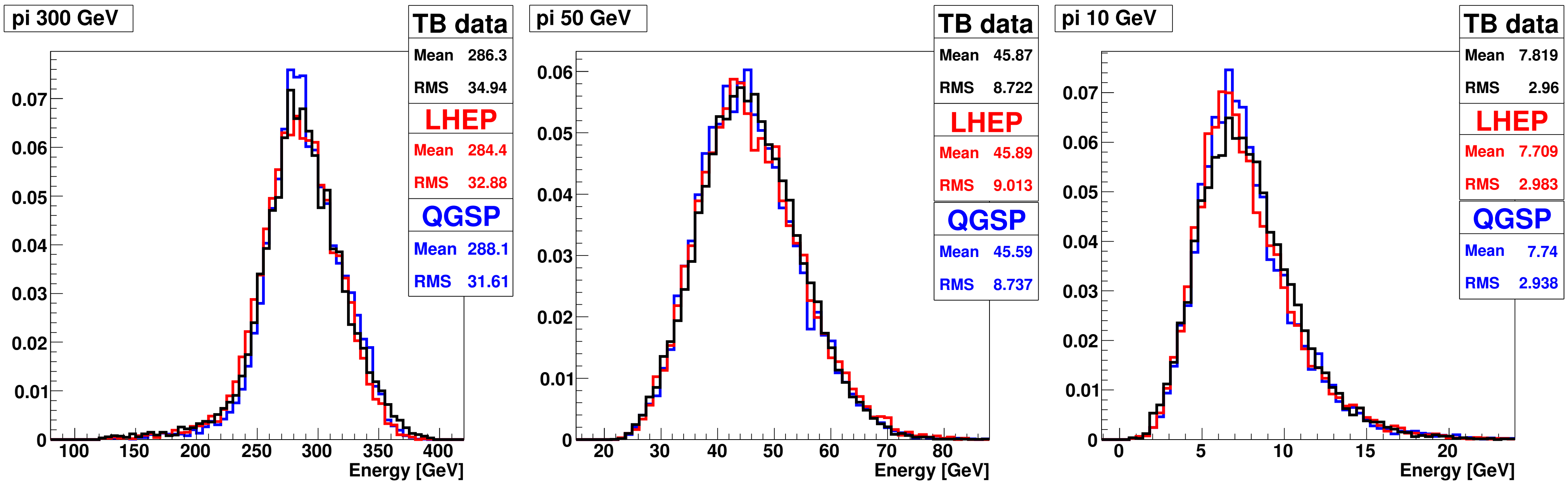


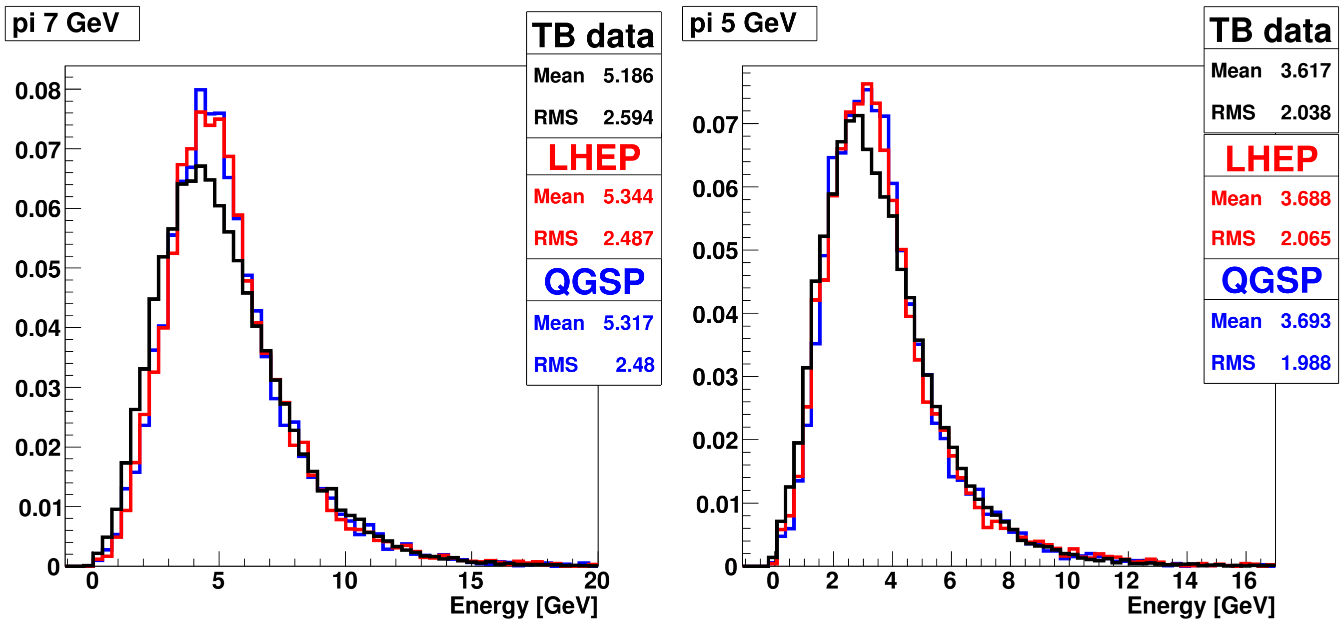
- electron contamination in pion beam
- interactions in beamline
- muons from pion decay



Caloimeter-based cuts are necessary to clean up the beam-interracted particles. These introduce systematic errors, but are the only way to enable comparison with the TB data.

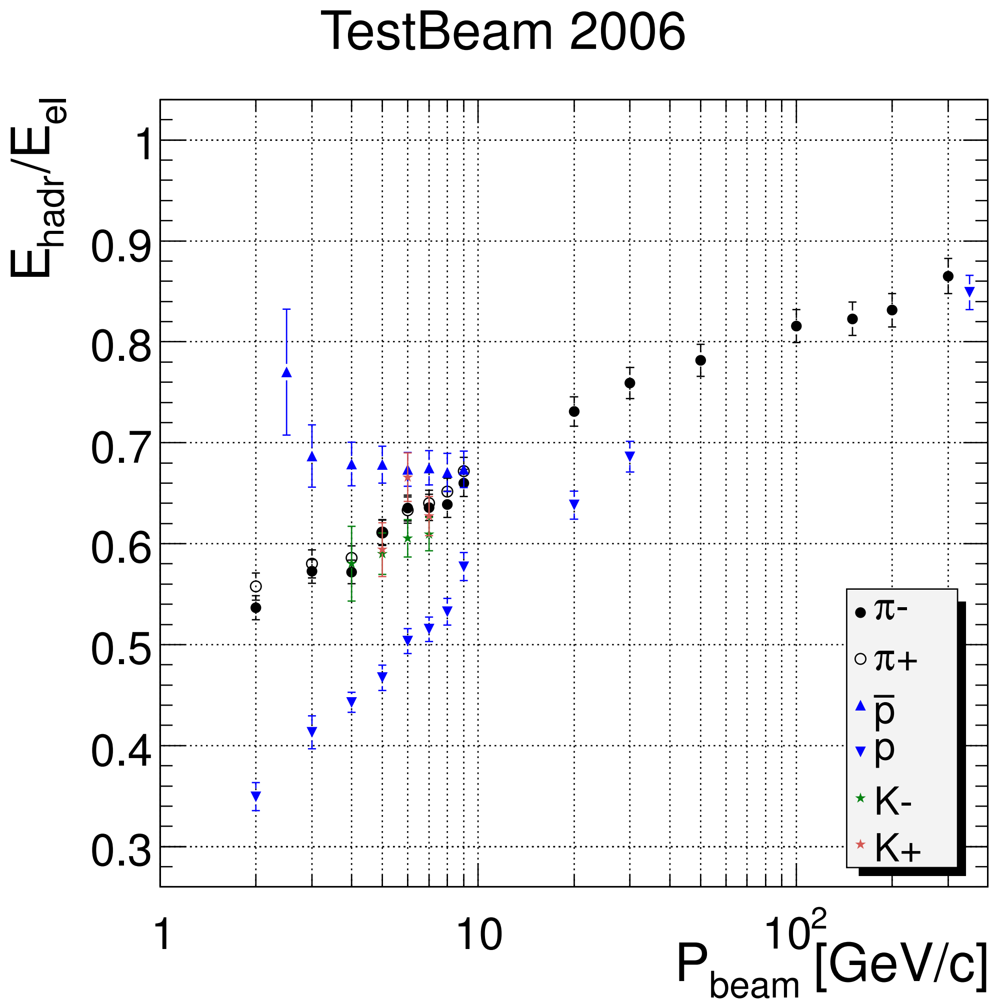
TestBeam results — pion response: energy spectra

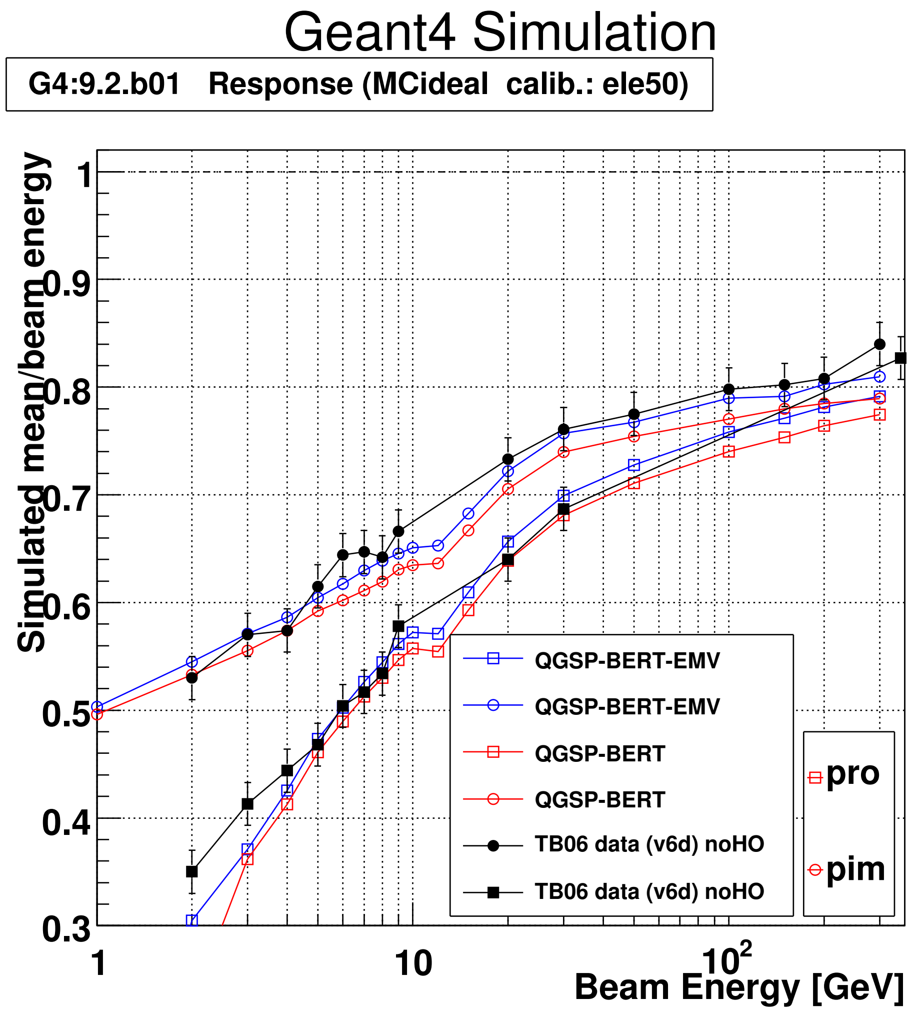


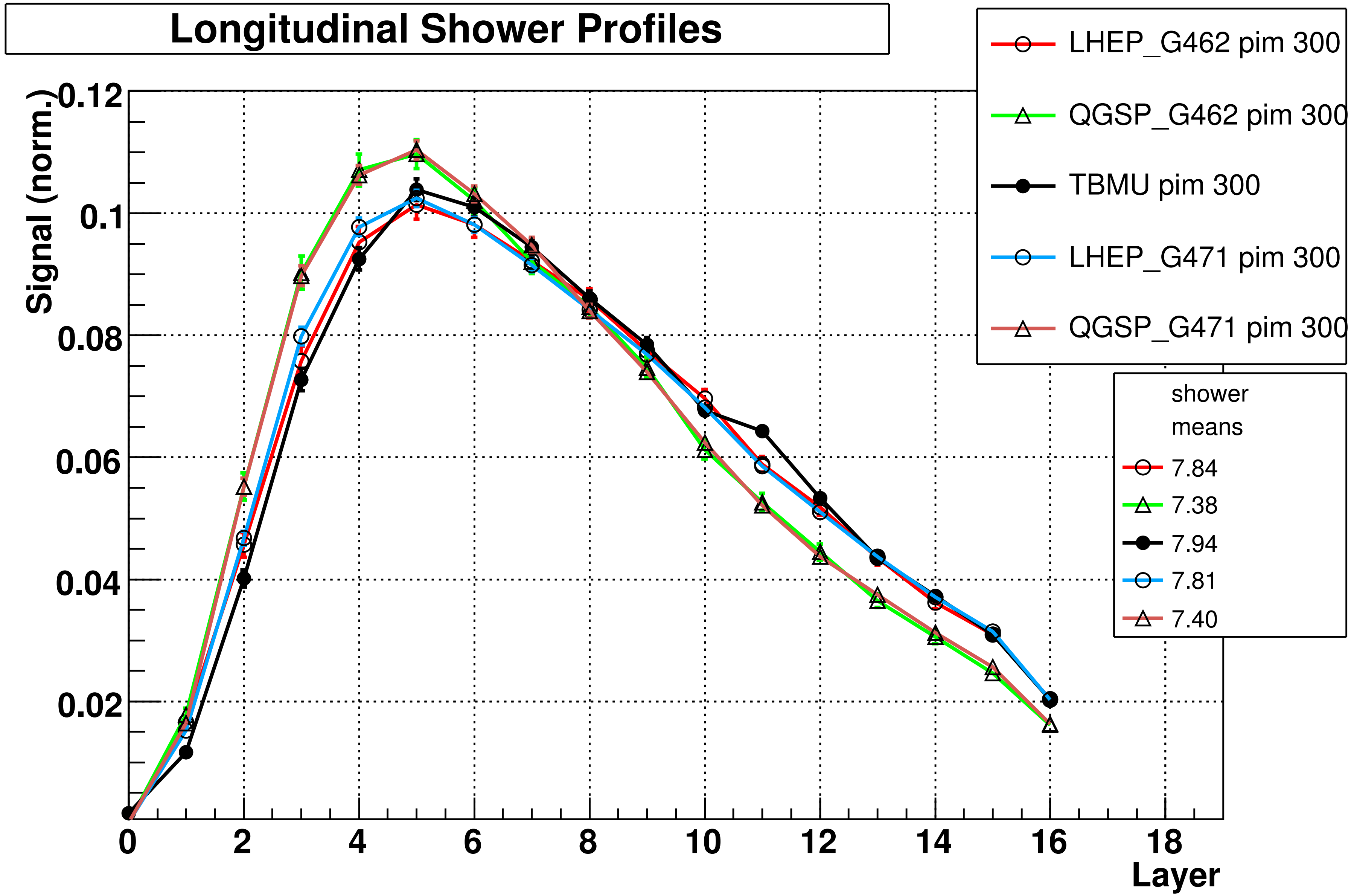


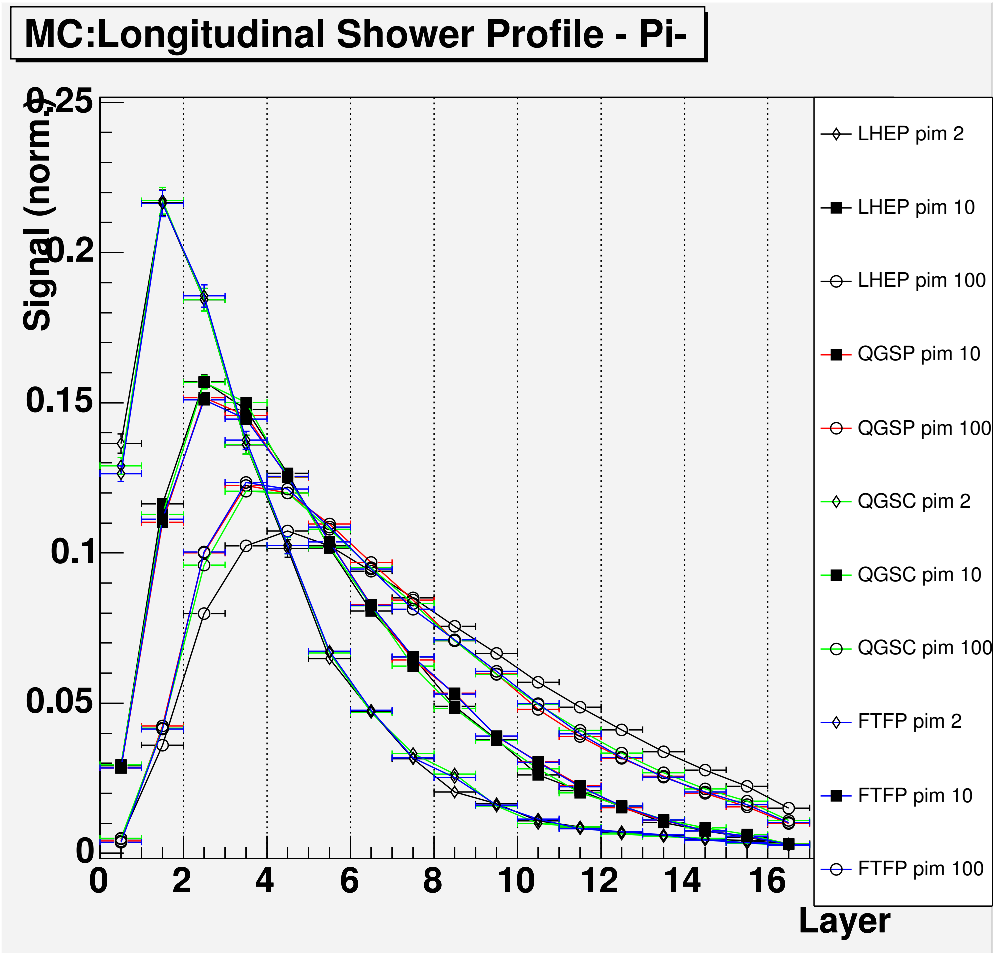
Good agreement with data.

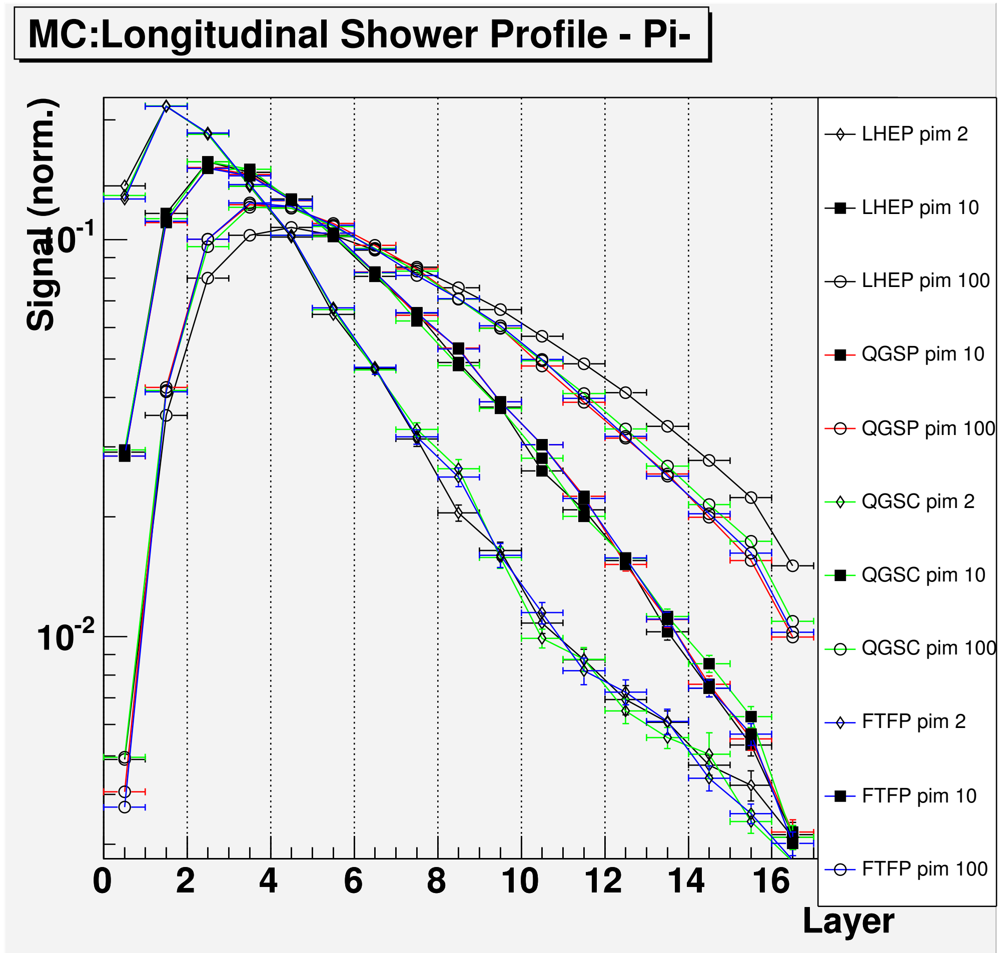
Comparison of TB06 data and Geant4 Linearity of Response






Longitudinal Shower Profiles
Signal (norm.)
0.12
0.1
0.08
0.06
0.04
0.02
0
2
4
6
8
10
12
14
16
18
Layer
LHEP_G462 pim 300
QGSP_G462 pim 300
TBMU pim 300
LHEP_G471 pim 300
QGSP_G471 pim 300
shower
means
7.84
7.38
7.94
7.81
7.40





Early simulations with G4.6.2_p2 showed that the parametrized physics list (LHEP) predicts different shower profiles than the theory-based lists (QGSP, QGSC, FTFP) at high energies. So we were curious what the test-beam data will look like.

- Calorimeters play a crucial role in detecting hadrons
- They can be of various kinds, depending on their application
- Their MonteCarlo simulation is very expensive in terms of CPU power
- CMS calorimeters have been studied in TestBeams in great detail before installing them in the experiment