Hadron particle detection
(with the CMS detector)

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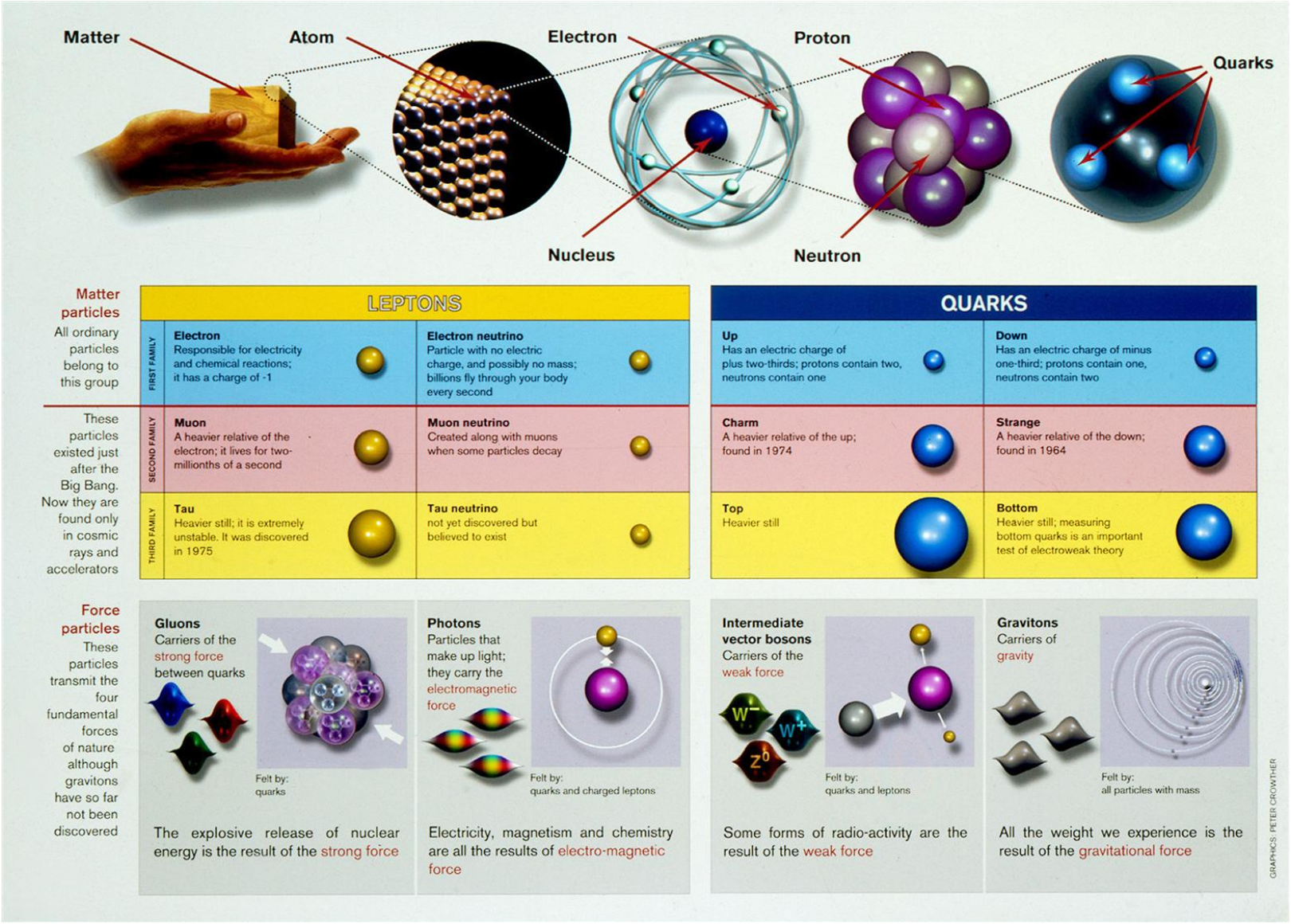
Sep.19, 2012, CERN

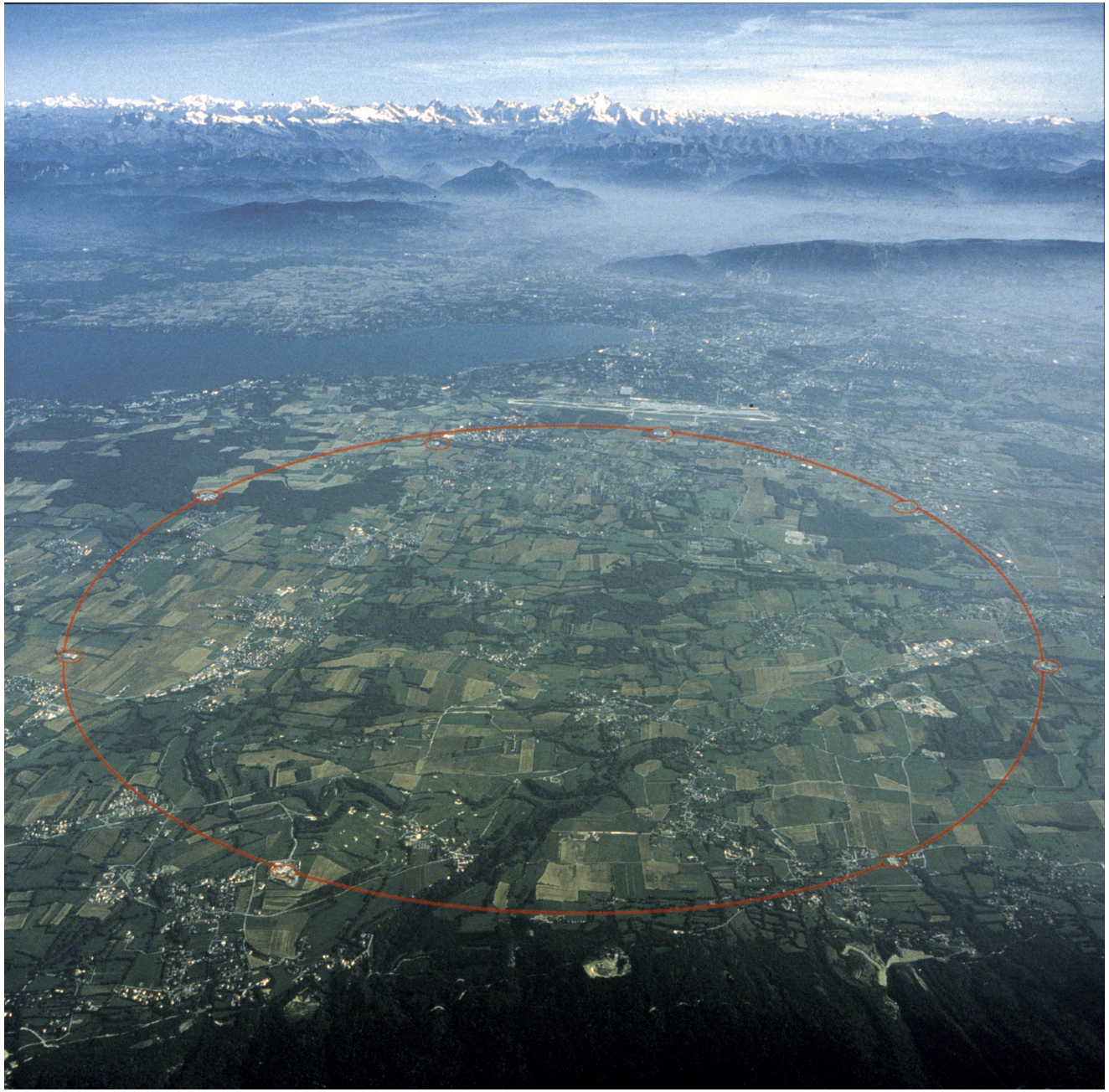
Outline

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

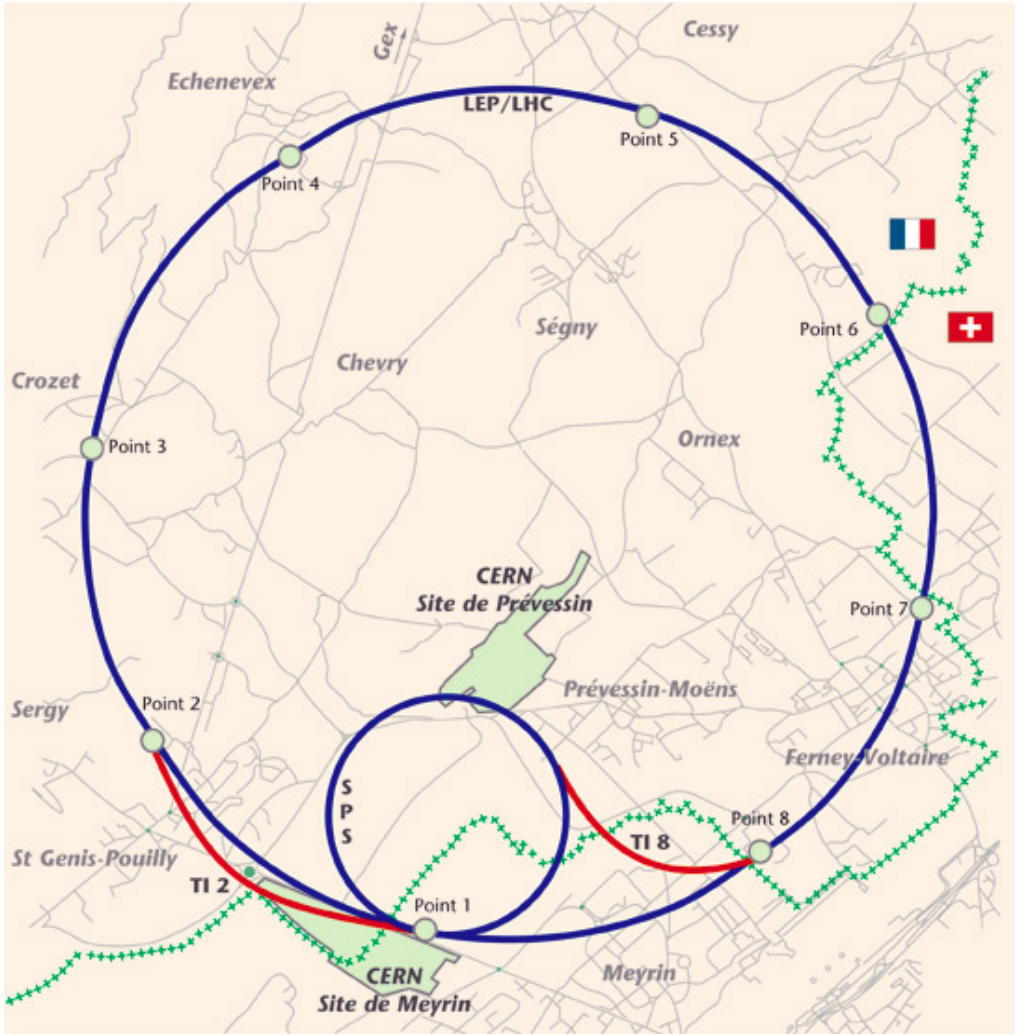


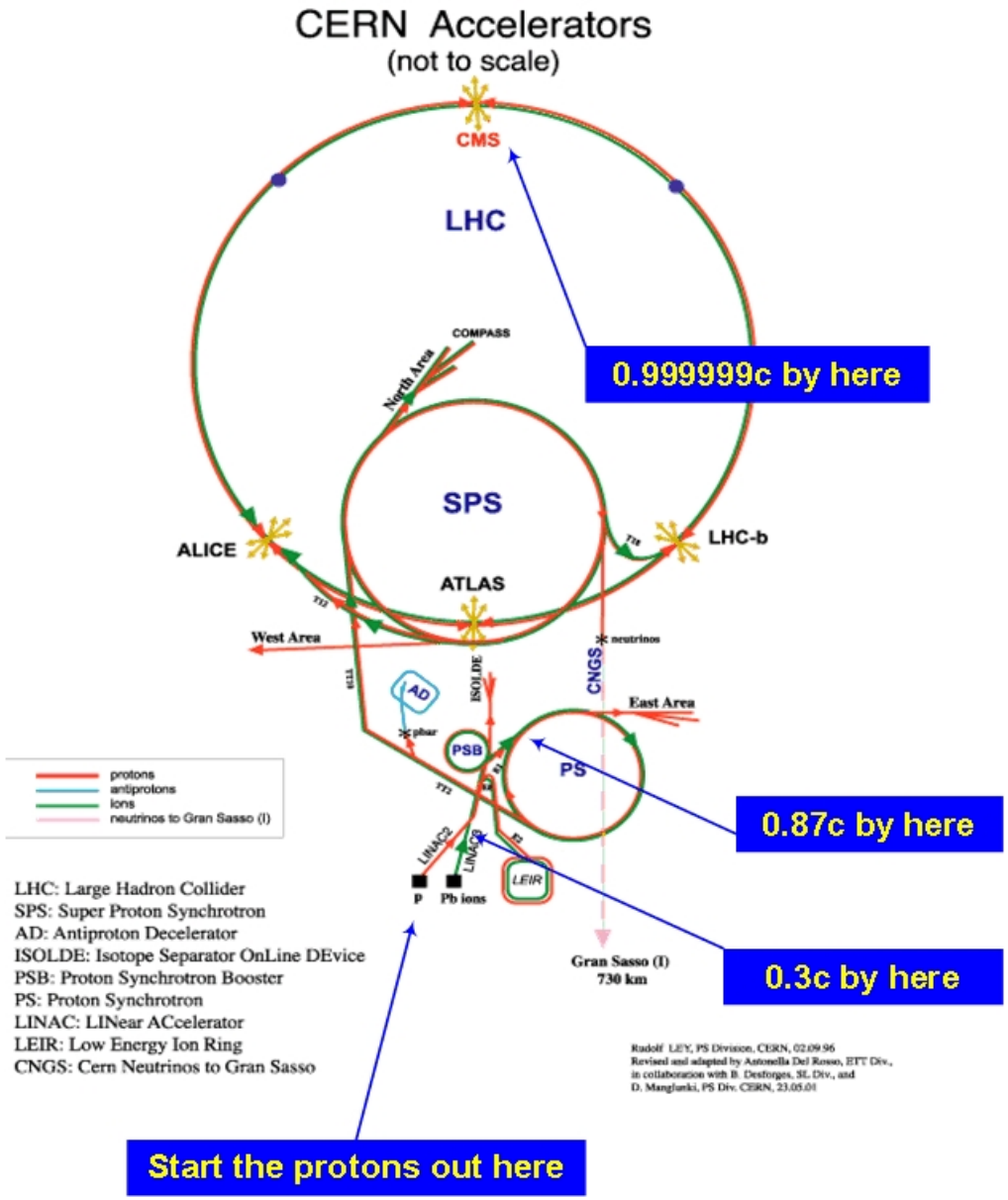
This is what we know about the particles that constitute our Universe. The only thing still missing WAS the Higgs-boson that gives mass to all the particles. Plus everything that we still don't know about...

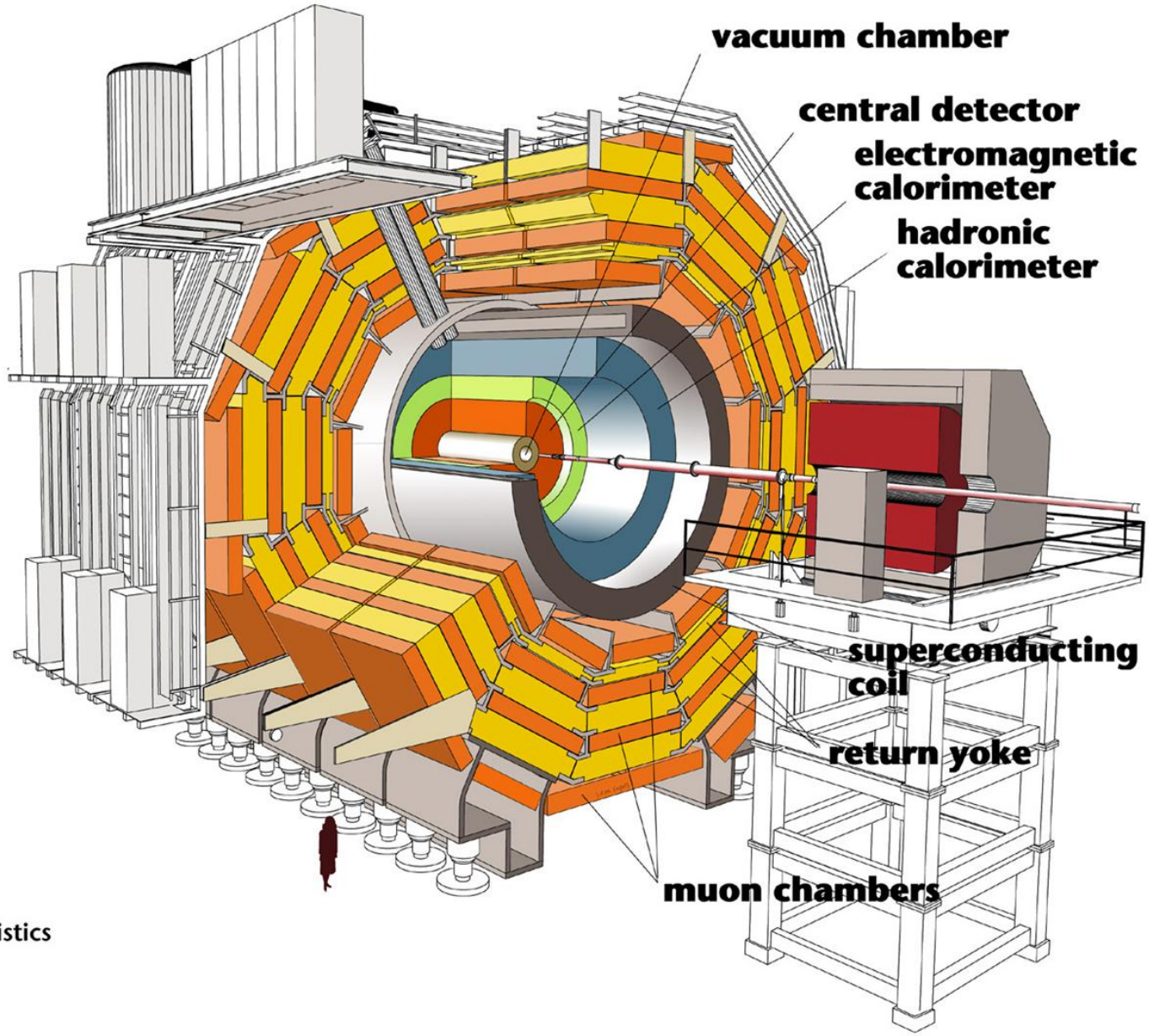
LHC, CERN, Geneva



CERN and the Accelerators Complex

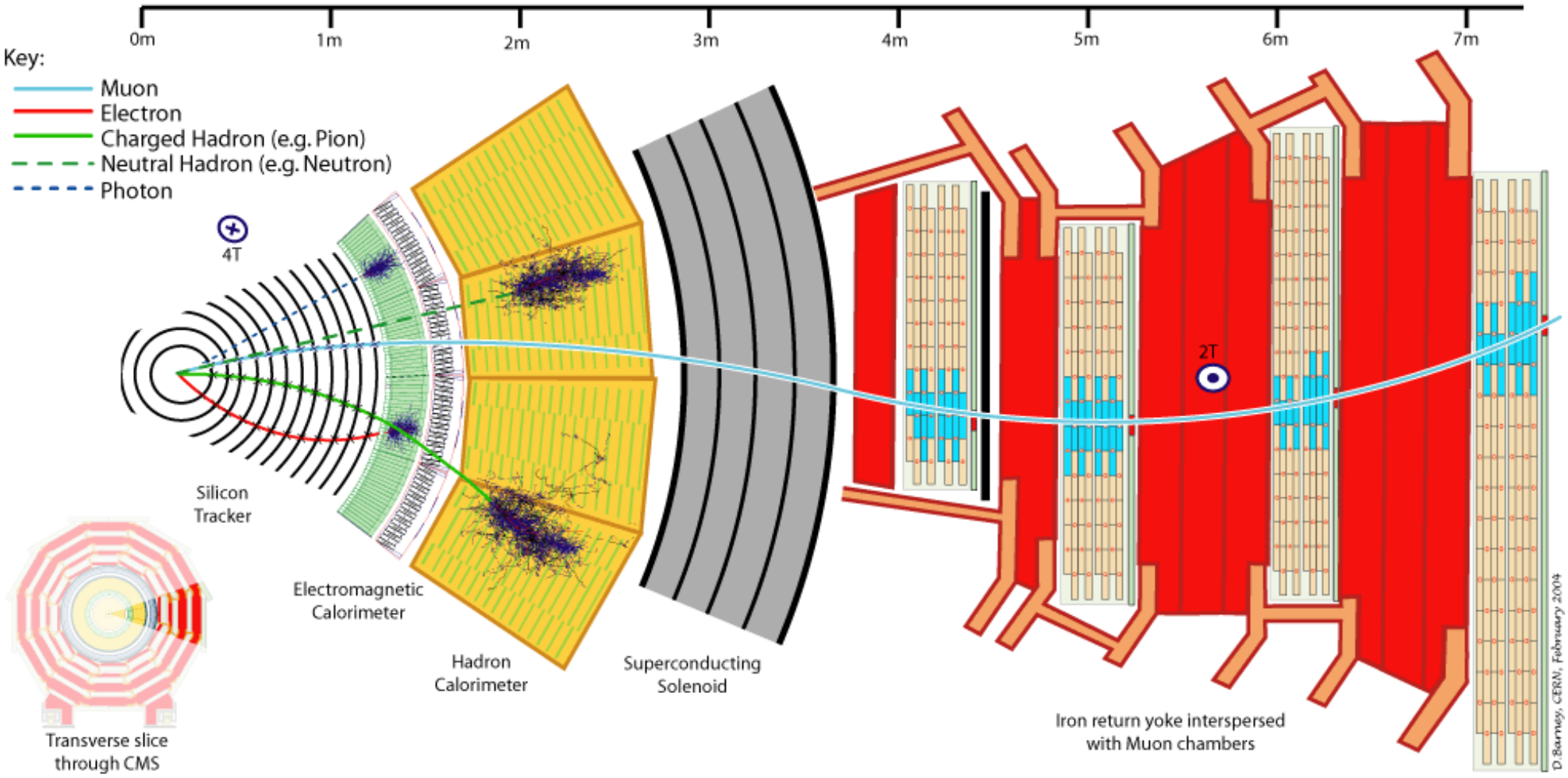






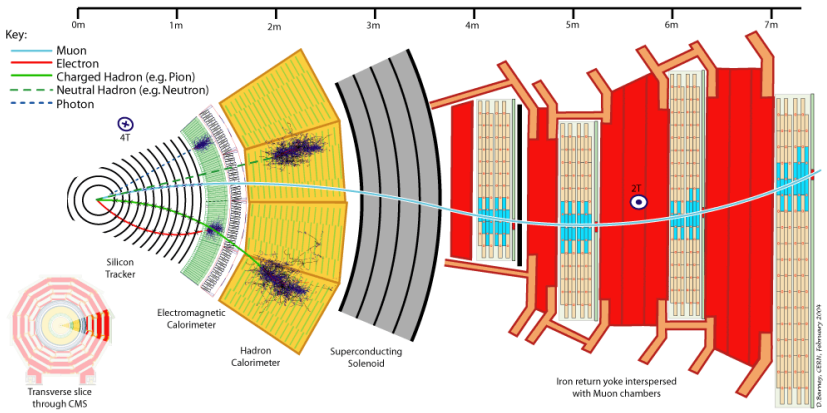
Detector characteristics

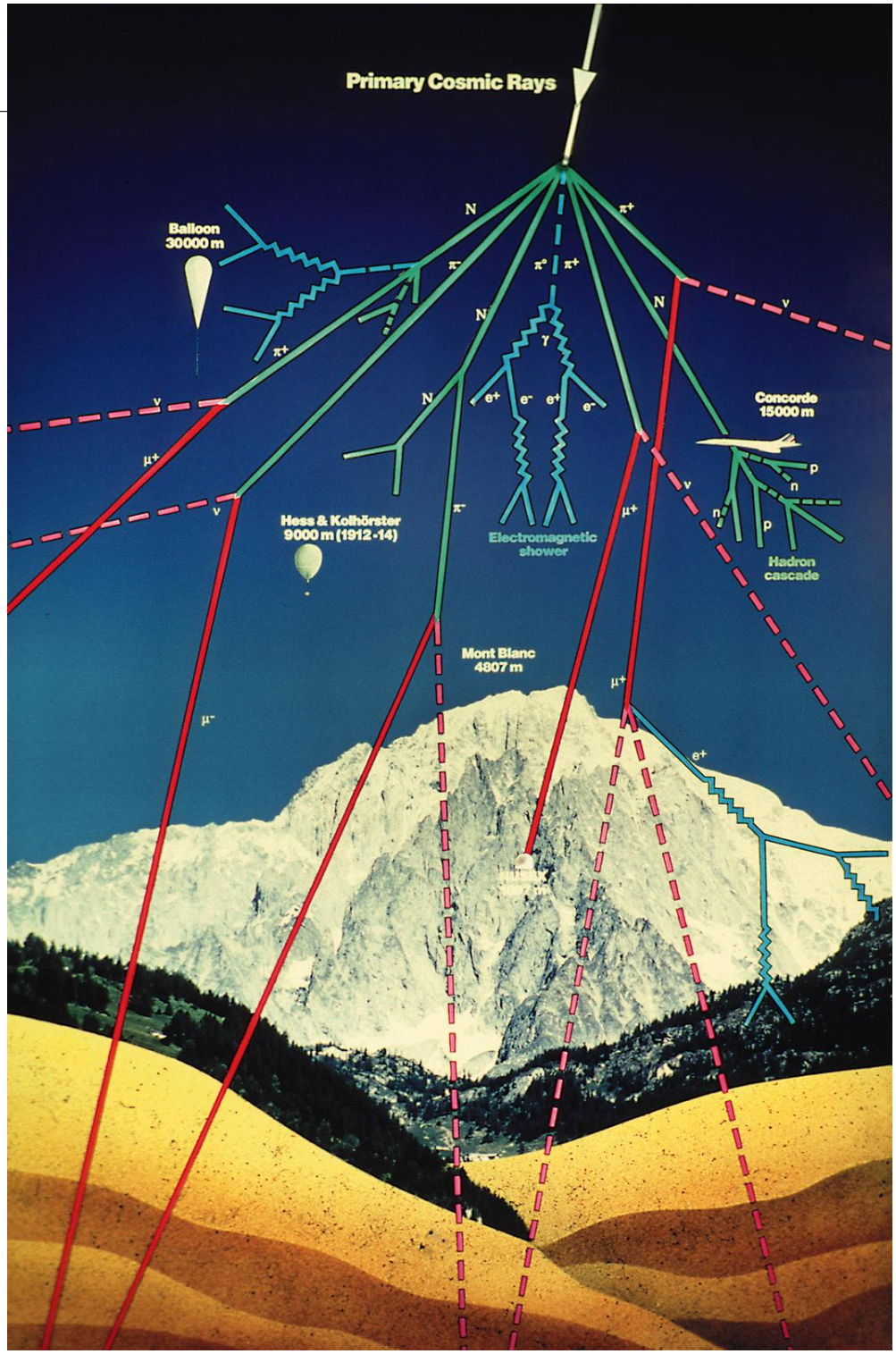
Width: 22m
Diameter: 15m
Weight: 14'500t


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

Atmospheric Showers

Something similar happens to the hardons in the atmosphere above us:



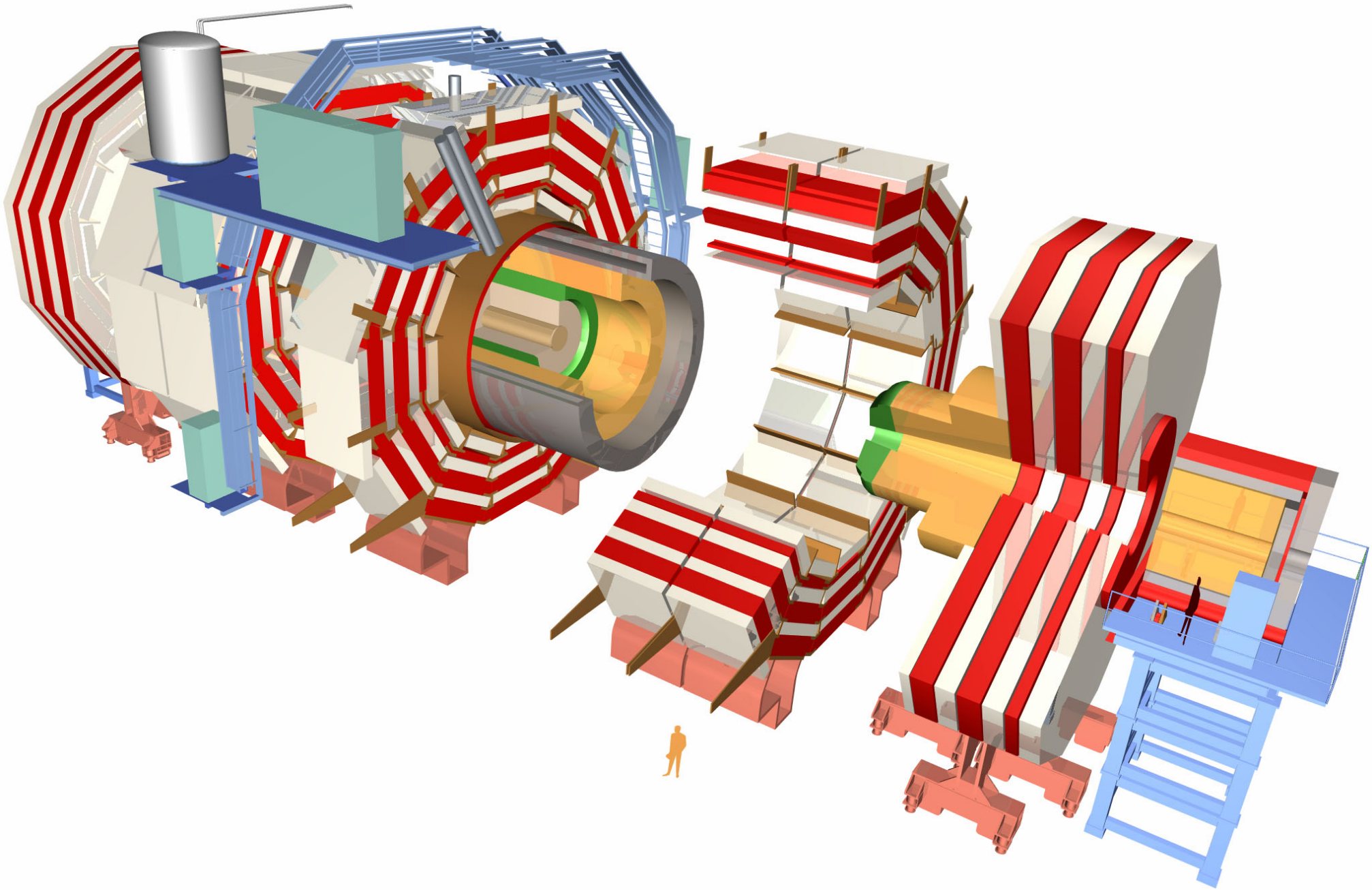


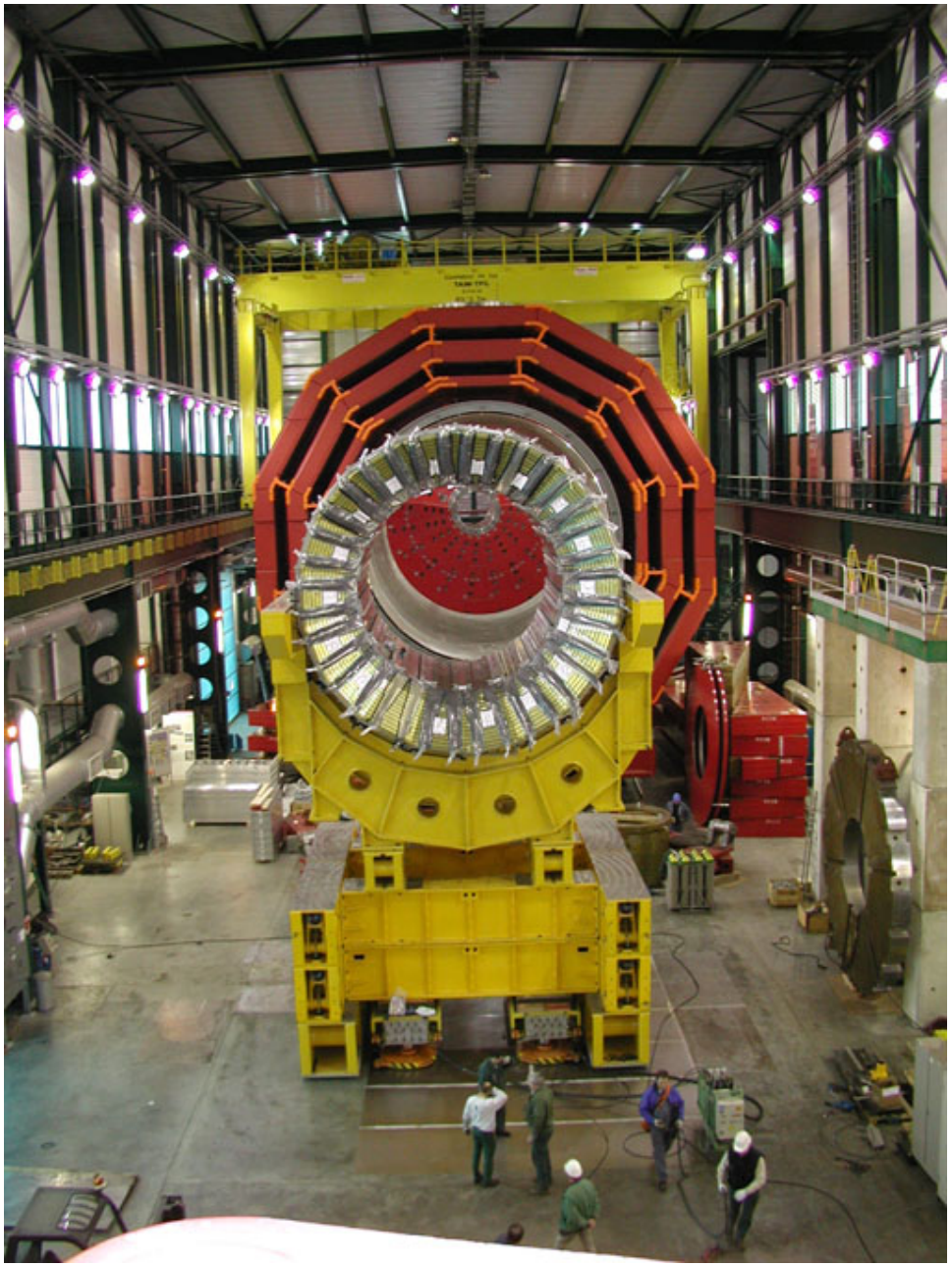
Function of Calorimeters:

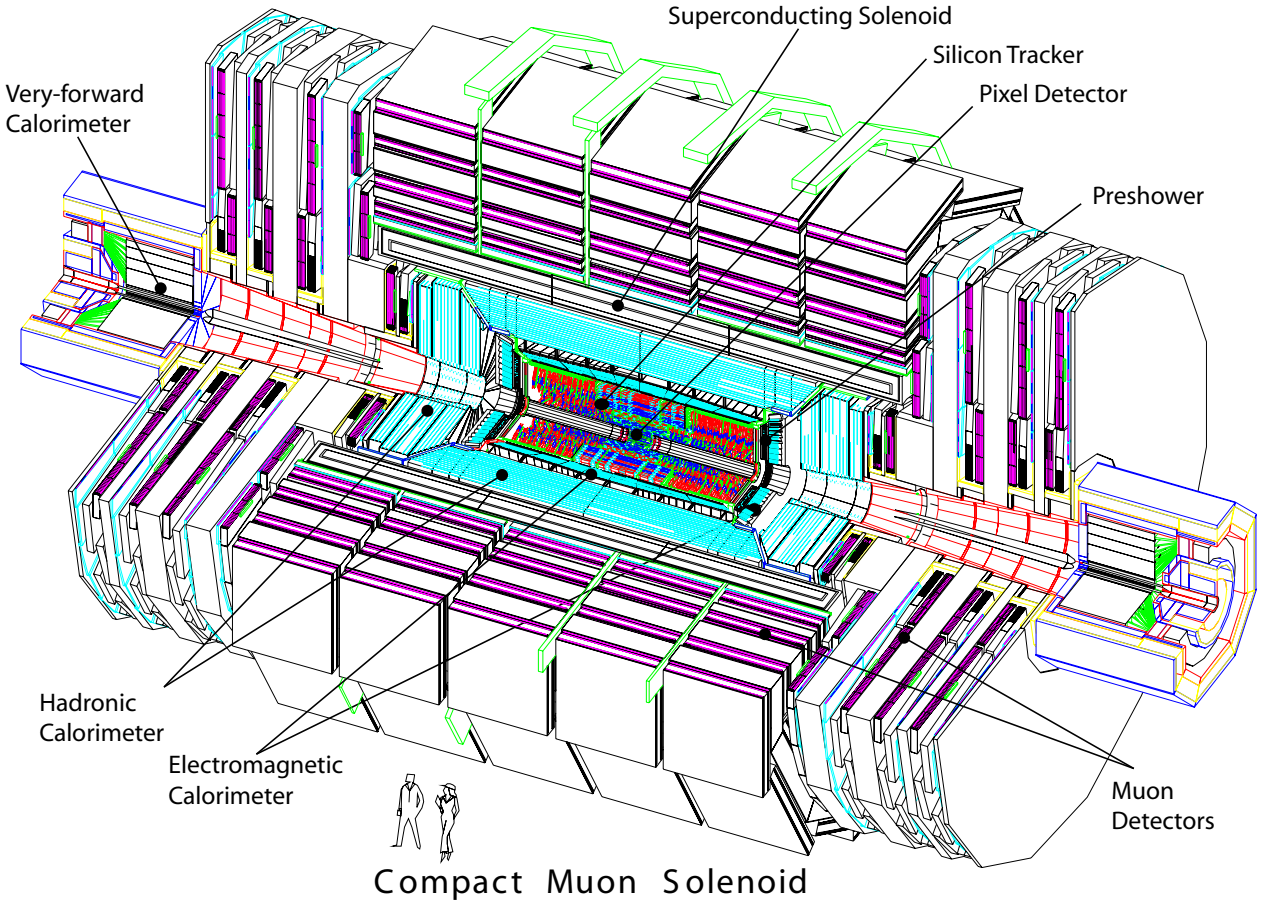
- Measure the energy of a hadron (in most cases - jets of hadrons)
- Provide hermeticity, so that missing energy can be measured

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

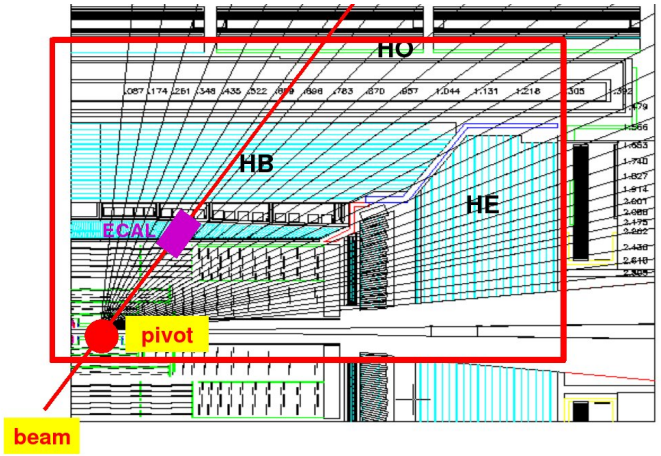
- Homogeneous vs. Sampling (structure)
- Solid vs. Liquid (medium)
- Scintillating vs. Cherenkov (signal)
- Compensating vs. Non-compensating (performance)







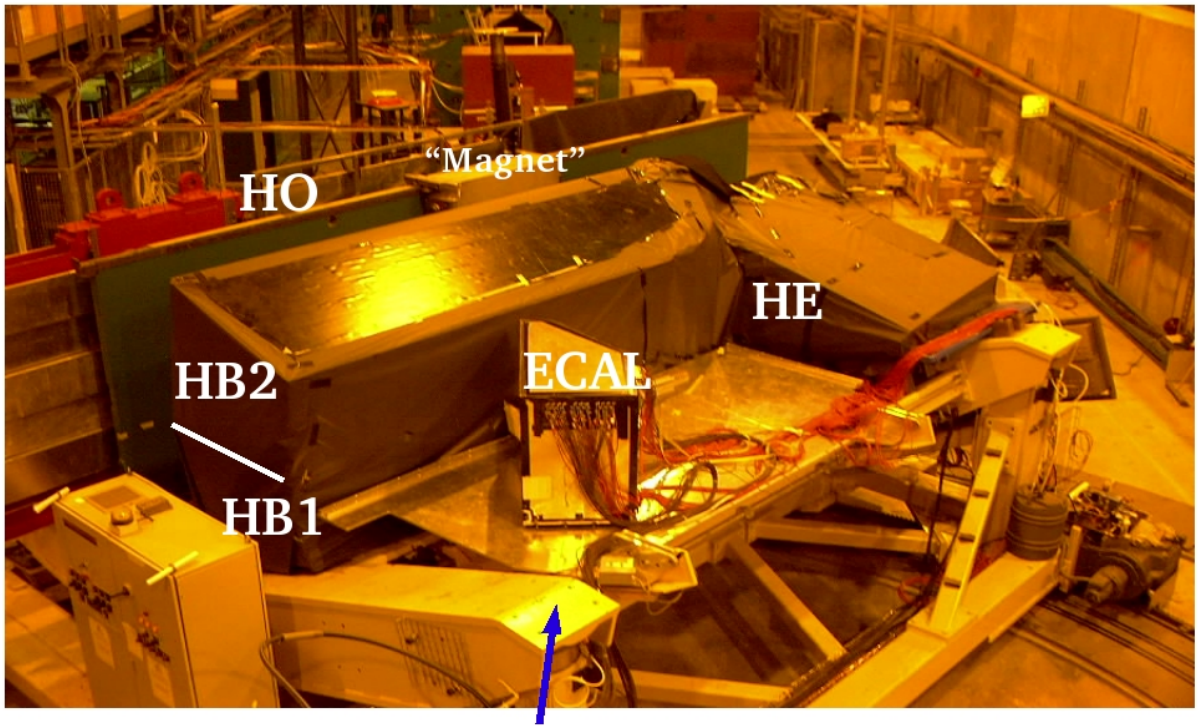
HCAL = Hadronic Calorimeter
ECAL = Electromagnetic Calorimeter
HB = HCAL Barrel
HE = HCAL EndCap
HO = HCAL Outer



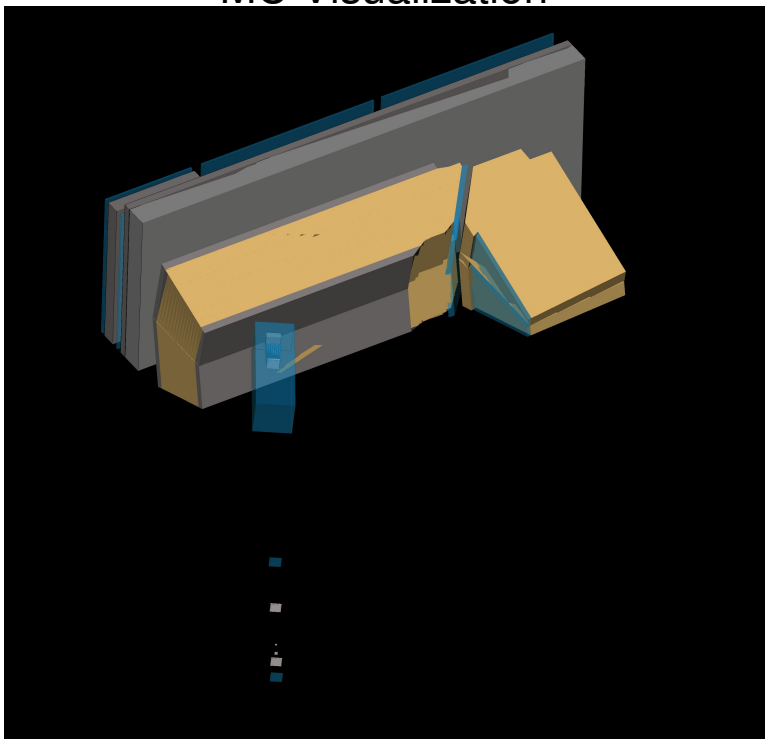
Calorimetric systems present on the Testbeam 2004 table.

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

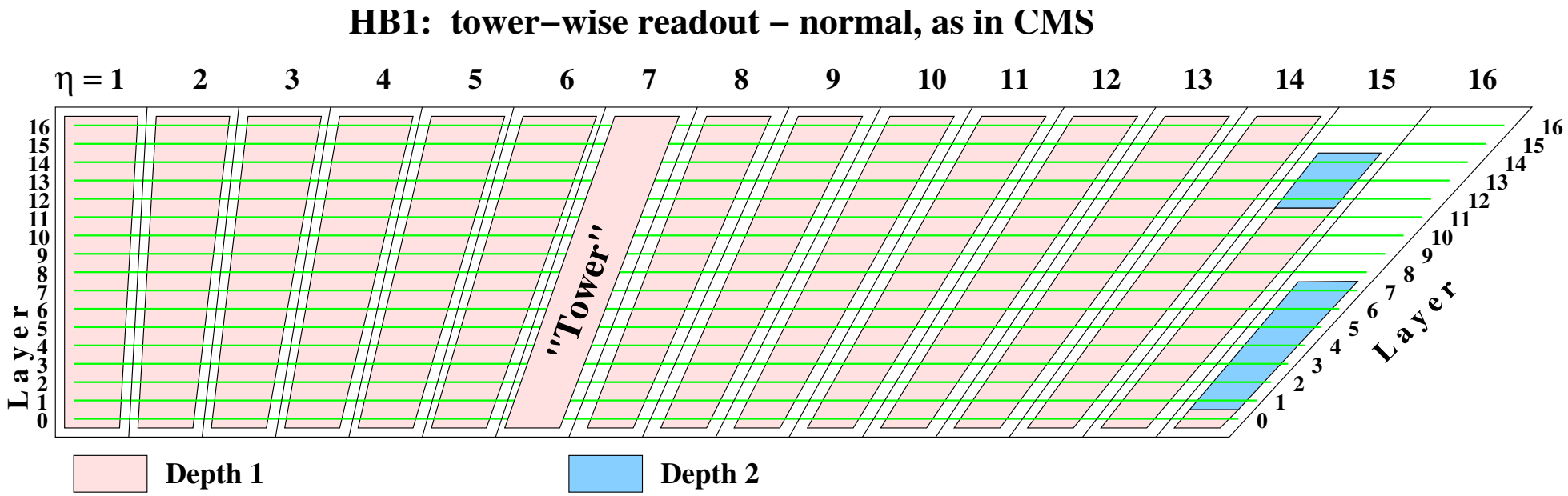


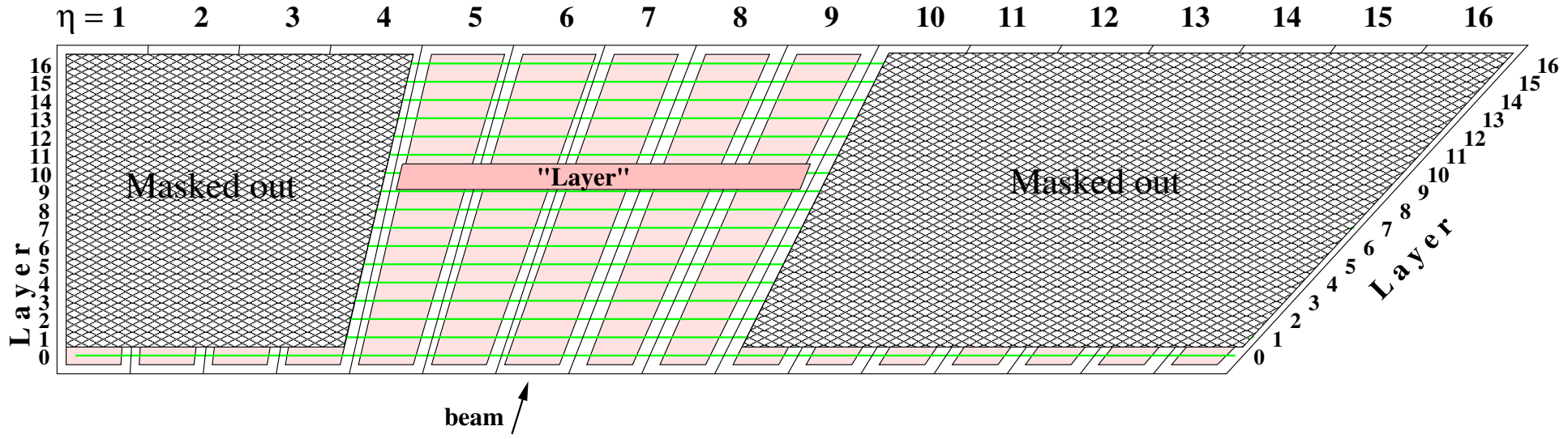
MC Visualization

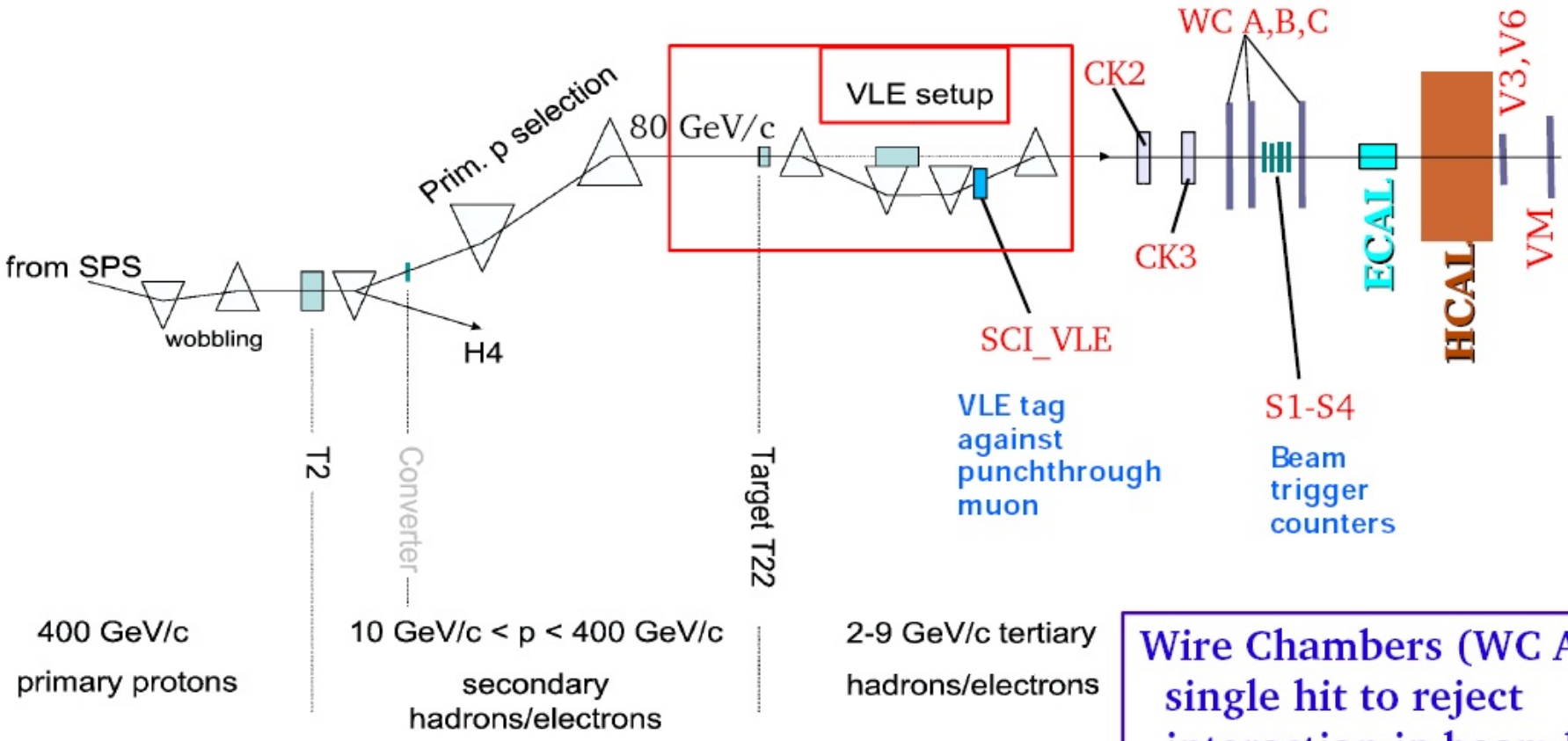


Moving table allows beam to be sent into arbitrary eta/phi tower of HCAL.
ECAL crystals always stay in the beam.


TENALIT
MOVITRAC


HB1: tower−wise readout − normal, as in CMS
η = 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Layer
"Tower"
Depth 1
Depth 2


HB2: Layer−wise readout − for longitudinal shower profile studies
η = 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Layer
Masked out
"Layer"
Masked out
beam

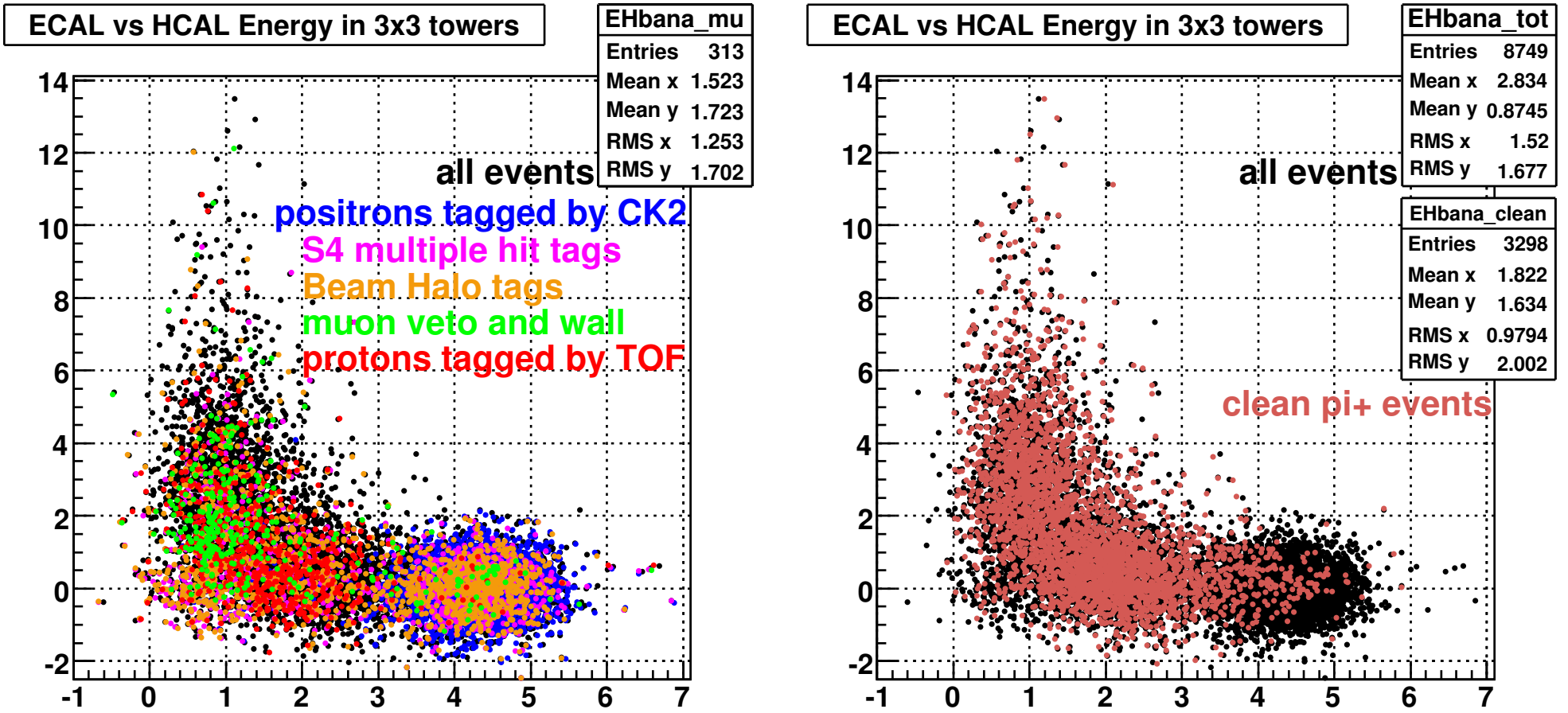


Wire Chambers (WC A,B,C):
single hit to reject interaction in beam line

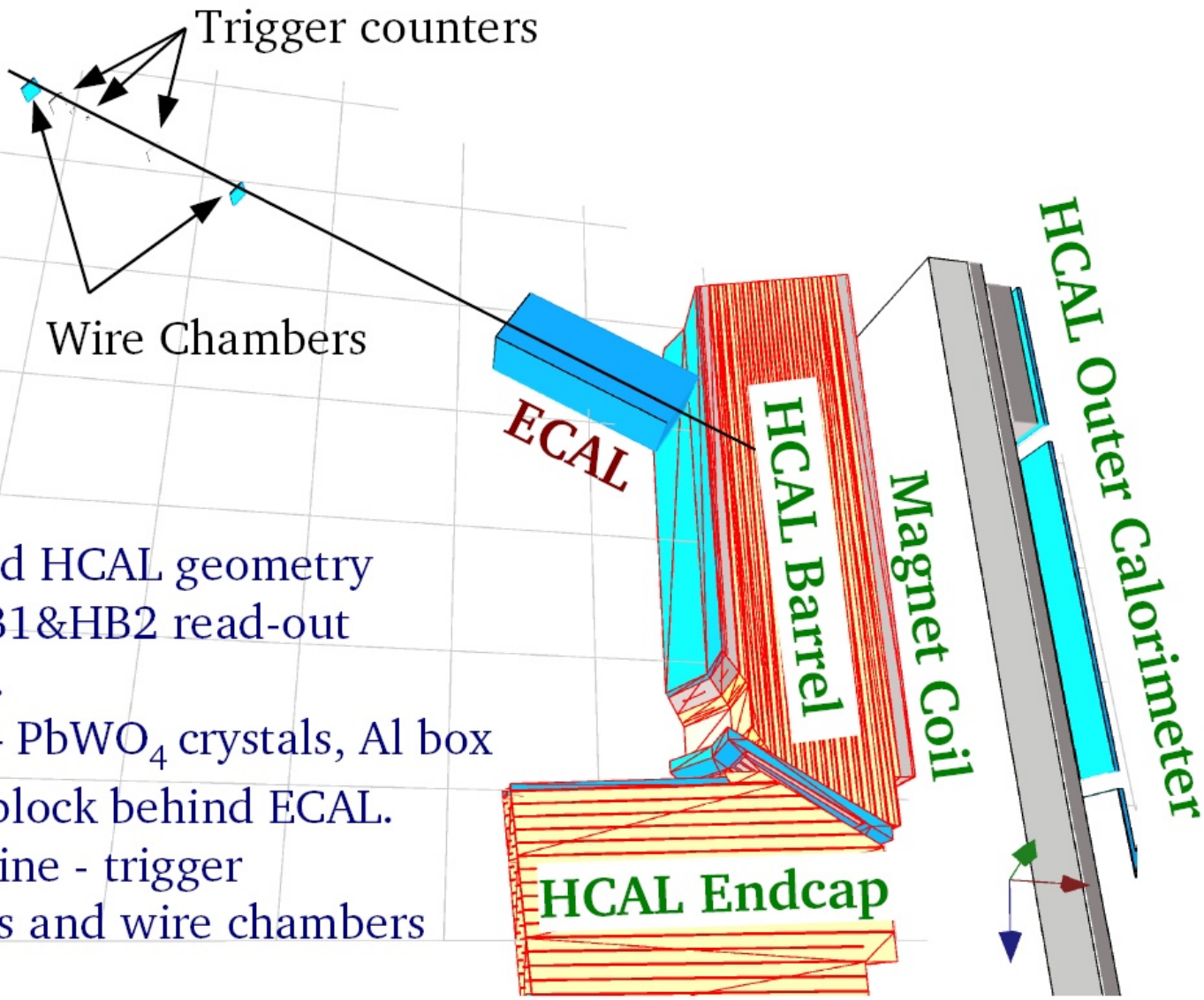
Available beam tunes:
pions 2-300 GeV
muons 80/150 GeV
electrons 9-100 GeV

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 the Test-Beam
Run#29665: 5GeV pi+



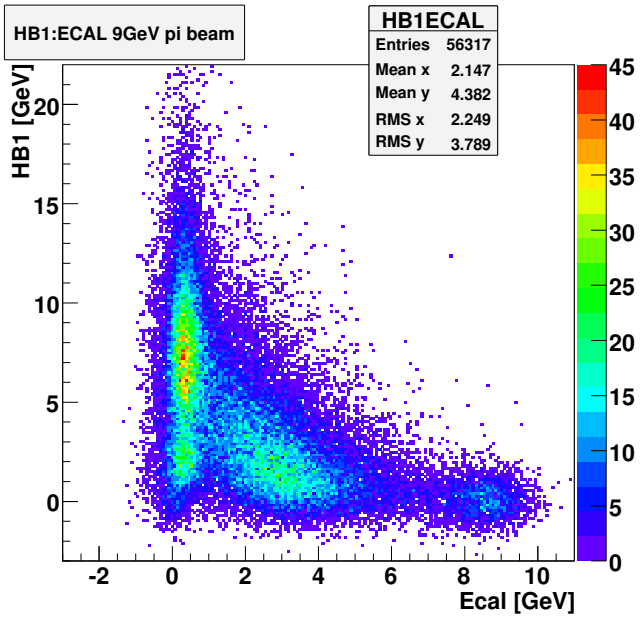
All simulations done with Geant4 toolkit



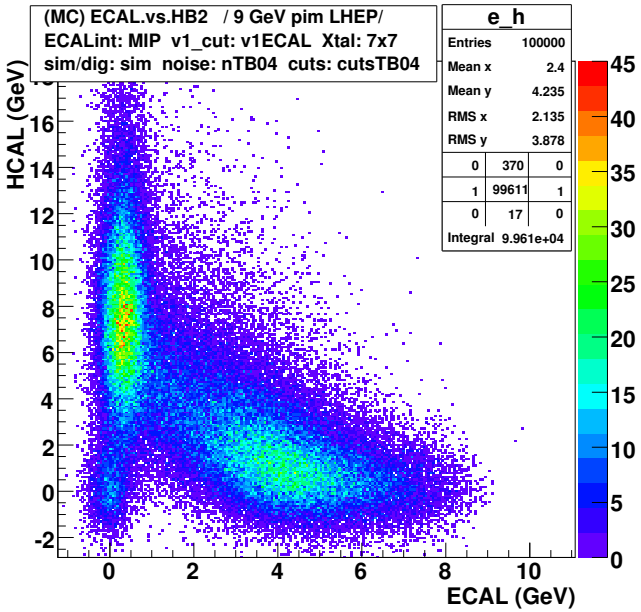
- Detailed HCAL geometry with HB1&HB2 read-out schema.
- ECAL – $PbWO_4$ crystals, Al box and Al block behind ECAL.
- Beam line - trigger counters and wire chambers

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

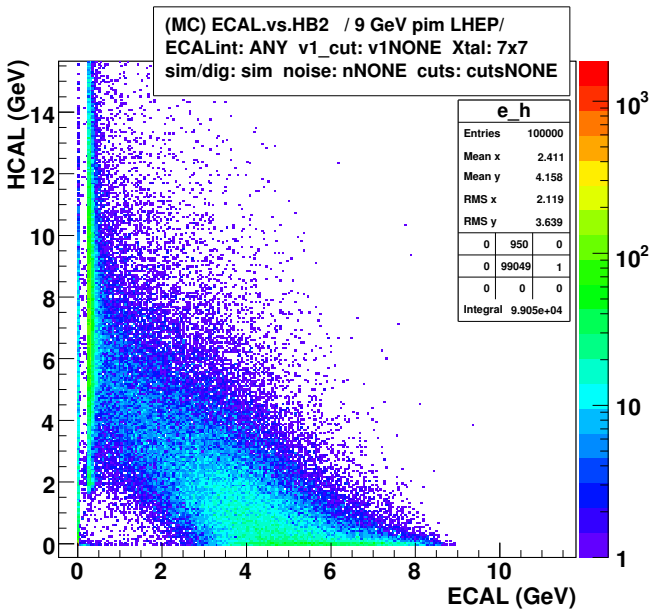
TestBeam data



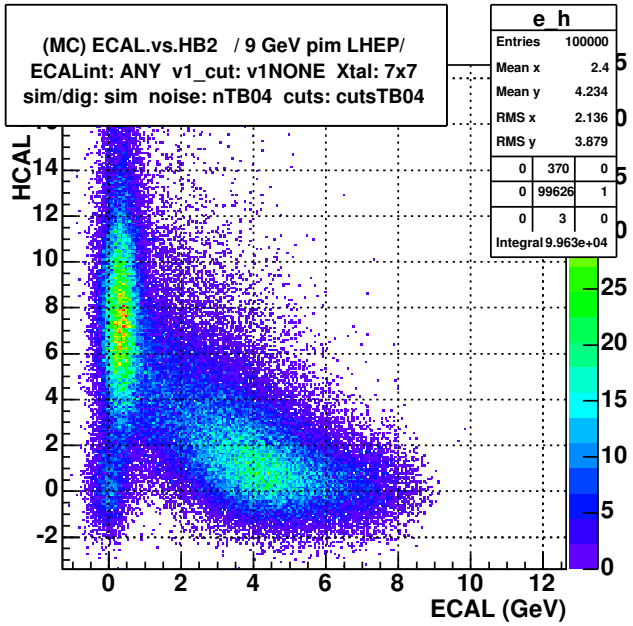
G4.6.2_p2 MC with noise

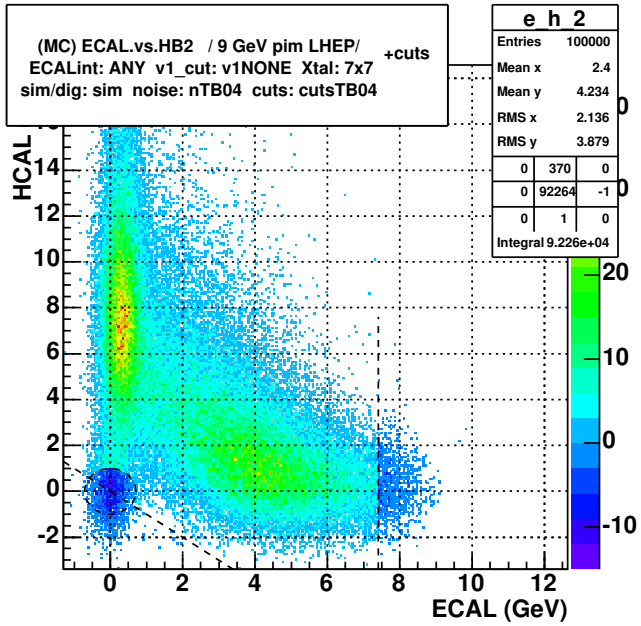


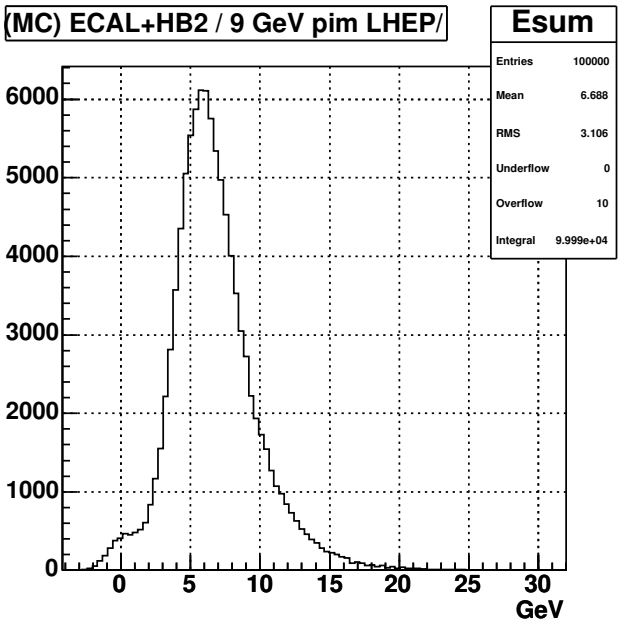
G4.6.2_p2 MC w/o noise

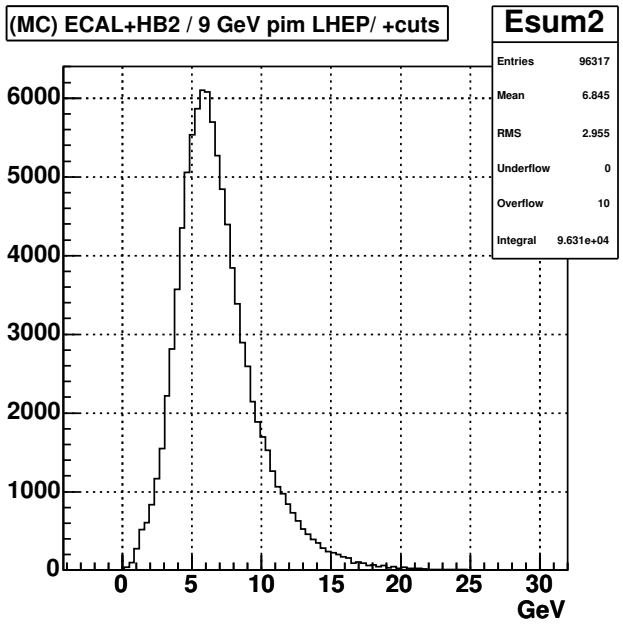


- electron contamination in pion beam
- interactions in beamline
- muons from pion decay

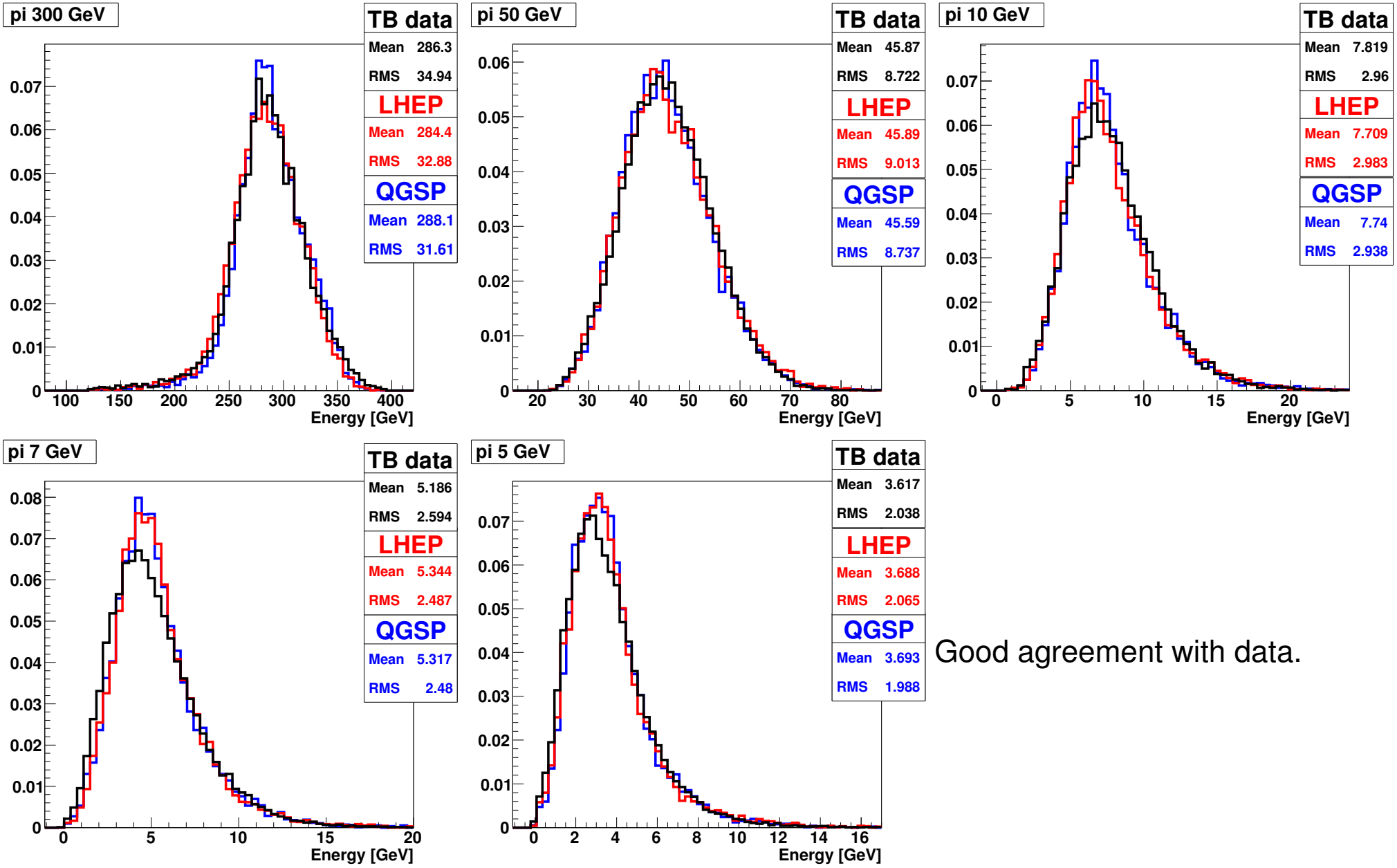








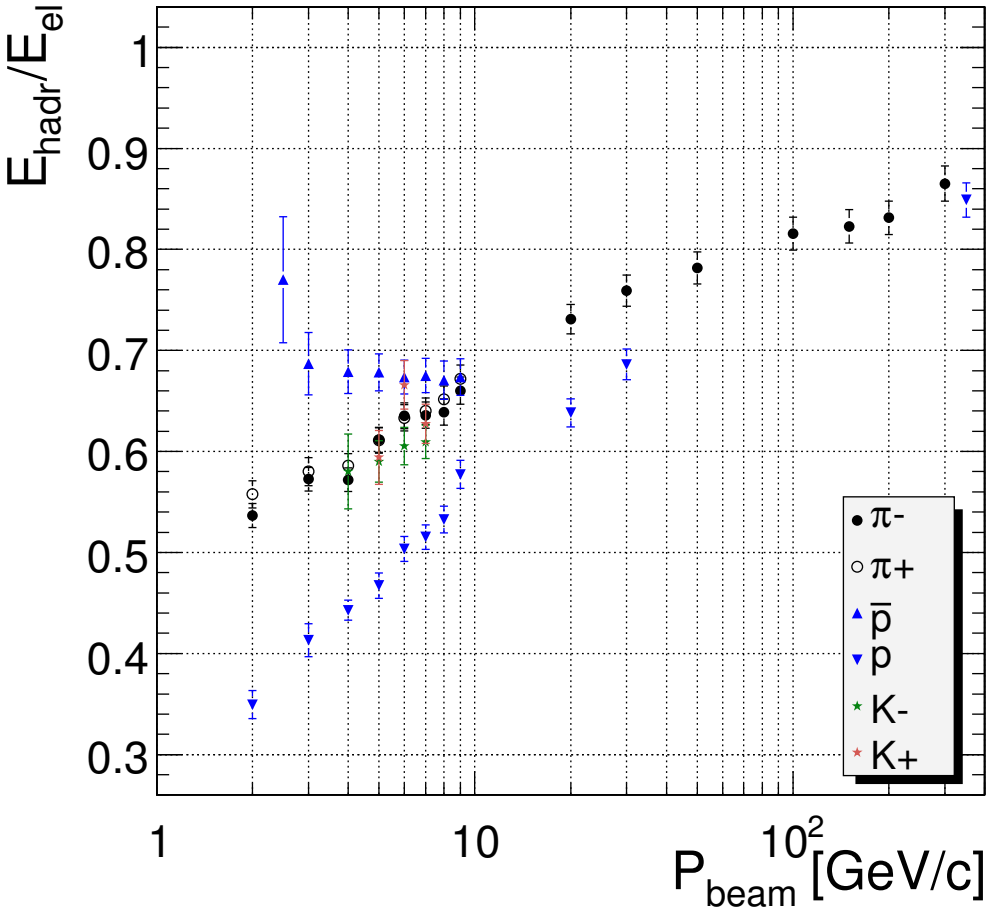
Calorimeter-based cuts are necessary to clean up the beam-interacted particles. These introduce systematic errors, but are the only way to enable comparison with the TB data.



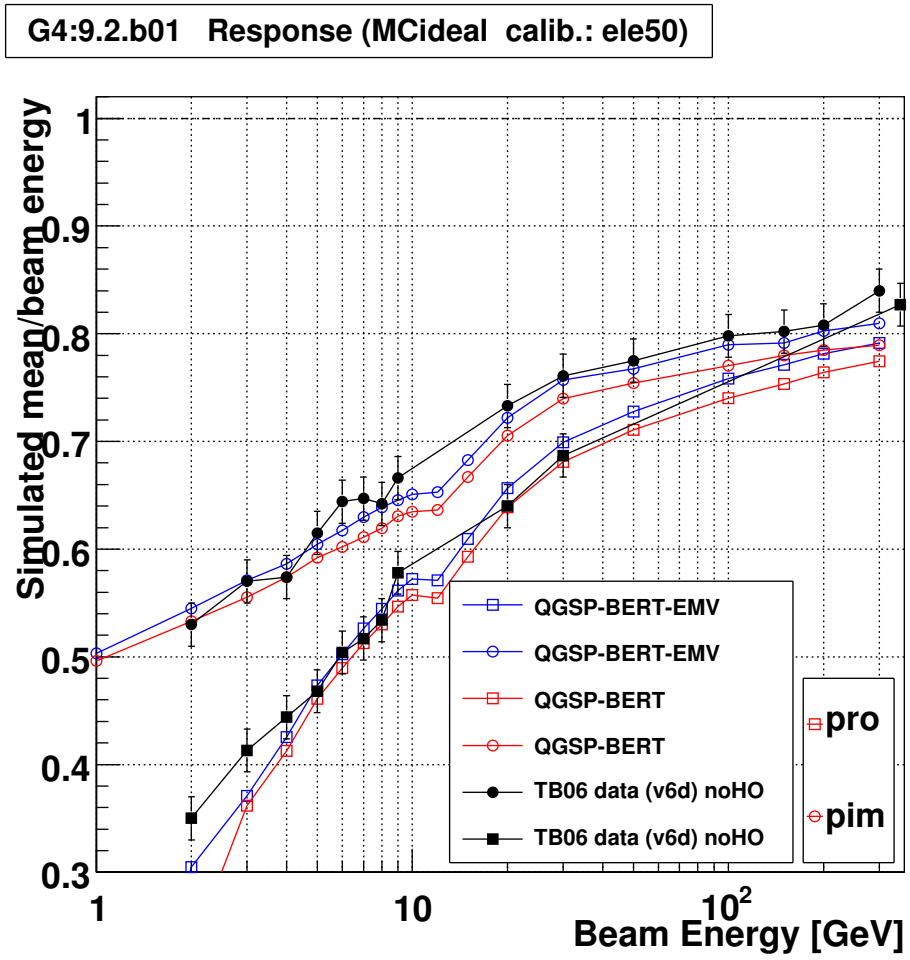
Good agreement with data.

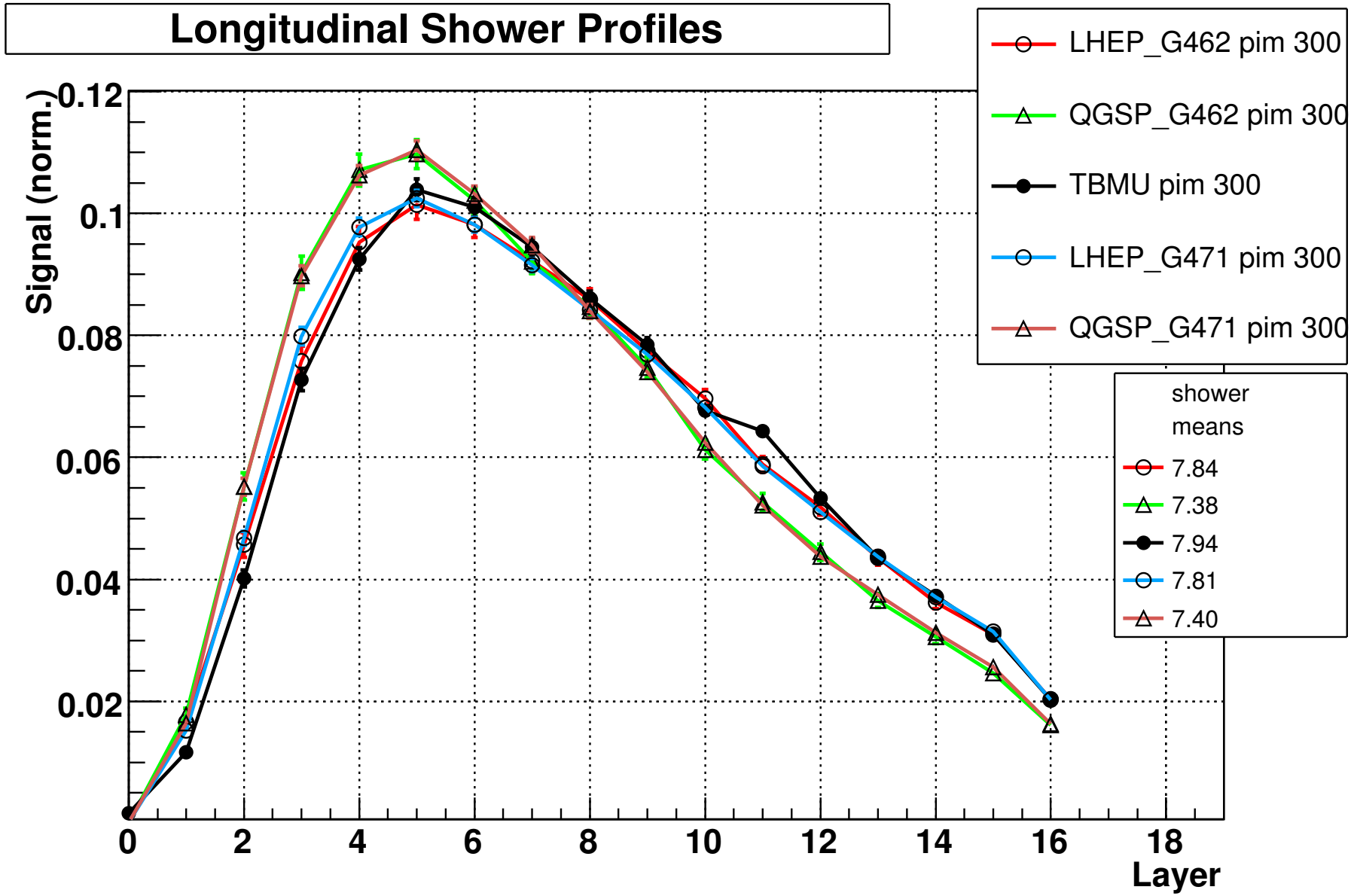
Comparison of Test-Beam data and Geant4 Linearity of Response

TestBeam Setup



Geant4 Simulation




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

Summary

- 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