

CMS validation Experience: Test-beam 2004 data vs Geant4

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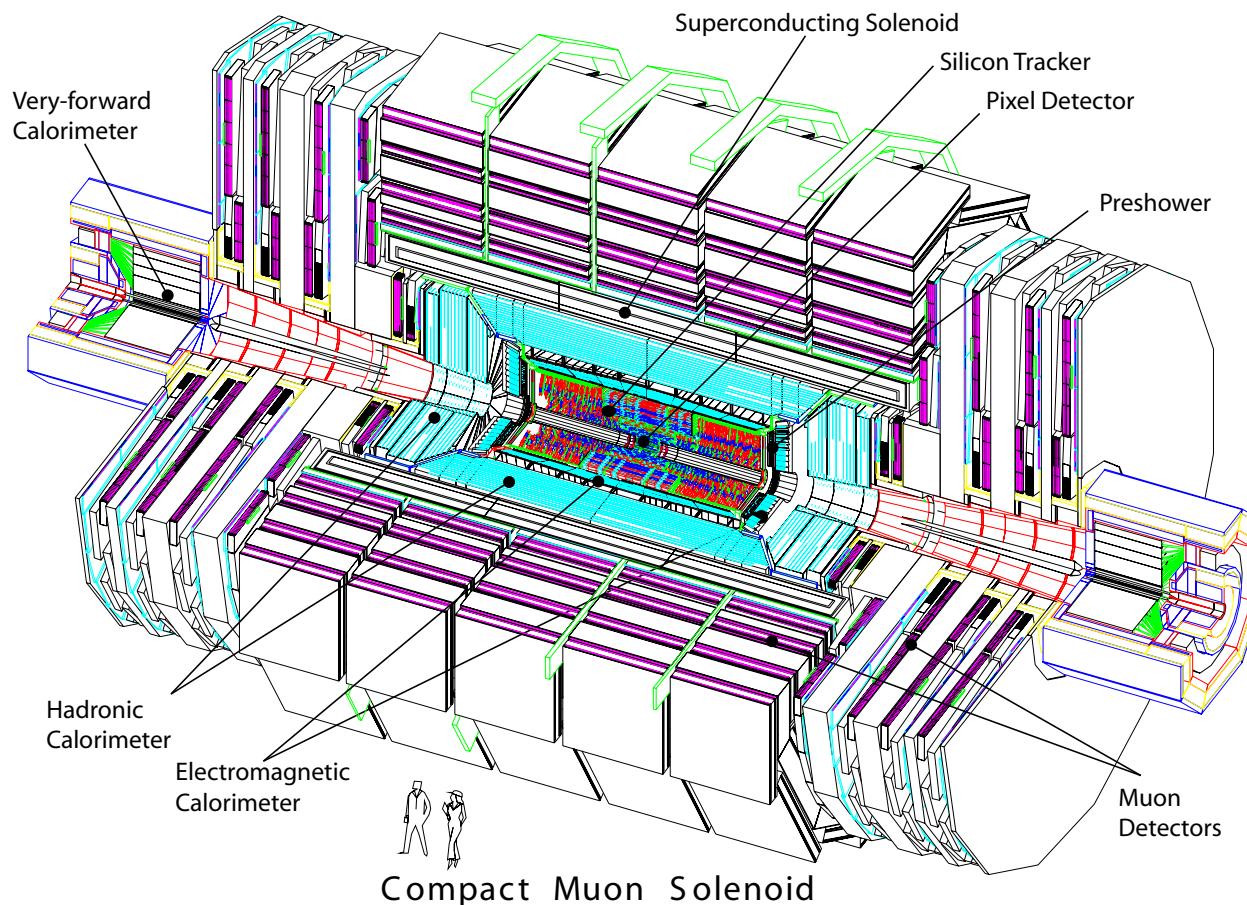
for

the CMS Collaboration

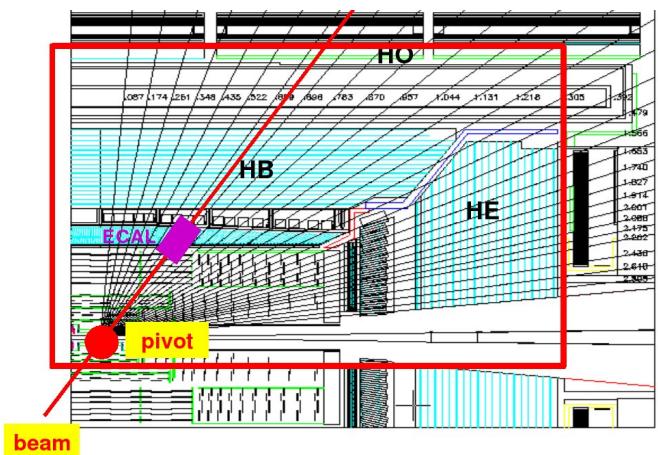
Hadronic Shower Simulation Workshop, September 6-8, 2006, Fermilab

Outline

- CMS detector and the TestBeam 2004 Setup
- Understanding TB04 data: Main difficulties
- TB04 Results and Comparison with MC simulation
- Simulation with various Geant4 versions
- Plans - CMS TestBeam 2006
- Conclusions



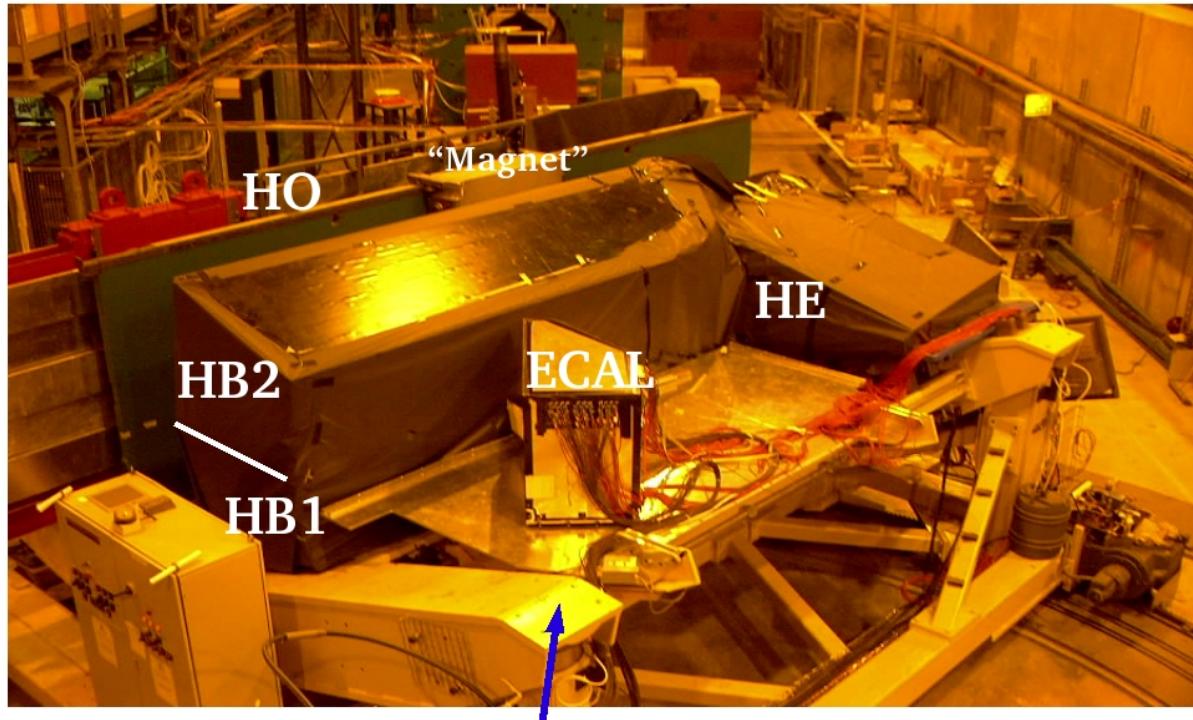
HCAL = Hadronic Calorimeter
ECAL = Electromagnetic Calorimeter
HB = HCAL Barrel
HE = HCAL EndCap
HO = HCAL Outer



Calorimetric systems present on the Testbeam 2004 table.

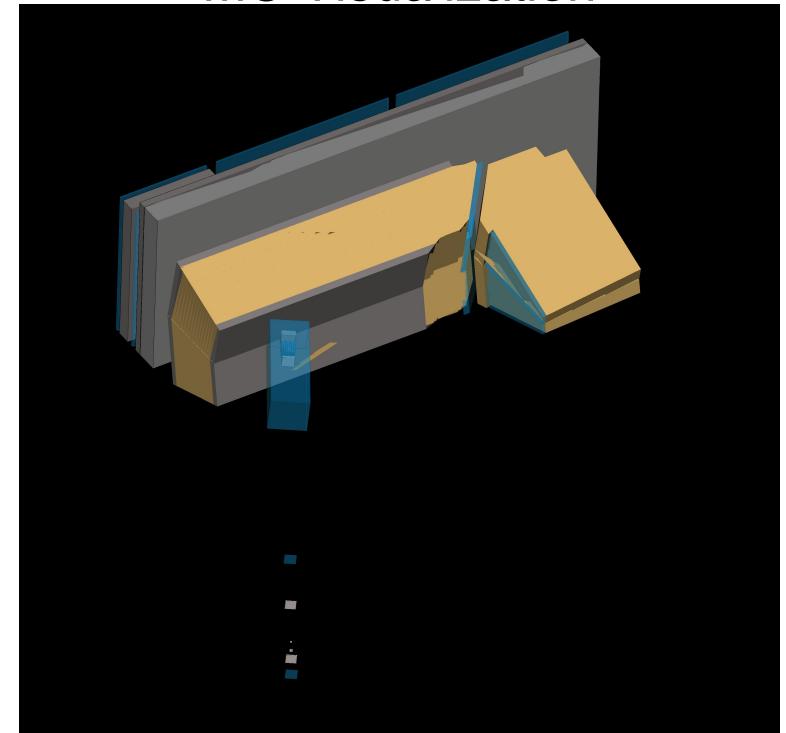
Pivot point corresponds to interaction point in CMS. ECAL is a matrix of 7x7 prototype crystals. HCAL Barrel modules are production wedges readout with real front-end electronics.

Photo of testbeam area

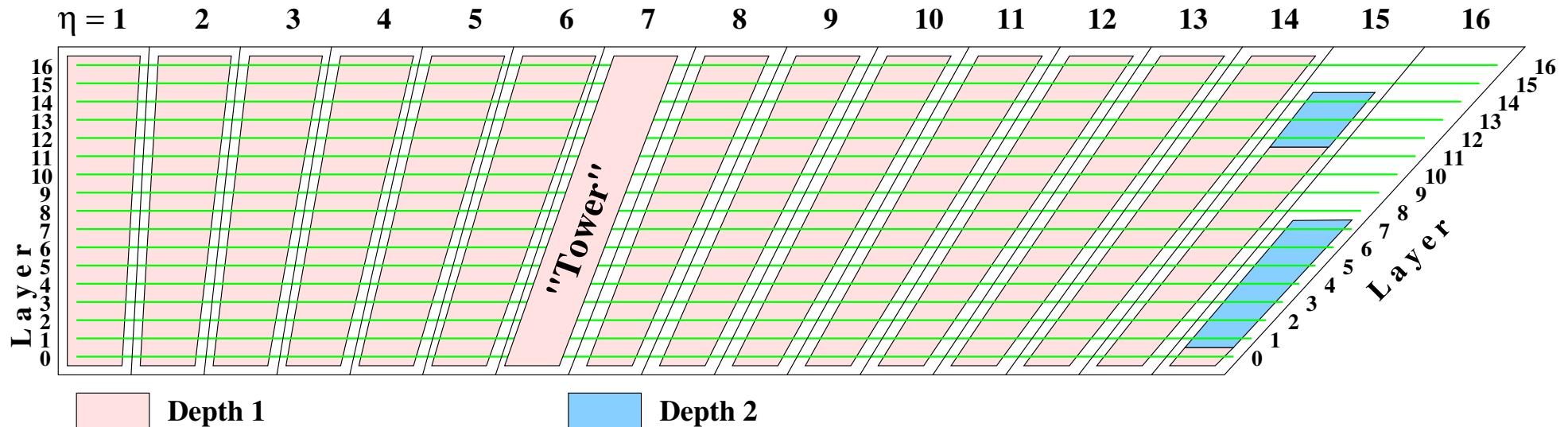
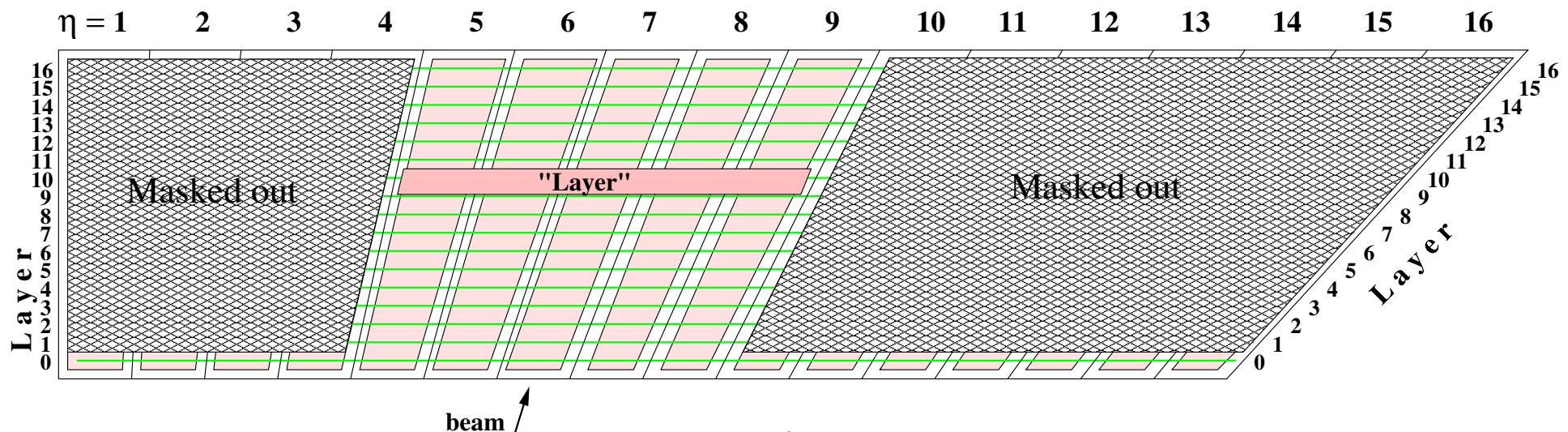


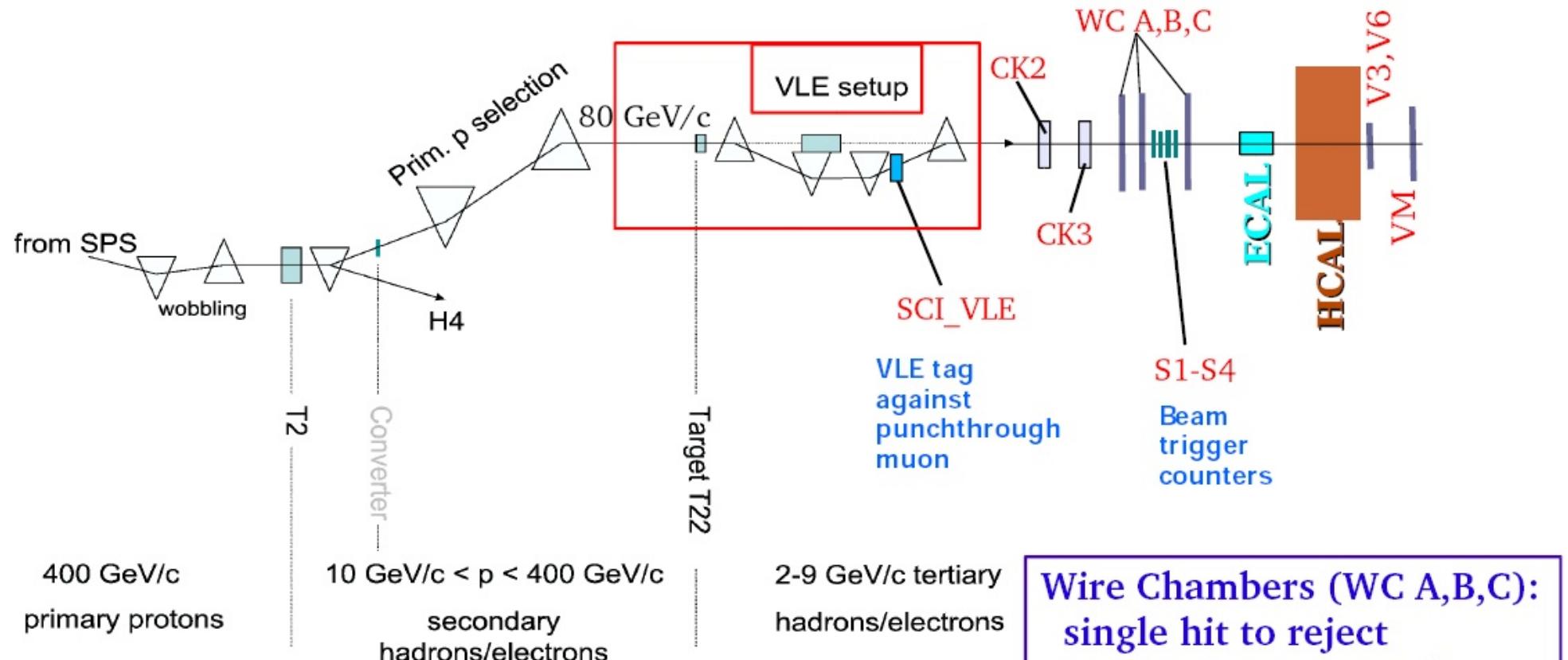
Beam from SPS.

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**



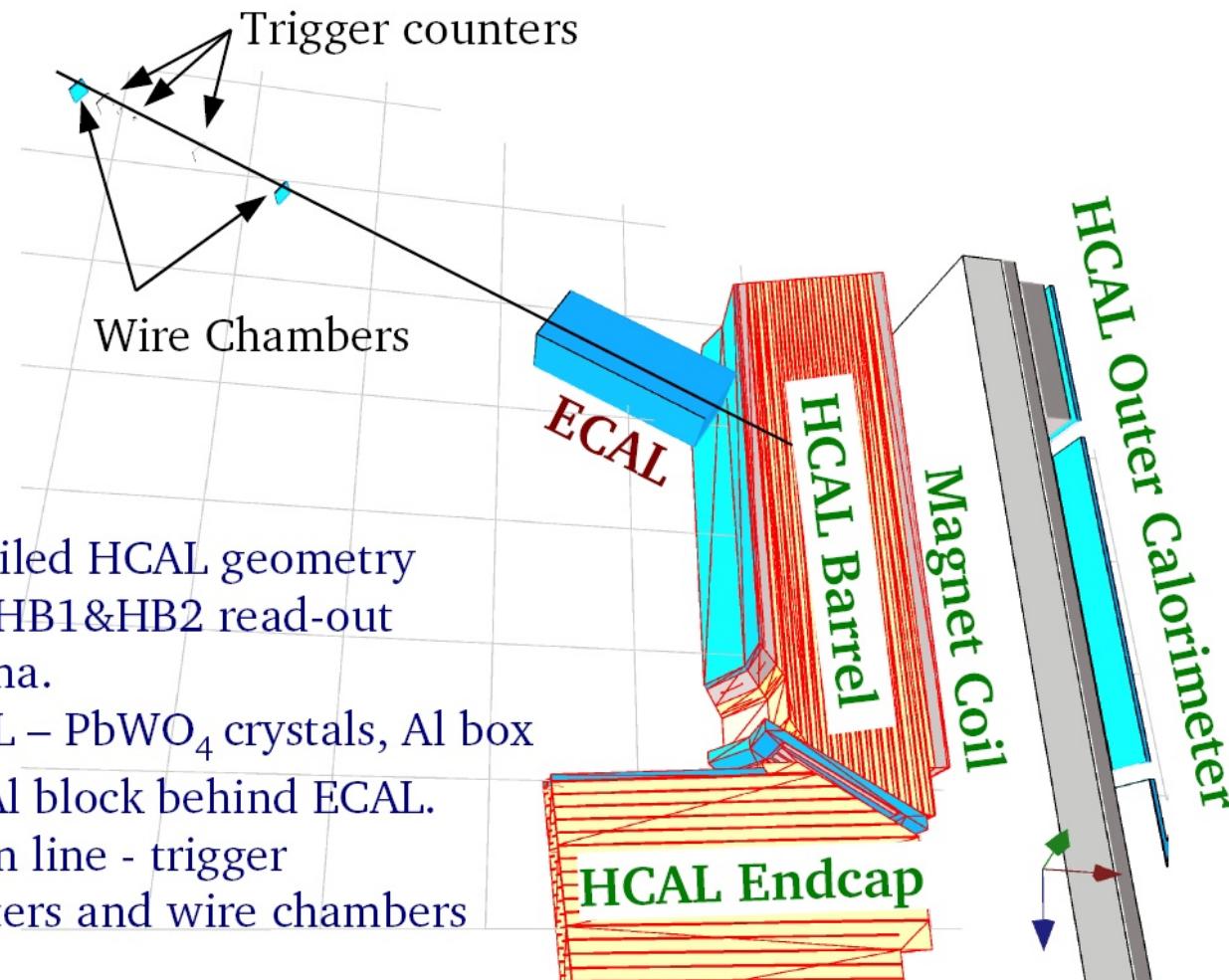
Available beam tunes:
pions 2-300 GeV
muons 80/150 GeV
electrons 9-100 GeV

P-ID:

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

All simulations in this study done with: G4.6.2_p02

and physics lists: LHEP-3.7,QGSP-2.8,QGSC-2.9,FTFP-2.8 (Pack.-2.5)

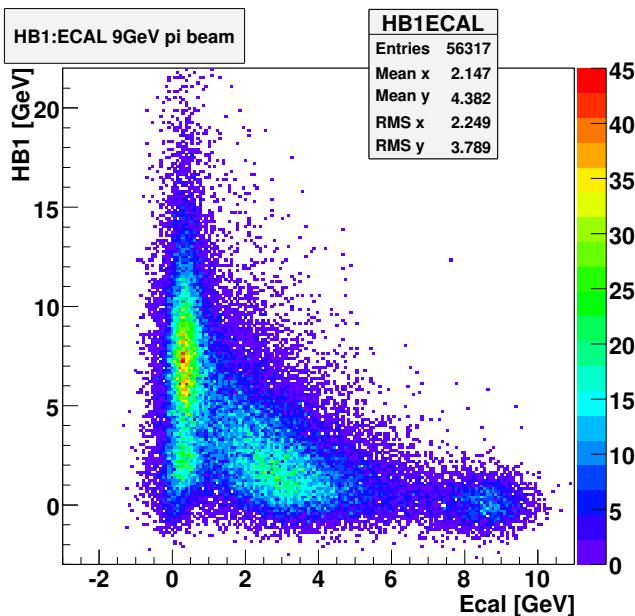


Also: Comparison with G4.7.1 at the end of this talk.

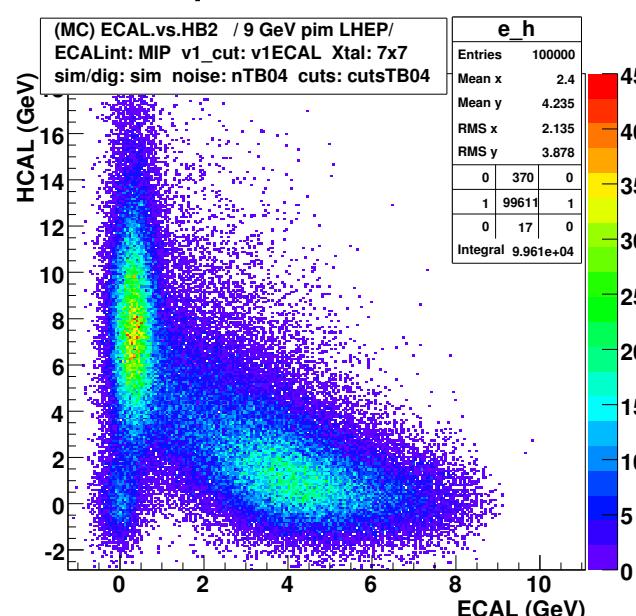
Ready to test with G4.8.1

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

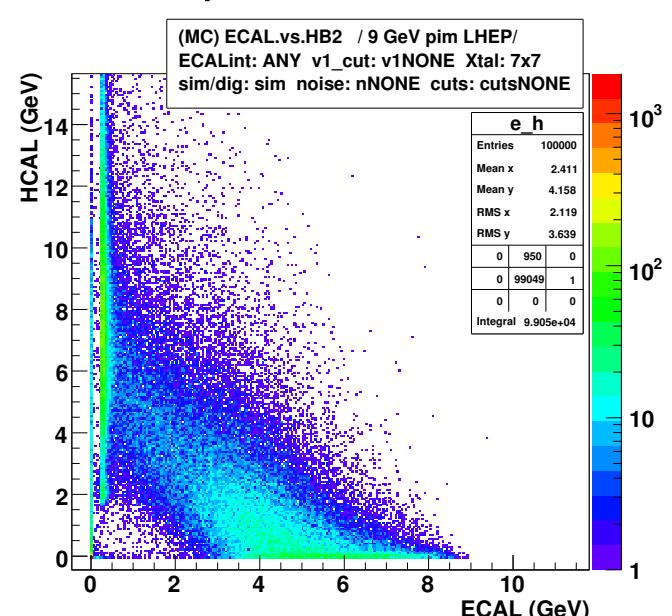
TestBeam data



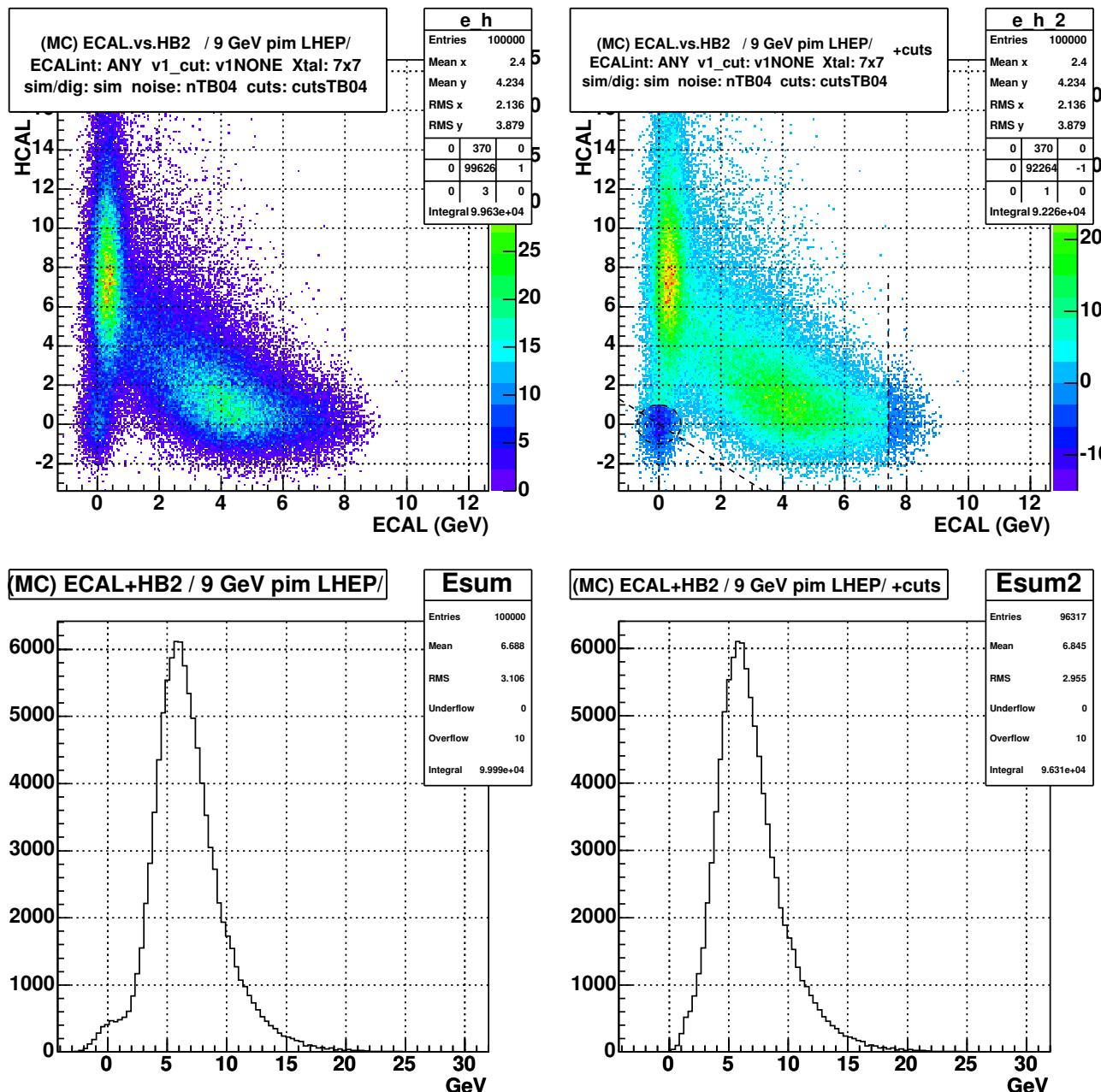
G4.6.2_p2 MC with noise



G4.6.2_p2 MC w/o noise



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



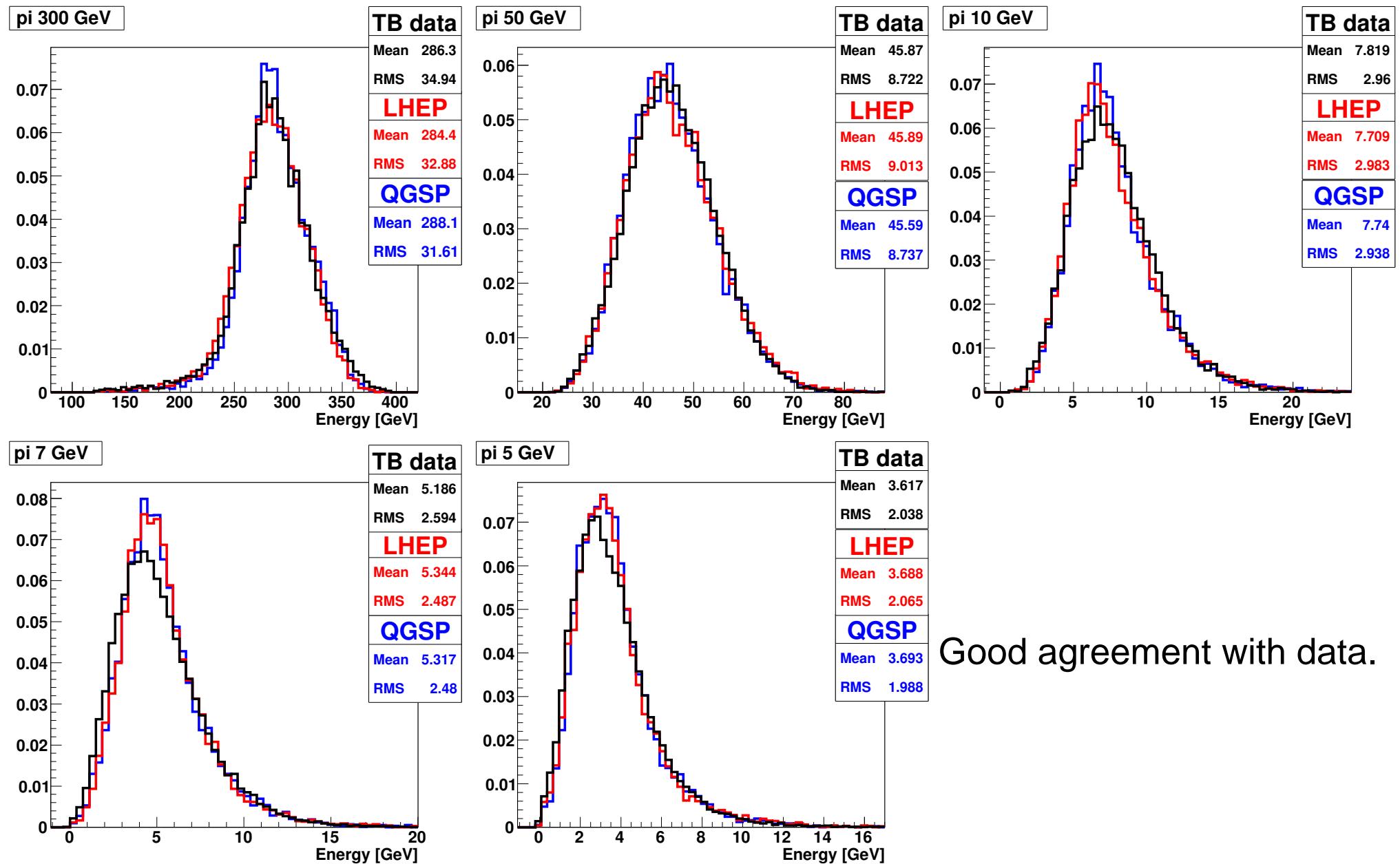
Caloimeter-based cuts are necessary to clean up the beam-interacted particles. These introduce systematic errors, but are the only way to enable comparison with the TB data.

Data

- Very Low Energies (VLE)
 - 2,3,5,7,9 GeV mainly π^\pm beam
 - with/without ECAL
 - HB1/HB2
 - Full particle identification
- Medium Energies (MED)
 - 10,15,20 GeV e^\pm, π^\pm beam
 - with/without ECAL
 - HB1/HB2
 - Partial particle identification
- High Energies (HIGH)
 - 30,50,100,150,300 GeV e^\pm, π^\pm beam
 - with/without ECAL
 - HB1/HB2

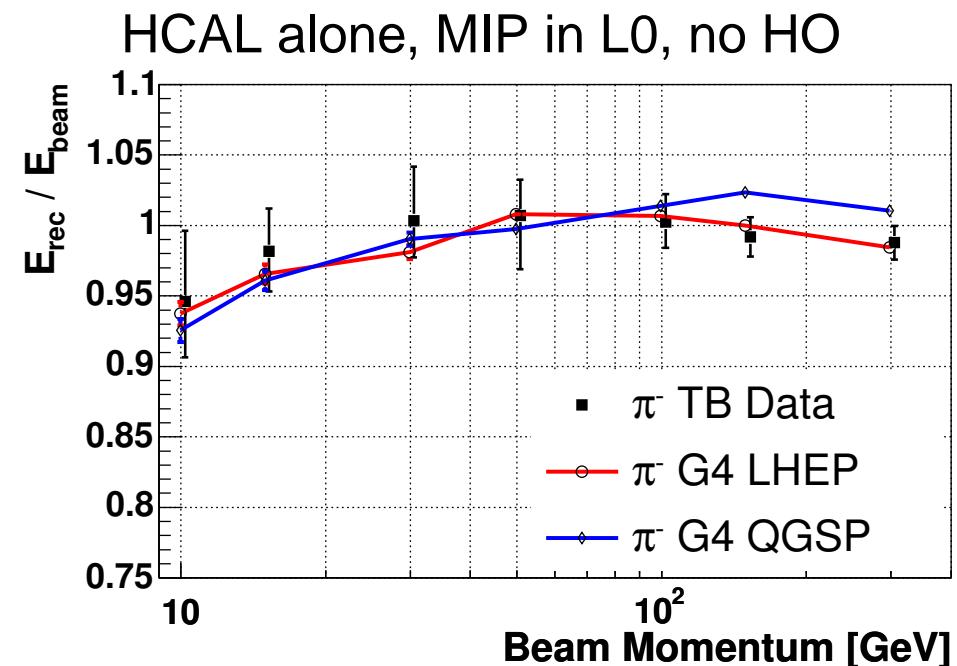
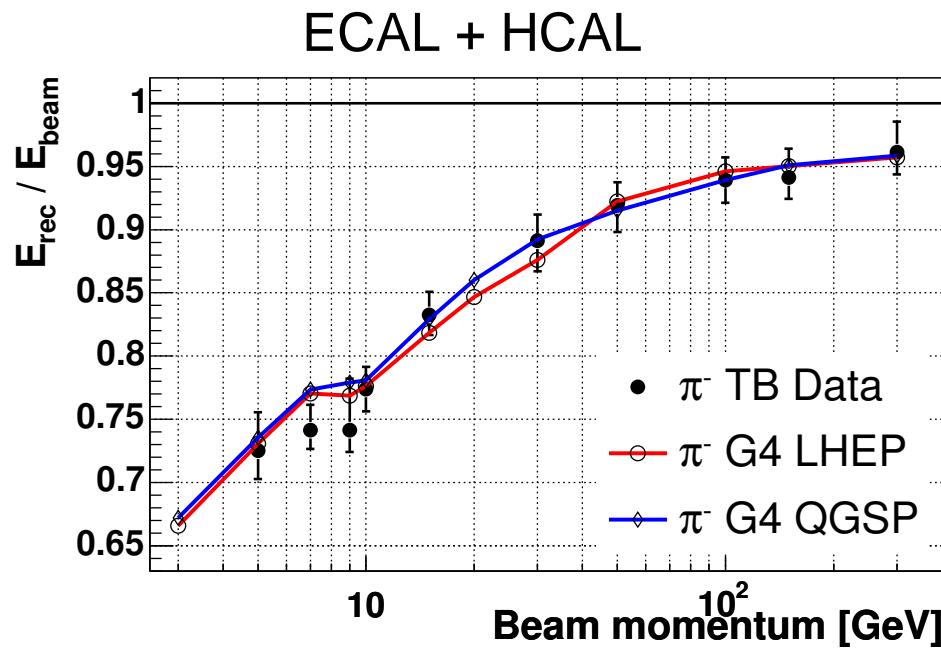
Simulation

- Very Low Energies (VLE)
 - 2,3,5,7,9 GeV e^\pm, π^\pm, p, K^\pm beam
 - with/without ECAL
 - HB2
- Medium Energies (MED)
 - 10,15,20 GeV e^\pm, π^\pm, p, K^\pm beam
 - with/without ECAL
 - HB2
- High Energies (HIGH)
 - 30,50,100,150,300 GeV e^\pm, π^\pm, p, K^\pm beam
 - with/without ECAL
 - HB2



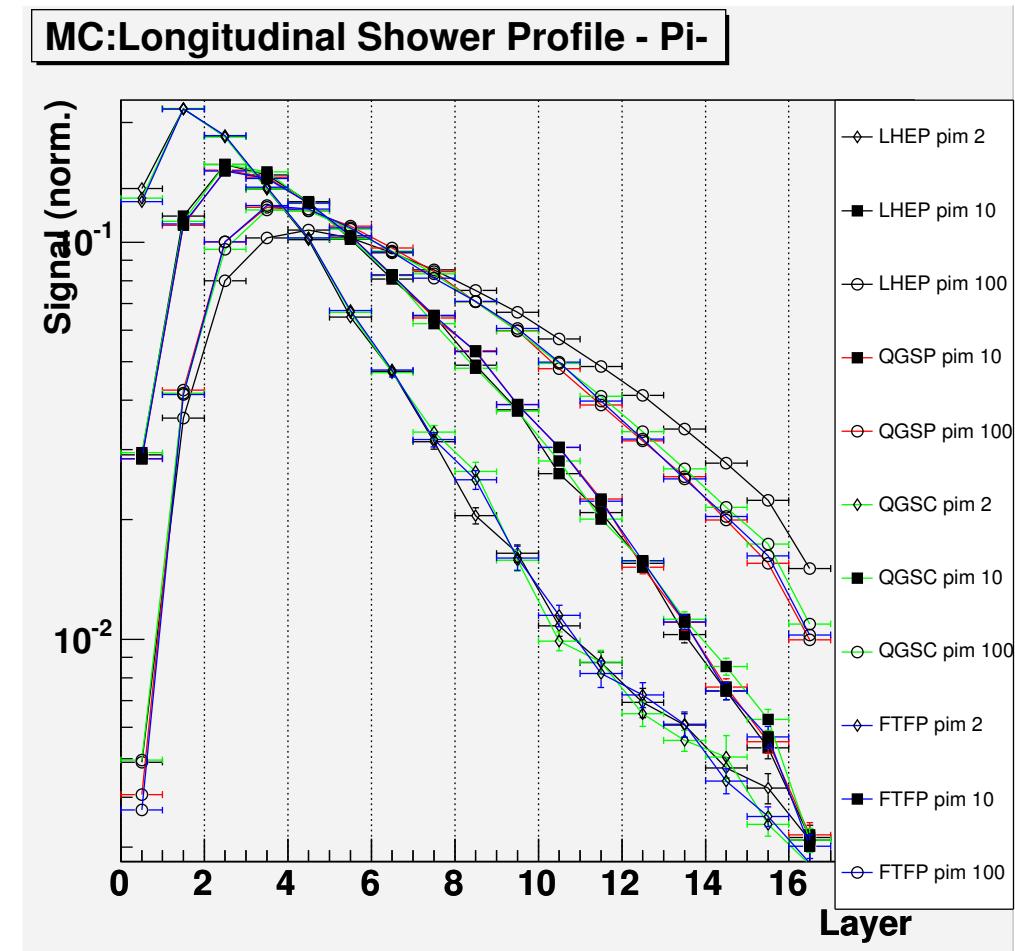
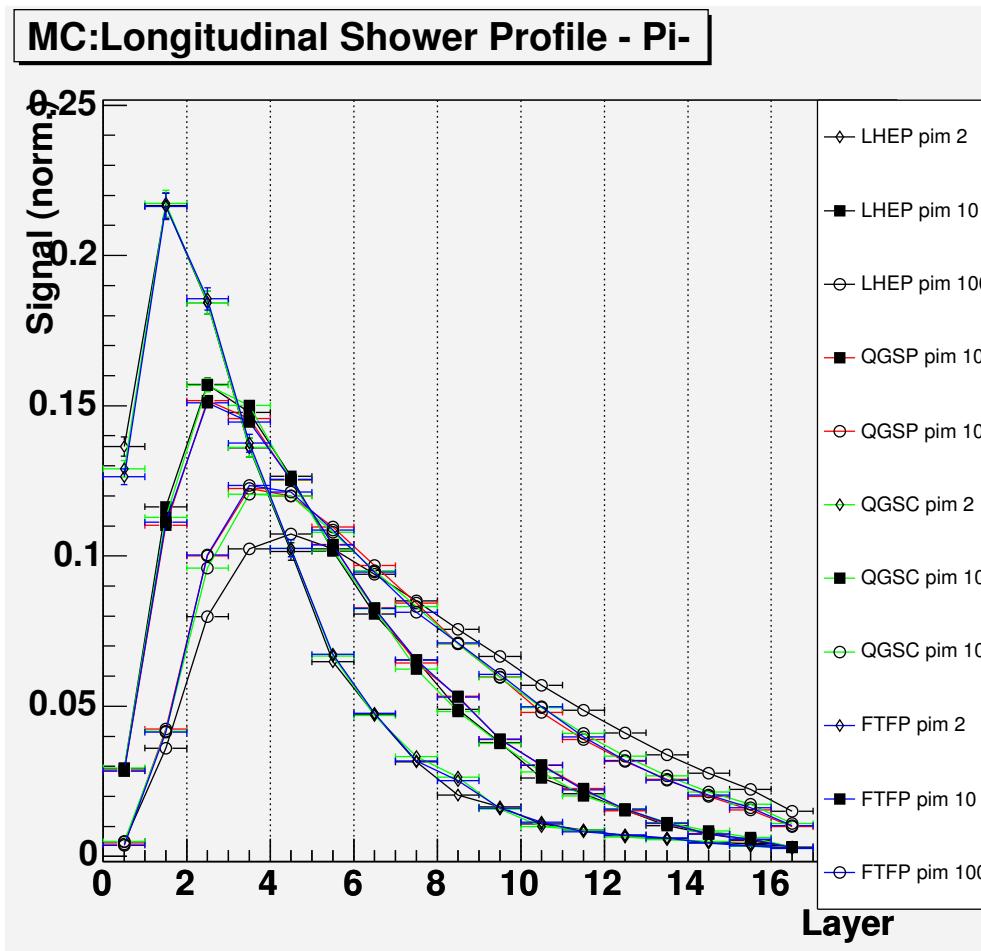
Good agreement with data.

Comparison of TB04 data and G4.6.2 p2: Linearity of Response

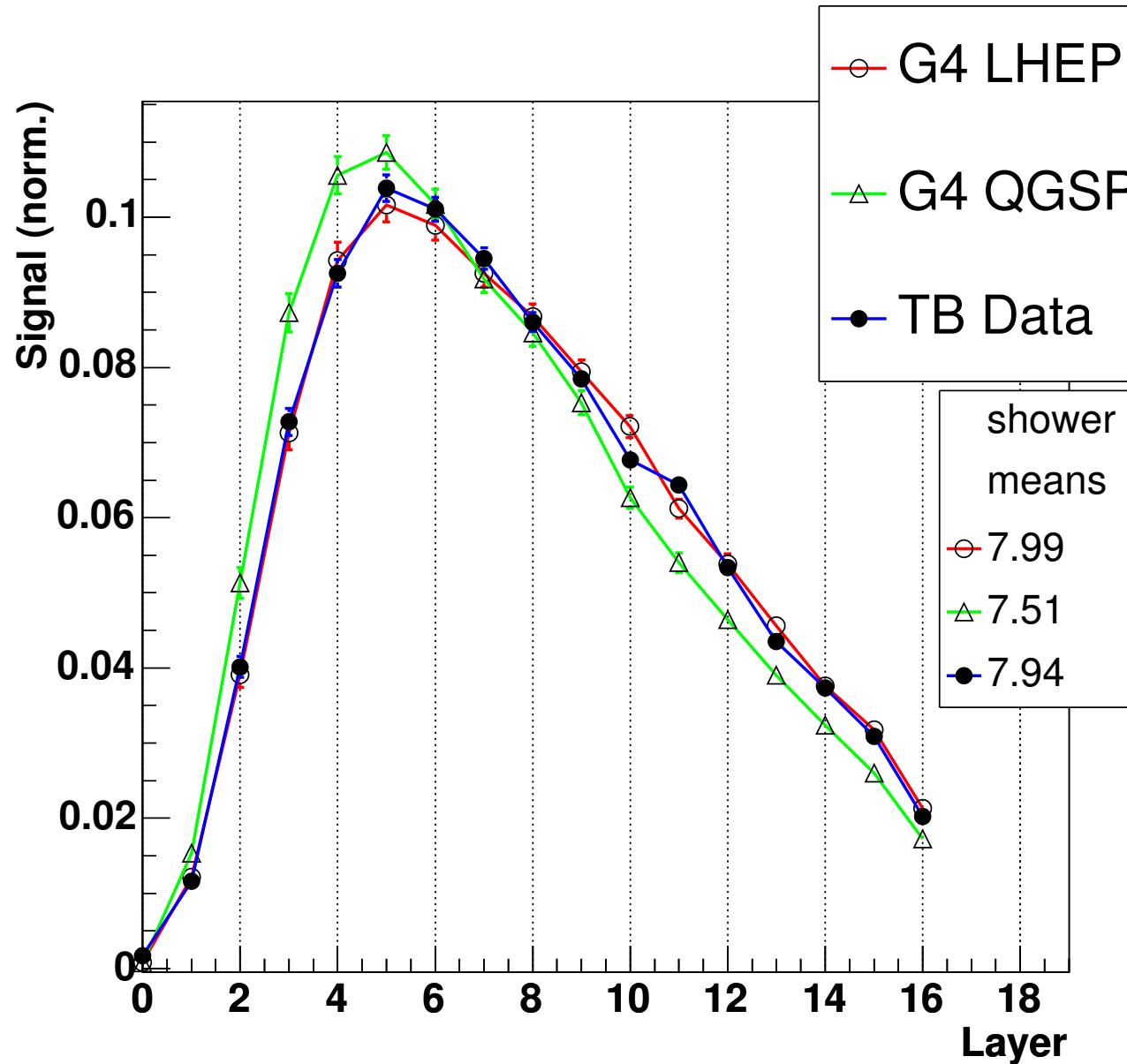


The combined system is simulated correctly by both physics lists. The slight non-linearity around 7GeV is still to be understood.

QGSP predicts more signal (=less leakage) at highest energies, most likely due to the shorter showers.
(see next)



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.

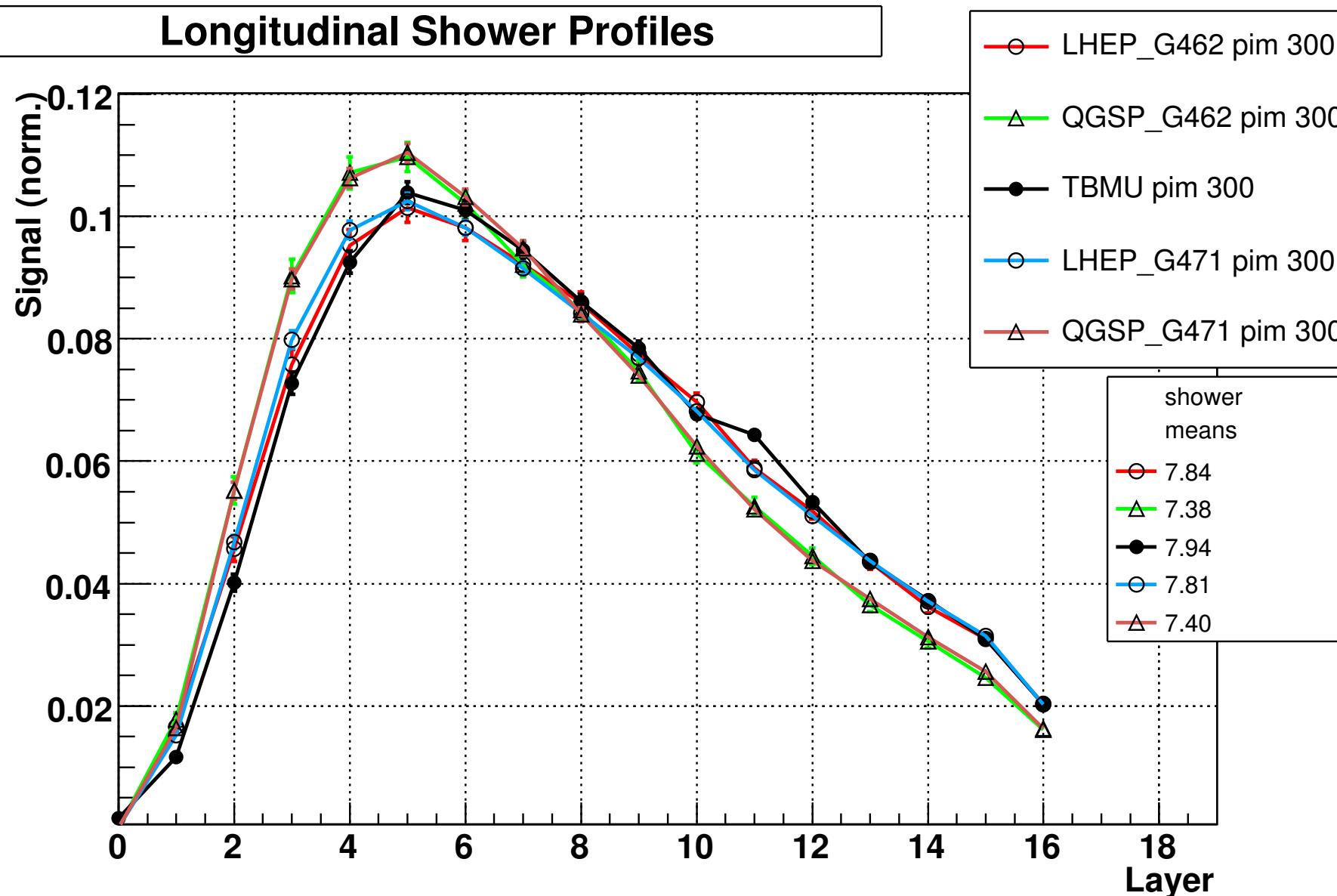


300 GeV pions, leaving MIP in ECAL and L0.

G4.6.2.p2 simulation

Data seems to agree better with LHEP list.

QGSP predicts shorter showers, better contained in the calorimeter.

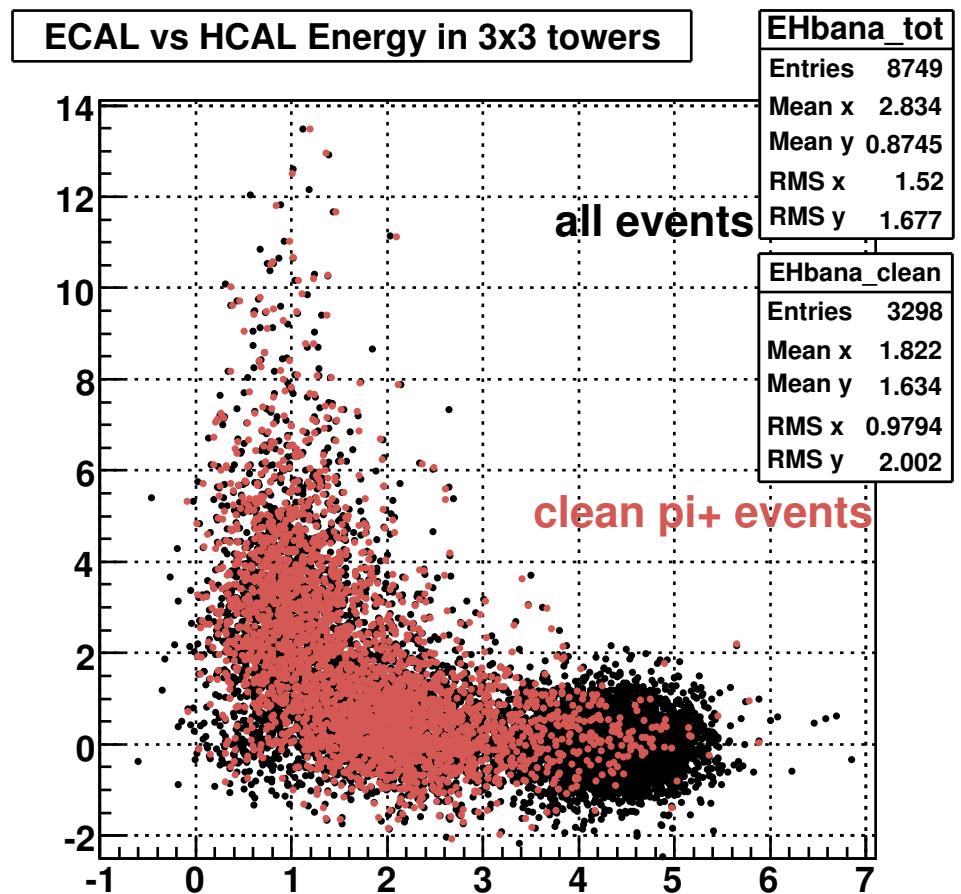
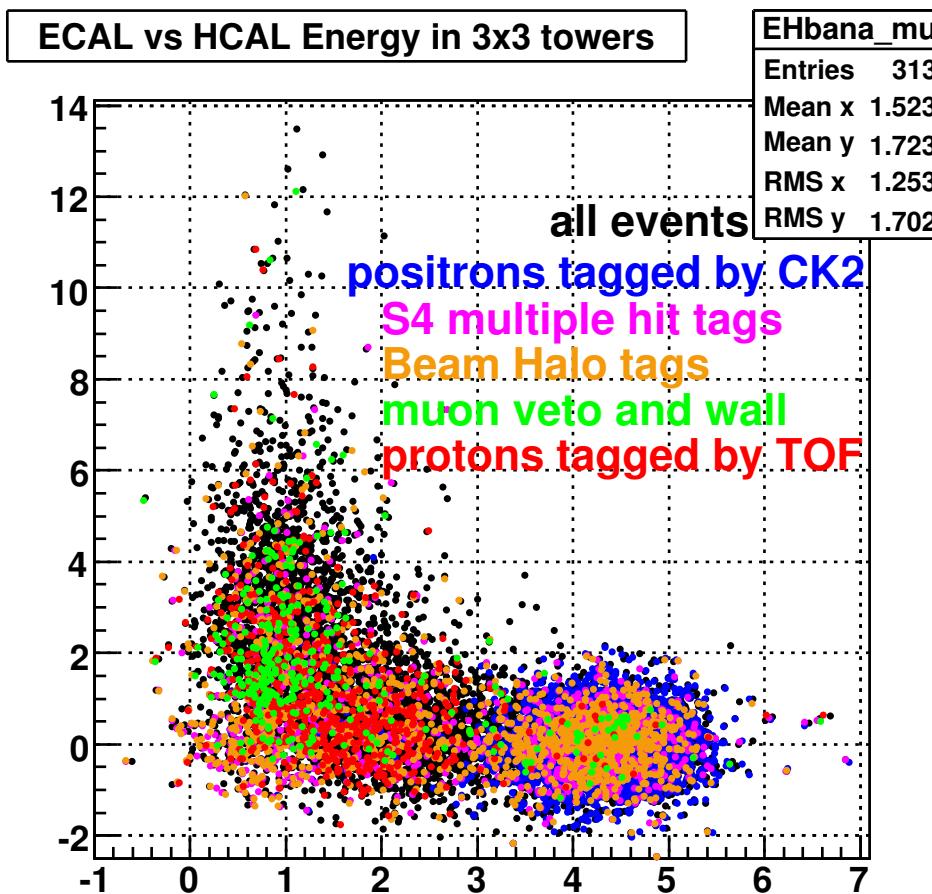


Combined ECAL+HCAL Test Beam 2006 is already under way.

Improvements over TB2004 include:

- real production ECAL module
- better beam particle ID
 - Time-Of-Flight system for particle ID at low beam momenta
 - (functioning) Cherenkov counters
 - Muon veto wall
- Beam cleaning (from beamline interactions) hopefully we'll get much cleaner beam, especially at low momenta, therefore no need for calorimeter-based cuts!
- use the Test-beam simulation for validation of newer releases of G4 and OSCAR producer inside CMSSW.

Example of beam clean-up possible in TB2006:(preliminary)
Run#29665: 5GeV pi+



- CMS ECAL+HCAL response measured in TB2004 agrees quite well with the predictions of Geant4.
- Parametrized physics list (LHEP) shows better agreement with data.
- Model-based QGSP list predicts shorter showers than we measured.
- Improvement of systematic uncertainties at low energies in TestBeam 2006 will allow for better comparison with MonteCarlo simulation.