



CMS concern in energy measurements and shower shapes of hadrons in calorimeter

S. Kunori, S. Piperov, S. Sharma, T. Yetkin, SB

Outline

- Introduction
- Energy Measurements
- Transverse Shower Profile
- Longitudinal Shower Profile
- Summary

September 14, 2007
G4 Workshop, Hebden House

Sunanda Banerjee
Fermilab



Hadronic Models in GEANT4

□ GEANT4 Versions Used:

- ❖ 4.7.1_p02
- ❖ 4.8.1_p02 (released 10-November-2006)
- ❖ 4.8.2_p02 (released 23-February-2007)
- ❖ 4.8.3_p01 (released 17-August-2007)
- ❖ 4.9.0_p01 (released 28-August-2007)

□ Physics Models used:

❖ LHEP

Collection of low and high energy parametrized models (descendant of GHEISHA)

❖ QGSP

Mostly theory based model: quark gluon string model

❖ QGSP_BERT

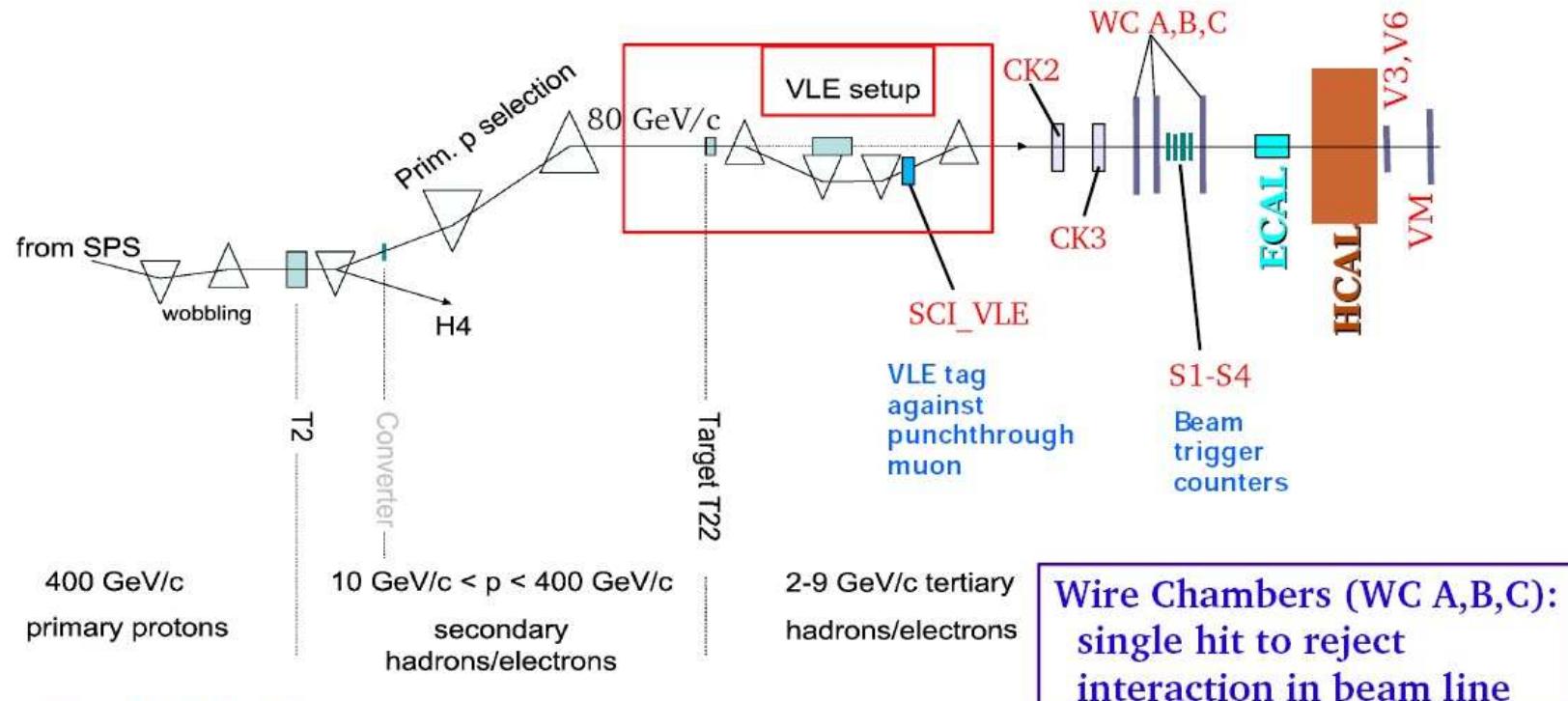
QGSP + Bertini Intra-nuclear Cascade Model

❖ FTFP

Similar to QGSP, but uses diffractive string excitation



CMS H2 Beam Line



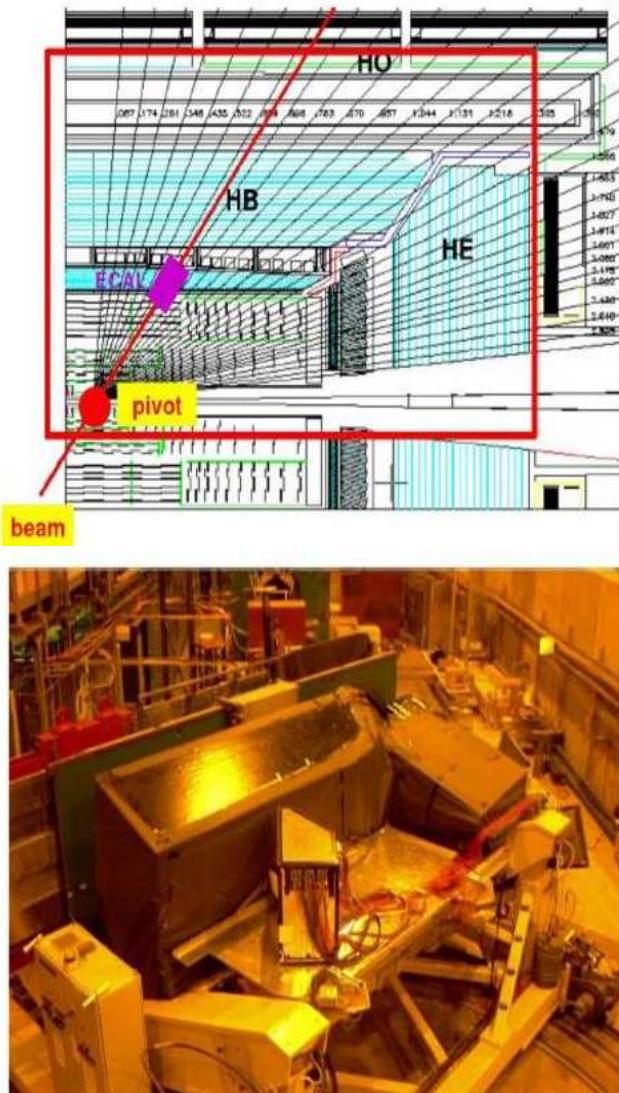
Available beam tunes:
pions 2-300 GeV
muons 80/150 GeV
electrons 9-100 GeV

P-ID:

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

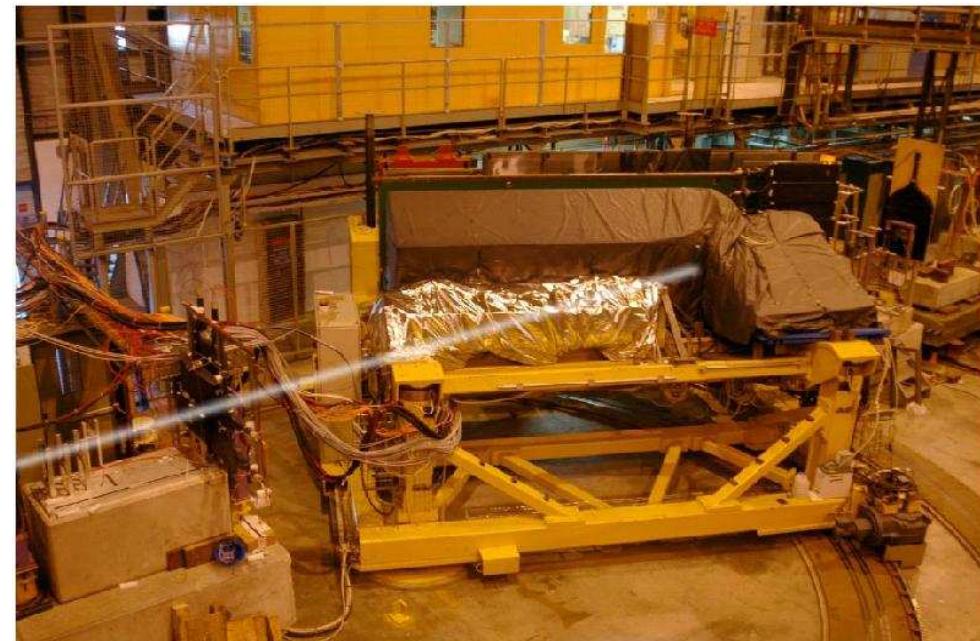


Detector Setup in H2



ECAL: PbWO₄ Crystals
14×14 cm² 2004
Real Super Module 2006

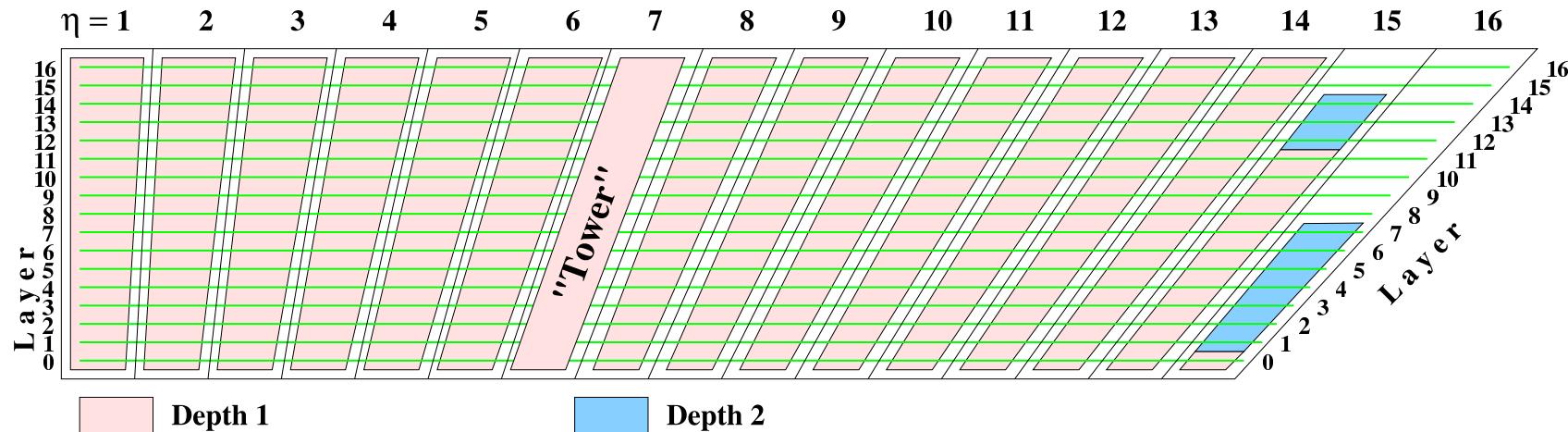
HCAL: Sampling Calorimeter
Brass 50 mm
Scintillator 3.7 mm



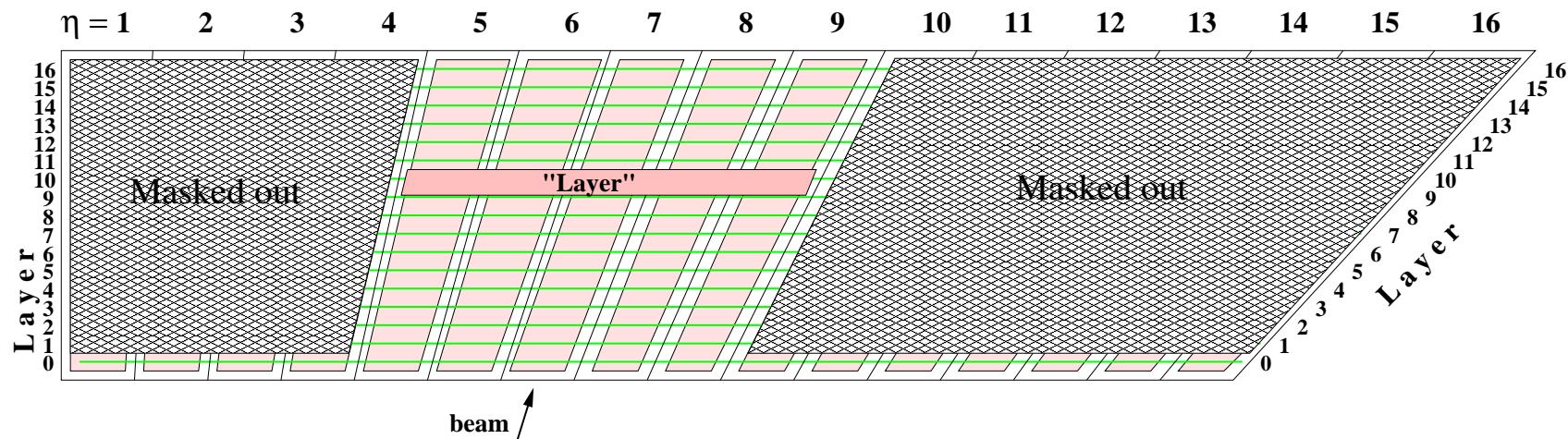


HCal Readout Scheme

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



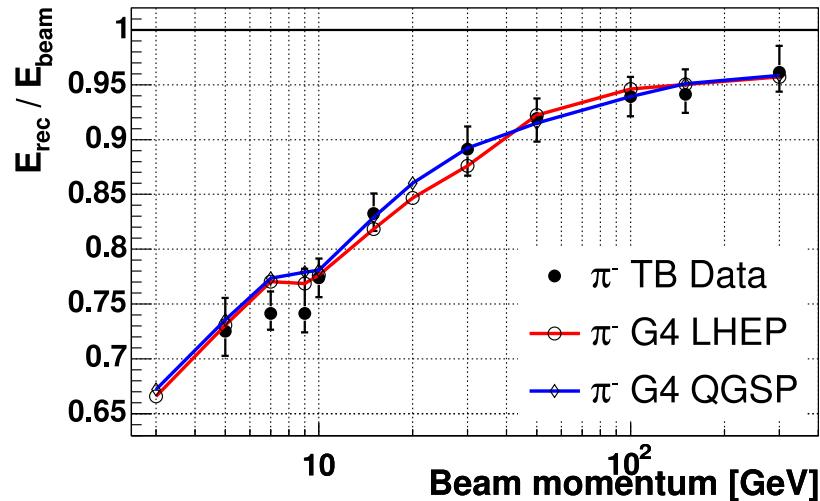
HB2: Layer-wise readout – for longitudinal shower profile studies





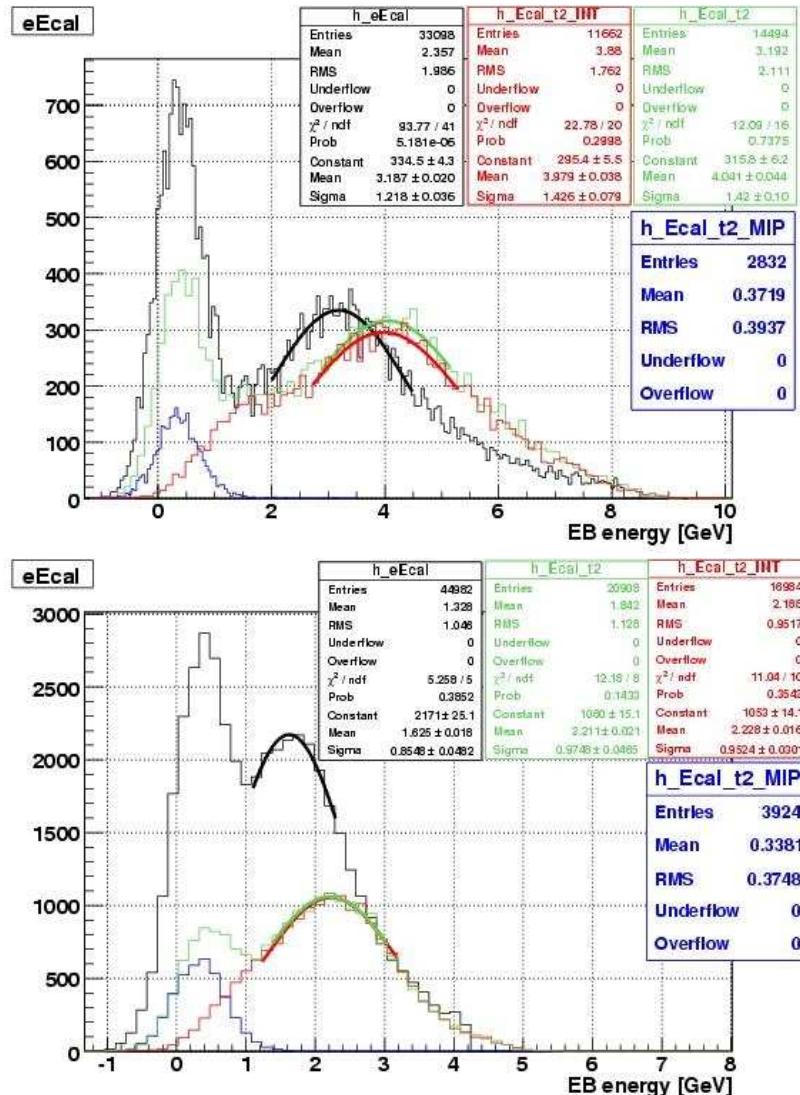
Energy Measurement (I)

Calibrate both ECAL and HCAL with electrons:



Both LHEP and QGSP are in good agreement with data.

But ...

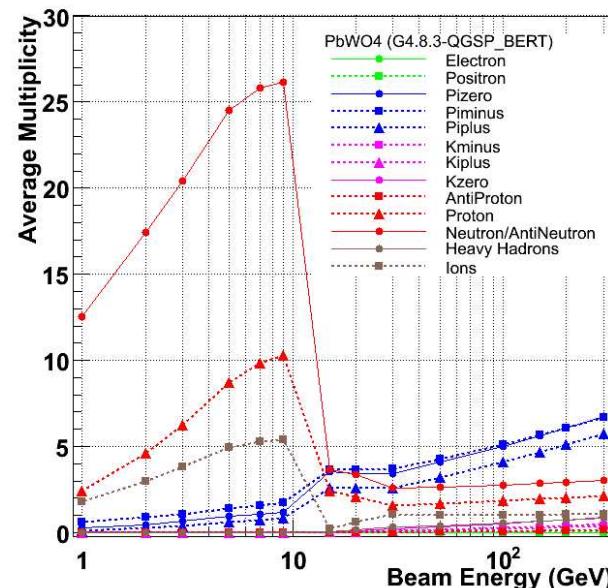
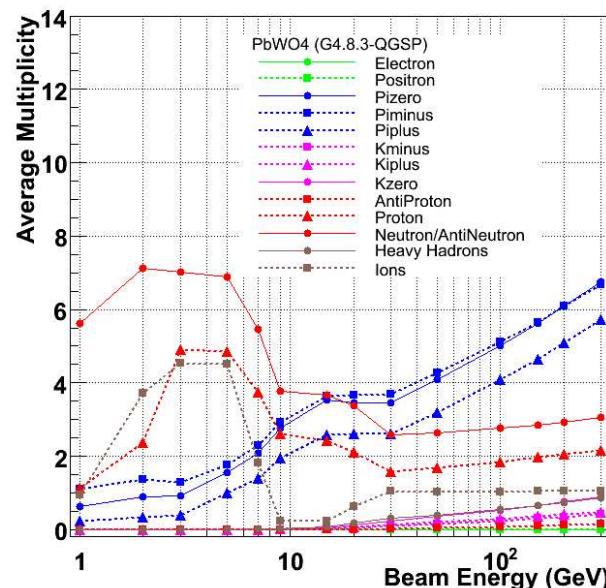




Energy Measurement (II)

G4 Predicts too much energy deposit in ECAL for low energy π 's
Birk's law does not help

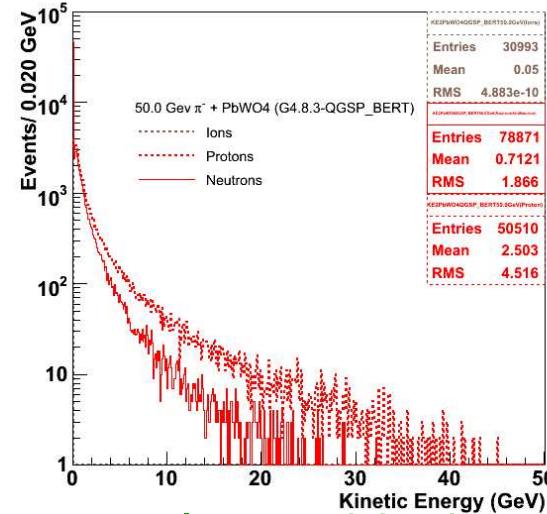
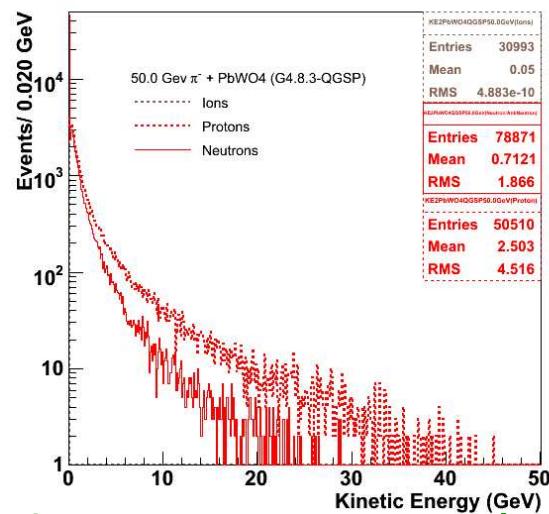
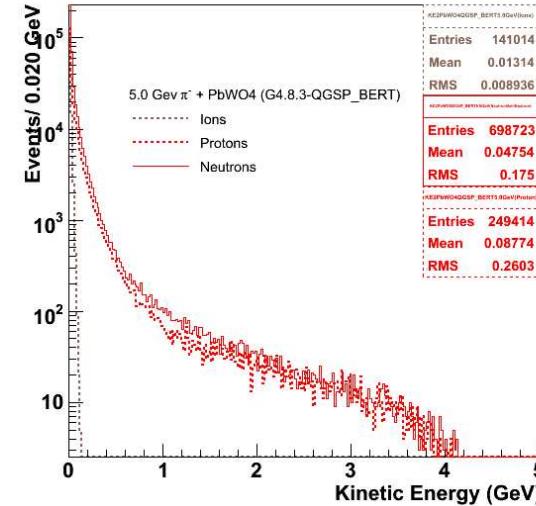
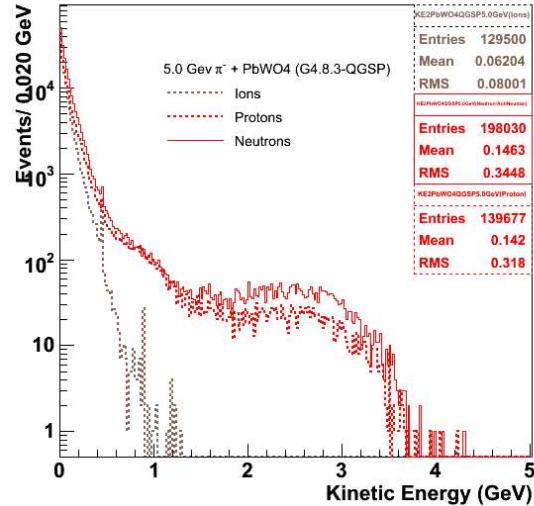
For a 5 GeV π^- : 54% of energy deposit due to e^+/e^- ;
13% due to mesons;
17% due to baryons;
14% due to ions



Too many baryons/hadrons at low energies



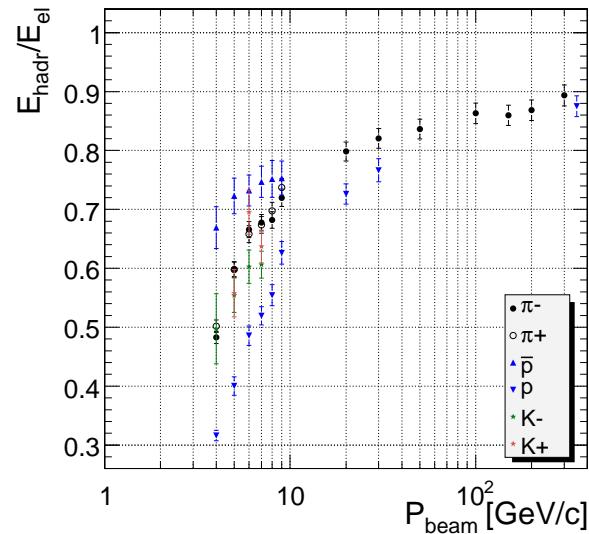
Energy Measurement (III)



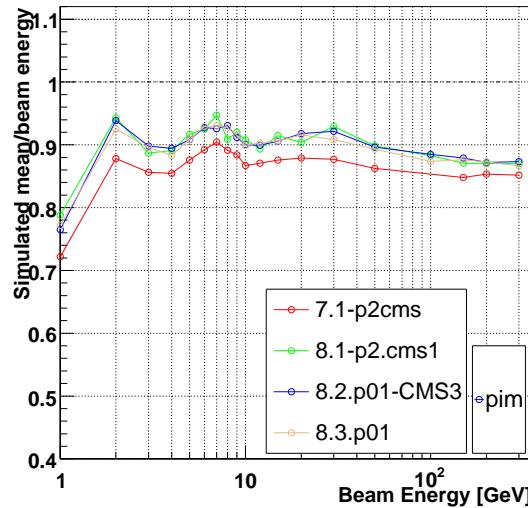
Also the energy spectrum looks very different at low and high energies



Energy Measurement (IV)

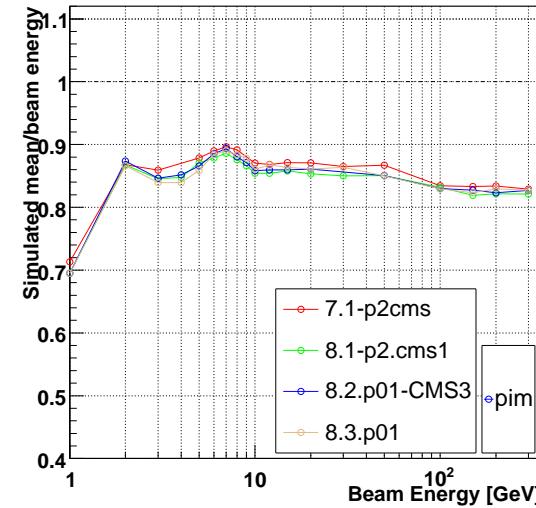


QGSP Response (MCidealMIP calib.: ele50)

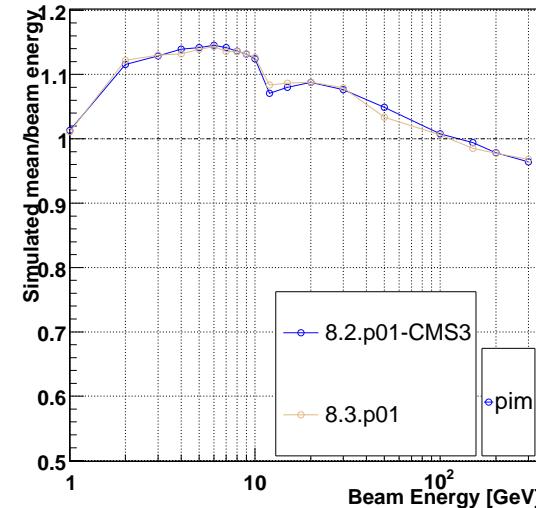


Energy spectrum too hard at low energies in sampling calorimeters as well

LHEP Response (MCidealMIP calib.: ele50)

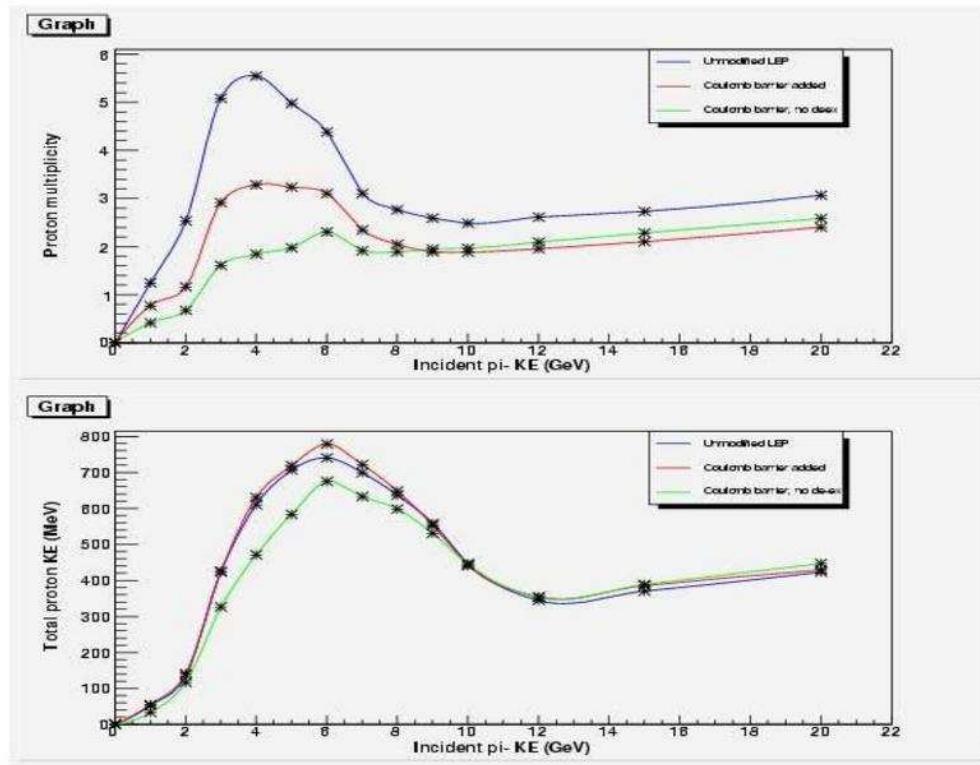


QGSP-BERT Response (MCidealMIP calib.: ele50)





Energy Measurement (V)



Dennis Wright

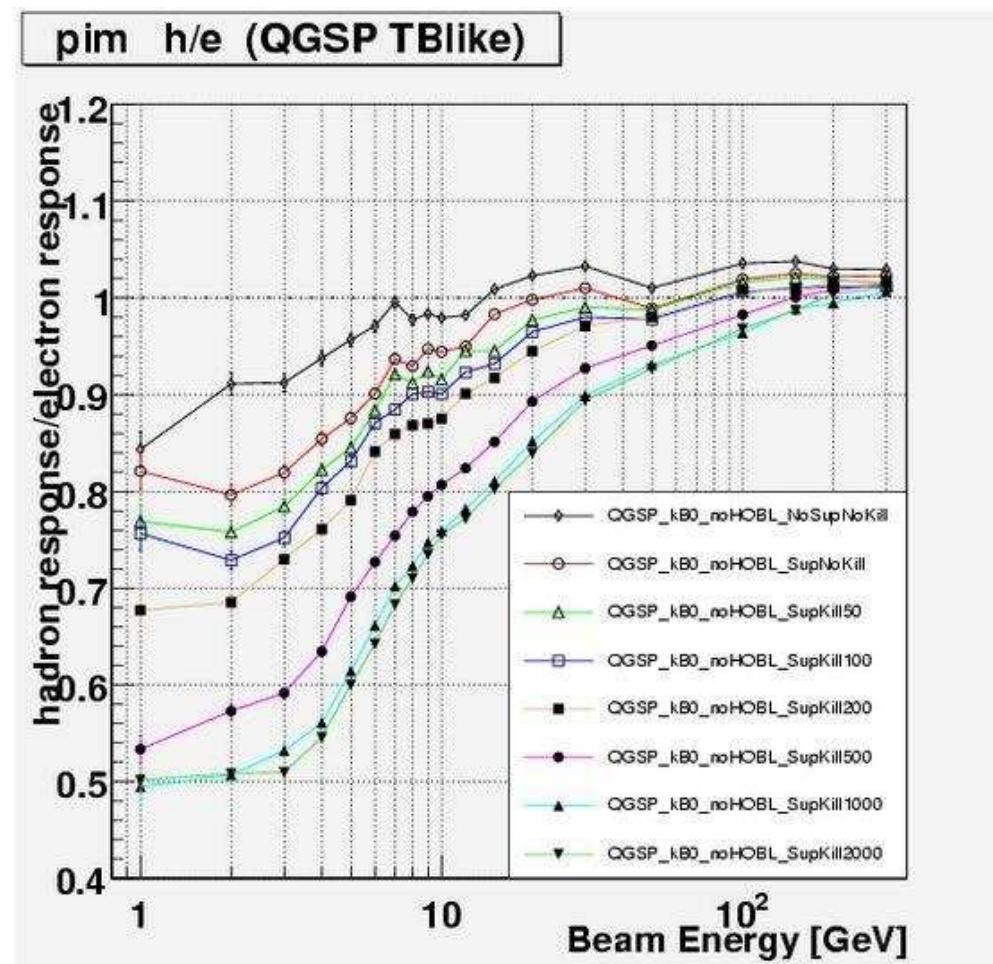
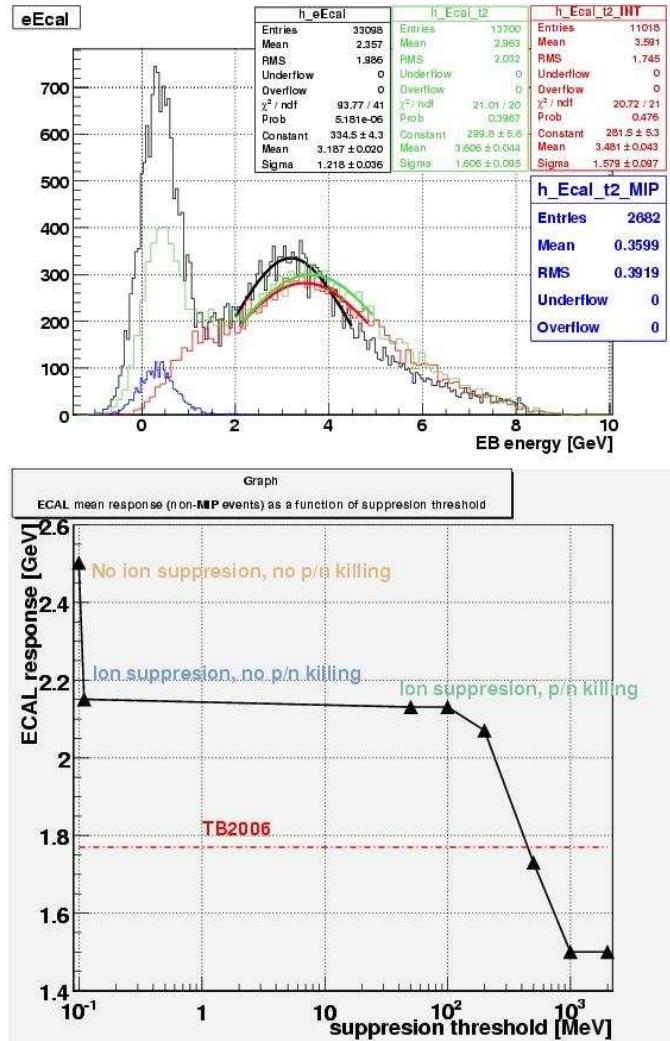
LEP model shown for π^-

1. the original model
 2. with Coulomb barrier added
 3. with Coulomb barrier added and nuclear de-excitation code removed
- \Rightarrow no solution yet



Energy Measurement (VI)

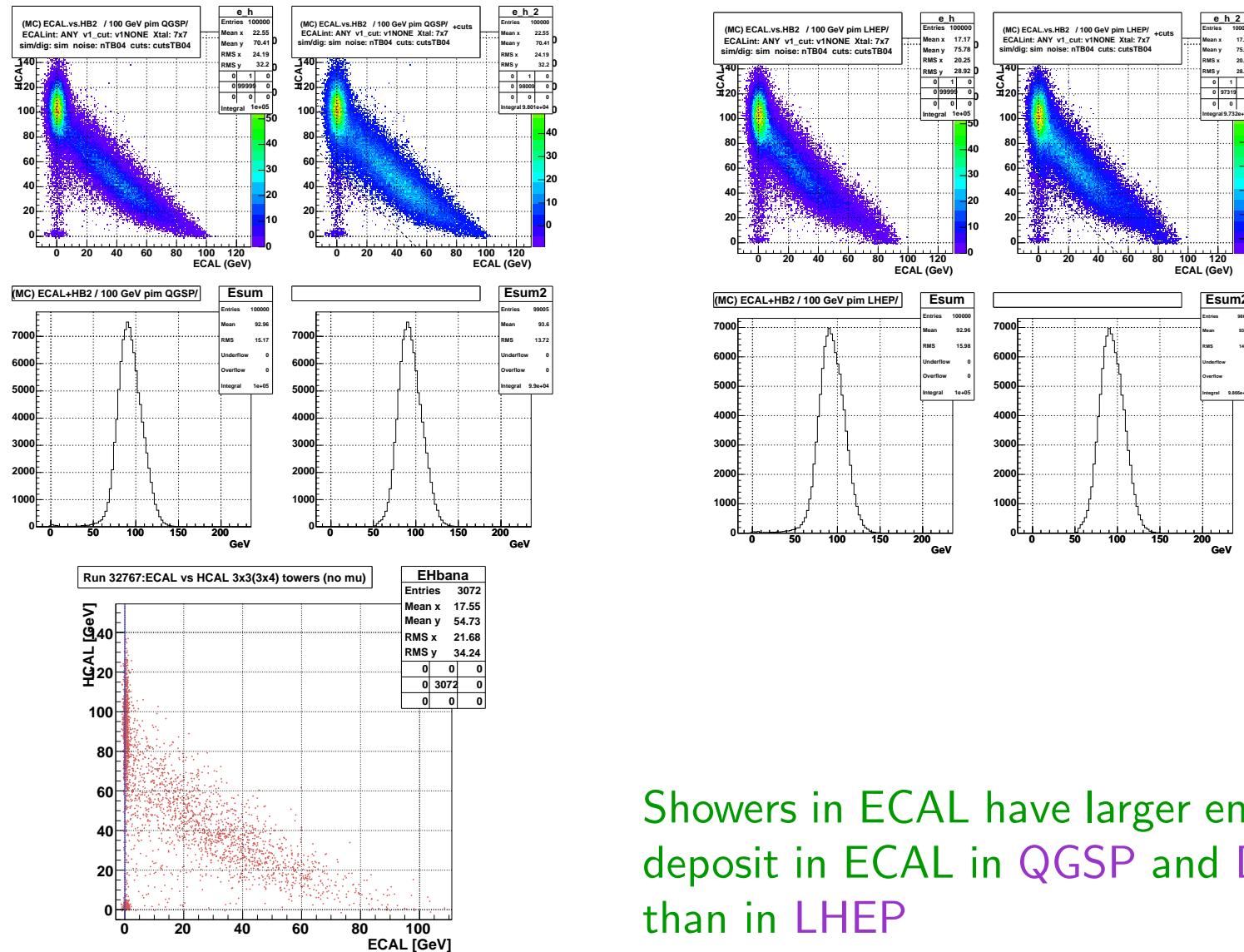
Temporary fix \Rightarrow suppress slow heavy particles



Looking for better/safer way to cure this



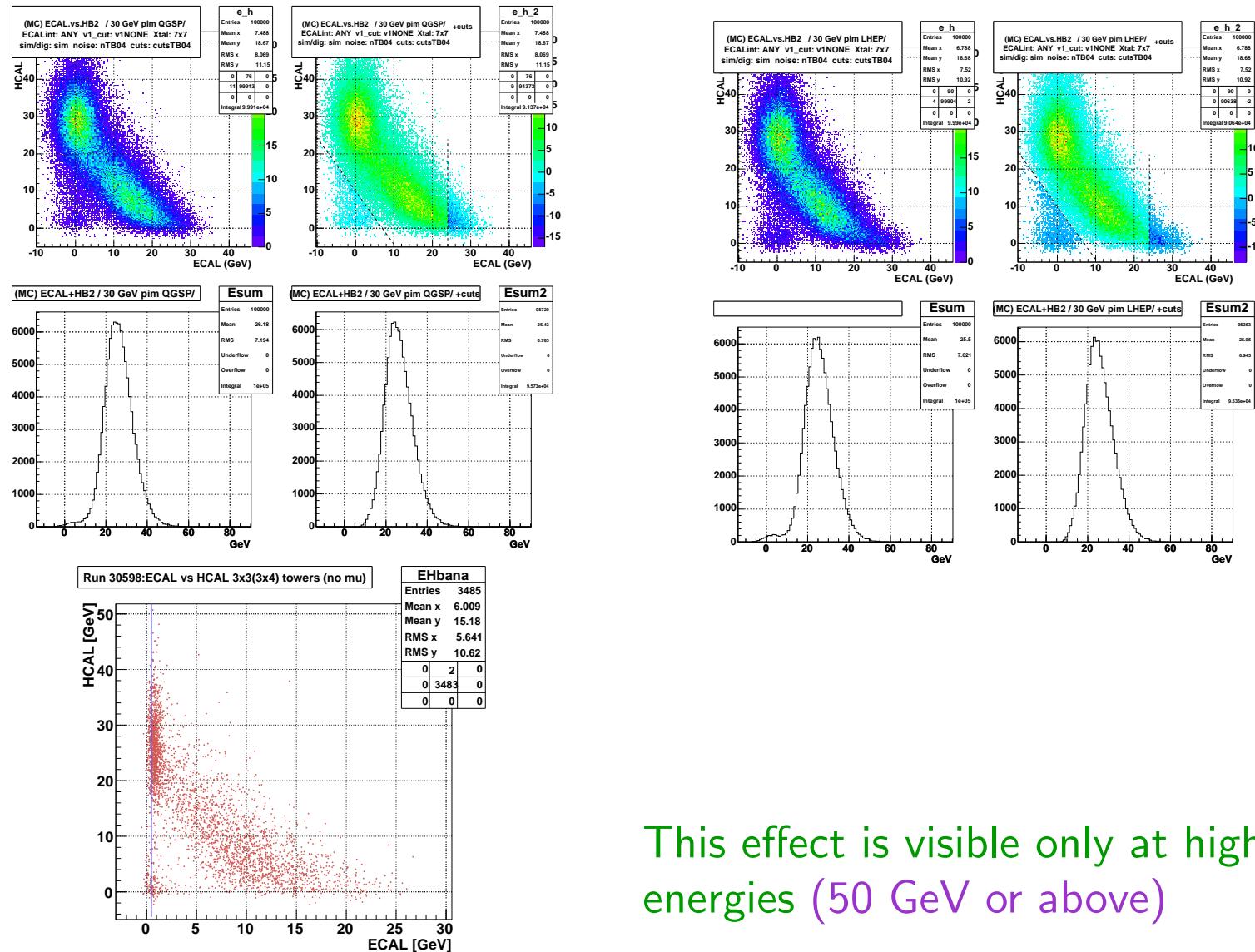
LHEP vs QGSP in Energy Measurement (I)



Showers in ECAL have larger energy deposit in ECAL in QGSP and Data than in LHEP



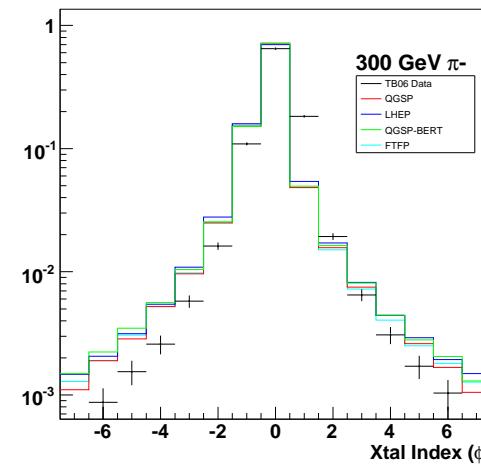
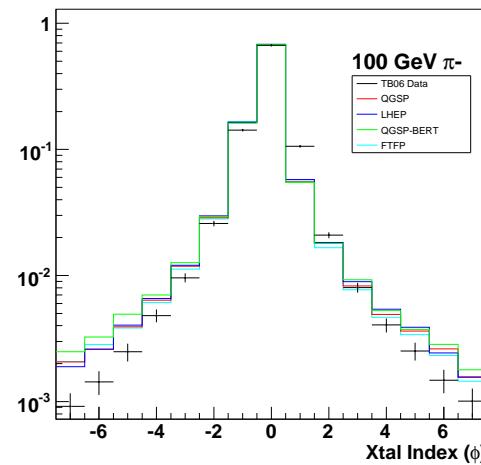
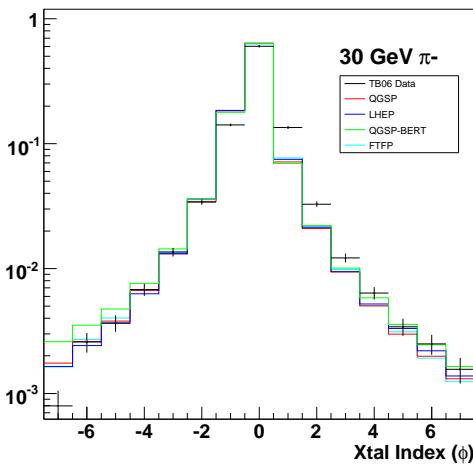
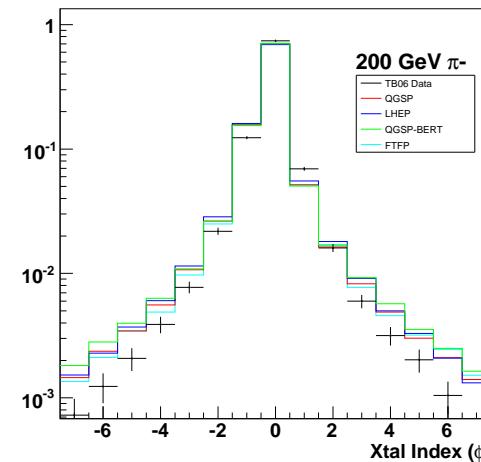
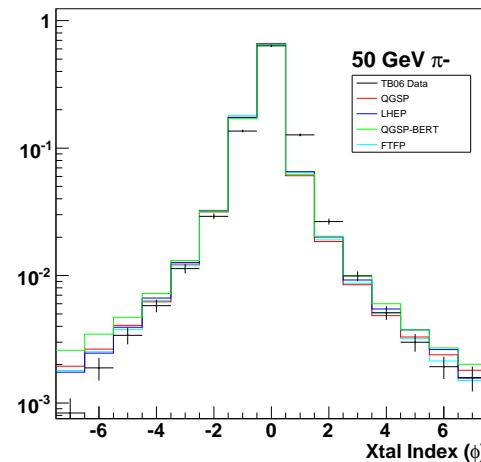
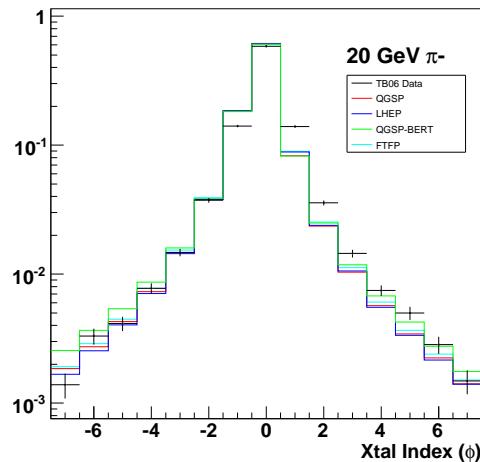
LHEP vs QGSP in Energy Measurement (II)



This effect is visible only at high energies (50 GeV or above)



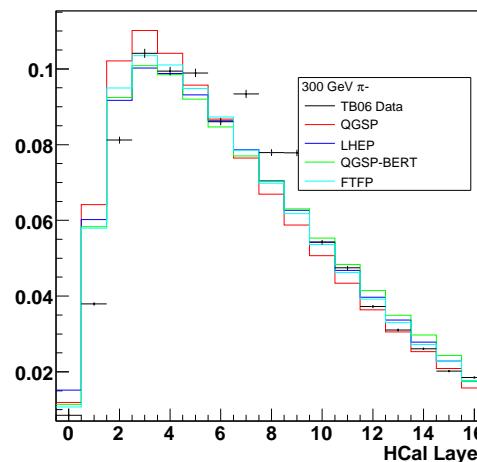
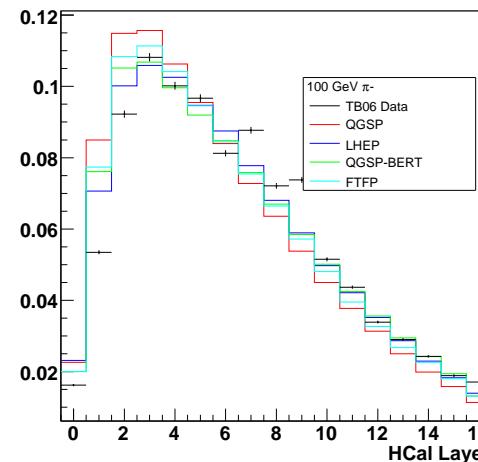
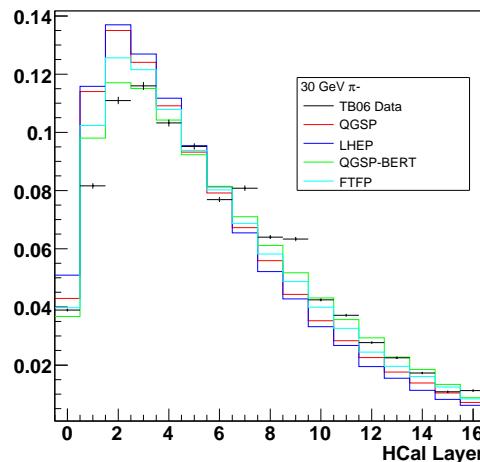
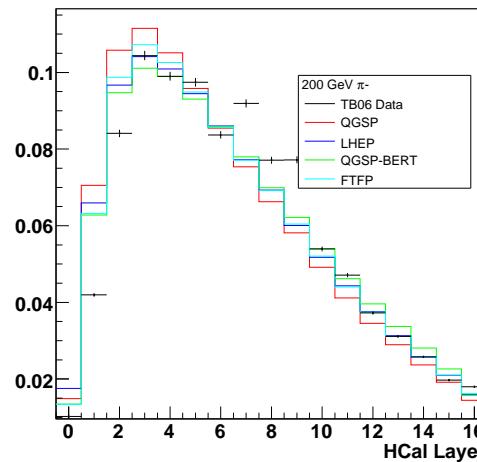
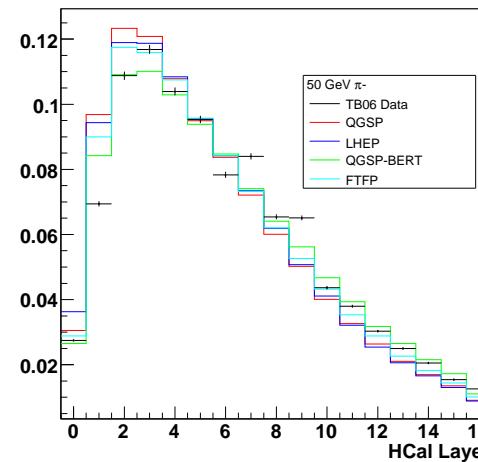
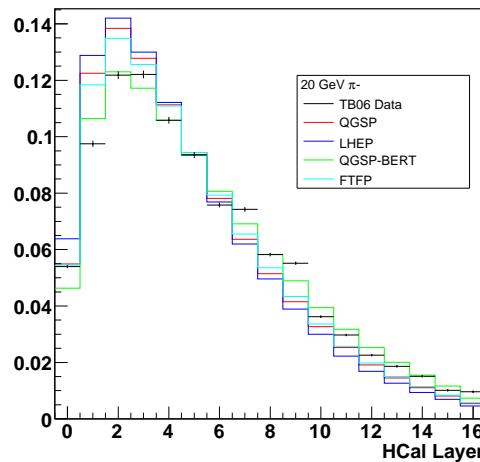
Transverse Shower Profile



- GEANT4 predicts faster growth in transverse shower size than data
- Effect of shower leakage is being investigated



Longitudinal Shower Profile (I)

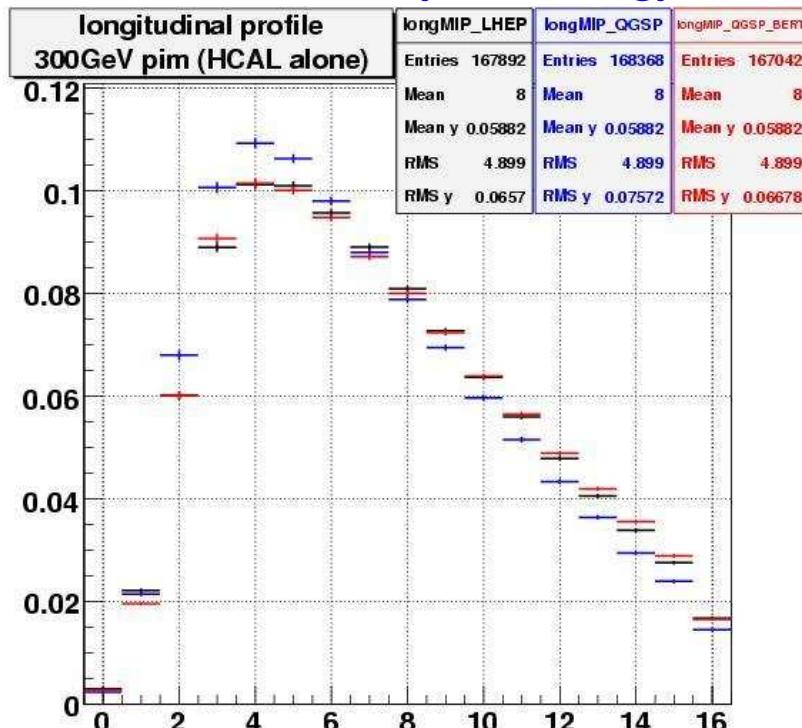


- ☐ QGSP_BERT physics list gives longer shower shape (in better agreement with data)

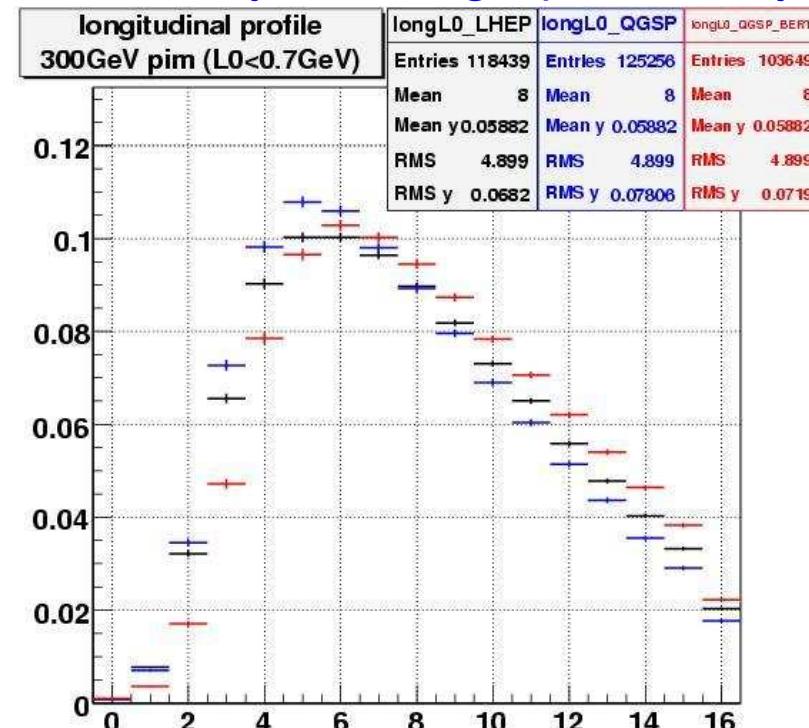


Longitudinal Shower Profile (II)

No cut on Layer 0 energy



Cut on Layer 0 - single particle only



Seems seeing backward scattered particles



Summary

- ❑ Transverse shower profile prediction is in fairly good agreement with data - only concern is the energy dependence
- ❑ Longitudinal shower profile prediction from Bertini model agrees better with data - seems to see backward protons (in agreement with data)
- ❑ Sees excess of energies in G4 models below 10 GeV
 - ❖ Small difference can be explained by Birk's law and Cerenkov lights in crystals. But observed difference is too large
 - ❖ Too much protons below 10 GeV in G4 model, more in Bertini model
 - ❖ π -production rate not smooth around 10-20 GeV in G4
- ❑ Tuning can be done in two ways:
 - ❖ Ignore slow protons and ions in calorimeter simulation - (get smooth curve over the energy region 1-300 GeV)
 - ❖ Fix physics model(s) in GEANT4