

# Comparison of CMS Calorimeter Response to Hadrons

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**GEANT4 vs TB2004/2006 data**

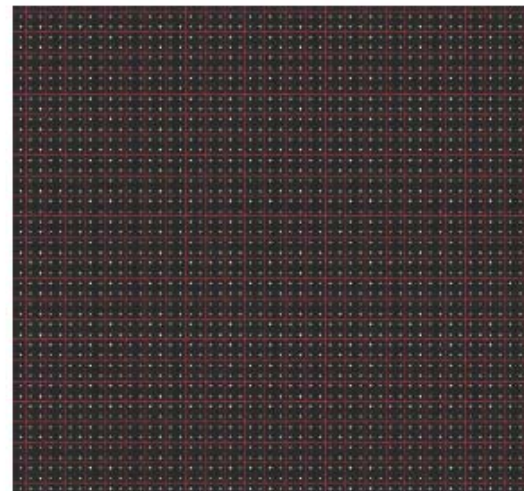
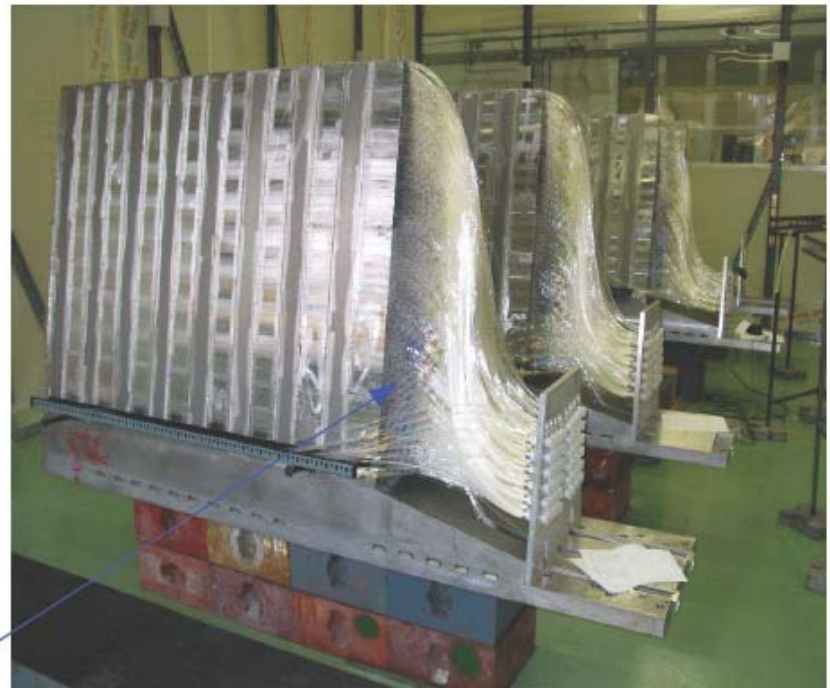
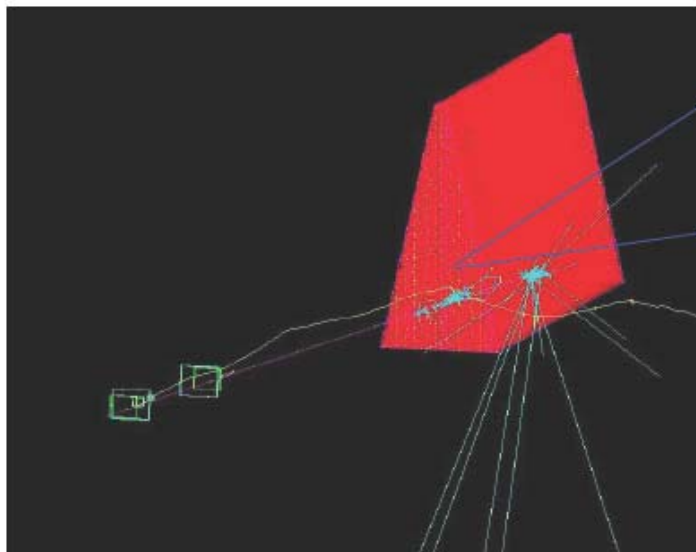
**1) HF(quartz fiber)**

**2) EB(PbWO4 crystal) + HB (brass/scintillator)**

# HF Test Beam Setup

One wedge and beam line elements.

Cerenkov detector- Sensitive to  $\pi^0$ 's

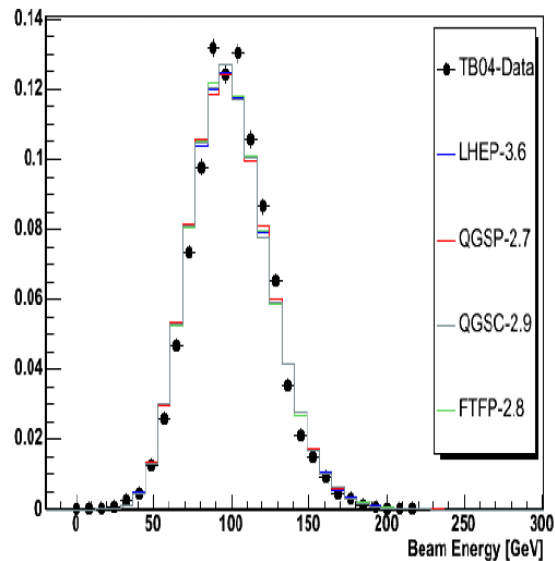


5 mm x 5 mm fiber segmentation

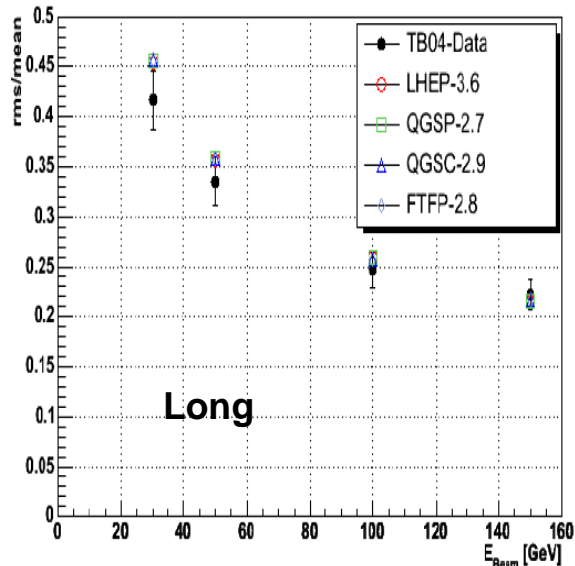
... L S L S L S ...  
... S L S L S L ...

Long

## 100GeV e-



## Resolutions – electron



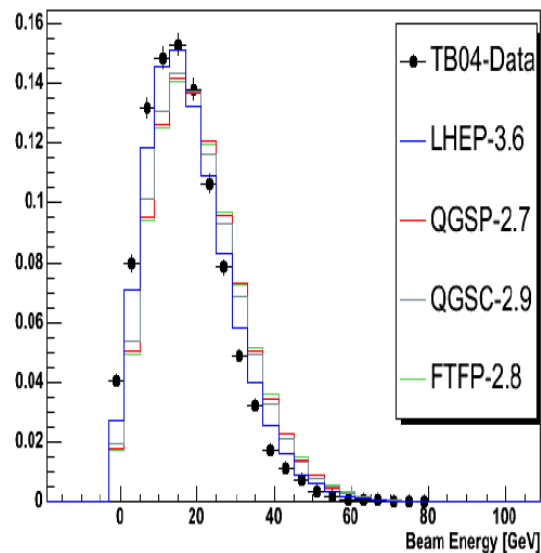
TB2004 HF  
Data vs G4.7.0

**Electron: Good agreement**  
→ Cerenkov light  
production & collection and  
PMT simulation  
implemented correctly.

**Pion: LHEP agrees.**  
→ Others: too much  $\pi^0$ 's.

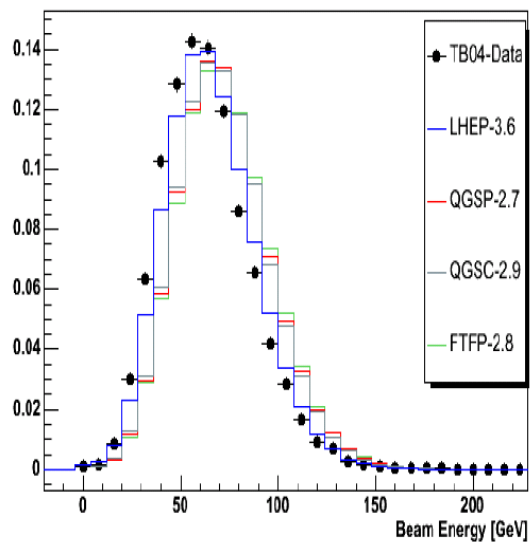
Long

## 30GeV pi-



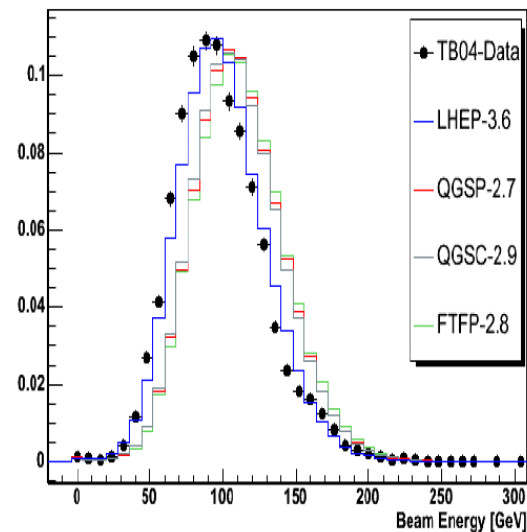
Long

## 100GeV pi-

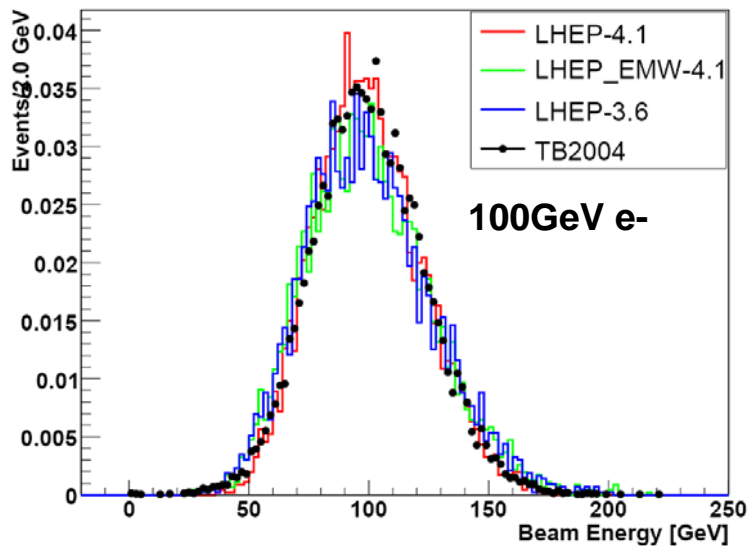


Long

## 150GeV pi-



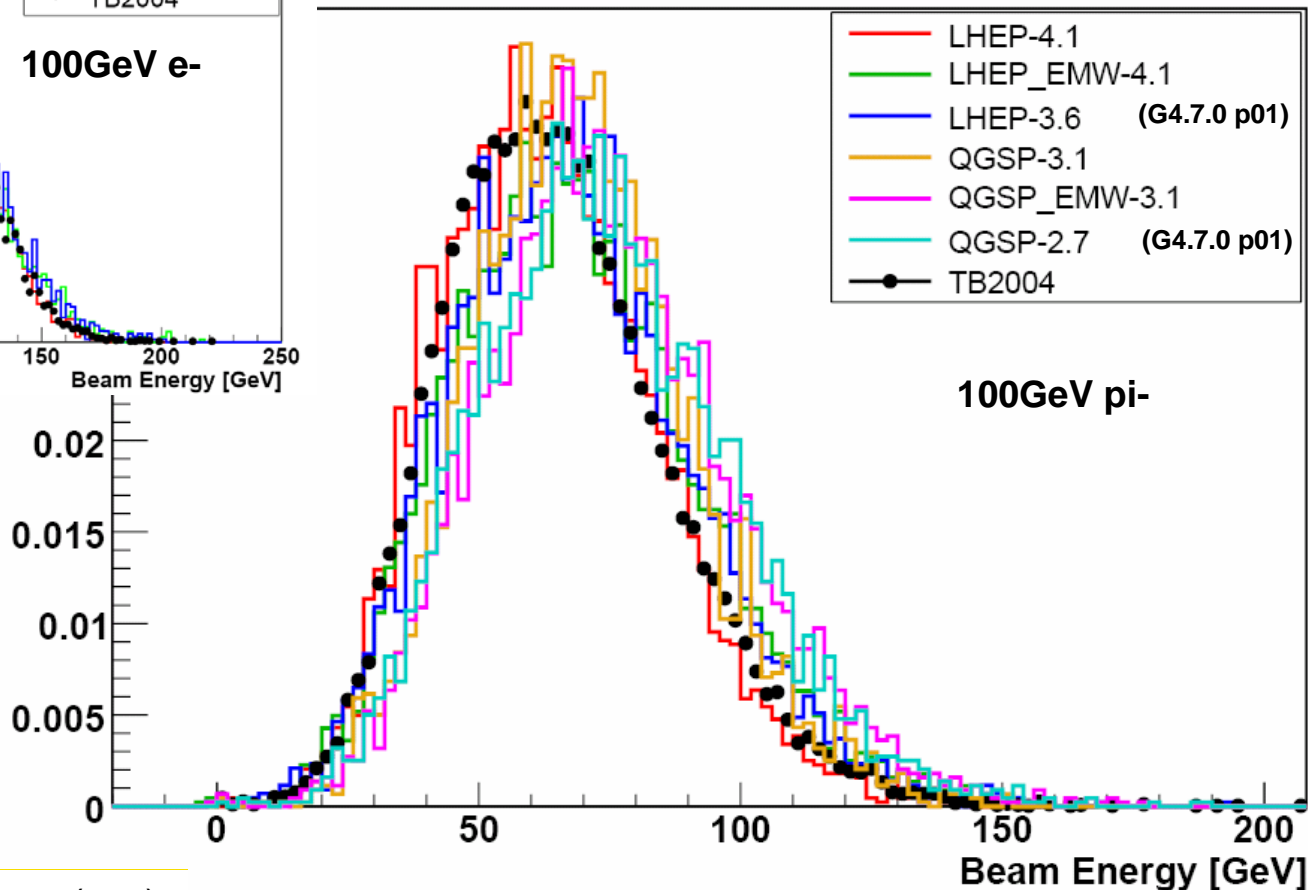
Long



HF response  
calibrated with  
100GeV e-

0.02  
0.015  
0.01  
0.005  
0

## HF (Long Fiber) Simulation (G4 8.1 p02)



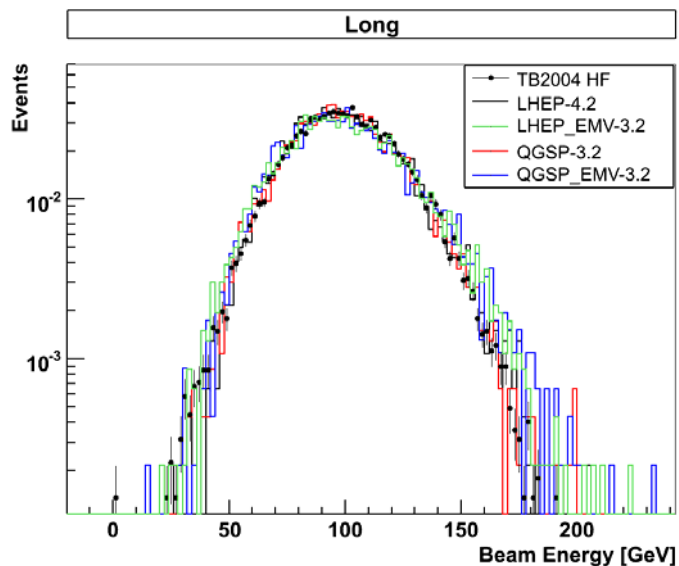
100GeV e- in HF (L) p.e. (rms)

LHEP-3.1	27.37 (7.20)
LHEP-4.1	34.38 (7.70)
LHEP_EMW-4.1	27.19 (7.21)

HF: Quartz fiber calorimeter  
Sensitive to pi0's in hadronic shower

**LHEP still agrees better with data.**

## 100GeV electron

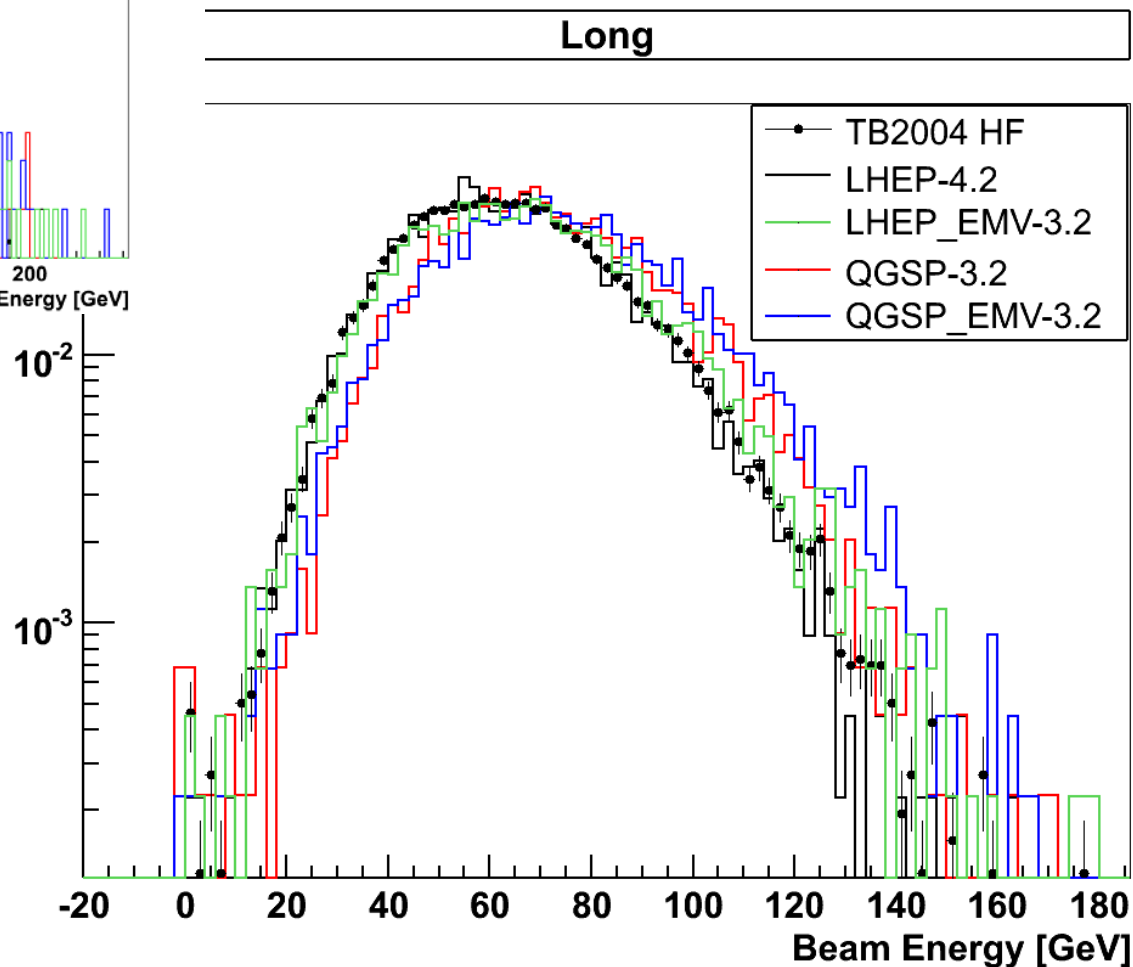


HF response  
calibrated with  
100GeV e-

**LHEP still shows better  
agreement with TB2004  
HF data than QGSP.**

## HF Long fiber simulation (G4.8.2 p02)

## 100GeV pi-

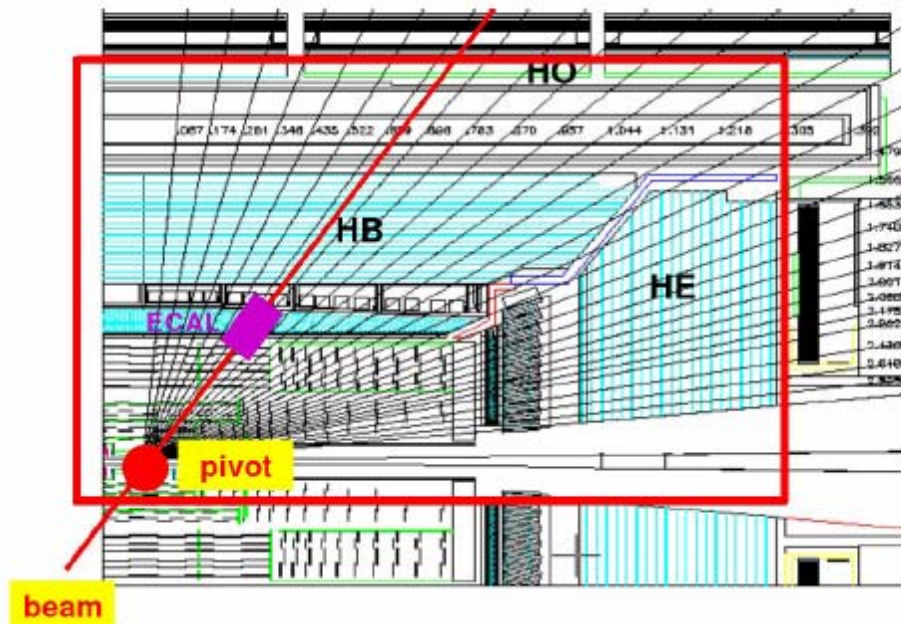




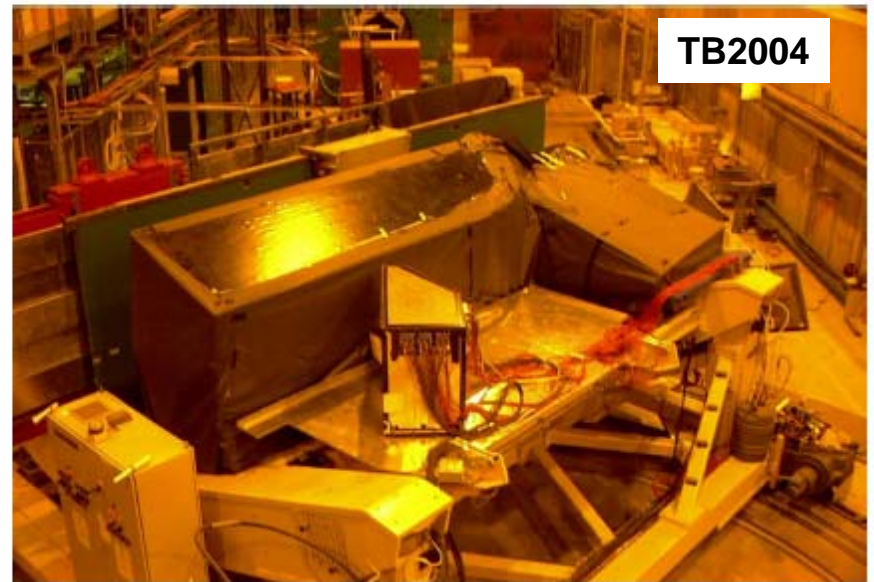
# ECAL + HCAL

ECAL: (PbWO<sub>4</sub> Crystals) - small 14x14cm (TB2004),  
a real super module (TB2006)

HCAL: brass (5cm) + scintillator (3.7mm) sampling

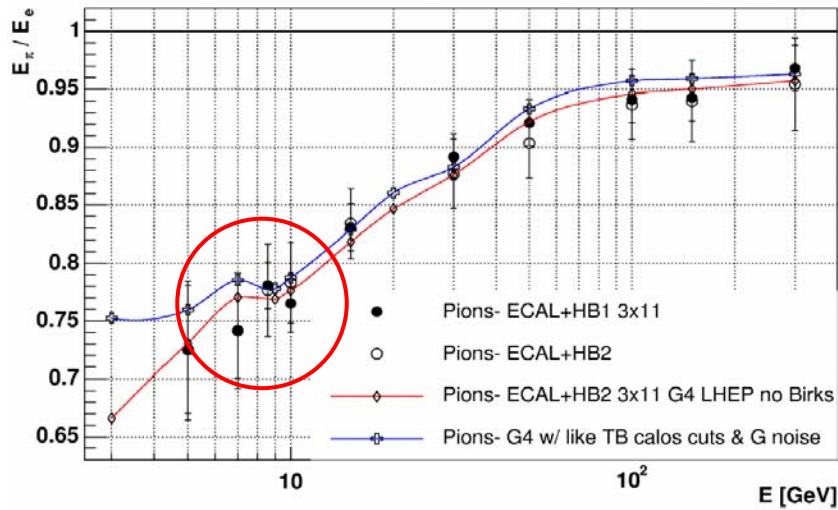


The part of CMS represented in the test-beam.



HB1 in normal configuration, HB2 - longitudinally segmented.

# *pi/e TB HB2 vs G4 LHEP (no Birks law)*

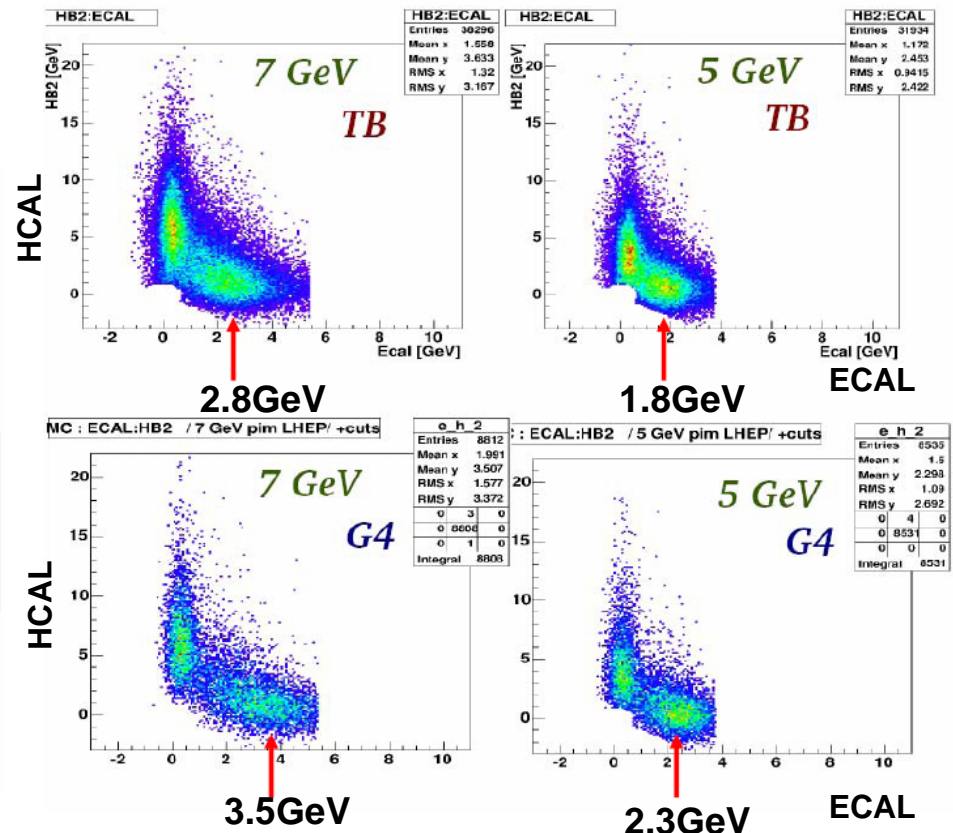
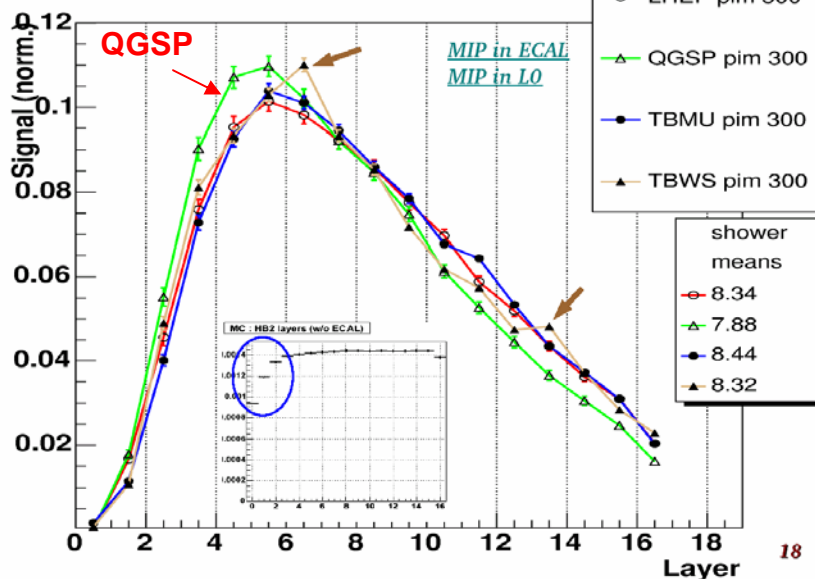


TB2004 HB  
Data vs G4

LHEP - good agreement with data, except for  $p < 10 \text{ GeV}$ .

QGSP – shorter shower profile.

## Longitudinal Shower Profiles



# CMS TB2006

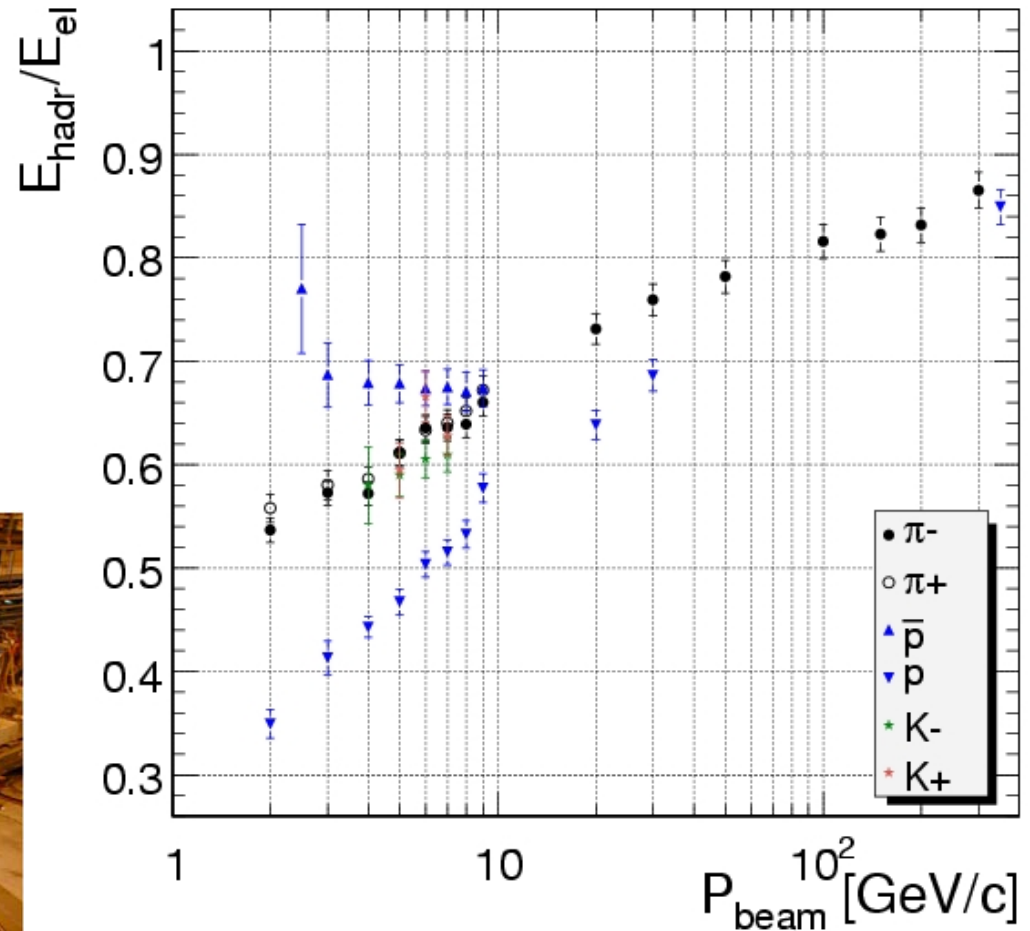
This analysis used-

ECAL: one barrel super module  
PbWO4 Crystals

HCAL: one barrel module  
Brass-Scitillator sampling cal

1 – 350 GeV in H2 beam line

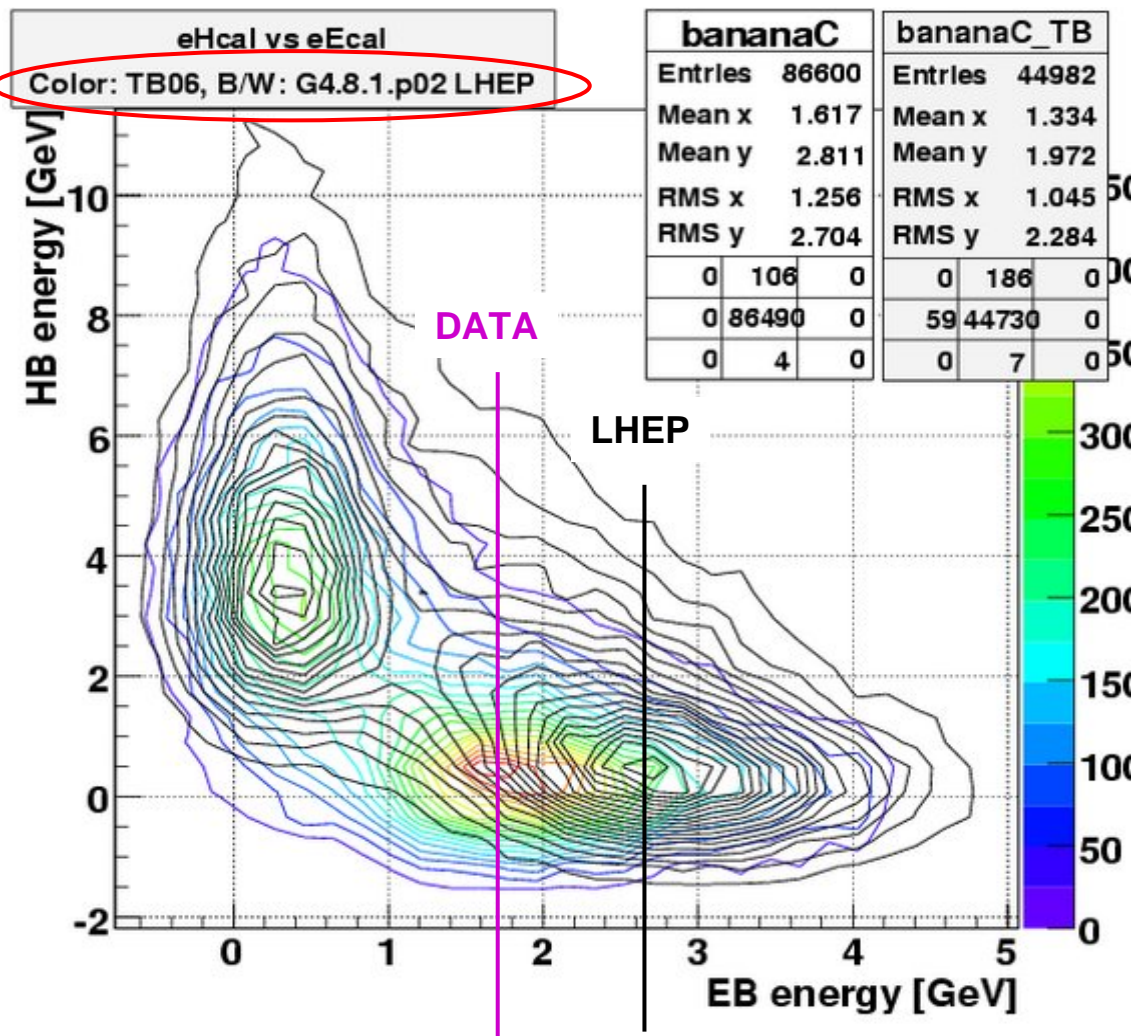
Better P-ID and beam clean-up.



( ECAL, HCAL calibrated with 50GeV electrons )



# 5GeV Pi- in ECAL(PbWO4)



TB2006 data  
vs.  
G4.8.1 P02

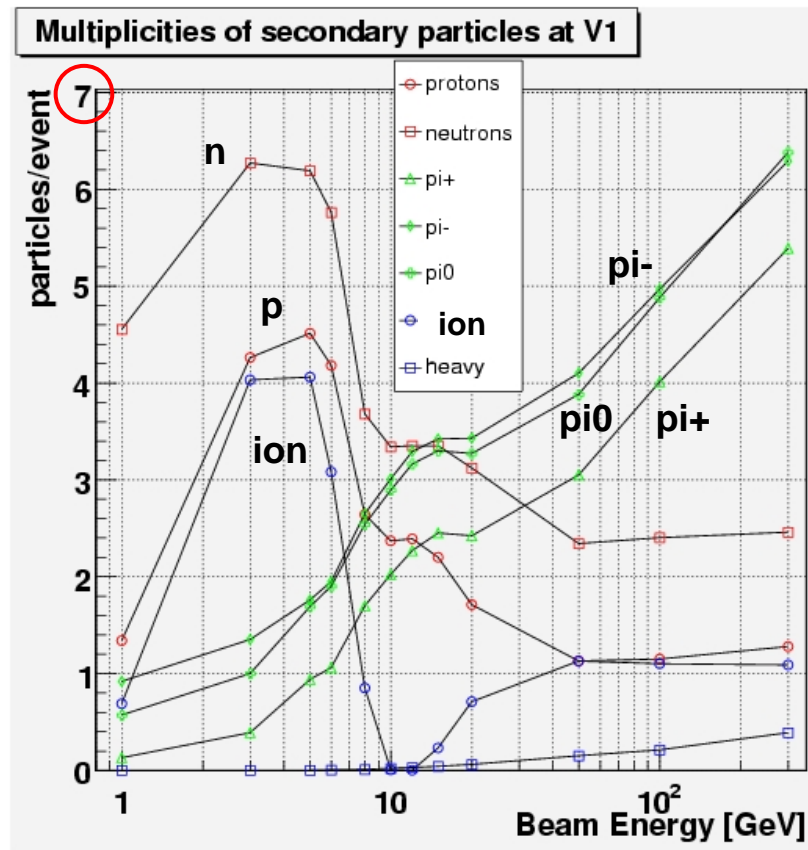
G4 Edep in ECAL  
for 5GeV pi-

e+/e-	54%
pi+/pi-/..	13
p/pbar	17%
ions	14%

Suppression of  
Proton/pbar/ions  
gives better agreement.

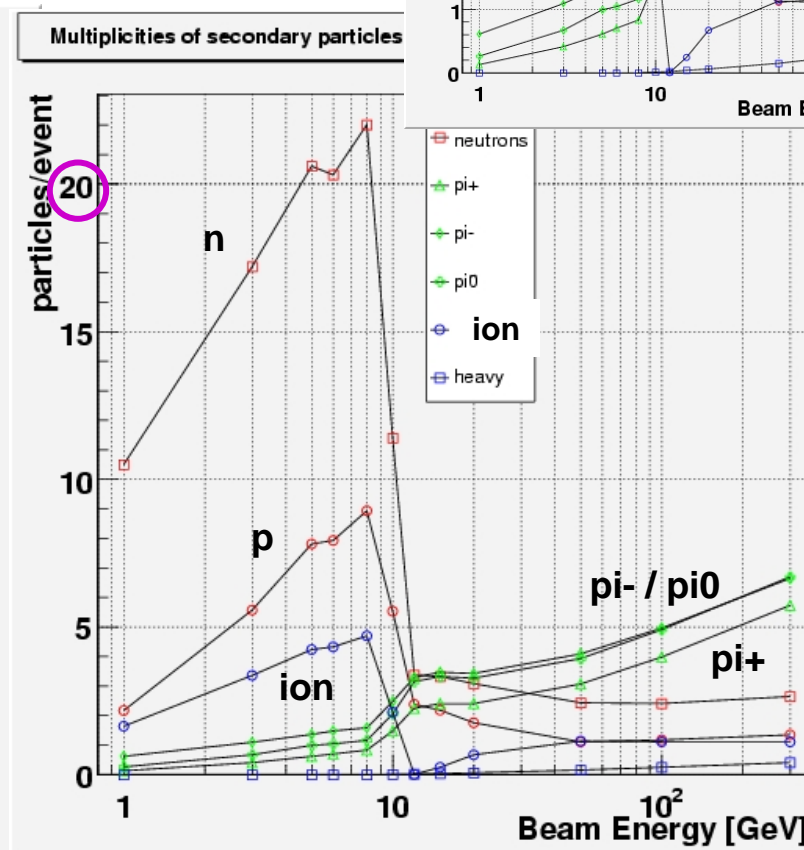
# Multiplicity of Secondary Particles at First Interaction Point

QGSP

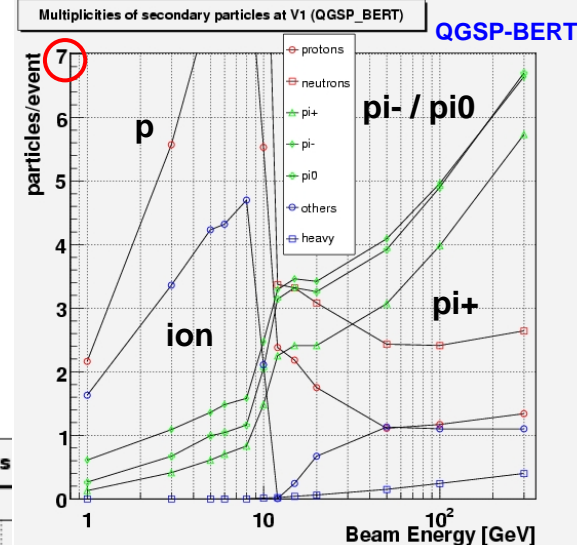


Too much neutrons / protons / ions ?

QGSP-BERT



Pion production not smooth around 10-20GeV.

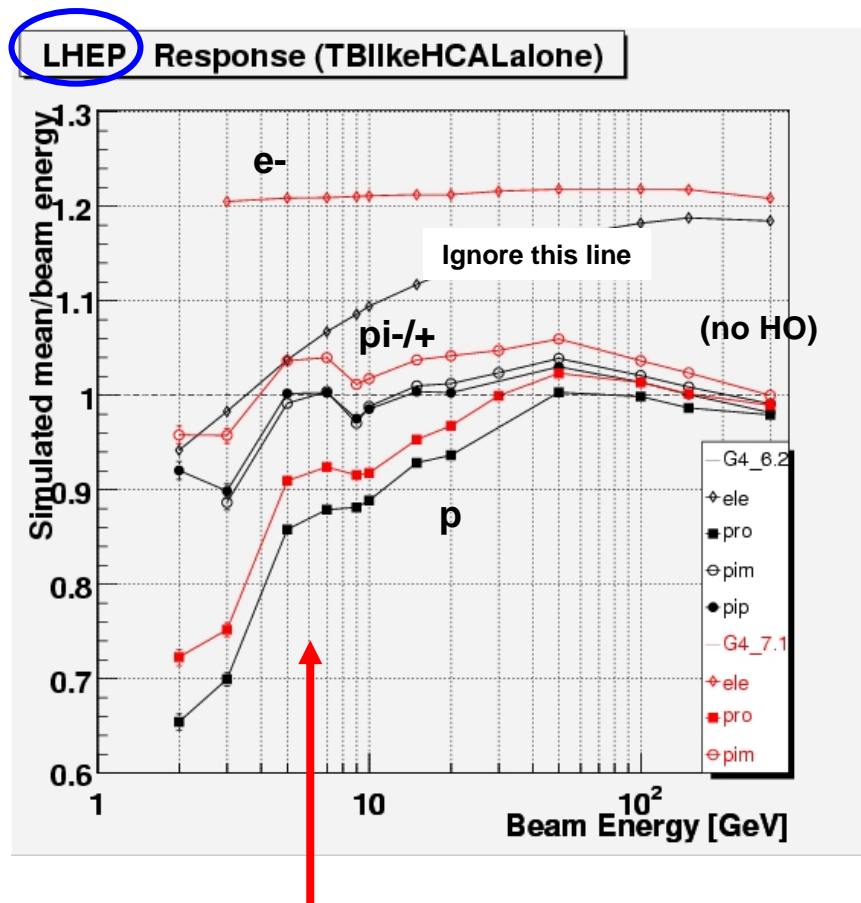
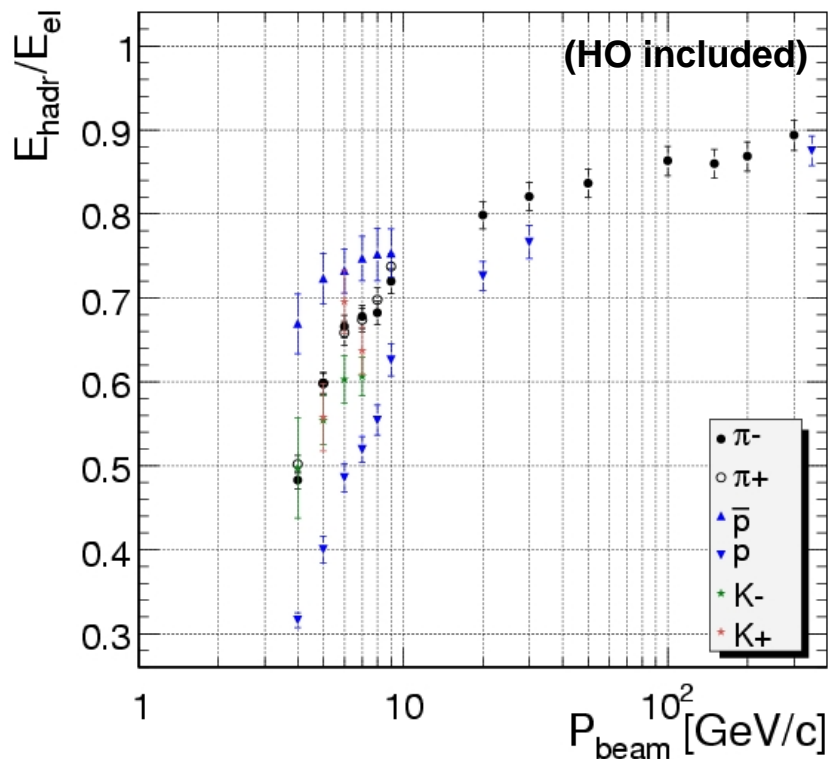


QGSP-BERT

# HCAL Alone

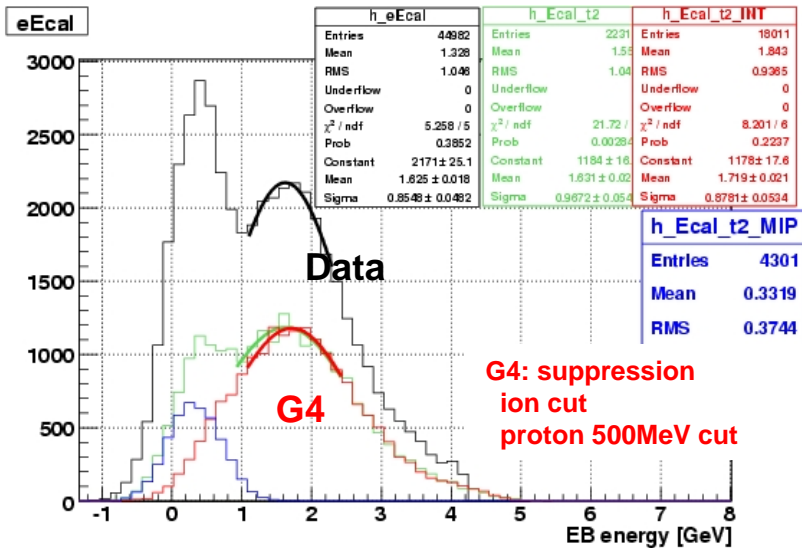
G4 (6.2, 7.1) for TB2004 setup

TB2006 Data

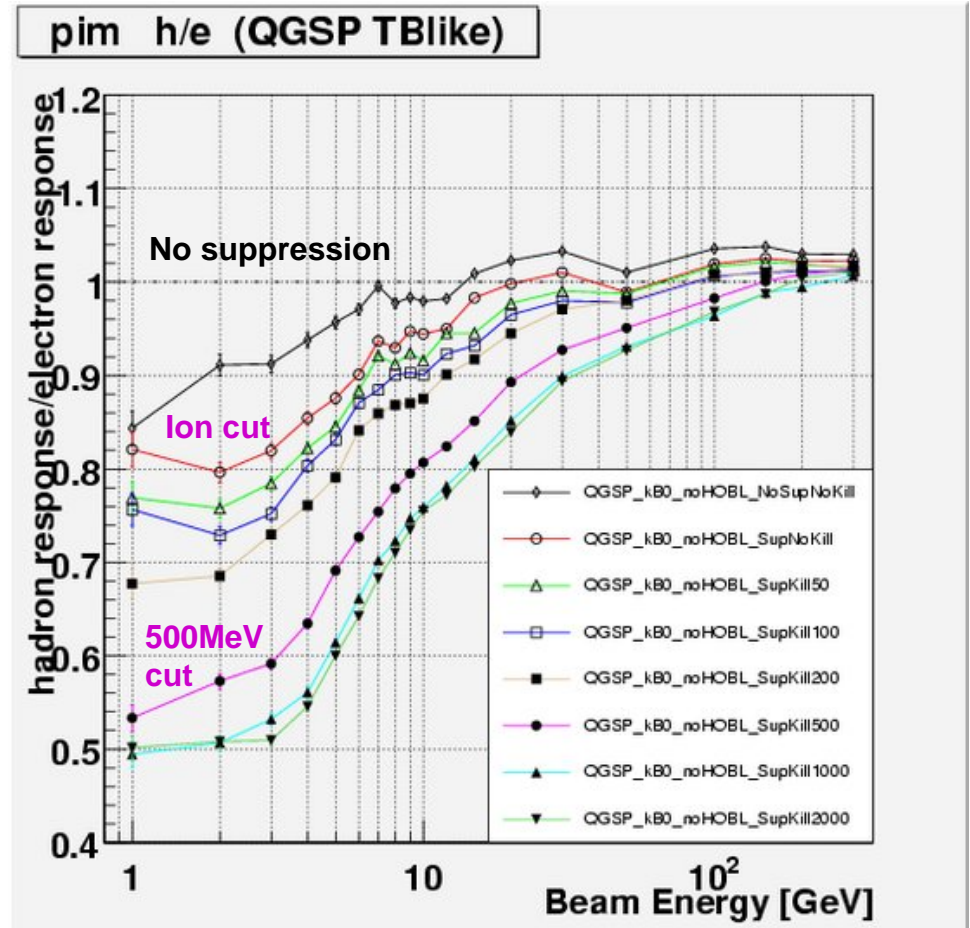
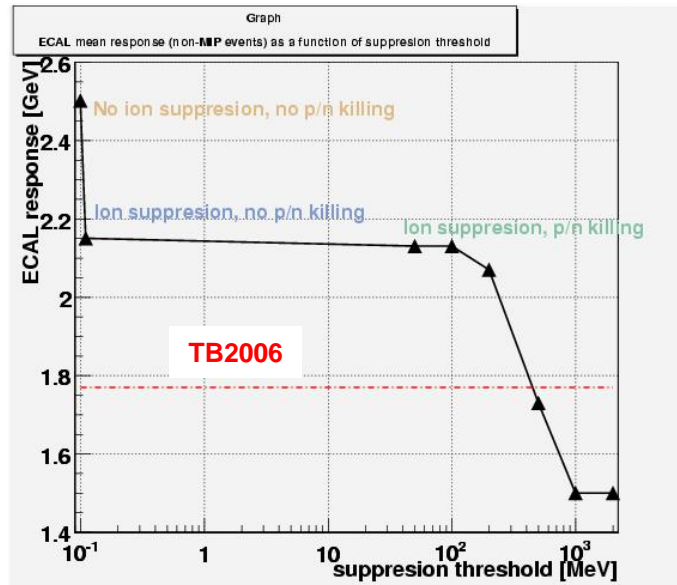


Seen in sampling calorimeter !  
Energy spectrum also too hard?

# Temporary Fix – Suppress slow heavy particles

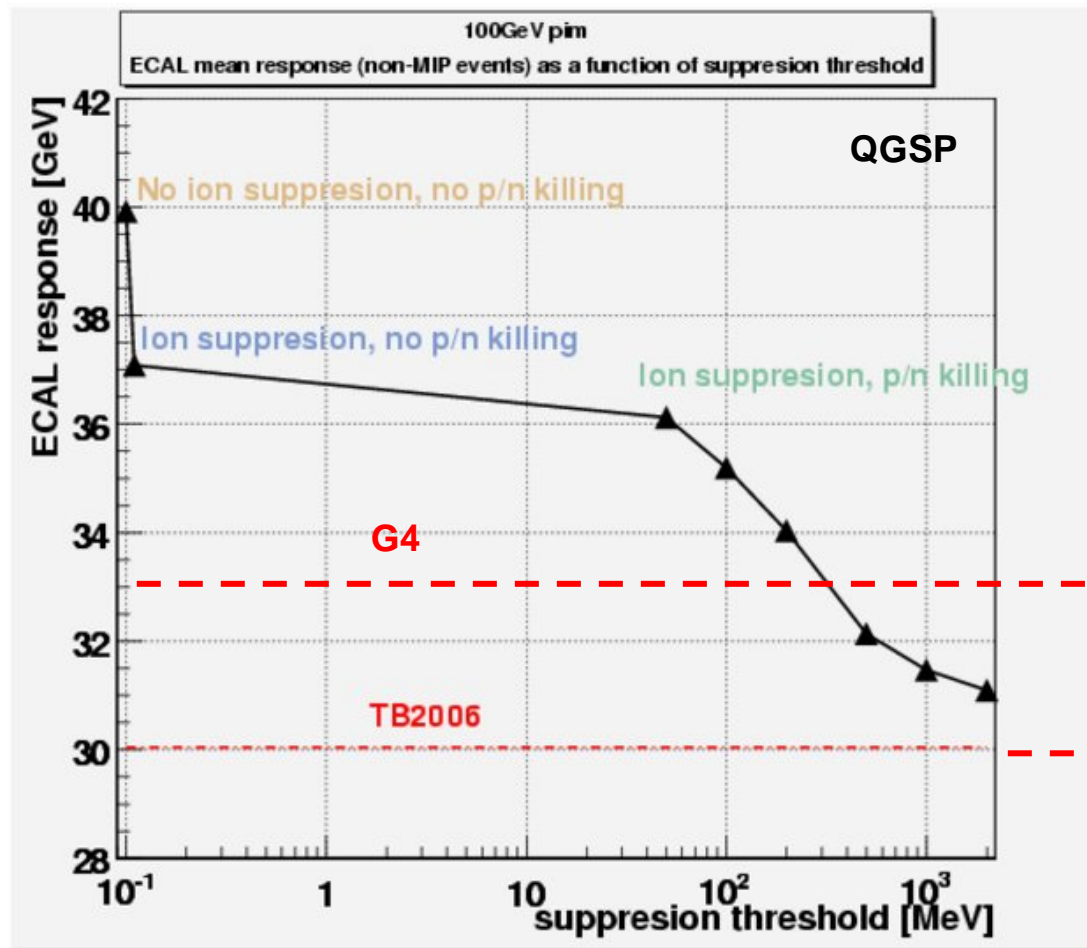


EB+ HB response to pi-





# 100GeV pi- in ECAL(PbWO<sub>4</sub>)



Excess pi<sup>0</sup>'s?

or

Cerenkov light?

Birks' law?

Else?

10%

Analysis in progress.

# Conclusion

- **Comparison with HF TB04**
  - LEHP still shows better agreement with data.
  - p.e. increased by 25% in LHEP 4-1.
- **Comparison with ECAL+HCAL (TB04/TB06)**
  - No update on longitudinal shower profile (yet)
  - Seeing excess energy in G4 below 10GeV
    - Small difference can be explained by Birks' law and cerenkov lights in crystals. But observed difference is too large.
    - Too much slow protons/ions below 10GeV in G4?
    - Pion production rate not smooth around 10-20GeV in G4.
- **Tuning – two ways**
  - Ignore slow protons and ions in calorimeter simulation
    - Get smooth curve in 1-300GeV
  - Fix G4 physics model(s).
    - Problem already reported to the G4 hadron physics group.
    - Discussion started with the G4 hadron physics group.