



# Evaluation of G4 Releases in CMS (Sub-detector Studies)

- Software used
- Electrons in Tracker
- Photons in the Electromagnetic Calorimeter
- Pions in the Calorimeter System

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(on behalf of CMS simulation team)



# Software Used



- Tracker, Electromagnetic Calorimeter and Combined Calorimeter system all use CMSSW version 0\_8\_1 for Geant4.7.1.p02 with some CMS specific changes
- For Geant4.8.1.p01, all sub-detector systems use CMSSW version 0\_9\_0\_pre2
- The different versions of CMSSW differ very little in handling hits and are identical in geometry
- Tracker and electromagnetic calorimeter studies use standard CMS detector for the geometry. The studies for the  $\pi$  showers use geometry of the calorimeter system only.
- Production cuts used are default CMS – typically 0.01 mm in pixel detector, 0.1 mm in tracker and pre-shower detectors, 1 mm in most parts of the detector
- Tests are run on 3.6 GHz dual processor with 4GB memory

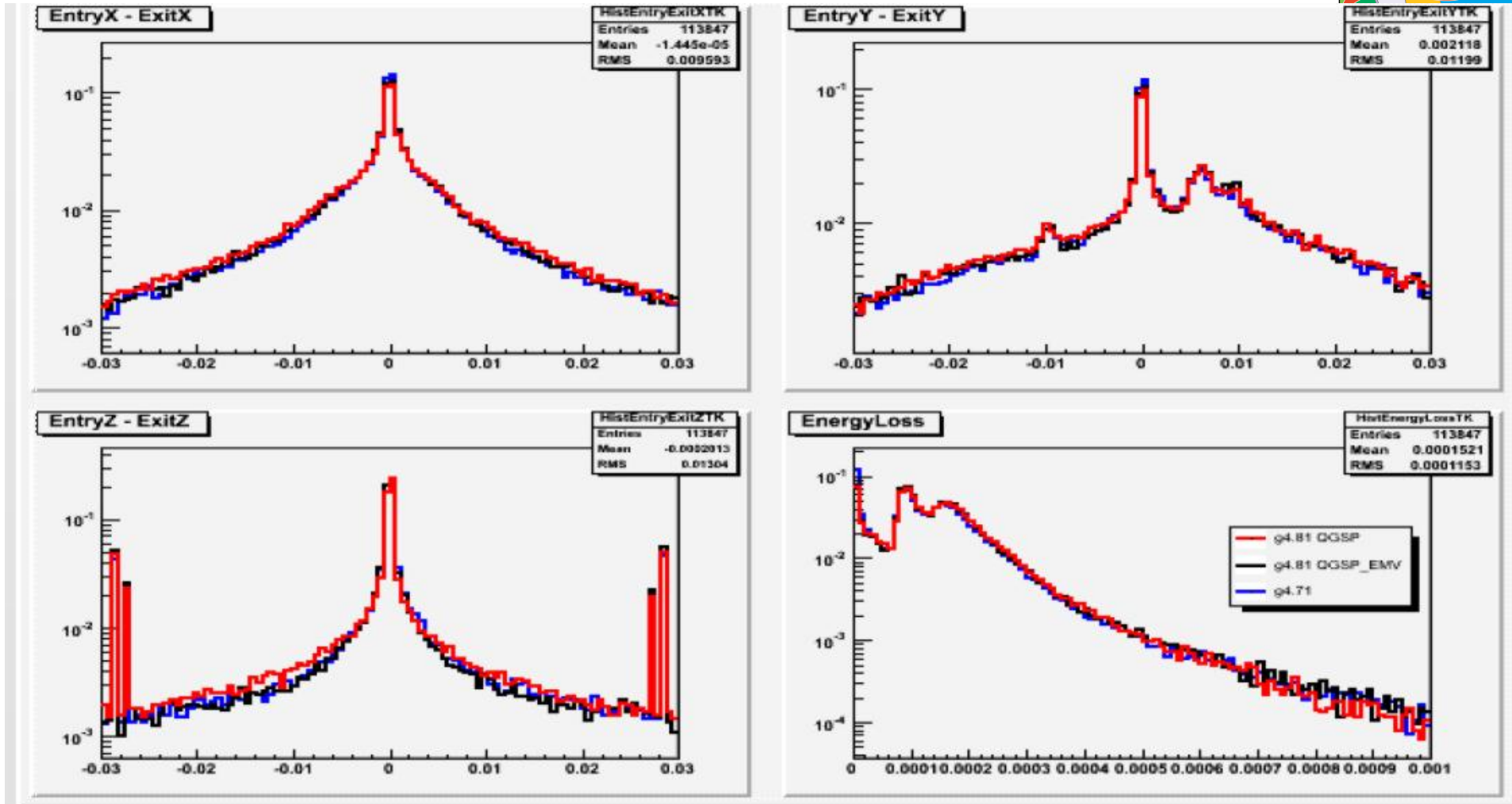
# Electrons in Tracker



- Geometry used : Entire CMS detector
- Event sample: 2000 electron events
- 20 GeV electrons generated with  $|\eta| < 3.5$  and  $-\pi \leq \varphi \leq \pi$
- Geant 4.8.1 QGSP sample was generated on a 3.2 GHz processor with 2 GB memory
- Process used: Particle Gun + Vertex Smear + G4 SimHit

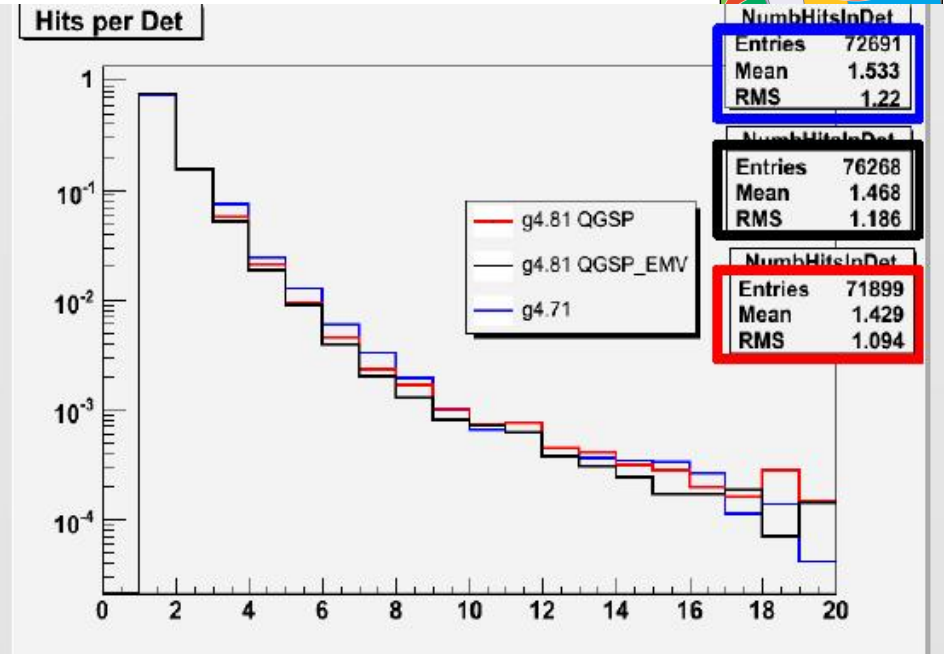
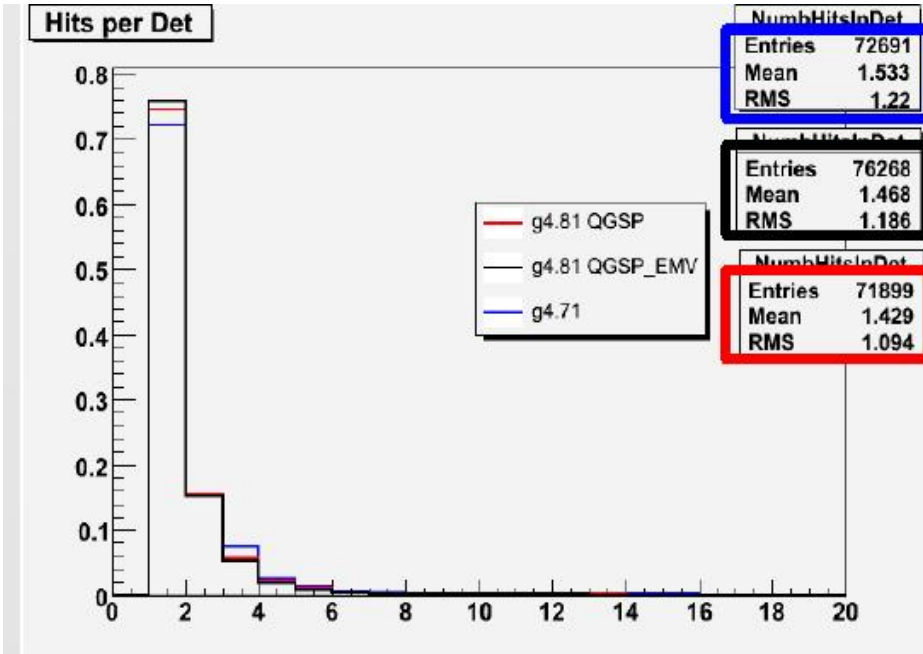
Geant 4.7.1.p02	QGSP 2.8	3.0 sec/event
Geant 4.8.1.p01	QGSP 3.1	4.6 sec/event
Geant 4.8.1.p01	QGSP_EMV	2.7 sec/event

# Tracker Hit Comparison



The hit quantities are similar in all the versions

# Tracker Hits



- Geant 4.8.1 QGSP shows slightly wider distribution in the  $\Delta z$  distributions
- Geant 4.7.1 gives more secondary hits than the new version. QGSP\_EMV has a mean somewhere in between

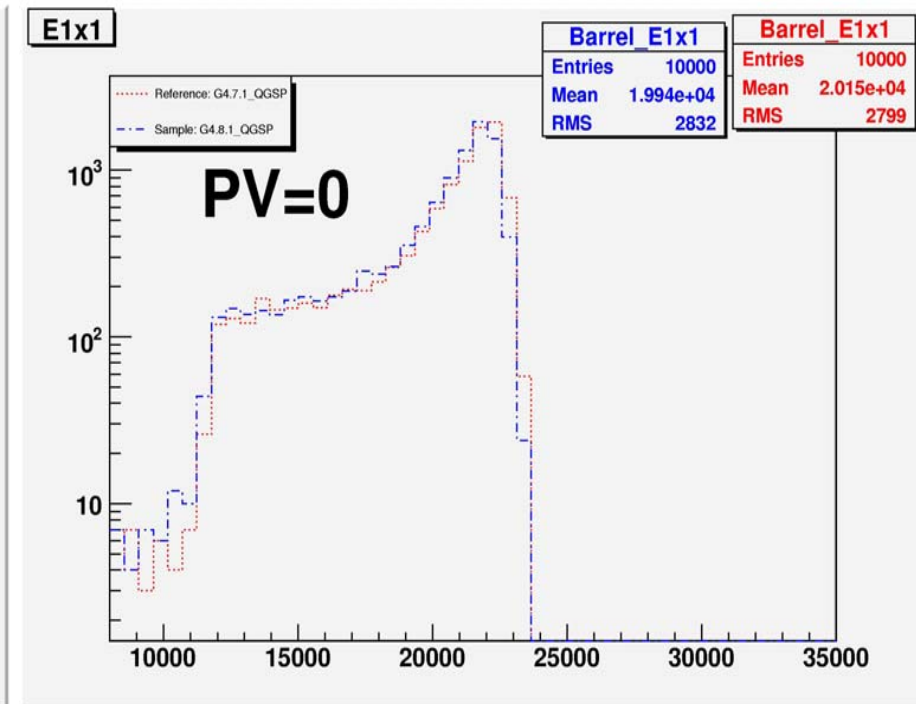
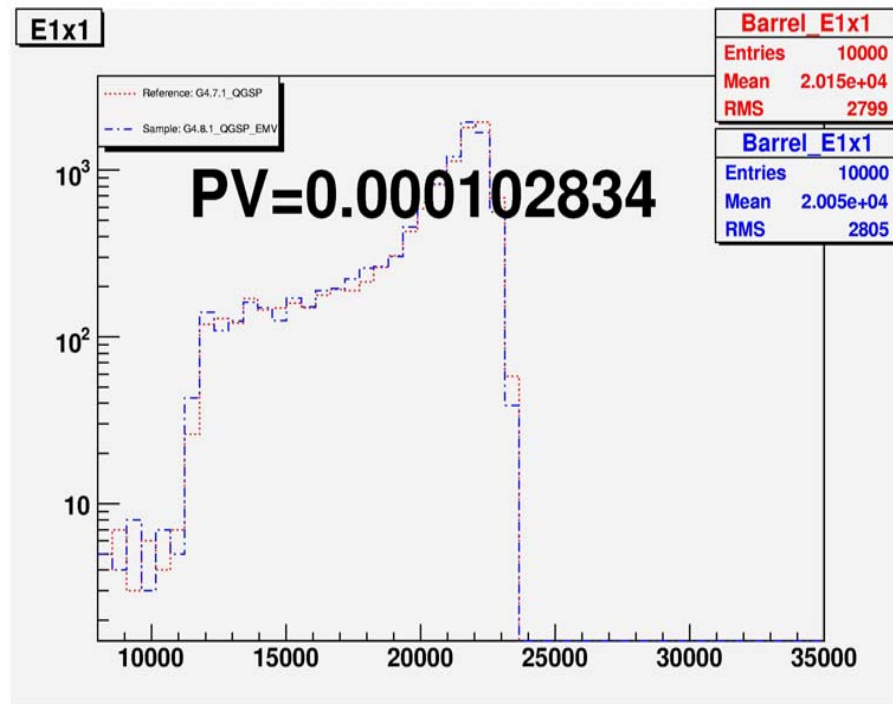


# Samples and Physics list



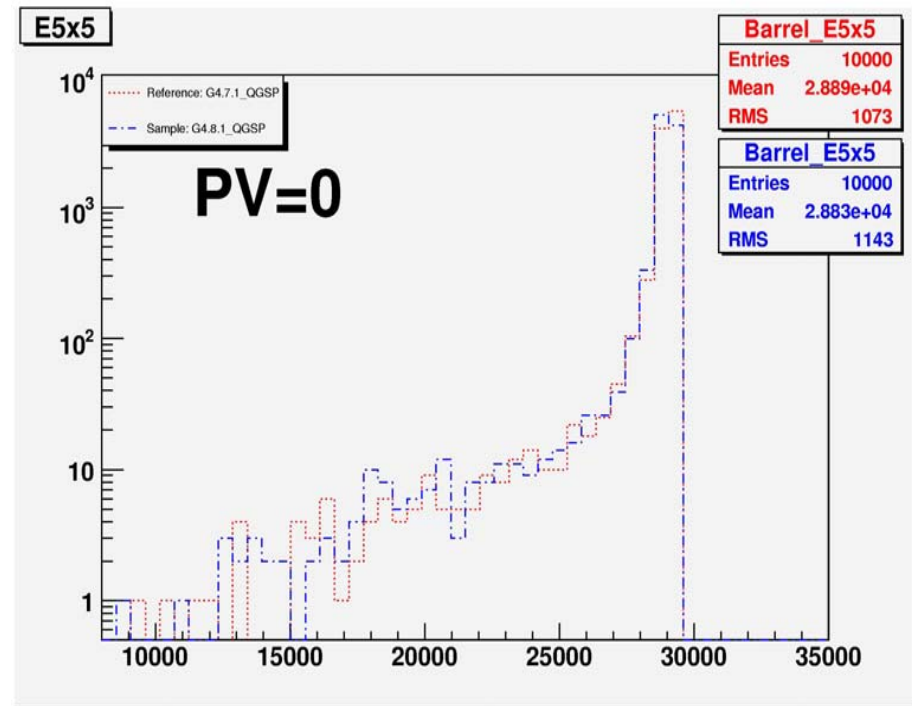
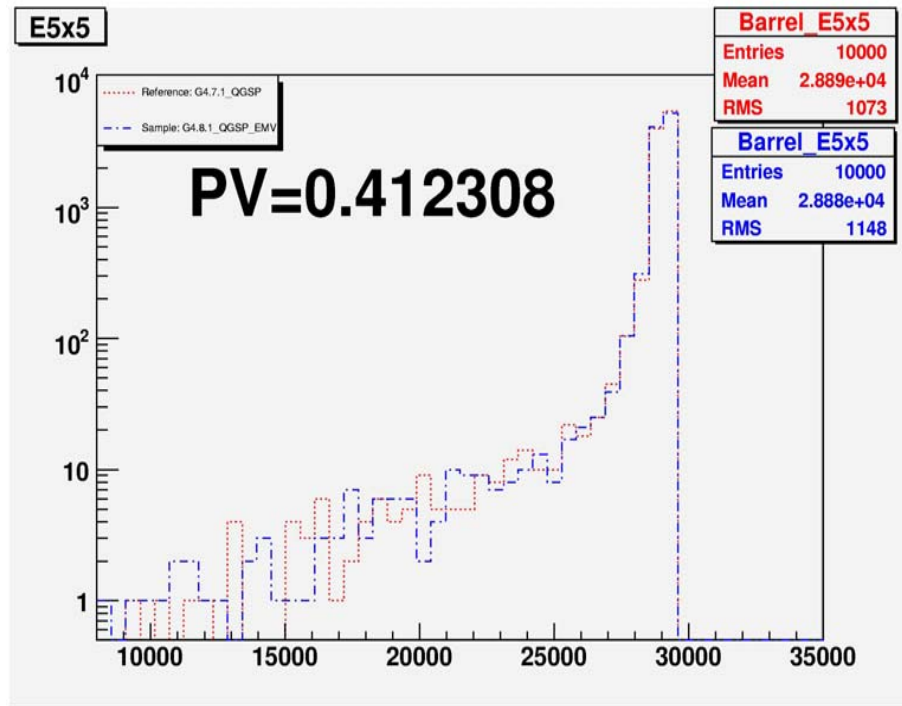
- Geometry used:
  - Entire CMS detector
- Samples used in tests:
  - Particle Gun
  - 10000 Photon:  $\eta=0.2$  ,  $-\pi \leq \varphi \leq \pi$  ,  $E=30$  GeV.
  - 10000 Photon:  $\eta=2.2$  ,  $-\pi \leq \varphi \leq \pi$  ,  $E=30$  GeV.
- Physics List used in tests
  - **Geant4.7.1\_QGSP** with CMSSW\_0\_8\_1.
  - **Geant4.8.1\_QGSP** with CMSSW\_0\_9\_0\_pre2\_g4\_81
  - **Geant4.8.1\_QGSP\_EMV** with CMSSW\_0\_9\_0\_pre2\_g4\_81

# Energy deposited in 1x1 Cluster in EB



- Geant471\_QGSP is close to G481\_QGSP\_EMV
- Obvious difference between G471\_QGSP and G481\_QGSP
  - G471\_QGSP gives the largest Energy deposition (mean= 20.15 GeV)
  - G481\_QGSP gives the smallest energy deposition (mean = 19.94 GeV)

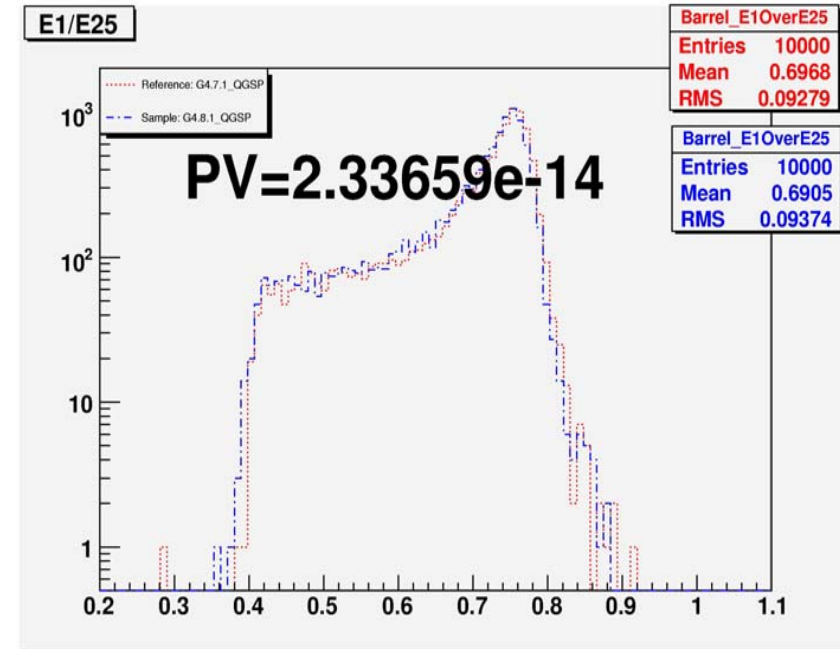
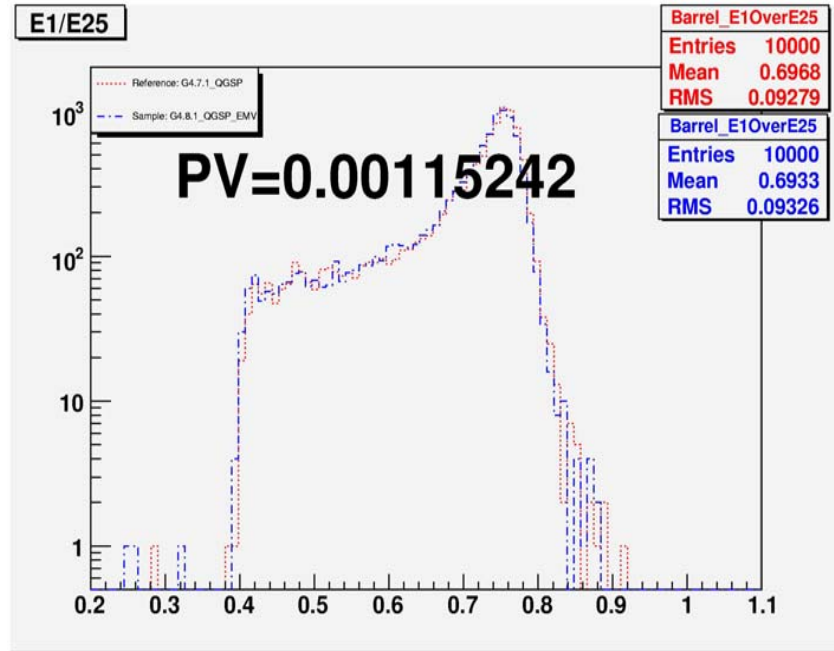
# Energy deposited in 5x5 Cluster in EB



- Geant471\_QGSP is very close to G481\_QGSP\_EMV
- Obvious difference between G471\_QGSP and G481\_QGSP
  - G471\_QGSP gives the largest energy deposition (mean= 28.89 GeV)
  - G481\_QGSP gives the smallest energy deposition (mean = 28.83 GeV)

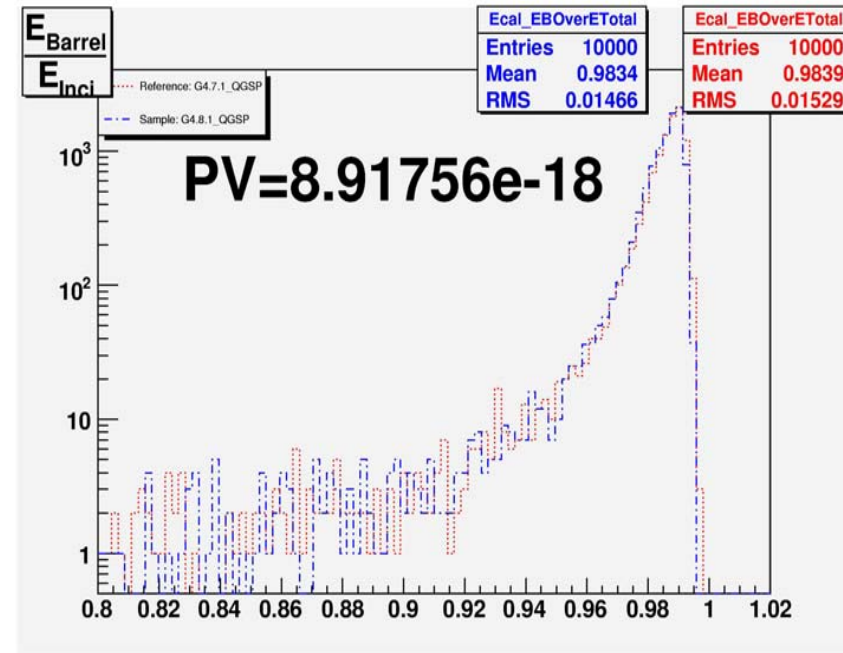
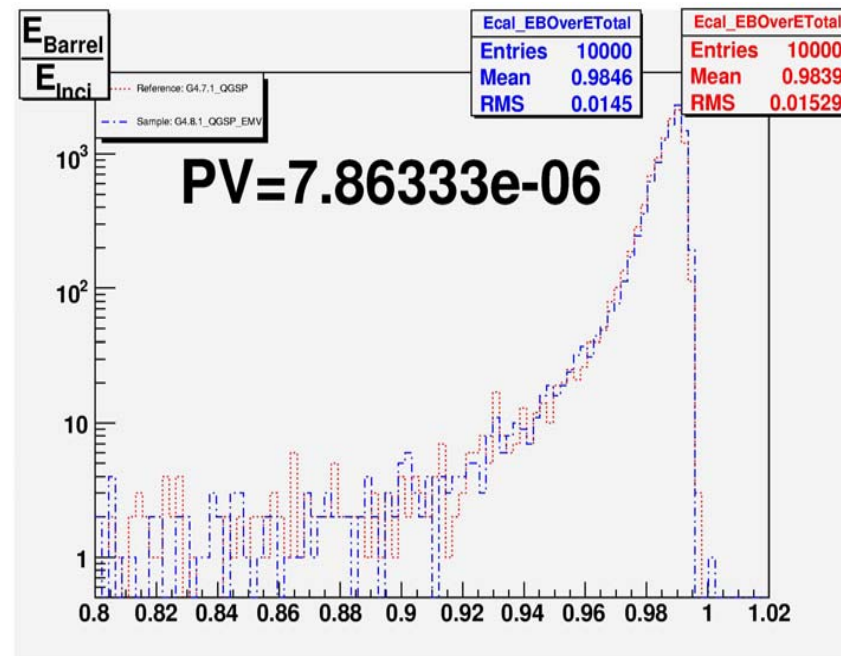


# Cluster Ratio in Barrel



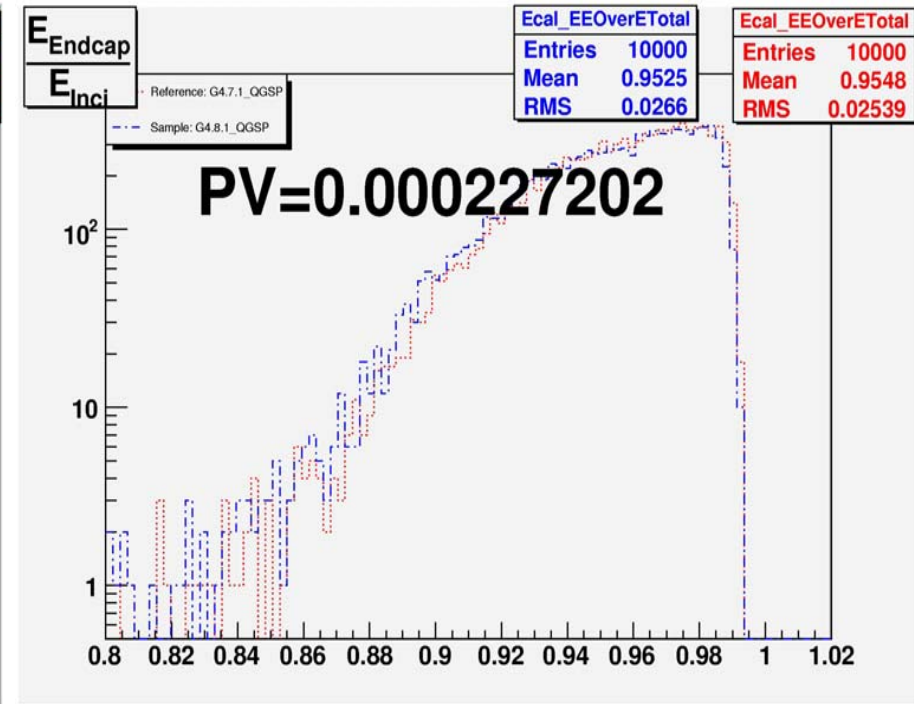
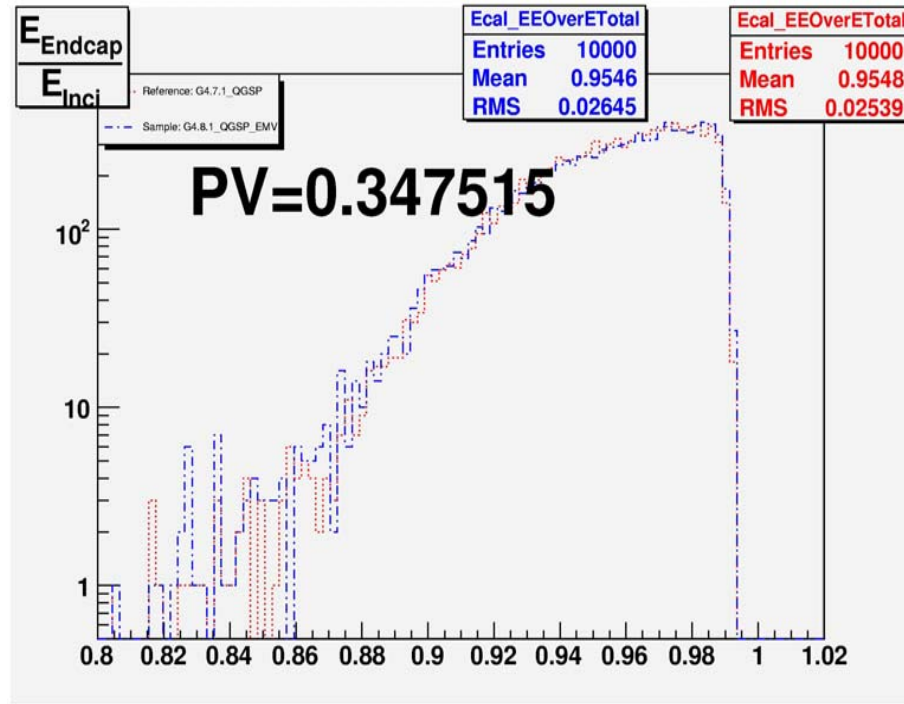
- G471\_QGSP: E1/E25 =0.6968
- G481\_QGSP\_EMV: E1/E25 =0.6933
- G481\_QGSP: E1/E25 =0.6905

# Percentage of energy deposited in EB



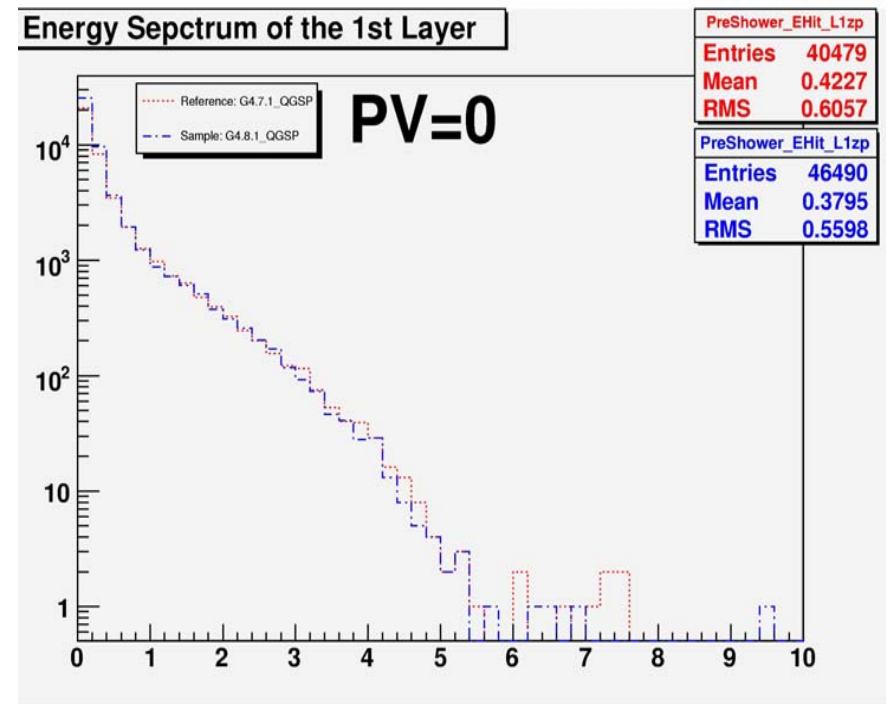
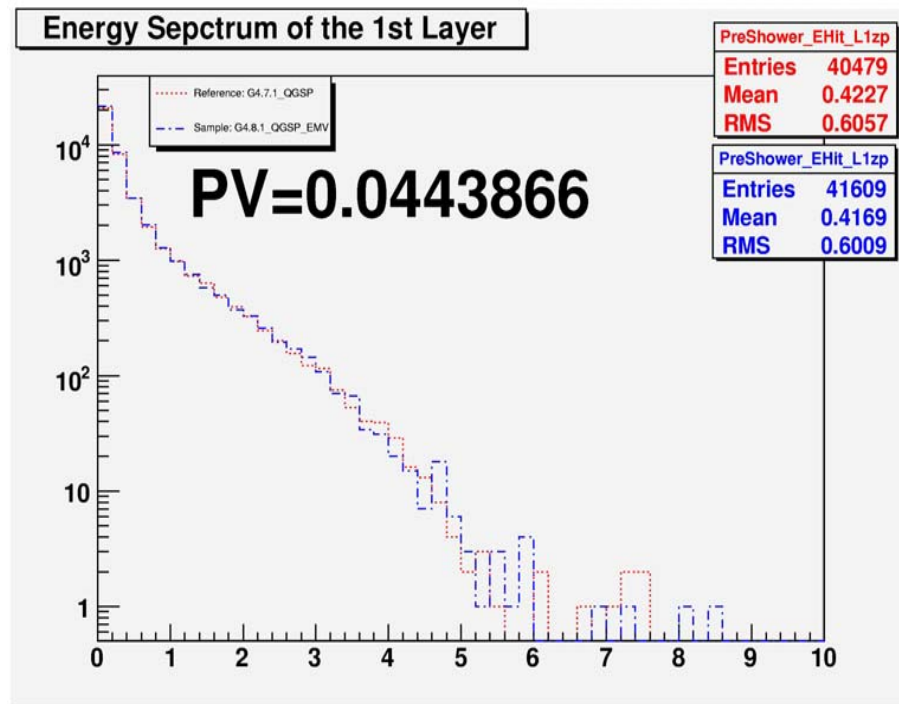
- $E_{\text{Inci}}=30$  GeV: Energy of incident particle.
- $E_{\text{Barrel}}$ : Energy deposited in Barrel.
- G481\_QGSP\_EMV: 98.46%
- G471\_QGSP: 98.39%
- G481\_QGSP: 98.34% (smallest)

# Percentage of energy deposited in EE



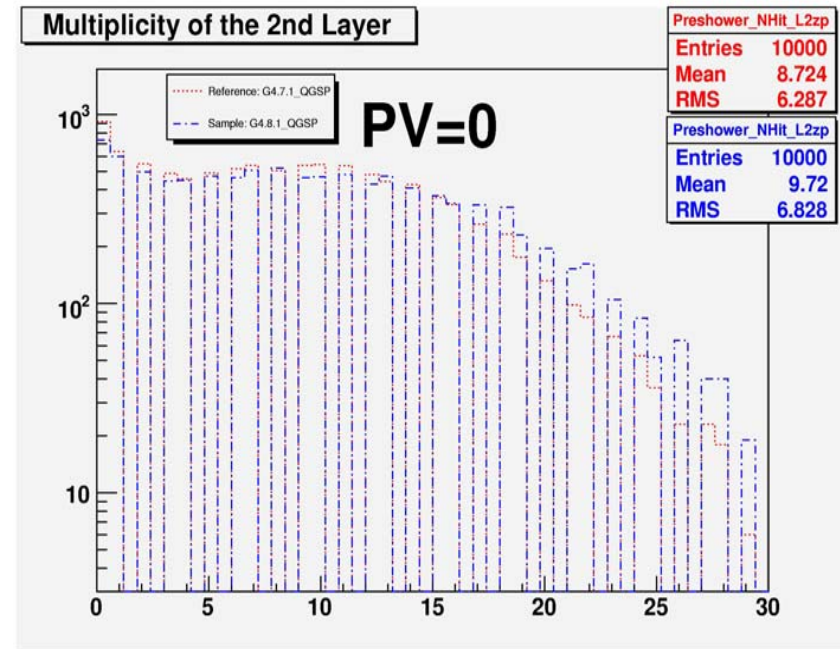
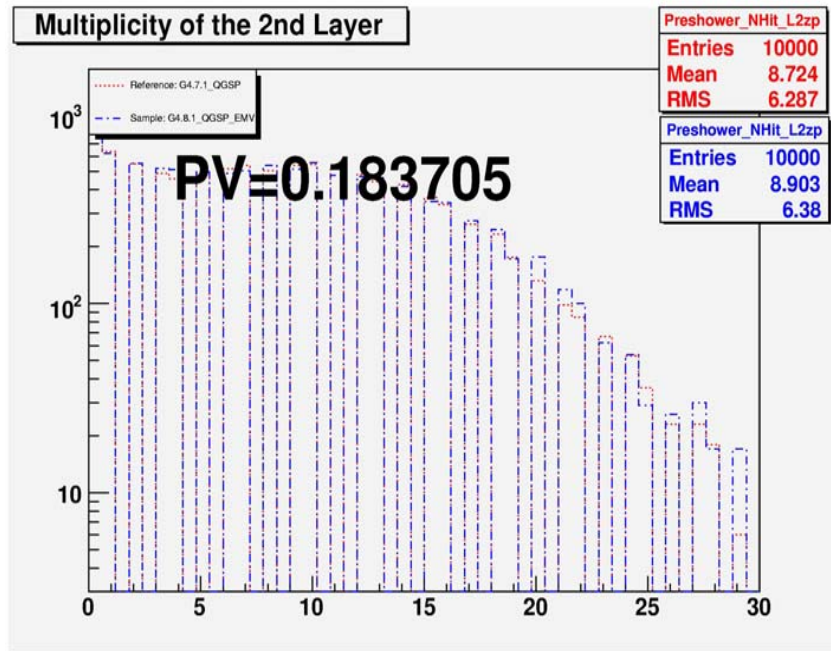
- $E_{\text{Inci}}=30$  GeV: Energy of incident particle.
- $E_{\text{endcap}}$ : Energy deposited in Endcap.
- G481\_QGSP\_EMV: 95.45%
- G471\_QGSP: 95.48%
- G481\_QGSP: 95.25% (smallest)

# Energy Deposit in 1<sup>st</sup> Layer of PreShower.



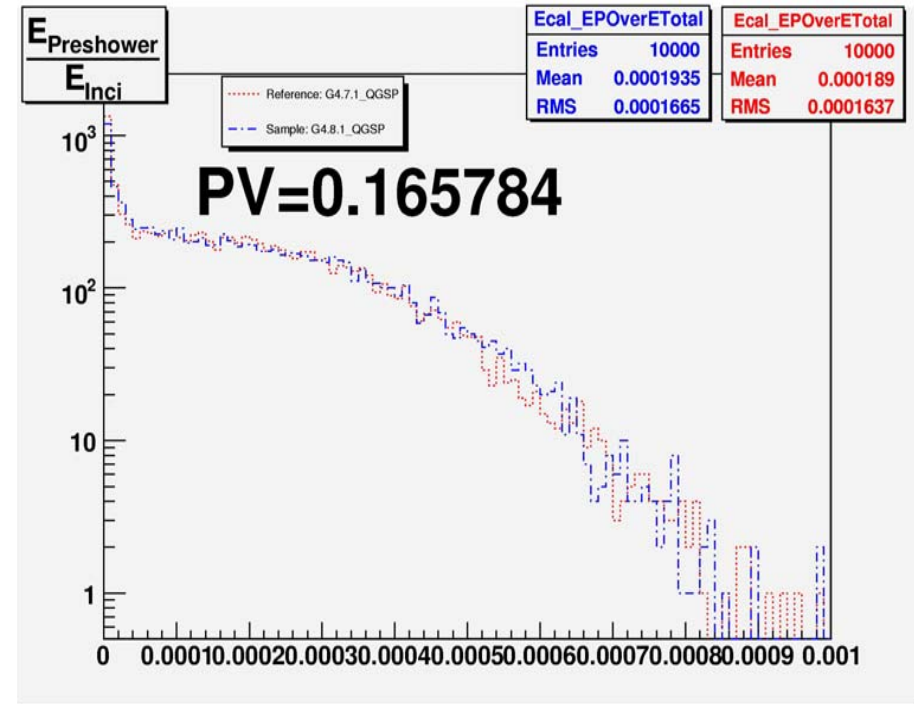
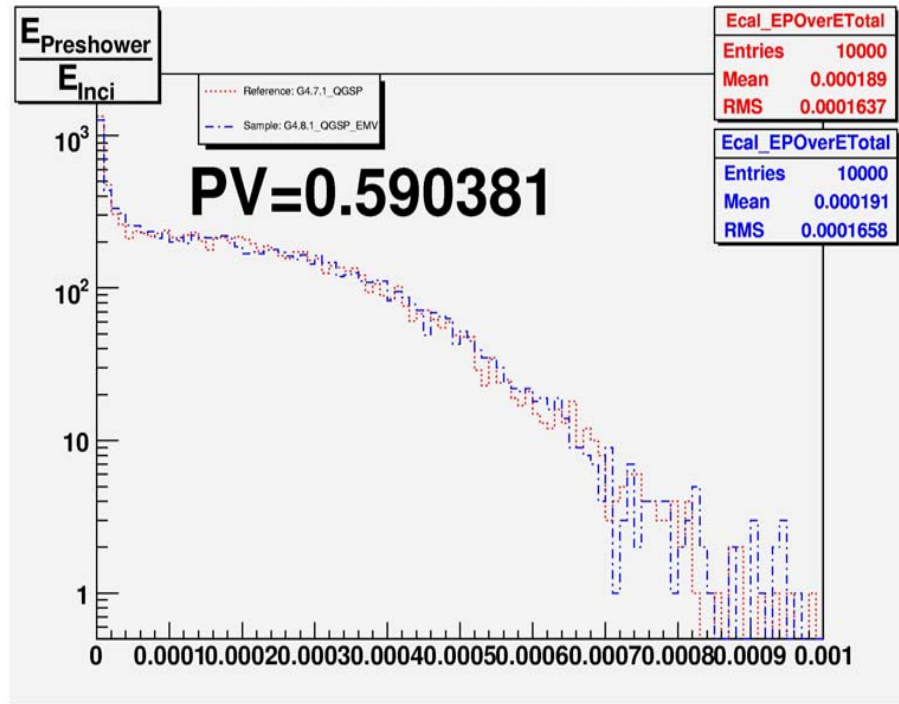
- The average energy of hits in Preshower:
  - G471\_QGSP: 0.4227 MeV
  - G481\_QGSP\_EMV: 0.4169 MeV
  - G481\_QGSP: 0.3795 MeV

# # Hits in the 2<sup>nd</sup> layer of Preshower



- The Average Hit Number in the 2<sup>nd</sup> Layer:
  - G471\_QGSP: 8.724
  - G481\_QGSP\_EMV: 8.903
  - G481\_QGSP: 9.72

# Percentage of energy deposited in ES



- Total energy deposited in the preshower detector is consistent among the 3 physics lists.

# Pions in the Calorimeter

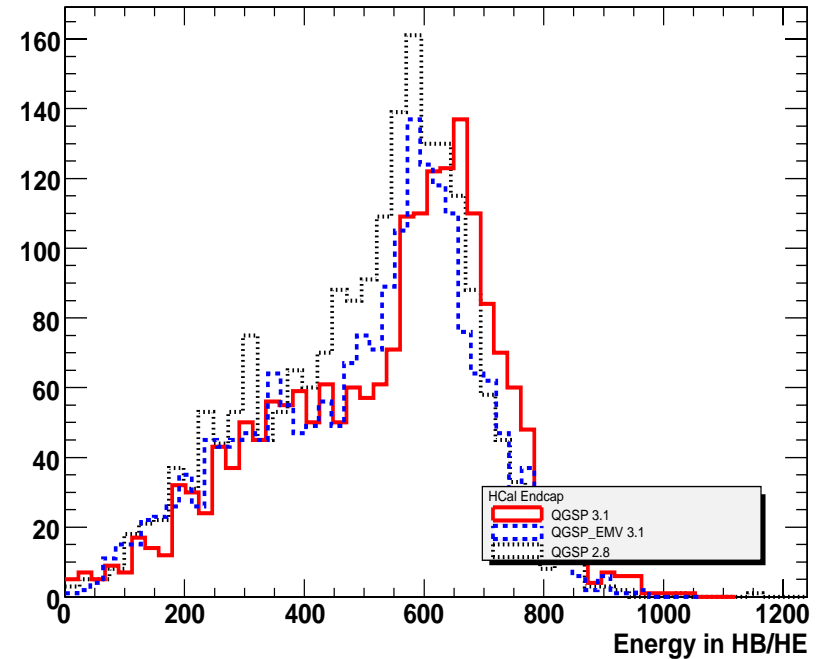
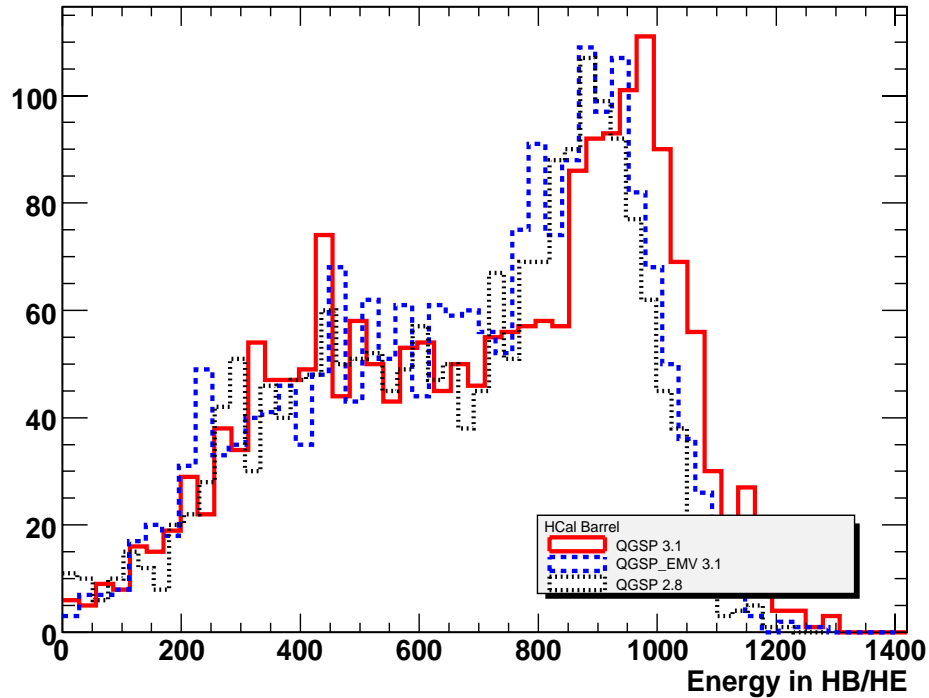


- Geometry used : Electromagnetic and Hadron calorimeter
- Event sample: 2000 pion events
- 100 GeV pions generated separately in the barrel ( $|\eta| \approx 0.3$ ) and the endcap ( $|\eta| \approx 2.1$ ) detectors with in a small  $\varphi$  window
- Process used: Particle Gun + Vertex Smear + G4 SimHit

Geant Version	Physics List	Barrel	Endcap
4.7.1.p02	QGSP 2.8	8.32 sec/event	7.44 sec/event
4.8.1.p01	QGSP 3.1	12.37 sec/event	10.19 sec/event
4.8.1.p01	QGSP_EMV	8.56 sec/event	7.29 sec/event



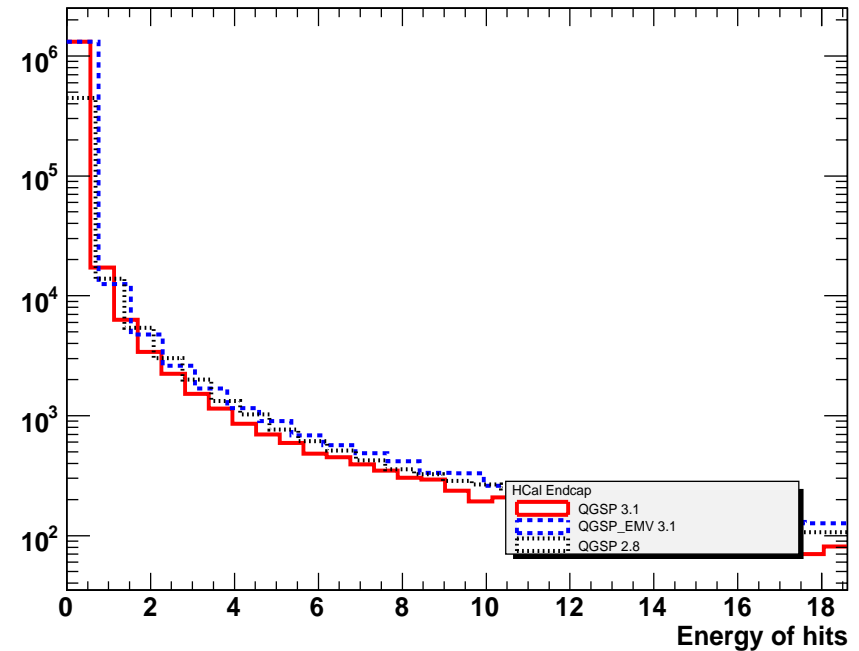
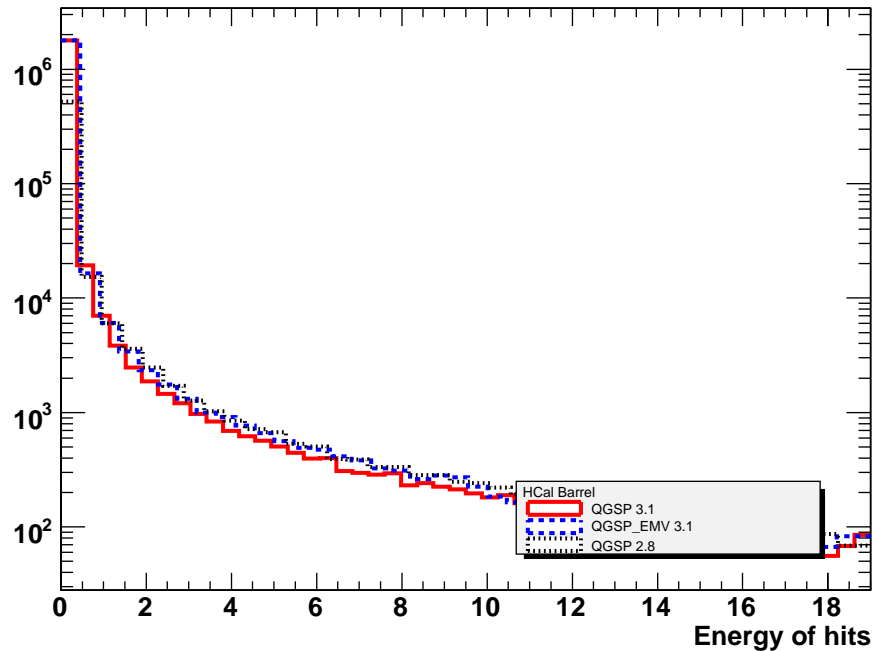
# Energy measured in HB and HE



- Geant 4.8.1 shows larger energy measurement (in particular the one with standard EM physics)
- Barrel and endcap show similar patterns

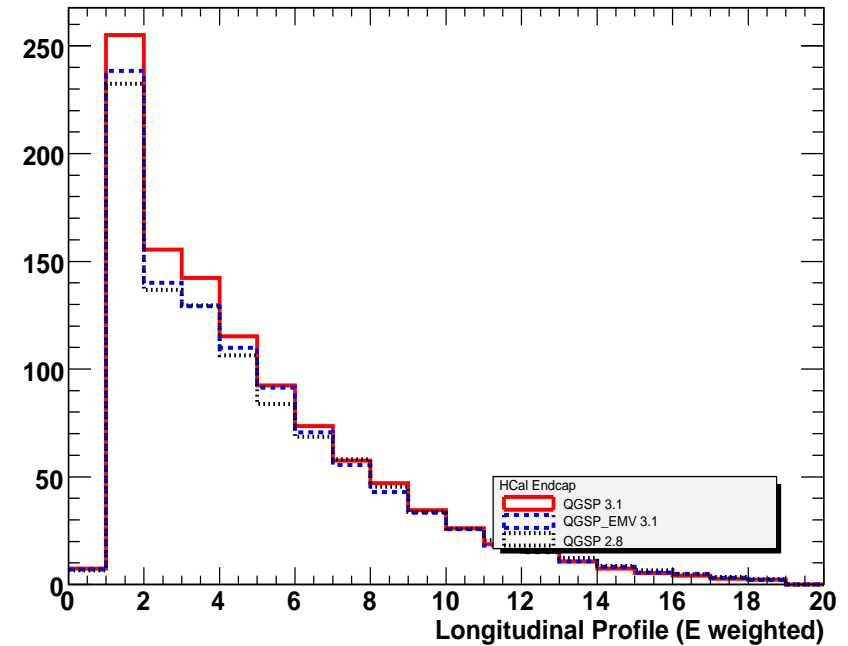
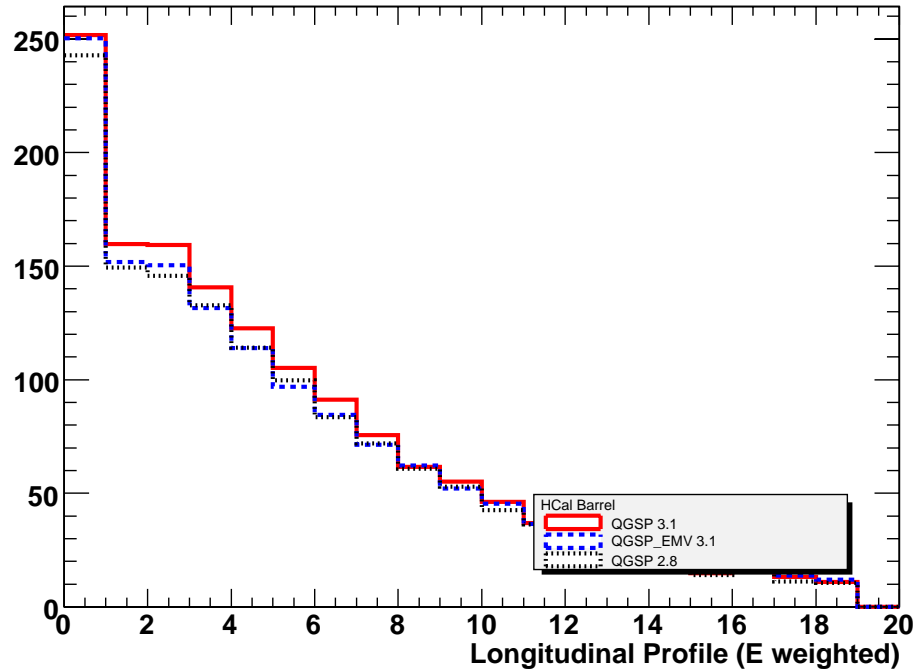


# Hit Energy in HB and HE



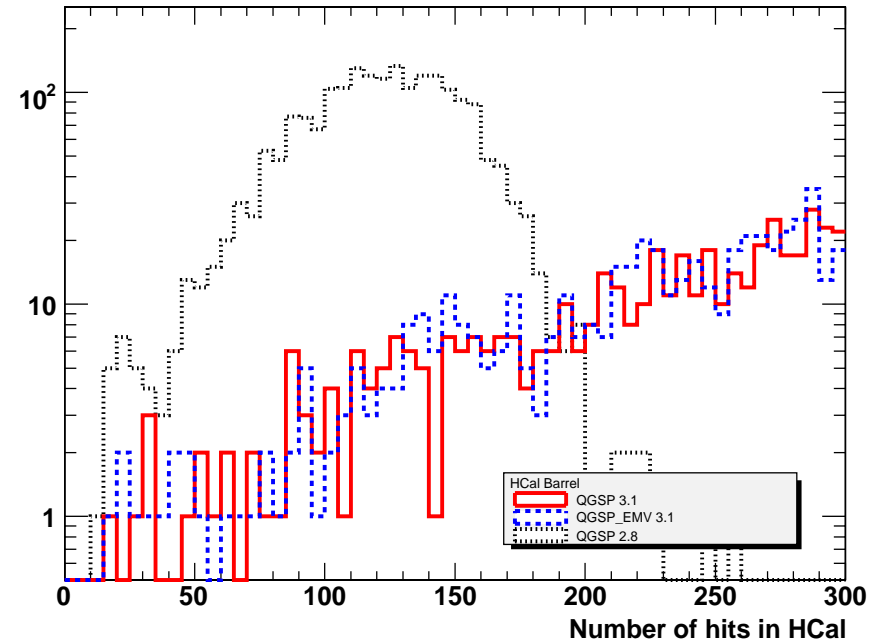
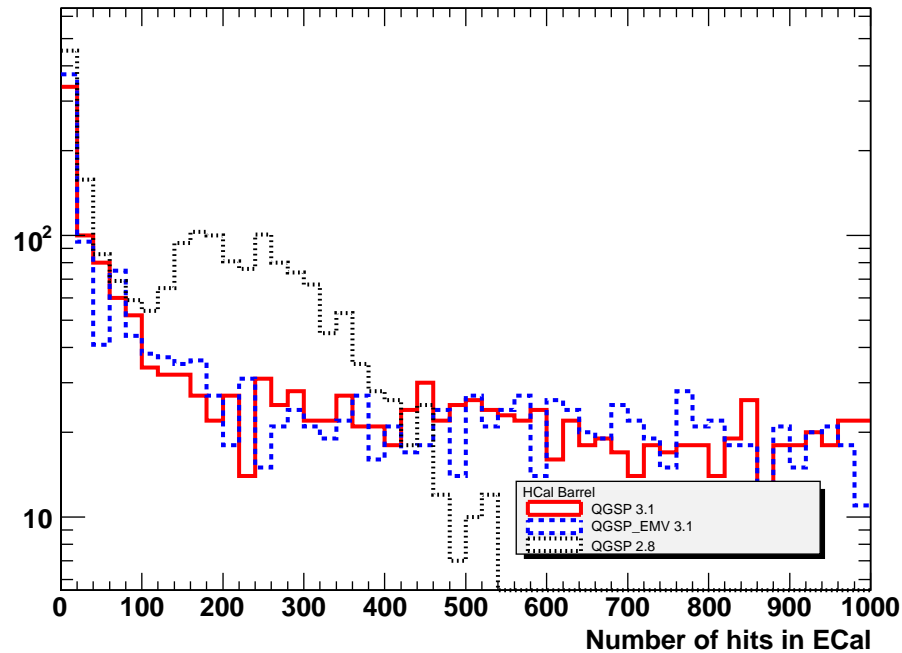
- Geant 4.8.1 shows softer spectrum for energy of individual hits
- This is a bit more pronounced with standard EM physics

# Longitudinal Shower Profile



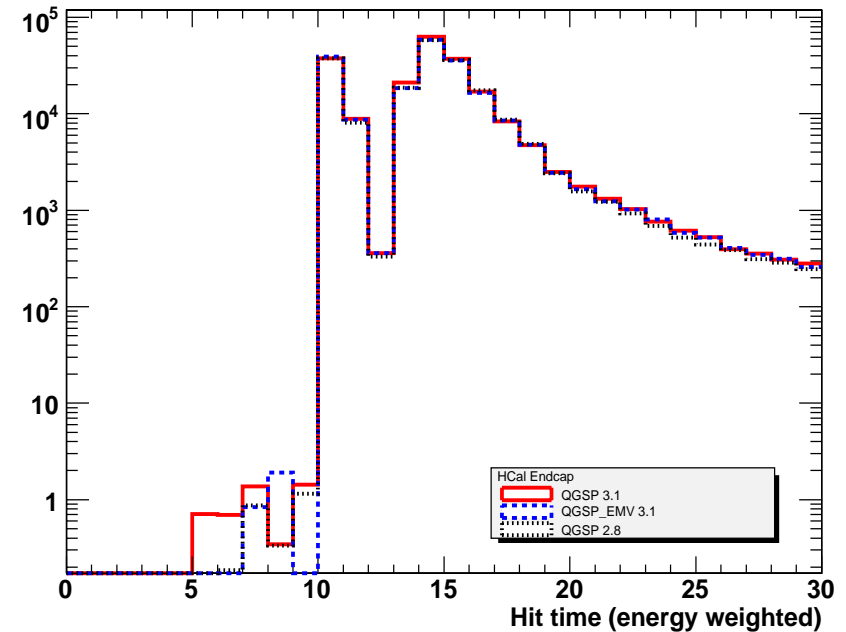
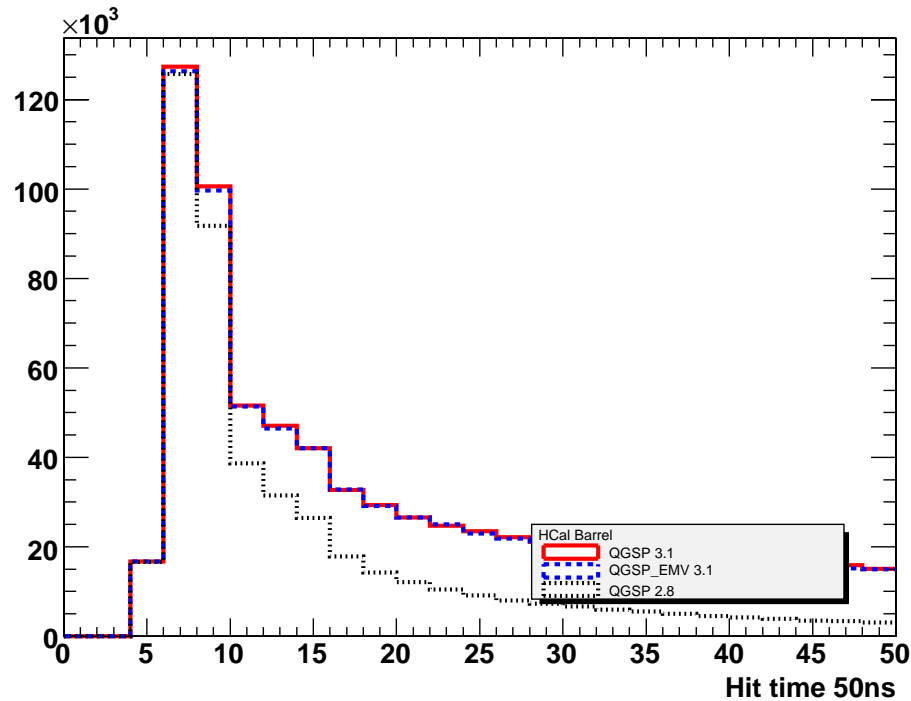
- The samples with Geant 4.8.1 show larger energy deposit in earlier layers but energy deposit in later layers are similar
- This enhancement is more pronounced with QGSP 3.1
- Barrel and endcap show similar patterns

# Number of Hits



- There are more hits in ECal as well as in HCal in the Geant 4.8.1 version
- A similar trend is observed for the endcap (not shown)

# Time Profile of Hits



- The extra hits in Geant 4.8.1 appear at a later time
- After energy weighting the time profiles are similar

# Summary and Outlook



- Tracker sees fewer hits in the version 4.8.1 for electrons (more study is being done to understand what happens)
- Transverse shower profile for photons in crystals is similar between QGSP 2.8 (4.7.1) and QGSP\_EMV (4.8.1). QGP 3.1 (4.8.1) shows slightly broader profile
- Longitudinal shower profile for hadrons show larger energy deposit at smaller depth but energy deposits at larger depths are similar
- Hit multiplicity in the showers increase (for both photons and pions). Average hit energy is smaller in the new version. The extra hits appear more at later time
- CMS has collected data with identified particle beams in 2006 and these data will be used to tune Geant4 physics in coming months