CALICE Meeting September 2008

Analysis of pion showers in the ECAL from CERN Oct 2006/2007 Data

– Status report –

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University of Cambridge

Introduction

- How much can we learn about hadronic showers using the ECAL alone?
  - Few showers are confined in the ECAL. But many start in the ECAL, so it's important to understand showers in the ECAL as well as the HCAL.
  - ECAL offers good spatial resolution – possibility to study properties of the primary interaction in some detail.
  - We do, by now, understand the behaviour of the ECAL data c.f. Monte Carlo, pretty well for electromagnetic processes.

Summary of data

- Reconstructed data

Energy	Pion	2006	2007
8 GeV	-	run300663	run330641
30 GeV	+	run300696	run331298
80 GeV	+	run300694	run331324

- GEANT4 simulations

Mokka version 6.3 p02 with physics lists...

- QGSP_BERT

  Theory based quark-gluon string model with Bertini Cascade model

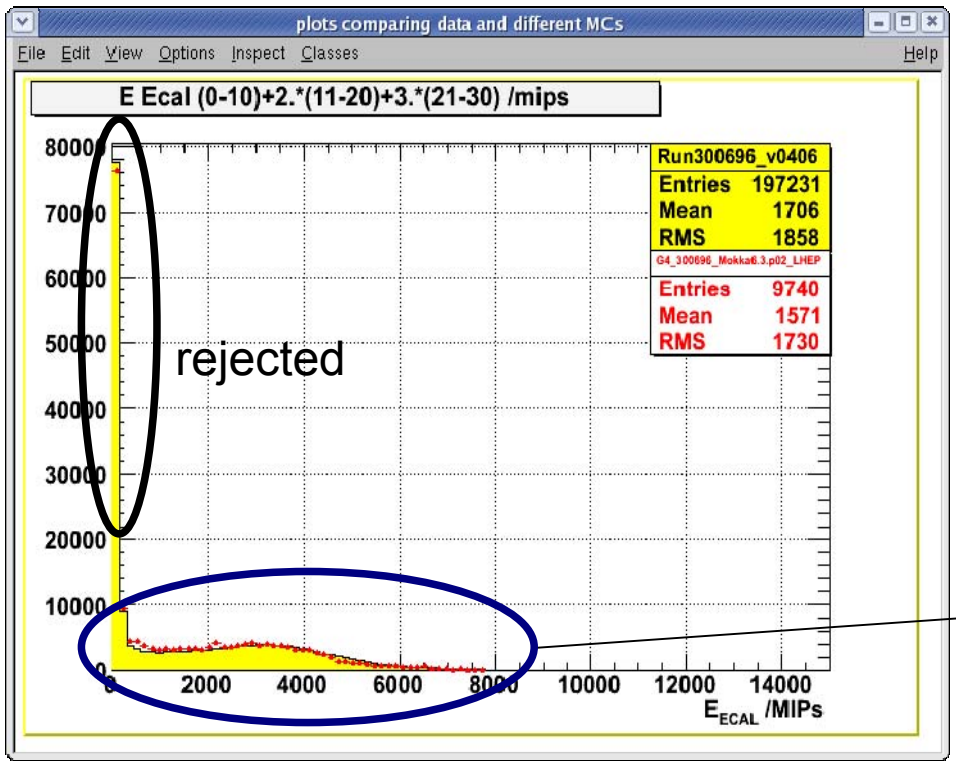
- LHEP

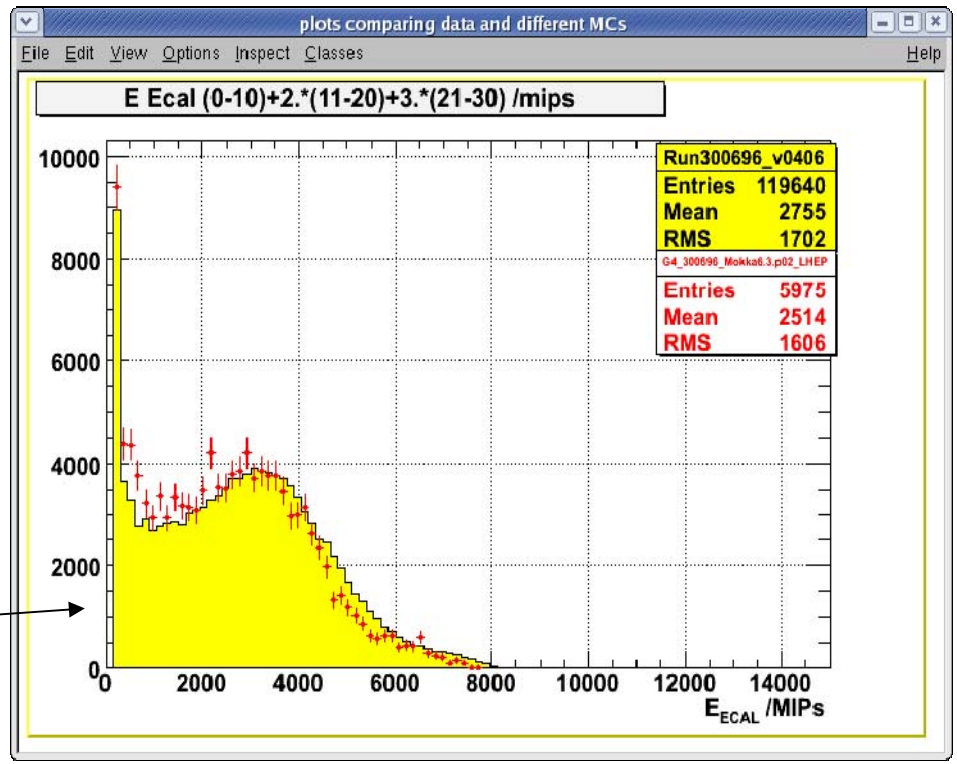
  Commonly used parametrised model

- LCPhys

  hybrid model, containing mainly models in QGSP_BERT and LHEP

Event Selection – Muon rejection

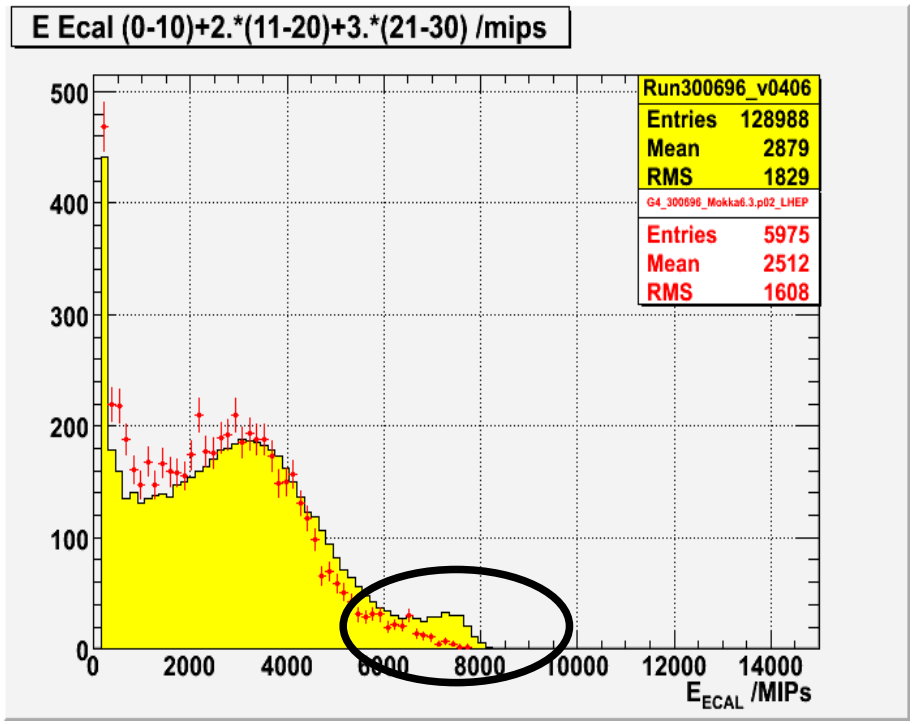




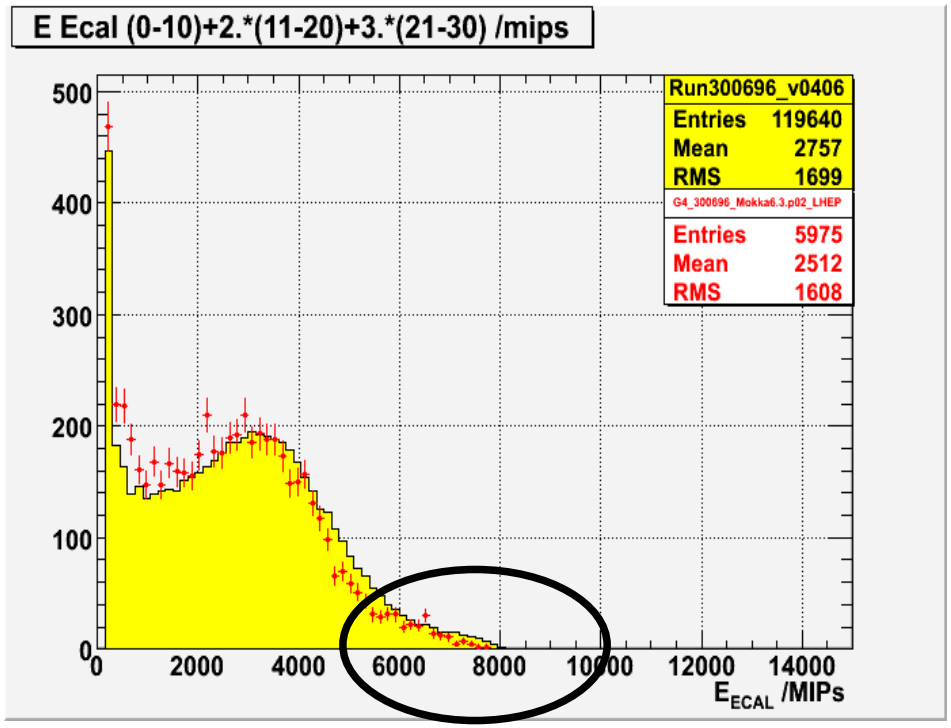
Low energy events are rejected to eliminate events which did not interact with ECAL (muons and non-interacting pions).

Event Selection – Electron rejection

30 GeV – data c.f. Monte Carlo



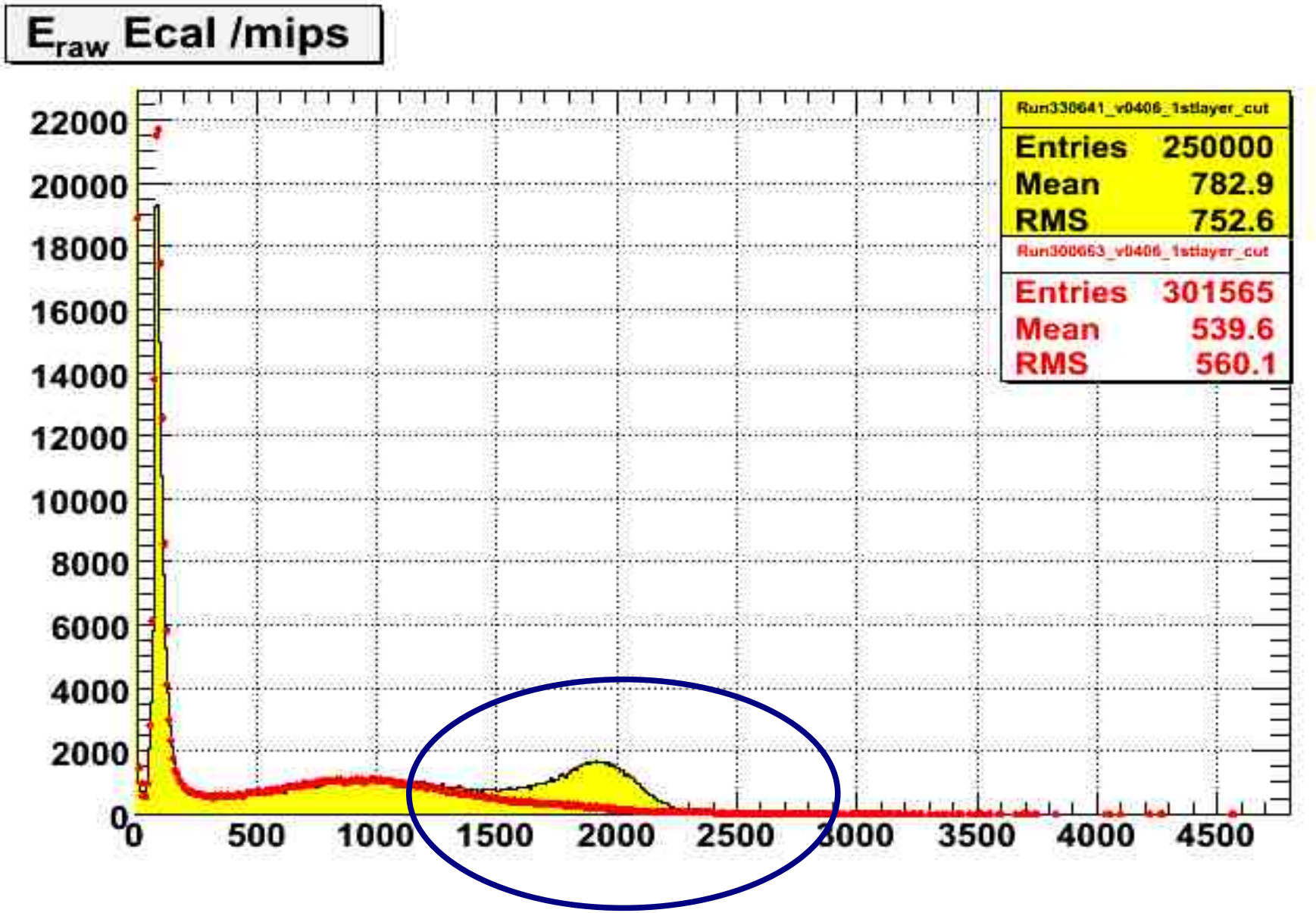
Before the Cut



After the Cut

Events with Cherenkov radiation, which are set to distinguish electrons from rest of the beam, are eliminated.

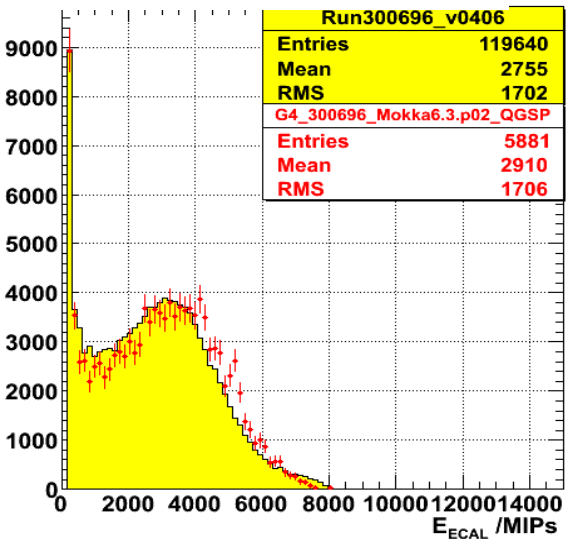
More Electron Events in low energy 2007 runs



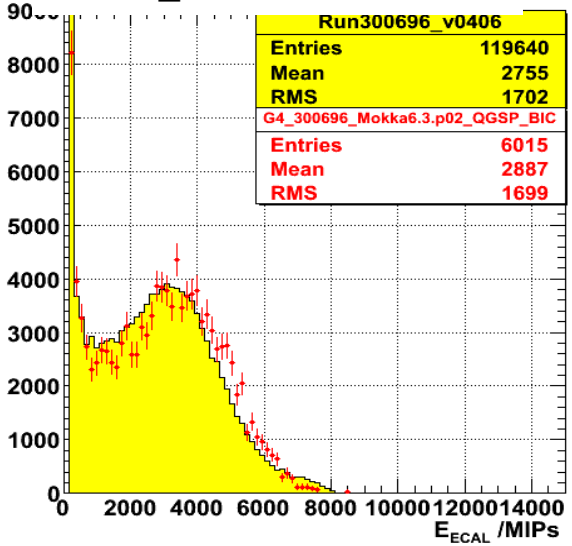
Run300696 (30GeV) vs Simulations

Total Energy Dissipated on ECAL

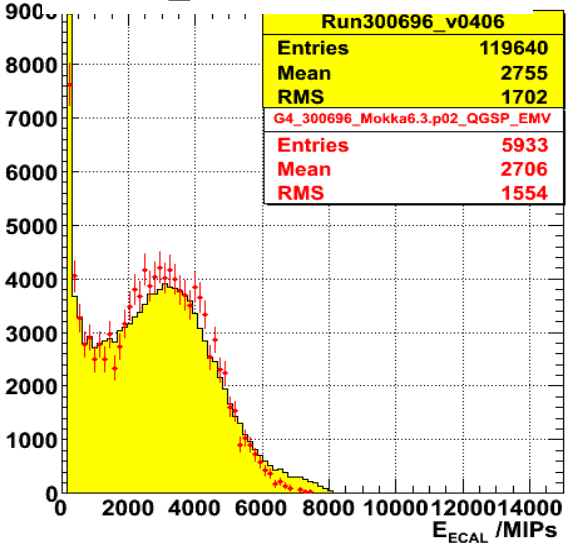
QGSP



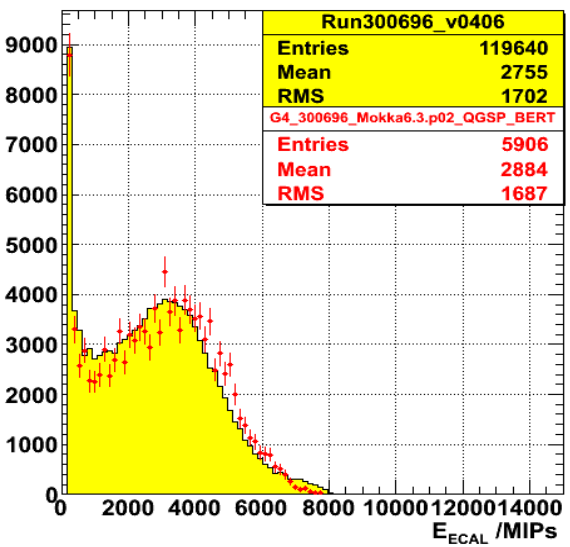
QGSP_BIC



QGSP_EMV



QGSP_BERT



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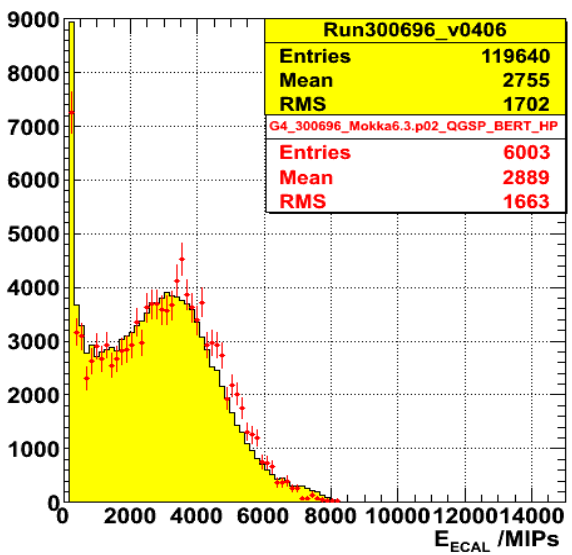
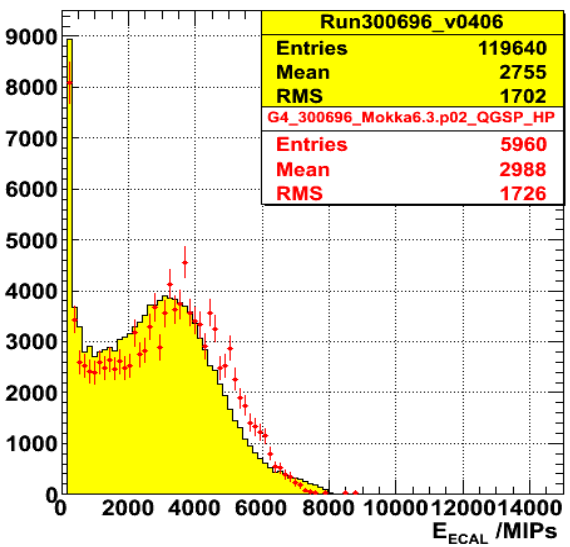


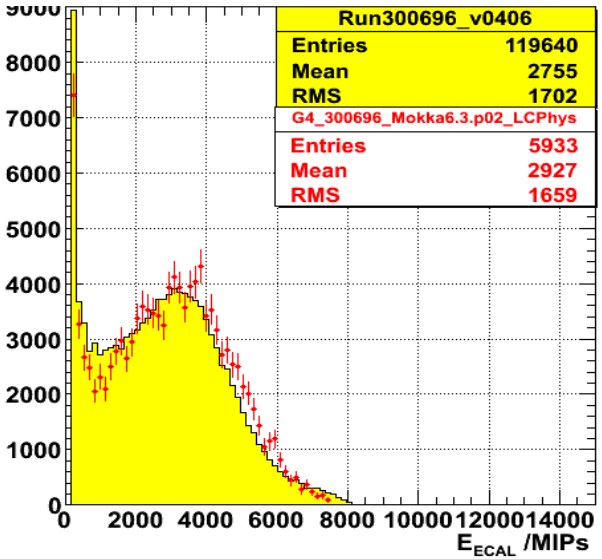
QGSP_HP



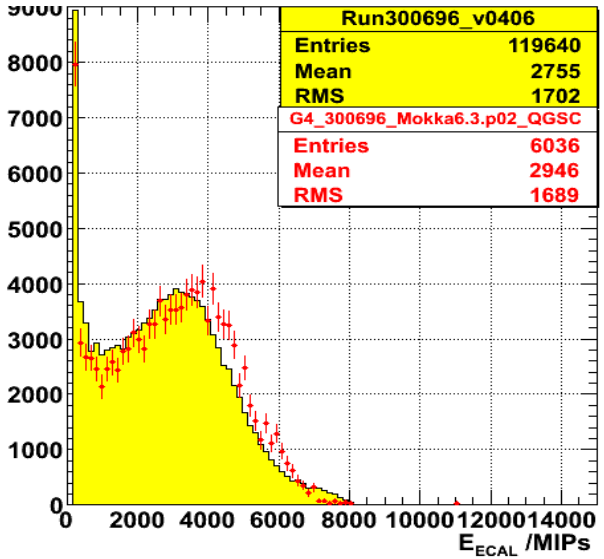
Run300696 (30GeV) vs Simulations

Total Energy Dissipated on ECAL

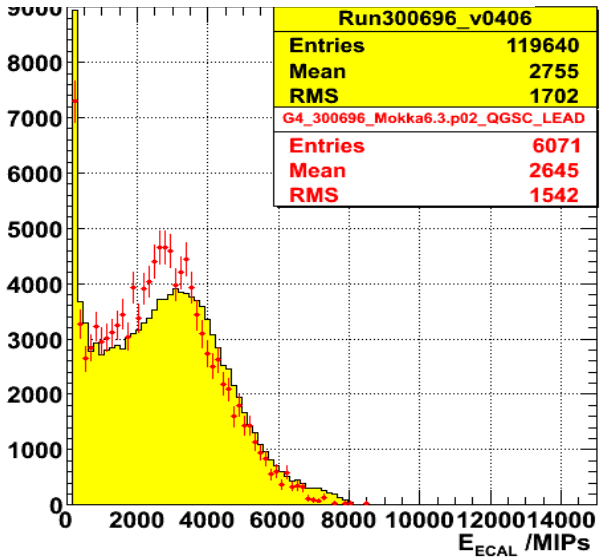
LCPhys



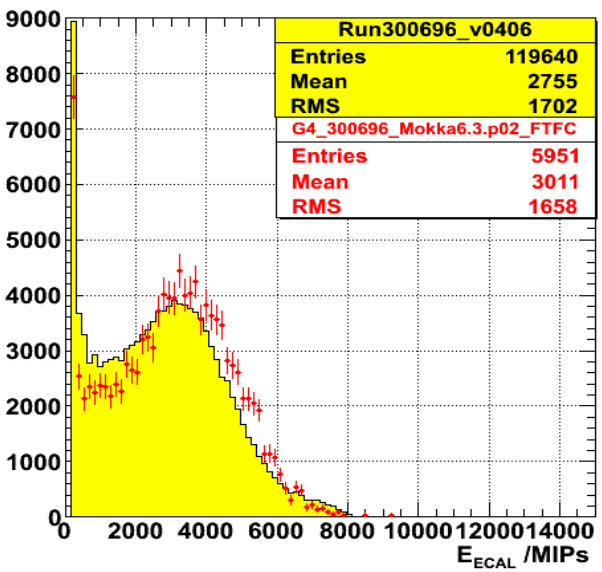
QGSC



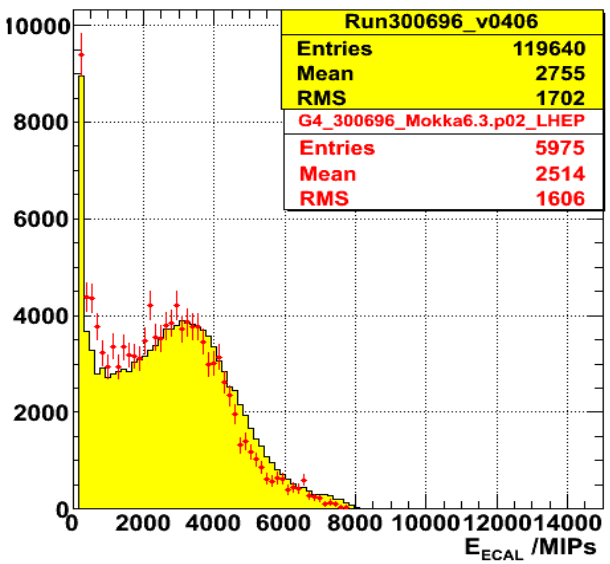
QGSC_LEAD



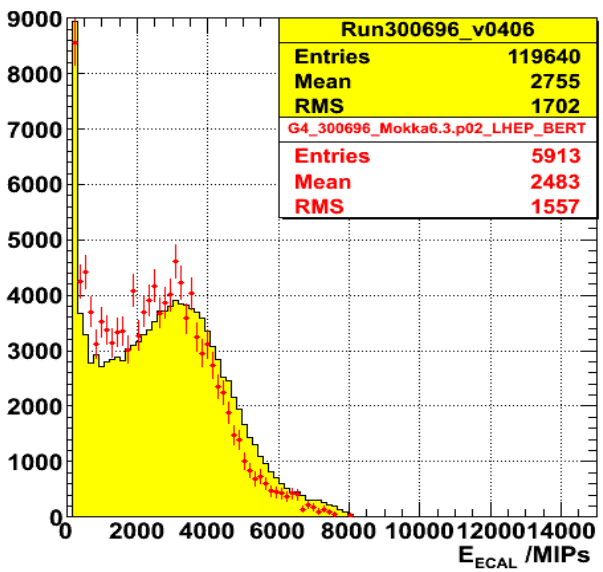
FTFC



LHEP



LHEP_BERT



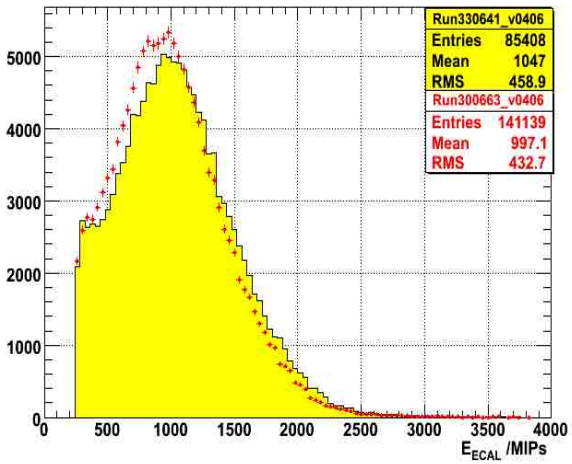
Before and after the radius-cut on 2006 and 2007 Data – Total Energy Deposited

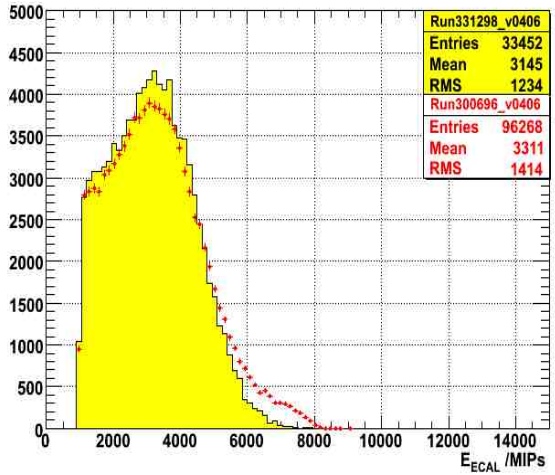
8 GeV -ve pion

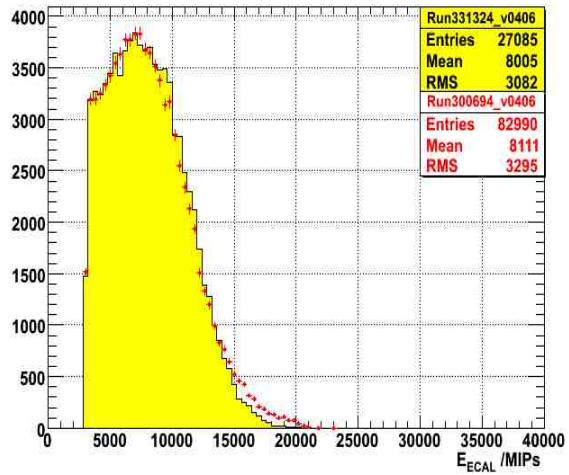
30 GeV +ve pion

80 GeV +ve pion

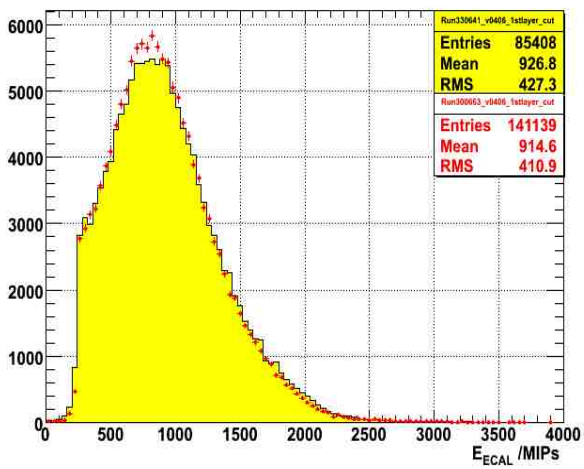
Before removing hits at r > 50mm

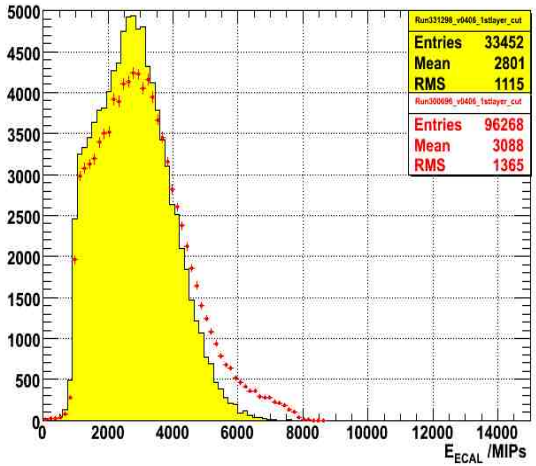


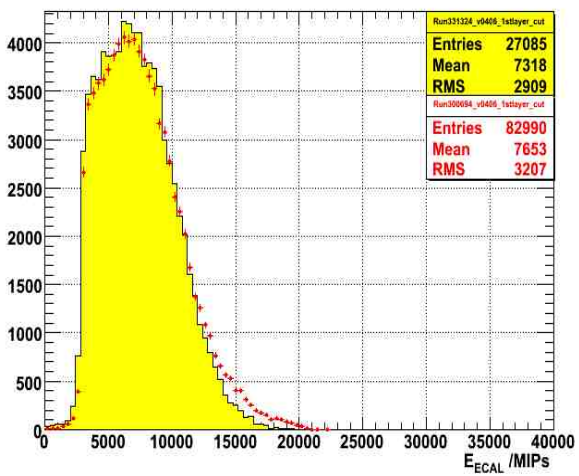




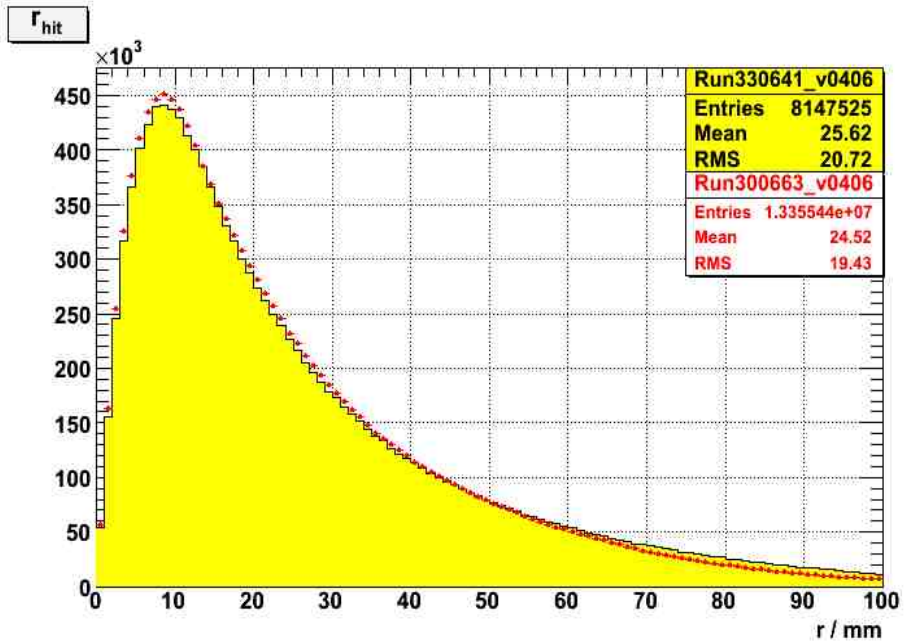
After removing hits at r > 50mm

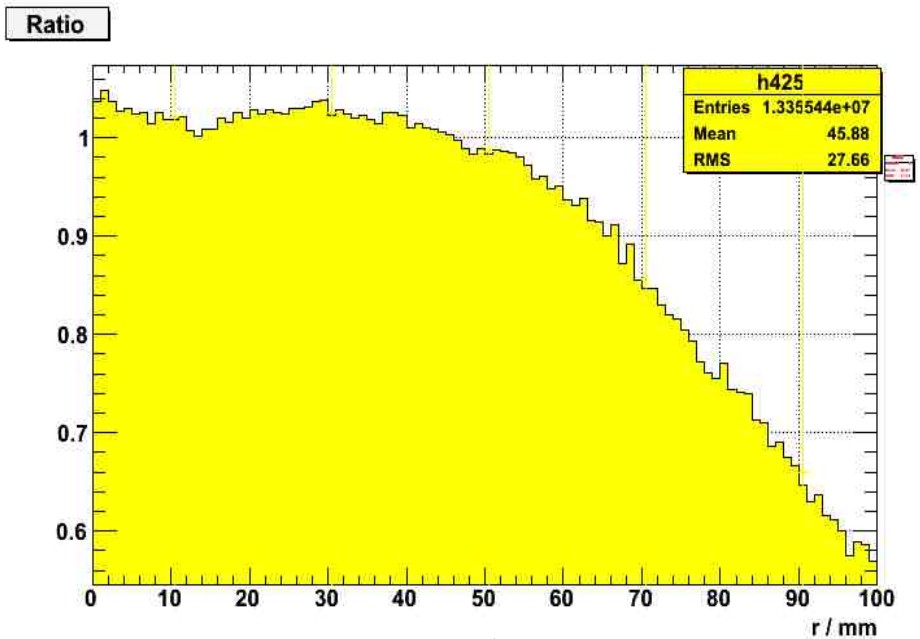






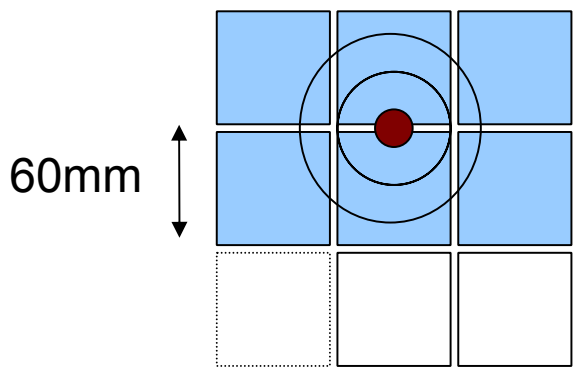
Event Selection – cut on hit radius



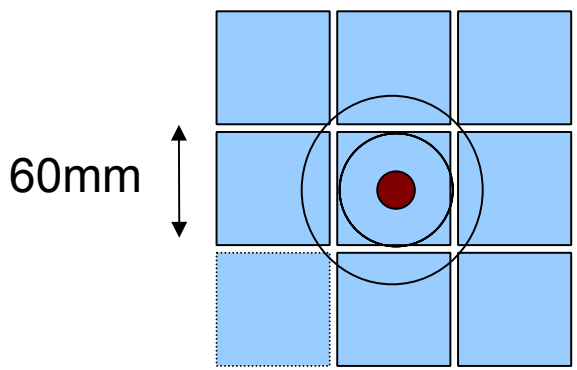


Clear decline in ratio at 50mm

2006 ECAL – 6 wafers



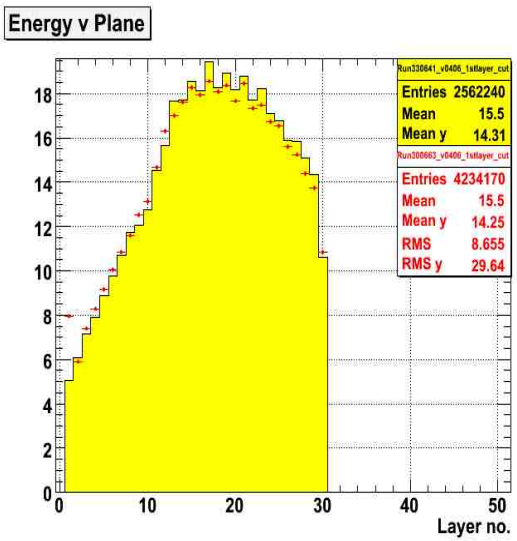
2007 ECAL – 9 wafers (mostly)

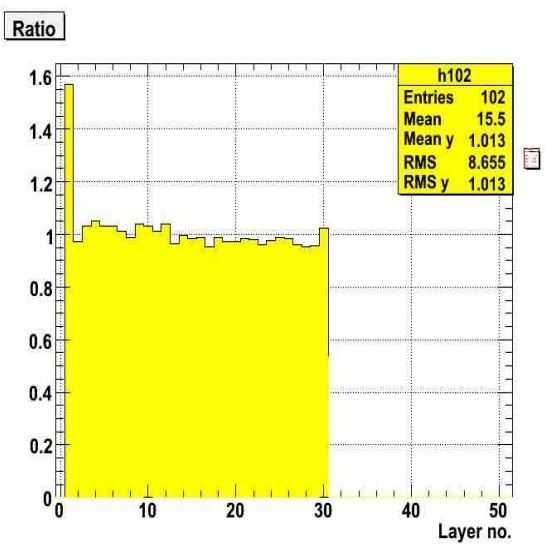


2007 vs 2006

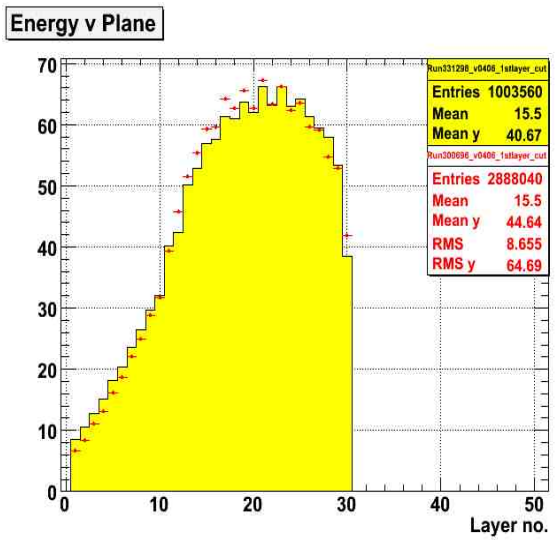
Longitudinal Energy Distribution

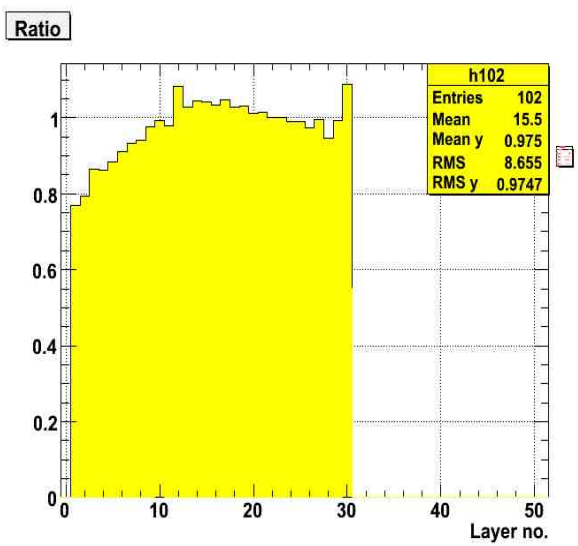
8GeV -ve Pion



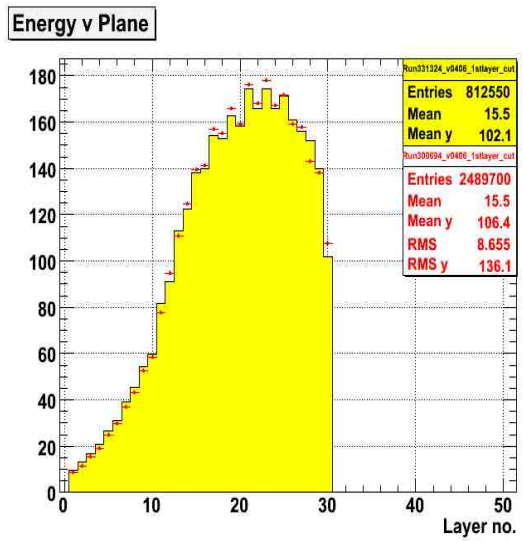


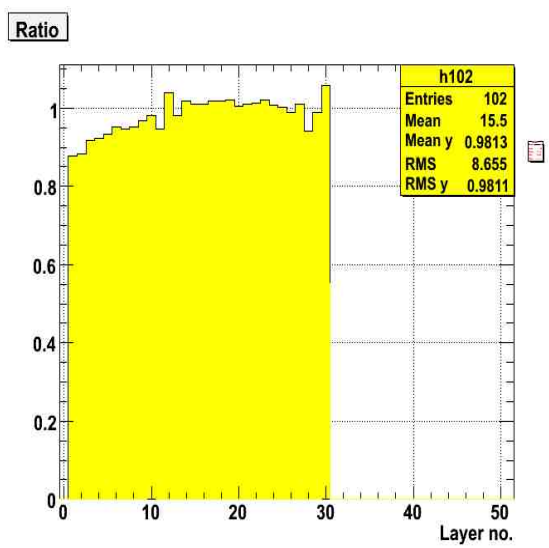
30GeV +ve Pion





80GeV +ve Pion

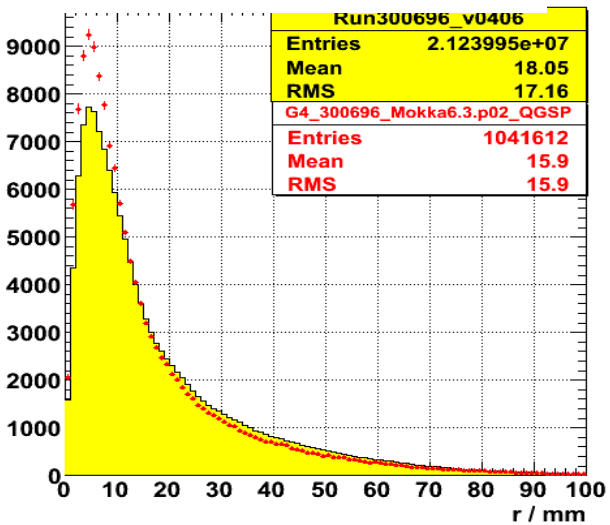




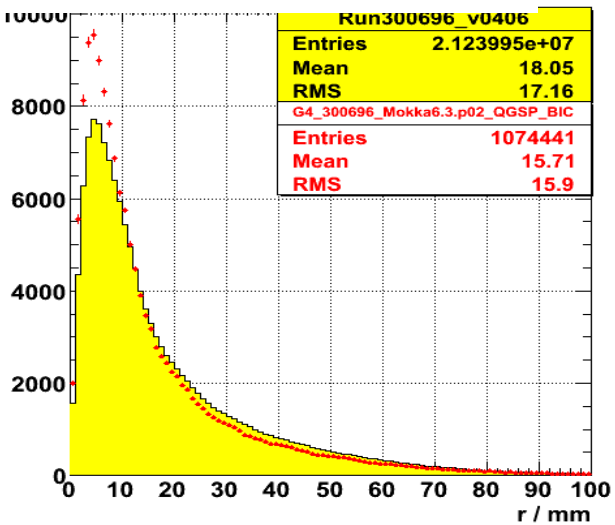
Run300696 vs Simulations

Radial Energy Distribution

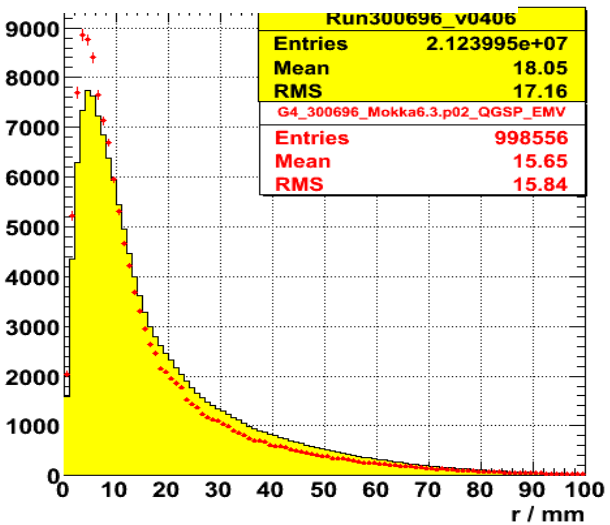
QGSP



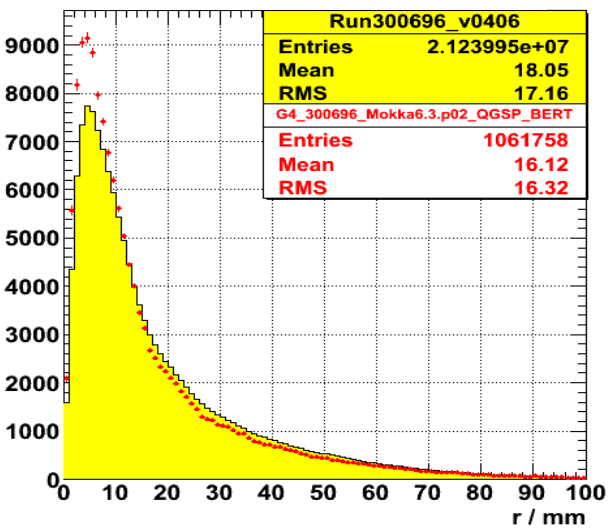
QGSP_BIC



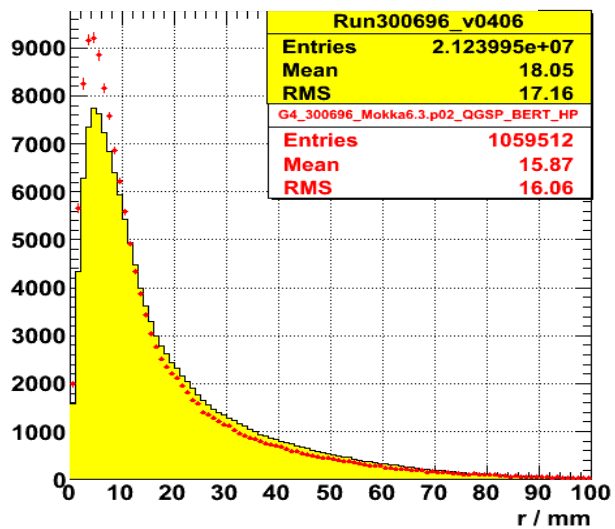
QGSP_EMV



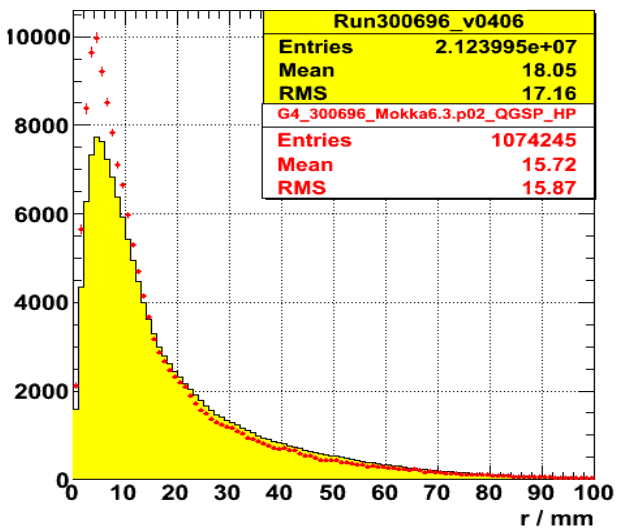
QGSP_BERT



QGSP_BERT_HP



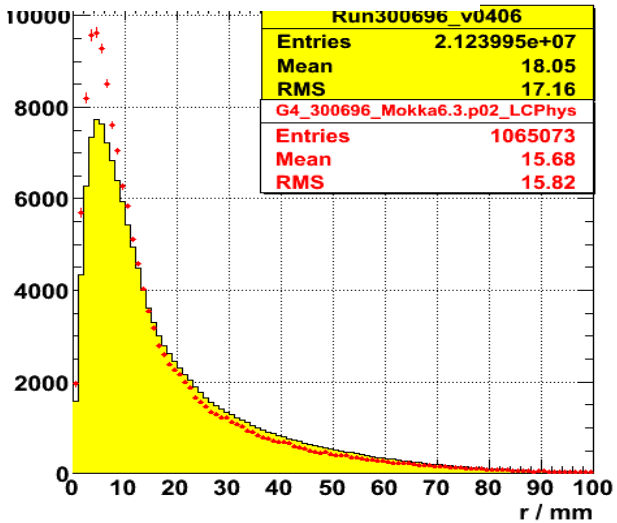
QGSP_HP



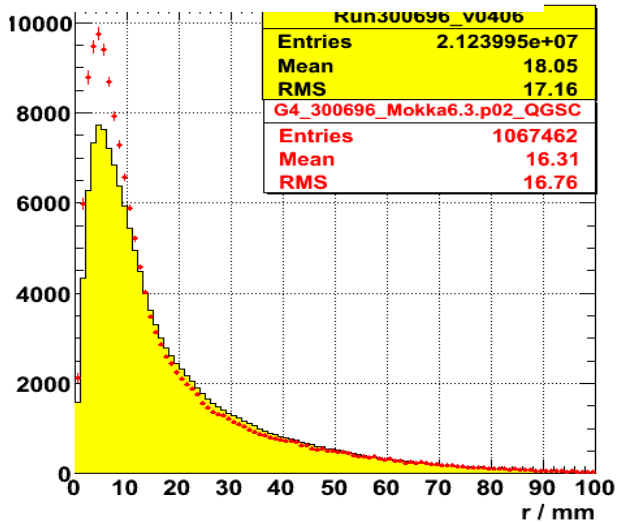
Run300696 vs Simulations

Radial Energy Distribution

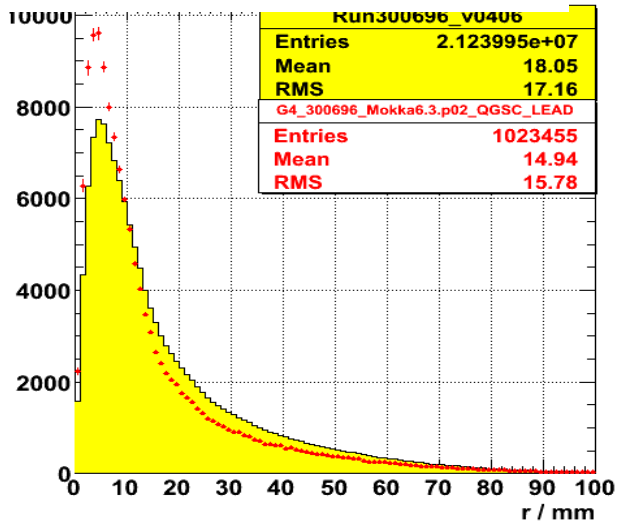
LCPhys



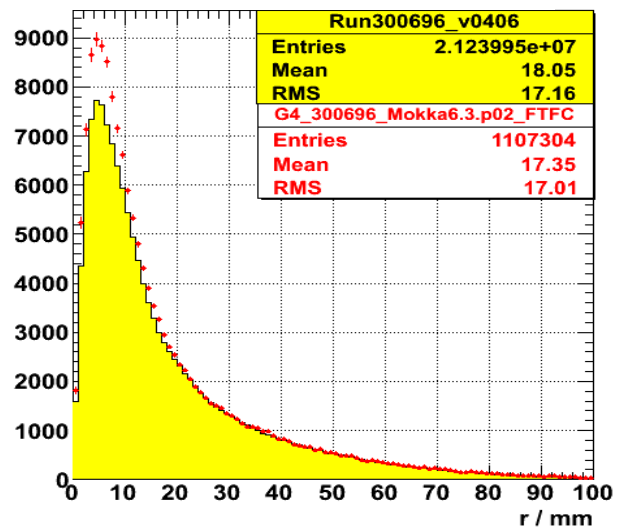
QGSC



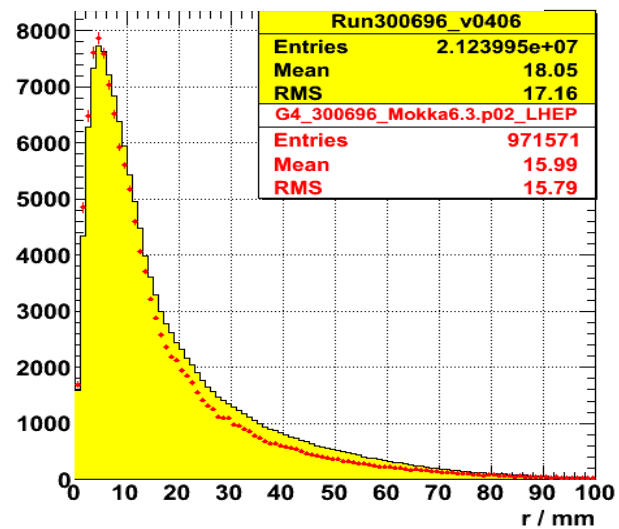
QGSC_LEAD



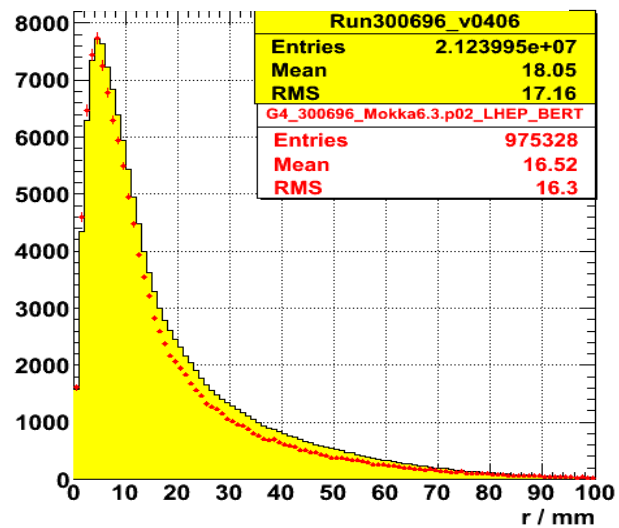
FTFC



LHEP



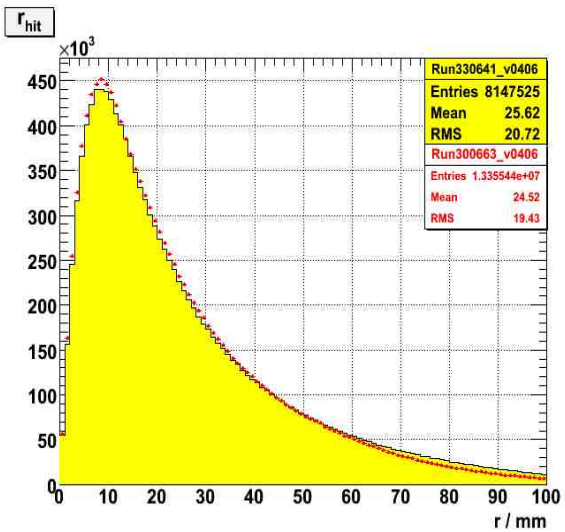
LHEP_BERT

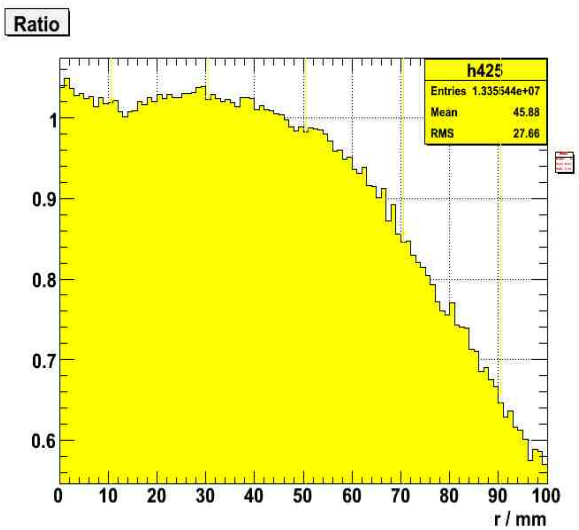


2007 vs 2006

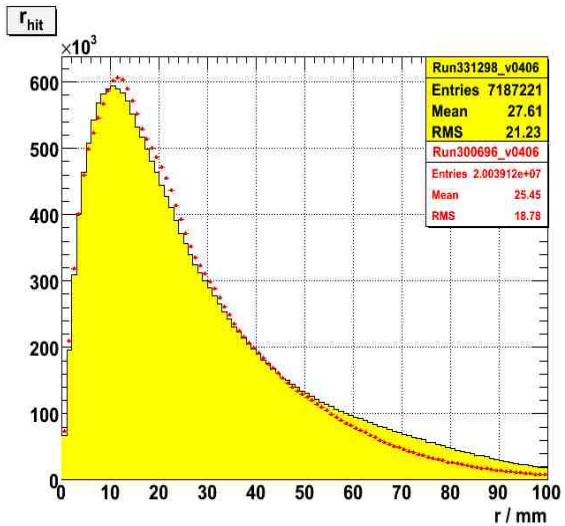
Radial Energy Distribution

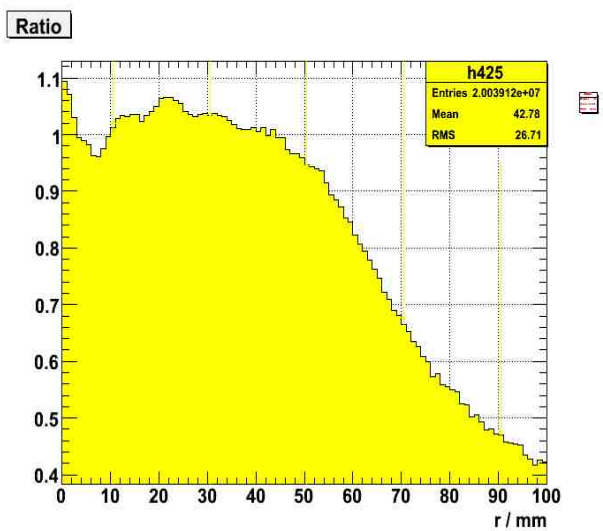
8 GeV -ve Pion



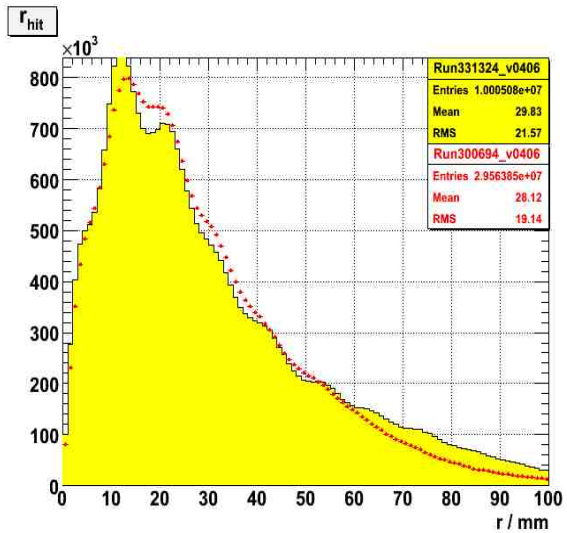


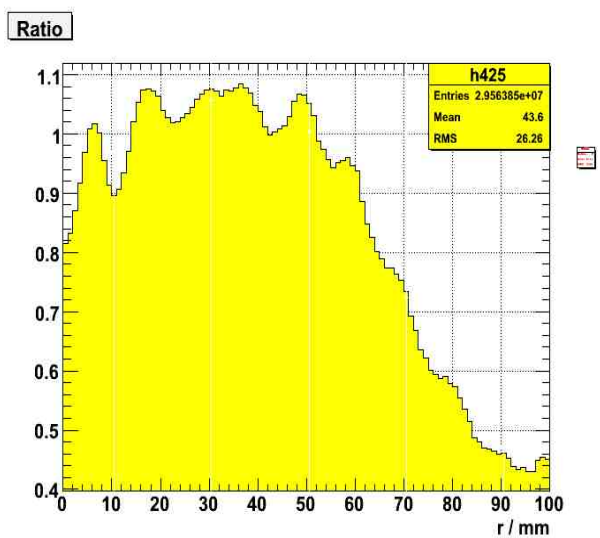
30 GeV +ve Pion



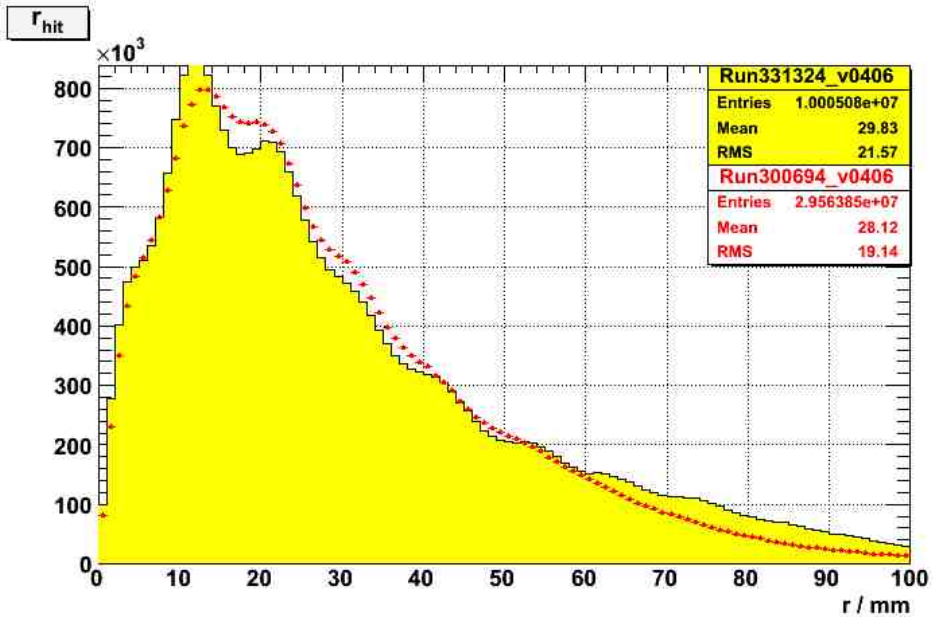


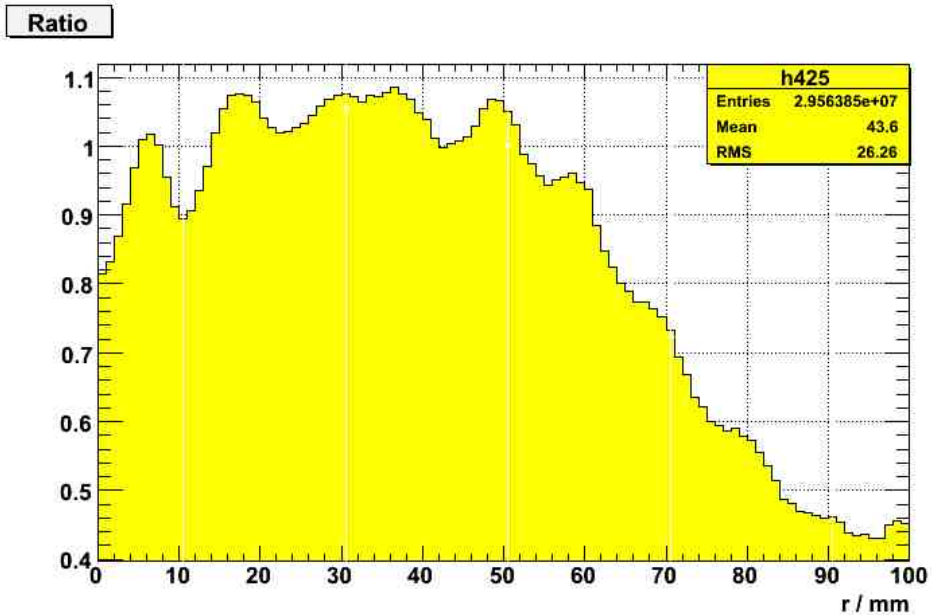
80 GeV +ve Pion





Oscillatory behaviour in transverse distribution (at higher energy runs)





80GeV +ve Pion

- Sinusoidal pattern with period 10mm
- Corresponds to size of 6x6 pads in a wafer
- 2007 runs have bigger amplitude

Possible Solution

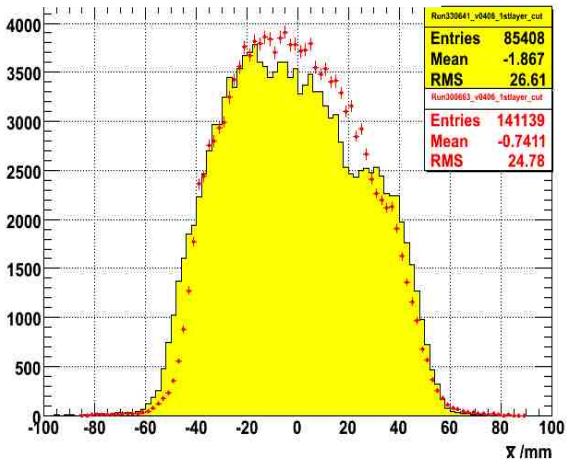
2006 and 2007 Data – beam shape

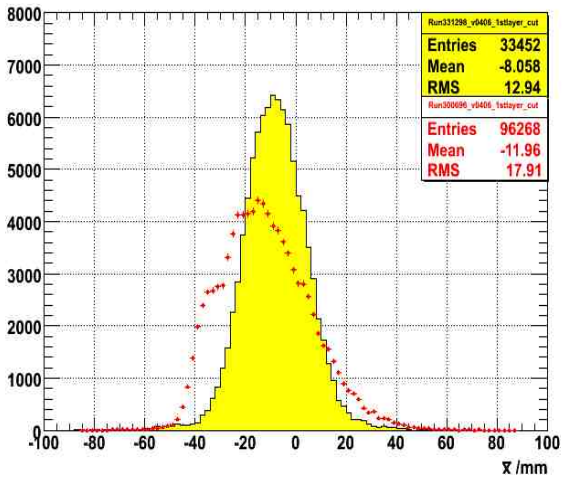
8 GeV -ve pion

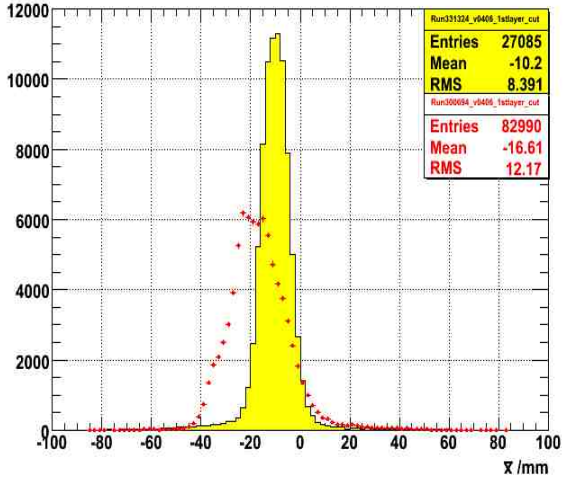
30 GeV +ve pion

80 GeV +ve pion

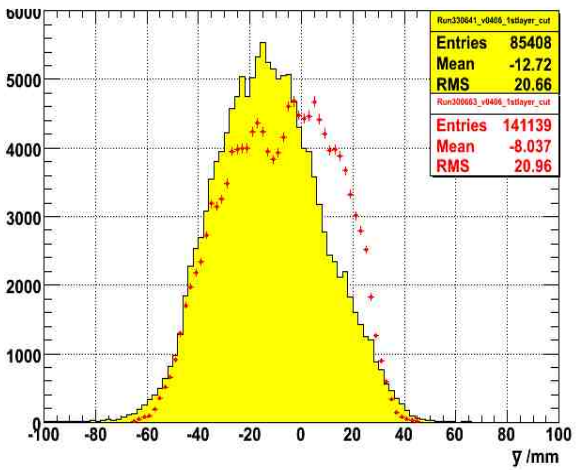
Average X position

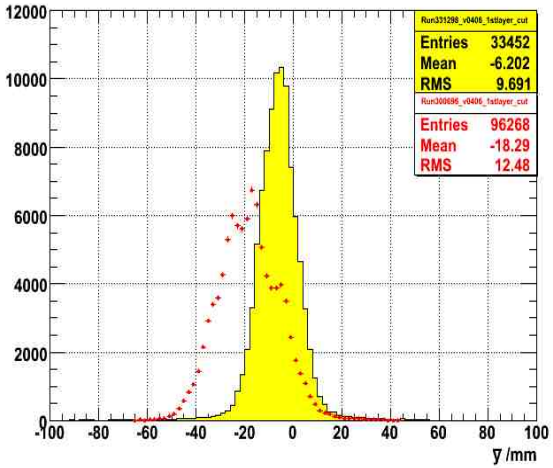


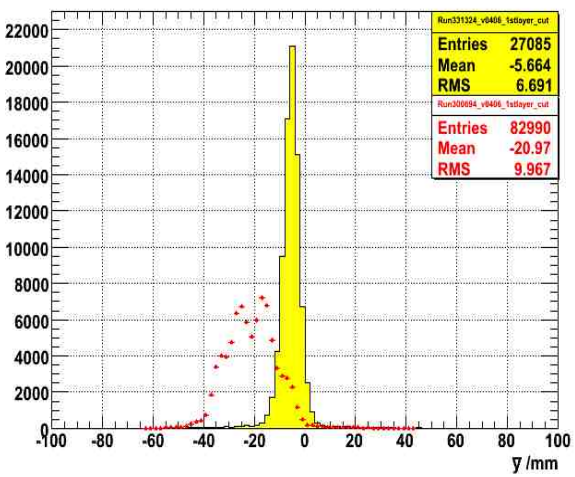




Average Y position

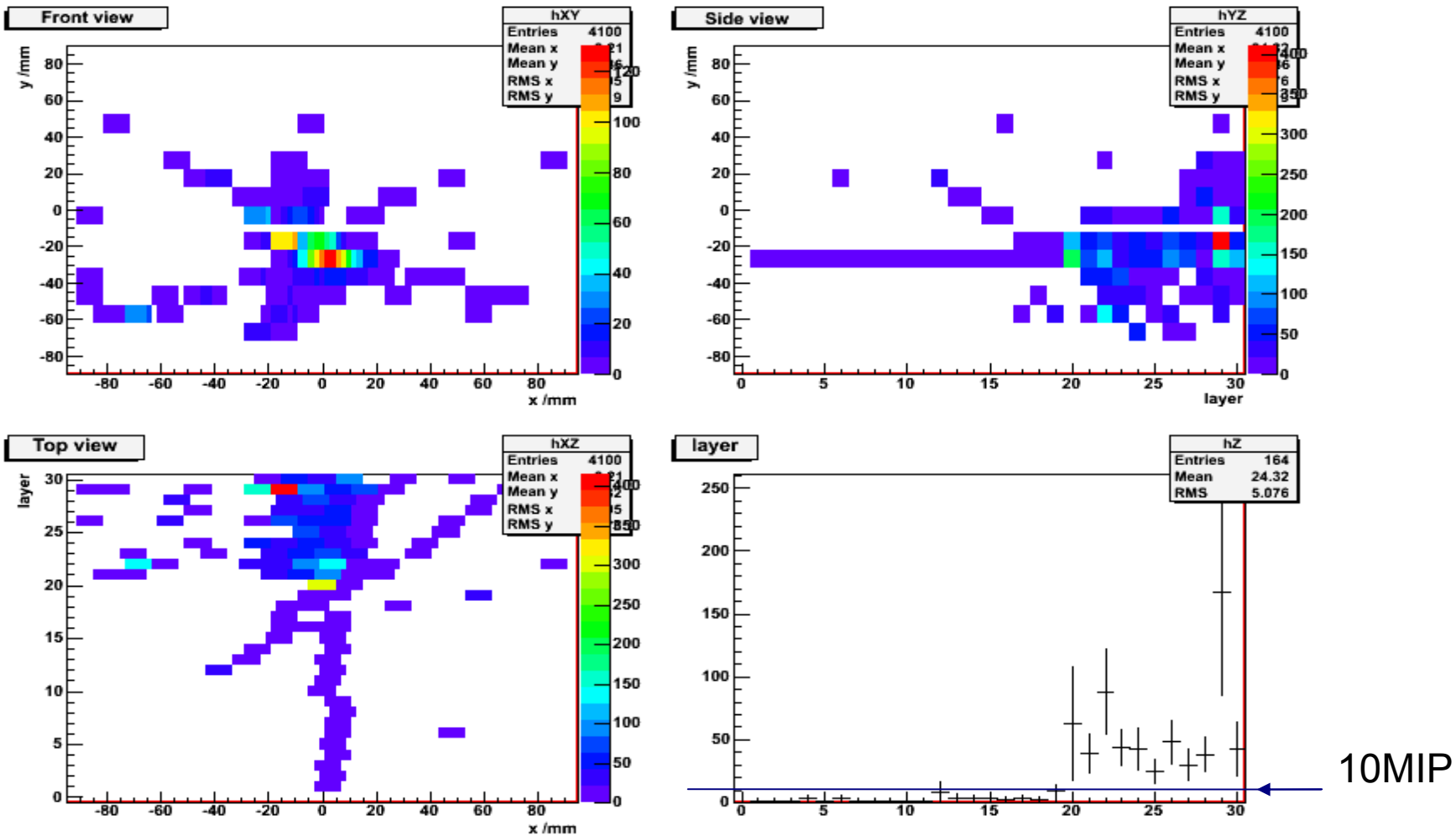






First interaction layer – Algorithm

Aim : To test the cross-section for primary interaction

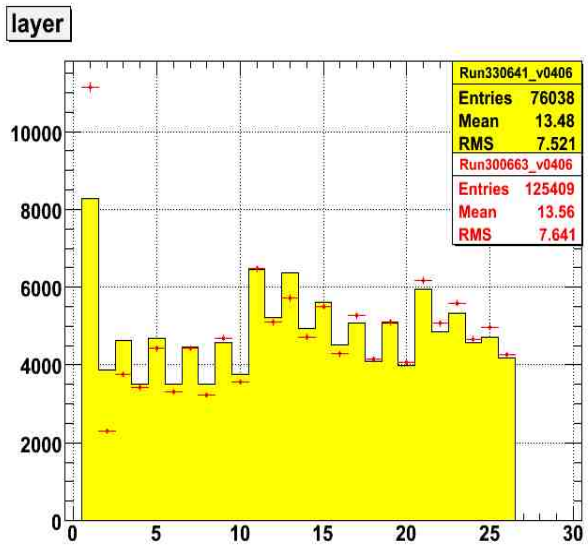


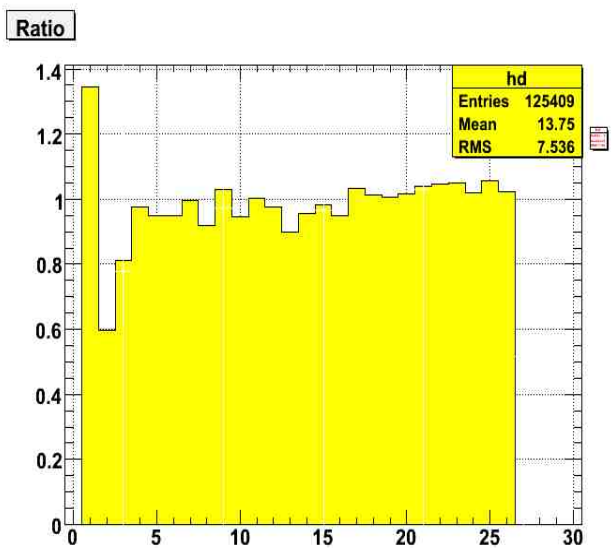
Identify the first layer which 3 layers out of 4 consecutive layers >10MIPs

2007 vs 2006

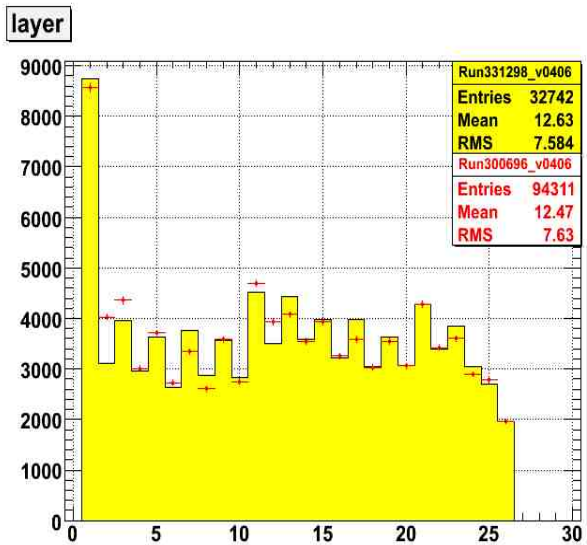
First interaction layer

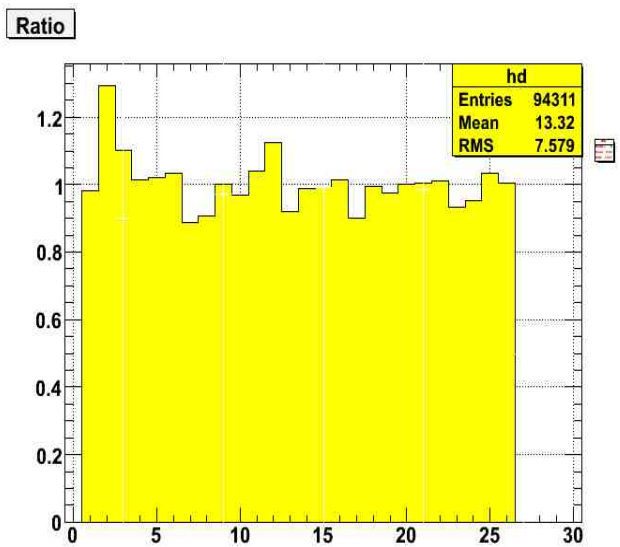
8 GeV -ve Pion



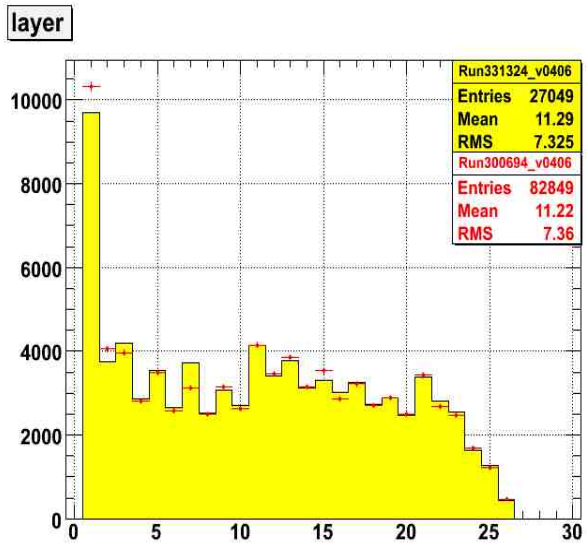


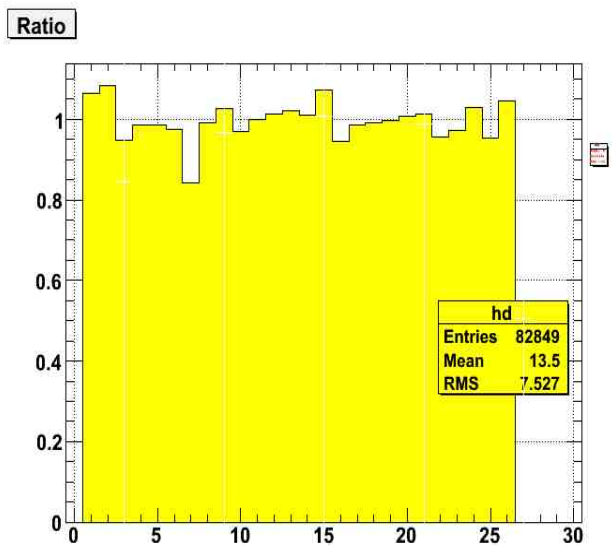
30 GeV +ve Pion





80 GeV +ve Pion

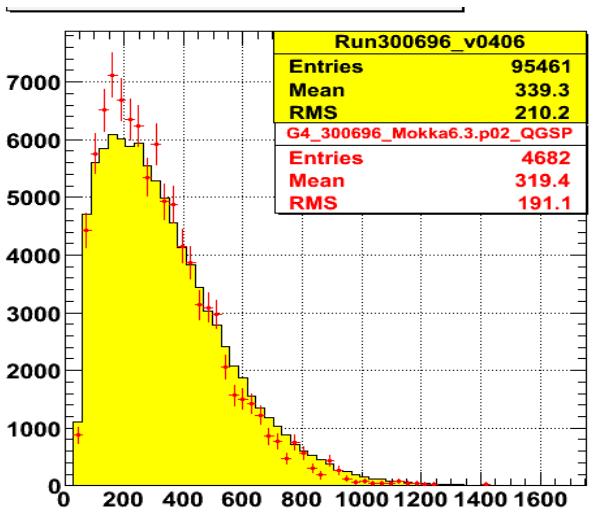




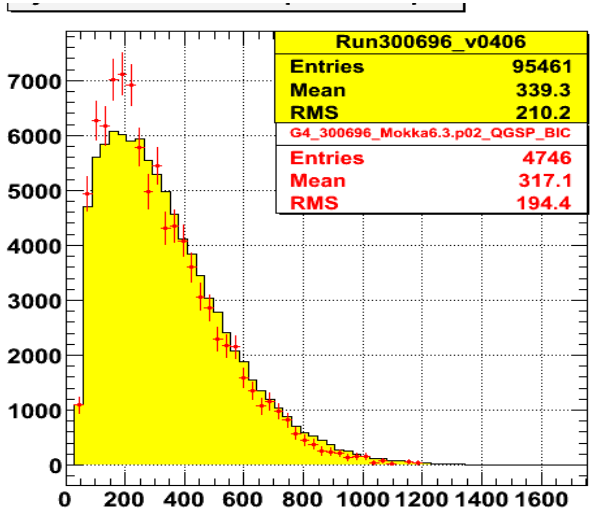
Run300696 vs Simulations

Shower Energy – first 5 layers after interaction

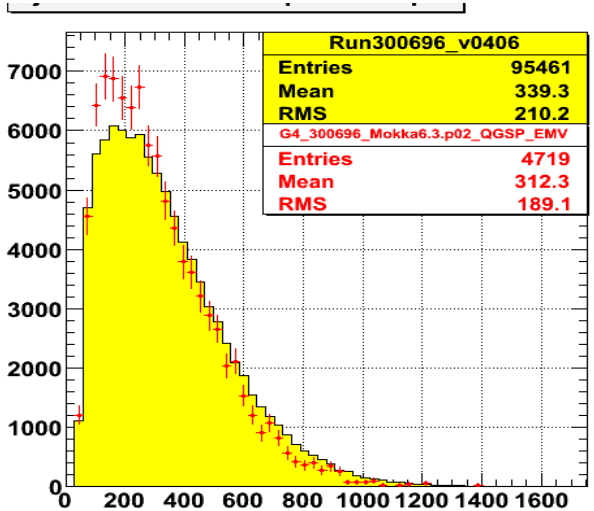
QGSP



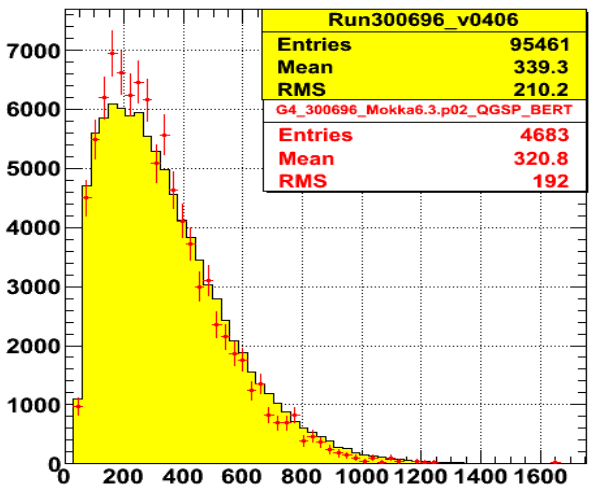
QGSP_BIC



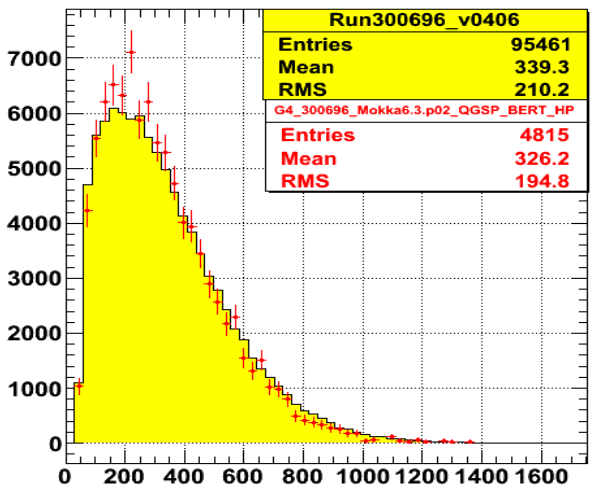
QGSP_EMV



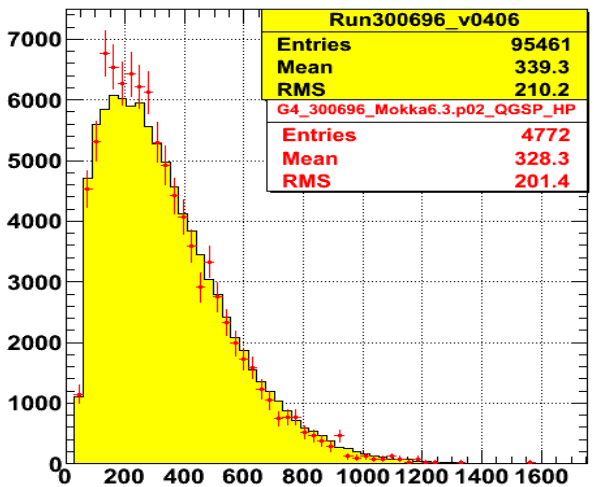
QGSP_BERT



QGSP_BERT_HP



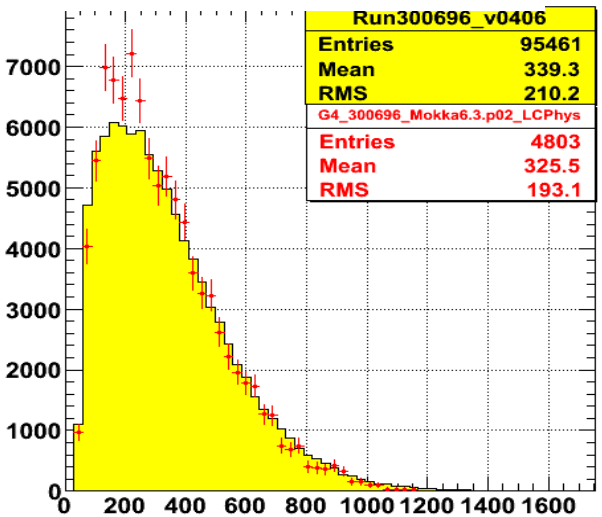
QGSP_HP



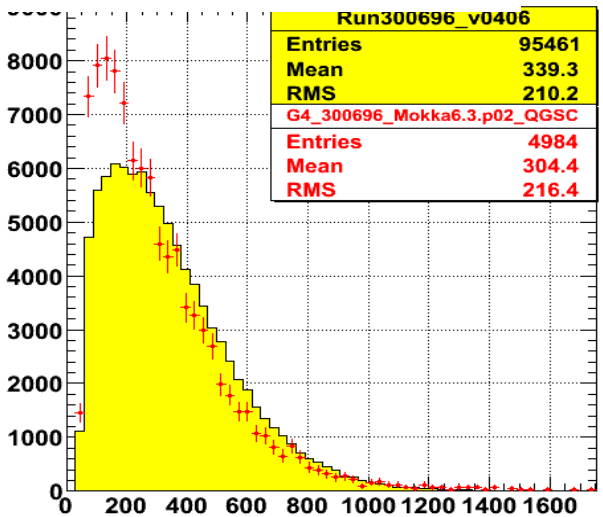
Run300696 vs Simulations

Shower Energy – first 5 layers after interaction

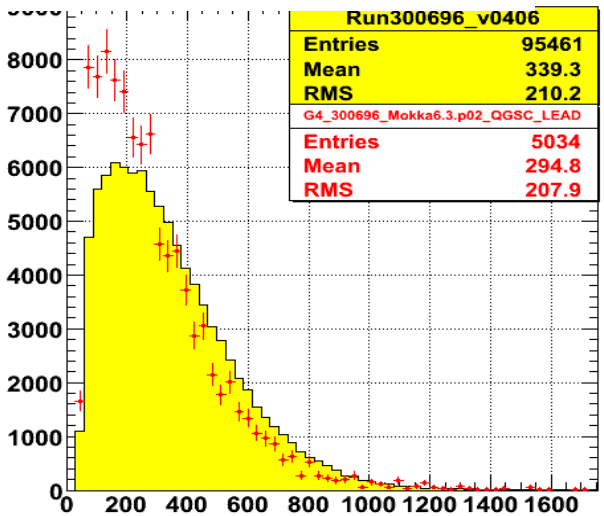
LCPhys



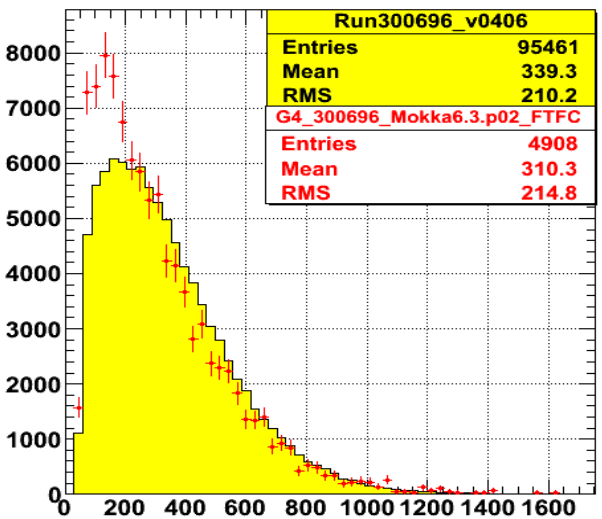
QGSC



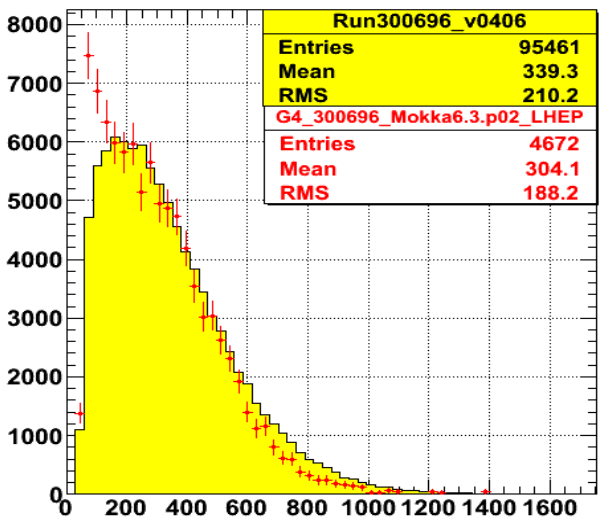
QGSC_LEAD



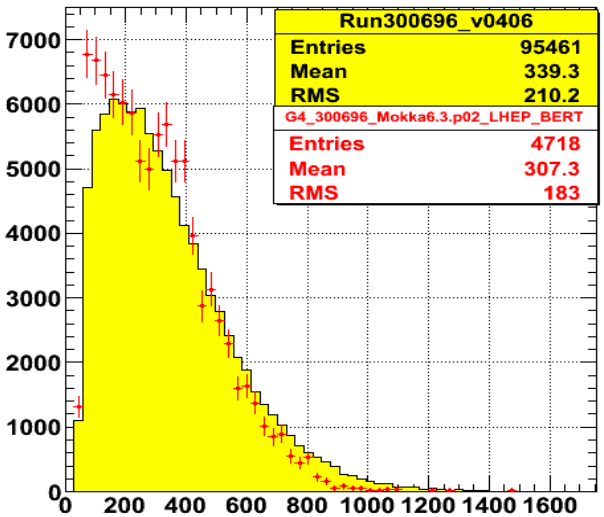
FTFC



LHEP



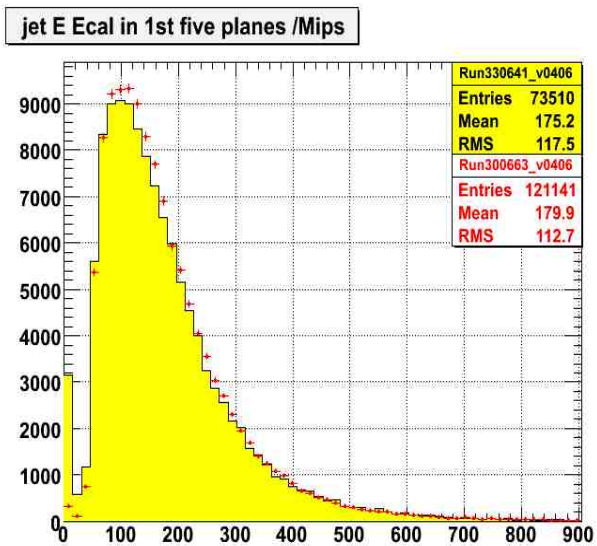
LHEP_BERT

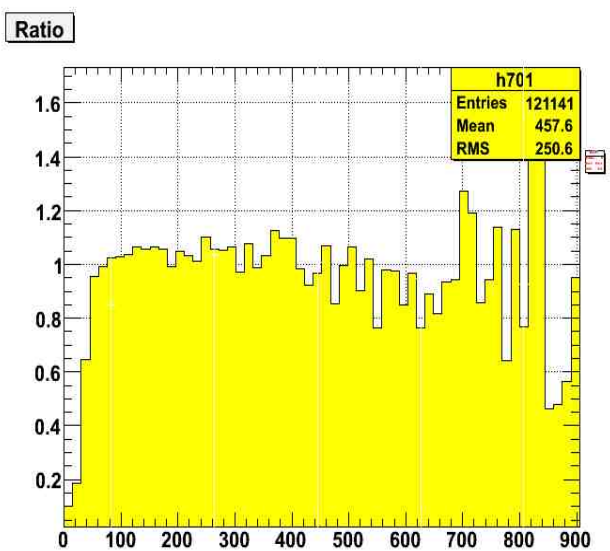


2007 vs 2006

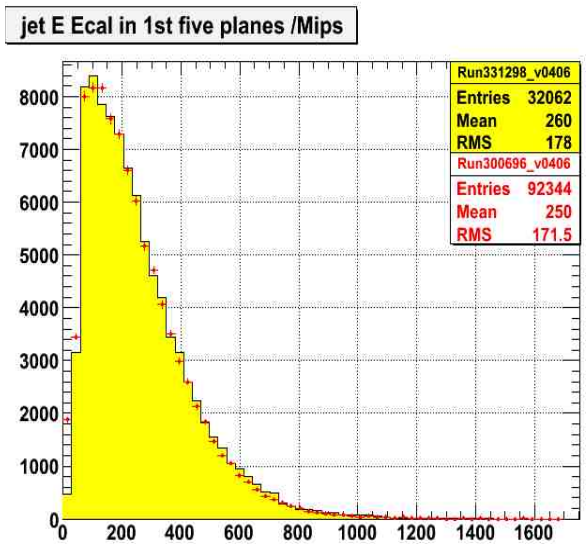
Shower Energy – First 5 layers after 1st interaction

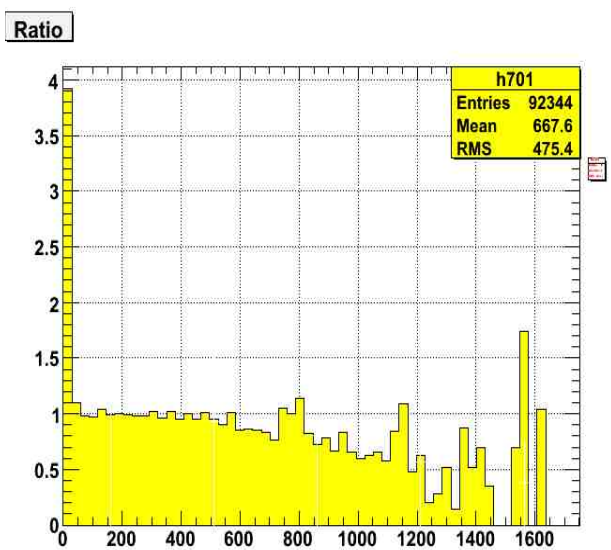
8 GeV -ve Pion



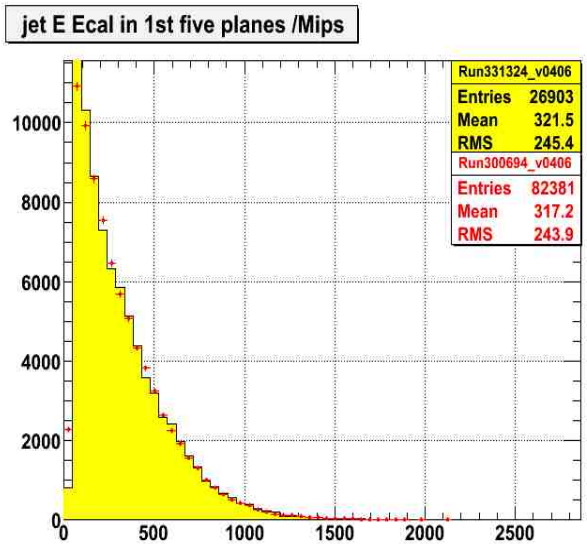


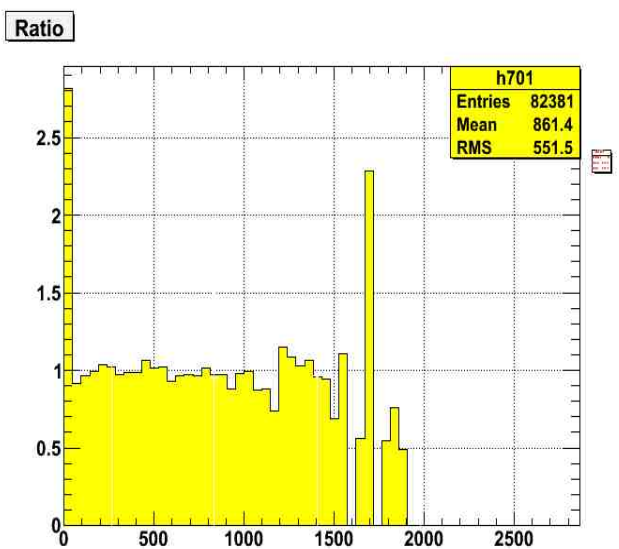
30 GeV +ve Pion





80 GeV +ve Pion





Summary

- Studied energy dependence of LHEP and QGSP_BERT from 6GeV to 80GeV c.f. data.
- Studied 12 different physics lists at Energy 30GeV using 2006 data
- ECAL certainly has some discrimination between hadronic models.
- Clear differences in the pion beam shape and content between 2006 and 2007 runs. 2007 beams are generally narrower than 2006.
- Change in the geometry of the ECAL has impact on the apparent response.
- As long as these differences are taken into account, 2006 runs and 2007 runs seem to agree with each other in most cases.
- But there are still differences which need explanation.

THE END

First Interaction layer using depth/X0

Attempt to obtain simple exponential decay for the first interaction layer

For every silicon layer, calculated amount of material previous to such layer in a consistent way.

W_X = sum of (depth of material / interaction length of material) before 'x'th silicon

first interaction layer against W_x is plotted with weight $1/(W_X - W_{X-1})$

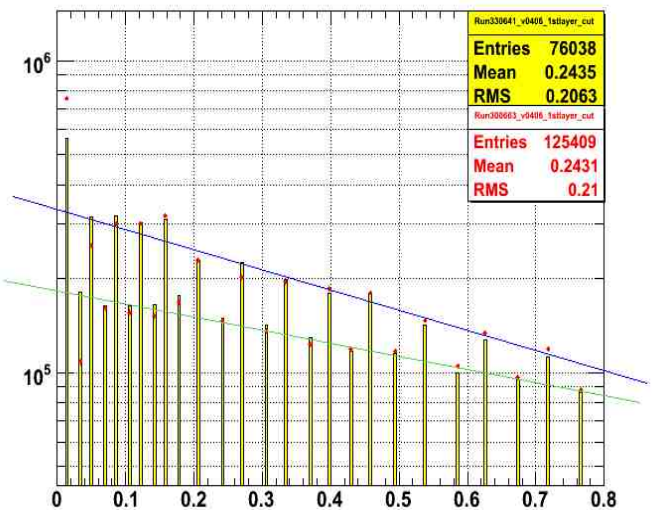
used following interaction length and depth values.

Material	Depth / mm	Lint / mm
C-fibre	0.3	546
Tungsten	1.4 x n	103.1
Aluminium	0.1	388.8
Air	0.58	701.1
PCB	2.1	483.4
Silicon	0.53	456

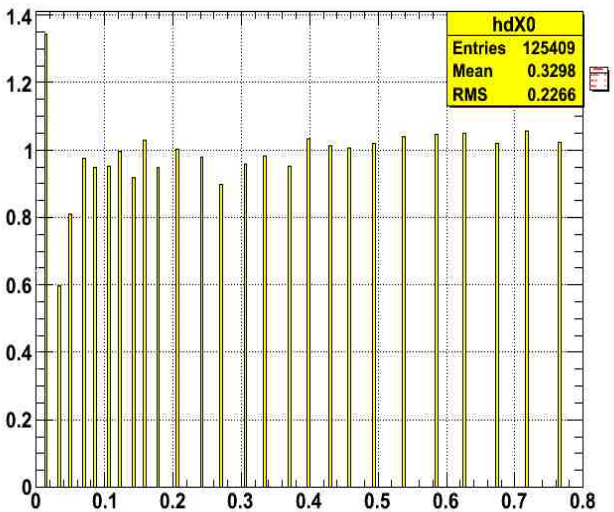
2007 vs 2006

First interaction layer

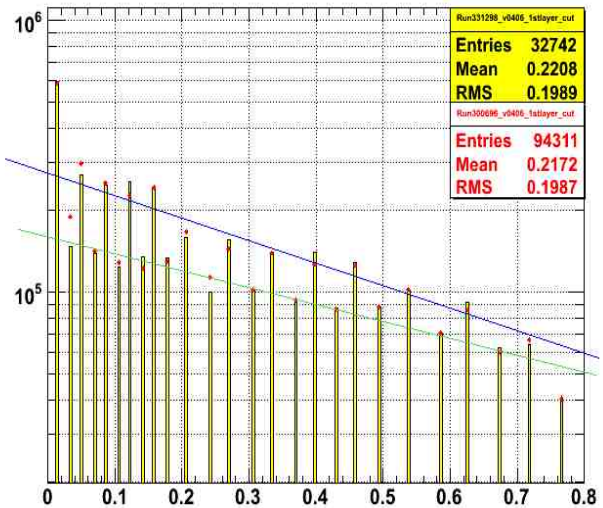
8 GeV -ve Pion



Ratio



30 GeV +ve Pion



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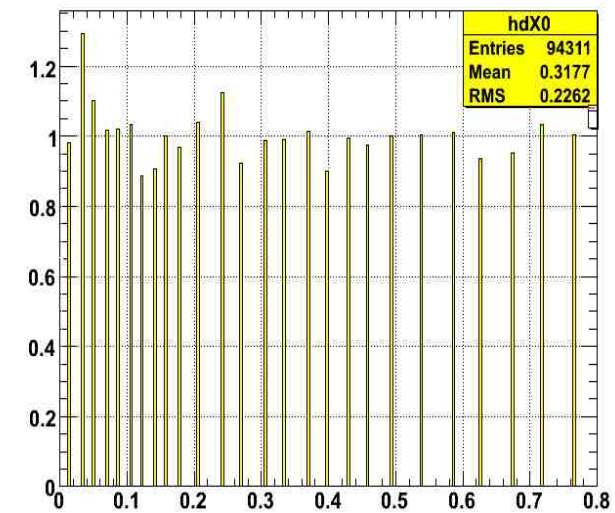
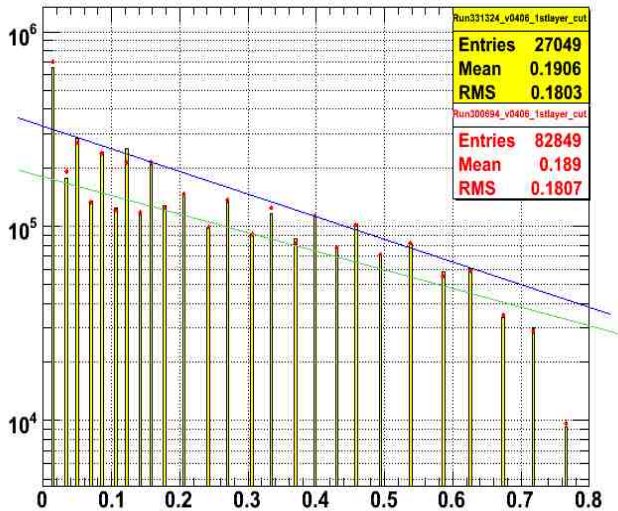
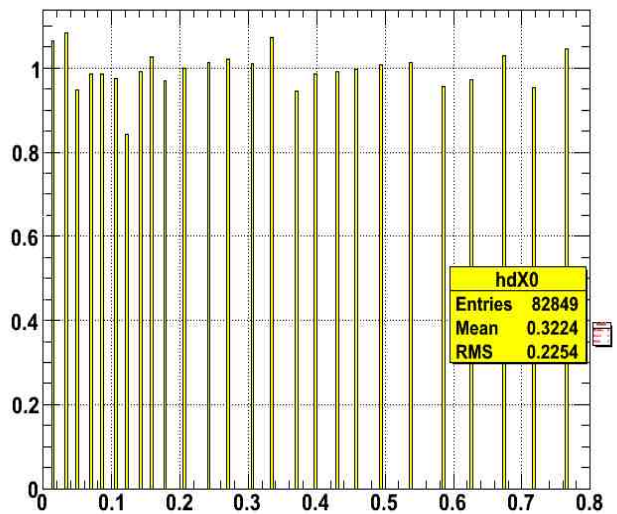


80 GeV +ve Pion



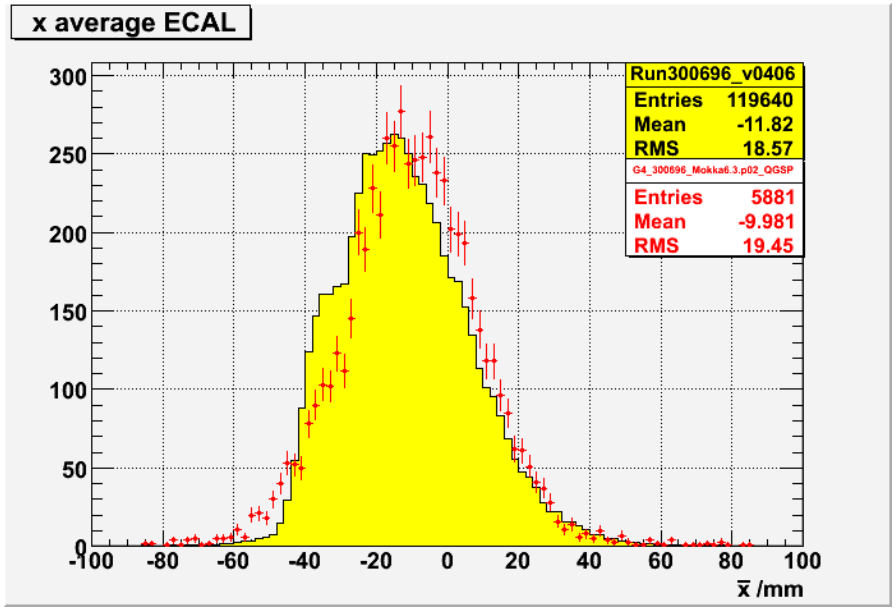
Ratio



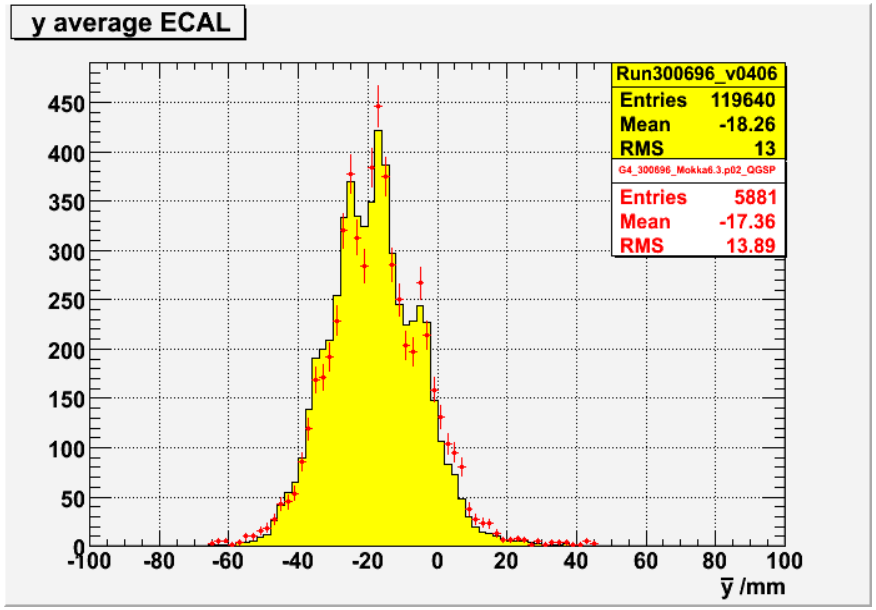
Overview of GEANT4 simulations

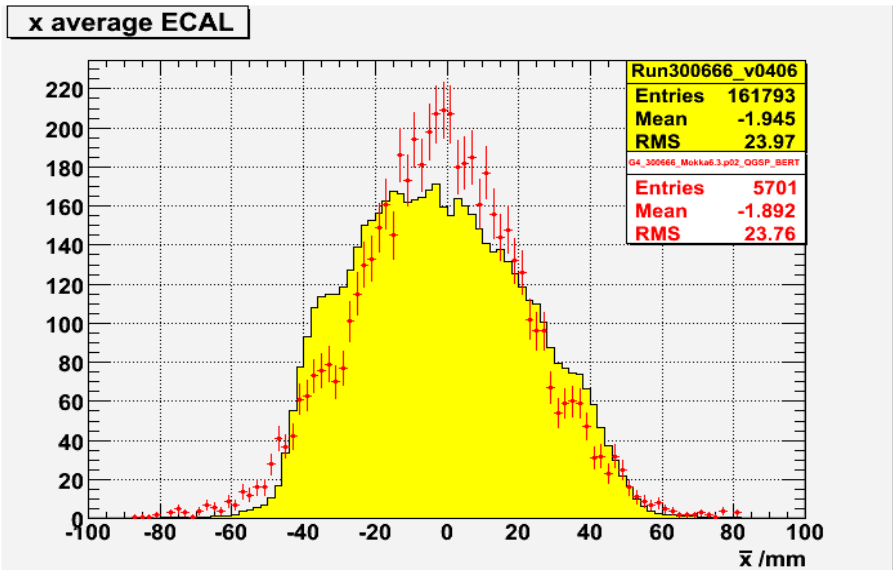
- QGSP
  - Quark Gluon-String with Precompound
  - Precompound (P) calls nuclear de-excitation routine
  - 12GeV – 50TeV (QGS)
- BERT
  - BERTini cascade
  - Unique evaporation model to de-excite the remnant nucleus
  - Up to ~10GeV
- LCPhys
  - Linear Collider Physics list by Dennis Wright (SLAC)
  - “best-guess selection of EM and hadronic physics processes for LC detector”
- LHEP
  - Low and High Energy Parametrized
  - Fast, parametrized model based on GHEISHA
  - Average Energy and Momentum are well described (conserved)

Beam Shape and Position

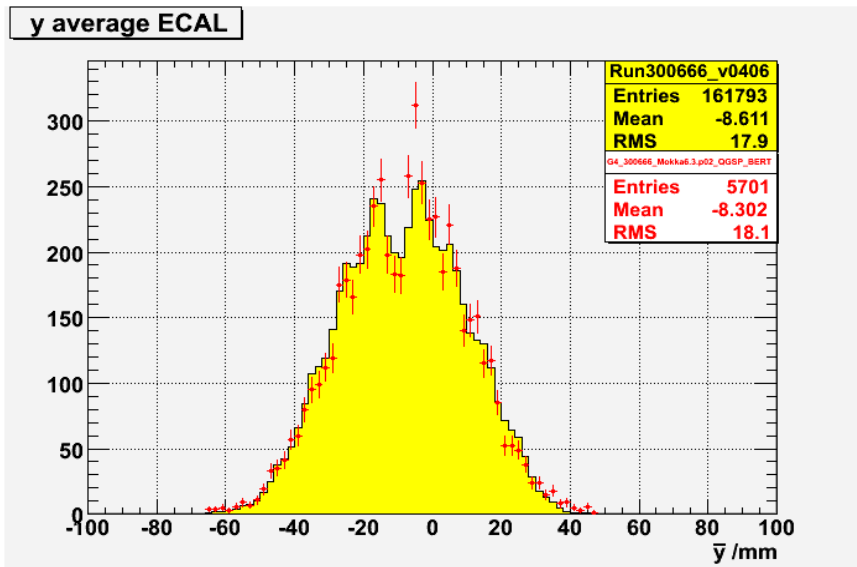


12GeV





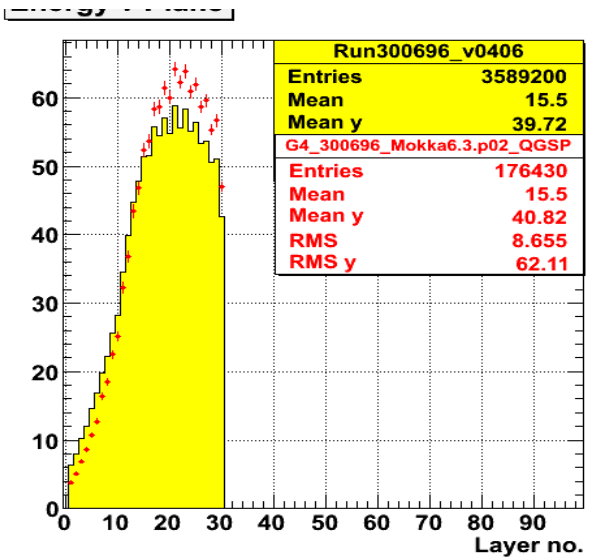
30GeV



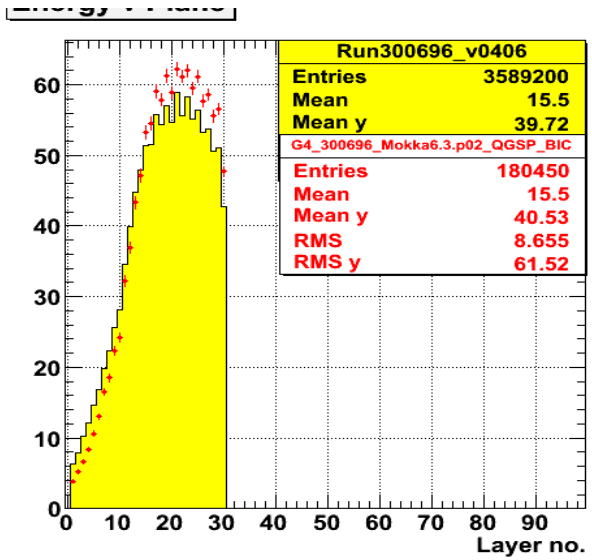
Run300696 vs Simulations

Longitudinal Energy Distribution

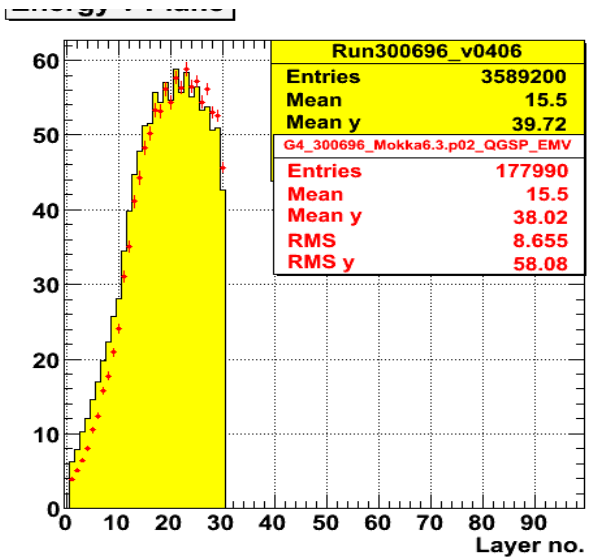
QGSP



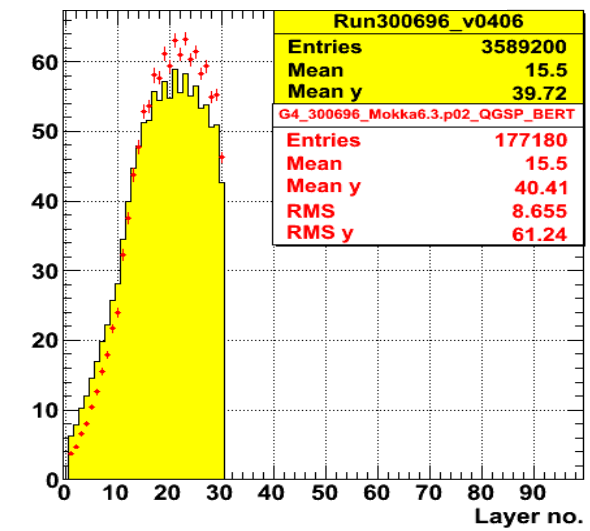
QGSP_BIC



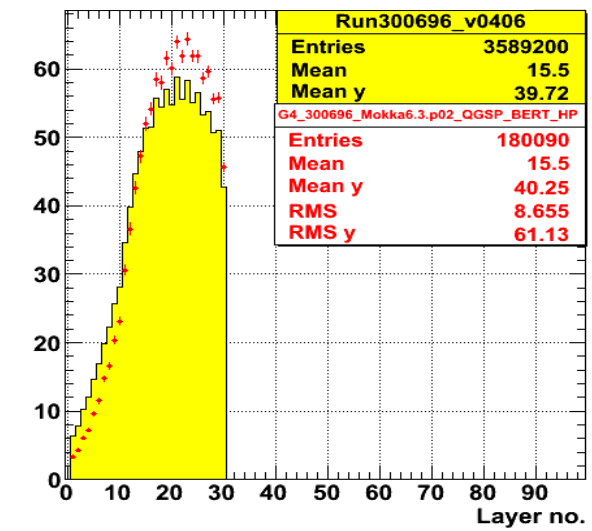
QGSP_EMV



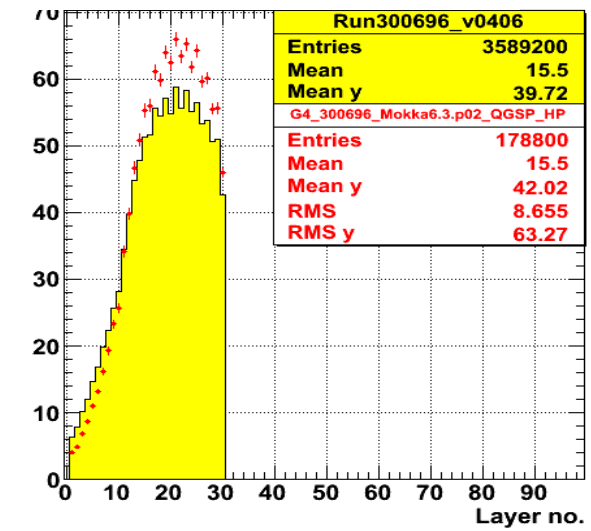
QGSP_BERT



QGSP_BERT_HP



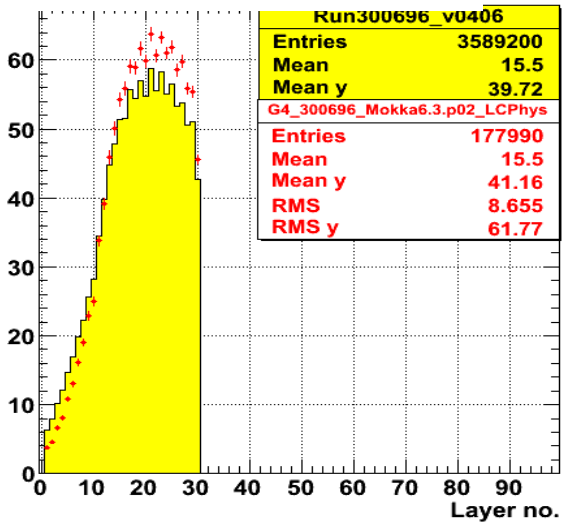
QGSP_HP



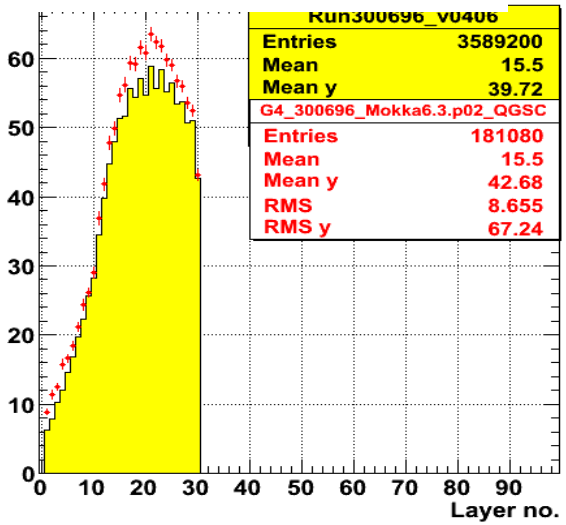
Run300696 vs Simulations

Longitudinal Energy Distribution

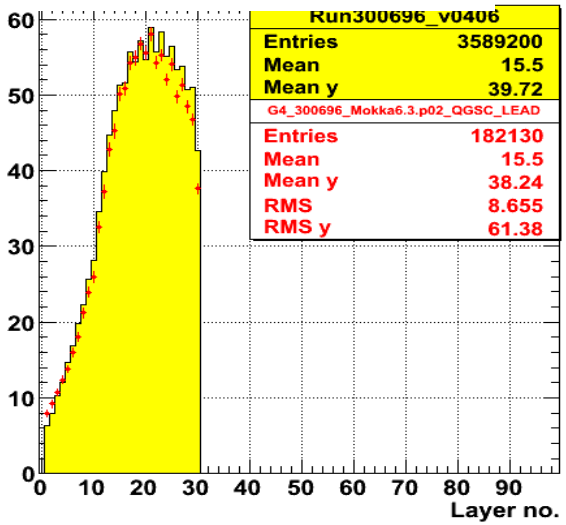
LCPhys



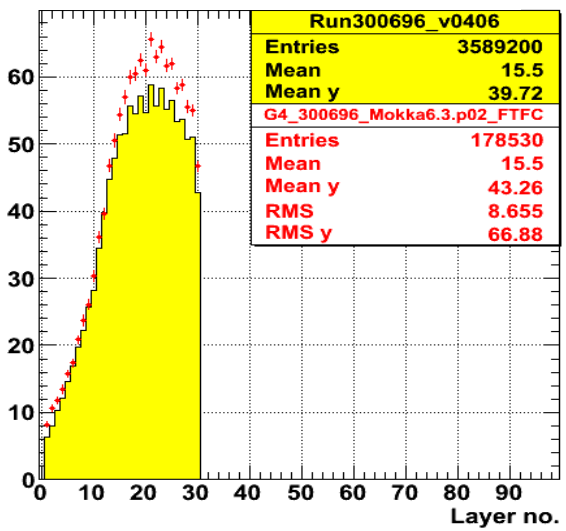
QGSC



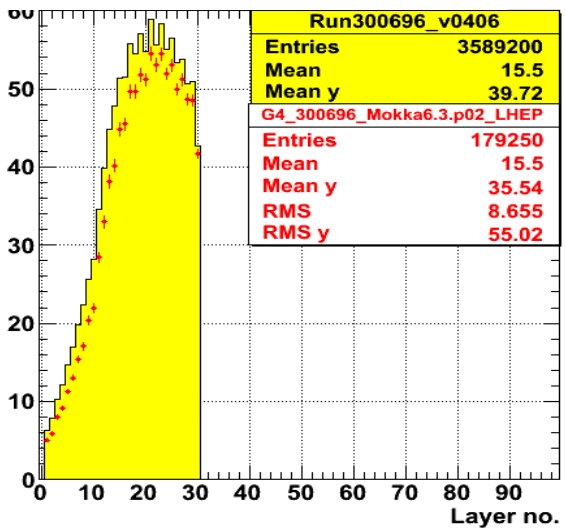
QGSC_LEAD



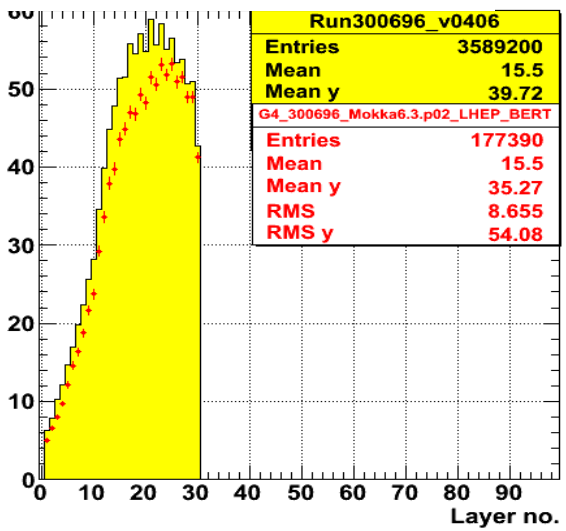
FTFC



LHEP



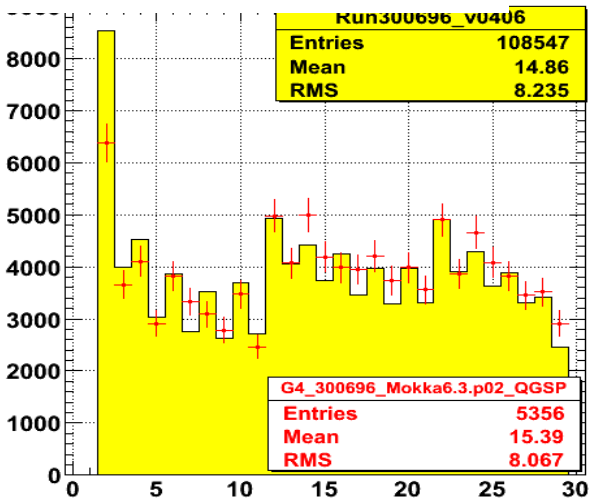
LHEP_BERT



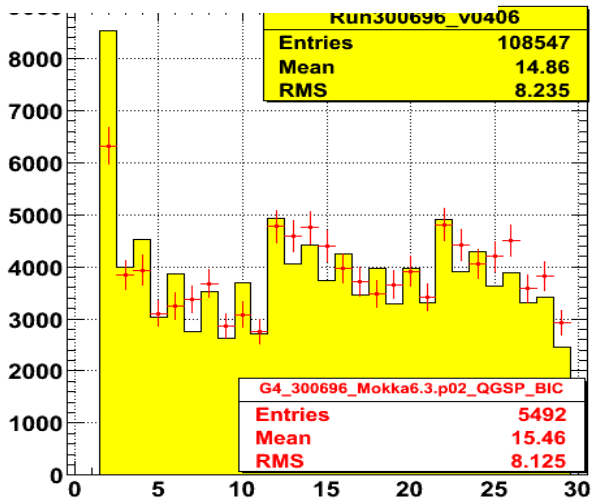
Run300696 vs Simulations

First interaction layer

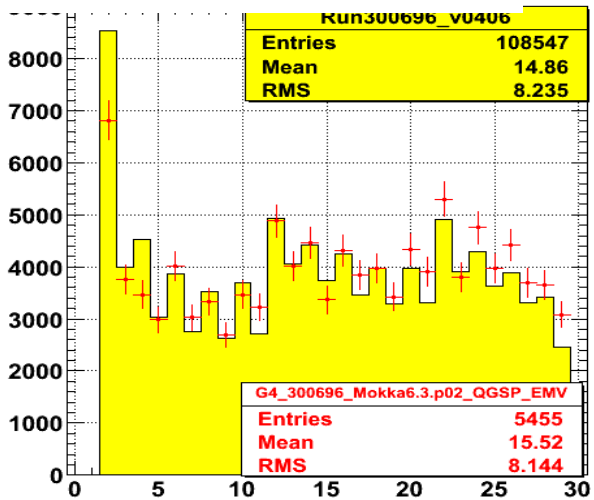
QGSP



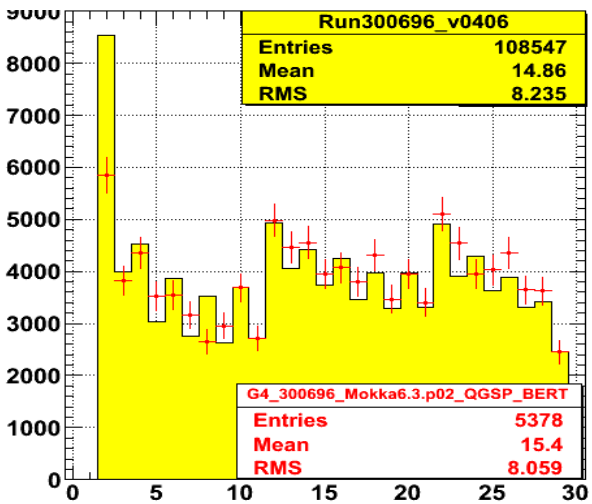
QGSP_BIC



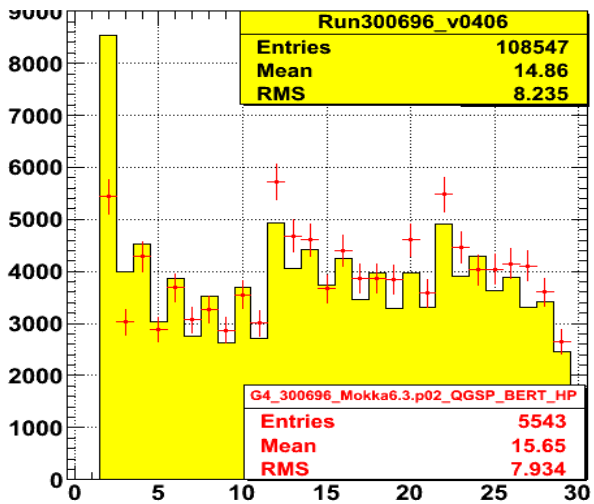
QGSP_EMV



QGSP_BERT



QGSP_BERT_HP



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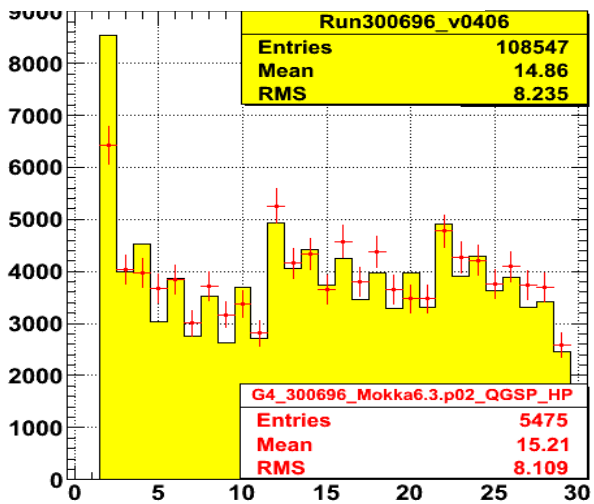
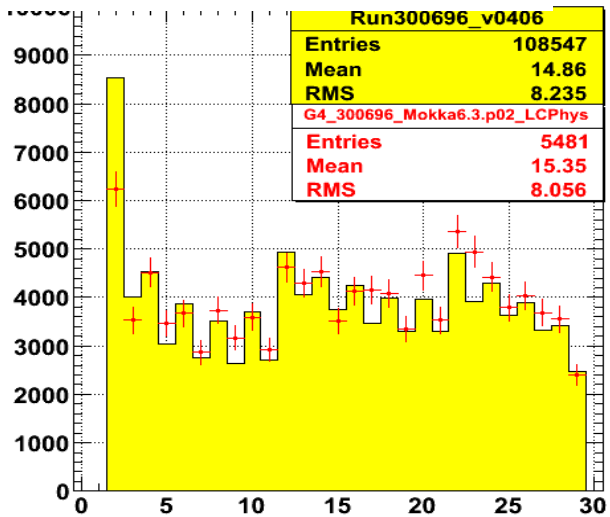


Run300696 vs Simulations

First interaction layer

LCPhys



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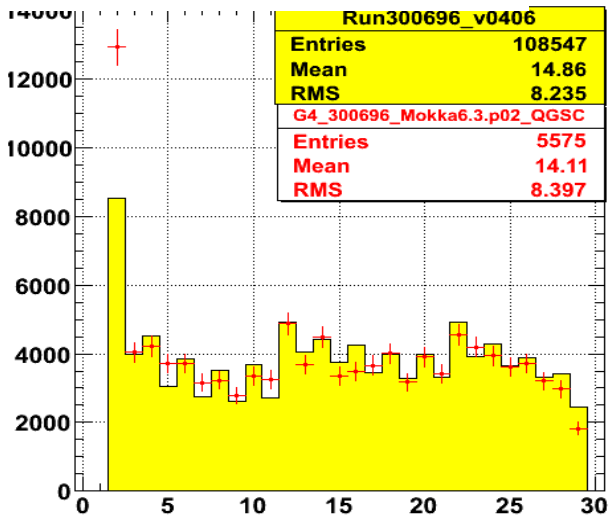

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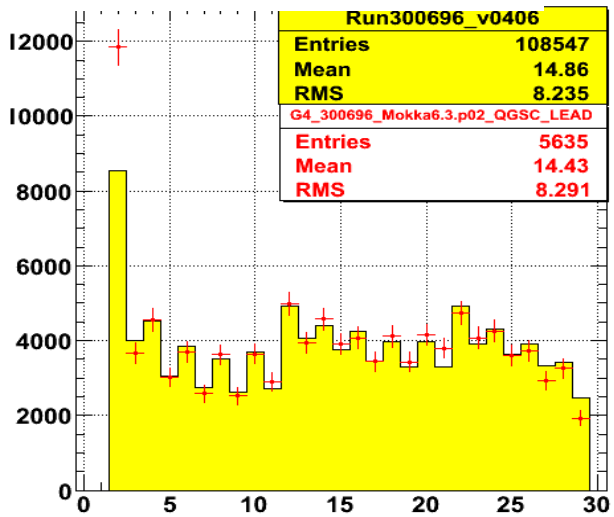
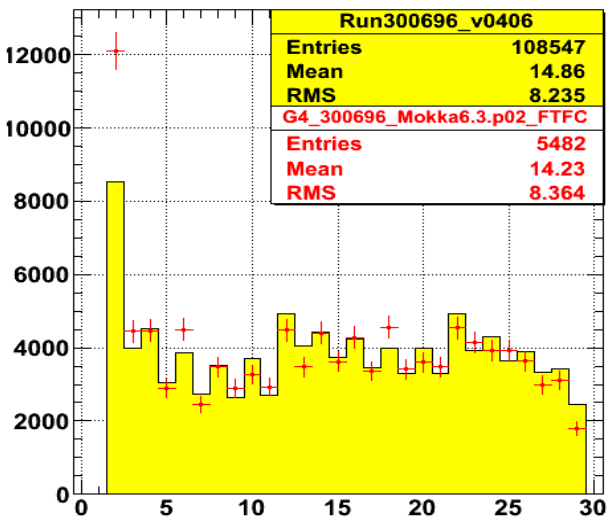


FTFC



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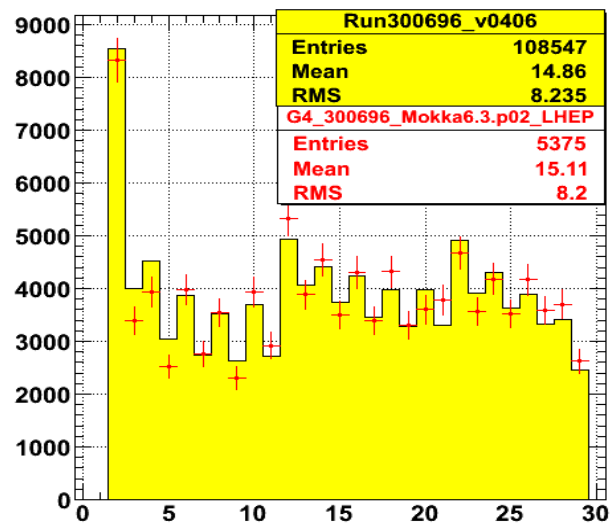

LHEP_BERT