Validation of Geant4.9.3 with CMS HCAL Test Beam Data

Outline

- Physics Lists and Geant4 Version
- CMS Test Beam Data
- Comparison with Default Physics List
- Comparison with the New List
- Summary

LCG Physics Validation
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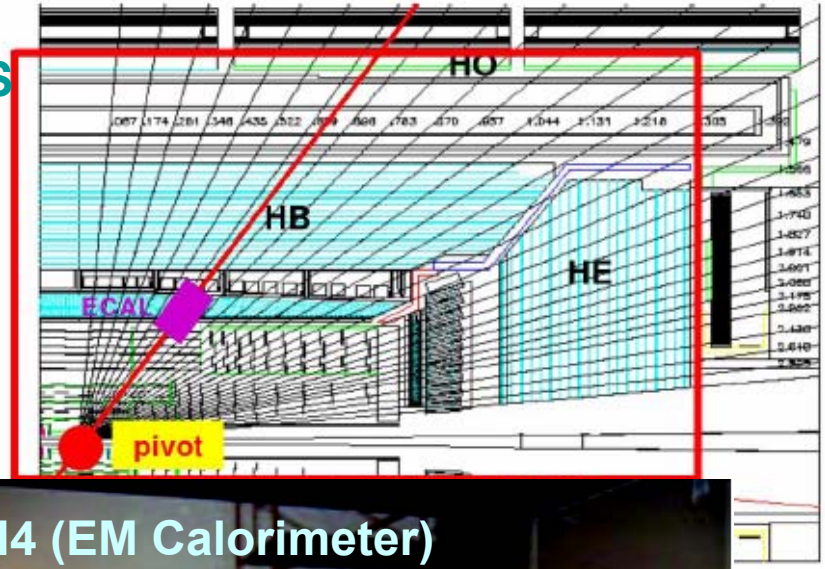
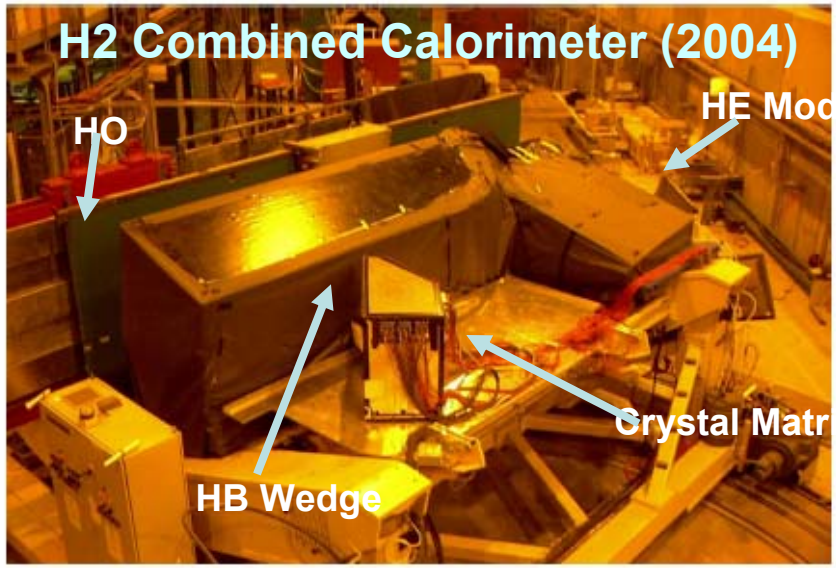
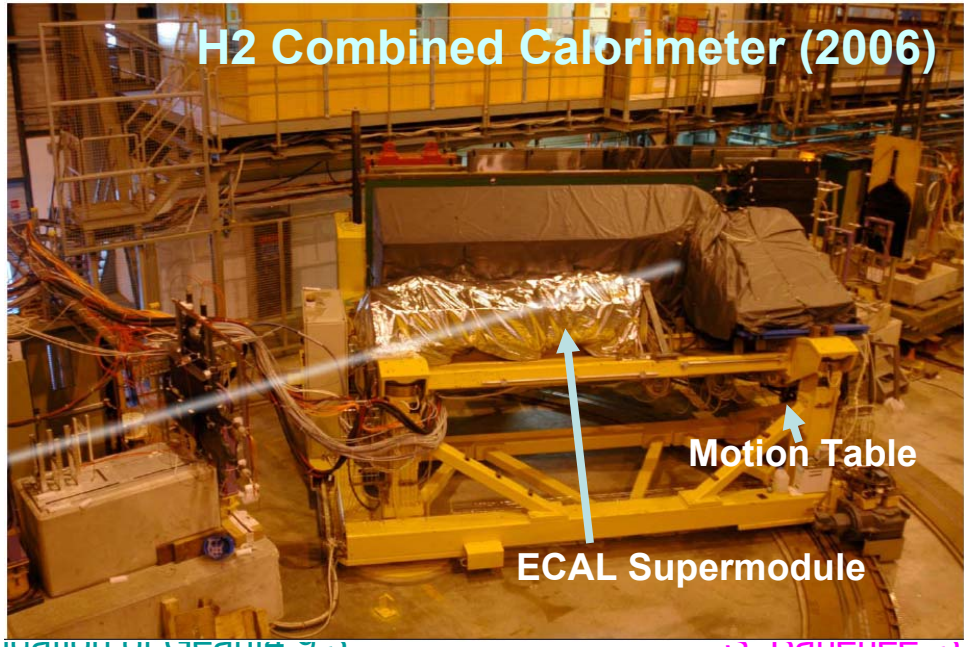
Physics Lists

- Several physics lists were validated using Geant4 version 9.3.b01using CMS test beam data with combined calorimeter
  - QGSP_FTFP_BERTINI, QGSC_CHIPS, QGSC_QGSC, …
- CMS has chosen QGSP_BERT_EML as its default physics list which uses a slightly modified version of _EMV for the EM physics
  - It uses “ApplyCut” option to enhance performance
  - Prooduction cuts are chosen to have similar physics performance as _EMV
- Also comparew with the newly available physics list CHIPS

CMS Test Beam Efforts





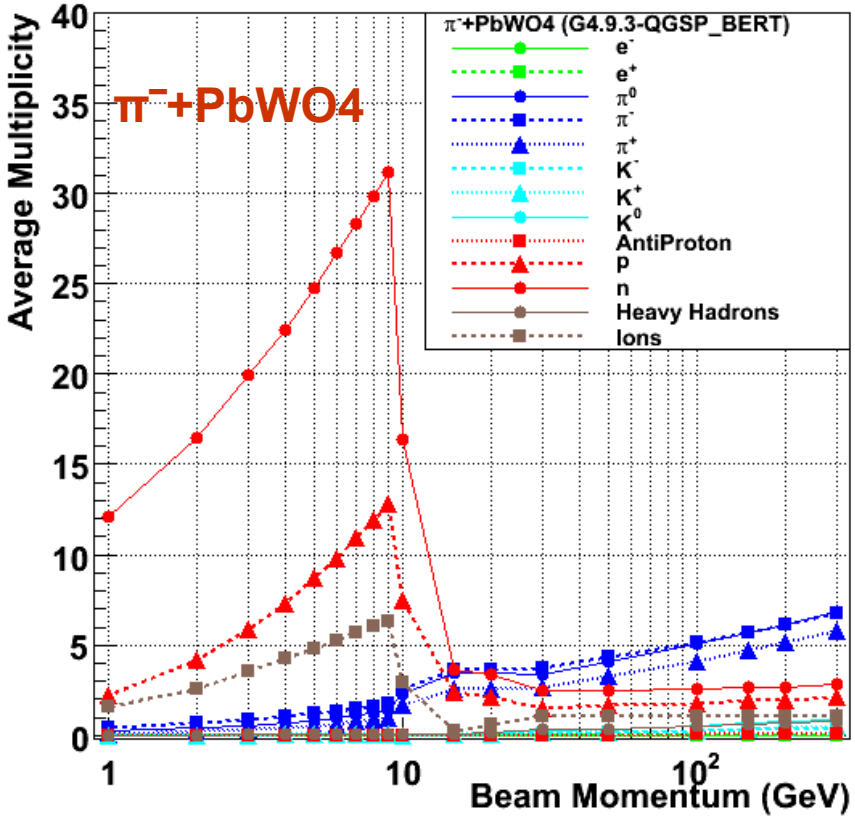


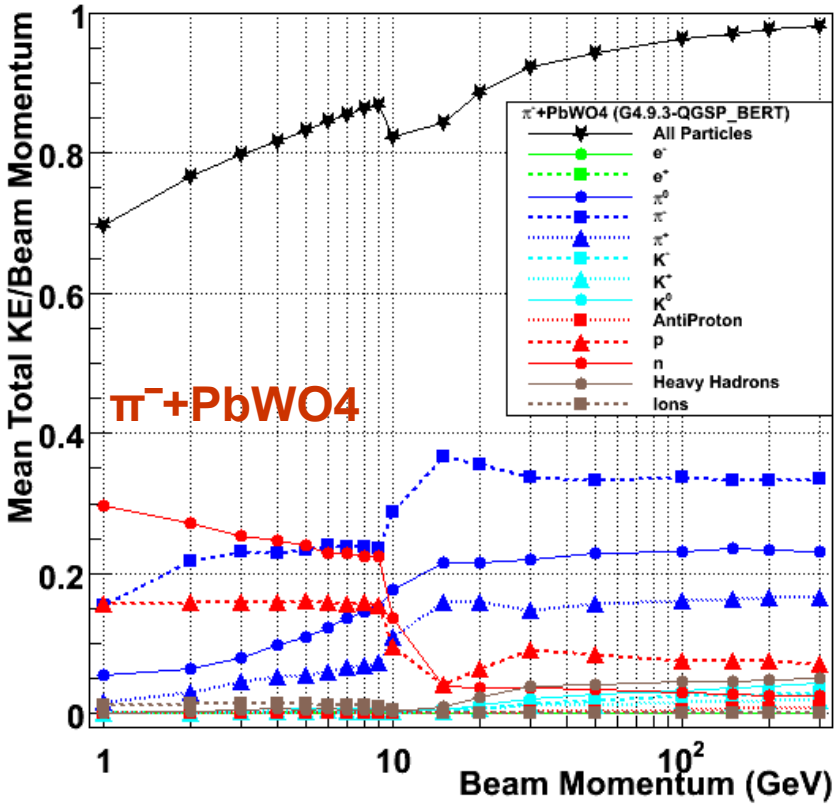
CMS Test Beam Data

- CMS uses prototypes of their hadron calorimeter modules (brass-scintillator sampling calorimeter) and one super module of electromagnetic calorimeter ($PbWO_4$ crystals) in the H2 test beam
- Uses negative and positive beams between 2-350 GeV/c with good particle identification for low energy beams
- Calibrates both ECAL and HCAL using 50 GeV/c electron beam. Inter-calibration of HCAL is done using radioactive source scan
- Measurements exist for
  - Total energy measurement in the calorimeter system
  - Fraction of MIP samples in ECAL and energy measurement of these MIP like events
  - Lateral shower profiles in ECAL and HCAL and longitudinal shower profile in HCAL

Default Physics List in CMS

- To study energy evolution we also monitor mean multiplicity and mean KE fraction of individual particles in collision of π^-/p beam in $PbWO_4$.

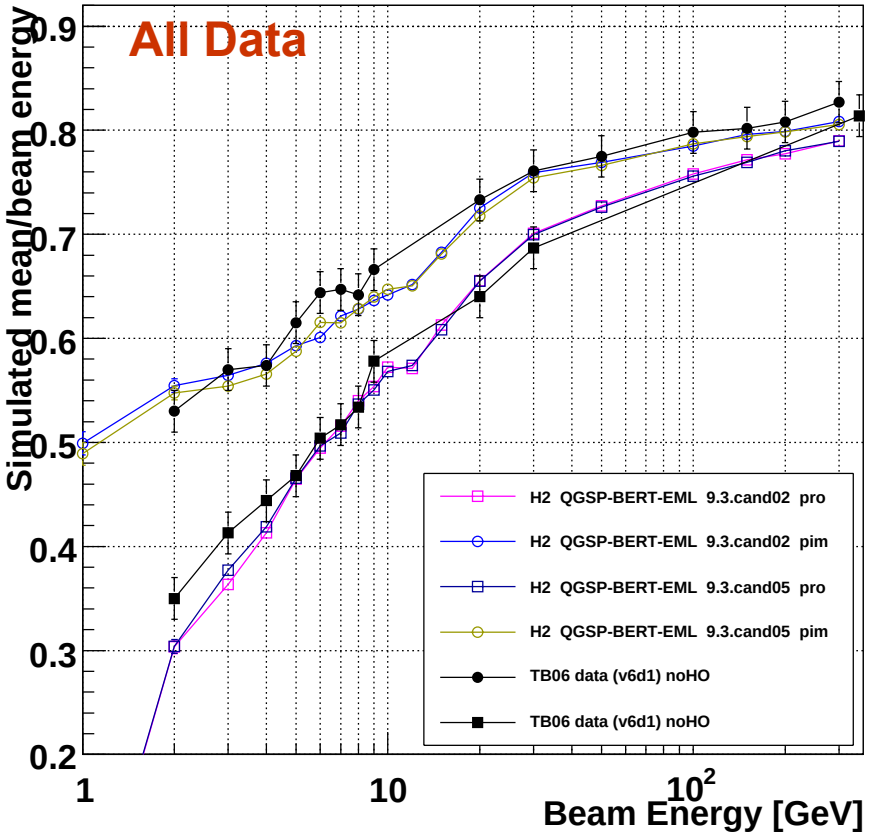




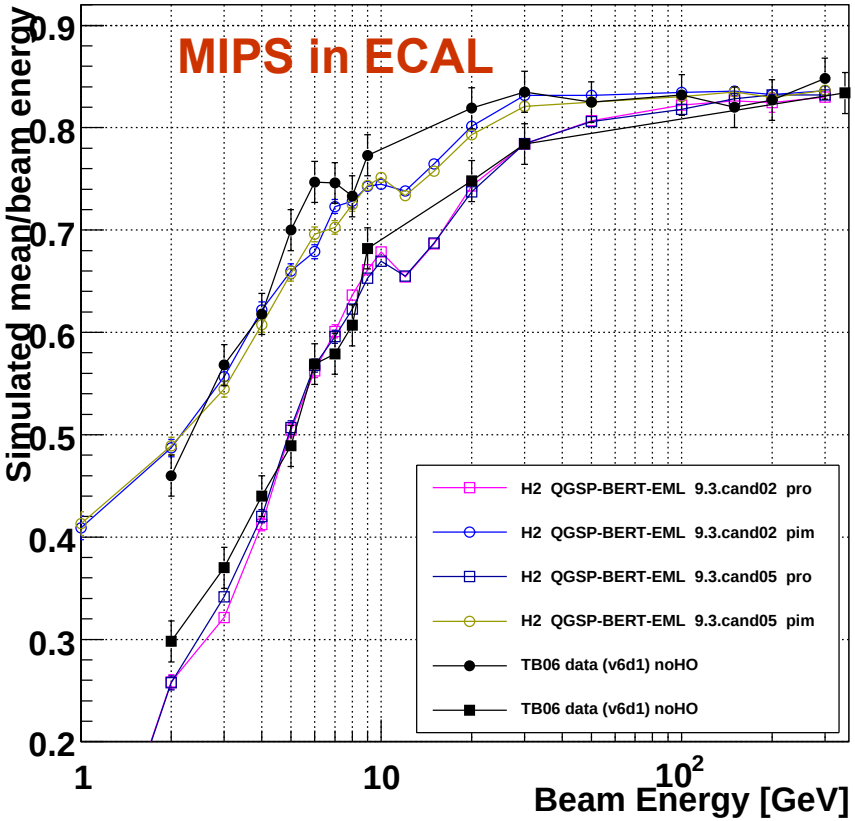
Large discontinuity in the transition region between models

Energy Measurements

Calo Response (MCideal calib.: ele50)



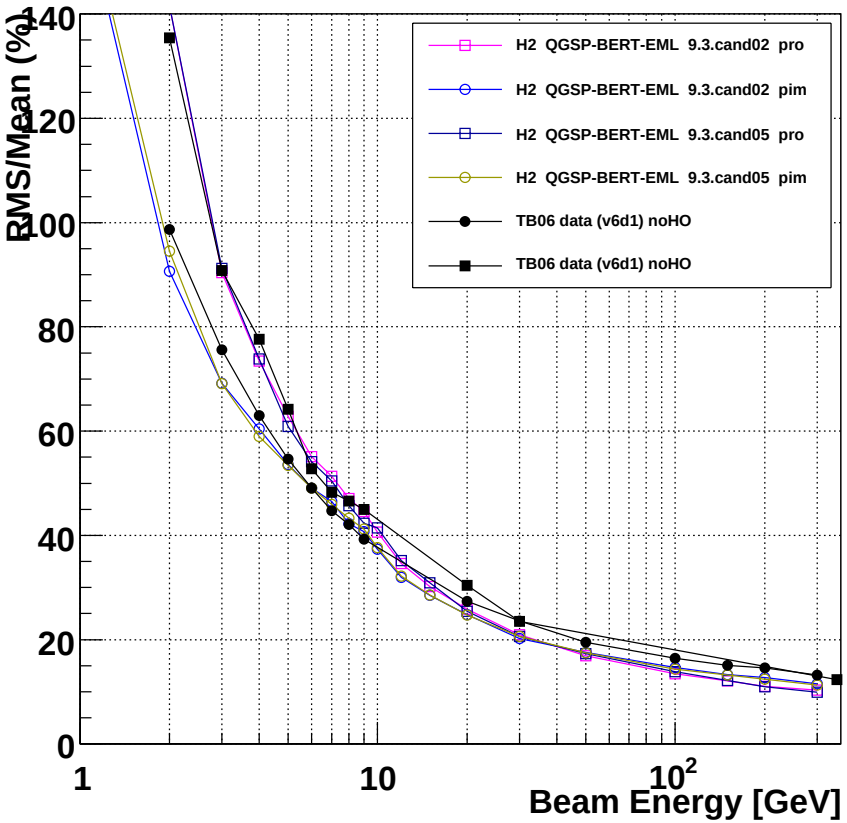
Calo Response (MCidealMIP calib.: ele50)



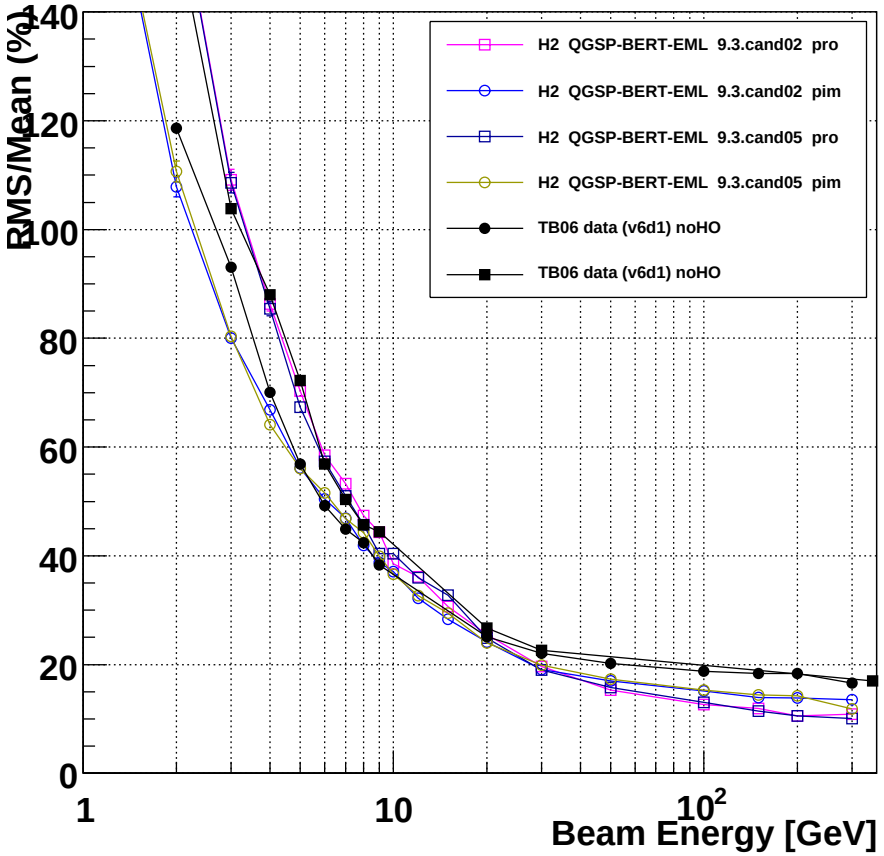
- Here we examined mean response as a function of beam energy for π^-/p for all data and MIP in ECAL
- We also compared with standard EM physics version (not shown)
- Best results from EMV and EMV+"ApplyCut" option

Energy Resolution

Calo Resolution (MCideal)

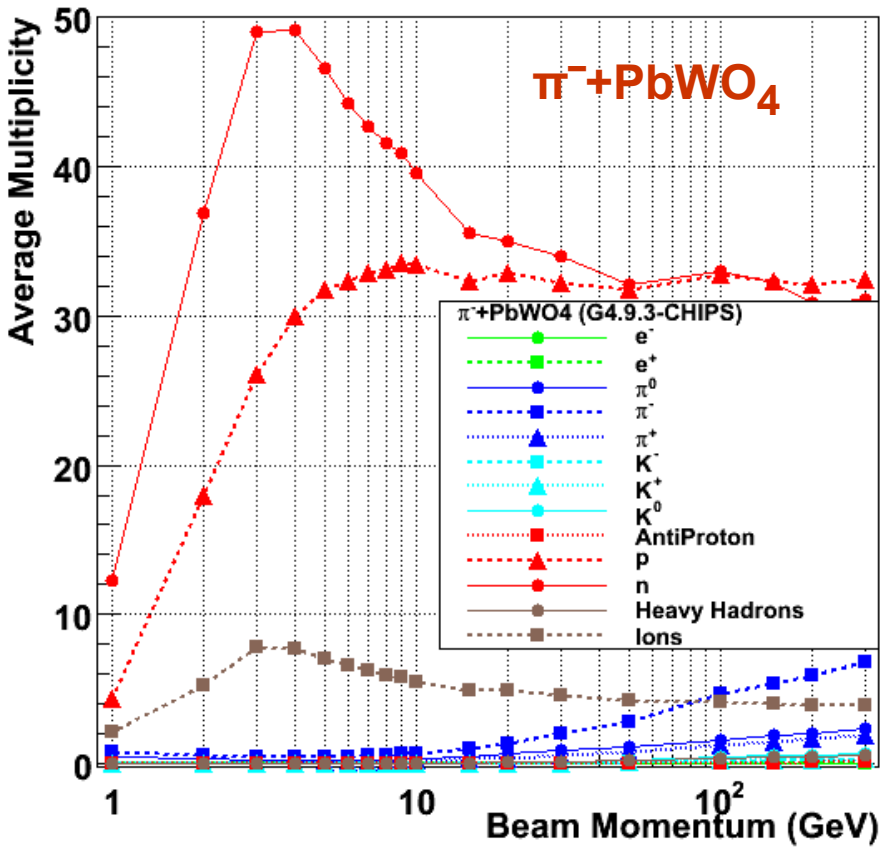


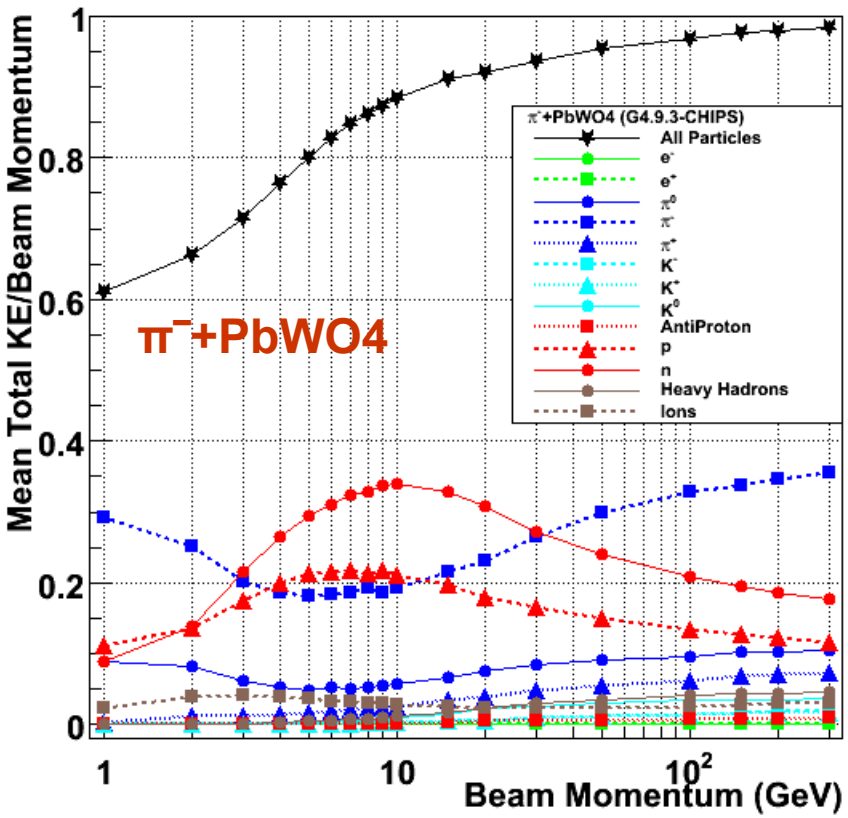
Calo Resolution (MCidealMIP)



- All versions predict very similar energy resolution
- Overall agreement is quite acceptable

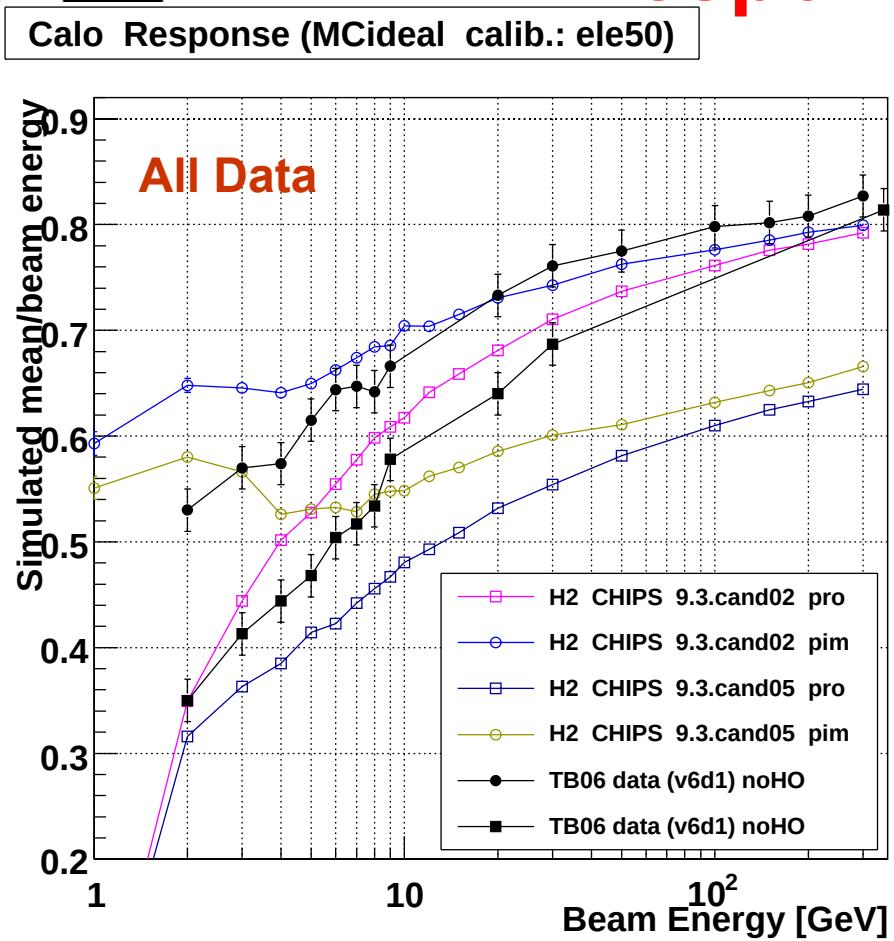
Energy evolution in CHIPS

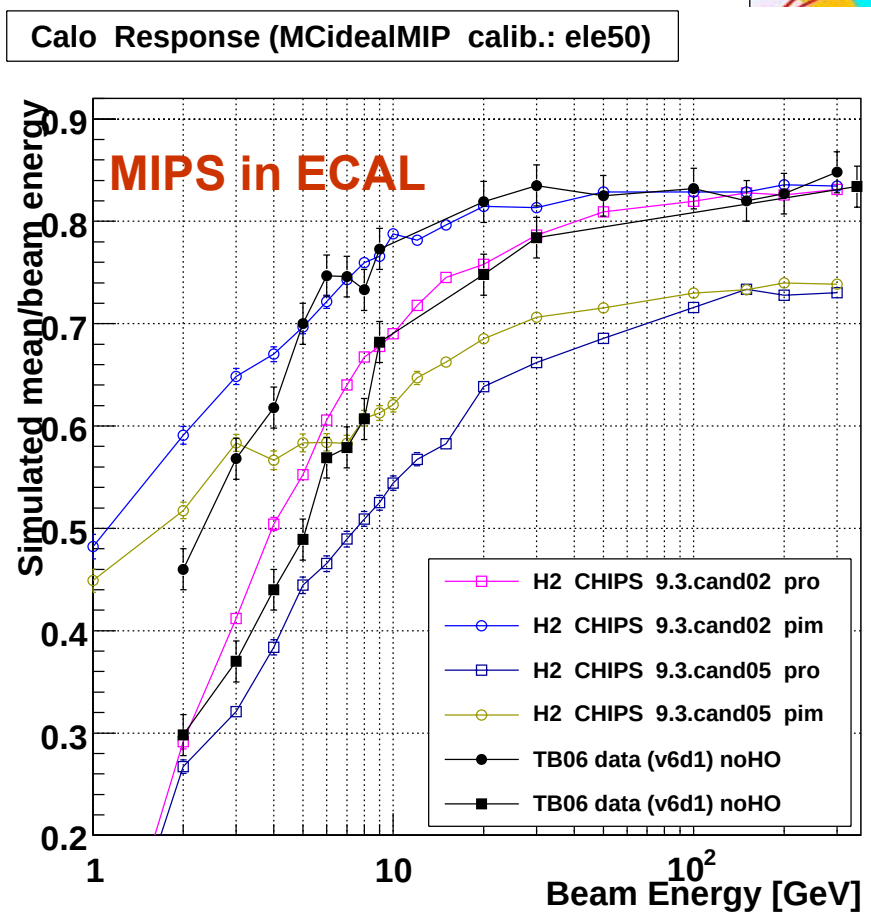




- Mean multiplicity distribution shows some transition for nucleons and ions at around 5-6 GeV
- Total KE fraction (summed over all particles) has rather smooth energy evolution

Response (CHIPS)

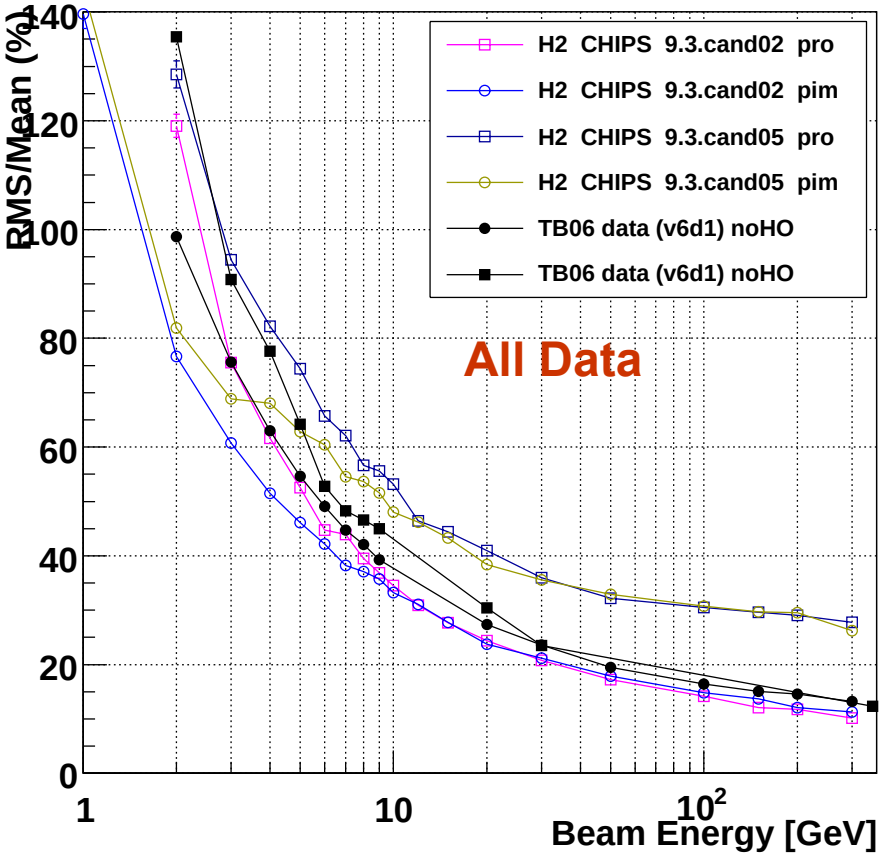




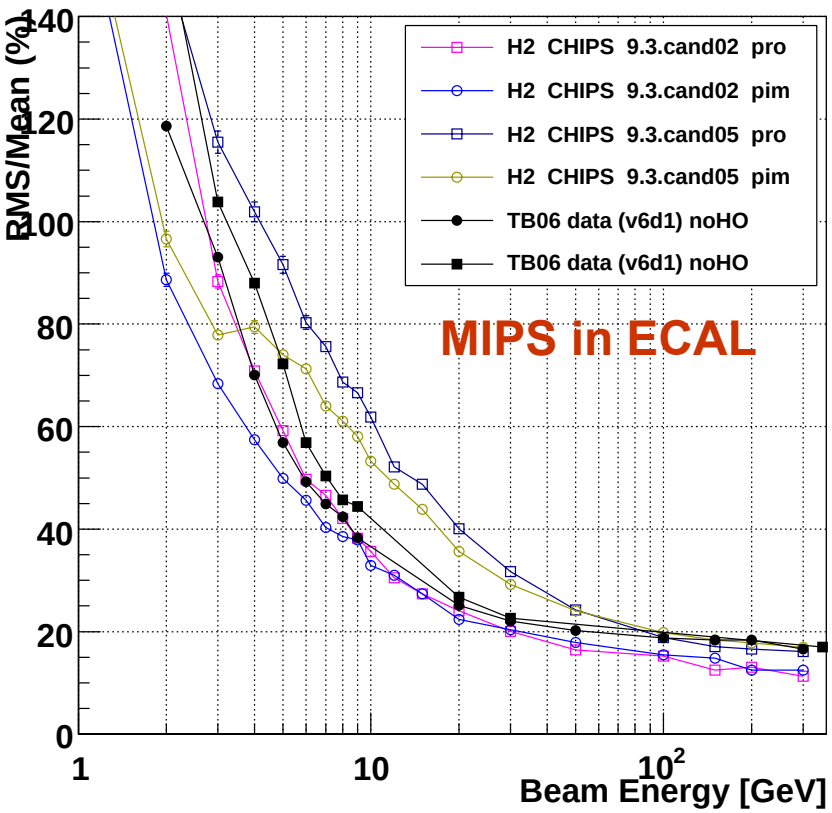
- Prediction of CHIPS changed enormously between 2 candidate release versions
- Predictions are above data at low energies and under the data at high energies for π^- beam

Resolution (CHIPS)

Calo Resolution (MCideal)

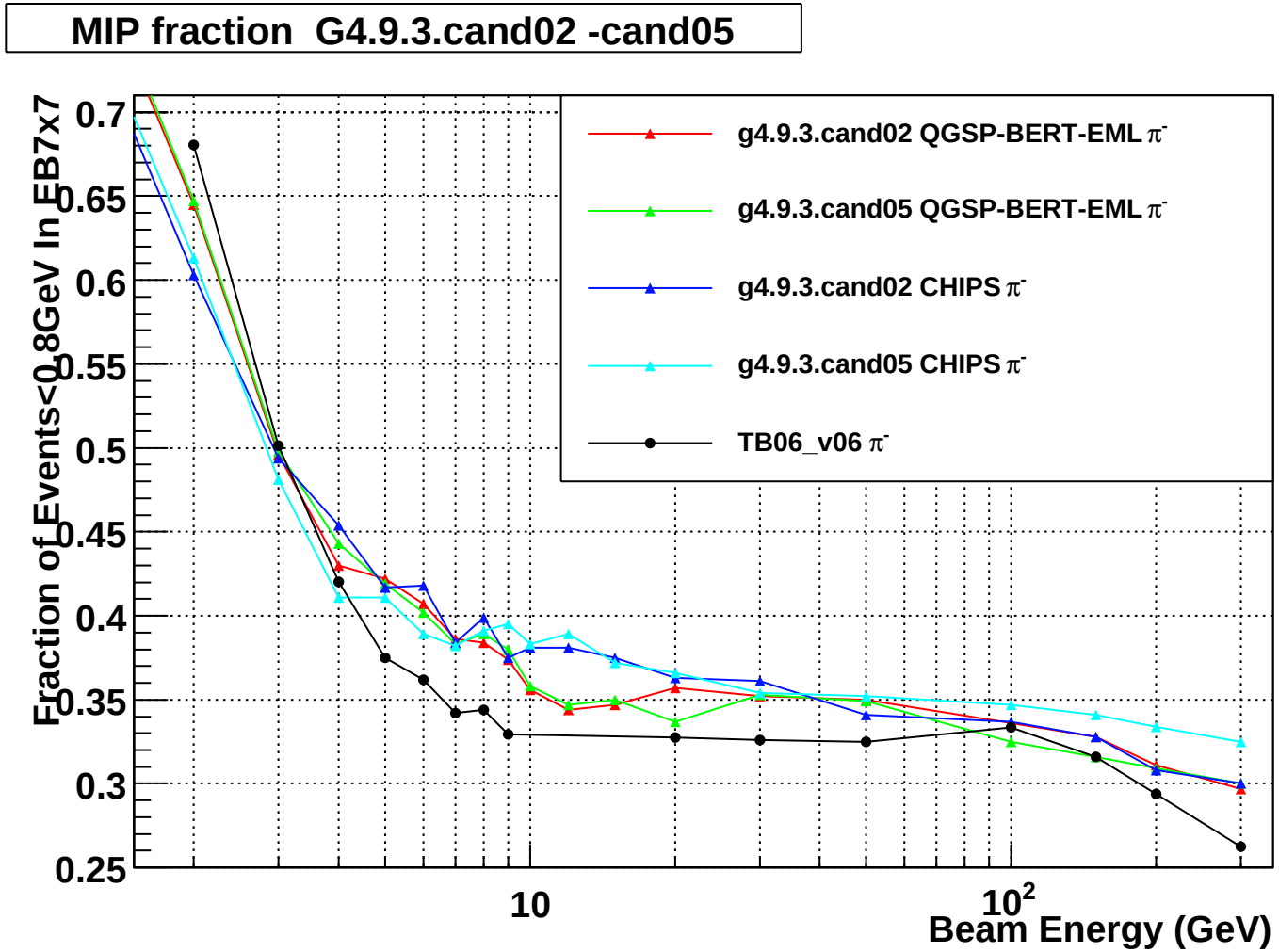


Calo Resolution (MCidealMIP)



- Too good resolution in MC prediction for π^- while the reverse is true for p

MIP Fraction



- Default physics list predicts somewhat higher MIP fraction between 6-50 GeV/c. This is similar to what was observed with 9.2.p01
- Agreement is poorer with CHIPS

Performance (Calorimeter Only Geometry)

Use QGSP_BERT_EML physics list on slc5_ia32_gcc434

	9.2.p01	9.3
t-tbar		
CPU	77.6	76.2
Size	1.25	1.25
Memory	531	534
Zee		
CPU	45.3	42.5
Size	0.63	0.61
Memory	520	521
MinBias		
CPU	10.9	10.7
Size	0.17	0. 17
Memory	512	513

Performance (Full Detector)

Use QGSP_BERT_EML physics list on slc5_amd64_gcc434

	9.2.p01	9.3
t-tbar		
CPU	87.0	81.0
Size	1.51	1.25
Memory	1403	1390
QCD(3.0-3.5TeV)		
CPU	334.6	315.5
Size	2.74	2.72
Memory	1510	1489
MinBias		
CPU	14.6	11.5
Size	0.26	0. 25
Memory	1287	1286

Summary

- QGSP_BERT_EML is the default physics list for CMS. It has discontinuity at ~ 9 GeV in both mean multiplicity and total KE fraction. Overall agreement with test beam data is quite satisfactory.
- CHIPS does not show discontinuity in mean multiplicity nor KE fraction. But the model shows some structure in these distributions around 6 GeV. The agreement with the data is much worse than predictions from QGSP_BERT_EML.
- The new Geant4 version has shown significant performance enhancement for different physics samples.
- The version 9.3 will be used as the dafault Geant4 version for CMS in future.