Comparison of Predictions from Geant4 Versions 10.3.ref08 and 10.3.ref09 with CMS TestBeam and Collision Data

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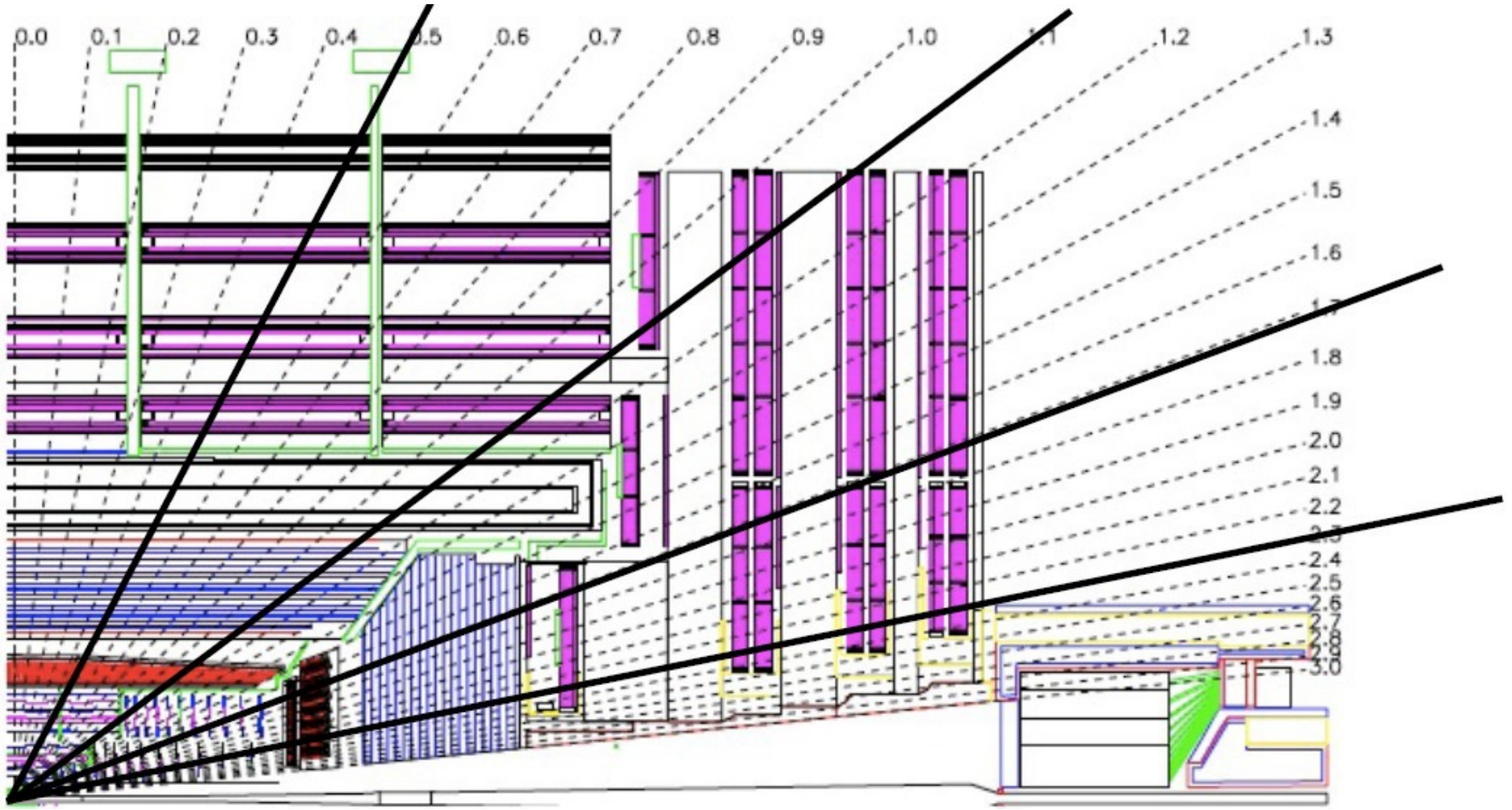
What is Done

- Compare ratio of calorimeter energy measurement to track momentum for isolated charged hadrons between data and MC
- For Data:
  - Use low luminosity runs taken during 2016B run period using Zero Bias and Minimum Bias triggers
- For Monte Carlo:
  - Generate single particle event sample using a flat energy distribution between 1 and 20 GeV
  - 100k events are generated with Physics List FTFP_BERT_EMM for Geant4 versions 10.2.p02, 10.4.beta, 10.3.ref08 and 10.3.ref09. Events are produced with a given admixture of pions, kaons and protons and anti-protons (as expected in minimum bias sample)
- Compare energy measured in the calorimeter (scaled by particle momentum)

Energy Measurements



- Select good charged tracks using standard cuts
- Propagate them to calorimeter surface and select those which are well isolated from other charged or neutral particles in the calorimeter surface
- Measure energy by combining energy measurements from a matrix of NxN cells around the cell hit by the extrapolated track to the calorimeter surface in four regions (two in the barrel, one in the endcap and one in transition region)

Collision Data (Narrow Cone)

- The level of disagreement between data and MC is between 2 to 7% in the three new releases depending on the region of the detector as well as the Geant4 version

Mean level of disagreement between MC and data

	$(E_{7x7}+H_{3x3})/p$ 10.2.p02	$(E_{7x7}+H_{3x3})/p$ 10.4.beta	$(E_{7x7}+H_{3x3})/p$ 10.3.r08	$(E_{7x7}+H_{3x3})/p$ 10.3.r09
Barrel 1	(2.4±0.4)%	(1.9±0.4)%	(2.8±0.4)%	(2.1±0.4)%
Barrel 2	(3.6±0.4)%	(5.0±0.4)%	(4.7±0.4)%	(5.4±0.4)%
Transition	(4.9±0.5)%	(7.3±0.5)%	(5.7±0.5)%	(6.3±0.5)%
Endcap	(3.1±0.6)%	(5.9±0.5)%	(4.3±0.6)%	(5.3±0.6)%

Collision Data (Wider Cone)

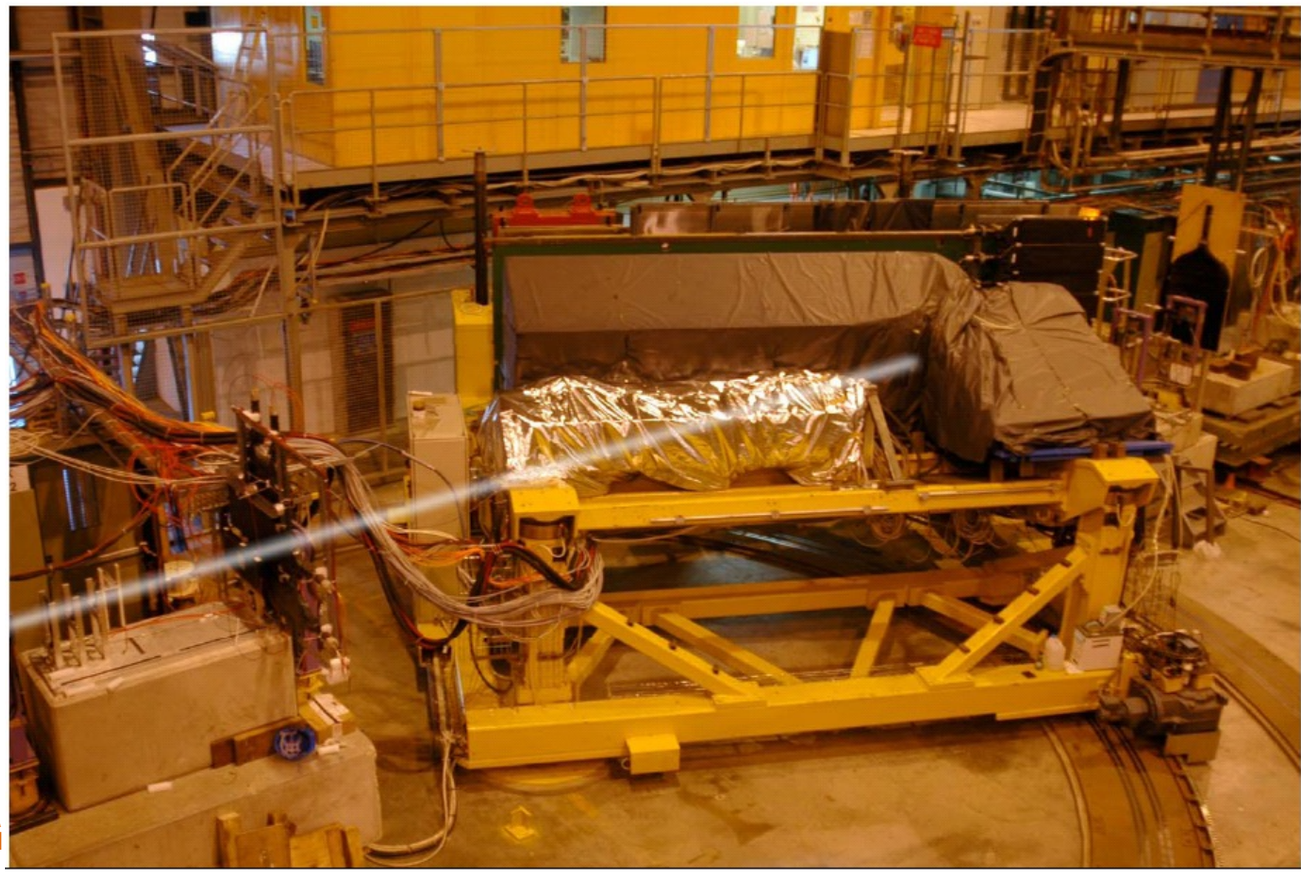
- The level of disagreement between data and MC is between 2 to 5% in the three new releases (slightly better than the agreement for narrower cone)

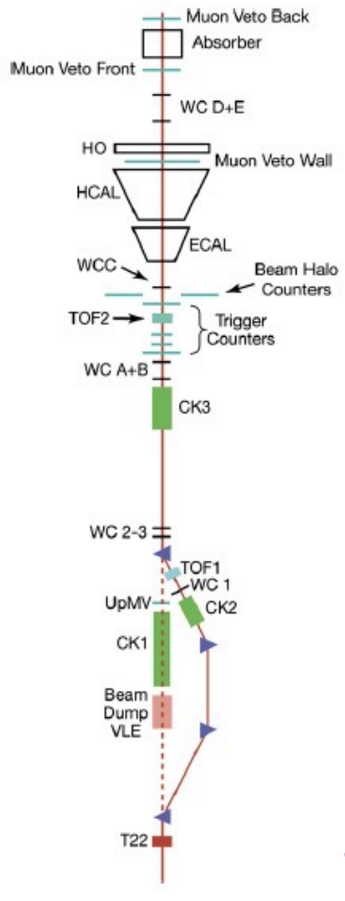
Mean level of disagreement between MC and data

	$(E_{11x11}+H_{5x5})/p$ 10.2.p02	$(E_{11x11}+H_{5x5})/p$ 10.4.beta	$(E_{11x11}+H_{5x5})/p$ 10.3.r08	$(E_{11x11}+H_{5x5})/p$ 10.3.r09
Barrel 1	(2.6±0.4)%	(1.9±0.4)%	(2.0±0.4)%	(2.3±0.4)%
Barrel 2	(2.2±0.4)%	(2.6±0.4)%	(2.8±0.4)%	(3.6±0.4)%
Transition	(2.2±0.5)%	(4.8±0.5)%	(3.5±0.5)%	(4.3±0.5)%
Endcap	(1.5±0.3)%	(3.9±0.5)%	(2.9±0.5)%	(3.8±0.5)%

2006 TestBeam Data

- CMS collected data with prototype of Hadron Calorimeter Barrel and a supermodule of the barrel Electromagnetic Calorimeter in the H2 test beam area at CERN during 2006.
- The data correspond to single particle response due to well identified particles over a large momentum range (2 to 350 GeV)
- The results consist of mean energy response (measured as the ratio of the total energy in the calorimeter to the beam momentum) or energy resolution as a function of beam momentum for different beam types and also the energy distribution for particles of a given type at a given momentum
- Use the setup described within CMSSW to simulate events with single particles.





What is Compared?

- Calibrate data as well as MC using 50 GeV electron beams
  - During calibration of HCAL a set up with no ECAL is used
- Compare predictions from the four Geant4 versions using the physics list FTFP_BERT_EMM
- Look into low momentum data (at or below 9 GeV/c) where the particle identification is rather good (using TOF, Cerenkov detector)
- Different versions of Geant4 provide very similar results
- The data distributions are wider than the MC predictions
- The mean level of agreement is around 10% for pions and protons

Summary

- Predictions from the physics list FTFP_BERT_EMM from Geant4 version 10.4.beta, 10.3.ref08 and 10.3.ref09 have been compared with the data as well as the Geant4 version in the current CMSSW release
- The level of agreement between data and Monte Carlo for the new versions of Geant4 are comparable to that from earlier version