CAN-050a

Longitudinal energy distribution in the FTFP_BERT physics lists of GEANT4 version 10.1

The CALICE Collaboration *

Abstract

This short note gives an additional comparison of the newest version of GEANT4 to the published Si-W ECAL data. The Si-W ECAL paper is published in Nucl. Instrum. Meth. A 794, 240-254 (2015) and can be found also on arXiv:1411.7215 (arxiv.org/abs/1411.7215). A comparison of the longitudinal, and radial, profile at 10 GeV in the physics list FTFP_BERT of version 10.1 of GEANT4 to the data is shown. The comparison shows a lower energy deposition in the simulated events, which can be attributed to a lower number of hits compared to the data.

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In version 9.6 of GEANT4 the longitudinal energy profile of pions at 10 GeV was not predicted well by the FTFP_BERT physics list. This in contrast to its satisfactory prediction of the profile in version 9.3 of GEANT4. Some errors have been identified by the GEANT4 developers in version 9.6 which are corrected in the new release. Recently the latest version (version 10.1) of GEANT4 became available for production within the CALICE simulation chain. In order to see if the prediction of the longitudinal energy profile was improved, a sample of 500 k events at 10 GeV have been generated and analysed in the same way as was done for the published analysis.

Figure 1 shows Fig. 24 (b) from the paper with the addition of the profile found in version 10.1 of GEANT4. The result from version 10.1 is closer to the data than the result from version 9.6, however the improvement is not sufficient to describe the data in a satisfactory manner. The fact that GEANT4 physics lists are tuned exclusively on thin target scintillator data, could still be a cause that for silicon the prediction deviates from the data.

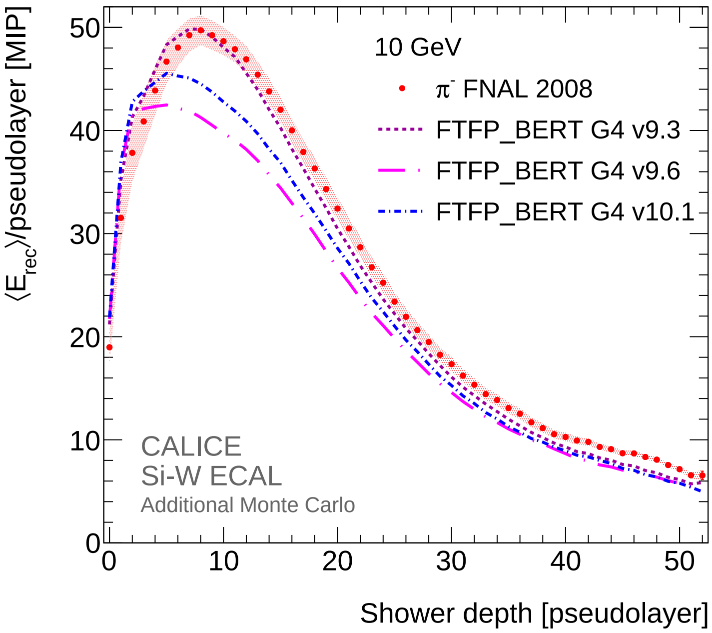

Figure 1: Longitudinal energy profile for 10 GeV pions compared to predictions from the FTFP_BERT physics list in different versions of GEANT4. This figure is an adaptation of Fig. 24 (b) from the paper.

The average hit energy per layer predicted in different versions of GEANT4 is also compared to data. Figure 2 shows a modification of Fig. 21 (c) from the paper; the data is now compared to only FTFP_BERT, but from 3 different GEANT4 versions. This observable is overall best described in version 10.1, but near the shower start the energy per hit is too high in all studied GEANT4 versions. Version 9.6 has a lower mean hit energy than version 10.1, which explains the improvement seen in the longitudinal energy profile.

A similar underestimation of the deposited energy is seen in the radial energy profile. Figure 3 shows an adjusted version of Fig. 11 (c) from the paper, where the FTFP_BERT physics list from 3 GEANT4 versions is compared to the data. The figure shows the radial distance of hits from the shower centre. The versions 9.6 and 10.1 underestimate the deposited energy on the right side of the peak, but the underestimation is much less than in the longitudinal profile. In the shower core (small radii) the energy deposition is even higher in version 10.1 than in the data. This overestimation of the energy in the shower core can also be seen in the mean hit energy as a function of the radius shown in Fig. 4, which is an adaptation of Fig. 13(c) from the paper, showing the FTFP_BERT physics list from 3 GEANT4 versions compared to the data. Version 9.6 and 10.1 describe the mean hit energy better for radii larger than 5 mm than version 9.3, however for smaller radii all 3 versions overestimate the mean hit energy. The deviation from the data is largest for version 10.1.

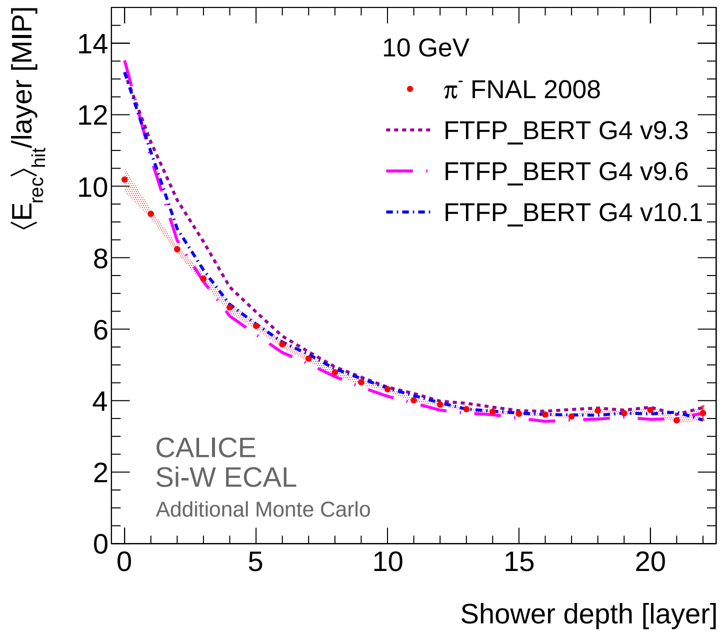

Figure 2: Mean hit energy per layer for 10 GeV pions compared to predictions from the FTFP_BERT physics list in different versions of GEANT4. This figure is an adaptation of Fig. 21 (c) from the paper.

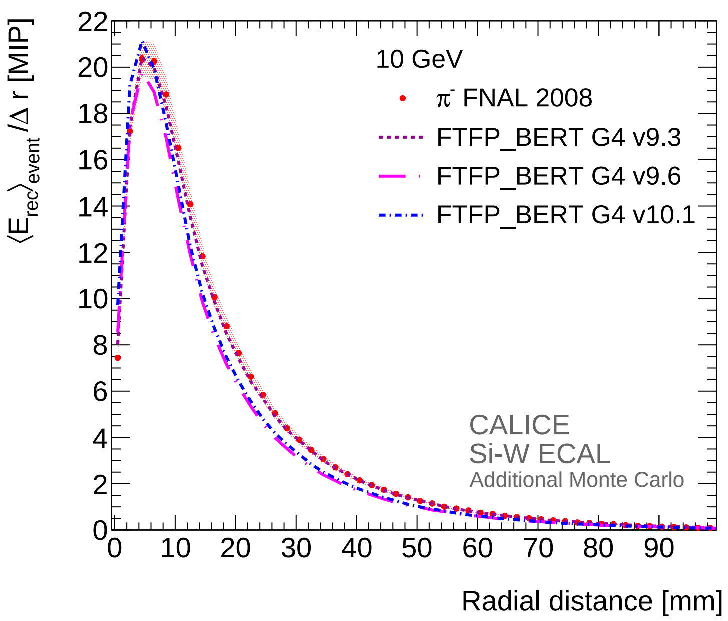

Figure 3: Radial energy profile for 10 GeV pions compared to predictions from the FTFP_BERT physics list in different versions of GEANT4. This figure is an adaptation of Fig. 11 (c) from the paper.

The average number of hits in a pion shower in the simulation is too low; in data it is 69.9, in version 9.3 it is 62.5, in version 9.6 it is 59.9 and in version 10.1 it is 60.5. Figure 5 shows the number of hits in the pion shower as a function of the hit energy. The ratio of the number of shower hits in the simulation to the number in data is shown. For version 9.6 the number of hits is about 10% too low at all hit energies while for version 9.3 and 10.1 the number of hits for higher hit energies is about 5% too high. A general trend is that there are less low energy hits in the simulation than in data, this effect extents too higher hit energies for version 9.6 and 10.1 than for version 9.3.

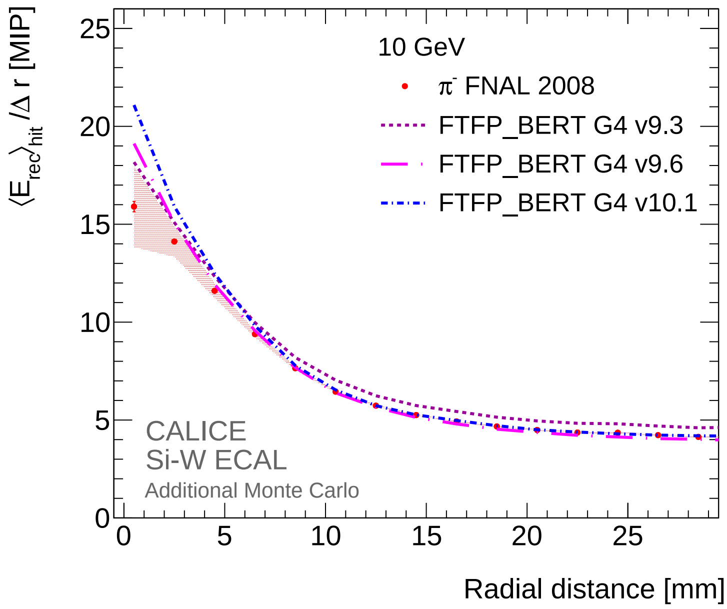

Figure 4: Mean hit energy as a function of radius from the shower core for 10 GeV pions compared to predictions from the FTFP_BERT physics list in different versions of GEANT4. This figure is an adaptation of Fig. 13 (c) from the paper.

Figure 6 shows the total number of hits in pion events as a function of the hit energy, again the ratio MC/data is shown. Clearly for version 9.6 the total number of hits is always too low. For version 9.3 and 10.1 the ratio is close to 1 for higher hit energies, while for lower hit energies there are not enough hits. This range of a too small number of hits is larger for version 10.1 than for 9.3. These last two figures suggests that the distribution of hits in the entire event is not the same in data and simulation.

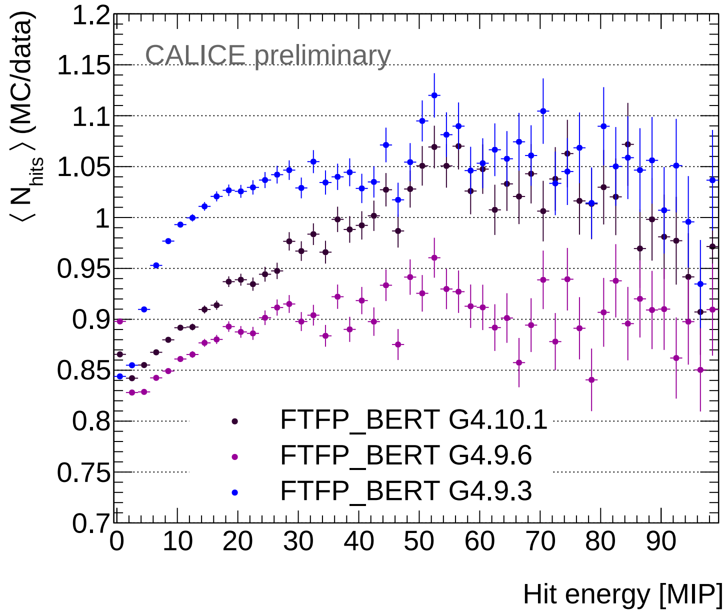

Figure 5: The ratio of number of hits in 10 GeV pion showers as a function of hit energy of hits in simulations to hits in the data for different versions of GEANT4.

The observed features in the simulated longitudinal energy profile; the overshoot of the data in the first few layers and the underestimation of the energy for subsequent layers, could be explained by the observed hit distributions. Hits in the beginning of the shower have higher energy than

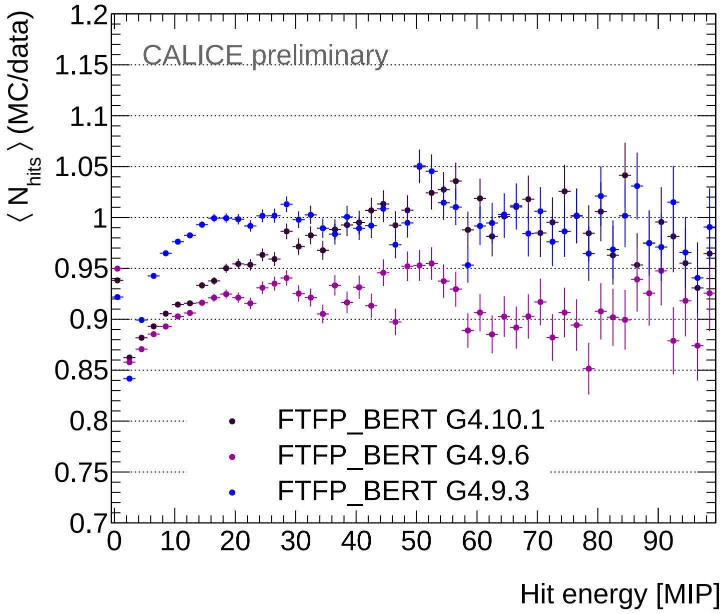

Figure 6: The ratio of total number of hits in 10 GeV pion events as a function of hit energy of hits in simulations to hits in the data for different versions of GEANT4.

hits further along. The excess of hits with high energies combined with the too high mean hit energy in the first layers can explain the overshoot in the longitudinal energy profile for the first few layers. The lower number of hits with smaller energy in the simulated events, combined with the agreement of the mean hit energy between simulation and data for layers beyond the first few, can explain the underestimation of the simulations of the longitudinal energy profile.