

Pion showers in highly granular calorimeters

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Abstract. New results on properties of hadron showers created by pion beam at 8–80 GeV in high granular electromagnetic and hadron calorimeters are presented. Data were used for the first time to investigate the separation of the neutral and charged hadron showers. The result is important to verify the prediction of the PFA algorithm based up to now on the simulated data only. Next, the properties of hadron showers were compared to different physics lists of GEANT4 version 9.3.

Keywords. International Linear Collider; particle flow algorithm; calorimeter resolution.

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1. Introduction

The CALICE Collaboration investigates different technology options for highly granular calorimeters for detectors at the future electron–positron colliders. The most advanced options, SiW electromagnetic calorimeter (ECAL) with a cell area of 1 cm² and scintillator-tile hadron calorimeter (HCAL) with a cell area of 9 cm² underwent thorough tests in beams of leptons and hadrons. The collected data are used to evaluate the potential of novel technologies and software developments leading to a significant improvement of jet energy resolution at the level of $\sim 30\%/\sqrt{(E/\text{GeV})}$ using the particle flow algorithm (PFA) [1]. The high granularity also allows detailed investigations of topology of hadron showers. In this contribution the comparison between data collected at CERN test beam in 2007 and GEANT4 simulations with several physics lists for pion showers with energy between 8 GeV and 80 GeV are presented.

2. Experimental test of PFA

The capability of PFA to recover neutral hadron energy in the vicinity of the charged hadron energy was tested experimentally. The neutral hadron was imitated by the removal of hits from the second charged beam particle in the calorimeters leaving the shower hits untouched. The hit positions of this ‘neutral hadron’ shower were shifted in the transverse direction by 5–30 cm and were superimposed with the hits from the other charged hadron. The energy of clusters was reconstructed using PandoraPFA algorithm [2]. The study was

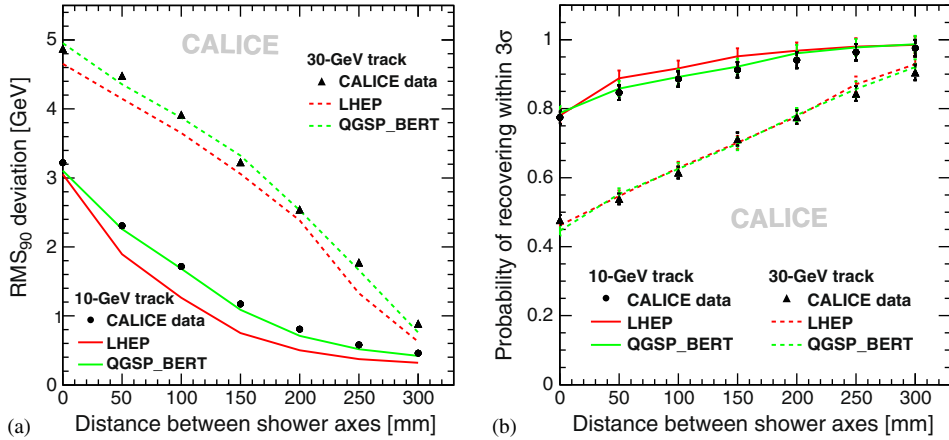


Figure 1. (a) RMS₉₀ deviation and (b) probability of neutral 10 GeV hadron energy recovered within 3σ from its real energy vs. the distance from charged 10 GeV (circles and continuous lines) and 30 GeV (triangles and dashed lines) hadrons for beam data (black) and for the simulated data LHEP (red) and QGSP_BERT (green).

done for 10 and 30 GeV pion beam energies [3]. Since the neutral hadron energy is known from the original calorimetry measurement of single charged particles, the reconstructed energy of the neutral cluster is a measure of the confusion due to the presence of the second cluster from the charged pion. The RMS₉₀, the r.m.s. deviation of the recovered energy from the energy measured in the calorimeter in the central region which contains 90% of the events, is shown in figure 1a. The RMS₉₀ is largest for 30 GeV charged and overlapping 10 GeV neutral hadrons. In figure 1b the probability to recover neutral hadron energy of the 10 GeV neutral hadron in the vicinity of the 10 and 30 GeV charged hadron within 3σ is plotted as a function of the shower axis distance. The probability increases significantly with the energy of the charged pion. In both cases, the data are compared to two physics lists, LHEP and QGSP_BERT in GEANT4. The data agree better with the QGSP_BERT physics list. The fact that the data and MC are in a good agreement allows one to consider the PandoraPFA program as a good reconstruction program for the future full size detector at the ILC.

3. Hadron shower properties

The hadron showers created by pions and taken in 2007 in the CERN H6 beam were measured by ECAL and HCAL. The extremely high granularity of calorimeters allows the investigation of three-dimensional structure of showers at high accuracy. Especially for the transverse shower profile no competitive measurements are available. The transverse shower width is important for the efficient separation of overlapping clusters in PFA algorithm. For each hit in the ECAL the transverse distance between the pad centre and the shower barycentre is calculated. By histogramming this radial distance, the transverse

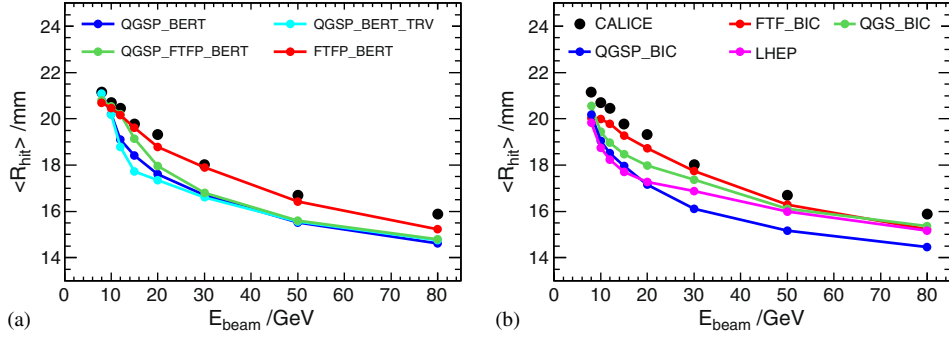


Figure 2. Mean energy weighted shower radius as a function of beam energy in ECAL. The data are compared with the prediction of simulation for different GEANT4 physics lists.

shower profile is constructed. The mean of the energy weighted shower radius as a function of energy is shown in figure 2 [4]. The observed shower becomes narrower with increasing energy. All the physics lists underestimate the shower width by 5–10%. The models FTF_BIC and FTFP_BERT lie closest to the data.

Also in the HCAL the high granularity allows us to locate accurately the first hard interaction. In about 74% of the cases the error in the position determination is ~ 3 cm [5]. The same procedure as described in the case of ECAL allowed construction of histograms of the transverse shower profile. Its mean value for several energies was compared with the GEANT4 simulation done for five physics lists. The ratio MC/data is shown in figure 3a. All the physics lists underestimate the shower width at all energies typically by $\sim 10\%$ (except for CHIPS). The longitudinal shower profile is interesting due to its sensitivity to the content of energetic hadrons, photons and low-energy nuclear fragments. The distribution of the energy dependence of the mean value for the longitudinal shower profiles compared to MC is given in figure 3b. The shower simulated with CHIPS predict

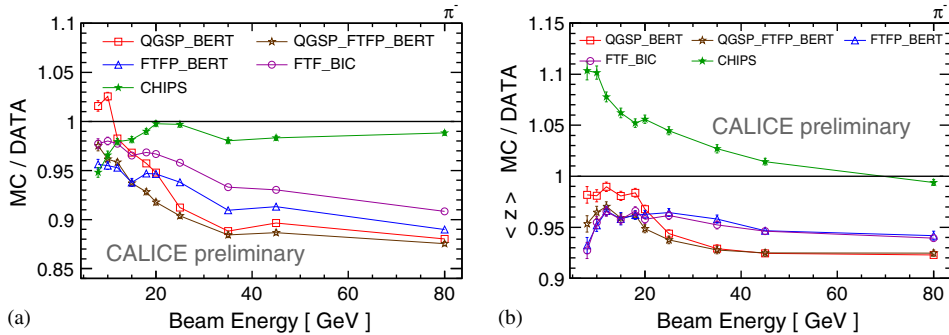


Figure 3. The ratio of simulation and data for (a) radial and (b) longitudinal shower profiles at several pion beam energies and for different GEANT4 physics lists in the HCAL.

a longer shower, all other physics list predict a shorter shower by $\sim 2\text{--}7\%$ in the whole energy range studied.

Acknowledgement

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