Hadron shower decomposition in a highly granular calorimeter

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The CALICE collaboration has developed and constructed highly granular electromagnetic and hadronic calorimeter prototypes to evaluate detector technologies for future linear collider experiments. The CALICE analogue hadronic calorimeter prototype is a sampling structure with 38 active layers comprised from small scintillator tiles individually read out by silicon photomultipliers as described in [1]. The calorimeter depth is about $5.3{\cdot}\lambda_I$ and total number of channels is 7608. The prototype was extensively studied during several test beam campaigns in two configurations: with tungsten or steel as absorber material. The unprecedented granularity allows to investigate both longitudinal and radial shower development and perform a detailed comparison between experimental data and simulations [2,3]. In this study we analyse response, resolution and spatial parameters of hadronic showers induced by positive pions and protons with initial energies from 10 to 80 GeV in the CALICE analogue scintillator-steel hadronic calorimeter. The experimental data is compared with simulations using Geant4 version 9.6 [4].

The observed difference in calorimeter response to pion and proton-induced showers can be mainly explained by available energy for baryons; this result is in agreement with that obtained in test beam studies of Fe-Scintillator ATLAS Tile calorimeter [5]. The high granularity gives a possibility to identify a position of the first inelastic interaction and therefore to disentangle the spatial shower development from the distribution of shower start position to compare different types of hadrons. Our study of spatial observables for pion and proton showers demonstrates that the mean shower radius and longitudinal centre of gravity of proton showers are on average 10% and 5% larger, respectively. All studied Monte Carlo models underestimate mean shower radius for pions by 5-10% [6].

Hadronic showers in a calorimeter are characterised by a relatively narrow core with high energy density surrounded by an extended halo. The core is usually formed by electromagnetic cascades arising from π^0 decay. To describe the shape of hadron shower profiles we represent them as a sum of two contributions: short and long (tail) components for longitudinal development and core and halo components for radial development. The behaviour of longitudinal tail and radial halo is well reproduced by simulations in the all studied energy range and was found to be very similar for pions and protons. While the predicted profiles at initial energy below 20 GeV are in agreement with data, above 20 GeV, the contributions from short and core components in simulated events are overestimated, the excess increasing with energy. The biggest observed difference between data and simulations is in a relative containment of the separated components.

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References

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