Use of Artificial Neural Networks for Improvement of CMS Hadron Calorimeter Resolution

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Introduction

We present a novel artificial neural network (ANN) based algorithm to improve the hadron calorimeter resolution to single particles.

Experimental Setup

Fig. 1 shows the experimental setup and various calorimeters involved in the CMS 2006 Test Beam (TB06).

Fig. 1 CMS Test Beam facility. The motion table rotates and tilts. Beam direction is indicated with the blue arrow.

Multivariate (ANN) Method

An ANN is used to model a particle shower, mapping individual inputs to calorimeter towers and a single output to known beam momenta.

A typical ANN with 1 hidden layer is shown in Fig. 2. A linearized version of the ANN without the hidden layer is also used in this study.

TB06 Method

A test beam calibration and energy correction procedure called the TB06 method[1] is used for benchmark comparison of resolution and energy response.

[1] Submitted to EPJ C

"The CMS Barrel Calorimeter Response to Particle Beams from 2 to 350 GeV/c"

The TB06 method corrects the combined calorimeter response in several steps:

1. Data is corrected by a function such that central energy value is equal to the beam momentum

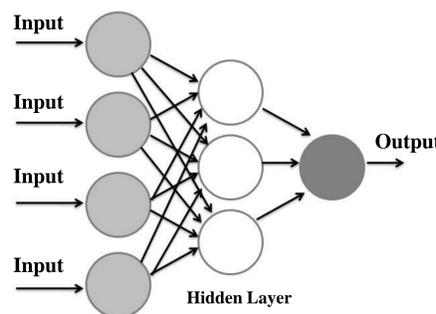2. Relative electromagnetic to hadronic energy deposition correction is applied

Fig. 2 ANN architecture with 1 input layer, 1 hidden layer and 1 output

Energy Response Comparison between TB06 and ANN Methods

Fig. 3 shows the comparison in calorimeter response between the TB06 method (left) and the ANN method (right) for π^- beams with momenta of 3, 9 and 100 GeV/c
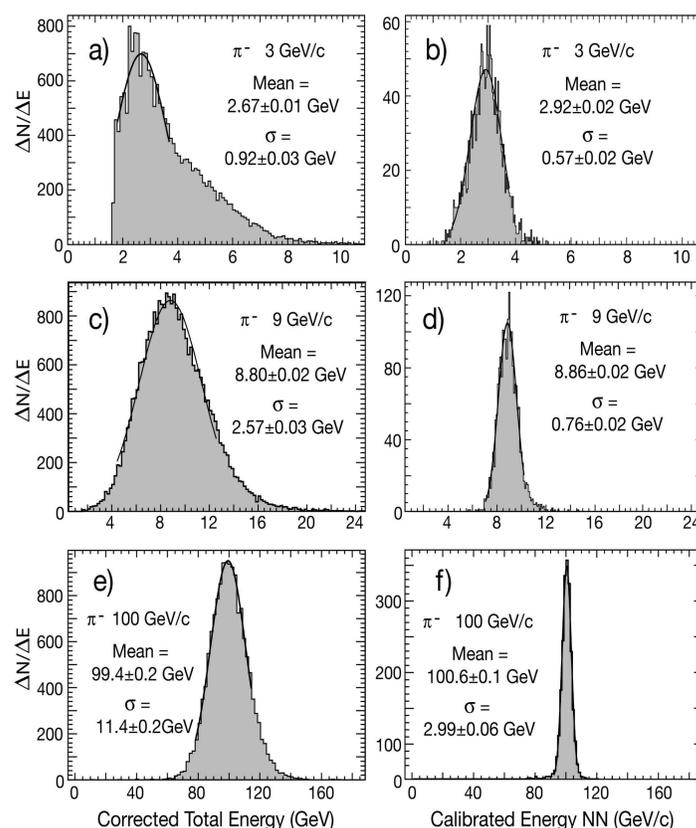

Fig. 3 Calorimeter response to various π^- beams using the TB06 method (left) and the multivariate method (right). Errors shown do not include systematics.

Resolution Summary

Fig. 4 shows the comparison in calorimeter resolution among the TB06, ANN and linear ANN methods.
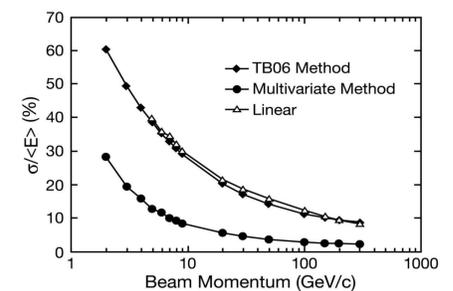

Fig. 4 Comparison of calorimeter resolution obtained with the TB06, ANN and linear ANN methods for beam momenta 2-300 GeV/c

Average Energy Response

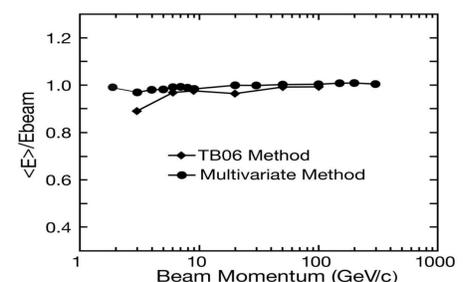Fig. 5 shows the mean energy response obtained with the TB06 and ANN methods.

Fig. 5 Comparison of mean energy response for the TB06 and the ANN methods

Discussion

As Fig 4. shows, the linearized ANN performs similarly to the TB06 method. Improvement in resolution comes from use of nonlinear network architecture which reflects the nonlinear nature of energy sharing among the calorimeter towers with inherently different response to particles of different momenta.

Conclusions

A nonlinear ANN based method leads to sizable improvement in the calorimeter resolution for single particles.