Discrimination of muons and hadrons inside calorimeter using Artificial Neural Network

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Introduction

The India-based Neutrino Observatory (INO) [1] is a proposed atmospheric neutrino experiment where a large magnetized Iron Calorimeter (ICAL) will be used as main detector. Atmospheric ν will fall in all directions to the calorimeter and neutrinos interact with the iron nucleons. In neutral-current (NC) interaction, hadrons are generated through the exchange of Z particles and in charged-current (CC) interaction, neutrinos interact weakly through the exchange of a W^+ or W^- boson to form charged particles i.e., muons will be produced from a ν_μ CC interaction.

In calorimetric measurements of neutrino interactions like in INO, hits generated by muons and hadrons together in an event due to charged-current ν interaction poses a challenge in identifying muon hits only. The separation of hits is essential for proper reconstruction of event parameters. From a collection of events accumulated by the calorimeter, it is necessary to make use of the selection criteria for (a) separating muon events from hadron events i.e., event-level separation and (b) separating muon hits from hadron hits for events i.e., hit-level separation. For that we have divided the inputs to artificial neural network into two category, in Category-I muon events will be mixed with hadron events separately i.e. event-level mixing and in Category-II input, hadron hits are embedded with the muon hits in an event in a calorimeter i.e., hit-level mixing.

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Inputs to Artificial Neural Network

The Artificial Neural Network(ANN) [2, 3] is a highly simplified model of the structure of biological human neural network. The work

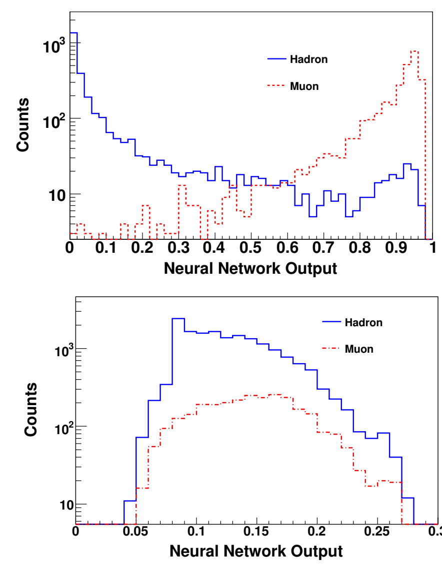

FIG. 1: ANN output spectra for category I (Top Panel) and category II (Bottom Panel). Reasonable distinction are seen for two types of particles. We apply a threshold of 0.5 for obtaining the efficiency and background fraction.

of unknown pattern recognition is divided into two parts, first is the training of the network for a known pattern or sample and the weights obtained from the training is applied to an unknown pattern to give an output which can be related to a result. In this study, inputs for the network are obtained from the response of the simulated INO iron calorimeter volume. A detailed description about the simulated INO ICAL detector is given in Ref. [4]. The number of hits in first 10 detector layers after the vertex is considered as input to the network. Muons being MIP particle leaves a long track inside the detector, whereas hadrons get absorbed leaving large number of hits in the first few layers. We have utilized this discrimination in hit multiplicity over the detector layers as the main criterion for separating muons and hadrons.

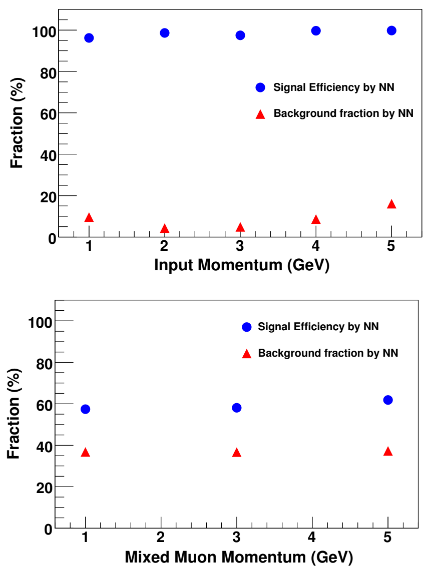

FIG. 2: Top Panel: Variation of discrimination efficiency and background fraction for Category I input at 0.5 threshold for different muon momenta events. Bottom Panel: Variation of efficiency and background fraction with different muon energies Category II input . Threshold is adjusted to obtain reasonable efficiency.

Results

Figure 1 (top and bottom) shows the ANN output spectra for category I and II respectively. The assigned target output value of ANN for muon and hadron event or hit are 0 and 1 respectively. For further discrimination a threshold is applied on the ANN output. So, muons and hadrons are the selected candidates just above and below the threshold respectively. For category I, ANN outputs are well separated for two types of particle and a threshold of 0.5 is applied for estimating the efficiency (ϵ) and background fraction (B_f). In this study, ϵ is defined as the ratio of the selected muon candidates to the total number of input muon events, whereas B_f is the ratio of the identified hadrons events to the total number of input hadrons events.

For Category I, the efficiency obtained is above 98% with associated background fractions of 10 %, as shown in figure 2 (top). Since muon event has on an average 1 hit/layer in all 10 layers whereas hadron event get absorbed after first few layers. For Category II, the ANN output spectra for muon and hadron hits are not well separated. As shown in the figure 1 (bottom), the hadron peak is shifted to ~ 0.08 and the muon peak lies approximately at 0.16, as a result we obtain 67% signal identification efficiency with $\sim$ 40 % background, as shown in figure 2 (right panel).

Acknowledgments

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