Proceedings of ICRC 2001: 515 © Copernicus Gesellschaft 2001

ICRC 2001

Applicability of ANN in the ARGO-YBJ experiment

ARGO-YBJ Collaboration

Abstract. We report the applicability of Artificial Neural Networks (ANN) in the ARGO-YBJ data analysis, i.e. inner or outer shower core position identification and γ-proton separation, With the MC samples from Corsika and a standard feed forward neural network, the results indicate that the rejection of outer showers induced by protons is more than 60% and the enhancement in the gamma ray sensitivity is about 37%

1 Motivation

The Sino-Italian ARGO-YBJ experiment locates at Yang-Ba-Jing (90^{o}31'50"E, 30^{o}6'38"N, 4300m a.s.l.) of Tibet, China. The main goal of the experiment is to search for Very High Energy γ point sources and HE Gamma Ray Bursts. The experimental setup is a coverage RPC carpet with an area of 97m x 103m(D'Ettorre et al., 1999) which consists of 14040 PADs. Each PAD is the detector minimum unit with 8 readout strips (i.e. the maximum number of recorded particles = 8). In order to increase the ratio of signals to noises, we have done a preliminary study on the γ-proton seperation using Artificial Neural Networks(ANN) technique(Bussino 1999). Our further Monte Carlo study indicates that the determination accuracy of event core position will affect the γ-proton identification power significantly and the key point for the determination of event core position is inner or outer event classcification. Here inner (or outer) event means the event real core located inside (or outside) of the central 71m x 74m full coverage carpet. In this note we mainly discuss on the identification power for the two classes of events.

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2 The Monte Carlo Study

2.1 The Monte Carlo samples

Firstly a large number of air shower events were generated using CORSIKA code 5.61 (Heck 1998). The primary energy spectrum for γ and proton in the energy range $100GeV - 10TeV$ is given by $N(E)dE = N_0E^{-2.7}dE$. At present only vertical incident events are used. Seccondly the detector response were simulated by using ARGO-G which is based on GEANT3 package for ARGO-YBJ detecotr. In this step a shower core is randomly sampled in a region of $-105m \leq x \leq 105m$ and $-105m \leq y \leq 105m$. Finally any event with fired PAD number $\geq$ 50 are taken as a Monte Carlo sample.

2.2 The neural netwok

A simple feed forward neural network with 3 layers (see Fig.1) is generated by the SNNS simulator[SNNS 2000] and the Back-Propagation mode is selected to train the net. There is only one hidden layer with 12 units.

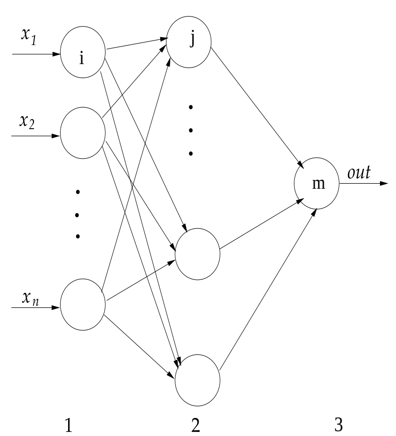

Fig. 1. A simple neural network with three layers of units

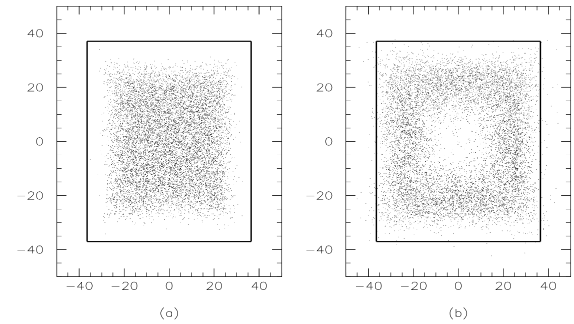

Fig. 2. Distributions of reconstructed shower core position. (a) for inner events, (b) for outer events. The box inside is the central full coverage carpet with the area of 71m x 74m

2.3 Input variables for the network

Fig.2 shows the distribution of reconstructed shower core position for inner and outer events. Considering the basic difference of the two classes of events, we take the following variables of each event as the net input.

(1) The mean value of hits lateral distributions,$\overline{r}$, $\overline{x}$, $\overline{y}$.

$$\overline{r} = \sum_{i=1}^{N_p} r_i \frac{n_i}{T_{hits}} \,,$$
$$\overline{x} = \sum_{i=1}^{N_p} \mid x_i \mid \frac{n_i}{T_{hits}} \,,$$
$$\overline{y} = \sum_{i=1}^{N_p} \mid y_i \mid \frac{n_i}{T_{hits}} \,.$$

where r_i is the distance from fired PAD to the carpet center, (x_i, y_i) the fired PAD coordinate, n_i the hit number in the PAD, T_{hits} the total hit number and N_p is the total fired PAD number.

Fig.3 shows the distributions of $\overline{r}$ for the two classes of events.

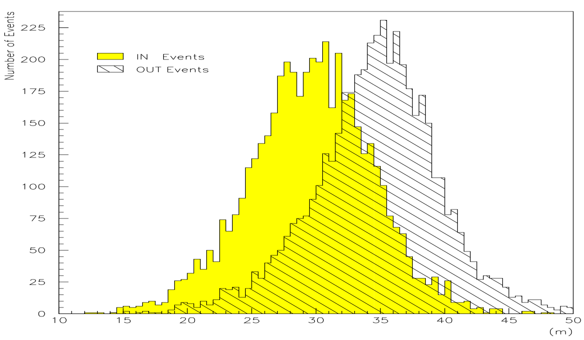

Fig. 3. Comparison of $\overline{r}$ distributions between the two classes of showers

(2) F_{30}, the fraction of hits within the circle with a radius of 30 meters. The F_{30} distributions for different events are shown in Fig.4.

(3) r_{rec}, the distance from the carpet center to each shower core reconstructed with fired PAD informations(see Fig.5) .

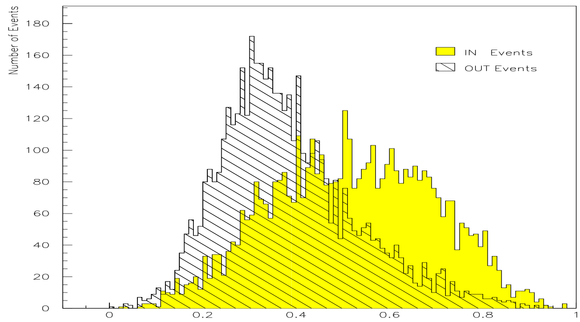

Fig. 4. F_{30} distributions for different events

(4) S, it is a function of two dimension distribution of hits(Qu 2001). Fig.6 shows the S distributions for the two classes of events.

3 Results and discussions

The network mentioned in section 2.2 was trained by 12,000 mixed showers which were induced by γ and protons respectively. Then we tested the network ability by another set of MC samples. The output distributions for events with $30 \leq N_{pad} \leq 500$ are shwon in Fig.7, Fig.8, $table1$ and $table2$. From these figures and tables it is seen that the pollution of outer γ is negligible and the discrimination power for γ induced showers is much higher than proton's.

The MC samples indicate that the outer events in the overall showers induced by primary protons is about 70%. So that the capability of core position identification will remove a large number of outer events and improve the real identification power for the γ-proton separation.

Table 1. The discrimination power for inner and outer shwoers induced by primary gamma rays for net output = 0.5

fired PAD number	30 - 50	50 - 100	100 - 150
acceptance of inner events	85%	93%	96%
acceptance of outer events	83%	87%	96%

Table 2. The discrimination power for inner and outer shwoers induced by primary protons for net output = 0.5

fired PAD number	30 - 50	50 - 100	100 - 150
acceptance of inner events	62%	74%	87%
acceptance of outer events	67%	68%	76%

The ratio of γ signals to proton background is proportional to $n(\gamma)\ /\sqrt{n(h)} \sim \eta_\gamma\ /\sqrt{1-\xi_p}$. Here $(1-\xi_p)$ is the acceptance for overall proton induced events (see table3). From table 3 it is seen that the enhancement in the γ events sensitivity is about 37%.

Table 3. The enhancement in the gamma ray sensitivity

net output	0.5	0.6	0.7	0.8	0.85
η_γ, inner γ accepted	89%	85%	79%	67%	56%
ξ_p, all protons rejected	57%	62%	67%	75%	80%
$\eta_\gamma / \sqrt{1-\xi_p}$	1.37	1.39	1.38	1.26	1.26

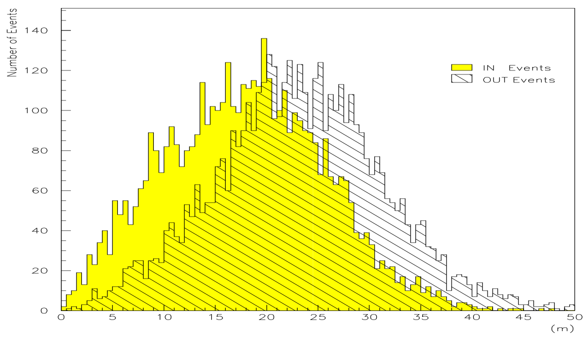

Fig. 5. The r_{rec} distributions

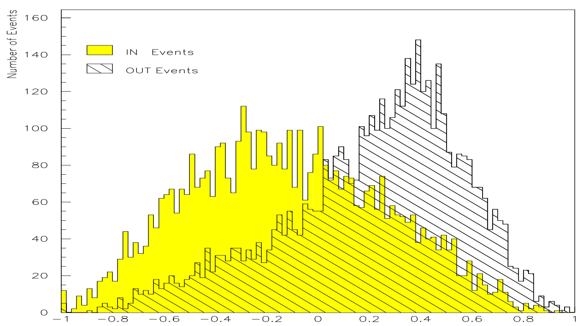

Fig. 6. The S distributions

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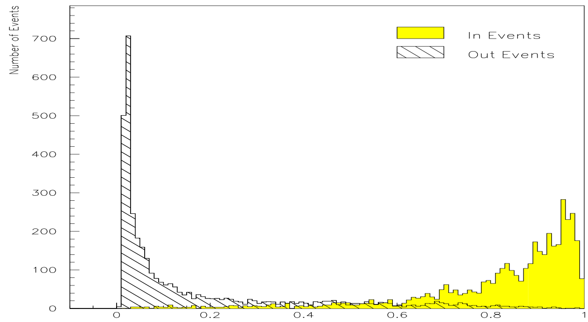

Fig. 7. Discrimination power for γ induced showers

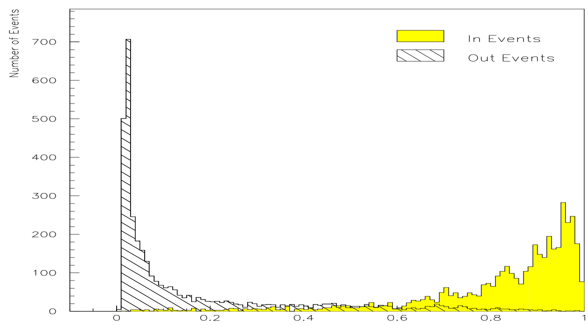

Fig. 8. Discrimination power for proton induced showers