Multicore Cosmic Shower in the ARGO-YBJ experiment

JING ZHAO[1],XINHUA MA[1] ON BEHALF OF THE ARGO-YBJ COLLABORATION
[1]*Institute of High Energy Physics, Chinese Academy of Science*

jzhao@ihep.ac.cn
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Abstract: Multicore events are characterized by the multiple structure in the electromagnetic component near the shower core and can be used to test hadronic interaction models embedded within the cascade simulation tools. The ARGO-YBJ experiment, a full coverage array of Resistive Plate Chambers (RPC) with an active area of 6700 m^2, provides a unique opportunity to investigate with high definition the phenomena near the shower axis. A preliminary study of the Extensive Air Shower(EAS) core structure performed by the ARGO-YBJ detector, and a preliminary Montecarlo simulation is presented as well.

Keywords: EAS; Multicore;ARGO-YBJ

1 Introduction

In the last half century, multicore events in EAS have been observed and investigated by different experiments: firstly by Mt. Norikura experiment, and later with mountain emulsion chambers (MEC) and hadronic calorimeter EAS-TOP[1, 2, 3, 4, 5, 6, 7, 8, 9, 10].The common interpretation of this phenomenon is jet production, which is essentially produced by the leading particle interactions with 'air' target nuclei. Therefore multicore events are good samples to study hadronic interaction models. Results on jet production cross section in p-Air interactions at $\sqrt{s} \approx 500$ GeV in EAS multicore events agree with the expected ones obtained by $p - \bar{p}$ collider data [10] at lower energy in the center of mass.

Emulsion chambers data show that some multicore events have high values for the physical parameter $\chi = \sqrt{E_1 E_2} r_{12} > 1000\ TeV\ cm$, where E_1, E_2 are the energies of two cores and r_{12} is distance between them. Such high χ events can not be explained properly by the present hadronic interaction models [12, 13] and certainly deviates from Monte Carlo simulations [14]. In the case of the MEC experiments, the multicore events were observed only in limited active area, so that the events with higher χ value (or p_T) at larger distance can not be investigated. The ARGO-YBJ experiment provides a good opportunity to study the Multicore events in a more precise way.

2 The ARGO-YBJ experiment

The ARGO-YBJ experiment is made by a single layer of Resistive Plate Chambers (RPCs) [11] housed in a large building (100×110 m^2). The experiment layout is shown in figure 1.

The detector has a modular structure: the basic module is a cluster (5.7×7.6 m^2), made of 12 RPCs (2.8×1.25 m^2 each). 130 of these clusters are organized in a full coverage carpet of 5600 m^2 with active area ∼93%; this central detector is surrounded by 23 additional clusters with a coverage of ∼26% ("guard ring") to improve the core location reconstruction. For the shower event each RPC has two readout methods: one is digital readout via 80 strips (6.75×61.8 cm^2), logically organized in 10 pads (55.6×61.8 cm^2), which are individually recorded and represent the space and time pixels of the detector. Due to a fixed strip density (see Figure 1), the particle density measurement saturates at about $20 particles/m^2$, corresponding to a primary energy of 200TeV. In order to extend the dynamic range to PeV region where the knee of the cosmic ray spectrum is located, which requires a measurement of the secondary particle density up to $10^4\ particles/m^2$, analog readout is implemented by instrumenting every RPC with two large size pads with the dimension of 140×125 cm^2 each, the so called BigPads.

In this paper we present a preliminary study of multicore events observed in the ARGO-YBJ data from October 2010 to February 2011.

3 The multicore data analysis

The selection and analysis method of multicore events is the same as the method mentioned in [18] .

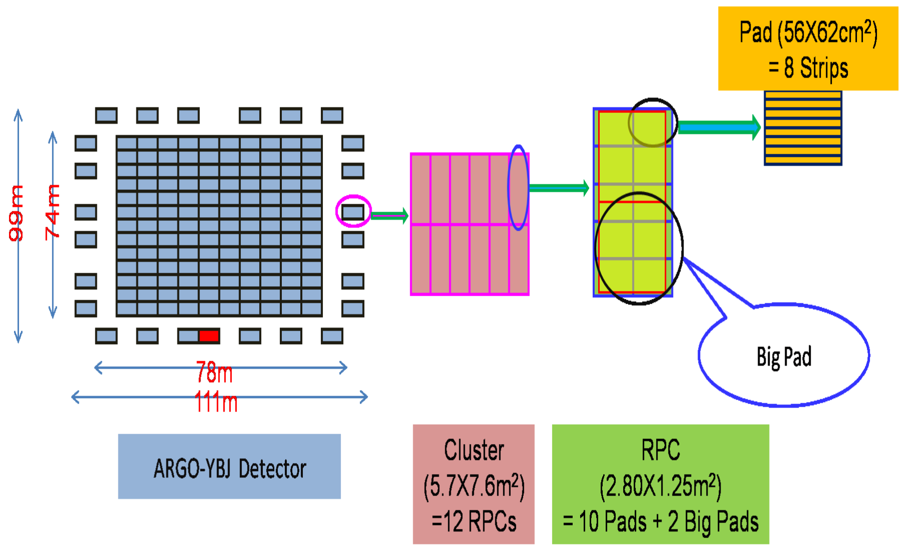

Figure 1: The ARGO-YBJ detector layout.

In the multicore selection procedure, we require at least a density of 100 particles$/m^2$ in the main EAS core and at least 50 particles$/m^2$ in the secondary core above the expected $\rho_{Fit}(r)$ values. We calculate the accidental coincidence event rate of two individual showers in time window of ARGO data acquisition:

$$n^{(2)} = 2\tau r_1 r_2 \tag{1}$$

where $n^{(2)}$ is the accidental coincidence rate, τ is the trigger time window, r_1 and r_2 is the counting rates of the two accidental coincidence showers. Using one month data, the counting rates are r_1=0.237 $/s$, r_2=0.112 $/s$. ARGO trigger time window is 2 μs. Therefore the accidental coincidence rate is only $1.06{\times}10^{-7}/s$(or $9.18{\times}10^{-3}/day$).

Figure 2 shows one real multicore event observed in the ARGO-YBJ data. The event has a well defined second core with a density of 477 $particles/m^2$ with an estimated significance of 5.9σ. Following the emulsion chambers technique: ρ_1 $(particles/m^2)$ is the first maximum density and ρ_2 the second one subtracted by the expected $\rho_{Fit}(r)$ values, and $r_{12}(m)$ is the distance between the two cores. The obtained χ^* value is scaled to the transverse momentum p_T of the particles (or jets) who generated the cores. The estimated value of the physical parameter for the selected event is $log(\chi^*) = 2.92$.

As for the data over four months, we get $3.78{\times}10^{11}$ EAS events. After EAS data selection (selection requirement see [18]) we get $2.53{\times}10^6$ high energy EAS events. 1356 multicore events are found in the selected EAS events,about 10 events/day. The corresponding χ^* distribution for the all events set is shown in figure 3.

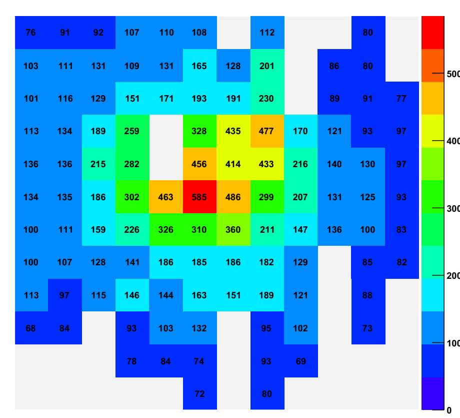

Figure 2: The particle density distribution of an EAS multicore event observed by the ARGO-YBJ detector. The sampling unit is the BigPad. For each BigPad the particle density is shown. The two BigPads with the maximum densities are indicated. Empty boxes correspond to poor functioning of the BigPads which are not used.

4 The Monte carlo simulation

A preliminary Montecarlo simulation has been performed in order to get the energy threshold of our experimental procedure and to check if multicore events at high χ^* (and so far the p_T) values can be expected or not in the frame of a fixed hadronic interaction model. EAS have been generated by the Corsika code [20] with QGSJETII as hadronic interaction model. The model is a typical one of QCD inspired models suitable as an approach for simulating the

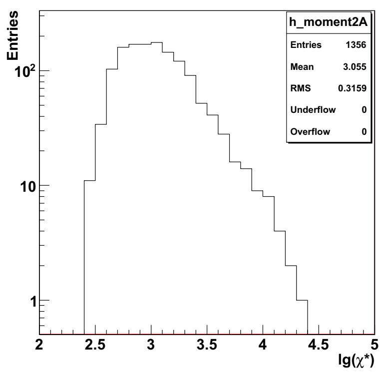

Figure 3: The $\chi*$ distribution for the selected multicore events.

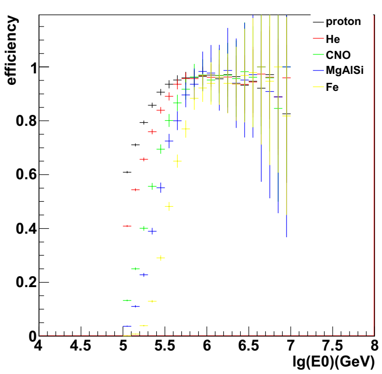

Figure 4: The MC event reconstruction efficiency.

multicore EAS events.

A set of 6.22×10^5 showers has been simulated corresponding to the equivalence of 10 days real time acquisition at ARGO-YBJ detector. The primary energy range is $10^{14} - 10^{16} eV$ and composition and primary spectrum are set as in [22]. The zenith angle ranges from $0°$ to $45°$ and azimuthal angle from $0°$ to $360°$. The observation level is fixed at the YangBaJing Observatory, 4300 m a.s.l.. The particle density distribution at the BigPads sampling points are therefore obtained considering only the experimental geometry.

For different primary nuclei, MC simulation gives detection efficiency of the ARGO carpet for events with Nhit≥5000 (Figure 4). For proton (Fe), detection efficiency is more than 80% above primary energy of 200TeV(500TeV). Moreover, distribution of difference between dropped core position and position of bigpad with the maximum particle density (Figure 5) indicates that resolution of core position decided by the position of BigPad with the maximum particle density is 0.7m.

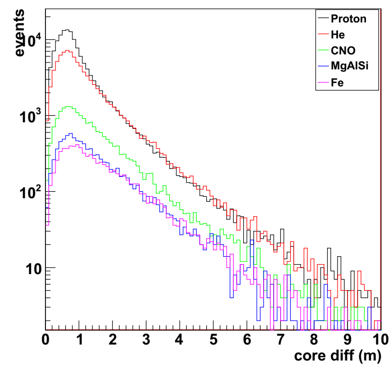

Figure 5: Distribution of difference between dropped core position and position of bigpad with the maximum particle density.

For CORSIKA simulation events, the development of multicore events beginning from the first interaction can be traced back. Figure 6 shows such an interesting simulation multicore event. From the figure we can see that the second core has one μ^+, which is generated from one π^+ decay. It indicates that the second core can be generated from a jet with large p_T.

The full detector simulation G4argo [23] has come into use. G4argo has considered the full simulation of ARGO hall structure, including steel, pillar and roof. Finally the same selection procedure to extract multicore events from the real data will be applied to G4argo simulated ones.

5 Conclusions

ARGO-YBJ data have been analyzed to search for multicore EAS events. A simple Montecarlo simulation has been made to check properties of real data. Both more real data and more full simulation of the ARGO-YBJ experiment will provide more details about the multicore EAS events in the near furture.

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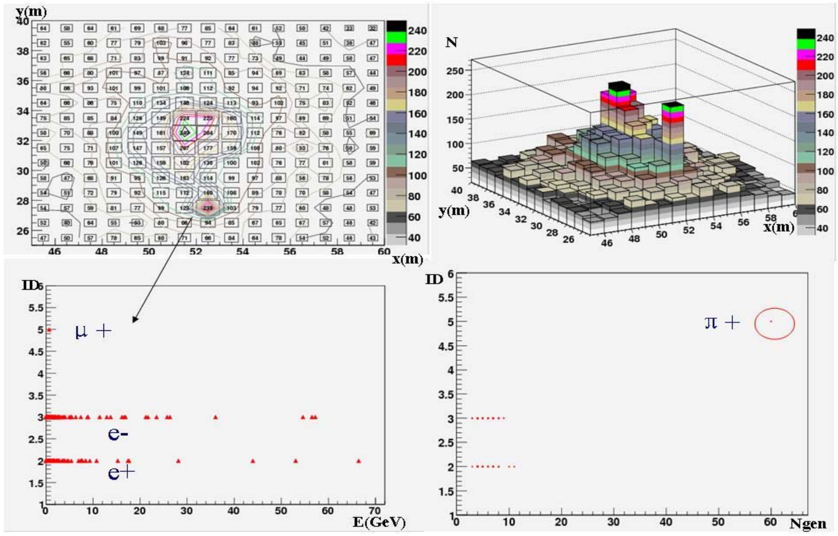

Figure 6: The up left figure is the full image of one simulation multicore event, the up right figure is the 3D view of this event. the down left picture is the energy distribution of muons, e^- and e^+ of this event‘s corsika data, the down right is distribution of generation particles.

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