The Arrival Time Distribution far from the Core of Air Showers above 10^{18} eV Measured in AGASA

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Abstract

In order to know the arrival time of electrons and muons far from the cores of giant air showers, a detector with two scintillators sandwiching a lead plate of 1 cm thickness (Leadburger) has been built and placed at one corner of the Akeno Giant Air Shower Array (AGASA). The arrival time distributions of each component around 1000 m – 2000 m from the core of showers with energies lager than $10^{18.5}$ eV are reported from data collected over 7 years. These data are compared with the results of the simulation.

1. Introduction

The arrival time around 1 km from cores of air showers had been observed with one layer scintillator with 30 m^2 area from 1986 to 1994 at AKENO [1]. From observed arrival time distributions of air showers with the primary energies from $10^{17.0}$ to $10^{18.5}$ eV, we had claimed that the shape of the arrival time distribution is strongly depended on the core distance, weakly depended on the zenith angle and the primary energy of air showers. That mean the shape relate to the height at the maximum development of air shower [2]. The second experiment is Leadburger with two layers sandwiching a lead plate of 1 cm thickness with 12 m^2 area started from 1995 [3]. If the information of a height of the maximum development of an air shower will be obtained from the arrival time distribution, we could obtain information of roughly primary composition . Same trial by muons has been doing at KASCADE experiment [4,5].

2. Experiment

The arrival time of top and bottom layers with 12 m^2 area are observed with the time resolution of 20 ns, opening gate from -120 to -40 μsec coming from AGASA trigger signal. 341 events whose densities of the signal is above 1 particle accompanied with air showers are collected over 7 years (till February 2002), under the condition of clearly air showers whose zenith angle is less than

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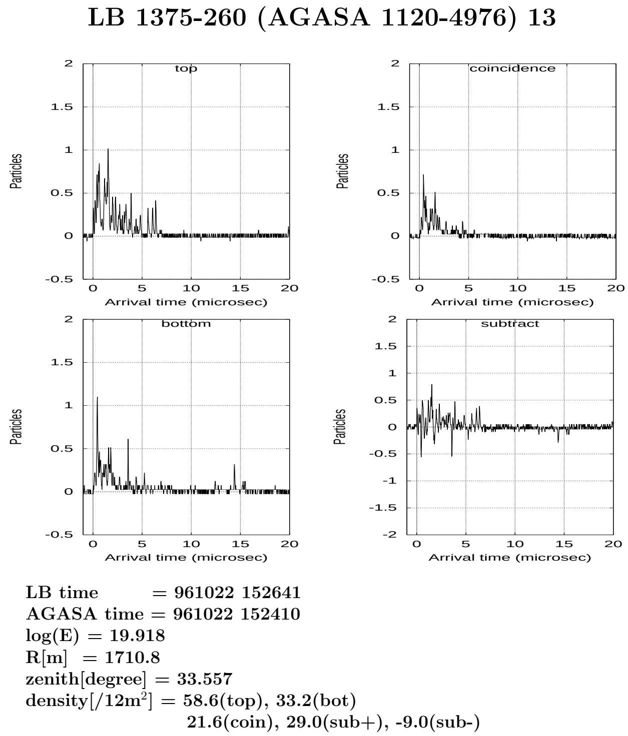
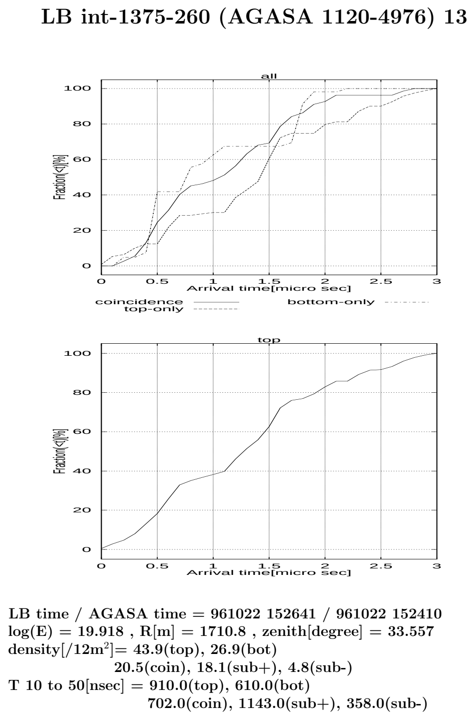


Fig. 1. The example of the arrival time distribution.

45 degree, the number of the hit detectors is more than 6. The number of events is 60 for energies above $10^{19.0}$eV, 281 for lower energy region between $10^{18.5}$ and $10^{19.0}$eV. The example of the arrival time distribution with energies of $10^{19.9}$eV, the core distance is 1700 m, is shown in Fig. 1. The left side figures in Fig. 1 are the arrival time distributions of top layer (upper figure) and bottom layer (lower figure). The right side figures in Fig. 1 are coincidence signals of both layers (upper figure) and signals to subtract bottom signals from top signals (lower figure). The plus region in the subtracted signals means observed signals only in top layer (we call "top-only"), the minus region means observed signals only in bottom layer (we call "bottom-only"). The coincidence signals are almost corresponded to muons, top-only signals and bottom-only signals is almost corresponded to electrons and photons respectively.

In order to understand characteristics of the arrival time distribution, the rise time distributions of same event are integrated the arrival time distribution from 0 to 3 μsec. The example of the rise time distribution is shown in Fig. 2. The upper figure in Fig. 2 shows the rise time distributions of coincidence (solid line), top-only (broken line), and bottom-only (dash-dotted line) respectively.



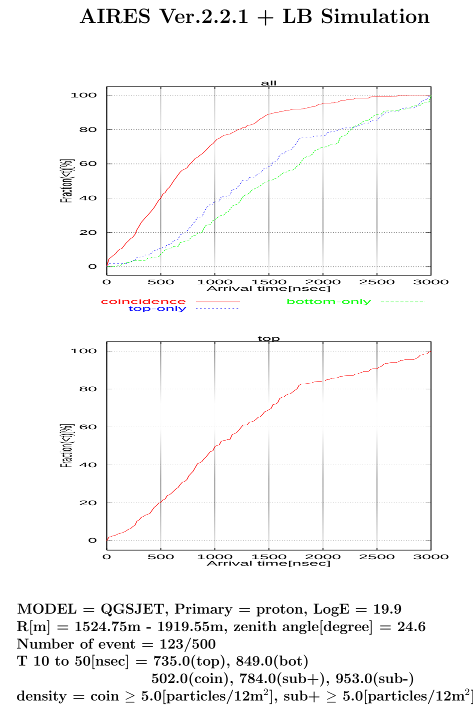


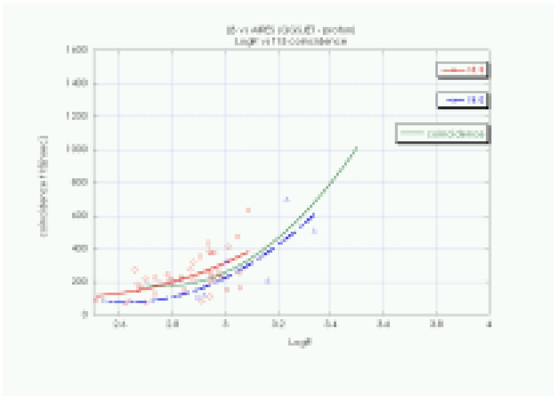
Fig. 2. Left Figure: The example of experimental rise time distribution

Fig. 3. Right Figure: The example of simulated rise time distribution

The lower figure in Fig. 2 shows the rise time distribution of charged particles observed only with top layer. We collect evnts with each density of coincidence and top-only more than 5 particles/12m^2 for describing rise time distributions. The number of event described one is reduced to 50 for energies above $10^{18.5}$eV, 7 for energies above 10^{19}eV, 43 for lower energy region between $10^{18.5}$ and $10^{19.0}$eV.

3. Discussion

We had simulated air showers with the code name of AIRES (Ver. 2.2.1) using the interaction model of QGSJET and SIBYLL at AKENO altitude. 500 air showers are simulated for each files of conditions with three kinds of primary nuclei (proton, iron, and gamma), and the energy resolution 0.1 decade between $10^{17.5}$ and 10^{21}eV. The zenith angle is fixed at 24.6 degree. The simulation is included with our detector simulation. In order to compare the same experimental event, the example of the simulated rise time distribution averaging with core distance between 1520 m to 1920 m is shown in Fig. 3 which model is QGSJET, the primary composition is proton and the energy is $10^{19.9}$eV. It is slight difficult to compare



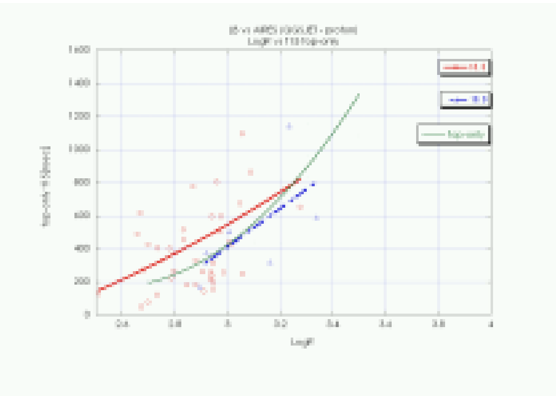


Fig. 4. Left Figure: The relation between T15 of coincidence and core distance

Fig. 5. Right Figure: The relation between T15 of top-only and core distance

the shapes of the rise time distribution, we choose the parameter of rise time from 10% to 50% of the rise time fraction (T15) in this time. Relation between T15 parameter and core distance is shown in Fig. 4 for coincidence, in Fig. 5 for top-only. In both figures, open circles and open triangles are presented experimental data with energies between $10^{18.5}$ and $10^{19.0}$eV and above $10^{19.0}$eV respectively. The thick solid lines (red) and the thick dash-dotted lines (blue) in figures are the averaged lines of experimental data for each energy region. The thin solid lines (green) are presented the average lines obtained from simulations with the model of QGSJET, proton primary. The fluctuation of top-only is larger than one of coincidence. However, the results of averaging simulation data are describing well experimental data.

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