SEARCH FOR LONG-LIVED MASSIVE PARTICLES IN EXTENSIVE AIR SHOWERS

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Abstract

Air showers containing delayed sub-showers which may be produced by a long-lived massive particle have been investigated by using twelve detectors. Ten events have been selected out as the candidates. However, a definite conclusion cannot be got at the present time.

1. Introduction

In our previous experiment, some effort to seek long-lived massive particles which may be produced in extensive air showers (EAS) was attempted (1) (2). Double-peaked coincidence pulses from plural detectors set at separate places in EAS array were investigated to observe these particles. This method is based on the following idea. If a long-lived massive particle is produced by a high-energy interaction in the upper atmosphere and it decays to some particles after long flight, the secondary products from them will arrive at ground as delayed sub-showers relative to main EAS particles. Four events were reported as candidates for the massive particles, and furthermore, three events were added by an observation after that time. This observation, however, was carried out by using a few detectors, and accordingly the information on the size of delayed sub-showers could not be obtained. A new extended experiment has been carried out by using twelve detectors in the Akeno EAS array to get more information. Some preliminary results are reported in this paper.

2. Experimental

Twelve scintillation counters for measuring the arrival-time distribution of EAS particles were set in the Akeno array (S2 station). The arrangement of detectors is shown in Fig. 1. In the figure, D1 and D2 detectors were piled up inserting iron sheets with total thickness of 10 cm between them. The signals from detectors A1∿A3 were transmitted to a storage oscilloscope (100 MHz, Iwatsu TS-8123) through co-axial cables with different length, respectively, and accordingly three signals were displayed on the same sweep of the oscilloscope. Detectors B1∿B3 and C1∿C3 were also operated by the same system. Signals displayed on each oscilloscope were send to a micro-computer (NEC PC-9801) through A/D converters and the pulse profiles were stored in a floppy disk. The pulses from detectors D1∿D3 were displayed on a normal storage oscilloscope (100 MHz, Tektronix 466), and recorded by an autocamera. Each oscilloscope was triggered by the coincidence pulses from the three detectors shown in the figure, and events accompanied by air shower master pulses from the Akeno array were recorded.

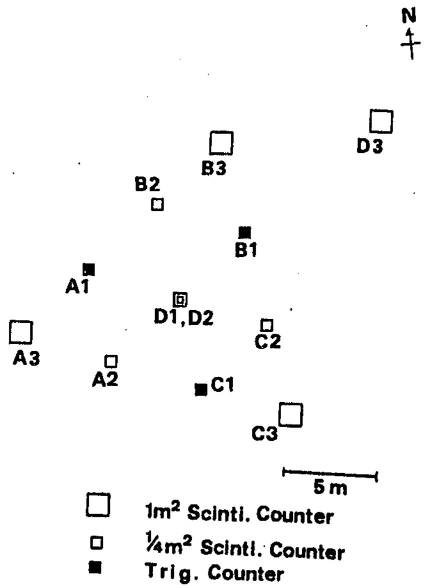

Fig. 1 Arrangement of detectors

3. Results

Pulses of 6300 showers were analyzed in detail. The core distances of 95% of analyzed showers are less than 75 m. In these showers, we found about 70 events whose pulses from three or more detectors showed double peaks and one or more of these delayed second pulses contained at least five particles.

However, 32 of these events show the second pulses with the same time delay (the time interval between the first peak and the second peak), considering the difference of the time response of each detector (4 ns). Further, only ten of these events show the double pulses from adjacent three detectors arranged in a regular triangular form. An example of these showers is given in Fig. 2. In most of these cases, delayed pulses do not distribute over these triangular areas. We have selected out these ten events as candidates containing the delayed sub-showers, and investigated various characters of these showers : shower age, incident angle and muon size et al. These showers show normal character in various points.

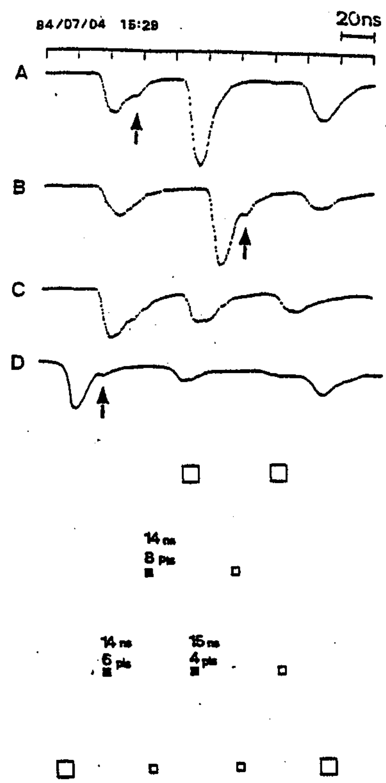

Fig. 2 An example of candidates containing delayed sub-showers

The EAS size is 3.0×10^6 and the core distance of the sub-shower is 35 m. The closed squares show the detectors with the second pulses and the figuers are the delay times and particle numbers of the second pulses.

4. Discussion

When the number of incident particles to a detector is small, spurious double pulses are produced due to the statistical fluctuation of the arrival-time distribution of main EAS particles. Using the average arrival-time distribution (HE 4, 7-2)(3) and the density distribution obtained by our experiment for various core distances, this effect was investigated by Monte Carlo simulation. An example of the results is given in Fig. 3. In the figure, observed integral numbers of double-peaked pulses, curve (a), are shown as a function of the time delay, and curve (b) is a result of the simulation. As seen in the figure, the observed numbers are much more than the calculated value. The origin of the difference is not clear. Any useful calculation about the fluctuation of the arrival-time distribution of electromagnetic shower particles or nuclear cascade particles is not obtained at the present time.

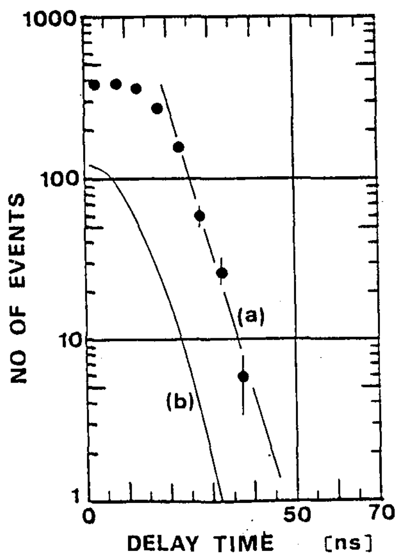

Fig. 3 Integral number spectrum of double-peaked pulses

The spreads of detectable delayed particles are of the order of 5 m from the present experiment, and then we could not get the detailed information about the structure of delayed sub-shower from our arrangement of detectors. A preliminary observation has been carried out by the compact arrangement which consists of 9 detectors within a regular triangle of 10 m sides. We have found three events which contain five or more pulses showing double peaked structure with the same time delay. Finally, to arrive at the conclusion about the long-lived massive particle, a more elaborate experiment is necessary.

references

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