Delayed Scintillator Pulses Observed with an EAS Array

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Abstract

The origin of delayed scintillator pulses observed with a small air shower array has been investigated. The triggering system of the array allowed delay time measurements in the region from 10 ns to 250 ns. The basic question is, whether these pulses are related to physical origin (e.g. delayed showers) or to instrumental origin. The new results of data analysis are presented and possible explanations are given.

1. Introduction

The origin of the delayed scintillator pulses in extensive air shower detectors is not clear. Different explanations have been proposed for this phenomenon (massive hadrons, extreme fluctuations in the arrival time, afterpulses in photomultipliers and random coincidences). In our earlier papers [1-3] we presented the properties of delayed scintillator pulses observed in a small air-shower array at the University of Turku, Turku, Finland (Fig. 1). The array was located 40 m above sea level. It consisted of an air-shower array (efficient area 400 m^2) and a hadron spectrometer. The shower size and axis location were determined by recording the charge of the density detector (DD) scintillation pulses. The active area of each DD detector unit was 0.8 m^2. The angles of incidences of the showers were determined by fast timing detectors (FT). The FT detectors were equipped with photomultiplier tubes Philips XP2020. The active areas of the FT detector were 1.0 m^2 (FT1) and 0.25 m^2 (FT2, FT3 and FT4). The signals from the FT detectors were fed through discriminators to a time-to-digital converter.

2. Measurements

In our earlier analysis we studied delayed pulses observed with the three outer fast timing detector (FT2, FT3, FT4). We calculated the probability of detecting delayed pulses as a function of particle number in the fast time detectors.

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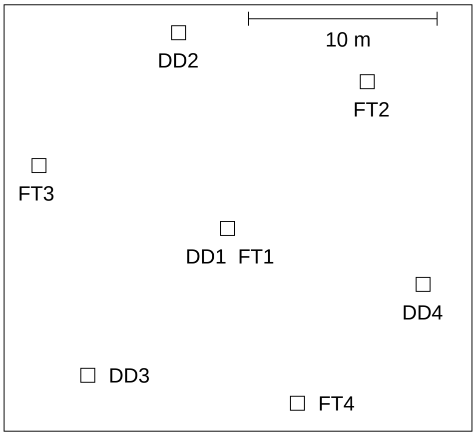

Fig. 1. Aerial view of the air-shower detector.

However, the approximate number of particles in each FT detector was calculated by using the shower parameters extracted from the density detector data (the pulse heights in the outer FT detectors could not be measured directly). In our present work we utilized the delayed pulse data from the central FT detector (FT1). Now the particle number detected in FT1 can be measured with the density detector (DD1), The detectors were placed one on top of the other (separated by a space of 2.9 m, and including a thin roof of the laboratory). For the present analysis we accepted all the shower events that met the triggering criterium of the array.

During the measurement period (June, 1993 – December, 1994) the data collection system was slightly modified. By reason of these modifications the length of the cable between the FT1 detector and the data acquisition system changed twice and thus we divided the data analysis into three periods. The first period lasted 11 months, the second period 1 month and the last period 6 months. The second period was very short and thus it was left out of analysis. During the period I the cable was 9 m long and during the period III it was 13.9 m long. During the period I we collected 61042 showers, during the period II 8784 showers and during the period III 49950 showers.

The time distributions of the FT1 delayed pulses are shown in Fig. 2. The highest peak in Fig. 2 (a) might be explained with reflected pulses in the cable (even a small impedance mismatch might produce a delayed pulse near 90 ns, if the main pulse is high enough to produce a reflected pulse that exceeds the input threshold of the time-to-digital converter). An old delay box was used for generating additional delays during the measurement period I, maybe it was producing reflected pulses. A low peak near 80 ns can be seen in both histograms. The origin of this peak might be explained by photomultiplier afterpulses.

The probability of detecting delayed pulses as a function of particle num-

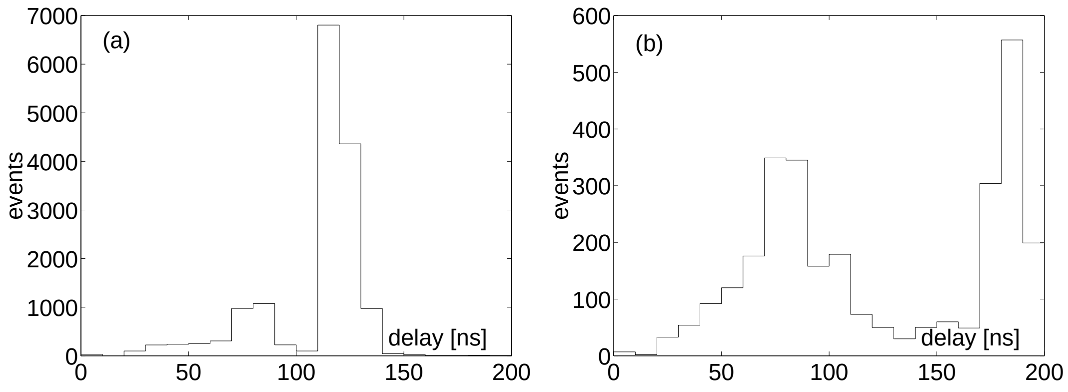

Fig. 2. Time distributions of delayed fast timing scintillator pulses (detector FT1) for the period I (a) and for the period III (b).

ber in the detector FT1 is shown in Fig. 3. Delays under 100 ns were accepted for the analysis (delays over 200 ns could be mixed with the end-of-time-window of the time-to-digital converter). Both curves show an increase with an increasing particle density below 40 particles/detector (Fig. 3 (a)) and below 20 particles/detector (Fig. 3 (b)). The increase with the particle density is in accordance with e.g. ref. [4]. However, the probability falls rapidly at high particle densities. An explanation to this behavior might be that at high particle densities the main pulse and delayed pulses overlap partially, thus making delayed pulses invisible.

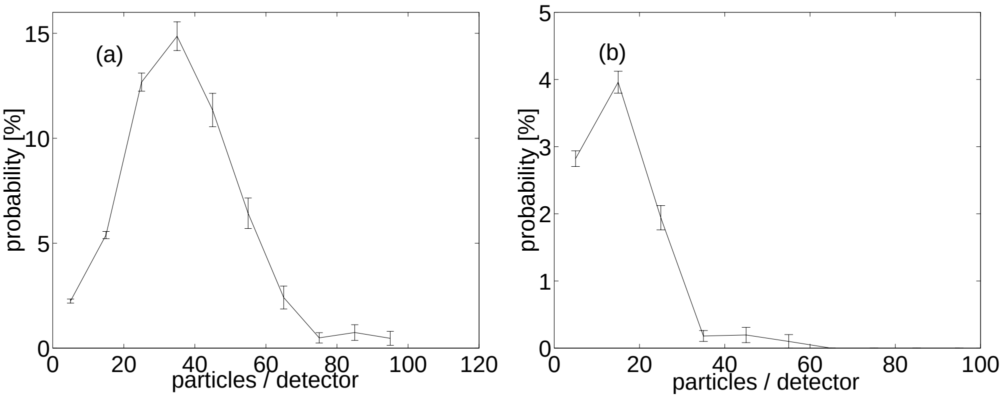

Fig. 3. Probability of detecting delayed pulses as a function of particle number in the fast timing detector FT1 for the period I (a) and for the period III (b).

3. Discussion

A detailed investigation of delayed scintillator pulses could be done with a waveform recorder. Unfortunately, such a device was unavailable during the measurements. The results of our analysis show that the origin of delayed pulses can be explained in many ways. Some delayed pulses can be explained by cable reflections, some by photomultiplier afterpulses and some by overlapping pulses. We would like to emphasize that before trying to find new particle physical interpretations we should always try to exclude possible explanations by the properties of the data acquisition system.

4. References

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