The Longitudinal Thickness of Air Shower Fronts

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1. Introduction Linsley (1983) has proposed a technique for the detection and analysis of air showers at large distances from the shower axis based on a measurement of the shower front thickness and the assumption that this thickness is closely related to the core distance. We have been investigating (Clay and Dawson 1984) some of the problems involved with realising such a technique and report here some related observations. We have been particularly interested in the practical problems of how consistent the measurements of the shower front would be, how one would use the measurement, and how the rate of triggered events would depend on the minimum pulse width required.

2. Apparatus We have used two of the 2.25 m^2 detectors (Prescott et al. 1983) of the Buckland Park array (separation ~ 11m) and recorded the pulse shapes from each detector when one of them produced a pulse greater than some specified width (~ 100ns). Any structure related to shower development ought to be reflected by agreement between the observed pulse shapes.

Oscilloscope recording was based on the digitising of an event by a Tektronix 7912 (500ns at 1ns intervals) and photography of a Tektronix 7834 at 50ns/division. Figure 1 includes an example of the single particle response of the 7912. The 7834 system had a rather similar impulse response, limited by the detector impulse response. The 7834 channel was used to trigger the recording system. Recording was triggered by the output of a pulse width discriminator (a coincidence between a prompt and a delayed sample of the waveform) at an amplitude a little below the single particle level. Thus the system triggered when either a broad pulse or a series of pulses was detected. The system also triggered on very large narrow pulses whose reponse at the one particle level still extended to 100ns. These triggers were easily recognisable.

3. Results The system was run first to see to what extent pulses from relatively close-by detectors agreed in terms of their width or pulse shape. 51 events were obtained with signals from both detectors and some of these are shown in figure 1.

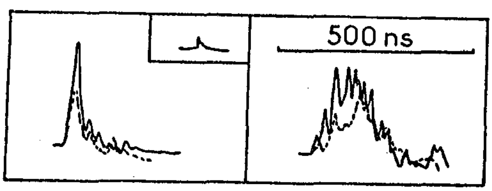

Fig. 1. Examples of pulses triggering the recording system. The outputs of two detectors closeby are shown for two events together with (insert) a single particle impulse response.

If Linsley's expression for the shower thickness against core distance is correct then these events are from showers at core distances of at least 200m and the detector spacing of 11m is rather small in comparison.

Firstly, we make the general observation that the pulses detected by the 7912 system (but triggered by a wide pulse in the other detector) all have widths at the single particle level which are $\gtrsim$ 100ns except for 8 events which showed no signal at all on the 7912 system. The latter events were for small numbers of particles in the triggering detector and we can probably say that these events simply had density fluctuations such that no particles passed through the second detector. In other words, broad pulses in one detector were always associated with broad pulses in a close-by detector.

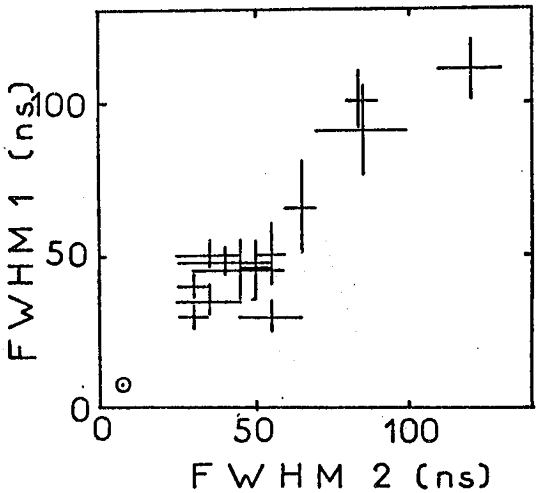

Fig. 2. The relationship between shower front thickness measured by two closeby detectors. The system impulse response is shown by a circle.

Figure 2 shows the relationship found between the full width at half maximum (FWHM) of the signals in the two channels in the cases for which such a parameter could be adequately defined (cases where, for instance, the leading edge of pulses were lost could not be used for this purpose). It would appear that there is a clear and well correlated relationship between measurements made in the two channels so that one can conclude that measurements can be made for such showers ($E_p \gtrsim 10^{17}$ eV, r $\gtrsim$ 200m) which truly represent the local shower width. Alternatively one might say that a measurement of the FWHM using a 2.25m^2 detector appears to make a physically reproducible measurement of shower longitudinal structure, at least over distances of the order of 11m. It does not, of course, indicate necessarily that the shower is not lumpy in its longitudinal distribution over larger distance intervals.

4. Effects of the Pulse Width Discrimination The pulse width discriminator reduces the number of triggers accepted from a scintillator by a very great deal, typically from 2×10^4Hz to ~ 10^{-4}Hz. Our system simply checks to see whether or not there is a pulse above the discrimination threshold at a given time after the first trigger. This can be simulated by very high density events due to shower cores falling on a detector which has a low level in its impulse response extending to 100ns. These can easily be eliminated by inspection or probably better by the use of a coincidence system.

If Linsley's expression for width versus core distance is roughly correct, we can determine our collecting area vs energy and using the known energy spectrum we can predict the number of events we expect to detect. This is of the order of 1 event hr^{-1} and such an event rate is found in practice although this depends substantially on the threshold chosen when only a single detector is used.

5. Further Work in Progress A pilot array using the technique is currently under design and construction at Buckland Park. It is expected to consist of five, $2m^2$ water Cerenkov detectors with a typical spacing of ~ 500m. Each site will be self-contained in terms of pulse shape discrimination, digitisation, and data storage in non-volatile memory but, in this particular case, fast timing will be used for direction finding with signals carried by cable to a central site. One site will be operated independently of the local mains power supply with solar panels as the power source as a pilot experiment for a major array of stand-alone detectors.

Digitisation is expected to be carried out at a sample rate of ~ 80MHz for up to 4 μs after the detection of each event by a pulse width discriminator. We have investigated a number of digitising systems and are building a pilot system based on LeCroy MVV200 charge coupled cell analog shift registers. The pilot system will be operational by mid 1986.

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References

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