1987ICRC....6..424L

A TEST OF THE LINSLEY EFFECT

W.S. Li, P.H. Ng and L.K. Ng
Physics Department, University of Hong Kong, Hong Kong

ABSTRACT

A 'roof top' mini array of scintillators with a carpet area equal to 2 m^2 has been used to detect EAS of primary particle energies $\geqslant 6\times10^{16}$ eV by means of the proposed Linsley effect[1]. In a 15-day preliminary run of the system, large showers with local particle densities greater than 1 particle/m^2 were recorded. Those with densities equal to 1.5 and 2 particles/m^2 were analyzed and presented. The results obtained are encouraging when compared with the Linsley predictions. It is found that with a scintillator carpet alone, large shower events can be identified if three or more than three particles fall on the carpet in each event.

1. Introduction. Exploration on the application of mini arrays to study the ultra high energy cosmic rays in the form of large showers has been keenly pursued by J. Linsley, particularly after the discovery of the UHE gamma-rays from Cygnus X-3 [2]. This is because many more newly designed shower arrays have been constructed and can be used as mini and super mini arrays for the detection of very large showers. This article reports a preliminary result obtained from our 'roof top' mini array, which is a modified version of the one presented previously [3].

2. The System. As shown in figures 1a and 1b, the 'roof top' mini array of scintillators consists of eight counter boxes arranged in a square with an empty box at the centre. The area of each scintillator is 50x50 cm^2 and viewed by a 5" fast photomultiplier. The maximum time delay from the photomultiplier

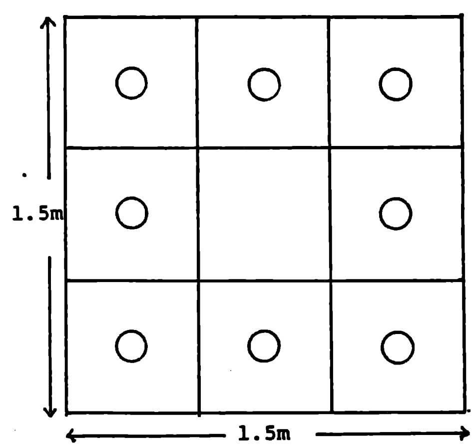

Fig. 1a. Top view of scintillator carpet with 8 counter elements

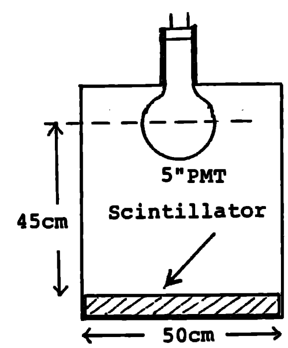

Fig.1b. Structure of each scintillator counter element

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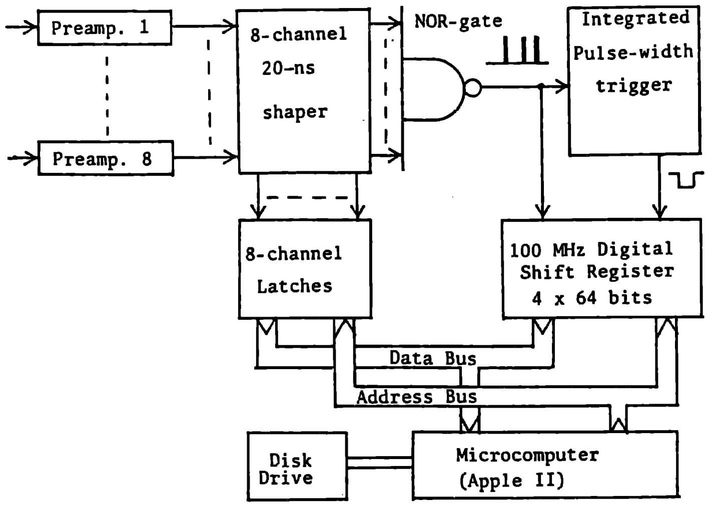

Fig.2. The electronic system

output to the anti-time-jitter preamplifier output is 3 ns. Figure 2 shows the electronic system in a block diagram.

For each shower event, outputs from the 8 counter preamplifiers are individually shaped to narrow pulses of 20 ns each. They are then combined together in the NOR-gate to form a pulse train. Since each channel has its own photomultiplier, preamplifier and shaper, the delay time from the particle arrival to the NOR-gate output does vary from channel to channel. Hence equalization of the delay time is essential. This was done by adjusting the length of the delay cable in each preamplifier. (Coaxial cables are used as delay cables.) The relative positions of the pulses in the train then give the relative arrival time of the particles entering different scintillators. The Integrated Pulse-width Trigger unit emits a gate pulse when the number of pulses in the pulse train exceeds one. The pulse train is temporarily stored in a set of four shift registers at a clock rate of 100 MHz on receipt of the gate pulse. Thus the arrival time is digitized and has a time resolution of 10 ns. The pulse train is then read by the microcomputer. The number of scintillators hit by the particles in a shower can also be read by the microcomputer from the 8-channel latches. Information of each event is stored in a floppy disk.

3. Data Selection. Data have been collected for a duration of 15 days at a counting rate of about 8 counts per hour. Most of the data collected do not belong to true large shower events. They should have come from the following sources:

(i) Chance coincidence of a nearby shower with another shower or with a single particle. This case has contributed most of the false events. They were easily recognized from the pattern of the pulse trains recorded and hence were rejected.

(ii) Chance coincidence of three single particles. The contribution was not very significant, and was corrected by the usual method.

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4. Results. After performing the above selection process, true large shower events with a time spread σ_1 of shower fronts $\geqslant 100$ ns and with the local particle densities $\rho_1 = 1.5\ /m^2$ and $2\ /m^2$ are collected and analyzed. They belong to showers of primary energies $\geqslant 6\times10^{16}$eV. The total number of counts in 15 days for $\rho_1 = 1.5\ /m^2$ is 84 and that for $\rho_1 = 2\ /m^2$ is 32. Figures 3 and 4 are their integral spectra as a function of the time spread σ_1. The error bars shown are not statistical, but are theoretical estimations from the ±10 ns uncertainty due to the digitization using the 100 MHz shift register. The error decreases rapidly as σ_1 increases. The theoretically predicted lines are obtained from our previous work [3] based on Linsley's idea, i.e.

$$\Phi(>\sigma_1, >\rho_1) = 9.07\times10^{6}\rho_1^{-1.7}\,\sigma_1^{n} \qquad \text{days}^{-1} .$$

The exponent n is determined by the Linsley's empirical formula [4],

$$\sigma_t(\text{ns}) = 2.6\ (r/30 + 1)^{b} ,$$

where r (in m) is the distance from the shower core. For b equal to 1.5, n is equal to -2.97. The upper and lower boundary lines with $b_{max} = 1.94$ and $b_{min} = 1.42$ are obtained from Linsley's later expression [2] for $10^{17} < E < 10^{20}$eV and r < 2 km. The corresponding values of n are -2.30 and -3.14 respectively.

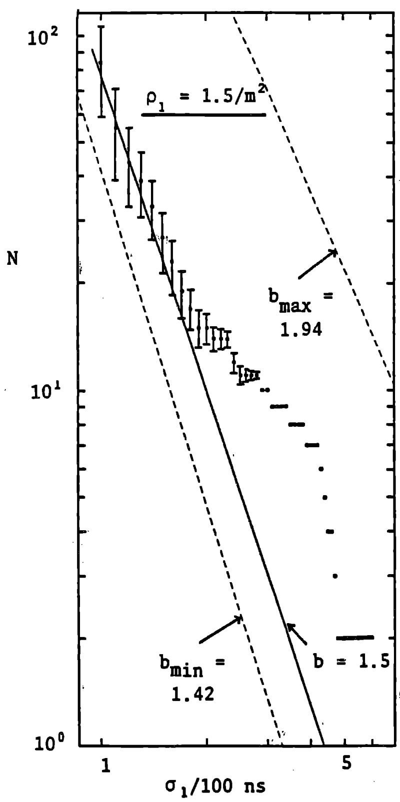

Fig.3. Integral spectrum of shower events in 15 days with $\rho_1 = 1.5/m^2$ in term of time spread σ_1

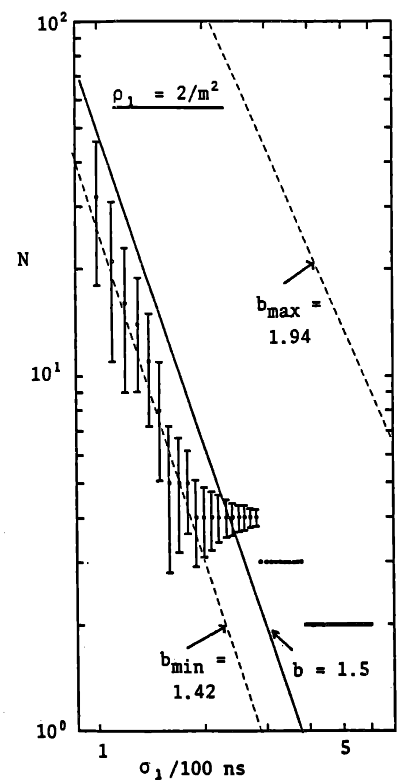

Fig.4. Integral spectrum of shower events in 15 days with $\rho_1 = 2/m^2$ in term of time spread σ_1

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5. Discussion. From figure 3, it is seen that in the 3-particle selection (i.e. $\rho_1 = 1.5\ /m^2$), the data points fit the proposed power law pretty well for $\sigma_1 \leq 200$ ns. For $\sigma_1 > 200$ ns, due to the scarcity of events, overestimation in the selection process is possible. From figure 4, it is seen that in the 4-particle selection (i.e. $\rho_1 = 2\ /m^2$), the chance that two of the four particles hit on the same scintillator would be higher. Consequently, the number of overall counts is below prediction. Again overestimation for larger values of σ_1 cannot be ruled out.

In Linsley's later expression[2],

$$<\sigma_t> = \sigma_{to}(r/30 + 1)^b \ .$$

σ_{to} has been re-adjusted from 2.6 to 1.6. Hence, we have re-calculated the boundary lines for both particle densities and the result obtained are shown in Table 1.

				Total counts in 15 days, N		
ρ_1	σ_{to}	b_{max}	b_{min}	N_{max}	N_{obs}	N_{min}
1.5	2.6 1.6	1.94	1.42	894.5 292.7	84	41.69 9.08
2	2.6 1.6	1.94	1.42	548 179.5	32	25.6 5.57

Table 1. Comparison of the predicted maximum and minimum total counts (N_{max} and N_{min}) with the observed total counts (N_{obs}), when σ_{to} is changed from 2.6 to 1.6

It can be seen that after the re-adjustment of σ_{to}, the observed total counts for both local particle densities, and hence the integral spectra are still within the predicted regions bounded by the re-adjusted maximum and minimum lines.

6. Acknowledgements. The authors would like to thank Professor W. Hazen for his generous assistance and support.

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