A NEW ARRAY FOR THE STUDY OF ULTRA HIGH ENERGY GAMMA-RAY SOURCES

Brooke G, Lambert A, Ogden P A, Patel M, Perrett J C,
Reid R J O, Watson A A and West A A.

Physics Department, University of Leeds, Leeds LS2 9JT, UK.

ABSTRACT

This paper describes the design and operation of a $32 \times 1\,m^2$ array of scintillation detectors for the detection of 10^{15} eV cosmic rays with an expected angular resolution of $<1^{\circ}$;† thus improving the present signal/background ratio for γ-ray sources. Data are recorded on a hybrid CAMAC and 'in-house' system which uses a laser and Pöckel-Cell arrangement to routinely calibrate the timing stability of the detectors.

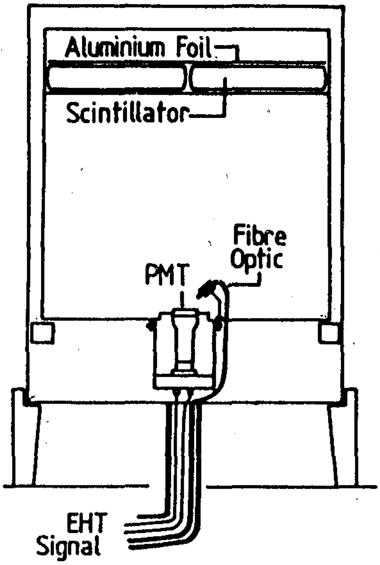
1. Introduction. The charged nature of the majority of cosmic ray primaries means that it is not possible to identify their source regions from measurements of the direction of the shower axis and thus most air shower groups have settled for a directional resolution of $\lesssim 5^{\circ}$ which is adequate for estimation of primary energy. With the recent discovery of pulsed gamma-rays from Cygnus X-3 (Samorski and Stamm 1983, Lloyd-Evans et al 1983), possible only because of its known periodicity, precise angular resolution assumes a new significance. It is to be expected that other sources, less luminous than Cygnus X-3, will be detected when arrays of enhanced sensitivity have been developed; improvement of angular resolution will be one of the key factors here and is especially important as some of the other signatures of the neutral primaries have now been questioned (Marshak et al 1985).

The array now under construction at Haverah Park, GREX, has been designed to trigger on showers with a shower size $N > 10^4$ particles; the full array becoming sensitive at $\sim 3 \times 10^4$.

2. The detector. A Philips 2312B photomultiplier tube (PMT) with a risetime of 2.5 ns and a gain of 3×10^7 at 2 kV, looks up at a $1\,m^2 \times 10$ cm block of NE102 plastic scintillator (Figure 1). The inside of the detector box is painted black to minimize the amount of reflected light reaching the PMT , thus improving the light pulse risetime. This is at the cost of a reduction in the amount of light reaching the tube. We do however use a sheet of aluminized foil above the scintillator to add substantially to the light yield without materially affecting the risetime. With this arrangement a single vertical particle passing through the scintillator produces > 50 photoelectrons in the PMT.

3. Description of the array. The array consists of 32 detectors of $1\,m^2 \times 10$ cm NE102 plastic scintillator positioned on 30 and 50 m grids (Figure 2). The centre of the array is coincident with the 50, 150 and 500 water-Cerenkov array run at Haverah Park by the Leeds University group. Signals from the anode of the photomultiplier (PMT) are transmitted along high bandwidth cable (Aerialite 363) to the recording electronics situated at the centre of the array. The array records a shower coincidence when any three detectors trigger at $> 1\,m^{-2}$ inside a $1\,\mu s$ window. Fast timing, for arrival direction, is started at 1/3

particle per detector. The contours of log(N) in Figure 2 show the sensitivity of the array to showers of different sizes.



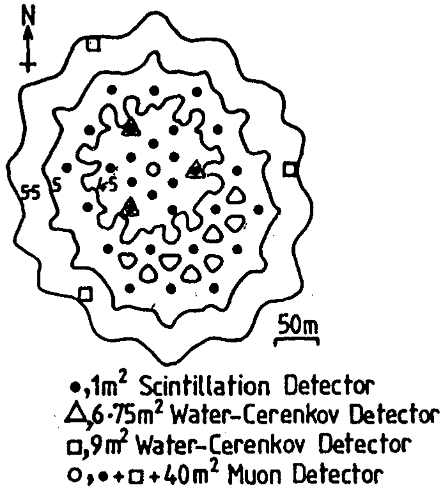


Figure 1: The GREX scintillation detector showing the arrangement of the PMT, scintillator and Fibre Optic cable.

Figure 2: Disposition of the GREX scintillation detectors in relation to the 50 and 150 m water-Cerenkov detectors and the 40 m^2 muon detector. The contours show the sensitive area of the array to showers of log(N) > 4.5, 5.0 and 5.5.

The GREX array transmits event triggers to various external arrays:- Nottingham University's 40 m^2 detector and the 50 and 150 m water-Cerenkov arrays. Every two hours a Timing Stability Pulse (TSP) is applied to monitor the gain and timing stability of the detectors. Figure 3 shows the set-up that is used to do this. The output from a 2 mW HeNe laser is modulated by a Pöckel-cell driven by an externally triggered step generator. The resulting light pulse has a 10 ns FWHM with a 1.5 ns rise-time. This is transmitted to all the detectors via 50/125 graded index fibre optic cable. The detectors trigger on this light pulse and the resulting signals are treated just as if a 32 fold coincidence was recorded.

The GREX system will be capable of supervising 32 detectors each working at a D1 trigger rate of 200 - 300 s^{-1} with only $\sim$1 - 3% deadtime (allowing 2 μs deadtime per background pulse). When the full system is in operation the main contribution to deadtime will be the event processing time or to be more precise the readout time via the slow, but cheap, CAMAC/GPIB interface. The readout time is very software-dependent and for that reason the code will be written in the C-language. The GPIB interfaces to an S100 based machine (North Star Horizon microcomputer) via an IEEE - S100 interface. GREX data will be merged with data from the 50 and 150 m water-Cerenkov arrays and then recorded on magnetic tape. The expected recording rate is $\sim$16 Mb of data per week corresponding to

∿ 10 events $\min^{-1}$. To help merge GREX data with muon data from the Nottingham University group the event time (± 1 ms) will be transmitted to their recording system after every event.

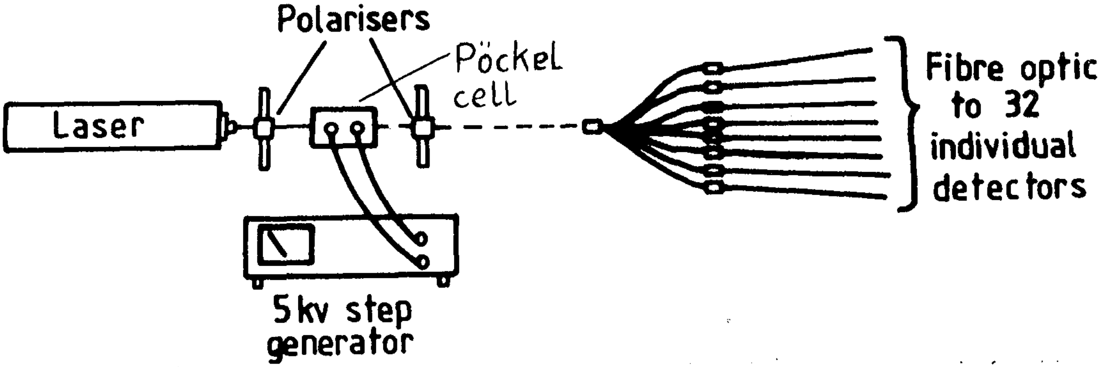


Figure 3: The timing calibration set-up. The Pöckel-cell chops a 10 ns wide light pulse with 1.5 ns risetime. The resulting light pulse is transmitted to all 32 detectors.

4. Recording electronics. The recording electronics in the new Haverah Park gamma-ray experiment, GREX, is a hybrid of commercial LeCroy modules (CAMAC based) and 'in-house' electronics. Figure 4 shows how the various systems are integrated. Signals from the detectors are transmitted to a discriminator board which incorporates the LeCroy MVL407 (quad ultrafast voltage comparator). The signal is split three ways:- one is integrated and input to a LeCroy ADC (4300), while the others are input into two quarters of the MVL407, referred to as the D1 and the D2 discriminators. If the D1 discriminator, set at ∿ 1/3 particle threshold, triggers, and if the D1 gate is open the LeCroy TDC (4208) connected to that channel starts counting at 1 GHz. The low D1 threshold is used to keep timing fluctuations to a minimum. If the D2 discriminator triggers, (threshold > 1 m^{-2}) a 1 μs coincidence window pulse is produced. If the D2 gate is open then the coincidence window pulse is transmitted to the majority logic board.

The majority logic board adds all the coincidence window pulses from the 32 possible D2 discriminators and then discriminates at three times the D2 level giving the 3-fold coincidence and producing a majority logic output pulse. This pulse is transmitted to the coincidence logic board and the event time board which latches the event time to a resolution of 1 ms.

When any TDC triggers the ADC input gate is opened and a fast clear pulse is generated after a 1 μs delay. The fast clear pulse will be 'gated out' if a coincidence is recorded by the majority logic board. If there has not been an event within 1 μs of the first TDC triggering then the fast clear pulse is allowed to clear the 4 TCDs and 2 ADCs. It takes 1 μs to clear all the LeCroy modules; thus there will be 2 μs deadtime per background pulse from any of the 32 detectors.

When a shower coincidence is recorded within 1 μs after the first TDC has triggered (time allowed for the shower to traverse the array) a common pulse is sent to all TDCs. At the end of the 1 μs the CAMAC 'look at me'

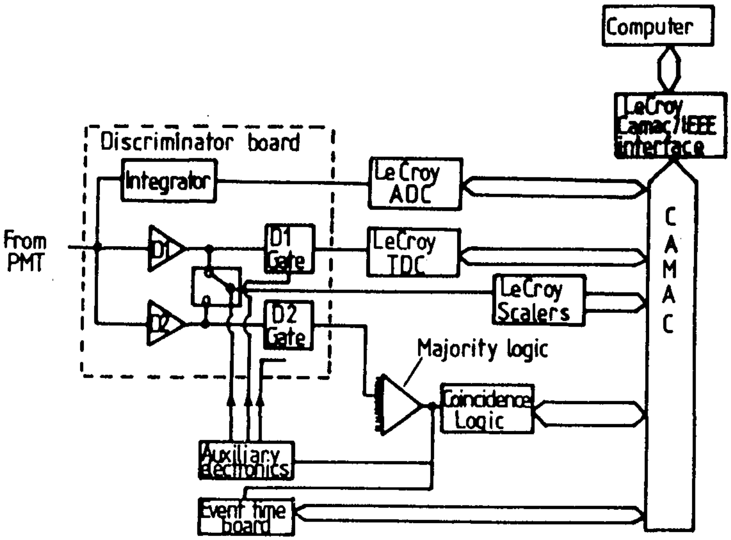


Figure 4: Schematic block diagram of the GREX recording electronics. The ADC, TDC, scalers and the GPIB interface are commercial LeCroy modules. The remaining electronics were built 'in-house'.

(LAM) flag is set. The TDCs are capable of recording positive and negative times, i.e. when a TDC triggers before or after the common start/stop pulse. In our system the three detectors that formed the coincidence will have negative times and the remaining detectors which have recorded particles associated with the shower will have positive times. The relative arrival times are recorded to a resolution of 1 ns. The LAM flag is tested by the controlling computer and when detected instructs the 8901 GPIB-CAMAC crate controller to read the data from all the LeCroy modules, event time-board, digital thermometer and barometer. When the event has been processed the TDCs, ADCs and auxiliary electronics are reset; thus the whole system becomes active at the same time.

5. Auxiliary functions. Fast clear pulses are generated on every background pulse, i.e. every time D1 triggers and thus a single noisy detector could result in a large deadtime. Monitoring of detector performance is achieved by recording the D1 and D2 rates. This is achieved with extra electronics, referred to as the auxiliary electronics in Figure 4, which switches the input to the LeCroy scalers (4434) alternately between D1 and D2 pulses. If a detector should become 'noisy' then its contribution to the system can be negated by closing the D1 and D2 gates.

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References

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