# THE IDENTIFICATION OF GAMMA RAY INDUCED EAS

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Abstract

Recently Stanev et al have suggested that some of the penetrating particles in "gamma-induced" EAS from Cygnus X-3 observed by the Kiel EAS group using a single layer of flash-bulbs under 880 g cm$^{-2}$ concrete, may be "punched through" photons rather than muons. This paper presents an analysis of the shielded flash-tube response from EAS detected at Haverah Park. The penetration of the electro-magnetic component through 20 cm of Pb has been observed at core distances $\lesssim$ 10 m.

1. Introduction Experiments carried out by the Kiel group [1] indicated an excess of showers of size $N \geq 10^5$ arriving from the direction of Cygnus X-3. Further, these showers exhibited the 4.8 hour modulation characteristic of well-determined X-ray measurements. The excess EAS were assumed to be primary $\gamma$ induced. Simulations by Wdowczyk et al [2], and McComb et al [3] comparing the muon densities from proton and gamma initiated showers of the same primary energy predicted that gamma induced showers would produce about 10% of total muons compared with proton induced showers.

Samorski and Stamm [4] (1983) used the Kiel array to investigate the muon content of the EAS produced by these "gammas" in the range $10^{15}$ - $10^{16}$ eV. The EAS detector consisted of 28 scintillator detectors of 1 m² each at distances up to 100 m from the centre of the array. A neon hodoscope of effective area 21.5 m² under 880 gm/cm² of concrete was used as a muon detector for muons of energy > 2 GeV.

In comparing the average number of muons in "on" and "off" source showers at core distances of approximately 10 m, they concluded that the difference in muon content of the two kinds of EAS was very small (< 20%). The densities of muons in the source showers appeared to increase more rapidly with shower size and fell more rapidly with core distance than normal showers.

Recently Stanev et al [5] carried out simulations in an attempt to explain this apparent discrepancy in the behaviour of "gamma induced" showers. Their calculations agreed with the work of McComb et al [3] in that only at $E_p > 10^{18}$ eV will photo production contribute a significant number of muons. In the primary energy range of the Kiel experiment, however, the number of photoproduced muons should still be very significantly less than the muon number in hadronic showers. Consequently Stanev et al investigated the number of photons that might "punch through" the 880 gm/cm² of concrete shield at approximately 10 m from the shower core. They concluded that only 30% of the muon density might be explained in terms of "punch through" gammas, assuming an overall detection efficiency for gammas of 40% for the neon flash bulbs.

2. Experimental Arrangement For several years the Nottingham group working at the Haverah Park EAS Array operated a detector of crossed neon flash tubes interleaved with lead absorber in order to identify and measure the arrival directions of muons.

The detector is shown in Figure 1. The top two boxes of crossed flash tubes (3.34 m²) have 5 cm of lead between them. The next two layers of flash tubes (4.18 m²) were covered by a further 5 cm and 10 cm of lead. Thus not only could the muons be clearly identified but the degree of accompaniment under 5, 10 and 20 cm of lead could be observed. The threshold energy for muons to penetrate the whole stack was approximately 350 MeV. Although this was less than that of the Kiel group, the number of cascade lengths of the total lead absorber compared with the concrete absorber was not significantly different.

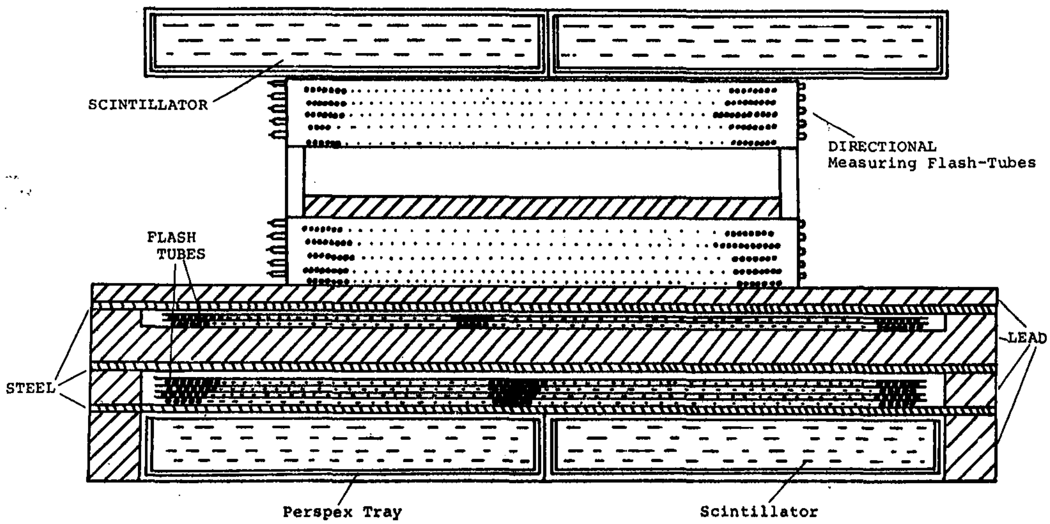


**FIGURE 1** The neon-flash tube muon detector

3. Analysis of Data Normally EAS with $E_p \geq 10^{17}$ eV were recorded and for this "punch through" study EAS have been selected with well determined core distances such that 20 m < R < 100 m. The sandwich of flash tubes and absorber enabled the muons to be unambiguously identified. The number of muons detected in the shower was measured along with the degree of electromagnetic punch through accompaniment (excluding obvious muon-induced knock-ons and bursts), under 5, 10

and 20 cm of lead. The water Cerenkov response at the same position in the EAS was also measured.

Figure 2 shows the frequency distribution of the electron accompaniment per muon capable of penetrating at least 5 cm of lead for two core distances, viz 20 m < R < 35 m and 20 m < R < 100 m. It is seen that within the statistical limits of the sample there is no significant change with limitation of the core distance to 35 m. The detected accompaniment per muon per flash tube layer under 5, 10 and 20 cm of Pb was found to be 2.48, 0.14 and 0.02 respectively. It is seen therefore from these observations that the degree of "punch through" from "normal" showers for 10 cm and 20 cm of lead is insignificant beyond 20 m from the axis. However this result may be attributed to the low photon energies found in EAS at these core distances.

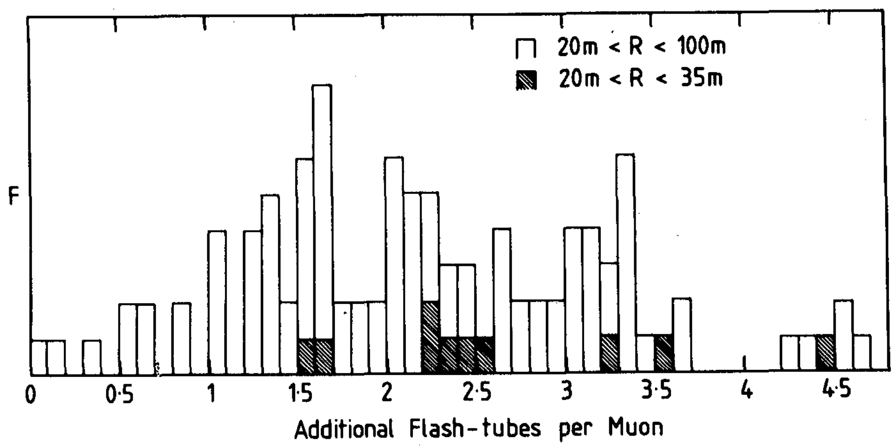


**FIGURE 2** Frequency distribution of electron accompaniment/muon

It should be noted that the Kiel measurements applied to core distances around 10 m and the Stanev calculations were for such small core distances. It is in this region of the EAS that photons of energies 10-100 GeV have a significant probability of causing punch-through effects. For a period of time, apart from being triggered by the 500 m Air Shower Array at Haverah Park the muon flash tube detectors were also triggered from large bursts (detected by the fully-shielded scintillator) in "local" showers. The details of these showers was not determined directly but it was possible by determining the muon/electron density ratio to identify EAS falling within about 10 m of the core.

For these events the ratio of the number of detected accompanying "punch-through" particles to the number of muons was found to be approximately 2:1. With the limitations of the technique it would appear that the degree of accompaniment capable of "punching through" 20 cm of lead is significant at core distances $\lesssim$ 10 m.

4. Conclusion Analysis of the data obtained with a crossed flash tube/scintillator array indicates that the degree of "punch-through" accompaniment of muons from EAS of $E > 10^{17}$ eV for $R > 20$ m capable of penetrating 20 cm of lead and being detected by flash-tubes is negligible. However there is a strong indication that within a core distance $R \lesssim 10$ m there is a significant increase in such accompaniment. Thus in order to reduce the possible contamination of observations from such an effect it is therefore clear that observations of the muon content of showers should be made at core distances $\gtrsim 20$ m. If observations are to be made at core distances of $< 10$ m then the detector must be capable of unambiguously identifying muons.

References

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