Unexplained Multiphoton Phenomenon

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In 1954 Schein, Haskin, and Glasser reported a cosmic-ray event consisting solely of at least sixteen highly collimated photons. Here we compare this event and four other similar ones reported in the literature. These five events show remarkably similar characteristics and the possibility of them all being fortuitous occurrences is essentially precluded. Their characteristics also make it unlikely that the photons originate from electromagnetic showers or multiply produced π^0 mesons. Some unexplained phenomenon seems indicated.

During the period from 1954 to 1956 there were several reports[1-4] of unusual events observed in photographic emulsions exposed to high-altitude cosmic rays. These events all involved the conversion of multiphoton jets into electron pairs within the emulsion. None of the authors had an explanation of their event but most pointed out they were not cascade showers nor multiphotons from the decay of π^0 mesons. Since then, no new events of this type have been reported and the original ones remain unexplained, perhaps examples of an undiscovered phenomenon. It is the purpose of this note to compare these events (there are five of them), and point out why it is difficult to explain them in terms of accepted physical processes. Individually, these events may be considered to be fortuitous occurrences, but when compared with one another they show so many similar characteristics it is difficult to escape the conclusion that they have a common origin.

The first of these events was reported by Schein, Haskin, and Glasser[1] in emulsions exposed for six hours at 100 000 ft altitude. Subsequently, four more rather similar events were reported by others[2-4] under similar conditions. All these events consist of multiphotons numbering 10–20, as evidenced by electron pair production occuring in the emulsions. In all of these events: (a) the total energy of the photons approximates 10^{11} eV; (b) no charged particles of any kind are found to accompany the incident photons; (c) the angular spread of the photons with energy $E > 1$ GeV/c^2 and converted in the first radiation length of emulsion is 10^{-3} to 10^{-4} radians. Table I gives the total energy of the various events, the number of photons converted in the first radiation length and the angular spread, all as reported by the various authors.

The uniqueness of these events is centered on two questions:

1. Can they be extreme statistical fluctuations of a conventional electromagnetic shower produced by a single photon?
2. Are they multiphotons originating from the decay of multiply produced π^0 mesons?

Concerning question 1, the authors make the following observations:

(a) The number of electron pairs occuring in the first radiation length of emulsion measured from the beginning of the events is large compared to the one or two to be expected in a normal electromagnetic shower.

(b) Multiphotons incident on one radiation length of converter would be converted, neglecting attenuation, with uniform probability throughout the converter. A conventional electromagnetic shower, which developed unusually rapidly from a single photon, however, must show conversions which increase with depth. A comparison of all five events shows a distribution of pair formation which is more or less uniform within the first radiation length of emulsion. Figure 4 or Ref. 3 shows this in a quantitative manner for their event.

(c) In electromagnetic showers produced by single photons the energy of the first pair must be greater than all succeeding pairs and in general, the pair energy is degraded with depth. The five events all depart from these conditions and specifically Fig. 4 and Fig. 5 of Ref. 2 show that the energy distributions of the electrons observed in their two events is very different from the energy distribution expected from electromagnetic showers as calculated by Arley.[5]

(d) If the jets represented an advanced stage in the development of a conventional shower the multiphotons would be accompanied by electrons. In all five events all electrons observed are attributed by the author to photon-produced electron pairs indicating a jet of pure photons.

In summary: The possibility of explaining these multiphoton events as statistical fluctuations of

TABLE I. Multiphoton events produced by cosmic rays recorded in photographic emulsions.

Reference	Total energy of photons in eV	Number of photons converted in first radiation length	Angular spread of photons in radians
Schein *et al.*[1]	$>5\times 10^{10}$	16	$\sim 10^{-3}$
Debenedetti *et al.*[2] (1)	$>4\times 10^{10}$	12	10^{-3}
(2)	$>6\times 10^{10}$	6 (25 in 1.5 r.l.)	10^{-4}
Koshiba *et al.*[3]	$\sim 10^{11}$	11	$\sim 10^{-3}$
Silva *et al.*[4]	$>10^{11}$	15	$<10^{-4}$

single-photon-produced electromagnetic showers seems excluded.

Concerning question 2, it is not possible to explain the events as multiphotons from multiply produced π^0 mesons for the following reasons:

(a) The two photons from a decaying π^0 meson are emitted at a laboratory angle which depends on the energy of the meson ($\langle\theta\rangle \sim 2M_{\pi^0}/E_{\pi^0}$). For example, an event with 10 photons and a total energy $E\sim 10^{11}$ eV would, if the photons came from π^0 mesons, have an angular divergence $\theta > 1.5\times 10^{-2}$ radians even neglecting the divergence of the π^0 mesons. This angle is inconsistent with the small observed divergences of $\theta\sim 10^{-3}$ to 10^{-4} radians.

(b) Multi-π^0 production is a consequence of nuclear or nucleonic interactions from which charged mesons should also be produced. The absence of charged particles in *all* the events argues against the production of multi-π^0 mesons.

A most significant feature of these five events is the absence of any other charged particles in the vicinity of the multiphoton jets. In spite of careful searches no charged particles other than the electron pairs could be found in the neighborhood of the jets. This suggests first, that the jets were initiated by an uncharged particle, presumably a photon, and second that the interactions must have been peripheral in character because secondary charged particles would be expected if appreciable momentum were transferred to the struck nucleon. Almost the full incident energy must then appear in the jets which suggests that photons with 10^{11} eV or greater can produce them. Measured intensities of cosmic-ray photons (NASA, TTF594) combined with the reported duration of the exposures and area of the exposed emulsions can be used to estimate the production cross section for these jets on the assumption they are produced by photons. This yields the surprisingly large cross section of $\sigma\sim 3\times 10^{-25}$ cm^{-2}. These estimates for the threshold energy and production cross section mean that the uncertainties[6] concerning the origin of these jets can be settled by an experiment at the National Accelerator Laboratory where the expected photon intensities above 10^{11} eV should be sufficient to produce several thousand events per hour.

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