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III-4-14. The Differential Electron Density Spectrum of Air Showers at High Densities

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Work on the Differential Electron Density Spectrum at high densities carried out at Sydney, Dublin and Jamaica has recently been published. (Proc. Phy. Soc. July **78** (1961) 103–112)

The overall result of the three stations and consideration of possible interpretation will be given by Professor McCusker in the Plenary Session on Thursday (III-4-33). Here I report on the result of continued work at the Jamaican Station in the period March 1958–June carried out by R. Reid, E. Page and K. Gopaulsingh.

The method consisted in counting the number of tracks crossing the mid planes of 2 counter controlled Wilson Cloud Chambers for each individual event. As the C.C's formed part of an array for determining the arrival direction of showers this number could be transformed into the number of tracks/unit area at right angles to the shower axis—*i.e.* the density. Fig. 1 shows the relative positions of the units within the array. The C.C's, of diameter 30 cms., illuminated depth 18 cms., were located with their axes at right angles to each other in a temperature controlled sub hut having a total roof $<2\,\text{gm/cm}^2$. They were triggered when the following 3 requirements were simultaneously satisfied:

(a) Either or both P.S.S.

Plus (b) At least one of 12 counters in an unshielded tray of area $0.25\,\text{m}^2$.

Plus (c) A three-fold pulse from a triangular array of 3 counters each of area 18.3 cm^2 situated *within 2 metres* of the Cloud Chambers.

Fig. 2 shows 4 C.C. pictures having densities 450, 1450, 4000 and 7500 p/m^2 respectively. In the density range 1000–5000 p/m^2 a total of 115 events were obtained, and the

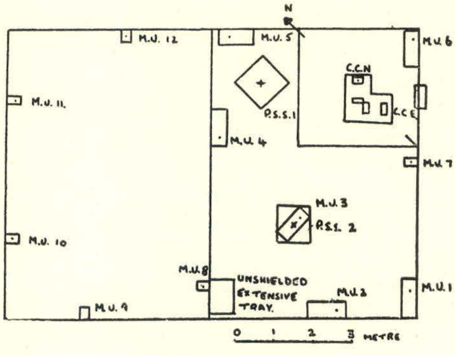

Fig 1.

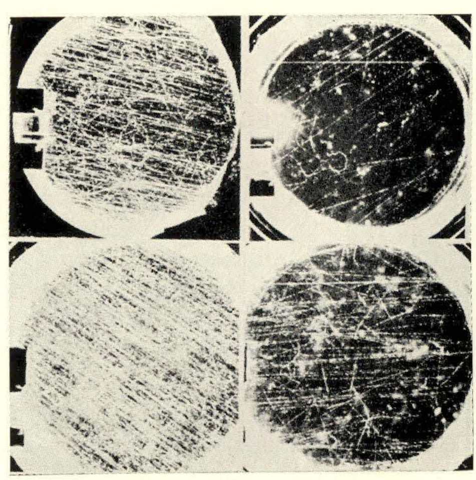

Fig. 2.

The author's name was added by JSC according to the programe.

number of events/unit density interval as a function of density is given in Fig. 3. This gives the actual experimental data. No correction has been applied either for triggering probabilities of the array or for Poissonian fluctuations in the chamber. The solid line gives the differential spectrum for exponent $\gamma=-3.5$.

In the high density region under discussion the effect of the P.S.S. trigger is small—it has been evaluated and results in the exclusion of 6% of showers. The main triggering bias arises due to the coincidence of the 3 small counters. In addition to this it is also necessary to consider the Poissonian fluctuations in the number of particles seen in the chambers. Both of these can be eliminated by the following procedure; the rate for n particles in the chamber for a given value of γ was determined from

$$R_n \propto \int_0^\infty (1-e^{-S\Delta})^3 \frac{e^{-A\Delta}(A\Delta)^n}{n!}\frac{d\Delta}{\Delta^\gamma}$$

where

S=area of 1 small counter
Δ=shower density
A=C.C. mid plane area
γ=differential exponent of the density spectrum.

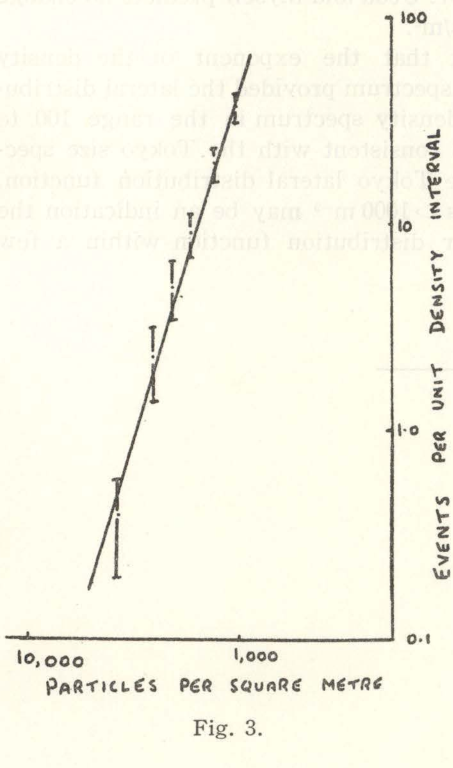

Fig. 3.

This computed spectrum, normalized to the total number of counts observed, was compared using a χ^2 test with the observed spectrum as γ was varied in steps of 0.1 in the range $\gamma=-2.0\rightarrow-5.0$ the computations being carried out on the Silliac computer at Sydney.

The best fit was obtained for $\gamma=-4.0$ which had a χ^2 probability $P=0.72$ and taking the values of γ where the probability falls to 5% the result is given $\gamma=-4.0\pm0.5$.

To ensure that the steep slope is not in some way due to the C.C. method, the differential density spectrum for the range 200–1000 p/m^2 where the result is already well known, was determined.

Any P.S.S.+extensive trigger which gave between 10 and 50 particles crossing the C.C. mid plane were used. (Approximately 7% of all events.) This gave a value of $\gamma=-2.6\pm0.3$.

Thus in conclusion we have found

(1) In the density range 200-1000 p/m^2 a value of $\gamma=2.6\pm0.3$ which is in good agreement with much previous work.

(2) From 1000-5000 p/m^2 $\gamma=-4.0\pm0.5$. This result is in agreement with results of similar experiments carried out in Dublin and Sydney and in so far as they cover the same range with earlier experiments of Norman using proportional counters and Prescott using Ionization Chambers.

Discussion

Kasha, H.: Since the density spectrum depends on the size spectrum and on geometrical factors, and since no analogous behaviour of the size spectrum has been observed, how would you explain your results?

Reid, G. C.: Firstly Dr. Zatsepin has reported that there is a change in the integral size exponent from 1.45 to 2.0 occuring at around $N=3\cdot10^5$ particles.

The change in the exponent of the density spectrum may result either from a change in the primary spectrum or from a change in the nature of nuclear interactions at around 10^{15} eV.

Zatsepin, G. T.: I have reported that the size spectrum obtained by Dr. Vernov *et al* at sea level has a change of the slope from 1.45 to 2.0. However, if you measure the density spectrum, the change of the slope cannot be greater than that of the size spectrum. So far, nobody obtained the exponent which is greater than 2. I think it is impossible to get the exponent of the density spectrum as great as 3. Rather I wonder if the cloud chamber is too complicated to measure the high density of particles.

McCusker, C. B. A.: Ueda and McCusker have produced a theory of extensive air showers in terms of definite changes in the characteristics of nuclear interactions which predicts both change in the γ of differential density spectrum at sea level of about 2.5 to 3.8 and also a change in the size spectrum at sea level at about $2\cdot 10^5$ of from 1.4 to 2.0 integral.

The effect of the density spectrum has been seen with proportional counters and ionization chambers. I myself believe that cloud chambers are well suited to it.

Tanaka, Y.: Here, I would like to refer to the value of the exponent of integral density spectrum in the range 10^3 to $10^4/\mathrm{m}^2$ at Mt. altitude which was obtained by Osaka City University group. This turned out to be about 1.5 without any change.

McCusker : Dr. Reid performed his experiment at sea level. Dr. Tanaka's quotation is about 3000 m above sea level. The theory of Dr. Ueda and myself predicts no change in the exponent at 3000 m below 10,000 particles/m^2.

Millar, D. D.: I should just like to remark that the exponent of the density spectrum should be the same as that of the size spectrum provided the lateral distribution remains independent of shower size. The density spectrum in the range 100 to 1000 m^{-2} obtained with the Sydney chambers is consistent with the Tokyo size spectrum with a knee at the size $3\cdot 10^5$ and with the Tokyo lateral distribution function. The larger slope reported by Reid for densities $>1000\,\mathrm{m}^{-2}$ may be an indication the showers of size $>10^6$ have a somewhat flatter distribution function within a few metres of the core.