10-100 Bev for events observed in the cloud chamber triggered for nuclear active particles "unassociated." The spectrum has a slope of 2.0 ± 0.2.

The absolute flux value for nuclear active particles at 800 gm/cm^2 for energies greater than 450 Bev deduced from our data is $(1\text{-}2.3) \pm 0.1 \times 10^{-7}$ particles cm^{-2} sec^{-1} sterad^{-1}. The uncertainty in the flux comes from the inexact definition of solid angle of acceptance for the spectrometer by the selection criteria detailed above. This value is consistent with the value expected from other similar estimates made at mountain altitudes reduced to our altitude by using an absorption mean free path for the nuclear active particles value of 120 g/cm^2. The flux expected from these data is 1.6×10^{-7} particles cm^{-2} sec^{-1} sterad^{-1}.

Finally, it should be pointed out that the measured energy spectrum of nuclear active particles would deviate from the true spectrum at sufficiently high energies depending upon the size of the detectors used. This is because at high energies depending upon the size of detectors used, many nuclear active particles are incident at the same time over the area of a single detector, the effect of which will be to flatten the spectrum. It will be ambiguous to interpret spectra obtained without considering this effect. For example, the average separation of nuclear active particles at 10^{12} ev for simultaneously incident particles are expected to be of the order of 70 cm and hence spectra deduced with detectors ~ 1 m^2 (as is our case) for energies $> 10^{12}$ ev lose their significance unless other means of resolution of nuclear active particles are incorporated in such large detectors.

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III-4-21. The Effect of Finite Thickness of Scintillators on the Determination of the Densities of Charged Particles in Air Shower Experiments

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In almost all air shower experiments, the size and the position of the cores of showers are deduced from a knowledge of the densities of charged particles at various locations in a horizontal plane. For the determination of the density of charged particles, three different types of detectors are being employed by different groups working on extensive air showers. They are

(i) Arrays of hodoscoped G. M. Counters (Russian groups)

(ii) Arrays of Conversi type Neon tubes (I.N.S. Tokyo)

(iii) Scintillators (M.I.T., Cornell, I.N.S., Bombay, Sydney)

It is to be expected that the densities determined from G. M. counter arrays will be close to the true values of the densities of charged particles, since the G. M. counters are known to have very low efficiency for the detection of γ-rays and the amount of matter by way of wall thickness will be almost negligible for either absorption of electrons or for the interactions of nuclear active particles. If the efficiency of Neon Hodoscopes are also small for γ-rays, then

* This paper was combined with III-4-19, III-4-20 and presented by B. V. Sreekantan.

they should be as good as G. M. counters. It is quite definite that if one uses scintillators, for the determination of the densities, then a correction is necessary to obtain the true values of the densities. There are conflicting results regarding this correction factor. The M.I.T. group[1] from an analysis of showers in which densities were recorded both by scintillators (6 cm thick plastic) and G. M. counters find that the density values deduced from G. M. counters are comparable the density values deduced from scintillators. However this result is based on analysis of only 27 showers. On the other hand Wallace[2] finds that the density values deduced from scintillators (liquid 10 cm) are systematically higher than those deduced from G. M. counter—on the average the scintillators giving a density higher by about 34%. Wallace also finds that the ratio of densities depends on the shower size and cores distance. The increase in density in scintillators has been interpreted as due to nuclear interactions, in the scintillators. The I.N.S. group[3] find that the densities determined from Neon Hodoscopes differ from those of scintillators (plastic, thickness 4.5 cm) by a factor which depends on the distance from the core of the shower. In view of these conflicting results and since we have used scintillators in our air shower array (previous paper), we thought it worthwhile to investigate the dependence of the density values on the thickness of scintillators used. For this purpose, a variable level liquid scintillator was used in conjunction with the air shower array at Ootacamund. This liquid scintillator was placed just a meter away from one of the plastic scintillators. The level of the liquid was varied from 1 to 8 cm and about 1000 air showers were recorded for each thickness, after calibrating the scintillators for single particles. The density values as determined from the liquid scintillator were compared with the density determined by the neighbouring plastic scintillator. Preliminary results are shown in Fig. 1.

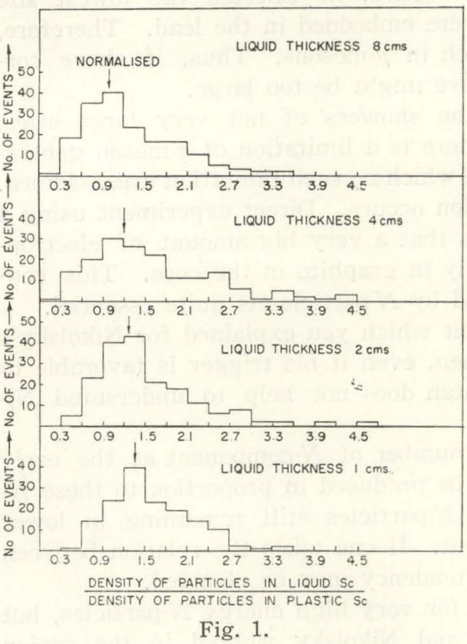

Fig. 1.

It is seen from Fig. 1, that with increasing thickness of liquid the density values decrease showing a slight absorption. The absorption mean free path is about 17–20 g/cm^2. The results indicate therefore that absorption of soft particles dominates over sensitivity to γ-rays and nuclear interaction at least up to a thickness of 8 cm of liquid. Further analysis of data is under progress and will be reported elsewhere.

References

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2) Wallace: Proc. Moscow Conf. II (1959) 316.
3) S. Fukui, H. Hasegawa, T. Matano, I. Miura, M. Oda, K. Suga, G. Tanahashi and Y. Tanaka (Pre-print)

Discussion

Kasha, H.: I would like to ask at what distance from the core was the scintillator response measured?

I would like also to note that it has been also observed by the Imperial College shower group that the absorption of particles (in water) is more pronounced than their multiplication.

Sreekantan, B. V.: For the present analysis, we have considered showers striking at a distance of more than about 5 meters. We will be making a detailed analysis as a function of shower size and core distance.

Oda, M.: 1) Are fluctuation of N-particles and μ-mesons uniquely related?

2) In connection with the parallelism of fluctuations of μ-and N-component, is there any possibility that some part of μ-mesons observed were N-component?

Sreekantan: 1) We find that there is positive correlation in the fluctuations of μ-mesons and N-particles in all the cases we picked up as having fluctuations in the μ-component.

2) That is a remote possibility. However, I must point out that the separation between the three μ-detectors were of the order of 15 metres. All the three units showed fluctuations by the same extent as can be seen from table III. Also the amount of matter above the μ-mesons detectors was more than 5 interaction mean free paths. It is more likely that they are μ-mesons and not nuclear active particles.

Millar, D. D.: In view of the interesting result that there is a positive correlation between the fluctuations in nucleon and μ-meson numbers in showers of a given electron size, it might now be valuable to think rather of the fluctuations in the electron component in showers of a given nucleon or μ-meson size, such fluctuations arising from the interactions which have occured within the last two or three mean free paths above the apparatus rather than in the first collision. A relatively local origin for much of the electron component in an air shower may follow from the indication of nuclear emulsion work of a cut-off in the π^0 spectrum from jets.

Zatsepin, G. T.: It is very interesting to see the positive correlation between the fluctuations of μ-mesons and N-particles. I remember that Nikolsky's result showed a knee on the dependence of N-particles on the size. There, he selected the lowest size showers in the apparatus in which counters were embedded in the lead. Therefore, he might have selected showers which were rich in μ-mesons. Thus, if above correlation exists, the lowest size point on his curve might be too large.

Secondly, I would like to mention that for the showers of not very large sizes, there will be such fluctuation, provided that there is a limitation of π-meson generation. However, we have made a calculation in which no such limitation was assumed. Then, we still found that such a big fluctuation occurs. Direct experiment using a thick graphite layer of about 200 g cm^{-2}, shows that a very big amount of electron-photon component can be generated occasionally in graphite in the core. This contribution of electron-photon component produced by N-particles is quite essential.

Miyake, S.: (to Dr. Zatsepin) About first point which you explained for Nikolsky's result, μ-meson is spread over large area. Then, even if his trigger is favorable to μ-meson, the tendency obtained by Dr. Sreekantan does not help to understand Nikolsky's result.

I understand the tendency as follows, if the number of N-component at the early stage is supposed to be large, μ-mesons will be produced in proportion to these N-particles, at the same time the effect of these N-particles still remaining in lower energy N-particles at later stage of development. If one takes the relation between μ-mesons and higher energy N-component, the tendency may be changed.

Zatsepin: The results of Nikolsky were not for very high energy N-particles, but for about 10^{10} ev. However, both Sreekantan and Nikolsky worked in the region within the distance of the order of 10 m from the core, where the energy spectrum is not very steep. Therefore, it may be possible that correlation of N-particles of 10^{10} ev with μ-mesons are the same as that of N-particles detected in neutron counter. On the other hand, if you pick up very high energy N-particles, say $10^{11}\sim10^{12}$ ev, I think that this correlation between N-particles and μ-mesons will disappear.

Dobrotin, N. A.: Sreekantan showed the comparison between N-particles associated and unassociated with EAS. The group of Grigorov showed that the proportion of N-particles associated and unassociated with EAS depends on the energy and hence on the dimension of the apparatus. Therefore, the slope of the spectrum would be different for different size of the apparatus. One has to be very careful to this effect.