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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part III

III-4-17. A Study on EAS at Mt. Norikura

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Main results obtained at Mt. Norikura (2770 m a. s. l.) are as follows; (1) Fluctuation of the lateral density distribution function near the axis and distant range has been studied and their relation on the average was shown. (2) Absorption length of shower rates was about 100 g/cm^2 from 10^5 to 10^6 in size. The length changes from 125 to 94 g/cm^2 depending on the classification by lateral structure. Apparent attenuation length of shower size were 140, 170 and 200 g/cm^2 for 10^{-11}, 10^{-12} and 10^{-13} cm^{-2} sec^{-1} str^{-1} in frequency, respectively. (3) Lateral distribution of N-component of different energy range has been obtained in the form of $\exp(-r/r_0)$ where r_0 is 20 m, 7 m and 2 m for the energies 2×10^8 10^{10} and 10^{11} ev, respectively. Integral energy spectrum at various distances from the axis has also been observed. From these data, total integral energy spectrum was obtained as $E^{-1.3}$. (4) The relation of total number of N-particles to the size of the shower was $N_N \propto N_e^{0.6}$ independent of the energy of N-particles. (5) The change of character of core has been found by means of energy flow trigger system at the size of 10^5. (6) Density spectrum and its area effect have been observed. (7) Core structure has been discussed from the cloud chamber pictures.

The electron photon component and N-component of EAS were observed by the experimental arrangements as shown in Fig. 1 at Mt. Norikura (2770 m a.s.l.). The data about electron component were obtained by 16 plastic density detectors, and the data about the N-component were obtained by the multiplate cloud chamber and two standard neutron monitors.

Main results which have been obtained are as follows.

(1) The lateral density distribution of electrons shows large fluctuation, as reported already at Moscow Conference, for the region near axis. (0−20 m) In the distant range, the lateral density distribution fairly agrees with N.K. function with the age parameter one of 0.8, 1.0 or 1.2 for the size 10^5 -10^8 particles. In some cases (about 5% of the total) observed showers are especially young (0.4−0.6 in s) or do not fit to the function at the central region, namely, densities are almost flat up to several meters.

Exponent α of lateral distribution expressed by $r^{-\alpha}$ near axis does not correspond in each case to the age parameter s of N.K. function which is determined mainly using distant range, but average value of α in the same s group shows following relation; $s=2.3-\overline{\alpha}$, though the exponent, α, shows large fluctuation.

The lateral density distribution of central part does not show the true age of the shower but it shows activity of core in further de-

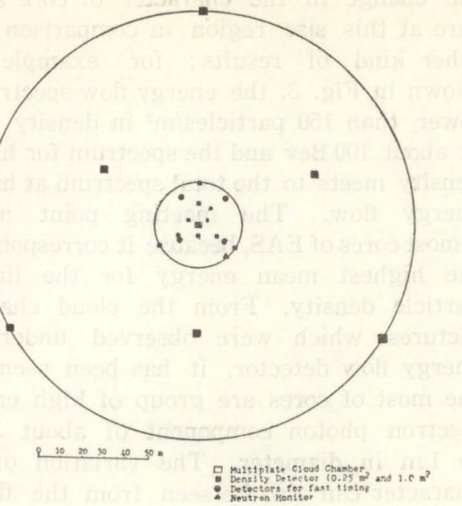

Fig. 1. Arrangement of the detectors. At the first stage, only 10 density detectors which are arranged in the circle of radius 20 m were used and 6 density detectors (1.0 m^2 area) were added at the position of 50 m and 100 m in the second series of observation.

velopment.

(2) The absorption length of shower rates was obtained from the angular distribution which has been observed by cloud chamber picture and first timing circuit. The absorption length was 104 ± 4 g/cm^2 for the size 10^5 and 114 ± 5 g/cm^2 for the size 10^6. The absorption length does not change largely with size, but for the groups divided by the value of α it varies from 125 to 94 g/cm^2 with α from 0.8 to 1.8. The result shows that the absorption length for young showers are largely dependent on the fluctuation of starting points and the length 94 g/cm^2 may be close to effective interaction mean free path.

From the size spectrum for each group of zenith angle, the apparent attenuation lengths of shower size are estimated as 140, 170 and 200 g/cm^2 for the frequency 10^{-11}, 10^{-12} and 10^{-13} cm^{-2} sec^{-1} str^{-1} respectively. If there is the correspondence in the size of the showers that larger one is always larger even after penetrating some depth, the apparent attenuation length will be true attenuation length. In other case, one can use this length as a maximum estimation of true attenuation length.

(3) The integral energy spectrum of N-particles were observed by neutron monitor and multiplate cloud chamber and the result was $E^{-1.0}$ within the energy range from 1 Bev to 1000 Bev using AS triggering method. To determine energy spectrum of N-particles in detail, lateral distribution for the limited energy in each size group and the energy spectrum at various distance ranges have been studied. The integral energy spectrum were obtained as $E^{-0.7\pm0.1}$, $E^{-1.1\pm0.2}$ and $E^{-1.5\pm0.2}$ for the events observed at distance 0-5 m, 5-10 m and more than 10 m from the shower axis, respectively. The lateral density distributions of N-particles for various energy ranges are approximated by an exponential function, $\exp(-r/r_0)$, and the characteristic length r_0 are obtained to be 20 m, 7 m and 2 m for the energies 2×10^8 ev, 10^{10} ev and 10^{11} ev respectively. These characteristic lengths were almost independent of size. Applying these function to the energy spectrum in the region 0-5 m, the density k, at the axis of shower is obtained and the total energy spectrum is expressed by $k(E)r_0^2(E)=E^{-1.3}$. The obtained spectrum is rather close to the energy spectrum of cosmic radiation unassociated with EAS.

Supposing the semiequilibrium state between N-component and electrons in the development of the EAS, and taking into account the difference of exponent of energy spectrum and well known absorption length of 125 g/cm^2 for unassociated nucleons, the attenuation length of EAS is estimated to be about 150 g/cm^2.

(4) The total number of N-particles was also obtained for each size group, from the same data. The total number of low energy N-component and high energy N-component show same relation with the size of EAS as follows;

$$N_N \propto N_e^{0.6\pm0.1}$$

In the case of some biased observation which is favorable to detect young showers of small size, the exponent for low energy neutron increases slightly and the exponent for high energy becomes slightly smaller for EAS less than 10^6.

There is some change in character of core at the size of 10^5 as described in later section. Below this size, we found sometimes very high energy N-particle whose energy is comparable to total electron component and most of cases there is almost no energetic nucleon in the core region. Because of very large fluctuation, it is very difficult to discuss about the average character in these lower size region. For EAS of size above 10^6, on the average, N-component has only about 10% in energy compared with electron photon component and the contribution of N-component to the total energy becomes smaller with the size, then, the attenuation length is mainly determined by high energy electron photon component near the axis. The estimated attenuation length from energy dissipation and mean energy per electron is about 130 g/cm².

(5) The combination of 2 cm lead plate and plastic scintillator has been used for the detector of energy flow of electron photon component. The size spectrum of EAS which has been detected by using energy flow detector as master pulse for the trigger, is shown in Fig. 2. In the figure, the change of the slope can be seen at about 10^5 and 10^6 in size. The change can be understood as the change in the character of core structure at this size region in comparison with other kind of results; for example, as shown in Fig. 3, the energy flow spectra for lower than 150 particles/m² in density meet at about 100 Bev and the spectrum for higher density meets to the total spectrum at higher energy flow. The meeting point means almost cores of EAS, because it corresponds to the highest mean energy for the limited particle density. From the cloud chamber pictures which were observed under the energy flow detector, it has been seen that the most of cores are group of high energy electron photon component of about 30 cm to 1 m in diameter. The variation of the character can also be seen from the fluctu-

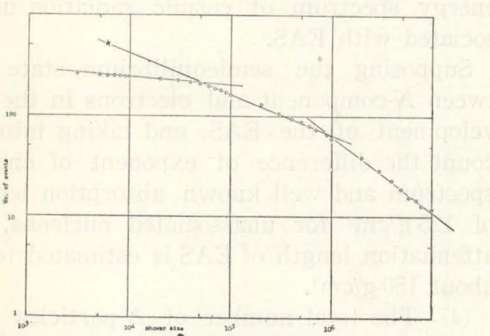

Fig. 2. Size spectrum of the EAS obtained by the energy flow triggering.

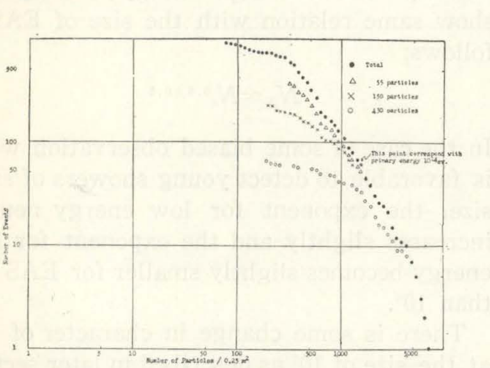

Fig. 3. Density spectrum observed by the scintillation counter placed under 2 cm lead absorber. Total working time was 238 hrs 22 min.

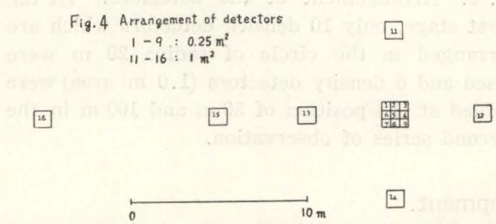

Fig. 4. Arrangement of detectors.

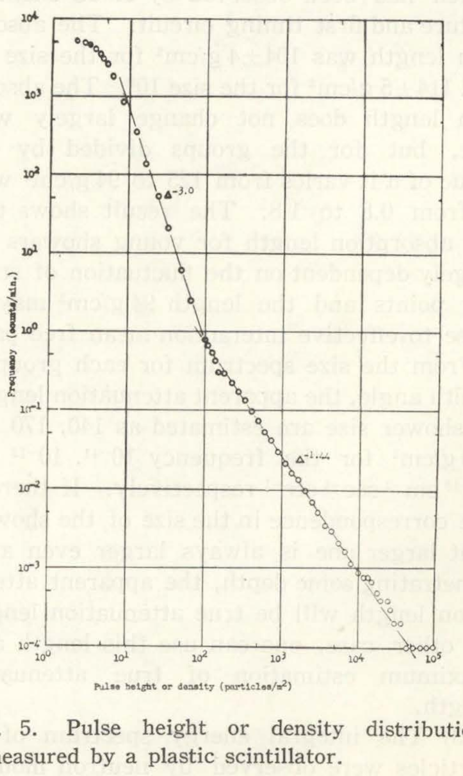

Fig. 5. Pulse height or density distribution measured by a plastic scintillator.

ation of mean energy of electrons; the fluctuation for size lower than 10^5 is very large and it becomes small for larger showers, and mean energy of electrons is decreasing with size.

(6) The density spectrum has been observed by experimental arrangement as shown in Fig. 4. The spectrum obtained is shown in Fig. 5, the exponent of the spectrum varies depending on detecting area; in this case 1.44 for 0.25 m^2 and 1.55 for 2.25 m^2. The spectrum has almost the same slope up to about 10^5 particles/m^2. Using the same arrangement, the lateral distribution of electron density near the axis has been studied in detail. The age parameter for the best fit *N-K* function distributes from 0.4 to 1.4 and several percent of total show special type of flat or steep structure beyond the function of above range.

(7) Finally, some special types of core structure has been discussed with the cloud chamber picture.

Discussion

Miura, I.: You showed some showers with different *s*-value, especially with small *s*. How is the lateral distribution at larger distances for such showers?

Miyake, S.: Most of them fitted one of the N. K. function with *s* 0.8~1.2 but some special showers shown above, show larger *s* distribution at larger distances.

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III-4-18. Extensive Air Showers at 4200 m*

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We have studied extensive air showers at an altitude of 4200 m (El Alto near La Paz, Bolivia, latitude 16° south) with apparatus previously employed in the MIT Agassiz air shower experiment at sea level[1]. We find the properties of EAS distinctly different at the higher altitude and are lead to the conclusion that the average atmospheric depth of maximum development for showers with a maximum of 2×10^8 particles is about 800 g cm^{-2}. The average lateral distribution at distances greater than 30 m from the core is markedly steeper than at sea level and, unlike the situation at sea level, it varies significantly with zenith angle. We have obtained a map of the celestial arrival directions of 195 showers with $N>10^8$ and six with $N>10^9$ corresponding to primary energies in excess of 10^{17} ev and 10^{18} ev respectively. Because of the geographic location most of the events come from the southern hemisphere. No anisotropy is evident.

The experiment employs plastic scintillation detectors to measure the density and arrival times of air shower particles at eleven points in a circular array 700 m in diameter (Fig. 1). The data are processed by an electronic computer which fits a prescribed

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† deceased.