changes from 2.2 ± 0.2 to 3.2 ± 0.3.

γ_s, γ_μ and the exponent of the energy spectrum, γ_p, are related as follows so far as the nature of EAS does not violently change[2] with respect to the size and it is essentially interpreted by a model described in reference 1):

$$\gamma_p=(1+B/A)\gamma_s \qquad \text{if} \quad \gamma_s<A/L$$

$$\gamma_p=\gamma_s+B/L \qquad \text{if} \quad \gamma_s>A/L$$

$$\gamma_p=a\,\gamma_\mu \qquad \text{if} \quad \gamma_\mu\sim E_0^{\,a}$$

With these relations and experimentally determined values of γ_s and γ_μ, γ_p is estimated as 1.9 ± 0.2 for lower energy and 2.5 ± 0.3 for higher energy, though these values of γ_p still should not be taken too literally because they were derived somewhat indirectly and they depend upon the model to some extent.

Thus, it is concluded that the energy spectrum of cosmic rays has a break or changes its exponent within a decade of energy range corresponding to the size 10^5 unless the nature of nuclear interaction changes in a peculiar way at a certain energy.

References

1) Fukui, Hasegawa, Matano, Miura, Oda, Suga, Tanahashi and Tanaka: Prog. Theor. Phys. Suppl. No. 16 (1960) 1.
2) Miura: III-2-22 of the present proceedings.

Discussion

Sreekantan, B.V.: The total number of μ-mesons in the entire shower plane are related to primary energy. Is it sufficient to measure the number within 200 m to relate the number to primary energy?

Zatsepin, G. T.: I agree with Sreekantan that 200 m is not enough to measure all mesons. About $\frac{1}{2}$ of all mesons have distance $r\leq200$ m from the axis. Only high energy μ-mesons $E\geq10^{10}$ eV are all inside $r\approx200$–150 m.

Hasegawa, H.: I made the geometrical correction in deriving the n_μ from observed density of μ-mesons. Therefore, I think that our n_μ is the total number of μ-mesons within the accuracy of numerical factor at most about 2 or so.

Fujimoto, Y.: Observation of gamma rays with emulsion chamber by our group gave the ΣE_{π^0} spectrum of nuclear interaction at mountain altitude as power $\gamma=2.3\pm0.2$ in the energy range of 10^{13-14} eV. This would correspond to the primary spectrum at around 10^{15} eV, and seems not in contradiction with the present data.

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III-2-3. Arrival Direction of Extensive Air Showers

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This report deals with the work of Tokyo AS project regarding the following questions;

1) Is appreciable portion of EAS produced by heavy primaries or not?

2) Also by gamma-rays?

3) The isotropy of AS has been generally admitted so far. But, suppose there any heavy- or gamma-primary initiated AS and we could select these showers, are they still isotropic?

In order to distinguish heavy-primary and gamma-primary initiated AS, we use $N-n_\mu$

diagram analysis which was explained in the previous report[1].

Fig. 1 shows an $N - n_\mu$ diagram for zenith angle less than 20°. Each point on the diagram represents the size N and the total number of μ-mesons, n_μ, of each EAS. Since we know the lateral distribution of μ-mesons, we may determine n_μ for each AS from observed density of μ-mesons at a known distance from the shower-axis. Points which

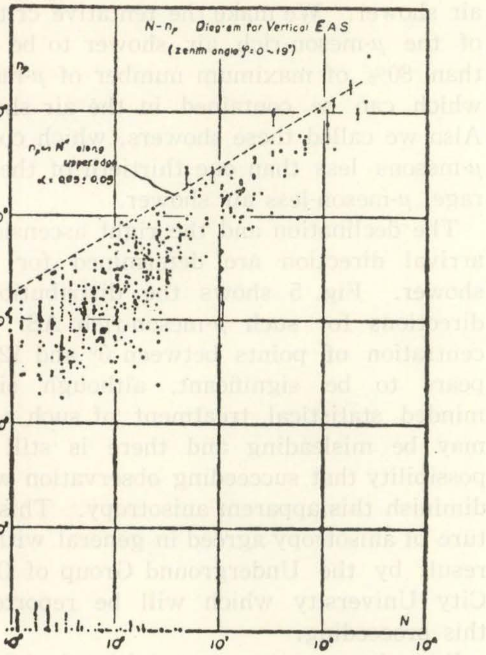

Fig. 1.

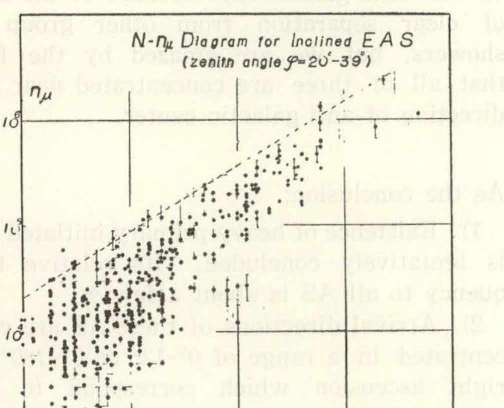

Fig. 2.

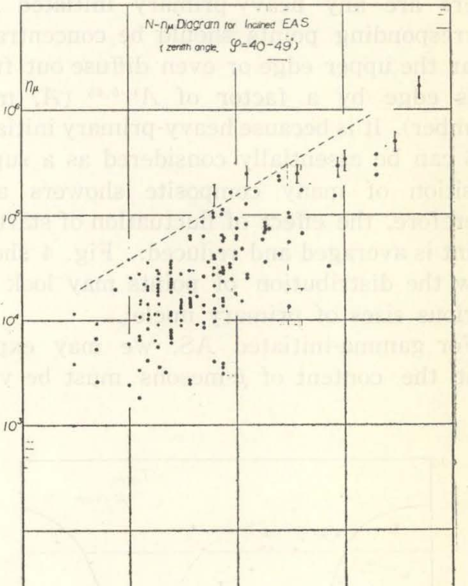

Fig. 3.

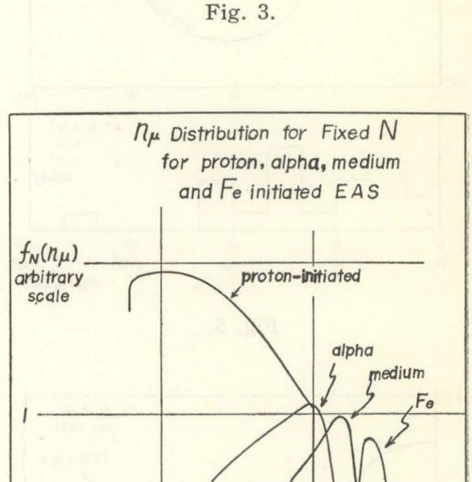

Fig. 4.

lie near the upper edge of the distribution of the points on the diagram correspond to AS which start near the top of the atmosphere and points near the lower edge start at low altitude.

It is quite reasonable to suppose that, if there are any heavy-primary initiated AS, corresponding points should be concentrated near the upper edge or even diffuse out from this edge by a factor of $A^{1-0.65}$ (A, mass number). It is because heavy-primary initiated AS can be essentially considered as a superposition of many composite showers and, therefore, the effect of fluctuation of starting point is averaged and reduced. Fig. 4 shows how the distribution of points may look for various sizes of primary nuclei.

For gamma-initiated AS, we may expect that the content of μ-mesons must be very small, probably 100 times less than usual.

It is quite reasonable, thus, to suppose that, if air showers are classified in terms of the proportion of the number of μ-mesons to the size, heavy-primary initiated air showers are condensed in the group of the μ-meson-rich air shower. We make the tentative criterion of the μ-meson-rich air shower to be more than 80% of maximum number of μ-mesons which can be contained in the air shower. Also we called these showers, which contain μ-mesons less than one thirtieth of the average, μ-meson-less air shower.

The declination and the right ascension of arrival direction are determined for each shower. Fig. 5 shows the distribution of directions for such μ-meson-rich AS. Concentration of points between 0^h and 12^h appears to be significant, although simple minded statistical treatment of such a case may be misleading and there is still fair possibility that succeeding observation would diminish this apparent anisotropy. This feature of anisotropy agreed in general with the result by the Underground Group of Osaka City University which will be reported in this proceeding.

Regarding gamma ray initiated AS, we have only three candidates and we hesitate to call them gamma rays because of the lack of clear separation from other group of showers, but we are amazed by the fact that all of three are concentrated near the direction of anti-galactic center.

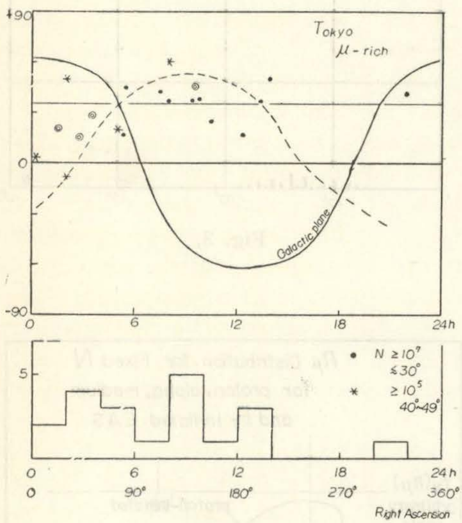

Fig. 5.

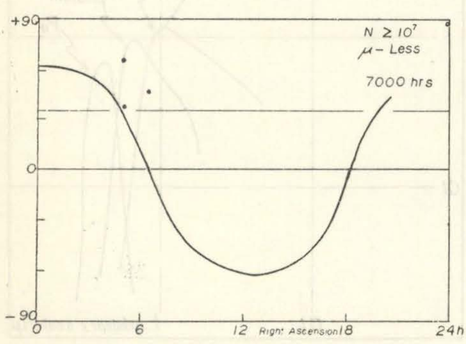

Fig. 6.

As the conclusion;

1) Existence of heavy-primary initiated AS is tentatively concluded. Its relative frequency to all AS is about a few %.

2) Arrival directions of these AS are concentrated in a range of 0^h–12^h or 0°–180° of right ascension which correspond to the region of the sky perpendicular to the arm of Galaxy.

3) AS which contain unusually few μ-mesons seem to come from the direction of Galactic anticenter.

References

1) Fukui, Hasegawa, Matano, Miura, Oda, Suga, Tanahashi and Tanaka: Prog. Theor. Phys., Supplement No. 16 (1960), 1.