JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN Vol. 17, SUPPLEMENT A-III, 1962
INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part III

III-4-15. Angular Distribution of the Penetrating Component of Extensive Air Showers at the Depth of 200 m.w.e.

E. L. ANDRONIKASHVILI, M. F. BIBILASHVILI, G. L. VARDENGA, T. V. GVALADZE, A. K. JAVRISHVILI, R. E. KAZAROV, R. V. KURIDZE and I. I. KHALDEIVA

Physical Institute, Academy of Sciences, Georgia SSR

In all the experiments performed with the aim of studying energy and lateral distributions of the penetrating component of E.A.S. It is necessary to know the angle of inclination of penetrating particles. The measurements of the angle of inclination are especially important, while studying the function of lateral distribution at distances less or of the order of $0.5\,H$ from the core of the shower, where H is the depth at which the detector of penetrating particles is placed underground. Just at such depths if the angle of inclination is not known a plateau is formed which has no physical sense.

It may seem at first that measurements of the angle of inclination of penetrating particles can be replaced by measurements of the angle of inclination of the shower axis. So far there have been no works confirming the agreement between the angular distribution of shower axes and that of μ-mesons of the shower. Half-quantitative estimation given later also shows some disagreement of these two distributions, which was to be expected. Besides, if to know the angle of inclination of penetrating particles one could determine the real path of the particles in the ground more exactly and that is necessary at measurements of the energy spectra of EAS penetrating particles.

The establishment of the angular distribution of penetrating particles was, therefore, one of the main problems for our group in the investigation of the EAS penetrating component at the depth of about 200 m.w.e. in Tbilissi.

We shall not describe experiments on the angular distribution of EAS axes in detail, we shall only indicate that though they were performed by different methods the direction of the axis was determined by the electron-photon component of EAS.

Cloud chambers were used in the most experiments. The mean angle of the registered shower particles was determined in them.

Certainly, the mean direction of the particles observed in some definite region of the shower would not coincide precisely with the direction of its axis. It is connected with the systematic deflection of the direction of the particle motion with respect to the shower axis. This disagreement is the more the bigger is the distance from the shower axis to the region where shower particles were registered. It also depends on the number of the particles used for the determination of the mean direction as at a small number of particles the probability of fluctuation of directions of separate particles increases with regard to this mean direction. The reduction of these effects can be achieved mostly by registration of electrons with the energy of the order of several Bev which pass, as it is known, near the EAS axis.

The data on the angular distribution of EAS axis were obtained by a many authors. The values of the exponent obtained in the distribution are approximated satisfactorily by the magnitude $n=8.3$ at sea level. Recently the method worked out by Bassi, Clark and Rossi was used to investigate the angular distribution of axes, the method consists in the determination of the angle of the inclination of the axis from the delay of the particles forming the front of the shower.

Let us consider some facts which can lead to the disagreement between the angular distribution of the penetrating component of extensive air showers and that of their axes. Extensive air showers registered at the same level of observation, which have an equal number of particles, but come at different zenith angles, originate from the primary particles with quite different energies. For instance, the shower, whose axis slope is about 45°, contains approximately eight times more particles in the maximum

This paper was read by G. E. Chikovani.

than the shower which falls vertically, at the level of observation they are registered as showers with the same total number of shower particles. In such an inclined shower the total number of μ-mesons will be approximately six times more than in the vertical one. Thus in investigating the auglar distribution of the penetrating component one has to expect some increase in the probability of registration for showers passing at bigger angles in comparison with the case determining the augular distribution of axis according to the electronphoton component. This effect somewhat decreased due to the following factors:

(1) the absorption of μ-mesons in the ground, which increases with the angle of inclination (2) the increase of the area where μ-mesons fall, which also increase with the angle of inclination. Therefore the probability of registration of μ-mesons decreases with their density. As a result of the above mentioned factors the increase of the probability of registration of EAS with the angle of inclination can lead to the decrease of the exponent in the law of the angular distribution by about a unity. The more exact calculation will be made later. The arrangement used for this investigation consisted of two parts, one on ground and the other underground. The one on the surface consisted of some correlated hodoscopes and selecting devices which selected and registered EAS. The data of the hodoscopes were used to determine the characteristics of extensive air showers (the total number of the particles, and coordinates of the axes). The underground part was a detector of penetrating particles, and consisted of a telescope. Lead filters with the total thickness of 25 cm were placed between the trays. The telescope gave the possibility to determine projections of the angles of inclination for penetrating particles in two reciprocally perpendicular planes. The maximum registered angle was equal to $37° \pm 4°$. The mean error was $\pm 5°$.

The results obtained, at the altitude of observation of 400 m above sea level, refer to the E.A.S. with the size of 10^5-10^6 shower particles. The axes which passed at distance of 0-80 m from the μ-mesons detector with a minimum energy of μ-mesons 40 Bev.

Histograms of the distribution of the cases

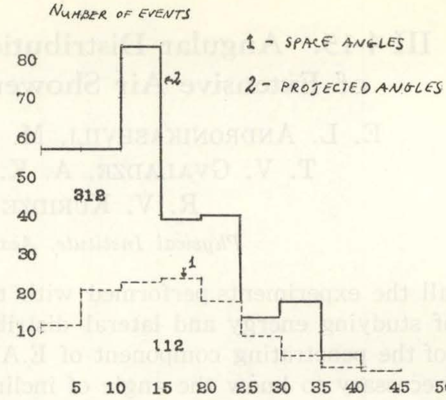

Fig. 1.

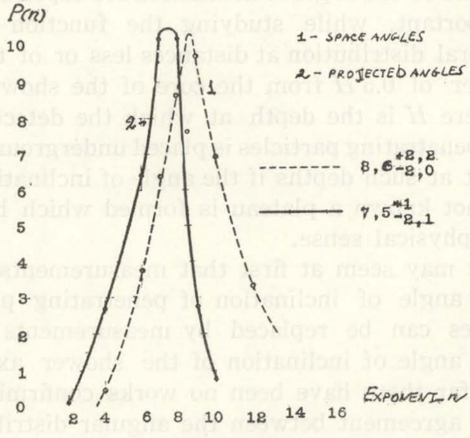

Fig. 2.

over the space and projection angles are given in Fig. 1. The histogram over the space angle was plotted for 112 cases, while the histogram over the projection angles was plottedt for 312 cases.

In order to determine the exponent, in the law of μ-meson angular distribution, the maximum likelihood functions were built for the observed space and projection angles.

These functions are given in Fig. 2. Curve 1 corresponds to space angles, curve 2 to projection angles. From these curves the most probable value of the exponent and its error can be easily found for both cases.

As if follows from the curves in Fig. 2 the exponent in the law of angular distribution for Extensive Air Showers penetrating particles, with the energy greater than 40 Bev is equal to

$$8.6^{+2.2}_{-2.0}$$

as determined over space angles, and to $7.5^{+1.0}_{-2.1}$ as determined over the projection angles.