particles corresponded the paper (1), and the energy spectrum in the region $10^9 \sim 5.10^9$ ev looked like $dE/E^{1.8}$.

A number of n. a. particles which was in agreement with an experiment was received in calculations (2). The fraction of secondary nucleons and antinucleons (Δ) among all the secondary particles, produced in the elementary act, considered to be equal 0.27. The latter seems to be a little bit higher in comparison with the majority of experimental data. However, if a great deal of observed characteristics of showers can be received by a method of calculation at some other values of Δ, a number of n. a. particles in air showers is determined mainly by the values of Δ (including hyperons). The table given above represents the number of n. a. particles in air showers at the mountain level calculated at different assumptions of the magnitudes of Δ. The magnitudes of $\Delta=0.27$ and 0.08 were received in the calculations (2) in which we used a model similar the hydrodynamical one for the description of nuclear interactions.

The calculation was carried out at $\Delta=f(E)$ with the account of the experimental data testifying the decrease of the energy fraction transferred to π-mesons at the increase of the interactive particle energy. For the region 10^{10} ev $\leq E \leq 10^{12}$ev and then it increases monotonously and at the level $E_0=10^{15}$ ev it becames 0.27. At $\Delta=0$ all the secondary particles are π-mesons. A free path for the nuclear interaction was taken as 75 g/cm^2 in every calculation mentioned above.

The comparison of calculated magnitudes with experimental data allows to draw a conclusion that at the collisions of particles with the energy 10^{10}-10^{12} ev an average fraction of nucleons, antinucleons and hyperons among all the secondary particles produced in elementary acts is large (>10%).

References

1) S. I. Nikolsky, Yu. N. Vavilov, V. V. Batov, DAN, USSR, III, (1956) 71.
2) S. I. Nikolsky, A. A. Pomansky—Proc. International Conf. II, 1960.

Discussion

Discussion for papers III-4-3, III-4-4 and III-4-5 is combined and given after the Paper III-4-5.

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-4-5. Energy Composition of the Extensive Air Shower Cores

E. I. TUKISH and S. I. NIKOLSKY
P.N. Lebedev Institute of Physics
Moscow, USSR

Measurements of an average value of energy of electron-photon (e-ph) and nuclear active (n. a.) components near an axis of the air shower were carried out by us earlier[1]. But both for comparison of the data carried out by means of different methods and for interpretation of experimental data, it is necessary to know distribution of the shower characteristics near the average value. The measurements of fluctuations of energy flux were carried out at the Pamirs (3860 m, 650 g/cm^2) in the autumn of 1959. The de-

* This paper was combined with III-4-3 and III-4-4 and presented by G. T. Zatsepin.

No manuscript has been received and the preprint is reprinted.

tector of n. a. particles and e-ph cascades of high energy consisted of 4 trays of ionization chambers with lead and carbon put between them (Fig. 1). The top trays comprised 12 and the other 20 (per each) ionization chambers. Two upper trays allow to determine an energy flux of the e-ph component of a shower and two lower ones to estimate energy of n. a. particles hitting the detector. The transition effect in the chamber walls can be neglected because they were made of polyethylene film 0.02 g/cm² thick. 10 hodoscope groups with 12 counters with the area of 330 cm² per each were arranged above the detector and 24 counters were arranged at the distance of 28 m from the detector center. This counter array allowed to determine N in the region of 10^3–10^6.

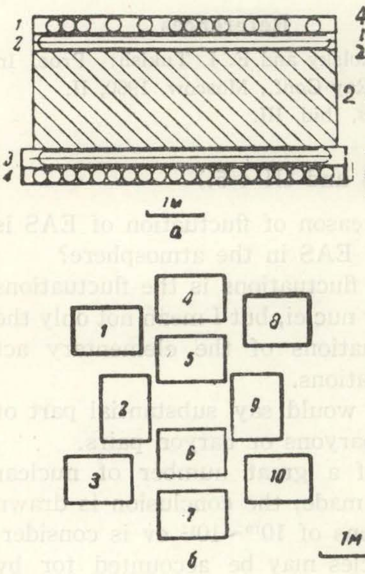

Fig. 1.

Hitting an air shower core within the detector area was determined by means of ionization chambers placed in two upper trays. The events were selected for which the maximum of ionization did not coincide with the side chambers.

Integral size spectrum of EAS in which energy of the e-ph component of core exceeded the pre-set is presented in Fig. 2. The top curve corresponds to the total ionization in the 2nd tray exceeded the passage 10^3 rel. particles along the average chord of the chamber. The lower curve– to the total ionization in the 3 adjacent chambers of the same tray exceeded the passage 10^4 rel. parts. Comparison of our experimental spectra with the size spectrum of EAS which hits the detector (Fig. 2, straight line) shows that an e-ph component of the shower core with $N \geq 10^5$ has the energy not less than $1.5\ 10^{11}$ev. An average energy of e-ph component of the core inside a circle 2.5 m in radii:

$$E_{eph} = (0.4\sim0.6)\cdot 10^8 N\,\text{ev}\,.$$

This value E_{eph} agrees with the results obtained earlier[1].

We determined relation between N and and energy of e-ph component of shower core E_{eph}, N and energy n. a. component of

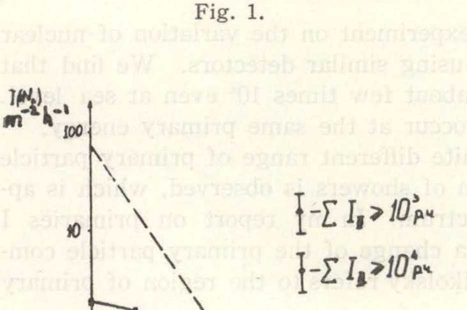

Fig. 2.

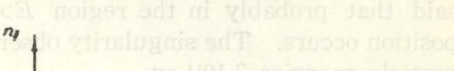

Fig. 3.

shower core E_{na}, and relation between E_{na} and E_{eph} in each recorded shower. Those relations have large fluctuations for an individual shower (see Fig. 3). The root mean square $1\pm(E_{eph}/N)$ expressed in relative units is equal to 1 ± 2.5 for shower with $N=10^4\sim10^5$ and to 1 ± 0.5 for $N\geq10^5$. Distributions of other relations have the same form:

$$1\pm(E_{na}/E_{eph})=1{}^{+3.0}_{-0.7} \text{ for } N=10^4\sim10^5 \text{ and}$$

$$1\pm(E_{na}/E_{eph})=1\pm0.7 \text{ for } N\geq10^5;$$

$$1\pm(E_{na}/N)=1{}^{+4.0}_{-0.8} \text{ for } N=10^4\sim10^5 \text{ and}$$

$$1\pm(E_{na}/N)=1\pm0.8 \text{ for } N\geq10^5$$

Large fluctuations in the EAS with $N<10^5$ are consequence of fluctuations of energy carried by a primary nucleon through the atmosphere. Decrease of fluctuations, as a shower size becomes more than 10^5, is connected with decrease of the role of separate energetically distinct particles that may be caused either by change of the elementary act character at $E_0>10^{14}$ ev., or by increase of the share of α-particles and heavier particles at the same value of energy[2].

References

1) S. I. Nikolsky and E. I. Tukish: Proc. Inter. Cosmic Ray Conf., Moscow, 1960, II.
2) B. Peters, ibid, III.

Discussion (for papers III-4-3, III-4-4 and III-4-5.)

Oda, M.: Could you exclude the possibility that the reason of fluctuation of EAS is mainly the fluctuation of the level of starting point of EAS in the atmosphere?

Zatsepin, G.T.: I believe that the main reason for the fluctuations is the fluctuations of the level where nucleon comes into collision with air nuclei, but I mean not only the first collision but also the subsequent one. The fluctuations of the elementary act are not of primary importance according to our calculations.

Yamaguchi, Y.: I would like to ask you if you would say substantial part of secondary particle produced by nuclear collisions are baryons or baryon pairs.

Zatsepin : In the report by Nikolsky on the basis of a great number of nuclear active particles found in EAS and of the calculations made, the conclusion is drawn that the fraction of baryons emitted in nuclear interactions of $10^{10}\sim10^{12}$ ev is considerable. It seems to me that some part of these particles may be accounted for by knock-on nucleons from the air nuclei.

Sreekantan, B.V.: We have done a similar experiment on the variation of nuclear active particles with shower size at sea level using similar detectors. We find that there is an indication of a change of slope at about few times 10^5 even at sea level. This shows that the change of slope does not occur at the same primary energy.

Zatsepin : Your result is concerned with a quite different range of primary particle energies where a change in the size spectrum of showers is observed, which is apparently due to the change in the primary spectrum. In my report on primaries I said that probably in the region $E>3.10^{15}$ ev a change of the primary particle composition occurs. The singularity observed by Nikolsky refers to the region of primary particle energies 3.10^{14} ev.