accompanied by additional showers, theses events were excluded.

Ezawa, H.: I would like to know the accuracy of energy measurement by the calorimeter of you.

Dobrotin: I think that the accuracy in our calorimeter is something like 30%.

Miesowicz, M.: I think it would be good to compare which of these results are in agreement with the fireball model introduced some years ago by us as a phenomenological hypothesis for explaining our experimental results. I think the main points which have been now confirmed are

1. The Lorentz factor of the emitting center is smaller than for nucleon after the collision.
2. Isotropic emission from the emitting center (fire-ball).
3. The independence of the energy of emitted particles on the primary energy.
4. The energy of the emitted particles does not depend on the mass of the fire-ball.

Dobrotin: I agree that our experimental data fit with the fire-ball model, introduced in the papers of the Polish group.

Mito: I would like to say your model as for the structure of fire ball is just the same as Dr. Niu's model.

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-6-2. Mountain-Altitude Studies of the Interaction of High-Energy Particles with Atomic Nuclei*

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Using 10-square-metre equipment (see Fig. 1) at 3,200 metres above sea level, studies were made of large ionization bursts corresponding to an energy transfer, to π^0-mesons generated in the equipment, of $E\pi^0$ from 2×10^{11} to 2×10^{13} eV.

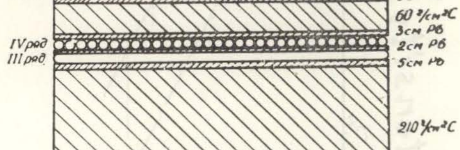

Fig. 1.

* This paper was read by V. S. Murzin.

The arrangement consisted of six trays of ionization chambers I-VI 330 cm long and 10 cm in diameter (I) situated under a combination filter of graphite and lead. It was possible to measure the ionization J in each separate chamber if $300\leq J\leq(50\text{-}70)\times10^3$ particles. (The magnitude of ionization J is expressed in the number of relativistic particles passing along the mean chord of the chamber perpendicularly to its axis and producing the given ionization.)

The following results were obtained.

I. In recording bursts by a large-area apparatus, a considerable portion of the bursts is generated by groups of nuclear-active particles falling simultaneously on the apparatus ("structural" bursts).

It is found that with increase in the mag-

Table I.

Magnitude of burst (number of particles)	Portion of "structural" bursts (II and IVth trays)		Portion of "structural" bursts (Ist and IInd trays)
	200 metres	3,200 metres	3,200 metres
$1.5\times10^3-4.5\times10^3$	$9.2\pm 0.5\%$	$16.0\pm 0.9\%$	$16.4\pm0.9\%$
$4.5\times10^3-10.5\times10^3$	$23.2\pm 1.6\%$	$39.6\pm 2.8\%$	$39.4\pm2.7\%$
$10.5\times10^3-75\times10^3$	$58\pm13\%$	$78.5\pm 7\%$	$74.5\pm8\%$
75×10^3	$90\pm10\%$	$83\pm12\%$	$95\pm5\%$

nitude of the recorded burst there is a decrease in the distance between the particles of these groups, while the portion of "structural" bursts increases.

Table I gives the portion of "structural" bursts as a function of the magnitude of the recorded burst J.

The smaller portion of "structural" bursts at 200 metres altitude above sea level (second column) is due to the greater contribution of *mu*-mesons.

Considering that the intensity of *mu*-mesons with energy $E\geq2\times10^{11}$ ev between mountain altitude and sea level does not change, and the intensity of single nuclear-active particles varies by a factor of 14 (just as the frequency of the "structural" bursts varies), we singled out of the single bursts those that are due to single nuclear-active particles and *mu*-mesons. The results are given in Fig. 2.

In the range of burst magnitude $2\times10^3\leq J\leq5\times10^4$ particles, the integral spectra of both types of bursts are of a power form $N(\geq J)=AJ^{-\gamma}$. Using the method of least squares, for the exponent γ of the spectrum of bursts due to single nuclear-active particles, we obtained $\gamma=1.98\pm0.09$, and for the burst spectrum due to *mu*-mesons we obtained $\gamma=2.22\pm0.14$.

From Fig. 3 it is seen that at 200 metres the contribution of *mu*-mesons to single bursts of magnitude $\sim10^3$ particles comes out to

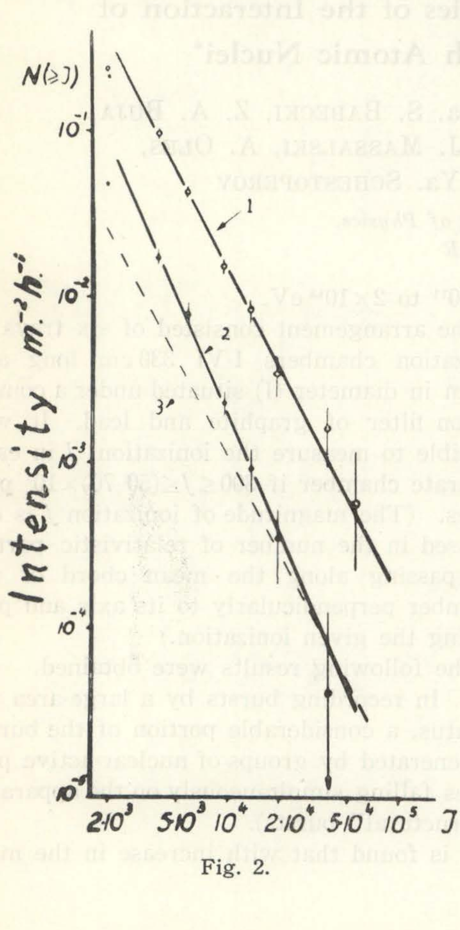

Fig. 2.

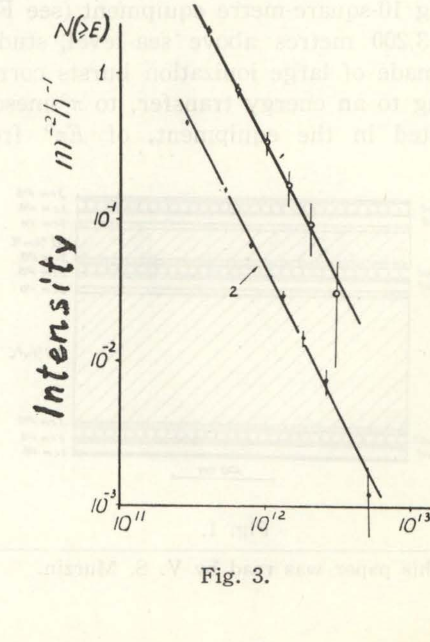

Fig. 3.

Table II.

Type of treatment of data	tray I	tray II	tray III	tray IV	Mean
"a"	1.30 ± 0.039	1.36 ± 0.027	1.37 ± 0.040	1.44 ± 0.039	1.37 ± 0.02
"b"	1.55 ± 0.046	1.63 ± 0.041	1.61 ± 0.050	1.57 ± 0.052	1.60 ± 0.02
"c"	1.91 ± 0.13	2.29 ± 0.13	1.95 ± 0.08	2.03 ± 0.08	2.02 ± 0.05
Single bursts	—	—	—	1.98 ± 0.09	1.98 ± 0.09

about 70, while that to bursts of magnitude $\sim 2\times10^4$ particles, about 50.

II. A study was made of the form of spectrum of ionization bursts as a function of the dimensions of the recording apparatus. To do this, a spectrum was constructed of bursts in which the magnitude of ionization is the sum total of ionization over all chambers of a given tray—treatment "a". (This treatment is equivalent to measuring the bursts of one chamber of dimensions 330×330 cm^2); a spectrum was constructed of bursts produced by single particles. Here, in the bursts produced by groups of nuclear-active particles, the separate burst "structures" were counted as independent bursts—treatment "b". This treatment is equivalent to measuring bursts by a chamber of dimensions 30×330 cm^2. A spectrum was constructed of bursts measured by separate chambers—treatment "c" (chamber dimensions, 10×330cm^2).

For all three types of treatment, the integral burst spectrum is of the power form $N(\geq J)=BJ^{-\gamma}$ with different exponent values γ of the spectrum.

Table II gives the values of γ, determined by the method of least squares, for bursts measured by different trays of chambers. The last column of the table gives the mean value of γ over all trays.

The difference in the values of γ is due to the fact that there is a diminishing effect, on the magnitude of the measured burst of groups of particles, with a decrease in the dimensions of the burst-recording apparatus.

From Table II it follows that:

1. The spectrum of ionization bursts measured by a large-area apparatus is not identical with the spectrum of nuclear-active particles at observation level;

2. The integral spectrum of ionization bursts in the magnitude range $10^3\leq J\leq10^5$ particles generated by separate particles has the exponent $\gamma=2.02\pm0.05$.

We did not detect any irregularities in the spectra up to bursts of magnitude 1.5×10^5 particles.

III. We compared the burst spectrum measured by separate chambers with the energy spectrum of nuclear-active particles measured at 3,200 metres altitude by means of an ionization calorimetre. Here, we correlated the energy E, conveyed to all π^0-mesons in the given interaction, with the magnitude of the ionization burst. The results are given in Fig. 3. From Fig. 3 it is seen that in the energy range E from 3×10^{11} to 3×10^{12} ev, the spectrum of bursts produced by separate particles is the same as the energy spectrum of nuclear-active particles. From this it follows that the inelasticity of interaction with atomic nuclei of graphite and lead in the indicated energy range remains constant.

IV. We analyzed the character of energy transfer to π^0-mesons in the recording of bursts produced by interaction in the upper filter of the apparatus by a single nuclear-active particle of energy $E\geq1.3\times10^{12}$ ev.

Since the energy transferred to the π^0-mesons in 60 gm cm^{-2} of graphite $E_{\pi^0}(60)$ and in 210 gm cm^{-2} $-E_{\pi^0}(210)$ are proportional to the

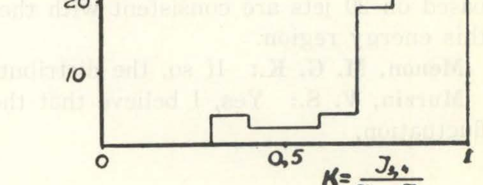

Fig. 4.

corresponding magnitudes of ionization $J_{3,4}$ and $J_{1,2}$ measured by the chambers of rows III, IV and I, II, we have

$$\frac{E(60)}{E(60)+E(210)}=\frac{J_{3,4}}{J_{3,4}+J_{1,2}}=K$$

The distribution of "K" is given in Fig. 4 for bursts in trays III, IV of magnitude $J_{3,4}\geq 7{,}500$ particles ($E(60)\geq 1.25\times 10^{12}$ ev).

From this figure it follows that:

1. The portion of energy K_{π°, conveyed to π°-mesons in the interaction of high-energy particles with an atomic nucleus, experiences great fluctuations.

2. The interactions are nearly totally inelastic, in which π°-mesons receive 70 to 90% of the energy of the primary particle.

3. When recording ionization bursts, those interactions are automatically selected, in which the π°-mesons receive the greater part of the energy of the primary particle. This selection is due to the steeply falling spectrum of primary particles.

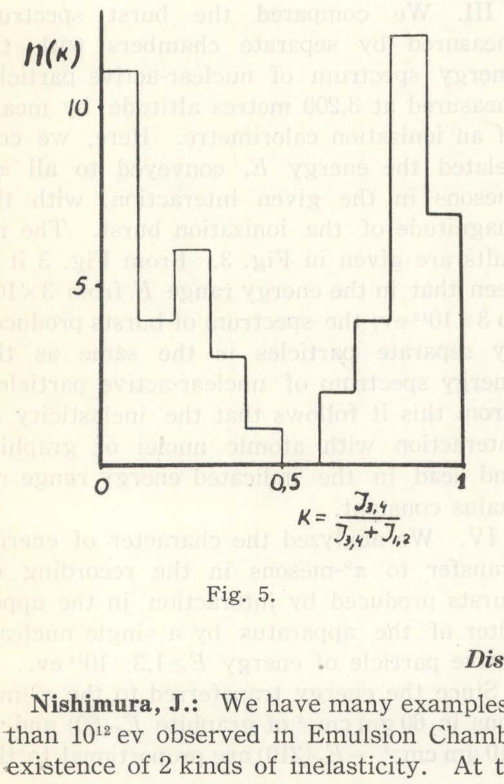

Fig. 5.

V. If it is required that a given quantity of energy should be transmitted to π°-mesons in the entire apparatus (and not in the upper filter, as in point V), that is, $E_{\pi^\circ}(60)+E_{\pi^\circ}(210)=E$, then in this case "$K$" will, in general outline, reflect the probability distribution of the transfer, to π°-mesons, of a given portion of energy of the primary particle—K_{π° in its interaction with a nucleus. (There will be no identity between K and K_{π°, because $E_{\pi^\circ}(60)+E_{\pi^\circ}(210)\neq E_0$, where E_0 is the energy of the primary particle.)

The distribution of K is given in Fig. 5 for cases of interaction of a single particle in the upper graphite filter (thickness, 60 gm cm^{-2}) on the condition that $E_{\pi^\circ}(60)+E_{\pi^\circ}(210)\geq 1.3\times 10^{12}$ ev.

From Fig. 5 it follows that the generation of π°-mesons in interactions with light nuclei is characterized by large fluctuations of K. The distribution of K has two maxima: one near $K=0.1$ and the other near $K=0.8$.

It is possible that this distribution of K corresponds to two essentially different types of interaction: the first, to peripheral interactions with low inelasticity ~0.3; the second, to central interactions with a nucleus with high inelasticity ~1.

Discussion

Nishimura, J.: We have many examples of nuclear events with primary energy higher than 10^{12} ev observed in Emulsion Chamber. Yet we are not so confident about the existence of 2 kinds of inelasticity. At this energy regions, the multiplicity of secondary particle is not so large. Furthermore particles in the forward cone carry away the most parts of the energy. The number of π° mesons in the forward cone is expected to be 1 or 2. So that one can expect a large fluctuation. Up to this time, our data based on 20 jets are consistent with the view as expected by statistical fluctuation at this energy region.

Menon, M. G. K.: If so, the distribution would be broader without two peaks.

Murzin, V. S.: Yes, I believe that the second peak can not be explained by the fluctuation.