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-1-9. The Study of the Composition of Primary Cosmic Radiation at the Altitude of 320 km

K. I. ALEKSEEVA, L. L. GABUNIA, G. B. ZHDANOV,
E. A. ZAMCHALOVA, M. I. TRETJAKOVA
and M. N. SHECHERBAKOVA

The Lebedev Institute of Physics and Moscow University, U.S.S.R.

Introduction

For the study of the composition of the primary cosmic radiation a small stack was used consisting of 10 sheets of emulsions NIKFI-ER (400 μ) with the dimensions of $10 \times 10\,\text{cm}^2$ and the sensitivity for the relativistic single-charged particles of about 20 blobs per 100 μ. The stack was exposed during the flight of the second space ship in the August of 1960 at the average altitude of 320 km, approximately for 24 hours, the latitudes being from 0 to 65°.

The aim of this work was to compare the possibilities of the instrument consisting of Čerenkov counters with the emulsion method of study of primary charge spectrum, in particular, for the determination of the relative intensity of the group of nuclei *Li*, *Be* and *B*.

As is known the usual method of identification of fast but not very heavy nuclei of cosmic radiation is based on the momentum measurement from the multiple scattering data and ionization ability by the δ-electrons counting and the gap analysis.

If scattering measurements and δ-electrons counting in hundreds of tracks are considered to be a hard and laborious process then the measurements of lengths of all gaps require still greater efforts. Thus, for example, within a working day, even an experienced technician can measure (with a specially adjusted microscope), the track of the order of 5 mm, *i.e.* the length which can hardly provide the possibility of separation, say, on the particles with the charges $z=5$ and $z=6$.

Because of that we have made an attempt to use in such experiments the apparatus for automatic measurements designed by the group of the workers in the Lebedev Physical Institute, headed by I.V. Shtranikh.

Due to the fact that the report on the design of this apparatus was made at the International Congress on nuclear photography, in the summer of 1960, and a detailed article was submitted for publication, we shall report here only on the principal features of operation of the device, and also on some experience of its three months operation.

In Fig. 1 the picture of the device is shown and in Fig. 2 the scheme of its operation. The image of a given part of the track multiplied by $\sim$200 times is projected on the transmitting television tube, after which it is subjected first to the background filter and to pulse formation and then to the analysis by ordinary alternate-line scanning. Simul-

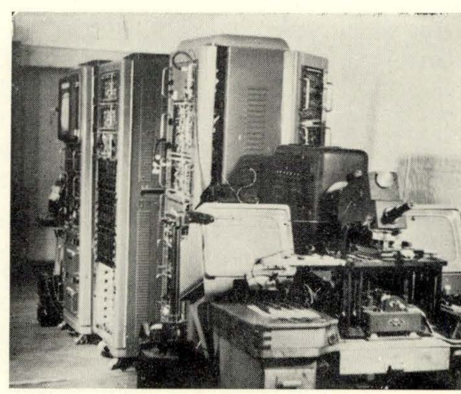

Fig. 1. Outer view of the installation.

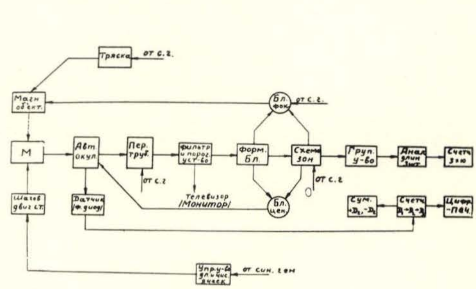

Fig. 2. A simplified block-scheme of the automatic measurements.

taneously, the small periodical up and down objective lens displacement ("shaking") is made which allows error signals to be obtained in order to control the objective lens movement for the automatic focusing of the measured track.

In the process of track scanning two more error signals are obtained which control the automatic correction of the track angle turn (by means of the Dove prism) and its automatic mounting in the centre of the working zone (by the ocular displacement). Simultaneously, 2 types of measuring signals are produced: a) the signal of the photodiode, which is proportional to the ocular displacement, *i.e.* to the first difference of the Y-coordinate of the track; b) the signals which are proportional to the number of the ajacent lines that hit on the gap, i.p. to the length of the intervals between blobs.

It should be noted that problem of automatization of measurements of this kind can not be considered as a simple one. The fact is in that case when the nuclei have the charge of 5-7, the average length of measured gaps equals 0.2-0.3 μ., which is comparable to the measuring standard, *i.e.* to the line width of the television image (0.15-0.18 μ).

The automatic measurements continued for about three months, and during this period over 100 tracks of the multicharged particles ($Z \leq 7$) were measured.

1. *Measurements of Multiple Scattering.*

The procedure of the automatic measurements was as follows. The track to be measured was followed along the X-axis and the initial point of the stage motor was put in coincidence with the corresponding track point. On the front panel of the machine the operator set the number of working cells and their length. The automatic following of the track was started by pressing the button and performed with the velocity of 50 μ per second.

The passage of the first measure cell was followed by the narrowing of the working zone to 1.5 μ, more accurate centering of the track along the axis of this zone and the reading of the first difference of the Y-coordinate by the corresponding decatron block. While the track moved along the next cell the received information was being printed on the paper tape, including both the first difference measured directly and the second and the third differences of Y-coordinated obtained by the reverse scales.

By performing the same procedure excepting the longitudinal displacement of the track, the data on the noises distribution can be received. Under normal conditions this distribution was displayed by the Gaussian curve whose dispersion did not exceed 0.1 μ. For the emulsion used the noises of the device were not important for cells ≥ 400 μ.

As the average length of the measured tracks (in one emulsion layer) was about 10 mm, the time of the measurement itself was equal to 7 min.

In Fig. 3 the mean values of the second differences D_2 (with the cell 800 μ) are displayed, these being measured once automatically and the other time (on the same track) by the usual visual method. The figure shows that in some cases a deviation of points occurs. As a rule, such deviations are induced by the abnormal operation of the machine.

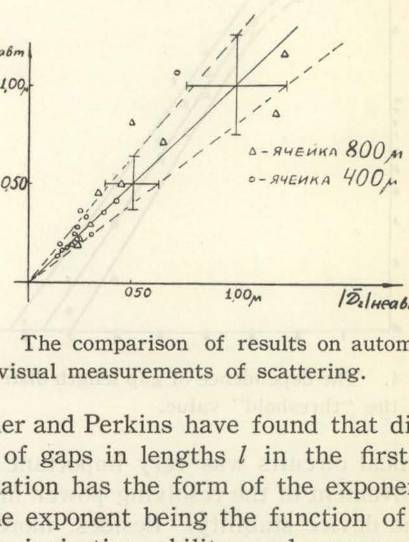

Fig. 3. The comparison of results on automatic and visual measurements of scattering.

Fowler and Perkins have found that distribution of gaps in lengths l in the first approximation has the form of the exponential one, the exponent being the function of the particle ionization ability, and consequently the function of the charge Z. In this case the slope of the corresponding curve in the semi-logarithmic diagram is of a very simple physical meaning, *i.e.* it gives the value reverse to the average length of the gap $t=\bar{\Delta}$.

The exponential character of gap distribution results in a peculiarity of measurements which is very important practically. The constant error in absolute value of the gap length yields the change of the absolute number of gaps in the given interval of l

values, but not the change of the slope of the straight line. The non-automatic measurements showed that the changes of such kind occurred, in particular, in proceeding from one emulsion layer to another, and also at different emulsion depths, different image quality, etc.

One of the most important adjustments of the device is the adjustment of the threshold which selects the signals from the grains. This value is considered to be the principal quantitative characteristic of the whole apparatus regime (see Fig. 4). The experiment proved that the optimum threshold corresponds to about 40% of the maximum blackening. The introduction of the automatic regulation of the amplification coefficient in the radio-

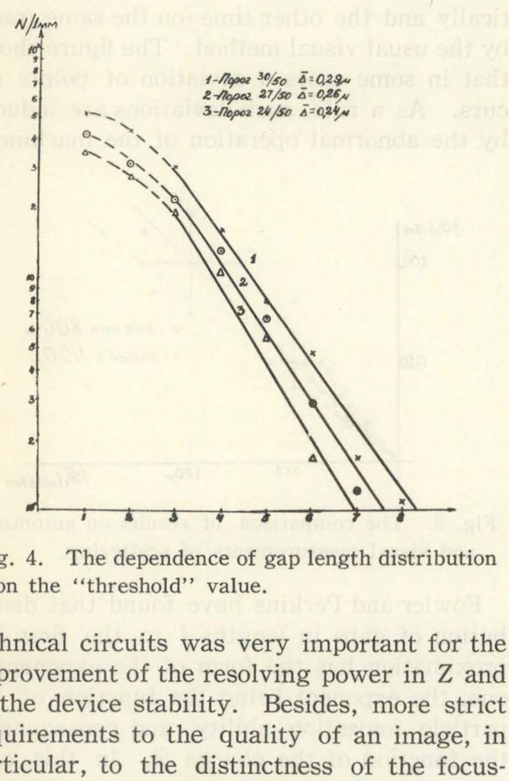

Fig. 4. The dependence of gap length distribution on the "threshold" value.

technical circuits was very important for the improvement of the resolving power in Z and of the device stability. Besides, more strict requirements to the quality of an image, in particular, to the distinctness of the focussing obliged us to reduce the engine vibrations effect by lowering the possible velocity of the track displacement at ionization measurements to $12\,\mu$/sec. Even this velocity still exceeds that of the visual measurements 10 times at least.

The fragmentation of rather fast nuclei in α-particles or in α-particles and protons served as calibration points.

To avoid the "drift" influence of the principal parameters we measured some of the calibration tracks daily.

The typical gap length distributions for the calibration tracks are given in Fig. 5 where they are compared with the corresponding data of visual measurements obtained on smaller lengths of tracks.

The accuracy of the ionization measurements can be estimated by the comparison

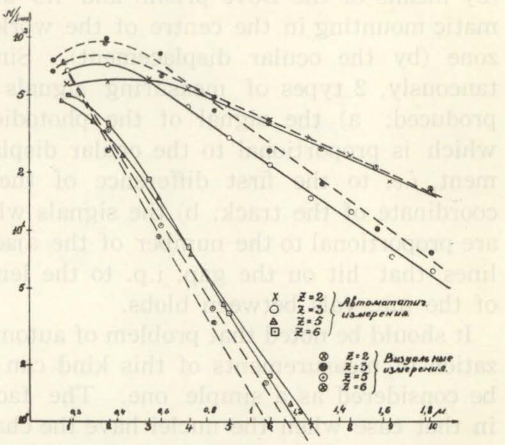

Fig. 5. The average gap length distributions for calibration tracks (full lines) and the corresponding data of nonautomatic measurements on the same parts of tracks (dotted lines).

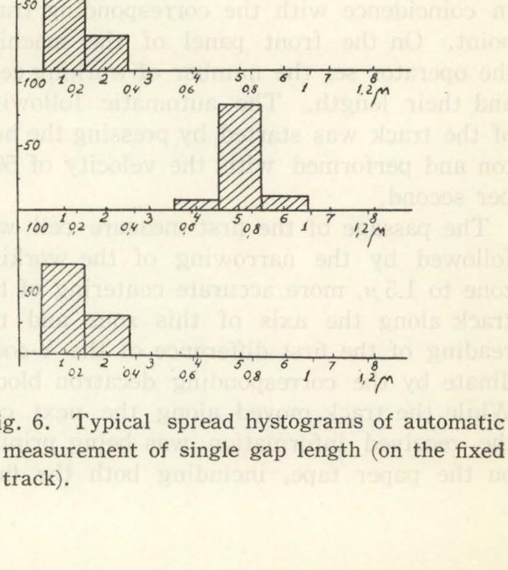

Fig. 6. Typical spread hystograms of automatic measurement of single gap length (on the fixed track).

of the spread of the gaps number in the given interval of lengths, due, on the one hand, to the emulsion reasons (statistical fluctuations of the track structure itself) and on the other hand to the random spread of the measuring errors of the instrument (Fig. 6).

The experiment showed that the instrument spread is of statistical character and, as a rule, does not exceed the spread of the emulsion origin.

At average lengths of 10 mm the error or t-value measurements is 8-10% for the values of Z between 5 and 6, and it appears adequate enough for the separation of the groups *Li*, Be, B and *C,N,O*.

For the increase of the resolving power in Z and for lowering the possibility of considerable errors, a comparison of several independent ionization measurement methods is highly desirable. In our work besides the comparison of automatic measurements of l-value with corresponding visual measurements (Fig. 7), two more values were used: the frequency of the δ-electrons N_δ and the relative length of all the gaps Σlg (see Fig. 8).

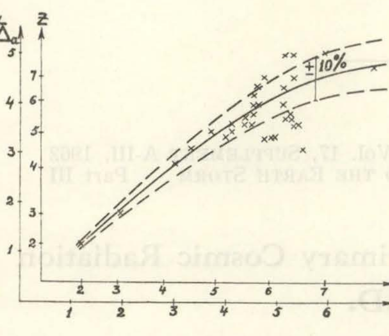

Fig. 7. The comparison of results of the automatic and visual measurement of the $\bar{\varDelta}$-value ($\bar{\varDelta}=t$-average gap length) for different Z-values.

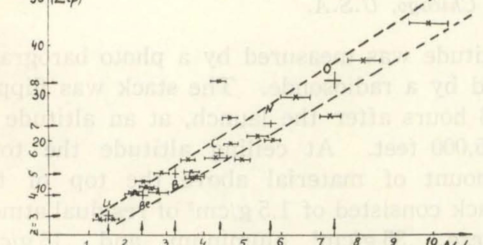

Fig. 8. The comparison of charge distributions in Z obtained by the determination of total gap length Σlg (per cent) and by the method of δ-electrons counting (N_δ).

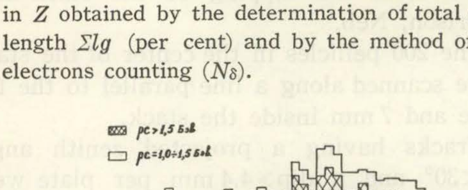

Fig. 9. The charge distribution for the group of primary nuclei with different momenta.

We display the obtained charge distributions of primary cosmic radiation particles in Fig. 9 where the group of particles with momenta pc$\geq$1.5 BeV per nucleon is separated, for which the limits of ionization ability variations depending on the velocity are equal to $\pm 7.5\%$. The amount of the substance above the emulsion is, on the average, about 8 g/cm^2.

The obtained results may be presented also in the form of the following table.

	Momenta:	Pc$\geq$1.5 *Bev*	0.8-1.5 *Bev*
The number	$Z=3-5$	18	25
of tracks	$Z=6-8$	45	32
observed.	$Z\geq 9$	15	13

The table shows that the ratio of intensities of the groups (light (L) and medium (M)) is 0.56$\pm$0.11 and the tendency for the decrease of this ratio with the increase of energy becomes appreciable. Both results are in qualitative accord with corresponding data of Aizu *et al.* (1) recently obtained at the depth 10 g/cm^2, and at the latitude of 61°N.

Taking into consideration recent data concerning fragmentation probabilities of nuclei (2) the above-mentioned L/μ ratio should be reduced by $\sim$25% to receive the estimation referring to free space.

References

1) H. Aizu, Y. Fujimoto, S. Hasegawa, M. Koshiba, I. Mito, J. Nishimura, K. Yokoi, M. Schein, Phys. Rev., **121** (1961) 1206.
2) C.F. Powell, P. Fowler, D.H. Perkins, The study of elementary particles by Photoemulsion method, Pergamon press, 1960 P. 374.

Discussion

Kaplon, M.F.: Isn't it possible that the counter results in the satellite need not suffer from the same effect as the emulsions—that is the acceptance of a finite solid angle viewed through the atmosphere? Would you comment?

Zhdanov, G.B.: Generally speaking you are right—this effect can be significant, but in the conditions of nonorientated sputnik, I suppose it is not important.

Daniel, R.R.: From the charge spectrum obtained by you it seems *Be* nuclei are more abundant than *Li*-nuclei. This seems to be in disagreement with the results of Dr. Shapiro and that of the Bombay group who got a very large number of *Li*-nuclei compared with that of *Be*. Could this be due to scanning loss of *Li*-nuclei in your experiment?

Zhdanov: I suppose that the scanning bias played not so important role in our experiments, especially for relativistic particles. May be the discrepancy can be partly explained by the poor statistics in our experiment.

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-1-10. The Heavy Nuclei in the Primary Cosmic Radiation at Sioux Fall, S.D.

H. AIZU and E. TAMAI
Dept. of Physics, Northwestern University, U.S.A.
AND
M. KOSHIBA and E. LOHRMANN
Dept. of Phys. Univ. of Chicago, U.S.A.

The detector consisted of a stack of 300 nuclear emulsions 15×20 cm, 600 μ thick. 280 of the emulsion sheets in the center of the stack were Ilford G5; at the end of the stack 10 sheets of Ilford K5 and 10 sheets of Ilford L4 were included. The stack was mounted in a gondola of 1.3 mm aluminum which was surrounded by a 7.5 cm layer of styrofoam. To obtain a well defined exposure the stack was mounted in a frame inside the gondola, which could be flipped at the end of the ascent of the balloon. The turning mechanism consisted of a Haydon electrical DC timing motor, which would, after a predetermined time, withdraw a lock and allow the frame with the stack to rotate by 90°. It was then held in its new position by a spring loaded lever fitting in a notch. In this new position, which the stack maintained during the flight at the ceiling, the 20 cm edge of the stack was vertical.

The stack was launched on September 4, 1959 from Sioux Falls, South Dakota. The altitude was measured by a photo barograph and by a radiosonde. The stack was flipped 2.3 hours after the launch, at an altitude of 125,000 feet. At ceiling altitude the total amount of material above the top of the stack consisted of 1.5 g/cm^2 of residual atmosphere, .35 g/cm^2 aluminum and .15 g/cm^2 styrofoam. The flight was terminated 8.8 hours after the flipping of the stack near Harrison, Neb.

The 200 pellicles in the center of the stack were scanned along a line parallel to the top edge and 7 mm inside the stack.

Tracks having a projected zenith angle $|\theta|<30°$ and a dip>4.4 mm per plate were accepted. However, in the first 4.5 cm from either end of the scanning lines only tracks going into the stack were accepted by choosing the acceptance angle to be between 0° and 30° and between 0° and −30° respectively. This guaranteed a potential length for all tracks of >12 cm; in most cases it was ≈20 cm. This was of great help in