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BRIEF COMMUNICATIONS

THE USE OF THE CRS CERENKOV RADIATION REFLECTED FROM SNOW FOR MEASURING THE ENERGY SPECTRUM OF HIGH-ENERGY PRIMARY COSMIC RAYS

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Experimental data are given on the energy spectrum of primary cosmic rays in the energy range of 10^{16}–10^{17} eV, measured by the Cerenkov method of reflection from snow.

The available experimental data on the shape of the spectrum of primary cosmic rays in the 10^{15}–10^{19} eV energy range show rather poor agreement. This situation calls for further experiments in this energy range with the use of various methods.

The present paper describes an original method proposed by Chudakov in 1972 [1]. A "Sfera" device was designed and produced [2–5] capable of measuring flashes (spots of light on the ground covered by snow) of the CRS Cerenkov radiation, which is a good measure of the primary particle energy. An advantage of this method is the possibility of effective observation over a large area (up to hundreds of square kilometers from an altitude of 20–30 km) using a fairly simple and small device.

The first attempt of measuring by this method was undertaken by Navarra [6]. Several events with a frequency of 4.2 h^{-1}, comparable to the expected value (2–10 h^{-1}), were observed, and then the work was stopped.

A schematic representation of the "Sfera" device is depicted in Fig. 1. An image of the spot of light is produced by a mosaic of 19 FEU-110 photomultipliers which are placed at the focal surface of a spherical mirror 1.2 m in diameter. The total viewing angle of the device is about 50°. A detailed description of the device and of the procedure is given in [5].

In [3] the possibility of obtaining an undistorted energy spectrum was tested by the mathematical simulation method and the energy threshold for the version of baloon measurements was determined.

In the present paper we report the results of measurements carried out in 1993 on the snow-covered surface of the Large Alma-Ata lake at an altitude of 2500 m above sea level. The lake area was about 0.7 km^2. The device was placed on a mountain ledge 160 m above the lake's level, so that the mean inclination of the optical axis to the horizon was 10°.

To diminish the energy threshold caused by the light background of the starlit sky, the photomultiplier photocathods were covered with dark-blue UFS-I light filters. Films that reradiated light to the region of maximum sensitivity of the photomultipliers were deposited onto the photocathods.

The transparency of the atmosphere and stability of the equipment were monitored by periodic measurements of the anode current of each of the photomultipliers, as well as by the counting rate of events.

Figure 2 shows a differential spectrum obtained from the sum of pulse amplitudes in the four central photomultipliers (in this case the largest part of the light spot was observed). The same figure shows a control spectrum measured by screened photomultipliers from events caused by the Cerenkov radiation in

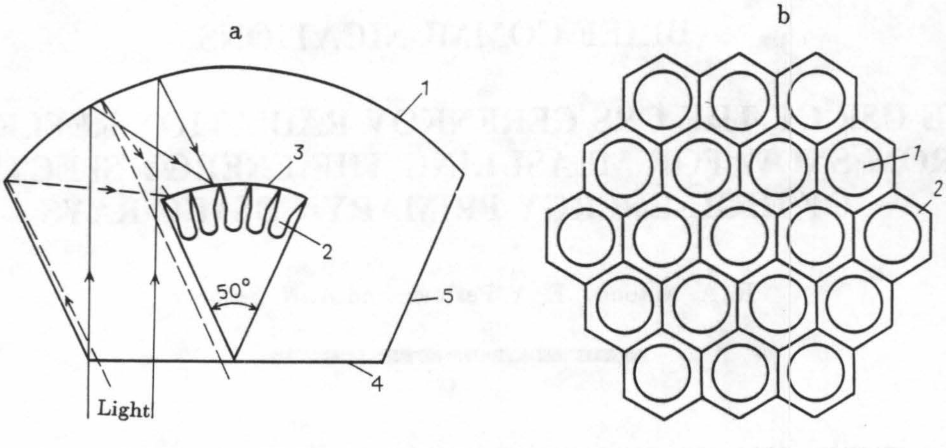

Fig. 1

(a) Schematic representation of the "Sfera" device: (1) mirror surface ($R = 0.75$ m); (2) photomultipliers; (3) focal surface; (4) aperture of the diaphragm ($R = 0.32$ m); (5) light limiting blinds. (b) Layout of photomultipliers on the focal surface: (1) photomultiplier; (2) hexahedral light collector.

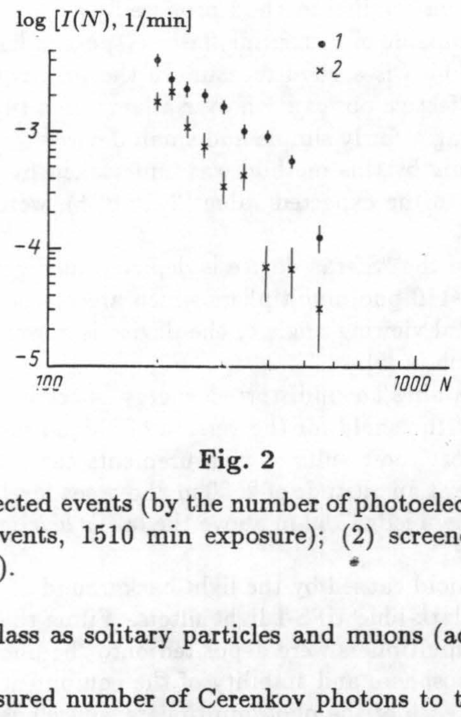

Fig. 2

Amplitude spectra of detected events (by the number of photoelectrons N): (1) nonscreened photomultipliers (4871 events, 1510 min exposure); (2) screened photomultipliers (1613 events, 956 min exposure).

the tube and in the light filter glass as solitary particles and muons (accompanied by δ-electrons) passed through them.

In going over from the measured number of Cerenkov photons to the energy of the primary particle, we carried out mathematical simulation of the device operation for the real geometry of the experiment. Here we made use of the results of measurements of the mean functions of the Cerenkov radiation spatial distribution for 10^{15}–10^{19} eV primary particles that had been conducted in Yakutsk [7].

When obtaining an energy spectrum one has to bear in mind that part of the light spot extends outside the lake surface area, and the effective observation area should be determined. To this end a random choice simulation was carried out with respect to the shower axis position uniformly over an area exceeding the lake surface, and with respect to the primary particle energy over a spectrum with the exponent of the differential spectrum equal to 3. For each event, the signal amplitude in each photomultiplier was computed and the condition of going beyond the threshold in the central and the adjacent photomultiplier was checked. In constructing the energy spectrum it was assumed that the angular distribution of incident showers is proportional to $\cos^3\theta$ [8], the effective solid angle Ω being equal to 1.6 sr.

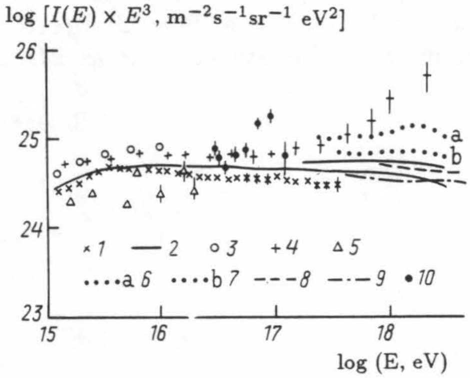

Fig. 3

Differential energy spectrum: (1) Moscow University [9]; (2) Akeno [10]; (3), (4) Tien-Shan [11]; (5) Samarkand [12]; (6) Yakutsk [13]; (7) Yakutsk [14]; (8) Haverah Park [15]; (9) USA, UTAH ("Fly's Eye") [16]; (10) present paper (25 h exposure).

The values of absolute fluxes of primary cosmic ray particles in the 10^{16}–10^{17} eV energy range obtained in the present experiment agree with the results of all other experiments (Fig. 3). The value of the energy spectrum exponent is less than that following from the experiments [9, 10] and is in better agreement with the results of [11].

The energy threshold in our case was determined not by the background light from the starlit sky, but by the low speed of operation of the recording equipment. In the baloon version, when the equipment is used that can measure events at a frequency of about 100 Hz, one may expect to obtain spectrum data in the energy range from $\sim 10^{15}$ eV to $\sim(3\text{–}5) \times 10^{19}$ eV (from altitudes ranging between 1 and 20–30 km) by a single quasicalorimetric method using a single "Sfera" device.

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