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ENERGY SPECTRUM OF PRIMARY COSMIC RAYS IN THE 10^{11} - 10^{15} eV ENERGY RANGE ACCORDING TO THE DATA OF PROTON-4 MEASUREMENTS

N.L. Grigorov, Yu.V. Gubin, I.D. Rapoport,
I.A. Savenko, B.M. Yakovlev
Institute of Nuclear Physics, Moscow State University;
V.V. Akimov, V.E. Nesterov
Institute of Space Research, Academy of Sciences of the USSR;
Moscow, U S S R

ABSTRACT: The methods of measurements are described in short. The results of measurements of the spectrum of all particles of primary cosmic rays in the 10^{11}-10^{15} eV energy range are presented. The results obtained are compared with the data of Proton-I,2,3 experiments.

The Proton-4 satellite carried IK-I5 instrument designed to measure the primary cosmic ray spectra in the 10^{11}- 10^{15} eV energy range and the cross-sections of inelastic interaction of high-energy protons with carbon and hydrogene nuclei. The design of the IK-I5 instrument has been described in /I/. Schematical view of the instrument is shown in Fig.I. The instrument consists of (I) detectors of the charge and direction of movement of particles, DD-I and DD-2 which are Čherenkov counters of large area with plexiglass radiators; (2) proportional counters PC2-PCII of which the PC2 and PCII counters are additional charge detectors and PC-3 and PC4 are interaction detectors; (3) ionization calorimeter used as energy detector and countaining I40 g/cm^2 of lead and 855 g/cm^2 of iron absorbers interplayered with ionization chambers ICI - ICI6; (4) replacable graphite and polyethilene targets arranged between PC2 and PC3; thin graphite targets arranged between PC7-PC II.

The measurements were carried out according to statistical and individual programmes. The integral and differentail discriminators and coincidence circuits were used in the statistical programme to select the events with given indications. Telemtric memory accumulated the numbers of events of each kind detected in each cycle of telemetry interrogation. When measuring the spectrum of all primary cosmic ray particles according to statistical programme the cases of energy release in the ionization calorimeter exceeding the given threshold values E_i were recorded. In this case no conditions were imposed on the kind of a particle, place of its entering the calorimeter and movement direction. The values of thresholds E_i covered the 2×10^{11} - 5×10^{15} eV energy range and divided this range into eight intervals. The numbers of pulses from the integral discriminators $E_1, E_2, E_3, E_4, E_5, E_7, E_{10}, E_{K1}$ were supplied to the telemetry.

In the individual programme the events were selected displayind the following indications: pulses were simultaneously produced in DD-I or DD-2, PC3 or PC4, PC5 or PC6 in any of PC7 - PC-I0; energy $E_6 > 2.5 \times 10^{13}$ eV was released in the ionization calorimeter. When these conditions were satisfied master were produced which triggered the circuits of multi-channel amplitude analyzers measuring pulse amplitude in each of the instrument detectors. The information from the amplitude analyzers was supplied to the telemetry memory.

The readings of the multi-channel amplitude analyzer which measured the value of total ionization in the calorimeter (the sum of the amplitudes from all ionization chambers) were used to plot the spectrum of all cosmic ray particles.

Fig.2 shows the integral energy spectrum of all particles measured on the basis of the two methods and normalized to the Proton-I,2,3 data at intensity of 10^{-4} cm^{-2} $ster^{-1}$ sec^{-1} /2/.

The results of the statistical and individual programmes are shown with right (+) and incluned (x) crosses respectively. The same figure presents averaged intensities of all particles according to the Proton-I,2,3 results (points).

The obtained spectrum of all primary cosmic ray particles in the 2×10^{11} - 10^{14} eV energy range agrees fairly well with the spectrum obtained from Proton-I,2,3 satellites. An irregularity is observed in the 10^{12} eV range which has been analyzed in detail in /3/. In the all particle energy range of 5×10^{12}-10^{15} eV the spectrum is of power law shape with an exponent of 1.60 ± 0.01. An increase in the spectrum exponent is observed at energies higher than $\sim 2 \times 10^{15}$ eV. The methodical effects (limitation of amplitudes in electronic circuits) should result in a steeper spectrum at energies higher than 10^{16} eV.

It is known that in the lower atmosphere the integral spectrum of hadrons and gamma-quanta in the 10^{12}-10^{13} eV energy range has an exponent $\gamma = 2 - 2.2$ /4,5/. One of the versions to explain the increase of the exponent subject to independence of the interaction path and inelasticy coefficient on particle energy was considered in /6/. The explanation was based on the assumption of the existence of two components of primary cosmic rays one of which dies out at an energy of $\sim 3 \times 10^{14}$ eV. As it can be seen from Fig.2 this assumption has not been confirmed by the direct measurements and hence other explanation should be sought for the increase in the exponent of the particle energy spectrum within the atmosphere compared with primary spectrum.

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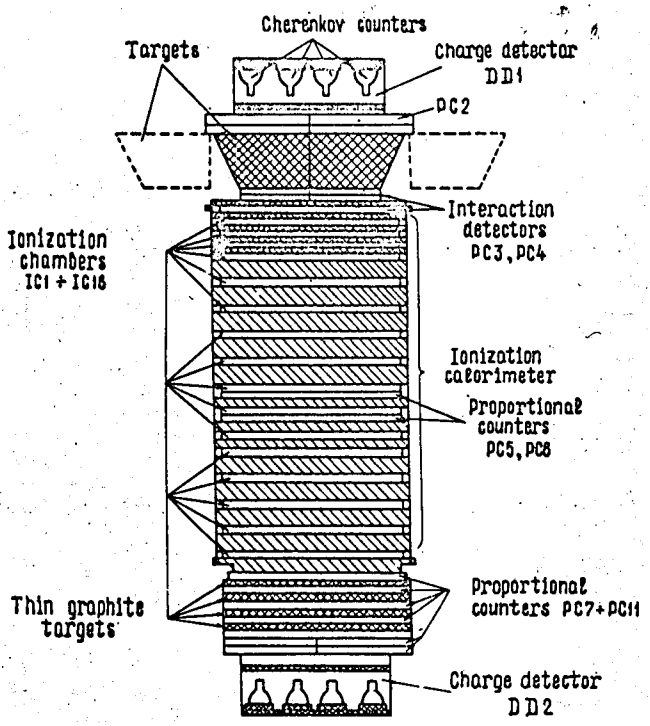

Fig.1. Schematical view of the IK-15 instrument.

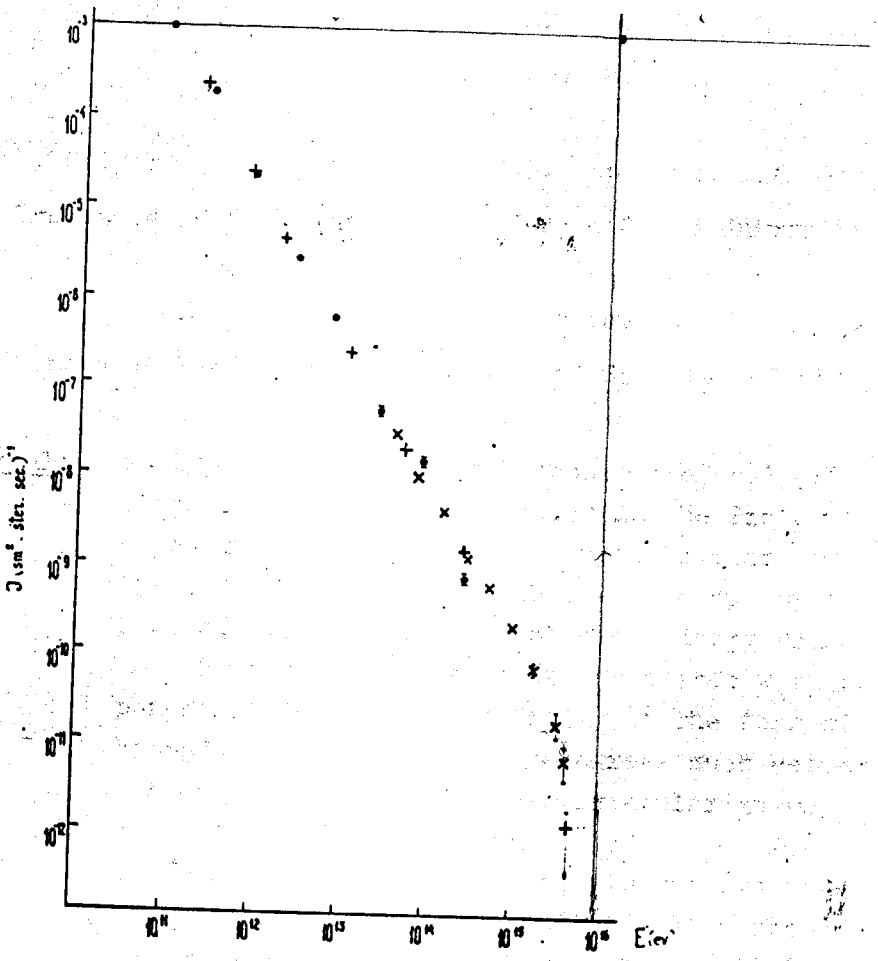

Fig.2. Energy spectrum of all particles:

● – the Proton –1,2,3 data;

+ × – the results of Proton–4 measurements according to statistical and individual programmes.