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ENERGY SPECTRUM OF COSMIC RAY α - PARTICLES IN $5 \times 10^{10} - 10^{12}$ eV/NUCLEON ENERGY RANGE.

N.L. Grigorov, I.D. Rapoport, I.A. Savenko

Institute of Nuclear Physics, Moscow State University, Moscow, USSR;

V.E. Nesterov, V.L. Prokhin

Institute of Space Research, Academy of Sciences of the USSR, Moscow, U S S R

ABSTRACT: The results of measurements of energy spectrum of primary cosmic ray α-particles in the $5 \times 10^{10}-10^{12}$ eV/nucleon energy range from Proton-3 satellite are presented. In the $5 \times 10^{10}- 5 \times 10^{11}$ eV/nucleon energy range the spectra of α-particles and protons are similar, the only difference is in intensity. The ratio of α-particle to proton fluxes of the same energies is 0.56 ± 0.1 .

I. Measurement technique

The SEZ-I4 instrument carried aboard Proton-3 satellite permitted the energy spectra of primary cosmic ray particles with different charges to be studied. Schematical view of the instrument is shown in Fig.I while various elements and detection systems are described in [I]. The nature of particle (its charge) was determined using a double proportional counter (see Fig.I in [I4]). The pulses from each proportional counter generated when particle passed through the detector affected differential discriminators isolating different nucleus groups. The α-particles were detected with differential discriminators which were in operation if the amplitudes of pulses, V, from the proportional countefs were within $2.7\, V_{prob.} \leq V \leq 8.0 V_{prob.}$ where $V_{prob.}$ is the most probable value of amplitude of the pulses generated in the proportional counter by a single-charge relativistic particle (by muon at sea level). If these discriminators were in operation simultaneousely in both proportional counters (within $\tau = 6x10^{-6}$ sec) signal Z_2 was produced.

Energy of α -particles was measured with ionization calorimeter consisting of steel plates between which plastic scintillators were inserted /I/. The plastic scintillators were viewed with two photomultipliers (PM-III, Fig.I) with mutial anode resistance. The PM signal amplitude was proportional to the energy released in ionization calorimeter and affected a row of integral amplitude discriminators with different thresholds of responce $E_i (i = I-9)$. Scintillation counters made of plastic scintillators and covering the whole area of the calorimeter were located above and under the ionization calorimeter (I,II, Fig.I). Operation of the amplitude discriminator Ei simultaneousely with signals from both scintillation counters resulted in the production of the signal denoted as E_{ci} . Located above the proportional counter was the detector of particle movement direction (DDI5, Fig.I) consisting of four directional Čerenkov counters which operated at single load. The direction detector was triggered by a single particle entering the instrument from its "inlet window" and may be triggered with a shower leaving the calorimeter with number of particles $\geq$ IO. However, such shower could not as a rule imitate α -particle for in this case the signal amplitude of the proportional counter located between the calorimeter and direction detector would be beyond the differential "window" Z_2.

The SEZ-I4 instrument detected coincidences of the signals from both proportional counter (Z_2), ionization calorimeter and scintillation counters (E_{ci}), and Čerenkov counter (DD), i.e.

complex signals denoted as Z_2DDE_{ci}. A Z_2DDE_{ci} event ment that at the moment of energy release E_i in the ionization calorimeter a particle with charge Z = 2 had passed through the direction detector and both proportional counters. The direction detector was connected to the detection system in such a way that such events could be detected with only a half of SEZ-14.

During the flight Z_2DDE_{ci} events acccumulated in the "operative memory" system were counted each 8.5 sec and memorized in the system of "long-term memory" which was interrogated during the periods of satellite-Earth communications.

2. Measurement results

The information obtained between the communication periods (6-12 hours of satellite flight) was treated in such a way that the number of the Z_2DDE_{ci} events was calculated for each measurement period and then the mean intensity of these events, I_{mrd}, was determined. The mean intensities per a measurememt period have made it possible to plot time dependence of the counting rate for the Z_2DDE_{ci} events and to establish that during the satellite flight the operation of the equipment was, as a rule, stable. It was also established that the Z_2DDE_{ci} counting rates were independent of the position of the target in the instrument/1/ which made it possible to average the intensities found over the whole period of the flight and to find $\langle I_{mrd} \rangle$ and their RMS errors (statistical error was taken for only rare Z_2 DDE_{ci} events). When calculating the averages those measurements were excluded for which the deviation from the average was in excess of tripled value of the RMS error of an individual measurement.

Such cases amounted to ~I% of the total number of measurements. Since the electron methods of particle detection are not sufficiently visual and make the estimation of various immitations difficult we chose the following procedure to elucidata their role in the detected intensity of the Z_2DDE_{ci} events.

As it is known the Proton-3 was not oriented with respect to a fixed direction and spinned irregularly with respect to its three axes. Therefore a part of the time the SEZ-I4 "inlet window" was directed to the Earth and the instrument could not detect the protons and α -particles of high-energies entering through the direction detector (DD). Denote such orientation "as down" and the Z_2DDE_{ci} measured at this orientation as J_α^{down}. A part of the time the "inlet window" was oriented to the upper hemisphere and the instrument could detect the protons and α - particles of high energies. Denote such orientation as "up" and the intensity measured at this orientation as J_α^{up}.

Using the readings of the three-component magnetometer carried on Proton-3 we could determine the SEZ-I4 orientation "up" and "down" for some positions of the satellite. As the measurement results have shown the counting rate from high-energy protons (the Z_I (N_I+ N_2) DDE_c events) ceased actually at the "down" orientation. At the "up" orientation the proton counting rate was maximum. Therefore, we have selected from the total period of the Proton-3 flight all the intervals during which the Z_I (N_I + N_2) DDE_{ci} counting rate was zero (the "down" orientation) and maximum (the "up" orientation) and determined the avarage intensities $\langle J_\alpha^{down} \rangle$ and $\langle J_\alpha^{up} \rangle$ for these time intervals. It appeared that $K = \frac{\langle J_\alpha^{up} \rangle}{\langle J_\alpha^{down} \rangle} = 3.4 \pm 0.6$. This value shows that the α - particle immitations did not contribute substantially to the detected intensity of the Z_2DDE_{ci} events. It should be noted that the real value of K must be higher since the averaging in determination of $\langle J_\alpha^{up} \rangle$ included the time intervals when the "inlet window" of the instrument could be partly shielded by the Earth.

To determine the ratios of the flux intensities of α -particles and protons of the same energies we proceeded as follows. The counting rates of the $Z_2DDE_{ci}(J_\alpha)_i$ and $Z_I(N_I + N_2)\ DDE_{ci}\ (J_p)_i$ events for the same time intervals were determined for 850 hours of the satellite flight. For the same value of index i the ratio J_α / J_p corresponds to the ratio of the detected fluxes of α - particles and protons which release energy $\geqslant E_i$ in the ionization calorimeter. For E_3, E_4, E_5 (α - particle detection began from energy $E \geqslant E_3$) we have obtained the same value within statistical errors. The value of $\langle J_\alpha / J_p \rangle$ averaged over the three energy thresholds appeared to be $0.57 \pm 0.I$. This ratio is not true since the probability that in both proportional counters an α- particle will produce a pulse amplitude in the $2.7\ V_{prob} \leq V \leq 8.0_{prob}$ interval is 0.7 according to our calculations and the probability of proton detection by both proportional counters is 0.8. Besides that a somewhat shorter interaction path of a primary α - particle in the ionization calorimeter as compared to that of proton leads to the fact that on the average the energy release of α - particles in the ionization calorimeter may be I0% higher than that of protons. Including these corrections we get that the intensity ratio

$$\left\langle \frac{J_\alpha}{J_p} \right\rangle = 0.56 \pm 0.01.$$

This ratio, with respect to the method of its measurement, is independent of the accuracy of determining absolute α-particle flux. To obtain the absolute values of the α-particle fluxes the measured frequency of Z_2DDE_{ci} detection was divided by the effective geometrical factor $\Gamma = C_I \cdot C_2 \cdot \Gamma_o = 26$ ster.cm^2, where Γ_o is the geometric factor of the instrument, $C_I = 0.7$ is the efficiency of α - particle detection by both proportional counters; $C_2 = 0.65$ is the coefficient including the shielding of the instrument by the Earth.

The energy thresholds were considered to correspond to the particle energies determined in the same way as for the protons/2/ taking account of the fact that the α - particle energy release in the ionization calorimeter is 10% higher than the energy release of the protons of the same energies.

Fig.2 presents the absolute intensities of α - particles with energies higher than the given energy (per a nucleon) obtained during 1270 hours of measurement period. Presented also for comparison are the results of measurements of α - particles/3,4,5,6/ and protons/2,4/ in cosmic rays obtained by other authors.

R E F E R E N C E S

1. N.L. Grigorov, G.P. Kakhidze, V.E. Nesterov, I.D.Rapoport, I.A. Savenko, et al. Space Research,V,383,I967
2. N.L. Grigorov, V.E. Nesterov, I.D. Rapoport, I.A. Savenko , G.A. Skuridin. Nuclear Physics (USSR) v.II,ussue 5,1058,1970
3. R.C. Anand, R.R. Daniel, S.A. Stephens et al. Proc. 9th Int. Conf.Cosmic Rays,London,1965,vol.I,p.362 .
4. R. Pinkau, U.Pollvogt, W.R.H. Schmidt ,R.W. Higgett. Proc. XI-th Int.Conf.Cosmic Rays, Budapest,1969. Measurement of the Primary Cosmic Ray Proton and Alpha-Particle Spectra above 10^{GeV}/Nucl.
5. Fowler P., Waddington C., Philos.Mag.1, 637 (I956)
6. P.Sain, Lohrmann, M. Teucher M. Phys.Rev.115,654,1959

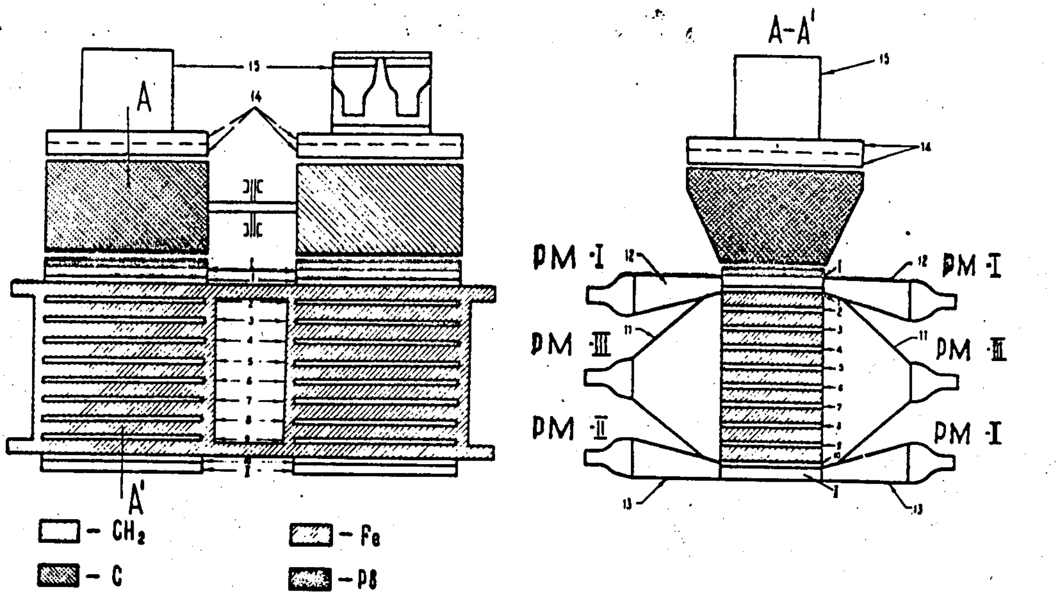

Fig.1. Schematical view of the SEZ-14 instrument:

1- interaction detector; 2 - Lower scintillation counter; 1-10 - scintillators of energy detector; 11-13 - diffusers of the energy detector, interaction detector, and lower scintillation counter respectively; 14- charge detector (double proportional counter); 15 - direction detector (Cerenkov counter).

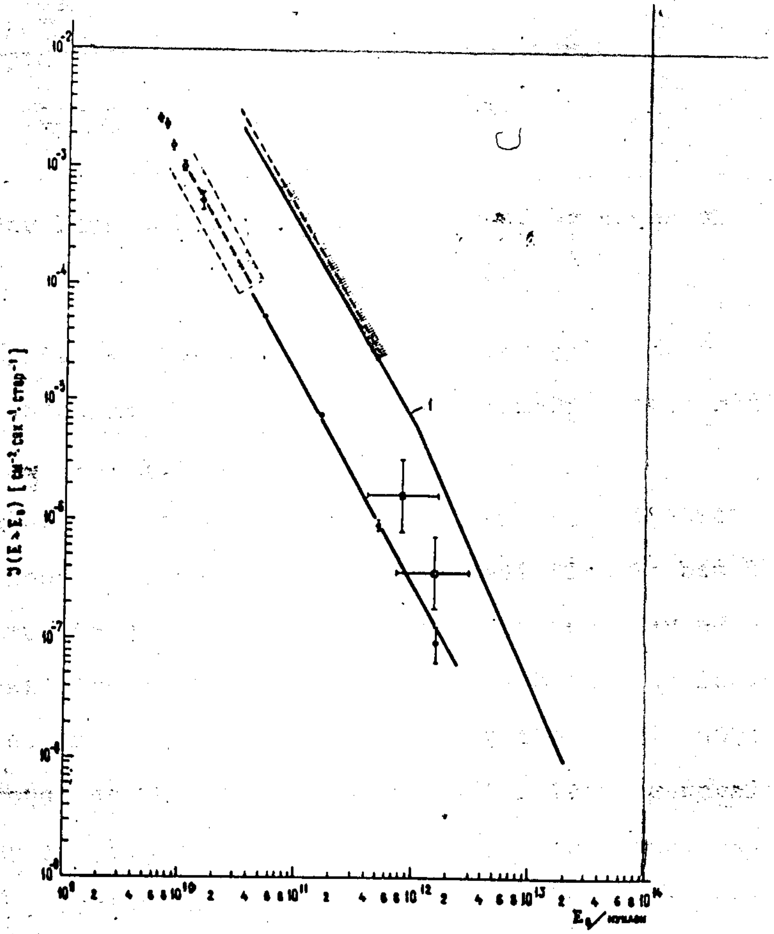

Fig.2. Energy spectra of α -particles and protons in primary cosmic rays

- the Proton-3 results;

- data from/3/

- data from/4/

- the results from/5/

- the results from/6/

1 – proton spectrum according to the data of Proton-1,2,3 measurements/2/.