COSMIC RADIATION MEASUREMENTS USING NUCLEAR EMULSIONS ONBOARD THE ZOND-5 AND 7 AUTOMATIC STATIONS

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1. INTRODUCTION

The automatic interplanetary stations Zond-5 (September 15-21, 1968) and Zond-7 (August 8-14, 1969) were equipped with emulsion packages to assess the radiation environment along the Earth-Moon-Earth trajectory. The packages consisted of 80 emulsion layers, each layer being 5 x 9 cm large and 400 micra thick. The packages were adjacent to the probe wall. The minimal shielding of the emulsions was 3 g/cm^2 thick. Fluxes and differential energy spectra of cosmic protons as well as spectra of neutron-produced recoil protons were measured by nuclear emulsions of the БР-2 and Я-2 type.

2. MEASUREMENT OF PROTON ENERGY SPECTRA

Differential energy spectra of protons were measured in three ranges by different techniques. Proton spectra were assessed in the ranges of 1-15 Mev, 20-100 Mev and 0.2-10 Gev for Zond-5 emulsions.

The emulsion (cloud) chamber located onboard the Zond-7 probe was used to determine proton spectra in the ranges of 1-40 Mev and 20-400 Mev. The 1-40 Mev proton spectrum was measured by the ranges of protons that entered the end of the photoemulsion layer to rest there. The tracks of protons in the emulsion chamber were followed from layer to layer until they came to a stop.

This technique made it possible to measure proton spectra in the range of 40 Mev. Using the range-energy ratio in the emulsion[1] and making necessary geometrical corrections[2], the range spectrum of protons was transformed into the energy spectrum.

The energy spectrum in the second range was determined measuring ionization transfer by the grain density in the charged particle track. Proton energy measurements were performed after calibration of the emulsion assemblies used. The calibration included the density of grains in the tracks of charged particles of the known nature and energy. For this purpose μ-mesons and electrons from $\pi \rightarrow \mu \rightarrow e^-$ decays and protons and μ-mesons obtained in the synchrocyclotron were used. This resulted in the equation indicating the grain density as a function of linear energy transfers.

The spectrum was estimated counting the number of particles that show LET corresponding to a given energy interval. In measurements the tracks were used whose inclination angle to the emulsion plane was not over $\pm 10°$. The tracks were observed by four physicists independently. Every spectrum was determined as a result of measurements of about 1500 tracks.

The spectrum of protons of up to 10 Gev was derived through an analysis of the ray distribution of "stars" formed due to the interaction between protons and emulsion nuclei. Fig. illustrates the ray distribution of stars detected during observations of emulsions. Altogether 511 stars were found and analyzed. Fig. 2 presents measurements of differential energy spectra of protons.

To determine the spectra of recoil protons formed during elastic scattering of neutrons on hydrogen nuclei, individual tracks of singly-charged particles that started and ended in the emulsion were detected. The energy of recoil protons was estimated by the length of their tracks

770 tracks of recoil protons were analyzed. The

differential energy spectrum of recoil protons was derived after introducing a geometrical correction for the exit of traces from the photolayer and a correction related to the background induced by alpha-active impurities in the emulsion. The spectrum is shown in Fig. 3.

3. PROTON DOSAGE EVALUATION

The proton energy spectra obtained by means of nuclear photoemulsions make it possible to determine the tissue dose value according to the equation[5]:

$$D_{(rem)} = \int_0^{E_{max}} \frac{dN(E)}{dE} \eta(E) dE$$

where $\frac{dN(E)}{dE}$ is the differential energy spectrum of protons and $\eta(E)$ is the specific dose equivalent for protons $(\frac{rem.cm^2}{proton})$. Using the values given in Ref. 3), the midtissue dose, surface dose and hemopoietic dose per flight were calculated. The estimates are given in Table 1.

Table 1

Flight dosages derived from proton spectra measured onboard the Zond-5 and 7 automatic stations (rem)

	Midtissue	Surface	At a depth of 5 cm	From neutrons
Zond-5	0.2	0.6	0.26	0.04
Zond-7	0.13	0.3	0.17	-

4. CONCLUSION

On the basis of the above measurements the conclusion can be made that behind the shielding of 3 g/cm^2 the peak of the proton energy distribution is in the range of 50 to 70 Mev. The difference in the values of proton fluxes and doses may be attributed to the different contribution

of the radiation belt protons. The determination of tissue doses has shown that the flight dosage they are responsible for makes approximately 0.5 rem. The total dose contribution from secondary neutrons amounted to 10-20% of the midtissue dose. The present paper does not discuss the contribution from heavy charged particles. According to the literature data, the midtissue dose induced by these particles constitutes 50% of the total dose[4]. The comparison of the dosage evaluations with the permissible values[5] allows the conclusion that, should no solar flare occurs, seven-day flights along the trajectories of Zond-5 and 7 probes are safe from the radiation point of view.

REFERENCES

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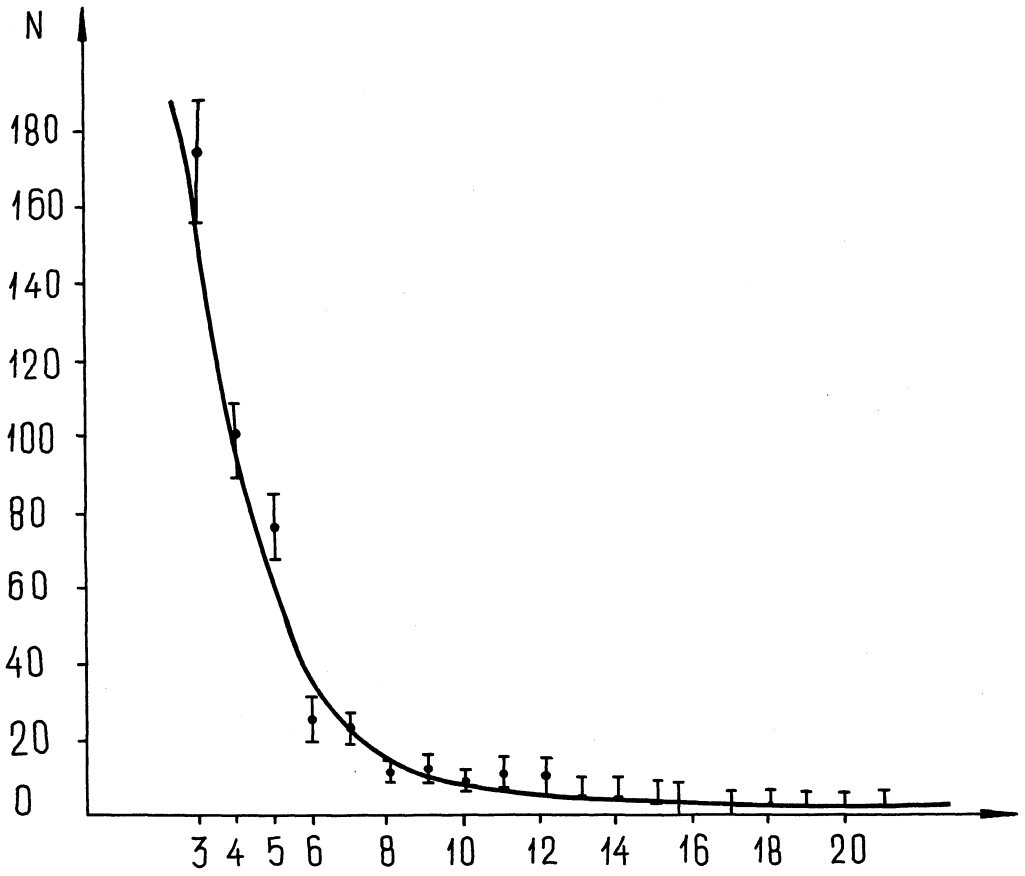

Fig. 1 The number of stars N as a function of the number of rays.n.

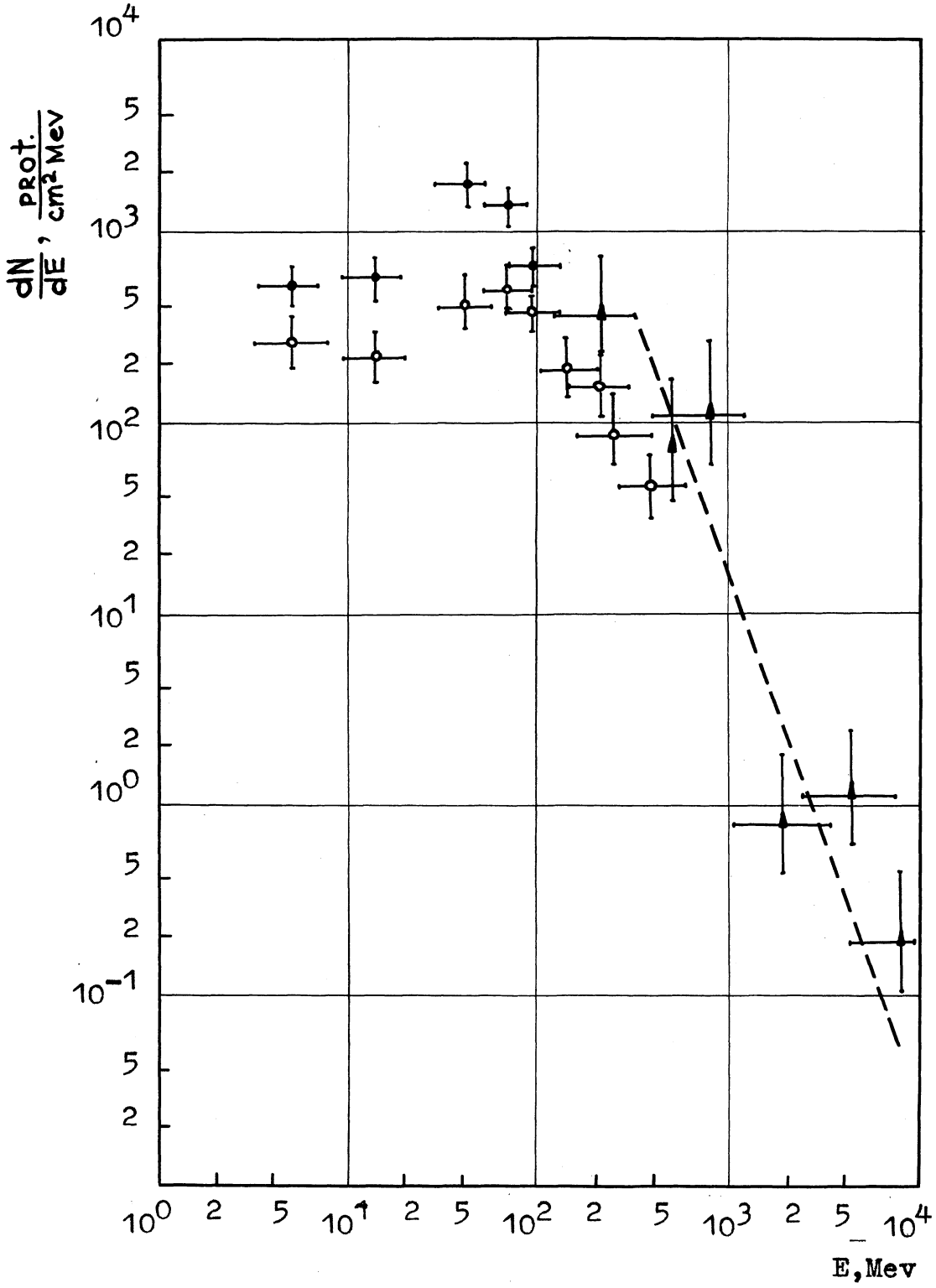

Fig.2. Proton spectra measured on board the "Zond-5" and "7" probes (●,▲ -"Zond-5"; ○ -"Zond-7"), as estimated by star formation extrapolation line.

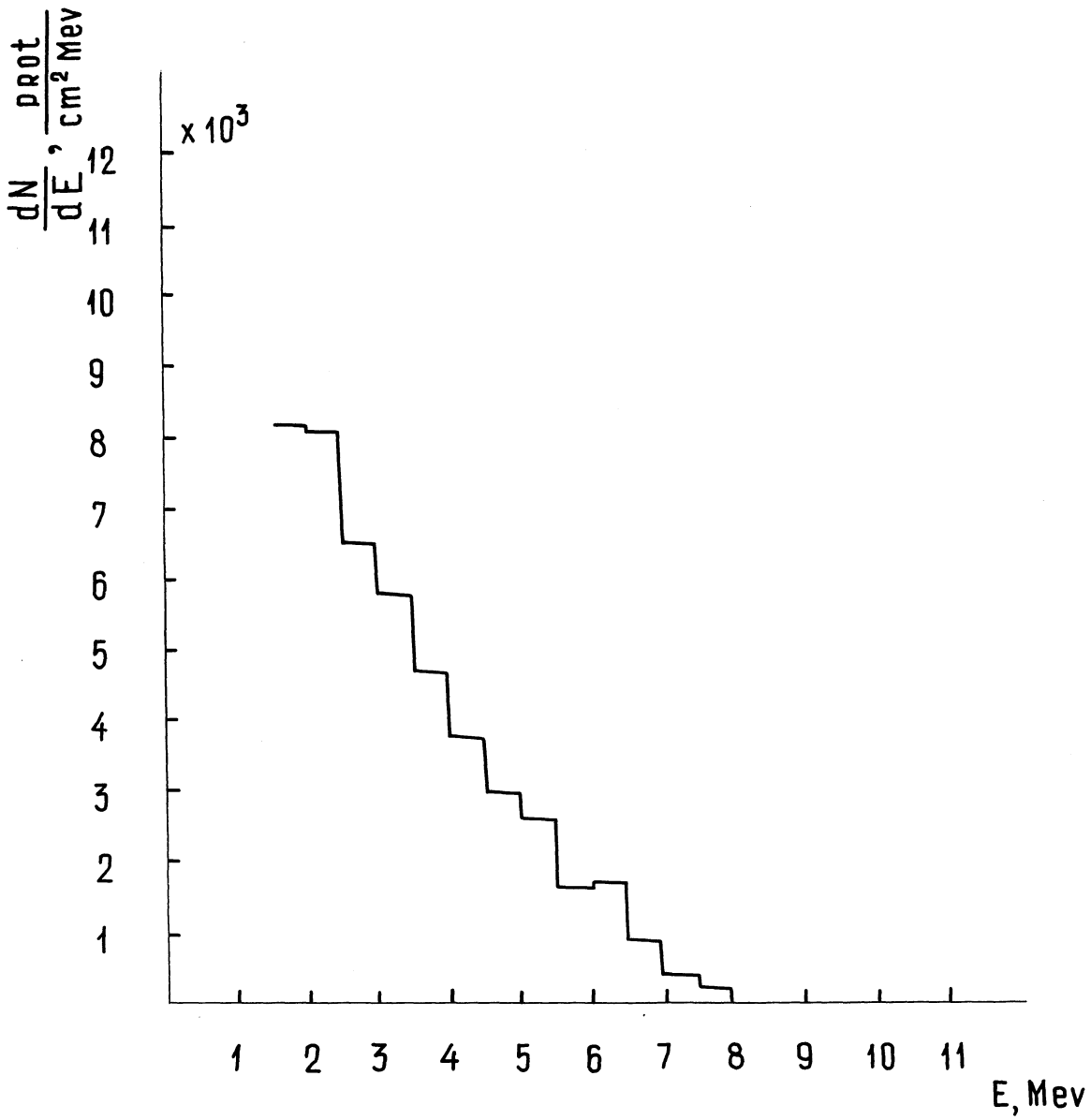

Fig. 3 The spectrum of recoil protons measured on board the Zond-5 probe.

DISCUSSION

Paper : Cosmic radiation measurements using nuclear emulsions onboard the Zond-5 automatic station

MAEDA : Would you give us more information about geometric conditions of the emulsion? Size and location in the ship, for example? What is the thickness of the shielding of emulsion? What kind of material surrounds the emulsion package?

SMIRENNY : Emulsion layers were placed at right angle to the probe wall. Each emulsion layer was 5 x 9 cm large and 400 micron thick. The shielding of the emulsions was about 3 g/cm^2 thick. The material of emulsion shielding was similar to aluminium.