ENERGY SPECTRA OF CASCADES PRODUCED BY PRIMARY COSMIC RAYS IN EMULSION CHAMBERS EXPOSED IN THE STRATOSPHERE.

V.G.Abulova, L.A.Hein, K.V.Mandritskaya, G.P.Sazhina, N.V. Sokolskaya, E.S.Troshina, A.Ya.Varkovitskaya, E.A.Zamchalova, V.I.Zatsepin.

Institute of Nuclear Physics,
Moscow State University, Moscow 117234, USSR

ABSTRACT

Five emulsion chambers were exposed in the stratosphere in 1978. Parameters of the exposure were the following: $S\Omega$ =0.628 m^2sr (for zenith angular interval of 25-60°), T=200 hours, P=13 g/cm^2. Three chambers with T=130 hours have been processed by now and about 1000 cascades were registered. For 135 events with energy higher than 3 Tev the type of primary particle was determined (proton, α-particle, heavy nucleus).

Experimental data were analysed to answer the question whether proton energy spectrum differs from spectra of α-particles and other nuclei in the several Tev region.

Construction of Chamber. Each emulsion chamber consisted of 24 lead plates with the area of 0.9m×0.48m. Upper 10 plates each of 1 mm thickness were interlayed with sheets of nuclear emulsion of 50μ thickness. Between other 14 plates of 5 mm thickness two X-ray emulsion films and one nuclear emulsion sheet were placed. One sheet of nuclear emulsion was placed above the upper layer of lead to discriminate interactions in the chamber cover which resulted in a shower just in this sheet.

Experimental Details. Methods of tracing of a shower in nuclear emulsion layers and of estimating of primary particle charge were described in our previous papers /1-4/. We would like to remember that standard deviation σ of measured values of coordinates was 180μ , accuracies of charge estimation for various groups of nuclei were σ_M =0.53, σ_H =0.93, σ_{VH}=1.5. The probability to take a background nucleus as a shower primary was less than 10^{-3}.

Each shower was characterizied by energy parameter $\mathcal{E}$, which was determined as the energy of electron-positron pair which would produce in the chamber a shower with the measured value of optical density in the cascade maximum. A form of cascade curve was not taken into account. The relative standard deviation of the value of ε was 10-15% in the energy range of 2-20 Tev.

Results are shown in table 1.

ε,Tev	P	α	A	F	SH	NI
≥ 3	52	14	15	23	25	7
≥ 5	10	8	7	14	11	2
≥ 10	1	5	2	5	4	0
≥ 20	0	2	2	0	1	0
≥ 40	0	1	0	0	0	0

Where α and A are the numbers of showers produced by α-particles and nuclei with $Z \geq 6$. (Nuclei with $Z=3 \div 5$ are practically absent in this energy region).

F is the number of showers appear to be members of air families, SH is the number of events with shower seen in the first layer of nuclear emulsion. A shower was assumed to be a proton one if it did not get into any previous groups. NI - not identifined showers, i.e. showers which we failed to trace along the trajectory.

Discussion. To interpret the data of table 1, it is necessary to calculate the relation between the value of ε and the energy of nucleus. Calculations of cascade curves from nuclei of various groups in lead were made in ref. /5/ in the core approximation of electromagnetic cascade theory. Now we somewhat refined this calculations through more correct treatment of p_t-distribution of particles in nuclear interactions. Nucleus-nucleus interaction is treated as a superposition of nucleon-nucleus interactions, as before. Fluctuations of the number of interacting nucleons and of the value of K_γ were taken into account.

In fig.1 the ratio of energy of nucleus E_A to ε is plotted versus ε. Deviation of the ratio from a constant value is connected with spatial dispersion of secondary particles in nuclear interactions. This effect is stronger for nuclei due to lower energy per nucleon in a nucleus.

In fig.2 the ratio of the number of showers produced by α-particles to that produced by other nuclei (a) and the ratio of the number of proton cascades to the number of cascades produced by nuclei (b) are shown. Solid, dashed and dotted lines correspond to ratios expected for "normal" primary mass composition and for models with depletion of proton component. As the "normal" masscomposition we take the one with equal spectral indices of all components (γ =1.7) and intensities shown in table 2.

	P	α	M	H	VH
I($\geq$1 Tev) $[m^{-2}hr^{-1}sr^{-1}]$	240	137	115	122	88
$S\Omega T\lambda\eta\xi$ $[m^2hr\ sr]$	30.9	35.5	37.0	34.6	31.2

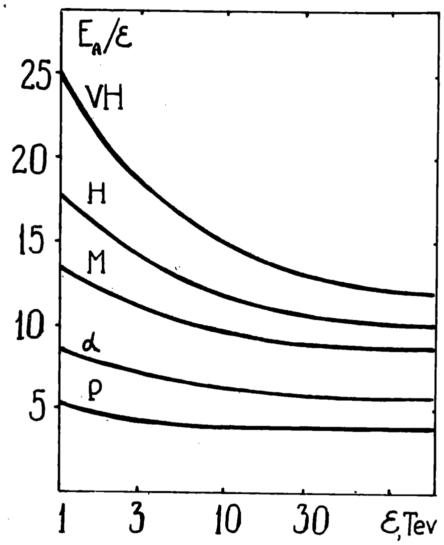

Fig.1. The ratio of energy of nucleus E_A to ε versus ε .

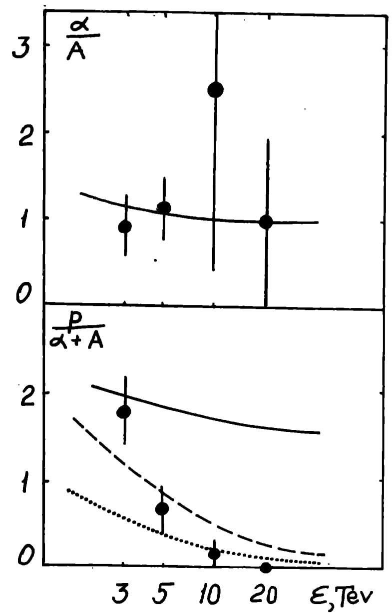

Fig.2. The ratio of the numbers of cascades produced by various primaries versus ε . Curves are calculated for different models of primary mass composition. Solid line - "normal" composition, dashed line - Grigorov model of the spectra, dotted line - model from ref./6/.

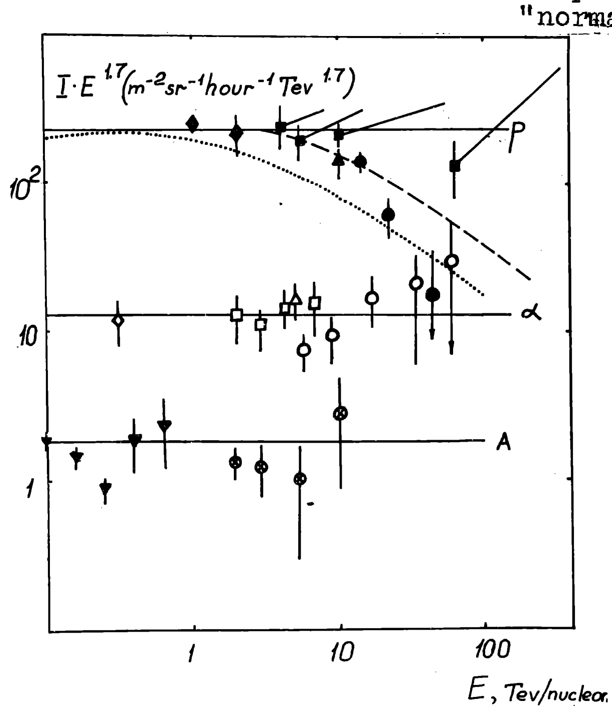

Fig.3. Intensities of the proton, α and nuclei fluxes versus energy per nucleon. Denotions for curves are the same as in fig.2.

♦, ◊ - p, α -M.J.Ryan /7/

▲, △ - p, α -S.Tasaka /8/

■, □ - p, α - JACEE /7/

▼-nuclei - M.Simon /9/

●, ○, ⊗ - p, α ,nuclei - present data.

The number of cascades with ε above a fixed value may be calculated according to the formula:

$$N(\geq\varepsilon) = I(\geq E(\varepsilon)) \times S\Omega T\lambda\eta\xi$$

where $I(\geq E)$ is the intensity of nuclei on the top of the atmosphere, $S\Omega T$ is the factor of exposure, λ is the efficiency of registration, η -the coefficient of absorption in the atmosphere, ξ -correction factor of intensity connected with the dispersion of ε due to experimental procedure.

Experimental data on p, α and A groups are shown in terms of absolute intensities in fig.3. One may conclude from fig.2 and 3 that experimental data on the spectra of α -particles and other nuclei do not contradict the idea about "normal" composition. On the contrary it is seen that the experimental number of protons is less than that expected from the "normal" composition. It is necessary to note that the group named "protons" may involve some omitted α, F and SH events, especially in the low-energy region. On the other hand, the probability of a proton to get into another group is small. Therefore, experimental energy distribution of protons and α-particles may be somewhat distorted by this effect. If it is so, real intensity of protons would be still lower than that shown in fig.3.

Conclusion. It is difficult to interpret the data obtained if not to assume a decrease of the proton part in the several Tev primary flux.

Referencies.

1. M.D.Dezhurko et al,Proc. 15 ICRC,11,72 (1977)
2. V.G.Abulova et al, Proc. 16 ICRC, 1, 358 (1979)
3. V.G.Abulova et al, Proc. 17 ICRC, 2, 114 (1981)
4. M.D.Dezhurko et al, Proc. 17 ICRC, 9, 315 (1981)
5. M.D.Dezhurko et al, Proc. 17 ICRC, 9, 324 (1981)
6. N.V.Sokolskaya et al, Proc. 18 ICRC, OG 4-3 (1983)
7. J.C. Gregory et al, Proc. 17 ICRC, 9, 154 (1981)
8. S.Tasaka et al, Proc. 17 ICRC, 5, 126 (1981)
9. M.Simon et al, Proc. 16 ICRC, 1, 352 (1979)