ENERGY SPECTRA OF PCR PROTONS AND NUCLEI OBTAINED WITH X-RAY EMULSION CHAMBERS USING DATA OF NEW STRATOSPHERIC EXPOSURES AND NEW METHODS OF PROCESSING

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Abstract

The experiment to study the energy spectra of protons and nuclei in > 10 TeV/particle region is being continued. Emulsion chambers were exposed in the stratosphere at 30 km altitude. Experimental data obtained in three long-duration flights in 1986,1987 with total exposure time of 470 hrs are presented and are compared with data of our previous experiments with total exposure time of 260 hrs.

Introduction. In 1975 and 1978 we made a series of flights of high-altitude balloons to study the energy spectra and chemical composition of primary cosmic rays (PCR). Identic emulsion chambers 8 cm (14.7 c.u.)thick and 0.4 m^2 in area were exposed. The mean exposure depth in the stratosphere was 11 g/cm^2 , the mean duration of a flight being 40 hours. The results were reported at 20 ICRC (Kanevsky B.L. et al,1987).In 1986 and 1987 four flights each of 155 hours were made, the mean depth in the athmosphere being 13 g/cm^2 .This paper presents preliminary data obtained in 3 flights with the total exposure of 470 hours. Emulsion chambers allows to determine an energy of cascades produced by primary particles in lead by measuring an optical density of dark spots in X-ray and nuclear emulsion. The type of a primary for each cascade was identify in nuclear emulsion layers upper than interaction point. Up to date in the exposures of 1986,1987 nuclei of the H and VH groups are identified.The efficiency of search for He and M nuclei in long exposures at high background is still lower than 100%. In the previous flights these nuclei were identified reliably. Attempts are being made to increase an accurasy of coordinate measurements in order to reliably identify all nuclei in long-duration exposures.

Energy measurements. The energy of cascades induced by primaries in chamber was measured by photometering X-ray and nuclear emulsion films. A photometering method was calibrated by method of track counting within a circle of radius of 50 μm in nuclear emulsion.For each flight,using 7-10 showers we found the coefficient of normalization of the energy measured by photometering to the energy determined counting tracks. The correlation between the energies after normalization is shown in Fig.1.

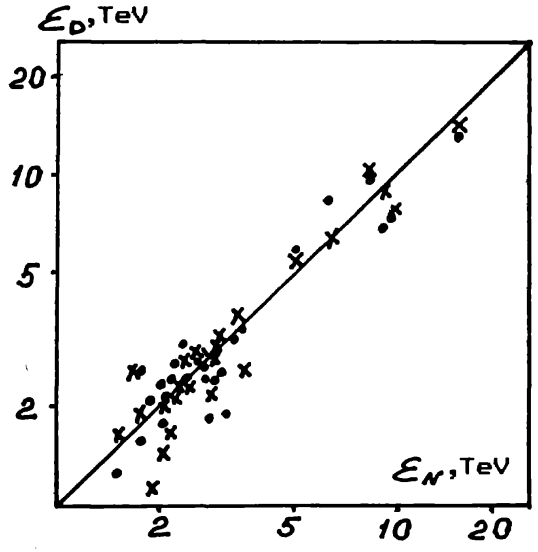

Fig.1.The correlation between energies determined by photometering $\mathcal{E}_D$ and by counting tracks $\mathcal{E}_N$

• photometering of X-ray films

x photometering of nuclear films

Photometering of nuclear films was used as an additional method to determine the cascade energy since the parameters of optical density curve for nuclear film significantly differs from those of X-ray film (Sazhina G.P. et al,1988). The use of photometering of X-ray and nuclear films enables obtaining two results the difference between which gives an estimation of methodical errors of the photometering method.

Cascade energy was determined in terms of EPC core theory normalized at 300 GeV to data of experiment (Hotta N. et al, 1980) The conversion of measured energy $\mathcal{E}$ to ΣE_γ allowing for the angular deviation of produced π^0-mesons was made as described in (Sazhina G.P. et al,1988). For the conversion of ΣE_γ to primary particle energy E_o, it was assumed that $\Sigma E_\gamma = \tilde{k}_\gamma \cdot E_o$, where $\tilde{k}_\gamma = (\int_0^1 k_\gamma^\beta \cdot f(k_\gamma) \cdot dk_\gamma)^{1/\beta}$. For this determination the primary particle intensity at a point E_o is equal to intensity in the energy release spectrum at a point $\Sigma E_\gamma = \tilde{k}_\gamma \cdot E_o$. For protons it was assumed that $f(k_\gamma) \sim \exp(-k_\gamma / \langle k_\gamma \rangle)$ with $\langle k_\gamma \rangle = 0.2$ and $\beta = 1.7$ that yields $\tilde{k}_\gamma = 0.25$. For nuclei the values of $\tilde{k}_\gamma$ are presented in (Abulova V.G. et al,1983). If the proton spectrum power index is larger than 1.7, $\tilde{k}_\gamma$ increases e.g., at $\beta = 2.0$ $\tilde{k}_\gamma = 0.265$ that leads to a decrease of proton intensity recalculated from the measured spectrum of cascades.

Results. Intensites of nuclei of H and VH groups are shown in Fig.2. Fig.3 shows the proton spectra obtained in our experiment in various exposures. As was mentioned above in long exposures in 1986 and 1987 in the proton group cascades induced by the He and M nuclei are not complitely separated. In new exposures the ratio of cascade numbers $N(p+He+M)/N(p) \approx 1.2$ whereas in the previous ones it is 1.4. When calculating the proton intensity this difference was accounted for by a factor independent on energy.

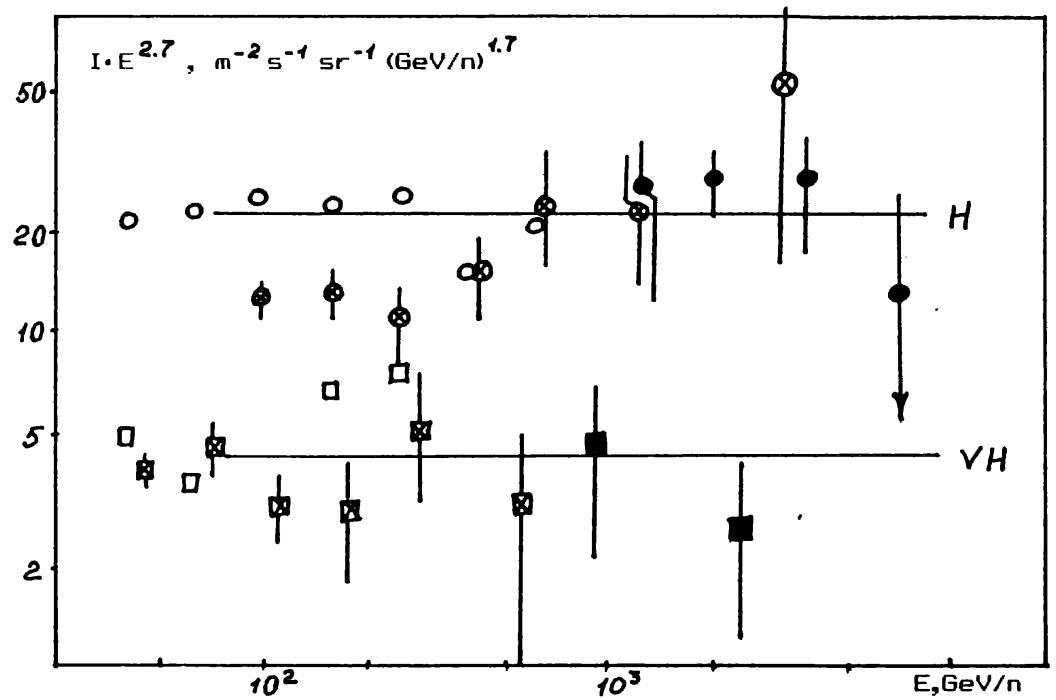

Fig.2. The energy spectra of H and VH-group nuclei.
○,□ – H and VH groups from (Simon M. et al,1980),
●,⊠ – from (Ivanenko I.P. et al,1989),
●,■ – our data,the summary of all exposures.

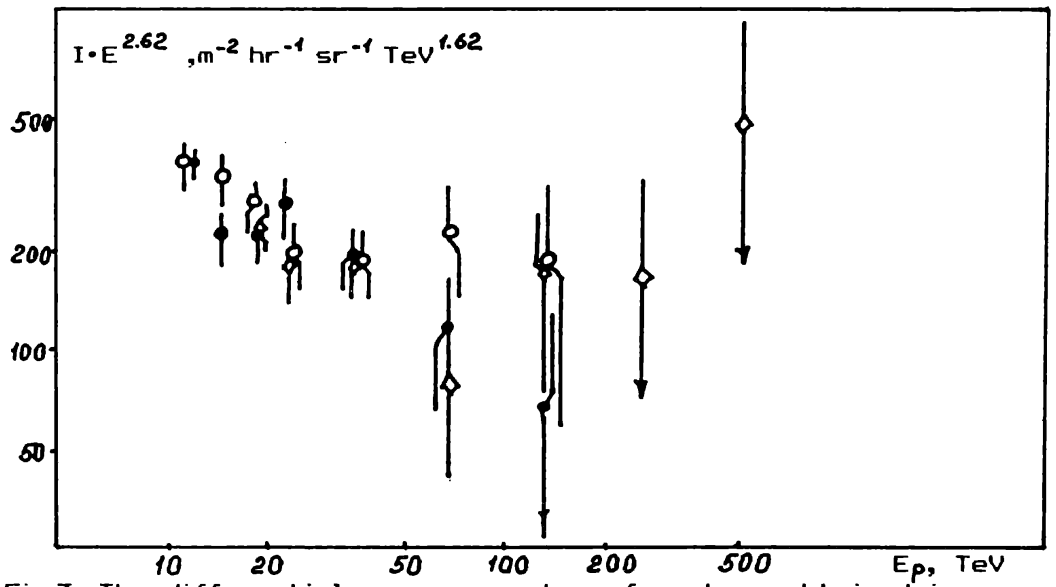

Fig.3. The differential energy spectra of protons obtained in various exposures by photometering of X-ray films.
● – the exposure of 1975,1978, T=260 hrs, the results for $E_p \geq 10.5$ TeV are presented
◇ – the exposure of 1986, T=310 hrs, $E_p \geq 15.2$ TeV
○ – the exposure of 1987, T=160 hrs, $E_p \geq 10.5$ TeV

The summary proton spectrum is shown in Fig.4.

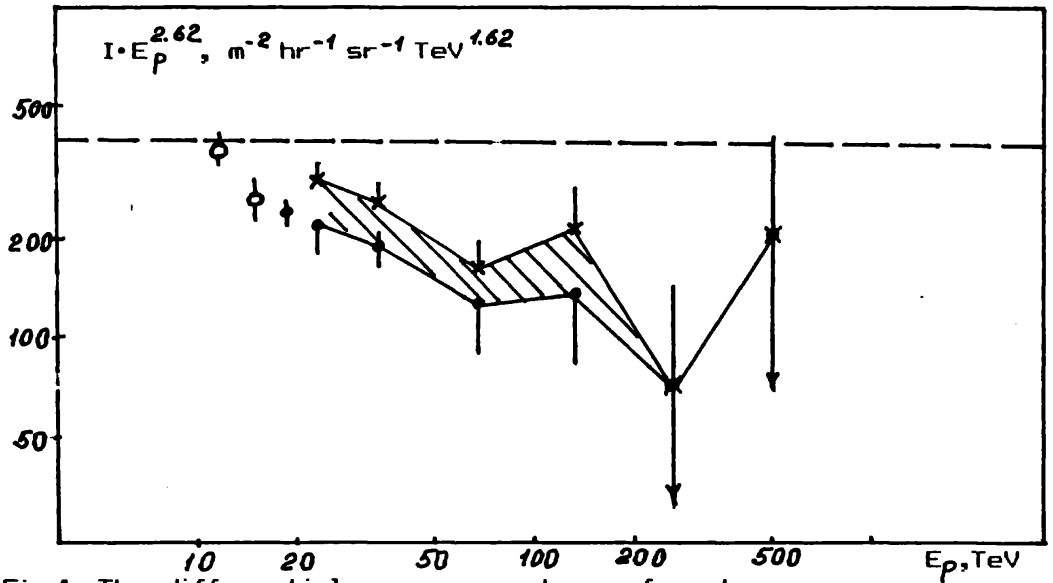

Fig.4. The differential energy spectrum of protons.
- ● – the summary data of all exposures obtained by photometering of X-ray films
- o – the data from 1975,1978 and 1987 exposures, for X-ray films
- × – the summary data of all exposures obtained by photometering of nuclear emulsion
- ---- the intensity of protons of the "standard" spectrum $I(\geq E_p, TeV) = 240 \cdot E_p^{-1.62}$, $m^{-2} hr^{-1} sr^{-1}$.

The values of spectral indices of the differential proton spectrum are the following:

obtained by X-ray films: $\beta+1 = 3.10 \pm 0.09$, $E_p \geq 10.5$ Tev
$\beta+1 = 2.91 \pm 0.16$, $E_p \geq$ 20 TeV
by nuclear emulsion: $\beta+1 = 2.95 \pm 0.14$, $E_p \geq$ 20 TeV

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