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HADRON ENERGY SPECTRUM RESTORED FROM MEASUREMENTS OF ELECTRON-PHOTON CASCADES IN X-RAY EMULSION CHAMBERS EXPOSED ONBOARD BALLOONS.

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ABSTRACT. In the present paper, analysis is made of electron-photon cascades (EPC) induced in X-ray emulsion chambers (XEC) exposed at the 12 and 60 g/cm^2 depths in the stratosphere. In the energy release range 2.5— 12.5 Tev a power index of hadron differential energy spectrum is $\gamma_h = -3.03 \pm 0.16$.

A comparision with earlier investigated γ-ray and muon spectra shows that nucleon and pion spectra are characterized by the same spectral indices that means scaling conservation in the fragmentation region for the primary particle energies 10 - 50 Tev. Spectral indices of proton and nuclei spectra are presumably essentially different.

EXPERIMENT. XEC used in the present experiment comprised 16 lead layers each 5 mm thick with area 0.5 m^2. Chambers were exposed at depths 12 and 60 g/cm^2 in the stratosphere in 1973 - 78 (Ivanova, M.A. et al, 1979). Up to date the processed exposure is 485 m^2 hr ster and statistics of EPC with $E \geqslant 2.5$ Tev ~ 1100 events. Registration of EPC by means of dark spots at several depths allows determination of EPC energy and shower production depth t c.u. The energy was determinated by comparing the measured greatest optical density with energy dependence of optical density at a maximum for e^+e^--pair (Ivanenko I.P. et al, 1980).

To plot a spectrum of energy releases from hadron interactions, Pb-jets, events with $t \geqslant 4$ c.u. were selected that completely excluded on electron-photon component from air. Due to small chamber thickness (~ 15 c.u. over the vertical) conditions of registration of cascades with various energy were different for this selection. As energy increases less and less part of a cascade curve lays within a chamber. To provide the same conditions of registration of various energy cascades, in each of 5 angular rangés (into which statistical material was devided) we assumed individual limitations on depth interval t c.u. within which interactions were selected. These limitations were: a distance from a starting point of interaction to a chamber boundary was $\geqslant$ 10 c.u., i.e. registrating of all cascades with the energy less than 12.5 Tev was reliable. Depth of the maximum of EPC from hadron with 12,5 Tev is ~ 8 c.u. In Fig. 1, solid lines are for a region of a acceptable values of $t_{c.u.}$ for fixed incident angle Ψ.

OG 2.1-3

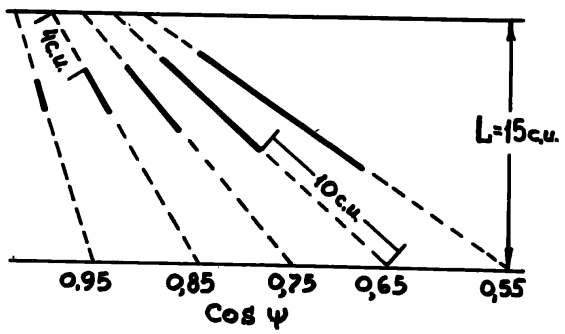

Fig 1 The limitations on depth interval τ c.u. for the selection $\geq$ 4c.u.

Table 1 lists the statistics and the measured energy spectra for various conditions.

Table 1

P g/cm^2	12 g/cm^2		60 g/cm^2		12+60
τ c.u.	$\geq$ 4	>0	$\geq$4	<4	$\geq$4
N (E= 2.5 - 12.5)	153	455	118	443	271
γ meas.	3.06±0.22	2.83±0.11	3.21±.25	3.10* ±0.11	3.13 ±0.15
γ after corrections	2.96 ±0.22	2.73 ±0.11	±3.11 0.25	±3.0 0.11	±3.03 0.16
part of γ-rays	0	17%	0	60%	0

* the value from (Ivanova M.A. et al, 1979)

CORRECTIONS. To study the influence of fluctuations and measurement errors on a hadron spectrum, hadron cascades in lead chamber has been simulated (Ivanenko I.P. et al,1980). In (Afanaseva L.G. et al,1980) it has been shown that ehergy transferred into a EP component in a layer $\leq$ 8 c.u. from the beginning of Pb - jet $\Sigma^{\tau} E_{\gamma}$ (<8 c.u.) is a value most close to measured and independent of hadron primary energy. Fig. 2 shows the ratio of energy "measured" by the maximum optical density E_{Φ_h} to ΣE_{γ}(<8 c.u.) and a value of $\sigma(E_{\Phi_h}/\Sigma E_{\gamma})$ vs ΣE_{γ}(<8 c.u.)

Allowance for appearing distortions of intensities leads to a decrease by ~ 0.1 in spectrum power indices (Table 1. γ after corrections).

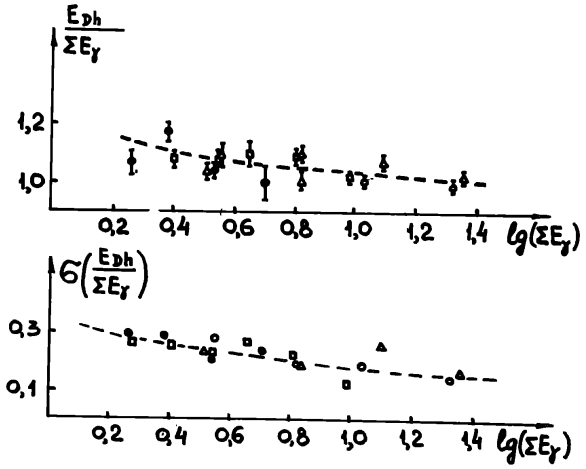

Fig. 2 $\frac{E_{Dh}}{\Sigma E_\gamma}$, $\sigma\left(\frac{E_{Dh}}{\Sigma E_\gamma}\right)$ for simulated cascades. Different points are for a different primary energies.

DISCUSSION Fig.3 shows spectrum power indices vs a content of pion cascades, i.e. cascades resulting from meson decay in the atmosphere. Stratospheric data are shown together with spectral index γ_π from muon experiment $\gamma_\pi = 3.0 \pm 0.07$ (Ivanova M.A. et al, 1981). The assumption of the power indices independent of the pion portion, i.e. scaling in fragmentation region, is the best description of these data.

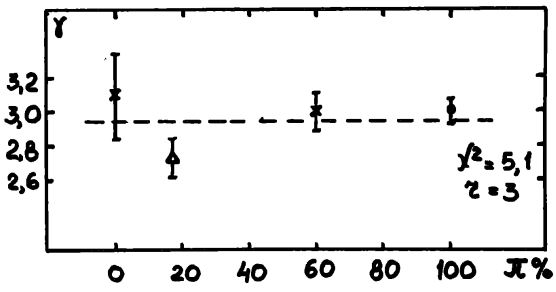

Fig.3 The dependence on the pion content in different selections.
▲ - 12 g/cm^2, $\tau \geq 0$; ▼ - 60 g/cm^2, $\tau \geq 4$ c.u. and < 4 c.u.; ▮ - muon experiment.

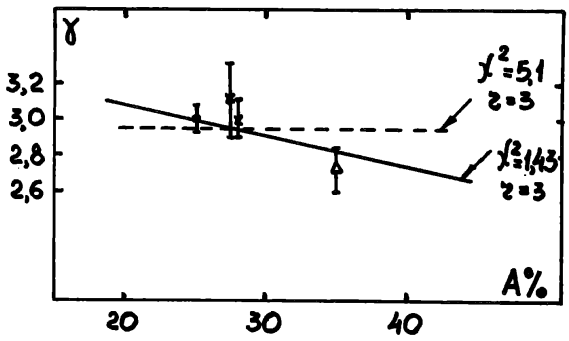

Fig.4 The dependence on the nucleus content

Fig.4 presents the same data vs a content of nucleus cascades in the selections, i.e. cascades induced by interactions of nuclei in the atmosphere and in a chamber. For muon data a fraction of nucleus cascades was assumed to be equal to 25%, i.e. a nucleon content in nuclei in a primary spectrum at "normal" chemical composition. In the selection for 12 g/cm^2 a content of nuc-

leus cascades is ~35% (Abulova V.G. et al, 1979). An assumption of p and nucleus spectrum power indices being equal $\gamma_\pi = \gamma_p = \gamma_A$ does not contradict by criterion χ^2. But the best description of the dependence of γ on a nucleus content is a assumption that nuclei spectra are harder than a proton spectrum.

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