SCALING VIOLATION IN THE FRAGMENTATION REGION OF INCLUSIVE NUCLEON SPEKTRUM

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Spectra of EAS associated with hadrons of various energies from 5 to 80 Tev have been investigated. Results could be interpreted as scaling vaiolation in the fragmentation region of secondary particles generated in inelastic interactions of primary protons at the energy above 30 TeV.

Simultaneous observation of high energy hadron and EAS let us investigate inclusive spectra of hadrons in the fragmentation region.

Significant part of hadron flux in the atmosphere are nucleons. The connection between the nucleon flux at the depth and the spectrum of primary nucleons is

$$F(\geqslant E,t)=\sum_{n=0}^{\infty} F(\geqslant E_0)e^{-t}(t^n/n!)\ x^{\gamma-1}$$

where γ - the index of the primary spectrum, $x=E/E_0$, t- the observation depth in units of mean free path for inelastic collisions. It should be noted that events with $n \leq 3$ at the depth of 700g/cm^2 dominate. Qualitive experimental picture is not changed considerably if one takes into account the energy dependent cross-section of hadron interaction as well as the inclusive spectrum of secondary hadrons.

The table shows the percentage of the primary protons which had only one inelastic collision at 700g/cm^2. The calculation was made with the accelerator cross-sections and inclusive spectra.

x	0.9	0.82	0.67	0.54	0.44	0.36	0.3
n=1	100	70	60	55	50	40	35

If we add to mention above that at $x \geqslant 0.3$ all observed hadrons are produced by primary protons then it is clear that analysis of hadron data and EAS accampanying them give us good oppotunity to investigate hadron inclusive spectra in the fragmentation part.

In this paper the total EAS spectrum of accompanying hadrons of given energy is considered.

It appears that for scaling model and constant mass composition of primaries the investigated spectrum of EAS for various E_h must be similar or must have scaling behaviar.

The experimental data of Tien-Shan complex installation /1/ on the spectrum of EAS associated with hadrons for energy intervales (5-7.5), (10-20) and (40-80) TeV are presen-

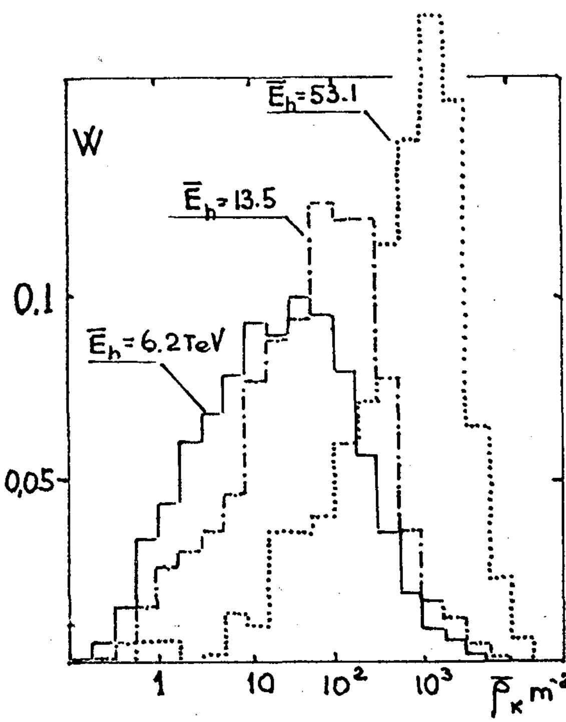

Fig.1 Spectra of EAS associated with hadrons of various energy (exper.) ρ_k-average density of particles in the centre $N_e = \rho_k \cdot 10^3$, $E_0 = 3 \cdot \rho_k$ TeV.

ted at fig.1. Separation of hadrons and measurement of its energy have been made by means of ionization calorimeter. The space resolution of the calorimeter is about 0.25x0.25m^2, that is why the hadron jet may consist of several hadrons. Our experimental data are related to the most energetic hadron jets in the calorimeter which occupy less than 0.75x0.75 m^2. We calculate the distribution of EAS for the average density of particles in the array which consists of 64 scintillator detectors and cover the area about 100 m^2 (ρ_k). The density of particles in the EAS centre has large fluctuations but it does not require knowledge of the lateral distribution of particles for E_0 estimation.

One can see that the experimental ρ_k distributions for various E_h presented in fig.1 have not the scaling character. The most probable value of ρ_k is not proportional to E_h ($\rho_k \sim E_h^{3/2}$) and the ρ_k distribution becomes narrower with increasing E_h. We can suggest three following reasons for this result:

1. Sistematic errors in the experiment.
2. Mass composition of primary cosmic rays is not constant.
3. The scaling violation in the fragmentation region of secondary hadrons.

The methodical effect can be evaluated by the following way. The fig.2 shows the fluxes of recorded hadron jets. In the first case the energy was obtained in the calorimeter over the square at 0.75xo.75 m^2 and in the second - the energy was determined over the square of 0.25x0.25 m^2 and multiplied by 1.5. The coefficient 1.5 was estimated from data on the lateral energy distribution for single hadron. The index of the hadron jet spectrum in the first case is $1+\gamma=1.6$ for larger square and $1+\gamma=1.75$ in the second case.

The results of our measurements of the total hadron jet flux in the energy range (200-2000) GeV /2/ are also shown in fig.2. The lack of calorimeter resolution doesn't effect intensities at these energies. It seems that our value for intensity is close to calculated one /2/ as well as to data /3/ obtained with spark chamber calorimeter. The power low fit for the data on hadron flux obtained with the help of X-ray film chamber /4/ in the energy range (20-500) TeV has

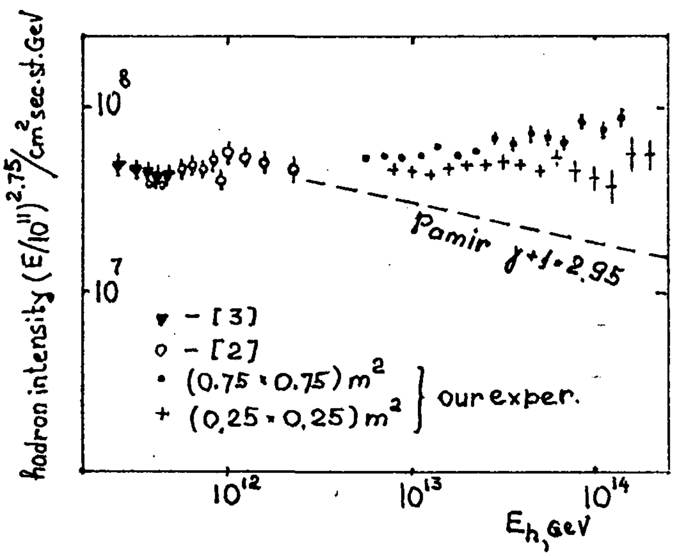

Fig.2 Hadron energy spectrum at mountains (H=700 g/cm^2)

the exponent $\gamma+1=1.95+0.05$ (and in the X-ray chamber with thick carbon layer $1+\gamma=1.8+0.15$).

The exponent γ is the most reliable value among X-ray film data and as one can see it does not differ much from our value of $1+\gamma = 1.75$ obtained for hadron jets in calorimeter region 0.25×0.25 m^2.

We extrapolated the hadron spectrum for $E \lesssim 1$ TeV with exponent $\gamma+1=1.95$ to the energy range $E>5$ TeV in order to estimate the error in determining the energy due to recording of jets. At the energy $E \sim 5$ TeV the value of overestimation is about 1.25 and at E=100 TaV ~1.5. The spectrum of EAS associated with hadron may be distorted due to different overestimation of the hadron energy but the difference is not more than 20% for energy changing from 5 TeV to 100 TeV. Therefor we can neglect this methodical effect.

The distortion of experimental spectrum may be due to primary nuclei. In this case the leteral combination of nucleons into jets increases the number of observed events with the same energy per nucleon becaus the energy losses of the leading nucleon are compensated by another nucleons of the primary nucleus. This ability will be studied.

We have simulated only two possibilites. We assumed the model of hadron nucleus interection /5/ based on accelerator data. In the first vertion of calculation we proposed that the index of primary energy spectrum changes from $\gamma+1=2.6$ to $\gamma+1=3.6$ at the primary proton energy $E_o=10 \cdot E_h$, were E_h is the energy of hadrons (histogram 2 in fig. 3). In the second version we suggested the reduction of the inclusive cross - section for the production of secondary nucleons with $X \geqslant 0.5$ by the factor 2 at the expense of increasing number of nucleons and pions with $x \leq 0.3$.

As one can see in fig.3 (histogram 3) the second version is in better agreement with the experiment than the first one which assumes the change of primary composition.

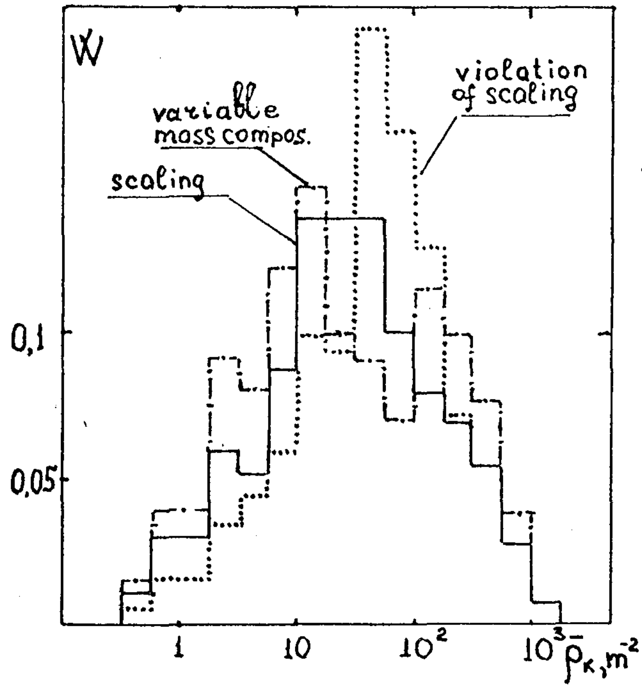

Fig.3 Spectra of EAS associated with hadrons (simulation).

Our conclusion about scaling violation in the fragmentation region of inclusive nucleon spectrum is not quite well-grounded. More detaled analises of experimental data, especially at $x \geqslant 0{,}3$ (pure proton region), and comparison with model simulation are necessary.

References

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