

EAS FLUCTUATION APPROACH
TO PRIMARY MASS COMPOSITION INVESTIGATION

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ABSTRACT. The analysis of muon and electron fluctuation distribution shapes by means of the statistical method of invers problem solution gives the possibility to obtain the relative contribution values of the five main primary nuclei groups. The method is model-independent for a big class of interaction models and can give good results for observation levels not too far from the development maximum and for the selection of showers with fixed sizes and zenith angles not bigger then 30° .

1. INTRODUCTION. The extensive air showers (EAS) are today the main and possibly the only information source about the mass composition of the primary cosmic radiation in the ultrahigh energies, because the use of the direct methods are still limited now to energies 10^{13} - 10^{14} eV.

The analysis of the dependences of the second momenta of the different component fluctuation distributions of the other EAS parameters /1-4/ shows, that the primary cosmic radiation at energies greater than 10^{15} eV can not consist of one nucleey type only and the content of primary protons and iron nuclei in the mixed mass composition must be essential.

2. METHOD. The EAS fluctuation distribution shapes have an essential sensitivity /1/ to the relative contributions of the five main nuclei groups: P, α , M, H, VH in the primary composition of the cosmic radiation with ultrahigh energy, but the information content could be derived with help of a complicated "noise" system /2, 5/. These fluctuation distributions can be treated as an invers problem /5, 6/ aiming to precise the information about the mass composition and to estimate the relative contributions w_{aj} of the j nuclei groups.

After this point of view /5, 6/ it is necessary to solve the invers problem starting from the equation:

$$W_i = \sum_{j=1}^5 M_{ij} \cdot w_{aj}$$

where M_{ij} is the matrix of the model and apparatus "noises" for a definite model calculation of EAS development and for definite EAS experiment (including detector types and arrangement, algorithms of the data treatment and so on); W_i are the the number of showers with a definite $K_\mu = (N_\mu / \langle N_\mu \rangle)$ and $N_e = \text{const}$ including the information in the i^{th} -been of the corresponding $W(K_\mu) = W(N_\mu / \langle N_\mu \rangle)$ experimental distribution also; w_{aj} are the relative contributions of the usual five ($j = 1-5$) main primary nuclei groups with $A = 1, 4, 14, 26, 52$ in the primary energy interval $E, E+dE$.

3. RESULTS AND DISCUSSIONS. Applying the statistical method of the invers problem solution, developed by V. Pavljuchenko/7/ by the analysis of pseudoexperimental fluctuation distributions $w(K_\mu)$ it is shown/6/, that the estimations w_{aj} are model-independent in the ranges of the errors $\sigma_{w_{aj}}$ if the conditions $|\alpha_{\text{ex}} - \alpha_{\text{cal}}| < 0.05$ and $(\sigma_\mu / N_\mu)_p < 0.5$ are satisfied. This is fulfilled for a big number of interaction models which describe eventhough the main phenomenological EAS characteristics, particularly the muon-size dependence $N_\mu \sim N_e^\alpha$, where α_{cal} is in the calculated relation $N_\mu \sim N_e^{\alpha_{\text{cal}}}$ and α_{ex} - the corresponding experimental value.

The value $(\sigma_\mu / N_\mu)_p$ depends on the interaction model and is conected with the shower maximum position over the observation level in the studed energy range and is a principal limit for the method of analysis. In this conection an optimal observation level exists for each energy interval, where the method of the fluctuation distribution shape analysis gives the best estimations w_{aj} for the primary mass composition.

The zenith angle interval, where the showers are registered, plays an important role in the shower fluctuation investigations. It is shown/8/, that the muon flux fluctuations in the interval $\theta < 60^\circ$ are not so informative as in $\theta < 30^\circ$, because the differences between P and Fe shower fluctuations decrease with θ (fig.1). But in the both cases, the relative change of (σ_μ / N_μ) remains no more than 15%, which is insignificant for the analysis of the fluctuation distributions shapes. Further, the expected differences between muon-size dependences

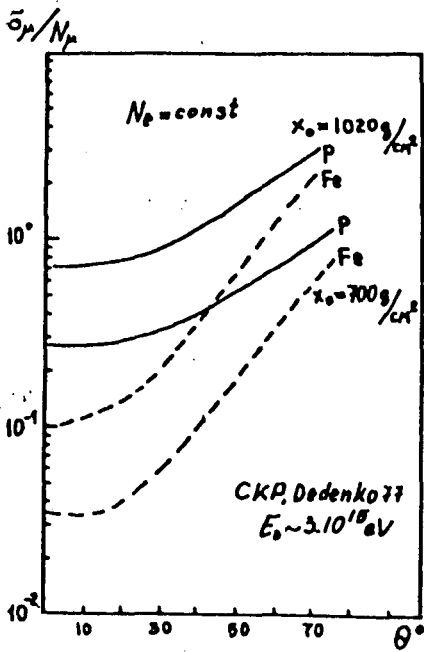


fig. 1

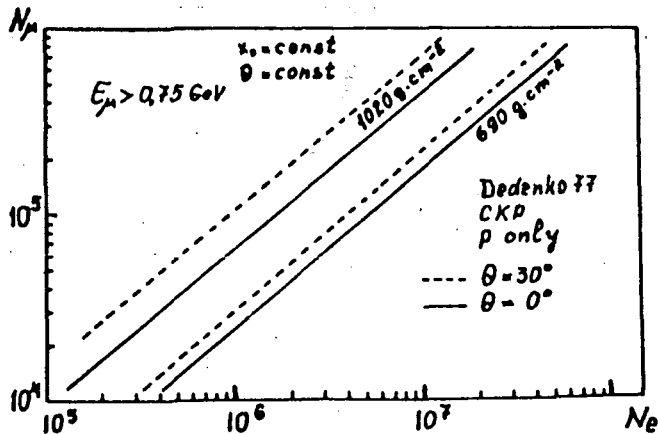


fig. 2

for $\theta = 0^\circ$ and $\theta = 30^\circ$ at mountain altitudes are $\sim 10\%$ (fig. 2) in distinction to the situation at sea level, where this difference becomes $\sim 50\%$. The corresponding Thien

Shan experimental data/9/ confirm this expectation for mountain altitudes (fig. 3). From here it follows, that the shower selection of axis in the zenith angel interval $\theta < 30^\circ$ is good enough for the further primary mass composition investigation.

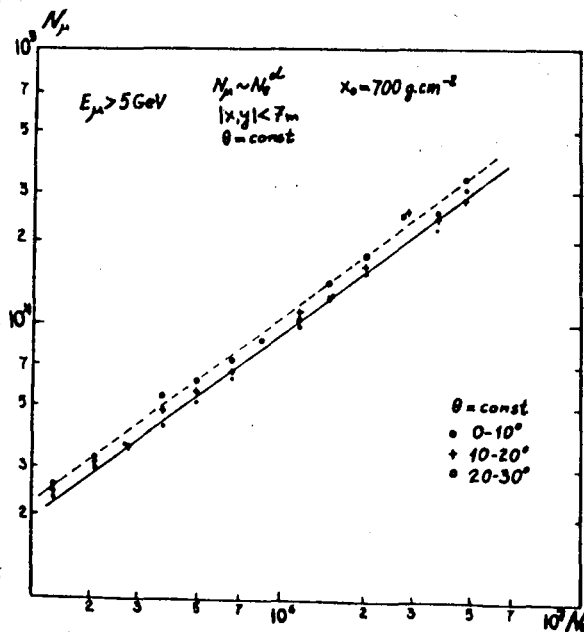


fig. 3

The relative primary nuclei group contributions w_{aj} obtained by the solution of the inverse problem are however distorted by two factors:

- 1) the method of the inverse problem solution/6/;
- 2) the efficiency of the registration of EAS, initiated by primaries with different atomic number A in the selection of showers with fixed size $N_e = \text{const}$ or fixed muon number $N_\mu = \text{const}$ at the observation level.

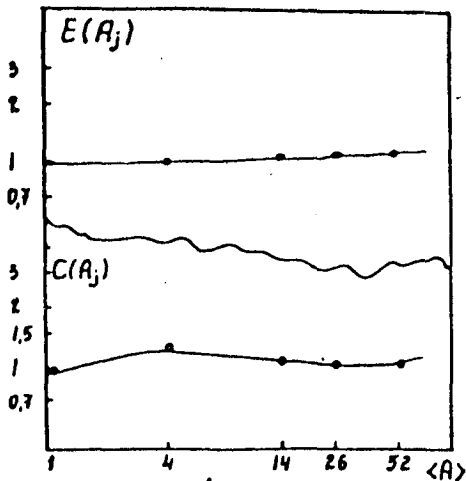


fig.4

These two distortions are described with the corresponding distortion functions: $C(A_j)$ and $E(A_j)$ (fig.4). It is shown, that the biggest systematical correction is necessary for the w_{aj} value. The efficiency function $E(A_j)$ remains very weak for showers at observation levels not too far from the development maximum.

4. CONCLUSIONS. Taking into account all these considerations and re-

marks, we conclude that the primary mass composition in the energy interval $10^{15} - 10^{16}$ eV, obtained on the basis of the Tien-Shan data/10/, is mixed and it remains rich on protons as that at lower energies:

A	1	4	14	26	52
$w_{aj}(\%)$	39 ± 4	13 ± 7	16 ± 6	17 ± 6	15 ± 5

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