T 2-14

MEASUREMENT OF CHARGES OF RELATIVISTIC NUCLEI IN THIN NUCLEAR EMULSIONS BY PHOTOMETRY METHOD

Dezhurko,M.D., Rakobolskaya,I.V., Sazhina,G.P., Zatsepin,V.I.

Institute of Nuclear Physics, Moscow State University,USSR

ABSTRACT

The paper presents a method of determination of charges of relativistic nuclei with $z \geqslant 6$ and angles Ψ to nuclear emulsions 60 um thick, in the range $30° < \Psi < 60°$, using scanning microphotometer. The dimensions of a photometer slit were 32×1.6 um^2 within a plane of nuclear emulsion. On the basis of calibration measurements amplitude A of a traced profile of a nuclear track was found to be proportional to $(z^2/\sin\Psi)^\alpha$, where $\alpha = 0.4 \pm 0.05$. An accuracy of determination of the charge of a nucleus recorded in n layers of nuclear emulsion is estimated. The discussed method is to be used for investigation of cosmic-ray chemical composition with X-ray emulsion chambers.

1. Introduction. When studying chemical composition of primary cosmic rays by the method of X-ray emulsion chambers(Abulova et al, 1981) a problem arises to determine the chrges of nuclei with z=6-26 and energy $\sim$ 1 TeV/nucleon recorded in several ($\sim$10) layers of nuclear emulsion 60 um thick, with zenith angles $30° < \Psi < 60°$. In the present paper, we analyse a reliability of determination of the charges of such nuclei by photometering their tracks in nuclear emulsion.

2. Measurement Technique. Measurements were made with scanning microphotometer IFO-451 at 125-fold multiplication. The photometer slit within a plane of nuclear emulsion was 32×1.6 um^2. The image of a nuclear track was located parallel to the slit and moved within a measuring diaphragm plane across the slit. When moving the track optical density of emulsion was registered. The obtained characteristic profile is given in fig.1.

We measured a traced profile amplitude a_i which was plotted relatively to the mean level of background as it is shown in fig.1.

Each measured track was traced 6-8 times. If a track length was considerably greater than the slit length, this series of measurements was repeated as many times as a track length comprised the slit length. In each series , four profiles with the greatest values of a_i were chosen. As a characteristic of the track we used a mean value A of the chosen amplitudes a_i in all measurement series obtained for the given tracks.

Every day, when photometering the same "reference" track was traced. Thereby, a stability of photometer work was controlled. Amplitudes measured on the same day were divided by a normalization coefficient proportional to the amplitude of the "reference" track measured that day.

3. Calibration Measurements. To determine the dependence of amplitude A on charge z and zenith angle Ψ of a nucleus, calibration measurements for relativistic nuclei of oxigen and carbon were made. Nuclear emulsion was exposed at accelerator to beams of C- and O-nuclei with energy $\approx$ 4 GeV/nucleon, at various angles. For, the measurements use was made of all nuclei penetrating the given

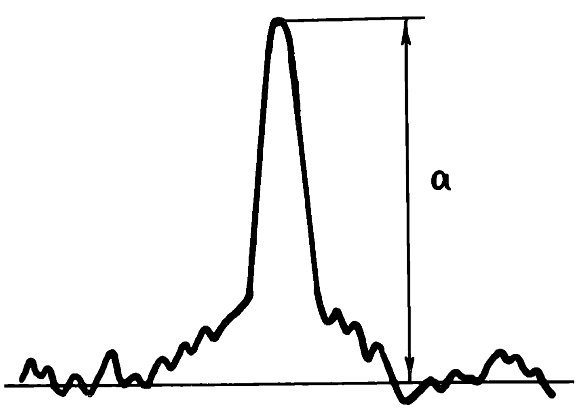

Fig.1.Determination of the amplitude of a track profile

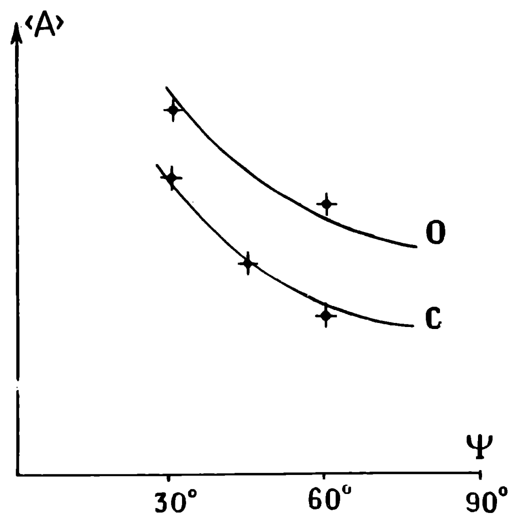

Fig.2. ‹A› as a function of Ψ, for C- and O-nuclei

area of nuclear emulsion. The dimensions of this area were chosen so that the area comprised 50 tracks of nuclei with the same zenith angles. For each track we measured a mean value A of the amplitude of its traced profiles . The obtained values of A were averaged over all tracks chosen.

The averaged over the chosen tracks value ‹A› as a function of zenith angle Ψ is shown in fig.2 for oxigen and carbon nuclei. To approximate experimental data, we used, as in paper (Kidd, 1973), the formula

$$\langle A \rangle = K \cdot (z^2/\sin\Psi)^{\alpha} \quad (1)$$

where α lies in range $0 < \alpha < 1$. Values of α and K were determined from a condition of the best agreement of calculated curves with experimental values. We obtained $\alpha = 0.4 \pm 0.05$ which is less than $\alpha = 0.68 \pm 0.02$ used in paper (Kidd, 1973). A value of parameter K depends on both nuclear emulsion parameters, i.e., dimensions and concentration of grains, a development regime (Katz,1969), and photometry conditions.

Using a deviation of individual values of A from $\langle A \rangle$ the relative rms spread of A for C- and O-nuclei was established to be $\sigma(A)/A=0.15$.

4. Determination of Charges of Primary Cosmic Ray Nuclei. The technique presented here was used to divide cosmic ray nuclei recorded in X-ray emulsion chambers(Abulova et al, 1981) into the groups M(z=6-9), H(z=10-19), and VH($z \geq 20$). In all, we found 43 nuclei with energies $\sim$ 1 TeV/nucleon and zenith angles $30° < \Psi < 60°$. These nuclei were registered, on average, in 8 layers of nuclear emulsion 60 um thick.

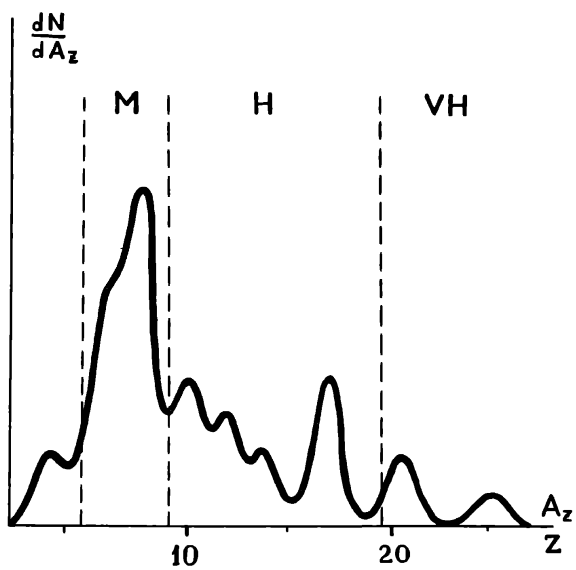

Fig.3. The found nuclei distribution over A_z

Each nucleus was photometered in all n layers where it was traced. Using n obtained values of profile amplitude A we obtained mean value $\langle A \rangle_{\Psi}$ which depended on the given nucleus chrge and zenith angle. The obtained values of $\langle A \rangle_{\Psi}$ were recalculated, on the basis of relation (1), to angle $\Psi = 90°$ by the formula

$$A_z = \langle A \rangle_{\Psi} (\sin\Psi)^{\alpha} \quad (2)$$

Values of A_z were the characteristics of nucleus charges. Fig.3 shows nuclei distribution over A_z. In this histogram, each nucleus is represented in the form of the Gaussian distribution with a mean value A_z and dispersion $\sigma(A)/\sqrt{n}$, where n is the number of emulsion layers in which this nucleus track was photometered.

The most numerous in cosmic rays nucleus group CNO can be clearly seen in the histogram and is in agreement with K determined in the calibration measurements. By the position of CNO peak we determined K in formula (1) more precisely and calculated the boundaries between groups of nuclei M,H, and VH. It turned to be that 23 of 43 nuclei formed group M, 14 nuclei - group H, and 4 - group VH. Two nuclei had charges less than 6.

5.Discussion. An accuracy of determination of A_Z for given nucleus depends on the number n of emulsion layers where this nucleus track is photometered and on a correctness of inserting corrections for the angular dependence and photometer work stability. Proceeding from this the following relation can be written for dispersion A_Z

$$D(A_Z) = D_\Psi + D_N + D(A)/n \quad (3)$$

Here dispersions D_Ψ and D_N characterize an accuracy of introducing the angular dependence and normalization coefficients for a photometer stable work and dispersion D A characterizes a spread in the measured amplitudes in various emulsion layers. On the basis of calibration measurements, $\sqrt{D_\Psi}$ is estimated as 4%. A control for a stable photometer work showed that $\sqrt{D_N}$ approaches 6%. Relative dispersions of A for various nucleus are: $\sqrt{D(A)_M}=15\%$, $\sqrt{D(A)_H}=12\%$, and $\sqrt{D(A)_{VH}}=8\%$.

Thus, for n=8 we have

$$\sqrt{D(A_Z)}_M = 7.9\% \quad \sqrt{D(A_Z)}_H = 7.2\% . \quad \sqrt{D(A_Z)}_{VH} = 6.5\% \quad (4)$$

From relation (1) it follows that for two nuclei with charges differing by 1 the corresponding difference Δ of amplitudes for various groups is

$$\Delta_M = 11\%, \quad \Delta_H = 5.8\% \quad \Delta_{VH} = 3.0\% \quad (5)$$

Comparing the attained accuracy (4) of determination of the amplitudes with the expected difference of amplitudes for neighbouring charges (5) we obtain that an accuracy of determination of charges by the present method for the nuclei groups corresponds to

$$\sigma(z)_M = 0.72 \quad \sigma(z)_H = 1.2 \quad \sigma(z)_{VH} = 2.2$$

References

1. Abulova,V.G. et al, 1981, 17th ICRC, OG-2.2-1
2. Katz,R and Kobetich,E.J., 1969, Phys. Rev., 186, 344.
3. Kidd,J.M. and Wefel,J.P., 1973, 13th ICRC, 1, 171.