

# Dependence of the secondary-particle multiplicity on the target-nucleus atomic weight and cross section of inelastic interactions

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We investigate the dependence of the multiplicity of the secondary particles on the energy of the primary particle and on the atomic weight of the target nucleus; we show how the secondary-particle multiplicity is connected with the inelastic-interaction cross sections in different nuclei.

Much interest is always paid to the investigation of the energy dependences of the multiplicity and of the interaction cross sections, these being among the most fundamental problems in strong-interaction physics. There is also a known connection between the average secondary-multiplicity and the interaction cross sections, which can be expressed by means of the total integral over the inclusive single-particle cross sections

$$\int f(x, P_1) dx dP_1 = \langle n_s \rangle \sigma. \quad (1)$$

The formula obtained by Kancheli<sup>[1]</sup> for the average multiplicity can be written in the form

$$\frac{\langle n_s(A, E) \rangle \sigma_{in}(A, E)}{\langle n_s(1, E) \rangle \sigma_{in}(1, E)} = A, \quad (2)$$

where  $\sigma_{in}(1, E)$  and  $\langle n_s(1, E) \rangle$  are the total inelastic cross section and the average multiplicity of the  $pp$  interaction, and  $\sigma_{in}(A, E)$  is the total inelastic cross section for the nucleon-nucleus interaction. It follows therefore

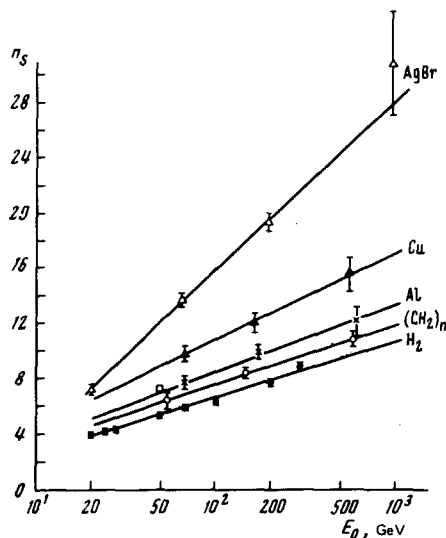


FIG. 1. Dependence of  $\langle n_s \rangle$  on the energy, data from ● - [1], ○, ×, ▲ - present data, □ - [4] (without error), △ - [12].

that one can expect a certain connection between the cross section ratios and the multiplicity on the nuclei and on the nucleon.

We have previously investigated the character of the dependence of the multiplicity on the atomic number of the target nucleus and the energy behavior of the multiplicity for different nuclei. In<sup>[2]</sup> are given preliminary data on the energy dependence of the multiplicity for  $t-e$  nuclei  $(CH_2)_n$  and Cu. In the present paper we continue the analysis of this dependence, using experimental data recently obtained for the Al nucleus.

Our data were obtained by exposing  $(CH_2)_n$ , Al, and Cu nuclei to cosmic rays in the magnetic spark spectrometer of the Tskhra-Tskaro Laboratory, located 2500 m above sea level in the Southern Caucasus. These data are based on the following material: 300 interactions with a  $(CH_2)_n$  polyethylene target, 230 with aluminum, and 280 with copper, in the primary-particle energy range 50–3000 GeV.<sup>1)</sup> It should be noted that the flux of the primary particles contains 45% protons, 40% neutrons, and 15%  $\pi^\pm$  mesons, and the apparatus registered their interactions with equal efficiency.

The entire analysis was made under the assumption that the energy dependence takes the form

$$\langle n_s \rangle = a + b \lg \frac{E_p}{m_p}, \quad (3)$$

which follows from the multiperipheral models. Figure

Table 1

	H	CH <sub>2</sub>	Al	Cu
A	1	10	27	63.5
a	$-1.26 \pm 0.10$	$-0.8 \pm 0.7$	$-1.1 \pm 1.0$	$-1.7 \pm 1.4$
b	$3.91 \pm 0.17$	$4.2 \pm 1.6$	$4.8 \pm 2.1$	$6.2 \pm 3.0$
f(10)	1	1.28	1.39	1.70
f(∞)	1	1.07	1.23	1.58
f(∞)/f(10)	1	0.84	0.89	0.93

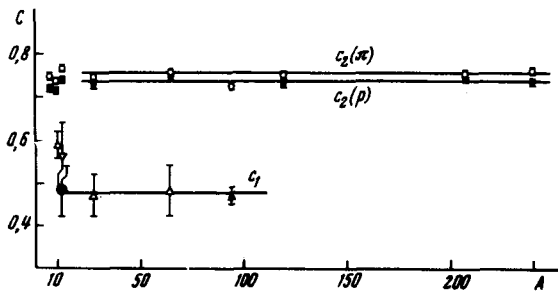


FIG. 2. Plots of  $[\sigma_{in}(1, E)/\sigma_{in}(A, E)]A^{0.7}$  and  $[\langle n_s(A, E) \rangle / \langle n_s(1, E) \rangle]A^{-0.3}$  against the atomic weight of the target, in accordance with the data from:  $\circ$ ,  $\bullet$  - [5],  $\square$  - [6],  $\triangle$  - [7],  $\circ$  - [8],  $\triangle$  - [9],  $\nabla$  - our present data.

1 shows these energy dependences for different nuclei and for  $pp$  interaction. [3] Table 1 gives the values of the parameters  $a$  and  $b$ . The errors of these parameters are large, since the investigated energy interval was small and there are practically no accelerator data, apart from individual emulsion studies that are subject to many shortcomings.

It should be noted that so far there are no good data permitting a firm choice between a power-law form for the energy dependence of the multiplicity, as predicted by statistical model, and predictions of the logarithmic type. The observed dependences can resolve this question only if more accurate data are obtained in a wider energy range.

The data obtained by us, in any case, lead to conclusion that the ratio  $f = \langle n_s(A, E) \rangle / \langle n_s(1, E) \rangle$  depends little on the energy (see Table 1) in the region  $E > 10$  GeV. This observation enables us to parametrize the dependence of this ratio on  $A$  in the form

$$\frac{\langle n_s(A, E) \rangle}{\langle n_s(1, E) \rangle} = c_1 A^\alpha. \quad (4)$$

As seen from Fig. 2, the ratio of the multiplicities really admits of such a parametrization, and in this case  $c_1 = 0.47 \pm 0.05$  and  $\alpha = 0.30 \pm 0.09$ . [2]

As follows from (2) and (4), the following relation should hold:

$$\frac{\sigma_{in}(1, E)}{\sigma_{in}(A, E)} A^{1-\alpha} = c_2 = \text{const.} \quad (5)$$

On the basis of the cross section data obtained in Serpukhov, [5] we investigated also this relation (Fig. 2).

From the parallelism of the functions  $c_1$  and  $c_2$  we can conclude that for medium and heavy nuclei, formula (2) holds true in the form

$$\frac{\langle n_s(A, E) \rangle}{\langle n_s(1, E) \rangle} \frac{\sigma_{in}(A, E)}{\sigma_{in}(1, E)} = kA, \quad (6)$$

Table 2

$E, \text{GeV}$	H	$\text{CH}_2$	Al	Cu	Average emulsion nucleus <sup>[12]</sup>
70	$2.1 \pm 0.1$	—	$2.4 \pm 0.3$	$2.3 \pm 0.3$	$1.65 \pm 0.07$
170	$2.00 \pm 0.05$	$1.9 \pm 0.2$	$2.1 \pm 0.3$	$2.0 \pm 0.2$	$1.60 \pm 0.05$
600	—	$2.1 \pm 0.2$	$1.91 \pm 0.20$	$1.7 \pm 0.3$	$1.4 \pm 0.2$

where  $k \approx 0.65 \pm 0.07$ .

Thus, our analysis enables us to predict the cross sections on light nuclei at high energies, on the basis of data on the cross section in  $pp$  collisions obtained with colliding beam. [10] In particular, the growth of the cross section on carbon, calculated from (6), agrees with the data obtained with the satellites of the "Proton" series. [11]

In Table 2 we give the values of  $\langle n_s \rangle / D$  (normalized mean value), where  $D = (\langle n_s^2 \rangle - \langle n_s \rangle^2)^{1/2}$  is the standard deviation. For the nuclei Al and Cu one cannot exclude the possibility of a small decrease of this value, which oscillates, just as in the case of the nucleon, about a characteristic value 2.0. The tendency to decrease is observed also in the emulsion data, [12] but there the value itself is underestimated, probably because the target nucleus is not pure.

In conclusion, the authors thank Academician E. L. Andronikashvili for constant stimulation of the laboratory work, and O. V. Kancheli, I. D. Mandzhavidze, and V. V. Abramovskii for useful discussions.

<sup>1</sup>Most data (95%) in the interval 50–1000 GeV.

<sup>2</sup>For  $A \geq 27$ .

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