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ЦЕНТРАЛЬНЫЙ НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ ИНСТИТУТ ИНФОРМАЦИИ И ТЕХНИКО-ЭКОНОМИЧЕСКИХ ИССЛЕДОВАНИЙ ПО АТОМНОЙ НАУКЕ И ТЕХНИКЕ

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STRUCTURE FUNCTIONS OF THE NUCLEI ^{12}C, ^{63}Cu, ^{208}Pb IN THE CUMULATIVE PROTON PHOTOPRODUCTION

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In a recent paper [1] we have shown that the invariant yield of protons in the reaction

$$\gamma + {}^{12}C \to p + X \qquad (1)$$

in the region $1 \leqslant \alpha \leqslant 2$ (in cumulative region) and $P_\perp \geqslant 0.5$ GeV/c is factorized

$$f(\alpha, P_\perp) \sim f_1(\alpha) \cdot f_2(P_\perp) \qquad (2)$$

with both functions having an exponential character

$$f_1(\alpha) \sim \exp(-\alpha/\alpha_0)$$
$$f_2(P_\perp) \sim \exp(-P_\perp^2/P_0^2) \qquad (3)$$

It is shown that the parameter α_0 averaged over all values of $P_\perp > 0.5$ GeV/c and found for $\alpha \geqslant 1.3$ is $\bar{\alpha}_0 = 0.141 \pm 0.004$ which agrees with the data from hadronic process of cumulative particle production on heavy nuclei (see e.g. [2]) and from deep-inelastic scattering of μ-mesons on ^{12}C [3] at the transferred momentum of $Q^2 \geqslant 50(\mathrm{GeV/c})^2$.

At present one may apparently consider generally acknowledged that cumulative particle production is related to the scattering on strong correlations (SC) of nucleons in nuclei (low-nucleon correlations, fluctuons, quark bags), concentrated in a volume whose radius is of the order of the size of nucleons. In such dense formations quark degrees of freedom apparently play a decisive role. In SC models the variable α is a portion of the SC momentum taken away by a nucleon from SC in the system where SC is fast. In this case, the experimentally measured yield $f(\alpha, P_\perp)$ represents a distribution of nucleons in SC and is determined by the momentum distribution of quark-partons in SC [4]

$$f(\alpha, P_\perp) = \mathrm{const} \left| \int \Psi_N(x_i, q_{\perp i})\, \Psi_{SC}(x_j, q_{\perp j}) \cdot dx_j\, dq_{\perp j} \cdot \delta(\alpha - \sum_1^3 x_i) \cdot \delta(P_\perp - \sum_1^3 q_{\perp i})\, dx_i\, dq_{\perp i} \right|^2 \quad (4)$$

where $\Psi_{SC}(x_j, q_j)$ and $\Psi_N(x_i, q_i)$ are the quark wave functions of SC and nucleons in SC, respectively; x_i, x_j, q_i, q_j are the variables of valent quarks. It is seen from (4) that measuring the distribution $f(\alpha, P_\perp)$ one may in principle define Ψ_{SC} assuming $\Psi_N(x_i\, q_i)$ to be known (e.g. from the experiments on deep-inelastic scattering of leptons on a nucleon). In other words, the cumulative particle production process allows to define, in principle, the quark distribution in the nucleus in the region $X > 1$.

In this paper we present experimental values of the yields of the reaction (1) for the nuclei ^{12}C, ^{63}Cu, ^{208}Pb and discuss the distribution in α of the value $R_{A/C} = f_A(\alpha, P_\perp)/f_C(\alpha, P_\perp)$ for the nuclei ^{63}Cu and ^{208}Pb at $P_\perp$ = 0.5 GeV/c.

Values of $f(\alpha, P_\perp)$ are plotted in table I. Figure 1 presents these data for ^{63}Cu and ^{208}Pb (for analogous figure for ^{12}C see [1]). Only statistical errors are shown. Systematical errors in estimates do not exceed 25%. It is seen that for ^{12}C [1] as well as for ^{63}Cu and ^{208}Pb the function $f(\alpha, P_\perp)$ is well factorized in the region $\alpha > 1$: $f(\alpha, P_\perp) = f_1(\alpha) \cdot f_2(P_\perp)$. In the region $\alpha \geqslant 1.5$ the distribution of $f_1(\alpha)$ is well expressed via exponent $f_1(\alpha) = c \cdot \exp(-\alpha/\alpha_0)$.

In table II the values of the parameter α_0 for $P_\perp$ = 0.50 - 0.95 GeV/c are plotted. In fig. 2a the dependences of α_0 on $P_\perp$ for ^{12}C (a) and on A (b) for $P_\perp$ = 0.5 GeV/c are shown. As is seen, first, α_0 at least in the region $P_\perp > 0.5$ GeV/c is independent of $P_\perp$ and on the average is equal to 0.134 ± 0.01 (the difference from the value $\bar{\alpha}_0$ =0.141 from ref. [1] is due to the fact that for calculations the region $\alpha > 1.5$ is taken instead of $\alpha > 1.3$ in [1]), where the factorization of $f(\alpha, P_\perp)$ is beyond doubt, and, second, at the fixed value of $P_\perp$ a tendency of the slight increase in α_0 with A is observed.

Table II

Value of the parameter α_0 in the representation $f_1(\alpha) = c \cdot \exp(-\alpha/\alpha_0)$ for various nuclei and $P_\perp$

A \ $P_\perp$	0.25	0.5	0.75	0.95
^{12}C	-0.126± 0.006	-0.137± 0.006	-0.132± 0.007	-0.134± 0.004
^{63}Cu	-0.125± 0.008	-0.140± 0.003	-	-
^{208}Pb	-0.134± 0.006	-0.155± 0.001	-	-

Investigators recently show great interest for the EMC-effect which consists in the fact that according to the data on deep-inelastic scattering of muons [5] and electrons [6] on nuclei, the distribution of quarks of free nucleons and nucleons in nuclei (at least up to iron) differ in the region $X < 1$. Discussing this problem in the case of the cumulative region ($X > 1$), authors of [4] have come to the conclusion that such an effect should be observed also at $X > 1$. As in the case of EMC-effect in ref. [4], the authors have considered the distribution in X of the ratio of the given nucleus structure functions to that of a deuteron for the cumulative nucleon production process. If the effect of nuclear medium on the nucleon structure changes with the increase in A, the analogous ratio for heavy and light nuclei should also change with X and A. In this aspect, of certain interest is the value $R_{A/c} = f_A(\alpha, P_\perp)/f_c(\alpha, P_\perp)$.

In fig. 3 the dependences of R on α for the nuclei ^{63}Cu and ^{208}Pb are presented. As is seen, accuracies of our experimental results allow to state that the value $R_{A/c}$ in the region $\alpha \geqslant 0.6 \div 2.0$ first increases beginning from $R_{A/c} = 1$ and, second, the heavier the nucleus the higher the $R_{A/c}$ (at least for $\alpha > 1.3$).

If deductions of [4] are extended to $R = f_A/f_c$ (instead of $R = f_A/f_d$), qualitatively it implies that the quark distribution of the objects that emit cumulative protons, i.e. strong correlations, become softer with the increase in A. In other words, the portion of the high momentum component of quarks in nuclei increases with A.

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Table I

Value of the yield $f(\alpha, P_\perp)$ of the reaction $\gamma A \to pX$ of the nuclei ^{12}C, ^{63}Cu, ^{208}Pb versus α, $mb \cdot c^3/GeV^2$ sr

$P_\perp$, ГэВ/c	α \ A	^{12}C f	^{12}C Δf	^{63}Cu f	^{63}Cu Δf	^{208}Pb f	^{208}Pb Δf
0.25	0.508	5.9	0.23				
	0.572	7.8	0.35				
	0.600	9.0	0.52	45	2.7	148	8.8
	0.657	12.5	0.38	65	2.33	240	8.4
	0.718	16.0	0.60	93	4.65	345	17.25
	0.754	19	0.72	-	-	-	-
	1.420	3.15	0.112	27	0.81	115	3.45
	1.49	1.55	0.109	14	0.84	56	2.2
	1.63	0.64	0.033	6	0.25	23	0.8
	1.78	0.165	0.0132	1.4	0.08	6	0.34
	1.87	0.09	0.0815	0.7	0.06	3.6	0.2
	2.11	0.0117	0.0012	0.12	0.012	0.56	0.05
0.5	0.656	2.05	0.09	10.19	0.39	24.7	1.08
	0.763	2.8	0.107	0.107	17	0.53	1.97
	0.823	3.3	0.172	18.2	0.99	67	3.36
	0.99	3.7	0.17	26	1.0	90	2.99
	1.3	1.6	0.03	13	0.5	48	1.85
	1.371	0.955	0.06	9.5	0.48	28	1.12
	1.43	0.676	0.05	6.4	0.32	19	0.76
	1.56	0.3	0.016	2.7	0.135	10	0.42
	1.68	0.134	0.007	1.19	0.05	4.7	0.18
	1.81	0.045	0.0068	0.456	0.068	1.99	0.3
	1.96	0.016	0.003	0.15	0.02	0.76	0.06

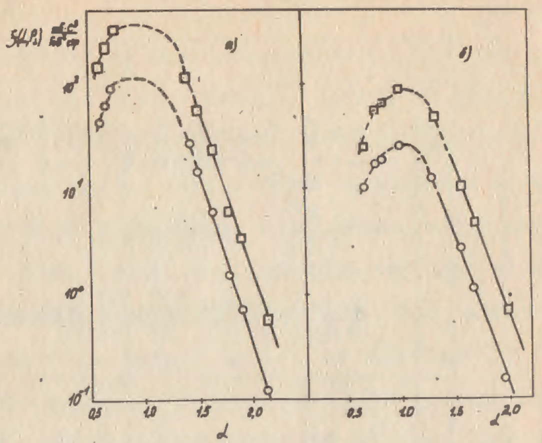

Fig. 1 Distribution of $f(\alpha, P_\perp)$ versus α for ^{63}Cu and ^{208}Pb: a) $P_\perp = 0.25$ GeV/c; b) for $P_\perp = 0.5$ GeV/c. Lines in the region $\alpha \geq 1.5$ are drawn by the method of least squares according to the relation $f \sim \exp(-\alpha/\alpha_0)$

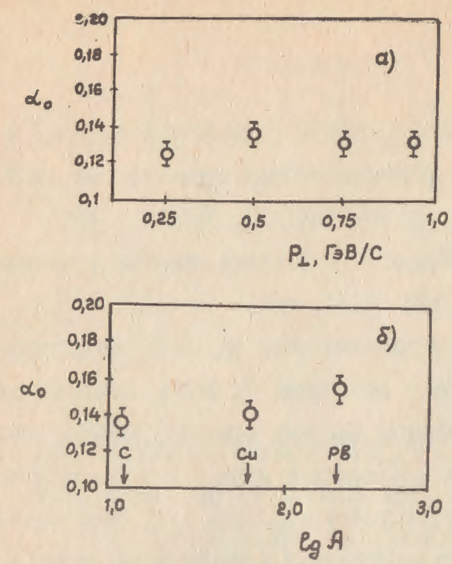

Fig. 2 Dependence of the parameter α_0 on $P_\perp$ for the nucleus ^{12}C (b) and on A for $P_\perp = 0.5$ GeV/c.

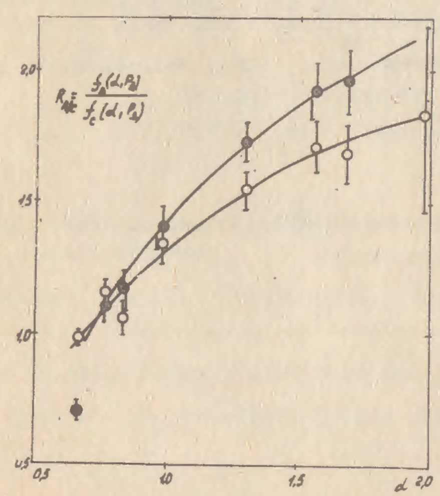

Fig. 3 Dependence of the value $R_{A/C} = f_A(\alpha, P_\perp)/f_C(\alpha, P_\perp)$ on α for $P_\perp = 0.5$ GeV/c. Points: ● – for ^{208}Pb, ○ – for ^{63}Cu.

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СТРУКТУРНАЯ ФУНКЦИЯ ЯДЕР ^{12}C, ^{63}Cu, ^{208}Pb В ПРОЦЕССЕ ФОТОРОЖДЕНИЯ КУМУЛЯТИВНЫХ ПРОТОНОВ

(на английском языке, перевод Л.Н.Багдасаряна)

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