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MULTIPLICITY, MOMENTUM AND ANGULAR CHARACTERISTICS OF π^- MESONS FOR pC, dC, αC AND CC INTERACTIONS AT 4.2 GeV/c PER NUCLEON

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1. INTRODUCTION

Interest in studying relativistic nucleus-nucleus interactions arises from the fact that under some definite conditions in such interactions the quark degrees of freedom should manifest themselves.

It has been established that quarks in hadrons are bound relatively weak. The characteristic momentum of a quark in a hadron is approximately 0.3 GeV/c. This means that if the momentum transfer (per quark) is much greater than 0.3 GeV/c, quarks can be treated as quasi-free particles.

Selection of interactions with large momentum transfers has led to the discovery of the cumulative effect and allowed one to estimate quark momentum distributions inside nuclei: quark-parton structure functions of nuclei. It should be stressed that cross sections quickly fall down with increasing momentum transfer above 0.3 GeV/c. Thus, the contribution of hard processes to the total inelastic nucleus-nucleus cross section is small.

In studies of multiple production processes it has been found that the mean transverse momenta of generated particles are of the same order of magnitude as the mean Fermi momenta of nucleons in the nucleus.

This implies that:

i) The contribution of hard processes to multiple meson production cross section is small.

ii) Nucleons (and not quarks) of interacting nuclei should be treated as quasi-free particles.

Therefore multiple production processes in relativistic nuclear interactions have to be described by models based on the assumption of independent interactions of nucleons from colliding nuclei.

Experimental data on multiple meson production in collisions of relativistic nuclei are important not only to check the above models but also to create a general picture of relativistic nuclear physics.

This paper is devoted to a study of characteristics of π^- production in interactions of light nuclei (p , d , α , C) with carbon at a projectile momentum of 4.2 GeV/c per nucleon. This paper is a continuation of a series of our studies of interactions of light relativistic nuclei with light and heavy targets in the 2 m propane bubble chamber, JINR [1-5].

In our previous papers results have been reported on inelastic cross sections of nuclei, π^- meson multiplicities for inelastic interactions with carbon and tantalum [1-3] and kinematic characteristics of π^- mesons generated on tantalum target [4,5] and in "central" CC interactions [5].

Estimates of the size of the interaction volume obtained using interferometry of identical particles are given for π^- mesons in paper [5] and more completely for various particles in papers [6,7]. The production of π^- mesons by relativistic nuclei at similar energy on different targets has been also studied using an SKM-200 streamer chamber [8-10].

2. EXPERIMENTAL DATA

Experimental data have been obtained using the 2m propane bubble chamber (Laboratory of High Energies, JINR) placed in a magnetic field of 1.5 T and exposed to beams of p, d, α, and C nuclei from the synchrophasotron with a momentum of 4.2 GeV/c per nucleon.

Interactions with propane in a chosen fiducial volume inside the chamber were scanned, measured on semiautomatic devices SAMET and reconstructed by the GEOFIT programme on a CDC-6500 computer.

Interactions with carbon nuclei were selected from all interactions of beam nuclei with propane (C_3H_8) using criteria based on the determination of the total charge of secondary particles, the presence of protons emitted backward and so on. This method, described in detail in [11], allows one to select 70-80% of all inelastic interactions with C (see Table 1). The designations in Table 1 are: N^{cal} is the number of inelastic interactions calculated from the cross sections σ^{in}_{AC} and σ^{in}_{Ap} with event registration efficiency in a propane bubble chamber taken into account [11], N^{sel} is the number of interactions selected using our selection criteria and n^{cal} and n^{sel} are the numbers of π^- mesons in N^{cal} and N^{sel} interactions, respectively*. 79-85% of all π^- mesons, produced in inelastic AC collisions, belong to events selected as interactions with C (see Table 1). The AC interactions, not satisfying the selection criteria, were collected together with inelastic Ap interactions to form a group of ambiguous events ($N^{in}_{Ap} + N^{in}_{AC}$) and were separated only statistically.

The corresponding π^- distributions from pp interactions were subtracted from the multiplicity, momentum and angular distributions of π^- mesons for the group of ($N^{in}_{pp} + N^{in}_{pC}$) events,

*All secondary negatively charged particles were taken as π^- mesons. The admixture of other particles does not exceed 1%.

Table 1

Numbers of events and π^- mesons

	pC	dC	αC	CC
N^{cal}	1834	2171	1872	1644
N^{sel}	1291	1722	1421	1212
N^{sel}/N^{cal}(%)	70.4	79.3	76.0	73.7
n^{cal}	641	1502	2060	2389
n^{sel}	537	1254	1638	2036
n^{sel}/n^{cal}(%)	83.8	83.5	79.5	85.2

and the results were summed with the distributions obtained for π^- from pC interactions which satisfied our selection criteria. The π^- multiplicity distribution in inelastic pp interactions was taken from [12]. The number of π^- mesons from inelastic pp interactions was estimated as described in [11]. The π^- distributions for CC interactions were obtained in a similar way. In this case the π^- distributions for Cp interactions obtained in our experiment were subtracted from the π^- distributions for the group of ($N^{in}_{Cp} + N^{in}_{CC}$) events*.

The momentum and angular distributions of π^- mesons for dC and αC interactions were obtained under the assumption that π^- distributions in unseparated dC and αC events are the same as the corresponding distributions for the whole group of ($N^{in}_{dp(\alpha p)} + N^{in}_{dC(\alpha C)}$) events. This assumption was unavoidable as there is no experimental data on π^- mesons from dp and αp interactions at 4.2 GeV/c per nucleon. Distortions in the π^- distributions are small because only 15-20% of π^- come from the unseparated group, and dC(αC) events, not satisfying the selection criteria, are mainly peripheral d and α interactions with quasi-free nucleons of the carbon nucleus, and they are similar to inelastic dp(αp) interactions in character. Because of a weak dependence of $\langle n_-\rangle^{in}_{Ap}$ on the atomic mass of the projectile (namely, $\langle n_-\rangle^{in}_{Np} = 0.30 \pm 0.01$ for N and $\langle n_-\rangle^{in}_{pTa} = 0.45 \pm 0.02$ [2] for Ta), $\langle n_-\rangle^{in}_{dp} = \langle n_-\rangle^{in}_{\alpha p} = \langle n_-\rangle^{in}_{Cp}$. The last number $\langle n_-\rangle^{in}_{Cp}$ obtained in this experiment is equal to $\langle n_-\rangle^{in}_{pC}$.

The mean multiplicity is calculated as $\langle n_-\rangle = \frac{n_-}{N^{in}}$ with N^{in} the number of inelastic interactions and n_- the total number of π^- mesons in these interactions with corrections for π^- losses.

*The distributions of π^- mesons for pC interactions were transformed into the antilaboratory system.

The azimuthal angle distributions of π^- mesons show that only for CC interactions there are some small losses (about 3%) towards the bottom of the chamber.

π^- mesons are well identified above a 70 MeV/c momentum. The losses of slow π^- mesons vary from 2.5% for pC to 4.5% for CC interactions. The most probable error in estimating the meson momentum is (6-8)%, the mean error $\Delta P_{\pi^-}/P_{\pi^-} = 11.5\%$, and the mean error in determining the emission angle $\langle\Delta\theta\rangle = 0.5°$.

3. MULTIPLICITY OF π^- MESONS

The multiplicity distributions of π^- mesons in interactions of light nuclei with carbon are shown in Fig.1; and their average multiplicities and dispersions, in Table 2. From Fig.1 it is seen that with increasing the atomic mass of the projectile the π^- multiplicity distributions become broader $(n_-^{max})^{pC} = 3$ and $(n_-^{max})^{CC} = 8$, and correspondingly the mean π^- multiplicity and dispersions increase. In our earlier papers /1-3/, in which π^- multiplicity distributions obtained from scanning data are presented, it is shown that for AC interactions the form of these distributions is nearly Poissonian. The π^- multiplicity distributions have been recently obtained from the events measured and compared to the Poisson distribution with $\langle n_-\rangle = \langle n_-\rangle_{exp}$ /13/. It has been shown that experimental and calculated probabilities are almost the same. One can also judge about similarity of both distributions from the relation between $\langle n_-\rangle$ and dispersion D_-. For the Poisson distribution $\langle n_-\rangle = D_-^2$. In Table 2 are presented the values of the ratio $\langle n_-\rangle/D_-^2$. They are compatible with unity within 2-3 standard deviations. The ratio $\langle n_-\rangle/D_-^2$ shows a certain tendency to decrease with increasing the atomic mass of the projectile.

Dispersion of the multiplicity distributions increases linearly with increasing $\langle n_-\rangle$. Approximating the experimental data by the linear function $D_- = a\langle n_-\rangle + b$, we get: $a = 0.70 \pm 0.02$, $b = 0.25 \pm 0.04$ with $\chi^2 = 0.8$/D.F.

It is known that for pp and np interactions over a wide momentum range (4-2070 GeV/c for pp and 4-400 GeV/c for np) the $D_\pm$ dependence on $\langle n_\pm\rangle$ is well described by the empirical linear Wróblewski formula /14/ $D_\pm = A\langle n_\pm\rangle - B$ with $A^{pp} = 0.580 \pm 0.004$, $B^{pp} = 0.560 \pm 0.015$ and $A^{np} = 0.56 \pm 0.01$, $B^{np} = 0.14 \pm 0.04$ /15/. Taking into account that for pp interactions $n_\pm = 2n_- + 2$ and for np $n_\pm = 2n_- + 1$ and $D_- = 1/2 D_\pm$, we have $D_-^{pp} = 0.58\langle n_-\rangle + 0.30$, $D_-^{np} = 0.56\langle n_-\rangle + 0.21$. Comparing these a and b parameters with those quoted above, one can draw the conclusion that dispersion in nucleus-nucleus interactions increases with $\langle n_-\rangle$ faster than in Np interactions.

Table 2

Multiplicities and dispersions of multiplicity distributions of π^- mesons for inelastic nucleus-nucleus interactions

	pC	dC	αC	CC
$\langle n_-\rangle$	0.33±0.02	0.62±0.03	I.07±0.05	I.52±0.08
D_-	0.54±0.02	0.7I±0.03	0.98±0.05	I.34±0.07
$\langle n_-\rangle/D_-^2$	I.I4±0.08	I.23±0.08	I.II±0.08	0,85±0,07
$\langle n_-\rangle^{DCM}$	0.42±0.0I	0,68±0.02*	I.I6±0.03*	I,49±0.02
D_-^{DCM}	0.58	0.77	I.08	I.47
$\langle n_-\rangle^{DCM}/(D_-^2)^{DCM}$	I.23	I.I5	I.07	0,70
$\langle n_-\rangle^{MSM}$		0.53±0.0I	0,84±0.0I	I.44±0.02
D_-^{MSM}		0.64±0.0I	0.89±0.0I	I.48±0.0I
$\langle n_-\rangle^{MSM}/(D_-^2)^{MSM}$		I,28±0.02	I,06±0,02	0,66±0,0I

* Calculated for an incident momentum of 4.5 GeV/c per nucleon.

Such an increase is characteristic of interactions with nuclei.

If we assume that nucleons from the projectile interact independently in the target nucleus, then we have the relation /2,16/

$$D_-^2 = \langle\nu\rangle(D_-^{NB})^2 + \langle n_-^{NB}\rangle^2 D_\nu^2 \qquad (1)$$

with D_- the dispersion of π^- multiplicity distribution from nucleus-nucleus AB interactions; D^{NB} the dispersion of π^-

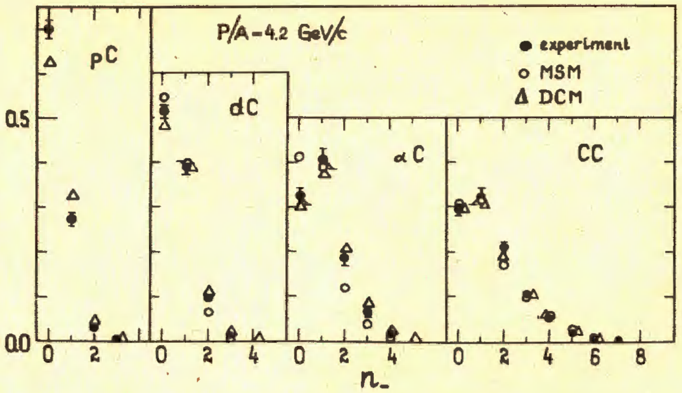


Fig.1. Multiplicity distributions of π^- mesons for pC, dC , αC and CC interactions; ● - experiment, o - MSM, Δ - DCM.

multiplicity distribution from nucleon-nucleus interactions; $\langle\nu\rangle$ the mean number of nucleons from nucleus A which interact with nucleus B ; D_ν the dispersion of the distribution of the number of nucleons from nucleus A participating in interaction with nucleus B; and n_-^{NB} the mean π^- multiplicity for nucleon-nucleus interactions.

From formula (1) it follows that the increase of the squared dispersion of the π^- multiplicity distributions in nucleus-nucleus interactions as compared to $\langle\nu\rangle (D^{NB})^2$ is caused by the term characterizing fluctuations in the number of interacting nucleons from the projectile. The contribution of this term is small for collisions of light nuclei, and it increases with increasing the atomic mass of interacting nuclei [2,17].

We shall now investigate the influence of projectile atomic mass on the mean π^- multiplicity. The approximation of the $\langle n_-\rangle$ dependence on A by power function $n_- = kA^\alpha$ does not give a good value of χ^2. At the same time a well defined linear dependence exists between the mean π^- multiplicity in (d,α,C) interactions with C and the mean number $\langle\nu\rangle$ of nucleons from the projectile which have interacted in the target $\langle n_-\rangle^{AC} = a + b\langle\nu\rangle$ (Fig.2), where a = 0.09±0.04 and b = 0.38±0.03. The mean values of ν have been obtained experimentally for deuteron and α primary beams using the relations $\langle\nu\rangle = 2\langle\nu_p\rangle$, $\langle\nu_p\rangle = (Z_A - \langle Z_A^{str}\rangle)$, where $\langle\nu_p\rangle$ is the mean number of interacting protons from the projectile nucleus A ; Z_A the charge of the nucleus A and $\langle Z_A^{str}\rangle$ the mean charge of stripping fragments from the nucleus A. The fragments with momentum $P_{lab}/Z > 3$ GeV/c and emission angle $\theta_{lab} < 4°$ are called "stripping" [2]. For CC interactions there are some difficulties in the experimental

Table 3

Average numbers of nucleons of the projectile nucleus A interacting with carbon nucleus

	dC	αC	CC
$\langle\nu\rangle^{exp}$	1.3±0.1	2.5±0.1	
$\langle\nu\rangle$ (2)	1.33	2.36	3.83
$\langle\nu\rangle$ MSM	1.3	2.0	3.5

estimation of $\langle\nu\rangle$ connected with the identification of fragments with Z > 2 from C projectile [16,18]. For these interactions $\langle\nu\rangle$ was calculated from the formula [19,20]

$$\langle\nu\rangle = A\,\sigma^{in}_{NC}/\sigma^{in}_{AC}\,, \tag{2}$$

where A = 12; σ^{in}_{NC} and σ^{in}_{AC} are the inelastic cross sections for NC and AC interactions, respectively, taken from ref. [3].

Formula (2) is obtained from the independent collision model (ICM) assuming that nucleons from the projectile interact with the target independently.

In Table 3 experimental values of $\langle\nu\rangle$ for dC and αC interactions are compared with numbers calculated from formula (2), using experimental cross sections, and with numbers calculated from the multiple scattering model (MSM) [21].

For dC interactions all three values of $\langle\nu\rangle$ agree. For αC interactions the value of $\langle\nu\rangle^{(2)}_{\alpha C}$ is closer to the experimental value of $\langle\nu_{\alpha C}\rangle$ than $\langle\nu\rangle^{MSM}_{\alpha C}$. For this reason in constructing the experimental dependence of $\langle n_-\rangle$ on $\langle\nu\rangle$ (Fig.2), we use for $\langle\nu\rangle_{CC}$ the estimate of $\langle\nu\rangle^{(2)}_{CC}$.

In Table 4 are shown mean values for π^- multiplicities calculated from the formula

$$\langle n_-\rangle^{AC} = \langle n_-\rangle^{NC}\langle\nu\rangle \tag{3}$$

with $\langle n_-\rangle^{NC} = 1/2(\langle n_-\rangle^{pC} + \langle n_-\rangle^{nC}) = 0.42\pm0.04$, as well as values of D_- calculated from formula (1) with $D_-^{NB} = 0.55\pm0.03$. All the calculated numbers are in good agreement with the experimental values (see Table 2). This shows that in interactions of light nuclei (d,α,C) with carbon the nucleons of the projectile interact with the target predominantly independently one from another.

In order to understand the mechanism of pion production in nucleus-nucleus interactions, the experimental π^--multiplicities were compared with results obtained from the Dubna version of the cascade model (DCM) [22] and from the multiple scattering

Table 4

Average numbers of π^- mesons and dispersions D_- calculated from formulae (3) and (1)

	dC	αC	CC
$\langle n_-\rangle = \langle n_-\rangle_{NC}\cdot\langle\nu\rangle$	0.55±0.05	1.05±0.08	1.61±0.11*
$D_-^{(1)}$	0.70±0.07	0.99±0.12	

* $\langle n_-\rangle^{CC}$ was calculated using formula $\langle n_-\rangle^{CC} = \langle n_-\rangle^{NC}\cdot\langle\nu\rangle^{(2)}$.

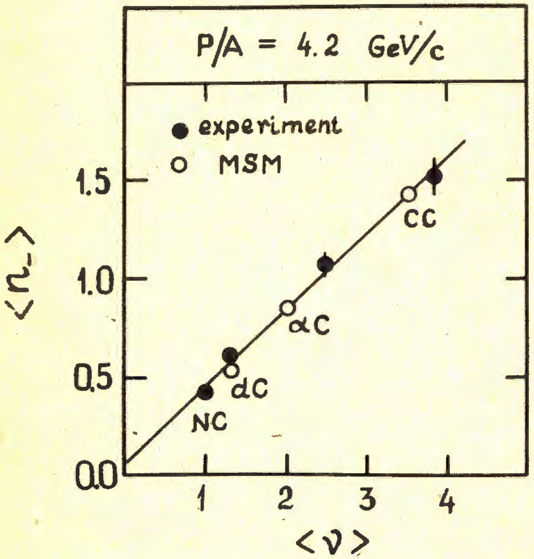


Fig.2. Average multiplicity of negative pions $\langle n_-\rangle$ as a function of the number of interacting nucleons from projectile ν. • - experiment; o - MSM. Straight line shows the dependence $\langle n_-\rangle = a + b\langle\nu\rangle$ for experimental points.

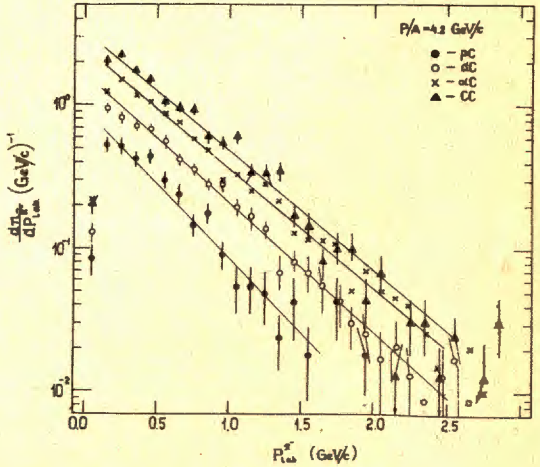
model(MSM)[20]. The value of $\langle n_-\rangle$ for pC interactions was also compared with $\langle n_-\rangle^{pC}$ obtained on the basis of the NUCRIN model[23] developed at the Karl Marx University in Leipzig. The multiplicity distributions of π^- mesons in pC, dC, αC and CC interactions predicted by DCM and MSM are shown in Fig.1, and the corresponding values of $\langle n_-\rangle$ and D_- are collected in Table 2. It can be seen that both models describe the experimental data well enough. The mean value of π^- multiplicity in pC reactions agrees, within errors, with $\langle n_-\rangle^{pC}_{NUCRIN} = 0.37\pm0.04$[23]. Thus, we see that the comparison of such characteristics of interactions of light nuclei as π^- multiplicity distributions, $\langle n_-\rangle$ and D_- with the independent interaction models[20,22] could not favour any of the models considered.

In experiments with the streamer chamber SKM-200[8-10] the dependence of $\langle n_-\rangle$ on the atomic mass of target was obtained for interactions of α and C with different targets (from Li to Pb). This dependence does not agree with predictions of the hydrodynamic model[24], the model of "wounded" nucleons[19] and the collective tube model[25], but it is well enough described by DCM[22], MSM[20] and SIM (Single Interaction Model)[26]. Thus, comparison of the full set of data on π^- multiplicities for nucleus-nucleus interactions at 4.2 GeV/c and 4.5 GeV/c per nucleon with theoretical models permits one to restrict the number of models adequate to the phenomena under study. It is necessary, however, to continue the comparison with models using other characteristics of secondary particles produced in nucleus-nucleus interactions.

4. MOMENTUM AND ANGULAR DISTRIBUTIONS OF π^- MESONS

The momentum spectra of π^- mesons in the laboratory system, normalized to the total inelastic cross sections $\frac{dn_-}{dP_{Lab}} = \frac{1}{\sigma_{in}}\cdot\frac{d\sigma^{\pi^-}}{dP_{Lab}}$, are shown in Fig.3. All four spectra in the momentum range above $P_{Lab} = 0.1$ GeV/c decrease exponentially with increasing π^- meson momentum, and slope parameters b for dC, αC and CC interactions are the same within the errors (see Table 5).

Fig.3. Spectra of π^- mesons in the laboratory system (normalized to σ_{in}) for pC, dC, αC, and CC interactions. Straight lines are the result of approximation of experimental data (above 0.1 GeV/c) by exponential function $f = ae^{-bP_{Lab}}$.



The π^- meson spectrum for pC interactions decreases somewhat quicker with increasing P_{Lab} than for interactions of isospin zero nuclei (with equal proton and neutron numbers) with carbon ($b^{pC} > b^{AC}$). From this one can conclude that π^- meson

Table 5

Values of parameter b obtained from approximation of the distributions dn_-/dp_{Lab} with formula $ae^{-bP_{Lab}}$

Parameters b $(GeV/c)^{-1}$	A	p	d	α	C
b_c	exp	2.43±0.12	1.96±0.07	1.91±0.06	1.89±0.06
b_c	DCM	2.21±0.06	2.07±0.05	1.88±0.03	1.92±0.04
b_c^{NUCRIN}		2.0± 0.2			
bTa	exp		2.8±0.1	2.6±0.01	2.6±0.05
χ^2_c	exp	1.50	1.27	2.72	3.34
χ^2_c	DCM	2.5	4.5	2.8	1.1
χ^2_{Ta}	exp		1.11	0.95	1.46

Table 6

Mean values of momentum and angular characteristics of π^- mesons

		pC	dC	αC	CC
$\langle P_{lab}^{\pi^-} \rangle$	exp	0.53±0.03	0.58±0.03	0.63±0.03	0.62±0.03
(GeV/c)	DCM	0.49	0.55*	0.62*	0.60
$\langle \Theta_{lab}^{\pi^-} \rangle$	exp	49.4±1.7	44.2±1.0	43.2±1.1	40.0±0.7
(degrees)	DCM	47.1	45.5*	43.1*	43.1
$\langle P_{\perp}^{\pi^-} \rangle$	exp	0.255±0.008	0.256±0.005	0.255±0.006	0.250±0.004
(GeV/c)	DCM	0.214	0.228*	0.245*	0.241
$\langle Y_{lab}^{\pi^-} \rangle$	exp	0.85±0.04	1.00±0.02	1.04±0.03	1.10 ±0.02
	DCM	0.85	0.98*	1.05*	1.05

*Calculated for an incident momentum of 4.5 GeV/c per nucleon.

spectra in nC reactions are more flat in comparison with the spectra from Fig.3 ($b^{nC} < b^{AC}$).

Average momenta of π^- mesons are given in Table 6. It is seen that for light nuclei $\langle P_{Lab}^{\pi^-} \rangle$ does not depend on the atomic mass. In AC interactions, on the average, π^- mesons are produced with greater momenta as compared to interactions of the same nuclei (d , a , C) with tantalum [4] ($\langle P_{Lab}^{\pi^-} \rangle^{ATa}$ = = (0.48+0.02) GeV/c). The comparison of angular distributions of π^- mesons in the laboratory system shows that the distributions become narrower when passing from d to C beam. As a result, the mean angle of π^- emission becomes ~10% smaller for heavier projectiles (see Table 6). Transverse momentum squared distributions

$$\frac{dn_-}{dP_\perp^2} = \frac{1}{\sigma_{in}} \cdot \frac{d\sigma^{\pi^-}}{dP_\perp^2}$$

for pC , dC , aC and CC interactions are all similar (Fig.4). Average transverse momenta of π^- mesons for these interactions are also the same within the errors (see Table 6).

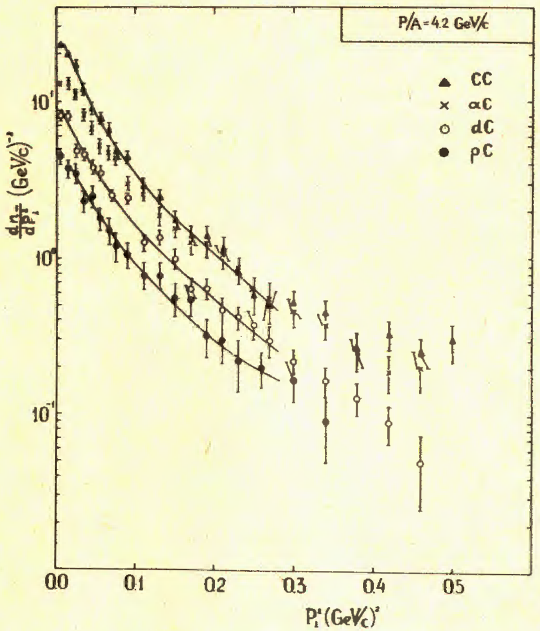


Fig.4. $P_\perp^2$ distributions of π^- mesons for pC , dC , aC, and CC interactions. Curves are the results of approximation of experimental data in the interval $0.1 < P_\perp^2 \leq 0.28$ by the formula with two exponents.

The distributions of $P_\perp^2$ shown in Fig.4 were fitted with the formula

$$\frac{dn_-}{dP_\perp^2} = ae^{-bP_\perp^2} + ce^{-dP_\perp^2} ,$$

and the parameters a , b , c , d resulting from the fit are collected in Table 7. The slope parameters b and d for interactions on tantalum are also given in Table 7 for comparison.

The longitudinal rapidity distributions for π^- mesons (Fig.5) show a little displacement towards greater y_{Lab} with changing the projectile from d to C .

Table 7

Values of parameters a, b, c, and d obtained from approximation of the distributions $dn_-/dP_\perp^2$ with formula $ae^{-bP_\perp^2} + ce^{-dP_\perp^2}$ for interactions of p, d, α, C with C and d, α, C with Ta.

	a (GeV/c)$^{-2}$	b (GeV/c)$^{-2}$	c (GeV/c)$^{-2}$	d (GeV/c)$^{-2}$	χ^2/D.F.
PC	3.4±1.4	34±12	2.2±1.6	9.7±3.2	0.5
dC	7.0±1.5	31±10	3.2±1.9	8.9±2.6	0.7
α C	14.5±1.8	33±8	5.0±2.1	8.1±1.9	0.5
CC	24.0±2.5	38±7	8.4±2.4	10.2±1.4	0.6
dTa		42±6		8±1	0.9
α Ta		39±5		8±1	0.9
cTa		44±4		8.5±0.5	0.9

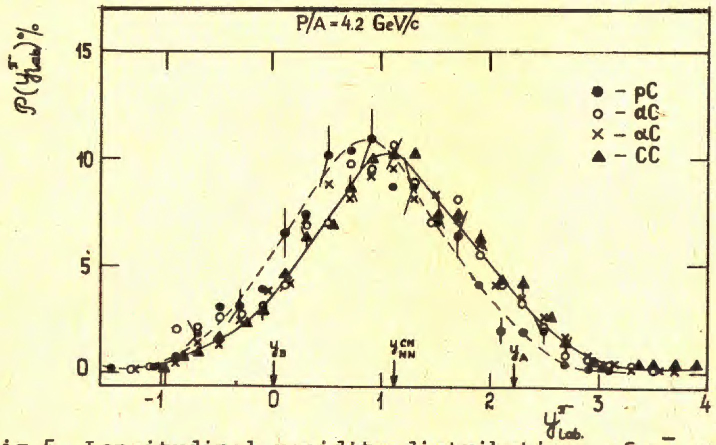


Fig.5. Longitudinal rapidity distributions of π^- mesons in the laboratory system for pC, dC, αC, and CC interactions. Curves are hand-drawn through the points for pC (- - -) and CC (——) to guide the eye.

The y_{Lab} distribution for CC interactions, as expected, is symmetric about y_{Lab} = 1.1 which corresponds to the value of NN centre-of-mass rapidity y^{CM}_{NN} (for 4.2 GeV/c per nucleon).

It is interesting to compare the π^- transverse momentum and rapidity spectra for different AC interactions in order to find what kinematic region in $P_\perp$ and in rapidity is responsible for the increase of the average π^- multiplicity with increasing the atomic mass of the projectile. Fig.6 allows one to conclude that the increase of n_- occurs for all $P_\perp$.

No particularly distinct region in $P_\perp$ is observed within our accuracy. Passing from dC to αC and CC interactions n_- increases uniformly for all rapidities within the errors (Fig.7).

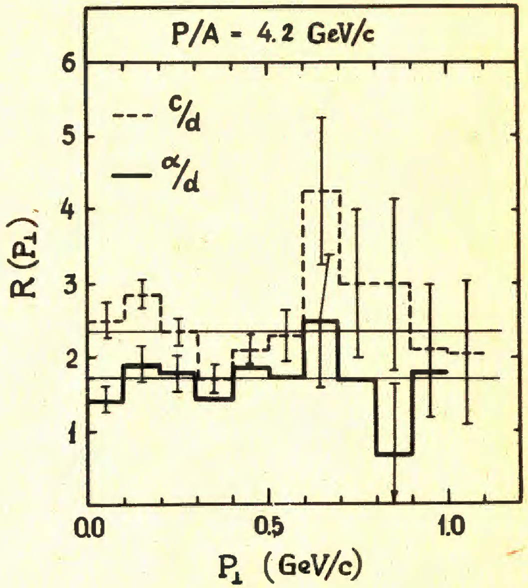


Fig.6. Ratio of π^- transverse momentum distribution for αC/dC (——) and CC/dC (- - -) interactions. Thin horizontal lines show the corresponding ratios of average total π^- multiplicities.

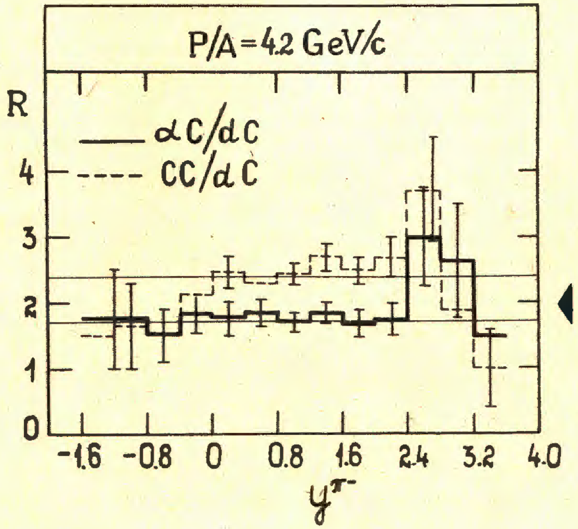


Fig.7. Ratio of π^- rapidity distributions for αC/dC (——) and CC/dC (- - -) interactions. Thin horizontal lines show the corresponding ratios of average total π^- multiplicities.

Table 8

Ratios of inclusive cross sections for π^- production for $y_{Lab}>0.6$

	$\sigma^{\pi^-}_{CC}/\sigma^{\pi^-}_{\alpha C}$	$\sigma^{\pi^-}_{CC}/\sigma^{\pi^-}_{dC}$	$\sigma^{\pi^-}_{\alpha C}/\sigma^{\pi^-}_{dC}$
experiment	2.7 ± 0.3	5.2 ± 0.6	1.9 ± 0.2
MSM	3	6	2

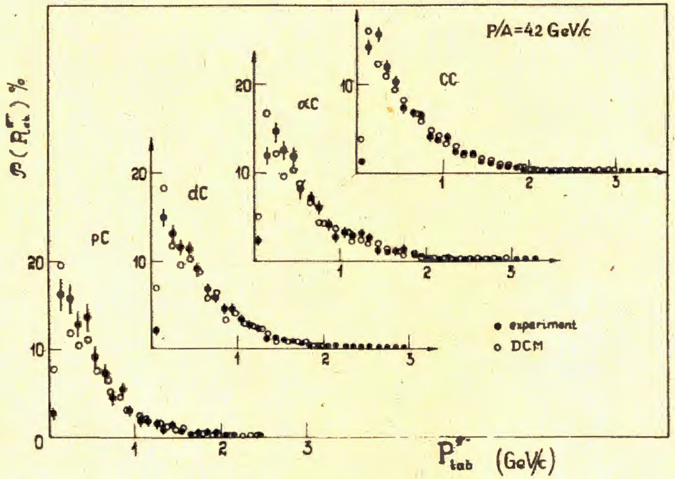


Fig.8. Comparison of experimental P_{Lab} distributions for pC , dC , αC and CC interactions with predictions of the Dubna cascade model (DCM).

It is possible only to speak about a tendency of an increasing role of the region of projectile fragmentation.

The experimental π^- spectra have been compared with the corresponding spectra calculated in the cascade model (DCM) (see Figs.8-10). For all four types of interactions DCM correctly predicts general features of the spectra. Only in the course of detailed comparison some differences are seen between experimental data and model calculations. The average values of P_{Lab}, θ_{Lab} and y_{Lab} from DCM are close to the experimental values, but it is possible to see in DCM spectra some redistribution of π^- mesons over the kinematically allowed region (Figs.8,9). The DCM values of $\langle P_\perp \rangle^{\pi^-}$ are lower than the ex-

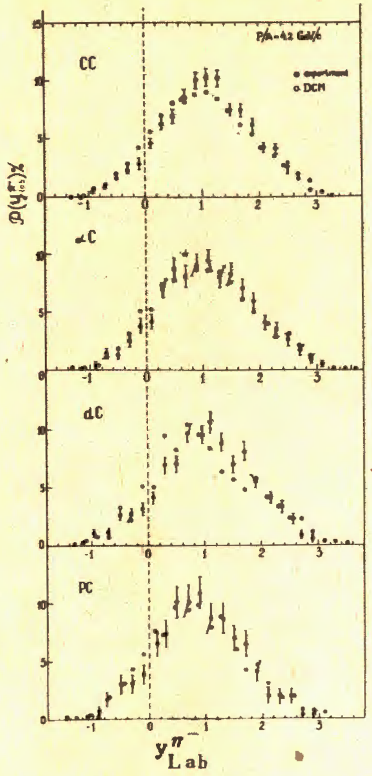
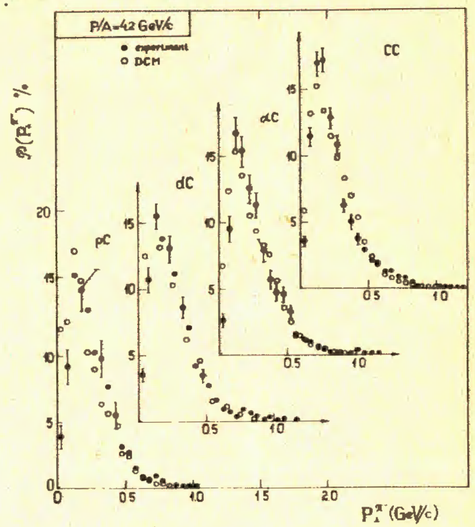


Fig.9. Comparison of experimental y_{Lab} distributions for pC, dC , αC, and CC interactions with the predictions of DCM.

Fig.10. Comparison of experimental $P_\perp$ distributions for pC , dC , αC, and CC interactions with the predictions of DCM.



perimental ones with the difference becoming smaller with increasing the atomic mass of the projectile (Fig.10). The multiple scattering model predicts that for interactions of different projectiles with the same target nucleus the following relation must be valid for inclusive cross sections for π meson production in the central rapidity region and in the region of beam nucleus fragmentation

$$\frac{\sigma(A_1B\to\pi^-+\dots)}{\sigma(A_2B\to\pi^-+\dots)}=\frac{A_1}{A_2}. \qquad (4)$$

At our beam energy formula (4) is expected to be valid for $A\ll B$.

To check relation (4), the inclusive cross sections for π^--meson production in the region $y^{\pi^-}_{Lab}>0.6$ were used which obviously fulfils the conditions of MSM. The results are given in Table 8. One can see that the ratios of experimental cross sections in the region $y^{\pi^-}_{Lab}>0.6$ are in good agreement with expectations from MSM.

5. CONCLUSIONS

The made comparison of inelastic pC , dC , αC , and CC interactions at P = 4.2 GeV/c per nucleon shows:

1. The average number $\langle\nu\rangle$ of nucleons from the projectile nucleus which participate in the interaction increases with increasing the atomic mass of the projectile.

2. The mean multiplicity of produced π^- mesons increases linearly with $\langle\nu\rangle$.

3. Dispersion of the multiplicity distribution of π^- mesons increases proportionally to their mean multiplicity.

4. The increase of the multiplicity from dC to αC and CC interactions is realized practically uniformly over the entire region of variation of $P_\perp$ and y_{Lab}.

5. Increase of projectile atomic mass (from 2 to 12) causes little changes to the shape of π^- kinematic distributions. The mean values of the kinematic variables studied do not change by more than 10%.

The general characteristics of inelastic interactions of light nuclei presented in this paper are sufficiently well described by the Dubna cascade model. The experimental multiplicities and ratios of inclusive cross sections of π^- mesons in dC , αC , and CC reactions are correctly reproduced by the multiple scattering model.

Thus, the inelastic interactions of light nuclei studied by us may be treated predominantly as a superposition of independent interactions of projectile nucleons with the target.

A slight asymmetry in π^- rapidity distributions observed for interactions of non-identical nuclei is caused by different contributions of cascade processes (secondary interactions) in the colliding nuclei.

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Множественность, импульсные и угловые характеристики π^--мезонов, образующихся в pC-, dC-, αC- и CC-взаимодействиях при импульсе 4,2 ГэВ/с на нуклон

Исследовались множественность, импульсные и угловые характеристики π^--мезонов, образовавшихся во взаимодействиях легких ядер (p, d, α, C) с ядром углерода при импульсе 4,2 ГэВ/с на нуклон. Показано, что средняя множественость π^--мезонов растет пропорционально числу нуклонов ядра-снаряда, участвующих во взаимодействии с ядром углерода. Обнаружена линейная зависимость дисперсии распределения по числу π^--мезонов от $\langle n_- \rangle$. Распределения π^--мезонов по $P_{лаб.}$, $\Theta_{лаб.}$, $P_\perp$ и $y_{лаб.}$ слабо зависят от атомного веса налетающего ядра. Экспериментальные данные удовлетворительно описываются каскадной моделью /дубненский вариант/ и моделью многократного рассеяния.

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Agakishiev H.N. et al. E1-84-321

Multiplicity, Momentum and Angular Characteristics of π^--Mesons for pC, dC, αC and CC Interactions at 4.2 GeV/c per Nucleon

Multiplicity, momentum and angular characteristics of π^- mesons produced in interactions of light nuclei (p, d, α, C) with carbon at a momentum of 4.2 GeV/c per nucleon are investigated. It is shown that the average multiplicity of π^- mesons, $\langle n_- \rangle$, increases proportionally to the number of nucleons of the projectile nucleus which participate in the interaction with a carbon nucleus. A linear dependence of the dispersion of the π^- meson multiplicity distribution on $\langle n_- \rangle$ is observed. The shape of the π^- meson distributions over $P_{lab.}$, $\Theta_{lab.}$, $P_\perp$ and $y_{lab.}$ weakly depends on the atomic weight of the projectile. The experimental data can be satisfactorily described by the Dubna version of the cascade model and by the multiple scattering model.

The investigation has been performed at the Laboratory of High Energies, JINR.

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