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INTERACTION CROSS SECTIONS AND NEGATIVE PION MULTIPLICITIES IN NUCLEUS-NUCLEUS COLLISIONS AT 4.2 GeV/c PER NUCLEON

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Ангелов Н. и др. E1 - 12548

Сечения взаимодействий и множественности отрицательных π-мезонов в ядро-ядерных соударениях при импульсе 4,2 ГэВ/с на нуклон

Представлены данные по неупругим сечениям и множественностям отрицательных пионов, образованных в столкновениях протонов, дейтонов, а также ядер ^{4}He и ^{12}C с импульсом 4,2 ГэВ/с на нуклон в пропановой пузырьковой камере с танталовыми пластинками.

Средние множественности и дисперсии распределения по множественности сравниваются с соответствующими величинами для нуклон-нуклонных соударений. Наблюдается отклонение данных для взаимодействий C-Ta от универсальной зависимости дисперсии от множественности. Множественности пионов оказываются пропорциональными числу нуклонов из падающего ядра, провзаимодействовавших в мишени.

Наши результаты не противоречат предположению о том, что нуклоны от падающих ядер взаимодействуют в мишени независимо.

Используя эффект интерференции тождественных частиц, удалось определить средний размер области испускания отрицательных пионов для C-Ta взаимодействий, который оказался равным $r = (3,3 \pm 0,6)$ fm.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1979

Angelov N. et al. E1 - 12548

Interaction Cross Sections and Negative Pion Multiplicities in Nucleus-Nucleus Collisions at 4.2 GeV/c per Nucleon

Data are presented on inelastic cross sections and multiplicities of negative pions produced in collisions of protons, deuterons, helium-4 and carbon-12 nuclei, all with incident momenta of 4.2 GeV/c per nucleon, in the propane bubble chamber with tantalum plates.

Average multiplicities and dispersions of multiplicity distributions are compared with those in nucleon-nucleon collisions. Deviation of C-Ta points from universal dependence of dispersion on multiplicity is observed. Pion multiplicities are found proportional to the number of nucleons from incident nucleus which interacted in the target.

Our results are not in contradiction with the assumption that nucleons from the incident nucleus interact independently in the target.

For C-Ta interactions the average radius of the pion emission volume has been determined by the interference method to be $r = (3.3 \pm 0.6)$ fm.

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1979

1. INTRODUCTION

Interest in studying inelastic interactions of relativistic nuclei has increased considerably in recent years. This was stimulated, on the one hand, by successes in developing intense nuclear beams from accelerators and, on the other hand, by fundamental theoretical ideas. In particular, in collisions of high-energy nuclei collective effects are expected which could cause an increase in the density of nuclear matter. In this case the multiple π-meson production might show features different from what is predicted by independent interaction models. Besides, study of nucleus-nucleus interactions may shed light on hadron-hadron interactions, which nowadays are also viewed upon as collisions of composite systems.

In this paper experimental data are presented on inelastic interactions of protons, deuterons, helium and carbon nuclei with tantalum ($A = 181$) and carbon ($A = 12$) nuclei at an incident momentum $P_0 = 4.2$ GeV/c per nucleon. Inelastic nucleus-nucleus interaction cross sections and characteristics of multiple π-meson production are obtained.

Similar studies have been made at JINR by the SKM-200 streamer chamber group [1] using several chemically simple targets (Li , C , Ne , Al , Cu , Pb) but with a helium beam only. Data from LBL [2] have been obtained using complex targets (LiH , NaF , BaI_2 , Pb_3O_4) exposed to C and Ar beams with momenta up to 2.9 GeV/c per nucleon.

2. DATA HANDLING PROCEDURE

The experiment has been performed using the JINR High Energy Lab. 2-m propane bubble chamber with three tantalum plates 1 mm thick inside the chamber volume. The interplate distance was 93 mm. The chamber was exposed to the beams of light nuclei ($A \le 12$) with momenta $P_0 = (2 \div 5)$ GeV/c per nucleon [3,4]. Figure 1 shows a typical interaction of a carbon nucleus with tantalum at a momentum $p_0 = 4.2$ GeV/c per nucleon.

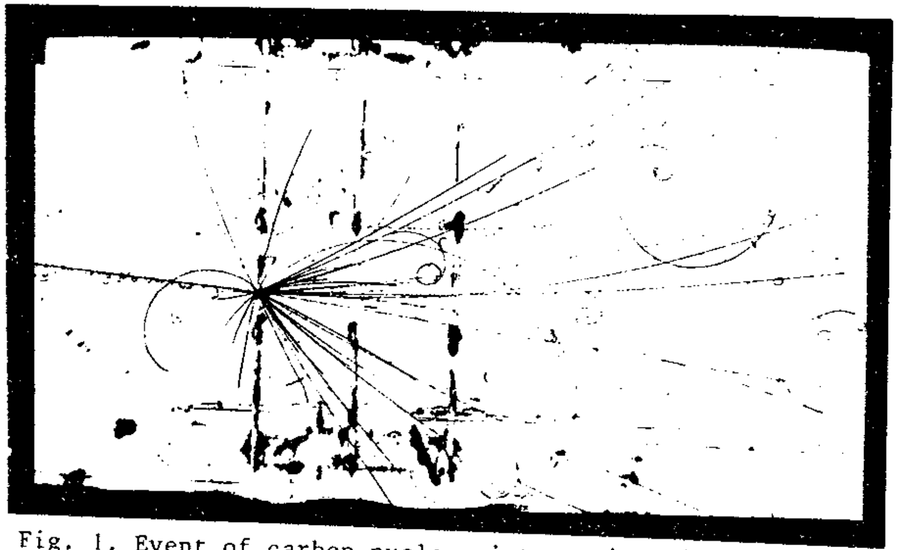

Fig. 1. Event of carbon nucleus interaction with tantalum at $p_0 = 4.2$ GeV/c per nucleon (total momentum of the incident nucleus is about 50 GeV/c).

The cross sections were determined from the scanning results by counting the number of beam tracks and the number of interactions [5]. The contamination of non-beam tracks among the beam tracks turned out to be insignificant for all our exposures ($\sim$ (1-3)%).

The events were recorded in target plates as well as in propane. The fiducial volume along the beam was in between the first and the third plates. The visual selection of stars in plates led to a certain contamination by events in propane in the near vicinity of the plates. This contamination amounted to (7±2; 9±3; 9±3; 13±4)% for p , d , He , and C exposures, respectively, and the corresponding corrections were made.

In each event the number of secondary tracks was determined and a classification of the tracks was made. Tracks of noninteracting fragments of the incident nucleus were identified among positive tracks [4]. The charge of such fragments was determined by ionization density, or, in the case of carbon exposure, also by means of counting δ - electrons [6]. All the negative tracks in a star, except the identified electrons, were considered as π^--mesons. According to the pp-data, the contamination by negative strange particles should not exceed 1%. The average threshold momentum starting from which π^--mesons were unambiguously identified, was $p_{min} = 70$ MeV/c for stars in propane and $p_{min} = 80$ MeV/c for events in tantalum. The contamination of π^--mesons by misidentified electrons did not exceed 3% for events in tantalum and was essentially zero for stars in propane.

The cross sections were determined on the basis of 8869 events in propane and 1554 events in tantalum, while the multiplicities of secondary particles were studied using 4401 events in propane and 4002 events in tantalum.

3. INELASTIC CROSS SECTIONS OF NUCLEUS-NUCLEUS INTERACTIONS

The cross sections were obtained from the formula:

$$N = N_0 [1 - \exp (-n \sigma x)] , \qquad (1)$$

where N is the number of events in tantalum (propane), N_0 is the number of beam tracks, n is the number of nuclei in 1 cm^3 of the target, x is the thickness of the tantalum target (propane layer) in the beam direction, and σ is the inelastic cross section. The densities of propane and tantalum were taken as 0.43 g/cm^3 and 16.6 g/cm^3, respectively. In order to extract the cross sections of interaction with carbon nucleus, we used the following relation

$$\sigma_{C_3H_8} = 3\sigma_c + 8\sigma_p . \qquad (2)$$

Here $\sigma_{C_3H_8}$ is the cross section for interaction with propane molecule, which is measured experimentally; σ_c is the cross section for interaction with carbon nucleus and σ_p is the same for the proton. The pp , dp , Hep, and Cp cross sections were taken from ref. [7]. The obtained cross sections correspond to

$$\sigma_{in} = \sigma_{tot} - \sigma_{el} - \sigma'_{el} - \sigma_{dif} , \qquad (3)$$

where σ_{tot} is the total cross section of nucleus-nucleus interaction, σ_{el} the elastic nucleus-nucleus cross section, σ'_{el} the scattering cross section with excitation of nucleus and σ_{dif} the cross section of diffractive dissociation of nuclei. Contribution of the coherent particle production process is insignificant at our energies.

Table 1 presents the inelastic cross sections (in barns) for the interactions of p , d , He , and C with carbon and tantalum nuclei. Figure 2 shows presently available data on the inelastic nucleus-nucleus cross section dependence on the atomic weight of the projectile nucleus A_i and of the target nucleus A_t /5/. Projectiles vary from proton to oxygen, while targets vary from deuterium to lead. The values of beam momenta per nucleon range from 1 to 5 GeV/c. Our data at 4.2 GeV/c per nucleon are shown by open circles in Fig. 2. Within experimental errors no energy dependence is observed.

Table 1

Inelastic nucleus-nucleus cross sections (in barns)

A_t \ A_i	p	d	He	C
C	0.250±0.015	0.38±0.02	0.44±0.02	0.79±0.05
Ta	1.67 ± 0.11	1.94±0.11	2.34±0.12	3.67±0.22

As is seen from the experimental data, the cross sections obtained in counter experiments are, as a rule, greater than those obtained in track-chamber experiments. Perhaps, this is due to the fact that in counter experiments σ_{in} is obtained indirectly as the difference between the total and elastic cross sections:

$$\sigma_{in} = \sigma_{tot} - \sigma_{el} \, . \qquad (4)$$

In such approach σ_{in} comprises cross sections of all processes different from elastic.

The solid line in Fig. 2 represents the calculations according to the model of "hard spheres" with overlap /8/

$$\sigma_{in} = \pi R_0^2 (A_i^{1/3} + A_t^{1/3} - b)^2 \, . \qquad (5)$$

The R_0 and b parameters were fitted to the experimental points from track chamber experiments, $R_0 = (1.48 \pm 0.03)$ fm and b = 1.32 ±0.05. The crosses represent the calculations according to the model of "soft spheres"/9/. The experimental values of nuclear radii have been taken from ref./10/.

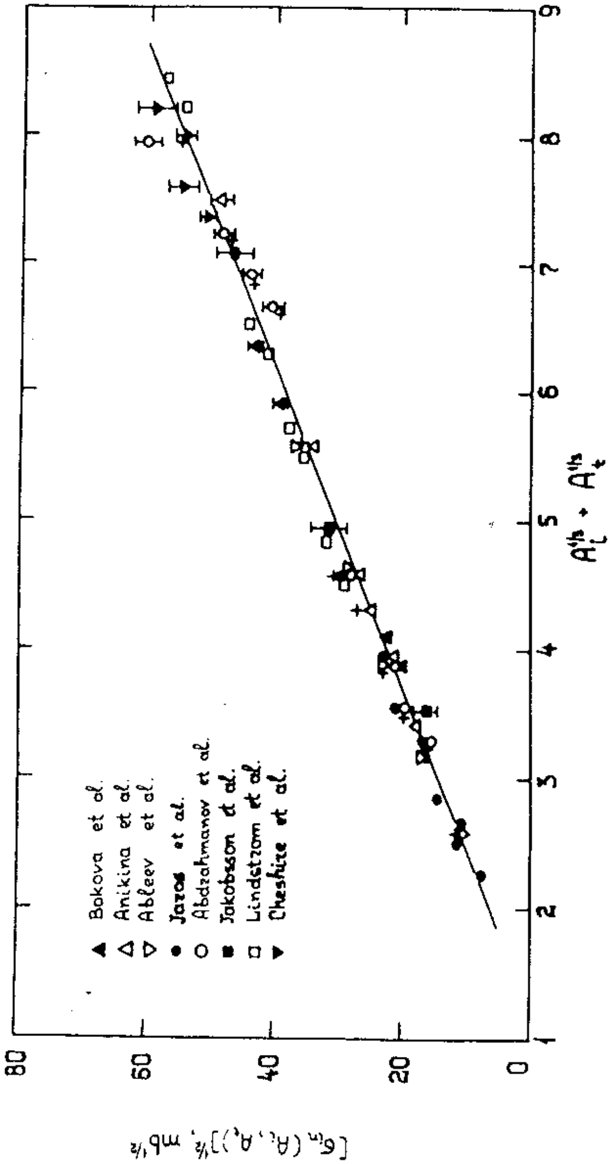

Fig. 2. Inelastic nucleus-nucleus cross sections as a function of the atomic weight of the projectile nucleus A_i and of the target nucleus A_t.

It is seen that the calculations in the framework of simple geometric models [8,9] are in satisfactory agreement with the experimental cross sections.

4. MULTIPLICITIES OF NEGATIVE SECONDARY π -MESONS

For comparison with other experiments and with theoretical calculations it is desirable to extract from the propane data the information on the interaction with carbon nuclei. Using the pp inelastic data [7] and the cross sections given in Table 1, one can obtain the π^--multiplicity distribution in pC -interactions by subtracting the corresponding distribution in pp -interactions from that in $p(C_3H_8)$-interactions. Using the obtained distribution for pC -interaction (which should be equivalent to Cp -interaction) and data from Table 1, one can also extract the corresponding distribution for CC -collisions. To obtain similar distributions in dC- and HeC-interactions, it is necessary to have experimental data on dp- and Hep -collisions which are at present not available for our energy. But it is quite safe to assume that at $p_0 = 4.2$ GeV/c per nucleon these distributions differ inessentially from the analogous distributions in pC-interactions. Indeed, from the pp [7] and pn [11] experimental data it is possible to obtain the average multiplicity of produced π^--mesons, $\langle n_- \rangle$, and the dispersion, $D_- = \sqrt{\langle n_-^2 \rangle - \langle n_- \rangle^2}$, in p -nucleon (pN) -interactions. It has turned out that the average multiplicity and the dispersion, if the normalization to the total pN cross section is used, are equal to:

$$\langle n_- \rangle = 0.30 \pm 0.015, \qquad D_- = 0.49 \pm 0.01 \qquad (6)$$

while for pC -interactions

$$\langle n_- \rangle = 0.33 \pm 0.02, \qquad D_- = 0.53 \pm 0.015 \qquad (7)$$

which supports our assumption. Thus, in order to obtain the π^--meson multiplicity distributions in dC- and HeC-interactions, we used the corresponding distribution in pN -collisions.

According to our estimates, the subtraction procedure and the uncertainty in the values of corrections might have caused an error of about 5% in our values of $\langle n_- \rangle$ and D_-.

Figures 3a,3b present the π^--meson multiplicity distributions in inelastic p-, d-, He-, and C -collisions with carbon and tantalum. The curves in these figures represent the Poisson distributions with the parameters taken from experiment. In Table 2, the values are given of average multiplicities, $\langle n_- \rangle$, and dispersions, D_-, for the interactions of projectile nuclei with carbon and tantalum. From Figs.3a,3b and from the values of the ratio $\langle n_- \rangle / D_-^2$ given in Table 2, it is seen that in the case of light incident nuclei the π^--meson multiplicity distributions are almost Poisson-like, though there is some tendency of the ratio $\langle n_- \rangle / D_-^2$ to decrease towards higher atomic numbers A_i of the incoming nucleus. In the case of carbon exposure

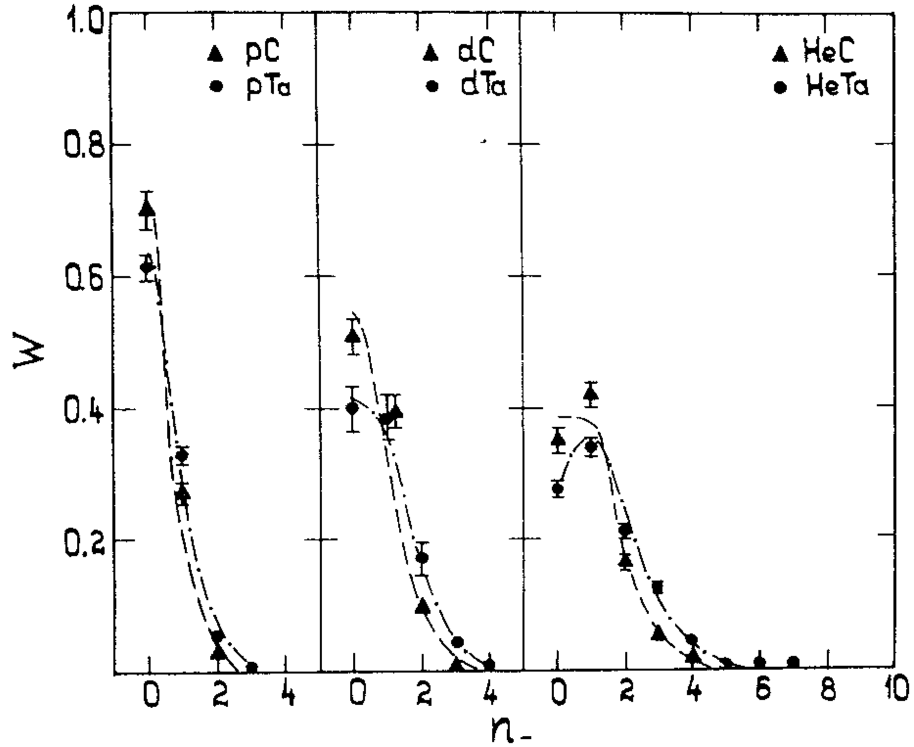

Fig. 3a. Multiplicity distributions of negative particles in inelastic p-, d-, He -interactions with carbon (▲) and tantalum (●). The curves represent the Poisson distributions with average values taken from the experiment.

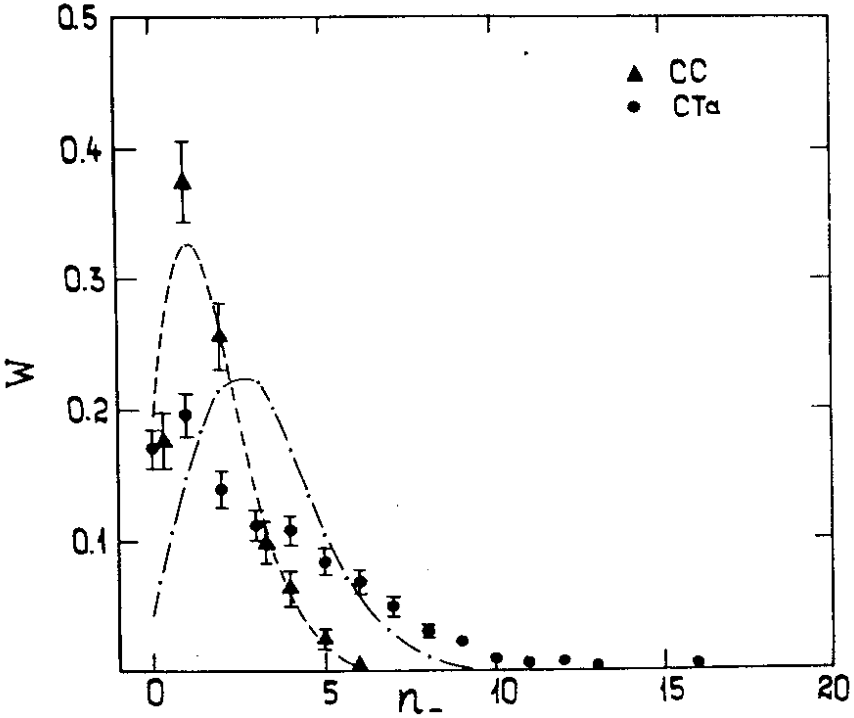

Fig. 3b. The same as in Fig. 3a, but for the incident carbon nucleus.

Table 2

Average multiplicities $\langle n_-\rangle$ and dispersions D_- of the π^- multiplicity distributions for interactions of projectile nuclei with carbon and tantalum

A_i	A_t	$\langle n_-\rangle$	D_-	$\frac{\langle n_-\rangle}{D_-^2}$
p	C	0.33±0.02	0.53 ± 0.015	1.17 ± 0.09
	Ta	0.45±0.02	0.62 ± 0.015	1.17 ± 0.08
d	C	0.60 ±0.04	0.69 ± 0.03	1.26 ±0.13
	Ta	0.88±0.07	0.86± 0.05	1.19 ± 0.15
He	C	0.97±0.05	0.94 ± 0.04	1.10 ± 0.10
	Ta	1.36±0.06	1.20 ± 0.04	0.94 ± 0.08
C	C	1.60±0.10	1.29 ± 0.07	0.96 ± 0.12
	Ta	3.12±0.12	2.77 ± 0.08	0.41 ± 0.03

the π^- -meson multiplicity distribution for C–Ta collisions is visibly wider than the Poisson distribution. However, it is worthwhile to note that if one selects C–Ta interactions without stripping particles ("central collisions"), then the π^- -multiplicity distribution for such events is also Poisson-like ($\langle n_-\rangle = 6.5\pm0.6$, $D_-^2 = 7.3\pm0.8$).

5. COMPARISON WITH N–N INTERACTION

In pp -collisions all events, except elastic scattering, are considered as inelastic ones. At our energy these are mainly processes where at least one π^0 is produced. From this point of view the processes with pion production in nucleus-nucleus interactions should be considered as the analogue of inelastic pp- collisions /1/. To measure experimentally the cross section of such a process is methodically difficult - so, in order to estimate the contribution of the events without particle production, we have calculated the cross sections σ_{in} and σ_{prod} according to the model of "soft spheres", which describes well the experimental values of σ_{in} /5/ . In Table 3 we present the calculated values of the ratio σ_{prod} to σ_{in} for our experiment. The values of the ratio $\sigma_{prod}/\sigma_{in}$ were used to obtain the values of $\langle n_-\rangle$ and D_- with normalization to σ_{prod}.

Table 3

Ratios of the calculated cross sections $\sigma_{prod}/\sigma_{in}$ for p-, d-, He-, and C-interactions with carbon and tantalum

A_t \ A_i	p	d	He	C
C	0.816	0.859	0.888	0.916
Ta	0.936	0.941	0.949	0.958

Figure 4 shows the dependence of the experimental values of D_- on the average multiplicities $\langle n_-\rangle$. Besides our data, Fig. 4 includes also the data on the interactions of helium nuclei with a momentum of 4.5 GeV/c per nucleon with various targets obtained from the streamer chamber in Dubna /1/. The straight line represents the empirical Malhotra-Wróblewski fit to inelastic pp -interactions in an energy range of 4÷400 GeV/c. It is seen that the experimental points for

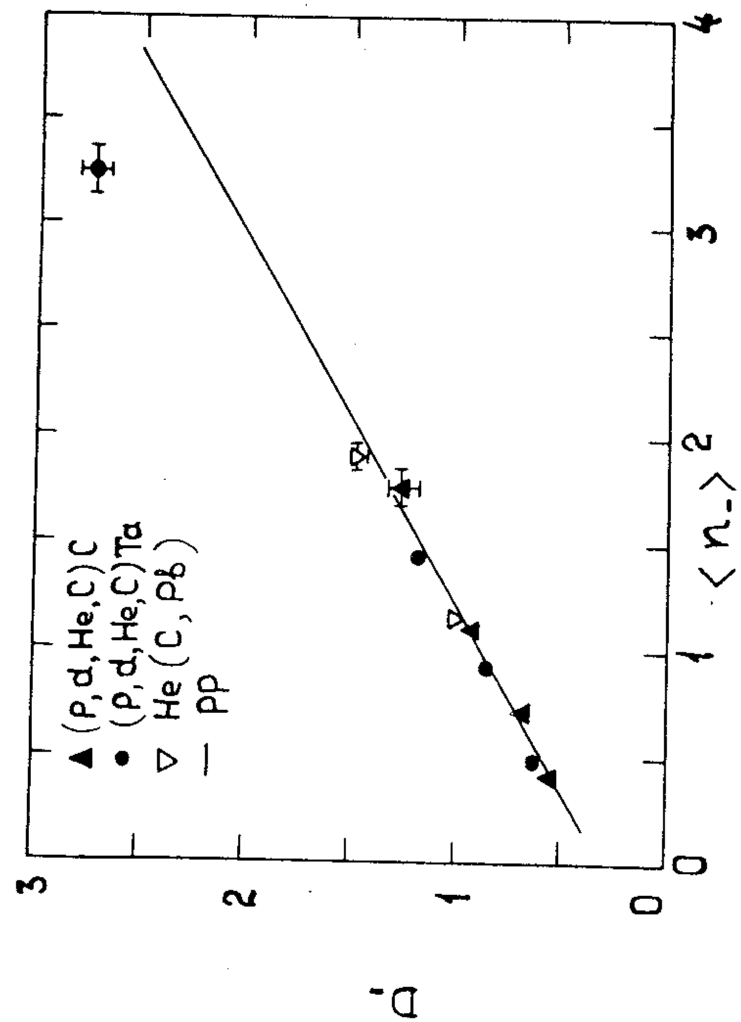

Fig. 4. Dependence of the experimental dispersion values $D_- = \sqrt{\langle n_-^2 \rangle - \langle n_- \rangle^2}$ on the average negative particle multiplicities $\langle n_- \rangle$ in pp and AA interactions. ▲, ● - our data, ▽ - data from ref./1/. The straight line represents the empirical Malhotra-Wróblewski dependence for inelastic pp interactions.

p-, d-, and He -interactions with various nuclei follow the Malhotra-Wróblewski linear dependence. Thus for the π^- -meson multiplicity distributions a certain similarity is seen between nucleus-nucleus and proton-proton interactions. This was first observed in the interactions of helium nuclei with various nuclear targets/1/. For carbon-tantalum interactions a deviation is observed from the linear dependence towards a relative broadening of the distribution. This deviation may be due to the increasing contribution to the dispersion D_- of the fluctuations in the number of interacting nucleons of the projectile nucleus.

If the experimental data on π^- -meson production in nucleon-nucleus interactions are taken as a basis and there is assumed the independent interactions of the nucleons of the projectile nucleus with the target nucleus, then the dispersion of the produced π^- -meson multiplicity distribution in nucleus-nucleus interactions takes the form *

$$D^2_{A_i A_t} = \langle \nu_i \rangle D^2_{NA_t} + \langle n_{NA_t} \rangle^2 D^2_\nu . \qquad (8)$$

Here $\langle \nu_i \rangle$ is the average number of nucleons of the projectile nucleus which has undergone the interaction, $\langle n_{NA_t} \rangle$ and D_{NA_t} are the average and the dispersion of the π^- -meson multiplicity distribution in NA_t -interactions, D_ν is the dispersion of the number of interacting nucleons of the projectile nucleus. It is seen from (8) that for large values of D_ν the second term becomes important.

The multiplicity distributions of negative π -mesons were analyzed in terms of the KNO-variables /13/. It turned out that for a unique description it was necessary to make use of the modified variable $Z' = (n_- - a)/\langle n_- - a \rangle$ introduced in ref./14/. The value of the a -parameter was obtained by means of linear approximation of the dependence of the moments $D_q = \sqrt[q]{\langle (n - \langle n \rangle)^q \rangle}$ on $\langle n_- \rangle$ for q = 2,3 and 4, and, on the average, it was equal to $a = -0.6$. The condition $D_q / \langle n_- - a \rangle = \text{const}$, necessary for the modified KNO-scaling, is valid for all types of interactions we have studied except C–Ta collisions (see Table 4). In Fig. 5 the multiplicity distribution of negative pions is presented in terms of

$$\langle n_- - a \rangle \frac{\sigma_{n_-}}{\sigma_{prod}} = \psi(z') \qquad (9)$$

* A similar formula for hadron-nucleus interactions was considered in ref./12/.

Table 4

Ratios of the moments of negative particle multiplicity distributions to the average values

A_iA_t	$D_2/\langle n_- - \alpha\rangle$	$D_3/\langle n_- - \alpha\rangle$	$D_4/\langle n_- - \alpha\rangle$
pC	0.57±0.04	0.62±0.04	0.79±0.05
pTa	0.59±0.03	0.62±0.04	0.82±0.05
dC	0.57±0.03	0.55±0.04	0.77±0.05
dTa	0.59±0.04	0.54±0.05	0.78±0.06
HeC	0.60±0.03	0.61±0.04	0.86±0.05
HeTa	0.59±0.02	0.55±0.03	0.81±0.04
C C	0.58±0.03	0.60±0.05	0.85±0.06
CTa	0.75±0.03	0.75±0.05	1.04±0.06

for p-, d-, He-, and C-collisions with carbon and for p-, d-, and He-collisions with tantalum. For comparison the experimental data on negative particles produced in pp-interactions in an energy range from 60 to 400 GeV [15] are also presented in the same figure. The value of the α-parameter for pp-interactions was obtained as described above and was equal to $\alpha=-0.5$. It is seen that all the presented distributions are similar and they may be approximated with the unique function (9) in the form proposed in ref. [14]. For $\psi(z')$ we obtain the following parametrization:

$$\psi(z') = 1.50\,(z' + 0.07)\exp(-0.34z' - 0.58z'^2) \qquad (10)$$

with $\chi^2/NDF = 1.82$.

6. DEPENDENCE OF THE NEGATIVE π-MESON MULTIPLICITY ON THE ATOMIC WEIGHT AND ON THE NUMBER OF INTERACTING NUCLEONS OF THE INCOMING NUCLEUS

Figure 6 presents the dependence of the average multiplicity $\langle n_-\rangle$ of negative particles on the atomic weight of the incoming nucleus A_i for two target nuclei: carbon and tantalum. If for the first point one takes the multiplicity corresponding to the interaction of "average nucleon" N with nuclear target calculated on the basis of the available NN and pA data [4]

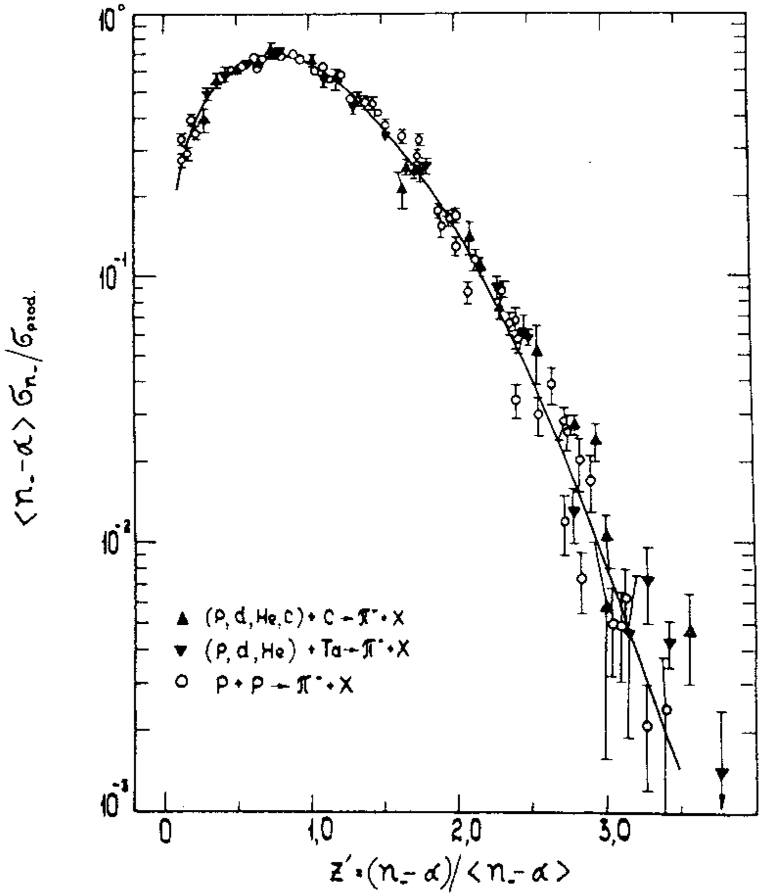

Fig. 5. Multiplicity distributions of negative particles in terms of modified KNO variables for nucleus-nucleus and pp collisions. The equation of the curve is given in the text.

$$\langle n_-\rangle_{NC} = 1/2(\langle n_-\rangle_{pC} + \langle n_-\rangle_{nC}) = 0.40\pm0.04,$$

$$\langle n_-\rangle_{NTa} = 1/2(\langle n_-\rangle_{pTa} + \langle n_-\rangle_{nTa}) = 0.55\pm0.03,$$

then it turns out that the $\langle n_-\rangle$ dependence on A_i is well described by the power function

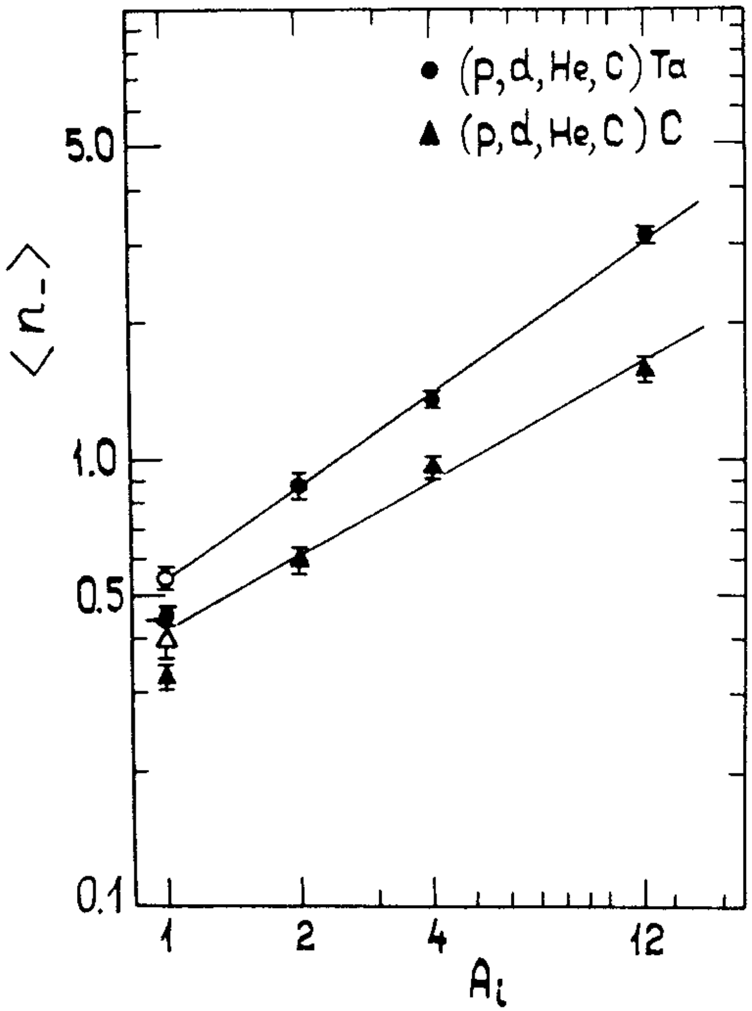

Fig. 6. Dependence of the average negative particle multiplicity $\langle n_- \rangle$ on the atomic weight of projectile nucleus A_i for p-, d-, He-, and C-collisions with carbon (▲) and tantalum (•). The calculated multiplicities for interactions of "average nucleon" are denoted by (Δ, 0). The straight lines are defined in the text.

$$\langle n_- \rangle = k\, A_i^{\alpha}. \quad (11)$$

For interactions with carbon we obtain

$k = 0.42 \pm 0.03$, $\alpha = 0.55 \pm 0.04$ at $\chi^2/NDF = 1.25$,

while for interactions with tantalum

$k = 0.54 \pm 0.03$, $\alpha = 0.70 \pm 0.03$ at $\chi^2/NDF = 0.70$.

So the dependence of the π-meson yield on A_i turns out to be strong, unlike the weak rise of the π-meson yield with A_t, which is observed in all the experiments on hadron-nucleus interactions ($\alpha \cong 0.1 \div 0.2$).

This strong dependence becomes clear if it is compared with the estimates of the average number, $\langle \nu_i \rangle$, of interacting nucleons of the incoming nucleus. Such estimates can be obtained if one determines the average charge of stripping particles $\langle q_s \rangle$. For (p, d, He, and C) interactions with the tantalum nucleus the values of $\langle \nu_i \rangle$ were presented in our previous paper /4/. The average number of interacting nucleons of the incoming nucleus was determined according to the formula

$$\langle \nu_i \rangle = 2(Z - \langle q_s \rangle), \quad (12)$$

where Z is the charge of the incident nucleus. Table 5 gives the values of the ratio $\langle n_- \rangle / \langle \nu_i \rangle$ for the collisions of "average nucleon" N and of d, He, and C nuclei with the propane molecule and with carbon and tantalum nuclei. This ratio characterizes the number of produced π^--mesons per one interacting nucleon of the incoming nucleus. The data for carbon target were obtained from the propane data under

Table 5

Values of the ratio $\langle n_- \rangle / \langle \nu_i \rangle$ or the numbers of produced negative particles per one interacting nucleon of the incident nucleus

A_i \ A_t	C_3H_8	C	Ta
N	0.37 ± 0.04	0.40 ± 0.04	0.55 ± 0.03
d	0.37 ± 0.03	0.39 ± 0.04	0.55 ± 0.05
He	0.37 ± 0.03	0.39 ± 0.04	0.50 ± 0.03
C	–	–	0.52 ± 0.06

the assumption that only one nucleon of the primary deuteron, or the helium nucleus interacts with hydrogen in the propane molecule. It is seen that for a given target the ratio $\langle n_- \rangle / \langle \nu_i \rangle$ is constant. Such a picture is expected if the nucleons from the incident nucleus interact independently in the target.

It is interesting to notice that the approximate independence of the ratio $\langle n_- \rangle / \langle n_{ch} \rangle$ on A_i and A_t, observed in ref./2/, is not supported by our data. This is a consequence of the fact that the average multiplicity of positive secondaries rises with increasing A_i weaker than that of negative particles /4/.

7. OBSERVATION OF THE INTERFERENCE EFFECT OF "LIKE" PIONS AND DETERMINATION OF THE SIZE OF THEIR PRODUCTION REGION IN C-Ta COLLISIONS

The space-time picture of the particle production process in nucleus-nucleus interactions is of great interest. For measuring the size of the pion emission volume r and its life-time τ in nucleus-nucleus collisions, the method based on studying the interference effect of "like" Bose-particles can be used. This method has been proposed and developed in detail by Kopylov and Podgoretsky/16/. Studying interactions of ^{40}Ar nuclei at 1.8 GeV/nucleon with complex targets BaI_2 and Pb_3O_4 the value of $r \cong (4\pm1)$ fm has been obtained in ref./17/.

If E_1, $\vec{p}_1$ and E_2, $\vec{p}_2$ are the energies and momenta of two particles emitted from the surface of an excited spherical volume with radius r and lifetime τ, then, as it was shown by Kopylov /18/, introducing the variables

$$q_0 = |E_1 - E_2| \qquad \text{and} \qquad \vec{q} = \vec{q}_\perp - \vec{n}(\vec{q}\cdot\vec{n}) \,, \tag{13}$$

where

$$\vec{q} = \vec{p}_1 - \vec{p}_2 \qquad \text{and} \qquad \vec{n} = \frac{\vec{p}_1 + \vec{p}_2}{|\vec{p}_1 + \vec{p}_2|} \,,$$

the probability to detect such a pair can be written as:

$$W(q_0, q_\perp^2) = \left[1 + \frac{(2J_1(q_\perp r)/q_\perp r)^2}{1 + (q_0 \tau)^2} \right] W_0(q_0, q_\perp^2) \,. \tag{14}$$

Here $J_1(q_\perp r)$ is the Bessel function of the first order, $W_0(q_0, q_\perp^2)$ is the "background" distribution, i.e., the distribution when the interference effect is absent. As is seen from (14), the probability to detect a pair of genetically connected like Bose-particles is greater than that for unlike particles. The less the energy difference of the two given particles and the less the angle between their momenta, the greater the effect.

The radius r and the lifetime τ of the emission volume of negative pions can be obtained by fitting the experimental distribution $dN(q_0, q_\perp^2)/d(q_0, q_\perp^2)$ with functions of the form (14). However, the statistics available so far do not permit one to fit the experimental distributions with two-dimensional functions, thus obtaining simultaneously both parameters r and τ. So the radius of the interaction volume has been obtained by fitting the one-dimensional distribution $R_{\pi^-\pi^-}$ with the function of the form

$$G(q_\perp^2) = a\left[1 + b\,\frac{4J_1^2(q_\perp r)}{(q_\perp r)^2} \right] \,, \tag{15}$$

which follows from (14) under the assumption that τ = const. The $R_{\pi^-\pi^-}$ distribution is defined as follows

$$R_{\pi^-\pi^-}(q_\perp^2) = \left\{ \frac{(dN/dq_\perp^2)^{eff}}{(dN/dq_\perp^2)^{bgr}} \right\}_{q_0 < 300\,\mathrm{MeV}} \tag{16}$$

where $(dN/dq_\perp^2)^{eff}$ is the $q_\perp^2$ differential distribution of $(\pi^-\pi^-)$ pairs produced in the same event, and $(dN/dq_\perp^2)^{bgr}$ is the similar distribution for $(\pi^-\pi^-)$ pairs from different events which we used as a "background distribution". The $R(q_\perp^2)$ distribution has been obtained under the restriction on the energy difference of the combined particles $q_0 <$ <300 MeV. Figure 7 shows the $R_{\pi^-\pi^-}$ distribution for C-Ta interactions. Fitting the function of the form (15) (shown in the Figure), we obtain that the radius of the pion emission volume is

$$r = (3.26 \pm 0.64)\ \mathrm{fm} \qquad \text{with} \qquad \chi^2/\mathrm{NDF} = 16.4/15.$$

8. CONCLUSIONS

From the review of the experimental data it follows that inelastic cross sections of relativistic nuclei interactions with nuclei are in reasonable agreement with the calculations according to the models based on geometrical picture.

The multiplicities of negative secondary pions appear to be proportional to the number of nucleons of the incoming nucleus, which have undergone interaction in the target.

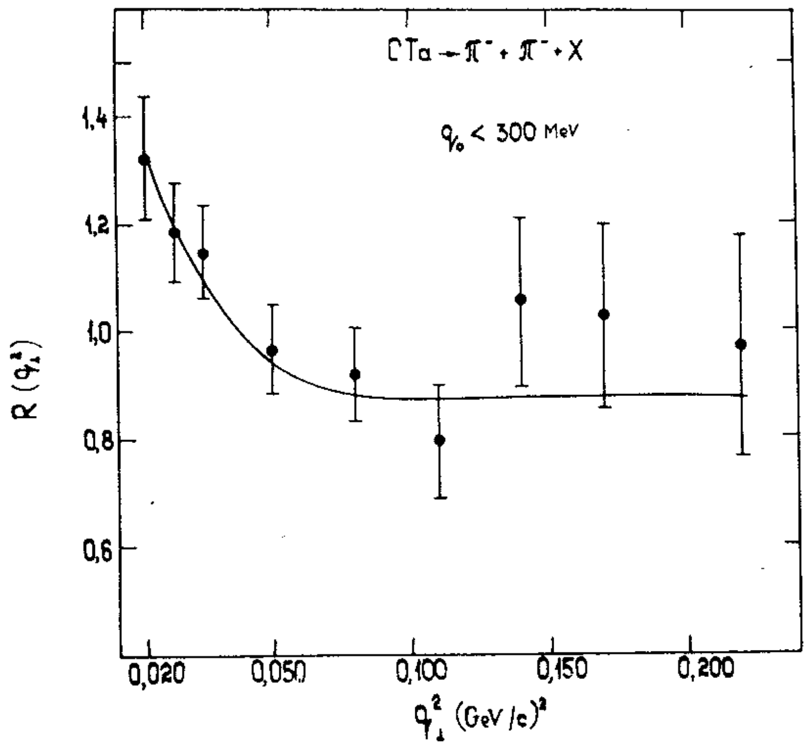

Fig. 7. $R_{\pi^-\pi^-}$ distribution as a function of $q_\perp^2$ for $q_0 < 300$ MeV for π^--meson pairs produced in C–Ta interactions.

The broadening of the π^--multiplicity distributions, observed in the carbon exposure of the tantalum target, indicates the contribution of a new source of fluctuations, which may be due to a random character of nucleon-nucleon collisions in nuclei. The composite structure of the interacting objects seems to manifest itself here.

Our results do not contradict the assumption of the independent interaction of nucleons of incoming nuclei with the target.

Using the "like"-particle interference effect, we have succeeded in measuring the average size of negative pion

emission volume in C–Ta interactions, which turned out to be $r = (3.3 \pm 0.6)$ fm.

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