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THE PROPERTIES OF NUCLEON CLUSTERS IN RELATIVISTIC NUCLEAR COLLISIONS

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1. INTRODUCTION

With the advent of relativistic nuclear collisions in laboratory, at Dubna (in 1970) and Berkeley (1974), a new scientific field has emerged from both the traditional domains of elementary particle physics and nuclear physics.

At present, the physics of relativistic nuclear collisions takes a leading place in the programme of investigations at the world's largest accelerators [1].

Such increasing interest of nuclear and particle physicists in these investigations is mainly motivated by hopes to obtain the states of highly excited nuclear matter including both the possibility of colour deconfinement and the realization of phase transition from hadronic matter to quark-gluon plasma (QGP).

The theoretical calculations made in the framework of lattice QCD predict [2] that the above-mentioned states can be obtained in relativistic heavy ion collisions either by «heating» the nuclear matter (in low quark density) to the temperatures around 150—200 MeV or by «compressing» it (at low temperatures) to the density approximately 5 times as large as the normal nuclear density, which is around 0.15 GeV/fm^3.

These predictions are of great importance for the construction of both the theory of strong interactions and modern nuclear theory, and also for the cosmology [3] and astrophysics [4]. The creation of QGP helps to realize in laboratory the hypothetic states of matter which in the early Universe took place in the inverse direction some 10^{-5} s after the Big Bang, and gives the possibility of studying these states at different stages of time up to the cooling of QGP (cosmic expansion) and its transformation into colourless objects — hadrons (hadronization process). On the other hand, the observation and study of the properties of a plasma of deconfined quarks and gluons will allow one to understand the nature of neutron stars and other cosmic objects which can be in the phase of some type of plasma.

However, to interpret the theoretical notions to the language of facts obtained in studies, it is necessary to set up some heavy ion experiments at high energies, which will provide one with unambiguous answer to such questions as:

— What kind of state is the state of highly excited nuclear matter in terms of the observed values?

— Does any similarity of excited matter thermalization appear?

— How could one observe the exhibition of quark-gluon degrees of freedom and colour deconfinement? And so on.

The results of many groups of physicists working in the field of relativistic nuclear physics answer to these questions [5] in part.

The present investigation is mainly devoted to search for and study of the states of highly excited nuclear matter in different types of hadron-nucleus and nucleus-nucleus collisions over an energy interval of 4.0—40 GeV/c by studying the properties of nucleon clusters with the aid of a new relativistic invariant method in the space of relative 4-velocities [6].

2. METHOD OF DATA ANALYSIS

In contrast to the traditional methods (e.g., inclusive or semi-inclusive), the new method allows us not only to apply experimental information in full, but also to order a complicated picture of nuclear collisions at high energies.

In the method, the processes of multiple particle production

$$\mathrm{I} + \mathrm{II} \rightarrow 1 + 2 + \ldots \qquad (1)$$

are considered in a space the points of which $u_i = p_i/m_i$ are 4-velocities, and positive invariant dimensionless quantities

$$b_{ik} = -(u_i - u_k)^2; \quad i, k = \mathrm{I}, \mathrm{II}, 1, 2, \ldots \qquad (2)$$

are basic variables describing the relative particle motion in this space.

One of the most important conclusions of the paper devoted to the analysis of multiple particle production in relative 4-velocity space is the existence of two characteristic distances in it: $b_1 \cong 0.01$ (nuclear scale) and $b_2 \cong 1$ (quark scale). Two intermediate asymptotic regions, $b_{ik} >> b_1$ and $b_{ik} >> b_2$, should correspond to these values. In these regions the probability distributions (or cross sections) W as a function of b_{ik}, i.e. $W(\ldots, b_{ik}, \ldots) = d\sigma/(\Pi d b_{ik})$, have to satisfy the properties of two general principles: the automodelity [7] and correlation depletion [8] principles.

In this connection, the clusters with relative velocities of particles inside the cluster, $0.01 \le b_{ik} << 1$, characterize highly excited nucleon matter (nucleon cluster production), and the clusters with internal relative velocities, $b_{ik} \ge 1$, quark-gluon matter (hadron jet production). The properties of these different 4-dimensional clusters should be described by formulae of the type

$$W(\ldots, b_{ik}, \ldots)|_{\alpha\beta \rightarrow \infty} \rightarrow [1/b^m_{\alpha\beta}]\,[W^\alpha(b_{\alpha k}, x_k = b_{\beta k}/b_{\alpha\beta}) W^\beta(b_{\beta i}, x_i = b_{\alpha i}/b_{\alpha\beta})],$$

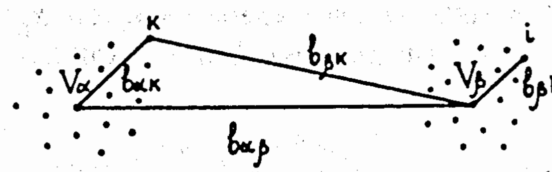

Fig.1. The diagram showing two groups of some noncorrelated secondary particle systems «α» and «β» which are considered as 4-dimensional clusters in the relative 4-velocity space

although they lie in various regions of the kinematical variables. Here α and β are two 4-dimensional clusters or some other noncorrelated (or weakly correlated) secondary particle systems which are considered as clusters in 4-velocity space; $b_{\alpha k}$, $b_{\beta k}$ etc. are squared relative 4-velocities, which can be understood from Fig.1.

Introduction of conception or relative distances into the 4-velocity space allows one to define and observe 4-dimensional clusters in this space which are hadron jets or nucleon clusters. It has been found [9] that nucleon clusters are mostly produced in the region $0.01 \le b_{ik} < 1$ and hadron jets, in the second one $b_{ik} >> 1$.

By clusters are meant (see Fig.1) the groups of points u_i (each point corresponds to the real particle), and the distance between them, b_{ik}, is much smaller than the average distance between all the points of the set or than the average distance between particles over the whole phase volume of the reaction.

The center of cluster (or jet axis) is determined as a single 4-vector $V_\alpha = \sum u_k / \sqrt{(\sum u_k)^2}$ extracted from the condition of minimum of the quantity $\sum b_k = -\sum (V_\alpha - u_k)^2$. Here summation is performed over all particles belonging to separate group of particle «α». The two clusters («α» and «β») are separated by minimizing the quantity

$$A_n = \min\{-\frac{1}{n_\alpha}\sum (V_\alpha - u^\alpha_k)^2 - \frac{1}{n_\beta}\sum (V_\beta - u^\beta_k)^2\}, \qquad (3)$$

representing the sum of 4-velocities squared of secondary particles relative to the cluster centers V_α and V_β (see Fig.1).

In this case the following condition is taken as a criterion of cluster separation: the distance $b_{\alpha\beta} = -(V_\alpha - V_\beta)^2$ between two centers of clusters α and β in the 4-velocity space should be $b_{\alpha\beta} \ge 1.0$ for nucleon clusters and $b_{\alpha\beta} \ge 10$ for hadron jets. It means that the average «size» of the cluster ($<b_k>$) in relative 4-velocity space is substantially smaller than the average «distances» ($<b_{\alpha\beta}>$) between them.

To determine the regions of cluster production, the variables X_{Icl} and X_{IIcl} are used. The 4-momentum fraction of colliding objects is carried away by these variables. They can be expressed as

$$X_{Icl} = \frac{m_{cl}^{\alpha(\beta)}}{m_I} \frac{(V_{\alpha(\beta)} u_{II})}{(u_I u_{II})} \quad \text{and} \quad X_{IIcl} = \frac{m_{cl}^{\alpha(\beta)}}{m_{II}} \frac{(V_{\alpha(\beta)} u_I)}{(u_I u_{II})} .$$

Here $m_{cl}^{\alpha(\beta)}$ is the effective mass of cluster α (or β), m_I the mass of an incident object, and m_{II} the target mass; for the nucleus $m_{II} \approx m_0$, where $m_0 = 931$ MeV.

The cluster was assumed to be produced in the projectile fragmentation region if $X_{Icl} > X_{IIcl}$, and in the target fragmentation region if $X_{IIcl} > X_{Icl}$.

In the further analysis the clusters produced in target fragmentation have been studied only because positively charged particles are identified better in this region.

Below the following quantities are used to characterize different properties of nucleon clusters and the products of their decay:

(i) $b_k = -(V - u_k)^2$ is the distance between all selected particles and the axis of the cluster;

(ii) $b_{I(II)cl} = -(u_{I(II)} - V)^2$ is the distance between the cluster and projectile (or target);

(iii) $F(b) = \frac{1}{N} \frac{2}{m_N^2} \int \frac{1}{\sqrt{b_k + b_k^2/4}} \frac{dN}{d\sigma d\Omega} d\Omega$ is invariant cross section $E\, d\sigma/dp$ expressed in terms of b_k and integrated on angular variables;

(iv) $F(b_{I(II)cl})$ represents invariant cross section $E_{cl} \frac{d\sigma}{dp_{cl}}$ expressed in terms of b_I (or b_{II}) and integrated on angular variables. The function $F(b_{I(II)cl})$ is written in the analogous manner as $F(b_k)$.

3. PROPERTIES OF NUCLEON CLUSTERS

The experiment was carried out with a 2m propane bubble chamber exposed to the beams of p, d, ^{4}He and ^{12}C nuclei at an incident momentum of 4.2 GeV/c per nucleon from the Dubna Synchrophasotron. Events were recorded in propane. The total statistics of the interactions is given in Table 1.

The methods of experiment and film information analysis are described in detail in papers [10].

Table 1

Type of interaction	P_{lab}, GeV/c	$b_{I\,II}$	Number of events
pC	4.2	7.16	6207
dC	4.2·A	7.16	8724
αC	4.2·A	7.16	3795
CC	4.2·A	7.16	10199
pC	10.0	19.4	2706
$\pi^- C$	40.0	570.0	8791

Protons were well separated from pions in the momentum range $150 < p < 900$ MeV/c by ionization density. The contamination of misidentified π^+ mesons was about 8% of the number of fast positively charged particles with $p > 1$ GeV/c, which were mainly fast protons [11]. The charges of fragments heavier than proton were determined by ionization density and also by counting δ electrons in the case of carbon exposure [12]. The contamination of such fragments was about 7% of the number of positive tracks in the momentum range from 1 to 2 GeV/c [12].

3.1. *Invariant $F(b_k)$ proton distributions.* The existence of nucleon clusters in the region $0.1 \le b_{ik} < 1$ has been studied for pC, dC, ^{4}HeC and CC interactions at a momentum of 4.2 GeV/c per nucleon. The events with $n_p \ge 2$ were selected. Spectator ($P_{lab} \le 250$ MeV/c) and stripping ($P_{lab} \ge 3.0$ GeV/c and $\theta \le 4°$) protons were excluded from analysis.

Invariant $F(b_k)$ proton distributions have been analysed to study nucleon cluster properties. The function $F(b_k)$ is invariant cross section $E\, d\sigma/dp$ expressed in terms of b_k and integrated on angular variables (see section 2(iii)).

Figs.2 and 3 present normalized functions $F(b_k)$ for clusters in pC, dC, αC and CC interactions. One can see that the given dependences have exponential character in pC and dC collisions:

$$F(b_k) = a_1 \exp[-b_k/\langle b_k \rangle]. \tag{4}$$

Invariant functions $F(b_k)$ for αC and CC collisions can be approximated as a sum of two exponential dependences:

$$F(b_k) = a_1 \exp[-b_k/\langle b_k \rangle_1] + a_2 \exp[-b_k/\langle b_k \rangle_2]. \tag{5}$$

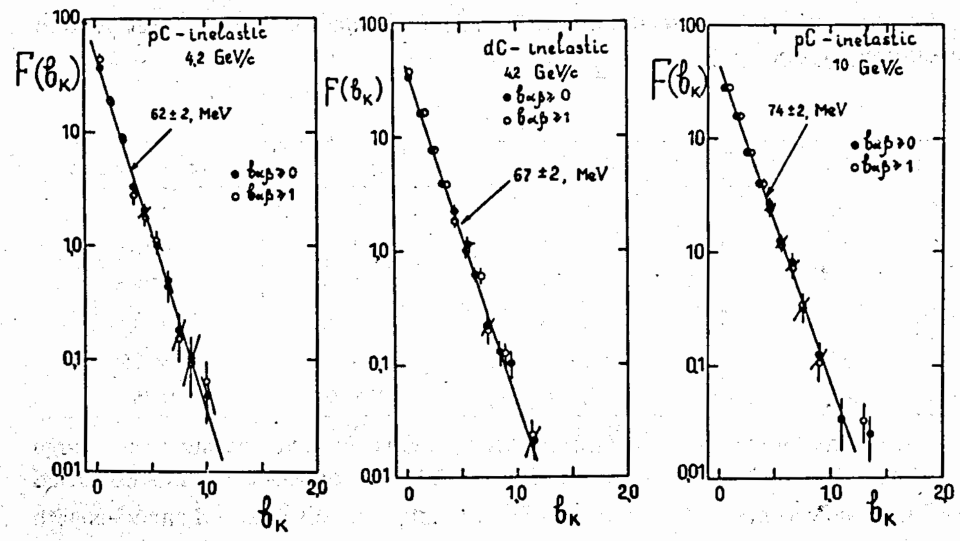

Fig.2. The normalized functions $F(b_k)$ for nucleon clusters in pC, dC (4.2·A·GeV/c) and pC (10·A·GeV/c) collisions

It is easy to show that the quantity b_k is unambiguously connected with the kinetic energy of particle in the cluster rest frame

$$b_k = 2E_k/m_k - 2 = 2T_k/m_k, \tag{6}$$

where E_k and T_k are the total and kinetic energies of protons in the cluster rest frame. It follows that one can calculate the «temperature» of the clusters defining the values of parameters $\langle b_k \rangle_1$ and $\langle b_k \rangle_2$ by approximation. In the present case, the slope of invariant cross sections $1/p\ (d\sigma/dT)$ in the cluster rest frame was determinated as follows

$$b_k = 2\langle T_k \rangle / m_k. \tag{7}$$

The values of temperature obtained in this manner in different collisions are given in Table 2. From these data one can draw a conclusion that clusters with $\langle T_k \rangle_1$ = 60—70 MeV are observed in all considered interactions. In addition, in αC and CC collisions clusters with higher temperature, $\langle T_k \rangle_2 \simeq$ 120—130 MeV, are observed. Systematic errors connected with identification of positive

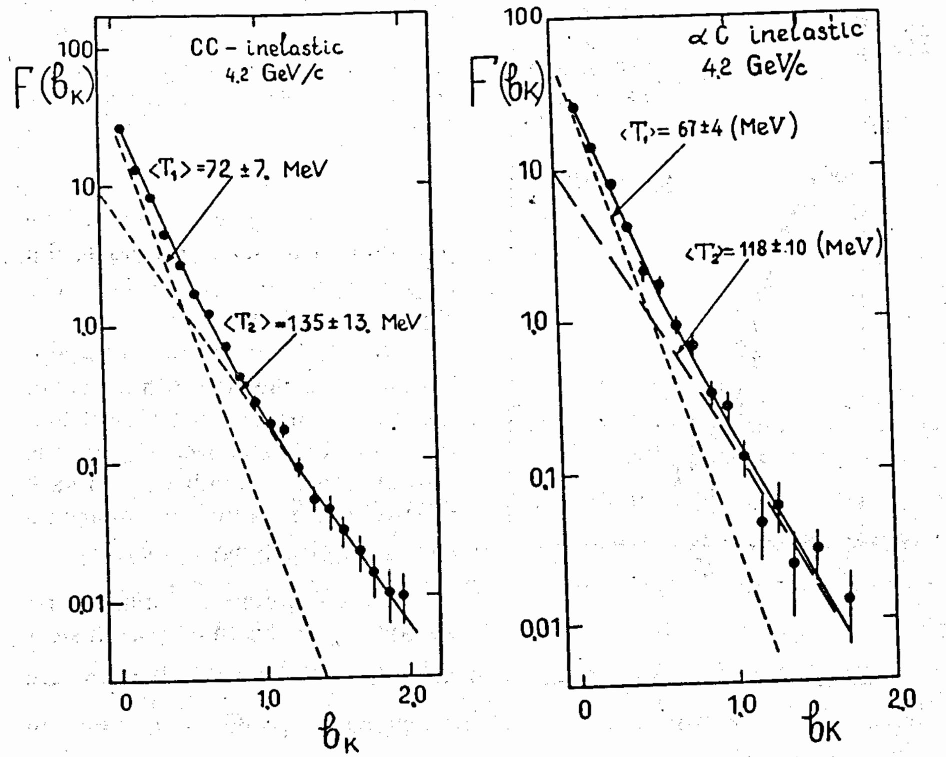

Fig.3. The normalized functions $F(b_k)$ for nucleon clusters in αC and CC (4.2·A·GeV/c) collisions

Table 2

Type of interaction	P_{lab}, GeV/c	Cluster I		Cluster II	
		$\langle b_k \rangle$	$\langle T \rangle_1$, MeV	$\langle b_k \rangle_2$	$\langle T \rangle_2$, MeV
pC	4.2	0.133±0.004	62±2	—	—
dC	4.2·A	0.147±0.002	67±1	—	—
αC	4.2·A	0.147±0.008	67±4	0.248±0.022	118±10
CC	4.2·A	0.154±0.014	72±7	0.288±0.028	135±13
pC	10.0	0.158±0.005	74±2	—	—
CC-multinucleon		—	—	0.256±0.005	120±2

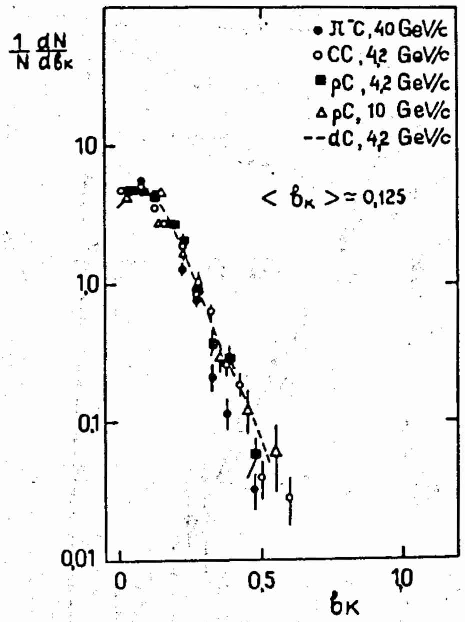

Fig.4. The proton distributions on variable b_k in the first type of clusters (with $\langle T_1\rangle = 60$—70 MeV), produced in π^-C, pC, dC, αC and CC collisions in the 4.2—40 GeV/c energy range

particles are about 10%. The contribution of such clusters is not large and, for example, in CC collisions is about (20 ± 6) %.

The study of proton properties from identical clusters with the aid of traditional variables has shown that they are produced mainly in the central region of rapidity y and have relatively large transverse momenta $\langle P_\perp^2\rangle = (0.51 \pm 0.05)\ (\mathrm{GeV/c})^2$.

In Fig.4 proton distributions on variable b_k in the first type clusters (i.e. with $\langle T_1\rangle \approx 65$ MeV), produced in pC, dC, αC and CC collisions, are compared with analogous data for π^-C interactions at $P_\pi = 40$ GeV/c. One can see that all distributions coincide within experimental errors.

Thus, the properties of nucleon clusters with $\langle T_1\rangle = 60$—70 MeV in accordance with automodelity principle [7], depend on neither the type of projectile nor its energy within an interval 4—40 GeV/c.

3.2. *Dependence of cluster properties on proton multiplicity.* The observation of clusters in αC and CC collisions with $\langle T_2\rangle = 120$—130 MeV could mean that in nucleus-nucleus collision an occurrance of new maximum in their production is connected with multinucleon interactions. The temperature of clusters has been defined depending on multiplicity n_p to study this problem.

Table 3 presents cross sections and temperature of clusters with multiplicity $n_p = 2$—7 in pC, dC and CC events. The dependence of $\langle T\rangle$ on multiplicity n_p is shown in Fig.5 as well.

One can see that the temperature in clusters in all the considered collisions grows with increasing of their multiplicity and reaches 120 MeV at $n_p = 6$ in CC collisions. However, in pC and dC collisions it is systematically lower than in CC ones at similar values of n_p.

Table 3

n_p	pC and dC			CC		
	Number of events	σ, mb	$\langle T\rangle$, MeV	Number of events	σ, mb	$\langle T\rangle$, MeV
2	212	19	49±2	447	47	58±2
3	358	32	64±2	514	55	82±2
4	119	11	77±3	335	36	94±2
5	26	2.3	92±9	204	22	112±3
6	—	—	—	110	12	120±3
7	—	—	—	68	7	—

The invariant (see section 2 (iv)) functions $F(b_{IIcl})$, describing cluster distributions relative to target nucleus for CC and pC collisions, are given in Figs.6 and 7. One can see that $F(b_{IIcl})$ with small proton multiplicity in clusters $n_p \le 4$ in CC collisions has low slopes, defined by parameters $\langle b_{IIcl}\rangle_1$ and $\langle b_{IIcl}\rangle_2$. These values can be found by approximation of the data by the sum of two exponential functions analogous to (5). At large multiplicities ($n_p \ge 5$) the behaviour of the $F(b_{IIcl})$ can be described by exponential dependence identical to type (4).

In pC collisions, only one slope is observed in the experimental distribution $F(b_{IIcl})$.

All parameters obtained by approximation of data by the exponential dependence of types (4) and (5) are given in Table 4.

Analyzing the data one can make a conclusion that the first slope of $F(b_{IIcl})$ is connected with cluster production with $\langle T\rangle_1 \approx 65$ MeV. The contribution of this type of clusters decreases with growing n_p and is not observed at all at $n_p \ge 5$.

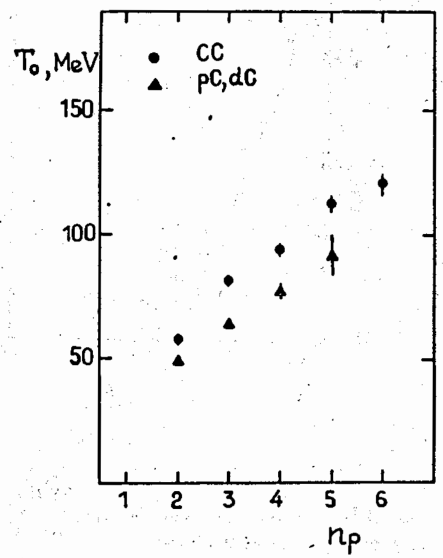

Fig.5. The dependence of $\langle T\rangle$ on multiplicity n_p for nucleon clusters produced in pC, dC and CC interactions

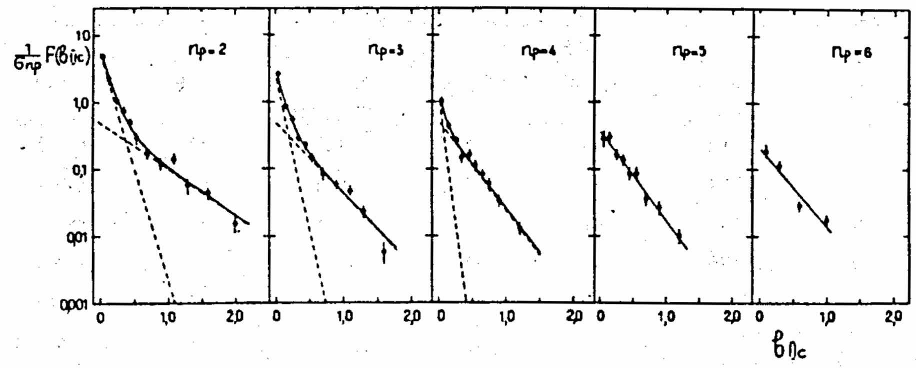

Fig.6. The invariant functions $F(b_{IIcl})$ describing cluster distributions relative to target nucleus for CC collisions

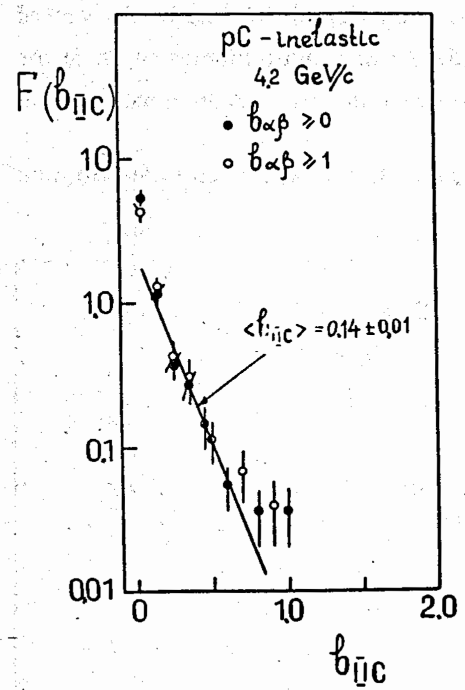

Fig.7. The invariant functions $F(b_{IIcl})$ describing cluster distributions relative to target nucleus for pC collisions

The second slope can be due to production of high-temperature clusters ($\langle T\rangle_2 \approx 130$ MeV). The contribution of clusters of this type is too little with small n_p for CC collisions and is not observed for pC ones within experimental errors.

The fact that the temperature in clusters in CC events at all values of n_p is higher than in pC and dC ones, can be explained by the presence of high-temperature components for all multiplicities.

Thus, the appearance of high-temperature clusters in CC collisions is connected with multinucleon interactions. The cross section of clusters with $n_p \geq 5$ is equal to 40 mb, i.e. it is $\cong 5\%$ of all inelastic CC collisions.

3.3. *The study of a possibility of the production of quasi-stationary states of nucleons in the clusters.* Independence of the properties of nucleon clusters with

Table 4

n_p	a_1	a_2	$\langle b_{IIcl}\rangle_1$	$\langle b_{IIcl}\rangle_2$
2	0.92±0.13	0.08±0.03	0.13±0.02	0.63±0.12
3	0.87±0.16	0.13±0.04	0.09±0.02	0.41±0.06
4	0.72±0.36	0.28±0.06	0.06±0.03	0.33±0.03
5	—	1	—	0.33±0.02
6	—	1	—	0.37±0.05

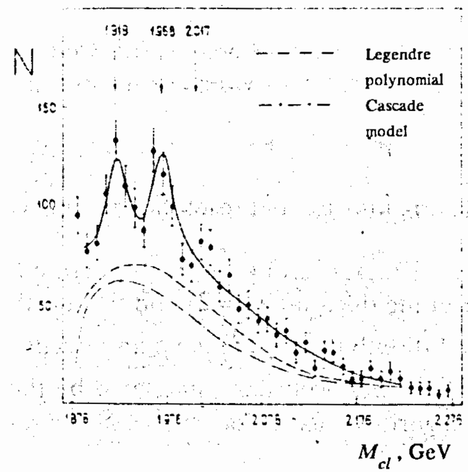

Fig.8. The effective mass spectra of clusters M_{cl} with $n_p = 2$

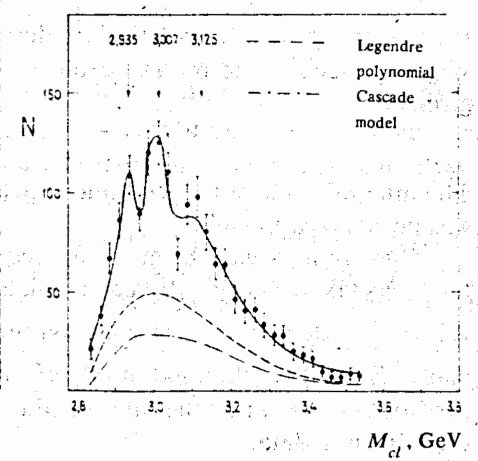

Fig.9. The effective mass spectra of clusters M_{cl} with $n_p = 3$

low temperature of the type of reaction shows that the process of cluster production characterizes fundamental properties of excited nuclear matter. In accordance with this, nucleon clusters seem to be decay products of some quasi-stationary multinucleon states.

For this purpose the effective mass spectra of clusters have been analyzed. Figs.8 and 9 show the effective mass spectra

$$M_{cl} = \left[\left(\sum E_i\right)^2 - \left(\sum P_i\right)^2\right]^{1/2} \qquad (8)$$

of clusters with $n_p = 2$ and 3, respectively. One can see that maxima, pointing to the possibility of production of nucleon resonance states, are observed for some values of masses M_{cl}. The errors in determining M_{cl} are small and equal to

2.5—4 MeV within the first two mass M_{cl} intervals at the phase space boundary at $n_p = 2$ and 3. Further, the value of the errors rises linearly with increasing cluster mass: $\sigma \approx -0.3 + 0.13 M_{cl}$.

To determine the masses and widths of possible nucleon resonances, experimental spectra have been approximated by an expression consisting of the sum of the Breit — Wigner functions corresponding to possible resonance states and a background term

$$F(M) = \sum_i \alpha_i BW(M) + \beta Ph(M). \tag{9}$$

Here α and β are the coefficients defining the contributions of the Breit — Wigner functions and the background term. The Breit — Wigner functions are given as

$$BW_i(M) = 1/[(M_{0i} - m)^2 + \Gamma_i^2/4]. \tag{10}$$

The integral value of the BW functions taking into account resolution functions was normalized to unity.

Two variants have been considered as a background term: (i) background term was taken as Legendre polynomials of the third (at $n_p = 2$) and the fourth (at $n_p = 3$) degrees; (ii) as a background distribution we assume an effective mass distribution obtained in pC, dC, αC and CC collisions simulated by the cascade model with the aid of the algorithm used for the analysis of experimental data.

The results of approximation of the experimental spectra by the function $F(M)$ are shown in Figs.6 and 7 by solid lines. Table 5 presents both the values of masses M_i and widths Γ_i of assumed resonances. One can see that in two- and three-proton clusters the first two enhancements with M_1 and M_2 are characterized by widths from some MeV up to some tens MeV, i.e. they are rather narrow. The masses M_1 and M_2 at $n_p = 2$ coincide within the experimental errors with the masses of narrow dibaryon resonances observed in paper [13] as well as in a number of other works [14].

Table 5

	$n = 2$		$n = 3$	
	M_i, GeV	Γ_i, GeV	M_i, GeV	Γ_i, GeV
1	1.919±0.003	0.023±0.012	2.935±0.011	0.071±0.020
2	1.967±0.004	0.010±0.015	3.007±0.006	0.016±0.015

Resonance structure could not be discovered in effective mass distributions of clusters with multiplicity $n_p \geq 4$ using the statistical data available at the present time.

Thus, the data obtained in this experiment show that in relativistic nuclear collisions the high excitation of nuclear matter is observed with production of quasi-stationary nucleon states with $\langle T\rangle_1 \approx 60$—$70$ MeV and a lifetime of around 10^{-22}s.

4. CONCLUSIONS

The analysis of different relativistic hadron and nuclear multiple particle production processes (π^-C, pC, dC, αC and CC) in a wide energy range (from 4.2 to 40 GeV/c) made within the new relativistic invariant approach to these processes, has established the following regularities:

(i) Two types of nucleon clusters characterized by different degrees of freedom of excited nuclear matter have been separated. The first type of the clusters has the «temperature» $\langle T\rangle_1 = (72 \pm 2)$ MeV and it is nearer to the parent target nucleus $\langle b_{IIcl}\rangle_1 = 0.14 \pm 0.02$ in relative 4-velocity space; the second one has $\langle T\rangle_2 = (135 \pm 13)$ MeV and is more distant from the parent target nucleus $\langle b_{IIcl}\rangle_2 = 0.52 \pm 0.05$.

(ii) Universality (i.e. independent of either the type of fragmenting system or collision energy) of the properties of low temperature nucleon clusters has been observed in the considered interactions. This fact should be treated as the generalization of the phenomenon known as «nucleon scaling». The asymptotic regime occurs at $p_{in} \geq 4.2 \cdot A \cdot$GeV/c.

(iii) The above-mentioned properties of the first type nucleon clusters are similar to those of hadron jets [15], but nucleon clusters are located in quite another region of kinematic variables as compared to quark jets. These results should be considered as exhibition of automodelity properties in the region of small b_{ik}, i.e. the existence of intermediate asymptotic regions of variable b_{ik} and independence in them of some invariant distributions of b_{IIcl}, b_{Icl}, $b_{\alpha\beta}$ and other large b_{ik} variables.

(iv) It was observed that nucleon clusters with $\langle T\rangle_1 \approx 72$ MeV can be interpreted as decay product of some possible multinucleon resonances with a lifetime of around 10^{-22} s.

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Свойства нуклонных кластеров

в релятивистских ядерных столкновениях

Образование нуклонных кластеров изучалось в различных ядро-ядро и адрон-ядро столкновениях в области энергий от 4,2 до 40 ГэВ/с. Свойства характеристик нуклонных кластеров исследовались с помощью нового релятивистски-инвариантного метода в пространстве относительных 4-скоростей. Обнаружено существование двух типов нуклонных кластеров, характеризующихся разными средними значениями температур: $<T>_1 = 60-70$ МэВ и $<T>_2 = 120-130$ МэВ. Установлено, что свойства характеристик нуклонных кластеров с низкой температурой *универсальны*, т.е. не зависят ни от типа фрагментирующей системы, ни от энергии столкновения. Асимптотический режим имеет место в области $p_{in} \geq$ $\geq 4{,}2$ А·ГэВ/с. Обсуждается зависимость температуры кластеров от множественности протонов в кластере. Показано, что рассматриваемые нуклонные кластеры можно интерпретировать как продукты распада некоторых мультинуклонных резонансов с ширинами в несколько МэВ.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

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The Properties of Nucleon Clusters

in Relativistic Nuclear Collisions

The production of nucleon clusters has been investigated in different hadron and nuclear reactions over an energy range from 4.2 to 40 GeV/c. We have observed the existence of two types of nucleon clusters characterized by different values of temperature: $<T>_1 = 60-70$ MeV and $<T>_2 = 120-130$ MeV. The characteristics of nucleon clusters are studied in terms of a new relativistic invariant approach in relative 4-velocity space. It has been observed that the properties of nucleon clusters with a low temperature are *universal*, i.e. independent of either the type of fragmenting system or collision energy. The asymptotic regime occurs at $p_{in} \geq 4.2$ A·GeV/c for nucleon clusters. The dependence of cluster temperature on proton multiplicity in the nucleon cluster was obtained. It was also shown that the nucleon clusters under consideration can be interpreted as decay products of some multinucleon resonances with a width of about a few MeV.

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

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