84-443

объединенный
институт
ядерных
исследований
дубна

E1-84-448

INVESTIGATION OF CORRELATION PHENOMENA IN NUCLEUS-NUCLEUS INTERACTIONS AT 4.2 GeV/c per NUCLEON

Alma-Ata—Baku—Belgrade—Bucharest—Dubna—Kishinev—Leipzig—Moscow—Prague—Samarkand—Sofia—Tashkent—Tbilisi—Ulan-Bator—Varna—Warsaw—Yerevan Collaboration

Submitted to the Xth International Conference on High Energy Physics and Nuclear Structure (Heidelberg, FRG) and to "Zeitschrift für Physik C"

1984

H.N.Agakishiev, N.Akhababian, D.Armutlijsky, A.M.Baldin, J.Bartke, R.Bekmirsaev, J.Bogdanowicz, A.P.Cheplakov, M.Ya.Chubarian, L.A.Didenko, A.P.Gasparian, N.S.Grigalashvili, V.G.Grishin, K.K.Gudima, K.Iovchev, I.A.Ivanovskaya, T.Kanarek, E.N.Kladnitskaya, D.K.Kopylova, M.Kowalski, A.A.Kuznetsov, V.B.Lyubimov, R.R.Mekhdiev, Z.V.Metreveli, V.F.Nikitina, M.I.Soloviev, V.D.Toneev
Joint Institute for Nuclear Research, Dubna, USSR

I.Ya.Chasnikov, M.I.Izbasarov, A.Kh.Vinitsky
Institite of High Energy Physics, Kazakh Academy of Sciences, Alma-Ata, USSR

O.B.Abdinov
Institute of Physics, Azerbaijan Academy of Sciences, Baku, USSR

S.Backovic, V.Damianovic, S.Drndarevic, D.Krmpotic, D.Krpic, L.Rak, L.Simic
Institute of Physics, Belgrade, Yugoslavia

E.Balea, O.Balea, V.Boldea, S.Hakman, T.Ponta
Central Institute of Physics, Bucharest, Romania

Yu.P.Keloglu
Kishinev State University, Kishinev, MSSR

K.Hansgen
University of Leipzig, Leipzig, GDR

N.N.Melnikova
USSR Academy of Sciences, Moscow, USSR

I.N.Erofeeva, S.I.Lyutov, V.S.Murzin, V.M.Popova, L.M.Shcheglova, S.Yu.Sivoklokov, L.N.Smirnova, A.N.Solomin, G.P.Toneeva
Scientific Research Institute for Nuclear Physics, Moscow State University, USSR

I.Dolejshi, Z.Trka, Ya.Trkova
Charles University, Prague, Czechoslovakia

F.A.Istmatova, M.M.Muminov, I.Suvonov
Samarkand State University, Samarkand, USSR

N.Angelov, L.Grekova, P.Georgiev, I.Lukarska, P.Markov,
H.Semerdzhiev, P.P.Temnikov
Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria

S.O.Edgorov, Sh.V.Inogamov, A.A.Yuldashev, B.C.Yuldashev
Physical and Technical Institute of the Uzbek Academy of Sciences, Tashkent, USSR

N.S.Amaglobeli, M.A.Dasaeva, R.A.Kvatadze, Yu.V.Tevzadze,
M.V.Topuridze
Tbilisi State University, USSR

Ts.Baatar, R.Togoo, D.Tuvdendorzh
Institute of Physics and Mathematics of Mongolian Academy of Sciences, Ulan-Bator, Mongolia

N.I.Kochnev, S.Prokopieva
Higher Machino-Electrotechnical Institute, Varna, Bulgaria

H.Bialkowska
Institute for Nuclear Studies, Warsaw, Poland

G.R.Gulkanian, Z.A.Kirakosian, S.A.Korchagin, I.M.Ravinovich
Yerevan Physical Institute, Yerevan, USSR

A.H.Khudaverdian
Yerevan State University, USSR

1. INTRODUCTION

In the last few years a picture of the nucleus as a system composed of nucleons has raised serious doubts. As long as momentum-energy transfer is comparable to Fermi momentum, this picture remains valid, but at energy transfers exceeding 1 GeV one could see the substructure of nucleus connected with quarks. This effect was predicted theoretically /1/, and first experimental indications were obtained in the investigation of cumulative particle production processes in hadron-nucleus interactions /2/. In a nucleus, with a certain probability, short range correlations are likely to be realized, which result in multiquark configurations. An avidence for multiquark degrees of freedom is obtained in many experiments on deep inelastic interactions of leptons and hadrons with nuclei /3-8/.

In this connection it is important to look for narrow dibaryon resonances. They may manifest themselves in kinematical characteristics of secondary particles generated in deep inelastic nuclear interactions. At relatively large momentum transfers correlated dinucleons may be knocked out from a nucleus and appear as bumps in the effective mass distribution of two nucleons.

High energy nucleus-nucleus collisions make it possible to realize essentially multinucleon interactions. Changing mass numbers of interacting nuclei, it is possible to vary the number of nucleons participating in a collision over a wide interval. The number of interacting nucleons appears as a new parameter in high energy nuclear physics. A study of characteristics of multiparticle production processes as a function of the number of interacting nucleons is one of the important tasks of relativistic nuclear physics. Perhaps, it is of great interest to study the features of secondary particle production, which in transverse momentum and rapidity space fall far from fragmentation regions of target and projectile nuclei.

High-energy inelastic nucleus-nucleus collisions are mainly a superposition of NN interactions. In NN interactions the resonance production, and particularly that of Δ isobars, proceeds with large cross sections. In multinucleon interactions a relatively large number of Δ isobars may be generated in a relatively small volume of the geometrical overlap of colliding nuclei. There exist almost no relevant experimental data. A study of manifestation of correlated particle emission in nucleus-nucleus interactions is the aim of this work.

2. EXPERIMENT

For studying correlation phenomena, it is proper to use track detectors as, e.g., bubble chambers. The experimental data on inelastic interactions of nuclei presented below were obtained from exposures of the 2m propane (C_3H_8) bubble chamber in beams of protons, deuterons, helium-4, and carbon-12 nuclei with a momentum of $P_0 = 4.2$ GeV/c per nucleon. The admixture of other beam particles in our experiment did not exceed 3%. The chamber was placed in a magnetic field of $B = 1.5$ tesla. Momenta of secondary charged particles were determined with a mean relative error of $\Delta P/P \simeq 0.1$ and their emission angles with a mean error of $\Delta\theta \simeq 0.5°$. A target composed of three tantalum plates 1 mm thick and 93 mm apart was mounted inside the chamber. This makes it possible to study inelastic interactions with carbon as well as with tantalum. Diproton resonances were also searched for in experimental data obtained earlier from an exposure of the propane bubble chamber in a 40 GeV/c π^- beam from the Serpukhov accelerator.

Events, which satisfied proper selection criteria [22], were classified as interactions with carbon nuclei of propane. These criteria guaranteed the selection of inelastic interactions with carbon. However, about 25% of peripheral interactions with carbon were lost in this procedure. Central CC and CTa interactions were also studied. As CC central collisions, events were selected which satisfied the following criteria: i) there are no carbon projectile spectator fragments with charge $Z \geq 2$; ii) the number of singly charged stripped projectile fragments $n_s \leq 2$; iii) the total charge of secondary particles $Q > 7$. Positively charged particles with a momentum of $P_+ \geq 3$ GeV/c and an emission angle of $\theta \leq 4°$ were taken as spectators. Central collisions amounted to about 15% of all CC inelastic interactions. As central CTa collisions, events were classified having no charged spectator fragments of projectile. They amounted to about 25% of all inelastic CTa interactions. Table 1 shows the numbers of different types of events used in the analysis.

Propane bubble chamber technique has some experimental limitations. Protons, deuterons and tritium nuclei with momenta less than 150, 250, and 350 MeV/c, respectively, are not seen in the chamber due to their short range in propane $R < 3$ mm. Negatively charged pions with momenta of $P_\pi \leq 70$ MeV/c ($\ell < 3$ cm) can be wrongly classified as protons. Positively charged pions are undoubtedly identified by ionization only for momenta of $P_\pi \leq 600$ MeV/c.

Interactions of deuterons, helium and carbon nuclei with carbon experimentally selected approximately fulfill isotopic symmetry. This allows one to use the procedure described below in order to select protons and heavier nuclei from all positively

Table 1

Statistics for different types of interactions

Type of interaction	πC	pC	dC	^{4}HeC	CC	CC central
Number of events	17000	1291	2126	1421	2200	1394

Type of interaction	dTa	^{4}HeTa	CTa	CTa central
Number of events	1362	868	1176	296

charged particles. In the region of $P_+ \leq 0.5$ GeV/c protons can be distinguished from π^+ mesons by ionization density and range. For positively charged particles with a momentum of $P_+ > 0.5$ GeV/c weights dependent on momentum and angle were introduced, which accounted for π^+ meson admixture. It was assumed that the numbers of π^+ and π^- mesons and also their momentum and angular distributions are the same. In the total number of positively charged particles with $P_+ > 0.5$ GeV/c the number of mesons, as evaluated from that of π^-, did not exceed 15%. Among all positively charged particles with a momentum of $P_+ \geq 1$ GeV/c and an emission angle of $\theta > 4°$ about 1% of particles were observed the ionization density of which was considerably greater than that of protons with a momentum of $P_p \geq 1$ GeV/c. These particles were classified as composite fragments without subdivision into deuterium, tritium and helium nuclei.

In a propane bubble chamber singly charged positive particles with momenta of $P_+ > 1.5$ GeV/c cannot be divided into protons and deuterons. Therefore in our sample of protons there is some admixture of deuterons. Further on all positively charged baryons (including composite fragments) will be called protons. Some methodical and physical results of experimental data analysis have been already published in papers [9-22].

To observe nontrivial correlations, the Dubna cascade-evaporation model (DCM) [23,24] was extensively used as a background. In this model inelastic nucleus-nucleus interactions are treated as successive quasi-free two-particle collisions described by the relativistic Boltzmann equation. The process of absorption of secondary pions by pairs of correlated nucleons was included in the calculations. The model also permits one to describe the emission of fast composite particles d, t, ^{3}He and ^{4}He by taking into account the interaction of cascade particles in the final state in the frame of the model of dynamical coalescence [24]. Radii of coalescence of nucleons in momentum space P_c, initially estimated from experimental spectra of particles produced in interactions of neon nuclei with uranium at $T_0 = 0.4$ GeV per nucleon, turned out to be independent neither of the primary energy of nucleus nor of the mass number of colliding nuclei. These values of P_c were used in the calculations. Such choice of coalescence radii is in agreement with the estimated[25] from a quantum-mechanical description of the process of formation of composite particles in hot nuclear matter.

3. DIBARYONS

Possible candidates for dibaryon states have been widely discussed recently. There would be states formed by two nucleons with strangeness $S = 0$, masses of $2140 \le M_{NN} \le 2450$ MeV and widths of (50-200) MeV and also states formed by lambda-hyperon and nucleon with strangeness $S = -1$, masses of $2120 \le M_{\Lambda p} \le 2360$ MeV and widths of (3-60) MeV. A detailed review of the experimental and theoretical situation on lambda-nucleon systems can be found in papers[26]. We shall limit ourselves to dibaryons with strangeness $S = 0$. Data related to this problem have been obtained in experiments on NN scattering[27-31], photodisintegration of deuteron[32-34] and pion-deuteron interactions[35-37]. There are also experimental data on "low-lying" resonances obtained by bubble chamber technique in the course of studying interactions of ^4He with protons at $P_{He} = 8.6$ GeV/c[38], interactions of π^--mesons with carbon nuclei at $P_\pi = 5$ GeV/c[39] and absorption of π^+-mesons by nuclei of freon at $T_\pi = 60$ MeV[40]. In these experiments indications have been obtained of the existence of narrow dibaryon states with masses: $M_1 = 2035 \pm 15$ MeV[38], $M_2 = 2137 \pm 17$ MeV[38], $M_3 = 1961 \pm 2$ MeV[39], $M_4 = 2016 \pm 3$ MeV[39], $M_5 = 2025 \pm 3$ MeV[40] and with widths, respectively, $\Gamma_1 = 30 \pm 23$ MeV, $\Gamma_2 = 59 \pm 20$ MeV, $\Gamma_3 = 11 \pm 4$ MeV, $\Gamma_4 = 30 \pm 14$ MeV, $\Gamma_5 \le 5$ MeV. In a recent paper[41] an experiment is described in which various neutron-proton reactions have been studied in a hydrogen bubble chamber at neutron energies from 1 to 5 GeV. In the effective mass spectrum narrow peaks were observed at masses of 1936 ± 2 MeV and 1962 ± 3 MeV and widths not exceeding 10 MeV.

It seems that probably only four narrow dibaryon states have been observed in the above experiments[38-41] at masses of about 1.93, 1.96, 2.02 and 2.14 GeV.

The existence of dibaryon resonances has been predicted by different theoretical models: multiquark clusters[42-46], joined springs[47,48], excitation of rotational degrees of freedom of a dinucleon state[49] and description of experimental data on the basis of pion-deuteron scattering at low energies[50]. A detailed information on this topic can be found in papers[51].

Data collected by our Collaboration on interactions of π^--mesons with carbon nuclei at 40 GeV/c and interactions of protons, deuterons, helium-4, and carbon-12 nuclei with carbon at 4.2 GeV/c per nucleon have been used to search for diproton resonances. In a propane bubble chamber, for protons with momenta between 200 and 500 MeV/c the effective mass resolution of two or three protons is of the order of a few MeV. The reason for this is that protons in the above momentum interval have ranges in propane between 1 and 25 cm, i.e., practically all are stopped in the chamber volume. Such protons were measured by range with a momentum error of $\Delta P/P \le 0.02$ and an emission angle error of 0.5 degrees. The experimental effective mass resolution of two protons for intervals: $M_{pp} \le 1912$ MeV, $1912 \le M_{pp} \le 1937$ MeV and $M_{pp} > 1937$ MeV turned out to be 1.5, 2.6 and 3.8 MeV, respectively.

Figure 1 shows the effective mass distribution of two protons for π^-, p, d, ^4He, and C interactions with a carbon nucleus, in which two or more protons are produced with momenta of $200 \le P_p \le 500$ MeV/c. Quantity $Q = M_{pp} - 2m_p$ is the decay energy. In the distribution in Fig.1 there are 3755 combinations from π^-C interactions and 5944 combinations from AC interactions. The shape of the distributions for the two classes of interactions turned out to be alike. The bin width in the Q distribution was 5 MeV. The effective mass, M, distribution was approximated by three Breit-Wigner terms

$$BW = \frac{M_R \Gamma_R M}{(M_R^2 - M^2) - M_R^2 \Gamma_R^2}, \qquad (1)$$

where M_R is the mass and Γ_R is the full width of a resonance, and by the background distribution obtained mixing protons from different events. The Breit-Wigner terms were multiplied by the background distribution in order to take into account the influence of phase space. The first two intervals in Q were not used for the fit as in this region there is a significant influence of final state interactions which we do not take into account in the background distribution. A solid line in Fig.1 shows the results of the fit (χ^2/N.D.F. = 1.2), a dashed one, the contribution of the background.

Table 2 gives the values of M_R and Γ_R obtained in the fit for the three possible resonances as well as their relative contributions α. It can be seen that the obtained values of masses and widths are in fair agreement with data of papers[38-41].

Figure 2 shows the effective mass distribution of three protons with momenta of $200 \le P_p \le 600$ MeV/c from the same interactions as in Fig.1. In the distribution in Fig.2 there are 1528 combinations from π^-C interactions and 3620 combinations from AC interactions. The bin width in the $Q = M_{ppp} - 3m_p$

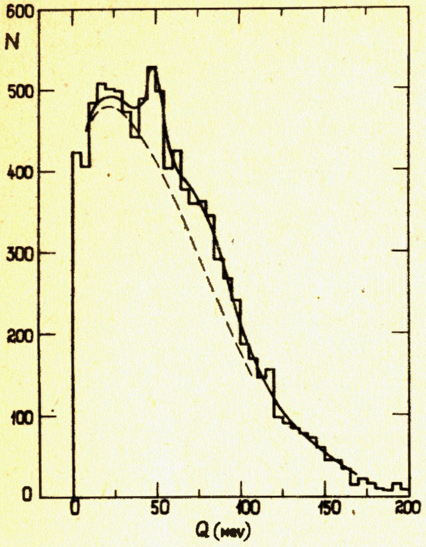


Fig.1. Two-proton effective mass distribution for protons with momenta of 0.2 $\leq P_p \leq$ $\leq$ 0.5 GeV/c. $Q = M_{pp} - 2m_p$.

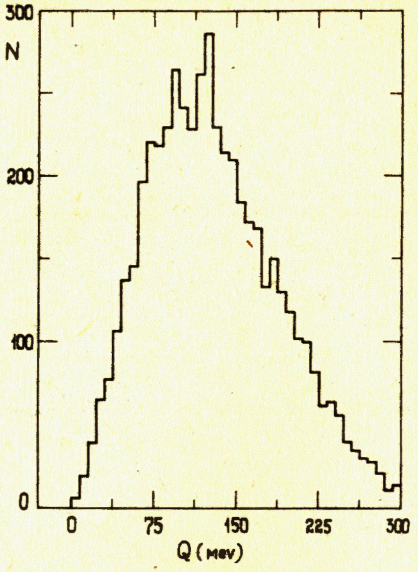


Fig.2. Three-proton effective mass distribution for protons with momenta of 0.2 $\leq P_p \leq$ $\leq$ 0.6 GeV/c.

Table 2

Parameters of the assumed resonances in two-proton system, χ^2/N.D.F.= 1.2

	R_1	R_2	R_3	Background
M (MeV)	1926$\pm$1.4	1964$\pm$3.6	2026$\pm$6.6	-
Γ (MeV)	11.0$\pm$1.9	32.4$\pm$3.2	31.9$\pm$5.2	-
α (%)	3.3$\pm$0.5	9.0$\pm$1.0	4.0$\pm$0.9	83.7$\pm$0.7

distribution is equal to 7.5 MeV. Bumps in a region of 2.90-2.95 GeV could be considered as an indication of a possible effect.

An attempt has been made to minimize the contribution of background processes to the analyzed effective mass spectra by introducing kinematic limitations on characteristics of secondary particles. For example, for π^-C interactions, events can be selected with a secondary π^- meson having a transverse momentum of $P_\perp \geq$ 0.3 GeV/c or $P_\perp \geq$ 0.5 GeV/c in which the sum of momentum vectors of two secondary protons lies near the production plane of the π^- meson with high $P_\perp$. In this way it is possible to select quasicomplanar events compatible with the hypothesis of knocking out a correlated two-proton pair from a carbon nucleus. It is necessary to point out that large bubble chambers with a relatively high stopping power for protons may be successfully applied for a search for and investigation of multiproton states. It would seem useful to use bubble chambers with such working liquids as propane, mixtures of hydrogen with neon or mixtures of propane with freon. Using heavier liquids is not advisable because of a considerably lower effective mass resolution and possible biases resulting from rescattering of protons in a heavy nucleus.

4. NUMBER OF INTERACTING NUCLEONS

In inelastic high energy nucleus-nucleus collisions depending on impact parameter, some nucleons of interacting nuclei remain as spectators. Previously /10,12,13/ mean numbers of interacting nucleons from d, He, and C projectiles colliding with tantalum have been determined on the basis of the experimentally measured mean charge of spectator fragments. Spectator fragments have characteristic momentum and angular distributions the widths of which are determined by the Fermi motion inside a nucleus. The identification of a spectator fragment or a nucleon is not quite unique. Nucleons of the colliding nuclei may be scattered quasi-elastically, and afterwards they have characteristics alike to those of spectator nucleons. Experimental conditions for identification of multicharged spectator fragments are relatively better. At a projectile energy of $E_0 \geq 4$ GeV per nucleon multicharged projectile fragments with charges $Z_f \geq 2$ are emitted within a very narrow angle of $\theta \leq 20$ mrad relative to the primary beam, while heavy spectator fragments of the target nucleus have a range in propane less than an observation limit of 2 mm. However, in any case, due to various uncertainties, the procedure of identification of spectator particle remains somewhat ambiguous.

Nevertheless, it is useful to characterize an inelastic collision of nuclei by a certain number, namely the mean number of nucleons participating in the interaction, considering spectator fragments of nuclei as noninteracting. In this experiment the number of nucleons participating in the interaction was determined from the number of interacting protons. The number of participating protons was determined by subtracting the number of π^+ mesons from the number of positively charged particles (without spectators).

The weight of π^+ mesons was evaluated from the ratio of the numbers of π^- and π^+ mesons in the momentum region $P_\pi \leq 500$ MeV/c. Approximately 50% of all π mesons fall into this region. Participant protons include some admixture of composite particles, mainly deuterons and tritons. At our primary energy positively charged particles with a momentum of $P_+ \geq 3$ GeV/c and an emission angle of $\theta \leq 4°$ were taken as a spectator of the projectile nucleus. As spectators of the target nucleus were taken protons, deuterons, tritium, and helium nuclei with momenta of $P_f \leq$ ≤ 0.3 GeV/c per nucleon.

Table 3

Ratio of the number of π^- mesons to the number of π^+ and π^- mesons with $P_\pi \leq 0.5$ GeV/c for interactions of d, ^{4}He, C with carbon and tantalum nuclei

Type of interaction	dC	^{4}HeC	CC	CC central	dTa	^{4}HeTa	CTa	CTA central
R	0.45 ± 0.02	0.47 ± 0.02	0.50 ± 0.02	0.48 ± 0.02	0.55 ± 0.02	0.52 ± 0.02	0.56 ± 0.02	0.56 ± 0.02

Table 4

Average numbers of participant protons, $\langle n_p \rangle$, and correlated average numbers of participant nucleons, $\langle N_{part} \rangle$. The values of $\langle n_p \rangle^{theor.}$ are calculated according to the DCM [23,24]

Type of interaction	dC	^{4}HeC	CC	CC central	dTa	^{4}HeTa	CTa	CTa central
$\langle n_p \rangle$	2.40 ± 0.03	3.27 ± 0.05	5.11 ± 0.08	8.35 ± 0.06	5.52 ± 0.12	8.64 ± 0.24	13.84 ± 0.37	29.96 ± 0.55
$\langle N_{part} \rangle$	4.4 ± 0.1	6.2 ± 0.2	10.2 ± 0.3	16.0 ± 0.5	11.2 ± 0.3	17.4 ± 0.5	28.5 ± 0.8	61.4 ± 1.2
$\langle n_p \rangle^{theor.}$	-	-	-	8.7	-	-	14.9	32.8

If colliding nuclei have the same numbers of protons and neutrons, the mean number of interacting nucleons equals twice the mean number of interacting protons. In this sense tantalum nuclei are not symmetrical. Also the selection procedure of interactions with carbon of propane and of central CC interactions leads to some asymmetry. In the symmetric case, when all isotopic channels in NN collisions are equally probable, multiplicities of π^+ and π^- mesons, their momentum and angular distributions should be the same. In table 3 are given the ratios of the number of π^- mesons to the sum of the numbers of π^+ and π^- mesons (for pion momenta of $P_\pi \leq 0.5$ GeV/c) for interactions

of d, He, C with C and Ta. For interactions with tantalum this ratio for π^- mesons is greater than 0.5 which is caused by an excess of neutrons over protons in tantalum nucleus. At our energies the multiplicity of π^- mesons produced in NN interactions is considerably higher than in PP interactions [52]. Interactions of protons with neutrons give in the mean the same numbers of π^+ and π^- mesons. For interactions with carbon another situation is observed: the fraction of π^- mesons is less than 0.5. This is caused by the event selection procedure which favours events in which interacting nucleons of the projectile are protons.

Knowing multiplicities of π^+ and π^- mesons and protons in NN interactions and an experimental excess or a deficit of π^- mesons, one can introduce suitable corrections into the numbers of interacting nucleons.

In Table 4 are collected the experimentally determined mean numbers of participant protons and the corrected mean numbers of participant nucleons, N_{part}. Errors in the mean numbers of proton participants are purely statistical, while those for nucleon participants include also some methodical uncertainties. In Table 4 are also given the mean numbers of proton participants obtained from the DCM model [23,24] with experimental conditions taken into account. From Table 4 it can be seen that our experimental data make it possible to choose classes of events with the number of participants varying over a wide range: $N_{part} \approx$ ≈ 5-60. It is necessary to stress that in interactions with a heavy nucleus of tantalum in the number of participants there are nucleons originated in secondly cascade interactions. In collisions with a carbon nucleus the influence of rescattering is much smaller. From Table 4 one can also see that theoretical values for the mean numbers of proton participants are slightly greater than experimental ones. This is also clearly seen if one compares the shape of distributions of proton participants. Perhaps, the DCM model slightly overestimates the number of cascade rescattering of secondary particles.

5. LARGE TRANSVERSE MOMENTA

We have pointed out earlier [21] that π^- mesons and protons with relatively high transverse momenta were observed in central CC collisions of p, d, ^{4}He, C with tantalum at 4.2 GeV/c per nucleon. Let us consider in more detail characteristics of such particles produced in d, ^{4}He, C interactions with carbon nucleus.

The inclusive transverse momentum squared distributions of all π^- mesons and protons produced in dC and CC central collisions are presented in Figs.3 and 4. An arrow shows the kine-

Table 5

Values of the slope parameters of the exponentials, $(GeV/c)^{-2}$ for proton and π^- meson $P_\perp^2$ distributions in dC, ^{4}HeC, CC, and CC central interactions

Type of particle / Type of interaction \ Parameter	Protons a	Protons b	π^--mesons a	π^--mesons b
dC	12.7+2.0	2.9+0.1	27.5+4.3	8.2+0.9
^{4}HeC	7.5+0.8	2.0+0.1	23.5+3.9	7.7+1.2
CC	7.0+0.5	2.0+0.1	24.9+1.9	6.1+0.9
CC central	5.6+0.4	1.9+0.1	21.8+1.3	5.6+0.7

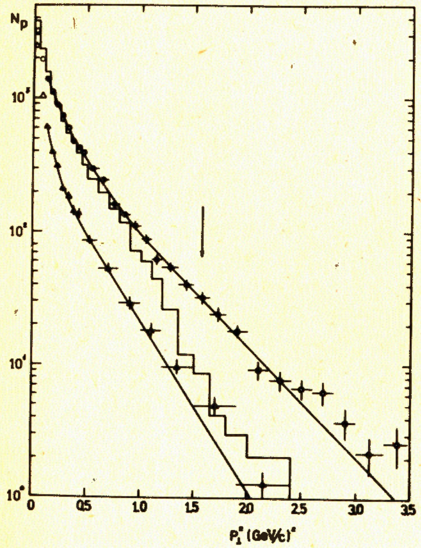


Fig.3. Inclusive proton $P_\perp^2$ distribution for dC(▲) *and* CC *central* (●) *collisions. The histogram shows the result of the DCM calculations for* CC *interactions.*

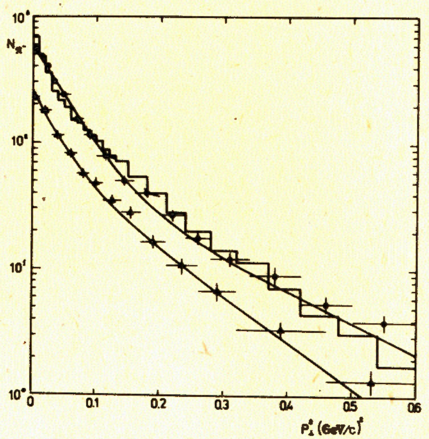


Fig.4. Inclusive π^- meson $P_\perp^2$ distribution for dC(▲) *and* CC *central* (●) *collisions. The histogram shows the result of the DCM calculations for* CC *interactions.*

matic limit for NN collisions. Open circles and triangles correspond to the fragmentation of the colliding nuclei, where protons with $P_p \le 150$ MeV/c are not detectable. The results of cascade model (DCM) [23,24] calculations for CC central collisions

are plotted as histograms. The result of the fit to a sum of two exponentials

$$N(P_\perp^2) = Ae^{-aP_\perp^2} + Be^{-bP_\perp^2} \qquad (2)$$

in the region of $P_\perp^2 \ge 0.1$ $(GeV/c)^2$ is shown by a solid curve. It is seen from Fig.3 that for $P_\perp^2 \ge 1$ $(GeV/c)^2$ the DCM calculations deviate from the data points. The π^- meson distributions (Fig.4) are qualitatively reproduced by the DCM. The calculated distribution for protons is normalized to the experimental data in the $P_\perp^2 \ge 0.1$ $(GeV/c)^2$ region while that for π^- mesons is normalized to the whole area of the experimental distribution.

Presented in Table 5 are the results of the approximation, according to (2), of the proton and π^- meson $P_\perp^2$ distributions in dC, ^{4}HeC, CC, and CC central collisions. It is seen that the slope of the proton distribution becomes more gentle with increasing the number of interacting nucleons. An analogous tendency is also observed for π^- mesons. Previously [21] we have published the results of the approximation of the proton $P_\perp^2$ distributions by a sum of three exponentials in CC interactions. The values of the first two slope parameters were somewhat greater than those presented in Table 5. Here we made a comparative analysis of the data within the $P_\perp^2$ intervals where the spectra are statistically reliable enough.

Experimentally π^- mesons, which escape the domain kinematically allowed for NN collisions, are observed in different nucleus-nucleus collisions. In order to enrich statistics for such events, we have summed up the $P_\perp^2$ spectra of π^- mesons produced in d, ^{4}He, C interactions with carbon and tantalum nuclei. The total number of π^- mesons amounted to ≈ 16000. Figure 5 shows the joint spectrum of π^- mesons with $P_\perp^2 \ge 0.3 (GeV/c)^2$. The histogram represents the DCM calculations summed up for CC central and CTa interactions. The simulated spectrum was normalized to the experimental one within a range of $0.3 \le P_\perp^2 \le 0.5 (GeV/c)^2$. The kinematic limit for NN collisions is indicated by an arrow. As is seen from Fig.5, the data for $P_\perp^2 > 0.5$ $(GeV/c)^2$ are not described by the DCM. The result of the fit to the sum of two exponentials (2) is shown by the solid curve. The slope parameters were found to be: a = (7.14+ +1.53) $(GeV/c)^{-2}$ and b = (2.45+0.56) $(GeV/c)^{-2}$.

Let us now consider the correlations in events which gave protons and π^- mesons with relatively high $P_\perp$. Presented in Table 6 and Fig.6 is the dependence of the average number of protons with $P_\perp \ge 1$ GeV/c (dots) and of π^- mesons with $P_\perp \ge 0.5$ GeV/c (triangles) on the average number of interacting nucleons in dC, ^{4}HeC, CC and in CC central collisions. A solid eye-leading line is drawn through the π^- meson points. It

Table 6

Avarage numbers of protons with $p_\perp \geq 1$ GeV/c and π^- mesons with $p_\perp \geq 0.5$ GeV/c, average transverse momenta for all participant protons and π^- mesons in dC , ^{4}HeC , CC , and CC central collisions

$\langle n \rangle$ \ $\langle P_\perp \rangle$ \ Type of interaction	dC	^{4}HeC	CC	CC central
$\langle n_p \rangle$ $P_\perp \geq 1$ GeV/c	0.12± 0.01	0.28± 0.02	0.37± 0.02	0.76± 0.03
$\langle n_{\pi^-} \rangle$ $P_\perp \geq 0.5$ GeV/c	0.075± 0.006	0.114± 0.009	0.160± 0.011	0.265± 0.014
$\langle P_{\perp p} \rangle$ (GeV/c)	0.463± 0.004	0.518± 0.005	0.504± 0.004	0.538± 0.005
$\langle P_{\perp \pi} \rangle$ (GeV/c)	0.266± 0.005	0.274± 0.005	0.256± 0.004	0.261± 0.003

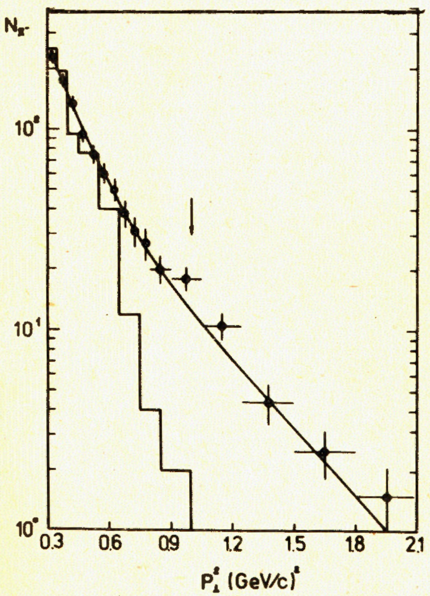


Fig.5. Inclusive π^- meson $P_\perp^2$ distribution summed up for d , ^{4}He, C *interactions with carbon and tantalum with $P_\perp^2 \geq 0.3$ (GeV/c)^2. The histogram shows the result of the DCM calculations.*

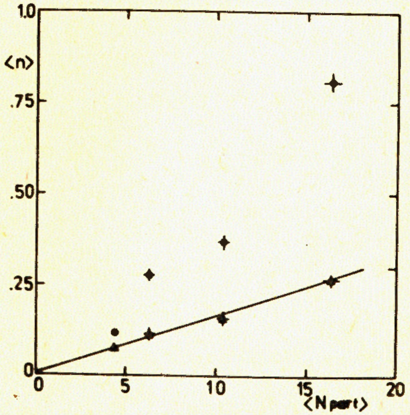


Fig.6. Average number of protons with $P_\perp \geq 1$ GeV/c (●) and π^- meson with $P_\perp \geq 0.5$ GeV/c (▲) as a function of the number of participant nucleons in dC, ^{4}HeC , CC, *and* CC *central collisions.*

is seen that the average number of π^- mesons with $P_\perp \geq 0.5$ GeV/c is proportional to the number of participant nucleons. For the average number of protons, $\langle n_p \rangle$, with $P_\perp \geq 1$ GeV/c an essentially stronger dependence is observed. A three-fold increase of the participant nucleon number results in a six-fold rise of the number of protons with $P_\perp \geq 1$ GeV/c. Besides, there is an indication of structure in this dependence. The strength of the $\langle n_p \rangle$ dependence increases when we transfer from dC to ^{4}HeC collisions. Then the dependence is weaker for inelastic CC interactions, and it again sharpens for CC central ones. Probably, a similar tendency, though less pronounced, is also true for π^- mesons (see Table 5 for the variations of the slope parameter b).The average transverse momentum of protons, $\langle P_{\perp p} \rangle$, also tends to increase irregularly.For CC central collisions the DCM underestimates significantly the value of $\langle P_{\perp p} \rangle$; it gives $\langle P_{\perp p} \rangle =$ $= 0.475$ GeV/c.

What possibly manifests itself here is a nuclear microstructure in the form of short-range correlations between nucleons. Interactions of deuterons with carbon may be considered as a good approximation of nucleon-carbon interactions due to a weak binding between proton and neutron in deuteron. In ^{4}He collisions with carbon, nucleon correlations begin to reveal themselves as the binding energy is essentially higher in ^{4}He nucleus than in deuteron. In the case of carbon beam the average number of protons with $P_\perp \geq 1$ GeV/c grows more slowly because the carbon nucleus has a distinct α-particle structure. Finally in CC central collisions, where the impact parameter is small and the number of participant nucleons is large, the increase of proton yield is of mainly combinatorial origin.

But there is yet another possible explanation of this phenomenon. If particles with $P_\perp \geq 1$ GeV/c are mainly direct deuterons, then the observed dependence of the average number of particles with high transverse momenta on the number of participant nucleons may take place as well. In the future we plan to study experimentally the composition of the set of particles with $P_\perp \geq 1$ GeV/c via characteristics of their secondary interactions. It should be noted that both explanations have in fact the same main point: the existence of nucleon-nucleon correlations in nuclei.

Let us consider angular correlations of protons with high transverse momenta in the azimuthal plane orthogonal to the beam direction. The distribution of pairs of protons with $P_\perp \geq$ ≥ 1 GeV/c versus difference, $\Delta\phi$, of their azimuthal angles in CC central collisions is shown in Fig.7. The histogram is the result of the DCM calculations. It is seen that there is a significant discrepancy between the model and the data. The model gives rise to an apparent effect of kinematic compensation in the region of $\Delta\phi = 180°$. In the experimental distribution there

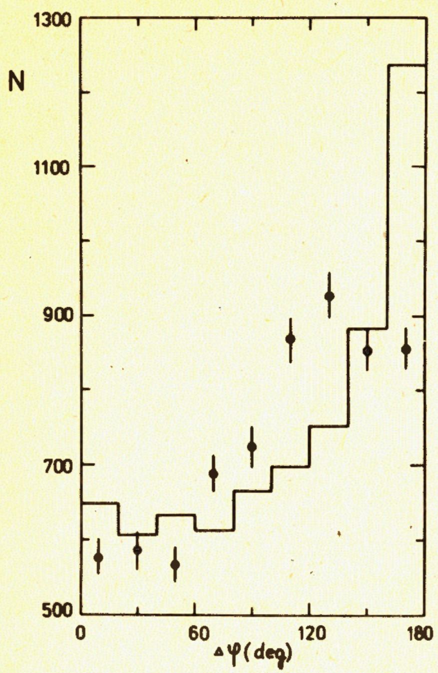


Fig.7. Azimuthal angular difference, $\Delta\phi$, between two protons with $P_\perp \geq 0.7$ GeV/c for CC central collisions. The histogram shows the result of the DCM calculations.

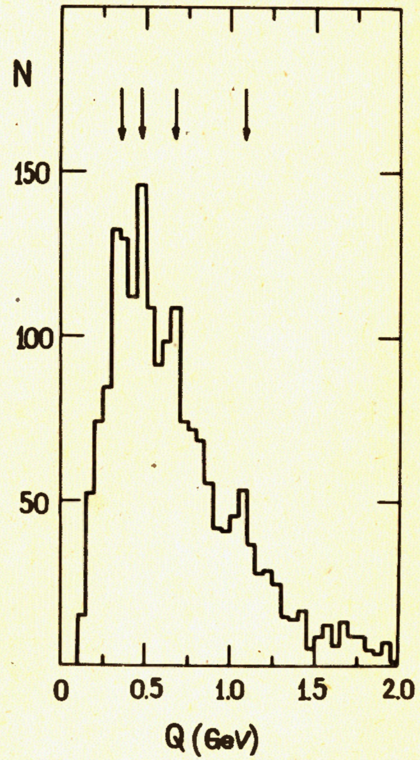


Fig.8. Effective two-proton mass spectrum for protons with $P_\perp \geq 0.5$ GeV/c and azimuthal angular difference $\Delta\phi = (120 \pm 60)°$ for CC central collisions with the number of such protons, $n_p = 3$ or 4. $Q = M_{pp} - 2m_p$.

is an essential excess over the theoretical one in the region of $\Delta\phi \simeq 120°$. This could be understood if there were a significant number of events in which a proton with high $P_\perp$ was balanced by a pair of protons. In other words, it is probably not a rare process when a proton knocks out a pair of protons, thus producing a triad of correlated particles as viewed in projection onto the azimuthal plane.

We came now to the point of possible observability of short-range nucleon-nucleon correlations in nuclear collisions. Presented in Fig.8 is the effective mass spectrum of two protons with $P_\perp \geq 0.5$ GeV/c, and with the azimuthal angle $\Delta\phi = (120 \pm 60)°$ between them for CC central events, where the number of such protons is $n_p = 3$ and 4. The Q variable was defined as

$Q = M_{pp} - 2m_p$. The experimental resolution in the invariant mass region around $M_{pp} \simeq 2.3$ GeV turned out to be about 50 MeV. The bin width for the Q distribution was chosen to be about 50 MeV. The bin width for the Q distribution was chosen equal to 50 MeV. The background distribution, calculated according to the DCM with experimental cuts taken into account, has a smooth shape without any peculiarities.

The assumed enhancements in the effective mass spectrum over a range of 2.22, 2.35, 2.55, and 2.93 GeV, which we consider as an indication of resonance structure, are shown by arrows in Fig.8. It is difficult to draw any definite conclusion about these resonances due to low statistics. But the total set of the data of this section shows interesting phenomena in nucleus-nucleus collisions when particles with high transverse momenta are produced.

6. TEMPERATURE AND DENSITY OF NUCLEAR MATTER

The production of strongly compressed and highly excited hadronic matter is one of the most intriguing /53-60/ aspects of relativistic nuclear physics. Possibilities of phase transitions of nuclear matter to pion condensate /53,54/ abnormal nuclear matter /55,56/ and quark-gluon plasma /58,59/ are widely discussed. The main question is what nuclear densities and temperatures are reachable at given atomic masses of colliding nuclei and their primary energy. Experimentally these parameters were measured for C, Ne, and Ar collisions at kinetic energies of 0.8 GeV and 2.1 GeV per nucleon /61,62/.

In this paper we have made an attempt to estimate the temperature and density of nuclear matter created in CC central collisions at P/A = 4.2 GeV/c. The temperature of nuclear matter has been determined from inclusive spectra

$$E\frac{d^3\sigma}{dp^3} = \frac{1}{p}\frac{d^2\sigma}{d\Omega\, dT} \qquad (3)$$

for negative pions and protons emitted at an angle $\sim 90°$ in the center-of-mass system (c.m.s.) of colliding nuclei. Here p and T are the c.m.s. momentum and kinetic energy of the particles, respectively. Taking particles emitted at angles of 90°, one can neglect the influence of peripheral collisions. We have analyzed the spectra (3) for protons and π^- mesons in the following intervals of angles θ : $(60 \div 120)°$, $(70 \div 110)°$ and $(80 \div 100)°$. The admixture of deuterons among protons in these angular intervals amounts to 3.5% as estimated according to the DCM, thus practically not affecting the value of the temperature obtained from the proton spectra.

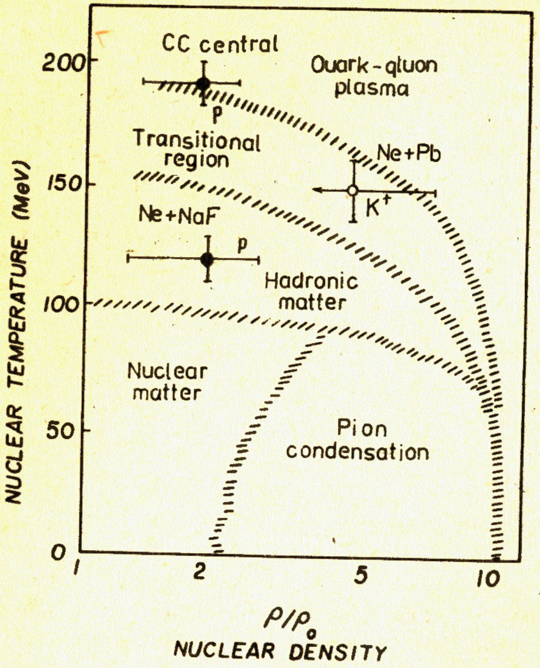


Fig.9. Theoretical boundaries for possible phase transitions of nuclear matter on the temperature-density plot. The result obtained for central collisions is shown along with the results of Refs.[61-63] *at lower energies.*

The inclusive spectra of protons and π^- mesons were approximated by the function

$$F(T) = A \exp(-T/T_0) \qquad (4)$$

The value of T_0 is the average kinetic energy of the particles, and hence it characterizes the temperature of nuclear matter at the stage of its expansion when the considered particles are emitted. Parameter T_0 is therefore commonly called an "apparent temperature". Results of the approximation show that the value of T_0 does not depend on the width of the angular interval within the experimental errors. The obtained values of the average temperature are: $T_0 = (190 \pm 5)$ MeV for protons and $T_0 = (127 \pm 3)$ MeV for π^- mesons. The temperature for protons is higher than that for pions. This apparently means that protons are emitted at an earlier stage of the expansion of nuclear matter than pions.

To evaluate the density of the excited nuclear matter, the method has been used[61-63] which is based on measuring the size of the interaction volume via identical particle interferometry[64-70] and on the estimation of the number of interacting nucleons from the colliding nuclei. If the interaction volume and the average number of participant nucleons are known, one can easily estimate the density of nuclear matter. It should be noted that two-particle interferometry gives information on the radius of the sphere on which particles become free of any interactions. Thus, if particles have a small free path in the nucleus or they are the decay products of resonances, the experimental value of the radius will be greater than that of the volume of nuclear matter at the early stage of its expansion.

The size of the particle emission region was determined by the analysis[71] of the two-proton correlations. The theoretical two-proton correlation function was calculated according to the formula from ref.[68]. The approximation of the experimental data for protons with $P \geq 0.5$ GeV/c gives the value of parameter r_0, assosiated with the size of the interaction volume, equal to $r_0 = (1.5 \pm 0.2)$ fm. The corresponding value of the density was calculated as

$$\rho = \langle N_{part} \rangle / (2\pi r_0^2)^{3/2}, \qquad (5)$$

and it turned out to be equal to $\rho = (0.30 \pm 0.08)\ \mathrm{fm}^{-3}$. The normal nuclear density for carbon nucleus was assumed to be $\rho_0 = 0.168\ \mathrm{fm}^{-3}$. Hence the density ratio was equal to $\rho/\rho_0 = 1.80 \pm 0.50$.

In Fig.9 we show theoretical boundaries for possible phase transitions of nuclear matter on a temperature-density diagram. The experimental data for CC central collisions along with the results of the experiments[61-63] at lower energies of colliding nuclei are also presented here. As is seen from this figure, the experimental point for CC interactions at 4.2 GeV/c is near the boundary of transition of hadronic matter to quark-gluon plasma.

7. MULTIISOBAR STATES

At energies of several GeV processes of excitation of isobars make up a considerable fraction of the inelastic nucleon-nucleon cross section[62]. Multinucleon central collisions of heavy ions can result in the formation of a volume of compressed nuclear matter where isobars are produced in reactions $NN \to N\Delta$ and $N\Delta \to \Delta\Delta$. If processes of isobar formation outrun their decay, $\Delta \to N\pi$, then the number of Δ isobars may in principle exceed the number of nucleons in the compressed volume. Thus, an unstable multiisobar state will arise, a kind of analogue to the pumped laser[72]. The decay of such a state would cause the coherent emission of a jet of identical π mesons with close values of momenta and angles.

Invariant mass, $M_{n\pi}$, spectra of groups of n pions of equal charge (n = 2,3,4) were analyzed. Preliminary data were published elsewhere[18,73]. The bin width for the $M_{n\pi}$ distributions was chosen equal to the average value of the experimental resolution in the range of small masses. The obtained resolution[73] was (20,40, and 60) MeV for n = 2,3, and 4, respectively. The experimental $M_{n\pi}$ distributions were compared to the background ones obtained by combining π^- mesons taken randomly from different events and normalized to the number of combinations in the

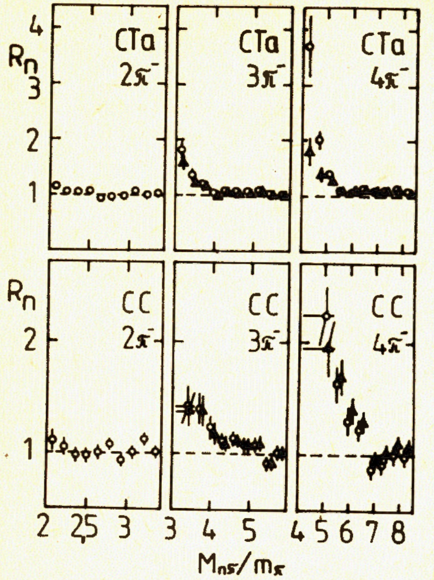
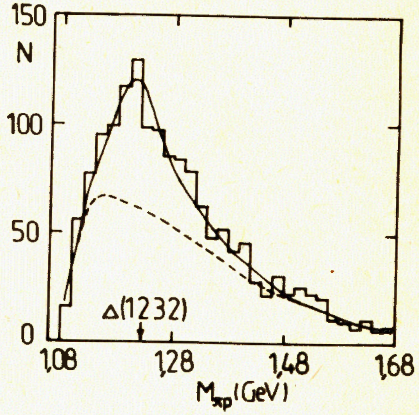


Fig.10. Ratio, R_n*, of the experimental to the background effective mass,* $M_{n\pi}$*, distribution for groups of* $n = 2,3,4$ π^- *mesons in* CTa *and* CC *central collisions.*

Fig.11. Effective mass distribution of protons and $\pi^{\pm}$ *mesons for* $\pi^{\pm}$ *mesons from the correlation region in* CC *central interactions. The solid curve shows the result of the fit to the superposition of the Breit-Wigner function and the background distribution (dashed curve).*



corresponding experimental distributions beyond some boundary value of $M_{n\pi}$. The shapes of the background distributions are well described by DCM. Presented in Fig.10 are the values of the ratio, R_n, (open circles) of the experimental $M_{n\pi}$ distributions to the background ones for groups of 2,3, and 4 π^- mesons produced in CTa and CC central interactions. It is seen that the experimental distributions exceed the background ones in the region of small $M_{n\pi}$ values. This excess becomes more apparent as n rises. This fact is indicative of the existence of correlations in the production of two, three, and four pions. As at our energy the cross section for the production of two and more π^- mesons makes up less than 3% of the inelastic cross section, this effect is the consequence of a considerable number of nucleon-nucleon interactions in one collision act. Black triangles represent the case when the background was made so that for each combination (n-1) pions were taken from one event and only

one pion from another. The remaining excess of R_n over unity in the range of small masses for such choice of the background indicates that there exist $3\pi^-$ and $4\pi^-$ meson correlations. As is seen from Fig.10, for $3\pi^-$ and $4\pi^-$ distributions the R_n values exceed unity over a wider range of masses for CC central collisions. This fact means that π^- mesons are emitted from a smaller volume in CC central collisions than in CTa ones.

π^+ mesons in CC and CTa interactions demonstrate a similar behaviour. For further analysis we used pions emitted from the "correlation region", i.e., pions which took part in at least one group of $n\pi$ with the value of $M_{n\pi}$ hitting from the region where $R_n > 1$. The contribution of Δ isobars was extracted from M_{π^+p} and M_{π^-p} spectra in CC central collisions. The spectator protons of colliding nuclei and π^+ mesons with a momentum of $P_\pi \geq 600$ MeV/c were excluded from the analysis. Note that pions emitted from the correlation region have small transverse momenta. To diminish a relative contribution of false combinations to the $M_{n\pi}$ distributions, the peripheral mechanism of isobar production was assumed. Therefore for each pion only one proton was appointed as a companion which gives the maximal angular difference in the azimuthal plane (perpendicular to the beam axis).

The experimental invariant mass, $M_{\pi p}$, distribution of $\pi^{\pm}p$ for $\pi^{\pm}$ mesons from the correlation region in CC central collisions is presented in Fig.11. A solid curve represents the result of the fit to the sum of Breit-Wigner function (1) and the background function (shown by a dashed curve). The values of the Δ-isobar mass and width were fixed in (1): $M_\Delta = 1232$ MeV and $\Gamma_\Delta = 120$ MeV. The background distribution was calculated according to the DCM under the same restrictions on the azimuthal angles as applied to the experimental data. The approximation was performed taking into account the experimental resolution for $M_{n\pi}$. The relative contribution of isobars was found to be 0.24 ± 0.04 at χ^2/N.D.F. = 0.86. The obtained value should be considered as a lower estimate of the isobar contribution due to bad background conditions for extracting the effect.

Thus, we have observed the effect of correlated emission of groups of identical π mesons connected with the formation of multiisobar states in many-nucleon nuclear collisions.

8. CONCLUSIONS

The analysis has been made of the vast experimental material on interactions of π^- mesons and light relativistic nuclei with carbon and tantalum nuclei. An indication of the existence of narrow diproton resonances has been obtained. It has been shown that a search for low-lying exotic multibaryon resonances by means of bubble chambers filled with propane and neon-hydrogen mixtures looks promising. It is not ruled out that multinucleon nucleus-nucleus collisions at high energies may provide a unique opportunity for a search for multiquark states.

Our results show that at energies of about 4 GeV per nucleon it is possible to reach the transitional region between hadronic matter and quark-gluon plasma.

The observed dependence of the average multiplicity of protons with $P_\perp \geq 1$ GeV/c on the number of participant nucleons looks rather intriguing and may be indicative of short-range nucleon-nucleon correlations. The formation of multiisobar states is observed in multinucleon interactions of carbon nuclei with carbon and tantalum nuclei.

Acknowledgements. We would like to express our deep gratitude to the technical staff of the 2-meter propane bubble chamber and to the scanning, measuring and processing teams for their contribution to this experiment.

REFERENCES

1. Baldin A.M. JINR, P7-5808, Dubna, 1971; Brief Comm.Phys., 1971, 1, p.35; Progress in Particle and Nuclear Physics, 1980, 4, p.95.
2. Baldin A.M. et al. JINR, P1-5819, Dubna, 1971; Stavinsky V.S. ECHAYA, 1979, 10, p.949; Baldin A.M. et al. JINR, E1-82-472, Dubna, 1982.
3. Cronin J.W. et al. Phys.Rev.D., 1975, 11, p.3105.
4. Kluberg L. et al. Phys.Rev.Lett., 1977, 38, p.670.
5. Antreasyan D. et al. Phys.Rev.D, 1979, 19, p.764.
6. Savin I.A. Proc. of the VI International Seminar on High Energy Physics Problems, 1981; JINR, D1,2-81-728, Dubna, 1981, p.223.
7. Aubert J.J. et al. CERN-EP/83-14, Geneva, 1983; Phys. Lett., 1983, 123B, p.275.
8. Bodek A. et al. Preprint UR 41/COO-3065-348, SLAC-PUB-3041, 1983.
9. Ahababian N. et al. JINR, 1-12114, Dubna, 1979; Angelov N. et al. JINR, 1-12424, Dubna, 1979; Gasparian A.P. et al. JINR, 1-80-778, Dubna, 1980.
10. Angelov N. et al. Yad.Fiz., 1978, 28, p.1304.
11. Angelov N. et al. Yad.Fiz., 1978, 27, p.1020.
12. Angelov N. et al. Yad.Fiz., 1979, 30, p.1590.
13. Angelov N. et al. Z.Phys.C, 1980, 5, p.1; Bartke J. Nucl.Phys.A, 1980, 335, p.481.
14. Baatar Ts. et al. Yad.Fiz., 1980, 32, p.1372.

15. Angelov N. et al. Yad.Fiz., 1981, 33, p.1046.
16. Gasparian A.P. et al. Yad.Fiz., 1981, 34, p.1328.
17. Angelov N. et al. Yad.Fiz., 1980, 31, p.411.
18. Agakishiev H.N. et al. Yad.Fiz., 1981, 34, p.1517.
19. Angelov N. et al. Yad.Fiz., 1980, 32, p.1582.
20. Baatar Ts. et al. Yad.Fiz., 1982, 36, p.431.
21. Agakishiev H.N. et al. Z.Phys.C, 1982, 12, p.283; 1983, 16, p.307.
22. Agakishiev H.N. et al. JINR, P1-84-35, Dubna, 1984; JINR, P1-83-662, Dubna, 1983.
23. Toneev V.D., Gudima K.K. Yad.Fiz., 1978, 27, p.658.
24. Toneev V.D., Gudima K.K. Nucl.Phys., 1983, A400, p.173c.
25. Schulz H. et al. Phys.Lett., 1983, B124, p.458.
26. Shahbazian B.A. Proc. of the Int.Conf. on Hypernuclear and Kaon Physics. Heidelberg, Germany, 1982, p.287; JINR, E1-82-446, Dubna, 1982; Nucl.Phys., 1982, A374, p.73.
27. Auer I.P. et al. Phys.Rev., 1981, D24, p.2008; Phys.Lett., 1977, B67, p.113.
28. Aprile E. et al. SIN Phys.Rep., 1981, 3, p.78.
29. Borisov N.S. et al. JETP, 1981, 81, p.1583.
30. Bystricky J., Lehar E. Nucleon-Nucleon Scattering Data. Karlsruhe, 1978.
31. Yokosawa A. Proc. of the Meeting on Two-Nucleon Systems and Dibaryon Resonances. Hiroshima, Japan, 1979; ANL-HEP-CP-80-01; Phys.Rep., 1980, 64, p.47.
32. Kamae T. et al. Phys.Rev.Lett., 1977, 38, p.468.
33. Ikeda H. et al. Phys.Rev.Lett., 1979, 42, p.1321.
34. Baba K. et al. Phys.Rev.C, 1983, 28, p.286.
35. Arvieux J. et al. SIN News Letters, 1980, 13, p.28.
36. Hoffiezer J.H. et al. Phys.Rev., 1981, C23, p.407.
37. Kanai K. et al. Prog.Theor.Phys., 1979, 62, p.153.
38. Glagolev V.V. et al. JINR, E1-83-59, Dubna, 1983.
39. Bayramov A.A. et al. JINR, P1-83-207, Dubna, 1983.
40. Verebryusov V.S. et al. ITEP, 273, Moscow, 1964.
41. Besliu K. et al. JINR, D1-83-815, Dubna, 1983.
42. Jaffe R.L. Phys.Rev.Lett., 1977, 38, p.195.
43. Lichtenberg D.E. Lett.Nuovo Cim., 1978, 23, p.339.
44. Matveev V.A. JINR, D1,2-12036, Dubna, 1978, p.137.
45. Matveev V.A., Sorba P. Nuovo Cimento, 1976, A45, p.257.
46. Mulders P.J., Aerts A.T., Swart J.J. Phys.Rev., 1980, D21, p.2653.
47. Ishida S., Oda M. Prog.Theor.Phys., 1979, 61, p.1401.
48. Imachi M. et al. Prog.Theor.Phys., 1976, 55, p.551.
49. MacGregor M.H. Phys.Rev., 1979, D20, p.1616.
50. Ferreira E., Perer Munguia G.A. PUC Report 05/81, Brasil.
51. Makarov M.M. UPhN, 1982, 136, 2, p.185; Lapidus L.I. JINR, P2-11762, Dubna, 1978; Ableev V.G. et al. JINR, E1-82-777, Dubna, 1982.

52. Flamino V. et al. Compilation of Cross Sections and Induced Reactions. CERN-HERA, 79-03, Geneva, 1979; Ivanovskaya I.A., Prokopieva S. JINR, P1-83-96, Dubna, 1983.
53. Migdal A.B. Rev.Mod.Phys., 1971, 50, p.107.
54. Weise W., Brown G.E. Phys.Rep., 1976, 27C, p.1.
55. Lee T.D., Wick G.C. Phys.Rev.D, 1974, 9, p.2291.
56. Lee T.D. Rev.Mod.Phys., 1976, 47, p.267.
57. Jacob H., Tran Thanh Van J. Phys.Rep., 1982, 88C, p.321.
58. Stöker H. et al. Phys.Lett.B, 1979, 81, p.303.
59. Gasparian A.P. JINR, P2-80-389, Dubna, 1980.
60. Ruck V., Gyulassy M., Greiner W. Z.Phys.A, 1979, 277, p.391.
61. Nagamiya S., Gyulassy M. LBL-14035, Berkeley, 1982.
62. Nagamiya S. Proc. of the Int.Conf. on Nucl.Phys., Florence, 1983.
63. Nagamiya S. UTPN-204, Preprint University of Tokyo, 1983.
64. Kopylov G.I., Podgoretsky M.I. Yad.Fiz., 1972, 15, p.392.
65. Kopylov G.I. Phys.Lett.B, 1974, 50, p.412.
66. Cocconi G. Phys.Lett.B, 1974, 49, p.459.
67. Yano F.B., Koonin S.E. Phys.Lett.B, 1978, 78, p.556.
68. Gyulassy M., Kauffman S.K., Wilson L.W. Phys.Rev.C, 1979, 20, p.2267.
69. Koonin S.E. Phys.Lett.B, 1977, 70, p.43.
70. Lednicky R., Lyuboshitz V.L. Yad.Fiz., 1981, 35, p.1316.
71. Akhababian N. et al. JINR, E1-83-670, Dubna, 1983.
72. Wakamatsu M. Nuovo Cim.A, 1980, 56, p.336.
73. Akhababian N. et al. JINR, E1-81-470, Dubna, 1981.

Received by Publishing Department
on June 27, 1984.

Агакишиев Г.Н. и др. E1-84-448

Исследование корреляционных явлений
в ядро-ядерных взаимодействиях при 4,2 ГэВ/с на нуклон

Методикой 2-метровой пропановой камеры с внутренней мишенью из тантала проведено экспериментальное исследование неупругих столкновений легких релятивистских ядер d , ^{4}He и C с ядрами углерода и тантала. Получено указание на образование узких дипротонных резонансов. В рамках термодинамического подхода показано, что многонуклонные CC-центральные взаимодействия находятся вблизи перехода ядерной материи в кварк-глюонную плазму. Наблюден эффект коррелированного испускания групп тождественных π -мезонов, обусловленный образованием мультиизобарных состояний в многонуклонных взаимодействиях ядер.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1984

Agakishiev H.N. et al. E1-84-448

Investigation of Correlation Phenomena
in Nucleus-Nucleus Interactions at 4.2 GeV/c per Nucleon

Inelastic interactions of light relativistic nuclei d , ^{4}He, and C with carbon and tantalum nuclei were investigated using the 2 m JINR propane bubble chamber with an internal tantalum target. An indication of the existence of narrow diproton resonances was obtained. Using the thermodynamical model, it was shown that the multinucleon CC central interactions are near the boundary of transition of nuclear matter to quark-gluon plasma. The correlated emission of groups of identical π mesons, caused by the formation of multiisobar states in multinucleon interactions of nuclei, was observed.

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1984