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INTERACTIONS OF RELATIVISTIC NUCLEI FROM THE DUBNA SYNCHROPHASOTRON. Fragmentation and Particle Production

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1984

Interactions of relativistic nuclei have been studied at Dubna since the early seventies. During this period of time the choice of nuclei accelerated in the synchrophasotron was being gradually enlarged and their intensity increased. Putting a new ion source with a 10 Joule CO_2 laser into service led to an increase of the intensity of a beam of carbon ions by a factor of about 10^2 and allowed one to add lithium and magnesium to the last year's list of accelerated nuclei [1]. Table 1 shows nuclear beams available at present (summer 1984). All these are external beams of fully stripped ions. Fast or slow ejection with 400 ms "flat top" is at the user's choice.

Table 1

Type of nuclei	Energy, GeV	Intensity per pulse	Ion source
p	9.0	4×10^{12}	duoplasmatron
d	8.2	1.5×10^{12}	duoplasmatron
d↑	8.2	5×10^{8}	"Polaris"
^{3}He	17.2	2×10^{10}	duoplasmatron
^{4}He	16.4	5×10^{10}	duoplasmatron
^{6}Li	24.6	1.5×10^{8}	laser
^{7}Li	23.9	2×10^{9}	laser
^{12}C	49.2	5×10^{8}	laser
^{16}O	65.6	5×10^{5}	"Krion"
^{22}Ne	81.0	10^{4}	"Krion"
^{24}Mg	100	10^{5}	laser

Cryogenic panels [2] are being installed inside the vacuum tank of the synchrophasotron in order to improve the vacuum, what is necessary for the acceleration of heavier nuclei. With all panels in place, what is expected by the year's end, one should be able to go to Z=18 (argon). For Z/A=0.5 nuclei the maximum kinetic energy is 4.2 GeV per nucleon (momentum $P_{max} \cong 5$ A GeV/c), what is substantially higher than at the Bevalac.

In more distant future there are plans to build the NUCLOTRON, a new synchrotron ring with superconducting magnets, which would be able to accelerate all ions up to about 6 GeV per nucleon [3]. A model superconducting synchrotron for a 1.5 GeV energy for protons, called the SPIN, is now near completion [4].

Physics experiments at the synchrophasotron use various visual track detectors (bubble and streamer chambers, nuclear emulsions) and

$\rightarrow p + \ldots$ at $P = 8.9$ GeV/c) allowed one to reach higher momentum transfers and revealed a discrepancy with the standard nucleon-nucleon interaction form (the "Paris" potential [30]), see Fig.1.

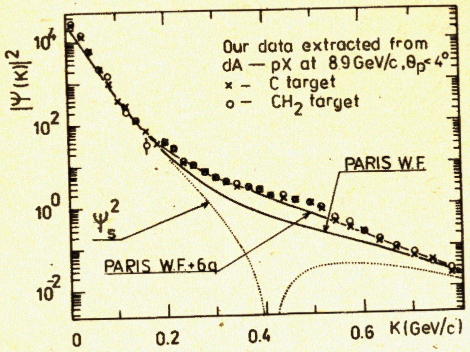


Fig.1. Nucleon momentum distribution in the deuteron [29] .

The "Dubna wave function" extracted from these data agrees with that from electroproduction experiments at SLAC [31], Kharkov [32], and Saclay [33] . The observed excess for $k \gtrsim 0.2$ GeV/c (k - relative nucleon momentum in deuteron) is interpreted as a manifestation of the six-quark component in the deuteron wave function: $\psi(d) = (1-\alpha)\,\psi(pn) + \alpha \cdot \psi(6q)$, with a value of about 10% for the "6q" admixture. The hybrid model of ref. [34] has been used for the description of the data. An investigation of the fragmentation of polarized deuterons could give additional information on the quark structure of the deuteron wave function [35] . Such an investigation is planned at Dubna by the same group.

For heavier nuclei, as pointed out in refs. [36,37] , the longitudinal momentum distribution in the fragmentation process with the removal of one nucleon, such as $^4He \rightarrow {}^3He$, or $^{16}O \rightarrow {}^{15}O$, will directly reflect the internal momentum distribution of a nucleon inside the nucleus. In such a reaction the longitudinal momentum distribution of the observed cluster of A-1 nucleons in the projectile rest frame must be equal to the momentum distribution of a single nucleon inside the projectile because of momentum conservation [24] .

The reaction $^4He \rightarrow {}^3He$ at $P = 8.6$ GeV/c has been studied at Dubna using the 1 m hydrogen bubble chamber [38] . The momentum distribution of the "spectator" ^3He fragments up to about 400 MeV/c can be satisfactorily described using the wave function of the ^4He nucleus given by Bassel and Wilkin [39] and the formalism developed by Kopeliovich and Potashnikova [40]. Alternatively, the charge density distribution as given by Sick [41] may be taken and the spectator momentum distributions obtained by a Monte-Carlo procedure. This method allows one to calculate momentum distributions not only for single nucleons but also for nucleon clusters as shown for the reaction $^4He \rightarrow {}^2H$ in ref. [42] . The same group is now studying the reaction

$^3He \rightarrow {}^2H$ at $P = 8.0$ and 13.5 GeV/c. Also the "Alpha" spectrometer group has begun to investigate $^3He \rightarrow p$ and $^3He \rightarrow d$ reactions at beam momentum from 6.0 to 13.5 GeV/c with the aim to extract the wave function, especially at higher values of internal momentum. A similar experiment with ^4He is planned. In order to describe the ^3He data, in ref. [43] the hybrid model was appropriately extended. Besides the "6q" admixture, a "9q" contribution was also included at a level of $\sim 10^{-3}$. The reaction $^{16}O \rightarrow {}^{15}O$ at $E/A = 2.1$ GeV was studied at Berkeley [37] with the result that a high-momentum part of the wave function should be modified. A similar reaction $^{16}O \rightarrow {}^{15}N$ at $E/A = 3.5$ GeV is being studied at Dubna using the 1 m hydrogen bubble chamber.

An evidence for the existence of multiquark configurations in nuclei and for their increasing role with increasing A comes also from the analysis of nuclear structure functions. A first indication was provided by experiments on cumulative particle production [44] . We call "cumulative" those processes of particle emission which proceed beyond kinematical limits of a single nucleon-nucleon collision (for a target at rest such processes would require a target heavier than nucleon mass). The emission of pions, kaons and antiprotons at backward angles (i.e., with high values of longitudinal momentum transfer) has been studied at Dubna in proton-nucleus collisions at 8.9 GeV. The results of this experiment are shown in Fig. 2a. It has been found [45] that inclusive cross sections factorize and can be expressed as a product of two universal functions:

$$\frac{E}{A}\,\frac{d^2\sigma}{p^2\,dp^2\,d\Omega} = C\;\varphi(p_\perp^2)\,\exp(-X/\langle X\rangle)\,,$$

where $\varphi(p_\perp^2) = 0.9\exp(-2.7\,p_\perp^2) + 0.1$ describes the transverse momentum dependence, X is a longitudinal scaling variable, and $\langle X\rangle = 0.14$ is a universal parameter. The variable X , closely related to the Bjorken variable $x = Q^2/2M\nu$, is defined as follows

$$X = \frac{(P_I \cdot P_i) - \frac{1}{2}m_i^2}{(P_I \cdot P_{II}) - M_I M_{II} - (P_{II} \cdot P_i)}\,,$$

where P_I and P_{II} are the four-momenta of colliding nuclei, M_I and M_{II} their masses, and the index i corresponds to a secondary particle. For deep inelastic lepton scattering, neglecting masses, X/A_{II} approaches x . The variable X is called the effective cumulative number, and in the rest frame of the fragmentating nucleus it is approximately equal to the minimum target mass $M_{min} = (E - p_{\parallel})/m_N$.

where E and $p_{\parallel}$ are the energy and longitudinal momentum of the produced particle, m_N is the nucleon mass. The "cumulative" region corresponds to $X>1$.

Similar results and the same value of the slope $\langle X\rangle = 0.14$ have been obtained in the proton-nucleus "cumulative" experiment at 400 GeV at Fermilab [46].

In quark-parton models the function $G(X) = \exp(-X/\langle X\rangle)$ is interpreted as a quark-parton structure function of the nucleus, and the value of $\langle X\rangle$ as an average longitudinal momentum of quarks in the nucleus [47]. At least two arguments can be given in favour of such interpretation of $G(X)$.

Firstly, the same value of $\langle X\rangle$ has been obtained in deep inelastic muon scattering on nuclei. The corresponding prediction was made by Baldin [9,48] and verified by the NA-4 experiment at CERN [49]. These results are shown in Fig. 2b, while Fig. 3 compiles the values of $\langle X\rangle$ for proton-nucleus "cumulative" experiments and for deep inelastic scattering of 280 GeV muons on nuclei. As deep inelastic lepton scattering is believed to represent interactions with quarks, the universal value of the slope parameter $\langle X\rangle$ for all discussed experiments indicates the quark nature also for cumulative processes.

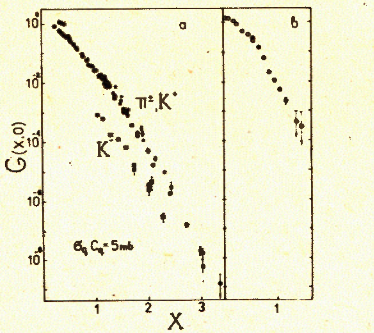


Fig.2. Invariant cross sections for cumulative meson production (a) and deep inelastic muon scattering (b) on nuclei [45,49].

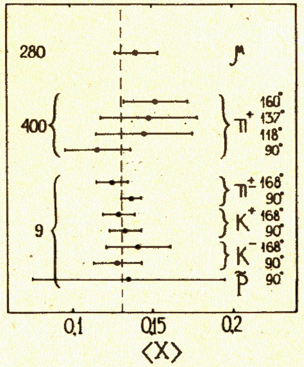


Fig.3. Compilation of the values of $\langle X\rangle$ obtained from various experiments.

Secondly, the value of $\langle X\rangle = 1/6$, close to the experimental value of 0.14, follows from quark counting rules. According to refs.[50,51], the expected behaviour is $(1 - X/i)^{6i-3}$ which approaches $\exp(-6X)$ already for not very large i.

Ratios of quark-parton structure functions for various nuclei, as obtained from the data on cumulative particle production, are shown in Fig. 4. In the region $X>1$ three sets of points are drawn: σ_{Pb}/σ_{D2}, σ_{Pb}/σ_{He} and σ_{Pb}/σ_{Al}. Their very different behaviour can be interpreted as a manifestation of multiquark configurations existing in nuclei. In the deuterium nucleus there are no configurations including quarks from more than two nucleons, while the aluminium nucleus differs a little, in this sense, from the lead nucleus. The comparison of structure functions for various nuclei [47] indicates that for $A\geqslant 20$ the amount of multiquark configurations in nuclei is stabilized at a certain level.

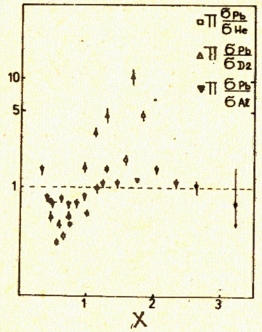


Fig.4. Ratios of nuclear structure functions obtained from cumulative meson production experiments at Dubna [47].

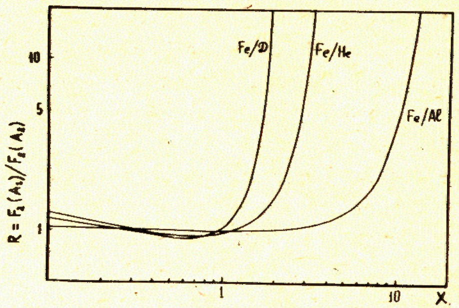


Fig.5. Ratios of nuclear structure functions calculated in the quark-parton model with multiquark bags [56].

These conclusions have been confirmed by experimental results on deep inelastic scattering of muons at CERN [52] and electrons at SLAC [53] on various nuclei. In these experiments it has been found that structure functions of Fe and D nuclei differ strongly, and their ratio cannot be explained by the known nuclear mechanism. This is often called "EMC effect" after ref. [52]. Results of these experiments are, however, restricted to $X<1$.

Of many theoretical papers aiming to explain the EMC effect we shall quote only a few. Faissner and Kim [54] and Kondratyuk and Shmatikov [55] claim that in order to describe the experimental data, the admixture of "12q" clusters in heavy nuclei should be as high as 15-25%. The latter authors stress that "12q" bags are not identical to alpha-particles, the quark distribution in a bag being different from that in a nucleon. Garsevanishvili and Menteshashvili [56], on the other hand, claim to need only "6q" clusters and a small admixture of "9q" clusters in order to describe the nuclear structure functions both in the $X<1$ and $X>1$ kinematical regions. In calculations they use a fixed bag radius of $r_q = 0.8$ fm. Fig.5 shows their results for the ratios of nuclear structure functions (note the log--log scale).

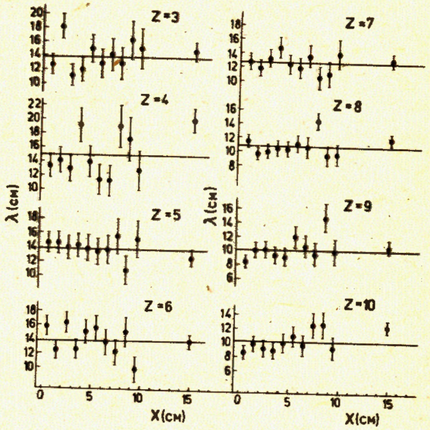
The fragmentation of a relativistic nucleus into several fragments can also provide interesting information on nuclear structure. Such investigations are still the domain of visual track detectors what, unfortunately, means limited statistics. In an emulsion experiment at Dubna it has been found that a relativistic ^{12}C nucleus with relatively high probability is broken into alpha-particles [57]. A similar evidence comes from the propane bubble chamber [58]. Preliminary data from the hydrogen bubble chamber also indicate a high fraction of alpha-particles among the fragmentation products of ^{16}O nuclei. However, it should be pointed out that these low-momentum-transfer processes are probably manifestation of "usual" alpha-clusters known from standard nuclear physics rather than of "12q" bags which should be searched for in high-momentum-transfer processes.

Speaking of the fragmentation of relativistic nuclei, one is tempted to say a few words about "anomalons" (nuclear fragments with anomalously high interaction cross sections), which have attracted great attention during the last years. Now it seems that the odds are against the existence of "anomalons": one can quote here several recent experiments using emulsions [59, 60], plastic detectors [61] and multilayer Cherenkov counters [62, 63]. As an example, I will show in Fig. 6 the results of the emulsion work by the Alma-Ata,etc.,Collaboration [59], in which statistics was high enough to allow fragments of all charges from $Z = 3$ to $Z = 10$ to be studied separately. No evidence for anomalons can be seen.

Concluding the first part of my talk, I would like to state that fragmentation processes of relativistic nuclei are perhaps "ordinary nuclear physics in a fast-moving reference frame" only at very low momentum transfers, while at higher momentum transfers they reflect the quark structure of nuclei. Quark-parton models assuming the existence of multiquark configurations in nuclei seem to be able to explain the behaviour of nuclear formfactors, deep inelastic lepton scattering and particle production in the cumulative region. Substantial differences exist, however, between various formulations of such models.

Coming now to the second topic, which is multiple particle pro-

Fig. 6. Mean free path of fragmentation products of ^{22}Ne nuclei in emulsion [59] - evidence against "anomalons".



duction, I would like to point out that <u>most</u> of the relevant experimental data obtained at Dubna, as well as at Berkeley, are <u>inclusive</u> data (cross sections, multiplicities, single-particle spectra, etc.). Inclusive measurements have recently become the subject of strong criticism as non-discriminative between various theoretical models and thus not useful for our understanding of the underlying physics (see, e.g., [64]). Let us, however, recall what we have learnt from the large-angle two-proton correlation experiment at Berkeley. The main result of this experiment was a direct observation of quasi--elastic NN scattering processes in collisions of relativistic nuclei [65] (Clean Knock-On, or CKO processes in the terminology of ref. [66]). For light nuclei, the contribution of these processes to the proton yield would amount to about 40%. An evidence has been also obtained that most of the protons suffer more than one NN collision [67]. A substantial role of NN scattering, both elastic and inelastic, could, however, be expected on the basis of general arguments given at the beginning of this talk. A successful description of experimental data by the cascade model supports this point of view (see below). Results of our earlier analysis of the interrelation between the number of produced pions, dispersion of their multiplicity distribution and number of interacting nucleons from the projectile nucleus also indicate the independent nucleon interaction mechanism [8]. So, we have not learnt anything exciting. In this respect interference (small--angle) correlations look much more interesting.

Multiple particle production has been studied at Dubna by means of the 2m propane bubble chamber with internal tantalum target plates, exposed to p, d, ^4He and ^{12}C beams at P/A = 4.2 GeV/c, and the 2 m streamer chamber "SKM-200" with various internal solid targets exposed to ^4He, ^{12}C and ^{16}O beams at P/A = 4.5 GeV/c. Small exposures of the bubble chamber to ^{22}Ne and ^{24}Mg beams have been also made for methodical purposes. Main results from the bubble chamber can be found in refs. [68-70], and those from the streamer chamber in refs. [71-73].

Let us look at some new results on interactions of p, d, ^4He and ^{12}C with carbon [74]. These reactions were selected from interaction events occurring in propane. Secondary tracks in about 2000 events of each group were measured, and single-particle inclusive distributions were obtained. Table 2 shows the average characteristics of secondary π^- mesons together with the predictions of the Dubna version of the cascade model - DCM [75]. Fig. 7 shows π^- rapidity distributions also compared to DCM. The agreement with the model is good.

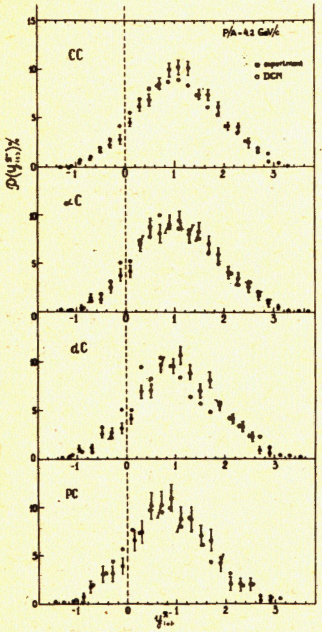


Fig. 7. Longitudinal rapidity of negative pions produced in interactions of p, d, He and C with carbon at p/A=4.2 GeV/c [74].

Data on π^o production in d-Ta and C-Ta collisions at 4.2 GeV/c per nucleon [76] are certainly worth mentioning. In the JINR propane bubble chamber gamma-quanta can be recorded with an average registration probability of ~8%. On the basis of 248 e^+e^- pairs from d-Ta and 855 e^+e^- pairs from C-Ta interactions it has been found that the average numbers of π^o mesons and their multiplicity distributions are the same as the corresponding distributions for π^-. In order to obtain the multiplicity spectra, the Tikhonov's regularization method was used in solving the system of equations. Fig. 8 displays the dependence of the average number of π^o versus the number of π^-. Contrary to NN interactions at the same energy per nucleon where $\langle n_o \rangle$ decreases with increasing n_-, in nucleus-nucleus collisions $\langle n_o \rangle$ increases with n_- up to $n_- = 2\langle n_- \rangle$.

This difference in behaviour seems, however, only to reflect the mechanism of multiple NN collisions in nucleus-nucleus interactions.

Table 2

		pC	dC	HeC	CC
$\langle n_- \rangle$		0.33 ± .02	0.62 ± .03	1.07 ± .05	1.52 ± .07
$\langle n_- \rangle$ / D_-^2	expt.	1.14 ± .08	1.23 ± .08	1.11 ± .08	0.85 ± .07
	DCM	1.23	1.15	1.07	0.70
$\langle p_\perp \rangle$	expt.	0.26 ± .01	0.26 ± .01	0.26 ± .01	0.25 ± .01
GeV/c	DCM	0.21	0.23	0.24	0.24
$\langle y_{Lab} \rangle$	expt.	0.85 ± .04	1.00 ± .03	1.04 ± .03	1.10 ± .03
	DCM	0.95	0.98	1.05	1.05

An interesting question in nucleus-nucleus collisions is how many nucleons participate in the interaction. The number of the interacting nucleons from the projectile nucleus, ν_p, can be determined experimentally by counting non-interacting (spectator) nucleons. In our earlier papers it has been shown that for a given target nucleus the multiplicity of produced pions is proportional to ν_p: $\langle n \rangle = a \langle \nu_p \rangle$.*) This relation confirms the conjecture about independent interaction in the target of nucleons from the projectile [8]. A direct determination of the corresponding number, ν_t, for the target nucleus is difficult, as low-energy fragments of the target nucleus are not detected. One could, however, use the asymmetry in the emission of secondary particles in order to determine ν_t [77]. The additive quark model with coloured strings of Białas et al. [78] provides a possible theoretical basis for such an approach. According to this model, particles emitted in the central region result from the break-up of coloured strings spanned between interacting quarks. Average velocity of particles created by this mechanism is determined by numbers of quarks (and thus also: nucleons) from the projectile, N_p, and from the target, N_t, "wounded" by the interaction. As it is natural to assume that the distribution of particles resulting from the break-up of coloured strings should be symmetric, then the velocity of a

*) Multiplicity distributions of negatively charged pions were published earlier on the basis of scanning alone.

symmetry system can provide a measure of the ratio of the numbers of interacting nucleons from target and projectile: N_t/N_p. Choosing the simplest method of finding the symmetry from the requirement of equality of the numbers of particles (pions) emitted into the forward and backward hemispheres*), one can find N_t/N_p from the formula

$$N_t/N_p = (\beta_o - \beta_{sc})/(\beta_o + \beta_{sc}) \quad ,$$

where β_o is initial nucleon velocity in the NN centre-of-mass system and β_{sc} velocity of the "symmetry system" relative to the NN system. For collisions of various light nuclei (d, ^4He, ^{12}C) with tantalum one obtains the numbers displayed in Table 3 and Fig.9. The ratio N_t/N_p decreases with increasing A_p as $A_p^{-(0.73 \pm .09)}$. Taking the values of N_p determined in our experiment (see Table 3), one can determine N_t. The obtained values of N_t are given in the lowest raw of Table 3. They show a very weak dependence on A_p.

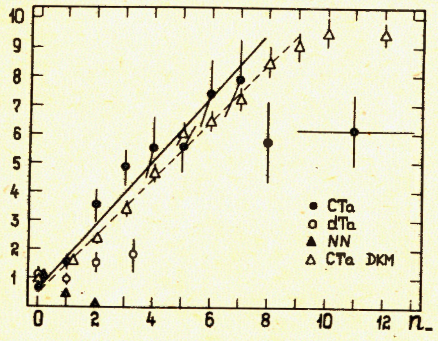


Fig. 8. Average number of neutral pions as a function of negative pion multiplicity in dTa and CTa interactions at p/A=4.2 GeV/c[76].

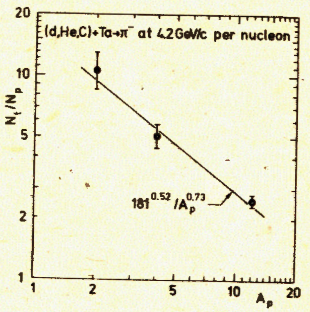


Fig. 9. Target-to-projectile ratio of the numbers of participant nucleons for interactions of d, He and C with tantalum [77].

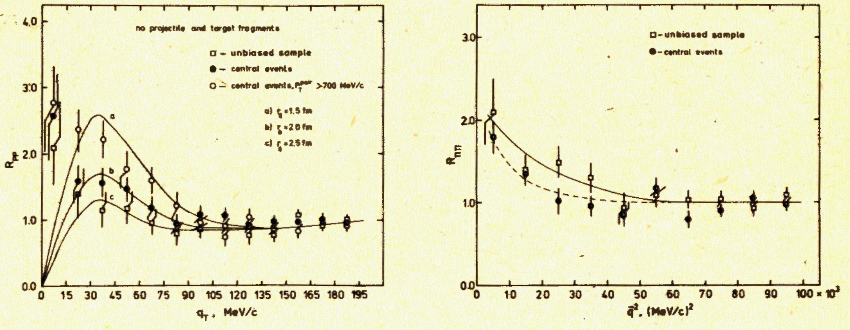
Table 3

	d-Ta	He-Ta	C-Ta
N_t/N_p	10.5 ± 1.9	5.0 ± 0.6	2.5 ± 0.2
$\langle N_p \rangle (n_- \geq 1)$	(1.7)+	3.3 ± 0.1	7.4 ± 0.1
$\langle N_t \rangle (n_- \geq 1)$	(15.9)+	16.5 ± 2.1	18.2 ± 1.1

+ extrapolated values

*) Rapidity distributions for pions show approximate symmetry about the median value.

In C-C interactions at 4.2 GeV/c per nucleon interference correlations have been studied both for $\pi^-\pi^-$ and pp pairs [79]. For $\pi^-\pi^-$ pairs the formalism of Kopylov and Podgoretsky [80] has been used, and for pp pairs - that of Koonin [81] and Lednicky and Lyuboshitz [82]. The obtained distributions are shown in Figs. 10 a, b. They yield the following values of the rms radii of the emission volume: $r(\pi\pi) = (2.8 \pm 0.7)$fm for an unbiased sample and $r(\pi\pi) = (3.8 \pm 0.9)$fm for "central" collisions. The corresponding values of r(pp) are about 4.3 and 3.5 fm with an estimated error of about 0.4 fm. Smaller value of r(pp) for "central" collisions (a tendency opposite to that of $r(\pi\pi)$) could be qualitatively explained using the thermodynamical model with two fireballs and taking the production of delta-isobars into account. More details are given in ref.[79].



a b

Fig. 10. Interference correlations for pp (a) and $\pi\pi$ (b) pairs for CC interactions at p/A = 4.2 GeV/c [79].

In connection with this topic I would like to make some comments on the use of two-particle interferometry [83]. The first point concerns the definition of the radius of the emission volume. In experimental papers various formulae are used for the description of the two-particle correlation function. In their derivation, various spatial distributions of the sources have been assumed (the surface of a sphere, several forms of Gaussian-type distributions), and thus the published values of the parameter called the "radius" of the emission volume cannot be always compared directly with results of other authors. In order to allow such a comparison, we propose to use the root-mean-square radius, as generally accepted for the description of the density distribution inside the nucleon and also for the model description of heavy-ion collisions at lower energies. This would mean the necessity of correcting some of the published results on the radius of the pion emission volume. The conversion factor to the rms radius is $\sqrt{3/2}$ for the Gaussian-type distribution in the form $\exp(-r^2/R^2)$, $\sqrt{3}$ for the distribution $\exp(-r^2/2R^2)$ and 1.0 when the sources are supposed to be uniformly distributed over the surface of a sphere of radius R. The factor $\sqrt{3/2}$ (or $\sqrt{3}$) should be also applied to the values of the parameter r_o obtained from proton-proton interferometry. Apart from the necessity of using a consistent definition of the radius, it seems also essential to compare results on the dimensions of the emission volume obtained in the same reference frame, as results of two-particle interferometry are not invariant under Lorentz transformation.

The second remark concerns the interpretation of the radius of the particle emission volume. The values obtained from both pion and proton interferometry are relatively large as compared to the rms radii of colliding hadrons (or of the smaller of colliding nuclei) and only weakly depend on the size of colliding objects. This is due to the fact that this method yields the values of the radii corresponding to the emission of particles after they become free of any interactions (decay of resonances, scattering from other hadrons). This would mean that the excited nuclear matter density estimates using pion and proton interferometry results for the radii are only lower limits and thus not really meaningful for the investigation of the equation of state.

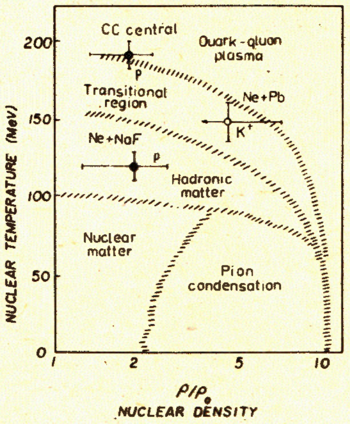
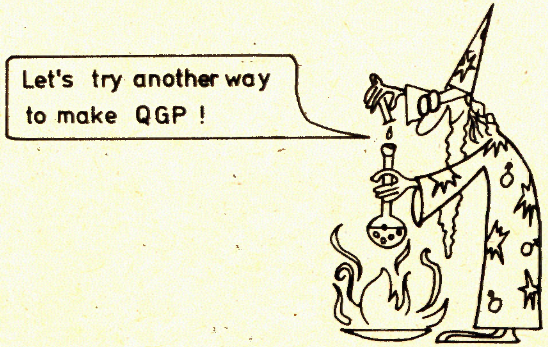


Fig. 11. Nuclear matter phase diagram with density and temperature estimates from various experiments [84].

Nevertheless, having no prompt leptons or photons at our disposal, such attempts are being repeated using hadrons. For C-C central collisions at 4.2 GeV/c per nucleon, and with additional selection $p_\perp \geqslant 500$ MeV/c, we have obtained $r^{rms}(pp) = (2.6 \pm 0.4)$fm, which, together with the total number of participating nucleons being about 17, gives an estimate of $\rho = (1.8 \pm 0.5)\rho_o$ for the density of hot nuclear matter. This value, combined with the "temperature" $T = (190 \pm 10)$ MeV estimated from the slope of the secondary proton spectrum, gives a point on the nuclear matter phase diagram as shown in Fig. 11 [84]. Though the above value of T, obtained from the invariant energy spectrum, might be somewhat overestimated, it seems that at moderate energies and for not very heavy nuclei, we may already be not far from a transition to the quark-gluon plasma....

And this is what one of the little people who supposedly live in Scandinavian woods and rocks (they are called t r o l l e n in Swedish and p e i k o t in Finnish) is thinking about our problems:



REFERENCES

1. Yu.D.Beznogikh et al. JINR,P9-84-246, Dubna, 1984.
2. N.I.Balandikov et al. JINR,P8-80-172, Dubna, 1980.

3. A.M.Baldin et al. Proc.Particle Accelerator Conference, Santa Fe, 1983; IEEE Trans.Nucl.Sci. NS-30, No.4, 1983, p.3247.
4. I.A.Shelayev et al. Proc.Internat.Conf. on High Energy Accelerators, Fermilab, 1983, p.416.
5. A.M.Baldin Proc. 6-th Intern.Conf. on High Energy Physics and Nuclear Structure, Santa Fe and Los Alamos, 1975, p.621; JINR, E2-9238, Dubna, 1975.
6. A.M.Baldin. Report to 7-th Intern.Conf. on High Energy Physics and Nuclear Structure, Zürich, 1977; JINR,E1-11368, Dubna, 1978.
7. A.M.Baldin. Proc. 19-th Intern.Conf. on High Energy Physics, Tokyo, 1978, p.455.
8. J.Bartke. Proc. 8-th Intern.Conf. on High Energy Physics and Nuclear Structure, Vancouver, 1979, p.481; Nucl.Phys. A335, 481 (1980).
9. A.M.Baldin. Proc.Intern.Conf. on Extreme States in Nuclear Systems, Dresden, 1980, v.2, p.1; JINR,E1-80-174, Dubna, 1980.
10. V.S.Stavinsky. Ibid, p.126.
11. M.I.Soloviev. Ibid, p.165.
12. J.Bartke. Report to Intern.Conf. on Nuclear Physics, Berkeley, 1980; JINR,E1-80-754, Dubna, 1980.
13. A.M.Baldin. Proc. 1981 CERN-JINR School of Physics, CERN 82-04, p.1.
14. A.A.Kuznetsov. Proc.Intern.Conf. on Nucleus-Nucleus Collisions, East Lansing, 1982; Nucl.Phys. A400, 493c (1983); JINR,E1-82--660, Dubna, 1982.
15. A.A.Kuznetsov. Proc. 6-th Intern.Conf. on High Energy Nuclear Physics, Balatonfüred, 1983, p.223; JINR,E1-83-334, Dubna, 1983.
16. J.D.Bowman, W.J.Swiatecki, C.F.Tsang. LBL-2908, Berkeley, 1973.
17. S.Nagamiya. Proc. Workshop on Quark Matter Formation and Heavy--Ion Collisions, Bielefeld, 1982, p.281.
18. P.Zieliński. GSI-82-13, Darmstadt, 1982.
19. B.S.Aladashvili et al. Nucl.Instr.Meth. 129, 109 (1975).
20. D.E.Greiner et al. Phys.Rev.Lett. 35, 152 (1975).
21. A.S.Goldhaber. Phys.Lett. 53B, 306 (1974).
22. G.F.Bertsch. Phys.Rev. C15, 713 (1977).
23. A.Bodek, J.L.Ritchie. Phys.Rev. D23, 1070 (1981); PhysRev. D24, 1400 (1981); UR-772, Rochester, 1981.
24. S.Nagamiya, M.Gyulassy. Adv.Nucl.Phys. 13, 201 (1983).
25. G.M.Chernov et al. Nucl.Phys. A412, 534 (1984).
26. L.E.Bengus et al. Pisma Zh.Eksp.Teor.Fiz. 38, 353 (1983).
27. L.Anderson et al. Phys.Rev. C28, 1224 (1983).
28. B.S.Aladashvili et al. Nucl.Phys. B86, 461 (1975).

29. V.G.Ableev et al. Nucl.Phys. A393, 491 (1983); A411, 541(E) (1983); Pisma Zh.Eksp.Teor.Fiz. 37, 196 (1983) /English translation: JETP Pisma 37, 233 (1983)/.
30. M.Lacombe et al. Phys.Lett. 101B, 139 (1981).
31. P.Bosted et al. Phys.Rev.Lett. 49, 1380 (1982).
32. I.L.Agranovitch et al. Yad.Fiz. 25, 1123 (1977) /English translation: Sov.J.Nucl.Phys. 25, 1117 (1977)/.
33. M.Bernheim et al. Nucl.Phys. A365, 349 (1981).
34. A.P.Kobushkin. Yad.Fiz. 28, 495 (1978) /English translation: Sov.J.Nucl.Phys. 28, 252 (1978)/.
35. A.P.Kobushkin, L.Vizireva. J.Phys.G: Nucl.Phys. 8, 893 (1982).
36. T.Fujita, J.Hüfner. Nucl.Phys. A343, 493 (1980).
37. J.Hüfner, M.C.Nemes. Phys.Rev. C23, 2538 (1981).
38. V.V.Glagolev et al. Phys.Rev. C18, 1382 (1978).
39. R.H.Bassel, C.Wilkin. Phys.Rev. 174, 1179 (1968).
40. B.Z.Kopeliovitch, I.K.Potashnikova. Yad.Fiz. 13, 1032 (1971) /English translation: Sov.J.Nucl.Phys. 13,592 (1971)/.
41. I.Sick. Lepton Scattering, presented at Conference on Few Body Systems and Nuclear Forces, Graz, 1978.
42. B.S.Aladashvili et al. Acta Phys.Slov. 31, 29 (1981).
43. V.V.Burov, V.K.Lukyanov, A.I.Titov, JINR,P2-83-749, Dubna, 1983; subm. to Z.Phys.A.
44. V.S.Stavinsky. ECHAYA 10, 949 (1979).
45. A.M.Baldin et al. JINR,E1-82-472, Dubna, 1982.
46. N.A.Nikiforov et al. Phys.Rev. C22, 700 (1980).
47. A.M.Baldin. JINR,E2-83-415, Dubna, 1983.
48. A.M.Baldin et al. JINR,1-82-28, Dubna, 1982.
49. I.A.Savin. Proc. 6-th Intern. Seminar on High Energy Physics Problems, JINR,D1,2-81-728, Dubna, 1981, p.223.
50. S.J.Brodsky, R.Blankenbecler. Phys.Rev. D10, 2973 (1974).
51. S.A.Gerzon. Yad.Fiz. 38, 1313 (1983).
52. J.J.Aubert et al. Phys.Lett. 123B, 275 (1983).
53. A.Bodek et al. Phys.Rev.Lett. 51, 534 (1983); 50, 1431 (1983).
54. H.Faissner, B.R.Kim. Phys.Lett. 130B, 321 (1983).
55. L.Kondratyuk, M.Shmatikov. ITEP-13, Moscow, 1984.
56. V.R.Garsevanishvili, Z.R.Menteshashvili. JINR.E2-84-314, Dubna, 1984.
57. M.I.Adamovich et al. JINR,E1-10838, Dubna, 1977.
58. Ts.Baatar et al. JINR.P1-80-209, Dubna, 1980.
A.P.Gasparian et al. JINR.P1-81-753, Dubna, 1981.
59. Alma-Ata, Bucharest, Dubna, Dushanbe, Erevan, Gatchina, Košice, Kraków, Leningrad, Moscow, Tashkent, Tbilisi, Ulan-Bator Collab.

Proc. 18-th Intern.Cosmic Ray Conf., Bangalore, India, 1983, Late paper volume, paper HE 2.2-30.
B.P.Bannik et al. Pisma Zh.Eksp.Teor.Fiz. 39, 184 (1984).
60. A.Z.M.Izmail et al. Phys.Rev.Lett. 52, 1281 (1984).
61. W.Heinrich et al. Phys.Rev.Lett. 52, 1401 (1984).
62. J.D.Stevenson, J.A.Musser, S.W.Barwick. Phys.Rev.Lett. 52, 515 (1984).
63. T.J.M.Symons et al. Phys.Rev.Lett. 52, 982 (1984).
64. M.Gyulassy. LBL-16800, Berkeley, 1983, Proc. BNL Workshop 1983, Nucl.Phys.A, in press.
65. S.Nagamiya et al. Phys.Lett. 81B, 147 (1979).
66. R.L.Hatch, S.E.Koonin. Phys.Lett. 81B, 1 (1978).
S.E.Koonin. Phys.Rev.Lett. 39, 680 (1977).
67. I.Tanihata et al. Phys.Lett. 97B, 363(1980).
68. E.O.Abdrahmanov et al. Z.Phys.C5, 1 (1980).
69. H.N.Agakishiev et al. Z.Phys. C12, 283 (1982).
70. H.N.Agakishiev et al. Z.Phys. C16, 307 (1983).
71. V.D.Aksinenko et al. Nucl.Phys. 324, 266 (1979).
72. V.D.Aksinenko et al. Nucl.Phys. A348, 518 (1980).
73. A.U.Abdurakhimov et al. Nucl.Phys. A362, 376 (1981).
74. H.N.Agakishiev et al. JINR,P1-84-35, Dubna, 1984,
75. K.K.Gudima, V.D.Toneev. Nucl.Phys. A400, 178 (1983).
76. G.P.Gulkanian et al. JINR,P1-83-805, Dubna, 1983; subm. to Yad.Fiz.
77. J.Bartke et al. JINR,E1-84-408, Dubna, 1984.
78. A.Białas, W.Czyż, L.Leśniak. Phys.Rev. D25, 2328 (1982).
79. N.Akhababian et al. JINR,E1-83-670, Dubna, 1983; Z.Phys.C, in press.
80. G.I.Kopylov, M.I.Podgoretsky. Yad.Fiz. 15, 392 (1972).
81. S.E.Koonin. Phys.Lett. 70B, 43 (1977).
F.B.Yano, S.E.Koonin. Phys.Lett. 78B, 556 (1978).
82. R.Lednicky, V.L.Lyuboshitz. JINR,E2-81-453, Dubna, 1981; Yad.Fiz. 35, 1316 (1981).
83. J.Bartke, M.Kowalski. Phys.Rev. C, in press.
84. L.A.Didenko et al. JINR.E1-84-354, Dubna, 1984.

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Взаимодействия релятивистских ядер на синхрофазотроне ОИЯИ. Фрагментация и рождение частиц

Обсуждаются результаты экспериментов на пучках релятивистских ядер, ускоренных на синхрофазотроне ОИЯИ, в первую очередь те, в которых проявляется кварковая структура ядер. Это - изучение фрагментации при больших переданных импульсах и рождение частиц в кумулятивной области. Обсуждаются также результаты по двухпионной и двухпротонной интерференции и их использование для определения плотности горячей ядерной материи, а также некоторые другие аспекты взаимодействий релятивистских ядер.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1984

Bartke J. E1-84-587
Interactions of Relativistic Nuclei from the Dubna Synchrophasotron. Fragmentation and Particle Production

Results of recent experiments with beams of relativistic nuclei from the Dubna synchrophasotron are reviewed, with emphasis on those which reveal the quark structure of nuclei. These are studies of fragmentation at high momentum transfers and of particle production in the cumulative region. Results on two-pion and two-proton interference correlations and their use for determination of the density of hot nuclear matter are also discussed, as well as some other aspects of interactions of relativistic nuclei.

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

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