Invited talk given at the Tenth International Conference on Particles and Nuclei, Heidelberg, July 30-August 3, 1984, Nuclear Physics, to be published.

Nucl Phys A434 (1985) 695c

NUCLEAR REACTIONS WITH LARGE MOMENTUM TRANSFERS AS A SOURCE OF INFORMATION ABOUT MULTIQUARK STATES IN NUCLEI

A.M.BALDIN

Joint Institute for Nuclear Research, Dubna, USSR

At many conferences of the past years, and at the present Conference as well, there has generally been heard a firm belief in the fact that at small distances, or at large momentum transfers, the atomic nuclei should manifest themselves as quark-gluon systems. An open question is where is the boundary starting with which the distances can be considered to be large and the nucleus can be described on the basis of hadronic degrees of freedom. The trouble is that the quark confinement effects occur at relatively small characteristic momenta of about 300 MeV. This means that the confinement radius is comparable with average internucleon distances and, strictly speaking, it is hard to isolate nuclear physics from QCD problems. In what follows, we give a criterion which picks out a region of nuclear reactions where the quark-gluon degrees of freedom are predominant. The aim of the present talk is to show that the study of this region gives evidence of the quark-parton structure functions of nuclei as independent[1] (irreducible to one-nucleon) objects of hadron physics.

The Dubna physicists have been engaged in the problem of quark distribution in nuclei since 1970 (see, e.g.[2,3]) on the basis of extensive experimental studies with relativistic nuclei beams from the Synchrophasotron. We extracted the properties of the structure functions of nuclei from the data on limiting fragmentation of nuclei[1,2]. Thus obtained properties were recently confirmed by experiments on deep inelastic scattering of leptons on nuclei[4,5,6]. This fact not only inspires us with the confidence that our ideas about the nature of limiting fragmentation of nuclei is valid, but also enables us to predict the results of future experiments on deep inelastic scattering of leptons on nuclei.

The deep inelastic lepton-nucleus scattering is so far studied in the region of the Bjorken variable $x < 1$ and is interpreted as revealing the difference in the internal structure of a nucleon inside the nucleus and a nucleon in empty space. Physicists engaged in the field of low-energy nuclear physics were aware of the existence of this difference. It is known, e.g., that the magnetic moment of the quasiparticles of nuclear matter noticeably differs from that of a free nucleon.

Of a special interest is, in our opinion, the region $X \gtrsim 1$ in which the scattering on a free nucleon is impossible, at all. From the point of view of the parton model X can be regarded as an effective number of nucleons (a multi-quark configuration) which can produce such a super-fast parton. The scattering and production of particles on nuclei in the region $X \gtrsim 1$ is given the name of cumulative effect. We consider that up to now the cumulative effect is the only source of information about multiquark states in nuclei.

Before going over to the discussion of the quark distribution in nuclei we define the boundary of the region in which the quark degrees of freedom become essential and the nucleons are no longer considered to be quasiparticles of nuclear matter. From the very beginning of the studies of nuclear reactions in the region of relativistic energies it was clear that in the collision of nuclei as composite objects the value of the four-momentum transfer cannot serve as a criterion for the passage from quasiparticles-nucleons to quasiparticles-quarks. For example, in a stripping reaction proceeding with an approximate conservation of four-momentum p_0 per nucleon, $^{12}C + A \to {}^4He + \ldots$, the four-dimensional momentum transfer is $(12p_0-4p_0)^2 = 64m_0^2$, where m_0 is the atomic mass unit. This value is much larger than the characteristic momentum of an individual quark. However such a collision does not affect the quark degrees of freedom since the momentum transfer is distributed among many particles. We characterize the energy of nuclei by an energy per nucleon since the energy and momentum should be divided by the number of particles inside the composite object if the collision is viewed at the level of constituents. At the same time, in relativistic quantum mechanics the particle number is not an invariant notion. It depends on the coordinate frame and, moreover, taking the quark-antiquark sea into account, the number of particles inside the hadron is infinite. The only relativistic invariant measure of the number of constituents inside a composite object is its rest mass. Therefore, we use the momenta and energies of hadrons and nuclei involved in the reaction which are attributed to the rest mass unit. In other words, we use four-dimensional velocities $\frac{p_i}{m_i}$.

As a quantitative criterion which selects the region of nuclear collisions, in which hadrons lose the role of the quasipartilces of nuclear matter, we employ:

$$b_{ik} = -\left(\frac{p_i}{m_i} - \frac{p_k}{m_k}\right)^2 = 2\left[\frac{(p_i p_k)}{m_i m_k} - 1\right] \gtrsim 5 , \tag{1}$$

where p_i are four-momenta, and m_i are the masses of hadrons involved in the reaction

$$I + II \to 1 + 2 + 3 + \ldots \tag{2}$$

Thus, as a locality measure of hadron interactions we take the relative four-velocity rather than the four-momentum transfer. The physical meaning of the criterion (1) consists in that for rather large relative velocities the interaction between the quarks entering object i and the quarks entering object k weakens so much that it can be treated by perturbation theory (here $i,k = I, II, 1, 2.$)

We discuss the arguments which underly criterion (1). According to criterion (1), for the collision of a relativistic nucleus I with a rest nucleus II we have

$$\frac{(p_I \cdot p_{II})}{m_I m_{II}} = \frac{E_I}{m_I} = \frac{E_I}{A_I m_0} \gtrsim 3.5 \qquad (3)$$

m_0= 931 MeV (the atomic mass unit), A_I is the atomic weight of nucleus I. The energy per nucleon $E_I/A_I \simeq 3.5 \div 4$ GeV, as is stressed in refs.[3], corresponds to the beginning of the asymptotic regime, limiting fragmentation of nuclei (scale invariance). From eq.3 it follows, in particular, that the division of the momenta by masses replaces, in a certain sense, the division by the number of constituents. We can also give the following experimental facts which testify in favour of criterion (1).

The transverse momentum pion distribution $p_\perp$ in multiple particle production processes is characterized by the value $\langle p_\perp \rangle \simeq 0.3 \div 0.4$ GeV. For $p_\perp > \langle p_\perp \rangle$ the cross sections sharply decrease. From the formula

$$\frac{(p_I \cdot p_i)}{m_I m_i} = \sqrt{1 + \frac{p_{i\perp}^2}{m_i^2}} \cosh (y_I - y_i) \qquad (4)$$

for the zero difference between the longitudinal rapidities y_I and y_i, and $\frac{p_\perp}{m_\pi} \gtrsim \frac{\langle p_\perp \rangle}{m_\pi} \simeq 3$ we get an estimate close to (1).

Also one well knows the short-range correlation effect in the rapidity space: at $\Delta y \gtrsim 1 \div 2$ the correlators in multiple particle production sharply decrease. By substituting $p_\perp = 0$ and $(y_I - y_i) \simeq 1 \div 2$ in eq.(4) we also get an estimate close to(1). The both properties can be represented as a principle of depletion of correlations in the radial rapidity space which is analogous to the Bogolubov's principle in statistical physics: the correlation between the parts of a strongly interacting system decreases monotoneously down to the level of a small perturbation with increasing distance between these parts in the rapidity space:

$$\frac{(p_I \cdot p_i)}{m_I m_i} = \cosh r_{Ii} = \cosh y_\perp \cdot \cosh y_\parallel \to \infty$$

where

$$\cosh y_\perp = \sqrt{1 + \frac{p_{i\perp}^2}{m_i^2}}\,; \quad y_\parallel = \frac{1}{2} \ln \frac{E_i + p_{i\parallel}}{E_i - p_{i\parallel}}\,.$$

In contrast to $p_\perp$ and y the quantity r is invariant with respect to rotations.

Similar estimates can be obtained from the study of the properties of jets. Criterion (1) is also in accordance with the present-day understanding of asymptotic freedom. The running coupling constant in QCD can be represented as follows

$$\alpha_s = \frac{1.4}{\ln Q^2/\Lambda^2} = \frac{1.4}{\ln[-(\frac{k}{\Lambda} - \frac{k'}{\Lambda})^2]} . \quad (5)$$

If by Λ we mean the characteristic mass and by k and k' the momenta of the hadron constituent, then eq.(5) can be rewritten in the form $\alpha_s = \frac{1.4}{\ln b_{ik}}$ and b_{ik} can be viewed as the squared difference between the velocity of an initial hadron $p_i/m_i \approx \frac{k}{\Lambda}$ and that of a knocked-out parton $p_k/m_k = \frac{k'}{\Lambda}$. In this case the value of α_s characterizes the weakness of the interaction of the knocked-out parton with the parent-hadron. In order that this final state interaction could be treated by perturbation theory, it would be necessary that $b_{ik} \gg 1$. From the formula $\alpha_s = \frac{1.4}{\ln b_{ik}}$ it follows that for large b_{ik} the hadron-hadron interaction changes smoothly with increasing b_{ik} and, respectively, the number 5 in eq.(1) is a matter of convention.

At the Santa Fe Conference in 1975 it was stressed[3b] that the b_{ik} values can be used to classify relativistic nuclear interactions: the region $b_{ik} \gtrsim 10^{-2}$ corresponds to the interaction of nuclei as weakly bound nucleon systems. The region $b_{ik} \gg 1$ corresponds to the interaction of hadrons as weakly bound quark systems. The region $0.1 \lesssim b_{ik} \lesssim 1$ is an intermediate one.

In a similar way we distinguish among nuclear collision processes on the basis of $b_{I\,II}$ values and, in particular, according to eq.(3), $b_{I\,II} > 5$ specifies the beginning of scale invariance. A generalization of scale invariance to relativistic nuclear collision processes[3] and the related experiments have resulted in the discovery of cumulative production of mesons and a number of regularities of limiting fragmentation of nuclei which will be discussed below.

In our first papers[3,2] it was already stressed that as far as scale invariance was interpreted on the basis of the local character of hadron interactions (automodelity) and the parton model, in nuclei there are two specific momentum scales starting with which an approximate scale invariance is realized. One of them corresponds to the case when the nucleon constituents, the partons, may be considered as quasi-free particles, and the other corresponds to the impulse approximation of nuclear physics in which the nucleons are taken to imply quasi-free particles. We considered the cumulative effect as a signal indicating that in nuclei there are "drops" of hadron matter (or multi-quark configurations) which, in their structure, strongly differ from free nucleons. This interpretation of the cumulative effect, that is, laws of particle production in the region of limiting fragmentation of nuclei outside the limits of one-nucleon collisions met objections during more than ten years. In numerous theoretical studies it was attempted to explain all the regularities of the cumulative effect within the framework of the proton-neuteron model by means of a correct account of relativistic effects and few nucleon correlations in nuclei (see, e.g.ref.[7]). Such attempts have succeeded in explaining the cumulative production of protons, deuterons and nucleus fragments, i.e. the effects in which it is practically impossible to separate the nucleon scale invariance (nuclear scaling) from the parton one. In addition, the cumulative production of baryon systems was until recently studied only in the range of relatively small $b_{ik}<1$ not satisfying the criterion (1). Following our classification they belong to the intermediate region and cannot be treated by a simple fragmentation model which we use for extracting quark-parton structure functions from the data on limiting fragmentation of nuclei. Since the structure functions are just the principal subject of my talk I have no possibility of dwelling upon new very intresting data of the Leksin's group on cumulative production of baryon systems submitted to the present Conference[8].

Many data on inclusive one-particle reactions in the region $b_{II}>b_{III}>5$: $1 \leq b_{III} \leq 15$ are presented at this Conference. To discuss multi-quark states in nuclei I mainly use the data of the Stavinsky's group who have studied in a most detailed manner $\pi^{\pm}$ and $K^{\pm}$ meson production in the region of limiting fragmentation of more than 20 nuclei, as well as the data on deep inelastic scattering of leptons on nuclei. It should be emphasized that the data for $b_{III}>500$[9], including the data on cumulative jet production[10], in accordance with criterion (1), confirm the data of the Stavinsky's group obtained mainly for $b_{III} \simeq 19$, and the weak dependence of the limiting fragmentation cross sections on b_{III} for $b_{III}>5$. The lower boundary of the cross sections obtained in these experiments is $\frac{1}{A_{II}} E_1 \frac{d\sigma}{d\vec{p}_1} \to 0.5 \times 10^{-35} cm^2 GeV^{-2}$ which corresponds to the pion momentum of 1.2 GeV/c or $b_{III} \simeq 17$. The conclusions about quark distribution in nuclei[1] were chiefly made on the basis of the data on the production of pions since they best satisfy criterion (1) because of their small mass.

The collision of hadrons with small transverse momenta and large values of the scale variable X in the limiting fragmentation region is described as a result of individual collisions of the quasi-free quarks of a fragmenting hadron with the quarks or gluons of the target. The spectator quarks which avoided collision carry the momentum fraction X of the fragmenting hadron. Hadronization of the quark to a hadron-fragment (color neutralization) is taken to be soft and the hadron-fragment distribution is assumed to coincide with the quark-spectator distribution. Thus, we may consider that the inclusive cross section of the process (2) in the region of limiting fragmentation of, for example, particle II (or nucleus II) is of the form

$$E_1 \frac{d\sigma_1^{II}}{d\vec{p}_1} = C_q^1 \cdot \sigma_q^I \cdot G_{II/q}(X, p_{1\perp}^2) \qquad (6)$$

where E_1 and $\vec{p}_1$ are the energy and momentum of the particle-fragment. We shall mainly use the data of the Stavinsky's group[2] for the case when particle 1 is a pion and particles I are protons and deuterons. The quantity $G_{II/q}(X, p_{1\perp}^2)$ is the quark-parton structure function of particle (or nucleus) II. More than twenty different elements have been used as fragmenting nuclei II. C_q^1 is the constant characterizing hadronization of quark q into hadron 1, σ_q^I is the cross section of the process in which quark q from hadron II passes throughout target I having avoided collision. The quantities $G_{II/q}(X, p_\perp^2)$, in their physical meaning, are universal momentum distributions of quarks q in nucleus II. The universality of $G_{II/q}(X, p_\perp^2)$ consists in that one and the same functions $G_{II/q}$ are taken to express the cross sections of different reactions with large momentum transfers proceeding on this nucleus. In particular, the cross sections for deep inelastic scattering of leptons on nucleus II

$$\ell + II \to \ell' + \ldots \qquad (7)$$

and the cross sections for lepton pair production

$$I + II \to \ell^+ + \ell^- + \ldots$$

are expressed in terms of the functions $G_{II/q}(X, p_\perp^2)$ and the cross sections for electromagnetic quark interactions. From eq.(6) it follows that the ratio of the inclusive cross sections for limiting fragmentation of different nuclei II' and II into identical particles (in our case, into pions) is equal to the ratio of their structure functions:

$$E_1 \frac{d\sigma_1^{II'}}{d\vec{p}_1} \Big/ E_1 \frac{d\sigma_1^{II}}{d\vec{p}_1} = \frac{G_{II'/q}(X, p_{1\perp}^2)}{G_{II/q}(X, p_{1\perp}^2)} \qquad (8)$$

For the case of deep inelastic lepton-nucleus scattering the Bjorken variable is expressed in terms of the momentum per nucleon p_{II}/A_{II}:

$$X = -\frac{q^2}{2(p_{II}/A_{II} \cdot q)} = -A_{II} \cdot \frac{q^2}{2(p_{II} \cdot q)} = A_{II}\, x \qquad (9)$$

where q is the four-momentum transfer in process (7), X changes in the limits $0 \le X < A_{II}$. Processes occurring at $X > 1$ are named cumulative. For reaction (2) the variable X, with due account of mass corrections, is of the form (particle 1 is a pion):

$$= \frac{(p_I \cdot p_1) - \quad {}^2}{(p_I \cdot p_{II}) - m_I m_{II} - (p_{II} \cdot p_1)}$$

and transforms into the variable (9), neglecting masses. In this limit we also have

$$X \approx \frac{m_1}{m_0} \cdot \frac{b_{I1}}{b_{III} - m_1/m_I \cdot b_{III}} .$$

From here it follows that there exists a region, in which $X > 1$ but criteria(1) are invalid, for example, cumulative production of baryon systems. In this region quarks cannot be considered to be quasi-free and the fragmentation model (6) describing quark stripping and pickup processes cannot be used.

We consider the experimental facts[2] which testify in favour of the model (6).

1. The cross section for processes (2) in the range $X \sim 1$, $p_\perp = 0$ is found to be no longer dependent on $b_{I\,II}$ for $b_{I\,II} \gtrsim 8$, that is, the regime of limiting fragmentation of nuclei begins at an energy of about 4 GeV/nucl. This is in good agreement with criterion (1).

2. The cross section for process (1) in the range $8 \leq b_{I\,II} \lesssim 500$ and $0.6 \leq X \lesssim 3.5$ is well approximated by a simple dependence:

$$E_1 \frac{d\sigma}{d\vec{p}_1} = \text{const}\, A_I^{1/3} \cdot A_{II}^{m(X)} \cdot \exp\left[-\frac{X}{\langle X \rangle}\right] \qquad (10)$$

The parameter $\langle X \rangle$ does not depend, within errors, on the quantum numbers of cumulative particles and is equal to 0.14 to an accuracy of 10%. The quantity $m(X) \approx 1$ for $X > 1$ and $A > 20$, while for $0.6 \leq X \leq 1$ it is approximated[2,3] by the dependence $m(X) \approx \frac{2}{3} + \frac{X}{3}$.

3. Within experimental errors, the cumulative production cross sections for pions and kaons for identical X's are in the following remarkable relationship to each other (see fig.1):

$$E_1 \frac{d\sigma}{d\vec{p}_1}(\pi^-) \approx E_1 \frac{d\sigma}{d\vec{p}_1}(\pi^+) \approx E_1 \frac{d\sigma}{d\vec{p}_1}(K^+) \gg E_1 \frac{d\sigma}{d\vec{p}_1}(K^-)$$

4. A good agreement between experiment and the model (6) in question has made it possible to determine the properties of the quark-parton structure functions for $0.6 \leq X \leq 3.5$ and $p_\perp = 0$:

$$G_{II/U}(X, 0) \approx \text{Const}\, A^{m(X)} \exp\left[-\frac{X}{0.14}\right] \qquad (11)$$

These properties were found to be universal for various nuclei. In particular, eq.(11) has enabled us to predict[1] the results of the NA-4 experiment on deep inelastic scattering of muons on carbon $\mu + {}^{12}C \to \mu' + \dots$. The structure function of the carbon nucleus extracted from the experiment[4] in the kinematic range $50 \leq Q^2 \leq 280$ GeV^2 and $0.6 \leq X \leq 1.5$ is in good agreement with eq.(11) (see fig.1). This experiment has well confirmed the existence of the cumulative effect ($X > 1$), although the obtaining of X's as large as the ones extracted from limiting fragmentation studies seems to be doubtful even by using such a powerful installation as the NA-4 spectrometer.

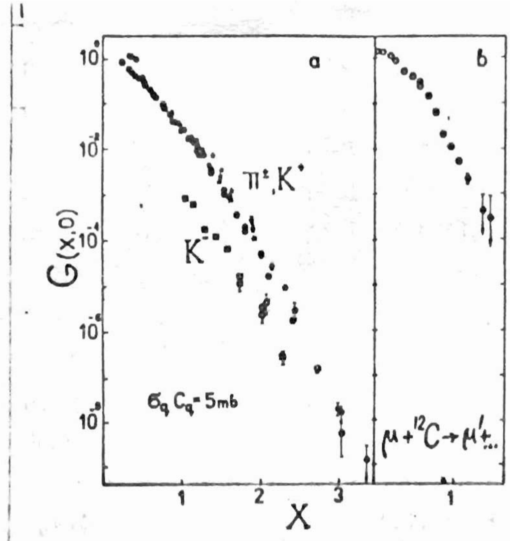

FIGURE 1

5. Deep inelastic lepton-nucleus studies have led to a psychological change in the attitude to the problems under consideration. Theorists were most strongly impressed by the EMC measurements of the ratio of structure functions per nucleon for the Fe and D nuclei[5]. Further experiments of the MIT-SLAC group[6] have confirmed this result and have given the A dependence of the structure functions of nuclei, which in the range $X \sim 0.5$ are in agreement with the above-mentioned $G_{A/q}(X)$ properties (see eq.11).

We define the ratio of the structure functions per nucleon for different nuclei

$$\frac{\sigma_{II'}}{\sigma_{II}}(X,p^2) = \frac{1/A_{II'} \cdot G_{II/q}(X,p_\perp^2)}{1/A_{II} G_{II/q}(X,p_\perp^2)}. \quad (12)$$

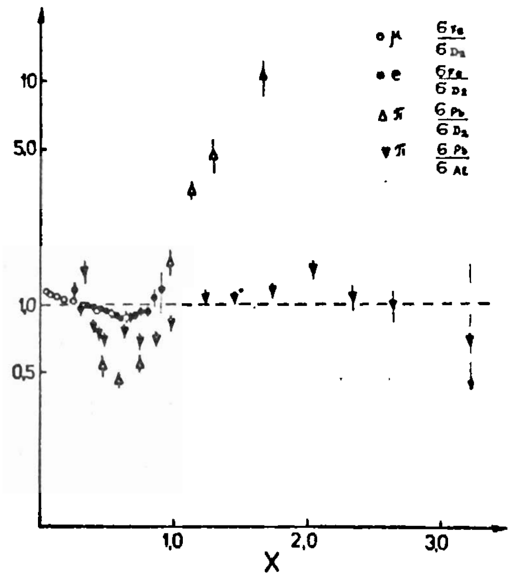

FIGURE 2

Fig.2 presents the earlier obtained experimental data on limiting fragmentation in the form of the ratio (12), there are also given the data of the EMC[5] and MIT-SLAC[6] studies on deep inelastic lepton-nucleus scattering. The qualitative agreement of the $\frac{1}{A} G_{A/q}(X)$ data obtained in essentially different experiments and different regions of momentum transfers serves as a good confirmation of the used model and the universality of the structure functions.

To discuss the available data on $1/A\, G_A(X)$ we consider three different regions of X in which the behaviour of $\frac{1}{A} G_A(X)$ is different and established with different degree of reliability.

1. The region $X \leq 0.2$. The main EMC result that the ratio of the Fe and D

structure functions exceeds unity has led to a large number of theoretical papers. The majority of them suggests that this is a contribution due to sea quarks[11,12], however, the proposed models describing this contribution are different. As the SLAC experiments showed, this effect needs to be further studied experimentally. It is impossible to extract the structure function from the data on limiting fragmentation of nuclei in this region since it goes beyond the limits of criterion (1). The study of this region is at a preliminary stage and the data are somewhat contradictory.

2. As is seen from fig.2, the decrease of the ration $\frac{\sigma_{Fe}}{\sigma_D}(X)$ in the range $0.3 \le X \le 1$ below unity is in agreement with the earlier established A dependence of the structure functions of nuclei (11) and is confirmed by SLAC experiments. As Fig.3 shows, though the data on the A dependence of $\frac{\sigma_A}{\sigma_{Pb}}$ $(X = 0.5)$ obtained on the basis of limiting fragmentation of nuclei and the SLAC deep inelastic scattering data differ from each other, they have the same behaviour, that is, the cross section decreases with increasing A.

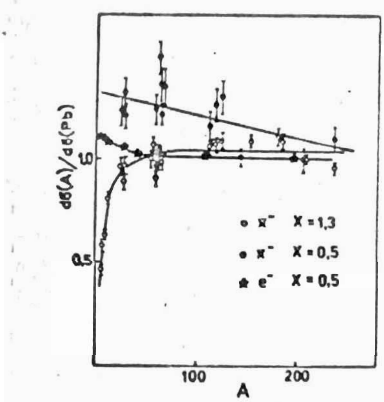

FIGURE 3

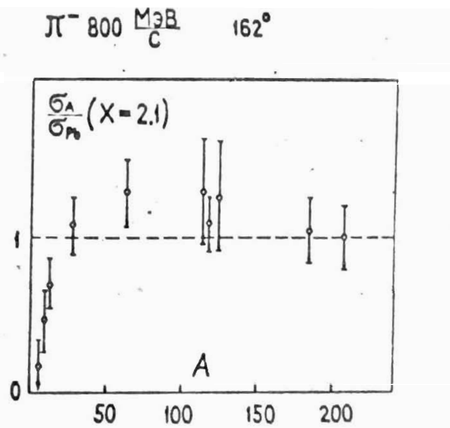

FIGURE 4

3. Of a special interest is the cumulative region $X > 1$. The difference in the A dependence of $\frac{\sigma_{II'}}{\sigma_{II}}(X)$ for $X > 1$ and $X < 1$ is especially clearly seen from fig.3. Although the most striking feature of the cumulative effect, the universal (for all the nuclei) X dependence of $G_A(X)$, $G_A(X) \propto \exp[-\frac{X}{0.14}]$, has been confirmed by lepton scattering studies[4] needs to be further explored. It should, however, be noted that this dependence has also been observed in cumulative production of jets[10] and earlier in cumulative production of baryon systems (see, e.g.[8]).

The properties of $G_A(X)$ for $X > 1$ are in good agreement with the idea about the cumulative effect as a result of interactions of multi-quark configurations existing in the nucleus and containing an effective number of nucleons equal to X. In this domain $\frac{\sigma_{Pb}}{\sigma_D}(X)$ (see fig.2) strongly exceeds unity, while $\frac{\sigma_{Pb}}{\sigma_{Al}}(X)$.

within errors, is unity over the whole region $1 \leq X \leq 3$. The D nucleus has no configurations consisting of quarks from more than two nucleons, this just explains the difference in the structure functions for deuterium and lead. At the same time, the Al nucleus little differs, in this sense, from the Pb nucleus. The data on the A dependence of $\frac{\sigma_A}{\sigma_{Pb}}$ ($X=1.3$) given in fig.3 indicate that over the whole region $A < 20$ this value is essentially smaller than unity and decreases with decreasing A. This means that not only in deuterium, but also in all the lightest nuclei up to $A \approx 20$ the multiquark configurations strongly differ from one another and from the multiquark configurations in heavy nuclei. Theorists who attempted to explain these phenomena by the presence of six-quarks configurations in nuclei will be distressed by the submitted to the present Conference A dependence of $\frac{\sigma_A}{\sigma_{Pb}}$ ($X=2.1$)(see fig.4) measured in the region $X \geq 2$ where nine- and twelve- quark configurations are predominant. Comparing fig.3 and 4 we see that the A dependences for $X=1.3$ and $X=2.1$, within errors, coincide.

Unfortunately, the $G_{A/q}(X)$ properties for $X > 1$ have not yet been discovered in deep inelastic lepton scattering and depend on the validity of the model(6). Nevertheless, I want to conclude my talk in the following manner. The data on the structure functions of nuclei for $X > 1$ definitely indicate that in nuclei there arise fluctuations of quark plasma which contain complicated multi-quark configurations which just generate superfast quarks-partons carrying away a large momentum. This idea together with criterion (1) indicate the limits of applicability of the proton-neutron nuclear model.

REFERENCES

1) A.M.Baldin, in Proc.Conf.on Extreme States in Nuclear Systems, Dresden, v.2, (1980), p.1 and JINR E1-80-545, Dubna (1980), JINR E2-84-415, Dubna (1983).
2) a. V.S.Stavinsky, Fizika Element.Chastits i Atomn.Yadra v.10, issue 5, Atomizdat (1979), p.950.
   b. V.S.Stavinsky, Proc. VIII Intern.Conf.High Energy Phys., Tbilisi (1976) A6-1 and ref. quated therein.
   c. A.M.Baldin et al., Contribution to this Conf. and JINR E1-82-472 Dubna (1982).
3) a. A.M.Baldin et al., Proc.Rochester Meeting APS/OPF (1971) p.131 and JINR, P1-5819, Dubna (1971).
   b. A.M.Baldin, Proc.of the VI Intern.Conf. on High Energy Phys. and Nuclear Structure, Santa Fe, (1975), 621.
   c. A.M.Baldin, Prog. in Particle and Nucl.Phys.v.4 Ed.by D.Wilkinson, Pergamon Press (1980) pp.95-132.
   d. A.M.Baldin, Proc.CERN-JINR School of Physics, Finland, CERN, Geneva 82-04 (1982)p.1
4) I.A.Savin, Proc.of the VI Intern.Seminar on High Energy Phys.Problems, JINR, D1,2-81-728, Dubna (1981), p.223.
5) I.I.Aubert et al., Phys.Lett., 123B, (1983), p.275.
6) A.Bodek et al., Phys.Rev.Lett., 50, (1983), p.1431.
7) L.L.Frankfurt, M.I.Strikman, Phys.Rep., 76 (1981), pp.215-347.
8) G.A.Leksin et al., Contribution to this Conference.
9) N.A.Nikiforov et al., Phys.Rev., D22, (1980), p.700.
10) A.M.Baldin et al., Jadernaya Fizika, v.39 (1984) p.1215.
11) A.I.Titov, JINR E2-83-460, Dubna (1983).
12) A.V.Efremov, E.A.Bondarchenko, JINR E2-84-124, Dubna (1984).