ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ
ДУБНА

3/IV-78

E2 - 11091

V.V.Burov, V.K.Lukyanov, B.L.Reznik, A.I.Titov

NUCLEAR DENSITY FLUCTUATIONS AND ELECTRON SCATTERING AT HIGH ENERGY

1978

E2 - 11091

V.V.Burov, V.K.Lukyanov, B.L.Reznik, A.I.Titov

NUCLEAR DENSITY FLUCTUATIONS AND ELECTRON SCATTERING AT HIGH ENERGY

Submitted to ЯФ

Буров В.В. и др. **E2 - 11091**

Флуктуации плотности ядра и рассеяние электронов большой энергии

Анализируется возможность обнаружения флуктуации сжатия ядерной материи в малых объемах в реакциях взаимодействия электронов с ядрами при больших передачах импульса. Для упругого и глубоконеупругого рассеяния электронов большой энергии дейтронами расчет согласуется с экспериментом в предположении, что дейтрон имеет несколько процентов примеси флуктонного состояния, проявляющего себя при больших передачах импульса как шестикварковый объект. Даны качественные предсказания поведения ядерных формфакторов при очень больших передачах импульса и сечений глубоконеупругих e A -реакций.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1978

Burov V.V. et al. **E2 - 11091**

Nuclear Density Fluctuations and Electron Scattering at High Energy

A possibility of finding the compressional fluctuations of nuclear matter in small volumes in the interactions of electrons with nuclei at large transfer momenta is analyzed. For elastic and inelastic scattering of high energy electrons by deuterons the calculation agrees with experiment under the assumption that a deuteron wave function has several per cent admixture of the fluctuon state developing at large transfer momenta as a sixquark object. The behaviour of nuclear elastic form factors at high transfer momenta and the cross sections of deep inelastic eA - reactions are predicted qualitatively.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna 1978

1. *STATEMENT OF THE PROBLEM*

The idea of compressional fluctuations of nuclear matter in small nuclear volumes (of an order of the nucleon) was suggested long ago [1] as an attempt to interpret "deuteron" peaks observed experimentally in the quasielastic scattering of protons with E_p=660 *MeV* in nuclei [2]. A strong correlation of nucleons at small distances was discussed also in view of the experiments on pd -elastic scattering at large angles [3]. In all those experiments the momentum transfer was approximately 6 fermi^{-1}. The same idea was tried to explain also the yield of deuterons, tritium and other light nuclei [4] from the quasielastic knock-out reactions [5]. However, it appeared that the latter reactions in that energy region were successfully explained in the framework of the usual shell model [6] and the hypothesis of fluctuons stayed to wait its application. Only recently this idea has essentially been revived owing to the experiments on cumulative particle production in the proton-nuclear collisions [7,8] of particles outgoing far from the kinematic limits in the corresponding reactions of collisions of free protons. Here the transferred momentum was of an order of about 10 fermi^{-1}, i.e., considerably larger than the previous one. New theoretical problems related to the cumulative effect were initiated in papers [7,9], where it was assumed that an incident particle interacts with a group of k nuclear nucleons as a whole. However, they did not consider in detail the problem whether these groups exist in a prepared from, fluctuons, or they are the nucleons in a tube in front of an incident particle. The new idea was to determine the pk-interaction cross sections using the scale-invariant behaviour of the corresponding pp-cross sections. Later to develop the mechanism of such an interaction the parton model of nucleons was used and a qualitative interpretation of some experimental regularities of cumulative production was given /10/.

In connection with the cumulative effect the idea of possible existence of nuclear "fluctuons" was studied in papers /11-13/. First, the phenomenological basis was used to calculate overlapping integrals of the square modulus fluctuon wave functions with the cross section of the proton fluctuon interaction at high energy in the impulse approximation /11,12/. Then a micromodel of this phenomenon was constructed /13/, which used the main simplest diagrams of subprocesses of the parton interaction of an incident particle with "collective" partons of a fluctuon resulting in the cumulative particle production in the corresponding kinematic regions. There were explained the main features of the phenomenon, i.e., extension beyond the kinematic limits of the elementary act, the exponential fall of curves of secondary particle spectra and the dependence of cross sections on atomic number of the target nucleus. To this end the fluctuons with nucleon up to $k=4$ were introduced, and it occurred that the size of the region of correlation of nucleons consisting of fluctuons was of the NN-core force radius order $r_\xi = 0.75$ *fm* and the same for all the fluctuons.

The success of such an interpretation forces one to verify the idea of fluctuons in nuclei when analyzing other processes of interaction of high energy particles with nuclei at large transfer momentum. As it was mentioned /11/, to such processes one can refer first of all the reactions of knock-out deuterons, tritium and other nuclear particles from nuclei and the elastic and deep inelastic scattering of electrons on nuclei with larger transfer momentum. The latter are most preferable due to the known electromagnetic nature of interaction of an incident particle with nucleus and its constituents.

The aim of this paper is to construct, using the idea of fluctuons, the form factors of elastic and the cross sections of deep inelastic inclusive processes in the electron-nuclear interactions within the region of large transfer momenta and to make some quantitative and qualitative calculations for these quantities for further experimental search.

2. *MAIN ASSUMPTIONS*

We suppose the existence of fluctuons in nuclei, the objects consisting of k nucleons and appearing at a short time of the compressional fluctuations of nuclear matter. They arise at the moment when nucleons draw together at distances of an order of the NN -core radius. The probability of this event has qualitatively been evaluated in ref. /1/ by using the classical theory of the fluctuations of noninteracting particle gas in the small volume $V_\xi = \frac{4}{3}\pi r_\xi^3 \ll AV_0$, where $V_0 = \frac{4}{3}\pi r_0^3$ is the nucleon volume. Taking into account the normalization of the cross section for interaction of the incoming particle with nuclei one gets the following results /12/

$$\beta_k^A = \binom{A}{k}\left(\frac{V_\xi}{V_0}\right)^{k-1} A^{1-k}. \tag{1}$$

In principle this quantity as well as the function of the fluctuon center of mass motion may be calculated in the framework of the known nuclear models. Qualitatively this wave function may be presented as an overlap integral in the fluctuation volume of the k single particle wave functions

$$\Psi_k(\vec R) = C_k \int \chi_k(\xi)\Phi_1(\vec r_1)\dots\Phi_k(\vec r_k)\{d\xi\}_{1\dots(k-1)} \simeq$$

$$\simeq C_k V_\xi^{\frac{k-1}{2}} \Phi^k(\vec R) \simeq C_k V_\xi^{\frac{k-1}{2}} n^{\frac{k}{2}}(\vec R), \tag{2}$$

where the internal wave function of a fluctuon, depending on the relative coordinates $\vec\xi_{ij} = \vec r_i - \vec r_j$ and on the nuclear density distribution function, obeys the normalization

$$\int|\chi_k(\vec{\xi})|^2\{d\xi\}_{1\ldots k}=1 \qquad \int n(\vec{R})d\vec{R}=1. \tag{2'}$$

Normalizing $\Psi_k(\vec{R})$ to the natural condition

$$\int|\Psi_k(\vec{R})|^2 d\vec{R}=\beta_k^A \tag{3}$$

one gets

$$C_k^2=\binom{A}{k}. \tag{3'}$$

Hence, the probability of finding in nuclei the fluctuons with masses $M_k=km$ and momentum $\vec{p}$ is as follows

$$W_k(\vec{p})=|\int\Psi_k(\vec{R})e^{i\vec{p}\vec{R}}d\vec{R}|^2=$$

$$=\beta_k^A(V_0A)^{k-1}|\int n^{\frac{k}{2}}(\vec{R})e^{i\vec{p}\vec{R}}|^2. \tag{4}$$

The other assumption is that the nucleons of a fluctuon being in the strongly compressed state lose their individuality and the fluctuon manifests itself as a unique object of mass $M_k=km$ in interactions with other particles. One may consider this interaction of high energy and momentum transfers by using the automodel behaviour of cross sections, the quark counting rules, the parton models and other methods of the elementary particle physics.

3. ELASTIC NUCLEAR ELECTRON SCATTERING

Nowadays the elastic eA-scattering is investigated up to $q^2\sim 1$ $(GeV/c)^2$ values of the momentum transfer. (Except the deuteron form factor measured up to $q^2\simeq 6.5$ $(GeV/c)^2$ /17/). It is rather difficult to explain the behaviour of the form factors at so large momentum transfer in the framework of conventional nuclear physics.

So far there is no clear physical picture of its behaviour. Till present one introduced nuclear clusters, short distance repulsion and other types of correlations in nuclei. As to the phenomenology it uses the radial variation additions to the smooth charge density distribution function $n(R)$ with the aim to explain the peculiarities of the form factor behaviour at large q^2. Their admixture turns out to be of some per cent.

In this section we show that the fluctuons in nuclei may give the reason for some specific features of form factors at large q^2.

Let us now consider the elastic scattering of electrons by deuterons. In this case the form factor has the form

$$F_d(q^2) = F_1^d(q^2) + \beta_d F_2(q^2), \tag{5}$$

where $F_1(q^2)$ is the usual deuteron form factor calculated with the nonrelativistic wave function, and $F_2(q^2)$ is the deuteron form factor in the fluctuon compressional state when the nucleons lose their individuality. The probability of the latter is defined by the value of β_d. The behaviour of $F_d(q^2)$ in the asymptotic region is determined by the quark counting rule

$$(q^2)^{n-1} F(n) \to \text{const}, \tag{6}$$

where n is the number of quarks in the system (for deuteron $n=6$). The detailed description of the ed form factor at large q^2 is achieved in the framework of more concrete models. So in refs. /17,20/ the experimental parametrization of the form factor was performed as follows:

$$F_2^I(q^2) = (1 + q^2/36\, m_Q^2)^{-5}, \tag{7}$$

where $m_Q = 0.28$ *GeV* is the "mass of quark" parameter, and

$$F_2^{II}(q^2) = (1 + q^2/m_0^2)^{-1}\, F_N^2(q^2/4), \tag{8}$$

where the parameter $m_0^2 = 0.28$ GeV^2 and F_N being the nuclear form factor.

Figure 1 shows the ratio F_d^{exp}/F_2. At large q^2 this ratio determines the contribution of the fluctuon state β_d in the deuteron

$$F_d^{exp}/F_2 = \beta_d \text{ at } q^2 \to \infty \tag{9}$$

since the contribution of F_1^d in this region becomes negligible. It is seen that β_d depends on the form of parametrization of the form factor in the region of $q^2 \simeq (1 \div 3)(GeV/c)^2$. Thus, F_2^I fits well the experiment mainly at large $q^2 > 3(GeV/c)^2$ and then the corresponding

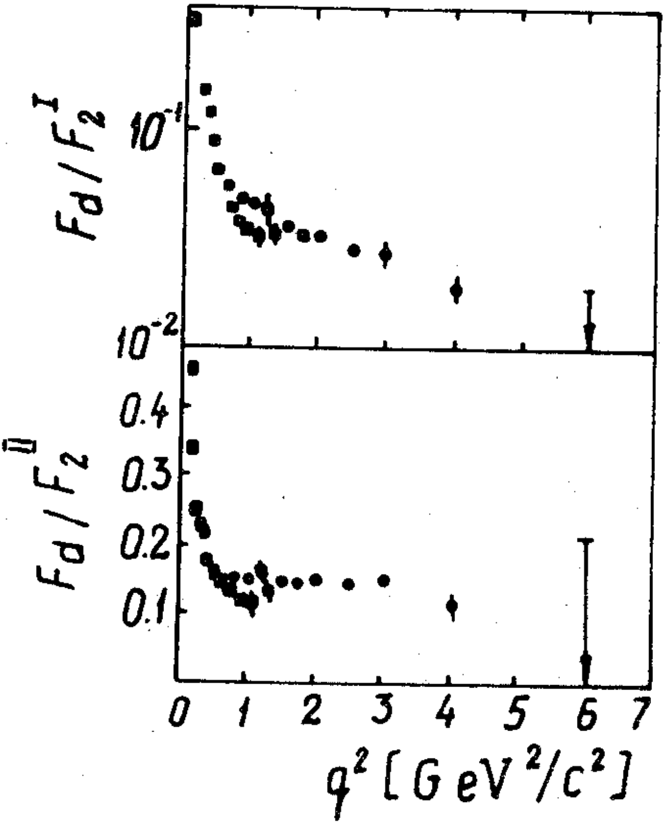

Fig. 1. a) the ratio of the experimental form factor of a deuteron $F_d(q^2)$ *to* $F_2^I(q^2)$ *(formula (7)); b) the ratio of* $F_d(q^2)$ *to* $F_2^{II}(q^2)$ *(formula (8)).*

β_d is of $(2\div4)\%$. On the contrary the form factor $F_2^{II}(q^2)$ is chosen so as to explain experiments in the intermediate region from $q^2 \sim 1$ $(GeV/c)^2$. In this case $\beta_d \simeq (12\div15)\%$. Consequently to find β_d means to find the set-on of asymptotics and the transition of the asymptotic behaviour of form factors to the low energy one. Nevertheless, it is of interest to compare these β_d values with those obtained from the analysis of the reactions of cumulative pion production. First, we note that as was shown in ref./13/ the contribution to the cumulative effect comes from the common influence of fluctuons consisting of $k = 1,2,3,4$ nucleons. However, for each fixed transfer momentum the fluctuon with fixed value of k gives the main contribution to the cross section, moreover this region of momentum transfer is not asymptotical. This leads to the necessity to modify the corresponding asymptotic structure functions in order to interpret the experimental data, namely at intermediate q^2. Therefore, it is not unexpected that the value $r_\xi/r_0 = 0.63$ obtained from the analysis of the cumulative effect on nuclei ^{12}C, ^{27}Al, ^{64}Cu, ^{208}Pb gives the value $\beta_d = 12.5\%$,* which is close to that obtained by analysing the ed -scattering with the help of the F_2^{II} form factor.

The analysis of the experimental data (*Fig. 1*) shows that the question on existence of fluctuations in nuclei can be raised only at large momentum transfer $q^2 > (1.5\div2)(GeV/c)^2$. However, the form factors for other nuclei at these large q^2 have not yet been measured. Therefore, our further consideration of the nuclear form factor behaviour will be of only qualitative character. As usual we represent the form factor as the product of the fluctuon form factor and the body form factor, i.e., Fourier - transformation of the square wave function of its c.m. motion. Then

---

* By the definition (1) the probability of a deuteron occupying the volume $2V_0$ to get into the volume V_ξ is equal to

$$\beta_d = \frac{1}{2}\frac{V_\xi}{V_0} = \frac{1}{2}\left(\frac{r_\xi}{r_0}\right)^3 .$$

$$F^A(q^2)=\sum_{k=1}^{A} F_k(q^2)\int |\Psi_k(\vec{R})|^2 e^{i\vec{q}\vec{R}}\, d\vec{R}. \tag{10}$$

Substituting (2) into (10) we get

$$F^A(q^2)=F_1\bar{F}_1+\frac{3}{4}\beta_2^A B_2 F_2\bar{F}_2+\sum_{k=3}^{A}\beta_k^A B_k F_k(q^2)\bar{F}_k(q^2), \tag{11}$$

where

$$F_k(q^2)=(V_0A)^{k-1}\int n^k(\vec{R})e^{i\vec{q}\vec{R}}\, d\vec{R} \tag{12}$$

is the form factor of motion of k -fluctuon normalized to unity at $q^2\to 0$. We do not perform here the general normalization of F^A since at $q^2\to 0$ we assume the smallness of all its terms except for the first one. $\bar{F}_1$ is the usual nuclear form factor calculated using nonrelativistic one particle functions. In the capacity of F_1 and F_2 we use the proton and deuteron form factors, respectively. Coefficient B_k takes into account the isotopic composition of the fluctuon containing k_p protons and k_n neutrons. For light nuclei it has the form

$$B_k=\binom{N}{k_n}\binom{Z}{k_p}\binom{A}{k}^{-1}\frac{1}{Z}. \tag{13}$$

The factor $(1/Z)$ results from the normalization of all form factors in (11) to 1 at $q^2\to 0$. We take into consideration that especially for a fluctuon of the deuteron type the statistical weight of the spin state 1 is equal to 3/4. The fluctuon form factors F_k can be found by using the quark counting rule (6).

Figure 2 demonstrates the calculation of the form factor for the nucleus ^{12}C by formula (11) with two terms $k=1,2$. As the deuteron form factor we choose the form (8), and the parameter β_2^A has been calculated at $r_\xi = 0.75$ *fm*, which is consistent with the data on cumulative pion production in the proton-nuclear collision and with the analysis of ed -scattering by using formulas (5), (8), (9). It is seen from *Fig. 2* that the contribution of the fluctuon admixture is rather small but it becomes sensitive at $q^2\simeq 0.4$ $(GeV/c)^2$ (if the symmetrized fermi-type density $n(r)$ is used in calculations /19/),

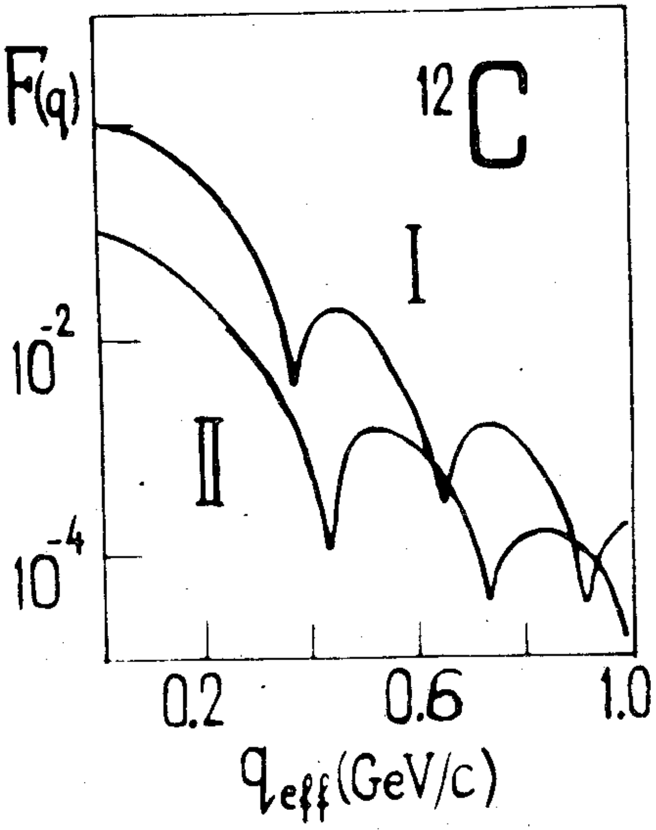

Fig. 2. I is the elastic form factor of the nucleus ^{12}C *calculated with nonrelativistic single-particle nuclear functions; II is the contribution of the fluctuation admixture* ($k=2$) *to the elastic form factor.*

i.e., just in the region where the nuclear form factors exhibit anomalies the nature of which is being investigated within the standard nonrelativistic nuclear physics.

4. *DEEP INELASTIC* eA *-SCATTERING*

We shall construct the theory of the deep inelastic electron scattering on nuclei by analogy with the one for the $ep \to e' + \dots$ elementary process. So, the main assumption is that the fluctuon can be considered as consisting of noninteracting partons. Then it is necessary to know the momentum distributions of partons in nucleons and fluctuons.

The cross section of the fundamental elementary subprocess of the electron-parton scattering at large momentum transfer $q^2 = -4E_e E_{e'} \sin^2(\theta/2) = -Q^2$ is/21,22/

$$\frac{d^2\sigma_i}{dQ^2 d\nu} = e_i^2 \frac{d\sigma_M}{dQ^2} \frac{x_i}{\nu} \delta(x - x_i)$$

$$x = \frac{Q^2}{2M\nu}, \tag{14}$$

where $x_i = p_i / kp$ is a part of the fluctuon momentum carried by parton of the type "i", $\nu = E_e - E_{e'}$ being the energy loss of an electron, p is the nucleon momentum and $d\sigma_M/dQ^2 = 4\pi\alpha^2/Q^4$ is the Mott cross section. Now introducing the probability $G^{(i)}_{q/k}(x_i)$ of finding a parton of the type "i" in a fluctuon with momentum kp, one can write down the cross section of the deep inelastic eA-process

$$\frac{d^2\sigma^A}{dQ^2 d\nu} = \sum_{\substack{k=1 \\ i=1,2,3}}^{A} \beta_k^A B_k \int dx_i \frac{d^2\sigma_i}{dQ^2 d\nu} G^{(i)}_{q/k}(x_i) =$$

$$= \frac{d\sigma_M}{dQ^2} \sum_{k=1}^{A} \beta_k^A B_k \frac{x}{k\nu} \sum_{i=1}^{3} G^{(i)}_{q/k}(x) e_i^2 \tag{15}$$

Then, the typical Fermi-impulse of fluctuons in nuclei is smaller than the considered transfer momentum and therefore may be neglected. For comparison with experimental data we rewrite the cross section (15) in terms of the nuclear structure functions W:

$$\frac{d^2\sigma^A}{dQ^2 d\nu} = \frac{d\sigma_M}{dQ^2} \frac{1}{\nu} [\nu W_{2A}(Q^2, \nu) + 2\nu W_{1A}(Q^2, \nu) \mathrm{tg}^2(\theta/2)] \times$$

$$\times \frac{E_{e'}}{E_e} \cos^2 \frac{\theta}{2} \tag{16}$$

(One can neglect the last term at small scattering angles). With the help of expression (15), we get

$$\nu W_{2A}(Q^2,\nu) = \sum_{k=1}^{A} \beta_k^A B_k \frac{x}{k} \sum_{i=1}^{3} e_i^2 \, G_{q/k}^{(i)}(x/k). \tag{17}$$

For further calculations it is necessary to know the explicit behaviour of $G_{q/k}^{(i)}(x)$. As concerns the quark counting rule at $x \to 1$, G is the power decreasing function with the exponent depending on the number of constituents, of the considered object (nucleons or fluctuons here). It can be written as follows/14,15/:

$$G_{q/k}^{(i)}(x) = \frac{1}{x} a k^2 (1-x)^{6k-3}, \quad x \to 1, \tag{18}$$

where "a" is the parameter defined from the elastic ep -scattering data, k is the number of nucleons in a fluctuon.

We stress here that expression (18) is valid only in the asymptotic region of $x \to 1$ and it must be modified for average x.

Note, that the deep inelastic scattering on nuclei is specified by the possibility of going beyond the kinematic limits in the elementary $eA \to e' + ..$ process over the variables of parton distribution in a nucleon. This peculiarity is typical for all reactions of the cumulative type /9/.

First consider the simplest case of the deep inelastic scattering on a deuteron. Using the known relation

$$\nu W_{2n} = \frac{2}{3} \nu W_{2p} \tag{19}$$

we obtain

$$\nu W_{2d} = \frac{5}{3} \nu W_{2p} + \beta_d \frac{x}{2} \sum_{i=1}^{3} G_{q/2}^{(i)}(x/2) e_i^2 \,. \tag{20}$$

Assuming that the parton distribution functions in the $k=2$ - fluctuon is independent of the type "i" of a parton, we have

$$\nu W_{2d} = \frac{5}{3} \nu W_{2p} + \frac{5}{3} \beta_d \frac{x}{2} G_{q/2}(x/2). \tag{21}$$

The comparison of the calculated structure function νW_{2d} with the experimental one /23/ is given in *Fig. 3*, where because of the finite Q^2 and ν the scaling variable x is replaced by x' /22/:

$$(x')^{-1} = \omega' = \frac{1}{x} + \frac{M^2}{Q^2} . \qquad (22)$$

The next parametrization of the experimental data for νW_{2p} has been used from ref. /24/

$$\nu W_{2p}(x') = \sum_{j=1}^{3} b_j (1-x')^{j+2} , \qquad (23)$$

$b_1 = 1.274$, $b_2 = 0.5989$, $b_3 = -1.675$. One can see that in the region of $\omega' \gg 1$ the first term in (21) gives the main contribution in νW_{2d} while in $\omega' \lesssim 1$ region the second one. The agreement with experiment has been obtained at $a\beta_d = 0.025$. From the normalization conditions (18) for the proton and deuteron one can extract the following estimation $a \approx 1.2$. Hence it follows that $\beta_d \approx 2\%$. The order of this value is the same as for that obtained from the analysis of the ed-scattering by using F_2^I form factor which gives the good parametrization of experimental data at large q^2. Since the comparison given in *Fig. 3* at $\omega' \lesssim 1$ also corresponds to the asymptotic region $x \to 1$ (what justifies the choice of $G^{(i)}_{q/k}(x)$ in the form (18)) the agreement between the values of β_d obtained in these different experiments is not accidental.

In ref. /25/ another approach was developed for the calculation of the deep inelastic ed-scattering where the collective effect was taken into consideration by modifying the deuteron nonrelativistic wave function at large q^2. Apparently /20/ it is just another interpretation of one and the same mechanism. The difficulties of the last approach will appear in describing the deep inelastic eA-scattering at $x \gg 1$, when it will be necessary to introduce phenomenologically specific many-particle residual nuclear interactions, to justify them, and to calculate the corresponding impulse distributions.

For qualitative understanding of νW_{2A} behaviour at $x \gg 1$ the reactions of the deep inelastic scattering

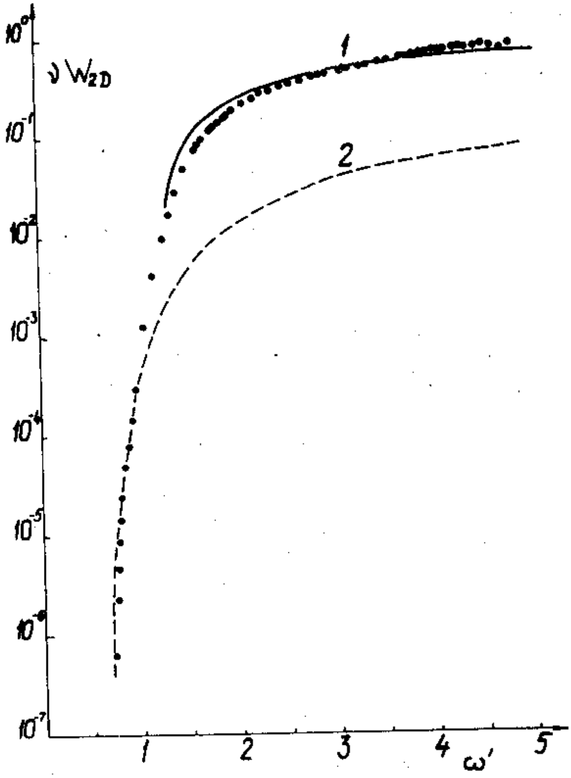

Fig. 3. 1 is the contribution of the deep inelastic scattering on a separate proton and neutron of a deuteron to the structure functions νW_{2d} *; 2 is the contribution to* νW_{2d} *of the deep inelastic scattering on a deuteron as a whole (fluctuon with* $k=2$ *).*

of electrons by nuclei, we make use of that only the terms with $k>x$ give the contribution to the sum (17) (as $G=0$ at $x/k>1$). Then, using the fact that for the given large x the main contribution into eq. (17) provides the term with $\bar{k}=x+1$ and also using the approximate formulas

$$k! \approx e^{k \ln k - k} \qquad (24)$$

$$\beta_k^A \simeq \frac{A}{k!}\left(\frac{V_\xi}{V_0}\right)^{k-1} = \frac{A}{k!}\beta_0^{k-1} \simeq \frac{A}{\beta_0} e^{-k(\ln k - 1 + |\ln \beta_0|)} \qquad (25)$$

$$\left(1 - \frac{x}{\bar{k}}\right)^{6(\bar{k}-1)+\gamma} \simeq \left(\frac{1}{x}\right)^{6x+\gamma} e^{-6} \qquad (26)$$

one can get the structure function as follows:

$$\nu W_{2A}(x) \approx e^{-ax} \qquad (27)$$

Here the parameter a does not depend on the atomic number A and increases logarithmically with x:

$$a = 7\ln x + |\ln \beta_0| + (\gamma + 1)\frac{\ln x}{x} - 1 \,. \qquad (28)$$

Thus, the main result is that in the deep inelastic scattering one must observe the strong decrease of the structure function at $x \gg 1$.

5. CONCLUSION

From the results obtained we can make the following conclusions.

1. The assumption about the fluctuations of the nuclear matter density in small volumes when the fluctuon nucleons approach each other at the distance of the nuclear core $r_\xi = 0.75$ *fm* admits a new approach to the problem of anomalous behaviour of nuclear form factors at large transfer momenta. It follows from the analysis of experiments on the ed -scattering that the contribution of these fluctuations can be of some per cent of the usual nuclear wave function. Evidently recent measurements of the nuclear form factors approach just the region $q \sim 5$ *fm*$^{-1}$, where the fluctuon structure of nuclei at small distances can be exhibited more clearly.

2. By interpreting the deep inelastic ed -scattering on the basis of the same idea, one can predict the cross sections of the deep inelastic scattering on nuclei, in particular, the behaviour of its structure function.

3. In this connection the measurement of the elastic and deep inelastic scattering of electrons at large transfer momenta with $q^2 > 1$ $(GeV/c)^2$ can be thought to be an important problem.

4. From the consideration of Sec. 2 it is seen that one of the most interesting and accessible problems of nonrelativistic nuclear physics and nuclear models is a correct construction of the fluctuon wave functions including the calculation of the probability of k nucleons to approach each other at the distance of the nuclear core order.

5. As for the relativistic nuclear physics the most interesting problem in it is the consideration of the structure of many-baryon systems and of the reactions where they take part. In particular, it is important to have, besides the asymptotic expressions, those for the structure functions of many-baryon systems applicable for the calculation in the region of real energies and transfer momenta.

REFERENCES

1. *Blokhintsev D.I. JETP, 1957, 33, p.1295.*
2. *Azhgirei L.S. et al. JETP, 1957, 33, p.1185.*
3. *Leksin G.A., Kumekin Yu.P. JETP, 1957, 33, p.1147.*
4. *Blokhintsev D.I., Tokhtarov K.A. JINR, P4-4018, Dubna, 1968.*
5. *Komarov V.I. Particles and Nuclei, 1974, 5, p.419.*
6. *Balashov V.V., Boyarkina A.N., Rotter I. Nucl.Phys., 1965, 59, p.417; Kudeyarov Yu.A. et al. Nucl.Phys., 1971, A163, p.316.*
7. *Baldin A.M. et al. Yad.Fiz., 1973, 18, p.79.*
8. *Leksin G.A. Third School of Phys. ITEP, Atomizdat, M., 1975, v.2, p.5.*
9. *Baldin A.M. Brief Comm. on Physics, No. 1, AN SSSR (1971); Particles and Nuclei, 1977, 8, p.429.*

10. *Efremov A.V. Yad.Fiz., 1976, 24, p.1208.*
11. *Burov V.V., Lukyanov V.K., Titov A.I. Proc. of Int. Conf. on Selected Topics in Nuclear Structure. JINR, D-9920, v. 2, p.432, Dubna, 1976.*
12. *Burov V.V., Lukyanov V.K., Titov A.I. Phys.Lett., 1977, 67B, p. 46; JINR, P2-10244, Dubna, 1976.*
13. *Burov V.V., Lukyanov V.K., Titov A.I. JINR, E2-10680, Dubna, 1977; JINR, P2-10927, Dubna, 1977.*
14. *Matveev V.A., Muradyan R.M., Tavkhelidze A.N. Nuovo Cim. Lett., 1973, 7, p.719.*
15. *Brodsky S., Farrar G. Phys.Rev.Lett., 1973, 31, p.1153; Phys. Rev., 1975, D11, p.1309.*
16. *Feynman R.P. Phys.Rev.Lett., 1969, 23, p.1415.*
17. *Arnold R.G. et al. Phys.Rev.Lett., 1975, 35, p.776.*
18. *Lukyanov V.K., Pol Yu.S. Particles and Nuclei, 1974, 5, p.955.*
19. *Burov V.V., Lukyanov V.K., Pol Yu.S. JINR, P4-9556, Dubna, 1976.*
20. *Brodsky S.J., Chertok B.T. Phys.Rev.Lett., 1976, 37, p.269.*
    Arnold R.G., Carlson C.E., Cross F. Phys.Rev. Lett., 1977, 38, p.1516.
21. *Feynman R.P. Photon-Hadron Interactions, 1972, W.A.Benjamin, Inc., Reading, Massachusetts.*
22. *Kuti J., Weisskopf V.F. Phys.Rev., 1971, D4, p.3418.*
23. *Schutz W.P. et al. Phys.Rev.Lett., 1977, 38, p.259.*
24. *Riordan E.M. et al. SLAC-PUB-1634, 1975.*
25. *Frankfurt L.L., Strikman M.I. LNPI-238, Leningrad, 1976.*

*Received by Publishing Department
on January 9, 1978.*

WILL YOU FILL BLANK SPACES IN YOUR LIBRARY?

You can receive by post the books listed below. Prices - in US $,

including the packing and registered postage

P1,2-7642	Proceedings of the International School of Young Physicists on High Energy Physics. Gomel, 1973.	623 pg	10.53
D3-7991	Proceedings of the II International School on Neutron Physics. Alushta, 1974.	554 pg	4.35
D1,2-8405	Proceedings of the IV International Symposium on High Energy and Elementary Particle Physics. Varna, 1974.	376 pg	3.89
P1,2-8529	The International School-Seminar of Young Scientists. Actual Problems of Elementary Particle Physics. Sochi, 1974.	582 pg	4.70
D6-8846	XIV Symposium on Nuclear Spectroscopy and Nuclear Theory. Dubna, 1975.	180 pg	3.70
E2-9086	Proceedings of the 1975 JINR-CERN School of Physics. Alushta, 1975.	462 pg	16.00
D13-9164	Proceedings of the International Meeting on Proportional and Drift Chambers. Dubna, 1975.	344 pg	10.00
D1,2-9224	Proceedings of the IV International Seminar on High Energy Physics Problems. Dubna, 1975.	307 pg	4.80
	Proceedings of the VI European Conference on Controlled Fusion and Plasma Physics. Moscow, 1973, v. I.	666 pg	21.00
	Proceedings of the VI European Conference on Controlled Fusion and Plasma Physics. Moscow, 1973, v. II.	466 pg	15.00
D13-9287	Proceedings of the VIII International Symposium on Nuclear Electronics. Dubna, 1975	469 pg.	6.6
D7-9734	Proceedings of the International School-Seminar on Reactions of Heavy Ions with Nuclei and Synthesis of New Elements. Dubna, 1975.	289 pg.	4.86
D-9920	Proceedings of the International Conference on Selected Topics in Nuclear Structure. Dubna, 1976.	452 pg.	15.00
D2-9788	Nonlocal, Nonlinear and Nonrenormalizable Field Theories. Proceedings of the IVth International Symposium. Alushta, 1976.	390 pg.	4.20
D1,2-10400	Proceedings of the XVIII International Conference on High Energy Physics. Tbilisi, 1976. 2 volumes.	1000 pg.	25.00
D9-10500	Proceedings of the Second Symposium on Collective Methods of Acceleration. Dubna, 1976.	292 pg.	11.00

D2-10533	Proceedings of the X International School on High Energy Physics for Young Scientists. Baku, 1976.	560 pg.	11.00
D1,2,14-10908	Proceedings of the International Symposium on Meson Chemistry and Mesomolecular Processes in Matter. Dubna, 1977.	348 pg.	11.00

Orders for the above-mentioned books can be sent at the address:

Publishing Department, JINR
Head Post Office, P.O. Box 79
101000 Moscow, USSR

Издательский отдел Объединенного института ядерных исследований.
Заказ 24341. Тираж 650. Уч.-изд. листов 1,01.
Редактор Э.В.Ивашкевич.
Корректор Т.Е.Жильцова. Подписано к печати 30.1.78 г.