MULTIQUARK STATES IN NUCLEI AND NUCLEAR EFFECTS IN DEEP INELASTIC LEPTON SCATTERING AND LEPTON PAIR PRODUCTION

BY V. R. GARSEVANISHVILI

Mathematical Institute of the Academy of Sciences of the Georgian SSR, Tbilisi*

M. E. BUZALADZE AND Z. R. MENTESHASHVILI

High Energy Physics Institute, Tbilisi State University, Tbilisi**

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The nuclear quark distribution functions are obtained in the framework of the multiquark cluster model and with these distribution functions Drell-Yan cross sections for lepton pair production processes in hadron-nuclear collisions are calculated. Significant nuclear effects are predicted for the ratios of cross sections in the region of large M and negative X_F. Results of the calculations are compared with existing experimental data.

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1. Introduction

Processes of cumulative particle production in hadron-nucleus and nucleus-nucleus collisions [1] and elastic lepton-nucleus scattering at large momentum transfer [2] revealed that consideration of nuclei as systems of quasi-independent nucleons is incomplete and it is necessary to take into account quark degrees of freedom when studying high energy nuclear interactions. Experimental data for particle production in the kinematic region forbidden by the nucleon-nucleon kinematics led to the conclusion that there exist multiquark states (different from nucleons) inside the nuclei. This was confirmed by the power-law fall-off of elastic form-factors of light nuclei at large momentum transfer, assuming the behaviour predicted by the quark counting rules [3].

Recent experimental studies of deep inelastic scattering on nuclear targets revealed

* Address: Mathematical Institute of the Academy of Sciences of the Georgian SSR, 380093 Tbilisi-93, Z. Rukhadze Str. 1, USSR.

** Address: High Energy Physics Institute, Tbilisi State University, 380086 Tbilisi-86, University Str. 9, USSR.

an essential difference between the structure functions of heavy and light nuclei (the so--called EMC effect) and gave rise to a new interest in the quark structure of nuclei. The discovery that the ratio of structure functions of iron and deuterium nuclei differs significantly from unity in the kinematical region $0.05 < x < 0.65$, was first made by the European Muon Collaboration [4] and has been confirmed by other experimental groups [5–7]. The data show that the structure functions of heavy nuclei are smaller at medium values of variable x ($0.2 < x < 0.7$) than that of a deuteron. At small values of x ($x < 0.2$) different sets of data show different behaviours for the structure function ratio: the EMC data [4] indicate an enhancement at small x, while the SLAC [5, 6] and BCDMS [7] data are consistent with unity. New data from the EMC [8] and BCDMS [9] collaborations show clearly that the structure function ratio exceeds unity for small x, but not to the same degree as the original EMC data. At $x > 0.7$ the data show a gradual rise of the ratio above unity. (For a review of the EMC effect, see [10]). Despite the uncertainty at small values of x, it seems that such behaviour of the structure function ratio contradicts conventional assumptions about the nucleus as a bound system of nucleons affected only by their internal Fermi motion, which predicts [11] no deviation from unity in the region $0 < x < 0.6$ and sharp rise for $x > 0.6$.

Different theoretical models have been proposed to explain the EMC effect (e.g. the pionic models [12], the dynamical rescaling models [13] and the conventional nuclear models [14]), among which the multiquark cluster model [15] should be noted. This model is based on the possibility of forming multiquark clusters in nuclei due to the overlapping of several nucleons and can not only explain the EMC effect in the region $0 < x < 1$, where the results of all the theoretical models mentioned are similar and do not differ qualitatively, but also makes predictions for the $x > 1$ region [16], which is not yet studied in modern experiments and where essential differences between the predictions of various models are expected. Hence, the experimental investigation of deep inelastic lepton--nuclear scattering in the region $x > 1$ is of great interest, as it may be critical for different models suggested for the explanation of the EMC effect.

As shown by the data on the EMC effect, quark distribution functions depend on the nuclear environment, so similar nuclear effects may occur in other high energy processes involving nuclei (e.g. lepton pair production in hadron-nuclear collisions, particle production at high $p_\perp$ on nuclear targets), where quark distributions play an important role. Recently such nuclear effects were observed in hadronic high-mass dimuon production processes [17]. Several authors [18] have proposed that the study of lepton pair production in hadron-nucleus reactions in a wide kinematical region can provide the information that is necessary for discrimination between models of the EMC effect.

In this paper we consider nuclear quark distribution functions in the framework of the multiquark cluster model and show that the EMC effect can be explained by taking into account the scattering on colorless multiquark configurations in nuclei. Then we use these quark distribution functions in calculations of Drell-Yan cross sections for lepton pair production in proton-nucleus and pion-nucleus interactions and predict the behaviour of cross section ratios in different kinematical regions. The predictions show significant nuclear effects in these processes.

2. *Nuclear quark distribution functions in the framework of the multiquark cluster model and the EMC effect*

Let us consider deep inelastic scattering of charged leptons on a nucleus with atomic number A. We assume that in the nucleus, together with nucleons (three-quark clusters), there are formed with definite probabilities the colorless multiquark configurations with six, nine, etc. quarks (in this connection see [19]), and that leptons interact with the nucleus by means of the exchange of virtual photons with quarks from these clusters. We also assume that the nuclear constituents contribute incoherently and that the final state interactions can be neglected in the deep inelastic region. Then the nuclear structure function can be represented by the sum

$$F_2^A(x) = \sum_{k=1}^{A} N(A, k) F_2^k(x). \tag{1}$$

The first term of the sum corresponds to the contribution from nucleons, the subsequent terms correspond to the six-quark clusters, nine-quark clusters and so on. The variable x is the usual Bjorken scaling variable $x = Q^2/2m\nu$, which in the case of scattering on a nucleus varies in the interval $0 < x < A$. (Q^2 is the 4-momentum transfer squared, ν is the transfered energy, m is the nucleon mass.) Bearing in mind that no dependence on Q^2 was observed in experiments on the EMC effect, we neglect the Q^2-dependence of the structure functions i.e. we assume exact Bjorken scaling. F_2^k in (1) denotes the structure function of a configuration which contains a $3k$-quark cluster and nucleons. The coefficients $N(A, k)$ in front of these structure functions can be interpreted as the effective numbers of $3k$-quark clusters in the nucleus A and satisfy the following condition of baryon number conservation

$$\sum_{k=1}^{A} kN(A, k) = A.$$

Obviously, the quantities $P_A^k = kN(A, k)/A$ can be understood as the probabilities of $3k$-quark cluster formation in a nucleus with atomic number A. In the paper [20] realistic wave functions were used to calculate these probabilities for light nuclei and the probabilities for heavier nuclei were predicted on the basis of these results. Here we use the parametrization of $N(A, k)$ in the form of the Bernoulli distribution

$$N(A, k) = \frac{A!}{k!(A-k)!} p(A)^{k-1}[1-p(A)]^{A-k}$$

which gives similar results for the probabilities P_A^k if we choose the parameter $p(A)$, determining the probability of a three-quark nucleon to get into a $3k$-quark cluster, in the form of a ratio of the cluster and nucleus cross sections $p(A) = 0.07\, A^{-2/3}$. The coefficient here has been obtained [21] by fitting the A-dependence of the EMC effect [6]. The coefficients $N(A, k)$ are rapidly decreasing functions of k and the main contribution to the nuclear structure function is given by the first few terms of the sum (1). Therefore, in our numerical calculations we restrict ourselves to three-, six- and nine-quark clusters. (The values of the probabilities P_A^k for different nuclei used in our calculations are $P_D^2 = 0.05$; $P_{Fe}^2 = 0.20$, $P_{Fe}^3 = 0.03$; $P_{Pt}^2 = P_W^2 = 0.27$, $P_{Pt}^3 = P_W^3 = 0.06$).

Now we proceed to the structure functions F_2^k. In the framework of the quasipotential formalism in "light front" variables [22], it can be shown that these structure functions can be factorized and expressed [23] via the structure functions of the multiquark clusters $F^{3k}(x)$ and the distribution functions of $3k$-quark clusters in nuclei $f_k(z)$, which describe the internal motion of clusters inside the nucleus:

$$F_2^k(x) = \int_{\frac{x}{A}}^{1} dz f_k(z) F_2^{3k}\left(\frac{x}{Az}\right). \tag{2}$$

According to the quark-parton model [24], the structure functions F_2^{3k} can be expressed as a sum of quark and antiquark distributions

$$F_2^{3k}(x) = x \sum e_i^2 [q_i^{3k}(x) + \bar{q}_i^{3k}(x)]. \tag{3}$$

Here e_i denotes the electric charge of a quark of flavor i, q_i^{3k} and $\bar{q}_i^{3k}$ are the quark and antiquark distribution functions in $3k$-quark clusters, respectively.

Using (1)–(3) we can obtain expression for nuclear quark (antiquark) distribution functions (per nucleon)

$$q_i^A(x) = \sum_{k=1}^{A} N(A, k) \frac{1}{A^2} \int_{\frac{x}{A}}^{1} \frac{dz}{z} f_k(z) q_i^{3k}\left(\frac{x}{Az}\right) \tag{4}$$

and similar expression for antiquark distribution.

We consider only three flavors of quarks (u, d, s). The u and d quark distributions can be written as the sums of valence and sea quark distributions ($u = u_v + u_s$, $d = d_v + d_s$) and we assume that the quark and antiquark distributions in the sea are the same ($u_s = \bar{u}_s = d_s = \bar{d}_s = 2s_s = 2\bar{s}_s = S$). For the valence and sea quark distributions in the proton we shall use the following expressions

$$xu_v^p(x) = 2.0723(1+0.5x)x^{1/2}(1-x)^3,$$

$$xd_v^p(x) = 1.1275(1+0.5x)x^{1/2}(1-x)^4,$$

$$xS^p(x) = 0.1825(1-x)^7.$$

Here isospin invariance is assumed so that the distribution of the u quarks in the proton is the same as that for the d quarks in the neutron and vice versa. The valence u and d quark distributions are normalized to the number of corresponding quarks in the proton and the sea quark distribution is normalized in such a way that proton's momentum fraction carried by gluons equals 55%.

The quark counting rules [3, 25] were used to determine the valence and sea quark distributions in multiquark clusters

$$xu_v^{3k}(x) \sim x^{1/2}(1-x)^{6k-3+\delta},$$

$$xd_v^{3k}(x) \sim x^{1/2}(1-x)^{6k-2+\delta},$$

$$xS^{3k}(x) \sim (1-x)^{6k+1+\delta}.$$

Here δ is connected with the spins of the quark and the cluster and equals 0 or 1 for clusters with an even or odd number of quarks, respectively. Both u and d valence quark distributions in multiquark clusters are normalized to $3k/2$ (assuming that clusters are isoscalar). Normalization of the sea quark distribution can be determined from the momentum conservation condition, assuming that the fraction of a multiquark cluster momentum carried by gluons, as in proton, equals 55%.

Let us proceed to the functions $f_k(z)$, which describe intrinsic motion of nuclear constituents. These functions must obey the following condition

$$\int_0^1 dz f_k(z) = 1.$$

The nucleon distribution function $f_N(z) = f_1(z)$ is connected with the nucleon momentum distribution in a nucleus $\varrho_N(\varrho)$ in the following way

$$f_N(z) = \int dp \varrho_N(p) \delta(z - p_+/m),$$

where $p_+ = p_0 + p_z$.

In the case of the deuteron we use the deuteron wave function squared as the nucleon momentum distribution $\varrho_N(p) = |\psi(p)|^2 = [\psi_0^2(p^2) + \psi_2^2(p^2)]$, where ψ_0 and ψ_2 are wave functions corresponding to S- and d-waves, respectively. In the numerical calculations we use the parametrization [26] of Gartenhause-Moravchik wave functions. Note that in deuteron the contribution of a six-quark state is only a small admixture to that of a two-nucleon state and it does not exceeds a few percent (in this connection, see [27]).

For heavy nuclei the Fermi gas approximation is valid and for the nucleon momentum distribution in the nucleus we can use the Fermi gas distribution

$$\varrho_N(p) = \frac{3}{4\pi p_F^3} \theta(p_F - |p|),$$

where p_F is the Fermi momentum.

Effects of the Fermi motion of multiquark clusters become important for values oj $x > 1.5$ so, as far as we concentrate on the region $x < 1$, we shall neglect these effects in our considerations.

In Fig. 1 the ratio of iron and deuteron structure functions is presented along with experimental data from the EMC [4] and SLAC [6]. One can see that while the nucleon contributions with Fermi motion (dashed curve) contradicts the data, incorporation of multiquark clusters (solid curve) improves agreement with experiment.

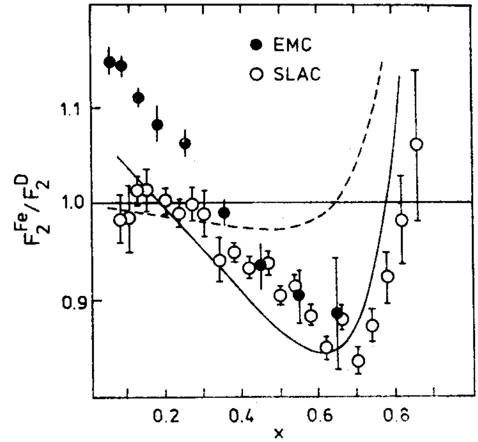

Fig. 1. The ratio of iron and deuteron structure functions. Data from [4] — ● and [6] — ○. Dashed curve — calculation with account of only nucleons and their Fermi motion; solid curve — with account of multiquark clusters

3. *Nuclear effects in the lepton pair production*

In this Section we use nuclear quark distribution functions in calculations of cross sections of high-mass lepton pair production processes in hadron-nucleus collisions. The main properties of lepton pair production in hadronic collisions have been explained in the framework of the Drell-Yan model [28], in which a quark from one of the hadrons annihilates with an antiquark from the other hadron, producing a virtual photon which creates a lepton pair. The Drell-Yan process corresponds to the continuum part of the lepton pair production cross section in the $M > 4$ GeV region and does not take into account the massive resonances of the J/ψ and Υ families. (For a review of the Drell-Yan process, see [29]).

According to the naive Drell-Yan model the differential cross section for this process can be written as

$$\frac{d\sigma}{dM^2} = \frac{4\pi\alpha^2}{9M^2}\int dx_1 dx_2 F(x_1, x_2)\delta(M^2 - x_1 x_2 s), \tag{5}$$

where

$$F(x_1, x_2) = \sum_i e_i^2[q_i^B(x_1)\bar{q}_i^T(x_2) + \bar{q}_i^B(x_1)q_i^T(x_2)]. \tag{6}$$

Here summation is over the flavor index i and e_i is electric charge of the quark of flavor i. q_i^B ($\bar{q}_i^B$) is the distribution of quark (antiquark) of flavor i in the incident hadron and $\bar{q}_i^T$ (q_i^T) is the distribution of antiquark (quark) of flavor i in the target hadron. x_1 and x_2 are the fractions of the longitudinal momentum of the incident and target hadrons carried by the annihilating quark and antiquark. In the hadron-hadron centre-of-mass frame the 4-momenta of the beam and target hadrons are $p_B = \left(\frac{\sqrt{s}}{2}, 0, 0, \frac{\sqrt{s}}{2}\right)$ and $p_T = \left(\frac{\sqrt{s}}{2}, 0, 0,\right.$

$- \frac{\sqrt{s}}{2}\Big)$, where $\sqrt{s}$ is the total c.m. energy. Then the longitudinal momentum of the lepton pair and its energy are equal to

$$p_L = \frac{\sqrt{s}}{2}(x_1 - x_2), \quad E_L = \frac{\sqrt{s}}{2}(x_1 + x_2).$$

So the invariant mass M of the lepton pair is given by $M^2 = x_1 x_2 s$.

In terms of the variables x_1 and x_2 the cross section (5) can be rewritten as

$$\frac{d^2\sigma}{dx_1 dx_2} = \frac{4\pi\alpha^2}{9sx_1x_2} F(x_1, x_2).$$

We will also use the following expression for the cross section for Drell-Yan process

$$\frac{d^2\sigma}{dM^2 dx_F} = \frac{4\pi\alpha^2}{9M^4}(1-\tau)\frac{x_1x_2}{x_1+x_2}F(x_1, x_2),$$

where $\tau = x_1x_2 = M^2/s$, $x_F = (x_1 - x_2)/(1-\tau)$ and $x_{1,2} = 0.5[(x_F^2 + 4\tau)^{1/2} \pm x_F]$.

In the case of lepton pair production in proton-nuclear collisions the function $F(x_1, x_2)$ depends on the products of proton and nuclear quark distribution functions

$$F^{pA}(x_1, x_2) = \tfrac{1}{9}[4u_v^p(x_1) + d_v^p(x_1)]S^A(x_2)$$
$$+ \tfrac{1}{9} S^p(x_1)[4u_v^A(x_2) + d_v^A(x_2)] + \tfrac{7}{6} S^p(x_1)S^A(x_2).$$

In different kinematical regions of the variables x_1 and x_2 different terms are dominant in this expression. At small values of x_1 the sea distribution in the proton is dominant and one can expect for the ratio of Drell-Yan cross sections a behaviour similar to the EMC effect. For $x_1 > 0.3$ contributions from proton valence quarks become dominant and the Drell-Yan process can provide information about the antiquark distributions of the target nucleus. In Fig. 2 we present the ratio of the Drell-Yan cross sections for iron and deuterium as a function of x_2 for different values of the variable x_1. For small values of x_1 the cross section ratio shows EMC-like behaviour determined by the ratio of valence quark distributions in nuclei. At large values of x_1 the cross section ratio corresponds to the ratio of nuclear sea quark distributions.

Experimentally measured cross sections for lepton pair production are larger than the ones computed according to the Drell-Yan model. Their ratio, the so-called K-factor, is approximately equal to 2 and is believed to be due to QCD corrections to the basic Drell--Yan subprocess — quark-antiquark annihilation into lepton pairs. (For a review of the K-factor, see [30]). In Fig. 3 the data [31] of the NA3 Collaboration for differential cross sections of high-mass dimuon production in 400 GeV/c proton-platinum interactions are presented together with the results of calculations in the Drell-Yan model with $K = 2$. One can see that the model compares well with the data. But the curves corresponding to the

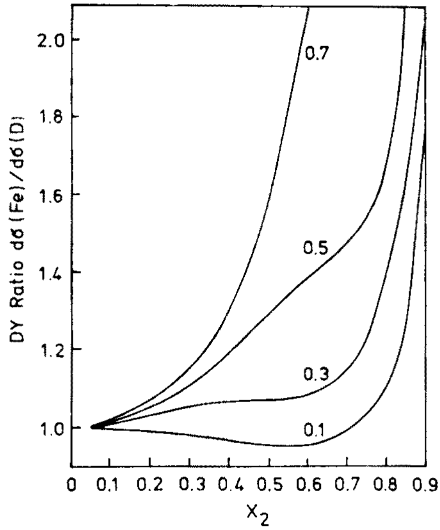

Fig. 2. Ratio of Drell-Yan cross sections $\frac{d\sigma}{dx_1 dx_2}$ for proton-iron and proton-deuteron interactions as a function of x_2 for different fixed values of x_1

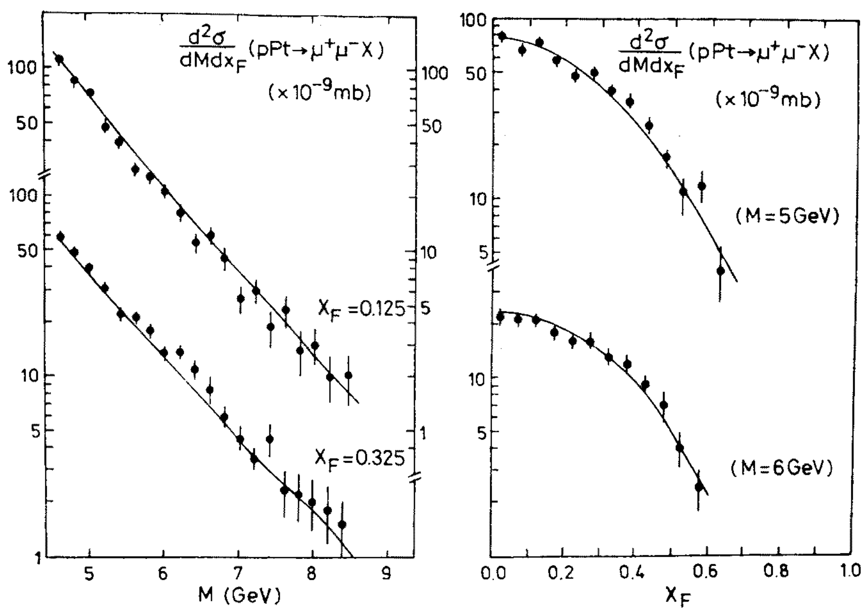

Fig. 3. Differential cross section of muon pair production in proton-platinum interactions at 400 GeV [31] as a function of M at fixed values of x_F (a) and as a function of x_F at fixed values of M (b)

calculations with and without the inclusion of the contributions from the multiquark clusters do not differ in this kinematic region.

For the ratios of cross sections multiquark cluster effects become more obvious. In Fig. 4 we present the ratio of Drell-Yan cross sections for lepton pair production in proton-iron and proton-deuteron interactions as a function of M and x_F. A large enhancement is predicted in the region of large M and negative x_F, which corresponds to the values of x_2 close to 1, where the multiquark cluster contributions become dominant.

In Fig. 5 predictions for the ratio of cross sections of the Drell-Yan process in π^-W and π^-D collisions are presented as a function of M and x_F. The following valence and sea quark distributions in the pion were used

$$xV_\pi(x) = 0.75x^{1/2}(1-x), \qquad xS_\pi(x) = 0.24(1-x)^5,$$

with normalization based on the number of valence quarks for V_π and on momentum conservation for S_π, assuming that 35% of the momentum of pion is carried by the gluons. It can be seen that again the region of large M and negative x_F appears to be more sensitive to nuclear effects, although some effect is also predicted for other regions.

Recently a nuclear effect comparable with that of lepton-nuclear deep inelastic scattering was observed by the NA10 Collaboration [17] in high-mass muon pair production on deuterium and tungsten by negative pions. In Fig. 6 their data for differential cross section ratios as functions of $\sqrt{\tau}$, x_F, x_1 and x_2 are presented along with the results of calcula-

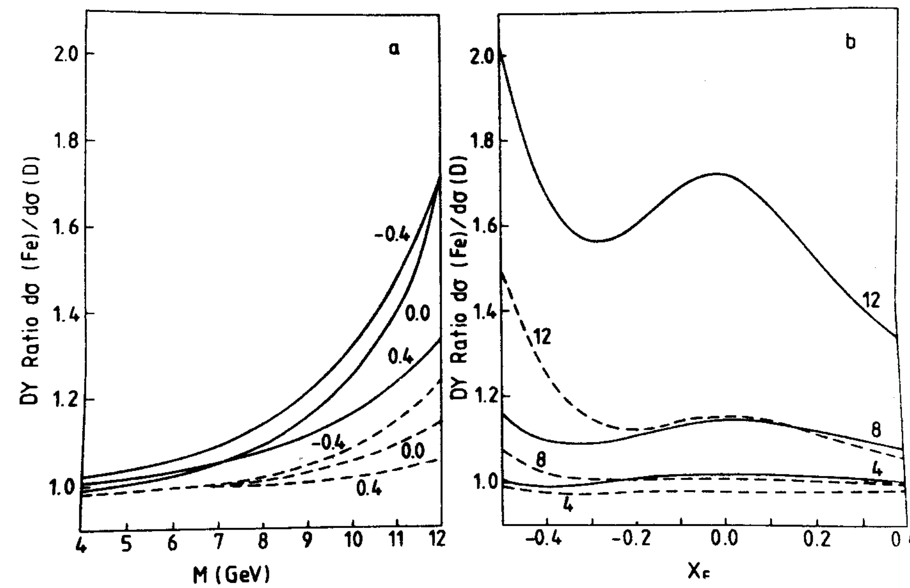

Fig. 4. Ratio of Drell-Yan cross sections $\dfrac{d^2\sigma}{dM^2dx_1}$ for proton-iron and proton-deuteron interactions at $\sqrt{s} = 20$ GeV as a function of lepton pair mass M at fixed x_F (a) and as a function of x_F at fixed M (b) with (solid curves) and without (dashed curves) account of multiquark clusters

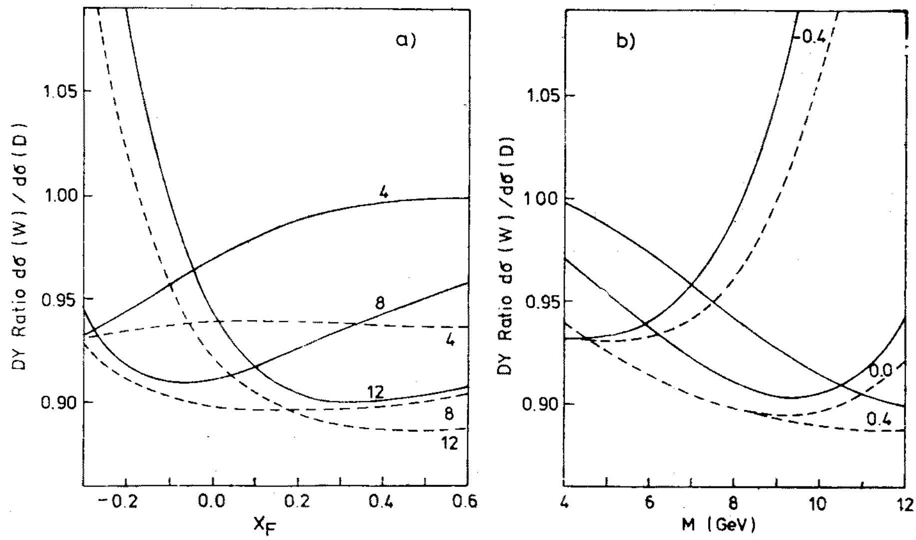

Fig. 5. Ratio of Drell-Yan cross sections $\frac{d^2\sigma}{dM^2 dx_F}$ for pion-tungsten and pion-deuteron interactions at pion energy 280 GeV as a function of x_F at fixed values of M (a) and as a function of M at fixed values of x_F(b). Designation of curves is the same as in Fig. 4

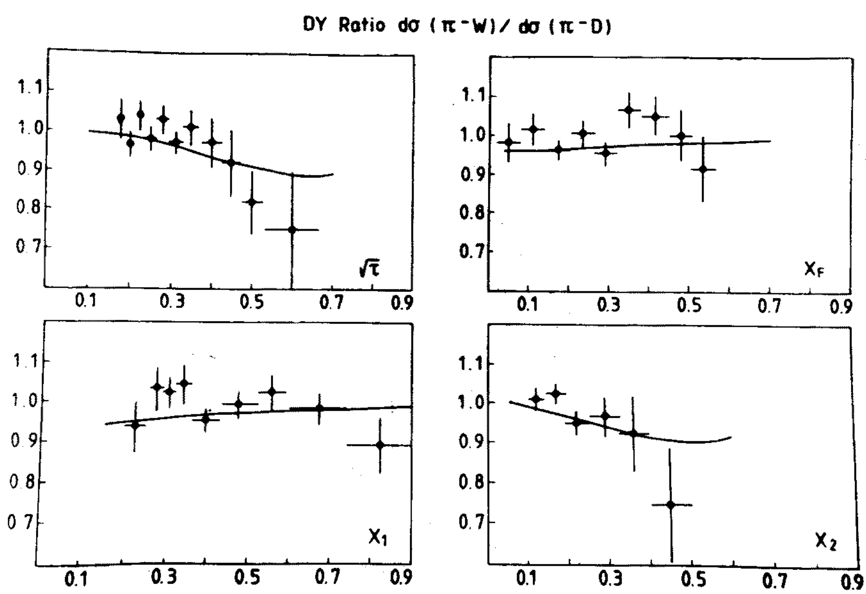

Fig. 6. Ratio of Drell-Yan cross sections for π^-W and π^-D interactions as a function $\sqrt{\tau}$, x_F, x_1 and x_2. Data from [17]

tions in the framework of the multiquark cluster model. Qualitative agreement of the model with the data is observed.

In summary, calculations of Drell-Yan cross sections with nuclear quark distribution functions obtained in the framework of the multiquark cluster model show that one can expect significant nuclear effects in high-mass lepton pair production in hadron-nucleus collisions, especially in the region of large M and negative values of the variable x_F. Systematic experimental study of these processes in a wide kinematical range can provide information on nuclear quark and antiquark distributions and distinguish models which describe correctly the quark structure of nuclei,

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REFERENCES

[1] A. M. Baldin et al., JINR preprint P1-5819, Dubna 1971; A. M. Baldin, *Part. Nucl.* **8**, 429 (1977); V. S. Stavinsky, *Part. Nucl.* **10**, 949 (1979).
[2] R. G. Arnold et al., *Phys. Rev. Lett.* **35**, 776 (1975); **40**, 1429 (1978).
[3] V. A. Matveev, R. M. Muradyan, A. N. Tavkhelidze, *Lett. Nuovo Cimento* **7**, 719 (1973).
[4] J. J. Aubert et al., *Phys. Lett.* **123B**, 275 (1983).
[5] A. Bodek et al., *Phys. Rev. Lett.* **50**, 1431 (1983); **51**, 534 (1983).
[6] R. G. Arnold et al., *Phys. Rev. Lett.* **52**, 727 (1984).
[7] G. Bari et al., *Phys. Lett.* **163B**, 282 (1985).
[8] J. Ashman et al., CERN preprint CERN-EP/88-06, Geneva 1988.
[9] A. C. Benvenuti et al., *Phys. Lett.* **189B**, 483 (1987).
[10] K. Rith, in: Proceedings of Int. Nuclear Physics Conf., Harrogate, UK, August 1986. Ed. by J. L. Durell, J. M. Irvine, G. C. Morrison, Vol. 2, p. 395.
[11] A. Bodek, J. L. Ritchie, *Phys. Rev.* **D23**, 1070 (1981).
[12] C. H. Llewellyn Smith, *Phys. Lett.* **128B**, 107 (1983); M. Ericson, A. W. Thomas, *Phys. Lett.* **128B**, 112 (1983); E. L. Berger, F. Coester, R. B. Wiringa, *Phys. Rev.* **D29**, 383 (1984); E. E. Saperstein, M. J. Shmatikov, *JETP Lett.* **41**, 53 (1985).
[13] F. E. Close, R. G. Roberts, G. G. Ross, *Phys. Lett.* **129B**, 346 (1983); *Phys. Rev.* **D31**, 1004 (1985); R. L. Jaffe, F. E. Close, R. G. Roberts, G. G. Ross, *Phys. Lett.* **134B**, 449 (1984); O. Nachtman, H. J. Pirner, *Z. Phys.* **C21**, 277 (1984).
[14] S. V. Akulinichev, S. A. Kulagin, G. M. Vagradov, *JETP Lett.* **42**, 127 (1985); *Phys. Lett.* **152B**, 485 (1985); B. L. Birbrair, A. B. Gridnev, M. B. Zhalov, E. M. Levin, V. E. Starodubsky, *Phys. Lett.* **166B**, 119 (1986).
[15] C. E. Carlson, J. J. Havens, *Phys. Rev. Lett.* **51**, 261 (1983); S. Date, *Progr. Theor. Phys.* **70**, 1682 (1983); A. I. Titov, *Sov. J. Nucl. Phys.* **40**, 50 (1984); W. Furmański, A. Krzywicki, *Z. Phys.* **C22**, 391 (1984); L. A. Kondratyuk, M. J. Shmatikov, *JETP Lett.* **39**, 389 (1984); *Z. Phys.* **A321**, 301 (1985); J. P. Vary, *Nucl. Phys.* **A418**, 195c (1984).
[16] V. R. Garsevanishvili, Z. R. Menteshashvili, in: Proceedings of the 7-th Int. Conf. on High Energy Physics Problem, Dubna 1984, JINR D1, 2-84-599, Dubna 1984, p. 157; J. P. Vary, in: Proceedings of the 7-th Int. Conf. on High Energy Physics Problems, Dubna 1984, JINR D1,2-84.599, Dubna 1984, p. 186.

[17] P. Bordalo et al., *Phys. Lett.* **193B**, 368 (1987).
[18] R. P. Bickerstaff, M. C. Birce, G. A. Miller, *Phys. Rev. Lett.* **53**, 2532 (1984); *Phys. Rev.* **D33**, 3228 (1986); N. P. Zotov, V. A. Saleev, V. A. Tsarev, *JETP Lett.* **40**, 965 (1984); T. Chmaj, K. Heller, *Acta Phys. Pol.* **B15**, 473 (1984); **B16**, 423 (1985); Y. Gabellini, J. L. Meunier, G. Plaut, *Z. Phys.* **C28**, 123 (1985); E. L. Berger, *Nucl. Phys.* **B267**, 231 (1986); A. Harindranath, J. P. Vary, *Phys. Rev.* **D34**, 3378 (1986).
[19] A. V. Efremov, *Part. Nucl.* **13**, 613 (1982); V. K. Lukianov, A. I. Titov, in: Proceedings of the XV Int. School on High Energy Physics, JINR D2, 4-83-179, Dubna 1983.
[20] M. Sato, S. A. Coon, H. J. Pirner, J. P. Vary, *Phys. Rev.* **C33**, 1062 (1986).
[21] V. R. Garsevanishvili, N. A. Kiknadze, Z. R. Menteshashvili, *Acta Phys. Pol.* **B19**, 439 (1988).
[22] V. R. Garsevanishvili, A. N. Kvinikhidze, V. A. Matveev, A. N. Tavkhelidze, R. N. Faustov, *Theor. Math. Phys.* **23**, 533 (1975); V. R. Garsevanishvili, V. A. Matveev, *Theor. Math. Phys.* **24**, 3 (1975).
[23] V. R. Garsevanishvili, Z. R. Menteshashvili, JINR preprint E2-84-374, Dubna 1984; *JETP Lett.* **40**, 1165 (1984).
[24] R. P. Feynman, *Photon-Hadron Interactions*, V. A. Benjamin Inc., Massachusetts 1972; F. E. Close, *An Introduction to Quarks and Partons*, Academic Press 1979.
[25] D. Sivers, *Ann. Rev. Nucl. Part. Sci.* **32**, 149 (1982).
[26] G. Alberi, L. P. Rosa, Z. D. Thome, *Phys. Rev. Lett.* **34**, 503 (1975).
[27] V. A. Matveev, P. Sorba, *Lett. Nuovo Cimento* **20**, 443 (1977); P. J. Mulders, A. W. Thomas, *Phys. Rev. Lett.* **52**, 1199 (1984).
[28] S. D. Drell, T. M. Yan, *Phys. Rev. Lett.* **25**, 316 (1970); *Ann. Phys.* **66**, 578 (1971).
[29] R. Stroynowski, *Phys. Rep.* **71**, 1 (1981); I. R. Kenyon, *Rep. Progr. Phys.* **45**, 1261 (1982).
[30] W. J. Stirling, in: Proceedings of the Drell-Yan Workshop, Fermilab 1982, Ed. by E. L. Berger, P. Malhotra, R. Orava, H. Thacker, p. 131.
[31] J. Badier et al., *Z. Phys.* **C26**, 489 (1985).