Preprint YERPHI-1304(90)-90

ԵՐԵՎԱՆԻ ՖԻԶԻԿԱՅԻ ԻՆՍՏԻՏՈՒՏ
ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ
YEREVAN PHYSICS INSTITUTE

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ELECTROPRODUCTION OF π^0- MESONS ON NUCLEI IN DEEP INELASTIC REGION

ЦНИИатоминформ
ЕРЕВАН-1990

Նախնատիպ ԵրՖԻ-1304(90)-90

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π^0-ՄԵԶՈՆՆԵՐԻ ԷԼԵԿՏՐԱԾՆՈՒՄԸ ՄԻՋՈՒԿՆԵՐԻ ՎՐԱ ԽՈՐԸ ՈՉ-ԱՌԱՁԳԱԿԱՆ ՏԻՐՈՒՅԹՈՒՄ

Ներկայացված ծրագիրը խորը ոչ-առաձգական տիրույթում մինչև 4,5 ԳէՎ էներգիայով էլեկտրոնների ցրման ԵրՖԻ-ում կատարվող փորձարարական հետազոտությունների մի մասն է՝ վիրտուալ ֆոտոնների կլանման և միջուկային միջավայրերում քվարկների հադրոնացման մեխանիզմների հետազոտման ուղղությամբ: Նախագծում ցույց է տրված (e, e', π^0) պրոցեսի իրականացման հնարավորությունը ԵրՖԻ-ում և քվարկների հադրոնացման պրոցեսի տարածա-ժամանակային կառուցվածքի հետազոտումը՝ այդ պրոցեսը բնութագրող մեծությունների կախումը ինչպես վիրտուալ ֆոտոնի (ν, Q^2), այնպես էլ գրանցվող հադրոնի $(z = E_h/\nu)$ կինեմատիկ բնութագրերից: Բերված են փորձարարական սարքավորման սպասվող բնութագրերը և փորձի մոդելավորման արդյունքները:

Երևանի ֆիզիկայի ինստիտուտ

Երևան 1990

Препринт ЕФИ-1304(90)-90

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ЭЛЕКТРОРОЖДЕНИЕ π^0-МЕЗОНОВ НА ЯДРАХ В ГЛУБОКО НЕУПРУГОЙ ОБЛАСТИ

Представленный проект является частью экспериментальной программы ЕрФИ по исследованию механизмов поглощения виртуальных фотонов и адронизации кварков в ядерной среде в процессах глубоко-неупругого рассеяния электронов с энергией до 4,5 ГэВ. В проекте рассмотрена возможность изучения реакции (e,e',π^0) и получения информации о пространственно-временной структуре процесса адронизации кварков, а также зависимости характеристик процесса формирования адронов от кинематических переменных виртуального фотона (ν , Q^2) и регистрируемого адрона ($z = E_h/\nu$). Приведены ожидаемые характеристики экспериментальной установки, и результаты численного моделирования эксперимента.

Ереванский физический институт
Ереван 1990

Preprint YERPHI-1304(90)-90

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ELECTROPRODUCTION OF π^0- MESONS ON NUCLEI IN DEEP INELASTIC REGION

The proposed project is a part of experimental program of Yerevan Physics Institute for the investigation of mechanisms of virtual photon absorption and hadronization of quarks in nuclear media in the processes of deep inelastic scattering of electrons with energies up to 4.5GeV. In this project we discuss the possibility for the study of reaction $(e,e'\pi^0)$ with a view of obtaining the information about space-time structure of quark hadronization process as well as the dependence of characteristics of hadron formation process on kinematical variables of the virtual photon (ν,Q^2) and of the detected hadron $(z=E_h/\nu)$. The characteristics of experimental set-up and also the results of computer simulation of the experiment are given.

Yerevan Physics Institute
Yerevan 1990

INTRODUCTION

From the viewpoint of strong interaction physics the processes of leptoproduction on nuclei in deep-inelastic region give interesting information both on the processes of hadrons formation from quarks and on the mechanism of quark transition through the nuclear matter [1-5].

According to modern understanding the virtual photon is believed to be transformed to a quark-antiquark pair in the rest system of nucleus, the pairs asymmetrical in momenta only being allowed to interact with the target due to finite lifetime of the virtual photon $\tau_{\gamma^v} \simeq 2\nu/Q^2$. In such an asymmetric pair the slow antiquark (quark) has a time to transform to a "dressed" or additive quark (valon) and annihilate with the quark (antiquark) of the nucleon of nucleus during the interval $\tau_p \simeq \nu/Q^2$ [6-11]. After the annihilation of slow antiquark (quark) the faster quark (antiquark) of the pair continues its flight through the nuclear matter, but the cross section of its interaction with nucleons of the nucleus is remarkably smaller (by the factor of m_c^2/Q^2, where $m_c \simeq 0.3$GeV [4,5,9-11]) than the characteristic hadronic cross-sections, as for the times of the order of τ_p the fast quark is "semidressed" and can pass to hadronic state only when the time $\tau_F \approx \nu/m_c^2 (m_c^2 \simeq 0.1\text{GeV}^2)$ is elapsed. The cross-section of the interaction of such a system (quark or quark-gluon system [2,5], or quark-antiquark dipole [4,5]) with the matter grows from $\sigma_q = \frac{m_c^2}{Q^2}\sigma_h$ at the instant $\sim\tau_p$ up to σ_h at the instant of fast hadron formation τ_F [1-5,11].

It is impossible to predict the behaviour of $\sigma(t)$ from σ_q to σ_h in the framework of perturbative QCD at least in the vicinity of $t \sim \tau_F$, where t is the time or space variable. For sufficiently large values of $Q^2>m_c^2$ in the range of $t\geq\tau_p$ one can make predictions for $\sigma(t)\sim t$ [2,5,7] in the framework of perturbative QCD. On the other hand, in the framework of naive parton model or the model of colored dipole, $\sigma(t)$ is expected to be $\sim t^2$ [4,5]. Detailed analysis of different mechanisms of fast hadron formation in the processes of leptoproduction on nuclei was made in Ref.[11]. Particular predictions for the value of $R=\sigma(\gamma^v A\to hX)/A\sigma(\gamma^v N\to hX)$ depending on the form of $\sigma(t)$ function are discussed below.

The above pattern for fast hadron formation assumes the fulfillment of the condition $\sigma(\gamma^v A)\simeq A\sigma(\gamma^v N)$ for total cross-sections of virtual photon absorption by the nucleus and nucleon, i.e. the absence of effects induced by the screening of photon interaction itself with nuclear matter. Experimental data on deep-inelastic interaction of leptons with nuclei show [12-14], that in the range of x_B variable from 0.05 to 0.3 under consideration in this project, this condition is practically approached (remember that $x_B=Q^2/2M\nu$).

1. TRANSPARENCY OF NUCLEAR MATTER

As a characteristic of space-time structure of hadron leptoproduction it is convenient to use the transparency of nuclear matter, which is defined as the ratio of differential cross-section of hadron leptoproduction on nucleus normalized to atomic weight to that on nucleon: $R=(d\sigma_A/A)/d\sigma_N$. Nuclear transparency is minimal in conventional Glauber model of hadroproduction on nuclei, when the hadron is produced directly at the interaction point of an incident particle with nucleus and the produced hadron h is able then to interact inelastically with intranuclear nucleons with cross-section σ_h coinciding with the usual cross-section of hN-interaction. The value of transparency is equal to the probability for the hadron to leave the nucleus without any inelastic interactions within it, i.e. without the loss of some notable share of its primary energy. It is worth-while to add in this connection, that at the measurement of nuclear transparency in leptoproduction process one should restrict to high energy part of the inclusive spectrum of hadron (i.e. to large values of the variable $z=E_h/\nu$, where E_h is the energy of detected hadron), as the contribution of secondary inelastic processes in the nuclear matter to this range of spectrum is insignificant. We shall confine in what follows to the part of spectrum, where the energy of hadrons is more than the half of the energy of virtual photon, i.e. where the value $z>0.5$.

If the process of leptoproduction exceeds the limits of Glauber scheme, i.e.occupies a finite space-time interval, then the transparency is higher than the minimum value R_{min}. The maximum value $R_{max}\sim 1$ is achieved when the hadron is formed outside the nucleus and its constituents may interact in the nucleus with negligible cross-section. If the mean absorption path of virtual photon in the nuclear matter much exceeds the size of nucleus (which is the case for not so small values of Bjorken variable $x_B>0.05$), then the probability that the fast quark produced at $\sim\tau_p$ instant and its induced in τ_F time fast hadron will not undergo inelastic interactions in the nucleus, is determined by the expression [1,2,5]:

$$R = \frac{1}{A}\int\rho(b,x)\exp\left[-\int_x^{\infty}\rho(b,t)\sigma(t)dt\right]dx\, d^2\vec{b} \qquad (1)$$

where $\rho(b,x)=\rho(r) = \rho_o\Big/\left[1+\exp\left(\frac{r-r_A}{a}\right)\right]$ is the density of nuclear distribution normalized by the condition $\int\rho(r)d^3r=A$, $a=0.54$ and $r_A=(0.978+0.0206A^{1/3})A^{1/3}$ [2]. $\sigma(t)$ is the interaction cross-section of the quark to which the virtual photon is transformed in the point $\vec{r}(\vec{b},x)$ of interaction with nuclear matter. This cross-section changes from σ_q in the $t=x$ point to σ_h at $t\geq(x+\tau)$, where τ is the characteristic time of the quark transition to hadron ($\tau\approx\tau_F$).

The dependence of R value on A, τ and σ_q is given respectively in Figs.1-3 at different fixed values of two others (assuming σ_h=20 mb). Results calculated for two models are shown, the first being based on perturbative QCD (the so-called model of quantum diffusion), in the framework of which $\sigma(t)\approx\sigma_q+(\sigma_h-\sigma_q)t/\tau$ for $t/\tau\ll1$ (solid curves in Figs.1-3);the second one based on naive parton model, in the framework of which the quark-antiquark pair is presented in the form of colored dipole [4], interacting with cross-section $\sigma(t)\approx\sigma_q+(\sigma_h-\sigma_q)(t/\tau)^2$ at $t/\tau\ll1$ (dashed curves in Figs.1-3). The account for the behaviour of $\sigma(t)$ in the vicinity of $t/\tau\approx1$ refers to the non-perturbative QCD and could not be given in the framework of perturbative QCD. Note, however, that the form of this function in the range $t/\tau\approx1$ does not essentially influence the value R, which is mainly determined by the behaviour of $\sigma(t)$ in the range $t/\tau\ll1$.

The dependence of τ and σ_q on kinematical variables of the virtual photon has been discussed by different authors

[1,2,4,5,11]. One can expect for these dependences [1-5] in accordance with modern concepts, based on perturbative QCD and naive parton model:

$$\tau \approx \nu z/m_c^2 \qquad \left(\text{or } \nu/m_c^2\right) \tag{2}$$

$$\sigma_q \approx \frac{m_c^2}{Q^2}\,\sigma_h \tag{3}$$

Essentially different z-dependence for τ is obtained in the framework of the LUND fragmentation model [15,16] whence follows $\tau \approx \nu(1-z)/m^2$ at $z \approx 1$.

The dependences of nuclear transparency on variables Q^2, ν, z and m_c^2 are shown respectively in Figs. 4-7 for different fixed values of the others.

Note that the results presented in Figs.1-7 are obtained without account of radiation corrections. One can expect that the radiation corrections would not be too large and we are conducting now their detailed analysis.

It follows from the data in Figs.1-7, that the difference between the behaviours $\sigma(t) \sim t$ and $\sigma(t) \sim t^2$ is expected to be small and poorly observable both for small $\nu \leq (2 \div 4)$GeV and large $\nu \geq (50 \div 100)$GeV values. Optimal for the study of behaviour of $\sigma(t)$ dependence is the range of $\nu \simeq (10 \div 20)$GeV and $Q^2 \geq 1\text{GeV}^2/c^2$. Such investigations will be carried out in SLAC in the framework of PEGASYS project [17]. However, as it follows from Fig.4, for $Q^2 > (1 \div 2)\text{GeV}^2/c^2$ the value of nuclear transparency R is practically independent of the value of Q^2 variable, while for $Q^2 < 1\text{GeV}^2/c^2$ the expected dependence of R on Q^2 is experimentally observable. On the other hand, the range of $Q^2 \leq 1\text{Gev}^2/c^2$ is also interesting for the fact that in this range the transition from the Glauber value for the nuclear transparency R_{min} to the characteristic maximum value for R at the given energy value ν takes place. Hence, the experimental investigation of the dependence of R on Q^2 in this very range is of particular interest. The proposed study of electroproduction of π^0-mesons in the range 2GeV≤ν≤4GeV and 0.3 $GeV^2/c<Q^2<1.5GeV^2/c^2$ will give the information about the dependence of τ and σ_q on variables Q^2,ν,z and m_c^2 (Figs.4-7), that is important for the verification of different models [2-5].

2. AVAILABLE EXPERIMENTAL RESULTS

It follows from the aforesaid, that the existing theoretical concepts of the mechanisms of hadron production in deep inelastic processes give different quantitative predictions about the nuclear transparency and the time of hadron formation. The situation with estimates following from the analysis of experimental data available is nearly the same. At present, the experimental data on the study of inclusive production of hadrons in the interaction of leptons with atomic nuclei are very limited.

The first such experiment was performed on the electron beam in SLAC at the energy E_e=20GeV [18]. The increase in transparency (decrease in absorbability) of a nucleus with respect to the yield of fast charged products of the hadronization of the virtual photon was observed for the first time. These data, however, does not provide sufficiently detailed information about the parameters, characterizing the space-time picture of hadron formation process. On the one hand it is connected with insufficient high statistical accuracy, and on the other - with the averaging of data in rather wide intervals in ν (from 3GeV to 17GeV at $\bar{\nu}$=10GeV) and in Q^2 (from Q^2=0.35GeV^2/c^2 to 1GeV^2/c^2 and from Q^2=1GeV^2/c^2 to 5GeV^2/c^2). It is interesting to note that the decrease in the absorbability of nuclear matter, i.e. the extended structure of hadron formation process, shows, yet at comparatively small values of Q^2(0.35GeV^2/c^2<Q^2<1GeV^2/c^2), this manifestation being even more pronounced than for the range 1GeV^2/c^2<Q^2<5GeV^2/c^2, contrary to the expected dependence of transparency on Q^2 (see Fig.4). Note, however, that in this experiment the charged hadrons were detected, in the inclusive spectra of which considerable may be the share of $\pi^{\pm}$ mesons from the process of coherent production of ρ^0 mesons on nuclei, the contribution of which grew with decreasing Q^2. This contribution is practically absent in spectra of π^0-mesons, the detailed experimental investigation of the electroproduction of which at fixed values of Q^2 in the range 0.3GeV^2/c^2<Q^2<1.5GeV^2/c^2 allows one to remove the available ambiguity in the Q^2-behaviour of nuclear transparency in this transition range.

The charged hadrons were also detected in the virtual photon fragmentation range in the experiment of EMC collaboration on the CERN SPS muonic beams of energy E_μ=200GeV. In the region of ν in the vicinity of 100 GeV and higher the nuclear matter was observed to be almost completely transparent relative to the hadron leptoproduction.

The analysis of these experiments as well as of the neutrino experiment [20] with SKAT chamber (Protvino) for neutrino energies E_ν<30GeV does not give more or less reliable information about characteristic dimensions of the quark hadronization process. So, the estimates of m_c^2 parameter (formulae 2), obtained in Refs. [20] and [19], are respectively

$(0.08\pm0.04)GeV^2$ and $\sim 2GeV^2$. It should be noted however, that the data of Ref. [19] are not statistically accurate at large values of $z (z\sim 0.7)$.

Such an uncertainty in the estimates of parameters characterizing the space-time structure of hadron formation process is due to the absence of systematic experimental data on the leptoproduction from different nuclei, when the kinematical variables ν, Q^2 and z are varied in sufficiently wide ranges as well as the absence of experiments for different types of final hadrons.

The proposed experiment on the electroproduction of π^0-mesons on different nuclei at the Yerevan electron synchrotron for different values of kinematical variables in the ranges $2GeV \le \nu \le 4GeV$; $0.3GeV^2/c^2 < Q^2 < 1.5GeV^2/c^2$ and $0.5 \le z \le 1$ could essentially span this gap. Kinematical variables and the feasible experimental range are given in Figs. 8 and 9.

3. MAIN AIMS OF THE PROPOSED EXPERIMENT.

In view of the aforesaid, we formulate the main aims and expected results of the proposed experiment.

1. Obtaining of first systematically and statistically sound data on the electroproduction of π^0 mesons on atomic nuclei for electron energies up to 4.5GeV, energy of virtual photon up to 4GeV and Q^2 to $1.5GeV^2/c^2$ and in the range of $z=E_h/\nu$ variable from 0.5 to 1.

2. Investigation of the transparency of nuclear matter relative to the electroproduction of π^0 (and then possibly η) mesons and determination of its dependence on kinematical variables ν, Q^2, z and the mass m_h of hadron.

3. Extraction of the cross-section of quark interaction with intranuclear nucleons σ_q and investigation of its dependence on above kinematical variables.

4. Identification on the basis of experimental data of most adequate ideas of space-time structure of hadron leptoproduction process, the estimate of fast hadron formation time and its dependence on kinematical characteristics of leptoproduction process.

4. EXPERIMENTAL SET-UP

We plan to perform the investigation of inclusive electroproduction of π^o-mesons from nuclei on the external beam of Yerevan electron synchrotron with the help of magnetic spectrometer "Electron" [21] (Fig.10). The electron beam (E_e=4.5GeV, $I \sim 2 \cdot 10^{10} e^-$/sec) is transported and focused on the solid remote-controlled targets (C,Al,Cu,Pb) by means of quadrupole lenses and a bending magnet. We also plan to take measurements with liquid hydrogen and deuterium targets. The thickness of targets has to be $\sim$(0.02÷0.05) radiation length and the beam monitoring is made by means of Faraday cup and secondary emission monitor with the accuracy of not worse than ~1% of the intensity measurement.

The scattered electrons are detected with the magnetic spectrometer, the minimal angle of which with respect to the direction of primary electrons is $\theta_e^{min} \sim 10^o$. The optical system of the spectrometer consists of two quadrupole lenses ML-15, ML-16 and vertical-deflecting magnet (SP-137). The detecting instrumentation includes the aperture scintillation counters, the 16-element momentum hodoscope and the system of electron identification. The separation of scattered electrons from hadronic and muonic backgrounds is by means of 12-channel total absorption Cerenkov spectrometer located at the end of spectrometric tract (see Fig.10). Each channel of the Cerenkov spectrometer is a hexahedral block of TF-1 type lead glass with 175mm diameter of inscribed circle and 350mm length, observed with PMT-49B type phototube. The parameters of magnetic spectrometer will be: range of analyzed momenta - $(0.5\div2.5)$GeV/c, momentum acceptance - ±10%, momentum resolution - ±0.5%, angular acceptance and angular resolution - 1msr and $\pm1^{o}$, respectively.

π^{o}-mesons will be detected by multichannel Cerenkov total absorption spectrometer consisting of 625 modules of TF-1 type lead glass with $40x40x400mm^{3}$ dimensions. The Cerenkov radiation is detected in the radiators by PMT-84-3 type phototubes. The control for the state of spectroscopic channels of the Cerenkov hodoscope during the experiment will be realized by means of spectrometer monitoring with gaseous nitrogen laser as a reference light source [22]. Experimental runs on a model spectrometer (the prototype of large spectrometer consisting of 25 analogous modules) showed that the energy resolution of the spectrometer averaged over all the spectrometer area makes $\Delta E/E=0.17/\sqrt{E}$ (ΔE is the FWHM value of the distribution). The analysis of shower energy release in neighbouring cells allows one to determine the coordinate of the decay photons at $E_{\gamma}\geq0.5$GeV with an accuracy $\sigma_{x}\simeq3$mm [23]. $1m^{2}$ area spectrometer (25x25 modules matrix) at a distance of $\sim(1.5\div2)$m from the physical target permits the detection of π^{o}- mesons with $E_{\pi^{o}}\geq1$GeV along the spectrometer axis with the efficiency not worse than ~15%. In this case the effective mass of two-photon pairs will be determined with the accuracy of $\sigma_{m}/m\sim8\%$.

5. MONTE-CARLO SIMULATION OF EXPERIMENT AND THE MAIN SOURCES OF BACKGROUND

The number of events detected in the experiment per unit time is determined by the expression

$$N_{ev} = N_e \cdot N_A \cdot \int_{\Delta\Phi} \left(\frac{d\sigma}{d\phi}\right) \eta \cdot d\phi \qquad (4)$$

where $d\sigma/d\phi$ is the differential cross-section of the process under investigation, $d\phi = dE' d\Omega' d\cos\theta_e d\varphi_e dP_\perp dP_\parallel d\varphi_\pi$ is the element of volume in the phase space of the reaction, N_e is the intensity of electron beam, N_A is the number of target nuclei per 1cm^2, η is the geometrical efficiency of the arrangement.

The cross section of inclusive electroproduction of π^o mesons on the nucleus with atomic weight A (Z protons and N neutrons) is related to the cross-section on proton by means of expression [12,24]

$$\frac{d\sigma(eA \to e'\pi^o X)}{dE' d\Omega' dp_\perp^2 dz} = \frac{A_{eff}}{A} \left[Z + N(1-x')\right] \frac{d\sigma(ep \to e'\pi^o X)}{dE' d\Omega' dP_\perp^2 dz} \qquad (5)$$

where $x' = Q^2/(2M\nu + M^2)$, A_{eff} is the efficient number of nucleons at averaged effective cross-section of quark-nucleon (pion-nucleon) interaction, determined in the framework of Glauber model. In its turn, the differential cross-section of π^o-meson electroproduction on proton is determined by the following factorized expression [24].

$$\frac{d^5\sigma(ep \to e'\pi^o X)}{dE' d\Omega' dP_\perp^2 dz} = \frac{d^2\sigma}{dE' d\Omega'} (ep \to e'X) \;\; D^{\pi^o}(Z) \cdot B \exp(-BP_\perp^2) \qquad (6)$$

In the W≥2GeV range the cross-section of deep inelastic scattering on proton $d\sigma(ep \to e'X)/dE'd\Omega'$ is determined with the help of Rittenberg-Rubinstein parameterization [12,25]. The slope of the transverse momentum distribution was experimentally determined in Ref.[24], $B=4,4(GeV/c)^{-2}$.

In Ref.[26] based on the analysis of experimental data on inclusive spectra of (anti) neutrinoproduction of charged pions an expression for the function of fragmentation of nonstrange u and d quarks in π^o-mesons was obtained:

$$D^{\pi^o}(z) = \left[0,366(1-z)^{1.43} + 0,273(1-z)^{2.49}\right]/z \qquad (7)$$

which is in good agreement with experimental data on the inclusive electroproduction of π^o-mesons on proton obtained in Ref.[24,27] (see Fig.11).

The results of calculations in the form of dependence of the number of events (N_{ev}) on Q^2 from ^{64}Cu nucleus at different energies of the virtual photon are shown in Fig.12. The simulated events were checked for the "detection" by the experimental set-up for the following values of parameters: energy and angular acceptance of the magnetic spectrometer $\Delta P=\pm 10\%$ and $\Delta\Omega=1msr$, corresponding to the distance of Cerenkov spectrometer from the physical target $L_{\check{C}}=200$ cm.

To estimate the number of experimentally detected events, return once again to Fig.(1-7). One can estimate, that the change in transparency of, e.g., ^{64}Cu nucleus with ~5% accuracy allows not only to find out any discrepancy with the Glauber mechanism of hadron leptoproduction, but also to draw definite restrictions on parameters, characterizing the space-time picture of this process. To achieve this accuracy for example, at $Q^2 \simeq 0.7 GeV^2/c^2$, $\nu \simeq 2.5 GeV$ and $I \simeq 2 \cdot 10^{10} e^-/sec$, it is necessary to measure the yield of π^o-mesons with (3-4)% statistical accuracy with ^{64}Cu and ^{2}D targets (~1000 events for each target). This implies about 300 hours of running time.

The main sources of background for the process of inclusive electroproduction of π^{o}-mesons are the reactions of elastic and inelastic production of vector mesons on nuclei, which have decay channels into π^{o}-mesons (indirect π^{o}-mesons). The contribution from the processes of incoherent production of vector mesons on nuclei was estimated to be ≤25% for the range of z variable z>0.5. The contribution from coherent production of ω-mesons on nuclei to the inclusive spectrum of π^{o}-mesons is maximum at $Q^{2}\sim 0$ (of the order of 10% for both the copper and carbon nuclei) and decreases with the increase in Q^{2}(~1% at Q^{2}=0.5GeV^{2}/c^{2}).

We are preparing the measurements of R on ^{12}C, ^{27}Al, ^{64}Cu and ^{207}Pb nuclei in the range of ν=(2÷4)GeV and Q^{2}=(0.3÷1.5)GeV^{2}/c^{2} with our experimental set-up, which will allow us to determine, on the basis of obtained data, the dependence of nuclear transparency on kinematical variables and to establish the most adequate viewpoint of space-time structure of hadron leptoproduction process.

6.CONCLUSIONS

One can see thus, that the parameters of the Yerevan electron synchrotron and of designed experimental setup would enable one to conduct series of investigations from the thorough study of the effects of nuclear medium on the mechanisms of virtual photons absorption and quark hadronization in the processes of deep-inelastic scattering of electrons.

The experimental set-up under construction is intended to become a basis for multipurpose complex set-up equipped with multichannel Cerenkov spectrometer and a magnetic spectrometer for the detection of charged hadrons (second stage of the arrangement) for simultaneous study of the processes of electroproduction of both neutral and charged hadrons.

The second stage of the set-up will permit more precise and detailed investigations of the process of quark fragmentation to different mass hadrons, the study of virtual Compton-effect on nucleons (nuclei) and of the coherent and quasi-elastic production of ω-mesons on nuclear target.

It should be noted, however, that some of the mentioned problems are included in experimental programs of other electron accelerator both operating and under construction (SLAC,CEBAF). These investigations cover mainly the range of higher Q^2 (e.g., the range of Q^2 in the PEGASYS project [17] at SLAC is $1GeV^2/c^2<Q^2<(10-15)GeV^2/c^2$) for which the methods of the description of quark fragmentation processes based on QCD become applicable as Q^2 increases (which are poorly investigated regarding the fragmentation in nuclear medium). On the other hand, the investigations proposed in the present cover the range of small and intermediate Q^2 $(0.3GeV^2/c^2<Q^2<1.5GeV^2/c^2)$, i.e., the "transition" range, in which, apparently, on essential change of space-time structure of hadron electroproduction process occurs. As was shown above, this change was directly observable in the experiments on nuclear targets.

Thus, the experimental investigations planned at the Yerevan synchrotron and other accelerators are mutually complementary in the study of fundamental properties on nuclear and subnuclear levels.

The authors are grateful to A.Ts.Amatuni and S.H.Matinyan for interest in this work and helpful discussions, to A.S.Aleksanyan and R.N. Pikhtelev for support and collaboration at initial stages of project development, to A.M.Kotsinyan, V.M.Dzhaloyan, V.G.Yakovlev, A.A.Shaginyan, G.E.Babayan for a series of calculations and the development of experimental technique connected with the project.

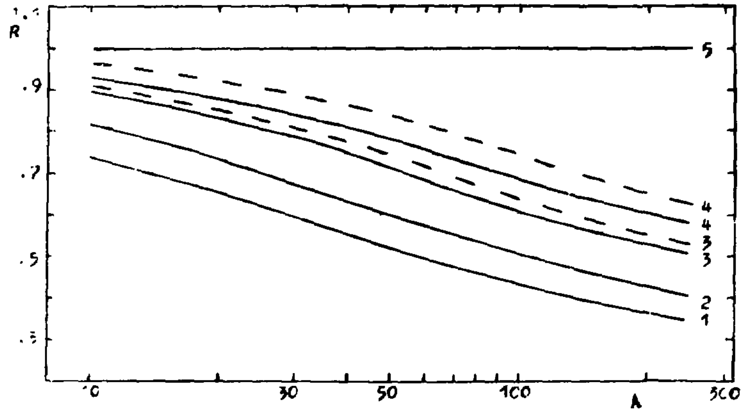
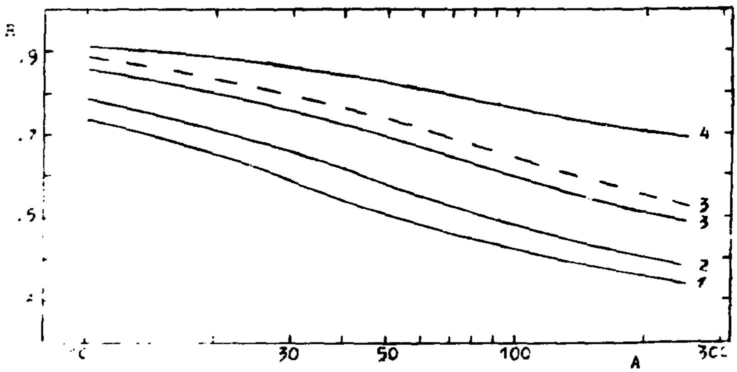


Fig. 1a



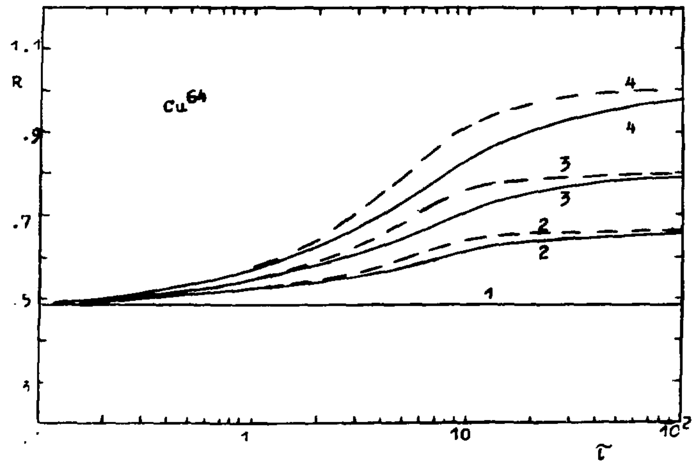

1.1
R
Cu^{64}
.9
.7
.5
.3
4
4
3
3
2
2
1
1
10
10^2
τ

Fig.2

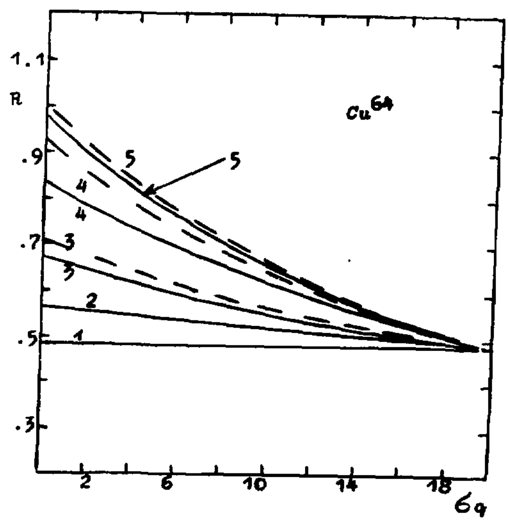

1.1
R
Cu^{64}
.9
.7
.5
.3
5
5
4
4
3
3
2
1
2
6
10
14
18
σ_q

Fig.3

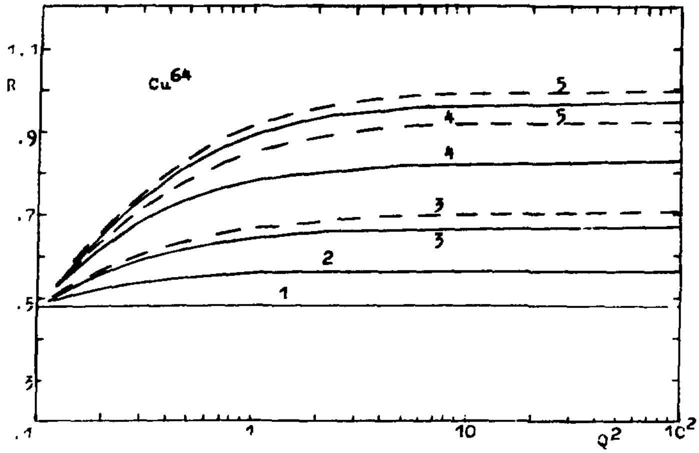


Fig.4

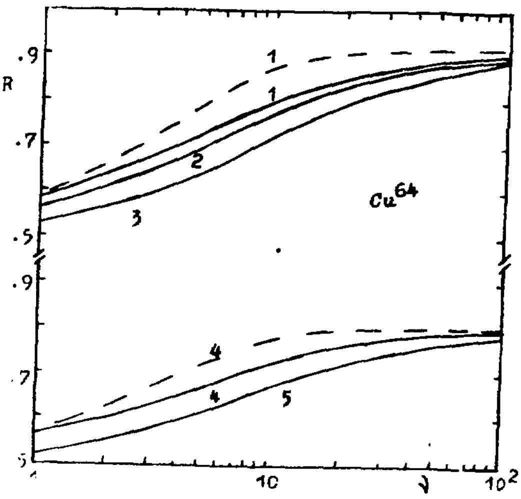


Fig.5

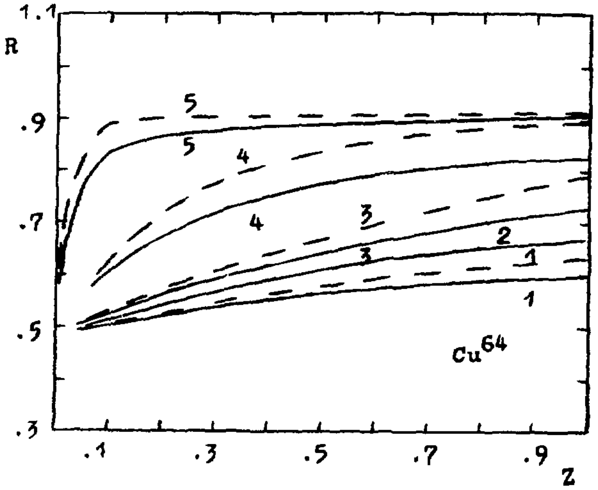


Fig.6.

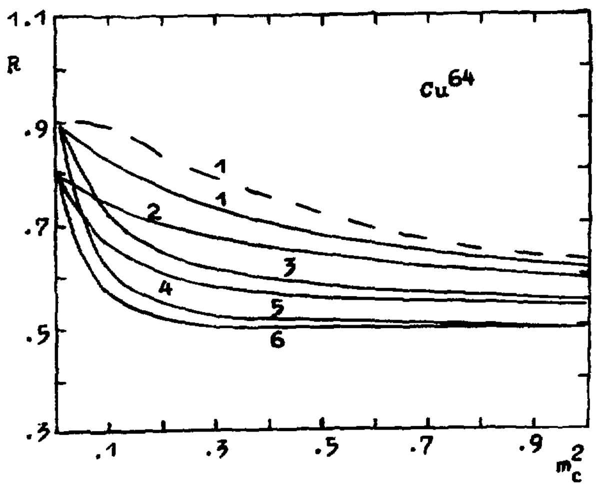


Fig.7

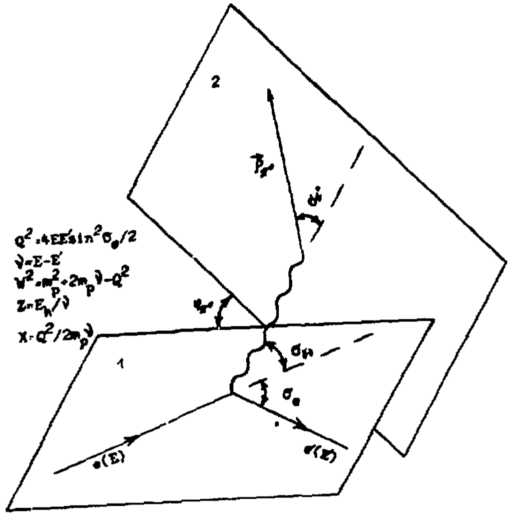

$Q^2 = 4EE'\sin^2\theta_e/2$
$\nu = E - E'$
$W^2 = m_p^2 + 2m_p\nu - Q^2$
$Z = E_h/\nu$
$X = Q^2/2m_p\nu$
1
2
e(E)
e'(E')
θ_e

Fig.8

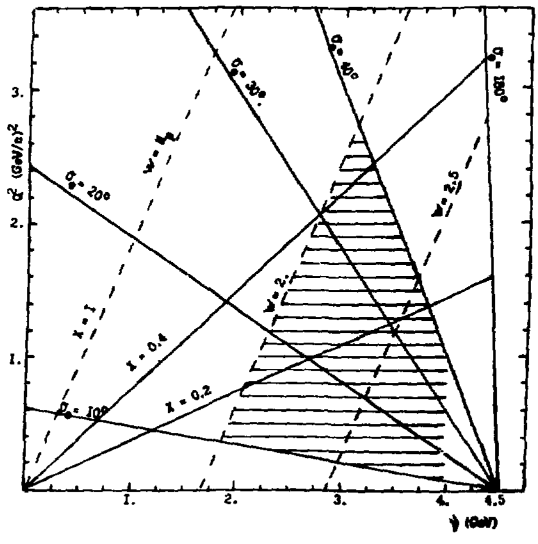

Q^2 (GeV/c)^2
ν (GeV)
1.
2.
3.
4.
4.5
X = 1
X = 0.4
X = 0.2
W = 2.
W = 2.5
$\theta_e = 10°$
$\theta_e = 20°$
$\theta_e = 30°$
$\theta_e = 180°$

Fig.9

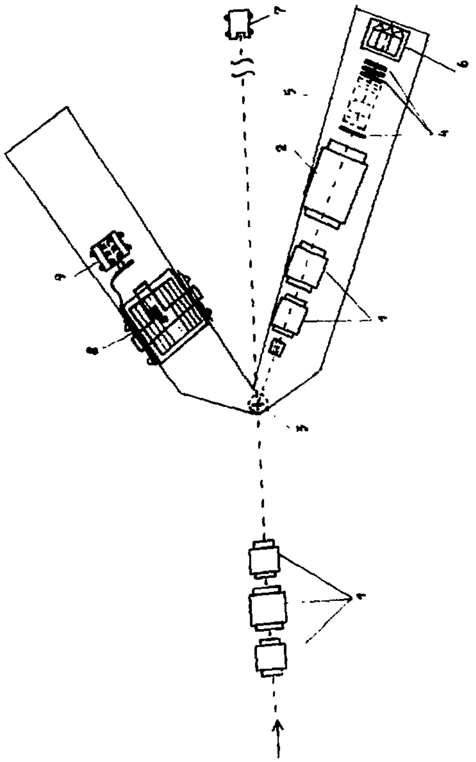
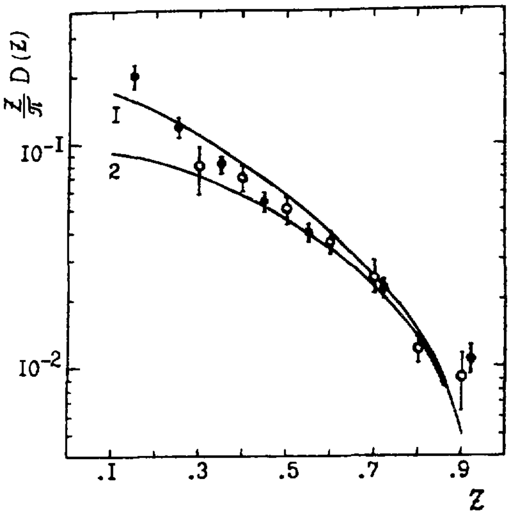
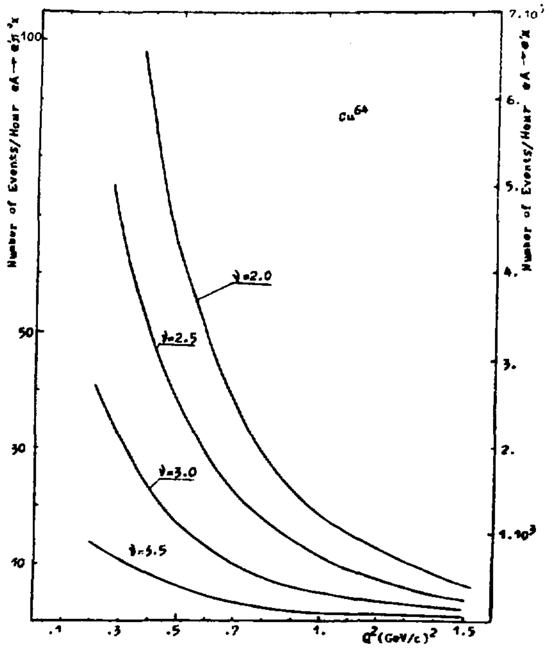


Fig10



Z/π D(Z)
I
2
IO^-I
IO^-2
.I
.3
.5
.7
.9
Z

Fig. 11



Cu^64
ν=2.0
ν=2.5
ν=3.0
100
50
30
10
6.
5.
4.
3.
2.
1.10^3
.1
.3
.5
.7
1.
1.5
Q^2(GeV/c)^2

Fig. 12

Figure Captions

Fig.1. Dependence of nuclear transparency R on atomic number A at $\sigma_q=0$(a): curves 1-$\tau=0$, 2-$\tau=1F$, 3-$\tau=3F$, 4-$\tau=5F$, 5-$\tau\to\infty$ and $\sigma_q=5mb$ (b); curves 1-$\tau=0$, 2-$\tau=1F$, 3-$\tau=5F$, 4-$\tau\to\infty$. Solid curves-$\sigma(t)\sim t$, dashed ones-$\sigma(t)\sim t^2$.

Fig.2. Dependence of R on $\tau(F)$ for ^{64}Cu nucleus. Curves 1-$\sigma_q=20mb$, 2-$\sigma_q=10mb$, 3-$\sigma_q=5mb$, 4-$\sigma_q=0$. Solid curves-$\sigma(t)\sim t$, dashed - $\sigma(t)\sim t^2$.

Fig.3. Dependence of R on σ_q(mb) for ^{64}Cu nucleus. Curves 1-$\tau=0$, 2-$\tau=1F$, 3-$\tau=3F$, 4-$\tau=10F$, 5-$\tau\to\infty$. Solid curves -$\sigma(t)\sim t$, dashed one-$\sigma(t)\sim t^2$.

Fig.4. Dependence of R on Q^2 (GeV^2/c^2) for ^{64}Cu nucleus. Curves 1-$\tau=0$, 2-$\tau=1F$, 3-$\tau=3F$, 4-$\tau=10F$, 5-$\tau\to\infty$. Solid curves-$\sigma(t)\sim t$, dashed ones-$\sigma(t)\sim t^2$.

Fig.5. Dependence of R on the energy of photon ν (GeV) for ^{64}Cu nucleus. Curves 1-$Q^2=1GeV^2/c^2$, z=0.7; 2-$Q^2=1GeV^2/c^2$, z=0.5; 3-$Q^2=1GeV^2/c^2$; z=0.3; 4-$Q^2=0.4GeV^2/c^2$, z=0.7; 5-$Q^2=0.4GeV^2/c^2$, z=0.3. Solid Curves-$\sigma(t)\sim t$, dashed ones-$\sigma(t)\sim t^2$.

Fig.6. Dependence of R on the value of z for ^{64}Cu nucleus, Curves 1-ν=3GeV, $Q^2=0.2GeV^2/c^2$; 2-ν=3GeV, $Q=0.4GeV^2/c^2$; 3-ν=3GeV, $Q^2=1GeV^2/c^2$; 4-ν=10GeV, $Q=1GeV^2/c^2$; 5-ν=100GeV, $Q^2=1GeV^2/c^2$. Solid curves -$\sigma(t)\sim t$, dashed ones-$\sigma(t)\sim t^2$.

Fig.7. Dependence of R on parameter m_c^2 (GeV^2) for ^{64}Cu nucleus. Curves 1-ν=10GeV, $\sigma_q=2mb$; 2-ν=10GeV, $\sigma_q=5mb$; 3-ν=3GeV, $\sigma_q=2mb$; 4-ν=3GeV, $\sigma_q=5mb$; 5-ν=1GeV, $\sigma_q=2mb$; 6-ν=1GeV, $\sigma_q=5mb$. Solid curves - $\sigma(t)\sim t$, dashed curves - $\sigma(t)\sim t^2$.

Fig.8. Kinematical diagram of π^o-meson electroproduction process.

Fig.9. Two-dimensional diagram in (Q^2,ν) plane for initial electron of $eA \to e'\pi^o X$ experiment.

Fig.10. Layout of experimental setup: 1-quadrupole lenses; 2-vertical deflection magnet SP-137; 3-target; 4-aperture scintillation counters; 5-momentum hodoscope; 6-12-channel total absorption Cerenkov spectrometer; 7-quantameter; 8-multichannel total absorption Cerenkov spectrometer; 9-gaseous nitrogen laser.

Fig.11. The function of nonstrange quark fragmentation to π^o-meson - curve 1, curve 2 - the function of direct fragmentation on nonstrange quark to π^o-meson. Experimental points are taken from Ref.[27].

Fig.12. Calculated dependence of the yield N_{ev} on Q^2 on ^{64}Cu nucleus at different energies of virtual photon. for d=1mm target, $I_e=2\cdot 10^{10} e^-$/sec, E=4.5GeV, $z \geq 0.5$, $\Delta P=\pm 10\%$, $\Delta\Omega$=1msr, area of Cerenkov spectrometer $S_{\check{c}}=1m^2$, distance from the target $L_{\check{c}}$=200cm.

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The manuscript was received December 7, 1990

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ЭЛЕКТРОРОЖДЕНИЕ π^{0}-МЕЗОНОВ НА ЯДРАХ В ГЛУБОКО НЕУПРУГОЙ ОБЛАСТИ

(на английском языке, перевод Г.А.Папяна)

Редактор Л.П.Мукаян

Технический редактор А.С.Абрамян

Подписано в печать 25/XII-90г.	Формат 60x84/I6
Офсетная печать.Уч.изд.л. I,5	Тираж 299 экз.Ц.22 к.
Зак.тип.№ 359	Индекс 2649

Отпечатано в Ереванском физическом институте
Ереван 36, ул.Братьев Алиханян 2

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ИНДЕКС 3649

ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ