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ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ
YEREVAN PHYSICS INSTITUTE

R.G.BADALYAN

ON THE POSSIBILITY OF INVESTIGATION OF TRANSVERSE AND LONGITUDINAL PHOTONS INTERACTION WITH PROTONS

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Ռ.Գ.ԲԱԴԱԼՅԱՆ

ՊՐՈՏՈՆՆԵՐԻ ՀԵՏ ԼԱՅՆԱԿԻ ԵՎ ԵՐԿԱՅՆԱԿԻ ՖՈՏՈՆՆԵՐԻ ՓՈԽԱԶԴԵՑՈՒԹՅՈՒՆՆԵՐԻ ՄԵԽԱՆԻԶՄՆԵՐԻ ՀԵՏԱԶՈՏՄԱՆ ՀՆԱՐԱՎՈՐՈՒԹՅՈՒՆՆԵՐԻ ՄԱՍԻՆ

Ցույց է տրված պրոտոնների հետ լայնակի և երկայնակի բևեռացված ֆոտոնների փոխազդեցությունների մեխանիզմների փորձարարական հետազոտության հնարավորությունը՝ ատոմային միջուկների վրա էլեկտրոնների քվազիառաձգական ցրման դեպքում։ Ընդ որում Q^2 արժեքները բարենպաստ են այն դեպքում, երբ գտնվում են 2 ԳէՎ^2 $\leq Q^2 \leq$ (6-10) ԳէՎ^2 տիրույթում։

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Երևան 1991

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R.G.BADALYAN

ON THE POSSIBILITY OF INVESTIGATION OF TRANSVERSE AND LONGITUDINAL PHOTONS INTERACTION WITH PROTONS

The possibility of investigation of transversely and longitudinally polarized photons interaction with protons in quasielastic electron scattering on atom nuclei is shown. For this investigation the favourable range of Q^2 is $2GeV^2 \leq Q^2 \leq (6-10)GeV^2$.

Yerevan Physics Institute

Yerevan 1991

Препринт ЕФИ-1339(34)-91

Р.Г.БАДАЛЯН

О ВОЗМОЖНОСТИ ИССЛЕДОВАНИЯ МЕХАНИЗМОВ ВЗАИМОДЕЙСТВИЯ ПОПЕРЕЧНЫХ И ПРОДОЛЬНЫХ ФОТОНОВ С ПРОТОНОМ

Показана возможность экспериментального исследования механизмов взаимодействия поперечно и продольно поляризованных фотонов с протоном в процессах квазиупругого рассеяния электронов на атомных ядрах. При этом благоприятными являются значения Q^2 в области $2ГэВ^2 \le Q^2 \le (6-10)ГэВ^2$.

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One of the interesting recent ideas is the hypothesis on (ν, Q^2) photon interaction with proton in elastic electron scattering on protons [1-3]. According to this hypothesis, the virtual photon interacts with that component of the proton wave function that is characterized by a spatial size of the order of $r(Q^2)<r_N$. $r(Q^2)=r_N$, if $Q^2 \le M_C^2$, where M_C is some characteristic hadronic mass which, apparently, determines the radius of color quark and gluon confinement $R_C \simeq 1/M_C$, r_N is radius of normal (conventional) proton.

The process of interaction of the virtual photon with proton in the latter's rest system is characterized by the time interval $\tau_P \simeq \nu/Q^2$, after which the proton wave function component with a transverse size of about $r(Q^2) \simeq \sqrt{M_C^2/Q^2}\, r_N$ or the color (quark-diquark) dipole receiving the whole ν energy of the virtual photon and during $\tau_F \simeq \nu/M_C^2 \simeq (Q^2/M_C^2)\tau_P$ time interval turns into a normal proton with usual sizes r_N [3,4].

Let us consider elastic electron scattering on nuclear protons. If provided, that the nucleus plays a passive role in the photon-proton interaction [5], or that the proton in nucleus interacts with the photon as the free proton does, then investigation of quasielastic electron scattering on nuclei will allow us to determine the change in the cross section of interaction of the proton having interacted with the photon (further in the text, tagged photon) with other nucleons in nucleus in the process of its motion through nuclear matter. By measuring nuclear matter transparency to the proton yield in quasielastic electron scattering on nuclei, we can get information about the change in the cross section of interaction of tagged proton with the other nucleons in nucleus, and, hence, about the change of its transverse size. So, if there is no change in the interaction cross section, then the value of nuclear matter transparency is expected to be close to the Glauber predictions [6], and if the tagged proton average sizes and hence the cross section of its interaction with intranuclear nucleons become smaller, then transparency of nucleus must be higher than the value determined by the Glauber model, and this difference is the larger, the higher the value of Q^2.

The value of nuclear matter transparency $R=\sigma(eA\to e'p(A-1))/Z\sigma(ep\to e'p)$, defined as the ratio of the cross section of quasielastic electron scattering on nucleus, normalized to the proton number in the nucleus, to the cross section of elastic electron scattering on proton, is a characteristic of tagged proton propagation through nucleus. It is assumed, that the tagged photon motion through nucleus may be described in the frameworks of the Glauber approach [6]. Minimal transparency occurs in the case when the tagged proton passing through nucleus may interact with nucleons in nucleus with σ_N cross section, which coincides with that of proton-nucleon interaction. If σ cross section of tagged proton interaction with the remaining nucleons in nucleus is smaller than σ_N cross section of proton-nucleon interaction, $\sigma<\sigma_N$, then nuclear matter transparency is higher than the minimal value determined by the Glauber model. The maximum value equal to unity is achieved at small values of $\sigma\simeq 0$, which may occur when $Q^2\gg M_c^2$.

Nuclear matter transparency is defined by [3-7]:

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

where $\rho(b,x)=\rho(r)$ is nuclear matter distribution density normalized to the condition of $\int\rho(r)d^3\vec{r}=A$, $b=|\vec{b}|$ and $r=\sqrt{b^2+x^2}$. In numerical estimations we used the Wood-Saxon distribution

$$\rho(r) = \frac{\rho_0}{1+\exp\left(\frac{r-r_A}{a}\right)} , \qquad (2)$$

where a=0.54 and $r_A=(0.978+0.0206\,A^{1/3})A^{1/3}$ [7]. In eq.(1) $\sigma(t)$ is the cross section of tagged proton interaction with intranuclear nucleons as a function of the time/space variable t. This value increases from σ_0 in the point of t=x (this is actually not a point, but a space-time region with $\tau_p\simeq\nu/Q^2$ dimensions), where an electron-proton interaction or a virtual photon absorption has taken place, to σ_N at $t\gg x+\tau_F$, where τ_F is the time characteristic of the color dipole (compressed proton) transition to a normal proton. In the frameworks of the color dipole hypothesis $\sigma(t)$ is expected as [5]:

$$\sigma(t) = \sigma_N-(\sigma_N-\sigma_0)\exp(-t^2/\tau_F^2) \qquad (3)$$

or, at $t/\tau_F\ll 1$ [4],

$$\sigma(t) \simeq \sigma_0+\frac{\sigma_N-\sigma_0}{\tau_F^2}t^2 , \qquad (4)$$

where $\sigma_0=(M_c^2/Q^2)\sigma_N$, $\tau_F=\nu/M_c^2$. σ_N is taken σ_N=40mb, this corresponding to the characteristic cross section of proton-nucleus interaction in the energy range of ~(1-10)GeV.

Figs.1 and 2 show the dependence of nuclear matter transparency R obtained by Monte Carlo simulation on the basis of the expressions (1)-(3), respectively, on the dimensionless variable Q^2/M_c^2 and Q^2 at different values of M_c^2. The value of R differs noticeably from that expected in the Glauber model, starting from $Q^2/M_c^2 \geq (10-20)$. Most likely, the value of M_c^2 is to be expected in the interval of $(0.05-0.1)GeV^2 \leq M_c^2 \leq 0.5GeV^2$ (see, in this connection, Ref.[5]). Consequently, the region over the variable Q^2 favourable for investigation of the mechanism of photon-proton interactions in the kinematics of quasielastic electron scattering on nuclei is $2GeV^2 \leq Q^2 \leq (6-10)GeV^2$.

The lower limit of Q^2 is taken such that the tagged proton kinetic energy is noticeably higher than the energy characteristic of the Fermi motion of nucleons in nucleus, i.e. $\nu \geq 1GeV$ (recall, that in the kinematics of quasielastic scattering $\nu = Q^2/2m_p$). At lower values of ν the effects like Fermi motion of nucleons in nucleus, multiple scattering of tagged proton on intranuclear nucleons at passage through the nucleus, etc., may become considerable. All these effects may complicate the picture of quasielastic electron scattering on nuclei in the region of $Q^2 \leq 2GeV^2$.

Till now, when considering the mechanism of photon-proton interaction, it was assumed that both transversely and longitudinally polarized photons interact with proton in the same manner. But this is not an evident assumption. If assumed that the mechanisms of interaction of transversely and longitudinally polarized photons with protons differ, and that only transverse photons interact with colour dipole or compressed proton, then for nuclear matter transparency R_T we obtain:

$$R_T(E,Q^2,M_c^2) = R_G + [R(Q^2/M_c^2) - R_G] \frac{\tau\mu_p^2}{\tau\mu_p^2 + \varepsilon} \qquad (5)$$

And if assumed, that with the compressed proton interacts only he longitudinally polarized photon, then

$$R_L(E,Q^2,M_c^2) = R_G + [R(Q^2/M_c^2) - R_G] \frac{\varepsilon}{\tau\mu_p^2 + \varepsilon} \qquad (6)$$

and

$$R_T(E,Q^2,M_c^2) + R_L(E,Q^2,M_c^2) = R(Q^2/M_c^2) + R_G \qquad (7)$$

In he expressions (5) and (6) $R(Q^2/M_c^2)$ is nuclear color transparency as a function of Q^2/M_c^2 (see Fig.1), $R_G = R(1)$ are the values of nuclear matter transparency determined by the Glauber model, $\tau = Q^2/4m_p^2$, m_p and $\mu_p = 2.79$ correspondingly are the mass and magnetic momentum of proton, ε is the degree of the virtual photon longitudinal polarization

$$\varepsilon = \frac{2(E^2 - EQ^2/2m_p - Q^2/4)}{Q^4/4m_p^2 + 2(E^2 - EQ^2/2m_p + Q^2/4)} \qquad (8)$$

where E is energy of primary electrons. At the given Q^2 $\varepsilon = 0$ (electron scattering angle $\theta_e = 180^0$) at $E = E_{min} = m_p(\tau + \sqrt{\tau + \tau^2})$ and tends to unity, $\varepsilon \to 1$ (electron scattering at small angles, $\theta_e \simeq 0$) at high primary electron energies.

Thus, at fixed Q^2 the nuclear matter transparency depends also on ε or, otherwise, on the initial electron energy E, and separately, on Q^2 and M_c^2. Fig.3 presents $R_T(E,Q^2,M_c^2)$ transparency of the ^{64}Cu nucleus as a function of E for $Q^2/M_c^2 = 20$ and 40. The dependence of $\Delta R = R_T(E,Q^2,M_c^2) - R(Q^2/M_c^2)$ on the initial electron energy E for $Q^2 = 2, 4$ and $6GeV^2$ is shown in Fig.4.

The results presented show, that when measuring the nuclear matter transparency with an accuracy of several per cents, it becomes possible to study separately the mechanisms of interaction of transversely and longitudinally polarized photons with proton. Undoubtedly, such investigations are valuable from the viewpoint of physical nature of longitudinal photons and can be carried out both at CEBAF (see Figs.2 and 3) and SLAC in the frames of PEGASYS collaboration [8].

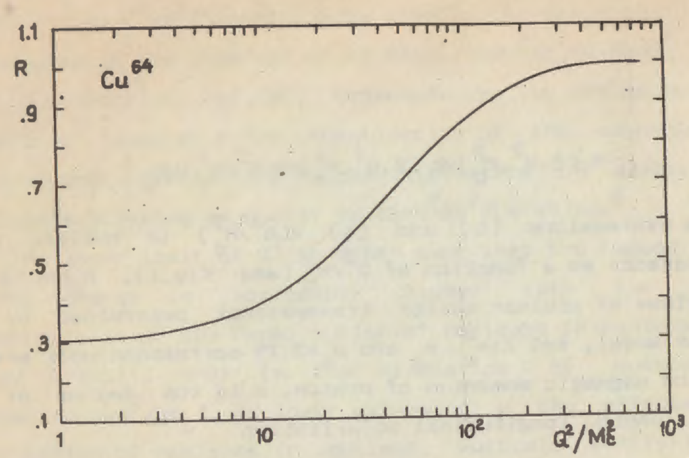

Fig.1

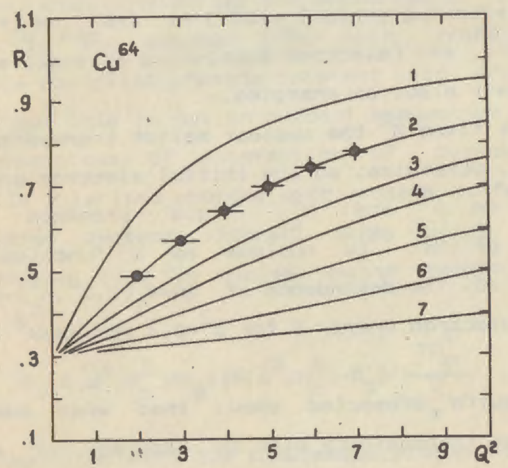

Fig.2

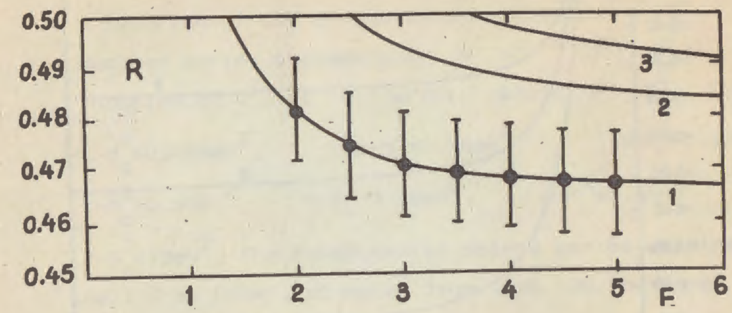

Fig.3a

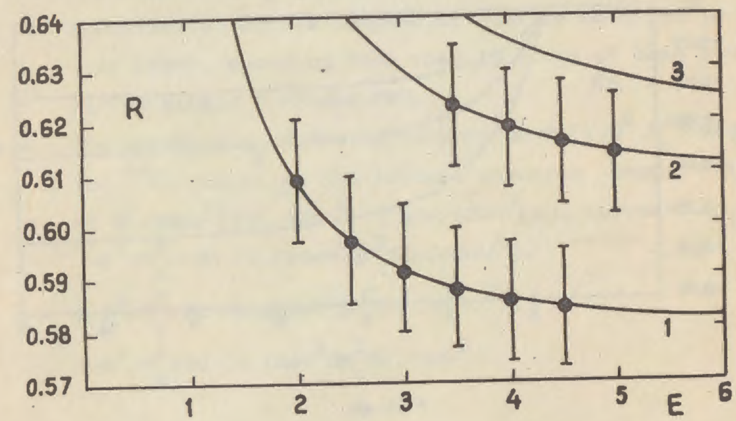

Fig.3b

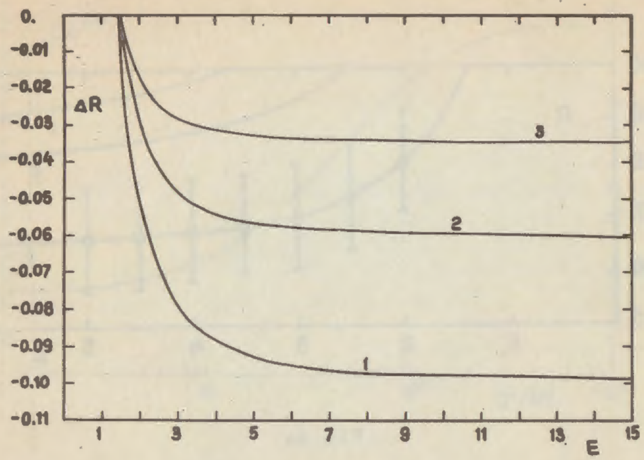

Fig.4a

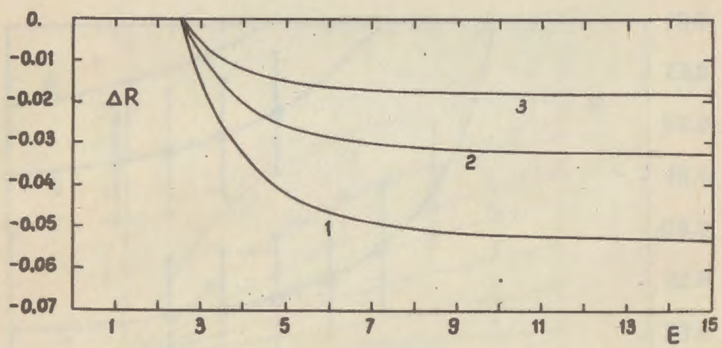

Fig.4b

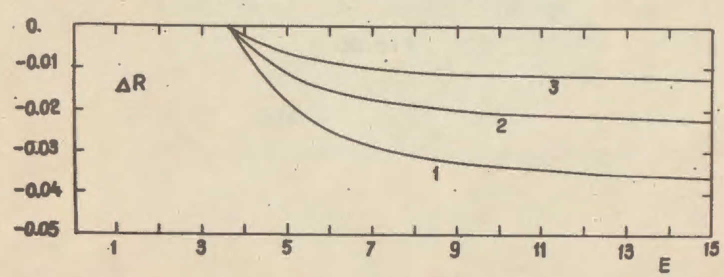

Fig.4c

Figure Captions

Fig.1 Nuclear matter transparency $R(Q^2/M_c^2)$ of ^{64}Cu nuclei as a function of the dimensionless parameter Q^2/M_c^2.

Fig.2 Nuclear matter transparency R of ^{64}Cu nuclei as a function of Q^2 at different values of M_c^2. Curves: 1-M_c^2=0.05GeV^2, 2-M_c^2=0.1GeV^2, 3-M_c^2=0.15GeV^2, 4-M_c^2=0.2GeV^2, 5-M_c^2=0.3GeV^2, 6-M_c^2=0.5GeV^2 and 7-M_c^2=1GeV^2. The experimental points may be obtained in Hall C at CEBAF, spending less than 130 hours of beam time (σR/R=0.02).

Fig.3 The dependence of $R_T(E,Q^2,M_c^2)$ of ^{64}Cu nuclei on the initial electron energy E(GeV) at Q^2/M_c^2=20(a) and 40(b). Curves: 1-Q^2=2GeV^2 (M_c^2=0.1GeV^2(a) and 0.05GeV^2(b)), 2-Q^2=4GeV^2 (M_c^2=0.2GeV^2(a) and 0.1GeV^2(b)), 3-Q^2=6GeV^2 (M_c^2=0.3GeV^2(a) and 0.15GeV^2(b)). The experimental points (σR/R=0.02) may be obtained in Hall C at CEBAF, spending less than 15 hours of beam time (ε varies within $0.47 \le \varepsilon \le 0.92$).

Fig.4 The dependence of the difference $\Delta R = R_T(E,Q^2,M_c^2) - R(Q^2/M_c^2)$ for ^{64}Cu nuclei on the initial electron energy E(GeV) at Q^2=2GeV^2(a), 4GeV^2(b) and 6GeV^2(c). Curves:
1-Q^2/M_c^2=100 (0.02GeV$^2 \le M_c^2 \le$0.06GeV^2),
2-Q^2/M_c^2=40 (0.05GeV$^2 \le M_c^2 \le$0.15GeV^2),
3-Q^2/M_c^2=20 (0.1GeV$^2 \le M_c^2 \le$0.3GeV^2).

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Р.Г.БАДАЛЯН
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(на английском языке, перевод Г.А. Папяна)
Редактор Л.П.Мукаян
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