# Interaction of longitudinally polarized vector mesons with nucleons and deep inelastic electroproduction process in nuclei

S. R. Gevorkyn

(Submitted 26 May 1980; resubmitted 1 July 1980)
Pis'ma Zh. Eksp. Teor. Fiz. **32**, No. 3, 258–261 (5 August 1980)

It is shown that a study of the ratio of the cross section for photoabsorption of transversely polarized photons by a nucleus, $R_A = \sigma_L(\gamma A)/\sigma_T(\gamma A)$, makes it possible to obtain new information about the total cross sections for interaction of longitudinally polarized vector mesons with nucleons.

PACS numbers: 13.75. – n, 25.30.Cg,

The deep inelastic electroproduction process in nuclei has recently been studied extensively both experimentally and theoretically.[1] An interest in this process has arisen because of the prediction of a screening effect in the total photoabsorption cross sections of virtual and real photons at small $x = Q^2/2M\nu$ ($Q^2 = -q^2$, where $q$ is the four-momentum of a virtual photon, $\nu = q_0$ is the energy of a virtual photon, and $M$ is the nucleon mass). A number of experiments performed in recent years makes it possible to state that, although there is no screening at large $Q^2$ (the ratio of the cross section for photoabsorption $\sigma(\gamma A)$ in the nucleus to the cross section for photoabsorption $\sigma(\gamma N)$ in the nucleon is equal to the atomic number $A$ of the nucleus, the value $A^{\text{eff}} = \sigma(\gamma A)/Z\sigma(\gamma p) + (A - Z)\sigma(\gamma n)$ for a small $x \approx 0.1$ differs markedly from unity ($A^{\text{eff}} < 1$); which indicates a presence of screening due to production of vector mesons in the nucleons of a nucleus, which are subsequently absorbed. The existing experimental data for total photoabsorption cross sections of real and virtual photons are in good agreement with the predictions of the vector-dominance model with allowance for the contact terms.[2] In the case of deep inelastic scattering of electrons by intermediate and heavy nuclei $A \gtrsim 20$, we can easily obtain the following equation by using a calculation technique developed in the theory of multiple rescatterings[1]:

$$R_A = \frac{A\,\sigma^L(\gamma N) + \mathrm{Re}\sum_V f_{\gamma V}^{L^2}(0)\,F(\Delta_V, \sigma_V^L)}{A\,\sigma^T(\gamma N) + \mathrm{Re}\sum_V f_{\gamma V}^{T^2}(0)\,F(\Delta_V, \sigma_V^T)}. \tag{1}$$

The symbols $\sigma^{T(L)}$ in this equation represent the total cross sections for interaction of transversely (longitudinally) polarized, virtual $\gamma$-ray quanta with nucleons and $f_{\gamma V}^{T(L)}(0)$ is the amplitude of the $\gamma N \to VN$ process, where $V = (\rho, \omega, \phi)$, at zero angle.

$$F(\Delta_V \sigma_V^{T(L)}) = \frac{8\pi^2}{\nu^2} \int \rho(\mathbf{b}, z_1)\,\rho(\mathbf{b}, z_2)\,dz_1\,dz_2 d^2b\,\exp\Big\{ i\Delta_V(z_1 - z_2) - \frac{\sigma_V^{T(L)}}{2} \int_{z_1}^{z_2} \rho(\mathbf{b}, Z_1)\,dz \Big\} \tag{2}$$

where $\rho(\mathbf{b},z)$ is single particle nuclear density and $\Delta_V = (m_V^2 + Q^2)/2\nu$ is the minimum longitudinal momentum transfer in the $\gamma N \to VN$ reaction.

$$\sigma_V^{T(L)} = \frac{4\pi}{i\nu} f_{VV}^{T(L)}(0) = \sigma^{T(L)}(VN)1 - i\alpha_V^{T(L)})\alpha_V^{T(L)} = \frac{\mathrm{Re} f_{VV}^{T(L)}(0)}{\mathrm{Im} f_{VV}^{T(L)}(0)}.$$

In deriving Eq. (1) we took into account the fact that the amplitude of the $\gamma N \to VN$ process is a slowly varying function of the momentum transfer, as compared with the nuclear density. In addition, we assumed that the $s$-channel helicity is conserved in the vector-meson electroproduction process, i.e., transverse (longitudinal) photons produce transverse (longitudinal) vector mesons.

Let us analyze the limiting (with respect to the energy $\nu$ of a virtual photon) cases of Eq. (1). For small energies ($\nu \lesssim 3$ GeV) the oscillations in the integration with respect to the longitudinal coordinates in Eq. (2) show that the contribution from the intermediate channels can be disregarded; therefore,

$$R_A = \frac{\sigma^L(\gamma N)}{\sigma^T(\gamma N)} \equiv r.$$

Thus, for small $\nu$ the ratio $\sigma_L/\sigma_T$ in the nucleus is the same as that in the nucleon.

Of greater interest if the region of deep-inelastic electroproduction, in which the relation $\Delta_V l_V \ll 1$($l_V = 1/\sigma_V \rho_0$ is free path length of a vector meson in the nucleus) is satisfied. In this case an integration in Eq. (2) with respect to the longitudinal coordinates gives the following expression:

$$R_A = \frac{A\,\sigma^L(\gamma N) + \dfrac{16\pi^2}{\nu^2}\mathrm{Re}\sum_V \dfrac{f_{\gamma V}^{L^2}(0)}{\sigma_L'}(A - N(0, \sigma_L'/2))}{A\,\sigma^T(\gamma N) + \dfrac{16\pi^2}{\nu^2}\mathrm{Re}\sum_V \dfrac{f_{\gamma V}^{T^2}(0)}{\sigma_T'}(A - N(0, \sigma_T'/2))}, \tag{3}$$

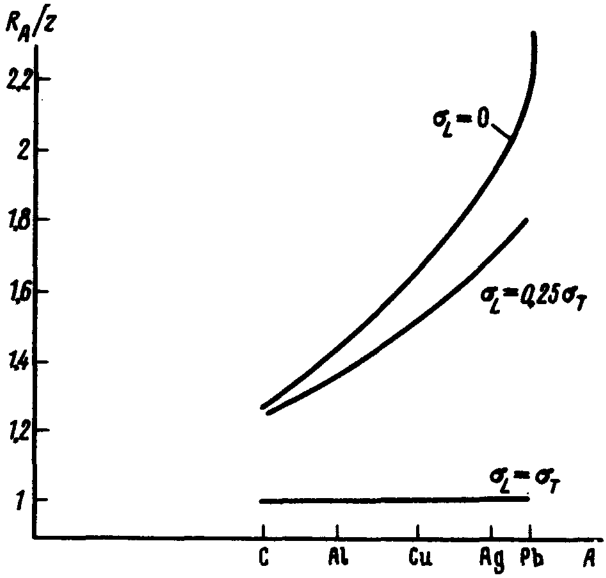


FIG. 1.

where $N(0,\sigma) = \int [1 - \exp(-\sigma \int_{-\infty}^{\infty} \rho(\mathbf{b},z)dz/\sigma]d^2b$ are effective nucleon numbers. Disregarding in Eq. (3) the ratio of the real part of the amplitude of elementary processes to the imaginary part and using the vector-dominance relations $f^{T(L)}_{\gamma V} = g_V f^{T(L)}_{VV}$, we obtain

$$R_A = r\,\frac{N(0,\sigma_L/2)}{N(0,\sigma_T/2)}\,. \tag{4}$$

The quantity $\sigma_T$ represents the total cross section for interaction of transversely polarized $\rho$ and $\omega$ mesons with nucleons (the contribution from the $\phi$ meson is ignored because of its smallness), which can be determined from the processes of coherent photoproduction of vector mesons in the nuclei, because of conservation of the $s$-channel helicity. Thus, Eq. (4) has one free parameter $\sigma_L$. Figure 1 shows the dependence of $R_A/r$ on the atomic number for different values of $\sigma_L$. In the calculations of the effective nucleon numbers, we chose the nuclear density in the form

$$\rho(\mathbf{b},z) = \rho_0 \,/\, 1 + \exp\left(\frac{\sqrt{\mathbf{b}^2 + z^2} - R}{a}\right), \quad R = 1.14\,A^{1/3}\,f, \quad a = 0.545\,f \qquad \sigma_T = 28 \text{ mb}.$$

We can see that by measuring $R_A$ in different nuclei in the region $\Delta l \ll 1$ [by limiting ourselves to $Q^2 \lesssim 1$ (GeV/$c$)$^2$, we obtain for $\nu$ an estimate $\nu \gtrsim 20$ GeV] we can determine the total cross section for interaction of longitudinally polarized vector mesons with nucleons.

The author thanks S. G. Matinyan and G. G. Mkrtchyan for useful comments and for their interest in this investigation.

[1]T. H. Bauer, R. D. Spital, D. R. Yennie, and F. M. Pipkin, Rev. Mod. Phys. **50**, 261 (1980).
[2]L. E. Ibanez and J. L. Sanchez-Gonez, Nucl. Phys. **B156**, 427 (1979).