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INFLUENCE OF COLOR SCREENING EFFECT ON INTERACTION OF HIGH ENERGY PHOTONS WITH NUCLEONS AND NUCLEI

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ԳՈՒՆԱՅԻՆ ԷԿՐԱՆԱՎՈՐՄԱՆ ԷՖԵԿՏԻ ԱԶԴԵՑՈՒԹՅՈՒՆԸ ՆՈՒԿԼՈՆԻ ԵՎ ՄԻՋՈՒԿՆԵՐԻ ՀԵՏ ԲԱՐՁՐ ԷՆԵՐԳԻԱՅԻ ՖՈՏՈՆՆԵՐԻ ՓՈԽԱԶԴԵՑՈՒԹՅԱՆ ՊՐՈՑԵՍՆԵՐԻ ՎՐԱ

Նուկլոնների և միջուկների հետ բարձր էներգիայի ֆոտոնների փոխազդեցության լրիվ կտրվածքներում հաշվի է առնված ֆոտոնի հադրոնային բաղադրիչի գունային էկրանավորումը:

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С.Р.ГЕВОРКЯН, Г.Р.ГУЛКАНЯН

ВЛИЯНИЕ ЭФФЕКТА ЦВЕТОВОЙ ЭКРАНИРОВКИ НА ПРОЦЕССЫ ВЗАИМОДЕЙСТВИЯ ФОТОНОВ ВЫСОКОЙ ЭНЕРГИИ С НУКЛОНАМИ И ЯДРАМИ

В полных сечениях взаимодействия фотонов высокой энергии с нуклонами и ядрами учтен эффект цветового экранирования в адронной компоненте фотона.

Ереванский физический институт

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S.R.GEVORKYAN. H.R.GULKANYAN

INFLUENCE OF COLOR SCREENING EFFECT ON INTERACTION OF HIGH ENERGY PHOTONS WITH NUCLEONS AND NUCLEI

The color screening effect in hadronic component of photon is taken into account in total cross sections of interaction of high energy photons with nucleons and nuclei.

Yerevan Physics Institute

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The interest to the processes of interaction of high energy photons with nucleons and nuclei is due mainly to the fact that they allow to study the hadronic structure of photon [1,2] .

The assumption that the high-energy photon interacts with matter turninc before that into vector mesons ρ, ω, φ was put forward more than twenty years ago (the vector dominance model). In this model the total cross section of interaction of real γ -quanta with nucleon $\sigma(\gamma N)$ is given in the following form:

$$\sigma(\gamma N) = \alpha \sum_{V} \frac{4\pi}{g_V^2} \sigma(VN) \tag{1}$$

In this expression $\sigma(VN)$ are total cross sections of interaction of vector mesons (ρ, ω, φ) with nucleons, $\frac{4\pi}{g_V^2}$ is coupling constant of photon with vector meson, α is electromagnetic interaction constant. The quantities $\frac{4\pi}{g_V^2}$ can be determined from the process of e^+e^- annihilation to hadrons (the values of these constants for ρ, ω, φ -mesons are equal respectively to [3] :

$$\frac{4\pi}{g_\rho^2} = 0.52, \qquad \frac{4\pi}{g_\omega^2} = 0.048, \qquad \frac{4\pi}{g_\varphi^2} = 0.072).$$

The total cross sections $\sigma(VN)$ can be expressed, using the quark model, via cross sections of πN and KN interactions

$$(\sigma(\rho N) = \sigma(\omega N) = 24\, m\text{б}; \quad \sigma(\varphi N) = 14\, m\text{б})$$

At these values the contribution of ρ, ω, φ to (1) amounts to ~ 90 % of $\sigma(\gamma N)$. It is customary to believe that this difference is due to the contribution of vector mesons with large masses. It is here assumed that the cross sections of their interaction with nucleons depend on meson mass as

$$\sigma(VN) \sim \frac{1}{M^2} \tag{2}$$

(the generalized vector dominance model). This assumption is difficult to understand within the framework of modern representations. Thus, e.g., if the impulse approximation for the quark model is valid, then there must take place equality of cross sections for mesons with identical quark composition. Moreover, if mesons with large masses are radial excitations of ρ, ω, φ mesons, then their cross sections must increase with mass rather than fall off.

At present, apart from ρ, ω, φ mesons, also the existence of two more vector mesons [3] ρ' (1600) and φ' (1680) is reliably established, for which $\frac{4\pi}{g^2_{\rho'}} = 0.28$, $\frac{4\pi}{g^2_{\varphi'}} = 0.017$. Assuming $\sigma(\rho' N) = \sigma(\rho N)$, $\sigma(\varphi' N) = \sigma(\varphi N)$, we shall obtain that the r.h.s. of (1) makes up about 160 μb, this considerably exceeding the value $\sigma(\gamma N) = 115$ μb ($E_\gamma \geqslant 30$ GeV) [4].

Account of other mesons from the families ρ, ω, φ will result in increase of this discrepancy (the contribution of vector mesons with hidden charm is small: ~ 3 μb).

The discrepancy mentioned can be removed if taking into account the color screening effect in the quark-antiquark pair [5].

It is well known [1] that the mean life-time of real photon in hadronic (quark-antiquark) state is determined by its energy V and mass of this state M :

$$\tau_0 = \frac{2V}{M^2} \tag{3}$$

Let us assume that the distribution density of distance $z = \tau$ from the transition point of photon to $q\bar{q}$ -pair till the target has the form: $p(z) = \frac{1}{\tau_0} e^{-z/\tau_0}$. If the photon-pair transition occurred at a distance z from the target, then from simple geometrical reasons [5] it follows that the transverse distance between quark and antiquark is:

$$r = \frac{p_\perp z}{V x (1-x)} \tag{4}$$

where $p_\perp$ is quark transverse momentum, x is a fraction of photon momentum carried by quark. If this distance is less than the mean square radius of vector meson r_0 , then due to the effect of mutual screening (by color) the pair will interact with the target with a cross section $\sigma(r)$ less than the cross section of meson-nucleon scattering. We shall use a simple parametrization [6] for this quantity:

$$\sigma(r) = \frac{\sigma(VN)}{r_0^2} r^2 \qquad \text{at} \qquad r < r_0 \tag{5}$$

If the transition $\gamma \to q\bar{q}$ occurs sufficiently far from the target, then the interaction of the pair with the latter takes place with hadronic cross section $\sigma(VN)$. In this approach the total cross section of photon-nucleon interaction turns out to be:

$$\sigma(\gamma N)=\alpha\sum_{v}\frac{4\pi}{g_v^2}\,\sigma(q\bar{q}N) \tag{6}$$

$$\sigma(q\bar{q}N)=\int_0^\infty p(z)\,\sigma(z)\,dz=$$

$$=\sigma(VN)\left\{e^{-z_0/\tau_0}+\frac{2-e^{-z_0/\tau_0}\left[1+(1+z_0/\tau_0)^2\right]}{(\tau_9/\tau_0)^2}\right\}=\sigma(VN)f(\beta) \tag{7}$$

where z_a is defined from (4) at $\tau=\tau_0$ and $\beta=z_9/\tau_0=1/2\,\tau_0 P_\perp$. This quantity can be determined while comparing expression (6) with experiment. If, in addition, we restrict ourselves to reliably known vector mesons ρ, ω, φ, ρ' (1600), φ' (1680) and suppose that the values of β for various mesons are practically the same, then for β we obtain the value $\beta\approx 0.5$. Account of other vector mesons whose existence is indicated (see, e.g. [7]) will lead to some increase in the value of β. Note that this value is in reasonable agreement with independent estimate $\beta=$ $=1/2\ \tau_0 P_\perp\approx 1/2\ \ 0.65\ \ 0.35\ \mathrm{GeV}\cdot f\ \ =0.57$.

Thus the account of screening in the $q\bar{q}$-pair allows one to describe the total cross section of γN interaction without involving the assumption about decrease of $\sigma(VN)$ cross sections with increasing vector meson mass.

Within the framework of the above-considered picture, one can readily obtain an expression for total cross section of interaction of high-energy photons with nuclei:

$$\sigma(\gamma A)=\alpha\sum_{v}\frac{4\pi}{g_v^2}\,\sigma(q\bar{q}A) \tag{8}$$

$$\sigma(q\bar{q}A)=\sigma(VN)N\left(0,\frac{\sigma(VN)}{2}\right)e^{-\beta}+$$

$$+\beta\int_0^1 e^{-\beta z}dz\,N\left(0,\frac{\sigma(VN)}{2}z^2\right) \tag{9}$$

where $N(0,\sigma) = \int d^2 b \, \frac{1-\exp(-\int \rho(\vec{b},z)dz)}{\sigma}$; $\rho(\vec{r})$ is one particle nuclear density.

Expression (9) is practically independent of γ -quanta energy (except for weak energy dependence $\sigma(VN)$). Calculated by formulae (8), (9), total cross sections of photon-nucleus interactions at the value β =0.5 are compared with high-energy experimental data [8,9] as shown in the Figure.

Note that within the limits of experimental errors no decrease of $\sigma(\gamma A)$ with increasing photon energy is observed, this being in agreement with the absence of energy dependence in (8) and (9).

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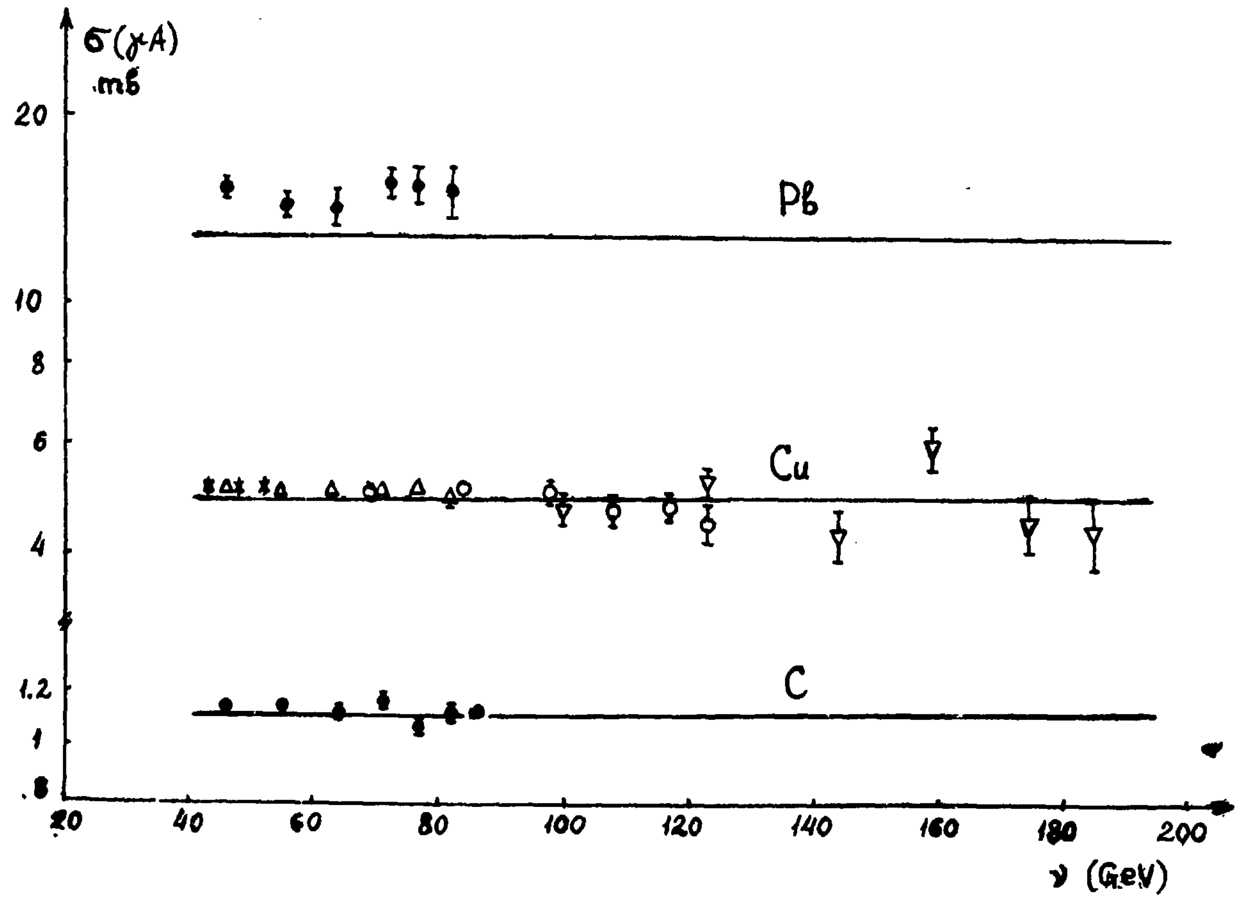

σ(γA)
mb
20
10
8
6
4
1.2
1
.8
Pb
Cu
C
20
40
60
80
100
120
140
160
180
200
ν (GeV)

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