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INCLUSIVE SPECTRA OF HADRONS IN PHOTON-NUCLEUS COLLISIONS

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ИНКЛЮЗИВНЫЕ СПЕКТРЫ АДРОНОВ В ФОТОН-ЯДЕРНЫХ СОУДАРЕНИЯХ

Показано, что, как и в случае полных сечений фотопоглощения в инклюзивных спектрах адронов, образованных в фотон-ядерных взаимодействиях, с ростом энергии фотона начинает доминировать адронная компонента фотона. Это приводит к изменению в А-зависимости инклюзивных спектров, что не противоречит существующим экспериментальным данным.

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It is shown that, as in the case of the photoabsorption total cross sections, in the inclusive spectra of hadrons produced in photon-nucleus interactions with the rise of photon energy the hadron component of the photon begins to dominate. This leads to the change in the A-dependence of inclusive spectra which does not contradict the available experimental data.

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As it is well known [1] in total cross sections of photoabsorption on nuclei $\sigma(\gamma A)$ with the rise of photon energy begins to dominate the hadron component of the photon conditioned by the possibility of photon transition into hadronic state before its interaction with the target. As a consequence the dependence of $\sigma(\gamma A)$ on the atomic number of target-nucleus changes (the hadron component is screened by the nucleus). This effect, predicted more than ten years ago [2], was discovered experimentally and investigated in quite a number of works. It turned out that one may describe quantitatively the whole totality of data on total cross sections of photoabsorption on nuclei of both real and virtual photons up to the energies of hundreds of GeV, assuming the validity of the vector dominance model with a 20% contribution from the contact terms [3].

Recently processes of multiple production of hadrons on nuclei are intensively investigated. To describe them a number of new hypotheses and models were suggested [4] for testing of which it is necessary to investigate the interactions of beams of particles of various nature with nuclei.

The processes of particle production on nuclei caused by photons have an unquestionable advantage that by a photon one may "feel" the whole nuclear volume. Then however arises the problem of the photon hadronic component, the consideration of which, as shown below, affects essentially the behaviour of inclusive spectra.

Let us consider the process of inclusive production of hadrons h on an arbitrary nucleus A by photons (real or virtual) $\gamma A \to hX$ in the incident photon fragmentation region.

The consideration of the photon hadronic properties can be carried out by analogy with the case of total cross sections [1-3] $\sigma(\gamma A)$. The photon incident on the nucleus may produce on one of the nucleons a vector meson (for simplicity we shall assume that it is a ρ-meson neglecting the contribution from other mesons) which after a number of collisions with nucleons produces a hadron h.

Using the standard methods of the multiple scattering theory [1] one may obtain for the spectrum of considered reaction in the region of low photon energy $\nu \lesssim$ 3 - 4 GeV the following expression:

$$x\frac{d\sigma}{dx d^2P_\perp} = \frac{1}{(2\pi)^3}\int d^2b\, d\alpha\; e^{i\vec{P}_\perp\vec{b} + i\alpha \ln x}\, \Omega_{\gamma h}(\alpha, \vec{b}) \times \tag{1}$$
$$\times\left[\frac{\sigma_{\rho N}}{\tilde{\sigma}_{\rho N}} N(0, \tilde{\sigma}_{hN}) - \frac{\Omega_{\rho\rho}}{\tilde{\sigma}_{\rho N}} N(\tilde{\sigma}_{\rho N}, \tilde{\sigma}_{hN})\right]$$

In this expression

$$N(\sigma_1, \sigma_2) = \int d^2b\, \frac{e^{-\sigma_1 T} - e^{-\sigma_2 T}}{\sigma_2 - \sigma_1} \qquad T(\vec{b}) = \int \rho(\vec{b}, z)\, dz$$

is the projection of the one-nucleon nuclear density function on the plane of the impact parameter $\left(\int \rho(r)\, d^3r = A\right)$;

$$\tilde{\sigma}_{xN} = \sigma_{xN}^{tot} - \Omega_{xx}(\alpha, \vec{b})$$

$$\Omega_{xy}(\alpha, b) = \int \frac{d\sigma_{xy}}{dx\, d^2 P_\perp}(x, \vec{P}_\perp)\, e^{-i\vec{P}_\perp \vec{b} - i\alpha \ell_n x}\, d^2 P_\perp\, dx$$

where $\frac{d\sigma_{xy}}{d^2P_\perp dx}$ are the inclusive spectra of the elementary acts $\gamma N \to h x$, $hN \to hX$, $\rho N \to \rho X$

Finally $\vec{P}_\perp$ is the transverse momentum of the hadron flying out from the nucleus and $x = E_h/\nu$ is the part of γ-quantum energy taken away by the hadron.

Because of the bulkiness of formulae for the general case we present below the expression obtained assuming the validity of the vector dominance model in the γ-quantum high-energy region ($\frac{m_\rho^2 + Q^2}{2\nu}\ell << 1$; m_ρ^2, Q^2 are the masses of ρ-meson and γ-quantum; $\ell = 1/\sigma\rho_0$ is the mean free path of ρ-meson in nucleus):

$$x\frac{d\sigma}{dx\,d^2P_\perp} = \frac{1}{(2\pi)^3}\int d^2b\, e^{i\alpha \ell_n x + i\vec{P}_\perp \vec{b}}\, \Omega_{\gamma h}(\alpha, \vec{b}) N(\tilde{\sigma}_{\rho N}, \tilde{\sigma}_{hN}). \quad (2)$$

As noted above the break of the vector dominance model is $\sim$ 20% and so the expression (2) must describe the spectra at high energies at least with such accuracy.

In its physical sense the expression (2) corresponds to the process of inclusive production of hadrons h caused by ρ-mesons.

Thus in the photoproduction inclusive spectra as well as in the cases of total cross sections of photoabsorption and cross sections of incoherent production [5] with the rise of photon energy a transition takes place in the A-dependence which affects essentially the behaviour of inclusive spectra on x and $P_\perp$.

As an illustration of the obtained formulae let us consider briefly the results of two experiments performed in kinematic regions where the expressions (1) and (2) must be valid.

In the work [6] the inclusive spectra of photoproduction of protons and pions on different nuclei were investigated at the energies $E_\gamma = 4.28$ GeV. It was found that for fast protons and pions ($P_\parallel = 2.4$ GeV) the cross sections vary with the atomic number according to the law $\sim A^{0.75}$. If one expands the expression (1) in powers of $\frac{\Omega}{6}$ the first term of this expansion will be proportional to the quantity $N(O\ 6)$ which depends on the atomic number as $A^{0.7}$ does. (For fast particles and not large transverse momenta the dependence of the atomic number is determined by the initial terms of this expansion).

On the other hand, at the virtual photon energies being equivalent to $V = 60$ GeV (the inclusive production of hadrons by μ -mesons with $E = 150$ GeV in the emulsion [7]) in the region $x \gtrsim 0.1$ the spectra of hadrons generated by μ -mesons, π -mesons and protons coincide within the limits of experimental errors, which to our mind, is a direct consequence of the expression (2).

Thus the available experimental data conform to the proposed picture of the photon interaction with atomic nuclei. For more definite conclusions new experimental data and concrete theoretical calculations are needed.

In conclusion let us note that all the above-stated does not contradict the recently developing models [8] in which the virtual photon is supposed to knock out from the nucleon the quark-parton which subsequently interacts with the nucleus. This mechanism corresponds to sufficiently great Q^2 only, while the region of applicability of the expressions (1) and (2) is limited by the virtual photon masses [1] $Q^2 \lesssim 1\left(\frac{GeV}{c}\right)^2$

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