ASSOCIATED MULTIPLICITY OF g-PARTICLE IN PROCESSES OF LEPTON PAIR PRODUCTION ON NUCLEI

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An expression has been obtained for mean multiplicity of g-particles accompanying the process of deep-inelastic lepton pair production on nuclei. The expression allows one to get information on structure peculiarities of leading hadron in this process.

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The investigation of multiplicity distribution of the so-called g-particles (which are mostly recoil protons with velocities $0.3 \lesssim \beta \lesssim 0.7$) in inelastic collisions of high energy particles with atomic nuclei allows one to obtain information on multiple interaction processes in nuclear matter. Ref. [1] describes within the multiple scattering theory the available experimental data on mean $\langle n_g \rangle$ multiplicity of protons with $T_p = 30$–300 MeV energies produced in interactions of different types of hadrons with atomic nuclei at high (50–400 GeV) energies. In this work, in particular, it is shown that an essential contribution ($\gtrsim 80\%$) to $\langle n_g \rangle$ comes from secondary interactions in nucleus of relatively low-energy pions from the target fragmentation region, while a contribution to $\langle n_g \rangle$ made by multiple rescattering of leading hadron interacting in nucleus with "usual" hadron-nucleon cross section is considerably less ($\lesssim 20\%$).

In Ref. [2] we obtain predictions for $\langle n_g \rangle$ (below, the recoil protons with 30–300 MeV energy will be implied) for the processes of deep-inelastic lepton-nuclear scattering allowing one to determine from a comparison with experiment the averaged cross section of interaction of knocked-out quark or products of its hadronization with the nucleus nucleon and thus to derive information on space-time picture of quark-parton hadronization.

The atomic nuclei experiments also offer a principal possibility to investigate the structural peculiarities of hadrons participation in deep-inelastic hadron-nucleus collisions. Thus, Ref. [3] predicts a possibility of revealing the role of the point-like configuration [4] of hadrons in the processes of the Drell-Yan lepton pair production on nuclei. According

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to [3], a dominant role in the processes of lepton pair production at large values of the Feynman variable ($x_{l\bar{l}} > 0.5$) is played by a part of the incident hadron wave function corresponding to a point-like configuration of hadron with a mean-square radius several times less than its "usual" one. The hadron of such configuration undergoes in the nucleus collisions with the effective cross section $\sigma^{ef}(x_{l\bar{l}})$ noticeably less than the hadron-nucleon one, σ_{hN}. The mean number of leading hadron collisions, $\bar{\nu}_{l\bar{l}}$, and the g-particles multiplicity, $\langle n_g \rangle_{l\bar{l}}$, decrease correspondingly.

The predictions for $\langle n_g \rangle_{l\bar{l}}$ versus $\sigma^{ef}(x_{l\bar{l}})$ are given in [3]. However, these theoretical estimations do not take into account the contribution to $\langle n_g \rangle_{l\bar{l}}$ from the secondary interactions of low-energy pions produced in the target fragmentation region although, as mentioned above, this contribution is dominant [1]. Therefore, more exact theoretical calculations are necessary in order to make quantitative conclusions on the dynamics of deep-inelastic lepton pair production on nuclei.

In this work, we have obtained the analytical expression for $\langle n_g \rangle_{l\bar{l}}$ as well as performed calculations which allow one, from the comparison with mean multiplicity of g-particles accompanying the Drell-Yan pair production on nuclei, to estimate the effective cross sections $\sigma^{ef}(x_{l\bar{l}})$ and, thus, derive information on properties of hadrons participating in deep-inelastic interaction. Using for $\langle n_g \rangle$ the expression obtained in [1], one can readily obtain in an analogous way the predictions for the most general case of the considered process when the leading hadron undergoes inelastic collisions with arbitrary cross sections σ_1, and σ_2, before and after lepton pair production in nucleus respectively. According to the results of Ref. [1] the expression for $\langle n_g \rangle_{l\bar{l}}$ has the form:

$$\langle n_g \rangle_{l\bar{l}} = \omega_0 + \omega \frac{\sigma_1 + \sigma_2}{2A} \int T^2(b) d^2 b + m_0 \omega_1 \left[1 - \frac{N(0;\sigma_3)}{A} \right]$$

$$+ m\omega_1 \left[\frac{\sigma_2 - \sigma_1}{\sigma_3} \cdot \frac{N(0;\sigma_3)}{A} + \frac{\sigma_1 + \sigma_2}{2A} \int T^2(b) + \frac{\sigma_1}{\sigma_3} \frac{N_1(\sigma_3)}{A} - \frac{\sigma_2}{\sigma_3} \right], \qquad (1)$$

where ω_0 is mean multiplicity of g-particles in deep-inelastic hadron-nucleon interaction, ω — in hadron-nucleon interaction, ω_1 — in interactions of low-energy ($p_\pi < 3$ GeV) pions from the target fragmentation region with nucleon. Making use of the estimations given in [2], we have:

$$\omega_0 = 0.10 \pm 0.01, \quad \omega = 0.15 \pm 0.01, \quad \omega_1 = 0.40 \pm 0.02$$

(the data are averaged over the number of the target nucleus protons and neutrons). m_0 is mean number of pions (of all signs) from the target fragmentation region, accompanying the Drell-Yan pair production; m is the analogous number for the hadron-nucleon collisions before and after the deep-inelastic interaction act. At sufficiently high initial energies (of the order of 100 GeV and higher) the quantity m is practically independent of collisions multiplicity, being equal to $m \approx 3$ [1]. No experimental data are available concerning m_0; the latter may depend on $x_{l\bar{l}}$ and differ from m. We assume that on the average $m_0 \approx m \approx 3$, this not contradicting, in particular, the data on deep-inelastic neutrino-nucleon interactions (see [2] and references therein). Note that the admissible error affects the calculation results for $\langle n_g \rangle_{l\bar{l}}$ insignificantly. σ_3 is averaged over momentum spectrum of low-energy pions for cross sections of pion-nucleon interaction; according to [1], $\sigma_3 \approx 27$ mb. $T(b) = \int \varrho(b, z)dz$ is a projection of one-particle nuclear density $\varrho(\vec{r})$ on the impact parameter plane, $\int \varrho(\vec{r})d\vec{r} = A$; the Fermi-type density is used in the calculations. $N(0; \sigma)$, $N_1(\sigma)$ are the so-called effective numbers:

$$N(0; \sigma) = \int \frac{1 - e^{-\sigma T(b)}}{\sigma} d^2b,$$

$$N_1(\sigma) = \int T(b) e^{-\sigma T(b)} d^2b.$$

The first two terms of expression (1) describe a contribution to $\langle n_g \rangle$ from the recoil protons produced in multiple collisions of leading hadron; the last two terms describe a contribution from interactions in the nucleus of the secondary low-energy pions from the target fragmentation region, produced in deep-inelastic interaction act (the third term) as well as before and after it (the fourth term). Fig. 1, 2 show the results of calculations with formula (1) performed for the following possible cases.

1. The leading hadron before and after the act of deep-inelastic lepton pair production preserves the properties of initial hadron and interacts in the nucleus with a cross section equal to the one of hadron-nucleon interaction, $\sigma_1 = \sigma_2 = \sigma_{hN}$.

2. Point-like configuration in the leading hadron is dominant before and after the deep-inelastic interaction [4] and multiple interactions in nucleus take place with cross sections noticeably less than the hadron-nucleon ones: $\sigma_1, \sigma_2 < \sigma_{hN}$ (Fig. 1 shows predictions for particular cases $\sigma_1 = \sigma_2 = 3$ mb and $\sigma_1 = \sigma_2 = 10$ mb).

3. In the leading hadron, before the deep-inelastic interaction act, there dominates a point-like configuration ($\sigma_1 \ll \sigma_{hN}$) which is "broken" as a result of the interaction, and the leading hadron undergoes then collisions in the nucleus with the "normal" hadronic cross section ($\sigma_2 = \sigma_{hN}$).

4. Before the deep-inelastic interaction act, the leading hadron preserves properties of the "normal" hadron and interacts with the cross section $\sigma_1 = \sigma_{hN}$, and after such

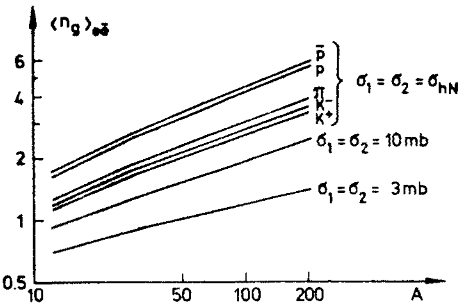

Fig. 1. The dependence of mean multiplicities of g-particles on the atomic number A of nuclei for the constant cross sections of leading hadron

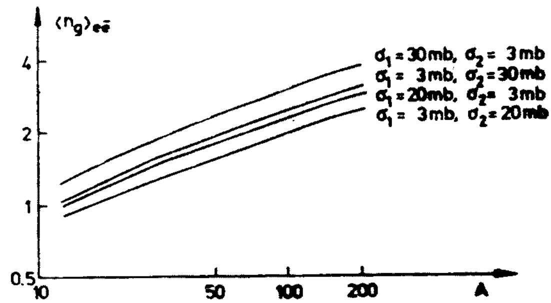

Fig. 2. The same dependence for the changing cross-sections of leading hadron

interaction it loses a part of its gluonic field and as a result the subsequent collisions in the nucleus proceed with noticeably less cross section ($\sigma_2 < \sigma_{hN}$).

As one can see from Fig. 1, 2, the predicted absolute values and A-dependences of mean multiplicity of g-particles are sensitive enough to parameters σ_1, σ_2 in order to extract them from experimental data.

Experiments on deep-inelastic lepton pair production (at different values of their effective mass and Feynman variable) with a simultaneous registration of accompanying g-particles compared with the results of calculations performed in this work may allow one to establish which of the above-mentioned mechanisms is realized, and may give an important information on strong interaction dynamics.

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