Coherent interaction of leptons with quarks in deep inelastic processes

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(Submitted January 20, 1975)
ZhETF Pis. Red. **21**, No. 6, 382–385 (March 20, 1975)

Coherent interaction processes with two or with three quarks are considered. It is shown that allowance for these processes leads to $W_2^{en}/W_2^{ep} \approx 1/3$ at $x \approx 2/3$ and $W_2^{en}/W_2^{ep} \approx 0$ at $x \approx 1$.

The quark-parton picture developed by Feynman[1] and by Bjorken and Pashos[2] describes quite adequately lepton-hadron collisions at large momentum transfers in the deep inelastic region. But a similar analysis of processes near $x=1$ (the region of elastic scattering and production of resonance with large momentum transfers) meets with difficulties. In the symmetrical quark-parton model[3,4] the ratio of the structure functions in the *en* and *ep* interactions at $x \approx 1$ should satisfy the inequality $W_2^{en}/W_2^{ep} \geqslant 2/3$. The experimental values of this ratio near $x=1$ are much smaller than 2/3.[5] The values $W_2^{en}/W_2^{ep} \approx 1/3$ can bé obtained in the asymmetrical quark-parton model.[4,6]

The composite quark model affords another possibility of getting around these difficulties. It is known that in composite systems the processes of elastic and quasielastic interaction proceed coherently. Coherent interactions should lead to other relations between the structure functions at large x. The present paper is devoted to allowance for the coherent states in the parton quark model.

The concept that hadrons are nuclear-like systems consisting of two (meson) or three (baryon) quasiparticles (quarks) that are separated on the averages by appreciable distances was the result of attempts to understand the $SU(6)$-symmetry mechanism. Evidence favoring this model was its success in describing hadron-interaction processes at high energies.[7–9] We proceed from the assumption that an analogy exists between the structures of the nuclei and the hadrons.

We turn to the interaction of a lepton with a composite system (assumed for simplicity to be deuteron-like, i.e., consisting of two particles). Two types of processes are possible here, and are shown in Fig. 1. In the first case after absorption of the photon, the component particles interact with one another, forming the initial particle or its excited state (Fig. 1a). These are coherent processes—the amplitudes of such interactions with different component particles interfere with each other, and the cross section for the interaction of the photon with the composite system is proportional to the square of the sum of the charges of the quarks: $\sigma \sim (\sum e_i)^2$. The second type of processes (Fig. 1b) is *incoherent*—the amplitudes of the interaction of the photon with the different quarks do not interfere with one another at large momentum transfers, and the cross

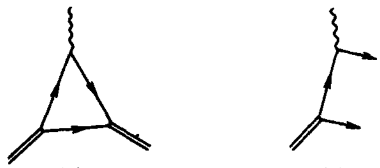

FIG. 1. Coherent (a) and incoherent (b) processes in the interaction of a photon with a composite system.

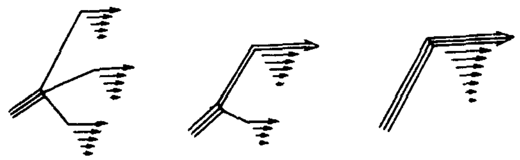

FIG. 2. Structure of rapidly moving nucleon: a) three spatially separated quarks surrounded by parton clouds, b) quark and diquark, surrounded by partons, c) triquark with cloud of partons.

section is proportional to the sum of the squares of the quark charges: $\sigma \sim \sum e_i^2$.

The parton hypothesis postulates that a hadron with large momentum P is a superposition of states of quasifree pointlike particles that carry a definite fraction x of the total momentum of this hadron. In different variants of the quark-parton model it is assumed that this representation of the hadron is valid up to $x=1$. Therefore the photon-hadron interaction is described in these models only by diagrams of type 1b. However, as we see in composite systems, the elastic and quasielastic interactions should be effected by processes of the first type. The physical reason for the appearance of coherent processes at large transfers consists in the following: At x close to unity, the relative momenta of the particles making up the hadron are large, corresponding to relatively small distances between the particles. At these short distances the particles interact with one another both before and after the absorption of the photon. Thus, in composite models it is necessary to modify the parton concepts in the region of large x.

In a composite nuclear-like model, the baryon consists of three spatially separated quasiparticles (quarks) surrounded by their clouds of quark-antiquark pairs. Therefore a rapidly moving baryon constitutes three spatially separated clouds of parton quarks surrounding the valent quark (Fig. 2a).[1)] The total momentum of each of the clouds is approximately equal to one-third of the baryon momentum. Thus, the quark-partons from these clouds have $x \lesssim 1/3$. The probability of finding in this configuration a parton in the region $x > 1/3$ decreases sharply with increasing x. The probability of finding an individual valence quark is maximal near $x=1/3$. The values $x=2/3$ are attained if two parton clouds overlap strongly. The valent quark-partons that are close to each other interact with the photon in coherent fashion. Such a system of two quarks will be called diquarks. A diquark can be surrounded by a cloud of partons (see Fig. 2b). The configuration 2b has a relatively low probability in comparison with 2a, but at $x \approx 2/3$ it makes the principal contribution. At $x \approx 1$, the three valent quarks form a single system (triquark). The triquark can also be surrounded by its own sea of partons (see Fig. 2b). In the region $x \approx 1$ the photon interacts mainly with the triquark, at $x \approx 2/3$ with the diquarks, at $x \approx 1/3$ with the valent quarks, and at $x \approx 0$ with the quark-partons of the sea. We consider here the external situation, when allowance for the coherent states does not lead to scaling violation. This requires that the form factors of the diquarks and triquarks not fall off with increasing momentum transfer.

Allowance for the coherent states of the valent quarks (diquarks and triquarks) leads directly to a number of qualitative consequences:

1) At $x \approx 1$, the structure functions in the deep inelastic electron-nucleon interaction are proportional to the charge of the triquark, which is equal to the charge of the nucleon $W \sim e_N^2$. Therefore, we have $W^{en}/W^{ep} \to 0$ for neutron and proton interactions as $x \to 1$.

2) At $x \approx 2/3$, the structure functions are proportional to the sums of the squares of the diquark charges: $W \sim \sum (e_N - e_i)^2$ (e_i is the charge of the valent quark). The ratio of the structure functions on the neutron and proton at these values of x is approximately equal to $W^{en}/W^{ep} \approx 1/3$.

3) At $x \approx 1/3$ the structure functions are proportional to the sum of the squares of the charges of the valent quarks, $W \sim \sum e_i^2$, and therefore $W^{en}/W^{ep} \approx 2/3$ in the region of $x \approx 1/3$.

Consequences (2) and (3) agree well with the experimental data. For the described hadron structure, a critical factor is the behavior of W^{en}/W^{ep} as $x \to 1$. There are still no experimental data that permit definite conclusions to be drawn.

The author is deeply grateful to A.A. Ansel'm, P.E. Volkovitskiĭ, V.G. Gribov, E.M. Levin, and V.M. Shekhter for useful discussions.

[1)]In the case of rapid hadron motion the radii of the clouds increase in the transverse direction, and the parton clouds overlap at sufficiently high energies. There exists, however, a region of moderately high energies in which the clouds do not overlap. We confine ourselves to that region.

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