# Deep, inelastic, Compton scattering as a test of the model with integral-charge quarks

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(Submitted 21 October 1980)

Pis'ma Zh. Eksp. Teor. Fiz. **32**, No. 11, 669–673 (5 December 1980)

The conditions under which the parton model can be used for the $\gamma N \to \gamma X$ process are investigated. The most suitable characteristic for testing the model with a broken color symmetry are determined. The available experimental data for deep, inelastic, Compton scattering of photons by a proton are analyzed in the context of the unified model with integral-charge quarks.

PACS numbers: 13.60.Fz, 13.60.Hb, 12.20.Hx

In spite of the fact that the hard processes have recently been intensively investigated theoretically and experimentally, the question whether the color $SU_c(3)$ symmetry is intact or broken has not been answered, and hence the true electric charge of a quark has not been determined unambiguously. Investigations performed within the framework of unified models[1,2] indicate that the data for deep inelastic scattering of leptons and $e^+e^-$ annihilation into hadrons do not favor any one of the existing theories. The measurements of lepton-lepton cross sections and of the anomalous magnetic moment of a muon impose severe constraints on the parameters of the model. The inequality

$$\frac{4\alpha(|q^2| \ll \mu^2)}{3\alpha_s(|q^2| \ll \mu^2)} \lesssim 10^{-4}$$

($\alpha$ is an invariant singlet charge and $\alpha_s$ is an invariant octet charge) must be satisfied.

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It was shown[3] that these constraints are satisfied if the current gluon masses are $\mu \lesssim 0.3$ GeV. Investigation of deep inelastic reactions with the participation of real $\gamma$ quanta is the most promising way of determining the electromagnetic properties of quarks. The processes $\gamma N \to \mu^+ \mu^- X$, $\gamma\gamma^* \to$ jets, $ep \to e\gamma X$, and $e^+e^- \to \gamma +$ jets have been analyzed by many authors.[4-9] Since all the mentioned reactions contain only one real photon, the true charge of a quark, as indicated by Witten,[4] can be determined by a rather imprecise measurement.

We shall formulate in this paper the condition under which the parton model for the $\gamma N \to \gamma X$ reaction can be used, determine whether the experimental data[10] can be explained in the context of QCD and the unified model with integral-charge quarks,[2] and determine the most suitable characteristics for testing the alternative quark models.

To determine the kinematic region of the parton subprocess, we analyze the diagram in Fig. 1(a)

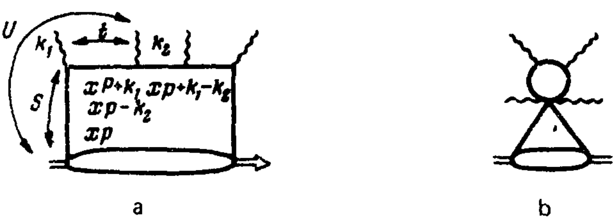


FIG. 1.

where $U$, $t$, and $S$ are Mandel'stam variables. The necessary conditions for identifying the parton subprocess in inelastic Compton scattering are

1. $xS \gg m_N^2$

2. $x(1-y) \gg \frac{m_N^2}{S}$, $(t \ll m_N^2)$

3. $(1-y)(1-x) \gg \frac{m_N^2}{S}$, $(m_x^2 \gg m_N^2)$

4. $xy \gg \frac{m_N^2}{S}$, $(xU \gg m_N^2)$,

where $m_x$ is the invariant mass of the finite state $\gamma = U/S$ and $x = t/s - U$. To isolate the pionization region, which cannot be calculated in terms of the standard perturbation theory and is described by diagrams such as those in Fig. 1b, we must analyze the jet processes with large $k_\perp$; hence, we obtain the condition

5. $$x = \frac{E_1 y}{m_N(1-y)}\left[1-\left(1-\frac{k_\perp^2}{E_1^2 y^2}\right)^{1/2}\right]; \quad x \approx \frac{k_\perp^2}{2m_N(1-y)yE_1};$$

$$\left(\frac{k_\perp^2}{E_1^2 y^2} \ll 1\right).$$

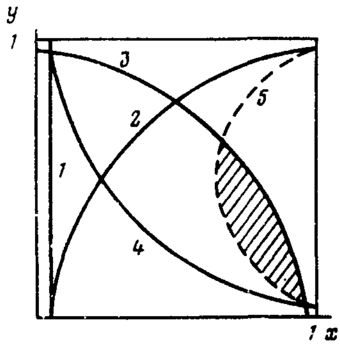


FIG. 2.

The diagram, which determines the common region for all kinematic constraints, is shown in Fig. 2. Thus, the conditions $E_1 \approx 21$ GeV $\gg m_N$, $E_2 \approx 10$ GeV $\gg m_N$, and $E_1 - E_2 \sim 10$ GeV $\gg m_N$ are, in fact, satisfied for the experimental data,[10] but the value $k_\perp^2 \sim 2$–$3$ GeV$^2$ can arbitrarily be assumed to be much larger than $m_N^2$. Therefore, the explanation of the measurement results[10] in terms of the parton model is preliminary. Analysis of the diagrams associated with the unified model[2] gives the following cross section for the $\gamma N \to \gamma X$ reaction, if the quark and gluon contributions are taken into account:

$$\frac{d^2\sigma^{unif}(\gamma N \to \gamma X)}{dE_2 d\Omega} = \frac{\alpha^2_{\text{qed}} \sum_a \bar{Q}_a [q_a(x) + \bar{q}_a(x)]}{2 m_N E_1^2 [1 - \sqrt{1 - k_\perp^2/E_1^2 y^2}]}$$

$$\times (y + 1/y)\left\{1 + \frac{1}{3} R_N(x)\left[10\left(y + \frac{1}{y}\right)^{-1} + 4\left(y + \frac{1}{y}\right) - 8\right]\right\}, \qquad (1)$$

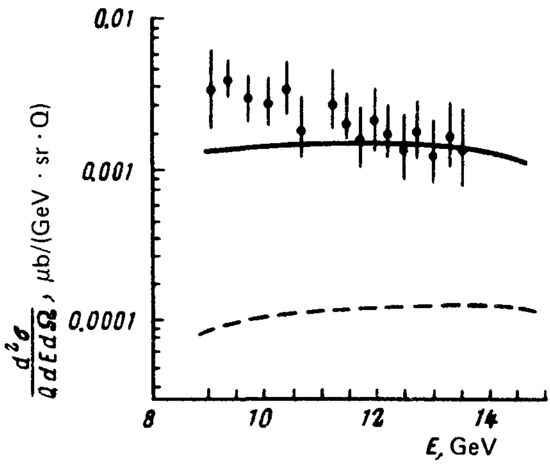


FIG. 3.

where $q_a(x)$ and $\bar{q}_a(x)$ are the distribution functions of quarks and $G^{\pm}(x)$ are the distribution functions of gluons within a hadron. The quantity $R_N(x) = \sigma_L/\sigma_T$ has the form

$$R_N(x) = \frac{1}{3}\,[(Q_1 - Q_2)^4 + (Q_1 - Q_3)^4 + (Q_2 - Q_3)^4]\,\frac{\left(G^+(x) + G^-(x)\right)}{\sum\limits_a \bar{Q}_a\,[q_a(x) + \bar{q}_a(x)]},$$

where $\bar{Q}_a = 1/3\,(\Sigma Q_i^4)_a$ for the integral-charge model $D = \Sigma Q_i^2 - 1/3\,(\Sigma Q_i)^2 = 2/3$. Let us examine the distribution functions of quarks and gluons that were proposed in Ref. 11. Specifying the values $k_\perp^2 = (1.7\ \text{GeV})^2$ and $E_1 = 21$ GeV, we can compare the predictions of the integral-charge theory with the data of Ref. 10. The dashed line in Fig. 3 represents the result of a QCD calculation and the solid line is defined by Eq. (1). Although Fig. 3 favors the unified model, the kinematic constraints written above hold us back from affirming that the quark charges are integral. To obtain clearer information, it would be desirable to measure the reaction of rescattering of $\gamma$ quanta by an isoscalar nuclear target normalized to a doubly differential cross section of deep inelastic process $eM_{i_o s_o} \to eX$. In this case an integral-charge model gives

$$\frac{d^2\sigma_{unif}^{\gamma M_{i.s.}}}{dE_2\,d\Omega} \Bigg/ \frac{d^2\sigma_{unif}^{eM_{i.s.}}}{dE_2\,d\Omega} = \frac{9}{5}\left(y + \frac{1}{y}\right)\frac{\left\{1 + \frac{20}{9}R_d\left[10\left(y + \frac{1}{y}\right)^{-1} + 4\left(y + \frac{1}{y}\right) - 8\right]\right\}}{\left\{1 + \frac{y}{(1-y)^2}(1 + R_d)\left[1 + \sqrt{1 - k_\perp^2/E_1^2 y^2}\right]\right\}}. \tag{2}$$

[A conversion to QCD can be realized by assuming that $R_d = 0$ and by substituting 17/45 for the coefficient 9/5 in the expression (2).] We can use the experimental value[1)] $R_d \approx 0.2 - 0.25$ for the quantity

$$R_d(x) = \frac{G^+(x) + G^-(x)}{10[u(x) + \bar{u}(x) + d(x) + \bar{d}(x)]}$$

in the region of intermediate values. If the measurements give a result that is just as inconsistent with QCD at an energy of the photon beam $E_1 \gtrsim 40$ GeV (as we can see,[12] the contribution of the leading orders is insignificant for a tenfold difference), then this may be the key argument in favor of integral-charge quarks proposed in Refs. 13 and 14.

The authors thank D. V. Shirkov, V. A. Matveev, and G. M. Vereshkov for a discussion of the results.

[1]Generally, the unified model makes it possible to calculate the value of $R$; moreover, the value ($R \approx 0.15$) agrees much better with the experiment than QCD.


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Translated by S. J. Amoretty
Edited by Robert T. Beyer