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We calculate the photon structure function in QCD in the intermediate region of the Bjorken variable $0.2 < x < 0.8$ ($x = \frac{-q^2}{2pq}$, where q^2 is the hard photon virtuality, p is the soft photon momentum). It is shown that without introduction of fitting parameters the experimental data can be described in the range $3\ GeV^2 \leq Q^2 \leq 30\ GeV^2$ $/Q^2=-q^2/$ not taking account for the leading logarithmic corrections. It is demonstrated that the corrections proportional to $\langle G_{\mu\nu}^2 \rangle$ to the hard photon scattering amplitude on the longitudinal soft photon and to the Callan-Gross relation vanish.

Fig. - 6, ref. - 16

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I. Introduction

There is no relaxation of interest to investigation of photon structure functions since the time of the Witten's paper. As he showed, in the framework of perturbative QCD it is possible to calculate the dominant at large Q^2 part of the structure function which is usually parametrized as follows:

$$F_2(x) = F_2^{P.t}(x) + F_2^{HAD}(x). \qquad (1)$$

Essential was the fact the perturbation theory contribution $F_2^{P.t.}$ (see Fig. 1) with the account of logarithmic corrections contains the term $\alpha_S^{-1}(Q^2)$ and, consequently, there arises a possibility as to "pure" Λ_{QCD} determination. However, an uncertainty in the function $F_2^{HAD}(x)$ corresponding to nonperturbative contribution gives rise to large difficulties on this way. To estimate the hadronic contribution there were as a rule used various variants of the vector dominance model (see, e.g. the review[2] and the recent discussion in ref.[3]) but there was not proposed a satisfactory algorithm for distinguishing $F_2^{Pt}(x)$ and $F_2^{HAD}(x)$. The attempts made in this direction[4,5] inevitably contained as a component the introduction of an additional parameter which complicated the obtaining of Λ_{QCD} from experimental data. The evenmore artificial in our opinion attempt to describe the experiment was made in[3] where logarithmic evolution started practically from Λ_{QCD} and the possibility of determining this parameter totally disappeared.

Another motive for discussions, directly connected with the preceding one, is the problem of existence of singularities at small x which appeared beyond the framework of the leading logarithmic approximation[4-7]. The convergence degree grows with the α_S degree increase and the problem of existence of the variable x region where the perturbation theory calculations remain valid become of a serious character. The calculation of nonperturbative corrections[8] revealed the existence of $x \to 0$ singularities in the terms of order $\langle G^2_{\mu\nu}\rangle / p^4$, $p^2 \gg \Lambda^2_{QCD}$ and that is why there is a hope for their mutual cancellation at their accurate account in $F_2^{P.t.}$ and F_2^{HAD}. Note also the paper [9] which deals with this problem where the structure function of virtual photon scattering was discussed disregarding power-like effects. In that paper it was also demonstrated that there arises natural cut off for radiative corrections to the moments of the structure functions which naively seem to be divergent.

Under the situation at hand it is natural to quantitatively consider $F_2(x)$ in the QCD framework without introducing fitting parameters. In this paper we calculate the nonperturbative contribution into $F_2(x)$ using the method close in its idea to the sum rule method[10] previously developed in refs.[11,12] for calculation of the nucleon structure functions in the region of intermediate x and Q^2.

The leading nonperturbative contribution into $F_2(x)$ at intermediate Q^2 and the Bjorken variable $x = \frac{Q^2}{2\nu}$, $\nu = pq$ emerges from accounting for quark interaction with gluon condensate. It is natural here to parametrize $F_2(x)$ as a contribution from the lower physical state-vector meson plus contribution of higher state continuum. The method suggested allows one to completely fix the x-dependence and the $F_2(x)$ structure function normalization making use of the calculation results of the main QCD diagrams in the region of the deep-inelastic scattering on the virtual photon. Incidentally, we reproduce unambiguously the form of the structure function of vector meson with transverse polarization in the intermediate x-region.

All the parameters on which the $F_2(x)$ depends are already known from QCD sum rules for the mass and leptonic width of vector meson and do not require fitting. Note also that the physical interpretation of individual contributions into $F_2(x)$ in our paper significantly differ from usual approach. Indeed, remind that in the language of QCD sum rules the physical ρ -meson determined by a part of the loop (the part of the dispersion integral over this loop dual to ρ -meson) and by the leading power corrections. That is why from the sum rule viewpoint the division of F_2 into $F_2^{P.t.}$, F_2^{HAD} inevitably contains the double counting: this is the sum of the contributions of states of two different bases - the quark-gluonic and hadronic. In our approach $F_2(x)$ consists from the very beginning of the contributions of hadronic states, the main of which is the ρ -meson contribution. The latter is dual to the part of the quark loop in Fig.1 and contains an extra term from nonperturbative interaction. The remaining part of the quark loop may be treated as a contribution of higher hadronic states.

The sketch of the paper is the following. In Sec.2 we discuss the method of calculation of the photon structure function.

This method is based on the expansion of the correlator of four electromagnetic quark currents. In Sec.3 we calculate the basic QCD diagrams which determine this correlator in the kinematical region of the virtual photon-virtual photon scattering. In Sec.4 we directly calculate the structure functions of the real photon and transverse ρ -meson and compare with the experiment. In Conclusion we briefly discuss the basic results of the paper and show possibilities for their precising.

2. Calculation Method of the Photon Structure Function

The suggested approach mainly repeats the one used in refs. [11,12] to calculate the nucleon structure function and for this reason we restrict ourselves by reminding basic moments. Let us consider the forward deep-inelastic scattering amplitude of virtual photon q^2 on the virtual photon p^2 via intermediate hadronic states. As was shown in refs. [11,12] the imaginary part of such an amplitude is determined by small distances if x is not too close to 0 and 1, and $|q^2|$, $|p^2| \gg R^{-2}$ where R is the confinement radius. This circumstance allows us to use the operator expansion, namely, to represent the amplitude at hand as a sum of the simplest diagrams of Fig.1 and as power corrections to them.

Thus, start with the four-point correlator:

$$V_{\mu\nu\lambda\rho}(p,q) = -i\int d^4z_1\, d^4z_2\, d^4z_3 \exp\{iq(z_1-z_2)+ipz_3\} \times \langle 0|T\{J_\rho(z_3)J_\mu(z_1)J_\nu(z_2)J_\lambda(0)\}|0\rangle, \tag{2}$$

where $J_\mu = \bar{q}\hat{Q}\gamma_\mu q$ is the electromagnetic quark current, and calculate the imaginary part $Im\, V_{\mu\nu\lambda\rho}$ over $S=(p+q)^2$ at fixed $p^2, q^2 < 0$ and $t=0$. In what follows we shall be interested in the configuration where one of the photons is strongly virtual ("sampler") and other is simply virtual ("target"), i.e. the scaling limit $|p^2| << |q^2|$, is in this case always $|p^2| \gg R^{-2}$. Then one should remain in all calculations the ground terms of the p^2/q^2 expansion. The $Q^2 = -q^2$ region where we shall work, is supposed to be such for the QCD logarithmic corrections to be inessential. All these conditions may, in principle, be satisfied if $|p^2| \approx 1\ GeV^2$, $Q^2 \approx 10\ GeV^2$.

It can be easily seen that arguments given in refs.[11,12] in favour of the operator expansion applicability are valid for $Im\, V_{\mu\nu\lambda\rho}$. The unit operator contribution is given by the imaginary part of the simplest diagrams of Fig.1. The reader acquainted with the QCD sum rule may readily reconstruct the next operators essential in this problem. First, one should account for the vacuum expectation value $\langle G^2_{\mu\nu}\rangle$(d=4), then $\langle \bar{\Psi}\Psi\rangle^2$ etc.

Suppose that we are able to calculate all the basic contributions into $Im\, V_{\mu\nu\lambda\rho}$. (The real calculation will be given below in Sec.3). Let us deal with the physical interpretation of the imaginary part of the correlator(I). Multiplying it by the four-vector of the photon polarization $e_\rho(p), e^*_\lambda(p)$ (in the general case - virtual) and summing over polarizations we may write for the appearing tensor the standard expansion over the structure functions of virtual photon:

$$+\sum_i e_\rho^i e_\lambda^{*i} \, \mathrm{Im}\, V_{\mu\nu\lambda\rho} = \left(-\delta_{\mu\nu} + \frac{q_\mu q_\nu}{q^2}\right) W_1(p^2, q^2, x) +$$

$$+\left(p_\mu - \frac{q_\mu \nu}{q^2}\right)\left(p_\nu - \frac{q_\nu \nu}{q^2}\right) W_2(p^2, q^2, x). \qquad (3)$$

Note that the main advantage and simplicity of the problem at hand comparing, for example, with the problem of determination of the nucleon structure function. There is not necessity here to extract the physical state of interest using a Borel-type borelization procedure. The photon is extracted from the very beginning because of the weak coupling with hadronic states.

The other feature of our problem is that even in the leading twist approximation the nonzero is the function $F_L(x)$ which determines the longitudinal photon interaction and which is zero for the nucleon scattering case. Note that in what follows we restrict ourselves by the ground terms of the p^2/Q^2 expansion, i.e. by the twist-2 operators in the operator expansion of the currents interacting with the hard photon, that corresponds to the scaling limit $\nu W_2 = F_2(P^2/\nu, x)$, $W_1 = F_1(P^2/\nu, x)$ and by the first power correction which is equivalent to the twist-4 operator account.

Note that, in principle, function $F_2(P^2/\nu, x)$ may be measured in the region where it is calculated in QCD. To this end an appropriate configuration in the process $e^+e^- \to e^+e^- +$ + hadrons is necessary (both intermediate photons are strongly virtual, $|p^2| \sim 1\,GeV^2$, $Q^2 \sim 10\,GeV^2$). In reality, however, such experiments are practically nonrealizable because of the smallness of the corresponding e^+e^- cross sections.

The question arises, whether it is possible using the QCD calculations in the region of large $p^2 \gg R^{-2}$, to reconstruct the limit

$$\lim_{p^2 \to 0} F_2(p^2/\nu, x) = F_2(x), \tag{4}$$

i.e. the structure function of the real photon? Our recipe of obtaining $F_2(x)$ is the following. The nonperturbative part in $F_2(p^2/\nu, x)$ is modelled by the ρ -meson contribution, and, generally speaking, by the transition contribution depicted in Fig.2b. Requiring coincidence of p^{-2} terms and p^{-4} terms at large p^2 we fix all unknown functions. The following transition to the limit $p^2 \to 0$ does not give rise to difficulties since the divergences at the limiting process do not arise.

It should be noted that the structure function language is more convenient for us than the moment language because the account of the operator $G^2_{\mu\nu}$ in the operator expansion leads to appearance of singularity at small x and the logarithmic divergence arises for the second moment of the structure function which needs a separate consideration. In our approach we may restrict ourselves by the region $x > 0.2$ and avoid such a problem.

3. QCD-Calculation of the Four-Current Correlator

Let us now proceed to direct calculation of imaginary part of the correlator 2 basing on the operator expansion. The calculation of the unit correlator contribution, i.e. of the imaginary part of the diagrams of Fig. 1, contains no news: these diagrams have been calculated many times in the literature (see, for example, the review[12] and more earlier papers cited there in). In the quark zero mass approximation and in the leading in p^2/Q^2 order the contribution of the diagram 1 into the structure function (i.e. the coefficient at the structure $p_\mu p_\nu$) is of the form

$$\left(\frac{3\alpha}{\pi}\sum_{u,d,s} e_q^4\right)^{-1} F_2 = \ln\left(\frac{2\nu}{-p^2 x}\right) x\left\{1+2x^2-2x\right\} + \left\{-2x+6x^2(1-x)\right\}, \tag{5}$$

where the first terms in both figure brackets correspond to the diagram of Fig. 1a, and the rest to the diagram 1b. Note that eq. (5) appears when there is summing up over all polarizations of virtual photon in (3), i.e. in the Lorentz gauge $\sum_i e_\rho^i e_\lambda^{*i}$ is replaced by $\frac{1}{2}\left(-\delta_{\lambda\rho}+\frac{p_\lambda p_\rho}{p^2}\right)$ - the density matrix of the nonpolarized photon. Next we shall need separate expressions for the structure function F_2^T of the transverse photon $\sum_{(\perp)} e_\rho^i e_\lambda^{*i} \to \frac{1}{2}\left(-\delta_{\lambda\rho}-\varphi_\lambda\varphi_\rho\right)$

$$\left(\frac{3\alpha}{\pi}\sum_{u,d,s} e_q^4\right)^{-1} F_2^T = \ln\left(\frac{2\nu}{-p^2 x}\right) x\left[x^2+(1-x)^2\right]-2x+8x^2(1-x) \tag{6}$$

and for longitudinal photon F_2^L (see the discussion in ref.[13]):

$$+ e_\rho^L e_\lambda^{*L} \to \varphi_\lambda \varphi_\rho$$

$$F_2^L \left(\frac{3\alpha}{\pi} \sum_{u,d,s} e_q^4 \right)^{-1} = 4x^2(1-x) \frac{\rho^2}{\rho^2 + \frac{m_q^2}{x(1-x)}} , \qquad (7)$$

where $\varphi_\lambda = \sqrt{\frac{-\rho^2}{\nu^2 - q^2\rho^2}} \left(q_\lambda - \frac{\rho_\lambda \nu}{\rho^2} \right)$ are known expression for the polarization vector of longitudinal photon, m_q is the quark mass (see, for example [14]). It can be readily seen that $F_2^T + \frac{1}{2} F_2^L = F_2$.

The next term of the operator expansion for the correlator (1) is the operator $G_{\mu\nu}^2$, the coefficient functions for which are determined by the diagrams of Fig.3. As usual, it is convenient to calculate them in the fixed point gauge for gluonic field using the standard expression for the massless quark propagator in external gluonic vacuum field. Substituting the expression for the propagator into all quark lines of the square diagram we get a set of diagrams of Fig.3 with all possible combinations of two gluonic insertions. The following momentum integration is made in the first nonvanishing order in p^2/Q^2 . For reliability these calculations were verified using the "REDUCE-2" program.

Let us give the result for the case when $Im\, V_{\mu\nu\lambda\rho}$ is multiplied by the density matrix of nonpolarized photon $\frac{1}{2}\left(-\delta_{\lambda\rho} + \frac{\rho_\lambda \rho_\rho}{\rho^2}\right)$. Then the coefficient at the structure in the leading twist is

$$\left(\frac{3\alpha}{\pi}\sum_{u,d,s} e_q^4\right)^{-1} F_2^{<G^2>} = -\frac{4\pi^2}{27}\frac{\langle \frac{\alpha_s}{\pi} G_{\mu\nu}^2 \rangle}{p^4 x} \tag{8}$$

and in the leading twist there is no contribution from the diagrams of Fig.3a.

Let us return to the expression of gluon condensate contribution into $Im\, V_{\mu\nu\lambda\rho}$ for the case of longitudinal photon, i.e. let us multiply the amplitude by $\varphi_\lambda \varphi_\rho$. After rather complicated calculations one can see that the structure function of longitudinal photons in the order $\langle G^2 \rangle / p^4$ vanishes. Thus, the gluon condensate in the leading twist contributes only to the structure function F_2^T of transverse photons.

We have separately calculated the power correction to the structure function $F_1(x)$ and, correspondingly, to the Callan-Gross relation. It appeared that the power correction from gluon condensate to $F_L(x) = F_2(x) - 2xF_1(x)$ is absent. Note that $F_L(x, p^2, Q^2 \to 0)$ and $F_2^L(x, Q^2, p^2 \to 0)$ must vanish (see, however, [13]) since, for example, the absence of $\langle G^2 \rangle$ at $p^2 \to 0$ in F_2^L is analogous to usual axial anomaly where, as known, the nonperturbative corrections are totally absent when calculating the correlator $\int \exp\{ipx + iqy\} \langle 0 | T \partial_\mu A_\mu(y) J_\alpha(x) J_\beta(0) | 0 \rangle$, where A_μ is the quark axial current. If such an analogy which is based on that in both cases the answer is fully determined by the pole singularities, is valid, then it may be expected that there are no any dimension corrections to the loop contribution in Fig.1 into F_2^L.

Analytical computer calculations made it possible to obtain the first power correction to (8) which breaks scaling. It is reduced to that eq.(8) must be multiplied by the factor

$$\left(1-\frac{3x^4\rho^2}{q^2}\right). \tag{9}$$

Note that the correction (9) is completely originated from the diagram 3c. Analogous correction to the function $F_L(x)$ appears to be zero in accordance with the above arguments.

It can be easily seen that the expression (8) is, in the essence, the main nonperturbative contribution to the photon structure function in the region of intermediate x. Indeed, the contribution of the operators $m_q\ \bar{\psi}\psi$ and $m_q\bar{\psi}\sigma_{\mu\nu}G_{\mu\nu}\psi$ where m_q is the quark mass, presented in Fig.4, is proportional to $\delta(1-x)$ or $\delta(x)$, i.e. it is originated in the region where the whole approach must not, generally speaking work. The s-imaginary part in the x-intermediate region will be contained in the α_s corrections to these terms of the operator expansion and to the terms proportional to $(\bar{\psi}\psi)^2$, i.e. the diagrams with additional exchange by hard gluon (of the type of Fig.5). The calculation of these diagrams, though technically complicated, may be performed in what follows for precising the results obtained.

The applicability region of the approximation we used at $x\to 0$ may be estimated from the expression for $F_2(x)$ itself. At standard choice [10, 12] $4\pi^2\langle\frac{\alpha_s}{\pi}G_{\mu\nu}^2\rangle=0.45\,GeV^4$. Numerically, this contribution becomes 30% from the contribution of a simple loop at $x\approx 0.2$. This means that at smaller x the disregarded higher terms of the operator expansion become essential.

Concluding this Section, we note that the result we have obtained for the correction from condensate $\langle G_{\mu\nu}^2 \rangle$ diverges with the result of the calculations made in ref.[8] for the function $F_1(x)$. There is a divergence by the factor 2 in the terms proportional to $1/x$ and in addition, other terms which are absent in our result, also arise in ref.[8].

4. Calculation of Structure Functions of the Real Photon and ρ -Meson with $|\lambda| = 1$. Comparison with Experiment.

Let us now proceed to calculation of the structure function of the real photon. To this end it is convenient to consider the nonperturbative part of $F_2^T - \tilde{F}_2^T$. On one hand, in the euclidean region $p^2 < 0$ it is given in our approximation by the contribution of the $\langle G_{\mu\nu}^2 \rangle$ condensate, and on the other hand, using analyticity we approximate it in the physical region by the contribution of ρ -meson and by a part of the simple loop. It is supposed that $Im_{p^2} \tilde{F}_2^T(x, p^2) = 0$ at $p^2 > S_0$, which is equivalent to the step model of continuum, or in the local duality language we refer the integration region $\frac{k_\perp^2}{x(1-x)} < S_0$ in the loop of Fig.1 to nonperturbative part of F_2^T. Thus, we have the following representations for $\tilde{\Pi} = \left(\frac{3\alpha}{\pi} \sum_{u,d,s} e_q^4\right)^{-1} \tilde{F}_2$

$$\tilde{\Pi} = - \frac{4\pi^2 \langle \frac{\alpha_s}{\pi} G_{\mu\nu}^2 \rangle}{27 x p^4} + \ldots \qquad (10)$$

$$\tilde{\Pi}=-x\left[\ln\left(1+\frac{s_0}{p^2}\right)+\left(\frac{p^2}{p^2+s_0}-1\right)\right]+\frac{f_\rho(x)m_\rho^4}{(p^2+m_\rho^2)^2}+$$

$$+\frac{\varphi(x)m_\rho^2}{p^2+m_\rho^2}+2x^2(1-x)\left[\ln\left(1+\frac{s_0}{p^2}\right)+\left(\frac{p^2}{p^2+s_0}-1\right)\right]. \qquad (11)$$

In eq.(11) the function $f_\rho(x)$ is proportional to the structure function of ρ -meson (see Fig.2a) with transverse polarization, while the function $\varphi(x)$ corresponds to ρ - meson transition into higher resonance (see Fig.2c). Comparing the terms at the powers p^{-2} and p^{-4} at $s_0 \ll p^2$ we may define the functions $f_\rho(x)$ and $\varphi(x)$. It can be easily seen, expanding in powers s_0/p^2, that $\varphi(x)=0$, i.e. the transverse ρ -meson transition into higher resonances is absent. Comparing the p^{-4} terms we the relation for $f_\rho(x)$

$$-\frac{4\pi^2\langle\frac{\alpha_s}{\pi}G_{\mu\nu}^2\rangle}{27x\,m_\rho^4}=-\frac{s_0^2}{m_\rho^4}\left[\frac{x}{2}-x^2(1-x)\right]+f_\rho(x), \qquad (12)$$

which is evidently, invalid in the region of small x, since $f_\rho(x)$ becomes negative. Note also that (12) cannot be considered in the region $x \to 1$, since $f_\rho(x\to 1)$ does not satisfy the relations following from quark counting rules. Besides, other disregarded nonperturbative contributions of the type $m\bar{\psi}\psi$ give a contribution at $x \to 1$.

To go over to the limit $p^2 \to 0$ we must add to the expression (6) the expression for $\tilde{\Pi}$ (11) taking into account eq.(12) and the condition $\varphi(x)=0$. The final expression for $F_2^T(x)$ has the following form:

$$F_2^T(x) = \frac{3\alpha}{\pi}\left(\sum_{u,d,s} e_q^4\right)\left\{x\left[x^2+(1-x)^2\right]\ln\frac{2\nu}{x s_0} + \right.$$

$$+ x\left[6x(1-x)-1\right] + \frac{s_0^2}{2m_\rho^4}x\left[x^2+(1-x)\right]^2 - \tag{13}$$

$$- \frac{4\pi^2}{27x}\frac{\langle\frac{\alpha_s}{\pi}G_{\mu\nu}^2\rangle}{m_\rho^4} .$$

Experimentally, the function $F_2(x)$ for a nonpolarized soft photon is studied, therefore, it is necessary to add the expression $F_2^L(x,\rho^2\to 0)$ to F_2^T . However, owing to the gauge invariance and to the presence of nonzero current quark masses, we have $F_2^L(x,\rho^2=0)=0$ and thus we may directly compare (13) with the experimental data. As is seen from Fig.6 we have a good agreement in the region $0.2< x < 0.8$ in a sufficiently wide energy range not taking account of logarithmic evolution effects. In our opinion, the Λ_{QCD} determination in this energy range is practically impossible though determination of Q^2 values, where the evolution effects become significant in our approach, needs a separate consideration. Let us once more emphasize that the agreement with the experimental data has been achieved without introducing fitting parameters.

Note that as a byproduct we have the relation (12) which gives the structure function of transverse ρ -meson in the region of intermediate x and Q^2 .

Indeed, one can readily see that the function $f_\rho(x)$ is connected with the structure function of transverse vector meson by the normalization relation

$$\left(\frac{e m_\rho^2}{g_V}\right)^2 F_{2\rho}(x) = \frac{3\alpha}{\pi} f_\rho(x) , \tag{14}$$

where $\frac{e^2}{4\pi} = \alpha$, g_V is the transition constant of the vector meson corresponding to one flavour with the unit charge

$$\frac{g_V^2}{4\pi} = \frac{1}{2}\frac{g_\rho^2}{4\pi} \simeq 1.27$$

(remind the definition $\Gamma(\rho^0 \to e^+e^-) = \frac{4\pi\alpha^2 m_\rho}{3 g_\rho^2}$).

Thus, in the region $0.2 < x < 0.8$

$$F_{2\rho}(x) = \frac{3 g_\rho^2}{16\pi^2}\left\{\frac{S_0^2}{m_\rho^4} x\left[x^2 + (1-x)^2\right] - \frac{8\pi^2}{27x}\frac{\langle \frac{\alpha_s}{\pi} G^2\rangle}{m_\rho^4}\right. . \tag{15}$$

And the integral

$$\int_{0.2}^{0.8} F_{2\rho}(x)\,dx = \int_{0.2}^{0.8} x\, F_{1\rho}(x)\,dx \simeq 0.5 \tag{16}$$

that reasonably agrees with available concepts on the quark-parton structure of ρ -meson.

In connection with the problem of small x note that the hope for possible cancellation of 1/x singularities at their mutual account in perturbative and nonperturbative parts of $F_2(x)$ is in our opinion unjustifiable. Really, one may expect that the cancellation of 1/x terms in perturbative corrections and perturbative part of $\langle G_{\mu\nu}^2\rangle$ but the nonperturbative contribution into $\langle G_{\mu\nu}^2\rangle$ inevitably remains and therefore in the region of small x one should sum and analyse the x^{-n} terms.

5. Conclusion

Thus, we convinced of the fact that the experimental data on the structure function $F_2(x)$ can be described in the central part of x values without introducing fitting parameters. The possibility of Λ_{QCD} determination is restricted only by the region of very large Q^2. In our approach the applicability limit for consideration in the small x-region can be easily established. Possible absence of corrections checked up for the lower dimension operator for F_2^L makes it possible to estimate the experimental determination of F_2^L as a pure test for QCD prediction.

Natural precising of the results obtained may include the analysis of contributions of higher dimension operators as well as the account of evolution effects and of mass difference $m_s - m_{u,d}$, i.e. the presence of SU(3) violation between ω, φ and ρ -mesons in the vector channel. The problem of calculation of the power corrections to cross section of heavy quark production in two-photon processes will be considered separately.

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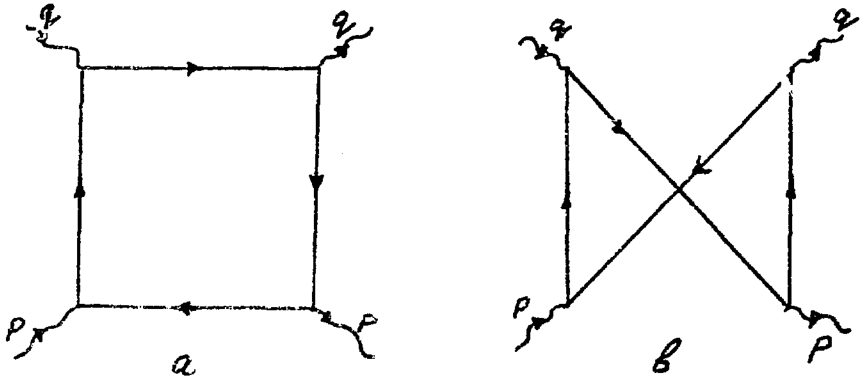

Fig. 1

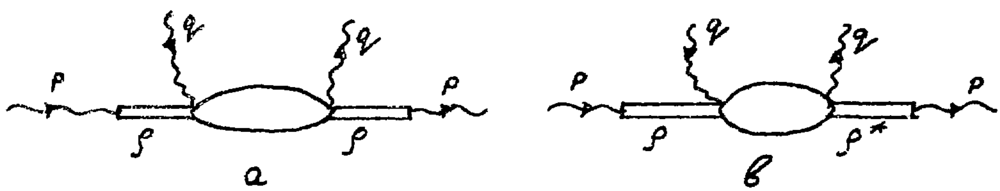

Fig. 2

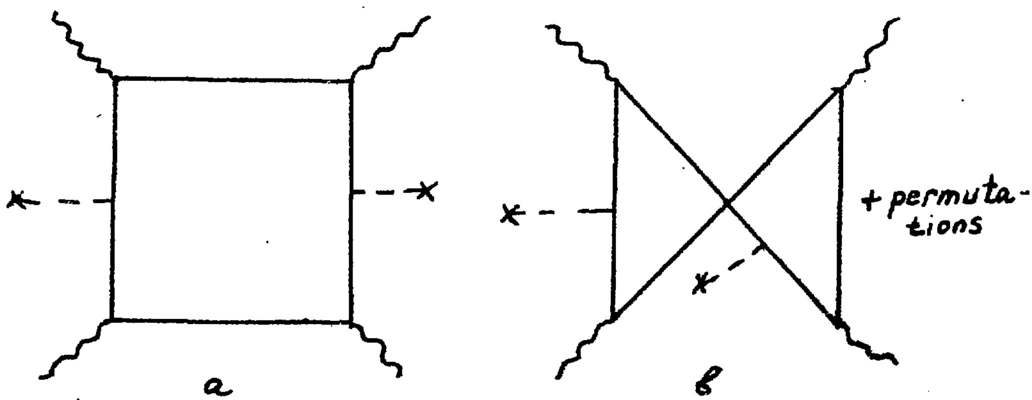

Fig. 3

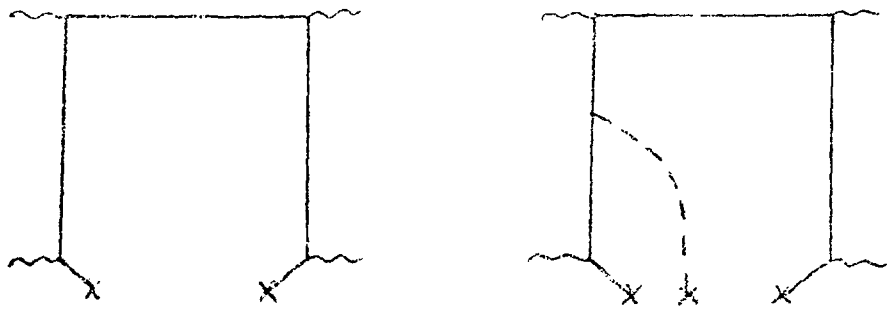

Fig. 4

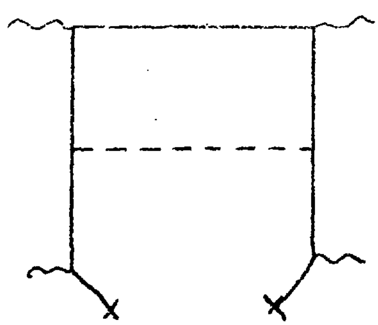

Fig. 5

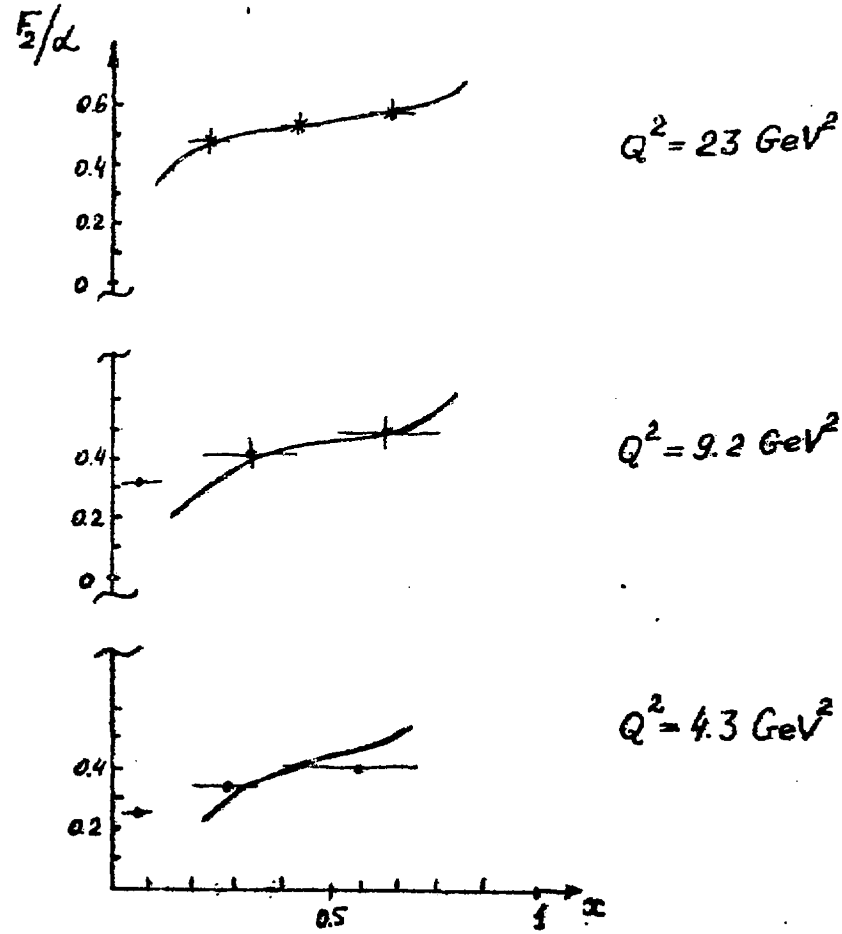

Fig.6. The comparison of the photon structure function (13) with experimental data of [15,16]:

$s_o = 1.5$ GeV^2 , $\langle \frac{\alpha_s}{\pi} G^2 \rangle = \frac{0.45}{4\pi^2}$ GeV^4.

Compilation is taken from ref. [3].

• PLUTO × TASSO

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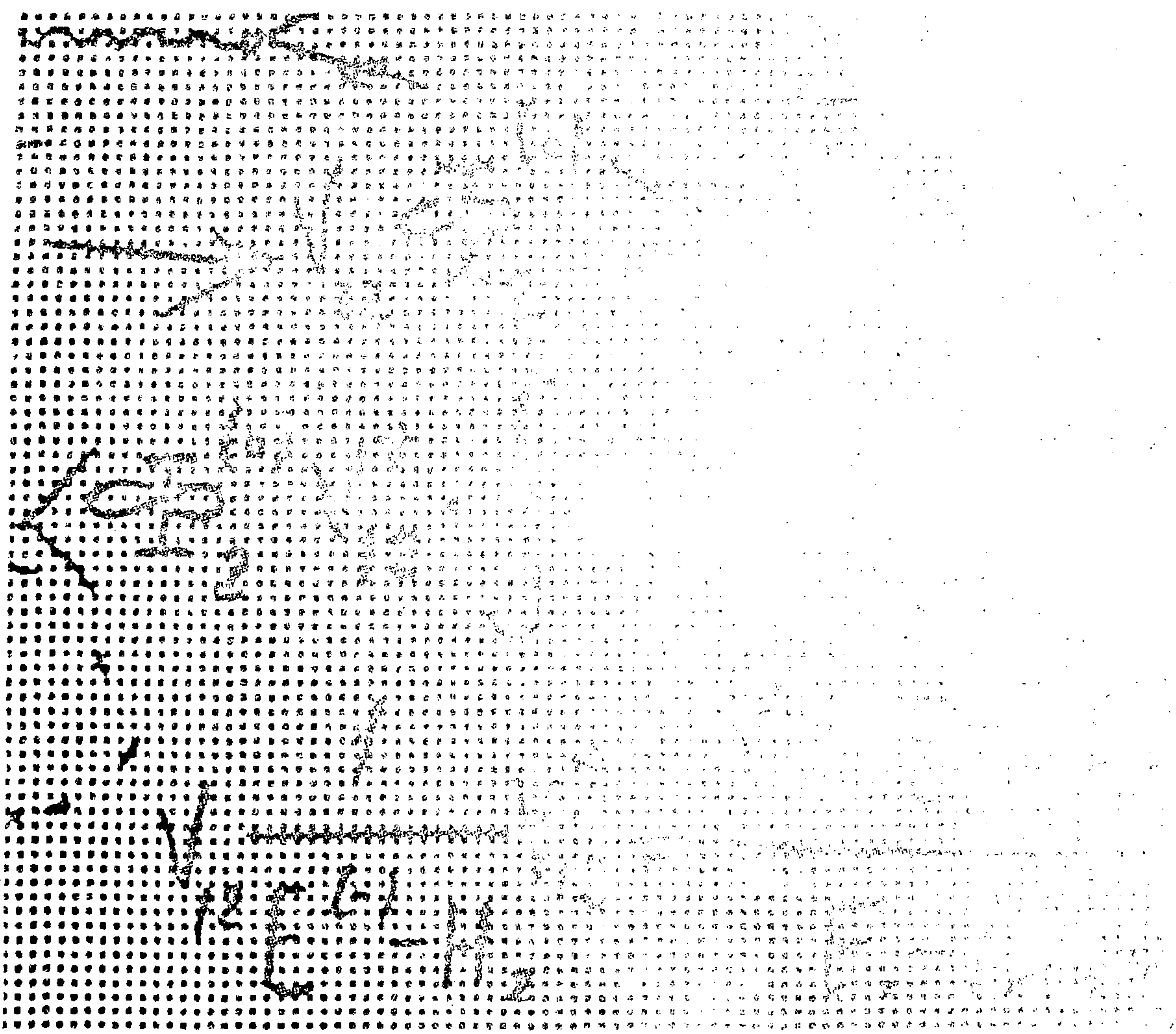

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