SEARCHING FOR QCD-VIOLATIONS IN DEEP INELASTIC STRUCTURE FUNCTIONS

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Abstract :

Due to the difficulties in extracting information from data of different experiments, a systematic procedure to look for QCD-violations in the Q^2-dependence of F_2 is discussed. The validity of the Callan-Gross relation is assumed. The proposal is illustrated in a well-known model which implies QCD-violations.

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Theoreticians interested in obtaining information out of experimental data, run into serious troubles whenever they try to compare results from different experiments. First of all there is the problem of the acceptances in different kinematical regions. Then, what is worse, different experiments are usualy based on different theoretical assumptions. The comparison of one experimental output to another is therefore very difficult.

Let us consider deep inelastic processes. It is known[1] that in order to get the nucleon structure functions F_1 and F_2 in μ-N scattering from the double differential cross-section one has to assume an extra-relation between them before extracting the desired result. Traditionally, one has been interested in obtaining F_2 and the assumed relationship has been the Callan-Gross relation $F_2 = 2x\ F_1$, in the form $R = \sigma_L/\sigma_T$. This relation has been in turn tested and, until recently, quite well satisfied in a somewhat restricted kinematical region[2,3].

One then has an obvious freedom in obtaining the results which are being searched. According to both theoretical prejudices and experimental facilites, one gives alternatively more relevance to R or to F_2. It was usual to assume the exact validity of the Callan-Gross relation, i.e. $R = 0$ and then to obtain F_2 whatever it could be. With the appearance of scaling violations and the great theoretical appeal of QCD, the present tendency seems to be on the other way around, namely, to fit F_2 according to QCD prescriptions -logarithmic violations of scaling- and to obtain afterwards the value of R, whatever it results[4].

In spite of possible inherent critizisms to QCD[5], it seems necessary to define a way for substracting good information off the experimental data. A priori there is no way how to decide which possibility has to be choosen. Nevertheless, one can take the attitude to follow a well settled hierarchy of possibilities.

One has at present, and at least, two main features not included in the naive quark-parton model :

i) the Q^2-dependence of the structure functions, in particular $k_\perp$-dependence,

ii) the effects arising from non-spin $\frac{1}{2}$ partons.

As a consequence, the Callan-Gross relation is no more valid and the structure functions deviate from exact scaling.

In Ref. 6 there is an estimation for the ratio σ_L/σ_T based on QCD arguments. The value found is $R \simeq 0.1$ to be compared with $R = 0$ of perfect scaling and only spin 1/2 partons. Thus taking R small (≤ 0.1) in extracting the structure function F_2 one is respecting the Q^2-dependence of QCD as far as R is concerned and let other possibilities -non log log Q^2 dependences- to appear in the structure function. This is turn means that we are not only taking into account partons of spin 1/2 but we disregard possible quark correlations that in some kinematical regions could give rise to effective contributions mimicking non-spin 1/2 partons. Certainly these effects are not easy to be found because their subtelty could be very easily masked by normal effects. But once one has a reliable phenomenological parametrization of F_2 one can now vary the detection angle and extract R searching therefore possible effects due to non-spin 1/2 partons. The whole procedure has of course to be checked by self-consistency.

The purpose of this note is to extract the consequences of fixing the Callan-Gross relation ($R \lesssim 0.1$) in obtaining the structure function F_2. We should remark that this attitude was previously suggested by G. Fox[1]. We illustrate the benefits of our choice by working out the structure function F_2 and the ratio R in the frame of a model which is known to have discrepancies with QCD. We perform our calculations for μN as well as for deep inelastic neutrinos scattering, in the framework of the model of Pati and Salam[7]. This model assumes that scaling is broken as a consequence of explicit colour shine, through gluon production. The gluons acquire mass because of spontaneous breaking of the gauge symmetry. For the parton distribution function we take the parametrization of Buras and Gaermes[8], and we evaluate the structure functions according to the Pati and Salam prescription[7]. Our calculation is therefore along the lines of Ref. 9.

Recently, Ball et al.[10] published data about F_2 showing a possible inconsistency with QCD and which were fitted in Refs. 11 and 9. To illustrate our proposal we extend the analysis to evaluate R for μN scattering. The results are shown in Table I (for $x = 0.16$) making noticeable that $R \simeq 0$ while F_2 contains deviations of QCD of the order of 15%. In Ref. 10 it is stated that with their value of R, the neutrino data of the Groot et al.[12] are neither against nor in favor of their results. However, de Groot et al.[12] show that σ_L/σ_T is very near zero. With the same parametrization used in relation with the Ball's data[10] we calculate F_2 and R for the neutrino case and our results are compatible with the experimental data[12].

The latest data on μN scattering are those of Anderson et al.[4]. Here F_2 is fitted according to QCD but R has an average value of 0.5 in evident disagreement with Callan-Gross. However, the kinematical region in x and Q^2 for which they present σ_L/σ_T is a region with an acceptance < 75%. Anderson et al.[4] conclude remarking that the gluons have a momentum distribution like that of the valence quarks. In other words, they found that at small x the quark sea dominates the scattering. This is in disagreement with the QCD parametrization of Ref. 8, which is noticeable only at very small x.

Going back to our calculation of structure functions in the Pati - Salam model, we are perhaps inconsistent if we use the QCD distribution of Buras and Gaermes for the region where colour shines, or the novelty here represented by colour. In Ref. 7 there is an estimation of the contribution of colour to F_2 under the assumption of a momentum distribution of gluons like the one of valence quarks. Their result is qualitatively like ours. Thus, if the specific details of how colour appears does not really matters at the very threshold, it means that colour is not appearing coherently but very softly.

Here one is faced with the following situation. Whatever new effect shows up in the structure function F_2, it is unfortunately screened by the main contribution which is presumably given by QCD. Therefore, we consider very convenient the definition[10] of a function A :

$$A = \frac{F_2^{exp}}{F_2^{QCD}} = 1 + \frac{F_2^{new}}{F_2^{QCD}} \qquad (1)$$

In order to illustrate the benefits of performing the analysis in terms of A, we make use again of the Pati - Salam model. This approach contains a threshold function $\rho(Q^2)$, which governs the appearence of colour effects. In

Ref. 11, a step function was used for ρ ; in Ref. 7 a parabola was guessed and in Ref. 9, a soft threshold was introduced. In Table II we show the values of A obtained for the different election above. It seems that as far as Ball et al. data[10] is concerned, the soft threshold is favored. This results disfavors in particular the step function election for ρ and consequently the physical interpretation adscribed to it[11]. However, for the sake our point here, we just want to stress the convenience of using definition (1), instead of F_2 directly, in order to get a deeper physical insight of the data.

We should comment on another difficulty related with the comparison of different experimental data where the parametrization are different even within QCD orthodoxy. The most dramatic difference arises when one compares μ-N with ν-N scattering. Neutrino data contain in general more information at small x values than the muon ones, because of the contribution of the quark-antiquark sea. Thus, one finds that having no general parametrization to be used as a point of reference one should adopt for exemple the one à là Buras and Gaermes found by de Groot et al.[12] as the best available.

We want to stress once again that independently of the reliability of QCD, it is a very useful model which account for the bulk of hadronic matter behaviour probed by leptons.

We restate therefore our algorithm to be used for searching new effects in the structure functions : We use QCD as standard reference point, assume the validity of the Callan-Gross relation and express F_2 in terms of the ratio A defined in Eq. (1).

Independently of the interpretation adscribed to the whole $F_2^{exp} = F_2^{QCD} + F_2^{new}$ one can parametrize now the data and then extrapolate it to other kinematical regions to extract R.

Our endeavours in this undertaking was to provide a standard procedure to extract good information from the experimental data. The algorithm mentioned above, was exemplified in the framework of the Pati - Salam model. Wheather colour really shines in deep inelastic lepton scattering is not the matter of this note. This model was considered as one specific example of a novelty and the proceedure proposed here is a way to analyse it.

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Q^2	$F_2^{QCD}(\mu N)$	$F_2^{QCD}(\mu N)+F_2^{new}(\mu N)$	$R = \sigma_L/\sigma_T$
10	0.281	0.281	0.00
20	0.267	0.361	0.012
30	0.259	0.371	0.023
40	0.254	0.332	0.027
70	0.244	0.281	0.030
100	0.238	0.261	0.030

TABLE I

Q^2 ρ	STEP FUNCTION	PARABOLA	GAUSSIAN
10	1.00	1.00	1.00
20	1.70	1.55	1.35
30	1.44	1.43	1.43
40	1.31	1.31	1.31
70	1.15	1.15	1.15
100	1.10	1.10	1.10

TABLE II

Values of $A^{\mu N}$ defined in Eq. (1), for $x = .16$

R E F E R E N C E S

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