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NONLEADING ENERGY BEHAVIOR AND THE BREAKING OF SCALING IN νW_2 *

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ABSTRACT

A recently proposed Regge model for describing the general features of on and off shell Compton scattering, using a simple form of scale breaking in q^2, is discussed and confronted with recent data. It is suggested that the mass size characteristic of the scale breaking is indicative, as well, of the relative contributions of the pomeron, $f-A_2$ and additional nonleading power behavior. The observed rapid approach to "scaling" in q^2 (at given ν) is seen to require a small characteristic mass which in turn requires a substantial nonleading contribution to the scaling function νW_2. Continuation of the resulting form to on shell scattering predicts a nonleading power contribution to $\sigma_{tot}(\gamma p)$; a recent CMSR analysis is consistent with this prediction.

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In this Letter we wish to point out the gradual accumulation of evidence in support of a fairly simple Reggeisation scheme for describing the main features of both on and off shell Compton scattering. The model incorporates a particularly simple form of scale breaking in the small q^2 region. The evidence also appears to support a substantial nonleading Regge contribution to $F_2(\omega)$ which would be consistent with the presence of a polynomial residue for the right signatured fixed pole[1] at $J = 0$.

In a recent paper[2] we analysed the available data on the electroproduction structure function $\nu W_2(\nu, q^2)$, for both proton and neutron targets, in a Regge model (which incorporates the pomeron, an $f - A_2$ type behavior with pure F coupling and nonleading power behavior $\nu^{-3/2}$) by demanding that the Regge be consistent with

(i) the existence of a fixed pole at $J = 0$ in $\nu T_2^{p,n}$ with residue linear in q^2 and magnitude suggested by the bare Born term (This would be the case if the fixed pole is entirely independent of the strong interactions.)[2,3];

(ii) the magnitude of the $\nu W_2^{p,n}$ data at the largest values of ω for which data is available in the scaling region, and

(iii) the quark model sum rule[4]

$$\int_0^\infty \frac{d\omega}{\omega} \left(F_2^p(\omega) - F_2^n(\omega)\right) = \frac{1}{3} .$$

Actual data were used in the sum rules resulting from (i) and (iii) out to the largest available ω data ($\omega \sim 12$) and for $\omega \gtrsim 12$ the Regge form was used. We found that satisfaction of the above three requirements would be possible if, and only if, a substantial nondiffractive component is present in νW_2 for large ν and q^2. This is contrary to some models[5] but, as pointed out by Gilman[6], the difference between the low energy data on proton and neutron targets and the success of the Bloom-Gilman sum rule[7] suggest the presence of some, perhaps substantial, nondiffractive component and $F_2(\omega)$ falling to less than 0.2 as $\omega \to \infty$. We found that no unique solution for the large ω behavior of $F_2^p(\omega)$ could be obtained by our analysis but we were able to severely limit the possibilities. In particular we obtained the following "typical" solution (the error in the parameters is of the order of 20%)

$$F_2^p(\omega) = 0.12 + 0.462\,\omega^{-1/2} + 4.02\,\omega^{-3/2} . \tag{1}$$

Note that we predict that $F_2^p(\omega)$ will fall significantly from its present maximum ($\sim$ 0.35 at $\omega = 5$). When NAL energies become available it will be possible to test the above prediction for the high energy, large q^2 behavior.

Having once obtained the above form for νW_2 in the scaling region it is desirable to relate it to on-shell Compton scattering. That is, we wish to make an interpolating ansatz for the scale breaking mechanism in the Regge region. The demand that $\nu W_2(\nu, q^2) \xrightarrow{q^2 \to 0} 0$, together with the requirement that as $\nu, q^2 \to \infty$, $\nu W_2(\nu, q^2) \to F_2(\omega)$ suggests the form

$$\nu W_2^p = \frac{q^2}{q^2 + m^2}\left(A + \frac{3B}{\sqrt{\tilde{\omega}}} + \frac{C_p}{\tilde{\omega}^{3/2}}\right) \tag{2}$$

with $\tilde{\omega} = 2M\nu/(q^2 + \mathscr{M}^2)$. (Forms for scale breaking via an $\tilde{\omega}$ such as this have been suggested by a number of authors[8], though by restricting their attention to presently available data, the pomeron and $f - A_2$ dependence are found to be quite large and the nonleading behavior is neglected altogether.)

Assuming such a simplified scale breaking ansatz, the important question is the size of the masses m and $\mathcal{M}$. These determine the relative contributions of pomeron and $f-A_2$ in on-shell $\sigma_{tot}(\gamma p)$ as compared to their relative contributions in the "scaling data" and the rapidity with which the $q^2 = \infty$ value is approached at given ν. The pomeron to $f-A_2$ ratio is roughly 5:3 in $\sigma_{tot}(\gamma p)$, while in the deep inelastic region we arrive at a ratio of roughly 1:4 and as a result both m and $\mathcal{M}$ will be quite small in our work (as compared to other similar parametrisations of this form). We find m = 0.37 GeV and $\mathcal{M} = 0.22$ GeV (we emphasise that these are rough estimates).[9] Thus we would predict that scaling is approached very rapidly as q^2 departs from zero, e.g. for a given ν we find that $\nu W_2(\nu, q^2)$ reaches 90% of its maximum value (at fixed ν) by $q^2 = 1\ (\mathrm{GeV}/c)^2$.

Support for such small masses has recently become available in the report of the SLAC μ-p scattering group.[10] Their results and the magnitudes predicted by our formula (2) are shown in Table 1. If the masses m and $\mathcal{M}$ were not so small the agreement would be lost very quickly. The $q^2 = 0.5$ points are particularly sensitive to $\mathcal{M}$. We note again that the rapid approach of νW_2 to a maximum is due, in our model, to the small mass which is in turn connected with the small ratio of diffractive to nondiffractive contributions in the scaling region so long as one believes that the two characteristic masses should be of the same order of magnitude. A larger pomeron would yield a larger characteristic mass and a slower approach to the maximum in νW_2.

Alto in Table 1 we give older data points from the SLAC electron group and the predictions of Eq. (2). Agreement is not as satisfactory (note that we have in no way tried to "fit" the data). There appear to be systematic discrepancies between the μ-p and electron groups' data at similar values of q^2 and ω which must be resolved before a precise fit would be meaningful.

So far we have avoided the question as to why the nonleading $\nu^{-3/2}$ term, which is necessary if the fixed pole is to have a polynomial residue, has not been seen in $\sigma_{tot}(\gamma p)$. The answer lies in the size of $\mathscr{M}$ which predicts for $\sigma_{tot}(\gamma p)$ the following Regge form[2]

$$\sigma_{tot}(\gamma p) = 100 + \frac{62}{\sqrt{\nu}} + \frac{14}{\nu^{3/2}} \qquad (3)$$

(σ in μb, ν in GeV). The size of the nonleading term's residue makes it obvious that a very sensitive test of the large ν $\sigma_{tot}(\gamma p)$ data is required in order to detect it. Such a test is provided by the continuous moment sum rule analysis recently performed by I. Shibasaki et al.[11] in which they found evidence for a $\nu^{-3/2}$ contribution with residue for $\sigma_{tot}(\gamma p)$ in the range 2 to 13 μb $(\mathrm{BeV})^{3/2}$ [12] which they identify with the P''. Such a term will contribute between 2 and 5 μb to $\sigma_{tot}(\gamma p)$ at $\nu = 1.68$ GeV.

We emphasise that the precise numbers given in this letter are not to be taken too literally, but we do feel that the general picture has considerable support as an overall description of νW_2 in the Regge region particularly with regard to the presence of an important nonleading contribution in νW_2 and the approximate interpolation between on and off shell scattering which predicts that $F_2(\omega)$ at $\omega = 100$ should have roughly the same relative Regge contributions as does $\sigma_{tot}(\gamma p)$ at $\nu \sim 3$ GeV.

An additional test of this picture will be provided by the 4° electron scattering data now being accumulated at SLAC. Data will be obtained in the region $0.1 \lesssim q^2 \lesssim 1\ (\mathrm{GeV}/c)^2$ and $\nu_{threshold} \lesssim \nu \lesssim 18$ GeV. The small q^2 data should, in our picture, be consistent with a very rapid rise toward the eventual scaling value at a given ν. In Figure 1 we exhibit the predicted magnitude of νW_2 in this region.

In conclusion we wish to stress once again that there appears to be evidence for nonleading contributions of importance in $F_2(\omega)$ and that a relatively simple scale breaking Regge form is capable of making this quite consistent with on-shell data and the apparent rapid approach in q^2 of νW_2 to its scaling value at a given value of ν.

It is not impossible, a priori, that the large nonleading term and the rapid approach to scaling are not connected at all; that is m and $\mathcal{M}$ might be quite different (m being small and $\mathcal{M}^2 \approx m_\rho^2$ for instance). The point of this letter is to give credence to the theoretically more palatable idea that they may both be small on the basis of existing experimental data and theoretical biases.

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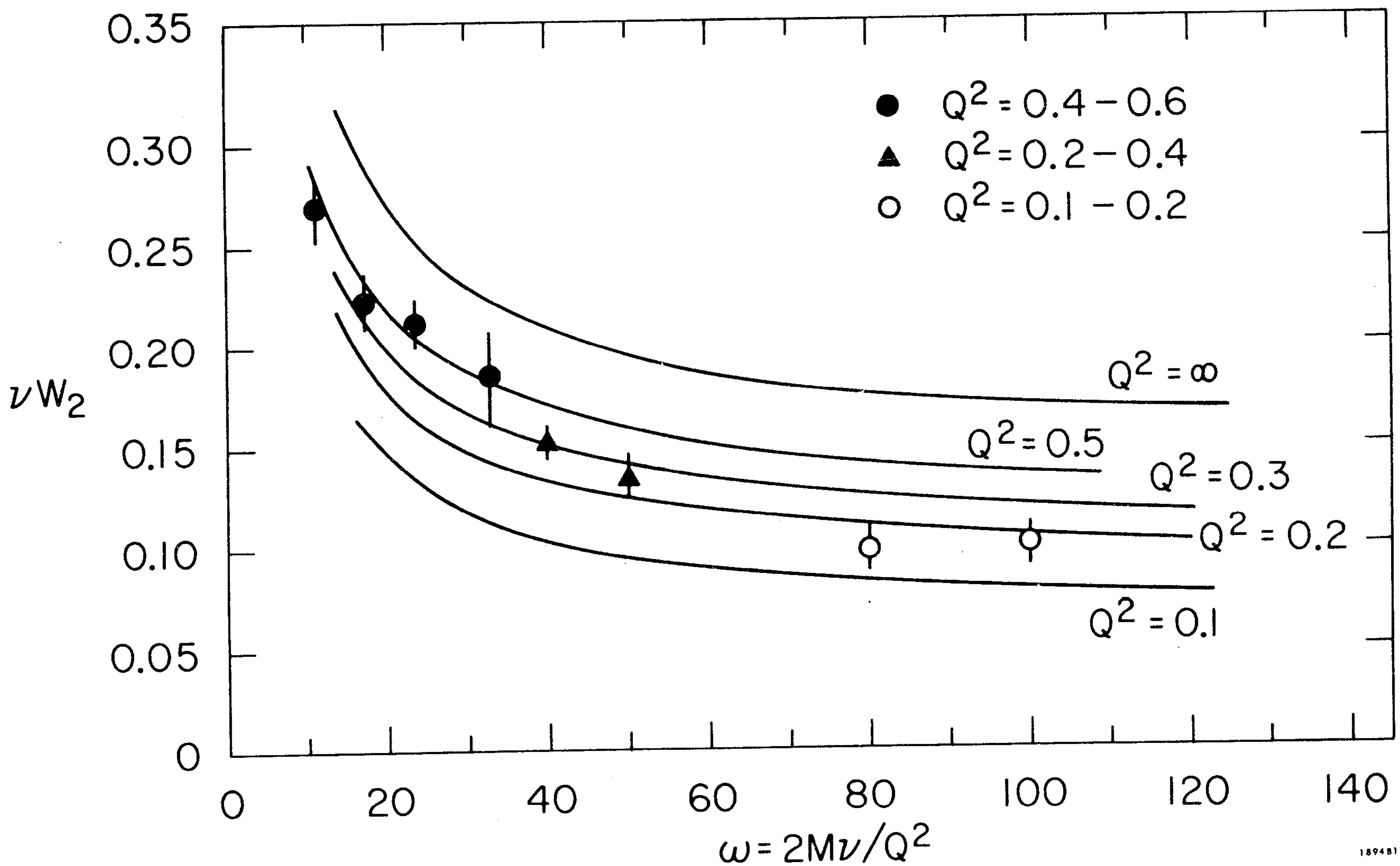
TABLE 1

q^2	$\omega = \frac{2M\nu}{q^2}$	$\nu W_2^{(data)}$	$\nu W_2^{(model)}$
0.1 - 0.2	80	0.098 ± 0.009	0.097
0.1 - 0.2	100	0.101 ± 0.011	0.095
0.3 - 0.4	11	0.233 ± 0.016	0.26
0.35†	13	0.247 ± 0.006	0.25
0.3 - 0.4	17	0.186 ± 0.019	0.21
0.29†	21	0.183 ± 0.01	0.19
0.25 - 0.4	25	0.266 ± 0.016	0.20
0.25†	28*	0.167 ± 0.015	0.17
0.2 - 0.4	40	0.152 ± 0.007	0.152
0.2 - 0.4	50	0.134 ± 0.011	0.14
0.4 - 0.6	11	0.268 ± 0.014	0.28
0.4 - 0.6	17	0.225 ± 0.013	0.24
0.4 - 0.6	24	0.213 ± 0.013	0.205
0.41†	29*	0.22 ± 0.02	0.18
0.4 - 0.6	33*	0.186 ± 0.023	0.187
0.5†	38	0.22 ± 0.04	0.17
0.6 - 0.8	12	0.276 ± 0.024	0.29
0.6†	14.5	0.285 ± 0.014	0.27
0.6 - 0.8	17	0.275 ± 0.026	0.25
0.6 - 0.8	23	0.272 ± 0.041	0.23
0.68†	33	0.25 ± 0.04	0.19
0.8 - 1.2	12	0.301 ± 0.032	0.31
0.8 - 1.0	16	0.236 ± 0.08	0.26
1.0†	19.5	0.28 ± 0.02	0.24

Data from reference 10 for $\omega \gtrsim 11$ and † from the SLAC eletron group for $q^2 < 1.0$ $(\mathrm{GeV/c})^2$. Where data is binned, the νW_2 is calculated at the bin center using Eq. (2) of text. Note that Eq. (2) is NOT a fit to the data but was derived from quite different considerations. The differences between the calculated νW_2 and some of the electron data points really represents inconsistencies between the data of the two groups, and with the electron data itself, e.g. consider the ω values in the range 28-33; the particular example denoted by the asterisks shows that electron groups $\omega = 29$ data point is too high.



0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
νW_2
0
20
40
60
80
100
120
140
$\omega = 2M\nu/Q^2$
$Q^2 = 0.4-0.6$
$Q^2 = 0.2-0.4$
$Q^2 = 0.1-0.2$
$Q^2 = \infty$
$Q^2 = 0.5$
$Q^2 = 0.3$
$Q^2 = 0.2$
$Q^2 = 0.1$
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Fig. 1