XA9643020 IC/96/154

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

RISE IN PROTON STRUCTURE FUNCTION

Fazal–e–Aleem

Haris Rashid

and

Shaukat Ali

INTERNATIONAL ATOMIC ENERGY AGENCY

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

MIRAMARE-TRIESTE

IC/96/154

United Nations Educational Scientific and Cultural Organization
and
International Atomic Energy Agency
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

RISE IN PROTON STRUCTURE FUNCTION[1]

Fazal–e–Aleem[2]
International Centre for Theoretical Physics, Trieste, Italy

Haris Rashid and Shaukat Ali
CHEP, University of the Punjab, Lahore–54590, Pakistan.

ABSTRACT

By the choice of a new scale factor we obtain a good qualitative fit to the HERA data for the proton structure function in the small x region which exhibits double asymptotic scaling. Any scaling violations in the future measurements when made in smaller bins will be of immense value.

MIRAMARE – TRIESTE

August 1996

[1]To appear in Proceedings of the *"Second QMATHIC Conference"*, Department of Physics, Gomal University, Dera Ismail Khan, Pakistan.

[2]Permanent address: CHEP, University of the Punjab, Lahore–54590, Pakistan.
E–mail: aleem@chep.lhr.erum.com.pk

Deep inelastic scattering (DIP) has been a very useful tool in probing the structure of hadrons [1,2]. The discovery of Bjorken scaling in the early sixties gave initial information about the substructure of fundamental particles. Later measurements of DIS helped us develop theoretical framework for QCD, the theory of quarks and gluons. In searching for the structure of hadrons, knowledge of the "structure functions" has played a very important role.

Study of DIP structure functions in the small -x kinematical region at present and future hadron colliders, HERA (Hadron Elektron Ring Anlage), LHC (Large Hadron Collider) and RHIC (Relativistic Heavy Ion Collider) is in the fore front of high energy physics. It has provided us an opportunity for *precise quantitative tests* of QCD. It also provides us an opportunity to search for new physics. By small x we mean that the ratio $x = p_t^2/s$ is much smaller than unity. Here p_t^2 is the the transferred momentum in a process and $\sqrt{s}$ is the c.m. energy. For these small-x processes reliable and accurate theoretical predictions are necessary. The precise measurements of the structure function in the small x-kinematical region [3-7] are of great importance. Very recently, measurements for the structure function have been made by the HERA experiments [6,7], ZEUS and H1. The striking feature of these results is the dramatic rise of proton structure function $F_2^P(x,Q^2)$ with decrease in x or increase in Q^2. The measurements have been made in the unexplored region $10^{-5} \leq x \leq 10^{-2}$ and $5 \leq Q^2 \leq 10^5$ GeV^2 . These results were of great surprise as they one the one hand displayed the expected large violations of the Bjorken scaling which grows larger with decrease in x but also deviated from Regge behaviour which predicts a nearly flat behaviour. Interestingly such a phenomena was predicted by Rujula et al [8] some twenty years ago. It emerges as natural consequence of the leading order renormalization group equations of pQCD.

Concept of *scaling*, has been beautifully exploited in DIP as we believe that when the momentum carried by the probe becomes very large, the dependence of the cross section on energy and momentum becomes very simple. Very useful results have thus been deduced in the parton model from such simple scattering behaviour as a consequence of scaling. It is known that main evidence for the pQCD for large x comes from the small violations of Bjorken scaling in the structure function F_2 (x;t) in the Bjorken limit of large $t \equiv \ln Q^2/\Lambda^2$ at fixed x. In an effort to give theoretical explanation of this unusual phenomena in the small x region, Ball et al [9-12] have shown that this non-Regge rise takes the form of a simple universal scaling law satisfied by $F_2(x, Q^2)$ at large Q^2 and small x.

It has been shown [12] that in the double limit of large t and small x, perturbative QCD makes definite scaling predictions by assuming the gluon distribution at scales of order 1 GeV to be reasonably soft at small x. They thus incorporate soft Pomeron [13] with intercept close to unity. We have extended the same concepts so as to give a *quantitative* agreement, which is essential for the stringent test of QCD, with the most recent HERA data on the proton structure function.

For sufficiently large Q^2 and small x, perturbative QCD predicts that the nucleon structure function should exhibit scaling in the two variables σ and ρ provided the small-x behaviour of the input to the perturbative QCD evolution is sufficiently soft. The *geometric mean* σ and the *ratio* ρ are defined by the equations

$$\sigma \equiv [\ln (x_0/x) \ln (a/a_0)]^{1/2}$$

$$\rho \equiv [\ln (x_0/x) / \ln (a/a_0)]^{1/2}$$

where $a \equiv \ln(Q^2/\Lambda^2)$. These asympotatic results have been derived [12] by writing the gluonic Altareli-Parisi equation at small x as a two dimensional wave equation, which propagates the gluonic distribution from its boundaries into the asymptotic region. These authors have scaled the structure function F_2^P by using a single multiplicative factor $R'_F \equiv N\sigma^{1/2}\rho e^{\delta\sigma/\rho}$; where $\delta = 61/45$. They have plotted $R'_F F_2^P$ on a logarithmic scale against the variable σ which is shown in Fig. 1. It has two characteristics:

1. when σ is large enough, all the data lie on a single line, quite independently of the value of ρ provided ρ is large enough.
2. On a logarithmic scale, the rise of rescaled proton structure function with σ is linear. The slope of the line is 2.37 ± 0.16.

The results of their computation as shown in Fig.1 are for $\rho = 1.4$, 2.2 and 3.2. It is observed that a good *qualitative* agreement with the recent HERA data is obtained. However we noticed that the rescaling of the proton structure function by Ball and Forte [12] do not place the experimental points on a straight line for $\sigma \leq 1.1$ where the measurements of x have been made to $\sigma = 0.2$. In order to get a *quantitative* agreement with the experimental data up to $\sigma = 0.2$, we propose a new scaling factor R''_F . Fig. 2 shows the proton structure function multiplied by a new scaling factor of $R''_F = R'_F\ e^{|2.2-\sigma|/4}$. It is evident from this figure that this choice of the scaling factor yields a *quantitative* fit to the experimental data.

Fig. 3 for D^o shows the proton structure function scaled by a factor $R_F \equiv e^{-2\gamma\sigma} R'_F$, $\gamma = 1.2$, plotted against σ on a linear scale and for values of ρ equal to 1.4, 2.2 and 3.2. Again we find only a good *qualitative* agreement with the experimental data. Similar is the case for the result for D^- which is shown in Fig. 4. Again a good *qualitative* results are obtained, if the rescaling is done by choosing a factor 0.7 R_F for D^o and 0.6 R_F for D^-. The computed results are shown in Figs. 5 and 6.

We thus find that on the whole a good quantitative agreement is obtained by the choice of rescaled structure function. It appears that the role which is played by gluon decays into gluons and quark anti-quark pairs can not be ignored. The importance of the splitting functions P_{gg} (x) and P_{gq} (x) is also to be projected as x goes to zero. In fact we have to determine at least in principle the behaviour of the gluon evolution equation at x in terms of light cone variable with a negative mass term [8,10,14].

It may be pointed out that our choice of the scaling factor is such that almost all the data even for very small values of x falls on the same line. It is for this reason that we choose Q_0 = 1 GeV. A different choice of Q_0 would have meant scaling violation which do not occur in the data. Flat curves in Figs. 5 and 6 indicate that the conventional Regge behaviour completely dominates the structure function as scaled in this paper. But a careful examination of the experimental data shows that higher twist corrections [15-19] to the structure function may be important while deriving the final conclusion. In fact the rescaling as done by us may give new dimension in understanding essential physics involving the rise in x.

ACKNOWLEDGMENT

One of us (FA) wishes to gratefully acknowledge the financial assistance from Pakistan Science Foundation. Hospitality at the International Centre for Theoretical Physics, Trieste, Italy under associateship scheme is also gratefully acknowledged. We (HR & SA) also wish to thank the organizing committee of "QMATHIC" and specially Prof. A. Waheed for warm hospitality extended at the University of Gomal, Dera Ismail Khan, Pakistan.

REFERENCES

1. G. Altarelli, Phys. Rep. **81**, 1 (1981)
2. Anselmino et al., Phys. Rep. **261**, 4 (1995).
3. A. Goussiou et al., DESY preprint F35D-95-13 (1996).
4. S. A. Guivitz Phys. Rev. **D52**, 1433 (1995).
5. F. Eisele, Summary talk at the Europhys. Conf. , Brussels, August 1995.
6. ZEUS Collaboration, Phys. Lett. **B316**, 412 (1993); Z. Phys. **C65**, 379 (1995).
7. H1 Collaboration, Nucl. Phys. **B407**, 515 (1993); **B439**, 471 (1995).
8. A. De Rujula et al, Phys. Rev. **D10** 1649 (1974).
9. R.D. Ball and S. Forte, Phys. Lett. **B358**, 365 (1995).
10. R.D. Ball and S. Forte, Nucl. Phys. **B39** (proceeding supplement), 25 (1995).
11. R.D. Ball and S. Forte, Acta Physica Polinica **B26**, 2097 (1995).
12. R.D. Ball and S. Forte, Phys. Lett. **B336**, 77 (1994); **B336**, 77 (1994).
13. A. Donnachie and P.V. Landshoff, Nucl. Phys. **B244**, 322 (1984); **B267**, 690 (1986).
14. A.D. Martin et al, Phys. Lett. **B306** (1993) 145.
15. T. Jaroszewics, Phys. Lett. **B116** (1982) 291
16. S.Catani & F. Hautmann, Phys. Lett. **B315** (1993) 157, Cavendish-HEP-94-01.
17. R.K. Ellis et al, Nucl. Phys. **B420** (1994)517.
18. J. Kwiecinski, Z. Phys. **29** (1985) 147.
19. A.H. Mueller & J. Qiu, Nucl. Phys. **B268** (1986) 427.

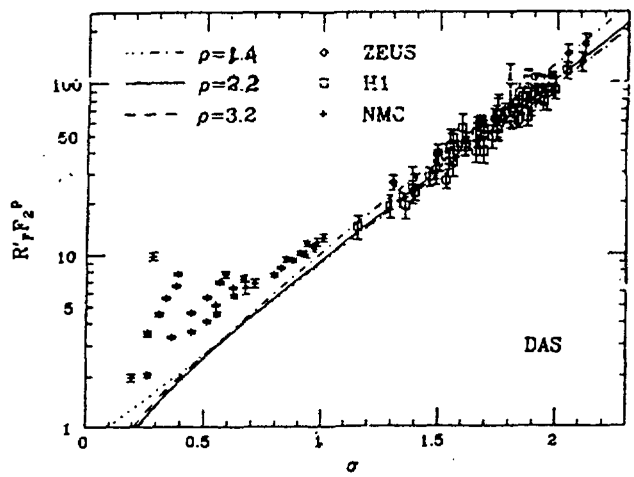


Fig. 1

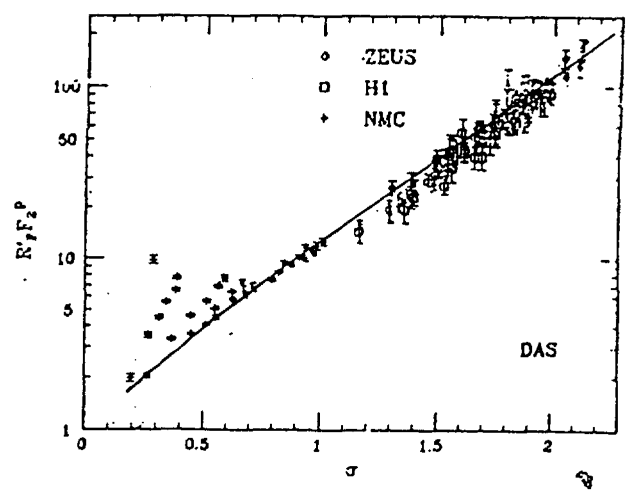
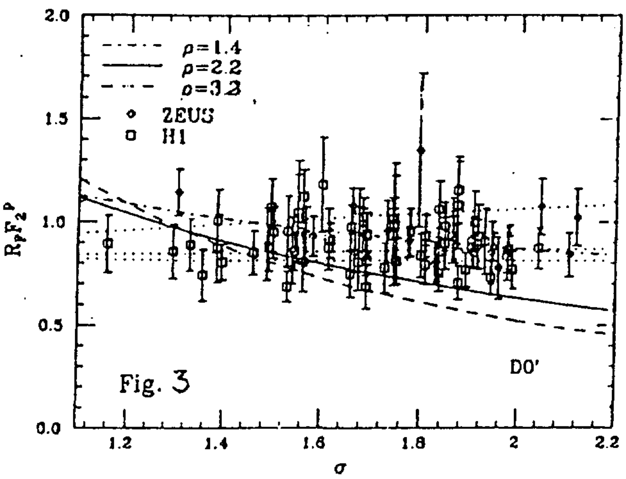
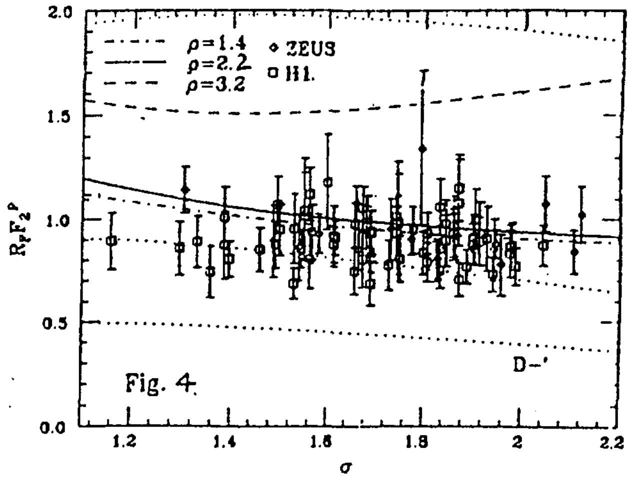


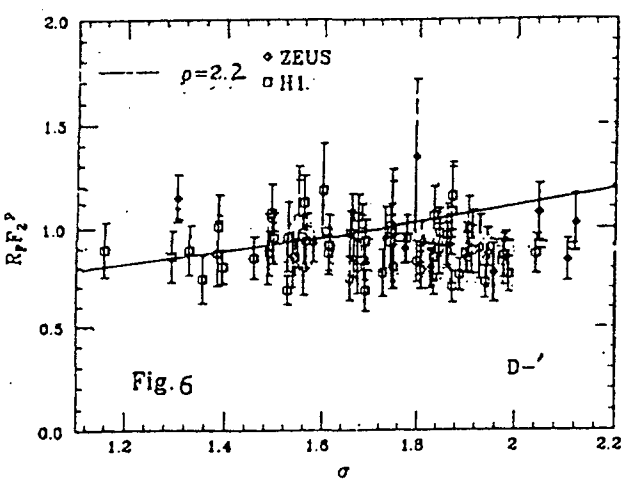
Fig. 2

Fig.1 The rise in F_2^p: $R'_F F_2^p$ vs σ along with the fitted curve as given in ref.[12].

Fig.2. The experimental data with the curve drawn with new scaling factor.







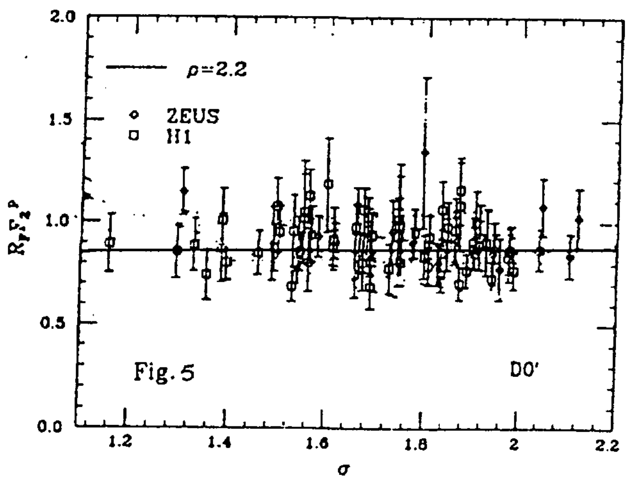


Fig.3.	Scaling plots of $R_F F_2^p$ vs. σ. The curves are those of the MRS parton distributions $D^{0'}$.
Fig.4.	As fig. 3, but with the curves now corresponding to $D^{-'}$.
Fig.5&6.	The experimental data along with the curves according to new scaling factor.