Ref.Th.2970-CERN

ON RECENT EVIDENCE FOR HIGHER TWIST EFFECTS
IN SEMI-INCLUSIVE DEEP INELASTIC NEUTRINO SCATTERING

P. Mazzanti

Istituto di Fisica and INFN, Bologna

R. Odorico

CERN--Geneva

Istituto di Fisica and INFN, Bologna

V. Roberto^{*)}

CERN--Geneva

Istituto di Fisica Teorica and INFN, Trieste

ABSTRACT

We discuss recent experimental evidence for higher-twist contributions in $\nu N \rightarrow \mu^- h^+ X$. We show that the observed effects are equally well reproduced by a longitudinal phase space model, with no free parameters. With an antineutrino beam instead the corresponding effect predicted by the LPS model is found to be opposite to that expected from the high-twist calculation, and thus a cleaner test of the theory is possible.

^{*)} "Angelo Della Riccia" foundation Fellow.

The effects of $1/Q^2$ corrections (higher-twist terms) to perturbative QCD may be, in principle, quite important in the evolution of structure functions up to moderate values of Q^2 ¹⁾. These contributions may be responsible for the somewhat different values of Λ (the parameter in the QCD running coupling constant α_s) which result from the analysis of deep inelastic scattering experiments covering different intervals of Q^2 [see, e.g., Ref. 2)].

Brodsky and Lepage ³⁾ have developed a systematic method for incorporating the corresponding hadronic binding effects in QCD perturbative calculations for a variety of processes. Applying such a procedure to $\pi N \rightarrow \mu^+ \mu^- + X$, Berger and Brodsky ⁴⁾ have predicted a dominant longitudinal polarization of the massive virtual photon at large x_F , which appears to be in some agreement with the data ⁵⁾. More recently, Berger ⁶⁾ has investigated high-twist phenomena in semi-inclusive deep inelastic processes $\ell N \rightarrow \ell' \pi X$, and predicted joint correlations in the variables $y = E_H/E_\ell$ and $z = E_\pi/E_H$. Evidence supporting these predictions has been presented at the Madison Conference by the CERN-Milan-Orsay collaboration, from neutrino data ($\bar{\nu} N \rightarrow \mu^- \pi^+ X$) collected in the Gargamelle bubble chamber ⁷⁾.

Because of the role of higher-twist corrections in the quantitative verification of perturbative QCD, it is of course important to clarify whether such a theoretical approach really provides a genuine dynamical understanding of the observed subasymptotic effects. In this note we discuss in some detail the $y - z$ correlations for semi-inclusive neutrino deep inelastic scattering reported in Ref. 7). We show that a conventional longitudinal phase space (LPS) model, with no free parameters, is able to reproduce quite well the observed effects, without need of a more specific dynamical scheme. More interestingly, we show that when the beam is changed from neutrinos to antineutrinos, the higher-twist calculation of Ref. 6) predicts an effect which is opposite to that expected from the LPS. Therefore, data for $\bar{\nu} N \rightarrow \mu^+ \pi^- X$ will provide a cleaner test of this theoretical approach.

According to the calculations of Ref. 6) bound state effects should produce, for modest values of Q^2 or for large z , a significant non-factorizing, non-scaling term in the doubly differential distribution in y and z . For $\nu p \rightarrow \mu^- \pi^+ X$ one obtains ⁶⁾:

$$z \sigma(z, y, Q^2) \propto (1-z)^2 + \frac{4}{9}(1-y)(p_T^2/Q^2) \quad (1)$$

And for $\bar{\nu} p \rightarrow \mu^+ \pi^- X$:

$$z \sigma(z, y, Q^2) \propto (1-z)^2 (1-y)^2 + \frac{4}{9}(1-y)(p_T^2/Q^2) \quad (2)$$

(The contribution from antiquarks in the target is neglected). The non-factorizing term should be negligible for $\pi^-(\pi^+)$ in $\nu(\bar{\nu})$ scattering. For neutrinos, a consequence of Eq. (1) is that the z distribution for low y is harder than that for high y , at low enough Q^2 (Fig. 1)^{*)}. This qualitatively agrees with what is observed experimentally (Fig. 2).

The LPS model we consider⁸⁾ is characterized by the following features:

- (i) hadrons are emitted independently in the current-target c.m.s. with flat rapidity distribution for mesons and flat x_F distribution for the recoil nucleon;
- (ii) input average multiplicities for the various meson species are taken from the data;
- (iii) transverse momentum distributions obey an $\exp(-6m_T)$ law;
- (iv) after the final state is generated by independent emission (with the correct charge balance), four-momentum conservation is restored by means of a simple algorithm.

The LPS model reproduces quite well the $y - z$ non-factorization effect observed for $\nu N \rightarrow \mu^- h^+ X$ ⁷⁾ (see curves in Fig. 2). Its origin in the model is a simple one. At low y (and then low c.m.s. energy) low multiplicities dominate, and therefore the probability that a hadron takes a large fraction of the available energy increases. As a consequence, the z distribution becomes harder. Because of the charge balance, in neutrino events low multiplicities contribute by far more positive than negative hadrons. The effect is therefore negligible for negative hadrons, as in the high-twist calculation^{**)}.

For antineutrinos, the LPS predicts qualitatively the same effect for negative hadrons ($\bar{\nu} N \rightarrow \mu^+ h^- X$, see Fig. 3). But the high-twist calculation⁶⁾ predicts now an exactly opposite effect (z distribution harder at high y than at low y), because of the additional $(1 - y)^2$ factor present in the main (low-twist) term of Eq. (2) (Fig. 1).

The curves of Fig. 1 are calculated taking $\langle p_T^2 \rangle = 1.94 \text{ (GeV/c)}^2$, which

*) Another way of putting in evidence the non-factorizing term is to consider the associate change in shape of the y distribution when moving from low to high z . Radiative corrections, however, may affect this kind of test.

***) For neutrinos, about half of the effect is actually due to recoil protons counted in $Dh^+(z)$. This contribution is, of course, absent for antineutrinos.

results from a fit to neutrino data⁷⁾ and assuming that $\int z D(z) dz$ is independent of the y range. Over-all scales are arbitrary. (The rather large value of $\langle p_T^2 \rangle$ may be interpreted as effectively including omitted mass terms⁶⁾).

In conclusion, the higher-twist prediction for $y - z$ non-factorization in $\nu N \rightarrow \mu^- \pi^+ X$ coincides with what is anyway expected from conventional ("low p_T ") dynamics. A real test is offered by $\bar{\nu} N \rightarrow \mu^+ \pi^- X$, where the corresponding expectations are mutually opposite. The answer should be available soon from antineutrino experiments performed in bubble chambers, which are now in the process of being analysed⁹⁾.

ACKNOWLEDGEMENTS

We would like to thank P. Renton for kindly allowing us to use his LPS FORTRAN programme, and F. Baldracchini who contributed at the early stages of this work.

One of us, V.R., wishes to acknowledge a number of clarifying conversations with A. Pullia on the data of the CERN-Milan-Orsay collaboration. Some useful remarks by A. De Rujula are also appreciated.

REFERENCES

1. L.F. Abbott and R.M. Barnett, Ann. Phys. 125 (1980) 276.
2. F. Sciulli, rapporteur talk at the XX International Conference on High Energy Physics, Madison (1980).
3. S.J. Brodsky and G.P. Lepage, SLAC-PUB-2478 (1980) and references therein.
4. E.L. Berger and S.J. Brodsky, Phys. Rev. Lett. 42 (1979) 940.
5. K.J. Anderson et al., Phys. Rev. Lett. 43 (1979) 1219;
M. Corden et al, CERN-EP/80-152 (1980);
J. Lefrançois, rapporteur talk at the XX International Conference on High Energy Physics, Madison (1980).
6. E.L. Berger, Phys. Lett. 89B (1980) 241.
7. CERN-Milan-Orsay collaboration, CERN-EP/80-124 (1980), and paper presented (by C. Matteuzzi) at the XX International Conference on High Energy Physics, Madison (1980).
8. P. Renton, private communication.
9. Fermilab-Serpukhov-Moscow-Michigan collaboration, Fermilab preprint PUB-80-62-Exp (1980) and references therein;
Amsterdam-Bologna-Padova-Pisa-Saclay-Torino collaboration, paper contributed to the XX International Conference on High Energy Physics, Madison (1980).

FIGURE CAPTIONS

- Fig. 1 : Expectations from high-twist effects for the z $D(z)$ distributions in $\nu N \rightarrow \mu^- \pi^+ X$ and $\bar{\nu} N \rightarrow \mu^+ \pi^- X$. The calculation of Ref. (6) is integrated with a fit to neutrino data⁷⁾. Over-all scales are arbitrary.
- Fig. 2 : Comparison of the predictions of the LPS model with experimental data⁷⁾ for $D(z)$ in $\nu N \rightarrow \mu^- h^+ X$ at low Q^2 and with different cuts in y .
- Fig. 3 : Predictions of the LPS model for $D(z)$ in $\bar{\nu} N \rightarrow \mu^+ h^- X$ at low Q^2 and with different cuts in y .

Fig. 1

Fig. 2

Fig. 3