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RECENT STRUCTURE FUNCTION RESULTS FROM CCFR

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A new structure function analysis of CCFR deep inelastic ν-N and $\overline{\nu}$-N scattering data is presented for previously unexplored kinematic regions down to Bjorken $x = 0.0045$ and $Q^2 = 0.3$ GeV^2. Comparisons to charged lepton scattering data from NMC[1] and E665[2] experiments are made and the behavior of the structure function F_2^ν is studied in the limit $Q^2 \to 0$.

Neutrino structure function measurements in the low Bjorken x, low Q^2 region can be used to study the axial-vector component of the weak interaction as well as to test the limits of parton distribution universality. We present a first measurement of the structure function F_2 in neutrino scattering, from the CCFR data, for $Q^2 < 1$ GeV^2 and $0.0045 < x < 0.035$. In this region where perturbative and non-perturbative QCD meet, we present a parameterization of the data which allows us to test the partially conserved axial current (PCAC) limit of F_2 in neutrino scattering.

The universality of parton distributions can be tested by comparing neutrino scattering data to charged lepton scattering data. Past measurements for $0.0075 < x < 0.1$ and $Q^2 > 1.0$ GeV^2 have indicated that F_2^ν differs from F_2^μ by 10-15%[3]. This discrepancy has been partially resolved by recent analyses of F_2^ν at $Q^2 > 1.0$ GeV^2 [4,5]. While we expect and have now observed that

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parton distribution universality holds in this region, this need not be the case at lower values of Q^2. Deviations from this universality at lower Q^2 are expected due to differences in vector and axial components of electromagnetic and weak interactions. In particular, the electromagnetic interaction has only a vector component while the weak interaction has both vector and axial-vector components. Vector currents are conserved (CVC) but axial-vector currents are only partially conserved (PCAC). Adler[6] proposed a test of the PCAC hypothesis using high energy neutrino interactions, a consequence of which is the prediction that F_2 approaches a non-zero constant as $Q^2 \to 0$ due to U(1) gauge invariance. A determination of this constant is performed here by fitting the low Q^2 data to a phenomenological curve developed by Donnachie and Landshoff[7].

In previous analyses a slow rescaling correction was applied to account for massive charm effects. This is not applied here since the corrections are model dependent and uncertain in this kinematic range. As a result, neutrino and charged lepton DIS data must be compared within the framework of charm production models, accomplished by plotting the ratio of data to theoretical model. The theoretical calculation corresponding to the CCFR data employs NLO QCD including heavy flavor effects as implemented in the TR-VFS(MRST99) scheme [8,9]. The theoretical calculation corresponding to NMC and E665 data is determined using TR-VFS(MRST99) for charged lepton scattering. Other theoretical predictions such as ACOT-VFS(CTEQ4HQ) [10,11] and FFS(GRV94) [12] do not significantly change the comparison. For acceptance, smearing, and radiative corrections we chose an appropriate model for the low x, low Q^2 region, the GRV[13] model of the parton distribution functions. The GRV model is used up to $Q^2 = 1.35$ GeV^2 where it is normalized to a LO parameterization [14] used above this. Finally, a correction is applied for the difference between xF_3^{ν} and $xF_3^{\overline{\nu}}$, determined using a LO calculation of $\Delta xF_3 = xF_3^{\nu} - xF_3^{\overline{\nu}}$. The recent CCFR ΔxF_3 measurement[4] is higher than this LO model[14] and all other recent LO and NLO theoretical predictions in this kinematic region. An appropriate systematic error is applied to account for the differences between the theory and this measurement.

The combination of the inclusion of the GRV model at low x and low Q^2, its effect on the radiative corrections, and removal of the slow rescaling correction help to resolve the longstanding discrepancy between the neutrino and charged lepton DIS data above $x = 0.015$. F_2 is plotted in Figure 1. Errors are statistical and systematic added in quadrature. A line is drawn at $Q^2 = 1$ GeV^2 to highlight the kinematic region this analysis accesses. Figure 2 compares F_2 (data/theoretical model) for CCFR, NMC, and E665. There is agreement to within 5% down to $x = 0.0125$. Below this, as x decreases, CCFR F_2 (data/theory) becomes systematically higher than NMC F_2 (data/theory). Differences between scattering via the weak interaction and via the electromagnetic interaction as $Q^2 \to 0$ may account for the disagreement in this region.

In charged lepton DIS, the structure function F_2 is constrained by gauge invariance to vanish with Q^2 as $Q^2 \to 0$. Donnachie and Landshoff predict that in the low Q^2 region, F_2^{μ} will follow the form[7]:

$$C\left(\frac{Q^2}{Q^2 + A^2}\right). \tag{1}$$

However, in the case of neutrino DIS, the axial component of the weak interaction may contribute a nonzero component to F_2 as Q^2 approaches zero. Donnachie and Landshoff predict that F_2^{ν} should follow a form with a non-zero contribution at $Q^2 = 0$:

$$\frac{C}{2}\left(\frac{Q^2}{Q^2 + A^2} + \frac{Q^2 + D}{Q^2 + B^2}\right). \tag{2}$$

Using NMC and E665 data, corrected in this case to be equivalent to scattering from an iron target using a parameterization of SLAC Fe/D data[15], we do a combined fit to the form predicted

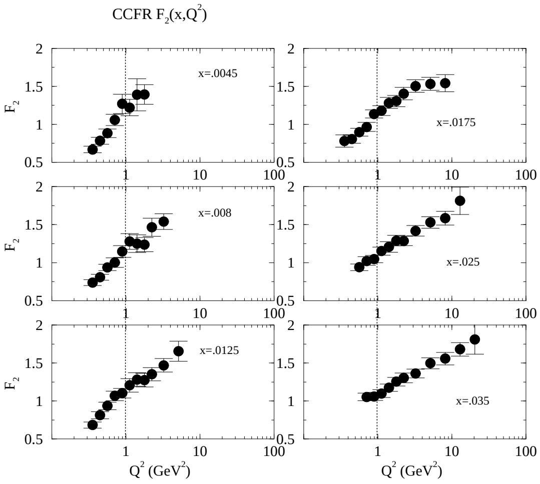

Figure 1: CCFR F_2 at low x, low Q^2. Data to the left of the vertical line at $Q^2 = 1.0$ represent the new kinematic regime for this analysis.

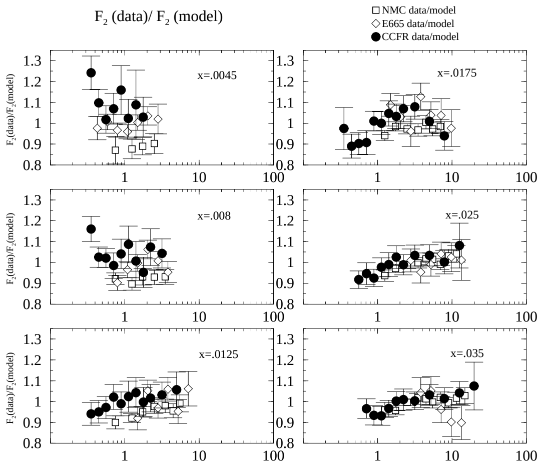

Figure 2: F_2 data/theory from CCFR ν-Fe DIS compared to F_2 from NMC and E665 DIS. Errors bars are statistical and systematic added in quadrature. Theoretical predictions are those of TR-VFS(MRST99).

for μ DIS and extract the parameter $A = 0.81 \pm 0.02$ with $\chi^2/DOF = 27/17$. The error on A is incorporated in the systematic error on the final fit. Inserting this value for A into the form predicted for νN DIS, we fit CCFR data to extract parameters B, C, and D, and determine the value of F_2 at $Q^2 = 0$. Only data below $Q^2 = 1.4$ GeV^2 are used in the fits. The CCFR x-bins that contain enough data to produce a good fit in this Q^2 region are $x = 0.0045$, $x = 0.0080$, $x = 0.0125$, and $x = 0.0175$. Figure 3 and Table 1 show the results of the fits. Error bars consist of statistical and systematic terms added in quadrature but exclude an overall correlated normalization uncertainty of 1-2%. The values of F_2 at $Q^2 = 0$ GeV^2 in the three highest x-bins are statistically significant and are within 1σ of each other. The lowest x bin has large error bars but is within 1.5σ of the others. Taking a weighted average of the parameters B, C, D, and F_2 yields $B = 1.53 \pm 0.02, C = 2.31 \pm 0.03, D = 0.48 \pm 0.03$, and $F_2(Q^2 = 0) = 0.21 \pm 0.02$. Figure 4 shows $F_2(Q^2 = 0)$ for the different x bins. Inclusion of an x dependence of the form x^β does not change the overall fits or χ^2s. However, the Donnachie and Landshoff mass parameter, B, appears to depend on x, with higher values corresponding to higher x. Thus, F_2 at higher x approaches $F_2(Q^2 = 0)$ more slowly than at lower x.

In summary, a comparison of F_2 from neutrino DIS to that from muon DIS shows good agreement above $x = 0.0125$, but shows differences at smaller x. This low x discrepancy can be explained by the different behavior of F_2 from ν DIS to that from e/μ DIS as $Q^2 \to 0$. CCFR F_2^ν data favors a non-zero value for F_2 as $Q^2 \to 0$.

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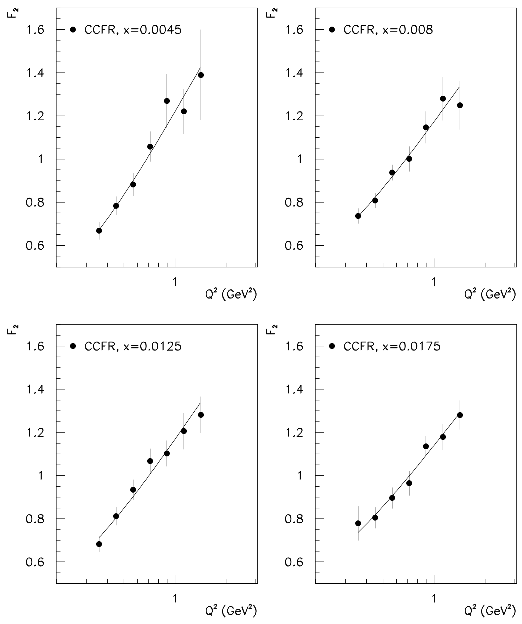
Table 1: Fit results for CCFR data. CCFR data is fit to Eq. 4 with $A = 0.81 \pm 0.02$ as determined by fits to NMC and E665 data. B, C, D, and F_2 at $Q^2 = 0$ results shown below. $N = 4$ for all fits.

x	B	C	D	$F_2^\nu(Q^2 = 0)$	χ^2/N
0.0045	1.49 ± 0.02	2.62 ± 0.26	0.06 ± 0.17	0.04 ± 0.10	0.5
0.0080	1.63 ± 0.05	2.32 ± 0.05	0.50 ± 0.05	0.22 ± 0.03	0.5
0.0125	1.63 ± 0.05	2.39 ± 0.05	0.40 ± 0.05	0.18 ± 0.03	1.0
0.0175	1.67 ± 0.05	2.20 ± 0.05	0.65 ± 0.07	0.26 ± 0.03	0.5



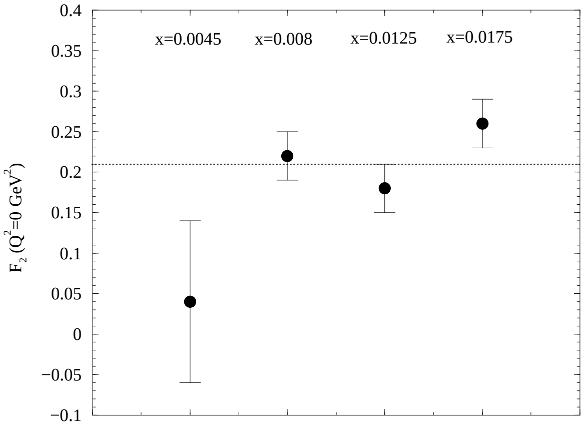


Figure 4: $F_2(Q^2 = 0 \text{ GeV}^2)$ from different x bins. A line is drawn at the weighted average of all four measurements.

Figure 3: Results from fit to CCFR data to extrapolate to $F_2(Q^2 = 0)$.

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