FERMILAB-CONF-00-0426-PPD

Recent structure function results from neutrino scattering at Fermilab [*]

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We report on the extraction of the structure functions F_2 and $\Delta xF_3 = xF_3^{\nu} - xF_3^{\overline{\nu}}$ from CCFR ν_μ-Fe and $\overline{\nu}_\mu$-Fe differential cross sections. The extraction is performed in a physics model independent (PMI) way. This first measurement of ΔxF_3, which is useful in testing models of heavy charm production, is higher than current theoretical predictions. The ratio of the F_2 (PMI) values measured in ν_μ and μ scattering is in agreement (within 5%) with the NLO predictions using massive charm production schemes, thus resolving the long-standing discrepancy between the two sets of data. In addition, measurements of F_L (or, equivalently, R) and $2xF_1$ are reported in the kinematic region where anomalous nuclear effects in R are observed at HERMES. [Preprint UR-1614, ER/40685/952]

Deep inelastic lepton-nucleon scattering experiments have been used to determine the quark distributions in the nucleon. However, the quark distributions determined from μ and ν experiments[1,2] were found to be different at small values of x, because of a disagreement in the extracted structure functions. Here, we find that the neutrino-muon difference is resolved by extracting the ν_μ structure functions from CCFR neutrino data in a physics model independent (PMI) way. In addition, measurements of ΔxF_3, F_L, and $2xF_1$ are presented.

The sum of ν_μ and $\overline{\nu}_\mu$ differential cross sections for charged current interactions on an isoscalar target is related to the structure functions as follows:

$$\begin{aligned} F(\epsilon) &\equiv \left[\frac{d^2\sigma^{\nu}}{dxdy} + \frac{d^2\sigma^{\overline{\nu}}}{dxdy}\right] \frac{(1-\epsilon)\pi}{y^2 G_F^2 M E_\nu} \\ &= 2xF_1[1+\epsilon R] + \frac{y(1-y/2)}{1+(1-y)^2}\Delta xF_3. \end{aligned} \quad (1)$$

Here G_F is the Fermi weak coupling constant, M is the nucleon mass, E_ν is the incident energy, the scaling variable $y = E_h/E_\nu$ is the fractional energy transferred to the hadronic vertex, E_h is the final state hadronic energy, and $\epsilon \simeq 2(1-y)/(1+(1-y)^2)$ is the polarization of the virtual W boson. The structure function $2xF_1$ is expressed in terms of F_2 by $2xF_1(x,Q^2) = F_2(x,Q^2) \times \frac{1+4M^2x^2/Q^2}{1+R(x,Q^2)}$, where Q^2 is the square of the four-momentum transfer to the nucleon, $x =$

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[*] To be published in proceedings of the XXXth INternational Conferencee on High Energy Physics, Osaka, Japan, July, 2000

This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.

$Q^2/2ME_h$ is the fractional momentum carried by the struck quark, and $R = \frac{\sigma_L}{\sigma_T}$ is the ratio of the cross-sections of longitudinally- to transversely-polarized W bosons. The ΔxF_3 term, which in leading order $\simeq 4x(s-c)$, is not present in the μ-scattering case. In addition, there is a threshold suppression originating from the production of heavy c quarks in a ν_μ charged current interaction with s quarks. For μ-scattering, there is no suppression for scattering from s quarks, but more suppression when scattering from c quarks.

In previous analyses of ν_μ data[2], structure functions were extracted by applying a slow rescaling correction to correct for the charm mass suppression in the final state. In addition, the ΔxF_3 term from a leading order charm production model was used as input in the extraction. These resulted in physics model dependent (PMD) structure functions[2]. In the new analysis reported here, slow rescaling corrections are not applied. ΔxF_3 and F_2 are extracted from two-parameter fits to the $F(\epsilon)$ distributions according to Eq. (1). However, in the $x > 0.1$ region, we extract values of F_2 with ΔxF_3 constrained to the NLO TR-VFS(MRST)[3] predictions. Since ΔxF_3 for $x > 0.1$ is small, the extracted values of F_2 are insensitive to ΔxF_3.

Fig. 1(left) shows the extracted values of ΔxF_3 as a function of x (above $Q^2 = 1$), including both statistical and systematic errors, compared to various theoretical methods for modeling heavy charm productions within a QCD framework. Fig. 1(right) shows the sensitivity to the choice of scale. With reasonable choices of scale, all the theoretical models yield similar results. However, at low Q^2, our ΔxF_3 data are higher than all theoretical models.

Our F_2 (PMI) measurements divided by the NLO TR-VFS(MRST) predictions are shown in Fig. 2(left). Also shown are F_2^μ and F_2^e divided by the theory predictions. Nuclear effects, target mass, and higher twist corrections are included in the calculation. As shown in Fig. 2, within 5% both the neutrino and muon structure functions are in agreement with the NLO TR-VFS(MRST) predictions, and therefore in agreement with each other, thus resolving the long-standing discrepancy between the two sets of data. A comparison using the NLO ACOT-VFS(CTEQ4HQ)[4] predictions yields similar results. Note that previously there was up to a 20% difference between the CCFR F_2 (PMD) and NMC data at $x = 0.015$, as shown in Fig. 2(right).

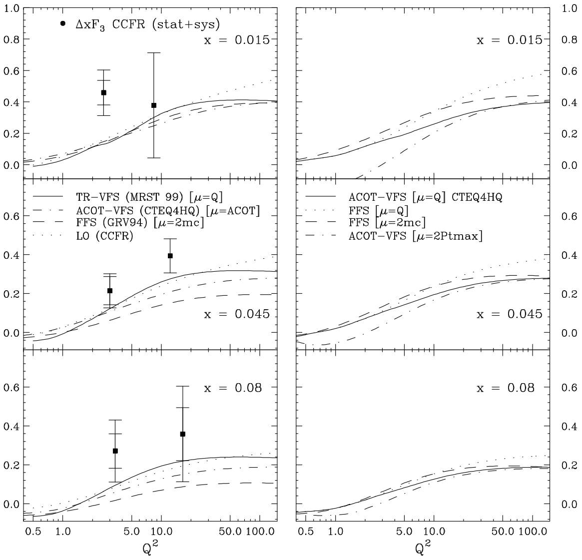

Figure 1. ΔxF_3 data as a function of x (above $Q^2 = 1$) compared with various schemes for massive charm production. (Left) TR-VFS(MRST99), ACOT-VFS(CTEQ4HQ), FFS(GRV94), and the CCFR-LO (a leading order model with a slow rescaling correction): (right) sensitivity of the theoretical calculations to the choice of scale.

Recently, there has been a renewed interest in R at small x and $Q^2 < 1$, because of the large anomalous nuclear effect that has been reported by the HERMES experiment[5]. Their measurement implies a large enhancement in F_L but suppression in $2xF_1$ in heavy nuclear targets. It is expected that any nuclear effect in R would be enhanced in the CCFR iron target with respect to the nitrogen target in HERMES, unless the origin of this effect depends on the incident probe (electron versus neutrino).

Values of F_L and $2xF_1$ are extracted from the

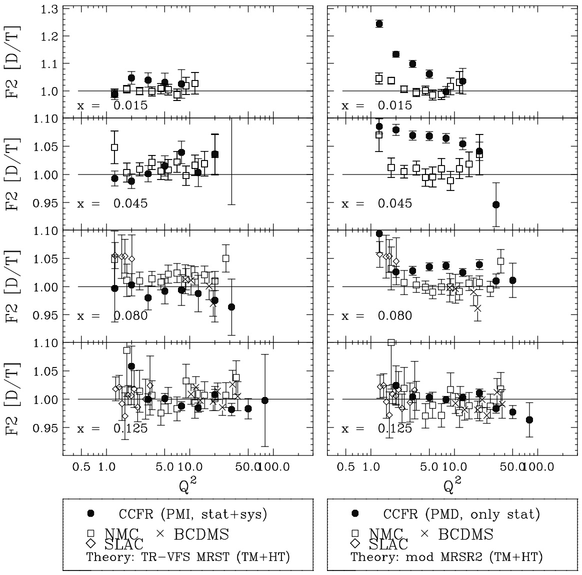

Figure 2. (Left) The ratio of the F_2^ν (PMI) data divided by the predictions of TR-VFS (MRST99) with target mass and higher twist corrections; (right) The ratio of the previous F_2^ν (PMD) data and the predictions of MRSR2. Also shown are the ratios of the F_2^μ (NMC, BCDMS) and F_2^e (SLAC) to the theoretical predictions.

sums of the corrected ν_μ-Fe and $\overline{\nu}_\mu$-Fe differential cross sections in different energy bins according to Eq. (1). An extraction of F_L requires knowledge of ΔxF_3. which we obtain from the NLO TR-VFS(MRST) calculation. Because of the large uncertainty in ΔxF_3 at low Q^2 region, an extrapolation of the curve which describes the measured CCFR ΔxF_3 data above $Q^2 = 1$ is used for the systematic error. Here we are interested in the relative Q^2 dependence of F_L and $2xF_1$.

Fig. 3 shows the preliminary values of F_L and $2xF_1$ as a function of Q^2 for $x < 0.1$. The inner errors include both statistical and experimental systematic errors. The outer errors represent the ΔxF_3 model errors added in quadrature. The curves are the predictions from a QCD-inspired leading order fit to the CCFR differential cross section data with $R = R_{world}$ (for neutrino scattering) which does not include the HERMES effect. Large anomalous deviations from the fit (e.g. 200 - 300%) are not seen in the CCFR data.

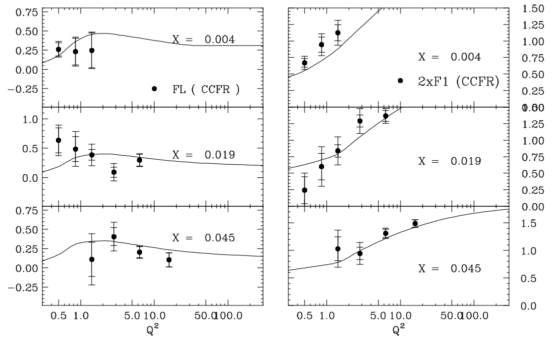

Figure 3. Preliminary measurements of F_L and $2xF_1$ as a function of Q^2 for $x < 0.1$, The curves are the predictions from a QCD inspired leading order fit to the CCFR differential cross section data with $R = R_{world}$ for neutrino scattering.

More details on this work can be found in reference 6 and 7.

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