FERMILAB-CONF-00-0432-PPD

International Journal of Modern Physics A,

NEW MESUREMENTS OF NUCLEON STRUCTURE FUNCTIONS FROM CCFR/NuTeV

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(Presented at DPF2000 by Arie Bodek for the CCFR/NuTeV Collaboration - UR-1615)

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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 for ΔxF_3, which is useful in testing models of heavy charm production, is higher than current theoretical predictions. Within 5% the F_2 (PMI) values measured in ν_μ and μ scattering are in agreement with the predictions of Next-to-Leading-Order PDFs (using massive charm production schemes), thus resolving the long-standing discrepancy between the two measurements.

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 were found to be different at small values of x, because of a disagreement in the extracted structure functions. Here, we report on a measurement of differential cross sections and structure functions from CCFR ν_μ-Fe and $\overline{\nu}_\mu$-Fe data. We find that the neutrino-muon difference is resolved by extracting the ν_μ structure functions in a physics model independent way.

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:
$F(\epsilon) \equiv \left[\frac{d^2\sigma^{\nu}}{dxdy} + \frac{d^2\sigma^{\overline{\nu}}}{dxdy}\right] \frac{(1-\epsilon)\pi}{y^2 G_F^2 M E_\nu} = 2xF_1[1+\epsilon R] + \frac{y(1-y/2)}{1+(1-y)^2}\Delta xF_3$.
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, $x = Q^2/2ME_h$ (the Bjorken scaling variable) is the fractional momentum carried by the struck quark,

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.

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, in a ν_μ charged current interaction with s (or $\overline{c}$) quarks, there is a threshold suppression originating from the production of heavy c quarks in the final state. For μ-scattering, there is no suppression for scattering from s quarks, but more suppression when scattering from c quarks since there are two heavy quarks (c and $\overline{c}$) in the final state.

In previous analyses of ν_μ data, 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 (used as input in the extraction) was calculated from a leading order charm production model. These resulted in a physics model dependent (PMD) structure functions. In the new analysis reported here, slow rescaling corrections are not applied, and ΔxF_3 and F_2 are extracted from two-parameter fits to the data. We compare the values of ΔxF_3 to various charm production models. The extracted physics model independent (PMI) values for F_2^ν are then compared with F_2^μ within the framework of NLO models for massive charm production.

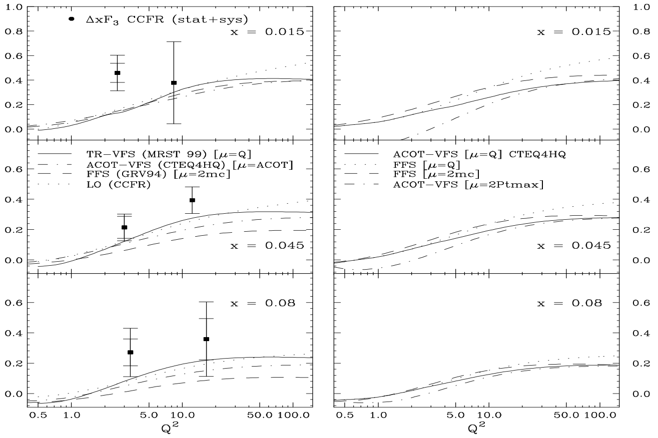

Fig. 1. ΔxF_3 data as a function of x compared with various schemes for massive charm production: RT-VFS(MRST), ACOT-VFS(CTEQ4HQ), FFS(GRV94), and LO(CCFR), a leading order model with a slow rescaling correction (left); Also shown is the sensitivity of the theoretical calculations to the choice of scale (right).

Because of the limited statistics, we use large bins in Q^2 in the extraction of ΔxF_3 with bin centering corrections. Figure 1 shows the extracted values of ΔxF_3 as a function of x, including both statistical and systematic errors, compared to various theoretical methods for modeling heavy charm productions within a QCD framework. Figure 1 (right) also 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 the theortical models. The difference between data and theory may be due to an underestimate of the strange sea at low Q^2, or from missing NNLO terms.

Values of F_2 (PMI) for $x < 0.1$ are extracted from two-parameter fits to the y distributions. In the $x > 0.1$ region, the contribution from ΔxF_3 is small and the extracted values of F_2 are insensitive to ΔxF_3. Therefore, we extract values of F_2 with an input value of R and with ΔxF_3 constrained to the TR-VFS(MRST) predictions. As in the case of the two-parameter fits for $x < 0.1$, no corrections for slow rescaling are applied. Fig. 2 shows our F_2 (PMI) measurements divided by the predictions from the TR-VFS(MRST) theory. Also shown are F_2^{μ} and F_2^{e} divided by the theory predictions. In the calculation of the QCD TR-VFS(MRST) predictions, we have also included corrections for nuclear effects, target mass and higher twist corrections at low values of Q^2. As seen in Fig. 2, within 5% both the neutrino and muon structure functions are in agreement with the 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 ACOT-VFS(CTEQ4HQ) predictions yields similar results. Note that in the previous analysis of the CCFR data, the extracted values of F_2 (PMD) at the lowest $x = 0.015$ and Q^2 bin were up to 20% higher than both the NMC data and the predictions of the light-flavor MRSR2 PDFs. More details on this work can be found in UR- 1586 (hep-ex/0009041, submitted to Phys. Rev. Lett. 9/00), and in U. K. Yang, Ph.D. Thesis, Univ. of Rochester (UR-1583, in preparation).

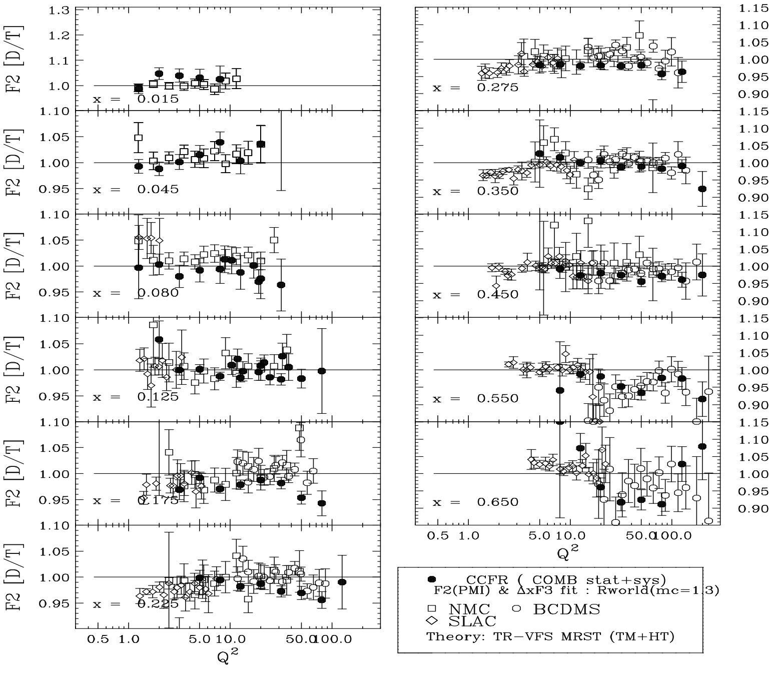

Fig. 2. The ratio (data/theory) of the F_2^{ν} (PMI) data divided by the predictions of TR-VFS(MRST) (with target mass and higher twist corrections). Both statistical and systematic errors are included. Also shown are the ratios of the F_2^{μ} (NMC,BCDMS) and F_2^{e} (SLAC) to the TR-VFS(MRST) predictions.