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EXTRACTION OF $R = \frac{\sigma_L}{\sigma_T}$ FROM CCFR ν_μ-Fe and $\overline{\nu}_\mu$-Fe DIFFERENTIAL CROSS SECTIONS

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We report on the extraction of $R = \frac{\sigma_L}{\sigma_T}$ from CCFR ν_μ-Fe and $\overline{\nu}_\mu$-Fe differential cross sections. R as measured in ν_μ scattering is in agreement with R as measured in muon and electron scattering. All data on R for $Q^2 > 1$ GeV^2 are in agreement with a NNLO QCD calculation which uses NNLO PDFs and includes target mass effects. We report on the first measurements of R in the low x and $Q^2 < 1$ GeV^2 region (where an anomalous large rise in R for nuclear targets has been observed by the HERMES collaboration).– UR-1635, Proceedings of DIS2001, Bologna April 2001

The ratio of longitudinal and transverse structure function, R ($=F_L/2xF_1$) in deep inelastic lepton-nucleon scattering experiments is a sensitive test of the quark parton model of the nucleon. Recently, there has been a renewed interest in R at small values of x and Q^2, because of the large anomalous nuclear effect that has been reported by the HERMES experiment [1]. A large value of R in nuclear targets could be interpreted as evidence for non spin 1/2 constituents, such as ρ mesons in nuclei[2]. Previous measurements of R in muon and electron scattering ($R^{\mu/e}$) are well described by the $R^{\mu/e}_{world}$ [3] QCD inspired empirical fit. The $R^{\mu/e}_{world}$ fit is also in good agreement with recent NMC muon data for R at low x, and with theoretical predictions [4] $R^{\mu/e}_{NNLO+TM}$ (a Next

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to Next to Leading (NNLO) QCD calculation using NLO Parton Distribution Functions (PDFs), and including target mass effects). Very recently the NNLO calculations for F_L and F_2 have been updated [6] to include estimates of the contribution from NNLO PDFs. The quantity $R^{\mu/e}_{NNLOpdfs+TM}$ is extracted by adding target mass effects to these calculations of F_L. For $x > 0.1$ it is expected that R^{ν} should be the same as $R^{\mu/e}$. However, for $x < 0.1$ and low Q^2 (in leading order), R^{ν} is expected to be larger than $R^{\mu/e}$ because of the production of massive charm quarks in the final state. We calculate a correction to $R^{\mu/e}_{world}$ for this difference using a leading order slow rescaling model with a charm mass, $m_c(= 1.3$ GeV) and obtain an effective R_{world} for ν_μ scattering (R^{ν}_{eff}). Here, we report on an extraction of R in neutrino scattering (R^{ν}), extending to low x and Q^2, ad compare to $R^{\mu/e}$ data and to predictions from R^{ν}_{eff}, $R^{\mu/e}_{world}$, and $R^{\mu/e}_{NNLOpdfs+TM}$).

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

$$F(\epsilon) \equiv \left[\frac{d^2\sigma^{\nu}}{dxdy} + \frac{d^2\sigma^{\overline{\nu}}}{dxdy}\right] \frac{(1-\epsilon)\pi}{y^2 G_F^2 ME}$$
$$= 2xF_1[1+\epsilon R] + \frac{y(1-y/2)}{1+(1-y)^2}\Delta xF_3. \qquad (1)$$

Here G_F is the weak Fermi 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 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, and $R = \frac{\sigma_L}{\sigma_T} = \frac{F_L}{2xF_1}$.

Values of R (or equivalently F_L) and $2xF_1$ are extracted from the sums of the corrected ν_μ-Fe and $\overline{\nu}_\mu$-Fe differential cross sections at different energy bins according to Eq. (1). An extraction of R using Eq. (1) requires a knowledge of ΔxF_3 term, which in leading order $\simeq 4x(s-c)$. We obtain ΔxF_3 from theoretical predictions [5] for massive charm production using the TR-VFS NLO calculation with the extended MRST99 and the suggested scale $\mu = Q$. This prediction is used as input to Eq. (1) in the extraction of R^{ν}. This model yields ΔxF_3 values similar to the NLO ACOT Variable Flavor Scheme (implemented with CTEQ4HQ and the recent ACOT suggested scale $\mu = m_c$ for $Q < m_c$, and $\mu^2 = {m_c}^2 + 0.5Q^2(1-{m_c}^2/Q^2)^n$ for $Q < m_c$ with $n = 2$). A discussion of the various theoretical schemes for massive charm production is given in a previous communication [5]. Because of a positive correlation between R and ΔxF_3, the uncertainty of ΔxF_3 play as a major systematic error at low

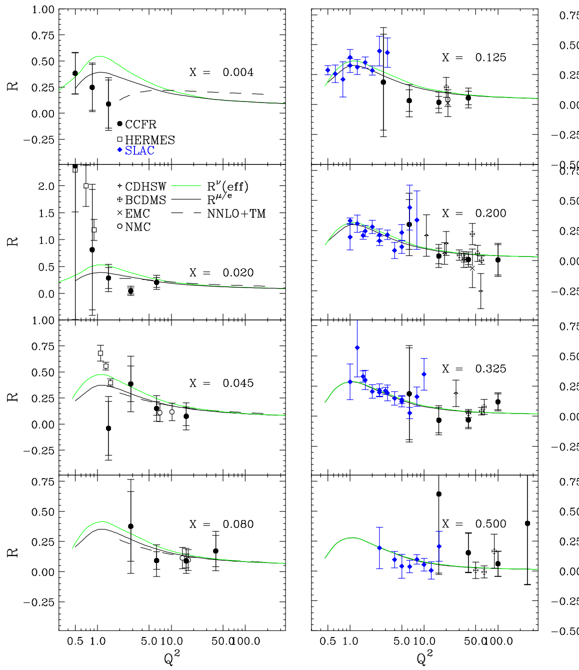

Figure 1: CCFR measurements of R^{ν} as a function of Q^2 for fixed x, compared with electron and muon data, with the $R^{\mu/e}_{world}$ and R^{ν}_{eff} ($m_c = 1.3$) fits, and with the $R^{\mu/e}_{NNLOpdfs+TM}$) QCD calculation including NNLO PDFs (dashed line). The inner errors include both statistical and experimental systematic errors added in quadrature, and the outer errors include the additional ΔxF_3 model errors (added linearly). Also shown are the HERMES results for R^{e}_{N14} at small x and Q^2.

x region. However, for $x > 0.1$, the ΔxF_3 term is small, and the extracted values of R^{ν} are not sensitive to ΔxF_3. For a systematic error on the assumed level of ΔxF_3, we vary strange sea and charm sea by ± 50 % (ΔxF_3 is directly sensitive to the strange sea minus charm sea). Note that the extracted value of R is larger for a larger input ΔxF_3 (i.e. a larger strange sea).

The extracted values of R^{ν} are shown in Fig. 1 for fixed x versus Q^2. The inner errors include both statistical and experimental systematic errors added in quadrature, and the outer errors include the additional ΔxF_3 model errors (added linearly).

At the very lowest Q^2 values, the model error is reduced because all models for ΔxF_3 approach zero around $Q^2 = 0.4$. This is because the strange quark distribution is expected to approach zero for Q values close to twice the mass of the strange quark. In addition, the very low Q^2 region is below charm production threshold. Note that the very low Q^2 and low x region is of interest because it is where HERMES reports [1] an anomalous increase in R^e for nuclear targets.

The CCFR R^ν values are in agreement with measurements of $R^{\mu/e}$, and also in agreement with both the $R^{\mu/e}_{world}$ and R^{ν}_{eff} fits. At low x, there are indications that the data may be lower than these two model predictions. New QCD calculation [6] of F_L and F_2 including both the NNLO terms and estimates of NNLO PDFs are used to determine $R^{\mu/e}_{NNLOpdfs+TM}$, by including target mass effects. These are shown as dashed lines in Fig. 1. There are large uncertainties in F_L from the NNLO gluon distribution at low x for $Q^2 <$ 5 GeV^2. Specifically, for $Q^2 = 2$ GeV^2 and $0.001 < x < 0.01$ the NNLO calculation with NNLO PDFs results in a dip in F_L with F_L approaching zero. It is interesting that there is also a dip in our measured values of R for x=0.019 and $Q^2 = 3$ GeV^2. However, for $Q^2 < 2$ GeV^2 and $0.001 < x < 0.01$ the NNLO calculation with NNLO PDFs also yields an unphysical negative value for F_L, which implies large uncertainties in the calculation. Another recent QCD calculation within a $ln(1/x)$ resummation framework (with resummed PDFs) also predicts [7] that R at small x and low Q^2 is lower than $R^{\mu/e}_{world}$.

Also shown are the HERMES electron scattering results in nitrogen. The HERMES data [1] for R are extracted from their ratios for R_{N14}/R_{1998} by multiplying by the values from the R_{1998} fit. The CCFR data do not clearly show a large anomalous increase at very low Q^2 and low x. 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. However, depending on the origin, the effects in electron versus ν_μ charged current scattering could be different.

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