International Journal of Modern Physics A

NuTeV Structure Function Measurement

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The NuTeV Collaboration

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The NuTeV experiment obtained high statistics samples of neutrino and antineutrino charged current events during the 1996-1997 Fermilab fixed target run. The experiment combines sign-selected neutrino and antineutrino beams and the upgraded CCFR iron-scintillator neutrino detector. A precision continuous calibration beam was used to determine the muon and hadron energy scales to a precision of 0.7% and 0.43% respectively. The structure functions $F_2(x, Q^2)$ and $xF_3(x, Q^2)$ obtained by fitting the y-dependence of the sum and the difference of the ν and $\overline{\nu}$ differential cross sections are presented.

Keywords: nutev; structure function.

Neutrino-nucleon deep inelastic scattering (DIS) probes the structure of the nucleon and QCD. [1] The NuTeV experiment is a high-energy fixed target νN scattering experiment, which combines two new features; Separate high-purity neutrino and antineutrino beams, used to tag the primary lepton in charged-current interactions, and a continuous precision calibration beam which improves the experiment's knowledge of the absolute energy scale for hadrons and muons produced in neutrino interactions. [2] 8.6×10^5 ν and 2.3×10^5 $\overline{\nu}$ charged-current (CC) interactions passing analysis cuts were collected during NuTeV's data taking run.

1. ν-Fe CC Differential Cross Section

The differential cross section is determined from

$$\frac{d^2\sigma^{\nu(\overline{\nu})}}{dxdy} = \frac{1}{\Phi(E)} \frac{d^2N^{\nu(\overline{\nu})}(E)}{dxdy}. \tag{1}$$

where $\Phi(E)$ is the $\nu(\overline{\nu})$ flux in energy bins. The cross section event sample is required to pass fiducial volume cuts, μ track reconstruction quality cuts, and minimum energy thresholds of $E_\mu > 15$ GeV, hadronic energy, $E_{HAD} > 10$ GeV, and neutrino energy, $E_\nu > 30$ GeV. Selected events are binned in x, y, and E_ν bins, and corrected for acceptance and smearing using a fast detector simulation. $Q^2 > 1$ GeV^2 is required to minimize the non-perturbative contribution to the cross section. NuTeV data ranges from 10^{-3} to 0.95 in x, 0.05 to 0.95 in y, and from 30 GeV to 300 GeV in E_ν.

The flux is determined from data with $E_{HAD} < 20$ GeV using the "fixed ν_0" relative flux extraction method. [1] The integrated number of events in this sample as $y = \frac{E_{HAD}}{E_\nu} \to 0$ is proportional to the flux. Corrections, determined from the data sample, up to order y^2 are applied to determine the relative flux to about the 1% level. Flux is normalized using the world average ν-Fe cross section $\frac{\sigma^\nu}{E_\nu} = 0.677 \times 10^{-38} cm^2/GeV$. [3]

The fast detector simulation, which takes into account acceptance and resolution effects, uses an empirically determined set of PDFs extracted by fitting the differential cross section. [4] The procedure is then iterated until convergence is achieved (within 3 iterations). Detector response functions are parameterized from the NuTeV calibration beam data samples. [2]

2. Structure Functions

The structure function $F_2(x, Q^2)$ is determined from a fit to the y-dependence of the sum of the $\nu, \overline{\nu}$ differential cross sections:

$$\left(\frac{d^2\sigma}{dxdy}^{\nu} + \frac{d^2\sigma}{dxdy}^{\overline{\nu}}\right) = \frac{G_F^2 ME}{\pi}\left[2\left(1-y-\frac{Mxy}{E}+y^2\frac{1+4M^2x^2/Q^2}{1+R_L}\right)F_2+y\left(1-\frac{y}{2}\right)\Delta xF_3\right], \quad (2)$$

where $F_2 = \frac{F_2^\nu + F_2^{\overline{\nu}}}{2}$, $R_L(x, Q^2)$ is the ratio of the cross section for scattering from longitudinally to transversely polarized W-bosons where, $2xF_1 = F_2\frac{1+\frac{4M^2x^2}{Q^2}}{(1+R_L(x,Q^2))}$. and $\Delta xF_3 = xF_3^\nu - xF_3^{\overline{\nu}}$. Cross sections are corrected for QED radiative effects and for 5.67% excess of neutrons over protons in our iron target before the sum is formed. [5] To extract $F_2(x, Q^2)$ we use ΔxF_3 from a NLO QCD model as input (TRVFS). [6] The input value of $R_L(x, Q^2)$ comes from a fit to the world's measurements. [7] NuTeV $F_2(x, Q^2)$ for neutrino scattering on iron is shown on Fig. 1 (left) compared with previous ν-Fe scattering measurements (CDHSW,[8] CCFR). [9] NuTeV F_2 is in agreement with CDHSW and CCFR for medium x ($0.03 < x < 0.4$). At high x NuTeV result agrees in level with CDHSW, but not in shape. NuTeV F_2 is systematically above CCFR for $x > 0.4$: 5% at $x = 0.45$, 10% at $x = 0.55$, 20% at $x = 0.65$.

Similarly the structure function $xF_3(x, Q^2)$ is determined from a fit to the y-dependence of the difference of the $\nu, \overline{\nu}$ differential cross sections:

$$\left[\frac{d^2\sigma^\nu}{dxdy} - \frac{d^2\sigma^{\overline{\nu}}}{dxdy}\right] = \frac{2G_F^2 ME}{\pi}\left(y - \frac{y^2}{2}\right) xF_3^{AVG}(x, Q^2) \quad (3)$$

where $xF_3^{AVG} = \frac{1}{2}(xF_3^\nu + xF_3^{\overline{\nu}})$. $F_2^\nu(x, Q^2) \approx F_2^{\overline{\nu}}(x, Q^2)$ are nearly identical so no additional model input is required. Cross sections are corrected for QED radiative

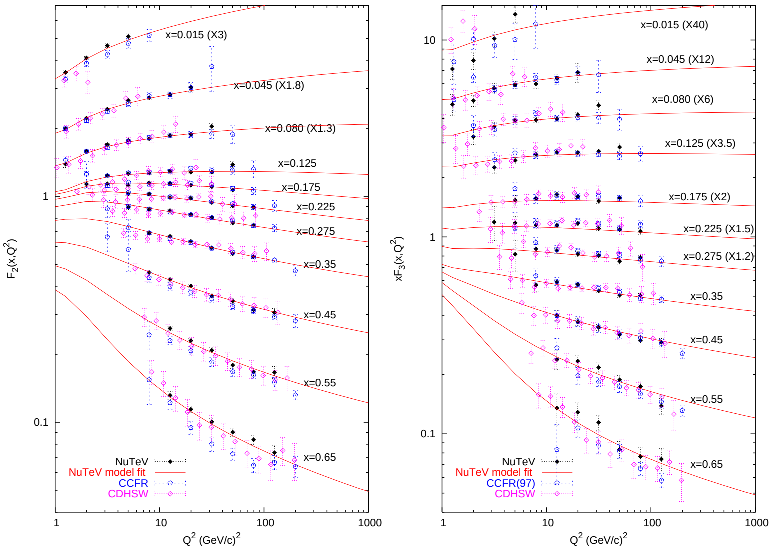

Fig. 1. Preliminary NuTeV F_2 (left) and xF_3 (right) in comparison with previous ν-Fe scattering experiments

effects and for 5.67% excess of neutrons over protons in our iron target before the difference is formed. [5] Fig. 1 (right) shows the NuTeV measurement of $xF_3(x, Q^2)$ from fits to the cross section difference. NuTeV xF_3 agrees with CCFR and CDHSW for $0.03 < x < 0.4$. For $x > 0.4$ NuTeV result agrees in level, but not in shape with CDHSW, and is systematically higher than CCFR(97). [3]

3. Conclusions

In conclusion, we have measured F_2 and xF_3 structure functions. NuTeV result is in good agreement with previous ν-Fe results over the intermediate x range ($0.03 < x < 0.4$). At high-x ($x > 0.4$) NuTeV result is systematically higher than CCFR result, it agrees in level with CDHSW, but not in shape.

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