Dimuon Production at NuTeV

M. Goncharov[4*], T. Adams[4], A. Alton[4], S. Avvakumov[7], L. de Barbaro[5], P. de Barbaro[7], R. H. Bernstein[3], A. Bodek[7], T. Bolton[4], J. Brau[6], D. Buchholz[5], H. Budd[7], L. Bugel[3], J. Conrad[2], R. B. Drucker[6], R. Frey[6], J. Formaggio[2], J. Goldman[4], D. A. Harris[7], R. A. Johnson[1], S. Koutsoliotas[2], J. H. Kim[2], M. J. Lamm[3], W. Marsh[3], D. Mason[6], C. McNulty[2], K. S. McFarland[7], D. Naples[4], P. Nienaber[3], A. Romosan[2], W. K. Sakumoto[7], H. Schellman[5], M. H. Shaevitz[2], P. Spentzouris[2], E. G. Stern[2], B. Tamminga[2], M. Vakili[1], A. Vaitaitis[2], V. Wu[1], U. K. Yang[7], J. Yu[3] and G. P. Zeller[5]

[*] *Presented by Max Goncharov*

[1] *University of Cincinnati, Cincinnati, OH, USA*

[2] *Columbia University, New York, NY, USA*

[3] *Fermi National Accelerator Laboratory, Batavia, IL, USA*

[4] *Kansas State University, Manhattan, KS, USA*

[5] *Northwestern University, Evanston, IL, USA*

[6] *University of Oregon, Eugene, OR, USA*

[7] *University of Rochester, Rochester, NY, USA*

Neutrino-nucleon deep inelastic scattering is a very effective way to probe the structure of the nucleon and to study the dynamics of heavy quark production. The presented analysis focuses on charm quark production in deep inelastic scattering of neutrinos and anti-neutrinos off a nucleon target. The data sample is based on opposite sign dimuon events obtained by the NuTeV experiment at FermiLab during the 1996-1997 fixed-target run.

1 Introduction

The NuTeV experiment collected a large sample of sign-selected neutrino and anti-neutrino deep inelastic scattering charged-current events. Charm production, approximately 10% of the total charged-current neutrino cross section, manifests itself in the NuTeV detector as a unique opposite sign final state. We present here our preliminary measurement of charm production, show that it agrees with previous analyses, and briefly discuss what should be the final outcome of this analysis.

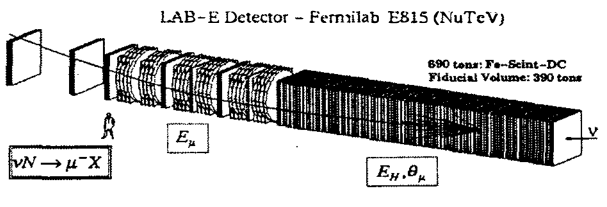

Figure 1: NuTeV detector: target(isoscaler, iron)-calorimeter and muon spectrometer. We measure hadron energy, muon energy and direction

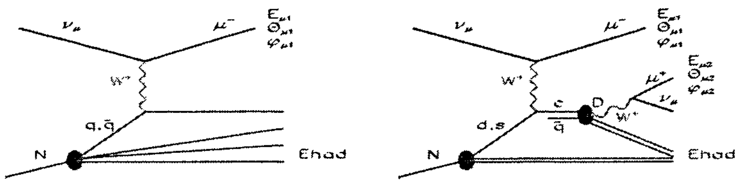

Figure 2: The Feynman diagrams for: a) charged current $\nu_\mu(\bar{\nu}_\mu)N \to \mu^-(\mu^+)X$. b) a dimuon event.

The NuTeV detector[1] is shown in Fig.1. It consists of two major parts: the target calorimeter and the muon spectrometer. A ν or $\bar{\nu}$ beam is incident on the target from the right. The neutrino interacts with a quark inside the iron target to produce a muon and a hadron shower. The calorimeter measures the energy of the hadron shower, and the toroid spectrometer measures the energy of the muon.

The event shown in Fig.1 is an example of a charged current deep inelastic scattering (DIS) event. Fig.2 contains the Feynman diagram for this process. Approximately 10% of charged-current interactions result in production of a charm quark from scattering off a d or s quark in the nucleon. The charm quark fragments[2] into a charmed hadron (usually a D-meson) which weakly decays 10% of the time into a muon that carries opposite charge from the primary muon. The leading order Feynman diagram for the described process is shown in Fig.2b. This dimuon event has a very distinct signature: two opositively charged muons and a hadron shower. An example is shown in Fig.3. The only significant background source for dimuon signal is from charged-current events with a second muon produced inside the hadronic shower as a result of π or K decay.

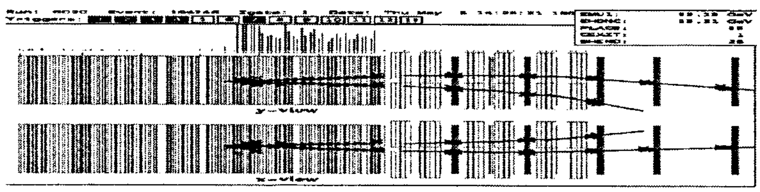

Figure 3: A dimuon event in the NuTeV detector

2 Charged-Current Charm Production

As mentioned above, neutrino charged-current DIS charm production results from scattering of a neutrino off d or s quarks in the nucleon. The Cabibbo suppression of scattering from d quarks greatly enhances the contribution of the s quarks. For ν induced events the d-valance quark contribution is approximately the same as for s quarks. But for $\bar{\nu}$ almost all events come from s quarks since charm production from $\bar{d}$ is small.

We select dimuon events from the full charged-current data sample and compare them to a Monte Carlo prediction that uses specific dimuon production and background models by performing a binned log-likelihood fit. As a result of the fit we extract the charm quark mass m_c, the shape and absolute value of strange sea, a charm fragmentation parameter and the mean meson decay branching ratio B_c (or, equivalently, V_{cd}). By using the same model we intend to present the result in a nearly model-independent dimuon cross-section table that would allow

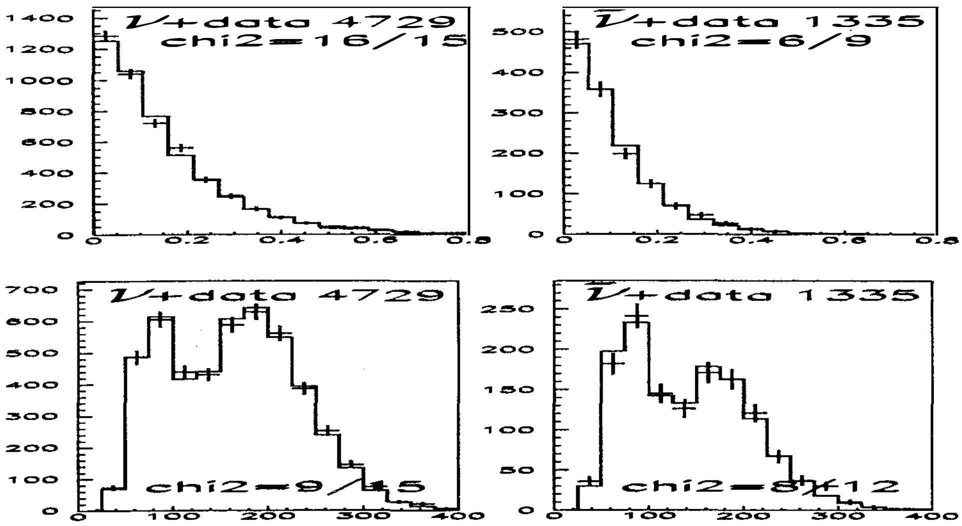

Figure 4: Top: Bjorken visible x. Bottom: total energy E (GeV), ν (left) and $\bar{\nu}$ (right) modes. The number of data events and χ^2 per degree of freedom are shown on the plots

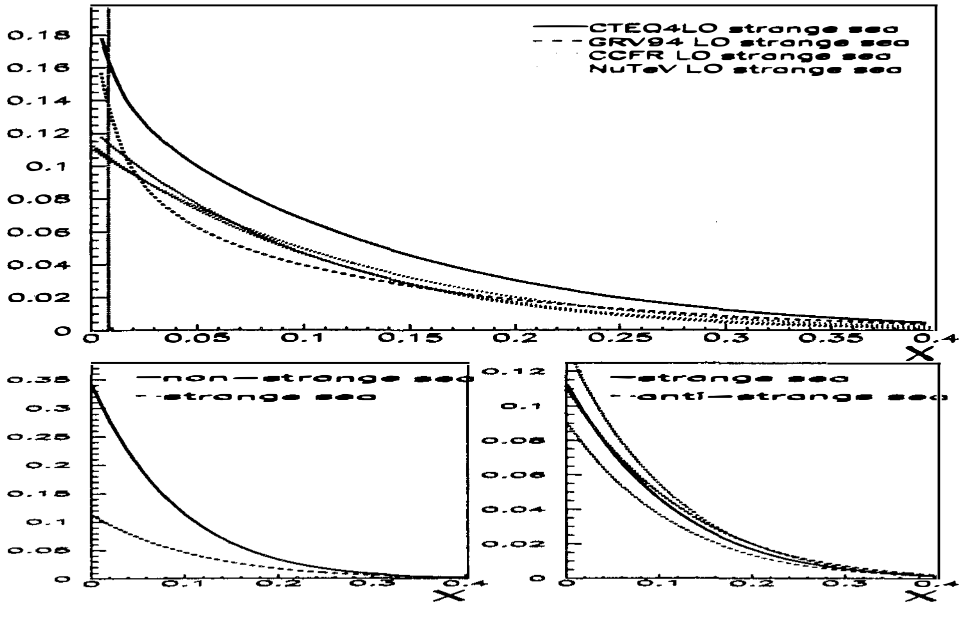

Figure 5: Top: world strange seas vs. x for $Q^2 = 16\ GeV^2$. Bottom left: strange vs. non-strange sea. Bottom right: strange vs. non-strange sea with statistical errors on strange sea. NuTeV cannot probe $s(\bar{s})$ below $x \approx 0.009$

testing of different models sensitive to charm production easy to do.

Dimuon data are selected with the following criteria: events must reconstruct inside the fiducial volume of the NuTeV detector with a hadronic energy $E_{had} > 10$ GeV and with two muons energies $E_{\mu 1}, E_{\mu 2} > 5$ GeV. At least one muon must be toroid analysed. At any moment it was known if experiment was running in ν or $\bar{\nu}$ mode. By looking at the sign of a toroid-analysed muon, the primary muon was always chosen to be of the appropriate sign.

We use a GEANT-based hit level Monte Carlo to simulate the dimuon (including background) signal in the detector. Exactly the same cuts are applied to Monte Carlo sample as to data. To perform a fit we bin Data and Monte Carlo in three variables: $x_{vis} = \frac{E_{vis} E_{\mu 1} \theta^2_{\mu 1}}{2m_p(E_{\mu 2}+E_{had})}$, $E_{vis} = E_{\mu 1} + E_{\mu 2} + E_{had}$, and $z_{vis} = \frac{E_{\mu 2}}{E_{\mu 2}+E_{had}}$ where the subscript vis refers to measured variables, $\mu 1$ is the primary muon and $\mu 2$ is the secondary muon. The Monte Carlo is absolutely normalised to the total charged current data sample. We use a simple leading order (LO) charm production model in which the strange sea follows same q^2 evolution as the non-strange sea. The strange and anti-strange sea can be different in shape from the non-strange sea by a shape function $(1-x)^\alpha$ and by an absolute level. As one can see in Fig.4, our model describes the data very well after the fit.

2.1 Results

In Fig.5 one can see our prediction for the strange sea and how it compares with the previous CCFR [4] measurement. The absolute level of strange sea is ~ 0.4 of the non-strange sea. Comparisons to the strange sea from several global fits are also shown. We agree with the CCFR measurement and the GRV prediction. We do not see any asymmetry between strange and anti-strange sea in the region shown. The extracted charm mass and V_{cd} also agree with the CCFR measurement.

$$m_c = 1.30 \pm .21 \pm 0.07 \; GeV/c^2$$
$$V_{cd} = 0.224 \pm .007 \pm .005$$

We intend to present this result in terms of a model-independent dimuon production cross-section table which will allow others to test predictions about models sensitive to charm production. Also on a cross-section table level it is easy to combine our measurement with previous the CCFR measurement, which will double the statistics of this preliminary measurement.

Acknowledgements

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