FLUX NORMALIZED CHARGED CURRENT NEUTRINO CROSS SECTIONS UP TO NEUTRINO ENERGIES OF 260 GeV*

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ABSTRACT

Preliminary measurements of flux normalized charged current neutrino cross sections are presented. From a sample of 6000 neutrino events with energies between 50 and 260 GeV we find that

$$\sigma_\nu/E_\nu = (0.67 \pm 0.04) \times 10^{-38}\ \mathrm{cm}^2/\mathrm{GeV}$$

independent of neutrino energy.

INTRODUCTION

The simplest model which describes deep inelastic neutrino scattering well is the quark-parton model. It predicts that the cross section should rise linearly with the incident neutrino energy. The simple scaling may be modified at low energies by the quark mass and transverse momentum corrections. The effects of gluon Bremsstrahlung, as calculated from QCD, lead to logarithmic deviations from scaling. At high energies there are propagator effects due to the mass of the W boson. Thus a measurement of the total neutrino cross section from the lowest to the highest possible energy provides us with important information on our current understanding of the nucleon and its interactions.

We present here the first measurement of the charged current neutrino total cross section up to an energy of 260 GeV.

BEAM AND APPARATUS

The measurements that are described here were made with a new narrow band neutrino beam and a new neutrino detector at Fermilab.

The new narrow band beam is designed to minimize wide band background and has a narrow momentum bite and small angular divergence in order to produce a neutrino energy spectrum as close as possible to the ideal flat distribution of two body π and K decay. The characteristics of this new beam are listed in Table I. The present data were taken with the secondary beam energy set to 200 and 300 GeV respectively.

The secondary particles (π/K) decayed in a 340m long evacuated pipe which began just downstream of the last beam magnet. They were monitored at the expansion port located about 100m downstream of this last magnet. The total particle intensity was measured by an ion chamber. The particle ratios π/K/p were measured by an integrating differential Cerenkov counter.

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Table I

Beam Parameters

Incident Proton Energy	400 GeV/c
Target Material	BeO
Incident Spot Size	2 x 0.5mm^2
Targeting Angles	
Horizontal:	11.96mr
Vertical:	1.125mr
Momentum Bite	±9%
Angular Divergence	
Horizontal:	±0.15mr
Vertical:	±0.18mr
Secondary Energy	100 - 300 GeV

Particle ratios are listed in Table II for different mean pion momentum.

Table II

Polarity	P_π [GeV/c]	K/π	P/π
+	198 ± 18	0.15 ± 0.009	3.94 ± 0.08
+	289 ± 26	0.25 ± 0.012	36.8 ± 0.7

The new separated function neutrino detector located downstream of a 910m muon shield is shown in Figure 1. The upstream portion is a 680 ton instrumented iron target followed by a 420 ton muon spectrometer. The entire detector has been moved into a hadron beam for calibration.

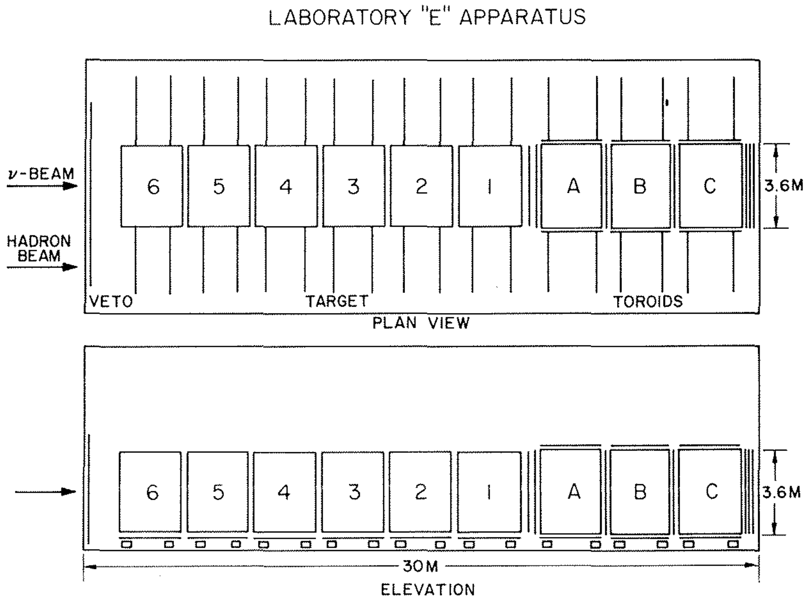

Fig. 1 Counter ν-experiment of the CFRR-Group at Fermilab

The iron target is instrumented with liquid scintillation counters for calorimetry and with spark chambers to track muons. The muon spectrometer is a magnetized iron toroid instrumented with acrylic scintillation counters to measure hadron energy and with spark chambers to track muons. A complete description is given in Table III. The calorimetric response was empirically determined from measurements made in a hadron beam.

Table III

Lab E Neutrino Detector

Target/Calorimeter	
Dimensions	3m x 3m x 20m
Weight	680 tons: Fe
Counters	10cm spacing
Hadron Energy Resolution	$\Delta E/E = 0.93/\sqrt{E[GeV]}$
Spark Chambers	20cm spacing
Angular Resolution	$\Delta\theta_\mu[mrad] = 0.30 + \frac{68}{p_\mu[GeV/c]}$
Muon Spectrometer/Calorimeter	
Dimensions	3.4m dia. x 10m
Weight	420 tons
Counters	20cm spacing
Hadron Energy Resolution	$\Delta E/E = 1.85/\sqrt{E[GeV]}$
Spark Chambers	80cm spacing
Muon Momentum Resolution	$\Delta p/p = 10\%$

ANALYSIS

The results presented here are based on 6000 charged neutrino interactions found in a cylindrical fiducial volume 1.27m in radius and 13.2m long. For each event the hadron energy was corrected for the measured attenuation in the scintillation counters and the muon energy was corrected for the energy loss in iron. In addition, a model independent azimuthal geometric efficiency was calculated for each event.

A correction was also made to account for the unsampled region of acceptance at very large x and y. This loss is less than 10% for low ν energies and decreases to about 2% for high energies.

The calculation of the neutrino cross section is quite straightforward with a dichromatic beam. The events in any given radial bin on the target may be divided into high energy neutrinos from K decay and low energy neutrinos from π decay due to the nature of the beam. The neutrino flux into each radial bin from each type of decay is readily calculated from the measured composition and properties of the beam and two body kinematics. As an example, Figure 2 shows the measured high energy neutrino distribution in the radial bin from 0 to 50cm compared with the predictions of a Monte Carlo which simulates the beam. The measured energies are based on calibrations done in the hadron beam. The means of these distributions differ by less than 1%.

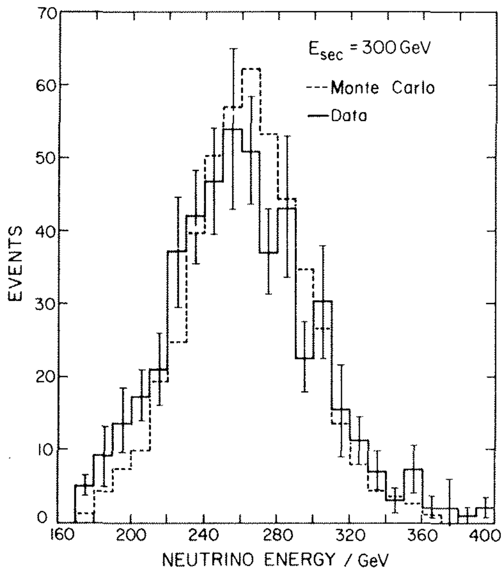

Fig. 2 Comparison of ν-energy distribution obtained from data and Monte Carlo

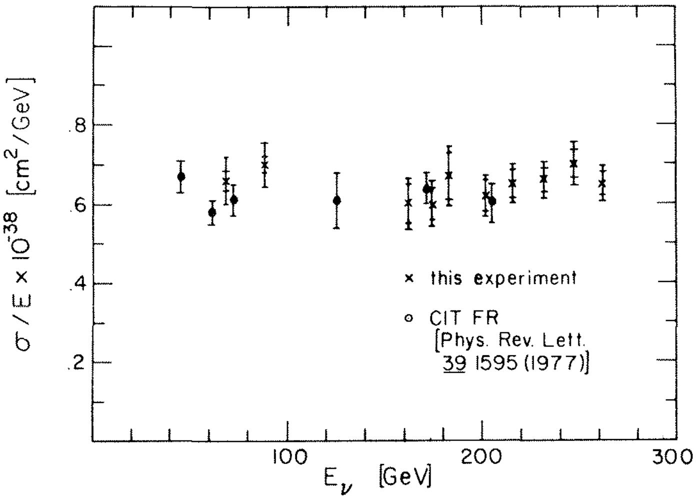

Fig. 3 Total cross section divided by the ν-energy for charged current events plotted against neutrino energy

The cross section divided by the energy is shown in Figure 3. These results have been corrected for a minimum muon energy of 2.4 GeV and empirically determined wide band background. The overall result is

$$\frac{\sigma}{E} = (0.67 \pm 0.04) \times 10^{-38}\ cm^2/GeV.$$

A previous result is also shown for comparison. There is no indication in the total cross-section data at the present level of experimental precision for any deviation from exact scaling up to neutrino energies of 260 GeV.