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γ AND ν DISTRIBUTIONS FOR NEUTRAL CURRENT
REACTIONS OF THE WEINBERG-TYPE

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ABSTRACT

The γ and ν distributions for inclusive neutrino and antineutrino reactions arising from a neutral current of the Weinberg-type are investigated in the framework of two quark parton models. While the ν distributions appear of little use at present, we show that by making a cut in the γ variable, one can determine $\sin^2\theta_W$ reasonably accurately, independent of the cross-section determination, even with the present "narrow-band" dichromatic neutrino beam at NAL.

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INTRODUCTION

Predictions for neutrino and antineutrino inclusive cross-sections on nucleons arising from a Weinberg-type neutral current interaction were presented by the author in previous papers ^{1),2)}. For this purpose, a simplified version of the Weinberg neutral current ³⁾ which neglected the charmed quark contribution was used in the framework of various three-quark parton models which fit the charged current data. Sehgal ⁴⁾ has also examined the same problem but in the framework of a four-quark parton model with different assumptions for the charmed quark contributions. Typically the results from the two analyses are quite similar and suggest that the neutral current to charged current cross-section ratios are given, for example, by $\sigma_o^{\nu N}/\sigma_{ch}^{\nu N} \simeq 0.27$ and $\sigma_o^{\bar{\nu} N}/\sigma_{ch}^{\bar{\nu} N} \simeq 0.43$ for $\sin^2\theta_W = 0.33$.

In the meantime, both the CERN Gargamelle group ⁵⁾ and the Harvard, Pennsylvania, Wisconsin neutrino collaboration ⁶⁾ at NAL have reported experimental observation of neutrino and antineutrino events without a visible emitted muon, a necessary signature for neutral current processes. The CERN data ⁵⁾ suggest consistency with the Weinberg model predictions for $0.3 \lesssim \sin^2\theta_W \lesssim 0.5$. The single leptonic candidate for $\bar{\nu}_\mu + e^- \rightarrow \bar{\nu}_\mu + e^-$, also reported by the Gargamelle group ⁷⁾, is consistent with a Weinberg angle in the range noted above.

It is of interest to suggest additional checks which experimentalists can make to test whether the Weinberg form for the neutral current is, in fact, the correct one. Here we examine the $y = \nu/E$ and $v = xy = q^2/2ME$ distributions, as well as their average values, for the Weinberg neutral current interactions in the quark parton model. Results for two special parton models are presented: one assumes the proton constituents are represented by the valence quark partons together with an $SU(3)$ symmetric sea of quarks and antiquarks; the other model assumes the antiquarks are all of the strange $\bar{s}$ variety.

Section I elaborates on these two parton models as well as summarizing the basic formulae. The y and v distributions are presented in Sections II and III, respectively. To investigate both y and v distributions with some degree of accuracy, monochromatic beams of neutrinos and antineutrinos are required. In Section IV we discuss the possibility of determining the Weinberg angle with the present "narrow-band" beams ^{*)} at NAL.

*) We refer to the dichromatic beam used by the Cal.Tech. neutrino group as described in Ref. 8).

I. TWO QUARK PARTON MODELS

We begin by summarizing the basic formulae needed for our analysis and refer the reader to Ref. 2) and to the papers of Gourdin ⁹⁾ for the more detailed points.

The differential cross-sections for inclusive neutrino and antineutrino reactions in the Bjorken scaling region can be written in the form

$$\frac{d^2\sigma^{\nu,\bar{\nu}}}{dx dy} = \frac{G^2}{2\pi} s x \left[(1-y)^2 F_{\pm} + F_{\mp} + 2(1-y)F_0 \right] \quad (I.1)$$

in terms of the variables $x = q^2/2M\nu$ and $y = \nu/E = 1-E'/E$, where q^2 and ν are the four-momentum squared and energy transferred to the outgoing lepton, $s = 2ME$, and the structure functions F_+ , F_- , and F_0 which depend only on x . In the quark parton model with spin $\frac{1}{2}$ constituents, the Callan-Gross relation ¹⁰⁾ requires $F_0 = 0$ while F_+ and F_- are related to the parton distribution functions ^{*}) $D_j(x)$, where $j = 1, 2, 3, -1, -2, -3$ for the p, n , and λ quarks and antiquarks, respectively.

The total cross-sections are just linear combinations of the first moments of the parton distribution functions, i.e., the fractional momentum d_j carried by the j^{th} quark parton :

$$d_j = \int_0^1 dx x D_j(x), \quad j = 1, 2, 3, -1, -2, -3. \quad (I.2)$$

Hence with the conventional Cabibbo form for the charged current interaction, the inclusive cross-section for $\nu_\mu + N \rightarrow \mu^- + X$ averaged over proton and neutron targets can be expressed as

$$\sigma_{ch}^{\nu N} = \sigma_0 \left[\frac{1}{3}(d_{-1} + d_{-2}) + (d_1 + d_2) \cos^2 \theta_c + 2d_3 \sin^2 \theta_c \right] \quad (I.3a)$$

while for the corresponding antineutrino process

$$\sigma_{ch}^{\bar{\nu} N} = \sigma_0 \left[\frac{1}{3}(d_1 + d_2) + (d_{-1} + d_{-2}) \cos^2 \theta_c + 2d_{-3} \sin^2 \theta_c \right] \quad (I.3b)$$

obtained by replacing d_j by d_{-j} . Here we have introduced $\sigma_0 = G^2 s / 2\pi$.

^{*}) In Feynman's notation, D_1, D_2, D_3 correspond to p, n , and λ quark parton distribution functions : $U(x)$, $D(x)$, and $S(x)$.

In Refs. 1) and 2) we neglected the charmed quark contribution and approximated the Weinberg neutral current by ^{*)}

$$J_2^{(0)} = (V-A)_2^3 - 2 \sin^2 \theta_W J_2^{em} \quad (I.4)$$

in terms of the third component of the V-A isospin current, the electromagnetic current and the Weinberg angle. With this form, the neutral current inclusive cross-section for $\mu + N \rightarrow \mu + X$ is given by

$$\sigma_0^{\mu N} = \sigma_0 \left\{ \frac{1}{2} [d_1 + d_2 + \frac{1}{3}(d_{-1} + d_{-2})] (1 - 2 \sin^2 \theta_W) + \frac{4}{27} [5(d_1 + d_2 + d_{-1} + d_{-2}) + 2(d_3 + d_{-3})] \sin^4 \theta_W \right\} \quad (I.5)$$

while the antineutrino counterpart is again obtained by replacing d_j by d_{-j} .

In what follows, we shall consider two quark parton models which fit the charged current data in order to illustrate the sensitivity of our results to the model chosen. Both models are of the equipartition type introduced by Gourdin ¹¹⁾ in which the fractional momentum carried by the j^{th} parton is proportional to the average number of type j partons :

$$d_j = \langle N_j / N_Q \rangle (1 - \epsilon) \quad (I.6)$$

where $\epsilon = 1 - \sum d_j$ is the fractional momentum carried by gluons ¹²⁾ present in the proton.

The first model, labelled (B2) in Ref. 1) and referred to as model I here, assumes that all antiquarks are of the $\bar{\lambda}$ variety and was fitted to the older SLAC data ¹³⁾

$$\begin{aligned} I_{\text{expt}}^{ep} &= \int_0^1 dx \, 2x F_T^{ep} = 0.18 \pm 0.018 \\ I_{\text{expt}}^{en} &= \int_0^1 dx \, 2x F_T^{en} = 0.12 \pm 0.012 \end{aligned} \quad (I.7)$$

and compared with the published Gargamelle results ¹⁴⁾ for the charged current cross-sections :

*) The neglected piece is isoscalar and expected to be small.

$$\begin{aligned}
 \sigma_{\text{expt}}^{\nu N} &= \sigma_0 (0.450 \pm 0.090) \\
 \sigma_{\text{expt}}^{\bar{\nu} N} &= \sigma_0 (0.170 \pm 0.034) \\
 \sigma_{\text{ch}}^{\bar{\nu} N} / \sigma_{\text{ch}}^{\nu N} &= 0.377 \pm 0.023.
 \end{aligned}
 \tag{I.8}$$

In particular, the average number of quarks is given by

Model I :

$$\begin{aligned}
 \langle N_1 \rangle &= 2, & \langle N_2 \rangle &= 1, \\
 \langle N_3 \rangle &= \langle N_{-3} \rangle = \frac{1}{2}, \\
 \langle N_{-1} \rangle &= \langle N_{-2} \rangle = 0,
 \end{aligned}
 \tag{I.9a}$$

with

$$\begin{aligned}
 d_1 &= 2d_2 = 4d_3 = 4d_{-3} = \frac{1}{2}(1-\epsilon), \\
 d_{-1} &= d_{-2} = 0, \\
 \epsilon &\simeq 0.365
 \end{aligned}
 \tag{I.9b}$$

for the fractional momentum carried by the quarks and gluons.

As a second model, we assume an $SU(3)$ symmetric set of quarks and antiquarks in the proton and use the integrated values of the F_2 distribution functions given by Bodek ¹⁵⁾

$$\begin{aligned}
 I_{\text{expt}}^{\nu p} &= 0.152 \\
 I_{\text{expt}}^{\bar{\nu} p} &= 0.108
 \end{aligned}
 \tag{I.10}$$

Hence we set :

Model II :

$$\begin{aligned}
 \langle N_j \rangle &= \langle N_1 \rangle - 2 \\
 &= \langle N_2 \rangle - 1 \\
 &= \alpha, & j &= 3, -1, -2, -3
 \end{aligned}
 \tag{I.11a}$$

$$\begin{aligned}
 d_1 &= \frac{2+\alpha}{3(1+2\alpha)}(1-\epsilon), \\
 d_2 &= \frac{1+\alpha}{3(1+2\alpha)}(1-\epsilon), \\
 d_j &= \frac{\alpha}{3(1+2\alpha)}(1-\epsilon), \quad j = 3, -1, -2, -3
 \end{aligned}
 \tag{I.11b}$$

and find $\alpha = 0.11$ and $\epsilon = 0.514$ are required to fit (I.10).

The cross-section results for model I have already been presented in Ref. 2) and will not be repeated here. For model II, we calculate

$$\begin{aligned}
 \sigma_{ch}^{\nu N} &= \sigma_0(0.415) \\
 \sigma_{ch}^{\bar{\nu} N} &= \sigma_0(0.172) \\
 \sigma_{ch}^{\bar{\nu} N} / \sigma_{ch}^{\nu N} &= 0.414
 \end{aligned}
 \tag{I.12}$$

for the charged current cross-sections. While the cross-section ratio is larger than that quoted in (I.8), the value is nearly in agreement with the value of 0.40 obtained after correction for the neutron excess in the freon chamber *).

The neutral current cross-sections and ratios are given in the Table for various Weinberg angles. The results for this model differ from those of model I by at most several per cent. From either the Table, or the appropriate table in Ref. 2), we see that the present CERN results ⁵⁾

$$\begin{aligned}
 (\sigma_0^{\nu N} / \sigma_{ch}^{\nu N})_{\text{expt}} &= 0.21 \pm 0.03 \\
 (\sigma_0^{\bar{\nu} N} / \sigma_{ch}^{\bar{\nu} N})_{\text{expt}} &= 0.45 \pm 0.09
 \end{aligned}$$

place the Weinberg angle conservatively in the range $0.3 \leq \sin^2 \theta_W \leq 0.5$.

*) See report by D.H. Perkins, in Ref. 14).

II. y DISTRIBUTIONS

The y distribution for the charged current reactions can be determined experimentally by measuring the energy E' of the outgoing muon together with the total energy E_h of the outgoing hadrons for each event. The ratio $y = \nu/E = E_h/(E' + E_h)$ then follows directly.

The quark parton model expressions for the neutrino and antineutrino y distributions follow from Eq. (I.1) with the help of Ref. 2) and are found to be

$$\left(\frac{d\sigma}{dy}\right)_{ch}^{\nu N} = \sigma_0 \left[(d_1 + d_2)(1-y)^2 + (d_1 + d_2) \cos^2 \theta_c + 2d_3 \sin^2 \theta_c \right] \quad (\text{II.1a})$$

and

$$\left(\frac{d\sigma}{dy}\right)_{ch}^{\bar{\nu} N} = \sigma_0 \left[(d_1 + d_2)(1-y)^2 + (d_1 + d_2) \cos^2 \theta_c + 2d_3 \sin^2 \theta_c \right]. \quad (\text{II.1b})$$

These y distributions, normalized to their respective total cross-sections, are plotted in Fig. 1 for the two different parton models discussed in Section I. Since in each case the antiquark contributions are small, the neutrino distribution is nearly flat, while the antineutrino distribution displays a strong quadratic dependence ^{*}). These results are in apparent agreement with both the Gargamelle data ¹⁴⁾ and the higher energy data from the Cal.Tech. neutrino group ⁸⁾ at NAL.

The average fractional energies carried off by the muons are calculated from Eq. (II.1) according to

$$\langle E'/E \rangle = 1 - \langle y \rangle$$

and are given in model I by

$$\langle E'/E \rangle_{ch}^{\nu N} = 0.5, \quad \langle E'/E \rangle_{ch}^{\bar{\nu} N} = 0.74 \quad (\text{II.2a})$$

and in model II by

^{*}) The effect of the sea is most apparent in the antineutrino y distribution near $y=1$.

$$\langle E'/E \rangle_{ch}^{\nu N} = 0.51, \quad \langle E'/E \rangle_{ch}^{\bar{\nu} N} = 0.71. \quad (\text{II.2b})$$

One will be able to compare these values with the results from the Gargamelle experiment in the near future ¹⁶⁾.

For the neutral current reactions, since the outgoing neutrinos cannot be detected, one must use a monochromatic beam of neutrinos with energy E as well as measure the total hadron energy E_h in order to determine $y = E_h/E$. Such monochromatic neutrino beams do not exist at present. The closest approximation occurs in the Cal.Tech. neutrino set-up ⁸⁾ at NAL, where two narrow-band beams (the so-called dichromatic beam) of neutrinos from $\pi_{\mu 2}$ and $K_{\mu 2}$ decays in flight are incident on a detector. The average energies in the two separated beams occur at $E \simeq 50$ GeV and $E \simeq 145$ GeV. As we shall later discuss in Section IV, it does appear possible to determine $\sin^2 \theta_W$ with this set-up.

The y distributions with the Weinberg neutral current follow from Eq. (I.1) :

$$\begin{aligned} \left(\frac{ds}{dy} \right)_0^{\nu N} = \sigma_0 \left\{ \frac{1}{2} [d_1 + d_2 + (d_{-1} + d_{-2})(1-y)^2] (1 - 2 \sin^2 \theta_W) \right. \\ \left. + \frac{1}{9} [5(d_1 + d_2 + d_{-1} + d_{-2}) + 2(d_3 + d_{-3})] [1 + (1-y)^2] \sin^4 \theta_W \right\} \end{aligned} \quad (\text{II.3})$$

and similarly for $\bar{\nu} N$ with d_j replaced by d_{-j} .

The predictions for the fractional energy lost by the neutrinos and antineutrinos are plotted in Fig. 2 as a function of $\sin^2 \theta_W$ for the two models of interest. In Fig. 3 we plot the y distribution for the inclusive ν and $\bar{\nu}$ reactions for different values of $\sin^2 \theta_W$.

A striking feature of Fig. 3 is that all curves pass through a common point for $(1-y)^2 = 1/3$ as is apparent from Eqs. (II.3) and (I.3). This feature is more general than the Weinberg model and should hold true in any case so long as the F_0 structure function is small. The y distributions for neutrino and antineutrino processes become equal for $\sin^2 \theta_W = 0.5$ as the V-A interference vanishes for this particular angle with isoscalar targets, cf., Eq. (I.4).

III. v DISTRIBUTIONS

We now turn our attention to the $v = xy = q^2/2ME$ distributions discussed first by Myatt and Perkins ¹⁷⁾ and, more recently, strongly advocated by Bjorken, Cline and Mann ¹⁸⁾. For this purpose, we can recast Eq. (I.1) into the form

$$\frac{d\sigma^{\nu, \bar{\nu}}}{dv} = \sigma_0 \int_v^1 dx \left[\left(1 - \frac{v}{x}\right)^2 F_{\pm} + F_{\mp} + 2\left(1 - \frac{v}{x}\right) F_0 \right] \quad (\text{III.1})$$

from which one sees that all points on a $\sigma^{-1} d\sigma/dv$ plot for a given inclusive process should lie along the same curve independent of the incident energy E .

For the charged current reaction, the v distributions are given by

$$\left(\frac{d\sigma}{dv}\right)_{ch}^{\nu N} = \sigma_0 \int_v^1 dx \left[\left(1 - \frac{v}{x}\right)^2 (D_1 + D_2) + (D_1 + D_2) \cos^2 \theta_c + 2D_3 \sin^2 \theta_c \right] \quad (\text{III.2})$$

with the antineutrino distribution obtained by the replacements D_j by D_{-j} and d_j by d_{-j} . In the case of the neutral current reactions, one obtains in the Weinberg model

$$\begin{aligned} \left(\frac{d\sigma}{dv}\right)_0^{\nu N} = \sigma_0 \int_v^1 dx \left\{ \frac{1}{2} [(D_1 + D_2) \left(1 - \frac{v}{x}\right)^2 + D_1 + D_2] (1 - 2\sin^2 \theta_W) \right. \\ \left. + \frac{1}{9} [5(D_1 + D_2 + D_{-1} + D_{-2}) + 2(D_3 + D_3)] [1 + \left(1 - \frac{v}{x}\right)^2] \sin^4 \theta_W \right\} \end{aligned} \quad (\text{III.3})$$

with the $\bar{\nu}N$ distributions obtained by the same prescriptions as above. The average v distributions follow from the above and are given by

$$\begin{aligned} \langle v \rangle_{ch}^{\nu N} &= \langle q^2/2ME \rangle_{ch}^{\nu N} \\ &= \int_0^1 dx \ x^2 \left[\frac{1}{12} (D_1 + D_2) + \frac{1}{2} (D_1 + D_2) \cos^2 \theta_c \right. \\ &\quad \left. + D_3 \sin^2 \theta_c \right] \sigma_0 / \sigma_{ch}^{\nu N} \end{aligned} \quad (\text{III.4})$$

and

$$\begin{aligned} \langle v \rangle_0^{\nu N} &= \int_0^1 dx \ x^2 \left\{ \frac{1}{4} \left[\frac{1}{6} (D_1 + D_2) + D_1 + D_2 \right] (1 - 2\sin^2 \theta_W) \right. \\ &\quad \left. + \frac{7}{108} [5(D_1 + D_2 + D_{-1} + D_{-2}) + 2(D_3 + D_3)] \sin^4 \theta_W \right\} \sigma_0 / \sigma_0^{\nu N}. \end{aligned} \quad (\text{III.5})$$

The advantage of the ν variable for the charged current inclusive reaction lies in the fact that $\nu = q^2/2ME = (E'/M)(1-\cos\theta)$ is determined simply by the observed energy and angle of the outgoing muon. In the neutral current process, on the other hand, the outgoing neutrino is not detected so that q^2 must be inferred from the measured hadron energy and momenta in a monochromatic neutrino beam. While no present experimental facility has such capability, we shall give the resulting distributions for possible future use.

To do this, we must specify the x dependence of the quark distribution functions, $D_j(x)$. To a good approximation, in model I, we take

Model I :

$$\begin{aligned} x(D_1 + D_2) &= 1.59 F_2^{ed}(x) \\ xD_3 &= xD_{-3} = 0.265 F_2^{ed}(x) \\ xD_{-1} &= xD_{-2} = 0 \end{aligned} \quad (\text{III.6a})$$

while in model II we take

Model II :

$$\begin{aligned} x(D_1 + D_2) &= 1.64 F_2^{ed}(x) \\ xD_{-1} &= xD_{-2} = xD_3 = xD_{-3} = 0.056 F_2^{ed}(x). \end{aligned} \quad (\text{III.6b})$$

For the deuteron structure function, we use the analysis of the new SLAC data by Bodek¹⁵⁾ and write

$$\begin{aligned} F_2^{ed}(x) &= 1.64(1-x)^3 - 3.58(1-x)^4 + 15.61(1-x)^5 \\ &\quad - 22.28(1-x)^6 + 9.19(1-x)^7. \end{aligned} \quad (\text{III.7})$$

In order to avoid the logarithmic divergence at $\nu=0$ arising with the above form, we demand

$$\lim_{\nu \rightarrow 0} \int_{\nu}^{\nu'} d\nu D_j(\nu) = \langle N_j \rangle.$$

The divergence is due to the wee parton contribution to $D_j(x)$ at small x which we have ignored in the simple models I and II.

The ν distributions are plotted in Fig. 4 for the charged current case with the dashed curves referring to model I and the solid curves to model II. The ν distributions for the neutral current reactions appear in

Figure 5 for various values of $\sin^2\theta_W$ only for model II. In Fig. 6 we plot the average values of y in $\langle q^2/2ME \rangle$ vs $\sin^2\theta_W$ for the two models in question. For the charged current reactions, the predicted values are

$$\begin{aligned} \langle q^2/2ME \rangle_{ch}^{\nu N} &= 0.130 \\ \langle q^2/2ME \rangle_{ch}^{\bar{\nu} N} &= 0.068 \end{aligned} \quad (\text{III.8a})$$

for model I and

$$\begin{aligned} \langle q^2/2ME \rangle_{ch}^{\nu N} &= 0.121 \\ \langle q^2/2ME \rangle_{ch}^{\bar{\nu} N} &= 0.072 \end{aligned} \quad (\text{III.8b})$$

for model II.

Again we observe that the νN and $\bar{\nu} N$ distributions are equal for $\sin^2\theta_W = 0.5$. The common point in the v distribution occurs when the following equality is satisfied :

$$\int_{\nu}^{\prime} dx \left(1 - \frac{\nu}{x}\right)^2 D_j(x) = \frac{1}{3} \int_{\nu}^{\prime} dx D_j(x) \quad (\text{III.9})$$

for all j . The actual value of the ratio $\frac{1}{\sigma} (d\sigma/d\nu)$ at that particular ν depends on the ratio

$$\int_{\nu}^{\prime} dx D_j(x) / d_j .$$

IV. REMARKS

The present imprecision with which the experimentalists can measure q^2 from the observed final hadron distribution alone renders the y distributions of little use for determining $\sin^2\theta_W$ in the neutral current reactions. This applies even for the average values of $q^2/2ME$.

With a monochromatic neutrino beam, however, one can measure the total hadron energy well enough to determine y for each event and then to measure accurately the y distribution even for neutral current events. Unfortunately, even the best present neutrino beams are only relatively narrow and, in fact, contain two bands of neutrinos from $\pi_{\mu 2}$ and $K_{\mu 2}$ decays. In the Cal.Tech. experiment ⁸⁾ at NAL, the average neutrino energy from $\pi_{\mu 2}$ decay is 50 GeV while that from $K_{\mu 2}$ decay is 145 GeV. Hence for total hadron energies less than 90 GeV, one cannot distinguish which band of neutrinos was responsible for the interaction due to the 40 GeV beam spread and apparatus resolution.

This suggests that one should make a cut on y of $y \geq 0.6$, for example, to separate cleanly those events arising from the higher energy K band neutrinos. One can then measure the number of neutrino events and the number of antineutrino events with $y \geq 0.6$. In the scaling region, to a good approximation, the fraction of neutral current events arising from the higher energy K band neutrinos is equal to the observed fraction of charged current events in that band. The fraction of neutral current events from K band neutrinos with $y \geq 0.6$ can then be calculated.

From Fig. 3 we have computed the expected ratio of the fraction of neutrino events with $y \geq 0.6$ and plotted this ratio in Fig. 7 vs $\sin^2\theta_W$ for models I and II. Unlike the average y distributions in Fig. 2 which are rather flat, the curves in Fig. 7 are rather steeply rising in the range $0.2 \leq \sin^2\theta_W \leq 0.8$. This flux independent technique can then serve as a useful tool for determining $\sin^2\theta_W$, aside from the cross-section method of Refs. 2) and 4).

$\sin^2 \theta_W$	$\sigma_o^{\nu N} / \sigma_o$	$\sigma_o^{\bar{\nu} N} / \sigma_o$	$\sigma_o^{\bar{\nu} N} / \sigma_o^{\nu N}$	$\sigma_o^{\nu N} / \sigma_{ch}^{\nu N}$	$\sigma_o^{\bar{\nu} N} / \sigma_{ch}^{\bar{\nu} N}$
0	0.219	0.086	0.39	0.53	0.50
0.20	0.146	0.066	0.45	0.35	0.38
0.33	0.113	0.068	0.60	0.27	0.40
0.40	0.100	0.073	0.73	0.24	0.42
0.60	0.082	0.108	1.32	0.20	0.63
0.80	0.092	0.171	1.86	0.22	0.99
1.00	0.130	0.262	2.02	0.31	1.52

TABLE : Neutral current neutrino and antineutrino cross-sections on nucleons for model II in units of $\sigma_o = G^2 s / 2\pi$. Ratios of these cross-sections relative to each other and to the charged current cross-sections are also given.

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FIGURE CAPTIONS

- Figure 1 : y distributions for the neutrino and antineutrino charged current reactions. The solid curves refer to model II, the dashed curves to model I.
- Figure 2 : Average lepton elasticities for the neutral current reactions as functions of $\sin^2\theta_W$. The same convention applies as in Fig. 1.
- Figure 3a : y distributions for the neutral current neutrino (solid curves) and antineutrino (dashed curves) reactions in model I for values of $\sin^2\theta_W$ indicated in the right-hand margin.
- Figure 3b : y distributions for the neutral current reactions in model II.
- Figure 4 : v distributions for the charged current reactions. The solid curves refer to model II, the dashed curves to model I.
- Figure 5 : v distributions for the neutral current neutrino (solid curves) and antineutrino (dashed curves) reactions in model II for particular values of $\sin^2\theta_W$.
- Figure 6 : Average values of v for the neutral current reactions as functions of $\sin^2\theta_W$ in model II (solid curves) and I (dashed curves).
- Figure 7 : Ratio of the fractional number of antineutrino events to the fractional number of neutrino events in the range $0.6 \leq y \leq 1.0$ as a function of $\sin^2\theta_W$ for the neutral current reactions. The solid curve refers again to model II, the dashed curve to model I.

FIG.1

FIG. 2

FIG. 3a

FIG.3b

FIG.4

FIG.5

FIG.6

FIG.7