CERN-EP/80-215/Add.1

3 February 1981

ERRATUM

The preprint

"Experimental study of neutral-current and charged current
neutrino cross-sections"

by the CHARM Collaboration (CERN-EP/80-215) contains an error which we would like to correct. The uncertainty of the absolute calibration of the beam current transformer ($\pm 3\%$) has been omitted in the evaluation of systematic errors on the charged current cross-sections. Please take note of the corrected values of the systematic errors underlined on the attached pages. The cross-section ratios, the value of $\sin^2\theta$, g_L^2 and g_R^2 and ρ are not affected by this part of the systematic error and therefore remain unchanged. The version which will appear in Physics Letters has already been corrected.

$$R = \frac{\sigma(\nu N \rightarrow \nu X)}{\sigma(\nu N \rightarrow \mu^- X)} = 0.320 \pm 0.010$$

and

$$\bar{R} = \frac{\sigma(\bar{\nu} N \rightarrow \nu X)}{\sigma(\bar{\nu} N \rightarrow \mu^+ X)} = 0.377 \pm 0.020 .$$

The systematic error in these results is small (about one third) compared with the statistical one.

Using a recent QCD model calculation by Kim et al. [9], taking the beam spectra and selection criteria of the present experiment into account, we deduce a value of the electroweak mixing angle of the Glashow-Salam-Weinberg model corresponding to

$$\sin^2 \theta = 0.220 \pm 0.014 . \quad (3)$$

Kim et al. [9] estimate an additional error of 0.009 on this value because of uncertainties in the model calculation. In fig. 1 we compare these results with previous measurements; the result of the model calculation is shown for different values of $\sin^2 \theta$.

Making use of the absolute normalization of the neutrino fluxes and weighting the spectrum assuming a linear rise of the cross-sections with neutrino energy, we measure the total CC cross-sections of neutrinos and antineutrinos on an isoscalar target (including the quasi-elastic contributions):

$$\begin{aligned} \sigma_{\text{tot}}(\nu N \rightarrow \mu^- X) &= (0.604 \pm 0.032) \times 10^{-38} \times E_\nu \text{ cm}^2 \text{ GeV nucleon}^{-1} \\ \sigma_{\text{tot}}(\bar{\nu} N \rightarrow \mu^+ X) &= (0.301 \pm 0.018) \times 10^{-38} \times E_{\bar{\nu}} \text{ cm}^2 \text{ GeV nucleon}^{-1}, \end{aligned} \quad (4)$$

and their ratio^{*)}:

$$r = \frac{\sigma(\bar{\nu} N \rightarrow \mu^+ X)}{\sigma(\nu N \rightarrow \mu^- X)} = 0.498 \pm 0.019 . \quad (5)$$

All cross-sections are averaged over the neutrino energy range 20 to 200 GeV.

*) Uncorrected for the shower energy cut, we find

$$r = 0.470 \pm 0.017 .$$

Table 2

Results of the analysis

R	$= 0.320 \pm 0.009 \text{ (stat)} \pm 0.003 \text{ (syst)}^a)$
$\bar{R}$	$= 0.377 \pm 0.020 \text{ (stat)} \pm 0.003 \text{ (syst)}^a)$
$\sigma_{\text{tot}}^{\text{CC}}$	$= 0.604 \pm 0.009 \text{ (stat)} \pm \underline{0.031} \text{ (syst)} \times 10^{-38} \times E_{\nu} \text{ cm}^2 \text{ GeV nucleon}^{-1}$
$\sigma_{\text{tot}}^{\bar{\text{CC}}}$	$= 0.301 \pm 0.008 \text{ (stat)} \pm \underline{0.016} \text{ (syst)} \times 10^{-38} \times E_{\nu} \text{ cm}^2 \text{ GeV nucleon}^{-1}$
r	$= 0.498 \pm 0.015 \text{ (stat)} \pm 0.012 \text{ (syst)}$
$\sin^2\theta$	$= 0.220 \pm 0.013 \text{ (stat)} \pm 0.004 \text{ (syst)}^b)$
$\sin^2\theta$	$= 0.230 \pm 0.022 \text{ (stat)} \pm 0.005 \text{ (syst)}^c)$

a) For shower energy $> 2 \text{ GeV}$.

b) From QCD model calculations. The systematic errors quoted do not include the uncertainties of the model.

c) From Paschos-Wolfenstein relation, see eq. (8).

EXPERIMENTAL STUDY OF NEUTRAL-CURRENT AND CHARGED-CURRENT
NEUTRINO CROSS-SECTIONS

CHARM Collaboration

M. Jonker, J. Panman and F. Udo
NIKHEF, Amsterdam, Netherlands

J.V. Allaby, U. Amaldi, G. Barbiellini¹⁾, A. Baroncelli, V. Blobel²⁾, G. Cocconi,
W. Flegel, W. Kozanecki³⁾, K.H. Mess, M. Metcalf, J. Meyer,
R.S. Orr, F. Schneider, V. Valente¹⁾, A.M. Wetherell and K. Winter
CERN, Geneva, Switzerland

F.W. Büsser, P.D. Gall, H. Grote, B. Kröger, E. Metz,
F. Niebergall, K.H. Ranitzsch and P. Stähelin
II. Institut für Experimentalphysik, Universität Hamburg^{*}, Hamburg, Germany

E. Grigoriev, V. Kaftanov, V. Khovansky and A. Rosanov
Institute of Theoretical and Experimental Physics, Moscow, USSR

R. Biancastelli⁵⁾, B. Borgia⁴⁾, C. Bosio⁵⁾, A. Capone⁴⁾, F. Ferroli⁴⁾,
E. Longo⁴⁾, P. Monacelli⁴⁾, F. de Notaristefani⁴⁾, P. Pistilli⁴⁾,
and C. Santoni⁵⁾
Istituto Nazionale di Fisica Nucleare, Roma, Italy

(Submitted to Phys. Letters)

-
- 1) On leave of absence from the Laboratori Nazionali di Frascati dell'INFN, Frascati, Italy.
- 2) Now at the II. Institut für Experimentalphysik, Universität Hamburg, Germany.
- 3) Now at the University of California, Riverside, Calif., USA.
- 4) Istituto di Fisica, Università di Roma, and INFN, Sez. di Roma, Italy.
- 5) INFN Sez. Sanità and Istituto Superiore di Sanità, Roma, Italy.
- * Supported by the Bundesministerium für Forschung und Technologie, Bonn, Fed. Rep. of Germany.

ABSTRACT

Samples of 9200 muon-neutrino and 3800 muon-antineutrino interactions on nuclei were obtained with the fine-grain calorimeter of the CHARM Collaboration at the CERN 200 GeV narrow-band neutrino beam. The interactions were classified as either neutral-current or charged-current processes on an event-by-event basis. Neutral-current and charged-current cross-sections in neutrino and antineutrino interactions are presented. From these results we deduce a statistically significant contribution of right-handed coupling to the neutral hadronic current, and a value of the electroweak mixing angle corresponding to $\sin^2\theta = 0.220 \pm 0.014$.

Measurements of deep inelastic neutrino and antineutrino scattering on isoscalar targets determine the strength of the left-handed and right-handed couplings of the neutral quark current from the following ratios of cross-sections [1]:

$$\begin{aligned}
 R &= \frac{\sigma(\nu_{\mu} N \rightarrow \nu_{\mu} X)}{\sigma(\nu_{\mu} N \rightarrow \mu^{-} X)}, \\
 \bar{R} &= \frac{\sigma(\bar{\nu}_{\mu} N \rightarrow \bar{\nu}_{\mu} X)}{\sigma(\bar{\nu}_{\mu} N \rightarrow \mu^{+} X)}, \\
 r &= \frac{\sigma(\bar{\nu}_{\mu} N \rightarrow \mu^{+} X)}{\sigma(\nu_{\mu} N \rightarrow \mu^{-} X)}.
 \end{aligned} \tag{1}$$

Results on these ratios were obtained with the CHARM detector [2] in the narrow-band neutrino beam of the CERN Super Proton Synchrotron (SPS). This beam focuses pions and kaons of $[200 \pm 9 \text{ (r.m.s.)}]$ GeV produced at 0° by the interaction of 400 GeV protons in a 3 mm diameter, 50 cm long, beryllium target. The central beam momentum is known with an accuracy of 1%. The beam entering the 300 m long decay tunnel is nearly parallel, with an angular divergence of ± 0.22 mrad in both planes due to the chromaticity of quadrupole focusing and to the finite target size. The decay tunnel is followed by a shield consisting of 180 m of iron, 2.5 m in diameter, and of 230 m of earth.

The neutrino energy spectrum consists of two components, corresponding to pion and kaon decays. The radial dependence of the neutrino energy spectra was calculated, taking into account the phase-space density of the secondary beam and all decay modes of pions and kaons. The relative amounts of the pion and kaon components, within the angular and momentum acceptance of the secondary beam, were determined experimentally from the K/π ratio measured in the narrow-band beam using the integrated current of a specially designed differential Čerenkov counter. The measurements yield [3] the ratios $K^{+}/\pi^{+} = (14.7 \pm 0.44)\%$ and $K^{-}/\pi^{-} = (4.9 \pm 0.15)\%$. These values agree, within 2%, with independent measurements

in a secondary beam of low intensity, where individual particle identification was achieved by a focusing, differential Čerenkov counter [4].

Various intensity monitors for both primary and secondary particles are placed in the beam line [5]. The extracted proton beam intensity is measured by a beam current transformer and also by a secondary emission monitor mounted ahead of the target. Another secondary emission chamber, downstream from the target, monitors the secondaries produced. A beam current transformer placed just before the entrance of the decay tunnel, after the last bending magnet, measures the intensity of the secondary hadron beam.

The flux of muons from π and K decays is measured by a system of solid-state detectors at various positions within the iron shield. After 30 m of shielding, eight such detectors, mounted on a circle of 15 cm radius centred on the beam axis, are used in order to minimize beam position instability effects and background.

The beam current transformer in the secondary beam provides a good measurement of the total number of pions and kaons in the antineutrino beam. In the neutrino beam, the pion and kaon fluxes are much more uncertain because of the large proton content of the positively charged hadron beam ($p/\pi = 4.4 \pm 0.2$) [3]. The shield measurement of the ratio of the muon fluxes in the neutrino and antineutrino beams is not affected by this problem. Therefore we have used the beam current transformer to obtain the absolute antineutrino flux, and the solid-state muon detectors to measure the ratio of the neutrino and antineutrino fluxes.

The absolute calibration of the beam current transformer is known to $\pm 3\%$ [3], while its temporal stability is estimated to be better than 1% as a result of a check against ionization chambers both in the secondary beam and in the shield, and against the solid-state muon counters in the shield. The relative calibration of the solid-state detectors is known to better than 1% [6], thus the effect of variations in the beam steering on the total muon detection efficiency is smaller than 0.5%. An absolute calibration of these detectors is therefore unnecessary.

The secondary hadron beam is accompanied by low-energy electrons produced in the matter (foils, air) traversed by the beam. A $(5.5 \pm 3)\%$ correction was applied to the signal of the beam current transformer for the contribution of these δ -rays [3].

The detection efficiencies for muons produced by the decays of pions and kaons in the secondary hadron beam are different. This effect was estimated by a Monte Carlo simulation of the muon trajectories in the shielding. According to the calculation, the acceptance of the solid-state detectors for muons from kaon decay is a factor of 1.30 ± 0.08 higher than for muons from pion decay. Corrections corresponding to the different K/π ratios were applied.

The flux of muons measured in the shielding was corrected for contributions from particles decaying before the momentum-defining slits. This background was determined experimentally with the momentum slits closed; it amounts to $(4.1 \pm 0.2)\%$ in the neutrino beam and $(3.4 \pm 0.2)\%$ in the antineutrino beam.

Dead-time effects in the neutrino detector were corrected using a signal from a threshold Čerenkov counter placed in the beam line and recorded independently during the active time of the target calorimeter and the gate time.

In order to have a consistency check on the monitoring of the neutrino beam, we have determined the event rate normalized to the absolute neutrino flux for different samples of the data. The spread of the distribution of these normalized event rates is compatible with being purely statistical.

The CHARM detector [2] consists of a calorimeter, containing 78 instrumented target planes surrounded by a magnetized iron frame, and a forward muon spectrometer. It has good energy and spatial resolution and a high power of pattern recognition. The trigger of the experiment required that at least four scintillator planes were hit and that the shower energy was larger than 0.5 GeV; hence, showers with energies as low as 1.5 GeV were detected with essentially full efficiency.

The fine spatial resolution of the calorimeter is such that classification of events as neutral-current (NC) or charged-current (CC) candidates may be made on an event-by-event basis.

The criteria used to select neutrino interaction candidates were that

- i) the interaction vertex lies within a fiducial volume chosen to ensure good pattern recognition and low background conditions; this fiducial volume covers an area of 120 cm (90 cm) radius perpendicular to the beam axis in neutrino (antineutrino) exposures, and extends longitudinally from target plate 7 to target plate 60, inclusive, corresponding to a target mass of 65 (37) tons;
- ii) the event contains no charged track entering the front or the sides of the detector;
- iii) the shower energy is greater than 2 GeV.

The neutrino event candidates were classified as CC or NC interactions according to the following criteria:

- i) a CC event has a track identified as a muon associated with the interaction vertex (a track is called a muon if it has a range corresponding to more than 1.0 GeV/c and if it is clearly visible outside the hadron shower for a length corresponding to a range of more than 0.67 GeV/c; the track is further required to have no kink or interaction within the ranges defined above);
- ii) all other events are classified as NC.

The automatic reconstruction and classification of all NC candidates have been verified by an eye scan. The 5% wrong classifications of these candidates were corrected individually. In the case of CC candidates, a sample was scanned and a correction, amounting to nine events, was applied accordingly.

We thus find 9200 neutrino and 3800 antineutrino CC and NC events (see table 1). These two samples of data were corrected for backgrounds and for various effects mixing NC and CC events. The following corrections have been considered:

- i) The wide-band background of events induced by neutrinos and antineutrinos produced by the decay of hadrons before the momentum slits in the beamline is evaluated using special runs during which the momentum slits were closed. The exposure in these runs is normalized relative to the normal data-taking exposure, using the secondary beam intensity as monitored by the secondary emission foil downstream from the target.
- ii) The number of cosmic-ray events classified as neutrino events is obtained by analysing data taken under identical trigger conditions while the accelerator was off. The total contribution of these events is small.
- iii) The number of events lost by the automatic pattern recognition is determined by an eye scan of a sample of the rejected events. On the basis of this scan we have added 21 (15) NC events and 16 (12) CC events to the neutrino (anti-neutrino) event samples.
- iv) The selection criteria for muon tracks results in a number of CC events being classified as NC events. This effect is mainly caused by muons leaving the sides of the detector before being identified and, to a lesser extent, by muons obscured by the hadronic shower. The contributions were evaluated using a semi-Monte Carlo method, where Monte Carlo generated muons were superimposed on showers of real events and then reconstructed.
- v) The decay in flight of pions and kaons in the shower can produce a muon track which satisfies the selection criteria for CC events. This correction was determined experimentally from an analysis of dimuon events [7].
- vi) The narrow-band beam contains a component of electron-neutrinos from K_{e3} decays. Neither their CC nor NC interactions give a muon in the final state, and have to be subtracted from the NC sample. The correction is calculated using the known K-decay branching ratios [8] and assuming electron-muon universality.

From the corrected event numbers listed in table 1 we obtain the following cross-section ratios on an isoscalar target for shower energies above 2 GeV:

$$R = \frac{\sigma(\nu N \rightarrow \nu X)}{\sigma(\nu N \rightarrow \mu^- X)} = 0.320 \pm 0.010$$

and

$$\bar{R} = \frac{\sigma(\bar{\nu} N \rightarrow \nu X)}{\sigma(\bar{\nu} N \rightarrow \mu^+ X)} = 0.377 \pm 0.020 . \quad (2)$$

The systematic error in these results is small (about one third) compared with the statistical one.

Using a recent QCD model calculation by Kim et al. [9], taking the beam spectra and selection criteria of the present experiment into account, we deduce a value of the electroweak mixing angle of the Glashow-Salam-Weinberg model corresponding to

$$\sin^2\theta = 0.220 \pm 0.014 . \quad (3)$$

Kim et al. [9] estimate an additional error of 0.009 on this value because of uncertainties in the model calculation. In fig. 1 we compare these results with previous measurements; the result of the model calculation is shown for different values of $\sin^2\theta$.

Making use of the absolute normalization of the neutrino fluxes and weighting the spectrum assuming a linear rise of the cross-sections with neutrino energy, we measure the total CC cross-sections of neutrinos and antineutrinos on an isoscalar target (including the quasi-elastic contributions):

$$\begin{aligned} \sigma_{\text{tot}}(\nu N \rightarrow \mu^- X) &= (0.604 \pm 0.027) \times 10^{-38} \times E_\nu \text{ cm}^2 \text{ GeV nucleon}^{-1} \\ \sigma_{\text{tot}}(\bar{\nu} N \rightarrow \mu^+ X) &= (0.301 \pm 0.015) \times 10^{-38} \times E_{\bar{\nu}} \text{ cm}^2 \text{ GeV nucleon}^{-1}, \end{aligned} \quad (4)$$

and their ratio^{*)}:

$$r = \frac{\sigma(\bar{\nu} N \rightarrow \mu^+ X)}{\sigma(\nu N \rightarrow \mu^- X)} = 0.498 \pm 0.019 . \quad (5)$$

All cross-sections are averaged over the neutrino energy range 20 to 200 GeV.

*) Uncorrected for the shower energy cut, we find

$$r = 0.470 \pm 0.017 .$$

From the measured cross-section ratios, we obtain the chiral coupling constants or, equivalently, the relative strength of the NC to CC coupling ρ and the electroweak mixing angle $\sin^2\theta$. The results are summarized in table 2. We first analyse the results within the framework of a $SU(2) \times U(1)$ gauge theory, in which no specific value of the parameter ρ is assumed.

We find the following values of the left-handed and right-handed coupling constants after correction for the strange sea and the shower energy cut:

$$\begin{aligned} g_L^2 &= \rho^2(u_L^2 + d_L^2) = 0.305 \pm 0.013 , \\ g_R^2 &= \rho^2(u_R^2 + d_R^2) = 0.036 \pm 0.013 . \end{aligned} \quad (6)$$

We thus obtain a non-zero value of the right-handed coupling with more than 90% confidence (see fig. 2) without constraining the value of ρ .

This result can also be expressed in terms of the parameters ρ and $\sin^2\theta$:

$$\begin{aligned} \rho &= 1.027 \pm 0.023 \\ \sin^2\theta &= 0.247 \pm 0.038 . \end{aligned} \quad (7)$$

In the framework of the Glashow-Salam-Weinberg model, NC and CC coupling have equal strength, $\rho = 1$. To obtain the electroweak mixing angle in the context of this model, we have made use of an equation proposed by Paschos and Wolfenstein [10]:

$$\frac{\sigma^{\nu}(\text{NC}) - \sigma^{\bar{\nu}}(\text{NC})}{\sigma^{\nu}(\text{CC}) - \sigma^{\bar{\nu}}(\text{CC})} = \rho^2(\frac{1}{2} - \sin^2\theta) . \quad (8)$$

Assuming $\rho = 1$ and inserting event numbers and the ratio of neutrino and anti-neutrino fluxes, we find for a 2 GeV shower energy cut^{*)},

$$\sin^2\theta = 0.230 \pm 0.023 .$$

Relation (8) holds only if the structure functions and their scaling violations in neutrino and antineutrino interactions are equal, if the charmed sea is negligible

*) Inserting the event numbers obtained with a 25 GeV shower energy cut, we find $\sin^2\theta = 0.224 \pm 0.025$.

and if the neutrino and antineutrino energy spectra are equal. We estimate an additional systematic error of ± 0.008 due to these effects, in agreement with the calculations of Paschos [11].

The systematic error in the results given in eqs. (6), (7), and (9) is composed of approximately equal contributions from the uncertainties in the various corrections applied to the raw data sample and from the uncertainties in the neutrino flux monitoring.

Assuming that the Callan-Gross relation [12] is valid and that the structure functions are equal for neutrino and antineutrino interactions, we evaluate the momentum sum rule, interpreted in the quark model as the fractional momentum carried by the quarks and antiquarks in the nucleon.

$$\frac{3\pi}{4G^2_{ME}} \left[\sigma_{\text{tot}}(\nu N \rightarrow \mu^- X) + \sigma_{\text{tot}}(\bar{\nu} N \rightarrow \mu^+ X) \right] = 0.44 \pm 0.02 . \quad (10)$$

To conclude, we have measured the cross-sections of deep inelastic neutrino and antineutrino scattering on isoscalar targets, making use of an event-by-event classification of NC and CC interactions. We find a statistically significant contribution of the right-handed coupling of the neutral hadronic current, interpreted in the standard model of Glashow-Salam-Weinberg as being due to the mixing with the electromagnetic current.

The strengths of the NC and the CC weak coupling are found to be equal to within $\pm 2.5\%$. The values of the left-handed and the right-handed coupling constants of the weak neutral hadronic current determined by these measurements, and the total cross-sections, agree with previous results obtained by different methods [13-17].

We most sincerely thank our many technical collaborators, and the members of the SPS staff for the excellent operation of the accelerator. G. Cavallari, H. Heyne, J. May, G. Sigurdsson and G. Stefanini for their competent help with the beam monitoring. We acknowledge the work of C. Busi on data reduction and analysis.

REFERENCES

- [1] See, for example, P.Q. Hung and J.J. Sakurai, Phys. Lett. 63B (1976) 295;
or L.M. Sehgal, Phys. Lett. 71B (1977) 99.
- [2] A.N. Diddens et al., CHARM Collaboration, preprint CERN-EP/80-63 (1980),
Nuclear Instruments and Methods (in press).
- [3] J. May, G. Sigurdsson and G. Stefanini (CERN), private communication.
- [4] H.W. Atherton et al., CERN 80-07 (1980).
- [5] G. Sigurdsson and G. Stefanini, CERN/NP/BEAM/75-1 (1975) (unpublished).
- [6] H. Heyne (CERN), private communication.
- [7] M. Jonker et al., CHARM Collaboration, Experimental study of opposite- and
same-sign dimuon events produced by neutrinos and antineutrinos (in pre-
paration).
- [8] Particle Data Group, Review of particle properties, Phys. Lett. 75B (1978).
- [9] J.E. Kim et al., Univ. Pennsylvania UPR 158T (1980) (submitted to Reviews of
Modern Physics).
- [10] E.A. Paschos and L. Wolfenstein, Phys. Rev. D 7 (1973) 91.
- [11] E.A. Paschos, Univ. Dortmund, DO-TH 80/12 (1980).
- [12] C. Callan and D.J. Gross, Phys. Rev. Lett. 22 (1969) 156.
- [13] J.B. Blietschau et al., Gargamelle Collaboration, Nucl. Phys. B118 (1977) 218.
- [14] P. Wanderer et al., HPWF Collaboration, Phys. Rev. D 17 (1978) 1679.
- [15] F.S. Merritt et al., CITF Collaboration, Phys. Rev. D 17 (1978) 2199.
- [16] M. Deden et al., BEBC ABCLOS Collaboration, Nucl. Phys. B149 (1979) 1.
- [17] M. Holder et al., CDHS Collaboration, Phys. Lett. 71B (1977) 222.

C. Geweniger, CDHS Collaboration, Proc. Int. Conf. Neutrino '79, Bergen, 1979
(eds. A. Haatuft and C. Jarlskog), vol. 2, p.392.
Bergen, Norway (1979).

J.G.H. de Groot et al., CDHS Collaboration, Z. Phys. C1 (1979) 143.

Table 1
Corrections to raw event numbers for shower energy > 2 GeV

	$\bar{\nu}$			ν		
	NC	CC		NC	CC	
Raw event numbers	1126 $\pm$ 34	2751 $\pm$ 53		2361 $\pm$ 49	6503 $\pm$ 81	
Wide-band and cosmic background	-143.8 $\pm$ 26.3	-244.0 $\pm$ 35.1		-95.4 $\pm$ 11.6	-112.6 $\pm$ 13.1	
μ selection criteria	-22.6 $\pm$ 2.2	+22.6 $\pm$ 2.2		-96.5 $\pm$ 9.3	+96.5 $\pm$ 9.3	
K and π decay in flight	+15.2 $\pm$ 3.1	-15.2 $\pm$ 3.1		+53.5 $\pm$ 10.9	-53.5 $\pm$ 10.9	
ν_e events from K_{e3} decay	-26.4 $\pm$ 3.0			-163.6 $\pm$ 10.0		
Corrected event numbers	948.3 $\pm$ 43.3	2514.4 $\pm$ 63.7		2059.0 $\pm$ 53.5	6433.4 $\pm$ 84.3	

Table 2

Results of the analysis

R	$= 0.320 \pm 0.009 \text{ (stat)} \pm 0.003 \text{ (syst)}^{\text{a)}$
$\bar{R}$	$= 0.377 \pm 0.020 \text{ (stat)} \pm 0.003 \text{ (syst)}^{\text{a)}$
$\sigma_{\text{tot}}^{\text{CC}}$	$= 0.604 \pm 0.009 \text{ (stat)} \pm 0.025 \text{ (syst)} \times 10^{-38} \times E_{\nu} \text{ cm}^2 \text{ GeV nucleon}^{-1}$
$\bar{\sigma}_{\text{tot}}^{\text{CC}}$	$= 0.301 \pm 0.008 \text{ (stat)} \pm 0.013 \text{ (syst)} \times 10^{-38} \times E_{\nu} \text{ cm}^2 \text{ GeV nucleon}^{-1}$
r	$= 0.498 \pm 0.015 \text{ (stat)} \pm 0.012 \text{ (syst)}$
$\sin^2\theta$	$= 0.220 \pm 0.013 \text{ (stat)} \pm 0.004 \text{ (syst)}^{\text{b)}$
$\sin^2\theta$	$= 0.230 \pm 0.022 \text{ (stat)} \pm 0.005 \text{ (syst)}^{\text{c)}$

a) For shower energy $> 2 \text{ GeV}$.

b) From QCD model calculations. The systematic errors quoted do not include the uncertainties of the model.

c) From Paschos-Wolfenstein relation, see eq. (8).

Figure captions

Fig. 1 : Comparison of the results of various experiments on R_V and $R_{\bar{V}}$ with the Glashow-Salam-Weinberg model. The rectangles indicate the $\pm 1\sigma$ limits. The data are taken with different cuts in shower energy (the cuts being 0 GeV, 4 GeV, 12 GeV, 15 GeV, and 10 GeV for experiments GGM [13], HPWF [14], CITF [15], BEBC [16], and CDHS [17], respectively. Our data have a cut of 2 GeV. The curve is obtained for our conditions following the model calculations of ref. 9, for different values of $\sin^2\theta$.

Fig. 2 : Best fit and confidence limits of 39%, 87%, and 99% on the chiral coupling constants as determined in this experiment. The drawn curves are lines of constant ρ , and the dashed curves are lines of constant $\sin^2\theta$.

Fig. 1

Fig. 2