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Experimental Study of x -Distributions
in Semileptonic Neutral-Current Neutrino and Antineutrino Reactions

The CHARM Collaboration

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Abstract

Using the CHARM detector 36000 deep inelastic neutral-current reactions of neutrinos (and 2000 of antineutrinos) from the 160 GeV narrow-band beam were recorded. The differential cross section $d\sigma/dx$ in the Bjorken scaling variable x was computed by unfolding the effects of limited acceptance and of resolution of the detector as well as the ambiguity of the energy of the incoming neutrinos (produced by π^- or K^- -decay).

Combining the results from the neutrino and antineutrino data, the structure functions F_2 and xF_3 and the antiquark momentum distribution measured via the NC coupling were determined. The distributions are in agreement with the corresponding CC distributions. Comparisons with deep inelastic muon scattering confirm the universality of nuclear structure functions as probed by the weak and the electromagnetic currents.

Structure functions and quark momentum distributions have been derived from several experiments from x -distributions of deep inelastic neutrino- and antineutrino-nucleon scattering via the weak charged-current coupling [1-3]:

$$\nu_\mu(\bar{\nu}_\mu) + N \xrightarrow{W^\pm} \mu^-(\mu^+) + X \quad (\text{CC})$$

A precise measurement of the momentum and direction of the outgoing muon allows the reconstruction of the kinematic parameters for single events.

In neutral-current reactions

$$\bar{\nu}_\mu + N \xrightarrow{Z^0} \bar{\nu}_\mu + X \quad (\text{NC})$$

the outgoing neutrino cannot be detected. The hadronic final state X together with the knowledge of the source of the entering neutrinos comprises all available information.

Consequently only few measurements of x -distributions in NC-reactions have been reported. A bubble chamber experiment (23 events from a 10 GeV neutrino beam) produced the first distribution [4], the CHARM collaboration reported an analysis of ≈ 2000 neutrino- and 860 antineutrino-events [5], and a measurement of ≈ 2300 neutrino- and 740 antineutrino-events at Fermilab was published without applying corrections for detector resolution effects [6]. No deviations from the corresponding CC distributions were reported.

We report here new results obtained from the analysis of 36000 neutrino-induced and 2000 antineutrino-induced events due to weak neutral current interaction with an isoscalar target.

The cross section of semileptonic (anti)neutrino scattering as a function of the Bjorken scaling variables x and y is written in terms of the structure functions xF_1 , F_2 and xF_3 :

$$\frac{d^2\sigma^\nu}{dx dy} = \frac{G^2 m_p E_\nu}{\pi} \left(\left(1 - y - \frac{m_p}{2E_\nu} xy\right) F_2^\nu(x, Q^2) + \frac{y^2}{2} 2xF_1^\nu(x, Q^2) + \left(y - \frac{y^2}{2}\right) xF_3^\nu(x, Q^2) \right)$$

$$\frac{d^2\sigma^{\bar{\nu}}}{dx dy} = \frac{G^2 m_p E_{\bar{\nu}}}{\pi} \left(\left(1 - y - \frac{m_p}{2E_{\bar{\nu}}} xy\right) F_2^{\bar{\nu}}(x, Q^2) + \frac{y^2}{2} 2x F_1^{\bar{\nu}}(x, Q^2) - \left(y - \frac{y^2}{2}\right) x F_3^{\bar{\nu}}(x, Q^2) \right)$$

where $E_{\bar{\nu}}$ is the energy of the incoming neutrino and the scaling variables are defined (with the hadron energy E_h and squared four-momentum Q^2 transferred to the nucleon of mass m_p) as:

$$y = E_h/E_{\bar{\nu}} \quad x = Q^2/2m_p E_h$$

At high neutrino energies $E_{\bar{\nu}} \gg m_p$, integrating over y and assuming the validity of the Callan-Gross relation $2xF_1 = F_2$ [7], one obtains:

$$\frac{d\sigma^{\bar{\nu}}}{dx} \stackrel{\text{def}}{=} \frac{G^2 m_p E_{\bar{\nu}}}{2\pi} F_{\pm}(x) = \frac{G^2 m_p E_{\bar{\nu}}}{\pi} \left(\frac{2}{3} F_2(x) \pm \frac{1}{3} x F_3(x) \right)$$

The structure functions can be determined by combining the “ x -distributions” $F_+(x)$ (for neutrinos) and $F_-(x)$ (for antineutrinos) which are directly related to the quark momentum distributions. With the valence-quark distribution $q_{val}(x)$ and assuming a symmetrical sea-quark distribution $q_{sea}(x) = \bar{q}_{sea}(x)$, the relations for an isoscalar target are:

$$\begin{aligned} F_2^{CC} &= \frac{3}{8} (F_+^{CC} + F_-^{CC}) = x(q_{val} + 2\bar{q}) + x(s - c) \\ xF_3^{CC} &= \frac{3}{4} (F_+^{CC} - F_-^{CC}) = xq_{val} \\ F_2^{NC} &= \frac{3}{8} (F_+^{NC} + F_-^{NC}) = x((u_L^2 + u_R^2 + d_L^2 + d_R^2)(q_{val} + 2\bar{q}) \\ &\quad - 2(u_L^2 + u_R^2 - d_L^2 - d_R^2)(s - c)) \\ xF_3^{NC} &= \frac{3}{4} (F_+^{NC} - F_-^{NC}) = x(u_L^2 - u_R^2 + d_L^2 - d_R^2) q_{val} \end{aligned}$$

where s and c denote the *strange*- and *charm*-quark contributions.

Defining the left- and right-handed coupling constants

$$g_L^2 = u_L^2 + d_L^2 \quad g_R^2 = u_R^2 + d_R^2$$

one gets for the structure function $x\bar{q}(x)$, neglecting the *strange*- and *charm*-quarks:

$$\begin{aligned} x\bar{q}^{CC} &= \frac{3}{16} (3F_-^{CC} - F_+^{CC}) \\ x\bar{q}^{NC} &= \frac{3}{16} \frac{1}{(g_L^2 + g_R^2)(g_L^2 - g_R^2)} ((3g_L^2 + g_R^2)F_-^{NC} - (g_L^2 + 3g_R^2)F_+^{NC}) \end{aligned}$$

or, with $\sin^2 \theta_W = 0.236$, as measured in this experiment [8], one gets:

$$\begin{aligned} F_2^{NC} &= 0.326 x(q_{val} + 2\bar{q}) + 0.07 x(s - c) \\ xF_3^{NC} &= 0.264 xq_{val} \\ x\bar{q}^{NC} &= 1.996 F_-^{NC} - 0.845 F_+^{NC} \end{aligned}$$

In the context of the Quark Model the structure functions are expected to be equal for NC and CC reactions apart from factors involving the coupling constants and a different contribution from s - and c -quarks to F_2 at small x .

The results reported here were obtained in a high statistics exposure of the CHARM neutrino detector in a $160\text{GeV}/c$ narrow band beam (NBB) [8]. Neutrinos and antineutrinos were produced in the decay of charge- and momentum-selected pions and kaons at the 450GeV CERN Super Proton Synchrotron. The 120m long beam line was tuned to a central momentum of $160\text{GeV}/c$ and accepted particles with a momentum spread of $\pm 6\%$ (r.m.s.). About 8m behind the last quadrupole, hadrons entered a 300m long decay tunnel, which was evacuated to a pressure of 0.15torr . At the end of the decay tunnel all surviving hadrons were absorbed in a 185m long iron shield. Muons were ranged out by a combination of the iron shield and a 220m long earth shielding following the iron.

The dominant two-body decays of pions and kaons produce a neutrino spectrum which is correlated with the distance r of the neutrino vertex from the beam axis, with an ambiguity due to the different masses of pions and kaons. The spectrum depends only on the π/K ratio, the optics of the magnetic focussing channel and on the dimensions of the decay tunnel; it can be reliably calculated. The relative amounts of pions and kaons in the beam were determined experimentally using a helium filled differential Čerenkov counter. The measurements yielded the ratios $K^+/\pi^+ = 0.1282 \pm 0.0028$ and $K^-/\pi^- = 0.0630 \pm 0.0033$.

The CHARM neutrino detector is a fine-grain calorimeter followed by an iron spectrometer with a toroidal magnetic field, and surrounded by a magnetized iron frame. The calorimeter has a sampling step corresponding to one radiation length or 0.22 absorption length, with scintillators, proportional drift tubes and streamer tubes as detecting elements. It is described in detail elsewhere [9]. The response of the calorimeter was calibrated in electron and pion beams in the range from 0.5 to $140\text{GeV}/c$ [10]. The energy of hadron showers is measured by the scintillators with a resolution of

$$\sigma(E_h)/E_h = 0.487/\sqrt{E_h/\text{GeV}} + 0.0127.$$

The lateral vertex position of hadron showers is determined by combining the measurements of all detection elements; the resolution is

$$\sigma(y) = (14.9/\sqrt{E_h/\text{GeV}} + 0.006E_h/\text{GeV}) \text{ cm}.$$

The hadron shower direction was determined for each event by searching in each projection for the median defined as the line from the vertex dividing the shower energy into two parts of equal magnitude. The angular resolution, depending on energy and angle of the shower, has to be known exactly for the unfolding of the x -distribution. In the test beam we found a resolution at small angles of

$$\sigma(\theta_h) = (0.141/\sqrt{E_h/\text{GeV}} + 0.52\text{GeV}/E_h)\text{rad}.$$

We determined the resolution function for the full angular range from the sample of 100'000 CC events recorded in the same exposure. For this purpose the measured angle was compared to the value predicted from the precise measurement of the muon angle and momentum, taking into account the shower energy and the kinematic constraints.

Details of the event selection are described in ref[8]. A total number of 140'000 neutrino induced events were identified. They were selected to have no visible entering track and more than 2GeV hadronic shower energy. The fiducial volume extended over 55 target plates leaving five plates at the beginning of the detector to reject incoming tracks and 18 plates at the end to ensure good shower containment. For this analysis events with a shower energy above 4GeV and vertex not more than 120cm away from the beam axis were used. This results in a cylindrical fiducial volume containing a mass of 69tons.

Each event was classified by an automatic pattern recognition program (Table 1). Selection criteria were applied which attempt to identify the physical processes and to minimize the corrections needed to relate the visible cross-sections to the physical cross-sections. If an outgoing muon was found with reconstructed vertex not more than 30cm away from the shower vertex, a momentum of at least 1GeV and a visible track outside the shower corresponding to more than 0.67GeV energy loss, the event was classified CC. All other neutrino reactions were classified NC.

The analysis of backgrounds and misclassifications was done carefully for the determination of $\sin^2 \theta_W$ and for the measurement of the total cross sections — details can be found in ref [8,11].

The main sources of background associated with the beam are neutrinos from decays of secondary hadrons before the momentum selection, which do not satisfy the energy-radius relation (wide-band background “WBB”), and electron neutrinos from K_{e3} -decay, giving no muon in CC reactions and consequently contributing to the events classified as NC.

Wrong classification of NC events is possible, because muons produced by π or K -decay in the hadronic shower can lead to classification as CC. On the other hand, CC events are misclassified if the muon of the reaction has less than 1GeV energy, or is not found because its track is hidden inside the shower, or leaves the detector at the side without being identified.

Table 1: Event Classification
Number of Events
with $E_h > 4\text{GeV}$ and $r < 120\text{cm}$

	Neutrino		Antineutrino	
	NC	CC	NC	CC
Raw Data	35954	101418	2108	5170
WBB+Cosmic rays	-1759	-3779	-236	-378
CC with unidentified muon	-3391	+3391	-36	+36
NC with decay muon	+1709	-1709	+94	-94
K_{e3} decays	-1943	-119	-66	-3
Corrected Data	30570	99202	1864	4731

In terms of the shower energy E_h and the shower direction θ_h with respect to the incoming neutrino beam axis, the scaling variable x is given by:

$$x = \frac{E_\nu(E_h - m_p) \sin^2 \theta_h}{2m_p(E_\nu \cos^2 \theta_h - (E_h - m_p))}$$

As stated above, the energy of the incoming neutrino is derived from the energy-radius relation with the ambiguity of the different masses of π - and K -parents. Consequently the value of x cannot be determined for single events.

For this reason, a procedure of statistical unfolding was used (see ref[12]). This method allows the reconstruction of the physical distribution, taking into account the entering neutrino flux $\Phi(E_\nu, r)$ and the resolutions in the variables E_h, θ_h and r (the distance of the vertex from the beam axis) measured for each event.

The measured distribution g^{DATA} is the result of the physical distribution $F(x)$ folded with the spectrum of the incoming beam and the experimental acceptance and resolution. The folding is described by the resolution function $R(E_h, \theta_h, r, x)$ which represents for each value of x the differential probability of measuring the set of parameters E_h, θ_h, r . With the distribution of backgrounds and misclassifications $B(E_h, \theta_h, r)$ this can be written as:

$$g^{DATA}(E_h, \theta_h, r) = \int R(E_h, \theta_h, r, x) F(x) dx + B(E_h, \theta_h, r).$$

The x -distribution was parametrized by a superposition of cubic spline functions $b_i(x)$:

$$F(x) = \sum a_i b_i(x).$$

Each spline function is a bell-shaped function defined over an interval of four equidistant knots. Outside this interval it is zero.

The superposition of sets of spline functions with decreasing distance between knots allows the representation of any function with increasing precision. In this way no assumption on $F(x)$ is introduced except that of a smooth slope inside an interval between two knots.

Given the resolution function, the contribution in the measured variables corresponding to each spline function can be calculated:

$$A_i(E_h, \theta_h, r) = \int R(E_h, \theta_h, r, x) b_i(x) dx$$

In the unfolding procedure a maximum-likelihood fit of the superposition of these three-dimensional distributions to the measured data is performed:

$$g^{DATA} = \sum a_i A_i + B$$

The resulting coefficients a_i represent the best description of the data, and the corresponding x -distribution is the physical result.

Actually, the variables $\mathbf{h} = \sqrt{E_h}$, $\mathbf{u} = \sqrt{E_h/2m_p} \cdot \theta_h$ and $\mathbf{r}$ were used for the fit, since the variation of resolution of h and u over their range is much smaller than for E_h and θ_h .

A procedure that unfolds resolution effects usually magnifies local fluctuations in the measured distributions. In order to reduce these oscillations of the resulting function, a method of regularization was applied as described in ref [12]. This is equivalent to a reduction of the local curvature of the result without changing the overall shape. After computing for each spline the “noise fraction” of its amplitude expected due to statistical fluctuations, splines of lower knot distance (and therefore higher noise fraction) were damped. The damping function decreases in such a way that significant contributions are not affected.

The procedure was tested on charged-current events, where a comparison with results using muon measurements is possible. A correction was applied for Bremsstrahlung of the outgoing muon in CC events, which shifted single points by a maximum amount of 5%.

Since the value of Q^2 for single events is not known, an explicit cut of low- Q^2 -events is not possible for this analysis — in contrast to CC analyses using the muon measurement. The mean Q^2 changes over the range of x (proportional to x) in the uncorrected distribution. Therefore a correction has been made for the Q^2 -dependence of the structure functions, known from previous experiments in CC reactions. This is particularly important if the distributions of neutrino and antineutrino reactions are compared, since the mean Q^2 is lower in the antineutrino case.

The Q^2 -dependence was parametrized in agreement with data from ref [1-3] (see the compilation in ref [13]) as:

$$\begin{aligned}
 R_2(x, Q^2) &= \frac{F_2(x, Q^2)}{F_2(x, 5\text{GeV}^2)} = \left(\frac{Q^2}{5\text{GeV}^2} \right)^a \\
 R_3(x, Q^2) &= \frac{x F_3(x, Q^2)}{x F_3(x, 5\text{GeV}^2)} = \left(\frac{Q^2}{5\text{GeV}^2} \right)^b \\
 a &= 0.161 - 0.906 x + 0.504 x^2 \\
 b &= 0.0388 - 0.375 x
 \end{aligned}$$

For low values of Q^2 where no measurements exist this parametrization was modified in such a way that it approaches constant values for Q^2 less than about 1GeV^2 .

The corresponding correction was taken into account in the unfolding program, and the result at a fixed value, chosen to be $Q_0^2 = 10\text{GeV}^2$, was computed. This affected the resulting distribution at low x (contents of first bin increased by 15%) and introduced the main systematic error of 5%, due to the uncertainty at $Q^2 < 1\text{GeV}^2$. Together with the uncertainty of shower energy calibration (neutrino induced showers may differ from pion showers at low energies) and of angular resolution, the systematic error is typically 6% and smaller at x -values above 0.3. Since the NC- and CC-distributions are influenced in the same way, these errors cancel in the comparison.

Fig. 1 shows the distributions in the scaling variable x for neutrinos $F_+(x)$ and for antineutrinos $F_-(x)$ for NC- and CC-coupling at $Q_0^2 = 10\text{GeV}^2$. The drawn curves are results of a fit described below. For a direct comparison of the results for neutral and charged current the cross section ratios $\sigma^{\nu NC}/\sigma^{\nu CC} = 0.3093$ and $\sigma^{\bar{\nu} NC}/\sigma^{\bar{\nu} CC} = 0.390$

as measured in the same exposure [8] were used. Only small deviations are expected due to slightly different sea-quark contributions. The distributions agree within the statistical errors of about 5% (Table 2).

Table 2: Measured x -distributions with statistical errors;
CC scaled by the NC/CC cross section ratios.

x -interval	$F_+^{CC} \cdot 0.3093$	F_+^{NC}	$F_-^{CC} \cdot 0.39$	F_-^{NC}
0 – 0.06	0.71 $\pm$ 0.03	0.72 $\pm$ 0.05	0.68 $\pm$ 0.07	0.60 $\pm$ 0.12
0.06 – 0.14	0.74 $\pm$ 0.02	0.78 $\pm$ 0.03	0.54 $\pm$ 0.05	0.43 $\pm$ 0.08
0.14 – 0.23	0.59 $\pm$ 0.02	0.54 $\pm$ 0.03	0.31 $\pm$ 0.04	0.24 $\pm$ 0.05
0.23 – 0.35	0.38 $\pm$ 0.02	0.35 $\pm$ 0.02	0.20 $\pm$ 0.03	0.08 $\pm$ 0.03
0.35 – 0.48	0.27 $\pm$ 0.01	0.24 $\pm$ 0.02	0.13 $\pm$ 0.02	0.04 $\pm$ 0.03
0.48 – 0.64	0.14 $\pm$ 0.01	0.17 $\pm$ 0.01	0.04 $\pm$ 0.01	0.11 $\pm$ 0.02
0.64 – 0.81	0.06 $\pm$ 0.01	0.06 $\pm$ 0.01	0.02 $\pm$ 0.01	0.04 $\pm$ 0.01
0.81 – 1	0.01 $\pm$ 0.01	0.01 $\pm$ 0.01	0.00 $\pm$ 0.01	0.00 $\pm$ 0.01

Using data from the antineutrino beam — in total 2000 NC-events — the structure functions F_2 and $x F_3$ and the sea-quark distribution $x \bar{q}$ for NC- and CC-reactions were then determined. The extracted distributions are shown in figs. 2-4. The small number of antineutrino events leads to comparably large statistical errors.

For the distributions of CC interactions (figs. 2a, 3a, 4a) we have made comparisons with other results in which the outgoing muon was used to determine the kinematics. The full curves give the result of a parametrization of these results at $Q_o^2 = 10 \text{ GeV}^2$ [13], and the full points give the results of structure functions reported previously by the same collaboration [1]. We note good agreement and take this as a confirmation of the method used here to determine the kinematics and the structure functions without using the outgoing muon.

We compared in fig. 2b $F_2^{NC}(x)$ with $\frac{18}{5}(g_L^2 + g_R^2)F_2^\mu(x)$, where F_2^μ was determined from muon scattering on carbon and reported at $Q_o^2 = 10 \text{ GeV}^2$ [15]. As expected in the quark model of the nucleon we find good agreement for $x > 0.29$; the average of the ratio

$$R_{F_2} = \frac{\frac{18}{5}(g_L^2 + g_R^2)F_2^\mu}{F_2^{NC}}$$

in the x region from 0.290 to 0.725 is

$$R_{F_2} = 1.13 \pm 0.10,$$

where F_2^{NC} was taken from the fit of table 3. For the integral of F_2^{NC} we find

$$\int_0^1 F_2^{NC} dx = 0.1646 \pm 0.0073,$$

using our measurements of the ratios

$$R^\nu = \frac{\sigma_{tot}^\nu(NC)}{\sigma_{tot}^\nu(CC)}, \quad R^{\bar{\nu}} = \frac{\sigma_{tot}^{\bar{\nu}}(NC)}{\sigma_{tot}^{\bar{\nu}}(CC)} \quad [8] \quad \text{and} \quad r = \frac{\sigma_{tot}^{\bar{\nu}}(CC)}{\sigma_{tot}^\nu(CC)} \quad [11] \quad \text{and} \quad \int F_2^{CC} dx [11],$$

and the relation

$$\int F_2^{NC} dx = \frac{R^\nu + rR^{\bar{\nu}}}{1+r} \int F_2^{CC} dx.$$

The valence quark structure function $x F_3^{NC}$ is compared in fig. 3b with the so-called electroweak interference structure function $x G_3$ which was determined from the interference of the electroweak and electromagnetic interaction in deep inelastic muon scattering [16]. For the average of the ratio

$$\frac{2(g_L^2 - g_R^2)x G_3}{x F_3^{NC}}$$

we find 0.98 ± 0.19 , taking again $x F_3^{NC}$ from the fit in table 3, in agreement with the quark model prediction.

The sea quark distributions $x \bar{q}(x)$ at $Q_o^2 = 10 \text{ GeV}^2$ were derived from the expressions given above (for CC $\frac{3}{16}(3F_- - F_+)$), neglecting the strange and charm quark sea, and are shown in fig 4. The full lines represent the result of a fit to a parametrization described below; the dotted curve in fig. 4a shows $x \bar{q}$ from a compilation of CC data [13] for which the outgoing muon was used to determine the kinematics.

The following parametrization of the valence- and sea-quark distributions was fitted to the measured points:

$$\begin{aligned} x q_{val}(x) &= N_{val} \frac{\Gamma(\alpha+\beta+1)}{\Gamma(\alpha)\Gamma(\beta+1)} x^\alpha (1-x)^\beta \\ x \bar{q}(x) &= \frac{1}{2} C (\gamma+1) (1-x)^\gamma \end{aligned}$$

The parameters of the best fits, shown as full curves in the figures, are given in table 3.

Table 3: Fit parameters for CC and NC distributions

	N_{val}	α	β	C	γ
CC	3.05 ± 0.13	0.455 ± 0.018	2.77 ± 0.08	0.155 ± 0.006	7.58 ± 0.61
NC	3.0	0.476 ± 0.030	2.75 ± 0.15	0.126 ± 0.008	8.0

The determination of the sea quark distribution from the difference of the structure functions F_2 and $x F_3$ is difficult with the present antineutrino statistics. For this reason the slope parameter γ and the number of valence quarks were fixed in the NC-fit. Fluctuations in the NC-distribution $F_-(x)$ (fig. 1b) result in a poor χ^2 of the fit; however, they do not distort the derived distributions $F_2(x)$, $x F_3(x)$ and $x \bar{q}(x)$.

The exponents α and β of the valence quark distributions of NC and CC are found equal within the errors, and the fraction of the nucleon momentum carried by sea quarks (neglecting strange and charm quarks) as probed by NC and CC interactions is found equal as well. We also note good agreement with the result $\bar{q}/(\bar{q}+q) = 0.154 \pm 0.012$ obtained by us from the ratio of deep inelastic CC antineutrino and neutrino cross sections [11].

In conclusion, we confirm the universality of nucleon structure functions as probed by weak charged current and neutral current neutrino and antineutrino interactions and by the electromagnetic current.

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Fig1: Distributions $F_{\pm}(x)$ obtained in the ν and $\bar{\nu}$ beam, corrected for experimental acceptance and resolution using an unfolding procedure described in the text. The distributions shown were evaluated at $Q_o^2 = 10\text{GeV}^2$, (a) for CC and (b) for NC interactions. The full curves are results of a fit to the parametrization given in the text.

Fig2: The structure functions $F_2(x)$ at $Q_o^2 = 10 \text{ GeV}^2$ derived from $3/8(F_+ + F_-)$ for (a) CC and (b) NC interactions. The full curves show the result of a fit to the parametrization given in the text; the dotted curve in (a) represents a compilation of charged-current data [13] and the full points results of the CHARM Collaboration [1] for which the outgoing muon was used to determine the kinematics. In comparison with F_2^{NC} we show in (b) $18/5(g_L^2 + g_R^2)F_2^\mu$ (open points) with F_2^μ derived from deep inelastic muon scattering on carbon [15]. An uncertainty of $\pm 3\%$ in the absolute normalization of F_2^μ is not included in the error bars.

Fig3: The structure functions $xF_3(x)$ at $Q_o^2 = 10\text{GeV}^2$ derived from $3/4(F_+ - F_-)$ for (a) CC and (b) NC interactions. The full curves show the result of a fit to the parametrization given in the text; the dotted curve in (a) represents a compilation of charged-current data [13] and the full points results of the CHARM Collaboration [1] for which the outgoing muon was used to determine the kinematics. In comparison with xF_3^{NC} we show in (b) $2(g_L^2 - g_R^2)xG_3$. xG_3 is the electroweak interference structure function determined from the charge asymmetry of deep inelastic muon scattering [16].

Fig4: The structure functions $x\bar{q}(x)$ of the non-strange sea at $Q_o^2 = 10 \text{ GeV}^2$ derived from the corresponding formulae described in the text for (a) CC and (b) NC interactions. The full curves show the result of a fit to the parametrization given in the text. The dotted curve in (a) shows $x\bar{q}$ from a compilation of charged-current data [13]. In the NC reaction only the integral of $x\bar{q}$ can be determined and agrees well with results obtained in CC reactions.

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