LIMIT ON RIGHT HANDED WEAK COUPLING PARAMETERS
FROM INELASTIC NEUTRINO INTERACTIONS

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ABSTRACT

Right handed weak quark currents coupled to the usual left handed weak lepton current would be seen in inclusive antineutrino scattering on nuclei as a contribution at large $y$ with the quark (not antiquark) structure function. We do not see such a term, and can therefore put an upper limit on the relative strengths of such right handed currents: $\rho^2 = \frac{\mathcal{G}_R}{\mathcal{G}_L} < 0.009$, 90% confidence. This measurement puts limits on the mixing angle of left-right symmetric models. In distinction to similar limits derived from muon decay or $\beta$ decay, our limits are also valid if the right handed neutrino is heavy.
In neutrino-hadron inclusive scattering, right and left handed weak quark currents have distinct y distributions. If the Lagrangian is purely left handed, such as, e.g.:

$$\mathcal{L} = \frac{G}{\sqrt{2}} \bar{u} \gamma_\mu (1 + \gamma_5) \nu \bar{u} \gamma_\mu (1 + \gamma_5) d$$

then the y distribution for antineutrino-quark and neutrino-antiquark scattering is of the form $(1 - y)^2$, and for neutrino-quark and antineutrino-antiquark scattering it is constant:

$$\frac{d^2 \sigma^V}{dxdy} = q(x) + (1 - y)^2 \bar{q}(x) \quad \text{(1a)}$$
$$\frac{d^2 \sigma^\bar{V}}{dxdy} = (1 - y)^2 q(x) + \bar{q}(x) \quad \text{(1b)}$$

Here $q(x)$ and $\bar{q}(x)$ are quark and antiquark structure functions respectively.

If right handed quark currents are also present, such as in the Lagrangian:

$$\mathcal{L} = \frac{G}{\sqrt{2}} \left[ \bar{u} \gamma_\mu (1 + \gamma_5) \nu \times \bar{u} \gamma_\mu \left[ c_L (1 + \gamma_5) + c_R (1 - \gamma_5) \right] d \right]$$

the y distributions of 1a) and 1b) become:

$$\frac{d^2 \sigma^V}{dxdy} = q(x) + \rho^2 \bar{q}(x) + (1 - y)^2 \left[ \bar{q}(x) + \rho^2 q(x) \right] = q_L + (1 - y)^2 q_R \quad \text{(2a)}$$
$$\frac{d^2 \sigma^\bar{V}}{dxdy} = (1 - y)^2 [q(x) + \rho^2 q(x)] + \bar{q}(x) + \rho^2 q(x) = (1 - y)^2 q_L + q_R \quad \text{(2b)}$$

where $\rho = |c_R/c_L|$.

Experimentally the two structure functions $q_L(x) = q(x) + \rho^2 \bar{q}(x)$ and $q_R(x) = \bar{q}(x) + \rho^2 q(x)$, are found from neutrino and antineutrino scattering on the basis of their characteristic y dependences. For instance, $q_R(x)$ for large y. In the absence of right handed currents, $q_L$ and $q_R$ are interpreted as the quark and antiquark structure functions respectively. Experimentally at large x, $q_R(x) \ll q_L(x)$. This puts an upper limit, at large x, on the sum of $\bar{q}(x)$ and $|\rho|^2 q(x)$. An upper limit on $\rho^2$ is obtained by setting $\bar{q}(x)$ to zero.

The analysis presented here is based on CERN-Dortmund-Heidelberg-Saclay data which have previously been analysed, assuming left handed currents only. In
Fig. 1 the ratio \( (\text{d}^{2}q^{\nu}/\text{d}y/\text{d}x) )/\text{d}^{2}q^{\nu}/\text{d}x/\text{d}y \) is shown for small and large \( x \), as function of \( y \). It is to be noticed that the ratio of antineutrino to neutrino cross sections becomes very small at large \( y \) and large \( x \). This is the basis of the evidence, in these experiments, against right handed currents. In Fig. 2 typical structure functions extracted from such \( y \) distributions are reproduced. The point is that \( q_{R}(x) = q(x) + \rho \tilde{q}(x) \) is very small at large \( x \) compared to \( q_{L}(x) \).

The following analysis is based on a total of 175,000 \( \bar{\nu} \) events and 90,000 \( \nu \) events, obtained in both wide and narrow band beams, in a magnetized iron detector\(^2\) at the CERN SPS. The upper limit on \( \rho^{2} \) is the upper limit on the ratio

\[
\left[ \frac{\text{d}^{2}q^{\nu}}{\text{d}x/\text{d}y} - (1-y)^{2} \frac{\text{d}^{2}q^{\nu}}{\text{d}x/\text{d}y} \right] / \left[ \frac{\text{d}^{2}q^{\nu}}{\text{d}x/\text{d}y} - (1-y)^{2} \frac{\text{d}^{2}q^{\nu}}{\text{d}x/\text{d}y} \right]
\]

for \( x \) and \( y \) both large. On the basis of 207 antineutrino and 445 neutrino events with \( x > 0.5 \) and \( y > 0.66 \), we find \( \rho^{2} = 0.000 \pm 0.005 \); \( |\rho|^{2} < 0.009 \) 90% confidence. The average four momentum transfer squared corresponding to these data is \( <Q^{2}> = 33 \text{ GeV}^{2}/c^{2} \).

In arriving at this result, mass correction terms of the order of \( Q^{2}/\nu^{2} \), which, for the sake of transparancy, have been omitted from the above equations, have been taken into account. They contribute a few tenths of a percent. It has also been assumed that \( R \), the ratio of longitudinal to transverse cross sections, is zero. A positive value of \( R \) would reduce \( |\rho|^{2} \).

This result limits theoretical models in which weak right handed quark currents are coupled to weak left handed lepton currents. Among such models are \((\text{SU}2)_{R} \times (\text{SU}2)_{L} \times (\text{U}1)_{F} \) models\(^3\) with two sets of intermediate bosons \( W_{L} \) and \( W_{R} \). These in general, are mixed in the symmetry breaking process to yield two mass eigenstates, \( W_{1} \) and \( W_{2} \), with masses \( M_{1} \) and \( M_{2} \), and mixing angle \( \theta \), such that left handed currents are coupled to \( \cos \theta \ W_{1} + \sin \theta \ W_{2} \) and right handed currents to \( -\sin \theta \ W_{1} + \cos \theta \ W_{2} \). For these models, \( C_{L} = \cos^{2} \theta / M_{1}^{2} + \sin^{2} \theta / M_{2}^{2} \) and \( C_{R} = \sin \theta \cos \delta (1/M_{2}^{2} - 1/M_{1}^{2}) \). The present upper limit for \( \rho \) limits \( \theta \). For \( \theta \) small, \( \theta \approx \rho / (1 - M_{1}^{2} / M_{2}^{2}) \). In Fig. 3 we show the constraint on \( \theta \) as function of \( M_{1}^{2} / M_{2}^{2} \).

Also shown are previous results\(^4\) from muon decay. This limit on \( \theta \) is somewhat higher than that based on precision measurements of the Michel parameter in muon decay\(^5\), however it applies also to models in which the right handed neutrino is heavy, where the muon result is inapplicable. It should also be noted that the \( Q^{2} \) domain is entirely different.

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FIGURE CAPTIONS

Figure 1: The ratio of antineutrino to neutrino cross sections, as function of $y$, at small and large $x$.

Figure 2: $q_L(x)$ and $q_R(x)$ in a particular $Q^2$ range.

Figure 3: Experimental limits on $\theta$ as function of $M_1^2/M_2^2$. Also shown are previous results from muon decay. $\xi_\mu$ refers to the limits obtained from the muon decay asymmetry. The muon decay results are not applicable to models in which the right handed neutrino is heavy. The presentation follows Ref. 4.

REFERENCES


4) Experimental limits on $M_1^2/M_2^2$ have recently been reviewed by Strovink, M. Strovink, Workshop on weak interactions, Blacksburg, Virginia, U.S.A., 1980.

Fig. 1
$20 \text{ GeV}^2 < Q^2 < 30 \text{ GeV}^2$

$q_L$ and $q_R$

Fig. 2
Fig. 3