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Some consequences of neutral current systematics

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Abstract. Two kinds of general consequences of the $\triangle S=0$ weak hadron neutral current independent of a gauge model are presented. Firstly are results which depend on the quark parton model. These involve bounds among neutrino inclusive cross-section and a bound on $Q(Z, N)$ in terms of these inclusive cross-sections. Secondly are results which are independent of the quark-parton model and depend only on the SU(3) structure of the most general $\triangle S=0$ neutral current. These tests of isospin and specially U-spin properties of the current are given for $\nu+N\rightarrow\nu+$hadron+anything, $\nu+N\rightarrow\nu+$baryon+meson and $e^+e^-\rightarrow$baryon+anti-baryon. In addition some conjectures are made with regard to the semi-inclusive neutrino-reactions using the quark parton model.

Keywords. Neutral current; quark parton model; SU(3) symmetry; exclusive and inclusive neutrino-reactions; e^+e^--annihilation; parity-violation in atomic physics.

1. Introduction

Since the discovery (Hasert *et al* 1973) of the strangeness conserving ($\triangle S=0$) weak hadronic neutral current, $\mathcal{N}$, there has been a lot of theoretical activity to analyse its consequences in various processes with a view to understanding its symmetry properties and determine its parameters from available data. Most of the work has been based on the use of the quark-parton model (QPM) and on a specific gauge model or both, though analyses independent of both are available. Representative references in which earlier work is cited are Budny and Scharbach (1972), Riazuddin and Fayyazuddin (1972), Albright *et al* (1973), Paschos and Wolfenstein (1973), Palmer (1973), Sehgal (1973) and (1974), Llewellyn-Smith and Nanopoulos (1974), Rajasekaran and Sarma (1974 and 1976), Ecker and Fischer (1976).

The popular Weinberg-Salam (W-S) model (Weinberg 1967 and 1972; Salam 1968) seems fairly successful in accounting for the limited data (Benvenuti *et al* 1976) available on the inclusive neutrino-nucleon cross-sections; however it gives too large a value for $Q(Z, N)$ the parity violating parameter in atomic physics (Bouchiat and Bouchiat 1974) as indicated by recent experiments (Baird *et al* 1976). Clearly it is important to have a model-independent estimate of $Q(Z,N)$ as well as further model-independent results which will pin-point the structure of the neutral current $\mathcal{N}$. In this note we present two kinds of new results:

(i) Results which depend on QPM and the vector (V) and axial-vector (A) coupling at the quark level but are independent of any gauge model. These involve bounds among inclusive neutrino-nucleon cross-sections and a bound for $Q(Z,N)$ in terms of these inclusive cross-sections. These are presented in section 2.

(ii) Results which are independent of QPM as well as gauge models and depend solely on the SU(3) structure of the most general $\Delta S=0$ hadronic neutral current $\mathcal{N}$. These tests of the isospin and particularly the U-spin properties of $\mathcal{N}$ are presented in section 3 for (a) the one particle semi-inclusive process $\nu+N\to\nu+$ hadron $+$anything; (b) the exclusive process $\nu+N\to\nu+$ baryon $+$ meson and (c) the annihilation process $e^+e^-\to$baryon$+$antibaryon. In addition some speculative conjectures are made for the one particle inclusive process using the quark parton model.

2. Results based on QPM

2.1. *Bounds for inclusive cross-sections*

Assuming the neutral current to be of V and A types, at the quark level, the most general form of the current for the u, d and s quarks is

$$\mathcal{N}_\mu = \sum_{q=u,d,s} q\,\gamma_\mu\,(v_q+a_q\gamma_5)\,q+\ldots, \tag{1}$$

where v_q and a_q are the unknown vector and axial coupling strengths for quark q and the dots indicate other quark contributions. Ignoring the sea of q-$\bar{q}$ pairs the integrated cross-sections for the inclusive ν and $\bar{\nu}$ scattering off proton and neutron targets are well-known (Sehgal 1973) and are given by ($E=$ incident ν or $\bar{\nu}$ laboratory energy)

$$\sigma_{\nu p,\,\bar{\nu}p} = \frac{2}{3}\frac{G^2ME}{\pi}\,[U(v_u^2+a_u^2\pm v_ua_u)+D(v_d^2+a_d^2\pm v_da_d)], \tag{2}$$

$$\sigma_{\nu n,\,\bar{\nu}n} = \frac{2}{3}\frac{G^2ME}{\pi}\,[D(v_u^2+a_u^2\pm v_ua_u)+U(v_d^2+a_d^2\pm v_da_d)], \tag{3}$$

where $U\equiv\int_0^1 x\,u(x)\,dx$ and $D\equiv\int_0^1 x\,d(x)\,dx$ are the integrated first moment of the u and d quark distributions $u(x)$ and $d(x)$ in the proton. Estimates from electroproduction data (Barger and Nanopoulos 1976) give $U\simeq 0{\cdot}31$ and $D\simeq 0{\cdot}20$. Earlier analyses referred to in the introduction try to put limits on the coupling parameters v_u, etc. using the experimental information on the two iso-spin averaged cross-sections $\sigma_{\nu N}$ and $\sigma_{\bar{\nu}N}$ defined by

$$\sigma_{\nu N\,(\bar{\nu}N)} \equiv \tfrac{1}{2}\,(\sigma_{\nu p\,(\bar{\nu}p)}+\sigma_{\nu n\,(\bar{\nu}n)}) \tag{4}$$

We use the experimental information $U>D>0$ and $\sigma_{\nu N}>\sigma_{\bar{\nu}N}$ together with the positivity of the cross-sections to obtain inequalities among the four cross-sections in (2) and (3). Each of the four cross-sections satisfies the same bounds namely

$$\frac{D}{2(U+D)}(\sigma_{\nu N}+\sigma_{\bar{\nu}N}) \leqslant \sigma_{\nu p}\ (\text{or } \sigma_{\bar{\nu}n},\text{ etc.}) \leqslant \frac{3U}{2(U+D)}(\sigma_{\nu N}+\sigma_{\bar{\nu}N}). \tag{5}$$

Define $\triangle_{p, n}^{(\pm)} = \sigma_{\nu p, \nu n} \pm \sigma_{\bar{\nu} p, \bar{\nu} n}$, the manipulation of (2) and (3) yields

$$\frac{D}{U} \leqslant \frac{\triangle_p^{(+)}}{\triangle_n^{(+)}} \leqslant \frac{U}{D}. \tag{6}$$

The solution of v_u^2, a_u^2, etc. in terms of the cross-sections with $\eta = 8/3\ (U^2 - D^2)\ G^2 ME/\pi$ gives

$$\eta v_u^2 \text{ or } \eta a_u^2 = (U\triangle_p^{(+)} - D\triangle_n^{(+)}) \pm [(U\triangle_p^{(+)} - D\triangle_n^{(+)})^2 - 4(U\triangle_p^{(-)} - D\triangle_n^{(-)})^2]^{\frac{1}{2}} \tag{7}$$

$$\eta v_d^2 \text{ or } \eta a_d^2 = (U\triangle_n^{(+)} - D\triangle_p^{(+)}) \pm [(U\triangle_n^{(+)} - D\triangle_p^{(+)})^2 - 4(U\triangle_n^{(-)} - D\triangle_p^{(-)})^2]^{\frac{1}{2}}. \tag{8}$$

The reality of v_u, etc. yields

$$b \equiv U\triangle_p^{(+)} - D\triangle_n^{(+)} \geqslant 2\,|\,(U\triangle_p^{(-)} - D\triangle_n^{(-)}\,| \equiv 2\,|\,a\,|, \tag{9a}$$

$$b' \equiv U\triangle_n^{(+)} - D\triangle_p^{(+)} \geqslant 2\,|\,(U\triangle_n^{(-)} - D\triangle_p^{(-)}\,| \equiv 2\,|\,a'\,|, \tag{9b}$$

since b and b' are positive (see (6)). Now (9a) and (9b) can be used to derive

$$(\sigma_{\nu N} + \sigma_{\bar{\nu} N}) \geqslant \left(\frac{U+D}{U-D}\right)\left|\triangle_p^{(-)} - \triangle_n^{(-)}\right|. \tag{10}$$

Using the values of U and D quoted above the factor on the right hand side is $\simeq 5$. Moreover (7) and (8) will yield bounds on the parameters v_u, v_d, etc. We exploit these to obtain a limit on $Q(Z, N)$ the parity violating parameter in atomic physics.

2.2. *Bound on* $Q\ (Z, \mathrm{N})$

The parity violating effective electron-nucleus potential (Bouchiat and Bouchiat 1974) for an atomic nucleus with Z protons and N neutrons is given by

$$V_{\text{eff}} = \frac{G g_A^0}{i 2\sqrt{2} m_e} [(\sigma \cdot \vec{\nabla}_r)\, \delta^{(3)}(\mathbf{r}) + \delta^{(3)}(\mathbf{r}) \sigma \cdot \vec{\nabla}_r] Q(Z, N). \tag{11}$$

The quantities in the square brackets refer to the electron and g_A^0 is the axial coupling constant of the electron. The relevant hadronic parameter is

$$Q(Z, N) = Z\,(2v_u + v_d) + N(v_u + 2v_d). \tag{12}$$

Using (7), (8) and (9) one can obtain the bound

$$\sqrt{\eta}\,|\,Q(Z, N)\,| \leqslant (2\,Z + N)\,[b + \sqrt{b^2 - 4a^2}]^{1/2} + (Z + 2N)\,[b' + \sqrt{b'^2 - 4a'^2}]^{1/2} \tag{13}$$

involving all the four cross-sections $\sigma_{\nu p}$, etc. which is however not fully determinable from the presently available data. A weaker bound in terms of the measured cross-sections can be obtained, namely

$$|Q(Z,N)| \leqslant \frac{3\sqrt{3}}{\sqrt{2}}(Z+N)\sqrt{R^{\nu}+R^{\bar{\nu}}R_c}, \tag{14}$$

where $R^{\nu} \equiv \sigma_{\nu N} / \sigma^c_{\nu N}$, $R^{\bar{\nu}} \equiv \sigma_{\bar{\nu}N} / \sigma^c_{\bar{\nu}N}$ and $R_c = \sigma^c_{\bar{\nu}N} / \sigma^c_{\nu N}$ with $\sigma^c_{\bar{\nu}N}$ and $\sigma^c_{\bar{\nu}N}$ being the charged current ν and $\bar{\nu}$ cross-sections for isospin-averaged nucleon targets. The above model-independent bound is true for an arbitrary mixture of v_u and v_d. For a pure isovector vector neutral current $v_u = -v_d$, one obtains the stronger bound

$$|Q(Z,N)| \leqslant \sqrt{\frac{3}{2}}\,|(N-Z)|\,\sqrt{R^{\nu}+R^{\bar{\nu}}R_c}. \tag{15}$$

For Bismuth ($Z = 83$, $N = 126$) with $R^{\nu} \simeq 0.25$ $R^{\bar{\nu}} \simeq 0.35$ and $R_c \simeq \frac{1}{3}$ the bounds (14) and (15) yield $|Q(Z,N)| \lesssim 460$ and 22 respectively. These numbers are to be compared with the $Q(Z,N)|_{\text{exp.}} \simeq -31\pm24$ and $+34\pm13$ (Baird *et al* 1976) for Bi with $g^0_A = 1$ and the value for the Weinberg-Salam model which is 85. Though the experimental number is still uncertain it is interesting that it is close to the bound in (15).

3. Tests of the SU(3) structure of the neutral current

The most general $\triangle S = 0$ hadron neutral current was given in terms of the u, d, s quarks in (1) above. It has the general SU(3) structure (suppressing the space-time structure)

$$\mathcal{N} = \mathcal{N}_v + \mathcal{N}_A = (v_3\mathcal{N}_V^{(3)} + a_3\mathcal{N}_A^{(3)}) + (v_8\mathcal{N}_V^{(8)} + a_8\mathcal{N}_A^{(8)})$$
$$+ (v_0\mathcal{N}_V^{(0)} + a_0\mathcal{N}_A^{(0)}) \tag{16}$$

Here $\mathcal{N}^{(3)}_{V,A}$, and $\mathcal{N}^{(3)}_{V,A}$ transform as the third and eighth component of an octet while $\mathcal{N}^{(0)}_{V,A}$ transforms as an SU(3) singlet. In terms of the quark parameters in (1), for example, $v_3 = 1\sqrt{2}\,(v_u - v_d)$, $v_8 = 1/\sqrt{6}\,(v_u + v_d - 2v_s)$ and $v_0 = 1/\sqrt{3}$ $(v_u + v_d + v_s)$. The general current has both an isospin I and U-spin, U, equal to 0 and 1. For the current to be a pure U-spin singlet $v_3 = \sqrt{3}v_8$ and $a_3 = \sqrt{3}a_8$. Furthermore if the current has $U = 0$ as well as no $I = 0$ from the nucleon-like quarks say for the axial part, as is true for the Weinberg-Salam model, then $a_3 = \sqrt{3}a_8 = -\sqrt{6}a_0$. A detailed check of the relations among and the magnitude of the neutral current parameters is hard though it is possible for the parameters of the axial part in e^+e^-—annihilation (see 3.4). For the neutrino-induced processes since only nucleon targets are available a full SU(3) analysis is unwarranted. However tests can be obtained for the isospin and U-spin properties. So far though only the isospin properties have been exploited in the literature and indications are that the full$\mathcal{N}$ has both $I = 0$ and 1 parts (Gourdin 1975). Despite the limitation to nucleon targets, tests are obtainable for a U-spin singlet neutral current, though not for a mixture of U-spin 0 and 1. We present our results for the various processes below under separate sub-heads.

3.1. $\nu+N \rightarrow \nu+h+$ *anything*

In these one particle semi-inclusive processes h is the observed hadron and N stands for proton (p) or neutron (n) target. The inclusive cross-section is given by

$$q_0 \frac{d\sigma_h^{\nu N}}{d^3q} = d\sigma_h^{\nu N} = \frac{G^2}{16(2\pi)^6 E} \int \frac{d^3q_2}{q_{20}} L_{\mu\nu} H_{\nu\mu}{}^N, \tag{17}$$

where

$$L_{\mu\nu} = q_{1\mu} q_{2\nu} + q_{1\nu} q_{2\mu} - \delta_{\mu\nu} (q_1 \cdot q_2) - \epsilon_{\mu\nu\lambda\sigma} q_{1\lambda} q_{2\sigma}, \tag{18}$$

$$H_{\mu\nu}{}^N = \epsilon_h \Omega \int d^4x d^4y d^4z \, e^{-iP.z} \, e^{-iq.(x-y+z)} \, \theta(x_0)\theta(y_0)$$

$$\langle N | [N_\nu(o), j_h^\dagger(y)] \, [j_h(x+z), N_\mu(z)] \, | N \rangle. \tag{19}$$

Here q_1, q_2 and q refer respectively to the four momenta of the incident ν, final ν and the observed hadron h. P is the total incident four momentum, Ω is the normalization volume, j_h is the source current for h and the factor ϵ_h is $\frac{1}{2}$ (or m_h) if h is a boson (or fermion). The average multiplicity of h for target N is defined by

$$\int \frac{d^3q}{q_0} d\sigma_h^{\nu N} = \langle h \rangle_N \, \sigma_h^{\nu N}. \tag{20}$$

If the neutral current is a U-spin singlet then one can obtain inequalities for $d\sigma_h^{\nu N}$ or $\langle h \rangle_N$ by observing that $H_{\mu\nu}{}^N$ is the norm of a vector. If h is a U-spin doublet (h_1, h_2) then one finds

$$\alpha_N \langle h_1 \rangle_N \geqslant \langle h_2 \rangle_N, \tag{21}$$

where α_N is a number. For $N = p$ (proton target) $\alpha_p = 2$ while for $N = n$ (neutron target) $\alpha_n = 3$. The above result is valid for $(h_1, h_2) = (K^+, \pi^+)$, (π^-, K^-), (p, Σ^+), (Σ^-, Ξ^-) and (D^+, F^+). For a U-spin triplet (h_+, h_0, h_-), one obtains

$$\beta_N \langle h_+ \rangle_N \geqslant \langle h_- \rangle_N, \tag{22}$$

where $\beta_p = 3$ and $\beta_n = 6$. The inequality involving $\langle h_0 \rangle$ is not so useful, since h_0 is usually a mixture of two particles. The above inequality applies, for example, to the cases $h_+ = K^0$, $h_- = \bar{K}^0$ and $h_+ = n$, $h_- = \Xi^0$.

In addition, directly from the conservation of additive quantum numbers like electric charge Q, etc., we have the sum-rule that the charge of the target $Q_N = \sum_h Q_h \langle h \rangle_N$, where Q_h is the charge of the hadron h. These can be used in conjunction with the U-spin inequalities above to obtain, assuming that the $\frac{1}{2}^{+}$-baryon and 0^{-}-meson octets saturate the charge conservation sum-rule, the result

$$a_N(\langle K^+\rangle_N+\langle p\rangle_N)-\langle K^-\rangle_N-\langle \Xi^-\rangle_N \geqslant \frac{a_N}{1+a_N}\,Q_N$$
$$\geqslant \langle \pi^+\rangle_N+\langle \Sigma^+\rangle_N-a_N(\langle \pi^-\rangle_N+\langle \Sigma^-\rangle_N), \tag{23}$$

where $N=p$ or n. Since most experiments are done on nuclei, the extension of the above inequalities to a nucleus ${}_ZA^N$ (with Z protons and N neutrons) is straightforward. Defining

$$\langle h\rangle_A = \frac{Z\sigma^{\nu p}}{Z\sigma^{\nu p}+N\sigma^{\nu n}}\,\langle h\rangle_p + \frac{N\sigma^{\nu n}}{Z\sigma^{\nu p}+N\sigma^{\nu n}}\,\langle h\rangle_n, \tag{24}$$

one can write down inequalities for $\langle h\rangle_A$'s, which are weaker than in (23), say. For a nucleus A, this becomes

$$3(\langle K^+\rangle_A+\langle p\rangle_A)-\langle K^-\rangle_A-\langle \Xi^-\rangle_A \geqslant \frac{2}{3}\,\frac{Z\sigma^{\nu p}}{Z\sigma^{\nu p}+N\sigma^{\nu n}}$$
$$\geqslant \langle \pi^+\rangle_A+\langle \Sigma^+\rangle_A-3(\langle \pi^-\rangle_A+\langle \Sigma^-\rangle_A). \tag{25}$$

Assuming the validity of U-spin symmetry at very high energies, the above inequalities should hold, according to the models, such as the Weinberg-Salam scheme, for which the weak neutral current is a U-spin singlet. Any violation of these inequalities would be favourable to models, which have a mixture of $U=0$ and $U=1$ parts.

3.2. *A conjecture*

We add here a conjecture, based on plausibility arguments, regarding some inclusive neutrino-processes at very high energies. The current is taken to be a U-spin singlet, so that the results are also applicable for the electroproduction case. We assume that, at high ν and q^2 and at large P_T for the produced hadron h, the W-boson (or the virtual photon) interacts with a quark q to directly produce the hadron h. Then considering only u- and d-quarks for a nucleon target one has from U-spin singlet property of the neutral current, for example,

$$d\sigma^{\nu u}_{\overline{K^0}} = d\sigma^{\nu u}_{K^0},$$

$$d\sigma^{\nu d}_{\overline{K^0}} \leqslant 3d\sigma^{\nu d}_{K^0}$$

Further taking an incoherent sum for the physical νp- and νn- scattering cross-sections in terms of the constituents, it is easy to see that

$$d\sigma^{\nu p}_{\overline{K^0}} - d\sigma^{\nu p}_{K^0} \leqslant d\sigma^{\nu n}_{K^0}. \tag{26}$$

In this we have assumed the momentum distribution function $u(x) \geqslant d(x)$. Therefore the inequality (26) should be true for the values of x for which $u(x) \geqslant d(x)$. Similarly, we can also write the inequalities

$$d\sigma^{\nu p}_{\pi^+} - d\sigma^{\nu p}_{K^+} \leqslant d\sigma^{\nu n}_{K^+}, \tag{27a}$$

$$d\sigma^{\nu p}_{K^-} - d\sigma^{\nu p}_{\pi^-} \leqslant d\sigma^{\nu n}_{\pi^-}. \tag{27b}$$

Stronger statements regarding the region of validity of these inequalities would require an explicit model of the production of h. We shall not go into it here, but defer it for a future publication.

3.3. $\nu + N \to \nu + B(8) + P(8)$

In this exclusive reaction $B(8)$ and $P(8)$ refer to the $\frac{1}{2}^+$ baryon and 0^- meson octets. Since the neutral current has $\Delta S = 0$, associated production of strange particles can be expected to be as copious as that of non-strange particles. For $\mathcal{N}$ which is a mixture of $I = 0$ and 1 one obtains two isospin relations

$$A(\nu n \to \nu p \pi^-) + \sqrt{2} A(\nu n \to \nu n \pi^0) = \sqrt{2} A(\nu p \to \nu p \pi^0) - A(\nu p \to \nu n \pi^+), \tag{28a}$$

$$A(\nu n \to \nu \Sigma^- K^+) + \sqrt{2} A(\nu n \to \nu \Sigma^0 K^0) = \sqrt{2} A(\nu p \to \nu \Sigma^0 K^+) + A(\nu p \to \nu \Sigma^+ K^0). \tag{28b}$$

The amplitude relation (28a) has been already noted and we state it for completeness here.

If $\mathcal{N}$ is a pure U-spin singlet then one obtains

$$\sqrt{2} A(\nu p \to \nu \Sigma^+ K^0) = \sqrt{3} A(\nu p \to \nu p \eta) - A(\nu p \to \nu p \pi^0), \tag{29a}$$

$$\sqrt{2} A(\nu p \to \nu n \pi^+) = \sqrt{3} A(\nu p \to \nu \Lambda K^+) - A(\nu p \to \nu \Sigma^0 K^+), \tag{29b}$$

$$\sqrt{3} A(\nu n \to \nu \Lambda K^0) - A(\nu n \to \nu \Sigma^0 K^0) = \sqrt{3} A(\nu n \to \nu n \eta) - A(\nu n \to \nu n \pi^0). \tag{29c}$$

The relations in (29a) and (29b) involving a proton target may turn out to be useful. These amplitude relations can be easily converted into inequalities among cross-sections.

3.4. $e^+ e^- \to B(8) + \bar{B}(8)$

This annihilation processes affords in principle the possibility of determining the SU(3) structure of $\mathcal{N}_A$ the axial part through the measurement of the cross-section difference Δ_B and the longitudinal polarisation $\bar{P}_B$ for baryon B, where

$$\Delta_B \equiv \frac{d\sigma^B(-\cos\theta)}{d\Omega} - \frac{d\sigma^B(\cos\theta)}{d\Omega} \simeq \frac{2\alpha^2}{e^2 M_Z^2} \cos\theta \, g_A^0 \, [G_A^0(s)]_B \, [G_M(s)]_B,$$

$$\bar{P}_B \equiv \frac{P(\cos\theta) + P(-\cos\theta)}{2} \simeq -\frac{2s}{e^2} \frac{g_V^0 \, [G_A^0(s)]_B}{[G_M(s)] \, M_Z^2}$$

in the approximation that the total center of mass $\sqrt{s} \ll M_z$ the mass of the neutral intermediate boson Z and small c.m. angle θ and can be obtained from the general expression given by Budny (1973). Further $g^0{}_V$ ($g^0{}_A$) are the vector (axial) coupling of the electron to Z while G_M is the Sachs magnetic form factor and $G^0{}_A$ is the axial form factor defined by Budny (1973). Measurement of $\overline{P_\Lambda}$ has been suggested to test an isoscalar axial part (Mani and Roy 1975).

For the general current $\mathscr{N}_A$ in (16) SU(3) will give 4 relations between the various $(G^0{}_A)_B$ which can be specialised for a U-spin singlet $\mathscr{N}_A$ to obtain the magnetic moment relations for a mixture of octet and singlet (Gupta and Kögerler 1975) or obtain further relations through the use of the quark model. However we do not present these results here since $\triangle_B$ difference of two large quantities and $\overline{P_B}$ are rather small and will be very hard to measure accurately. Nevertheless the possibility may be kept in mind for completeness.

3.5. $e^+e^- \to \overline{B}(8) + B(10)$

This reaction is interesting because the $\frac{3}{2}^+$ baryon decuplet $B(10)$ has a U-spin $\frac{3}{2}$ quartet ($\triangle^-$, Σ^{*-}, Ξ^{*-}, Ω^-). Since ($\overline{\Xi^-}$, $\overline{\Sigma^-}$), form a U-spin doublet the cross-sections σ_Σ and σ_Ξ for ($e^+e^- \to \overline{\Sigma^-} \Sigma^{*-}$) and ($e^+e^- \to \overline{\Xi^-} \Xi^{*-}$) will vanish unless the neutral current has either a $U=1$ or $U=2$ part, the latter signifying higher dimensional representations (like 27, etc.) than a singlet and octet in the current. Restricting ourselves to a singlet and octet mixture as in (16) (which is obtainable from the usual quark model) only $U = 1$ will contribute so that $\sigma_\Sigma = \sigma_\Xi$. These reactions proceed solely through the neutral current, since the electromagnetic current has $U=0$, so that just their observation would signal the presence of a $U \geqslant 1$ part in either the vector or axial part of the neutral current and would clearly be of importance in distinguishing between gauge models.

4. Conclusion

In summary, we point out the main features of our work. The results presented are some general consequences of the weak neutral current, independent of a gauge model. The bound on $Q(Z,N)$ is numerically obtainable from the available neutrino-data, though there is a stronger limit, as shown earlier, which must await some further experimental results. The SU(3) tests of the general neutral current can be easily generalised to include other similar cases. For example, in the inclusive neutrino-reactions, considered earlier, the final hadron h may also belong to the baryon octet. These tests may be particularly of interest at very high neutrino energies, which are now available.

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