NEUTRAL WEAK CURRENTS?

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One four-vermion interaction variant connected with neither intermediate particles nor with the concept of weak neutral currents is considered. This variant could lead, in principle, to the existence of process of the type $\nu_\mu + N \to \nu_\mu +$ hadrons and $\nu_\mu + e \to \nu_\mu + e$.

Recent experiments with neutrino beams of high energy [1, 2] have revealed muonless neutrino events of the type

$$\nu_\mu + N \to \nu_\mu + \text{hadrons}. \tag{1}$$

In the opinion of the authors of the cited papers, these experiments point to the existence of heavy leptons or neutral weak currents. Neutral currents were sought earlier in weak interactions, but the problem of their existence became particular pressing after attempts were made to formulate a unified theory of weak and electromagnetic interactions [3, 4].

References [3, 4] are not only of tremendous theoretical signficance, but have also contributed to new experimental research on neutrino physics [1, 2], to which we have referred.

It seems, however, too early to interpret the experimental data only from the point of view of the Weinberg-Salam theory, in which the neutral currents are connected with the existence of a neutral intermediate boson Z. It can be shown that processes of type (1) admit of other schemes, besides the existence of heavy leptosn and neutral currents. The alternatives that will be discussed below are not particularly attractive, but they are relatively "economical" and should be rejected only on the basis of experiments. I shall stop to discuss one such possibility.

Assume that in a four-fermion interaction a decisive role is played somehow by the electric charge, and that the interaction takes place between any two pairs of fermions only when each pair has a summary electric charge different from zero. In other words, four-fermion interaction can take place only if two and only two of the fermions are charged.

A characteristic of four-fermion interaction is its ability to produce both scattering and particle conversion; but of course, conversion processes are quantitatively limited by the fact that the strangeness violation be minimal (i.e., $\Delta s = 0$ or 1); this is natural in all composite hadron models. In addition, certain conservation laws must hold (for the baryon, lepton, and electric charges). Furthermore, we make one ad-hoc assumption, viz., that the change $\Delta\alpha$ of the hadrons is equal to the hadron strangeness change Δs in leptonic decays (expansion of the $\Delta\alpha = \Delta s$ rule). This requirement is connected with the empirical data, and particularly with the absence of processes of the type $K^+ \to \pi^+ + e^+ + e^-$, etc.

Pairs with, say, positive charge are classified in the table in three groups, in accord with some obvious attributes. For example, the interaction scheme of the pairs of the first group is analogous to the classical scheme of Feynmann and Gell-Mann and of Marshak and Sudarshan with charged currents.

The interaction takes place between pairs of each groups, of course, only if the conservation rules and the rule $\Delta\alpha = \Delta s$ are satisfied. There is also an interaction of each pair with itself. The corresponding fundamental processes are indicated in the table.

Group	Charged pair	Main processes
1	e^+ – e-neutrino μ^+ – μ^+ neutrino proton - neutron proton - lambda	ν_e-e scattering; weak nucleon forces; μ decay; β decay; μ capture and their inverse processes; nonleptonic and leptonic decays of strange particles.
2	e^+ – μ-neutrino μ^+ – e-neutrino	$\nu_\mu - e$ scattering μ decay
3	proton - e-neutrino proton - μ-neutrino e^+ – neutron μ^+ – neutron e^+ – Λ μ^+ – Λ	Elastic scattering of both neutrinos by nucleons; weak elastic scattering of electrons and muons by nucleons; β capture, μ capture and their inverse processes; scattering of electrons and muons by Λ particles.

An important difference between this interaction and the interaction with intermediate charged bosons is that the former admits of some other elastic processes which the latter does not. For example, there appear neutrino-nucleon scattering processes, which have recently been observed [1, 2]. The $\nu_\mu e$ scattering process should exist [5], and the process $\mu \to e + \gamma$ should not. Also absent is the process $\mu^- + A \to e^+ +$ hadrons, which contradicts the lepton conservation law in certain schemes. Processes of the type $K^+ \to \pi^+ + e^+ + e^-$, $K^+ \to \pi^+ + \nu + \tilde{\nu}$, etc., are absent, since they are ofrbidden from the very outset by the requirement $\Delta\alpha = \Delta s$. The abdence of the processes $K^+ \to \pi^+ + e^+ + e^-$ etc. is the greatest difficulty in the Weinberg scheme with neutral currents, since these processes should appear already in first order in the weak constant.

The formulation of this scheme in terms of the intermediate particles is attractive since, in addition to ordinary intermediate charged bosons, rather exotic particles might appear ("baryoleptons" etc.). In essence, the concept of weak currents becomes lost in the scheme, in spite of the fact that the currents were preserved in some manner in the language of "pairs." This was done to facilitate the description of the scheme using a well known language. It would have been more consistent, however, to avoid the word "pair" and to stipulate the existence of a true four-fermion interaction between arbitrary fermions of which two, and only two, are electrically charged. In first order in the weak constant, there take place those processes in which the conservation laws hold for the various charges, as well as the rule $\Delta\alpha = \Delta s$ in leptonic decays of strange hadrons. It can be noted that processes with $\Delta s = 2$ and processes of the type $K \to \pi + e^+ + e^-$ etc. are forbidden in the scheme (in first order), but the processes $e + \Lambda \to e + \Lambda$, $\mu + \Lambda \to \mu + \Lambda$, etc. are allowed.

What distinguishes this scheme from others? There is no neutrino-neutrino scattering in first order in this scheme. There should likewise be no electron-electron scattering in first order in the weak-interaction constant, which does exist in Weinberg's scheme. The latter process is no longer very far from becoming observable.

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