Allowance for the damping due to the reflected ions leads, for times $t \gg 1/\omega_{pi}\alpha_s$, to the following formula for the amplitude of the ion-acoustic soliton:

$$a_s(t) = \frac{a_s(0)}{\left(1 + \sqrt{\frac{a_s(0)}{24}}\gamma_s t\right)^2}, \quad \gamma_s = -\frac{\omega_{pi}}{n_0} v_{ph}^2 \frac{\partial f_{oi}}{\partial v_{ph}} \tag{9}$$

$f_{0i}(v)$ is the equilibrium distribution of the ions, and $\omega_{pi} = (m_e/m_i)^{1/2}\omega_{pe}$.

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HADRONIC SYMMETRIES AND GAUGE THEORIES OF WEAK AND ELECTROMAGNETIC INTERACTION

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1. Unified renormalizable theories of weak and electromagnetic interactions with spontaneously-violated gauge invariance have been extensively discussed of late [1 - 7]. These theories make it possible to describe in a unified manner both weak and electromagnetic interaction, unifying the photon and the $W^{\pm}$ bosons (usually with one more neutral vector meson) as gauge fields.

The proposed models [1 - 5] make it possible to describe purely leptonic processes, but when they are generalized to include hadrons, many difficulties are raised by the observed SU(3) and SU(6) symmetries of the strong interactions. Thus, 12 quarks are needed in [2] to construct the known SU(3) baryon multiplets, and seven and eight quarks are needed in the models of [3, 4]. In addition, in view of the integer charge of the quarks in the models of [3 - 5], SU(6) symmetry is lost for baryons.

2. We propose in this article a renormalizable theory of weak and electromagnetic interactions with spontaneously-violated SU(2) × U(1) gauge symmetry, including the usual SU(3) quarks with fractional charge, and allowing us to preserve the observed hadronic symmetries.

We postulate the usual SU(3) triplet quark (p, n, λ), two new quarks p' and q with charges +2/3 and -1/3, and two new heavy neutron leptons, electronic (E) and muonic (M), in addition to e, ν_e, μ, and ν_μ. The strong SU(5) interactions are invariant, and the observed SU(3) symmetry is the low-energy limit of the global SU(5) symmetry if the quarks p' and q are much heavier than the triplet (p, n, λ).

The gauge vector fields, the SU(2) triplet (W^+, S^0, W^-) and the singlet B^0, are introduced in accordance with

$$i\partial_\mu \to i\partial_\mu + g\vec{\tau}\,\vec{W}_\mu + g' Y B^\circ_\mu \,. \tag{1}$$

They prevent anomalies connected with the axial current [8] from appearing in the theory we use, following [5], multiplets of like dimensionality for the right and left particles. Then

$$B_\ell = \begin{pmatrix} p\cdot\cos\theta - p'\sin\theta \\ n \end{pmatrix}_\ell \,, \quad B' = \begin{pmatrix} p\sin\theta + p'\cos\theta \\ \lambda \end{pmatrix}_\ell$$

$$B_r = \begin{pmatrix} p \\ q \end{pmatrix}_r \quad \text{and} \quad B'_r = \begin{pmatrix} p' \\ n \end{pmatrix}_r \tag{2}$$

are doublets with $Y = 1/3$ and q_ℓ and λ_r are singlets with $Y = -2/3$. Here θ is the Cabbibo angle. For the leptons, analogously, $(\nu_e, e)_\ell$ and $(\nu_\mu, \mu)_\ell$ are left-hand and $(E, e)_r$ and $(M, \mu)_r$ are right-hand doublets with $Y = -1$ and E_ℓ, M_ℓ, ν_{e_r}, and ν_{μ_r} are singlets with $Y = 0$.

The masses of the vector fields are introduced with the aid of the Higgs mechanism [9], and we postulate a triplet of scalar mesons (ϕ^+, ϕ^0, ϕ^-) with $Y = 0$ and two doublets: $\xi = (\xi^0, \xi^-)$ with $Y = -1$ and $\tilde{\xi} = (\xi^+, \bar{\xi}^0)$ with $Y = 1$. The vacuum mean values of the neutral components of the scalar fields, $\langle\phi^0\rangle = v/\sqrt{2}$ and $\langle\xi^0\rangle = u$ can be chosen to be real. Then

$$m^2_{W^\pm} = g^2(u^2 + v^2) \text{ and } m^2_Z = g^2u^2/\cos^2\alpha \,, \tag{3}$$

where $\tan\alpha = g'/g$ and $Z_\mu = \cos\alpha\, W^0_\mu - \sin\alpha\, B^0_\mu$. The photon $A_\mu = \cos\alpha\, B^0 + \sin\alpha \times W^0_\mu$ remains massless, and the charge is

$$e = 2g\sin\alpha \,. \tag{4}$$

3. The interactions of $W^\pm_\mu$ and Z_μ with the currents are of the form

$$\begin{aligned}
&\frac{g}{\sqrt{2}} W^+_\beta [\bar{\nu}_e\gamma_\beta(1+\gamma_5)e + \bar{E}\gamma_\beta(1-\gamma_5)e + \bar{\nu}_\mu\gamma_\beta(1+\gamma_5)\mu + \bar{M}\gamma_\beta \times \\
&\times (1-\gamma_5)\mu] + \text{h.c.} + \frac{g}{\cos\alpha} Z_\beta \Big[\frac{1}{2}\bar{\nu}_e\gamma_\beta(1+\gamma_5)\nu_e + \\
&+ \frac{1}{2}\bar{E}\gamma_\beta(1-\gamma_5)E - \cos 2\alpha\,\bar{e}\gamma_\beta e + \frac{1}{2}\bar{\nu}_\mu\gamma_\beta(1+\gamma_5)\nu_\mu + \\
&+ \frac{1}{2}\bar{M}\gamma_\beta(1-\gamma_5)M - \cos 2\alpha\,\bar{\mu}\gamma_\beta\mu\Big] + \frac{g}{\sqrt{2}} W^+_\beta[\bar{p}\gamma_\beta(1+\gamma_5)n\cos\theta + \\
&+\bar{p}\gamma_\beta(1+\gamma_5)\lambda\sin\theta + \bar{p}'\gamma_\beta(1+\gamma_5)\lambda\cos\theta - \bar{p}'\gamma_\beta(1+\gamma_5)n\sin\theta + \\
&+\bar{p}\gamma_\beta(1-\gamma_5)q + \bar{p}'\gamma_\beta(1-\gamma_5)n] + \text{h.c.} + \frac{g}{\cos\alpha} Z_\beta\Big\{(\bar{p}\gamma_\beta p + \bar{p}'\gamma_\beta p') \times \\
&\times \left(\cos^2\alpha - \frac{1}{3}\sin^2\alpha\right) - \bar{n}\gamma_\beta n\left(\cos^2\alpha + \frac{1}{3}\sin^2\alpha\right) + \\
&+ \frac{1}{2}\bar{\lambda}\gamma_\beta\left[\gamma_5 - \left(\cos^2\alpha - \frac{1}{3}\sin^2\alpha\right)\right]\lambda - \frac{1}{2}\bar{q}\gamma_\beta\left[\gamma_5 + \left(\cos^2\alpha - \frac{1}{3}\sin^2\alpha\right)\right]q\Big\}.
\end{aligned} \tag{5}$$

From this we find readily that if

$$\cos 2\alpha \frac{u^2 + v^2}{u^2} = -1 \text{ and } \alpha = 60° (120°), \tag{6}$$

then, in the local limit, a curious symmetry appears in the effective Lagrangian of the elastic interaction between neutrionos and leptons or light quarks:

$$\frac{G}{\sqrt{2}} [\bar{\nu}_e \gamma_\beta (1 + \gamma_5) \nu_e (\bar{\mu} \gamma_\beta \mu - \bar{e} \gamma_\beta \gamma_5 e) + \bar{\nu}_\mu \gamma_\beta (1 + \gamma_5) \nu_\mu \times$$
$$\times (\bar{e} \gamma_\beta e - \bar{\mu} \gamma_\beta \gamma_5 \mu) - |\bar{\nu}_e \gamma_\beta (1 + \gamma_5) \nu_e + \bar{\nu}_\mu \gamma_\beta (1 + \gamma_5) \nu_\mu \times$$
$$\times (\bar{n} \gamma_\beta n - \bar{\lambda} \gamma_\beta \gamma_5 \lambda)]. \tag{7}$$

It must be emphasized that the compatibility of the two conditions (6) for the mixing angle α is nontrivial, and although we see no reasons for this incidentally quite reasonable choice of the parameters, the Lagrangian (7) seems very attractive. We note that according to (7) we have $\sigma_{\nu_\mu e} = \sigma_{\nu_\ell e} = (1/3)\sigma_{\nu_e e}(V - A)$, which does not contradict the experiments (cf., e.g., [6]). Estimates show that the cross sections predicted by (7) for the processes $\nu_\mu + N \to \nu_\mu$ + hadrons likewise do not contradict the known experimental limitations.

4. The lepton masses are generated by an interaction in the form

$$g_1 \left[\frac{u}{2} \bar{L}_r L_\ell - \bar{L}_r (\vec{\tau} \vec{\phi}) L_\ell \right] + g_2 (\bar{L}_r \xi) E_\ell + \text{h.c.} \tag{8}$$

which yields $m_\ell = g_1 u$ and $m_E = g_2 u/\sqrt{2}$ (and analogously for muonic leptons). The neutral leptons E and M are not observable in usual experiments if they are heavier than the K meson.

For hadrons we take the interaction

$$f_1 \bar{B}_r (\vec{\tau} \vec{\phi}) B_\ell + f_2 \bar{B}_r (\vec{\tau} \vec{\phi}) B'_\ell + f_3 \bar{B}'_r (\vec{\tau} \vec{\phi}) B_\ell + f_4 \bar{B}'_r (\vec{\tau} \vec{\phi}) B'_\ell +$$
$$+ f_5 (\bar{B}_r \tilde{\xi}) q_\ell + f_6 (\bar{B}'_r \tilde{\xi}) q_\ell + f_7 (\bar{B}_\ell \tilde{\xi}) \lambda_r + f_8 (\bar{B}'_\ell \tilde{\xi}) \lambda_r +$$
$$+ f_9 \bar{B}_r B_\ell + f_{10} \bar{B}_r B'_\ell + f_{11} \bar{B}'_r B_\ell + f_{12} \bar{B}'_r B'_\ell . \tag{9}$$

Eliminating the nondiagonal terms of the mass matrix by a proper choice of the constants, we obtain $m_p = f_1 v/\cos\theta$, $m_n = f_{11} - f_3 v/2$, $m_q = f_5 u/\sqrt{2}$, $m_\lambda = f_8 u/\sqrt{2}$, $m_{p'} = f_4 v/\cos\theta$. The masses of all quarks can be chosen arbitrarily, and in particular $m_p = m_n$, $m_\lambda > m_{p,n}$, and $m_{q,p'} \gg m_{p,n,\lambda}$. The case $m_q = m_{p'}$ is of interest, for in this case the breaking of the SU(5) symmetry is minimal and this symmetry reduces to SU(3) × SU(2).

Strong interactions might be transferred by the gluon and by the scalar and pseudoscalar σ^i_k and π^i_k mesons belonging to the $(5, \bar{5}) \pm (\bar{5}, 5)$ representations of the chiral SU(5) × SU(5) group. If the interaction of the σ^i_k and π^i_k mesons with the $\vec{\phi}$ and ξ fields can result in a spontaneous violation of the symmetry in the σ_m^i meson system, then this could lead, as a result of the vacuum mean values $<\sigma_k^i>$, to terms of the type of the bare masses used in (9). On the other hand, in the absence of an interaction between the hadrons and the σ_k^i and π_k^i fields, the hadrons would be massless and we would then have an exact SU(5) × SU(5) symmetry of strong interactions. In this case, possibly, we might be able to fit the PCAC hypothesis into the framework of this scheme, in analogy with the σ model of Gell-Mann and Levy [10].

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DISTRIBUTION WITH RESPECT TO THE TRANSVERSE MOMENTUM IN THE MULTIPERIPHERAL MODEL

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In an earlier paper [1, 2] we proposed a multiperipheral model that ensures a constant cross section of particle interaction at high energies. We obtain here the distribution with respect to the transverse momenta of the muons produced in this model in collisions between two particles, and show that it agrees fairly well with experiment [3 - 6]. Let us recall the main features of the model.

To obtain a non-decreasing total cross section at reasonable values of the coupling constants it is necessary to take into account the dependence of the amplitudes on the pair energies [2] and the possibility of emission of different types of particles. Therefore, besides pion exchange, we take into account exchange of the ρ and ω trajectories and allow the production of π, ρ, ω, f, and A_2 mesons.

Then the matrix element shown in Fig. 1a takes the form

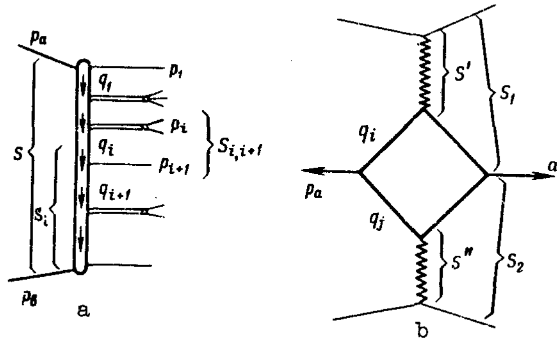

Fig. 1