$$\tilde{\nu} = \frac{\partial L}{\partial \omega} = 2\omega \left[1 + \frac{\omega^2 - \omega_o^2}{\omega^2(\gamma + 1)}\right] \phi^+\phi \ . \qquad (14)$$

At low density $\tilde{\nu}$, these equations again lead to an expression in the form (5')

$$E = (\omega(k) - \epsilon_F)\,\nu .$$

However, $\omega(k)$ should be determined from (8). This formula yields the frequency of the π^- mesons, and if ω is replaced by $-\omega$ it yields the π^+-meson frequency [2]. It is easy to see that as $\tilde{\nu} \to 0$ and if the condition

$$\xi = \frac{3\sqrt{3} f^2 k^2 n}{\omega_o^3} = 1$$

is satisfied, the sum of the π^-- and π^+-meson frequencies vanishes, i.e., the already mentioned instability for pair production sets in. Since pair production is not taken into account in our model, we can use it only for $\xi < 1$.

An analysis of equations (12), (13) and (14) at arbitrary density $\tilde{\nu}$ shows that no first- or second-order phase transitions occur in the considered model, up to very high density of nuclear matter, i.e.,

$$E(\tilde{\nu}) > E(0) .$$

It was suggested in [3] that proton stars ($\tilde{\nu}_p = \tilde{\nu}_\pi = n$) can exist. This suggestion is not corroborated in our model. It is difficult to say whether the result remains the same also in a more realistic calculation.

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GAUGE MODELS OF WEAK INTERACTION AND SUPERCHARGED HADRONS

N. N. Nikolaev
Institute of Theoretical and Experimental Physics
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The possibility of searches for supercharged (charmed) hadron in a neutrino experiment and in PP interactions at high energies is discussed.

One of the most characteristic features of gauge models of weak interaction is the need **for** including supercharged (charmed) hadrons in the model (see the review [1] and the literature cited there). It follows from the absence of the $K_L \to 2\mu$ decay [1, 2] that supercharged hadrons R cannot be heavier than 7 - 10 GeV, and the mass difference between the K_L and K_S mesons yields even more stringent albeit less reliable estimates, namely $m_R \lesssim 2 - 3$ GeV (see also the review [3]).

The purpose of the present article is to emphasize that the need for using [2, 4] the Glashow-Iliopoulos-Maiani procedure [5] to eliminate neutral currents with $\Delta S = 1$ fixes rigidly the decay properties of the R-hadrons of lightest mass (heavy R-hadrons would decay strongly into lighter ones). Namely, the probabilities of of the β decays $R \to N l \nu$, $R \to Y l \nu$, etc. should be comparable with the probabilities of the nonleptonic decays:

$$B_\beta(R) = \frac{\Gamma(R \to \ell + \nu + \text{hadrons})}{\Gamma(R \to \text{hadrons})} \gtrsim 1.$$

This makes it possible to verify reliably the existence of R-hadrons with masses up to 10 GeV even in the present experimental searches for the W boson; this would serve as a critical test for weak-interaction gauge models.

Thus, in neutrino experiments the reactions $\nu_\mu N \to \mu R$ should proceed with the usual weak cross sections, of the order of the cross sections of the observable reactions $\nu_\mu N \to \mu Y$ or, in certain models, even with cross sections of the order of the cross section of the reactions $\nu_\mu N \to \mu N$. Owing to the instantaneous β decays, this would lead [6] to the characteristic μe lepton pairs. The search for such pairs, which are usually regarded as symptoms of W-boson production, in the neutrino experiment now under way with the Batavia NAL accelerator, would provide a reliable test of the existence of R-baryons with masses up to 10 GeV.

The situation with the possibility of observing R hadrons in PP collisions is less certain. Owing to the rigorous conservation of the supercharge in strong interactions, the R-hadrons can be produced only by superneutral pairs. Since the production of a large mass leads to large momentum transfer, the most convenient kinematically is diffraction dissociation of the incident proton into a pair comprising an R-baryon and an R-meson. After fast β decays, such reactions will look like direct lepton production in the target, and the produced lepeons will have transverse momenta up to $p_\perp \simeq m_R/2$, while the invariant mass of the lepton pair can be quite large, up to masses on the order of the R-hadron mass.

It is difficult to estimate the cross section for the production of such a pair. If we start from multiperipheral models, then it is reasonable to expect $\sigma_R \simeq 10^{-2} - 10^{-3}$ of the total cross section near threshold. However, σ_R cannot be too small, by virtue of the global SU(n) symmetry of strong interactions, a symmetry broken only by the particle masses (n is the total number of quarks, including the supercharged ones). Therefore the fact that experiment reveals no direct production of leptons with $\sigma_R \lesssim (10^{-4} - 10^{-5})\sigma_{tot}$ must apparently be interpreted as the absence of R-hadrons with masses lower than those allowed by the kinematics of the reaction. If R-pair production is compared with W-boson production, then in the first rough approximation, without allowance for the difference in the kinematics and in the registration conditions, the lower limit for the W boson mass is also the lower limit for the R-pair mass. It would be very interesting to analyze in detail, with allowance for the difference in the kinematics of the two processes, the results of the last experimental search for W-bosons with colliding PP beams at CERN, where a lower bound $m_W \gtrsim 17$ GeV was established for the W-boson mass [7].

We shall now explain why $B_\beta(R) \gtrsim 1$. To eliminate from the neutral current the experimentally forbidden $\bar{\lambda}n$ component, one introduces [5] in addition to the usual isodoublet (p, n_θ) a second isodoublet (p', λ_θ), where p' is a new supercharged quark. The neutral current then takes the form $\bar{n}_\theta n_\theta + \bar{\lambda}_\theta\lambda_\theta = \bar{n}n + \bar{\lambda}\lambda$, and does not contain a component with $\Delta S = 1$. Moreover, only this procedure makes it possible to suppress neutral currents with $\Delta S = 1$ also in higher orders in the weak interaction [2, 4]. The weak current with a p' quark takes the form $p'\bar{\lambda}_\theta = -\bar{p}'n \sin\theta + \bar{p}'\lambda \cos\theta$, but in some models [8] it is possible to have also a current $\bar{p}'n$ or $\bar{p}'\lambda$, with (V + A) structure. Therefore β decays into hyperons should have a probability larger than or of the order the probability of β decays into nucleons. We now recognize that the probability of β decays into nucleons. We now recognize that the probabilities of the β decays $R \to \ell\nu N(Y)$ are proportional to the fifth power of the energy release, and the probabilities of the nonleptonic decays are proportional only to the first power of the energy release at large m_R. Experiment yields for hyperons $B_\beta(Y) \simeq 10^{-3}$, and then $B_\beta(R) \simeq 1$ already at $m_R \gtrsim 2.5$ GeV. With further increase of m_R, the growth of $B_\beta(R)$ may not cease because of the form factors, if account is taken also of the "inelastic" β decays $R \to \ell + \nu$ + hadrons (if we assume $m_A \simeq m_V \simeq$ 1 GeV, then the form factors and inelastic channels play no role at $m_R < 2.5$ GeV). The lifetimes of the R-hadrons should then be very short, $\tau_R \lesssim 10^{-12}$ sec, since the decay probabilities obviously do not contain small quantities due to the Cabibbo angle, and their direct observation in tracks would be a very difficult task.

In the simplest case, the $N \to R$ transition does contain a Cabibbo angle, and then $\sigma(\nu_\mu N \to \mu R) \simeq \sigma(\nu_\mu N \to \mu Y)$. On the other hand if the (V + A) currents $\bar{p}'n$ do exist in the model, then $\sigma(\nu_\mu N \to \mu R) \simeq \sigma(\nu_\mu N \to \mu N)$. From an analysis of the already available data on neutrino reactions [9] we can find that $m_R \gtrsim 2$ GeV. Analogous estimates for m_R follow also from experiment [10] on the search of the W boson and from experiment [11] on the measurement of the spectra of heavy muon pairs.

As noted by L. B. Okun', the discussed effects, which are connected with R-hadron β decays, may be nonexistent if one introduces specially new particles into which the R hadrons decay with a probability higher than the β-decay probability. Within the framework of gauge theories, this can be done only with new non-Higgs scalar mesons with a gauge-invariant interaction containing vertices of the type $f\bar{p}'N\xi$ and $f\bar{p}'Y\xi$, with a constant $f \geq Cm_R^2$. The structure of this interaction can be quite arbitrary, and only vertices of the type $f(\bar{\lambda}n + \bar{n}\lambda)\xi$ are forbidden, since they lead to too large a difference between the K_L and K_S meson masses: $\Delta m_{\zeta_0} \gtrsim (m_R/m_K)^4 \Delta m_{exp}$. The predominant role in the decays of such mesons would be played by the nonleptonic channels due to the vertices $f\bar{N}N\xi$, $f\bar{N}Y\xi$, and $f\bar{Y}Y\xi$. In the experiment, they would take the form of very narrow resonances with widths determined only by the resolution of the apparatus. It would be extremely difficult to observe them in hadronic processes, owing to the small production cross section and the corresponding large background. The situation is much better in neutrino experiments, where there is practically no background. In this case it is necessary to search for events in which a very narrow heavy resonance (R-baryon) is produced in a neutrino reaction with the already discussed usual weak cross section, and decays into hadrons and one more very narrow mesic resonance (ξ meson). If interactions with ξ mesons, accompanied by a change of strangeness, occur in the model, then such resonances would be characterized by comparable probabilities of the decays with $\Delta S = 0$ and $\Delta S = 1$. In the discussed variant with ξ mesons, the search for R-hadrons by means of cascade decays seems more complicated than a simple search by means of μe pairs. But even in this case it would be possible to reach R-hadron masses $m_R \approx 10$ GeV in the NAL neutrino experiment.

We emphasize once more, in conclusion, the importance of experiments aimed at searches for supercharged hadrons. If experiments show that $m_R \gtrsim 10$ GeV, this would be a weighty argument against weak-interaction gauge models in which the Barth-Halpern-Ioshimura procedure for including hadrons in the model is not used (for a detailed discussion of the inclusion of hadrons in gauge models see the review [1] and also [3, 4, 8, 13]).

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After the submission of this article, another article was published by G. Snow (Nucl. Phys. B55, 1973), also discussing the properties of supercharged hadrons, in which similar conclusions are drawn concerning their experimental observation. Snow does not mention the possibility of a variant with existence of scalar ξ mesons and decays $R \to \xi$ + hadrons.

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