μ is forbidden in a theory with an additive conservation law. If there were no muon conservation law at all, then electrons may be produced with a boson which decays into pions. The detection of electrons produced by ν_μ, together with a boson of only leptonic decay modes, would be strong evidence in favor of a multiplicative selection rule.

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†Alfred P. Sloan Foundation Fellow.

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[4]The assignment given here of the additive quantum number is conventional. A linear combination of this quantum number with lepton number would give another conserved quantum number whose physical implications are the same.

[5]The assignment of muon parity +1 to baryons, pions, etc., follows from the existence of nonleptonic transitions among such particles, and is unique up to factors $(-1)^{\text{baryon number}}$ or $(-1)^{\text{charge}}$ which have no physical significance.

[6]See, e.g., C. N. Yang and J. Tiomno, Phys. Rev. 79, 495 (1950). The properties of multiplicative conservation laws are discussed by G. Feinberg and S. Weinberg, Nuovo cimento 14, 5711 (1959).

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SPIN OF THE K'

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Recent experimental work on high-energy K-N collisions at Berkeley has been shown by Alston et al.[1] to suggest the existence of an unstable particle K',[2] formed from a K meson and a pion. They further assign to it a mass ~878 Mev, full width 23 Mev, and isospin 1/2. We shall investigate below, on the basis of the assumption that the pions produced from K-N collisions come entirely from the decay of K', whether K' is a vector or a scalar boson. We find that a vector K' fits the experimental data better than a scalar K'.

The following interactions are considered:

$$K' \text{ with spin } 0,\; H_I = mG\phi_{K'}\phi_K\phi_\pi; \tag{1}$$

$$K' \text{ with spin } 0,\; H_I = \frac{G}{m}\frac{\partial\phi_K}{\partial x_\mu}\frac{\partial\phi_\pi}{\partial x_\mu}\phi_{K'}; \tag{2}$$

$$K' \text{ with spin } 0,\; H_I = \frac{G}{m}\frac{\partial\phi_{K'}}{\partial x_\mu}\frac{\partial\phi_K}{\partial x_\mu}\phi_\pi; \tag{3}$$

$$K' \text{ with spin } 0,\; H_I = \frac{G}{m}\frac{\partial\phi_\pi}{\partial x_\mu}\frac{\partial\phi_{K'}}{\partial x_\mu}\phi_K; \tag{4}$$

$$K' \text{ with spin } 1,\; H_I = G\left(\phi_\pi\frac{\partial\phi_K}{\partial x_\mu} - \frac{\partial\phi_\pi}{\partial x_\mu}\phi_K\right)\phi_{K'}{}^{\mu}. \tag{5}$$

For the process $K^- + p \to K'^- + p$, shown in Fig. 1, the total cross section using the first interaction is

$$\sigma_1 = \frac{g^2}{4\pi}\,\frac{m^2G^2}{4\pi}\,\frac{\pi}{4M^2|q_1|_L{}^2}\int\frac{\Delta^2}{(\Delta^2+\mu^2)^2}d\Delta^2,$$

$$\frac{m^2G^2}{4\pi} = \frac{4\lambda m_0{}^2}{3[(m_0{}^2 - m^2 - \mu^2)^2 - 4m^2\mu^2]^{1/2}},$$

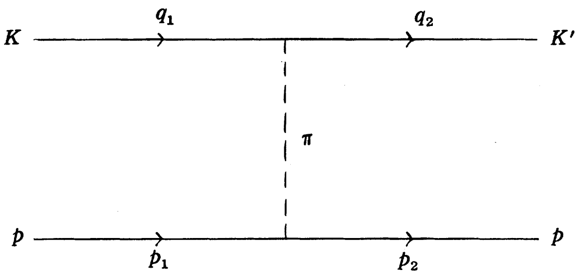

FIG. 1. K' production from K-N collision.

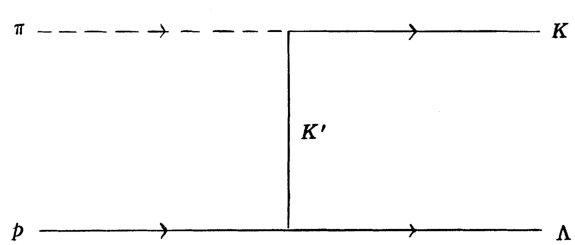

FIG. 2. K' exchange diagram.

where g is the renormalized pion-nucleon coupling constant, m_0 and λ are the mass and width of the unstable particle K', and Δ^2 is the square of the momentum transfer between the nucleons. These equations are similar to Eqs. (5) and (2) of Bég and DeCelles[3] except that in the present work the isotopic spin factors are taken into account. This is important because K' has two possible channels of decay into a K meson and a pion. Similar equations can easily be obtained for cases (2) to (5). Using $m_0=878$ Mev, incident pion momentum 1.15 Bev/c, we find

$$\begin{aligned}
\sigma_1(\text{mb}) &= 0.0678(\lambda g^2/4\pi)\times 10^{-2},\\
\sigma_2(\text{mb}) &= 0.1865(\lambda g^2/4\pi)\times 10^{-2},\\
\sigma_3(\text{mb}) &= 0.1205(\lambda g^2/4\pi)\times 10^{-2},\\
\sigma_4(\text{mb}) &= 0.01565(\lambda g^2/4\pi)\times 10^{-2},\\
\sigma_5(\text{mb}) &= 0.854(\lambda g^2/4\pi)\times 10^{-2},
\end{aligned} \tag{6}$$

where λ is in Mev.

However, we are in fact interested only in the process $K^- + p \to \bar{K}^0 + \pi^- + p$ which, as before, is said to proceed according to

$$K^- + p \to K'^- + p \to \bar{K}^0 + \pi^- + p.$$

Hence we have to multiply the results (6) by an isotopic spin factor 2/3. Taking $g^2/4\pi = 14.5$, $\lambda = 23$ Mev $\pm 20\%$, we find

$$\begin{aligned}
0.121 \text{ mb} &\le \sigma_1 \le 0.181 \text{ mb},\\
0.332 \text{ mb} &\le \sigma_2 \le 0.497 \text{ mb},\\
0.215 \text{ mb} &\le \sigma_3 \le 0.321 \text{ mb},\\
0.0278 \text{ mb} &\le \sigma_4 \le 0.0417 \text{ mb},\\
1.52 \text{ mb} &\le \sigma_5 \le 2.28 \text{ mb}.
\end{aligned}$$

The experimental results show that $\sigma = 2 \pm 0.3$ mb,[1] so that it seems that a vector K' fits the experimental data better than a scalar K'.

Further evidence for this conclusion may be obtained from a re-examination of the work of Tiomno et al.[4] on the process $\pi^- + p \to K^0 + \Lambda^0$. We consider one K' exchange only, i.e., the diagram shown in Fig. 2, using the interactions (1) and (5) for the $K'K\pi$ vertex. With the incident pion kinetic energy 960 Mev, $m_0 = 878$ Mev, $\lambda = 23$ Mev, we get

$$\sigma = 0.0574\, g_S^{\,2}/4\pi,$$

$$\sigma = 0.00499\, g_{PS}^{\,2}/4\pi,$$

for scalar and pseudoscalar couplings, corresponding to K' with spin 0; and

$$\sigma = 1.24 G_V^{\,2}/4\pi,$$

$$\sigma = 0.871 G_{PV}^{\,2}/4\pi,$$

for vector and pseudovector couplings, corresponding to K' with spin 1. Taking the experimental total cross section as $0.67 \text{ mb} \le \sigma \le 0.93$ mb,[5] we get

$$\begin{aligned}
11.7 &\le g_S^{\,2}/4\pi \le 16.2,\\
134 &\le g_{PS}^{\,2}/4\pi \le 186,\\
0.54 &\le G_V^{\,2}/4\pi \le 0.75,\\
0.79 &\le G_{PV}^{\,2}/4\pi \le 1.07.
\end{aligned}$$

If we assume that $g_{K'YN} \le g_{KYN} \le g_{\pi NN}$, we see that either a vector K' or a pseudovector K' gives a good fit.

Curves for the differential cross section for the production of Λ^0 together with the experimental results of 83 events at the incident pion kinetic energy, 960 Mev,[5] are shown in Fig. 3. They are normalized to the same area under the experimental histogram by taking appropriate g's and G's. Again vector K' gives a good fit.

Though all the present calculations favor a

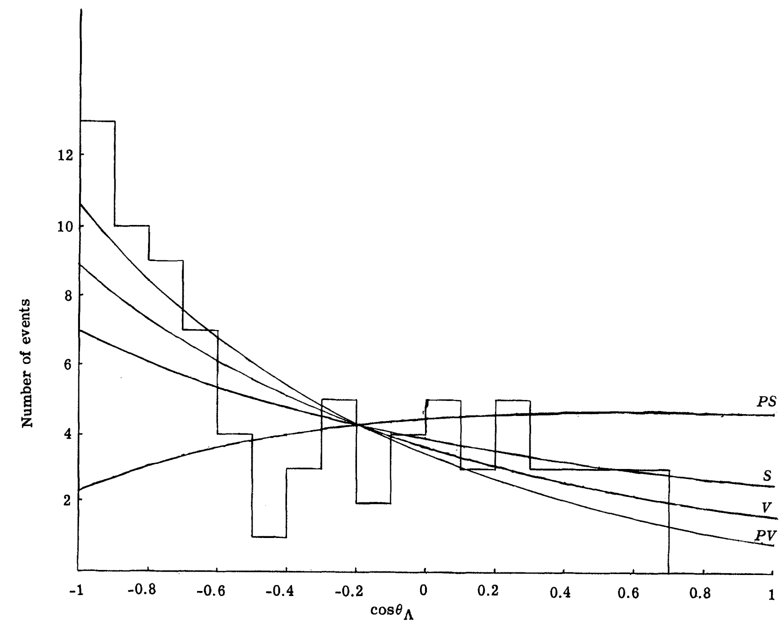

FIG. 3. Comparison of the experimental histogram of 83 events from bubble chamber, for the associated production $\pi^- + p \rightarrow K^0 + \Lambda^0$ at 960 Mev, with the theoretical predictions based on the assumption of exchange of a K'. All the curves are normalized to the same area under the histogram. Θ_Λ is the c.m. angle between the incident pion and Λ.

P-wave resonance, they do not exclude the possibility that K' can have spin zero because of the uncertainty of m_0 and λ.

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COUPLED INTEGRAL EQUATIONS OF THE OMNÉS-MUSKHELISHVILI TYPE

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In this note the Omnés method[1] of solution of certain singular integral equations is extended to the case of coupled equations. This problem arises in connection with many-channel γ reactions. The extension proposed here is the analog of Bjorken's generalization of the N/D method.[2]

Let us consider a many-channel reaction:

$$\begin{aligned} a+b &\rightarrow c_1+d_1 \\ &\cdots \\ &\quad c_n+d_n, \end{aligned} \qquad (1)$$

and denote by f_i the matrix elements for these transitions.