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[1] W. H. Barkas *et al.*, Phys. Rev. **105**, 1037 (1957); H. H. Heckman and F. M. Smith (private communication); W. W. Chupp (private communication). For completeness we have included the measurements on 1.35 meters reported in the following: Chamberlain, Chupp, Goldhaber, Segrè, Wiegand, Amaldi, Baroni, Castagnoli, Franzinetti, and Manfredini, Nuovo cimento **3**, 447 (1956); Amaldi, Castagnoli, Ferro-Luzzi, Franzinetti, and Manfredini, Nuovo cimento **5**, 1797 (1957).

[2] Chamberlain, Goldhaber, Jauneau, Kalogeropolous, Segrè, and Silberberg, *Proceedings of the Padua-Venice International Conference on Mesons and Recently Discovered Particles, September 22–28, 1957* [Nuovo cimento (to be published)].

[3] Goldhaber, Kalogeropolous, and Silberberg, Phys. Rev. **110**, 1474 (1958), preceding Letter.

[4] J. S. Blair, Phys. Rev. **95**, 1218 (1954). The charged-black-sphere model is the same as in this reference except that we have used the WKB approximation for the Coulomb phase shifts.

[5] For large angles where the Coulomb effect is small the charged-black-sphere model can be approximated by the optical model for black-sphere scattering, yielding $d\sigma/d\Omega = R^2[J_1(KR\sin\theta)/\sin\theta]^2$, which is symmetrical about 90°.

[6] See, for example, the calculations reported by R. E. Ellis and L. Schecter, Phys. Rev. **101**, 636 (1956).

[7] A. E. Glassgold, Phys. Rev. **110**, 220 (1958).

[8] H. P. Duerr and E. Teller, Phys. Rev. **101**, 494 (1956).

[9] H. P. Duerr, Phys. Rev. **103**, 469 (1956).

[10] Recently Duerr [Phys. Rev. **109**, 1347 (1958)] has also shown the disagreement between the strong attractive potential and various experimental data.

Conserved Currents in the Theory of Fermi Interactions*

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Feynman and Gell-Mann[1] have proposed a scheme in which the vector Fermi interactions are described in terms of an interaction with itself of a vector current. In a similar way the axial vector coupling may be thought of as a self interaction of an axial vector current. Furthermore, they propose to add strangeness-violating terms to these currents in order to account for strange particle decays. In order to account for the almost precise equality of the vector coupling strengths in β decay and μ decay, Feynman and Gell-Mann suggest, in analogy with electrodynamics, that the vector (strangeness conserving) current is conserved. It is also a fact that the axial vector strengths are nearly equal for the two processes. Supposing that this equality may turn out to be precise, one might attempt to understand this in terms of a conserved axial vector current. Without here going into the subtleties associated with a precise definition of the axial vector interaction constant in such a circumstance, we shall show that such a conserved axial current can be ruled out on experimental grounds. We shall also show that a scheme involving conserved strangeness-violating currents (either vector or axial vector) can probably also be ruled out. As for the original Feynman Gell-Mann scheme concerning the conserved vector current, independent tests have been proposed by Gell-Mann.[2]

Consider first the strangeness-conserving axial vector current. Taylor[3] has made the important observation that if the conserved current ideas hold here, then $\pi\to e+\nu$ and $\pi\to\mu+\nu$ are forbidden. This is a desirable result as regards the unseen electron mode; as for the μ-meson mode, Taylor argues that perhaps the μ meson does not couple according to the scheme under discussion. We think this possibility would remove all motivation for the scheme. In any case, a consideration of β decay shows that electrons cannot couple according to the scheme. Let $j_\mu{}^A$ be the conserved current in question. The matrix element for the axial vector part of β decay would have the structure

$$M^A = i\bar{u}_e\gamma_\mu\gamma_5(1+\gamma_5)u_\nu\langle p|j_\mu{}^A|n\rangle, \tag{1}$$

where, on general invariance grounds,[4]

$$\langle p|j_\mu{}^A|n\rangle = i\bar{u}_p\{a\gamma_\mu\gamma_5 + ib(p-n)_\mu\gamma_5\}u_n. \tag{2}$$

The coefficients a and b are functions of $(p-n)^2$. Conservation of $j_\mu{}^A$ implies

$$(p-n)_\mu\langle p|j_\mu{}^A|n\rangle = 0; \tag{3}$$

hence

$$b = -2ma/(p-n)^2, \tag{4}$$

where m is the nucleon mass. From (1) and (2) we find, after carrying out reductions, that the matrix element for β decay contains an axial vector term with coefficient $g_A \equiv a$, and a *pseudoscalar* term with $g_P \equiv m_e b$, where m_e is the electron mass. From (4) it follows that

$$g_P/g_A = -2m_e m/(p-n)^2. \tag{5}$$

This ratio is energy dependent but always very large ($\gtrsim 10^3$) and can surely be ruled out experimentally.

Let us now turn to the proposed strangeness-violating currents. Suppose all hyperons have the same parity, taken to be even. Then, as with pion decay, the occurrence of $K\to\mu+\nu$ rules out the idea of a conserved vector (axial vector) current if K is scalar (pseudoscalar). To deal with the alternate possibilities, consider the processes $K\to\pi+\mu+\nu$, $K\to\pi+e+\nu$. Depending on the K-meson parity, the matrix element is

$$M_{PS} = \bar{u}_l\gamma_\mu(1+\gamma_5)u_\nu\langle\pi|j_\mu{}^V|K\rangle, \tag{6}$$

or

$$M_S = \bar{u}_l\gamma_\mu\gamma_5(1+\gamma_5)u_\nu\langle\pi|j_\mu{}^A|K\rangle,$$

where $\bar{u}_l$ (l denoting lepton) is $\bar{u}_e$ or $\bar{u}_\mu$, and, on invariance grounds

$$\langle\pi|j_\mu{}^{V,A}|K\rangle = c(p_K+p_\pi)_\mu + d(p_K-p_\pi)_\mu, \quad (7)$$

where c and d are functions of $(p_K-p_\pi)^2$. The conservation law would imply that

$$(p_K-p_\pi)_\mu\langle\pi|j_\mu{}^{V,A}|K\rangle = 0; \quad (8)$$

hence

$$d = \frac{m_K{}^2 - m_\pi{}^2}{(p_K-p_\pi)^2}c. \quad (9)$$

It is now a simple matter to show that the decay rate ω is given by

$$\omega = \frac{1}{384\pi^3 m_K{}^3}\int_{m_l{}^2}^{(m_K-m_\pi)^2} d\lambda^2\, |c(-\lambda^2)|^2 \times\{[(m_K+m_\pi)^2-\lambda^2][(m_K-m_\pi)^2-\lambda^2]\}^{\frac{3}{2}} \times\left\{2-\frac{3m_l{}^2}{\lambda^2}+\frac{m_l{}^6}{\lambda^6}\right\}, \quad (10)$$

where m_l is the lepton mass (m_e or m_μ). The coefficient c depends on the pion energy through $\lambda^2 = m_K{}^2 + m_\pi{}^2 - 2m_K E_\pi$ (in the K rest system). Although this function is unknown, it is clear that the present scheme implies rigorously $\rho \equiv \omega_{e3}/\omega_{\mu3} > 1$. If one supposes that c is a constant, then $\rho = 2.5$. Experimentally, this ratio appears to be smaller than unity.[5] To the extent that this can be firmly established, one can rule out the scheme of conserved strangeness-violating currents.

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[1] R. P. Feynman and M. Gell-Mann, Phys. Rev. **109**, 193 (1958).
[2] M. Gell-Mann (to be published).
[3] J. C. Taylor, Phys. Rev. **110**, 1216 (1958).
[4] M. Goldberger and S. B. Treiman (to be published).
[5] Alexander, Johnston, and O'Ceallaigh, Nuovo cimento **3**, 478 (1957).

Possible Method of Investigating Gyromagnetic Ratios of Short-Lived Nuclear States with Fast Neutral Beams*

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It is well known that nuclear reactions, e.g., proton capture or Coulomb excitation, produced by a charged particle beam incident on unaligned nuclei, will in general produce a partial alignment of the product nuclei. Thus, for example, any gamma radiation emitted by the product nucleus may have an anisotropic angular distribution with the beam direction as the axis of symmetry. Further, if a magnetic field B is placed perpendicular to the beam direction, the excited product nucleus will precess with the Larmor frequency around the axis of the field with angular frequency

$$\omega_L = g(\mu_N/\hbar)B,$$

where g is the gyromagnetic ratio and μ_N is the nuclear magneton. This assumes that the effect of interatomic fields can be neglected. Thus at decay the axis of symmetry for gamma-ray emission is rotated through an angle

$$\theta = \omega_L t,$$

where t is the time the individual product nucleus spends in the magnetic field.[1] For $t \sim 10^{-10}$ sec and values of the gyromagnetic ratio $g \simeq 1$, a value of B of the order of 300 000 gauss would result in a precession angle of about 10 degrees.

Such high magnetic fields can be obtained by the use of pulsed magnets.[2] However, under these conditions, the deflection of the incident charged particle beam by the fringe field of the magnet would become excessive and obscure the precession effect.

To overcome this difficulty, it is proposed to use a fast atomic hydrogen beam H^0 in the 1–2 Mev range, which will remain undeflected by the fringe field. On entering the target material the atomic hydrogen is immediately stripped. Since the range of the resultant proton beam in the target is of the order 10^{-2} cm, the effect of the field on this portion of the particle trajectory is small. For example, a value of B of 300 000 gauss would turn a 2-Mev proton beam through an angle of 1 degree. The incident beam direction is therefore largely preserved.

We have generated a 1-Mev H^0 beam in the following way. An $H_2{}^+$ beam of 2-Mev energy was disassociated by allowing it to pass through a hydrogen gas stripper, thus producing an H^0 and an H^+ beam. The H^+ beam was swept away by a magnetic field leaving only the H^0 beam. The conversion efficiency for the process at this energy was found to be about 9%. Hence conventional high-voltage accelerators can be used to produce fast atomic hydrogen beams whose intensity is of order 10^{14} particles per second.

It is intended to use such beams in conjunction with pulsed fields of 500 000 gauss to investigate gyromagnetic ratios of states whose lifetime is of order 10^{-9} sec.

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[1] A. Abragam and R. V. Pound, Phys. Rev. **92**, 943 (1953).
[2] H. P. Furth and R. W. Waniek, Rev. Sci. Instr. **27**, 195 (1956).