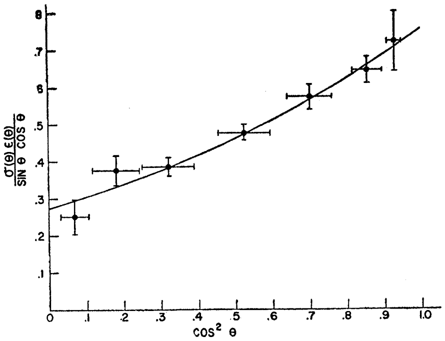

FIG. 2. The data of Fig. 1 are plotted in the form $\epsilon\sigma/\sin\theta\cos\theta$ *versus* $\cos^2\theta$. The equation of the solid line is given in the text.

from the second carbon target. The asymmetry observed was 0.004 ± 0.007 at a scattering angle of 10°.

A measurement has been made of the angular distribution of the asymmetry produced by scattering the polarized beam from liquid hydrogen. The scattered protons were detected with a counter telescope, which, at each angle θ, included a copper absorber of sufficient thickness such that only elastically scattered protons were counted, i.e., no particles accompanying meson production were counted.

Figure 1 shows the observed asymmetries. The polarization in *p-p* scattering can then be obtained from ϵ through the relation $P_H(\theta)=\epsilon(\theta)/(0.45\pm0.05)$. Figure 2 is a plot of $\sigma(\theta)\epsilon(\theta)/\sin\theta\cos\theta$ *vs* $\cos^2\theta$, where θ is the center-of-mass scattering angle, and $\sigma(\theta)$ is the unpolarized scattering cross section normalized to 1 at 90°.[2] If $\sigma(\theta)\epsilon(\theta)/\sin\theta\cos\theta$ is assumed to vary as $\alpha+\beta\cos^2\theta+\gamma\cos^4\theta$ (only ^3P and ^3F states contributing), a least squares fit to the observed values yields the solid line of Fig. 2.

The equation of this line gives

$$\sigma(\theta)P_H(\theta)=\frac{\sigma(\theta)\epsilon(\theta)}{(0.45\pm0.05)}$$
$$=K\sin\theta\cos\theta(1+b\cos^2\theta+c\cos^4\theta),$$

with $K=0.62\pm0.14$, $b=1.0\pm0.7$, $c=0.63\pm0.77$, where b and c are connected by the relation $c=1.6\pm0.3-0.98b$.

This contrasts with results at about 320 Mev[3,4] which seem to require considerably different values[5] for the coefficients of $\cos^2\theta$ and $\cos^4\theta$. Furthermore, our data agree with Chicago results[6] at 439 Mev within the somewhat larger statistical errors of the latter.

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† To be submitted by J. A. Kane in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Carnegie Institute of Technology.
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Mesonic Corrections to the Beta-Decay Coupling Constants

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RECENT analysis of the *ft* values in superallowed beta transitions have indicated that the Fermi and Gamow-Teller coupling constants (g_F and g_{GT}) are of approximately the same absolute magnitude.[1–5] Nevertheless, as several authors have pointed out,[6,7] the experimental data now require one to conclude that g_{GT}^2 is slightly larger than g_F^2. It is the purpose of this letter to suggest that such a difference may not be a property of the fundamental beta interaction itself, but that it is, at least partially, a consequence of certain radiative effects, involving primarily the emission and reabsorption of a π^0 meson.

The recently determined accurate *ft* values for O^{14} (3275 ± 75)[8] and Cl^{34} (3220 ± 200)[9,10] (which are almost certainly $0\rightarrow0$ transitions with $|\int 1|^2=2$, $|\int\boldsymbol{\sigma}|^2=0$, assuming only charge independence), provide a direct determination of g_F. In the notation of Gerhart[8] we have

$$[|\int 1|^2+R|\int\boldsymbol{\sigma}|^2]\times ft=6550\pm150\text{ sec},\qquad(1)$$

where $R=g_{GT}^2/g_F^2$.

For transitions between ground states of mirror nuclei which have closed shells of 0, 2, 8, 20 protons and neutrons ± one nucleon, the single-particle estimates[11] $|\int\boldsymbol{\sigma}|_{\text{S.P.}}^2$ for the G-T matrix elements should be reasonably good. We have used the four known mirror transitions of this kind for which the *ft* values are known fairly accurately[12] to attempt an approximate determination of the ratio R.[13] The results are shown in Table

TABLE I. Values of g_{GT}^2/g_F^2 deduced from beta transitions between nuclei with closed shells of protons and neutrons ±1 nucleon.

Transition	ft[a]	$\|\int 1\|^2$	$\|\int\sigma\|_{\text{S.P.}}^2$	$R=g_{GT}^2/g_F^2$[b]
n^1-H^1	1280 ± 250	1	3	$1.37^{+0.4}_{-0.3}$
H^3-He^3	1014 ± 20	1	3	1.82 ± 0.1
$O^{15}-N^{15}$	3950 ± 200	1	0.33	1.97 ± 0.4
$F^{17}-O^{17}$	2320 ± 100	1	1.4	1.30 ± 0.15

[a] See reference 12.
[b] See reference 13.

I. These ratios are always larger than one. However, because of fluctuations, possibly associated with cooperative effects or experimental uncertainties, it is difficult to interpret them precisely. In order to make a rough comparison with theory, we might choose the arithmetic mean of the above ratios, namely 1.6. For other transitions in which the Gamow-Teller interaction participates, e.g., He^6, N^{13}, Ne^{19}, etc., the value of $|\int\boldsymbol{\sigma}|^2$ and thus the value of R as deduced from Eq. (1) depend sensitively on details of nuclear structure.

One should of course expect mesonic corrections to beta processes as well as to electromagnetic interactions; in fact the effect which alters R may be regarded as more elementary than the corresponding anomalies in the magnetic moment, since the virtual mesons do not interact. The lowest-order process involving a single π^0 is shown in Fig. 1. One might expect Chew's[14] approximate formulation of meson theory, involving a cutoff and renormalization, to apply perhaps about as well here as it does to the magnetic moment problem. According to this procedure the modified amplitude for beta decay is

$$(P\nu e|\Gamma|N)' = (P\nu e|\Gamma|N) + \sum_{\pi^0}[(P|V|P'\pi^0) \times (P\nu e|\Gamma|N')(N'\pi^0|V|N)]/(\epsilon_{\pi^0})^2, \quad (2)$$

where

$$(N'|V|N'\pi^0) = -(P|V|P'\pi^0) = (4\pi)^{\frac{1}{2}}(f/\mu)(2\epsilon)^{-\frac{1}{2}}(i\boldsymbol{\sigma}\cdot\mathbf{k}).$$

A straightforward calculation gives

$$\frac{(P\nu e|\Gamma|N)'}{(P\nu e|\Gamma|N)} = \begin{cases} 1-3\delta & \text{for allowed Fermi transitions,} \\ 1+\delta & \text{for allowed Gamow-Teller transitions,} \end{cases} \quad (3)$$

where

$$\delta = (f^2/3\pi)\int_0^{x_{\max}} x^4(1+x^2)^{-\frac{3}{2}}dx$$

and $R^{\frac{1}{2}} = |g_{GT}/g_F| = 1+4\delta$ to the second order in the coupling constant. To take all second-order processes into account one ought to add contributions from diagrams corresponding to wave function renormalization, but to the first order in δ these do not change $R^{\frac{1}{2}}$. More detailed calculations are planned. Using Chew's renormalized coupling constant and cutoff,[15] $f^2=0.058$ and $x_{\max}=5.51$, one obtains $\delta=0.079$ and $R_{\text{th}}^{\frac{1}{2}}=1.32$. The "mean" experimental $R^{\frac{1}{2}}$ is 1.25. In view of the experimental uncertainties and the crudeness of the theoretical estimate, this kind of agreement must be regarded as accidental. Of course, the above estimate refers to the free neutron and ignores cooperative effects such as exchange corrections, which may be significant in H^3, and quenching[16] which may become important in heavy nuclei. The existence of this mesonic perturbation of the correct sign and approximately right magnitude makes it possible to assume that the unperturbed Gamow-Teller and Fermi coefficients are exactly equal, in accordance with various hypotheses about the universal Fermi interaction.[17] We note also

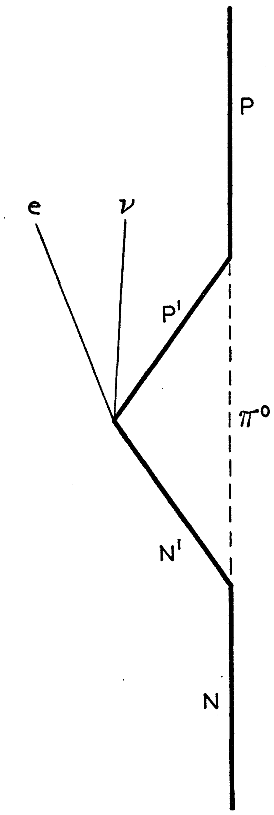

FIG. 1. Lowest-order mesonic correction to beta decay.

that this correction is present to the *same* extent in muon capture, but absent in muon decay; the effective Fermi constant for the μ decay should, for this reason, be slightly different from its value for μ capture and N decay. For example, if $R=1.6$, then the quantity[17,18] λ is changed from 1.2 to 1.0.

We would like to thank Professor N. Kroll, Professor M. Ruderman, and Professor R. Sherr for several illuminating discussions and Dr. J. B. Gerhart for informing us of his results before publication.

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Antiproton Production

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RECENTLY a few Letters have appeared[1] which discuss the cross sections for antiproton production in nucleon-nucleon collisions, at energies which will soon be available at Berkeley. We should like to point out that there may be a more profitable way of producing antiprotons, by first producing a very energetic π meson which in turn produces an antiproton in colliding with a nucleon.

The reaction

$$p+N\rightarrow p+N+p+\bar{p}, \qquad (1)$$

where N is a nucleon, has a threshold of $6Mc^2$ (5.6 Bev) for the incident proton. However, if we consider the two-step reaction,

$$\begin{aligned} p+N&\rightarrow N+N+\pi, \quad \text{(a)} \\ \pi+N&\rightarrow N+p+\bar{p}, \quad \text{(b)} \end{aligned} \qquad (2)$$

the threshold for this double reaction, if we use the most energetic π produced in (a), is about 4.4 Mc^2 (4.1 Bev) for the incident proton in (a).

For the following reasons, then, we think that the reaction (2) may be more useful at Berkeley energies:

(i) If the N in (1) is a proton, the cross section is very small near threshold, since there are 3 final protons, one of which must be in at least a p-state.

(ii) For a given proton energy, say $\sim 7Mc^2$, reaction (2) will be a good deal above threshold, whereas (1) will not. Also in (b) of (2) there are only *three* final particles and thus the density-of-states factor will be considerably more favorable than for (1). The problem is then to produce the high-energy π mesons.

We can give a rough estimate for the cross sections for (1) and for (2b). We assume that we have protons of K.E.$\sim 7Mc^2$. Then we estimate the cross section for (1). The total energy in the c.m. system is about 4.24 Mc^2 and so the kinetic energy to be divided among the four final particles is 0.24 Mc^2. We estimate the matrix element crudely by conserving momentum at each vertex in Fig. 1 and putting in a factor $g/(2\omega)^{\frac{1}{2}}$ for each vertex, where g is the coupling constant and ω the meson energy. We can rearrange the vertices in 4! ways; we get $\frac{3}{2}g^4$ for

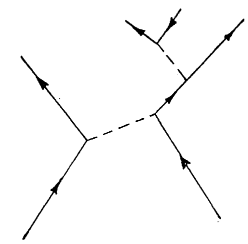

Fig. 1. Feynman diagram of reaction (1).

the matrix element. Combining this result with the density-of-final-states factor, we get

$$\sigma_{pN}\approx 0.54(g^2/4\pi)^4(T_1/M)^{7/2}\text{ mb},$$

where T_1 is the kinetic energy available in the c.m. system. In this example, $T_1\approx 0.24Mc^2$.

Now a proton of $7Mc^2$ could produce a meson of $6Mc^2$. The energy available in the c.m. system of (2b) is about $3.65Mc^2$ and thus the kinetic energy available is about $0.65Mc^2$. Using the same type of estimate for the matrix element as above, we get

$$\sigma_{\pi N}\approx 22(g^2/4\pi)^3(T_2/M)^2\text{ mb}.$$

This gives

$$\frac{\sigma_{\pi N}}{\sigma_{pN}}\approx\frac{2000}{g^2/4\pi},$$

which is at least 200 if $g^2/4\pi\approx 10$. ($g^2/4\pi$ is quite likely smaller than 10.) Thus it seems that if more than about 0.1 percent of the protons can produce high-energy mesons, reaction (2) would be better.

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Modified Nucleon Propagators*

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THE need for nonperturbation methods in meson theory has been increasingly felt in recent years. There are, however, several difficulties associated with them, one of which has been recently pointed out by Feldman.[1] He has found that a new (nonrenormalizable) type of divergence appears when one uses modified

Fig. 1. Kernels for self-energy graphs.