stant over the range of energies used in the experiment. Hence, the cross section for absorption is

$$\sigma(E)=\frac{\sigma_R}{[2(E-E_R')/\Gamma_a]^2+1},$$

where E_R' is equal to $E_0+(E_0^2/2Mc^2)$. The second term in this expression represents the energy of recoil in the absorption. The width Γ_a is here distinguished from the intrinsic width because of the Doppler broadening due to the thermal motion of the nuclei in the absorber.[6]

The intensity of the radiation transmitted through the absorber is given by

$$I(\theta)=\int_0^\infty N(E,\theta)e^{-\rho\sigma(E)}dE,$$

where ρ is the number of nuclei per unit area of the absorber. The transmitted intensity has a minimum when E_R is equal to E_R', i.e., when $\cos\theta_R=p_\gamma/p$, where p_γ and p are the momenta of the gamma ray and the radiating nucleus, respectively. With $E_p=1.76$ and $E_\gamma=9.18$ Mev, it follows that $\theta_R=80.8°$.

The function $I(\theta)$ is plotted in Fig. 1 for various values of the parameter Γ. Each curve is normalized to pass through the point of maximum absorption. For the data taken with $\Delta\theta=0.6°$, good agreement is obtained with $\Gamma=0.4$ kev. The Doppler broadening in the absorption process may now be neglected since it is less than 0.1 of this width. After correcting for the width of the slit, we obtain $\Gamma=(0.35\pm0.1)$ kev. This value confirms the recent result of Marion and Hagedorn[7] that $\Gamma<0.4$ kev. The depth of the valley in the plotted curves for $\Delta\theta=0.6°$ corresponds to a cross section $\sigma_R=(0.79\pm0.10)$ barn at resonance for the absorption $N^{14}+\gamma\rightarrow N^{14*}$. This value of the cross section leads to $(2I+1)\Gamma_\gamma=29$ ev, where I is the spin of the excited state and Γ_γ is the partial width for the emission of the 9.18-Mev radiation. With this value of $(2I+1)\Gamma_\gamma$, we obtain a cross section $\sigma_R(p,\gamma)=33$ mb at resonance for the capture process. If this result is increased by 10% to include transitions to the excited state at 6.44 Mev, it may be compared with the result $\sigma_R(p,\gamma)>64$ mb given by Marion and Hagedorn as computed from the measurements of Seagrave.[8]

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General Partial Wave Analysis of the Decay of a Hyperon of Spin $\frac{1}{2}$

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THIS note is to consider the general problem of the decay of a hyperon of spin $\frac{1}{2}$ into a pion and a nucleon under the general assumption of possible violations of parity conservation, charge-conjugation invariance, and time-reversal invariance. The discussion is in essence a partial wave analysis of the decay phenomena and is independent of the dynamics of the decay. *Nonrelativistic approximations are not made on either of the decay products.*

In the reference system in which the hyperon is at rest there are two possible final states of the pion-nucleon system: $s_{\frac{1}{2}}$ and $p_{\frac{1}{2}}$. Denoting the amplitudes of these two states by A and B, one observes that the decay is physically characterized by *three* real constants specifying the magnitudes and the relative phase between these amplitudes. One of these constants can be taken to be $|A|^2+|B|^2$, and is evidently proportional to the decay probability per unit time. The other two constants are best defined in terms of experimentally measurable quantities. We discuss three types of experiments:

(a) The angular distribution of the decay pion from a completely polarized hyperon at rest.

It has been pointed out before[1] that the distribution is proportional to

$$[1+\alpha\cos\chi]d\Omega, \tag{1}$$

where $d\Omega$ is the solid angle of the pion momentum vector $\mathbf{p}_\pi$ and χ is the angle between $\mathbf{p}_\pi$ and the spin of the hyperon. The constant α is given by

$$\alpha=2\,\mathrm{Re}(A^*B)/(|A|^2+|B|^2), \tag{2}$$

and characterizes the degree of mixing of parities in the decay.

That the distribution is of the form (1) follows immediately from the assumption that the spin of the hyperon is $\frac{1}{2}$. One easily proves (2) by considering the decay probabilities for the cases $\chi=0$ and $\chi=\pi$. In the former case the amplitude of decay is $(A+B)$ and in the latter $(A-B)$. One therefore obtains $(1+\alpha)/(1-\alpha)=|A+B|^2/|A-B|^2$, which results in (2).

Recent experiments[2] have indicated that the absolute value of α is quite large for Λ^0 decay. With improved statistics these experiments can establish beyond doubt that parity nonconservation is not peculiar to neutrino processes. It is, however, not possible to determine the sign of the parameter α through the experiments quoted above, as the sign of the polarization of the Λ^0 in the production process is unknown. Further, it appears that these experiments cannot give an accurate measurement of the magnitude of α because of the difficulty in determining the degree of polarization of the Λ^0 produced. Another method of measuring α which does not depend on the degree and sign of a polarized hyperon beam is found in the following type of experiment:

(b) The longitudinal polarization of the nucleon emitted in the decay of unpolarized hyperons at rest.

The degree of longitudinal polarization (i.e., average spin along the direction of motion divided by $\frac{1}{2}\hbar$) is easily shown to be $-\alpha$. To see this, we consider the decay of a hyperon at rest, with spin$=+\frac{1}{2}\hbar$ along the $+z$ axis, into a nucleon traveling along the $+z$ axis and a meson along the $-z$ axis; and then the decay of a hyperon, with spin$=-\frac{1}{2}\hbar$ along the $+z$ axis, into the same final states. An incoherent mixture of the two cases gives a description of the decay of unpolarized hyperons. By the conservation of the z component of angular momentum the spin of the nucleon is respectively equal to $+\frac{1}{2}\hbar$ and $-\frac{1}{2}\hbar$ for the two cases. Furthermore the two cases correspond to the experiment discussed under (a) for $\chi=\pi$ and $\chi=0$, respectively. The probabilities for the two cases are, according to previous discussions, proportional to $|A-B|^2$ and $|A+B|^2$. The incoherent mixture of the two cases therefore gives a longitudinal polarization for the nucleon equal to

$$(|A-B|^2-|A+B|^2)/(|A-B|^2+|A+B|^2)=-\alpha.$$

It is well known[3] that the scattering of high-energy protons by nuclei offers a good method of analyzing the polarization of high-energy protons as well as determinating the sign of the polarization. A measurement of the parameter α, together with its sign, through such methods may not be impossible. We remark that once the value of α is determined, the experiments of type (a) could be used to determine the degree and sign of the polarization of the hyperons.

(c) Transverse polarization of the nucleon emitted in a given direction in the decay of a polarized hyperon.

The remaining parameter describing the decay process can be determined only through a measurement of the transverse polarization of the nucleon emitted from a polarized hyperon decaying at rest. Let $\frac{1}{2}\hbar\hat{s}$ be the spin of the hyperon, where $\hat{s}$ is a unit vector. The probability for the emission of a nucleon in the direction $\hat{p}$ (=unit vector) is, according to (1), proportional to $1+\alpha\cos\chi$, where $\cos\chi\equiv-\hat{p}\cdot\hat{s}$. The spin of the nucleon in its own rest system can be shown to be $\frac{1}{2}\hbar$ times the unit vector

$$(1+\alpha\cos\chi)^{-1}[(-\alpha-\cos\chi)\hat{p}+\beta\hat{p}\times\hat{s}+\gamma(\hat{p}\times\hat{s})\times\hat{p}], \quad (3)$$

where

$$\beta=-\mathrm{Im}(A^*B)/(|A|^2+|B|^2), \quad (4)$$

$$\gamma=(|A|^2-|B|^2)/(|A|^2+|B|^2). \quad (5)$$

The three parameters α, β, and γ are related through the identity

$$\alpha^2+\beta^2+\gamma^2=1. \quad (6)$$

One could therefore write also

$$\beta=(1-\alpha^2)^{\frac{1}{2}}\cos\phi, \quad \gamma=(1-\alpha^2)^{\frac{1}{2}}\sin\phi. \quad (7)$$

The geometrical description of the polarization vector (3) is quite simple. It is a unit vector, in agreement with the fact that the nucleon moving in a given direction $\hat{p}$ is in a pure state. Its longitudinal component (i.e., projection along $\hat{p}$) has the value

$$(-\alpha-\cos\chi)/(1+\alpha\cos\chi). \quad (8)$$

Its transverse component has the polar angle ϕ in the plane determined by $\hat{p}\times\hat{s}$ and $(\hat{p}\times\hat{s})\times\hat{p}$ if one chooses the former vector to be along the $+x$ axis and the latter along the $+y$ axis.

The two parameters α and ϕ together with the decay probability determine completely the kinematical aspects of the decay of the hyperon. One easily verifies from (7), (4), (5), and (2) that knowing α and ϕ one can compute A and B up to a common multiplicative factor.

The ranges of the parameters α and ϕ are given by

$$-1\leqq\alpha\leqq1, \quad -\pi\leqq\phi<\pi. \quad (9)$$

The sign of ϕ has a physical meaning: positive values of ϕ imply positive values for γ, and consequently a preponderance of $s_{\frac{1}{2}}$ over $p_{\frac{1}{2}}$ in the final states. Negative values of ϕ imply the reverse situation. Geometrically, a positive ϕ implies an acute angle between the transverse polarization and the spin of the hyperon, therefore a preference for non-spin-flip decays, i.e., a preference for $s_{\frac{1}{2}}$ final states.

Additional requirements are imposed on the parameters if time-reversal invariance is assumed to hold. For Λ^0 decay the conclusion[1] is essentially that A and B are real, relative to each other, implying that $\beta\cong0$, or in other words $\phi\cong\pm\frac{1}{2}\pi$. A measurement of ϕ in Λ^0 decay therefore gives a test of time-reversal invariance in Λ^0 decay.

In the case of a hyperon decay with two final channels, such as $\Lambda^0\rightarrow p+\pi^-$ and $\Lambda^0\rightarrow n+\pi^0$, there would appear six parameters describing the transition, three for each channel. In principle there exists another real parameter which describes the relative phase of the transition amplitudes into the two channels. Such a parameter is, however, extremely hard to measure experimentally, and is at present only of academic interest. If the Λ^0 decay interaction is invariant under time reversal, then the number of real parameters is reduced from seven to four.

We conclude with the remark that the large asymmetry observed in the experiments of reference 2 shows that the production process $\pi^-+p\rightarrow\Lambda^0+K^0$ is a surprisingly good polarizer of Λ^0 spin, and that the decay $\Lambda^0\rightarrow\pi^-+p$ is a good convenient analyzer. These facts open the way to a possible measurement[4] of the magnitude and the *sign* of the gyromagnetic ratio of Λ^0 which does not seem completely hopeless. For example, in a magnetic field of 200 000 gauss, the spin of Λ^0 would precess through an angle of 33° in 3×10^{-10} sec if its magnetic moment is one nuclear Bohr magneton.

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[3] See, e.g., the review article by L. Wolfenstein, *Annual Review of Nuclear Science* (Annual Reviews, Inc., Stanford, 1956), Vol. 6, p. 43.

[4] It has been pointed out before that the magnetic moment of a hyperon may be measured by using the angular asymmetries in the hyperon decay as an analyzer. M. Goldhaber, Phys. Rev. **101**, 1828 (1956).

Errata

Meson Production by Mesons, SAUL BARSHAY [Phys. Rev. **103**, 1102 (1956)]. In Eq. (9),

$$\exp[i(-\mathbf{k}_1-\mathbf{p}_n-\mathbf{p}_m)\cdot\mathbf{y}]$$

should read:

$$\exp[i(-\mathbf{k}_1-\mathbf{p}_n+\mathbf{p}_m)\cdot\mathbf{y}].$$

In Eq. (21), $\cos2(\theta_1-\theta_2)$ should read: $\cos2(\phi_1-\phi_2)$. In comparing Table I with experiment it would be best (in view of the static model of the nucleon used here) to take the energies given under the heading "Incident-meson kinetic energy" as total available kinetic energies in the pion-nucleon center-of-mass system. The cross sections given are then somewhat larger in magnitude than those given in the work of Franklin[1] on this subject. Large production cross sections near threshold have been found in recent important measurements in the U.S.S.R.[2]

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[2] V. G. Zinov and S. M. Korentchenko, "Pion Production by π^--p Collisions near Threshold," preprint, Joint Institute of Nuclear Research, U.S.S.R.

Associated Production of Hyperons and *K* Mesons, SAUL BARSHAY [Phys. Rev. **104**, 853 (1956)]. In the sigma-sigma-π-meson interaction, the matrices denoted by τ_α are the three-by-three isotopic spin matrices. In Fig. 1(d), the intermediate state baryon should be labeled Σ^0.

Interaction of 0.5- and 1.0-Mev Neutrons with Some Heavy Elements, R. C. ALLEN, R. B. WALTON, R. B. PERKINS, R. A. OLSON, AND R. F. TASCHEK [Phys. Rev. **104**, 731 (1956)]. 0.2 barn per steradian should be subtracted from the ordinate scale of the U^{235} curve in Fig. 3.

Analysis of the $B^{11}(d,n)C^{12}$ Reaction by Nuclear Stripping, GEORGE E. OWEN AND L. MADANSKY [Phys. Rev. **105**, 1766 (1957)]. The equation defining $\mathbf{r}$ which follows Eq. (10) should read: $\mathbf{r}=\mathbf{r}_{n(1)}-\mathbf{r}_{p(1)}$.

Equation (17) should have a phase $(+i)$ instead of $(-i)$. It should read:

$$f_D(k_1R_1)=(+i)2(3\pi)^{\frac{1}{2}}(-V_1)\Gamma_1(R_1)j_1(k_1R_1).$$

The definition of $\mathbf{K}_2$ [preceding Eq. (20)], the relative wave vector of the heavy-particle neutron, is in a direction opposite to that physically required. The proper definition of $\mathbf{K}_2$ is

$$\mathbf{K}_2=\mathbf{k}_n+\frac{M_n}{M_B}\mathbf{k}_D.$$

This correction changes the phase of $G_H(K_2)$, Eqs. (22) and (24), from $(+i)$ to $(-i)$.

With these sign changes the discussion of the phases on page 1771 will read as follows: "The sign of the interference term depends upon the phase of h_D and h_H. Equations (16) and (17) show that the phase of $G_D(K_1)f_D(k_1R_1)$ is $(+i)$. Equations (24) and (25) show that the phase of $G_H(K_2)f_H(k_2R_2)$ is $(-i)$. Therefore the sign of the interference term is positive."

Incorporation of these corrections does not alter in any way the conclusions of the derivation.

Field Effect in Germanium at High Frequencies, H. C. MONTGOMERY [Phys. Rev. **106**, 441 (1957)]. The field effect mobility appropriate to Fig. 5(c) is $\mu_p-\mu_n'+\mu_n+\alpha_1\mu_n'$ and not $\mu_p+\alpha_1\mu_n'$ as stated. Hence, the difference between low- and high-frequency field effect mobility does not contain the Schrieffer correction, and a determination as discussed in the second paragraph on p. 445 is not only impractical, as stated, but is not possible in principle from small signal measurements. The author is indebted to Dr. Ichiro Nakada for pointing this out.

Angular Distribution of Protons from the $Ca^{42}(d,p)$-Ca^{43} Reaction, C. K. BOCKELMAN, C. M. BRAAMS, C. P. BROWNE, W. W. BUECHNER, R. R. SHARP, AND A. SPERDUTO [Phys. Rev. **107**, 176 (1957)]. On p. 180, line 9, "it is seen that a large value of $R=7.5\times10^{-13}$ cm is needed to fit the theoretical maximum of Fig. 5 to the experimental maximum from β-decay evidence" should read: "it is seen that a large value of $r=7.5\times10^{-13}$ cm is needed to fit the theoretical maximum of Fig. 5 to the experimental maximum. The third excited state at 0.991 Mev is believed to be a $\frac{3}{2}^+$ state from β-decay evidence."

Approximate Wave Functions for the *M*-Center by the Point-Ion Lattice Method, BARRY S. GOURARY AND PERRY J. LUKE [Phys. Rev. **107**, 960 (1957)]. In footnote 5 of this paper, we wrote: "Professor Inui has kindly checked his calculations and finds that because of the values of the interionic distance