culation was made for semiconductors, whereas our result is for a metal, so that a quantitative comparison is hardly possible. Nevertheless the existence of a resistivity maximum in the region of the magnetic transition of metals confirms the theory and the deductions made from our previous work about the effect of disorder of the magnetic moment on the electrical resistivity of ferromagnets at low temperatures.

[1] E. I. Kondorskiĭ, O. S. Galkina, and L. A. Chernikova, JETP **34**, 1070 (1958), Soviet Phys. JETP **7**, 741 (1958).

[2] M. A. Krivoglaz and S. A. Rybak, J. Tech. Phys. (U.S.S.R.) **28**, 940 (1958), Soviet Phys.-Tech. Phys. **3**, 876 (1958).

Translated by R. Berman
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POSSIBILITY OF AN EXPERIMENTAL TEST FOR FORM FACTORS IN THE THEORY OF THE UNIVERSAL FERMI INTERACTION

HE TSO-HSIU

Joint Institute for Nuclear Research

Submitted to JETP editor October 28, 1959

J. Exptl. Theorêt. Phys. (U.S.S.R.) **38**, 648-650 (February, 1960)

THERE is great interest at present in a test of the form factors in the theory of the weak interaction. These form factors are commonly expressed by "weak magnetism" terms and by pseudoscalar interaction terms.[1] Unfortunately, however, this effect is small in beta decay, is difficult to examine, and up to now has not been observed.[2] In the present note we calculate the process of μ capture by spin-$\frac{1}{2}$ nuclei without emission of neutrons and protons, supposing that after the capture the nucleus makes a transition from the spin-$\frac{1}{2}$ state to the spin-$\frac{3}{2}$ state. The density matrix of the initial state has the form[3]

$$\frac{1}{4}(1 + \sigma_p \xi_p + \sigma_\mu \xi_\mu + \varepsilon \sigma_p \sigma_\mu), \quad (1)$$

ξ_p and ξ_μ are the polarizations of the nucleus and the muon; they are equal to each other for the triplet state and equal to zero for the singlet state; $\epsilon = \frac{1}{3}$ for the triplet state and $\epsilon = -1$ for the singlet state. The density matrix can also be written in an analytic form for a mixed state. Here ϵ takes on values between -1 and $\frac{1}{3}$ and characterizes the distribution of muons between the singlet and triplet states. We will take as the nuclear matrix element that of Chou Kuang-Chao and Maevskiĭ.[4] We neglect the momenta of the proton and muon in the initial state. After calculation we get the probability for the transition of the nucleus from spin-$\frac{1}{2}$ to spin-$\frac{3}{2}$ in the form

$$W = (G^2 Z^3 / 2\pi^2 a_\mu^3) N_0 |M_{G.T.}|^2 q^2 (1 - q/Am_p),$$

$$N_0 = (1+\varepsilon)\left[\lambda^2 + \frac{\lambda\beta}{3}(2\mu + 2 - f + \lambda) - \frac{\beta^2}{12}(\mu + 1)(2f - 2\lambda - \mu + 1)\right] + \frac{\beta^2}{12}(\mu + f + 1 - \lambda)^2. \quad (2)$$

Here G is the Fermi constant; a_μ is the muon Bohr-orbit radius; q is the neutrino energy, λ is the ratio of the Gamow-Teller and Fermi constants, equal to 1.25 for beta decay; μ is the anomalous gyromagnetic ratio which characterizes "weak magnetism" and is equal to 3.7; f is the pseudoscalar coupling constant, equal to about 8λ for muon capture by protons; $\beta = q/m_p$; A is the atomic number; $|M_{GT}|^2$ is the square of the matrix element for Gamow-Teller transitions, which, as Ioffe showed,[5] is equal to

$$|M_{GT}|^2 = |M_{GT}^\beta|^2 (1 - \tfrac{1}{3} q^2 \langle r^2 \rangle_A), \quad (3)$$

where M_{GT}^β is the matrix element for the corresponding beta decay, $\langle r^2 \rangle_A$ is the mean square charge radius, corresponding to the axial vector transition and equal to the square of the radius obtained from the transition of nuclei related to a single isotopic multiplet.

We see from (2) that if the muon is captured by a nucleus in the singlet state, that is, $\epsilon = -1$, and if the process is considered without form factors, then $\mu = f = 0$ and $\lambda = 1$, and this process is completely forbidden in our approximation. But if a form factor exists, then this transition is possible and its probability is on the order of $\frac{1}{8}$ of the ordinary transition. In such a way, an experiment on capture in the singlet state can serve as a criterion for the presence of form factors.

The result obtained is connected with the fact that in the transition considered the neutrino is always in the $J = \frac{1}{2}$ state if the muon and nucleus are in the singlet state, and conservation of angular momentum completely forbids this process, except when the neutrino carries away orbital momentum. As is well known, a form factor is always tied up with $l = 0$. Therefore, if the number of neutrinos with $J = \frac{1}{2}$ is small, the contribution from the form factors is comparable to that from other terms which we neglect. An analogous situation exists in nuclei with spin greater than $\frac{1}{2}$.

It is well known that for μ capture from a singlet state in a metal, a muon which is in a higher state in the hyperfine structure has a large probability of making a transition into a lower state and giving its energy to a conduction electron.[6] For example, the probability of such a transition in Al is $\sim 10^6$ sec^{-1}. Thus for light nuclei we can test for the presence of a form factor by comparing the transition probabilities in metals and nonmetals. The muons in nonmetals are distributed statistically among the hyperfine state levels (if there is not some other kind of transition mechanism). In addition, a muon in a higher hyperfine state can also make a magnetic dipole transition to a lower state. It is known[7] that the probability of this transition varies as Z^{*q}, where Z^* is the effective charge. Thus for nuclei heavy enough to have an effective charge greater than 35, almost all the muons at a high hyperfine level make the transition to a lower state. Of course, a strong magnetic field would effect the magnetic dipole transition, and we could change the distribution of muons among the states of the hyperfine distribution.

The authors express their gratitude to Ya. A. Smorodinskiĭ for his interest in the work and his examination of the results, and also to Chou Huang-Yuan, Chou Kuang-Chao, A. E. Ignatenko, and I. S. Shapiro for useful comments and advice.

[1] Ya. A. Smorodinskiĭ, Usp. Fiz. Nauk **48**, 653 (1959).

[2] A. I. Alikhanov, Report at the Kiev Conference on High Energy Physics, 1959 (preprint).

[3] I. M. Shmushkevitch, Nuclear Phys. **11**, 419 (1959).

[4] Chou Kuang-Chao and V. Maevskiĭ, Acta Physica Sinica **15**, 377 (1959).

[5] B. L. Ioffe, JETP **37**, 159 (1959), Soviet Phys. JETP **10**, 113 (1960).

[6] V. L. Telegi, Phys. Rev. Letters **3**, 59 (1959).

[7] H. Primakoff, Revs. Modern Phys. **31**, 803 (1959).

Translated by W. Ramsay
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MOMENTUM DISTRIBUTION OF PARTICLES PRODUCED IN INELASTIC N-N COLLISIONS AT E = 9 Bev

V. S. BARASHENKOV, WANG PEI, and V. M. MAL'TSEV

Joint Institute for Nuclear Research

Submitted to JETP editor November 13, 1959

J. Exptl. Theoret. Phys. (U.S.S.R.) **38**, 650-652 (February, 1960)

FIGURES 1 and 2 show theoretical and experimental momentum spectra of particles of different kinds, produced in inelastic collisions between nucleons (in the center-of-mass system of the colliding nucleons). The theoretical spectra are calculated with the statistical theory,[1] while the experimental results are taken from reference 2. Statistical measurement errors are indicated.

The table lists the values of the average momenta of the nucleons and pions, $\bar{p}$, calculated from the data of Figs. 1 and 2. The experimental values of $\bar{p}$ for the laboratory system of coordinates were obtained by the Lorentz transformation from the mass system under the assumption that in the p-p collisions the angular distributions of

	Pions		Protons	
	Experiment	Theory	Experiment	Theory
$\bar{p}_{l.s.}$, Bev/c	1.0±0.2	1.46	3.6±0.5	2.9
$\bar{p}_{c.m.s.}$, Bev/c	0.40±0.1	0.57	1.24±0.25	0.79

the pions and nucleons in the center-of-mass system are symmetrical with respect to the angle $\theta = \pi/2$. (This assumption agrees with the theoretical and experimental results obtained in references 3 and 4.) The values obtained are close to the values of $\bar{p}$ obtained in reference 5 from an analysis of the interaction between protons and photoemulsion nuclei, $\bar{p} \approx p_{sp} = (3.0 \pm 0.5)$ Bev/c for protons and $p \approx p_{s\pi} = (1.0 \pm 0.2)$ Bev/c for pions (p_{sp} is the momentum of fast protons, $p_{s\pi}$ is the momentum of fast pions).

It is seen from the table and from the diagrams that the experimental momentum spectra of the nucleons are harder and the spectra of the pions are softer than those calculated theoretically. Accordingly, the theoretical energy losses to the production of new particles in one act of inelastic p-p interaction, ΔE, is equal to $\sim 58\%$ of the primary-nucleon energy (of which approximately 50% is consumed for the production of pions and approxi-