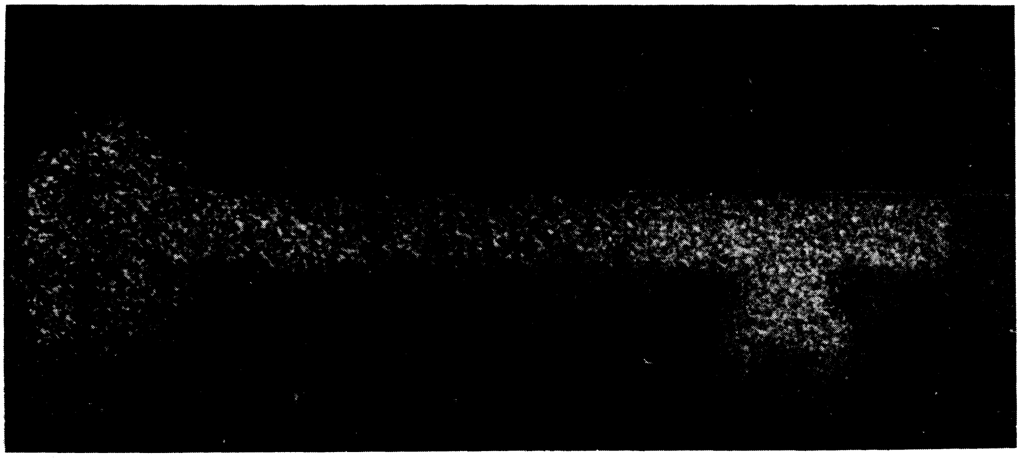

FIG. 3. Image of a key placed 20 cm in front of the chamber, with the chamber exposed through the glass window. The tube operated at 50 kv and 10 ma. The actual exposure was less than the sensitivity time of the chamber (on the order of a millisecond).

sensitivity of such systems to penetrating radiations. Actually, the production of ionizing particles in a liquid under the influence of a penetrating beam has a high probability because of the large density of the liquid, where the ionizing particles form bubbling centers which generate visible bubbles measuring from 1 micron to a fraction of a millimeter, depending on their growth time prior to the illumination flash. The intense scattering of light by such bubbles, the density of which depends on the local intensity of the penetrating beam passing through the object, produces an image of the object in reflected or transmitted light.

By varying the intensity of bubbling of the liquid and the time of illumination, it is possible to vary the sharpness of the image over a wide range. Image distortion due to the ionizing-particle track lengths can be made negligibly small at quantum energies up to several hundreds kev and neutron energies up to several Mev, owing to the smallness of the transverse projections of the paths of the secondary electrons and the recoil protons.

The use of a high-speed cyclic bubble chamber (see, for example, reference 1) makes possible either high-speed intermittent or continuous visual examination of objects. (When the cycle frequency exceeds 10 cps, the eye perceives a continuous image).

We have obtained the first test photographs of a key (see Fig. 3), using the same bubble chamber at 50 kv and 10 ma (the actual exposure time is less than the sensitivity time of the chamber, which is on the order of several milliseconds).

In spite of the very inconvenient conditions (great thickness of the chamber and of the glass, poor geometry, and large distance to the object because the key was placed outside the case in which the chamber and the illuminating lamps were installed), even the first photographs yielded relatively satisfactory image contrast. It is interesting to note that both negative and positive shadow images can be obtained, depending on the placement of the illuminating lamps and the degree of intensity of the scattering.

In conclusion, we consider it our pleasant duty to thank Yu. I. Skanavi and A. I. Demeshina for graciously permitting us to use the x-ray apparatus, and also thank K. V. Filippova, V. N. Mikhalenko, and A. F. Nalgranyan for useful advice.

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CAPTURE OF POLARIZED μ^- MESONS BY DEUTERONS

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THE capture of polarized μ^- mesons in deuterium has been investigated theoretically by Überall and Wolfenstein.[1] However, it is assumed in their work that the polarized μ^- meson is captured by an unpolarized nucleus. Actually, because of the long lifetime of the μ^- meson in the K shell, the nucleus is also polarized in this case;[2] the calculations for the capture in hydrogen with account of this circumstance were given in reference 3.

For μ-mesodeuterium, it is necessary to consider separately the capture from states with total momentum $F = 3/2$ and $F = 1/2$. Corresponding density matrices have the form:

$$\rho_+ = \frac{1}{4}\left[1 + \frac{3}{5}\lambda_+ \mathbf{j}(\sigma_1 + \sigma_2 + \sigma_\mu)\right]\frac{4 + \sigma_\mu(\sigma_1 + \sigma_2)}{6}\,\frac{3 + \sigma_1\sigma_2}{4},$$

$$\rho_- = \frac{1}{2}[1 + \lambda_- \mathbf{j}(\sigma_1 + \sigma_2 + \sigma_\mu)]\frac{2 - \sigma_\mu(\sigma_1 + \sigma_2)}{6}\,\frac{3 + \sigma_1\sigma_2}{4}. \quad (1)$$

Here σ_1, σ_2 and σ_μ are the spin operators of the nucleons and the μ meson. In comparison with the formulas set forth in reference 2, there is in (1) the additional factor $(3 + \sigma_1\sigma_2)/4$, which is a projection operator on the state of the system of two nucleons with spin 1 (deuteron).

In what follows we start from the Hamiltonian of interaction in the form of Lee and Yang,[4] but with the wave functions of the electron replaced by the functions of the μ^- meson, and we employ the notation adopted in reference 1. For the probability of emission of a neutron in the energy range dE and solid angle $d\Omega$, we have

$$dW = p_+ dW_+ + p_- dW_- = \frac{M^2 dE d\Omega}{(2\pi)^4 \pi a^3} I_0 [1 - A\cos(\mathbf{j}, \mathbf{p})], \quad (2)$$

$$I_0 = I_{tt}\, a_{FF} + [I_{tt} + 3p_-(I_{tt} + I_{ss})](a_{GG} - \tfrac{2}{3} a_{GP}) + (1 - 3p_-) I_{tt} \cdot 2\,\mathrm{Re}\left(a_{GF} - \tfrac{1}{3} a_{GP}\right), \quad (3)$$

$$I_0 A = I_{tt}'[(p_+\lambda_+ - \tfrac{1}{3} p_-\lambda_-) b_{FF} + (p_+\lambda_+ - \tfrac{4}{3} p_-\lambda_-) \times (b_{GG} - 2\,\mathrm{Re}\, b_{GP}) + (p_+\lambda_+ + \tfrac{2}{3} p_-\lambda_-) \cdot 2\mathrm{Re}(b_{GF} - b_{FP})] + I'_{ss}\, p_-\lambda_-(3b_{GG} + \tfrac{4}{3}\,\mathrm{Re}\, b_{GP}). \quad (4)$$

Here dW_+ and dW_- are the respective capture probabilities from the quadruplet and doublet states of mesodeuterium; p_+ and p_- are the probabilities of formation of these states. In these formulas, as in those of reference 1, terms proportional to $|C_P|^2$ are neglected. The polarization of the neutron $\langle\sigma\rangle$ when pseudoscalar interaction is neglected is shown to be the following:

$$I_0[1 - A\cos(\mathbf{j}, \mathbf{p})]\langle\sigma\rangle = -a\frac{\mathbf{p}}{p} + c\mathbf{j} - d\left[\frac{\mathbf{p}}{p}, \mathbf{j}\right],$$

$$-a = I'_{tt}\left(p_- - \tfrac{1}{3}\right) b_{FF} + \left[\left(3p_- - \tfrac{1}{3}\right) I'_{tt} + 4p_-\,\mathrm{Re} I'_{st}\right] b_{GG} - 2\mathrm{Re}\left\{\left[\left(p_- + \tfrac{1}{3}\right) I'_{tt} + p_- I'_{st}\right] b_{GF}\right\}, \quad (5)$$

$$c = I_{tt}\left(p_+\lambda_+ + \tfrac{2}{3} p_-\lambda_-\right) a_{FF} + \left[\left(p_+\lambda_+ + \tfrac{8}{3} p_-\lambda_-\right) I_{tt} - 4p_-\lambda_- \times \mathrm{Re}\, I_{st}\right] a_{GG} + 2\mathrm{Re}\left\{\left[\left(p_+\lambda_+ - \tfrac{4}{3} p_-\lambda_-\right) I_{tt} + p_-\lambda_- I_{st}\right] a_{GF}\right\},$$

$$-d = p_-\lambda_- \cdot 2\,\mathrm{Im}\,[(2b_{GG} - b_{GF}) I_{st}']. \quad (6)$$

In the case of universal V—A interaction[5] and neglect of the renormalization of constants on account of strong interaction ($C_S = C'_S = C_P = C'_P = C_T = C'_T = 0$; $C_V = -C'_V = -C_A = C'_A = G/\sqrt{2}$) the probability of capture from the quadruplet state is shown to be equal to zero* and the formulas become simplified

$$I_0 = 3G^2 p_-(3I_{tt} + I_{ss}), \qquad I_0 A = 3G^2 p_-\lambda_-(I'_{tt} - I'_{ss}); \quad (7)$$

$$-a = -6G^2 p_-(I'_{tt} + \mathrm{Re}\, I'_{st}), \qquad c = 6G^2 p_-\lambda_-(I_{tt} - \mathrm{Re}\, I_{st}),$$

$$-d = -6G^2 p_-\lambda_-\,\mathrm{Im}\, I'_{st}. \quad (8)$$

These equations are consistent with those obtained from the formulas of Überall and Wolfenstein under similar assumptions (V—A interaction and absence of renormalization of the constants). In this case an additional factor $3p_-$ appears in the expression for capture probability (in contrast with reference 1); the distribution of neutrons with respect to energy can be obtained by summing the graphs F and G in Fig. 1 of reference 1 and by multiplication of the result by $3p_-$. In the parameter of asymmetry and polarization, the difference consists in replacing the polarization of the μ meson P by $-3\lambda_-$. Account of strong interactions leads to renormalization of the constants (strictly speaking, these will also be form factors depending on the energy of the neutrino, but in the fundamental region, i.e., for ν close to μ, they are approximately constant) and effectively to the appearance of pseudoscalar coupling;[7] in this case the deviation from reference 1 appears to be more significant.

Making use of the completeness of the wave functions of the system of two neutrons, we find the distribution over direction of the emergent neutrino dW and the mean asymmetry of flight of the neutrons $\langle\mathbf{p}\cdot\mathbf{j}\rangle$:

$$dW_\nu = \frac{\bar{\nu}^2}{(2\pi)^2 \pi a^3} d\Omega_\nu I_D [1 - B\cos(\mathbf{j}, \nu)], \quad (9)$$

$$I_D = \xi\left[a_{FF} + (1 - 3p_-) \cdot 2\mathrm{Re}\left(a_{GF} - \tfrac{1}{3} a_{FP}\right)\right] + (\xi + 3p_-)\left(a_{GG} - \tfrac{2}{3}\,\mathrm{Re}\, a_{GP}\right), \quad (10)$$

$$I_D B = \xi\left[\left(p_+\lambda_+ - \tfrac{1}{3} p_-\lambda_-\right) b_{FF} + (p_+\lambda_+ + \tfrac{2}{3} p_-\lambda_-) \times 2\mathrm{Re}(b_{GF} - b_{FP}) + (p_+\lambda_+ - \tfrac{4}{3} p_-\lambda_-)(b_{GG} - 2\mathrm{Re}\, b_{GP})\right] + (1 - \xi) p_-\lambda_-\left(3b_{GG} + \tfrac{4}{3}\,\mathrm{Re}\, b_{GP}\right), \quad (11)$$

$$\langle \mathbf{p}\mathbf{j}\rangle = \tfrac{1}{6} B\bar{\nu}; \qquad \xi = \tfrac{1}{2}\left(1 - \int |\psi_d|^2 \cos \nu r\, dr\right); \quad (12)$$

for $\psi_d = \left(\frac{\alpha}{2\pi}\right)^{1/2} \frac{e^{-\alpha r}}{r}$ we obtain $\xi = \frac{1}{2}\left(1 - \frac{2\alpha}{\bar{\nu}} \tan^{-1}\frac{\bar{\nu}}{2\alpha}\right) \approx 0.11$ ($\bar{\nu} = 94$ Mev.)

For V--A interaction and neglect of renormalization of the constants, we have

$$I_D = 3G^2 p_-(2\xi + 1), \qquad B = (2\xi - 1)/(2\xi + 1).$$

We now write down the expression for the probability dW_1 of capture with the formation of two slow neutrons with energies E_1 and E_2 ($E_1, E_2, \lesssim 10$ Mev):

$$dW_1 = \frac{\nu M^2}{(2\pi)^4 \pi a^3} dE_1 dE_2 d\Omega_1 I_1 [1 + C \cos(\mathbf{j}, \mathbf{p}_1)]; \quad (13)$$

$$I_1 = |J_t|^2 a_{FF} + [|J_t|^2 + 3p_-(|J_t|^2 + |J_s|^2)](a_{GG} - \tfrac{2}{3} a_{GP}) + (1 - 3p_-)|J_t|^2 \cdot 2\mathrm{Re}(a_{GF} - \tfrac{1}{3} a_{FP}); \quad (14)$$

$$I_1 C = \frac{\bar{\nu}^2 - p_1^2 - p_2^2}{\bar{\nu} p_1} \Big\{ |I_t|^2 \Big[(p_+\lambda_+ - \tfrac{1}{3} p_-\lambda_-) b_{FF} + \left(p_+\lambda_+ - \tfrac{4}{3} p_-\lambda_-\right)(b_{GG} - 2\mathrm{Re}\, b_{GP}) + (p_+\lambda_+ + \tfrac{2}{3} p_-\lambda_-) \times 2\mathrm{Re}(b_{GF} - b_{FP}) \Big] + p_-\lambda_- |J_s|^2 (3b_{GG} + \tfrac{4}{3} \mathrm{Re}\, b_{GP}) \Big\}. \quad (15)$$

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*A similar effect was noted in the capture of hydrogen from the triplet state.[6]

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CYCLOTRON RESONANCE IN LEAD

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THE phenomenon of cyclotron resonance predicted by Azbel' and Kaner[1] was observed in the case of lead by a number of authors.[2-4] The graphs of the dependence of the ratio R(H)/R(0) on the intensity of the magnetic field H show[2-3] a shallow minimum near 1000 oe of width ~1000 oe defined by several experimental points. The record of the quantity dR(H)/dH given in the brief communication by Kip et al[4] also contains only one broad minimum in the field range up to 2000 oe and, in addition to that, approximately ten minima for values of H = 2000 – 5000 oe.

In the present work, due to the utilization of a highly sensitive method of measurement — a resonator with rectilinear high frequency currents flowing in the sample, and very pure lead used for the preparation of the sample — several tens of cyclotron resonance minima have been observed for different orientations of the magnetic field (of intensity 150 – 3000 oe) with respect to the crystallographic directions. In our experiments the dependence of the quantity $X^{-1} \partial X/\partial H$ on $1/H$ was measured, where X is the surface reactance of the metal. The sample was a single crystal of lead characterized by the resistance ratio $\bar{\rho}_{20°C}/\bar{\rho}_{3.75°K} = 1.4 \times 10^5$ (reference 5, sample No. 6), which yields the value for the parameter $\omega\tau \approx 50$; the measurements were carried out at 2.4°K at a frequency of 9.4×10^9 cps. The single crystal grown from melt in a glass container had the shape of a rectangular plate of dimensions $13 \times 6 \times 1$ mm^3; its surface was untreated. The tetragonal crystal axis is directed along the plate, the binary axes parallel to its two smaller dimensions. The high frequency currents flow along the plate, the magnetic field vector may rotate in the plane of the plate.

The method is based on measuring the frequency modulation of the signal from an oscillator using a traveling-wave tube the resonator of which contains the sample, resulting from modulation of the magnetic field applied to the sample. The frequency F of this measuring oscillator is compared with the frequency of a similar standard oscillator stabilized by a superconducting lead resonator of high quality factor;[6] the frequency stability of the comparison oscillator is better than 10^{-9}.