In a suitable coordinate system (5) and (6) can be interpreted as describing the gravitational field of empty space with almost Euclidean metrics.

The generalization of (1) to general relativity is to be performed with a method analogous to that used by the authors for the spin-1 case.[6]

A full account will be published in *Arkiv för Fysik.*

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Lifetime Measurements by Conversion Line Shift: Lifetime of the 40-kev State of Tl^{208}

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(Received July 29, 1957)

BURDE and Cohen[1] have demonstrated that the 24.5-kev *L*-conversion line (*A*-line), which de-excites the 40-kev level of Tl^{208}, exhibits a Doppler shift, which is caused by the recoil velocity of Tl^{208*} nuclei shot out of a Th(B+C) source by alpha decay of ThC. This shift may be reduced by placing a very thin foil in front of the source, which stops some of the recoiling Tl^{208} nuclei before they have emitted conversion electrons. By measuring the line shift as a function of source-to-foil distance the lifetime of the 40-kev state may in principle be determined if the initial velocity of the recoil nuclei is known. In this way Burde and Cohen[2] found a half-life of $(1.0\pm0.5)\times10^{-12}$ sec for this state, on the assumption that all Tl^{208*} nuclei leave the source with their full recoil velocity $V=(M_\alpha/M_{Tl^{208}})V_\alpha$. Experiments rather similar to those of Burde and Cohen undertaken at this institute cast some doubt on the validity of this assumption for sources prepared by the usual collection technique.[3] When investigating the distribution of active nuclei in such sources it appeared that a considerable fraction of these nuclei penetrates rather deeply into the source backing foil.[4] Such nuclei will lose part or all of their recoil energy in traversing the foil after alpha decay. The penetration of active material into the source backing seems to be due partly to diffusion of Tn gas through the source foil and partly to the alpha recoils accompanying the decay (Tn→)ThA→ThB.

These effects were first investigated by depositing Th(B+C) by recoil collection from Tn on several stacks of thin Zapon foils, placed at small distances. The activity of these foils was found to decrease as $\exp[-d(\mu g/cm^2)/(100\pm20)]$.

The same result was obtained with Formvar foils and also when the first foil of a stack was covered with a thin layer of aluminum or silver, deposited by evaporation. This effect is thought to be mainly due to diffusion of Tn gas. The activity of the first foil tended to be higher than expected from the exponential intensity distribution. This surplus activity must be due to the collection of ions by the accelerating field. These ions are deposited on the surface of the foil and partly pushed into it by α recoils.

The fraction of Tl^{208} nuclei escaping from Th(B+C) sources deposited on foils of varying thickness could be determined directly by placing them for some time on an aluminum disk, which captures the 3-min Tl^{208} activity, and measuring the ratio of intensity of the 2.62-Mev gamma line of the captured activity to that present in the source foil. A part of the Tl^{208} nuclei leaving the source foil may not be captured by the disk, e.g., because they are reflected. The contribution of this effect was estimated from measurements with sources made by vacuum evaporation of Th(B+C) from a tungsten ribbon (on which the activity had been deposited by the usual collection method). In this case the Th(B+C) atoms reach the source foil with thermal velocities and should therefore penetrate only very little into it. Thus the escape fraction should be near 0.5; however, only a fraction 0.3 of the Tl^{208} nuclei was captured by the disk. After correction for this effect it was found that for source foils as used by Burde and Cohen only about 30% of the recoil nuclei which give rise to coincidences contribute to the line shift. If one assumes a continuous velocity distribution for these nuclei, a maximum midpoint shift of $\sim0.2\times$the "ideal" maximum possible shift would result.

If we try to introduce this into Fig. 7 of the paper of Burde and Cohen,[2] we find $T_{1/2}\approx4\times10^{-12}$ sec, which gives $\tau_\gamma\approx180\times10^{-12}$ sec. This agrees very well with the lifetime calculated recently by de-Shalit[5] for an $(s_{1/2},g_{9/2})$ configuration of Tl^{208}.

The authors are much indebted to Professor Brinkman, director of this laboratory, for his stimulating interest in this research.

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Measurement of Beta Asymmetry in the Decay of Polarized Neutrons*

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(Received July 25, 1957)

SINCE the neutron is one of the simplest entities showing beta emission, the symmetry properties

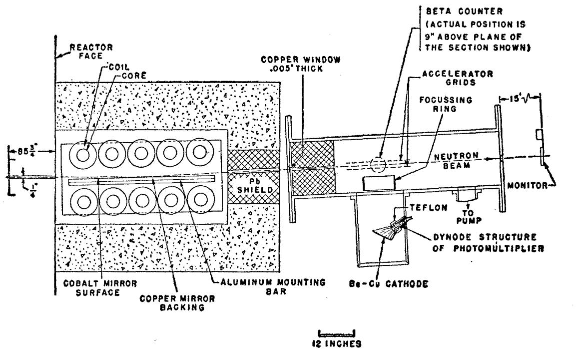

FIG. 1. Horizontal section through the apparatus used in detecting the decay of polarized neutrons. The section is taken at the level of the center of the beam. The angle between the beam and the mirror is greatly exaggerated for clarity.

of the decay of the neutron are clearly of interest in connection with the recent advances[1–3] in our knowledge of the character of beta decay. In an attempt to improve the understanding of the nature of the neutron's beta decay, we have measured the relative probability of beta emission by the neutron in the directions respectively parallel and antiparallel to the spin of the neutron.

This measurement was made with the arrangement shown in outline in Fig. 1. The neutrons measured were in a thermal beam taken from the Argonne Research Reactor, CP-5, through a hole $85\frac{3}{4}$ in. long, $\frac{1}{4}$ in. wide, and 8 in. high. This beam was polarized by reflection from a 5-in. high mirror of 95% Co and 5% Fe magnetized in a vertical direction by a field of about 250 oersteds.[4] At a grazing angle of about 8 minutes the reflected beam contained a total of 7×10^7 neutrons per sec and was $87\pm7\%$ polarized (as determined by using another cobalt mirror as an analyzer). To keep the neutrons in a definite vertical orientation, a vertical field of about 10 gauss was applied to the vacuum chamber in which the decays were observed. The lead shield in this chamber was made, in part, of an alloy including 0.5% by weight of lithium to minimize gamma rays from neutron capture. The gamma flux left after these shielding measures was less than 100 mr/hr in the beam.

Neutron decays were observed by coincidences between a beta detector and a proton detector. The beta detector was a plastic scintillator 0.21 in. thick and 5 in. in diameter. Pulses from the beta detector were accepted if they corresponded to an energy loss of 110 to 610 kev. The protons were detected by the method used by Robson[5] and by Snell, Pleasonton, and McCord,[6] in which the protons are accelerated to about 12 kev in a system that focuses them on the cathode of an electron multiplier. In our case the cathode was an ellipse of Be-Cu 5 in. long by 4 in. high, activated in place by heating to a dull red heat by electron bombardment.[7] The remainder of the electron multiplier was an uncesiated dynode structure from a DuMont 6292 photomultiplier. Amplified pulses from the beta and proton detectors were fed through pulse-height analyzers into a coincidence circuit in which a coincidence pulse was produced if (a) both proton and beta pulses were of appropriate size and (b) the proton pulse arrived between 0.2 and 1.8 μsec after the beta pulse. Moreover, the output of the coincidence circuit was a pulse of a size which was dependent on the delay. This pulse was fed to a 20-channel pulse-height analyzer which thus gave a display of the number of coincidences *vs* the time following the beta pulse (up to 1.8 μsec). In this display the neutron decays showed quite clearly as a peak near 1 μsec delay—the time of flight to the proton counter. About 0.15 coincidence counts per minute were obtained in a typical measurement.

Measurements were made with neutrons polarized straight up and straight down and with and without a steel shim 0.010 in. thick placed at the entrance to the vacuum chamber. This shim completely depolarizes a beam of thermal neutrons and thus gives a null measurement for both field directions. The result was as follows:

$$\frac{\text{Intensity parallel to neutron spin}}{\text{Intensity antiparallel to neutron spin}}=0.62\pm0.10.$$

When corrected for the solid angle of the beta detector and for the imperfections of the polarization (the mean beta velocity, $\langle v/c\rangle$, is taken as 0.80) and expressed in the usual way, the angular distribution relative to the neutron spin direction becomes

$$W(\theta)=1-(0.37\pm0.11)(v/c)\cos\theta.$$

The error given in this result is almost entirely due to the statistical fluctuations in the measurements. The estimated uncertainties in the corrections make a very small contribution.

In view of the developments referred to earlier,[1–3] the beta decay of the neutron is to be described by 8 parameters (some or all of which may be complex if time-reversal invariance fails). It may be of interest, however, to compare the present result with the predictions of some simplified variations of the general theory which have been proposed.

(1) Two-component neutrino theory[8]:

−0.08 or −1.00,

(2) Twin-neutrino theory[9,10]: −0.53,

(3) Parity conservation in Fermi interactions[11]:

−0.21 or −0.86,

In all these predictions it is assumed that

$$x^2 \equiv \frac{\text{sum of squares of Gamow-Teller coupling constants}}{\text{sum of squares of Fermi coupling constants}} = (1.15)^2.$$

In the predictions giving two values of the coefficient, the first corresponds to $x<0$ and the second to $x>0$. It should be noted that in the event of failure of time-reversal invariance the Gamow-Teller—Fermi interference term in the two-component neutrino theory might be reduced to make the theory consistent with the present measurement.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

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Polarized Positrons from Ga^{66} and Cl^{34} †

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(Received August 2, 1957)

SEVERAL experiments[1] have shown that positrons emitted in Gamow-Teller beta transitions are polarized in their directions of motion ($\boldsymbol{\sigma}\cdot\mathbf{p}$ positive). We find this to be true also for positrons emitted by Ga^{66}, which is probably a pure Fermi transition. Preliminary results for the pure Fermi transition of Cl^{34} also indicate the same sign for $\boldsymbol{\sigma}\cdot\mathbf{p}$.

Positrons in a selected energy band were magnetically focused on a Lucite converter (Fig. 1). High-energy photons from two-quantum annihilation are almost completely circularly polarized in the direction of the positron spin.[2] This polarization was measured by absorption in an iron analyzer[3] which can be magnetized parallel or antiparallel to the incident positron momentum. For high-energy positrons the gamma rays are emitted in a narrow forward cone. This permits the use of a low-transmission magnetic spectrometer[4] without undue loss of intensity. With 1% transmission and a 12-cm thick analyzer, about 1000 counts per minute were obtained when 3-Mev positrons from a 20-mC Ga^{66} source were focused on the converter. The pulse-height spectrum from the 3×3 inch scintillation counter was remarkably flat. Uncertainties introduced by small shifts in pulse height due to stray magnetic fields or other causes were therefore small. Extensive lead shielding was provided to reduce the background due to nuclear gamma rays. Under the experimental conditions described above, scattered gamma rays contributed about 20% of the pulses above 2 Mev. For smaller pulses the background rose sharply. Repeated checks showed that effects of the analyzer field on the counter or on the positron trajectories did not contribute any measurable systematic error. A sequence of reversing lens and analyzer currents and interchanging various circuits was designed to average over possible small instrumental asymmetries.

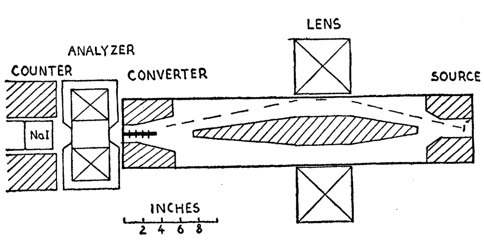

Fig. 1. Experimental arrangement for measuring longitudinal polarization of high-energy positrons.

Figure 2 shows the results obtained for the conditions described above. The ordinate is the fractional difference between counting rates for the two analyzer field directions, after correction for background. Some data were also obtained at lower positron energies and others with a thinner analyzer. These are summarized in Table I.

Results obtained with Cl^{34} are less extensive and satisfactory than for Ga^{66}, primarily because the

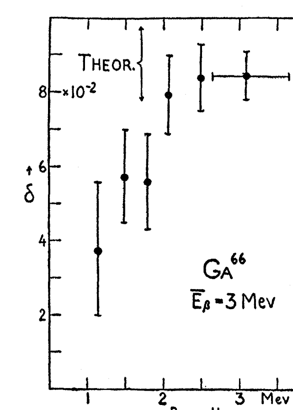

Fig. 2. Effect of field direction on transmission of annihilation radiation from Ga^{66} through analyzer.