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INVESTIGATION OF PARITY NONCONSERVATION IN THE REACTION $n + p \rightarrow d + \gamma$

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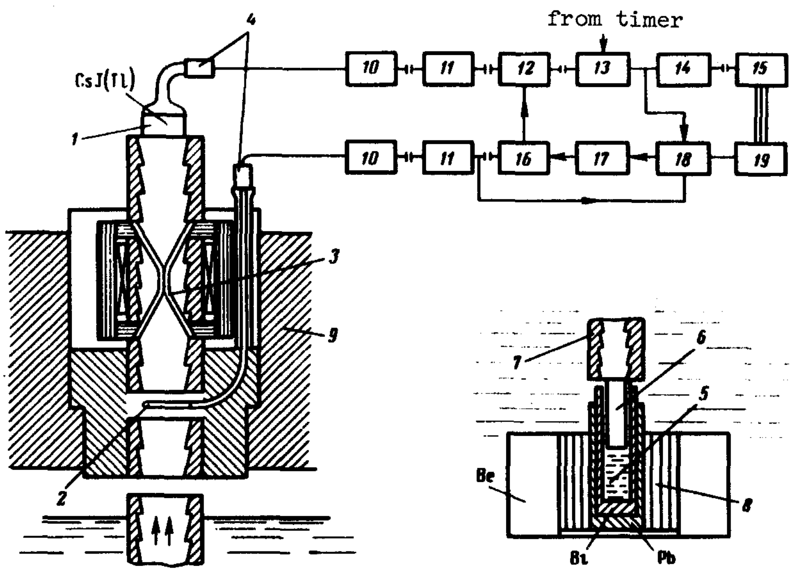
Measurement of the circular polarization of the γ quanta in the reaction $n + p \rightarrow d + \gamma$ makes it possible to determine directly the isoscalar part of the amplitude of the weak nucleon-nucleon interaction [1]. The absence of any appreciable amplification in this case causes the magnitude of the effect to be of the order of the ratio of the weak interaction to the strong one. Measurement of so small a polarization is a rather difficult task, but can be accomplished by using the procedure of integral γ-quantum detection [2]. The most important in this case is to obtain as powerful a source of gamma quanta of this reaction.

We describe here the organization of an experiment and preliminary results of the measurement of the circular polarization of gamma quanta in radiative capture of thermal neutrons in hydrogen. The experimental setup is shown in the figure.

The gamma source was a light-water neutron trap in the active zone of the VVR-M reactor of the A. F. Ioffe Physico-technical Institute. The trap was protected against gamma radiation from the zone by a screen of lead and bismuth. The effective source activity was about 10^{16} gamma-kV/sec at a volume trap of about 3 liters and a neutron flux $\sim 3 \times 10^{14}$ neut/cm^{2}sec at its center.

The gamma quanta from the trap were fed to the polarimeter through a 4-meter collimator channel. A "flow-through" collimator was used with an effective magnetized-absorber thickness



Experimental setup: 1 - measuring detector, 2 - monitoring detector, 3 - magnetized absorber, 4 - photodiodes, 5 - target, 6 - evacuated cylinder, 7 - 4-meter collimator, 8 - active zone, 9 - reactor shield, 10 - dc amplifier, 11 - amplifier, 12 - differential amplifier, 13 - erase circuit, 14 - tuned amplifier, 15 - output amplifier, 16 - rgulated amplifier, 17 - control circuit, 18 - correlator, 19 - pendulum filter.

~60 mm, previously used in [3]. The effective counting rate of the gamma quanta in the measuring detector was about 5 x 10^{10} sec^{-1}. A monitoring detector was placed in front of the magnetized absorber. The use of the monitor was necessitated by the fact that the relative fluctuations of the reactor neutron flux, i.e., the fluctuations of the gamma-flux intensity, amount to about (1 - 2) x 10^{-3} at frequencies 1 - 20 Hz. This exceeds by almost two orders of magnitude the level of the statistical fluctuations of the measuring-detector current. To compensate for the intensity fluctuations, the signals of the monitoring and measuring detectors were fed, after suitable amplification, to a differential amplifier whose difference signal contained only the statistical fluctuations of the currents of both detectors and the measured signal.

The polarimeter magnetization switching frequency was 0.5 Hz at a stability $\sim 10^{-7}$. The periodic signal was separated from the difference signal with a pendulum filter.

To prevent deterioration of the compensation by the relative drift of the channels, a correlator was used to determine the magnitude and sign of the correlation of the difference signal and the monitor signal, and thus change the gain of the monitor channel until the correlation decreased to zero.

At the compensation level attained in the experiment, the difference-signal fluctuations still exceeded the expected value by 1.5 - 2 times.

The screening of the water volume against the radiation of the reactor active zone is due to the large background of circularly polarized bremsstrahlung gammas from the beta decay of the fission fragment. The effective circular polarization of the gammas in the active zone, as verified by direct measurements, is (1 - 2) x 10^{-3}. The bremsstrahlung gamma quanta fall into the collimater channels after being scattered by the target material in the trap. The external-radiation background was determined by placing in the trap targets having scattering characteristics close to those of water and gamma quanta known to be unpolarized. Beryllium and graphite were used as such targets. Several experiments were performed with different targets in the water volume, at different shield thicknesses, making it possible to choose the required screen thickness. The results of such experiments are summarized in Table I. In calculating the effect due to the bremsstrahlung gamma quanta, account was taken of only the internal bremsstrahlung and of the effective beta spectrum of uranium fission fragment, measured in [4].

The control null experiment to check on the absence of false effects due to the polarimeter entailed a number of difficulties, due to the absence of a source of polarized gamma quanta of the (n, γ) reaction with approximate energy 2 MeV. Some of the experiments were therefore performed with ^{24}Na sources, which emit gamma quanta of 2.7 MeV energy and multipolarity E2. The limited activity of the ^{24}Na source (~10 000 Ci) did not make it possible to attain gooud accuracy, yielding $\delta = -(0.3 \pm 0.4) \times 10^{-7}$.

Another part of the control experiments was performed with a titanium target in the trap. The gamma quanta emitted in the reaction $^{48}Ti(n, \gamma)^{49}Ti$ reaction, with energy 6 - 7 MeV and multipolarity E1, can be regarded as practically unpolarized.

These experiments have shown that the relatively harder gamma quanta of titanium can, under certain conditions, produce a number of false effects, so that this control experiment

Table I

Results of experiments with different targets in the trap and calculated effect of bremsstrahlung for a water target

Thickness of trap lead screen / Target	$\delta \cdot 10^6$			
	0	1 cm	3 cm	6 cm
H_2O – calculated	– 5.0	– 1.7	– 0.17	– 0.01
H_2O – experimental	– 5.5 ± 0.5	– 1.2 ± 0.3	–	–
Be – experimental	–	– 2.0 [1] ± 0.4	–	–
Graphite - exp. (from Table II)	–	–	–	0.0 ± 0.025 *

$\delta = \Delta U/U$, where U is the γ-quantum intensity in the measuring detector and ΔU is the change of intensity upon remagnetization of the polarimeter.

*The value of U with water in the trap was used in the calculation of δ for the Be and graphite targets.

Table II

Results of last experiments. Trap shielded with 35 mm lead and 35 mm bismuth

Target	H_2O	Ti	H_2O	H_2O	C	Ti
$\delta \cdot 10^7$	– 0.8 ± 0.4	0.5 ± 0.5	– 0.88 ± 0.35	– 1.5 ± 0.55	0.0 ± 0.25	0.6 ± 0.5

is not fully identical with the main experiments, although it is possibly more critical.

By way of a preliminary result, we present the latest measurement data, obtained under identical conditions with different targets. These data are arranged in Table II in chronological order.

It is seen from the table that the weighted value of the effect obtained for three series with water in the trap is $\delta = -(1.0 \pm 0.23) \times 10^{-7}$, corresponding to a polarization $P_\gamma = -(1.8 \pm 0.4) \times 10^{-6}$. If only the errors of the control experiments listed in Table II are taken into account, then the result can be written in the form $P_\gamma = -(1.8 \pm 0.9) \times 10^{-6}$

However, taking into account the aforementioned shortcomings of control experiments with hard gamma quanta, we must regard, at the present stage, the estimate $0 \leq -P_\gamma < 3 \times 10^{-6}$ as a more reliable estimate.

This estimate can apparently be useful for the analysis of various models of weak-interaction Hamiltonians, which predict an anomalously large amplitude for the weak nucleon-nucleon interaction.

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ANOMALOUS QUANTUM OSCILLATIONS OF SURFACE IMPEDANCE

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It is known that the condition of thermodynamic stability of the homogeneously magnetized state, $(\partial H/\partial B)_T > 0$, is violated periodically (with periodicity in H), owing to the de Haas - van Alphen effect, at sufficiently low temperatures ($\pi^2 T < \hbar\Omega$, where $\Omega = eB/mc$ is the cyclotron frequency) [1]. In analogy sith the vapor-liquid system, it can be shown that there exist critical points $T_0^{(i)}$ and $H_0^{(i)}$, at which $\frac{\partial H}{\partial B}(T_0^{(i)}, H_0^{(i)}) = 0$, $\frac{\partial^2 H}{\partial B^2}(T_0^{(i)}, H_0^{(i)}) = 0$, and $\frac{\partial^3 H}{\partial B^3}(T_0^{(i)}, H_0^{(i)}) > 0$. Depending on the boundary conditions, there occurs at $T < T_0$ either a stratification into phases (a domain structure) with different values of the induction B_1 and B_2 (if $\vec{H}$ is parallel to $\vec{n}$, where $\vec{n}$ is the normal to the surface), or else a jumpwise change of the induction from B_1 to B_2 (if $\vec{H} \perp \vec{n}$) [1]. Such a singularity should affect the propagation in the metal of electromagnetic waves at a frequency ω such that the system has time to "adjust itself" to the thermodynamics, i.e., under the condition $\omega\tau \ll 1$ (τ - free path time).

Let us assume, for simplicity, that the dispersion is isotropic, and that the depth of penetration δ, the free path time τ, and the external magnetic field are such that $\delta > \ell >$ (R is the radius of the electron orbit), and $T > T_0$. In this case the connection between the current and the electric field is local ($\vec{j} = \sigma\vec{E}$), and all that is left to solve the problem of the penetration of the electromagnetic wave in the metal is to specify the connection between the alternating components of the magnetic field $\vec{h}$ and the magnetic induction $\vec{b}$. In the linear approximation (the estimate is presented below) this connection is given by $h = (\frac{\partial H}{\partial B})_T b$ (if $\vec{h} \parallel \vec{H}$) and $h = (1 - 4\pi M/B)b$ (if $\vec{h} \perp \vec{H}$). We see therefore that near the critical point we have $\mu = b/h = (\partial H/\partial B)_T^{-1} \to \infty$ if $\vec{h} \parallel \vec{H}$ and μ has no singularities if $\vec{h} \perp \vec{H}$. In the case considered by us, that of the normal skin effect, the penetration depth is $\delta = c(2\pi\sigma\omega\mu)^{-1/2}$, and if $\vec{h} \parallel \vec{H}$, then $\delta \sim \sqrt{(\partial H/\partial B)_T} \to 0$. Thus, at sufficiently low temperatures, anomalous quantum oscillations occur in the surface impedance $Z \sim \mu\delta \sim \sqrt{\mu}$; these oscillations are essentially anisotropic with respect to the mutual orientation of the vectors $\vec{h}$ and $\vec{H}$.

Deferring the detailed calculations to a separate communication, we shall point out now