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PARITY NON-CONSERVING EFFECTS IN nγ-REACTIONS

V.M. Lobashov and V.A. Nazarenko

Leningrad Nuclear Physics Institute, Academy of Sciences of the USSR, U.S.S.R.

Résumé - L'état actuel du problème de la violation de la parité spatiale dans les réactions nγ est discuté.

Abstract - State of the art of the P-violation problem for nγ-reaction is discussed.

The radiative neutron capture reaction has been the first process to reveal the parity violation effect in nuclear forces: indeed, an asymmetry in the angular distribution of γ-rays emitted in the capture of polarized neutrons by the 115Cd nucleus has been found in the well-known experiment by Abov et al./1/.

Nearly 20 years have passed since that time. P-violating effects have been detected and measured in a number of nuclear processes, from the electromagnetic decay of polarized and unpolarized nuclei to heavy nucleus fission and neutron optics.

As for the nγ-reactions, all the information on such effects available until recently is limited by the data listed in Table 1, which includes two well-known cases of 117Sn and 117Sn, a less known case representing a preliminary result on 35Cl, and results obtained in studies of the np→αd and nd→tr reactions in LETPI (Academy of Sciences of the USSR) and Institute Laue-Langevin (Grenoble).

Table 1. P-violating effects in nγ-reactions (data as of 1 July 1982)

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Type of transition</th>
<th>Quantity measured</th>
<th>Experimental result</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>113Cd (nγ)144Cd</td>
<td>MI(EI)</td>
<td>aγ</td>
<td>(4.1±0.8)×10^{-4}</td>
<td>/2/</td>
</tr>
<tr>
<td>117Sn (nγ)146Sn</td>
<td>MI(EI)</td>
<td>aγ</td>
<td>(5.0±1.2)×10^{-4}</td>
<td>/3/</td>
</tr>
<tr>
<td>35Cl (nγ)36Cl</td>
<td>MI(EI)</td>
<td>aγ</td>
<td>(6.0±1.5)×10^{-4}</td>
<td>/4/</td>
</tr>
<tr>
<td>np→αd</td>
<td>MI(EI)</td>
<td>Pr</td>
<td>(8.1±1.3)×10^{-4}</td>
<td>/3/</td>
</tr>
<tr>
<td>nd→tr</td>
<td>MI(EI)</td>
<td>aγ</td>
<td>(4.4±0.6)×10^{-4}</td>
<td>/5/</td>
</tr>
<tr>
<td>35Cl (nγ)36Cl</td>
<td>MI(EI)</td>
<td>aγ</td>
<td>(1.5±0.5)×10^{-4}</td>
<td>/6/</td>
</tr>
<tr>
<td>np→αd</td>
<td>MI(EI)</td>
<td>Pr</td>
<td>(1.3±0.45)×10^{-6}</td>
<td>/7/</td>
</tr>
<tr>
<td>nd→tr</td>
<td>MI(EI)</td>
<td>aγ</td>
<td>(0.6±2.1)×10^{-7}</td>
<td>/8/</td>
</tr>
<tr>
<td>35Cl (nγ)36Cl</td>
<td>MI(EI)</td>
<td>aγ</td>
<td>(7.8±3.4)×10^{-6}</td>
<td>/9/</td>
</tr>
</tbody>
</table>

Note: The effects observed in the total and radiative cross sec-
tions of neutron nucleus interaction revealed in LNPI /10,11/ are not considered here since they are of a somewhat different nature.

This situation can be apparently attributed to difficulties which seemingly should inevitably face experimenters engaged in corresponding studies. Indeed, it was earlier believed that success of an experiment was determined to a considerable extent by a lucky selection of a nucleus to be studied (and for the given nucleus, of a suitable \( \gamma \)-transition as a rule, of multipolarity \( M1 \) whose structural factors would result in a substantial enhancement of the bare effect (its magnitude being small, i.e. on the order of \( 10^{-7} \).

Next, one had to isolate reliably this \( \gamma \)-transition, since otherwise the matrix elements of transitions to different spin states having opposite signs may cancel one another thus resulting in a zero net effect. (In the case of measuring the asymmetry of \( \gamma \)-ray transmission, the situation is aggravated by the existence of the so-called spin-factor). While the isolation of a desired \( \gamma \)-transition against the background of a complex spectrum from an \( \alpha \)-reaction is in itself a hard experimental problem, it entails also a substantial reduction of count rate, with the results that the time required to obtain statistically reliable data may take up, as a rule, several months.

These considerations seemed to imply that one can hardly expect a noticeable effect for most nuclei, particularly in \( \gamma \)-reactions with predominantly \( E1 \) transitions for which the so-called kinematic enhancement factor \( \sim \frac{v}{c} \), where \( v \) is the velocity of nucleons in the nucleus and \( c \) is the velocity of light, acts in the opposite direction. As for an attempt of looking for P-violating effects in a group of closely lying \( \gamma \)-lines without their separation, this seemed totally hopeless.

Last year this viewpoint which appeared to be only natural has quite unexpectedly been invalidated in experiments carried out on the LNPI reactor /12/. It has been found that even under conditions of integral \( \gamma \)-ray recording when the spectrum of an \( \alpha \)-reaction contains hundreds of \( \gamma \)-transitions the P-violating effects do not vanish in some cases and may even be comparatively large \( (10^{-3} - 10^{-4}) \), no matter what transitions, \( M1 \) or \( E1 \), are predominant.

Two P-violating effects were measured simultaneously: 
- the asymmetry of \( \gamma \)-emission with respect to the spin of the captured polarized neutron; 
- the circular polarization in the radiative capture of unpolarized thermal neutrons.

The apparatus used in the asymmetry measurement is typical for such experiments. A beam of transversely polarized neutrons from a polarizing neutron guide \( A \approx 2.7 \lambda \) passed through the sample under study with scintillation detectors placed on both sides of it. The asymmetry was looked for in the form \( W \sim (1 + a_{\gamma} [\sigma, \mathbf{\hat{k}}]) \), where \( a_{\gamma} \) is the asymmetry coefficient, \( \sigma \) the neutron spin, and \( \mathbf{\hat{k}} \) the \( \gamma \)-photon momentum. One measured the relative change in the intensity of \( \gamma \)-rays detected by the scintillators associated with the neutron spin flip which was effected once every two seconds by means of a high frequency adiabatic flipper.

The values of the asymmetry coefficient \( a_{\gamma} \) obtained in this way and corrected for the background, beam polarization and average cosine of the angle between \( \sigma \) and \( \mathbf{\hat{k}} \) are listed in the last column of Table II.
Table II. Experimental and calculated values of the P-violating effects in the integral spectrum of the $n^-$-process.

<table>
<thead>
<tr>
<th>Target nucleus</th>
<th>Effect $\times 10^{-5}$</th>
<th>$P_r$ exp.</th>
<th>$P_{\text{theor.}}$</th>
<th>$P_{\text{theor.}}$</th>
<th>$P_{\gamma13}$</th>
<th>$P_{\gamma14}$</th>
<th>$\alpha_{\text{theor.}}$</th>
<th>$\alpha_{\text{theor.}}$</th>
<th>$\alpha_{\gamma13}$</th>
<th>$\alpha_{\gamma14}$</th>
<th>$\alpha_{\text{exp.}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl</td>
<td>$6.4^{+0.5}_{-0.4}$</td>
<td>1.0</td>
<td>2.0</td>
<td>0.5</td>
<td>0.86</td>
<td>0.13</td>
<td>-2.8</td>
<td>0.15</td>
<td>1.95</td>
<td>$2.0^{+0.5}_{-0.4}$</td>
<td></td>
</tr>
<tr>
<td>Br</td>
<td>$3.1^{+0.2}_{-0.5}$</td>
<td>7.5</td>
<td>11</td>
<td>3</td>
<td>4.7</td>
<td>0.26</td>
<td>0.13</td>
<td>0.14</td>
<td>-1.82</td>
<td>$2.4^{+0.5}_{-0.1}$</td>
<td></td>
</tr>
<tr>
<td>$^{81}$Br</td>
<td>$16.1^{+1.1}_{-0.4}$</td>
<td>0.3</td>
<td>0.18</td>
<td>0.1</td>
<td>0.76</td>
<td>0.41</td>
<td>0.24</td>
<td>0.16</td>
<td>-18.2</td>
<td>$2.4^{+0.5}_{-0.1}$</td>
<td></td>
</tr>
<tr>
<td>$^{13}$Cd</td>
<td>$1.9^{+0.5}_{-0.1}$</td>
<td>8.1</td>
<td>21.7</td>
<td>3</td>
<td>7.4</td>
<td>0.14</td>
<td>-18.2</td>
<td>0.2</td>
<td>-0.15</td>
<td>$2.4^{+0.5}_{-0.1}$</td>
<td></td>
</tr>
<tr>
<td>Sn</td>
<td>$-0.1^{+0.2}_{-0.1}$</td>
<td>2</td>
<td>1.03</td>
<td>1.3</td>
<td>0.76</td>
<td>0.41</td>
<td>0.24</td>
<td>0.16</td>
<td>-18.2</td>
<td>$2.4^{+0.5}_{-0.1}$</td>
<td></td>
</tr>
<tr>
<td>$^{117}$Sn</td>
<td>$8.1^{+2.4}_{-0.3}$</td>
<td>7</td>
<td>21.7</td>
<td>3</td>
<td>7.4</td>
<td>0.14</td>
<td>-18.2</td>
<td>0.2</td>
<td>-0.15</td>
<td>$2.4^{+0.5}_{-0.1}$</td>
<td></td>
</tr>
</tbody>
</table>

Note: asterisk denotes the values for the isotopes calculated by expression $P_{\text{theor.}} = P_{\gamma} \sum \sigma_k C_k B_k / \sigma_1 C_1 B_1$, where $\sigma_k$ is thermal neutron capture cross section for the kth isotope, $C_k$ its abundance in natural sample, $B_k$ the neutron binding energy.

A nonzero effect is seen to have been observed for chlorine, bromine and lanthanum (of natural isotopic abundance).

The second effect, i.e., the circular polarization of $\gamma$-rays from unpolarized nuclei, was measured on the apparatus shown schematically in Fig.1. This apparatus was built to study the circular polarization of $\gamma$-rays in radiative $n^-$-capture, and we shall consider it in more detail when discussing this experiment. (A more detailed description of this apparatus may be found in /15,16/.

The targets under study were placed into a light-water neutron trap at the center of reactor core, protected from $\gamma$-radiation from the latter by lead screens. The targets represented mixtures of the corresponding compound (NaCl, NaBr, La$_2$O$_3$) with graphite powder packed in an air-tight zirconium cylinder. In the case of Sn, Cd, Zr and Pb a metal target was used. $\gamma$-rays from the target were led out through reactor tank water by means of a collimating channel to a polarimeter located above the reactor.

The effect was derived, as usually, from the relative variation of the $\gamma$-ray intensity resulting from the polarimeter remagnetization which was performed once every two seconds: $\delta = 2(\gamma^+ - \gamma^-)/(\gamma^+ + \gamma^-)$. The circular polarization was found as $P_{\gamma} = \delta / \epsilon$, where $\epsilon$ is the polarization efficiency equal to 5%. The results of these measurements are presented in the first column of Table II. Nonzero circular polarization was found for the three nuclei revealing also a nonzero asymmetry, i.e. chlorine, bromine and lanthanum as well as for a natural tin sample on which the asymmetry was not measured. If, however, the circular polarization thus found is recalculated for one isotope assuming all the effect obtained on natural tin to be due to the isotope $^{117}$Sn (this assumption appears to be justified if we compare the rotation of the plane of polarization for neutrons passing through natural tin and tin-$^{117}$ samples /17/ it turns out to be $(8.1^{+2.4}_{-2.0}) \times 10^{-5}$ whereas practically no asymmetry has been
observed: $\alpha_r = (0.24 \pm 0.16) \times 10^{-5}$.

The possible contribution of $\tau$-quanta from the reactor core and structural materials of the screens and targets (i.e. lead and zirconium) was checked in control experiments carried out with corresponding targets and was not observed. The circular polarization found cannot be also due to bremsstrahlung from the $\beta$-decay of nuclei produced in neutron capture by the isotopes of the natural abundance mixture used in targets or by impurities, which is supported both by the corresponding calculations and by results of measurements performed after each reactor shutdown when there is no $\gamma$-ray background from the $\nu\tau$-reaction and thus the effect of the bremsstrahlung should be enhanced.

Thus the existence proper of relatively large $10^{-3} - 10^{-4}$ $\tau$-violating effects in the integral spectrum of $\nu\tau$-reactions on a number of nuclei has been reliably established by two independent methods.

As for its theoretical interpretation, it should be noted before mentioning the first attempts in this direction that it is made difficult by the absence of complete and reliable data on the spectra of neutron capture $\tau$-rays from the nuclei in question. In circular polarization measurements which seemingly should lend themselves more readily to interpretation because of the absence of the abovementioned spin factor this point is particularly essential since the sensitivity of such measurements varies over the spectrum, with the presence of a 7 cm polarimeter absorber in the way of the $\tau$-rays only complicating the situation.

Two recently published papers /13,14/ present calculations taking into account the enhancement of $\tau$-violating effects near the $\beta$-wave compound resonance /18/.

One can hardly doubt that this mechanism is involved also in our particular case. In any case, for the three nuclei exhibiting this effect ($^{64}$Sr, $^{129}$Sn, and $^{$85}$I$) a $\beta$-wave resonance is known to exist close to the thermal region. However whether this mechanism can account completely for the magnitude of the effect or not remains an open question.
Both publications make use of a statistical approach which assumes complete statistical independence of the matrix elements for $\gamma$-transitions between different states. Under these conditions the average (i.e. experimentally measured) magnitude of the effect turns out naturally to be zero, so that calculations yield only an rms estimate of the effect, and it is this estimate that is presented in Table II together with the experimental data.

If we follow Sushkov and Flambaum /13/ and consider the results of the calculations as "a very crude estimate", one has to admit that they agree quite well with the experiment. A more careful analysis shows that these calculations /13/ systematically underevaluate the effect, particularly if we take into account that the contribution from the cascade $\gamma$-rays should reduce the theoretical estimate still further by a factor 2 to 3, which is admitted by Sushkov and Flambaum /13/.

The results of ref. /14/ agree, on the whole, even better with experiment, however for some nuclei they also exhibit a discrepancy which in the case of tin reaches a factor of ~ 6. Note that Bunakov et al. /14/ used in their calculation radiative force functions $S_\gamma$ (E1) and $S_\gamma$ (M1) which describe satisfactorily hard $\gamma$-transitions in a number of spherical nuclei. However the validity of their application for the nuclei studied by us is not obvious. Alternative theoretical approaches to this problem assume the existence of a certain coherence in PNC effects, i.e. a correlation between the matrix elements of transitions between different states.

One may conclude this part of the report by saying that apparently there is still no adequate description of the PNC effects in integral spectra and one has to continue theoretical and experimental work along these lines which hopefully will provide a deeper insight into the nature of enhancement of the PNC effects and properties of highly excited nuclear states.

The second part of the report deals with a new experiment on the measurements of the circular polarization of $\gamma$-rays from the $np \rightarrow d\gamma$ reaction. This elementary reaction is related to few-nucleon systems whose theoretical interpretation should seemingly be simpler and more reliable. At the same time if one looks carefully at Table III (taken from ref. /9/) listing the results of experiments and theoretical calculations for all the few-nucleon systems studied up to now good agreement between theory and experiment will be evident for $pp$-scattering only.

Table III. Comparison of experiment with theory. Few nucleon systems.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Theory</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$pp$-scattering, 15 MeV</td>
<td>$A_z = 1.5 \times 10^{-7}$</td>
<td>$(1.7 \pm 0.8) \times 10^{-7}$</td>
</tr>
<tr>
<td>45 MeV</td>
<td>$A_z = 2.8 \times 10^{-7}$</td>
<td>$(2.3 \pm 0.8) \times 10^{-7}$</td>
</tr>
<tr>
<td>$pd$-scattering, 45 MeV</td>
<td>$A_z = 1.4 \times 10^{-7}$</td>
<td>$(0.35 \pm 0.85) \times 10^{-7}$</td>
</tr>
<tr>
<td>$pd$-scattering, 46 MeV</td>
<td>$A_z = 5.5 \times 10^{-7}$</td>
<td>$(0.30 \pm 1.3) \times 10^{-7}$</td>
</tr>
<tr>
<td>$ph_20$-scattering, 6 GeV</td>
<td>$A_z = 1.1 \times 10^{-7}$</td>
<td>$(2.65 \pm 0.60) \times 10^{-6}$</td>
</tr>
<tr>
<td>$np \rightarrow d\gamma$ (therm. neutrons)</td>
<td>$P_\gamma = 6.10^{-8}$</td>
<td>$-(1.30 \pm 0.45) \times 10^{-6}$</td>
</tr>
<tr>
<td>$nd \rightarrow d\gamma$ (therm. neutrons)</td>
<td>$A_\gamma = 0.5 \times 10^{-7}$</td>
<td>$(0.6 \pm 2.1) \times 10^{-7}$</td>
</tr>
<tr>
<td></td>
<td>$a_\gamma = 1.10^{-6}$</td>
<td>$(7.8 \pm 3.4) \times 10^{-6}$</td>
</tr>
</tbody>
</table>
In the case of nd -scattering and asymmetry in the np -capture process the experimental accuracy is insufficient to permit a definite conclusion, while in the other cases serious discrepancy between the calculations and measurements can be seen to exist. At the same time it should be pointed out that the theoretical figures for the effects presented in the Table were calculated using the meson-nucleon coupling constants which describe quite satisfactorily a broad class of PNC experiments carried out at low excitation energies.

This situation is possibly determined by the smallness of the effect involved there being no grounds for expecting its enhancement. An additional difficulty encountered in studying radiative capture of thermal neutrons is the existence of ever present PNC effects in complex nuclei which has been demonstrated in the preceding section of the report and will be discussed below.

The first experiment on the measurement of the circular polarization of γ-rays from the np → dγ reaction completed in LMPl in 1971 has yielded \( \gamma = \frac{1}{2} \frac{P_r = -(1.30 \pm 0.45) \times 10^{-8}}{\text{which exceeds by almost two orders of magnitude the theoretical prediction. Numerous attempts at a theoretical interpretation of this result have not met with success. Note also that its statistical reliability is only three standard deviations.}} \)

The general scheme of the new experiment remained essentially the same (Fig.1), in that as a proton target water of the reactor first circuit at the core center is used. The enhancing of intensity of thermal neutron flux in the water cavity produces a very strong source of np -capture γ-rays of \( \sim 10^{15}/s \). Gamma rays from the source are led out through a collimating channel to a transmission type polarimeter, its diamond-shaped absorber (see Fig.2) being magnetized by two 200 A coils.

To obtain reliable results, two formidable problems have to be solved:

1. To remove the contribution from the core γ-rays polarized at a level of \( 10^{-3} \) due to the bremsstrahlung radiation of electrons emitted by uranium fission fragments in fuel elements (it should be recalled that the polarization looked for is on the order of \( 10^{-7} \));

2. To compensate for reactor power fluctuations which at the polarimeter switching frequency (1 Hz) are of order \( \sim 10^3 \), while the statistical fluctuations in the count of γ-rays recorded in the detector are about 100 times smaller.

To solve the first problem, the water cavity is screened by lead shields with the total thickness brought up to 80 mm. A new method was employed in this experiment to compensate for reactor power fluctuations. Earlier one used for this purpose a monitoring detector mounted beneath the polarimeter, its signal being subtracted from the signal of the main detector. Because of different geometric arrangement of the two detectors total cancellation of the fluctuations could not be achieved in principle. Besides, the smaller efficiency of the monitoring detector (it could not be made thicker because of the absorption involved) increased the statistical error by about 20%.

In the new experiment, the polarimeter is divided into two equivalent sections arranged at the same level symmetrically with respect to the beam and magnetized in opposite directions. Gamma-rays pas-
sing through each section are detected by separate scintillation detectors made up of identical CsI (Tl) crystals operating in the integral mode.

In the subsequent subtraction of the current signal of one detector from that of the other, the in-phase part of the signals due to reactor power fluctuations is subtracted while the signals of interest due to the circular polarization of $\gamma$-rays should add since the two polarimeter sections are oppositely magnetized. In this way a practically complete compensation, down to the statistical level, has been achieved.

The associated electronics employs CAMAC crates.

The sensitivity of the apparatus to polarization has been increased by a factor of two compared with the first experiment and brought to a level corresponding to an error in $P_\gamma$ measurement of $\pm 1.3 \times 10^{-6}$ per day.

Measurements were started with a double lead screen surrounding the water cavity of total thickness 60 mm, just as in the first experiment.

The results of the main (with water in the cavity) and control experiments are given in the first column of Table IV.

Among the numerous control experiments performed the most important ones are:

1. To check the contribution of reactor core $\gamma$-rays to the effect, the water was displaced from the cavity by a graphite target in a zirconium shell. The scattering characteristics of graphite for $\gamma$-rays are very close to those of water, with a practically zero neutron absorption cross section.

2. The effect of fast neutrons whose scattering from the cavity and screen material can result in their polarization and hence, in a polarization of the neutron capture $\gamma$-rays was checked by means of a target made of a powder mixture of graphite and boron-10. This target suppressed the thermal neutron flux by a factor of five while enhancing the fast neutron effect if it does exist. At the same time this experiment provides an additional check on the possible effect of core $\gamma$-rays.

3. For a zero control experiment a target of titanium was used whose $\gamma$-rays, primarily of E1 multipolarity, were assumed to be
unpolarized.

The result obtained in measurements with water, $\delta = (0.74 \pm 0.11) \times 10^{-7}$, corresponds to a polarization $P_\gamma = -(1.55 \pm 0.25) \times 10^{-6}$ in full agreement with the first experiment.

Table IV. Results of the main and control measurements of circular polarization in the $np \rightarrow d\gamma$ process; $\delta \times 10^7$.

<table>
<thead>
<tr>
<th>Target</th>
<th>2 layer screen around water cavity</th>
<th>2 layer screen + cylindrical Pb displacers</th>
<th>3 layer screen around water cavity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_2O$</td>
<td>$-0.74 \pm 0.11$</td>
<td>$-0.015 \pm 0.105$</td>
<td>$-0.09 \pm 0.16$</td>
</tr>
<tr>
<td>$C$</td>
<td>$-0.93 \pm 0.17$</td>
<td>$-0.13 \pm 0.09$</td>
<td></td>
</tr>
<tr>
<td>$B$</td>
<td>$-0.57 \pm 0.11$</td>
<td>$-0.15 \pm 0.09$</td>
<td></td>
</tr>
<tr>
<td>$D_2O$</td>
<td>$-0.12 \pm 0.12$</td>
<td>$0.11 \pm 0.24$</td>
<td>$0.41 \pm 0.13$</td>
</tr>
</tbody>
</table>

Note: The results obtained with titanium target do not exclude the existence of a circular polarization effect in the $^{48}Ti \ (n\Gamma) ^{49}Ti$ reaction (see the first part of this report). If, however, this effect comes from the left-right asymmetry in the Compt. scattering of $\gamma$-rays from polarized electrons (instrumental asymmetry), its contribution in measurements with water in the cavity should not exceed in polarization a value $1 \times 10^{-7}$ because of the energy dependence involved (see ref./15/).

However in contrast to the first experiment /7/, the same result, within experimental accuracy, was observed also in the control measurements with the graphite and boron targets, $P_\gamma (C+B) = -(1.40 \pm 0.20) \times 10^{-6}$, indicating a spurious effect which could be due to the core $\gamma$-ray contribution.

To check this assumption, a third external screen consisting of dia. 36 mm aluminium pipes filled with lead was added. The results obtained after this are presented in the second column of Table IV. The effect is seen to have disappeared (or, at least, to have dramatically reduced) in control experiments, however it is no more present in the water target measurements as well.

These data yield for the circular polarization of $\gamma$-rays in the $np \rightarrow d\gamma$ reaction a value /16/ $P_\gamma \leq 5 \times 10^{-7}$ at a 90% confidence level. The final measurements were carried out with a new three-layer solid screen of total thickness 80 mm in lead using in place of graphite in the control experiment heavy water which has the same scattering and absorbing characteristics for $\gamma$-rays as $H_2O$. The results of these measurements are given in the last column of Table IV.

An analysis of all the data presented in Table IV taking into account the effect observed with the $C, ^{40}B$ and $D_2O$ targets yields for the circular polarization of $\gamma$-rays in the $np \rightarrow d\gamma$ process
a value

\[ P_y = (1.8 \pm 1.8) \times 10^{-7} \]

The effect observed in the first experiment was most probably due to residual penetration of core \( \gamma \)-rays through the cavity screens.

The zero result of the graphite target control experiment 
\( \delta(C) = (0.01 \pm 0.16) \times 10^{-7} \) could be due to the presence of an uncontrolled impurity (say, chlorine, at a \( \sim 10^{-2} \) wt % level) possessing a large \( P \)-violating effect in the radiative neutron capture process (see part one of the report) which could bring about compensation of the core \( \gamma \)-ray contribution. There were no grounds then to assume that an impurity could affect substantially the integral spectrum.

Thus new experiments have on the one hand, permitted us to reconcile the theory with the \( np \rightarrow d\gamma \) process, and on the other, revealed a remarkably high "survivability" of the \( P \)-violating effects in \( n\gamma \)-reactions under integral detection of \( \gamma \)-rays.

References.