RESEARCHES OF PROPERTIES OF A SYMMETRY OF FUNDAMENTAL INTERACTIONS

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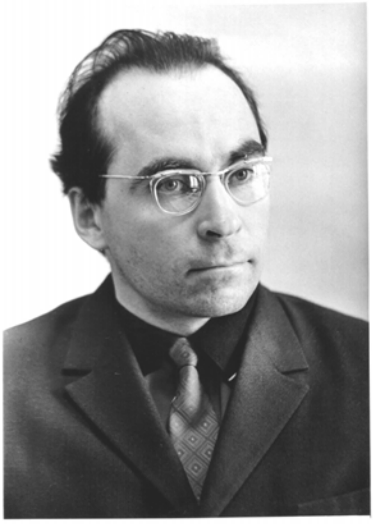
Surprising feature of human memory: that was many years ago is remembered, as if it would be "yesterday", and the recent events have less steep impress. Probably, it is connected not only to the properties of the memory, but also to that the past always is associated with the young, best years of life. Not the last role thus



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plays, certainly, and the significance of events, distribution of which in time is determined "by madam Good Luck". In this schedule we had luck: we came in Phystech in lab of L.I. Rusinov at the end of 50-th Years (V.L. in 1957, V.N. in 1958), when it was just shown, that one of the fundamental laws of physics, the conservation law of spatial parity, is upset in weak interactions. This discovery being one of the most considerable in the modern physics, resulted in a severe "shock" of existed time-space conceptions. It opened new capabilities, and we well remember that a spirit of romanticism and overall enthusiasm, which has griped of physical community. The new ideas and proposals were emerging almost each day: V-A-theory, the conserning vectorial the current, the combined parity, the two-component neutrino, the universality of a weak interaction... Our small in the number group (except for us it included an radio designer and a technician) immediately joined in this precipitant flow, which bore many new questions demanding the experimental answers.

The maiden experiments were connected to research of β-γ correlations with the purpose of check some (as it is now known, not the most relevant) predictions of the theory. They have allowed to accumulate a definite experience, to run in experimental techniques, to enter into a range of problems, to find our place.

To middle of 60-s our group already become a sector and it was able to do the more serious works. To that time the mainstream of researches was also determined.

Effects of parity-non-conservation in nuclear forces

In 1964 the publication [I] by Yu.G. Abov, P.A. Krupchitsky and Yu.A. Oratovsky appeared, informing about observation by them of asymmetry $\mathbf{A}_\gamma$ of γ-quanta in the reaction of polarized neutron capture by ^{113}Cd. And in the beginning of 1965 the work by F. Boehm and E. Kankeleit [2] was published, where the circular polarization of γ-quanta in the decay of unpolarized nuclei ^{181}Ta was found. Both effects testified to violation of P-parity in nuclear electromagnetic transitions and were interpreted as a demonstration of weak nucleon - nucleon interaction in nuclei. The existence of such interaction was forecast by a hypothesis of a universal weak interaction, pushed by M. Gell-Mann and R.P. Feynman, R.E. Marshak and E. Sudarshan in 1958. The reiterated attempts of experimental endorsement of this hypothesis, undertaken up to the activities mentioned above, had no success. It not seemed surprising, as the matter concerned a observation of effects conditioned by the weak internucleon interaction at a background of the strong interaction, which is 6 – 7 orders of magnitude stronger. The situation was a little eased for γ-decay of nuclei, for which regular nuclear γ-transition on any causes is retarded, so effects of weak NN-interaction (parity non-conservation) are rather increased. It turned out, that the value of such an enhancement can be up to 1000 times, and consequently, it is possible to expect an appearance of the effects of non-conserving of parity at a level of 10^{-4} and even greater. The effects of such an order were found in works of Yu. Abov et al. [1]: $\mathbf{A}_\gamma = (-\ 3.7 \pm 0.9)\cdot 10^{-4}$ and F. Boehm et al. [2]: $\mathbf{P}_\gamma = (-\ 2.0 \pm 0.4)\cdot 10^{-4}$.

Both groups used a conventional then the "counting" technique with separate detecting of particles. Because of limitations imposed by the resolving power of detectors and an electronics engineering, it did not allow to increase a intensity of a source for obtaining the best statistical accuracy and increased the time of experiment (each of them took not less than year!). And as a result, it lowered a confidence to the obtained value. It was absolutely clear, that the new approach and new methodical ideas is needed to improve accuracy of measurements and mainly the statistical one.

Such an approach was offered by V.M. Lobashev in [3]. It consisted in giving up customary pulse technique of registration of intensity of γ-quanta. V. Lobashev offered to measure a current of the detector with resonant selection and accumulation of the periodic component of the signal, when the intensity of a flux of γ-quanta is changed synchronously with switching a direction of magnetization of a polarimeter (in measurement of circular polarization of γ-quanta) or at the revolution of a spin of a neutron (in case of measurement of asymmetry $\mathbf{A}_\gamma$).

Subsequently this method received a title "integral method". For the first time it was realized by group in a staff of V.M. Lobashev, V.A. Nazarenko, L.F. Saenko, L.M. Smotritsky and G.I. Kharkevich at creation of the installation, the scheme of which is given in Fig.. Rather exotic for the nuclear physics device, a pendulum of astronomical clock with high Q-factor, was utilized as the storage of an effective periodic signal. The swings of the pendulum were free, with a driving force being proportional to an output current of the detector.

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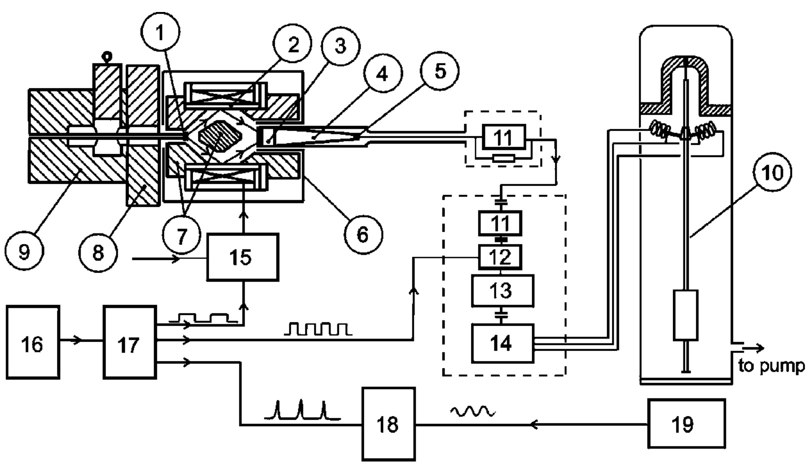

clock, *18* is phase meter, *19* is photoelectric system

This installation was utilized for the measurement of the circular polarization (c.p.) of γ-quanta in a number of γ-sources.

The maiden experiments with γ-source of ^{181}Ta have shown, that the result, published by F. Boehm and E. Kankeleit, is simply incorrect: our measurements [4] at a confidence level of 95 % gave the value $P_\gamma < 2\cdot 10^{-5}$. The capabilities of a conventional pulse technique, used by F. Boehm, in essence mismatched to the problem of the reliable measurement of so small polarization and to the correct account of the "false" factors imitating effect.

In subsequent our experiments [5, 6] c.p. of γ-quanta of ^{181}Ta was found at a level 30 times smaller, compared to Boehm's result: $\mathbf{P}_\gamma = -(6.0 \pm 1.0)\cdot 10^{-6}$ and for ^{175}Lu γ-quanta $\mathbf{P}_\gamma = +(4.0 \pm 1.0)\cdot 10^{-5}$.

These experiments were done carefully and with a high statistical accuracy, they had a number of check experiments. As a matter of fact they have put a final point in a problem of the evidence of the existence of weak NN interaction (soon our results were confirmed in a number of other labs of world, while the pioneer data of Abov's group could not be reproduced by other researchers within 8 years, though authors themselves confirmed them twice). In 1974 the above-named works together with researches of Abov's group were awarded by the Lenin prize " For the detection and research of effects of the violation of parity in nuclear electromagnetic transitions ".

As next object of researches the nucleus of ^{41}K was selected forming after β-decay ^{41}Ar. The nucleus ^{41}K is a near-magic one, therefore, there was a hope, that such thin effects as nucleon correlations will not render severe influencing for theoretical interpretation of results of the experiment. But argon is a gas, and it is not simple to create a compact source with high activity. Furthermore, half-life of ^{41}Ar is only 1.87 h, that complicated a problem in addition.

For the solution of this problem on the reactor WWR-M of PNPI the closed loop with circulation of gaseous argon at a pressure of 100 atmospheres was built. A gas was irradiated in the active zone of the reactor and was condensed in the source unit. Further the γ-quanta coming out of a source were analyzed for circular polarization.

The obtained result was $\mathbf{P}_\gamma = +(2.0 \pm 0.4)\ 10^{-5}$ [7]. It once again confirmed the existence of effect which is not contradicting to theoretical estimations, but, as well as other experiments with nuclei it has not allowed to advance in the definition of the amplitude of weak N-N interaction, because the unknown nuclear-structural factors of amplification of the effect were existing. Namely this value is especially interesting to the theory.

Certainly, from the very beginning of the study of weak interaction in nuclei it was clear, that from the point of view of theoretical interpretation, it would be ideal to measure P-odd effects for "pure" nucleon-nucleon system (or, at least, for a few-nucleon one). But such measurements are extremely difficult, as in this case there are no grounds to expect any amplification of effects. And this means, that we have to be able reliably to measure the effects of the order of $\approx 10^{-7}$ (!).

One of such type experiments, the measurement of c.p. of γ-quanta in reaction of the radiative capture of an unpolarized neutron by proton ($np \to d\gamma$), was offered by V. Lobashev in [8]. For obtaining a high-intensity source of γ-quanta of the reaction studied it was offered to use a water cavity in the reactor core as a proton target. The size of the water cavity has to be optimized to produce in this volume the greatest possible flux of thermal neutrons.

This proposal was realized at the reactor WWR-M of PNPI in two stages. The maiden cycle of experiments was made in 1968-1972 [9]. The second one was made in 1979 – 1983 [10]. The water cavity formed in the centre of the active zone of the reactor, gave a high activity of source of γ-quanta from the reaction of np-capture: $\approx 10^{16}$ s^{-1} in a volume of the target of $3\cdot 10^3$ cm^3. The γ-quanta were moved out from a source through a 4 m layer of water protection of the reactor with the help of the vertical channel-collimator. The circular polarization was analyzed by a polarimeter of a special design. The integral method of registration of the γ-quanta was used.

Among set of problems, which one should be decided, here we would like to mark two of them. Both are bound with location of the target inside of the reactor.

The first one is an elimination of the contribution from γ-quanta of an active zone. As the direct experiments shown, these γ-quanta have the polarization $\approx (1-2)\ 10^{-3}$. It is conditioned by a bremsstrahlung of β-electrons of fission products of uranium in fuel units of a reactor. This contribution was suppressed by selection of the conforming geometry of experience and by placement of lead-bismuthic screens around the water cavity. At the maiden stage the effective thickness of screens was 60 mm, on second one amounted to 80 mm. Arrangement in the active zone of the composite device, of a water cavity with screens up to 500 kg of weight and removal of the large number (up to 90 pieces) fuel units, has demanded of the reactor staff of unconditional boldness and large activity on alteration of all the management and the protection systems of the reactor.

The second problem is conditioned by that fact, that a level of a fluctuation of the reactor power, and consequently of the neutron flux, on frequency of the remagnetization of the polarimeter is $\approx 10^{-3}$, that exceeds a level of a statistical fluctuation of the number of γ-quanta in the detector ($\approx 10^{10}$ s^{-1}) two order of magnitude. This increases a statistical error of measurements by the same value. For compensation of fluctuations of reactor power at the first stage the monitor detector was utilized. It was arranged under the polarimeter, and its current signal was subtracted from a signal of the main detector, that was arranged after a polarimeter, with the help of the special electronic circuit. At the second stage, the differential polarimeter consisting of two identical sections, arranged symmetrical relatively an axis of a beam of γ-quanta, was used. The sections were magnetized in opposite directions. The γ-quanta, passed through each of these sections, were detected by the separate detectors. At the subsequent subtraction of one signal from the other, a part of a signal, conditioned by fluctuations of the reactor power, was cancelled, while a desired signal from the circular polarized γ-quanta was stored, since the direction of magnetizing of sections of a polarimeter was opposite.

The first stage of experiment testified to the existence of the effect of circular polarization at a level of three standard deviations: $\mathbf{P}_\gamma = -(1.30 \pm 0.45)\cdot 10^{-6}$, that almost two orders of magnitude exceeded the estimations obtained in the different theoretical approaches.

Unfortunately, for technical reasons, immediate prolongation of experiments at the reactor of WWR-M was impossible. Such a possibility arose only in 1979, when our reactor started to operate with new type of fuel units WWR-M5.

The new cycle of measurements was done with modernized setup, with reinforced shielding of a water cavity, and it had the numerous check experiments. These measurements gave for the c.p. of γ-quanta of np-capture the value:

$$\mathbf{P}_\gamma = (1.8 \pm 1.8)\, 10^{-7}, \text{ which means that at a confidential level 90 \%} \ \mathbf{P}_\gamma < 5\cdot 10^{-7}.$$

Despite of achievement of record accuracy in measurement of the c.p. of γ-quanta (with allowance for polarization efficiency of a polarimeter, equal to ≈ 5 %, this corresponds to accuracy $\approx 10^{-8}$ for the measurement of asymmetry), the effect of the weak neutron-proton interaction was not found.

Later non-zero value of the effect in research of other elementary nucleon-nucleon system was discovered by other authors in proton-proton scattering, but for a neutron-proton system it is not found till now.

Simultaneously in our lab there were researches of other P-odd effects on nuclei.

The discovery by group of G.V. Danilyan in ITEP of parity non-conservation in fission of heavy nuclei in capture of polarized neutrons stimulated search for effective methods of separate registration of light and heavy fragments under conditions of the high intensity of the fission acts. And again it has appeared possible to apply an integral technique with separation of light and heavy fragments due to their different path in the gas proportional chamber.

By this method it was not only uniquely confirmed the existence of P-violation effect in nuclear fission, but also the so-called left-right asymmetry of breakage of fragments relatively to a spin of a captured neutron was found [11]. It testified to one or maximum to two-channel dynamics of fission and indicated, that the effect of the parity violation is determined by mixing of the small number of neutron resonances, having eliminated thus "mystical" explanations of this phenomenon.

Hereinafter the method of separation of light and heavy particles on their path in the proportional chamber was advanced in application to reactions of neutron capture in light nuclei (^{3}He, ^{6}Li, ^{10}B) [12]. It has allowed to receive very low limits on value of P-odd effects for these reactions and to watch here a left-right asymmetry.

By group in a staff V.A. Vesna, E.A. Kolomensky, V.M. Lobashev, A.N. Pirozhkov, L.M. Smotritsky and N.A. Titov in 1981 a new P-odd effect was detected: dependence of total cross-section and cross-section of the radiative capture on a helicity of a neutron for nuclei ^{117}Sn, ^{139}La and for natural mixture of isotopes of bromine [13]. The data obtained with thermal neutrons demonstrated, that the effect in the total cross-sections is completely determined by effect in the radiative capture, that uniquely indicated to their connection with compound-resonances. The impressive measurements of a group from Dubna were the direct evidence of this fact [14]. They found the dependence of total cross-sections on a helicity of the neutrons near P-wave resonances for ^{81}Br, ^{111}Cd, ^{117} Sn and ^{139}La.

Other completely unexpected effect was found in our lab in measurement of the circular polarization and asymmetry of γ-quanta in an integral γ-spectrum of the nγ-reactions on nuclei [15]. It has appeared, that even in this case, when the γ-spectrum contains hundreds of γ-transitions between states with different spins and parities, P-odd effects do not "come to nothing" compensating one another, and they have large enough value: for nuclei C1, Br and Sn at a level of $\approx 10^{-5}$, and in a case of La even of the order 10^{-4}. Later these effects were explained within the framework of the statistical approach and, if such description is fair, the analysis of integral effects gives more simple (from the experimental point of view) way of obtaining the information about a weak matrix element, than data analysis for partial γ-transitions.

Search for effect of violation of time invariancy. The neutron electric dipole moment (EDM)

The ruin of a conservation law of spatial parity originated the experiments on check of accuracy of other conservation laws, in particular, time parity or T-invariance. In 1964 J.H. Christenson et al. [16] have notified about an observation of violation of T-invariance in the decay long-lived K^0-mesons. There arose a question about possibility of finding this phenomenon in other processes. In this respect most perspective is a search for electrical dipole moment of fundamental particles in particular of neutron. The experiments on looking for EDM of a neutron already had a certain history. The executed in 50-th Years by N. Ramsey et al. the first experiments set an upper limit for neutron EDM : $\mathbf{d_n} < 5\cdot10^{-20}$ e·cm. Ramsey used a so-called magnetic resonance method with separate oscillating fields H_1 and area of a constant homogeneous field H_0 between them, where the spin of a neutron precessed around of the field direction.

For search of the neutron EDM in the area of a field H_0 the electrical field E was superimposed parallel to H_0, and the direction of the electrical field could be reversed. If EDM is not equal to zero, it will interact with the electrical field. This interaction will be added to interaction of the neutron magnetic moment with a magnetic field H_0, that will result in a shift of the resonance curve or an alteration of counting rate at the fixed frequency.

Despite of an apparent simplicity of the scheme of experiment, its realisation is a rather difficult task: the value of the frequency shift at the reversal of the electrical field is extremely small. For example, for the electrical field of ± 25 kV·cm^{-1} the frequency shift amounts to $2.5\cdot\cdot10^{-5}$ s^{-1} for EDM = 10^{-24} e·cm.

With respect to Ramsey's result the reserve for improving accuracy still was available; however soon it became clear that it is restricted by a limit of $\approx 3\cdot10^{-24}$ e·cm. Afterwards this limit was reached by group Ramsey-Miller at the high-flux reactor in Grenoble.

Meanwhile in 1968 F.L. Shapiro [17] has offered to use for looking up EDM ultracold neutrons (UCN), i.e., neutrons with speed less than 6 – 7 m·s^{-1} or with energy of about of 10^{-7} eV. The remarkable property of these neutrons is their capacity to experience the total internal reflection from boundary vacuum-material at any angle of incidence, if the neutron speed is less than some critical value, which depends on kind of material on the boundary. Due to this property UCN can be retained ("be stored") in a closed volume for a long time, in principle up to a lifetime of a neutron. Thus a time of interaction of neutrons with the device (spectrometer) and accuracy of measurements are increased.

Just this idea was utilized by our group in experiments aimed at search for EDM of a neutron, conducted at the WWR-M reactor since 1968. It was necessary to start "from zero point".

At the first stage the problem of a injection from the reactor enough intense ($\approx 10^3$ 1/s) UCN flux (in Dubna, where they were identified for the first time, the counting rate was several neutrons per second), development of methods of their polarization, storage and detecting was put. The different materials (aluminium, magnesium, beryllium) were tested as a converter, on which a part of thermal neutrons is transformed to ultracold ones due to inelastic scattering. The influence of surface quality of a neutron guide on a yield of UCN was investigated, the material for its manufacturing was selected, and the methods of a polishing of the surface were designed. The different materials for manufacturing the chamber of the spectrometer, in which the neutrons should be stored, were tested. The methods of polarization and detection of UCN were worked out.

As a result of these activities [18] the vertical channel of UCN with the beryllium converter, stainless steel neutron guide (intra-reactor part) and glass neutron guide covered with ^{58}Ni was built at the WWR-M reactor of LNPI. The intensity of UCN beam at the output of the neutron guide of size 6×7 cm^2 amounted to ≈1500 1/s. The UCN polarization, obtained by a method of passing of neutrons through a magnetized ferro magnetic film, was 70 – 75 %.

At the same time there was a manufacturing of a spectrometer for search for EDM. The chamber of the spectrometer represented the cylinder 50 cm in diameter and 6 cm of height, with flat lids, serving as electrodes. The walls of the chamber were made of a quartz glass with the mat surface coated with beryllium oxide (isolator), the lids were manufactured from metallic beryllium. The high voltage (≈150 kV) was applied to these lids. The sign of electrical field varied each 200 s.

The maintenance of high stability of resonant conditions was a serious problem. For the solution of this task the chamber was placed into three-layer screen from permalloy, and the system of external and internal (on the basis of cesium quantum magnetometers with optical pumping) stabilization of the magnetic field was used.

The first experiments, made in 1975, with the equipment described above have shown, that the sensitivity of the installation is characterized by an uncertainty in EDM determination of $\approx 10^{-22}$ e·cm·d^{-1}. In essence, these first measurements had demonstrated a possibility of using UCN for search for the neutron EDM. And though their sensitivity has appeared poor, they have urged to revise the approach used, to advance a technique and to refine the installation.

The principal moment in realisation of any measurements is the detection and elimination of sources of false effects. It is specially difficult to make, when the speech goes about extremely small effects. In experiments of Ramsey's type in practice there is no possibility to do a "zero" check experiment. Here a main source of false effect is non-parallelism of electrical and magnetic fields, which, when switching of an electrical field, results in frequency shift of a resonance, equivalent to EDM (in centimetres):

$$e \cdot \mathbf{d_n} = \mu_\mathbf{n} \cdot (\mathbf{v}/\mathbf{c}) \cdot \sin\alpha \approx e \cdot 0.7 \cdot 10^{-22}\, \mathbf{v} \cdot \sin\alpha,$$

where $\mathbf{v}$ is the speed of a neutron, and α is angle between $\mathbf{E}$ and $\mathbf{H}$.

When using UCN, this effect in practice is absent due to the small speed of the neutrons. However, other obstacles (the instability of intensity and of resonant conditions, influence of breakdowns and switching of an electrical field etc.) remain the major sources of false effects. To eliminate them (or at least to suppress), the differential measurement method was offered and carried out. The single chamber system of "storage" of neutrons was substituted by two-chamber one with the opposite direction of an electrical field in chambers. The high voltage was applied to a mean electrode dividing the chambers, while a top and bottom lids were kept at a zero potential. Each chamber was coupled with its own analysing and detecting systems by a separate neutron guide. This means, that the sign of EDM effect, measured separately for each chamber, should be opposite as the electrical field $\mathbf{E}$ in chambers is opposite in direction. At the same time both chambers, arranged one above other, are in a common field $\mathbf{H_0}$ and they also have a common system of oscillating fields $\mathbf{H_1}$. Therefore all effects produced by instability of the magnetic field, of the resonance frequency or phase, should have the identical sign and value. In practice it allows to eliminate the influence of such effects during the data analysis obtained for two channels, and also to increase sensitivity of experiment by a factor of 2. The two-chamber system has allowed to reduce sharply the influence of switching effects of the electrical field, as well as the effect of instability of neutron intensity.

The classic method of Ramsey with separate oscillating fields used at early stages of our experiments, generally speaking, is not too suitable for UCN, as in this method the efficiency of spin-flip of a neutron depends on a dispersion of neutron speeds in a beam (note, that the UCN spectrum is not monochromatic). With understanding this situation, we have elaborated an "adiabatic" version of this method [19], which removed the indicated shortage and permitted to increase the sensitivity in EDM measurements nearly by a factor of 2.

The essential modernization of the system of the analysis of neutron polarization was made. The method "of the double analysis of polarization " was designed and applied with each component of neutron polarization being detected separately (at the resonance frequency the intensities for both components are approximately equal). This allowed to increase the detected intensity of neutrons by a factor 2. At a two-chamber system with the double analysis of the polarization we had four detectors, that allowed us to make the comparison and the correlation analysis of the data and to determine a possible systematic error and a cause of its origin.

Here it is necessary to say, that the conditions of a overcrowded experimental hall of the reactor, filled in with installations with strong magnetic fields, are completely unfavourable for high-precision measure ments: the level of a fluctuation of a magnetic field in the location of the EDM spectrometer is too great. For elimination of their influence (together with the two-chamber system and the double analysis of polarization) the method of stabilization of resonant conditions by the automatic tuning to the frequency of a resonance under the indications of the cesium magnetometer had played an essential role.

All these steps have allowed us in practice completely to suppress the influence of systematic effects imitating EDM, whereas the group, working on the high-flux reactor of Institute of Laue-Langevin in Grenoble, had the results with the dispersion that exceeded a statistical error more than two times.

To increase the UCN intensity, we began to work with a beryllium converter cooled down up to 30 K, that increased the intensity by a factor of 10 – 12. Next we worked with the liquid hydrogen sources of a different design, placed in centre of the active zone of the reactor, that has allowed us to receive the UCN beams with the intensities: at the first stage of about $5 \cdot 10^4$ n·s^{-1}, and then $\approx 10^5$ n·s^{-1} (in more detail see the article of A.P. Serebrov in this book).

In the experiment of Ramsey the beam of thermal neutrons passed through the chamber of the spectrometer in $2 \cdot 10^{-2}$ s. In our first experiments described above, in which the so-called "flowing" method was used, this time was ≈1.5 s. Subsequently it was increased up to 5 s, and with the transition to "accumulative" version with UCN storage in the chambers this time became ≈100 s.

At the page 9, Fig. 1, of this edition the scheme of the installation is showed, which was used at different stages of measurements. The result of the last experiments has given for EDM of a neutron the value [20]:

$$\mathbf{d_n} = (+2.6 \pm 4.0 \pm 1.6) \cdot 10^{-26} \text{ e·cm},$$

where the first error is statistical, second one is systematic. This corresponds to the upper limit for EDM at a 90 % confidence level:

$$|\,\mathbf{d_n}\,| < 9.7 \cdot 10^{-26} \text{ e·cm}.$$

Similar on accuracy the result was obtained by the international group of physicists in a competition to which our researches were realized [21]:

$$\mathbf{d_n} = (-3 \pm 2 \pm 4) \cdot 10^{-26} \text{ e· cm}.$$

This last work is made on the high-flux reactor of Institute Laue-Langevin using the ultracold neutrons in version of a single chamber spectrometer that, in our view, cannot guarantee the correct account of systematic effects.

The record level of the accuracy, achieved in two indicated works, has allowed to reject a lot of theories, forecasting an existence of EDM at higher level.

Completing this part, it would be desirable to say, that tens of people participated in the EDM experiment for its long history, and it is difficult to enumerate all their names. However main of them, having paid the greatest creative contribution at the different stages of researches, should be called. They are: A.P. Serebrov, V.F. Ezhov, S.N. Ivanov, G.D. Porsev, I.S. Altarev, Yu.V. Borisov, A.I. Egorov, Yu.V. Sobolev.

Other (or concomitant) experiments

The gamma quanta and their polarization properties as the tool of research, apart from search for effects of parity violation, were repeatedly used in our lab in a number of other experiments. Here we put only two such examples.

a) In connection with measurements of a small circular polarization of γ-quanta in experiments on looking for P-odd effects in nuclear forces on a boundary of 60-es and 70-es by P. Bock [22] and also by V.M. Lobashev and L.M. Smotritsky [23], it was revealed anomalously large (as contrasted to predictions of the quantum electrodynamics) value for the factor of the left-right asymmetry in Compton scattering of γ-quanta with oriented electrons in ferromagnetic scatterers with relatively large thickness. The detail analysis of this anomaly has enabled one to establish, that the mechanism of originating this phenomenon is connected to dependence of value of the observed asymmetry on the distance between points of location of the first and the second scatterers at double scattering. The further study of this process has shown, that the large asymmetry arises in the case, when the γ-quantum flies along the direction of the magnetization of a ferromagnet after the first act of scattering. The value of resultant effect increases with distance gone by

γ-quanta in the ferromagnet. This phenomenon was interpreted in [24] as effect of a rotation of the plane of polarization of γ-quanta at passing through medium with polarized electrons. The rotation originates from the spin-spin interaction of electrons with photons (it is an analogue of Faraday's effect for the light passing through magnetized medium). Theoretically such an effect was forecast by V.G. Baryshevsky and V.L. Luboshits, who together with V.M. Lobashev, A.P. Serebrov and L.M. Smotritsky were registered as the authors of the discovery of this phenomenon.

b) The measurement of the circular polarization of γ-quanta proved to be a rather effective method at research of one more problem, the problem of structure of a deuteron. The deuteron is the simplest bound system from two nucleons, therefore, the study of a nature of interaction in it is the extremely important for understanding fundamental properties of nuclear matter. It would seem, that in this case all can be accurately calculated. Meanwhile during many years there was a namely almost 10 % discrepancy between the experimentally measured and theoretically calculated values of a capture cross-section of thermal neutrons by protons. Among numerous attempts of explanation of this discrepancy the hypothesis of G. Brait and M.L. Rustgi [25] has appeared in 1971. They offered to take into account an admixture of the triplet $^3S_1$ state to the main capturing ^1S_o state. The authors of the hypothesis have also offered an experiment for its check by measuring angular distribution of γ-quanta in the reaction of capture of polarized neutrons by polarized protons. In view of known experimental difficulties this experiment was not realized.

Meanwhile we offered and fulfilled the other experiment [26], much more sensitive and simple. It consisted in measurement of the circular polarization of γ-quanta in capture of polarized neutrons by unpolarized protons. The fact is that if the neutron capture takes place from a ^1S_o state, the information about initial polarization of the neutron is completely lost. The capture from a $^3S_1$ state results in origin of the circular polarization ≈) of γ-quanta, and its value is determined by an interference of amplitudes of capture from ^1S_o and $^3S_1$ states, while in experiment offered by Brait and Rustgi the asymmetry depends on a square of amplitude of transition from a $^3S_1$ state.

Within one week of measurements the statistics testifying to the absence of circular polarization of γ-quanta in investigated reaction with accuracy of ≈1.5 % was taken. It corresponded to that the relative contribution to cross-section of np-capture due to transition amplitude from $^3S_1$ state does not exceed $\approx 2\cdot 10^{-4}$, i.e. the result completely disclaimed a hypothesis of G. Brait and M.L. Rustgi. Note that later the discrepancy between the theoretical and experimental values of thermal neutron-proton capture cross-section was explained mainly by the contribution of meson exchange currents, though the small discrepancy still remains. Subsequently we repeated this experiment twice with more perfect engineering for achievement of better accuracy, in hope to receive more fundamental information about NN-interaction. Here we have in view to obtain supplementary data about the wave functions of continuum, the check of orthogonality of triplet wave functions of continuous and discrete states of the np-system, a possible contribution of quark degrees of freedom, the phenomenology of parity violation and so on.

The result of the last experiments made by group in a staff of A.N. Bazhenov, L.A. Grigorieva, V.V. Ivanov, E.A. Kolomensky, V.M. Lobashev, V.A. Nazarenko, A.N. Pirozhkov and Yu.V. Sobolev is as follows [27]:

$$P_\gamma = -(1.5 \pm 0.3)\cdot 10^{-3}.$$

This value agrees satisfactorily with theoretical one, calculated within the framework of existing conceptions.

The present plans of our collective are connected with prolongation of activities on the search for the neutron EDM and the research of P-odd effects in the np-system and in light nuclei. Any considerable progress in accuracy in EDM-experiment demands an essential (at the least by one-two orders of magnitude) increase of intensity of UCN sources. This, in turn, puts forward the new requirements to a technique of the control for possible systematic effects, bound mainly with instability of magnetic resonance conditions in storage chambers of UCN. The solution of two of these very complicated problems, apparently, is already impossible without cooperation with the scientists from foreign scientific centres. Now together with group of Prof. W. Heil from Mainz University (Germany) we develop in essence a new magnetometric system on the basis of polarized ^3He [28]. At the Munich University in department of Prof. S. Paul a solid deuterium source of UCN of a new generation for the created FRM-II reactor (TUM, Germany) is designed with the active assistance of research fellows of our lab.

The realization with indispensable accuracy of experiments for the measurement of asymmetry A_γ of gamma quanta from the reaction np → dγ and P-odd effects in reactions with polarized neutrons with light nuclei (^{6}Li, ^{10}B) allows to hope to obtain values of the constants of weak meson-nucleon coupling. These works are planned to carry out on a polarized neutron beam of the reactor PIK.

In summary it would be desirable to say following. The experiments described above encompass more than 40-year period. Much has changed for these years. We started in the famous A.F.Ioffe Physical-Technical Institute of Academy of Sciences of the USSR. Then there was a branch of the PhTI in Gatchina, LNPI of AS of USSR and, at last, PNPI of RAS. The staff of lab has been changing, people were coming and going. Some the most worthy of them today are the heads of exploratory collectives and laboratories (see corresponding articles in this edition). Invariable there is only the creative atmosphere in which we lived and worked all these years and without which the described experiments would be simply impossible. So long as this imaginative atmosphere is saved, there will be also new discoveries and new interesting outcomes.

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