RESULT ON THE MEASUREMENTS OF THE P-ODD ASYMMETRY OF EMITTED γ-QUANTA IN THE $^{10}B(n,\alpha)^7Li^* \rightarrow {}^7Li(g.st.)$ REACTION WITH SLOW POLARIZED NEUTRONS

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Abstract

A series of ultra-sensitive experiments has been carried out in 2001-2009 at the ILL measuring *P*-odd asymmetry in γ-quanta emission in the nuclear reaction $^{10}\mathrm{B}(n,\alpha)^7\mathrm{Li}^* \rightarrow \gamma + {}^7\mathrm{Li(g.s.)}$ with polarized cold neutrons. The resulting value of the asymmetry coefficient is $\alpha_{P\text{-}odd} = +(0.0 \pm 2.6_{stat} \pm 1.1_{syst}) \times 10^{-8}$. These experiments profited from high-intensity PF1B neutron facility and a new version of the integral measuring method: for decreasing experimental uncertainties, the frequency of neutron spin-flip was higher than a typical reactor power noise frequency. Using the new value, we constrain the weak neutral current constant in the cluster model framework to $f_\pi^{^{10}B} \leq 0.6\times10^{-7}$ (at 90% c.l.). This constraint agrees with that following from the nuclear reaction $^6\mathrm{Li}(n,\alpha)^3\mathrm{H}$: $f_\pi^{^6Li} \leq 1.1\times10^{-7}$ (at 90% c.l.). However, they both contradict to the "best" value in the quark model by Desplanques, Donoughe, and Holstein $f_\pi^{\mathrm{DDH}} = 4.6\cdot10^{-7}$.

Introduction

Present experiment has been performed within a framework of program on determination of the weak meson-nucleon coupling constants, especially a pion constant f_π (in the literature f_π is also frequently called h_π or h^1_π.), which is dominated by neutral currents in the nucleon-nucleon (NN) weak interaction.

Our current understanding of nuclear parity violation is far from complete [see, e. g. Refs. 1 – 3]. Still there is the question how to describe NN parity violation starting from the Standard Model. The difficulty is twofold: these experiments require high precision to discern the small parity violation signal, and in theory, the nonperturbative character of the quark-gluon dynamics makes a "first-principle" formulation of parity violation NN interactions as yet impossible. From the other hand, the study of PV phenomena is valuable for many reasons [see, e. g. Ref. 4]. First of them, it is only way to study the neutral weak interactions between quarks at low energy.

The most complete theoretical description of NN parity violation is an approach of Desplanques, Donoghue and Holstein (DDH) [2, 5]. According this model, at low energy the electroweak NN interaction is described in terms of the exchange of the lightest mesons π, ρ, ω. Weak NN-potential is parameterized by a set of weak meson-nucleon coupling constants: f_π, h_ρ^0, h_ρ^1, h_ρ^2, $h_\rho^{'1}$, h_ω^0, h_ω^1, where subscript denotes the meson-mediator, and superscript is the amount of the isospin transfer (ΔT). All the physics of W and Z gauge bosons exchange between the quarks is hidden inside of these constants. The f_π constant is important because it is completely determined by electroweak neutral currents. DDH provided theoretical "reasonable ranges" and "best values" for the meson-nucleon coupling constants using SU(6) symmetry, constraints from non-leptonic hyperon decay data, and the quark model to estimate the experimentally unconstrained terms. The experimental results from nuclear and hadronic PV measurements have been analyzed using the DDH framework, leading to constraints on combinations that typically enter PV observables [1, 3, 6, 7]. The results are in general agreement with the DDH reasonable ranges, though the ranges themselves are quite broad, and the constraints from different experiments are not entirely consistent with each other. A particular quandary involves f_π. The constants, which are dominated by charged currents, are in consistent with the DDH "best values". From other side, the neutral current f_π constant varies within a broad range from 0 up to ~ $9 \cdot 10^{-7}$ for different experiments (the DDH "best value" $f_\pi = 4.6 \cdot 10^{-7}$). A conceptually simple observable sensitive to f_π is the P-odd asymmetry of emitted γ-quanta from the np→dγ reaction with thermal polarized neutrons. However, the expected effect is only $2 \cdot 10^{-8}$ in the best case, and reaction cross section is rather small ~0.2 b.

We suppose that nuclear reactions of light nuclei (A=6-10) with polarized slow neutrons is the most promising candidate to study the weak neutral current properties in nucleon-nucleon (NN) processes. Such nuclei could be described, for instance, in framework of cluster and multi-cluster models [8, 9] if the excitation energy is <25-30 MeV; P-odd effects could be estimated at least for the nuclear reactions with ^{10}B and ^{6}Li.

Using this method, the authors of ref. [10] calculated P-odd effect in the nuclear reaction $^{6}Li(n,\alpha)^{3}H$ in terms of meson exchange constants:

$$\alpha_t^{theory} \approx (-0.45 f_\pi + 0.06 h_\rho^0) = -2.8 \times 10^{-7} . \quad (1)$$

After a series of experiments in 2002, 2005, 2006 at the ILL reactor, we obtained an experimental value for this asymmetry [11] $\alpha_t^{\exp.} = (-8.8 \pm 2.1) \times 10^{-8}$, and constrain for the weak neutral current constant $f_\pi \le 1.1 \times 10^{-7}$. This value is by far smaller than the DDH "best value".

Authors of refs. [12, 13], using multi-cluster approach, calculated the P-odd asymmetry of γ-quanta emission in the transition $^{7}Li^* \to {}^{7}Li + \gamma$ (M1), $E_\gamma = 0.478$ MeV following the reaction $^{10}B(n,\alpha_1)^{7}Li^*$ induced by polarized cold neutrons:

$$\alpha_\gamma^{theory} = 0.16 f_\pi - 0.028 h_\rho^0 - 0.009 h_\rho^1 - 0.014 h_\omega^0 - 0.014 h_\omega^1 \quad (2)$$

Using the DDH "best values" for the exchange constants, eq. (2) yields the value: $\alpha_\gamma^{DDH} = 1.1 \times 10^{-7}$. Note that if the weak neutral current constant were equal zero, the cluster models (2) would suggest the asymmetry value $\alpha_\gamma^{DDH} = 0.3 \times 10^{-7}$. Our experiments in 2001-2002 and in 2007 [14-16] provided a P-odd asymmetry value in the nuclear reaction (2) equal to $\alpha_\gamma^{raw} = (2.9 \pm 2.7) \times 10^{-8}$; "0-test" resulted to $\alpha_{0-test} = -(2.1 \pm 2.8) \times 10^{-8}$. Here, recent measurement of this asymmetry is presented.

Principle of measurement and the experimental setup

The experiments were curried out on high-intense PF1B beam of polarized cold neutrons [17] at the Institut Laue-Langevin (ILL), Grenoble, France. The average neutron wavelength at PF1B was equal $\langle \lambda_n \rangle = 4.7$ Å. The neutron beam cross-section at the sample position was equal 80 mm by 80 mm, the total neutron flux at the sample ~3×10^{10} s^{-1}, and the neutron polarization $P = (92\pm2)\%$.

A typical scheme of experiment is shown in Fig. 1. The neutron spin $\vec{\sigma}_n$, the γ-quantum momentum $\vec{p}_\gamma$ and the neutron momentum $\vec{p}_n$ were set as follows: $\vec{\sigma}_n \| \vec{p}_\gamma \perp \vec{p}_n$. P-odd effect could be observed in the asymmetry of the γ-quanta emission angular distribution:

$$\frac{dN_\gamma}{d\Omega} \sim 1 + \alpha_{P-odd} \cos\theta , \qquad (3)$$

where θ is the angle between $\vec{\sigma}_n$ and $\vec{p}_\gamma$. The magnetic field guiding the neutron spin, and the γ-quantum momentum, were set parallel to each other with an accuracy of $\varphi = 10^{-2}$ sr.

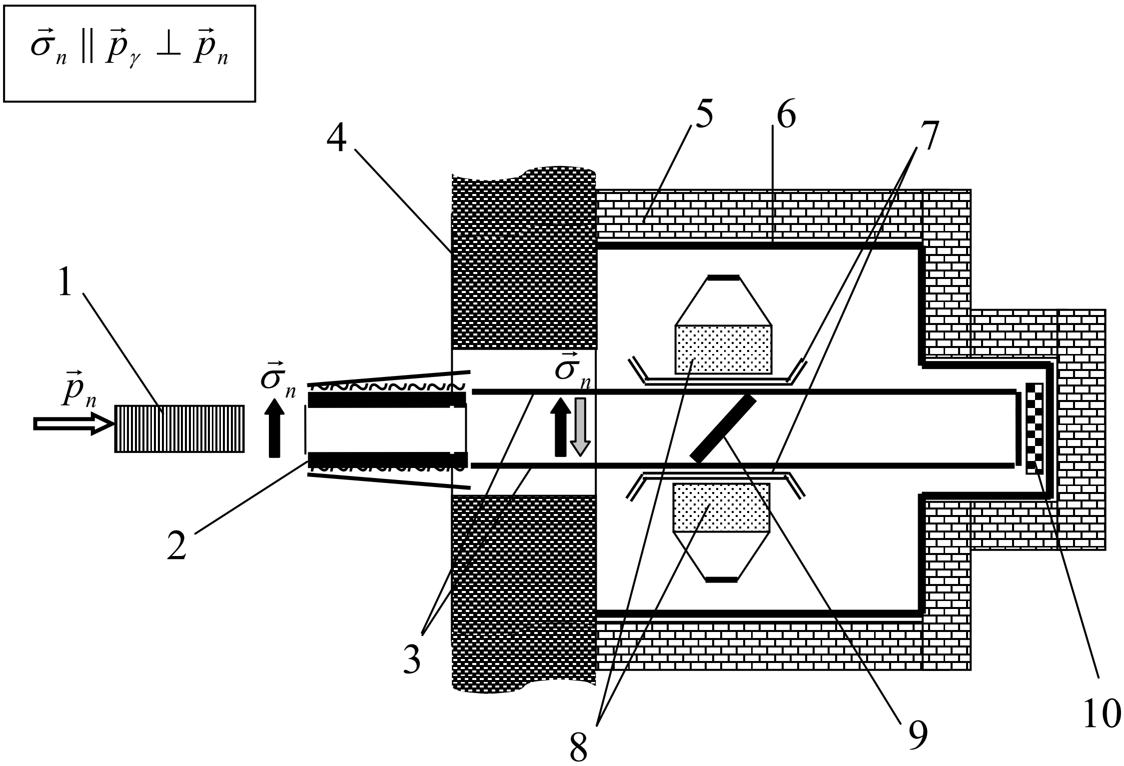

Fig. 2. A scheme of the experimental setup:
1 – polarizer; 2 – adiabatic "spin-flipper"; 3 – tube made of boron rubber filled in with flowing-through ^4He; 4 – concrete wal; 5 – lead shielding; 6 – boron rubber; 7 – Helmholtz coils; 8 – detectors; 9 – the sample; 10 – lithium absorber.

The guiding magnetic field is produced by Helmholtz coils; it is reversed periodically during measurements. The strength of guiding magnetic field was equal to several Oersteds; no magnetic materials were used to build the experimental setup. The neutron polarization is reversed via switching high-frequency flipper, placed at a distance ~1 m from the detector; the flipper frequency is ~20 kHz.

The sample is amorphous powder ^{10}B with isotopic enrichment of 85% and the total weight of 50g, enclosed in an aluminium case measuring 160×180×5 mm. The sample was covered with an aluminium foil with a thickness of 14 μm on the neutron entrance side and installed in the neutron beam; an angle between the beam axis and the sample surface was equal 45°. Mostly a neutron was absorbed in the sample emitting an α-particle and a γ-quantum. The distance between the sample centre and the centre of each detector is 75 mm. Each γ-quanta detector consists of an NaI(Tl) crystal with a diameter of 200 mm and a thickness of 100 mm. "Hamamatsu" S3204-03 photodiodes with a size of 18×18 mm^2 were used to detect scintillation photons. The photodiodes are connected to the NaI(Tl) crystals via Plexiglas light-guides. The detectors were inserted into aluminium-alloy cases placed symmetrically on two opposite sides of the sample. The electric-current preamplifiers used in our experiment convert the detector current I_{det} into the output voltage U_{out} so that it is equal $U_{out} = I_{det}R_{fb}$, where R_{fb} is the resistance feedback. The output voltages (their constant terms) were equal to U_{out} ~ 1-2 V and the resistance feedback were R_{fb}~ 70 MΩ, i.e. the detector currents were I_{det} ~ 200 μA. The variable term of the detector output signal (voltage) was enhanced by a factor of about 30.

The setup was surrounded with lead protection with the thickness of 15 cm. The internal surface of the lead shielding was covered with borated rubber or a borated polyethylene. The polarizer and spin-flippers were protected with boron collimators. The detectors were protected with boron rubber. We used boron for the protection, but avoided ^{6}Li, as the asymmetry of ^{8}Li β-decay (the energy of 12-14 MeV, resulting from a 10% admixture of ^{7}Li is as high as $\alpha_{P-odd}^{^8Li} \sim 3\%$ [18]. This asymmetry could compromise the results with false P-odd effect. Background scattering (with no sample) was found to be as low as 5% compared to scattering in the sample.

The measuring procedure and data treatment

To achieve an accuracy of ~10^{-8} in the asymmetry measurement, any fluctuations in the electronics or reactor neutron flux, as well as any interference with external electric signals or other false effects, have to be minimized. We used two detectors in the electric current mode and a method to compensate for eventual false effects described elsewhere (see, for example [11, 19]).

To compensate for fluctuations in the reactor power, we used special measuring procedures involving a pair of detectors. In the experiments 2001-2002 we used the analog integrators in order to measure the detector current. In the integral method, electrical signals can be presented as the sum of their constant and variable components. The "number of events" in a time interval is proportional to the sum of the variable U/K and constant U_C components of the signal, integrated over this interval. The coefficient K describes the amplification of the variable component of the signal. As $U_C >> U$ and $U_C{}^+ \cong U_C{}^- = U_C$, the normalised asymmetry coefficient is given by:

$$a_{\text{P-odd}} = (U^+ - U^-)/(2KU_C) . \quad (4)$$

For every detection channel, four consecutive voltages $U_1^+, U_2^-, U_3^-, U_4^+$ are combined in a "single measurement" and added as follows: $U^+ = U_1^+ + U_4^+$, $U^- = U_2^- + U_3^-$. Each value $U_1^+, U_2^-, U_3^-, U_4^+$ is the voltage at the preamplifier output averaged over the interval T of the main experiment; the interval T defines the duration of a "single measurement" $4T$ and the frequency of switching the neutron spin. These combinations allow us to suppress linear drifts. Both detectors measure simultaneously the same process but provide opposite signs for the asymmetry effect; fluctuations in the reactor power will have an identical impact in both detectors and will carry the same sign. The asymmetry was calculated for each single measurement in every detector. Formulas for the effects in each measuring channel are given in ref. [11]. In both channels the results of N subsequent measurements in a series were summed; the constant component of a signal was measured ones per each interval T.

The calculated effects $\alpha_i^{(1)} = \left(U_i^{+,(1)} - U_i^{-,(1)}\right)/2$ and $\alpha_i^{(2)} = \left(U_i^{+,(2)} - U_i^{-,(2)}\right)/2$ for the two detectors are of opposite sign; these values are measured synchronously. Therefore, taking advantage of the double detectors, by calculating $\bar{\alpha}_{\text{comp}}$ the asymmetry value is doubled, and the effect of fluctuations in the reactor power is subtracted due to subtraction of one value from the other. The compensation coefficient L is calculated for every series of single measurements with the condition that the variation $D\left(\bar{\alpha}_{\text{comp}}\right)$ of the average value of the absolute effect $\bar{\alpha}_{\text{comp}}$ is minimal. The final result is averaged over all series; the weight is taken into account.

To further compensate false asymmetries we changed the direction of the guiding magnetic field and measured an equal number of series for both directions. For the averaged values we took into account the direction reverse of actual P-odd effect due to reverse of the guiding magnetic field. The field direction was reversed every 4 minutes.

We emphasise that the three stages of signal evaluation work with differences:

1. between variable parts of the signals (absolute effect of P-odd asymmetry) $\alpha = U^+ - U^-$ for opposite neutron spin polarisations; these differences are calculated for every pair of measurements for both detectors,
2. between the absolute effects for the two detectors $\alpha_i = \alpha_i^{(1)} - L \cdot \alpha_i^{(2)}, \quad i = 1 \div N$. Since P-odd asymmetries in the detectors have opposite signs, the effect is doubled. These differences are calculated for each direction of the guiding magnetic field (referred to as "$\rightarrow$" and "$\leftarrow$"),
3. between the effects for each direction of the guiding magnetic field: $\alpha_i(\rightarrow) - \alpha_i(\leftarrow)$, $i = 1 \div N$. P-odd effects are added in this case, because they have opposite signs.

At each of the 3 stages of calculation described above, we subtract values measured for two opposite conditions. Effects of equal sign and equal size thus cancel, and the asymmetry persists. The identical treatment of the results for two detectors and for the two directions of guiding magnetic field thus allows us to avoid completely any noticeable influence of parasitic electromagnetic effects.

A new version of the integral measuring method was first used to measure P-odd asymmetry in ref. [20]: the frequency of neutron spin flip was higher than the typical frequency of the reactor power noise. It has been shown in ref. [21] that the asymmetry measurement uncertainty is only due to frequencies higher than the spin-flip frequency. The spectral noise density decreases sharply at high frequency; so the corresponding systematics could generally be suppressed.

A significant fraction of light is lost in the γ-detectors, as a photodiode sensitive area is much smaller than the diameter of a NaI(Tl) crystal; we therefore had to amplify the electronic signals significantly. This amplification caused a “microphone effect” in the electronic channels induced by mechanical vibration of the preamplifiers. As the effect depends on electronic channel, it is not subtracted by the measuring procedure described in ref. [19]. Spin-flipping with high frequency “cuts” low-frequency non-correlated components of the two signals and therefore reduces the corresponding uncertainty. In order to suppress the microphone effect, we built a new electronic system measuring the current. It is adapted to neutron spin-flip frequencies of 0.01-50 Hz. In 2007 and 2009, we carried out in the ILL two measurements of P-odd asymmetry in the reaction $^{10}B(n,\alpha)^7Li^* \to \gamma \to {}^7Li(g.s.)$ using new system of experiment control and read out. All measurements were carried out in series of ~4 minutes. The frequency of neutron spin flip was equal to *5 Hz*. In order to reduce effects of apparatus asymmetry and radio noise, we reversed the direction of the guiding magnetic field at the sample ("→" or "←") in every series using Helmholtz coils. We measured an equal number of series for two field directions in analogy to ref. [11]. This procedure reversed the neutron spin and the measured asymmetry sign respectively. Thus the subtracted signal contains double asymmetry; in contrast, apparatus-related false asymmetries are subtracted. As the spin-flip frequency was not high enough to minimize the measurement uncertainty, we used also the scheme of compensation for reactor power fluctuations.

In contrast to the experiment studying the nuclear reaction with ^{6}Li [11], in which a "zero" experiment was carried out (aluminium foil covered sample for preventing charged particles to penetrate into the ionization chamber), we cannot carry out an analogous experiment in the integral current mode with the ^{10}B sample, as γ-quanta from the neutron reaction with boron cannot be separated from those from other reactions with impurity nuclei. We therefore performed two test experiments of other kind.

One test consisted in measuring without ^{10}B sample but with the aluminium foil only that usually was covering the sample. Then neutron beam penetrates the material behind the sample position and produces γ-quanta, in contrast to measurements with ^{10}B sample (the neutrons are otherwise absorbed by sample in the main experiment). Therefore, this is not a true "zero" test, but a check for false *P*-odd asymmetry related to the apparatus. The statistical accuracy of such measurements is not higher than in the experiment with ^{10}B sample. The measurement with the aluminium foil provided the result (2007): $\alpha_{0-test}^{^{10}B,\exp.} = (4.2 \pm 7.3) \times 10^{-8}$.

The second test investigated possible false effects due to (n, γ) reactions in the apparatus material with scattered neutrons. The ^{10}B sample is replaced by a target that scatters neutrons but does not emit γ-quanta in (n, γ) nuclear reactions. If the scattering by this test target is much stronger than that by the ^{10}B sample, the false effects are greatly enhanced. Graphite is such an "ideal" scatterer. Its absorption cross-section for thermal neutrons is only $\sigma_{n\gamma} = 3.8\times10^{-3}$ b, but its scattering cross-section is $\sigma_S = 4.8$ b. A target of natural graphite scattered ~43% neutrons. Using this value and taking into account the cross-sections of absorption and scattering in boron as well as the values of the constant (spin-independent) parts of the detector signals in the experiments with boron and graphite, we calculated contribution of false *P*-odd effect due to neutron scattering in boron and the consequent absorption in the apparatus materials: $\alpha_{scatt.,^{10}B}^{calc.} = (2.7 \pm 3.0) \times 10^{-9}$. Obviously, the corresponding correction is small.

Besides, ~0.002 of neutrons scatters in air in vicinity of the sample. Assuming 100%-scattering in graphite, taking into account the cross-sections of neutron absorption in boron and the scattering of neutrons in air, correcting for the ratio of constant parts of signals in analogy to the previous calculation, we constrain the effect of neutron scattering in air: $\alpha_{scatt.,air}^{calc.} = (3.5 \pm 3.9) \times 10^{-8}$. This is the most significant eventual contribution to the measured *P*-odd effect. It was present in all measurements; therefore we took it into account when making “0”-tests.

P-odd asymmetry coefficient in the reaction on boron was equal: $\alpha_{P-odd}^{^{10}B,\,\exp.} = -(1.1 \pm 8.2) \times 10^{-8}$, taking into account background measurements only with aluminum foil.

Experiment in 2009

A new measurement of P-odd asymmetry in the reaction with boron was carried out in 2009.

We noticed in 2007-year experiment that relative uncertainty of measurements in the reaction with boron and that in the "0-test" (normalized to constant signal in the boron measurement) were approximately equal. On the other hand, the uncertainty in the "0-test" should be much smaller because currents in γ-quanta detectors in "zero" experiments were much smaller than currents in the main experiment with boron. We concluded that there have been high-energy γ-quanta in all experiments; their energy of E_γ = 5-7 MeV was typical for (n, γ) – reaction in constrictive materials and in air in detector vicinity; the intensity of such γ-quanta in the main experiment and in the "0-test" were approximately equal. In the integral detection method, the current in detectors is proportional to NE_γ, where N is the number of γ-quanta, and E_γ is the γ-quanta energy, thus even small amount of γ-quanta of high energy could increase considerably the measurement uncertainty as the energy of γ-quanta in the reaction (1) is only E_γ = 0.478 MeV.

In order to decrease the amount of such high-energy γ-quanta we built a new system to deliver neutrons to the target. It included a tube with the length of 2m made of boron rubber filled in with flowing-through ^{4}He. Substitution of air by helium allowed decreasing of neutron scattering; scattered neutrons were totally absorbed in the boron rubber; helium consumption was ~100 l/day. The boron target of enriched ^{10}B isotope was installed inside the tube close to the γ-quanta detectors.

This modification decreased the relative uncertainty in the main measurements by a factor of 1.2. The measurement resulted to the P-odd asymmetry value ${}^{raw}\alpha_{P-odd}^{^{10}B,\,\exp.} = -(2.0 \pm 2.5) \times 10^{-8}$ measured for 31 days. The principle gain in the experimental accuracy arrived from the "0-test", in which the intensity of γ-quanta produced in the aluminum foil became small. Compared to the uncertainty of measurements without using helium-filled tube, now the uncertainty decreased by a factor of 3 (from 1.5×10^{-7} to 0.5×10^{-7} per day). The "zero" measurements resulted to the following contribution to the P-odd asymmetry: $\alpha_{0-test}^{^{10}B,\,\exp.} = -(1.3 \pm 1.6) \times 10^{-8}$. This value is normalized to constant signals in the main measurements with the boron target; it is corrected for finite neutron polarization and the average cosine of the solid angle covered by the detectors. Taking into account the "0-test" we get the following result for the 2009-year experiment: $\alpha_{P-odd}^{^{10}B,\,\exp.} = -(0.7 \pm 3.0) \times 10^{-8}$.

The table 1 presents values of the P-odd asymmetry coefficients of γ-quanta emission in the reaction $^{10}B(n,\alpha)^7Li^* \to \gamma \to {}^7Li(g.s.)$ as well as results of "zero" experiments measured in all performed experiments in ILL (all data are taken into account; no 3σ-cut is applied). Table 2 indicates measured and estimated systematic effects and corrections in our measurements.

Table 1. P-odd asymmetry coefficients of γ-quanta emission in the reaction $^{10}B(n,\alpha)^7Li^* \to \gamma \to ^7Li(g.s.)$ as well as results of "zero" experiments.

	$^{raw}\alpha_{P-odd}^{^{10}B,\,\exp.}$	$\alpha_{0-test}^{^{10}B}$	$\alpha_{P-odd}^{^{10}B,\,\exp.}$
ILL, 2001-2002	$(2.7\pm3.8)\times10^{-8}$	$-(0.9\pm4.8)\times10^{-8}$	$(3.6\pm6.1)\times10^{-8}$
ILL, 2007	$(3.1\pm3.8)\times10^{-8}$	$(4.2\pm7.3)\times10^{-8}$	$-(1.1\pm8.2)\times10^{-8}$
ILL, 2009	$-(2.0\pm2.5)\times10^{-8}$	$-(1.3\pm1.6)\times10^{-8}$	$-(0.7\pm3.0)\times10^{-8}$
Average measured value			$(0.0\pm2.6)\times10^{-8}$

Table 2. Measured and estimated systematic effects and corrections in measurements.

1) Neutron polarization	(92±2)% (*)
2) Left-right asymmetry	$<10^{-9}$ (**)
3) Stern-Gerlach steering asymmetry	$<10^{-10}$ (*)
4) ^{8}Li beta decay	$<9*10^{-12}$ (**)
5) False P-odd effect from impurities	$<= 8*10^{-10}$ (*)/(**)
6) P-odd asymmetry in secondary reactions involving α-particles emitted from the studied reaction	$\lvert\alpha_n^{sec}\rvert < 1.6\times10^{-13}$ – for fast neutrons, $\lvert\alpha_\gamma^{sec}\rvert < 4\times10^{-17}$ – for γ-quanta. (**)
7) Asymmetry caused by difference in energy of emitted γ-quanta	$\lvert\alpha^{Dop}\rvert \le 8.0\times10^{-9}$ (**)
8) Electromagnetically-induced false effect	$\alpha_{noise} = (-5.1\pm7.1)*10^{-9}$ (*)
8) "0"-test	$\alpha_{0-test}^{^{10}B,\,\exp.} = -(1.3\pm1.6)\times10^{-8}$ (*)

(*) – measured; (**) – calculated.

Thus, we obtain the final result: $\alpha_{P-odd}^{^{10}B,\,\exp.} = (0.0\pm2.6(stat.)\pm1.1(sys.))\times10^{-8}$.

Discussion and estimation of the weak neutral current constant

One could estimate the weak neutral current constant value using the cluster nuclear model, the measured value of P-odd asymmetry coefficient in the γ-quanta emission in the reaction $^{10}B(n,\alpha)^7Li^* \to \gamma \to ^7Li(g.s.)$, and the value of the weak charged current constant $h_\rho^0 = -11.4\times10^{-7}$, as this has been done in studying the reaction $^6Li(n,\alpha)^3H$ [11]. We used eq. (2) and "the best" values of constants $h_\rho^1 = -0.2\times10^{-7}$, $h_\omega^0 = -1.9\times10^{-7}$ and $h_\omega^1 = -1.1\times10^{-7}$ within DDH theory.

Thus, the weak neutral current constant and its uncertainty would be given by $f_\pi^{^{10}B} \approx -(2.0\pm1.6)\times10^{-7}$, or, at *90%* confidence level: $f_\pi^{^{10}B} \le 0.6\times10^{-7}$.

The existing data is sufficiently precise to state that the weak neutral current constant in the reaction $^{10}B(n,\alpha)^7Li^* \to \gamma \to {}^7Li(g.s.)$ is smaller than the "best DDH value". As mentioned above, the constraint for the weak neutral constant obtained in the reaction with ^6Li [11] in the cluster model framework [10] $f_\pi^{^6Li} \le 1.1\times10^{-7}$ is also smaller than the "best DDH value". Finally, we conclude that two measured constraints (with ^{10}B and ^6Li) for the weak neutral constant agree with each other but contradict to the "best DDH value" $f_\pi = 4.6\times10^{-7}$.

Fig. 2 shows a plot of constraints for the weak interaction constants following from different experiments. We used a diagram from ref. [22] updated by new data measured in the reactions $^6Li(n,\alpha)^3H$ and $^{10}B(n,\alpha)^7Li^* \to \gamma \to {}^7Li(g.s.)$ treated in accordance with the cluster model. As it is seen in the Fig. 2, our data agree well with results of other experiments; we suppose that application of the cluster model is justified.

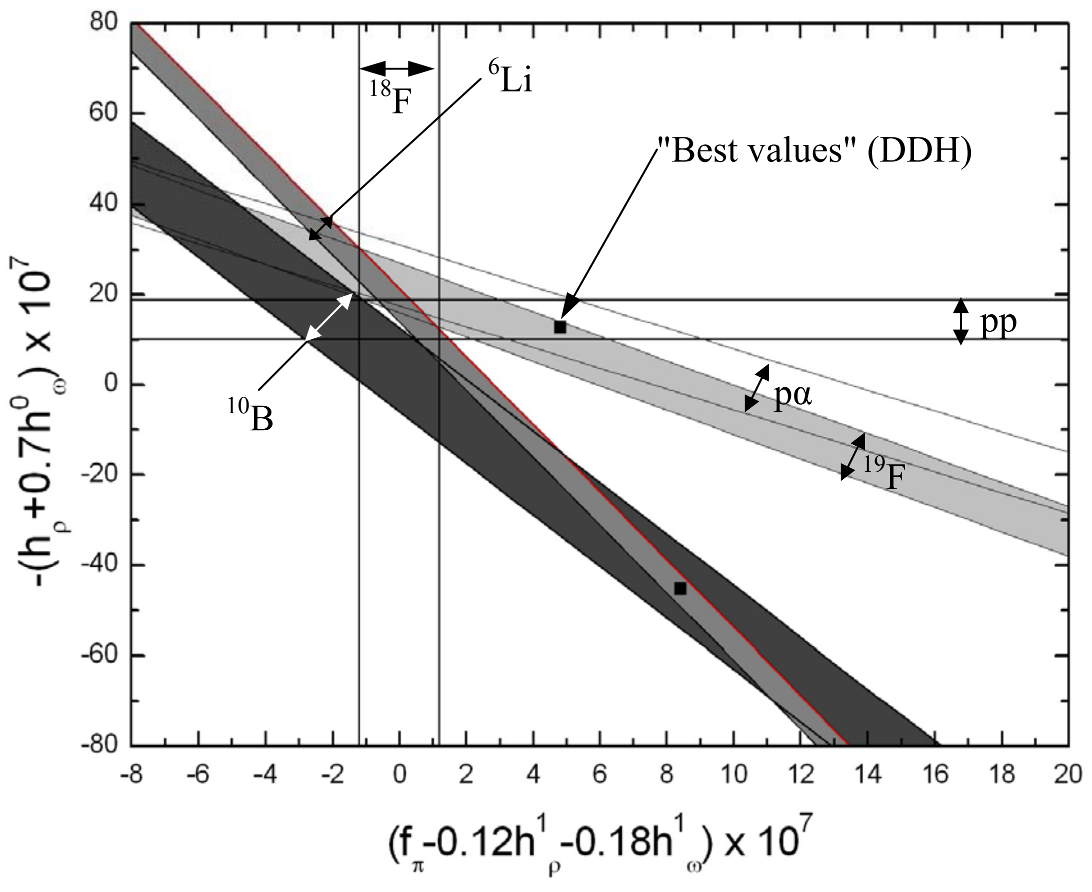

Fig. 2. Experimental constraints for the weak interaction constants.

Conclusion

We measured P-odd asymmetry in γ-quanta emission in the reaction $^{10}B(n,\alpha)^7Li^* \to \gamma \to {}^7Li(g.s.)$ and in "0" tests using in the last experiment a new method based on the neutron polarization switching with a frequency higher than the frequencies of reactor power fluctuations. This method allowed reducing the asymmetry uncertainty to δ ~ 1.4×10^{-7} per day, that is compatible to the uncertainty in P-odd asymmetry in the reaction $^{6}Li(n,\alpha)^{3}H$, where measurements were carried out using ionization chamber, in which external non-synchronous components of detector noise are absent [11]. Further significant increase in accuracy due to methodical improvements is not expected.

If the measuring time in new experiments will be as long as 120-150 days, the accuracy would increase twice. Such a measurement would improve the accuracy in P-odd asymmetry measurement to δ ~1×10^{-8}, taking into account the present result. In this case, we might hope to get non-zero P-odd effect.

We would like to underline that recent progress in the experimental methods and facilities allows us to measure reliably non-zero asymmetry values of the order of 5×10^{-8}-10^{-7} in reactions of polarized cold neutrons with light nuclei, thus giving access to studies of the weak neutral currents. However, we understand limitations of the theoretical models used and invite specialists in the field to contribute to theoretical analysis of the problem.

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