SOURCES OF THE SYSTEMATIC ERRORS IN MEASUREMENTS OF ^{214}Po DECAY HALF-LIFE TIME VARIATIONS AT THE BAKSAN DEEP UNDERGROUND EXPERIMENTS

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The design changes of the Baksan low-background TAU-1 and TAU-2 setups, allowing one to improve a sensitivity of ^{214}Po half-life (τ) measurements up to $2.5 \cdot 10^{-4}$, are described. Different possible sources of systematic errors influencing the τ-value are studied. An annual variation of ^{214}Po half-life time measurements with an amplitude of $A = (6.9 \pm 3) \cdot 10^{-4}$ and a phase of $\varphi = (93 \pm 10)$ days was found in a sequence of the week-collected τ-values obtained from the TAU-2 data sample with total duration of 480 days. The 24 h variation of the τ-value measurements with an amplitude of $A = (10.0 \pm 2.6) \cdot 10^{-4}$ and a phase of $\varphi = (1 \pm 0.5)$ h was found in a solar day 1 h step τ-value sequence formed from the same data sample. It was found that the ^{214}Po half-life averaged at 480 days is equal to (163.45 ± 0.04) μs.

PACS: 06.20.Dk; 23.70.+j

INTRODUCTION

At the last time in works intended to search for limits of the realization of the decay constant conservation law, a level of sensitivity not less than $2 \cdot 10^{-4}$ was reached for several radioactive isotopes. In the work [1], the authors showed that an amplitude of a possible annual variation of the ^{198}Au half-life ($T_{1/2} = 2.69445$ days), that was measured with the relative uncertainty of $\pm 7 \cdot 10^{-5}$, does not exceed $\pm 2 \cdot 10^{-4}$ of the central value. Variations with periods from several hours up to one year were excluded at the level of $9.6 \cdot 10^{-5}$ (95% C.L.) during the measurements of the ^{137}Cs half-life ($T_{1/2} = 10942$ days) [2]. The annual

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variation was excluded at the level of $8.5 \cdot 10^{-5}$ (95% C.L.). Variations of an activity with the periods of 3–150 days were excluded at the level of $2.6 \cdot 10^{-5}$ (99.7% C.L.) during the measurement of the ^{40}K activity [3]. It was shown that an amplitude of the annual variation does not exceed $6.1 \cdot 10^{-5}$ (95% C.L.). Variations of an activity with the periods less than one year were excluded at the level of $4 \cdot 10^{-5}$ during the measurement of the ^{232}Th activity [3], too.

A count rate of the detector recording the source radiation was a subject of investigations in all of the mentioned works. A high sensitivity of the measurements was reached by using a relatively high count rate ($\sim 10^3$ s^{-1}), by the control and stabilization of conditions of the measurements and by the use of additional arrangements for shielding the setups against of outer background.

The reached limitations multiply exceed amplitude values of $\sim 1.5 \cdot 10^{-3}$ of the ^{32}Si and ^{226}Ra count rates of annual variations discussed in [4]. The authors examined possibilities of an appearance of such variations as a result of seasonal variations of the detector characteristics or of the one of an annual modulations of the isotope decay rates themselves under the action of an unknown factor depending of the Earth–Sun distance. It is obvious that any conclusions about a possible new physical effect could be made only after complete exclusions of variations caused by the influence of the known terrestrial geophysical, climatic, and meteorological factors on the source-detector couple count rates.

Unfortunately, not all such factors could be detected and be taken into account during the measurement and data processing. For example, an annual variation with the amplitude of $(4.5 \pm 0.8) \cdot 10^{-5}$ was found as a result of a processing of the collected during 500 days data sample of Earth's surface measurement with ^{40}K source in [3]. It was found that this variation corresponded completely to the known annual variation of the cosmic rays intensity and could be explained by a cosmic rays background event contribution to the total detector count rate. A variation with the ~ 300 days period and of $4 \cdot 10^{-5}$ amplitude was found in the data collected during 480 days in the underground measurement with the ^{232}Th source. It was found that this variation correlated with a variation of a daily averaged deadtime per event and could be explained by a modulation of the RC circuit providing the shaping time of the amplifier.

The weak point of the experiments intended to monitor the stability of a controlled radiation count rate is their high sensitivity to the similar variations of measurement conditions. It seems that this shortcoming becomes unimportant in the case of the decay constant determination based on a direct registration of a nuclear lifetime between its birth and its decay. The same method was realized by us in [5] for the ^{214}Po which decays with 164.3 μs half-life [6] by emitting the 7.687 MeV α-particle. This isotope appears mainly in the excited state ($\sim 87\%$) in the ^{214}Bi β-decay. Half-lives of the excited levels do not exceed 0.2 ps [7] and they discharge instantly relative to the scale of the ^{214}Po half-life. Energies of the most intensive γ-lines are equal to 609.3 keV (46.1% per decay), 1120 keV (15.0%),

and 1765 keV (15.9%). So, the β-particle and γ-quantum emitted at the moment of the birth of ^{214}Po nuclear form the start signal and the α-particle emitted at the decay moment forms the stop signal. Measurements of "start-stop" time intervals allow one to construct decay curve at an observation time and to determine the half-life time from its shape. The ^{226}Ra source ($T_{1/2} = 1600$ y) was used as a generator of ^{214}Bi nuclei which arise in the decay sequence of the mother isotope.

The direct measurement of a nuclear lifetime allows one, moreover, to study the radioactive decay law itself. The theoretical models discussed in [8,9] predict that the decay curves could deviate from the exponential law in the short- and very long-time regions of the time scale. The theoretically predicted [10–12] so-called quantum Zeno effect consisting in a slowing down of the decay rate in the case of constant observations at the decaying object presents a special interest. Experimentally the Zeno effect was found in repeatedly measured two-level system undergoing Rabi transitions [13], but not observed in spontaneous decays.

At the first stage of our measurements, a limitation to the possible annual variation amplitude was set at the level of $3.3 \cdot 10^{-3}$. Factors limiting a sensitivity were revealed and ways of its optimization were designed.

In the present work, the fulfilled improvements of the setups, of measurement methods, and of data processing are described. An analysis of possible sources of systematic errors is performed and obtained results are presented.

1. METHOD OF MEASUREMENTS

The TAU-1 and TAU-2 setups used in [5] consist of the two scintillation detectors D1 and D2 each. The D1 consists of two glued discs of a plastic scintillator (PS) 18 mm in diameter (d) and 0.8 mm thick (h). A thin transparent radium spot was deposited preliminary in the center of the inner surface of one disc. The detector D1 records β-particles from the ^{214}Bi decays and α-particles from the ^{214}Po decays. The massive detector D2 consists of NaI(Tl) crystals destined for γ-quanta detections.

In the TAU-1 setup there was used a single NaI(Tl) crystal ($d = 80$ mm, $h = 160$ mm) as D2. The D1 is placed at the end of D2. The light collection is fulfilled from a surface of the PS disc installed on a Teflon reflector.

In the TAU-2 setup there were used two NaI(Tl) crystals (D2a and D2b with $d = 150$ mm and $h = 150$ mm) placed at the ends one to another with the gap of 10 mm. The D1 is placed into a gap between D2a and D2b. The light collection is fulfilled from a lateral side of the PS disc installed into deep narrow well with a reflecting wall.

The measurements were carried out in the underground low-background conditions at the Baksan Neutrino Observatory of the Institute for Nuclear Research RAS (BNO INR RAS, North Caucasus). The TAU-1 setup was located in the

underground laboratory "KAPRIZ" at the depth of 1000 m of water equivalent in a low-background shield made from Pb (10 cm) + Fe (15 cm) + W (3 cm). The time duration of the measurements was equal to 1038 days. The value of the half-life time τ ($\tau \equiv T_{1/2}$) deduced from the analysis of the integrated decay curve was found to be equal to (162.73 ± 0.10) μs.

The TAU-2 setup was located in the low-background room in the underground laboratory DULB-4900 [14] at the depth of 4900 m of water equivalent within the additional shield made from Pb (15 cm). The time duration of the measurements was equal to 562 days. The τ-value was found to be (164.25 ± 0.12) μs.

As one can see from the shown results, both τ-values agree with the table ones within 1σ table limit. However, they differ from one another at the level of 13σ due to our statistics. Such a large difference indicates the presence of a systematic error in the experimental results.

The τ-value equal to $(163.58 \pm 0.29\,(\text{stat.}) \pm 0.10\,(\text{syst.}))$ μs, that is lying between our values, was measured at the Gran Sasso in the recent work [15].

A possible source of the supposed error could be a small difference of sampling frequencies of the two digital oscilloscopes (DO) used for the digital record of pulses. A time duration of reference square-wave pulses from a high stability pulse generator was measured by both DOs in order to determine such a possible difference. It was found that difference of measured time durations does not exceed ± 1 time-channel for the 3400 time-channels pulse or the uncertainty is not more than $3 \cdot 10^{-4}$.

Later both setups were considerably modernized to improve the sensitivity.

In the TAU-1 setup the single-crystal detector D2 was substituted for the two-crystal detector, that is similar to one used at the TAU-2. The PS discs in the D1 detector were replaced by two silicon surface-barrier semiconductor detectors (SiD) with the diameter of a sensitive region of 25 mm. In the preliminary measurements it was found that the SiD lost forever its working characteristics at the ~ 0.5 y if an active spot of the source was deposited on the window surface in the way described earlier. The source was made as separate hermetic bag composed of the two plastic film discs each 2.5 μm thick and with the active spot deposited on the inner surface of the one disc. The source was installed hermetically between the two SiDs.

In the TAU-2 setup just a similar source was installed between the fresh PS discs in the detector D1 because of a scintillation characteristic degradation of the PS under the active spot as it was also found at the first stage of measurements. The subsequent studies proved that the detection property degradations of the D1 detectors in both the setups were excluded. An activity of ^{226}Ra was equal to 50 Bq in each source.

Registrations of the pulses in both setups are carried out by the two-channel digital oscilloscope LA-n20-12PCI which is inserted into a personal computer (PC). Pulses are digitized with 6.25 MHz frequency (160 ns/channel).

The DO-pulse registration starts by a signal from the D2 which detected ^{214}Bi decay γ-quanta. A D2 signal opens a record of a pulse sequence within time window of 655.36 μs in which the first time interval of 81.92 μs represents an event "prehistory" and the last period of 573.44 μs represents an event "history". Duration of a "history" exceeds three ^{214}Po half-lives. The digitized pulses in the TAU-1 recorded into the PC memory on the whole. Total count rate was equal to ~ 6 s^{-1}. A daily information volume was equal to ~ 10 Gb.

In the TAU-2 setup each detected event is analyzed by the "online" program. A number of pulses and their time delays are defined for each event. "Wrong" events are excluded. Only appearance times and amplitude values of pulses attributed to the "right" events were recorded in the PC memory. A complete information for each event allows one to process data in different pulse amplitude regions in the sequel. A count rate of the "right" events was equal to ~ 12 s^{-1}. A rate of the information accumulation was equal to ~ 25 Mb·day^{-1}.

2. RESULTS OF MEASUREMENTS AT TAU-1

Spectra of coincident pulses collected by the TAU-1 setup during 270 h are shown in Fig. 1. The spectrum a represents the data from the detector D1 and the spectrum b is the data from the detector D2. An amplitude threshold value of triggering pulses in the D2 channel corresponds to 450 keV. The main peak of the spectrum a conforms to the 7.69 MeV α-particle from the ^{214}Bi decays. The peaks from decays of the ^{226}Ra (4.79 MeV) and ^{222}Rn (5.49 MeV) are also presented at the spectrum. They were formed mainly as a result of random coincidences of the D2 background pulses with amplitude values above the threshold one and of the D1 α-pulses with the corresponding energy that came into the frame of the window duration.
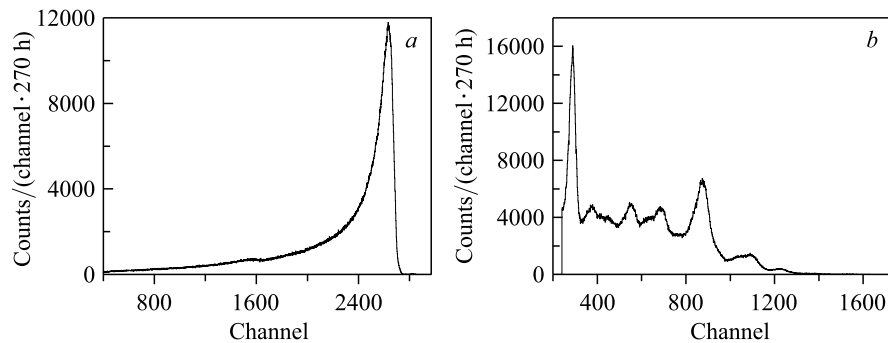

Fig. 1. Spectra of the coincided in 573.44 μs D1 (spectrum a) and D2 (spectrum b) pulses collected by the TAU-1 setup in 270 h

The D2 background is created by a residual radioactivity of the shield and of the detector materials and also by γ-quanta from decays of the ^{214}Pb appearing in the ^{226}Ra decay sequence. Random coincidences form a temporal-uniform background that is situated under the exponential decay curve which is produced by the true delayed γ–α coincidences from decays of the ^{214}Po nuclei. A small part of random coincidences is created by the ^{214}Po α-pulses that have no accompanying γ-pulses in those cases when a ^{214}Po nucleus appeared as a result of the ^{214}Bi β-decay on the ground level ($\sim$ 13%), or in the cases when the normal ^{214}Po decay was delayed for a time more than the time window duration.

A spectrum of the ^{214}Bi β-particle energy-depositions in the SiD makes up a small part of the ^{214}Po α-particle energy-depositions because of the absence of a pulse amplitude dependence on particle types. The β-particle and α-particle pulses are overlapping at short delay times, and, as a result, amplitude values of summarized pulses will fall into the right slope of the α-peak in the spectrum. Owing to this reason, the decay curve constructed for the narrow energy region corresponding to this slope will be enriched in the events with the short delay times in comparison with the lower energy events. These decay curves will show different values of the τ. The τ-value will depend on the low delay times and on the cut threshold value of a decay curve at a process of its fitting by an approximation curve. It seems that difference of the found τ-values could be unessential at the appropriate value of the threshold.

In Fig. 2, a, a start-stop delay distribution is shown obtained as a result of a processing of the data collected in 116 days at the TAU-1 setup. In addition, at these measurements the TAU-1 was shielded with Pb (15 cm) + Cu (8 cm) and was situated near the TAU-2 setup in the DULB-4900. An algorithm of the "offline" program provided the determinations of the maximum positions t_{1m} and
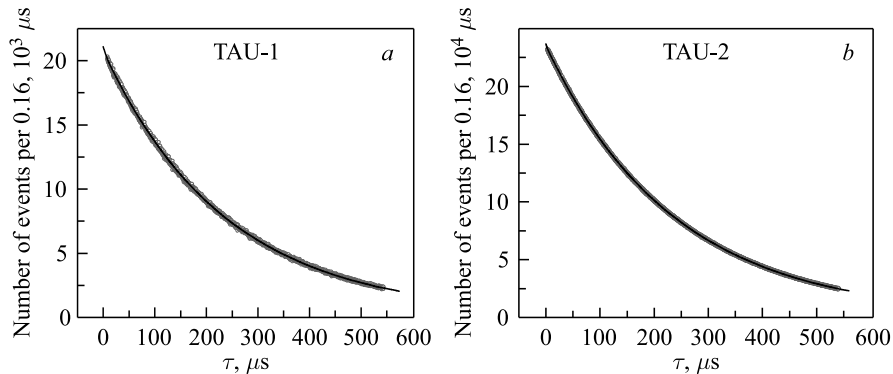

Fig. 2. a) A start-stop delay distributions obtained in 116 days at the TAU-1 ($\tau = (163.85 \pm 0.19)$ μs). b) A decay curve of the ^{214}Po obtained in 480 days at the TAU-2 ($\tau = (163.45 \pm 0.04)$ μs)

t_{2m} of pulses from D1 and D2, used for the determinations of the delay times. The following step puts into operation a correction on the pulse front durations t_{1f} and t_{2f} in order to find start points of the pulses.

A value of the delay time Δt was calculated as $\Delta t = (t_{1m} - t_{1f}) - (t_{2m} - t_{2f})$. The delay times distribution shown in Fig. 2 is approximated by an exponential function in the form

$$y = \mathbf{a} \cdot \exp\left(-\ln\left(2\right) \cdot t/\tau\right) + \mathbf{b} \tag{1}$$

by means of variations of the parameter values $\mathbf{a}$, $\mathbf{b}$ and of τ according to the algorithm of the minimum χ-square method. A value of the half-life time τ is found from this approximation. The approximations were repeated many times using different threshold cuts to reveal a possible influence of the β-particle pulse in the D1 channel on a determination accuracy of the γ–α delay time measurements. The dependences of the obtained τ-values on the cut threshold ones (curve *1*, left scale) and on the corresponding $\mathbf{b}$-values of background contributions (curve *2*, right scale) are shown in Fig. 3, *a*. They look like strictly antiphased at the used right vertical scales.
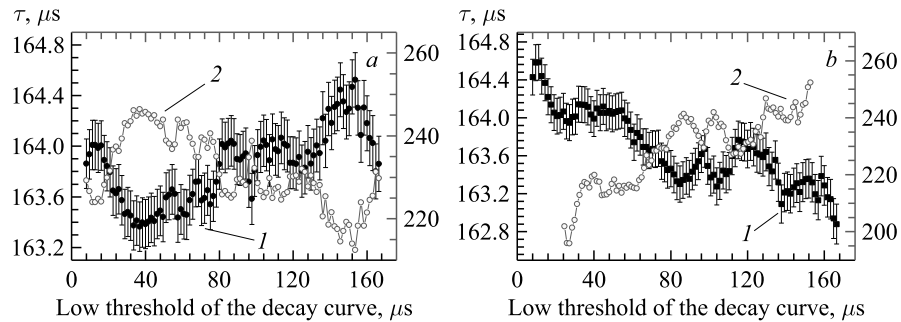

Fig. 3. Dependences of a half-life τ-value (curve *1*, left scale) and a background base amplitude $\mathbf{b}$ (curve *2*, right scale) on a decay curve cut threshold obtained with the TAU-1 in the DULB-4900 (*a*) and in the KAPRIZ (*b*)

In the present experiment before data recording, an event selection is realized strictly under the requirement of *the presence of one and only one event within time window of 0–560 μs of "history"*. In accordance with statistical laws [16], a distribution of random coincident events (under this selection rule) will be uniform within chosen time interval. This means that an amplitude value of the background contribution does not depend on the delays between the D2 and D1 pulses. So, the observed variations of $\mathbf{b}$-values reflect only ratio changes of exponent-background for concrete part of decay curve due to using formal approximation rules. In other words, a shape of the decay curve is not described by a single exponent within the time region of 10–30 μs at a level of an accuracy of $\sim 0.4\%$.

A more precise value of the τ could be found in the case when the amplitude **b** of the background contribution would be known. Such a possibility was found at the present phase of the experiment during the data analysis.

The method consists in the measurement of the delays between the D2 start pulses and the preceded D1 pulses within settled time interval, that is from the "prehistory". A distribution of the delay times for such random events will be the same as for the random events in the "history". Unfortunately, in the before collected data determination, the preceded delays were impossible because the "online" PC treatment program of a preliminary event selections excluded such events before the recording. At present time this prohibition is eliminated and all TAU-1 events are collected.

In principle, the difference between the τ-value measurements obtained at the TAU-1 and TAU-2 setups could be explained by the other way. The different gravitation potentials at the KAPRIZ and DULB-4900 laboratories could be a reason of such a difference, if there is any dependence of the τ-value on values of the gravitation potentials at places on the Earth where the setups are situated. A gravity force in the DULB-4900 is less by $1 \cdot 10^{-4}$ than the one in the KAPRIZ laboratory due to the gravitation of the rock mass above the deep laboratory as was measured in [17]. This difference is much more than the periodic variations of the Earth surface gravitation potential caused by the Sun or by the Moon orbital moving.

In order to check this assumption, the TAU-1 setup was replaced from the DULB-4900 laboratory into the KAPRIZ one. The conditions of the measurements and data processing were kept by chance in the same way. Time of the data accumulation was equal to 88 days. The results, that are similar to data shown in Fig. 3, a, are presented in Fig. 3, b. One can find from a comparison of the data in regions of minimal τ-values at 24 μs that the τ-value is equal to (163.5 ± 0.2) μs in the DULB-4900 place and is equal to (164.0 ± 0.2) μs in the KAPRIZ place. The results are in agreement within the 1.5σ interval.

3. SEARCH FOR LONG DURATION VARIATIONS OF THE TAU-2 DATA

A scintillation detector D1 in the TAU-2 has a relative α/β light output equal to ~ 0.1 [18]. Because of it, the pulses from α- and β-particles have the comparable amplitudes. This circumstance was used at a preliminary selection of the "useful" events by the "on-line" program preparing the data for a PC recording. The record program selects only the events with two pulses in the D1 channel. The first of them (β) is in a prompt coincidence and the second one (α) is in a delayed coincidence with the start pulse (γ) in the D2 channel. The corresponding spectra of the β-pulses (spectrum c) and α-pulses (spectrum b) from
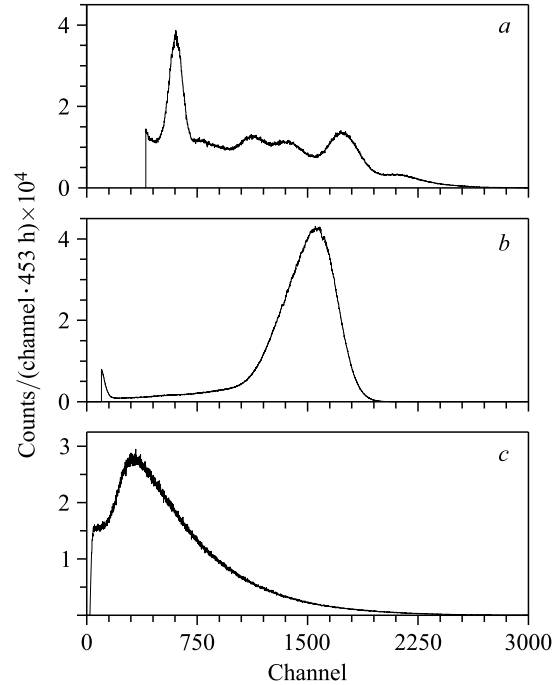
Fig. 4. Spectra of the delay coincident D1 (spectrum *b*) and D2 (spectrum *a*) pulses and the spectrum *c* of the first D1 pulses collected by the TAU-2 setup in 435 h

the D1 detector and of the γ-pulses (spectrum *a*) of the D2 detector collected in 435 hours are shown in Fig. 4. The peak at the channel ~ 1550 on the spectrum *b* is formed by the 7.69 MeV α-particles. The total time of the data collection is equal to 480 days in the period of October 2012–January 2014.

A decay curve constructed for the total data set is shown in Fig. 5, *b*. The dependences of the τ-value measurements (curve *1*, left scale) and of the defined **b**-parameter values (curve *2*, right scale) on the cut threshold values are presented in Fig. 5, *a*. The value of the τ is equal to 163.45 ± 0.04 at the threshold of 24 μs. It is compatible with the τ-value within 1σ interval, that was found in the DULB-4900 experiment with the TAU-1.

The constant linear contributions of 500, 1000, and 1400 were subtracted from the decay curve data to test a dependence of the procedure for the **a**-, **b**- and τ-values definitions on the background contributions. The **a**-, **b**- and τ-values were determined with the standard procedure for each new decay curve. The **a**- and τ-values were found to be the same for all three background contributions, and the **b**-value was reduced exactly by the subtracted constants.
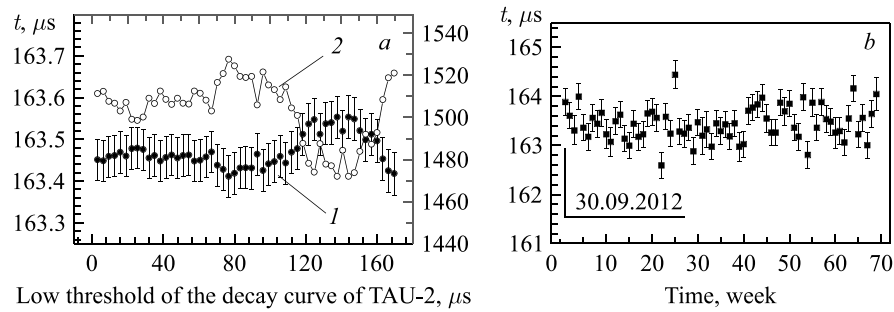
Fig. 5. *a*) Dependences of a half-life τ-value (curve *1*, left scale) and a background base amplitude **b** (curve *2*, right scale) on a decay curve cut threshold obtained with the TAU-2. *b*) Dependence on time of the τ-value obtained at the TAU-2 with the week step

This means that: 1) a shape of the background contribution is really flat since in the opposite case the parameters of the exponent should be changed to compensate an increased contribution of the background nonlinear part; 2) an accuracy of the separation of the experimental decay curve form by the exponential part and by the flat one does not depend on the background values in the treated limits.

The time-continuous data set was divided into the equal duration time intervals to search for possible time variations. The decay curves have been constructed for each data portions and the corresponding τ-values have been defined. So, the continuous time-interval sequence of the τ-value measurements within the specified time step has been found. The dependence of the found τ-values on time with a week time step of the distribution is shown in Fig. 5, *b*. The τ-values were defined by means of a χ^2-approximation of the decay-curves, each collected during 7 days, by an exponential function (1). The used time window of delays was (3.2–560) μs.

There is the statistically more powerful maximum likelihood method for estimation of exponent parameters in experimental data treatments, but in order to use it a value of the background contribution **b** should be determined by means of an independent direct measurements or of any additional data analysis.

To search for a possible annual variation of the found τ-data, they were normalized to the averaged values and were compared with the periodical function

$$f(t, \varphi) = [1 + A \sin (\omega(t + \varphi))], \tag{2}$$

where $\omega = 2\pi/365$ days^{-1}, t — a day of year, A — an amplitude of the variation, φ — a phase shift relative to the 1st January. Here A and φ are used as trial parameters to find the best fit. The φ-parameter was varied from 1 to 365 with the step of 1 day. A correlation coefficient $k(\varphi)$ between τ-value sequence and
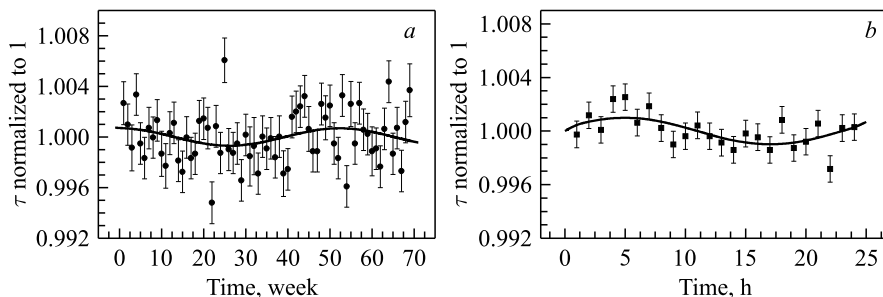
Fig. 6. *a*) Dependence on time of the normalized on average τ-value obtained at the TAU-2 with the week step (black points) and an approximation function (2) $f(t) = [1 + 6.9 \cdot 10^{-4} \sin (2\pi/365(t+93))]$ (curve). *b*) Dependence with 1 h step of the τ-value on solar day time, curve — $f(t) = [1 + 1 \sin (2\pi/24(t+1))]$

$f(t,\varphi)$ was calculated for each φ-value. The maximum value $k = 0.23$ has been reached at $\varphi = (90 \pm 10)$ days. So, the φ-phase value of the periodical function was found. Then a choice of A-value corresponding to the χ^2 minimum was done and was found to be $A = (6.9 \pm 3.0) \cdot 10^{-4}$. A maximum of the $f(t,\varphi)$ has been achieved on September 22. The corresponding dependences are shown in Fig. 6, *a*.

The other natural periodic variations exist which are connected with the rotation of the Earth around its axis. In particular, oscillations with periods of 24 h in the Sun's time. Sidereal time is related to such phenomena. A τ-values sequence obtained for the one hour step decay curves putting in the 24 h Sun day averaged from the TAU-2 data collected during 16 months is shown in Fig. 6. The normalized sequence was approximated by expression (2), where $\omega = 2\pi/24$ h^{-1}. A maximum correlation value of $k = 0.6$ was found for $\varphi = (1.0 \pm 0.5)$ h, $A = (10.0 \pm 2.6) \cdot 10^{-4}$ at the $\chi^2 = 1.49$ for $N = 23$. The corresponding dependences are shown in Fig. 6, *b*. There are no variations in the similar data sequences treated in the sidereal time which exceed statistical dispersions with the values higher than $A \leqslant 3 \cdot 10^{-4}$ (90% C.L.).

4. RESULTS AND DISCUSSION

The fulfilled modernization of the TAU-1 and TAU-2 setups allowed us to improve considerably a stability of the results and a sensitivity of long-duration measurements of a half-life value of the ^{214}Po decay as follows from the description given above. An assumption that obtained in [5] $\sim 0.9\%$ difference of the τ-values measured at the old-version of TAU-1 and of TAU-2 setup versions could be connected with the difference of the calibrations of the used digitizers,

was examined by means of measurements of the stable rectangle pulse durations. It was found that an accuracy of the DO calibrations was not worse than $3 \cdot 10^{-4}$. A hypothesis about possible correlation of τ-values measured by the old TAU-1 and TAU-2 and of values of gravity in the corresponding underground laboratories was tested. The values of a gravitational acceleration in the used two laboratories differ by $1 \cdot 10^{-4}$. Firstly, a measurement was done with the TAU-1 setup at one laboratory and then it was repeated at the other one. A weak dependence of the measured τ-values on decay curve cut thresholds in the low delays region was obtained in both the series. The changes of the τ-values do not exceed 3σ or $3.7 \cdot 10^{-3}$ for the (3.2–30) μs threshold changes at the achieved statistical level. A difference of the τ-values at the threshold of 30 μs does not exceed a value of $3.7 \cdot 10^{-3}$ and this difference is much lower than the one measured in [5]. The statistics of measurements in each laboratory should be increased to a further improvement of the estimation accuracy.

A dependence of the τ-value on a decay curve cut threshold could be explained by small distortions of the exponent form at low delay times due to mistakes of the "offline" program in the processes of determinations of real delays in cases of front overlapping of β-pulses and of α-pulses. The τ-value variations at the time delay above ~ 60 μs could be connected with statistical deviations of the exponent form since the statistical weights of such deviations changed at the threshold growth. The approximation program redistributes the exponent part and background line contributions in accordance with these weights. Variations of the τ-value and the background contribution $\mathbf{b}$ are in antiphase in accordance with expression $\Delta\tau/\tau \approx -0.037 \cdot \Delta\mathbf{b}/\mathbf{b}$, as is seen in Figs. 3, a and 5, a.

It is evident that contribution $\mathbf{b}$ is really constant under any part of the exponent. A steadiness on the $\mathbf{b}$-values of the χ^2-algorithm of ORIGIN used for a decay-curve division between the exponent part and background line part was tested by comparing the results extracted by the program in the processing of the decay curves obtained as results of constant line subtractions from the primary decay curves. The identical exponent parameters were found in all the tested cases. The background values $\mathbf{b}$ were found to be equal to the difference of the primary $\mathbf{b}$-value and subtracted constant values. This observation gives a certainty in the interpretation of the data time sequences with different time steps.

The uncertainties of interpretations could arise on account of possible independent changes of the exponent and of the background parameters during the chosen time step under influences of the external reasons. The values of the parameters could be found by different ways, in principle. First, the τ-value for a long time interval could be calculated as average of the τ-values for short component time intervals. Second, the parameters could be obtained from the decay curve collected during the whole analyzed time interval by using the standard approximation procedure. Third, the background contribution $\mathbf{b}$ could be excluded from a number of variable parameters before the approximation proce-

dure by using the constant value obtained by means of a normalization of the total data set **b**-value to the number of events in the analyzed time interval. A value of a standard deviation will decrease in accordance with the ratio of the time step duration to the total measurement time duration. An adequacy of these approaches was examined for the week step data decomposition. It was found that all methods gave similar results but differ in details.

An independent measurement of the background contribution value should be done to obtain the result unambiguity. It was aware of possibility of realization of such measurements by using delays between random coincide D1-pulses from "prehistory" and starting D2-pulses. Another possibility could be realized by the admixing of seldom specially prepared stable generator pulses to the flow of the real pulses. An admixture could be done by direct input of the pulses into the electronic chain or by the pulse lighting of the PMTs.

The amplitude and phase in the annual variation of the τ-value sequence with the week data step was found to be $A = (6.9 \pm 3.0) \cdot 10^{-4}$ and $\varphi = (93 \pm 10)$ days.

In order to check a possible occurrence of cyclical variations with twenty-four hour period, the total data set collected in 16 months was transformed to the 24 h data set by summing the information within the same numbered hour in the repeated 24 h fragmentation. The transformation was repeated for solar, lunar and stellar times. The twenty-four hour variation with the amplitude $A = (10.0 \pm 2.6) \cdot 10^{-4}$ and phase $\varphi = (1 \pm 0.5)$ h was found in the studied sequences averaged in the solar time.

There were no any day variations with amplitudes exceeding the statistical data straggling ($A \leqslant 3 \cdot 10^{-4}$ at 90% C.L.) in the sidereal time.

It is possible to suppose that the annual variation and the twenty-four hour one can have a common origin. In principle, the found effect of the decay constant variation could be created by variations of the DO sampling frequency; by variations of the delay times of the D1 and D2 pulses due to possible variations of the PMT's time characteristics under the action of the Earth magnetic field variations; by an unknown physical effect synchronized with the day Earth circulation and with the annual one.

An instability of the DO characteristics could be created by a noticeable changing of an environmental temperature. However, due to the continuous monitoring it was shown that temperature in the TAU-2 compartment is constant within the limits of $(26.5 \pm 0.2)\,°C$. This means that the temperature variations should be excluded from the list of possible reasons of the τ-variations.

Variations of the supply powers were not considered as an instability source because of all electronic systems fed by stabilized voltages. So, by the discussed reasons it seems not likely that DO characteristics instability could be a reason of the observed τ-variations.

Possible influence of the Earth magnetic field variations on the PMT's characteristics is supposed to be investigated in the nearest future.

In the result of the treatment of the whole data sample recorded by the TAU-2 setup during 16 months, the new value of ^{214}Po half-life time averaged over the total observation period was found to be $\tau = (163.45 \pm 0.04)$ μs. The value is compatible with the values from other measurements. Using this new value of decay constant τ, it is necessary to take into account the mechanisms shown above.

CONCLUSIONS

The results of analysis of the data obtained with the upgraded TAU-1 and TAU-2 setups at the new step of measurements are shown in the present work. The setups are intended to carry out a long-term control of the ^{214}Po half-life constant value. It is shown that the constant feels the twenty-four hour variation and the annual one of an unknown nature. The measurements are in progress.

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