Verification of a reliability of the ^{213}Po half-life results measured for decays on exited and ground levels

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Measurements under the program

Search for decay constant time variations.

^{214}Po ($T_{1/2}$ = 163.47 ± 0.03 μs),
^{213}Po ($T_{1/2}$ = 3.705 ± 0.001 μs),
^{212}Po ($T_{1/2}$ = 294.09 ± 0.07 ns).

Tasks of the experiment

1. Search for decay constant time variations.

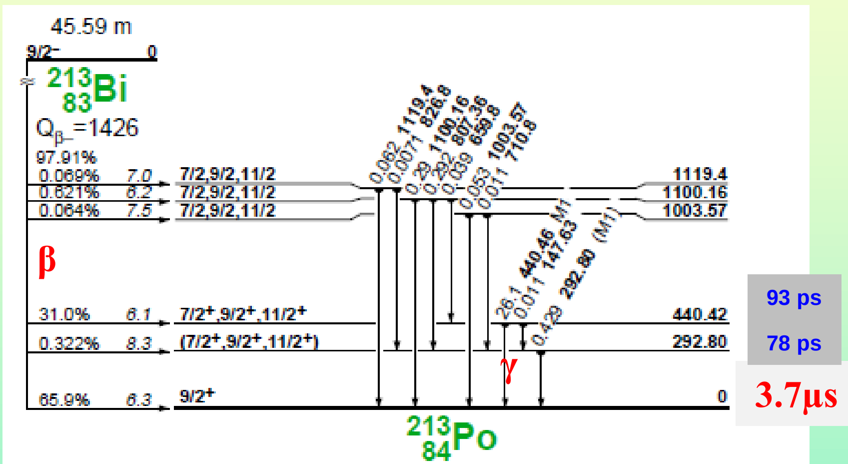
No theoretical predictions about decay constant time variations exist nowadays. We have only experimental results.

Decay rate variations = F{ 1. Count rate instability (background; electric and magnetic fields; temperature; pressure; humidity; aging; source-detector characteristics …) 2. Half-life variations **}**

Decay rate measurements → Life time measurements

^{229}Th as a source of ^{213}Po

^{229}Th (α, $T_{1/2}$= 7340 years) → ^{225}Ra (β, $T_{1/2}$= 14.5 days) → ^{225}Ac (α, $T_{1/2}$= 10.0 d) → ^{221}Fr (α, $T_{1/2}$= 4.8 min) → ^{217}At (α, $T_{1/2}$=$3.23 \cdot 10^{-2}$ s) → ^{213}Bi (β, $T_{1/2}$=46 min) → ^{213}Po (α, $T_{1/2}$= $3.7 \cdot 10^{-6}$ s) → ^{209}Pb (β, $T_{1/2}$= 3.3 h) → ^{209}Bi



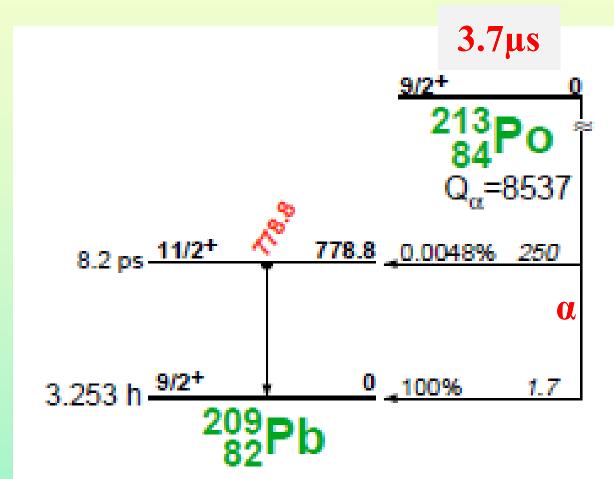


Fig.1. Decay schemes ^{213}Bi and ^{213}Po

γ(440 keV, 26.1%/dec.) + (β + α)

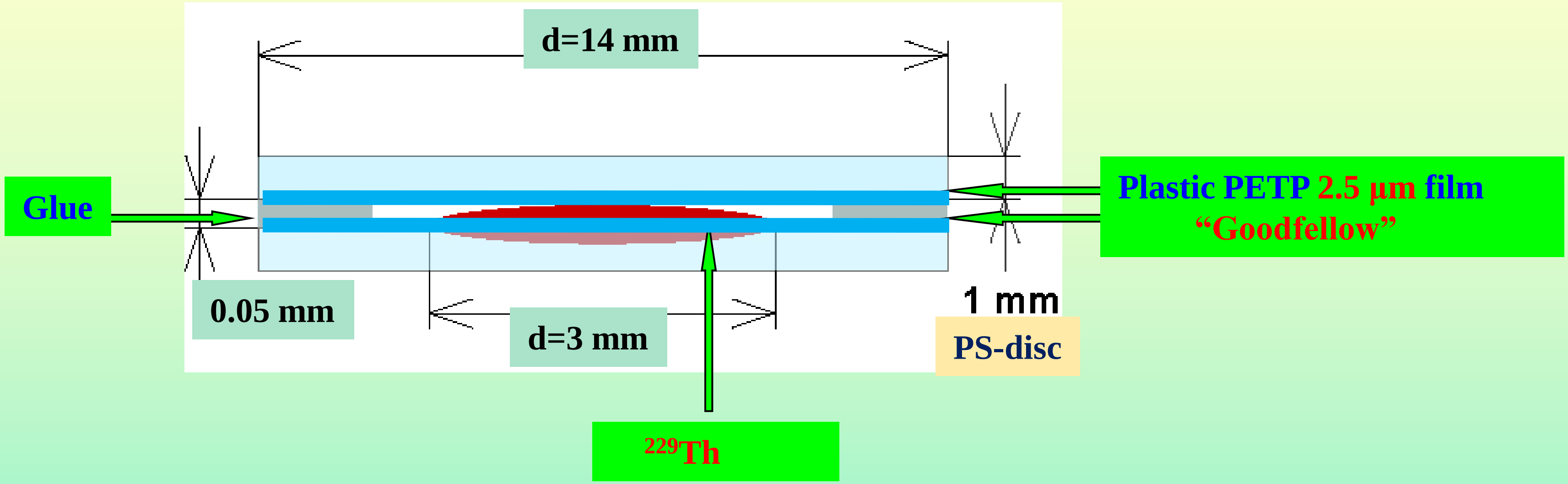


Fig.2. (^{229}Th)-source +
+ PS-detector

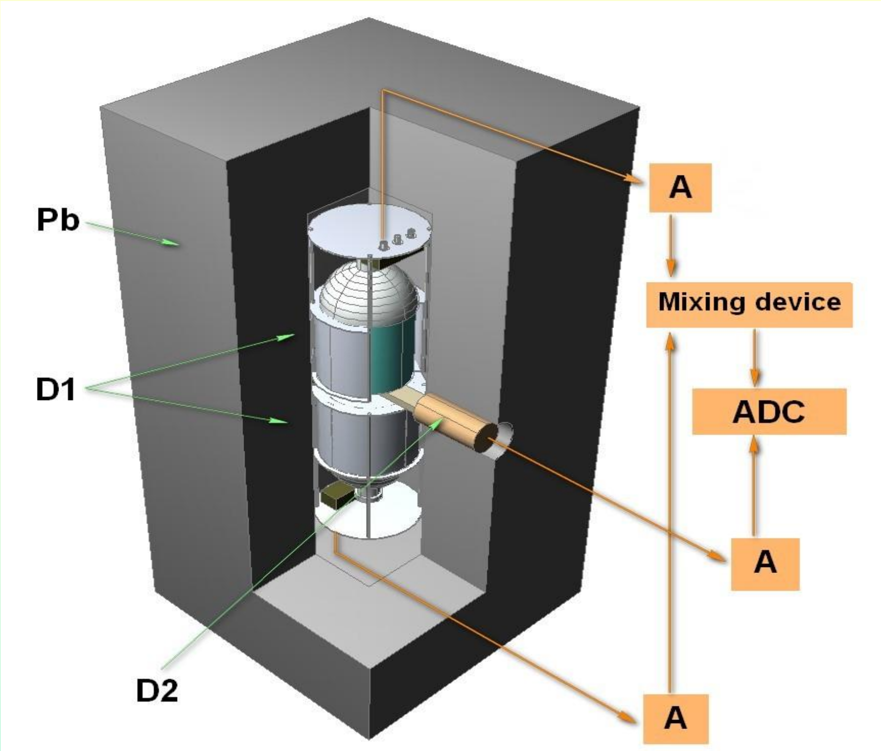


Fig.3. Schematic view of TAU-3 installation

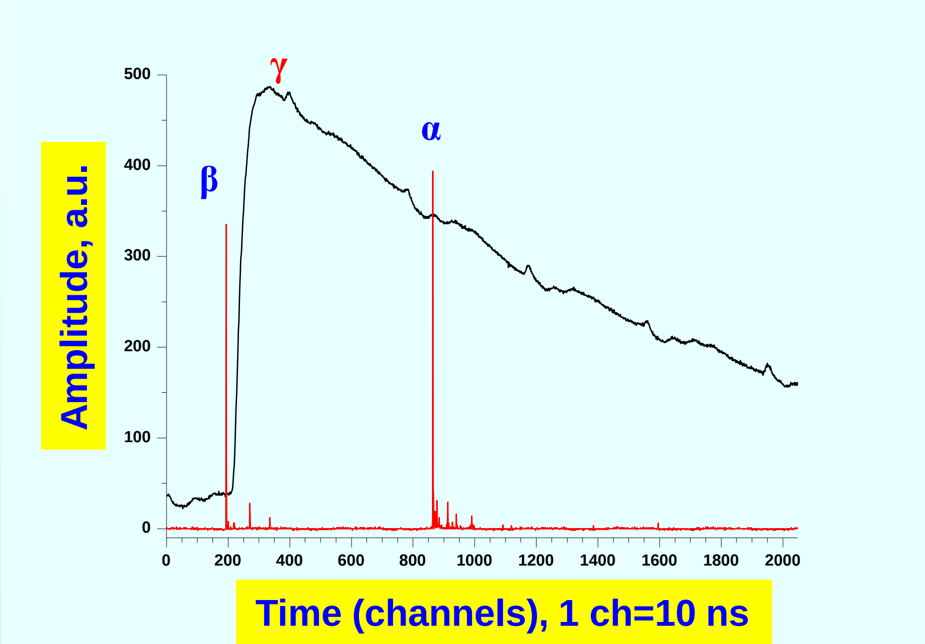


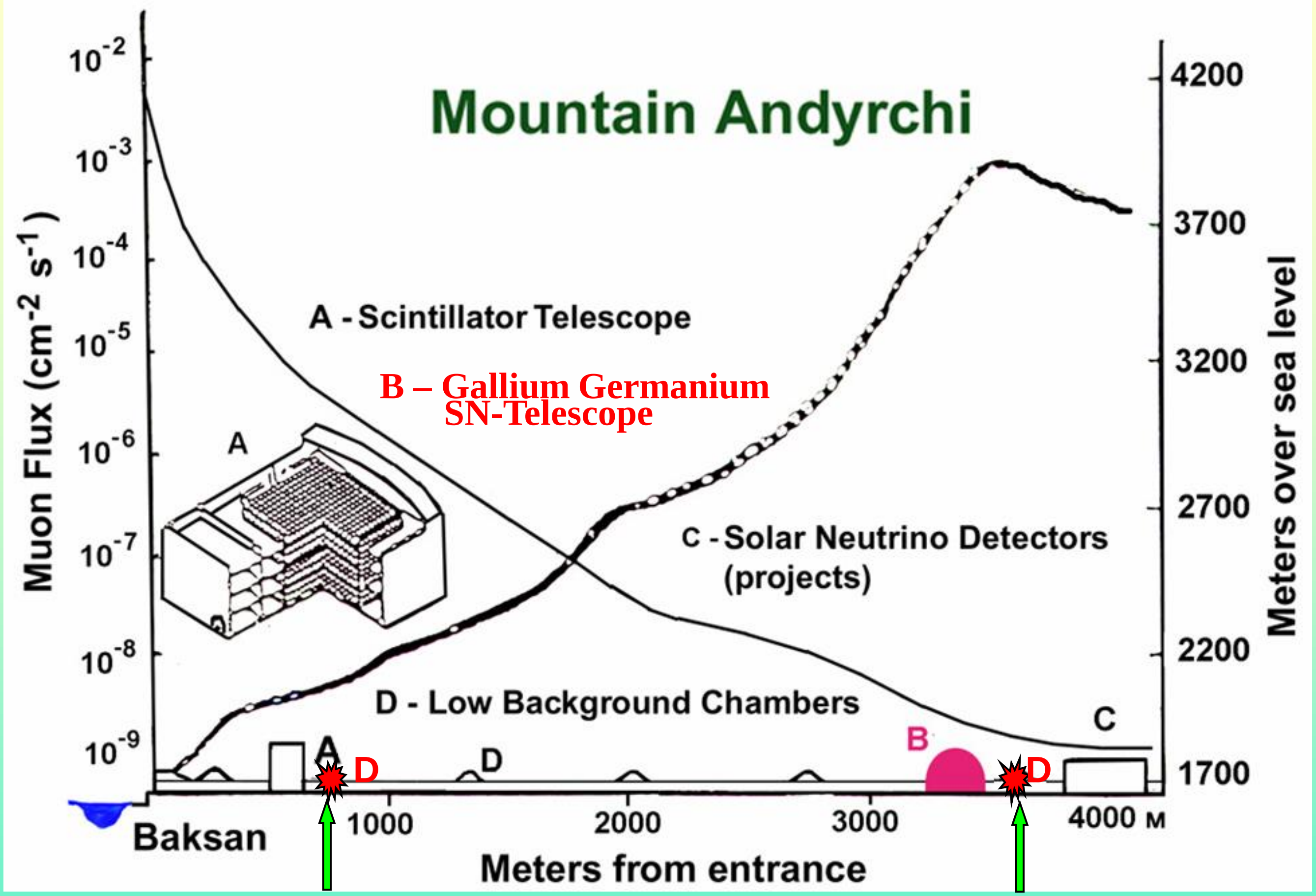
Fig.4. Sample of the ^{213}Bi - ^{213}Po decay event

TAU-3 → 4900 m w.e.

NaI(Tl)×2 - 150×150 mm

25 cm PE+1mm Cd+(15 cm+15 cm Pb)

A ≈ 150 Bk



KAPRIZ
TAU-1, (L=620 m, T=(20±2)^{o}C)

DULB-4900
TAU-2, (L=3670 m, T=(26.5±0.2)^{o}C)

Fig.5. Schematic view of BNO underground laboratories

Time of measurement - TAU-3 – 622 days; τ=3.705±0.001 μs

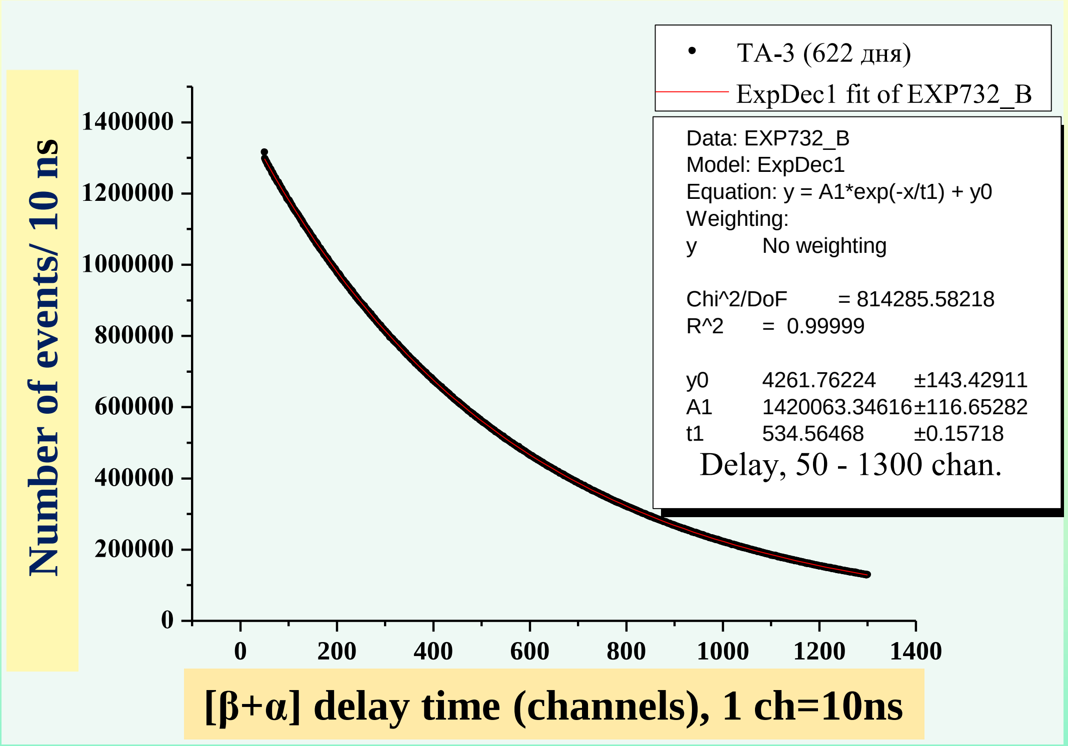


Fig.6. Distribution of delay time between β-pulse (start) and α-pulse (stop).

$$\Sigma 1/\sigma^2\{Y-f(t)\}^2 \rightarrow \min; \quad f(t) = A\cdot\exp(-t/\tau) + B$$

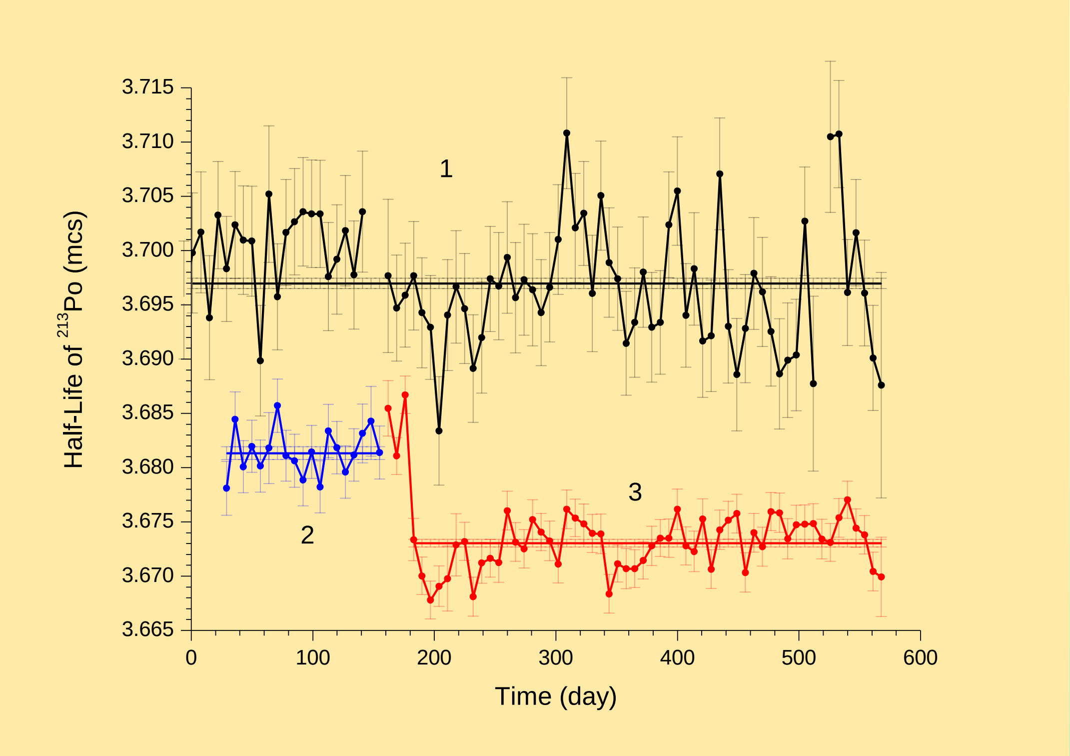
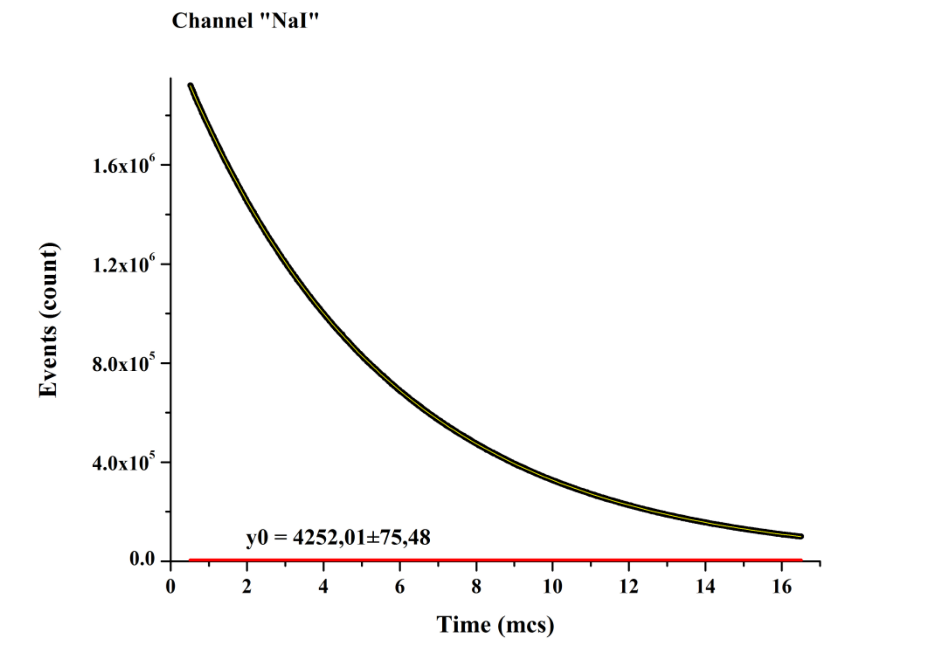


Fig.7. **Time dependences of the weekly averaged ^{213}Po half-life values. Upper diagram (black) is for triple coincidences (20–570 day of measurement); lower diagram is for double coincidences – blue color is 20-162 day of measurement (DOS NI-5124), red one is 164-570 day of measurement (DOS LA-n10-12PCI). Straight line segments correspond to the half-life values of ^{213}Po obtained from the decay curves accumulated over the measurement time equal to the length of these segments.**



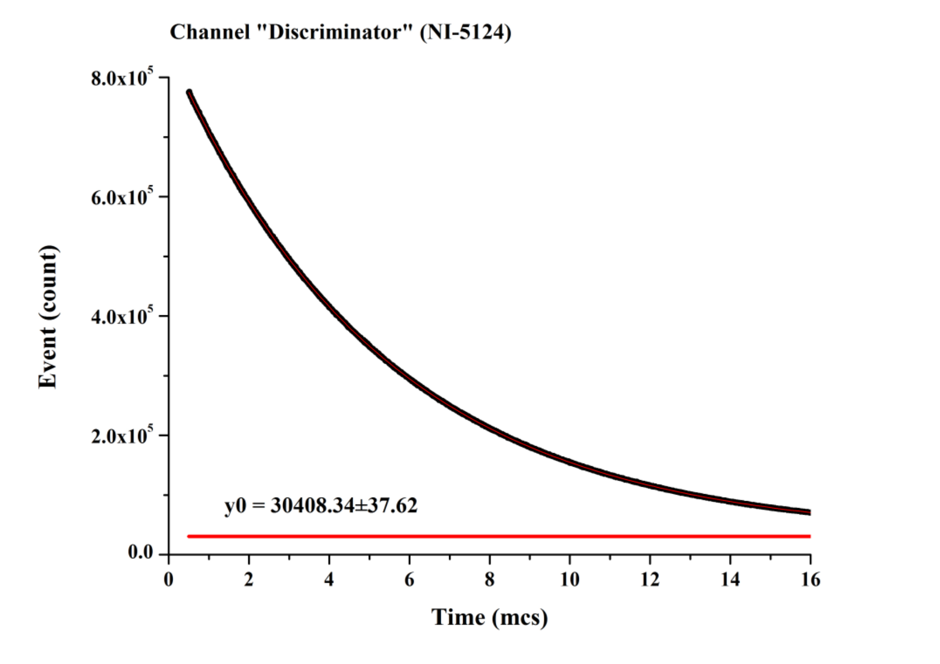


Fig.8. Decay curve for the triple coincidence events

$T_{1/2} = 3.6970 \pm 0.0005$ mcs

Fig.9. Decay curve for the double coincidence events

$T_{1/2} = 3.6774 \pm 0.0006_{stat.} \pm 0.0038_{syst.}$ mcs

$\Delta T_{1/2} = 0.0196 \pm 0.0008_{stat.} \pm 0.0038_{syst.}$ mcs

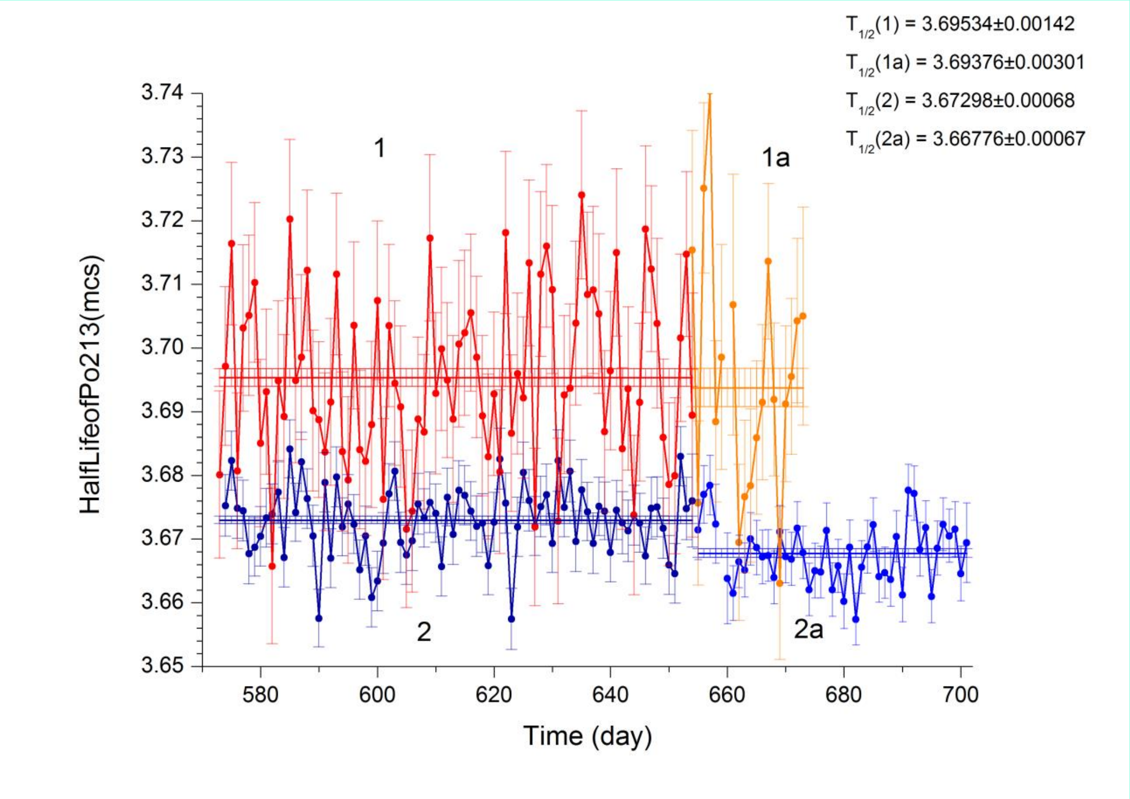


Fig. 10. **Graphs of average daily values of ^{213}Po lifetime in double (2, 2a) and triple coincidence (1 and 1a) channels for the interval 573 – 701 days. After 654 days, the oscilloscopes in the channels were swapped.**

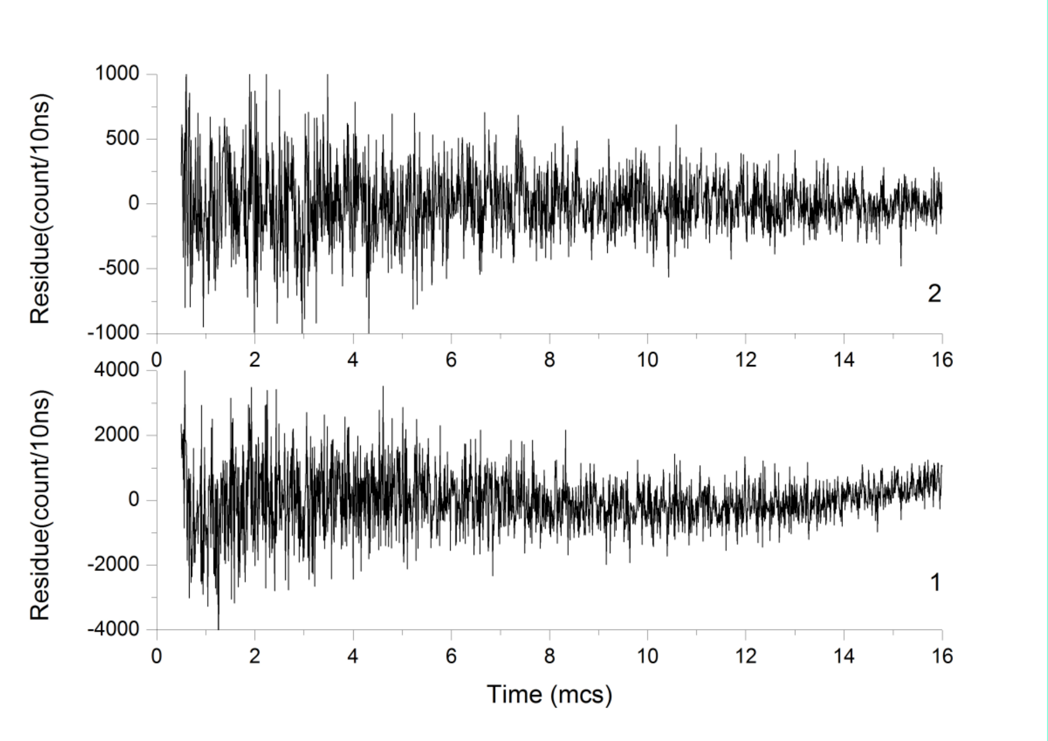


Fig.11. Dependences of the distributions of differences between the experimental and approximating decay curves. The upper graph is three-fold coincidences, the lower graph is two-fold coincidences.

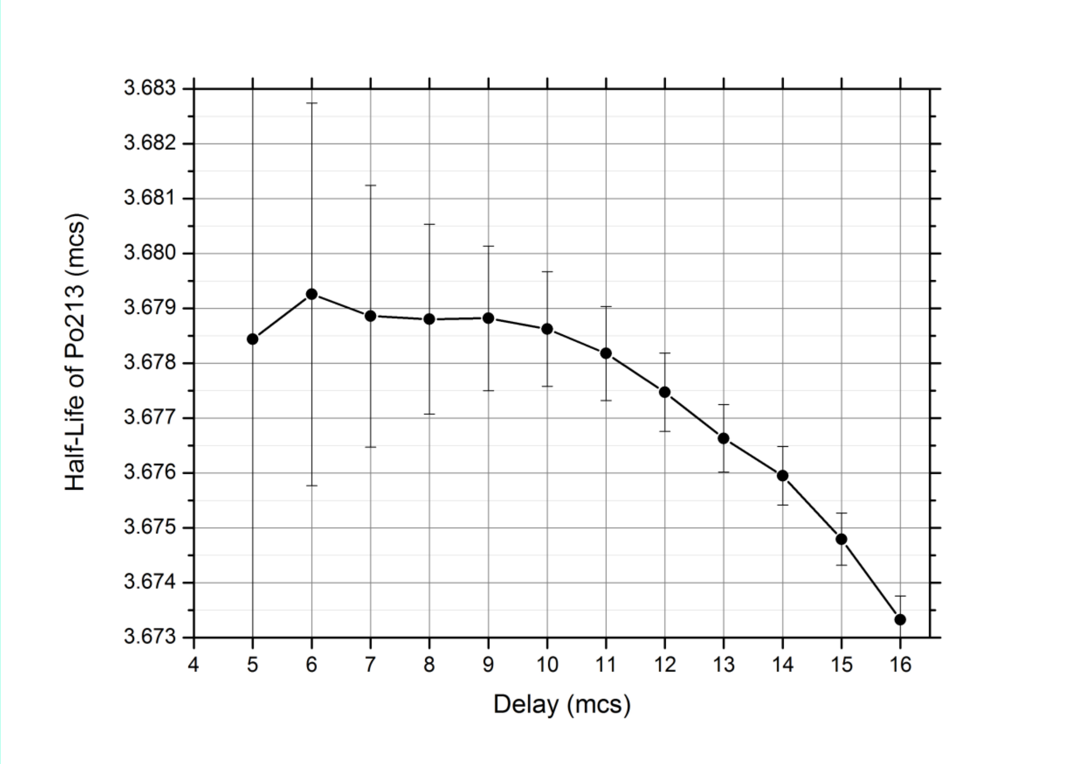


Fig. 12. **Dependence of the half-life of ^{213}Po through the ground level on the maximum value of the delay interval boundary**

Conclusions

1. The paper describes the methodology and presents the results of searching for possible methodological reasons for the origin of the difference in the half-life values of the α-active isotope ^{213}Po formed in the decays of …$^{213}Bi \rightarrow ^{213}Po$… through the excited level of 440.4 keV ($T_{1/2}$= 3.6970±0.0005 μs) and in decays through the ground level ($T_{1/2}$ = 3.6774 ± 0.0006 $_{stat.}$ ± 0.0038 $_{syst.}$ μs). The observed differences are many times greater than the delays created by the lifetime of the excited level.
2. It is shown that the presence of this difference does not depend on the type of digital oscilloscopes. It is established that distortions of the decay curve of ^{213}Po through the ground level, introduced by the shaper of the starting pulses of the oscilloscope recording, are not the cause of the difference in the half-life periods. Other possible reasons for the observed difference that have been tested have also not been confirmed.
3. At present, the main reason for this difference is assumed to be an unaccounted component of the process of ^{213}Po nucleus formation during decay through an excited level.