SSC RF–IPPE

ГОСУДАРСТВЕННАЯ КОРПОРАЦИЯ ПО АТОМНОЙ ЭНЕРГИИ «РОСАТОМ»

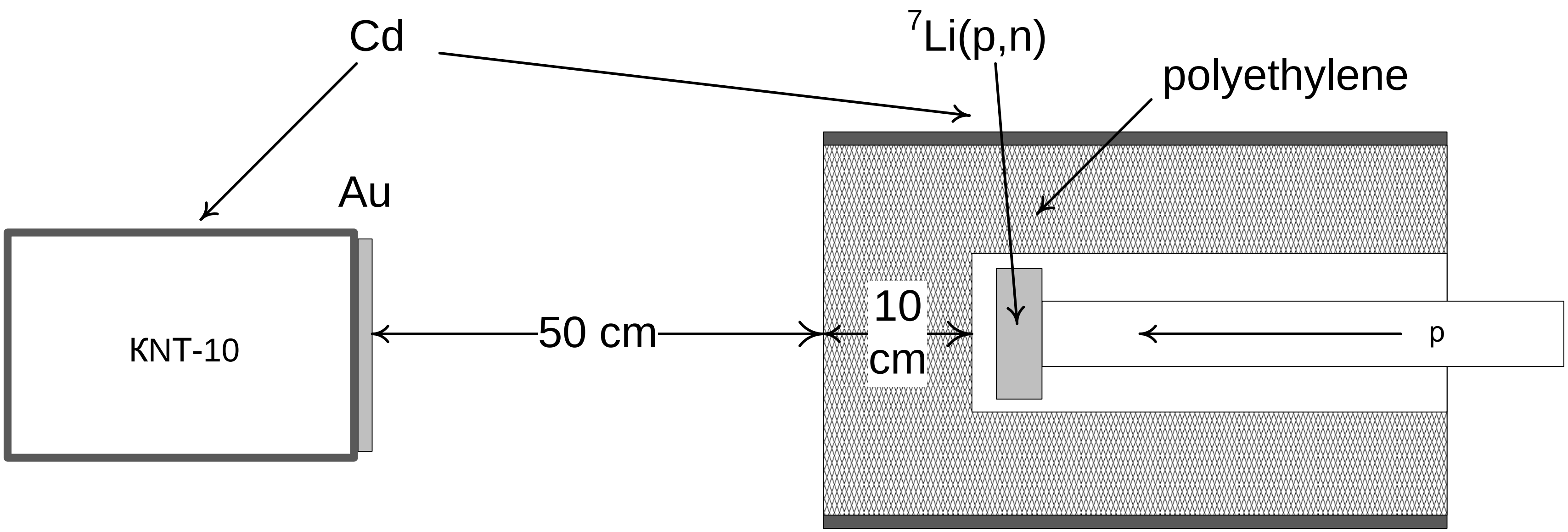
Formation and measurement of the thermal neutron beam at the Tandetron accelerator

Mitrofanov K.V., Egorov A.S., Gremyachkin D.E., Piksaikin V.M.
JSC "SSC RF – IPPE"

Introduction

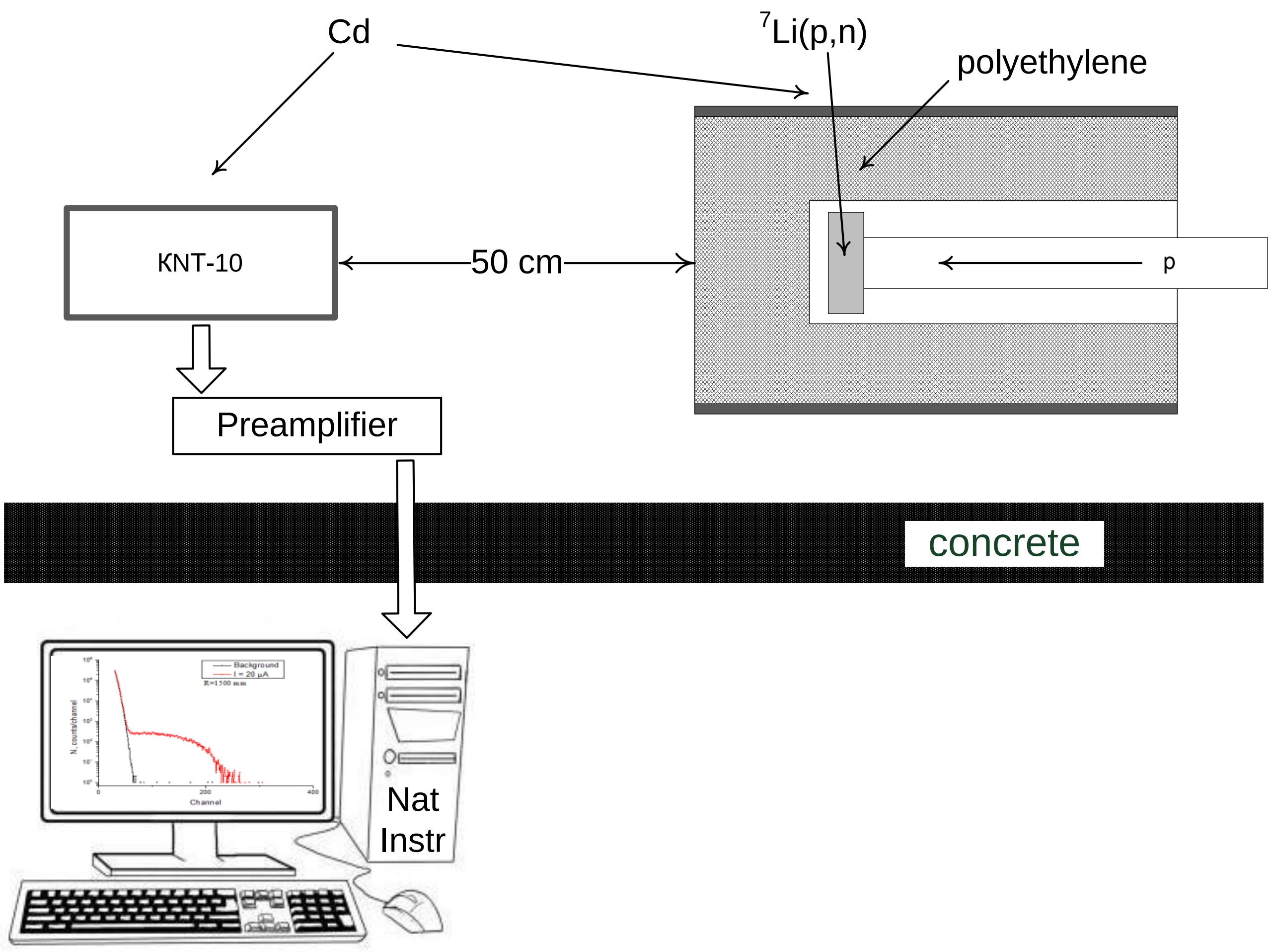
The neutron beams generated at accelerators using nuclear reactions with well-known parameters are widely used in neutron physics and in many practical applications. This work is devoted to the formation of the thermal neutron beam and the measurement of its intensity and spatial distribution at an angle of 0° to the beam axis using an activation method and an ionization chamber with a solid boron radiator KNT-10 that is not sensitive to γ-radiation. The nuclear reaction of ^{7}Li(p,n) on metallic lithium installed in a cooled target device of the Tandetron accelerator was used as a neutron source.

Experiment

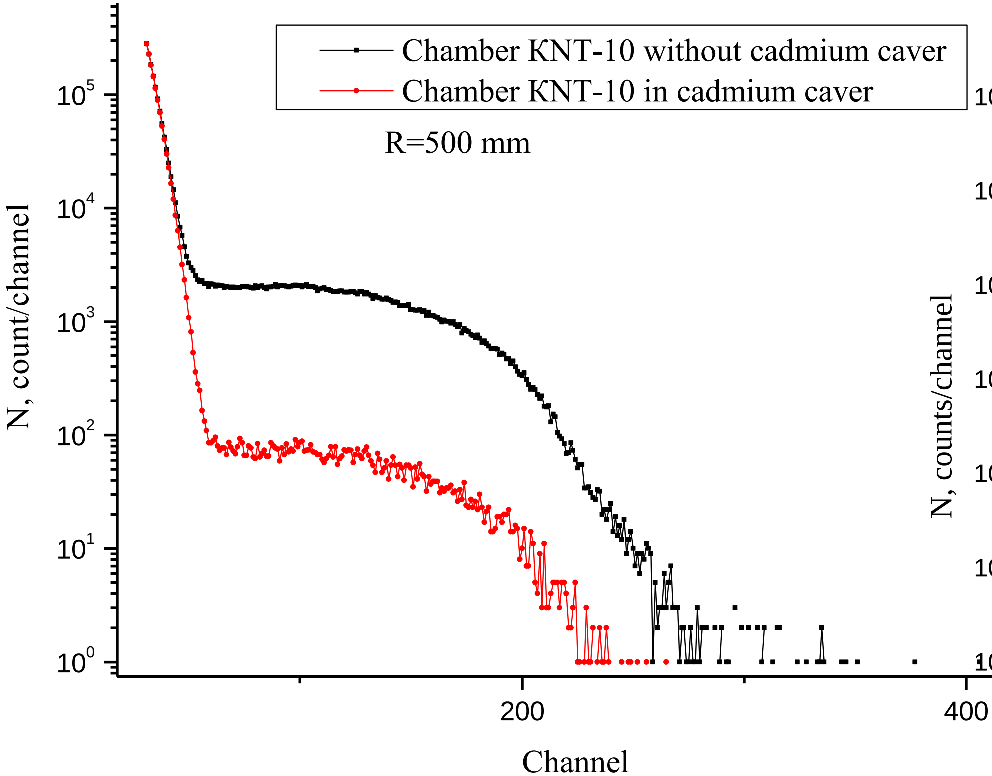


Scheme of measurement for determining the thermal neutron flux by the gold foil activation method and for determining the cadmium ratio using the camera KNT-10.

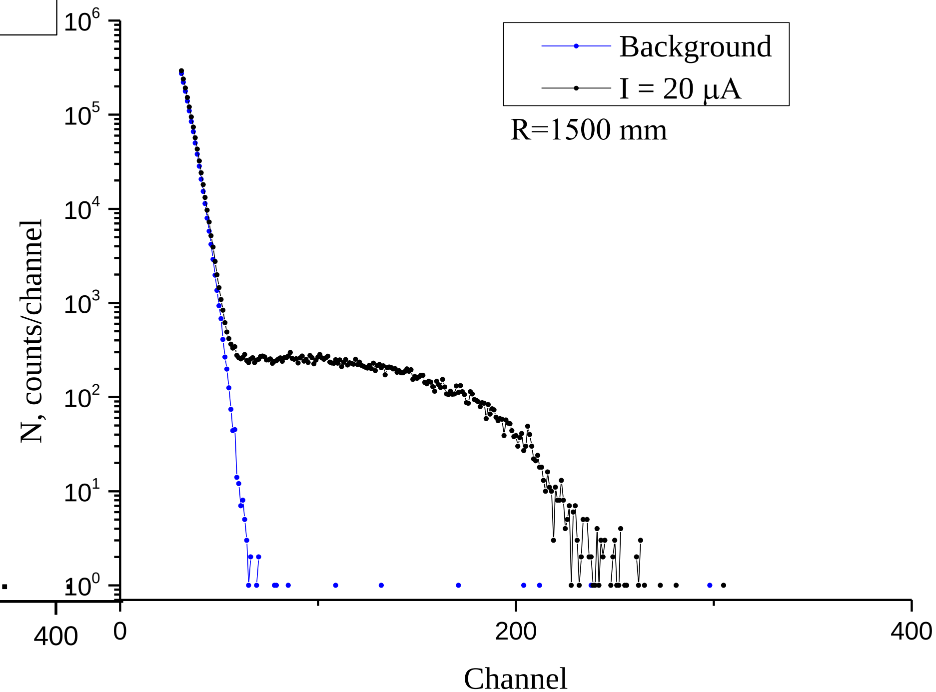
KNT-10 experiment for neutron flux and cadmium ratio



Apparatus spectra of KNT-10



The neutron spectra measured by the KNT-10 ionization chamber at a distance of 50 cm from the moderator with cadmium caver and without it.



The amplitude distribution of the KNT-10 ionization chamber with the accelerator current turned on and off.

Cadmium ratio

The cadmium filters, which intensively absorb thermal neutrons, are used to separate the effects of activation from thermal and resonant neutrons. The cadmium neutron absorption cross section equal 2450 barn in the thermal region and decreases rapidly with increasing of the neutron energy. It decreases to 1 barn near the boundary of the thermal and resonant regions of the neutron energy. As a result, a 0.5 mm thick cadmium plate absorbs almost all thermal neutrons falling on it with an energy E <0.4 eV and passes resonant neutrons.

To determine the intensity ratio of thermal and resonant neutrons, we used the method of measuring the cadmium ratio, where $C1$ and $C2$ are the sensitivity of the detector, respectively, to thermal and resonant neutrons, φth is the thermal neutron flux, φr is the resonant neutron flux [1].

$$R_c = \frac{C_1\varphi_{th} + C_2\varphi_r}{C_2\varphi_r}$$

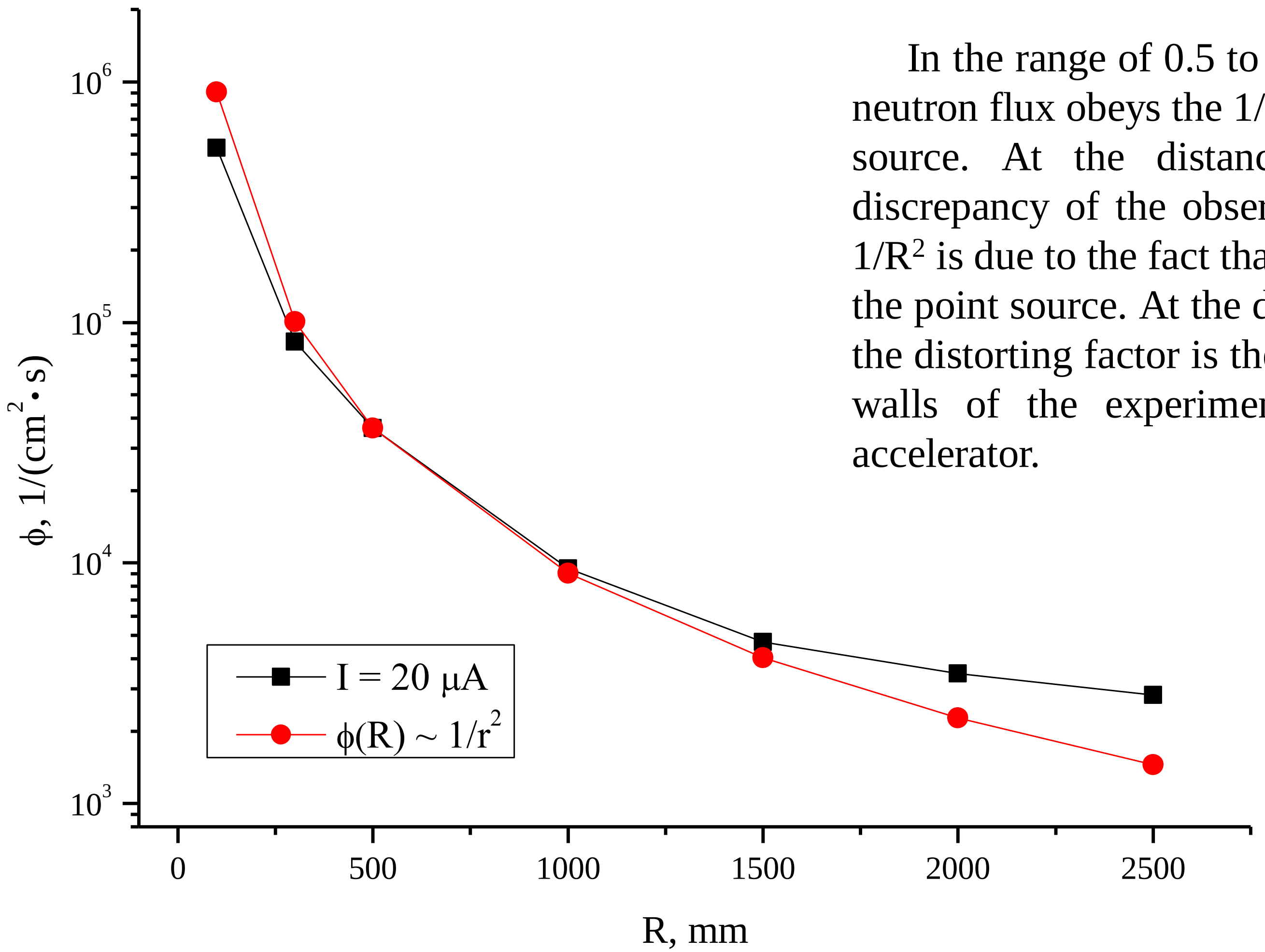
The following expression can be written for the cadmium ratio measurement in the case of a neutron detector with a sensitivity proportional to 1/v, which takes into account the energy distribution of resonant neutrons dE / E. Introducing the dependence of the cross section on the neutron energy, we obtain

$$R_c - 1 = \frac{\varphi_{th}\dfrac{1}{\sqrt{0.025}}}{\varphi_r \displaystyle\int_{0.4}^{\infty} \frac{dE}{E^{3/2}}} = 2\frac{\varphi_{th}}{\varphi_r}.$$

In this experiment, an ionization chamber with a solid boron radiator KNT-10, which is not sensitive to γ-radiation, was used to measure the cadmium ratio. KNT-10 is an ionization two-electrode chamber with a solid boron (^{10}B) coating [2]. It is known that the reaction cross section $^{10}B(n,\alpha)$ obeys the 1/v law. Therefore, the above expression for estimating the intensity of thermal and resonant neutrons based on measurements of the cadmium ratio is quite correct for analyzing the results for both the KNT-10 ionization chamber and the activation of the gold indicator.

Integrating these spectra and dividing the obtained values one by one, we obtain the average flux ratio 28.99, from which we determine the cadmium ratio: R_{Cd} = **58.98**. The obtained sufficiently high value of the cadmium ratio allows us to further neglect the effects of resonant neutrons.

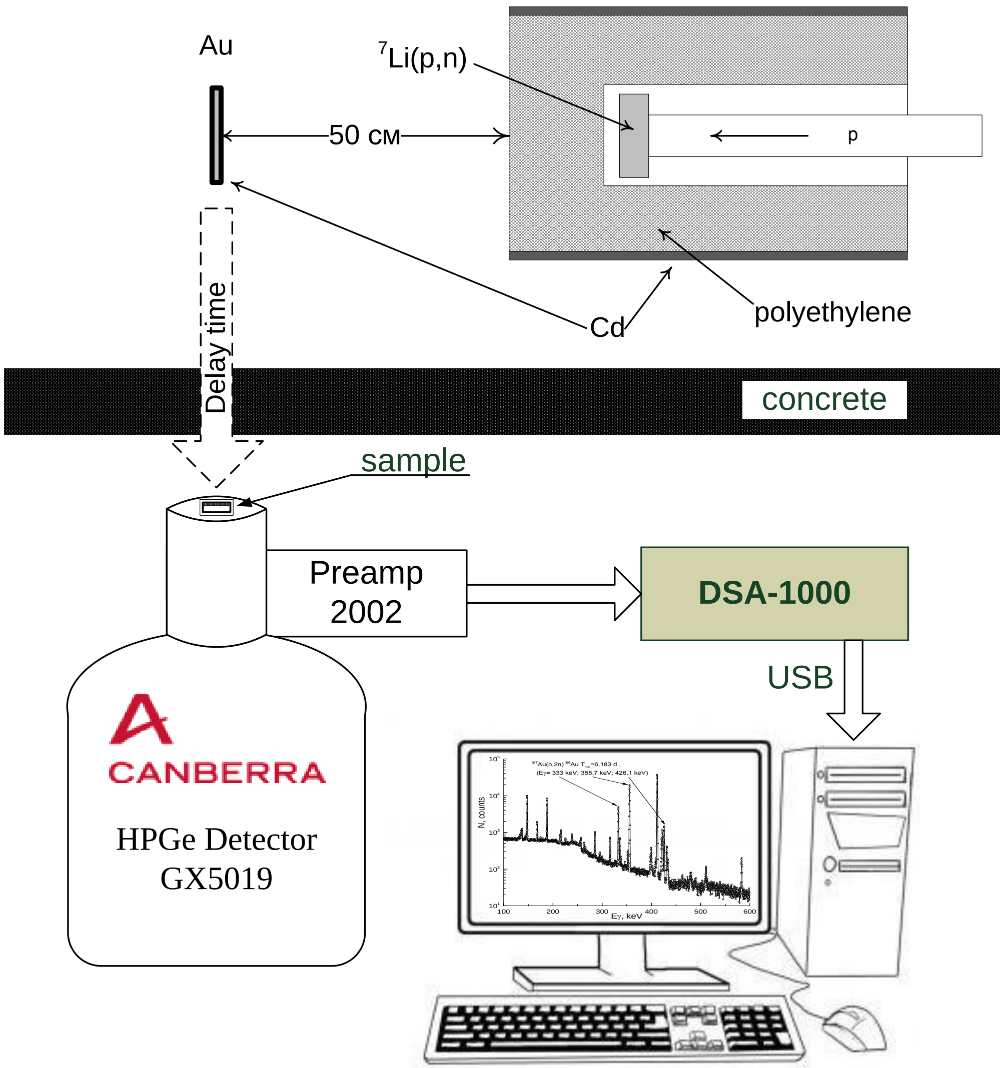
Spatial distribution

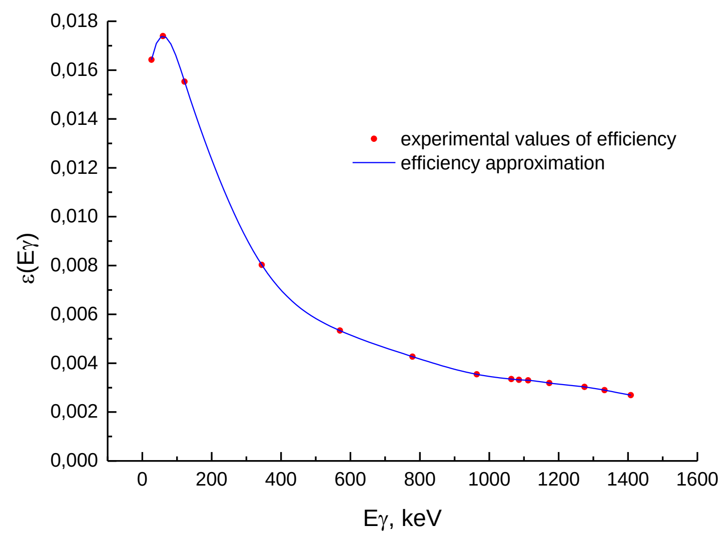


In the range of 0.5 to 1.5 m the dependency of the neutron flux obeys the $1/R^2$, which is valid for a point source. At the distances less than 0.5 m, the discrepancy of the observed dependence on the law $1/R^2$ is due to the fact that the source is different from the point source. At the distances of more than 1.5 m, the distorting factor is the neutrons reflected from the walls of the experimental hall of the Tandetron accelerator.

The spatial distribution of thermal neutron flux at the Tandetron accelerator.

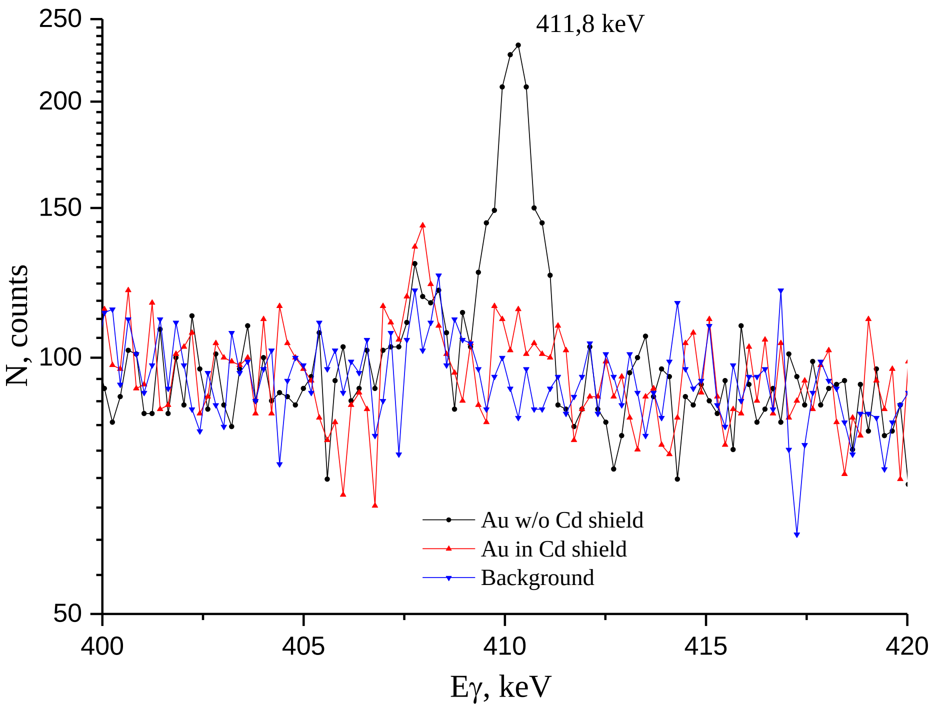
Au and HPGe experiment to obtain absolute neutron flux



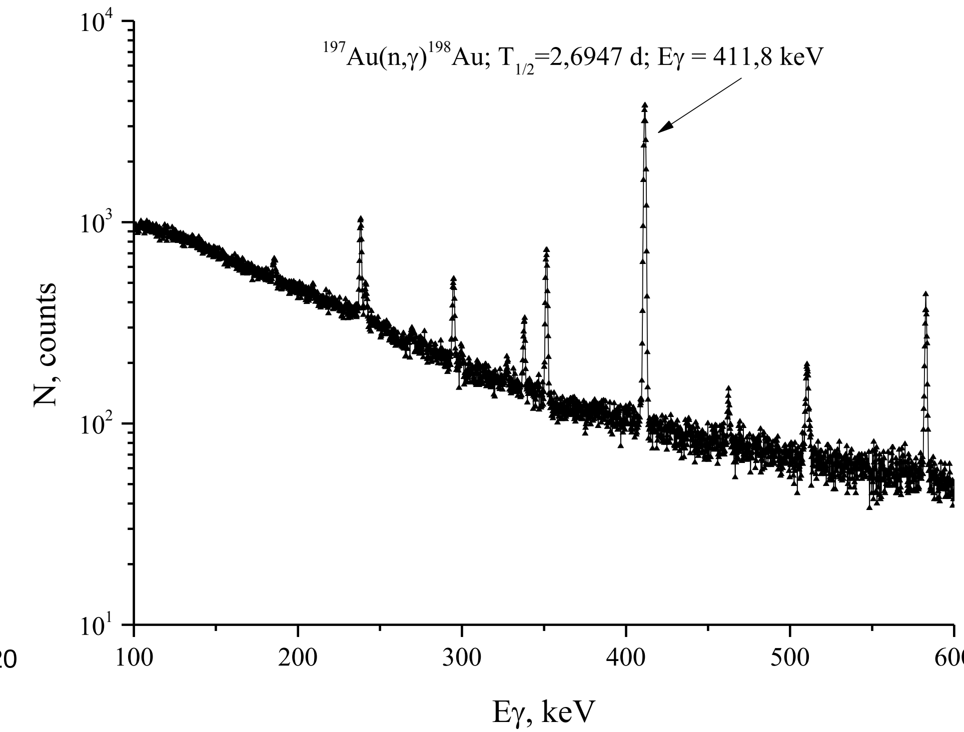


The efficiency of Ge(Li) gamma-spectrometer.

Au monitor



Two Au samples irradiated in the Cd cover and without the Cd cover in comparison with background measurement.



The apparatus spectrum of gamma rays of the $^{197}Au(n,\gamma)^{198}Au$ reaction products in the gold sample after its irradiation in the neutron flux.

Thermal neutron flux

SSC RF-IPPE

Then the neutron flux Φ can be determined using the expression

$$\Phi = \frac{S_{peak}}{\frac{m}{\lambda \cdot A} \cdot \varepsilon_\gamma \cdot f \cdot g \cdot N_a \cdot (1 - e^{-\lambda \cdot t_{irr}}) \cdot e^{-\lambda \cdot t_d} \cdot (1 - e^{-\lambda \cdot t_m}) \cdot \sigma}$$

The thermal neutron flux density is determined by the following formula

$$\Phi_{th} = \Phi \cdot \frac{(R_{cd} - 1)}{R_{cd}}$$

The average thermal neutron flux Φ_{th} was obtained as a result of analyzing the activation gamma spectra of the irradiated Au monitor by the neutron flux from the ^{7}Li(p,n) reaction on a thick target bombarded by protons with an energy Ep = 2.3 MeV and at a current of 20.6 μA. The average thermal neutron flux Φ_{th} is equal **$3.63 \cdot 10^4$** neutrons/(cm^2·s) at the distance of 50 cm from the moderator.

Conclusion

Based on the obtained absolute value of the thermal neutron flux and the measured spatial distribution of the thermal neutron flux, it can be concluded that the scale of the change of the absolute value of the thermal neutron flux at the Tandetron accelerator using this neutron moderator design and the $^7Li(p,n)$ reaction varies from the maximum value of **$5.31 \cdot 10^5$** n/(cm^2·s) at the proton current of 20 μA at the distance of 100 mm from the target to the minimum value of **14.12** n/(cm^2·s) at the proton current of 0.1 μA at the distance of 2500 mm from the target.

Thank you for your attention!