AURA Setup Testing at the IREN Neutron Beam

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The AURA setup, which meant for measuring the anisotropy of neutron angular scattering on the different targets (including gaseous ones), is located for testing at the 15-m flight path of IREN facility now.

1. The AURA setup and the goal of its constructing

The AURA setup contains the detecting and measuring modules, and, in addition, units for neutron beam shaping and guide. The detecting module (turn-table with fastened in it target and four ^{3}He-counters in shielding containers) is placed in the gap of neutron guide before the beam catcher. There are two collimators in the neutron guide, which forms the beam to 8 cm diameter. Two ^{3}He-counters are used for neutron beam monitoring. They are placed before the first collimator in unformed neutron beam. Electronic modules for the detectors operation, units for detectors power supply and PC for experiment control and information buffering are situated outside the beam outlet zone.

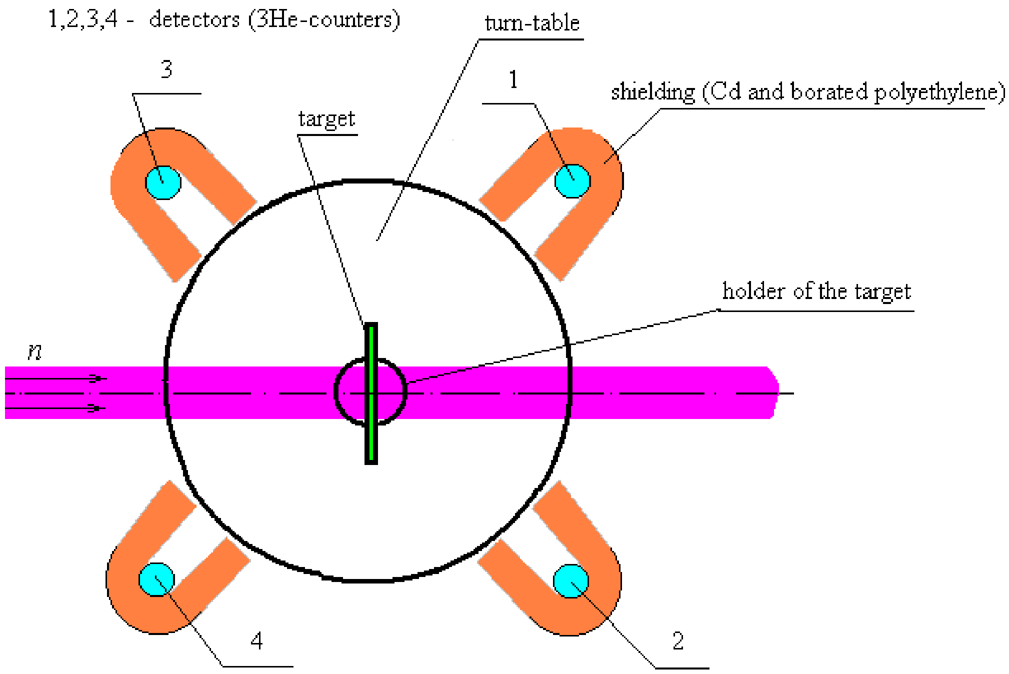

Fig.1. Scheme of the detecting module of AURA setup for the solid samples investigating.

The AURA setup testing was carried out for checkout of measurement uninterrupted duty and program debugging. The control program is produced to change positions of detectors at given parameters in different regimes including hands-off operation. The data compilation (separately for each exposition) is realized in 8 spectrums (for four rotating counters, which turn out alternately in two positions).

The AURA setup is created for precision experiment to extract the neutron-electron scattering length from angular asymmetry of scattering slow neutrons using the time-of-flight method [1]. For these investigations, which are related to fundamental ones, noble gases will be applied as scatterers. The success of the experiment will facilitate neutron electromagnet structure clearing.

2. The detecting module of AURA setup

The setup for measuring the angular scattering of neutrons by solid samples (test experiments) is schematically shown in Fig.1. The sample is placed at the centre of the turn-table. Neutrons scattered forward (~ 45^0) and backward (~135^0) are detected by four ^{3}He-counters (with 32 mm diameter and 200 mm length). All ^{3}He-counters (4 detectors and 2 monitor counters) are filled by helium up to 8 atm pressure, surrounded by shields of borated polyethylene and covered by cadmium.

3. The measuring module of AURA setup

The turn-table is rotated by means of stepper motor with the 8SMC1-USBh-B1-1MC block, which is controlled by computer. Eight -channel time-coder is connected with the computer through USB-2 port and records signals from all detectors and monitor counters. Counters pulses entry to the time-coder [2] via preamplifiers and after the block, which is amplifier, former and signal converter simultaneously.

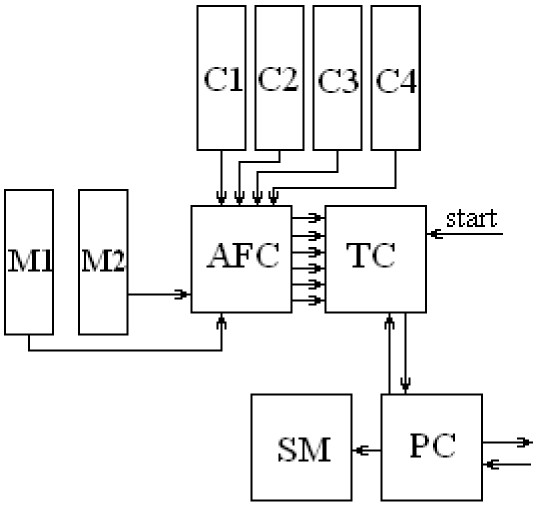

Fig.2. Scheme of the measuring module of the AURA setup. C1, C2, C3, C4 are detectors with preamplifiers, M1, M2 are monitor counters with preamplifiers, AFC is amplifier-former-signal converter unit, TC is time-coder, SM is stepper motor, PC is computer.

4. The AURA setup operation

Six time-of-flight spectrums from neutron detectors and monitors are measured simultaneously. After the end of given exposition at the first position the turn-table with the detectors is clockwise rotated to 180^0 and after exposition in the second position returns to the first position counterclockwise. In this way measurement continues until the cycle of given number of expositions will be completed or until STOP command. Thus, all counters measure neutron scattering to backward and to forward angles alternately. Changing the counters positions allows to eliminate an uncertainty connected with flapping of detectors solid angle.

A filter of Ag was placed at the beginning of the neutron guide. Using the time-of-flight spectrum of monitor counter placed into the neutron beam after the second collimator the flight path and start pulse delay were obtained. Two visible resonance crevasses of silver at 5.145 eV and 16.3 eV (see Fig.3) allowed us to determine that at the end of neutron guide the flight path is 13.85 m. But keeping in mind the distances from the end of guide to the center of the turn-table, where the scatterer is placed, and from the target to detector we determined that the real flight path is 15.0 m. Time between start pulse and the burst is $t_0 \approx 7$ mcs. This t_0 value was also obtained directly from the position of gamma flash at time-of-flight spectra. Thus, neutron energy, which corresponds to each time channel i, can be calculated by formula

$$E_i\,(\mathrm{eV}) = \left(\frac{72.3 \cdot 15.0}{t_i - t_0}\right)^2 = \frac{1176140}{(t_i - 7)^2}.$$

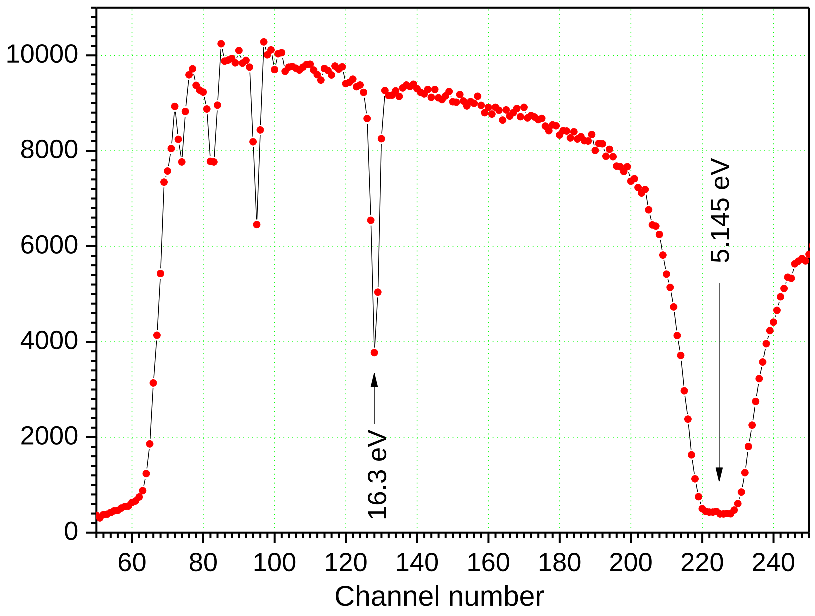

Fig.3. Segment of neutron spectra of monitor counter with resonance crevasses of silver 5.145 eV and 16.3 eV. Width of the time channel is 2 mcs.

5. Evaluation of IREN intensity

The neutron beam was bounded to diameter of 80 mm by paraffin-boric collimator. ^{3}He- counter was placed vertically in the beam, as it is shown in Fig.4. The area of beam profile covered by the counter is ~ 22 cm^2. For determination of observable neutron flux at the neutron energy E_n=5 eV we used two spectra measured during 5 min (see Fig.5).

Number of counts in the interval mentioned in the Fig.5 is 8500 pulses, and it corresponds to the value 1.29 pulses/(cm^2·s·eV). As an efficiency of our ^{3}He-counter (according to Monte-Carlo calculation with taking into account the counter diameter) for the energy 5 eV is ε = 0.18, we determined that the neutron flux is 14.2 neutrons/(cm^2·s·eV). Using the data of neutron flux on the 100 m flight path obtained in paper [3] for reactor IBR-

30 with water moderator of 4 cm thickness at 1 kW power and corresponded for these conditions the source intensity of $4.8 \cdot 10^{13}$ neutrons/s we compared our data with the data of [3].

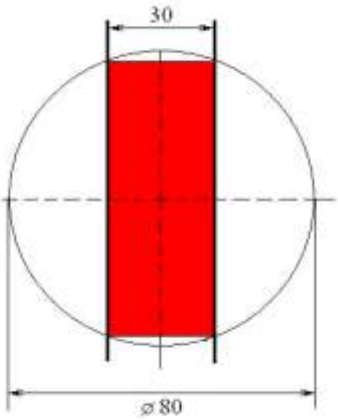

Fig.4. Placement of ^{3}He-counter in the neutron beam. The beam direction is perpendicular to the figure flat.

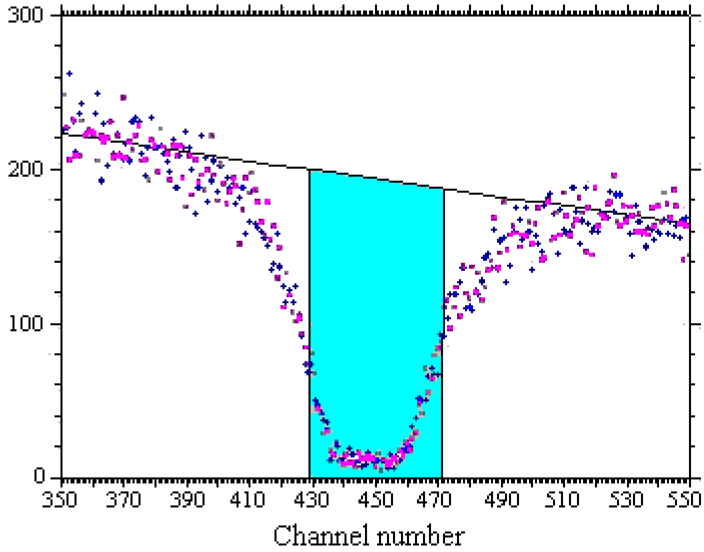

Fig.5. Neutron spectrum in the energy region 5 eV measured during 5 min. The blue area marks the interval between 428 and 471 channels, which corresponds to ΔE=1 eV. Width of the time channel is 1 mcs.

Making this comparative analysis we introduced the multiplier $\mu=(13.85/100)^2= 0.019$ to take into account the difference of flight paths and determined that at the 100 m flight path our neutron flux would be 0.136 neutrons/($cm^2 \cdot s \cdot eV$). In the mentioned paper [3] the neutron flux at the 100 m flight path at the power 1 kW was 55 neutrons/($cm^2 \cdot s \cdot eV$). Thus, we have the flux 404 times less than in [3], and our estimation shows that the IREN intensity is $1.2 \cdot 10^{11}$ neutrons/s now.

6. The АУРА setup testing

The AURA setup was tested with solid samples- scatterers in order to increase the statistics of scattered neutrons. So the speculative measurements were carried out with cadmium, wolfram and acrylic plastic.

The part of the spectra measured with cadmium with 0.5 cm thickness by one of detectors in two positions are shown in Fig.6, and spectra of neutrons scattered forward and backward by wolfram with 0.3 cm thickness for the same detector are shown in Fig.7.

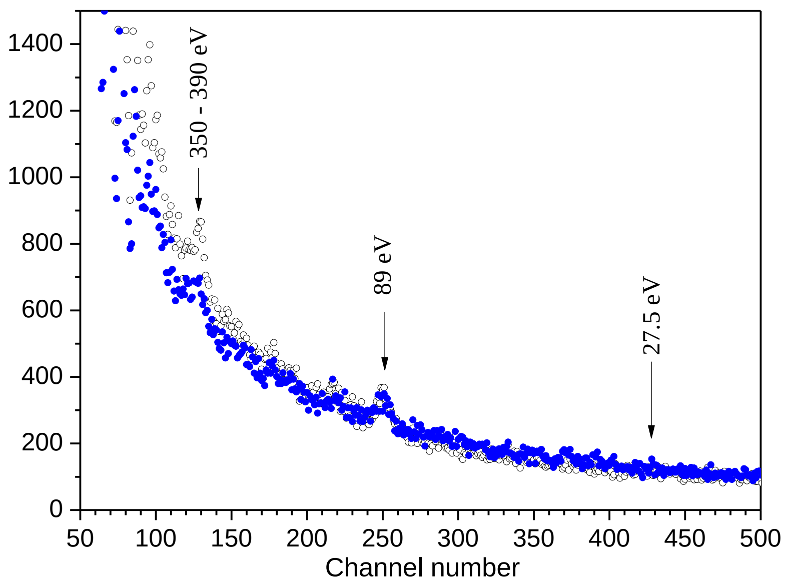

Fig.6. Time-of-flight spectra of neutrons scattered by Cd obtained with the 1-st detector at the neutron scattering backward (open points) and at the scattering forward (blue solid points). Width of the time channel is 0.5 mcs.

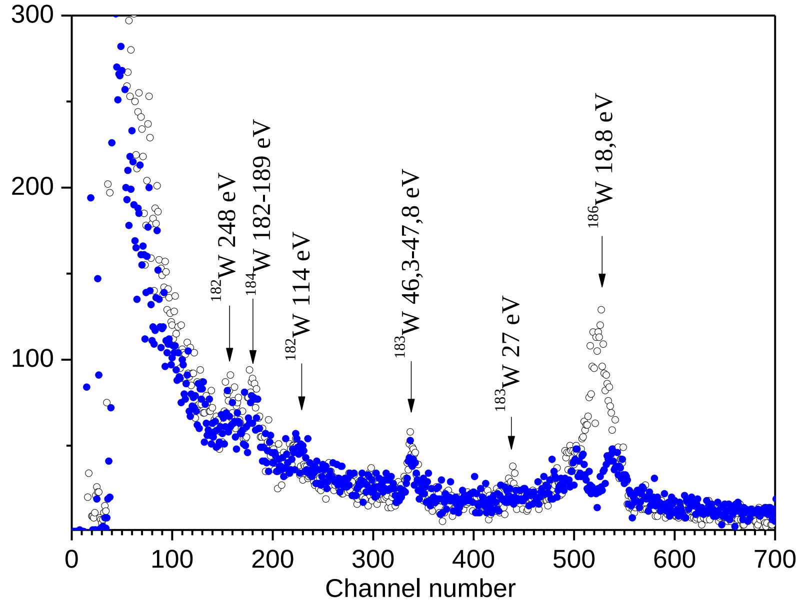

Fig.7. Time-of-flight spectra of neutrons scattered by W obtained with the 1-st detector at the neutron scattering backward (open points) and at the scattering forward (blue solid points). Width of the time channel is 0.5 mcs.

The cadmium resonances are higher at the spectrum of neutrons scattered backward. When neutrons are scattered forward multiple scattering and capture in the sample distort a scattering pattern appreciably.

The wolfram resonance with the energy 18.8 eV stands out against of the other resonances, which are clearly visible on the time-of-flight spectra. When neutrons are scattered forward this resonance comes down due to multiple scattering and capture in the sample.

Time-of-flight spectra for neutrons scattered by acrylic plastic are presented in Fig.8 for all four detectors. It is obvious that neutron scattering is realized forward in preference, as it must be if neutrons are scattered by hydrogenous sample (hydrogenous sample does not scatter neutrons in backward hemisphere). The entrance gaps of detectors 2 and 4 were covered by plates of silver, which have neutron resonance at the energy 5.15 eV. For these counters there is visible crevasse at the energy ~ 10 eV in the spectra of neutrons scattered forward (at 45^0), as just neutrons with this initial energy after scattering by hydrogen at 45^0 have the energy corresponded to the silver resonance 5.15 eV.

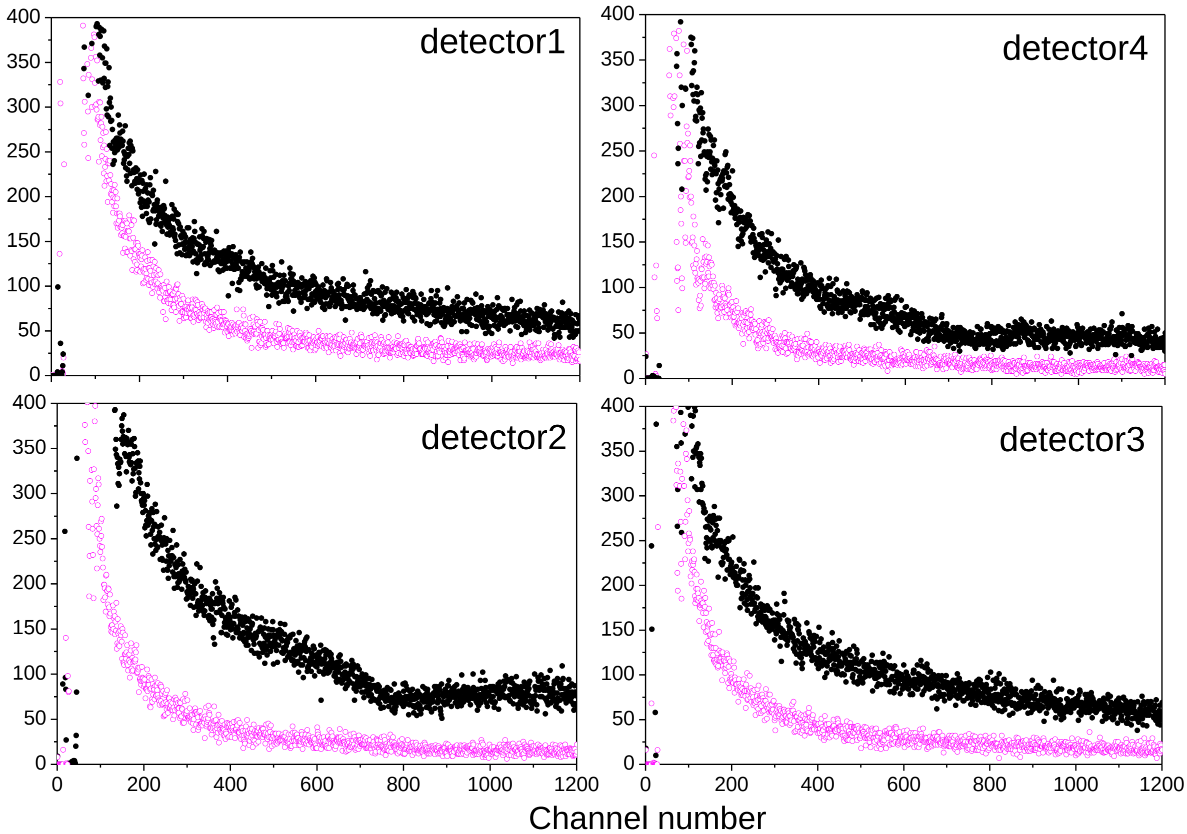

Fig.8.Time-of-flight spectra of neutrons obtained for neutron scattering by acrylic plastic at the scattering backward (open pink points) and forward (solid black points). Width of time channel is 0.5 mcs.

Conclusion

During the test measurements the new program complex debugging was made. Testing the AURA setup measuring module with 8-channel time-coder was carried out at the IREN facility neutron beam. In the course of the test measurements control programs faults were discovered and corrected.

References

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