CROSS SECTIONS STRUCTURE RESEARCH AT INR SPALLATION NEUTRON SOURCE INSTALLATION INES

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Abstract. Calibration results of installation INES are presented. Research carried out by TOF method on 50 meter flight base of the pulsed neutron source RADEX. Measurements were performed using the 8-sectional liquid (n,gamma) detector. Proton linac was operating with parameters: energy of protons 209 MeV, repetition rate 50 Hz, pulse current 8 mA, pulse duration 1 microsecond. Average neutron flux 13000 n/cm^{2}sec on target was measured. As spectrometric data acquisition system, new single-channel high speed modules were used. Proportional He-3 counter with new fast amplifier was used as accelerator's proton beam intensity monitor.

1. INTRODUCTION

Installation INES is created to investigate neutron cross sections and make measurements of effective group cross sections for metal alloys and other nuclear reactor materials, which were made using enriched isotopes.

Effectiveness of measurements grow due to making two types of experiments: both absolute cross sections measurements and comparable measurements, using as a calibration pattern the same alloy material, made using usual chemical elements of natural isotope composition.

There are 62 chemical elements in nature which are mixtures of stable isotopes, which can be separated and used in nuclear technics as alloys with perfected qualities. Among them 23 two-isotope chemical elements and 39 elements with even 'Z' value, each of those has 3 and more stable isotopes. Group cross sections of materials and alloys, based on separated isotopes, depend on separation quality and must be measured experimentally.

INES allows to get experimental group cross sections for alloys, produced by industry for usage in cores of nuclear reactors. This gives an opportunity to compare and check precise theoretical calculation results.

2. EXPERIMENTAL PROCEDURE

The experiment was carried out at the 50-meter flight path of the INR RADEX pulsed neutron source. Proton linac was operating with energy of protons 209 MeV, repetition rate 50 Hz, pulse current 8 mA, pulse duration 1 microsecond which corresponds to 1.6 MW pulsed power and averaged value 13000 n/cm^{2}sec on the surface of the detector's surface. The 209 MeV proton beam is injected into tungsten target, resonance neutron spectrum is formed using water moderator.

The gamma rays were detected using 8-sectional liquid scintillator contained in 40-liter tank equipped with FEU-110 photomultiplier. The total gamma detection efficiency of the liquid scintillator amounts to about 30%.

Detector has pulse length 30 nanoseconds and allows usage of coincidence multiplicity method to extract (n, γ) cross sections also in energy region upper then resolved resonances. Effect and background can be distinguished also in upper energy groups.

Fig.1. 8-sectional liquid (n, γ) detector.

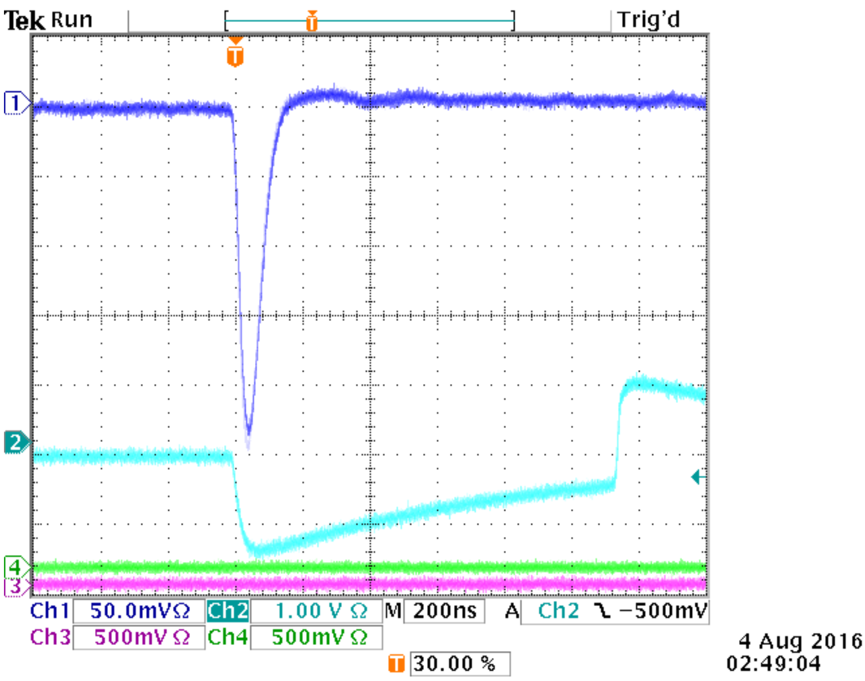

Fig.2. Test signals of the He^3 monitor's preamplifier.

Previously used He^3 monitor's front end electronics provided pulse length 6 mcs and maximum load 80 kHz.For measurements with accelerators which provide smaller pulse length compared to IBR-30 which had 4 mcs, in cooperation with John Scarley (New York University) we created new front-end electronics.

New amplifier design uses modern electronic element base. He-3 detector, equipped with it, provides pulse length 350 nanoseconds, the same as the shortest INR proton linac beam. Maximum work load of He^3 monitor with new front-end electronics was measured using Cf-252 neutron source, its value is approximately 900 kHz.

Metal plates of Au^{197}, Ta^{181} and U^{238} were used during INES calibration measurements. Beam length was 1 mcs, data acquisition system's channel width was chosen 133 nanoseconds. This choice provided energy resolution of 22 nanosec/meter and acceptable measurement time. All 50 Hz spectrum includes 150375 histogram channels.

DATA ANALYZIS AND RESULTS

Resulting product of TOF measurements is a table of 28 (or 299 in BNAB-93 standard) group cross section values, which are used by reactor calculation programs as initial data.

To get these group cross sections values using TOF spectra as a raw material, few new programs (on language C++) during current year were written.

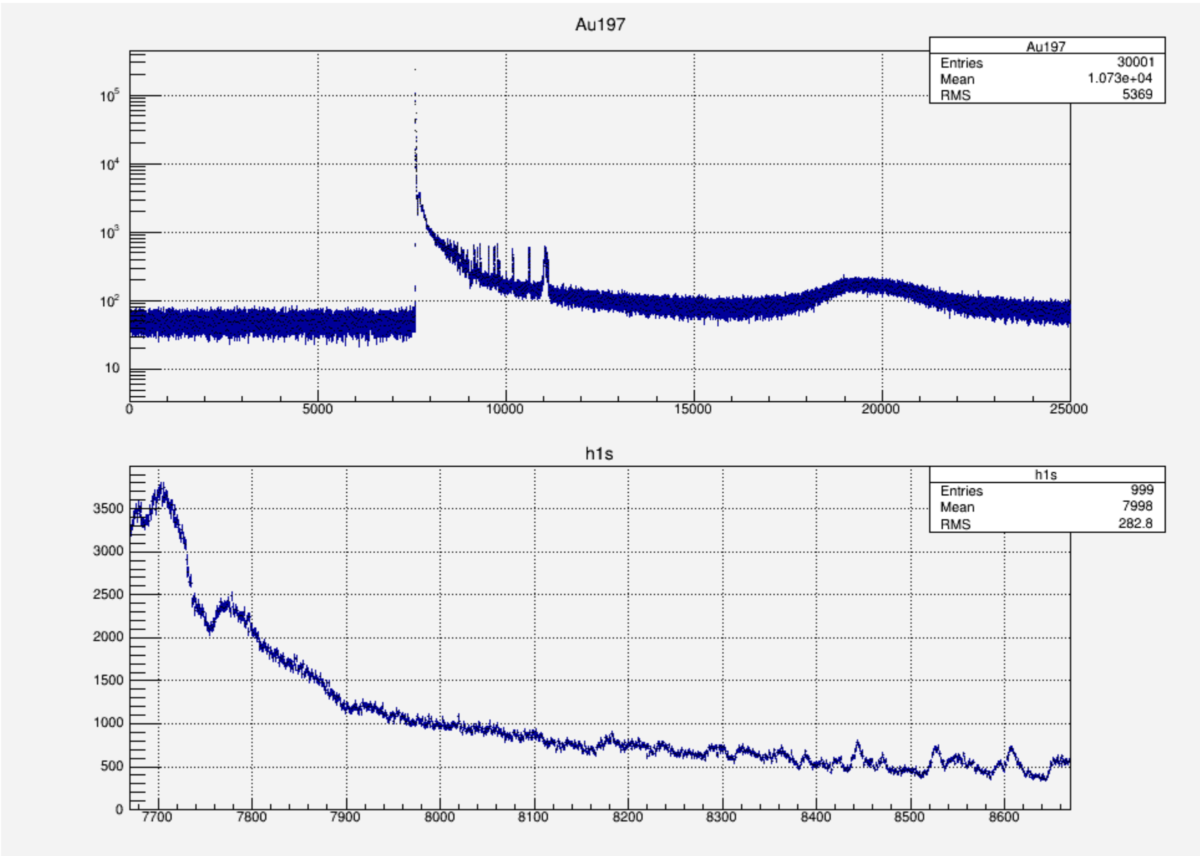

Fig.3. Screen of the program for preliminary observation of experimental TOF spectra.

Each experimental TOF spectra is automatically analyzed by method of form, considering that form of resonance in ideal case is determined by Breit-Wigner formulae. Program marks candidate peaks by red markers, and after that,it is trying to find resonance parameters for them. For the case when calculation converges, program is painting red curve above candidate peaks, which are recognized as resonances by chosen parameter which can be changed inside program.

Example of TOF Au-197 spectra recognition process on fig.4 is shown. At chosen analysis parameters, resonances at 57.92 eV, 60.1 eV and 78.27 eV and their resonance parameters are automatically determined.

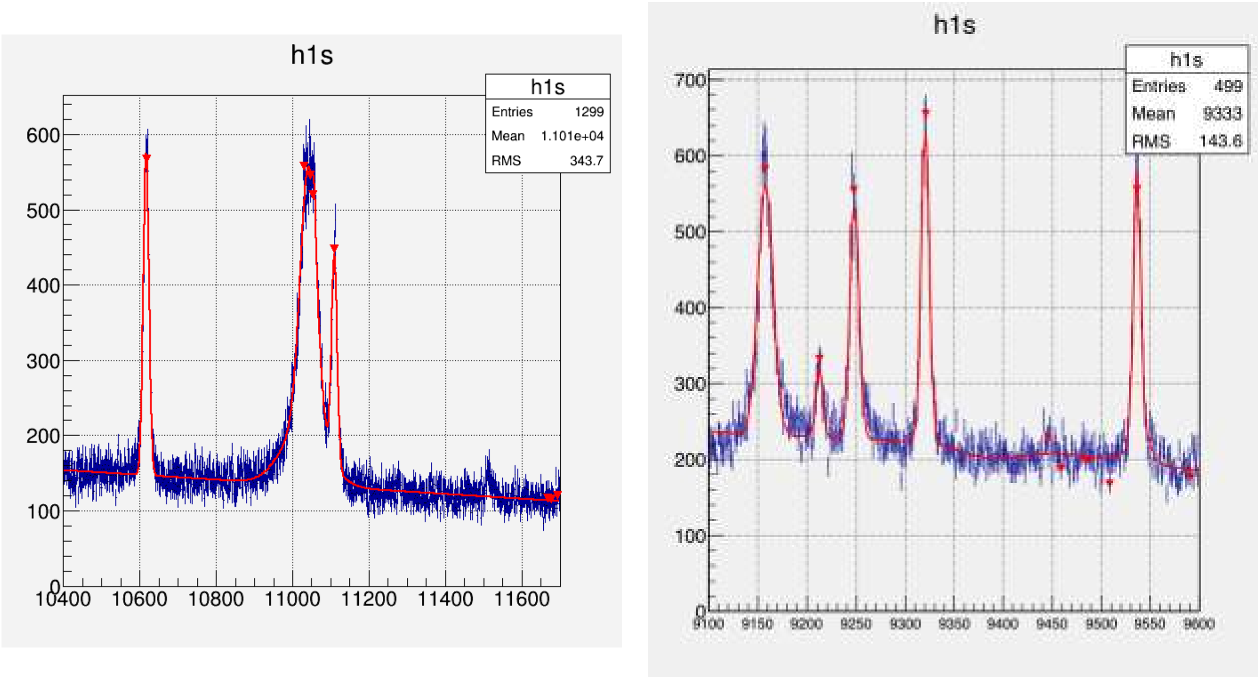

Fig.4. Screens of the program for extracting resonance parameters.

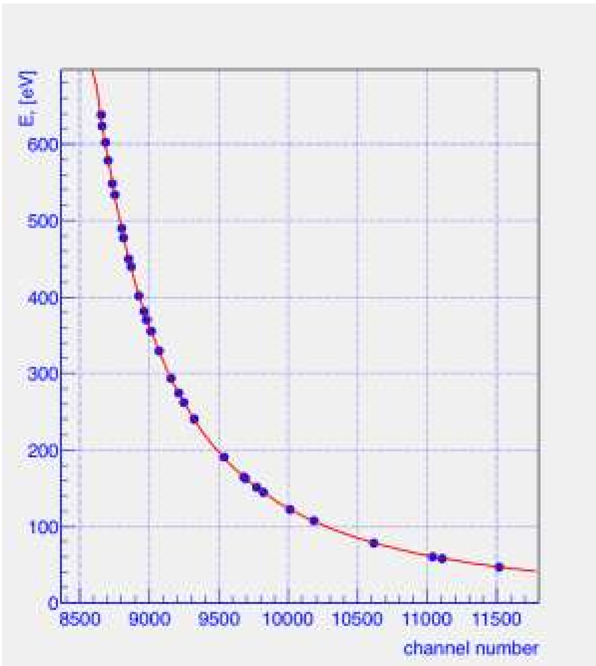

Fig.5. Calibration results for energy axis of installation INES.

One of tasks during present measurements was precise calibration in energy axis of installation INES. Calibration was made by 30 recognized peaks, using ENDF-BVII data as standard. Red curve is theoretical correlation between channel number and resonance energy, blue markers are BNL data.

Experimental TOF spectra before deletion of background, was compared with curve of capture cross section for Au^{197}. We can see coincidence in the energy axis between experimental (blue) and standard lines. Resonance at 59.9 eV is observed smaller than its original value because of big internal block-effect value in thick Au^{197}, chosen to make observable upper resonances. For definition of all cross section curve without block-effect it's necessary to measure plates of patterns with different thicknesses.

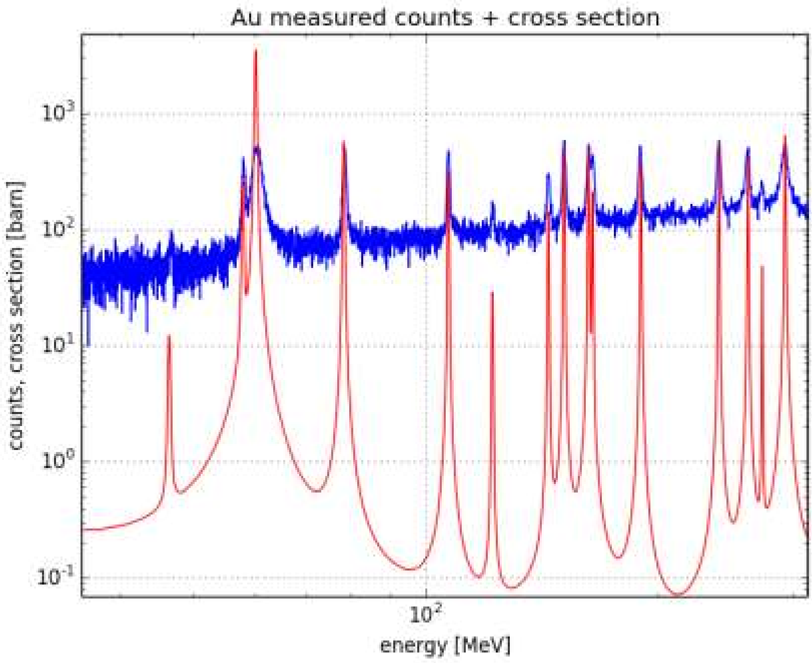

Fig.6. Experimental counts with background (blue) and standard cross section for Au^{197}.

4. CONCLUSION

During work cycle of the proton accelerator TOF spectrums of total and capture cross sections were measured. Calibration of energy axis for installation INES was provided using neutron capture cross sections of Au^{197}, Ta^{181} and U^{238} as standard data.

During measurements few created in INR new blocks of equipment were used. Among them fast preamplifiers for He^3 counters, single-channel coders, HV sources, fast data acquisition system. Their stable work was proven.

New programs for data analysis were written for computer in LINUX operation system. They provide resonance parameters definition and group cross sections extraction using experimental TOF spectrums as entering data.

Experimentally shown, that installation INES is able to make measurements of isotope compositions and group cross sections for alloys of structural and fissile materials. INES is able to determine both isotope enrichment of selected isotope in alloy, and alloy's group cross sections. This applied direction of work becomes an important supplement to previous research program [1].

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REFERENCES

1. Yu.V. Grigoriev, D.V. Khliustin, et al. The Investigation of the Resonance Neutron Cross Sections Structure and the Spectrometer Parameters for the Pulsed Neutron Sources RADEX and IREN-1. 61th International Conference 'Nucleus-2011', p. 65, Russian Federal Nuclear Center – All-Russian Institute of Experimental Physics. 10 - 14 October 2011, Sarov.

2. G.N. Vyalov, Yu.V. Ryabov, Yu.V. Grigoriev, D.V. Khliustin, Zh.V. Mezentseva, S.B. Borzakov. Proton Beam Separation for Simultaneous Operation of Two Installations at the INR Linear Accelerator. ISINN-20, May 2012, E3-2013-22, p.216, JINR, Dubna.