MEASUREMENTS OF GAMMA RAYS FROM THE INELASTIC SCATTERING OF 14.1 MeV NEUTRONS USING THE TAGGED NEUTRON METHOD

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Abstract

At the Joint Institute for Nuclear Research, in the frame of the TANGRA project [1], we started the second set of measurements of the inelastic scattering (INS) of 14.1 MeV "tagged" neutrons on a number of isotopes. The 14.1 MeV neutrons are produced in the $D(T,\alpha)n$ reaction by the VNIIA ING-27 portable neutron generator [2], which has a 64 Si-pixel charge particle detector, incorporated into its vacuum chamber. By registering the alpha particles, we "tag" the corresponding neutrons which, according to the reaction kinematics, are emitted in the direction nearly opposite to that of the alpha particles.

We used an array of 22 hexagonal NaI(Tl) crystals for spectrometry of the coincided with α-particles characteristic γ-rays following the INS-reaction on the nuclei under investigation.

The signals from NaI(Tl) were fed to a computerized 32-channel data acquisition system from JINR AFI Electronics [3], which was used for digitizing the analog signals from the detectors and storing the waveforms on the computer hard-drive for further off-line analysis.

In current set of measurements, we succeed to measure the gamma-ray spectra from the INS of 14.1 MeV neutrons on a number of light elements. Here we report and discuss the preliminary results for some of the investigated samples.

Keywords: Gamma-rays, spectrometry, multichannel analyzer, neutron source.

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1. Experimental setup

The experimental setup consisted of the ING-27 and Fe-shielded NaI(Tl)-array. The scheme of the experimental setup is shown in Fig.1 (left) and the photo is in Fig.1 (right). The target is located at a distance of 805 mm from the neutron source. The gamma-ray detectors are placed around the target with a step of 15 degrees at a distance of 320 mm from the target. The 40cm thick iron shielding was used to protect the gamma detectors from the direct neutron beam. Only one central pixel of the alpha-particle detector was used for producing the tagged neutron beam.
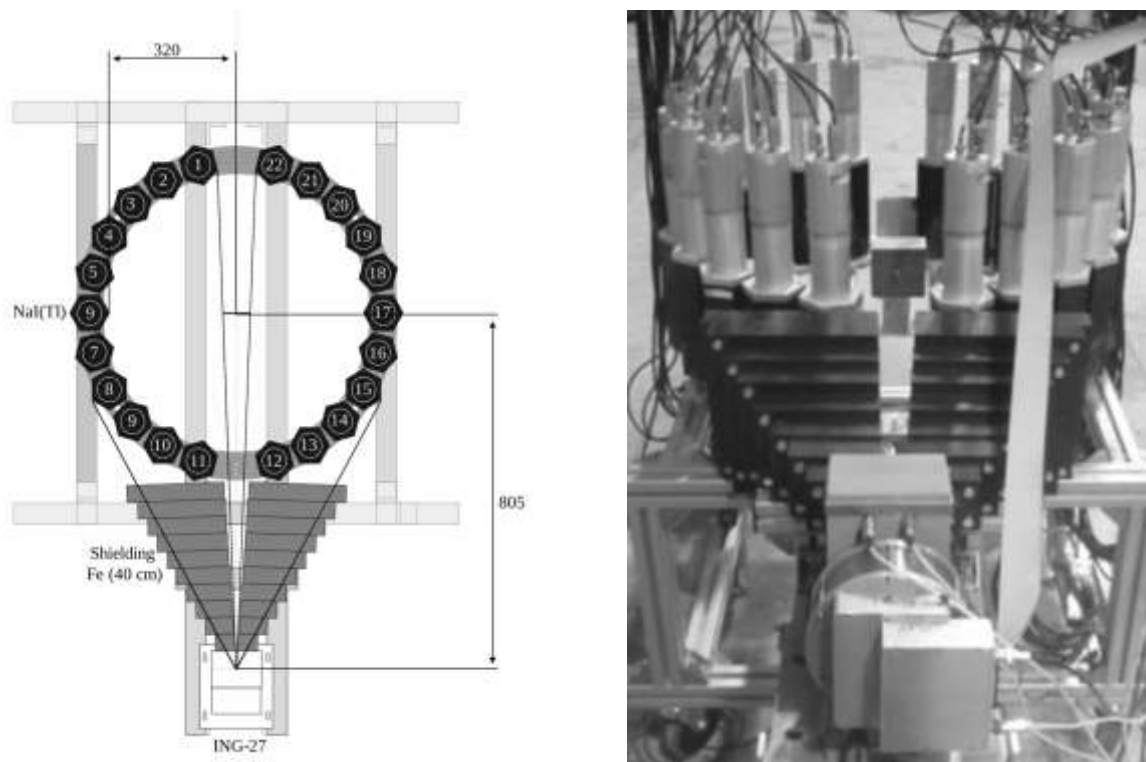
Fig. 1 The scheme (left) and the photo (right) of the experimental setup

In Fig. 2 are shown the samples from Lead (^{208}Pb), Carbon (^{12}C), Iron (^{56}Fe), Bismuth (^{209}Bi) and Aluminum (^{27}Al) of the same size – 100×100×50 mm.
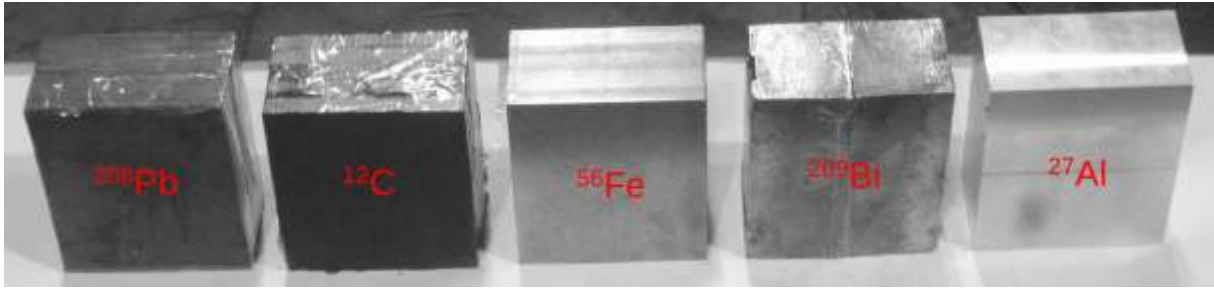
Fig. 2. Same of samples in TANGRA-project

2. Data acquisition and analysis

Data taking lasted 8h/sample. In Fig. 3 one can see a (triple) coincidence – the signals from the x-coordinate (ch # 23) and y-coordinate (ch # 22) of the ING-27 α-detector with a signal from the γ-detector (ch # 3). The data were saved on the computer hard disk as list-mode data and were analyzed offline in the ROOT environment [4].
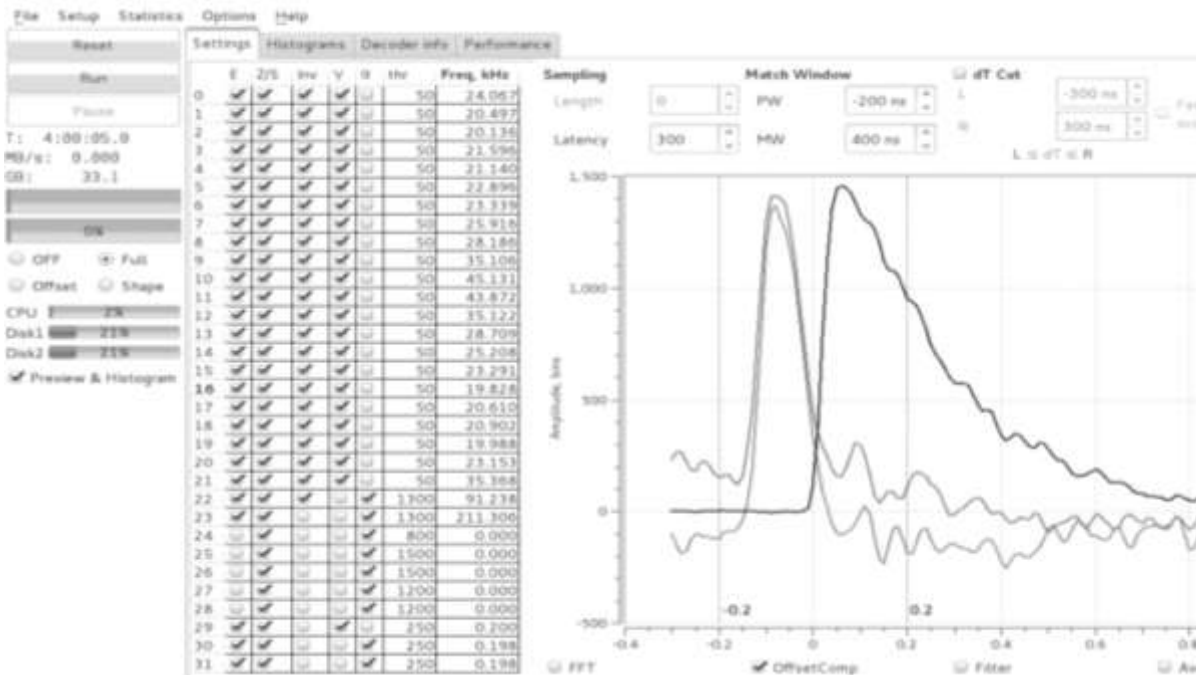

Fig. 3. DAQ system software main panel

The energy calibration of the collected amplitude spectra was done using standard (calibration) "point"-type gamma-sources. The time-spectra ('start' from α-detector and 'stop' from any of the γ-detectors) from the Al-sample are shown in Fig. 4. The first peak is arising from the neutrons scattered on the Fe-shielding (A), the second is from the inelastic scattering of neutrons on the sample (B) and the last one is from the interaction of the fast neutrons with the detector nuclei (C).
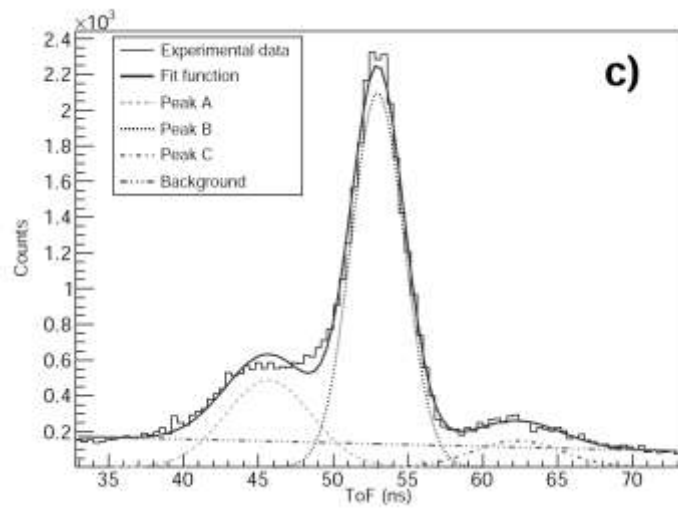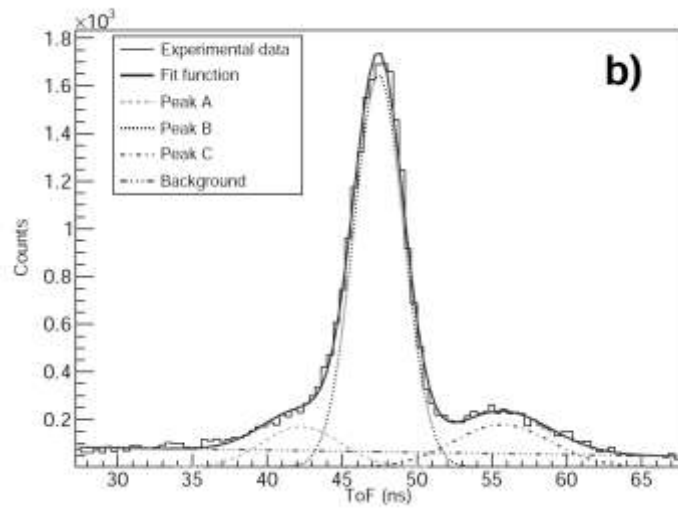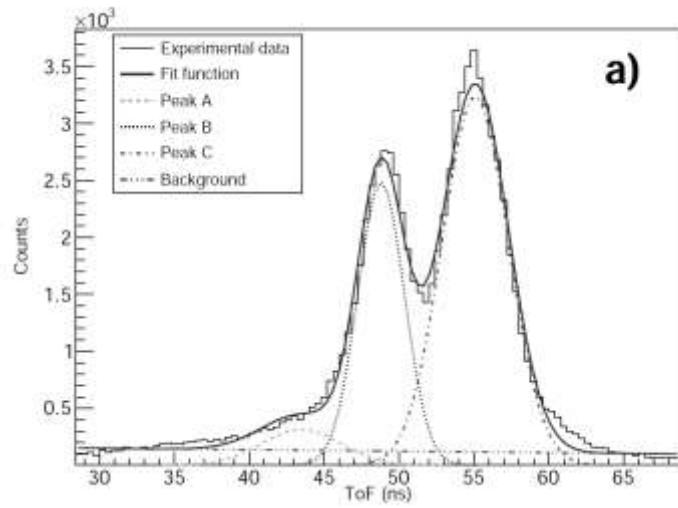
Fig. 4. ^{27}Al *sample: the time spectra from the detectors at 15˚ (a), 90˚ (b) and 165˚ (c).*

In Fig. 5 to 6 we show the comparison of the total energy spectra of gamma-rays (top spectra) and the spectra obtained within a time-window corresponding to 3σ width of the central gamma-peak in of time-of-flight spectra (see Fig.4, peak B). In this way, the radiation background in the "untagged" spectra was reduced by about 70%.
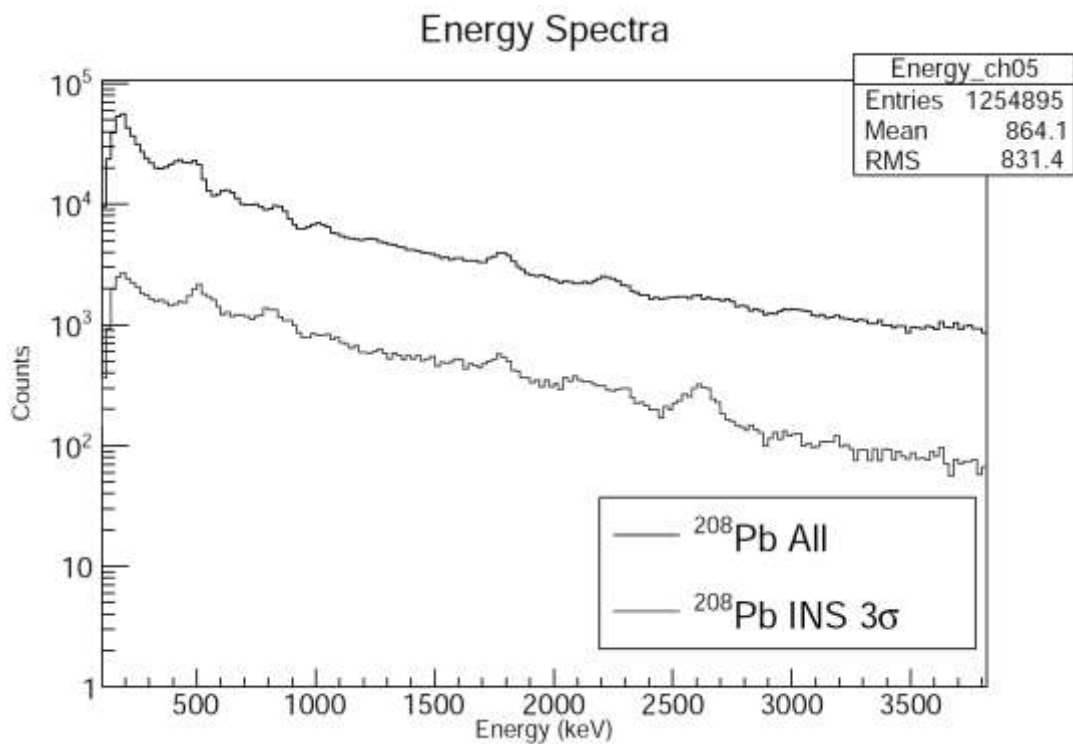

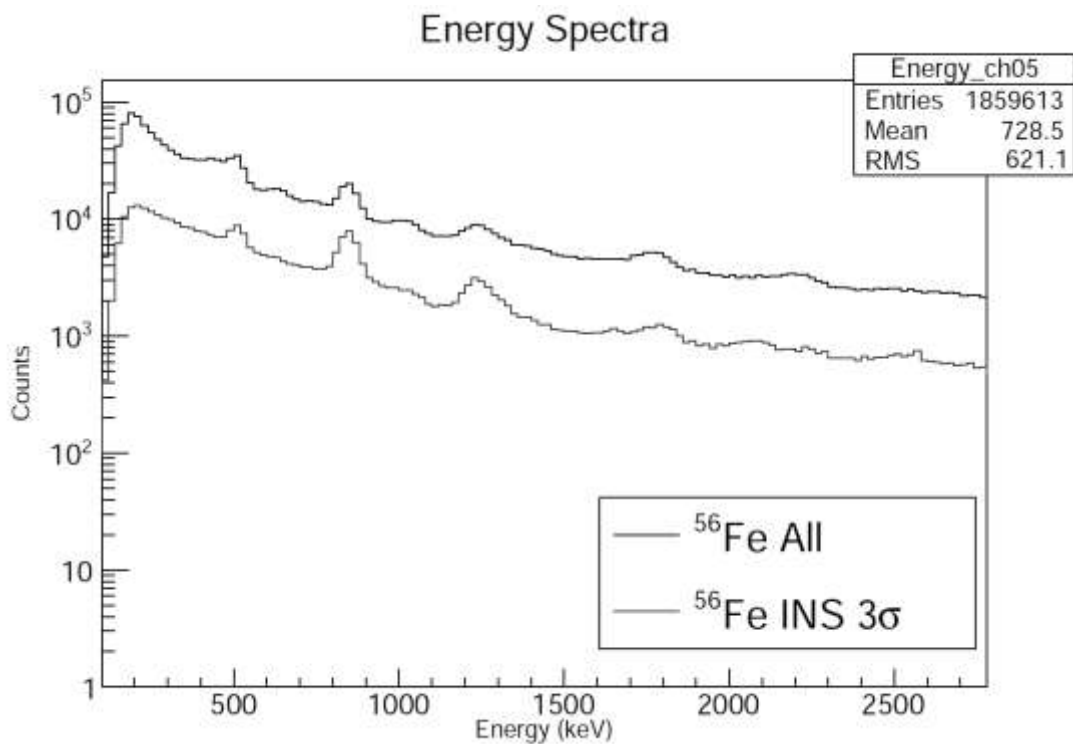Fig. 5. ^{208}Pb sample: energy spectra from the detector at 90˚

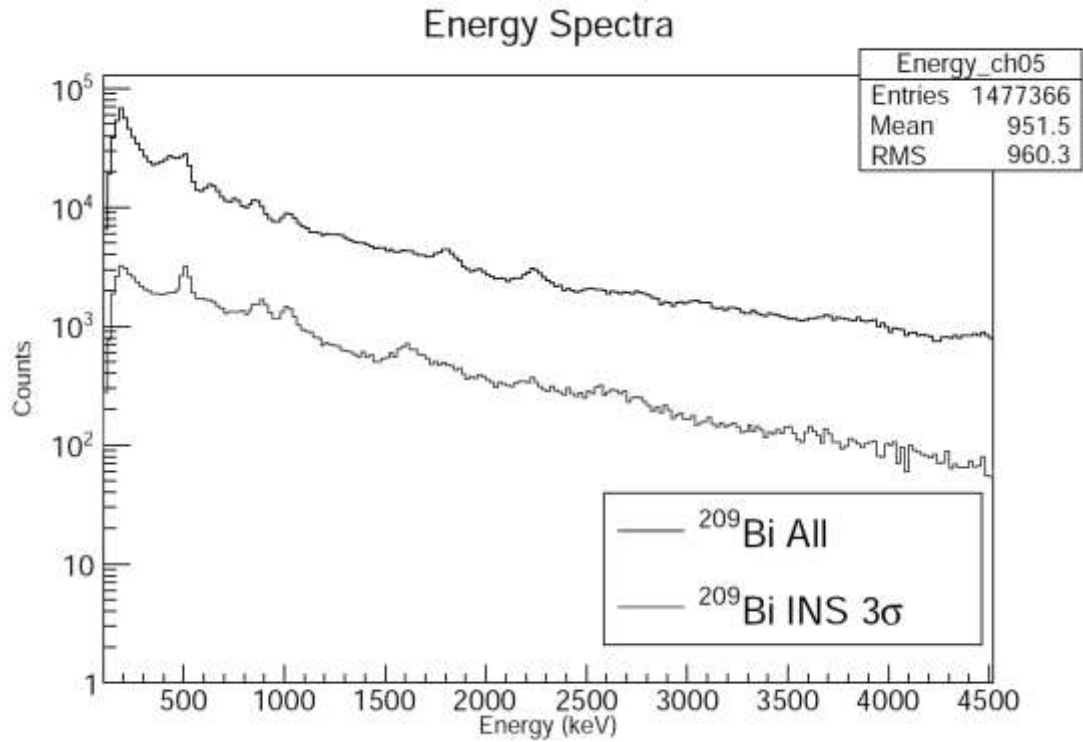Fig. 6. ^{56}Fe sample: energy spectra from the detector at 90˚

Energy Spectra

Energy_ch05	
Entries	1477366
Mean	951.5
RMS	960.3

— ^{209}Bi All

— ^{209}Bi INS 3σ

Fig. 7. ^{209}Bi sample: energy spectra from the detector at 90˚

Energy Spectra

Energy_ch05	
Entries	1634838
Mean	1020
RMS	1014

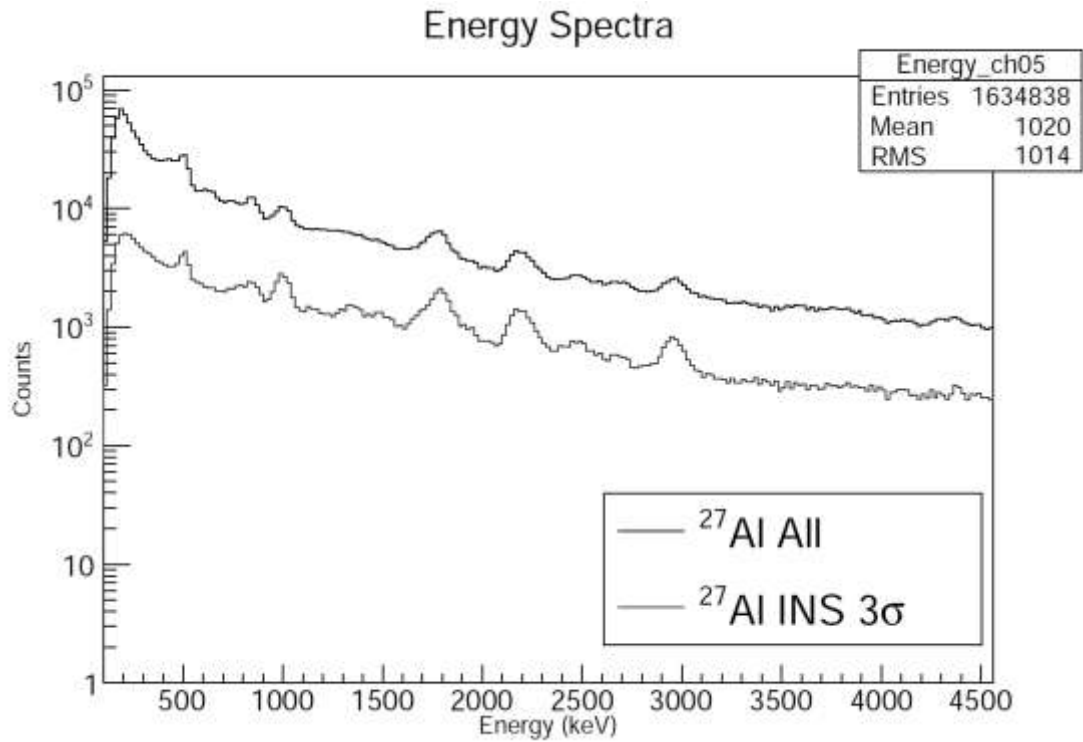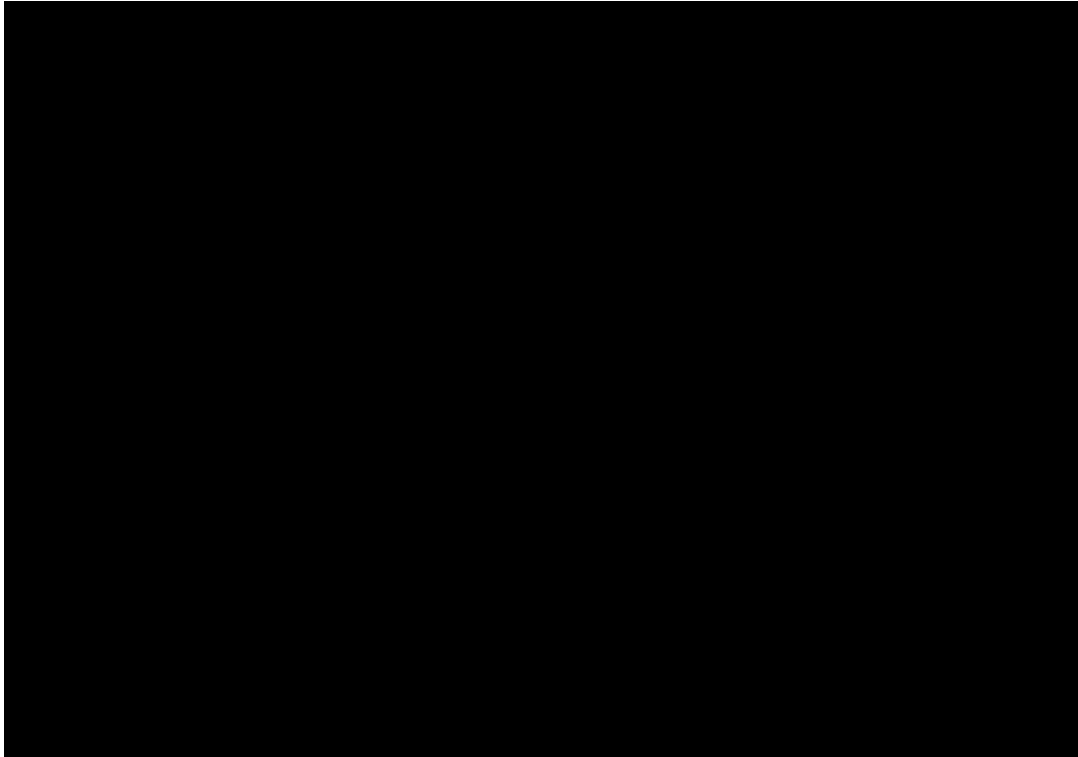— ^{27}Al All

— ^{27}Al INS 3σ

Fig. 5. ^{27}Al sample: energy spectra from the detector at 90˚

In the table below are listed the main characteristics of the identified γ-lines from the INS of 14.1 MeV neutrons on the target nuclei. The gamma-lines data are taken from ref. [5].

Table 1.

3. Conclusions

By using the target neutron method (TNM) we reduced by ~70% the radiation background in the collected pulse-height spectra. As a result of this we were able to identify the main characteristic gamma-lines from the INS of 14.1 MeV neutrons by the investigated elements.

4. Acknowledgment

References

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