DATA PROCESSING AUTOMATIZATION FOR GAMMA-SPECTROMETRY DIAGNOSTICS OF NEUTRON ACCELERATOR BNCT*

T.A. Bykov, Novosibirsk State University, Novosibirsk, Russia
D.A. Kasatov, Budker Institute of Nuclear Physics, Novosibirsk, Russia

Abstract

There is the accelerator-tandem at the Nuclear physics institute in Novosibirsk which is suitable for malignancies treatment such as glioblastoma and melanoma using BNCT methods.

There are different gamma spectrometry diagnostics which apply under this project. One of these is used to determine the parameters of the neutron beam. The method is to irradiate a set of activation foils with neutrons. Then measure the gamma-spectrum of foils using gamma detector. Based on these data it can be calculated the activity of foil, as well as the amount and the energy of neutrons.

For data processing of these diagnostics there was developed software which is used for convenient display of gamma-spectrometer data and the activity of the foil. Software allows setting a canal calibration and the sensitivity calibration which is needed to calculate the foil activity.

INTROCUTION

One of the most important and still unsolved problems is dosimetry of BNCT on all the stages of treatment. [1] Experiments are carried out to determine the parameters of generated neutron flow, using activation methods, and accompanying gamma-radiation. In this experiments it was used the spectrometric complex with NaI scintillator which must have automatic and operative data processing. The data processing task include automatic calibration, noise reduction, determination of the energy of the peak and the substance activity.

For these tasks the software was developed which allows processing the data in semi-automatic mode.

SUBJECT AREA

Activation method is used for determination of the current and the spectrum of neutrons. The special set of foils is used for the experiments (Au, Co, Cu, Fe, In, 5.2% Lu-Al, 81.3% Mn-Cu, Mo, NaCl, Sc, W). These foils are irradiated with neutrons during the experiment. Then the gamma-spectrum of foils using gamma detector is measured. Output spectrum data and period of measurement are saved into special file with specified format. As a result of the experiment there is a set of files with the spectrum data for every foil. These files are the input data for developed program.

These data have the following features. The graph of

the spectrum has a shape of decaying exponent with a peak in the Gaussian form for some energy, and also the noise which has about the same amplitude on the entire spectrum (see Fig. 1).
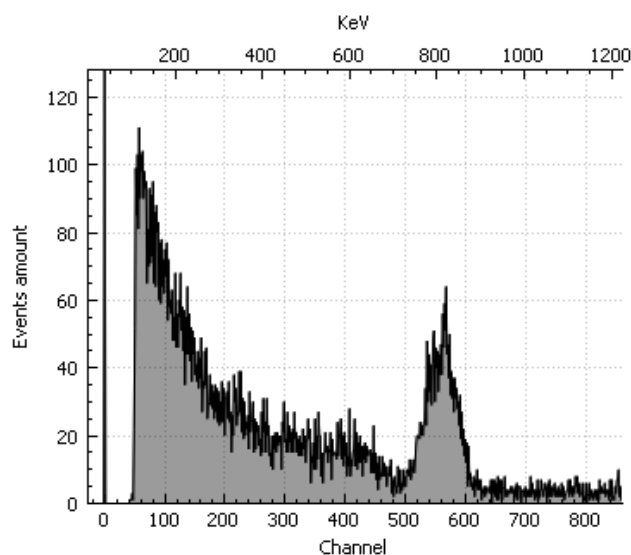

Figure 1: The graph of the spectrum of manganese isotope (^{56}Mn).

The noise amplitude in the spectrum is depends on the period of measurement and background during the measurement.

The number of peaks may be different and depends on the substance.

DATA PROCESSING

In the program the data processing consists of the following steps performed sequentially.

Noise Reduction

This module uses discrete wavelet transform.[2] The obtained spectrum data are represented as a mathematical function of amplitude by time i.e a signal with amplitude by time. The wavelet transform converts the signal from the time-amplitude representation to the time-frequency representation. In this subject area the useful information in the signal is a low-frequency component with large amplitude, i.e, trend, while noise is a high-frequency component and has a small amplitude.

The signal is decomposed into transform coefficients, then the coefficients with the amplitude below a user-specified values are reset to zero. and then performed the inverse wavelet transform. As a result, all of the useful low-frequency component of the signal remains, and small high-frequency noise is removed.

Biorthogonal spline wavelet was selected as a mother wavelet, which provides the necessary smoothness of the result signal. The user must enter a value that is a percentage of the noise in the signal. (see Fig. 2)
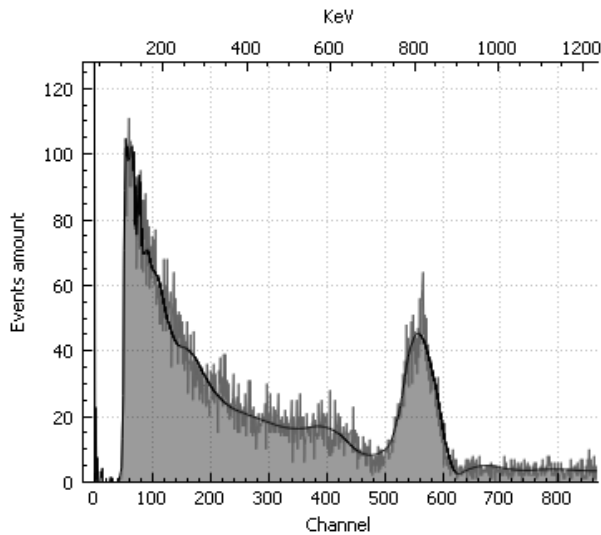

Figure 2: The result of smoothing using wavelet transform with the noise threshold of 6%.

Calibration

To display the data by values of energy, calibration needed. It is assumed that the energy values are linearly dependent on the channel values. So coefficients of the calibration are sets with the coefficients of line function. The user can enter the coefficients of the calibration line, also he has the opportunity to enter the channel values and the energy values, so the calibration coefficients will be calculated by the least squares method. In the figure one the upper horizontal scale shows the energy, and the bottom shows the channels.

Peak Determination and Activity Calculation

The measured isotopes have known parameters such as: the number of emitted gammas, their energy, their percentage and isotope's half-life. All these parameters are stored in the program, and it is possible to edit them.

Gamma detector saves in the file number of registered events for each channel. And the actual number of the emitted gammas is much different from that which records the detector due to imperfections of the detector. Part of gammas just does not hit the detector. The part that reaches the detector is scattered on adjacent channels. Thus in Figure 3 it is shown a normal distribution of the detected gammas. So the number of events is calculated as the integral of a gauss for a given energy.

In the Figure 4 the inputs are: the "Peak channel", the "Probability", it is the probability the gamma-quantum to emit, and the "Window", it is the maximum Gauss width.

The field "Events amount" displays value of the integral. This value divided by the duration time displays into the field "Real activity". This is the activity measured by the detector, but without taking into account the

sensitivity calibration. Activity multiplied by the sensitivity calibration coefficients displayed into the field "True active".
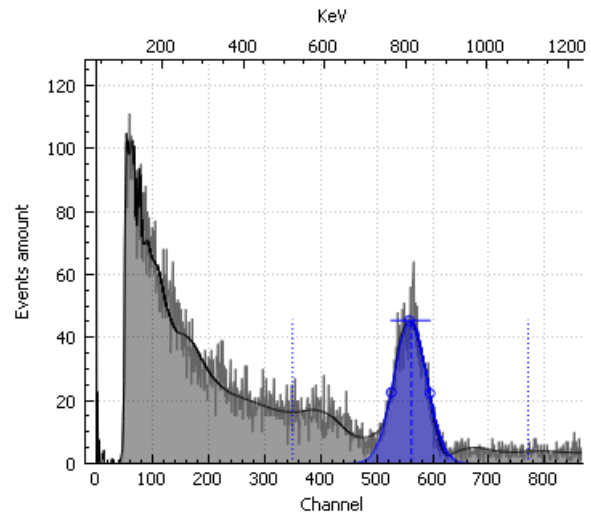

Figure 3: The Gaussian function is fitted in a peak of energy 847 KeV for ^{56}Mn.

The program calculates the Gauss by three points: the top which can be set by the user, and the two values in the middle of the height of Gauss.

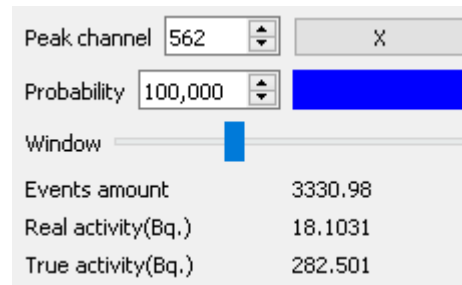

Figure 4: The user interface for the input of the peak parameters.

Sensitivity Calibration

Sensitivity in the channel - it is the true activity ratio, i.e. the activity that should be for that substance, to the activity measured by the detector. As in the case of calibrating the channels it is assumed that the channel sensitivity dependence is linear. So coefficients are sets with the coefficients of line function. It is possible to input these coefficients, or to calculate these coefficients, using the least squares method for channels values and the sensitivity values. The sensitivity values represented by the real activity and the true activity.

Restoring the Initial Activity

Substance activation - is the number of active cores obtained after irradiation. The resulting isotope begins to decay immediately after irradiation emitting gamma rays. And different substances have different half-life. At the moment, there is no way to measure all foils at the same time, so foils are measured separately and while measured

the first foils, the rest decay before the start of measurement. So the measured foil activity will be less than after the neutron irradiation. Substance activity decreases exponentially with time. Figure 5 is a graph of substance decay. Knowing the start and end of the measurement, and activity it is not difficult to restore the initial activity.
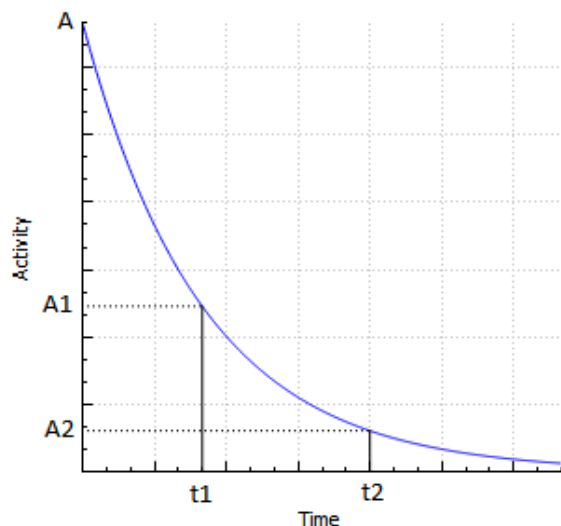

Figure 5: Graph of radioactive decay. Where the time t1 and t2 are the time of the start and the end of measurement, A1, and A2 - the activity at this time.

Activity measured by the detector and calculated by the program is ΔA = A1 - A2. The initial activity is restored with the equation (see Eq. 1)

$$A = \frac{\Delta A}{2^{-\frac{t1}{T}} - 2^{-\frac{t2}{T}}} \qquad (1)$$

In equation 1 A is the amount of the resulting isotope after irradiation, or activity, ΔA is the activity resulting from the measurement, t1 - start time measurement, t2 - time measurement end, T - the half-life.

Restoration of the Neutron Spectrum by Activity

To restore the neutron spectrum used SAND II (Spectrum Analysis by Neutron Detectors). One of the input parameters for the calculation is the initial activity of the substance which is already calculated, and many other parameters. All these parameters are automatically passed from the main program to this program. Currently, this module is not implemented.

USED TOOLS

The program is implemented in C++ using the Qt 5.7 framework for the user interface. To display graphs used QCustomPlot library. For wavelet transform and calibration calculation used GSL library.

CONCLUSION

Currently developed program allows the processing of data only in semi-automatic mode. This means that after measurements on spectrometric complex, it is necessary to collect information and enter it into the program. It does not allow to see the result of the measurement real time. As a result of this work it is planned to develop a fully automated gamma spectrometric complex where data processing will take place without user participation. Implemented modules: noise reduction, channel and sensitivity calibration, the determination and calculation of peak activity. the modules of restoring the original activity and neutron spectrum calculation is not implemented.

REFERENCES

[1] S. Taskaev, V. Kanygin, Boron neutron capture therapy, (Novosibirsk: Russian Academy of Sciences, 2016), 216.
[2] A. N. Yakovlev Introduction to wavelet transform, (Novosibirsk: Publishing House of Novosibirsk State Technical University, 2003), 104