CHARACTERISTICS OF POSITION-SENSITIVE PLASTIC SCINTILLATION DETECTORS

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Abstract

This work is devoted to the calibration of plastic scintillation detectors and comparison of their parameters. Long plastic detectors with photomultiplier tubes (PMT) at both ends were chosen for the study. The choice stems from the goal of obtaining position resolution using time information from both PMTs.

The measurements were carried out for two types of detectors with the same dimensions (5×10×100 cm). The first type is a plastic detector manufactured by EPIC CRYSTAL, Shanghai, China. It has a PMT model CR105 from HAMAMATSU. The second type is a plastic detector manufactured by ELJEN TECHNOLOGY, USA. It is equipped with a PMT model ETEL 9266KEB from ELECTRON TUBES.

The purpose of this study was to determine the main characteristics and optimal operating conditions of the detection system. The tests were carried out with ^{137}C and ^{60}Co gamma radiation sources. A digital signal recorder DSR-2/32, was used for data collection and preliminary analysis.

1. INTRODUCTION

At the Joint Institute for Nuclear Research (JINR, Dubna, Russia), within the framework of the TANGRA project (TAgged Neutrons and Gamma RAys) [1], experiments on the study of inelastic scattering of fast neutrons are continuing [2]. Various types of detectors are used to study reactions with neutrons, including plastic scintillators.

Plastic scintillators are often used in measurements with neutrons, most often using the time-of-flight technique [3,4]. This is due to a number of advantages that these detectors have: fast response, low cost, and the ability to manufacture a scintillator of almost any shape and volume.

Long plastic detectors with PMTs at both ends of the detector were chosen for the study. For the first time a detector with such characteristics was used by Charpak G. et al. [5]. The choice is due to the goal of obtaining positional resolution using time information from both PMTs.

The purpose of this study was to determine the detector characteristics (the time, position response, the attenuation length of light in the scintillator) and to select the PMT optimal voltage.

2. DESCRIPTION OF DETECTORS AND RESEARCH METHODS

The measurements were carried out for two types of detectors with the same overall dimensions (5×10×100 cm). The first type is a plastic detector manufactured by EPIC CRYSTAL, Shanghai, China [6]. It has a PMT, model CR105, from HAMAMATSU [7]. The second type is a plastic detector manufactured by ELJEN TECHNOLOGY, USA [8]. It is equipped with a PMT model ETEL 9266KEB, from ELECTRON TUBES [9]. A photo of the detectors and their schematic view are shown in Fig. 1 and 2, respectively.

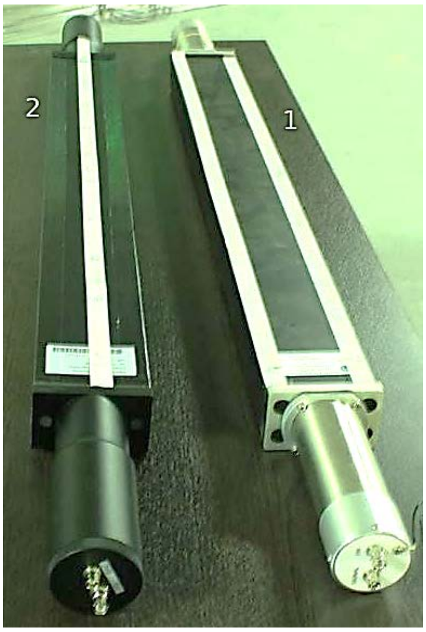

Fig. 1. Plastic scintillation detectors from ELJEN TECHNOLOGY (1), and EPIC CRYSTAL (2).

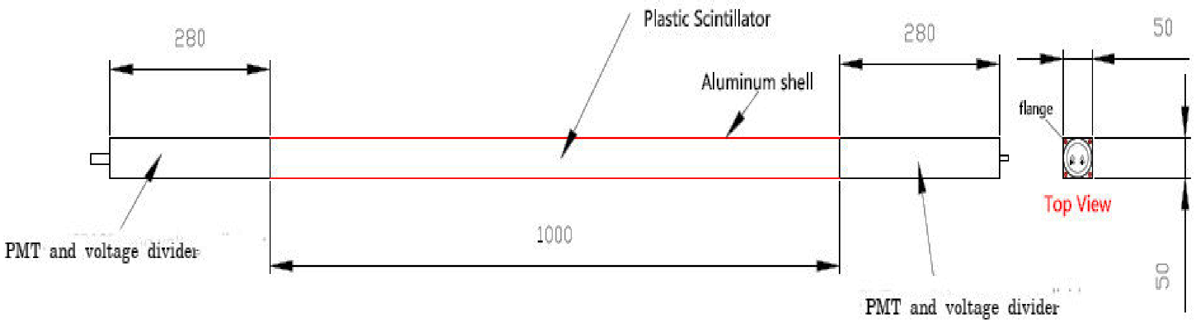

Fig. 2. The schematic view of the studied detectors [6].

The tests experiments were carried out with ^{137}Cs and ^{60}Co point-like gamma-ray sources. The digitizer DSR-2/32 was used for data collection and preliminary analysis.

The selection of the optimal voltage on the PMT was carried out using the point sources, which were alternately placed in the center (at the same distance from each PMT) in front of the detector. The spectra obtained in the experiment with a ^{60}Co source are shown in Fig. 3.

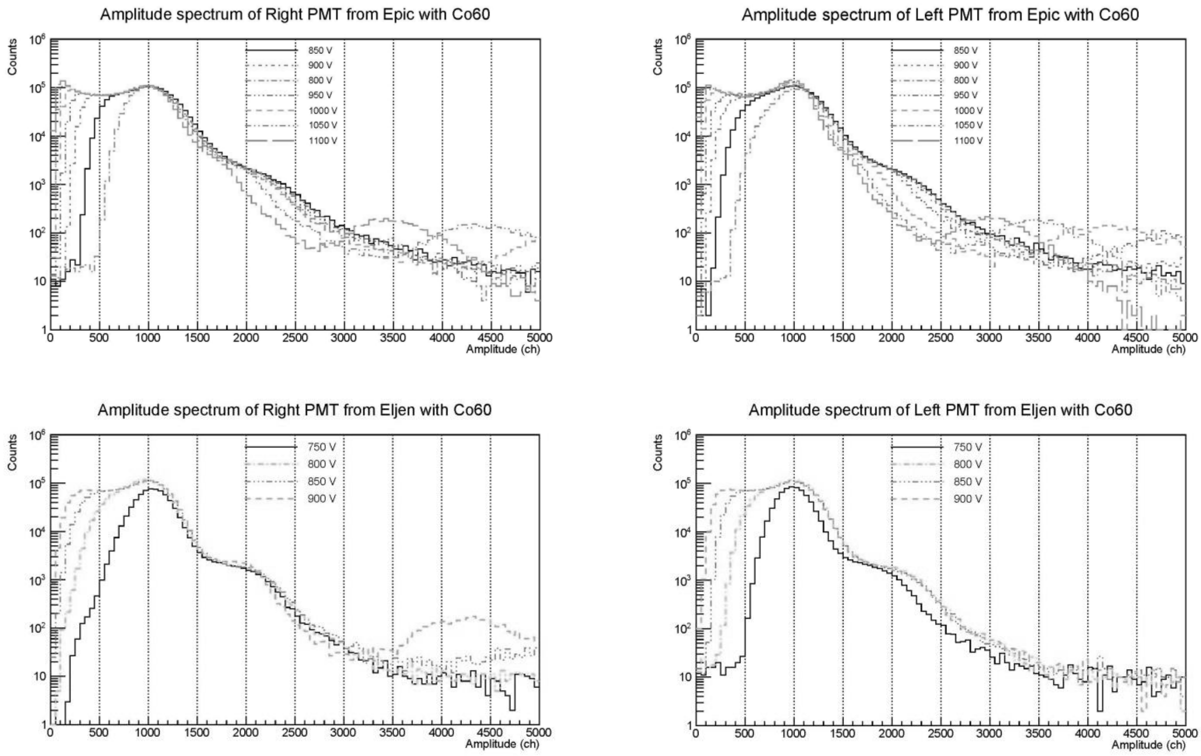

Fig. 3. Amplitude spectra of the right and left photomultipliers from the EPIC CRYSTAL and ELJEN TECHNOLOGY detectors.

Further, to study the characteristics of the detector, depending on the place of interaction of gamma radiation with the scintillator and select the optimal parameters of the system in the desired mode, the concept of "position coordinate" (or X coordinate) of the particle's passage through the detector is introduced. It can be obtained from the time difference between the signals received from the left (T_L) and right (T_R) PMT [3]:

$$X \sim (T_L\text{-}T_R). \tag{1}$$

In addition, the necessary input value is Q_{GM} – an integral charge, which is proportional to the energy of the incident particle. It is calculated as the geometric mean between two signals from the PMTs, practically does not depend on the hit position [10] and can be used as particle energy:

$$Q_{GM} = \sqrt{Q_L Q_R}, \tag{2}$$

where Q_L and Q_R are signals from the left and right photomultipliers, respectively.

The example of obtained amplitude spectra one can see on figure 4.

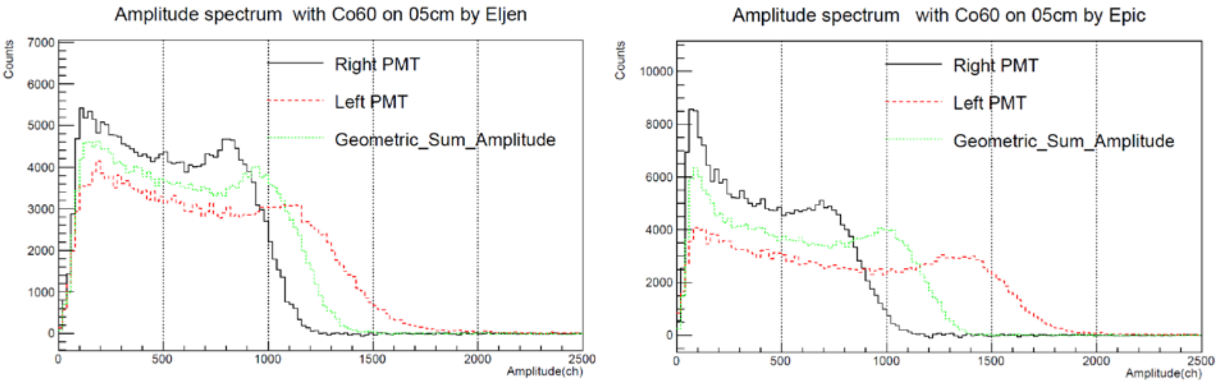

Fig. 4. Amplitude spectra of the right and left PMTs and their geometrical sum from the ELJEN TECHNOLOGY (left) and EPIC CRYSTAL (right) detectors.

Using the above expressions (1, 2), the time resolution was obtained. In figure 5, one can see examples of time spectra with EPIC detectors at a voltage of 950 V (with a threshold of 100 keV (a) and 700 keV (b)) and ELJEN detectors at a voltage of 850 V (with a threshold of 100 keV (c) and 700 keV (d)).

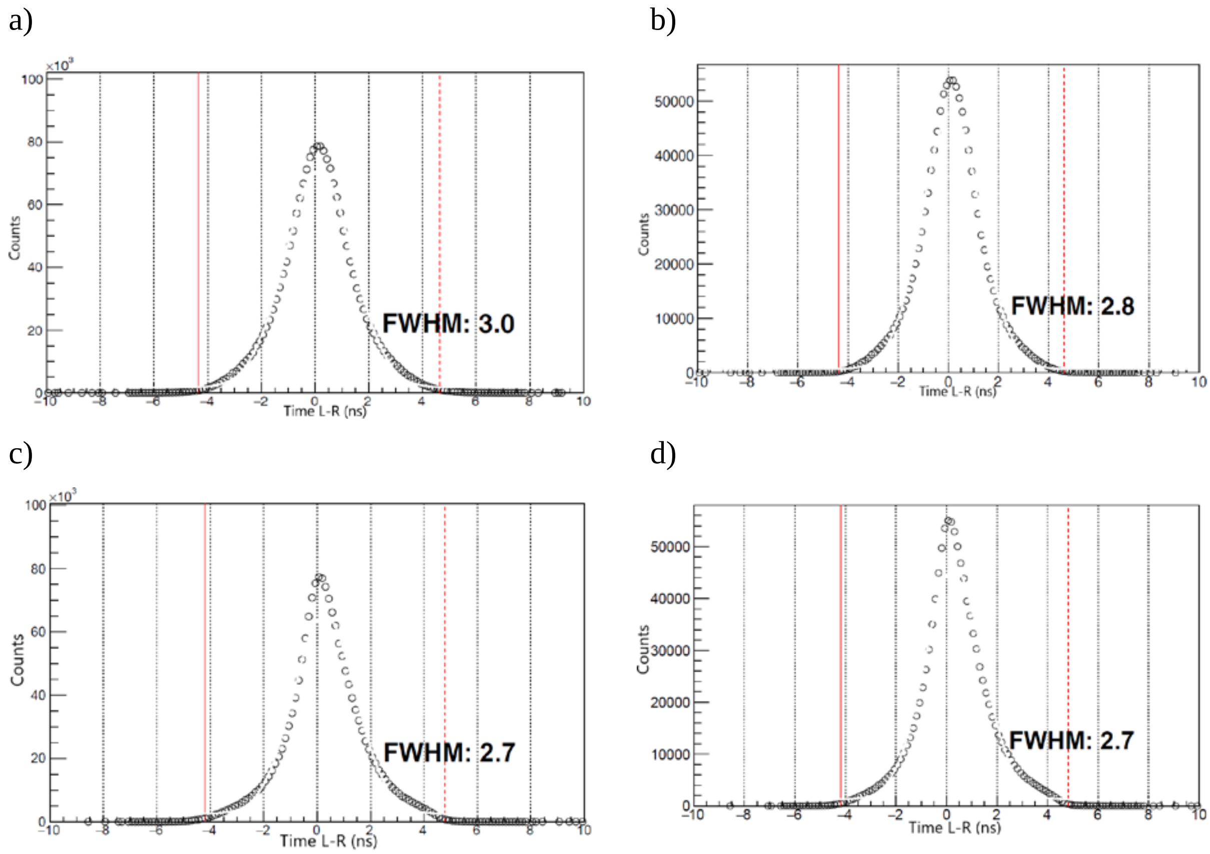

Fig. 5. Time spectra (T_L-T_R) for detectors: EPIC at a voltage of 950 V and an interaction threshold E_{thr} = 100 keV (a), E_{thr} = 700 keV (b) and ELJEN at a voltage of 850 V and an interaction threshold E_{thr} = 100 keV (c), E_{thr} = 700 keV (d).

The full width at half maximum (FWHM) was determined for each peak in the time spectrum at different voltages applied to the PMT. The obtained values include the contributions from the signal delay by the registering electronics and PMT. Figure 6 shows the FWHM dependence of the time peak on the PMT voltage for the EPIC and ELJEN detectors at the threshold of 100 and 700 keV. The data obtained were used to select the optimal voltage parameters for the detectors.

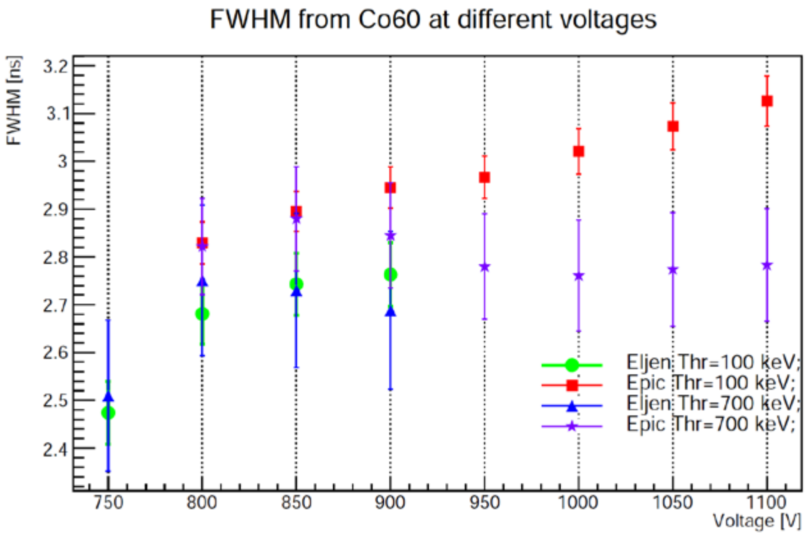

Fig. 6. FWHM of the time peak versus PMT voltage for the EPIC and ELJEN detectors with thresholds 100 and 700 keV.

Additional measurements were carried out with point radiation sources to obtain information about the interaction position or the X coordinate of the particle and other detector characteristics. During the experiment, γ-quanta from ^{137}Cs and ^{60}Co radioactive sources were collimated with lead bricks. The source and collimator assembly were moved along the length of the plastic detector with a step of ~ 14–15 cm (Fig.7).

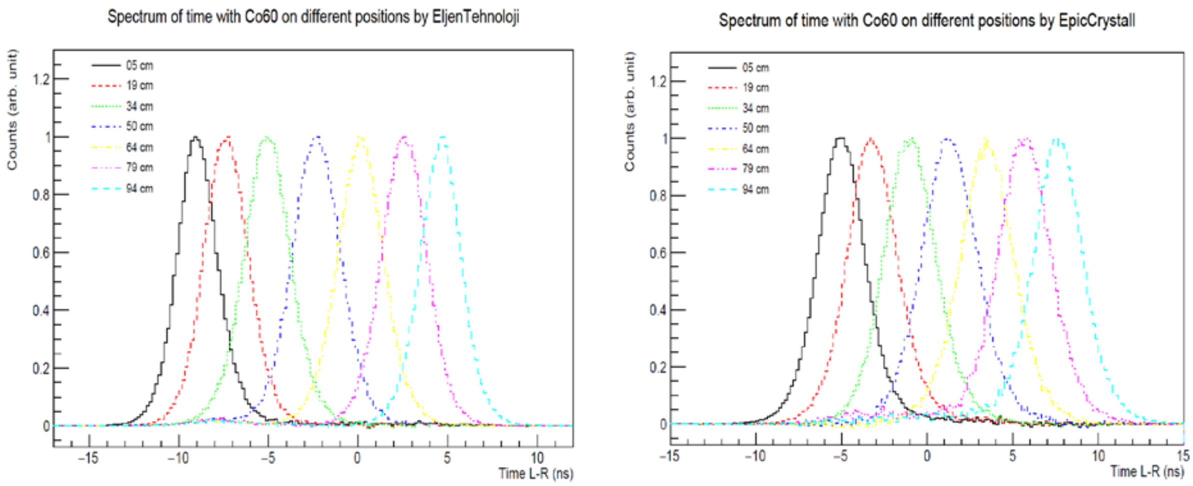

Fig. 7. The time difference spectra, obtained with ^{60}Co radioactive sources and collimator assembly for various distances of the exposed part from one end by the ELJEN (left) and EPIC (right) detectors.

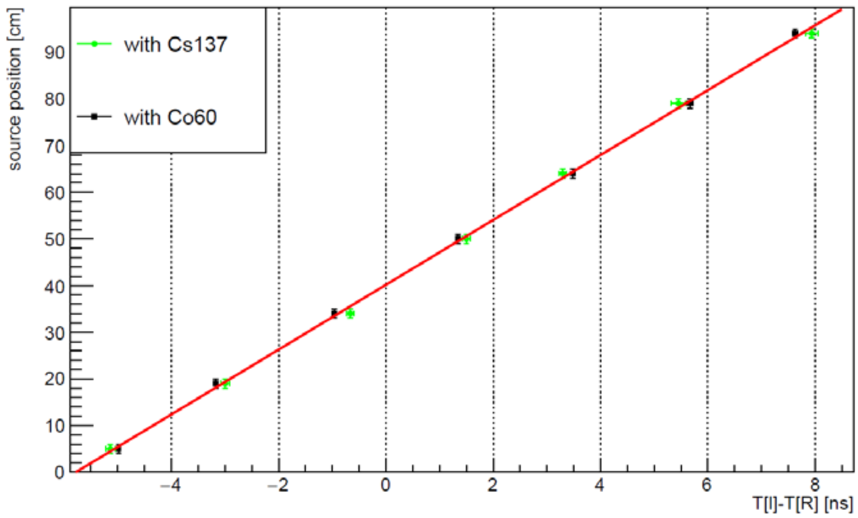

Fig. 8. Measured time difference versus the position of the radiation source for the EPIC detector. Experimental data were obtained with a ^{60}Co source (squares) and with a ^{137}Cs source (circles). The solid line is the fit of a linear function to the experimental data.

As can be seen from Fig. 8 (example of experimental data obtained with the EPIC detector), the dependence of $(T_L\text{-}T_R)$ on the source position is linear. The obtained dependence was used to determine the position resolution of the both detectors (Fig. 9).

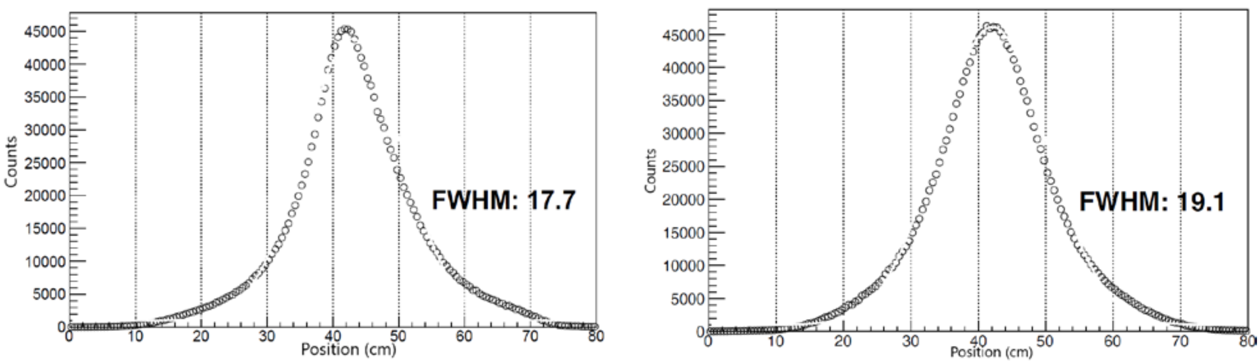

Fig. 9. Position resolution for ELJEN (left) and EPIC (right) detectors measured with a γ ray beam from a ^{60}Co point source collimated using appropriately placed lead bricks to illuminate a 0.5 cm wide portion of the plastic scintillator.

Another quantity characterizing the detector is the attenuation length of light in the scintillator (λ), determined from the exponential decay of the amplitude of the scintillation burst signal A with distance x [11]:

$$A(x) = Aexp\left(\frac{-x}{\lambda}\right). \tag{3}$$

Figure 10 shows the experimental amplitudes of the scintillation burst signals depending on the position of a ^{60}Co point source for ELJEN and EPIC detectors.

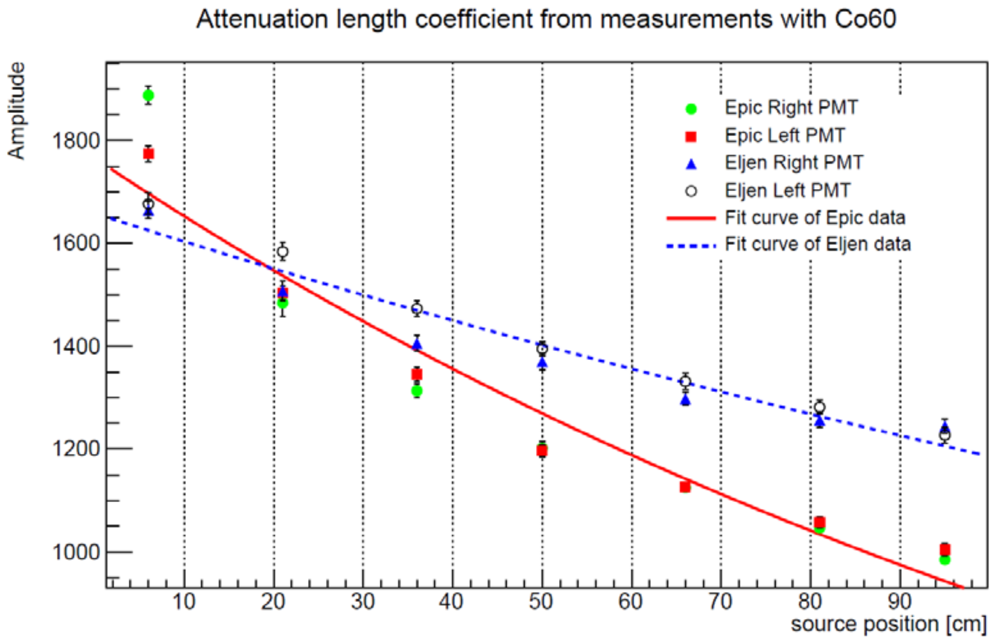

Fig. 10. Experimental amplitudes of scintillation burst signals as a function of the position of a ^{60}Co point source for ELJEN and EPIC detectors.

Then, using exponential approximation according to dependence (3), the values of the attenuation length of light in the scintillator for each of the detectors were obtained.

3. CONCLUSION

The article discusses the features of working with long plastic detectors from two different manufacturers – EPIC and ELJEN, their main characteristics are obtained. Calibration was carried out using ^{137}Cs and ^{60}Co point sources.

As a result of the study: the average time resolution obtained for EPIC detector was ~ 2.9 ns and for ELJEN ~ 2.5 ns. The uncertainty of the position coordinate (position resolution) was ~ 19.1 cm for EPIC and ~ 14.7 cm for ELJEN detectors. The obtained values of the light attenuation length in the scintillator were 151.5±2.1 cm for EPIC and 298.3±9.3 cm for ELJEN detectors.

In the future, it is planned to continue studies of the characteristics of detectors with a portable neutron generator ING-27.

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