**Technique for online monitoring of plastic scintillator characteristics of detectors**

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**Abstract.** The possibility of determination of plastic scintillation detector characteristics by usage of measurement results and numerical modeling is studied in this paper. One of the main characteristic of scintillation detectors, defining the amplitude of output signal at the particle registration, is light collection that depends on the transparency and reflection coefficient of scintillator. A technique based on a comparison between the signals of particles measured in various places of the scintillator and the results of numerical simulation is suggested. Using experimental data and numerical modeling for the sample laboratory detector, the main characteristics of the scintillator were obtained. This technique can be used for online monitoring of the scintillator properties during the long-lasting space experiments.

**1. Introduction**

Scintillation detectors, based on various types of scintillating materials, are widely used as ionizing radiation detectors for scientific and technical purposes, both in ground-based and space experiments. Especially it should be noted plastic scintillation detectors because of their manufacturability for production with any sizes and forms and relative low cost.

The determination of the scintillation detector characteristics is needed for their effective application in experiments. One of the important characteristic of scintillation detectors is the efficiency of light collection for the detector. This is defined as by scintillation material properties (absorption length for photons) as by light reflecting properties of detector planes depending on the surface processing quality and their coverage materials. These parameters define energy resolution and efficiency of scintillation detectors. It is important to define the characteristics in space experiments when instruments are unavailable for services and testing. For example there are several scintillation detectors in PAMELA space spectrometer. During launching an instrument was exposed by acceleration and vibration. Temperature change and cosmic radiation can influence detector characteristics during the flight. So it needs to know how basic detector characteristics degrade in order to obtain reliable experimental data. Especially such information is important for long-lasting cosmic experiments. Usually for calibration of scintillation detectors during the flights methods based on light-emitting diodes (LED) signals are used [1]. However in this case only integral information about detector degradation can be received. In reality the degradation can be caused by deterioration of the scintillator characteristics (transparency, reflection ability, light yield, light collection) and decreasing photodetector sensitivity. It is also possible to determine the detector characteristics, using amplitude signal information at the registration of charged particles in various places of the scintillator.
Below we consider the technique to determine the scintillator properties (transparency, reflection ability) and the possibility of their monitoring during long-lasting space flight.

2. Procedure of numerical modeling light collection of a scintillation detector

In figure 1 the scheme of a scintillation detector and the photon trajectory are presented.

![Figure 1. The scheme of a scintillation detector for numerical modeling.](image)

For each incident particles energy losses are defined by ionization in scintillator. The energy losses determines the number of generated photons in a scintillation flash. The photon propagation in scintillation detector is simulated by means of Monte Carlo method, assuming that photon angular distribution under generation is isotropic. Each photon is traced in scintillator from the point of generation to the photodetector, taking into account transparency and boundary reflection of scintillator. The probability of photon absorption during propagation in scintillator substance is defined by the equation:

$$P(x) = 1 - e^{-\frac{R}{\lambda}}$$

where $R$ is the distance travelled, and $\lambda$ is the absorption length [2]. If a photon is not absorbed along the path to the boundary of a detector then reflection process is modelled. The probability of photon loss under reflection is:

$$P(\eta) = 1 - \eta$$

where $\eta$ is the reflection coefficient.

The part of generated photons reaches the photodetector determining the light collection ($\varepsilon_d$):

$$\varepsilon_d = \frac{N_d}{N_0}$$

where $N_0$ – the number of generated photons in a scintillation flash and $N_d$ – the part of photons collected by photodetector.

3. Results of laboratory measurement

The sample laboratory scintillation detector with dimension 15x15 cm$^2$ was used for measurement light collection. Photomultiplier tube (PMT) is located at the distance of 2.5 cm from one of the faces. To determine the amplitude of the signals in different zones of the detector pair of monitor scintillation counters (2x2 cm$^2$) were used for generation of trigger signal (in coincidence) at passing cosmic muon through the counters. The scheme of location these zones of the laboratory detector and the PMT is shown in figure 2.
Figure 2. The scheme of laboratory measurement.

Table 1 presents the average amplitudes ($U$) of output signal with their statistical errors of the sample detector for each zone. $N$ is the number of zone.

| $N$ | 1   | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  |
|-----|-----|----|----|----|----|----|----|----|----|
| $U$, mV | 293±23 | 128±14 | 94±11 | 93±10 | 82±9 | 79±6 | 66±6 | 50±5 | 40±3 |

4. Modeling results and its comparison with laboratory measurement

Simulation of particle detection by scintillator plate with various values of absorption length ($\lambda$) and reflection coefficients ($\eta$) was carried out. As an estimation of agreement between modeling results and the experimental measurement data were used value of $\chi^2$ by using least square method. Figures 3 and 4 present the dependences of relative amplitude ($U/U_{\text{max}}$) on distance (R) from PMT for various values of absorption lengths and reflection coefficients. $U_{\text{max}}$ and $U$ are the modeling amplitude for distance 2.5 cm and R respectively. Points on the graphs are experimental data in zones 1-3 (see chapter 3).

Next step was simulation relative output amplitudes in all zones (4-9) of the laboratory detector for various values of parameters ($\lambda$, $\eta$). Some examples of results are presented in figure 5. The modelled values and experimental data for the whole detector are shown in figure 5. The solid curve 1 corresponds $\lambda=180$ cm and $\eta=0.98$. The dashed curve 2 corresponds $\lambda=50$ cm and $\eta=0.8$. The curve 1 has excellent agreement with experimental data ($\chi^2=0.5$). The second curve has rather big difference from experiment points ($\chi^2=50$). Typical values for the absorption length of plastic scintillators are ~1-2 meters [3]. So these parameters obtained by simulation are reasonable.

Presented analysis gives the possibility to suggest the technique for determination the scintillator characteristics (absorption length, reflection ability). This technique is based on comparison between measurement data and numerical simulation results of relative amplitudes of output signals in various places of scintillator.
Figure 3. The dependence of relative amplitudes on distance from PMT for different absorption lengths ($\lambda_4=25$, $\lambda_2=100$, $\lambda_3=200$, $\lambda_4=400$). Reflection coefficient $\eta=0.97$

Figure 4. The dependence of relative amplitudes on distance from PMT for different reflection coefficients ($\eta_1=0$, $\eta_2=0.8$, $\eta_3=0.96$, $\eta_4=1.0$). Absorption length $\lambda=160$ cm

Figure 5. The dependence of light collection on the particle input position. ($\eta=0.98$, $\lambda_0=180$ cm)
5. Conclusion
This paper presents the results of modeling, laboratory measurements and estimation of the parameters of the sample plastic scintillation detector. It is suggested the technique for determination of scintillator characteristics (absorption length, surface reflection), based on comparison between measurement data and numerical simulation results of relative amplitudes of output signals in various places of scintillator. This technique allows to carry out online procedure of the calibration and monitoring of scintillation detectors during long-lasting space experiments.

Acknowledgements
The part of this work was performed within the framework of the Center FRPP supported by MEPhI Academic Excellence Project (contract 02.03.21.0005, 27.08.2013). The part of this work was supported in frame of the Union State program Monitoring–SG.

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