PROCEEDINGS OF SCIENCE

Development of the prototype of a large-volume liquid scintillation detector with photosensors based on silicon photomultiplayers

I.M. Dzaparova,[a,*] **A.F. Yanin,**[a] **E.A. Gorbacheva,**[a] **A.N. Kurenya,**[a] **V.B. Petkov,**[a] **I.B. Unatlokov**[a] **and A.A. Shikhin**[a]

[a] *Institute for Nuclear Reseach of RAS, prospekt 60 letiya Oktyabrya 7a, Moscow 117312, Russia*

E-mail: dzaparova@yandex.ru, yanin@yandex.ru

At present, the Institute for Nuclear Research of RAS carries out work on the creation of a large-volume scintillation detector at the Baksan Neutrino Observatory (BNO) to register natural low-energy neutrino fluxes, including from astrophysical sources. One of the prototypes of such a detector being developed at the BNO is an acrylic sphere with a diameter of 500 mm filled with a liquid scintillator. Matrices of silicon photomultipliers (SiPM) as photosensors are used to measure the total light output from the interaction of particles in the scintillator and to obtain images of such events. This approach makes it possible to separate useful events from background ones and thereby to lower the background when monitoring Supernova explosions in our Galaxy. The paper describes the prototype of a large-volume detector and presents the measurement results.

The Multifaceted Universe: Theory and Observations - 2022 (MUTO2022)
23-27 May 2022
SAO RAS, Nizhny Arkhyz, Russia

[*] Speaker

© Copyright owned by the author(s) under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

PoS(MUTO2022)002

1. Introduction

The project of a large-volume scintillation detector at the Baksan Neutrino Observatory is aimed to investigate a wide range of tasks [1]. Extremely high requirements are placed on the registration of rare events for both the external and internal background of the detector. Research studies of the prototype detector with a mass of 0.5 tons of liquid scintillator located in low-background conditions of the gallium-germanium neutrino telescope laboratory were carried out. The calculations of the detector response were made and the results of measuring the radioactive background from the elements of the detector design are presented in [2].

Another detector prototype also based on an acrylic sphere is described in this work. The outer diameter of the sphere is 500 mm. A liquid scintillator based on white spirit was filled in. Matrices of silicon photomultipliers (SiPM) are used as photosensors not only to measure the total light output from the interaction of particles in the scintillator, but also to obtain images of such events. Obtaining an image of an event in a scintillator with a resolution sufficient to distinguish a track about 2 cm long will make it possible to separate the events from a supernova explosion from the background ones. The possibility of employing SiPM matrices in large liquid scintillation detectors is considered in [3]. The SiPM characteristics were studied and images of the events obtained in our previous prototype with the detector based on a plastic scintillator [4].

2. Detector prototype design and data acquisition system

At the moment the task is to create the data acquisition program and develop the methodology for reconstructing images of the events in a scintillator. Therefore, the prototype of the detector is located in the laboratory building on the surface of the earth in conditions of a high background of atmospheric muons. The geometry of the optical collector was chosen for muon registration reasons.

The acrylic sphere of the prototype detector with a diameter of 500 mm is made by gluing together two hemispheres. In turn a hemisphere is made by blowing from a transparent acrylic sheet (Plexiglas) with a thickness of 12 mm and is thinned to 3.6 mm to the center of the sheet for this diameter. The optical collector of the detector is implemented on a triple-magnification Fresnel lens with a diameter of 300 mm and a focal length of 120 mm. So the optical properties of the entire optical path are determined by the superposition of the properties of the lens and the sphere.

Presently two matrices are installed and a total volume for them with sides of about 17 cm is viewed. The working volume was measured by a LED mounted on the lever and two protractors, the platform with which was fixed in a technological hole in the sphere above [5]. According to the measurement results, the distance from the surface of the sphere to the lens is 400 mm and the location of the matrix is 140 mm behind the lens when the image size of the LED on the matrix at the near and far walls of the sphere differs by no more than a factor of 1.2.

SiPM matrices (ARRAY-60035-64P-PCB, 8 x 8 SiPMs, total square 25.4 cm^2) of the Irish company SensL were selected as photosensors. The maximum sensitivity of the matrix (420 nm) coincides with the maximum spectral sensitivity of the scintillator.

PoS(MUTO2022)002

The MDU3-GI64X2 data acquisition system (produced by AiT Instruments) has 128 channels and is a compact device that allows one to quickly start measurements with matrices using the test program from the manufacturer. The total signal from each matrix and the sum of all 128 SiPMs are output to the connectors on the front panel. The MDU3-GI64X2 block contains two 64-channel boards of 12-bit charge–sensitive converters. In the measurements, a trigger from the internal discriminator was used with the threshold ensuring the registration of muons. Signals from the board preamps are transmitted to MDU3-GI64X2 via micro–coaxial cable assembly. Based on the measurement results, one of the visualized events was chosen and is represented in Fig. 1.

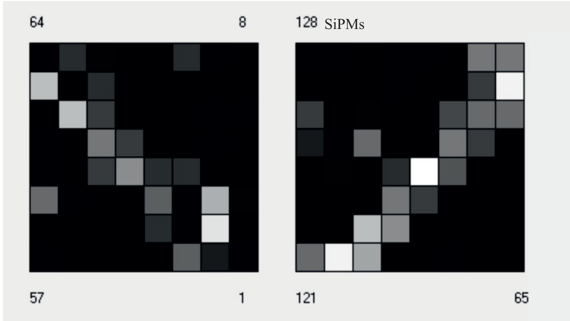

Figure 1: Visualized image of an event obtained by two matrices

3. Calibration measurements

Obtaining an image of an event in the detector scintillator requires connecting more matrices. In such a system, it is planned to generate a trigger signal with a vacuum photomultiplier (PMT). Measurements were carried out with Photonis XP4500B. In order to compare the response of the entire matrix and the vacuum PMT to the same luminous flux, measurements were carried out. The LED was placed in a tube with an inner diameter of 19 mm, in which a plate was placed after the LED to attenuate and make the luminous flux more uniform. The tube was located close to the photocathode surface of the PMT (then to the surface of the SiPM matrix) and provided an equal illuminated area. The signals from the SiPM matrix are transmitted via the preamplifier board to MDU3-GI64X2, summed there and used to measure the energy release of the matrix by digital oscilloscope. The signal from PMT was taken from the anode and fed to the input of the oscilloscope. Pulses from the generator were applied to the LED of such an amplitude that the response to the light pulse was higher than the noise level of the matrix. The charge spectra for comparison are presented in the Fig. 2. The SiPM matrix was supplied by 26V and the gain according to the characteristics from the manufacturer must be 1.8 * 10^6. At a high voltage of 1945 V for PMT, recommended by the manufacturer, the gain was near 2.5 * 10^6 (for the used divider type C , intermediate). The ratio of the maxima in the spectra is 2.07 (PMT / SiPM matrix). The charge spectrum of the SiPM matrix, as a response to the same luminous flux, has a distribution close to normal compared to the PMT (kurtosis is 0.002, for PMT this value is 0.455). The spectra also differ in the asymmetry index - 0.11 for the SiPM matrix, and 0.67 for the PMT. Estimating

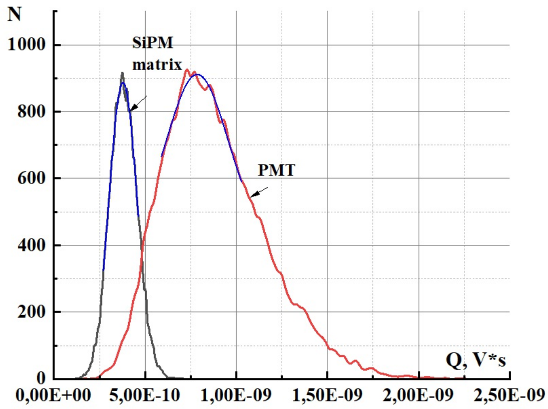

Figure 2: Charge spectra from SiPM and PMT for the same luminous flux from the LED

PoS(MUTO2022)002

the energy resolution from the measured spectra (as the ratio of full width at half maximum to the maximum value), the matrix and the PMT have similar parameters (0.513 / 0.503).

4. Conclusion

Research studies were carried out for the detector prototype based on an acrylic sphere with a diameter of 500 mm filled with liquid scintillator based on white spirit with two SiPM matrices as photosensors. A data processing and event construction program was created to visualize the registered events. Calibration measurements were carried out to evaluate the response to the same light flux of the PMT and the SiPMs matrix. Photonis XP4500B parameters such as the response time, the photocathode size, and gain will allow us to view the working volume and use the anode signal to generate a trigger. The next task is to increase the number of SiPM matrices and develop a technique for constructing a three-dimensional image of an event.

5. Acknowledgements

This work is supported by the Ministry of science and higher education of the Russian Federation under the contract 075-15-2020-778.

References

[1] I.R. Barabanov, L.B. Bezrukov, A.V. Veresnikova, Yu.M. Gavrilyuk, A.M. Gangapshev, V.Yu. Grishina et. al., *Neutrino Observatory for studies of natural neutrino fluxes for purposes of geo- and astrophysics*, 2017, *Phys. Atom. Nuclei*, Vol. 80, p.p. 446–454.

[2] Malyshkin Yu.M., Fazliakhmetov A.N., Gangapshev A.M., Gavrin V.N., Ibragimova T.V. et. al., *Modeling of a MeV–scale particle detector based on organic liquid scintillator*, *Nuclear Inst. and Methods in Physics Research*, A 951 (2020) 162920

[3] V.B. Petkov , *Prospects of the search for neutrino bursts from supernovae with Baksan Large Volume Scintillation Detector*, 2016, *Physics of Particles and Nuclei*, Vol. 47, No. 6, p. 975. arXiv.1508.01389

[4] A.F. Yanin, I.M. Dzaparova, E.A. Gorbacheva, A.N. Kurenya,V.B. Petkov, and A.V. Sergeev, *Development of the Scintillation Track Detector Based on multichannel Photodetectors*, 2018, *Physics of Particles and Nuclei*, Vol. 49, No. 4, pp. 804–812.

[5] I. Dzaparova, A.Yanin, E. Gorbacheva, A. Kurenya, V. Petkov, A. Shikhin, *Calibration of the prototype of a large–volume scintillation detector with photosensors based on silicon photomultiplier matrices*, 2021, *Izv. Krymsk. Observ.* Vol 117, No. 1, pp. 76–81.

PoS(MUTO2022)002