FAST NEUTRON DETECTORS WITH SILICON PHOTOMULTIPLIER READOUTS

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Abstract

This work presents the fast neutron detection performance of two different silicon photomultipliers from two manufacturers. Fist SiMP (MAPD-3NK) from Zecotek Photonics consists of deeply burned cells and have an active area of 3.7x3.7 mm^2. The second one (MPPC-S12572-010P) from Hamamatsu, however, has surface cell structure and an active area of 3x3 mm^2. Both SiMPs have the same pixel density of 10000 mm^{-2}. Both SIPMs coupled to Stilbene (5*5*5 mm^3) and p-terphenyl (5*5*5 mm^3) plastic scintillators were tested using a PuBe neutron source. Charge comparison and zero crossing n/g discrimination techniques were performed for the detectors and obtained results were compared. Obtained results indicated good fast neutron detection performance of the SiPMs and give a possibility to use these type of neutron detectors in fast neutron detection applications.

Motivation

The Silicon photomultipliers (SiPM) have received a great deal of interest as light readouts in many scientific and commercial applications such as: high energy physics, neutrino physics, medicine, radiation monitoring and others [1]. Despite of wide application fields their advantages significantly overcome the performance previously achieved and open new possibilities. Fast neutron detection is of particular interest in the fields of explosive detection, environmental radiation detection, military and deep space exploration as well as for nuclear waste detection and monitoring. The ability to detect neutrons and characterize their sources is essential for a variety of nuclear security and safeguards tasks. For decades, the standard method of doing so has been the use of 3 He proportional counters, but an increase in its demand coupled with a decrease in production has created a push for the development of alternative methods of detecting neutrons. The scintillation detector is one of promising candidates to replace 3 He detectors [2]

PARAMETERS OF THE SIMPs AND THE SCINTILLATOR

Two types of Silicon photomultipliers with a very high pixel density have been used in the experiment. The first one is Zecotek's MAPD-3NK type device with an active area of 3.7x3.7 mm2. The MAPD-3NK has high PDE (≈40%) at pixel density of 10000 pixel/mm2 due to deeply buried micropixel design [3-4]. The second sensor is Hamamatsu's MPPC of S12572-010P type device produced on base of standard surface-pixel technology. The S12572-010P has an active area of 3x3 mm2 and pixel density of 10000 mm-2. Its PDE is 12 % at the operation voltage [5].

Properties of Stilbene crystal and plastic scintillators

Crystal	Stilbene (5*5*5 mm^3)	Plastic (5*5*5 mm^3)
Density, g/cm3	1.22	1.08
Decay constant, ns	3.5	4.6
Max emission, nm	390	420
Full light output, ph/MeV	20000	8600

Experimental setup

The diagram of the experimental setup is depicted in Fig. 1. The stilbene and/or plastic scintillator of 3x3x10 mm3 size is coupled to the MAPD-3NK and the MPPC. Both scintillator are well wrapped with multiple layers of white Teflon tape on all sides except one side attached to the diode with special optical grease. The generated signal by the both diodes is amplified by a preamplifier and is recorded by CAEN DT5720B Desktop Waveform Digitizer (4 Channel 12- bit 250 MS/s). Data is taken in the self-triggering mode of the digitizer. The recorded data are saved for offline analysis in a computer. All the data analysis has been performed using a script written in a data analysis framework ROOT developed by CERN.

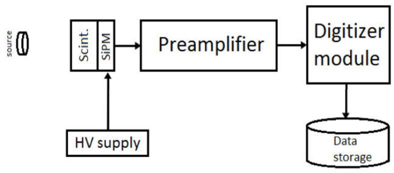


Fig. 1. Experimental setup.

Experimental results

Since almost all neutron fields coexist with an associated γ-ray component while scintillator detectors are sensitive to both gamma rays and neutrons. The discrimination between neutrons and γ rays (n/γ) becomes a key technical problem in the field of neutron detection. It is used some organic scintillators to overcome this problem. Stilbene is one of the most popular radiation detection material due to their pulse shape discrimination (PSD) properties and fast timing performance. Neutron and gamma discrimination in these types of scintillators is performed using different discrimination techniques. The most commonly used techniques are charge comparison (CC) and zero-crossing (ZC) [6]. In this method, a long integral and total integral are defined and the ratio of these two values is taken as a pulse shape parameter (PSD). In the zero-crossing method, PSD is performed due to the zero-crossing time of the suitably shaped signal. Both methods have been performed offline using special scripts written programming language C++ and the ROOT framework. Examples of neutron and gamma ray pulses are shown in Fig. 2.

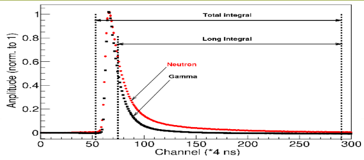


Fig. 2. Example of a light pulse recorded for the detector consisting of MAPD and Stilbene scintillator. Depiction of the charge comparison method for neutrons and gamma rays has been shown, too.

In Fig. 3 two-dimensional PSD plots obtained using CC method and pulse height spectra are presented for the MAPD coupled to stilbene

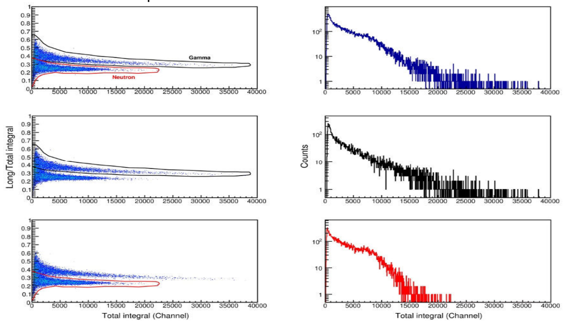


Fig. 3: Pulse shape discrimination plot and pulse height spectra for the MAPD coupled to stilbene

In Fig. 4 two-dimensional PSD plots obtained using CC method and pulse height spectra are presented for the MPPC coupled to stilbene.

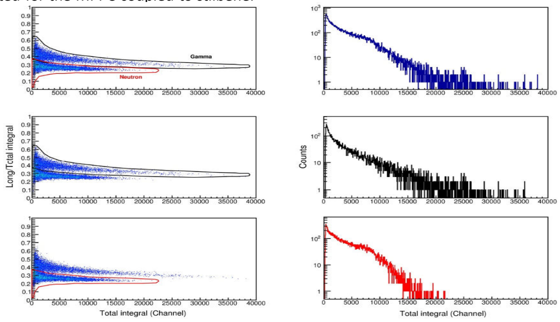
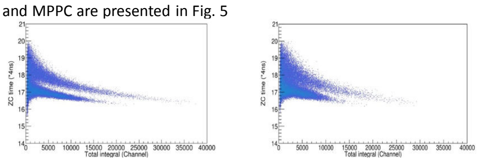


Fig. 4: Pulse shape discrimination plot and pulse height spectra for the MPPC coupled to stilbene

2D plots of ZC time versus total integral of pulse with Stilbene scintillator coupled to both the tested MAPD and MPPC are presented in Fig. 5



PSD has been performed for plastic scintillator but has not been observed any neutron and gamma discrimination. PuBe pulse hight spectra for MAPD and MPPC coupled to plastic scintillator were shown in Fig. 6

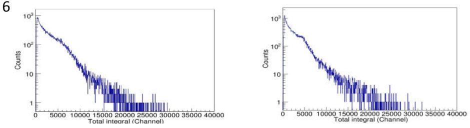


Fig. 6. PuBe pulse hight spectra for MAPD and MPPC coupled to plastic scintillator

Conclusion

The obtained results shows a good performance of the studied SiPMs as light readouts in neutron detectors based on stilbene. Figure of merit is obtained about 0.8 for both SiMPs. The n⁄γ discrimination by the ZC method for MPPC is worth in comparison with MPPC. The obtained results show that the neutron detector based on plastic is able to use as a counter. These detectors do not give any information about particle type. The detailed discussion of the results obtained with both PSD methods will be presented in the full paper.

Reference

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Acknowledgments

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