Progress in the creation of a matrix track detector

Устинов В.В.[a,b1], *Кутинова О.В.*[a,b], *Сакулин Д.Г.*[a,b], *Сухов Е.В.*[a,b], *Устинов Д.В.*[a,b]

Ustinov V.V.[a,b], *Kutinova O.V.*[a,b], *Sakulin D.G.*[a,b], *Sukhov E.V.*[a,b], *Ustinov D.V.*[a,b]

[a] Объединённый институт ядерных исследований, Дубна, Московская область, 141980, Россия

[b] Государственный университет «Дубна», Дубна, Московская область, 141982, Россия

[a] Joint Institute for Nuclear Research, Dubna, Moscow region, 141980, Russia

[b] Dubna State University, Dubna, Moscow region, 141982, Russia

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Разработан двухплечевой трековый сцинтилляционный детектор на основе матриц SiPM. Детектор необходим для получения треков части в монолитных сцинтилляторах. В ходе измерений получены хорошо распознаваемые треки от космических мюонов с использованием линзы Френеля.

A two-arm track scintillation detector based on SiPM matrices has been developed. The detector is necessary to obtain part tracks in monolithic scintillators. During the measurements, well-recognized tracks from cosmic muons were obtained using a Fresnel lens.

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Introduction

Presently the nature of dark matter is unknown. A particular difficulty in detection of dark matter is the extremely small cross-section of interaction with media. An actual problem is to assembled highly sensitive detectors to search for direct signals from dark matter particles. A liquid xenon detectors (LXe) are the most promising in this field. However, the spatial resolution of such detectors is not better a few cm.

A LXe detector is being developed at the JINR Laboratory of High Energy Physics. The detector will be represents a cylindrical vessel with windows for readout scintillation light in the detector media. At the initial stage, it is planned to develop a single-phase liquid xenon detector with active volume of ~ 0.5 liters. After that, it is supposed to perform a gradual scaling of the detector.

A position-sensitive photodetectors is needed to accurately reconstruct the topology of events. This task can be performed using matrices based on silicon photomultipliers (SiPMs) with possible segmentation up to 12×12 cells (according to information from manufacturers).

[1]E-mail: ustinov@jinr.ru

Configuration of track scintillation detector

A two-arm 128-channel track detector has been developed. The detector is based on two Onsemi SiPM matrix (8×8 cells) with active area $6 \times 6mm^2$ [1]. Arms oriented at 90 degrees relative to each other. A cubic plastic scintillator (polystyrene) with a detentions of $10 \times 10 \times 10cm3$ (one liter volume) is temporarily used as the active part of the detector. The radiation from the particle track passing through the active part of the detector (plastic or liquid scintillator) will be focused and projected onto matrices through the optical system (set of lens) [2]. Information about triggered SiPMs from the matrix was supplied through a circuit board with integrated amplifiers [3] to the data acquisition system based on ADC64s2 [4]. All elements of the detector are located in metal frame and light insulated from external influences and among themselves (fig. 1).

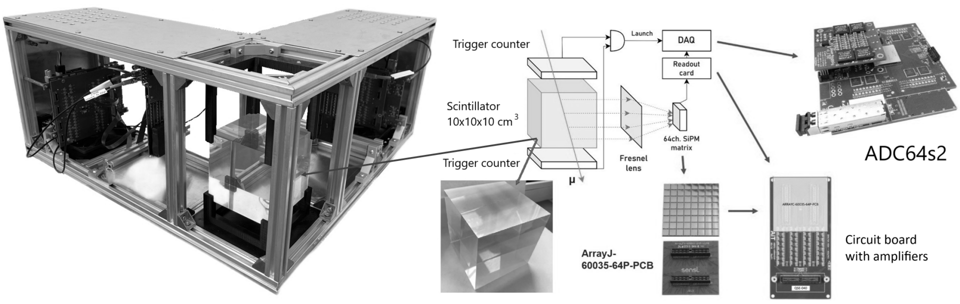

Fig. 1. Two-arm track scintillation detector and scheme of readout

Calibration of the detector on laser source

The calibration was performed using a blue 450 nm picosecond laser. The laser signal was applied individually to each SiPM channel via 1.2 mm optical fibers and special 64-channel matrix holder. The fibers were assembled into a bundle and connected to laser output. Thus, channel-by-channel calibration of both matrices was performed. This calibration system allows getting a direct correspondence of the SiPM with the channel in the ADC. Various figures were built in the holder to demonstrate the correctness of the visualization algorithm (fig. 2, 3). As results of the individual channels calibration, we have full correspondence of the ADC channels and SiPMs.

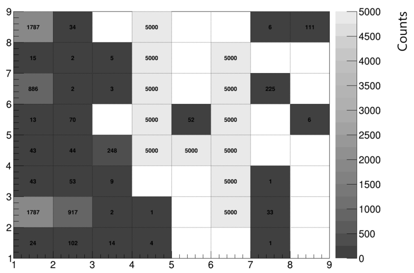

Fig. 2. The number of triggers in each SiPM cell on condition data taking of 5000 events

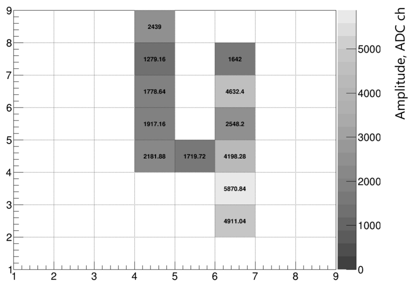

Fig. 3. The mean amplitudes in each SiPM cell on condition data taking of 5000 events

Obtaining muon tracks by detector

The next step was to obtain tracks in the case of direct contact of the matrix with the scintillator. Trigger counters with dimensions $10 \times 10 \times 8mm^3$ [5] were used to selection the area under study (vertical row, see fig. 4). However, the signals received in this case have an uncertainty of the place of passage of the particle (fig. 5). Some cells have weak amplitudes and are cut off along with the threshold at analyses. The spatial resolution may be calculated as $\sigma = n/2\sqrt{3}$, where n – number of vertical triggered cells multiplied by the cell pitch (7.2 mm). Thus, the spatial resolution is 4.2 mm in the case of direct contact of the matrix with the scintillator.

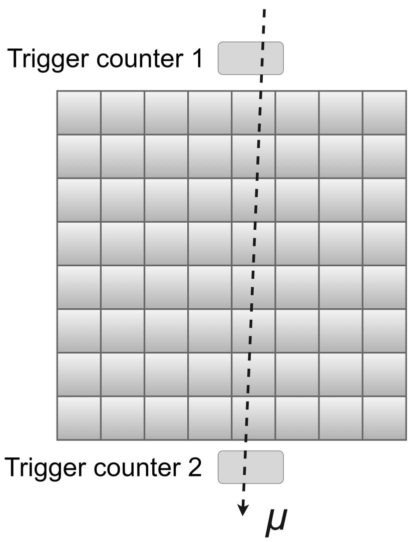

Fig. 4. The principle of a select investigation area

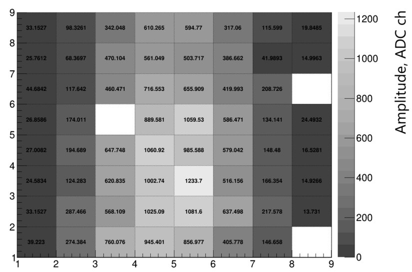

Fig. 5. The signals from SiPM matrices in direct contact with scintillator

After this, measurements were carried out with a short-focus Fresnel lens with a focal length of F = 2 cm. The lens was installed at a distance of 10 cm (5F) from the scintillator. The SiPM matrix was installed from 3 cm (1.5F) from lens.

Trigger counters also selected the area under study. As a result, well-recognized tracks from cosmic muons have been obtained from both arms of the detector (fig. 6). Tracks from cosmic muons are stacked in a vertical row with accuracy up to the SiPM cell size. However, the light loss was about 50% compared to the case of direct contact between the matrix and the lens. The spatial resolution was 2.1 mm.

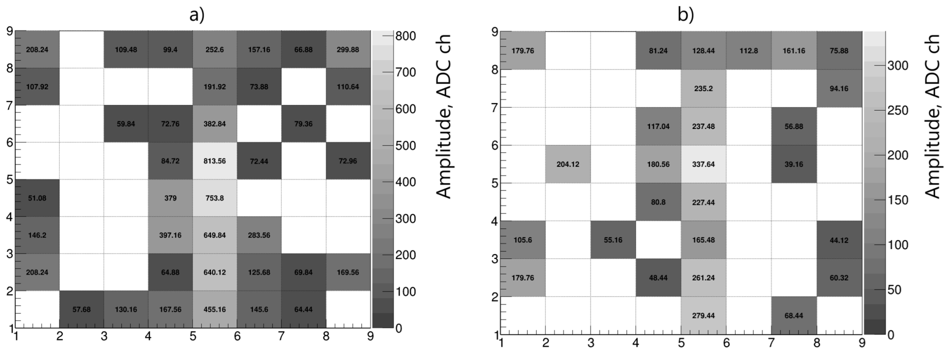

Fig. 6. Tracks from Fresnel lens obtained by both arms of detector

It is proposed to use SiPM with an active cell size of 3×3 mm to improve the spatial resolution. Commercially available matrices manufactured by Onsemi with segmentation of 12×12 cells [6]. The noise effects will be reduced by means the size of the active cell. In this case, the spatial resolution may be about 1.2 mm (the cell pitch is 4.2 m). Segmented scintillation cells and wavelength shifting fibres light to transfer light to SiPMs also can be used to improve resolution instead of monolithic scintillators.

Conclusion

A two-arm track scintillation detector has been developed. Well-recognized tracks from cosmic muons with a short-focus Fresnel lens were obtained. The spatial resolution was 2.1 mm. The next stages of the work is supposed to tests the detector with CAEN electronics (DT5550W Readout System for SiPM matrices [6]) and new Onsemi 12×12 matrices [7] to improve spatial resolution, and tests with liquid scintillators as an active volume.

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