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Investigations of SiPM based large scintillation detectors

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Investigations of SiPM based large scintillation detectors

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Abstract. Different types of light concentration for large fast scintillation detectors with silicon photomutipliers as photosensors for the satellite based gamma-ray telescope GAMMA-400 are analysed. Some proposals for their possible implementations are made.

The satellite based gamma-ray telescope GAMMA-400 has in its structure large fast scintillation detectors with silicon photomutipliers (SiPM) as photosensors (figure 1, detectors AC, S1, S2, S3, S4). During the development of these detectors the properties of the SiPM allowed to measure the number of photoelectrons detected with the irradiation of AC detector prototype module (plastic scintillator Bicron-408 1280x100x10 mm^3) in the accelerator positron beam. High SiPM amplitude resolution allows distinguish separate peak for the definite number of photoelectrons (figure 2). By this method it was found, that SiPM at one end of long (1.2 meter) plastic scintillation counter detects from 75 (from the close end) to 25 (from the far end) photons. It may be not sufficient, especially for time-of-flight measurements, performing with these detectors. To increase the efficiency of charged particles detection it is necessary to raise the amount of collected light. So we investigated the possibilities to concentrate the light.

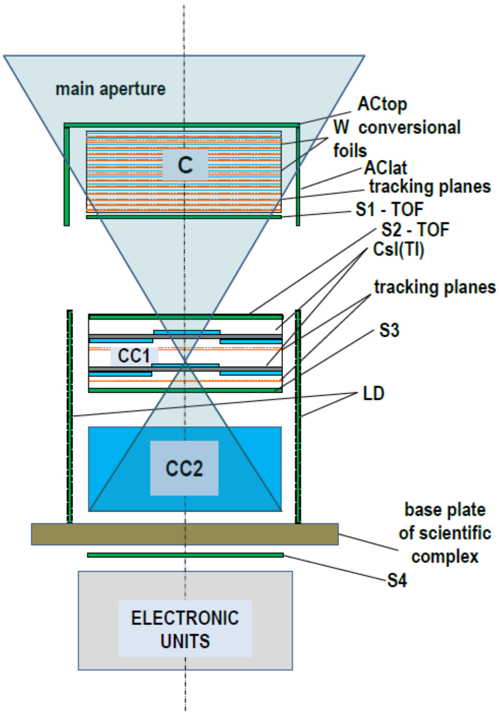

Figure 1. The layout of GAMMA-400 gamma-ray telescope [1]

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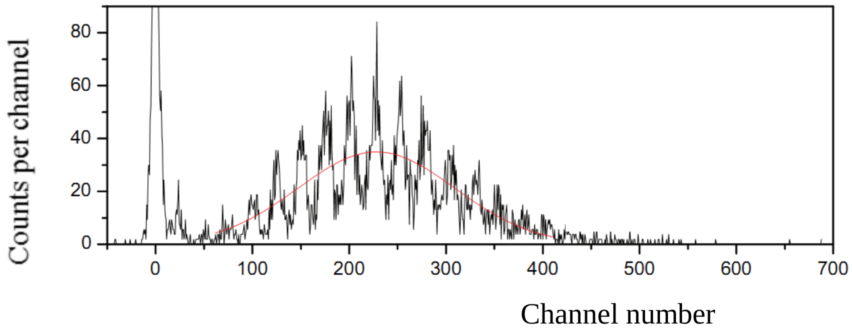

Figure 2. The layout of the SiPM amplitude spectrum at low level light illumination.

Two schemes of light concentrators were analyzed: with conical polymethylmethacrylate light guides [2] (figure 3) and Compound Parabolic Concentrator [3] (figure 4).

In both cases the main disadvantage of light concentrators is their considerable length (some centimeters), that is not suitable for space device.

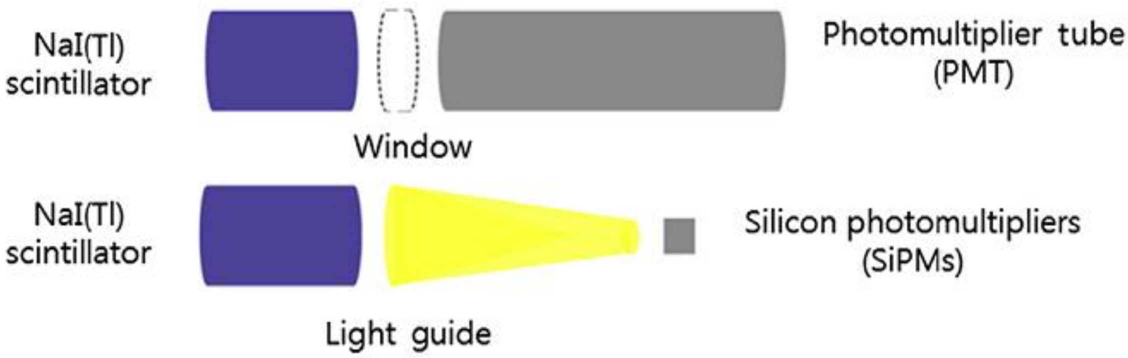

Figure 3. The scheme of the photomultiplier replacement with SiPM with light concentrator [2]

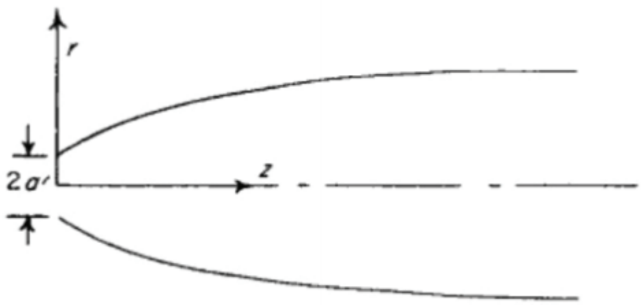

Figure 4. The profile of Compound Parabolic Concentrator (CPC) [3].

We analyzed also the implementation of Fresnel lens, which is often used for solar cells as light concentrators (figure 5). Their advantages are small thickness and weight that is essentially for space devices. Nevertheless, used as the concentrator, Fresnel lens asks to remove SiPM at the focal length.

Taking into account light collection efficiency as a function of incident photon angle [3] (figure 6), it is interesting to test the usage of Fresnel lenses also in the opposite direction to create a parallel light beam. In this case, we can put the lens directly on the surface of scintillator.

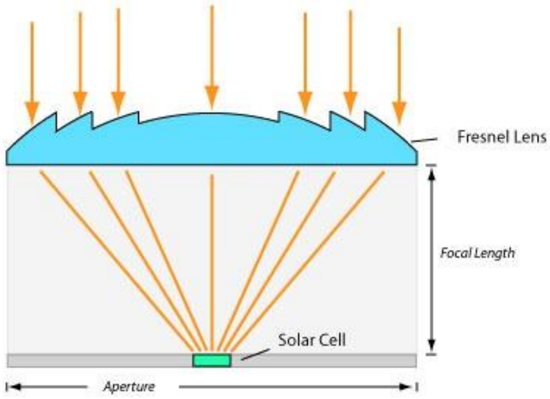

Figure 5. The scheme of light concentration with the use of Fresnel lens.

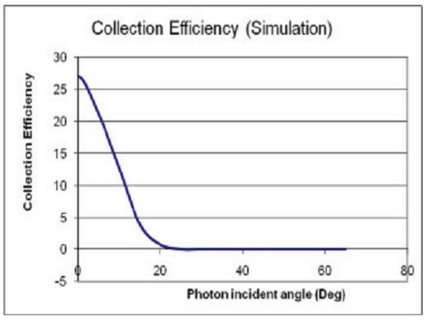

Figure 6. Simulated collection efficiency as a function of incident photon angle [3].

Conclusion

The implementation of Fresnel lens as light concentrator is discussed. We plan experimentally test these possibilities.

Acknowledgement

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