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Silicon photomultipliers as a readout system for scintillating calorimeters

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Summary. — In recent years silicon photomultipliers (SiPMs) have been proposed as a new readout system for scintillation detectors; these devices are characterized by a low bias voltage, a small dimension and the insensitivity to magnetic fields, making them a suitable alternative to the photomultiplier tubes (PMTs) in many experimental situations. The performances of FBK-irst SiPMs have been evaluated in different testbeams performed at CERN. The first setup consists of amplified SiPMs, characterized in terms of signal-to-noise ratio, efficiency and time response when connected to a tracker/calorimeter composed of plastic scintillator bars. In the second setup the performances of non-amplified SiPMs have been evaluated in terms of linearity and energy resolution when connected to two scintillator-lead shashlik calorimeters.

PACS 29.40.Mc – Scintillation detectors.
PACS 29.40.Wk – Solid-state detectors.
PACS 29.40.Vj – Calorimeters.

1. – The silicon photomultipliers

The Silicon PhotoMultipliers are devices composed by a matrix of pixels connected to a common output. Each pixel, which has a typical dimension of 20–100 μm, can be considered as a diode reverse biased below its breakdown voltage working in Geiger mode [1]. The response of each pixel is digital, but the analog information can be obtained considering the number of fired pixels (for a moderate photon flux). The main advantages of SiPMs wrt PMTs are a low bias voltage, simple readout, small dimensions, low cost and the insensitivity to magnetic fields.

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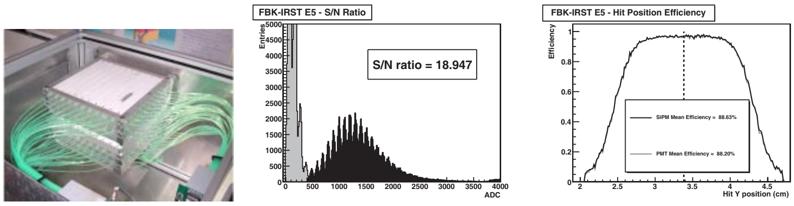

(a) (b) (c)

Fig. 1. – The EMR prototype (a); spectrum (b) and efficiency (c) obtained with a non-irradiated SiPM.

2. – Silicon photomultipliers tests

The first tests have been performed with a scintillating tracker/calorimeter, a prototype of the Electron Muon Ranger (EMR) of the MICE experiment [2]. The prototype consists of 8 x-y planes with 10 $1.5 \times 1.9 \times 19\,\text{cm}^3$ plastic scintillator bars each; each bar is readout by 4 0.8 mm WLS fibers, connected to a plastic mask which holds $\sim 1\,\text{mm}^2$ SiPMs. Different amplified devices has been tested before and after irradiation; for what concerns the non-irradiated and the gamma-irradiated devices, good results have been obtained in terms of signal-to-noise ratio, efficiency and linearity (see fig. 1). Worse results have been obtained with neutron-irradiated devices, which show a severe performance degradation.

The second tests have been performed using non-amplified SiPMs with a sensitive area of $\sim 1\,\text{mm}^2$ and $9\,\text{mm}^2$ connected to two scintillator-lead shashlik calorimeters; the first one is composed by 41 tiles of plastic scintillator and 40 tiles of lead for a total of

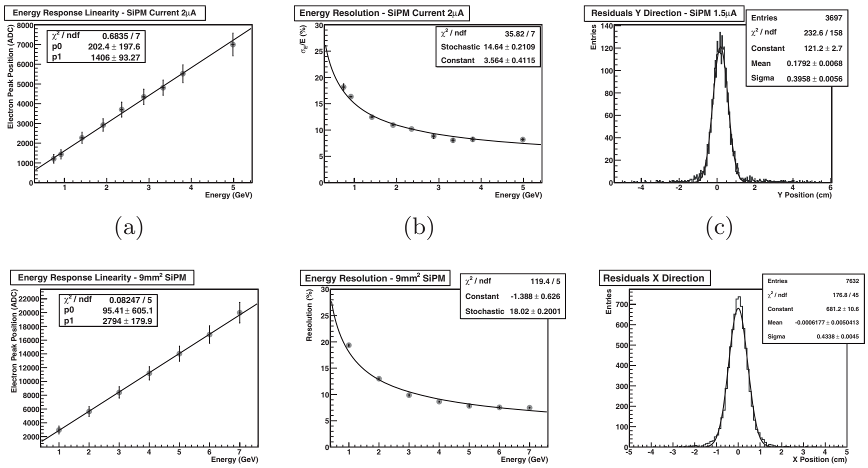

Fig. 2. – Linearity (a), energy (b) and spatial resolution (c) obtained with the small shashlik calorimeter; linearity (d), energy (e) and spatial resolution (f) obtained with the large shashlik calorimeter.

24 X_0: each tile is 3.27 mm thick with an area of $8 \times 8\,\mathrm{cm}^2$. The second calorimeter consists of 70 4 mm thick scintillator tiles and 69 1.5 mm thick lead tiles with an area of $11.5 \times 11.5\,\mathrm{cm}^2$, for a total of 19 X_0. The readout is performed using 64 0.8 mm WLS fibers for the small device and 144 1.2 mm WLS fibers for the larger one; the fibers are then collected in bundles for a total of 16 readout channels for both the calorimeters. The performances of the devices have been evaluated in terms of linearity, energy and spatial resolution (see fig. 2), obtaining results comparable or even better to the ones obtained with the multianode PMTs.

REFERENCES

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