Results from Silicon Photo-Multiplier neutron irradiation test

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Abstract

Silicon photo-multipliers, often called "SiPM", are semiconductor photon detectors built from a square matrix of avalanche photo-diodes on common silicon substrate. SiPM have been proposed for several different applications in High Energy Physics, in particular where a large detection granularity is needed.
In this presentation the results of a radiation hardness test performed at the Frascati Neutron Generator are presented. Several SiPM of different manufacturers have been irradiated integrating up to 7 10^{10} 1-MeV-equivalent neutrons per cm^2. For the first time, their performance have been recorded during the neutron irradiation and a gradual deterioration of their properties was found to happen already after an integrated dose of the order of 10^8 1-MeV-equivalent neutrons per cm^2.

The Frascati Neutron Generator (FNG)

FNG uses a deuteron beam accelerated up to 300 keV impinging on a deuteron target to produce a nearly isotropic 2.5 MeV neutron output via the $D(d,n)^3He$ fusion reaction. The beam current at the target can be regulated up to 1 mA resulting in a maximum neutron production rate of 5 10^8 neutrons on the whole solid angle per second. Through the monitoring of the rate of associated emitted particles, protons or alpha, the neutron emission rate can be monitored on-line. This gives the unique possibility of measuring the effect of neutrons as long as the irradiation takes place.

On-Line Measurements

Six devices produced by the IRST and four produced by the Hamamatsu have been tested with neutrons. Depending on the distance from the production point, in four days of test, the SiPM integrated between 0.18 and 7.32 1-MeV-equivalent neutron per cm^2.
The current drawn by each device and its dark counting rate were continuously monitored and recorded while being irradiated. Fig. 1 shows that the current drawn by the SiPM starts to increase soon after the beginning of the irradiation. No differences between the current behavior of tested devices were found. The effects of the different neutron fluences are not visible at the level we operated.
The neutron flux was kept off for a whole night while the currents were recorded. No significant recovery effects appeared. The absolute value of the current and the increasing rate, once the flux was back on, didn't change.
The neutron beam has been paused several times in order to perform low voltage scans during the irradiation runs and to measure the effects on the dark currents and on the dark counting rates for different bias values.

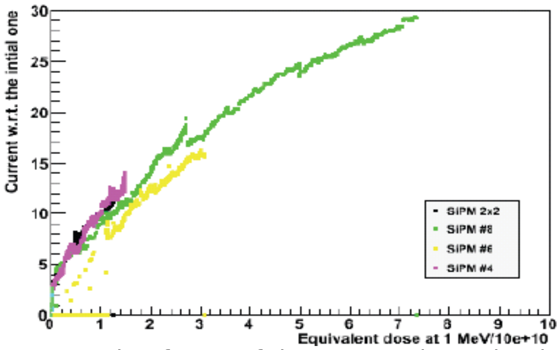

Fig1: Increasing factor of the current drawn by the SiPM as a function of the integrated neutron dose.

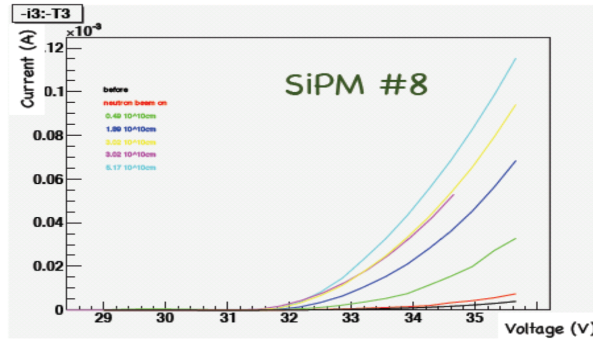

Fig2: Measured currents as a function of the low voltage supply after different integrated doses

In the low voltage scans the current behavior changed rapidly with the integrated dose as it is shown in Fig.2.

Off-Line Measurements

The SiPM have been tested with cosmic rays before and after the neutron irradiation and the charge spectra obtained are shown in Fig 3.

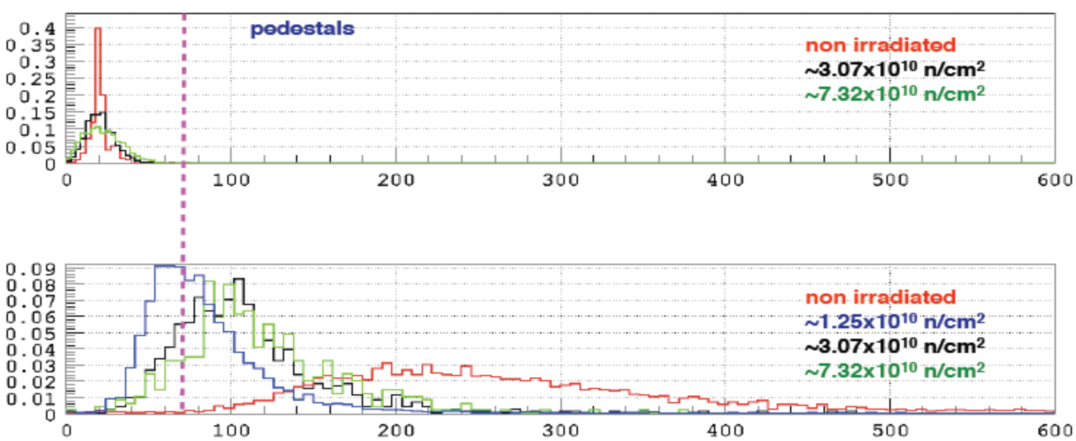

Fig3: SiPM charge spectra with cosmic rays before (top) and after (bottom) the neutron irradiation.

After the neutron irradiation, the gain was found to be about the half of the initial one (Fig.3 Bottom) and the noise pedestals (Fig. 3 Top) are much broader. The main effect is an important reduction of the detection efficiency from more than 95% to about 70%.