Detection of Vacuum Ultra-Violet light by means of SiPMs with and without a wave-length shifter coating for High Energy Physics experiments

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ABSTRACT

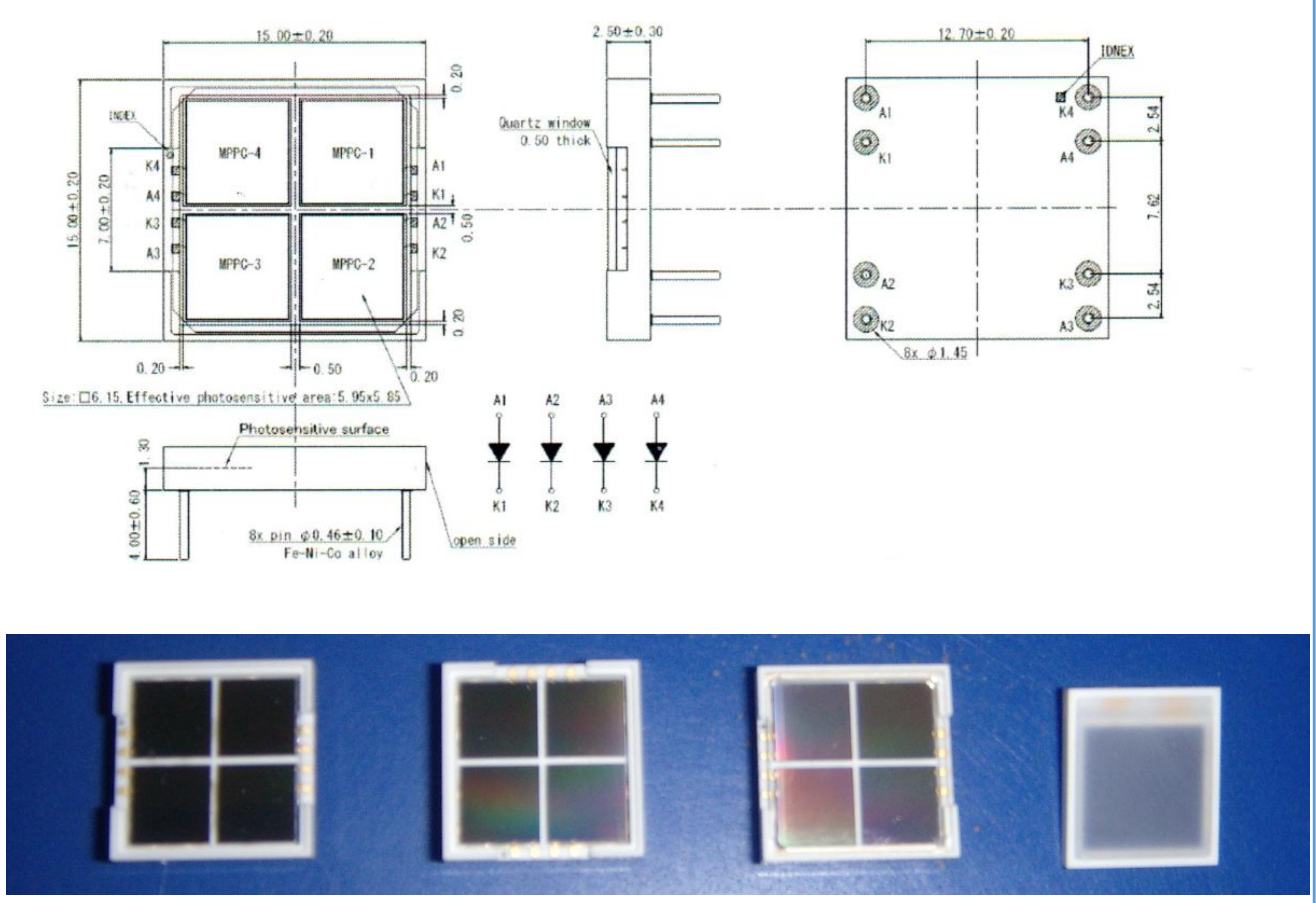
Silicon Photo-Multipliers (SiPMs) are widely proposed as light detectors in many high energy physics experiments. The performance of these devices for the detection of scintillation light of liquefied noble gases, such as LXe or LAr, emitting photons in the Vacuum Ultra-Violet region, will be presented. The detection of these VUV photons is very difficult considering that most of the usual photo-detector windows, are not transparent to VUV radiation. In this work, a comparison between the performance of a number of SiPM arrays for the direct detection of VUV light or for the use with a wave-length shifters deposited by evaporation, has been carried out.

Introduction

A number of innovative experiments dedicated to neutrino and rare-events physics are using liquefied noble-gases both as target and as detector. These media have the remarkable property to efficiently produce scintillation photons after the passage of ionizing particles. Scintillation light, which is used for trigger and timing purposes, is emitted in the Vacuum Ultra Violet region. In detail: the scintillation light coming from LXe or LAr is at 175nm and at 128nm respectively. The detection of these wavelength photons is very difficult considering that most materials are not transparent and absorbs VUV radiation. A solution comes from using the device without any window and a particular treatment on the surface or depositing a wavelength shifter (WLS) on the standard window. At the moment, the most used light detectors in liquefied noble gas experiments are photomultiplier tubes with glass window, covered by Tetra-Phenyl Butadiene (TPB) as wavelength shifter. In this work the possibility of detecting VUV light with commercial SiPM arrays is presented.

Hamamatsu SiPM arrays for VUV detection

In the last years Hamamsatsu Photonics K.K. has started studies on SiPM (commercially called by the company Multi Pixel Photon Counter) in order to detect VUV light. We have tested a third version (called VUV3, available with or without a quartz window) and a fourth version (called VUV4). The three devices we have testd are in the form of an array made of four 5.95x5.85mm^2 SiPM. Each one has 13923 cells of 50 μm pitch, ceramic package, with a geometrical fill factor of 60%. As reference, a classic large area photodiode (Hamamatsu model S3590-08), covered with TPB has been used. In Fig. 1 a scheme of the devices is presented together with a picture of the tested devices.



Quantum Efficiency measurement in the VUV range

First the absolute Quantum Efficiency has been measured in the VUV range: all the pixels in each array have been connetcted in parallel, no bias voltage, in order to work as photodiode, without any gain. In Fig. 2, the results are shown

For those measurements, the experimental system developed at the INFN laboratory in Pavia (Italy), allows the characterization of optical detectors in term of absolute Quantum Efficiency (QE%) in the VUV range of the optical spectrum that has been utilized. It consists of a vacuum chamber where light produced by a continuous deuterium lamp is separated by a MacPherson 234 monochromator and then directed alternatively toward a NIST calibrated reference photodiode or toward the device under test. A comparison between the current delivered from the two devices, provides the absolute Quantum efficiency of the detector under test. In Fig.2 it is shown that VUV4 is able to detect 128nm (liquid Argon scintillation wavelentgth) with a good efficiency (more than 20%). Moreover at 175nm (Lxe emission wavelegth) the efficiency is higher in comparison to the previous version. The best efficiency is still for the photodiode covered with TPB. At 128nm and 175nm, we also evaluated the beaviour of the devices when illuminated at angles different from 0. The response is presented in Fig. 3. The behaviour is very similar for all the devices.

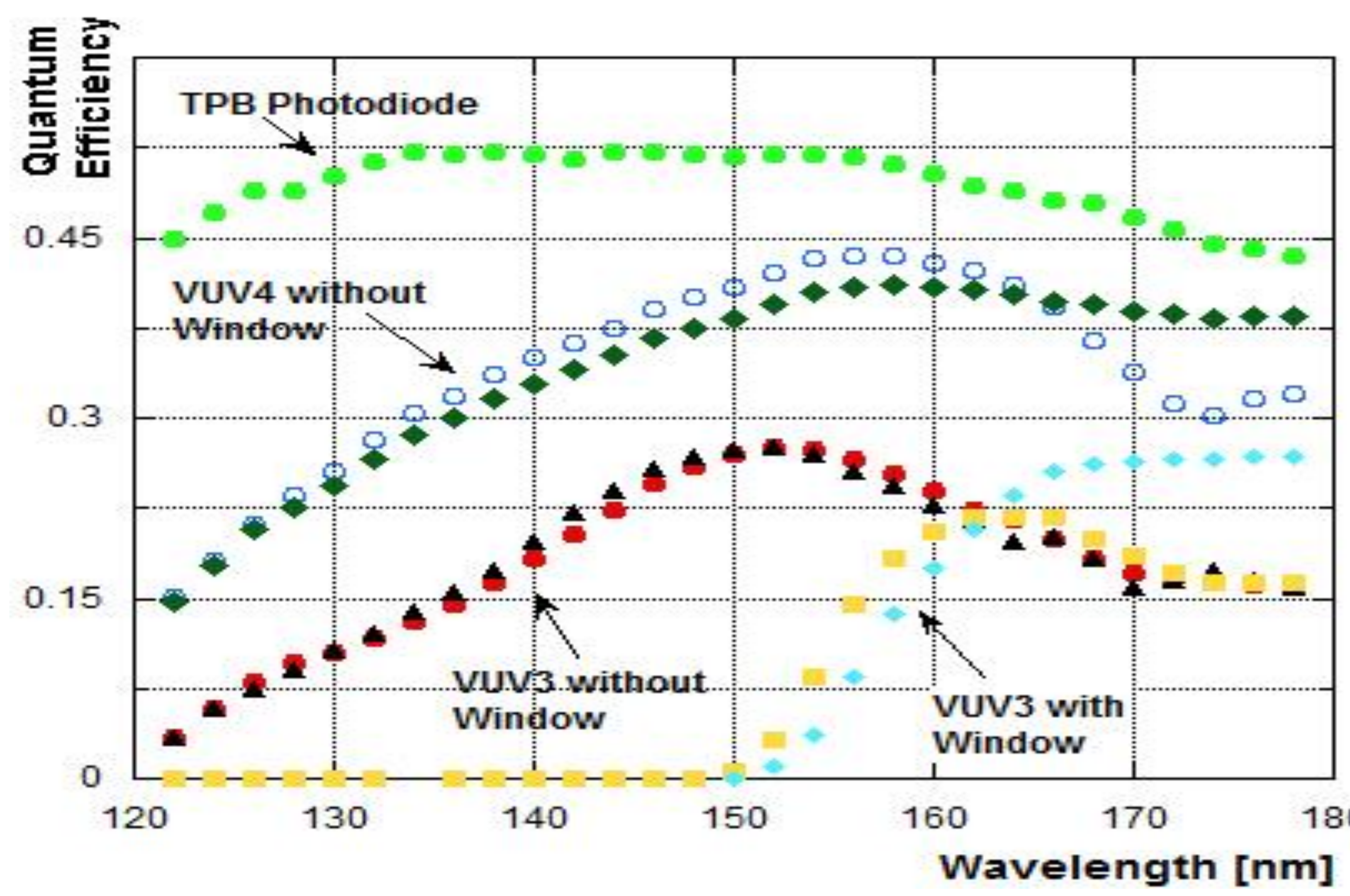


Fig.2: the absolute Quantum Efficiency

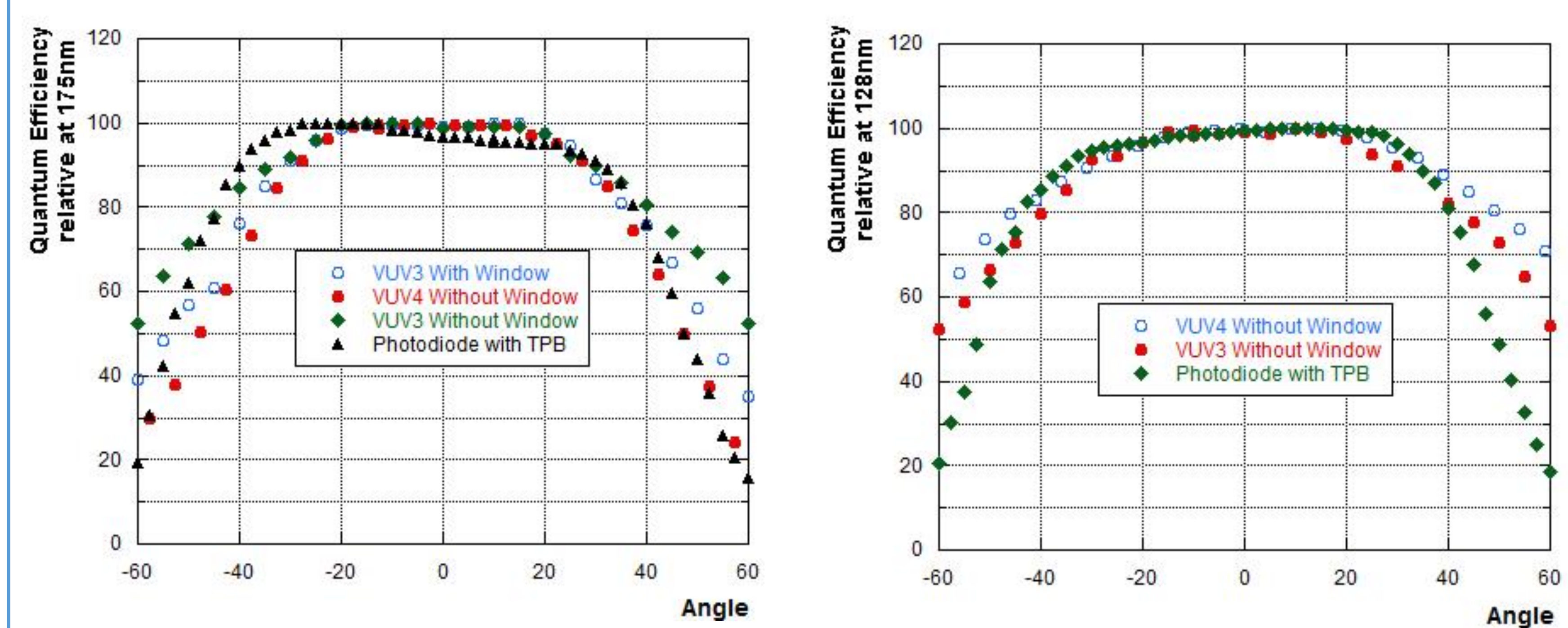


Fig. 3: relative Quantum Efficiency at 175nm (left) and at 128 nm (right)

The Hamamatsu VUV4 SiPM array

Considering the results in Quantum Efficiency, we decided to investigate the performances of the VUV4 array, as usual with the 4 SiPM connected in parallel. First we measured the I-V current at various temperature starting from -60°C to +60°C by using a thermal chamber F.lli Galli Genviro -030LC (see Fig. 4, left) and calculate the breakdown voltage. In this way, we measured a temperature coefficient of 44.5mV/°C (see Fig. 4, right).

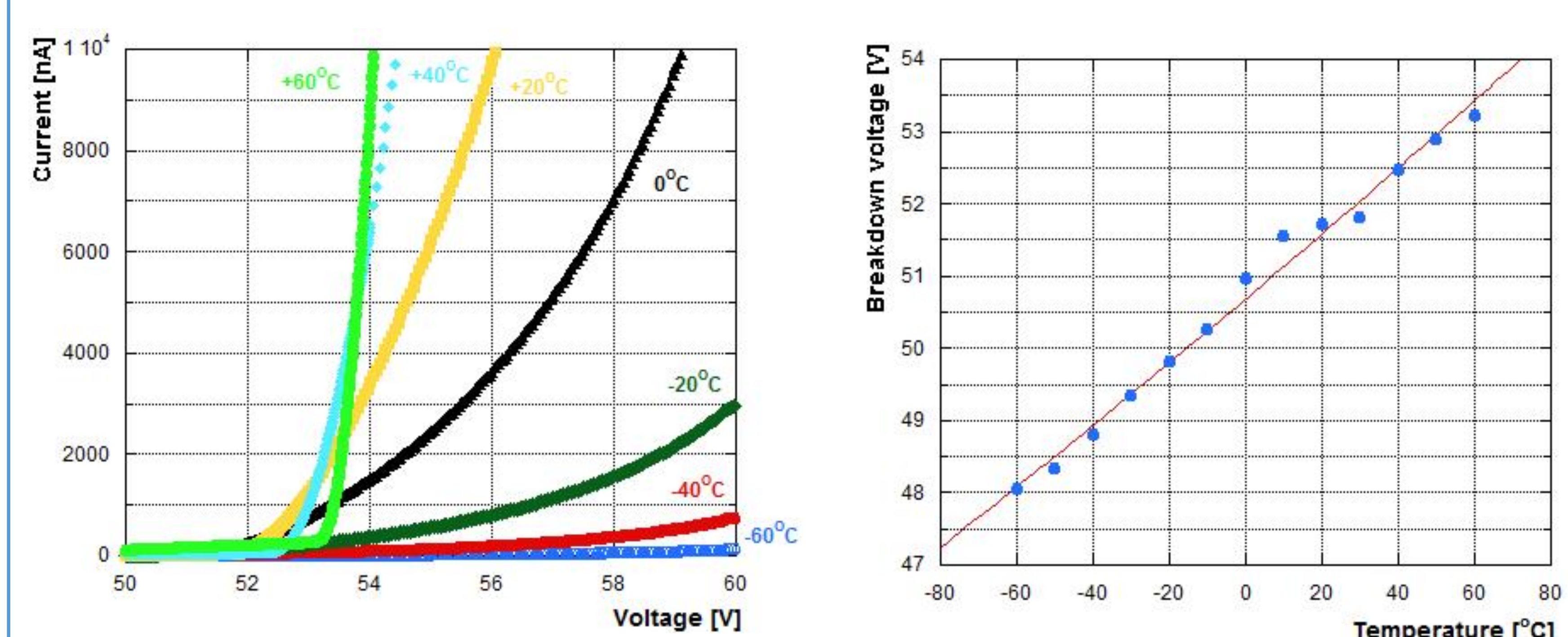
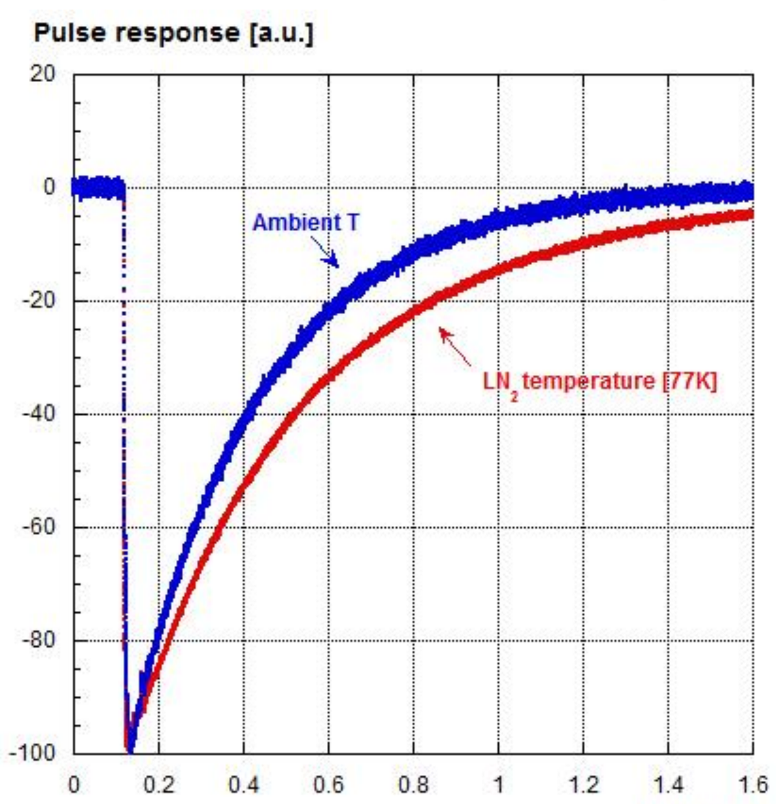


Fig. 4: I-V curve at various temperature (left) and temperature coefficient (right)

The VUV4 array at cryogenic temperature



Finally the Hamamatsu VUV4 array has been inserted in a dewar filled with liquid Nitrogen (77K) and illuminated by an Hamamatsu Picosecond Laser Pulser PLP10-040 at 407nm wavelength, 60ps pulse width. The device has shown the capability to work also in cryogenic environment. In Fig.5 a comparison between the pulse shape at ambient temperature and at 77K is shown. In Fig. 5, the signal shape is presented.

Fig. 5: pulse shape comprison at ambient-77K

Conclusions

In the last years Hamamatsu has improved the SiPM production technology and is now able to provide SiPM with a good Quantum Efficiency also for the detection of liquid argon scintillation light (128 nm).