Study of SiPM custom arrays for scintillation light detection in liquid argon Time Projection Chambers

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The detection of the Vacuum Ultra Violet (VUV) scintillation light produced in liquefied noble gases after the passage of ionizing particles is a major technological challenge. The realization of novel design photo-devices operating at cryogenic temperature is mandatory for a number of applications in high energy physics as neutrino oscillations measurements and dark matter searches. The Liquid Argon Time Projection Chamber (LAr TPC) technology was originally proposed by C. Rubbia in 1977, as a novel concept for an imaging massive neutrino detector that allows three-dimensional event reconstruction with high accuracy and precise calorimetric measurement.

When a charged particle crosses the liquid argon volume ionization and scintillation light emission occur. Ionization electrons are drifted by a suitable electric field towards the read-out anode, made of wire planes, allowing spacial reconstruction of the tracks with a resolution of the order of the wire pitch (∼1 mm\textsuperscript{3}). While electrons drift towards the wires planes with typical times of the order of ms, scintillation photons are prompt (with characteristic time constant in the order of µs), allowing their use for trigger and timing purposes.

Silicon Photo-Multipliers (SiPMs) are semiconductor-based photo-detectors able to reach gains of the order of 10\textsuperscript{6}. This feature, together with the possibility to operate these devices under strong magnetic fields, makes the SiPMs excellent candidates to substitute traditional large area cryogenic Photo-Multiplier Tubes (PMTs), which are currently the state of the art for LAr VUV scintillation light detection, once their window is coated with Tetra-Phenyl Butadiene (TPB) to shift the VUV to visible light.

For a direct comparison between SiPM-based photo-devices and a cryogenic PMT, three different 4 × 4 custom SiPM arrays have been realized, based on 3 × 3 mm\textsuperscript{2}, 40 µm cells AdvanSiD ASD-NUV3S-P and AdvanSiD ASD-RGB3S-P single SiPMs and 50 µm cells Hamamatsu S12572-050P SiPMs, for a total window area of 12 × 12 mm\textsuperscript{2}. The reference PMT is an Hamamatsu R5912, 8 inches diameter window, TPB covered.

SiPMs array windows were directly deposited with TPB to convert VUV to visible light. Both SiPMs arrays and the PMT have been deployed in an existing facility at CERN, namely a 50 litres LAr TPC. This chamber has an active volume of 32 × 32 × 46.8 cm\textsuperscript{3}, enclosed in a stainless steel vessel in the shape of a bowed-bottom cylinder 90 cm high, 30 cm radius. The active volume corresponds to 67 kg of Liquid Argon (T=87K at 1 atm, ρ=1.395g/cm\textsuperscript{3}). Ionization electrons produced by the passage of charged particles drift vertically toward the anode by means of a constant electric field of 500 V/cm. The anode is made of two orthogonal planes of 128 wires each one. The wires pitch is 2.54 mm. A campaign of measurement has been carried out by exposing the 50 litres LAr TPC to cosmic rays. SiPMs and PMT signals are digitized by a flash ADC at 1 Gsa/s sampling. Charge signals induced on wires are read out with the standard icarus electronic chain made with custom j-fet based low noise (about 1000 e\textsuperscript{-}) warm preamplifiers followed by 10 bit fadc sampling at 2.5 MHz. Digitized signals are continuously stored in circular memory buffers and transferred to mass storage when triggers occur.

The behavior of SiPMs in LAr is investigated in term of breakdown voltage, noise and gain. Moreover the sensitivity at λ = 128 nm of the different arrays is compared to the PMT one to evaluate their trigger and timing capability.