PMT R9420 Test Results

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1. Introduction

The Pierre Auger Observatory is planned to operate until the end of 2024. An upgrade program has been elaborated in order to provide additional measurements to address some Physics important questions. Several components are proposed for the Auger upgrade. In this note we descibe the test performed on a PMT candidate to be employed in the plastic scintillator detector proposed for the Surface Detector (SD) upgrade. Infact, a complementary measurement of the shower particles will be provided by a plastic scintillator plane positioned above the existing Water-Cherenkov Detectors (WCD). This allows the sampling of the shower particles with two detectors having different responses to muons and electromagnetic particles. The design of the Surface Scintillator Detectors (SSD) is simple, reliable and they can be easily deployed over the full 3000km^2 area of the SD. More than this the use of scintillator detectors across the entire Observatory will also make possible direct comparisons of Auger measurements with other experiments like Telescope Array [1].
The SSD consists of a 4 m^2 unit divided in two modules of extruded plastic scintillator which are read out by wavelength-shifting (WLS) fibers coupled to a single photo-detector. The photomultiplier choosen for the SSD is the Hamamatsu R9420, head-on type, 8-stage PMT with a 38mm bialkali photocathode. This PMT shows good quantum efficiency at the wavelength of interest (in the green region) associated with an excellent linearity range (when the PMT is supplied through a tapered ratio divider) of up to 200 mA of peak anode current for an operating gain of 7 x 10^5.
We tested two PMTs R9420, one having a divider with an active circuit. We used a purely resistive divider with the progressive voltage ratio on the last stages in order to obtain anode pulse with high current and good linearity. The divider has been finalized in the Lecce electronic laboratory.

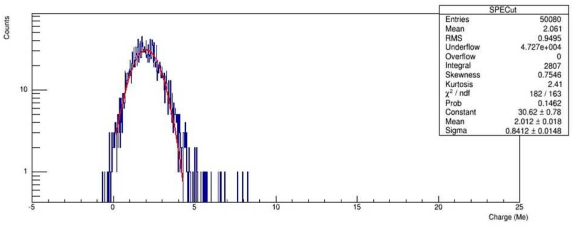

Figure 1. Single photoelectron for R9420 PMT with passive divider.

2. Measurement Results

In the Astroparticle Lecce Laboratory we have already the facility used to test PMTs for the upgrade programs and for the standard deployment of the detector, see [2] for details.
In order to get the absolute gain of the phototube at a certain voltage, the single photoelectron spectrum is measured. This measurement is performed setting the PMT at 1500 V and setting the LED in order to get signal on the first dynode only 10% of the time. In fact, the photoelectron emission process from the photocathode follows the Poisson statistic, therefore the absence of photoelectrons 90% of the time ensures a very low contamination of event having two or more photoelectrons.
To avoid unexpected instability effects due to low powering, the LED was flashed at high intensity. The single photoelectron condition was reached using optical filters characterized by different transmittance. A series of preliminary measurements were performed at a fixed LED voltage and using different optical filters. The SPE condition was reached using an F30 filter with 0.01 % transmittance. Fig.1-2 show the SPE spectrum for the two PMTs under test after the background subtraction. We get a gain of 1.3 x 10^6 at 1500 V for the PMT with the passive circuit and a gain of 2.01 x 10^6 at 1500 V for the PMT with the active circuit.

After measuring the SPE gain, we obtained the gain curves for both PMTs fixing the led voltage

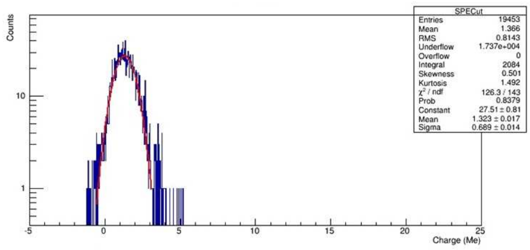

Figure 2. Single photoelectron for R9420 PMT with active divider.

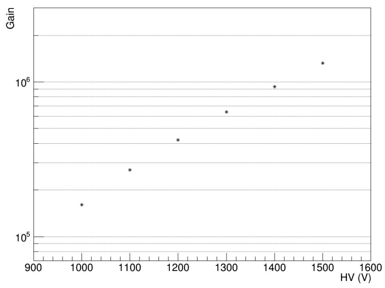

Figure 3. Gain curve for the PMT with the passive divider.

and varying the applied high voltage to the PMT as you can see for Fig.3-4.

As we mentioned before, one of the most serious concern is the necessity of having PMTs which have a linear response over a large dynamic range. The requirement is to have linearity within $\pm 5\%$ up to an anode current of 100 mA at the nominal gain. In order to measure the linearity of the tested PMT we used the double LED method. This idea is simple: the system pulses two blue LEDs (LED_1 and LED_2) independently and in succession, followed by simultaneous pulsing of the two LEDs together (LED_{12}). Varying the light intensity of the two LEDs we define as

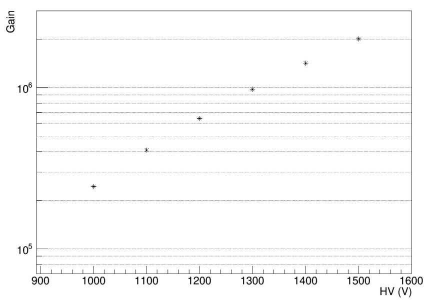

Figure 4. Gain curve for the PMT with the active divider.

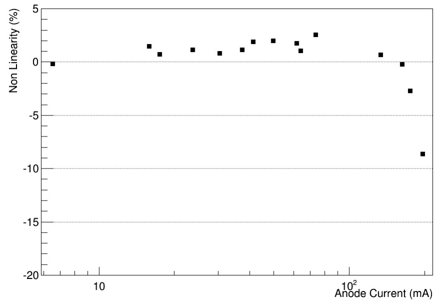

Figure 5. Non Linearity ratio vs Anode Current for the R9420 PMT with passive divider. The measuremets is performed at 1000 V PMT applied voltage.

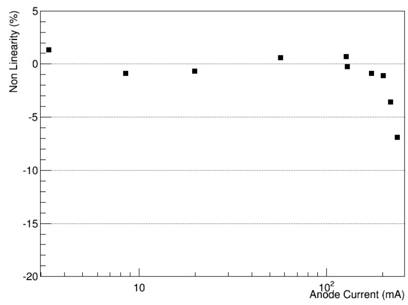

Figure 6. Non Linearity ratio vs Anode Current for the R9420 PMT with active divider. The measuremets is performed at 1200 V PMT applied voltage.

Non Linearity (NL) the following ratio:

$$NL = \frac{(Q_{LED_{12}} - (Q_{LED_1} + Q_{LED_2}))}{(Q_{LED_1} + Q_{LED_2})}\% \qquad (1)$$

and we plot this as a function of the anode current corresponding to (LED_{12}) condition. Measurements on the peak amplitude data and integrated charge (Q) were performed. Fig.5-6 show the Linearity measurement results for the two PMTs under test evidencing good linearity well over 100 mA.

REFERENCES

1. *Telescope Array Experiment*, http://www.telescopearray.org/
2. G. Cataldi et al., GAP 2015-004