A PMT test facility for the AUGER experiment

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1. Introduction

The Pierre Auger Observatory (PAO) was designed to study the EAS and an important characteristic of the experiment consists in the fact that two complementary air-shower techniques are implemented. This is known as *hybrid* concept and consists of a combination of a large surface array detectors, to measure particle at ground level, together with fluorescence detectors, to measure the development of air shower in the atmosphere above the array.

Extensions of the Auger experiment will profit of continuous test study and optimization of PMT. In Auger, the Cherenkov light is detected by three 9" PMTs (XP1805 from Photonis). In Malargue the SDECO PMT test facility is running since 2002 and has been fully used in order to test all the PMTs actually deployed in the AUGER array. The system has been designed to completely test 16 PMTs at the same time[2].

The entire system is controlled by a PC based on a Linux OS4 which control the DAQ based on a CAMAC system and some dedicated boards to control, through a NIM multipurpose I/O PCI (6025E) board, HV and LED controllers. The system is quite obsolete and complicated. Lecce group took in charge the maintenance of the system and the implementation of an upgrade in order to make it more efficient and easy to manage. A reproduction of the test station have been built in Lecce in order to reproduce the principal test and prepare an upgrade on a VME system. In the following a brief description of the recent measurement effectuated in Lecce's laboratory.

2. Experimental Setup

The measurement program follows the performance specifications required for the Auger experiment. The PMTs need to have a large dynamic range, a good linearity, a low counting rate and a low breakdown voltage. In order to check these parameters we setup a test facility in the Lecce Astroparticle Laboratory (see Fig.1). A dark box (70x70x70 cm^3) hosts one PMT at a time. The detector under test can be positioned looking towards the box roof where a light source is positioned. Dark tight connectors plate for signals transmission and power is on the box panel. We have characterized a PHOTONIS PMT (XP1805) instrumented with one of the bases designed for the Auger experiment that is powered up by a custom made DC-DC HV power supply. The light source we used to perform the measurements consists of a LED Pulser controlled through a National Instruments USB-2659 Board connected to the data acquisition computer.

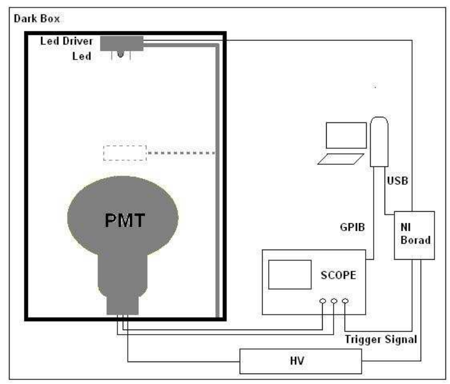

Figure 1. Schematic view of the experimental setup.

In the next sessions, a short description of the measurement is reported.

3. Dark Pulse Rate

The dark pulse rate is defined by the number of signals that are above a certain threshold when no light is incident on the photocathode. When a PMT is exposed to the light, if it is turned on it takes a certain time for recovering from the effect of the dark current. This current is caused mainly

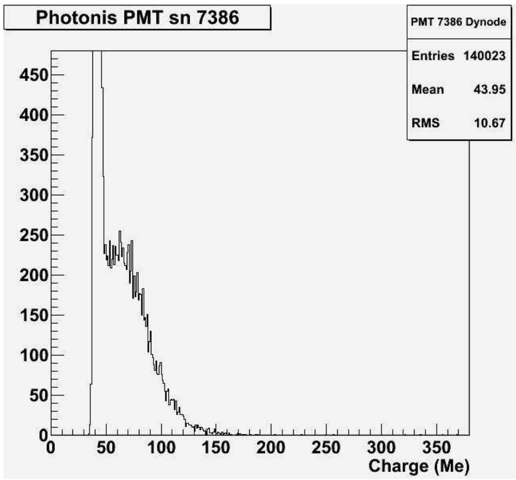

Figure 2. Single photoelectron spectrum for PHOTONIS PMT SN 7386.

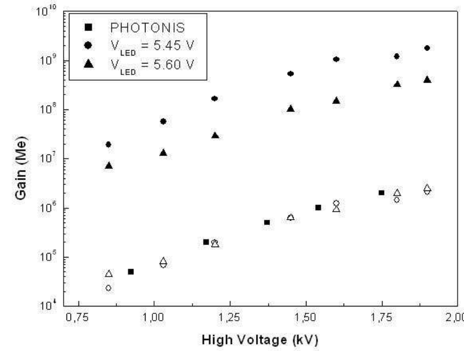

Figure 3. Gain curve as a function of voltage for the tested PMT. Mesurements were performed for two different values of the LED voltage (filled dots). The calibration results (open dots) are comapred with the measurement performed by PHOTONIS.

by the leakage current and thermoionic emission. To get the dark pulse rate we perform a 2 hours measurement triggering on the noise and calculating the events fraction as a function of the threshold (divided by the time window). After 2 hours, the rate of the dark pulse is below 10 KHz, that is in agreement with the Auger PMT requirements.

4. Single Photoelectron Spectrum

An important characterization of a PMT is the gain curve respect to the applied HV.
In order to get the absolute gain of the phototube at a certain voltage, the single photoeletron spectrum is measured. This measurement is performed setting the PMT to a gain of $\sim 2\times10^6$, according to the specifications given by the PHOTONIS and setting the LED in order to get signal on the first dynode only 10% of the time.The single photoelectron condition was reached using optical filters characterized by different transmittance. Fig. 2 shows the SPE spectrum for the PMT under test. The first peak is the pedestal and the second peak is due to 1 photoelectron events. From this measurements we infer for HV = 1450 V a gain G = 0.63×10^6 in agreement with the data-sheet.

5. Gain vs Voltage

In the previous section we calculated the absolute gain at the voltage applied for SPE. To get the gain as a function of voltage, the LED intensity has been fixed and the PMT HV has been varied. The relationship between gain and input voltage is described by:

$$G = kV^{\beta} \quad (1)$$

with γ and β to be determined from measurements.

The calibration and normalization is done applying the following formula:

$$G = \frac{(Q - Q_{ped})}{(Q - Q_{ped})_{SPE}} \times G_{SPE} \quad (2)$$

In Fig. 3, the results are shown togheter with the measurement performed by Photonis. For this PMT, the measured fit parameters are $\gamma = 3.189$ and $\beta = 1{,}7251$.

6. Non-Linearity Measurements

As we mentioned in Sec. 1, the necessity of having PMTs which have a linear response over a large dynamic range is crucial. The calibration of each SD station is done using single muons which are constantly passing through it [3], while a cosmic ray air-shower consists of thousands of particles entering a given station.
The Auger SD PMTs must be operated at low gain ($\sim 2\times10^5$) in order not to saturate the digitizing electronics at the highest expected signals. At the same time, the PMT must be linear over a range extending from a few to about 10^5 photoelectrons [4]. The requirement is to have linearity within ±5% up to an anode current of 50 mA at the nominal gain.
In order to measure the linearity of the tested PMT we used the dual pulse method, which allows to avoid the need of a reference linear PMT or of a calibrated light source.
The LED was positioned in two different positions respect to the PMT (close and far). Acting on the LED biasing voltage, the light intensity was raised in order to reach the PMT saturation

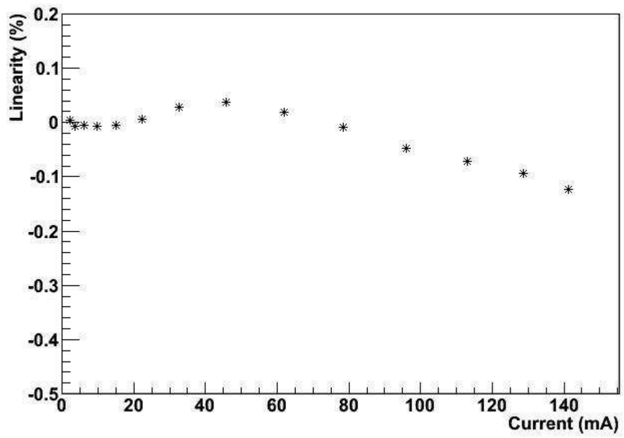

Figure 4. Linearity as a function of the anode current.

current at the closer position only.

The deviation from linearity is given by:

$$\eta = \frac{(I_C/I_F) - k}{k} \quad (3)$$

where I_C and I_F are the measured anode currents at the close and far position from the PMT and the constant k result from the fit to I_C/I_F performed at very low light level, before the onset of saturation effects.

From Fig.4, which shows the measured linearity η as a function of the currrent measured in the close position I_C, we can see that the tested PMT meets the non-linearity requirement.

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