A robot to characterize the photocathode response of the HAWC 8” photomultipliers

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***Abstract*. The high-energy gamma ray observatory HAWC at Volcan Sierra Negra, Mexico will reuse the 900 Hamamatsu R5912 photomultipliers from Milagro. In order to characterize their present performance it is necessary to scan the active area of the photocathode measuring the quatum efficiency and gain. To do this a robot with a two limbed spherical arm was constructed that can move a light source over the surface of the photomultiplier. The robot and its control hardware and software will be described as well as the measurement of the response of some of the PMTs.**

***Keywords*: HAWC, photocathode, calibration**

I. Introduction

Milagro [1] was a water-Cherenkov observatory that operated at an elevation of 2650 m.a.s.l. at Jemez Mountains in New Mexico. Milagro demonstrated that a surface array detector with a wide field of view (2sr) and nearly 100% duty cycle can discover new sources of TeV gamma rays at energies between 10 and 100 TeV, and map the diffuse emission from the plane of our Galaxy As the next generation, the HAWC [2] observatory has been designed to operate at 4100 m.a.s.l. at Sierra Negra volcano, Mexico, in a joint effort of scientists from US and Mexico. By increasing the altitude, the physical area, and an optimized design, HAWC will have an improved angular resolution, larger effective area, lower energy threshold and better background rejection. These improvements can be accomplished without any new technology, but only a modest upgrade to the existing Milagro components. The biggest and critical improvement (in the design) is the optical isolation of the PMTs, since they will be deployed in a 5.0 m deep by 7.3 m diameter commercial corrugated steel water tanks (∼300 tanks).

II. Requeriments

The PMTs will be anchored to the bottom and upward-facing (3 per tank) so HAWC will re-use the 900 8” Hamamatsu PMTs from Milagro. At the moment all the PMT (bases and connectors) are being refurbished and they have to be calibrated (gain, quantum efficiency, operational High Voltage etc.). Because of the large photocathode surface, it also necessary to measured the gain as function of the position on the photocathode. This information will be also useful in the design of possible light collectors which could improve the performance of HAWC [3]. In order to minimize time and possible uncertainties, an automated process has been implemented to carry out the measurements. The main component of such automatic process is a robotic arm which is able to position a light source in any place on the photocathode surface.

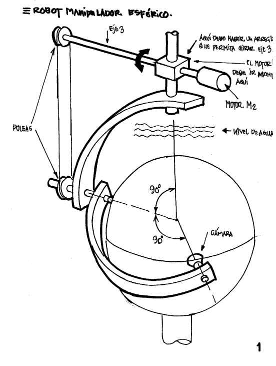

Fig. 1. Artistic drawing of the robotic arm, showing the robot components.

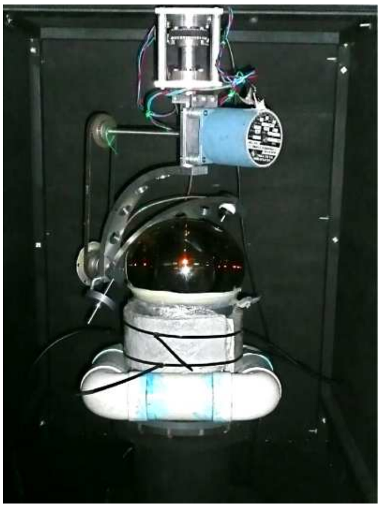

Fig. 2. Picture of the robotic arms inside the black box and the 8” photomultiplier at the measuring position

III. Experimental Set Up

The robot has an articulated spherical arm with the inner segment having a 25.4cm radius and a light source at its end that can be moved in theta and phi directions (Fig.1) and thereby sweep the entire surface of the

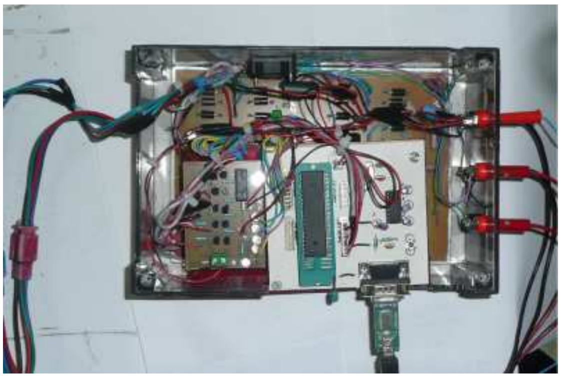

Fig. 3. Picture of the controller box

Fig. 4. control software interface

photocathode.

The arm segments are moved by stepper motors. The external one is driven directly, while the inner one through a pulley and a toothed belt. Both arm segments have counterweights to reduce the torque needed to move them.

In Figure 2 one sees the robotic arm mounted on a light-tight box with a PMT in measuring position. The inner arm has alignment holes that allow the centering of the photomultiplier, keeping the photocathode-light source distance constant.

The stepper motors are actuated from a controller box (Figure 3) that has microprogrammed instructions in an EPROM and which accepts commands from a PC through an USB port. With an external high current 5V DC power source it moves the arms in either direction. The control software has been developed in Visual Basic and has an user friendly interface (Figure 4).

The light source chosen is a ultra bright (9000 mcandles) blue LED whose emission is center at 470 nm, and extends from 440 to 500 nm. In order to collimate the light spot, the LED was inserted into an end-cap, which is attached to a 1 mm clear plastic fiber BICRON BC-98 . The distance between the fiber and the PMT is adjusted such as the beam spot is around 3 mm at the PMT surface, Fig. 5.

The LED is driven by 8012B HP pulse generator with a square pulse of 10 nsec width, the amplitude can be

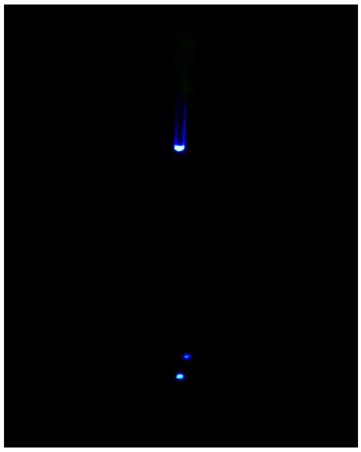

Fig. 5. Image of the optical fiber illuminating the photocathode surface and being reflected on both sides of the glass envelope

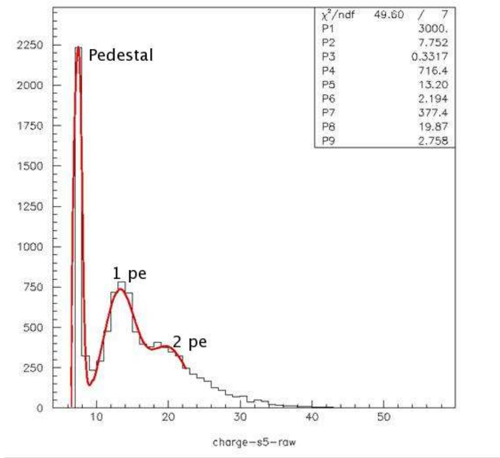

Fig. 6. Histogram of the response of the photomultiplier when illuminated with the blue LED operated in the single photoelectron level. The red line is a 3 gaussian fit to it.

adjusted to get from one single photoelectron (PE), Fig. 6, to a few hundred of them. The working frequency is 1 kHz.

The data acquisition (DAQ) has been done by a CAMAC system (Wiener CC32 USB controller, 2282A TDC Lecroy and 2249A QDC) controlled by a Laptop running under Scientific Linux 4.5. That we have two computers running with different operating systems for the control of the robot and for the DAQ was a result of the availability of those systems and the lack of time. The next step is to control the whole system with one single software code (probably under LabView) so the scanning could be done completely automatic. The trigger for the DAQ is taken from the pulse generator trigger, this allows to measure the time resolution of the PMT as function of the number of PE and monitor the efficiency of the photocathode. Figure 7 shows a schematics of the electronics.

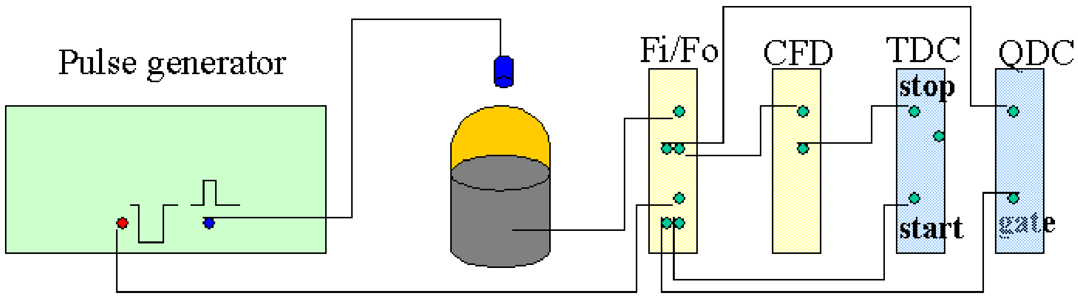

Fig. 7. Electronics squematics

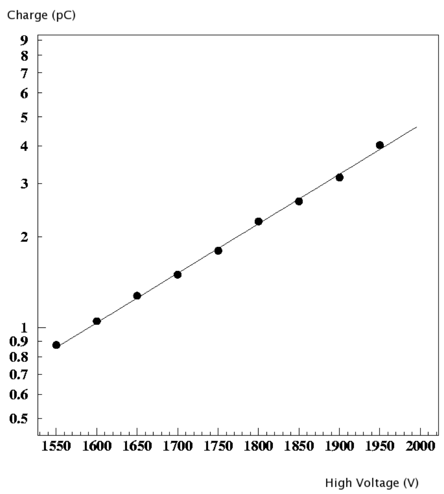

Fig. 8. gain vs high voltage. The solid line represets an exponencial fit.

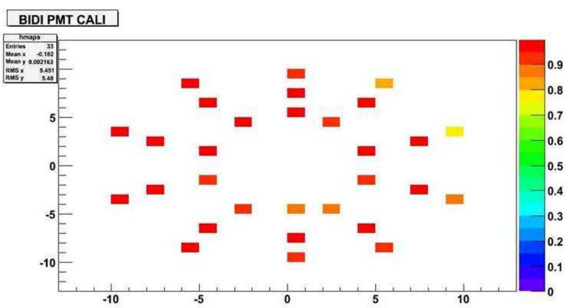

Fig. 9. Two dimensional contour color projection of the photocathode.

IV. TEST

The calibration system has been tested by characterizing one of the PMTs from Milagro. As first step, a single PE spectra is taken (see Fig. 6), at the central top point (theta=0, phi=0, theta=90 means the equator of the PMT). Then, the gain dependence as function of the high voltage is measured, Fig. 8. With this result an operation voltage of 1800 Volts (the single PE is very well separated from the pedestal) was chosen and the scan on the surface of the PMT was carried out in steps of 36 degree in Phi and 20 degree in theta. To monitor any gain change, the single PE peak position was measured. In order to determine the single PE position, a triple gaussian fit (Pedestal, fisrt PE, second PE) was carried out, Fig. 6. Any change in the quantum efficiency can be monitored by measured the ratio between the pedestal peak and the rest of the spectra. Figure 9 show the map obtained from this measurements. As it can be seen, the gain for this PMT is rather constant at leas at least until 60 degree.

V. CONCLUSIONS

A robot has been constructed that can sweep a light souce over the spherical surface of the photocathode of the 8” photomultipliers that will be used in HAWC The first measurements have been done at the single photon counting level. Studies of the stability and reproducibility of the measurements are in progress as well as calibrations at much higher light level. A better integration of the control and DAQ software is needed for fully automated operation which is needed to calibrate the 900 photomultipliers inherited from Milagro

VI. ACKNOWLEDGMENTS

This work has been supported by Direccion General de Apoyo al Personal Academico (DGAPA), UNAM through the project numberIN0015507.

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