

Tests of PMT uniformity for the GRAPES-3 experiment

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It is observed that the response of the PMT varies across the photo-cathode leading to certain non-uniformity. To select PMTs having uniform efficiency across the photo-cathode, an X-Y scanner with appropriate light source has been designed to measure PMT photo-cathode response. Here we present the results of uniformity measurements on the PMT response.

1. Introduction

GRAPES-3 is an extensive air shower experiment operating at Ooty (E76.7 °, N11.4°, 2200m asl), in south India. It consists of about 300 scintillation detectors each having an area of 1m² and 16 large area muon detectors having a total area of 560m². There are two kinds of scintillation detectors. The first type is conical shaped detector with a PMT directly viewing the scintillator. The second type is flat detectors overlaid with wave-length shifting fibers in parallel grooves called fiber detector. In the case of conical shaped detector, non-uniformity of quantum efficiency is not of any significance because the distance between PMT and scintillator is large and the photons from scintillator reach PMT surface after several reflections and uniformly illuminate the PMT photo-cathode. On the other hand, in the flat type detector the photons collected by the WLS fibers are transferred to the PMT through an optically coupled cookie. Because the WLS fibers are coupled to a local area of the PMT surface, the response of the PMT varies with the position of the cookie. Thus the response of the PMT becomes non-uniform if the quantum efficiency varies across the face of the PMT. A flat detector has 4 scintillator blocks each viewed by a group of 18 WLS fibers and each group is terminated at a separate cookie. Since these 4 cookies are attached to the PMT surface at a different location, non-uniformity of quantum efficiency becomes important for the flat type detector. We are using a fast 2 inch diameter photomultiplier, ETL 9807B with blue-green sensitive alkali photo-cathode from Electron Tubes [1]. To select PMTs having uniform quantum efficiency, we have designed a system for measurement of the uniformity using a precision X-Y scanner.

2. System

In figure 1 the system used to measure the PMT uniformity is shown. It contains a light tight box where the X-Y scanner and nine sockets facing the same direction, to mount a set of nine PMTs are placed. Thus a total of nine PMTs can be scanned simultaneously. The main component of this system is the X-Y scanner, which is operated using two stepping motors to move it along two orthogonal directions (X and Y) with high positional resolution, in steps of 1 μm. There are two plates, placed on the X-Y scanner each having 9 pin-holes of 1 mm diameter to serve as a nine beam collimator. Under the lower plate there is another plate on which nine green LEDs are fixed as light source. The wave-length of the LED output is 525 nm which is in the range of sensitivity of the emission spectra of WLS fiber[2]. When triggered, the LEDs produce a light pulse, with a width of 30 ns. The light pulse emitted from LED is collimated through the two pin holes of the two plates

above it, finally reaching the PMT surface with small angular spread. We have used a CAMAC based data acquisition system for generating the trigger pulse for the LED. The operation of X-Y scanner is controlled by a serial interface.

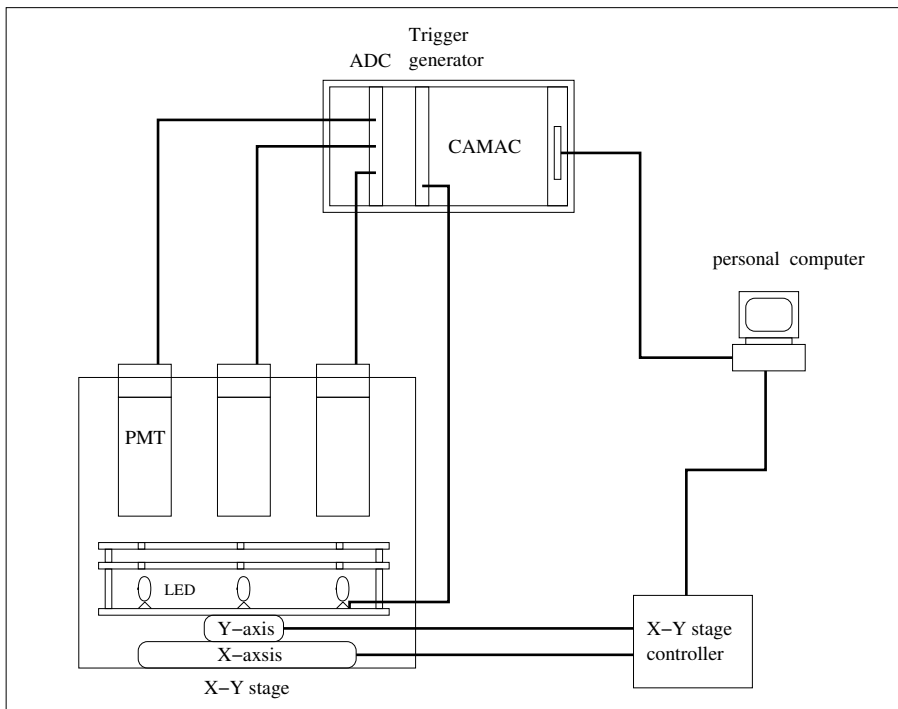


Figure 1. System for PMT uniformity test. A charge sensitive 32 channel ADC module and a trigger generator module is located in CAMAC crate. Serial communication is used between PC and X-Y controller to position the X-Y scanner.

3. Experiment

The X-Y scanner is used in a programmed mode to scan a square area larger than the size of the PMT photocathode by scanning the PMT on pre-determined step size. At each location data is collected by triggering the LED a fixed number of times as detailed below, which takes about one hour to complete scan.

1. Step width in X and Y directions is 1 mm.
2. Intensity of LED is adjusted to yield around 100 photo-electron.
3. Number of times LED triggered at each position is 200.
4. Scanning area is $65 \times 65 \text{ mm}^2$ to cover a total area of PMT surface.

4. Results

In figure 2 uniformity of the PMT photo-cathode is shown for a typical PMT. Vertical axis represents mean ADC counts after subtracting the pedestal. To characterize the variation of the quantum efficiency of the PMT surface, we determined the mean and rms deviation within the area of a circle of radius 20 mm from the center of the PMT as shown by an arrow in figure 3. This is necessary because the PMTs display a rapid decrease in their quantum efficiency near the outer edge. The present PMT shows an rms variation of 6.5% within 20 mm of the center. In figure 3 the response of the same PMT is shown along two different directions. The plot on the left shows the PMT response along X-axis and the plot on the right shows the response along Y-axis. In the figures 2 and 3 one can see a dip in the response and the depth of the dip is about 30 % below the mean value. Almost all PMTs we checked displayed such a dip in their response at the same location. If the area of the dip is excluded then the rms variation of this PMT reduces to 4.4% which may be considered to be fairly uniform. In figure 4 the response of a PMT having large non-uniformity is shown. This PMT has an rms variation of 10.7% in the selected fiducial area.

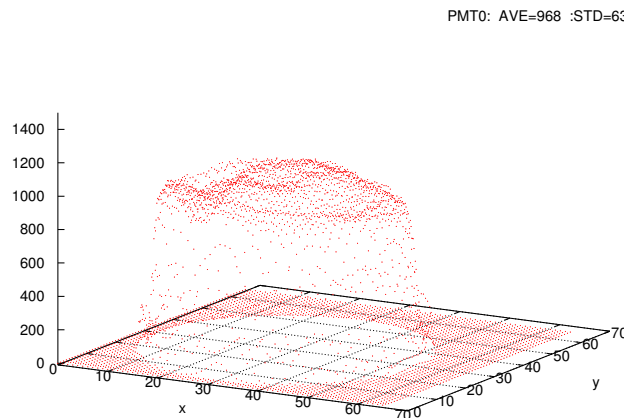


Figure 2. Uniformity of a typical PMT, the rms variation of this PMT is about 6.5%.

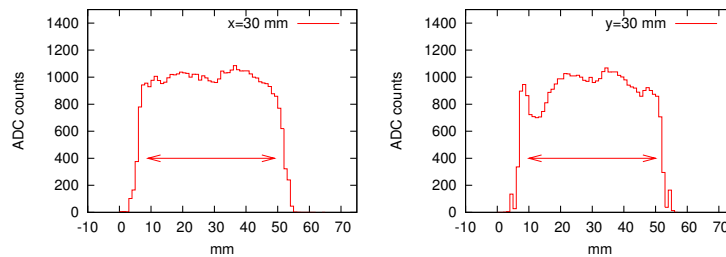


Figure 3. Left plot shows the uniformity along the X-axis and the one on the right shows response along Y-axis. Arrows show the range of an area used to determine the mean and rms variation.

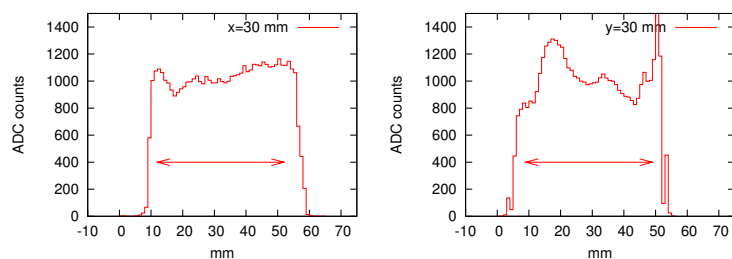


Figure 4. A PMT having large variation in its response. In the right plot response varies from -30% to 40% from its mean value.

5. Conclusion

The X-Y scanner developed to measure the response of the PMT has successfully measured the uniformity of quantum efficiency across the photo-cathode. The X-Y scanner allows identification of the area of uniform response on the PMT surface which can be used to locate the WLS fiber cookies. This has permitted successful utilization of a number of PMTs with rather non-uniform response which otherwise would not have been possible.

6. Acknowledgements

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References

- [1] DS_9807B Series Issue, Electron Tubes Inc.
- [2] Scintillation Materials, Kuraray Co.,Ltd.