

Study of the Influence of the Earth's Magnetic Field on PMTs for Pierre-Auger Surface Detectors

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Abstract

We have tested the influence of the Earth's magnetic field on the candidate PMTs for the Surface Array Detectors for the Pierre-Auger Observatory, being constructed in Malargue, Argentina. These are 8-inch PMTs from EMI (9353KB-728), Hamamatsu (R5912-SA2128) and 9-inch PMTs from Photonis (XP1802/FLB-544). They were tested for three different gains: 10^5 , 10^6 and 10^7 . We have found that the largest effect is seen in EMI PMTs and is of the order of 25%, i.e., depending on the orientation, the signal from PMTs changes by up to 25% for the same incident light level.

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1 Introduction

It is important to study the effect of earth's magnetic field on Auger PMTs, since there will be no magnetic shielding on them, and because of their large photocathode area, the effect of the magnetic field might be significant. Orienting the PMTs appropriately can give a better signal resolution. The UCLA Pierre Auger group has set up facilities to measure this effect in lab. The measurement techniques, setup and results are described below.

2 Setup

Figure 2.1 shows the experimental setup used to measure the effect of the PMT orientation on the output signal for a constant incident light signal. The PMT was placed facing downward in a cylindrical box made of white foam interior. The box was 25 cm deep. An LED (470 nm) was placed at the bottom of the box. Both the bottom and the walls of the box were diffuse white colored. A layer of diffusive tape was put on top of the LED to diffuse the light, and ensure uniform illumination of the photocathode.

Once the PMT was placed at the top of the box, the whole PMT-Box-LED assembly could be rotated as one unit. This ensured that the relative orientation, and the distance between the PMT and the LED did not change as the PMT orientation was changed. This is important, because one has to ensure constant light intensity at the PMT face during rotation in order to extract the effect or orientation on the PMT output.

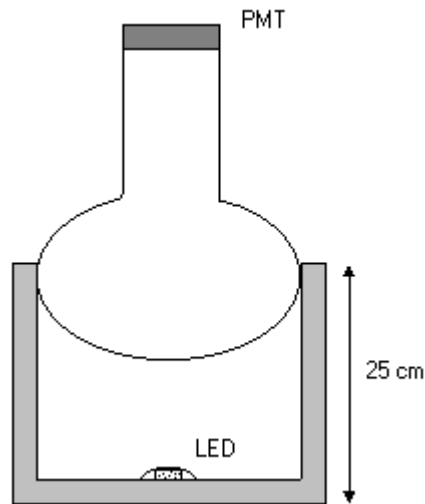


Figure 2.1 Schematic of the LED and PMT used for magnetif field study.

The experiment was performed in a dark box, isolated from outside light. The pin assignments for Hamamatsu and EMI PMT's is shown in Figure 2.2.

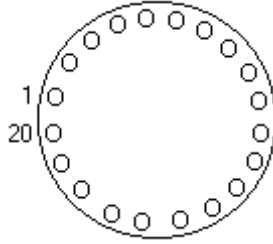


Figure 2.2 Pins 1 and 20 on the socket of a PMT (Hamamatsu and EMI)

3. Measurements

In a series of measurements, we analyzed the influence of the Earth's magnetic field on the PMT output for a given gain and constant photocathode illumination. The PMTs were placed in a vertical position (i.e. their axis was in the vertical direction) facing downwards.

We adjusted the intensity of the LED such that the PMT output was well in the linear region. The LED was pulsed at a frequency of approximately 1KHz.

The PMT-LED assembly was rotated anticlockwise around the vertical axis in steps of 30 degrees and data were collected for each of the angles at different gains. Again, since the PMT-LED assembly was rotated together as one unit, the relative orientation between the LED and PMT was always the same, so that the amount of light at the photocathode did not change as the assembly was rotated. A LeCroy 2249W ADC was used to digitize the PMT signal, and a LabView based program was used to acquire data and analyze it.

The results for the three PMTs are shown in Figures 3.1 (EMI), 3.2 (Hamamatsu), and 3.3 (Photonis).

The quantity plotted in these figures is the percent deviation of the PMT signal relative to the average as a function of angle. For EMI and Hamamatsu PMTs, the angle 0 degrees corresponds to the case when Pin 20 is facing the local North, and 90 degrees means Pin 20 facing West. The dynodes for EMI and Hamamatsu are aligned such that Pin 20 facing north also corresponds to the First dynode facing South.

In the case of Photonis, the socket was connected to the PMT through fairly long flying leads, and the socket could move relative to the pins on the PMT base. As a result, designating the orientation of the PMT by the pin number on the socket is not useful. The direction in these PMT's was marked by the two square holes in the cylindrical metal structure surrounding the dynodes. The angle 0 degrees, for Photonis PMTs, corresponds to the case when the two square holes are facing the local magnetic north.

The horizontal component of the Earth's magnetic field in the lab at UCLA was measured to be 0.26 Gauss and the vertical component was 0.47 Gauss. For comparison, the horizontal magnetic field in Malargue is 0.2 Gauss, and the vertical component is -0.14 Gauss.

We can see from Figure 3.1 that for EMI 9353KB the relative change in the signal is about 25% (position of 0 vs. 90 degrees). The optimal signal is obtained when pin 20 is oriented towards the local magnetic North. Additionally, the relative change in the signal

does not depend on the gain (within the error of measurement). A North-South symmetry is also seen.

A similar behavior is also seen in Hamamatsu (Figure 3.2), although the effect is smaller (~12%). One reason for the smaller effect on Hamamatsu PMTs is their larger first anode area, compared to that of EMI.

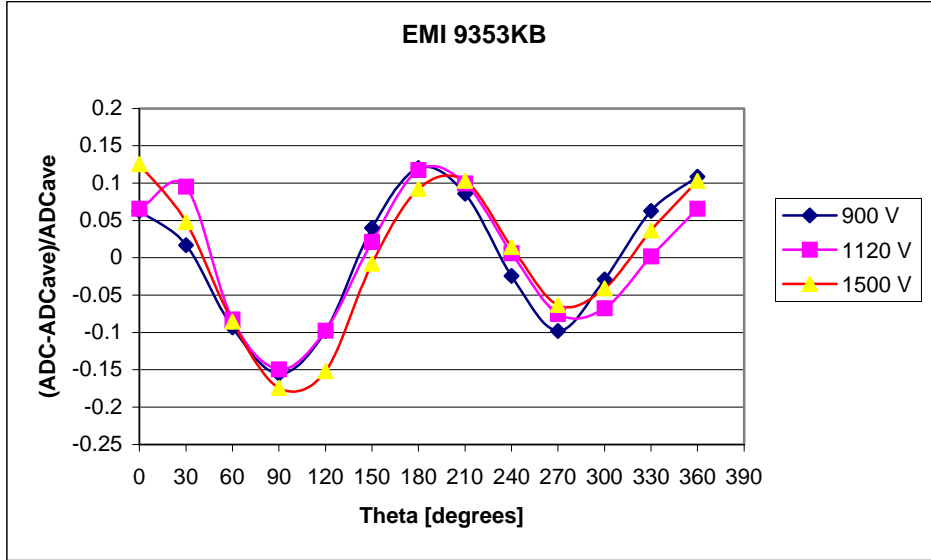


Figure 3.1 The deviation of PMT output relative to the average as a function of angle Pin 20 makes relative to the local magnetic north for EMI 9353KB-728. The three curves correspond to gains of 10^5 (900 V), 10^6 (1120 V), and 10^7 (1500 V).

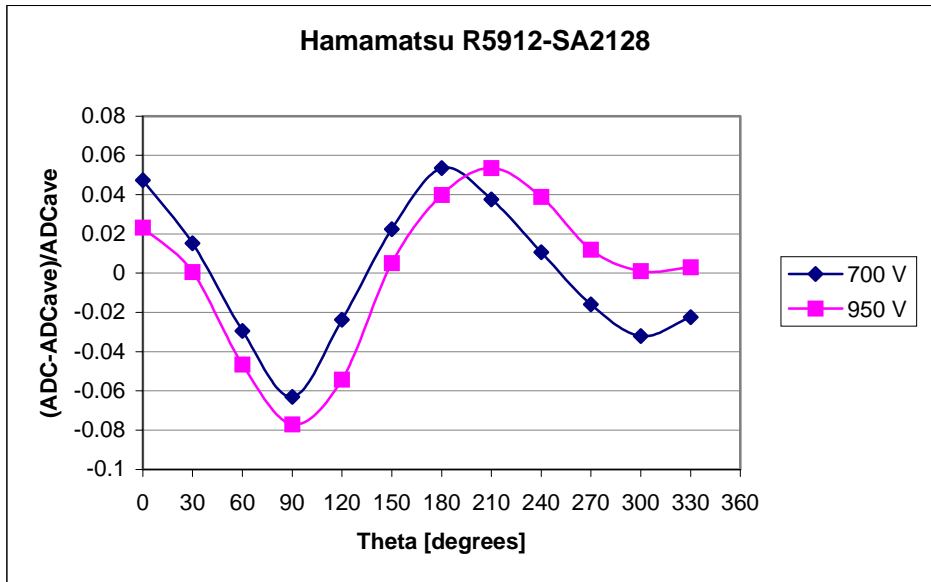


Figure 3.2 The deviation of PMT output relative to the average as a function of angle Pin 20 makes relative to the local magnetic north for Hamamatsu R5912-SA2128. 9353KB-728. The two curves correspond to gains of 10^5 (700 V), 10^6 (950 V).

For Photonis (Figure 3.3), the PMT output again changes by up to 25%, depending on the orientation. The first dynode in Photonis is foil type. Therefore, the angle 0 degree here does not correspond to the same dynode orientation as EMI and Hamamatsu. This explains the different shape of the graph for Photonis. Two cycles in the graph are still visible though, if we move the points between 0 and 30 degrees to the end of the graph (between 360 and 390 degrees).

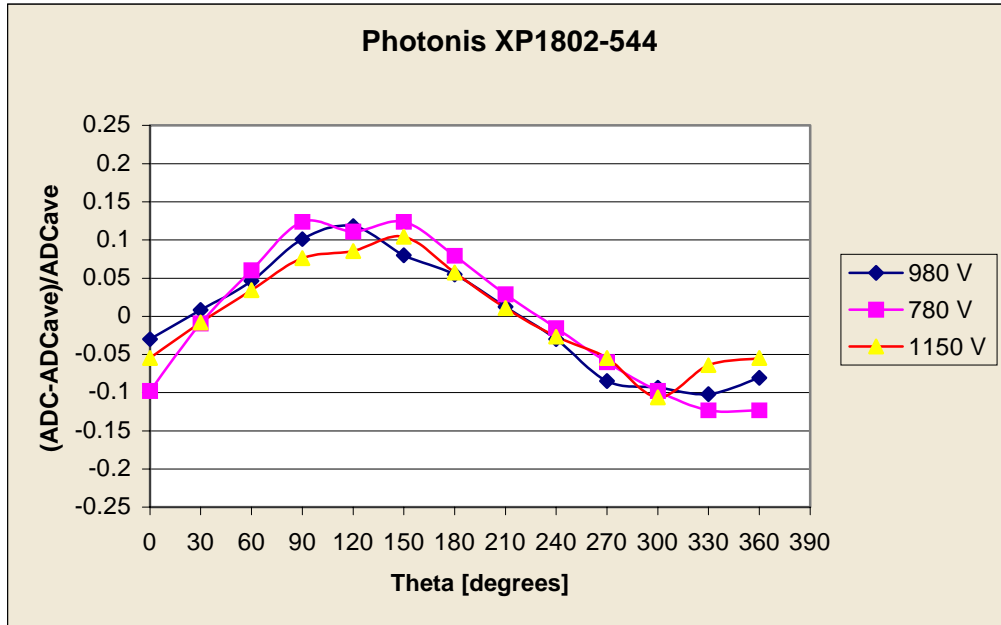


Figure 3.3 The deviation of PMT output relative to the average as a function of angle Pin 20 makes relative to the local magnetic north for Photonis XP1802-544. The three curves correspond to gains of 10^5 (780 V), 10^6 (980 V), and 10^7 (1150 V).

4. On-Site Verification

During the electronics installation on site, we had the opportunity to verify these measurements independently in Malargue (late February-early March). Due to time constraints only a minimal verification was performed. PMT 3 in the test tank “Laura” was used. This was an ETL PMT. The trigger for the data was a threshold trigger (80 mV) on the sum of all three anode signals. The DAQ system used was that installed by the group from BUAP (Mexico). (Thanks especially to Humberto Salazar and Eduardo Cantoral). This system recorded the scope traces and then integrated them to obtain a total charge for each PMT. The anode signals were used. The gain was approximately 3×10^6 . Because of the method of the cables entering the fez, the orientation of the PMT was known to approximately 10 degrees. There was no optical coupling between the PMT and the window.

Three reliable data runs were taken. The PMT was aligned with pin 20 (the notch) approximately north, approximately west and approximately northwest. (The PMT was of

course facing down.) A duplicate run with the notch pointing north was performed to ensure there was little trigger bias. To ensure that we were looking at through-going muons and not small showers near a PMT, a cut was imposed on the data that each PMT detect 10% of the total charge in the event. (This cut was suggested by Jim Beatty of PSU in a different context.) The data for the runs with the notch north and west are shown in Figure 4.1 below.

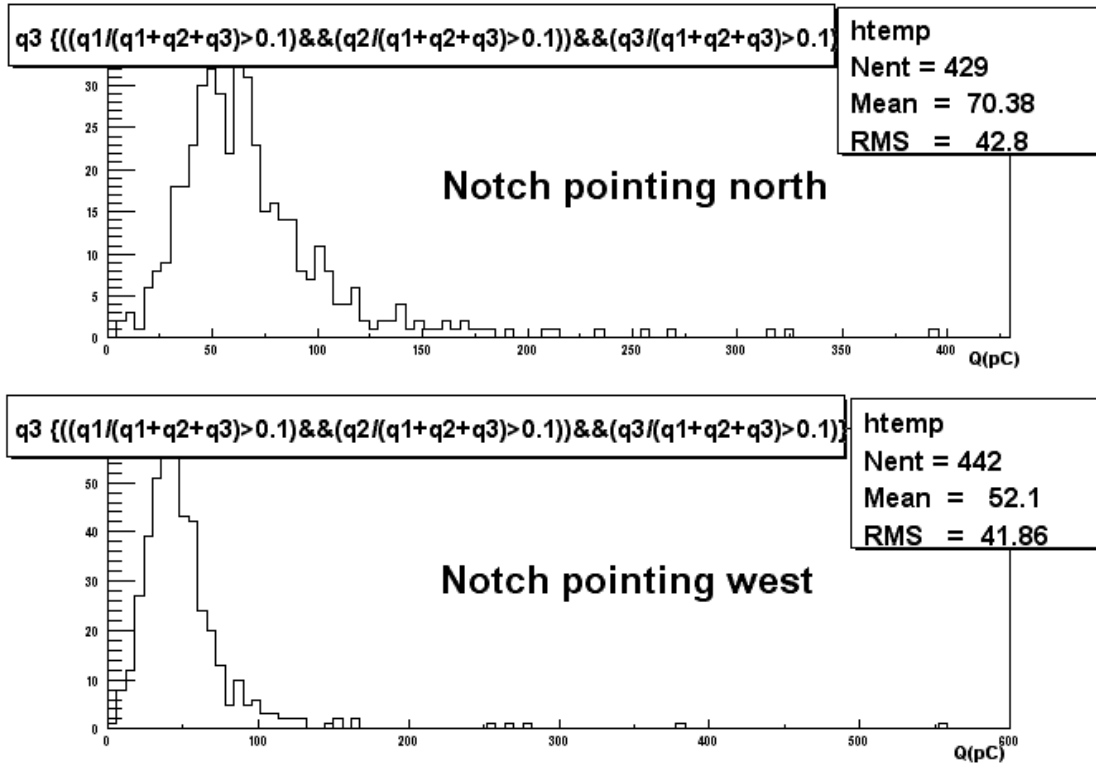


Figure 4.1 The EMI PMT output for through-going muons for different PMT orientations. These measurements were done in the Galpon water tank in Malargue. The gain was kept constant at 3×10^6 .

There is a difference of $\pm 15\%$ from the average value.

As a check a run was performed with the notch pointing approximately northwest (Figure 4.2) and the result is intermediate between west and north although not exactly in the middle.

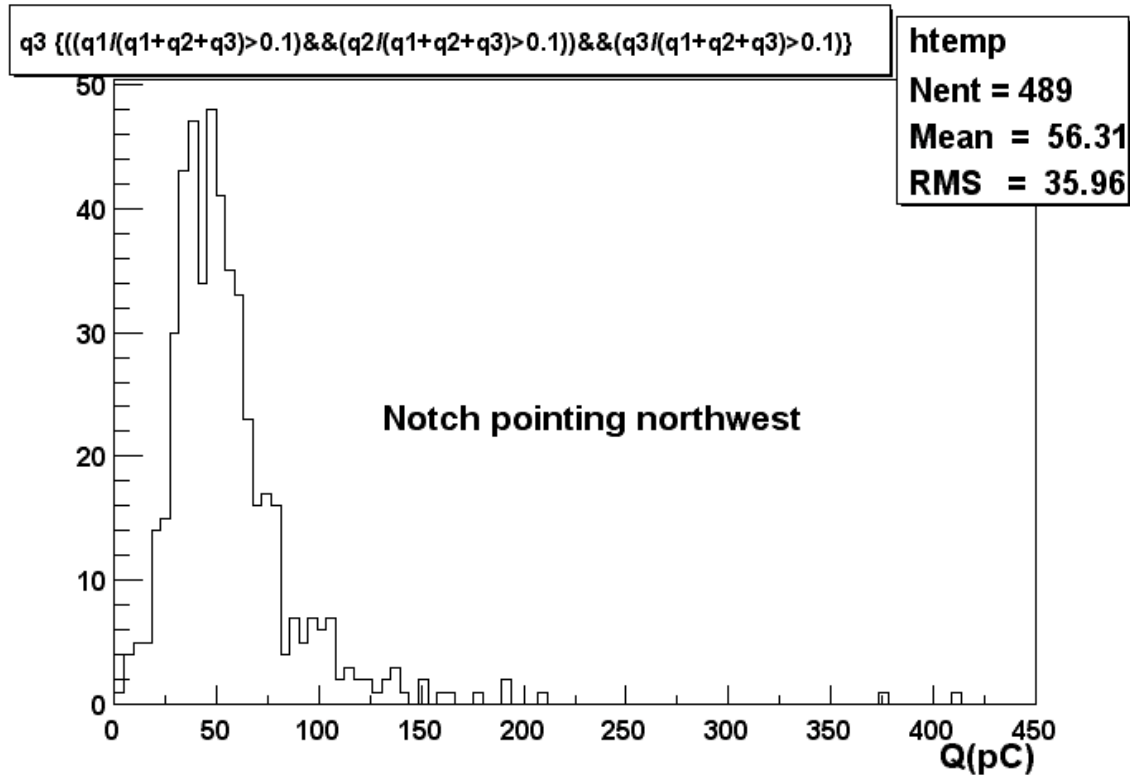


Figure 4.2 Through going muon signal from the Galpon PMT, with pin 20 facing northwest, at a gain of 3×10^6 . The mean charge is in between those observed for North and West orientations.

Clearly this verification is incomplete, however it gives confidence that the lab measurements are correct and can be used as a guide for PMT installation in the field. Some photographs and experimental details may be found at <http://www.physics.ucla.edu/~jillings/work/>.

5. Summary

We have studied the effect of earth's magnetic field on the Auger PMTs both in lab and also on site in Malargue. The lab studies show that the PMT output for the same incident number of photons at a constant gain can change by up to 25% for EMI and Photonis PMTs and by 12% for Hamamatsu PMTs depending on the PMT orientation. One reason for the smaller effect on Hamamatsu PMTs is its larger first dynode.

In the High Voltage ranges used in these studies, no clear effect of HV is seen.

For Hamamatsu and EMI, the optimum orientation (largest anode signal for a given gain and a given number of photons at the photocathode) is Pin 20 facing local magnetic north. For Photonis, the optimum orientation corresponds to case when the two square holes in the cylindrical metal structure surrounding the dynodes face 120 degrees (clockwise) from local magnetic north.

An independent study of the effect of magnetic field on EMI PMTs was also carried out on site in Malargue using the through going muon signals in the Galpon water

tank (Laura). The results of this study are consistent with the measurements made in the lab at UCLA.