

# **Effect of Earth's Magnetic Field on Production Photonis PMTs**

A. Tripathi, K. Arisaka, T. Ohnuki, P. Ranin

**University of California, Los Angeles**

**3 December, 2001**

## **Abstract**

We report the results of a study of the effect of earth's magnetic field on the production PMTs (Photonis XP1805/D1).

# 1. Introduction

In the past, we have reported the results of our study of the influence of earth's magnetic field on EA PMTs [1], namely, Hamamatsu R5912, ETL9353KB and Photonis XP1802. In the production array, Photonis XP1805/D1 PMTs will be used. These PMTs have only 8 dynodes, compared to 11 dynodes in XP1802. This modification in the number of dynodes was done in order to enhance the PMT linearity over a large dynamic range at low gain. Since modifications were done to the dynode chain, it is necessary to repeat the magnetic field measurements for the new PMTs.

We report the results of measurement of the effect of earth's magnetic field on Photonis XP1805/D1 PMTs, and demonstrate that the energy resolution is affected by the PMT orientation relative to earth's magnetic field.

## 2. The Experimental Setup

The experimental setup used for these measurements is identical to the one described in [1].

## 3. The Measurements

A pulsed blue LED was used to uniformly illuminate the photocathode of the PMT (Photonis XP1805/D1, S/N 598), which was operated at a gain of  $2 \times 10^5$  (1305 V), the proposed operating gain in the experiment. The LED intensity was tuned down such that the number of photoelectrons produced was 10-15.

The PMT was mounted with the photocathode facing down, and was rotated in 30 degree steps, and the anode signal was amplified using the Orsay amplifier, and was digitized with a LeCroy 2249A ADC at each orientation. The LED intensity was kept constant during the process.

Figure 1 shows the definition of the rotation angle used in this document. The angle 0 degrees corresponds to the case when the short pin on the PMT is facing local magnetic north, with the photocathode facing vertically downward. The PMT was rotated **clockwise** (while looking down on the PMT) from this starting position. Note that this convention is different from the one used in [1].

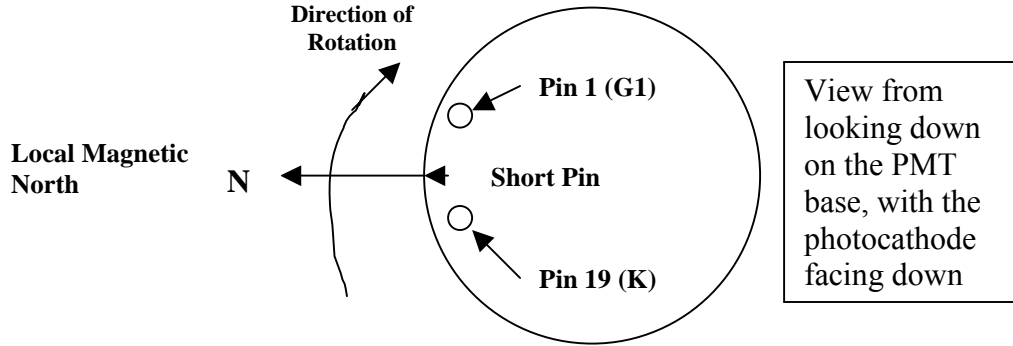
The energy resolution is determined by the number of photoelectrons *collected* at the first dynode. The magnetic field affects the trajectories of photoelectrons from the photocathode to the first dynode, and as a result, affects the collection efficiency. Therefore, for a given fixed number of *photons* incident on the photocathode, the number of *photoelectrons collected* at the first dynode is affected by the PMT orientation relative to the earth's magnetic field.

The number of photoelectrons *collected* at the first dynode is proportional to the quantity  $(\mu/\sigma)^2$ , where  $\mu$  is the mean and  $\sigma$  is the standard deviation of the gaussian distribution of the anode signals resulting from a constant number of *photons* incident on the photocathode.

Since the LED intensity was kept constant during the measurements, any change in the quantity  $(\mu/\sigma)^2$  as a function of PMT orientation is an indication of a change in the number of photoelectrons *collected* at the first dynode, that is, the change in collection

efficiency as a result of the effect of earth's magnetic field. A change in the collection efficiency directly affects the energy resolution.

We measured both the mean anode signal, and the quantity  $(\mu/\sigma)^2$  for a given PMT orientation.

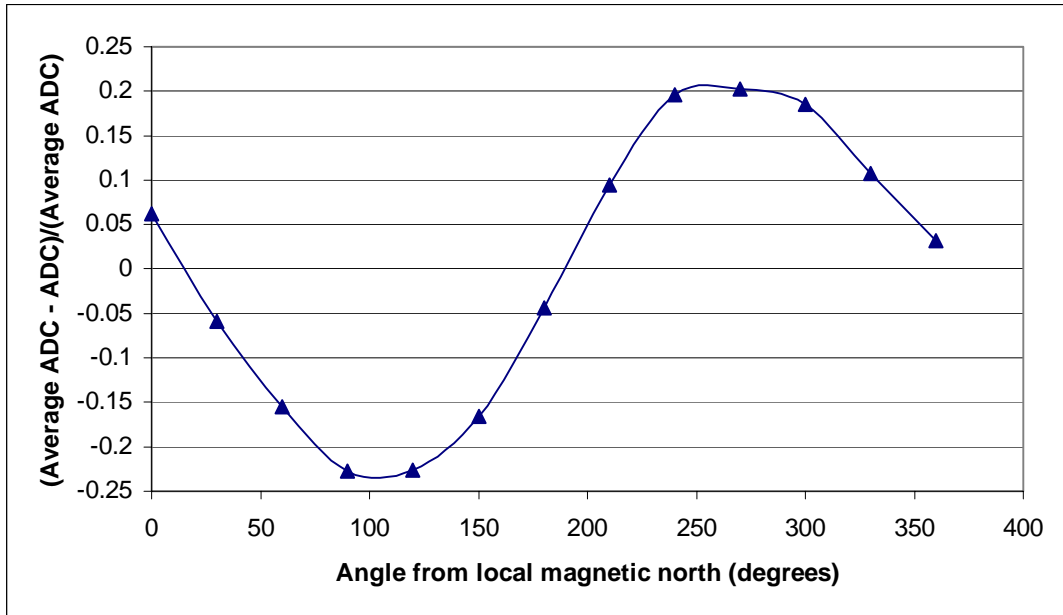


**Figure 1** A schematic showing the definition of the angle, and the direction of rotation used in this document with respect to the earth's magnetic field. The angles used in this document are the angles between the short pin and the local magnetic north, when the PMT is rotated in a clockwise direction with the photocathode facing down.

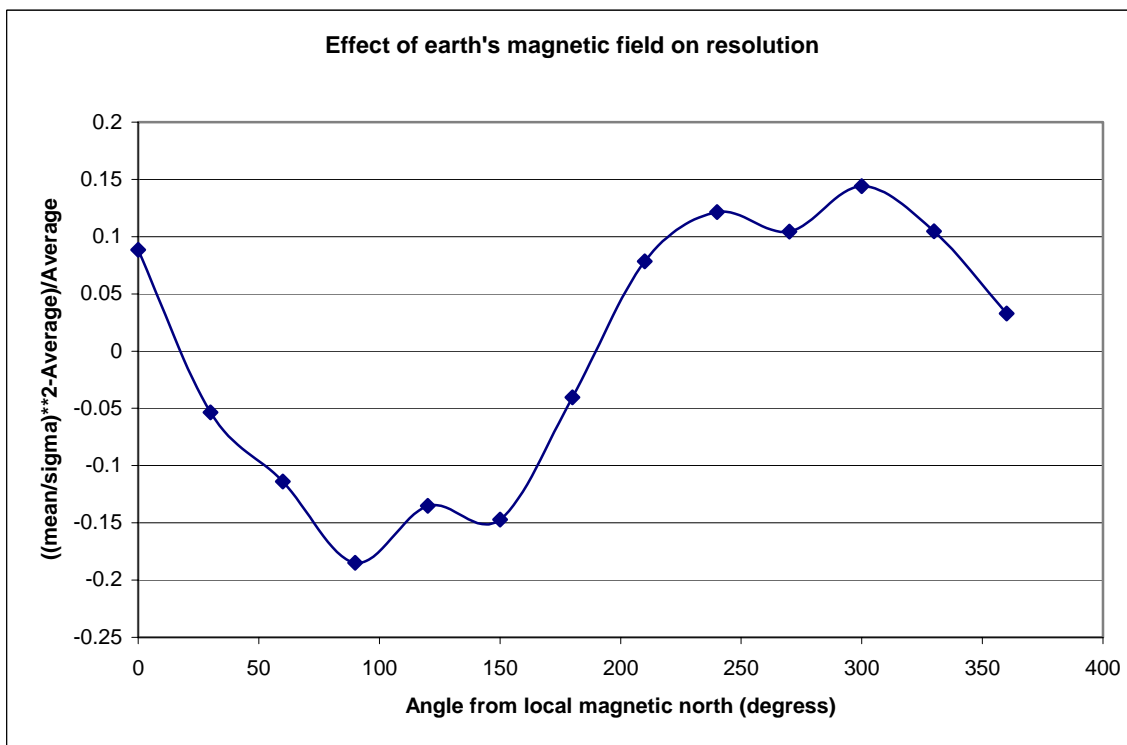
## 4. The Results

The effect of earth's magnetic field on the anode signal of Photonis XP1805 PMT is shown in Figure 2. It can be seen that the anode signal can vary by up to 42% depending on the PMT orientation, for a fixed number of photons incident on the photocathode.

Figure 3 shows the effect of the geomagnetic field on the photoelectron collection efficiency, which is the relevant quantity from physics point of view. The Y-axis shows the deviation of the quantity  $(\mu/\sigma)^2$ , which is proportional to the photoelectron collection efficiency, from the average  $(\mu/\sigma)^2$  of all data points. Clearly, the photoelectron collection efficiency can change by up to 30% depending on the PMT orientation.



**Figure 2** Effect of earth's magnetic field on the anode signal for Photonis XP1805 PMT. The X axis shows the angle the short pin makes with respect to the local magnetic north, measured in a clockwise direction. The Y axis shows the fractional deviation of the anode signal from the average of all data points.



**Figure 3** Effect of earth's magnetic field on the photoelectron collection efficiency for Photonis XP1802 PMT. The quantity  $(\mu/\sigma)^2$  is proportional to the photoelectron collection efficiency, since the number of photons incident at the photocathode is fixed.

## 5 Summary

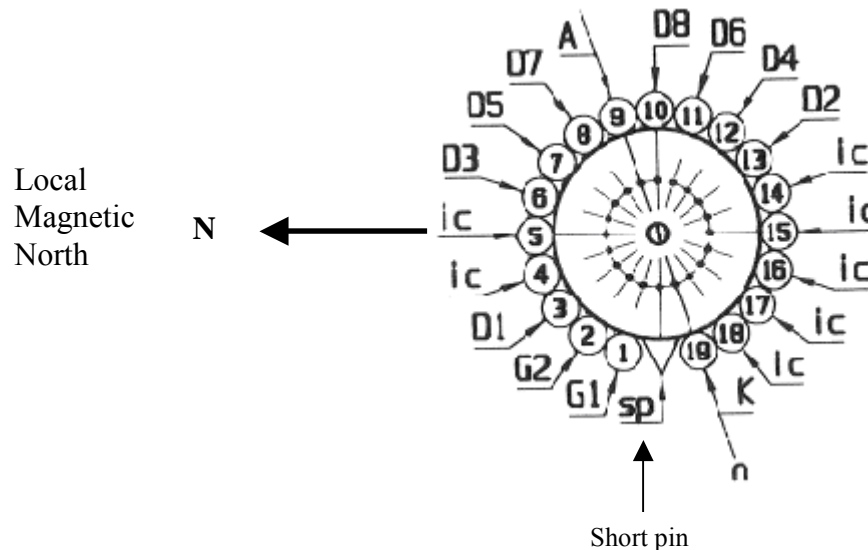
We have repeated the measurement of the effect of earth's magnetic field on Photonis XP1805/D1 PMT, to be used in the pre-production and production surface detectors. In addition, we have also measured the effect of the magnetic field on the photoelectron collection efficiency of the PMT. The photoelectron collection efficiency can change by up to 30% depending on the PMT orientation.

In order to achieve the best energy resolution, the Photonis XP1805 PMTs must be oriented such that the short pin makes an angle of 270 degrees with respect to the local magnetic north, in the clockwise direction, with the photocathode facing vertically down. This also corresponds to pin 5 (Figure 4) facing local magnetic north.

## 6 Conclusion

For a constant number of photons incident on the photocathode, the anode signal is clearly affected by the PMT orientation relative to earth's magnetic field. More importantly, photoelectron collection efficiency is significantly affected by the geomagnetic field, making it important to orient the PMTs in the field such that the photoelectron collection efficiency is maximized.

In the field, the Photonis XP1805 PMTs must be oriented according to Figure 4. This orientation corresponds to the case when pin 5, as shown in the pin diagram in Figure 4, faces local magnetic north, with the photocathode facing vertically down.



**Figure 4** The optimum orientation for Photonis XP1805/D1 PMTs. It corresponds to pin 5, as shown above, facing local magnetic north with the photocathode facing vertically downwards. The view shown here is looking down on the PMT base, with the photocathode facing down.

## 7 References

1. P. Ranin, A. Tripathi, K. Arisaka et. al., Study of the Influence of the Earth's Magnetic Field on PMTs for Pierre Auger Surface Detectors, Auger technical note **GAP-2001-006**.

