COMPARISON OF PHOTONIS AND IPN-ORSAY TEST BENCHES USED FOR THE PHOTONIS XP 1805 PMT GAIN MEASUREMENTS

A. Creusot, B. Genolini, T. Nguyen Trung, J. Pouthas
Institut de Physique Nucléaire d'Orsay, IN2P3-CNRS, Université Paris-Sud Orsay, 91406 Orsay Cedex, France
F. Foucher, P. Lavoute
Photonis, Avenue Roger Roncier, 19106 Brive-La-Gaillarde, France
G. Navarra
Dip. Fis. Generale, Univ. Torino, Istituto Nazionale di Fisica Nucleare - Sezione di Torino, via P. Giuria 1, 10125 Torino, Italy

September 26, 2002

Abstract

This document presents the results of measurements performed at IPN Orsay with Photonis development group engineers in order to compare the Photonis and the Auger collaboration test benches used for the calibration of the Photonis XP 1805 photomultiplier tubes. The gain and the peak-to-valley ratio were measured with the Photonis and Auger bases. Data were taken with the Photonis spectroscopy data acquisition and a standard Auger system based on a CAMAC charge ADC. The comparison of the results with the different set-ups is presented as well as the results of the influence of the Earth's magnetic field on the gain and on the peak-to-valley ratio.

Keywords: surface detector; photomultiplier base; photomultiplier gain; calibration; single electron response

1. INTRODUCTION

The Surface Detectors (SDs) of the Pierre Auger Observatory (PAO) [1] make use of three photomultiplier tubes (PMTs) per station. The PMT chosen for the production is the Photonis XP1805. The PMTs are tested by Photonis before delivery and extensive controls are performed by the collaboration. In July 2002, more than 130 Photonis XP1805 PMTs equipped with the IPN-Orsay bases [2, 3] had been tested at UCLA [4]. A systematic difference was observed on the PMT gains: at the same high voltage, the gains were higher than the ones given by Photonis. This systematic difference was also observed by UCLA, INFN-Torino and IPN-Orsay during the measurements for the selection of the tube manufacturers.

The Photonis set-up is different from the PAO collaboration one. Therefore, comparative measurements of the test benches were undertaken. They were performed with Photonis development group engineers on July 2002 at IPN Orsay. Single electron response spectra were measured on the same PMT with both set-ups to compare the gain and the peak-to-valley ratio. The PMTs were equipped with the Photonis test bench base and the two types of SD production bases [2, 3]. The influence of the Earth's magnetic field was also measured because the Photonis test bench makes use of a magnetic shield.

2. SET-UP

2.1 Installation compatible with the two benches

All the measurements were performed with the same PMT. The PMT was equipped with a base, and placed vertically in a light-tight box, as shown in Figure 1. The box comprises light-tight feed-throughs compatible with different types of bases (i.e. with BNC, SHV for external high voltage power supplies (HVPSs), and the SD slow-control connectors), including an optical fiber feed-through coming from an external LED driven by a HP 8082A pulse generator. The tube was placed on a support, above the output of the optical fiber, so
that it was facing the center of the photocathode. The box was rotated in order to measure the influence of
the Earth’s magnetic field.

![Diagram](image)

**Figure 1** Installation in the light-tight box. The feed-through plate is compatible with both Photonis and PAO bases.

### 2.2 The Photonis data acquisition

The Photonis PMT calibration set-up is summarized in Figure 2. The PMT is placed in a light-tight box. The
dynodes are protected by a magnetic shield, which consist in a mu-metal cylinder. The PMT is polarized by a
resistive base with a negative high voltage. The voltage repartition is the same as that of the PAO SD base.
The anode signal is measured by a spectroscopy chain: a charge preamplifier followed by a shaper. The data
acquisition consists in a multi channel analyzer, which measures the counting rate and the peak amplitude of
the output of the shaper (shown in Figure 2). The chain is calibrated with a reference XP2020 PMT. The
acquisition is triggered according to the acquired signal level: 0.2 times the charge of the single electron
peak. In order to increase the single electron peak, a pulsed LED is used to generate single photoelectrons at
a rate of around 10 kHz. The signal driving the LED is such that less than 10 % of the commands produce
one photoelectron (cf. Ref. [5], p. 4-12).

![Diagram](image)

**Figure 2** Overview of the test bench used by Photonis. The pulse shape at the amplifier shaper output is shown on the right side.
2.3 The IPN-Orsay data acquisition

The calibration system used in the IPN Orsay test bench is summarized in Figure 3. Similarly to the other groups of the PAO collaboration (INFN Torino, UCLA), it relies on the LeCroy 2249 QDC CAMAC module, which has a resolution of around 0.25 pC/channel (the calibration of the module used in Orsay yields 0.24 pC/channel). The Orsay group uses an external wide band amplifier with a calibrated gain of 23 to measure the anode signals. The PMT is placed vertically in a light-tight box. The bases used are the PAO SD ones [2, 3], equipped with ETL or SDS high voltage power supplies. The slow control is a dedicated circuit powered by two voltages (+ and -12 V). The command is set using a potentiometer. The slow control circuit has outputs to control the command voltage, the base high voltage monitoring, the base current monitoring, and the base temperature sensor output. The voltages are read on an Agilent 34401A multimeter. Single photoelectron spectra are obtained by injecting photons with a pulsed LED. The data acquisition trigger and the gate of the QDC are generated from the synchronization output of the pulse generator. The value and the width of the LED command are set so that there are less than 10 % of events with a charge greater than that of the pedestal.

![Figure 3 Overview of the test bench used at IPN Orsay.](image)

3. Single electron response

All the single electron response measurements for the comparison of the gain measurement methods were performed without shielding, with the orientation as regards to the Earth's magnetic field yielding the best gain according to Ref. [6]. They were all performed at the voltage given in the Photonis data sheets to reach a gain of $10^5$. All the tests were first performed on PMT S/N 1057. The PAO SD bases used were the bases equipped with ETL S/N 10112 HVPS and SDS S/N 46013614 HVPS. Before starting the measurements, the Photonis data acquisition was calibrated with the reference XP2020 PMT. Then, before each measurement on the XP1805, the high voltage was set to the value of the data sheet, which correspond to channel 100 on the Photonis data acquisition. The pulse counter of the Photonis data acquisition was used to determine when the PMT noise counting rate was stable. Then, an single electron measurement was performed by using the Photonis data acquisition system. Once it was finished, the external cables were changed in order to make a measurement with the IPN Orsay data acquisition. An example the histograms obtained with the different methods on the same tube powered at the same voltage is shown in Figure 4.
The comparison of the measurements with the different bases and the different data acquisition systems is presented in Table 1. It shows that the influence of the base is negligible since the same peak-to-valley ratio is measured and that the same gains are measured with the same data acquisition. A systematic ratio between the two measurement methods is observed. It has been checked that it does not depend on the cable length nor on the gate width used in the Orsay method to drive the QDC.

<table>
<thead>
<tr>
<th>PMT base</th>
<th>Data acquisition</th>
<th>Measured gain (×10^6)</th>
<th>Peak to valley ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDS 46013614</td>
<td>Spectroscopy</td>
<td>1.0</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>QDC</td>
<td>1.2</td>
<td>1.8</td>
</tr>
<tr>
<td>ETL 1012</td>
<td>Spectroscopy</td>
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<tr>
<td></td>
<td>QDC</td>
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<td>1.9</td>
</tr>
<tr>
<td>Photonis</td>
<td>Spectroscopy</td>
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<td>2.0</td>
</tr>
<tr>
<td></td>
<td>QDC</td>
<td>1.3</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Table 1 Comparison of results for the same value of the high voltage put on the tube S/N 1057. This value was determined so that the single photoelectron peak correspond to channel 100 on the Photonis data acquisition (referred as “Spectroscopy” in the “data acquisition” row). The PAO system based on the 2249 module is referred as “QDC”. The two first bases tested are PAO SD bases, with the two different kinds of HVPS. The third base is the resistive base Photonis uses for its tests.

An additional calibration was performed on the Photonis charge preamplifier with the preamplifier calibration input. A pulse generated by the HP 8082A signal generator, measured with the oscilloscope, was injected at this input. According to the values given in the preamplifier notice, the sensitivity of the acquisition chain would be 0.19 pC/channel. However, according to the calibration performed with the XP2020, the sensitivity of the acquisition chain should be 0.16 pC/channel. Therefore, the reference XP2020 and its base were checked at Photonis. It appeared that the actual gain of the XP2020 was 20% higher than previously estimated, which is in agreement with the results of the charge preamplifier calibration.
4. INFLUENCE OF THE EARTH'S MAGNETIC FIELD

The influence of the Earth's magnetic field was measured using the Photonis data acquisition system on tubes S/N 1057 and 1073. The tubes were placed vertically in the light tight box as described previously. Great care was given to the cable placement to reduce the picked noise which can have an influence on the results. The tube orientation was changed by rotating the box. The reference for the angles is the same as in Ref. [6].

The influence of the magnetic field on the gain is presented in Figure 5. The measured gain variations are consistent with the ones measured in UCLA [6], shown in the same figure. The influence on the peak to valley ratio is presented in Figure 6. It follows nearly the gain curves. When the ratio is small, the measurement is more difficult, which explain a probable measurement error for one point in one curve (second point of the curve of the PMT S/N 1073 in Figure 6).

![Figure 5](image1)

*Figure 5: Relative gain as a function of the PMT orientation (relative to the mean gain). Measurements performed on PMTs S/N 1057 and 1073 with the Photonis base and spectroscopy data acquisition. The results from UCLA measurements (see Ref. [6] for more details) are also presented.*

![Figure 6](image2)

*Figure 6: Peak to valley ratio as a function of the PMT orientation. Measurements performed on the PMTs S/N 1057 and 1073 with the Photonis base and spectroscopy data acquisition.*
5. CONCLUSIONS

The measurements performed at Orsay with Photonis development group engineers clearly show that the type of base (Photonis or PAO) has nearly no influence on the results obtained from the single photoelectron response.

A part of the systematic difference in gain measurements obtained with Photonis and the PAO test benches came from different methods of calibrations: Photonis relies on a reference XP2020 PMT, whereas the PAO collaboration rely on calibrated LeCroy 2249 charge ADCs. Photonis performed a careful calibration of their measurement chain found that the gain of the reference XP2020 PMT was 20 % higher than previously estimated.

Concerning the influence of the Earth's magnetic field, the results of the measurements performed at UCLA [6] were confirmed.

6. REFERENCES


