Available online at www.sciencedirect.com

ScienceDirect

Nuclear Instruments and Methods in Physics Research A 567 (2006) 27–30

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

www.elsevier.com/locate/nima

Characterisation of improved photocathode in large hemispherical photomultiplier

D. Dornic[a,*], B. Genolini[a], C. Moussant[b], T. Nguyen Trung[a], J. Pouthas[a]

[a]*Institut de Physique Nucléaire d'Orsay, IN2P3-CNRS, Université Paris-Sud 91406 Orsay Cedex, France*
[b]*Photonis, Avenue Roger Roncier, 19106 Brive La Gaillarde, France*

Available online 12 June 2006

Abstract

This document presents a study on an improved bi-alkali photocathode used on large hemispherical photomultiplier tubes (PMTs). The process has been applied on a sample of the Photonis XP1805, the 9 in. PMT used in the Pierre Auger Observatory experiment and compared to a sample of the standard production ones. Measurements of the photocathode sensitivity, the spectral response and the relative detection efficiency were performed on the samples of standard and improved PMTs to characterise this new photocathode process. Current measurements of the photocathode sensitivity show a mean improvement of around 19% at 400 nm. Comparative pulse measurements of the relative detection efficiency confirmed this result. Additional measurements were performed in order to determine if the new process could have secondary effects. The noise rate decay time after exposure lasts to a few tenths of hours. The dark count rate is more sensitive to temperature but remains lower than 10 kHz at 15 °C. The afterpulse probability is increased but remains very low with the type of tube used in this study.

PACS: 85.60.Ha

Keywords: Photomultiplier; Phototube; Bi-alkali photocathode; Quantum efficiency; Detection efficiency

1. Introduction

The large photomultiplier tubes (PMTs) are currently used in astroparticle and neutrino experiments where they have to detect low levels of light. Therefore, the photocathode quantum efficiency (QE) is one of the key parameter for the choice of a PMT. So far, it has been limited to around 25% at maximum (around 400 nm) for large PMTs.

Photonis has developed a new semi-transparent bi-alkali process to increase the QE. It was applied on the XP1805 [1], the 9 in. diameter PMT chosen by the Pierre Auger Observatory [2,3]. Around 5000 pieces have been ordered for this experiment.

To test this new process, key parameters were measured on a batch of standard and improved PMTs: the photocathode sensitivity, the spectral response, the relative detection efficiency (product of the quantum and collection efficiency) and the photocathode uniformity.

Others measurements were performed to determine possible secondary effects of the new process: the stabilization time, the dark count rate and its dependence to temperature, and the main afterpulse characteristics.

2. Photocathode characterisation

The first parameter measured is the photocathode luminous sensitivity, i.e. the photocathode current at a given light intensity. The light source is a tungsten filament lamp at a colour temperature of 2856 K calibrated for luminous intensity [4]. Measurements were performed in the blue domain with a Corning Blue filter (Corning CS 5–58, polished to half-stock thickness) [4] and in the white region without any filter.

A set of results on 785 standard PMTs has been taken from the Pierre Auger Observatory production at Photonis in 2004. The mean cathode sensitivity is 9.32 μA/l mF in the

*Corresponding author. Tel.: +33 1 69 15 75 51.
E-mail address: dornic@ipno.in2p3.fr (D. Dornic).

0168-9002/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2006.05.053

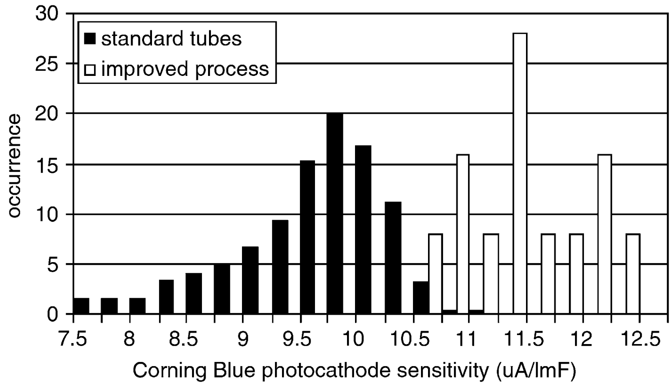

Fig. 1. Photocathode Corning blue sensitivity (in black, standard and in white, new process PMTs).

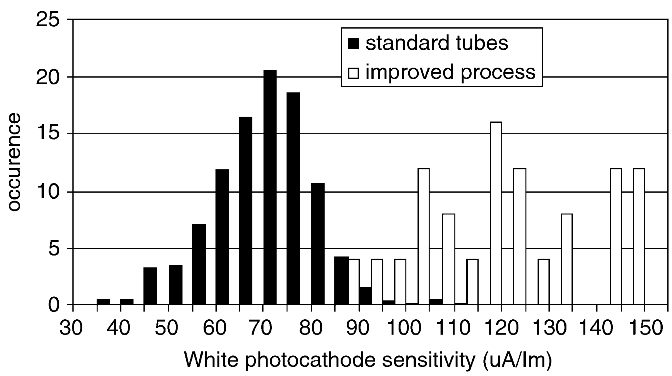

Fig. 2. Photocathode white sensitivity (in black, standard and in white, new process PMTs).

blue region (Fig. 1) and 68.37 μA/l m in the white domain (Fig. 2).

A batch of 25 enhanced PMTs was measured. The mean cathode sensitivity is around 11.35 μA/l mF in the blue region (Fig. 1) and around 118.00 μA/l m in the white domain (Fig. 2). The increases due to the photocathode improvement are around 19% and around 42% in the blue and white region, respectively.

Spectral response measurements were performed on 4 standard and 3 improved PMTs to explain this increase in sensitivity. The PMTs were taken at the nominal characteristics (9.6 μA/lmF for the standard PMTs and 11.8 μA/lmF for the new process PMTs in the blue region). The results (Fig. 3) show a general increase of the QE over the whole wavelength range. At 400 nm, the QE reaches 32% (average on the 3 measured PMTs). At 650 nm, in the red domain, the QE is increased by around 75%. This extension of the spectral response in the red region explains most of the difference between the blue and white measurements.

The homogeneity of the photocathode is checked on a batch of new process PMTs. The photocathode sensitivity is measured by scanning of the photocathode with a narrow beam of light normal to the surface. It has been

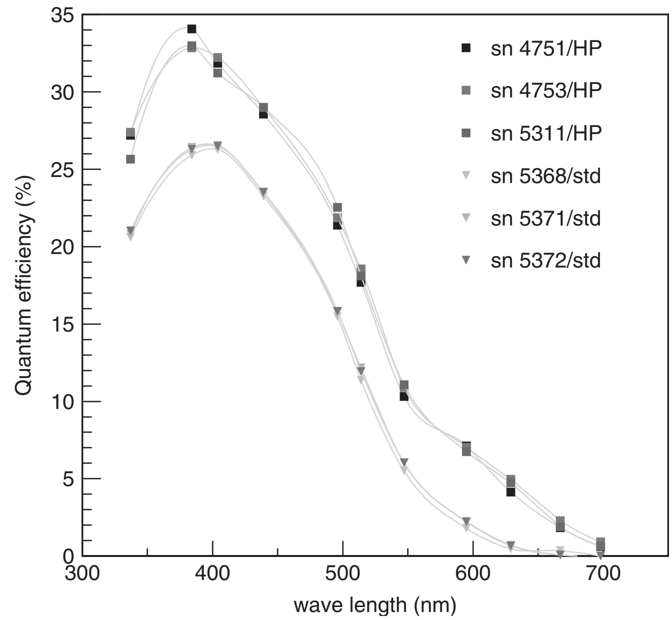

Fig. 3. Spectral response for 3 standard PMTs (std, triangular marker) and 3 enhanced PMTs (HP, square marker).

found that this new process conserves the same good photocathode uniformity.

To confirm the results, comparative measurements on the relative detection efficiency were performed with a dedicated test bench. The light source comes from the interaction of alpha particles (^{241}Am source) in a small fast plastic scintillator (Bicron BC 422). This light source is very stable, homogeneous and noiseless. The trigger is given by a fast PMT (Photonis XP2020) directly coupled to the scintillator through a light guide in order to collect large number of photoelectrons (around 80). This ensures a very good timing reference and allows a good PMT noise rejection. The measured PMT is placed vertically at a large distance of 2.5 m from a light source in order to obtain a quasi-parallel light and an injected light level of one photoelectron (yield of few percents of non-zero pulses). All the measurements are performed at a given gain (3×10^6). The measurements are performed with a 100 mm diameter diaphragm placed in front of the PMT at the photocathode centre. The PMT is oriented relatively to Earth's magnetic field according to Auger recommendations [5]. The PMT pulse charge is measured with a CAMAC LeCroy 2249A ADC.

The ratios of the number of pulses detected by all PMTs under test and by the trigger PMT are measured in order to compare the detection efficiency between the two PMT families. This calculation is performed on the charge histograms obtained by triggering the data acquisition with the trigger PMT at a threshold of 50 photoelectrons. The background is measured in the same set-up, with the light source hidden. The background charge histogram is subtracted from the measured PMT one. Then, the ratio between the counts in the tested and trigger PMT is