Investigating the time properties of an improved 3" Hamamatsu photomultiplier for the KM3NeT Neutrino Telescope

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Abstract. The Hamamatsu R14374-02 3-inch photomultiplier tube is an improved version of the previous R12199-02 model. It will be used for the completion of the KM3NeT neutrino telescope. Five hundred photomultipliers have been characterized for dark count rate, timing spread, and spurious pulses with a dedicated dark box apparatus.The results are compared with the model R12199 used in the first phase of construction of KM3NeT.

1 Introduction

KM3NeT is a research infrastructure composed of a network of deep-sea neutrino detectors located in the Mediterranean Sea [1–3]. The large number of involved photodetectors for th KM3NeT project raised the need for a detailed characterization of the PMTs. This is essential for the performance of the entire experiment. Both detectors share a common technology i.e a modular structure of multiple detection units that compose the matrix-like structure of both detectors. Each DU can be seen as a string of digital optical modules (DOMs) attached at a fixed distance between each other via a string kept almost vertical by a buoy. The DOM [7] is a 17-inch pressure resistant glass sphere with 31 3-inch PMTs inside. The time requirements for the KM3NeT PMTs were formerly reported in [5] and we report them again here in Table 1 for ease of reading. The Hamamatsu R12199-02 PMT was the photodetector chosen for the first phase of the KM3NeT detector. It is a 3-inch-diameter hemispherical PMT with 10 dynodes and standard bialkali metal photocatode. In a second phase Hamamatsu released an improved version of the tube named R14374. The scope of this paper is to present the measurements performed on the latter PMT and to compare some of them with those reported in [5],in order to determine compliance with the technical requirements of the experiment and to present the technical improvements.

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Photocathode diameter	> 72 mm
Nominal Voltage for gain 3×10^6	900÷1300 V
Peak-to-Valley ratio	> 2.0
Transit Time Spread (FWHM)	< 5 ns
Dark count rate (0.3 s.p.e. threshold, at 20 °C)	2000 c.p.s. max
Prepulses between −60 ns and −10 ns	1.5% max
Delayed pulses between 15 ns and 60 ns	5.5% max
Late afterpulses between 100 ns and 10 μs	15% max

Table 1: Requirements for the main characteristics of PMTs to be used in the KM3NeT detectors (s.p.e. is for single photoelectrons; c.p.s. is for counts per second).

Figure 1: The dark box apparatus and two trays of R14374 PMTs ready for test

The dedicated studies on critical parameters done for the former PMT model were replicated with the new model..

2 Characterising the time properties of the Hamamatsu R14374 vs R12199 photomultipliers

The time characteristics of single photo electron creation and detection as well as the intrinsic dark noise of a PMT are of fundamental importance for photon counting application. The measurements were conducted with a set of 500 PMTs equipped with the digital base used for the commissioning of the KM3NeT experiment.

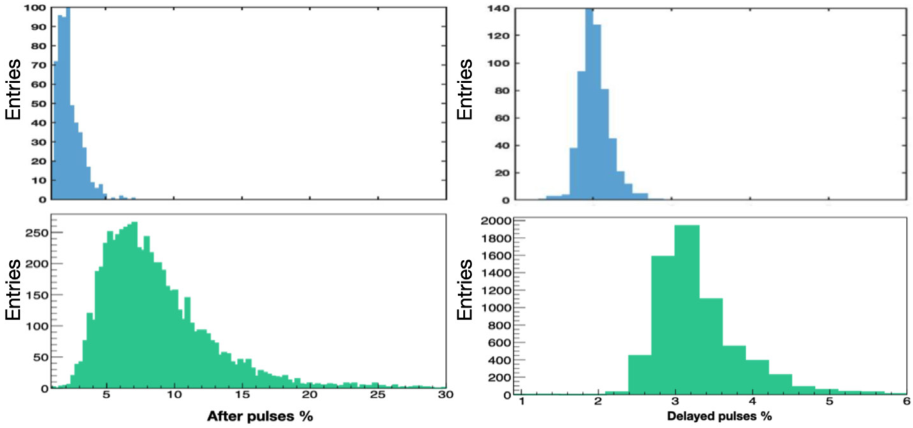

Figure 2: Measurements of the rate of delayed pulses and after pulses for a set of 500 PMTs R14374 (top row) and, for comparison, for the R12199 model as reported in[5].

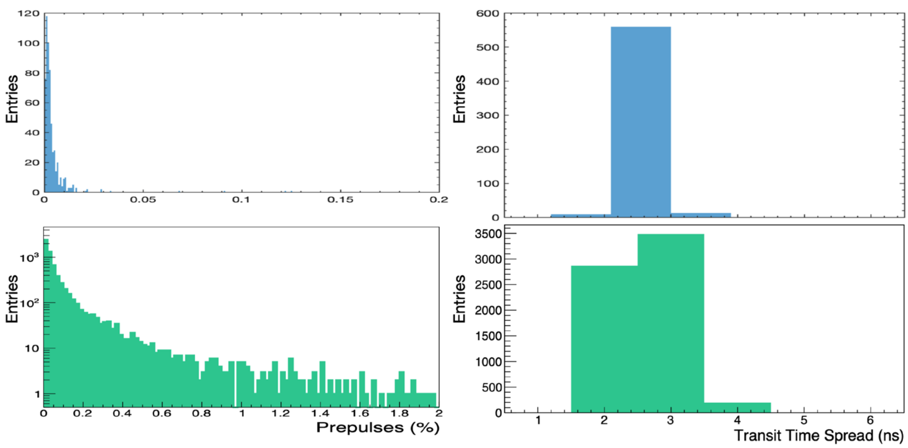

Figure 3: Measurements of the rate of pre pulses and transit time spread for a set of 500 PMTs R14374 (top row) and, for comparison, for the R12199 model as reported in[5].

The measurements were performed with the Dark Box described in [8]. The dark box replicates in a laboratory environment the structure of a downsized detector string composed of two digital optical modules. The dark box can host 62 PMT tubes per measurement and provides in a semi automatic way a report for every PMT in terms of dark noise counts, tuned high voltage for a specific gain, spurious pulses response properties: prepulses, afterpulses and delayed pulses. As a source, a continuously tunable repetition rate diode-pumped picosecond laser is used. The output of the laser is fed into a one to 62 optical fiber splitter with an intensity splitting accuracy below one percent. The time duration of a measurement is roughly one day. The results of the analysis produced by the dark-box apparatus are gathered and summarized statistically. This specific apparatus was previously used by [5] to perform measurements on a set of 5000 measurements of the previous R12199 model by Hamamatsu. The comparison in the analysis of delayed and afterpulses is reported in Figure 2. Figure 3 shows the results and the comparison of the old measurements on the bottom row compared to the new ones on top row for transit time spread and prepulses.

3 Conclusions

The measurements performed on a set of 500 PMTs and the comparison with the results reported in [5] reveal a large difference between the two models. The distributions of both afterpulses and delayed pulses are almost non overlapping in favour of the new model and also the dispersion of the distributions is narrower. The prepulses are reduced by more than one order on magnitude and the transit time spread is smaller and less scattered. Further research and a deeper characterization of the PMT are ongoing, but the results obtained already shows that the new model of 3” inch PMT that is already in use will improve the overall characteristics of the performance of the KM3NeT detectors.

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