Investigation of Hamamatsu H8500 MAPMT Noise Properties

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Abstract

Investigation of typical dark count properties of Hamamatsu H8500 Multianode PMT. This study is based on the test tickets provided by Hamamatsu with each H8500 MAPMT. It is mainly concerned with correlations of noise and gain and the average dark count rate and how it compares to MC models used for the CLAS12 RICH.

1 Introduction

Hamamatsu provides test tickets detailing several quantities and a relative gain map with each H8500 MAPMT. The relative gain maps were found to typically agree within 10% with the gain maps extracted from laser scanner data in Frascati and Glasgow. The other quantities reported on the test tickets are shown in Tab. 1.

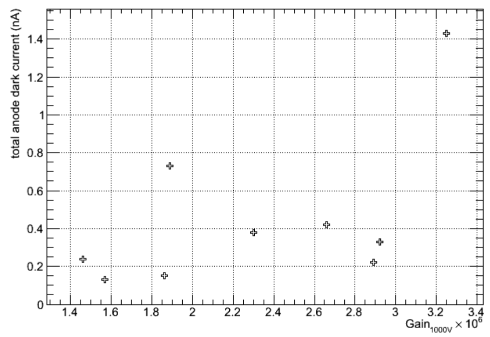
Quantity	Units
Cathode Luminous Sensitivity	μA/lm
Anode Luminous Sensitivity	A/lm
Anode Dark Current	nA
Cathode Blue Sensitivity Index	
Gain	

Table 1: Test ticket quantities.

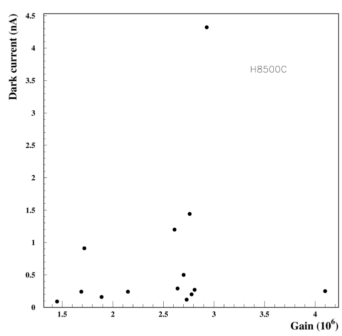
The blue sensitivity should be irrelevant to the application in a RICH detector [1]. The luminous sensitivities deal with the photocathode properties which are not part of this note. The dark current and the corresponding dark counts are not measured within the laser teststand measurement protocol and thus, so far, no limits have been established for the CLAS12 RICH. This note concerns itself with average noise properties as reported on the test tickets. This study is based on the data of 9 H8500 MAPMTs bought for a scintillating fibre project in Glasgow in 2010 and 28 H8500 MAPMTs bought for the CLAS12 RICH prototype by LNF Frascati. All 9 H8500 from Glasgow are standard bialkali, normal glass window types. Of the 28 H8500 MAPMTs from LNF Frascati 14 are standard bialkali, normal glass window types while the other 14 H8500 MAPMTs have a UV entrance window.

2 Dark Current & Dark Counts

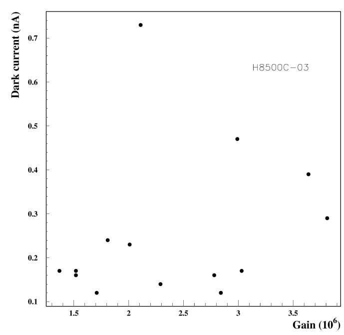
The dark current measured by Hamamatsu is for the entire MAPMT, i.e. for single channel this numbers needs to be divided by 64. First of all, a correlation of dark current and PMT gain is investigated. However, no clear correlation could be established (see Fig. 1). Nevertheless, it is obvious that a few PMTs exhibit excessive dark current values which need to be rejected in a RICH application.



(a)



(b)



(c)

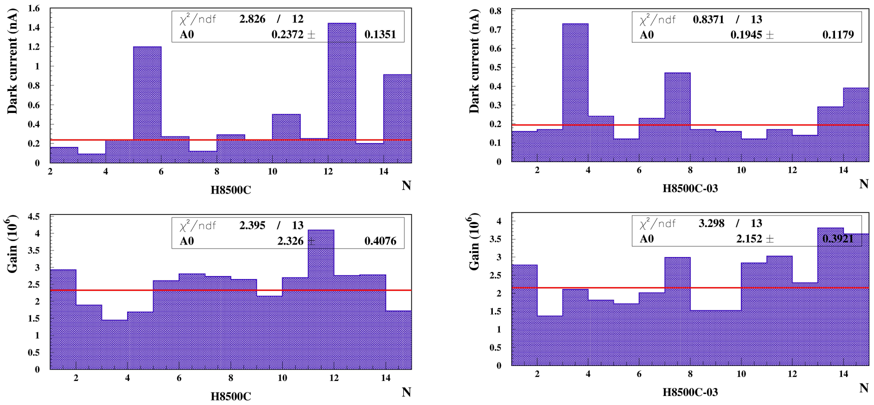
Figure 1: Dark current as a function of MAPMT gain for (a) 9 H8500C from Glasgow, (b) 14 H8500C from Frascati, and (c) 14 H8500C-03 with UV entrance window from Frascati.

The average gain and dark current of the 28 MAPMTs from Frascati, see Fig. 2, shows no significant difference between standard and UV entrance window types.

The average dark count rate R_{dc} can be computed from the dark current, assuming that essentially all dark counts are single photoelectron signals, by

$$R_{dc} = \frac{I_{dc} dt}{G \times e}, \tag{1}$$

with I_{dc} being the dark current, the time interval dt which is set to 1 s to get R_{dc} in counts per second, G is the MAPMT gain, and e is the elementary charge. The average dark count rate for the 9 H8500C from Glasgow is shown



(a) (b)

Figure 2: Average gain and dark current for (a) 14 H8500C and (b) 14 H8500C-03 with UV window from Frascati.

in Fig. 3. Again, the two MAPMTs with excessive dark currents stand out while the remaining MAPMTs have a dark count rate between 500–1000 cps. It should be stressed once more that this number corresponds to the entire MAPMT with 64 channels, so individual channel rates would be much smaller.

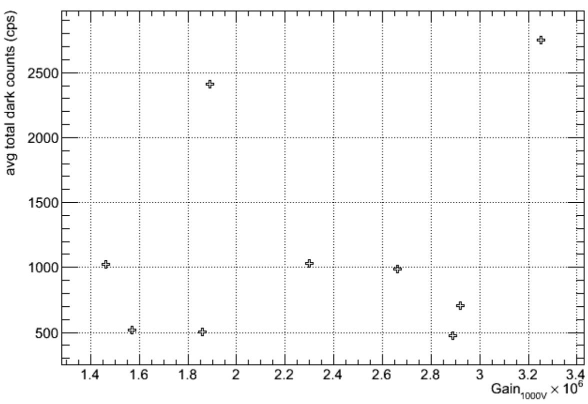
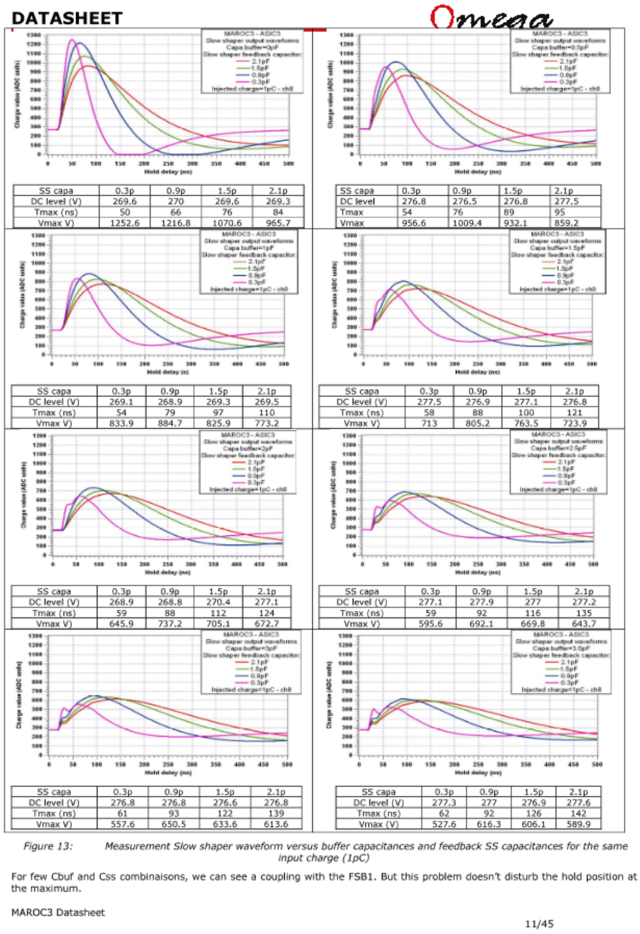


Figure 3: Average dark count rate of the 9 H8500C from Glasgow as a function of MAPMT gain.

3 Dark Count Modelling in MC

During the comparison of the 2012 CERN data and MC of the CLAS12 RICH prototype with 28 H8500 MAPMTs a dark count probability ρ_{dc} of 3×10^{-4} was introduced, corresponding to 0.54 dark counts per event, to achieve agreement between MC and data. How does this number agree with the estimated dark count rates above? Assuming 1 kcps dark count rate a time window of approx. 300 ns is necessary to explain the value of ρ_{dc}. This time window might be even as small as 15 ns depending on how to add the dark counts of several MAPMTs. Looking at the slow shaper signal properties of the MAROC3 chip [2] (see Fig. 4) this time window seems not unreasonable. Although the noise signal is then not sampled at its peak the amplitude is still above threshold and would be registered as a hit.



DATASHEET

Omega

SS capa	0.3p	0.9p	1.5p	2.1p
DC level (V)	269.6	270	269.6	269.3
Tmax (ns)	50	66	76	84
Vmax V)	1252.6	1216.8	1070.6	965.7

SS capa	0.3p	0.9p	1.5p	2.1p
DC level	276.8	276.5	276.8	277.5
Tmax	54	76	89	95
Vmax	956.6	1009.4	932.1	859.2

SS capa	0.3p	0.9p	1.5p	2.1p
DC level (V)	269.1	268.9	269.3	269.5
Tmax (ns)	54	79	97	110
Vmax V)	833.9	884.7	825.9	773.2

SS capa	0.3p	0.9p	1.5p	2.1p
DC level (V)	277.5	276.9	277.1	276.8
Tmax (ns)	58	88	100	121
Vmax V)	713	805.2	763.5	723.9

SS capa	0.3p	0.9p	1.5p	2.1p
DC level (V)	268.9	268.8	270.4	277.1
Tmax (ns)	59	88	112	124
Vmax V)	645.9	737.2	705.1	672.7

SS capa	0.3p	0.9p	1.5p	2.1p
DC level (V)	277.1	277.9	277	277.2
Tmax (ns)	59	92	116	135
Vmax V)	595.6	692.1	669.8	643.7

SS capa	0.3p	0.9p	1.5p	2.1p
DC level (V)	276.8	276.8	276.6	276.8
Tmax (ns)	61	93	122	139
Vmax V)	557.6	650.5	633.6	613.6

SS capa	0.3p	0.9p	1.5p	2.1p
DC level (V)	277.3	277	276.9	277.6
Tmax (ns)	62	92	126	142
Vmax (V)	527.6	616.3	606.1	589.9

Figure 13: Measurement Slow shaper waveform versus buffer capacitances and feedback SS capacitances for the same input charge (1pC)

For few Cbuf and Css combinaisons, we can see a coupling with the FSB1. But this problem doesn't disturb the hold position at the maximum.

MAROC3 Datasheet

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Figure 4: MAROC3 slow shaper signal shape [2].

4 Conclusions

Analysing the test ticket data available for 37 H8500 MAPMTs it was found that the dark current has no strong correlation with gain. However, there are MAPMTs with excessive dark currents so that a limit should be placed on this quantity when tendering a large order for the CLAS12 RICH. The average dark current was found to be $0.21 \pm 0.09\,nA$ (cf. Fig. 5). Moreover, the estimated

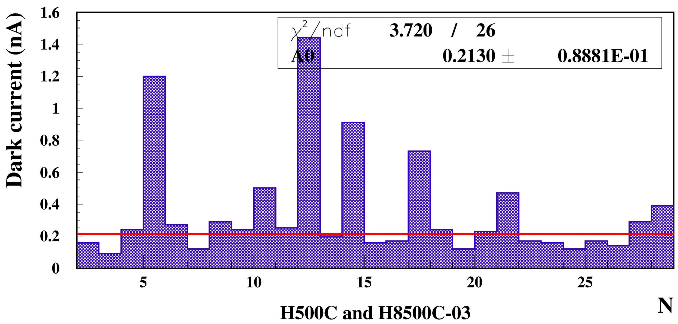

Figure 5: Average dark current of the 28 H8500 MAPMTs from Frascati.

average dark count rates offer an explanation for the dark count probability needed in the MC description of the prototype detector. Since there was no timing information of the hits available during the previous test experiments to separate dark counts from the Cherenkov signal it seems a good idea to consider adding timing capability to the frontend electronics of the CLAS12 RICH. Such information was used in the BaBar DIRC to reduce beam-induced background by setting a 8 ns-coincidence window.

A Test Ticket Data

Serial No	Gain	Cathode Lum. Sens.	Anode Lum. Sens.	Dark Current	Cath. Blue Sens. Index
CA3906	1.86	60.7	113.0	0.15	9.8
CA4121	2.89	66.1	191.0	0.22	10.5
CA4126	2.66	51.5	137.0	0.42	8.97
CA4129	3.25	58.4	190.0	1.43	8.89
CA4149	1.89	59.8	113.0	0.73	8.93
CA4287	1.57	67.4	106.0	0.13	10.5
CA4295	1.46	66.1	96.5	0.24	10.3
CA4302	2.30	63.9	147.0	0.38	10.2
CA4307	2.92	59.9	175.0	0.33	10.1

References

[1] T. Hakamata *et al.*, *Photomultiplier Tubes -Third Edition (Edition 3a)-*, Hamamatsu K.K., August 2007

[2] MAROC3 Datasheet, Draft October 2010