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LATEST PROGRESS WITH MICROCHANNEL PLATE PMTS*

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INTRODUCTION

Microchannel-plate (MCP) PMTs are the sensors chosen for the two DIRC detectors for hadron identification of the PANDA experiment, a barrel DIRC (BD) surrounding the interaction point cylindrically in ~50 cm radial distance from the beam axis and an endcap disc DIRC (EDD) covering the forward hemisphere [1, 2]. Within less than a decade this type of PMTs underwent many improvements and proved to be the best photon sensor option for both DIRCs. In 2019 the bidding process for the MCP-PMTs of the BD was initiated and is still ongoing. Therefore, the PMT mass production has not started yet and our work focused on further tests and improvements of new tubes. Besides other important activities the main tasks were the measurement of the quantum efficiency (QE) and the collection efficiency (CE) of various new MCP-PMTs, the suppression of distorting oscillations in the anode signals of Photonis tubes, and the ongoing lifetime measurements of several types of MCP-PMTs.

COLLECTION EFFICIENCY

The detective quantum efficiency (DQE = CE*QE) of a PMT is the probability that a photon incident at the photo cathode (PC) produces a measurable signal at the anode. While the QE can easily be measured with the appropriate tools and is typical between 20 and 30% in its peak, the CE is much more difficult to determine. To compare the CE of different MCP-PMTs we developed a measurement procedure to get access to this important quantity.

In principle the CE can be determined by comparing the number of photo electrons (p.e.) being collected at the anode after the amplification stage to that being emitted at the PC. By applying Poissonian statistics and at low photon rate (15 kHz) and intensity (~1 p.e.) to avoid saturation effects the former can be simply deduced from the pulse height spectrum measured at the anode. The measurement of the p.e.s emitted at the PC is more complicated and can only be done by directly measuring the PC current. At 15 kHz photon rate and an intensity of ~1 p.e./light pulse this, however, is extremely small (fA) why higher photon rates (50 MHz) are used. The correlation between the high photon rate necessary to measure the PC current and the low photon rate needed to determine the number of amplified p.e.s is monitored by a reference photo diode.

In Table 1 some CEs measured with the above described procedure are compared. The uncertainties are estimated to be in the order of 10%. 63% CE seems to be a reasonable value for the standard Photonis MCP-PMT 9001394, as is the 95% CE for the new tube 9002108. With ≳30% QE these new high collection efficiency (HiCE) tubes [3] may reach an excellent DQE of up to 30%. This type of MCP-PMTs is preferred for the BD. One can also see in the table that a film in front of the MCPs, as is applied in the Hamamatsu JS0022, reduces the CE significantly.

SIGNAL OSCILLATIONS

If several photons arrive at the PC within a narrow time window the anode signals of the MCP-PMT may start oscillating. This was first observed in Photonis Planacon tubes [4]. We see the same effect for both Photonis and Hamamatsu MCP-PMTs. The amplitude and frequency of these oscillations, visible in a ringing after the main pulse, depends on the signal height and the number of fired pixels. It gets worse by increasing these two parameters. The main problem arising from this effect is that it may cause fake hits in an experiment and has to be minimized.

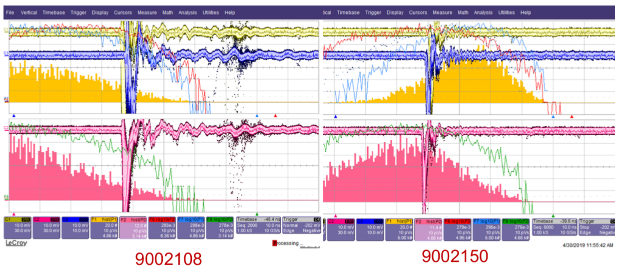

Figure 1: Comparison of the oscillations in the Photonis 9002108 (standard backplane) and 9002150 (modified backplane) MCP-PMTs. The full PC was homogeneously illuminated with ~7 photons per pixel and laser pulse. At this intensity the 9002150 shows significantly lower oscillations.

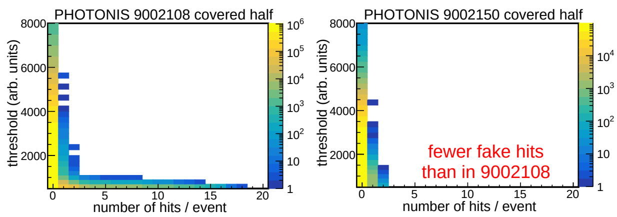

Figure 2: Comparison of crosstalk hits between the Photonis 9002108 and 9002150, which has a modified backplane to reduce the oscillations. Shown are the fake hits measured at the covered half of the sensor for different thresholds.

To reduce these oscillations Photonis has recently developed a new backplane which was first applied in the MCP-PMT 9002150. In the plots in Fig. 1 the oscillations caused by a fully illuminated photo cathode for an MCP-PMT with

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Table 1: Collection efficiency for several MCP-PMTs.

Manufacturer	Photonis	Photonis	Hamamatu	Photek	Hamamatsu
S/N	9001394	9002108	JS0022	A1171005	KT0001
Comments	non-ALD	ALD, HiCE	ALD		ALD
Film	no	no	before MCP	no	between MCPs
CE	(63 ± 6)%	(95 ± 9)%	(39 ± 4)%	(83 ± 8)%	(76 ± 8)%

old (9002108) and new backplane (9002150) are compared. It is clearly visible that the ringing is significantly dampened and has a higher frequency for the improved 9002150.

The amount of possible fake hits was investigated with a GSI TRB/PADIWA DAQ system. In this measurement half of the MCP-PMT was covered while the open side was homogeneously illuminated with ~1 photon/pixel. Although hits are only expected at the open PC half we observe fake hits also on the covered half which are due to crosstalk or the above described oscillations. Only the three most left and right anode rows of the 8x8 pixel PMT were read out to eliminate hits in only partly covered pixels. At low threshold, up to 18 hit pixels per laser pulse were observed in the 9002108 tube with the old backplane, as seen in Fig. 2 (left). In the 9002150 with the modified backplane only a maximum of 2 pixels per laser pulse shows fake hits. A side effect of the new backplane is that the pulse heights at 10^6 gain are ~25% lower mainly due to a broadening of the pulses. This is a acceptable result for the MCP-PMTs of the BD.

LIFETIME

During an anticipated PANDA running time of ≳10 years at full luminosity the DIRC MCP-PMTs will collect more than 5 C/cm^2 integrated anode charge (IAC). To ensure that the PCs will not be seriously damaged before this charge is accumulated, countermeasures as coating the MCP pores with an atomic layer deposition (ALD) technique were applied to reduce the aging and improve the lifetime significantly. Since several years we are studying the lifetime of different types of test MCP-PMTs by permanently illuminating selected tubes with a photon rate comparable to that expected in PANDA and by measuring the QE of the sensors in more or less regular time intervals [5]. In Fig. 3 the current lifetime results are compared for several Hamamatsu and Photonis ALD-coated tubes. The data for non-ALD PMTs are also shown. Most of the measured ALD-coated MCP-PMTs well excel the PANDA requirement of 5 C/cm^2 IAC, the best tube from PHOTONIS (9001393) with 2 ALD-layers even reaching >25 C/cm^2 without any sign of PC damage. This is a factor of >100 better than the IAC reached with standard non-ALD MCP-PMTs. Unfortunately, a viable MCP-PMT from Photek Ltd for lifetime measurements has not been delivered yet. This would be urgently needed to qualify their tubes for a possible use in PANDA.

CONCLUSIONS

Our F&E work for GSI shows that the performance parameters of the recent MCP-PMTs from Photonis and Hamamatsu are well suited for an application in both PANDA

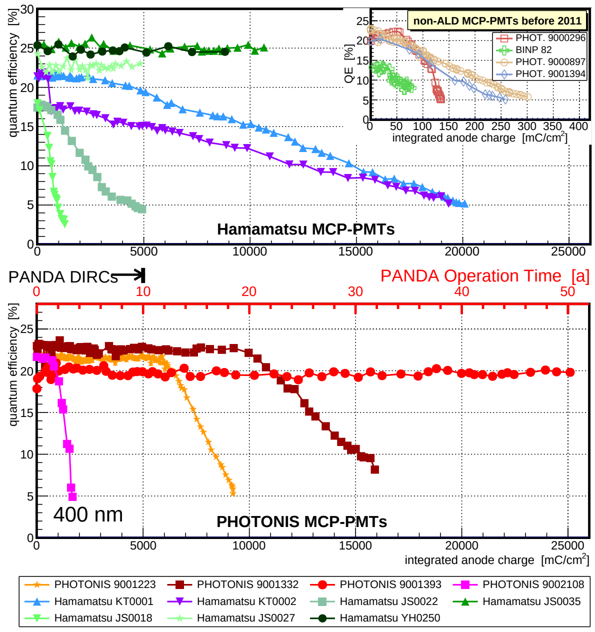

Figure 3: Current status of the lifetime measurements of ALD-coated MCP-PMTs (compared to non-ALD tubes).

DIRCs. Some parameters even excel the requirements. Unfortunately, only a "crippled" tube from Photek Ltd could be tested. In general, the recent progress in enhancing the DQE to almost 30% and the tube's lifetimes of usually above 10 C/cm^2 is impressive. Also the reduction of annoying oscillation phenomena in the latest Photonis PMT is encouraging. The mass production of MCP-PMT for the BD is about to be started, which will then be quality-checked in Erlangen.

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