Photon Detection Systems for Modern Cherenkov Detectors

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Open Problems in Hadron Physics

Nuclear Physics Detector group
Core requirement: Kaon Identification

PANDA DIRCs

CLAS 12 RICH
Cherenkov Counters

Nuclear Physics Detector group

PANDA
Disc
DIRC

CLAS 12 RICH
Fast position sensitive photon detectors

Delay [ns]
-0.4  -0.2  0  0.2  0.4

Counts
0  1000  2000

Time Resolution (Q > -0.08 pC && Q < -0.02 pC) = 49 ps

Time Resolution (Q > -0.50 pC && Q < -0.25 pC) = 41 ps

Burle 25 µm
Burle 10 µm
BINP #73 6 µm
The Hpnmo is more compact than the Hrnhhd has a wider spectral sensitivity and an improved single photon response. The Hrnhh device however has a more efficient active area than the Hpnmo packaged and less dead area surrounding the pixel matrix. This is an important factor when the imaging functionality of the RICH detector is considered. Table 1 displays the parameter differences between the MAPMT's.

### Table 1: Parameter specifications of the Hrnhh and Hpnmo MAPMT's

<table>
<thead>
<tr>
<th>Parameter</th>
<th>H8500 MAPMT</th>
<th>H7546 MAPMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixel Size [mm]</td>
<td>2.5 x 2.5</td>
<td>2.5 x 2.5</td>
</tr>
<tr>
<td>Pixel Pitch at Centre [mm]</td>
<td>2.5 x 2.5</td>
<td>2.5 x 2.5</td>
</tr>
<tr>
<td>Effective Active Area [mm]</td>
<td>30 x 30</td>
<td>30 x 30</td>
</tr>
<tr>
<td>Dimensional Outline W x H x D [mm]</td>
<td>50 x 50</td>
<td>50 x 50</td>
</tr>
<tr>
<td>Window Material</td>
<td>Borosilicate Glass</td>
<td>UV Glass</td>
</tr>
<tr>
<td>Photocathode Material</td>
<td>Bialkali</td>
<td>Superbialkali</td>
</tr>
<tr>
<td>Spectral Response [nm]</td>
<td>400 - 1000</td>
<td>400 - 1000</td>
</tr>
<tr>
<td>Peak Wavelength [nm]</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>Quantum Efficiency [V]</td>
<td>657</td>
<td>657</td>
</tr>
</tbody>
</table>

Considering such differences in the design specifications of both MAPMT's, the tests performed aimed to compare and investigate the applicability of each MAPMT to the CLASik RICH detector.
Precision Pixel Studies

Nuclear Physics Detector group
3.2 Efficiency Tests

The light level settings for single photoelectron detection with the Hwutv MAPMT had to be altered from those concluded to be optimum for the Hxupp MAPMT. The OD of the ND filters had to be increased due to the superior quantum efficiency of the Hwutv cathode material (see Table 1).

The finalised settings for single photoelectron detection with the Hwutv MAPMT were selected as a cumulative OD of 7x for the ND filters and a supply voltage of 1500 V to the MAPMT.

Figure 8a shows the spectrum obtained for pixel s of the Hwutv MAPMT with the light centred upon it and the aforementioned light level settings. Upon inspection of Figure 8a it appears possible that the spectrum is for more than one photoelectron since the peak to valley ratio is rather high.

Figure 8b shows the global efficiency map of the Hwutv MAPMT in response to a point mm step size laser scan of its entire surface and with the light level settings used to obtain the spectrum shown in Figure 8a. The sr channels readout are indicated by the 5 rows of red efficiency responses in Figure 8b.

The remaining sr channels were not connected at all to the QDC modules. It is unclear why the response from pixel s' is so low at around 0.5 to 0.7. This is possibly due to a faulty or low efficiency electronic.

The result in Figure 8b shows typical pixel efficiencies lying above 0.5 with
Silicon PhotoMultiplier

SPMArray4 (SensL)

SPMMini (SensL)
Digital Filters

5.3 Waveform Sampling and the Application of Digital Filters to SiPM Signals

The expressions for $\text{MWD}$ and $\text{MA}$ actions of the filter are given in eqns (s) and (t) to the $\text{V}$ baseline. The $\text{MA}$ was equivalent to passing the $\text{MWD}$ signal through a lowpass filter designed to compensate for the convolution of the SiPM signal with noise, hence restoring waveforms.

The signal was sampled at a rate of $\text{r}_q \text{GSPS}$ the oscilloscope resolution was set to $\text{r}_q \text{ppps}$ and the device was not self-triggered. The laser intensity was controlled by attenuation filters.

The pixel's signal waveform was sampled by the SPMArray signals and analysing them. It was found that a large pedestal noise factor resulted in a function.

A pulse height spectrum was produced from the overlay of the filter outputs (see figs 9 and 10). This is the result of applying a moving window deconvolution $\text{hMWDi}$ to the data. It then performed a moving average $\text{hMAi}$ on the baseline noise and dark count signals.

As an initial cross-check to the origin of the low photopeak resolution, the function parameters for the SiPM fit were varied. It was found that a large pedestal noise factor resulted in a function.

Figure 7:

In eqns (w) $M$ is the sample number effective in restoring the signal baseline level and signal pileup $e$.

$M_{WD}(i) = (x(i) - x(i - M)) + \frac{1}{\tau} \sum_{j=i-M}^{i-1} x(j)$
MCP PMTs

Nuclear Physics Detector group  with F. Uhlig, A. Lehmann, A. Britting, W. Eyrich, S. Reinicke Universität Erlangen-Nürnberg

**Photonis XP85112**

\[ \sigma = 33 \text{ ps} \]

![Graph showing photon counting and time resolution for Photonis XP85112](image)

**XP85112 (using WavePro 7300A)**

![Graph showing the relation between magnetic field and time resolution](image)
MCP PMTs

Nuclear Physics Detector group with F. Uhlig, A. Lehmann, A. Britting, W. Eyrich, S. Reinicke Universität Erlangen-Nürnberg

![Graphs showing gain vs. B-field for different voltages](image-url)
MCP PMTs

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Photonis XP85112 #9000897 MCP Count Rates

Uniformity 1:1.2

Photonis XP85112 #9000897 MCP Gain

Uniformity 1:3.2
Offline Studies
with ATLAS Forward Physics Project (Quartic test beam @CERN SPS)
Offline Studies

with ATLAS Forward Physics Project (Quartic test beam @CERN SPS)
Rate Stability of various MCP-PMTs

photons / cm² (at gain = 10⁶)

Barrel | Endcap

<table>
<thead>
<tr>
<th>Type of MCP-PMT</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>✭ BINP #73 (6 µm)</td>
<td></td>
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<tr>
<td>▲ Photonis XP85011 (25 µm)</td>
<td></td>
</tr>
<tr>
<td>▼ Photonis XP85013 (25 µm)</td>
<td></td>
</tr>
<tr>
<td>□ Photonis XP85012 (25 µm)</td>
<td></td>
</tr>
<tr>
<td>★ Photonis XP85112 (10 µm)</td>
<td></td>
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<tr>
<td>● Hamamatsu R10754-00-L4 (10 µm)</td>
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</tbody>
</table>

normalised gain

10⁻¹

10⁻² 10² 10³ 10⁴ 10⁵ 10⁶ 10⁷ 10⁸

current / area [pA/cm²]

10⁻¹
• Modern detectors in hadron physics require high rate particle identification detectors

• Cherenkov detectors are the method of choice of PANDA at FAIR and CLAS 12 at Jefferson Laboratory

• These detector system require position sensitive, very fast photon detection system

• We studied position dependent responses of MAPMTs, SiPM Arrays and MCP-PMTs

• MCP-PMTs look promising, but have serious issues at high rates and with cathode lifetime

• New generation of PMTs needed?