Study of Timing and Efficiency Properties of Multi-Anode Photomultipliers


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Motivation

Using PMTs in Cherenkov detector:
DIRC particle identification subsystem in BaBar detector
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\( \approx 11000 \) EMI 9125FLB17 PMTs,
- 1.7 ns timing resolution, 30 mm diameter
Measuring PMT position and photon arrival time
Timing mainly used for signal vs. background separation
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Event display without (top) and with (bottom) time cut
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Performance:

<table>
<thead>
<tr>
<th></th>
<th>Current limit</th>
<th>Could be improved by</th>
</tr>
</thead>
<tbody>
<tr>
<td>size of bar</td>
<td>≈ 4.1 mrad</td>
<td>focusing optics</td>
</tr>
<tr>
<td>size of PMT pixel</td>
<td>≈ 5.5 mrad</td>
<td>smaller pixel size</td>
</tr>
<tr>
<td>chromaticity</td>
<td>≈ 5.4 mrad</td>
<td>better time resolution</td>
</tr>
<tr>
<td>$n = n(\lambda)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total single photon</td>
<td>≈ 9.6 mrad</td>
<td></td>
</tr>
<tr>
<td>total per track</td>
<td>≈ 2.4 mrad</td>
<td></td>
</tr>
</tbody>
</table>

Event display without(top) and with(bottom) time cut
**Motivation**

**Burle MCP 85011**

- **Multiplier**: 25 µm pore MCP
- **Effective area**: 51 mm × 51 mm
- **Packing density**: 67%
- **Spectral response**: 165 nm ... 660 nm
- **Gain**: $0.5 \times 10^6$
- **Uniformity**: 1: 1.25
- **Transit time spread**: 50 ps ... 60 ps

(All data from company data sheets)

**Hamamatsu PMT H-8500**

- **12 stage metal channel dynode**: 49 mm × 49 mm
- **Effective area**: 49 mm × 49 mm
- **Spectral response**: 300 nm ... 650 nm
- **Gain**: $1 \times 10^6$
- **Uniformity**: 1:3
- **Transit time spread**: 400 ps

(All data from company data sheets)
Motion Controlled Setup

**Light source**
- Pilas pico-second laser
- $\lambda = 635 \text{ nm} / 430 \text{ nm}$
- $\sigma_{\text{pulse}} < 35 \text{ ps} / 60 \text{ ps}$
- Operated in single photon mode

**Motion Controller:**
- Repeatability $< 7 \, \mu \text{m}$
**Motion Controlled Setup**

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**PMT**
- Hamamatsu H-8500/Burle MCP-85011

**Laser Intensity Monitoring**
- Two standard PMTs used for calibration (Photonis XP2262B, EMI 9125FLB17)
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Amplifier
- Elantec, EL2075C, $40\times$, 2 GHz bandwidth
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Readout
- Single threshold discrimination
- CAMAC based readout
- 500 ps per count TDC (LeCroy 2277) connected to Linux PC
Scans: 100 $\mu$m $\times$ 1 mm
Efficiency relative to Photonis XP2262B PMT.
Burle more uniform, but Hamamatsu higher peak efficiency.
2D Efficiency Comparison – Blue (430 nm)

**Burle**

**Hamamatsu**

**Scans:** 500 μm × 1 mm

Efficiency relative to Photonis XP2262B PMT.

For Cherenkov detectors the more relevant wavelength region.

Burle more uniform; similar efficiencies.
Timing

Pilas @ one point on PMT

Burle: narrow main components smaller MCP-to-cathode gap version: smaller tail.
Timing

To measure timing properties:
need faster electronics!

Using Burle MCP with reduced MCP-to-cathode gap: 750 µm (std: 6 mm)
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Time-to-amplitude converter
Sample-and-hold
VME based 12-bit ADC
⇒≈ 25 ps resolution
Using Burle MCP with reduced MCP-to-cathode gap: 750 µm (std: 6 mm)
Hit Time distribution fitted with double Gaussian + flat background.
Plotting sigma of narrow Gaussian.
Very uniform, very good timing ($\approx 70$ ps)
Outside of pad, low number of hits $\Rightarrow$ larger uncertainty.
Prototype and Test Beam

- Focusing optics eliminates effect of bar size
- Smaller pixels improve the $\theta_c$ resolution
- Smaller expansion region reduces amount of background hits
- $< 100$ ps timing enables better signal vs. background separation
- $< 100$ ps timing enables partial correction of chromatic effect
Prototype and Test Beam

How to correct for chromatic effect?

- Precision timing (< 100 ps) for propagation time
- Use dispersion effect to constrain $\lambda$

Calculation:

3.66 m long DIRC fused silica bar: $\approx$ 1 ns difference over 300 nm to 650 nm range
Prototype and Test Beam

- Prototype has been build
- Single fused silica bar
- Spherical mirror for focusing
- Mineral oil as matching liquid (KamLAND)
- 4 Burle MCPs
  2 Hamamatsu PMTs

Test beam (≈ pions @ 10 GeV) at SLAC in Nov 04, Dec 04, Feb 05

Goals:
- validate design
- measure and correct chromatic effect