New 50-cm diameter Photodetectors

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R&D of 50cm PDs

Goal
Development of a 50cm high performance photodetector which can be used in a water Cherenkov detector for a long time

R&D Flow

- As a first step, we developed 20cm HPD and 50cm high-QE Super-K PMT
- Photodetector test in a 200-ton water tank to confirm the usability of new photodetectors is ongoing
- We report the R&D status of 50cm high-QE HPDs and B&L PMTs

Super-K PMT

50cm

QE~22%
well-known

High-QE SK PMT

QE~30%

50cm high-QE box&line PMT

50cm high-QE HPD

High-QE R3800

Normal-QE R3800

20cm Hybrid Photo-Detector (HPD)

Test

200-ton tank

Okajima’s talk
Box&line PMT

Super-K PMT (Venetian Blind dynode)
- Various drift path
- Might miss dynode

Box&line PMT (Box&line dynode)
- Unique drift path
- Large acceptance

Advantage of B&L PMT
- Unique drift path → Better timing and 1PE resolution
- Large acceptance → Better collection efficiency
50cm B&L PMT prototype

This prototype for HK is an improved version of 50cm B&L PMT used in KamLAND.

- Apply the high-QE photocathode
- Change the photocathode shape
- Add a focusing electrode
- Expand the first dynode
- Change the bulb shape
- High-QE
- Large effective area
- High Collection efficiency
- Survive under 90m water level

Effective area: 43cm

50cm KamLAND B&L PMT
• High-QE photocathode

• B&L PMT: 32% at 400nm (SK PMT: 22%)

• QE and CE are uniform over 46cm area of the photocathode
Hybrid Photo-Detector

Advantage

- Simple structure → Low cost production possibility
- Short drift length → Fast timing response
- High first step gain → High single photoelectron resolution

Challenge

- Difficulty in handling 8kV
- No experience to use in a water Cherenkov detector
• To keep high-CE (~95%), the size of AD should be 20mm diameter
• Since 20mm AD has a large capacitance, we have been developing a low noise preamplifier
  • We have 2 types of preamp. and can see 1PE peak in both type
  • But not enough S/N and response speed
• For this test, we measured the prototype of HPD with 5mm AD (same AD size as 20cm HPD)
Waveforms

- HPD and B&L PMT are faster than SK PMT

<table>
<thead>
<tr>
<th></th>
<th>HPD (20cm HPD w/o amp.)</th>
<th>B&amp;L PMT</th>
<th>SK PMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise time (ns)</td>
<td>7.4 (1.7)</td>
<td>6.7</td>
<td>10.6</td>
</tr>
<tr>
<td>Fall time (ns)</td>
<td>11.5 (2.7)</td>
<td>15.2</td>
<td>13.1</td>
</tr>
<tr>
<td>Pulse width in FWHM (ns)</td>
<td>17.1</td>
<td>13.0</td>
<td>18.5</td>
</tr>
</tbody>
</table>

8” HPD w/o preamp.
HV: 8kV, AD bias: 260V
Rise time: 1.7ns
Fall time: 2.7ns

HPD itself has very fast response.
The shape of gain curve of B&L PMT is almost same as that of SK PMT.

Both HPD and B&L PMT has the gain of $10^7$. 

$HV = 8kV$
Dark rate of high-QE B&L PMT is same level as that of high-QE SK PMT
Timing & Charge

1PE timing distribution

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</thead>
<tbody>
<tr>
<td>Timing resolution σ (ns)</td>
<td>1.4 (1.1)</td>
<td>1.1</td>
<td>2.1</td>
</tr>
<tr>
<td>FWHM (ns)</td>
<td>3.4 (3.3)</td>
<td>4.1</td>
<td>7.3</td>
</tr>
<tr>
<td>1PE resolution σ/µ</td>
<td>16% (12%)</td>
<td>26%</td>
<td>53%</td>
</tr>
<tr>
<td>Peak to Valley ratio</td>
<td>4.0 (5.2)</td>
<td>4.5</td>
<td>2.2</td>
</tr>
</tbody>
</table>

HPD calculated timing resolution FWHM: 0.75ns (20mmφ AD w/o preamp)

- Both box&line PMT and HPD show better timing and charge resolution than Super-K PMT
Multi-PE distribution

50cm high-QE HPD

50cm high-QE Box&line PMT
High-QE SK PMT

Multi-PE peaks are clearly seen in both HPD and B&L PMT
- B&L PMT prototype is near final version

- In this August, we install 3 high-QE B&L PMTs into the tank. We will start the test of these PMTs in the tank from this September.

- Development of the preamplifier for 50cm HPDs will finish until this year.
Summary

- We have been developing new 50cm PDs for Hyper-K
- Basic performance of 50cm high-QE HPD and box&line PMT prototype was measured
  - Confirmed better performance than Super-K PMT
  - Details (noise, efficiency, etc) will be also measured soon
- Development of preamplifier for 20mm AD HPD is ongoing
- We will select the best photodetector in 2016