The PMT testing system for the Daya Bay Experiment

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OUTLINE

• MOTIVATION
• INTRODUCTION TO THE PMT TESTING SYSTEM
• EXAMPLES OF SOME TESTING RESULTS
The anti neutrino detector modules

\[ \bar{\nu}_e + p \rightarrow e^+ + n \]
\[ n + p \rightarrow d + \gamma(2.2\,\text{MeV}) \]
\[ n + Gd \rightarrow Gd^* + \gamma(8\,\text{MeV}) \]

Total of 8 detector modules, 4 modules for the far site, 2 modules for each near site. 192 8” PMTs/module, 1536 PMTs totally. Hamamatsu R5912
The muon veto system

Hamamatsu PMTs & PMTs from MACRO*
289 near, 384 far.

*A Monopole, Astrophysics and Cosmic Ray Observatory

A MACRO 8” PMT
PMT requirements

- **TO DETECT SINGLE OPTICAL PHOTON:**
  good quantum efficiency and a spectral response matching the emission spectrum of the liquid scintillator.

- **TO HAVE GOOD CHARGE RESPONSE:**
  good peak-to-valley ratio.

- **ENERGY RELATED TO THE NUMBER OF OPTICAL PHOTONS:**
  excellent linearity over a broad range

- **TO MINIMIZE THE NOISE:**
  low dark current, pre-pulse, after-pulse

- Since the PMTs will be installed once, and not easily accessible later, to insures that the PMTs satisfy the requirements, a comprehensive PMT testing process is necessary
The System Overview

DAQ – data acquisition system.
Slow Control — system that controls different hardware components.
Analysis – analysis of data.
Local DB – local DB to keep records of different tests.

Collaborators: UCLA, LBNL, DGUT
Two major steps: Burn-in and Main Test

• Burn in to stabilize the gain and detect early abnormal behaviors
  72 Hours burn in
  48 PMT tubes per batch
  High Voltages and Currents monitored by the control PC
  LED light fed into PMTs and signals monitored by oscilloscope

• Main Test (measurements of the parameters of PMTs)
  16 PMT tubes per batch (15 + 1 reference)
  12 hours high voltage adaptation with dark rate and gain monitored by the control PC
  Then, all the measurements
The Test Stand Layout

CAEN SY1527 HV supply unit → PMT Box

Signal splitter and amplifier → Signal

LED

Pulse

BNC 575

CAMAC Crate & Electronic Boards

Local Database

Slow Control
Implementation
CAMAC/NIM
CAEN SY1527
LabVIEW
ROOT
Result examples of Hamamatsu PMTs.

After 720 minutes (12 hours), the dark rate and the gain are stable. The PMTs are ready to be tested.

A typical Single Photo Electron spectrum at Gain $10^7$

Typical energy resolution for SPE is about 30%, and the P/V ratio is above 2.5
The non-linearity for all PMTs tested is smaller than 5%, for signals up to 500 P.E. level.
Gain, Dark Rate vs HV

At $10^7$ gain, the dark rate is $1\sim2$ KHz.

At $3\times10^7$ gain, the dark rate is smaller than 10 KHz, most are $3\sim5$ KHz.

Graph

**Fit Results**

<table>
<thead>
<tr>
<th>Ch #1</th>
<th>Tube SD0070</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV0</td>
<td>1516.1</td>
</tr>
<tr>
<td>Constant</td>
<td>1663.62</td>
</tr>
<tr>
<td>Alpha</td>
<td>6.48057</td>
</tr>
</tbody>
</table>

3 Dark Rate Thresholds (around ½ P.E level)

- 4mV
- 5mV
- 6mV
Current Status

• The PMT testing facility at DGUT is ready for normal operation. (We spent about 1 month after initial setup to debug the system, resolve issues with the noise pick-up etc.)

• So far, several Hamamatsu PMTs have been tested and they seem to pass the test easily.

• There are 300 PMTs from Hamamatsu just delivered to DGUT, which are expected to be tested in next two months or so.
<table>
<thead>
<tr>
<th>Measurement</th>
<th>Parameter</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain vs High Voltage</td>
<td>High voltage (V0) for gain 10^7</td>
<td>Maximum Gain must be no less than 3x10^7 at a HV of no more than 2KV</td>
</tr>
<tr>
<td>SPE at Gain 10^7</td>
<td>FWHM</td>
<td>Not an acceptance criteria</td>
</tr>
<tr>
<td>SPE at Gain 10^7</td>
<td>Peak to Valley ratio</td>
<td>&gt;2.5</td>
</tr>
<tr>
<td>Linearity at Gain 10^7</td>
<td>linearity</td>
<td>&lt;2% at 40mA, &lt;5% at 60mA</td>
</tr>
<tr>
<td>Dark Rate vs High Voltage</td>
<td>Dark Rate</td>
<td>&lt; 10kHz at ¼ PHE threshold</td>
</tr>
<tr>
<td>Pre pulsing</td>
<td>Fraction of pre pulses</td>
<td>&lt;5%</td>
</tr>
<tr>
<td>Rise/Fall Time</td>
<td>10%-90% of pulse height</td>
<td>Rise&lt;5ns, Fall&lt;10ns</td>
</tr>
<tr>
<td>After pulsing</td>
<td>Fraction of after pulses</td>
<td>&lt;5%</td>
</tr>
<tr>
<td>Gain, Dark Rate in 12 hours</td>
<td>Stability of Gain, and Dark Rate</td>
<td>Case by case</td>
</tr>
</tbody>
</table>