Characterization of the Hamamatsu R11265 multi-anode photomultiplier tube with single photon signals

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The LHCb RICH upgrade

The LHCb RICH upgrade is driven by the need to increase the luminosity of the Large Hadron Collider (LHC) at CERN. Two RICH detectors provide particle identification through the measurement of the Cherenkov angle of photons produced in the RICH radiator.

The Cherenkov photons are currently detected by hybrid photodetectors (HPDs) coupled to a readout chip integrated in the vacuum envelope of the tube. The readout speed is limited to 1 MHz by the readout chip.

The upgrade planned for the next years aims to increase the luminosity by a factor of ten. To cope with the higher occupancy, the electronics must withstand a full 40 MHz readout speed, to match the bunch crossing rate of the LHC.

In the case of the RICH subdetectors, the baseline for the upgrade is to replace the HPDs with multi-anode photomultiplier tubes.

The Hamamatsu R11265

The table summarizes the main characteristics of the R11265.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral Response Range</td>
<td>185-650 nm</td>
</tr>
<tr>
<td>Window Material / Thickness</td>
<td>UV glass / 0.8 mm</td>
</tr>
<tr>
<td>Geometrical Dimensions</td>
<td>26.2 x 26.2 mm</td>
</tr>
<tr>
<td>Photocathode Minimum Effective Area</td>
<td>23 x 23 mm\textsuperscript{2} (480)</td>
</tr>
<tr>
<td>Number of Pixels / Dimensions</td>
<td>64 x 64 x 2 x 2 mm\textsuperscript{3}</td>
</tr>
<tr>
<td>Number of Dynodes</td>
<td>12</td>
</tr>
<tr>
<td>Maximum Supply Voltage</td>
<td>1000 V</td>
</tr>
<tr>
<td>Gain</td>
<td>1 x 10\textsuperscript{5} at 1000V</td>
</tr>
<tr>
<td>Anode Dark Current (Each anode)</td>
<td>0.4 nA</td>
</tr>
<tr>
<td>Rise / Transit Time</td>
<td>0.6/5.1 ns</td>
</tr>
<tr>
<td>Uniformity Between Each Anodes</td>
<td>1:3</td>
</tr>
</tbody>
</table>

Gain and uniformity

The single photoelectron gain of the device was measured with the standard HV bias ratio from Hamamatsu. The mean signal for pixel 10 is about 1.9 MeV at 850 V.

The single photon response of the PMT was tested at different temperatures in a Votachi-4018 environmental chamber, from -30\textdegree to 50\textdegree. The measurements show a gain decrease with increasing temperature. The gain is roughly proportional to T\textsuperscript{-1/2} (where T is the absolute temperature).

The measurements were completed with a measurement of the variation of dark count rate, which is expected to increase at higher temperatures.

Gain vs temperature

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The LHCb RICH detector

The LHCb RICH detector is shown in red. The HPDs with embedded readout chip currently employed in LHCb are also shown.

Ma-PMTs for the LHCb RICH

For the LHCb RICH upgrade, we characterized three Ma-PMTs from Hamamatsu: the H9500, the R7600 and now the R11265.

As indicated by Hamamatsu, the R7600 is more suitable than the H9500 for single photon counting applications such as RICH detectors. In particular, in the H9500 we found a significant amount of crosstalk at the single photon level, which is negligible in the R7600.

The R7600 was extensively characterized and found compliant with the requirements of the LHCb RICH, but the invasive border of the device would call for the use of a tube in front of the device to increase its active area.

The R11265, recently made available by Hamamatsu, has a larger active area and overcomes this limitation. Its characteristics are currently being measured, but are expected to be very similar to those of the R7600.

Gain uniformity

The gain uniformity of the device was measured at the single photoelectron level, and found compliant with the Hamamatsu specifications, which are given for continuous single photoelectron level, and found compliant with the requirements of the RICH subdetectors.

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