Photosensors for the T2K 280m Near Detector

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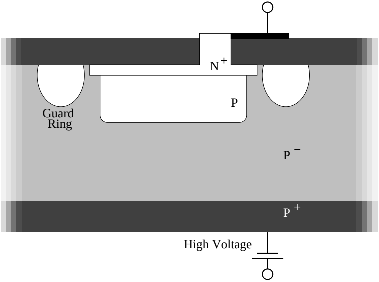
Device Operation

- GAMPD devices are constructed from an array of APD cells or pixels.
- The device is biased such that each cell is held above the Geiger breakdown voltage.
- Geiger Mode amplification occurs between the N^+ and P regions *below*

- Charge given by.

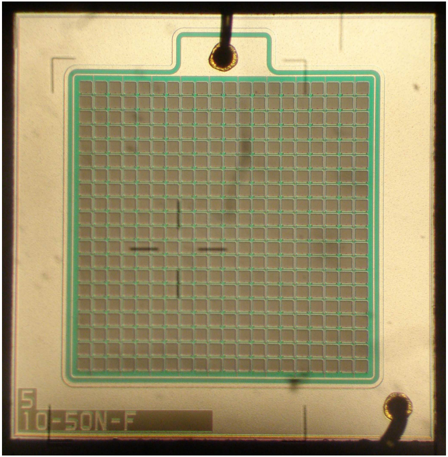
$$Q_{Pixel} = C_{Pixel}\left(V_{bias} - V_{breakdown}\right)$$
$$Signal = \sum Q_{Pixel}$$

- Guard ring used to reduce neighbouring pixel activation (crosstalk).



Topology for GAMPD type Device

20x20 Microcell array

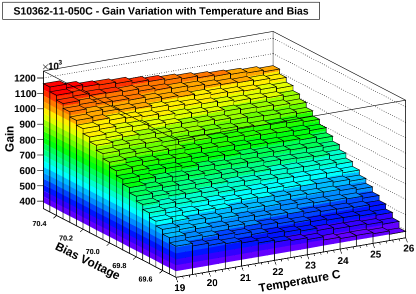


Hamamatsu S10362-11-050

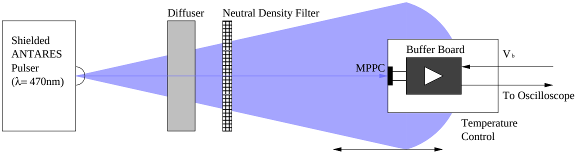
- 400 Pixels.
- ∼70V Operating voltage.
- 10^5–10^6 Gain.
- 1mm^2 Active area.
- 250–500kHz Dark count rate.
- 50mV/°C Breakdown voltage temperature relationship.
- Photon detection efficiency similar to vacuum PMT

Parameters Under Study

- Gain as a function of bias and temperature
- Geiger Breakdown voltage as a function of temperature
- Pixel capacitance
- Dark count rate
- Afterpulse and cross talk probability
- Photo detection efficiency as a function of bias and temperature

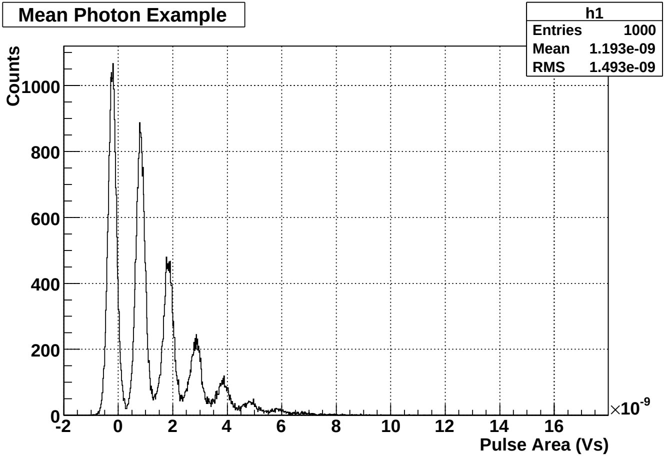


Photon Detection Efficiency



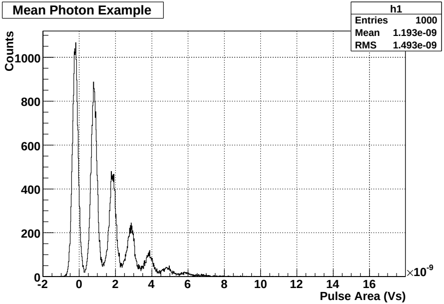
- ANTARES LED pulser used to give a uniform flash of photons
- Calibrated filters used to reduce the number of photons at the MPPC to a desired level.
- Pulse area is integrated for each LED flash and a spectrum generated
- Mean number of photoelectrons extracted

Single Photoelectron Structure



Mean Pixels Fired

Raw Spectrum



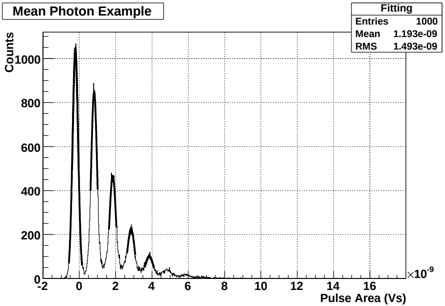
Mean Pixels Fired

- Fit photoelectron peaks
- Rebin spectrum in photoelectrons
- Put spectrum into integer bins and apply Poisson fit

- Extract arithmetic mean
- Extract mean from Poisson fit
- Extract mean from Poisson zero probability

Mean Pixels Fired

Step 1



Mean Pixels Fired

- **Fit photoelectron peaks**
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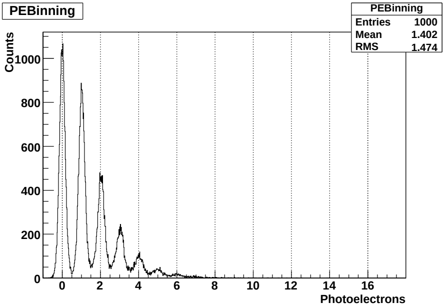
Mean Pixels Fired

Step 2



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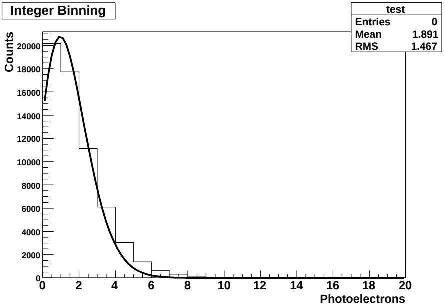
Mean Pixels Fired

Step 3



Mean Pixels Fired

- Fit photoelectron peaks
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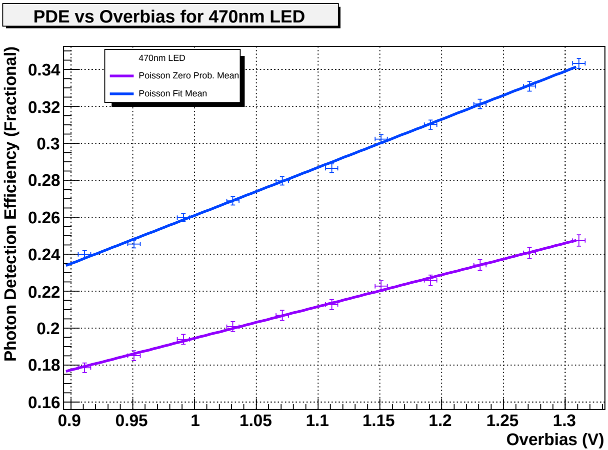
3 Methods to Extract Mean Pixels Fired

1. Arithmetic Mean $= 1.891$
2. Poisson Fit Mean $= 1.48938 \pm 0.00007$
3. Poisson Zero $=$

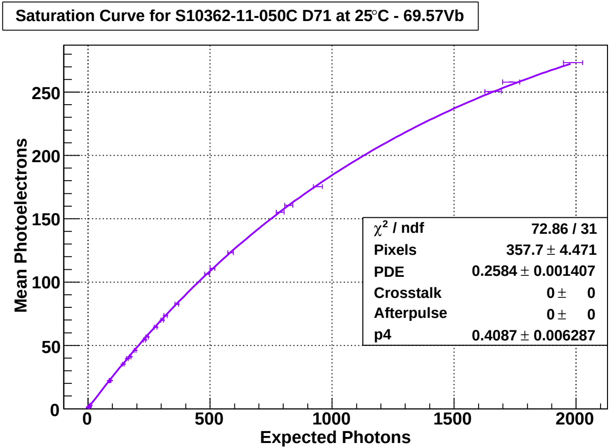
$$
\begin{aligned}
P(k,\lambda) &= \frac{\lambda^k e^{-\lambda}}{k!} \\
P(0,\lambda) &= \frac{\lambda^0 e^{-\lambda}}{0!} &= e^{-\lambda} \\
\lambda &= -ln(P(0,\lambda)) &= -ln\left(\frac{\#_{\text{bin0}}}{\#_{\text{Total}}}\right) \\
\lambda &= 1.100 \pm 0.008
\end{aligned}
$$

- Cross talk and Afterpulsing causes excesses in higher bin numbers.
- – A Poisson fit is dependant on the number of counts in each bin. Thus extract the mean photoelectrons fired + cross talk
- Poisson Zero method does not weight the counts depending on number of photoelectrons.

PDE as a function of Bias



Linearity Curve Sample



$$N_{fired} = N_{total}\left[1 - exp\left(\frac{-N_{photon} \times PDE}{N_{total}}\right)\right]$$

Conclusion and Goal

- PDE extracted for low intensity LED pulser, shown to increase with over-bias.
  - Expected as it becomes easier to initiate Geiger discharge with higher electric fields
- None linearity observed when increasing number of photons incident on the MPPC.
  - Expected due to limited number of pixels
  - Multiple photons incident on one pixel will only produce a one pixel fire.

GOAL Take measurement of PDE for final T2K MPPC devices using Y11 fibre and ECal connector
  - Final tests of experimental setup underway, preliminary PDE measurements have been made