Effect of anode and cathode luminous sensitivity on photomultiplier tube readings for use in the CHANDLER neutrino detector

VIRGINIA TECH

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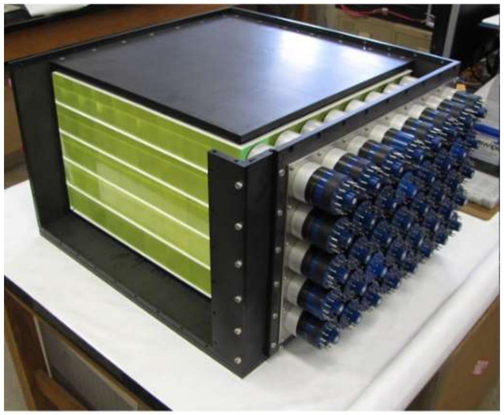
Background

The MiniCHANDLER neutrino detector is designed to monitor nuclear reactors by capturing the neutrinos produced by fission in the core using inverse beta decay (IBD) [1]. The photons produced in the scintillators from this decay are reflected through the rows of cubes to the photomultiplier tubes (PMTs), which then convert them into an amplified electric signal. We can analyze this signal to understand the original properties of the neutrino and, by extension, the contents of the reactor core.

Since the PMTs are a crucial part of detector operation, understanding how they will behave once installed is crucial to understanding how the detector will operate. Each PMT on the detector has an associated anode luminous sensitivity (ALS) and cathode luminous sensitivity (CLS), provided by the manufacturer. These numbers were calculated using brighter light than what we see in our detector, so we wanted to see if we could still use them to predict what the readings from the PMTs would be [2]. Based on the testing procedure used to calculate ALS and CLS, we predicted that ALS would influence average pulse height and CLS would influence the root mean square (RMS) of the average pulse height.



The MiniCHANDLER neutrino detector

Methods

From preliminary testing, we were able to produce the following hypotheses:

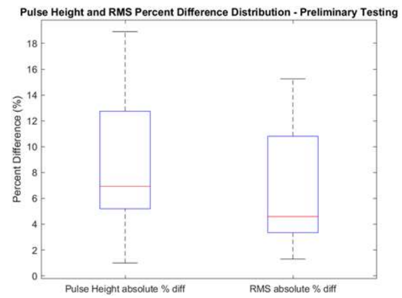
$$pulse\ height \approx control\ pulse\ height \cdot \frac{ALS}{control\ ALS}$$

$$RMS \approx \frac{pulse\ height}{CLS \cdot \frac{control\ pulse\ height}{control\ RMS\ \cdot control\ CLS}}$$

For a direct measure of CLS, we used relative RMS:

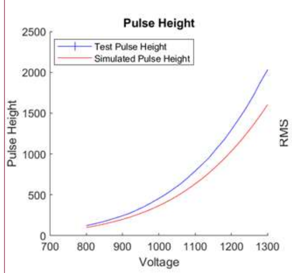
$$relative\ RMS = \frac{RMS}{pulse\ height}$$

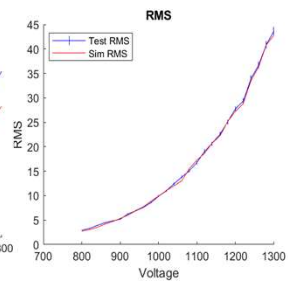
Using these formulas, we were able to use one of the four PMTs as a control and simulate the average pulse height and RMS of the other three across a voltage range of 800-1300 V. To compare the simulation and test, we calculated the percent difference between the two:



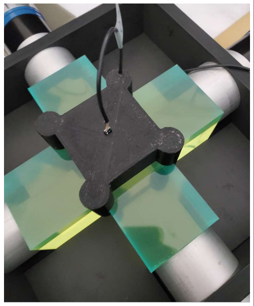
Issues that came up in preliminary testing :

- Temperature/time-dependent factors
- PMT rotational orientation
- “Burn in” period

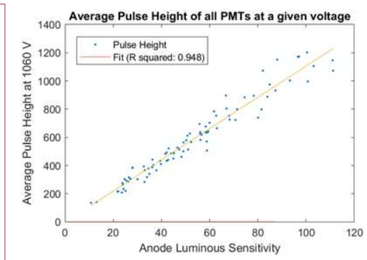


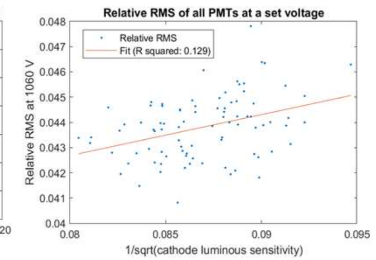


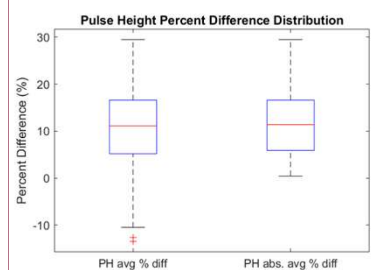
Example plots of simulation and test

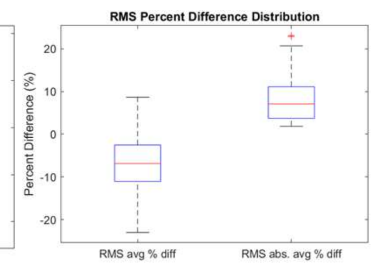


Testing setup inside the dark box









Conclusion

From the data, we can gather that ALS correlates with average pulse height and CLS loosely correlates with relative RMS. In the future, we would like to investigate additional factors that may make the simulation more accurate and testing the current PMTs again to look for variation in PMT behavior.

Acknowledgements

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References

[1] A. Haghighat *et al.*, “Observation of Reactor Antineutrinos with a Rapidly Deployable Surface-Level Detector,” *Phys. Rev. Applied*, vol. 13, no. 3, p. 034028, Mar. 2020, doi: 10.1103/PhysRevApplied.13.034028.

[2] Hamamatsu Photonics K.K., “Photomultiplier Tubes: Basics and Applications,” *Hamamatsu,* 4th ed. 2017.