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Introduction

The following is an overview of an analysis for the warm high voltage cables connecting to the external PMT flange. The analysis was performed to ensure the cables would perform at the required manner.

Short and Break Test

We first wanted to check each cable to verify the absence of any shorts or breaks in the conduction material. To do this, we connected a cable testing unit (CTU) to one end of the cable, and an LED to the other. The CTU is a battery operated device with three lights: one red light to show the battery is supplying power, another red light to show there is at least one short in the cable, and one green light to show the cable is experiencing a voltage difference. If this green light and the LED on the other end of the cable illuminate, the cable being testing is free from any breaks. We connected the CTU and the LED to each of the 40 cables, as described above, and found that all cables were free from any shorts or breaks.

High Voltage Test

After verifying the absence of any shorts or breaks, we moved on to the high voltage test to see if the PMT cables could standoff to high voltage. We connected the cables to a high voltage power supply on one end, and on the other end, we connected them to a divide by 1000 box which was connected to a multimeter. The divide by 1000 box reduces the voltage enough (by a factor of 1000, due to a 1000 ohm resistor) so that our multimeter can make a good reading of the voltage difference through the cable. After connecting a cable accordingly, we increased the voltage output of our HV power supply to 2000 volts. Ideally, when subjecting the cable to 2000 volts, the multimeter should give a reading around 2.0 volts; a reading significantly less than this would suggest problems with the cable itself, or its connectors. After conducting this high voltage test on each of our 40 warm cables, it was found that they all produced a reading of around 1.9 volts, meaning these cables can standoff to high voltage.

Agitation Test

The final test conducted involved agitating (hence, agitation test) the cables to ensure they could withstand a light amount of stress. The set up was similar to the same test performed above, though when the cable was connected, we would lightly agitate it; which included tugging and bending all parts of the cable while making sure the pulse shown on the oscilloscope did not fluctuate. It would be wise not to agitate the cable too much, as you do not want to be the source of the faulty cable. Any fluctuation of this pulse would indicate a problem with the cable being tested.

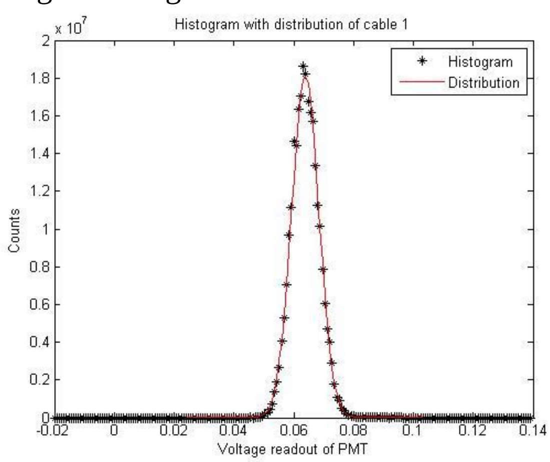
PMT Test

The high voltage test showed that these PMT cables can sustain voltage differences needed to power a PMT. Therefore, since all of the cables passed this test, we could then set up a comprehensive test to verify these cables could power a PMT without causing damage or bad data.

PMT Test Setup

To setup this test, we needed a few materials: a PMT, an LED, a pulse generator, a high voltage power supply, a low voltage power supply, an oscilloscope, and a joiner box. We found a cardboard box and installed the LED and PMT in this box using Velcro. The low voltage power supply and the pulse generator are connected to the joiner box, and the joiner box is then connected to the LED, thus creating controlled pulses of light. Also, the pulse generator is connected to the oscilloscope. The PMT is connected to the high voltage power supply, by the warm PMT cables we are testing, and it is also to the oscilloscope for data collection. The cardboard box was closed and wrapped with a black garbage bag to effectively create a 'dark-box' for optimal PMT data collection.

After setup was complete, we began the testing process for each of our 40 warm PMT cables. To do this, the low voltage output was set to 9 volts, and the pulse generator was set to have outputs of: 10 kHz, +4 volts, and a width of 20 ns. The high voltage output was adjusted to -1900 volts. The oscilloscope was set to histogram the minimum voltage reading, averaged over 1000 data points. For each cable, we took data in this manner for 30 minutes, or around 60,000 entries into each cable's histogram. Once the desired amount of data was collected, the histogram data was saved as a .csv file, and subsequently as a .dat file, for analysis. Below is an example of the histogram along with a distribution fit:



Analysis

From the histogram for each cable, a Gaussian fit was assigned to the distribution; both the mean (μ_A) and standard deviation (σ_A) were extracted from this fit. The follow are derivations from which we generated 4 plots.

$$\text{Q} = \text{Average Charge collected by PMT}$$
$$= \int I\, dt = \frac{1}{R}\int V\, dt = \frac{1}{R} * Area\ of\ Pulse$$
$$= N_{pe} * gain_{PMT} * e$$

Where N_{pe} is the number of photoelectrons interacting with the cathode, $gain_{PMT}$ is the amplification factor of the PMT, and e is the charge of the electron. Since the area of the pulse is proportional to the amplitude (A), multiplied by some proportionality constant (k), Q equals:

$$\text{Q} = \frac{k}{R}A$$

As for σ_A

$$\sigma_A = \frac{R}{k}\sigma_\mu = \frac{R}{k}\sqrt{N_{pe}} * gain_{PMT} * e$$

If you do some algebra:

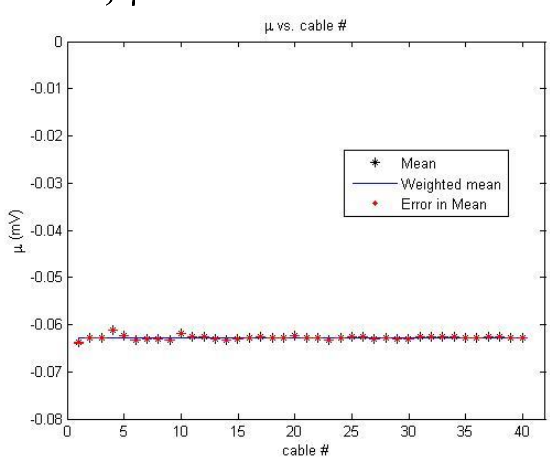
$$\left(\frac{\mu_A}{\sigma_A}\right)^2 = N_{pe}$$

$$\frac{\sigma_A^2}{\mu_A} = \frac{R * gain_{PMT} * e}{k} \propto gain_{PMT}$$

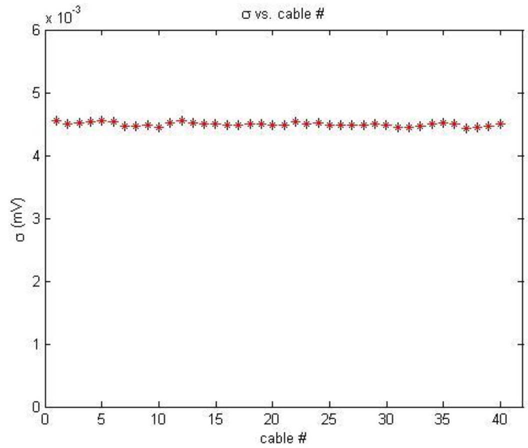
Assuming R and k remain constant, R in this case was the 50Ω termination from the PMT.

The following are the plots generated from these derivations, all of which are a function of cable number:

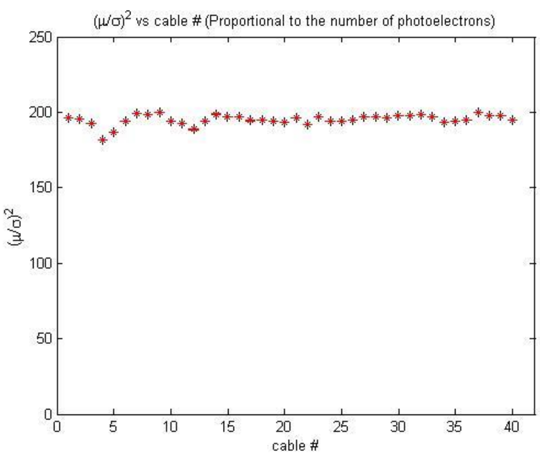
1.) μ as a function of cable number



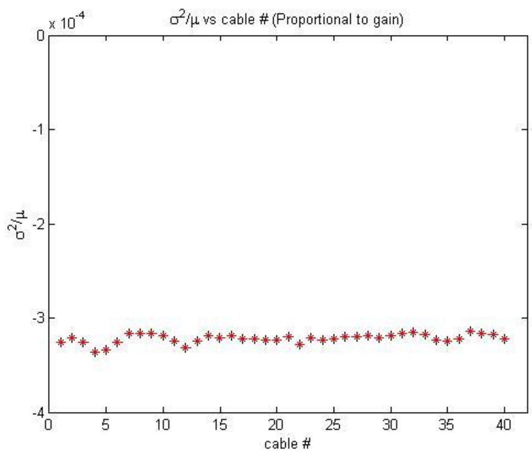
2.) σ_A as a function of cable number



3.) $(\mu_A/\sigma_A)^2$ as a function of cable number



4.) σ_A^2/μ_A as a function of cable number



Conclusion

The four tests described above were meant to determine if the 40 warm PMT cables in question are in the appropriate condition to function for MicroBooNE. Lack of the appropriate condition could result in blown PMTs or bad data collection. At the conclusion of the four tests, all 40 of the cables passed. It is noteworthy that one of cable 13's connectors is slightly bent, making it more difficult to connect this cable with others. However, this does not seem to affect the performance of the cable, as determined from the four tests. Therefore, we believe that all 40 of the warm PMT cables are in the appropriate condition to be installed. If at all curious about the data or analysis program, please refer to the .zip file which is in the same docdb location as this note.