Semester Report

1. Abstract

This report will focus on the process of assembly and the procedure of plateauing scintilator paddles. It is the authors’ desire to inform the reader of the general process of plateauing the paddles so that the reader will be able to use these (or other) scintilator paddles at their highest efficiency and performance. The results the authors obtained are contained in this report, as well as several warnings of various problems that were encountered when performing these procedures.

The purpose of the procedure known as plateauing is to determine the most efficient and accurate range in which the Photo Multiplier Tubes (PMT) and scintillator paddles work. The main idea behind plateauing is to record the count rate at various voltages and find a region where the count rate levels off; hence forming a plateau. This plateau represents the region in which the PMT/paddle combination is the most efficient.

1. Main Report
2. Design and Assembly of Scintillator Paddles

For this report, two sets of scintillators were used, QuarkNet paddles and Muon Tomography Station (MTS) paddles. The MTS is comprised of four scintillators arranged in a box-like geometric pattern. The QuarkNet paddles are simply two scintillators attached to PVC pipes for ease of movement. The QuarkNet paddles are rectangular 31 x 26 cm scintillators, and the MTS paddles are rectangular 61 x 45.5 cm scintillators and are of a higher quality than the QuarkNet scintillators. The Photo Multiplier Tubes (PMT) used are the same for both paddle types; various options for attaching the PMT to the scintillator were discussed and the chosen option was to cut a circular groove in the scintillator paddle itself. A circular “bit” was machined with which to cut the groove. This was accomplished by cutting a ring of optical sandpaper and attaching that to the circular “bit” and then used in conjunction with a drill press to cut out the groove to fit the PMT into.

While wearing gloves the scintillator is very carefully unwrapped from its shipping paper. The scintillator is then laid out on woven white cloth which is measured and pre-cut before wrapping. The cloth is wrapped around the scintillator material and black electrical tape is used to attack the cloth. A small section of the white material is cut out with a craft razor to make space for the PMT to attach to the scintillator.

*\*Note\* The tape is attached to the cloth. It is NOT attached to the scintillator material.*

The white cloth-wrapped scintillator is then used to measure out the black plastic covering for the outside layer. The plastic is attached in the same way as the cloth. Several pieces of black plastic material are used to ensure that the entire outside is covered with the black plastic and then a small section is cut out to allow the PMT to be attached directly to the scintillator. After securing the black plastic to the scintillator all the seams, corners, and other possible light entrances are covered with black electrical tape. Electrical tape is used because it does not conduct electricity, it has a strong adhesive, and it seals well.

After this process is completed, optical grease is applied to the PMT, and the PMT is attached to the scintillator using the circular groove. To make sure that it is flush and aligned, one person holds the PMT while one or more people hold the scintillator and another person uses electrical tape to affix the PMT to the scintillator. Tape is placed on the sides of the PMT and then run around the scintillator to pull the PMT tight against the scintillator. Tape is then wrapped around the PMT several times and run at a diagonal to the scintillator. This is done four times to give a good cross-bracing for the PMT. Tape is then wrapped around the PMT and the tape going to the scintillator in order to tighten and secure the PMT even more. Tape is then used to cover any areas that may allow light to enter the scintillator paddle around the PMT. A final look at the finished scintillator paddle is done to inspect it for any areas that might allow light to enter, in which case more tape is applied to cover the hole or seam.

After the scintillator paddle is completed, it is set on its respective supporting structure and aligned. Clear packing tape is then used to secure the finished scintillator paddle in place. A band of tape is wrapped twice around the assembly nearer to the PMT and cut; a different band of tape is used nearer the bottom. The same procedure is applied to the sides. The packing tape is then wrapped 3-4 times around the PMT and its supports to hold it in place. Small holes are then cut in the tape at the points where holes are present in the supports so that zip ties can be used to further secure and hold the PMT in place. This entire procedure is repeated for each scintillator paddle.

1. Procedure

The first thing that needs to be done is to make sure the QuarkNet Digital Acquisition DAQ card will communicate with the computer being used. After plugging the card into the computer – via USB for the new card- run HyperTerminal to start connecting the card. When the program is brought up, a window will pop up that asks for a name for the project; type in an easy name to find again later, and click “OK”. In the next window, “Connect To”, click on the “Connect Using” tab and select the COM port where the USB is connected, and then hit “OK”.

*\*Note\* The COM port will change depending on the computer. If the program is not responding when ran, try a different COM port.*

In the COMX properties window, where x is the COM port selected, change Bits per second to 115200, and change Flow Control to Xon / X off. All other settings should be unchanged.

If the card has been set up correctly, the program will respond when the card is plugged into that same USB port. To test whether the card did connect, type HE and hit enter. This should bring up a list of commands for the card. If it did not, unplug and replug in the USB connector. If the card still does not respond, follow the Note listed above.

After the card is set up, use the TH command to set the desired thresholds for your cards.

*\*Note\* Make sure to measure the threshold across each port after setting the TH levels on the card. The card and program will not correspond correctly, and the set TH level will unlikely be the same as what is passing through the card. Adjust the set TH levels correctly to achieve the desired settings when you measure across the card.*

For this next part, use the command “WC 00 0F” . This sets the card to read any single hits on any channel. Make sure the scintillator being measured is connected to the correct port and all gain settings on the gain box are set to 0.

After setting everything up, the first measurements taken should be to plateau the counter. To set up for this, slowly increase the gain on the voltage gain box until a reasonable starting count rate appears.

*\*Note\* The starting rate is chosen by the person taking measurements. For smaller scintillators, the rate is just above when the card first starts getting hits. For larger paddles, the starting point could be anywhere upwards of 5 counts per second.*

Record that voltage via voltmeter and use that as a starting point for the run. Clear the counter on the card and start a timer, then record the number of counts after a predetermined amount of time (three minute runs were used for the purposes of this report.).

After the run is complete, increase the voltage by a small increment (anywhere from 2-10 mV depending on how close the voltage on the gain box is getting to the desired voltage level) and repeat the process. As the data is being gathered, graph the voltage on the gain box versus the rate of counts per second.

In order to find the plateau, look for a place in the graph where the slope flattens out a little before climbing again. That flat section is the plateau. This plateau represents the voltage region where the PMT is the most efficient and accurate. Sometimes the graph will not appear to level out or pause in its ascent; if this is the case, calculate the theoretical flux rate and find the voltage at which the flux rate is equivalent to (or at least as close as possible to) the theoretical rate. The equation for the theoretical flux rate is approximately 1 count per cm2 of material per minute.

Repeat this procedure for each scintillator paddle.

After finding the plateaus for each paddle individually, find the plateau for combinations of paddles. This is first done for sets of two paddles. To do this, set the DAQ card to count coincidences between the two paddles to be plateaued, – use the command “WC 00 1F” - then set one paddle at its plateau voltage found in the single plateau graphs.

Turn the amplitude voltage on the other paddle down and then up until a reasonable count rate appears - same as before. Use this as the starting point for the run.

Increase the voltage in small increments for the counter being plateaued, just like when plateauing the individual paddles. Repeat the same procedure used for plateauing the single paddles from this point on. Then repeat the above steps varying the OTHER paddle (i.e. the one previously held constant).

Repeat this procedure for each combination of two paddles.

After plateauing the combinations of two paddles, if the plateau regions on the coincidence graphs did not reach the desired levels, as found in the equation earlier, use coincidence plateauing again with the new plateau values in order to find a more accurate plateau region – this is unlikely to be a problem with larger paddles.

*\*Note\* The plateaus for each paddle should not change by a large amount after being plateaued in combination with another paddle.*

After all the plateauing has been completed, set up the scintillator paddles for coincidence readings. For each combination of paddles, do a moderate length run – 15 minute runs for this paper – and have the card count the number of coincidences in this time period. Make sure to get the rate for each of these setups, counts per second.

For this paper, a second set of plateaus were run with a higher threshold level than the first set. The process is exactly the same after setting the correct threshold in HyperTerminal.

c. Problems

* In the beginning, the computer would not read the card. This was remedied by downloading the patch for the DAQ card being used. The correct settings for the card were found later by trial and error; however, a bit of research later discovered a site that also gave these settings. This helped prove the settings being used for the card were correct. This also brings up the problem that most computers will have a different COM setting for the card. Because of this, each computer must go through some trial before these experiments can be run.
* When setting the threshold voltages for the plateauing, it was discovered that the values set in HyperTerminal were not the actual values passing through the card. A short test was run to see how the numbers in HyperTerminal related to the actual threshold across the card. This data is presented in the Data and Calculations section of the report – Refer to Table 1 and Graph 1.
* During the single plateauing of the paddles for this report, a light leak was found in paddle 1/ 4 when it was turned on for the horizontal measurements; however, due to the position of this leak, it had no affect on the previous vertical plateau, and after covering up the leak, measurements continued as normal.

d. Data and Calculations

The first bit of data pertains to the threshold values of the program and measured threshold values of the card. As mentioned in the problems section of the report, these two values are not equal to one another. This causes two things to occur. The first is that one must derive what value to set the program at to get the desired threshold across the card. The second being that the lowest threshold value setting for the program corresponds to a higher measured threshold value. This means that there is a limit to how low the threshold settings for the scintillators can be – for this paper those values are about 35 mV.

The data for the card used in this paper is presented below.

Graph : Threshold Graph

The table below shows what values to set into HyperTerminal to achieve the desired threshold of 35 mV, with the card for the above graph of course.



Table : Settings for HT to get 35mV on this card

With the thresholds set, data collection for the scintillators can begin. The first to be discussed here is the 35mV runs for the MTS scintillators. Before starting the runs, a theoretical flux was calculated to show about where the plateau for the graphs should appear. To do this, simply take the measured area of the scintillators paddles. For every 1 square centimeter of material, one should get 1 count rate per minute.

*\*Note\* This number only works for when the paddles are arranged horizontally.*

For the MT paddles, the theoretical flux is about 2776 counts per minute, so for a three minute run, the plateau should be around 8328 counts, or 46.3 counts per second. This not only helps identify the plateau region, but it gives a good idea where the starting points for plateauing should be. With a number this high, a starting point of 2+ counts per second is reasonable depending on how defined a graph is needed to see the plateau region.

The following two pages contain the data and graphs for the 35 mV setting. The first page contains graphs for the Top and Bottom scintillator paddles of the MTS setup. The second page contains graphs for the side scintillators, 1/4 and 2/3. The data for these four graphs can be found in the tables of Appendix A. The horizontal plateaus for the side panels and the data for those are found in Appendix B.

*\*Note\* The voltage in the tables has an error of ±1%.*

Graph : Top MT Scintillator @ 35mV

Graph : Bottom MT Scintillator @ 35mV

Graph : Side 1/4 Scintillator @ 35mV

Graph : Side 2/3 Scinillator @ 35mV

These graphs show that the plateau region for each MTS scintillator is about the expected -value of 46.3 Hz except for the top scintillator, whose plateau value is about ~51.5 Hz according to the single plateaus. The plateau voltage for each of the paddles is as follows: Top, 0.670mV; Bottom, 0.547 mV; 1/4 Side, 0.685 mV; 2/3 side, 0.706 mV. All four scintillator graphs can be seen in the graph below. Take note that this is with the side paddles arranged vertically.

Graph : All four scintillators @ 35 mV

With the MTS single paddles plateau voltages, finding the coincidence plateaus comes next. As mentioned in the procedure section, this is done by using two scintillators. Set up the HyperTerminal program to read coincidences across two paddles, and set one of the two paddles to its plateau voltage found during the single plateaus. For the MTS paddles, the top paddles was the control value – set at 0.670V-, and when it came time to plateau that paddle, the bottom panel was used at the control – set at 0.547 V. The graphs for these can be seen on the next two pages. The data tables are found in Appendix C.

Graph : Bottom Coincidence Plateau w/ Top set at 0.670 V

Graph : Side 2/3 Coincidence Plateau w/ Top set at 0.670 V

Graph : Side 1/4 Coincidecne Plateau w/ Top set at 0.670 V

Graph : Top Coincidence Plateau w/ Bottom set at 0.547 V

The plateaus for these graphs are far larger than with the single plateau graphs. This allows the plateau voltages to be identified much easier. The coincidence plateau voltages found in these graphs confirm the plateau voltages found using the single plateau method.

After finding all the plateau voltages for each MTS paddles and confirming those values with the coincidence plateauing, the voltage box was set so that each paddle was at their corresponding plateau voltages. Several coincidence runs were taken between various combinations of the paddles as well as one run using all four paddles. These were carried out with a 15 minute time instead of the 3 minute time of the plateauing process. The table of these runs can be seen below.



Table : Counts and Rate for 35 mV MTS setup with plateau voltages

The first thing one should notice is that the Sum of Counts does not equal the amount of counts found when all four paddles were run. **\*\*\*We are not sure why the Sum of Counts does not equal the total for All 4 Paddles, it is something that we will investigate and report on in our following revision\*\*\***

The QuarkNet scintillators, 1 and 3, were plateaued next. These two were plateaued at the 35mV threshold settings for both single and coincidence plateauing. Unlike the MTS scintillators, the coincidence plateauing was carried out twice to see if using a higher set value –for the control counter- would influence the plateau voltage, and as the graphs on the below and on the next page will show, this is the case until the set value gets close to its plateau. While upping the voltage did change the Rates for the coincidence of paddle #3, it did not actually change where the plateau was. This data will show that the plateau for scintillator 1 to be at 0.603 V and scintillator 3 at 0.561 V.

*\*Note\* The single plateau for paddle #3 was taken; however, it was lost somewhere along the line.*

Graph : QuarkNet Scintillator 1 at 35 mV single plateau

Graph : Scintillator 3 w/ 1 at 0.555 V coincidence plateau

Graph : Scintillator 3 w/ 1 set at 0.603 V coincidence plateau

Graph : Scintillator 1 w/ 3 set at 0.561 V coincidence plateau

Graph : Scintillator 1 w/ 3 set at 0.584 V coincidence plateau

**Appendix A**



Table 4: Data for 1/4 Scintillator @ 35 mV



Table 6: Data for 2/3 Scintillator @ 35 mV

Table 3: Data for Top Scintillator @ 35 mV



Table 5: data for Bottom Scintillator @ 35 mV

**Appendix B**

Graph : 1/4 Scintillator Horiziontal @ 35 mV

Graph : 2/3 Scintillator Horizontal @ 35 mV



Table 7: 1/4 Scintillator Horizontal @ 35 mV Data



Table 8: 2/3 Scintillator Horizontal @ 35 mV Data

**Appendix C**

Table 12: Top Coinc. w/ Bottom set at 0.547 V Data



Table 11: 1/4 Side Coinc. w/ Top set at 0.670 V Data



Table : 2/3 Side Coinc. w/ Top set at 0.670 V Data



Table 9: Bottom Coinc. w/ Top set at 0.670 V Data



**Appendix D**



Table 15: Scintillator 3 w/ 1 set at 0.603 data

Table 16: Scintillator 1 w/ 3 set at 0.561 V data



Table 1: Scintillator 3 w/ 1 set at 0.555V data

Table 1: QuarkNet Scintillator 1 35 mV plateau data



Table 1: Scintillator 1 w/ 3 set at 0.584 data

1. Conclusion

This report details the assembly process of the new scintillator paddles which were built for the Muon Tomography Station, as well as the procedure of plateauing them for optimizing efficiency. The results of the plateauing process were reported on for both the QuarkNet and MTS paddles. Hardware and software problems were encountered and resolved, the steps taken to resolve them are reported on above. Overall, the authors hope that this report will function as a guide to help the behavior and procedure of assembling and plateauing scintillator paddles be better understood and allow anyone to assemble and plateau their own paddles with ease.