A Brief Summary of Research Preformed at APD in the Summer of 2019

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1 Abstract

Within the summer of 2019 the writer conducted research under Dr. Whitbeck of Texas Tech University within the high energy physics department, looking into the interactions of beta particles on scintillators by using SiPMs on Fermi-Lab built boards. The primary purpose of this write up is so that those whom follow in this research may pick up where the writer is leaving off.

2 Introduction

During the summer of 2019 the writer performed scintillator characterization in order to test efficiency and the effects from outside sources. In total to detect electrons that are sourced from beta decay with a high level of efficiency was the ultimate goal of the research performed. These scintillators were characterized in order to begin prototyping the trigger system on the future LDMX (Light Dark Matter eXperiment). From that the LDMX will begin to analyze dark matter on the sub-GeV scale, which currently is uncharted territory because most experiments have been performed on WIMPs (GeV to TeV range). LDMX seeks to understand if rare reactions occur which cause a mysterious loss of energy when an electron beam goes through an apparatus, which would be indicative of dark matter production. The prototyping of the trigger system proves essential in order to reduce the noise generated from the beam energy and to lessen the empty events so that dark matter events may be effectively analyzed. The writer performed extensive testing on scintillators in order to test different properties of their luminosity between the materials and the presence of a source. Scintillators work on the principle that when a charged particle impacts the scintillator, the particle will be absorbed and the scintillator will emit the energy absorbed in the form of light. In order to read out the photon emissions a Silicon Photomultiplier(SiPM) is utilized which can also be able to tell the difference between different events if used effectively. The SiPM works on the basis that it consists of an array of photodiodes (which converts light into an electrical current) which work in that on the correct amount of voltage the pixels will be sensitive to single photons from the scintillator. Hence, to have sufficient effectivity, the SiPM must be coupled with the scintillator so that a vast majority of the photons have contact with the SiPM, which can be provided through a mechanical structure which will allow them to be sufficiently connected. Thus a mechanical structure deemed the "Mayan" was developed. The Mayan designed is the initial holding component for 4 thin scintillators, and it also has a slight opening so that the SiPM may be coupled in order to read the photons emitted, from this LDMX will expand so that instead of 4 thin scintillators being used, 50 will be used. The testing is critical to LDMX in order to emphasize the dark matter events and minimize the noise created from the electron beam, so that dark matter will be able to be analyzed with relative ease.

3 Materials and Methods

Initially, Dr. Whitbeck assigned the writer to solder the Hamamatsu S14160-4050HS onto the FermiLab PoRCA boards so that the scintillators may be tested in this mechanical environment that will be discussed at a later point. To solder, the Weller WESD51 was used in which one SiPM was successfully soldered onto the board, but after that point not another one was soldered, by the writer, Ian, or Dr. Whitbeck. Epoxy was used but failed as well as a heat gun. The efforts were deemed futile and to be retired for a later point. One issue that later cropped up, is that the one that was successfully soldered fell off at a later point due to excess stress. From this point the writer began to design the mechanical structure meant to house the SiPMs and scintillators so that the components may be tested. To prototype the design, the software SketchUp was utilized and then the design was prepped for printing in the software Ultimaker Cura, and finally the design was printed in Dr. Whibeck's personal 3D printer, the Monoprice Mini Delta. A handful were designed and tested, such as what is deemed as the Mayan, which was used to hold the scintillators in place above the SiPMs. Further the top piece (and thus the bottom as they are complementary) were printed that would hold the board in place, as well as to house the peltier may be placed so that the temperature does not rise too high. Finally, "spacers" were needed as the board sat too high on the top and bottom plates for the Mayan's legs to sit on the plates, hence a spacer was designed that would fill this gap. (Figure 2/6) During these times testing was also preformed on the SiPMs. Firstly the breakdown voltage was tested on all 3 completed devices (2 were the Hamamatsu S13360-3050PE and 1 was the Hamamatsu S14160-4050HS) in which the data will be included. In order to find such a voltage was put through the board while the board was in a dark space (using a dark blanket and a cardboard box) using the Keithley 2410 multi meter. Table three shows the testing of the first SiPM (Hamamatsu S14160-4050HS). More measurements that were taken after this effort were finished, but suspicious due to illogical numbers and both the Keithley 2410 and Keithley 2000 seemed to give odd number (likely due to grounding). (Table 3) After such the testing moved towards recording the frequency of the SiPM at different voltages from the Agilent 6634B (high voltage) and having the Agilent E3648A (low voltage) constant, while also having the Tektronix TDS 1002 read the frequency. On the mechanical configuration the board was placed against the holder so that the SiPM would sit in a designed hole in the holder with the scintillator being close. The holder also was outfitted with a hole that could have the Sr-90 placed in it. From there this was placed in this dark space once again so that the readings won't be noisy. The high voltage was hooked up to the low voltage then went to the PoRCA board, and the board was also connected to the oscilloscope. The source (Sr-90) was either present or not in order to see the change, and the scintillator (Eljen Technology EJ-228) was present throughout testing. (Table 2) Penultimately, testing went underway on the peak to peak voltage read outs from the Tektronix TDS 1002 of which 128 read outs were averaged so that the curve may smooth out, from that 3 different triggers were tested to see differences as well as the 3 different scintillators. The same configuration as the last one was used. It should be noted all testing was done in the dark by utilization of the dark blanket. (Figure 3/Table 4) Finally, the Hamamatsu R580UV was used to test the difference in frequency with and without the source present as well as a change in voltage. (Table 1) In this set-up the NIM Crate (LeCroy 1403) was used along with the Quad Scalar and Present Counter Timer (C.A.E.N. N1145), Coincidence Unit (LeCroy 465), Octal Discriminator (LeCroy 623B), 4 Channel High Voltage Power Supply (C.A.E.N. N472). Due to an instability that came to prominence during the last tests the Agilent E3648A was switched out for Tektronix PS 280 which proved to be more stable. Besides this modification the set up stayed the same. From this the Tektronix DPO 7254 was used to create a histogram of the read outs from the SiPM, a capability the Tektronix TDS 1002 did not posses. (Table 1/Figure 1) Thus forward the writer and Dr. Whitbeck began to work on creating a system of such in which a PMT (Hamamatsu R580UV) would act as a trigger to the SiPM reading, in order test the photoelectron spectrum. In order to analyze the read out from the oscilloscope a program was formed to take the data (of time and size of pulse) and be put in a text file. The writer then assisted Dr. Whitbeck in creating a python program that would take apart the data to formulate a plot that may be used to seek the different events.

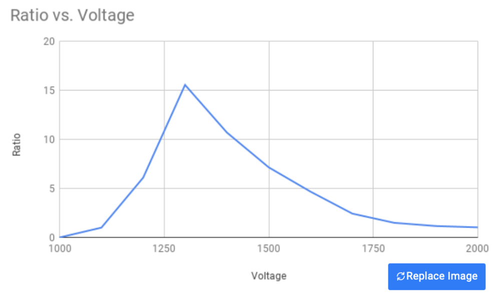

Figure 1 › Ratio vs. Voltage from PMT Readings

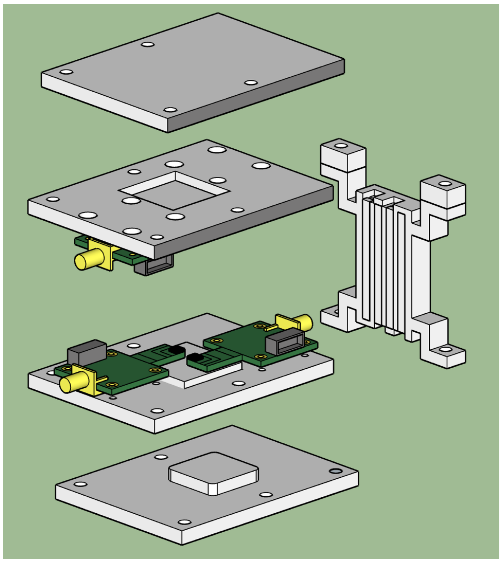

Figure 2 › Mechanical Set Up(Exploded)

Table 2: Frequency based on voltage and source radiation

Voltage(V)	Freq(no radiation)	Freq(radiation)
40	<10Hz	3.8kHz
42	540kHz	2.08MHz
44	2.48MHz	4.28MHz
46	3.14MHz	4.9MHz
48	2.62MHz	4.74MHz
50	2.02MHz	4.31MHz

Table 3: SiPM(1)Hamamatsu S14160-4050HS

Voltage (Volts)	Current(Micro Amps)
-1	-105.0015
15	0
39.6	17.8
41.2	77
41.8	105.1

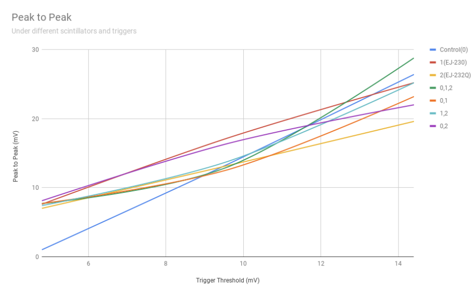

Figure 3 › Peak to Peak under the conditions of different trigger thresholds and scintillators

Table 4: Peak to Peak using different scintillators and triggers(mV)

Scintilator	4.8	9.6	14.4
0(EJ-228)	7.2	13.4	26.4
1(EJ-230)	7.6	17.2	25.2
2(EJ-232Q)	7	13.2	19.6
0,1,2	7.7	13	28.8
0,1	7.7	12.6	23.2
1,2	7.4	13.8	25.2
0,2	8.1	16.4	22

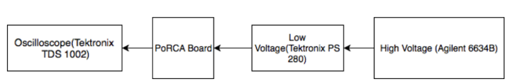

Figure 4 › Diagram of the initial testing

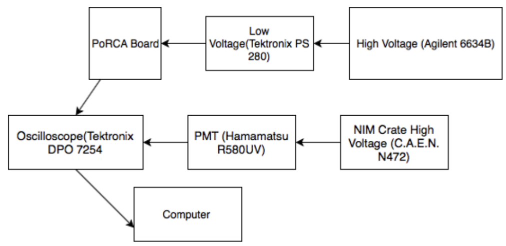

Figure 5 › Diagram of the later testing

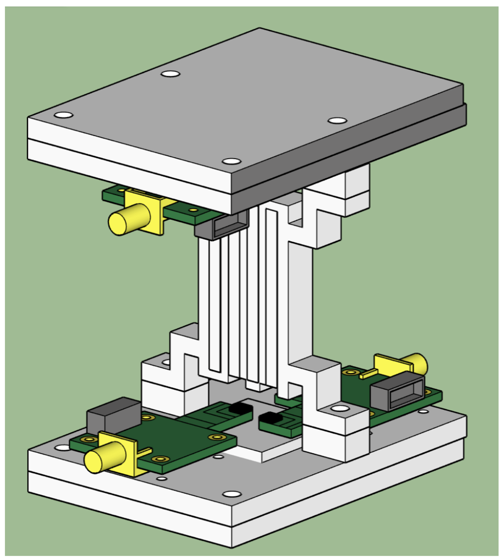

Figure 6 › Mechanical Set Up

4 Discussion

One important note that should be a precaution, is that the metal of the oscilloscope must not be in contact with the scintillator box because contact will cause the component to short, consequently providing incorrect results. To note the current work on the project primarily consists of Dr. Whitbeck's work on building replacement boards to the PoRCA so that the SiPM (Hamamatsu S13360-3050PE) can be easily soldered onto the board. In turn this mean the larger SiPM (Hamamatsu S14160-4050HS) will not be used for the time being unless the soldering is outsourced. Dr. Whitbeck also created a new 3D piece that holds the Hamamatsu R580UV's scintillator in place to act as a trigger to the SiPM readings that go onto the Tektronix DPO 7254 and would hold the SiPM in place as well as hold a space for reflective pieces and the Eljen Scintillators. From these readings a histogram may be compiled and utilized to read out the number of incidences. To note all data taken as well as all designs are in the APD Journal in Evernote that Dr. Whitbeck will share with the reader. If there are any concerns or comments to any research done by the writer feel free to contact at mostephen@reed.edu, or by texting 806-778-9403.

5 Acknowledgments

The writer would personally like to give a gracious thanks to the High Energy Department for the phenomenal opportunity, but most particularly to Dr. Whitbeck for planning, coordinating, and all the time put into the writer's work. Best of luck in your future research.