PSEC Summer Writeup

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1 Introduction

1.1 LAPPDs and Margherita

Large-Area Picosecond Photo-Detectors (LAPPDs) are photo-multiplier tubes that present a major advance in time-of-arrival detection over current technologies, using microchannel plates for precise time and position measurements of photons[1]. Once operational, these detectors are intended to have timing resolution down to a single picosecond, an improvement by a factor of 10-100 over existing instruments. This proves beneficial to optimizing particle detection across a wide array of instruments, such as Optical Time Projection Chambers (OTPCs).

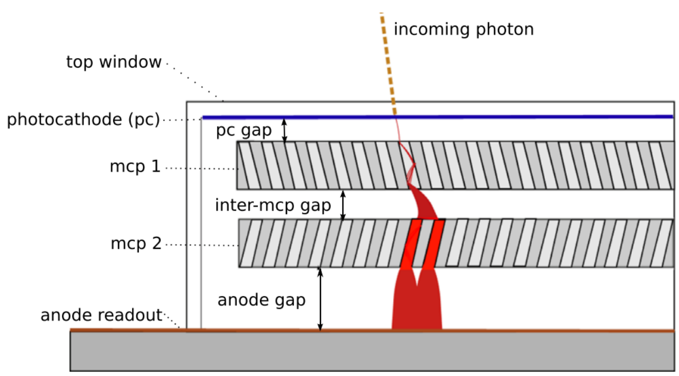

Figure 1: A side view of basic LAPPD operation

The PSEC team is currently working on an in-situ approach to fabricating these tiles. Such a method entails completely constructing LAPPDs without the need for moving the window inside a vacuum chamber, a modification which would save both on time and overall production cost. Margherita II presents the second generation device capable of in-situ LAPPD production; lessons learned from the first iteration have been applied with the aim of creating a model more ready for commercial production.

1.2 Personal Involvement - DAQ Commissioning

My work with PSEC began in late May, and ran until early August for a total of 10 weeks with the group (save for a small hiatus in July for an independent study abroad). At this point, Margherita II consisted only of the main chamber on top of the main chassis. Along with other summer students, my responsibilities for the summer entailed installing, troubleshooting, and ensuring the operation of the unit's Data Acquisition System (DAQ) in addition to designing and constructing several other mechanical components of the Margherita's heating system.

2 Data Acquisition System (DAQ) Overview

2.1 Purpose

To successfully cesiate and bake LAPPD tiles in-situ, the Margherita must maintain control over several environmental factors, namely temperature and pressure. To this end, a system capable of recording and processing these variables is crucial to ensure the proper conditions exist for cesiation. A Data Acquisition System (DAQ) fulfills this need by providing a central hub to which various sensors provide information. Through this arrangement, various temperature, pressure, and other measurements can be read simultaneously to a single server, providing an instantaneous overview of the current working conditions of the Margherita.

2.2 Base Components

As a 'middleman' between multiple sensors and a server, the DAQ operates using several input and networking devices. The following components form the core of the system:

Component	Quantity
LabJack U-6 DAQ[2]	1
Mux80 AIN Expansion Board[3]	1
CB37 Terminal Board[4]	4
Raspberry Pi[5] 3	1
Ethernet Switching Port	1
Power Brick	1

Table 1: DAQ Components

The two major components of this setup are the Labjack and Raspberry Pi, which are as follows:

2.2.1 Labjack U-6

The Labjack U-6 represents the bread and butter of the DAQ system. Connected to the four CB37 terminal boards through the Mux80 expander, the Labjack has the ability to read in over 119 analog inputs and output this data through a single channel. The unit also possesses an onboard temperature sensor useful for signal calibration (outlined in the Thermocouple section below).

2.2.2 Raspberry Pi 3

Connected directly to the Ethernet Port, the Raspberry Pi provides a gateway between the Labjack and outside server. Connected directly to the U-6 by USB, the Pi reads in the signal before sending the data on its way to the PSEC2 server. This exchange is mediated by Python code stored on the Pi (which will be discussed in the 'Programming' section below)

2.3 DAQ Layout

The DAQ occupies the entirety of Margherita II's lower chassis, with different mounting schemes for each component to accommodate each piece's spatial needs as seen below in Fig. 1

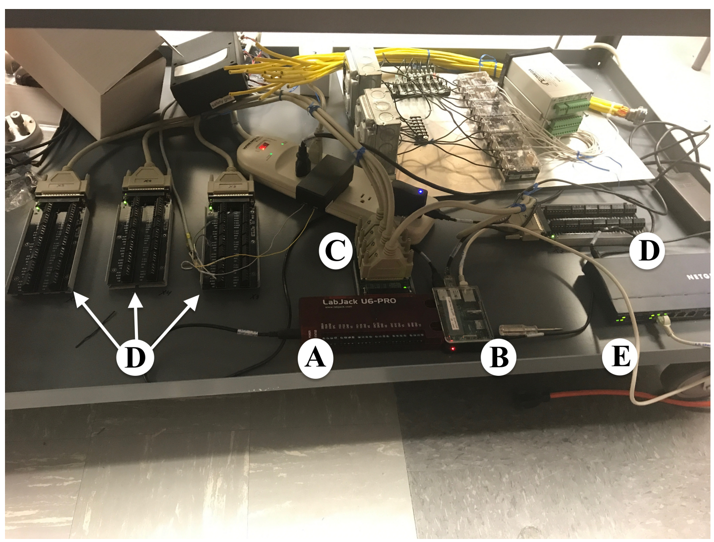

Figure 2: DAQ Setup - arrangement of (A) the Labjack U-6, (B) Raspberry Pi, (C) Mux80 board, (D) CB37 terminals, and (E) Ethernet switching port

The Labjack attached directly to the chassis through two screws, while the CB37s mounted by means of a 'Snaptrak' (plastic mount designed specifically for the CB37 boards) screwed in similarly to the Labjack. The Pi was mounted by means of rolled electrical tape; its coincidence with the Labjack serves to pressure the computer into remaining mounted. The Ethernet and Power stations remain free to move about the chassis for further wiring as the DAQ progresses

Each CB37 board connects to the Mux80 by means of a serial cable; care was taken to properly label each board and cable with its respective designation (seen in Fig. 3) per the Mux80 chart, as the analog inputs of the CB37 now correspond to different channels when run through the Labjack. This change is denoted by labeling each board with a designator from X2 to X5; these names correspond to the Mux80 manual, and decide which channels now correspond to which inputs on each board.

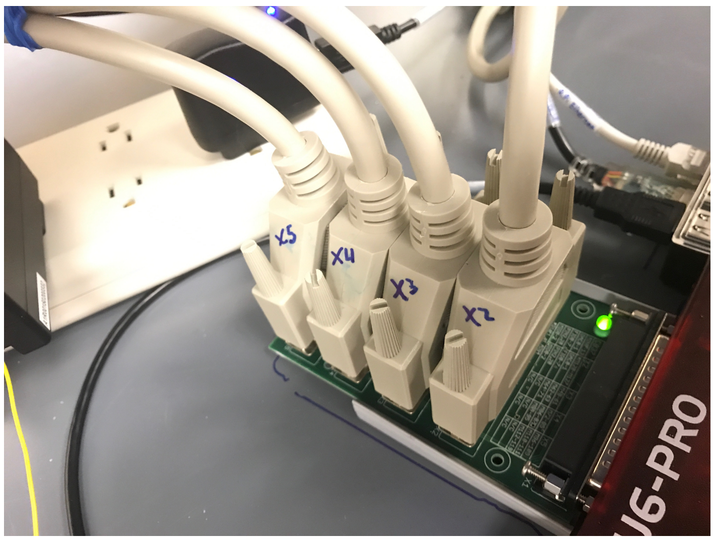

Figure 3: Connection and labeling of serial cables connected to the Mux80

3 Commissioning the DAQ

With the base components of the DAQ installed, sensors could now be wired directly into the system, with measurements following shortly after. The two types of sensors employed to monitor the Margherita II environment consisted of pressure gauges and thermocouples ?the process by which each is attached are outlined below.

3.1 Single-Ended vs. Differential Measurements

Before diving into the specifics of each instrument's connection to the Labjack, it is worth clarifying the different connections by which the sensors may be connected. Each type of connection provides advantages and disadvantages in signal measurement, resulting in the use of both single and differential measurements across the Margherita's sensors.

Single-ended measurements present the simplest type -here, the voltage is measured as a difference between a single channel and its connection to ground. Though simpler to wire, signal 'noise' may be present only on the lead to the Labjack.

Differential wiring, on the other hand, measures the voltage as a difference between two live channels, with no reference to ground. As the signal now runs across two channels, one can isolate noise by cross-referencing both inputs, a task handled in this case by the Python code running on the Raspberry Pi.

3.2 Organization

When dealing with the DAQ, the need for organization was readily apparent. With sensors placed over the entire chassis of the instrument, proper cable management was necessary to prevent overcomplicating an already complex system. Thus, extreme care was taken to properly label and organize all cables and sensors. The following practices proved successful in keeping clutter and disorganization to a minimum, and are highly recommended in future application:

- Labeling cables with descriptive names at **both** ends
- Bundling cables which ran to similar areas together (i.e., all small tube manifold thermocouple cables)
- Drilling sizable holes to allow cables to run through the top of the cart rather than over the sides
- Keeping detailed logs of which cables run to which input channels
- Arranging the non-static components of the DAQ (such as the power block and network port) to better accommodate additional equipment and cables

3.3 Pressure Gauge

The Margherita employs a Pfeiffer PKR 251 cold-cathode gauge[6] to monitor the internal pressure of the cesiation chamber. Such a measurement allows one to monitor the levels of outgassing (the release of absorbed gases by metal and other components found in the tile chamber), and ensure a vacuum during a tile's cesiation.

The main Pfeiffer gauge cable splits into six smaller wires: two are responsible for carrying signal, two transmit DC power to the sensor, one serves as an "identification" cable, and one works as a shield. The wires are color coded in Fig. 4 below, with their respective circuitry purposes outlined.

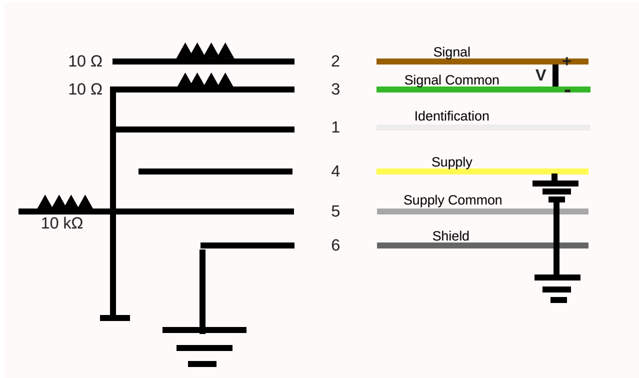

Figure 4: Breakdown of gauge cable wiring

To connect the gauge into the DAQ, all six wires must be connected to their respective inputs. Extra caution should be employed when connecting the supply wires; failure to correctly assign them to the correct voltage channel may lead to permanent biasing of the gauge signal, and can damage the gauge itself.

First, the two cables responsible for power should be connected to a male DC input jack, with the supply common (yellow) cable running to the positive terminal, and supply cable running to negative. This arrangement can be seen in Fig. 5 below.

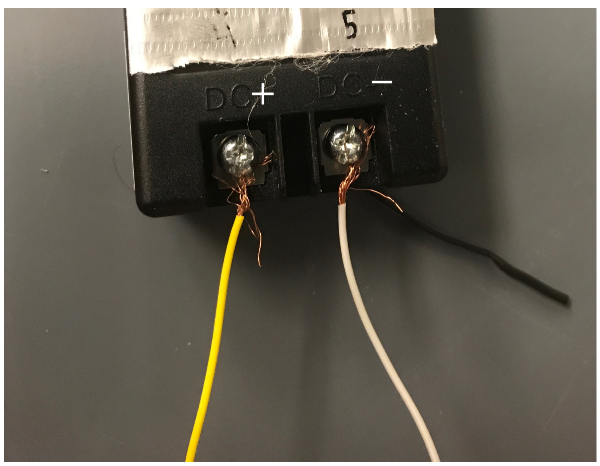

Figure 5: Wiring of supply cables to power supply

Next, the Identification (white) and shield (metallic) cables should be run into a ground input, preferably near the top of the board (as seen in Fig. 6).

A differential measurement setup is used with the gauge to reduce induced noise in the signal. Per the instructions provided with the Mux80, an offset of eight channels is

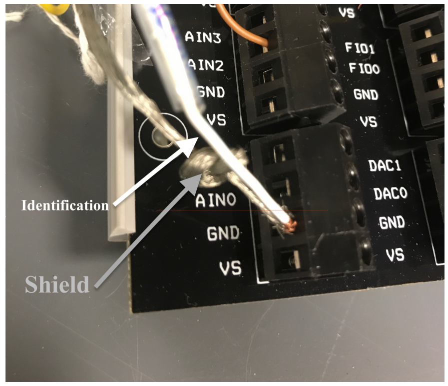

Figure 6: Connection of ground cables

used to differentiate between the positive and negative signal channels needed for floating measurements. Next to the ground input used for the shielding and identification wires, one attaches the positive signal (brown) cable, taking care to ensure that the given AIN port is indeed positive per the Labjack manual –a list of designated "positive" input channels can be found in the reference material, reducing the possibility of biasing of the signal channel.

To finish creating a "differential' ' measurement, the negative (green) signal channel must now go to a designated "negative' ' channel. When employing differential measurement, the negative channel is offset from the positive by eight spaces -for example, if one was to use AIN48 as their positive channel, AIN56 would take the negative measurement. An example of differential wiring with the Mux80 is given in Fig. 7.

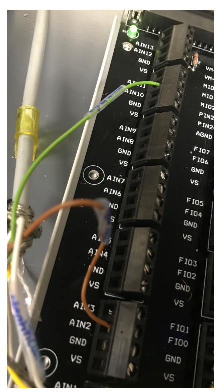

Figure 7: Differential wiring of signal channels

At this point, the gauge is fully connected to the DAQ and should be capable of transmitting pressure readings.

3.4 Thermocouples

Monitoring the temperature across various regions of the Margherita proves crucial to the proper construction of an LAPPD tile - from consistently maintaining cesium in a liquid state to ensuring critical components don't overheat, temperature management is key to the successful operation of the device.

Thermocouples provide the means by which temperature can be measured easily and efficiently on a large scale. The devices operate on the principle of Seebeck voltage - when differing metals are heated, a voltage difference arises between them at a point spatially separated from the heated end[7]. Thus, thermocouples consists of two dissimilar metals attached to an area of thermal interest (the "measurement" end) and a "cold junction" end at which a voltage difference is taken using a differential measurement across the two metals. Though many types of these devices with varying ranges and applications exist, the Margherita DAQ makes exclusive use of Type K thermocouples[8]. With an extensive temperature range (-400 to 2300 F) and easy installation, these devices are more than capable of meeting the temperature measurement needs of Margherita II.

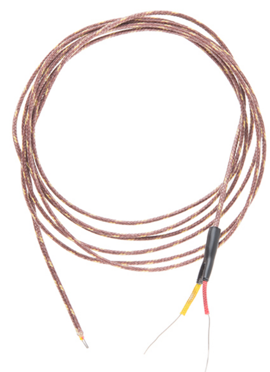

Figure 8: A type K thermocouple identical to those used on Margherita II, with cold junction end on the left and measurement end on the right

3.4.1 Placement

The complete placement of thermocouples across Margherita II is given below in figure 9 below:

Thermocouples placement occurs largely at central junctions, as seen across the large tube manifold connections and Swagelocks of the small tube manifold. Additionally, sensors along the length of the cesium source or 'J-Tube' (Zone 2 in the figure) ensure that the stored cesium remains at a consistent temperature as it travels into the small tube manifold. Devices within the tile chamber serve to monitor temperature during the firing of plates, a measurement just as crucial as internal pressure. All told, there are 32 thermocouples

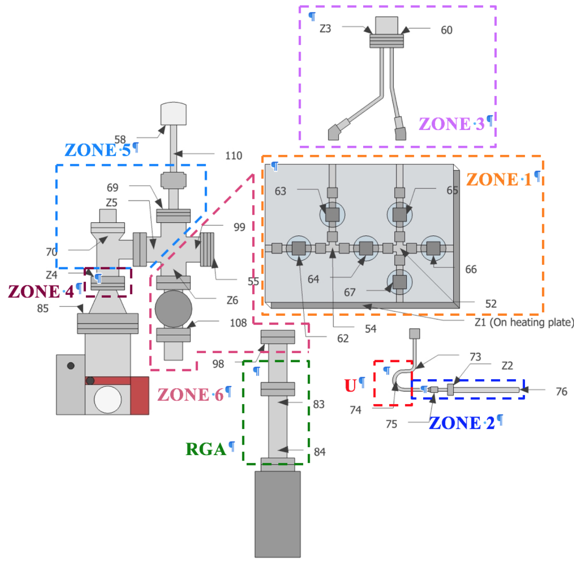

Figure 9: The complete placement of thermocouples across Margherita II. Specific 'zones' denote thermocouples running to a similar area (i.e., the small tube manifold) - Diagram courtesy of Hannah Tomlison

placed across Margherita II including those running to the heater relay (discussed in the Other Tasks section).

3.4.2 Installation

Compared to the Pfeiffer gauge installation, thermocouples require a bit more handiwork but are much less complicated in terms of wiring. The area of interest is sanded down using sandpaper to provide better grip before the thermocouple's measurement end is attached and set using cement. Scotch tape is used during this process to relieve strain and ensure the end remains attached while the cement sets. As a side note, one can never use too much strain relief - continued frustration arose when thermocouples refused to remain attached while the cement set, resulting in numerous do-overs and wasted time. Once the thermocouples are firmly attached, any tape used in the process should be removed to prevent accidental outgassing from melting plastic.

Once properly attached, all that remains to connect the thermocouple is running the cold junction end inputs into any analog input channel on a CB37 board. These connections are single-ended; as the thermocouple itself measures differentially, and the temperature measurement doesn't need to be exactly as precise as the pressure reading, single-ended readings accommodate the needs of the Margherita well. The only exception comes with

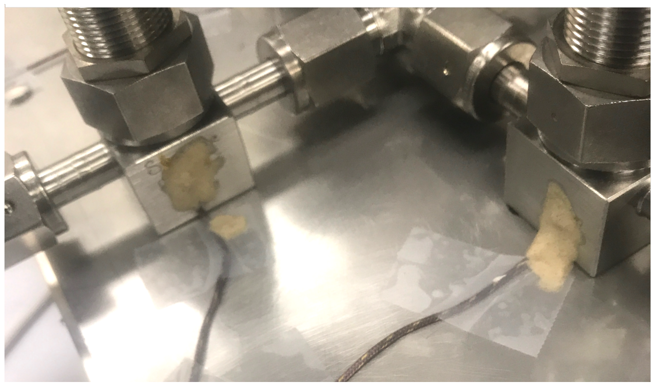

Figure 10: Two examples of a properly cemented and strain-relieved thermocouple

the internal thermocouples reading the temperatures of the plate chamber; as these measurements require a greater degree of precision, differential measurements are employed. The same offset wiring used with the pressure gauge is used here, with a resistor added to the circuit to prevent the thermocouples from being completely afloat.

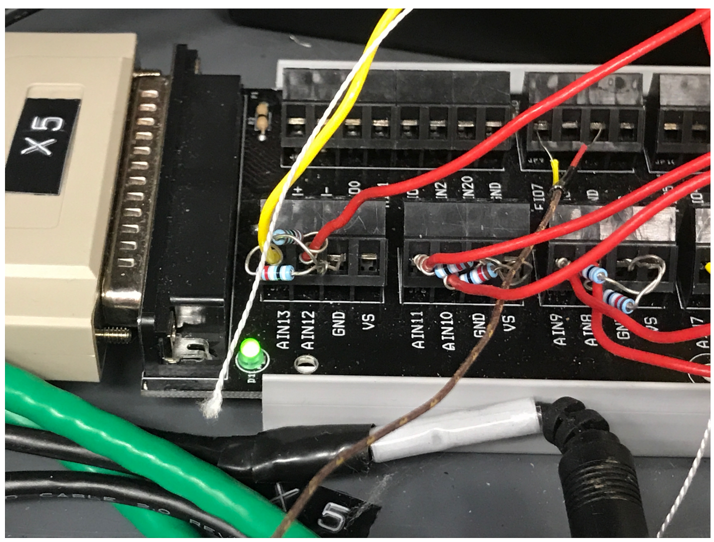

Figure 11: X5 internal thermocouple wiring with added resistors

3.4.3 Calibration Thermocouples

To account for any error in measurement originating from the CB37 boards themselves, offsets are calculated using the Labjack's temperature sensor. A thermocouple is run from the Labjack gauge to an input on each CB37 - from here, the ’margLogger2.py’ takes the temperature as measured by the thermocouple (running through the board) and compares it to the temperature measured by the Labjack. Any difference between the two measurements is taken as the channel’s ’offset,’ or error introduced by the CB37. This value is then subtracted from all values measured through the board. As they connect to the Labjack itself, these thermocouples could not be cemented - electrical tape is used to connect them to the temperature gauge on the U-6 instead.

3.5 Programming

The code responsible for managing Margherita II’s DAQ is practically identical to that on Margherita I; though several iterations of debugging files were created over the summer, the final product functions just like the code ported from the original Margherita. ’marglogger2.py’ is the file responsible for reading and logging all information from the DAQ. The file can be found on pi41, accessible through margherita@psec2.uchicago.edu.

To add a sensor to the code, the following steps are required:

1. Begin by opening a linux terminal from one of the desktop computers in the PSEC laboratory
2. SSH into the PSEC server with the command ssh ¡username¿@psec2.uchicago.edu
3. From the PSEC server, SSH into the margherita using margherita@psec2.uchicago.edu - ask one of the senior members for the password
4. From the Margherita home directory, access the Raspberry Pi – at the time of writing, this is accomplished by typing ’pi41’ into the command line.
5. From the Pi home directory, cd into the MargheritaCode directory
6. Open the ’marg2Logger.py’ file using an editor of your choice
7. Find the ’muxChans’ variable and add the new sensor using the following array format
    - Element 1: The channel number per the Mux80 expansion chart
    - Element 2: Is the measurement differential? If so, enter a 1. If not, enter a 0.
    - Element 3: The CB37 board the sensor is connected too - if a thermocouple runs into board X3, one would enter 3 here
8. Save the edited code and quit the editor using the command :wq!

The structure of the code is quite simple: once one has designated all of the channels in use across the CB37s (distinguishing between thermocouple and pressure gauge readings), the program iterates through each channel and records the voltages being sent from the

Labjack. Special care should be taken to properly input all channel information into the program; improper distinctions between single-ended/differential measurements and pressure/temperature channels will lead to skewed data and may crash the entire program. Again, it is highly important to maintain a neat, organized log of which channels correspond to which sensors to prevent frustration.

Using both thermocouple and pressure gauge libraries, the program is able to convert voltages from both types of sensors into useful measurements. In the case of the thermocouples, the program first iterates through each CB37 and calculates its voltage offset by comparing the measured temperature on the Labjack to that of the board. The difference (taken to be signal noise) is subtracted from all readings emanating from the board before they are converted to actual temperatures. These readings are logged in an output file, which can then be used for documentation and graphing. Though I participated in debugging of the actual sensor code, charting with the 'marg2logger.py' file began during my short hiatus -please refer to Hannah Tomlinson, John Judge, or even Madeline Bernstein's report for more information on the specifics of converting the raw data to real-time charts.

4 Other Tasks

4.1 Small Tube Manifold Heating Plate

Responsible for the delivery of cesium to the tile chamber, the small tube manifold (STM) requires a heating mechanism so as to maintain the element in a liquid state. To this end, the DAQ team was responsible for designing and constructing a device which could maintain the STM at the necessary temperatures.

The heating element provided for this task came in the form of a 12' long rope heater, necessitating some ingenuity as to how such an unwieldy coil could be used to best cover a rectangular area. The winning solution proved to be looping the heater around a series of bolts to optimize coverage of the entire manifold before sandwiching the coil between two metal plates, shown in figure 12 below.

Built to the exact dimensions of the STM, this heating plate mounted handily to the bottom and provided a suitable source of heat to maintain cesium at liquid temperatures. Figures 13, 14, and 15 below show the internal workings, final product, and its mounting to the STM.

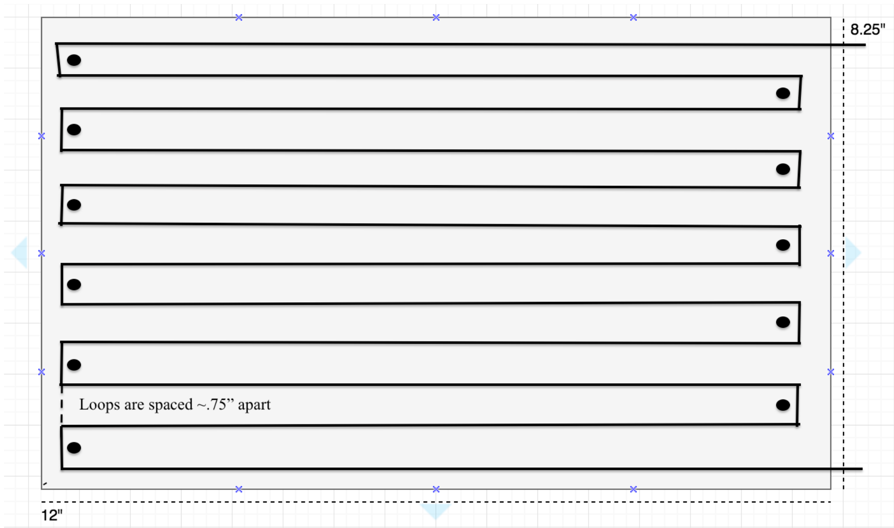

Figure 12: A rough internal diagram of the heating plate - the wire (shown in black) loops around bolts drilled through two aluminum plates (grey), with the cable inputs sticking out the rightmost end of the plates

Figure 13: An internal view of the heating plate

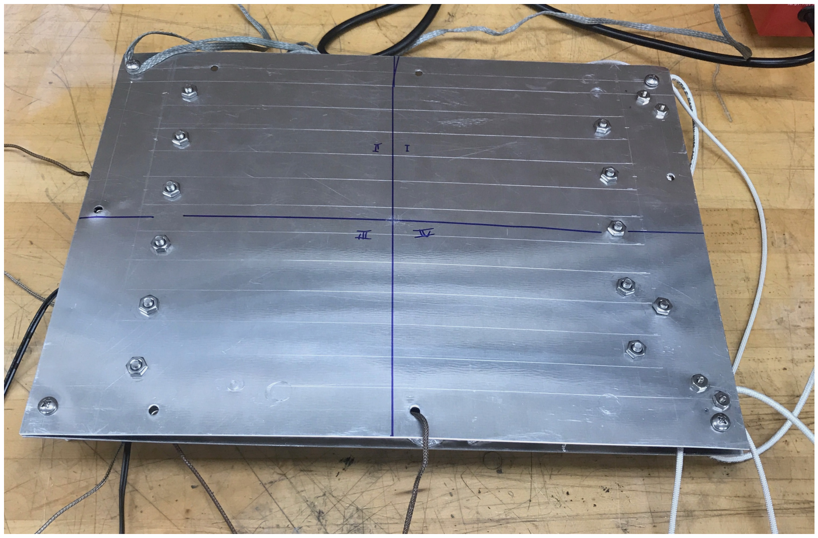

Figure 14: The final product

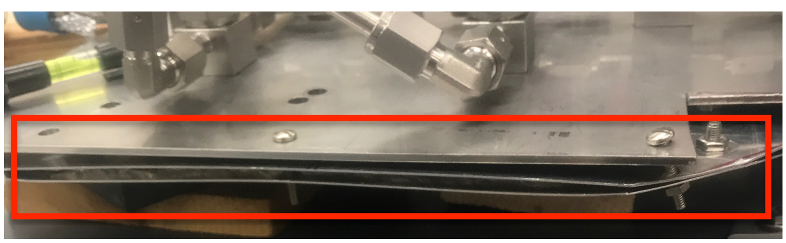

Figure 15: The heating plate assembly attached to the STM

5 Acknowledgements

With little background in experimental physics, I was slightly apprehensive of jumping headfirst into work with PSEC - however, at the end of the summer, I find myself appropriately knowledgeable in wiring sensors, designing and fabricating components, writing and debugging Python code, and a multitude of other skills. Working hands-on with Margherita II has opened an entirely different side of physics I only had vague conceptions of coming in. Many thanks to Dr. Henry Frisch, the PSEC team, my fellow DAQ team members (Hannah Tomlinson, John Judge, Rohan Lopez, and Nicole Dombrowski), and all others to making this such an informative and enjoyable experience.

6 Sources

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