Building a Tiny LArTPC to Measure Low Energy Events

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August 12 2022

1 Introduction

Neutrinos, one of the fundamental particles, are the most abundant particle in the universe. They come from all kinds of different sources, such as the sun, the Big Bang, supernovae, extragalactic sources, etc [1]. While they are the most abundant particle, they also interact with matter very weakly. [3] Liquid Argon Time Projection Chamber (LArTPC) has unique properties that can be used to detect neutrinos by measuring the resultant charge and light after the interaction between neutrino and argon particles. However, in LArTPCs light is collected with very low efficiency. Therefore, the project explores adding photosensitive dopants to the TPC to convert more light particles into charged particles. It will enable us to explore the physics in low energy region. Additionally, we will be testing the performance of LArPix V2.

2 LArTPC

A LArTPC provides precise digital readout of charged particle trajectories, enabling a detailed picture of the aftermath of neutrino and other particle interactions. Charged-particle interaction products in the detector's liquid argon bulk produce scintillation photons and tracks of ionized electrons. By applying an electric field to the argon bulk, electrons can be drifted across meter-long distances through the sea of argon atoms to wire planes strung in front of a light collection system along the sides of the TPC. Resulting times and amplitudes of electron-induced charge signals and photon-induced light collection system signals can be used to reconstruct product trajectories to in 3D as shown in Fig. 1.

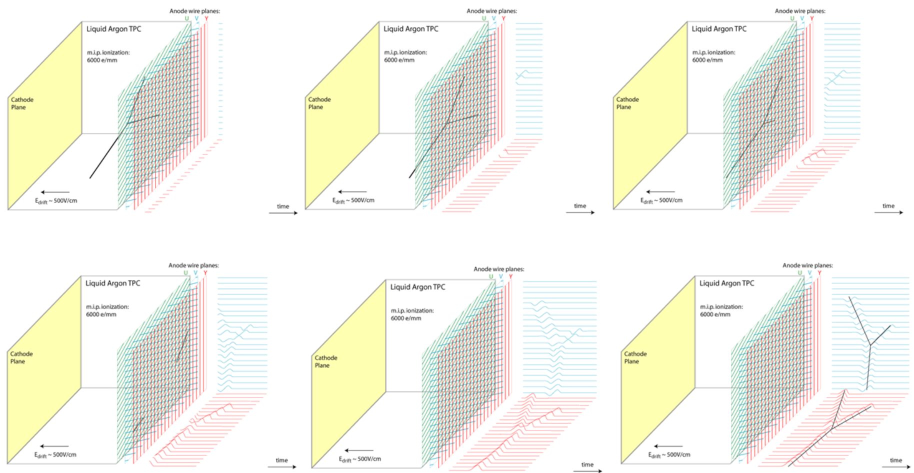

Figure 1: Scientific Diagram of the LArTPC in time. (From [4]).

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3 Motivation: DUNE + Low Energy Events

The Deep Underground Neutrino Experiment is an international flagship experiment to unlock the mysteries of neutrinos. DUNE consists of massive neutrino detectors at Fermilab in Illinois and Sanford Underground Research Facility in South Dakota. The project is focused on understanding neutrinos more in-depth and answering certain questions regarding the particle, such as accelerator neutrinos, neutrino oscillations, and supernovae neutrinos [2] which aligns with our project's motivation as well.

DUNE is also a great way to learn more about low energy physics. Our project is focused on low energy R&D (Research & Development) questions devoted to lowering the existing threshold of the technology while improving the precision to search for new physics. It provides a possibility to be used in DUNE. While LArTPCs are great tools for detecting neutrinos, light is collected with very low efficiency. Therefore, a precise energy measurement (%) at low energy requires the combination of light and charge measurements. We hope to increase the efficiency of light measurements. In order to do so, we propose adding photosensitive dopants to convert some of the scintillization light to ionization charges.

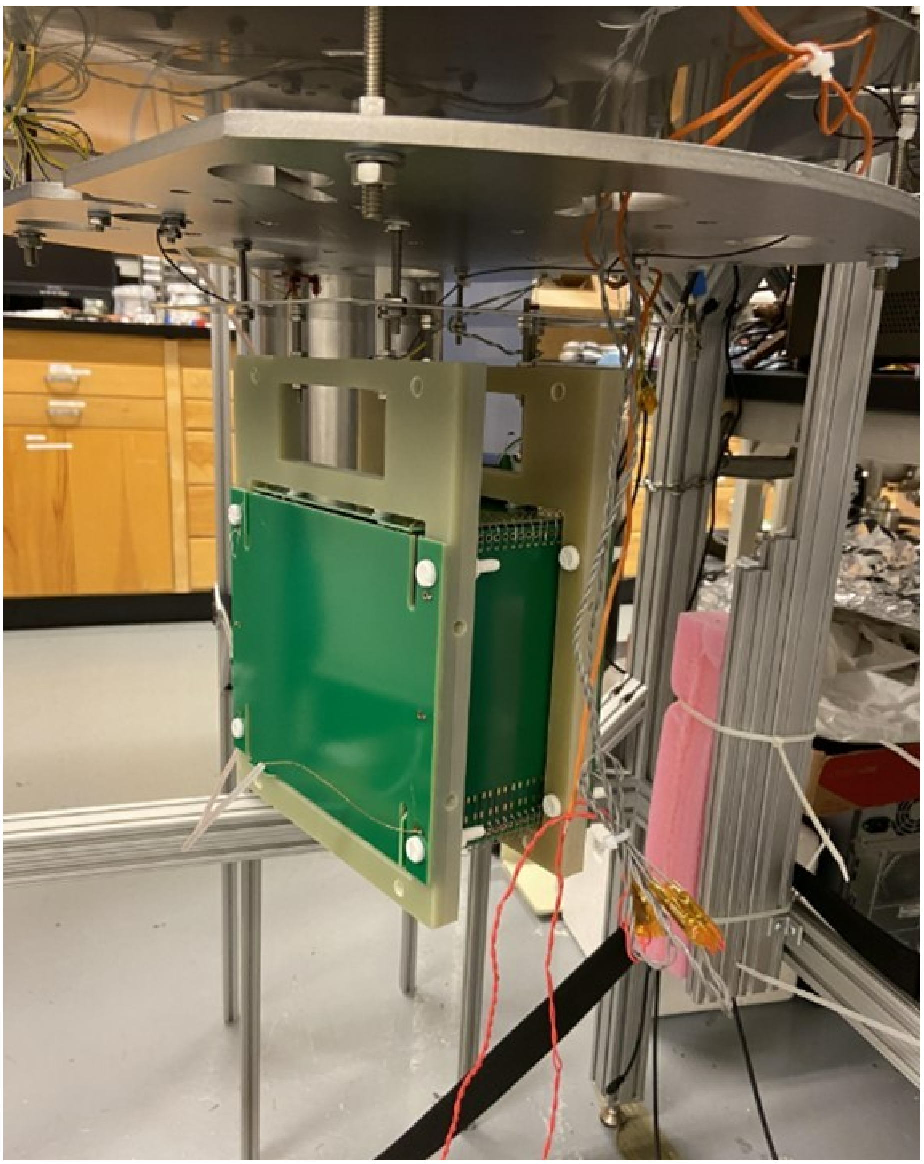

Figure 2: Completed tiny LArTPC at Lawrence Berkeley National Laboratory. The drift path of the charge is from the cathode to anode. (From LArPix Documentation).

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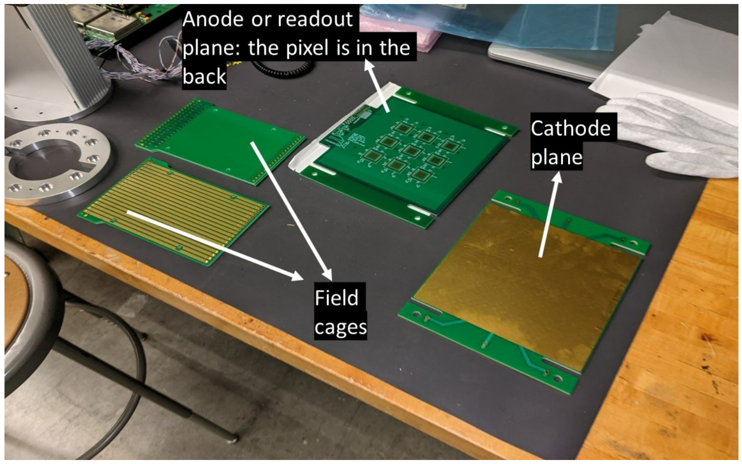

Figure 3: Components used to build the Tiny LArTPC. (From LArPix Documentation).

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In addition to the motivations mentioned above, we also hope to find a better understanding of LArPix (Liquid Argon Pixel) V2 as shown in Fig. 2 while also lowering the threshold and improving the precision of the data measurement. The different components used to build the TPC are as shown in Fig. 3. Upon successful completion of the TPC assembly, it will be deployed in the cryostat Blanche at PAB (Proton Assembly Building).

4 Steps to Build a LArTPC

In this section, we will go over the steps that we took in order to build the LArTPC.

4.1 Paperwork & Preparing Work Area

In order to get permission to work at PAB, we completed the TSW (Technical Scope of Work) and upon successful review of that paperwork, we started preparing to assemble the TPC. Additionally, we also prepared on the ORC

(Operational Readiness Clearance) to get approval to start our tests.

Additionally, after the arrival of the TPC components, we prepared our work area to reduce the risk of any accident by preparing anti-static mats and attaching them to the table in our work area. We also wiped all the instruments with isopropyl alcohol in order to ensure cleanliness of the products.

4.2 Mechanical Designs

In order to ensure proper stability of the TPC inside the cryostat, we decided to use a metal plate, which will be connected to both the cryostat lid and the TPC through different set of rods as shown in Fig. 4.

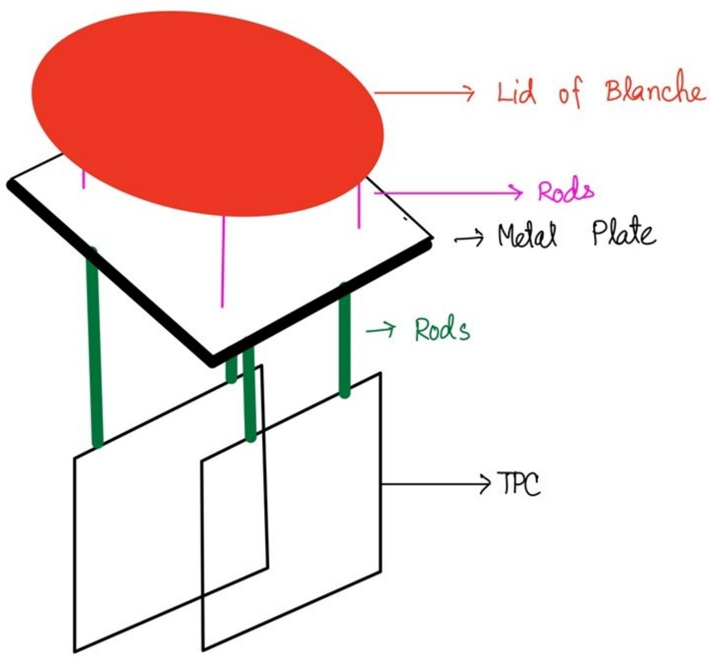

Figure 4: Diagram of TPC when Deployed in Blanche.

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The location of the holes on the Blanche lid do not correspond with the location of the TPC frames. Therefore, we used the location of the holes on the lid that we obtained from the engineering designs in order to create the mechanical design in Fig. 5.

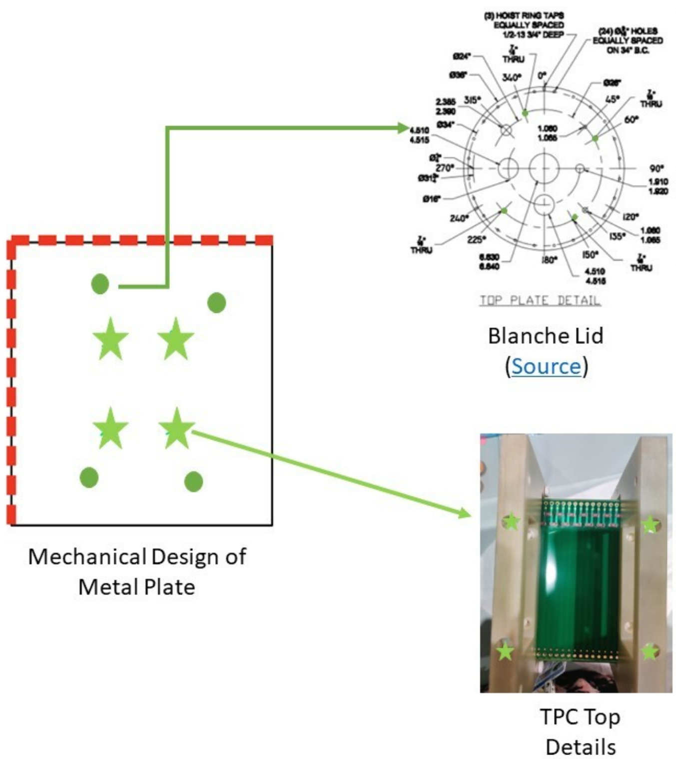

Figure 5: Detailed design of metal plate and the corresponding locations on Blanche lid and TPC. The circles correspond to the location of the holes on the lid and the stars correspond to that of the TPC.

However, the actual inside view of Blanche lid is very different than that of the engineering design as shown in Fig. 6. So, we decided to use metal strips instead of a metal plate to hold the TPC. We will be using two metal strips, one long and one short. The long strip will be attached to the screws marked in Fig. 6. Then, we will be attaching the short strip to the center of the long strip as shown in Fig. 7

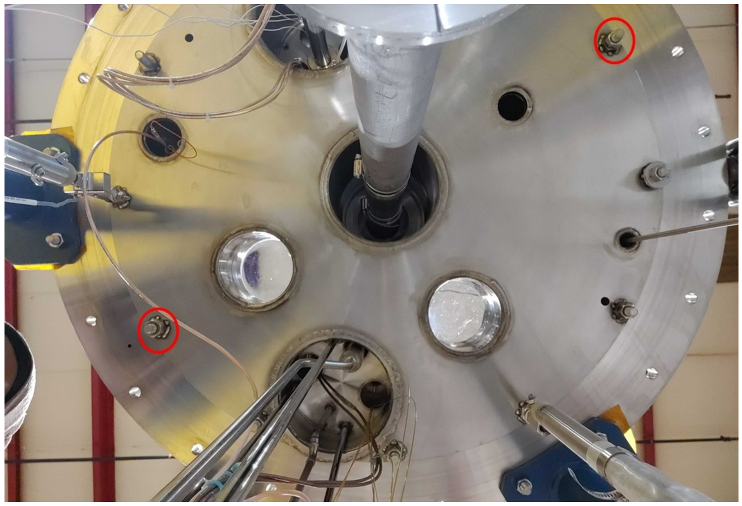

Figure 6: Inside view of the Blanche lid. The screws shown in red circles will be used to affix the metal strips.

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4.3 Test Electronics

The goal for conducting the tests on the resistors of the field cage was to ensure none of them were shorted. We initially tested with a multimeter which did not work because each of resistors had a resistance of 100(7) MΩ, which is beyond the highest range of all the multimeters available at PAB. Instead, we used a Picoammeter which was provided with 10 V of voltage by the voltage source as shown in Fig. 8.

The tiny TPC consists of four field cage panels and each of them have twenty resistors in series. According to our tests, none of the resistors were shorted and the resistance value ranges that we got from the measurements are as shown in Fig. 9

4.4 Test Assembly

We conducted a test assembly to ensure proper functionality of all elements as well as test existing assembly procedure to find out if we needed to make any

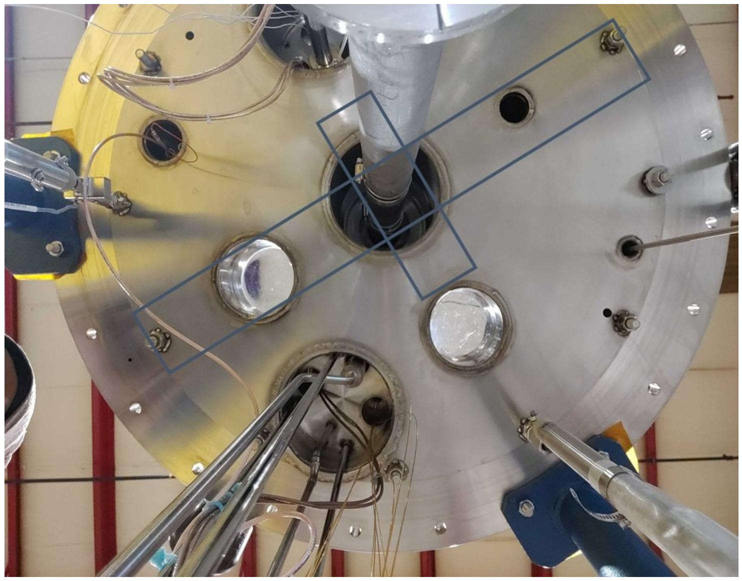

Figure 7: Proposed idea to use metal strip to stabilize the TPC inside Blanche.

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changes. We followed the procedure as shown in Fig. 10.

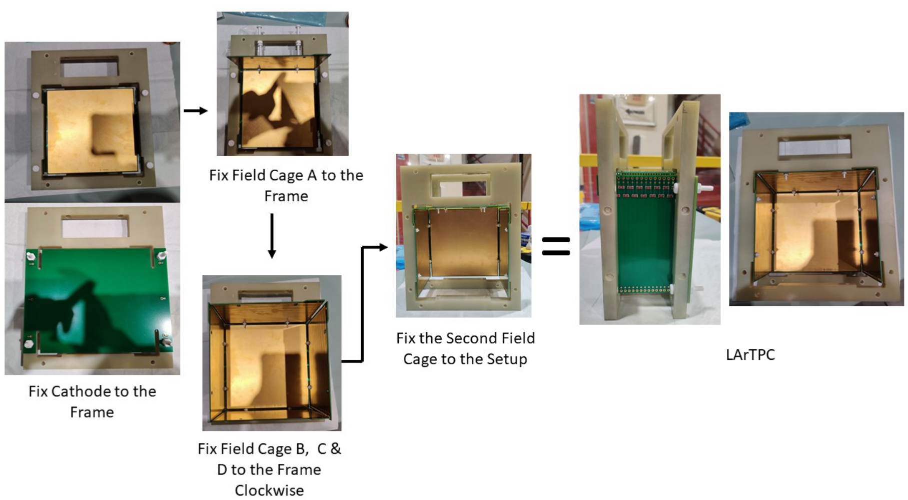

Figure 10: Diagram of the TPC Assemble Procedure.

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However, we decided to make some changes to this procedure and instead

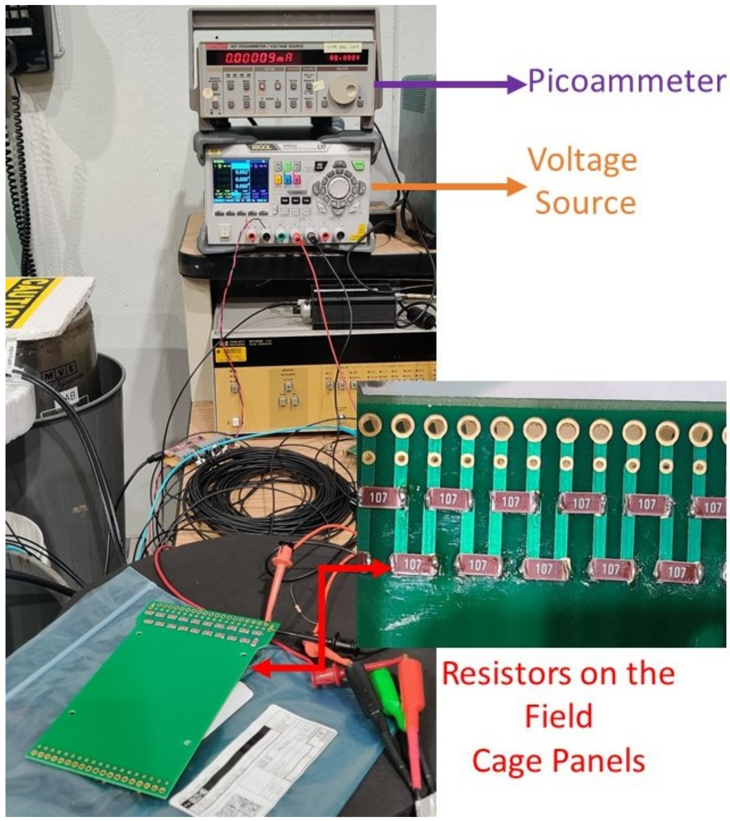

Figure 8: Test setup used to test for shorted of the resistance on the field cages.

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adopt the following order.

- Screw in the large screws through the 2 pairs of holes that are between the top and bottom pairs of holes of the frame. Tighten them using nuts and turn the frame over so that it is standing on the screws and there is space between the frame and the surface.
- Attach one of the field cages to the frame and make sure to keep track of which field cage is going in which spot.
  - We started with field cage A and then attached B, C, and D, respectively, moving clockwise.

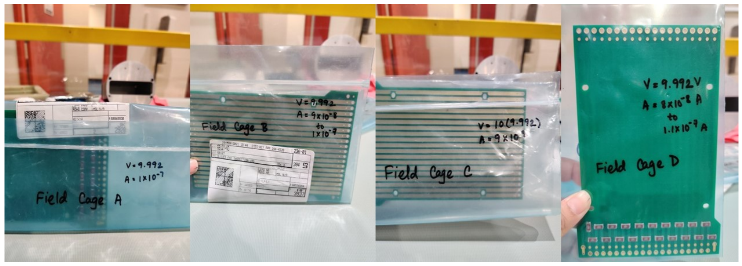

Figure 9: Range of the resistance values for each field cage.

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  - The screws used for the bottom pair of holes of the frame (Field Cage C in our case) have a different size than the other ones.

- After attaching all four of the field cages to one of the frames, slide in the second frame so that the holes of the frame and the field cages align with each other. Then tighten the screws using nuts so that all the copper stripes of one field cage align with the stripes of their adjacent field cages.

- Then we unscrew the large screws that were used to lift the frame at the very beginning. We then attach the cathode to the frame using the large set of screws, nuts, and washers.

4.5 Soldering

In order to ensure continuous connection through all the resistors, we will be soldering the adjacent field cages. To do so, it is important to verify that the panels of both of the field cages are parallel to each other as shown in Fig. 11

4.6 Cable and Gauge Calculation

The Pixel Array Controller And Network (PACMAN) receives 24 V from an external current limited DC power supply Powertec Model 6C3000 and works as a controller for the charge readout system. The current will be less than 1 A.

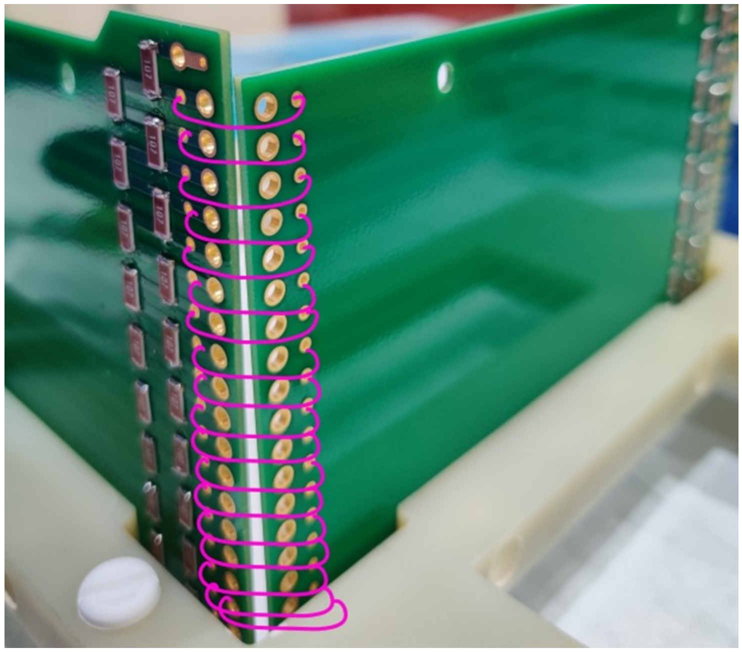

Figure 11: Drawing for the soldering.

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The PACMAN will then be connected to the anode and the schematic of the connection as shown in Fig. 12.

Initially, we predicted that we will need a 18 AWG wire to connect the PACMAN with the power supply based on experience from different groups who have used similar setups. In order to confirm our prediction we used the table and Ohm's law to calculate the gauge of wire we need for the setup as shown in Fig. 13. We assumed that we will be using a 1 km length wire and as per that assumption, we need a wire with 19 AWG or higher.

5 Future Steps

- Completing Mechanical Design for the Metal Strips
- Finding the right size of flanges for the controller and the cables

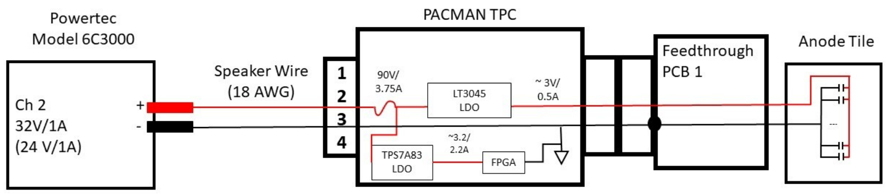

Figure 12: PACMAN Controller DC Power Distribution.

- Finalizing the cables needed for power supply and other connections
- Conducting acceptance test on the Anode/Pixel plane
- Conducting bench tests of the TPC once it is assembled
- Deploying the TPC in the Cryostat
- Collecting data in the following three steps
  - Background/cosmic data
  - Radioactive source
  - Photosensitive dopants
- Analyze the data

6 Conclusion

We successfully completed reception tests of the field cage, conceptual design of the support, and field cage assembly instructions for the field cage in preparation for the remaining TPC components. We developed documentation for assembly and mounting of the TPC to the Cryostat and drafted the remaining elements to obtain ORC approval. This work achieved substantial preparation steps crucial to TPC deployment in future work.

Assuming the wire length, l = 1 km and voltage, V = 24 V. We calculated, I = V/(R*l) to find the AWG number required for our system.

R = 20.9428 Ohm (AWG = 18)

```
In[ ]:= 24 / (20.9428 × 2)
Out[ ]= 0.572989

In[ ]:= 20 / 20.9428
Out[ ]= 0.954982
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R = 26.40728 Ohm (AWG = 19)

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In[ ]:= 24 / (26.40728 × .5)
Out[ ]= 1.81768

In[ ]:= 20 / 26.40728
Out[ ]= 0.757367
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Therefore, we concluded that we need a wire with at least AWG = 19 and higher.

Figure 13: Detailed Calculation for the Gauge value of the cable using Ohm's Law.

7 Acknowledgement

I thank my supervisors Joseph Zennamo and Fernanda Psihas for their guidance, insight, and support throughout this productive summer. Additionally, special thanks to LeRayah Neely-Brown and Will Barden for their support and insights during the whole summer. Also, a huge thank you to Fermilab and the SIST program for allowing me to participate in this research this summer.

References

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