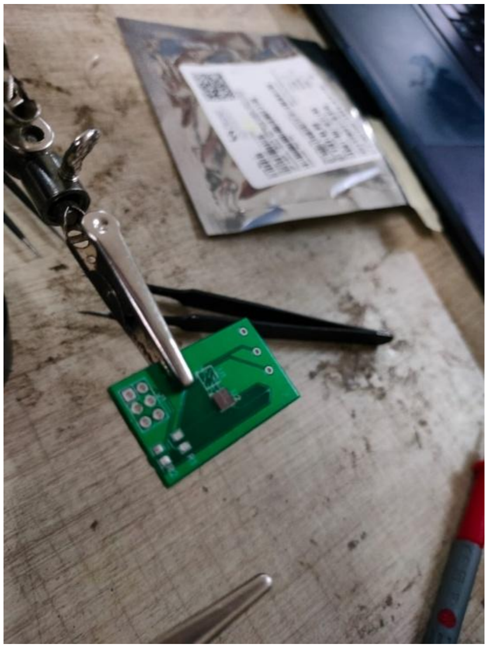
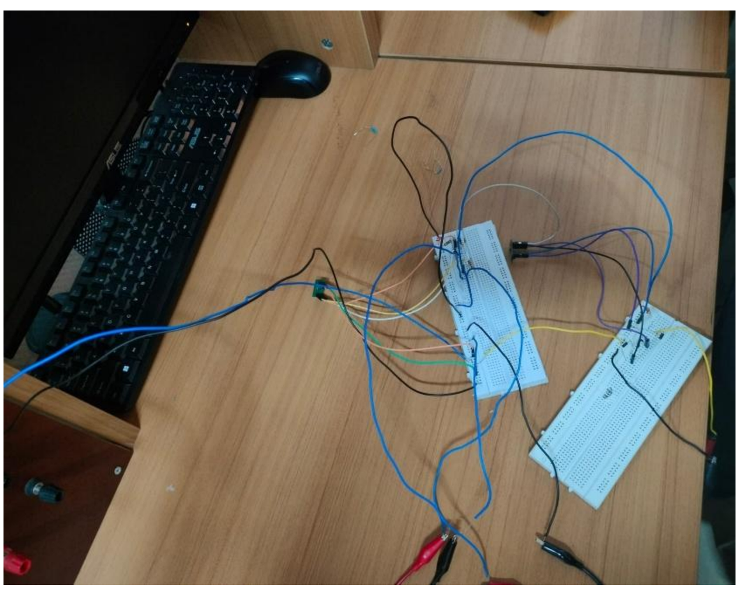
1) **Prototype testing - Breadboards :**

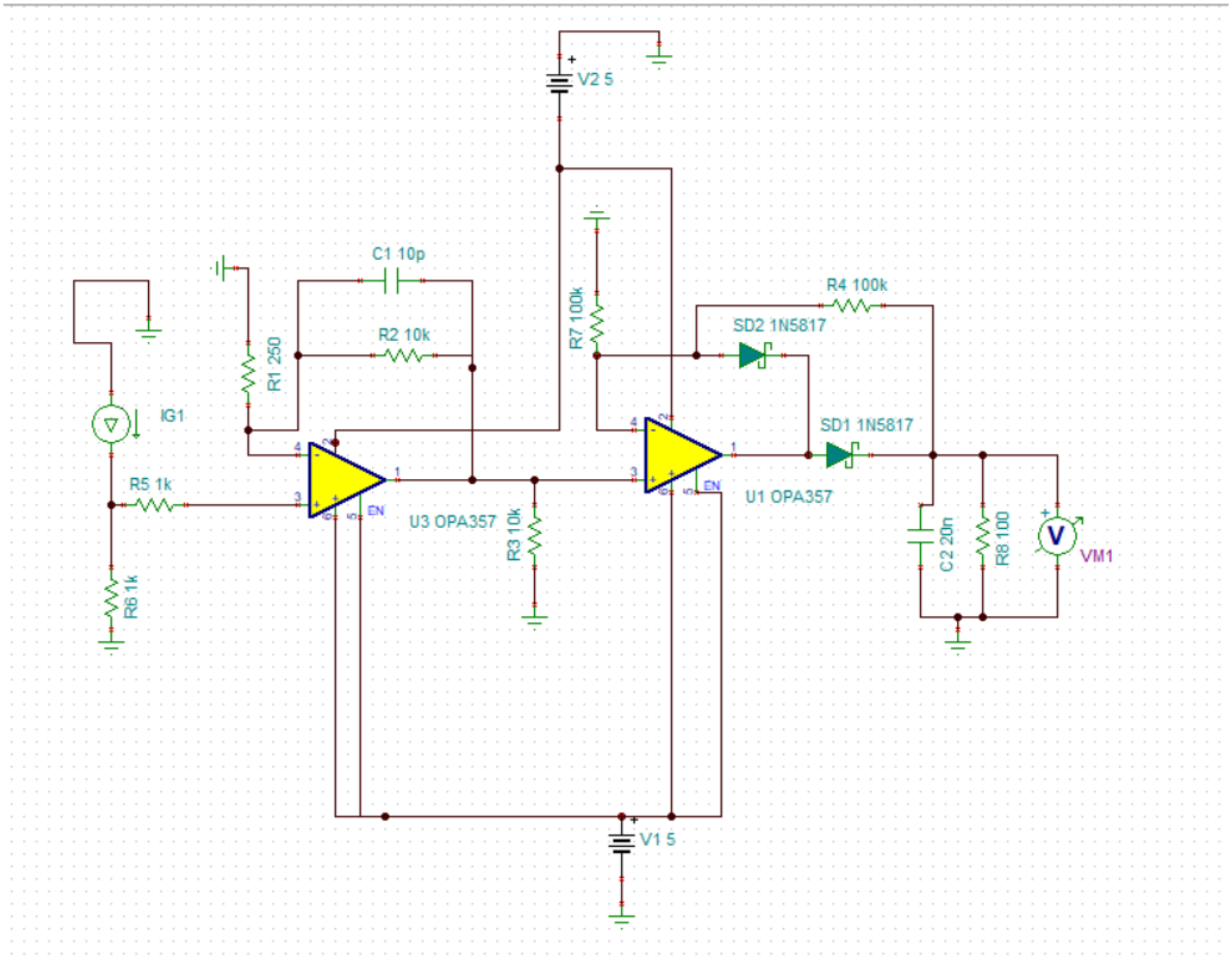


→ **The SiPM PCB**



The connections are made on the breadboard, and the circuit's reliability is tested using a function generator and an oscilloscope.

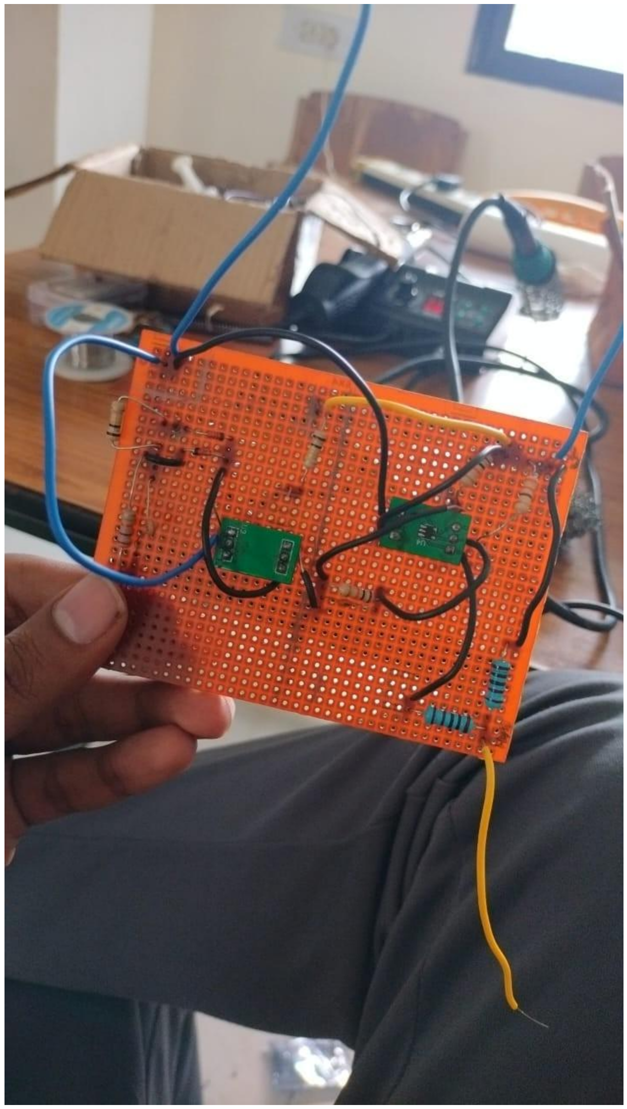
**The Readout electronics comprises the following subsystems:**




- **Signal Amplification**: The output signal from the SiPM is typically weak, so an amplifier circuit is needed to boost the signal strength. This is crucial for ensuring that the signal is strong enough for further processing by the microcontroller.
- **Amplifier Design**: The amplifier circuit is designed to match the characteristics of the SiPM, ensuring it can handle the specific voltage and current requirements of the photodetector while also providing a clean, noise-free signal to the onboard microcontroller.
- **Peak detector circuit Design**: The circuit is designed so as to capture and maintain the peak amplitude of the analog input. We have implemented an active peak detector using OPA356 op-amp.


The green signal is the input fed from the function generator, and the cyan signal is the output that can be seen in the oscilloscope. As the output suggest,s the peak is being detected and getting held for some time.

## 2) Prototype testing - Perfboard:



The circuit is built on a perf board, and the connections are tested using a function generator and an oscilloscope. The perfboard reduces the noise experienced in breadboards

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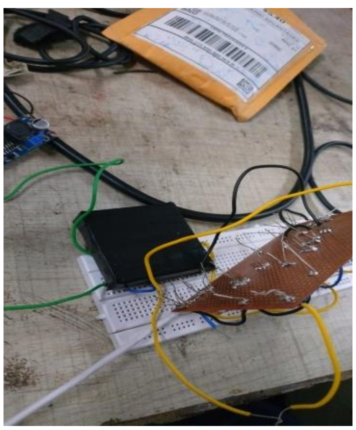
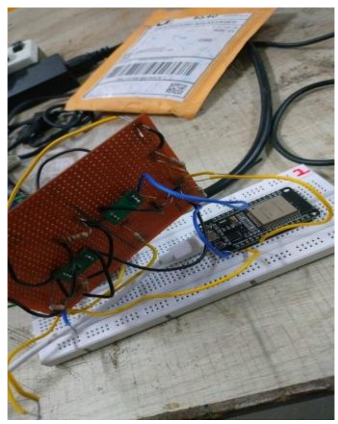
**The red signal is the input, and the green signal is the output. A delay between the input signal and the output signal can be observed because of the use of PN diodes instead of Schottky diodes.**

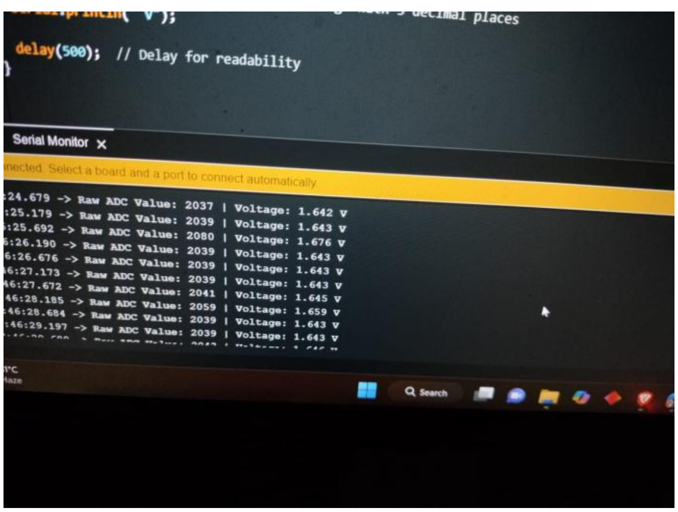
### 3) Prototype testing - Perfboard + microcontroller :

The perfboard circuit is used with the SiPM PCB and the scintillators to detect muons using an ESP32 microcontroller. The circuit remains the same, and the output of the readout circuitry is given as input to the analog pin of the ESP32. The scintillator is completely wrapped in aluminum foil and then black taped.

The scintillators used are BC408 and additive-manufactured scintillators. The scintillators were fabricated using an acrylate photo-curing monomer as the base matrix. The monomer has aromatic rings in its structure. For scintillation, 2,5-diphenyloxazole (PPO) was used along with a wavelength shifter. To induce photo-curing, a photo-initiator (BAPO) was used in a small amount. The cocktail was poured into the VAT of the 3D-printer, and 100 µm layers were printed on top of each other to form the desired structure.





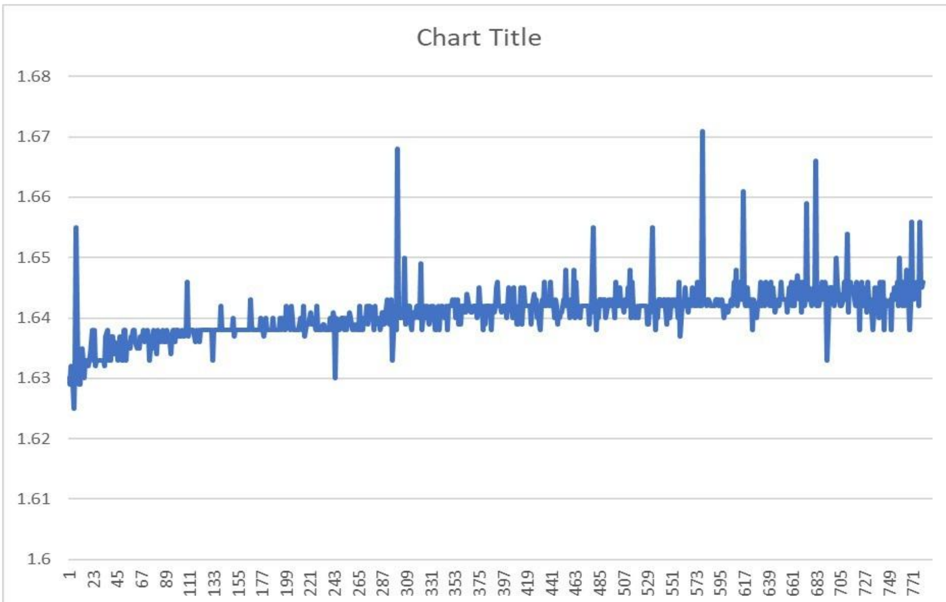



**The spike in the voltage can be translated as the muon count that hits the scintillator area.**

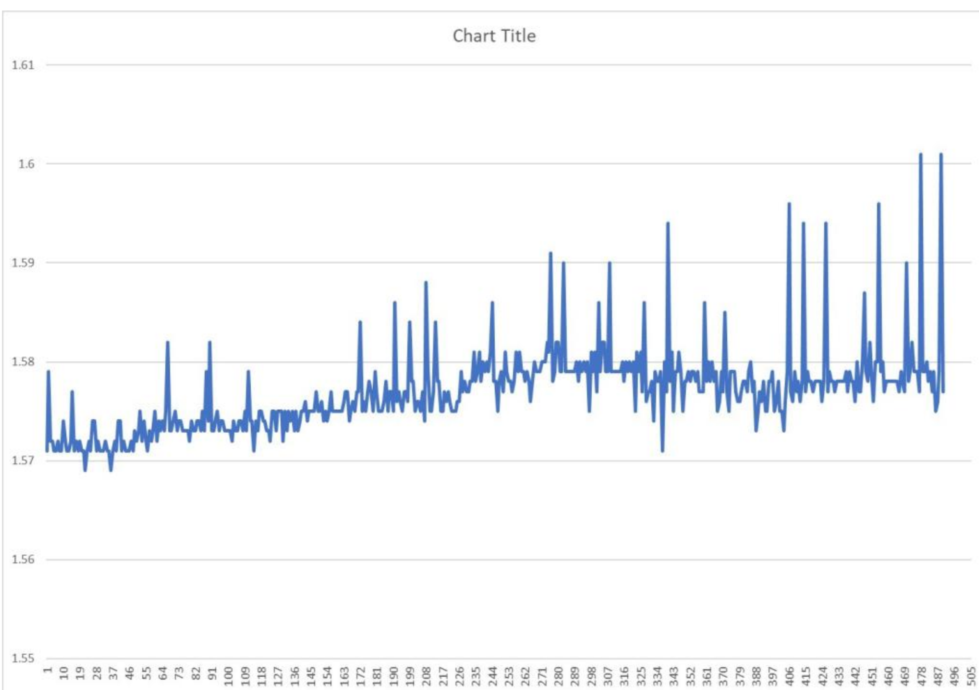
### 4) Graphing the results for all the scintillator samples

The same setup is used to quantify the number of muon hits for 5 minutes.

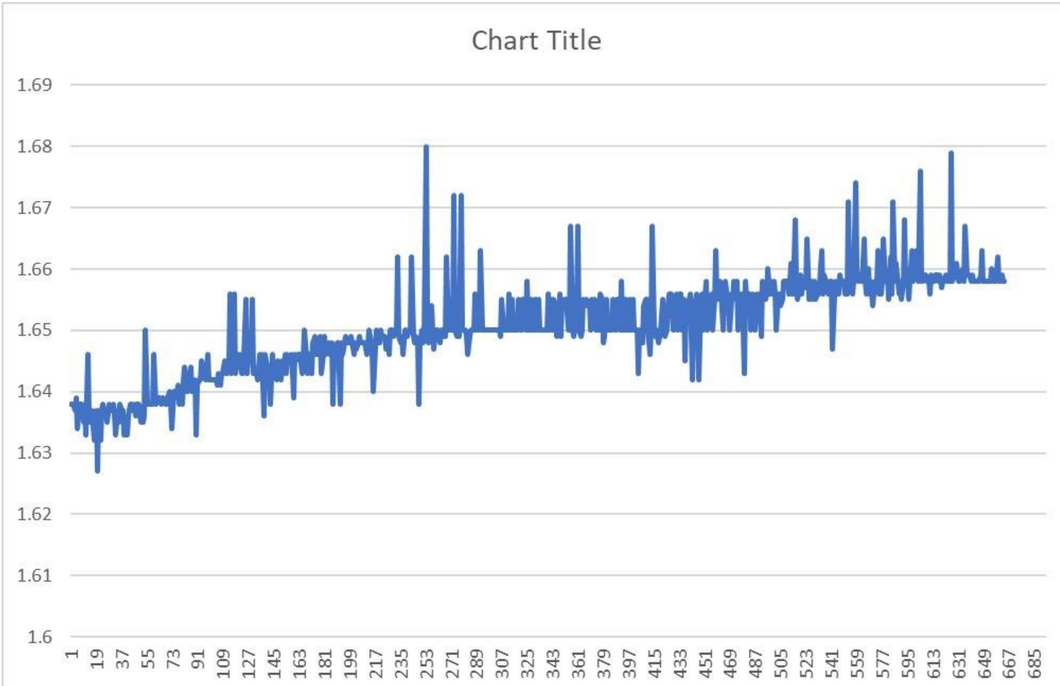
Sample 1: BC408



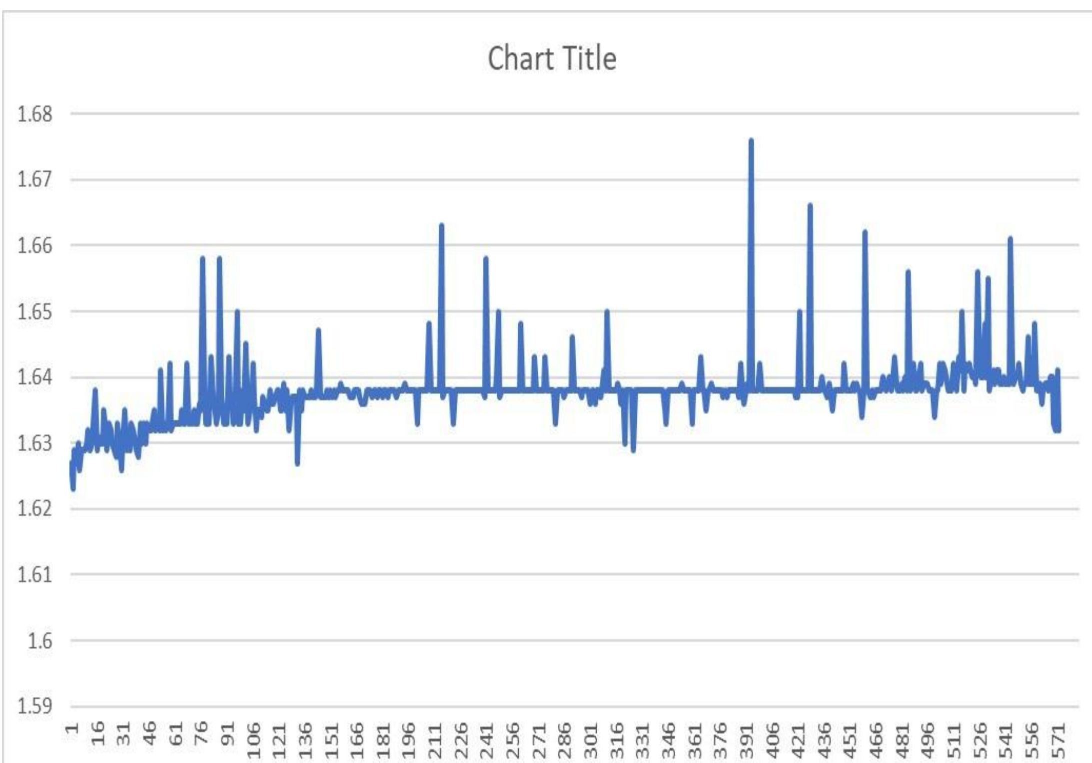

Sample 2: Additive-manufactured scintillator with a width of 3.9mm



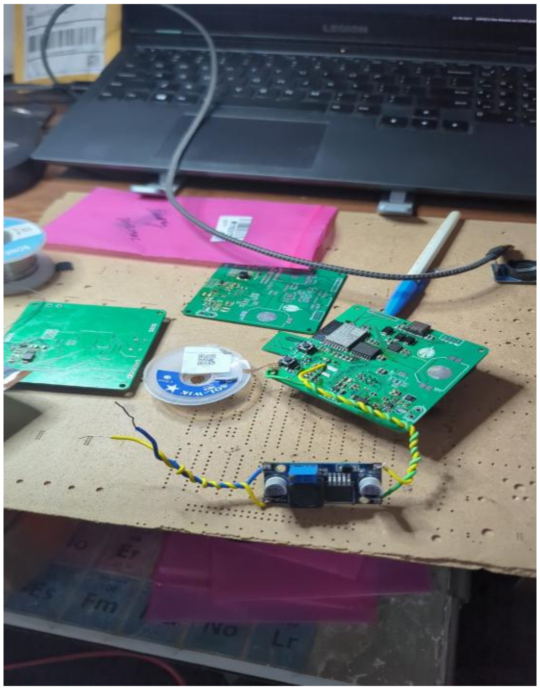
Sample 3: Additive-manufactured scintillator with a width of 6.2mm

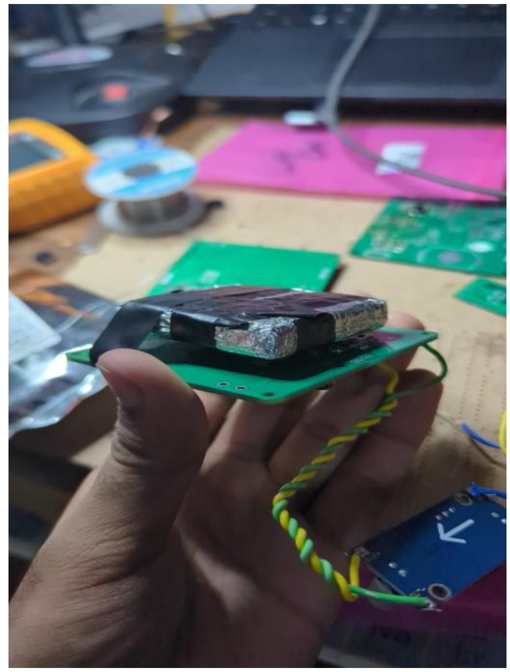



Sample 4: Additive-manufactured scintillator with a width of 8.2mm

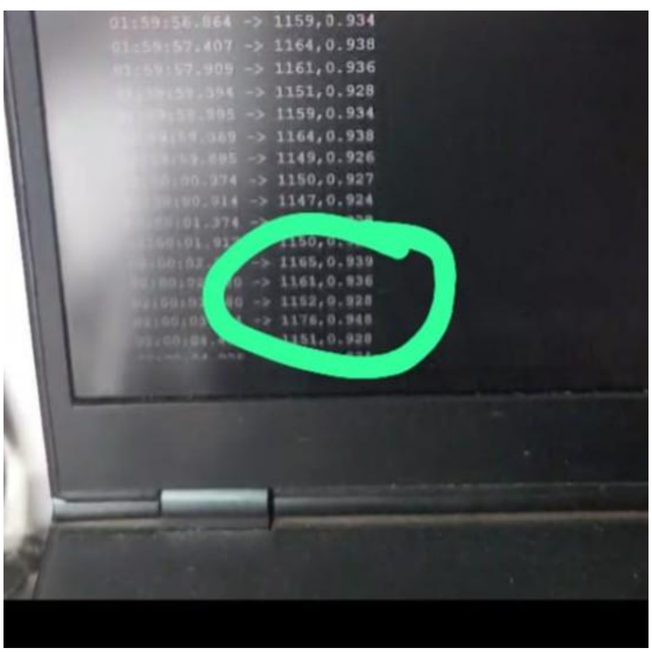


**5) Moving into final assembly - PCB production and testing**





The PCB has been designed and then assembled.




When a muon interacts with the scintillator material, a brief burst of light is produced, which is then detected by the photodetector (such as a SiPM). This is represented by the sharp spike in the voltage signal. A quick electrical pulse is produced by this interaction, and the oscilloscope shows this as a clear peak. The system can determine how many muons have passed through the scintillator area over time because each of these voltage spikes represents a single muon event. Researchers can measure muon flux and investigate associated cosmic ray phenomena by examining the frequency and features of these spikes.

# TIMELINE

MUON DETECTION SUBSYSTEM