Assembly and Characterization of an RPC Detector

For Muon Tomography Applications - The TOMAR Project

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LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS

What is an RPC ?

- An RPC is a gaseous particle detector, when a charged particle, crosses the gas it causes ionization. The strong electric field creates an electron avalanche, which induces a signal on the readout electrodes. This allows us to determine the position and timing of the particle.

Aplications in tomography :

- Tomography is an imaging technique used to reconstruct the internal structure of an object without physically opening it.

- RPCs provide precise particle tracking for the reconstruction process.

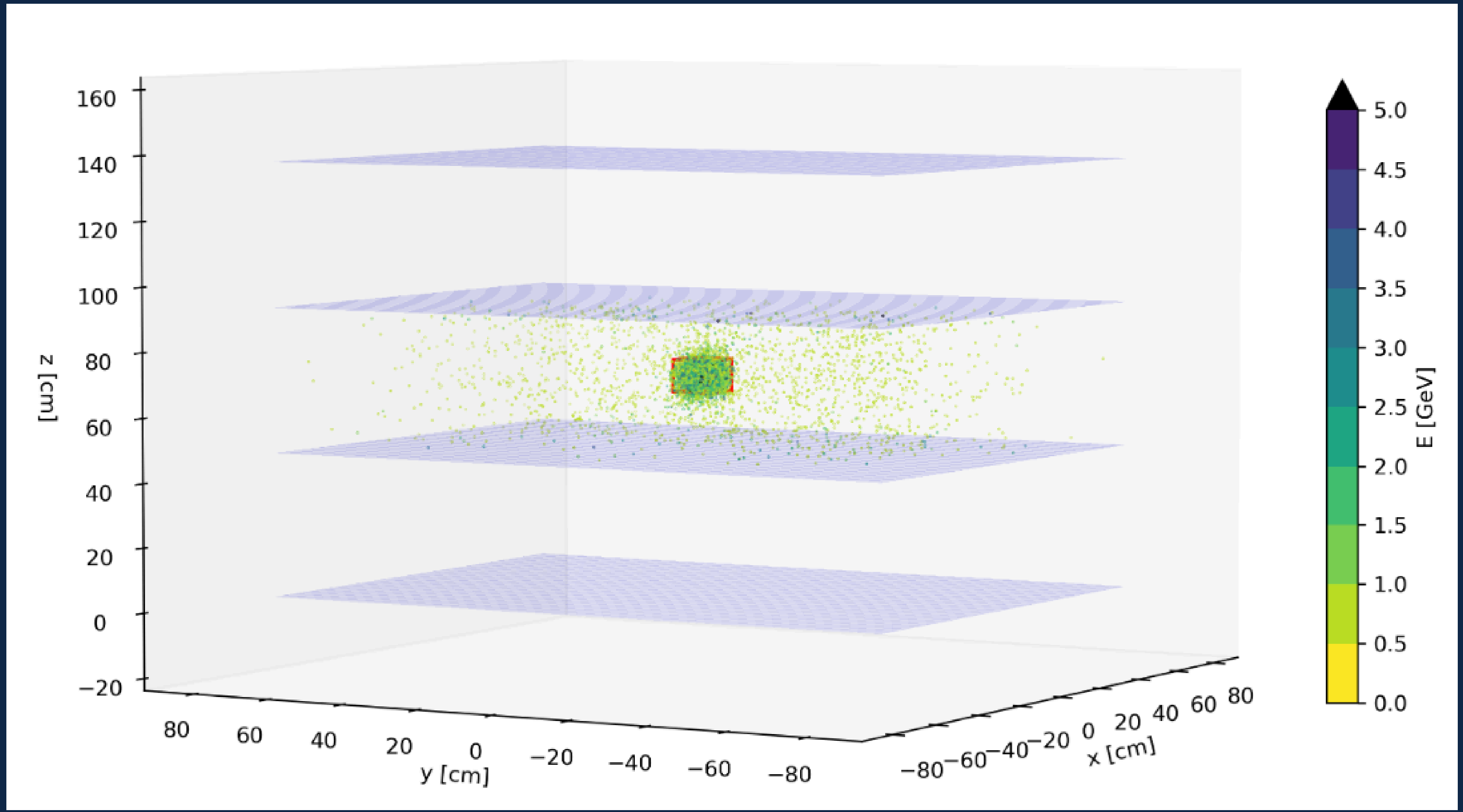


Fig.1 - Example of a tomography image reconstruction with a tungsten volume between the plates

TOMAR Plate Architecture

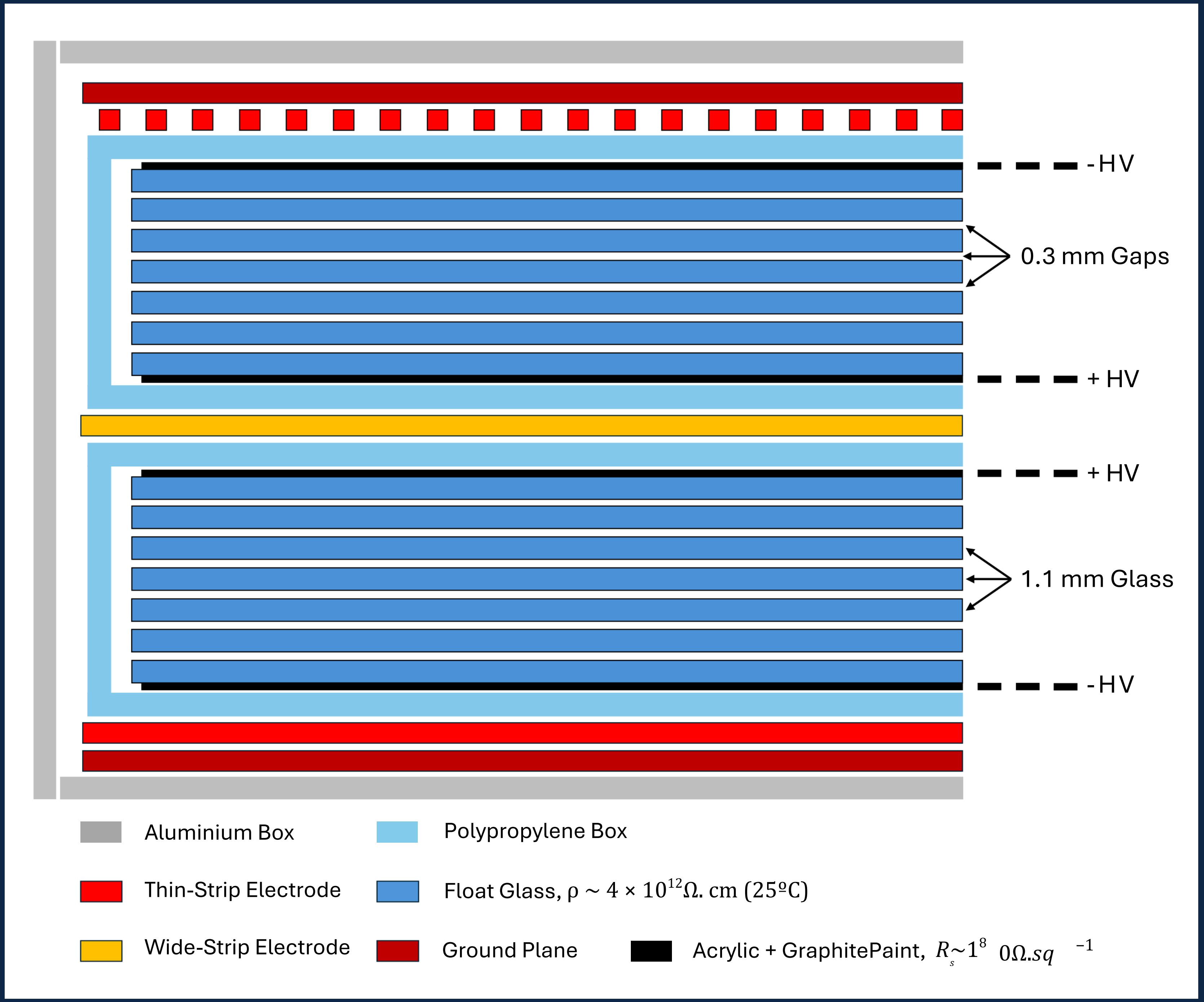


Fig.2 - TOMAR RPC Module Architecture.

Readout Electrodes

Fig.3

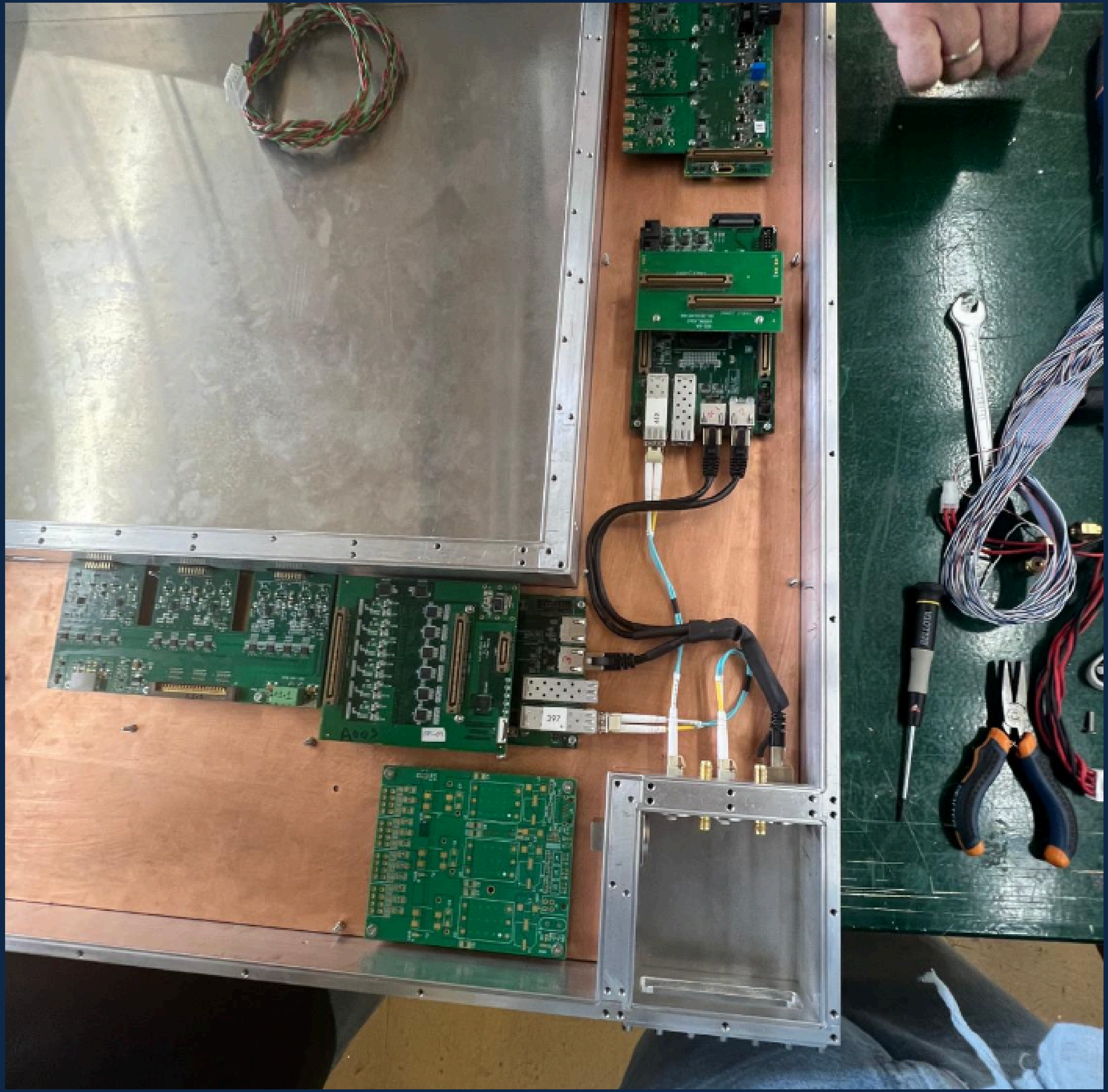
Thin-strip eletrodes

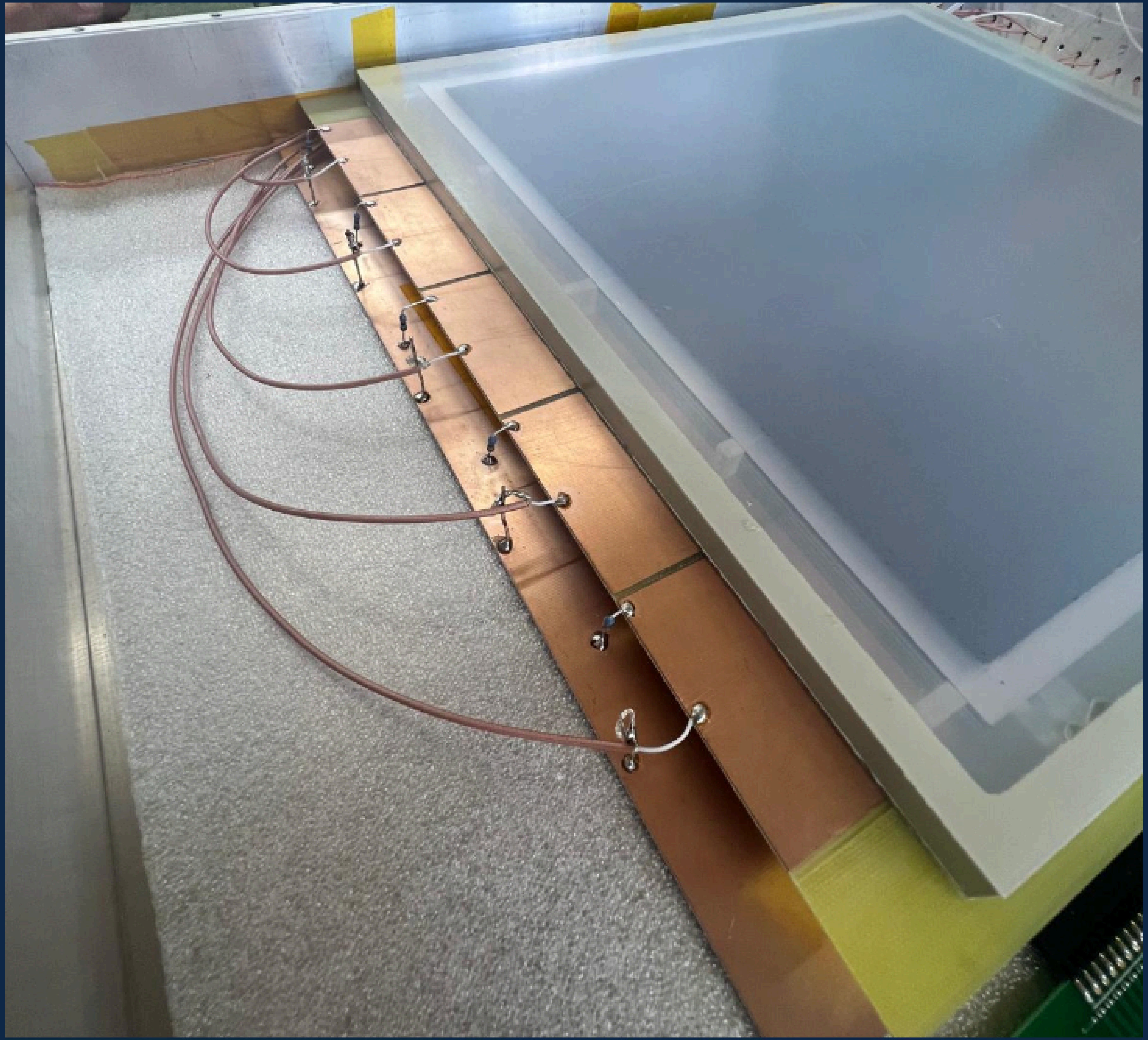
144 strips per side with a 1.5mm pitch. Oriented orthogonally on top and bottom to provide precise X/Y transverse coordinates.

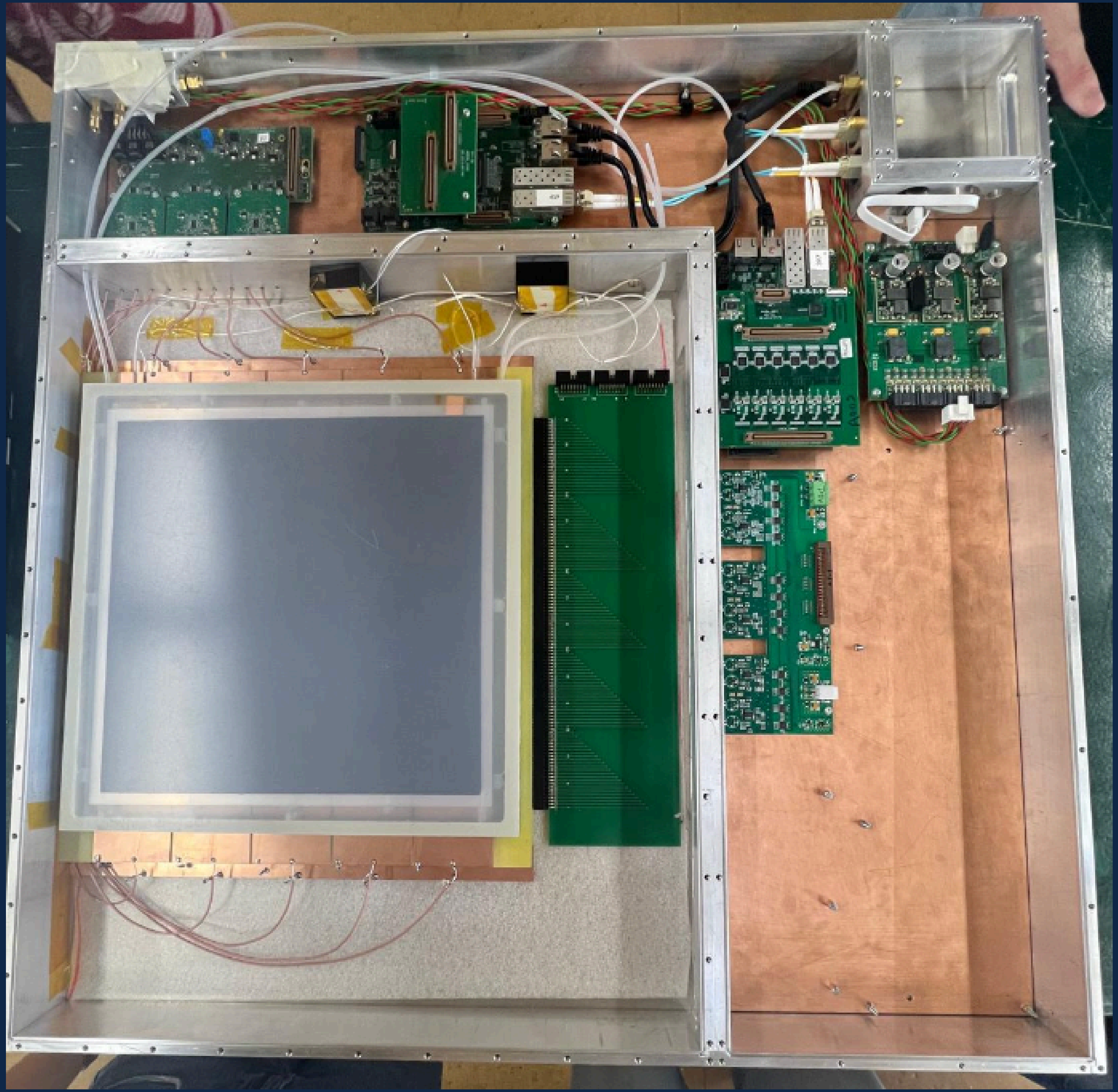
Fig.4

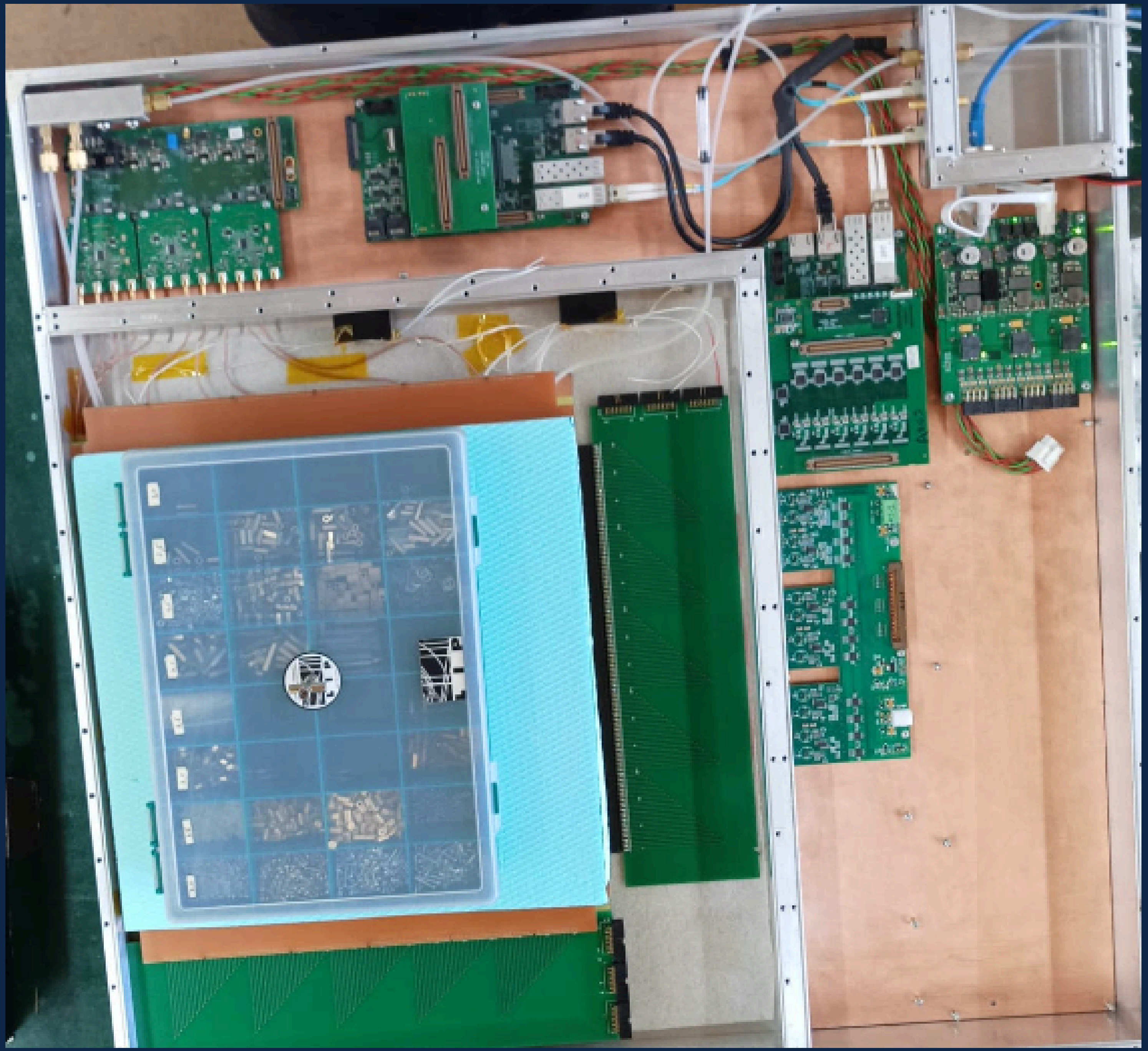
Wide-Strip Electrodes

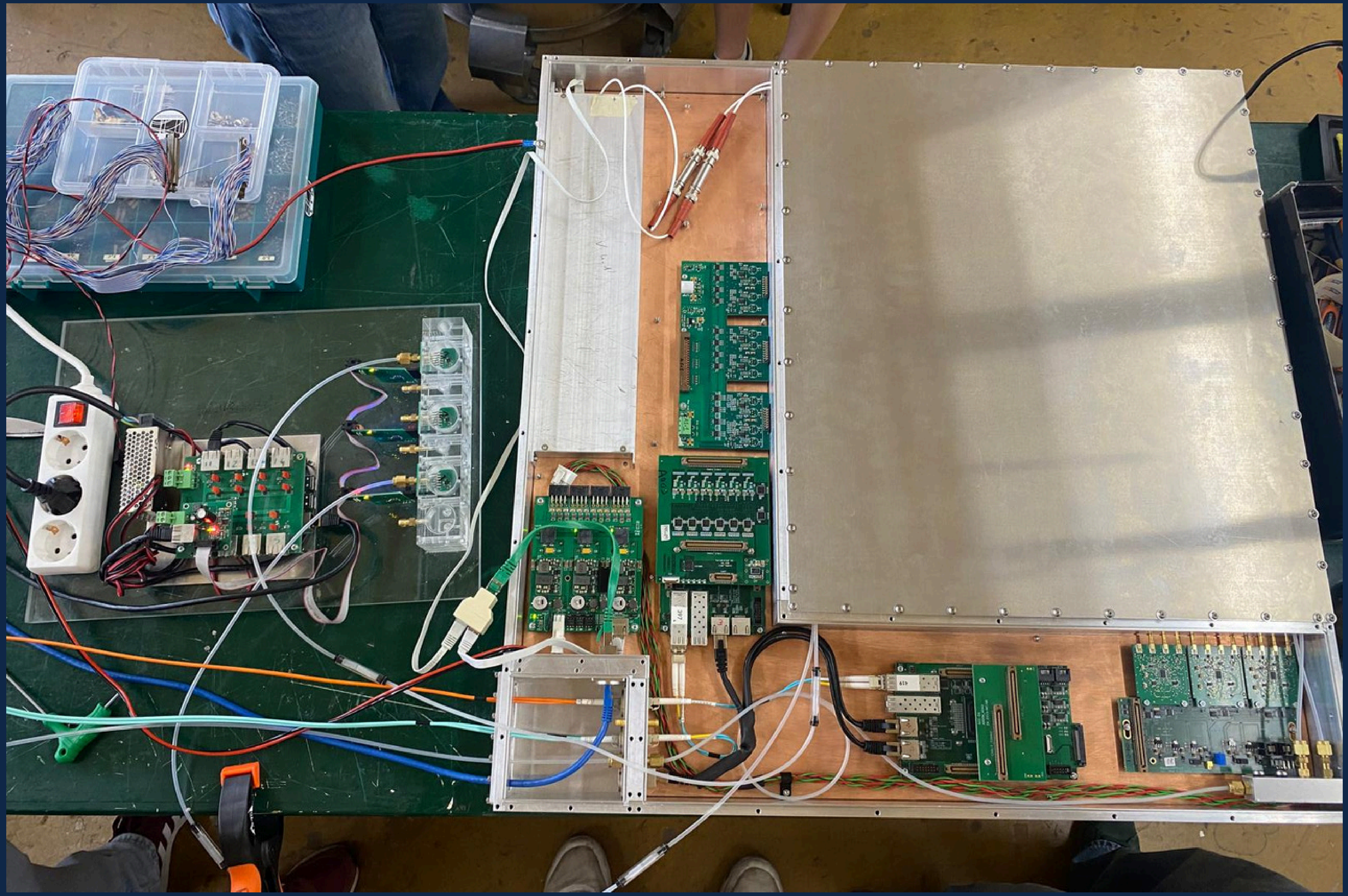
Six central strips for precise timing and charge estimation. Read out from both ends to determine the longitudinal position via signal propagation time.

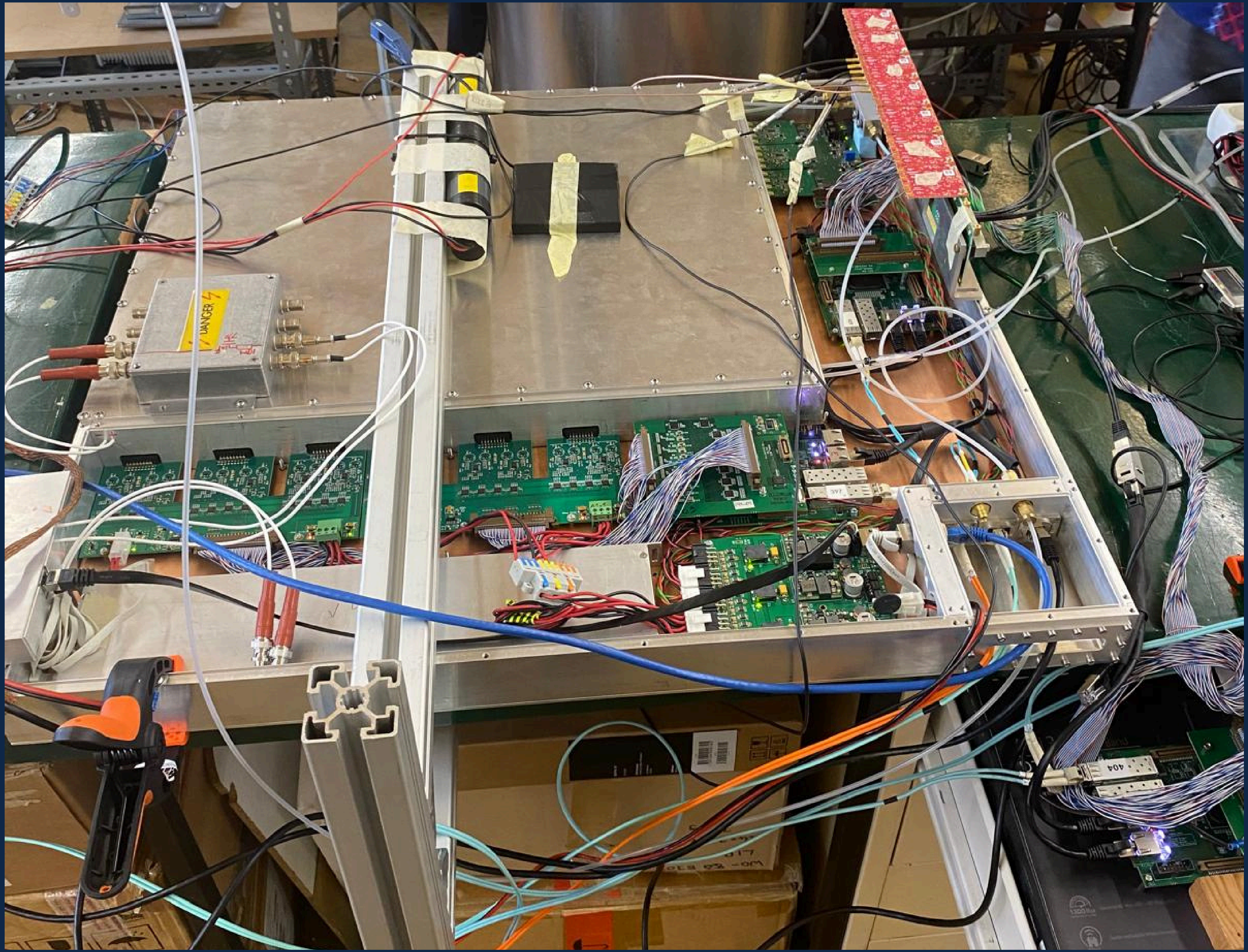












Experimental Setup & Electronics

- High Voltage (HV): I2C controlled power module with three RC filter circuits to reduce electrical noise.
- Low Voltage (LV): Powers every system inside the aluminium box.
- Fast FEE: Current-sensitive amplifiers for wide-strips (timing/charge), interfaced with a TRB-TDC system.
- Slow FEE: Charge-sensitive amplifiers for thin-strips. Uses a Signal Merging PCB (SMPCB) to multiplex analog signals, interfaced with a TRB-ADC system.

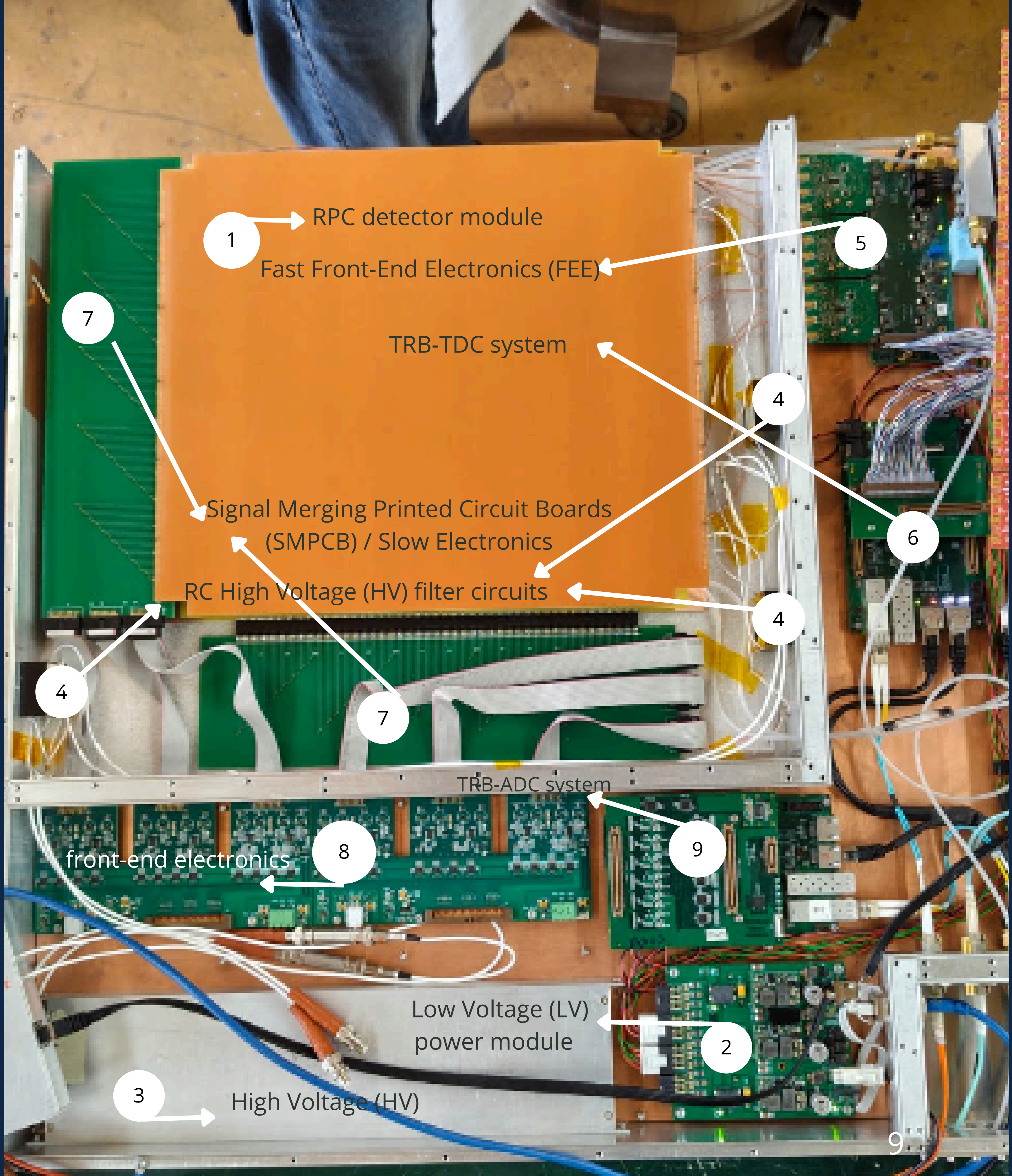


Fig.5 - Experimental setup with caption

Gas Mixture & Trigger Telescope

Operating Gas

- Mixture of Tetrafluoroethane and SF6.
- Tetrafluoroethane provides primary ionization.
- Highly electronegative SF6 captures free electrons, reducing effective gain and suppressing streamer formation.

Muon Telescope

- Two plastic scintillators placed above and below the module.
- Read by Silicon Photomultipliers (SiPMs).
- Central Trigger System (CTS) requires tight time coincidence to validate cosmic-ray muons.

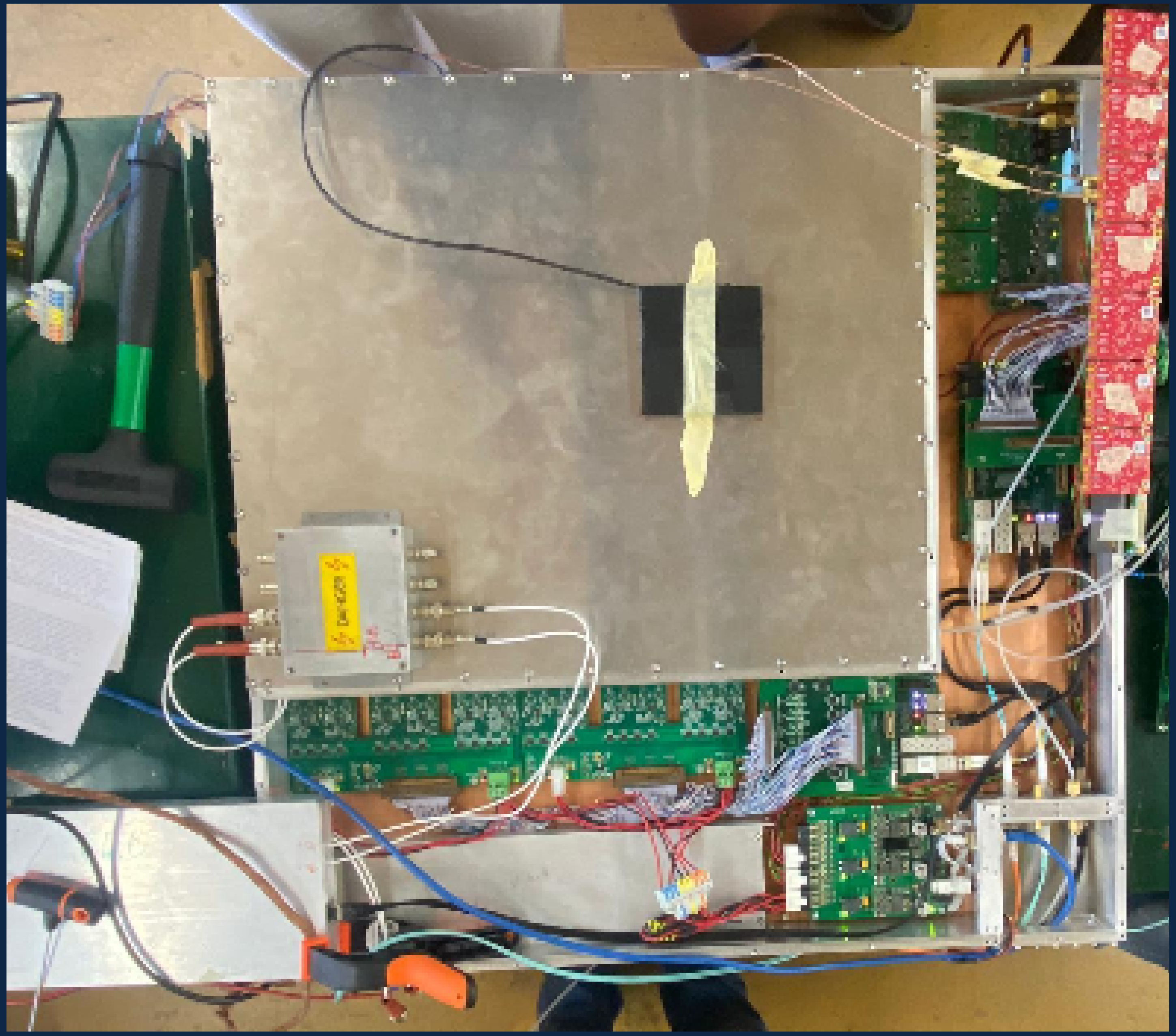


Fig.6 - Plate with a cintillator

Wide-Strip Data Analysis

Charge, Position, and Efficiency Results

Charge Spectra & Avalanche Regime

Charge Estimation

Total charge (Q) is computed from the sum of front and back Time-over-Threshold (TOT) values.

Streamer Identification

While standard avalanches dominate below ~195ns, a logarithmic scale reveals low-probability, high-charge streamer pulses for breakdown analysis.

Uniform Response

Individual charge spectra across strips show a uniform shape and consistent peak positions, demonstrating homogeneous gas gain.

Charge Spectra & Avalanche Regime

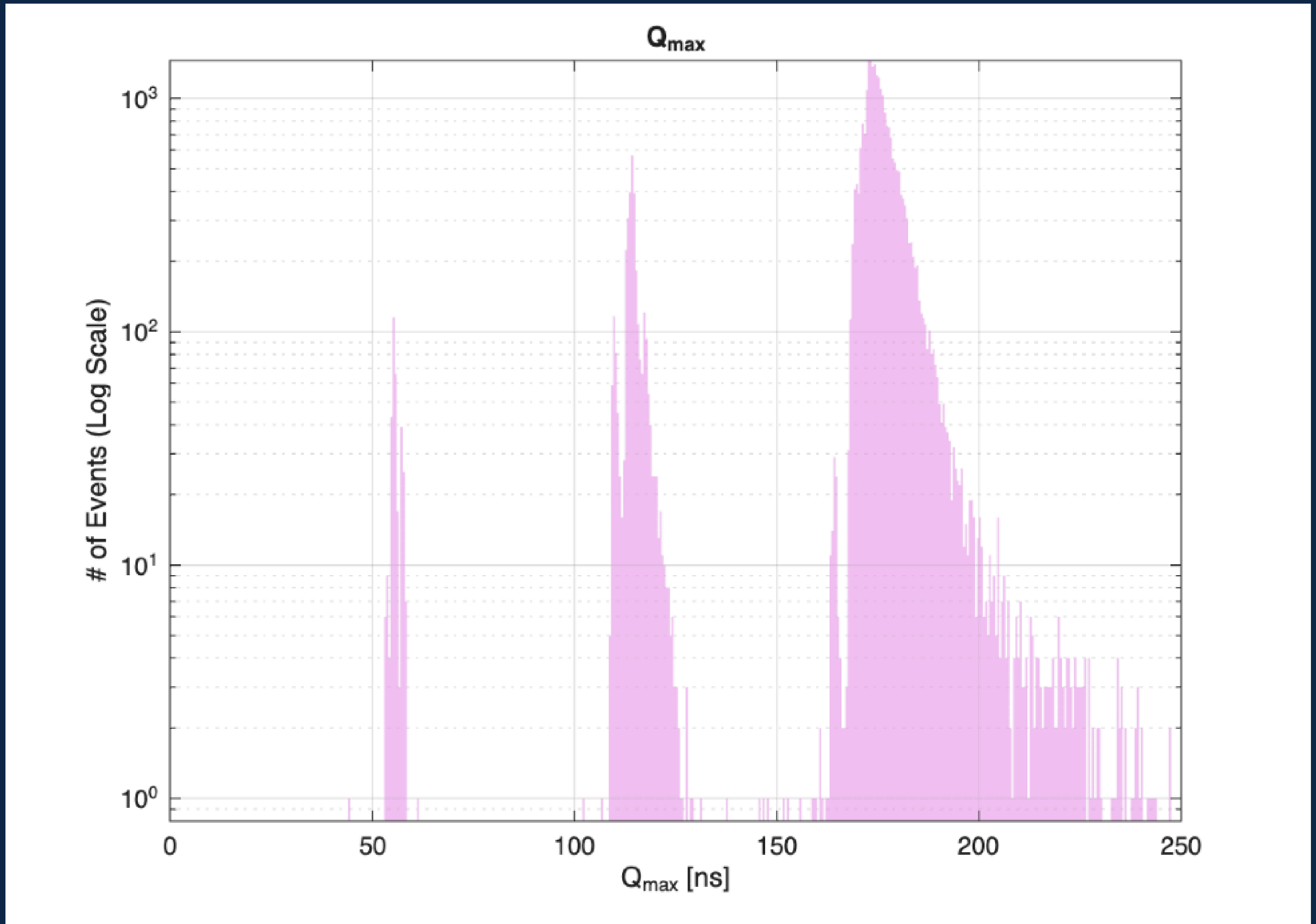


Fig.7 - Distribution of the maximum charge

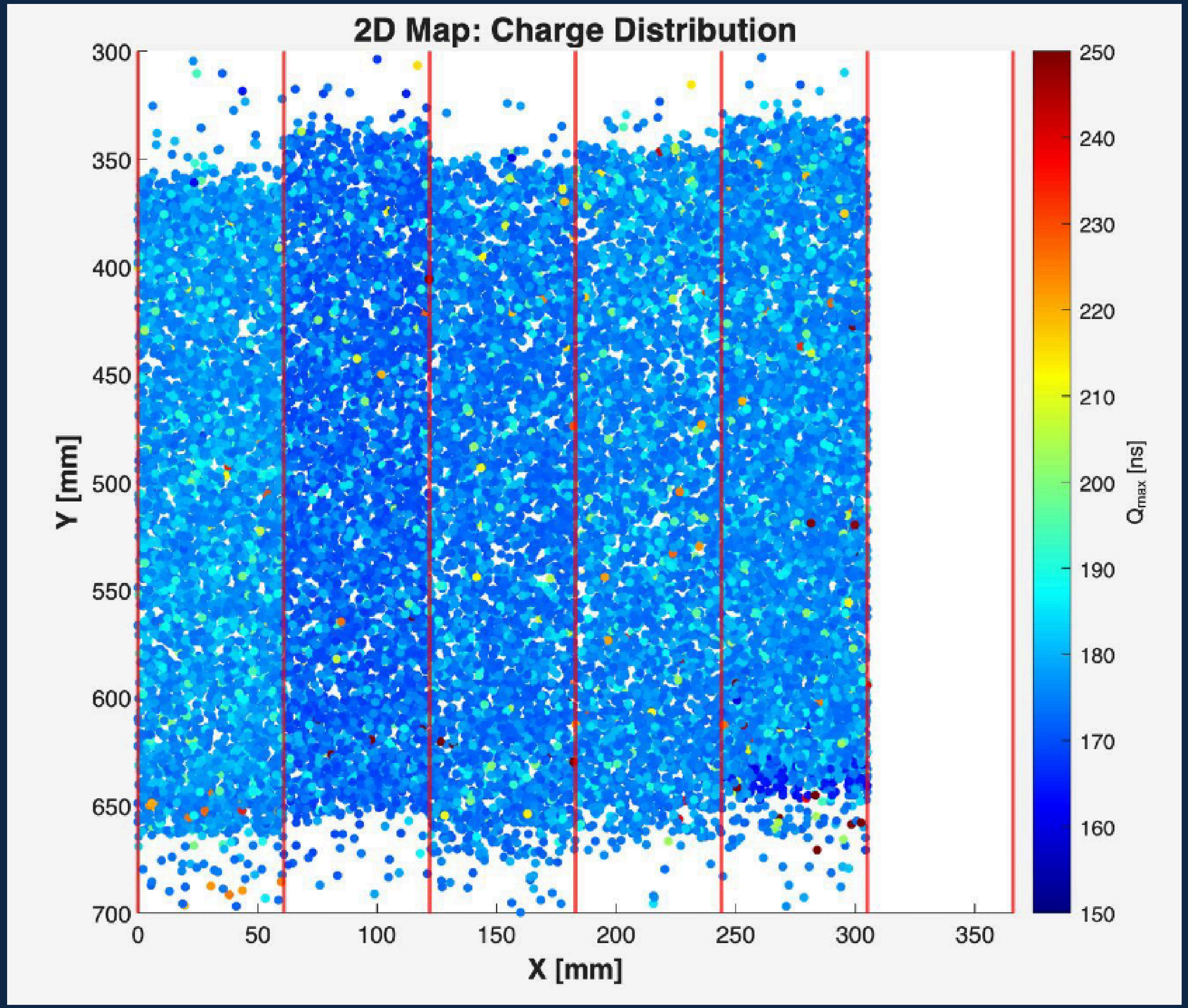


Fig. 8 - 2D reconstruction in self-trigger mode

2D Event Reconstruction

- Y-Axis (Longitudinal): Calculated from the time difference between signal arrivals at both ends of the wide strip.
- Utilizes a calibrated signal propagation speed of 171 mm/ns.
- X-Axis (Transverse): Assigned to the wide strip registering the maximum charge.
- Mapping allows verification of the geometric acceptance window defined by the scintillators.

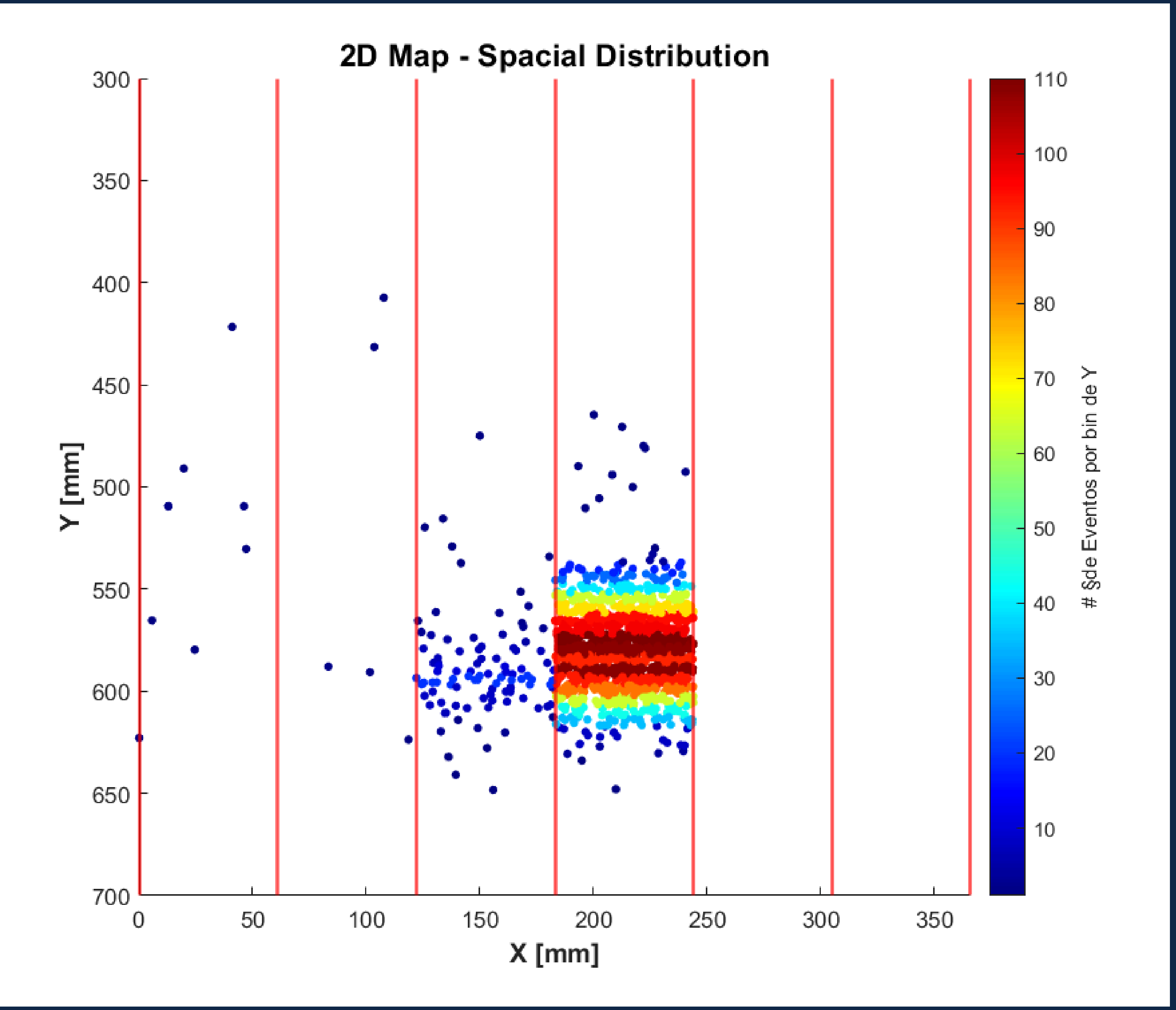


Fig.9 - 2D event reconstruction across the dectector plane in scintillator trigger

High Voltage Efficiency

Efficiency Calculation

- Performance was analyzed using the trigger based on the scintillator telescope. Events were only considered if the cosmic-ray muon passed through both reference scintillators.

$$\varepsilon\,(\%) = \frac{\#\text{ events in RPC}}{\#\text{ events in 2 Scintillators}} \times 100$$

>90%

Efficiency

at 8.9 kV Applied Voltage

Thin-Strip Data Analysis (Next Steps)

Charge Profile Characterization

Signal spreads across multiple channels, modeled as a continuous charge profile

Position resolved via charge centroid + cross-check with coarse wide-strip position

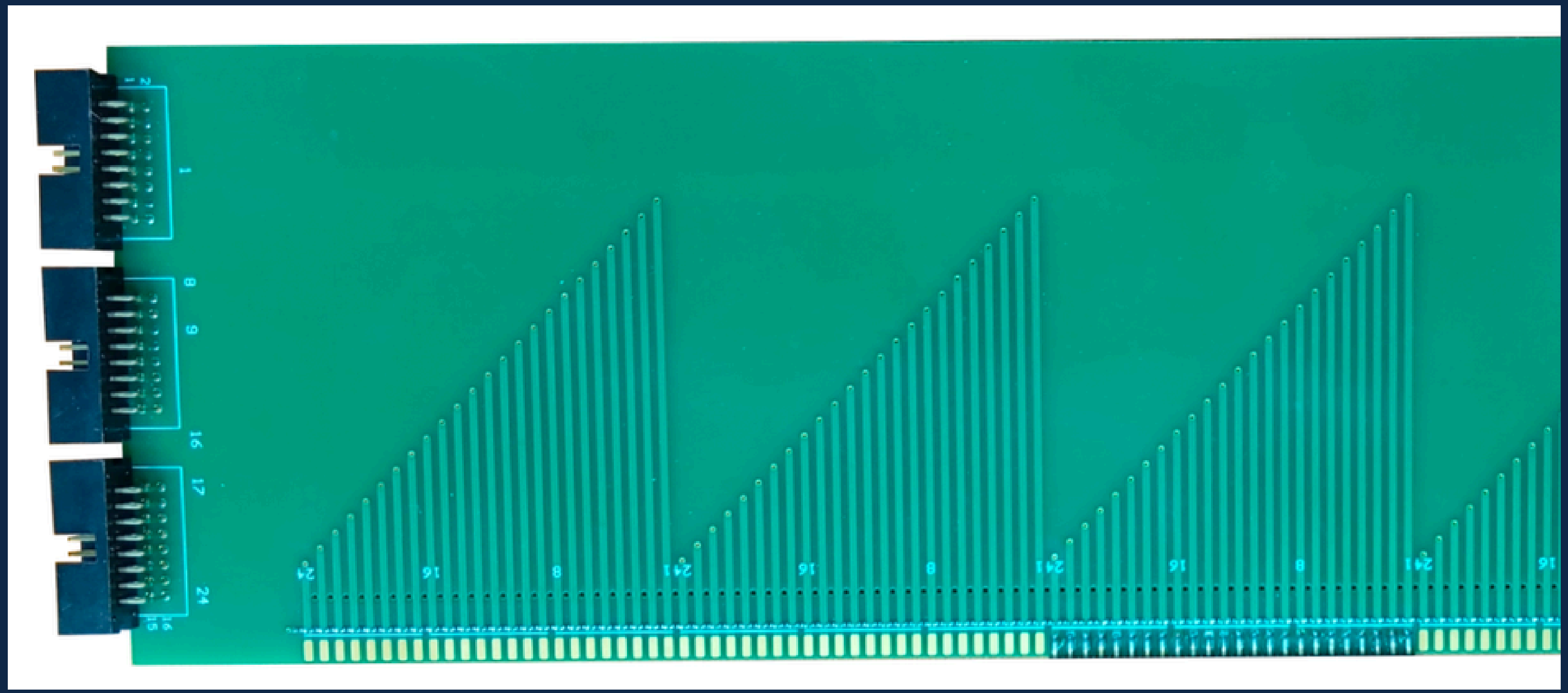
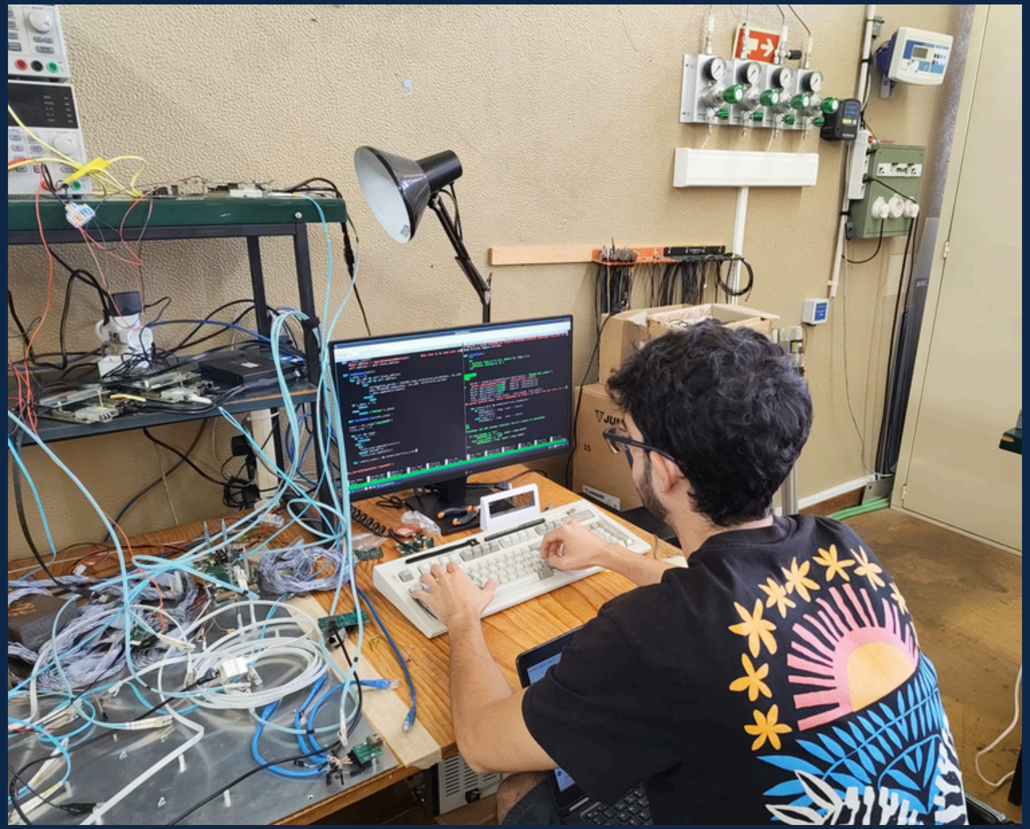


Fig. 10 - Signal Merging Printed Circuit Board (SMPCB) connecting thin strips in parallel



Thank You!

Questions?

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