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UNIVERSIDADE D COIMBRA

LIP
LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS

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Characterisation of Sealed RPC Chambers

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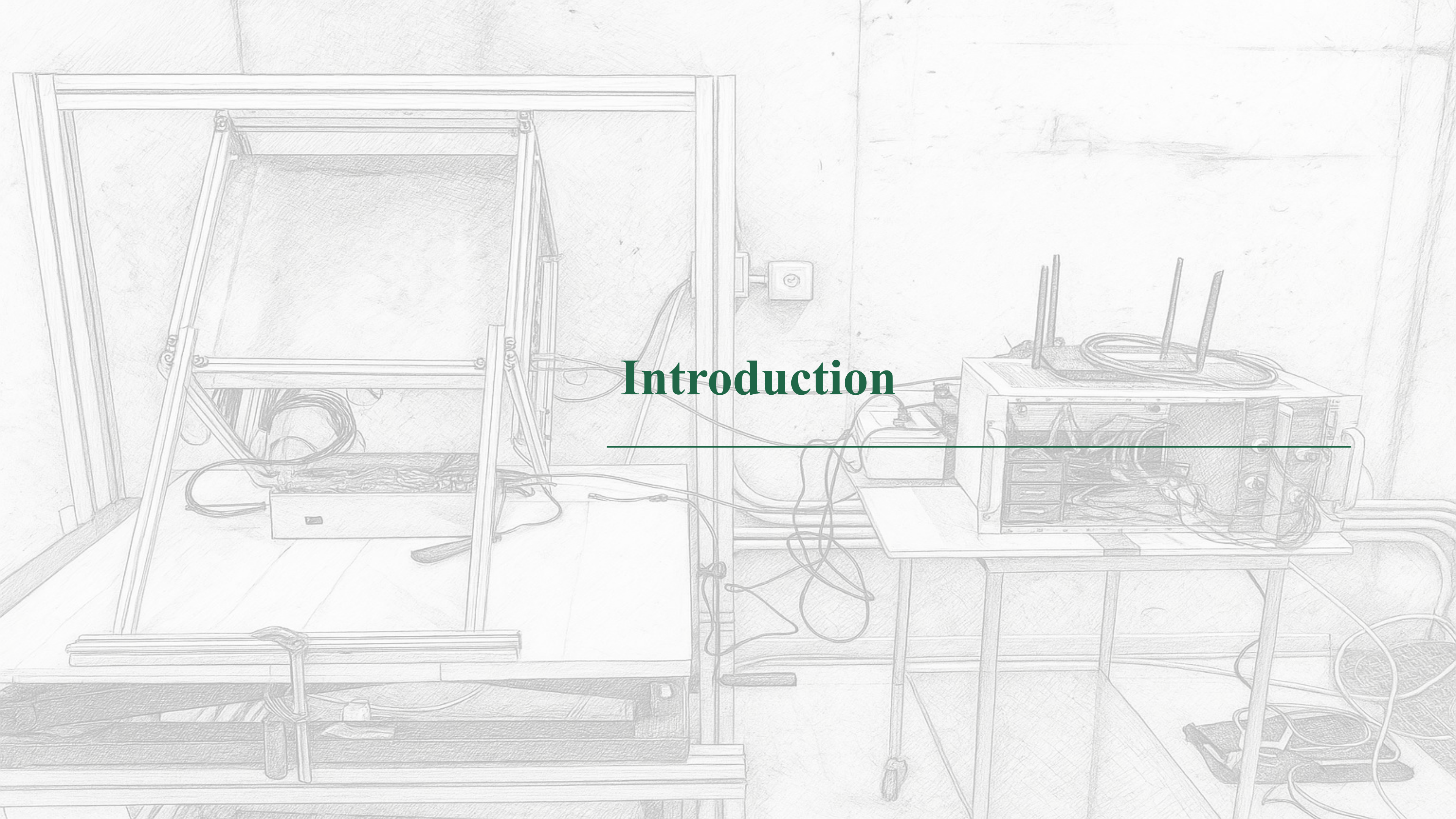
Introduction



RPCs - Resistive Plate Chambers

- Are widely used particle detectors
- Excellent performance and high time resolution
- Low construction cost

Traditional RPCs require continuous gas flow of hydrofluorocarbons (HFCs), which have high global warming potential and require special gas systems.

Sealed RPCs

Sealed RPCs (sRPCs) are *hermetically sealed*, so they don't require continuous gas flow. This makes sRPCs more eco-friendly and easier to operate.

HOWEVER:

Their performance can be affected by changes in temperature and pressure.

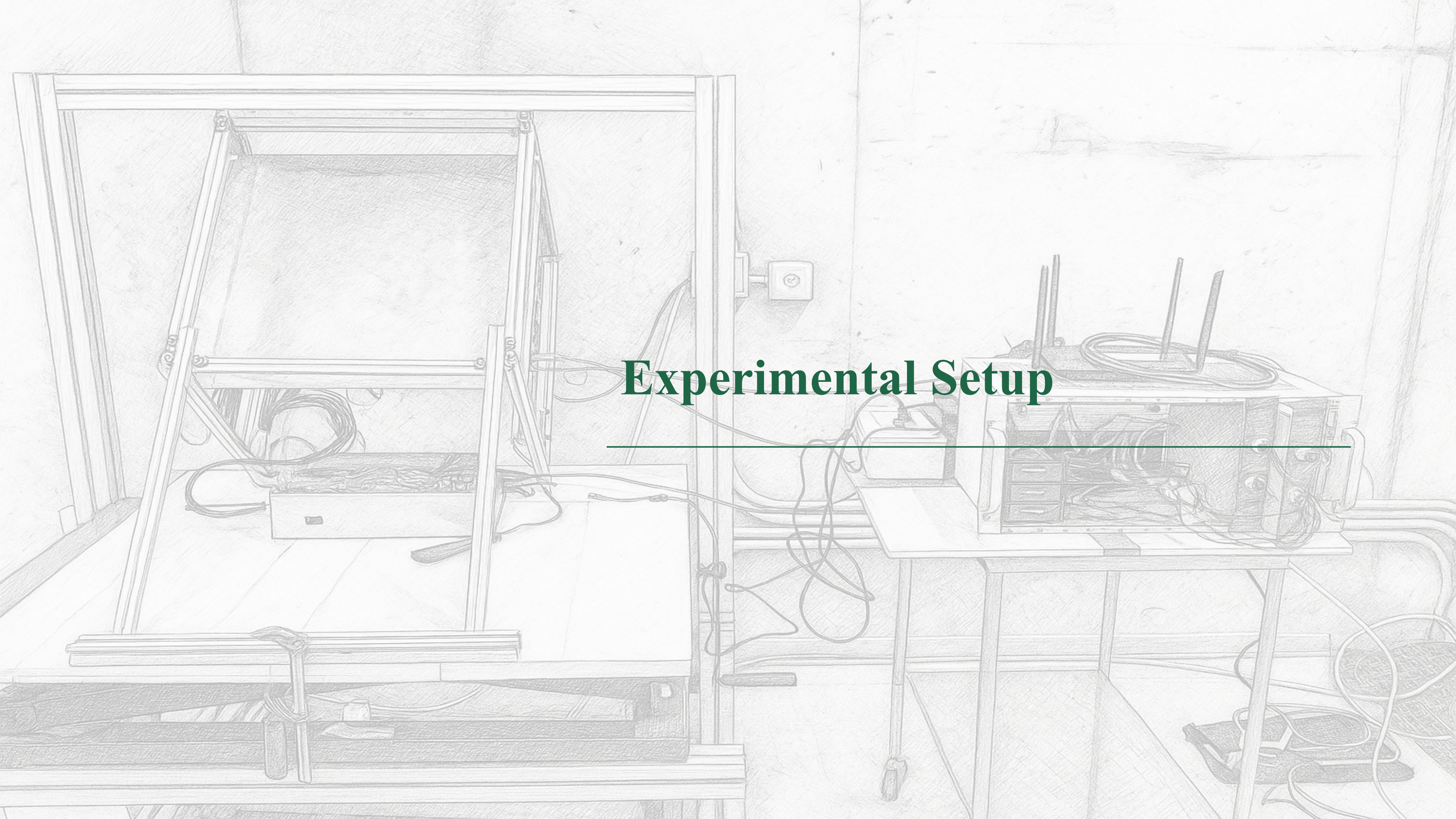
Goals

- Characterize the **performance of sealed RPC** under real conditions for cosmic ray detection;

- Evaluate the **stability and efficiency** of the sealed RPCs over time, without a continuous gas renewal system;

- Investigate the **environmental effects** (temperature, pressure, humidity) on the performance of sealed Resistive Plate Chambers (sRPC).

Experimental Setup



The sRPC Gaseous Detector

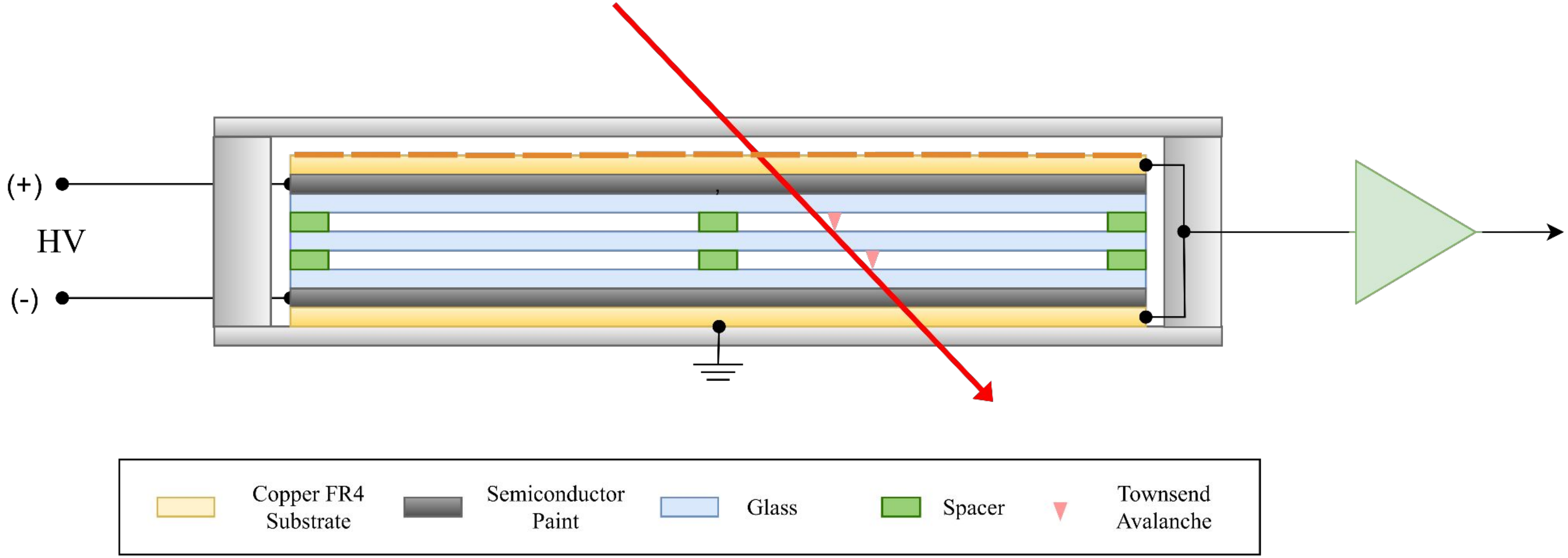


Figure: Sketch of the inner structure of the sRPC module [1].

Assembly of RPC detector

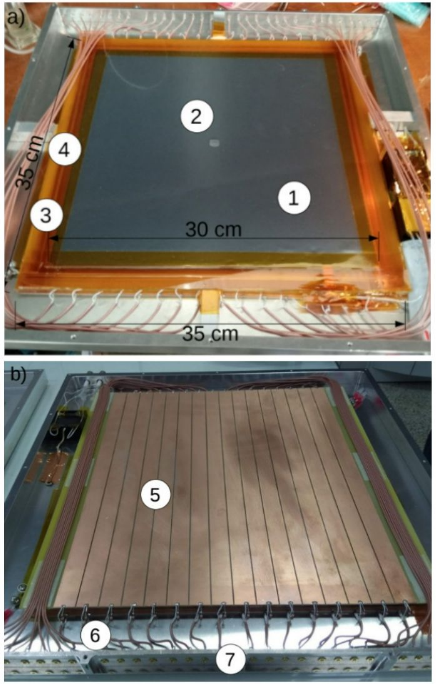
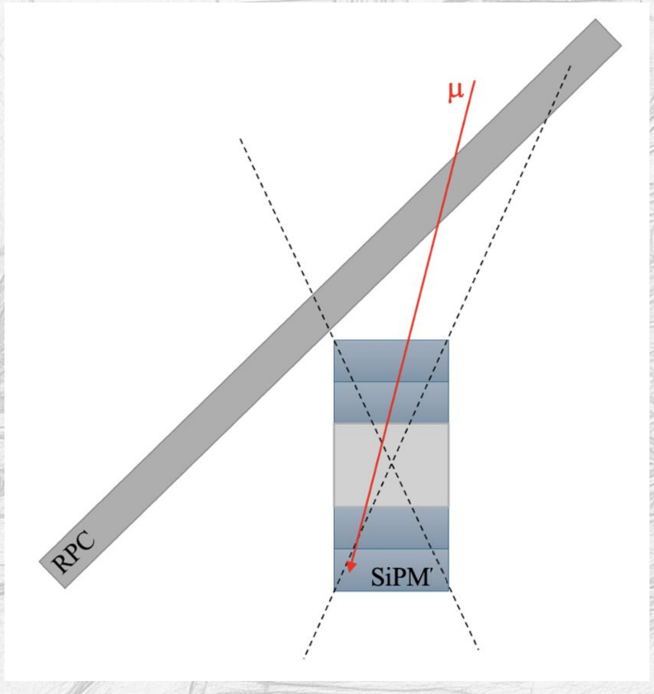


Figure: The interior of the sRPC [1].

- Components of RPC detector:

1. HV Layer;
2. Central spacer;
3. Strip spacer;
4. Mylar and Kapton layers;
5. Readout strip plane;
6. Coaxial cables;
7. MMCX RF connectors.

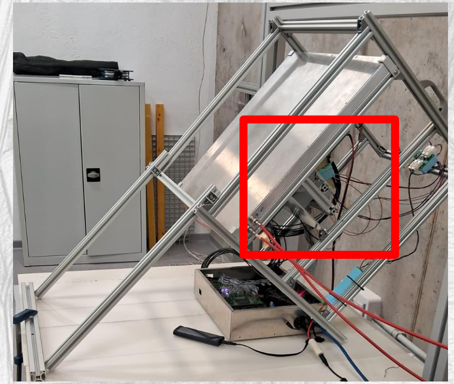
Setup Detection: Muon Telescope



Components of the Muon Telescope:

- 1 sRPC;
- 4 SiPMs;
- Polystyrene Block.

Location of SiPMs



Components of RPC detector

1. sRPC;
2. SiPMs;
3. Aluminium Structure;
4. DAQ;
5. Extra Unit nVMe M.2 SSD.

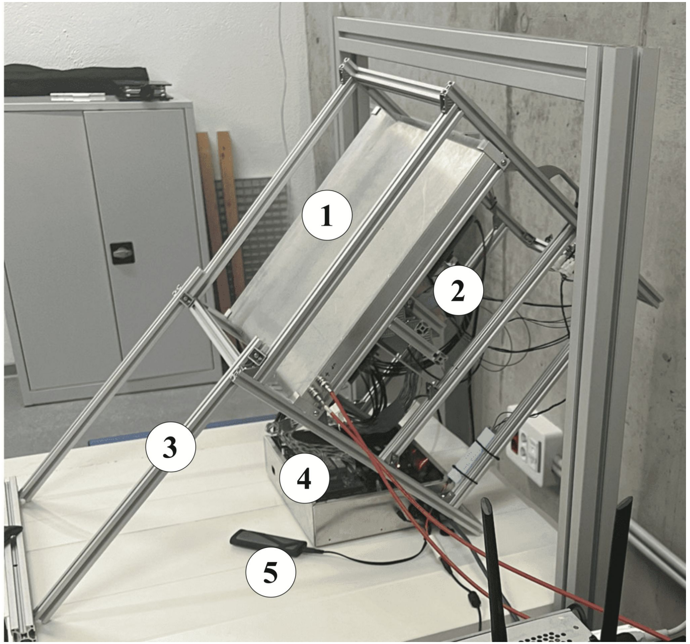


Figure: Assembly of setup sRPC. 1. sRPC; 2. SiPMs; 3. Aluminium Structure; 4. DAQ; 5. Extra Unity nVMe M.2 SSD[1].

Assembly of RPC detector

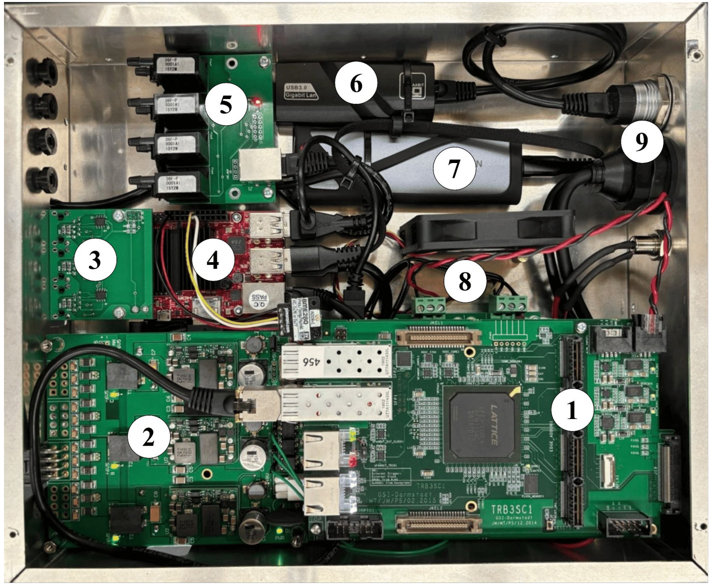
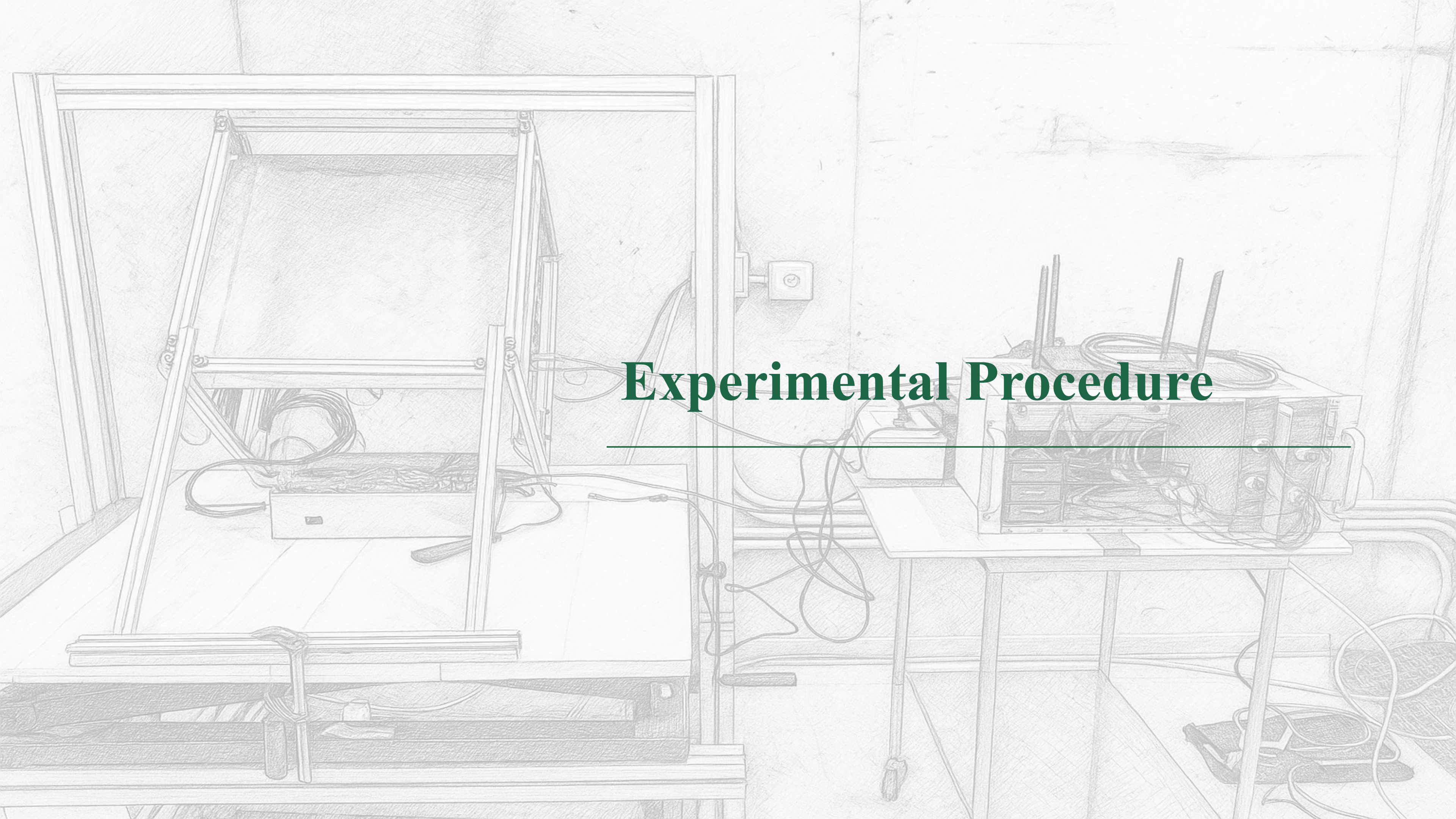


Figure: DAQ system and intern circuits [2].

- Components of FEE:

1. FPGA Board TRB3SC;
2. LV Power System;
3. I2C Board;
4. Mini-PC;
5. Gas Sensor Module;
6. USB Adapter Ethernet;
7. NVMe M.2 SSD;
8. Relay Control Board;
9. Power and computer connections.

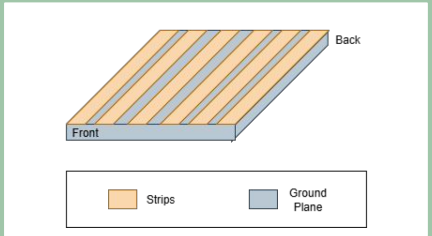


Experimental Procedure

Signal Readout and Key Quantities

sRPC strips read out from both ends via Front-End Electronics (FEE). Independent "front" (F) and "back" (B) signals are obtained in each channel, then the average time and charge per strip is calculated:

$$T = (T_F + T_B)/2 \qquad Q = (Q_F + Q_B)/2$$



To determine the two-dimensional position of each particle in the sRPC:

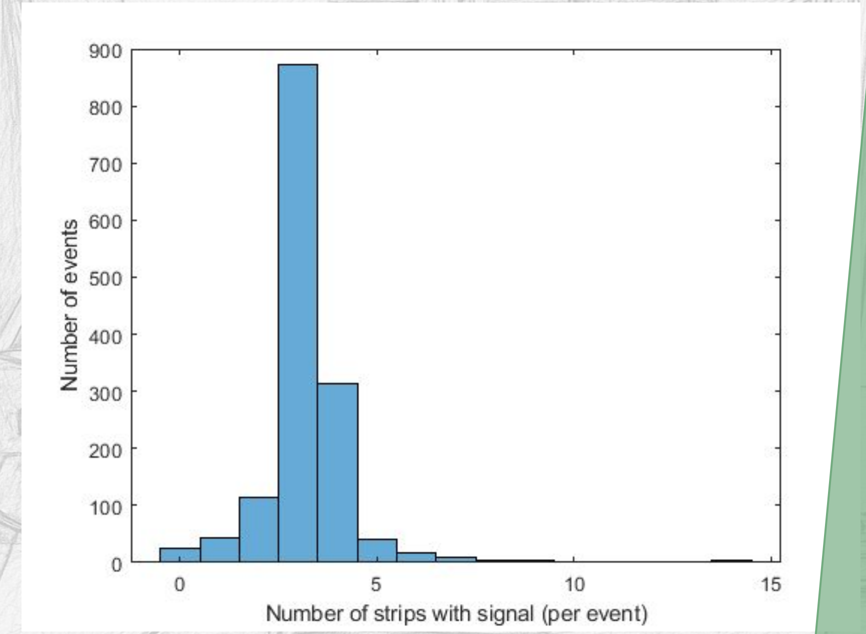
- Position X: strip with maximum charge;
- Position Y: calculated using the time difference between the front and back signals:

$$Y = v \cdot (T_F - T_B)$$

, with propagation velocity of

$$v = 165\ mm/ns$$

Multiplicity Analysis



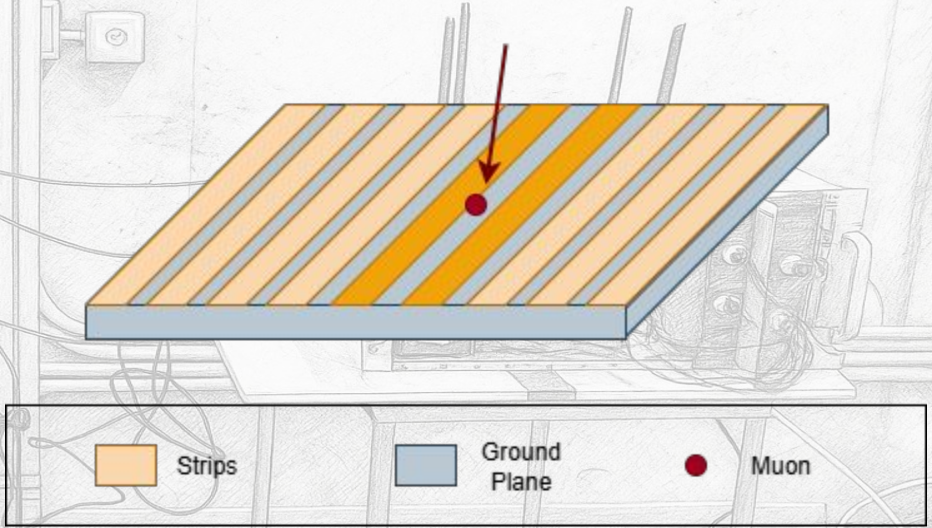
- Multiplicity = number of strips registering a signal per event.
- Most events show signals in 3 or 4 strips due to charge spreading and capacitive coupling.
- Electronic crosstalk causes small signals in adjacent strips.
- Events with very high multiplicities are rare and usually associated with noise and crosstalk.

Sum of the two maximum charges

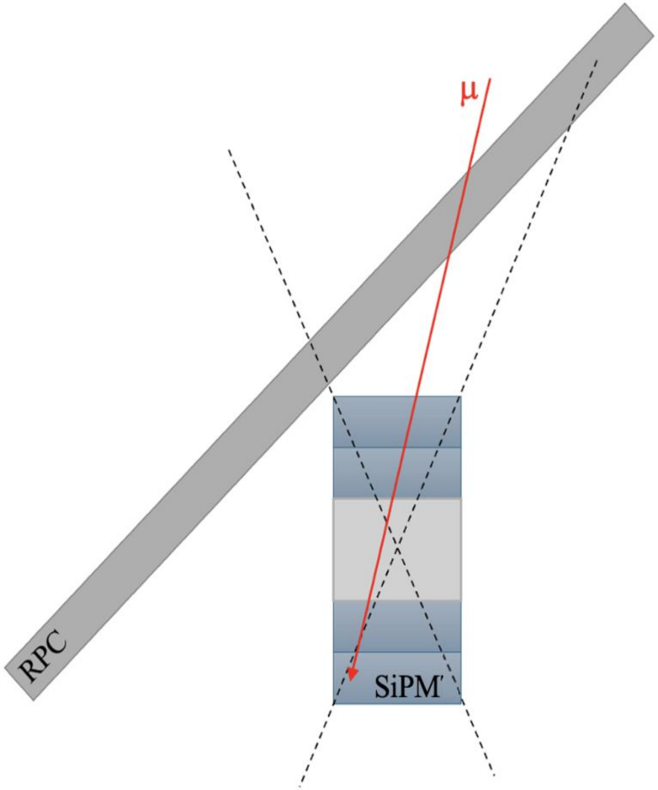
Total charge induced per event

↓

Sum the charges of the two strips with the strongest signal



The inclusion of more than two strips has been tested, but the extra contributions are noise or crosstalk.



Muon selection and Efficiency

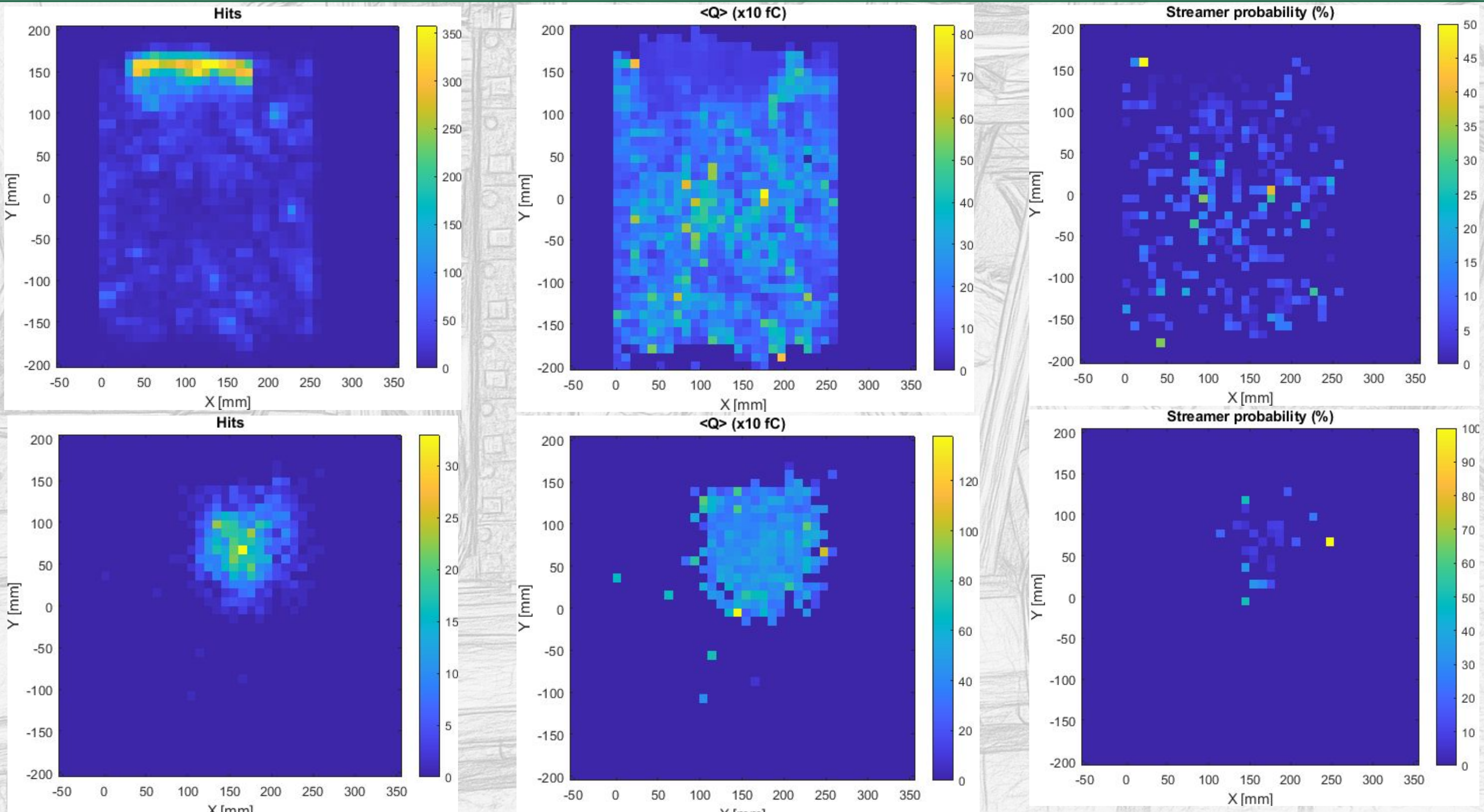
3 types of filtration

- Multiplicity four
- Time difference cut
- Charge cut to avoid scintillator edges

$$\varepsilon\,(\%) = \frac{\#\text{ events in RPC}}{\#\text{ in 4 Scintillators}}$$

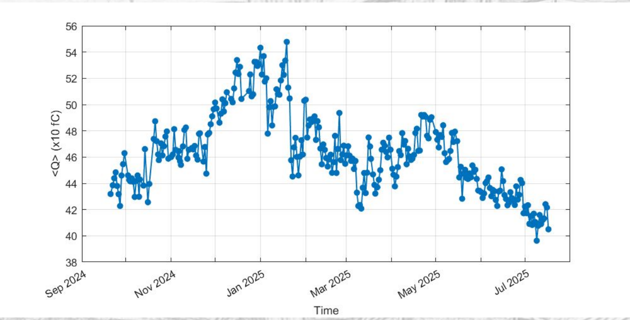
≈ 98 %

Performance Maps

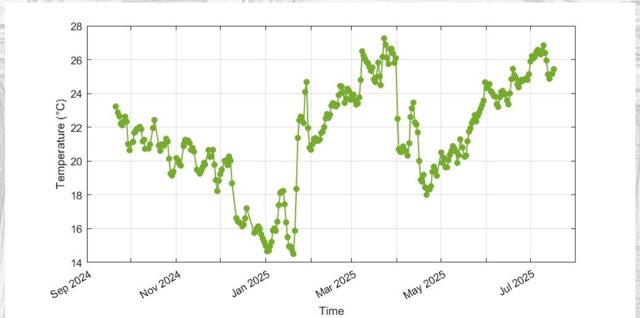


Results

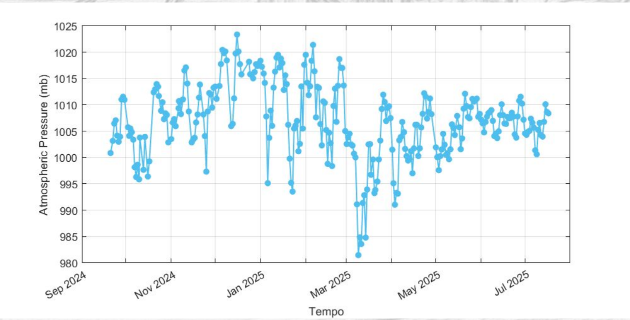
Charge, Temperature, Pressure, Humidity Relat.



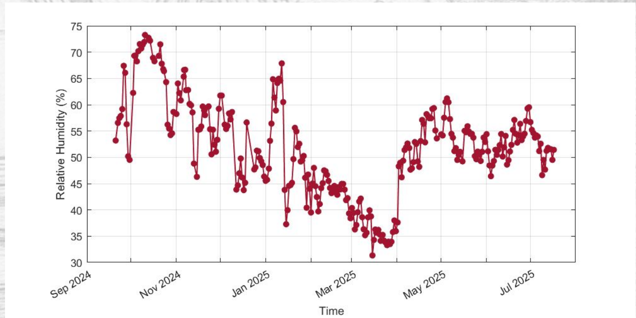
(a) Charge distribution



(b) Temperature (ºC)

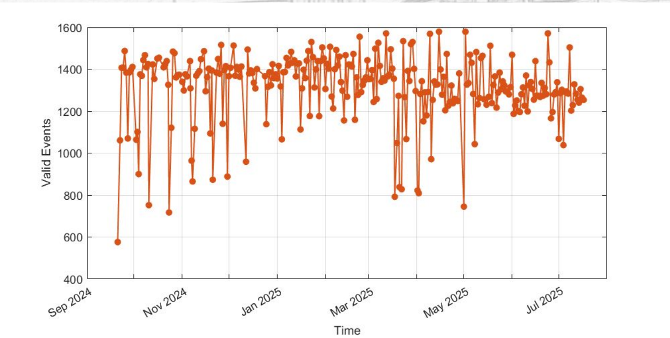


(c) Pressure (mbar)

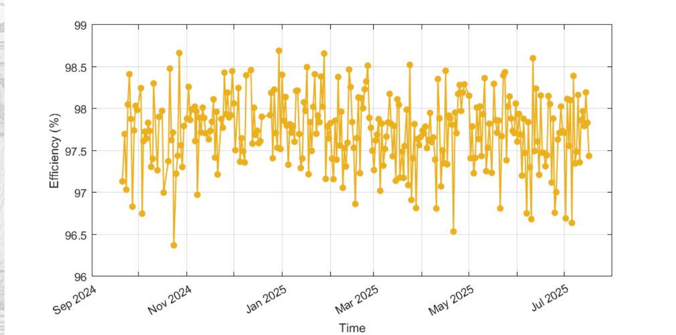


(d) Humidity relativity (%)

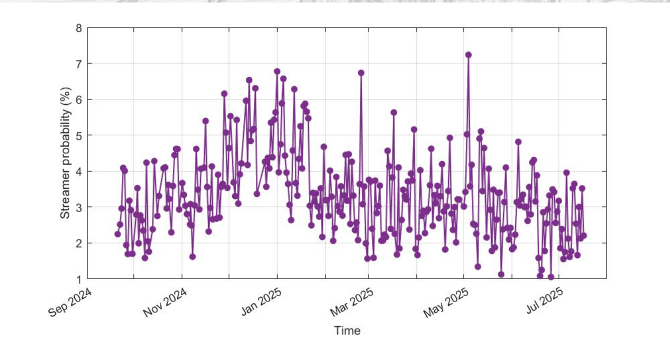
Valid Events, Efficiency, Streamer Probab. and Rate.



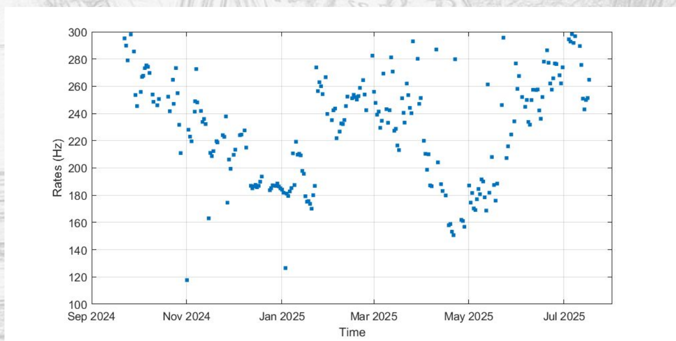
(a) Valid Events



(b) Efficiency (%)



(c) Streamer probability (%)



(d) Rates (Hz)

Environmental behavior of sRPC's and RPC's

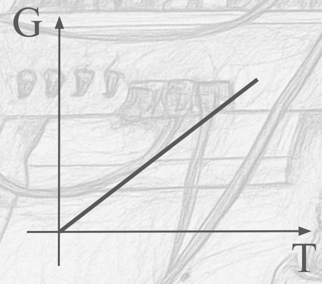
Non-sealed RPC

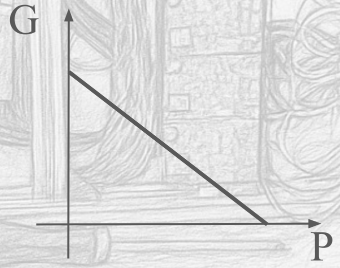
- **For Pressure and Volume constant:**

$$T\uparrow:\ n\downarrow N\downarrow \frac{E}{N}\uparrow G\uparrow$$

- **For Temperature and Volume constant:**

$$P\uparrow:\ n\uparrow N\uparrow \frac{E}{N}\downarrow G\downarrow$$



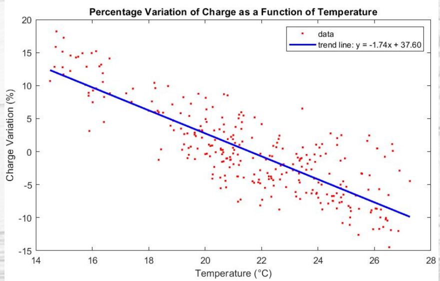


**** E = V/d ; G ~ E/N**

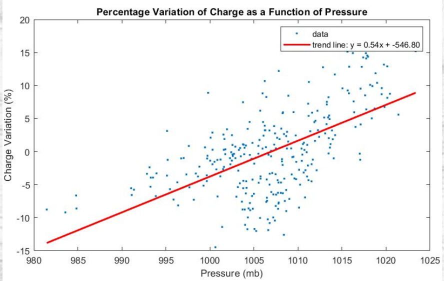
Sealed RPC

$$T\uparrow:\ P_{in}\uparrow V_{in}\uparrow d\uparrow E\downarrow G\downarrow$$

$$P_{out}\uparrow:\ P_{in}\uparrow V_{in}\uparrow d\downarrow E\uparrow G\uparrow$$



Correlation between Temperature and Charge (y = - 1.74x +37.60)

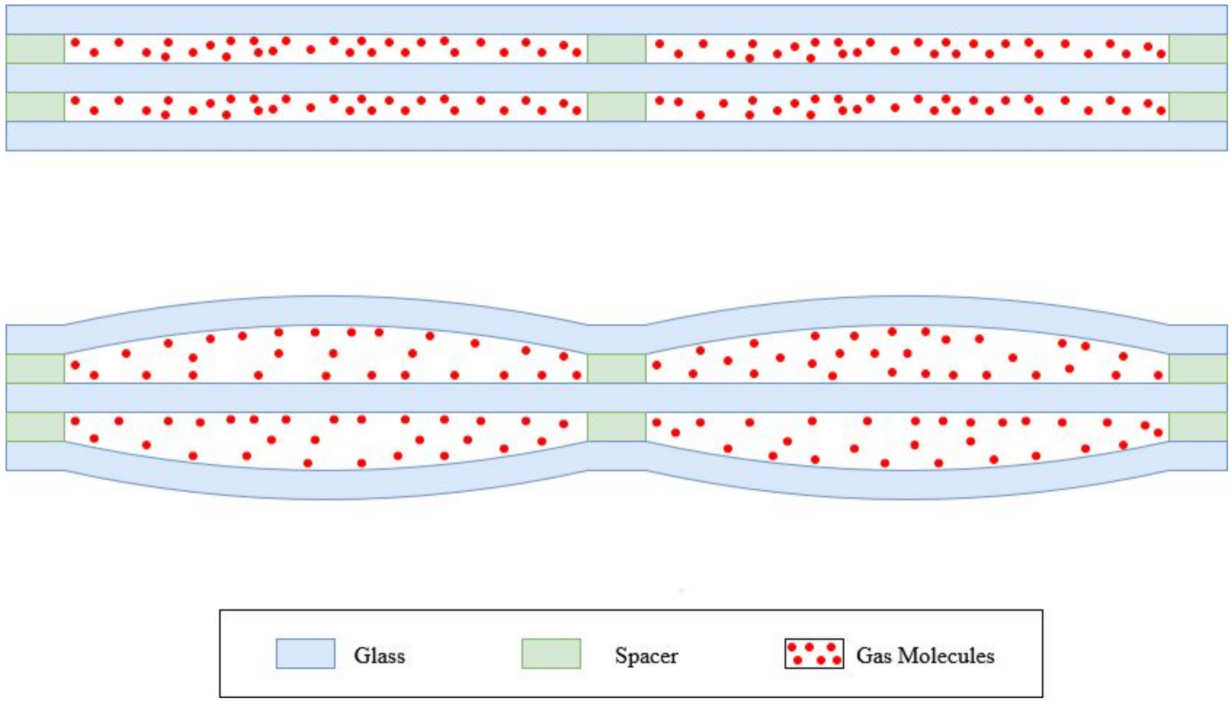


Correlation between Pressure and Charge (y = 0.54x - 546.80)

Gas density variation with Pressure and mechanical deformation

$P_{EXT} = P_{INT}$

$P_{EXT} < P_{INT}$



Conclusion

- The sRPCs showed stable operation and high efficiency (~98%) over a one-year period.
- Performance is strongly correlated with temperature and pressure, affecting mean charge and event rates.
- The detector demonstrates robustness and long-term stability with high efficiency. However, the average charge induced in the detector shows an inverse correlation with temperature and a direct correlation with atmospheric pressure.
- Being a preliminary study, future work will focus on long-term stabilization strategies, which will also allow for a clearer understanding of the effects of temperature and pressure on the sRPCs.


Thank you !

References

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