Characterization of sealed RPCs under strong irradiation source

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LIP

Providing context and motivation

RPCs - Particle Gaseous Detectors

- Excellent performance
- High time resolution
- Low construction cost

Rely on the purity of the gas to keep their performance stable

But there's may be degradation of gas purity

- leaks and permeability in the system that allow atmospheric gases and humidity to enter
- the release of HFCs

- purification and cleaning systems are needed
- the release of HFCs are bad for the environment - greenhouse gas

Providing context and motivation

WE NEED TO:

develop RPCs that contain gas but are hermetically sealed after construction: **SRPCs - sealed RPCs -** verifying that they are efficient and that there are no problems with gas contamination or degradation

sRPC Structure and Operation

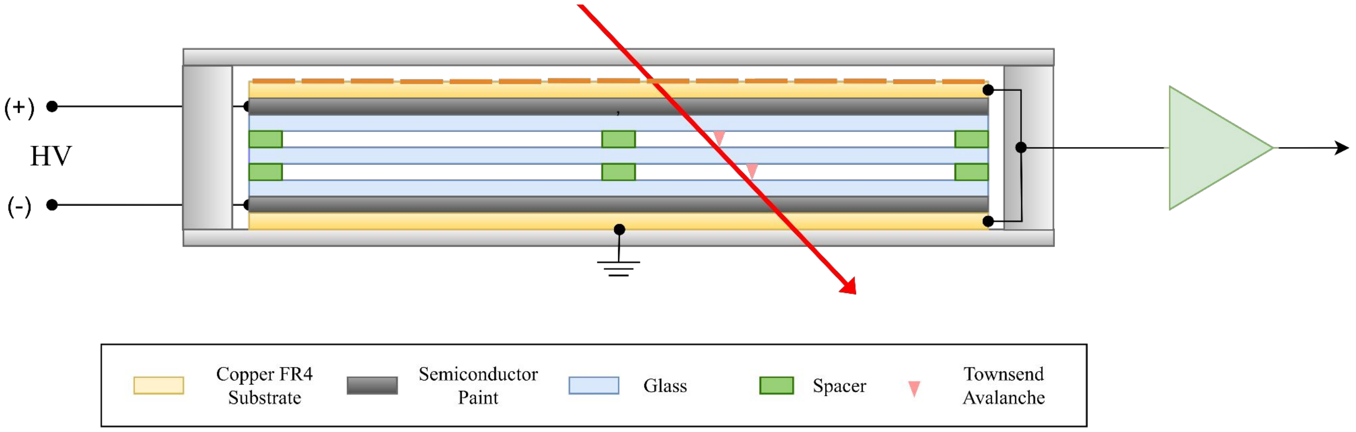


Fig. 1 - Assembly of sRPC.

1. A particle passes through the RPC and interacts with the gas atoms;
2. The electrons are knocked out of the gas atoms and free electrons are created;
3. Then they collide with other gas atoms, causing a chain reaction - "avalanche" where many more electrons are generated.

sRPC Structure

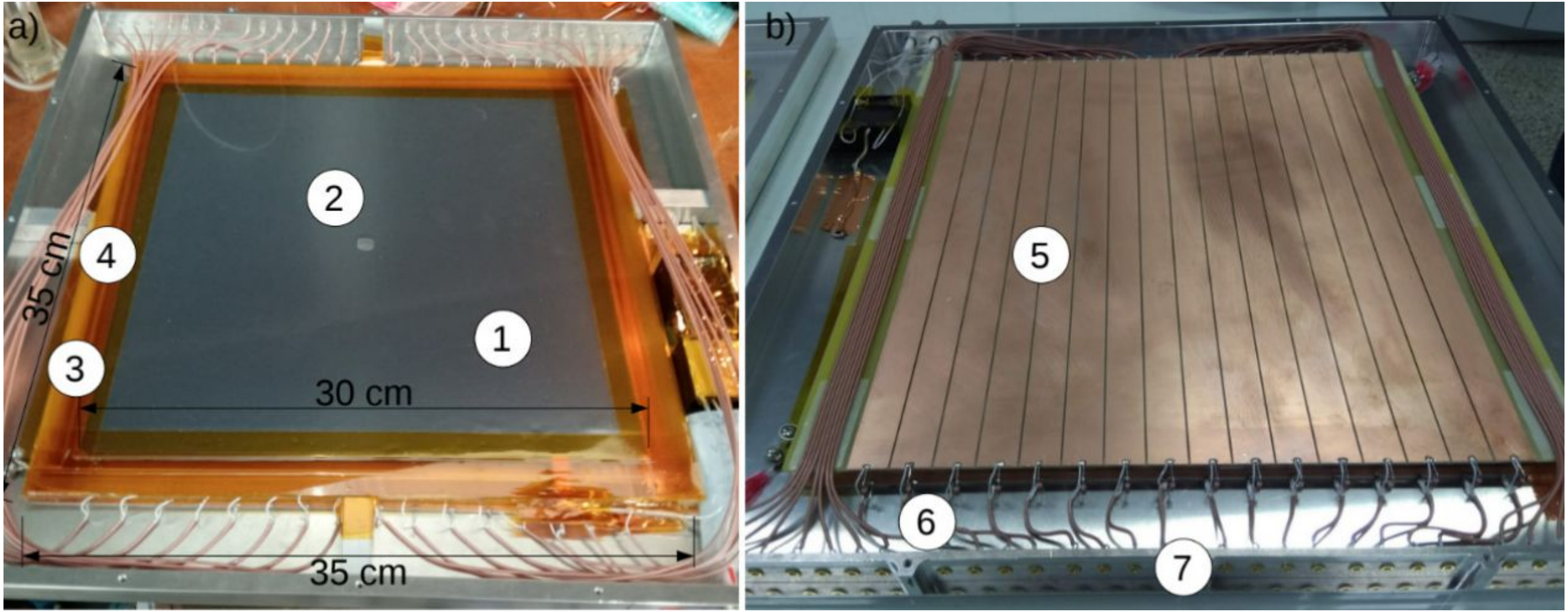
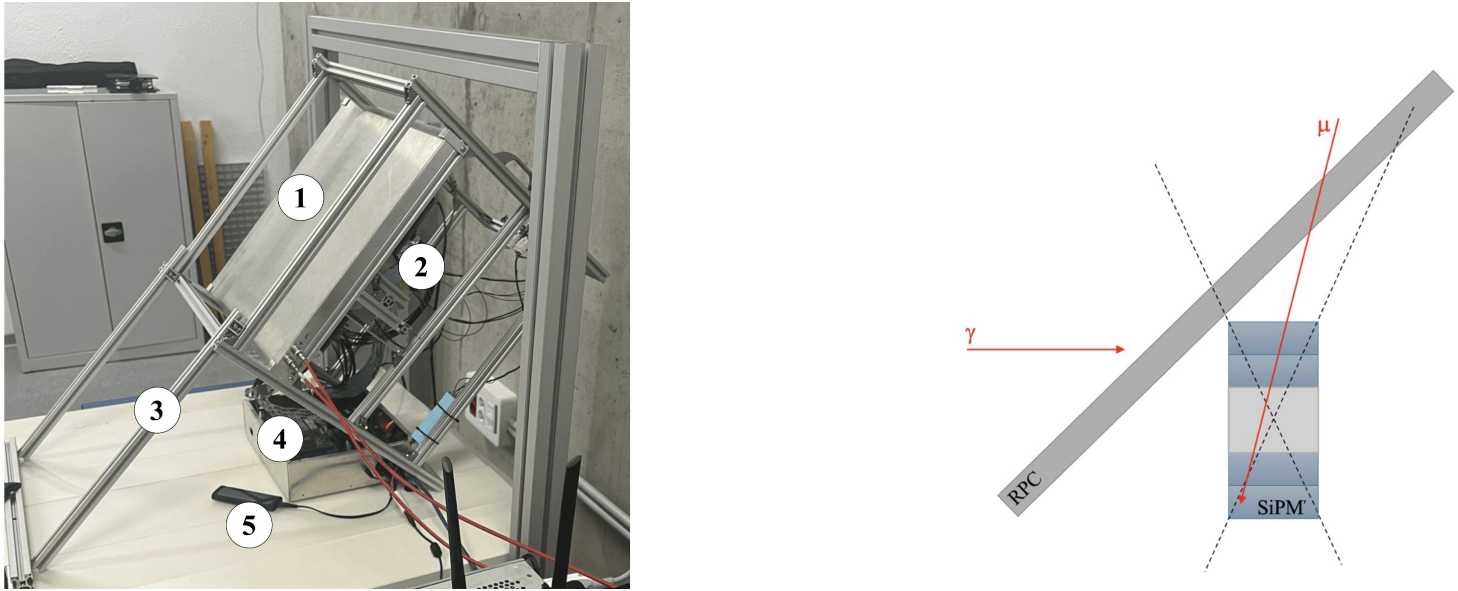


fig.2 - The interior of the sRPC. a) 1- HV layer, 2- Circular spacer in the center of the active area, 3- Strip spacer all around de the periphery and 4- Mylar and Kapton layers; b) sRPC plane showing: 5- Readout strip plane, 6- Coaxial cables and 7- MMCX RF feedthrough connectors.

Experiment's Goals

- To test the detector performance with no gas flow and see if there is no degradation. For that, we analyze the detector in terms of efficiency, charge, sbackground and number of streamers after prolonged exposure to a high radiation source.

Setup



(a) (b)

Fig. 3 - (a) Assembly of muon telescope: 1. sRPC; 2. Scintillators with SiPMs; 3. Aluminium Structure; 4. DAQ; 5.Extra Unity nVMe M.2 SSD. (b) Position of scintillators with sRPC and particles flux.

DAQ - Data Acquisition System

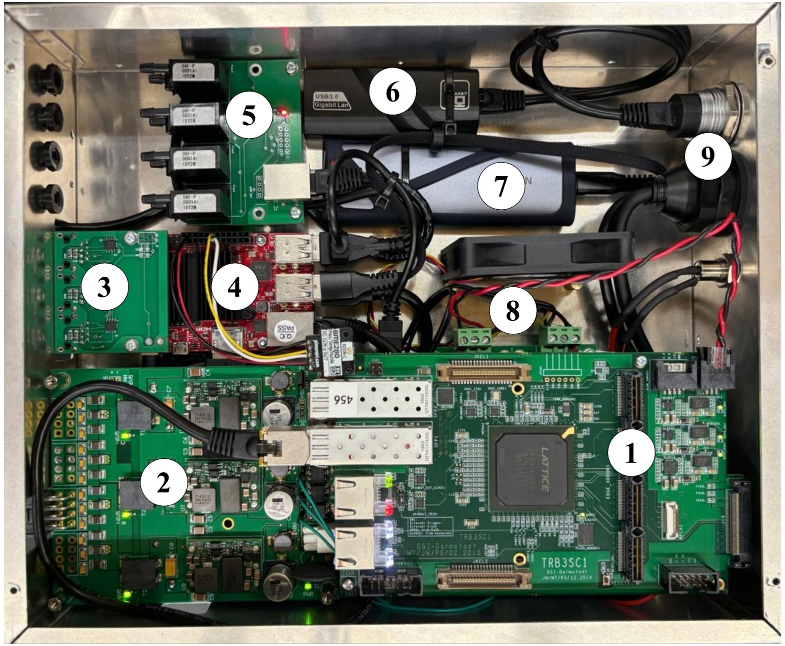


Fig. 4 - Assembly of DAQ: 1. FPGA Board TRB3SC1; 2. LV Power System; 3. I2C distribution board; 4. Mini-PC, 5. Gas Sensor Module , 6. USB Adapter Ethernet; 7. NVMe M.2 SSD; 8. Relay Control Board

Data analyses - sRPC spatial response

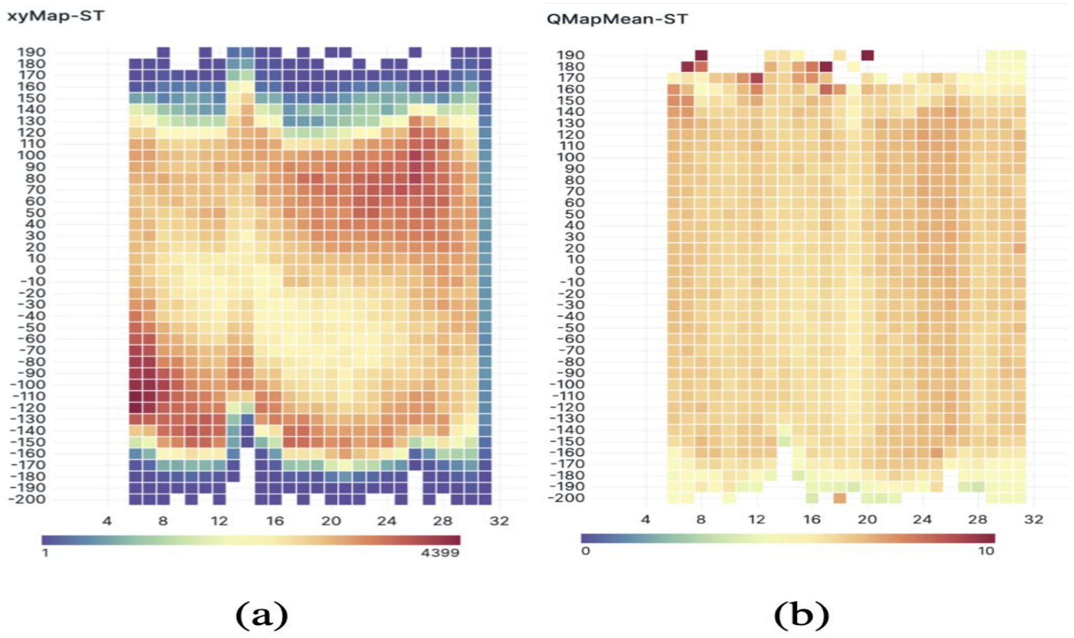
The average front ($\frac{Q_F+Q_B}{2}$) and back ($\frac{T_F+T_B}{2}$) values from each strip corresponds to the time and charge of the induced signal, respectively.

To determine the position of a particle in the RPC in 2-Dimensions:

- **X direction position:** strip with the highest value of charge
- **Y direction position:** after knowing X, Y is computed by:

$$\frac{T_F-T_B}{2}$$

Data analyses - sRPC spatial response



- results of a scan performed using HV = 6 KV

➔ There's a **homogeneous distribution** across the entire RPC surface in both plots.

Fig. 5 - (a) number of all particles (hits) that the sRPC detects, (b) average charge of these detections as a function of the position (X and Y) within each of the planes.

Muon Trigger

We needed to **filter the coincidence signals** from the scintillators to ensure that they **only correspond to the passage of muons**;

Procedure

1) **Collection of several coincidence data points** from the four scintillators, varying the position between the source and the scintillators;

2) **Remove the background signal (gamma radiation)** — limit the signals received — only signals when there were coincidences in the 4 scintillators, the signal width, corresponding to the charge was greater than 240ns and the time had a standard deviation of less than 2.5 ns were accepted.

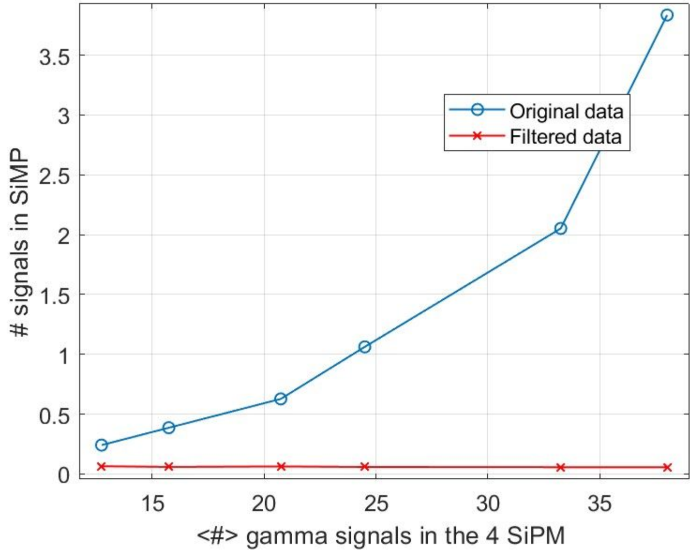
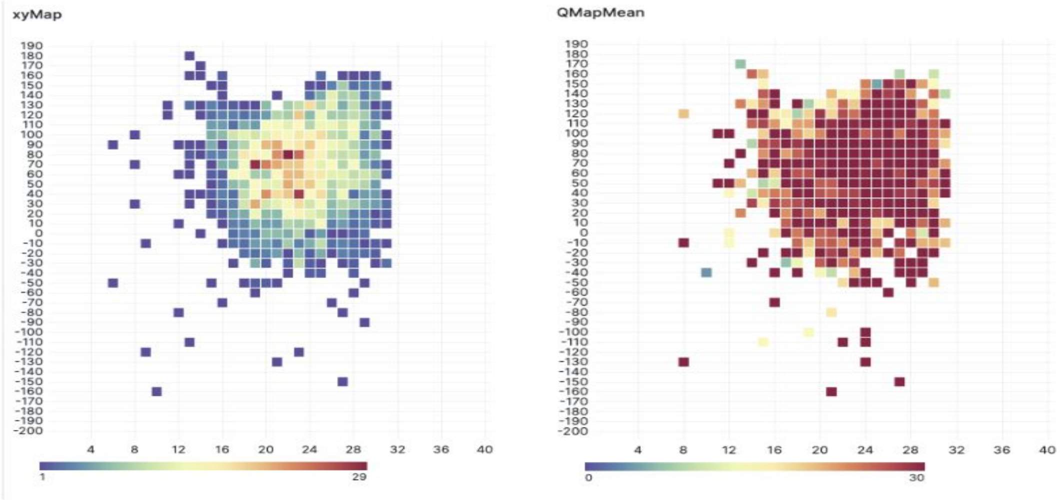


fig. 6 - #all signals in the scintilltors in function of# gamma signals in the 4 scintillators

Muon Trigger



(a) (b)

- results running the muon trigger

→ The two XY-maps using the muon trigger reveals the position of the scintillator telescope, behind the sRPC

Fig. 7 - (a) number of signals (hits) that the sRPC detects using the muon filter, (b) average charge of these detections as a function of the position (X and Y) within each of the planes.

Efficiency of sRPC

$$\varepsilon\,(\%) = \frac{\#\ events\ in\ RPC}{\#\ events\ in\ 4\ Scintillators} \times 100$$

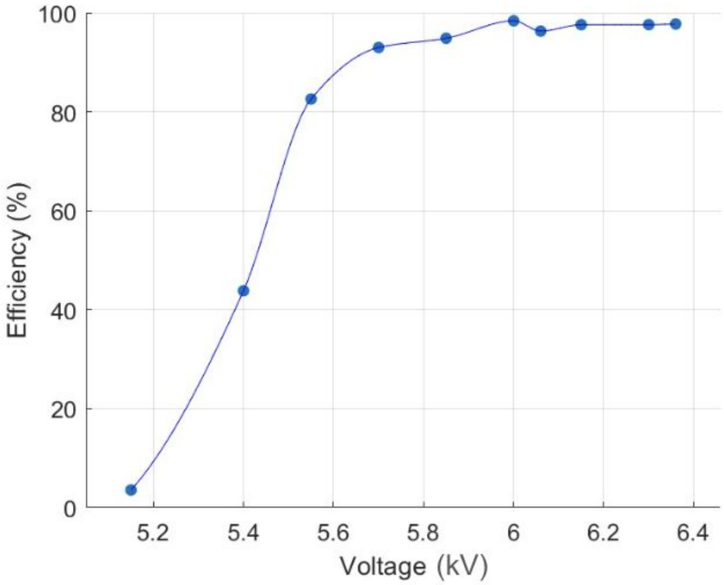


fig. 8 - efficiency as function of Voltage

Santiago's Laboratory

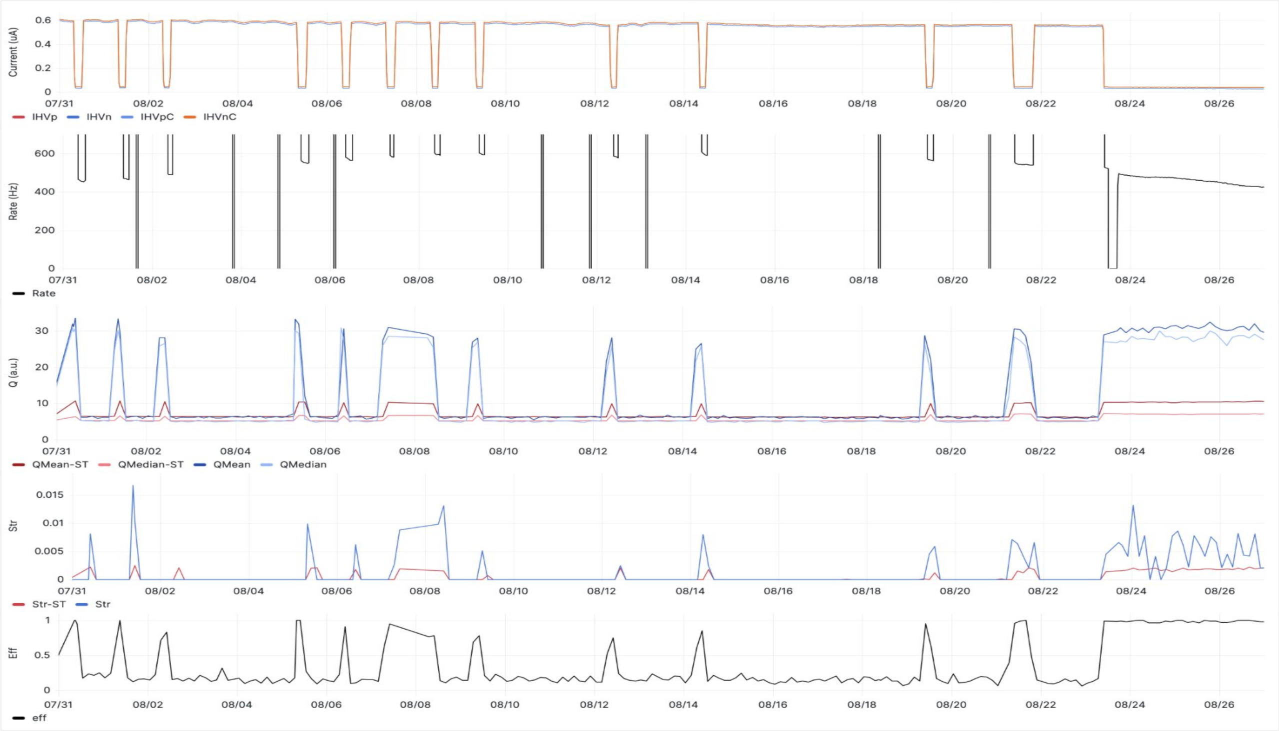
- To **test the sRPC**, we put the detector under a high radioactive source at Santiago's laboratory for 23 days.

Fig. 9 - The detector under strong irradiation (Co-60) in Santiago's laboratory

- ➔ Irradiate the sRPC for 20 hours and then turn it off for the remaining 4 hours each day.

During these 4 hours, we were able to run the muon trigger and compare the collected data over the course of several days.

Santiago's Laboratory



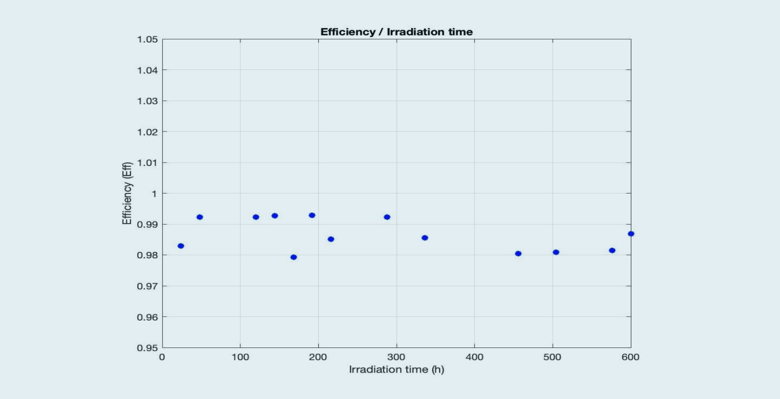
Background - number of signals generated without a radioactive source

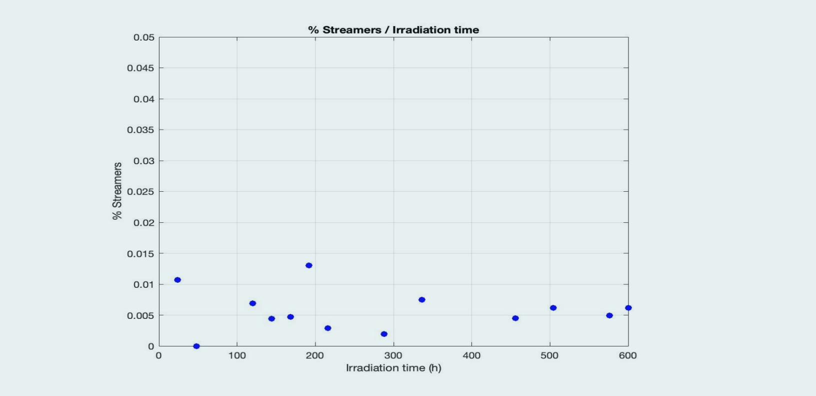
<Q> - average charge of signals

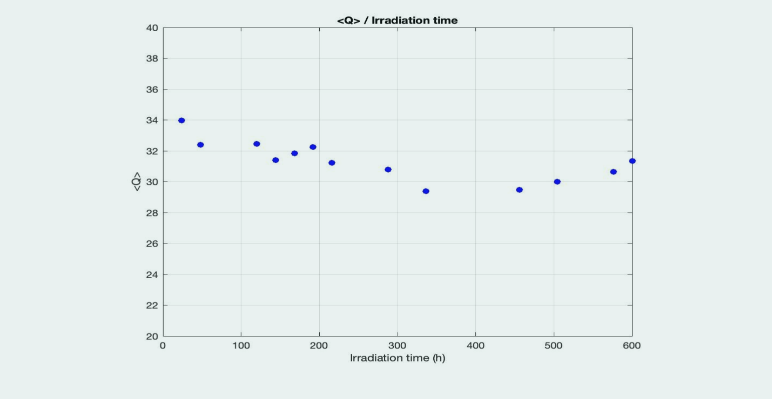
Streamers - number of events above a certain level

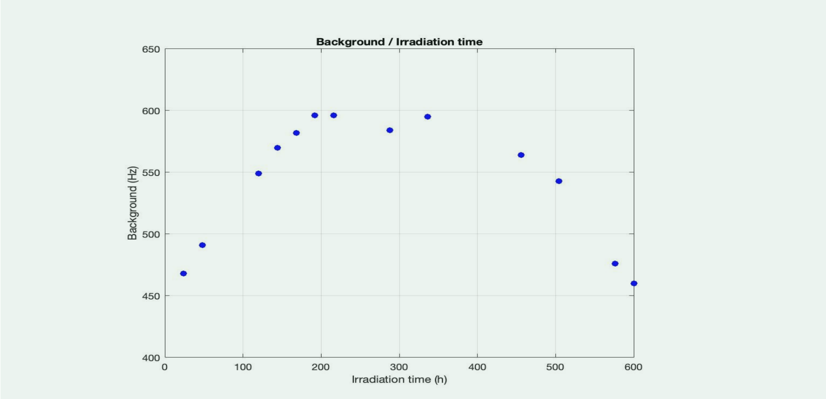
Fig. 10 - Results exposing the detector to a high radioactive source

Analysis and Results









Conclusions

- **Detector Performance:** efficiency — 98%-100%**:** remains high and the percentage of streamers is low.

- **Potential for long operations:** The results indicate the feasibility of the sRPC

References

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[2] Korcyl, G., Maier, L., Michel, J., Neiser, A., Palka, M., Penschuck, M., ... & Ugur, C. (2015). A users guide to the trb3 and fpga-tdc based platforms.

[3] Xarepe, M., Aumann, T., Blanco, A., Corsi, A., Galaviz, D., Johansson, H. T., ... & R3B collaboration. (2023). Resistive plate chambers for precise measurement of high-momentum protons in short range correlations at R3B. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, *1055*, 168445.