6th DRD1 Collaboration meeting

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Warsaw 10th October 2025

RPC manufacturing and characterization

DRD1 gaseous detector school presentation.

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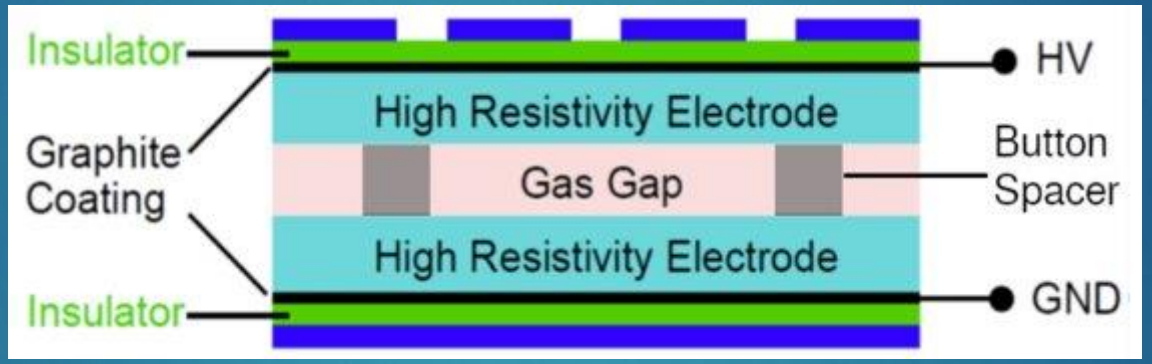
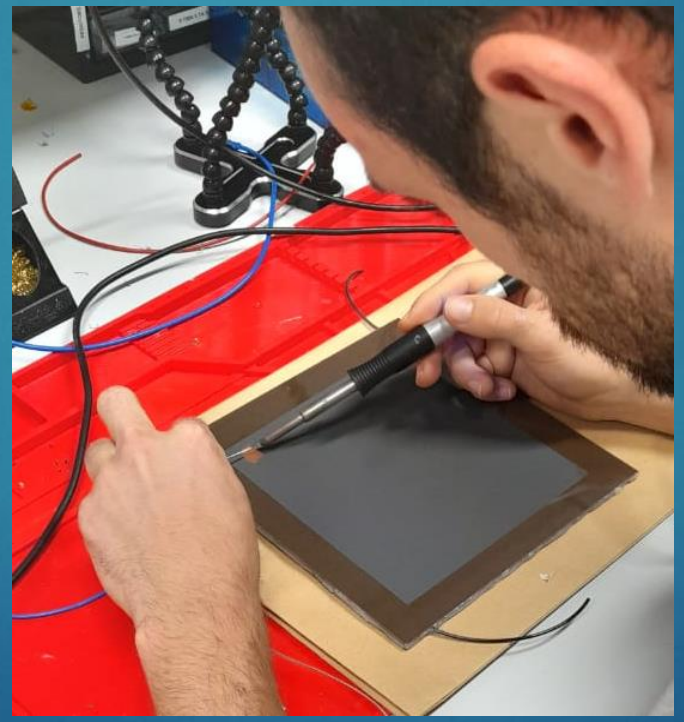
Introduction

- Fast gaseous detectors that consist of two parallel plates, an anode and a cathode, both made of a very high resistivity plastic material and separated by a thin gas volume. The electrodes are transparent to the signal, which are instead picked up by external metallic strips.



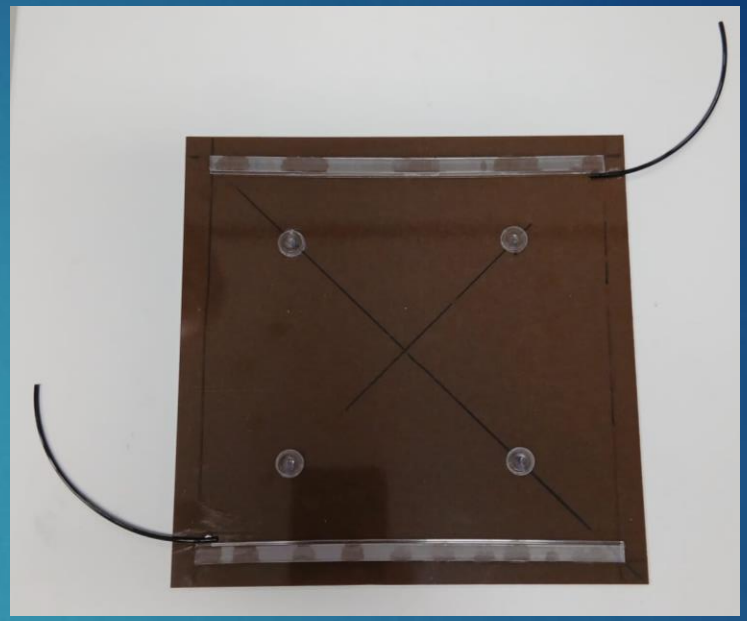
- Known for having good spatial and time resolution.
- Main applications: muon trigger at the LHC experiments, such as CMS, ATLAS and ALICE.
- Advantage: simple design of the detector and its robustness (capability to cover large detector areas at a low cost).
- It's so simple that they give us the opportunity to build one.

RPC manufacturing



Mechanical assembly

- **Raw material for the RPC assembly:**
  - 2x(10x10) cm^2 High Pressure Laminated (HPL) bakelite plates.
  - 2 mm width spacers and frames.
  - Loctite glue, hot glue gun/sticks.

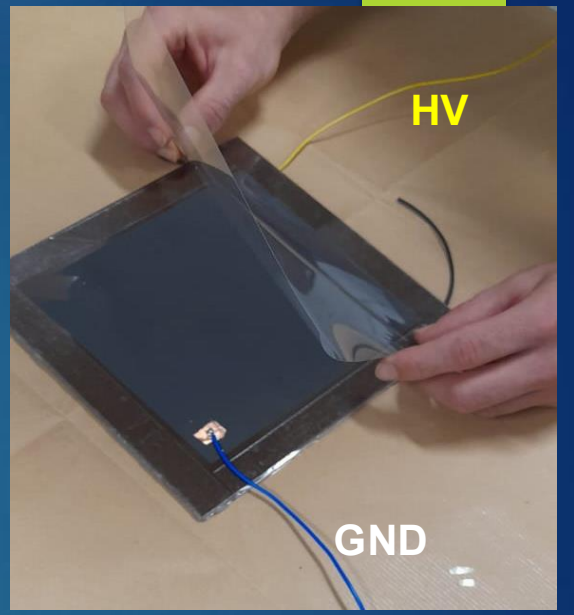


Procedure:

1. The spacers and frames were glued evenly on the surface of the Bakelite.
2. The two plastic tubes on opposite corners of the plates serve as the gas inlet and outlet.
3. The second plate glued on top of the first.
4. The gas sealing was guaranteed by the hot glue deposited on the detector edges and a lot of hand pressure.

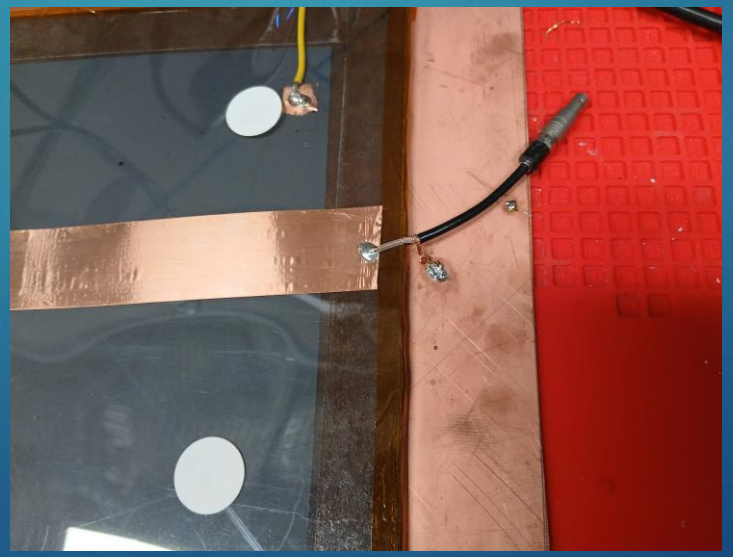
Electrical connections

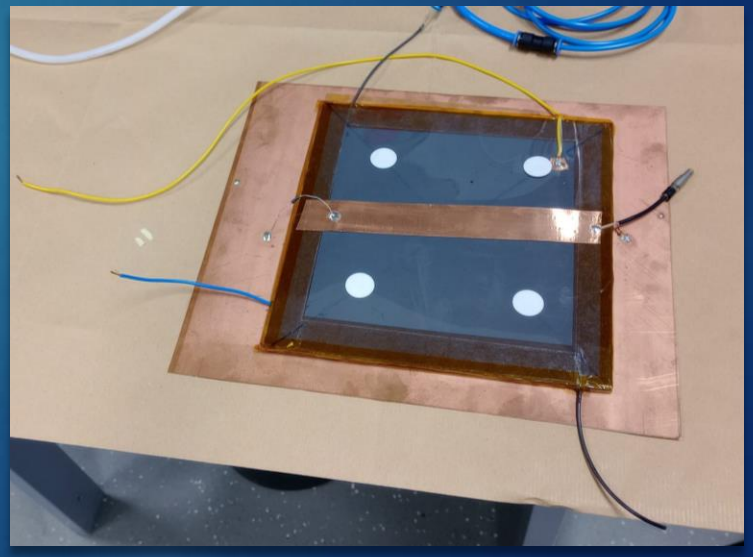
- **Raw material for the RPC assembly:**
  - Copper and kapton tape.
  - Graphite spray, PET film.
  - HV/GND connections for power supply.



Procedure:

1. The graphite was deposited on both detector sides leaving a copper tape strip exposed for the HV and GND connections.
2. Pet film foils and kapton tape were applied over all the electrode surfaces to prevent current leakage.
3. One copper strip was attached on the cathode surface over the PET film and read out with LEMO cable.

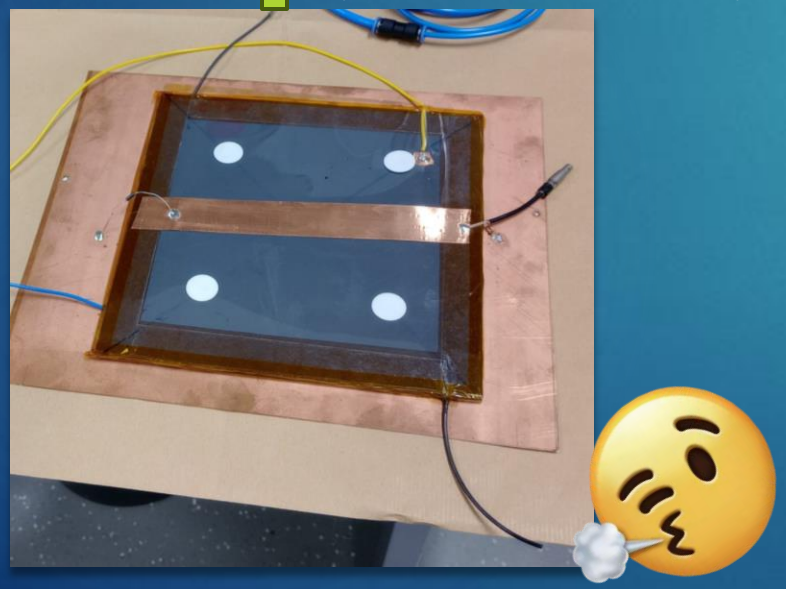


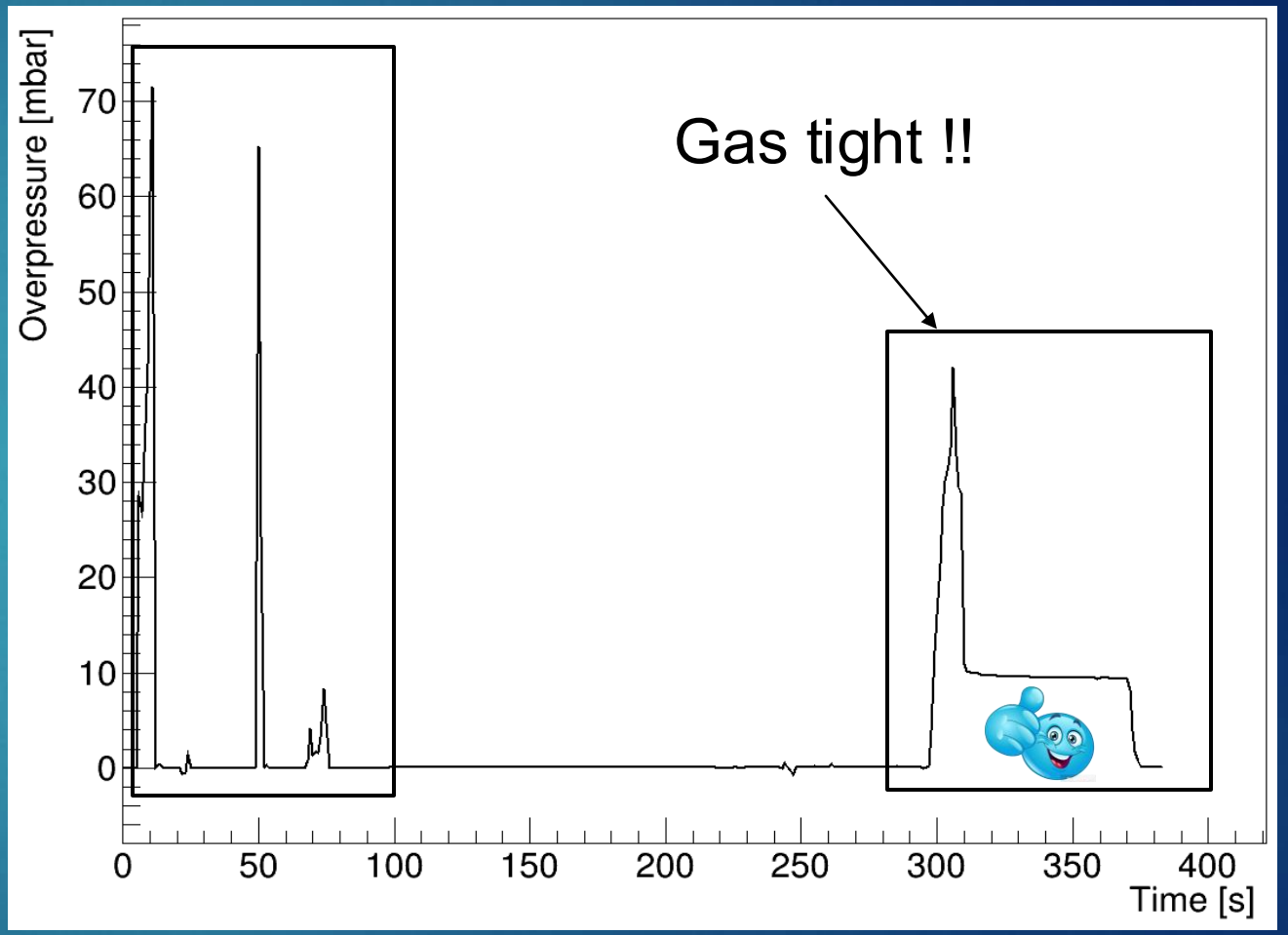


Gas sealing

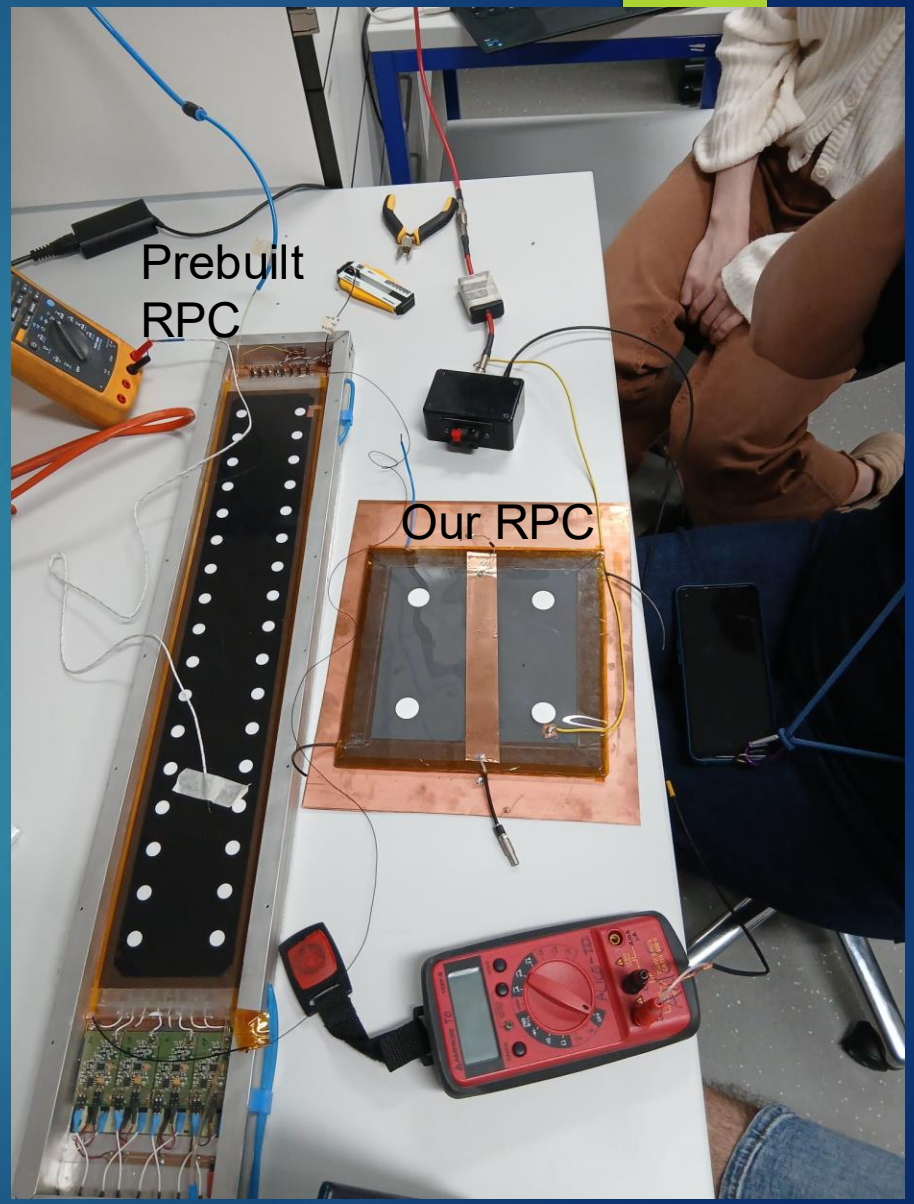
- The detector's sealing capacity was tested by measuring the pressure difference between the air blown into the detector and the ambient pressure in the laboratory.

https://www.testo.com/en-FI/testo-510-i/p/0560-1510





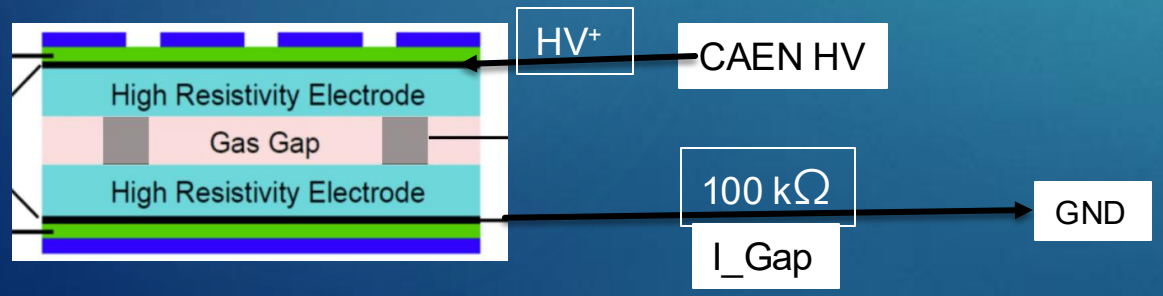
Prebuilt RPC characterization

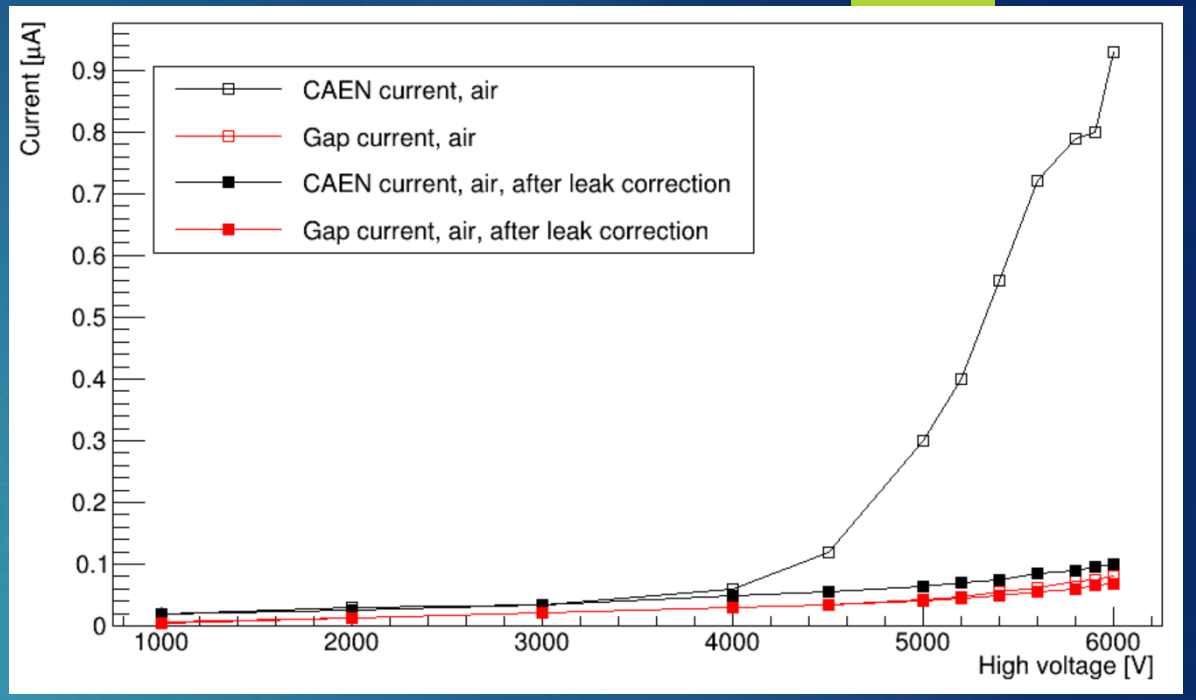


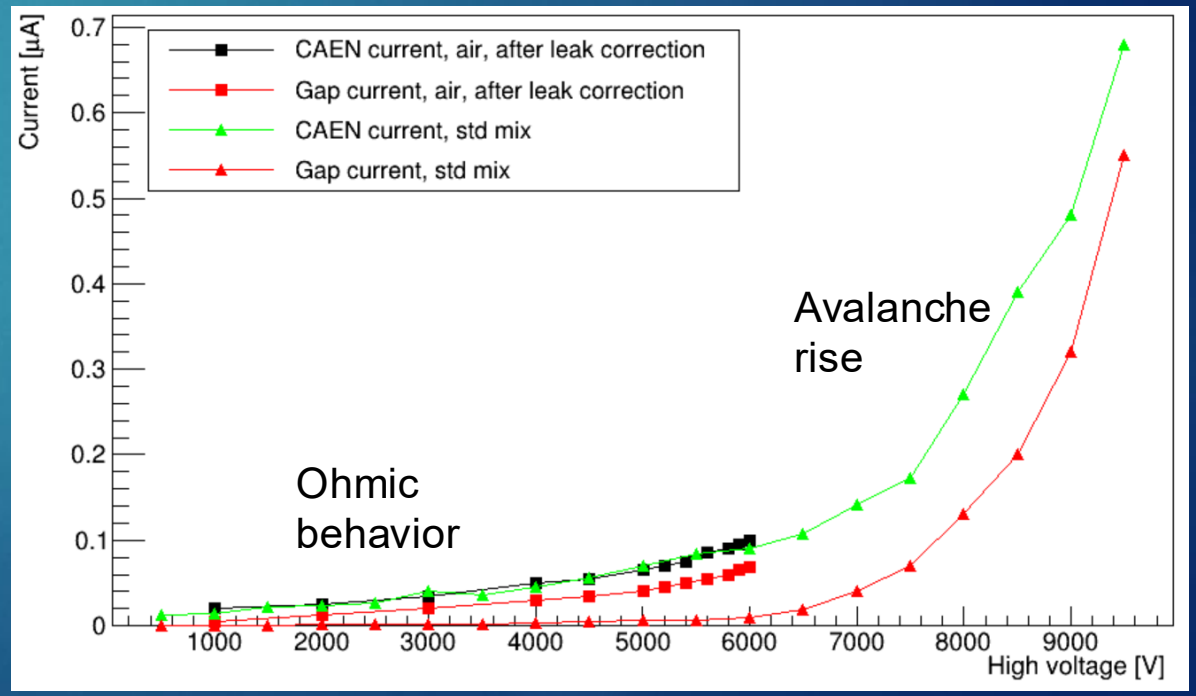
Current characteristic curve

- The detector response was firstly studied measuring the current that flows through it varying the HV in air;
- Leakages were searched by simultaneously measuring the **current supplied by the CAEN HV** module and the g**ap current**, obtained from the voltage drop across a 100 kΩ resistance (I_Gap = V/100kΩ);
- The observed leakage was most probably caused by contact between the RPC and the surrounding metal cage;
- The RPC was then filled with the correct gas mix and the I(HV) curve was repeated allow us to reach higher voltages.

94.7% $C_2H_2F_4$, 5.0% i-C_4H_{10}, 0.3% SF_6

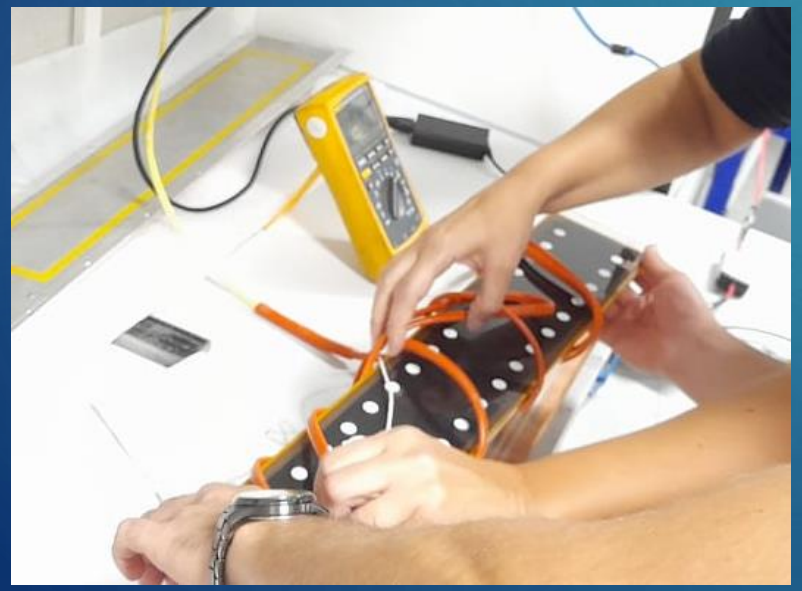


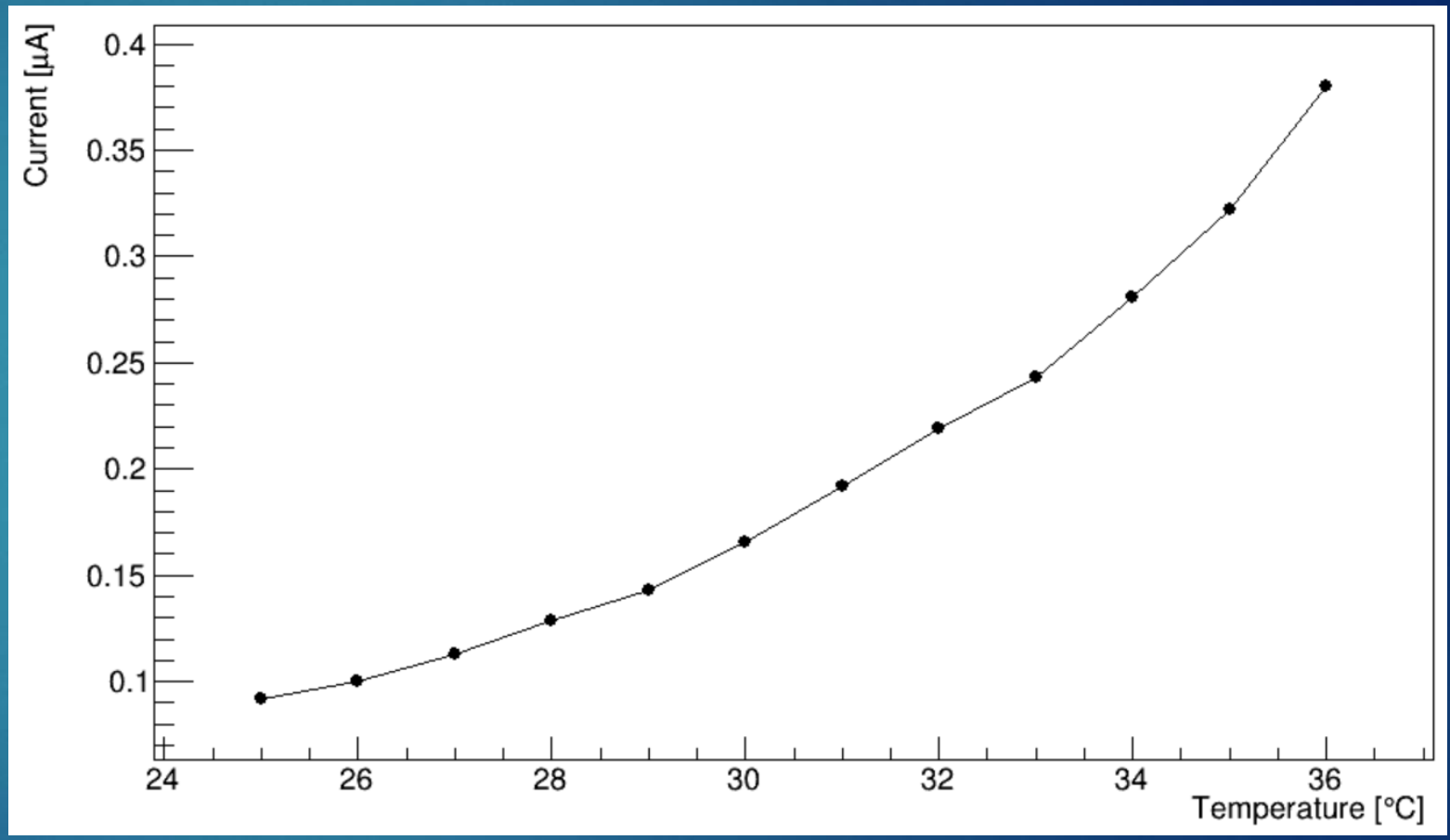




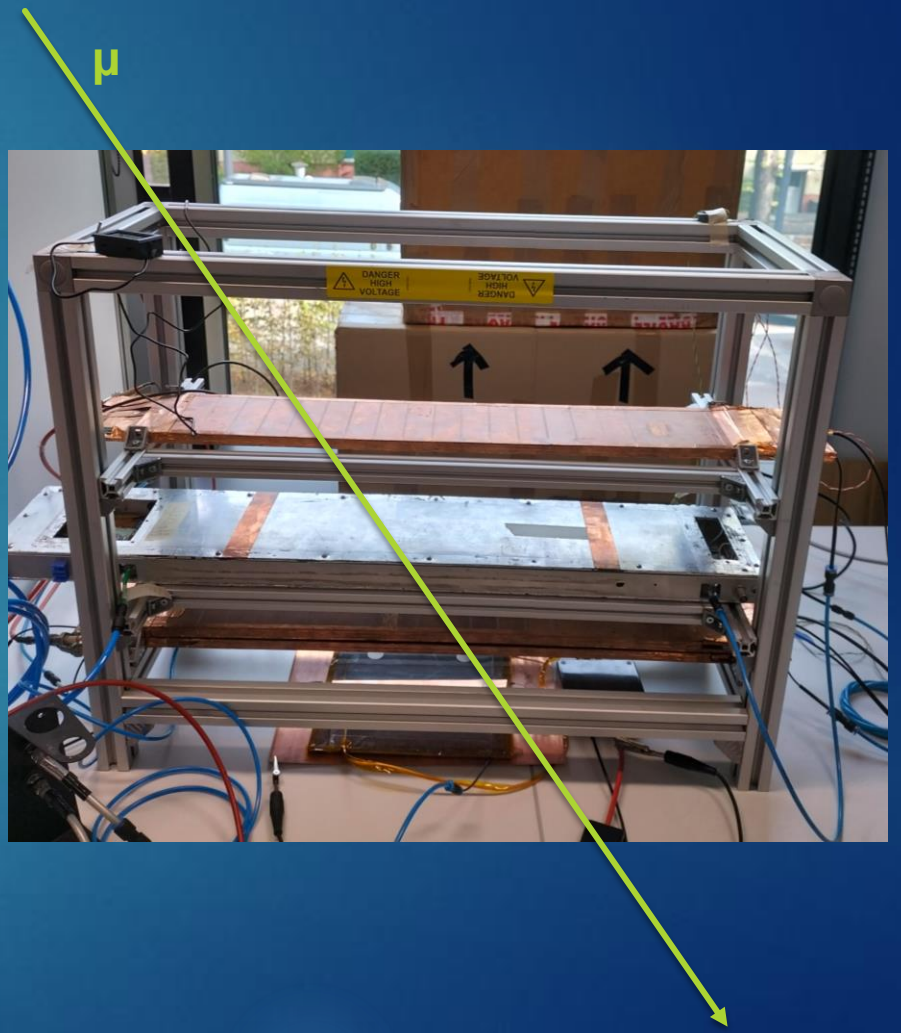
Gap current dependence on temperature

- A temperature variation affects the gas density and the bakelite resistivity, resulting in a variaton of the current;
- the gap current was measured heating the RPC with a heating-band wrapped around the detector;
- HV kept constant at 6 kV.





RPC characterization

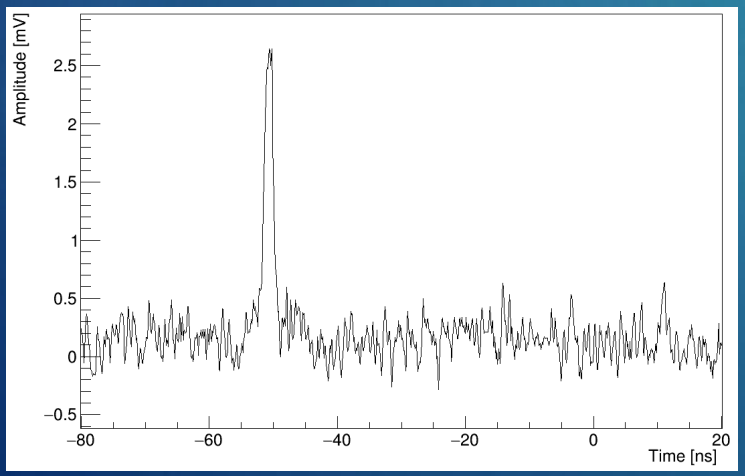


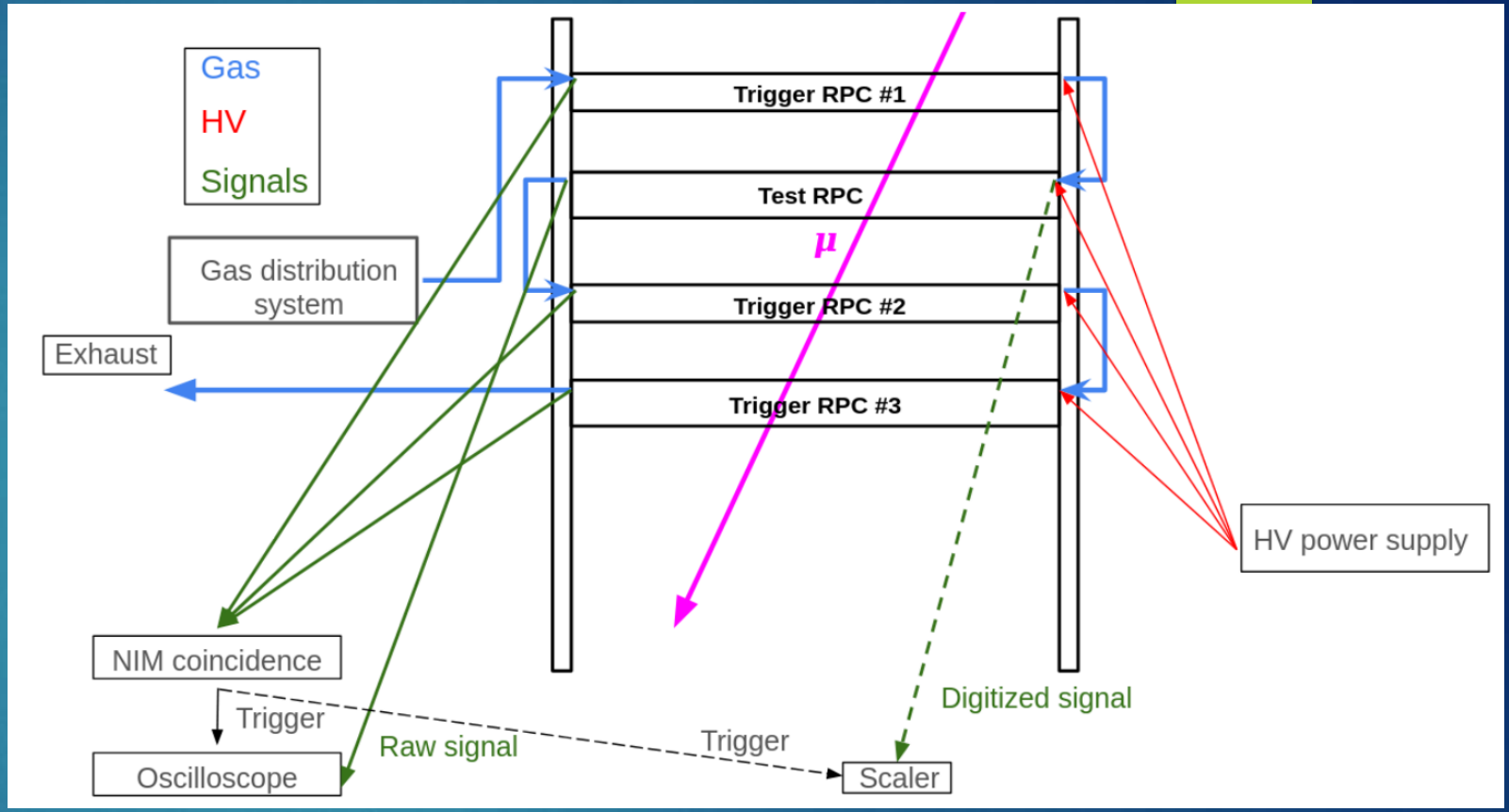
Setup

- 3 RPCs coupled to a double stage amplification readout chain, were employed to create a triple coincidence trigger;
- 4th RCP as a test chamber
- Every detector is filled by flushed in series the standard RPC gas mixture:

$94.7\%\ C_2H_2F_4,\ 5.0\%\ i\text{-}C_4H_{10},\ 0.3\%\ SF_6$

- Charge and time resolution measurements were performed on the raw waveforms induced in the test RPC

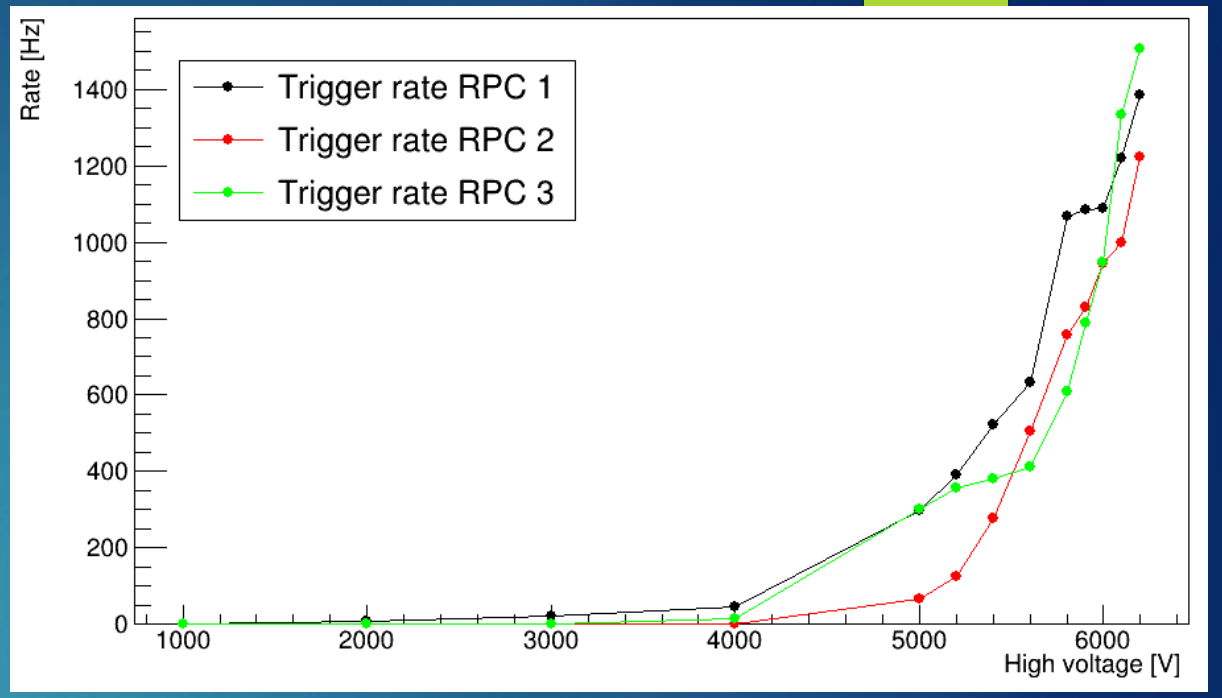


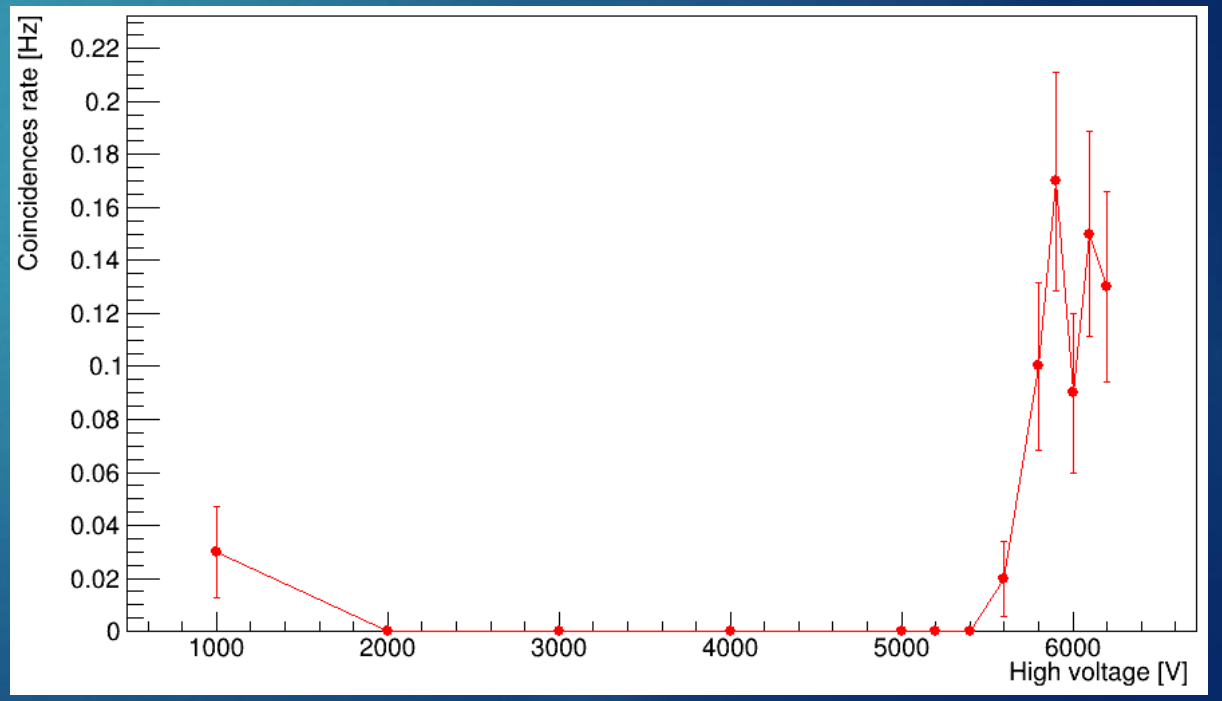


Telescope characterization

- The trigger RPCs were powered using a single HV channel;
- The telescope working point (WP) was chosen by evaluating the trigger rate of each detector, as well as the triple and fake coincidence rate;
- Coincidences were measured using a time window (tw) of 20 ns;
- Applying 6000 V to the detectors we get a coincidence rate of 0.12 Hz, the plateau value for our apparatus;
- the fake trigger coincidence rate was:

$$\mathrm{Fakef} = f_1 \cdot f_2 \cdot f_3 \cdot \mathrm{tw}^2 < 10^{-6}\,\mathrm{Hz}$$

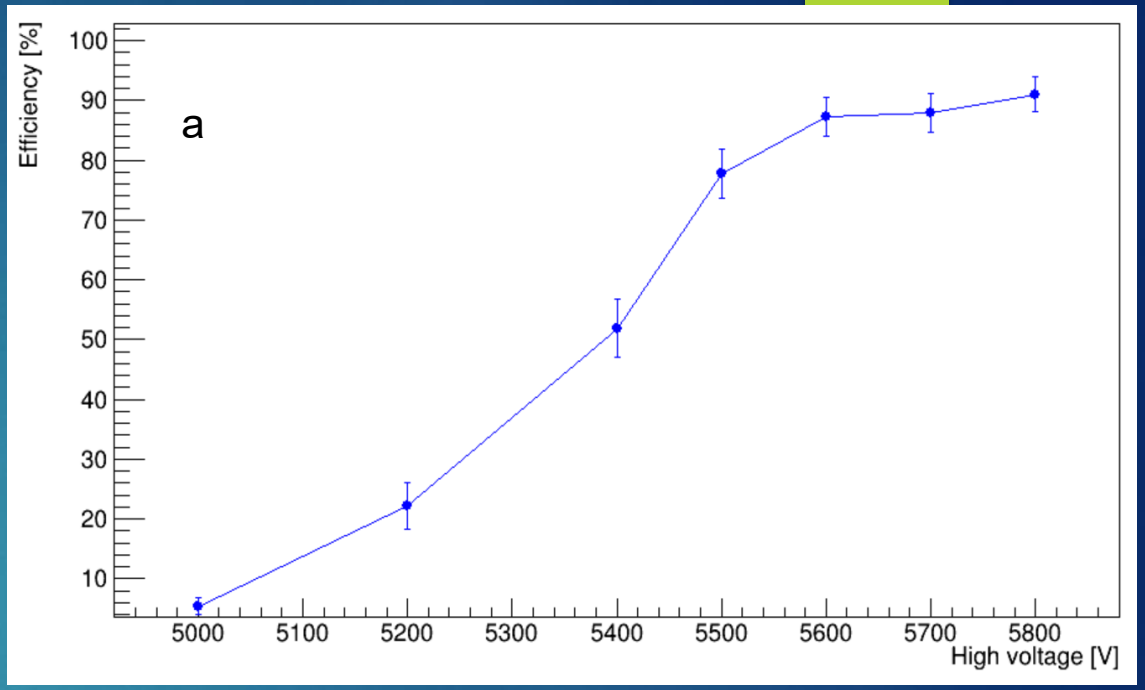


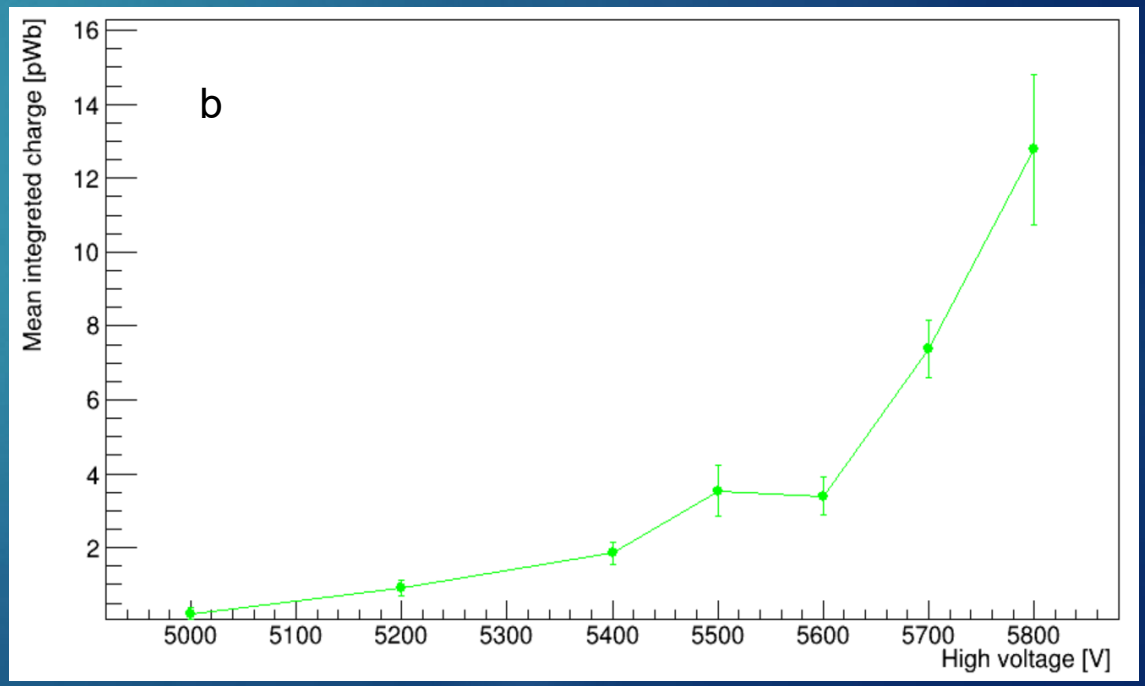


Test RPC working point

- To choose the test RPC WP we measured:
  a. detector efficiency defined as test RPC counts/Triple coincidences.
  b. integrated charge of the signal;

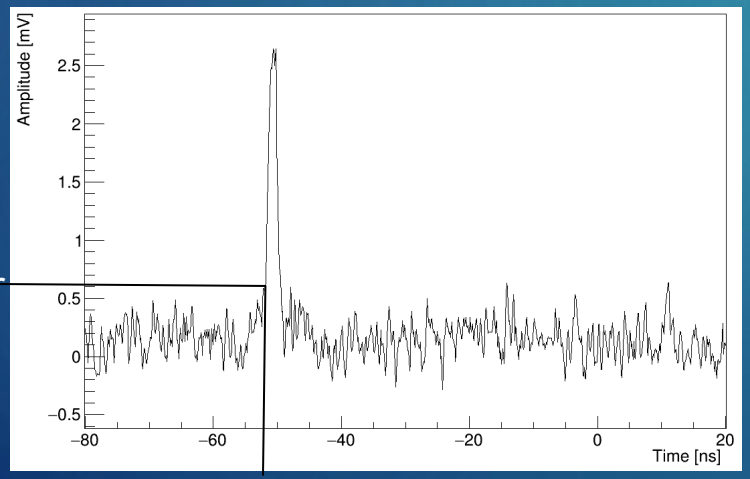
- We decided to operate with 5750 V to get enough detector efficiency and to avoid higher charge values that could damage the instruments.

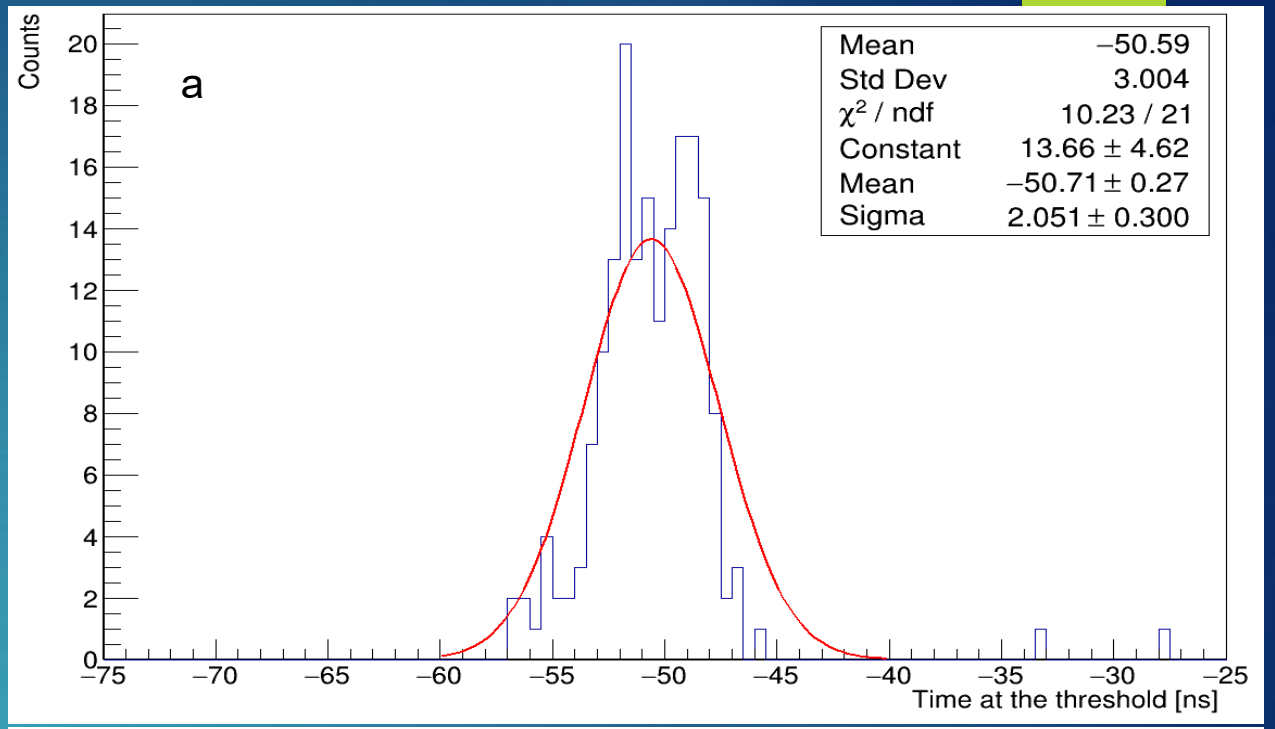


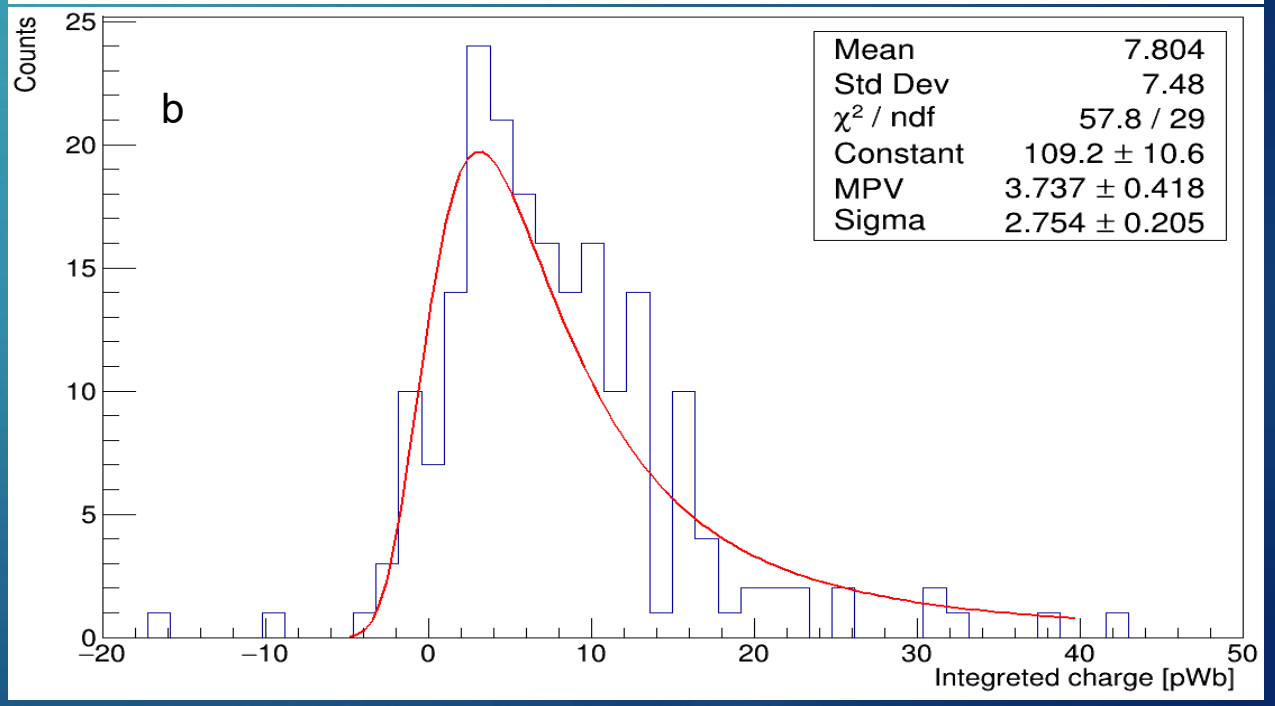


Characterization results

- Using the triple coincidence trigger we collect muons events measuring for each one the time at which the signal reach the threshold of 0.6 mV (a) and calculating the integrated charge (b).





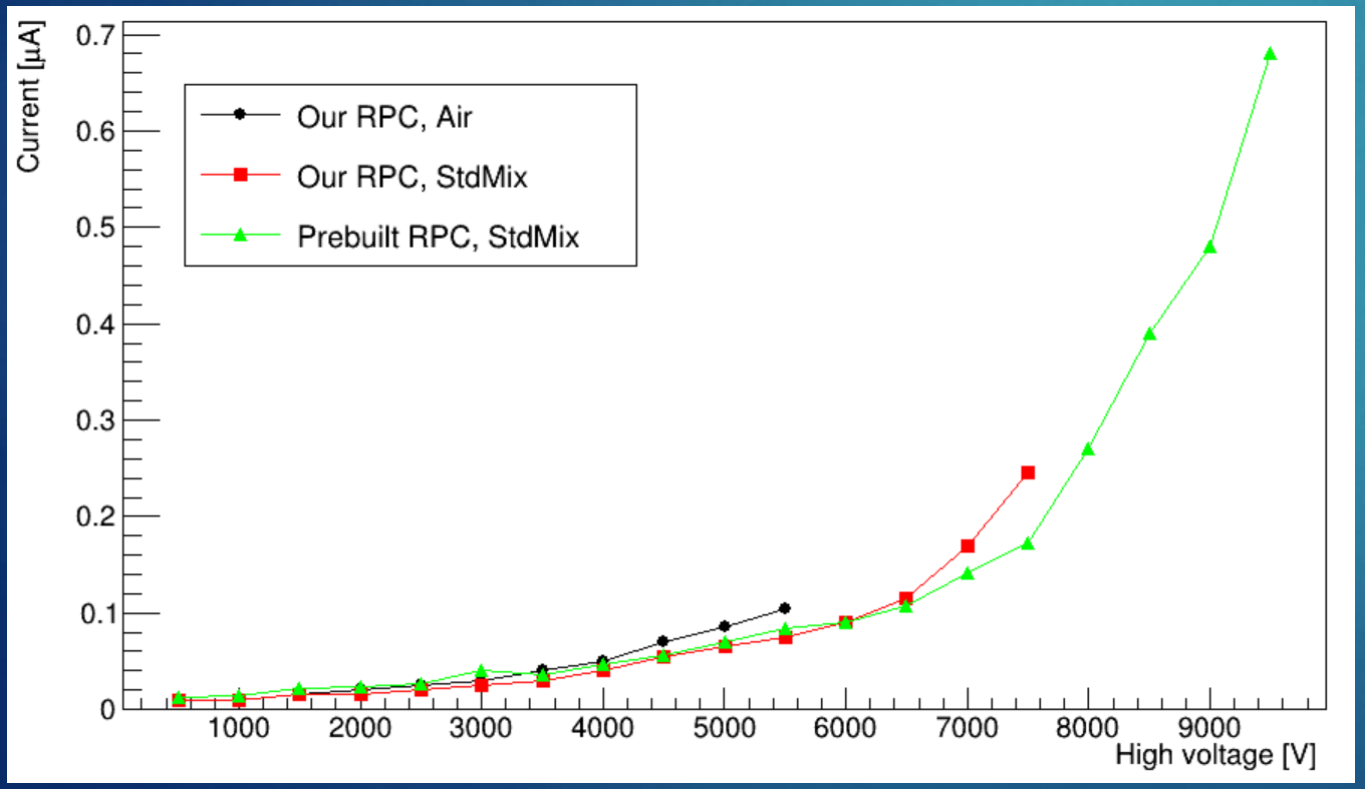


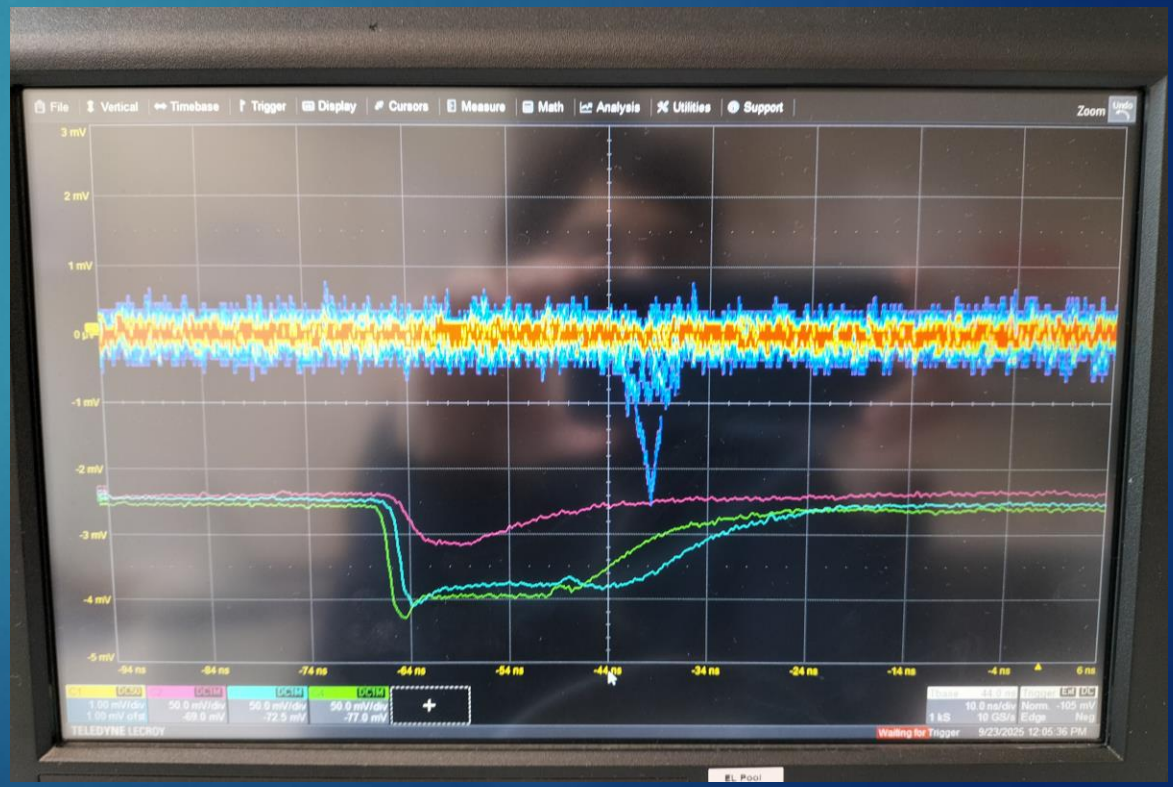
Our RPC charatcerization – one step too far?

For demonstration purposes, you can also attach a copper tape “strip” on top of the PET foil and solder a lemo cable to it, to mimic a readout strip. The GND of the lemo cable can be connected to any reference ground.

From the safety point of view, we cannot guarantee a proper protection from current discharges

- The CAEN current was measured filling our homemade RPC with air and with the standard gas mix and varying the HV;
- thanks to the good sealing it was also possible to see few cosmic rays events with the homemade RPC;
- we stop the HV scan TPC because it starts to deviate from the behavior previously observed with the prebuilt RPC.





From group 3

Thank you for your attention
and thanks to our tutors, teachers and especially to the school organizers!

Backup

Integrated charge

- Example of the measurement method.
- The signal integral was calculated within two predefined time windows.
- The baseline was determined in a time window that does not contain the signal.
- This baseline was then subtracted from the result of the integration in the first time window.