MODERATION OF THE AVALANCHE GAS DISCHARGE THROUGH A QUASI-UNIFORM ELECTRIC FIELD DEVICE: **THE RESISTIVE CYLINDRICAL CHAMBER**

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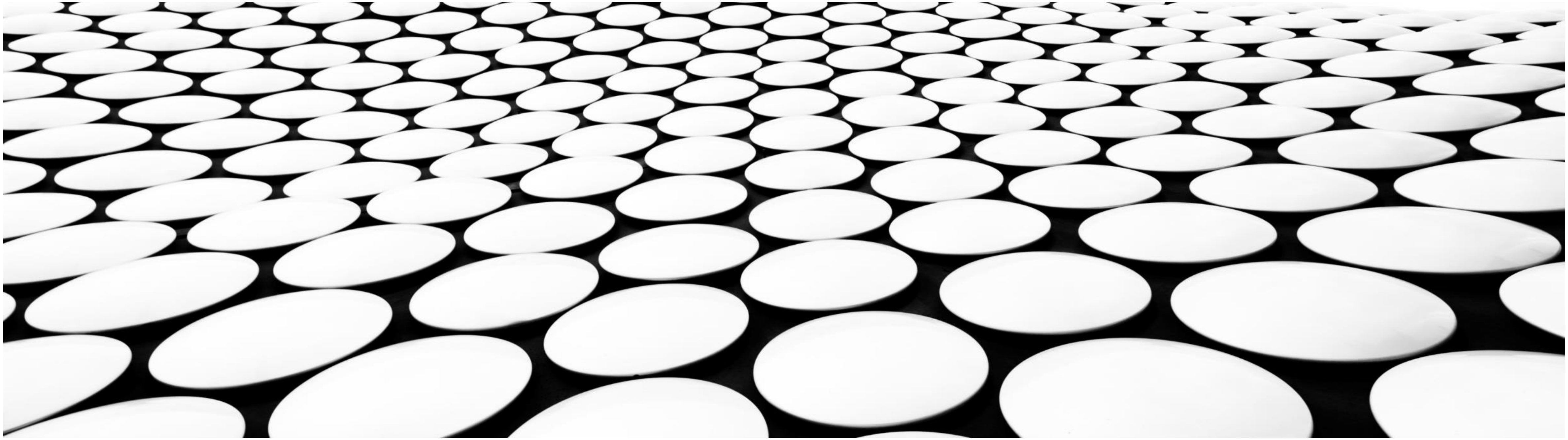
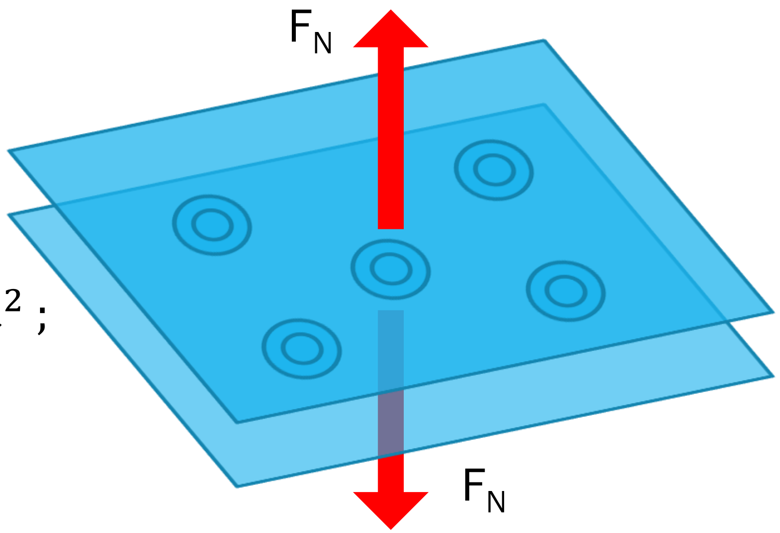


PLANAR GEOMETRY WEAKNESS

- **Mechanical strength**

The force exerted on the bonding surfaces of the pillars increases proportionally to the difference in pressure with respect to the outside of the gas volume and with respect to the size of the detector



$$p_{pillar} = \frac{F_N}{n_{pillar} * S_{pillar}} = \frac{\Delta p * S_{detector}}{n_{pillar} * S_{pillar}} \rightarrow \Delta p = 2\ bar\ ;\ S_{detector} = 10\ kcm^2\ ;\ S_{pillar} = 0{,}2\ cm^2\ ;$$

$$\downarrow$$

$$p_{pillar} = \frac{10^2}{n_{pillar}}\ kbar$$

The planar geometry is not suitable to be pressurized unless significantly increasing the density of pillars or building a complex mechanical structure that counterbalances internal forces

The tensile strength of Bakelite is about 1,2 $kbar$

- **Discharge quenching factor**

In a uniform electric field, the quenching of the avalanche discharge is mainly due to the gas mixture, the electrode properties and the electric field strength. The geometric factor affects the discharge growth only through the space charge effect.

CYLINDRICAL GEOMETRY FEAUTURES

- **Mechanical features**

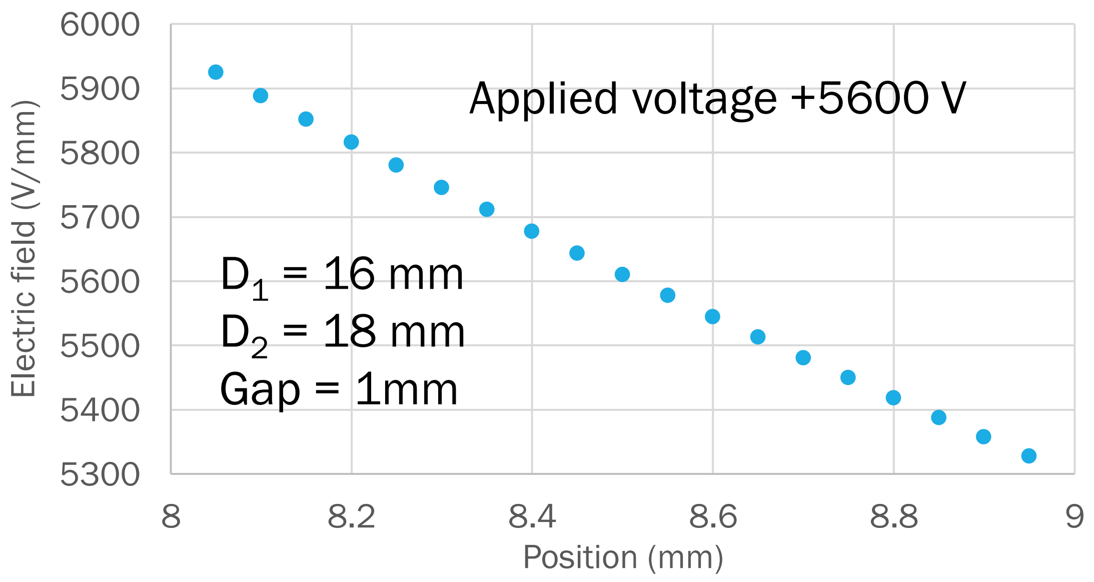
In a cylindrical geometry detector, the forces balance to hold the electrodes in place. There are no glued pillars, and the side walls can be reinforced using metal pipes without loss of sensitive area. This allows you to work with a large difference in pressure compared to the external environment.

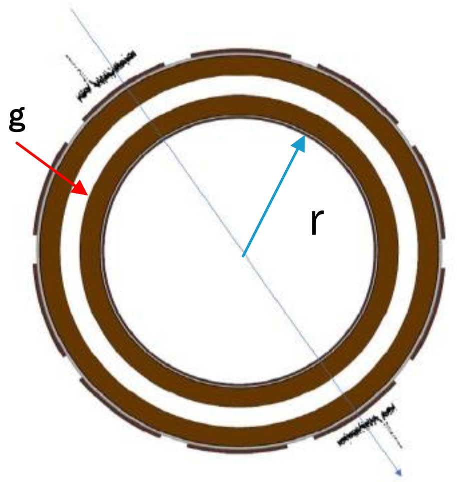
- **Electric field**

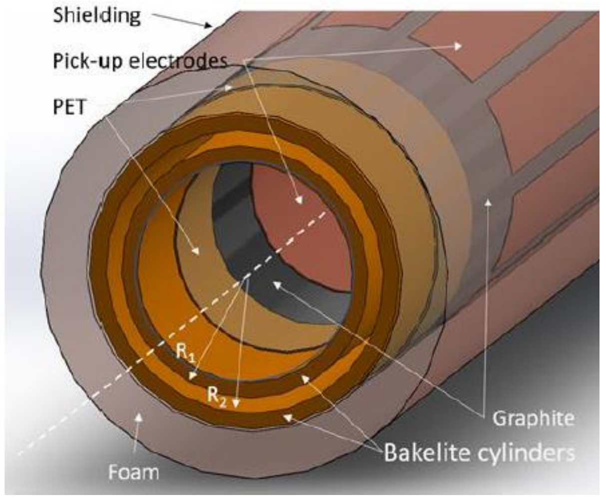
The electric field inside the gas volume has a trend that depends on the curvature radius and the gas-gap thickness. It is possible to move continuously from a radial geometry field (g>>r) to a uniform field (g<<r).

- **Read-out and tracking**

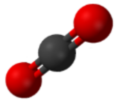
the ring structure of the gas target allows to identify up to two points in space (except for tangential traces). The read-out system can be optimized to track the direction of incident particles or to maximize charge collection by accumulating the total signal on a single coaxial conductor.







CYLINDRICAL GEOMETRY: WHY?



The gas pressurization would allow to:

1. Increase the gas target density, with a consequent increase in intrinsic efficiency

   → MRPC time response with thin single gap configuration

   → light eco-friendly CO_2 based gas mixtures

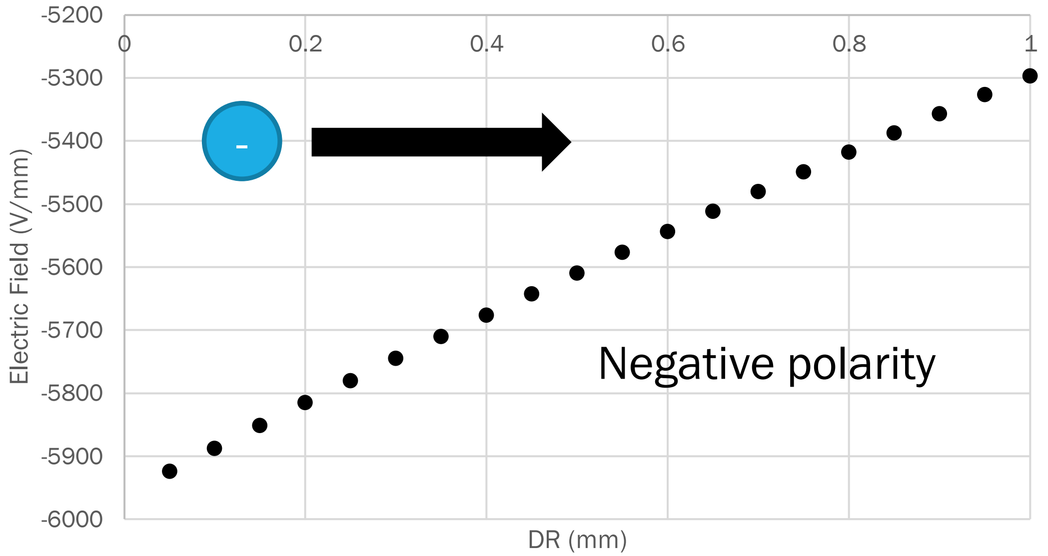
2. Use the detector in hostile environments such as space

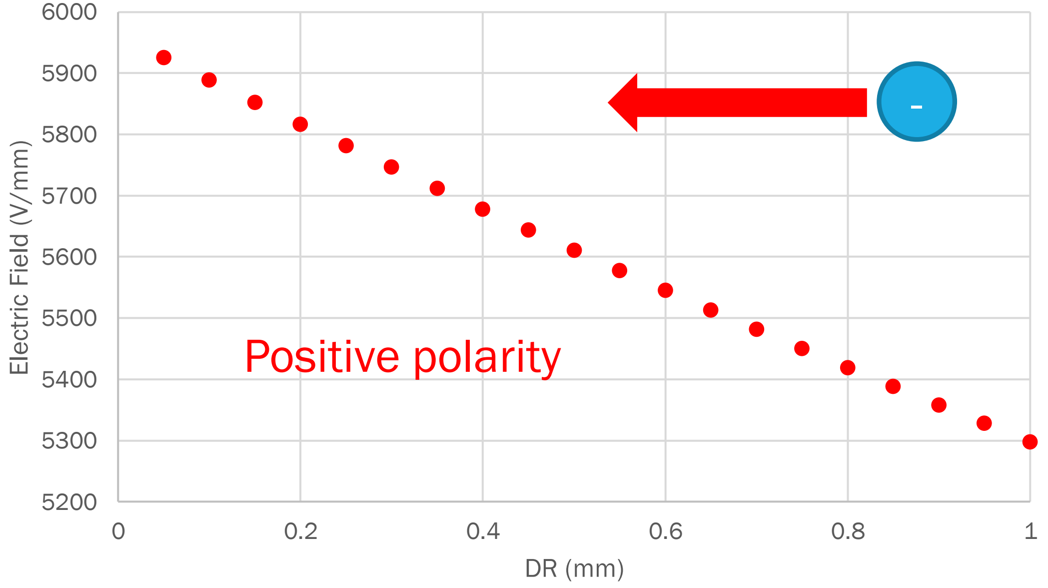
The electric field gradient, depending on the polarization allows to

1. Contribute to the gas discharge quenching

   → new eco-friendly gas components

2. Increase the charge collection efficiency enhancing the multiplication in the initial part of the gas gap
3. Study the dependencies and optimize the time resolution





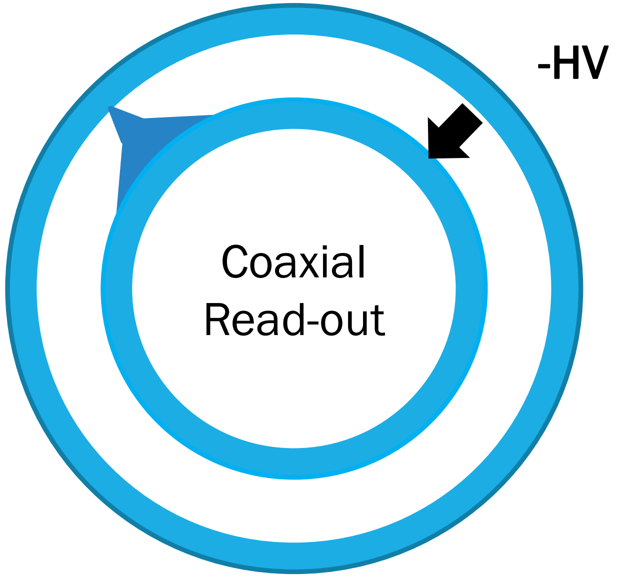
AIM OF THE TEST

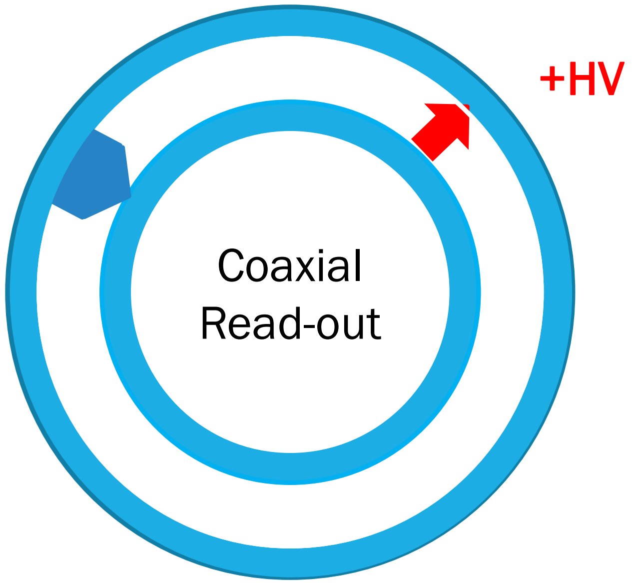
The test consists in demonstrating the correct functioning of the device with a quasi-planar cylindrical geometry

Furthermore, consists in characterizing the efficiency, the time response and the shape of the signals in the two polarization conditions. The prototype was designed to emphasize asymmetry, thanks to a non-negligible field gradient.

Under positive polarization conditions, multiplication is expected to occur mainly in the region close to the cathode, which can be described, to a rough approximation by a multiplication followed by drift model.

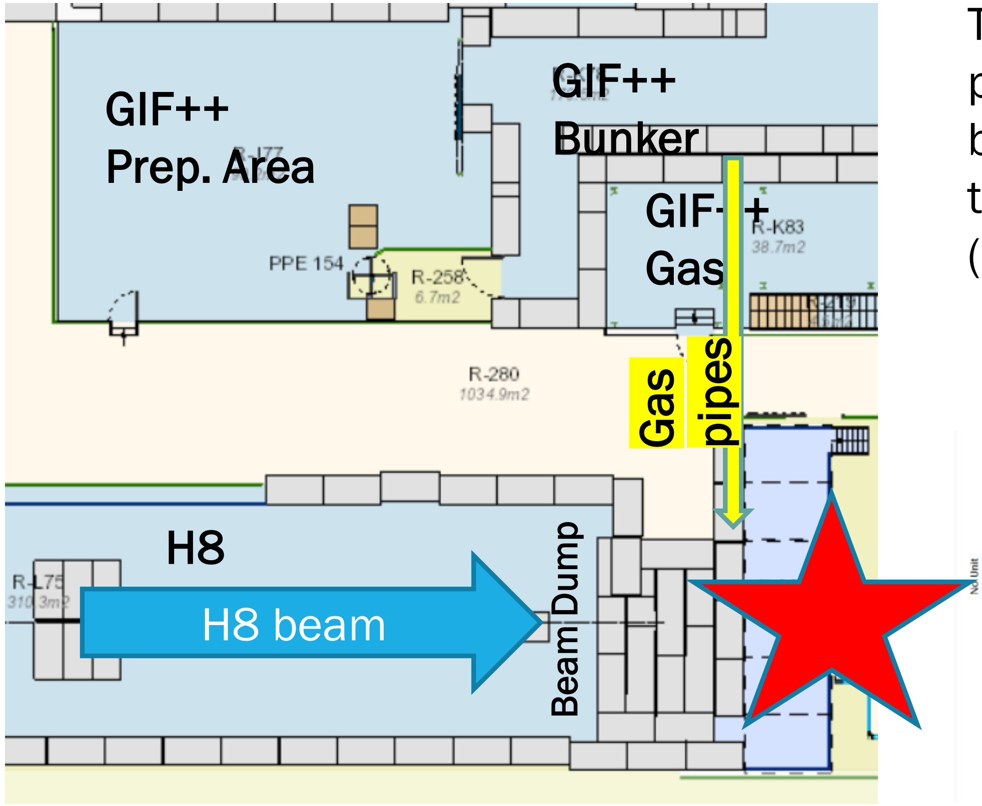
On the contrary, in negative polarization, multiplication increases as electrons approach the anode, roughly approximating a system characterized by drift followed by multiplication





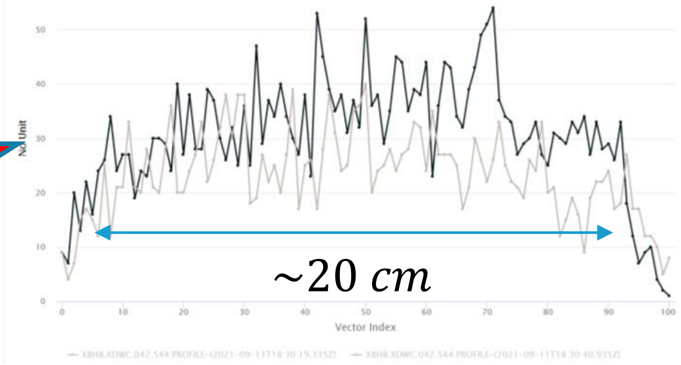
EXPERIMENTAL FACILITY

The test was carried out at the CERN SPS (H8 beam line), using the beam in parasitic mode.

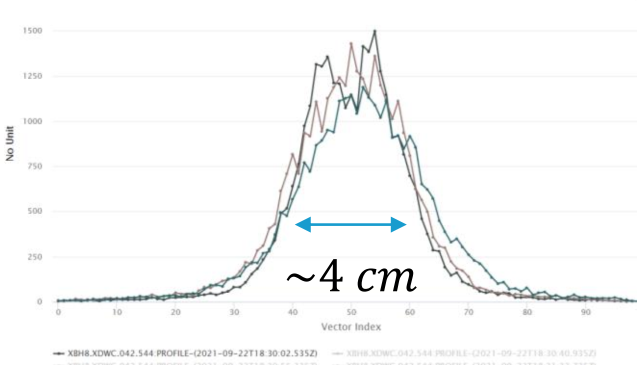


The system was installed downstream from the beamline dump platform. Two different beam profiles were used: tertiary muon beam with a moment of 165 GeV/c; secondary beam dumped in the upstream platforms with respect to the test platform (PPE168, PPE158 … PPE138)

Secondary dumped beam profile



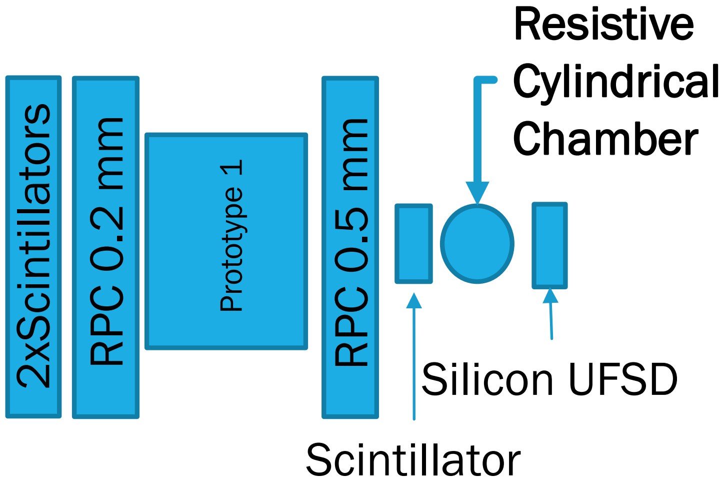
Tertiary muon beam profile

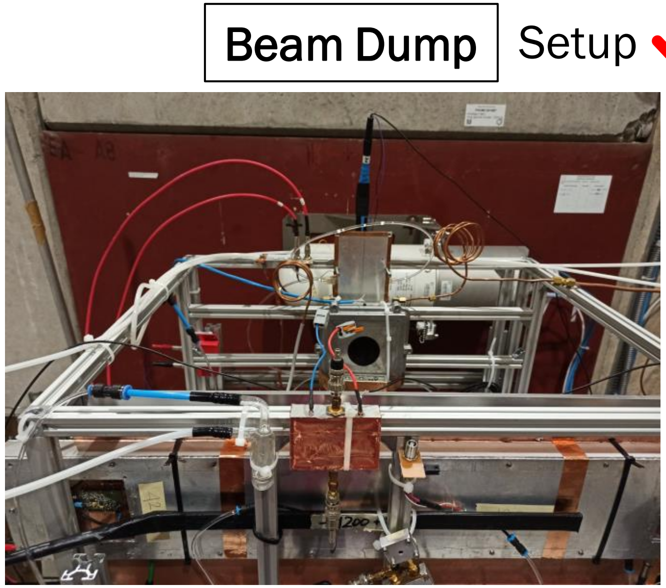


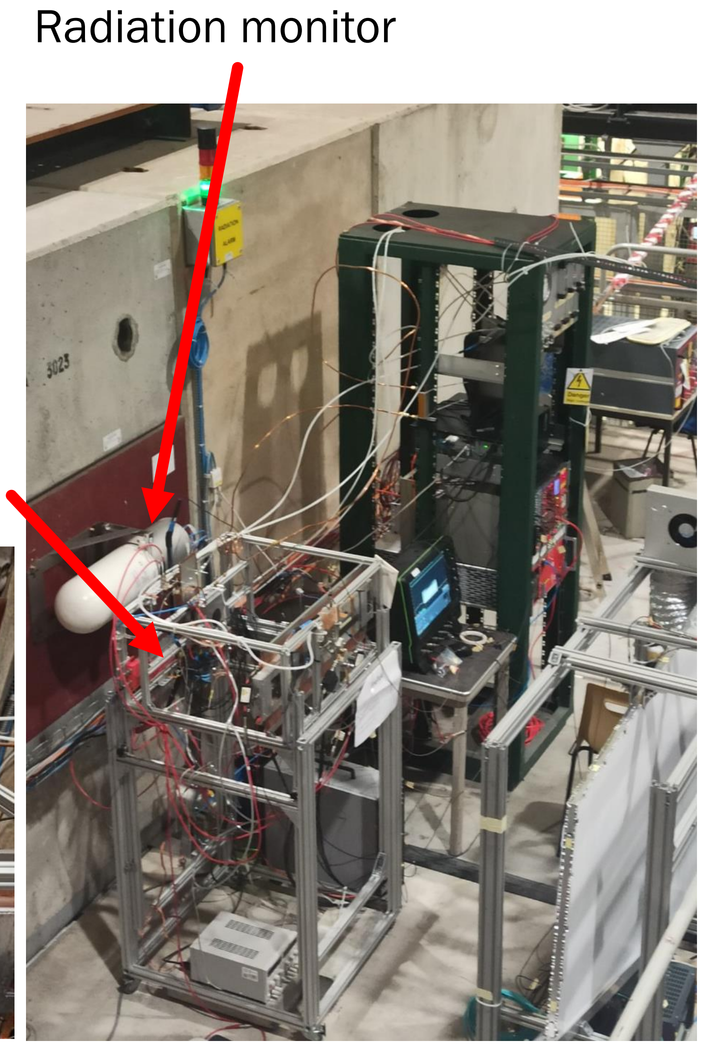
EXPERIMENTAL SET-UP

The experimental setup consists of three scintillators used as triggers and other prototypes taken as reference. A UFSD silicon detector was coupled to the RCC to improve acceptance with respect to the trigger, nevertheless, given the small dimensions of the prototypes compared to the profile and the intensity of the beam, a compromise was chosen between geometric acceptance and trigger rate.

The DAQ device is the CAEN V1742 Digitizer (12 bit, 5 GS/s)







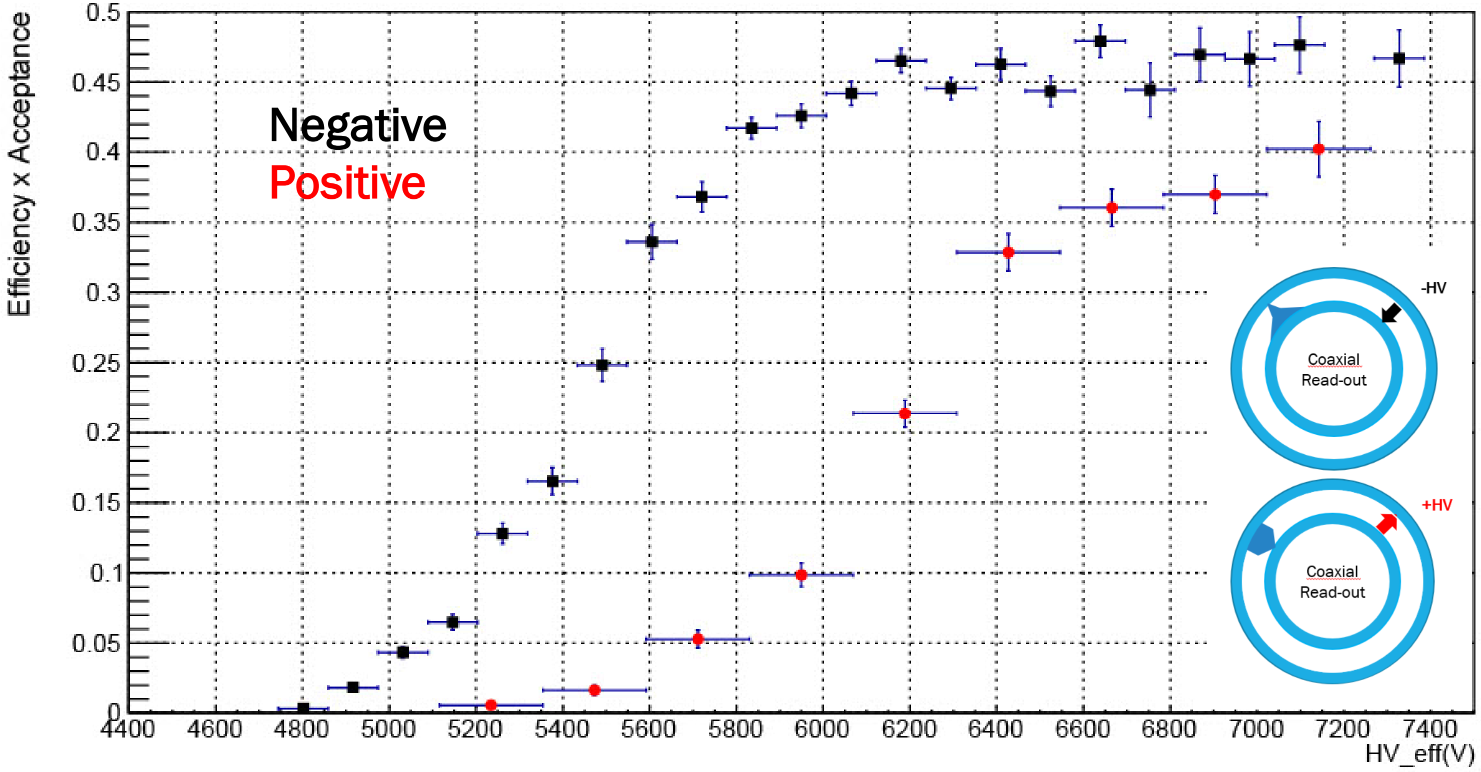
Gas mixture: **94.7% TFE + 5% iC_4H_{10}+0.3%SF_6**

EFFICIENCY

The efficiency was measured using a threshold set at 5 standard deviations from the mean value of the noise pedestal of the digitizer (about 5 mV).

No preamplifier was used in order to preserve the shape of the signal.

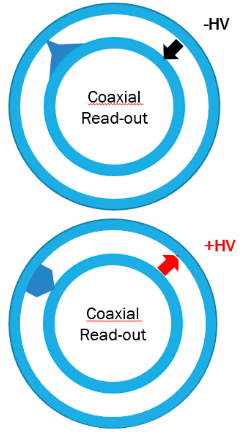
In addition to the trigger signal, the coincidence of three other detectors on the beam line was requested offline.

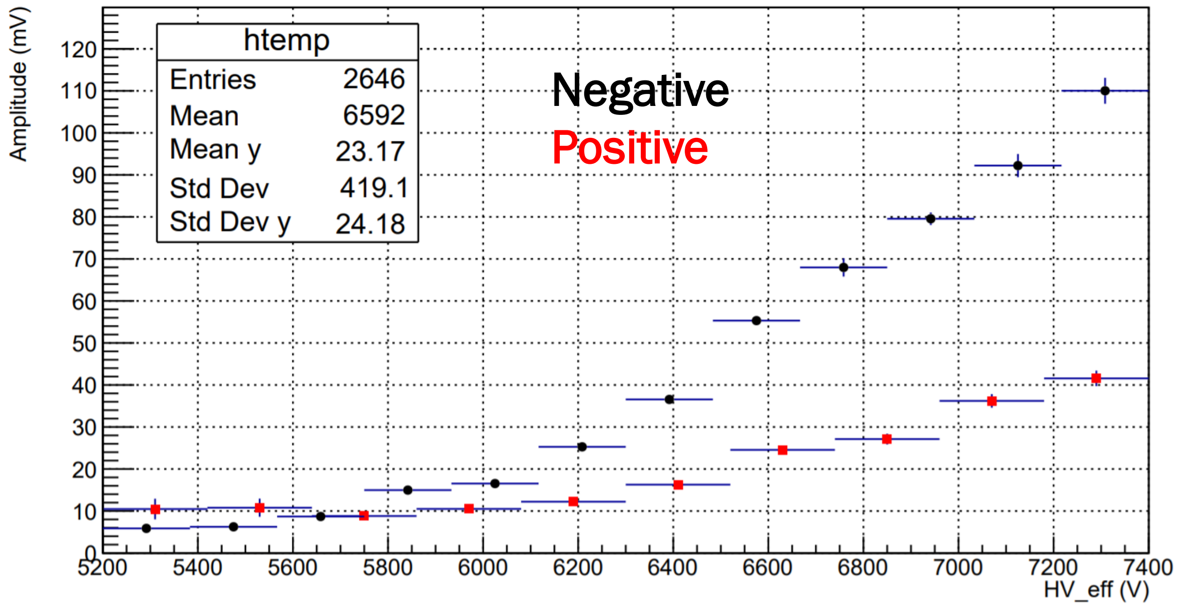


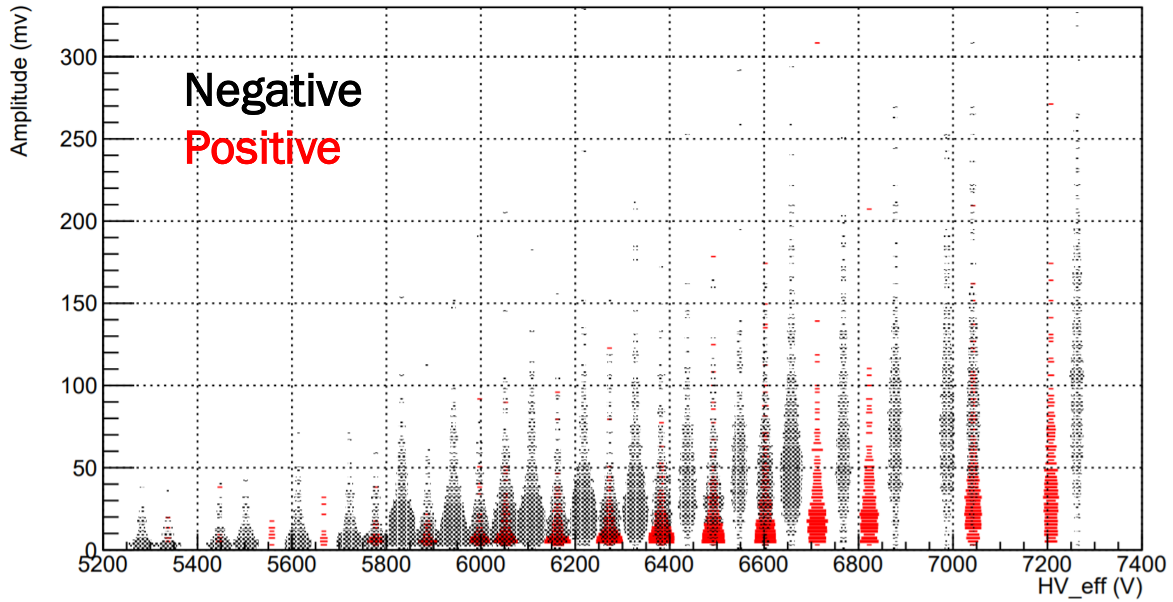
The trend of the efficiency curves clearly shows the asymmetrical response of the detector with respect to the bias voltage. In the case of positive bias, in which the multiplication occurs mainly in the first steps, the efficiency knee shifts towards higher voltage values. A reduction in the plateau value is also observed, indicating that the useful gap is thinner than in the case of negative polarization.

AMPLITUDE DISTRIBUTION

The amplitude distributions of the signals reflect what has been observed in the measurement of efficiency. The signals produced under positive polarization conditions are significantly smaller.
Despite the very large amplitude of the signals, the temporal analysis shows that the working regime is that of a saturated avalanche

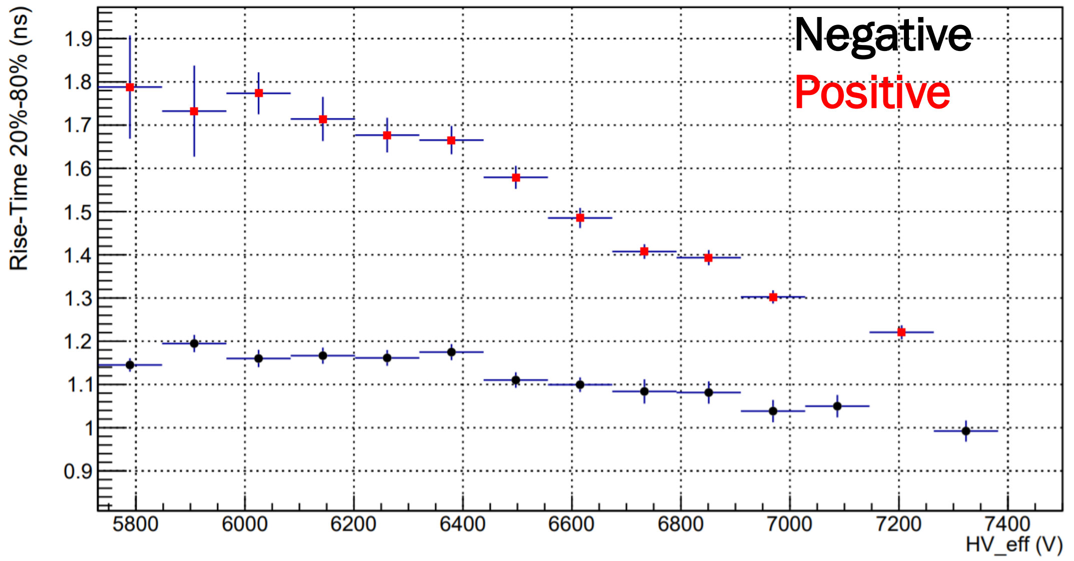


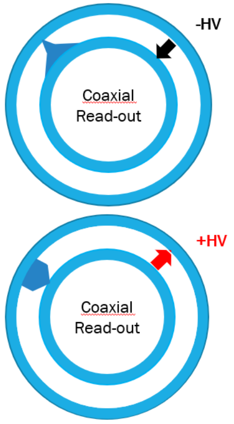


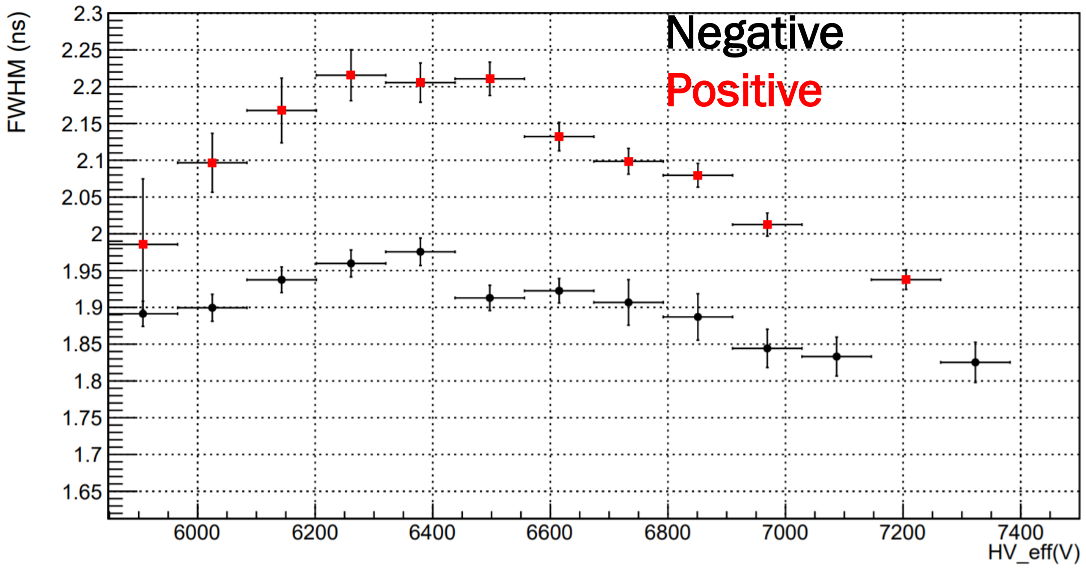


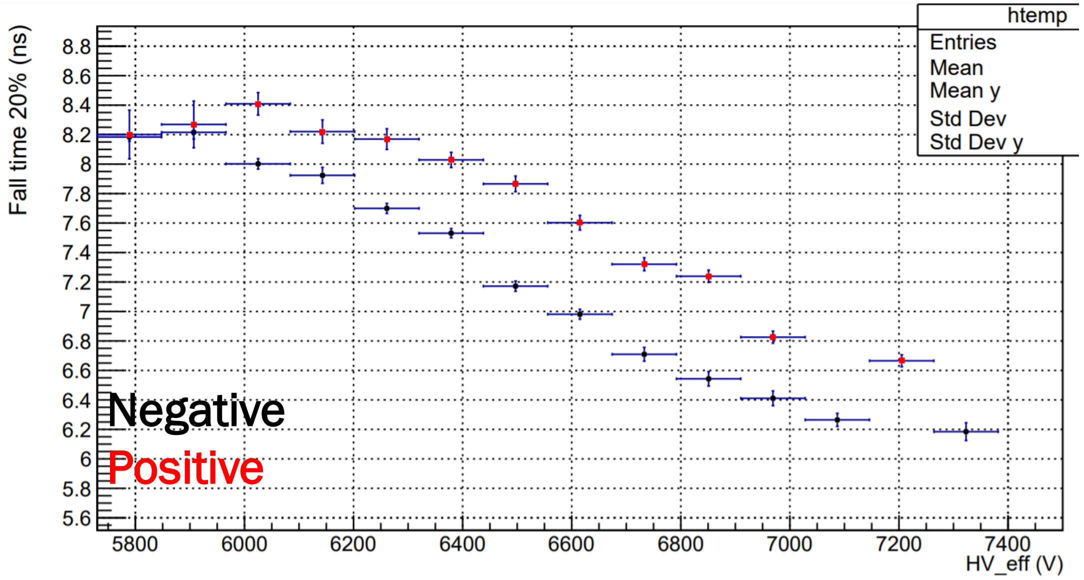
TIME RESPONSE (1)

The time response was characterized by measuring the crossing time of some set thresholds. Signals produced in positive polarity conditions are systematically larger. In this condition, the fall time is longer, as expected, meaning that the electrons produced near the cathode give a significant contribution to the signal. The rise time trend is affected by the fact that the signals in negative polarity are significantly higher

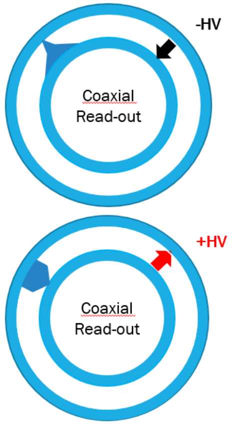


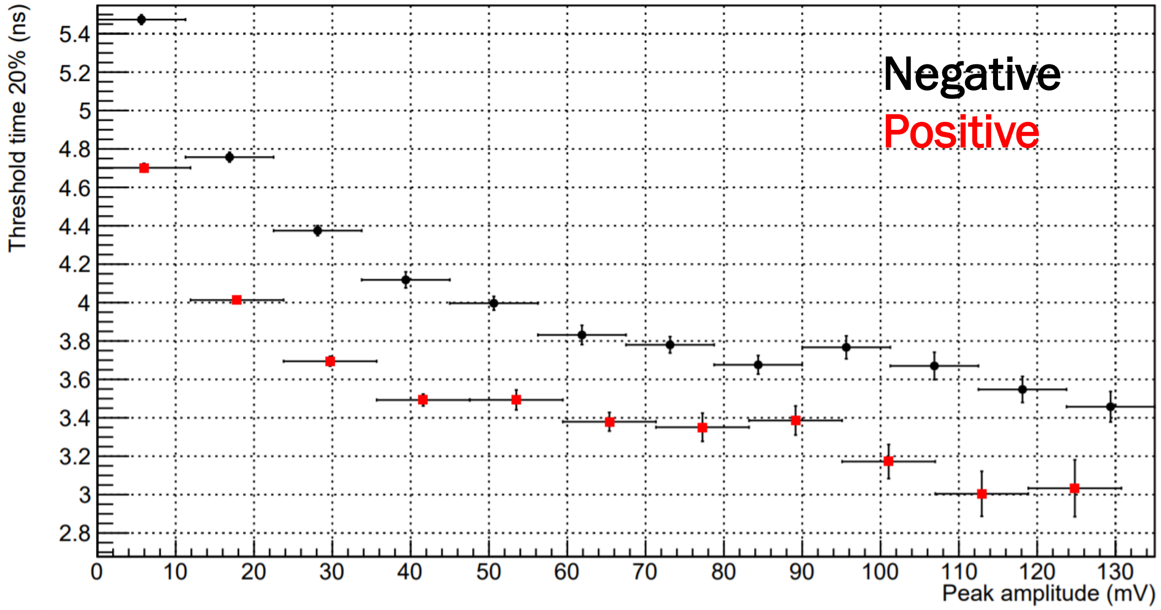


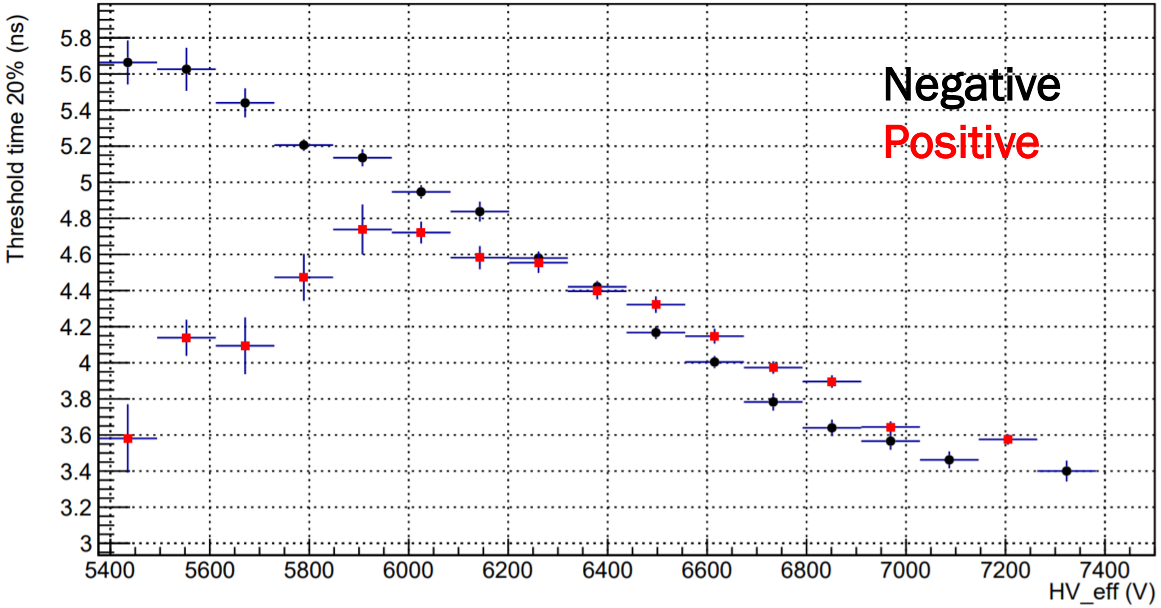




TIME RESPONSE (2)







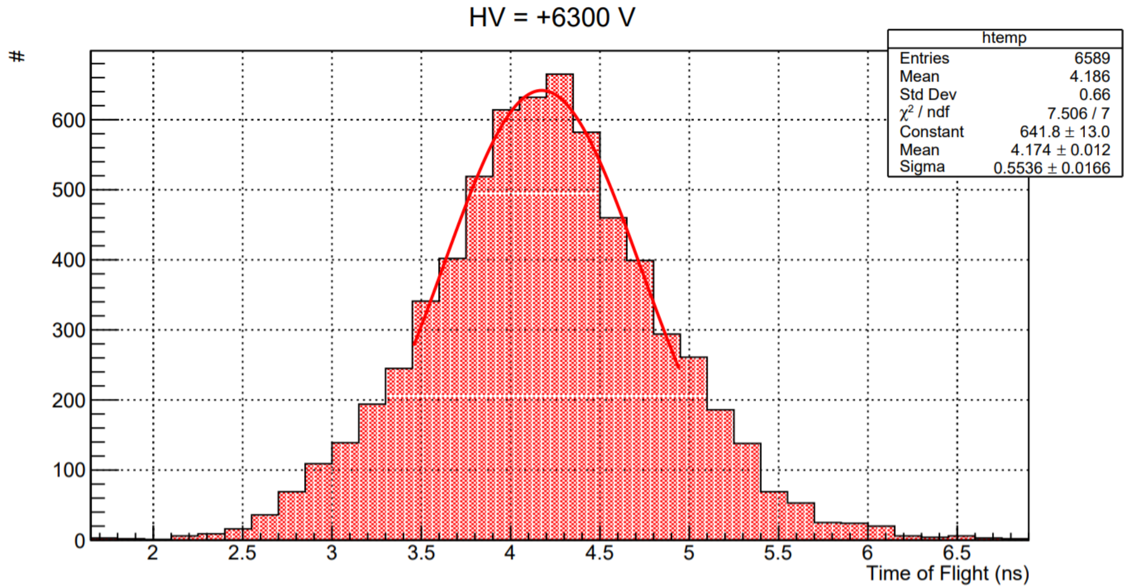
The arrival time was measured using an RPC detector with two coupled 0.2mm gaps as a reference.

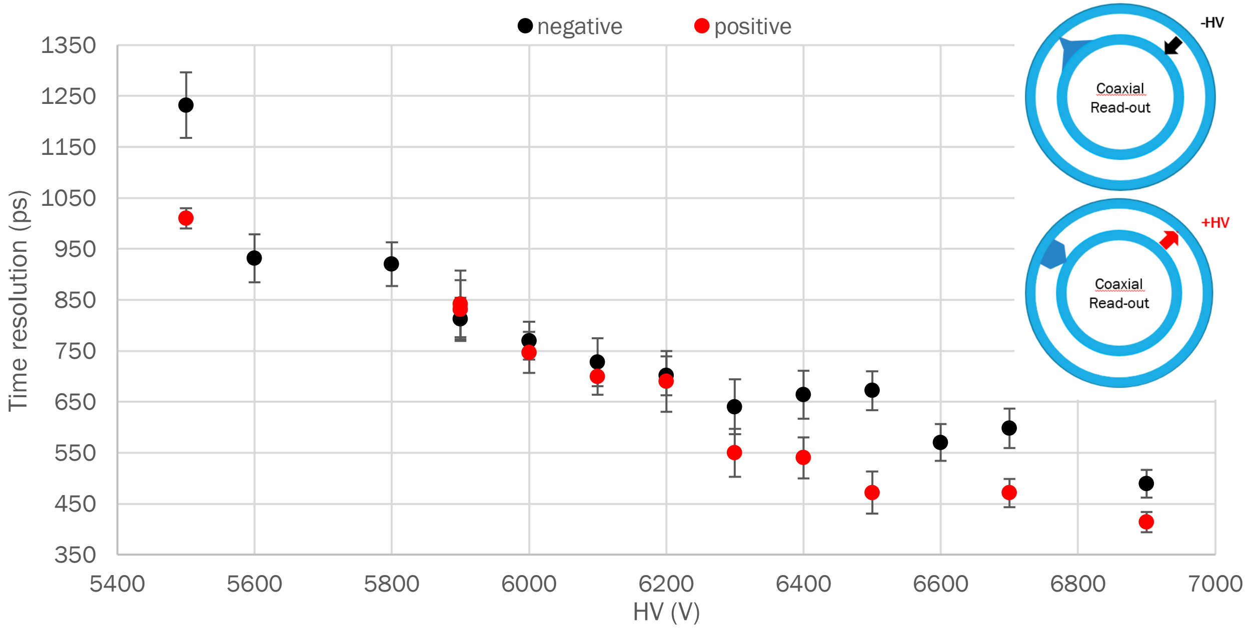
Since the amplitude of the signals at fixed voltage is significantly different between the two polarities, the arrival time has been studied as a function of the pulse amplitude.

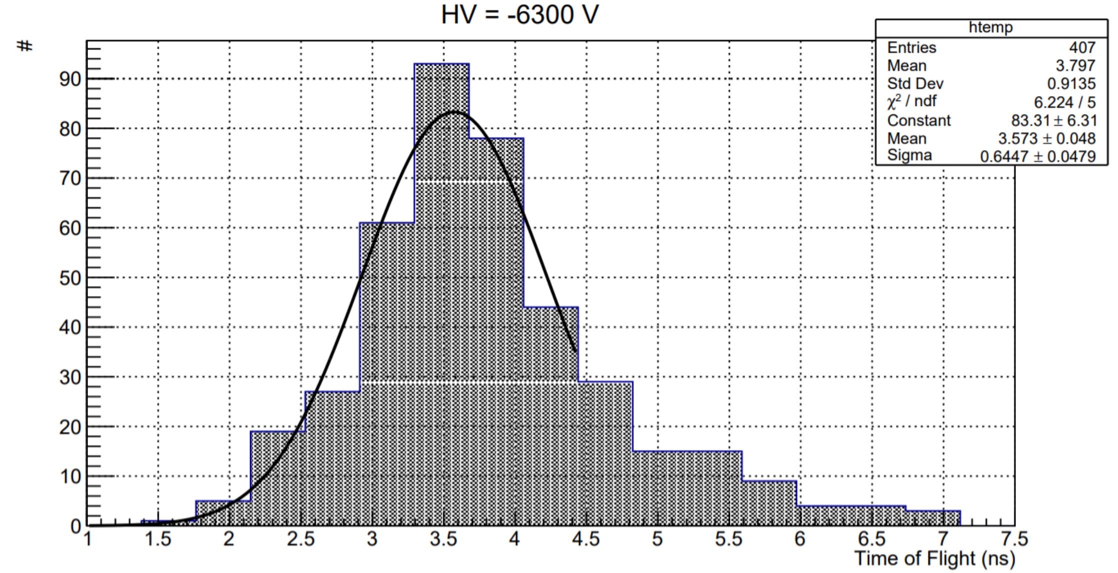
It can be observed that with the same amplitude, the signals produced in positive polarity systematically anticipate those produced in negative polarity.

TIME RESOLUTION

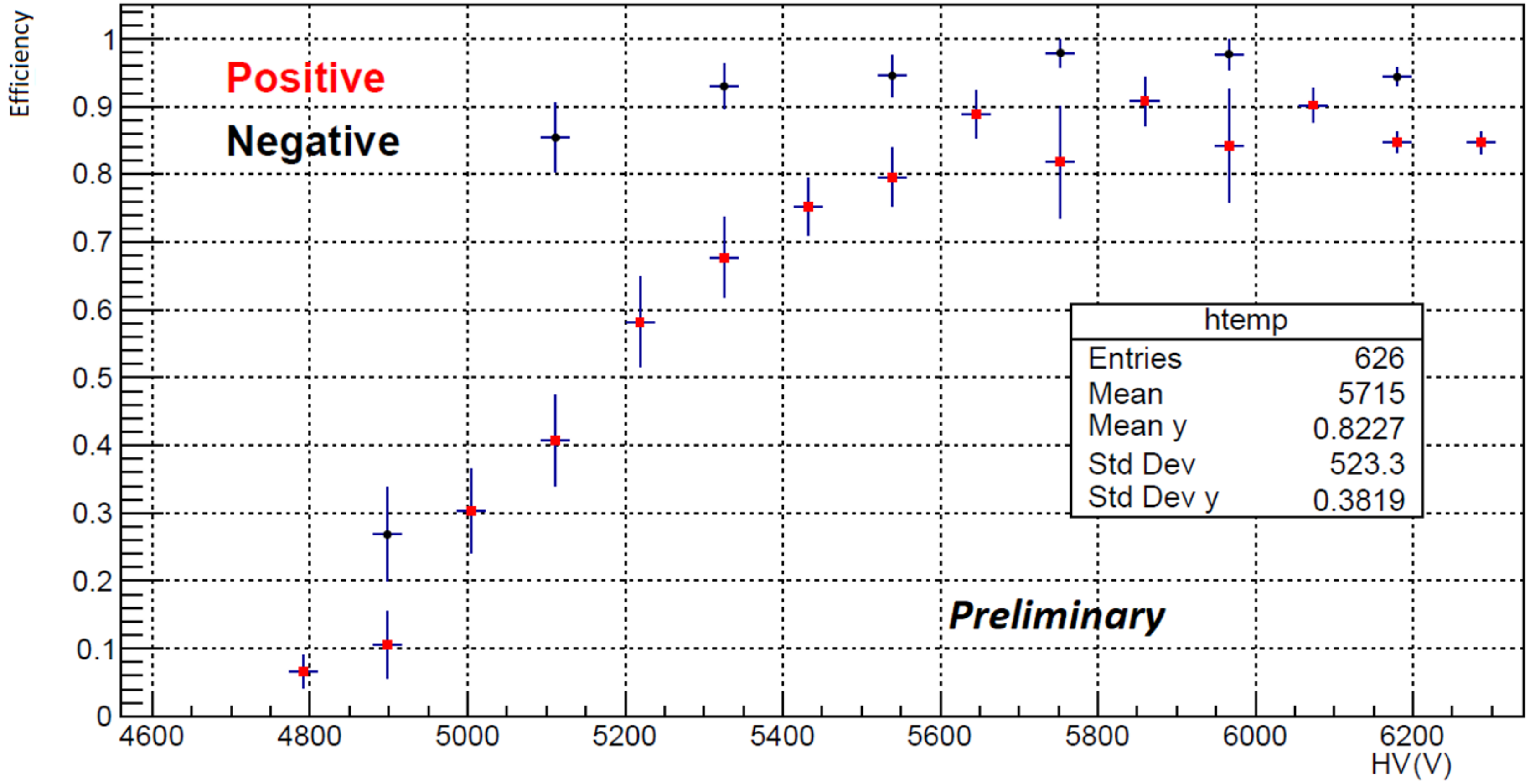
The time resolution was estimated by measuring the time of flight with respect to an RPC detector with 0.2 mm gas-gap whose time resolution is less than 170 ps.
The time resolution improve as the applied voltage increases and for high field values it is systematically better in the case of positive polarization, in which multiplication occurs mainly near the cathode (behavior like that of a thinner gap).







EFFICIENCY WITH FRONT-END PREAMPLIFIER



In this measure the UFSD pixel detector was used to optimize geometric acceptance at the expense of statistics .

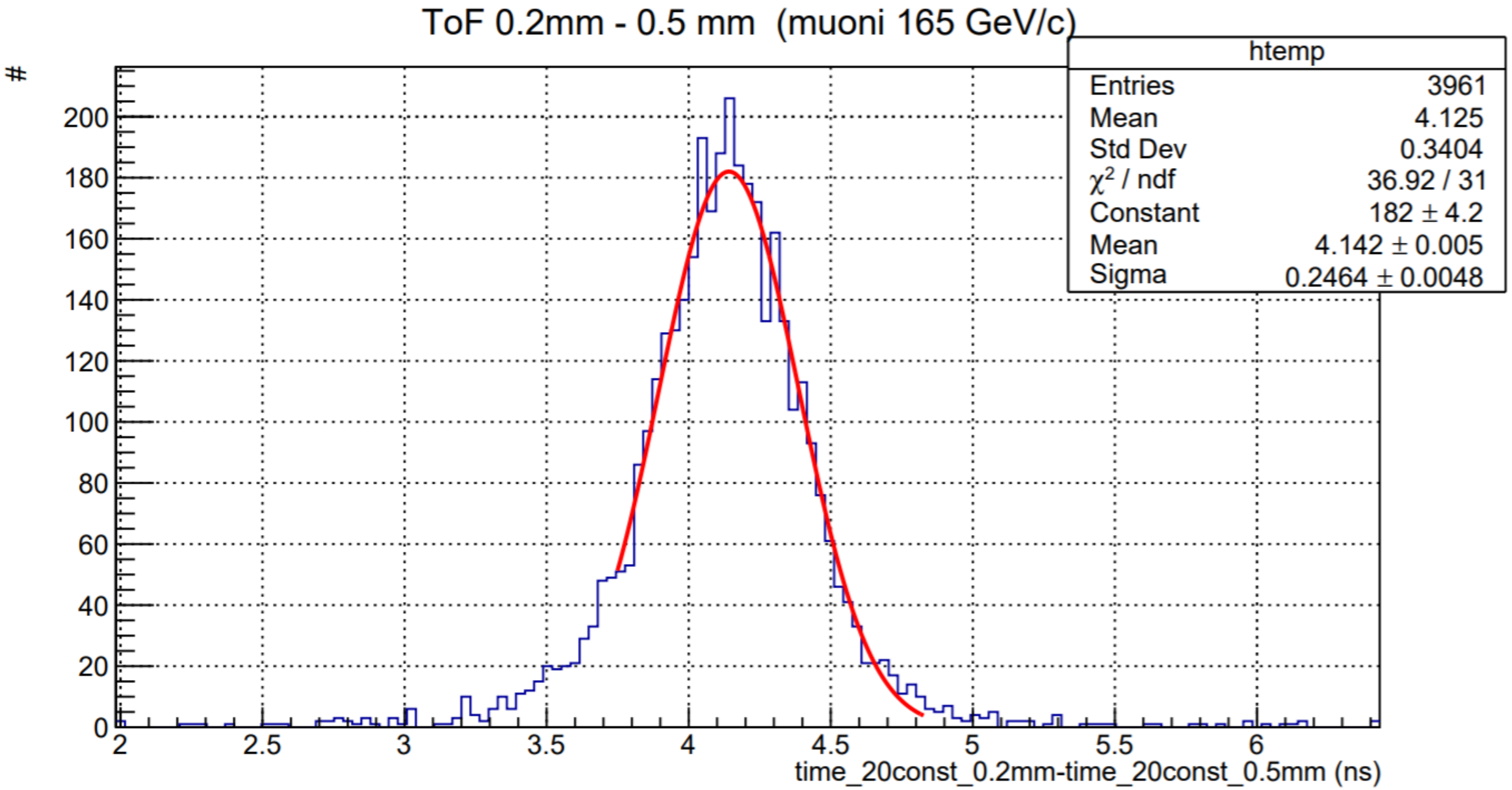
A Front-end preamplifier with 1 GHz bandwidth and 50 Ohm input impedance has been used.

With the front-end electronics, even the configuration in positive polarity reaches excellent performance levels

CONCLUSIONS

- The correct operation of a cylindrical geometry device with a quasi-uniform electric field, operated by fluxing the same gas mixture used for the RPC detectors of the ATLAS experiment, has been demonstrated.
- All the measured quantities highlighted the asymmetry of the response with respect to the polarity of the supply voltage, highlighting how the electric field gradient affect the development of the avalanche discharge in the gas
- This test represents the first step towards the development of cylindrical geometry detectors with a calibrated field for the intended purpose
- Further investigations are necessary to fully understand the link between the temporal evolution of the signal and the electric field

0.2 mm RPC TIME RESOLUTION



The time resolution of the double 0.2 mm gap RPC detector was estimated by measuring the time of flight compared to a 0.5 mm gas gap RPC detector.
Total jitter is dominated by fluctuations from the 0.5mm detector.