The Resistive Cylindrical Chamber, a new detector based on the generalization of the RPC detectors to the quasi-planar field

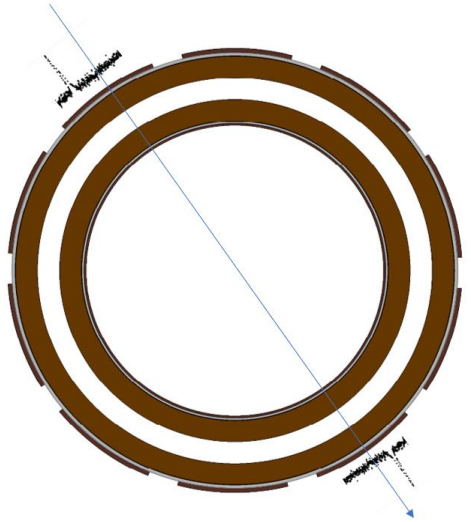
A. Rocchi and R. Cardarelli on behalf of RCC collaboration

IFD2022 - INFN WORKSHOP ON FUTURE DETECTORS

OCT 17 – 19, 2022

BARI, VILLA ROMANAZZI CARDUCCI

The Resistive Cylindrical Chamber



The RCC detector is a device consisting of two concentric cylinders of resistive material. The detector's stratigraphy is like that of an RPC, but the cylindrical geometry introduces new control parameters on the detector's response, as well as extending its use to hostile environments thanks to the high strength mechanical structure

Gas pressurization :

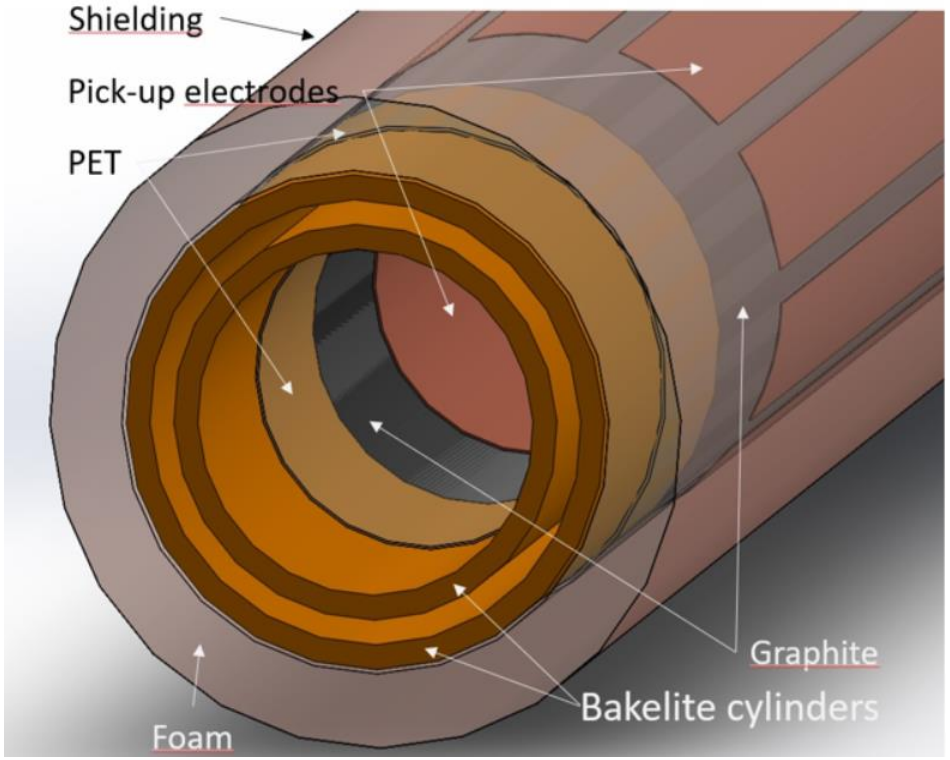
1. Increase the gas target density, with a consequent increase in intrinsic efficiency
   → MRPC time response with thin single gap configuration
   → light eco-friendly CO_2 based gas mixtures
2. Use the detector in hostile environments

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

Double gap:

1. Tracking capability
2. Improvement in time resolution and efficiency



SIMULATION: ELECTRIC FIELD GRADIENT AND PRIMARY IONIZATION

In the RCC detector the electric field has a cylindrical geometry and is much more approximable to a planar field as the gas-gap is negligible with respect to the radius of the internal electrode. This feature allows to design detectors with different responses according to the experimental needs:

- it is possible to reproduce the same performances of an RPC in an easily pressurized cylindrical structure;
- it is possible to design a detector with a non-negligible field gradient to increase the time resolution and suppress the transition to the streamer regime

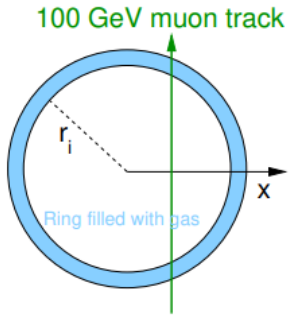
The RCC detector has a double gap structure, which can be exploited for tracking measurements and to increase efficiency and time resolution

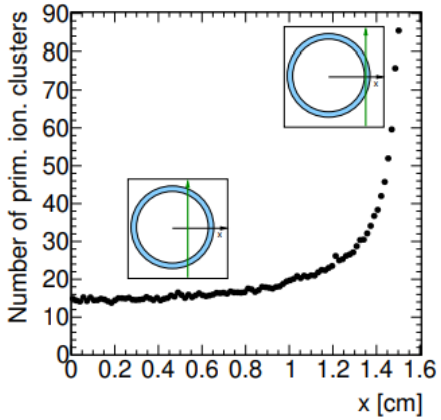
$$E(r) = \frac{V}{r\ ln\frac{R_o}{R_i}} \sim \frac{V}{R_i ln\frac{R_o}{R_i}} - \frac{V}{R_i ln\frac{R_o}{R_i}}\frac{r-R_i}{R_i}$$

$$R_o - R_i \ll R_i$$

→ weak dependence on thin gas gaps

Primary ionization with pressurized CO_2

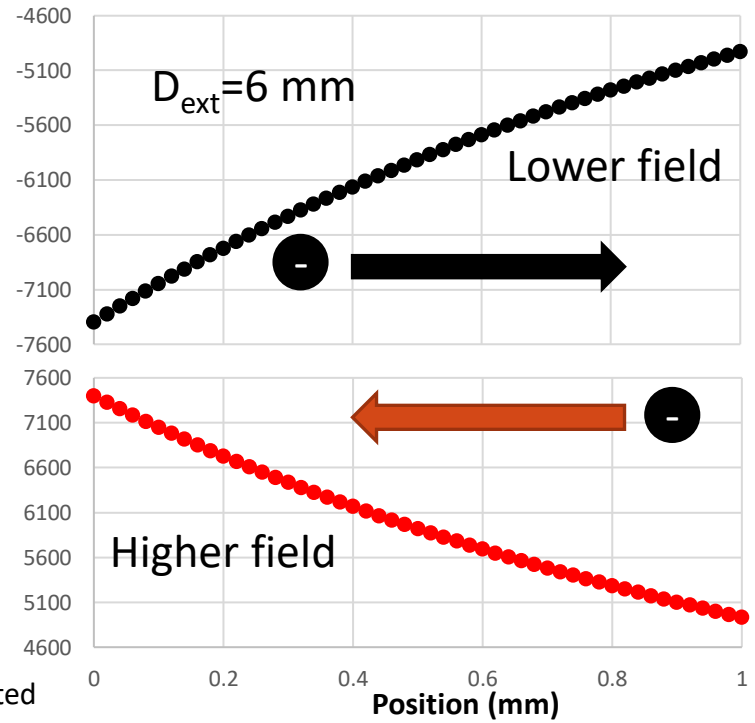




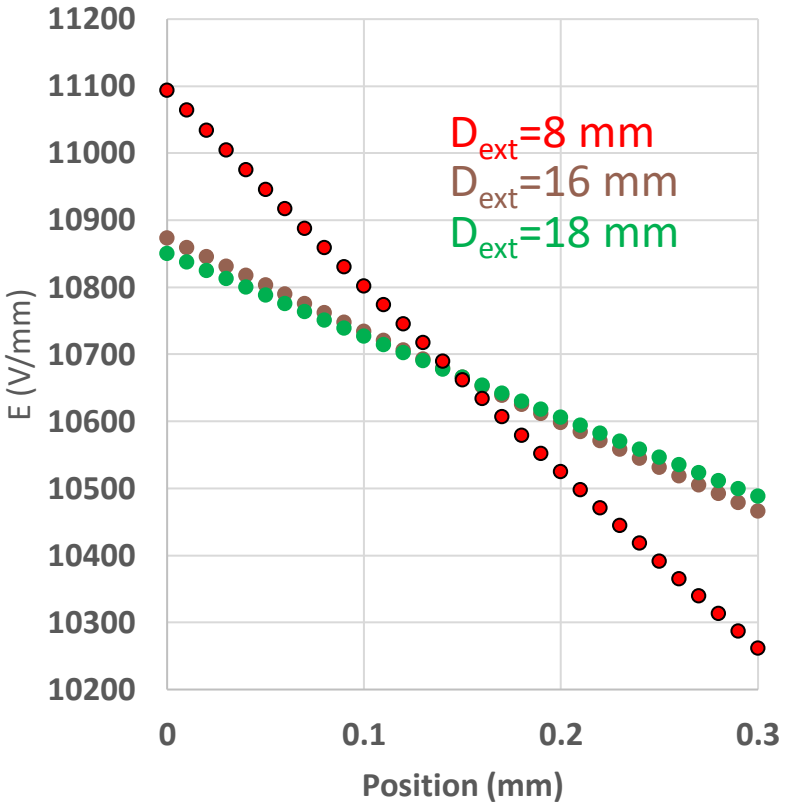
⇒ Small number of primary ionization clusters: ~14 for $r \lesssim r_i$.

[Simulation of the avalanche creation in resitive circular chambers Oliver Kortner, XVI Workshop on Resistive Plate Chambers and Related Detectors]

Gas-gap 1 mm



Gas-gap 0.3 mm

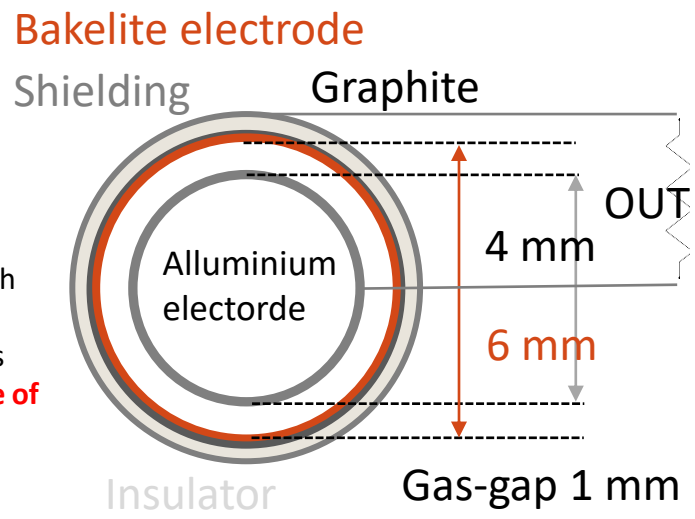


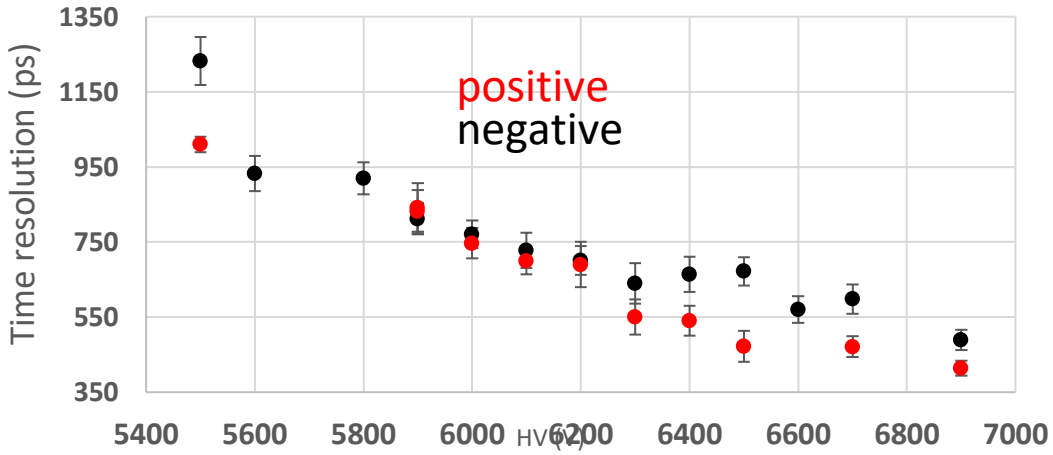
DETECTOR DESCRIPTION AND RELIMINARY RESULTS (1 mm GAS-GAP)

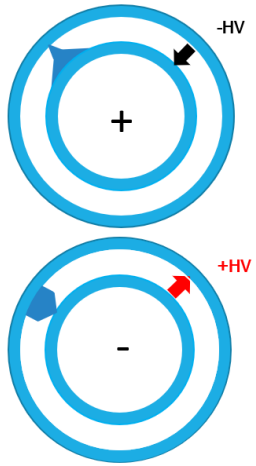
[Development of Resistive Cylindrical Chambers, R. Cardarelli, XVI Workshop on Resistive Plate Chambers and Related Detectors]
[Moderation of the avalanche gas discharge through a quasi-uniform electric field device: the Resistive Cylindrical Chamber, A. Rocchi, VCI2022]

The response of a 1 mm gas-gap RCC was studied with the detector described in figure. The smaller radius electrode consists of an aluminum cylinder. A significant separation is observed between the working points of the detector in the different polarities. **The intrinsic efficiency is lower in the case of positive polarization as if the useful gas-gap decreases.**

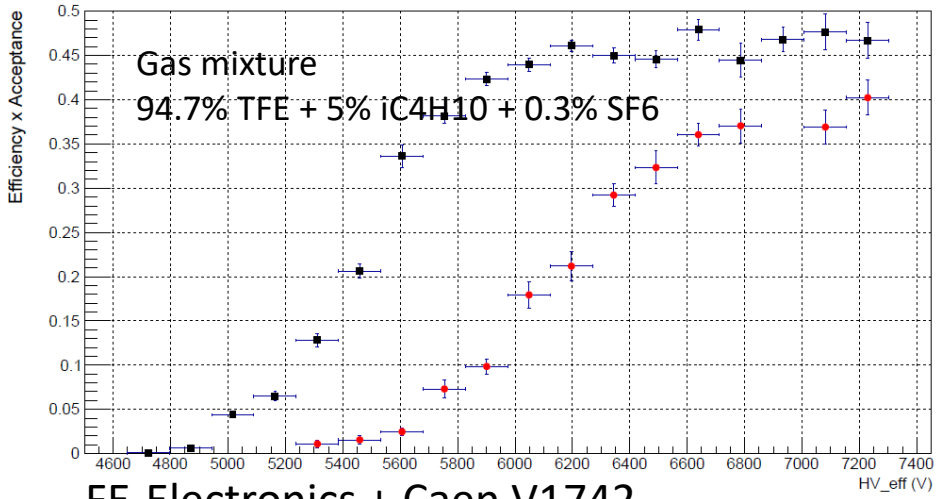
The time resolution was measured using an RPC detector with two coupled 0.2mm gaps as a reference.
The time resolution improve as the applied voltage increases and for high field values it **is systematically better in the case of positive polarization, in which multiplication occurs mainly near the cathode (behavior like that of a thinner gap**).



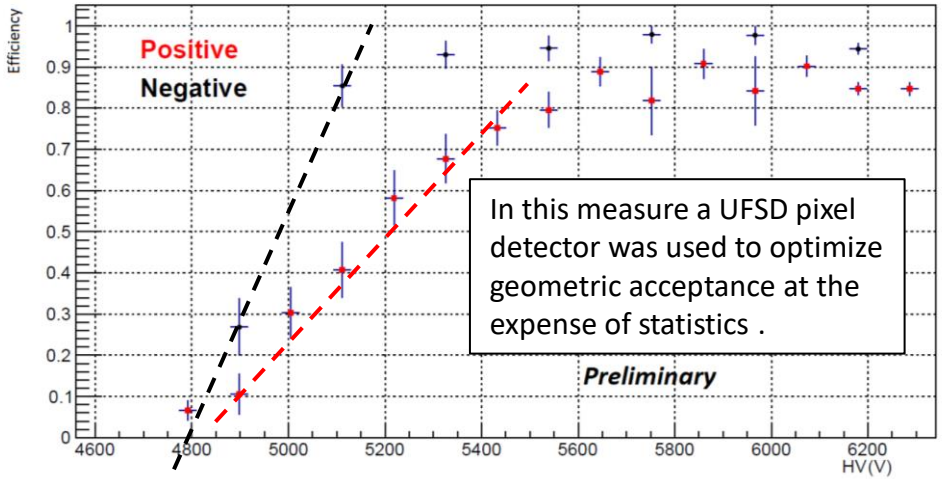




Caen V1742



FE-Electronics + Caen V1742

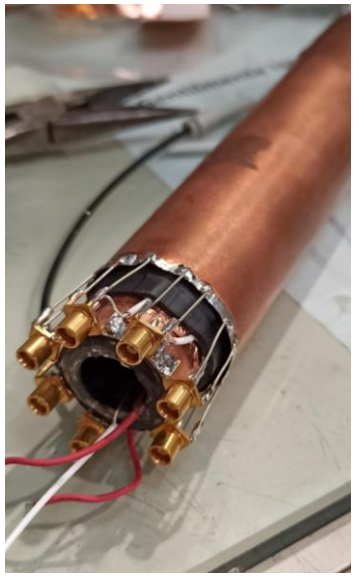


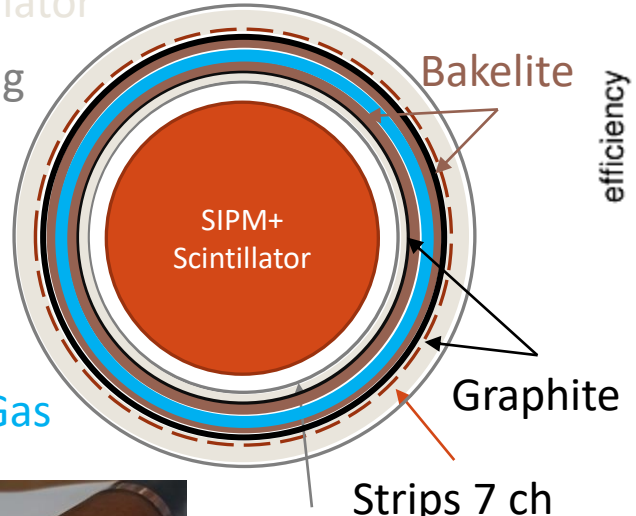
DETECTOR DESCRIPTION AND RELIMINARY RESULTS (0.3 mm GAS-GAP)

[Thanks to Alessandro Paoloni for the SIPM detector and electroinics]

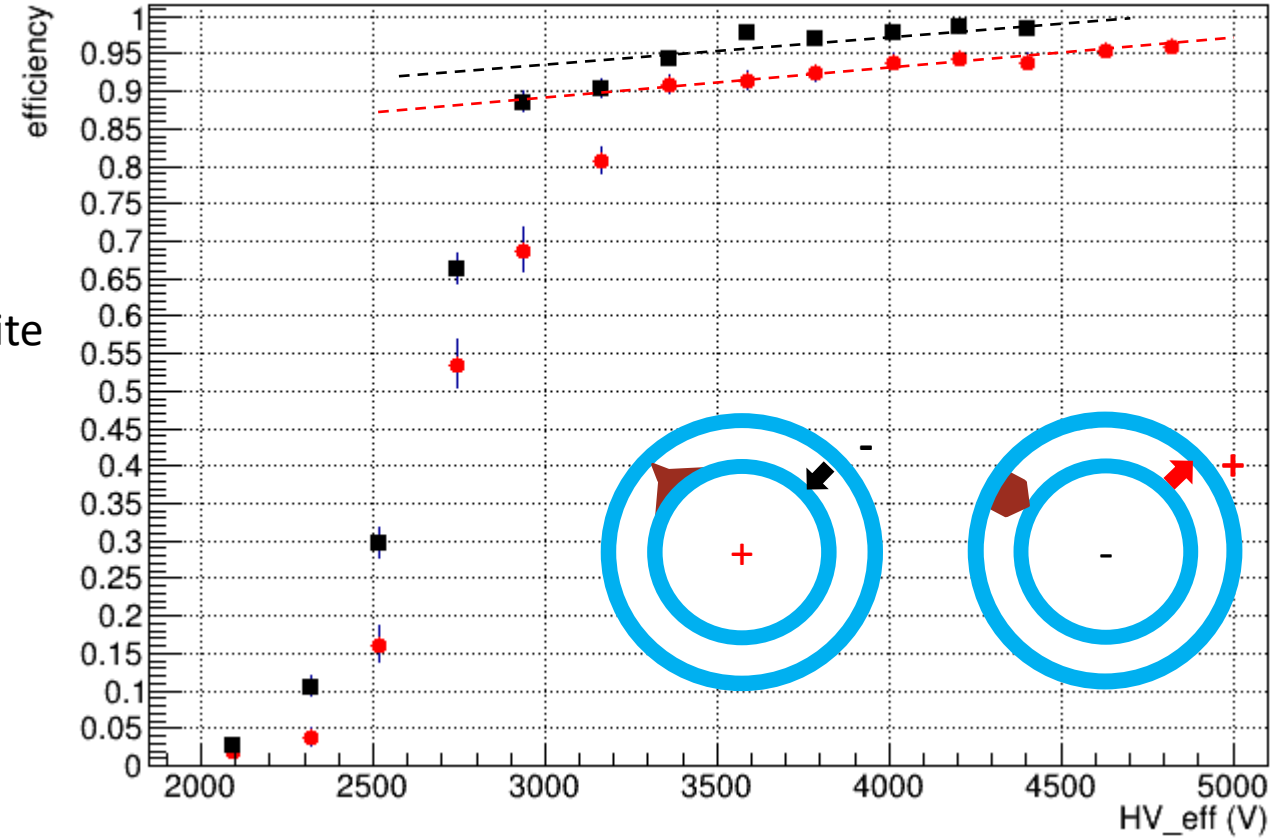
The detector described in figure was characterized with muons of 180 GeV / c. A small difference can be observed between the working points in different polarities. Also In this configuration the detector has a lower intrinsic efficiency in positive polarity.

The internal detector made it possible to close the angle of acceptance and discriminate the tangential traces





Gas mixture
94.7% TFE + 5% iC4H10 + 0.3% SF6

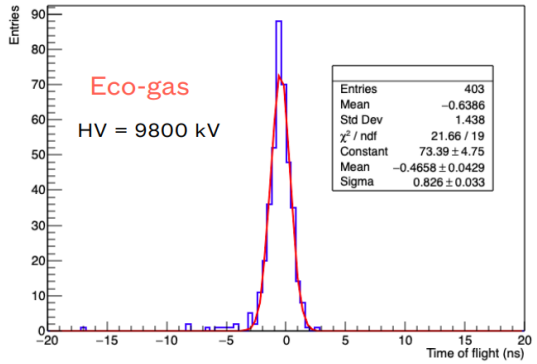


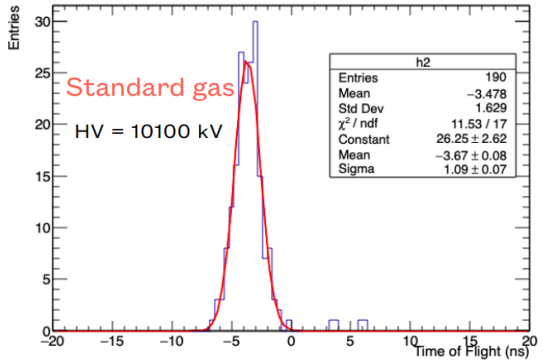
STUDY WITH HIGH PRESSURIZED CO_2

[On a new environment-friendly gas mixture for Resistive Plate Chambers, G. Proto, XVI Workshop on Resistive Plate Chambers and Related Detectors]

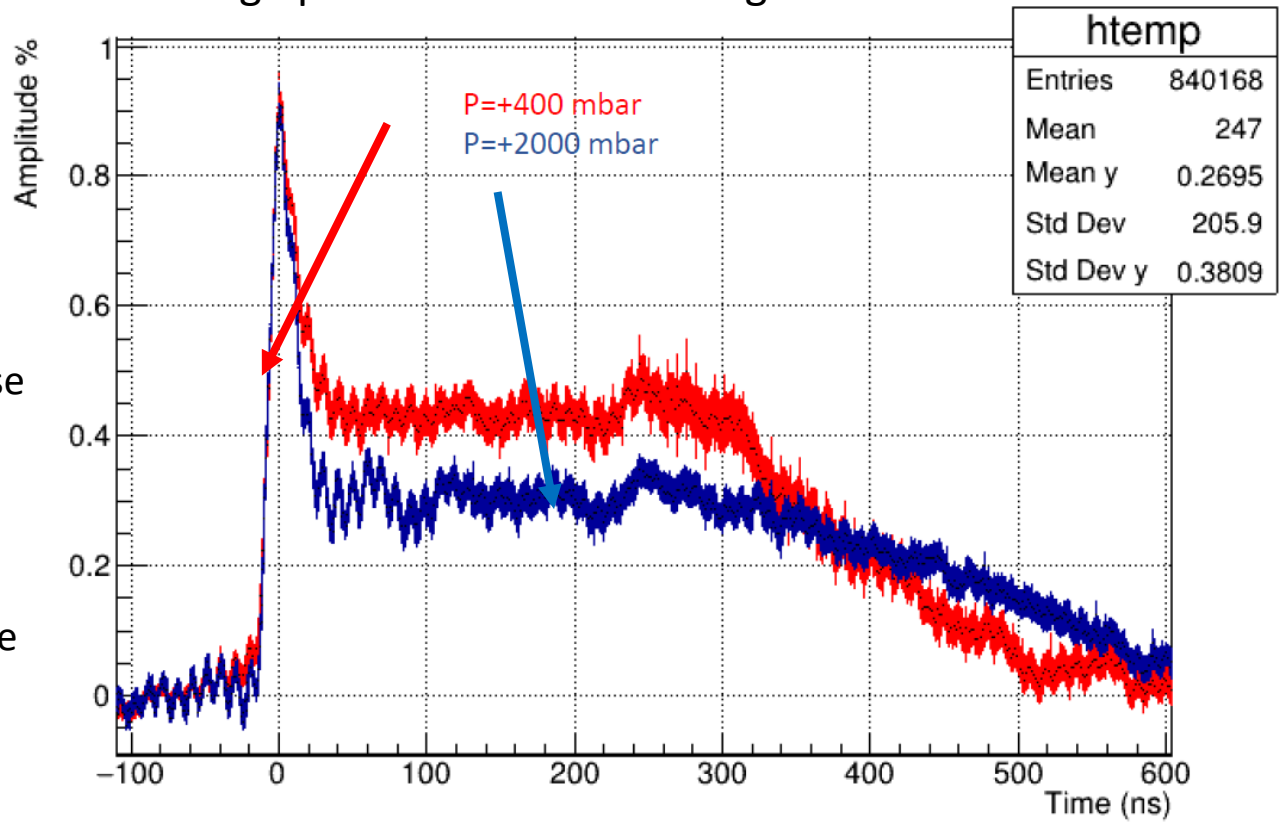
Studies on new eco-friendly gas mixtures show that mixtures with a high concentration of CO_2 lead to an improvement in the time resolution at expense of the intrinsic efficiency of the detector.

σ_{Eco} = (0.83 ± 0.03) ns
σ_{STD} = (1.09 ± 0.07) ns





Average profile of normalized signals



The RCC thanks to the pressurization of the gas-gap allows to increase the density of the gas recovering the loss of efficiency even for thin gas gaps

The effect of the pressure is visible from the ion signal profile:
as the pressure increases, the instantaneous current decreases as the drift speed of the ions decreases and the duration of the signal increases accordingly. The amplitude of the electronic signal is unchanged

Conclusions

The functionality of the detector has been demonstrated with prototypes of different structures (1 mm gas-gap, 0.3 mm gas-gap)

As expected, the asymmetry in the detector response with respect to the polarity of the applied voltage increases when the thickness of the gap increases with respect to the internal radius

The effect of suppression of the avalanche in positive polarization leads to a reduction of the intrinsic efficiency but to an improvement in the time resolution, as if the useful gas-gap were thinner

This effect can also be studied to suppress the transition to the streamer regime in gas mixtures with low quenching potential

Perspectives

Systematic study of RCC detectors with different radius and gas-gaps

Study of the response with high concentration of CO_2