RCC (Resistive Cylindrical Chamber)

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RCC collaboration

INFN sez. Tor Vergata
RPC meeting, CERN 26/09/2022

Introduction

- the experimental observation of the increase in temporal resolution with the decrease in the thickness of the gas gap led to the introduction of RPC with thin gaps, however this involves a decrease in efficiency, to overcome this problem multigap MRPC was introduced.(Crispin Williams, Paolo Fonte et alt)

- A possible solution to increase the efficiency of the RPC is to increase the pressure with the same thickness of the gap, this solution is possible only by introducing a cylindrical geometry. (Roberto Cardarelli)

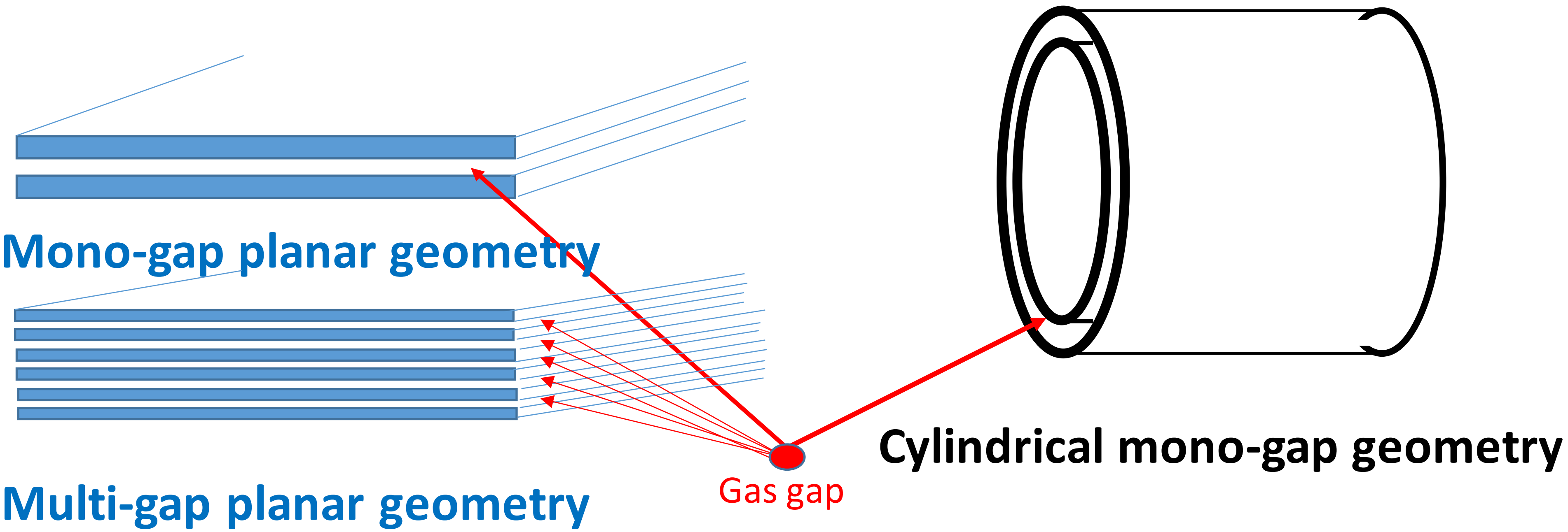
Detector with almost uniform electric field but different geometry

RPC

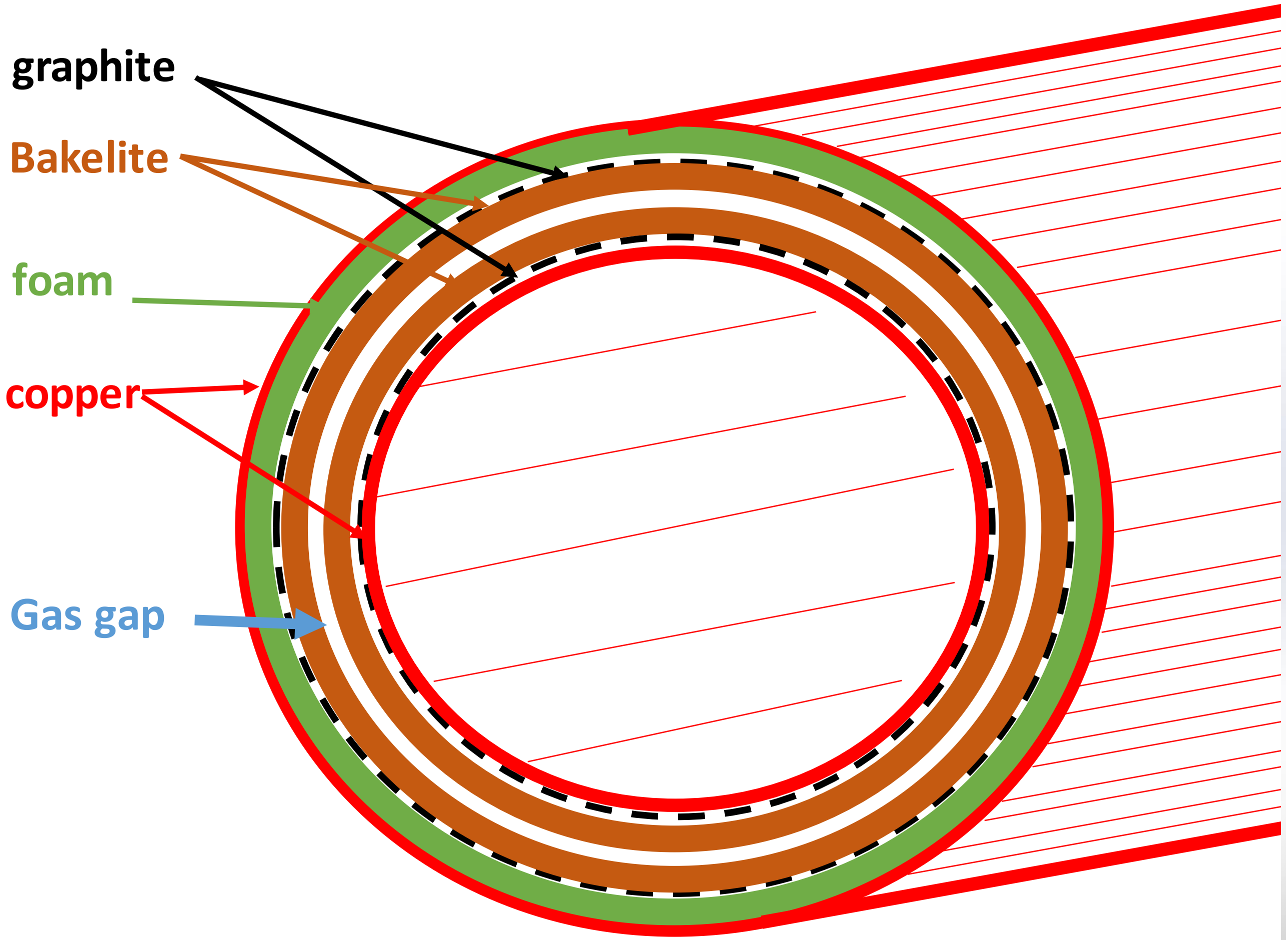
RCC (R*esistive* Cylendric Chamber)

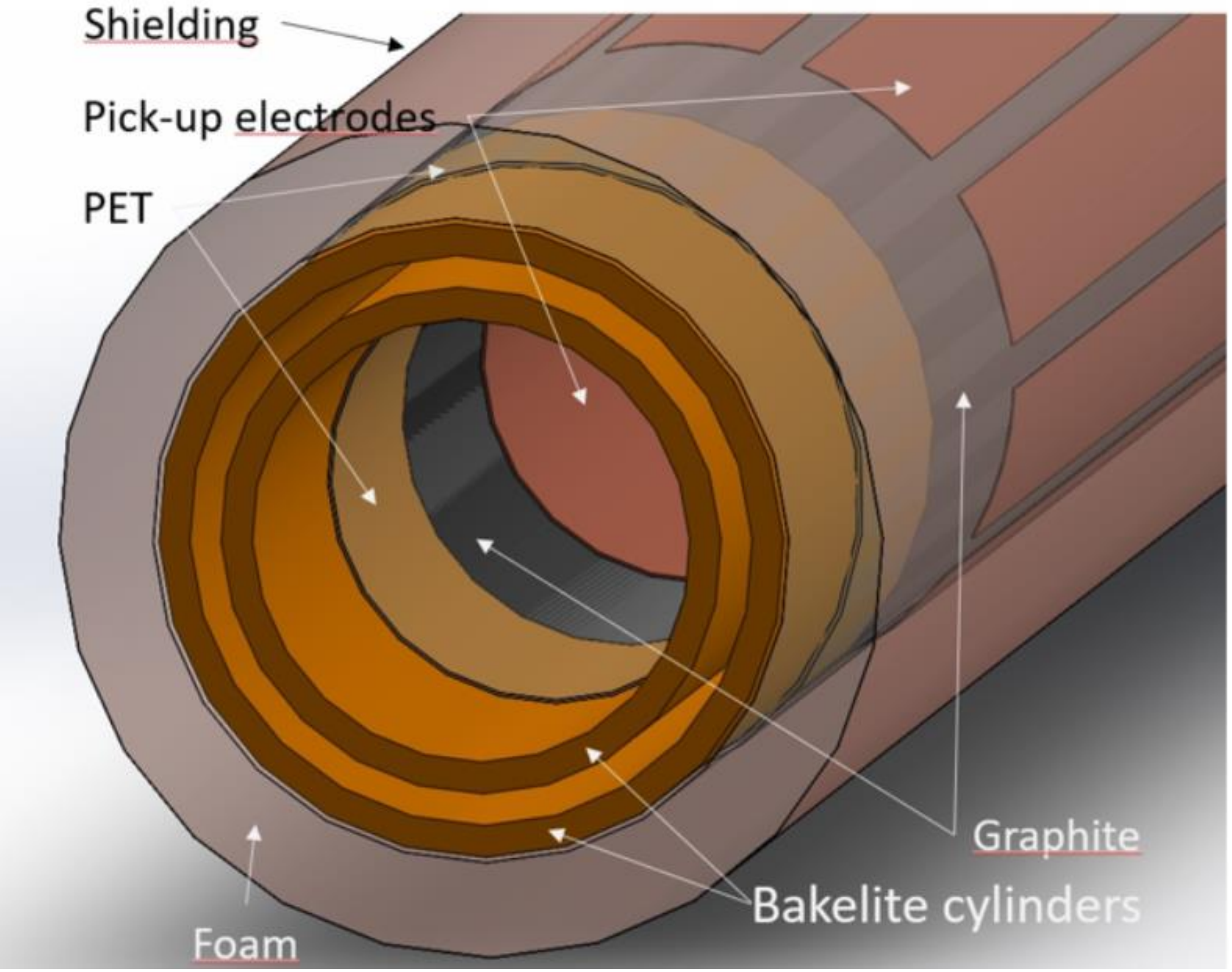
Low pressure solution

High pressure solution



RCC structure





Electric field in cylindrical geometry

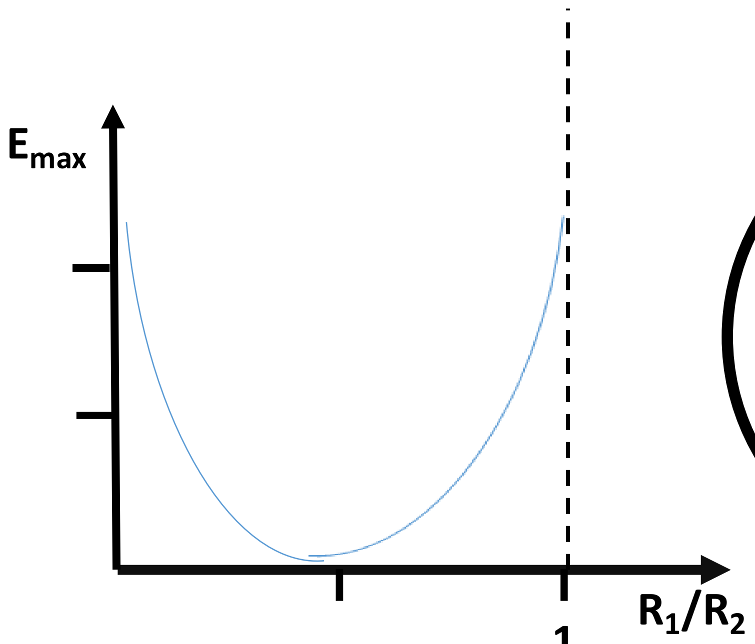


fig1

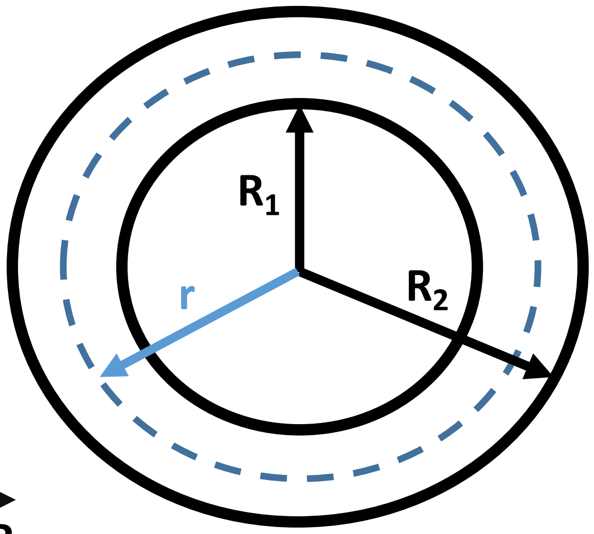


fig2

(1) $$E=(V/r)/\log(R_2/R_1)$$

(2) $$E_{max}=(V/R_1)/\log(R_2/R_1)$$

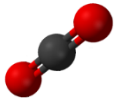
In fig (1) the E_{max} trend is graphically represented as a function of the ratio R1 / R2

From (1) it is clear that the electric field E reaches its greatest value on the surface of the inner cylinder, that is for r = R1, while as r increases it decreases until it reaches its smallest value at r = R2; ie on the surface of the outer cylinder

There are two cases:

- for R2 / R1 <(1 / e) we have the gas discharge rate at Townsend
- for R2 / R1> (1 / e) we have the spark rate

Cylindrical Geometry: Why?

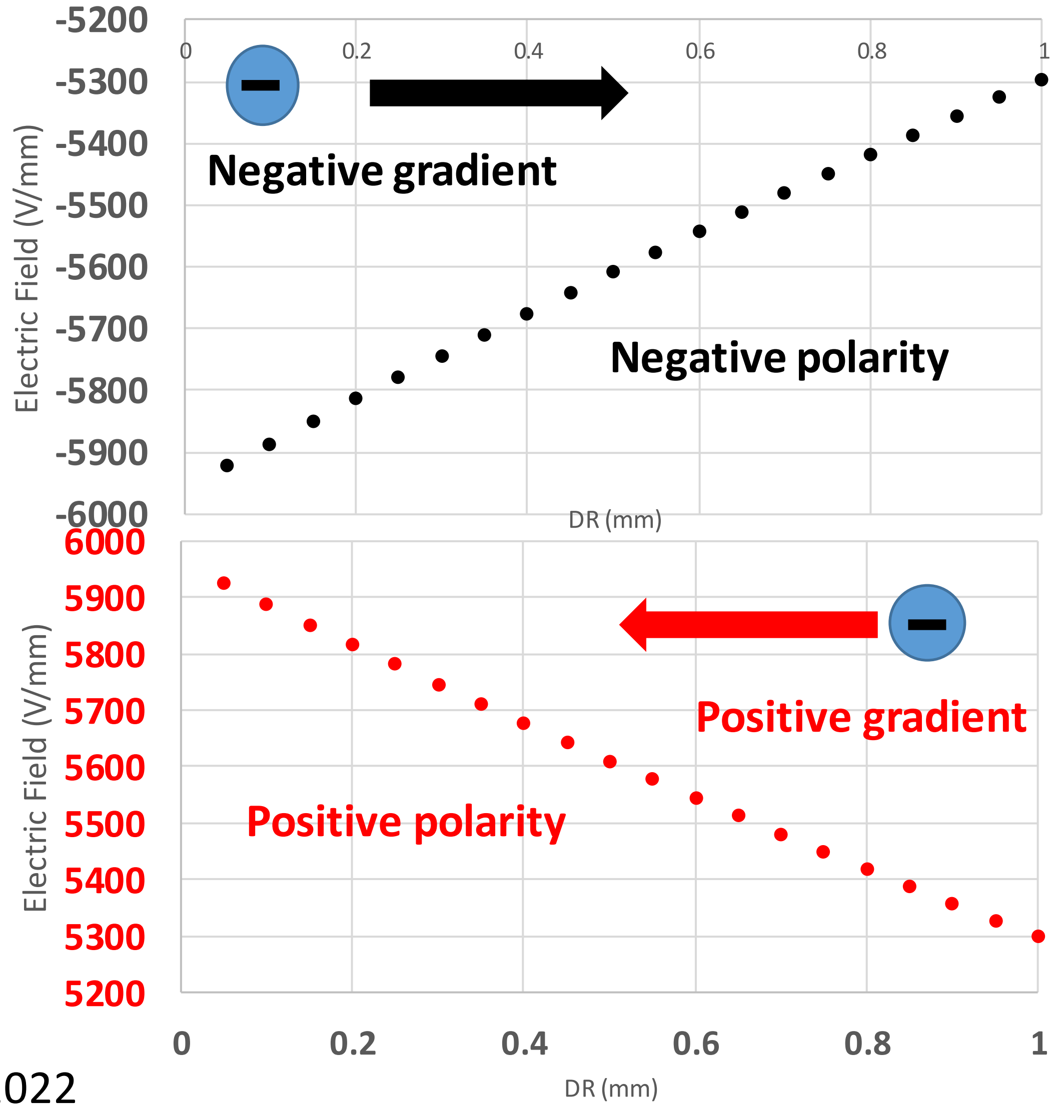


The gas pressurization would allow to:

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 

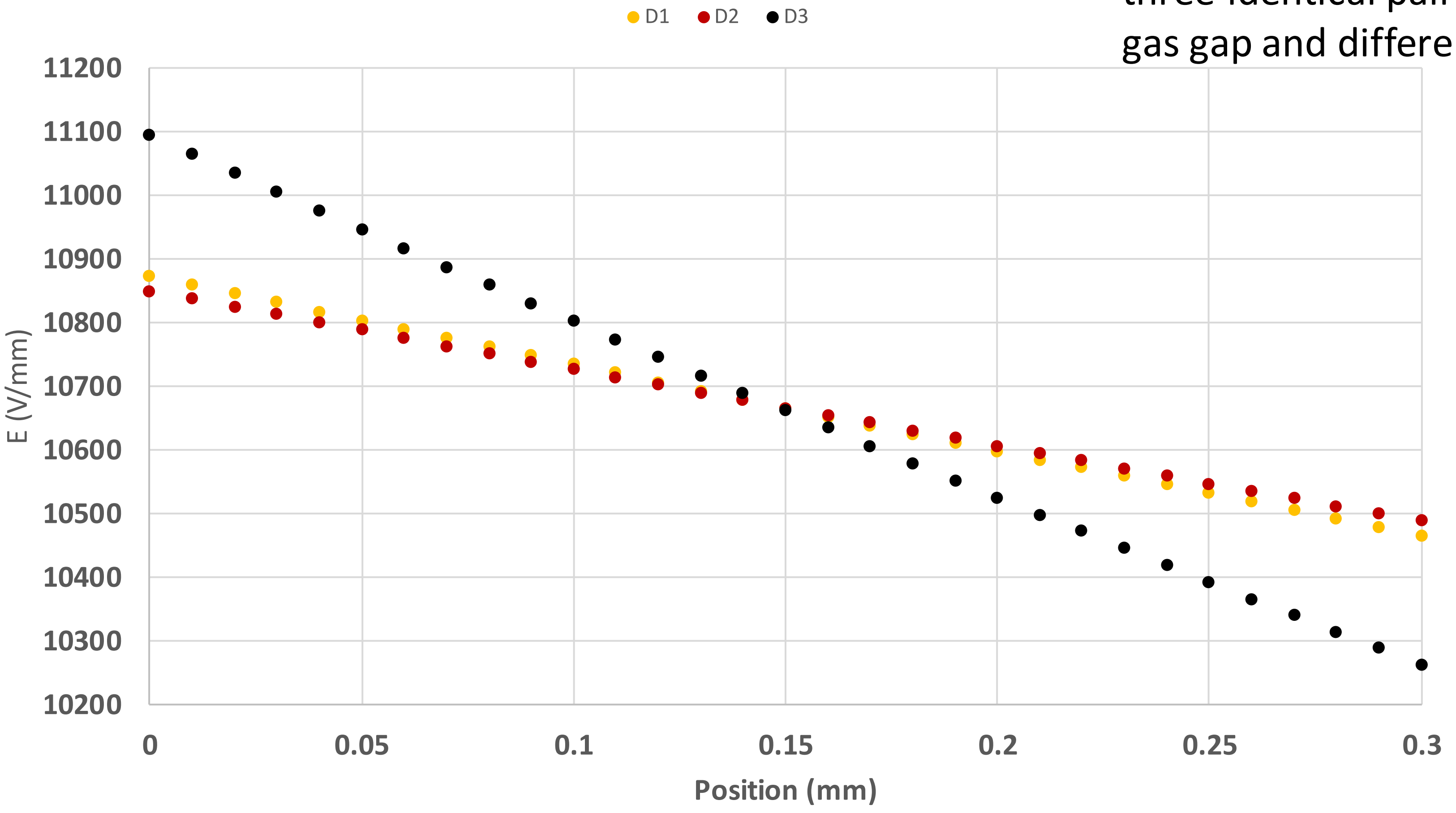
The electric field gradient, depending on the polarization allows to

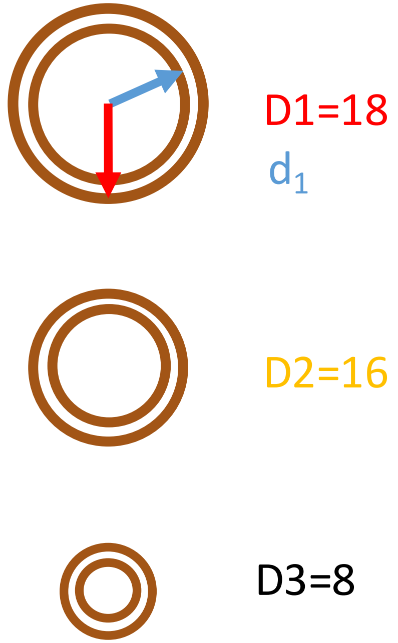
1. Contribute to the gas discharge quenching
   → new eco-friendly gas components
2. Increase the charge collection efficiency enhancing the multiplication in the initial part of the gas gap
3. Study the dependencies and optimize the time resolution



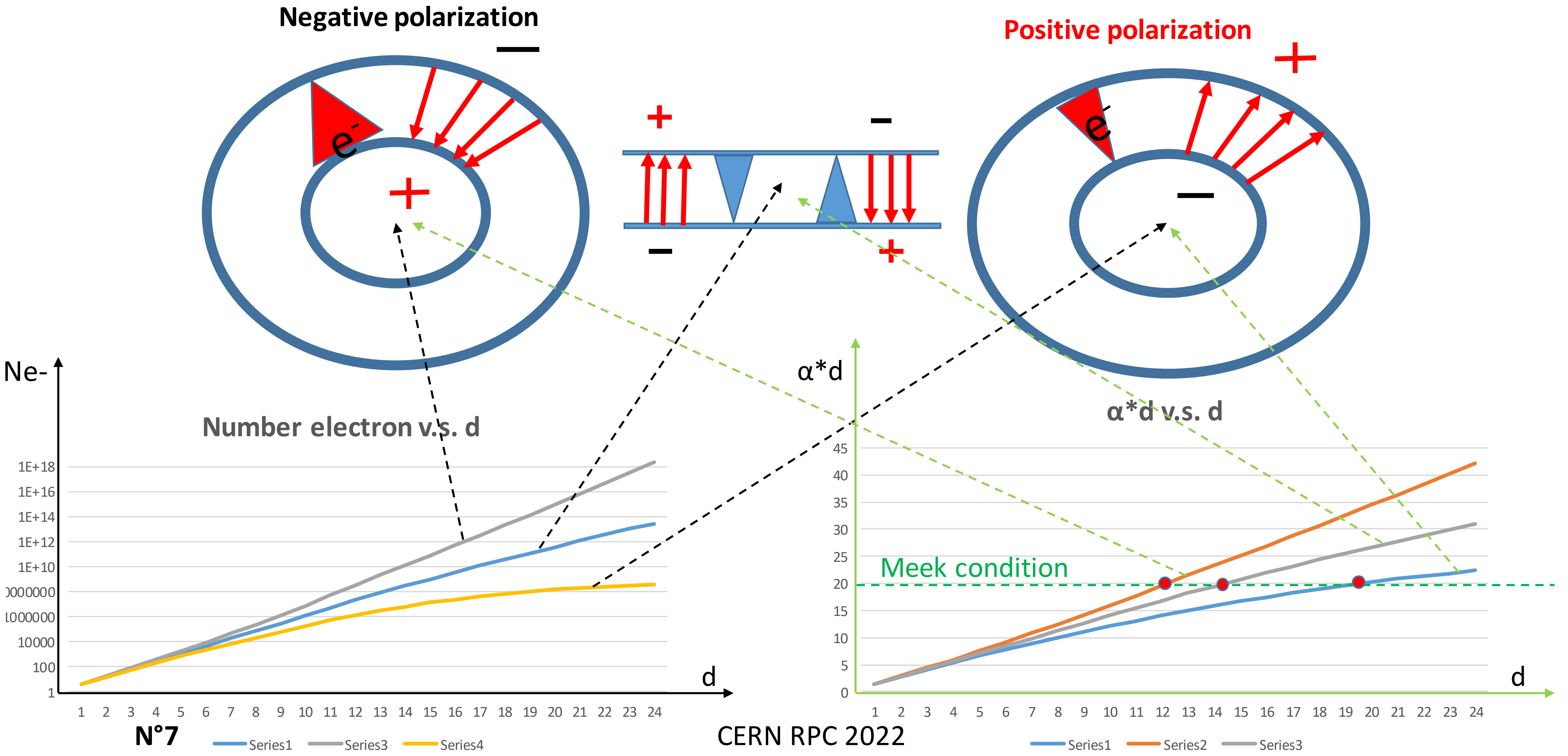
Different gradient for different d_n/D_n

three identical pairs of detectors with 0.3 mm gas gap and different radius of curvature





Electrons valence evolution RCC and RPC



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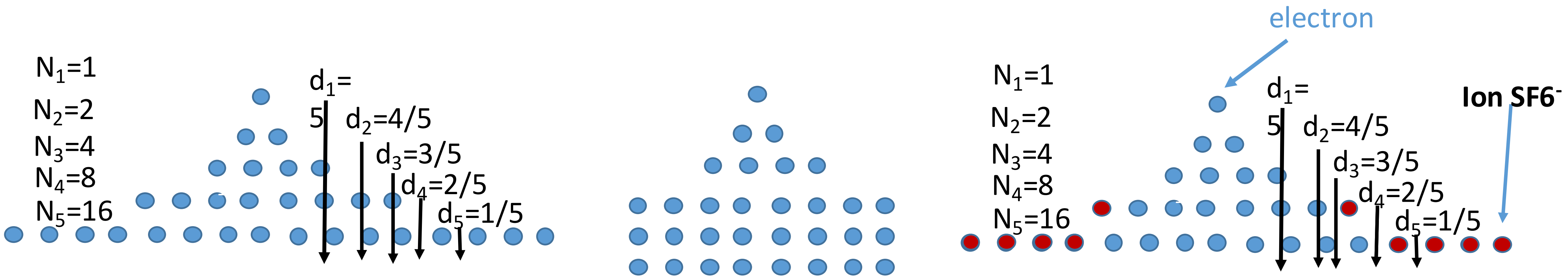
CERN RPC 2022

Avalanche evolution in the RCC and RPC and pront charge calculated with Ramo's theorem



$Q=Q_0\sum N_i*d_i$ = 15,4/31 Q_0

1*5+2*4/5+4*3/5+8*2/5+16*1/5=15.4

Exponential evolution

$Q=Q_0\sum N_i*d_i$ = 18,3/31 Q_0

Saturated evolution

Geometric effect

$Q=Q_0\sum N_i*d_i$ = 13/31Q_0

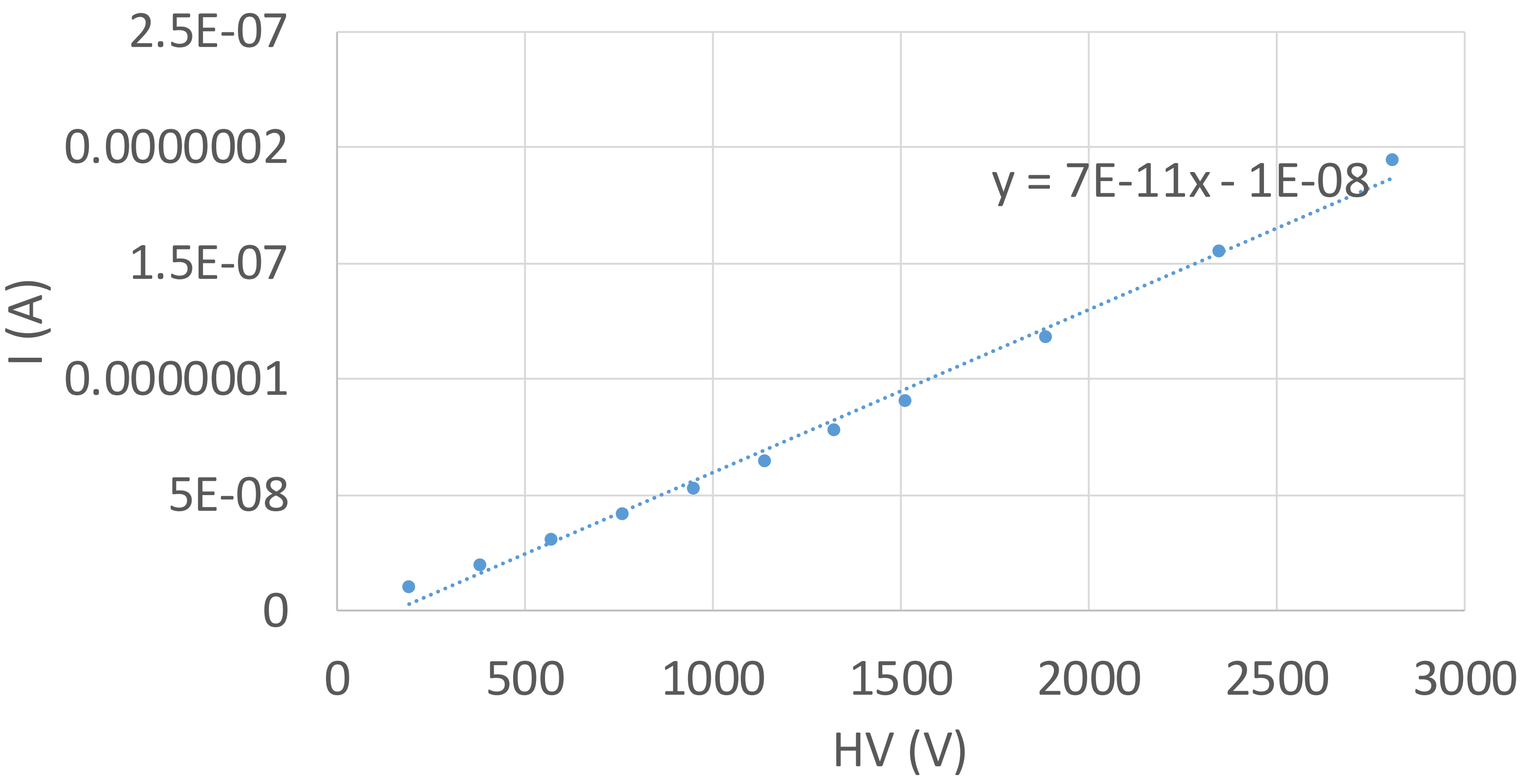
1*5+2*4/5+4*3/5+6*2/5+8*1/5=15.4

Saturated evolution with SF6

The comparison of the prompt charge for three case:

1) **Exponential evolution of the electrons avalanche negative polarization in the RCC**
2) **Saturated evolution of the electrons avalanche positive polarization in the RCC**
3) **Saturated evolution of the electrons avalanche in the RPC with SF6**

Cylindrical bakelite electrode resistivity for material available CERN magazine



$$\rho = 4{,}3 \times 10^{12}\ \Omega\ \mathrm{cm}$$

Cylindrical geometry

- The cylindrical geometry is very interesting in the case the external pressure is different respect to the internal gas gap pressure, two important cases:
- **The external pressure is very low**, application in space
- **The internal pressure of the gas gap is very high**, for instance 2-10 bar,

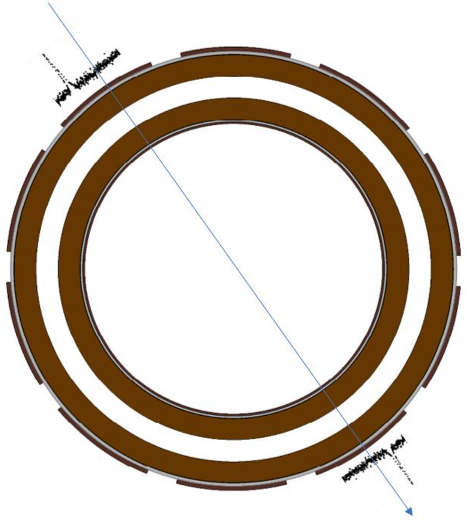
  this high pressure is useful to increase the performance of the

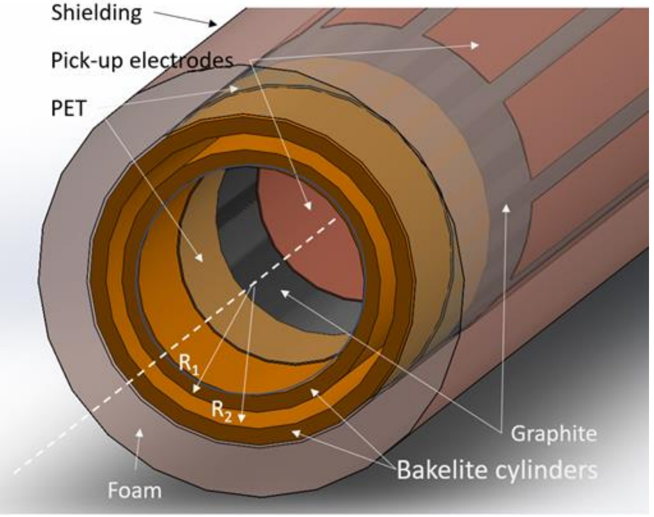
  detector in the range of ps time resolution , high

  efficiency per single gas gap and spatial resolution (30-50 um).

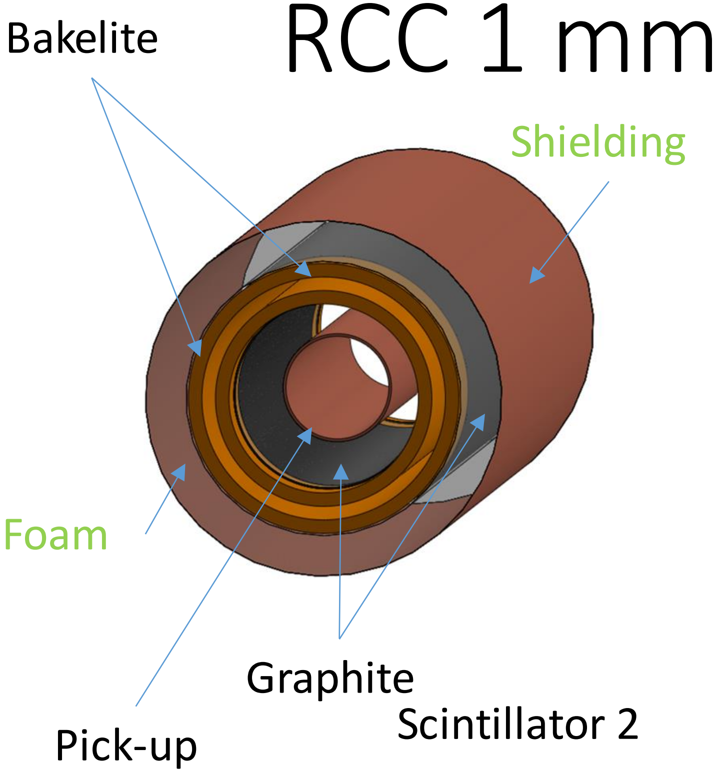
Prototypes

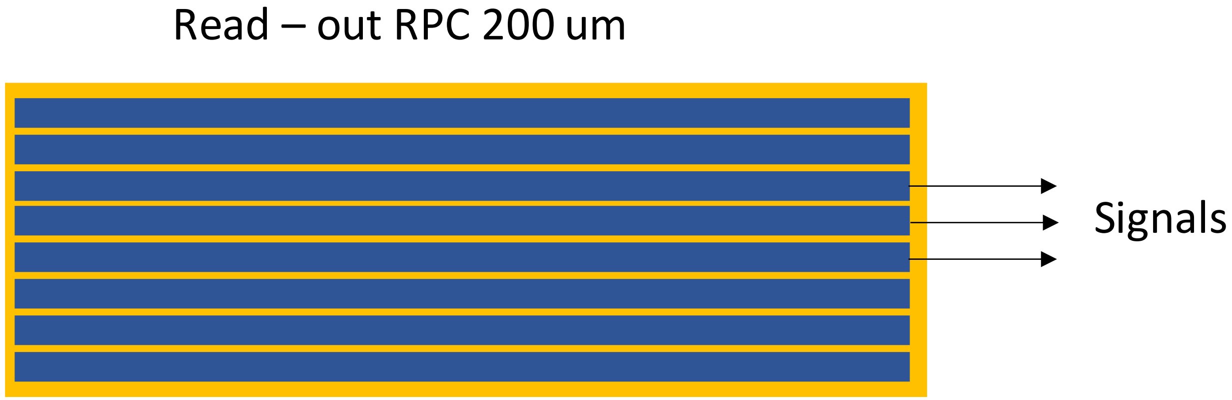
- **RPC Cylindrical chamber with 1 mm gas gap:**
  - Feasibility study of Resistive Chylindrical chambers
  - Effcet of the electric field gradient on the detector performance
- **RPC Cylindrical chamber with 0.2 mm gas gap :**
  - Effcet of the gas pressure on the detector performance
- **RPC Cylindrical chamber with 1 mm gas gap, metallic ground electrode, integrated with MDT detector:**
  - Feasibility study of Resistive Chylindrical chambers integrated with MDT detector (same gas mixture, same readout pick-up)



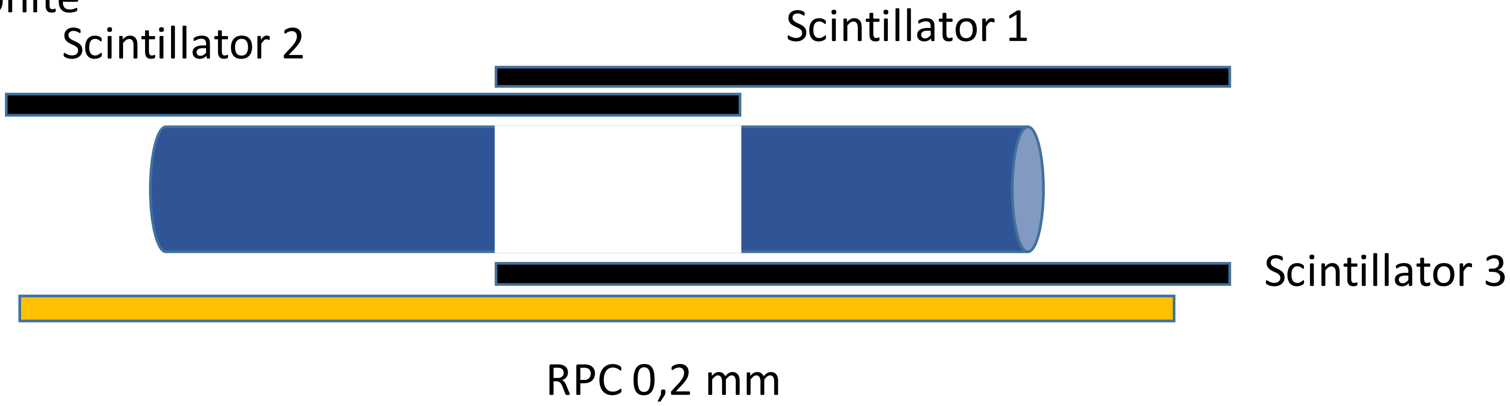


RCC 1 mm gap(experimental setup)

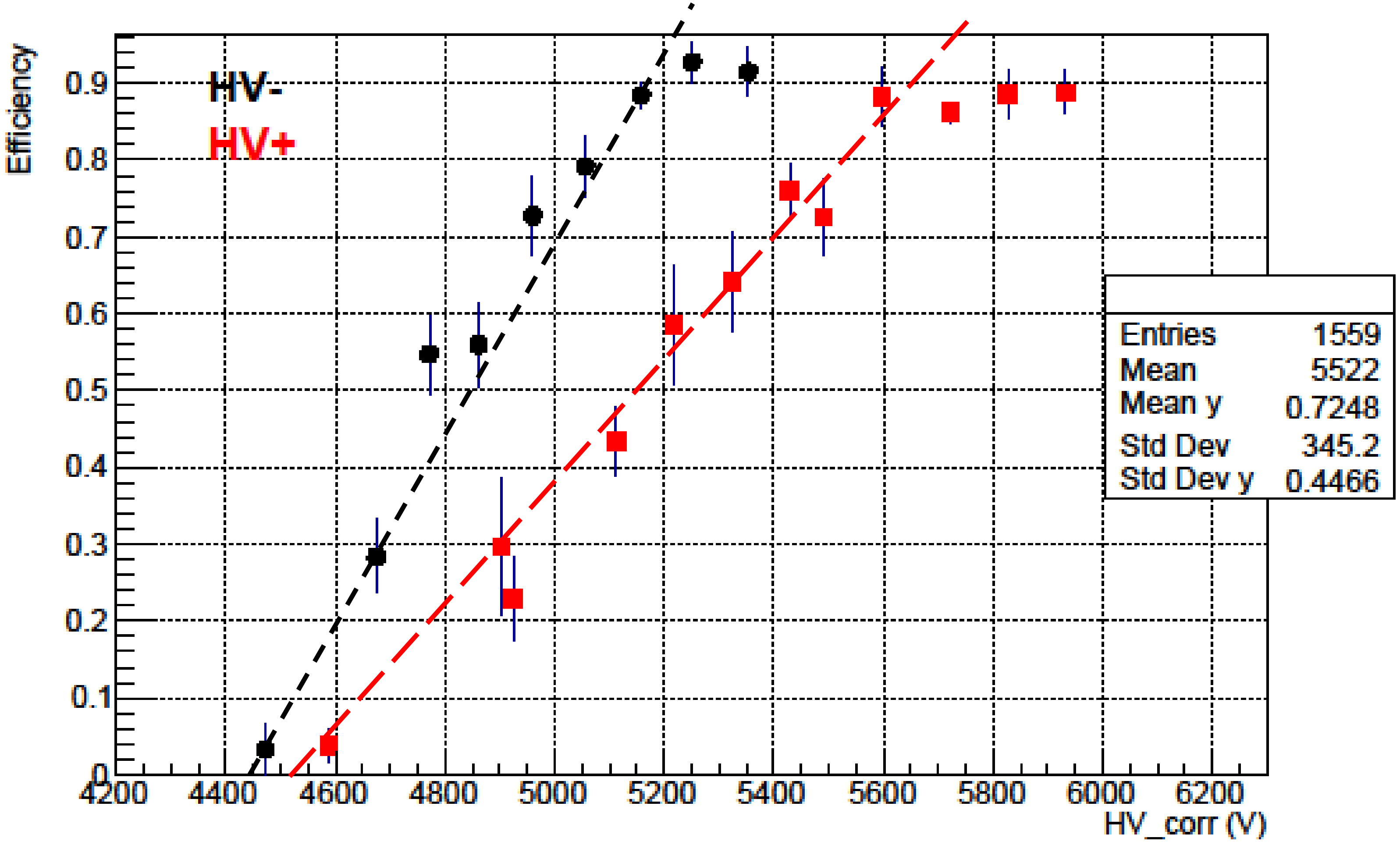




Trigger: Scint 1 And Scint 2 And Scint 3



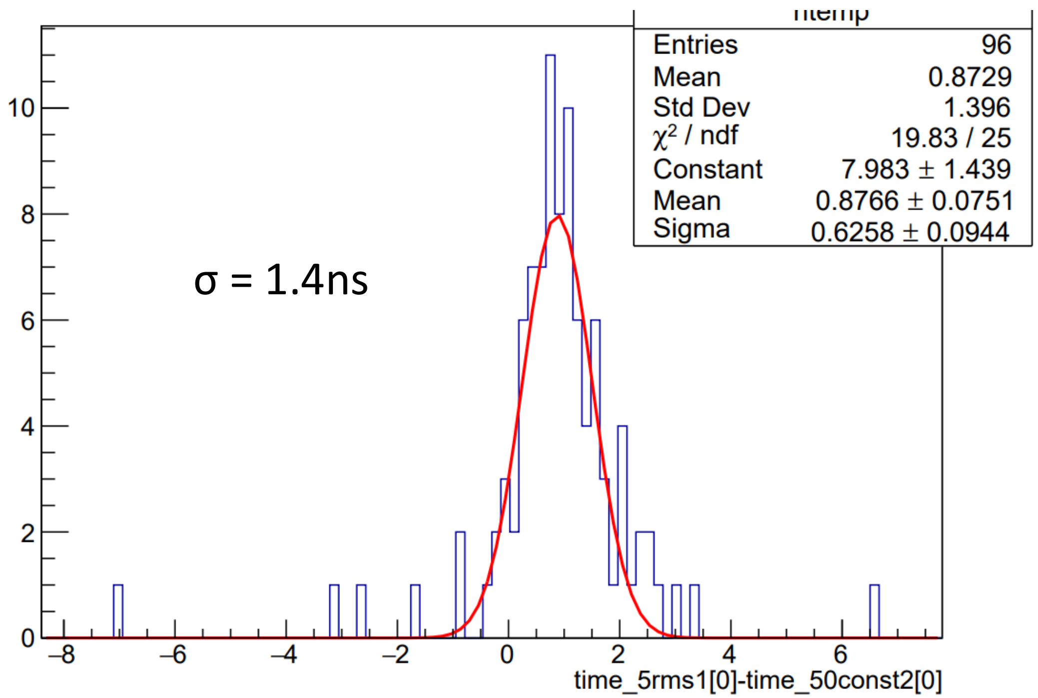
RCC 1 mm gap efficiency



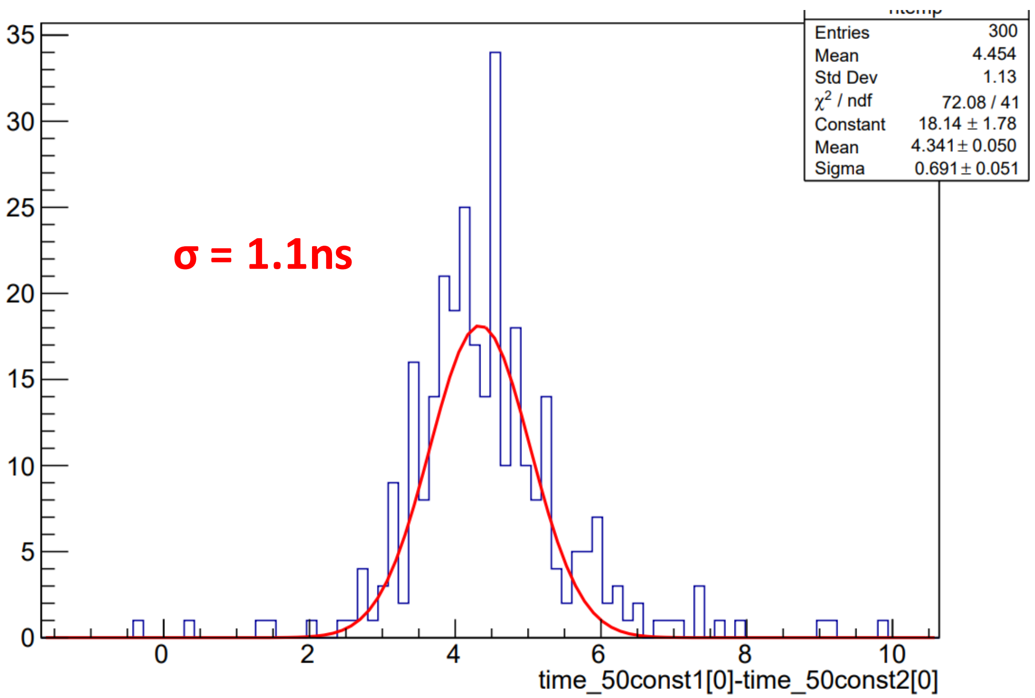
RCC 1 mm gap

(time of flight as respect to RPC 0,2 mm)

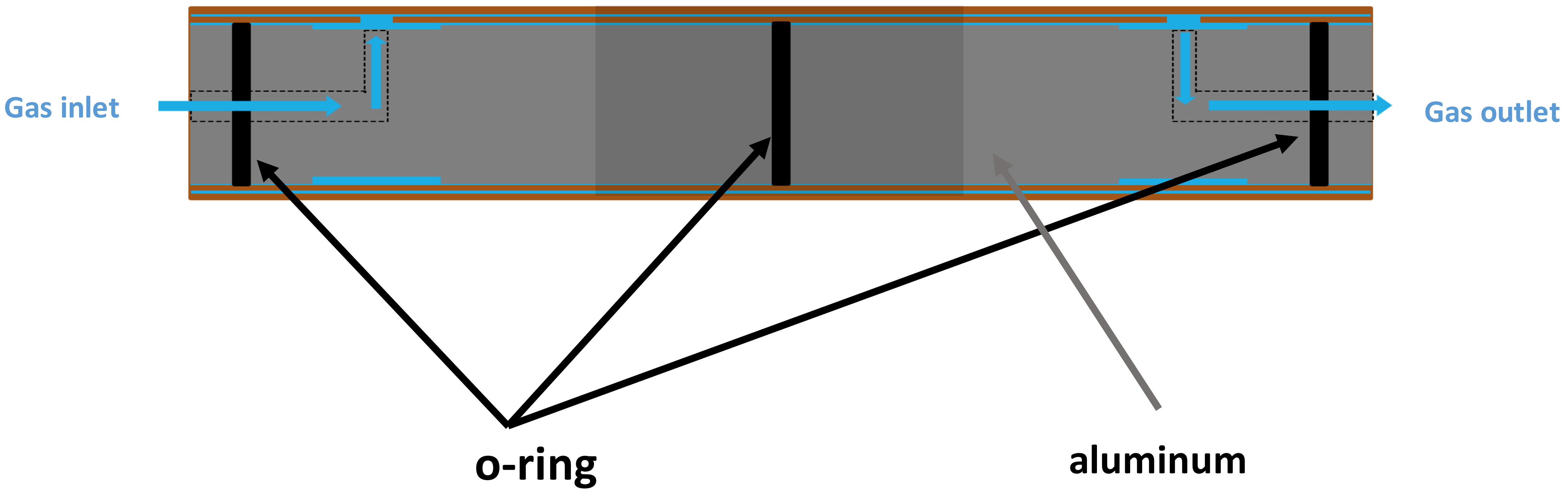
Polarization HV -



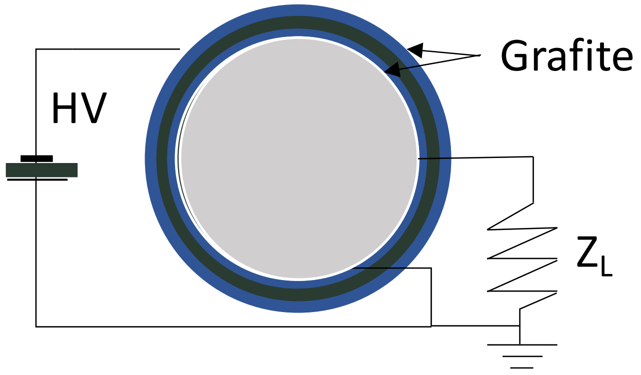
Polarization HV +



RCC Up-to 10 bar pressure resistant with contribution of Monaco university



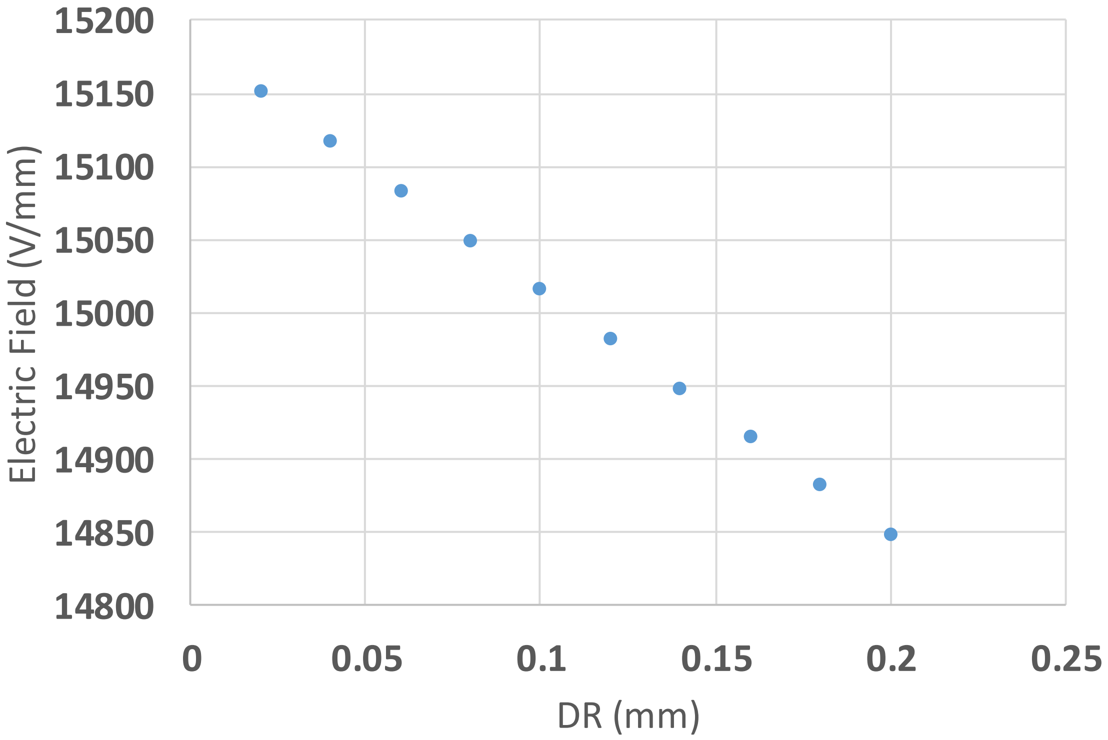
RCC 0.2 mm gap R1=17,6 mm R2=18 mm(prototype design)



D_1 = 17,6 mm
D_2 = 18 mm
Gap = 0,2 mm

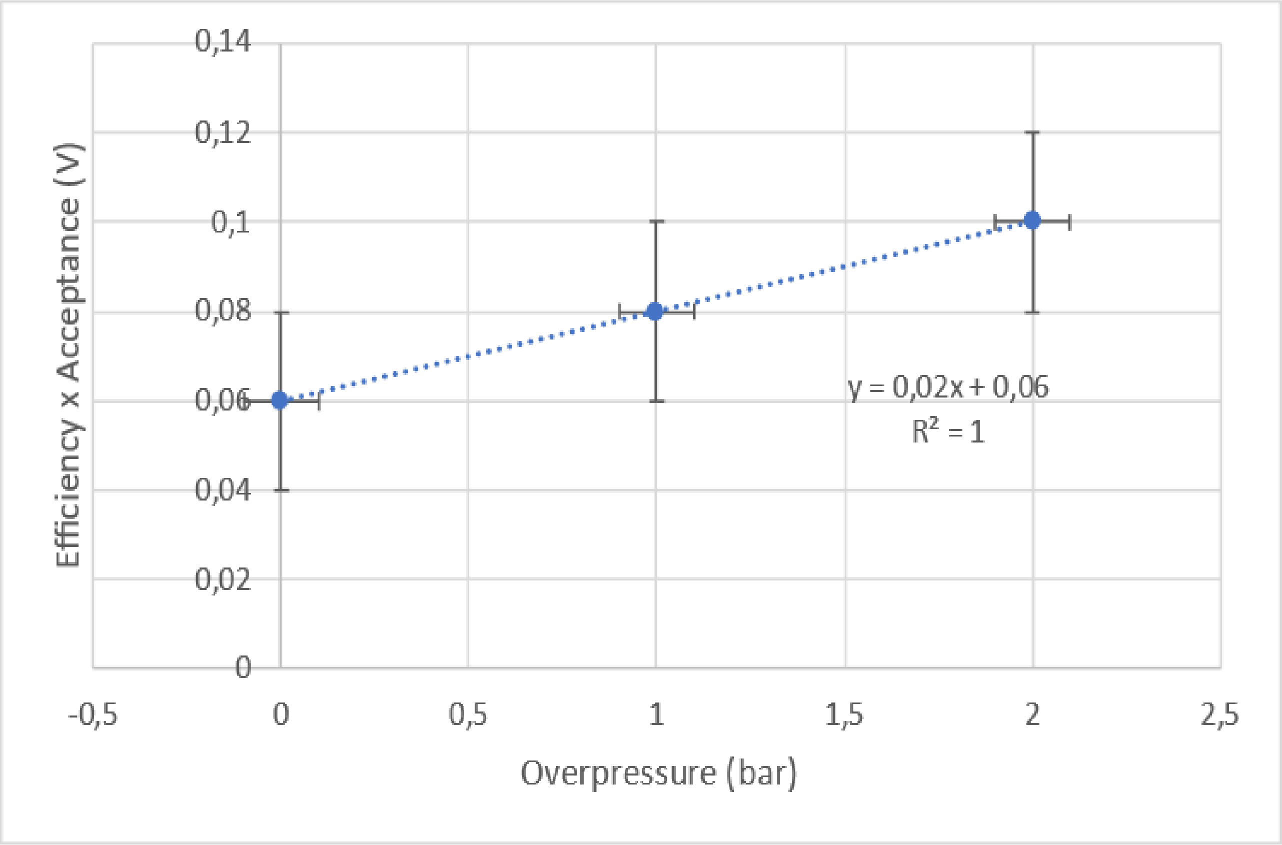
Electric field inside the gas gap with ΔV=+3000 V

$$E(r) = -\frac{V}{r\,log\frac{R_1}{R_2}}$$

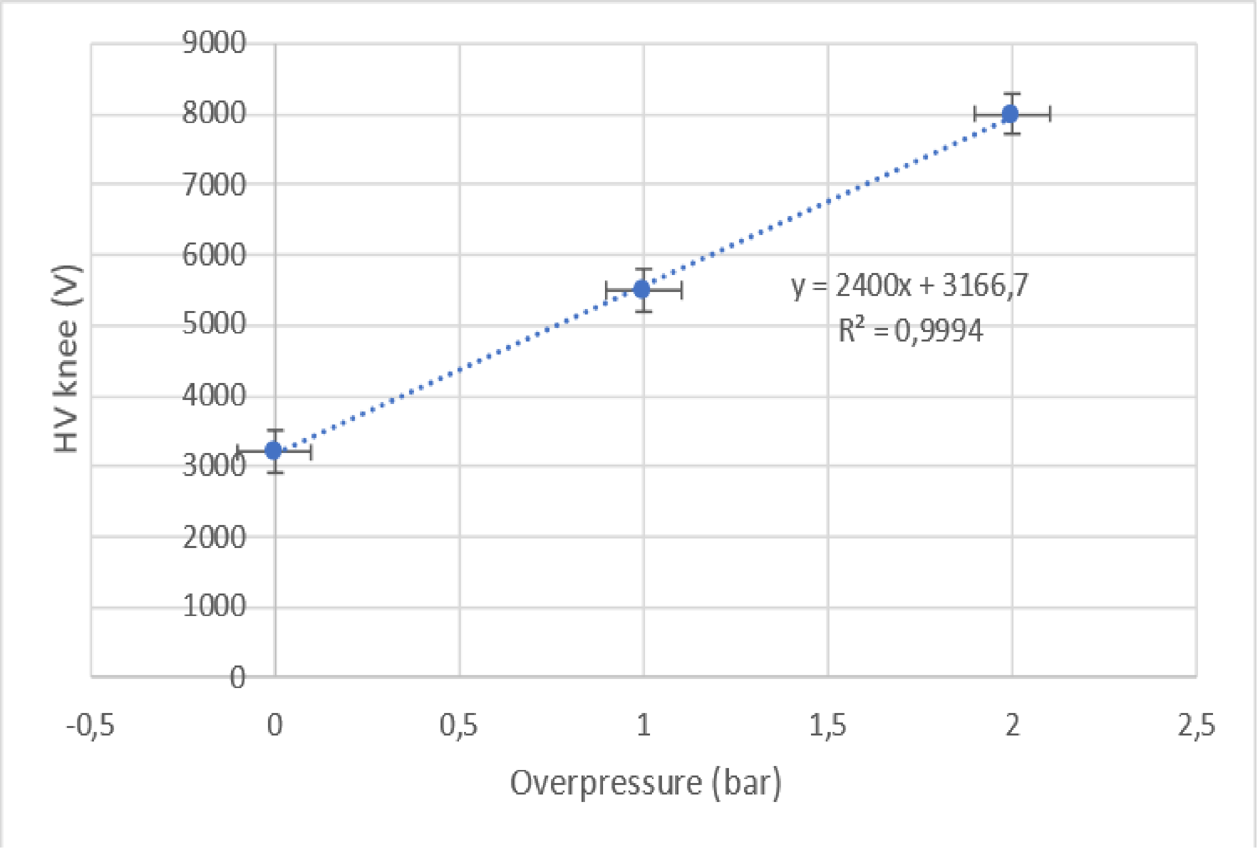


Efficiency x acceptance RCC 200 µm negative HV - CO_2 100%

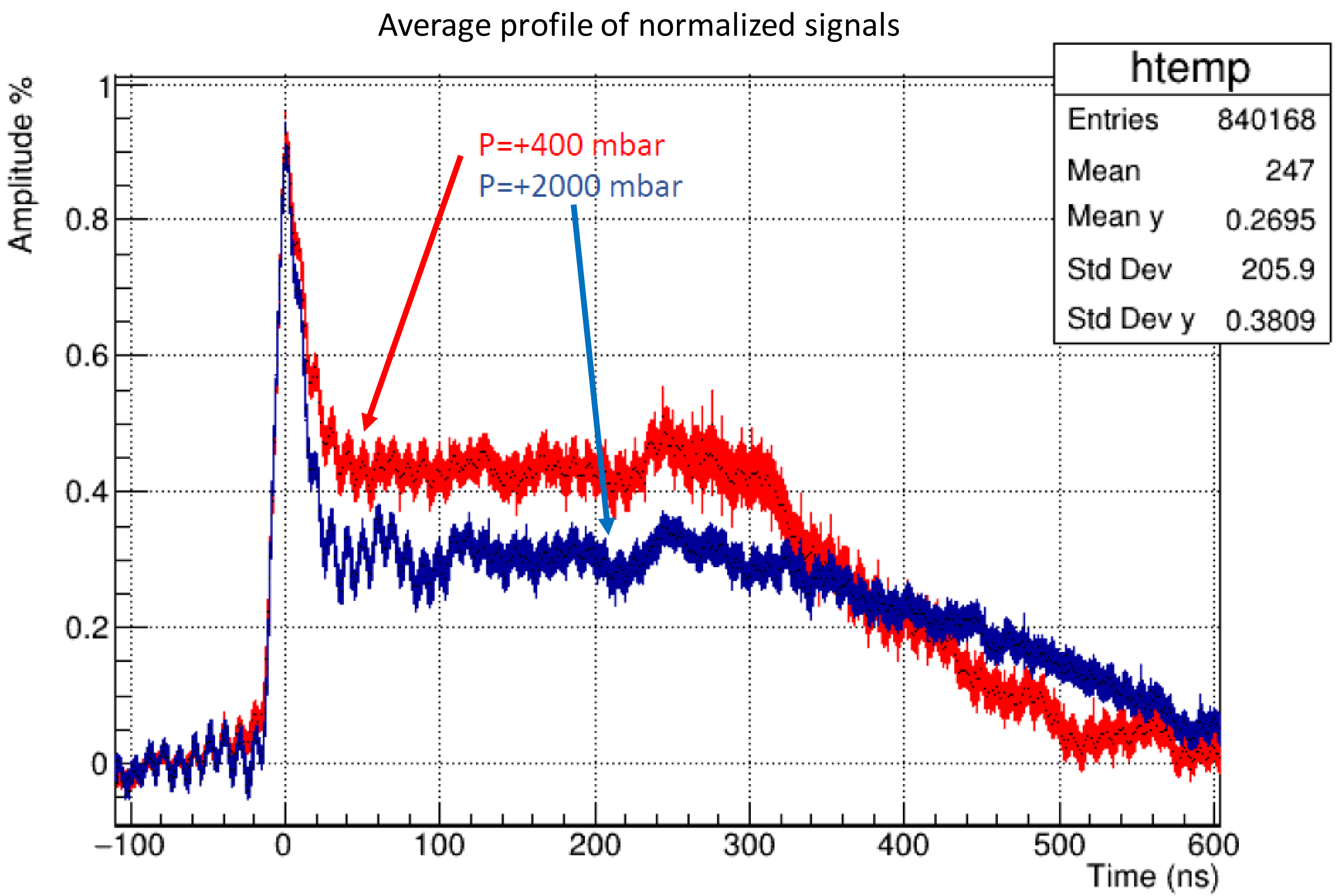
Efficiency plateau as function of the gas pressure



Efficiency knee as function of the gas pressure



RCC 0.2 mm gap (signals average)



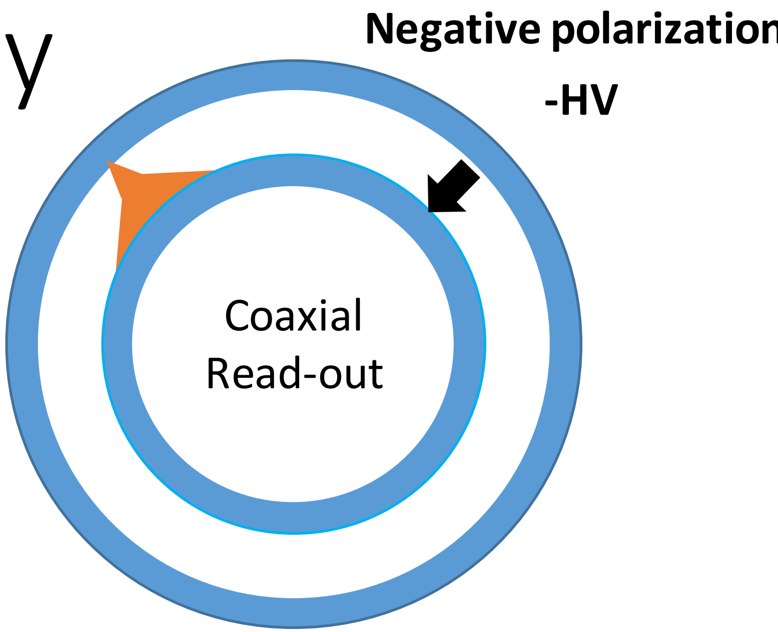
Aim of the test in G++ CERN facility

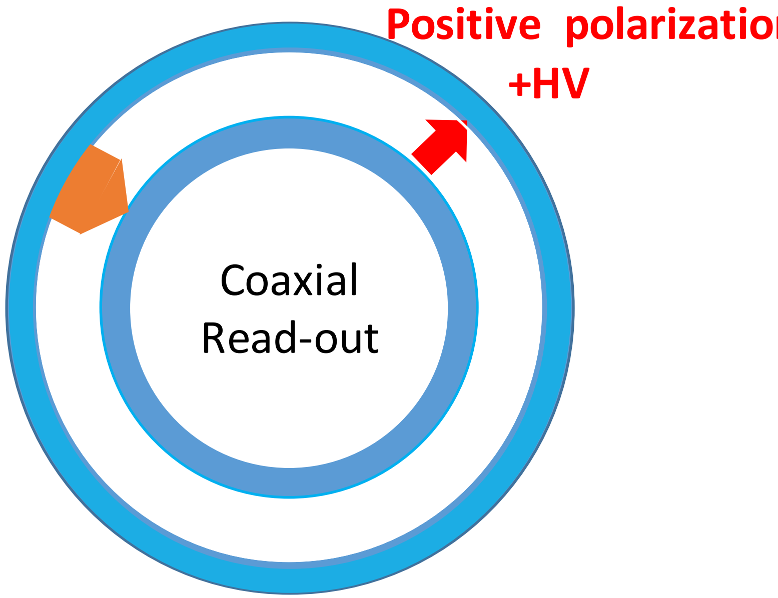
The test consists in demonstrating the correct functioning of the device with a quasi-planar cylindrical geometry

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.

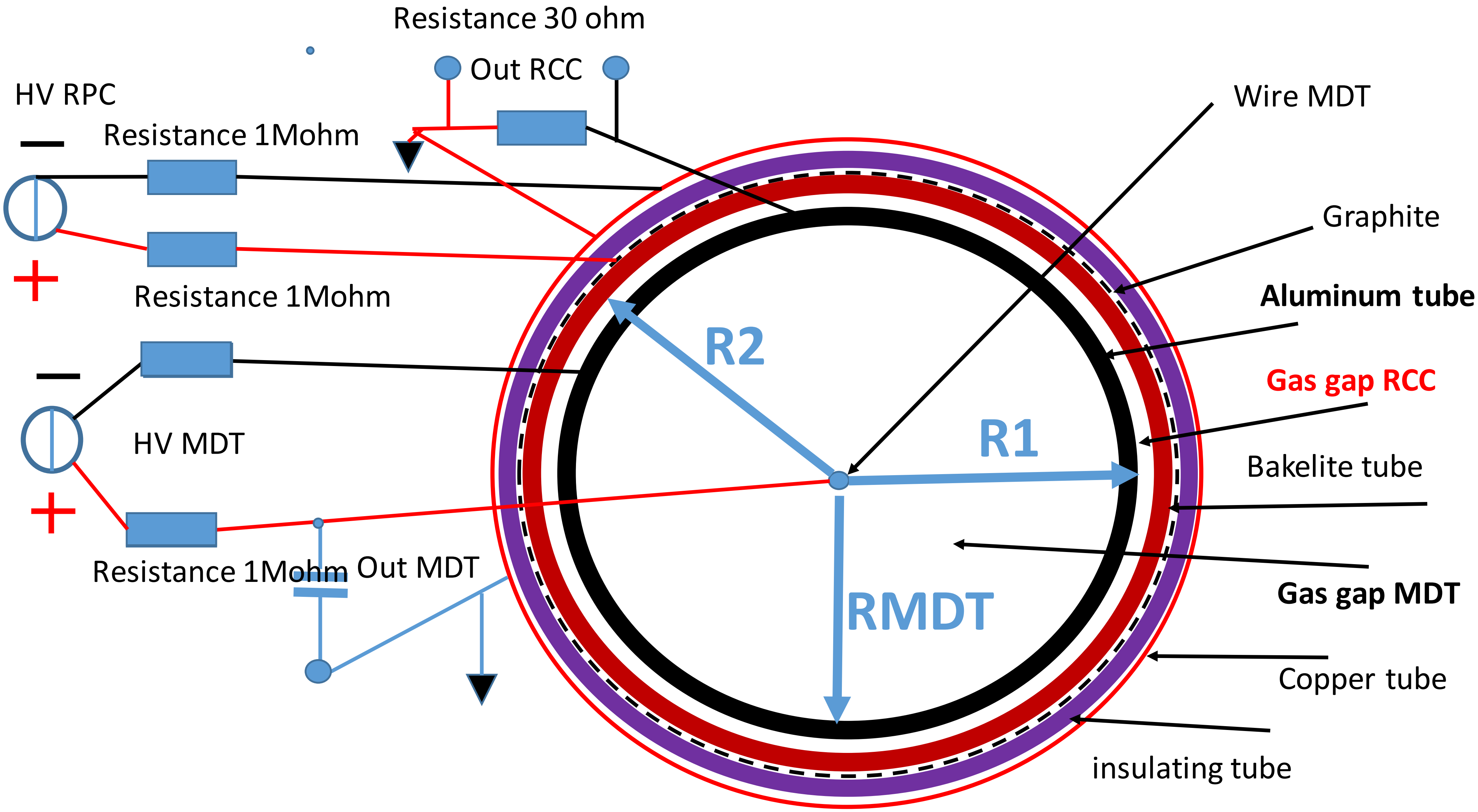
Under positive polarization conditions, multiplication is expected to occur mainly in the region close to the cathode, which can be described, to a rough approximation by a multiplication followed by drift model.

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



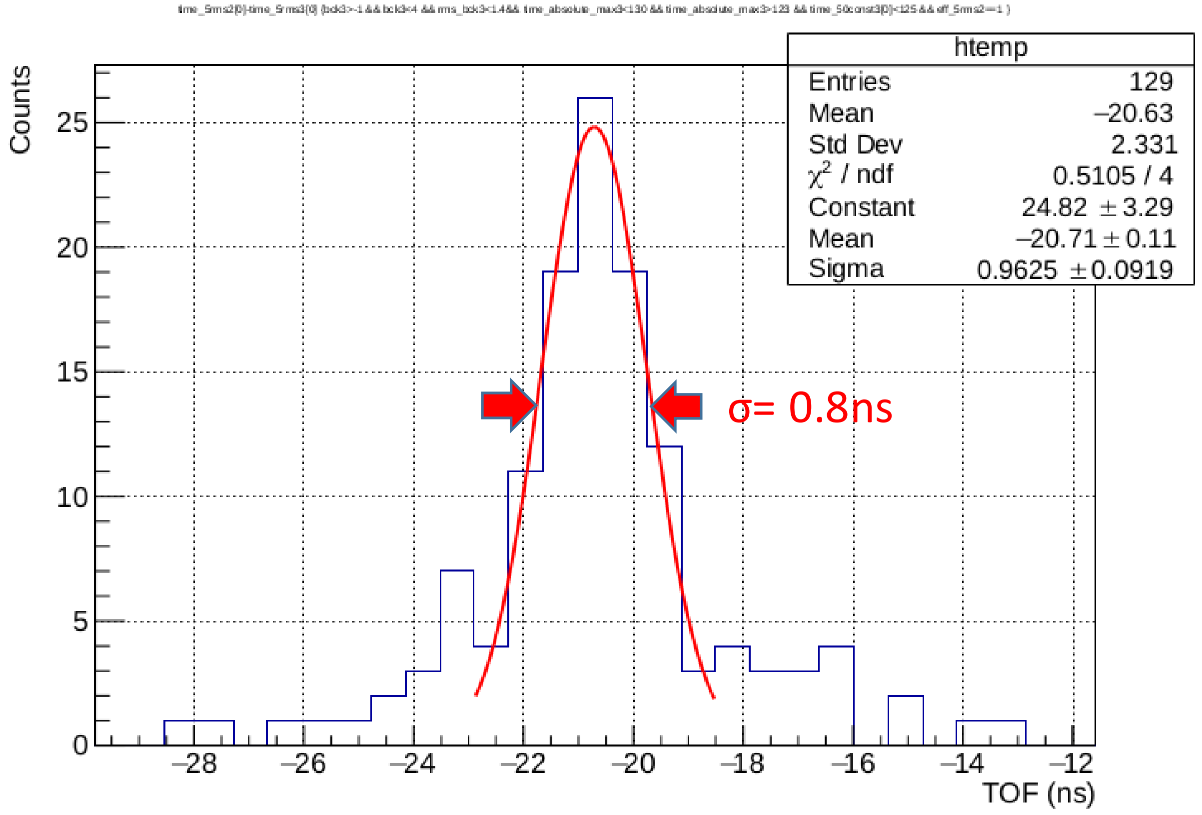


MDT+RCC R1=16mm R2=18mm RMDT=14mm
High Time Spatial resolution

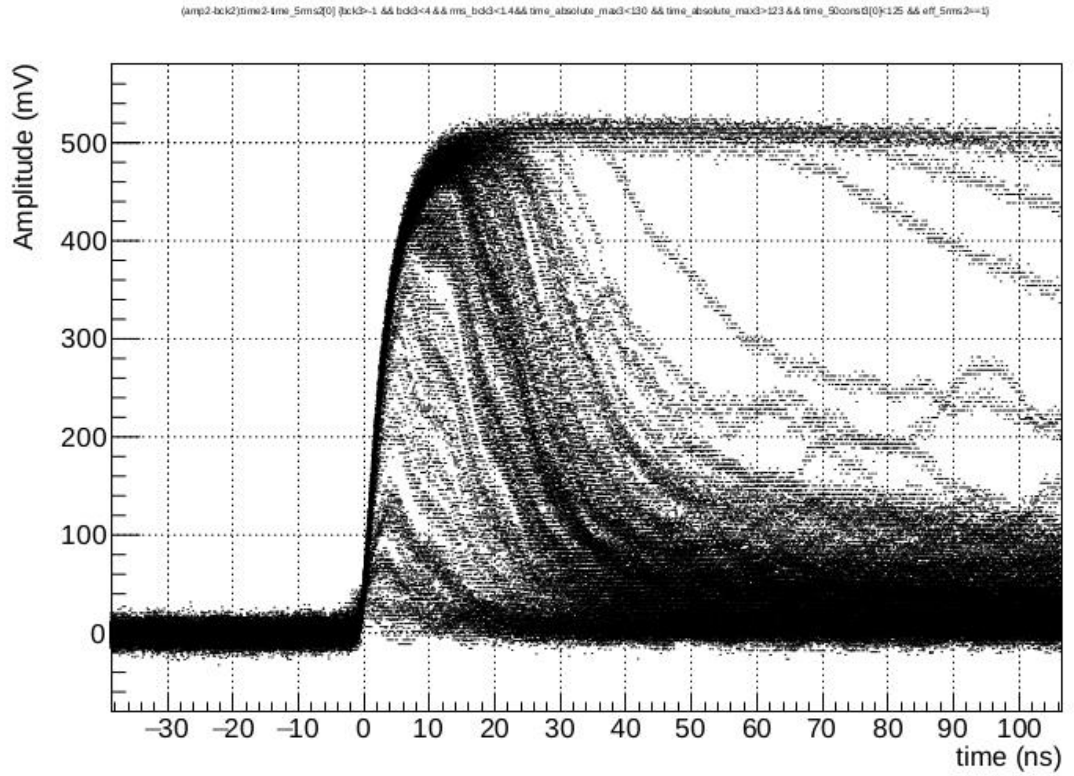


RCC + MDT

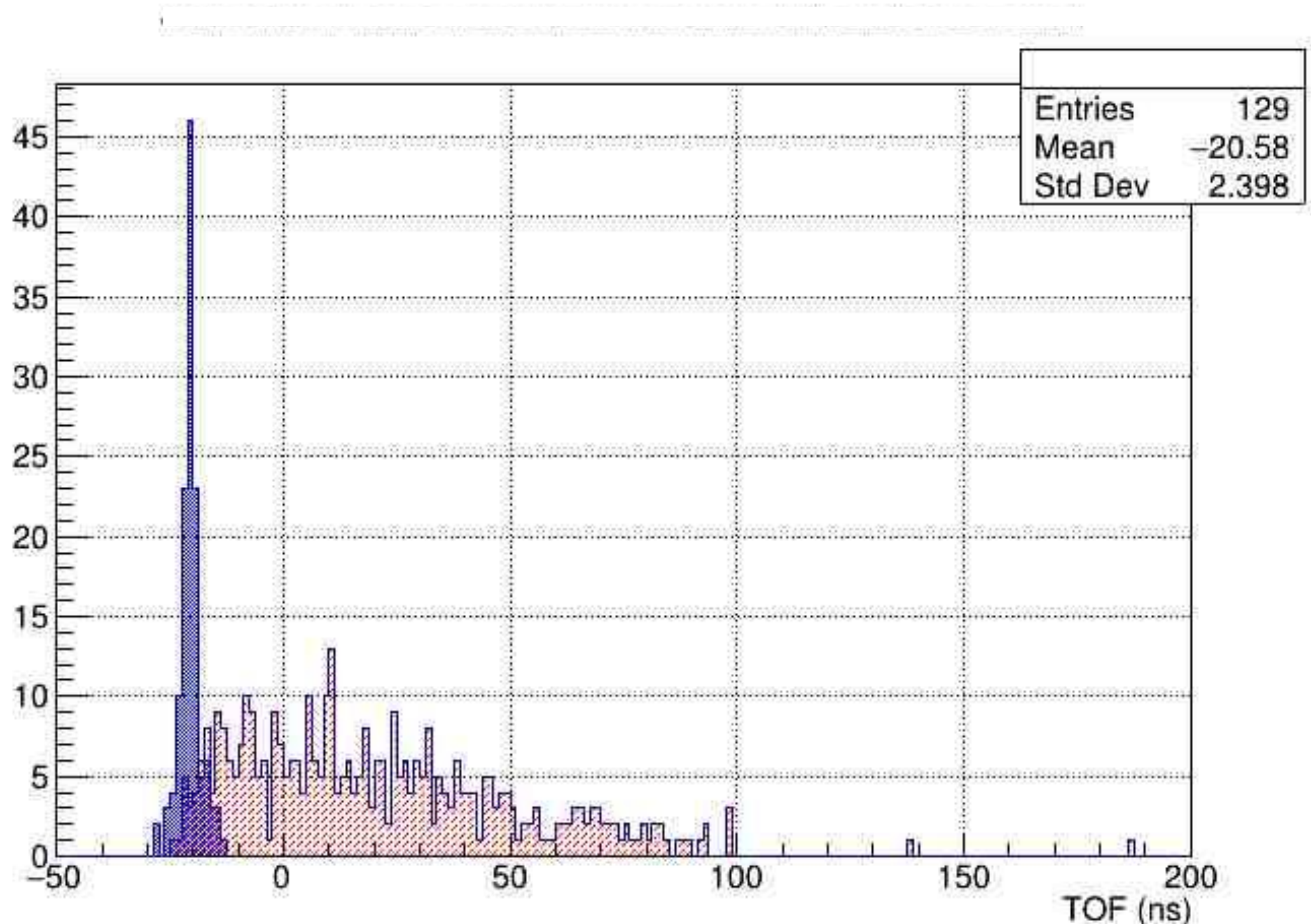
RCC time resolution



RCC Signals std_mixture

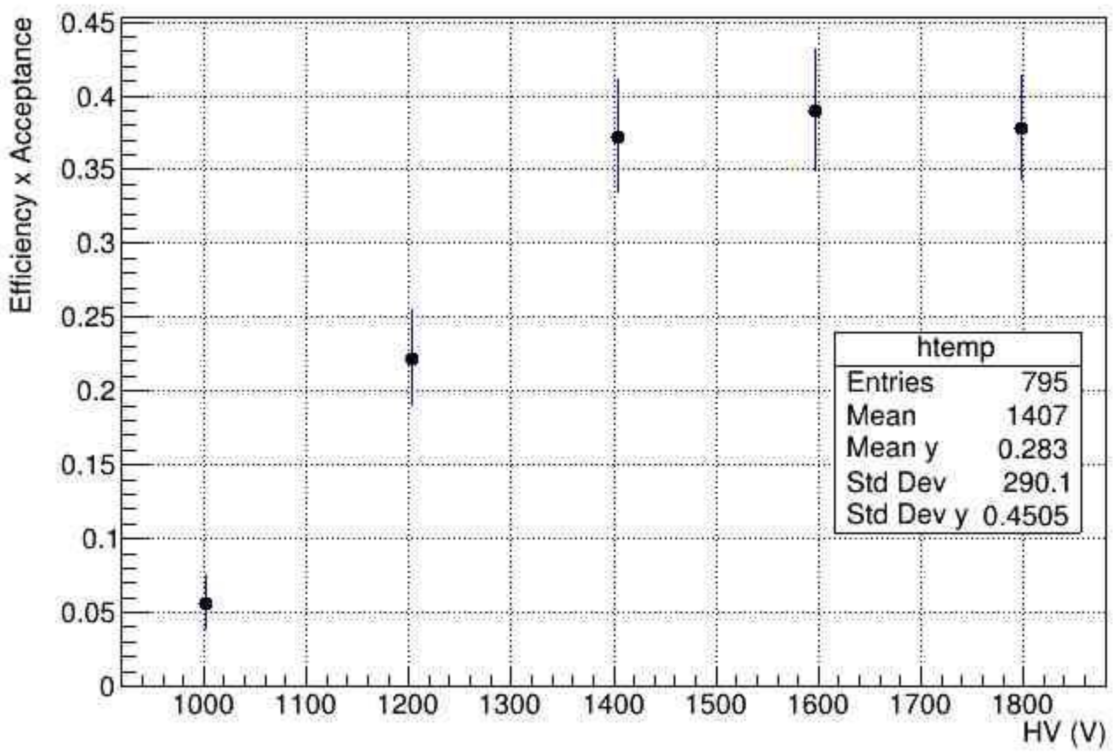


TOF with respect to the trigger signal
MDT Ar-CO2 (86%-14%) vs RCC mix std

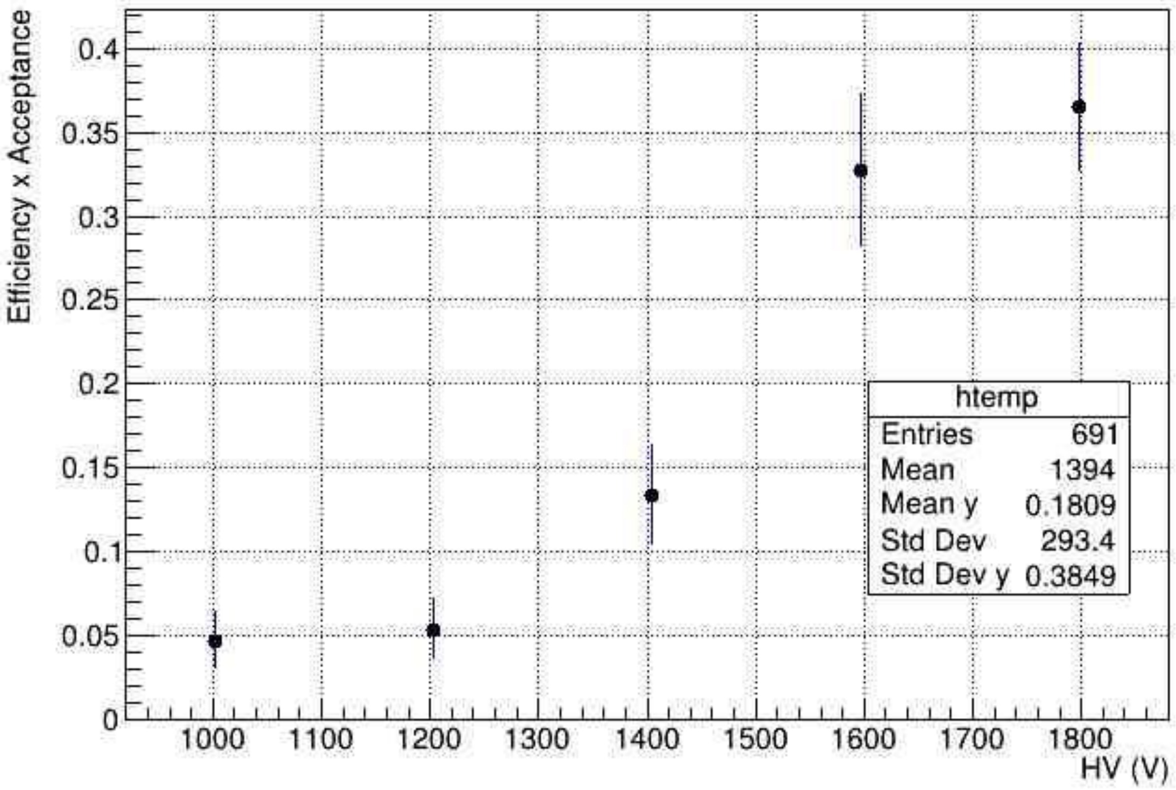


MDT Efficiency Ar-CO2 (86%-14%)

Pick-up on the wire

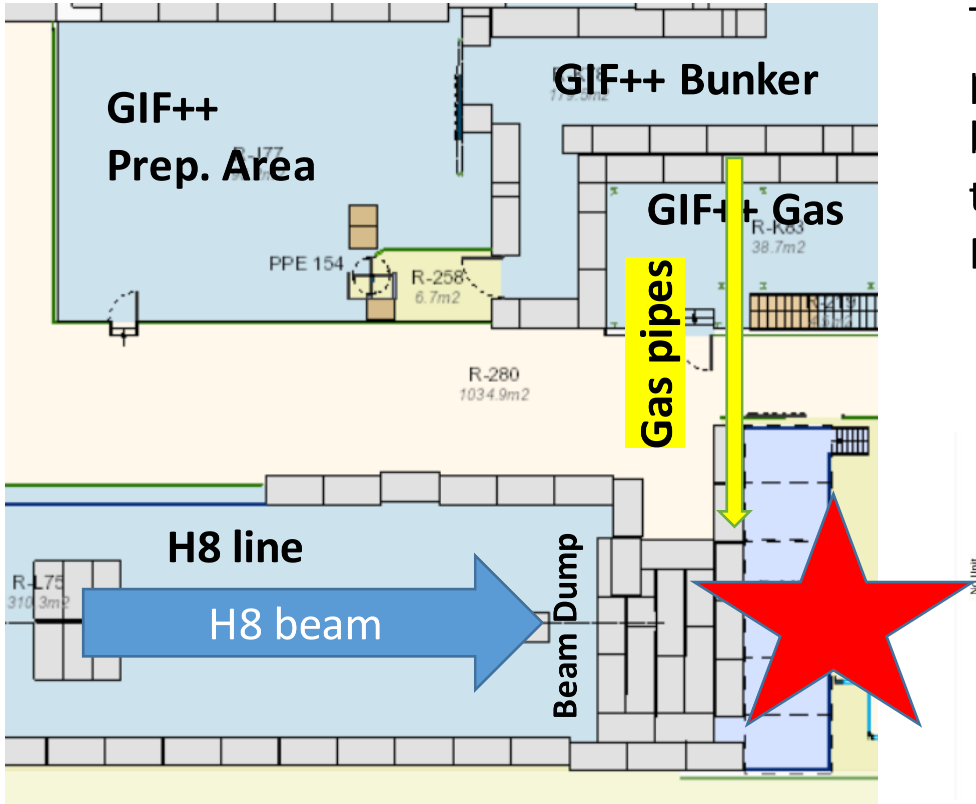


External pick-up



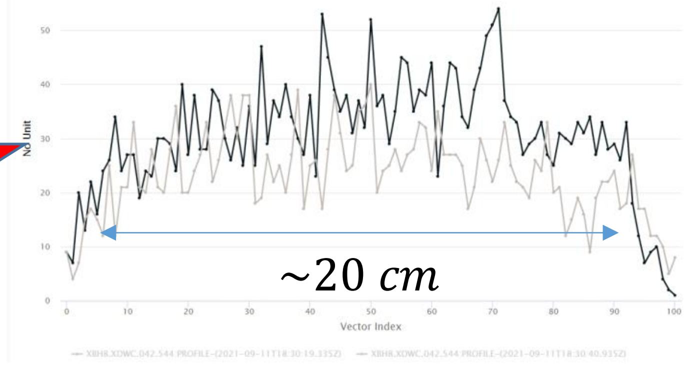
Experimental Facility

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

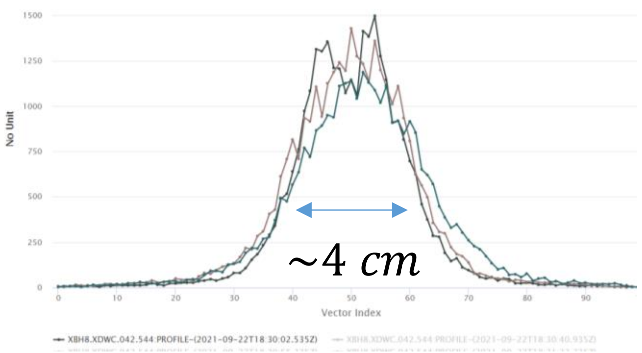


The system was installed downstream from the beamline dump platform. Two different beam profiles were used: tertiary muon beam with a moment of 165 GeV/c; secondary beam dumped in the upstream platforms with respect to the test platform (PPE168, PPE158 … PPE138)

Secondary dumped beam profile

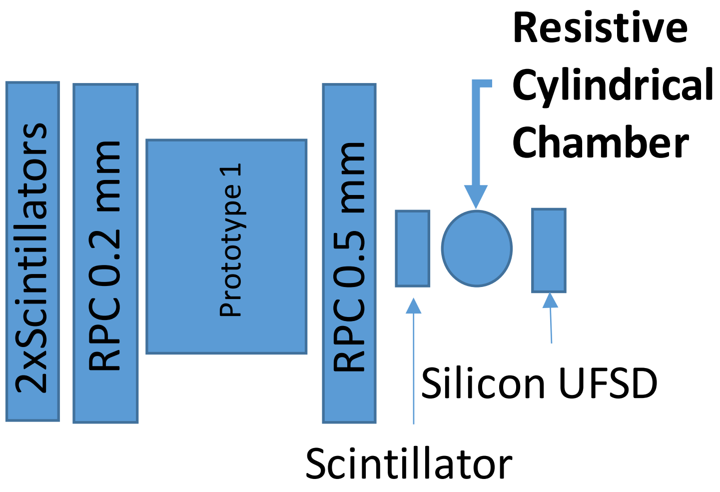


Tertiary muon beam profile



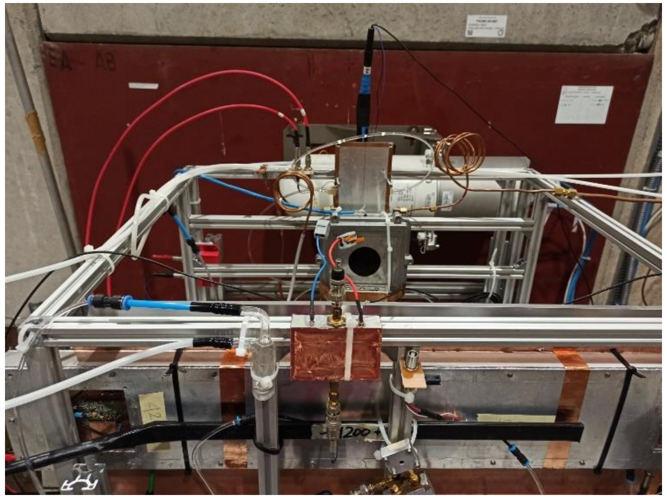
Experimental Set-up

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)

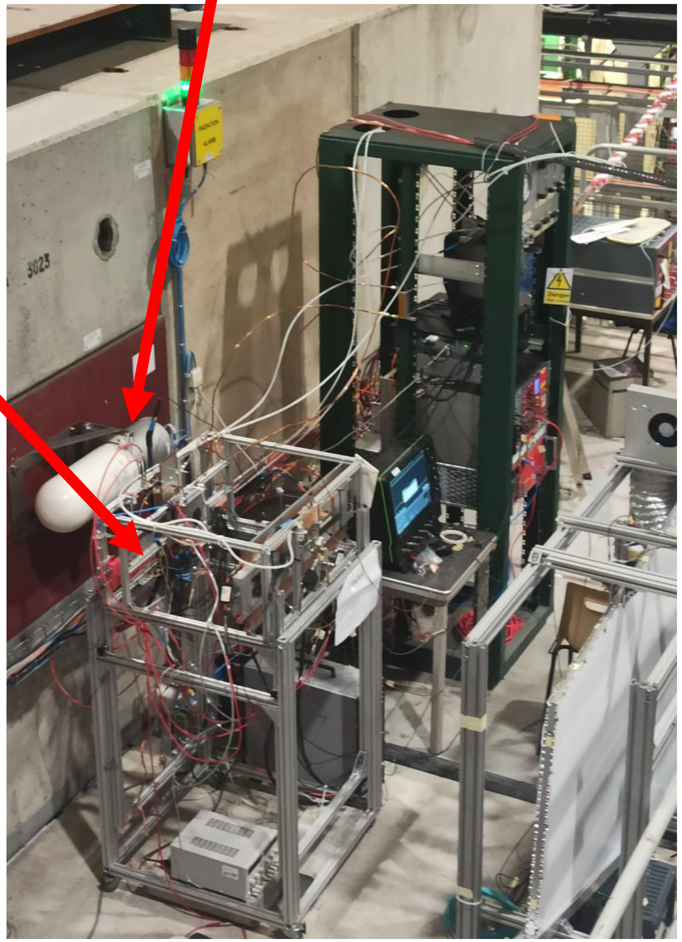


Gas mixture: **94.7% TFE + 5% iC4H10+0.3%SF6**

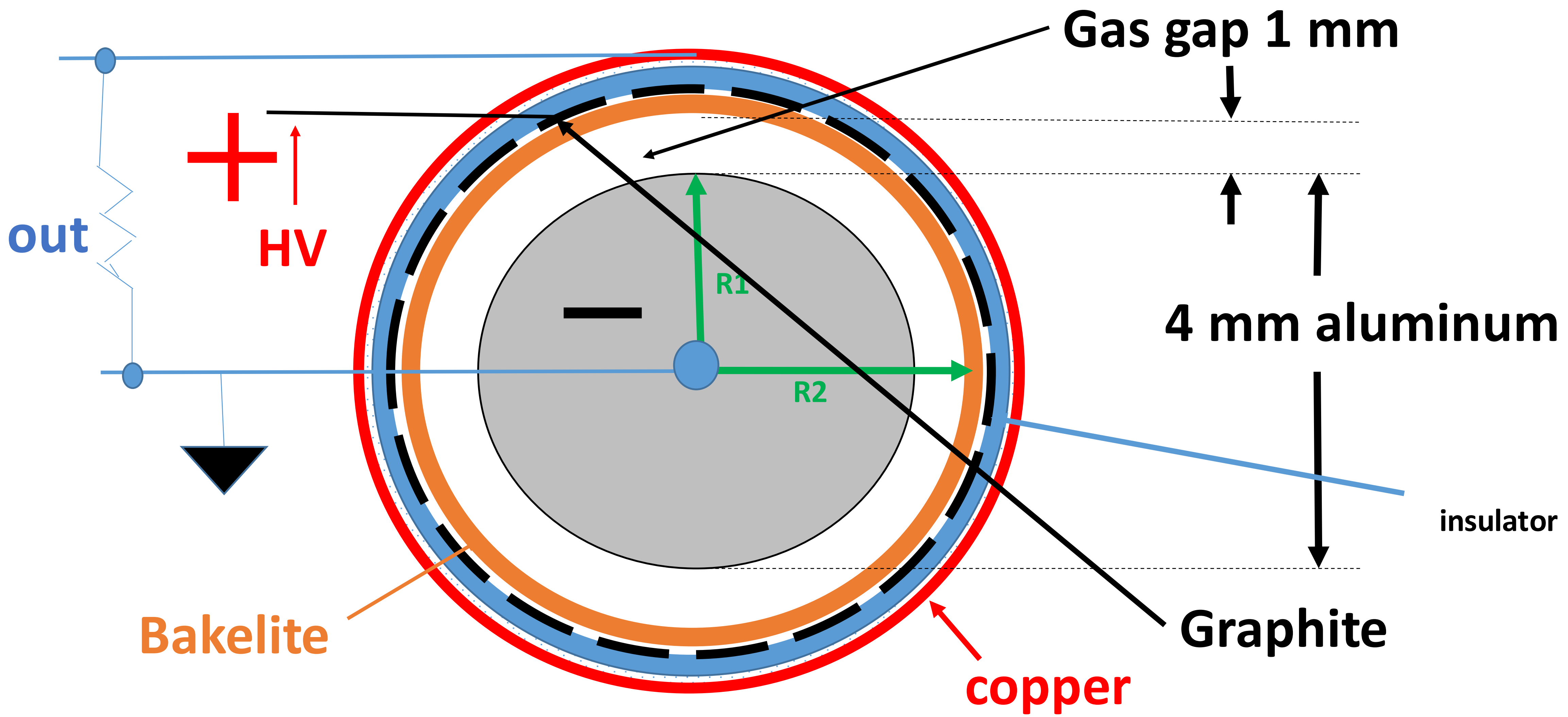
Beam Dump Setup



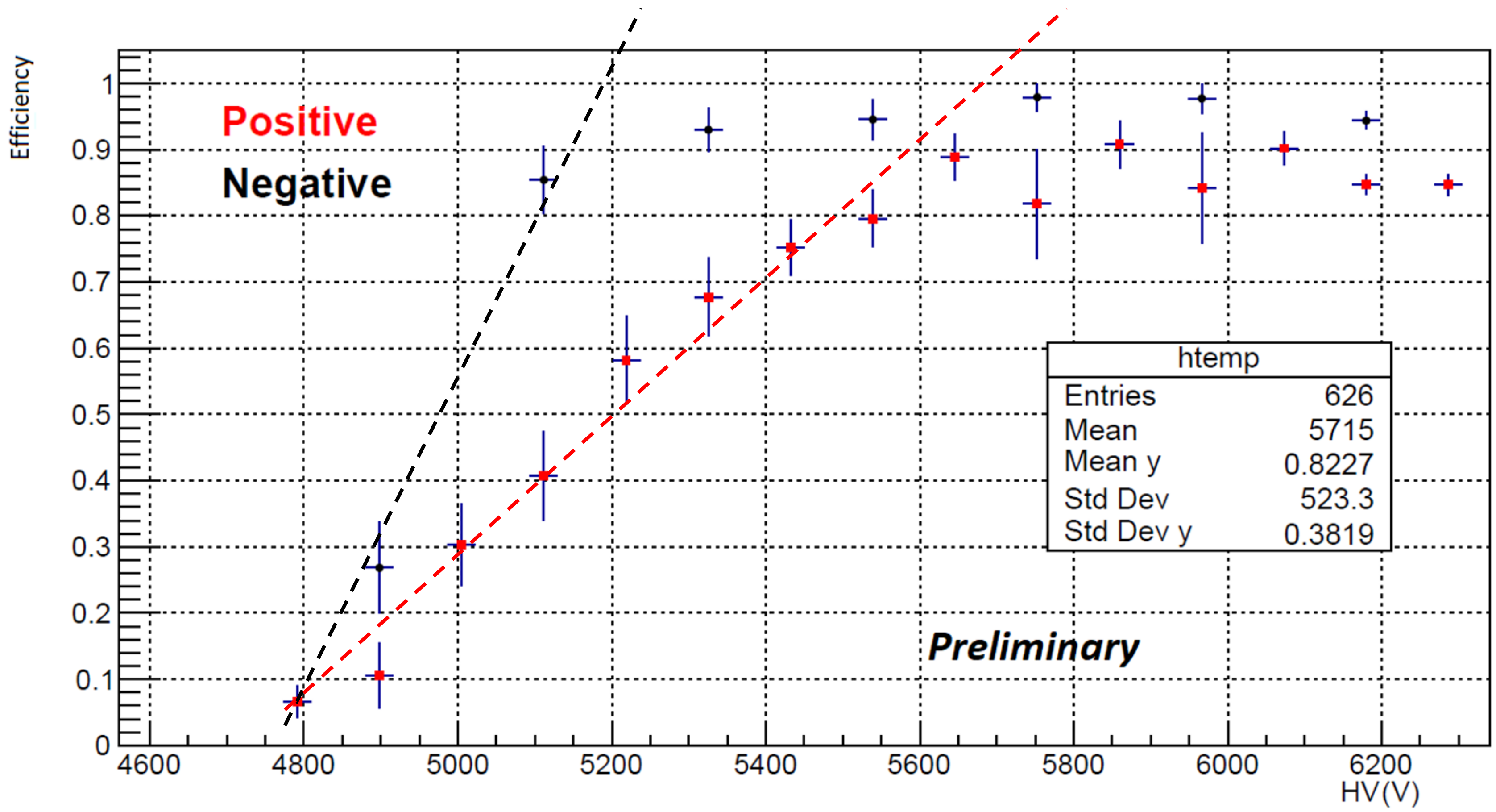
Radiation monitor



RCC under test at H8



Efficiency with Front-End preamplifier

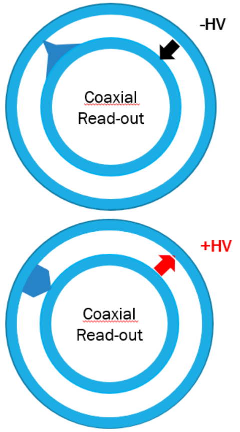


In this measure the UFSD pixel detector was used to optimize geometric acceptance at the expense of statistics .

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

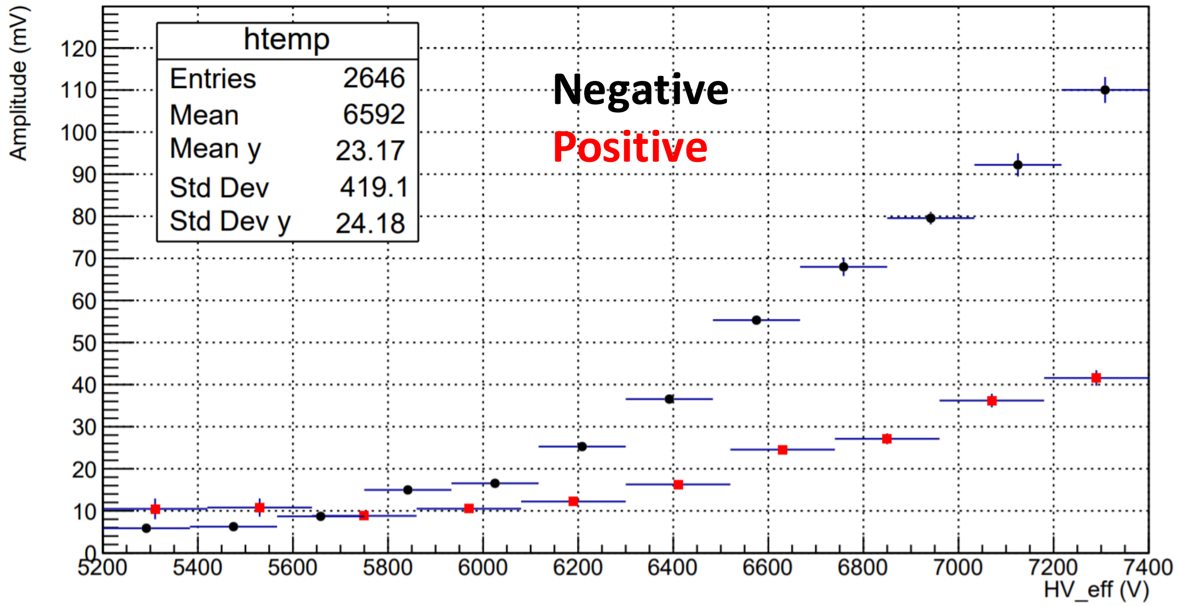
With the front-end electronics, even the configuration in positive polarity reaches excellent performance levels

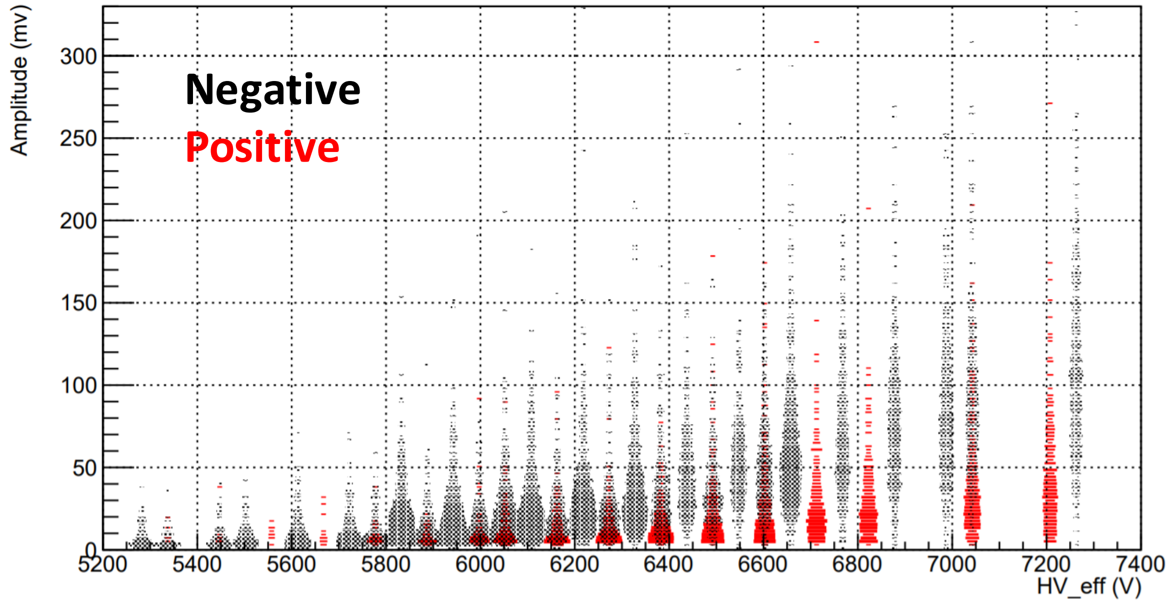
Amplitude distribution



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.

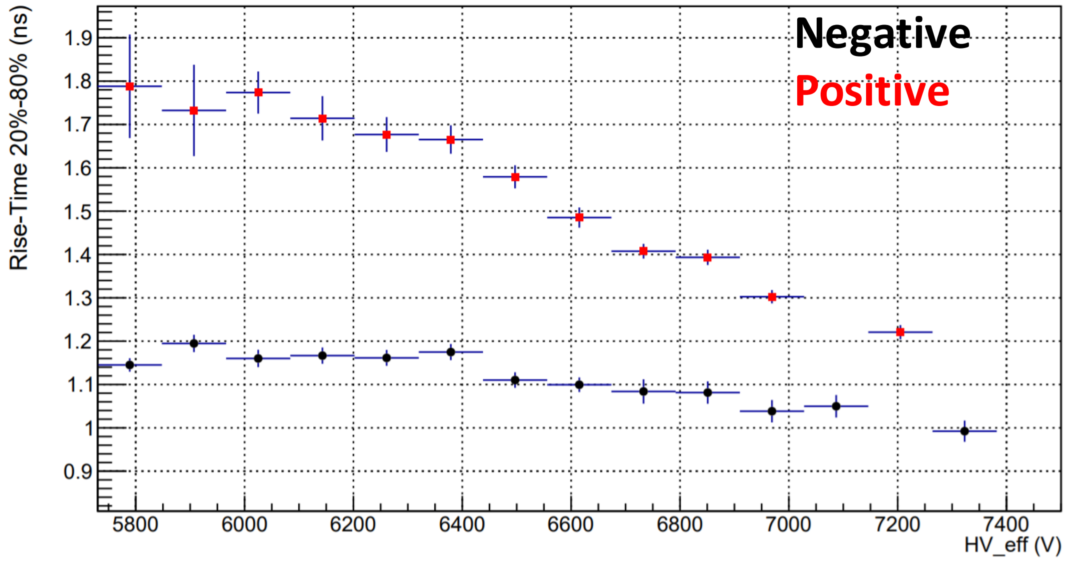
Despite the very large amplitude of the signals, the temporal analysis shows that the working regime is that of a saturated avalanche

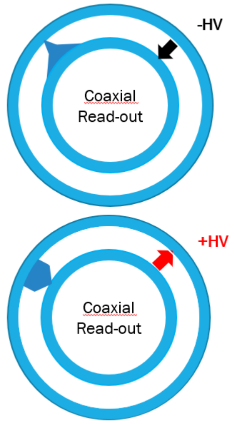


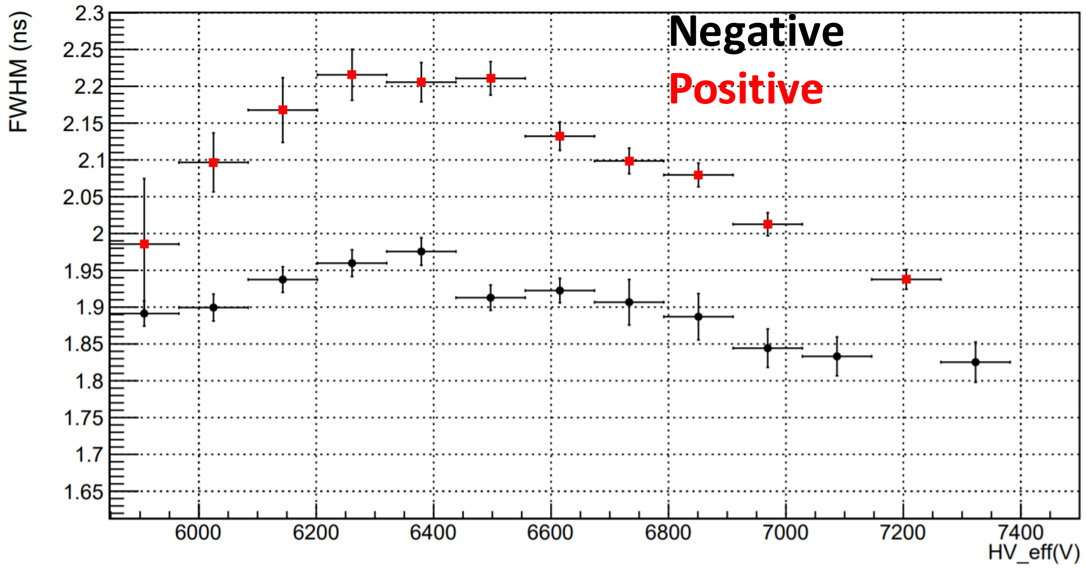


Time response (1)

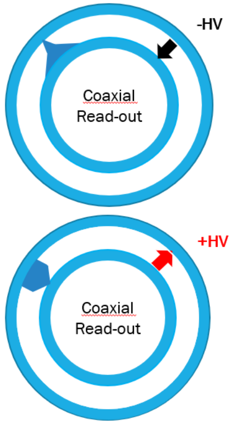
The time response was characterized by measuring the crossing time of some set thresholds. Signals produced in positive polarity conditions are systematically larger. In this condition, the fall time is longer, as expected, meaning that the electrons produced near the cathode give a significant contribution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

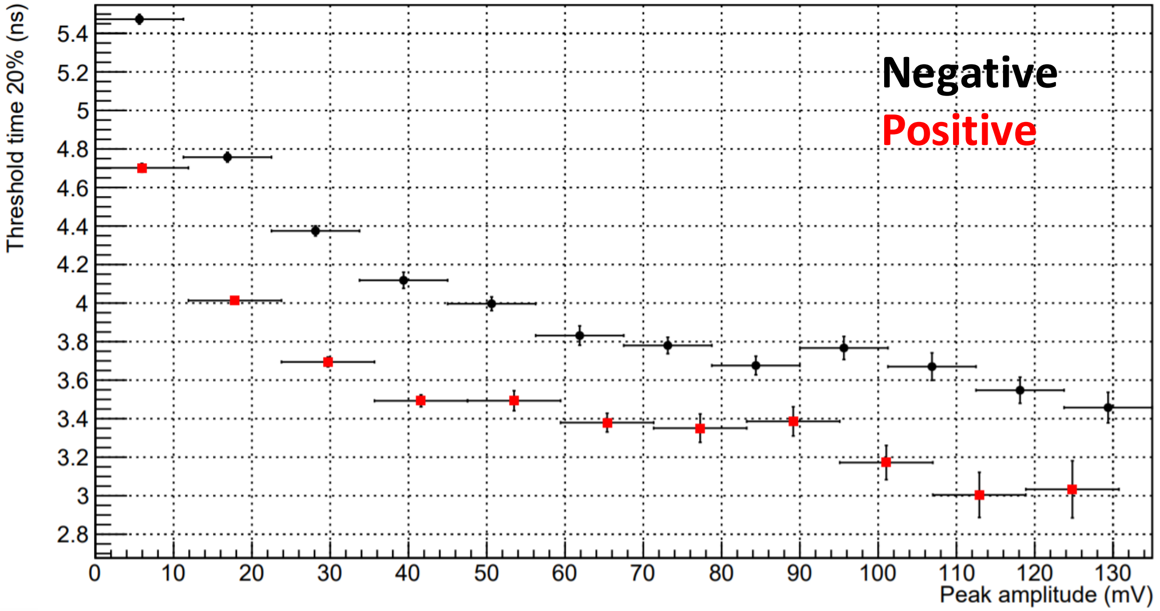


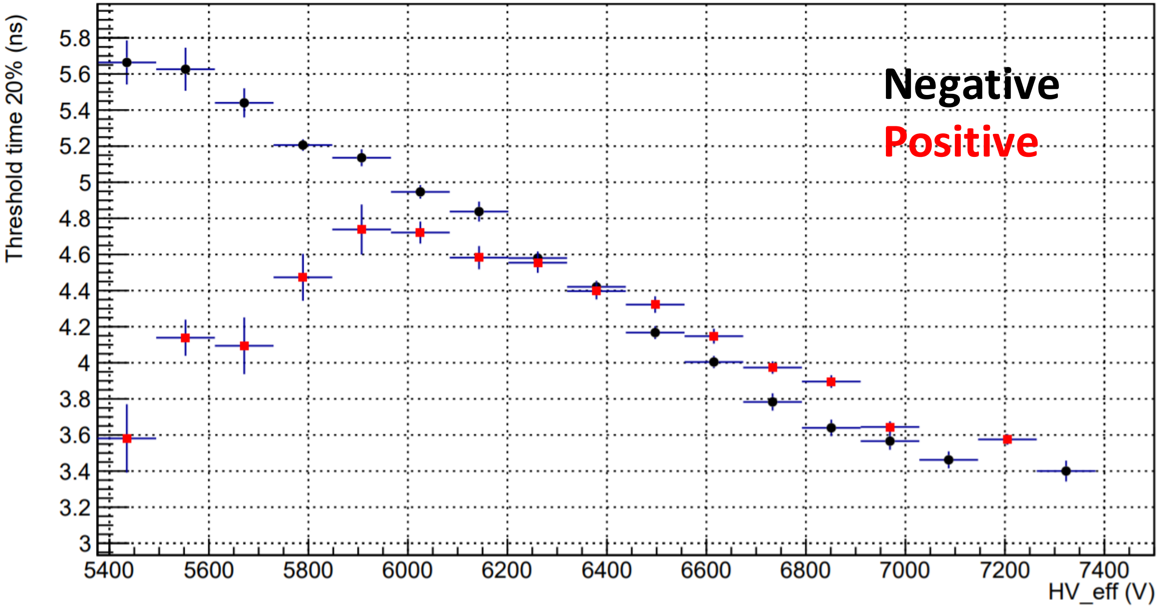




Time response (2)







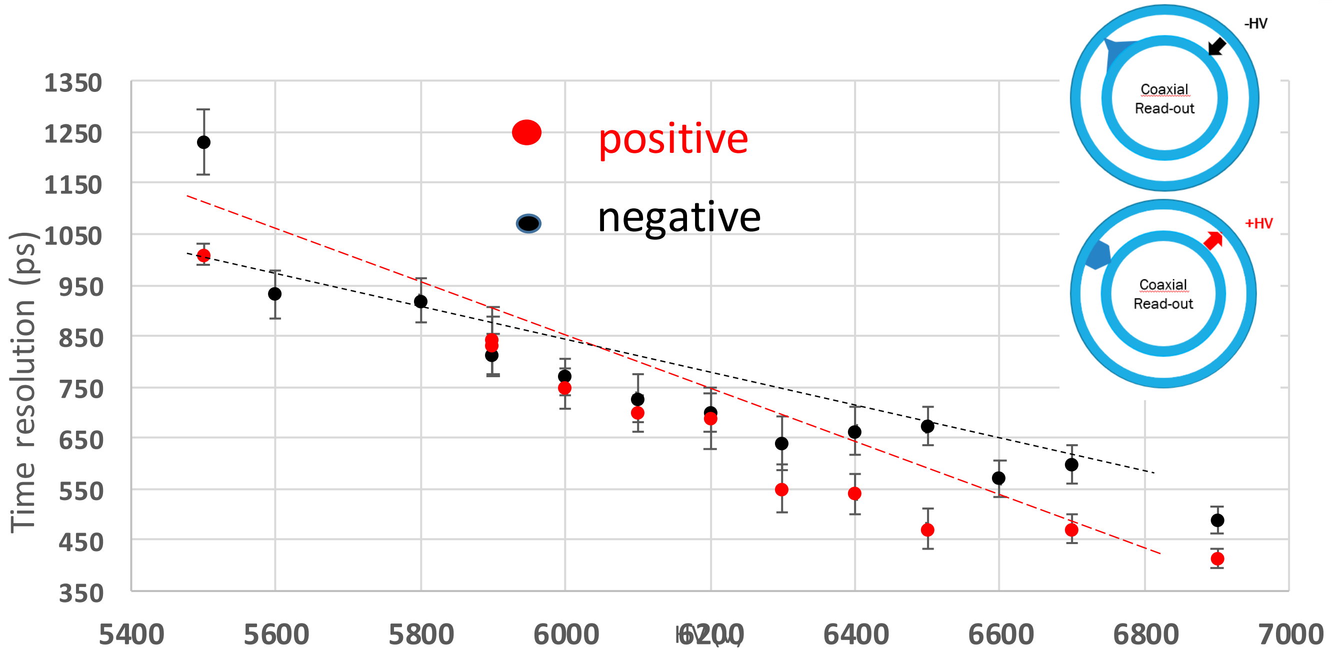
The arrival time was measured using an RPC detector with two coupled 0.2mm gaps as a reference.

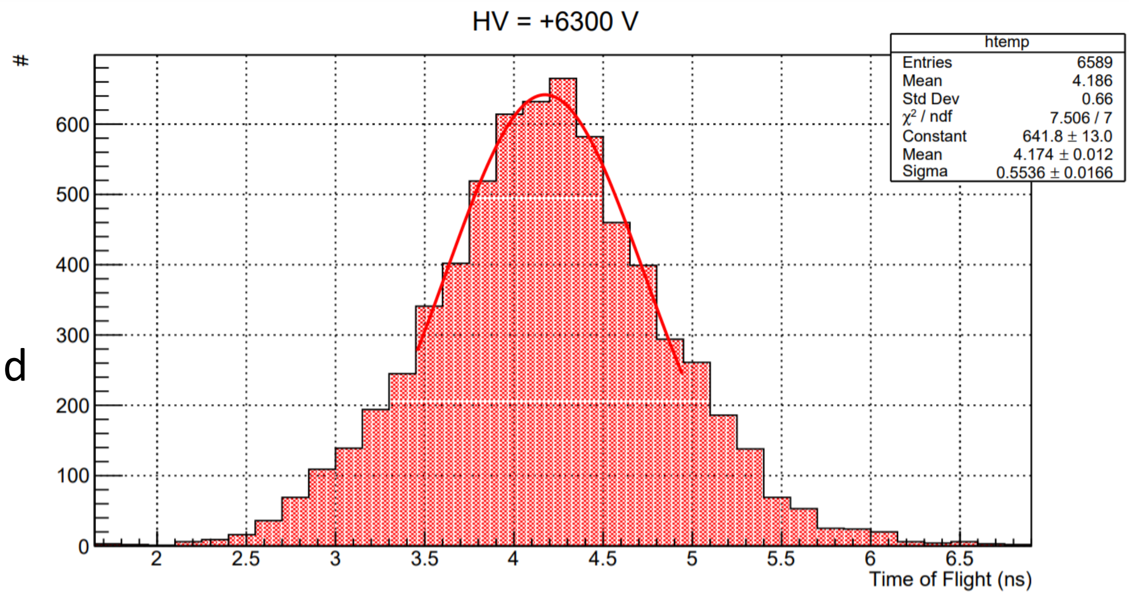
Since the amplitude of the signals at fixed voltage is significantly different between the two polarities, the arrival time has been studied as a function of the pulse amplitude.

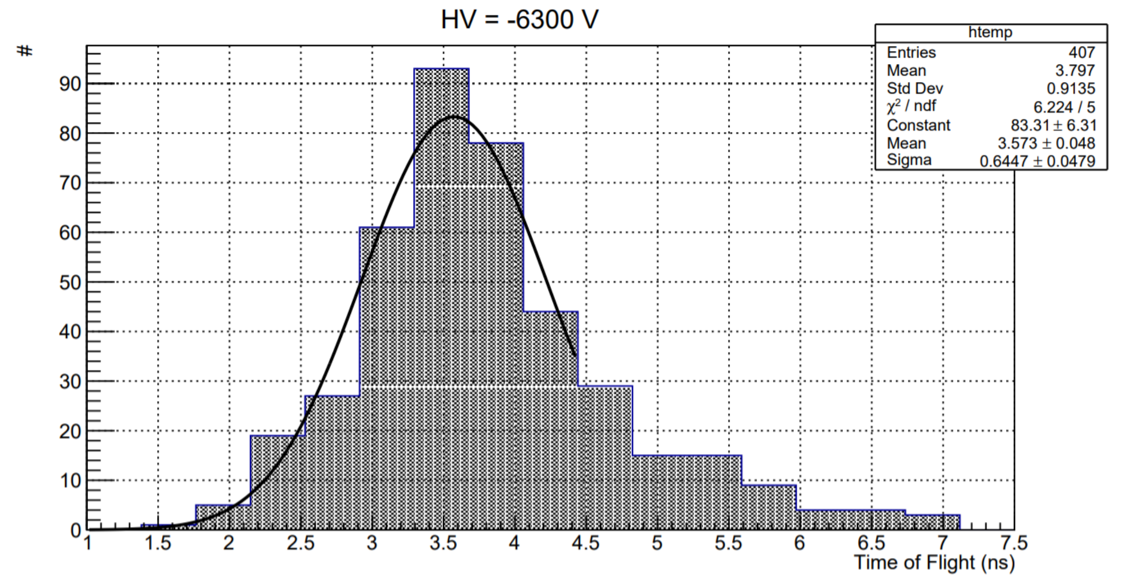
It can be observed that with the same amplitude, the signals produced in positive polarity systematically anticipate those produced in negative polarity.

Time resolution

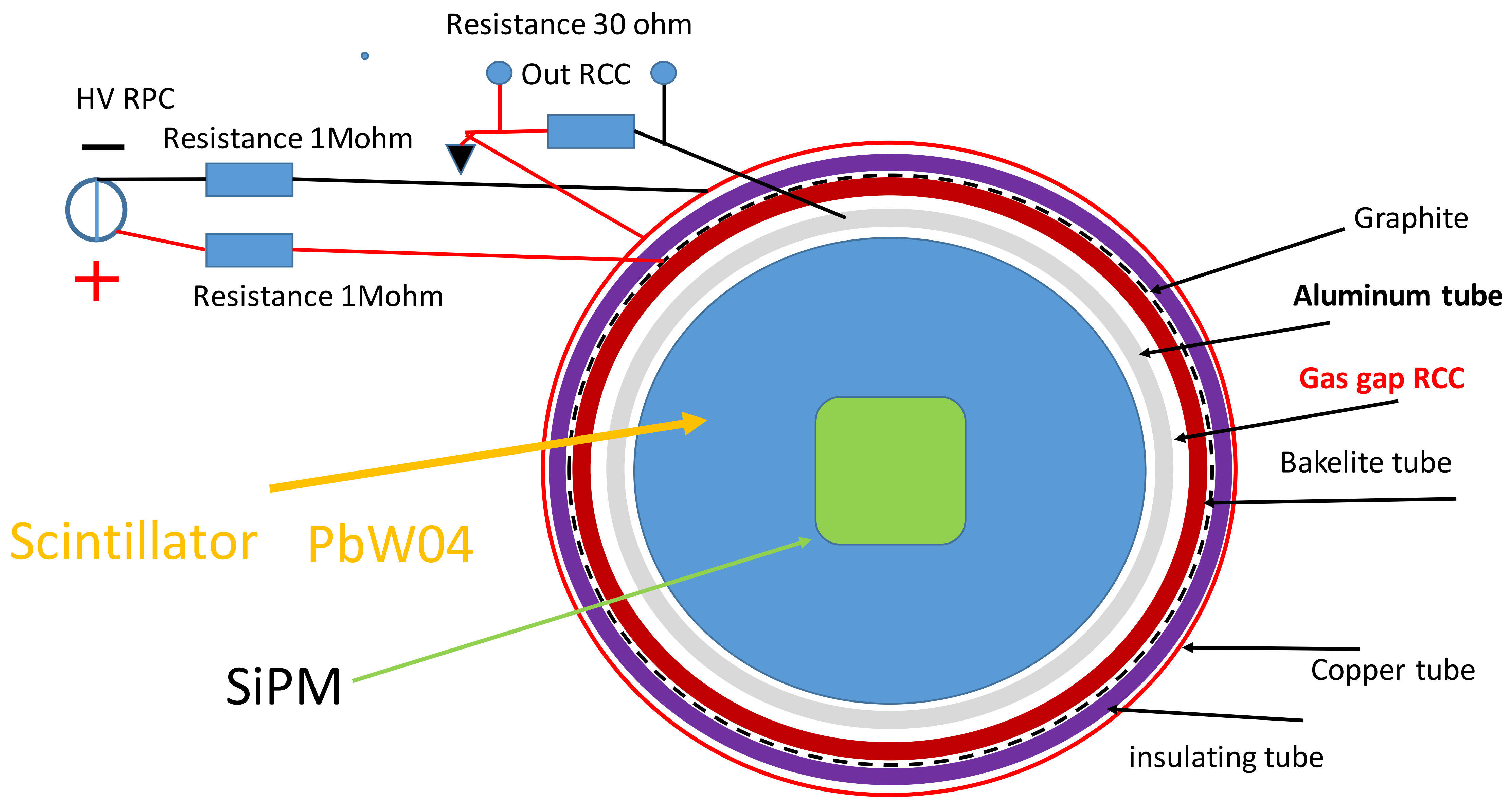
The time resolution was estimated by measuring the time of flight with respect to an RPC detector with 0.2 mm gas-gap whose time resolution is less than 170 ps.
The time resolution improve as the applied voltage increases and for high field values it is systematically better in the case of positive polarization,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





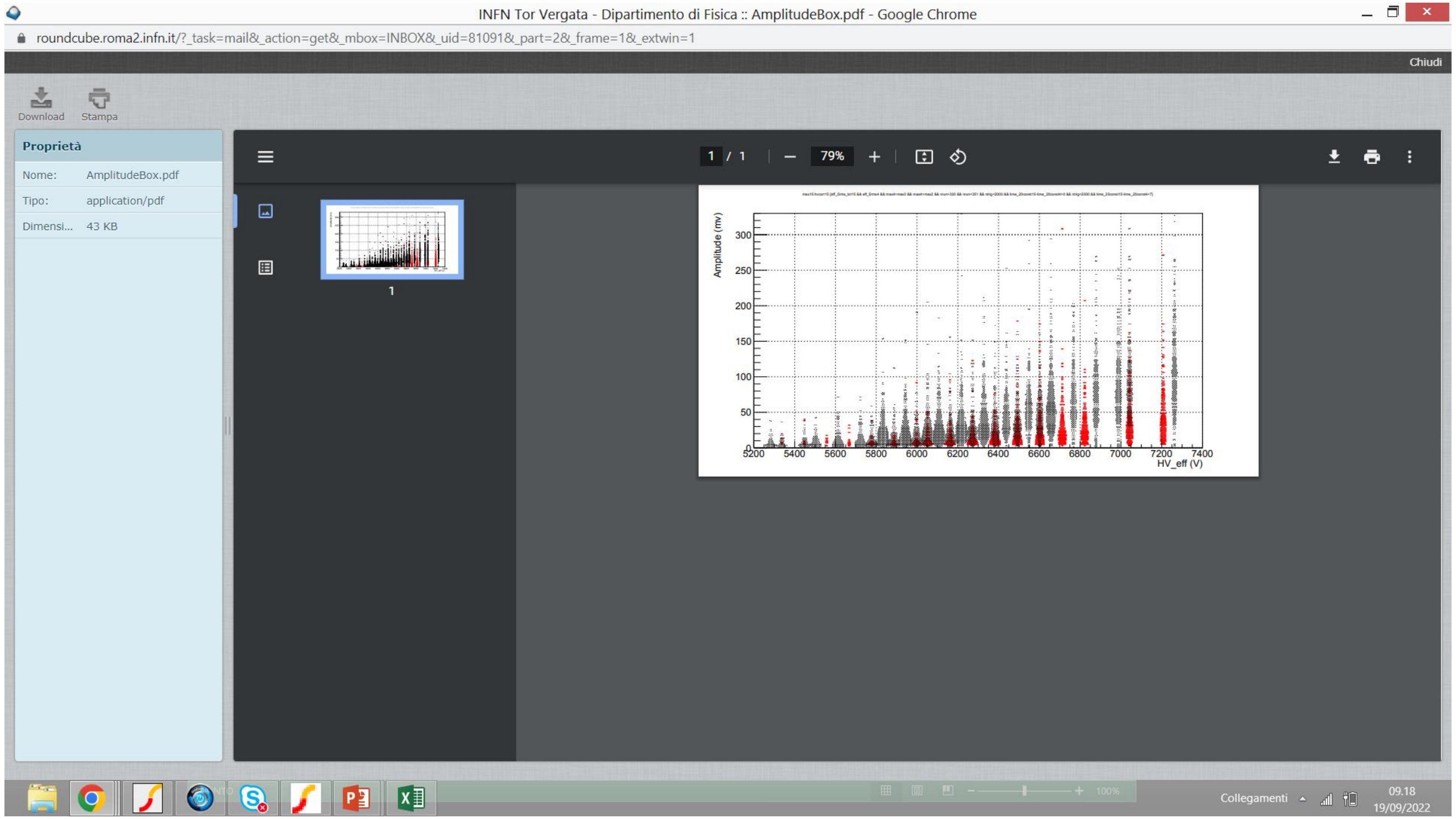


Scintillator + RCC High Time, spazial and Energy resolution



Conclusions

- The RCC is very promising detector for:
- Tracking and timing in the future experiment requiring 50um, 10ps resolution
- Large carpet in the space and in the future lunar sites
- Easily use ecogas mixtures by exploiting geometric quenching and at least use a single gas such as CO_2
- High time resolution and high efficiency with a single thin gap by increasing the density of the active target with pressure instead of making a multigap detector.
- RCCs are easily built in industrial way


INFN Tor Vergata - Dipartimento di Fisica :: AmplitudeBox.pdf - Google Chrome
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79%
Amplitude (mv)
300
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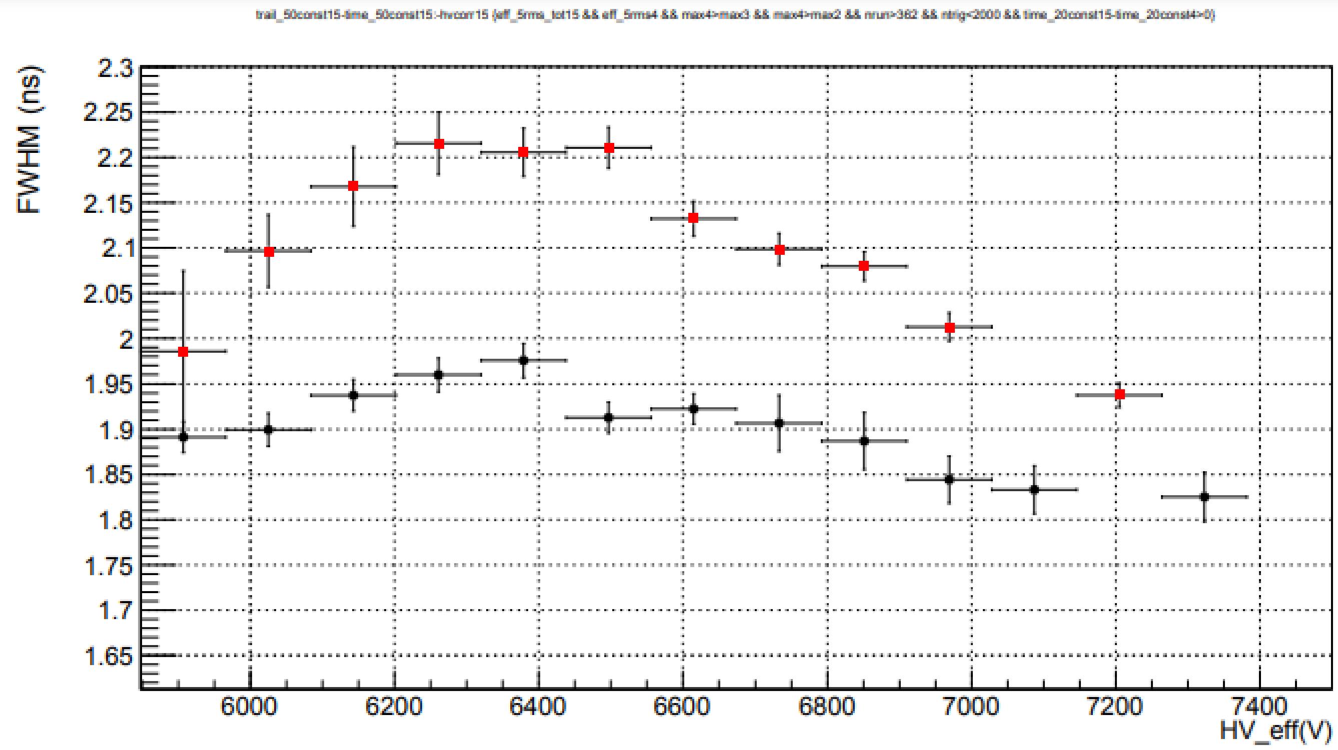
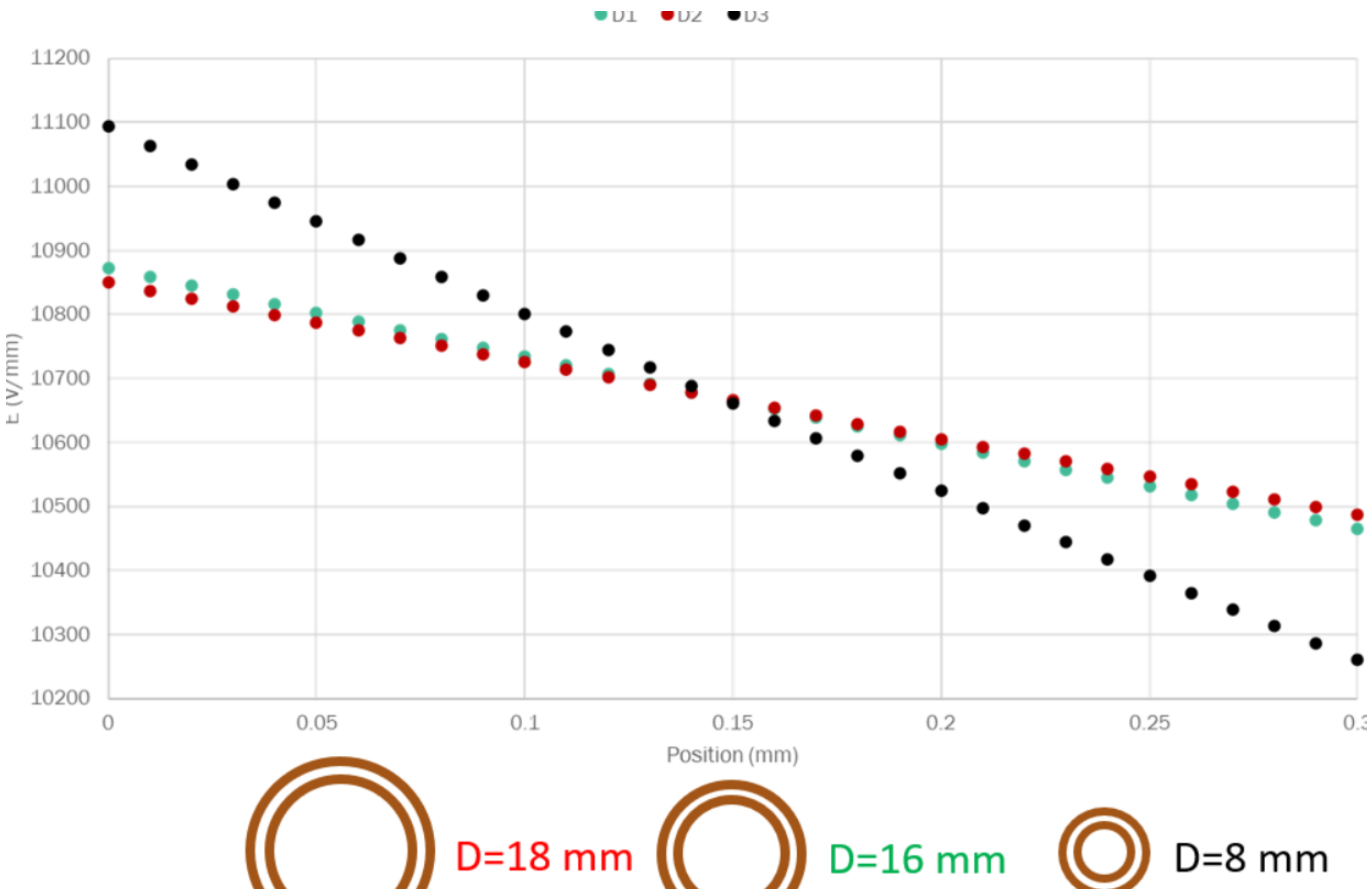
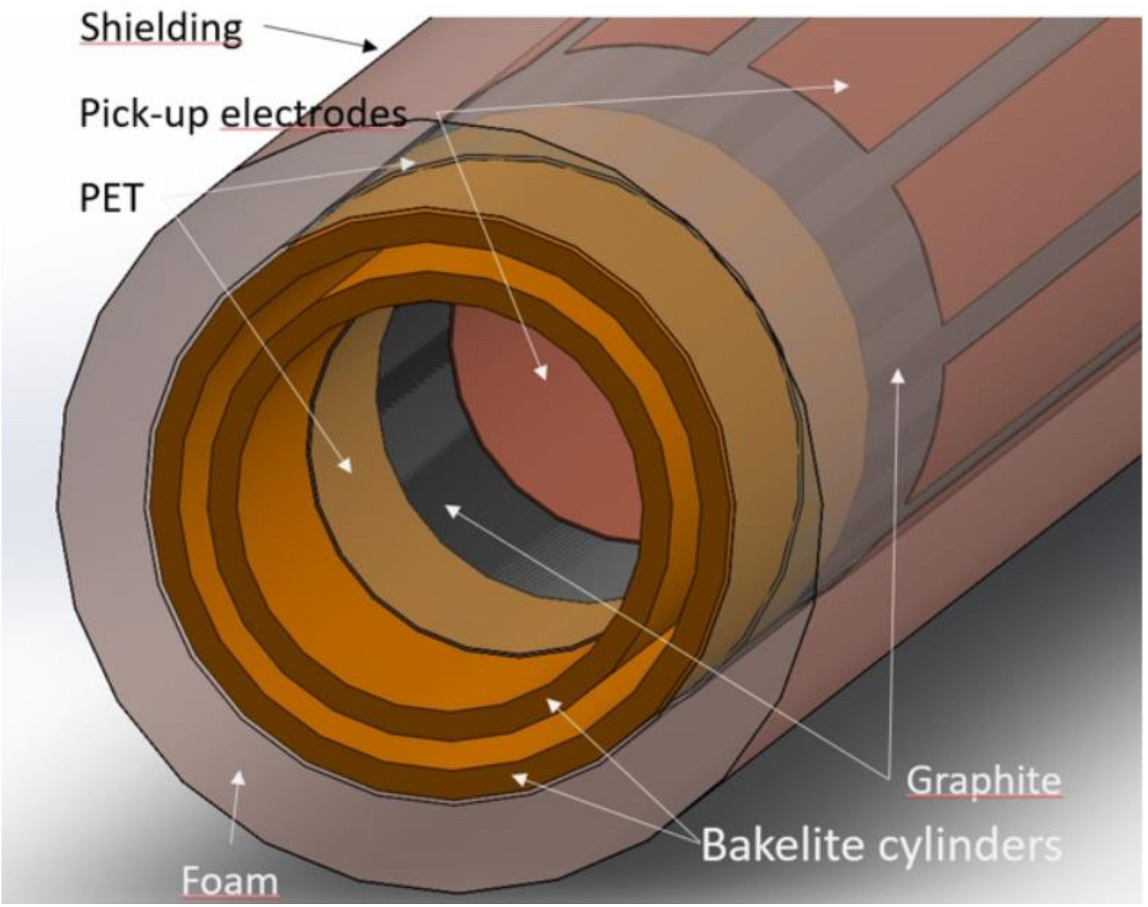
6000
6200
6400
6600
6800
7000
7200
7400
HV_eff (V)
Collegamenti
09.18
19/09/2022

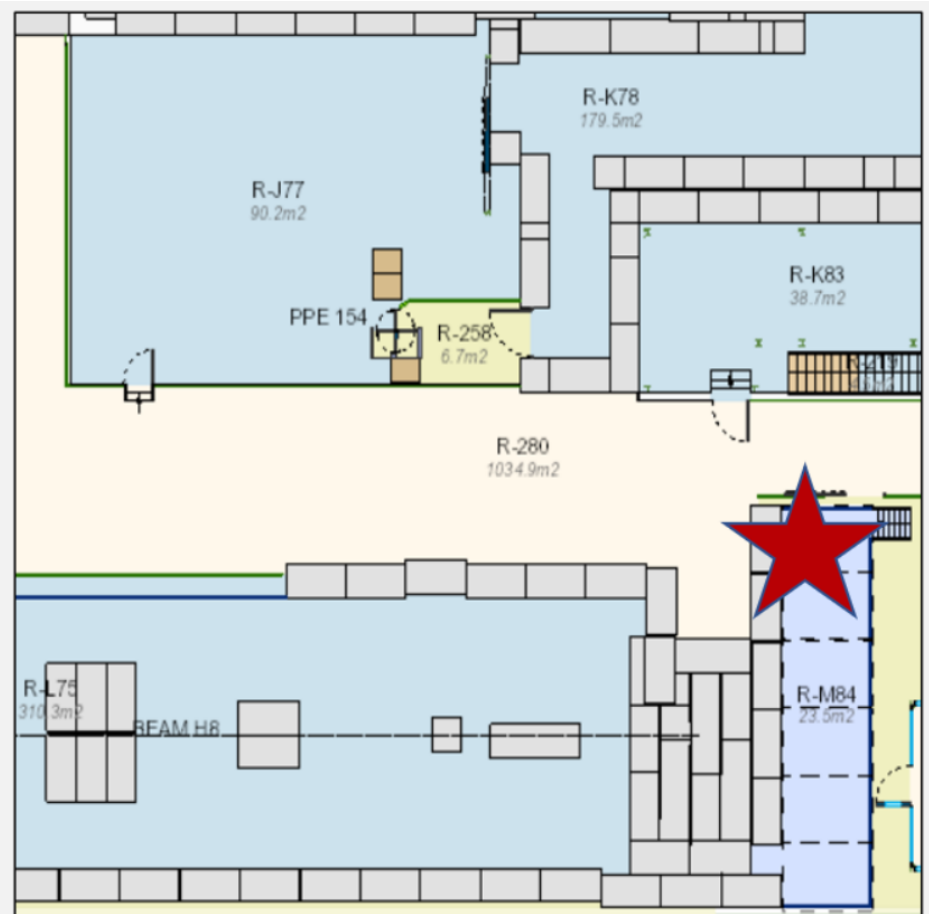


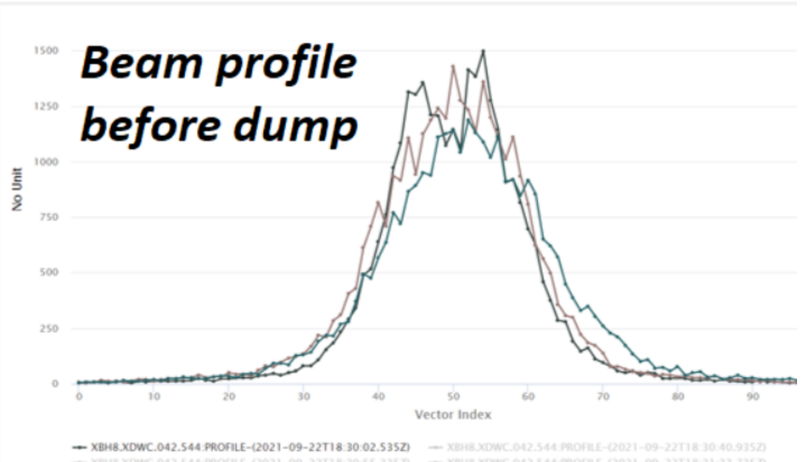
trail_50const15-time_50const15:-hvcorr15 (eff_5rms_tot15 && eff_5rms4 && max4>max3 && max4>max2 && nrun>362 && ntrig<2000 && time_20const15-time_20const4>0)
FWHM (ns)
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
6000
6200
6400
6600
6800
7000
7200
7400
HV_eff(V)



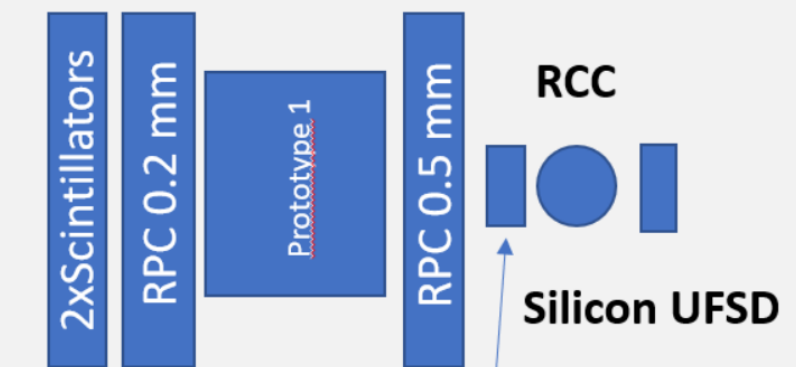
D1 D2 D3
E (V/mm)
Position (mm)
D=18 mm
D=16 mm
D=8 mm

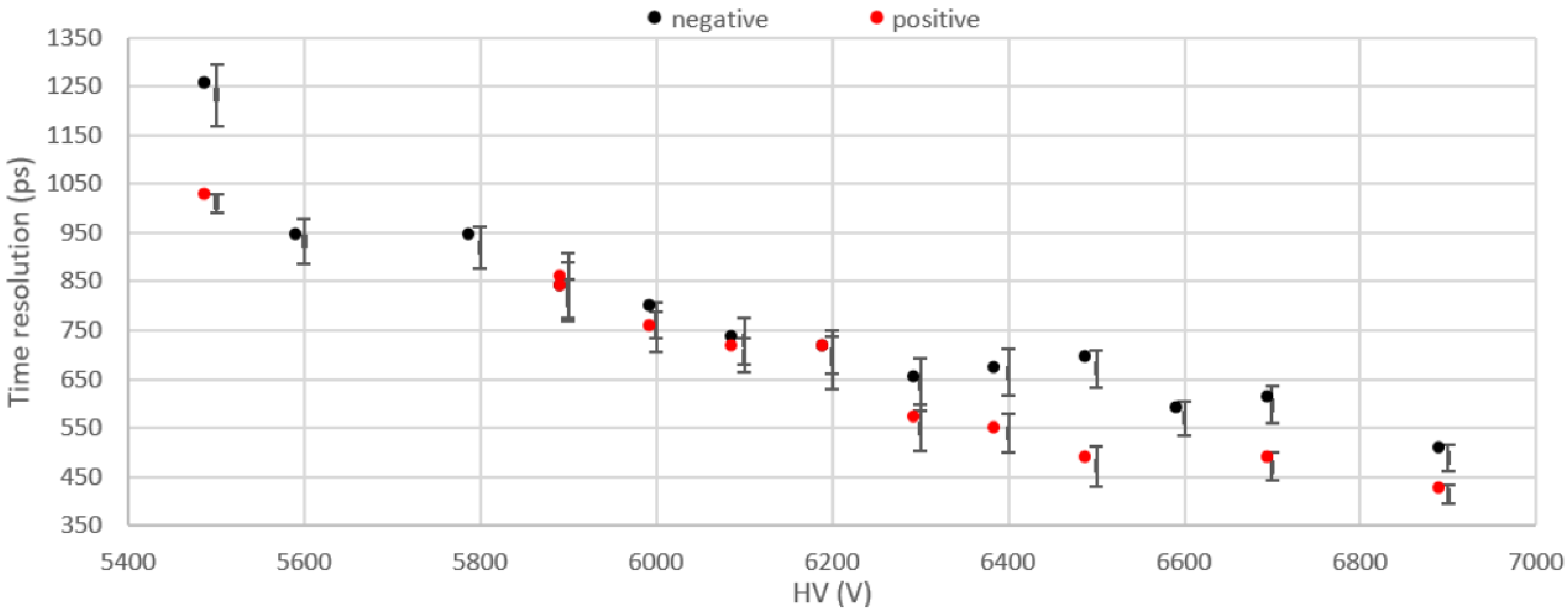

Shielding
Pick-up electrodes
PET
Graphite
Bakelite cylinders
Foam





Experimental set-up





negative
positive
Time resolution (ps)
1350
1250
1150
1050
950
850
750
650
550
450
350
5400
5600
5800
6000
6200
6400
6600
6800
7000
HV (V)