Characterization of Glass Multigap RPC Detectors with Alternative Gas to SF_6

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EP-DT
Detector Technologies

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Outline

- Greenhouse gases emission in High Energy Physics
- Multigap Resistive Plate Chambers: introduction and operating principles;
- Goal and Study methodology;
- Detector construction;
- Gas distribution simulation;
- Laboratory setup;
- Novec 4710 as SF_6 alternative;
- Conclusion.

Greenhouse gas emissions

EU fluorinated gases regulation (2014):

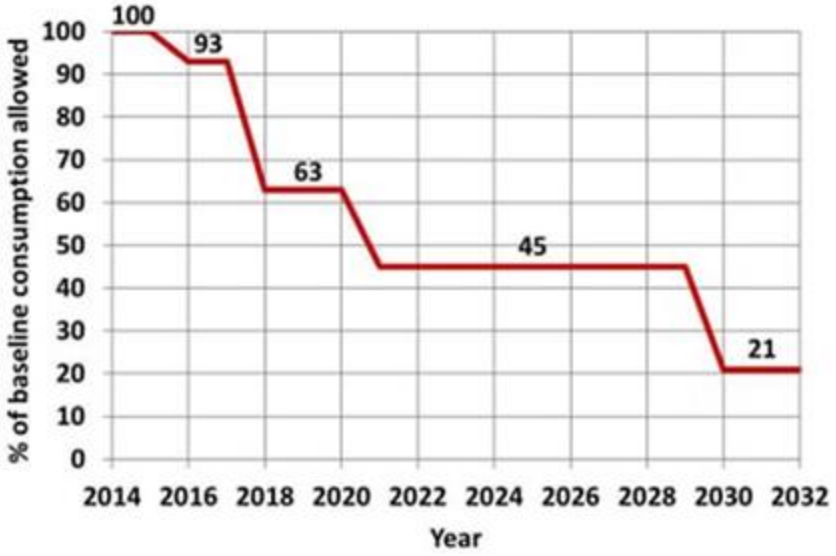
- Reducing products availability of fluorinated GHGs;
- This regulation already affected fluorinated gases prices.

CERN Environment Report:

- Reduce GHG emissions by 28% by the end of RUN3;

CERN gas team developed different strategies to reduce GHG emissions:

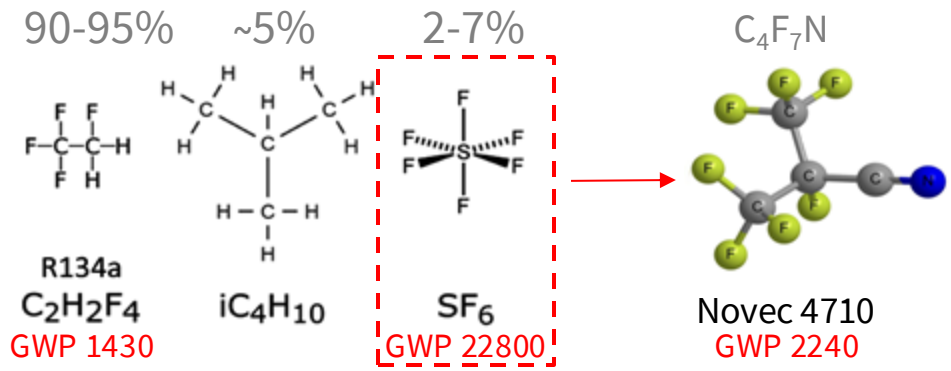
- Development of gas recirculation systems;
- Optimization of current gas systems technologies and recuperation plant;
- Research on alternative eco-friendly gases.

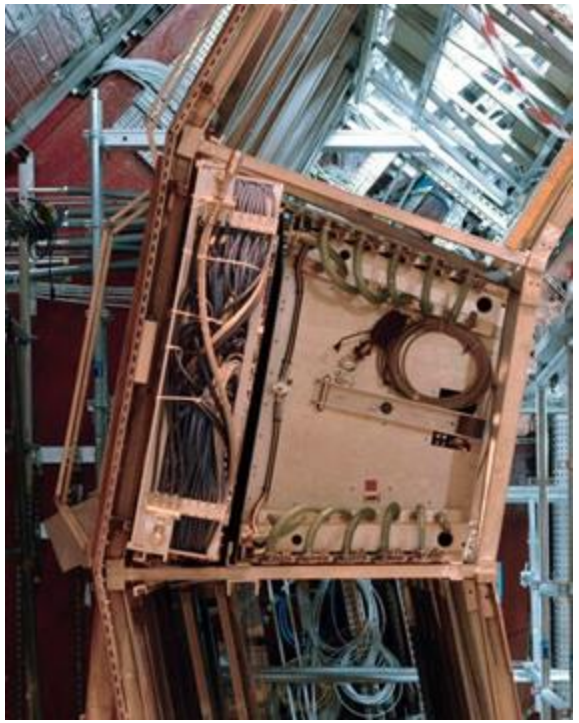


Collaboration with Lyon University for application to **Glass MRPC**.

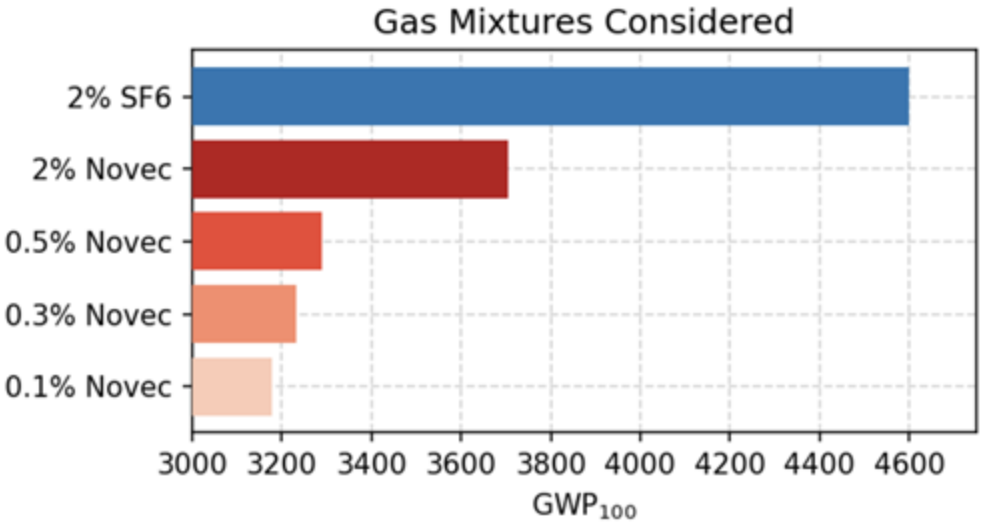
Multigap Resistive Plate Chambers: Introduction

Multigap Resistive Plate Chambers (MGRPC) Detectors are mainly used for their excellent time resolution properties: ≤100 ps.





ALICE TOF detectors

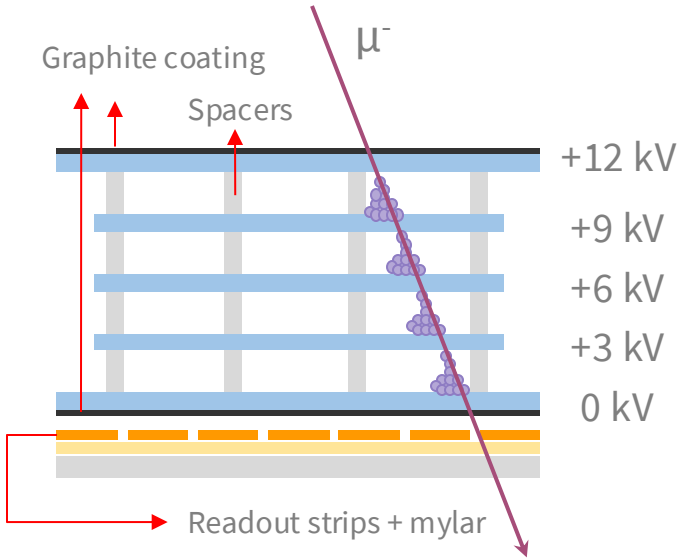


Possibility to reduce tCO_2eq emission by 20%-30%

MRPC operation

Structure:

- Planar resistive electrodes made of glass;
- Electrodes separated by spacers;
- Gas gap between the electrodes filled with gas mixture;
- Copper strips for signal readout.

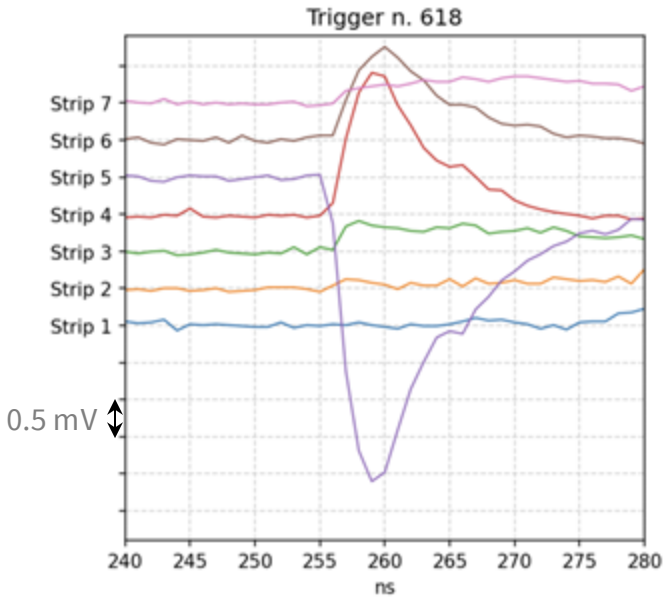


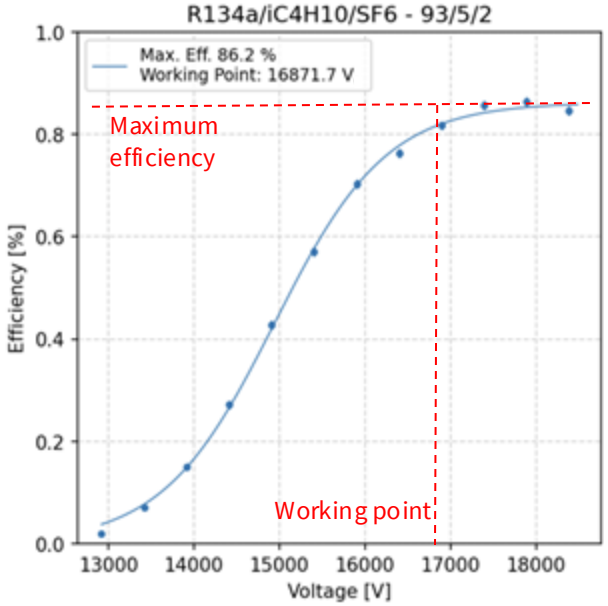
Foremost parameters:

- Prompt charge;
- Efficiency;
- Working point: voltage where the efficiency reach 95% of its maximal values, plus 150 V;
- Time resolution.

Operating principle:

- High voltage applied to the external electrodes;
- The inner electrodes reach the stability thanks to the electrostatic;
- Gas ionization inside the gap;
- Charge multiplication;
- Charge induction on readout strips.





Goal and Study methodology

The **goal** of this work is to enhance the construction of the detector while maintaining low production costs. Additionally, we aim to identify an alternative gas mixture that ensures high detector performance, with a particular emphasis on time resolution.

April-May 2024

1. Setup installation, Construction and Characterization of a first prototype;

June-July 2024

1. Optimization studies to improve detectors constructions:
   - Materials and techniques;
   - Flow distribution simulations;

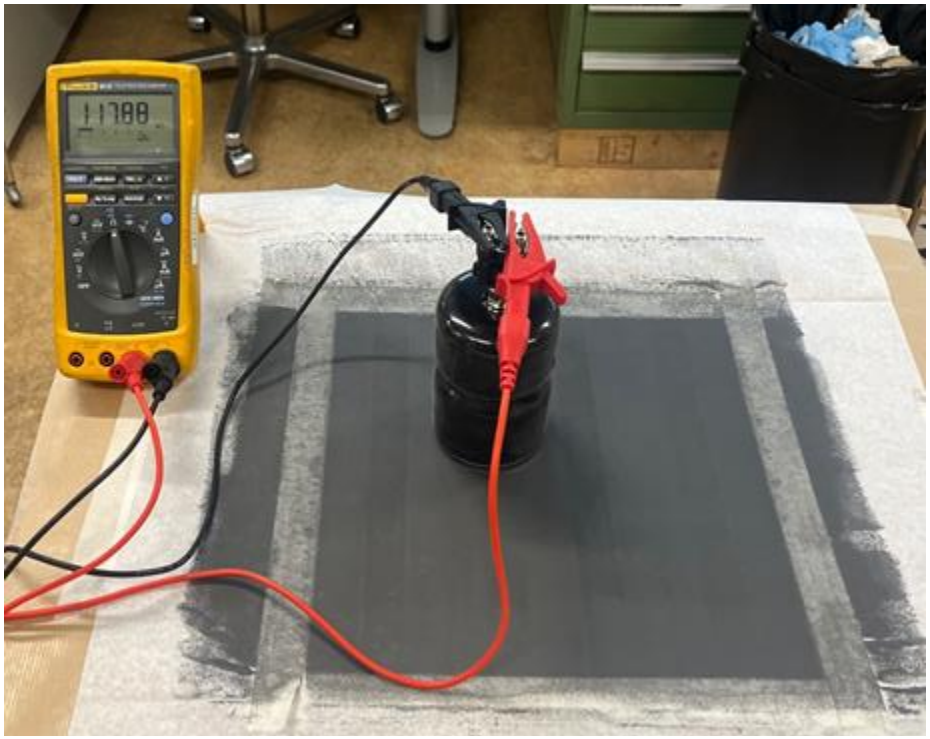
Aug.-Sept. 2024

1. Characterization with alternative gas mixture:
   - Novec 4710 as SF_6 replacement;
   - Alternative to the R134a;

Foreseen

1. Time resolution characterization with the alternative gas mixture.

Detector construction: Graphite Varnish



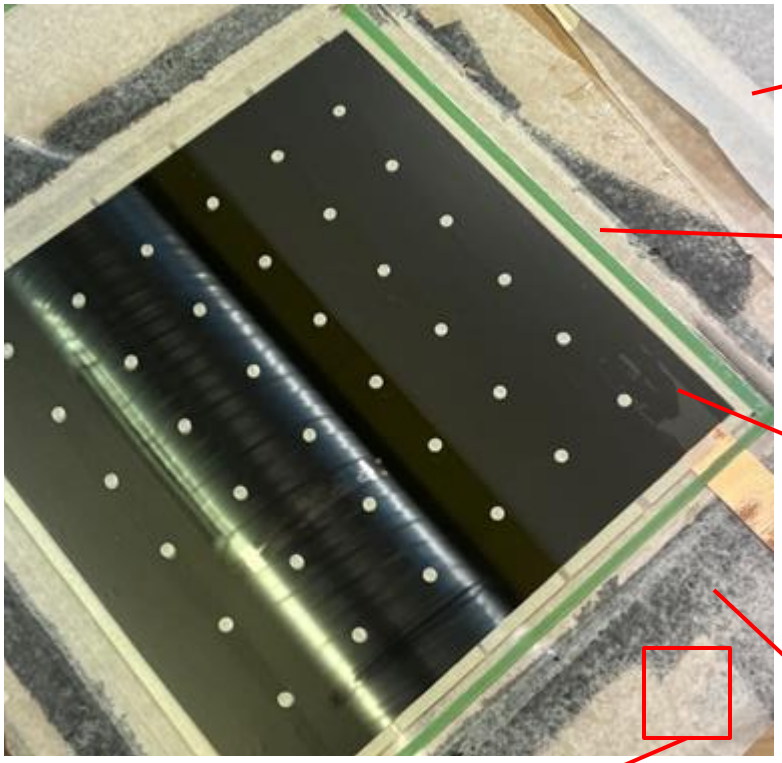
Desired detector features:
- 4 gaps, 0.25 mm each;
- Glass sheets 30 cm x 30 cm [active area 27 cm x 27 cm];
- Glass thickness 0.3 mm;
- Graphite layer ~ MΩ cm.

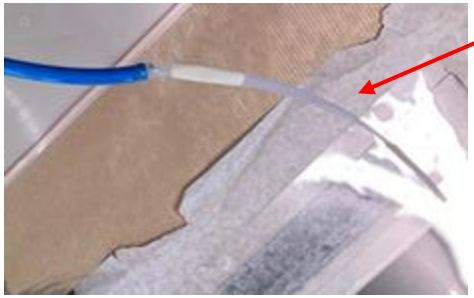
Graphite layer Varnishing:
- Mix of GRAPHIT 33 and PLASTIK 70 (Kontakt Chemie);
- Spread with microfiber roller;
- Resistivity measured with a Concentric Ring Probe.

Example of measured resistivity

1.1 MΩ cm	1.6 MΩ cm	1.8 MΩ cm
1.2 MΩ cm	1.2 MΩ cm	1.4 MΩ cm
1.2 MΩ cm	1.2 MΩ cm	1.4 MΩ cm

Detector construction: Spacers





6 mm plastic pipe glued to 3 capillaries pipes of 1 mm diameter.

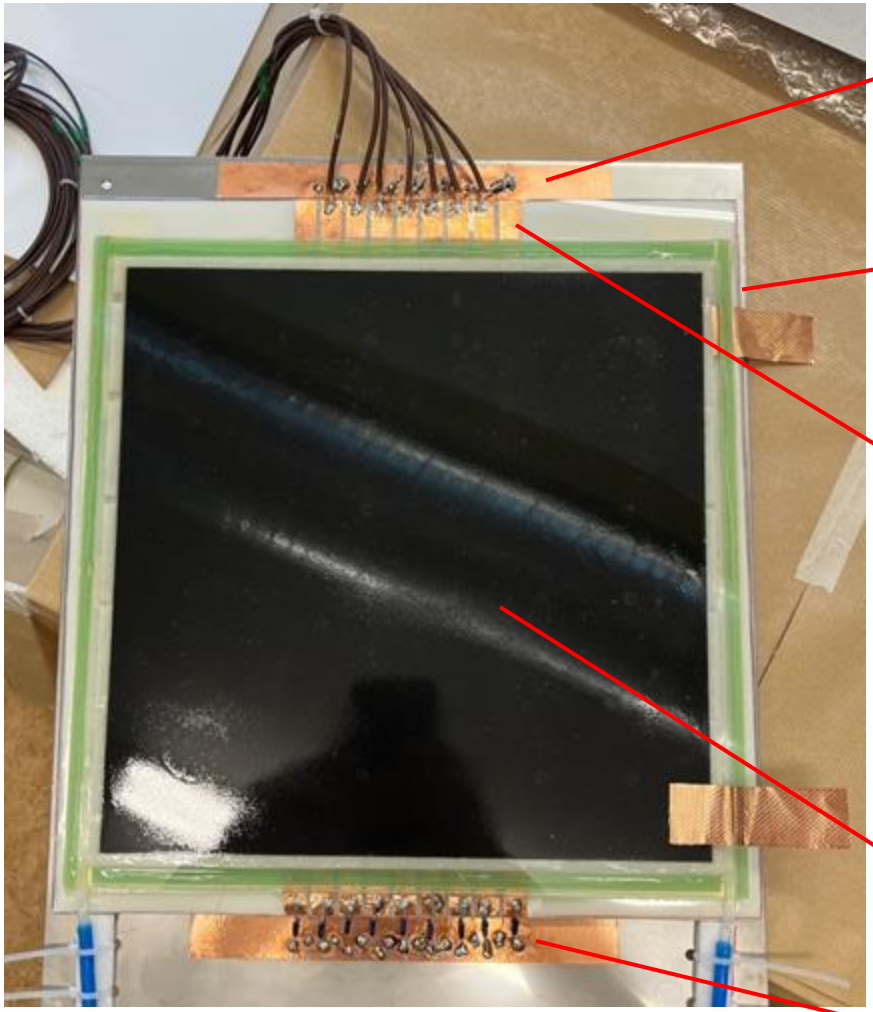
HV connection:
- Copper tape with conductive glue (CW2400, CircuitWorks).

Circular Spacer (mylar + glue):
- 5 mm diameter;
- 0.25 mm thickness in total;
- Placed every 4 cm;

Inner Lateral Spacer (mylar + glue):
- 5 mm width;
- 0.25 mm thickness in total;
- separated by 1 mm increasing spaces;
- glued on one or both sides.

External Lateral Spacer (fiberglass+glue):
- 3 mm width;
- 1.2 mm thickness.

Detector construction: Readout



LEMO cable connected to the electronics.

Detector sealed with bicomponent resin glue (Araldite 2011).

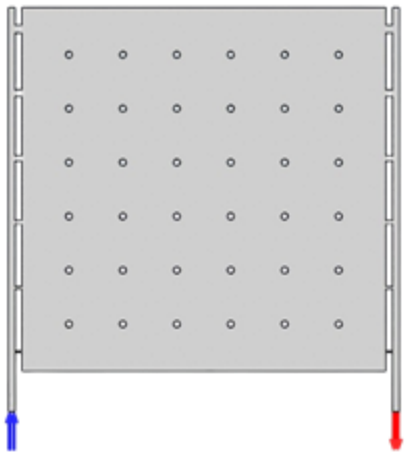
strip plane.

2 cm width copper tape, 1 mm gap;
1 mm thick mylar;
5 mm thick polystyrene.

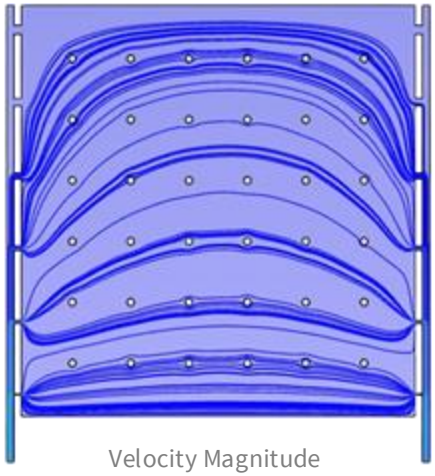
Urethane protective layer.

50 Ω resistances.

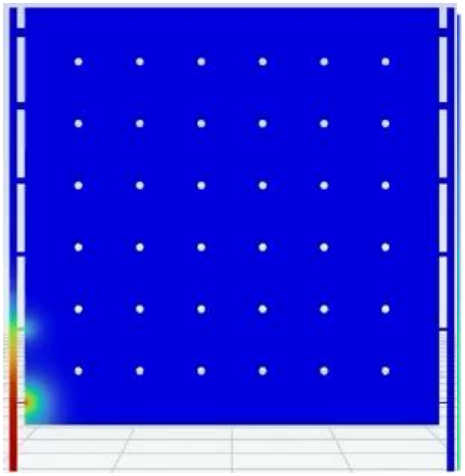
MRPC flow simulation



Prototype #1
now in use



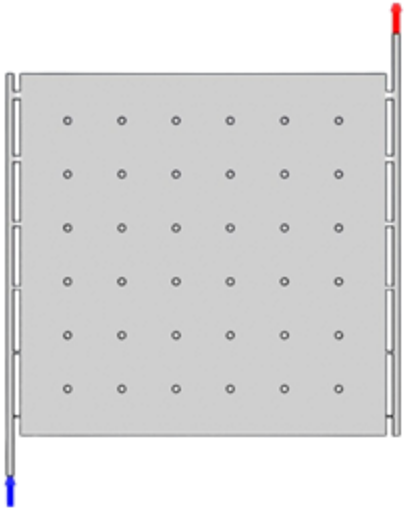
Time: 67 m
MIN(%freon): 99.5%



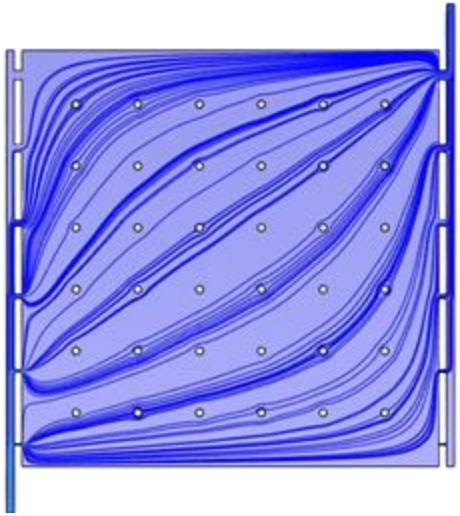
Simplification: 1 gas gap
Performed with ANSIS

Steady State
laminar
0.5 ln/h

Transient
Air -> Freon



Prototype #2
Future
improvement



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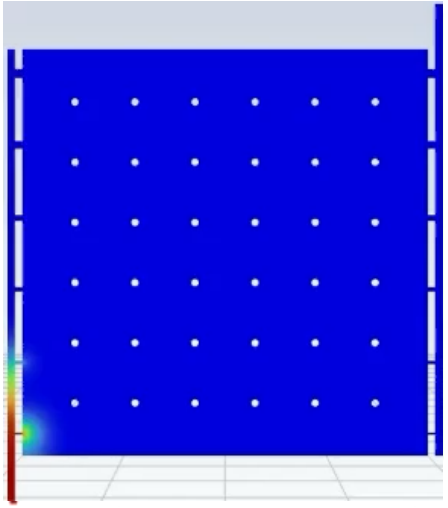
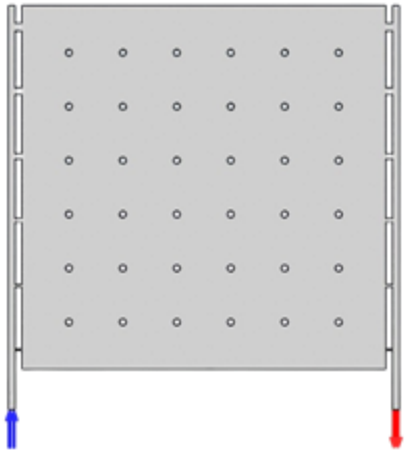


Simulation by F. Benazzo

MRPC flow simulation



Prototype #1
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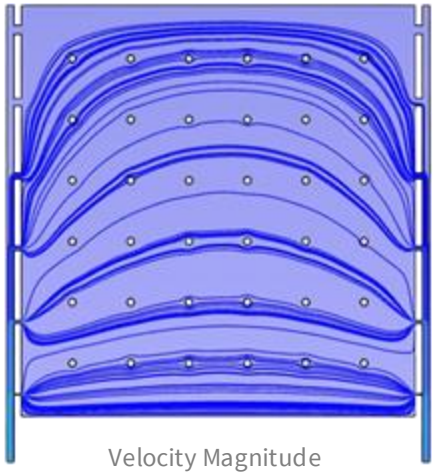

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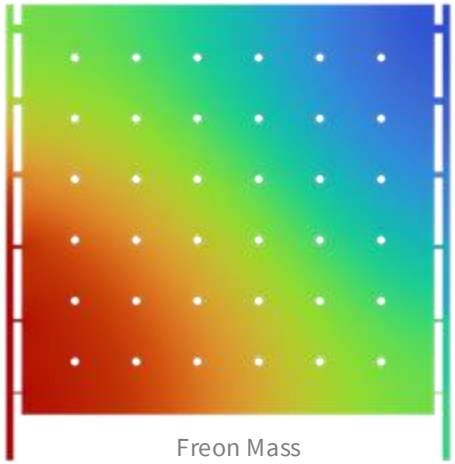

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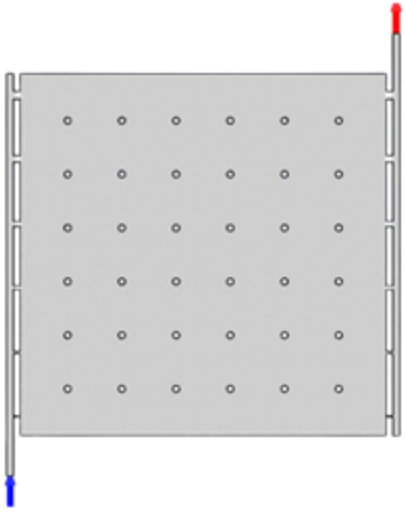

Prototype #2
Future
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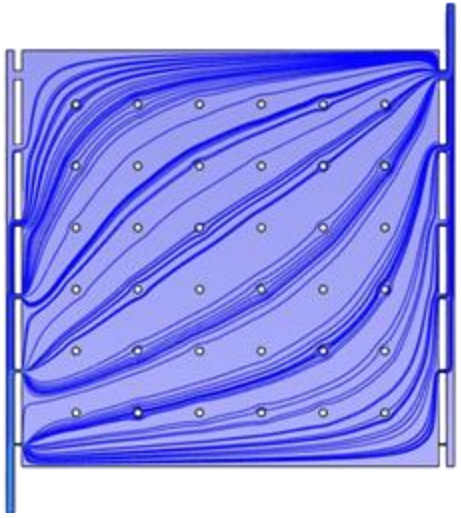

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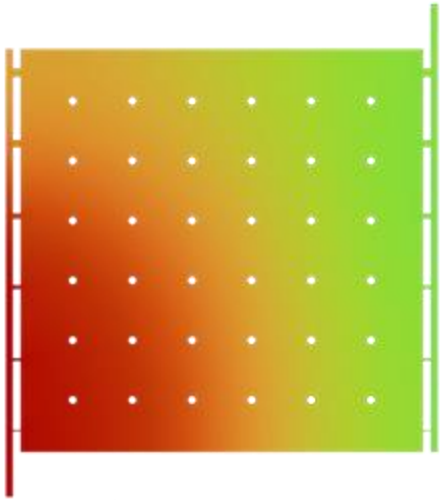
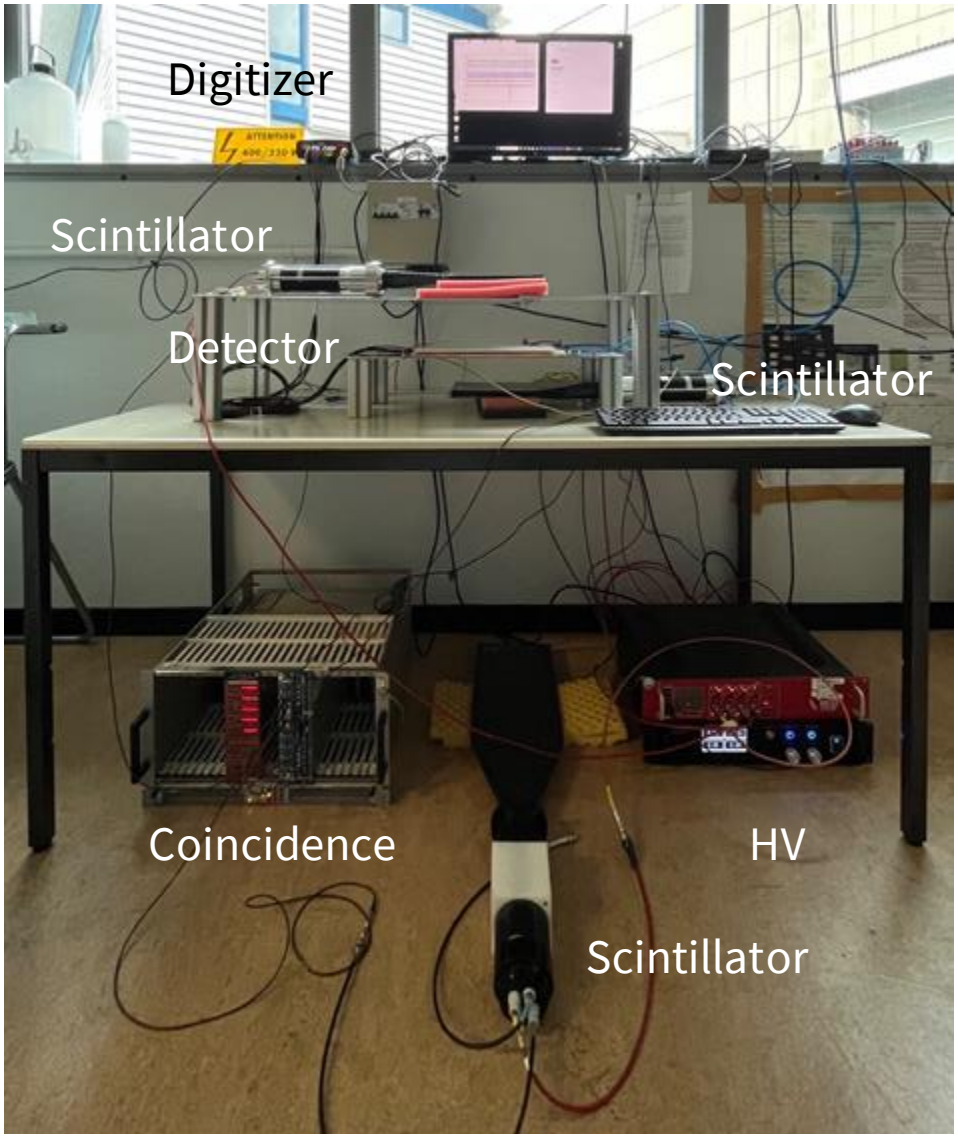


Simulation by F. Benazzo

Setup



4-gaps Glass MRPC;
7 strips, 2 cm width;
-> strips home made with copper tape and mylar;

0.3 mm Glass thickness;
0.25 mm Gap thickness;

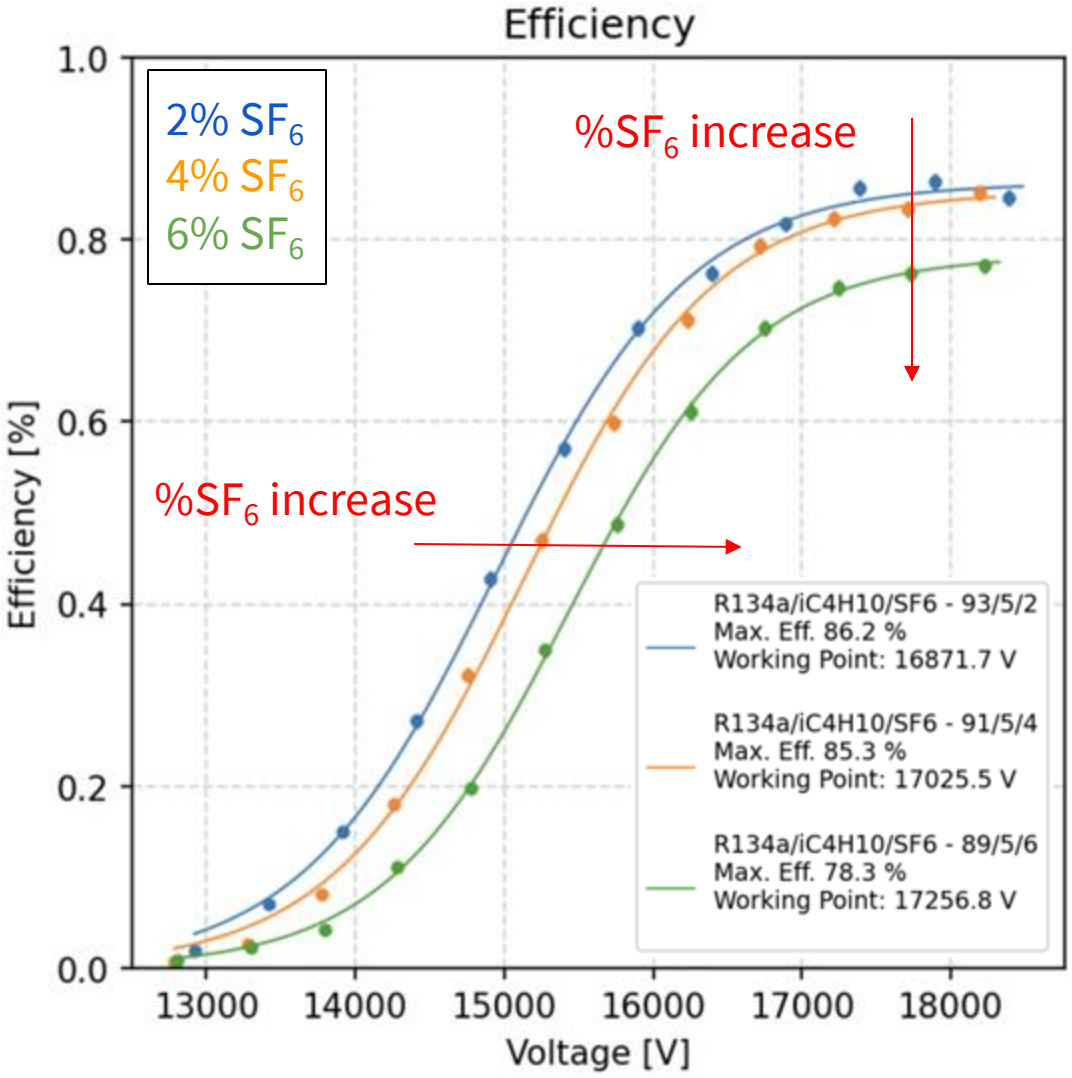
Coincidence obtained with three scintillators + 1 scintillator veto;

Dedicated HV module +30/-30 kV from ESDEMC;

Data acquisition made with Digitizer Desktop v1730 (2 mV Thr., ~68 fC);

Pressure and temperature sensor located near the detector.

Variation of SF_6 concentration

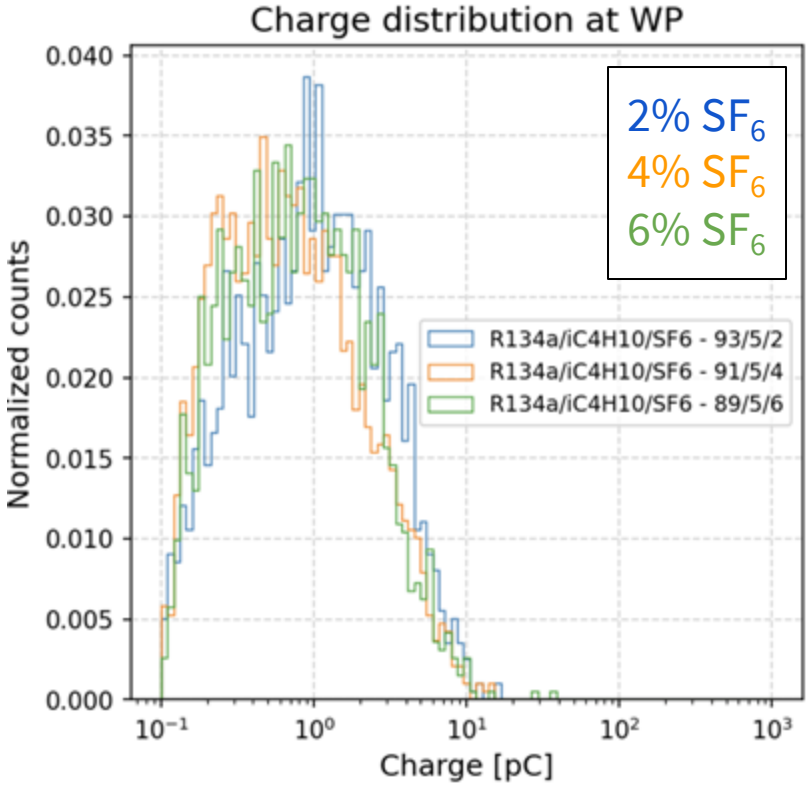


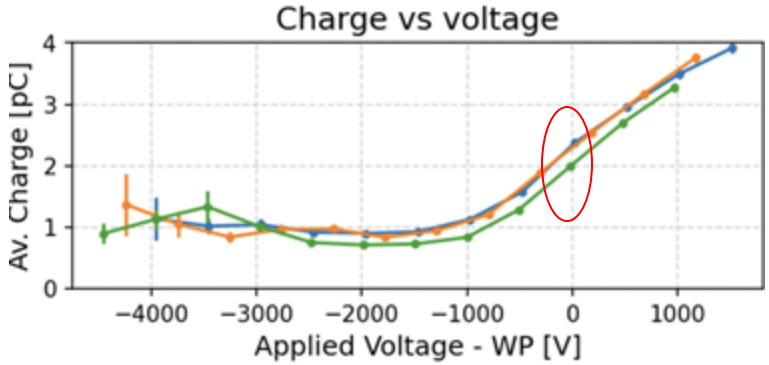
% SF_6 increase -> WP increase:
- ~250 V for 2% increase.

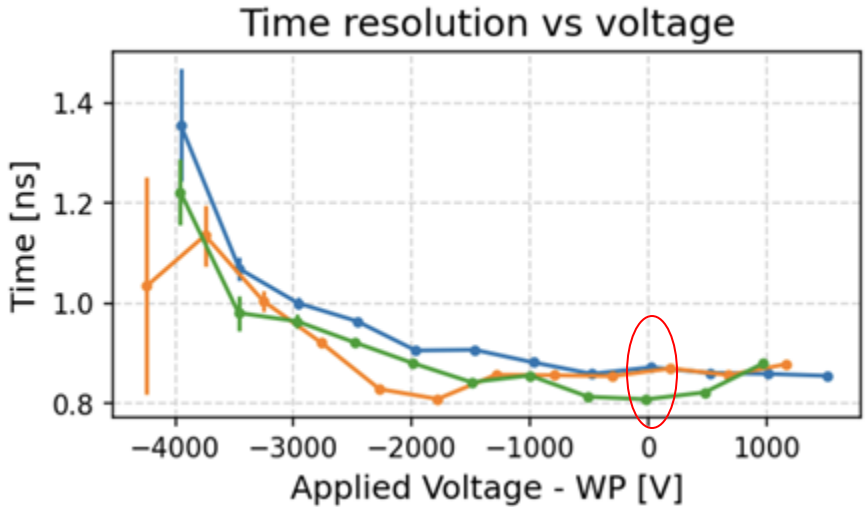
% SF_6 increase -> Max. Eff. decrease:
- 1% between 2% and 4%;
- 8% between 4% and 6%.

-> possibly loss of signals for a high %SF_6 due to the high electronegativity.

Variation of SF_6 concentration



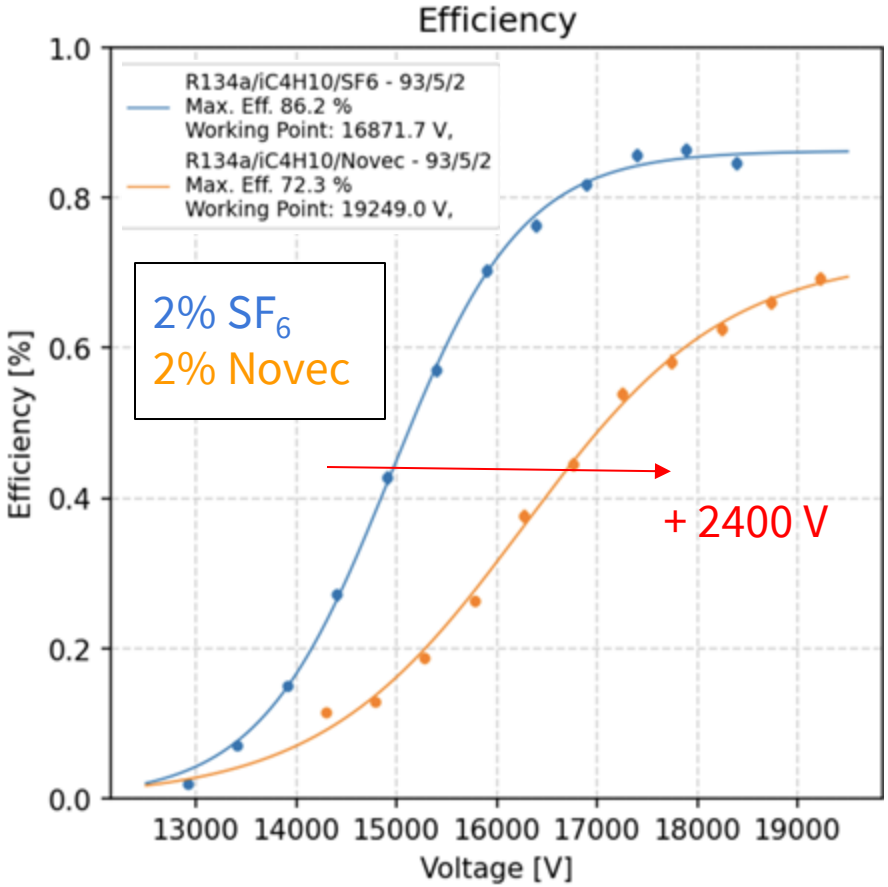


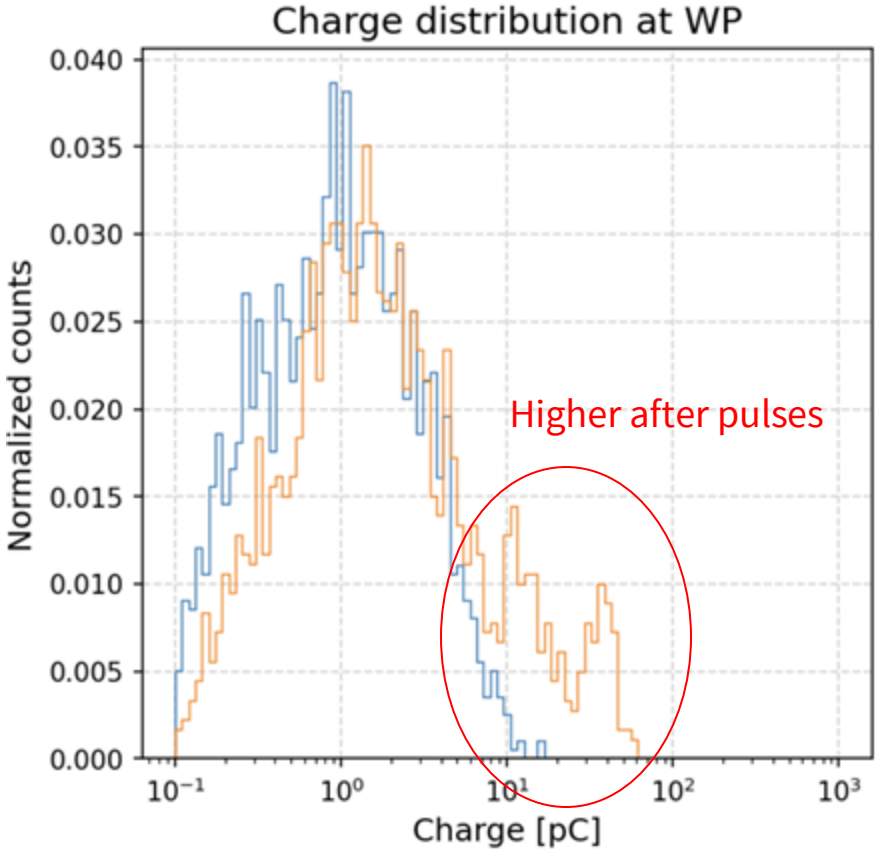


- **Charge distribution** @ WP lower with the higher %SF_6 (~0.5 pC);
- **Time resolution** @ WP similar between the different gas mixtures.

2% SF_6 gas mixture used as references in the next slides

Novec 4710 as SF_6 alternative



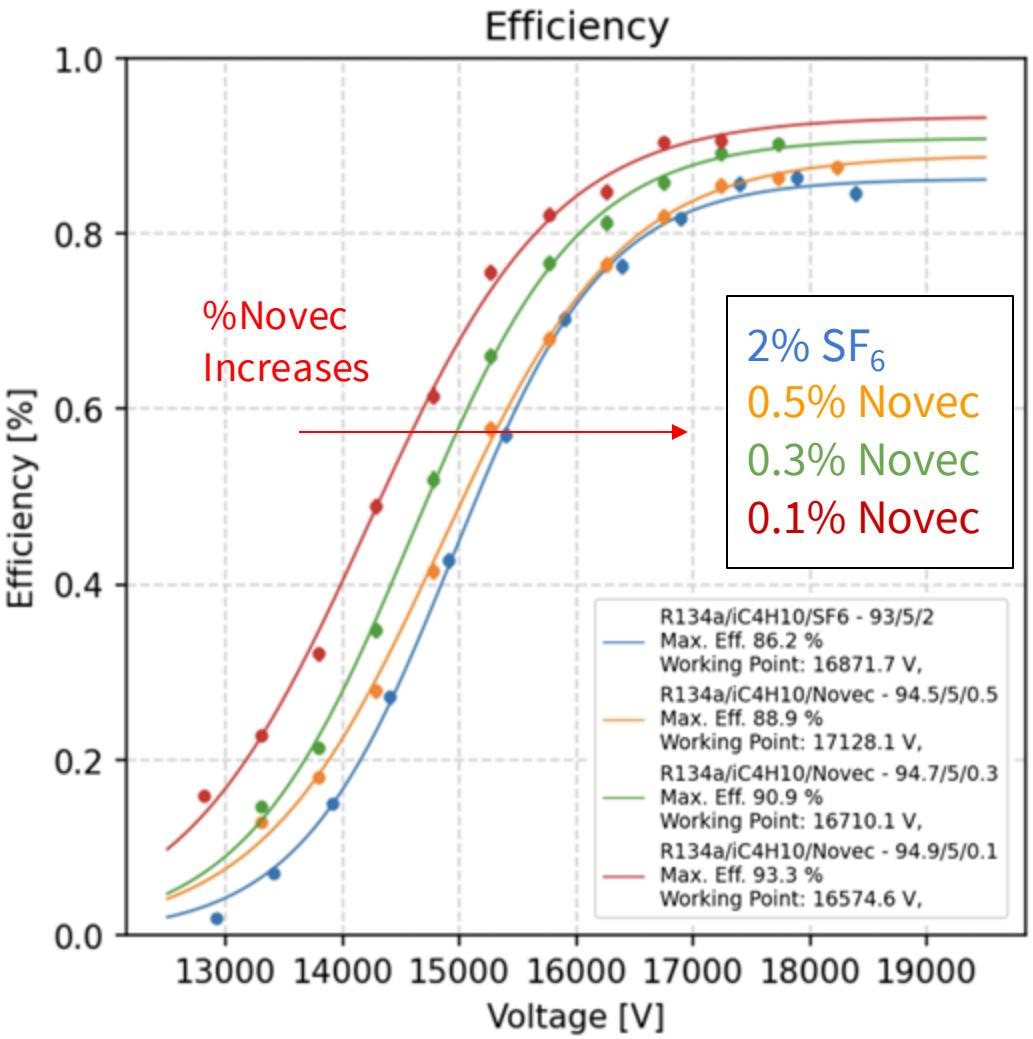


First attempt was to compare the concentration 1:1:

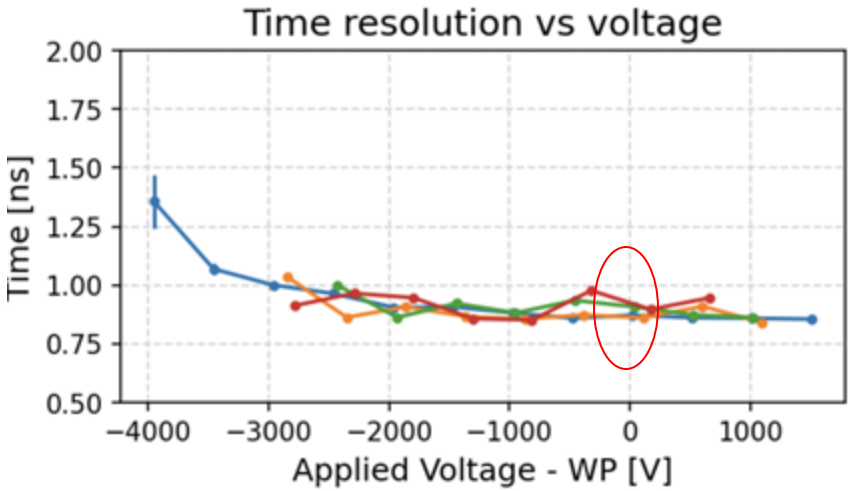
- Novec 4710 more effective in trapping e^- wrt SF_6
  -> It confirm the behaviour seen in HPL RPC.

→ Start to investigate %Novec lower than 1%

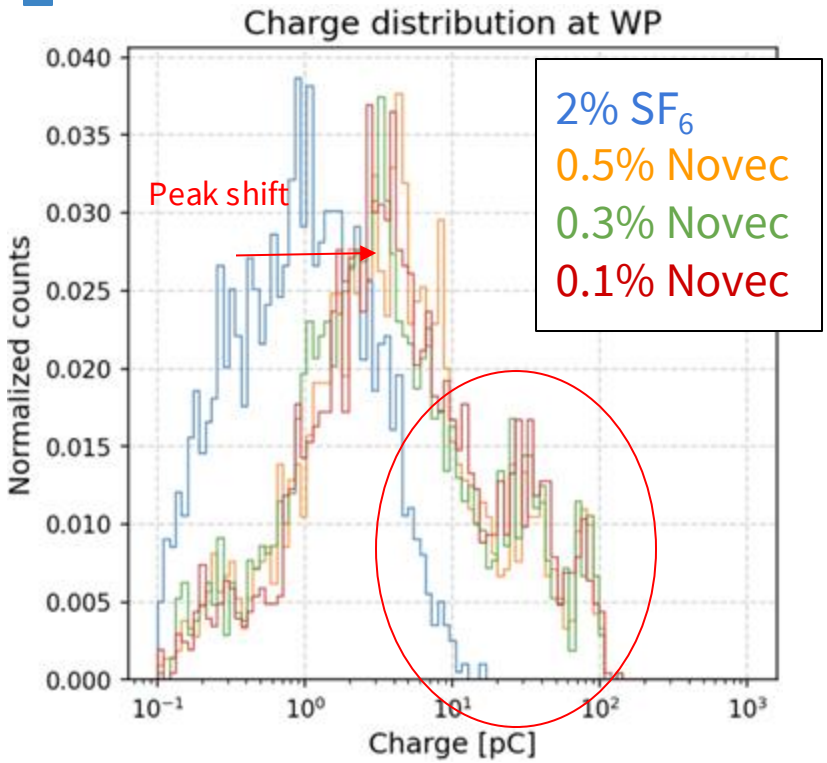
Variation of Novec 4710 concentration

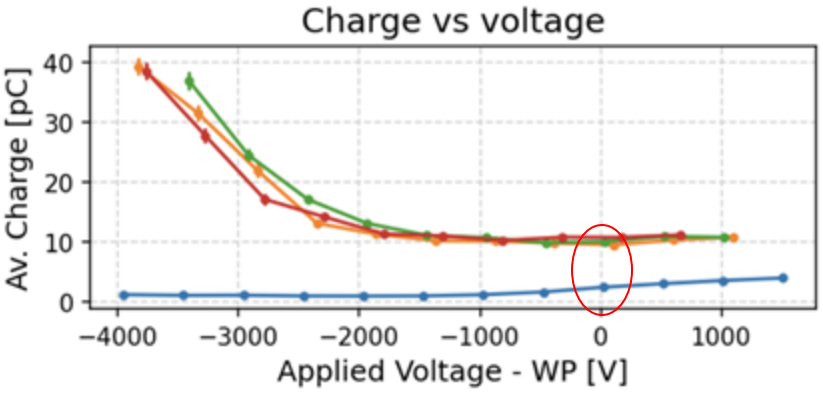


- 0.3% Novec gas mixture shows a similar WP wrt 2% SF_6;
- Novec gas mixture shows slightly higher maximum efficiency;
- WP increase of ~300 V for 0.2% increase of Novec 4710;
- signal time arrival wrt trigger signal similar between the gas mixtures.

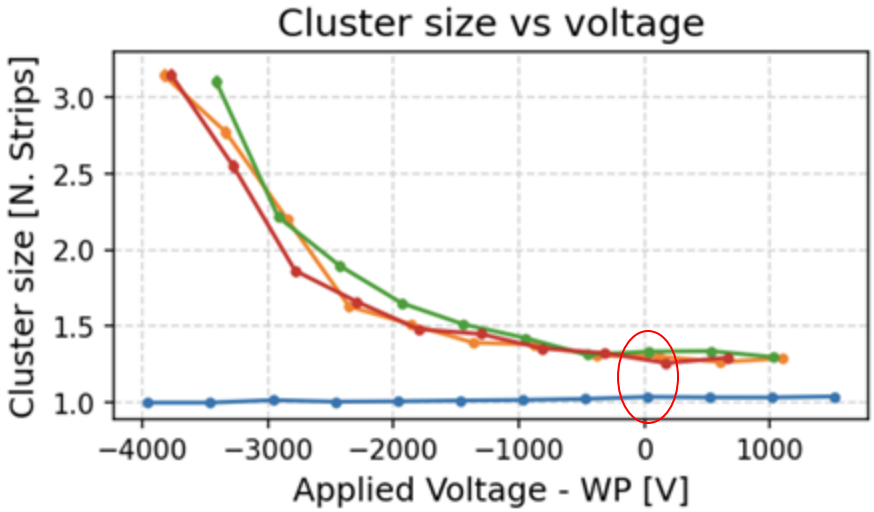


Variation of Novec 4710 concentration





- Novec gas mixtures show higher avalanche charge (+ 7pC) and a second peaks in the charge distribution;
- The higher charge inside the detector could justify the higher cluster size (+0.3 N. strips).



Conclusion

- The detector's construction, together with the flow distribution simulations, highlight the criticality and possible future design improvement;

- Novec 4710 seems to be a promising alternative to the SF_6:
  - 0.3% Novec gas mixture presents similar WP and efficiency wrt 2% SF_6 gas mixture -> **28% tCO_2eq less**;
  - 0.1% Novec gas mixture present lower WP (~300 V) and similar efficiency wrt 2% SF_6 gas mixture -> **30% tCO_2 eq less**;

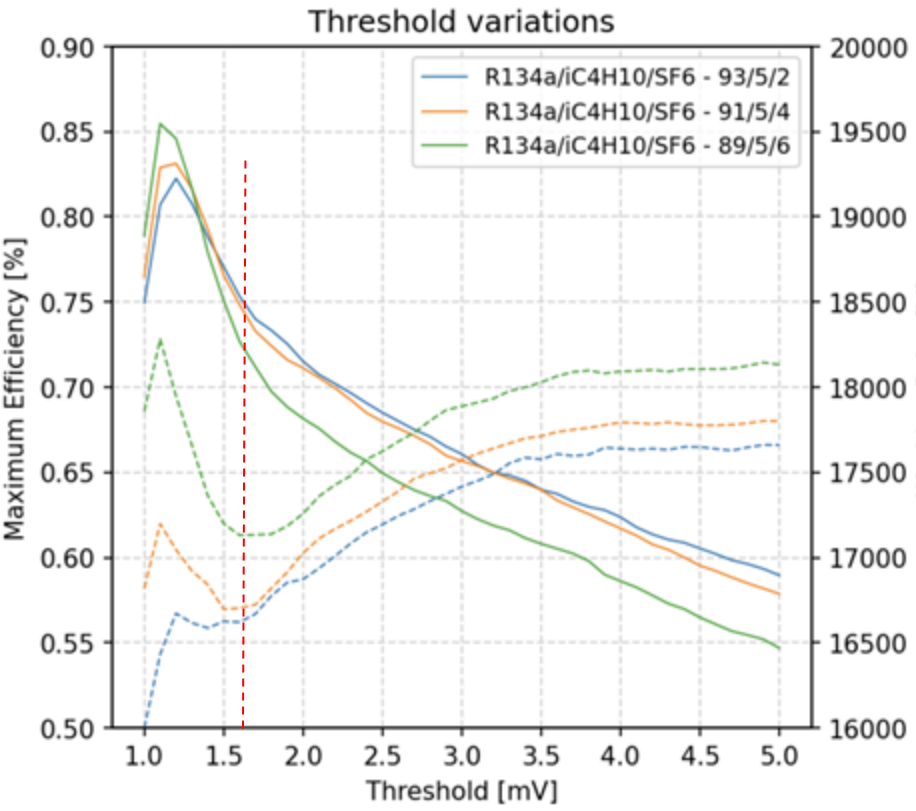
- Novec gas mixture presents higher after pulses and charge (~ 7pC more);

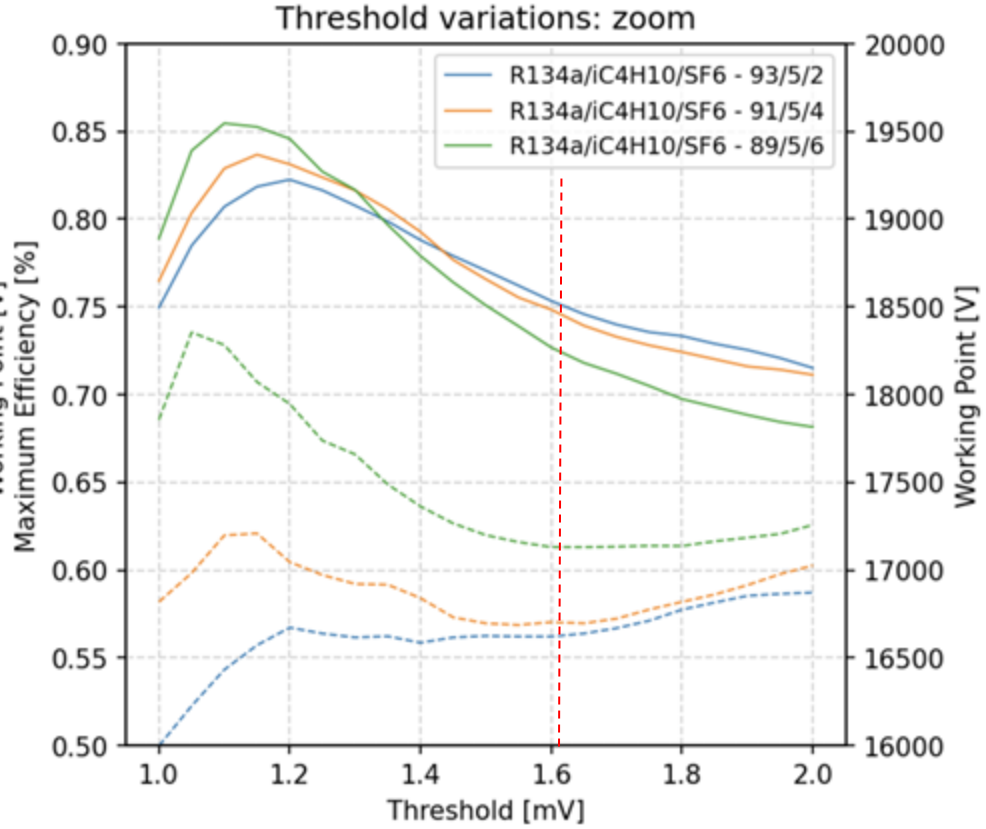
- The time resolution will be investigated further, using both the CAEN digitizer V1742 and the Petiroc 2A board.

Backup

Summary: selected thr

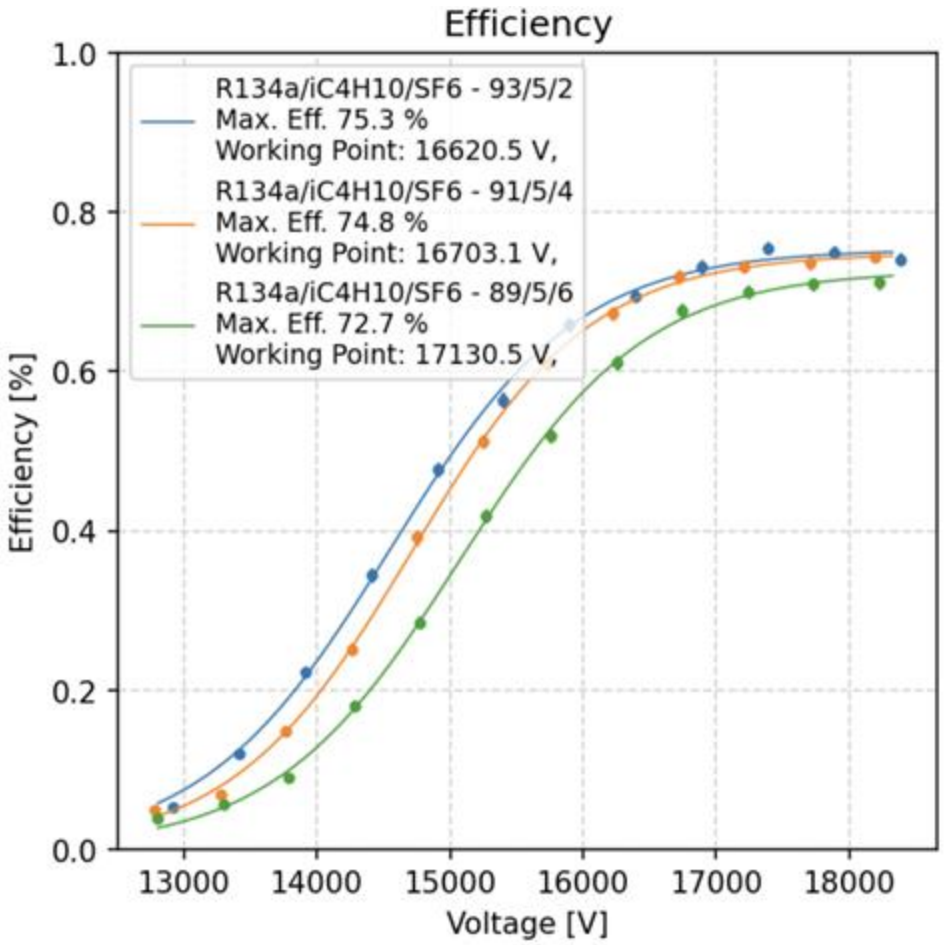
- Efficiency
-- WP



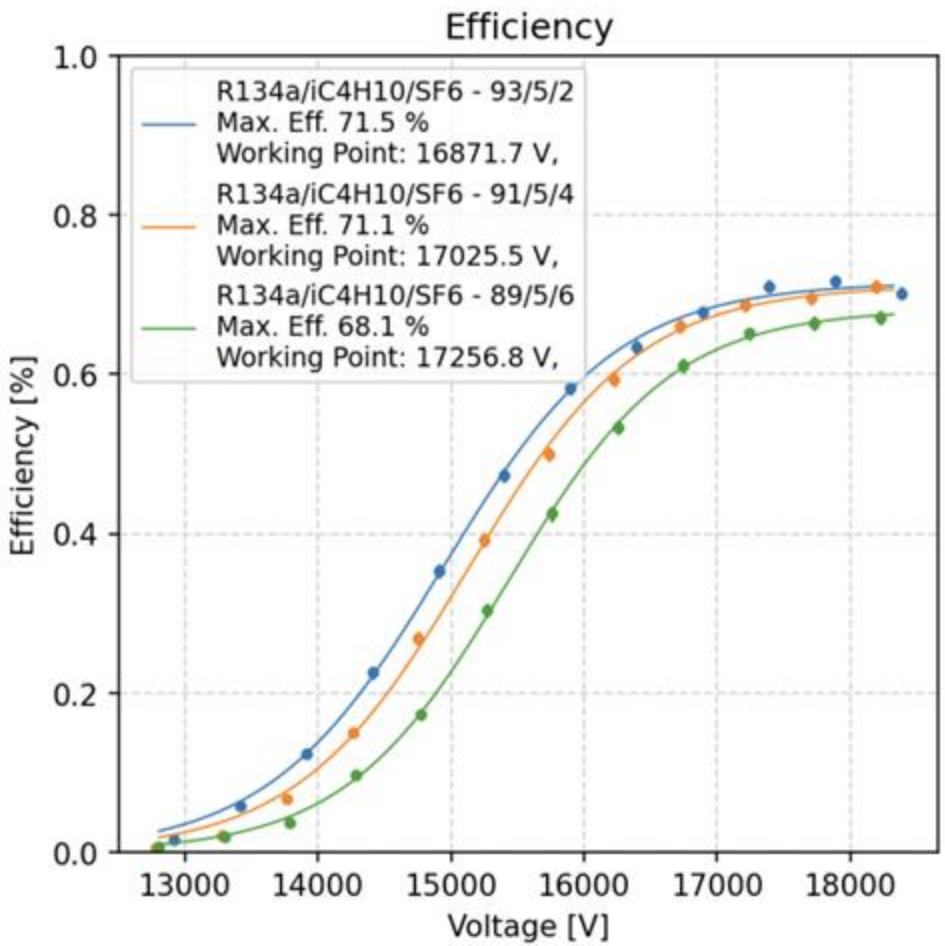


-> Minumum of WP as THR values?

Summary: selected thr



1.6 mV



2 mV