

# Characterization of Glass Multigap RPC Detectors with Alternative Gas to SF<sub>6</sub>

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EP-DT  
Detector Technologies

1. Université Claude Bernard Lyon I  
2. CERN

# 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<sub>6</sub> alternative;
- Conclusion.

# Greenhouse gas emissions

## EU fluorinated gases regulation (2014):

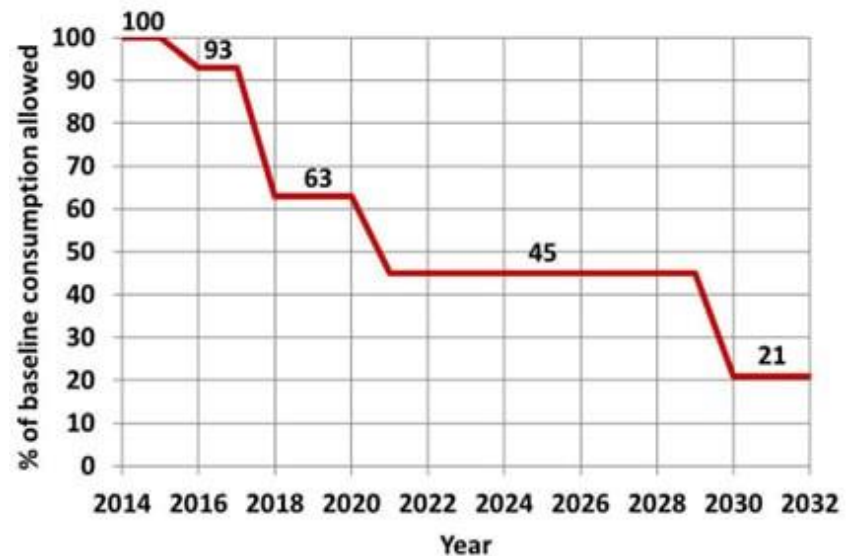
- Reducing products availability of fluorinated GHGs;
- This regulation already affected fluorinated gases prices.

## CERN Environment Report:

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

### CERN gas team developed different strategies to reduce GHG emissions:

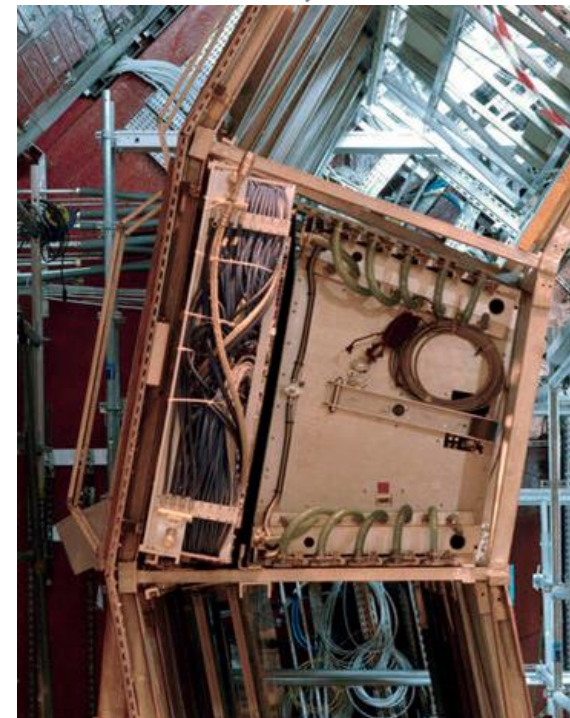
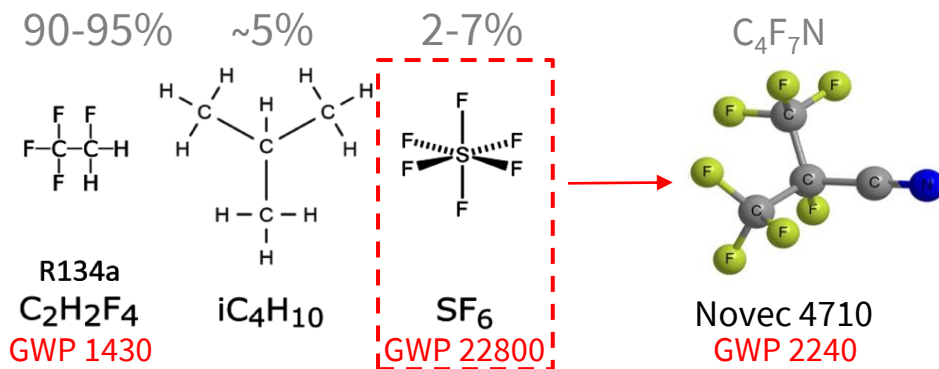
- Development of gas recirculation systems;
- Optimization of current gas systems technologies and recuperation plant;
- Research on alternative eco-friendly gases.



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

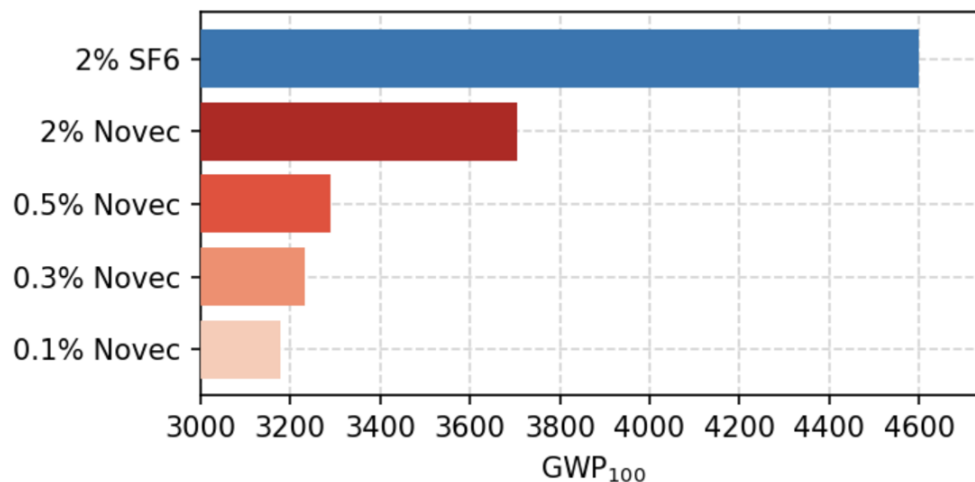
# Multigap Resistive Plate Chambers: Introduction

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



ALICE TOF detectors

Gas Mixtures Considered

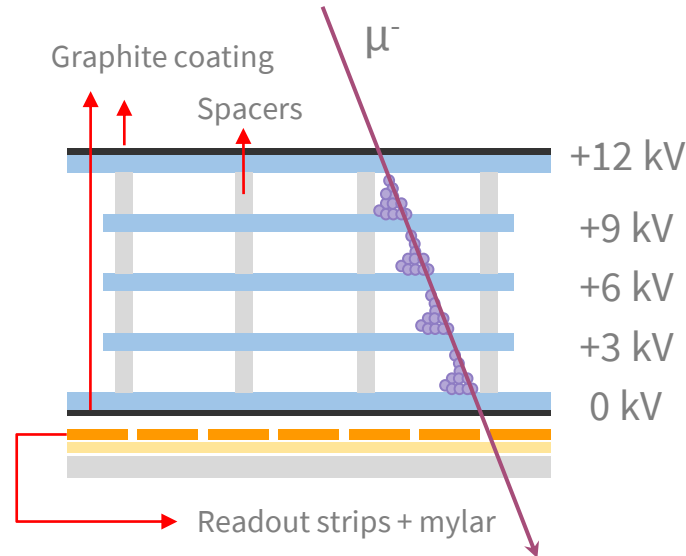


Possibility to reduce tCO<sub>2</sub>eq emission by 20%-30%

# 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.

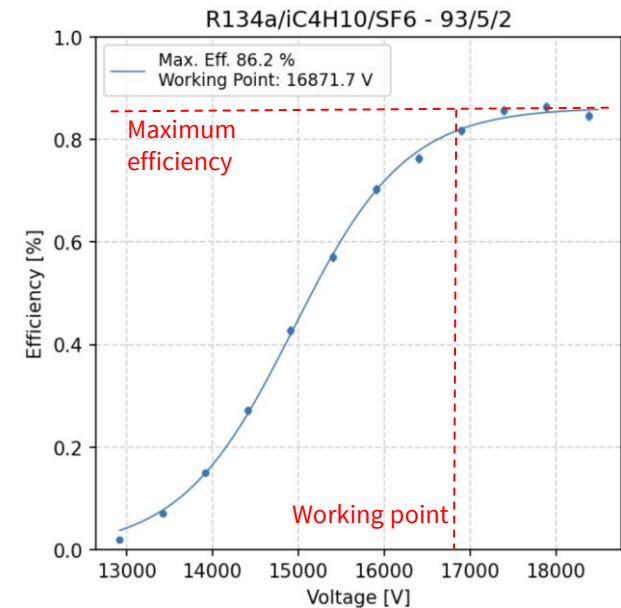
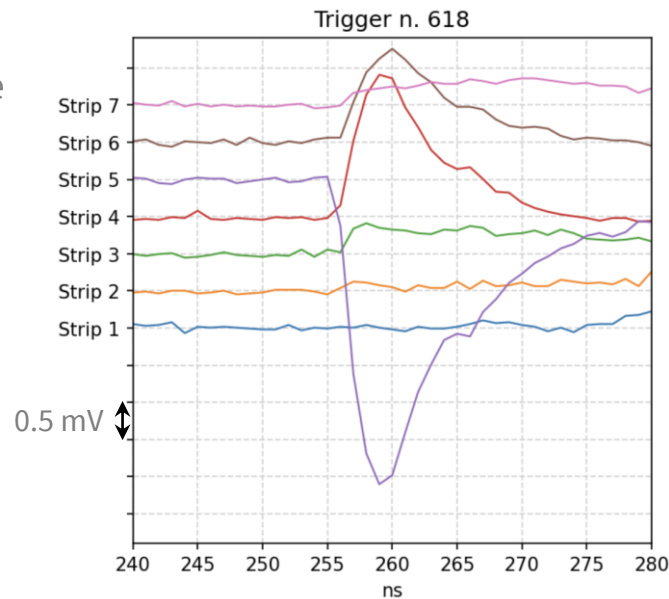


## Foremost parameters:

- 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;

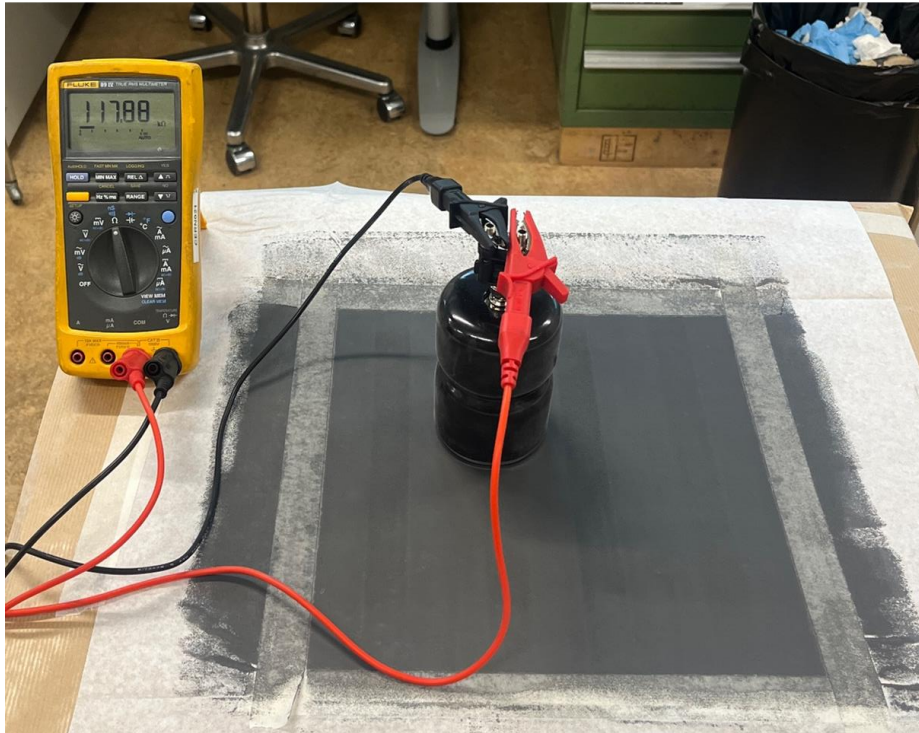
Aug.-Sept. 2024

1. Characterization with alternative gas mixture:
  - Novec 4710 as SF<sub>6</sub> replacement;
  - Alternative to the R134a;

Foreseen

1. Time resolution characterization with the alternative gas mixture.

# Detector construction: Graphite Varnish



## Graphite layer Varnishing:

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

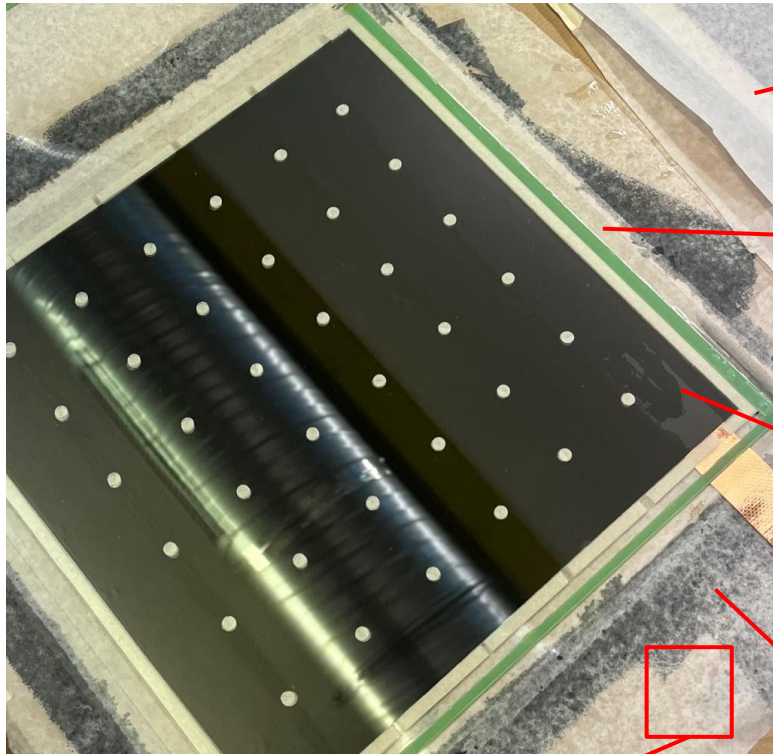
## Desired detector features:

- 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 ~ M $\Omega$  cm.

## Example of measured resistivity

1.1 M $\Omega$ cm	1.6 M $\Omega$ cm	1.8 M $\Omega$ cm
1.2 M $\Omega$ cm	1.2 M $\Omega$ cm	1.4 M $\Omega$ cm
1.2 M $\Omega$ cm	1.2 M $\Omega$ cm	1.4 M $\Omega$ cm

# Detector construction: Spacers



## HV connection:

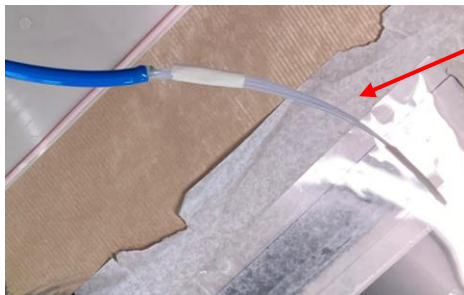
- Copper tape with conductive glue (CW2400, CircuitWorks).

## 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.



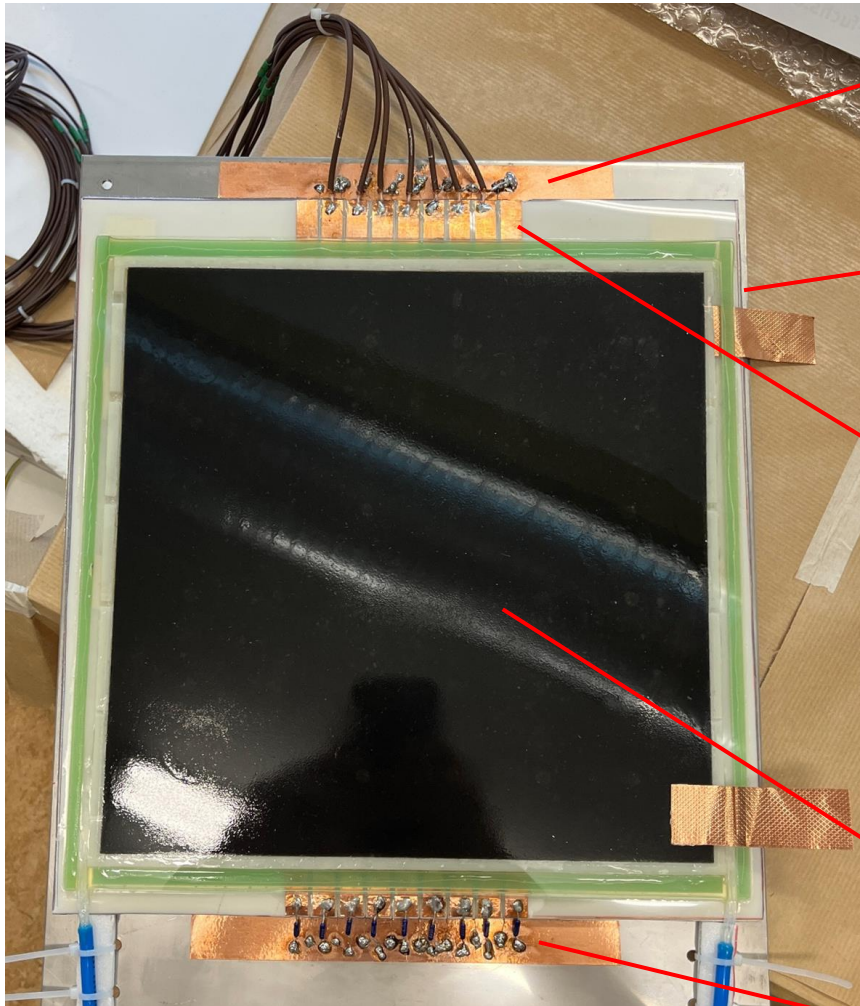
6 mm plastic pipe  
glued to 3 capillaries  
pipes of 1 mm  
diameter.

## 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;

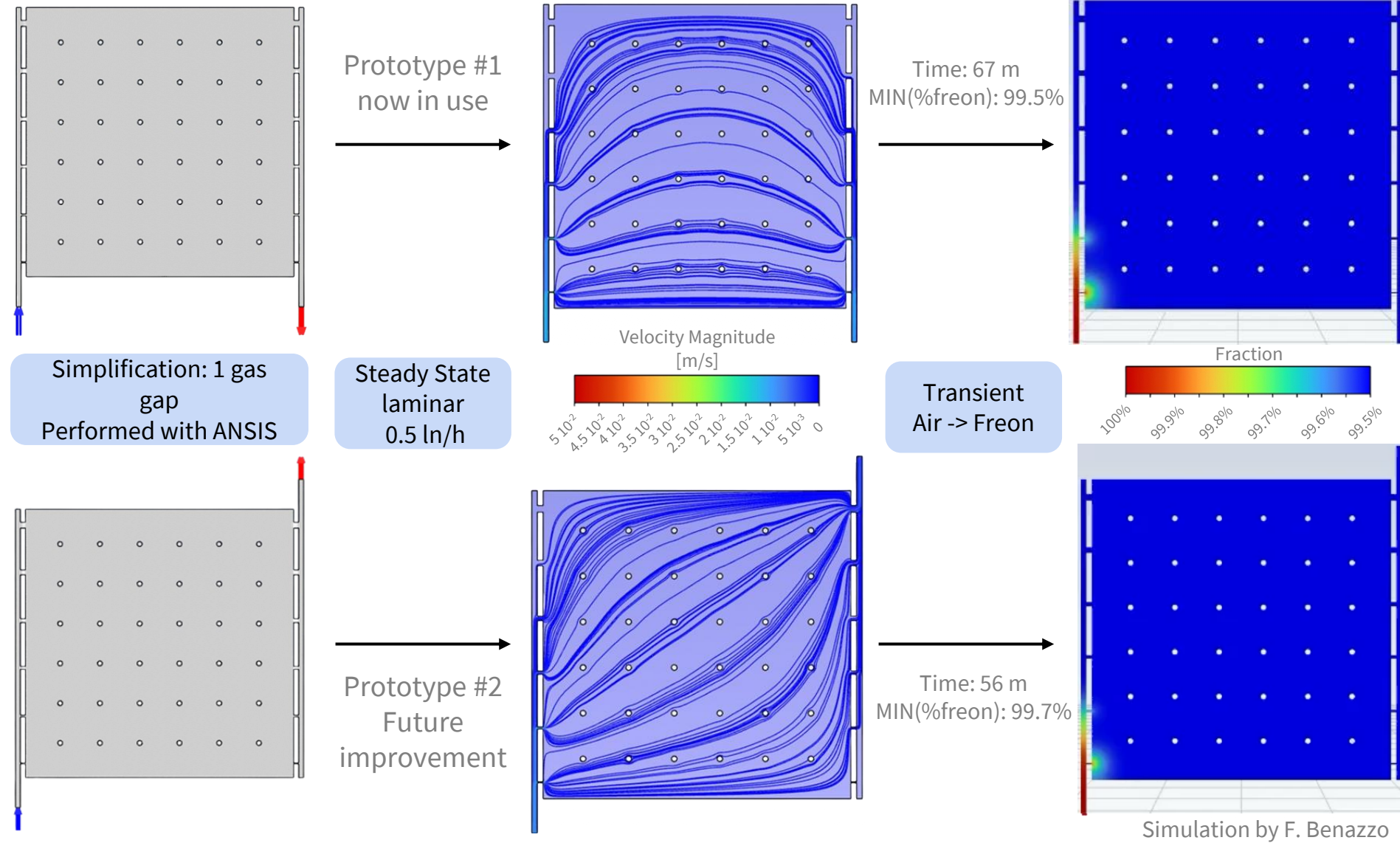
1 mm thick mylar;

5 mm thick polystyrene.

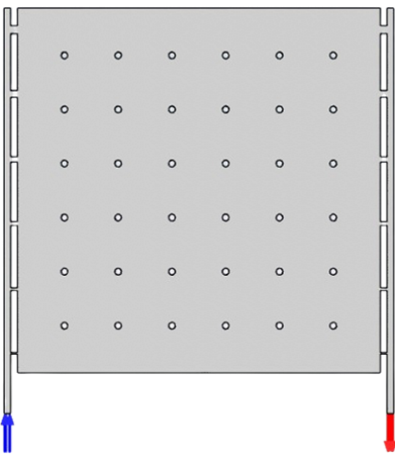
Urethane protective layer.

50  $\Omega$  resistances.

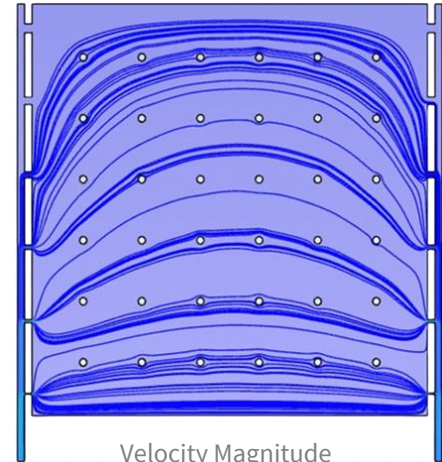
# MRPC flow simulation



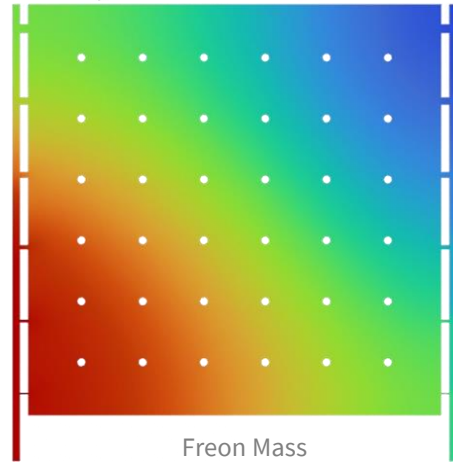
# MRPC flow simulation



Prototype #1  
now in use



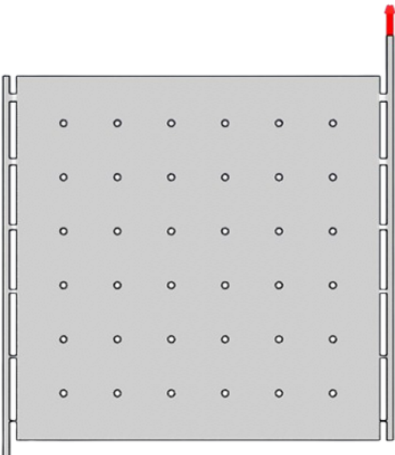
Time: 67 m  
MIN(%freon): 99.5%



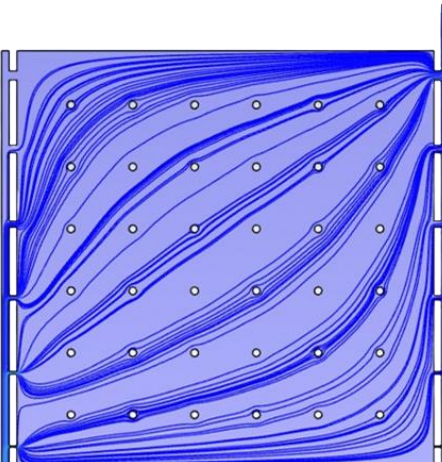
Simplification: 1 gas gap  
Performed with ANSYS

Steady State  
laminar  
0.5 ln/h

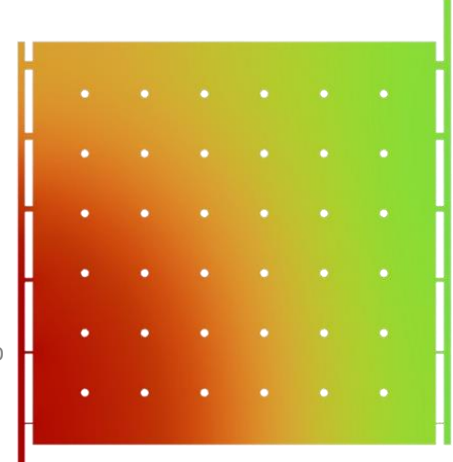
Transient  
Air -> Freon



Prototype #2  
Future  
improvement

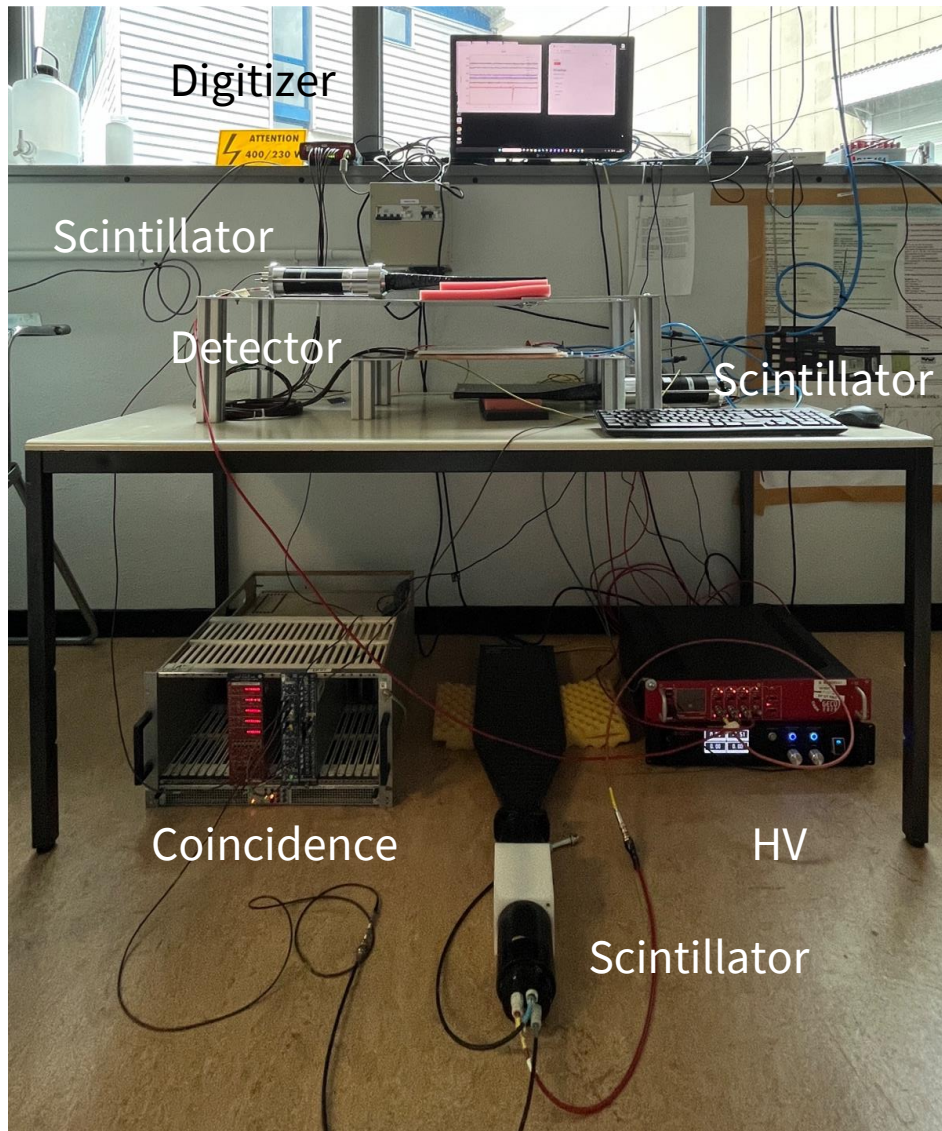


Time: 56 m  
MIN(%freon): 99.7%



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;

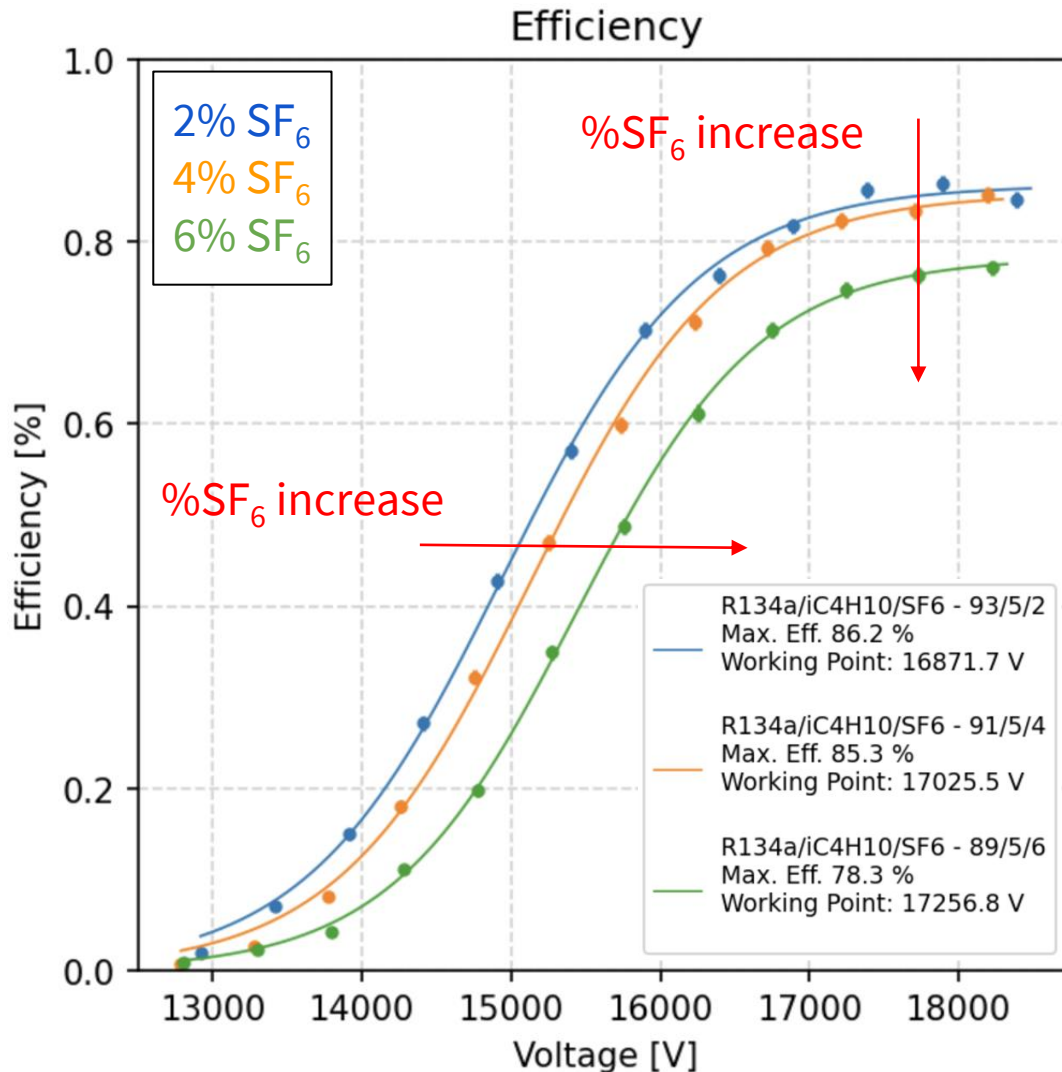
Coincidence obtained with three  
scintillators + 1 scintillator veto;

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<sub>6</sub> concentration



% SF<sub>6</sub> increase -> WP increase:

- ~250 V for 2% increase.

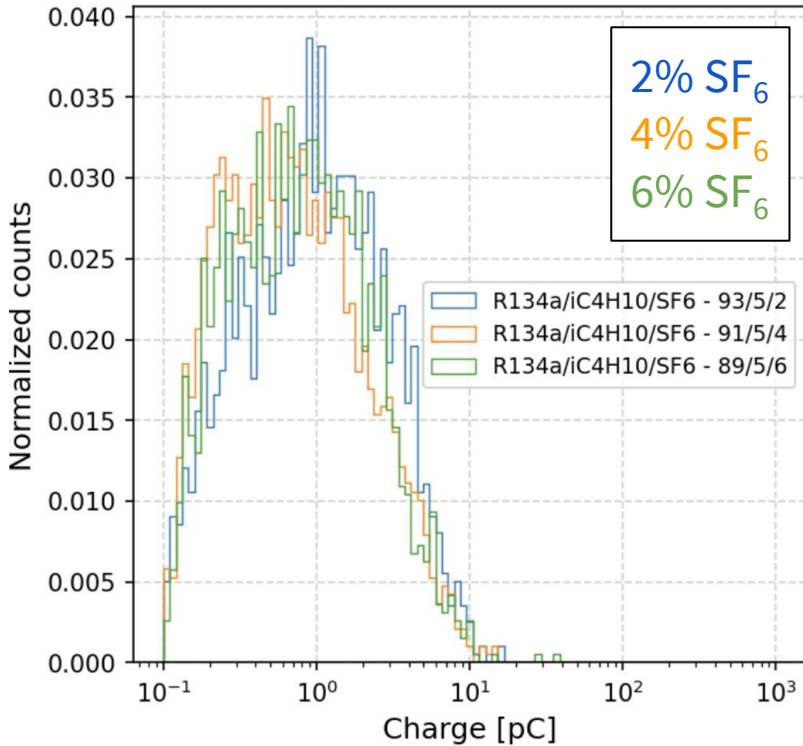
% SF<sub>6</sub> increase -> Max. Eff. decrease:

- 1% between 2% and 4%;
- 8% between 4% and 6%.

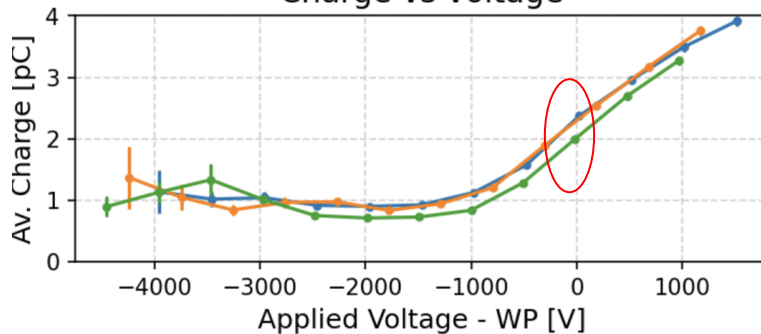
-> possibly loss of signals for a high %SF<sub>6</sub> due to the high electronegativity.

# Variation of SF<sub>6</sub> concentration

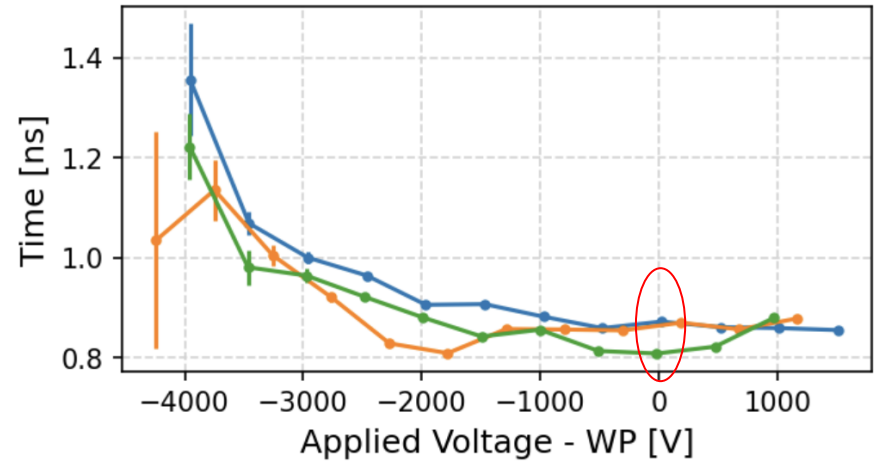
Charge distribution at WP



Charge vs voltage



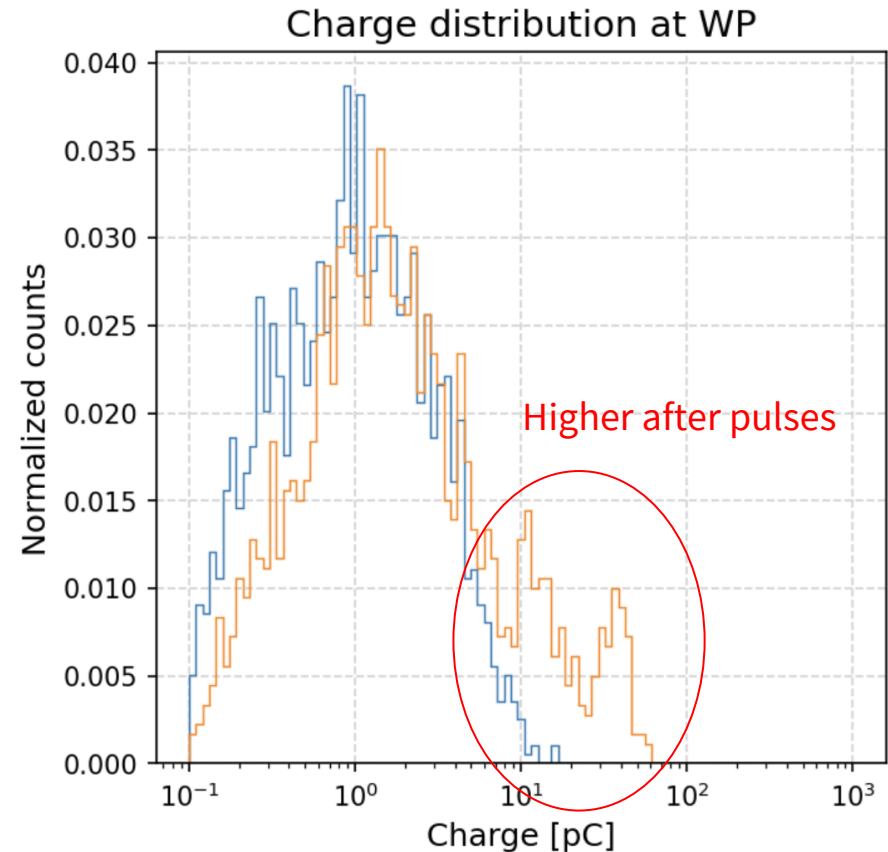
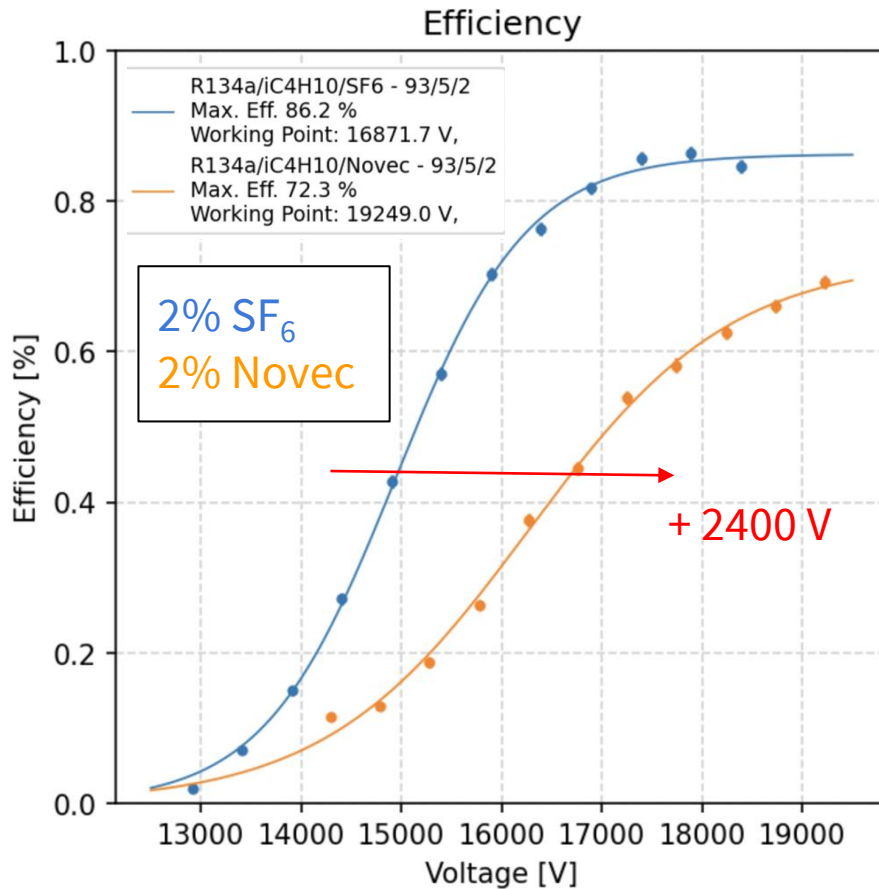
Time resolution vs voltage



- **Charge distribution** @ WP lower with the higher %SF<sub>6</sub> (~0.5 pC);
- **Time resolution** @ WP similar between the different gas mixtures.

2% SF<sub>6</sub> gas mixture used as references in the next slides

# Novec 4710 as SF<sub>6</sub> alternative

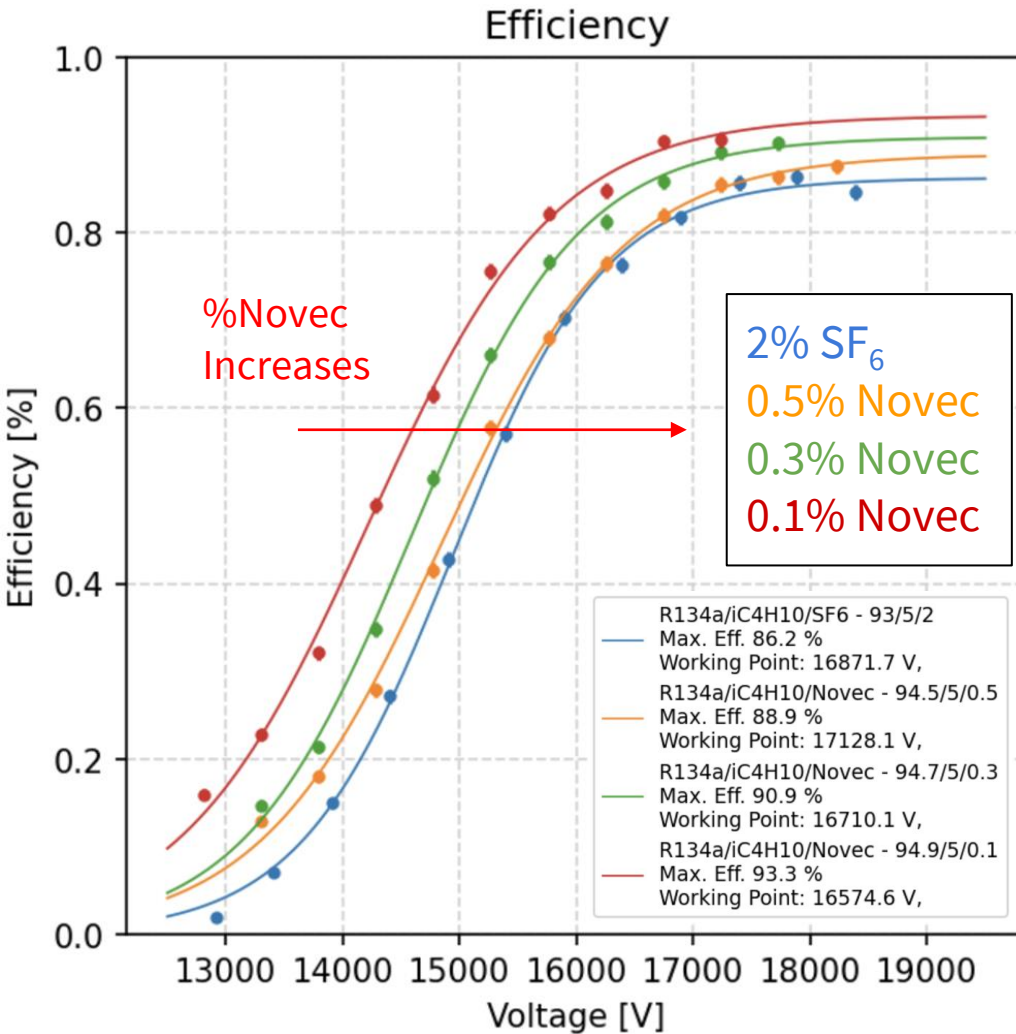


First attempt was to compare the concentration 1:1:

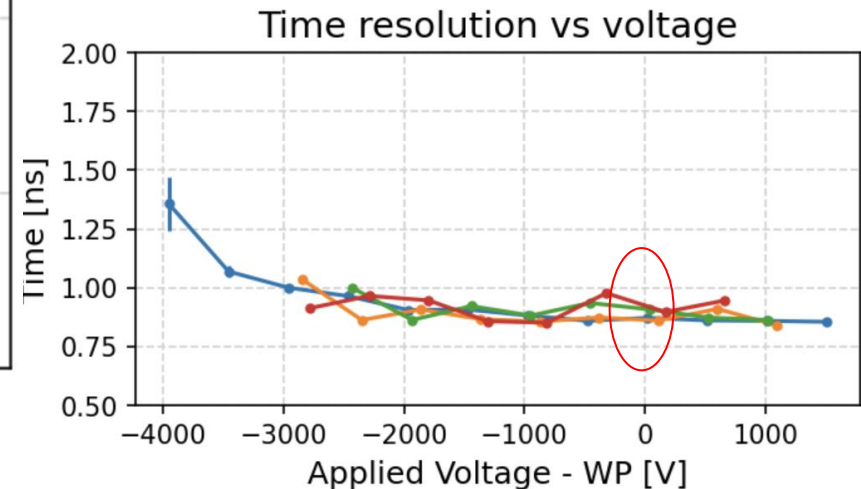
- Novec 4710 more effective in trapping e<sup>-</sup> wrt SF<sub>6</sub>
- > It confirm the behaviour seen in HPL RPC.

Start to investigate %Novec lower than 1%

# Variation of Novec 4710 concentration

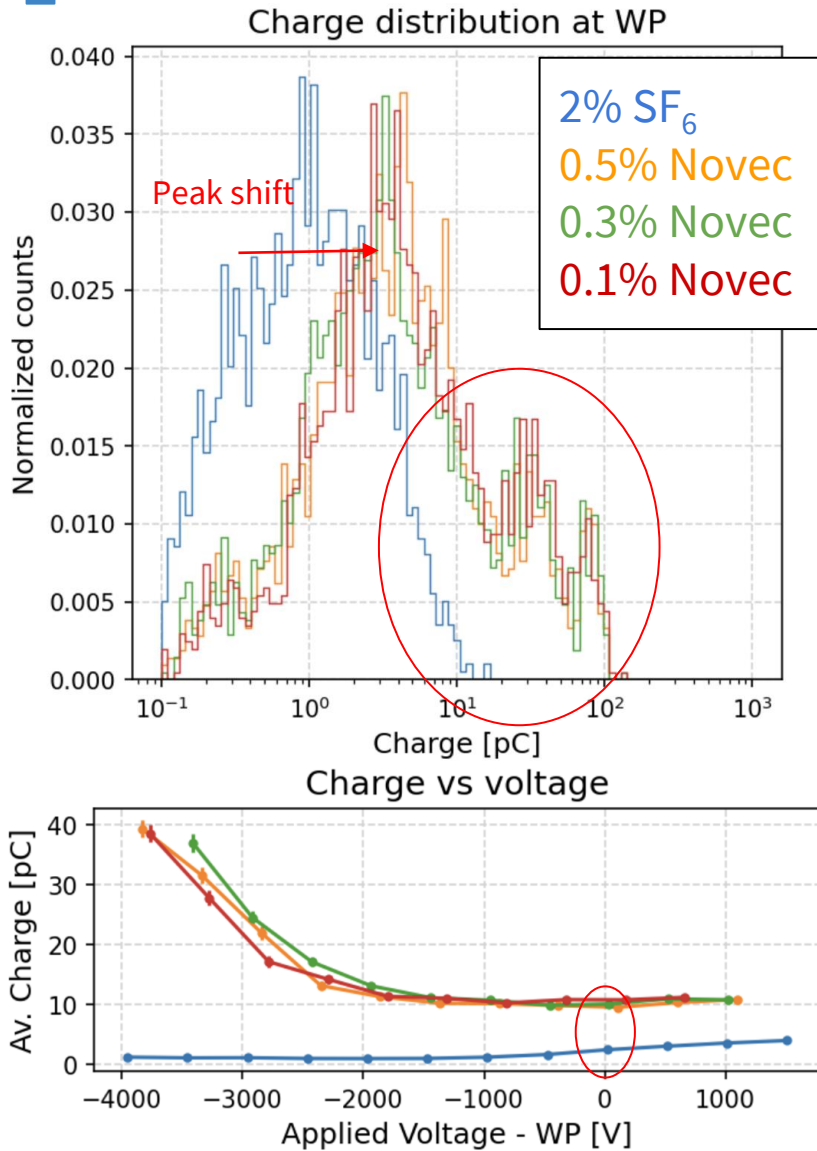


- 0.3% Novec gas mixture shows a similar WP wrt 2% SF<sub>6</sub>;
- Novec gas mixture shows slightly higher maximum efficiency;
- WP increase of ~300 V for 0.2% increase of Novec 4710;
- signal time arrival wrt trigger signal similar between the gas mixtures.

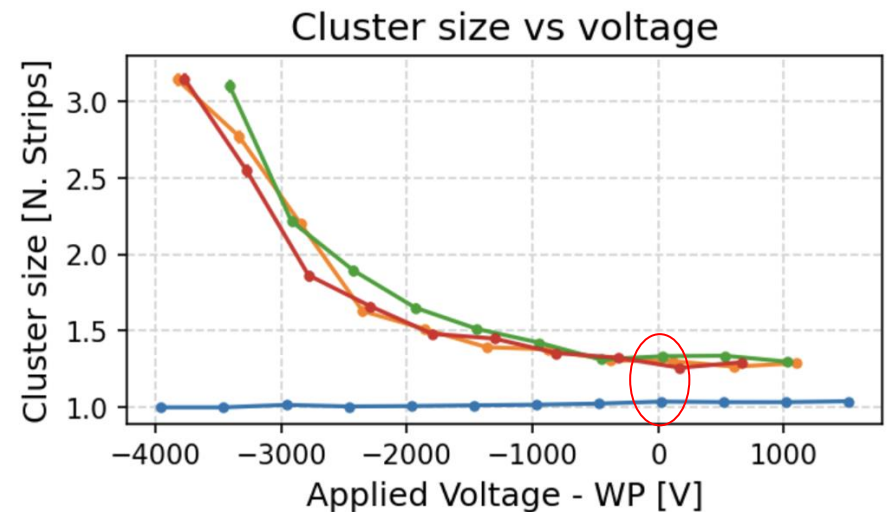




# Variation of Novec 4710 concentration

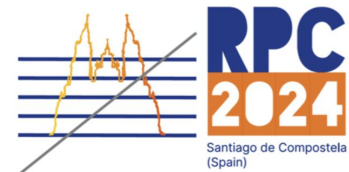


- Novec gas mixtures show higher avalanche charge (+ 7pC) and a second peaks in the charge distribution;
- The higher charge inside the detector could justify the higher cluster size (+0.3 N. strips).



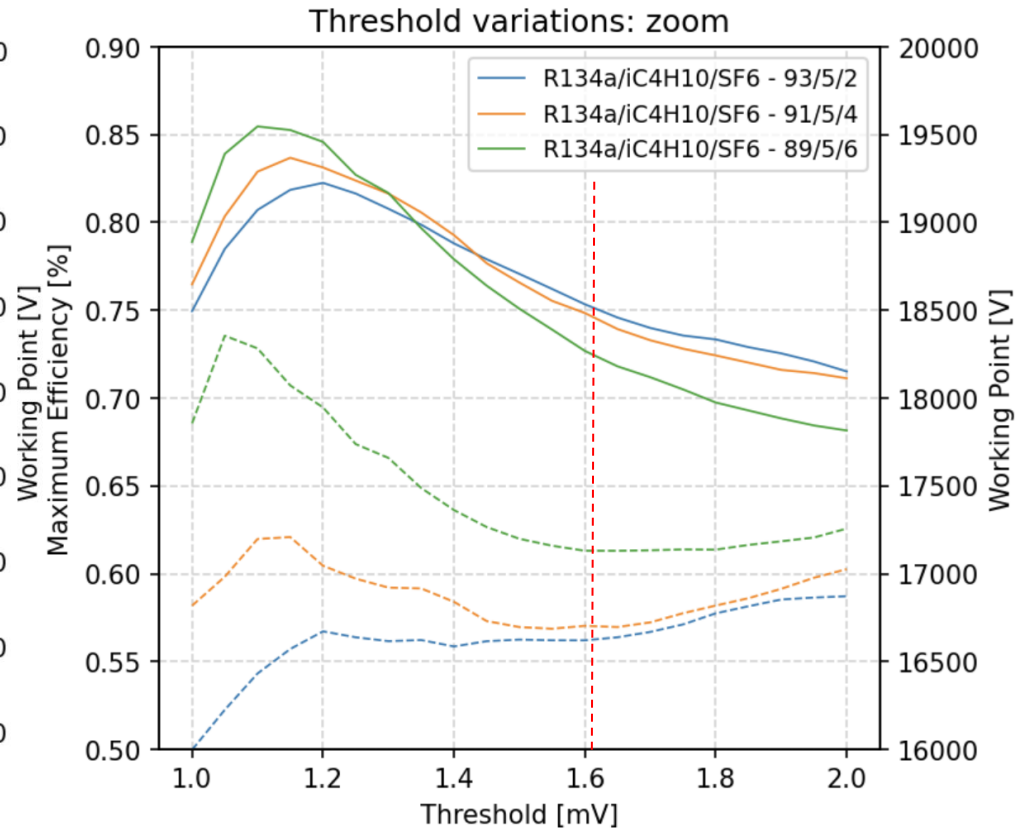
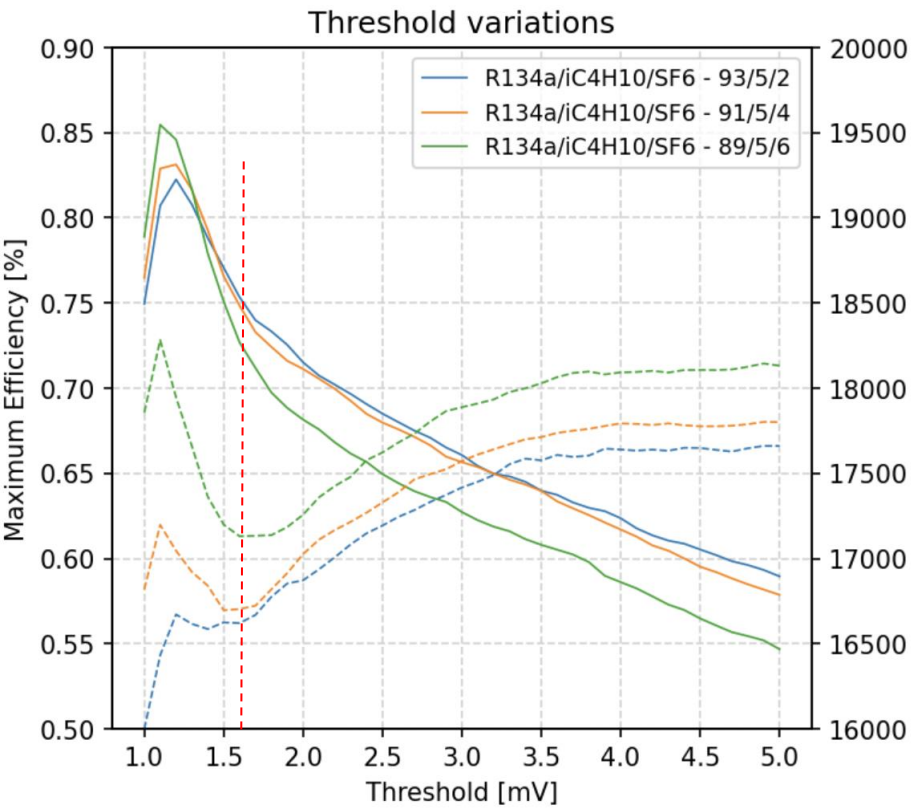
- The detector's construction, together with the flow distribution simulations, highlight the criticality and possible future design improvement;
- Novec 4710 seems to be a promising alternative to the SF<sub>6</sub>:
  - 0.3% Novec gas mixture presents similar WP and efficiency wrt 2% SF<sub>6</sub> gas mixture -> **28% tCO<sub>2</sub>eq less**;
  - 0.1% Novec gas mixture present lower WP (~300 V) and similar efficiency wrt 2% SF<sub>6</sub> gas mixture -> **30% tCO<sub>2</sub> 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

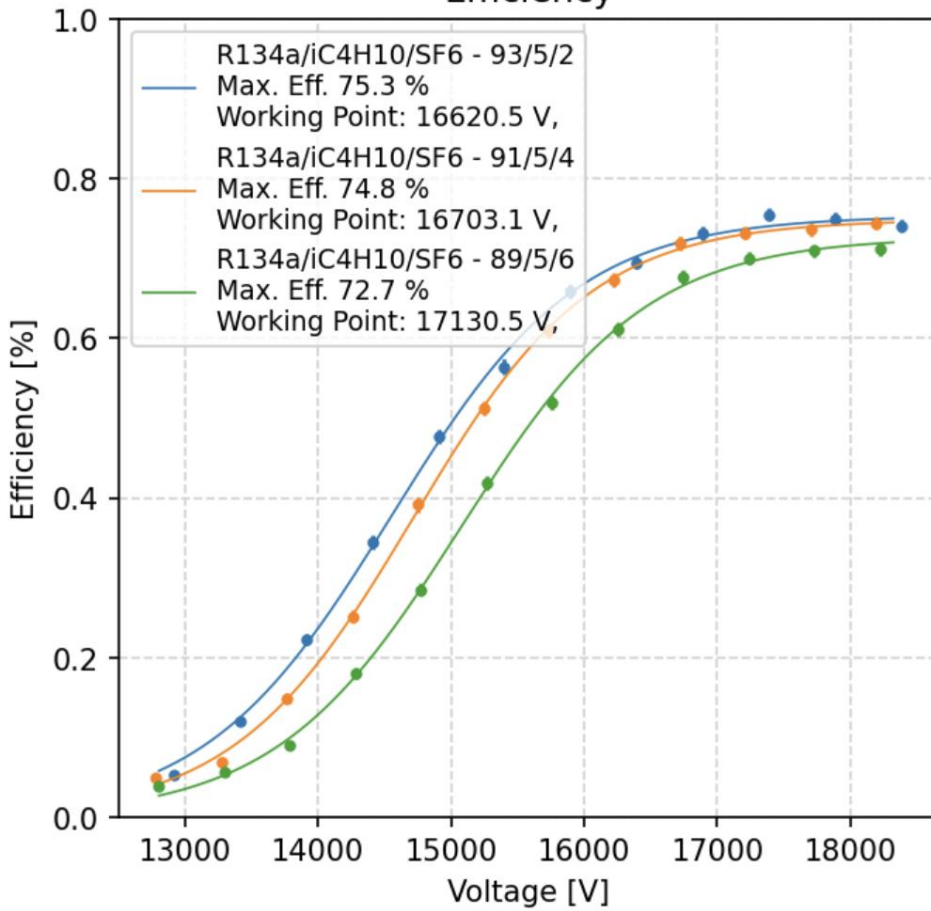
- Efficiency  
-- WP



-> Minimum of WP as THR values?

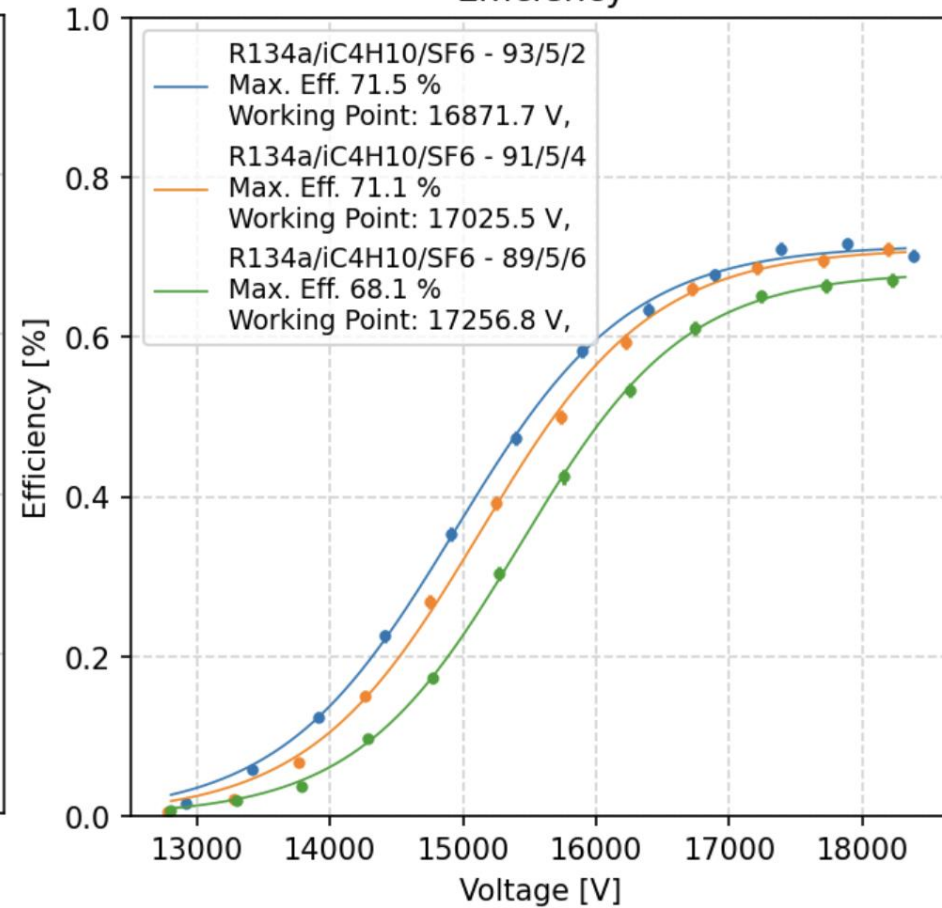
# Summary: selected thr

Efficiency



1.6 mV

Efficiency



2 mV