# Preliminary aging studies of improved RPC gaps operated with HFO based mixtures

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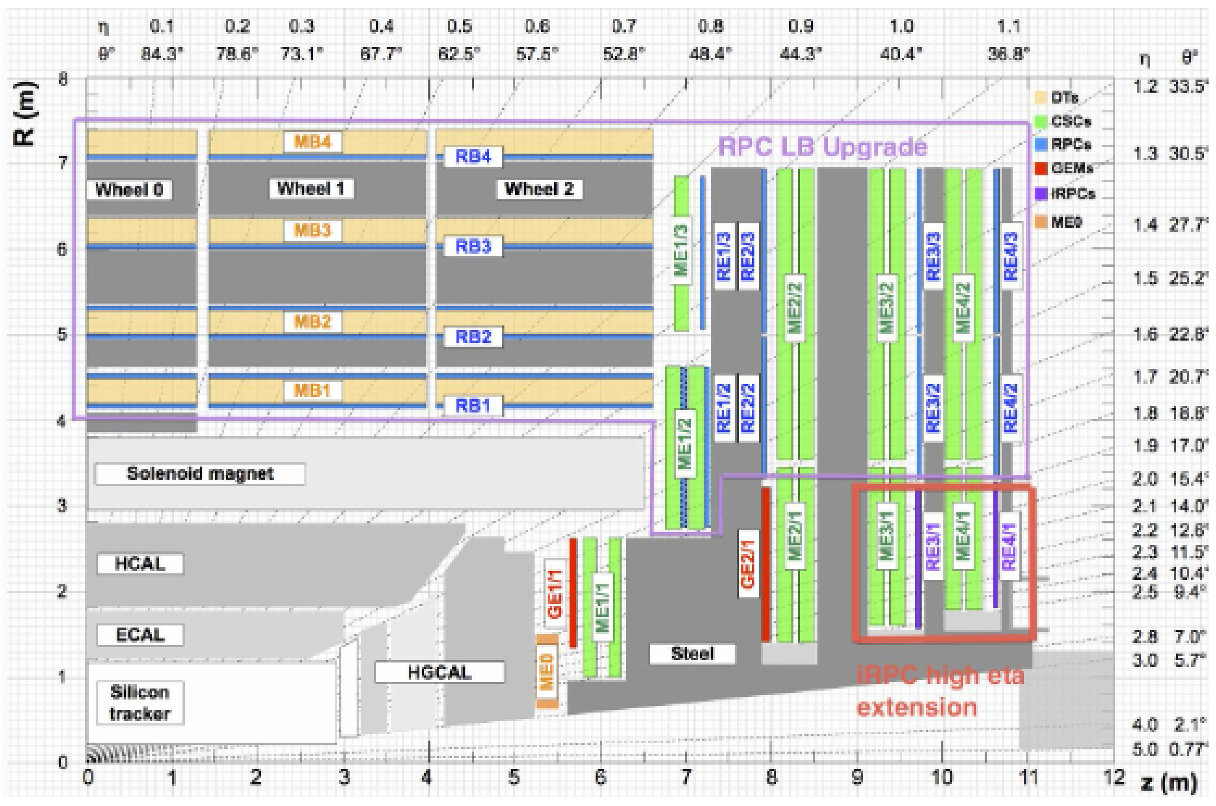
## 1 Introduction

The Compact Muon Solenoid (CMS) is one of the four primary experiments at CERN's Large Hadron Collider (LHC). The muon system utilizes Resistive Plate Chambers (RPCs) in the barrel and endcap regions, functioning in avalanche mode to deliver accurate position and timing data. In the framework of the CMS Upgrade project for the High Luminosity phase, new improved RPCs (iRPC) have been developed to enhance the legacy performances in the most RPC forward region of the experiment, extending the coverage from $|\eta| = 1.9$ to 2.4.




This is a schematic longitudinal cross-section of one quarter of the CMS detector, highlighting the various subsystems that make up the Muon Detector. The current RPC chambers are shown in blue, while the positions of the new upgraded RPC stations (RE3/1 and RE4/1) are marked in violet.

## 2 Alternative Gas Mixtures for RPC detectors

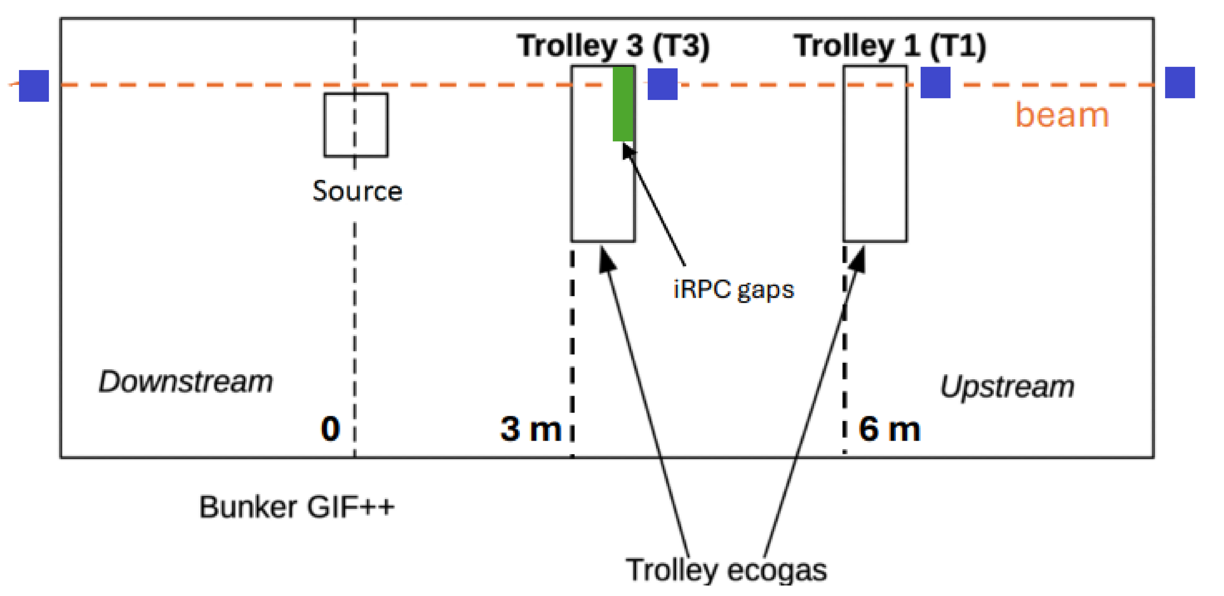
RPCs at the CMS experiment are operated with a gas mixture containing around 95% Tetrafluoroethane (TFE), commonly known as R-134a, which has a global warming potential (GWP) of 1430. To comply with European regulations [4] and explore environmentally friendly gaseous mixture alternatives for long-term RPC operation, CMS RPC within the RPC EcoGas@GIF++ collaboration has launched a longevity study operating the chambers with HFO/$CO_2$-based eco-friendly candidate mixtures. This poster reports of a preliminary aging study of the gaps resulting after around one year of irradiation at GIF++ at CERN.

| Mixture | TFE | HFO | $CO_2$ | i-$C_4H_{10}$ | $SF_6$ | $GWP_{mix}$ |
|---|---|---|---|---|---|---|
| STD | 95.2 | 0 | 0 | 4.5 | 0.3 | 1485 |
| ECO2 | 0 | 35 | 60 | 4 | 1 | 476 |
| ECO3 | 0 | 25 | 69 | 5 | 1 | 527 |
| GWP | 1430 | 7 | 1 | 3 | 22800 | - |

$CO_2$ increases streamer probability, so SF6 is used to keep it low, requiring its current levels. ECO2 was chosen for testing the single and double gap RPC prototype in this campaign due to its efficient performance in previous studies [2].

## 3 Experimental Setup

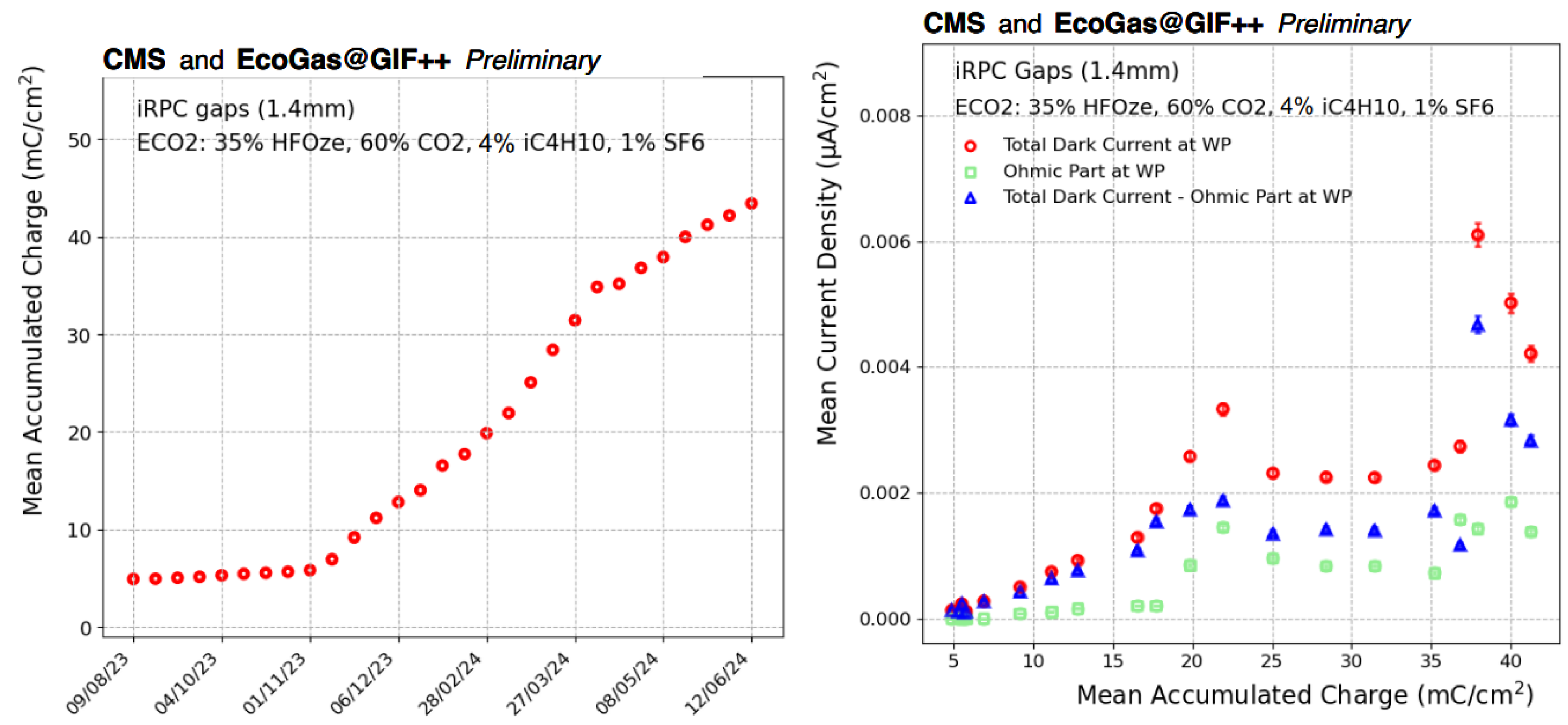
The prototype was equipped with iRPC gaps which were placed on either side of the readout copper strips. These iRPC gaps were constructed using High-Pressure Laminated (HPL) electrode material, characterized by a thickness of 1.43 mm, a bulk resistivity ranging from 1.17 to 1.39 × $10^{10}$ $\Omega$ cm, and a gas gap of 1.4 mm [3]. The signal readout was carried out using KODEL front-end electronics. The prototype was placed in the upstream irradiation zone, roughly 4 metres from the source. The data acquisition system utilized a muon trigger, achieved through the coincidence of four scintillators shown in blue.




The performance was monitored during the aging campaign using weekly scans with the source off, to calculate charge integration and accumulation.

## 4 Aging Studies

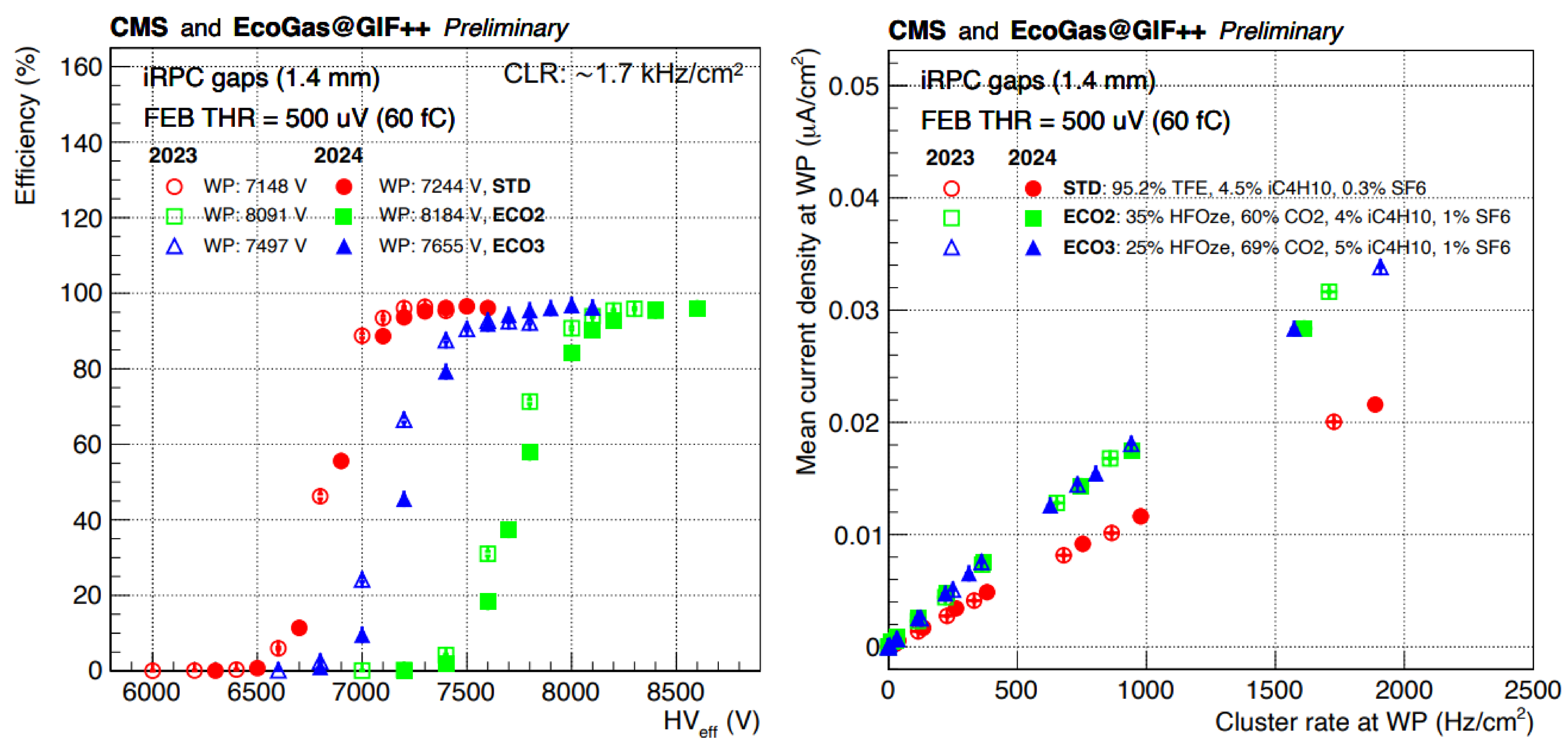
After November 2023, the mean accumulated charge between both gaps in the RPC prototype began to increase (left). Dark current, ohmic, and physical (dark current - ohmic) contributions at the working point (WP) 8.1 kV are shown as mean current density against mean accumulated charge. A non-linear relationship between accumulated charge and dark current emerges beyond 15 mC/cm², with instability above 35 mC/cm². Further study is required to understand these behaviors (right).




Mean Accumulated charge against time (left). Mean accumulated charge against mean current density (right).

### 4.1 Performance Verification

A comparison was made between the data collection campaign conducted in 2023, prior to the start of the aging campaign, and in 2024, after accumulating approximately 45 mC/cm² of charge. A slight increase in WP values was observed. Despite these increases, no reductions in efficiency measured at the WP were detected (left). The currents from both measurement campaigns are consistent and show stable behaviours after irradiation (right).




Efficiency curve at 1.7 kHz/cm² for years 2023 and 2024 (left). Mean current density as a function of cluster rate for years 2023 and 2024 (right)

## 5 Conclusion

The aging campaign conducted in August 2023 highlights the effects of charge integration of the RPC prototype, showing only minor changes in overall performance with an accumulation of approximately 45 mC/cm² charge. A small increase in the WP was observed, but no efficiency losses were detected at the measured WP. The campaign will continue, focusing on further exploring the long-term aging effects using the ECO2 gas mixture.

## References

[1] M. A. Shah, et al. "The CMS RPC detector performance and stability during LHC RUN2". JINST 14 C11012 (2019).

[2] J. R. Barahona Quintanilla "Efficiency studies of RPC detectors with eco-friendly gas mixtures in high radiation rate environments". cds.cern.ch/record/2824927.

[3] Amrutha Samalan " Improved Resistive Plate Chambers for Phase 2 upgrade of CMS ". cds.cern.ch/record/2841609/files/CR2022223

[4] Eurpean Commision "EU-Rules". climate.ec.europa.eu/eu-action/fluorinated-greenhouse-gases/eu-rules$_en$