



Searching for an eco-friendly gas mixture for the ALICE Resistive Plate Chambers

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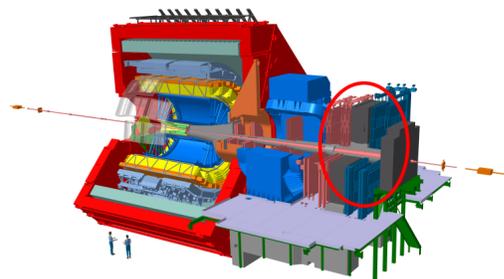
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Introduction

- Resistive Plate Chambers (RPC) are gaseous detectors with planar geometry employed for muon detection in LHC experiments
- In the ALICE detector:

- 72 single gap RPCs
- Gas gap: 2 mm
- Electrodes: 2mm
- Total volume: 0.3 m³



ALICE detector

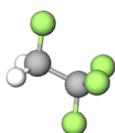
- Gas mixture: 89.7% C₂H₂F₄, 10% i-C₄H₁₀, 0.3% SF₆
- Provide Muon IDentification (MID) in forward rapidity region

Issues with fluorinated gases

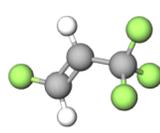
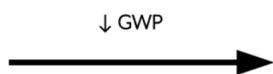
- C₂H₂F₄ and SF₆: fluorinated greenhouse gases (F-gases)
- Global Warming Potential (GWP) = energy trapped in atmosphere by a ton of gas if compared to a ton of CO₂ (GWP(CO₂) = 1)
- GWP of ALICE RPC gas mixture ~ 1350
- New EU regulations imposed phase-out in production (with related cost increase) and use of F-gases
→Effort to reduce the GWP of our mixture and possibly find a more eco-friendly one by the start of LHC Run 4

Search for a new gas mixture

- Replace C₂H₂F₄ (R134a) with C₃H₂F₄ (tetrafluoropropene or HFO-1234ze)



R134a

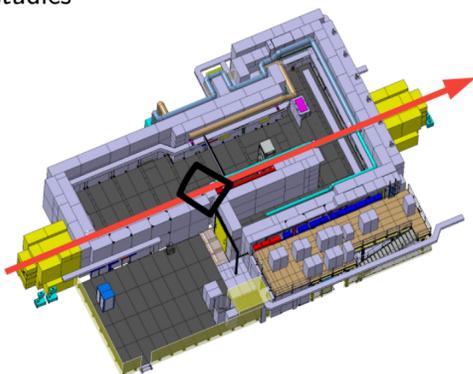


HFO-1234ze

- Similar chemical structure and low GWP (~ 6)
- Full replacement not possible, lower first Townsend coefficient
→Working voltage over 15 kV
- Diluted with CO₂ to lower working voltage

Characterisation of C₃H₂F₄-based gas mixtures

- Studies with cosmic muons found various HFO + CO₂ mixtures
- Better characterization carried out in beam tests
- GIF++ @ CERN: 12.5 TBq ¹³⁷Cs source for aging studies
- μ beam to study detector performance
- Beam + source to study rate capability
- ECOgas@GIF++ (ALICE, ATLAS, CMS, EPDT, LHCb/SHiP) collaboration for these studies

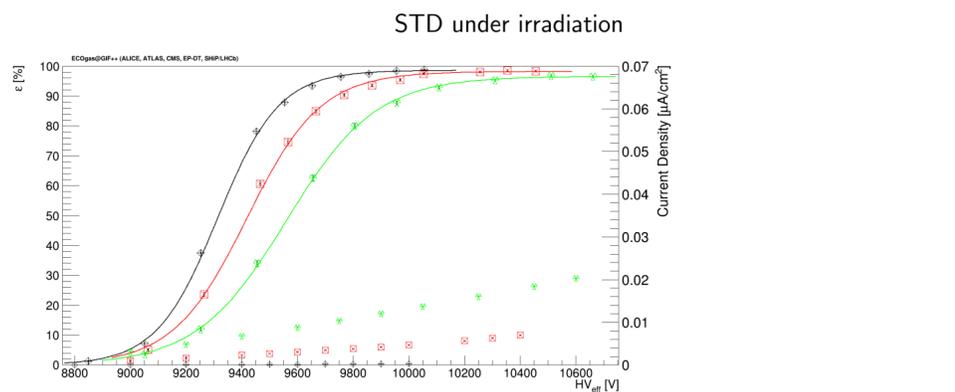


GIF++ bunker

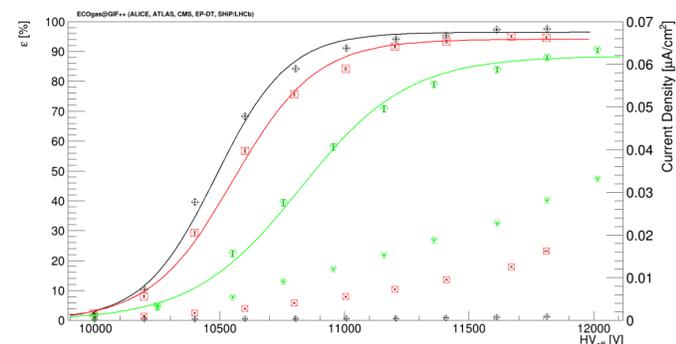
Beam tests at GIF++

- ALICE-like detector prototype tested
 - 50x50 cm²
 - 2D readout (x and y coordinates)
 - 16 readout strips per plane
 - 3 cm strip pitch
- Three gas mixtures tested
 - STD (reference): 94.5% C₂H₂F₄, 4.5% i-C₄H₁₀, 1% SF₆ GWP ~ 1500
 - ECO2: 35% HFO, 60% CO₂, 4% i-C₄H₁₀, 1% SF₆ GWP ~ 231
 - ECO3: 25% HFO, 69% CO₂, 5% i-C₄H₁₀, 1% SF₆ GWP ~ 230
- Signal discriminated and digitized by ALICE FEERIC readout
- DAQ with TDC
- 10x10 cm² trigger area

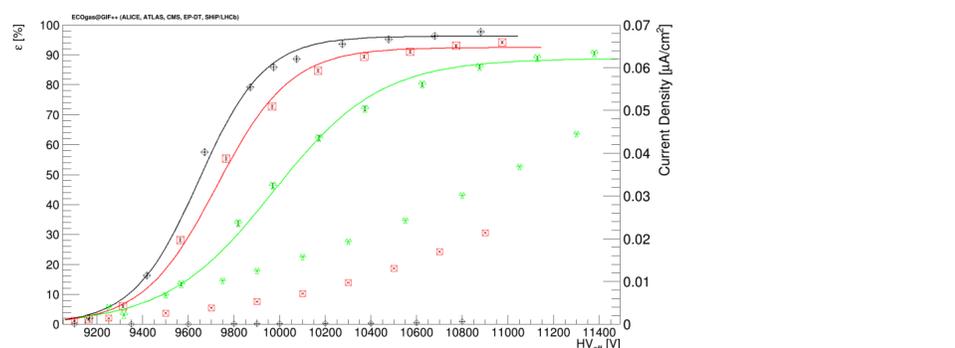
Beam test results



ECO2 under irradiation



ECO3 under irradiation



- Efficiency and current density vs high voltage
- Shift to higher voltages and max efficiency drop for high rates
→Rate capability effect
- 5 Hz/cm², 100 Hz/cm² (ALICE-like), 300 Hz/cm²
- Shift to higher voltages for higher HFO fractions
- Double absorbed current wrt STD (at fixed rate)

Conclusion and future plans

- Beam Test @ GIF++ with different irradiation conditions
- Two mixtures tested (ECO2 and ECO3)
- Efficiency curves shifted to higher voltages wrt STD
- Satisfactory efficiency at ALICE-like rates in Runs 3 and 4
- Higher currents wrt STD
→Long-term irradiation test to monitor evolution in time