

Overview of RPC operation with HFO-CO₂ based mixtures at the GIF++ facility

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on behalf of RPC ECOGAS collaboration



EP-DT
Detector Technologies



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Outline

- RPC ECOGAS collaboration
- Studies on HFO+CO₂ based gas mixtures
- Conclusions

RPC ECOGAS collaboration

RPC ECOGAS collaboration

Motivation

- Different RPC communities testing eco-friendly gases
- Up to now no eco gas mixture was found to fulfill requirements for already installed RPCs at LHC
 - Layout is fixed
 - Not possible to change FEB
 - Not possible to change HV cables
- It is fundamental to search for new eco-gases for RPC detectors for LHC and not-LHC experiment as well as for future applications

The ECOGAS collaboration is a joint effort between CERN Gas team, ATLAS-RPC, ALICE-RPC, CMS-RPC, LHCb-SHIP communities

- Started in 2019
- First results presented at EPS-2019
<https://indico.cern.ch/event/577856/contributions/3420164/>

Goal: performance study of several eco-friendly gas mixtures for RPCs operated at different LHC-like background conditions at GIF++

Received funds from AIDAInnova (Task WP 7.2)

Deliverables

- Identification if suitable eco-friendly gas mixture for RPC operation under gamma irradiation
- Long term performance studies on RPC detectors operated under gamma irradiation
- Detector performance with muon beam and gamma background
- F- based impurities production measurements

https://indico.cern.ch/event/1014152/contributions/4256819/attachments/2205329/3731186/AIDAInnova_Overview_CERN_Beneficiaries.pdf

Laboratory activities

Independent activities

HFO-based gas mixtures studied in laboratories from different universities/institutes

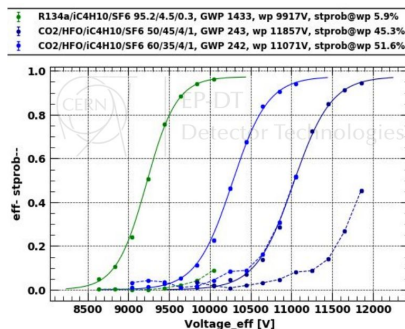
- TOR-Vergata
- INFN-Bari
- INFN-Frascati
- CERN Gas Group
- INFN-Torino

Objectives

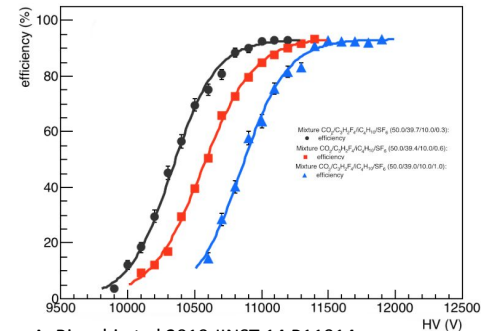
- Find eco-friendly gas mixture to be tested at GIF++
- Confirm and compare results with different detectors, FEBs electronics, analysis pipelines



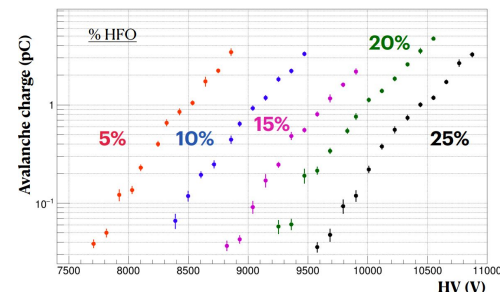
LHCb-SHIP setup: L. Congedo, A. Pastore



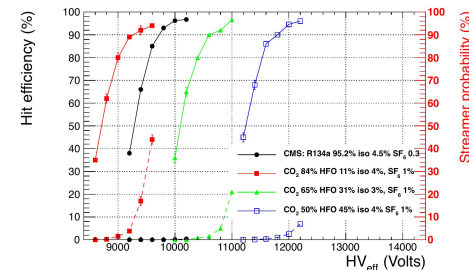
G. Rigoletti CERN Gas Group -> characterization of ECOGAS1 and ECOGAS2 mixtures



A. Bianchi et al 2019 JINST 14 P11014



G. Proto Tor-Vergata -> Studies on low HFO gas mixtures



D. Piccolo INFN-Frascati -> characterization of HFO+CO2 based gas mixtures

Gianluca Rigoletti

ECOGAS Setup

One setup, several detectors, shared technologies

GIF++

- ^{137}Cs source
- Located on SPS H4 line in North Area at CERN

Setup

Mechanics:

- Single trolley installed at GIF++

Detectors:

- Bakelite, 1.4-2 mm single and double gap RPCs
- Currents reading of all chambers
- One chamber equipped with FEB electronics

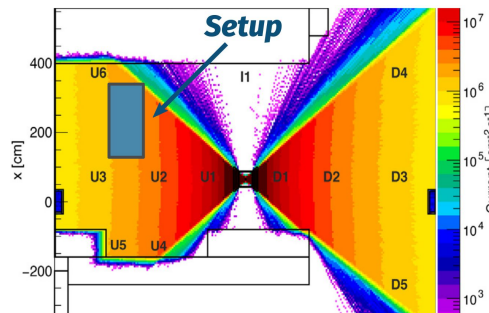
Gas system:

- Mixer up to 4 components
- Open mode operation
- Humidified gas mixture $\sim 40\%$ RH

Control system:

- CMS-RPC Web DCS for detector control
- Grafana for monitoring gas and detector monitoring

GIF++ gamma field



Grafana web monitoring

RPC	Gap type
CMS-GT	2 mm, double gap
CMS-K	1.4 mm, double gap
ALICE	2 mm, single gap
EP-DT	2 mm, single gap
ATLAS	2mm, single gap

Detectors installed

Studies on HFO+CO₂ based gas mixtures

HFO+CO2 studies under irradiation

Studies started in 2019

4-components gas mixture chosen:

- HFO + CO2 (no R-134a)
- GWP ~ 26 (GWP_{std. mix.} ~ 1430)
- Good performance results from laboratory tests (<https://arxiv.org/abs/1605.08172>)

First selected gas mixture based on laboratory activities:

ECOGAS1 = HFO/CO2/i-C4H10/SF6 45/50/4/1

Performance studies:

Working point estimation under gamma irradiation

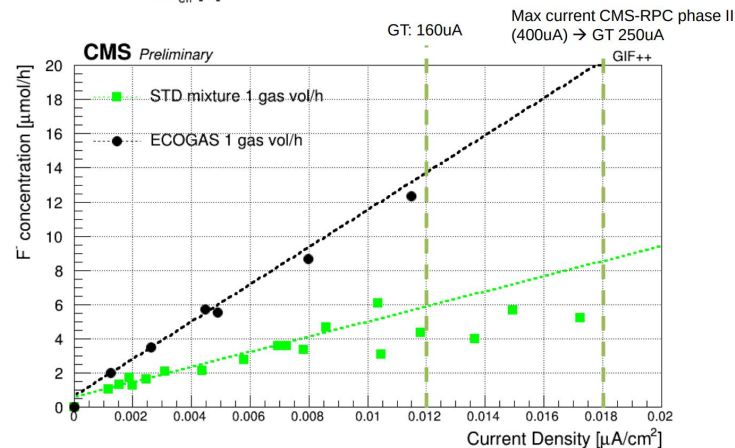
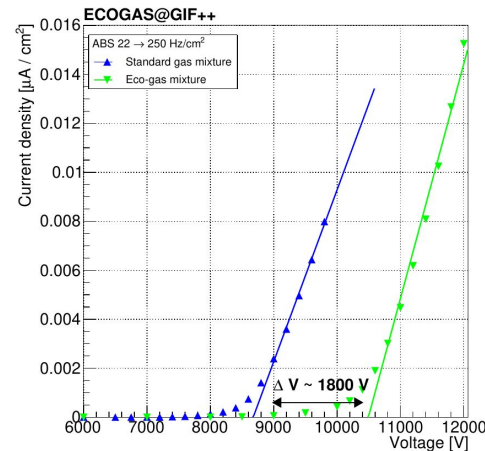
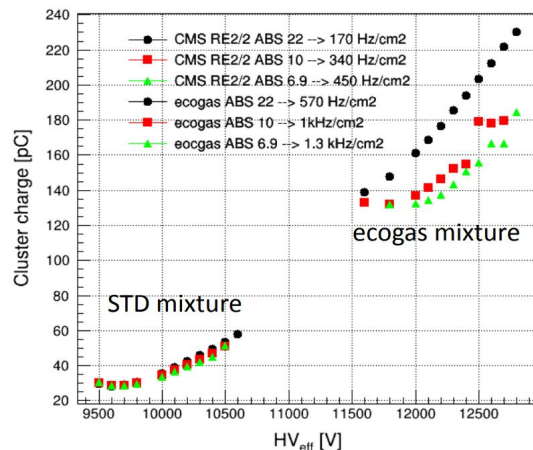
- Estimation by currents curve
- Positive working shift of 1.5-1.8 kV

Counting rate and cluster charge measurement

- Ecogas mixture charge @ w.p. ~ 180 pC
- Standard gas mixture @ w.p. ~ 30-37 pC

F- production measurement

- Ecogas F- production 2.5 times higher than std. gas mixture



HFO+CO2 studies: issues

Few issues addressed with ECOGAS1 mixtures

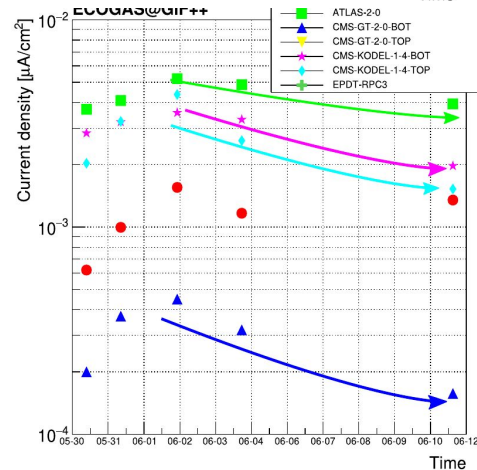
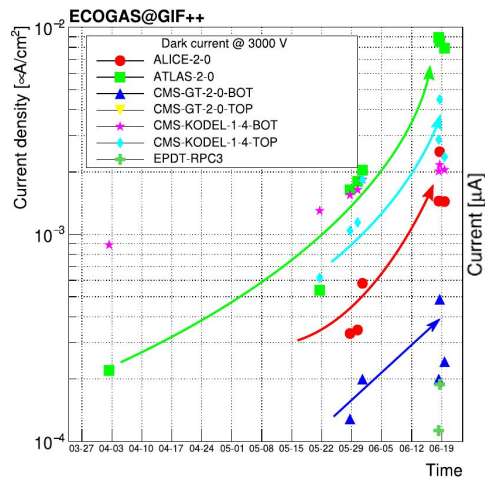
- Working point too high for LHC operation
- Dark and physics currents increase

Tests were conducted on the possibility to reverse the aging effect

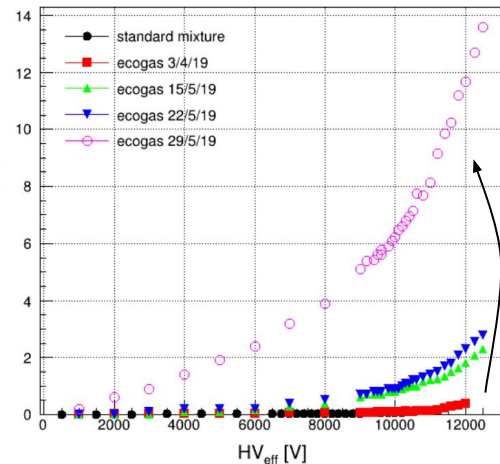
- Detectors operated at higher flow
- High Voltage at 5000-7000 kV: no multiplication occurs
- Partial recovery -> ohmic currents lowered

Issues at detector level

- 1 detector disconnected due to its high currents
- 1 detector disconnected due to HV connection issues
- 1 detector replaced due to detector issues



CMS-GT-2-0-BOT



HFO+CO2 studies: other mixture

New gas mixture with less HFO was put under test:

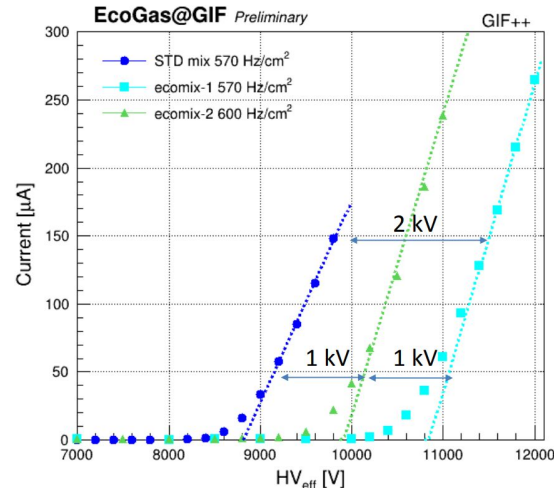
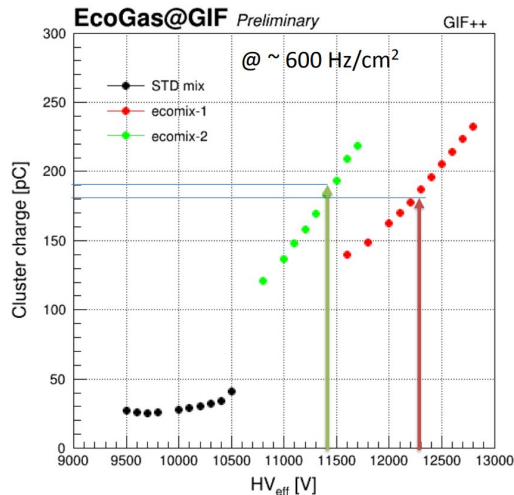
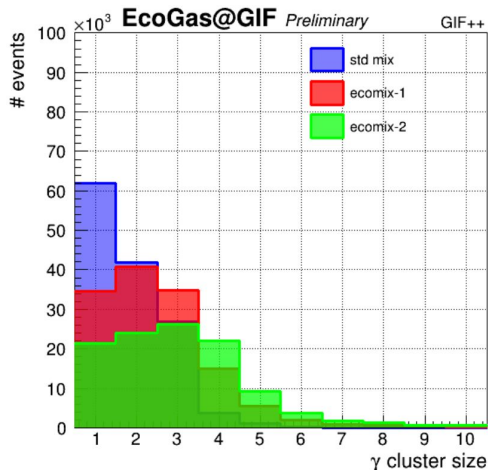
ECOGAS2= HFO/CO2/i-C4H10/SF6 35/60/4/1

The new gas mixture was characterized:

- Working point estimation
- Cluster rate and charge measurement

New long-term irradiation campaign started:

- Ohmics and irradiation currents monitored

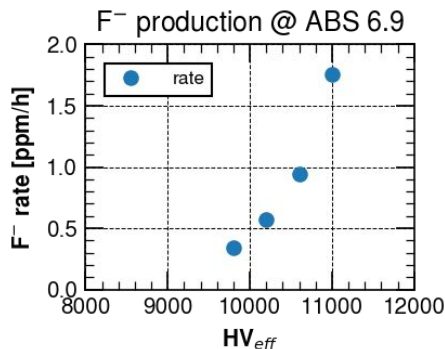
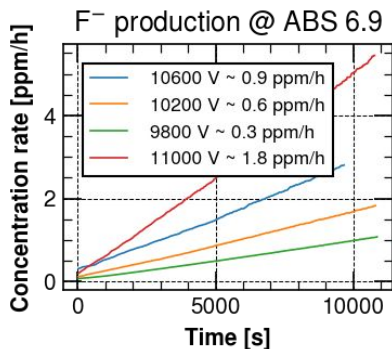


Gas	W.P. _μ	Cluster charge	Cluster size
Std. mix.	9600 V	~ 40 pC	1.8 strips
ECOGAS1 (45% HFO)	11600 V	~ 180 pC	2.6 strips
ECOGAS2 (35% HFO)	10600 V	~ 190 pC	3.3 strips

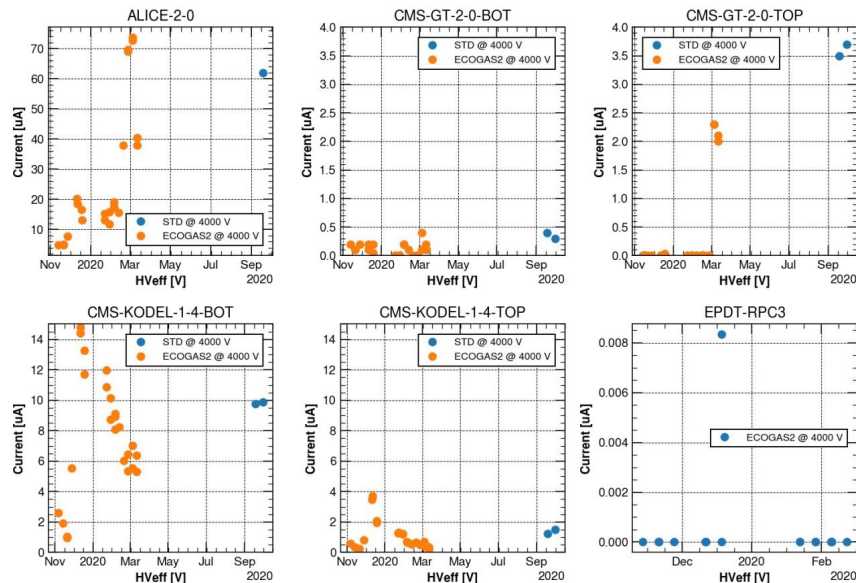
HFO+CO₂ studies: long-term ECOGAS2 mixture

Long term studies with ECOGAS2 mixture started

- No clear signs of aging up to now
 - Some detector with stable ohmic currents
 - Some with increased ohmic currents
 - Some with decreased ohmic currents
- System restarted with ECOGAS2 mixture at beginning of 2021
 - Irradiation campaign ongoing



Raw data: detector from different production sites under test



F- production with ECOGAS2 and gamma irradiation

- Tests started
- Comparison with standard gas mixture to be completed

Conclusions

Two HFO-CO₂-based gas mixtures tested at GIF++

- ECOGAS2 mixture selected and studies ongoing

New HFO-based gas mixtures studied in laboratories

- TOR-Vergata
- INFN-Bari
- INFN-Frascati
- CERN
- INFN-Torino

Several tests to perform

- Long term stability (ongoing)
- F⁻ production (ongoing)
- Gamma rate at different background conditions
- Muon beam + gamma background efficiency

Challenges

- Long term studies: stable irradiation conditions, different detector types, FEBs

Gas mixture

Composition

CMS-RPC

R-134a/i-C₄H₁₀/SF₆ 95.2/4.5/0.3

ECOGAS1

R-1234ze/CO₂/i-C₄H₁₀/SF₆ 45/50/4/1

ECOGAS2

R-1234ze/CO₂/i-C₄H₁₀/SF₆ 35/60/4/1

Thank you!