Long-term Performance Studies of Resistive Plate Chambers with Environmentally Friendly HFO/CO2 Gas Mixtures at the GIF++ Facility

Gianluca Rigoletti on behalf of the RPC ECOGAS @ GIF++ collaboration

02/09/2023

Outline

RPCs at LHC

- GHGs consumption

Alternative gases to R-134a

- R-1234ze as alternative to R-134a

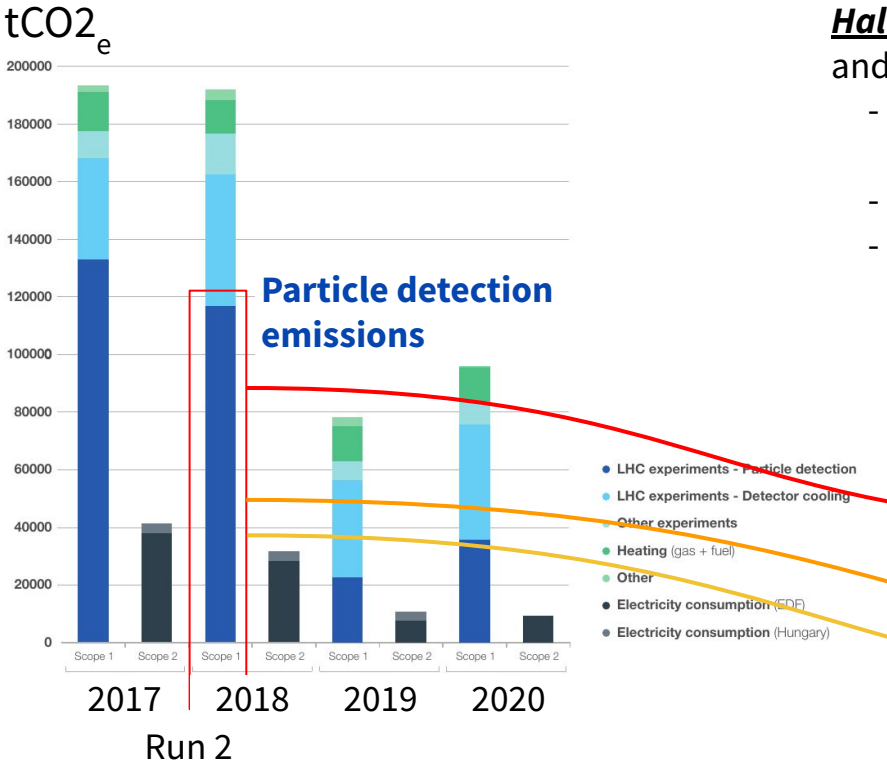
Short and long term studies on HFO-based gas mixtures

- Muon beam + Gamma background tests

Conclusions

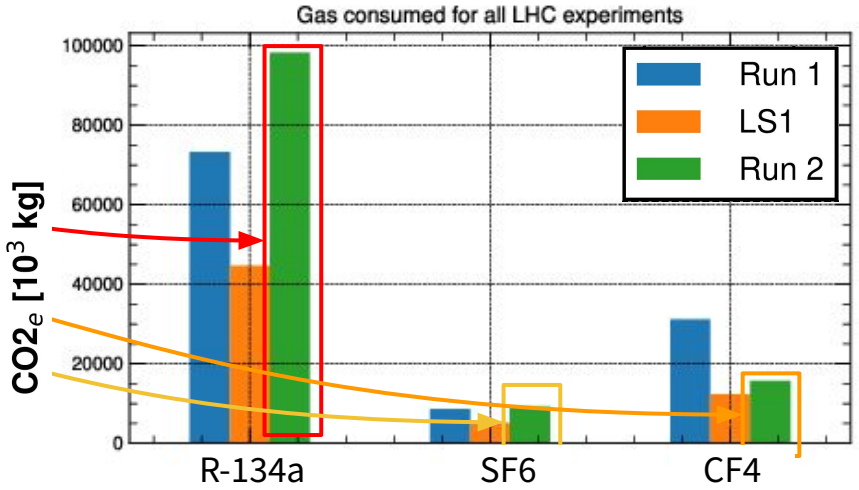
Greenhouse gases consumption

https://hse.cern/environment-report-2019-2020



CERN emissions during 1 year of Run 2 ~ **220 000 tCO2e**
Half of them from particle detectors → mostly due to leaks and operation

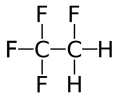
- **C2H2F4/R-134a** biggest contributor → leaks from RPC detector during operation
- **CF4** → due to operation of CSC and RICH systems
- **SF6** → Related to RPCs as R-134a



RPC gas mixtures at LHC

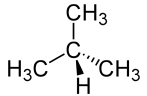
- **HPL** RPCs: ATLAS, CMS, ALICE
- Gas mixture made of 3 components: **R-134a**, **i-C4H10**, **SF6** + ~40% RH (for electrode resistivity)
- **>90%** of the GWP due to **R-134a**
- ~**5-7%** due to **SF6**

R-134a
~95 %



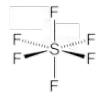
GWP
1430

i-C4H10
~5 %



GWP
3.3

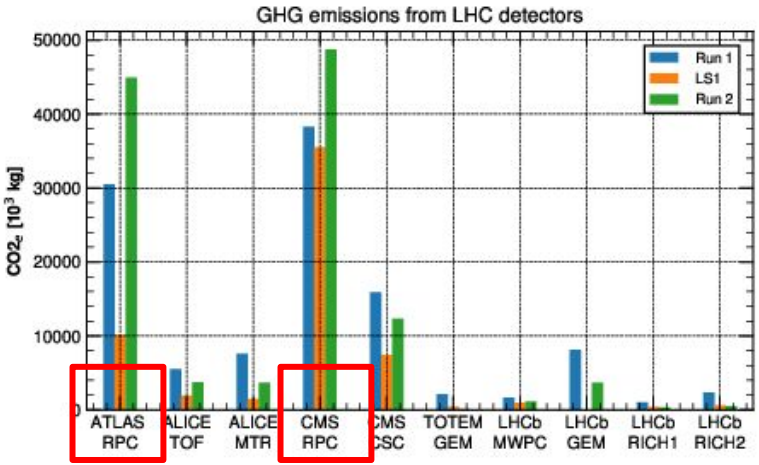
SF6
~0.3 %



GWP
22800

RPCs accounts for ~ **85%** of GHG emissions from particles detectors at **CERN**:

- **Leaks** at **detector** level → reparation campaign
- Gas mixture replacement → **environmental** and possibly **economical**

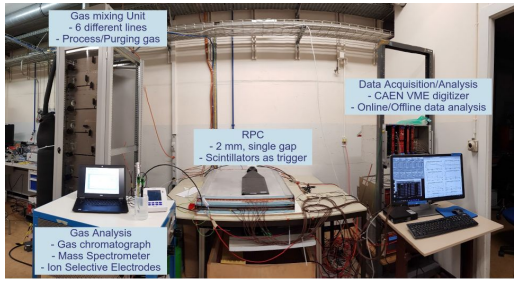


Studies on eco-friendly gas mixtures

Motivations

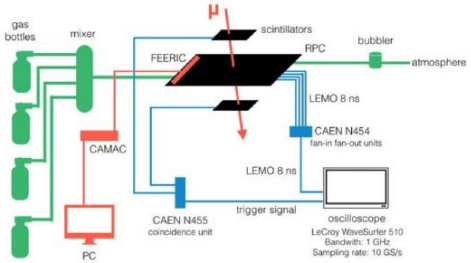
- **Several works** done by different universities and institutions
- Up to now **no eco-gas mixture found** to fulfill requirements for RPC at LHC
- Research on new eco-gases fundamental for LHC and for future applications

CERN Gas Group lab.



INFN Bari lab.

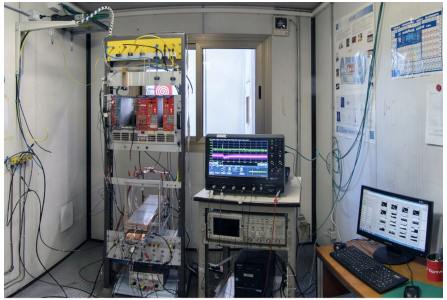
Torino Laboratory



Sketch of the experimental setup in the Torino laboratory
A. Bianchi et al. 2020 JINST 15 C04039

INFN Frascati lab.

Rome Tor Vergata Lab



RPC ECOGAS @ GIF++ Collaboration

Joint effort among different groups and institutes

CMS-RPC, ATLAS-RPC, EP-DT, ALICE-MID, LHCb/SHiP

Started in 2019

RPC Detectors

- High Pressure Laminate: single gap, double gap, 1, 1.4, 2 mm gas gaps with different thicknesses
- Common infrastructure: shared DCS, Gas System and mechanical support

Studies in the AIDA Innova Task WP 7.2.3

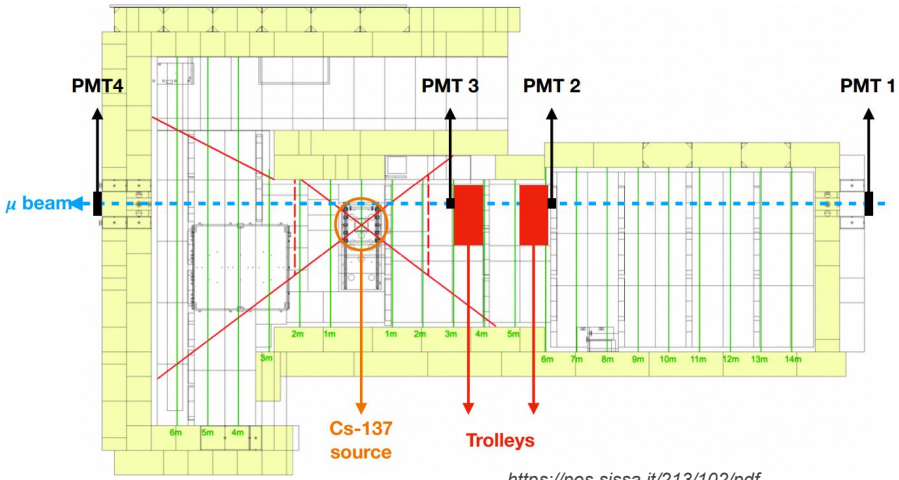
- Validation of suitable eco-friendly gas mixture for RPC operation under gamma irradiation
- Long term performance studies on RPC detectors operated under gamma irradiation
- Detector performance with muon beam and gamma background
- F-based impurities production measurements

Goal: characterization of HFO-based gas mixtures with LHC-like background radiation

Experimental Setup

Gamma Irradiation Facility

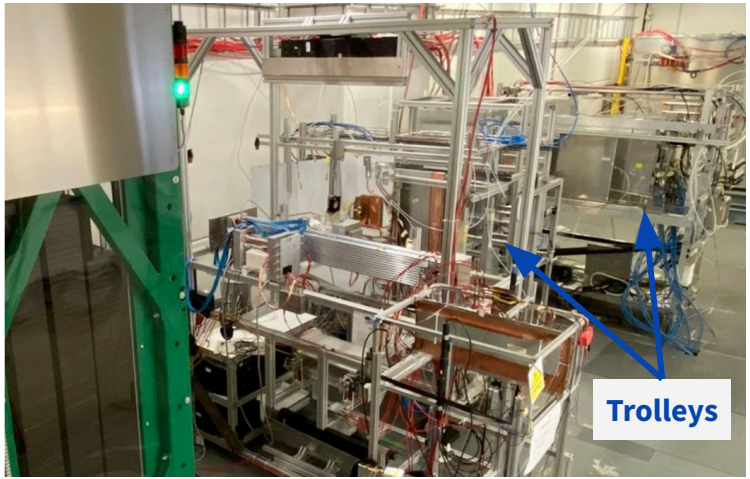
- Bunker area with a ^{137}Cs source of ~12.5 TBq
- Located at the CERN North Area, on the H4 line
- A muon beam of 100 GeV/c present
- Gamma flux can be regulated using a set of lead filters (ABS)



https://pos.sissa.it/213/102/pdf

Experimental setup

- One common Gas System: Small replica of LHC gas systems, operated in open mode
- HV and electronics: dedicated power supply and readout electronics for each detector
- Mechanical installations: 2 trolleys at different distances from the gamma source



Activities of the ECOGAS collaboration

Aug 2022
Start of aging

Gas mixture tests

ECO1 → 45% HFO + 50% CO2 + 4% iso + 1% SF6
high w.p. and high currents after ~ 20 mC/cm2 integrated charge

2014

RPC ECOGAS @ GIF++ collaboration started

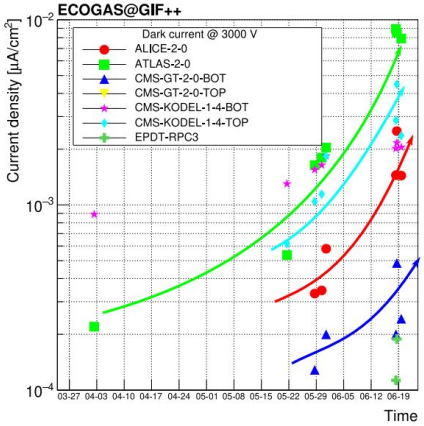
2021 Test Beam

2022 Test Beam

2023 Test Beam

Independent lab. activities on RPC with eco-gases

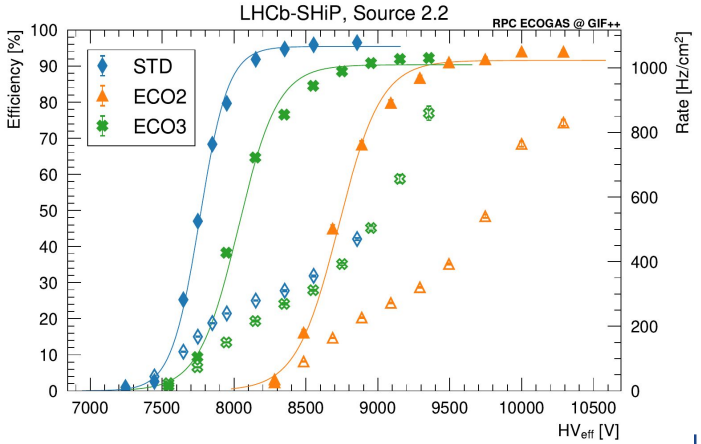
2018/2019



PoS EPS-HEP2019 (2020)

STD, ECO2, ECO3 test beam

ECO2 → 35% HFO + 60% CO2 + 4% iso + 1% SF6
ECO3 → 25% HFO + 69% CO2 + 5% iso +1 % SF6



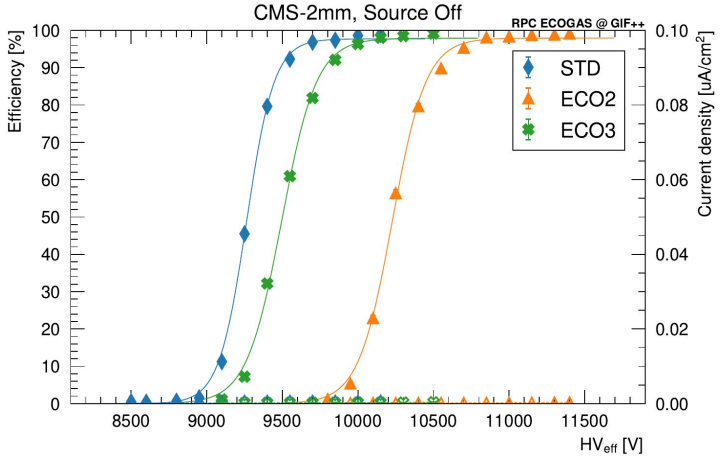
Short term performance: test beam campaign

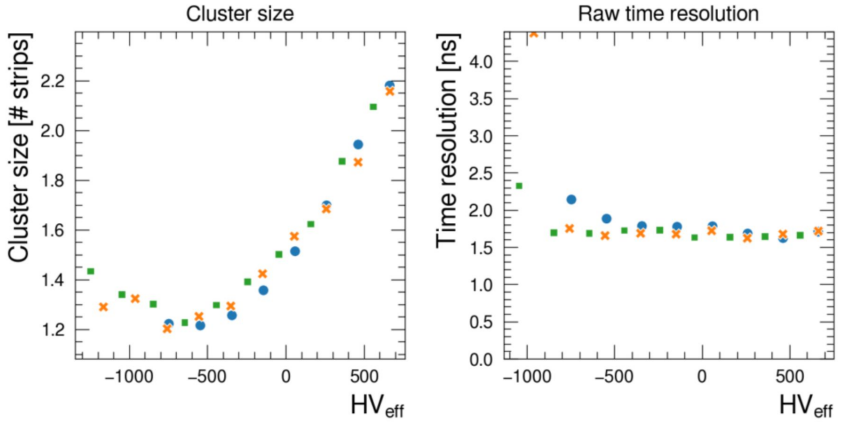
Detector performance with muon beam

- **Working point** with ECO-gas mixtures is **higher**:
  - +250 V with ECO3
  - +1000 V with ECO2

- **Max**. efficiency ~ **98-99%** for 2 mm gaps → good trigger properties

- **No** significant **changes** in **cluster size** and **time resolution** → good space and timing properties compared to std. gas mixture

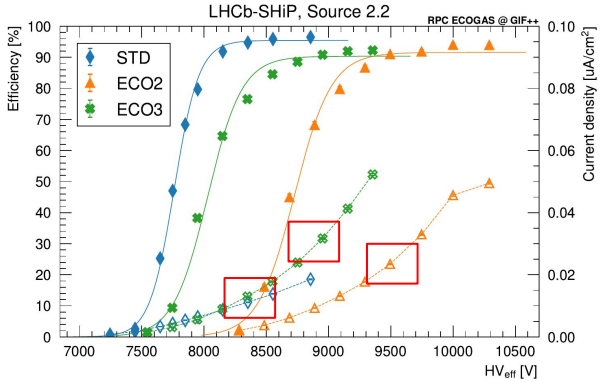


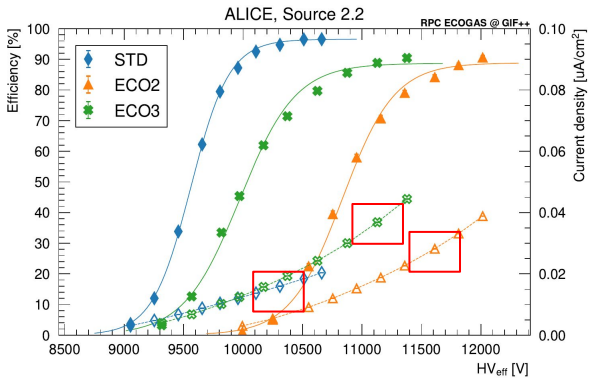


Short term performance: test beam campaign

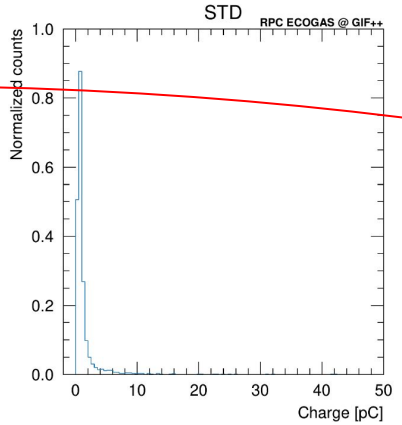
Higher background currents with respect to Standard Gas Mixture

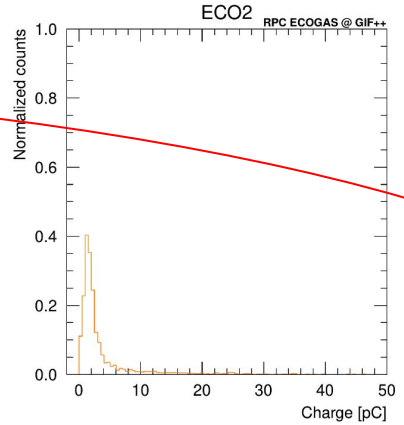
- ~ 50% with ECO2
- ~ 100% with ECO3

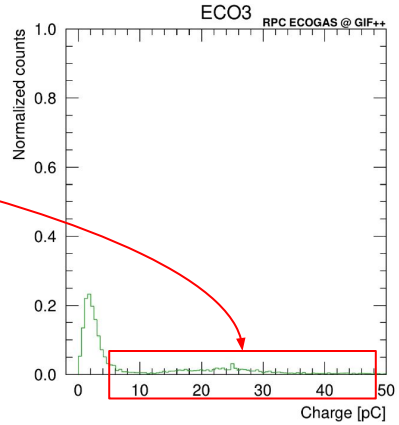




Higher concentration of CO_2 → higher charge content at w.p.



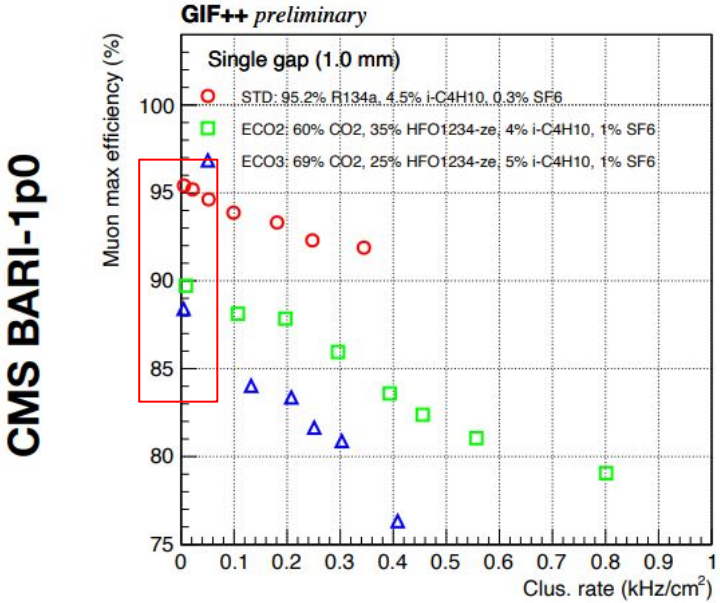




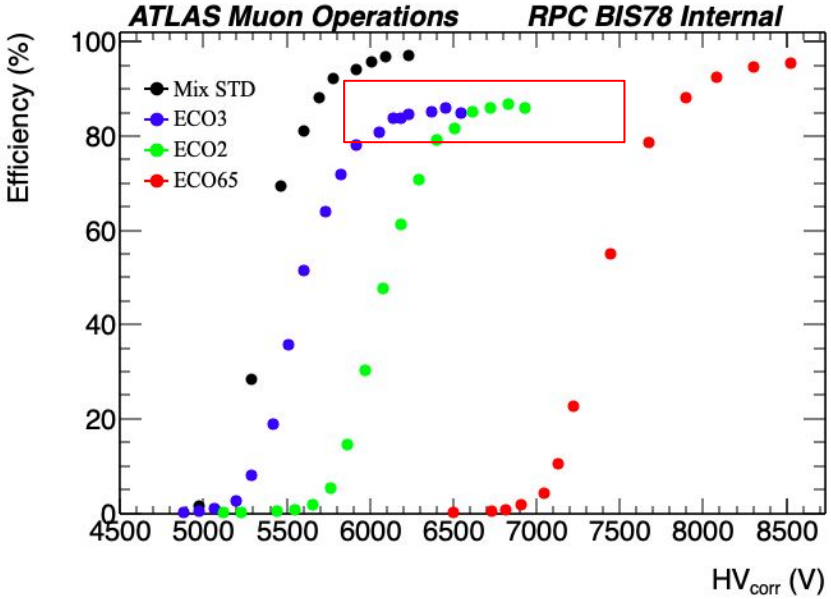
Tests with thinner gaps

Tests performed on gas gaps of 1 mm from ATLAS for BIS upgrades and CMS

D: Ramos ICNFP 2023



G. Aielli, RPC 2022



Higher content of CO2 decreases the maximum efficiency plateau

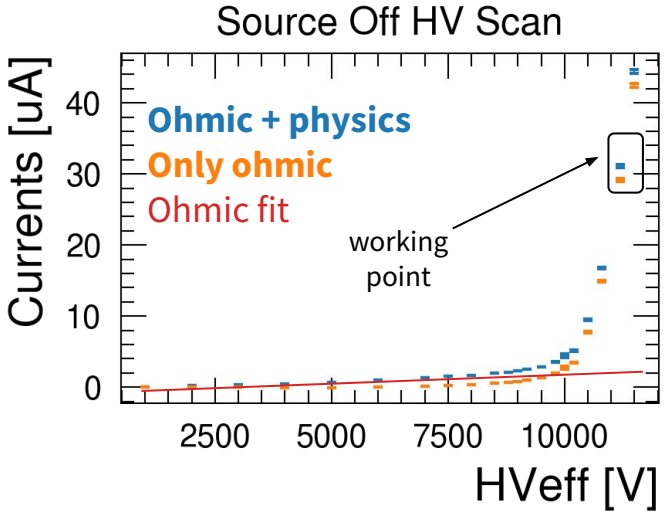
Long term tests: irradiation campaign

Long term irradiation tests

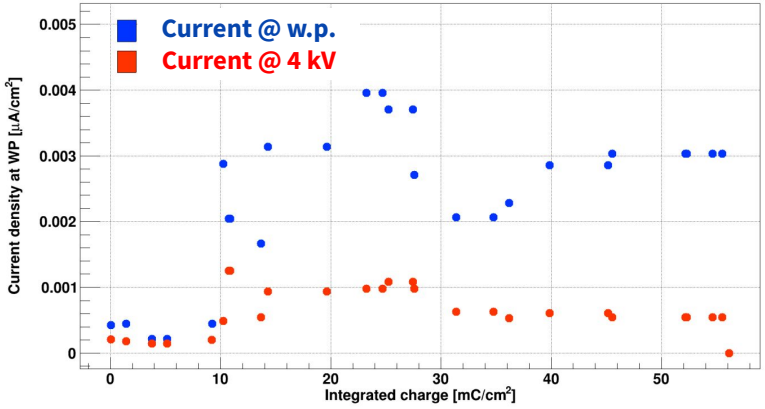
- Detector continuously flushed at ~ 1 vol/h
- Detectors continuously irradiated @ GIF++
- Weekly voltage/current scans at source off to assess detector performances

50-100 mC/cm2 integrated

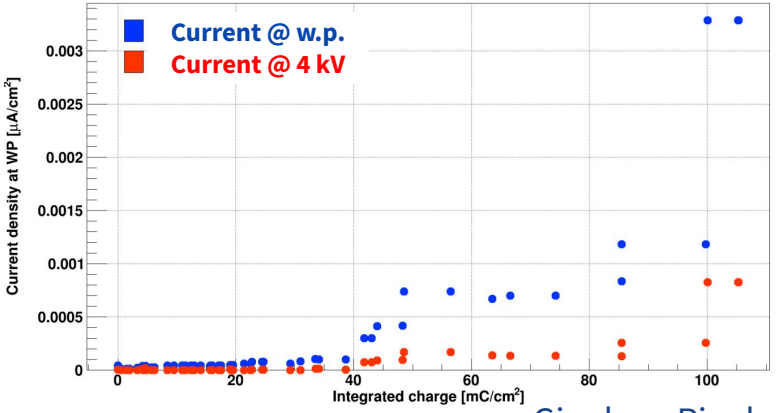
- Constant ohmic behaviour for most of detectors
- General increase of currents @ w.p.



ALICE - 2 mm single gap



Ship - 1.6 mm single gap

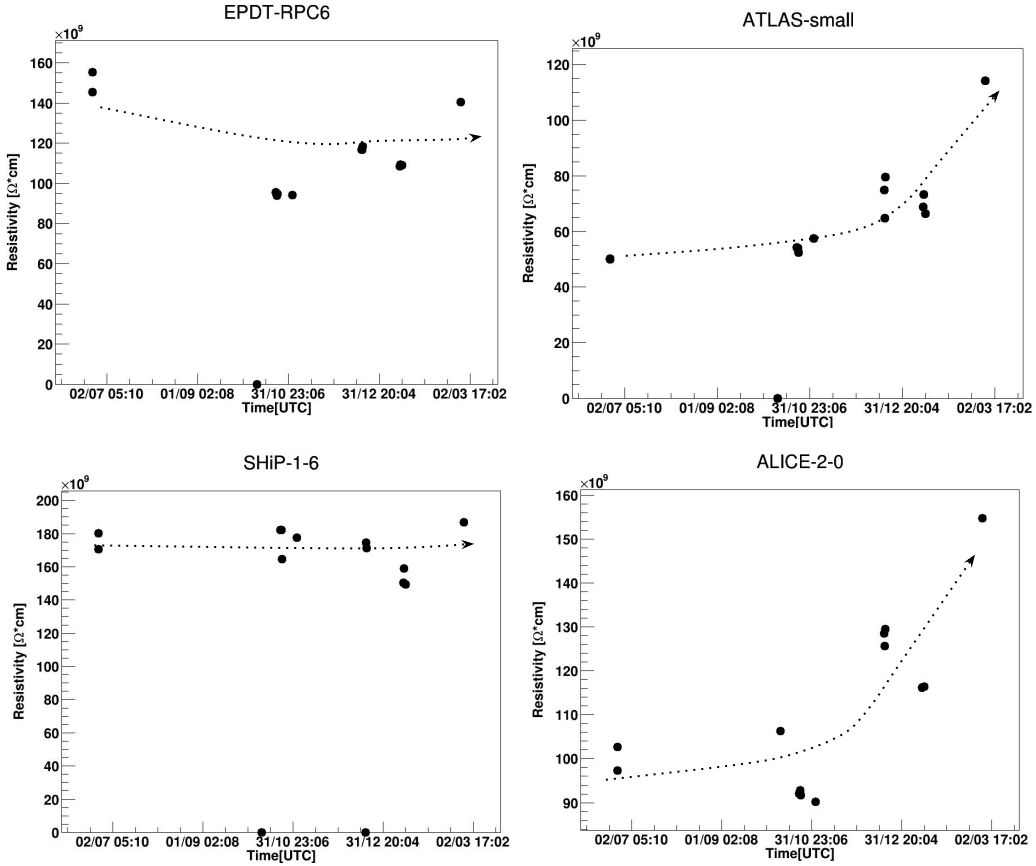


Long term tests: resistivity measurements

Resistivity measured with Argon

- Measurements performed regularly over irradiation campaign
- Values normalized over temperature of 20 °C

- Stable resistivity for EPDT and ALICE detectors
- Increasing behaviour in ATLAS and ALICE chambers



Conclusions

ECO-gases for RPC applications

- Low GWP gas mixtures advisable for **environmental** reasons and for **economical**/market ones
- **RPC ECOGAS @ GIF ++** collaboration → joint effort between CERN EP-DT, ALICE, ATLAS, CMS, LHCb/SHiP

Tests on HFO-based gas mixtures

- Initial tests performed on **HFO**/**CO2**/i-C4H10/SF6 gas mixture
- Tests on different HFO/CO2 gas mixtures: ECO1, ECO2, ECO3
  - ECO1 (45% HFO) → high currents, performance unstable → discarded
  - **ECO2** (35% HFO) → higher working point but **stable performance** → selected for **long-term tests**
  - ECO3 (25% HFO) → lower working point but decreased efficiency plateau
- Test beam campaign performed on 2021, 2022 and 2023 ongoing
  - **Similar performances** observed among chambers from different experiments
  - **ECO2** and **ECO3** have **higher currents** but good time resolution and cluster size
- Long term irradiation campaign
  - Irradiation at GIF++ with 137 Cs source
  - 50-100 mC/cm2 integrated
  - Stable currents at low voltage, increasing @ working point → under investigation

Thank you