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

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On behalf of the RPC Ecogas Collaboration

ABSTRACT: The Resistive Plate Chambers (RPC) are gaseous detectors largely used at CERN LHC experiments for muon identification, reconstruction and triggering. The standard gas mixture used is composed by a freon-based gas mixture containing $C_2H_2F_4$ and SF_6, both greenhouse gases (GHG) with a high Global Warming Potential (GWP). Efforts are being made to reduce the usage of this GHG gases, and ongoing studies are being carried out in order to replace it for eco friendly gas mixtures. Preliminary results with HFO indicates that the high voltage working point, the stream probability at the efficiency knee, cluster size and the accumulated charge are higher.

Introduction

The RPCs were originally designed to be operated in streamer mode, using a mixture of argon and butane [1]. However, due to the rate limitation related to the stream mode operation, the saturated avalanche mode was proposed, requiring the change of the gas mixture [2]. The first RPC working with a freon based mixture (CF_3Br) was prohibited due to the environment protection as this gas is known to damage the ozone atmospheric layer. After that, the Tetrafluoroethane $C_2H_2F_4$, commercially known as R-134a was used to replace it. This gas was subjected to several R&D tests and it has been largely used in LHC projects as the main gas to enhance the ionization in the RPCs [3, 4, 5]. However the $C_2H_2F_4$ has GWP around 1430, in which the reference is the CO_2 GWP being 1. In this context, the European Community has been adopting regulations in order to respect the Kyoto protocol, that is to prohibit gases with GWP > 150. Even though this is not applicable to scientific organizations, CERN is pushing the LHC experiments to replace the $C_2H_2F_4$ with gases with lower GWP. Therefore, this has led to many R&D studies with possible eco-friendly gas mixtures [6, 7, 8]. The family of the HydroFluoroOlefin (HFO) have been identified by the industry as a low GWP. In this work we are going to comment what have been done in the research for the new RPC gas mixtures using this gas.

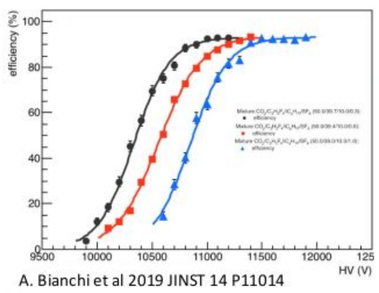
RPC Ecogas collaboration

There are different RPC communities testing eco-friendly gases. The ECOGAS collaboration is a joint effort composed by several CERN experiments, ALICE-RPC, ATLAS-RPC, CMS-RPC, LHCb, SHiP and CERN gas team. Their goal is to study the performance of different eco-friendly gas mixtures for RPCs operated at LHC-like background conditions at the Gamma Irradiation Facility (GIF++) [9]. More specifically, the collaboration aims to: Identify eco-friendly gas mixture for RPC operation under gamma irradiation, ageing studies on RPC detectores operated under gamma irradiation, detector performance with muon beam and gamma background, F- based impurities production measurements. The first studies began in 2019 and were published in [10].

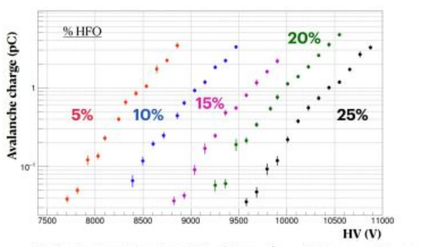
Laboratory activities

There are also independent activities being done in laboratories from different universities/institutes: TOR-Vergata, INFN-Bari, INFN-Frascati, CERN Gas Group. INFN-Torino. The objective of these activities is to find eco-friendly gas mixtures to be tested at GIF++ and confirm/compare results with different detectores, FEBs electronics, analysis pipelines.

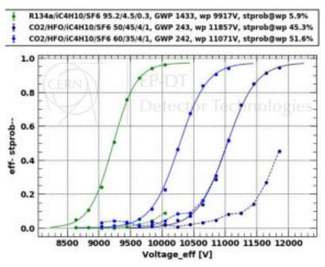
L. Congedo, A. Pastore, INFN Bari -> RPC muon telescope.



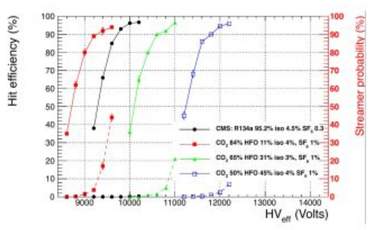
A. Bianchi et al 2019 JINST 14 P11004



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



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

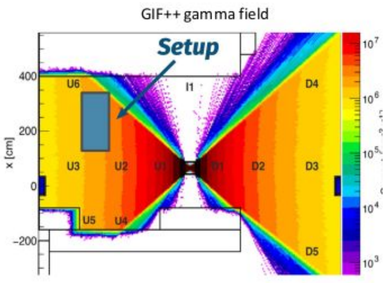


D. Piccolo INFN-Frascati -> characterization of HFO+CO2 based gas mixtures

ECOGAS Setup in GIF++

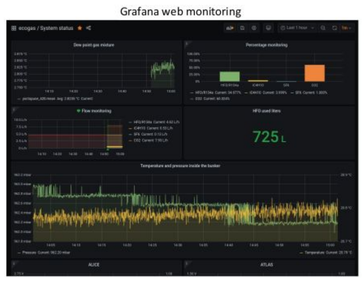
The GIF++ is a facility that can provide a powerful gamma irradiation from a 14 TBq ^{137}Cs source combined with a high energy charged muon beam with momentum up to 100 GeV/c. The setup consists of one single trolley with five detectors installed. The detectors operates with HPL (bakelite) with 1.4 mm and 2.0 mm, single and double gap RPCs. All detectors have currents reading and one chamber is equipped with FEB electronics. Conversely, the gas system is composed with a mixer of up to 4 components working in open mode operation. The relative humidity is required to be around 40 % by controlling manually the dew point at 4 °C. In order to monitor the system a grafana webpage is used. Also, to control and monitory a CMS-RPC Web DCS is used to take data and perform scans.

GIF++ gamma field



ECOGAS setup at GIF++

Grafana web monitoring

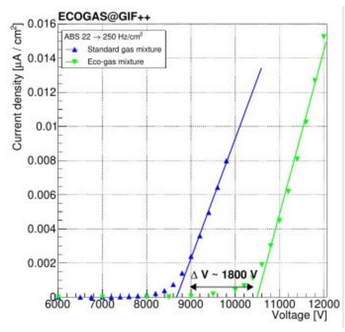


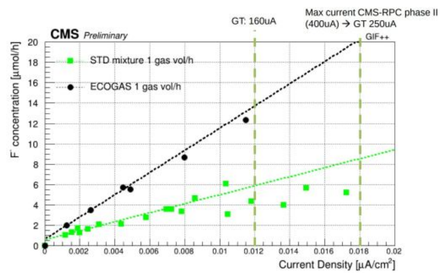
Detectors installed

RPC	Gap type
CMS-GT	2 mm, double gap
CMS-Kodel	1.4 mm, double gap
Alice	2 mm, single gap
ED-DT	2 mm, single gap
ATLAS	2 mm, single gap

HFO+CO2 studies under irradiation

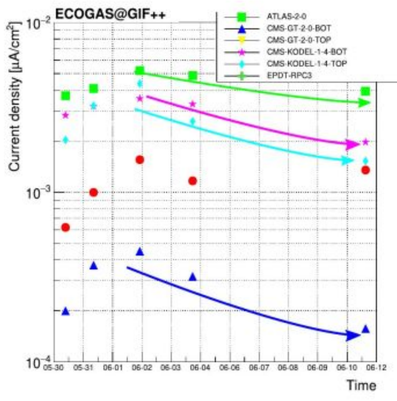
The irradiation studies started in 2019 with 4-components gas mixture chosen. The first selected gas mixture based on laboratory is called ECOGAS1, with 45 % HFO, 50 % CO2, 4 % iC4H10, 1 % SF6. The performance studies have concluded that: The working point (WP), that is the work voltage of the detector, was shifted 1.5-1.8 kV positively, and the F^- production was found 2.5 times higher than the standard gas mixture.

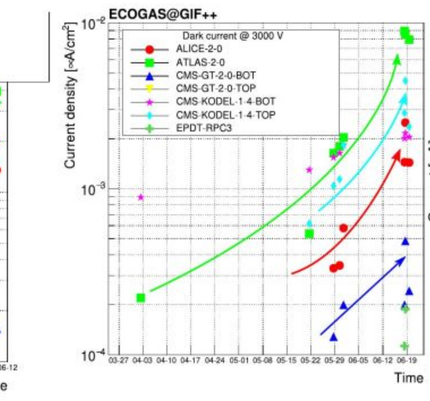


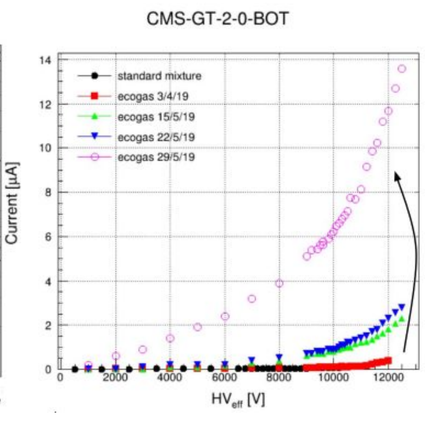


HFO+CO2 studies: issues

The main issues observed was the clear increase of the WP, that is too high for LHC operation, and dark and physic currents increase. In order to study the reversibility of the aging effect, tests were done: detectors operating at higher gas flow and HV kept at 5000 - 7000 V. In this voltage range no multiplication occurs and partial recovery was seen, *i.e* ohmic currents lowered. Other than this, one detector was disconnect due to its high currents, one detector was disconnected due to HV connection issues and one detector was replaced.

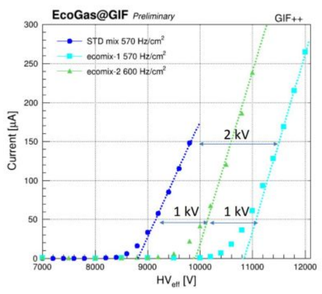


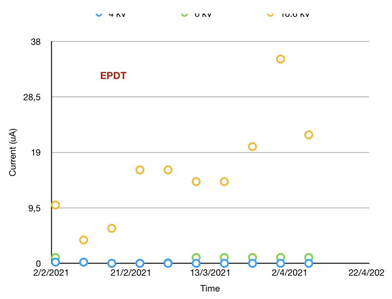


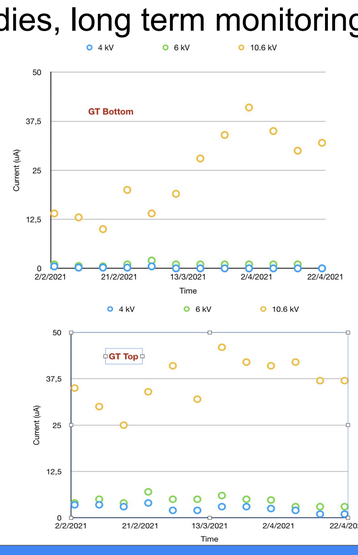


HFO+CO2 studies: second mixture

A new mixture with less HFO is being tested as well, it is called ECOGAS2 with 35 % HFO, 60 % CO_2, 4 % iC_4H_{10}, 1 % SF_6. The WP found is 1 kV greater than the standard gas WP and 1 kV lower than the ECOGAS1 WP. Besides, the long term studies with this mixture started. So far, no clear signs of aging. The ohmic current is stable, while some increase and fluctuation (under study) is visible at working voltages.. At the beginning of 2021 the system restarted with ECOGAS2 mixture and there are studies ongoing (F^- production, rate scan studies, long term monitoring).







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