Studies of RPC operations with ecological gas mixture under irradiation at GIF++

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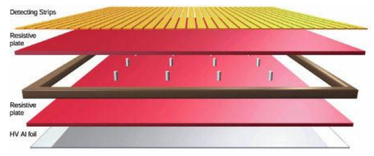
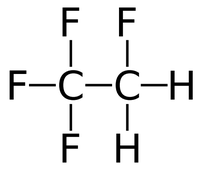
RPC and eco-friendly gas mixtures

Resistive Plate Chambers at the LHC:

- Used in ATLAS, CMS and ALICE experiments
- Gas mixture based on ~95% of *C2H2F4*



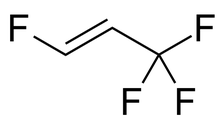
C2H2F4/R134a



GWP 1430

- *C2H2F4* has a high ***Global Warming Potential*** ($GWP_{10\ years}$ = 1430)
- European regulation aims at *reducing the use* of *C2H2F4*

C3H2F4/HFO1234-ze



$GWP_{HFO1234-ze}$ = 6

- *HFO-1234ze* is a ***suitable alternative*** of *C2H2F4* in refrigerants industry
- Tests were started on using *HFO* based gas mixture for ***RPC detectors***

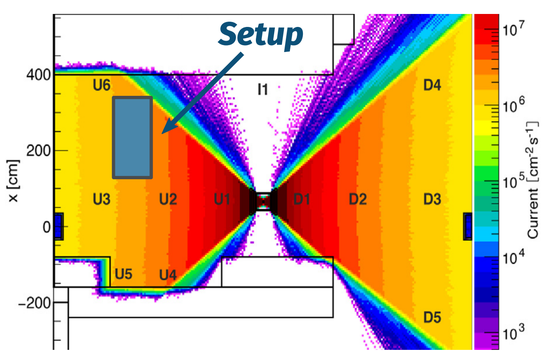
Goal: to characterize the HFO-based gas mixtures for RPC under LHC like background conditions

Experimental setup

- 5 ***HPL chambers*** under test: *ATLAS, ALICE, CMS-GT, CMS-KODEL, CERN-EPDT*
- 4 component ***gas mixer*** + ***humidifier*** module
- *CAEN SY1527* ***HV mainframe*** with two *A1526* boards
- *WEB-DCS* ***software*** designed by CMS group
- *Grafana* web-app for ***monitoring***

Chamber name	Gap [mm]	Type
CMS-GT-2-0	2	Double gap
CMS-KODEL-1-4	1.4	Double gap
ATLAS-2-0	2	Single gap
ALICE-2-0	2	Single gap
EPDT-RPC3	2	Single gap

CERN Gamma Irradiation Facility (GIF++)



- Situated on *H4* SPS ***beam line***
- A *14 TBq* source of ^{137}Cs simulates the background radiation expected at ***High Luminosity LHC***
- System of filters (*ABS*) allows to regulate the ***gamma background rate***

Results

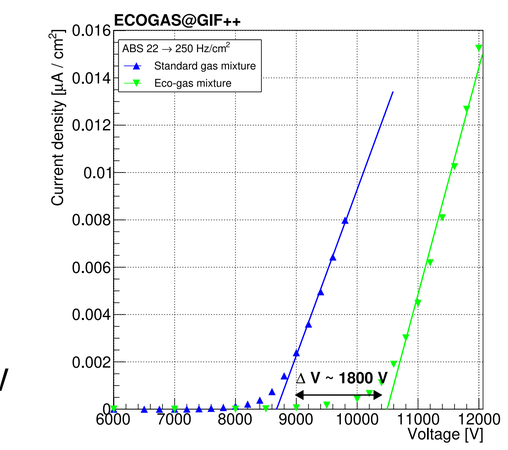
Characterization of the gas mixture

Working point of the gas mixture

- Test started with gas mixture of:

$HFO/CO_2/iC_4H_{10}/SF_6$ 45/50/4/1

- ***Working knee*** defined as the voltage at which the current is dominated by irradiation conditions
- ***Working point*** estimated from cosmics HV scans

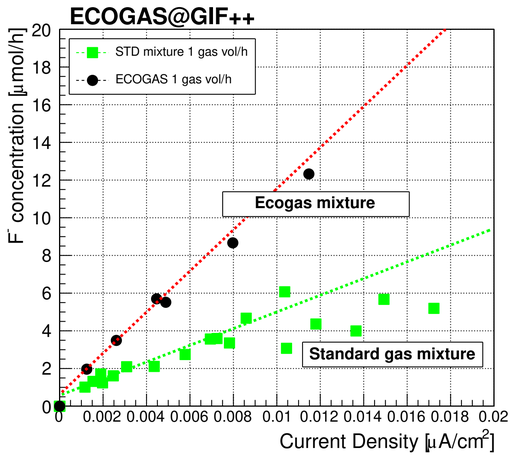


Chamber	$\Delta V(Knee_{Std.\ Gas\ mixture} - Knee_{HFO\ gas\ mixture})$
ALICE	1660 V
ATLAS	1420 V
CMS-GT-TOP-2-0	1670 V
EPDT-RPC3	1670 V

- ***Δknee*** = 1.5-2 kV between the *HFO* based gas mixture and the *ATLAS/CMS* standard gas mixture

Measurements on HF production

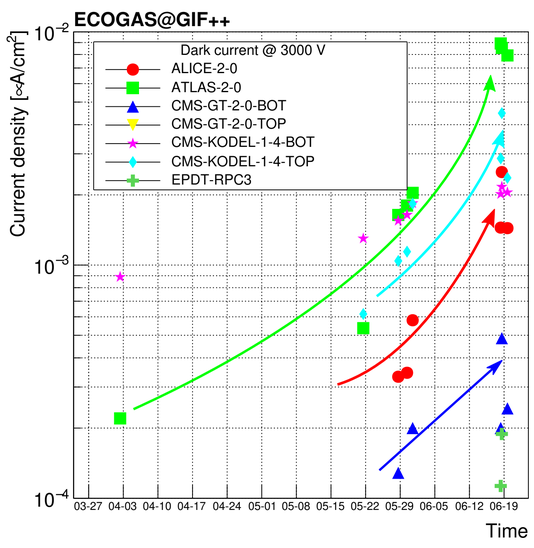
- **F-** are produced from the ***C2H2F4*** and ***HFO*** molecule when operating the detectors ***under radiation*** and ***high electric fields***
- The F^- combines with H_2O to form ***HF acid***
- The ***HF production*** can be measured using ***Ion Selective Electrodes (ISE)***
- The ***HF*** *concentration* was measured for both the ***ATLAS/CMS gas mixture*** and the ***HFO based gas mixture***
- The test was performed using the ***CMS-GT*** *chamber*
- The ***HF production*** rate is ***~2 times higher*** for ***HFO*** based gas mixture

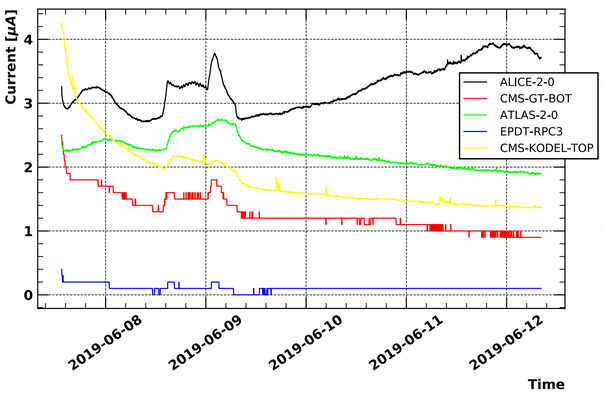


Ageing tests

Irradiation campaign

- Physics current trend monitoring during irradiation
- ***Current scans*** performed over weeks by ***without radiation***
- Results show an increase of the dark currents for all the chambers

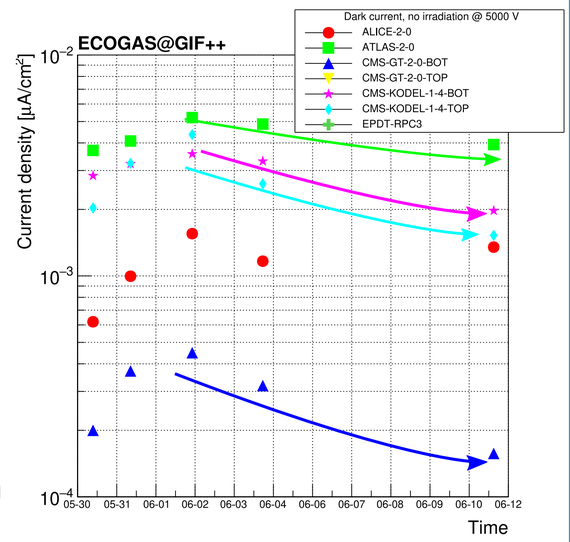




- ***Dark currents monitored*** under no irradiation condition for ~ 15 days
- Observed a **decrease of the current** for most of the chambers
- The time taken to observe decrease was about ~ ***4 days***

Ongoing studies on the strategies to stop the increase of the dark currents

- Deep understanding of the correlation between ***HF*** production and ***dark currents***
- ***Resistivity measurements***
- ***Fine tuning*** on the gas mixture composition



Conclusions

- Tests on *HFO* based gas mixtures under background radiation ***are ongoing***. The ***HFO*** based gas mixture was ***compared with respect to*** the the ***ATLAS/CMS*** gas mixture
  In particular:
  → The ***current knee*** appears to be between 1.5-2 kV ***higher***, depending on the chamber and the ***irradiation conditions***
  → The ***HF production*** rate in the *HFO* mixture appears to be ***higher*** than the *ATLAS/CMS* standard gas mixture
- An ***ageing test*** on the chambers with the *HFO* based gas mixture ***is ongoing***. ***Preliminary*** results indicate that:
  → There is an ***increase in the dark and physics currents*** with the increase of the time of irradiation
  → The ***currents***, both dark and physics, tend to become ***lower*** by switching off the chambers over a ***time range of 15 days***
- The tests will be carried on to better characterize the *HFO* properties:
  → ***Change gas mixture*** while keeping *HFO*
  → Studies on ***HF production*** under different ***flow conditions***