Studies on RPC detectors operated with environmentally friendly gas mixtures in LHC-like conditions

EP-DT
Detector Technologies

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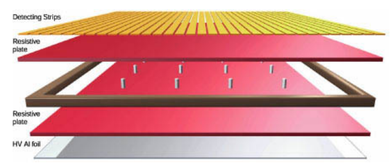
Resistive Plate Chambers at LHC

Resistive Plate Chambers (**RPC**) at LHC
- Used in **ALICE**, **ATLAS**, **CMS**
- Gas mixture based on ~ **95%** of **R-134a** (GWP = 1430)

European regulation F- gases of 2014
- **Limit** amount on on the market
- **Ban** use where eco-friendly alternatives are present
- **Require** proper checks on equipment

Availability and price evolution
- Availability of R-134a during Run 3 expected to be **33% of Run 2**
- Price increase of ~100% with respect to 2015

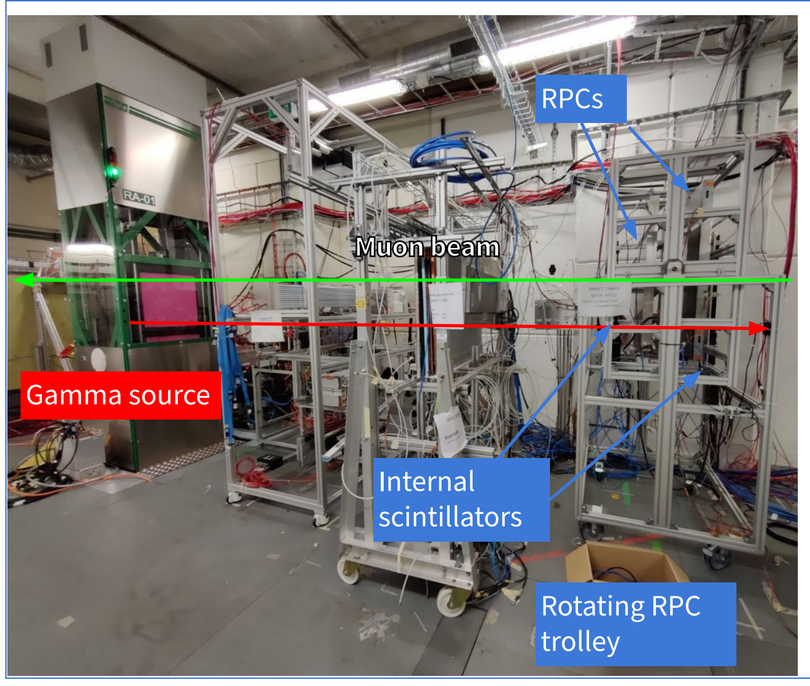


R-134a	i-C4H10	SF6
~95 %	~5 %	~0.3 %
GWP	GWP	GWP
1430	3.3	22800

GOAL:

Find lower-GWP gas mixture for RPC that requires no change in currents installations (HV, FEBs, gas systems)

Experimental Setup



Detectors
- HPL, 2 mm single gaps

Gas System
- LHC-like components
- Open/Closed loop modes

DAQ and monitoring
- CAEN V1730, 0.122 mV/ADC
- External + internal scintillators trigger
- Grafana monitoring dashboard

Analysis
- Raw waveform analysis
- HV scans at different ABSs for different gas mixtures

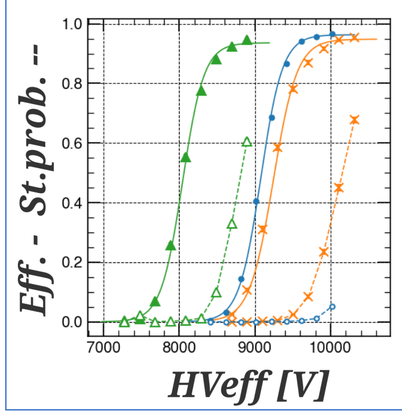
Alternatives to R-134a: tests with cosmics muons

R-1234ze as main R-134a alternative

- **Cannot be replaced 1:1**, working point too high
- Around ~ **70 % of CO2** needed to achieve w.p. of standard gas mixture
- When used with CO2, **R-1234ze** shows **higher currents** than the R-134a equivalent mixture

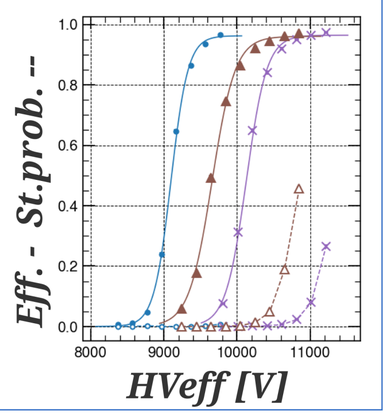
R1234ze + R-134a gas mixtures

- Working point higher than standard gas mixtures -> higher stress on electrical components
- Streamer contamination improved w.r.t. to HFO only gas mixture (<= 10% @ w.p.)



R-134a vs R-1234ze
- Std. gas mixture.
- 25% R-134a + CO2
- 25% R-1234ze + CO2

R134a + R-1234ze
- Std. gas mixture.
- R-134a/HFO + 40% CO2
- R-134a/HFO + 50% CO2

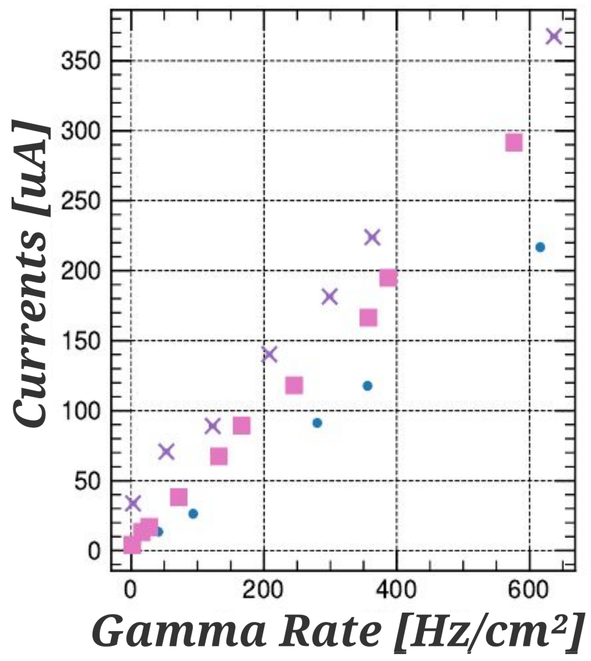


Alternatives to R-134a: tests in LHC-like conditions

RPC tested with **muon beam** and **gamma background**, up to **500-600 Hz/cm2** gamma hit rate

- Tested **R1234ze + R-134a** gas mixtures with CO2 and Helium
- **He**-based gas mixture shows **lower currents** than CO2 equivalent one
- Currents with both **He** and **CO2** are **higher** than **standard** gas mixture when evaluated at rates > 400 Hz/cm2

- Std. gas mixture.
- R-134a/HFO + 50% CO2
- R-134a/HFO + 30% He

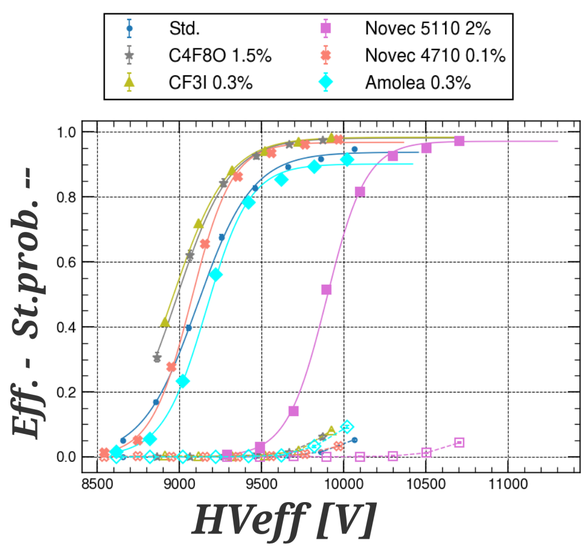


Alternatives to SF6

Laboratory tests

Tested alternatives

- **C4F8O**: discrete performance at 1.5%, but high GWP (~8000)
- **CF3I**: excellent performances at 0.3%, but mutagenic toxicity -> forbidden for LHC operation
- **Novec 5110**: discrete performances at 2% but almost liquid at ambient temperature
- **Novec 4710**: excellent performance at 0.1%. Further investigations needed to understand its reactivity with H2O
- **Amolea 1224yd**: good performances at 0.3%. Furhter tests needed to understand its impurities creation



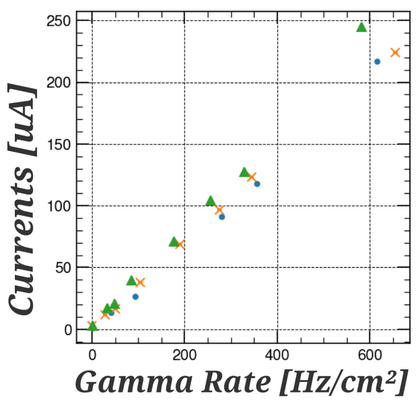
Novec 4710 and **Amolea 1224yd** tested with muon beam and gamma rate (~ 500 Hz/cm2)

- **Novec 4710** shows **excellent** performances at **0.1%**
- Novec 4710 at **0.3%** shows higher working point and **higher currents**

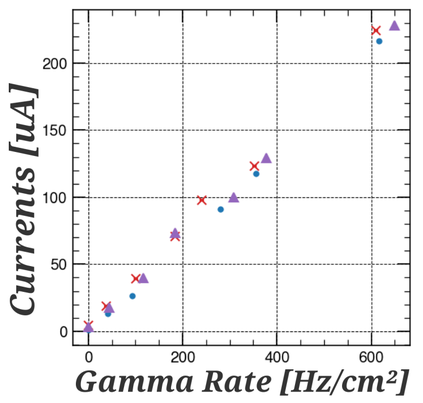
- **Amolea** shows **good** performances at **0.3%**
- Amolea tested at **0.5%**: no significant current increase but **working point ~ 250 V** higher than standard gas mixtures

LHC-like condition tests

- Std. gas mixture.
- 0.1% Novec 4710
- 0.3% Novec 4710



- Std. gas mixture.
- 0.3% Amolea
- 0.5% Amolea



Studies on impurities production

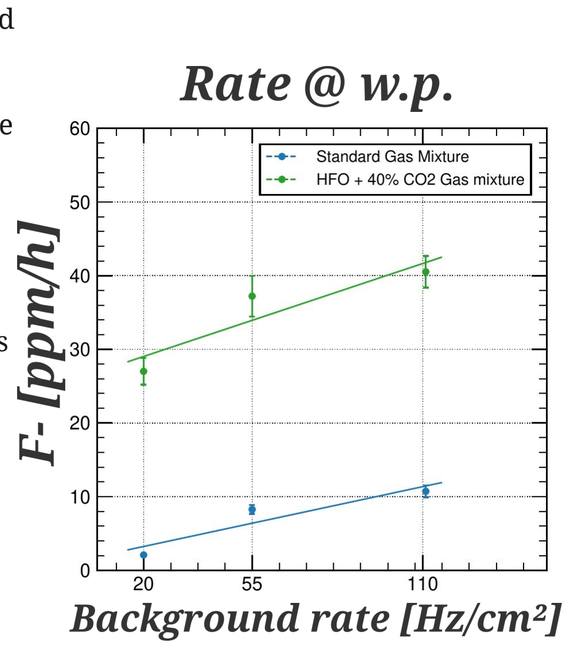
Freon molecules **breaking** under high electric field and gamma irradiation -> F- ions produced
F- combines with H2O -> **HF formation**
HF is an **aggressive** compound which may damage RPC inner surfaced -> it may affect **long-term performances**

F- production characterization

- Tested **std**. gas mixture and **HFO** gas mixture
- **RPC irradiated** at w.p. and different gamma rates
- **Gas** output analyzed with **Ion Selective Electrodes**

Results

- At fixed irradiation: F- linear with Currents
- F- production depends on the internal efficiency of the chamber
- **HFO** is **breaking** 10 times **more** easily than **R-134a**



Conclusions

- **Addition of CO2 or He required to lower w.p. when using HFO in the gas mixture**
  - 10% of CO2 lowers of 200 V and 10% of He of 600 V
- **He usage is still a matter of concern in LHC caverns: CO2 is preferable**
  - Presence of PMT in calorimeters
- **Higher concentrations (> 30-40%) of CO2 increases streamer contamination and currents**
  - Same applies for He
- **HFO shows higher currents than R-134a**
  - Streamer probability and cluster size are comparable
- **Addition of R-134a helps stabilizing performances in terms of currents and streamers**
  - Good compromise between safety-environment-performance
- **SF6 could be substituted by Novec 4710 or Amolea 1224yd**
  - Novec 4710 more electronegative than SF6, Amolea similar to SF6
- **Both SF6 alternatives requires more long term studies and characterization of their chemical reactivities**
  - Novec 4710 may react with water, while Amolea contains Chloride