Characterization of RPC Operation with Eco-Friendly Gas Mixture

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My studies: I’m a graduated physics student. Now I’m attending particle physics master courses.

My project here at CERN is about testing RPC performances with new eco-friendly gas mixtures, in order to reduce the greenhouse gas emissions coming from particle detectors.
A **Greenhouse gas (GHG)** is a gas that irradiates thermal energy, it **contributes** to cause the greenhouse effect.

**How to estimate emissions?**

**Global Warming Potential (GWP):** index of the energy absorbed by an emitted gas relative to CO$_2$ whose GWP is 1.

CERN strategy to **reduce GHG emissions**$^1$:

- Act directly on experiment’s leaks;
- Gas **recirculation** systems;
- Gas **recuperation** systems;
- Use of **new environmentally friendly gases**.

**RPC standard gas mixture:**

- 95.2% $C_2H_2F_4$, also called R134a (GWP 1430);
- 4.5% $iC_4H_{10}$ (GWP 3.3);
- 0.3 % $SF_6$ (GWP 22800).

$^1$ NIM A; R&D strategies for optimizing greenhouse gases usage in the LHC particle detection systems. R.Guida, B. Mandelli.

https://doi.org/10.1016/j.nima.2019.04.089
RPC (Resistive Plate Chambers)

**How it works:**
- Intense and constant electric field;
- Suitable gas mixture flowed inside;
- When a particle passes through, it produces primary ionization electrons which start a multiplication;
- The produced charge reaches the bakelite sheets inducing a signal on the readout strips.

**Main parameters:**
- Rate capability;
- Efficiency;
- Streamer probability;
- Time resolution (FWHM of the time distribution);
- Cluster size (Number of consecutive strips fired);

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**Graph:**
- Horizontal scale 20 ns/square
- Vertical scale 20 mV/square
GAS MIXING RACK
- Can mix up to 6 different gases;
- With MFC can measure precisely the gas flow.

RPCs SETUP
- 2 scintillators used as trigger for cosmics muon;
- 2 bakelite RPCs single gap (2mm).

GAS ANALYSIS
- Gas chromatograph and mass spectrometer (GCMS);

ACQUISITION SETUP
- Digitizer V1730 (2Vpp, 500 MS/s, 14 bit);
- Coincidence measures system.
I’ve also taken into account **two different signal analysis**, one using **ROOT with C++** and the other using **Python**, and I compared them:

1. Deeply understand RPC signal analysis;
2. Adapt the two scripts to receive the same input data;
3. Compare their outputs underlining the differences;
4. Modify one of the two script while the other one is better;
5. Rewrite the algorithm when, for few events, both software fails(*)

(*) An example:

Consecutive fired strips = 2

Output script A = 7
→ Noise counted as signal.

Output script B = 1
→ Undershoot hides the fuchsia signal.
**GOAL**

Test RPCs performances using new gas mixtures with eco-friendly components.

[Ongoing] HFO instead of R134a long term stability measurements are giving first promising results².

[Ongoing] C₄F₈O gas instead of SF6 (current work);

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The high-luminosity LHC (HL-LHC), with the increasing luminosity, will produce higher particle background.

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At Gamma Irradiation Facility (GIF++), located in H4 beam line in EHN\textsubscript{1}, studies of long term detector response under high irradiation condition.

Measure of long term aging for 2 RPCs with HFO standard mixture, irradiated with:

- 13.2 TBq source of $^{137}$Cs (662 keV gamma);
- Up to 100 GeV muon beam.

Measurements seem to show a RPC current variation before and after the irradiation.

What’s going on?
Wanting to investigate a possible current recovery:

1. Bring the two RPCs in lab256 without irradiation;
2. The RPCs are maintained switched on with different flow and voltage conditions;
3. Take current scan day by day.

- High raise of current few days later the irradiation;
- Currents lower with time;
- Better recovery indexes for higher flows and voltages;
- Weak dependence on temperature and pressure.
Outlooks:
- Improve the signal analysis software, correcting it, adding new features and making it more efficient;
- Take more data with HFO gas mixture at GIF++, trying to understand current behaviour and to find best recovery conditions;
- Analyse $\text{C}_4\text{F}_8\text{O}$ data and try new eco-friendly gases instead of SF$_6$ (Ongoing measurements and analysis).

What I learned here:
- Working with other people in a team, operating together, sharing ideas, reporting my progresses to my supervisors and learning a lot by them;
- Improving my confidence with programming languages (ROOT, Python);
- Increasing my manual and theoretical knowledge in the field of electronics (installing and using modules, installing and programming sensors, ...);
- Learning about gaseous detectors (especially RPCs and GEM);
- Acquiring information on the job on gas systems, their singular components and how to properly treat gases.

A special thank to my supervisors