Characterization of RPC Operation with Eco-Friendly Gas Mixtures

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

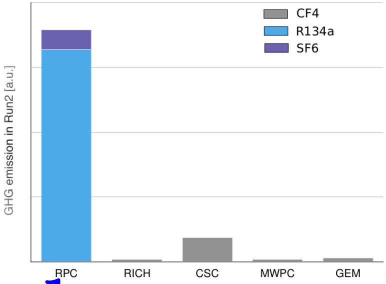
My project here at CERN is about testing RPC performances with **new eco-friendly gas mixtures**, in order to **reduce the greenhouse gas emissions** coming from particle detectors.

What are greenhouse gases?

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.



RPC systems (used in ATLAS, CMS, ALICE) **have the highest LHC GHG emissions** principally due to **detector leaks** (Under repair now).

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**.

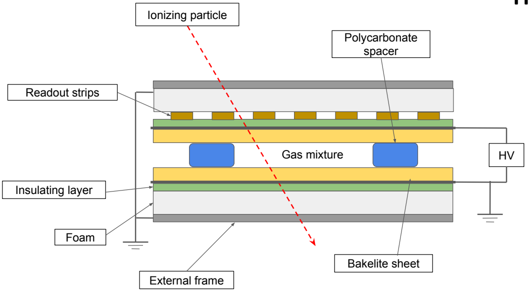
MY WORK

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

CERN EP-DT Detector Technologies

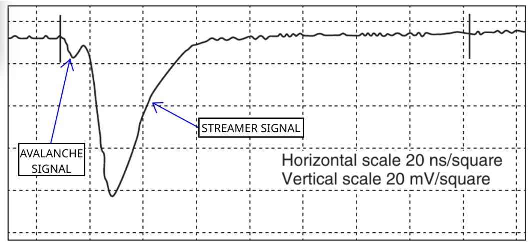


How it works:

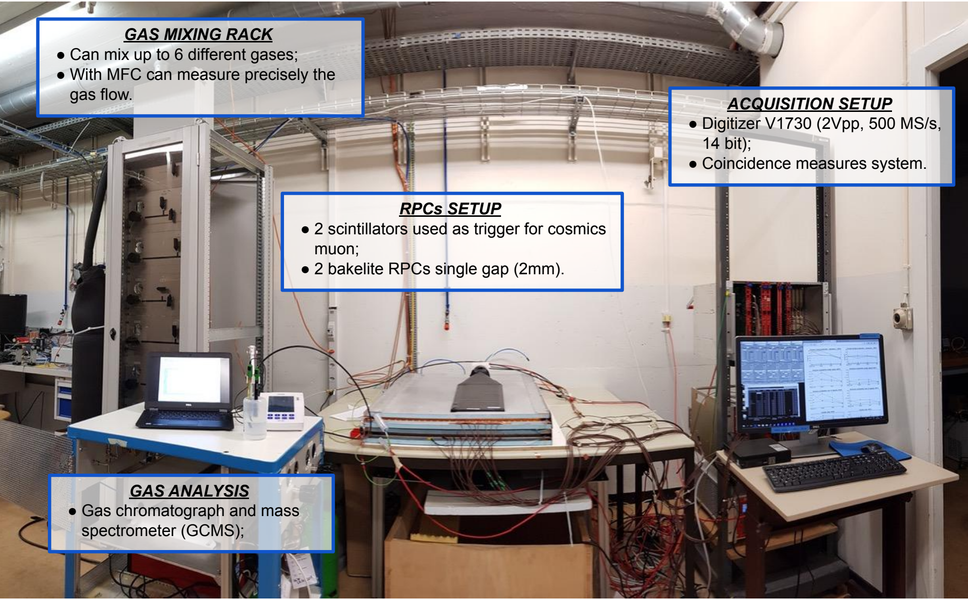
- Intense and constant electric field;
- Suitable gas mixture flowed inside;
- When a particle passes through, it produces primary ionization electrons which start a multiplication;
- The produced charge reaches the bakelite sheets inducing a signal on the readout strips.

Main parameters:

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



Setup at lab256



GAS MIXING RACK

- Can mix up to 6 different gases;
- With MFC can measure precisely the gas flow.

ACQUISITION SETUP

- Digitizer V1730 (2Vpp, 500 MS/s, 14 bit);
- Coincidence measures system.

RPCs SETUP

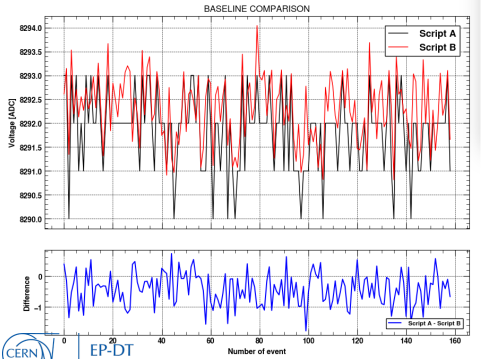
- 2 scintillators used as trigger for cosmics muon;
- 2 bakelite RPCs single gap (2mm).

GAS ANALYSIS

- Gas chromatograph and mass spectrometer (GCMS);

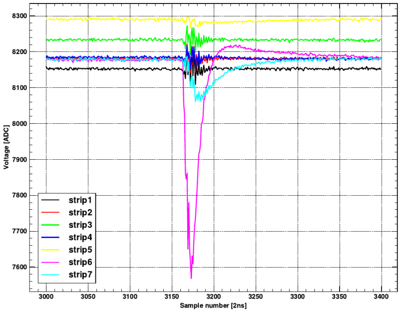
I've also taken into account **two different signal analysis**, one using **ROOT with C++** and the other using **Python**, and I compared them:

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.

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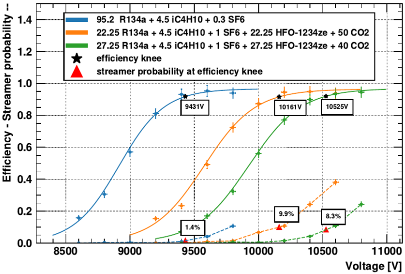
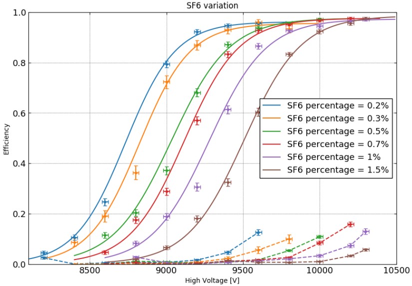
GOAL

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

[Ongoing] **HFO instead of R134a** long term stability measurements are giving first promising results[2].

[Ongoing] **C_4F_8O gas instead of SF6** (current work);





2. NIM A; Performance studies of RPC detectors with new environmentally friendly gas mixtures in presence of LHC-like radiation background. R. Guida, B. Mandelli, G. Rigoletti. https://doi.org/10.1016/j.nima.2019.04.027

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

$\Downarrow$

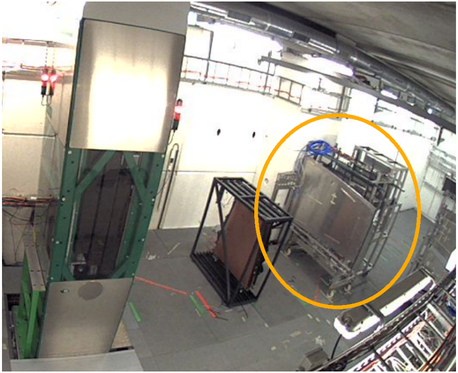
At Gamma Irradiation Facility (GIF++), located in H4 beam line in EHN_1, studies of long term detector response under high irradiation condition.

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 seems to show a **RPC current variation before and after the irradiation**.

What's going on?



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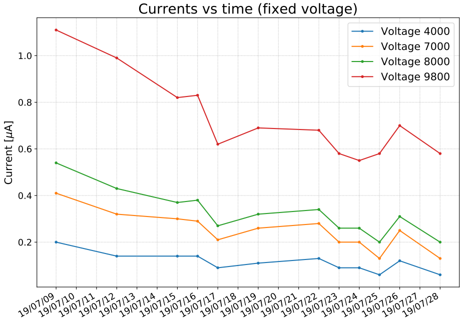
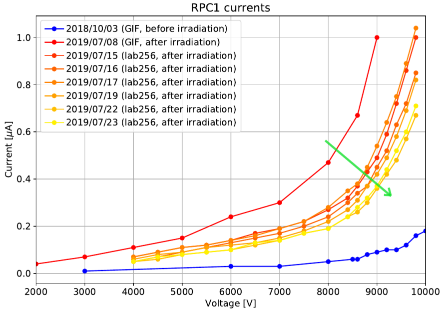
Wanting to **investigate a possible current recovery**:

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.

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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 C_4F_8O 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