RPC EcoGas@GIF++ setup

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Overview

- The ECOgas@GIF++ collaboration and its aims
- Experimental setup
- Aging studies and ISE measurements
- Beam tests results
- Conclusions and future plans

Why ecogas for RPCs?

- RPCs employ gas mixtures containing a high fraction (> 90%) of fluorinated gases ($C_2H_2F_4$ and SF_6) with high Global Warming Potential (GWP)
  - $C_2H_2F_4$ ~ 1430, SF_6 ~ 22800
- EU regulations imposed a progressive phase down of F-gases production and usage
- Search for more eco-friendly gas mixtures for RPCs
- R&D campaign started by replacing $C_2H_2F_4$ with a combination of $C_3H_2F_4$ (**HFO**, GWP ~ 6) and **CO_2**

[1]GWP = measure of how much heat is trapped by a ton of gas if compared to a ton of CO_2 in a 100-years period (GWP CO_2 = 1 by definition)

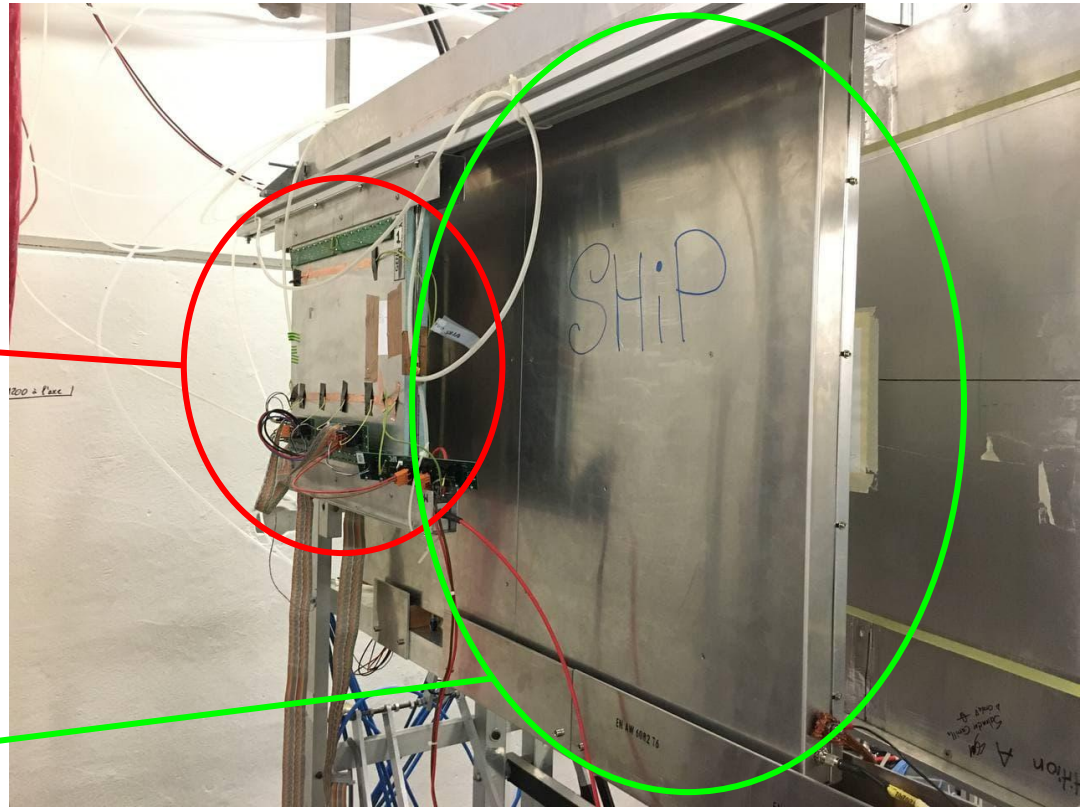
The ECOgas@GIF++ collaboration

- Collaboration among several groups (ALICE, ATLAS, CMS, EP-DT and SHiP/LHCb)
- Dual aim of the collaboration:
  - Long-term stability studies under irradiation
  - Performance studies in beam tests
- Each group provided RPC prototypes to be tested
- Common effort for manpower, resources and materials
- Different bakelite production, electrode thickness and gas gap thickness
- Project supported by the Aida Innova project (task 7.2)

The setup - Trolley 1

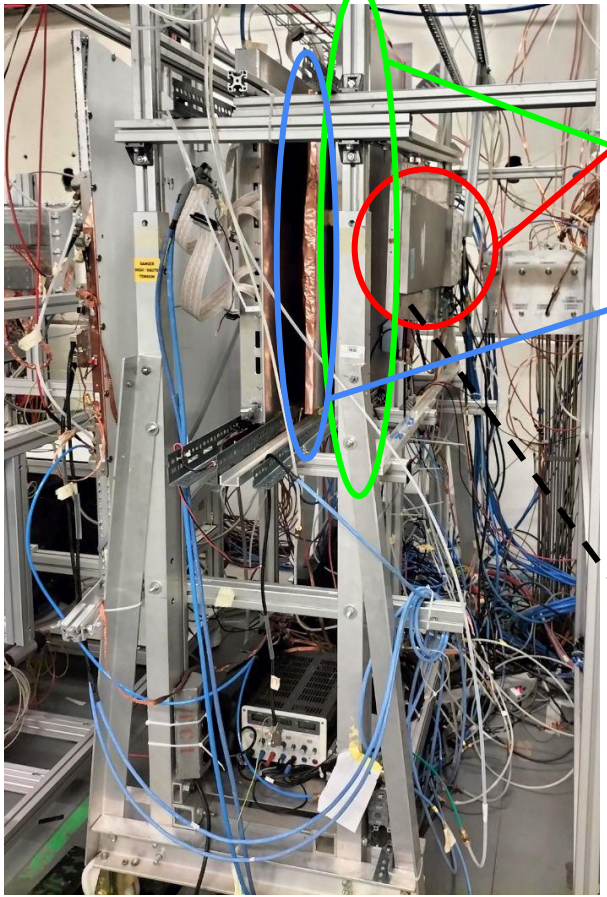
ALICE RPC:
-50x50 cm^2
-2 mm thick bakelite electrodes
-2 mm single gas gap
-2D readout, 16 strips per plane
-Strip pitch ~ 3 cm
-TDC or digitizer readout

SHiP/LHCb RPC:
-70x100 cm^2
-1.6 mm thick bakelite electrodes
-1.6 mm single gas gap
-2D readout, 32 strips per plane
-Strip pitch ~ 1 cm
-TDC readout



Picture of trolley 1 - Upstream - 6 m from the source

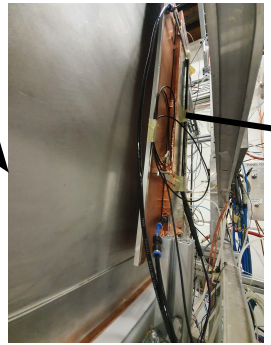
The setup - Trolley 3



CMS RE1_1 RPC:
-2 mm thick bakelite electrodes
-2 mm double gas gap
-1D readout, 128 strips
-Strip pitch ~ 1.2 cm
-TDC readout

Bari-1p0
-1 mm thick bakelite electrodes
-1 mm single gas gap
-1D readout, 32 strips
-Strip pitch ~ 1.27 cm
-TDC readout
70x100 cm^2

EP-DT RPC:
-70x100 cm^2
-2 mm thick bakelite electrodes
-2 mm single gas gap
-1D readout, 7 strips
-Strip pitch ~ 2.1 cm
-Digitizer readout



ATLAS (small) RPC*:
-10x50 cm^2
-1.8 mm thick bakelite electrodes
-2 mm single gas gap
-1D readout, 1 strip (3 cm thick) + confirmation scintillator on RPC
-Digitizer readout

Picture of trolley 3 - Upstream - 3 m from the source

Gas mixtures tested during beam time

- ATLAS/CMS standard gas mixture:

  95.2% $C_2H_2F_4$, 4.5% i-C_4H_{10}, 0.3% SF_6 -> GWP ~ 1430

- ECOmix 2:

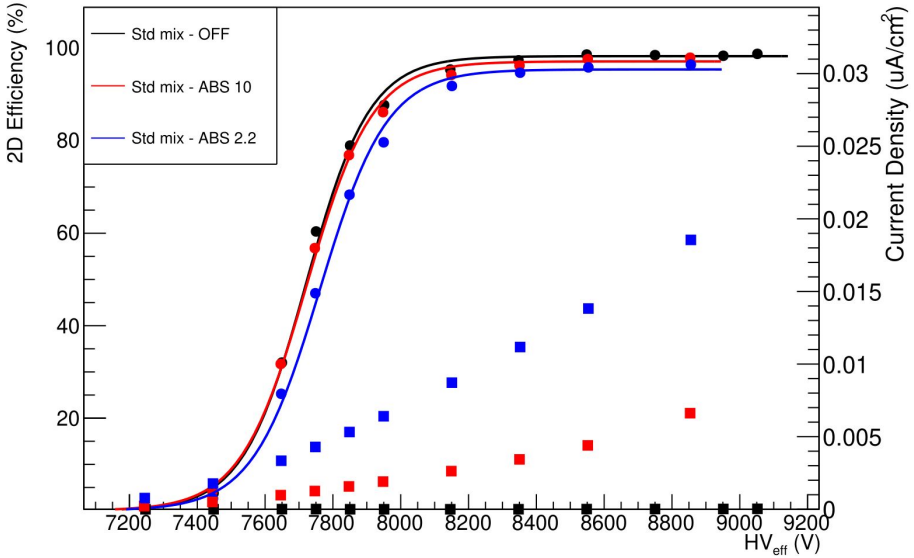
  35% HFO, 60% CO_2, 4% i-C_4H_{10}, 1% SF_6 -> GWP ~ 230

- ECOmix 3:

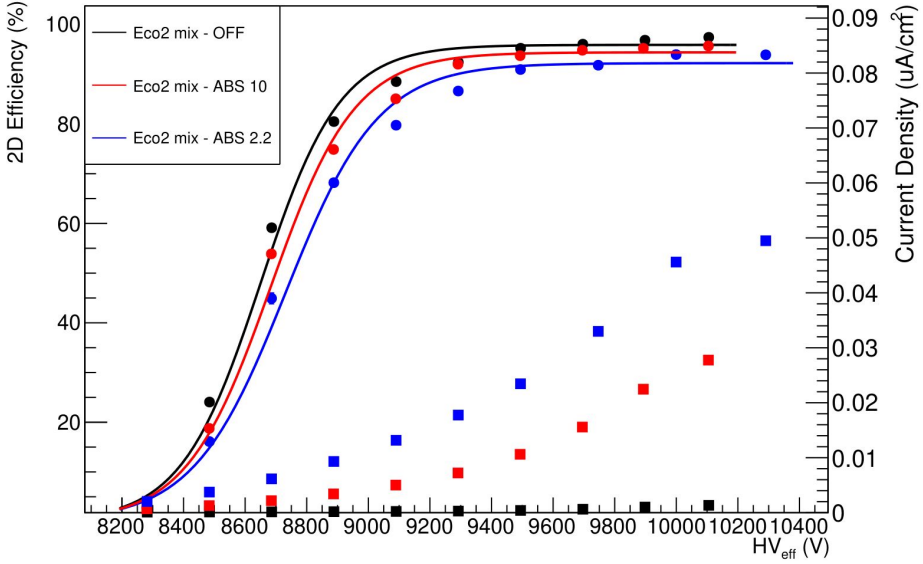
  25% HFO, 69% CO_2, 5% i-C_4H_{10}, 1% SF_6 -> GWP ~ 230

Long term irradiation campaign - 1

- Irradiation campaign with ECO2, since it showed better performance in beam test, with all RPCs
  - Current stability and resistivity monitored over time
- Problem
  - Currents are much higher with ecogas wrt standard gas mixture



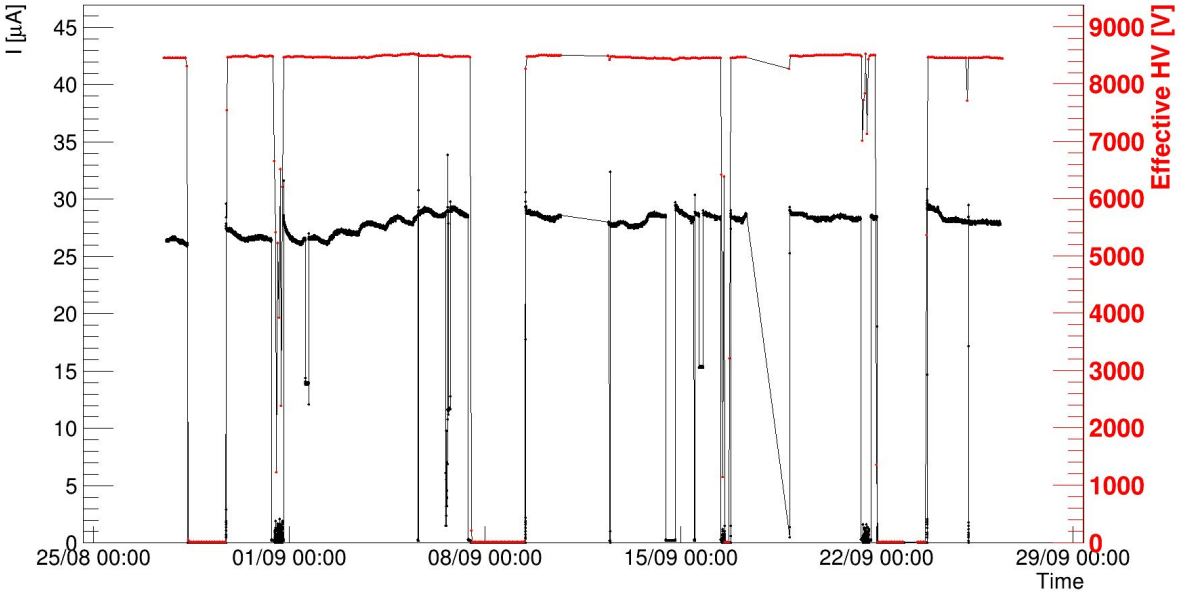
Standard gas mixture



ECO2 gas mixture

Long term irradiation campaign - 2

- Solution
  - For preliminary aging studies we irradiate at 50% efficiency
  - Results shown for SHiP RPC, 1.6 mm single gas gap -> 8.7 kV corresponds to 50% efficiency at 2.2

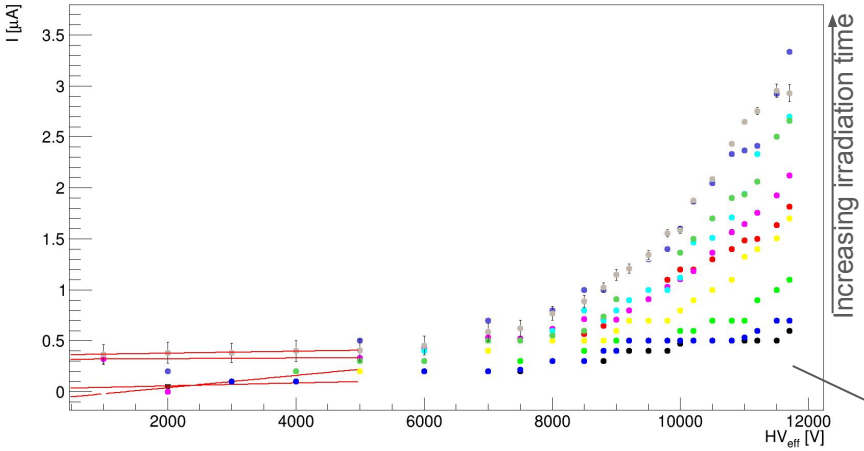


Trend of absorbed current by the SHiP RPC - 1.6 mm single gas gap

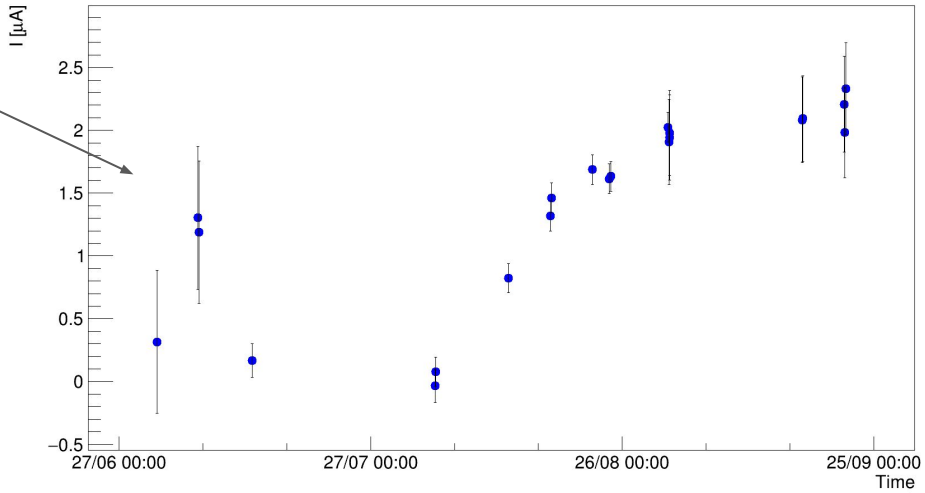
- Weekly source off current scans
  - Monitor dark current stability
- Once every two months
  - Ar is flushed into the RPCs to measure resistivity

Long term irradiation campaign - 3

- Source off weekly scans results



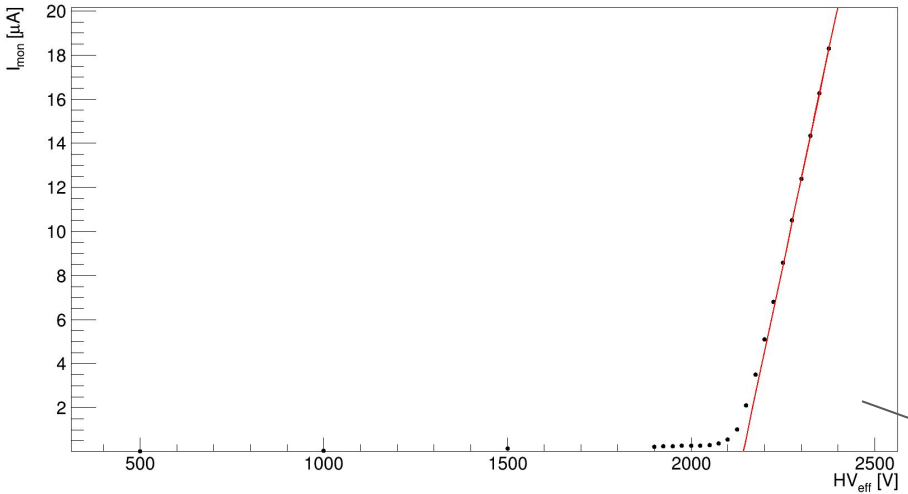
- Ohmic part of the dark current estimated at working point - linear fit of the curves from 0-4 kV



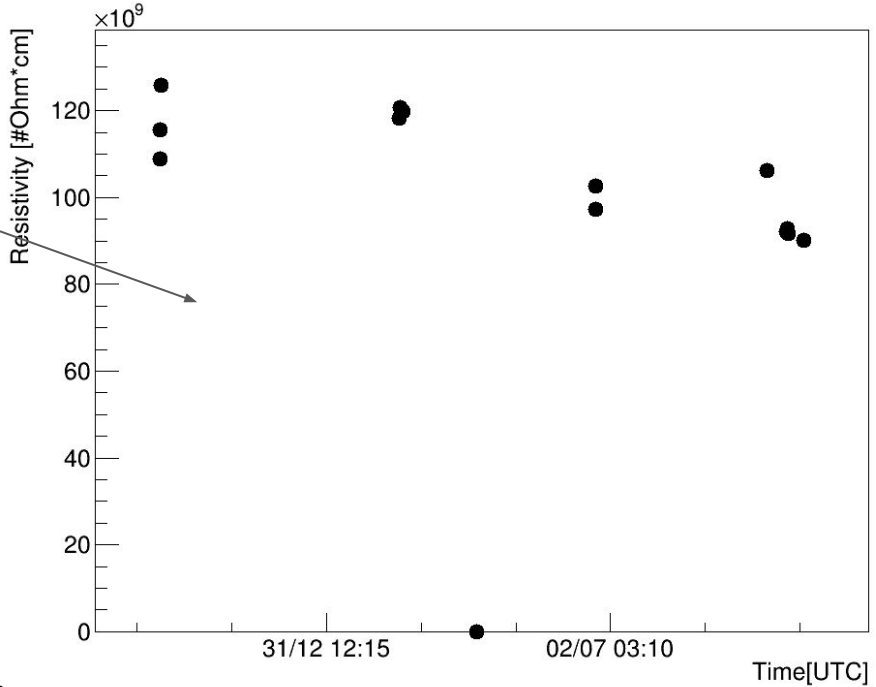
- Subtracted to get the real physics current at working point
- Plotted as a function of time

Long term irradiation campaign - 4

- Resistivity trend in time



- When flushed with pure Ar
  - Plasma is created inside the gap
  - Short circuit between the two bakelite layers
  - Ohmic trend of the current



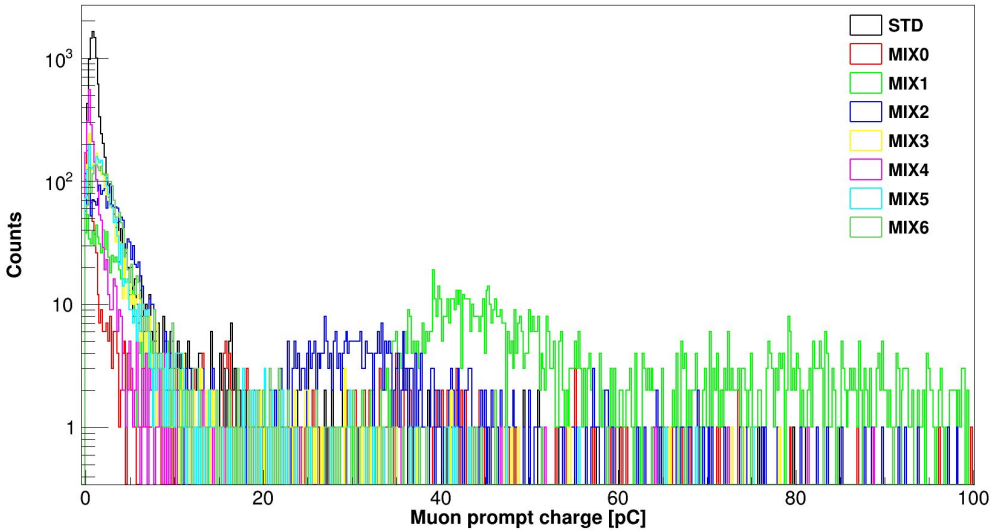
- Slope of the fit = 1/R
- Resistivity = R*S(surface)/2d(electrode thickness)

Beam test preliminary digitizer studies

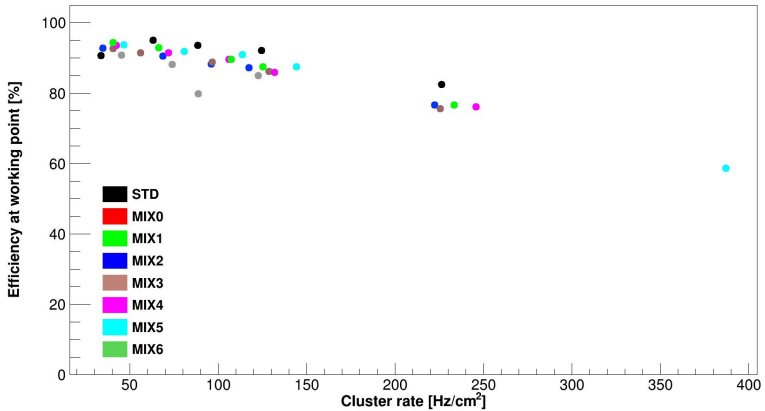
- ALICE RPC equipped with digitizer readout
  - 7 mixtures tested, changing CO_2/HFO ratio from 95/0 to 55/40
  - Source OFF and under irradiation - analysis still ongoing, preliminary results

Mixture	R134a (%)	HFO (%)	CO2 (%)	i-C4H10 (%)	SF6 (%)
STD	95.2	0	0	4.5	0.3
MIX0	0	0	95	4	1
MIX1	0	10	85	4	1
MIX2	0	20	75	4	1
MIX3	0	25	69	5	1
MIX4	0	30	65	4	1
MIX5	0	35	60	4	1
MIX6	0	40	55	4	1

Mixtures tested



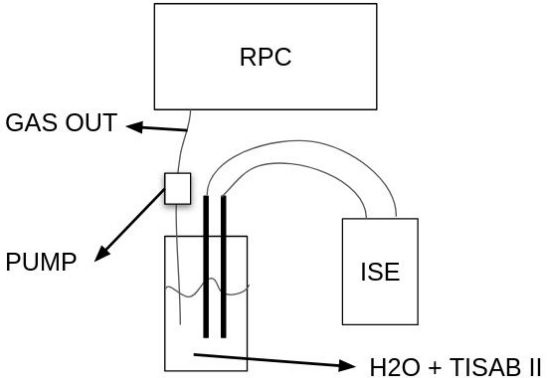
Muon prompt charge spectra for different eco-friendly gas mixtures



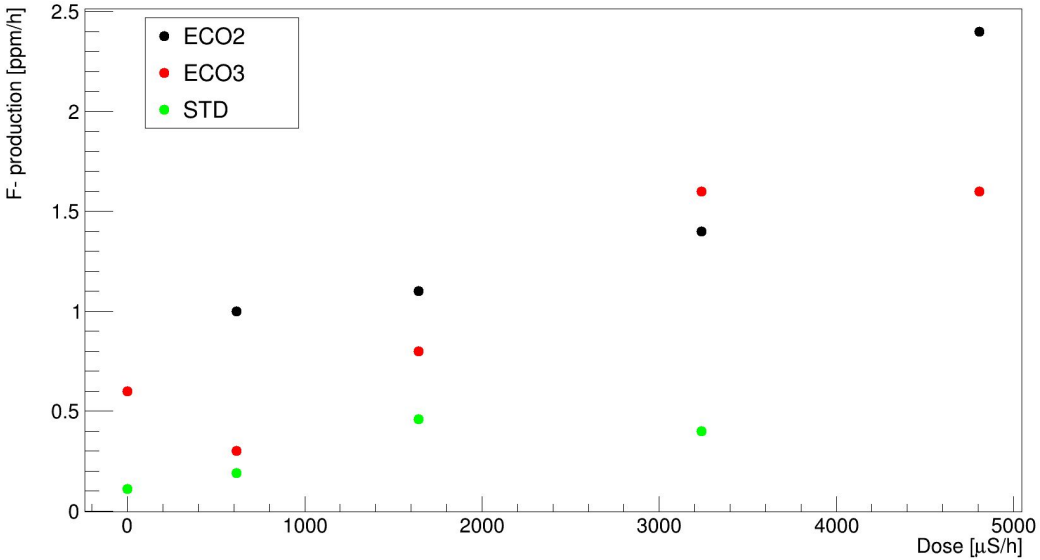
Efficiency drop at working point for different eco-friendly gases

ISE measurement - preliminary

- Presence of fluorine in the gas mixtures
  - Gas radiolysis under irradiation
  - F^- ions could combine with H_20 (humidified gas mixture)
  - Production of HF that could damage the bakelite



ISE measurement setup



F^- ions production as a function of the instant dose rate

- Ion Selective Electrode (ISE) measurements to quantify the production of F^- ions
  - Output gas is bubbled in distilled water + TISAB II
  - Continuous measurement of F^- ions concentration
  - Production in ppm/h estimated
  - Hints to higher production for eco-friendly gases

Conclusions

- Ongoing R&D campaign for $C_2H_2F_4$ replacement with $C_3H_2F_4$ + CO_2 in RPC gas mixture
  - April-May 2022 beam time R&D studies with ALICE RPC and digitizer readout
  - July 2022 beam time to re-validate last year results (STD+ECO2+ECO3)

- Irradiation campaign with ECO2 is currently ongoing
  - Seems stable so far (to be investigated further since we are irradiating at 50% efficiency)

- Preliminary ISE measurement shows increase F^- ions production with eco-friendly gases
  - To be investigated further

- R&D study on a few eco-friendly mixtures with digitizer:
  - Varying CO_2/HFO ratio from 95/0 to 55/45
  - Data needs further analysis
  - Study of charge spectra could reveal interplay of CO_2 and HFO

Future plans & requests

- Aging campaign currently ongoing with ECO2 gas mixture (60% CO_2 and 35% HFO)

- Possibly perform new and more systematic ISE measurement for HF production

- **Request from ECOgas**:
  - We would like to have a dedicated HFO line
    - Up to now we use small bottles placed in the gas room
    - Frequent replacement (every 3 weeks or so) with risk of leaks and always require a person on site for the change
  - We would like to install two RadMon sensors on our trolleys to measure the instant dose rate to have a measure of the real radiation to which we are exposing the detectors

Thank you for your attention!