ECOgas@GIF++ setup

Luca Quaglia[1] on behalf of ECOgas@GIF++ collaboration

[1]University and INFN TORINO

Overview

- The ECOgas@GIF++ collaboration and its aims
- Experimental setup
- Beam tests preliminary results
- Other activities @ GIF++
- 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[1] (GWP)
  - ➢ $C_2H_2F_4$ ~ 1430, SF_6 ~ 22800
- EU regulations imposed a progressive phase out 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**

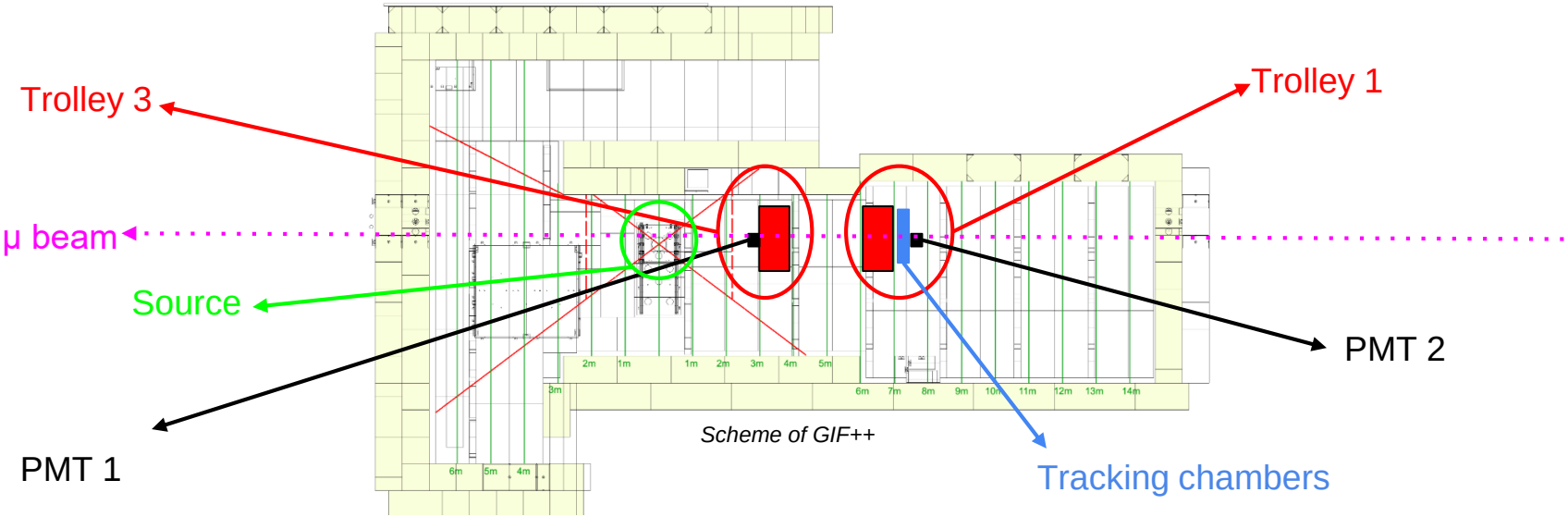
[1]GWP = measure of how much heat is trapped by a ton of gas if compared to a ton of CO_2 in a 100-years period (GWP CO_2 = 1 by definition)

The ECOgas@GIF++ collaboration

- Collaboration among several groups (ALICE, ATLAS, CMS, EP-DT and SHiP/LHCb)
- Each group provided RPC detector(s) to be tested
- Common effort for manpower and resources
- Different bakelite production, electrode thickness and gas gap thickness
- Long term aging campaign is ongoing @ GIF++ following promising lab results with cosmics
- Two eco-friendly gas mixtures have been tested during the 2021 beam periods

Beam test setup - General

- RPCs are hosted on two CMS-RPC trolleys (**Trolley 1** and **Trolley 3** in the following)
- Located upstream of the source (~ 3 m trolley 3 and 6 m trolley 1)
- **Beam trigger** provided by the coincidence of two 10x40 cm^2 scintillators (perpendicular to the beam and to each other) with the external ones (10x10 cm^2 effective area)
- **Tracking** provided by two CMS RPCs with orthogonal strips behind trolley 1

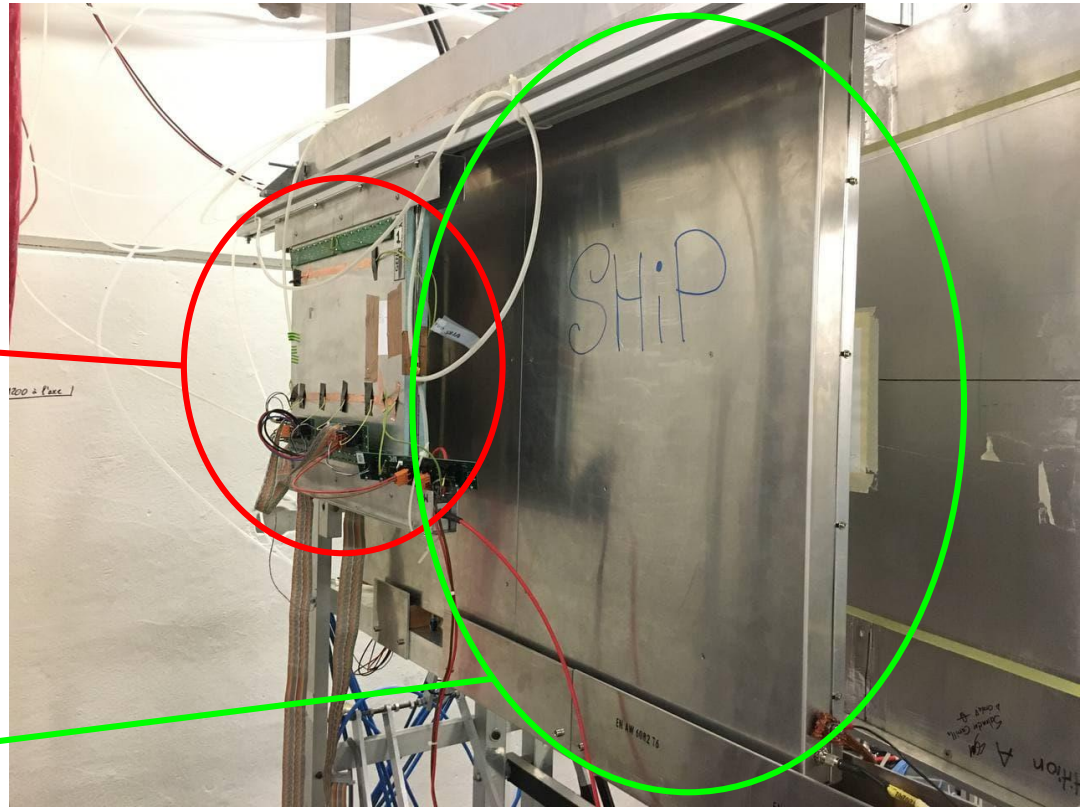


Scheme of GIF++

The setup - Trolley 1

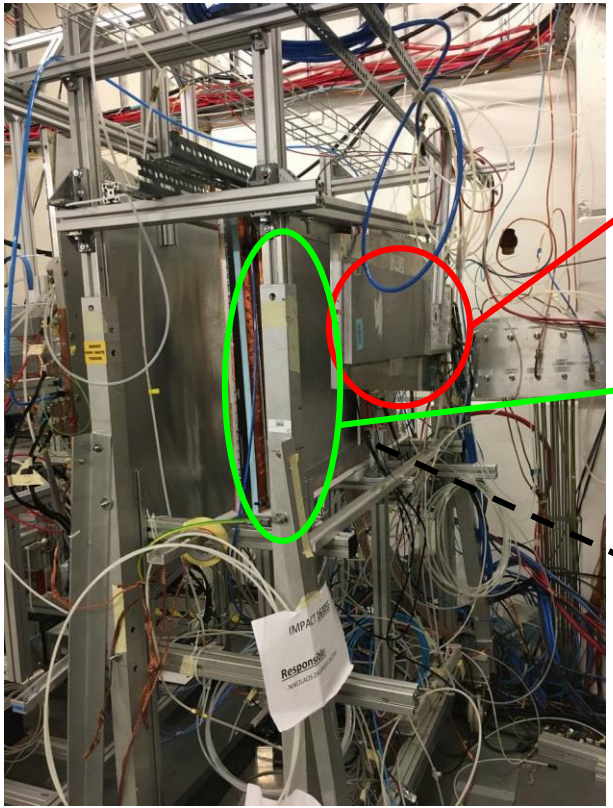
ALICE RPC:
-50x50 cm^2
-2 mm thick bakelite electrodes
-2 mm single gas gap
-2D readout, 16 strips per plane
-Strip pitch ~ 3 cm
-TDC readout

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

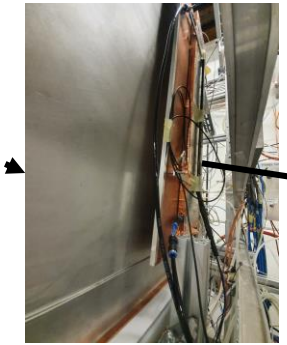
The setup - Trolley 3



Picture of 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

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

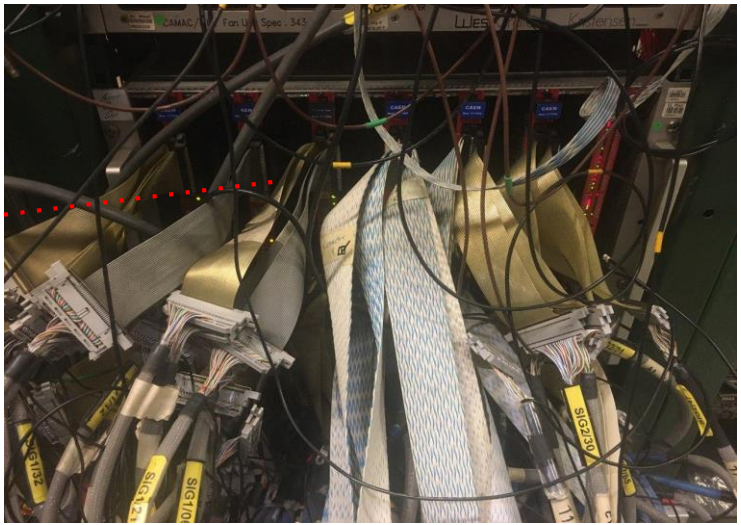


ATLAS (small) RPC*:
-10x50 cm^2
-1.8 mm thick bakelite electrodes
-2 mm single gas gap
-1D readout, 1 strip (3 cm thick) + confirmation scintillator on RPC

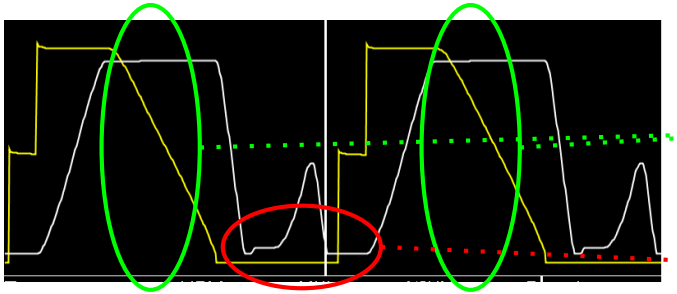
*ATLAS upgrade RPC also tested with ecogas discussed in Giulio's talk

TDC Dual-Readout (ALICE, CMS, SHiP/LHCb)

- 6 TDCs (CAEN V1190) in VME crate (rack area)
- 1 VME-USB bridge
- 10 RPCs (DAQ system shared with CMS-RPC setup)
- 768 total channels
- 1 common DAQ with web interface (webdcs)



TDCs in VME crate



SPS cycle

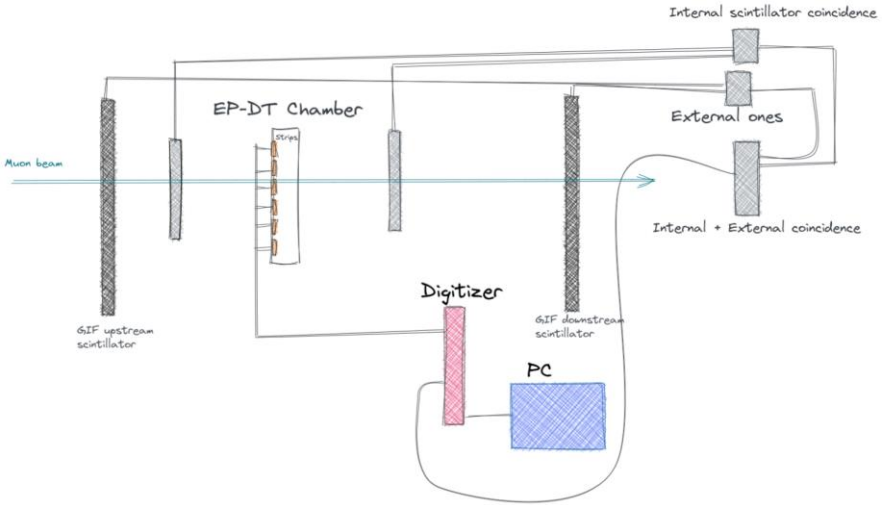
During spill (SPS spill signal active): PMT trigger, muon data

Outside spill (SPS spill signal inactive): random trigger, rate data

Dual-Readout

Digitizer readout (EP-DT, ATLAS)

- EP-DT: Digitizer in the rack inside the bunker
- ATLAS: Digitizer in the rack area
- Signal taken directly from the strips (50-Ohm terminated)
- Full waveform digitized



Scheme of digitizer DAQ

- EP-DT DAQ steps:
  - Long autotrigger acquisition (1.2 ms window) for rate measurements
  - Shorter PMT-triggered window for efficiency measurements

Gas mixtures tested during beam time

- ATLAS/CMS standard gas mixture (July + September + October):

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

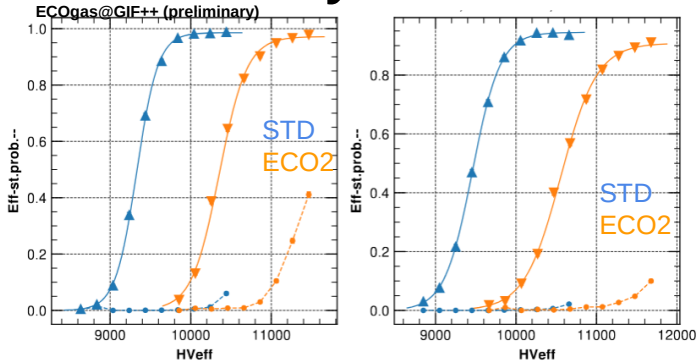
- ECOmix 2 (July + September + October):

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

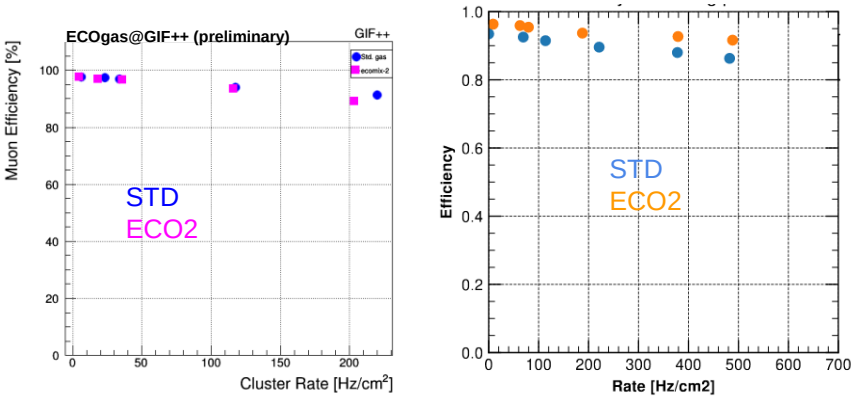
- ECOmix 3 (October):

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

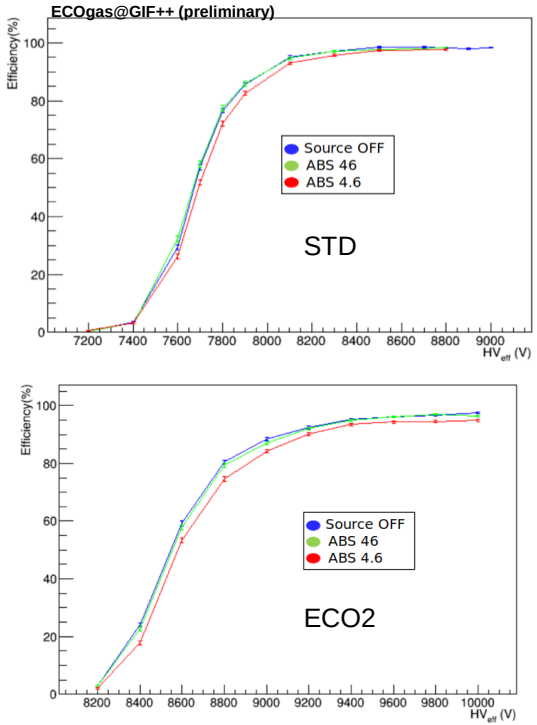
Preliminary TB results (1)



Efficiency curves for source OFF (left) and source ON (right-350 Hz/cm^2) for 2 mm gap

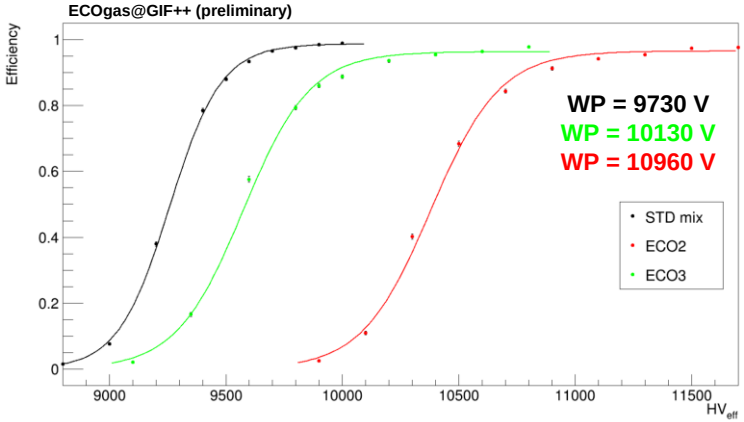


Drop of efficiency at the working point for STD and ECO2 for 2 mm gap
Left is readout by TDC, right by digitizer

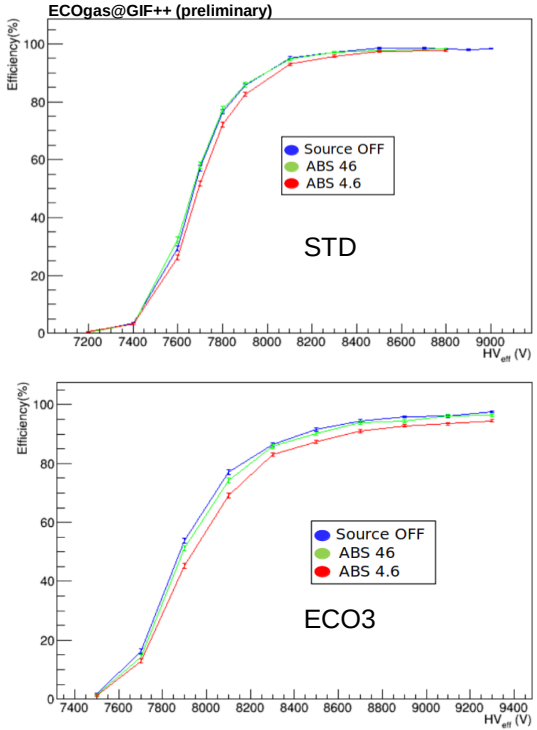


2D efficiency for 1.6 mm gap with STD (top) and ECO2 (bottom) at different ABS

Preliminary TB results (2)



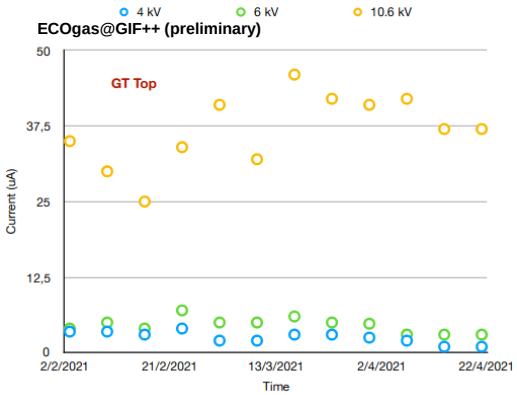
Efficiency curves for the three tested mixtures (source OFF 2 mm gap)



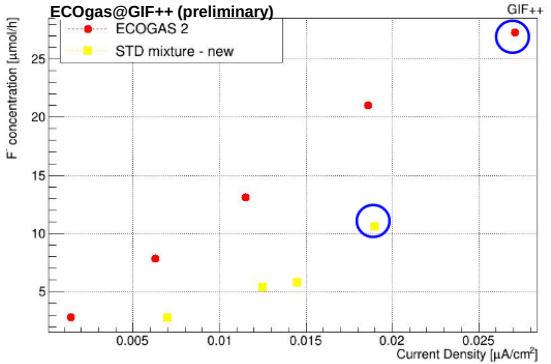
2D efficiency for 1.6 mm gap with STD (top) and ECO3 (bottom) at different ABS

Other activities

- Irradiation campaign with ECO2 with EP-DT and CMS RPCs
  - Issues with other chambers and lack of manpower (COVID) to replace them
  - Current stability monitored over time
- Remote weekly shifts to monitor the system
  - Humidity check, data logging and weekly current trend
- First F^- ions production campaign to compare ECO2 and STD



Trend of absorbed current during irradiation



F^- ion production as function of current density

Conclusions

- Ongoing R&D campaign for $C_2H_2F_4$ replacement with $C_3H_2F_4$ + CO_2 in RPC gas mixture
- Irradiation campaign with ECO2 before the TB
  - Detector stability, chosen for beam test
- Two mixtures tested during beam time:
  - ECO2
    - Satisfactory values of efficiency reached
    - Working point shifted by ~ 1 kV to higher voltage wrt STD gas mixture (observed with cosmics and confirmed by TB)
    - Efficiency drop 2% larger for same rate wrt STD
  - ECO3
    - WP shifted by ~ 0.5 kV wrt STD (Very preliminary)
    - Slightly larger efficiency drop wrt ECO2
    - In-depth analysis ongoing

Future plans & requests

- New ISE measurements campaign for fluoride production (with all three mixtures) starting from next week

- New irradiation campaign will start after complete analysis of TB data and after the GIF++ Christmas break

- **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

Thank you for your attention!

BONUS - Beam profile with tracking RPCs