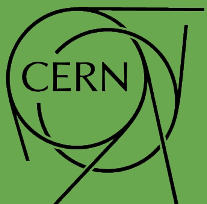


CMS GAS SYSTEM R&D

R. Guida, B. Mandelli, A. D'Auria, M. Corbetta



EP-DT
Detector Technologies

OUTLOOK

- ❑ **Gas Recuperation Plant**
 - ❑ CF4 Recuperation - CSC
 - ❑ R134a Recuperation - RPC
- ❑ **RPC Distribution Regulation Valves**
- ❑ **RPC Dummy Chambers**
- ❑ **RPC Ecogas**

GAS RECUPERATION

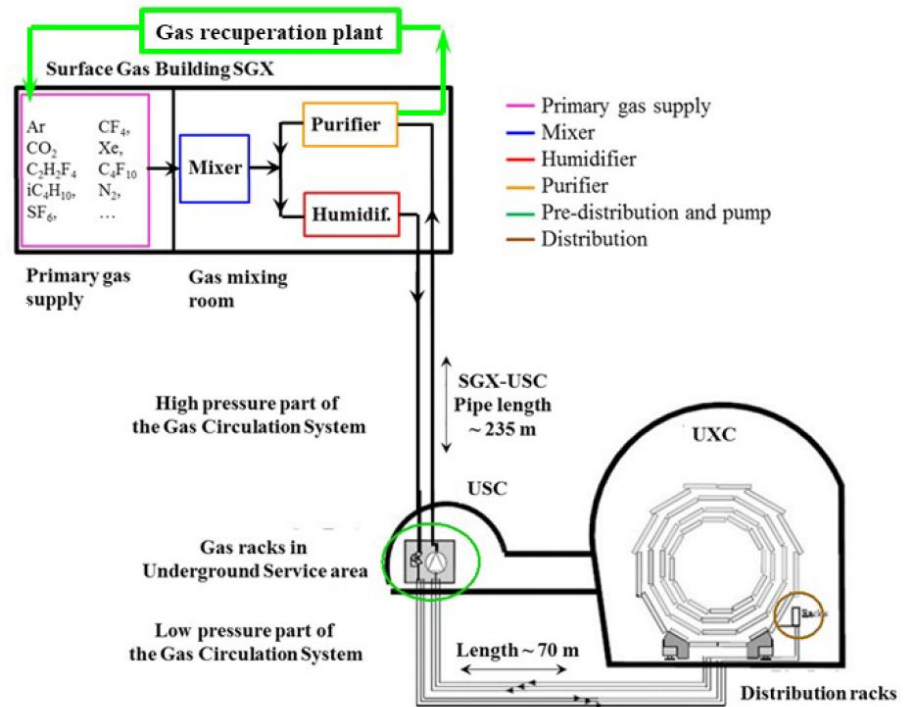
Several LHC gas system are already using recuperation plants

→ PROS

- ◆ Further reduction in gas consumption
- ◆ Level of N₂ impurities under control
- ◆ Operation at lower detector pressure

→ CONS

- ◆ Additional complexity of the gas system
- ◆ Dedicated R&D
- ◆ Gas mixture monitoring necessary



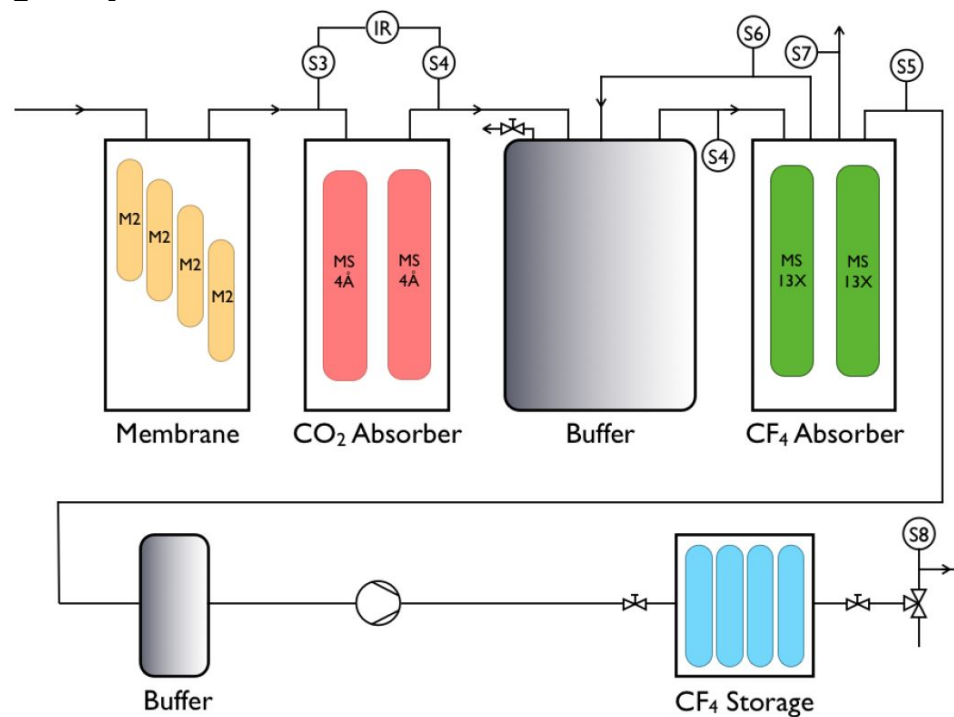
CF₄ RECUPERATION - CSC

- **The technical challenge:**

- It is the first plant built for CF₄ warm adsorption
- It is a completely non-standard gas system

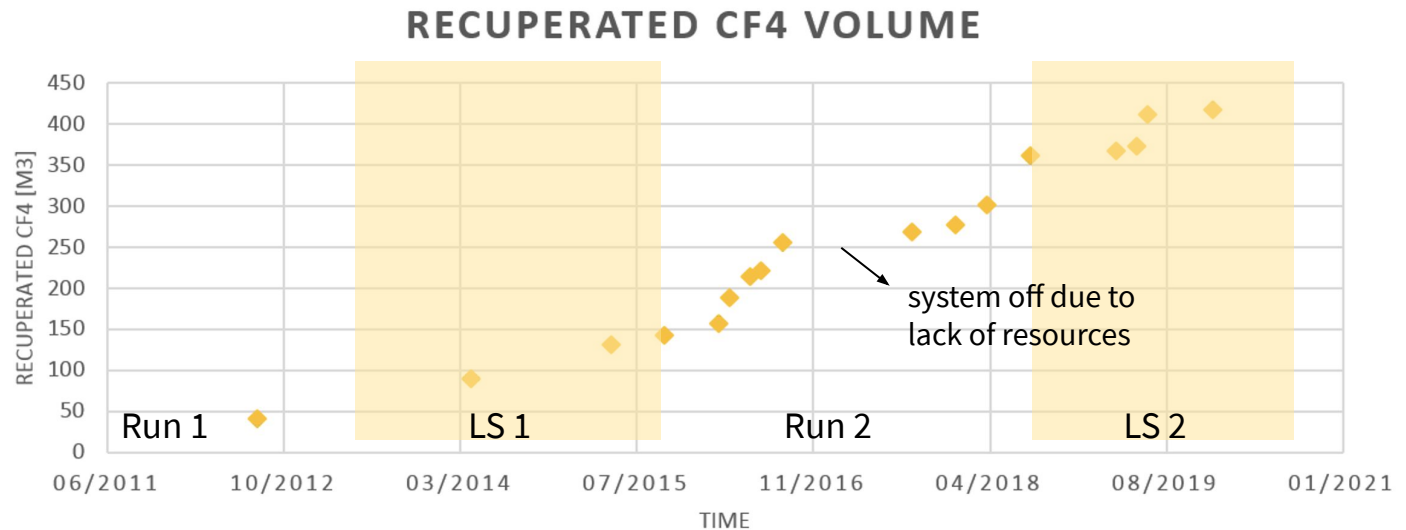
- **The modules:**

- Input to plant
- Membrane separation module
- CO₂ adsorption module
- CF₄ adsorption module
- CF₄ compression module
- Recuperated CF₄ injection m
- Infrared analysis module
- SWC monitoring module



CF₄ RECUPERATION - CSC

- **STATUS:** in operation since 2012, a lot of tuning/upgrades done
- **420 m³** of recuperated CF₄ (eq. to 1 year of operation at 10%)
50k Chf at today price, 200 kChf at 2010 price ...
- **Recuperation efficiency** improved : today **60%**
- CF₄ consumption reduced by 40% starting from 2018



CF₄ RECUPERATION - CSC

→ INPUT TO PLAN:

- ◆ Ok for operation
- ◆ **Plant input flow affects recuperation efficiency:**
compromise between CSC Gas System operation and Exhaust flow stability

→ MEMBRANE FOR SEPARATION MODULE:

- ◆ Working with good efficiency (~ 70%)
- ◆ Installation of new flowmeters
- ◆ Test new High Sensitivity membrane

→ CO₂ ADSORPTION MODULE:

- ◆ Ok for operation

→ CF₄ ADSORPTION MODULE:

- ◆ Leak in column B, maintenance necessary > 1 week stop might be needed
- ◆ New pump test and installation
- ◆ Valves timing test to optimize recuperation cycles

CF₄ RECUPERATION - CSC

→ CF₄ COMPRESSION MODULE:

- ◆ Test and installation of new compressor
- ◆ New storage tank to be installed

→ CF₄ INJECTION:

- ◆ Ok for operation, working at design condition (see next slides)

→ GC ANALYSIS:

- ◆ Ok for operation

→ CF₄-CO₂-Ar IR ANALYZER:

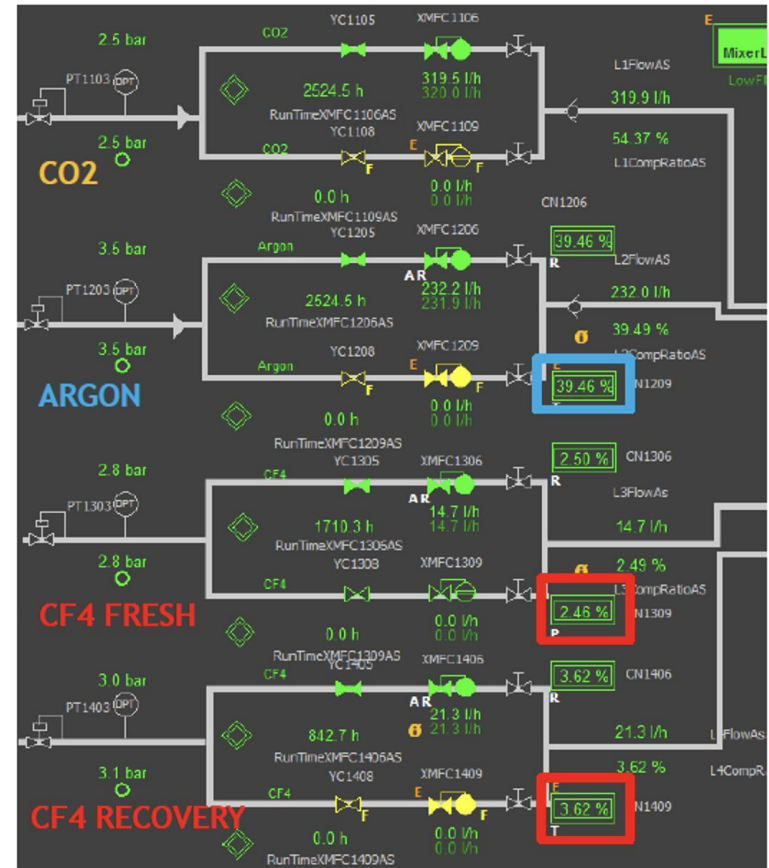
- ◆ Calibration necessary

→ CF₄ SWPC MONITORING

- ◆ Stable operation since 2015 (see next slides)

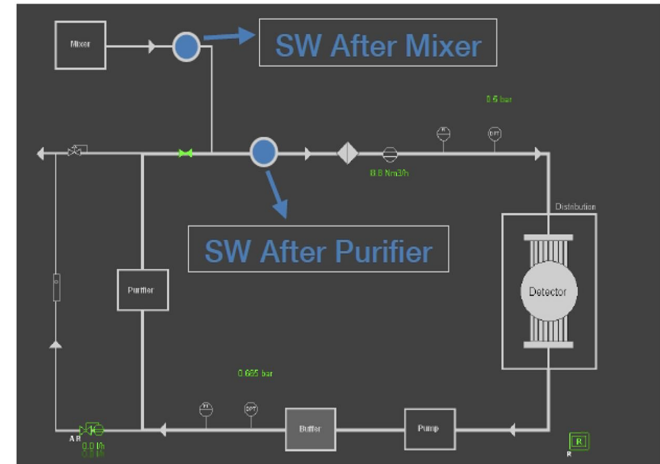
CF₄ RECUPERATION - CSC

- By design, the reinjection is half of the total CF₄ of the mixture
- MFCs have to be properly set to take into account CF₄ pollution
- The tuning of MFCs is done thanks to GC analysis, comparing the mixture to standard mixer injection
- Mixer operation with recuperated CF₄ for around 20% of Gas System operation time

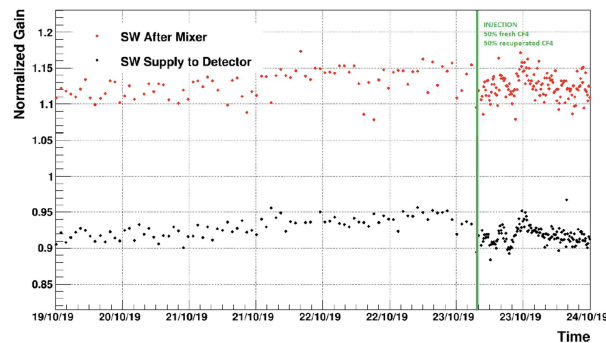


CF₄ RECUPERATION - CSC

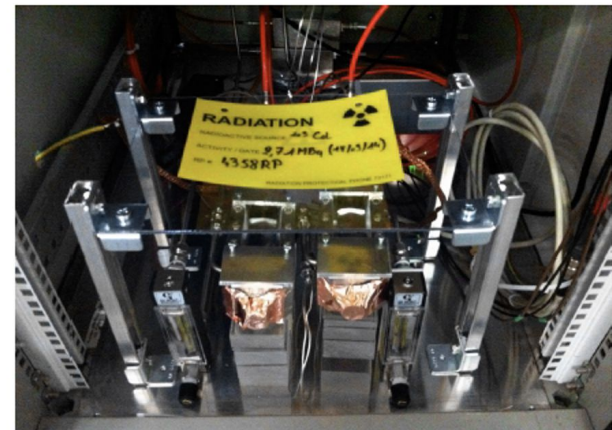
- Single Wire Chambers are installed After Mixer and After Purifier
 - Amplification gain monitored > peak position
 - Rate around 400 Hz
- SWPC are used to monitor ordinary operation but also to *check Mixer tuning during Recuperated CF₄ Injection*



CMS CSC gas monitoring Corrected



available to CSC people on DIP and on webpage
<https://cms-csc-gas-monitoring.web.cern.ch/cms-csc-gas-monitoring/>



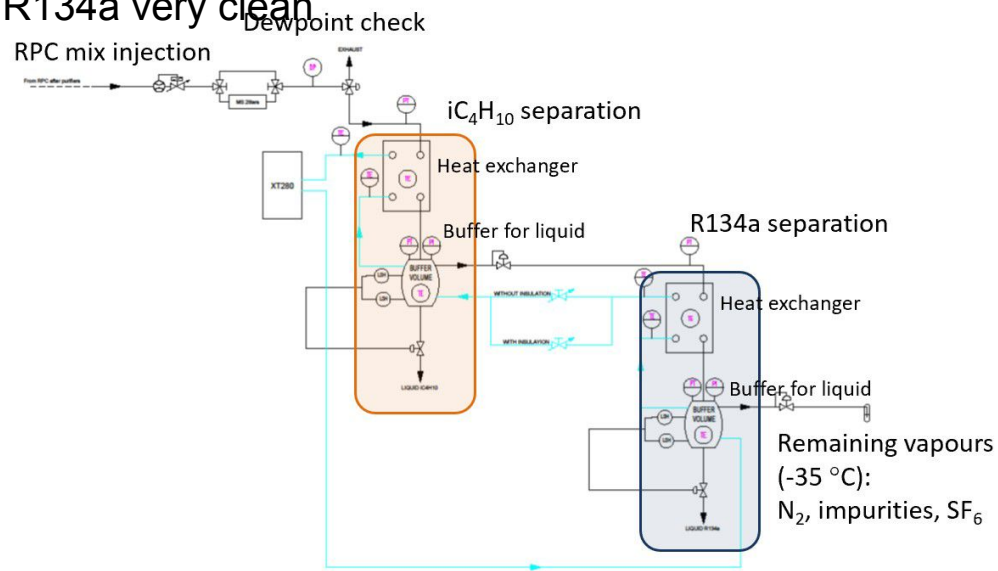
R134a RECUPERATION - RPC

Prototype 0:

built for ATLAS-RPC in December 2018 (low flow, 100 l/h)

→ Promising results

- ◆ High efficiency (close to 100%)
- ◆ N₂ removed to same level as in new R134a
- ◆ Recuperated R134a very clean



R134a RECUPERATION - RPC

Prototype 1:

connected to CMS-RPC in December 2019,
test started around mid-January 2020

→ Goals:

- ◆ Run with higher flows (500-1000 l/h)
- ◆ Test compressor and R134a storage
- ◆ Reuse recuperated R134a for RPC operation

Recuperation
prototype

Compressor

Recuperated
R134a storage



R134a RECUPERATION - RPC

Prototype 1:

full system (cold separator, compressor, storage) started at 300 l/h

→ **BUT:**

- ◆ Presence of iC4H1 and SF6 when system operated with compressor
- ◆ Problems due to higher flow (300l/h vs 100l/h)
- ◆ Adjust settings to integrate new components

now running at same conditions as on ATLAS (100l/h, no storage)

- ◆ good quality of recuperated R134a
- ◆ study impact of flow and new components

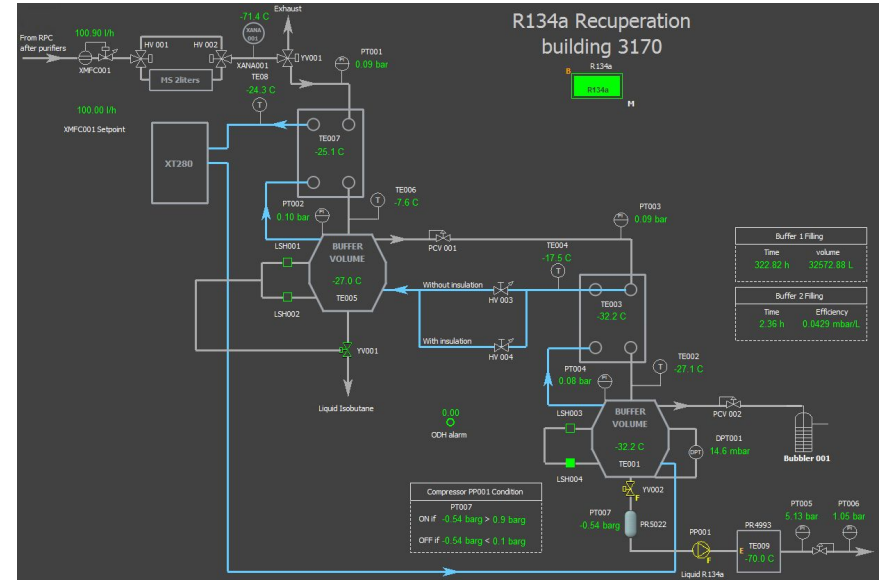
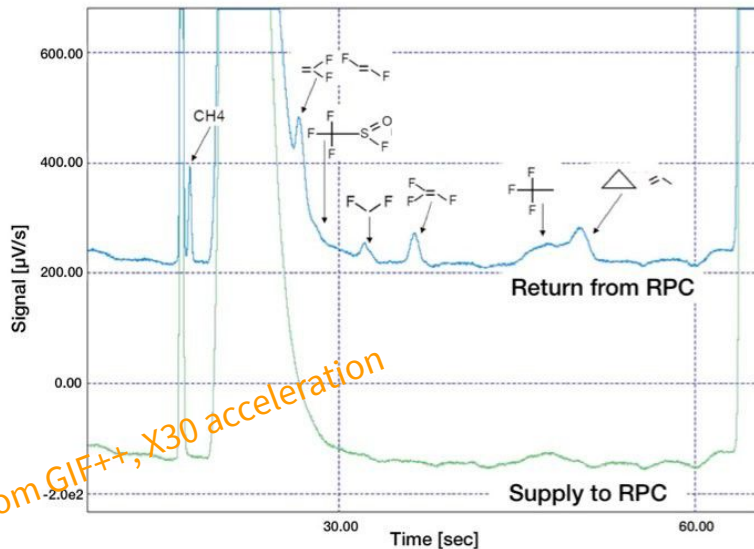
→ **Next:**

- ◆ Operation with higher flow > additional heat-exchanger ordered > 1 week test
- ◆ Compressor + Storage > 2 weeks test after addition of a new component
- ◆ Mixer Re-Injection > 2 weeks test

R134a RECUPERATION - RPC

→ Next Steps:

- ◆ Optimize new configuration settings
- ◆ Studies on HFCs impurities separation, to be evaluated before Run3
- ◆ Possible SF6 recuperation



Molecule	Boiling point (°C)	Molecule	Boiling point (°C)
C2H2F4	-26	C2H2F2(e)	-42
iC4H10	-12	CH2F2	-51
SF6	-64	CHF3	-84
		C2HF3	-51
CH4	-161	C2H3F3	-47
C2H4F2	-117	C3H6 (propene)	-33
CF4SO	110	C3H6 (cyclopropane)	-47
C2H2F2(z)	-20		

DISTRIBUTION OPTIMIZATION - RPC

Replacement of manual valves with automatic regulation

→ Manual valves present to equalize pressure between different detector zones

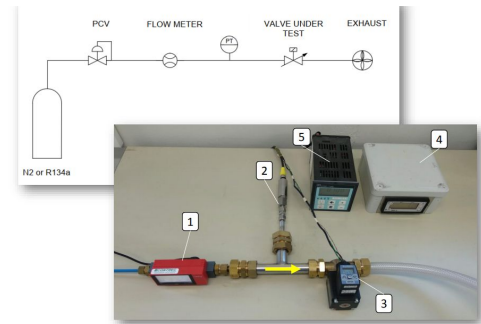
About 16 different models tested

Challenging requirements:

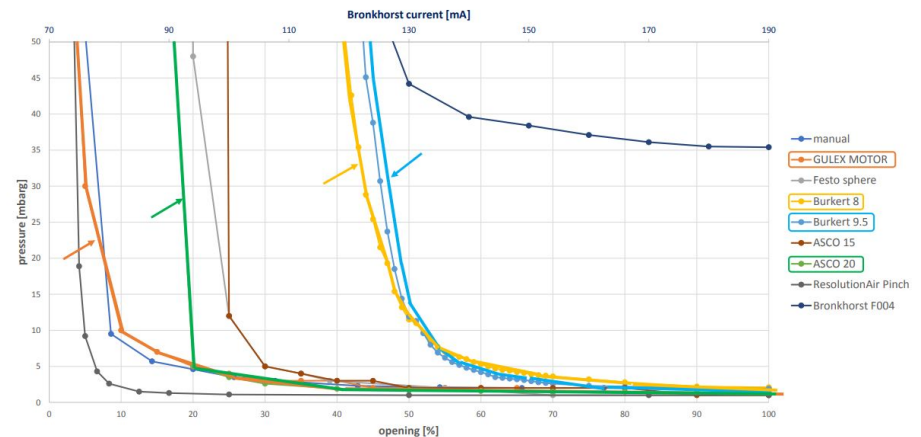
- **Low cost** (28 will be installed)
- **Small dimension**,
limited space available in distribution racks
- Designed for **low pressure** (~100 mbar)

LAB Test Setup

1. Flowmeter
2. Pressure sensor
3. Tested Valve
4. Pressure reading
5. Controller



General Comparison – 16 l/min N₂

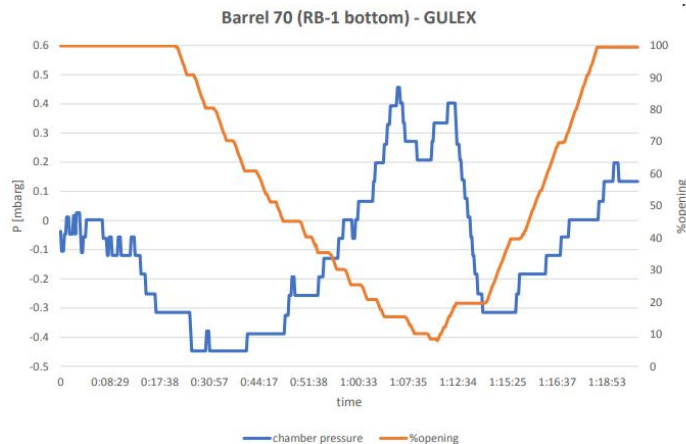


DISTRIBUTION OPTIMIZATION - RPC

4 valves installed on CMS-RPC distribution racks

for testing on real system

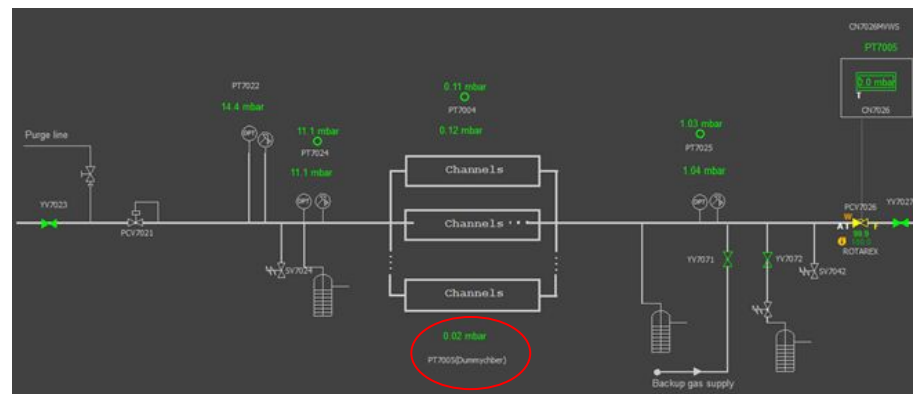
- Detector pressure regulation is done by sensors at rack level
- Particularly critical during filling and emptying phases



DUMMY CHAMBERS - RPC

Automatic regulation of distribution rack will be done by Dummy Chambers

- pressure sensors already present at detector level cannot be used due to risk of leak development
- “dummy chambers” are volumes that simulates real chambers
- 28 chambers to be installed (one per distribution rack)
- 4 dummy chambers already installed, under test





ECOGAS COLLABORATION - RPC

Common working group for the RPC community

- ATLAS, ALICE, CMS and Gas Group participating
- Common setup at GIF++
- Results presented at EPS2019 conference



<https://indico.cern.ch/event/577856/contributions/3420164/>

UNIVERSITÉ
DE LYON

Studies of RPC operations with ecological gas mixture under irradiation at GIF++

Gianluca Rigoletti
on behalf of ECOGAS collaboration
Université Claude Bernard Lyon I (FR)

HEP2019

RPC and eco-friendly gas mixtures

Resistive Plate Chambers at the LHC:

- Used in ATLAS, CMS and ALICE experiments
- Gas mixture based on ~95% of C₂H₂F₄

C2H2F4
FC(F)C(F)F
 GWP 1430

- C₂H₂F₄ has a high **Global Warming Potential** (GWP₁₀ years = 1430)
- European regulation aims at **reducing the use of C₂H₂F₄**

C3H2F4
FC(F)C(F)F
 GWP_{HFO1234ze} = 6

- HFO-1234ze is a **suitable alternative** of C₂H₂F₄ in refrigerants industry
- Tests were started on using HFO based gas mixture for **RPC detectors**

Goal: to characterize the HFO-based gas mixtures for RPC under LHC like background conditions

Experimental setup

- 5 **HPL chambers** under test: ATLAS, ALICE, CMS-GT, CMS-KODEL, CERN-EPDT
- 4 component **gas mixer + humidifier** module
- CAEN SY1527 **HV mainframe** with two A1526 boards
- WEB-DCS software** designed by CMS group
- Grafana** web-app for **monitoring**

Chamber Name	Gap [mm]	Type
CMS-KODEL-2	2	Double gap
CMS-KODEL-1-0	1,4	Double gap
ALICE-0	2	Single gap
ALICE-2-0	2	Single gap
EPDT-RPC3	2	Single gap

CERN Gamma Irradiation Facility (GIF++)

- Situated on H4 SPS **beam line**
- A 14 **Tbq** source of ¹³⁷Cs simulates the background radiation expected at **High Luminosity LHC**
- System of filters (ABS) allows to regulate the **gamma background rate**

