EP-DT
Detector Technologies

Gas mixture quality studies for the CMS RPC detectors during LHC Run 2

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Outline

Previous studies on RPC gas mixture

The CMS RPC gas system

Gas chromatograph analysis campaign for CMS RPC during LHC Run2

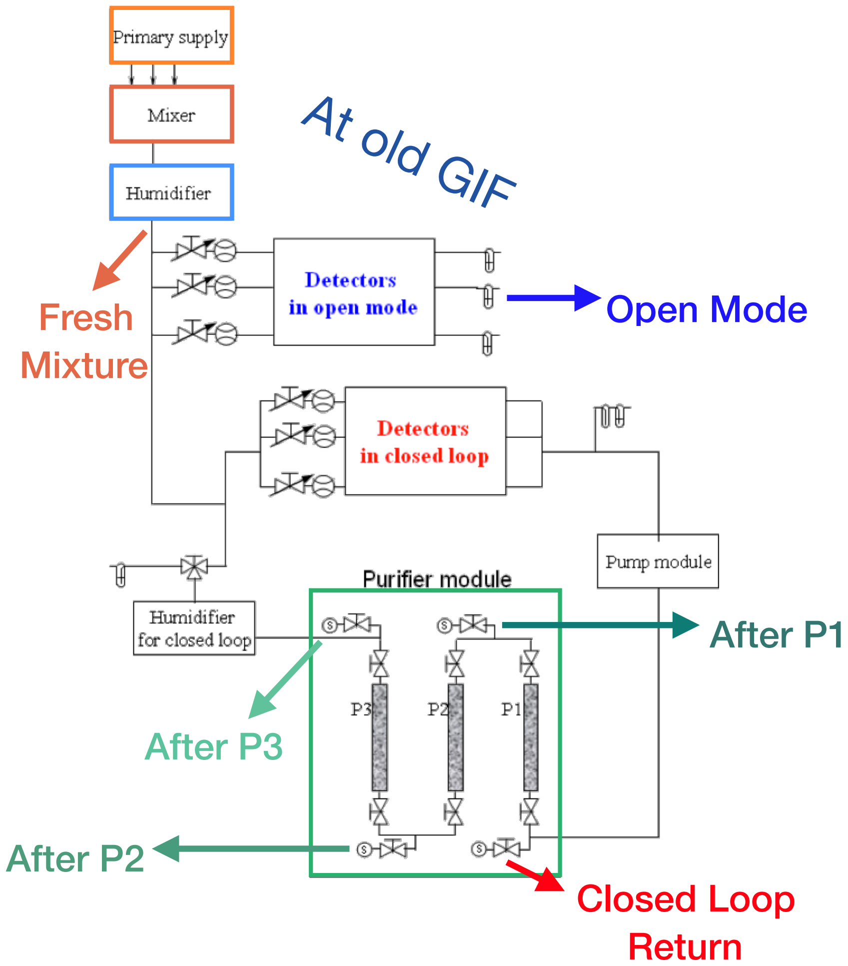
Fluoride measurements for CMS RPC during LHC Run2 and at GIF++

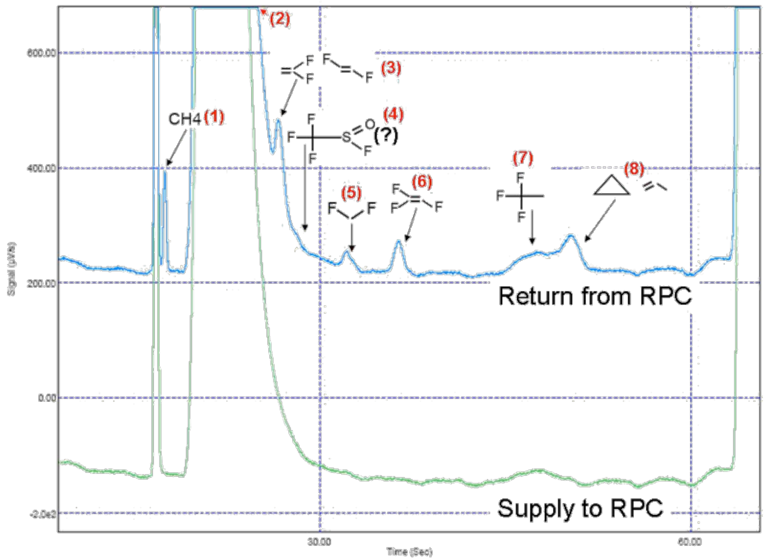
Conclusions

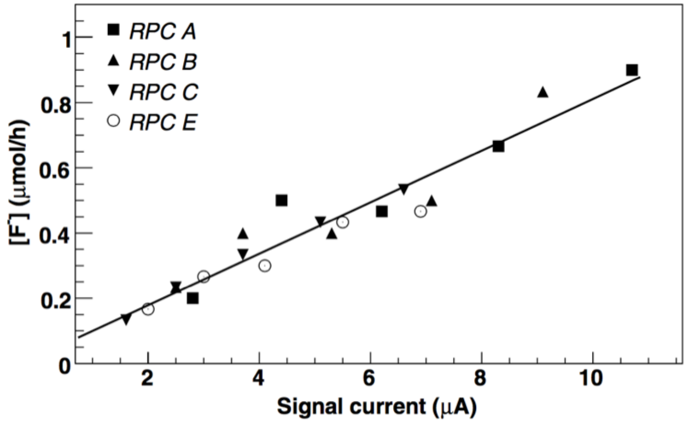
RPC gas mixtures studies: history

RPC2005

- Under the effects of high background radiation and electric field, $C_2H_2F_4$ molecule breaks into fluorine radicals
  - Creation of F^- radical free
  - Sub-products in the order of hundreds ppm
  - Accumulation in case of closed loop system
- Cleaning agents help in reducing these impurities
  - Help but they do not completely remove
  - Different types of cleaning agents necessary
- Gas recirculation fraction plays a key role
  - With 100% recirculation: high concentration





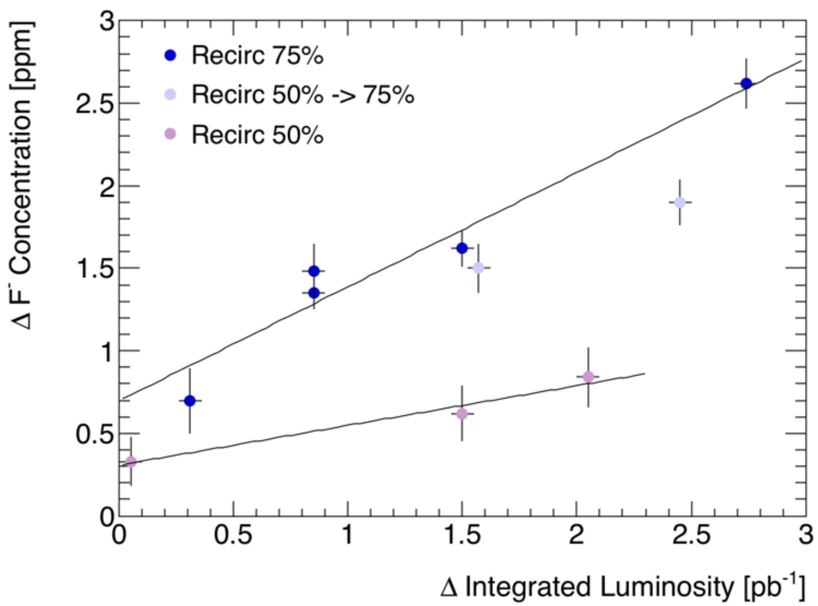


The ALICE MTR case

RPC2018

Creation of impurities due to the $C_2H_2F_4$ breaking

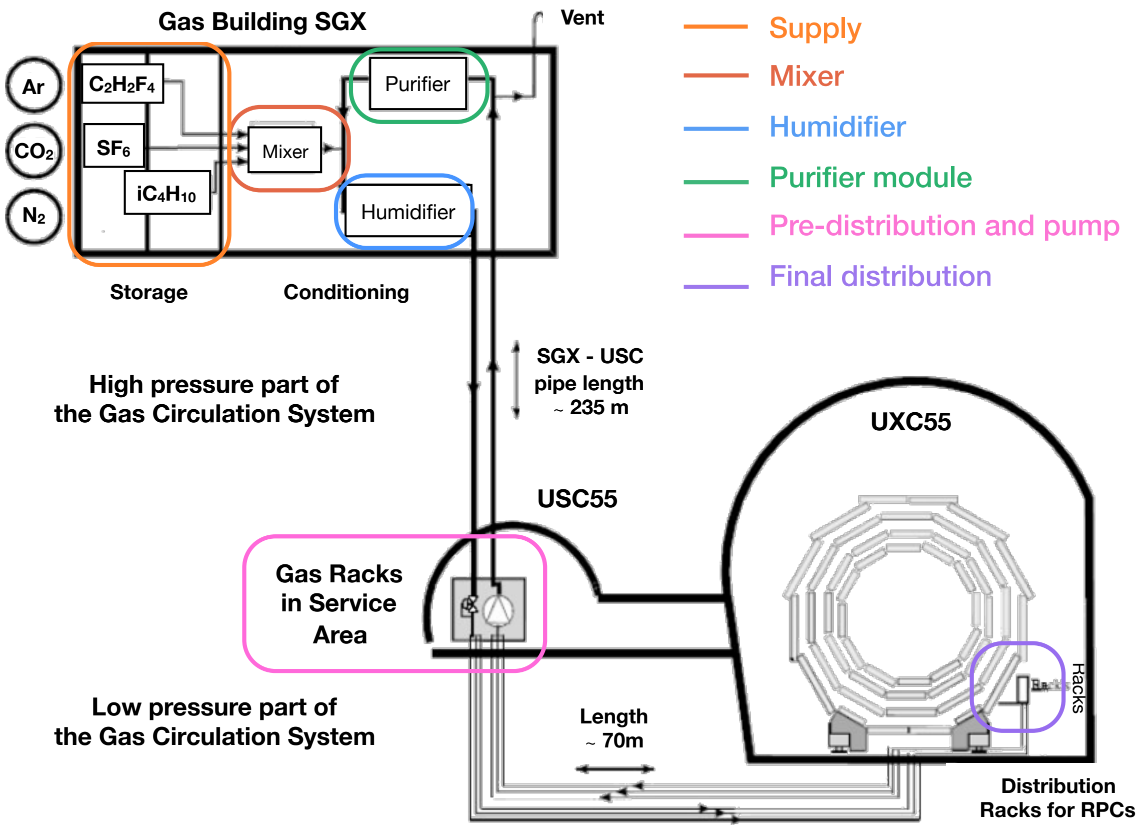
- Electric field and radiation play a key role
- Not all of impurities can be absorbed by the cleaning agents
- Very high recirculation fraction leads to higher impurities concentration



Clear correlation of F-radical creation with gas system and integrated luminosity

- Higher recirculation fraction -> higher concentration of impurities
- Impurities concentration increases with integrated luminosity

CMS RPC gas system

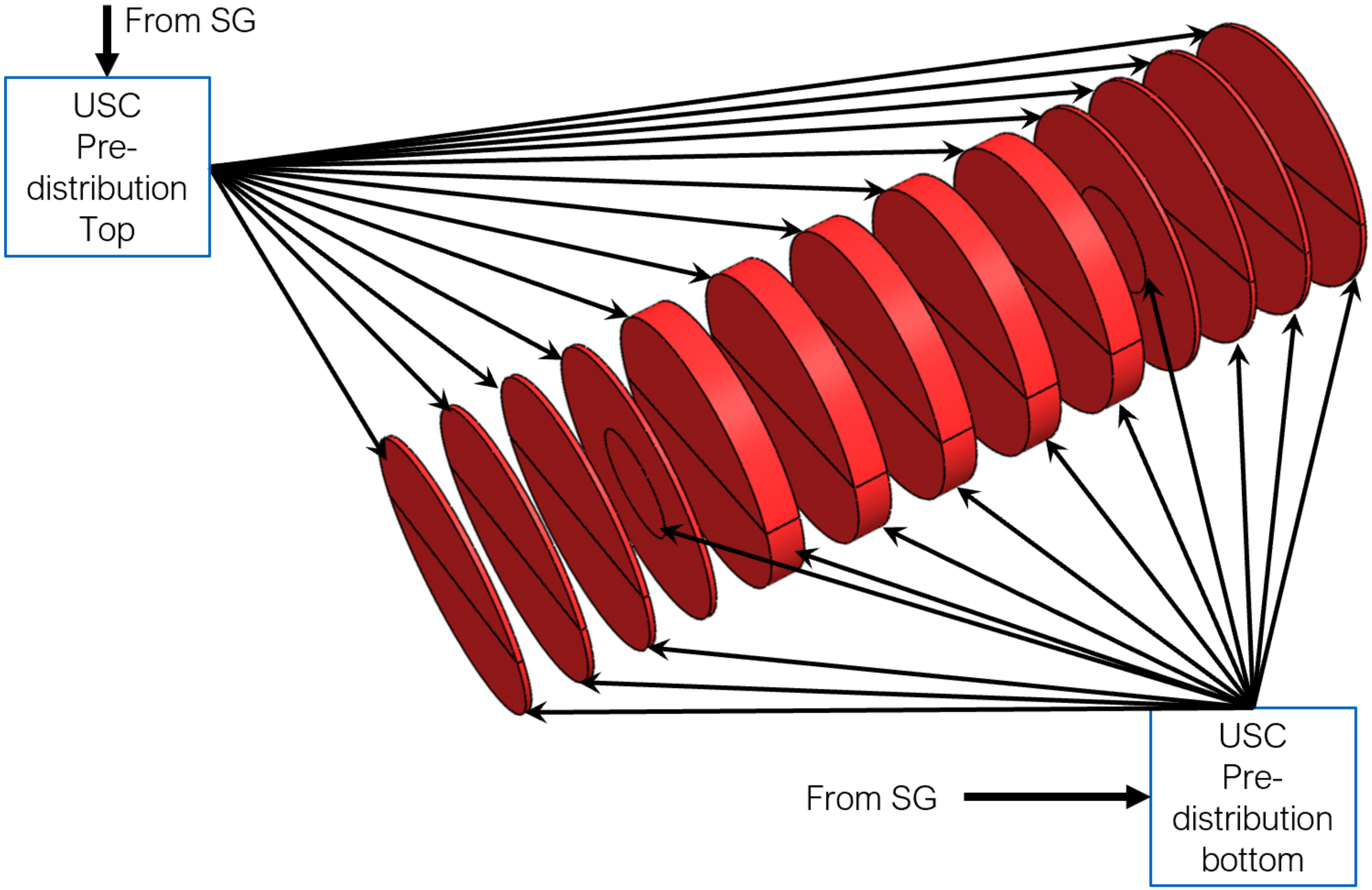


- GHG and expensive gas mixture make recirculation system compulsory
  - ~ 80% of detector GHG emission is from RPC systems (ATLAS, CMS, ALICE)
  - CMS RPC gas system recirculates 85-90% of gas
- Critical points in recirculation systems
  - Pressure and flow regulation for each chamber
  - Possible accumulation of **impurities**
  - Use of cleaning agents compulsory

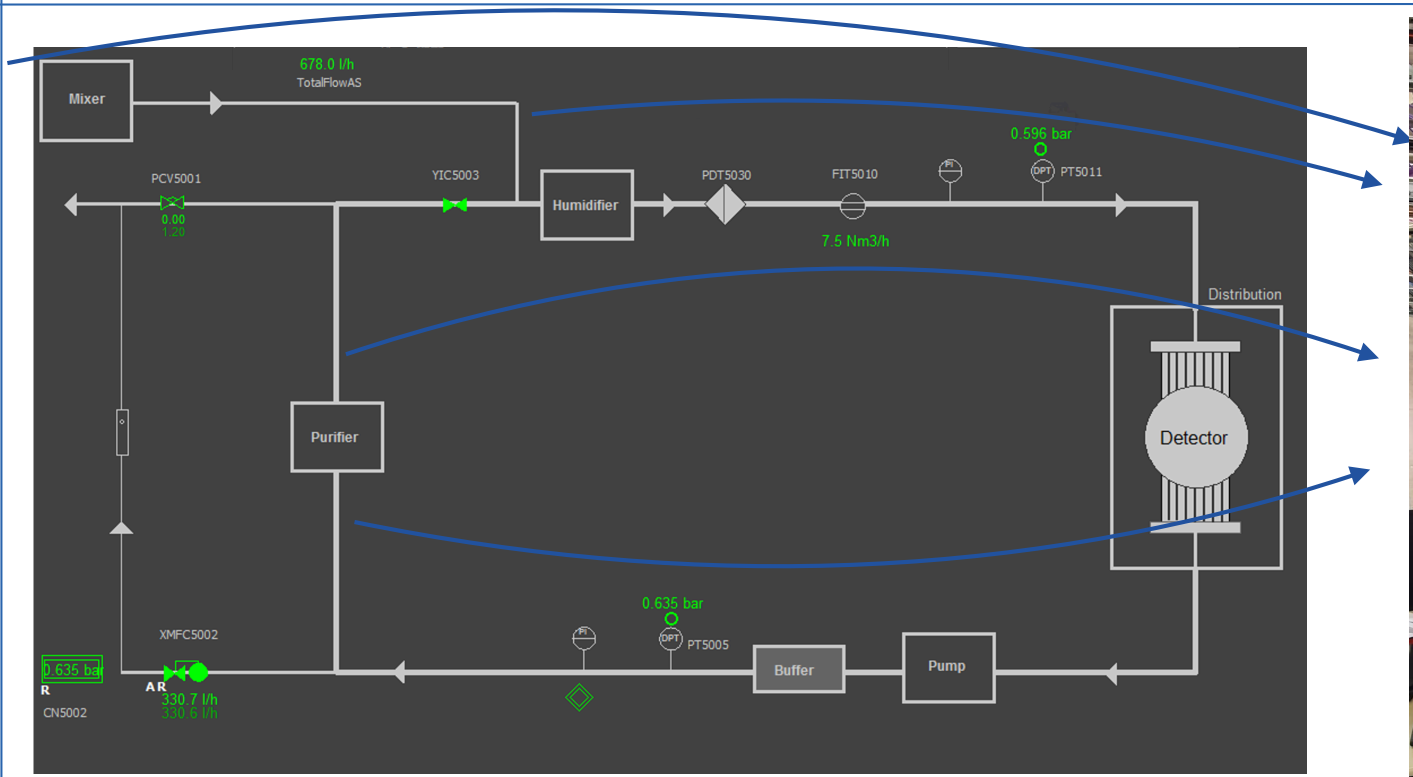
CMS RPC gas system

CMS RPC gas system has the unique feature of:

- Individual distribution to 30 modules, i.e. 30 different areas of the experiment
- Allowing to analyse gas quality for each area, i.e. where background is different
- Finally, tune the gas flow for each single module according to impurities measured

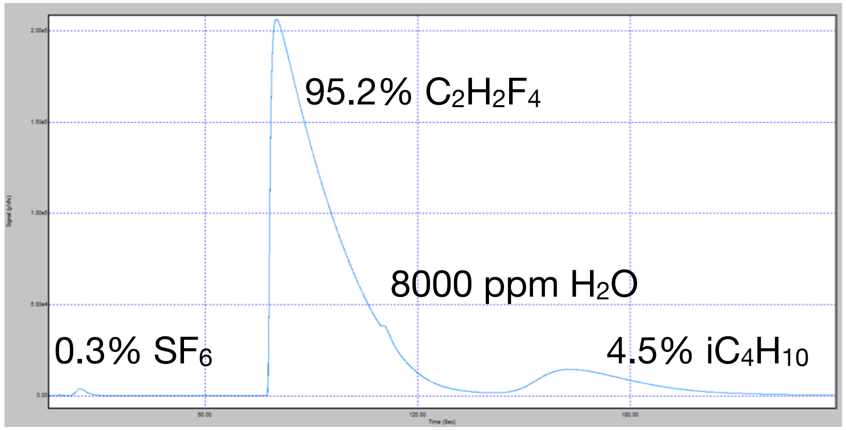


Gas analysis for the CMS RPC gas system



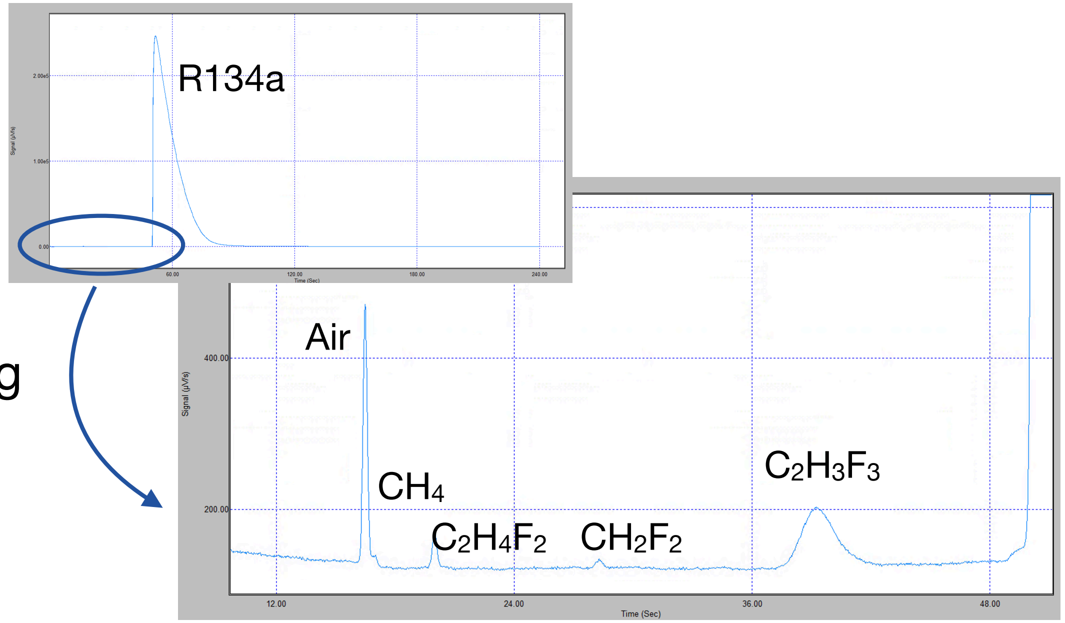
Gas Chromatograph analysis

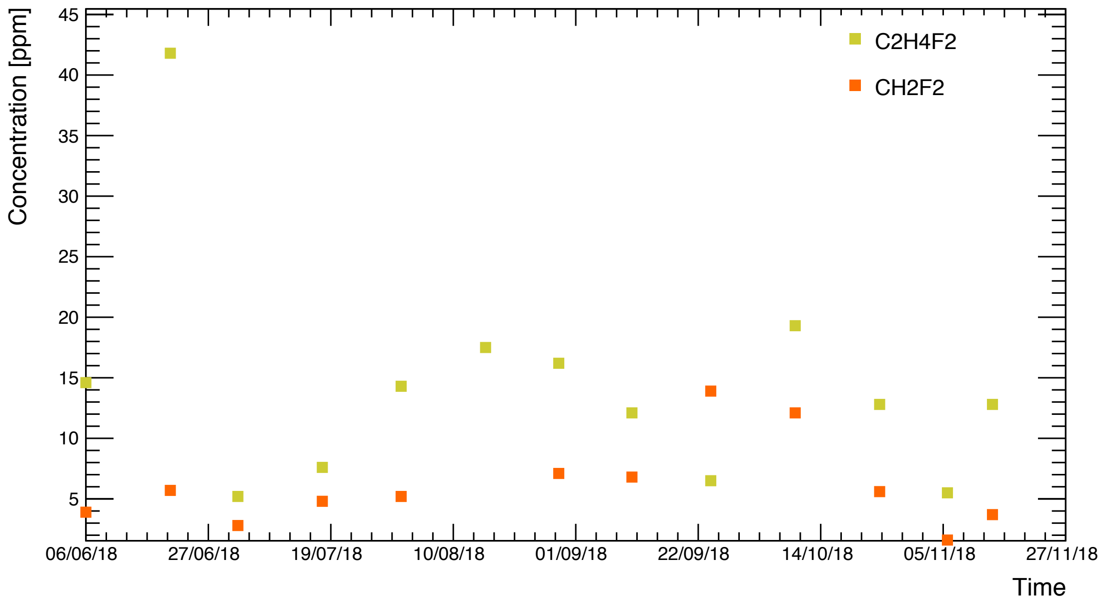
- Gas Chromatograph: it separates and quantifies the gas mixture components
  - Measurements are in uV vs time
  - Sensitivity ~ppm
- Bi-weekly analysis during LHC Run 2
  - Different analysis points: R134a supply, mixer, before and after each purifier column



Quality of R134a used in RPC at LHC

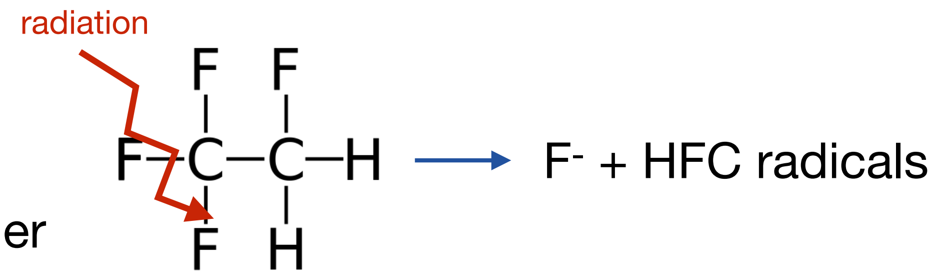
- R134a is an industrial liquid refrigerant
  - Not a high quality needed in industry
- R134a is manufactured by reaction of trichloroethylene with hydrogen fluoride
  - Some sub-products can be created
- R134a used at CERN has a first cleaning process at the provider
  - Different types of cleaning agents necessary
  - Not always perfect quality of Freon
  - Sub-products at the level of ppm

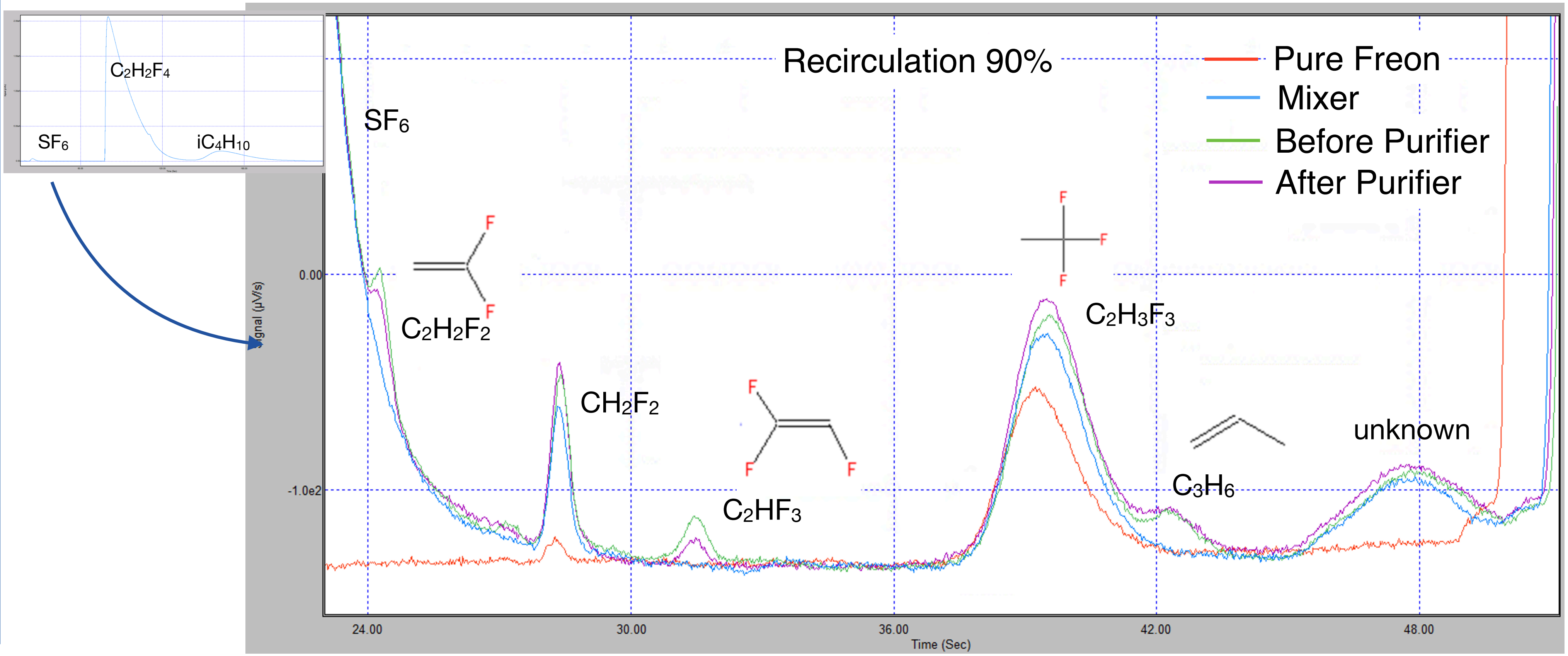




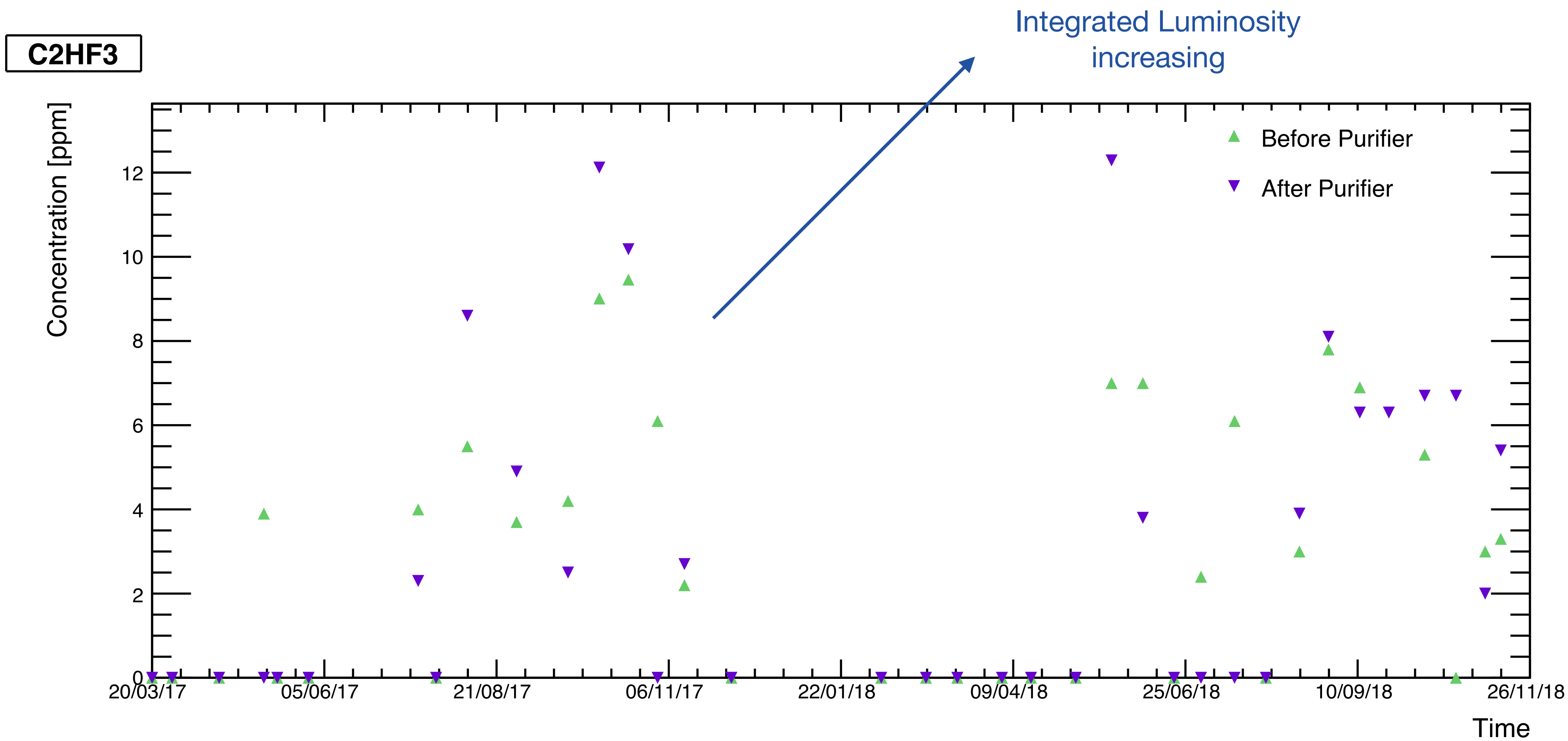
GC analysis of the CMS RPC gas mixture

- Identification and quantification of impurities
  - Clearly created from $C_2H_2F_4$ breaking
  - Concentration is of the order of tens of ppm
  - Same impurities as seen in test at GIF
- Difference between "before" and "after" purifier
  - Purifiers help in eliminating impurities
- GC analyses every 2 weeks in RUN 2



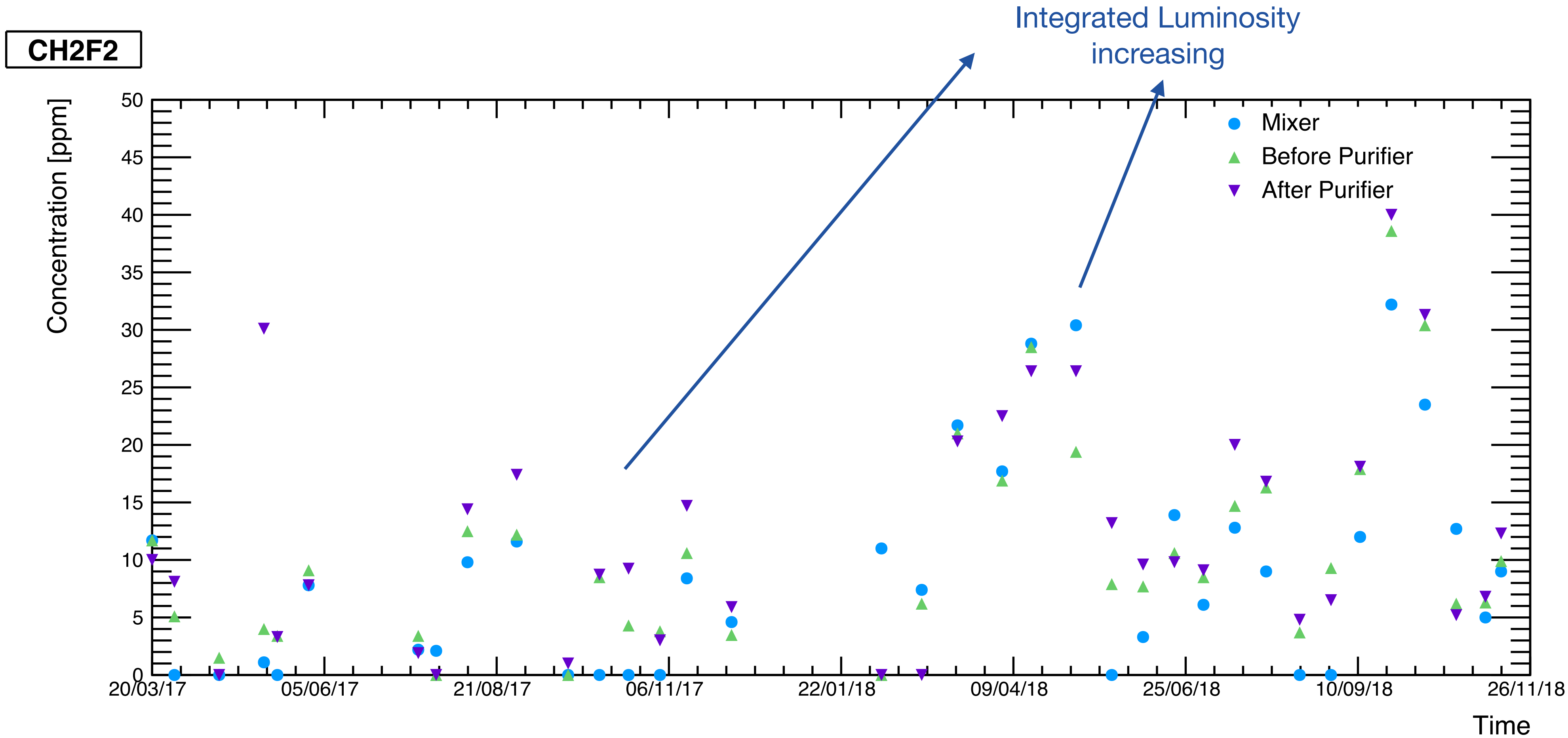


Impurities in the CMS RPC gas mixture



- Gas analysis performed before and after the purifier during LHC Run 2
  - At the beginning of each Run (2017 and 2018) the concentration of impurity C_2HF_3 is zero
  - C_2HF_3 starts to appear in the gas after few weeks of Run
  - Concentration seems to increase with the increase of integrated luminosity in 2017 but it looks more stable in 2018
- Purifier is not always 100% efficient in removing this impurity
  - But it keeps the C_2HF_3 concentration stable during 2018

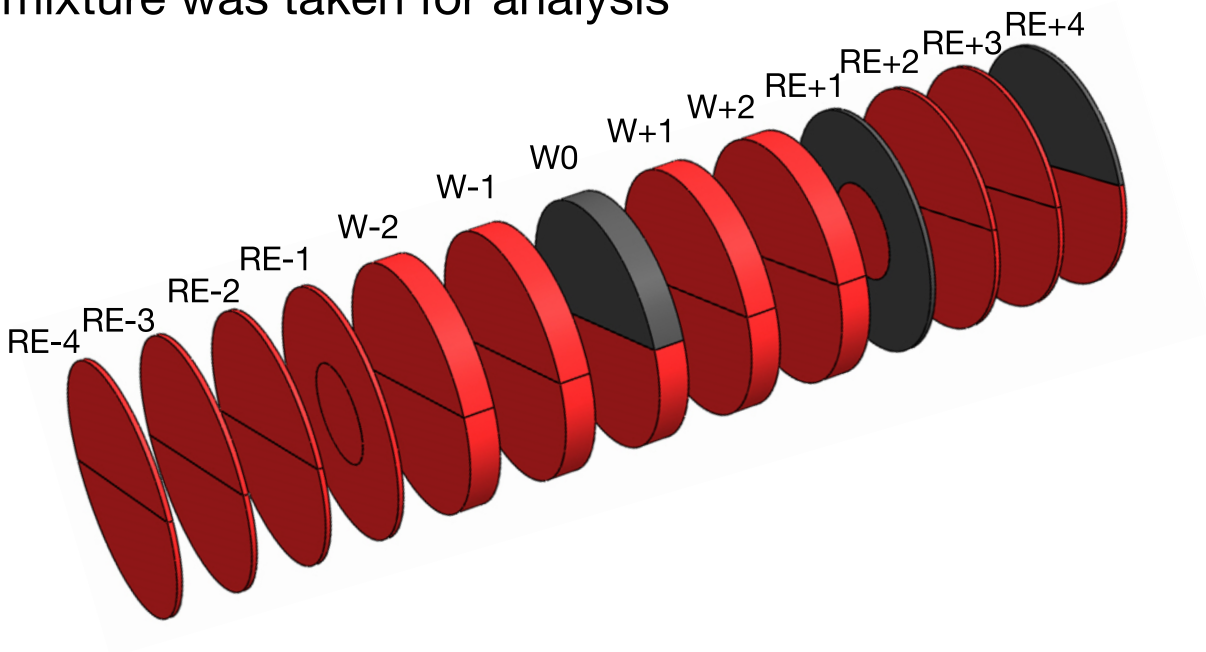
Impurities in the CMS RPC gas mixture



- CH_2F_2 impurity already present in the fresh gas mixture (coming from R134a)
  - Concentration often below 10 ppm
- CH_2F_2 concentration seems to increase with the increase of integrated luminosity
  - Higher concentration in 2018
- Purifier does not always remove the impurity
  - Nevertheless CH_2F_2 concentration

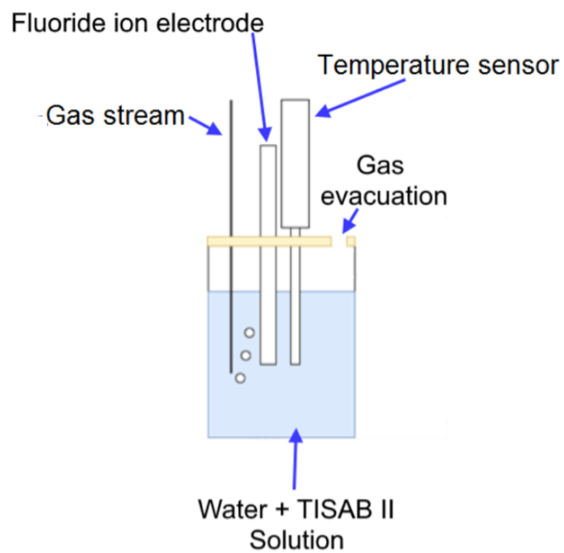
Gas analysis for the CMS RPC gas system

In black the regions from where the gas mixture was taken for analysis



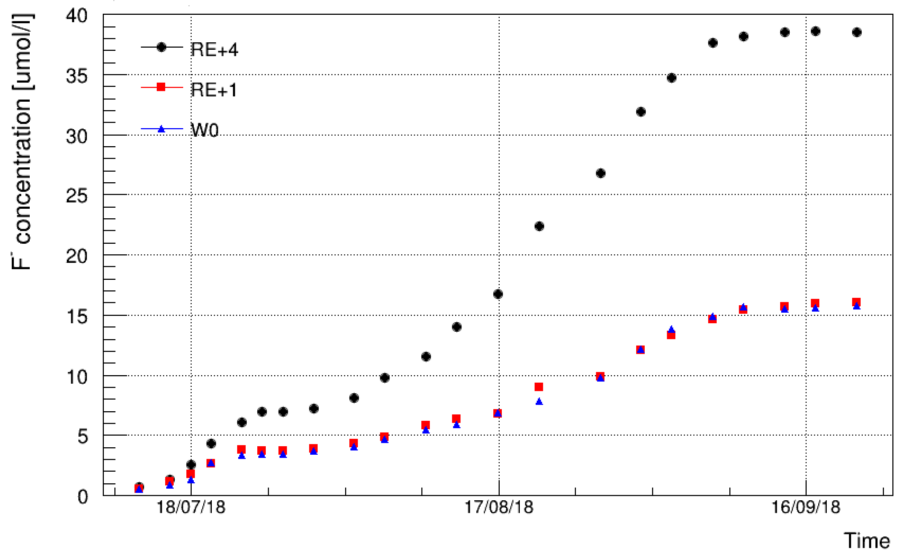
Ion Selective Electrode (ISE) station

- It measures fluoride ions in aqueous solutions
  - When the F^- sensing element is in contact with a solution containing fluoride ions, an electrode potential develops.
  - The potential depends on the level of free fluorine ions in solution (Nernst equation)
- Gas mixture is bubbled in water+TISAB II solution
  - Bubbler efficiency in trapping the HF



Fluoride measurements for CMS RPC

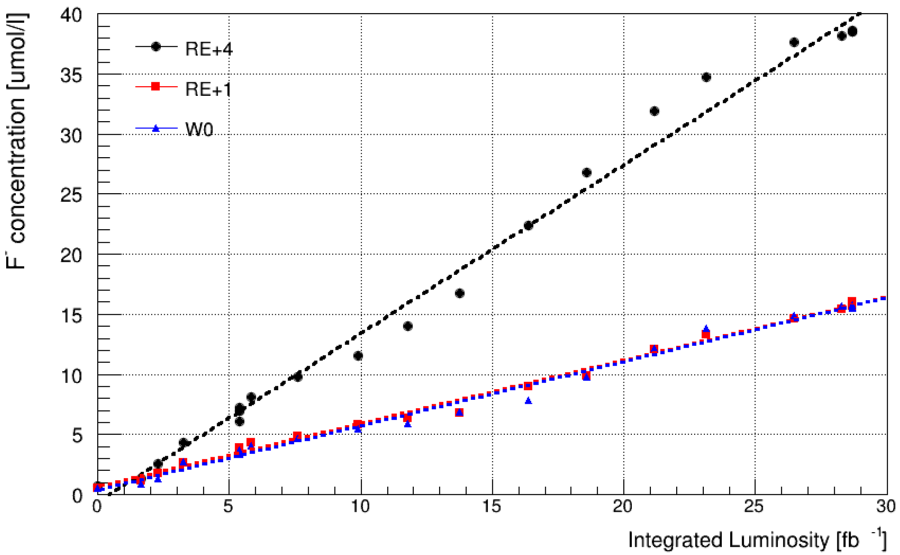
HF measurements performed during LHC Run 2 (July - November 2018)



Detector	Gas exchange (vol/h)	Rate (Hz/cm²)
Endcap RE+4	1.1	~ 40
Endcap RE+1	0.7	<10
Barrel W0	0.6	<10

F^- accumulates over time in the 3 sampling points

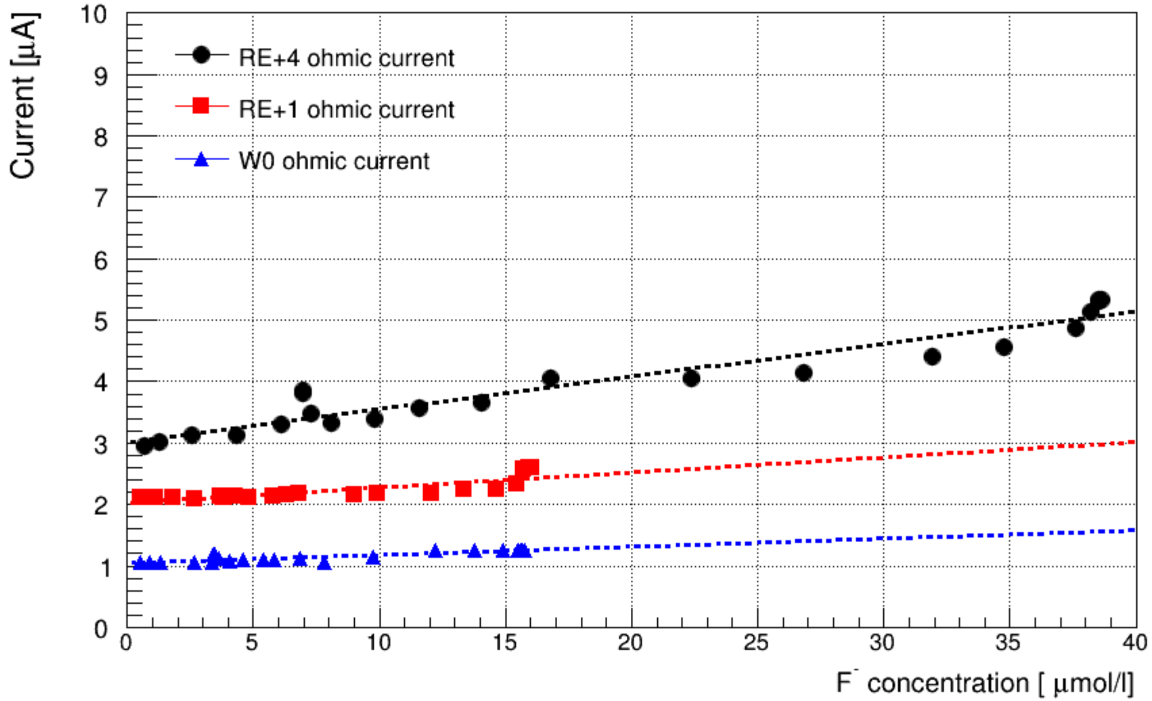
F^- production increase with integrated luminosity



- W0 and RE+1 have similar F^- accumulation
  - They have similar gas exchange and background rate
- RE+4 has higher F^- concentration
  - It has ~4 higher background rate wrt W0 and RE+1
  - But it has a higher exchange flow

Ohmic currents vs F- production

The ohmic current and the F^- concentration have a linear correlation with respect to the integrated luminosity



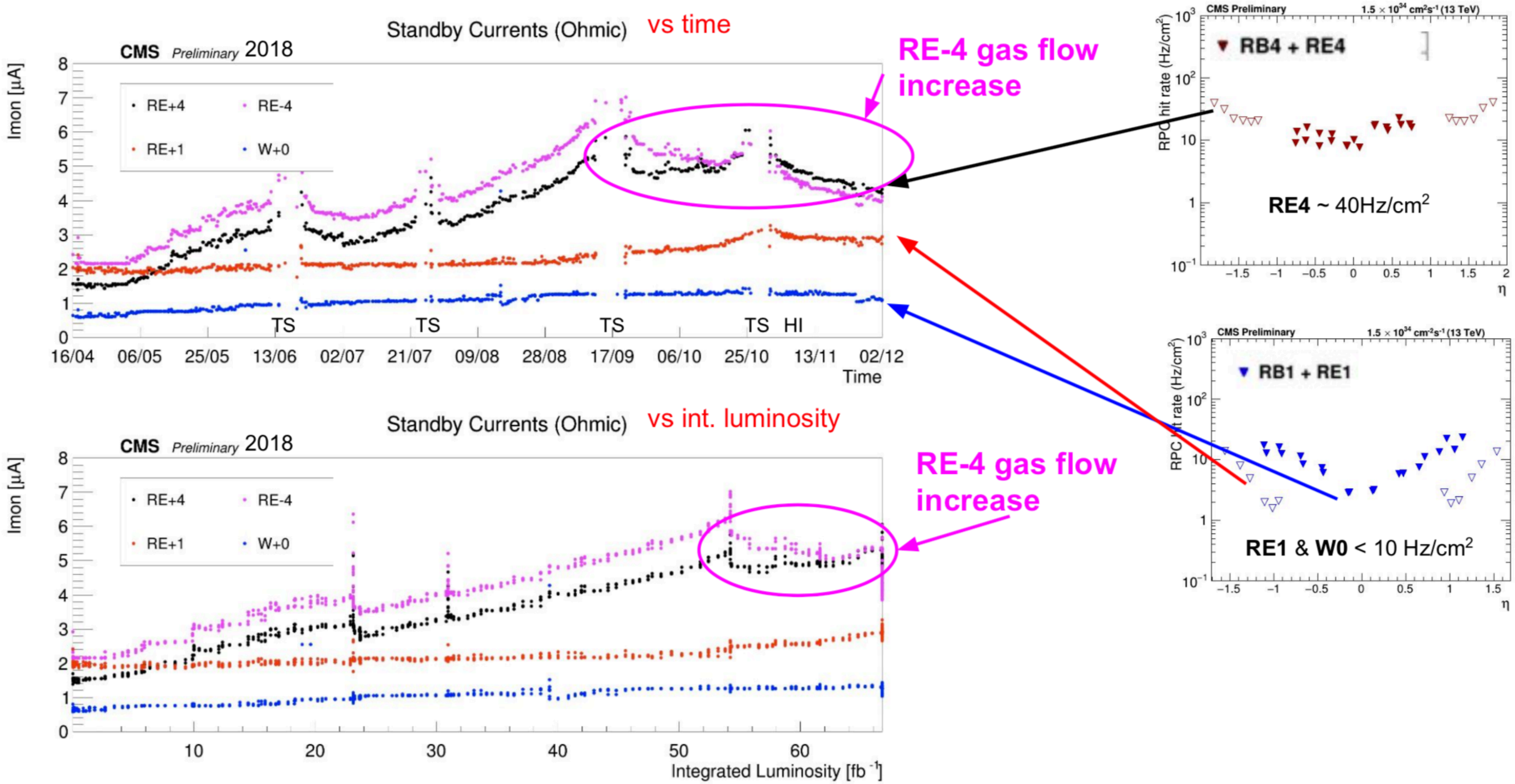
- W0 and RE+1: lower background —> lower HF —> lower ohmic current increase
- RE+4: higher background —> higher HF production —> higher ohmic current increase

Does HF form a conductive layer on the electrode therefore increasing the ohmic current?

Measurements of F^- concentration can be used to tune the flow needed for the best possible operation

RPC ohmic currents and gas flow

During LHC Run 2 the gas flow for RE-4 was increased
to verify any possible correlation between ohmic currents and gas flow



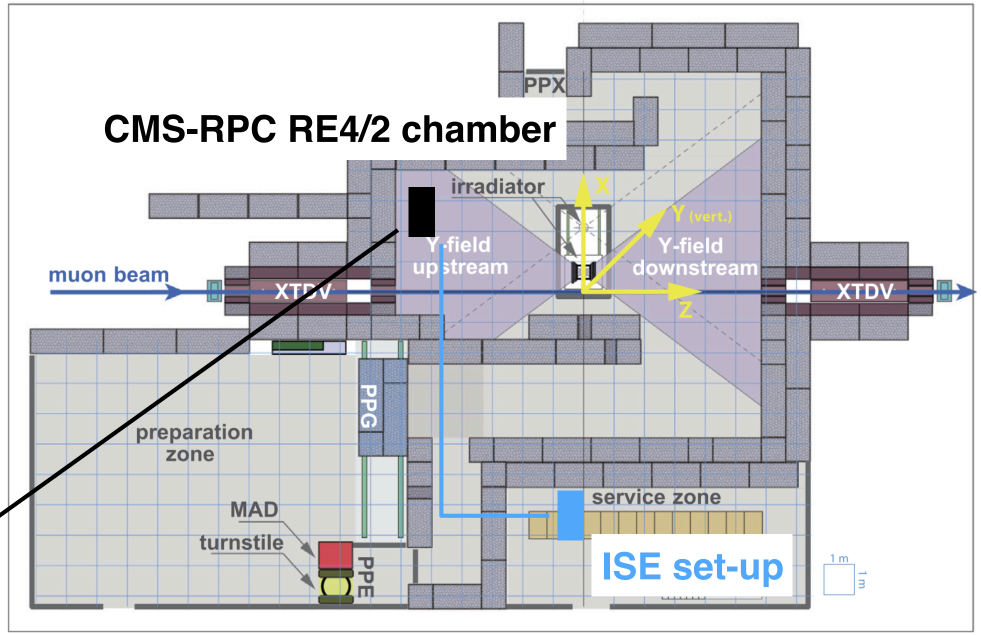
- The Ohmic current is influenced by the background and gas flow
  - The increase of the gas flow in RE-4 lead to a decrease or stability of the ohmic currents over time

During LHC Run 3 the gas flow can be adjusted for each single RPC wheel
to have stable ohmic currents

F⁻ measurements at GIF++

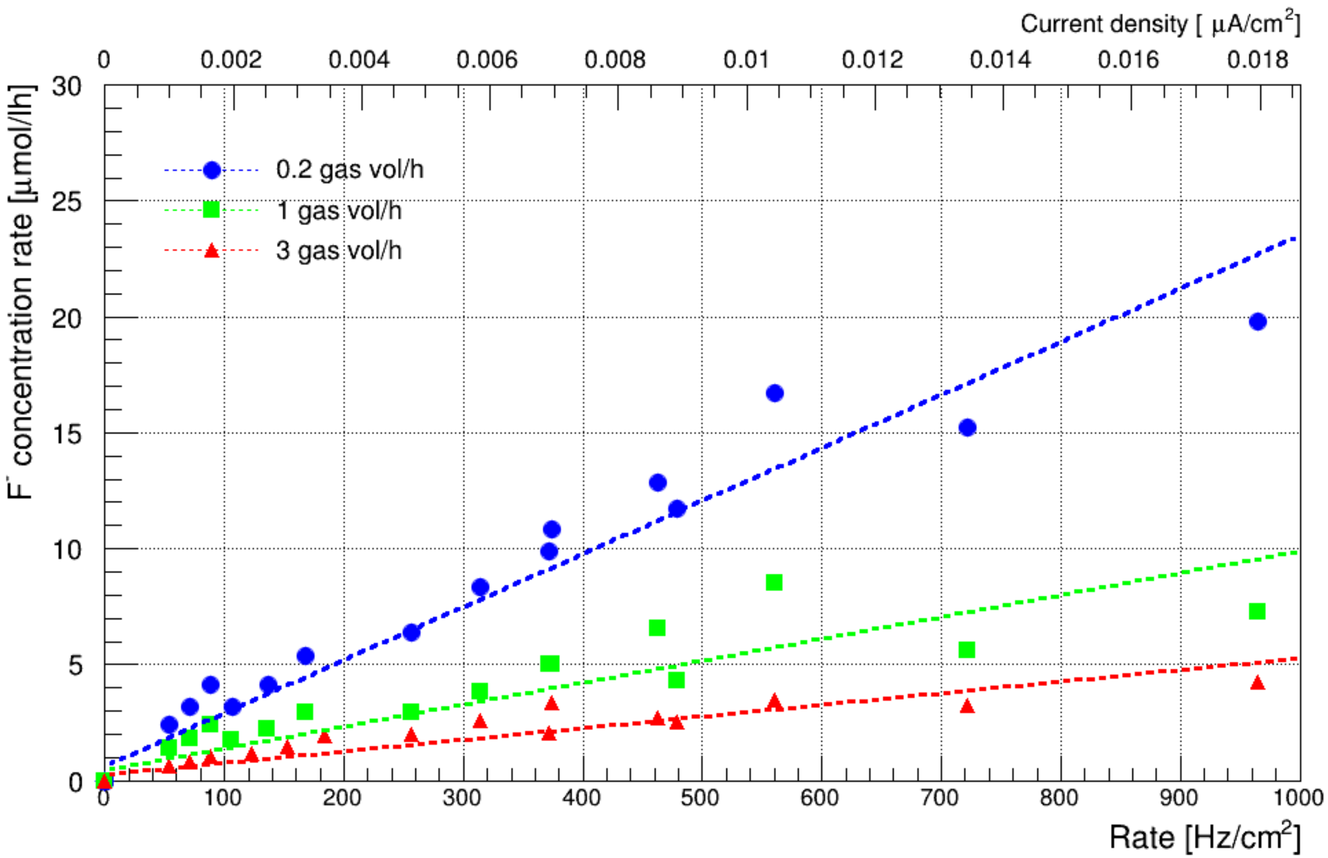
Studies of F⁻ production rate as a function of
the background rate and of the detector gas flow

- Test performed at GIF++ by irradiating a CMS-RPC RE4/2 spare chamber
  - Scan in HV at different background rates and gas flows
- Gas mixtures tested: RPC standard



F- measurements at GIF++

Studies at different background rates and detector gas volume exchange



- F- concentration depends linearly on the background
  - Same behaviour observed at CMS
- Higher gas volume exchanges bring to a lower F- concentration rate

These studies can help in finding the gas volume exchange needed to have the desired F- concentration at a specific background rate

Conclusions

CMS RPC systems is operated under gas recirculation

- Gas recirculation fraction is ~90%

Creation of F-radicals due to the $C_2H_2F_4$ breaking

- Electric field and radiation play a key role
- Not all of impurities can be absorbed by the cleaning agents

Intensive gas analysis campaign for the CMS RPC system during Run 2

- Gas analysers used: GC (for impurities) and ISE (for F^-)
- Several gas points have been analysed in the gas system
- Gas analysis also performed for different RPC wheels for the F^- production

Clear correlation of F-radical creation with integrated luminosity and gas flow

- Impurities concentration and F^- production increase with integrated luminosity
- F^- production is lower with higher gas flow

Studies on possible correlation between RPC ohmic currents and F^- production

- The Ohmic current is influenced by the background and gas flow
- During LHC Run 3 the gas flow can be adjusted for each single RPC wheel to have less F^- production