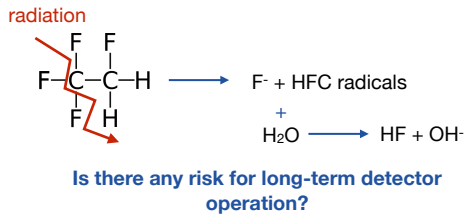
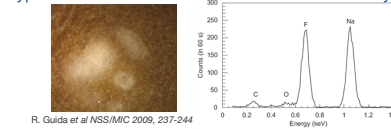


## Production of fluoride in F-gases

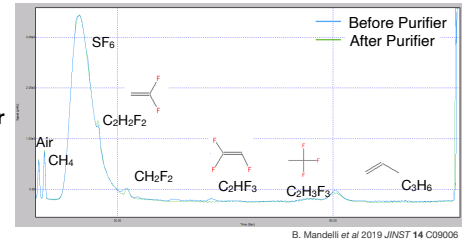
*Under the effects of high background radiation and electric field, C<sub>2</sub>H<sub>2</sub>F<sub>4</sub> molecule breaks into fluorine radicals*



- Creation of **F<sup>·</sup>** radical free: very chemical reactive
- HF very reactive** and dangerous
- Sub-products in the order of hundreds **ppm**
- Accumulation** in case of gas recirculation system
  - Cleaning agents help in reducing these impurities
- Not well know the maximum limit for **safety of the detector**



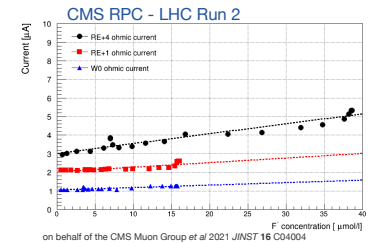
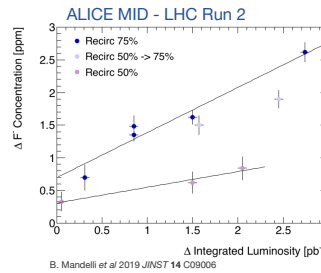
Impurities in the ALICE MID recirculation system



## Fluoride production in LHC RPC systems

Systematic measurements performed during LHC Run 2 by EP-DT Gas team in ALICE MID and CMS RPC systems

- Gas chromatograph (**GC**), Mass Spectrometer (**MS**) and Ion Selective Electrode station (**ISE**)
- ALICE MID HF measurements
  - Before and After Purifier
  - At two different gas recirculation fractions
- CMS RPC HF measurements
  - Sampling in Barrel and Endcap regions: different radiation background
- Sub-products in the order of tens **ppm**



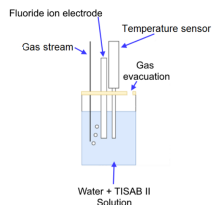
- Higher recirculation fraction: higher concentration of impurities
- Impurities increase with integrated luminosity

- W0 and RE+1 lower background, lower HF, lower ohmic current increase
- RE+4: higher background, higher HF, higher ohmic current increase

## Experimental set-up

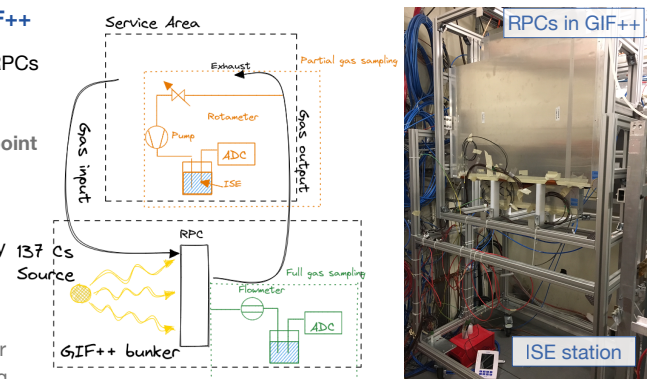
### Ion Selective Electrode (ISE) station

- It measures fluoride ions in aqueous solutions
  - When the F<sup>-</sup> 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
  - Bubbling efficiency in **trapping the HF**



### HF production measurements at GIF++

- Test performed at **GIF++** by irradiating 2 RPCs detectors with 662 keV gamma
  - Scan in **HV** and at different **ABS**
  - Measurements performed at **working point**
  - Gas analyzed at the output of the irradiated detector
- Optimization of the existing methods:** increase the accuracy of measurements by improving parameter monitoring and measurements procedure
  - Different types of electrodes tested
  - Gas sampling inside and outside bunker
  - Partial gas sampling or full gas sampling



## HF production in C<sub>2</sub>H<sub>2</sub>F<sub>4</sub> based gas mixtures

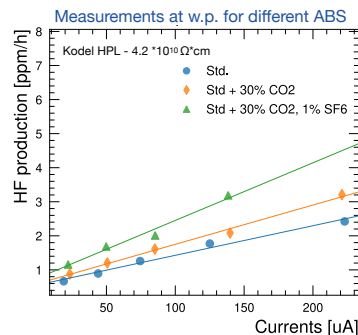
Is the HF production proportional to the quantity of C<sub>2</sub>H<sub>2</sub>F<sub>4</sub>?

- Addition of 30% CO<sub>2</sub> to standard gas mixture
  - Currents very similar to std gas mixture at working point
- 30% CO<sub>2</sub> + std produces the same amount of HF as the std. gas mixture

HF production is not proportional to amount of F-gases in the mixture

HF productions depends on charge developed inside the detector

- Comparison of two gas mixtures with different SF<sub>6</sub> concentrations
- It seems that with more SF<sub>6</sub>, the HF production increases



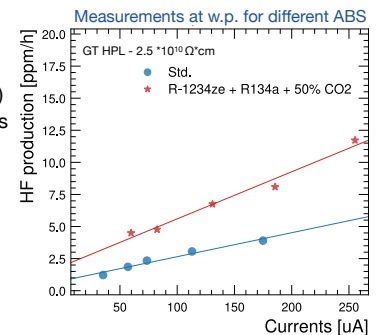
## HF production in presence of HFO

What is the different between HFO (C<sub>2</sub>H<sub>3</sub>F<sub>4</sub>) and R134a (C<sub>2</sub>H<sub>2</sub>F<sub>4</sub>)?

- HFOs have a very short atmospheric lifetime
  - They are destroyed easier than C<sub>2</sub>H<sub>2</sub>F<sub>4</sub>
- RPC operated with HFO-based gas mixture have higher currents with respect to std gas mixture

- Gas mixture tested: 50% CO<sub>2</sub> (necessary to lower the w.p.), 22% HFO and 22% R134a (+iC<sub>4</sub>H<sub>10</sub> and SF<sub>6</sub>)
- HF production higher than standard gas mixture even if the amount of HFO is only ~20% (+20% of R134a)

HF production is higher in presence of HFO at same detector current



## Conclusions

The HF production in the RPCs has to be carefully evaluated and taken into account for the long-term operation. During LHC Run 2, the HF production was measured in the ALICE and CMS RPC systems, confirming the previous results obtained in laboratory condition: HF production is proportional to radiation dose and detector currents. It has been demonstrated that the HF production cannot be lowered by simply adding an inert gas to the standard gas mixture since it is not proportional to amount of F-gases in the mixture. Furthermore, the usage of HFO gases in the future has to be carefully evaluated for the long-term operation as the HF production will be higher with respect to the standard gas mixture even if HFO will be used in lower concentrations.