Studies on impurities and F-radicals production in gaseous detectors operated with Freon based gas mixtures at LHC Experiments

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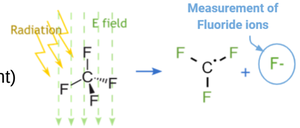
Operation of gaseous detectors with Freon gases

Freon gases are used Gaseous detectors @LHC Experiments
- CF_4 : Wire Chambers, Gas Electron Multipliers (GEM)
- $C_2H_2F_4$ (R134a), SF_6 : Resistive Plate Chambers

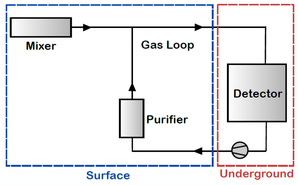
Freon gases + Electric Field + Radiation
= **Gas molecules break up**



Products are highly reactive
- Polymerized deposits (Hydrofluoric Acid if H_2O present)
- Etching compounds

Impurities production depends on many different operational factors:
type of Freon gas, gas mixture composition, gas flow rate, electric field in detector volume, irradiation rate..

Operation with gas recirculation:
- Gas Mixture not sent to exhaust, re-injected in the gas system
- Lower GHG emission + gas cost
- Impurities produced in gas system or chamber can accumulate
- Purifier module designed for O_2/H_2O removal
- *What is the action of Purifier on Fluoride impurities?*

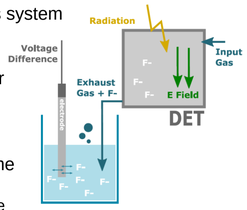


Measurement of Fluoride Impurities

Fluoride impurities production quantified with measurement of Fluoride ion (F^-)

Ion Selective Electrode (ISE) Station
- Specific electrode for Fluoride in solution
- Sample solution with TISAB II to stabilize response

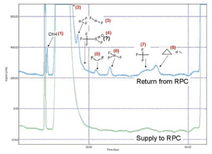
Measurement:
- Gas sample from detector exhaust/gas system bubbled into sample solution
- Fluoride ion released in sample, other mixture component exhaust to air
- Fluoride ion interacts with electrode, voltage difference is produced
- Electrode voltage is proportional to Fluoride concentration in sample volume



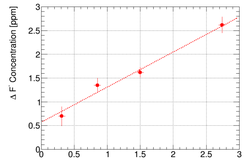
*Fluoride ion concentration measured for sample solution volume, not detector/gas system volume

Resistive Plate Chambers with R134a and HFO

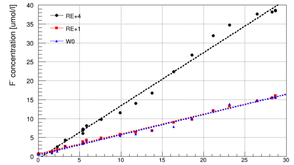
Impurities Production in RPCs with R134a Mixture @LHC
- Impurities produced in RPCs operated with R134a-based mixture in high-rate radiation environment (R134a/iC_4H_{10}/SF_6 + RH40%)
- Impurities quantified with F- measurement
- $F^- + H_2O \rightarrow$ HydroFluoric Acid
  HF can significantly damage chambers
- Test in RPCs of CMS and ALICE during Run2
- Sampling points in various detector sections
- Continuous sampling of return gas 24/7, electrode measurements twice a week



Results :
- Fluoride accumulation increase linearly with LHC Integrated Luminosity
- Detectors in regions more exposed to radiation show a higher Fluoride production rate (CMS RPC, RE+4)

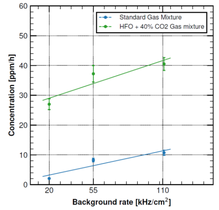


ALICE MTR



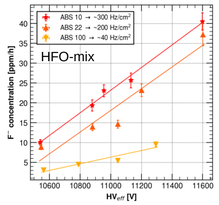
CMS RPC

Fluoride Production in RPCs with HFO Mixture @GIF++
- HFO possible candidate for RPCs eco-friendly gas mixture (HFO/$C_2H_2F_4$/CO_2/iC_4H_{10}/SF_6 27.25/27.25/40/4.5/1)
- RPCs irradiated with ^{137}Cs source (14 TBq, γ ~ 0.1 MHz/Cm^2)
- Fluoride sampled at chambers exhaust



HFO-mix vs Standard mix:
- Operation with HFO-mixture yields to Fluoride production rate ~4 times higher than operation with Standard mixture
- HFO break up rate ~ 10 times higher than R134a under same γ irradiation

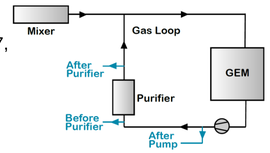
HFO-mix Fluoride production:
- HV scan with different irradiation rates
- Fluoride concentration linear with HV increase ~ detector current
- Fluoride production rate increases with the increase of radiation rate



Triple-GEMs with CF_4

Triple-GEMs can be operated with CF_4 to improve time resolution
Standard mixture composition is Ar/CO_2/CF_4 in fractions 45/15/40

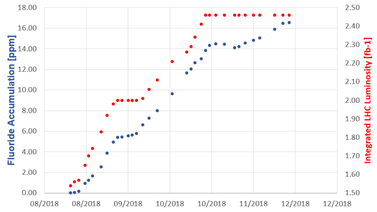
Fluoride production in Triple-GEMs @LHCb – Run2
- Fluoride measurement in sampling point at the common return lines, sum of Fluoride produced in all operating chambers
- Sampling before and after the Purifier module
- Continuous sampling of return gas 24/7, electrode measurements twice a week



Results :

Before purifier sample shows *proportionality of Fluoride accumulation and LHC Integrated Luminosity*

Flat periods = technical stops
No LHC Luminosity,
no Fluoride production



Fluoride production characterization @GIF++
- Fluoride sampling at chambers exhaust in different conditions
- Triple-GEMs irradiated with ^{137}Cs (14 TBq, γ ~ 60 MHz/Cm^2)

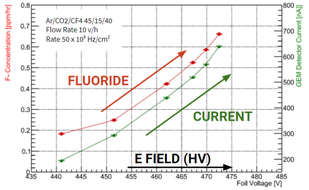
Results :

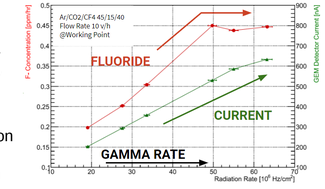
CF_4 concentration
- Fluoride stable up to 50% CF_4
- <10% increase for higher CF_4
- F- does not strongly depend on CF_4 content in gas mixture

Input flow rate
- Lower Fluoride for higher flow rates
- High flows allow faster transit of CF_4

Electric field
- Higher E field, Fluoride increase
- Bigger electron avalanches, higher amplification gain ~ charge density

Radiation rate
- Current increase, Fluoride saturation
- More avalanches but same amplification gain, less CF_4 broken





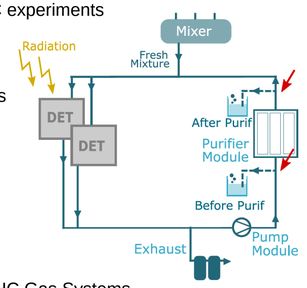
Fluoride Impurities with Gas Recirculation

Several gas detector systems at LHC experiments are operated with gas recirculation:

Pros
- Reduced operational costs
- Lower Greenhouse Gas emissions

Cons
- Compromised gas mixture quality
- Accumulation of impurities (N_2, O_2, H_2O, Fluoride)

Standard Purifier module allows H_2O and O_2 removal



Purifier effect on Fluoride tested in LHC Gas Systems (CMS RPC, ALICE MTR, LHCb GEM) and @GIF++
- Sampling points in gas recirculating systems located before and after Purifier module, continuous sampling during LHC Run / chambers irradiation

Fluoride accumulation measured before Purifier
No accumulation in the sampling point after Purifier module for all the gas mixtures/detectors/gas systems tested
Purifier module traps Fluoride, gas mixture can be safely re-injected

Conclusions

Fluoride impurities are produced in gaseous detectors volume when operated with Freon gases in high-rate radiation environment

Resistive Plate Chambers
- **Operated with R134a in LHC Run2 (ALICE/CMS)**
  Fluoride production linear with Integrated Luminosity
  Sections exposed to higher radiation show higher impurity production
- **Operated with HFO @ GIF++**
  Fluoride linear with RPCs detector current
  For equal detector current, more Fluoride produced with higher irradiation rate
  Operation with HFO-mix produces ~ 4 times more Fluoride than Standard mixture (break up HFO/R134a ~ 10)

Triple-GEMs
- **Operated with CF_4 in LHC Run2 (LHCb)**
  Fluoride production follows Integrated Luminosity
  No accumulation during stops of LHC activity
- **Operated with CF_4 @ GIF++**
  Various operational factors influence Fluoride production
  Higher gas flows help decreasing impurity accumulation
  Increase of electric field and radiation both yield to higher production

Fluoride impurities with Gas Recirculation
- Standard LHC Purifier module guarantees safe operation
- Fluoride is trapped: no accumulation with gas recirculation