Gas mixture monitoring techniques for the LHC Detector Muon Systems

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The Gas Systems for LHC Muon detectors

Surface Gas Building SGX

- Primary gas supply
- Mixer
- Humidifier
- Purifier
- Pre-distribution and pump
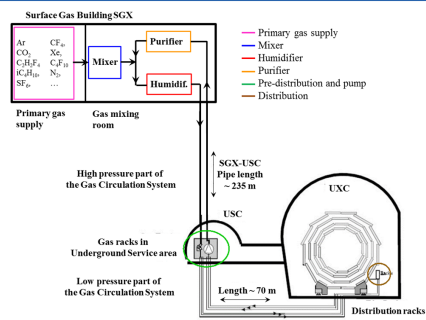- Distribution

30 Gas Systems at LHC

The gas systems are complex apparatus that have to ensure an extremely high reliability in terms of stability and quality of the gas mixture delivered to the detectors.

- **Different types of operation**
  Open mode or recirculation system
- **300 gas racks all over CERN**
  60 PLCs and ~ 3 km of pipes for each system
- **Huge detector systems**
  Thousand of m² and up to 800 m³

10 Types of gaseous detectors at LHC

- **Several gas used:**
  Ar, CO_2, CF_4, C_4F_{10}, iC_4H_{10}, SF_6, $C_2H_2F_4$, nC_5H_{12}, H_2, O_2, CH_4, Xe, Ne, N_2
- **More than 20 gas mixtures**

The gas mixture is the detector's sensitive medium: a correct and stable composition is a basic requirement for good and safe long term operation

Verification and monitoring of the gas mixture quality is fundamental

For more info, see R. Guida talk on 23/05/17 (R2-Experimental detector systems):
"The gas systems for the detectors at the LHC experiments: overview of the performances and upgrade strategy in view of the High Luminosity LHC phase"

Why is gas mixture monitoring necessary?

The **gas mixture and gas systems** can affect **detector operation** because of:
- wrong **gas mixture compositions**
- bad **quality** of the supplied gases
- accumulation of **impurities** in the recirculation system
- **gas parameters** (pressure, gas flow, cleaning agents, etc.)

These variations can have an impact on detectors':
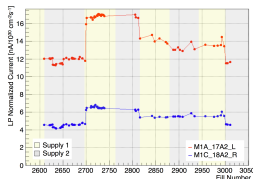- dark current
- gas gain
- operation voltage

Gas mixture composition
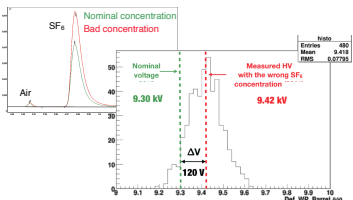
Mass Flow Control deviation in RPC mixture:
- SF_6 concentration from 0.3% to 0.45%
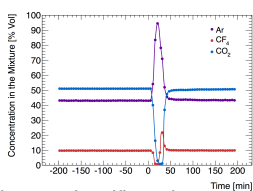- Increase of 120 V operational voltage

Gas supply quality

Change of gas bottle:
- GEM gain fluctuations in coincidence with changes in the CF_4 gas supplies
- Quality composition of the CF_4

**Gas system operation**

Change of purifier column:
- CO_2 is almost completely absorbed for about one hour by the purifier
- Destabilisation of gas mixture composition

Standard gas analysis techniques used at LHC experiments

O₂, H₂O and IR analysers

Each experiment is equipped with a **standardized analysis rack for O_2 and H_2O** measurements and, when necessary, infrared light analysers.

- Process controlled through the general **Gas Control System** of the experiment by means of an industrial PLC.
- **All gas sampling points** from the different detectors on the experiment are connected to the analysis rack. The software control **regularly scans** the selected gas lines.
- Anomalies can allow to **detect** gas supply quality or the detector air intake/leak.
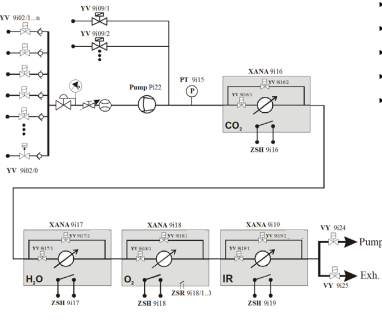
Gas Chromatograph

Six GCs are installed in the LHC experiments
- **Identification of all gases** used at LHC experiments
- **Monitoring** of the stability of the mixture composition
- Check for possible other **impurities**
- Precision up to **ppm** level
- Analysis of **several sampling lines**
- Possibility to **automatize** the analysis thanks to multi-way valve (in CMS analysis of 46 gas lines)
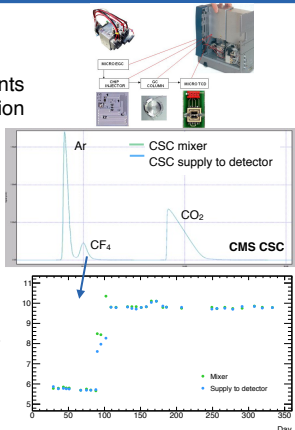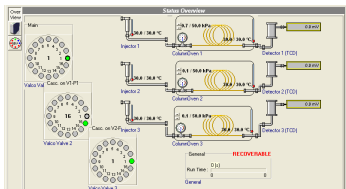

Alternative gas analysis techniques under development

Impurities in gas recirculation systems

Impurities can enter in the gas system because of leaks or detector permeability. Under the effects of high electric field and radiation, complex gas molecules can break inside the detector volume creating new chemical species.
All impurities can accumulate in the gas recirculation system.

- **Gas Chromatograph** allows to separate all gas components and to determine their concentration
- **Mass Spectrometer** allows to identify gases
- **Ion Selective Electrode Station** allows to quantify the F^- pollution present in the system
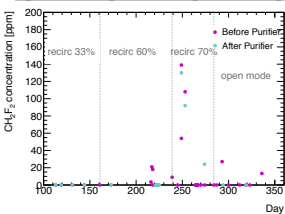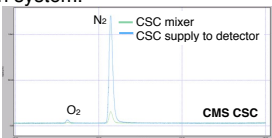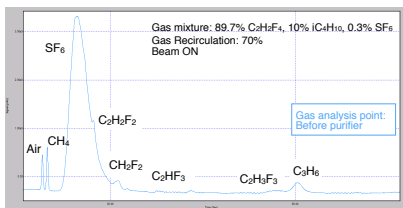
Gaseous detector for gas monitoring

Single Wire Proportional Chambers can be used to monitor the gas mixture

- **Very sensitive device**: large drift volume
- **Monitoring** of: gas variation (< 0.1%), presence of impurities and aging validation (<< 1 ppm)
- **Online and continuous gas monitoring**
- Implementation in the CMS CSC gas system
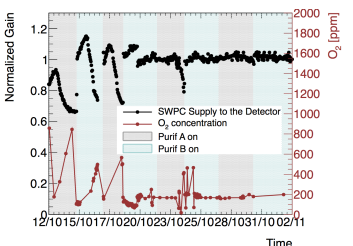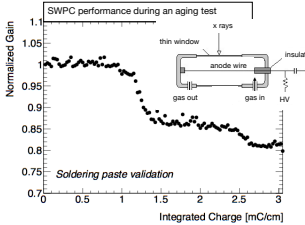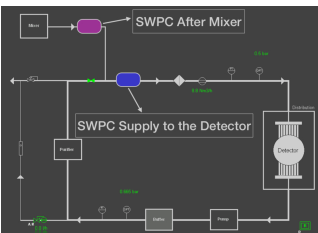
Conclusions

About 30 gas systems are delivering the proper gas mixture to the gaseous detectors at the CERN LHC experiments. Quality and composition of gas mixtures are essential for avoiding temporary or unrecoverable degradation of detector performance. The verification and monitoring of the gas mixture quality is therefore crucial. Several standard and alternative gas analysis techniques have been established and are in use at CERN for all experiments. Thanks to the implementation of these gas monitoring systems it is possible to spot any gas variation and to correlate detector performance with gas mixture related problem.