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Systematic study of RPC performances in polluted or varying gas mixtures compositions: an online monitor system for the RPC gas mixture at LHC

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Aim of the study

In ATLAS and CMS experiments the RPC gas mixture is 95.2% $C_2H_2F_4$ / 4.5% iC_4H_{10} / 0.3% SF_6. This gas mixture is distributed to the RPC detectors by a complex gas system which works recirculating about 90-95% of the gas.
The correctness of the mixing ratio between the primary gas is fundamental for a good and safe long term operation of the RPC detector. Therefore the mixture composition is continuously monitored: accidents/failures are always possible and in fact the injection of SF_6 changed to 0.45% causing a change in the RPC performances at the CMS experiment in April 2011.

Currently the gas mixture composition is checked weekly by means of a Gas Chromatograph (GC). In this study we propose the principle for an alternative monitoring system of the RPC gas mixture in order to have an online checking of the RPC gas quality.

Gas Chromatographic analysis of the RPC gas mixture

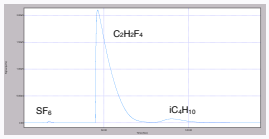


Figure 1. Typical Gas Chromatogram of the RPC gas mixture obtained with a microGC.

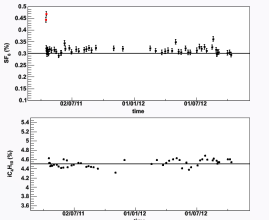


Figure 2. Trend of the SF_6 and iC_4H_{10} concentration during the LHC running period. The red dots represent the SF_6 variation happened in April 2011.

RPC Gas System at LHC

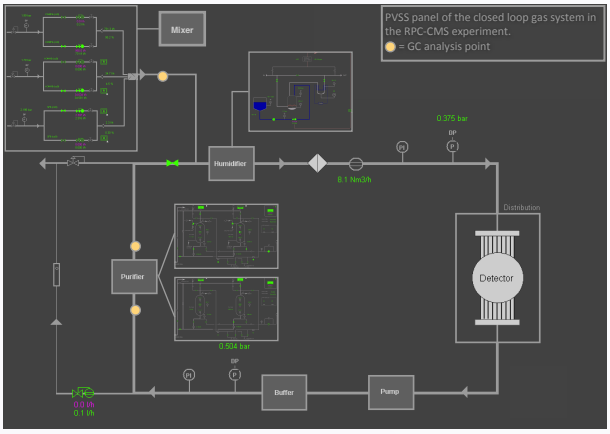


Figure 3. Schematic view of the CMS-RPC gas system.

Detector performances related to the gas mixture

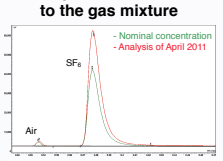


Figure 4. Comparison of two Gas Chromatograms showing the SF_6 concentration for two different periods.

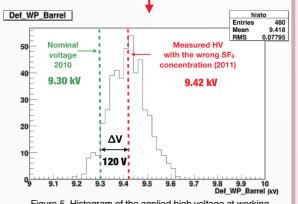
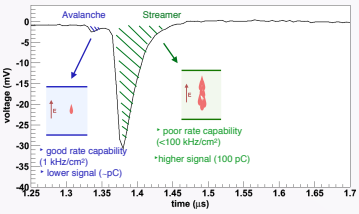


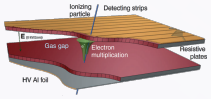
Figure 5. Histogram of the applied high voltage at working point for the CMS-RPC barrel region. It is visible a shift of about 120 V in April 2011 data with respect to 2010 data.

The analysis procedure and experimental set-up

Principles of the Resistive Plate Chamber

RPC signal parameters taken into account:
- Pulse integrated charge
- Pulse height
- Event time





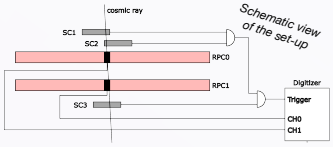
RPC features analysed:
- Efficiency.
- Average charge for the avalanche and streamer region.
- Average total charge.
- **Event frequency for the avalanche and streamer region.**
- Time resolution.

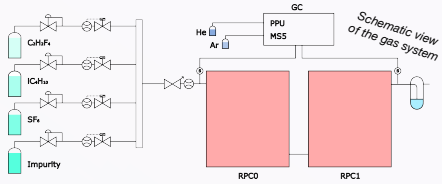
Variation of the gas mixture during the test

Gas	Concentration
SF_6	0% - 0.48%
iC_4H_{10}	1.7% - 7.0%
Air	1200 ppm - 12000 ppm
Ar	0% - 3.8%
CF_4	0% - 1%
CO_2	0% - 3.5%

Experimental set-up

- Standard high pressure laminate RPCs
- Scintillators (SC) for trigger
- Data acquisition by Desktop Waveform Digitizer



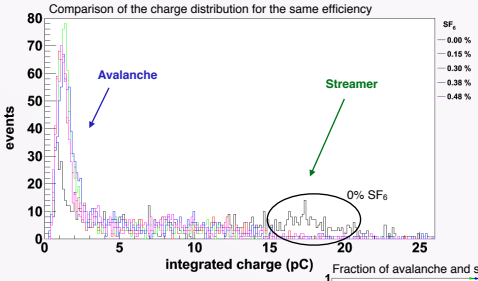


- Gas mixture is checked by means of a Gas Chromatograph (GC)
- Dedicated gas system for the controlled injection of different types of impurities

Two examples of the results obtained

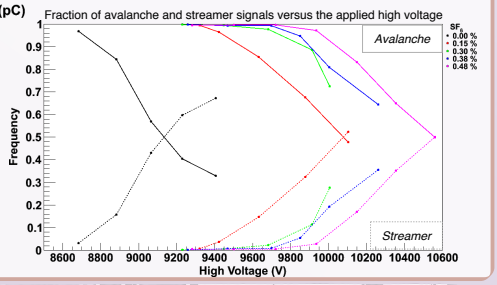
The SF_6 case

SF_6 is an electronegative gas which captures free electrons



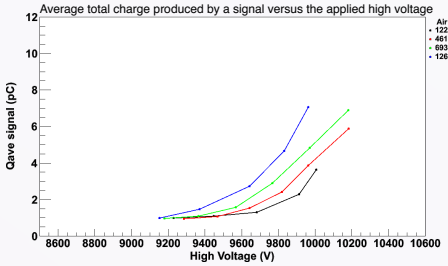
- SF_6 decreases the average pulse charge limiting the charge development.
- With the increasing of the SF_6 the number of streamer signals is reduced.
- Without SF_6 a lower high voltage is needed to reach the efficiency obtained with higher SF_6 concentration.

- Frequency of the avalanche and streamer signals at the same RPC efficiency.
- With less SF_6 the number of streamer signals is higher (at the same efficiency).
- With the increasing of the high voltage the streamer signals become predominant.



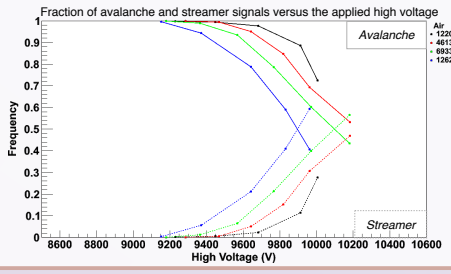
The Air case

Air is one of the most common pollutant in the gas systems



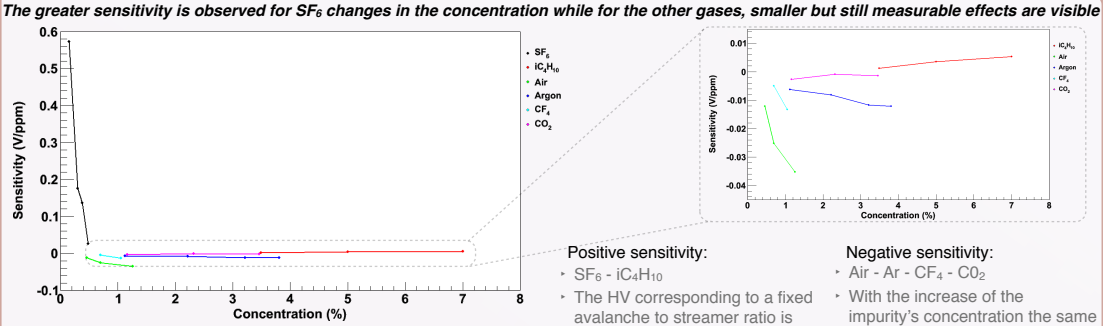
- Air can enter in gas system because of leaks, poor quality of the primary gas supplies or during maintenance operations.
- Air is usually present in the order of few ppm in LHC gas systems.
- At the same high voltage the charge increases with the increasing of the Air concentration.

- With the increasing of Air concentration, the number of streamer signals increases (at the same high voltage).
- The behavior is opposite to the one of SF_6.
- Usually RPCs work in avalanche mode.
- Air affects the RPC performances.



Conclusion: the RPC sensitivity for different gas mixtures

The greater sensitivity is observed for SF_6 changes in the concentration while for the other gases, smaller but still measurable effects are visible

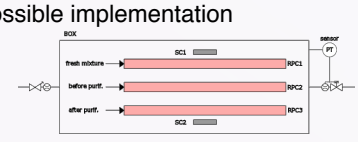


On the y-axis the high voltage change per variation of the gas/impurity concentration is reported: this parameter allows quantifying the sensitivity of the RPC working parameters for different concentrations.

Positive sensitivity:
- SF_6 - iC_4H_{10}
- The HV corresponding to a fixed avalanche to streamer ratio is increasing with increasing concentration.

Negative sensitivity:
- Air - Ar - CF_4 - CO_2
- With the increase of the impurity's concentration the same avalanche to streamer ratio is reached at lower HV.

A possible implementation



The RPC most sensitive parameter is the avalanche to streamer ratio

- Possible to detect **gas variations** of the order of **100 ppm**.
- Very **fast** (30 min) detection of problem due to the analysis of the collected charge.
- An **online** gas mixture monitoring which can run 24h/24h.
- The system can be easily integrated in RPC LHC gas systems.
- Different points of gas analysis already availabe.