PH-DT
Detector Technologies

Detector operation with gas recirculation systems: the RPC case

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Instrumentation Days on Gaseous Detector
IPNO, Orsay - 25-26 June 2014

Outline

- RPC detectors at LHC
  - Main parameters and working conditions
- RPCs gas system
  - The closed loop gas circulation
  - Limits on the present configuration
- Closed loop operation and gas filtering
  - Experimental set-up at the GIF
  - Characterization of the purifiers
- Test of purifiers configurations
  - Comparison of the different configurations tested
  - Optimization of purifier configurations
  - Monitoring of the impurities
- Implementation of new configuration at LHC
- Conclusion

RPC detectors at the LHC Experiments

Experiment	ATLAS	CMS	ALICE (MTR)	ALICE (TOF)
Material	Bakelite	Bakelite	Bakelite	Glass
Layout	Single-gap	Double-gap	Single-gap	Multi-gap
Read-out (coordinate)	2	1	2	2
Surface (m^2)	7500	3750	140	171
Volume (m^3)	15	15	0.3	18
Expected background rate (Hz/cm^2)	10	Barrel: 10 Endcap:100	10	50
Integrated charge (mC/cm^2)	500	Barrel: 50 Endcap: 500	50	25
Gas system operation	Closed loop	Closed loop	Open mode*	Closed loop
Gas mixture	$R134a/iC_4H_{10}/SF_6$	$R134a/iC_4H_{10}/SF_6$	$R134a/iC_4H_{10}/SF_6$ $Ar/ R134a/iC_4H_{10}/SF_6$	$R134a/SF_6$

*Upgrade to closed loop gas system on going

Overview

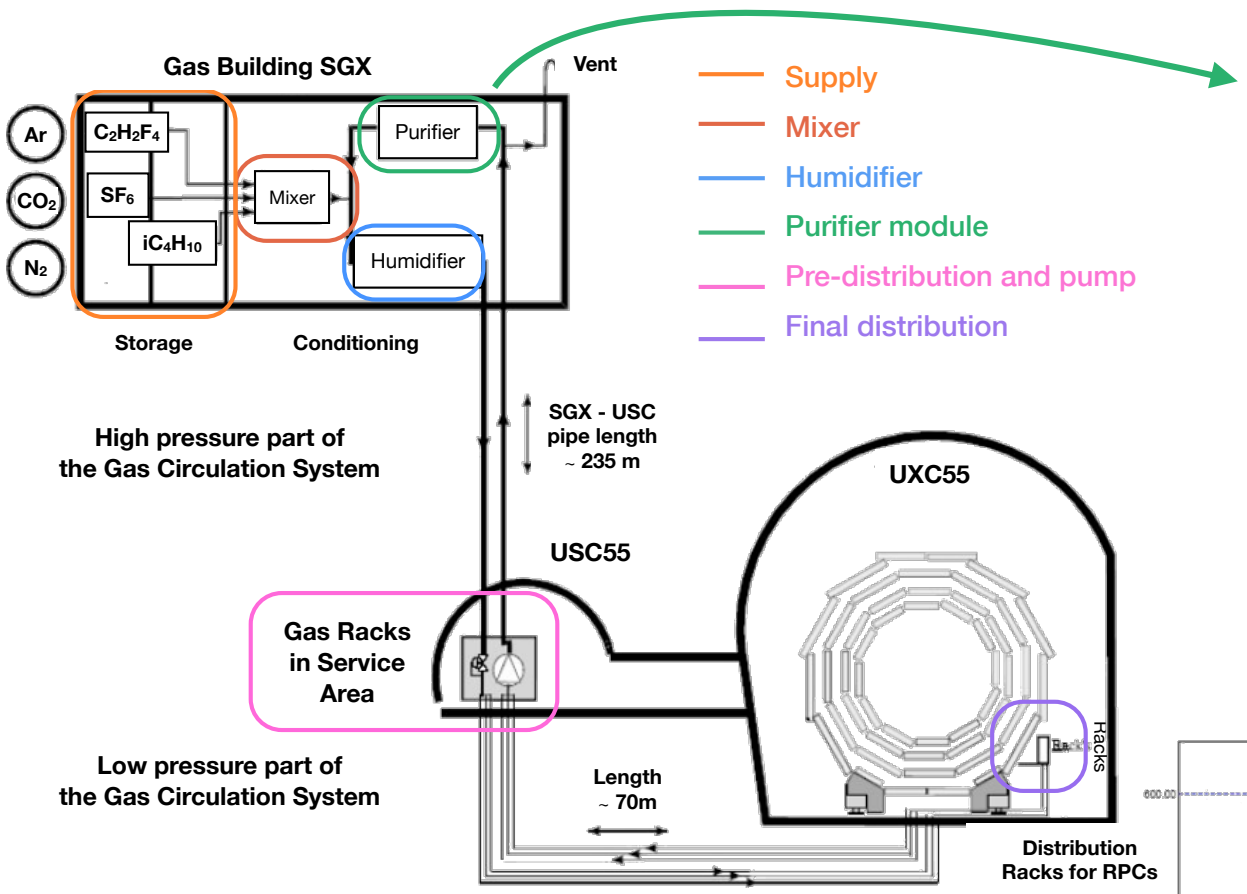
RPC detectors at the LHC Experiments

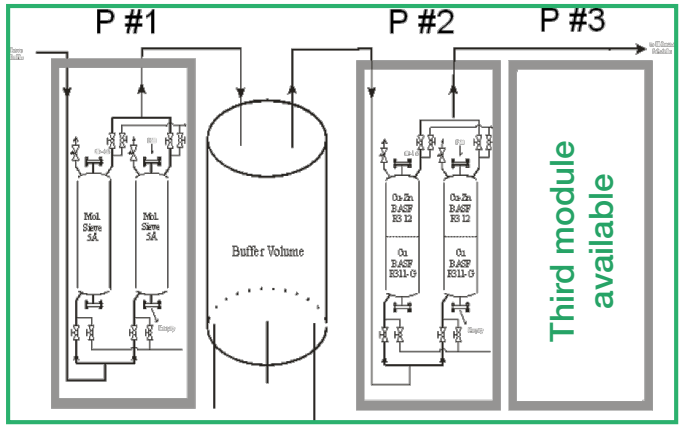
Why RPCs for application in LHC Experiments need a "particular care"?

- Large size systems (~15 m^3 of gas volume and ~10^3 m^2 of sensitive area)
- Very expensive gas mixture: 600 kCHF/year per experiment
- Very long period of operation expected (at least 10 years)
- Very high level of background radiation expected
- Integrated charge never reached before:
  - 50 mC/cm^2 for ALICE and CMS
  - 500 mC/cm^2 for ATLAS
- Basically impossible to operate the gas system in open mode
  - technical and financial reasons
  - nowadays with 10% of fresh gas replenishing rate (600 l/h), the cost is 1000€/day
- Closed loop operation
  - gas mixture quality: presence of impurities in the return gas of irradiated RPCs
  - possible bad RPC performance due to impurities
  - gas mixture purification is needed

Motivation

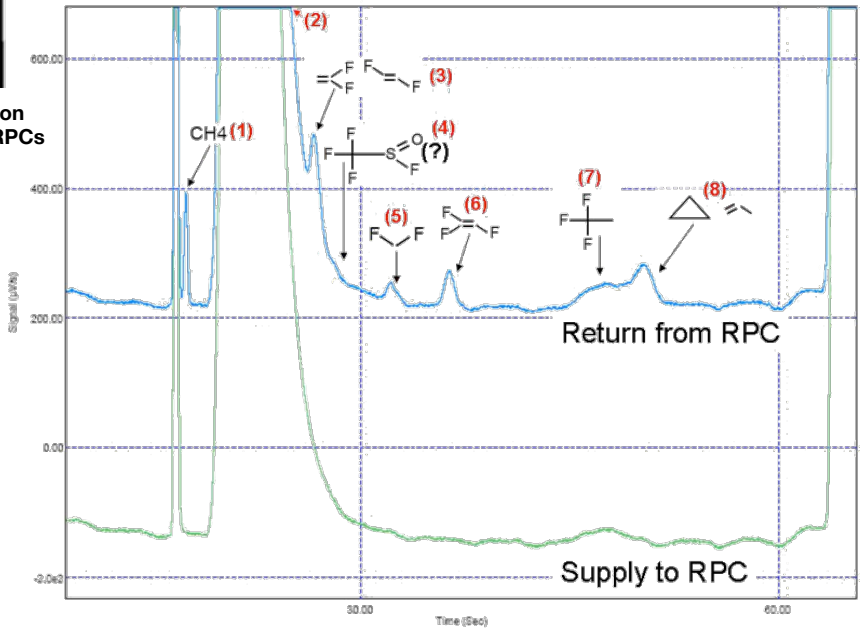
RPCs Gas System





Purifier 1: - MS (10%5Å+90%3Å)
- lifetime 1.5 day

Purifier 2: - Cu-Zn and Ni-Al_2O_3
- lifetime 15 day



System limitations

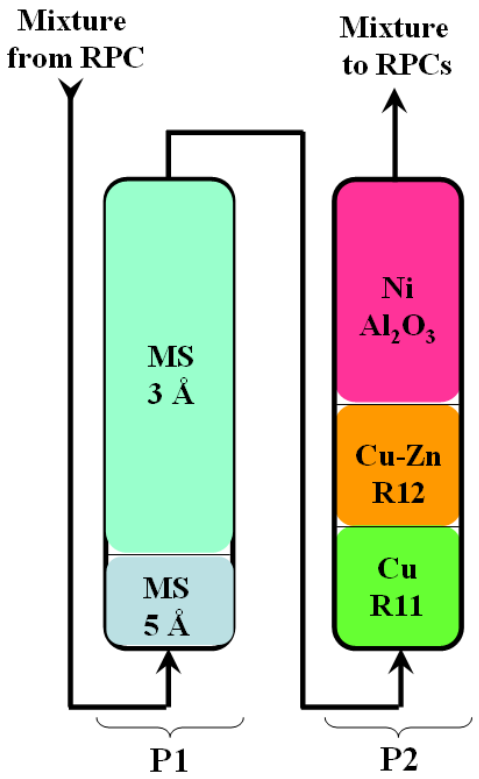
- Not all the extra-components produced during RPCs operation are removed
  - Detector performances can be affected if impurities are not properly removed
- Not possible to work in open mode
  - Technical and financial reason

Closed loop gas recirculation

RPCs Gas System

Limits of currently used purifiers configuration:

1. Not all the extra-components produced during RPCs operation are removed.
2. Very short cycle
3. Too many regeneration cycles



Limiting factor if flow increase is needed

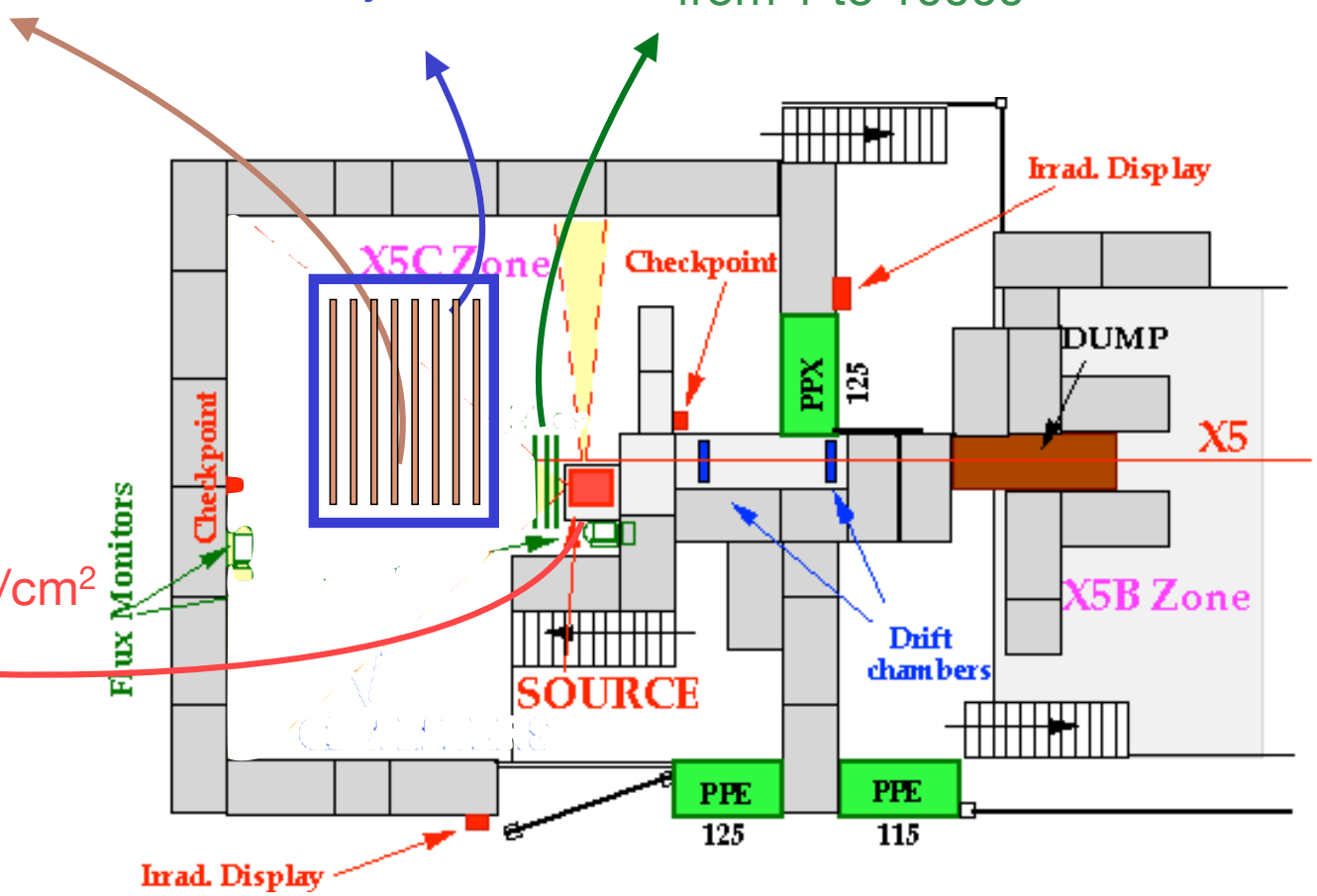
	Purif. 1	Purif. 2
number of regenerations	91	30
Pre-SaturationVol (m^3)	160	850
process gas flow (m^3/h)	5	5
Pre-SaturationTime (h)	33	163
Pre-SaturationTime (day)	1.4	6.8
Regeneration time (min)	480	360
Regeneration temperature (°C)	220	200
Conditioning time (min)	150	720
Conditioning flow (l/h)	*100*	*100*
Conditioning time (vol)	10	50

Experimental set-up at the GIF

16 RPC gaps
with standard HPL

- Set of lead filters allowing to modulate the radiation intensity
- Absorption factor: from 1 to 10000

Tent with temperature and humidity controlled

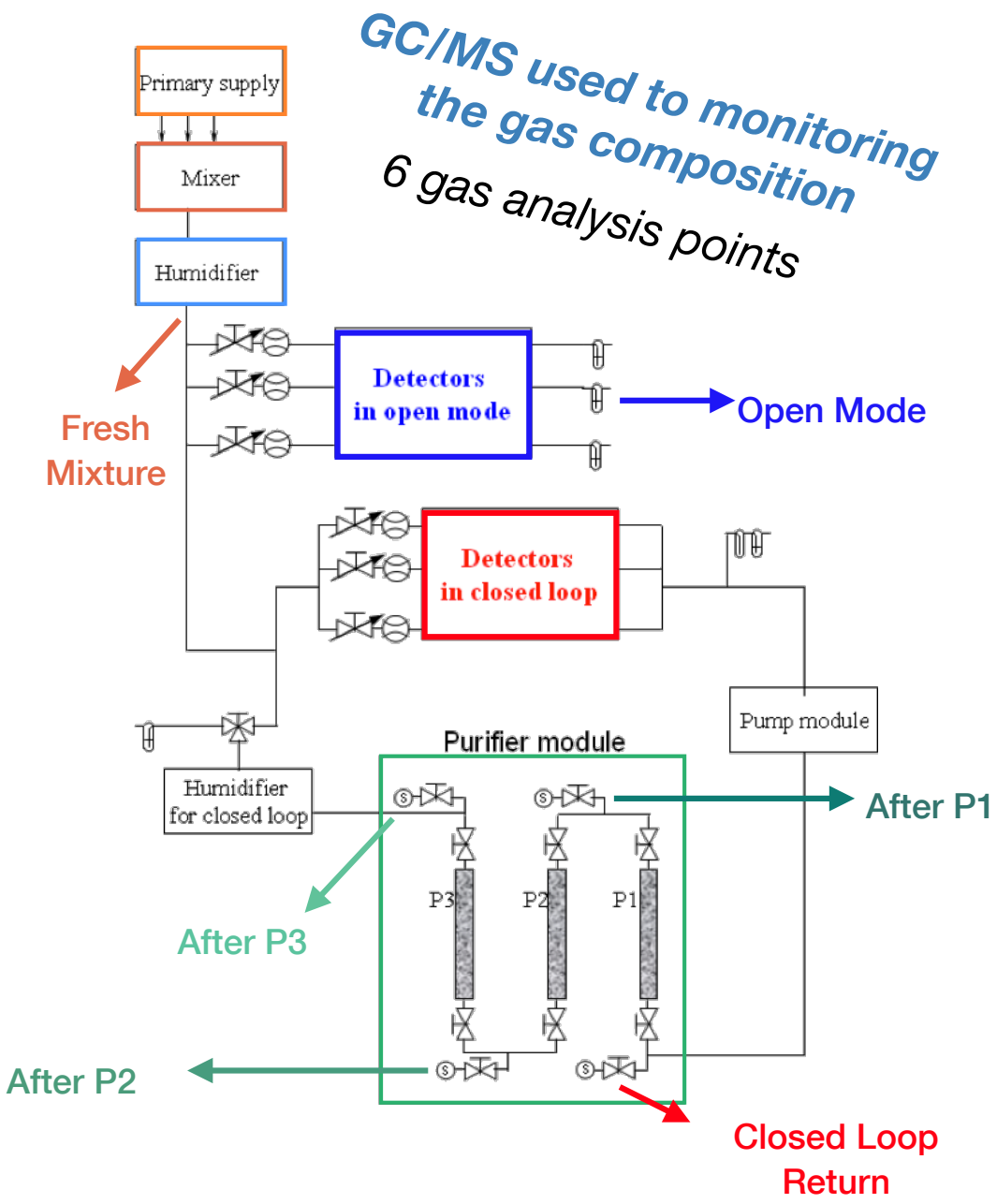


- ^{137}Cs source (γ 662 keV): 590 GBq
- At ~2m: 1cGy/h
- RPC counting rate ~200Hz/cm^2
- Accelerator factor: ~30

GIF: Gamma Irradiation Facility

Overview

Experimental set-up at the GIF



Two set of chambers:

- **Open mode**: reference and characterization of the impurities.
- **Closed loop**: filtering and/or accumulation of impurities. **Long term operation** for final validation

Flexible system:

- Easily to change configurations
- Easily replacement of purifiers
- Possibility to install different detectors

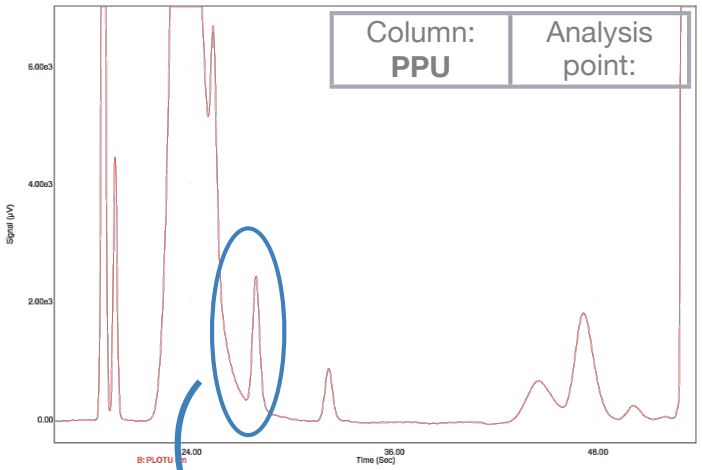
Small replica of LHC gas system

The gas system

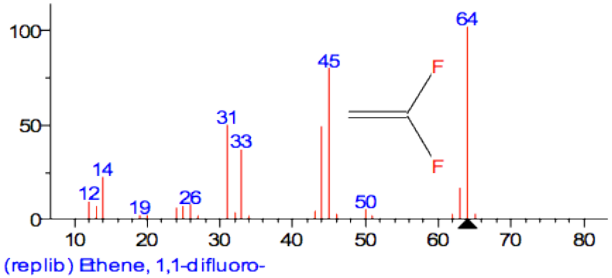
Experimental set-up at the GIF

MicroGC-MS

always in use



$C_2H_2F_2$



- GC measures gas concentration
  - ppm level
- GC coupled with a MS
  - Identification of impurities
- 3 different columns
  - Separation of different types of impurities

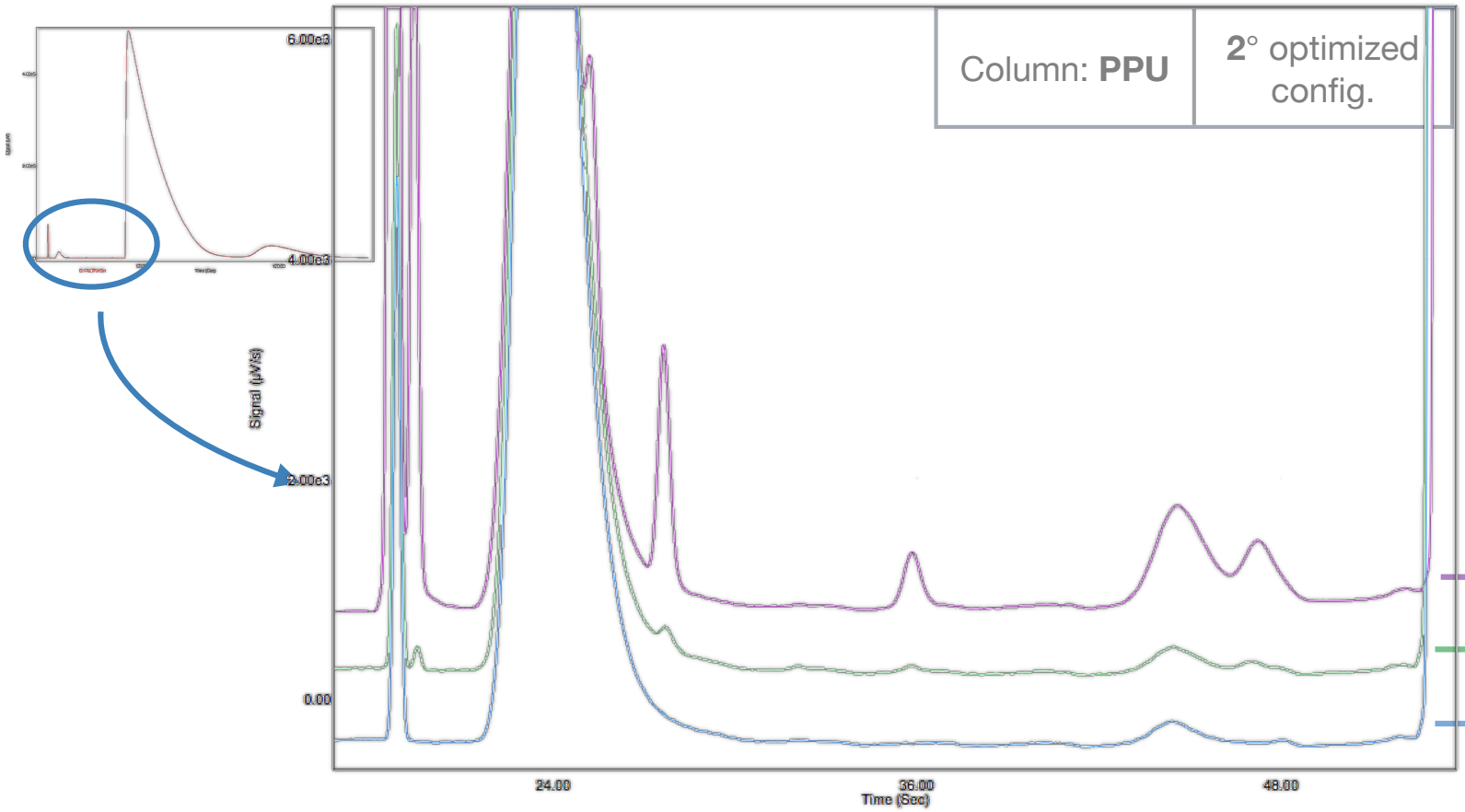
for dedicated studies

F^- station and liquid chromatography (HPLC)

- Based on bubbling the gas mixture in water
- Measurement of the fluoride concentration in water solution

Gas analysis instruments

Experimental set-up at the GIF



- After about 50 days of operation
- Impurities in open mode are less than in closed loop
- In the closed loop the impurities accumulate
- The task of purifiers: avoid exponential increase of the impurities in the closed loop

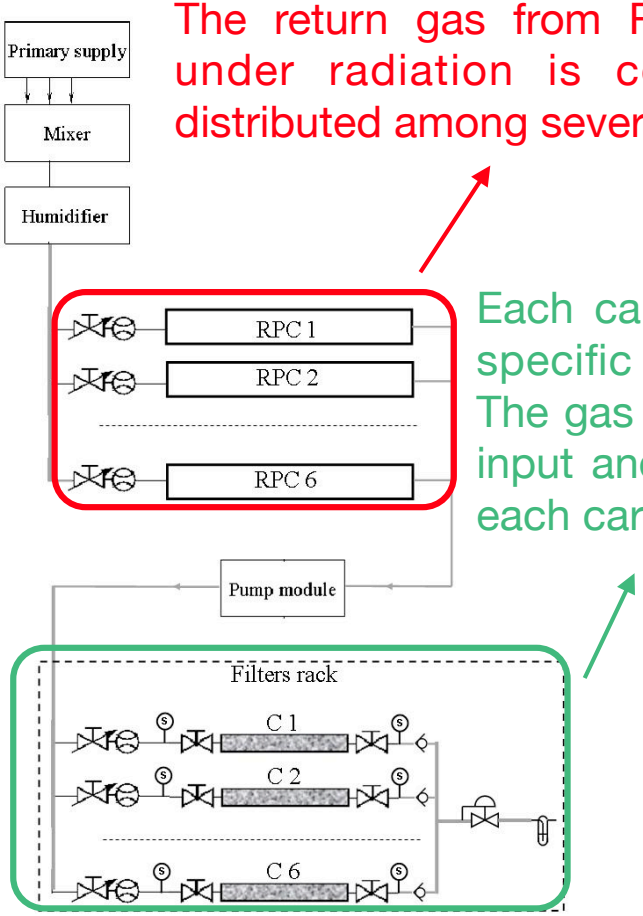
Example of RPCs operation in different conditions

Characterization of the purifiers

Numerous cleaning agents are available

Basic characterization to verify the performance with the specific RPC gas mixture

Experimental set-up

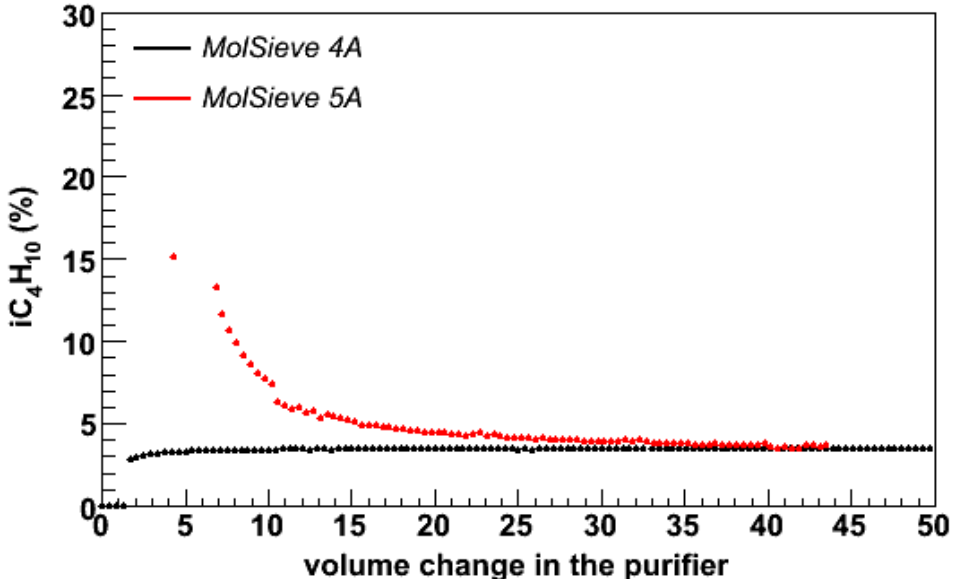


The return gas from RPC operated under radiation is collected and distributed among several cartridges.

Each cartridge contains a specific cleaning agent. The gas is analysed at the input and at the output of each cartridge

Conditioning phase

- Conditioning phase: some purifiers need a preparation time
  - At start-up they absorb a component of the gas mixture
- MolSieve 5 Å
  - It absorbs $C_2H_2F_4$
  - Relative concentration of other components increases

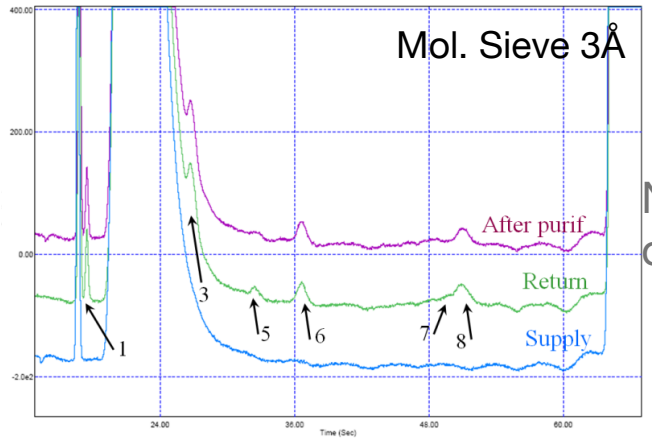


Set-up and conditioning phase

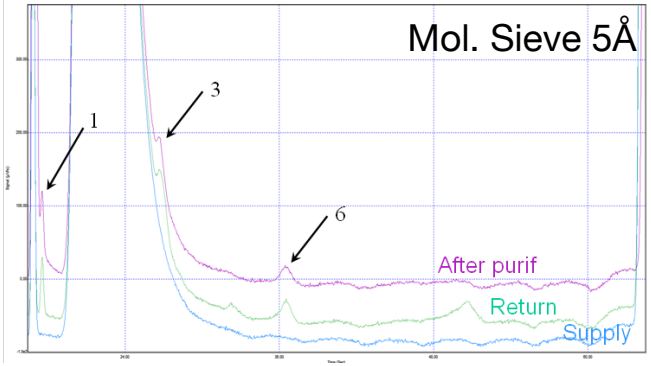
Characterization of the purifiers

Molecular Sieves

- They filter H_2O (as they should)
  - capacity ~150 g(H_2O)/kg(MolSieve)
- They filter some extra impurities
- They absorb part of the RPC mix
  - Conditioning phase needed



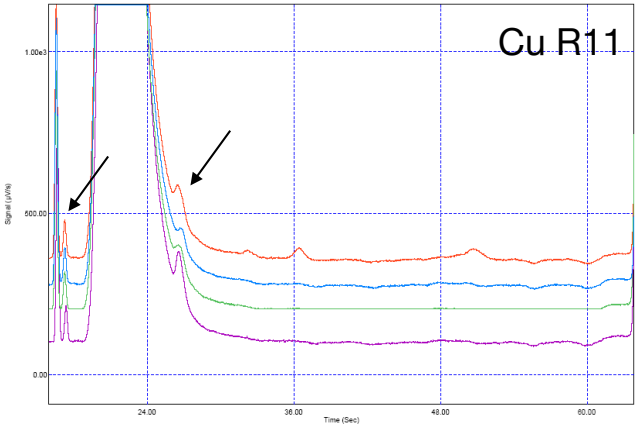
Not effective wrt other impurities!



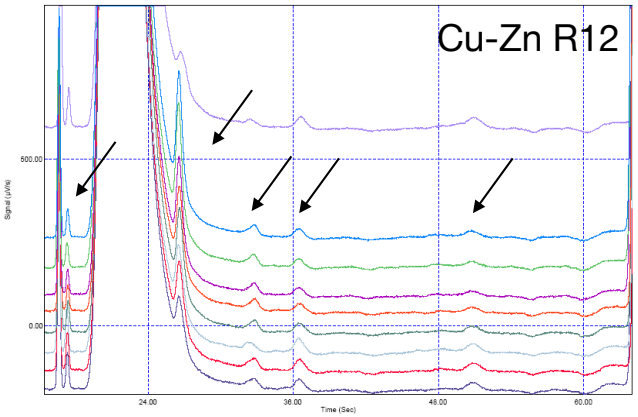
Many impurities are filtered

Cu/Zn

- They filter O_2 (as they should)
  - capacity ~5 g(O_2)/kg(catalyst)
- They filer H_2O
  - capacity ~50 g(H_2O)/kg(catalyst)
- R11 filters additional impurities, R12 does not and it enhance an extra component



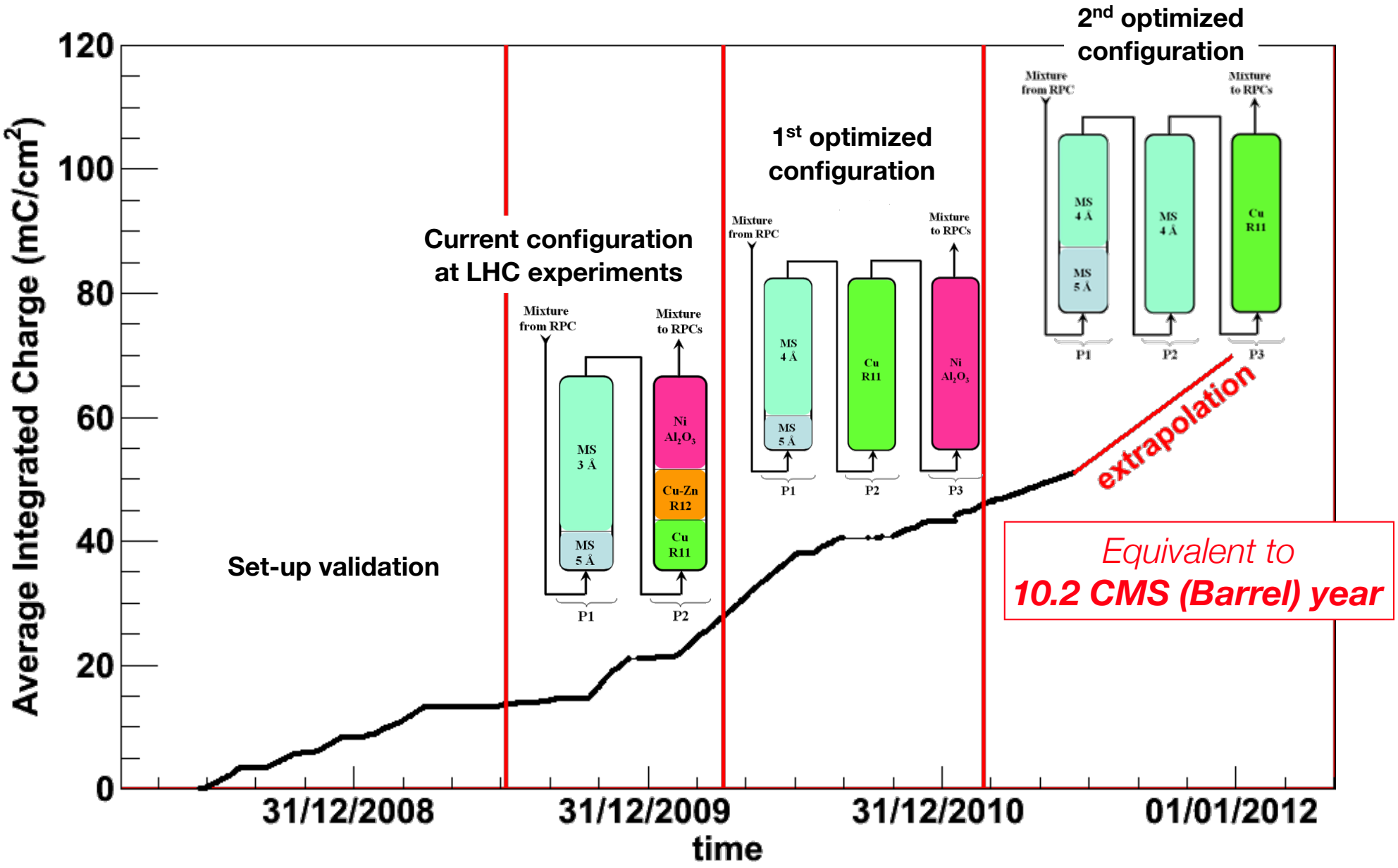
R11 seems to be quite effective



R12: basically no extra components filtered.
Some components are enhanced.

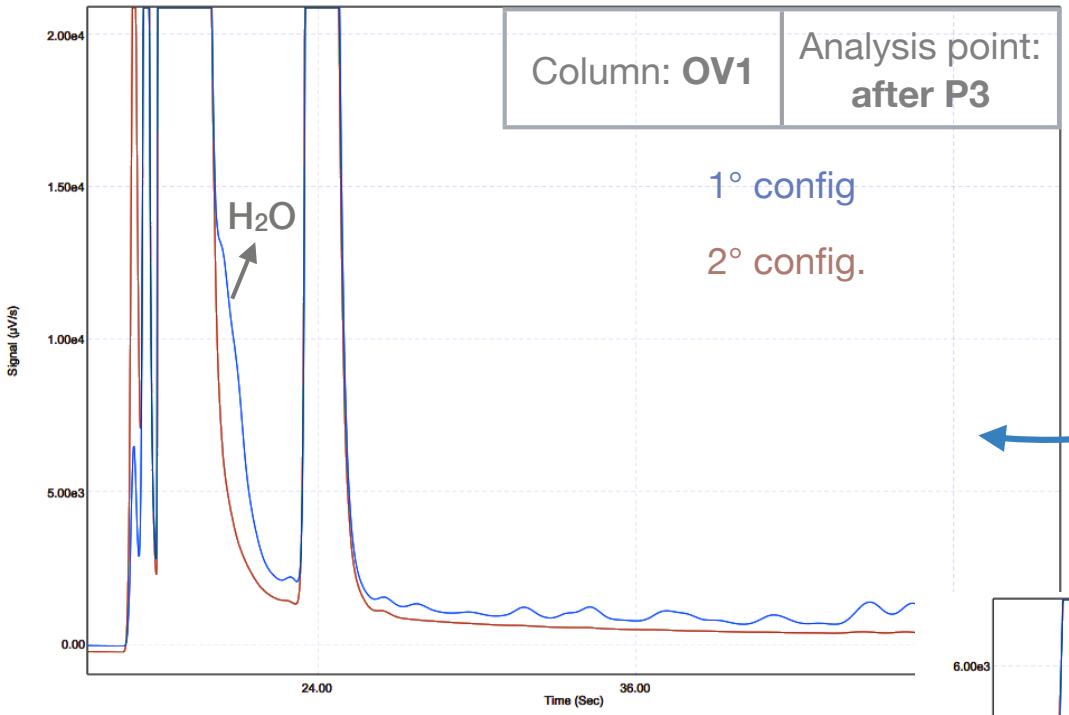
Molecular Sieve and Cu/Zn

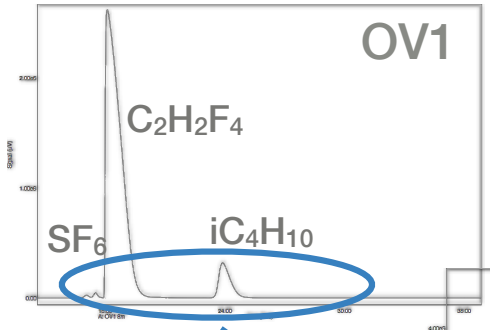
Purifiers configurations tested

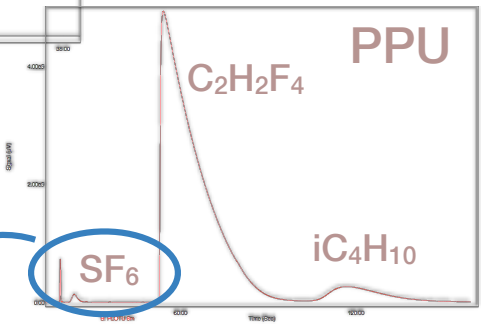


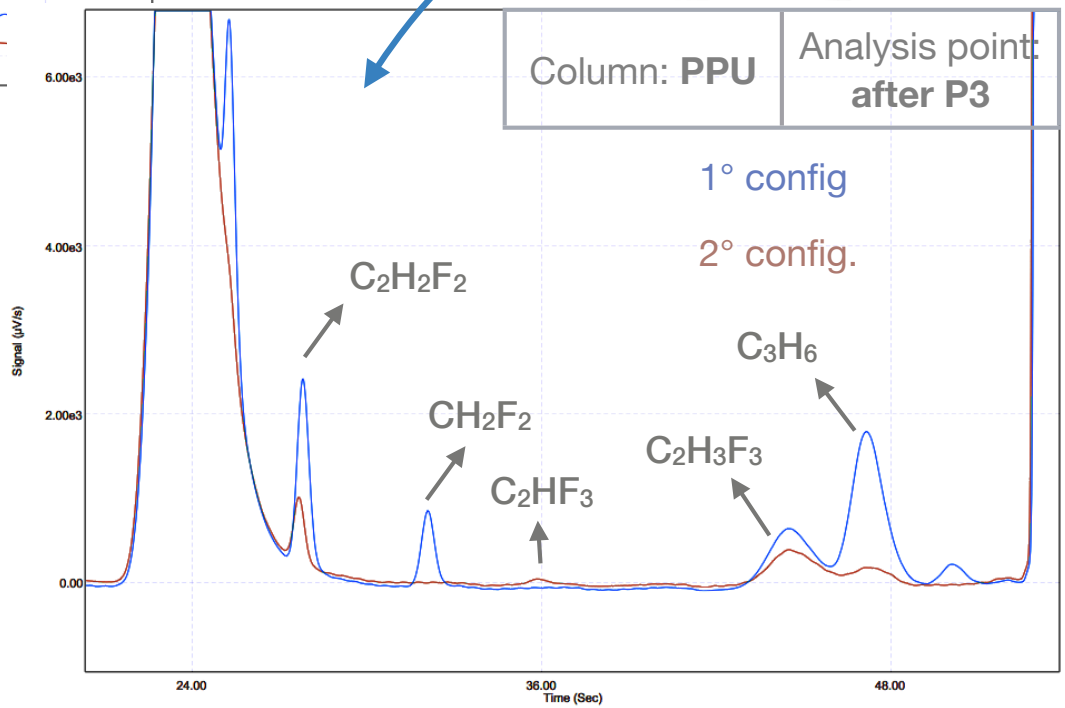
Overview

Results on new purifiers configuration





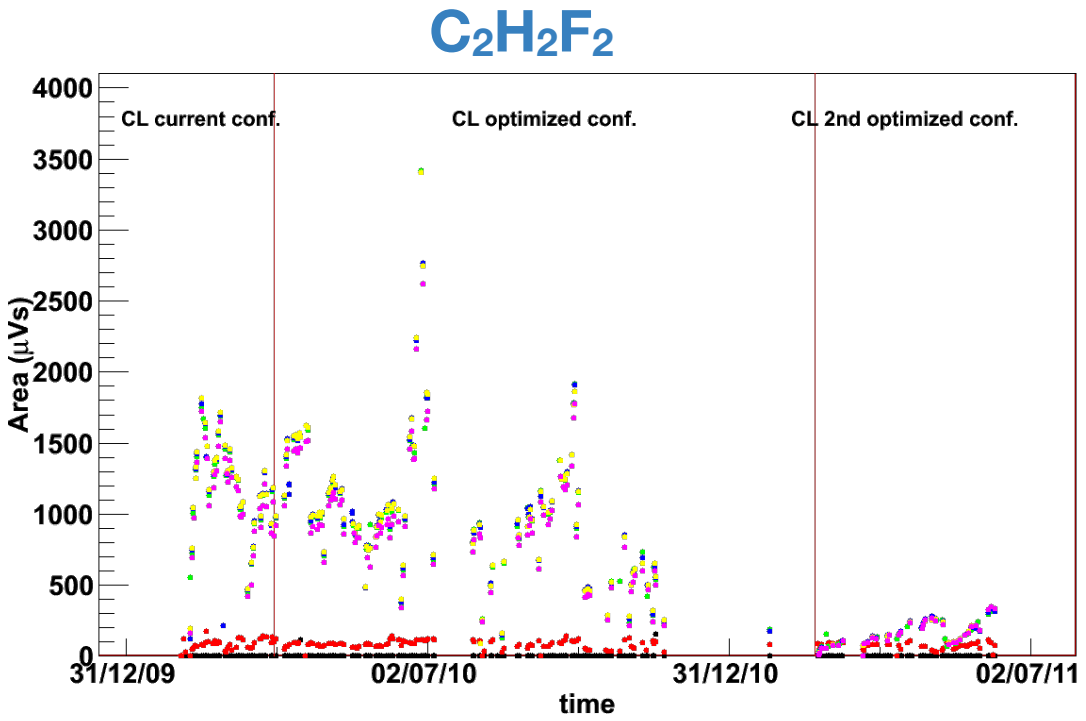


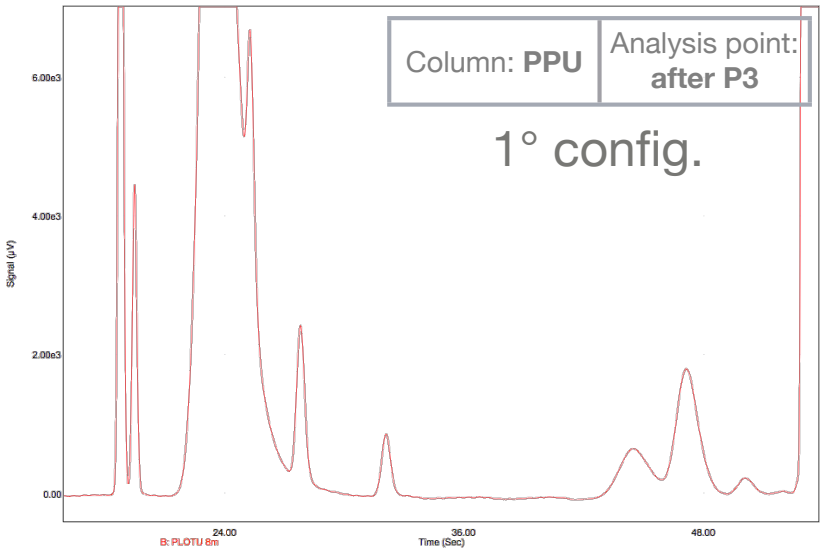


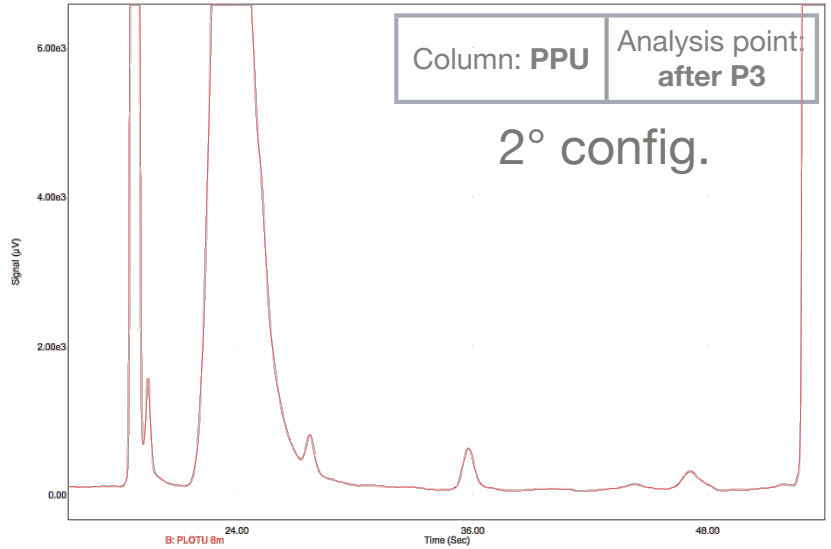
- ~ 50 days of operation
- H_2O is present in the first configuration
- Identification of many impurities
- In the 2° configuration there are less impurities (some disappear!)

1st vs 2nd configuration

Results on new purifiers configuration



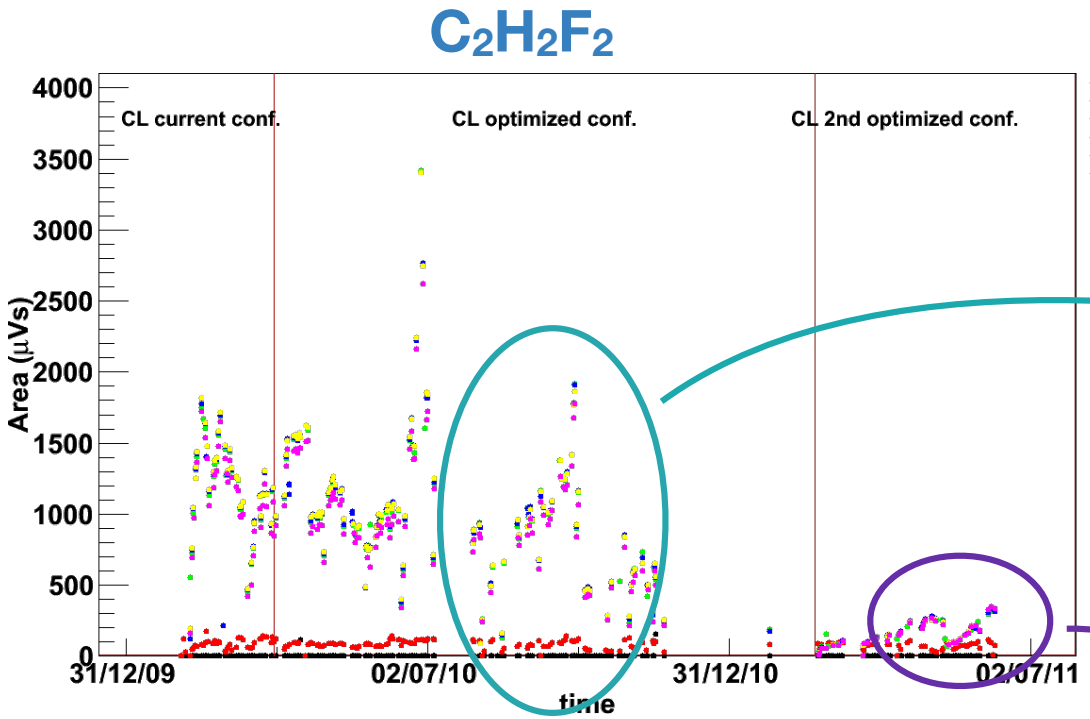


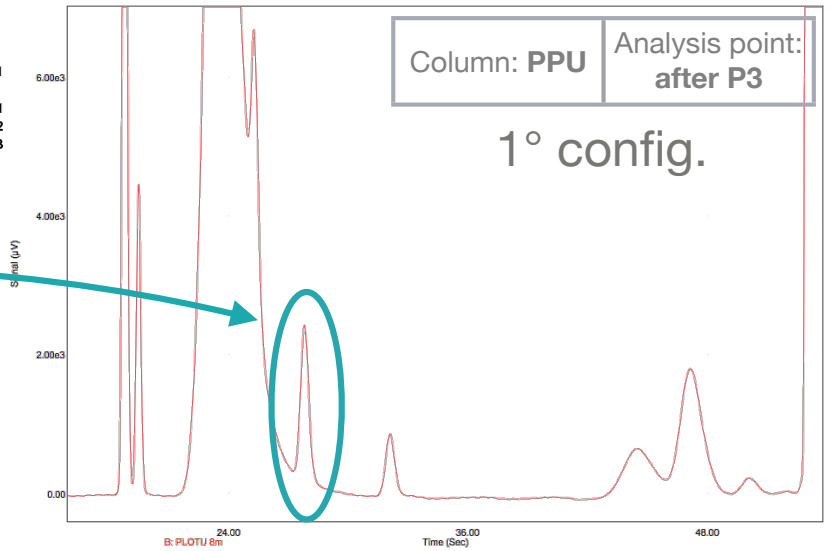


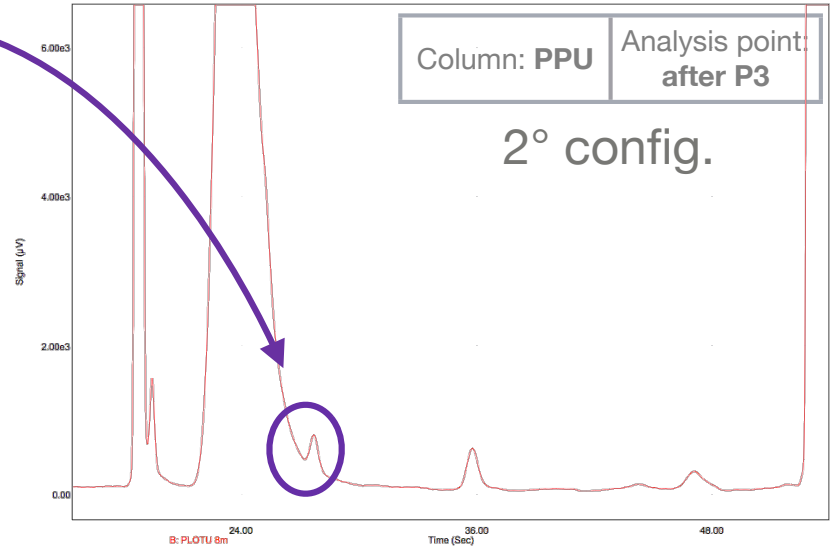
- Impurities are constantly monitored
- Impurities are significant lower in the second configuration
- Impurities increase when the purifiers are almost saturated or when the amount of fresh gas is too low

Monitoring of the impurities

Results on new purifiers configuration







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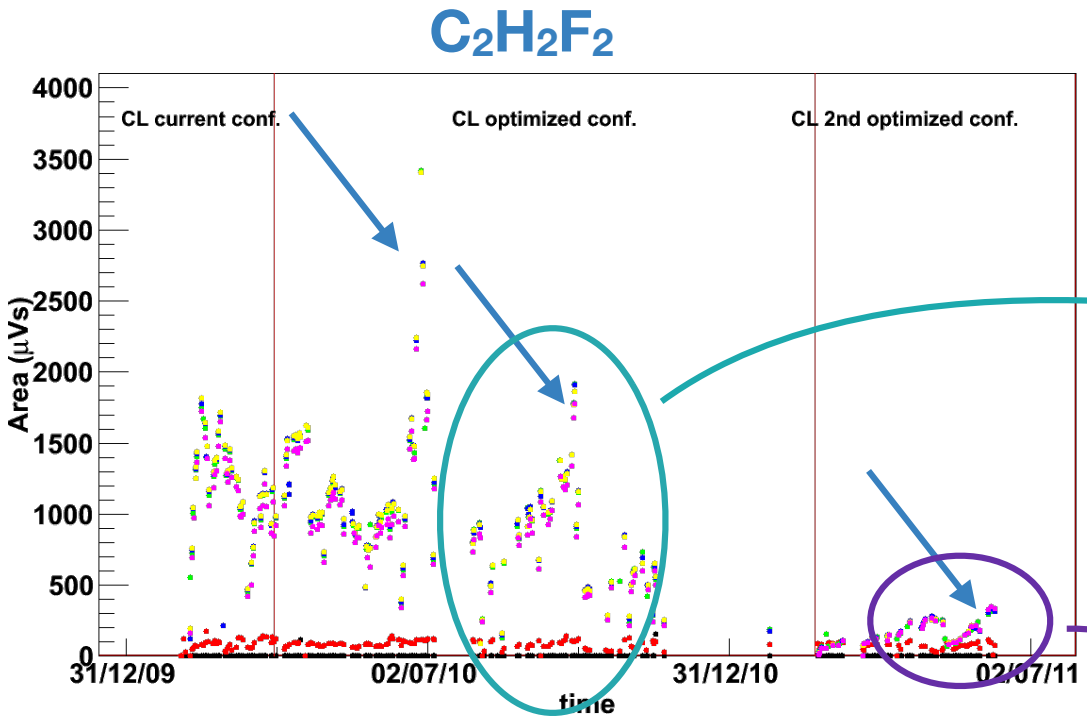

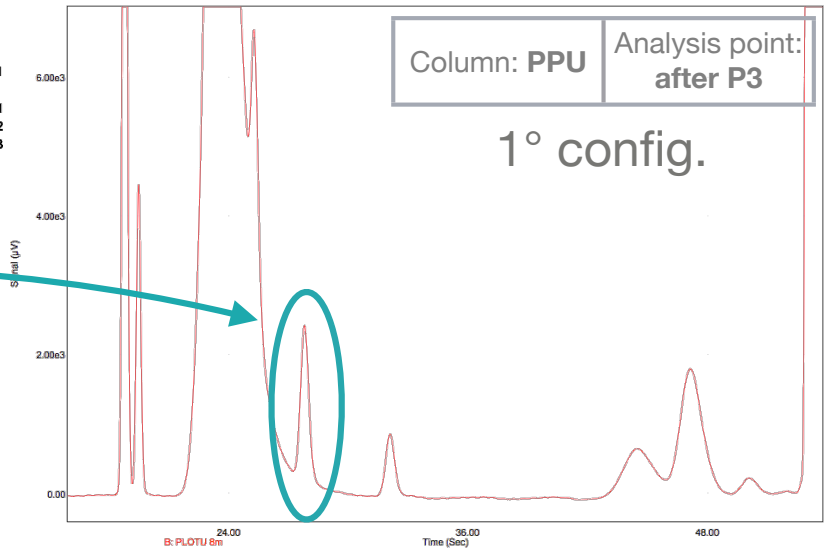

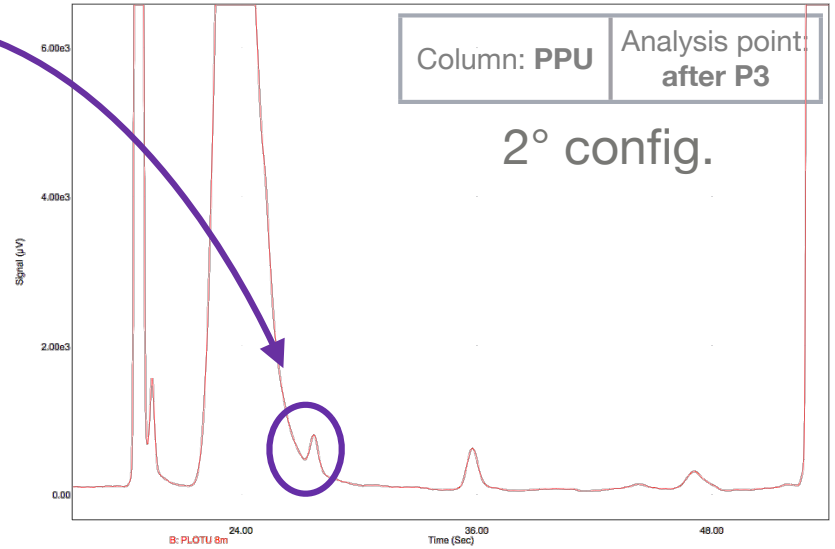

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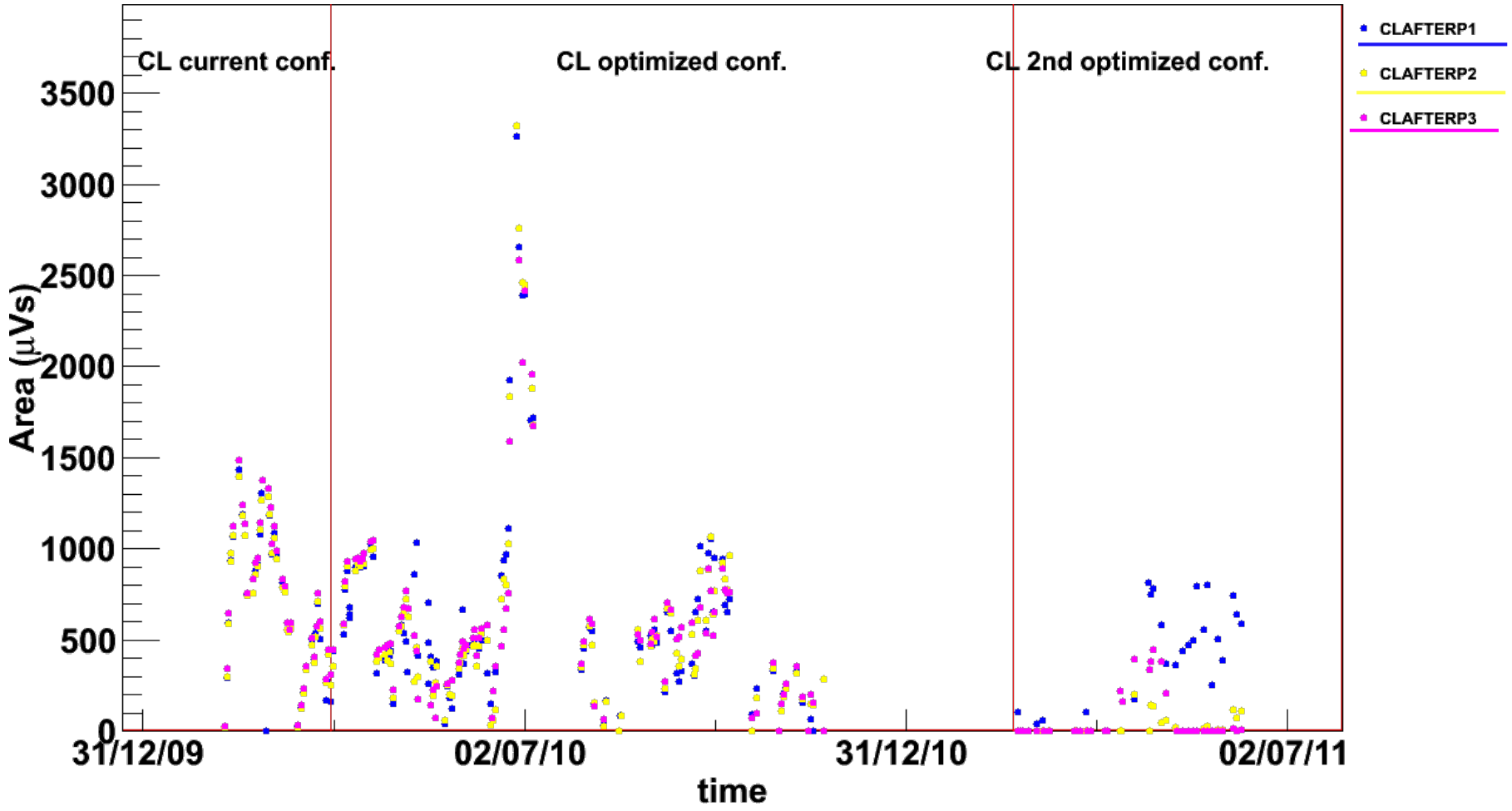
Monitoring of the impurities

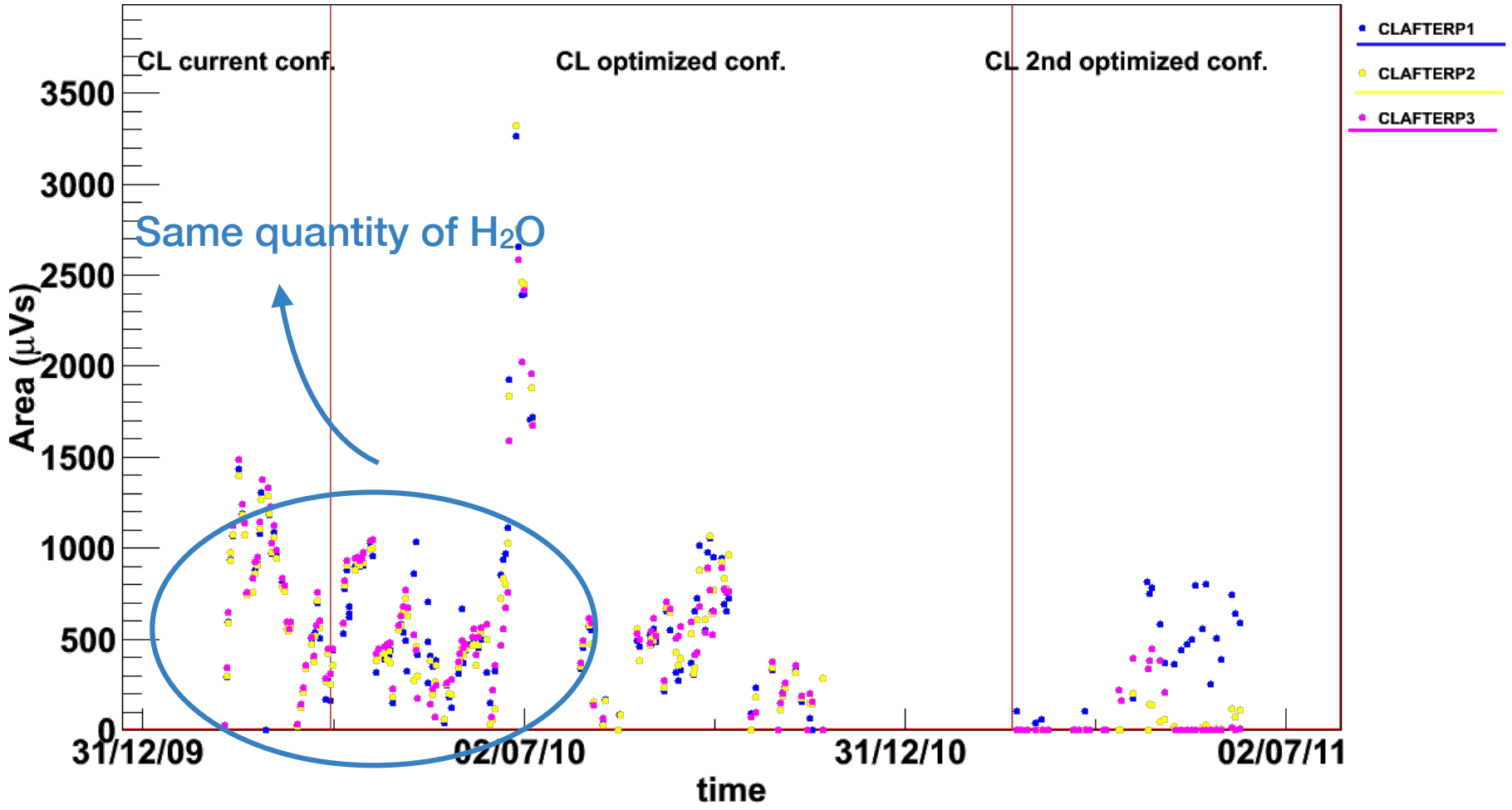
Results on new purifiers configuration



- The presence of H_2O is still high in the 1° configuration
- In 2° configuration there is less water after the purifiers
- It is possible to continue running when P1 is saturated. The purifiers module last longer.

The H_2O absorption

Results on new purifiers configuration



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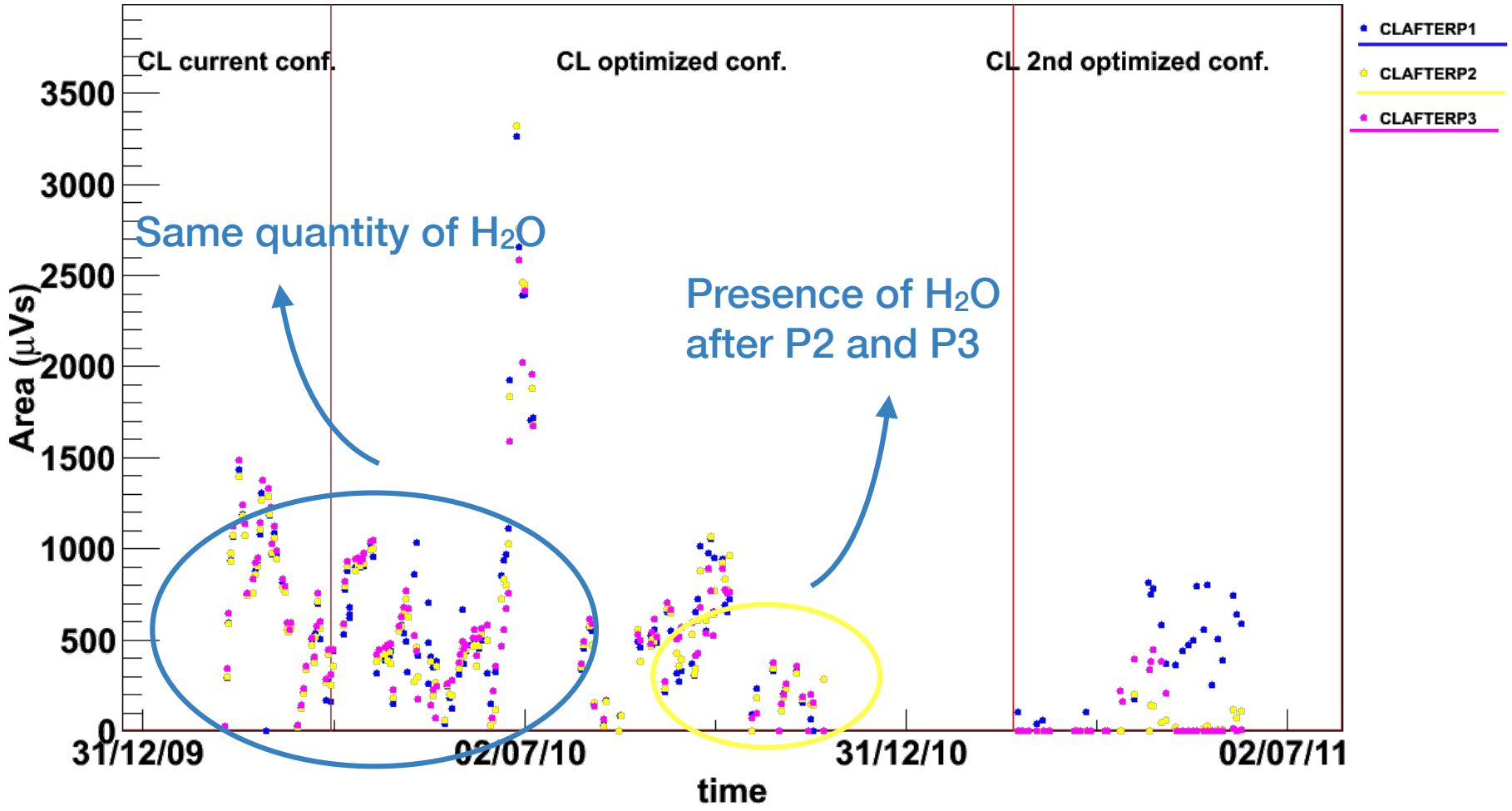

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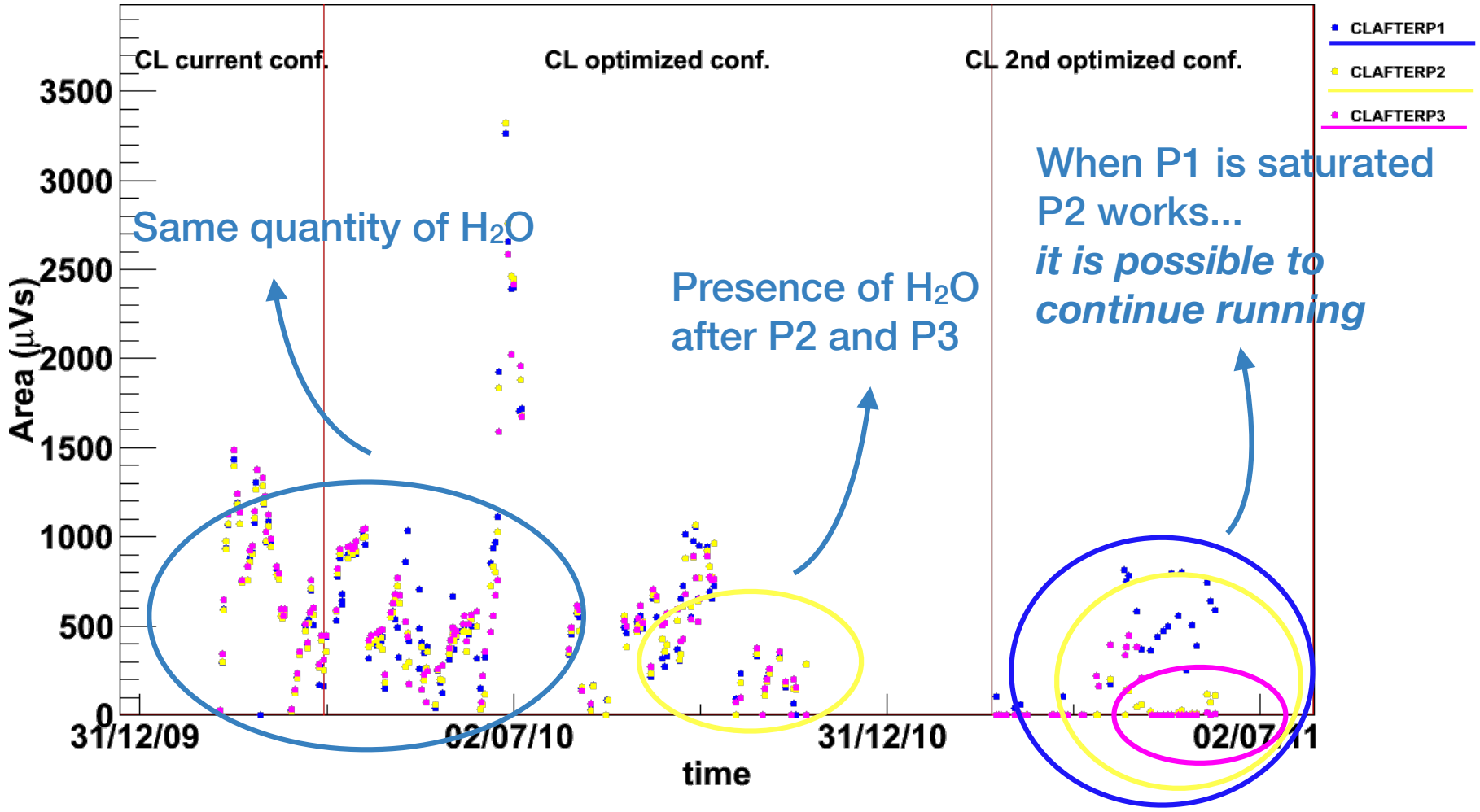

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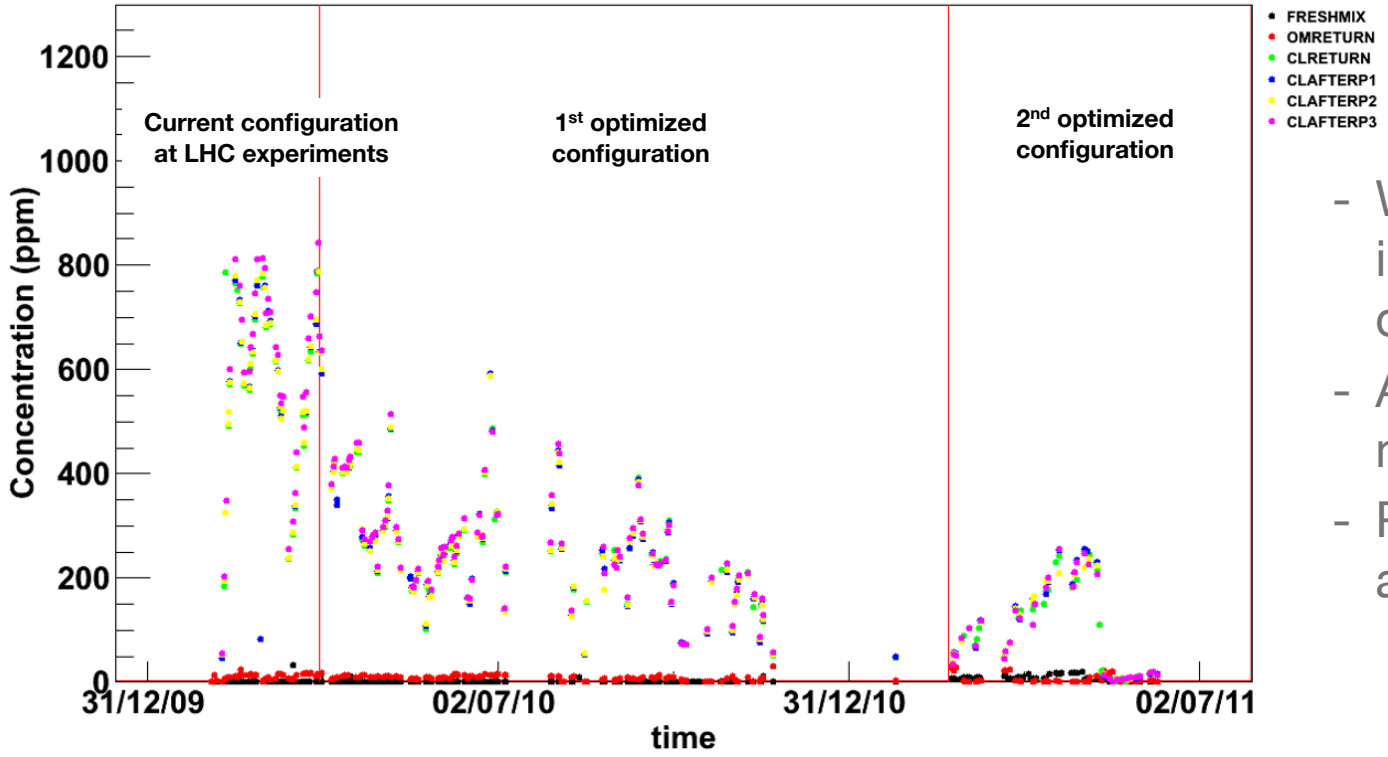
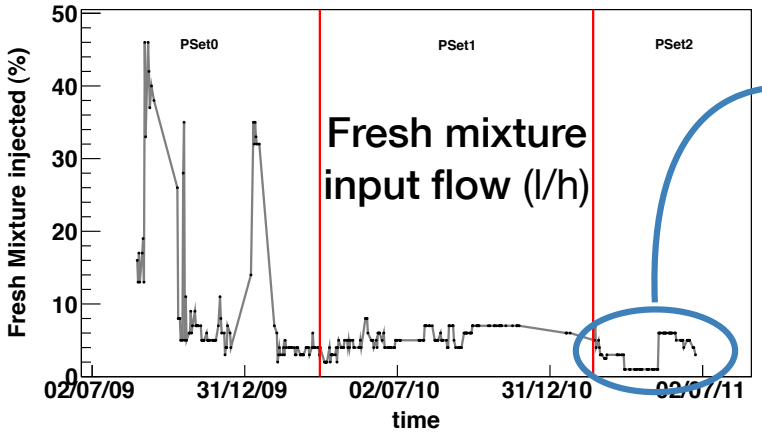
Results on new purifiers configuration

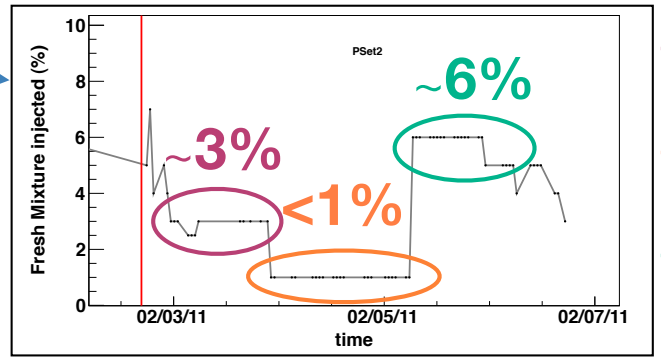
Impurities vs % of fresh gas

Example for one impurity



- Without fresh gas injection the system does not work well.
- A percentage of fresh mixture is mandatory.
- Purifiers are needed to absorb impurities.





The impurity concentration is relatively high.
The impurity concentration is high.
The impurity is under control.

Results on new purifiers configuration

Impurities vs % of fresh gas

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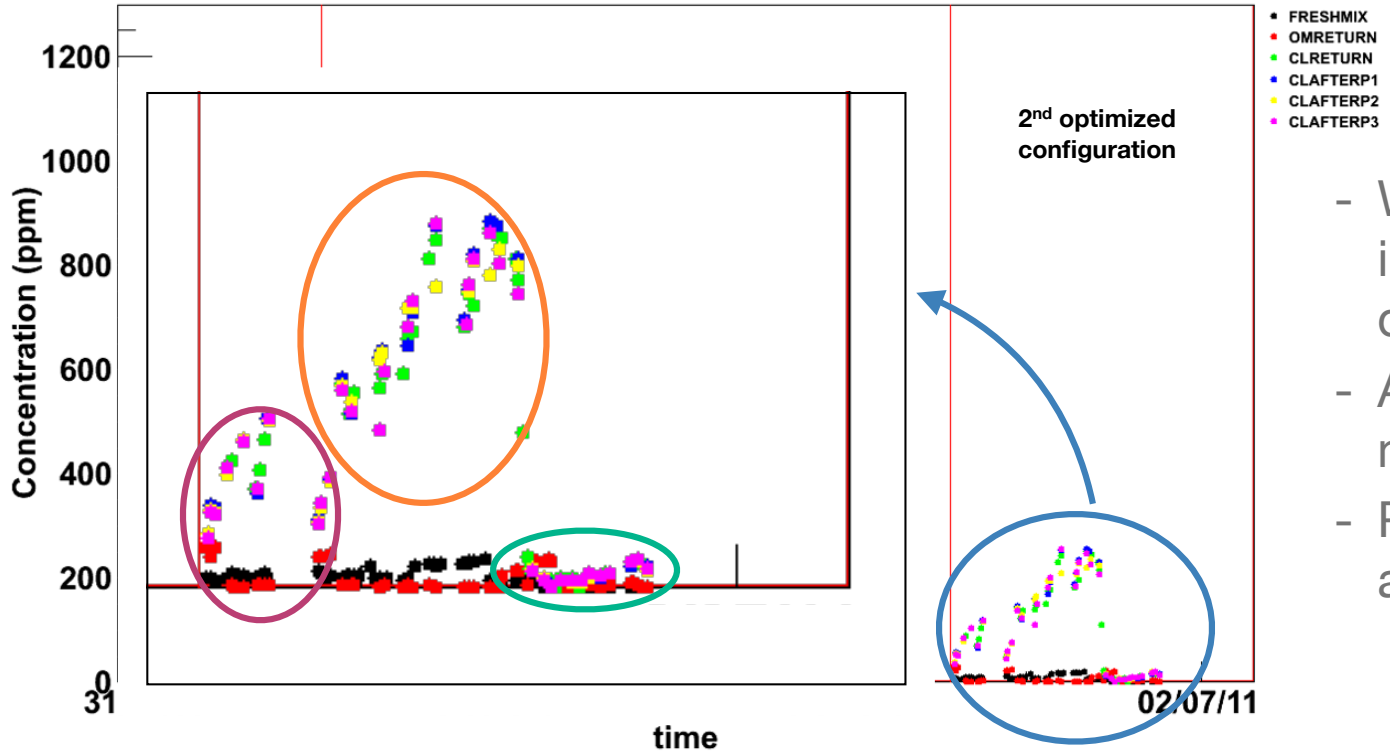

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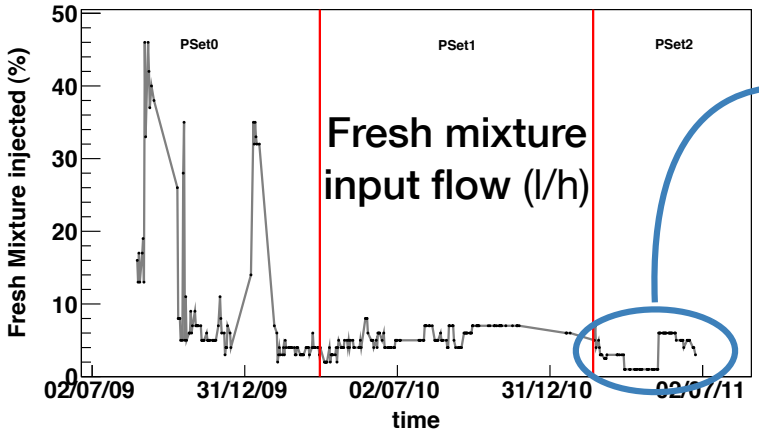

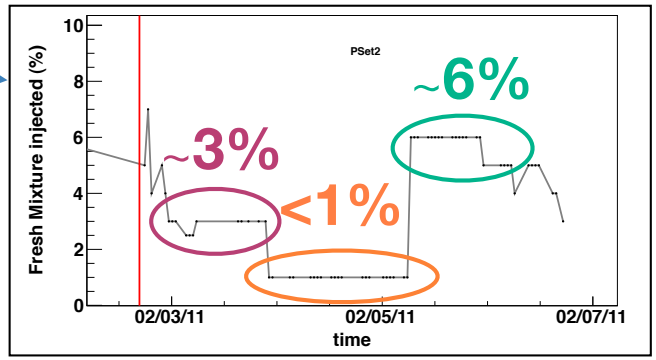

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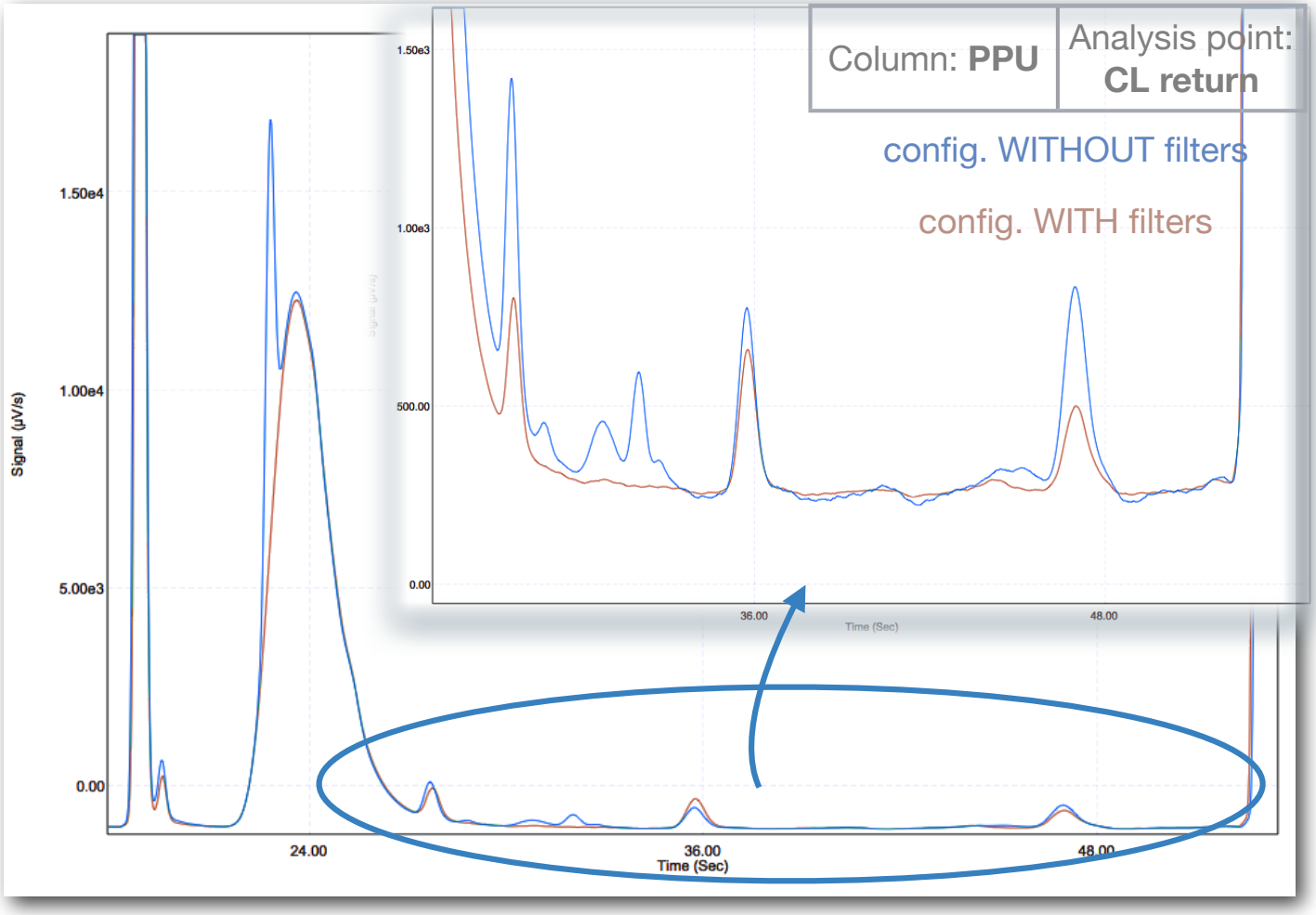
Results on new purifiers configuration

Purifiers are really needed!

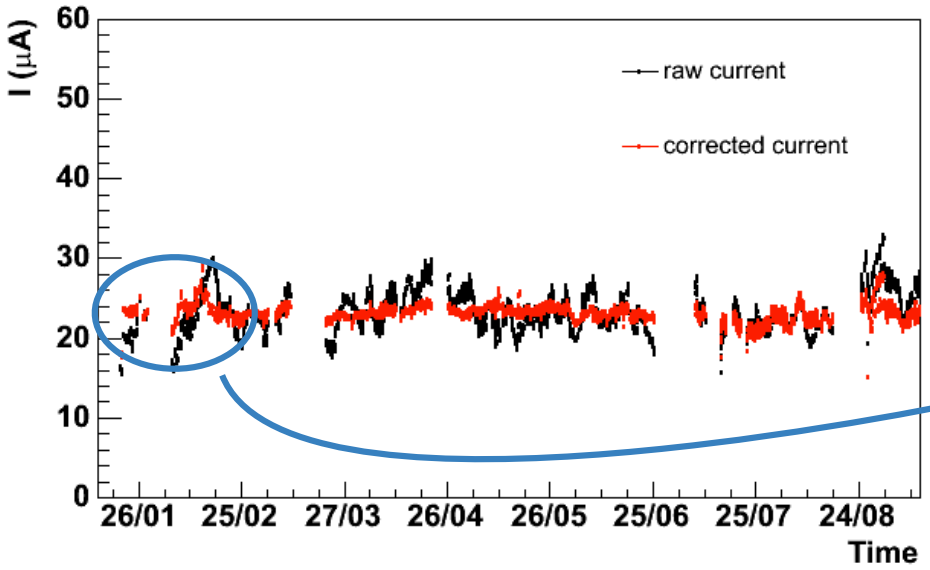


- The fresh mixture injection is about 6%
- After 6 days without filters the impurities concentration increase significantly!
- Some new impurities appear

System without filters

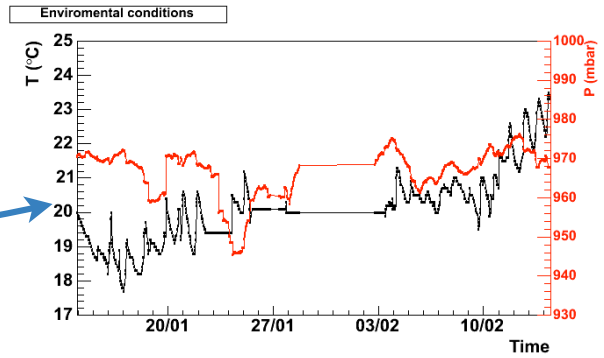
RPC performances

Current stability

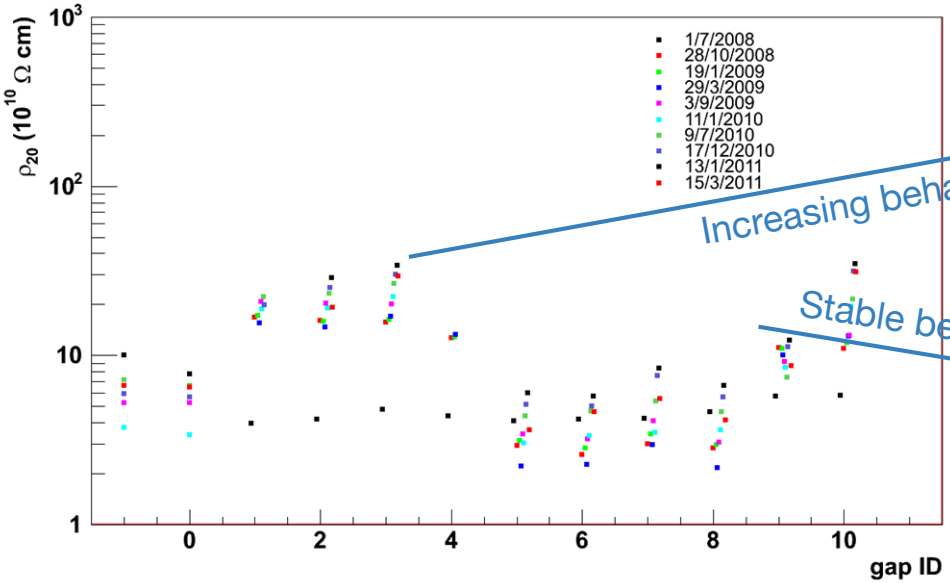


Total integrated charge: 50 mC/cm²

Current raw data are corrected according to atmospheric pressure and temperature variation



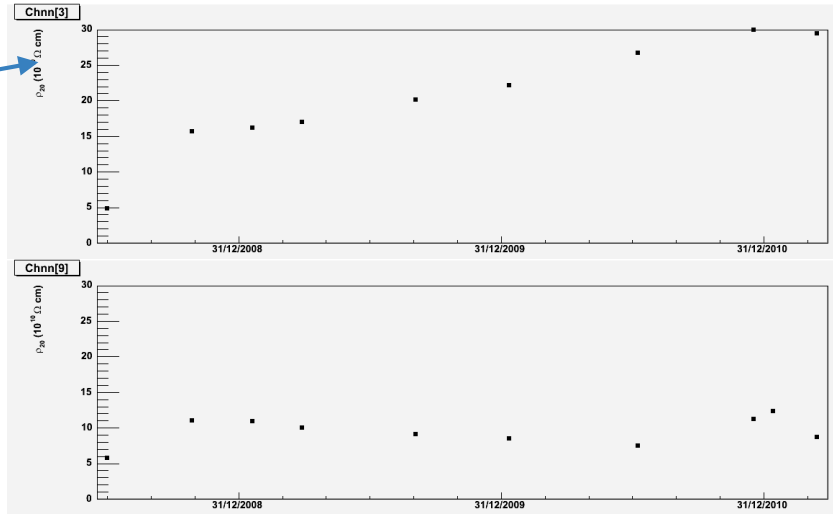
Bakelite resistivity



Increasing behavior

Stable behavior

Bakelite resistivity is a crucial parameter for RPC performances

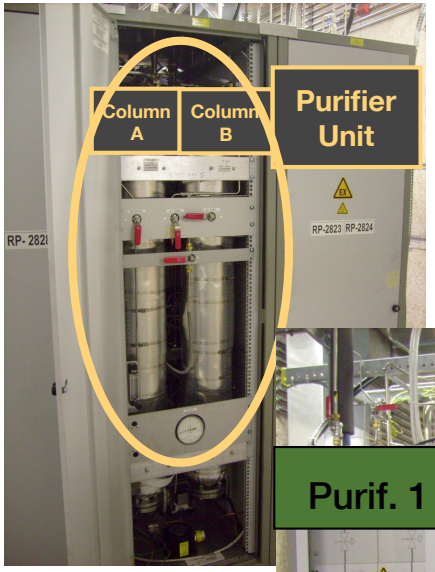


Check of RPC basic functionalities

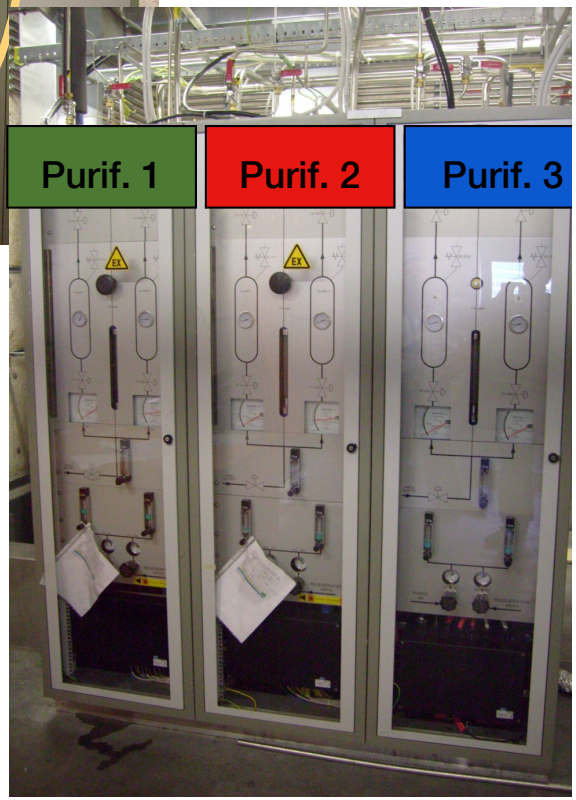
Implementation in the LHC RPC gas systems

Characteristics of the two configurations

Current LHC configuration	New optimized configuration
2 purifiers	3 purifiers
purif. 1(90% MS3Å+10% MS5Å) purif. 2 (metallic catalyst)	purif. 1(90% MS4Å+10% MS5Å) purif. 2 (MS4Å) purif. 3 (metallic catalyst)
not all impurities are filter	most impurities are filter
low capacity to absorb water	water absorption increased by a factor 2
cycle time very short	optimization of the cycle time with different filters
high number of regenerations over one LHC running	less number of regeneration
no possibility to increase the gas flow	possible to increase the gas flow by a factor >1.5



- Gas flow: 6 m^3/h.
- Column capacity: 24



Implementation with Purifier 3 during LHC shutdown

Conclusion

- A detailed and systematic analysis of the exhausted gas from heavily irradiated RPCs has been performed.
  - Several impurities from the exhausted RPC gas have been detected and identified.
  - The concentration of impurities (~1000 ppm) has been monitored and is correlated with the saturation of the purifiers.
- Several purifiers configuration has been tested at the GIF.
  - A new optimized configuration for the LHC gas systems has been found.
  - The new purifiers configuration allows improving the purifiers run cycle and the filtering performances for the RPC systems at LHC.
- The set of RPCs operated at the GIF (heavily irradiated) shows a very stable behavior with the optimized configuration.
  - After correction for environmental condition the RPC currents are very stable over all the test period (2008-2012, for an equivalent accumulated charge of 52 mC/cm^2).

Thanks for your attention

Back-up slides

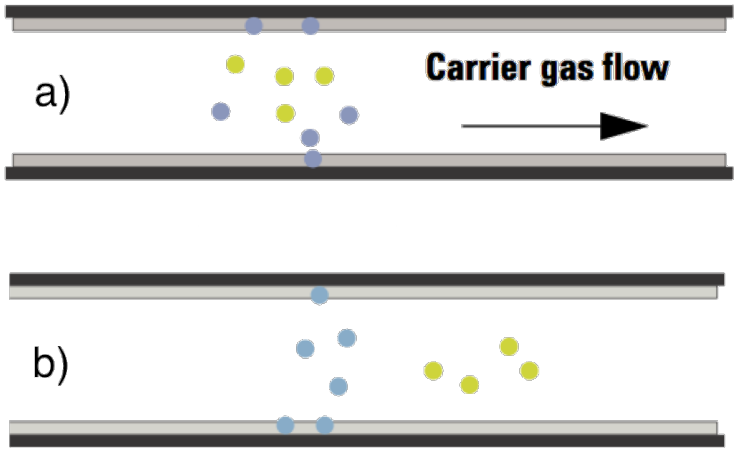
Gas Chromatograph

Fundamentals of Gas Chromatography

- It separates mixtures into individual components.
- GC creates a time separation.
- The mixture passes through a column containing a material that retards some components more then other → separation.
- The components are detected by the TCD.
- The result is a gas chromatogram (µV versus time).
- The components are identified by the retention time.
- Their concentration is given by the peak area.

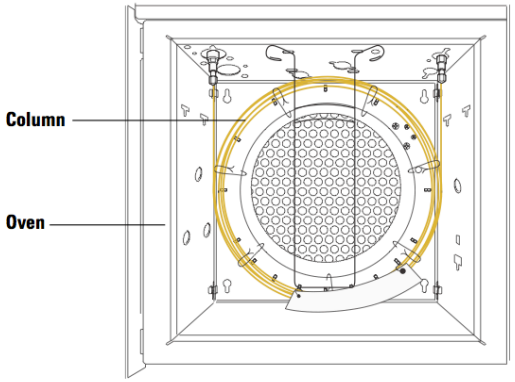
The column

- Different types of column.
- The coating inside the column separates the components.
- Some components are more attracted than other to the coating.

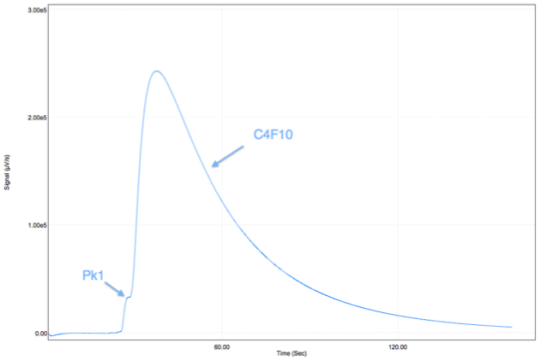


Fundamentals

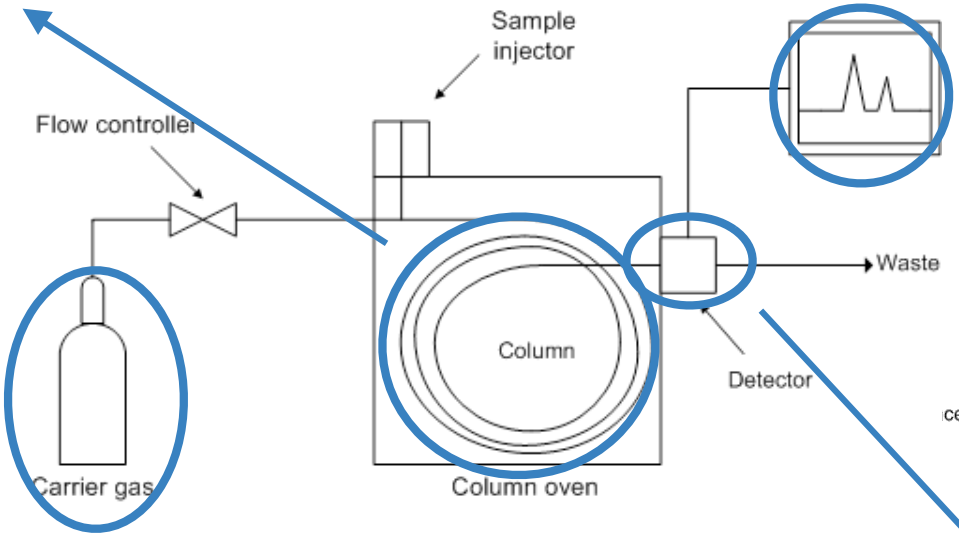
Gas Chromatograph



- Choice and thickness of column coating.
- Column length and diameter.
- Choice of carrier gas and flow rate.
- Oven temperature.



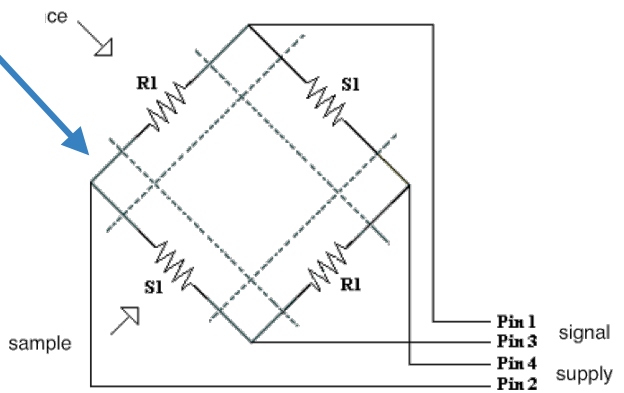
- µV versus time



- Carrier gas used as reference.
- Usually He or Ar (depends on what y0u want to identify)

- One way for carrier gas, the second for the analytical column flow.
- When the analytical flow is pure carrier gas, bridge is equilibrated and signal is zero.
- The analytical flow causes fluctuation in the filament temperature → bridge desequilibrated.

Wheatstone bridge



Fundamentals

Characterization of the purifiers

	$MS\,3Å$	$MS\,4Å$	$MS\,5Å$	$Cu\ R11$	$Cu/Zn\ R12$	$NiAl_2O_3$	$NiSiO_2$
Conditioning (volume changes)	3	10	50	20	20	15	15
Main component filtered	H_2O	H_2O	H_2O	O_2/H_2O	O_2/H_2O	O_2/H_2O	O_2/H_2O
Nominal absorption capacity for the main component filtered (g (O_2/H_2O) /kg)	140	170	130	5/50	5/50	15/50	15/50
Impurities							
(1) CH_4	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged
(2)	Not present	Not present	Not present	Not present	Present up to 400 volume changes	Not present	Present up to 400 volume changes
(3) $C_2H_2F_2$	Unchanged	Unchanged	Back after 1000 vol. changes	Unchanged	Enhanced	Unchanged	Unchanged
(4) CF_4SO	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered
(5) CH_2F_2	Unchanged	Filtered	Filtered	Unchanged	Unchanged	Unchanged	Unchanged
(6) C_2HF_3	Unchanged	Unchanged	Filtered	Filtered	Filtered	Filtered	Filtered
(7) $C_2H_3F_3$	Unchanged	Filtered	Filtered	Filtered	Filtered	Present up to 150 volume changes	Unchanged
(8) C_3H_6	Unchanged	Filtered	Filtered	Filtered	Present up to 450 volume changes	Present up to 150 volume changes	Unchanged

Summary table