Long term validation of the optimal filters configuration for the RPC gas systems at the LHC experiments

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Outline

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

RPCs for 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	$R134a/iC_4H_{10}/SF_6$	$R134a/iC_4H_{10}/SF_6$	$R134a/iC_4H_{10}/SF_6$ $Ar/R134a/iC_4H_{10}/SF_6$	$R134a/iC_4H_{10}/SF_6$

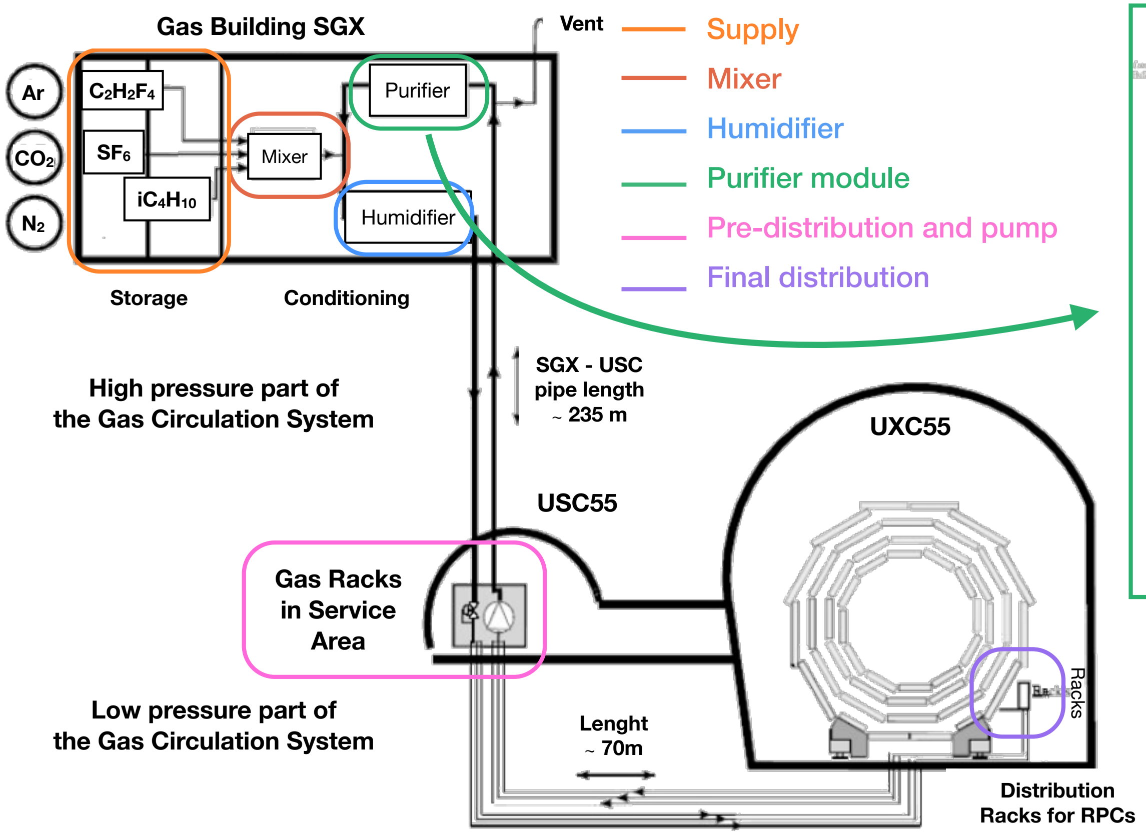
RPCs for LHC experiments

Why RPCs for application in LHC experiments need a “particular care”?

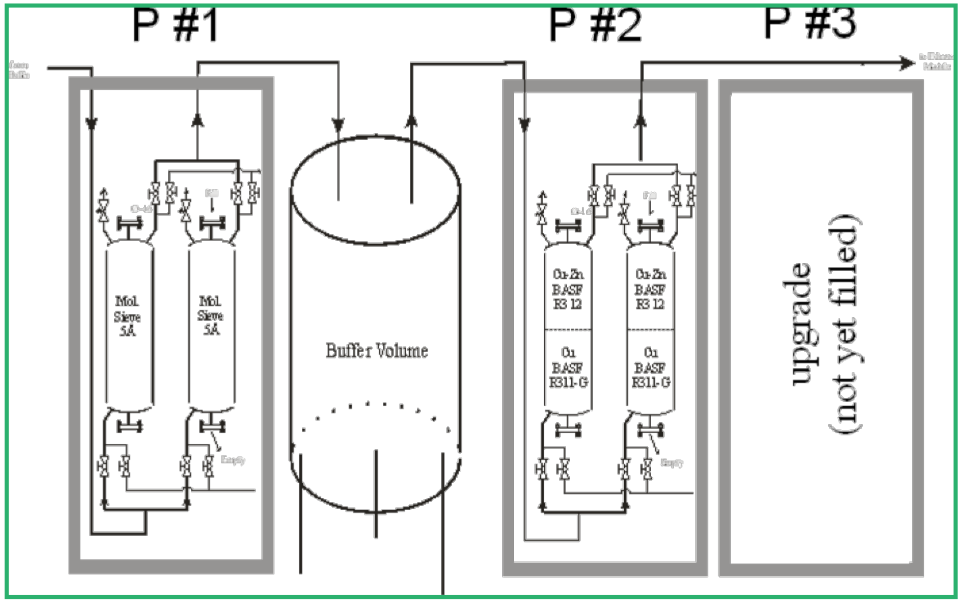
- Large size systems (~15 m^3 of gas volume and ~10^3 m^2 of sensitive area).
- Very expensive gas mixture: $6 \cdot 10^6$ CHF/year per experiment.
- Very long period of operation expected (at least 10 years).
- Very high level of background radiation expected.
- Integrated charge never reached before:
  - 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 worsening of RPC performance due to impurities
  - gas mixture purification is needed

RPCs gas system:
closed loop gas circulation

Layout of the gas distribution system



Current purifiers configuration



Purifier 1: - MS (10%5Å+90%3Å)

- lifetime 1.5 day

Purifier 2: - Cu-Zn and Ni-Al_2O_3

- lifetime 7 day

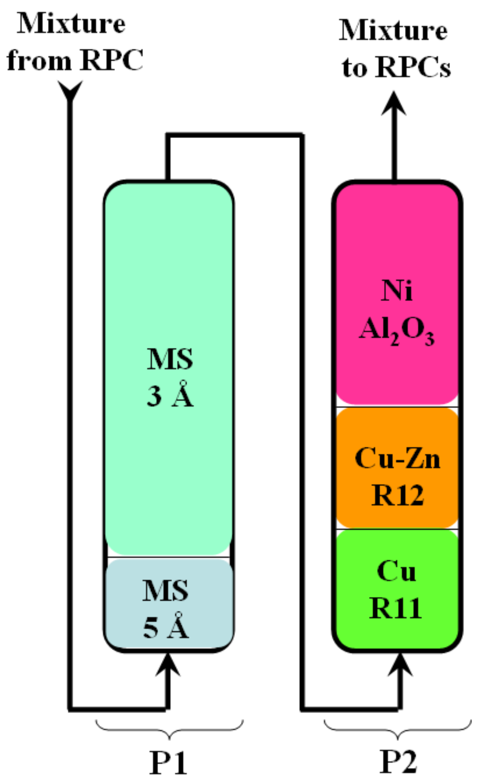
Problems nowadays

- Not all the extra-components produced during RPCs operation are removed.
- Technical problems during operation.
- Third module available...

RPCs gas system:
limits on present purifiers configuration

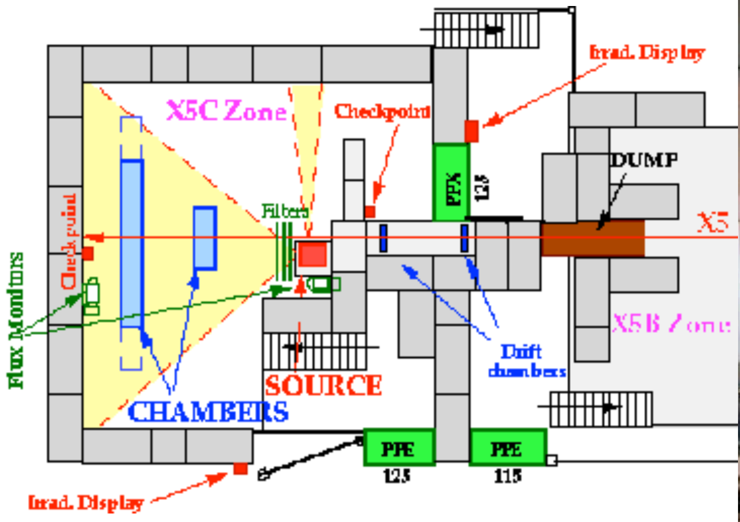
Limits of currently used purifiers configuration:

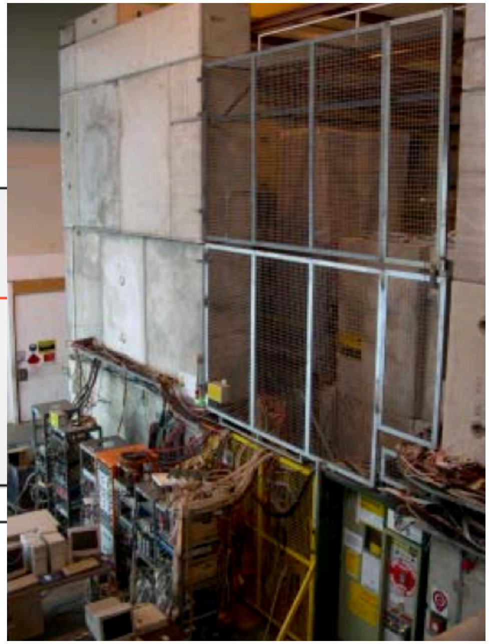
1. Not all the extra-components produced during RPCs operation are removed.
2. Very short cycle   Limiting factor if flow increase is needed
3. Too many regeneration cycles



	Purif. 1	Purif. 2
Number of regenerations	91	30
Pre-SaturationVol (m^3)	160	180
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

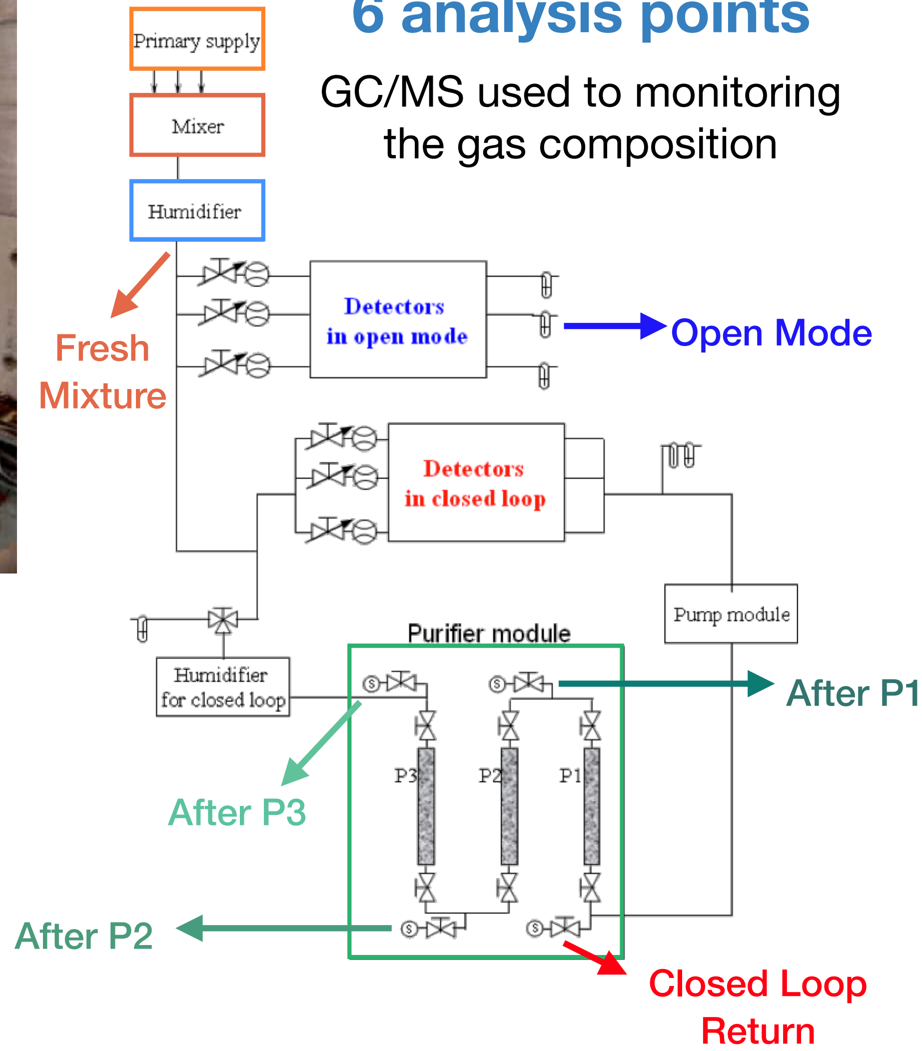




- GIF (Gamma Irradiation Facility) at CERN
- ^{137}Cs source (γ 662 keV): 590 GBq.
- At ~2 m: 1 cGy/h.
- RPC counting rate: ~200 Hz/cm^2.
- Accelerator factor: 30.
- Gas system: small replica of LHC gas systems.
- 6 points of analysis.
- Gas mixture: 94.7% $C_2H_2F_4$, 5% iC_4H_{10}, 0.3% SF_6

6 analysis points

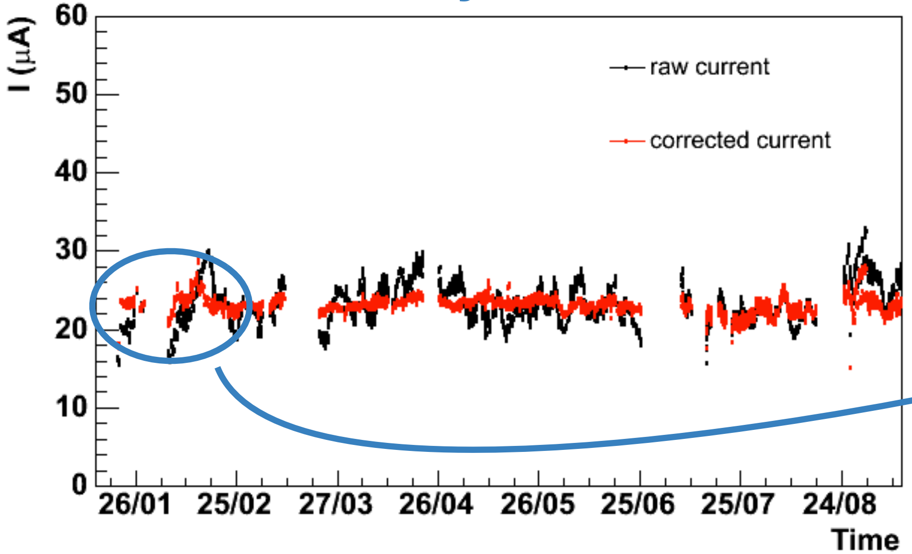
GC/MS used to monitoring the gas composition



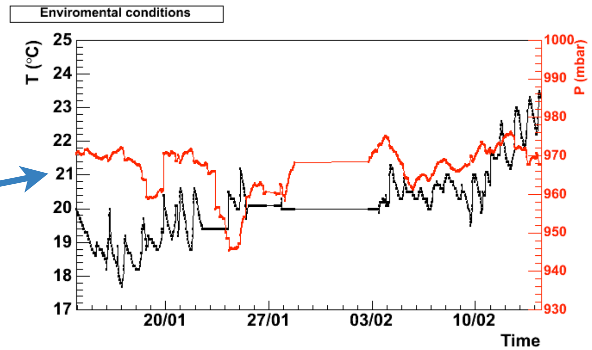
Thanks to ATLAS and CMS for providing parts of the test set-up.

RPC performances check

Current stability

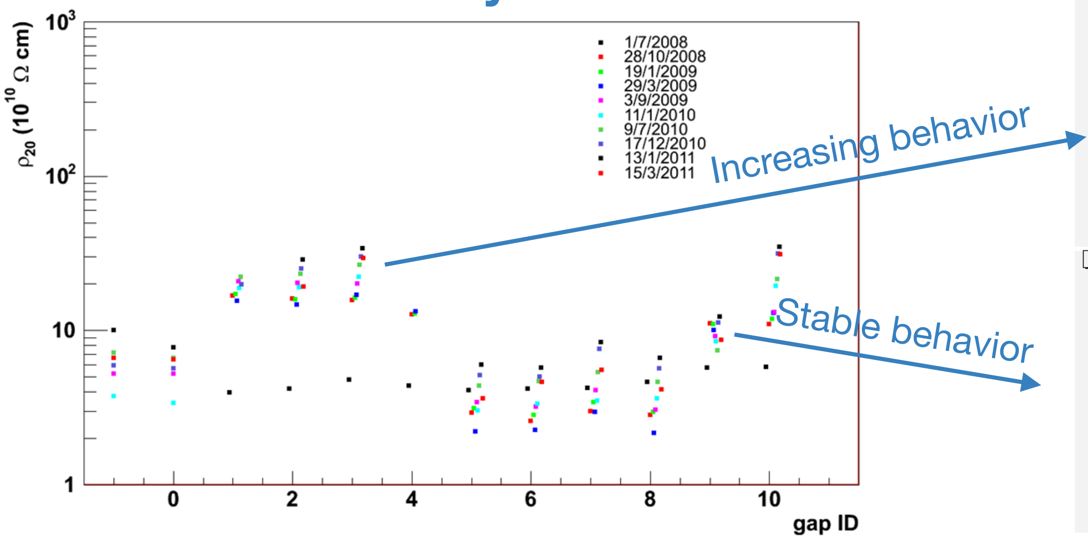


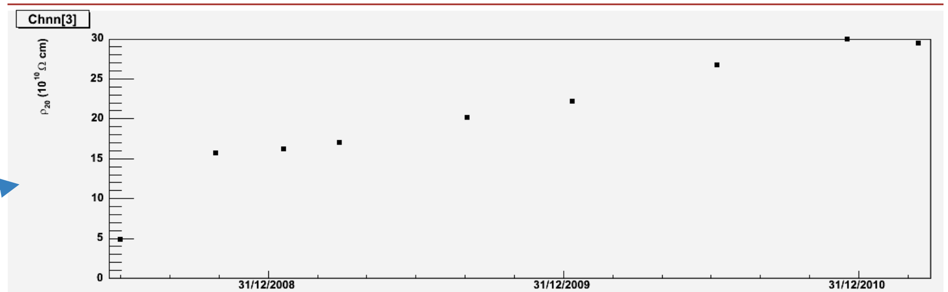
In order to verify the stability of the current we corrected the raw data according to atmospheric pressure and temperature variation

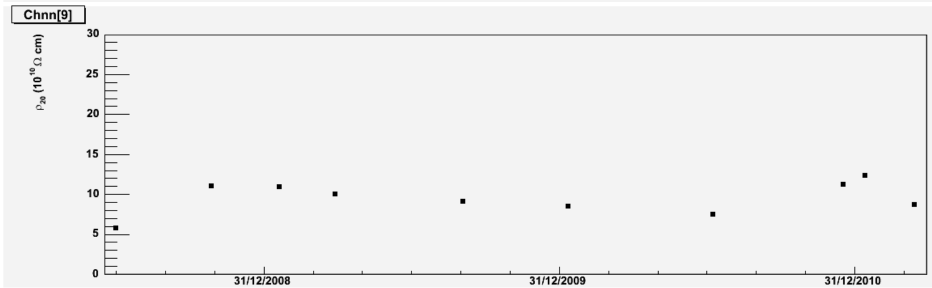


The total integrated charge is 50 mC/cm^2 in the whole test

Bakelite resistivity





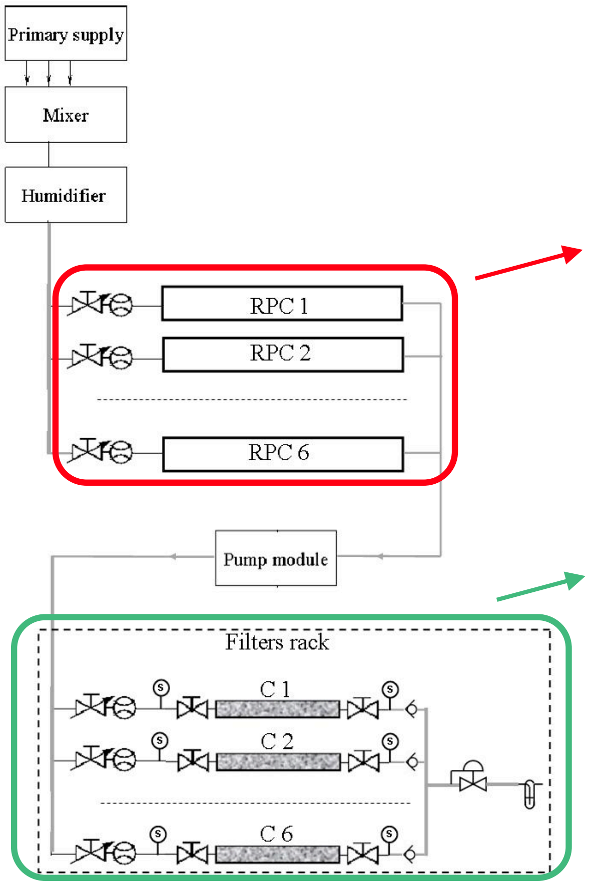


Characterization of the purifiers

Numerous cleaning agents are available.

A basic characterization is needed in order to verify the performance with the specific RPC mixture

Experimental set-up



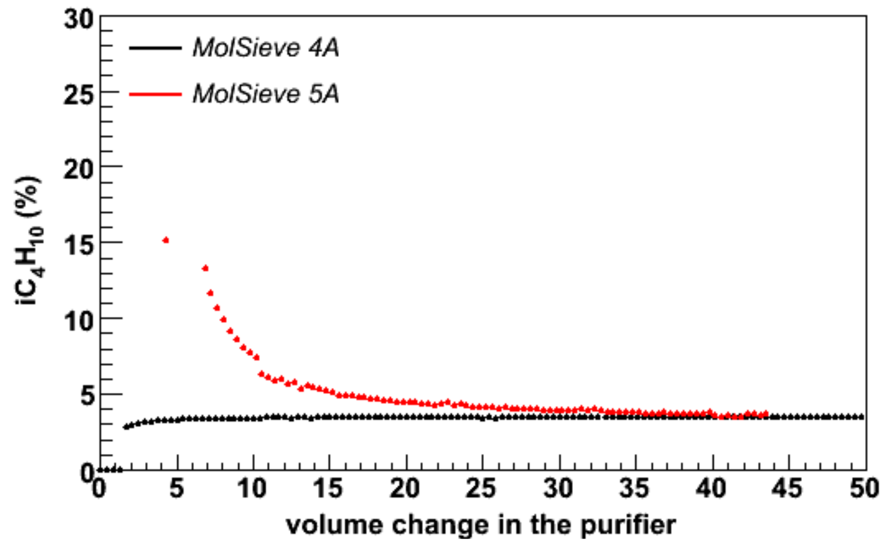
The return gas from RPC operated under high gamma radiation is collected and distributed among several small cartridges.

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

Conditioning phase

is when a mixture component is also absorbed.

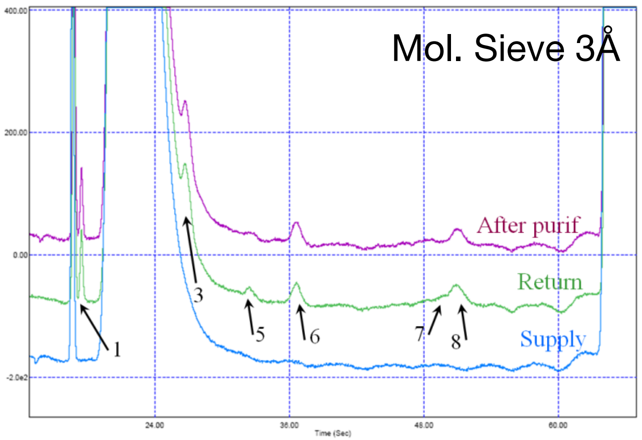
Some purifiers (see example of mol.sieve 5 Å) need a preparation time (conditioning phase) because at start-up they absorb a mixture component (in the example the $C_2H_2F_4$ is absorbed and as a result the iC_4H_{10} concentration increases).



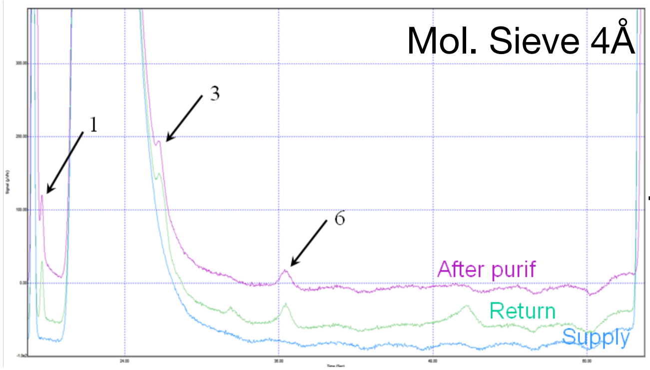
Characterization of the purifiers

Molecular Sieves

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



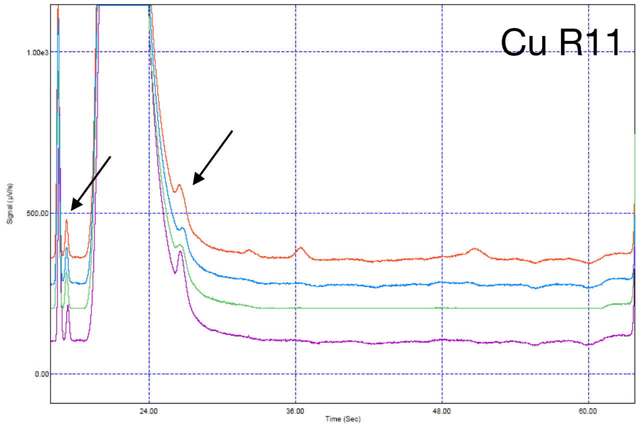
It is not effective wrt other impurities!



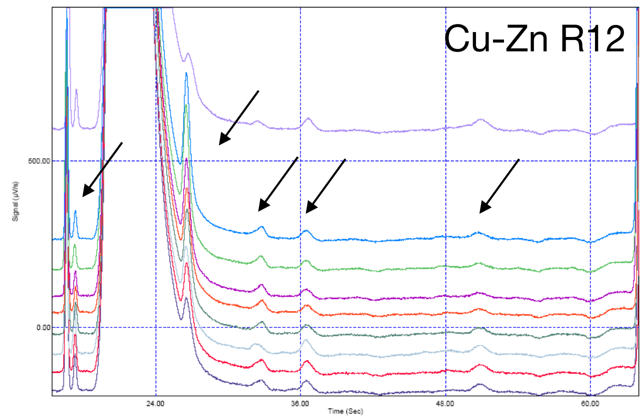
Many impurities are filtered

Cu/Zn

- filter as they should O_2
  (capacity ~ 5 g(O2)/kg(catalyst))
- H_2O (capacity ~ 50 g(H_2O)/kg(catalyst))
- R11 filters additional impurities, R12 does not and it enhance an extra component

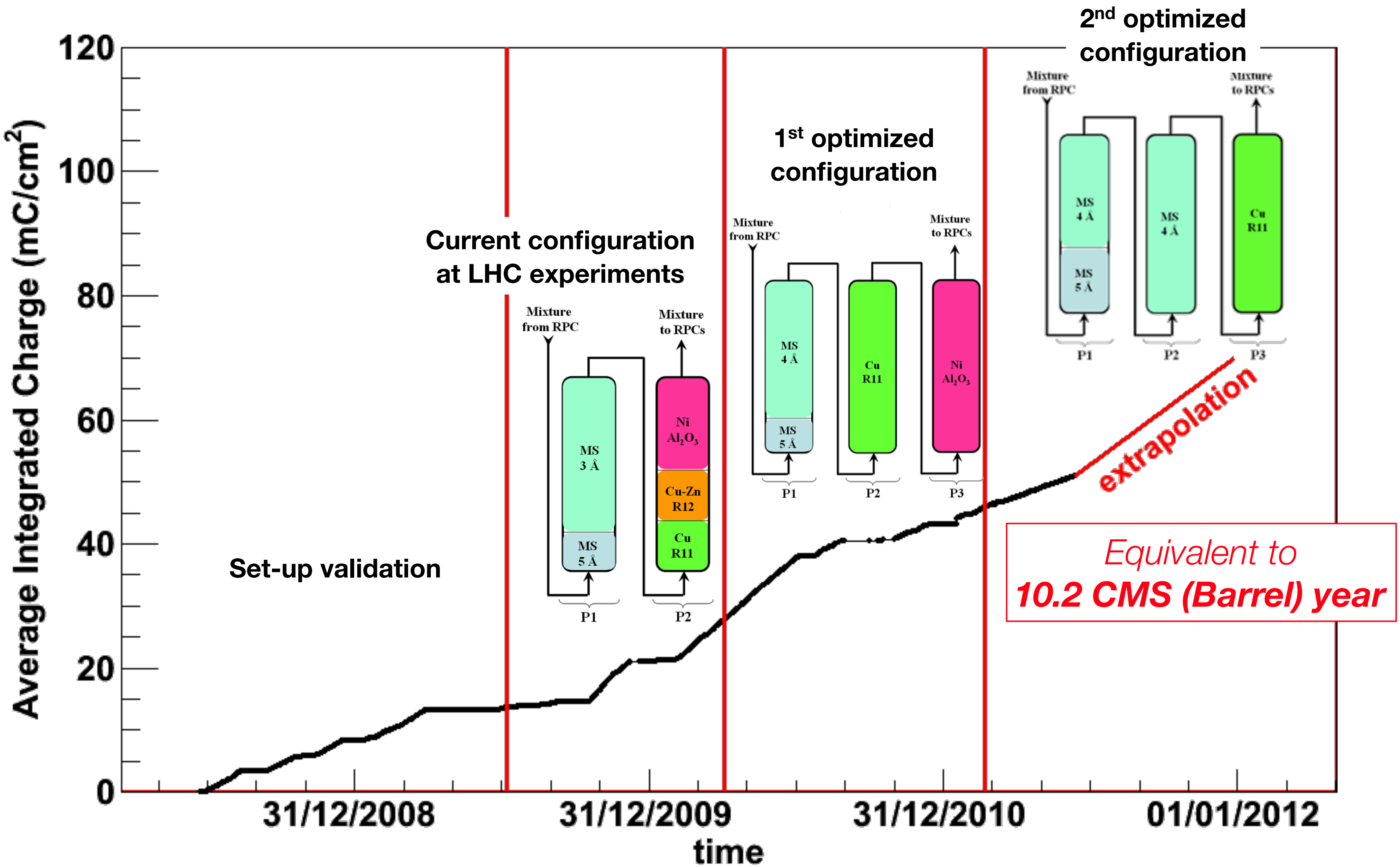


R11 seems to be quite effective

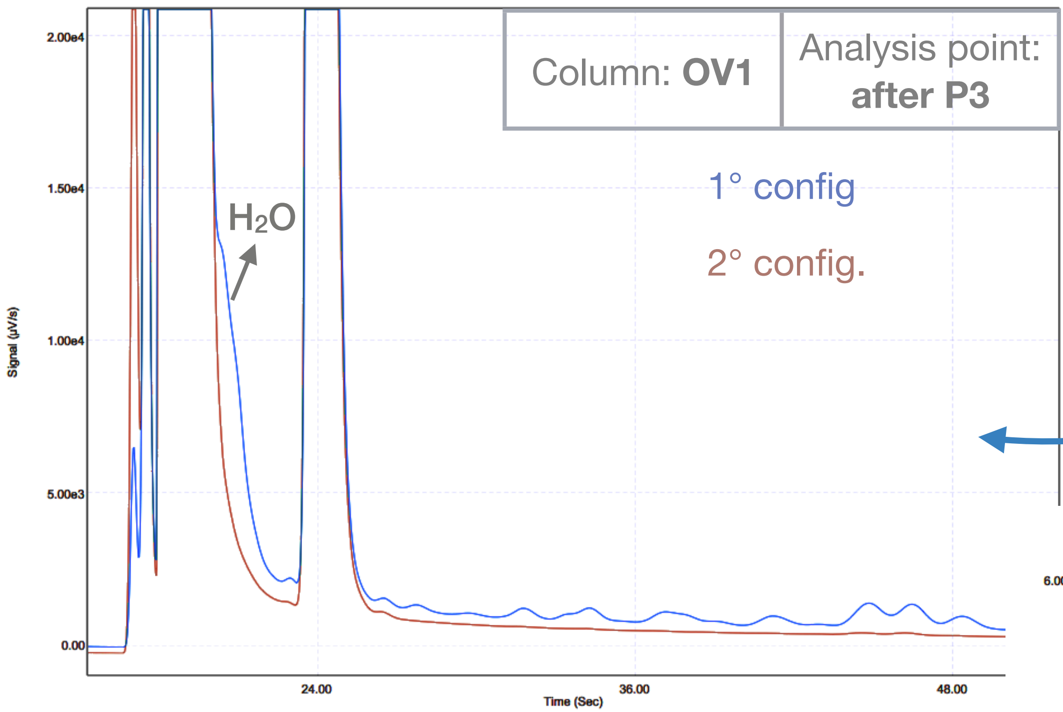


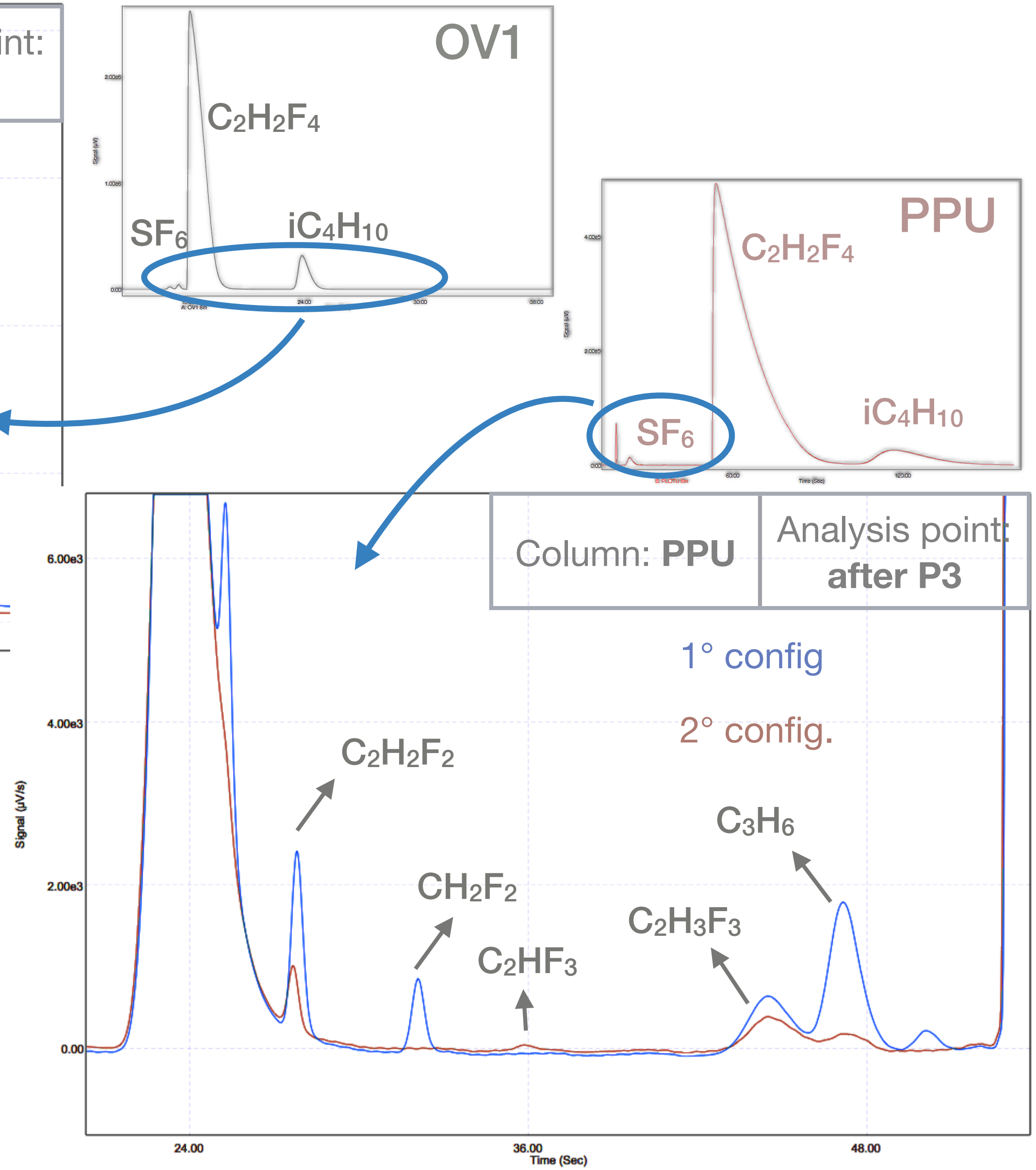
R12: basically no extra components filtered.
Some components are enhanced.

The purifiers configurations



Results on new purifiers configuration: 1st vs 2nd configuration

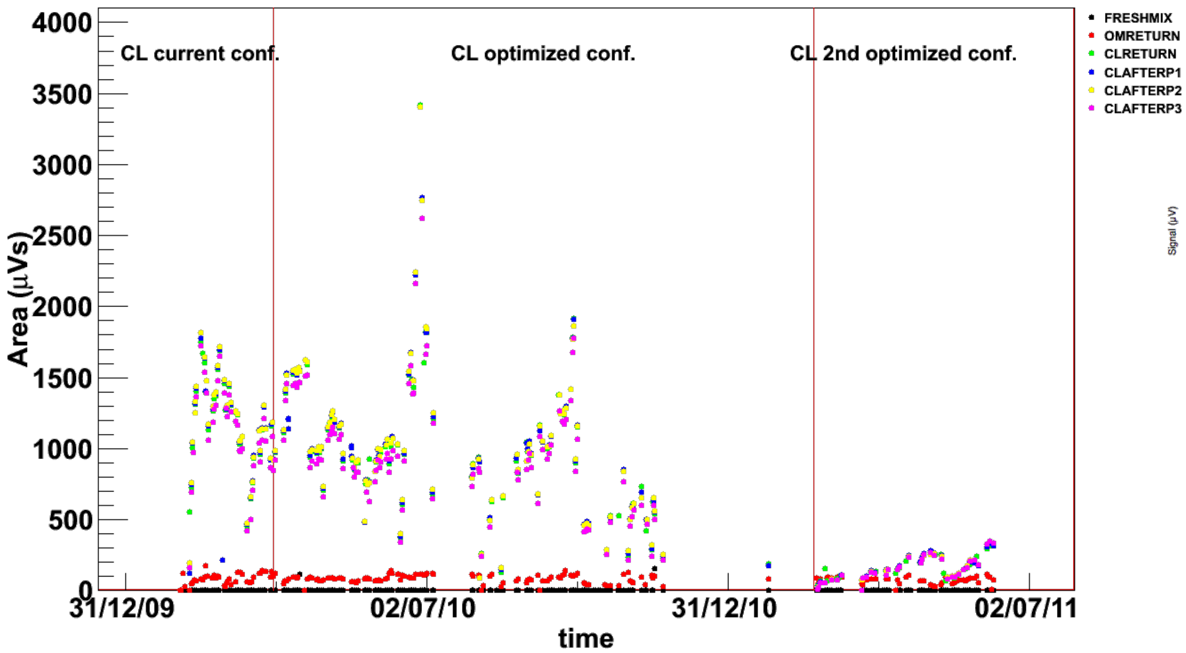


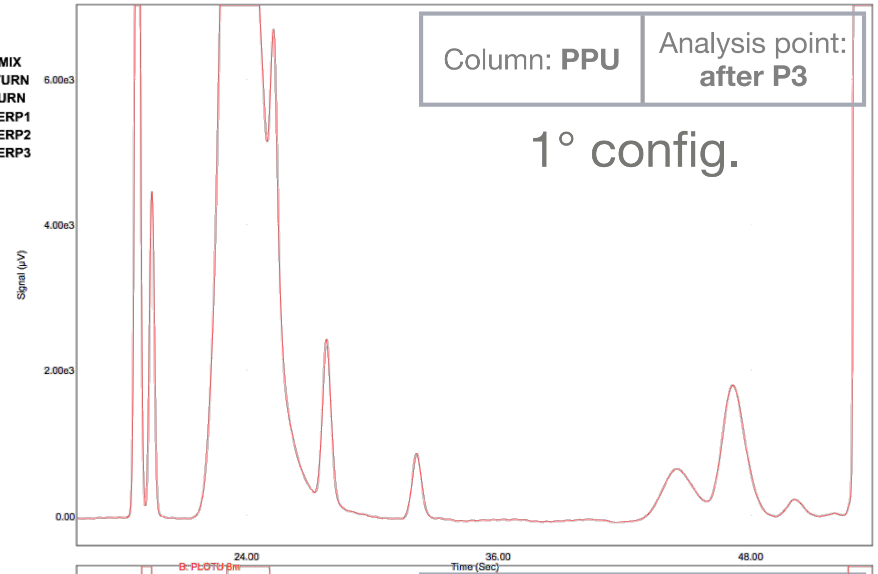


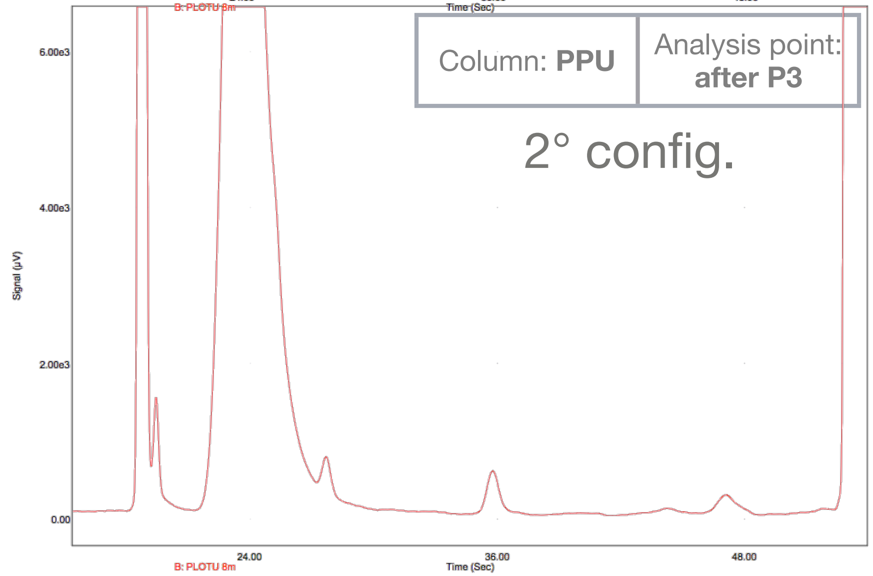
- After about 50 days of operation.
- H_2O is present in the first configuration.
- Identification of many impurities.
- In the 2° configuration there are less impurities (some disappear!).

Results on new purifiers configuration: monitoring of the impurities

$C_2H_2F_2$

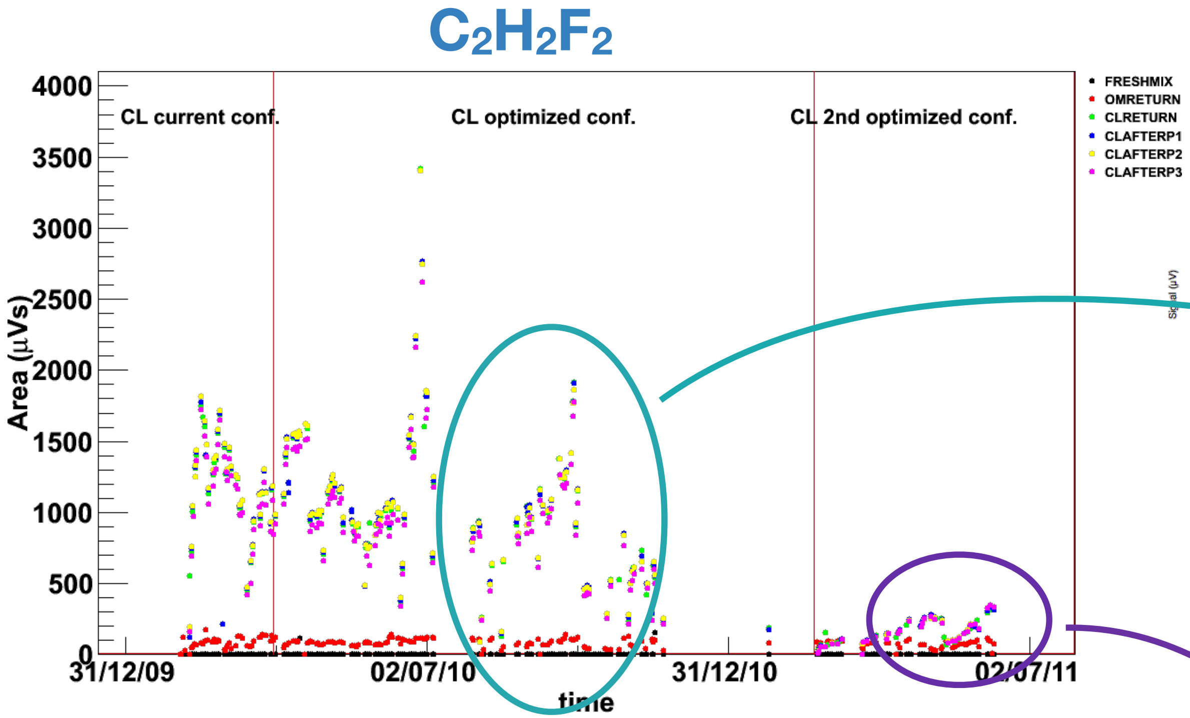


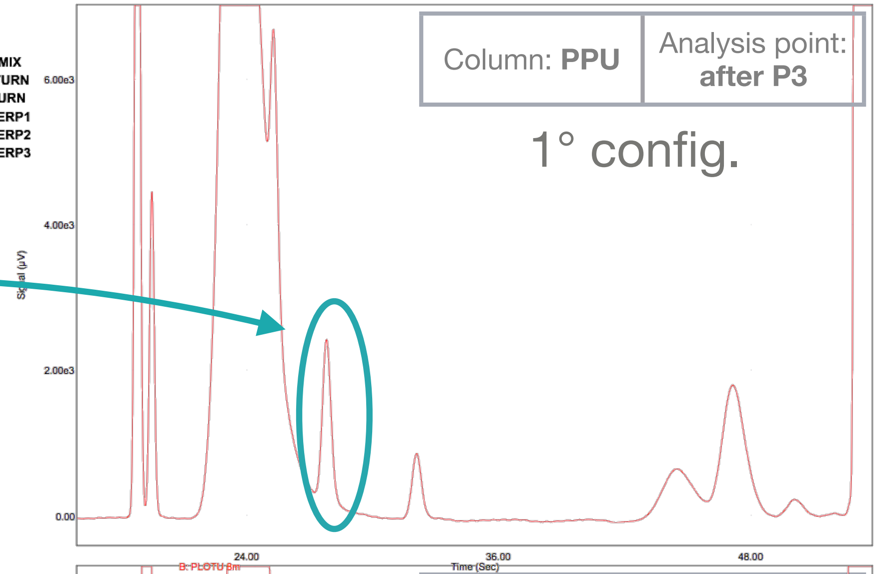


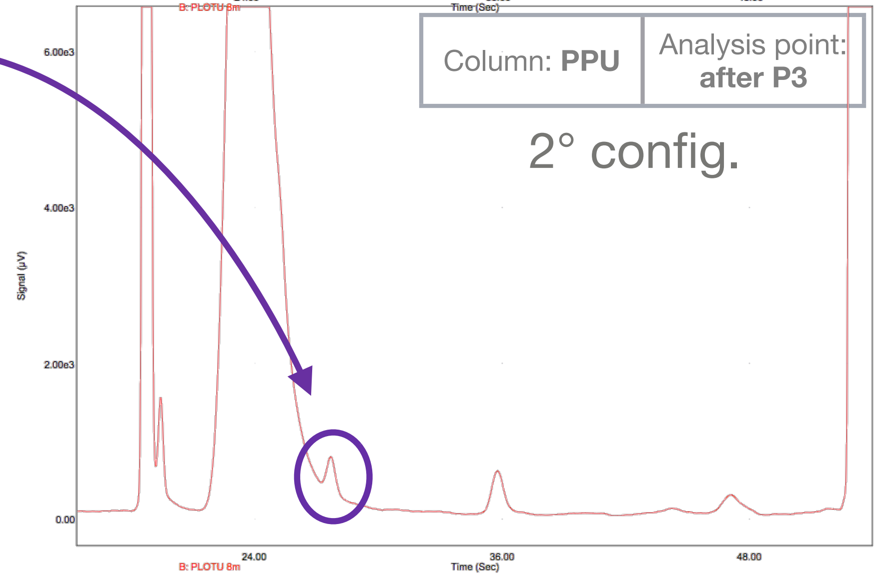


- The impurities are constantly monitored.
- They are significant lower in the second configuration.
- Impurities increase when the purifiers are almost saturated or when the amount of fresh gas is too low

Results on new purifiers configuration:
monitoring of the impurities







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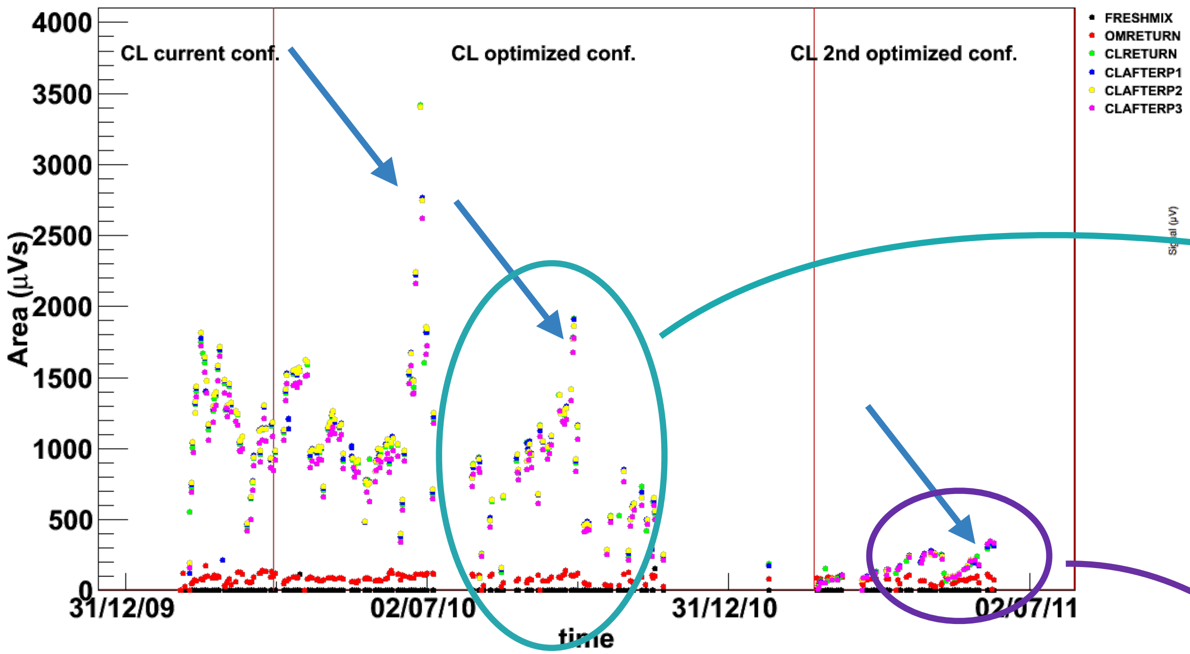

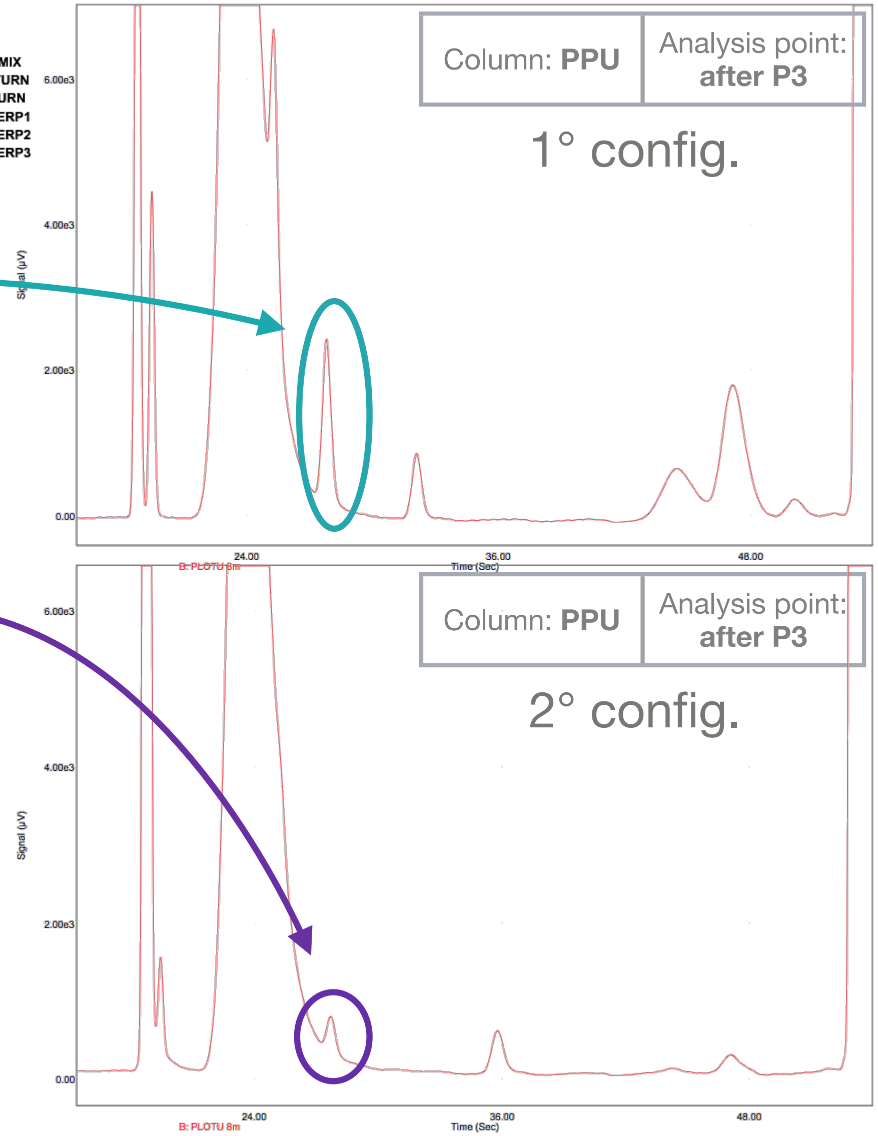

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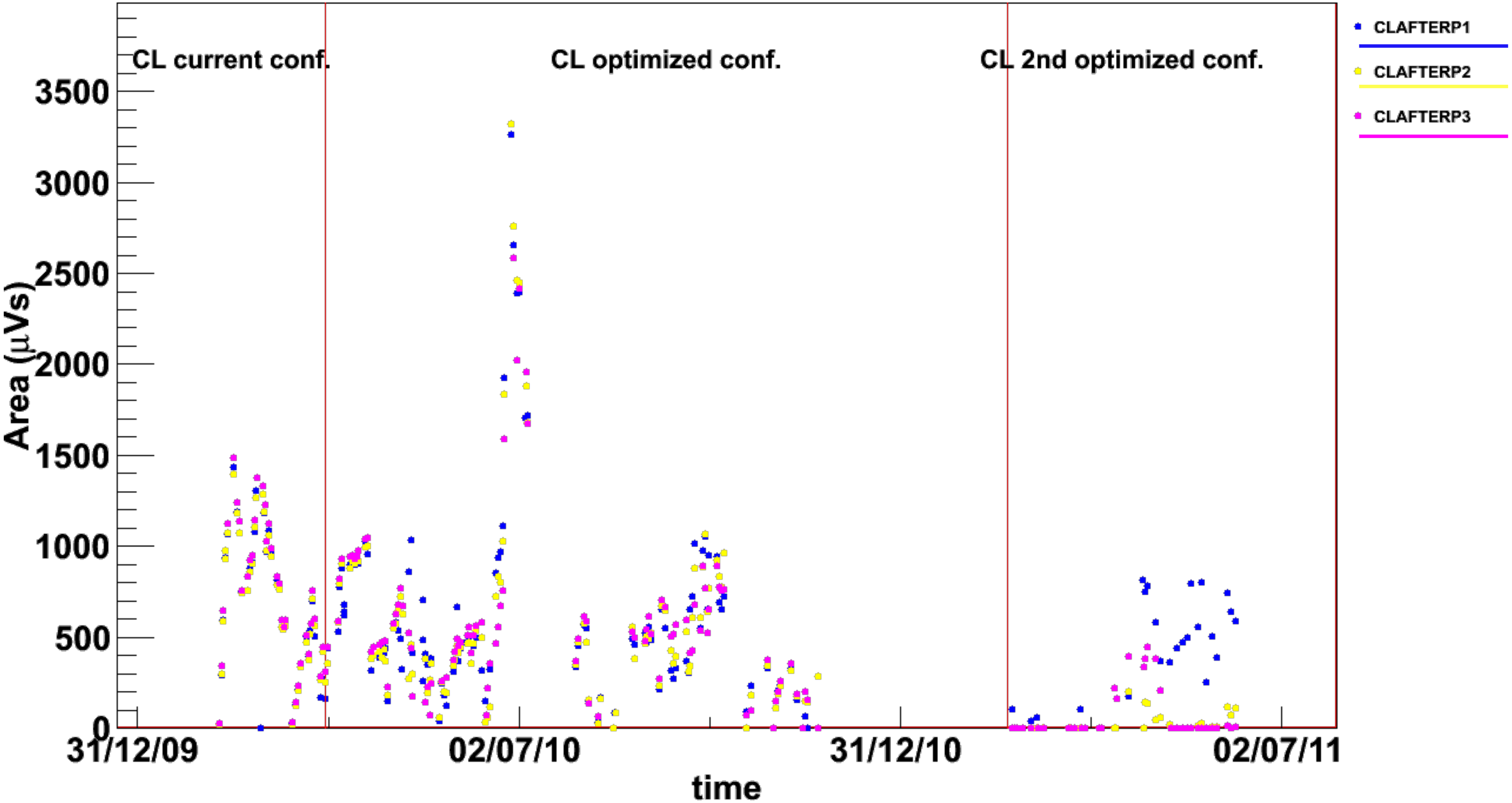
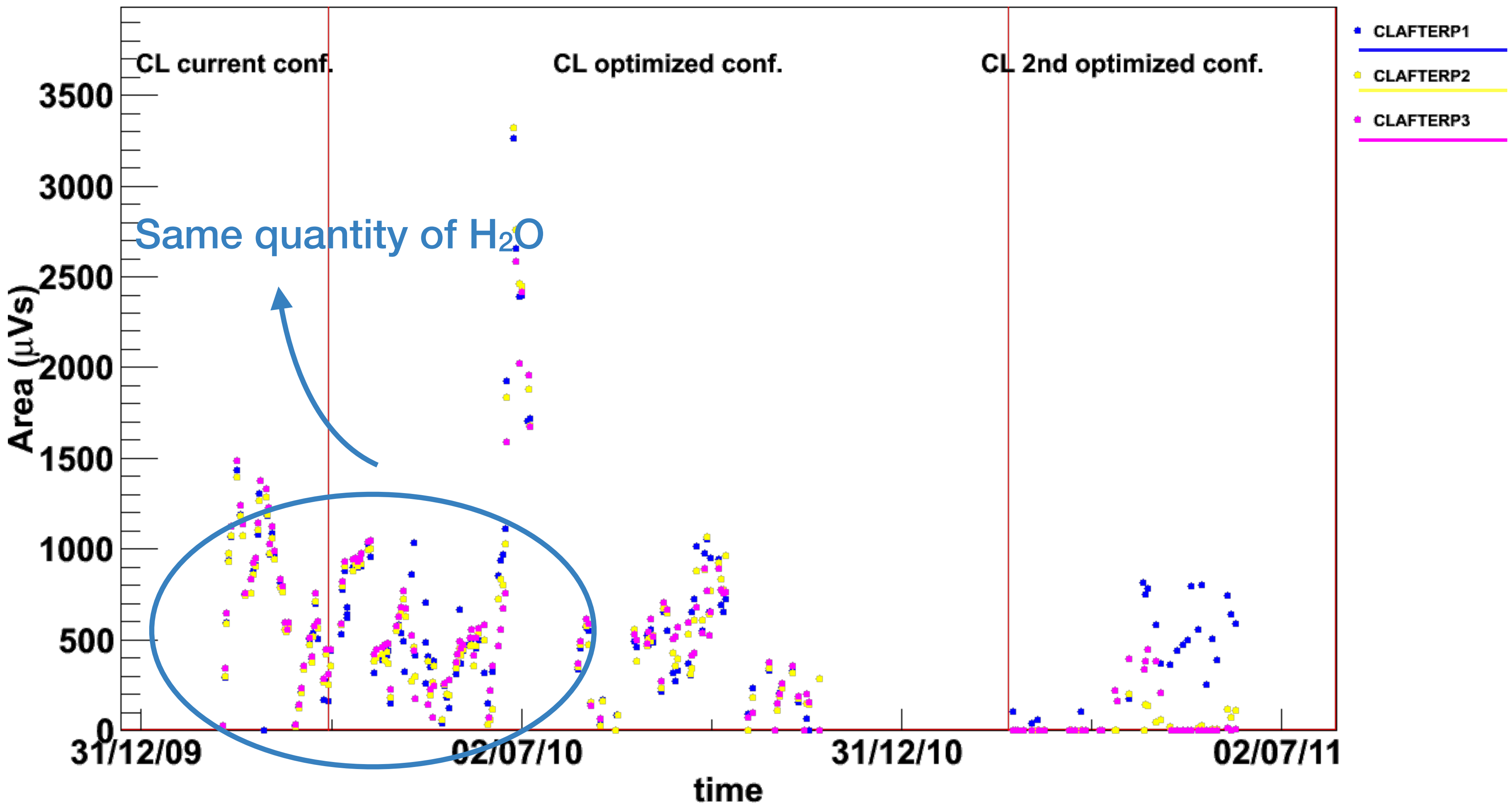
Results on new purifiers configuration:
the H_2O absorption



- The presence of H2O 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.

Results on new purifiers configuration:
the H_2O absorption



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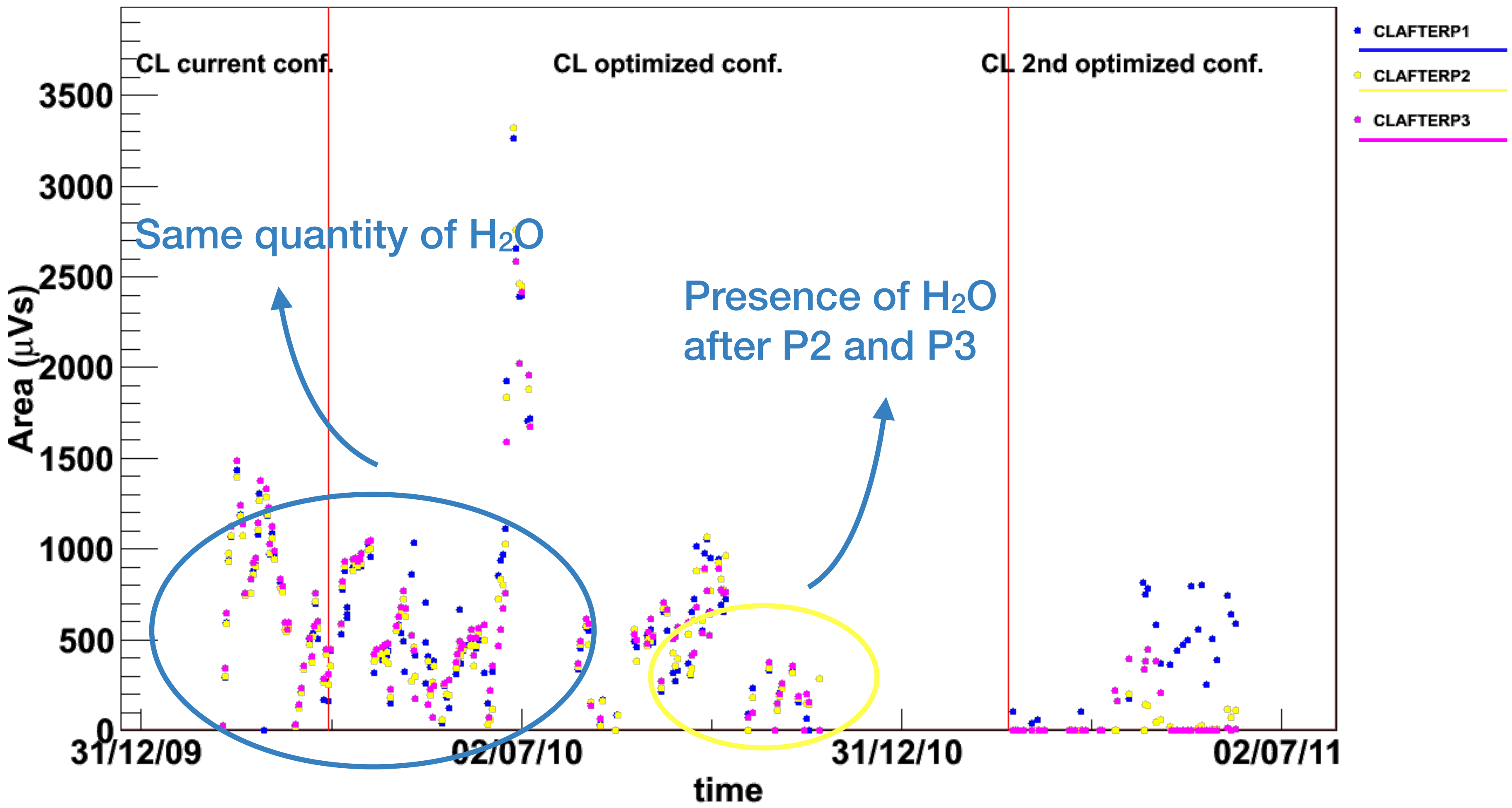

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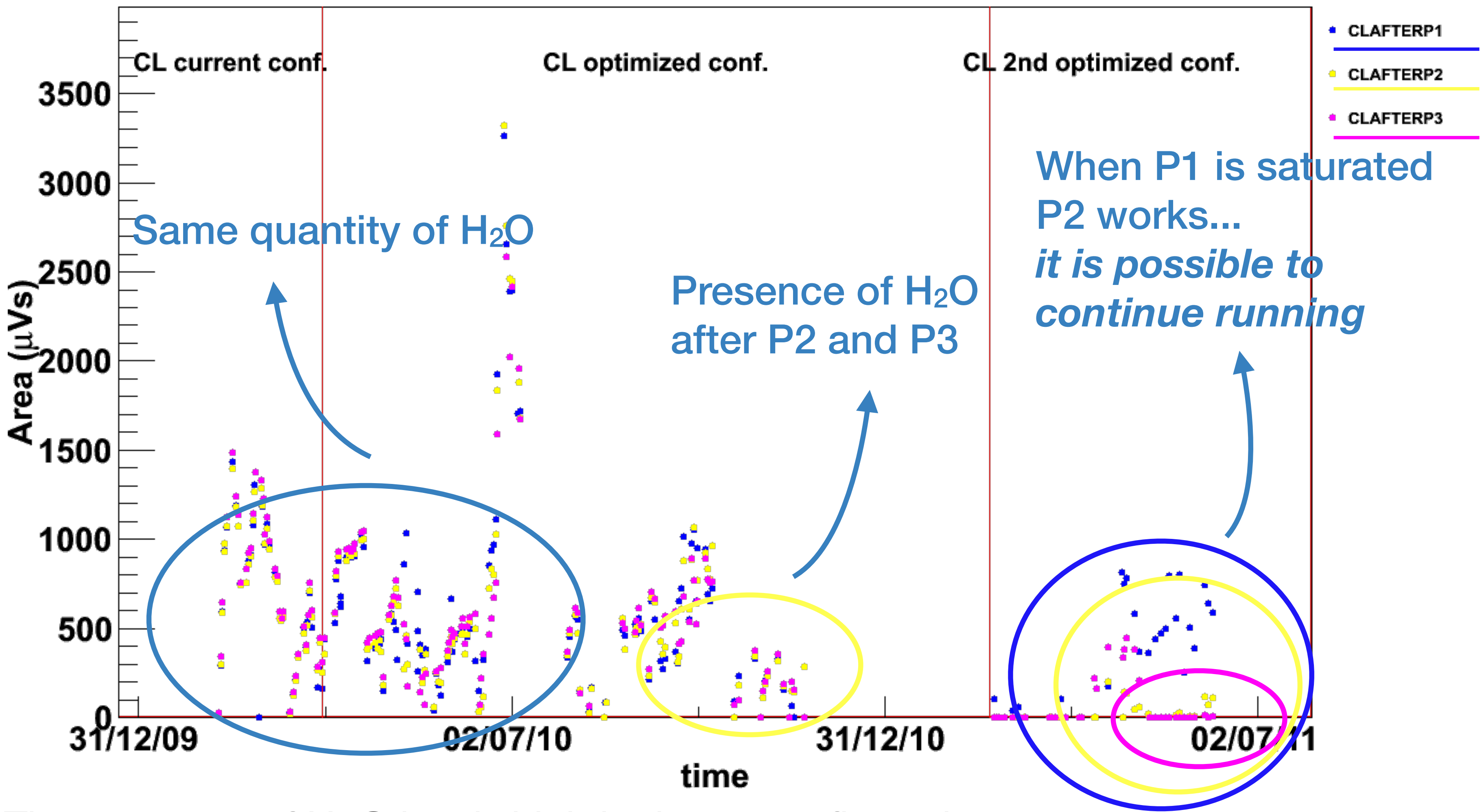

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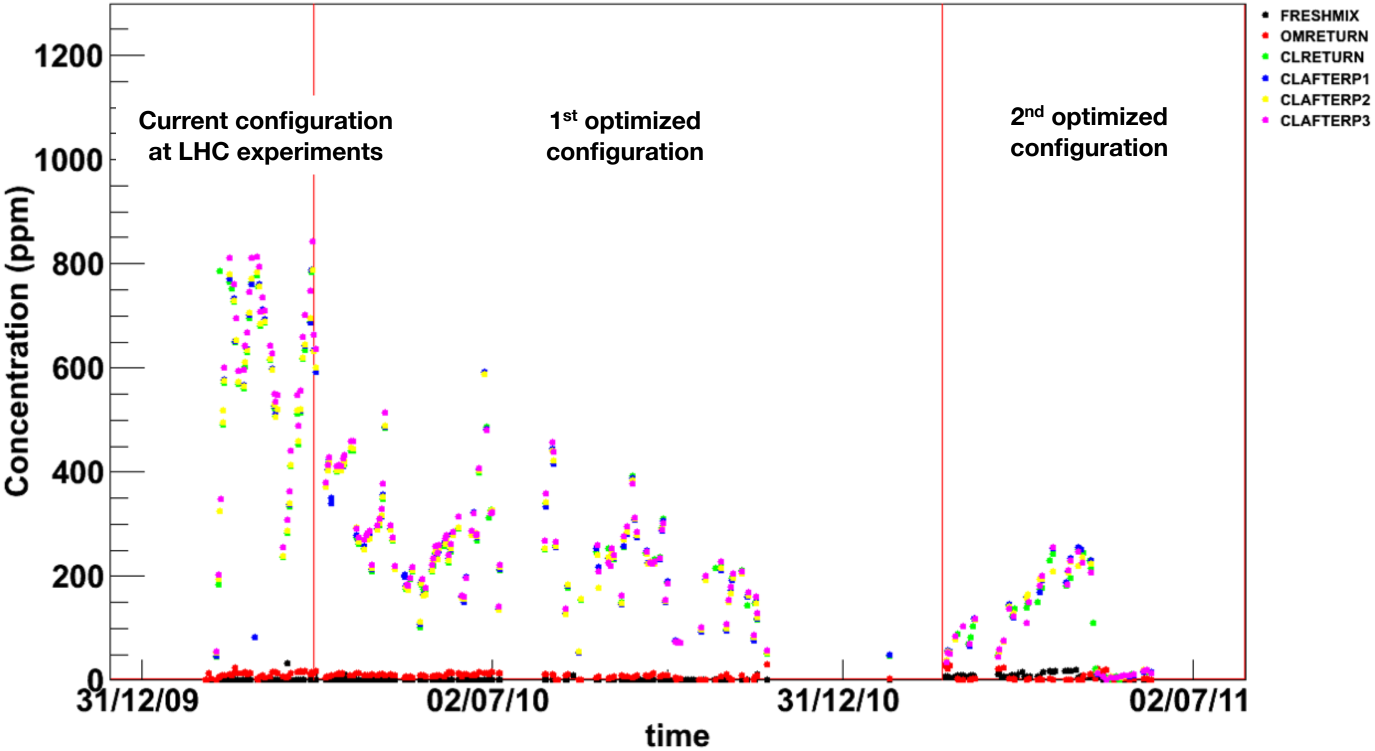
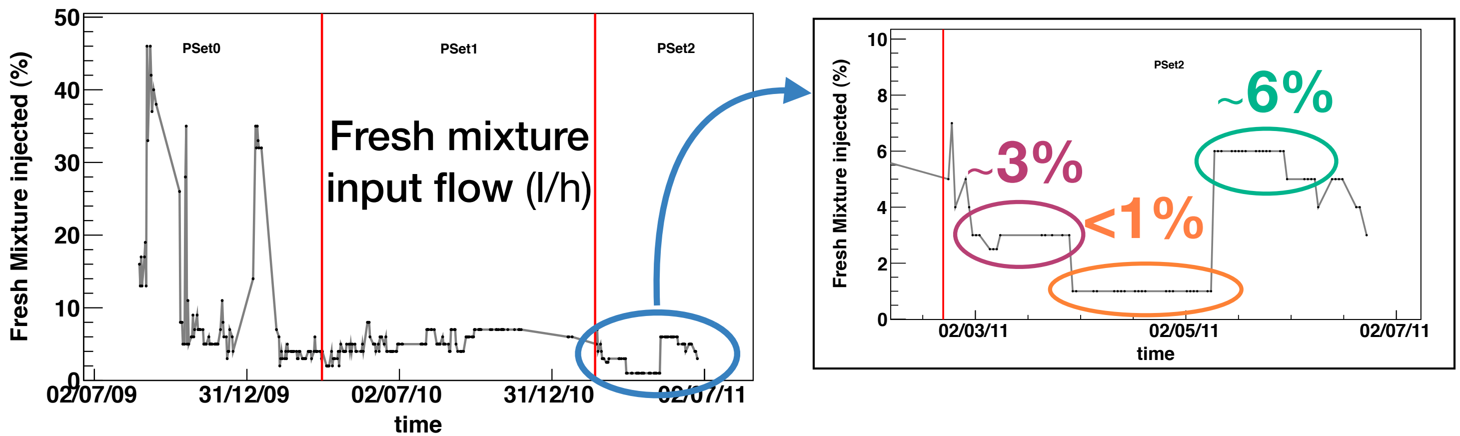
Results on new purifiers configuration:
impurities vs % of fresh gas



Example of 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.

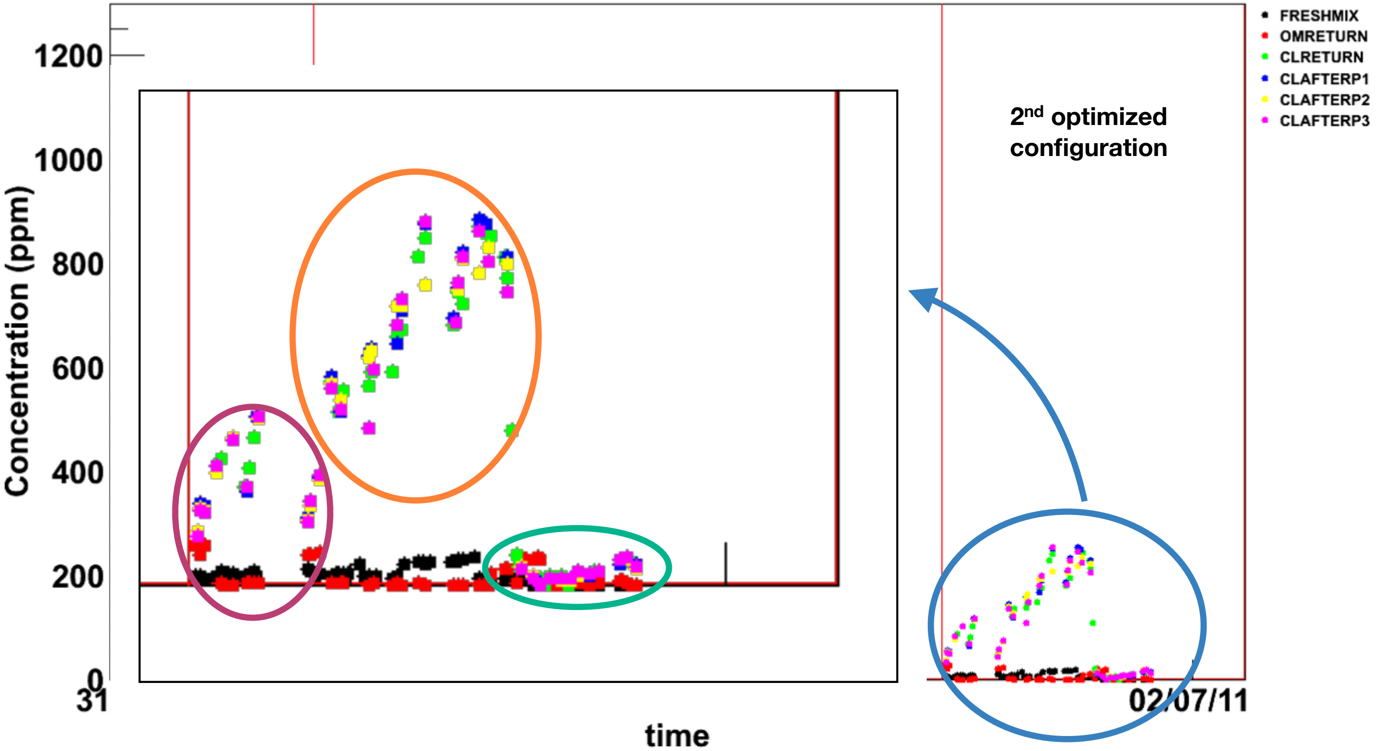


The impurity concentration is relatively high.

The impurity concentration is high.

The impurity is under control.

Results on new purifiers configuration: impurities vs % of fresh gas



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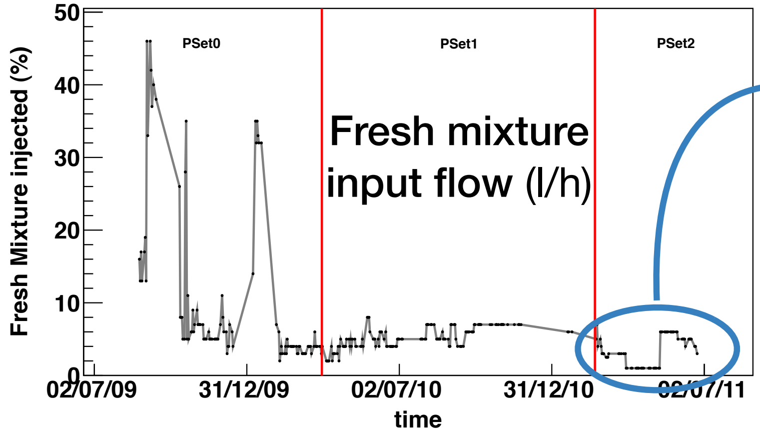

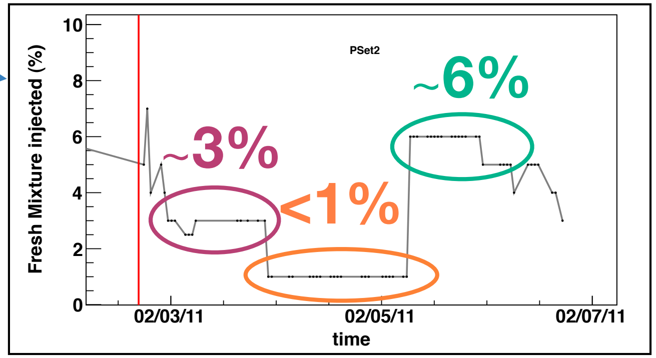

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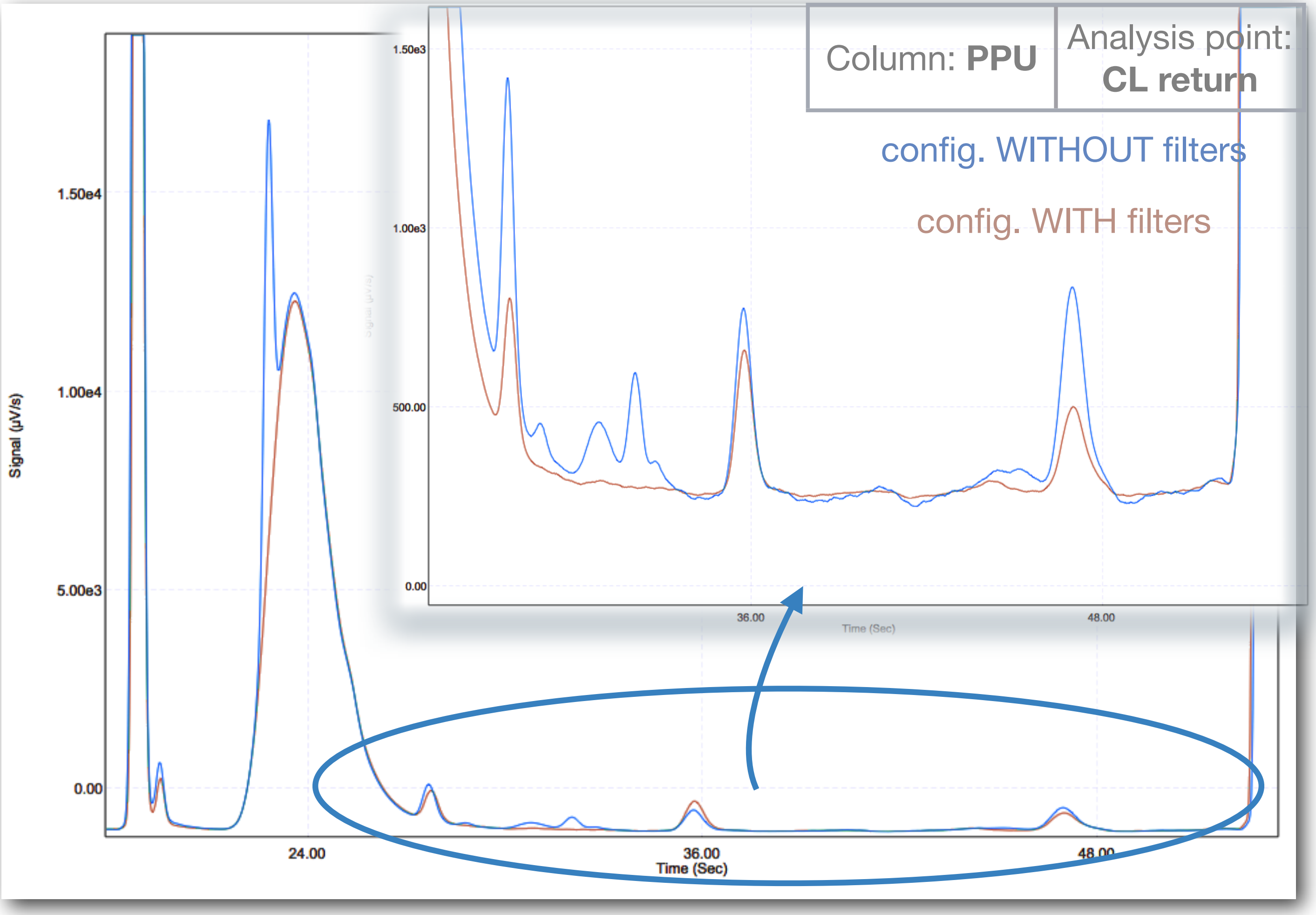
Results on new purifiers configuration:
system without filters



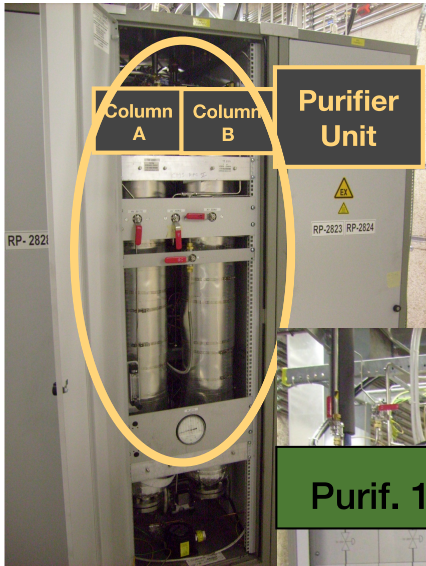
- The fresh mixture injection is about 6%.
- After 6 days without filters the impurities increase a lot!
- Some new impurities apeear.

→ **Purifiers are really needed!!!**

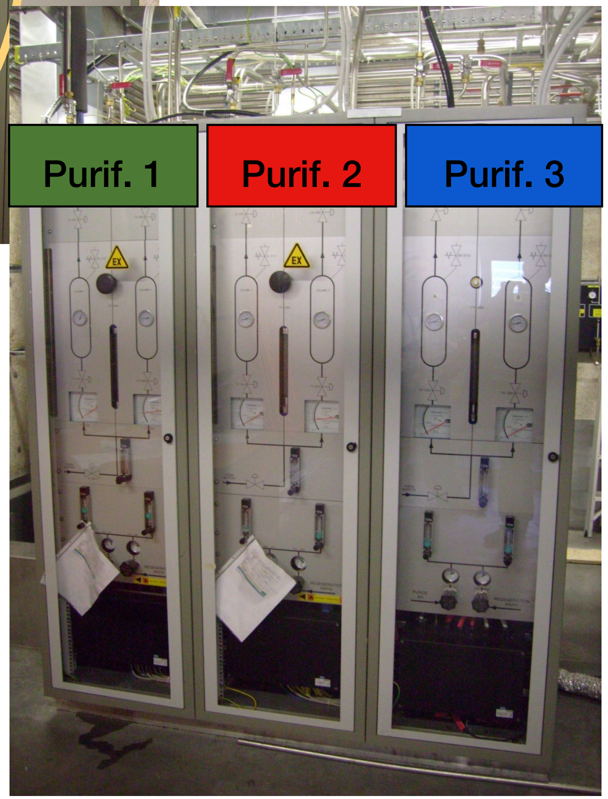
Implementation in the LHC RPC gas systems

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 l.



Implementation with Purifier 3 during the next shutdown

Conclusions

Conclusions

- 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.

Conclusions

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  - 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.

Conclusions

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  - 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-today, for an equivalent accumulated charge of 52 mC/cm^2).

Thanks for your attention

Tools for analysis

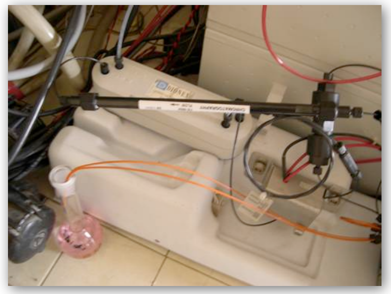
microGC-MS

always in use

- It gives a signal in V.
- It allows to quantify ppm of impurities.
- 3 columns: allowing separation for different type of impurities.
- Coupled with the Mass Spectrometer: allowing identification of impurities.

F^- station and liquid chromatography (HPLC)

for dedicated studies



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

MS 5A	noble gas, O_2, N_2
PPU	C_1 to C_4, CO_2, CH_4, H_20
OV1	C_4 to C_{12}