EP-DT
Detector Technologies

Gas Systems for Particle Detectors

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on behalf of the EP-DT/Gas Service Team

Outlook

- Introduction
- Gas systems for LHC experiments:
  - Automation
  - Modularity
  - Reliability
- Gas systems description:
  - Construction
  - Building blocks
- Gas systems performances:
- A closer view to ALICE-TPC
- Conclusions

Gas systems for the LHC experiments

- The basic function of the gas system is to mix the different gas components in the appropriate proportion and to distribute the mixture to the individual chambers.
- 30 gas systems (about 300 racks) delivering the required mixture to the particle detectors of all LHC experiments.
- Gas mixture is the sensitive medium where the charge multiplication is producing the signal.
- Correct and stable mixture composition are basic requirements for good and stable long term operation of all detectors.

Summary of the sub-detector gas systems at the LHC experiments.

14 Closed loop detector gas system; 11 Single pass detector gas systems

3 Flushing systems for N_2, CO_2, and compressed air

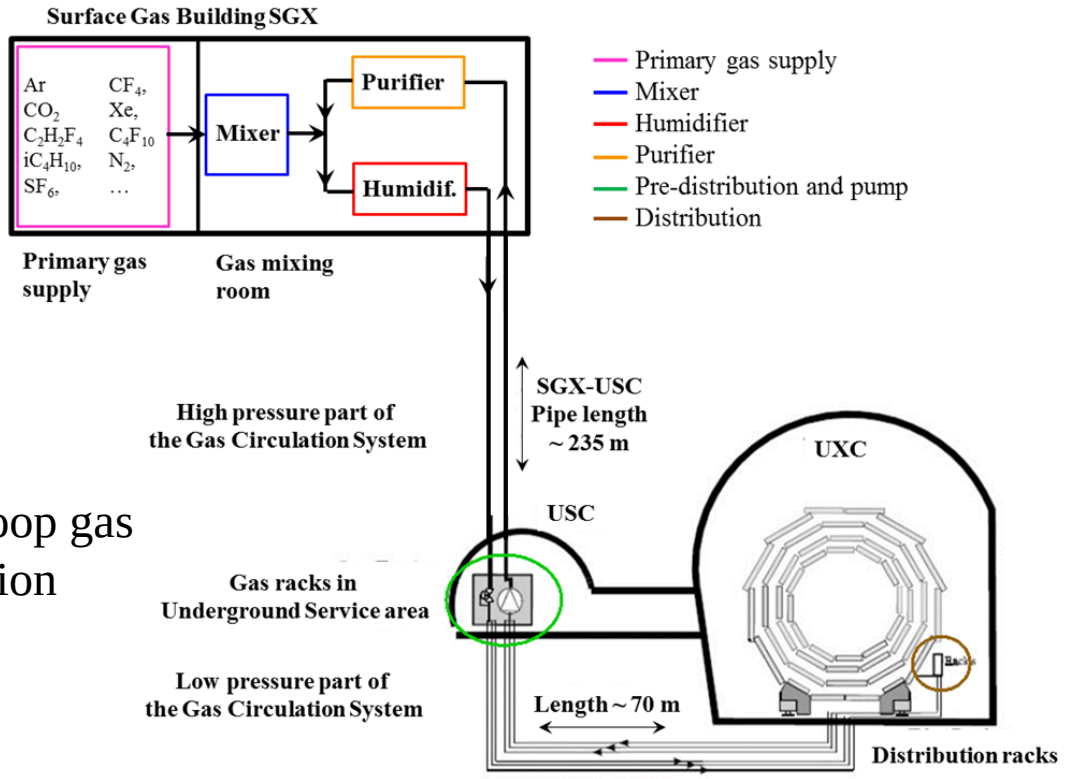
LHC Point 1 ATLAS	LHC Point 2 ALICE	LHC Point 5 CMS and TOTEM	LHC Point 8 LHCb
MDT	TPC	DT	OT
CSC	TRD	CSC + CF_4 recovery	Muon MWPC
TGC	TOF	RPC	Muon GEM
RPC	HMPID	T1-CSC (Totem)	RICH1
TRT	CPV	T2-GEM (Totem)	RICH2
LUCID(*)	PMD	SX5 + 904(*) Mixers	
ID flushing	Muon Track.	ID Flushing	
TRT CO_2 Cooling	Muon Trig.		

Gas systems for the LHC experiments

Gas systems extend from the surface building to the service balcony on the experiment following a route few hundred meters long.

- Primary gas supply point is located in surface building
- Gas system distributed in three levels:
  - Surface (SG)
  - Gas Service room (USC)
  - experimental cavern (UXC)

Large detector volume (from m^3 to several 100 m^3) and use of expensive gas components:
→
The majority is operated in closed loop gas circulation with a recirculation fraction higher than 90-95 %.



Gas system: design requirements

Gas systems (as detectors) are subject to severe requirements on material & gas for safe detector operation:

- Mainly (or exclusively) stainless steel pipe and components
- Need to validate most of the gas system components
- Documentation for QA and operation/maintenance follow up
- Monitoring of gas system operation
- Monitor of supply gases and mixture composition
- Evaluation of operational cost
- Flexible design to accommodate detector requirements/upgrades
- Careful evaluation of
  - resources for operation
  - resources for maintenance activity
  - Stability required
  - Balance requirements vs safety (as much as possible)

Gas system construction: modularity

- Gas systems are made of several modules (*building blocks*): mixer, pre-distribution, distribution, circulation pump, purifier, humidifier, membrane, liquefier, gas analysis, etc.
- Functional modules are equal between different gas systems, but they can be configured to satisfy the specific needs of all particle detector.
  - Implementation: control rack and crates (flexible during installation phase and max modularity for large systems)

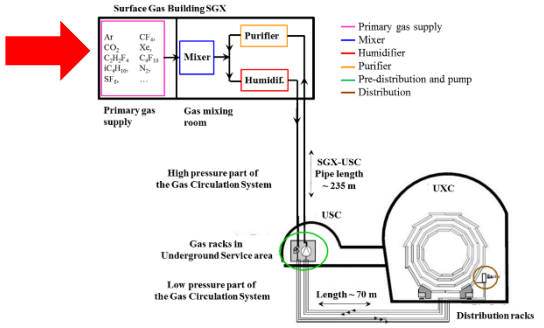
Control rack

Control crate (PLCs)

Modules crates Profibus connection to control crate

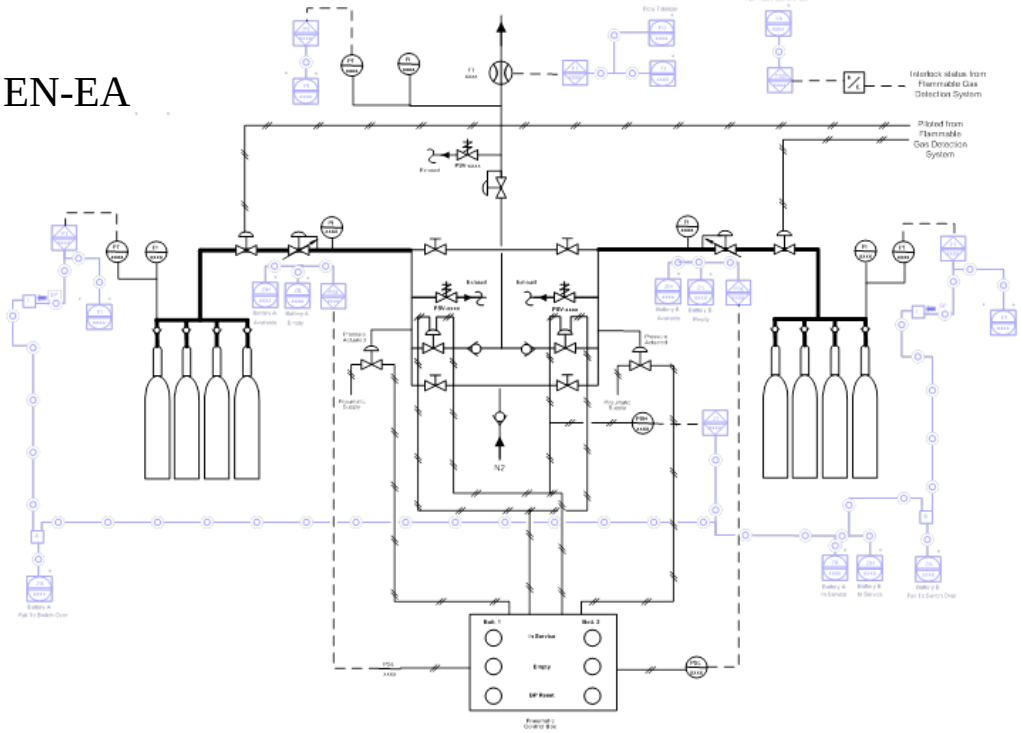
Gas supply monitoring system

- Monitoring for :
  - Ensuring reliability: make sure standby battery is availability
  - Gas flow for each gas supply
  - Gas quality (via analysis devices) before in service operation



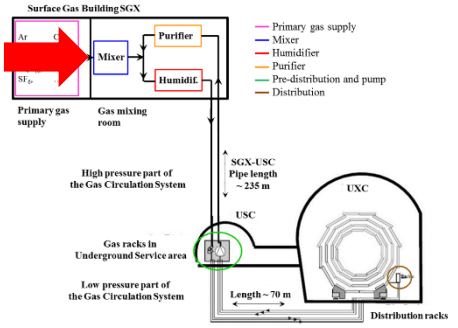
- Operational Warnings and Alarms:

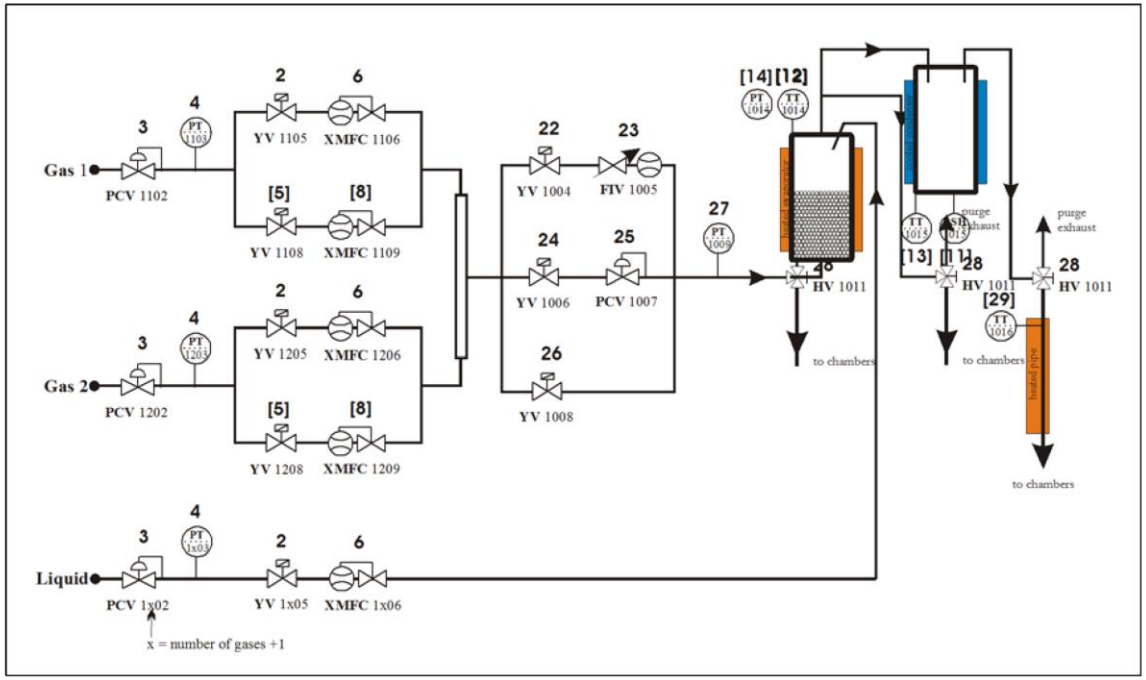
- Implemented in collaboration with EN-EA



Mixer module

- Standard Mixer module can have <u>up to 4 input lines</u> (gas and liquid).
- Primary task: provide the sub-detector with a suitable gas mixture during run.
- Different needs for filling or purging (i.e. high flow or different mixture)
- <u>Mixture injection regulated according to detector need</u>:
  - Correction for atmospheric pressure change
  - Mixture replacement in the detector
  - Recuperation efficiency or leak rate
- Warning/Alarms available:
  - Gas supply pressures
  - Flow not stable/reliable
  - Flow regulation (Mixing ratio)



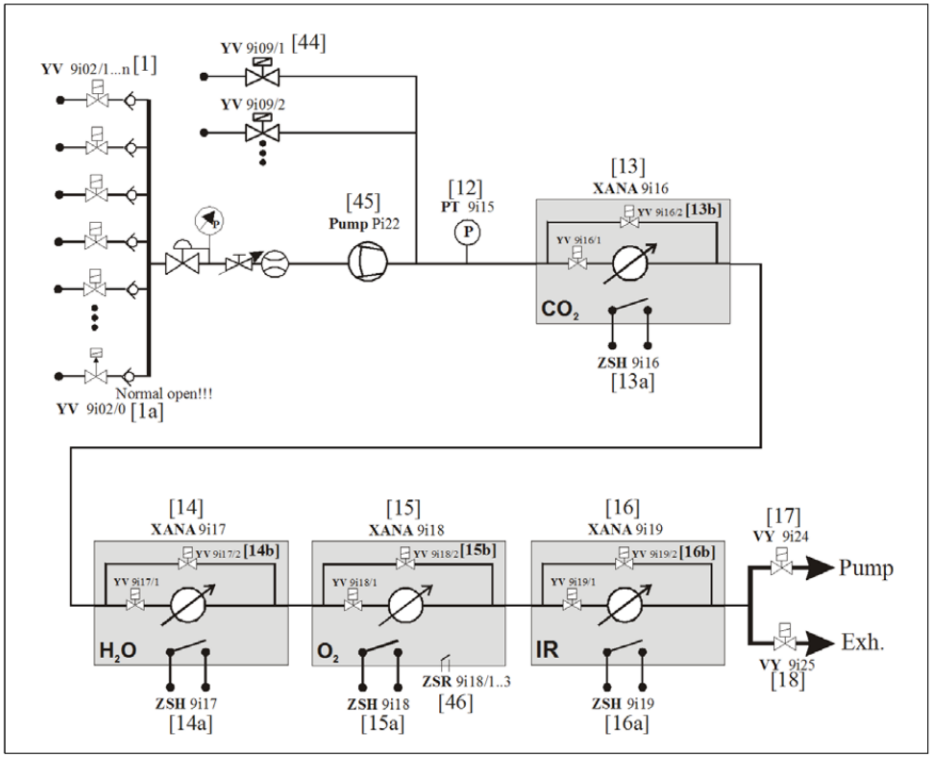


Gas analysis module

basically everywhere

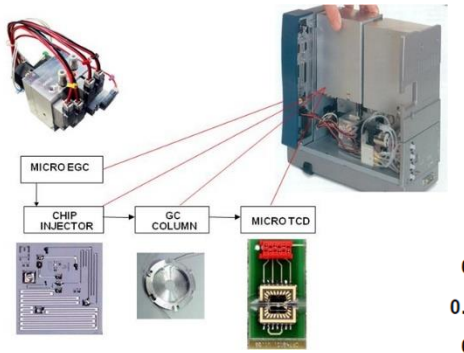
- Used to analyze the gas mixture
- Two types: gas source selected by means of standard valves or special n-way valves.
  - Several sample chains may be organized in several physical location.
  - Each sample chain completely independent

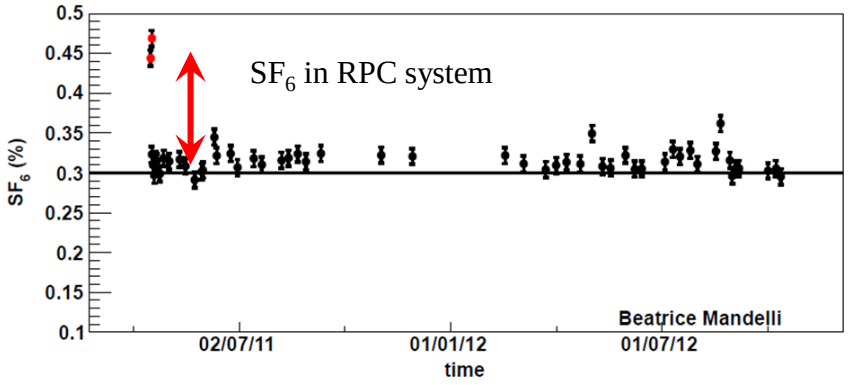
- The module operated in automatic mode
- Alarm and data exchange with detector DCS
- Used for safety (flammability level)
- Gas chromatographs connected for more specific analysis



Gas analysis module

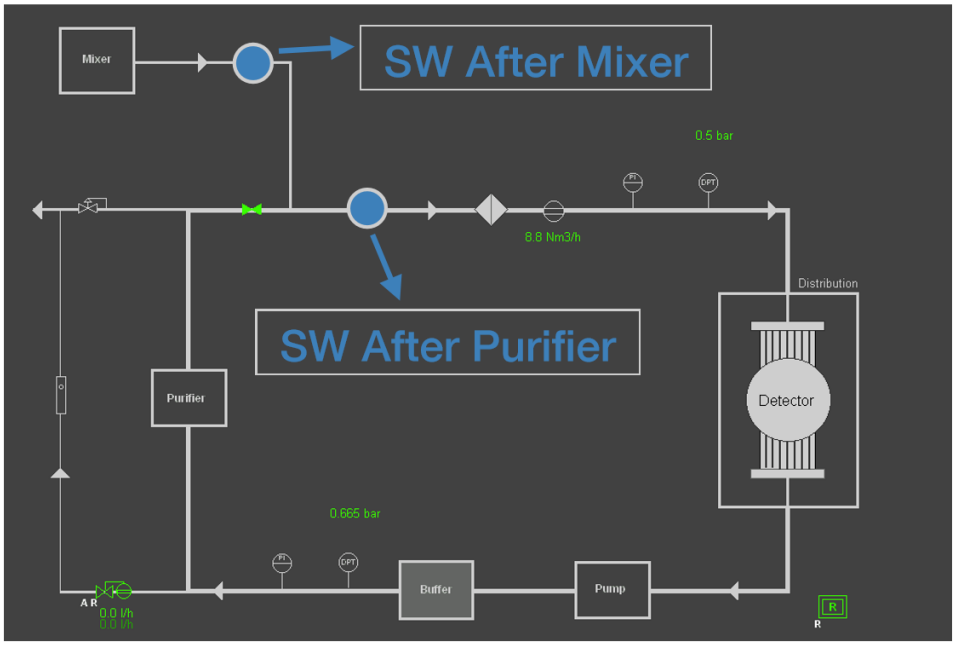
- Fully automated O_2 + H_2O analysis module
- Gas chromatographs are used to monitor:
  - Stability of mixture composition
  - Presence of more complex impurities

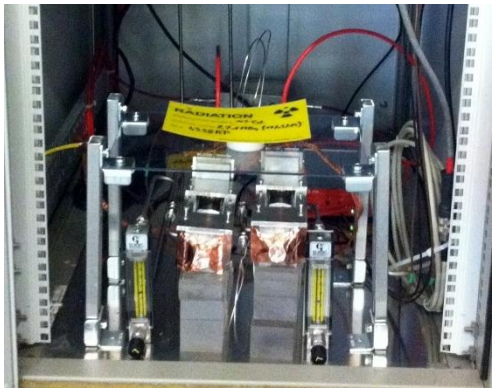


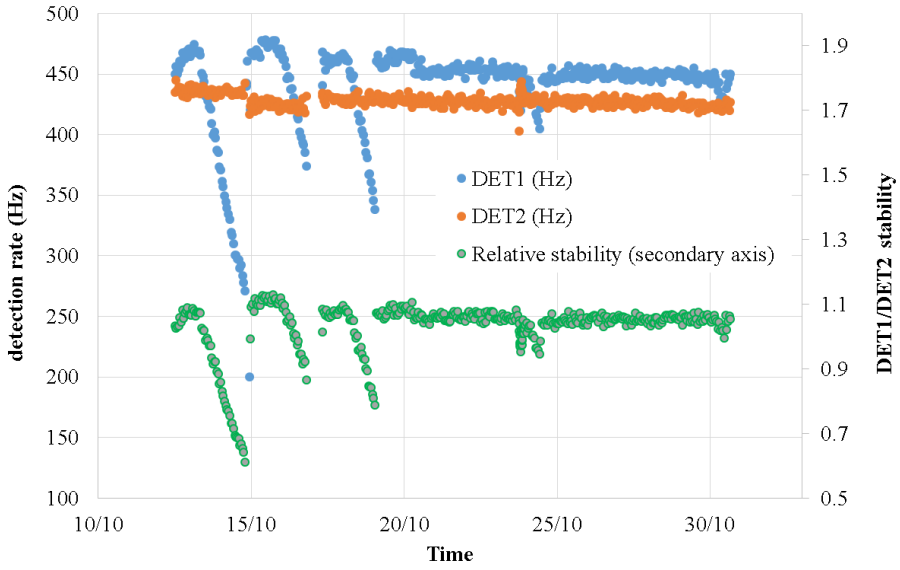


Gas analysis module

Monitoring system based on detector performances
Example of Single Wire chambers application for the CMS-CSC example



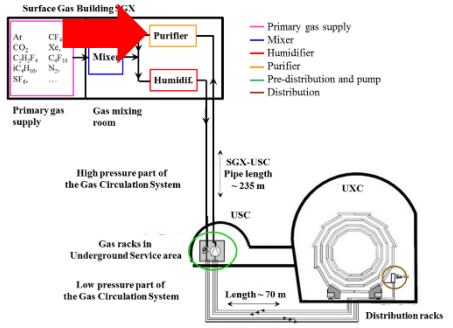


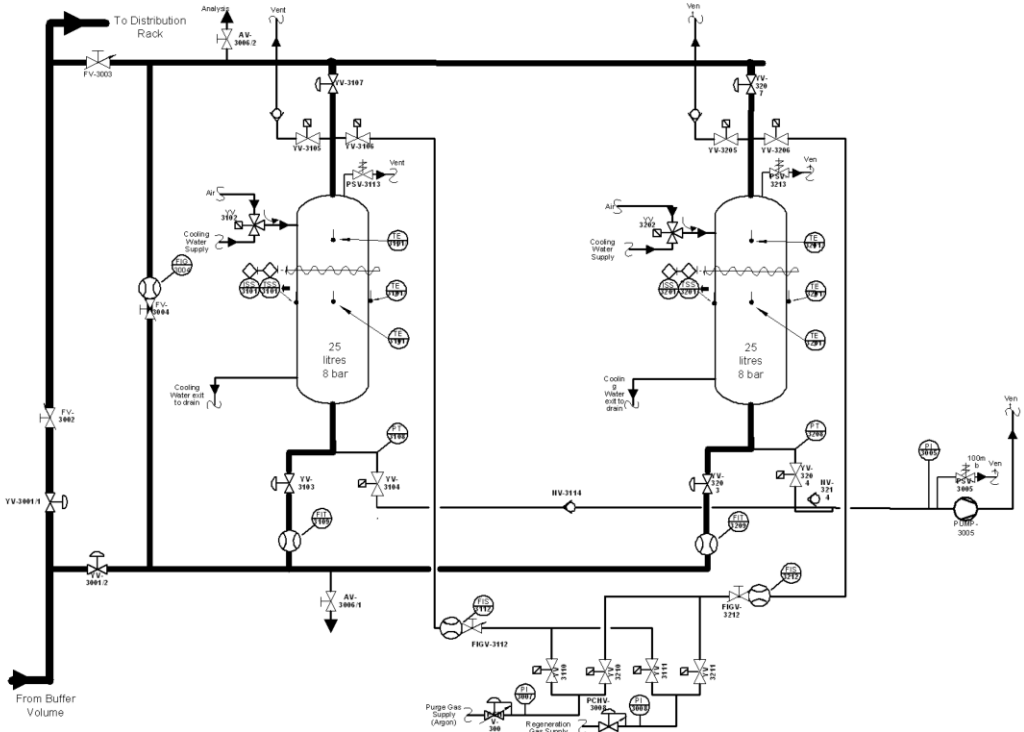


Purifier module

- One of the most complex modules
- Used to remove O_2, H_2O and more from mixture
- Fully automated cycle
- 2 x 24 l columns filled

  with suited absorber:
  - Molecular sieves
  - Metallic catalysts
  - others

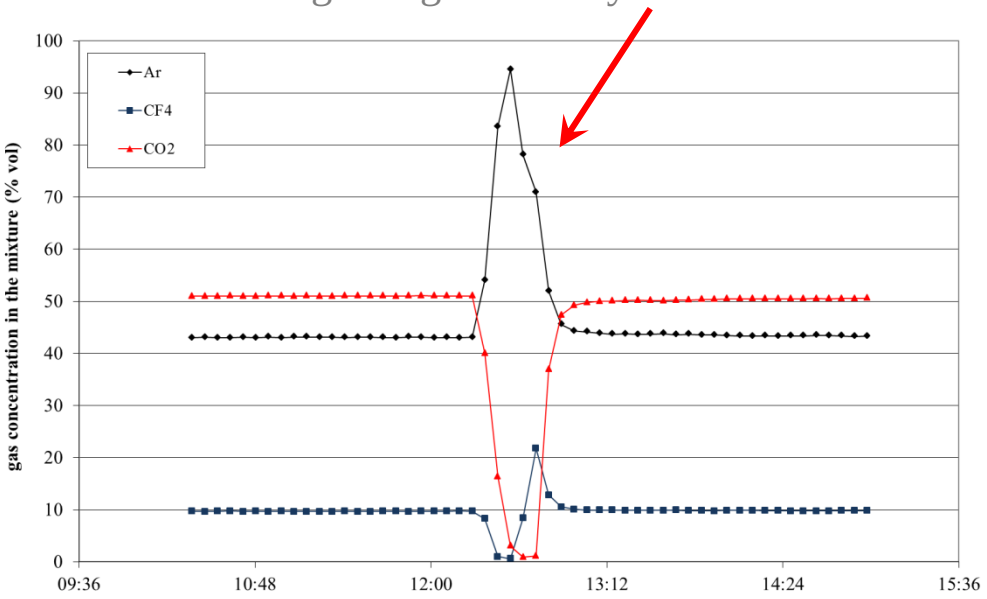




Purifier module

Many modules operational with many different gas mixtures and cleaning agents

- A lot of experience and developments:
  - Example: cleaning agents absorb not only impurities → mixture was destabilized at the beginning of each cycle

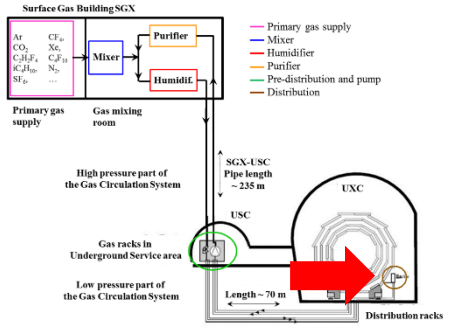


Distribution module

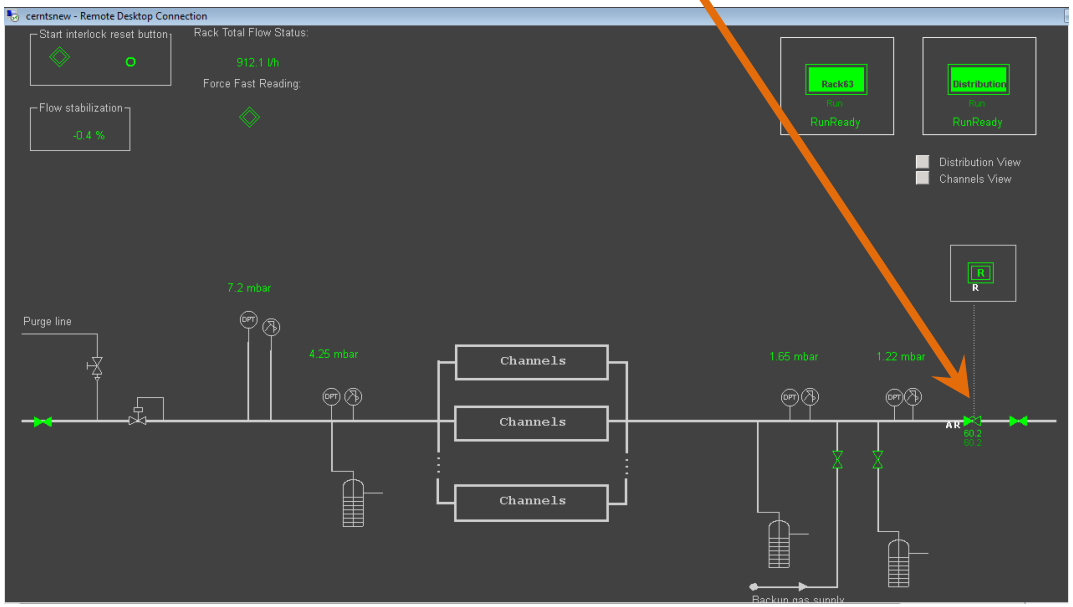
Mixture distribution modules equipped with:

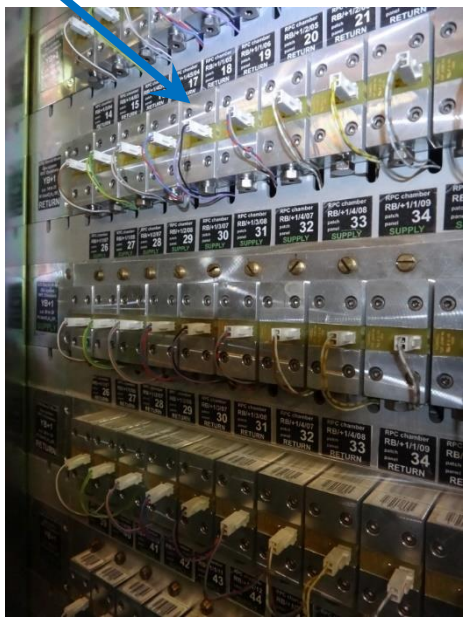
- Supply and return flow read-out system developed in the team
- Pressure/Flow regulation system

At channel/chamber level



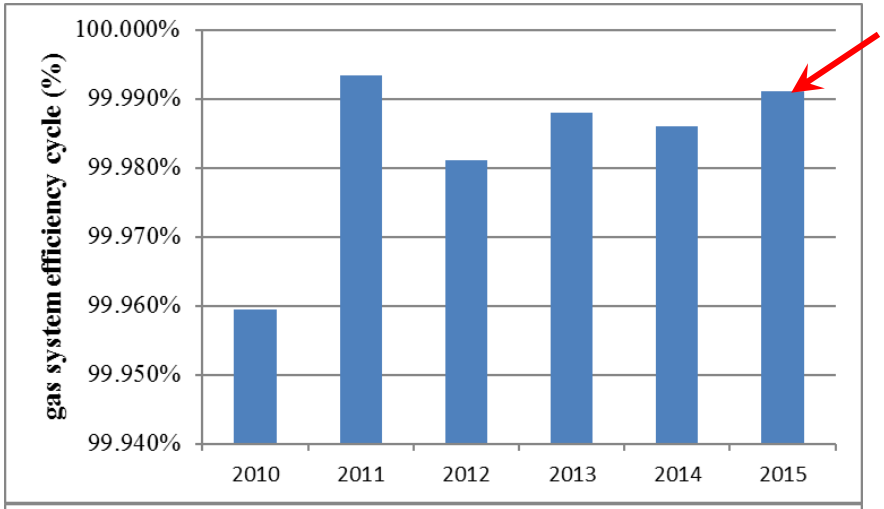
Distribution unit: controls view

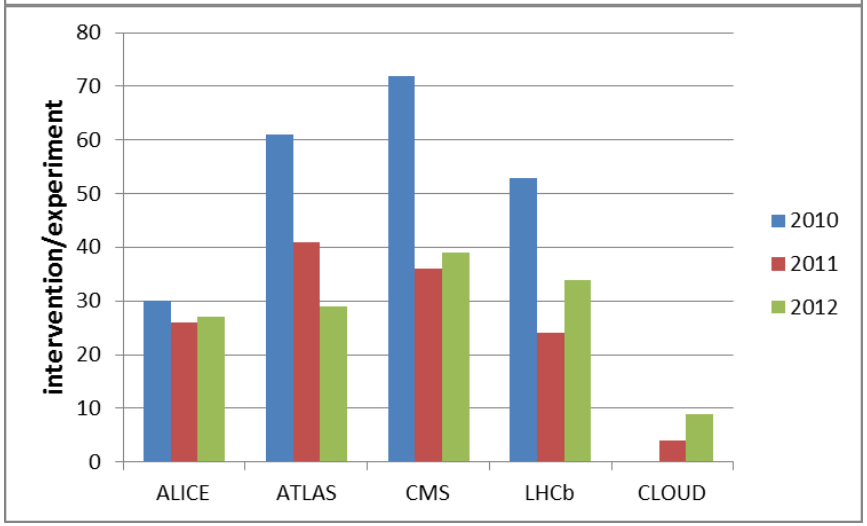




Reliability over the past years

- Results from analysis of the interventions performed during 2010-2015

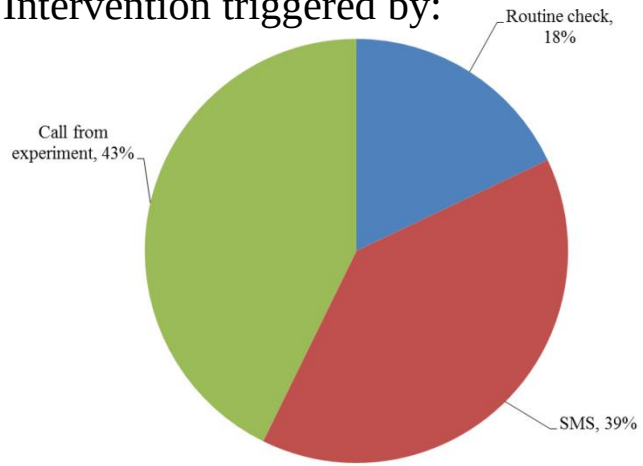




On average less than 1h/year/system of downtime
(power-cuts and outside events excluded)

24/24h on-call service provided

Intervention triggered by:



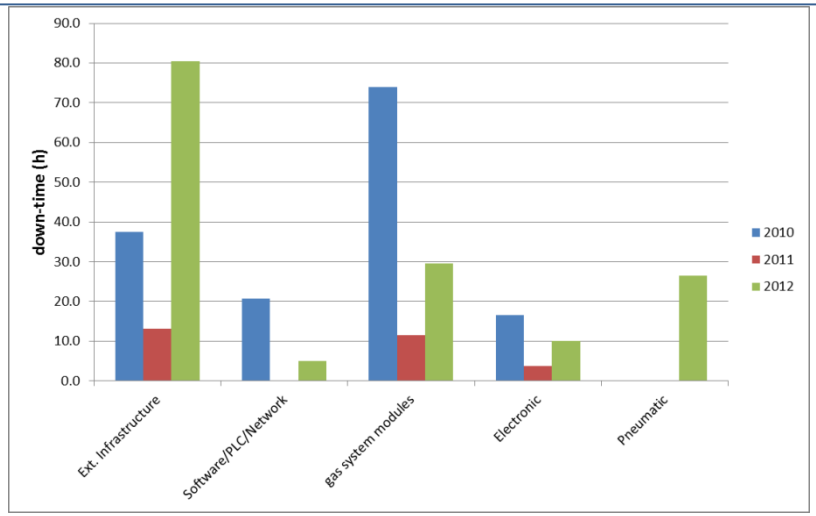
Intervention are

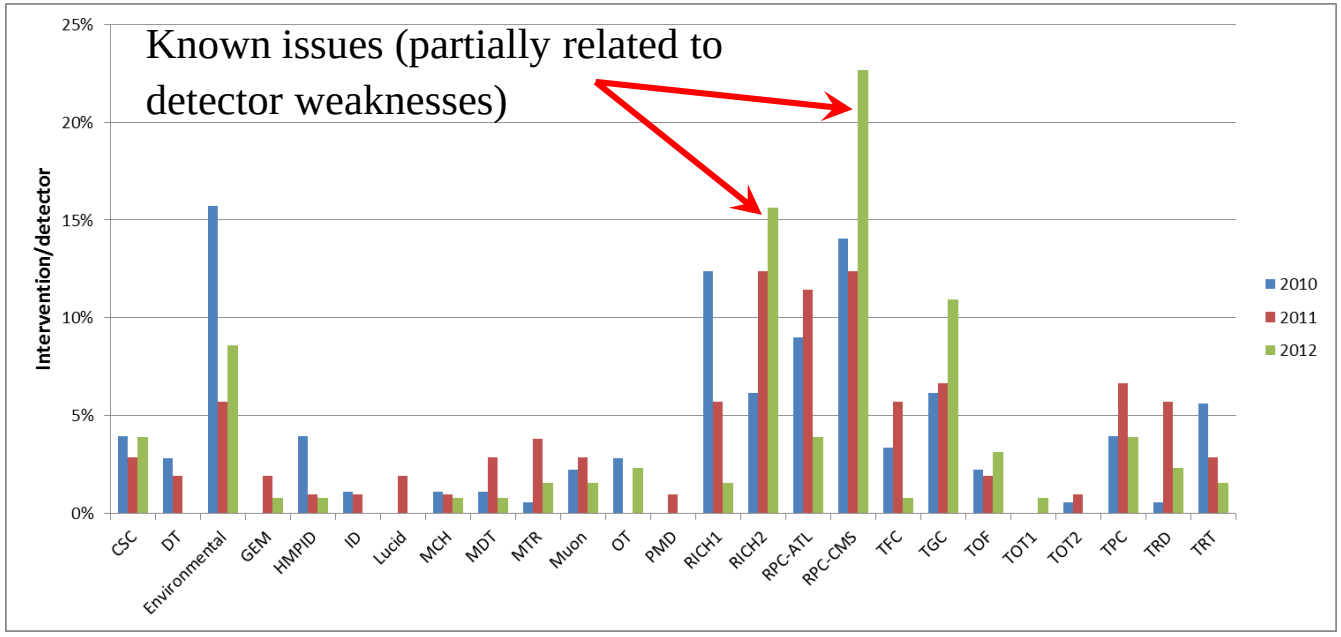
- Equally distributed between experiments
- Decreasing with time ☺

Reliability over the past years

Sources of down-time, analysis:

Issues with gas system modules account only for a small fraction of the total

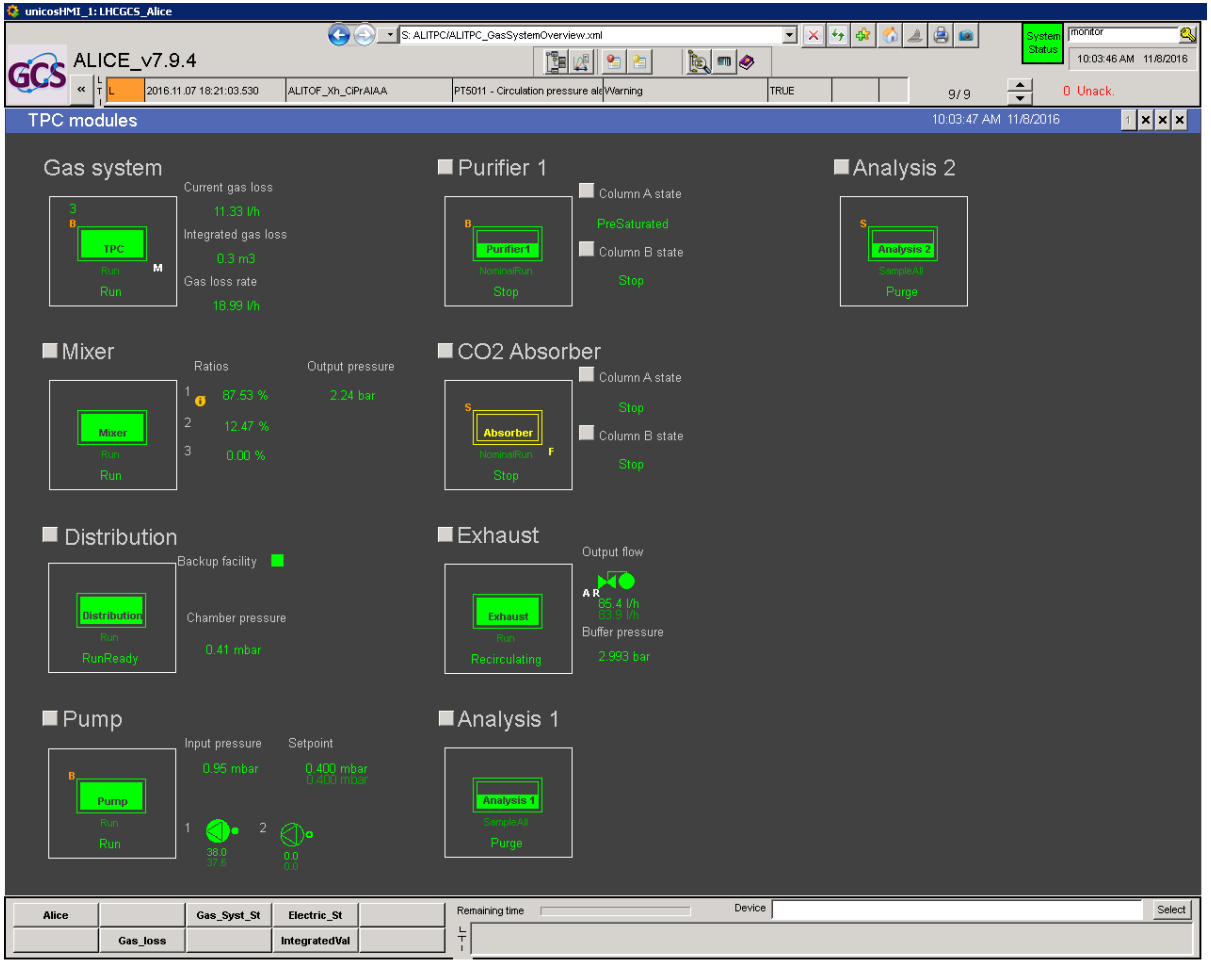




The ALICE-TPC gas system: overview

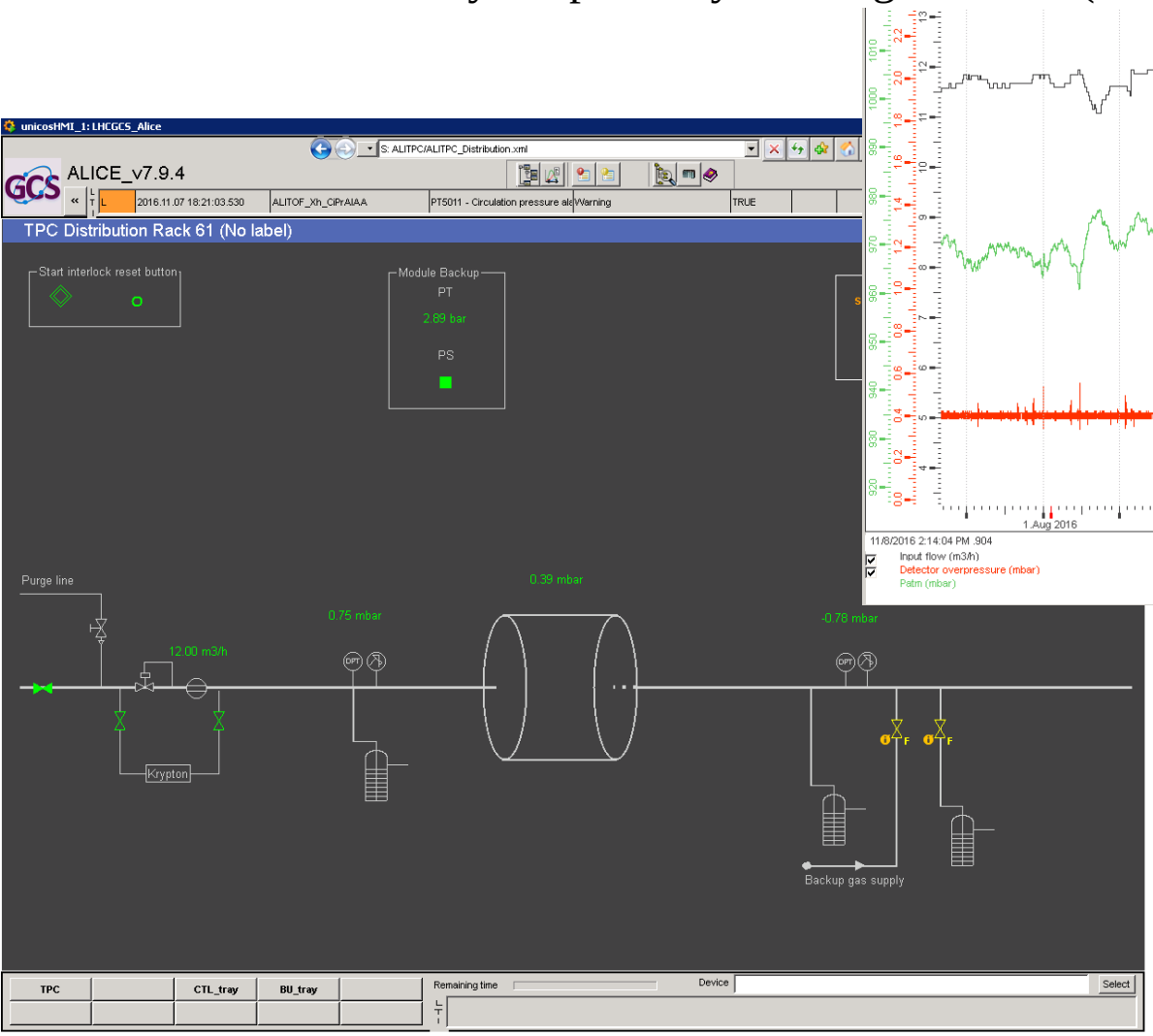
Overview of the modules from the Gas Controls Software interface:

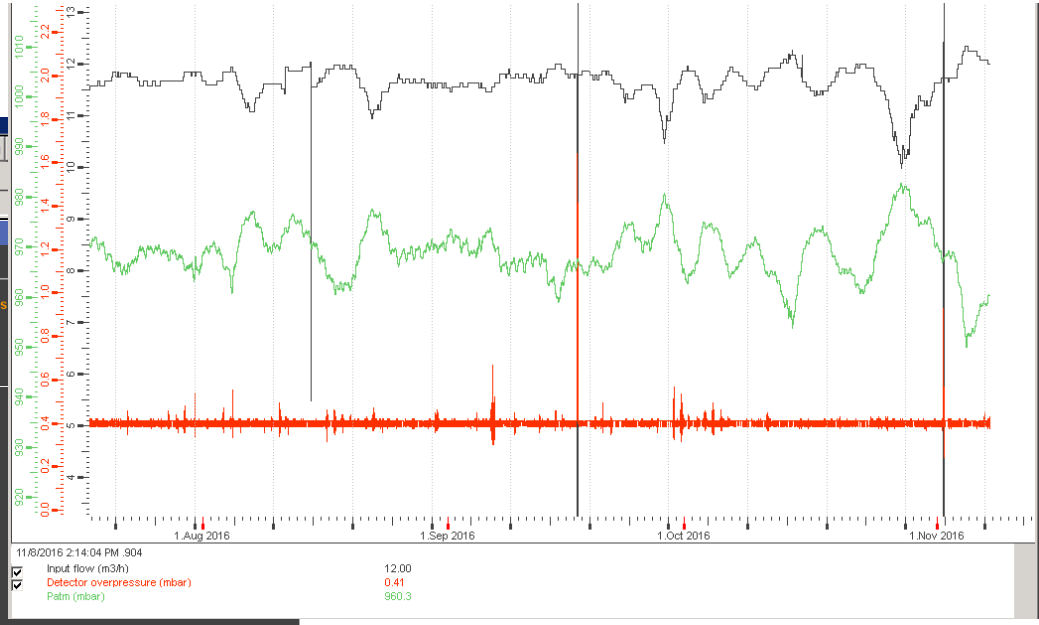
Functional modules of the TPC gas systems



The ALICE-TPC gas system: Distribution

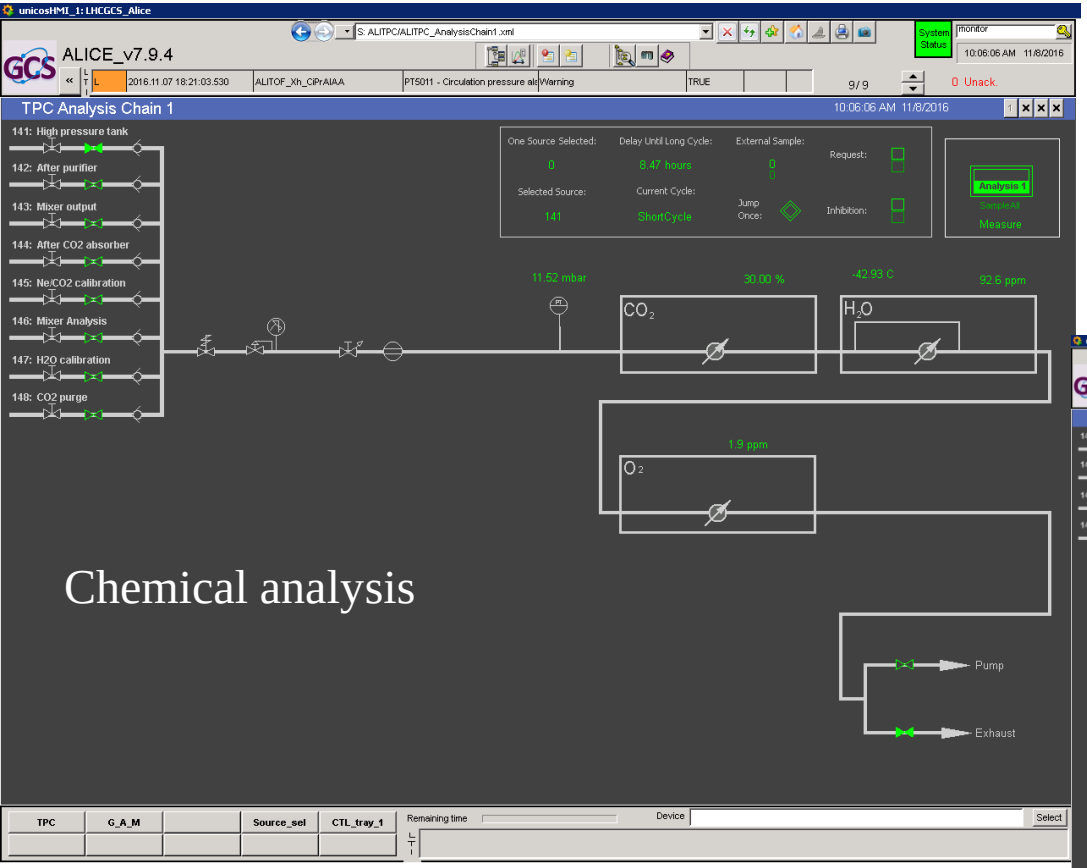
Gas distribution is very simple: only one large volume (90 m^3)

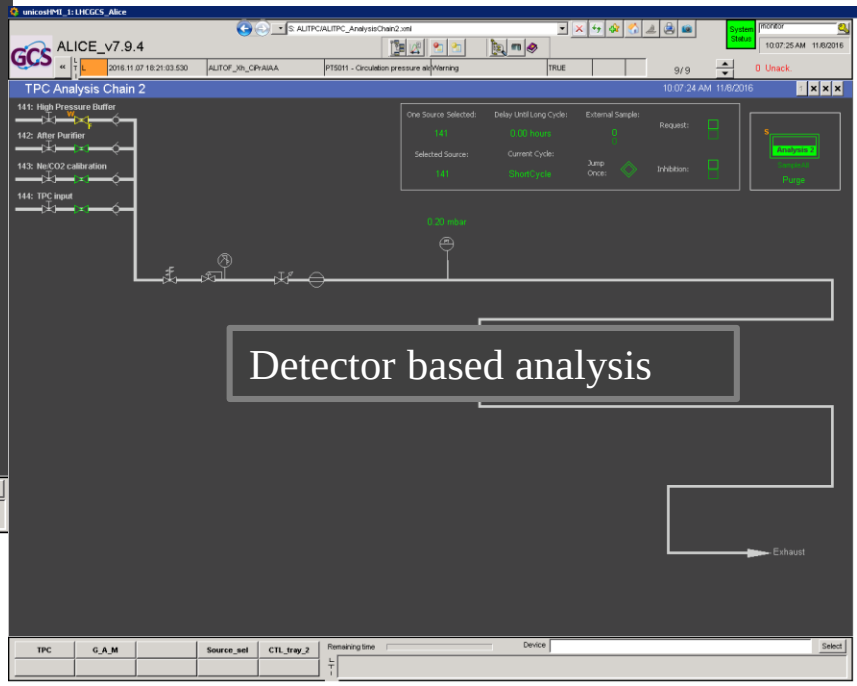




The ALICE-TPC gas system: Analysis

Dedicated gas analysis: no interconnections with other gas systems





Conclusions

- 30 gas systems (about 300 racks) delivering the required mixture to the particle detectors of all LHC experiments.
- Designed and built according to functional modules:
  - Simplified maintenance and operation activities for the team
  - Fully automated systems with remote control/monitoring
  - few examples have been briefly presented
- Gas systems have demonstrated an impressive relaiability level:
  - On average about 1 h downtime/year (excluded external causes, i.e. power-cuts, …)
- Maintenance and consolidation are fundamental to ensure reliability at long term