

Development of a Modular Gas Monitoring System (GMS) for Real-Time Quality Assessment in Gaseous Radiation Detectors

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07/10/2025



EP-DT
Detector Technologies



**DRD1 COLLABORATION
MEETING**

06-10 OCTOBER 2025 **WARSAW**

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Gas monitoring systems overview

- Motivations
- Requirements

Gas Monitoring System project

- Design and specifications
- Prototyping and construction
- Final design and considerations

Conclusions

Monitoring gas quality in gaseous detectors

Gas detector performance is greatly dependent on the gas mixture

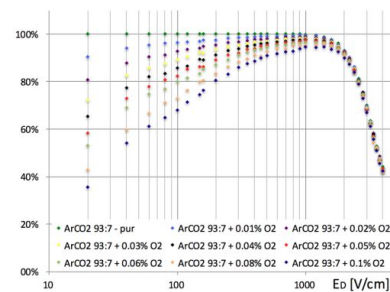
- Gas parameters, such as **pressure**, **temperature**, plays a crucial role in signal formation processes
- Small amount of “**impurities**” or “pollutants” affect performances
- Environmental gases may enter in the detector through material diffusion, leak tightness

Different gaseous detectors have different sensitivities to the gas mixture quality

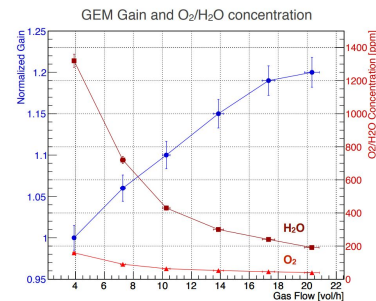
- MPGD/Wire chambers $\Rightarrow$ gain drop with ppm of O₂/H₂O
- RPCs $\Rightarrow$ HPL requires ~thousands ppm H₂O for correct operation, glass no H₂O

Monitoring gas quality is fundamental

- For large detector installation
- For small laboratory and set-up installation as well

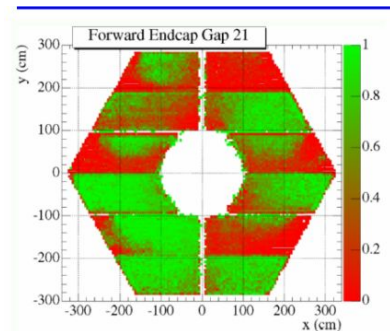


[Signal Formation Processes in Micromegas Detectors and Quality Control for large size Detector Construction for the ATLAS New Small Wheel, Fabian Kuger](#)

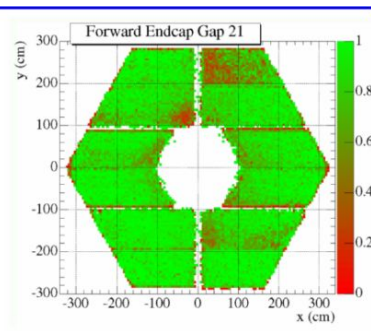


[M. Corbetta et al. MPGD 2019](#)

BaBar RPC det. eff.
no humidity



BaBar RPC det. eff.
30% RH



[Changqiao Lu & Kirk McDonald](#)

Requirements for a gas monitoring system

What are the most important parameters to monitor?

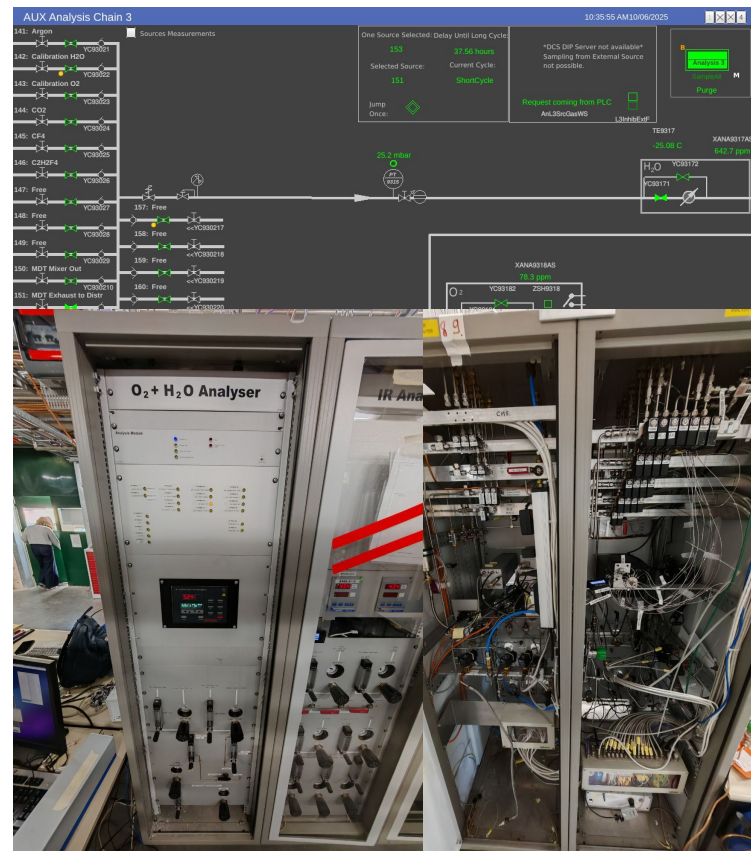
Physical parameters: pressure, flow, temperature

Gas mixture quality: H₂O, O₂, N₂, free radicals,...

Large detector installations perform different analyses on the gas

- **Physical parameters:** industrial grade pressure, flow and temperature sensors
- **Chemical composition:** industrial grade analyzers, such as capacitive sensors, infrared analyzers, chilled mirrors, gas chromatographs
- Analyses can be
 - **Continuous:** critical parameters (e.g. pressure, flow, flammable gas concentrations)
 - **Automatic + periodical:** long-term effects parameters (e.g. O₂, H₂O)
 - **Manual/Semi-auto + periodical:** e.g. gas chromatograms, F- measurements

LHC analysis module



Gas Monitoring System: CERN's summer student project 2025

Goal: design and build a portable monitoring system that can be used for small laboratories and setup

Part of CERN's Summer Student programme

- Within the **DRD1 collaboration**: developed system available for lab and test beam to all DRD users
- Synergy between CERN's gas detector and gas systems group

Features

- **Multi-parameter monitoring** (pressure, flow, gas mixture quality)
- **Reliable**: should make use of validated analyzers for gas detectors
- **Portable**: should fit in a small case
- **Open source**: every institute should be able to build one by following open source documentation
- **Standalone**: only requirements should be the power supply
- **Plug & Play**: once configured, should require minimal intervention
- **Modular**: should allow to be modified and possibly extend its core functionalities

Gas Monitoring System: technologies

Employed technologies

Gas piping: stainless steel, LHC-like

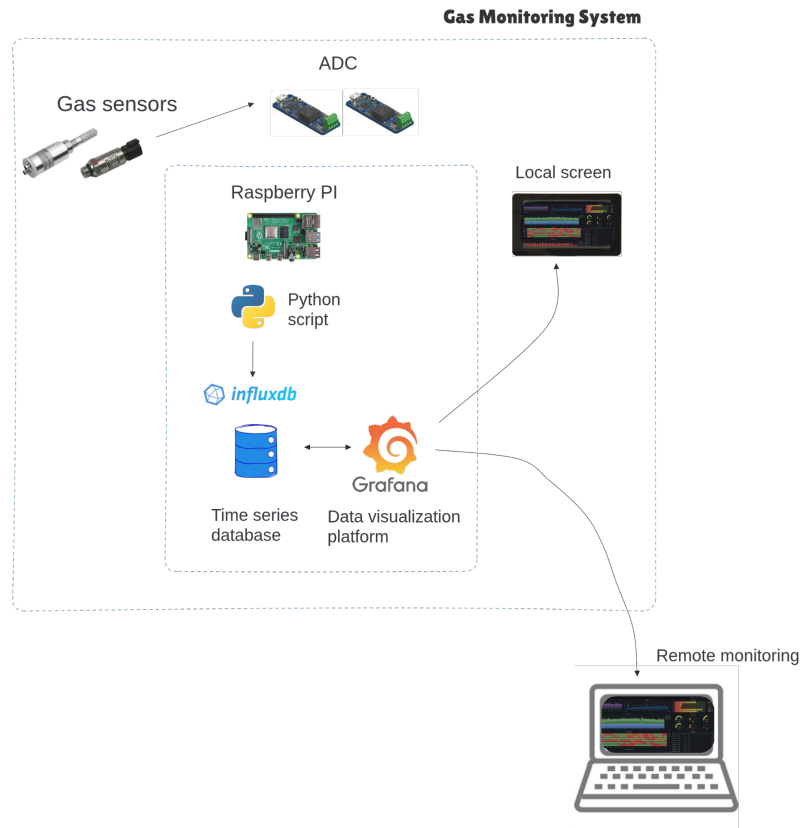
Gas components: pressure, H₂O, O₂, flow + environmental (pressure, temperature, relative humidity)

ADC + Readout: Raspberry Pi + commercial ADC boards (Yoctopuce). Both can be swapped with other technologies

Data acquisition: python scripts

Data ingestion: time series database (InfluxDB)

Data visualization: Grafana



Design and construction of the GMS





Building blocks

01 Sensors

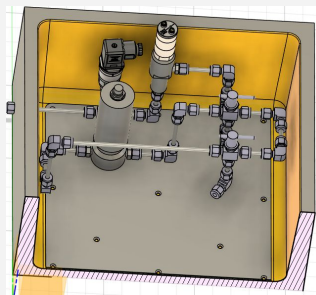
Humidity

Flow

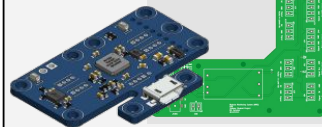
Oxygen

Pressure

02 Mechanics



03 Electronics



04 UI



Gas components

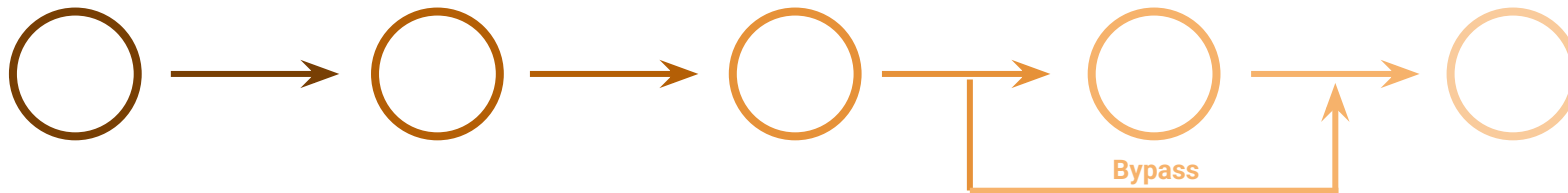
Detector output

Pressure

Humidity

Oxygen

Flow



First Sensor
Danfoss MBS9200



Vaisala
DMT 143



PST
SenzTx Oxygen Transmitter



Omron
D6F-P0010A1
D6F-P0001A1

Mechanical design

Mechanical design focused on compactness and portability

Gas components + electronics fitting in a 38.7 x 39.4 x 26 cm³ peli case

Initial Prototype built on a base plate

Used to estimate size of the final model and integration sensors + electronics

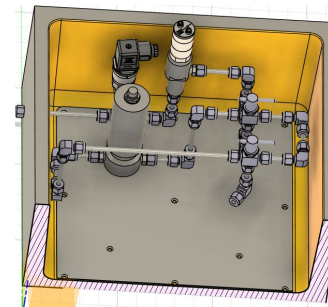
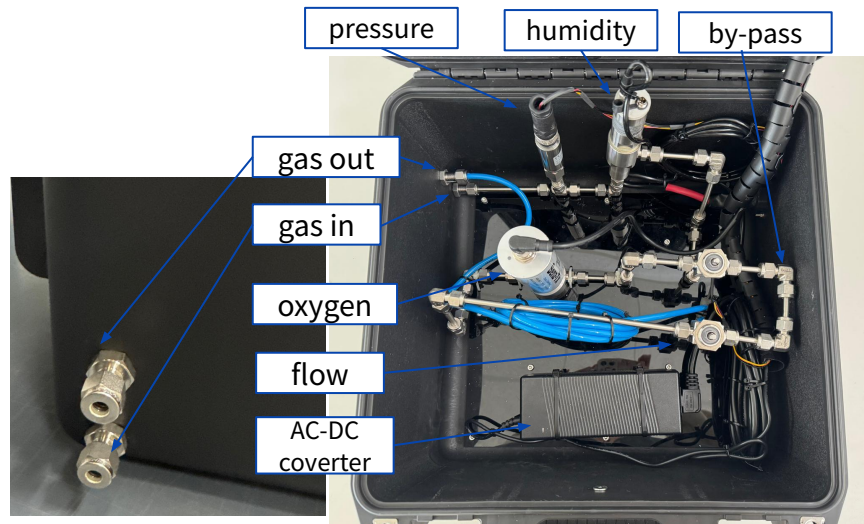
User Interface

On the side of the pelican: gas inlet and outlet connectors

Final model

3D design

Straight stainless steel piping + Swagelok connectors OD 6 mm + Swagelok 3-way valves



Electronics

Custom design to interface sensors with ADC and RPi

- 3D printed parts to accommodate the electronic components
- Custom PCB designed to simplify wiring

Multiple power supply lines

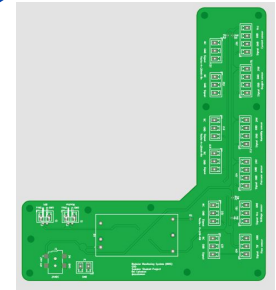
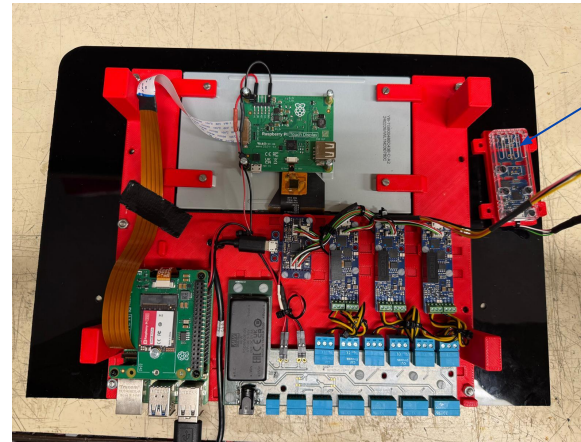
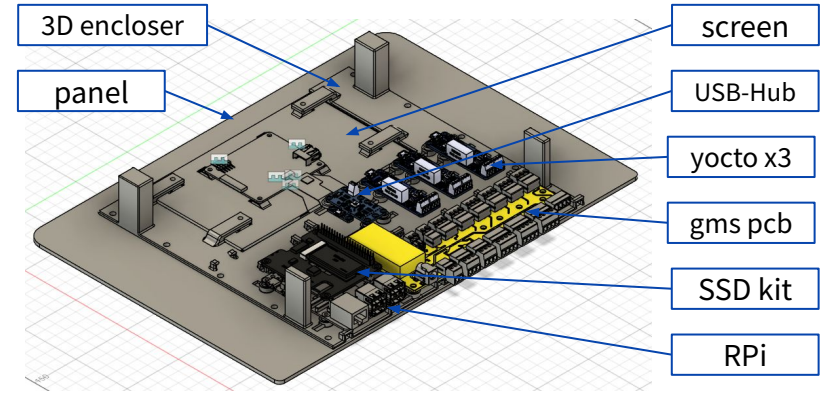
- 24 V for most of industrial sensors
- 5.1 / 4 A for RPi + flow sensors

Supported I/O interfaces

- 4..20 mA input for PT sensors, H2O sensor, O2 sensor
- 0-10 V for flow sensor
- 1 spare 4..20 mA + 1 spare 0-10 V for additional sensors

System operation tools

- NVMe for data storage
- Yocto-USB-Hub for one point connection from the Yoctopuce models to the RPi
- Single power input



Data acquisition and visualization

Running software using open source solutions

Approach focused on making the system available to every interested institute: open docs and open source

https://gitlab.cern.ch/osalomon/gms/-/blob/main/gms_quick_start_guide_ver01.pdf

Data acquisition

Python script using available ADC APIs

Data storage

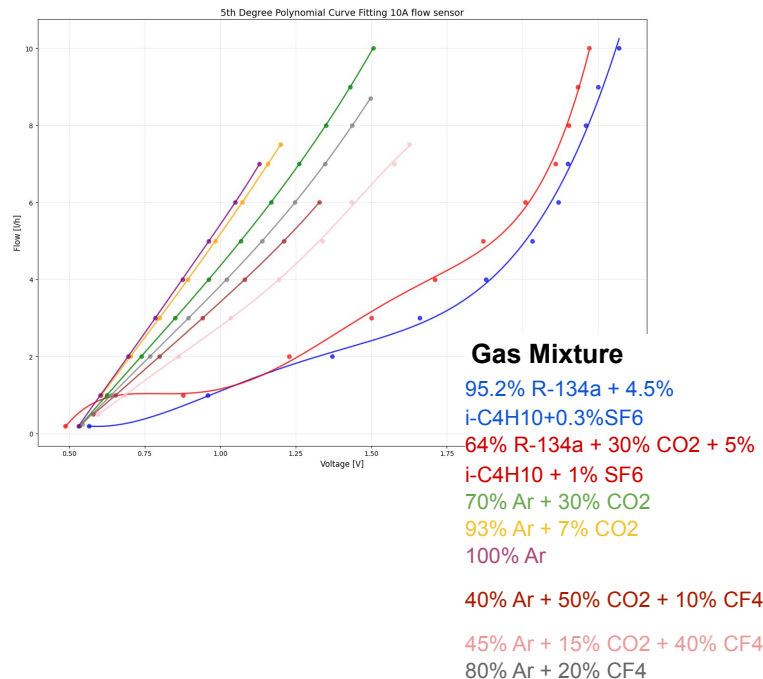
- Local **InfluxDB** instance, optimized for time-series data
- Optional: possibility to use external InfluxDB instance

Data visualization

- Local **Grafana** instance for dashboard + alert
- Optional: possibility to use an external grafana instance

Sensors calibration

As a part of CERN's Summer Students project, **flow sensors** were **calibrated** for commonly used gas mixtures



Conclusions

A portable gas monitoring systems was designed and produced for gaseous detectors

- Designed **for the DRD community**: available units at CERN and instructions to build copies
- Focused on **portability**, ease of construction and **open documentation**
- Dedicated mechanical and electrical design/drawings done
- Assembly instructions, BOM, installation guide, and quick setup guide are available on GitLab

Gas parameters examined: Pressure, humidity, oxygen, flow, environment parameters

- Sensors reliability checked and sensor calibration performed on flow sensors

Software and hardware selected for simplicity and availability

- Employing hardware easily available
- Using open source technologies

One unit was built, available at the GDD. Another unit is being built

- Documentation and assembly instructions being validated
- Ongoing identification of improvement for future models

