





BSU Institute
for Nuclear Problems



TPC cooling and thermal stabilization system: status

XVII Collaboration Meeting of the MPD Experiment at NICA

April 21 – 23, 2026

Speaker: Alexander Fedotov

Introduction

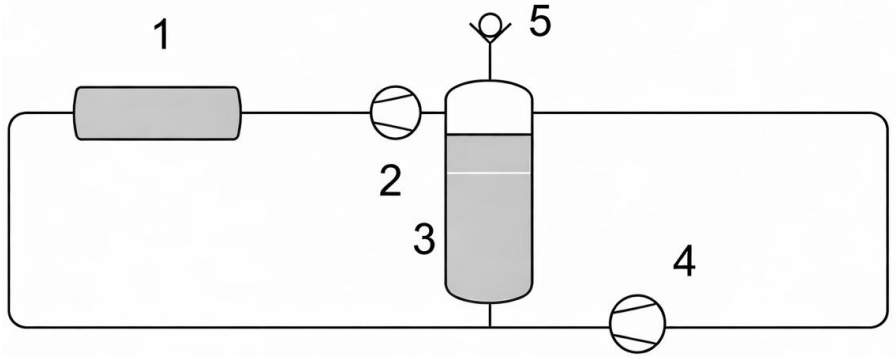
Needs of TPC:

- Efficient cooling of high-power electronics;
- Minimization of temperature gradients;
- Safe operation of unique electronics.

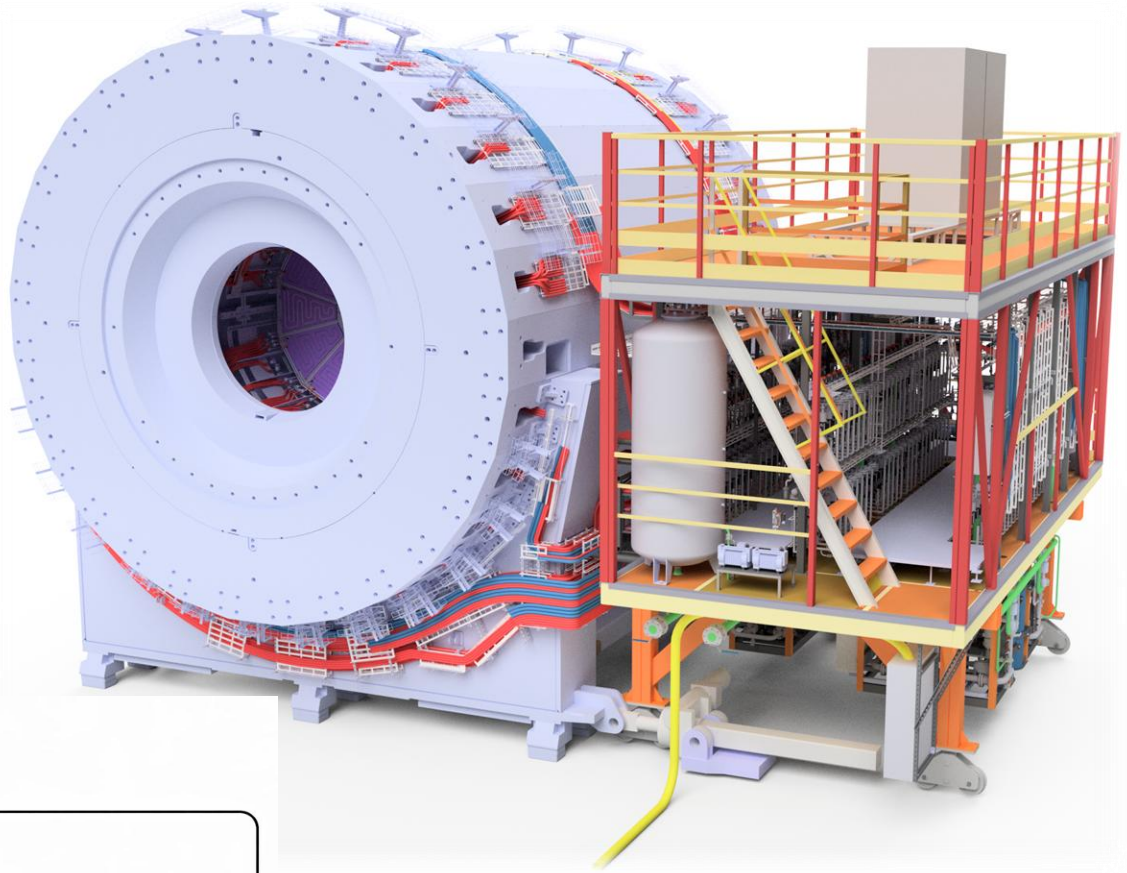
Solution: 1994 - Michel Bosteels proposed a **sub-atmospheric leakless cooling system** (LCS)

Water pressure < ambient pressure of 1 atm

(1) - heat exchanger
(2) - vacuum pump
(3) - water tank
(4) - circulation pump



Conceptual scheme of LCS



LCS on a platform

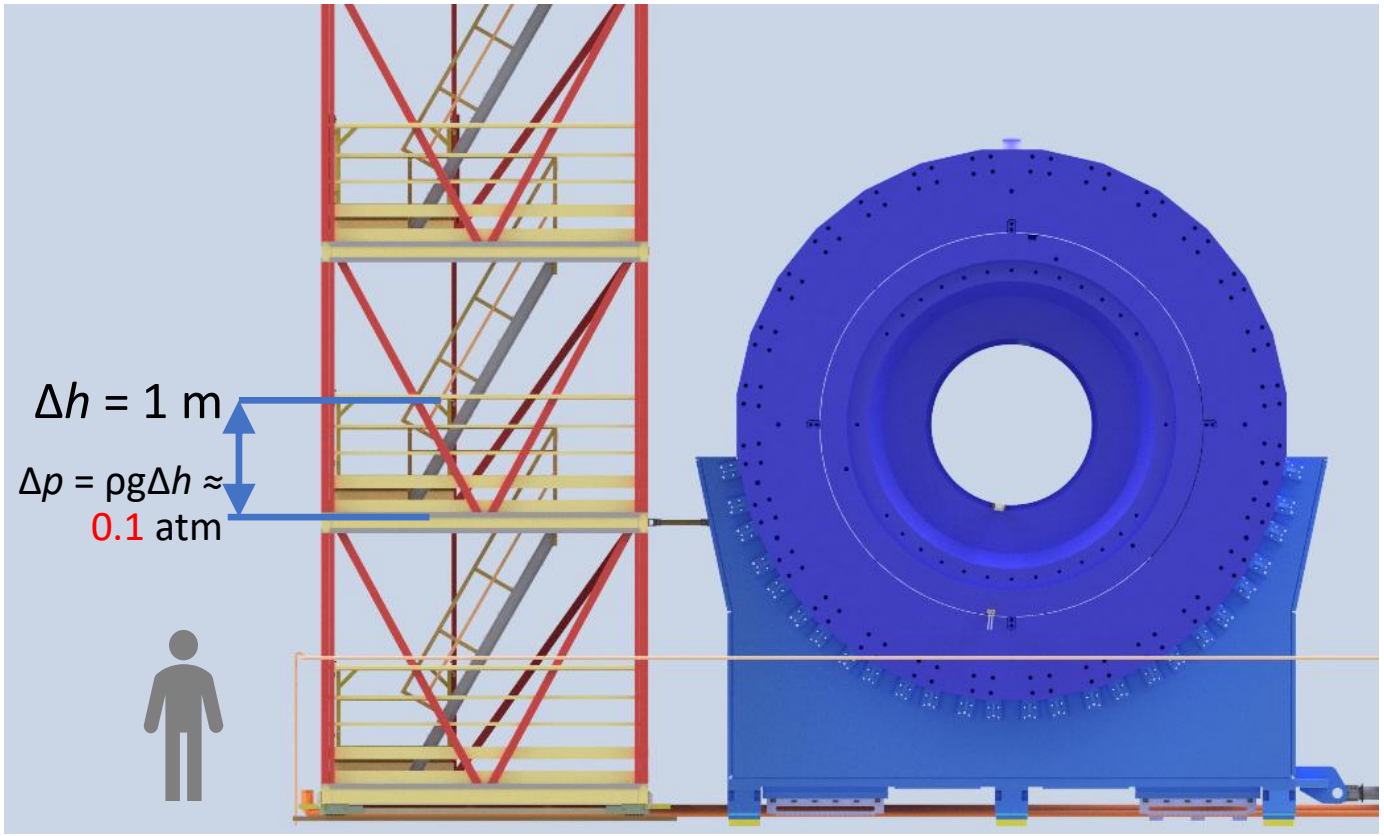
Leakless cooling and thermal stabilization system (CaTSS)

Hydrostatics makes leakless control hard on tall detectors

- Each meter of height changes water pressure by $\rho g \Delta h$ = 0.1 atm.
- MPD height ≈ 8 m;
- If p_{abs} is above 1 atm, leaks are possible;
- If p_{abs} is below 0.1 atm risk of cavitation increases

Very narrow pressure gap is available for operation!

Computational design was needed as pressure drops is due viscous and inertial losses



MPD and a platform

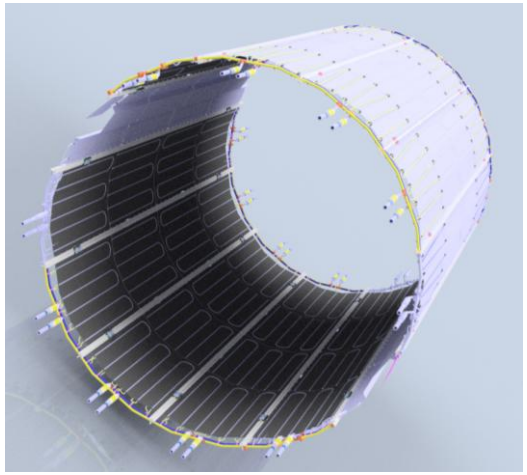
Leakless system of MPD

System parameters:

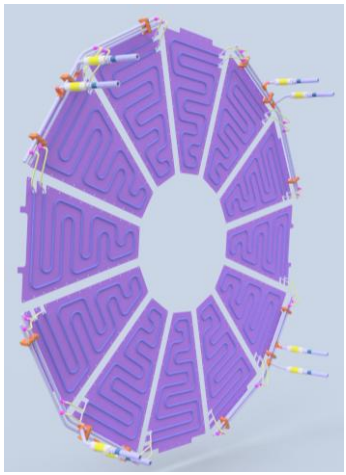
1. Total power: 20 kW
2. Total flow: 60 m^3/h

Leakless regime of operation: absolute pressure in TPC & ECAL < 1 atm.

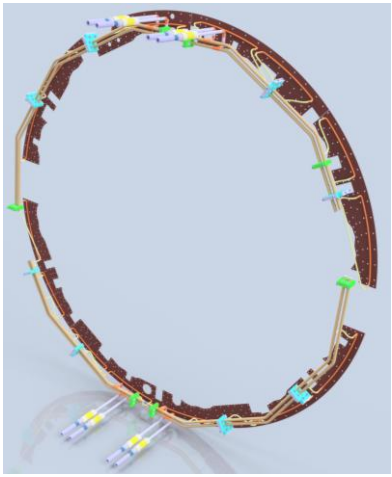
Thermal stabilization of TPC working gas mixture of 0.1 K according to STAR & ALICE



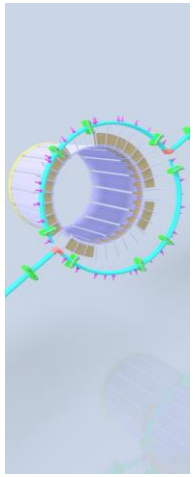
Outer thermal screen



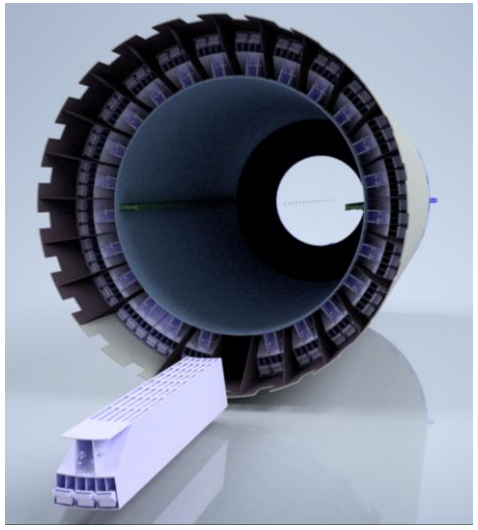
Frontal thermal screen



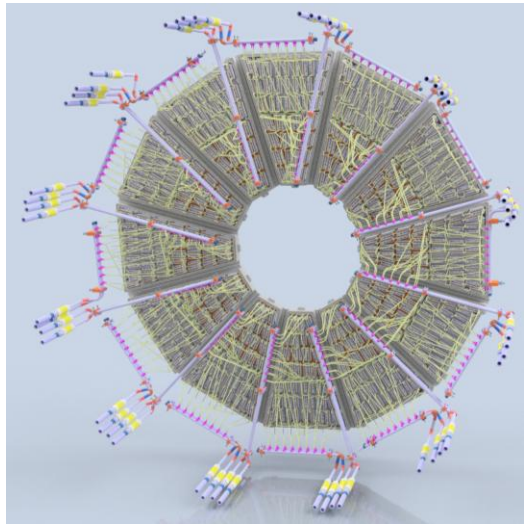
Flanges



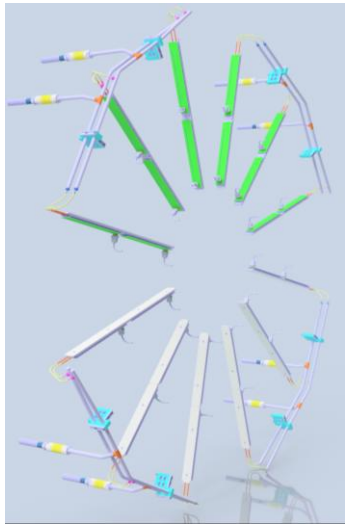
Internal thermal screen



ECAL



SAMPA & FPGA electronics + ROC cases



LVDB and reading controllers

The outline

Structure of the talk (25 mins’):

1. First full-scale leakless run at MPD hall;
2. Air leak image recognition;
3. CFD note on flow patterns.

Leakless test run

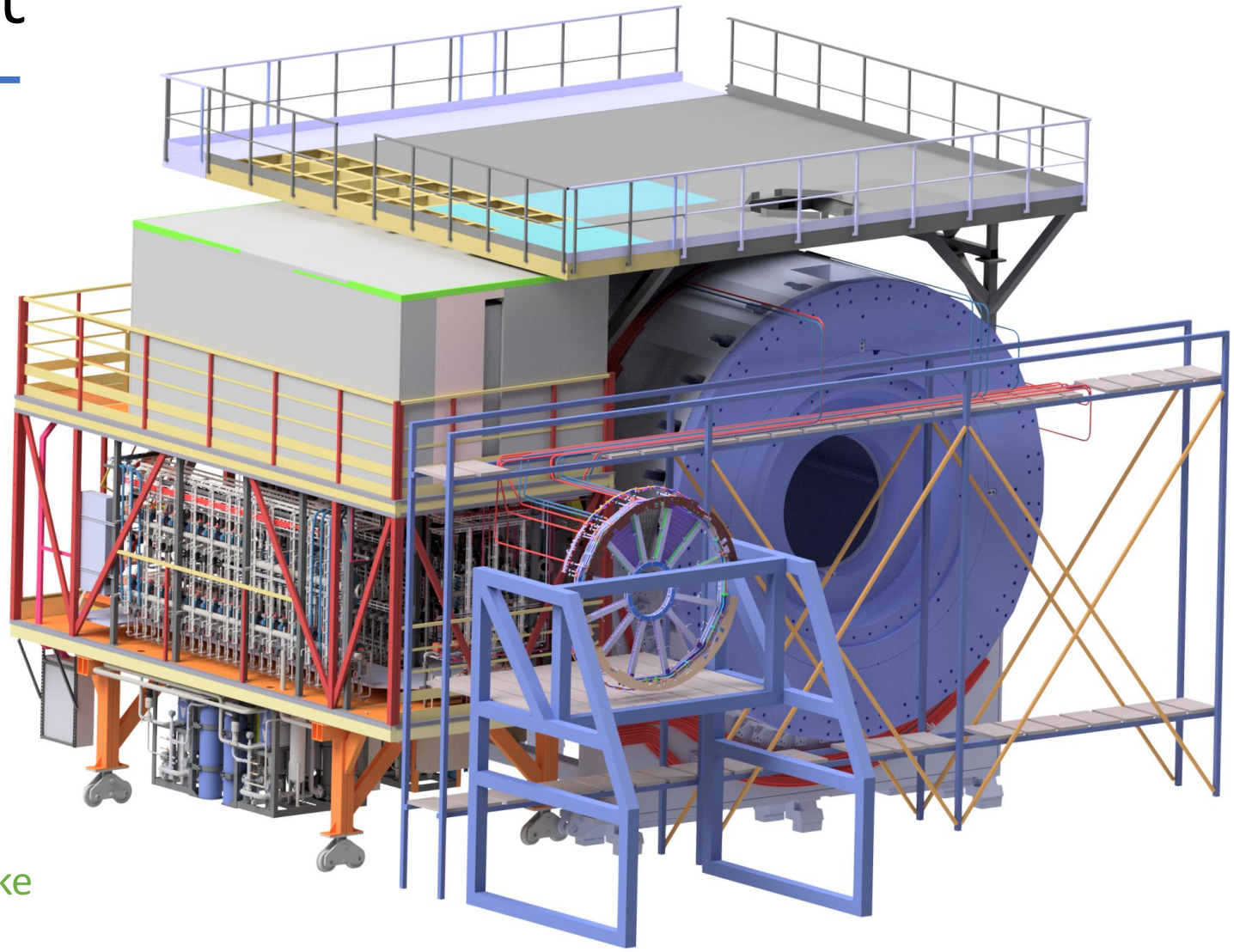
Scheme of experiment

Goal: testing the leakless mode with final radiator prototypes under realistic piping conditions (elevation, bends, and length)

The service wheel was equipped with a frontal thermal screen, ROC case, SAMPA, FPGA, and LVDB radiators.

Position of service wheel relative to MPD:

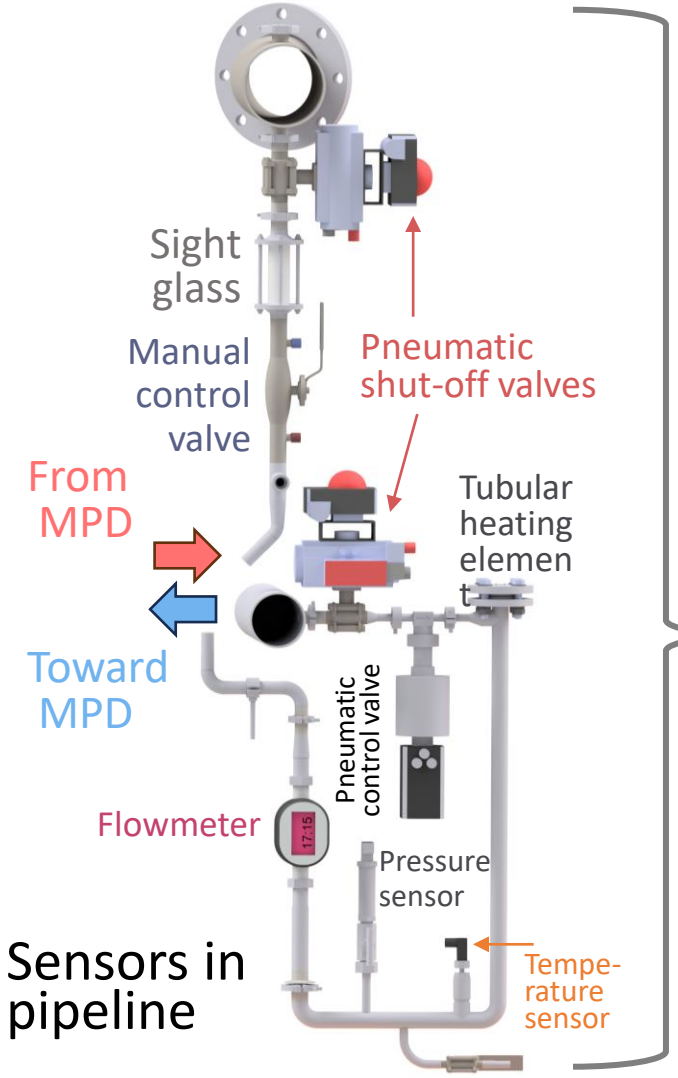
- Same height and trace through MPD yoke windows as real;
- 1.5x-2x longer horizontal pipeline than real.



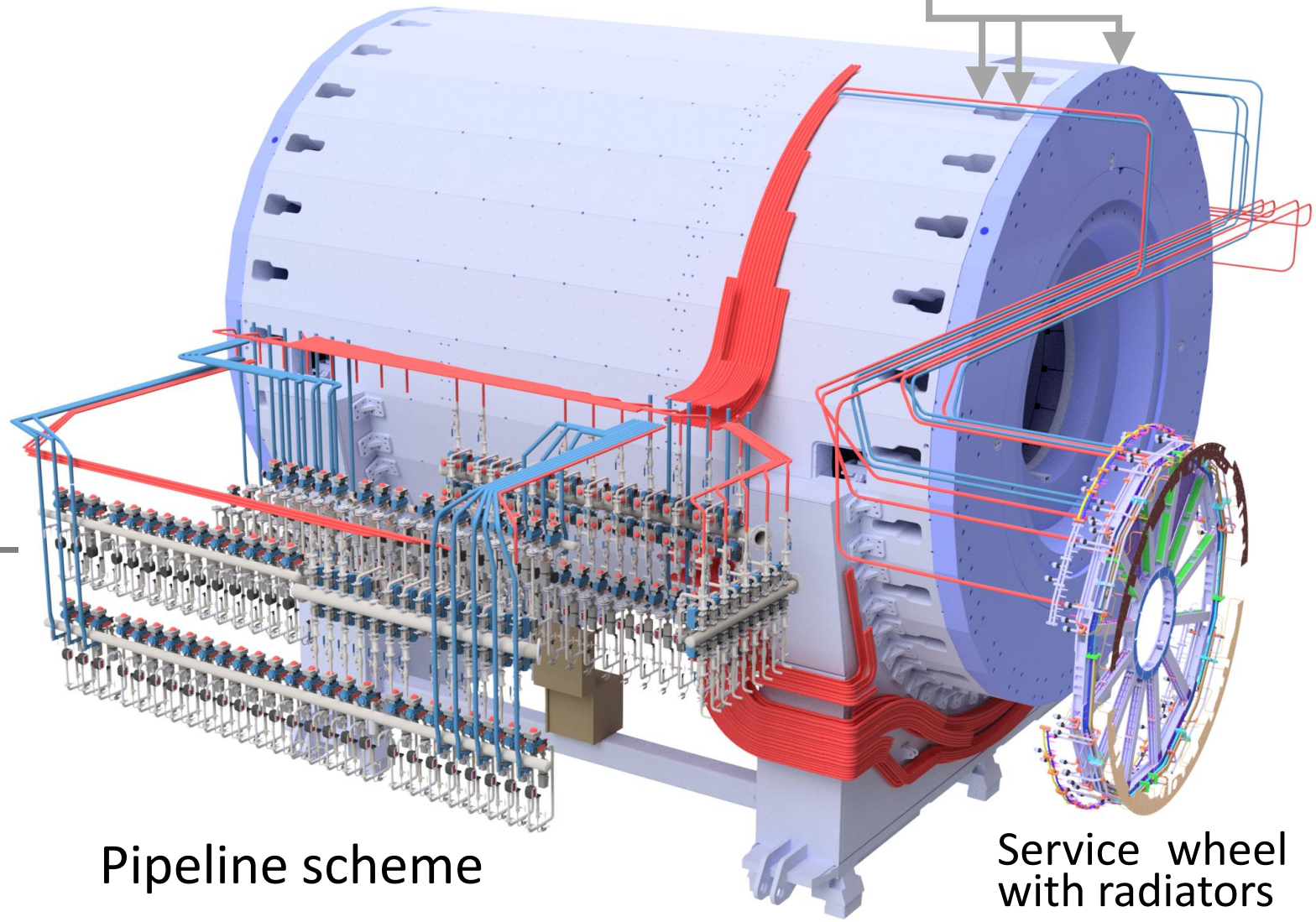
Scheme of experiment

Scheme of experiment

Additional pressure sensors installed in MPD yoke windows for each line



Sensors in pipeline



Pipeline scheme

Service wheel with radiators

Control panel

Vacuum tank pressure

At the top

At the bot-tom

Pressure after control valve

Pressure at inlet and outlet MPD windows

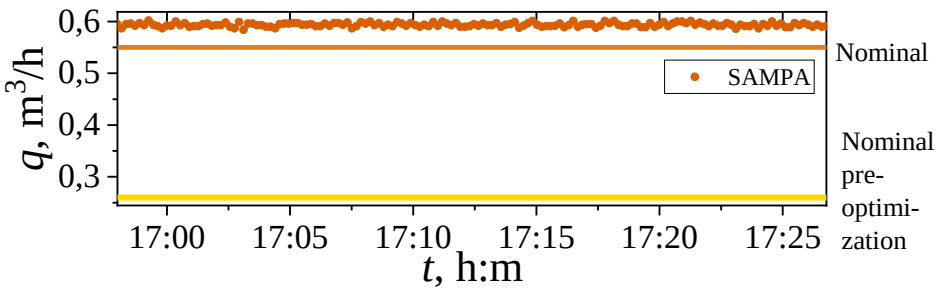
Control valve opening

Vacuum pump frequency

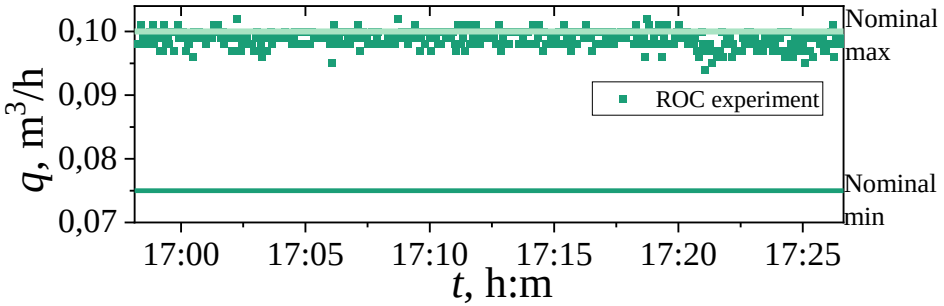
Circulation pump frequency



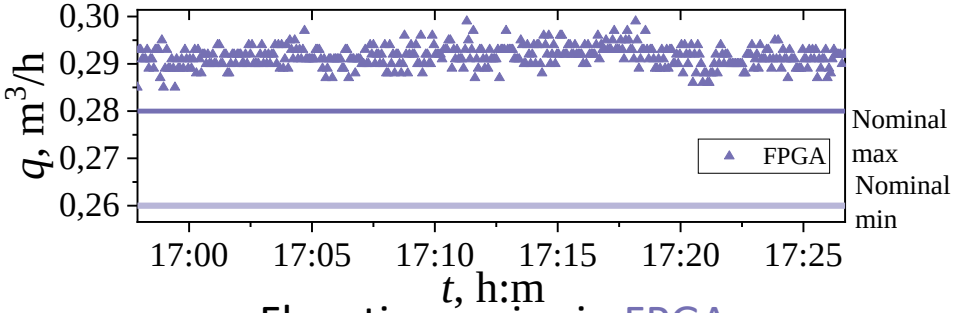
Position 12 (highest)



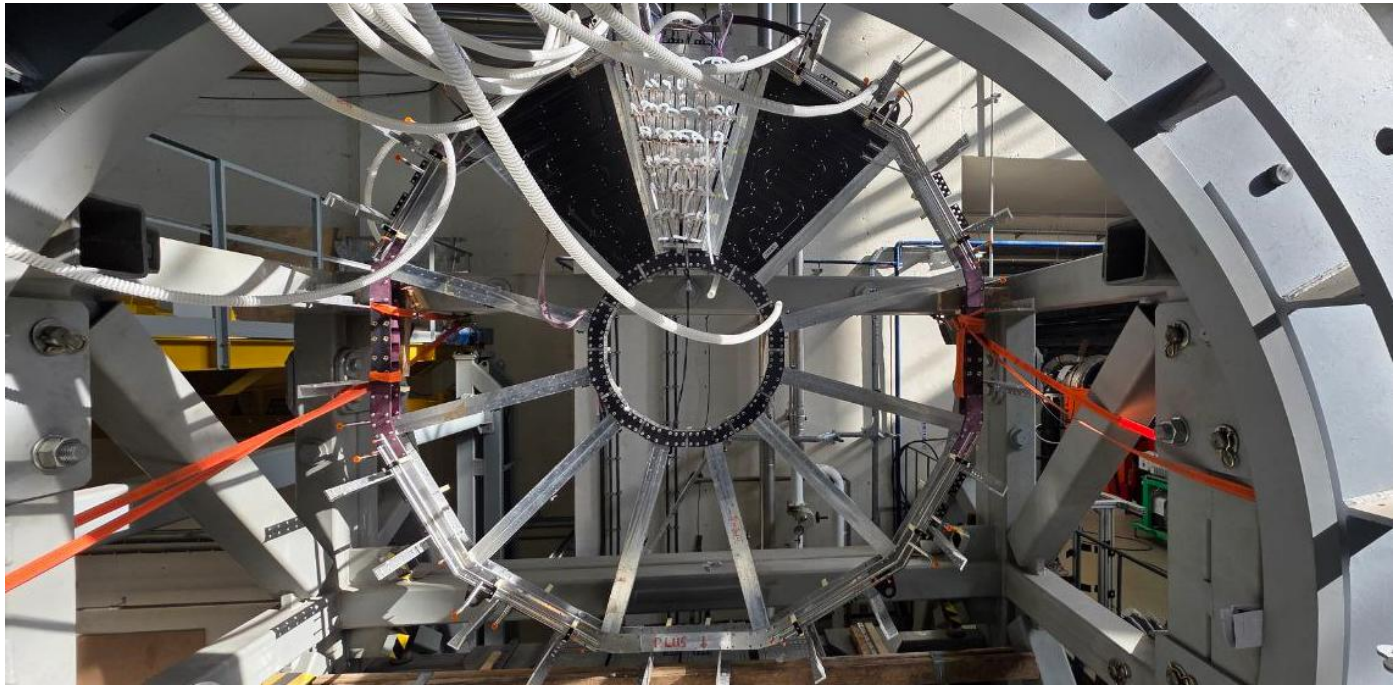
Flow timeseries in SAMPA



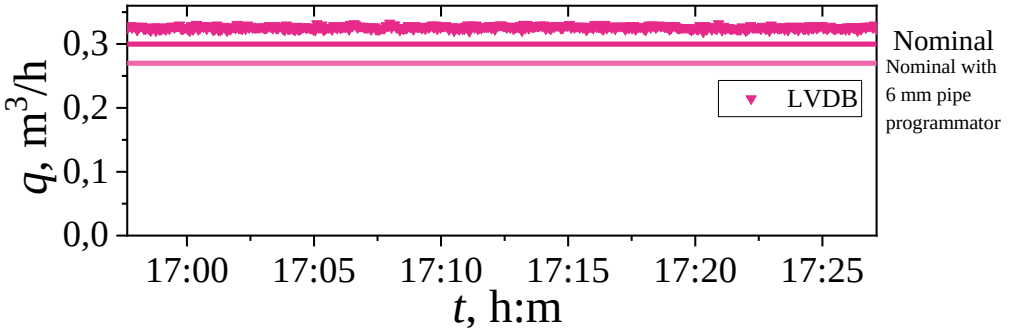
Flow timeseries in ROC case



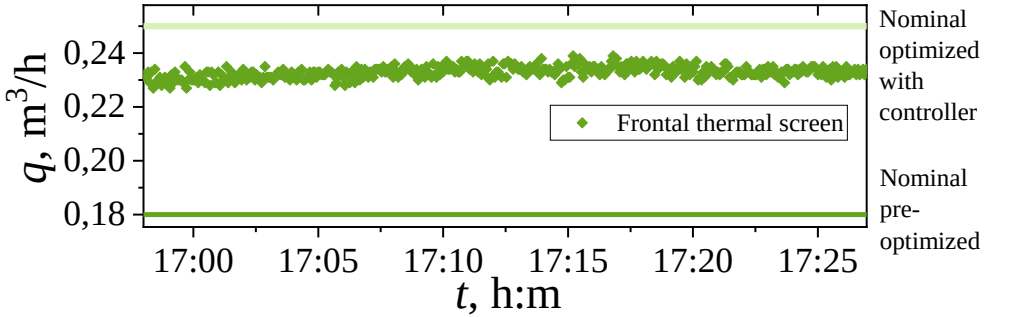
Flow timeseries in FPGA



Flow timeseries in LVDB

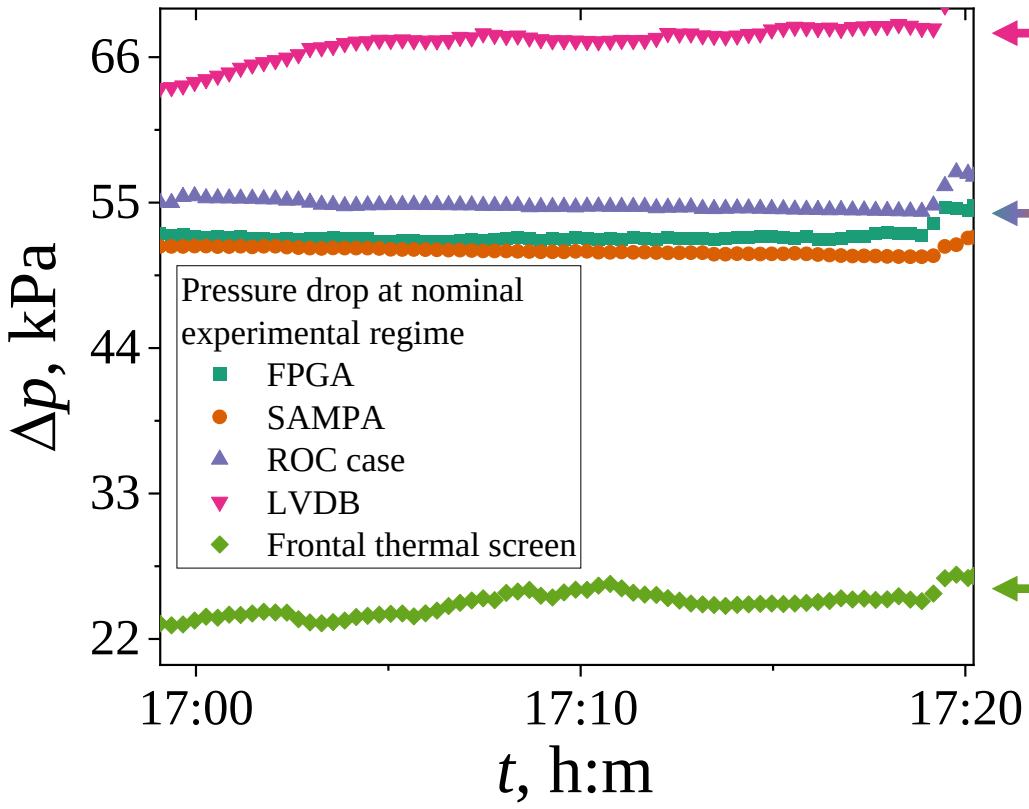


Flow timeseries in Frontal thermal screen



Position 12 (highest)

Pressure drop between inlet and outlet windows of MPD yoke in nominal regime at p_{tank} = 0.35 atm:



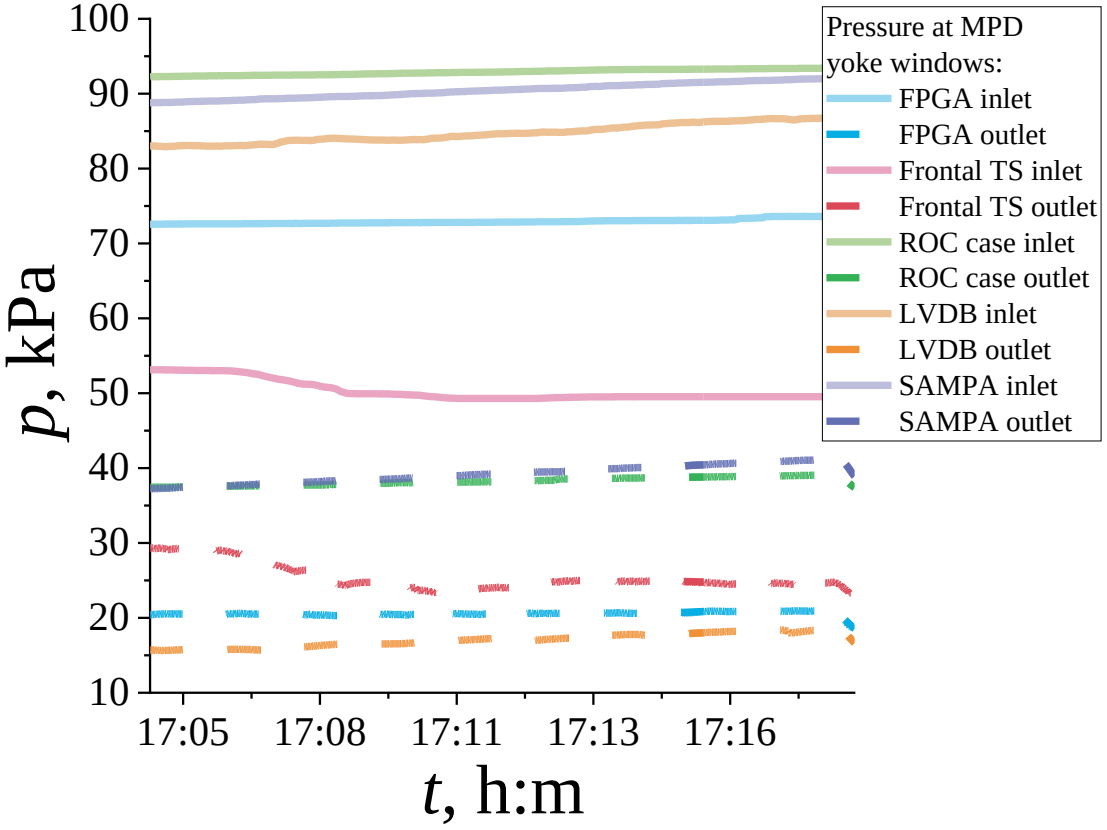
Surprisingly high for LVDB

OK for ROC case, FPGA, SAMPA

Great reserve for frontal thermal screen

Absolute pressure at inlet and outlet windows of MPD yoke in experimental nominal regime:

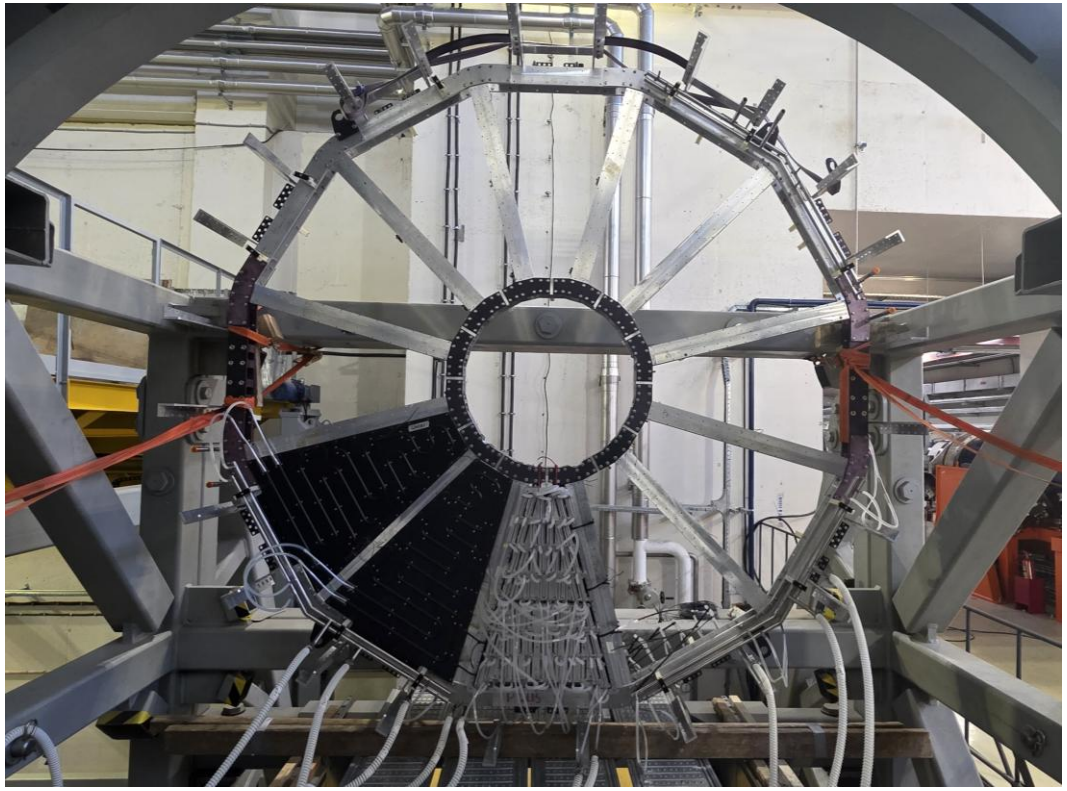
Leakless is OK!

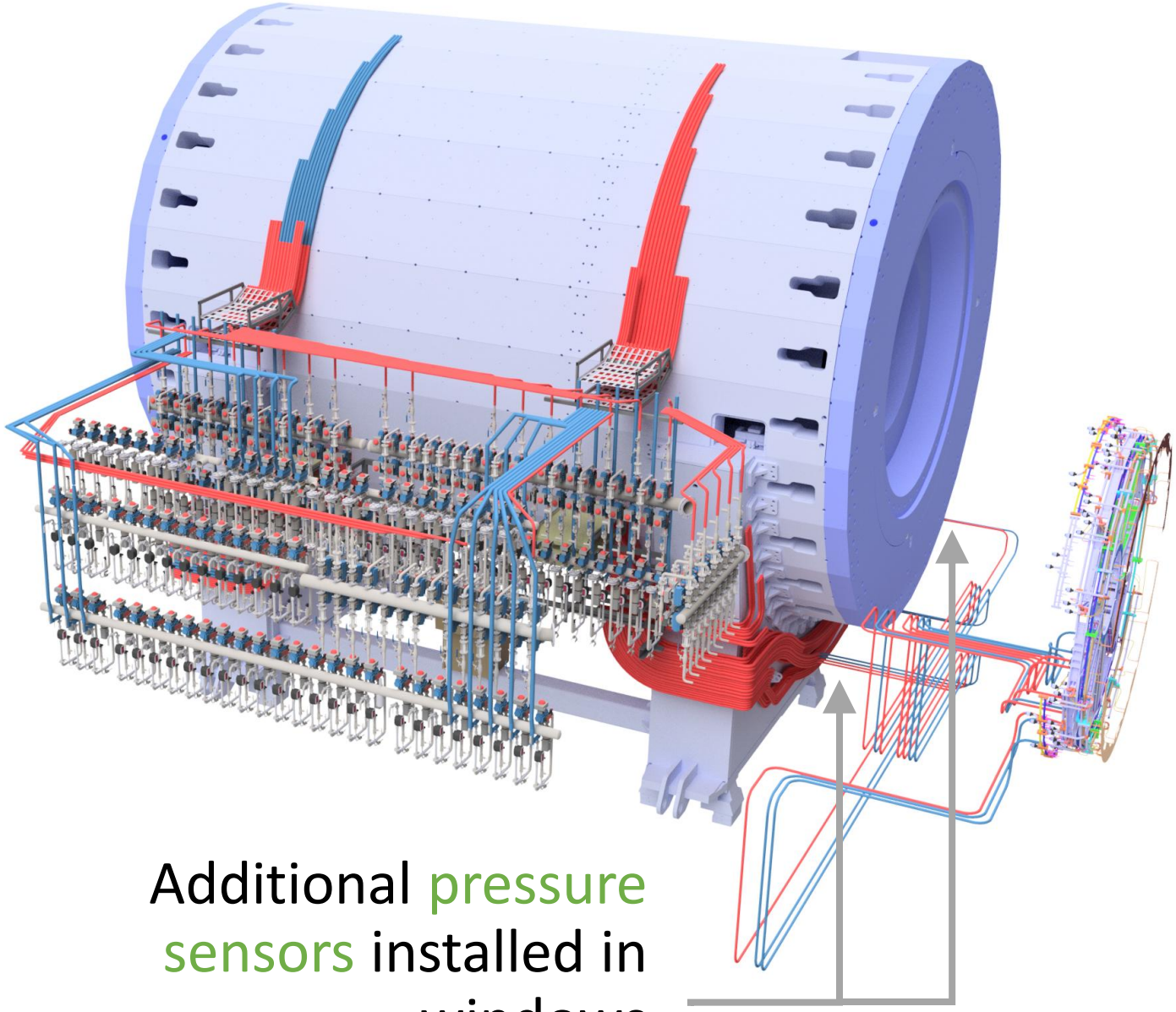


Position 6 (lowest)

Lowest possible position of ROC chamber

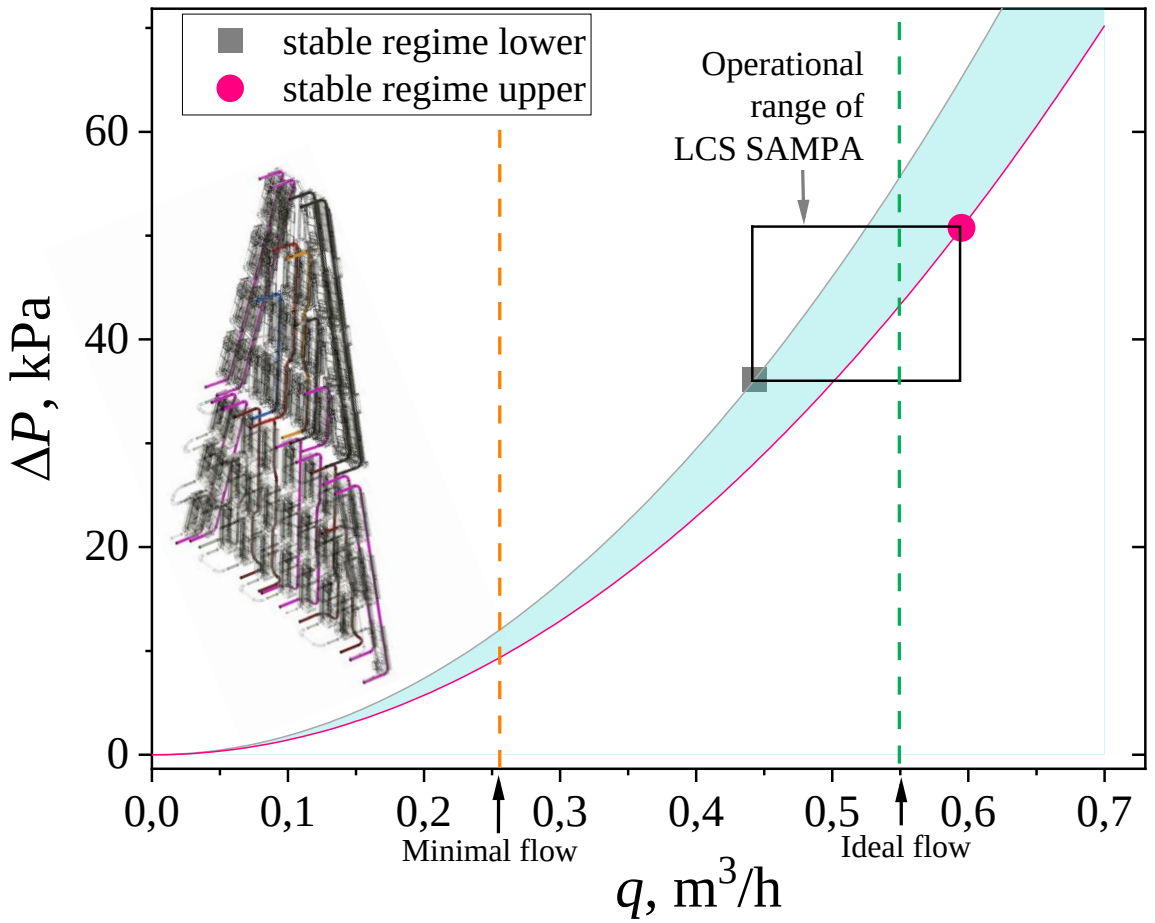
- Lengths of pipes 2-times higher than nominal



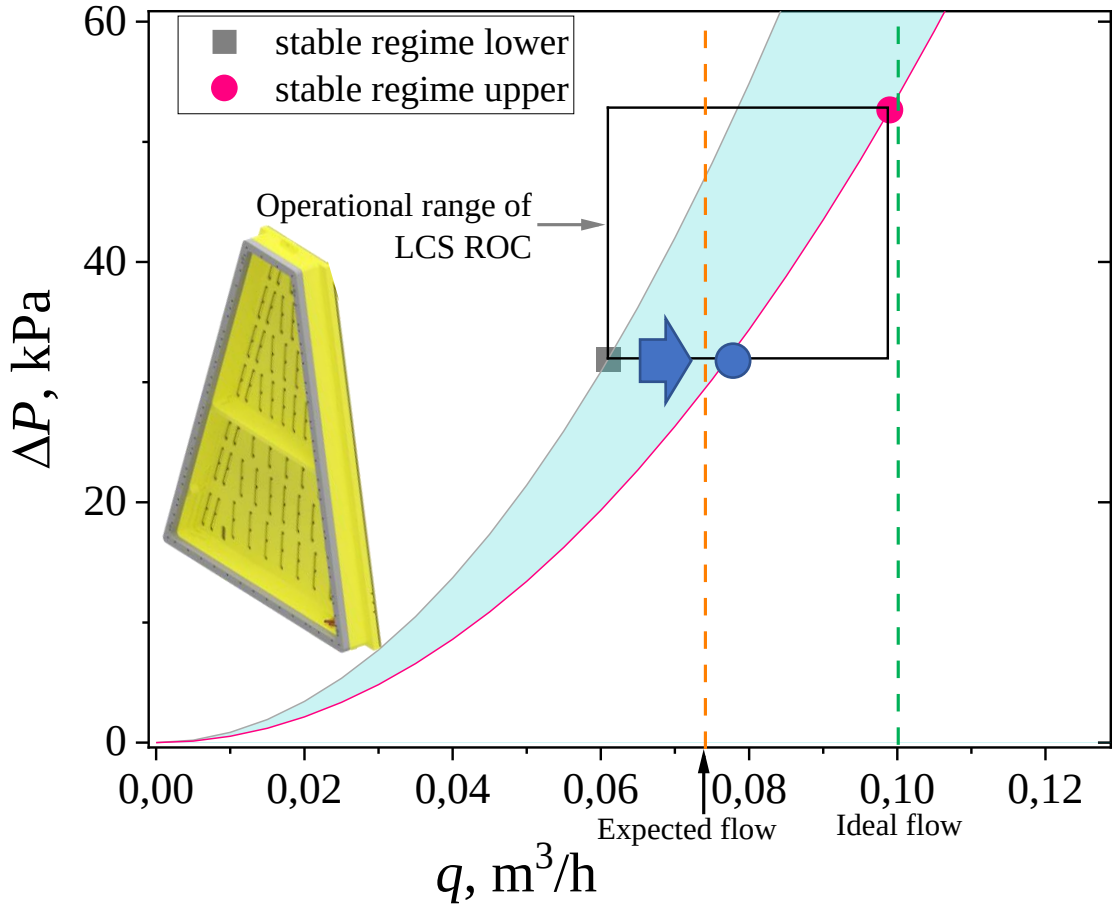


Additional pressure sensors installed in windows

Pressure-flow characteristics

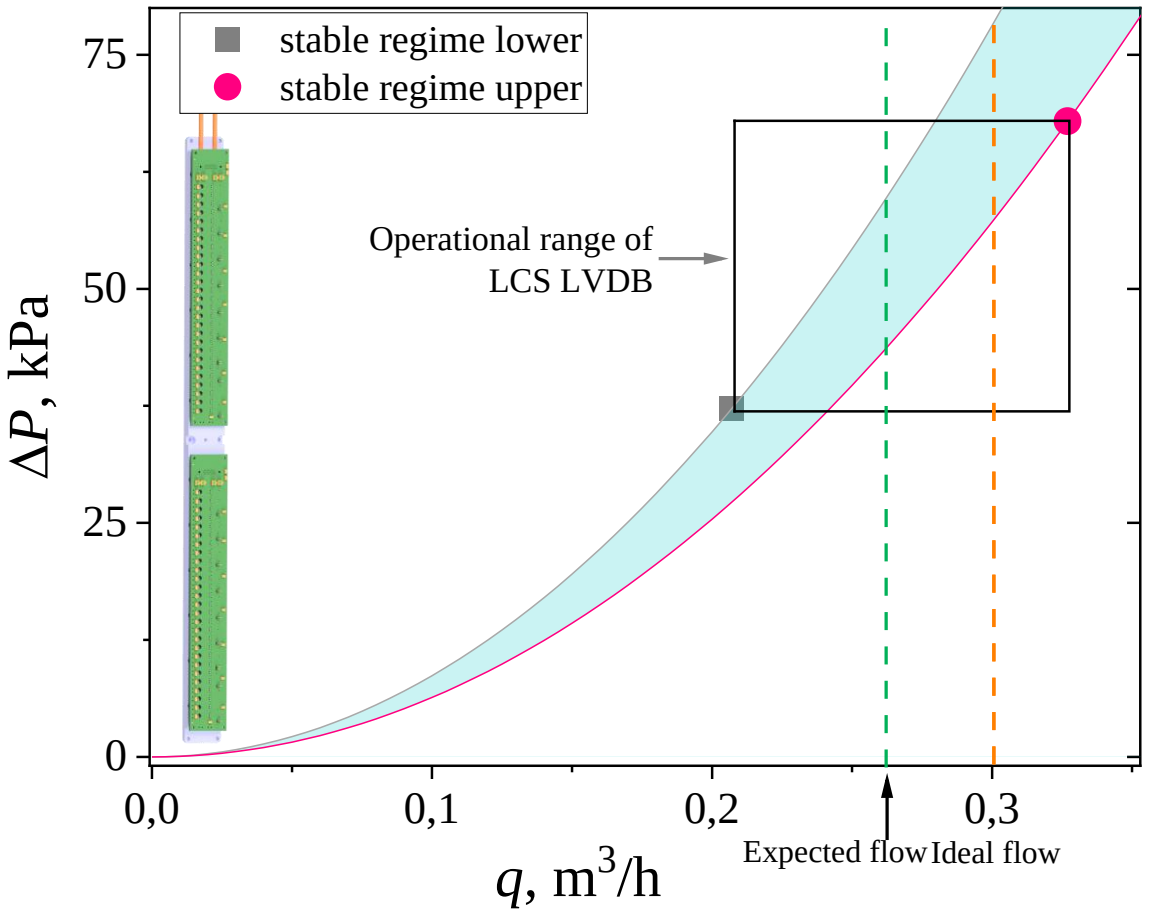


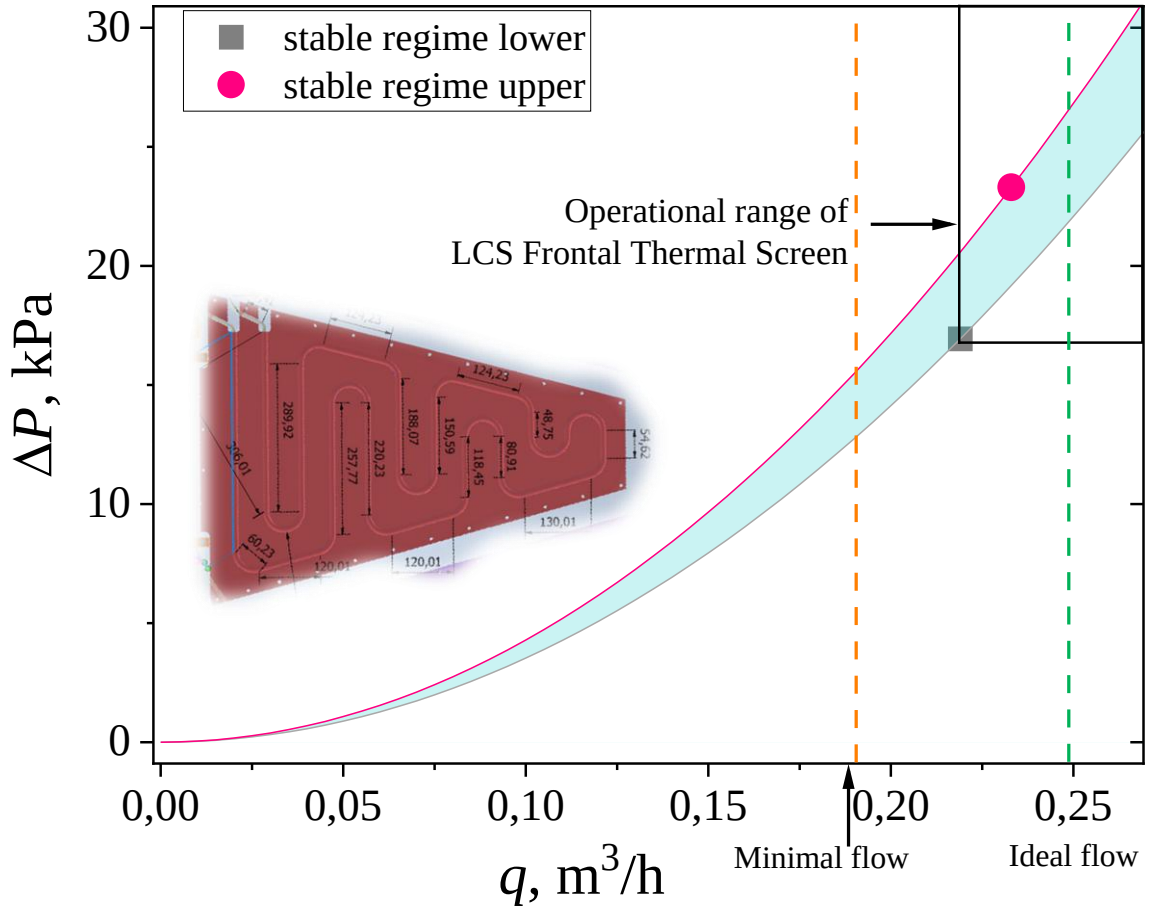
SAMPA is completely OK for all positions



The ROC case is OK for upper positions, but in the lowest contour showed 0.062 m³/h, while 0.072 m³/h was expected due to pressure losses across the doubled pipeline length at this experiment

Pressure-flow characteristics

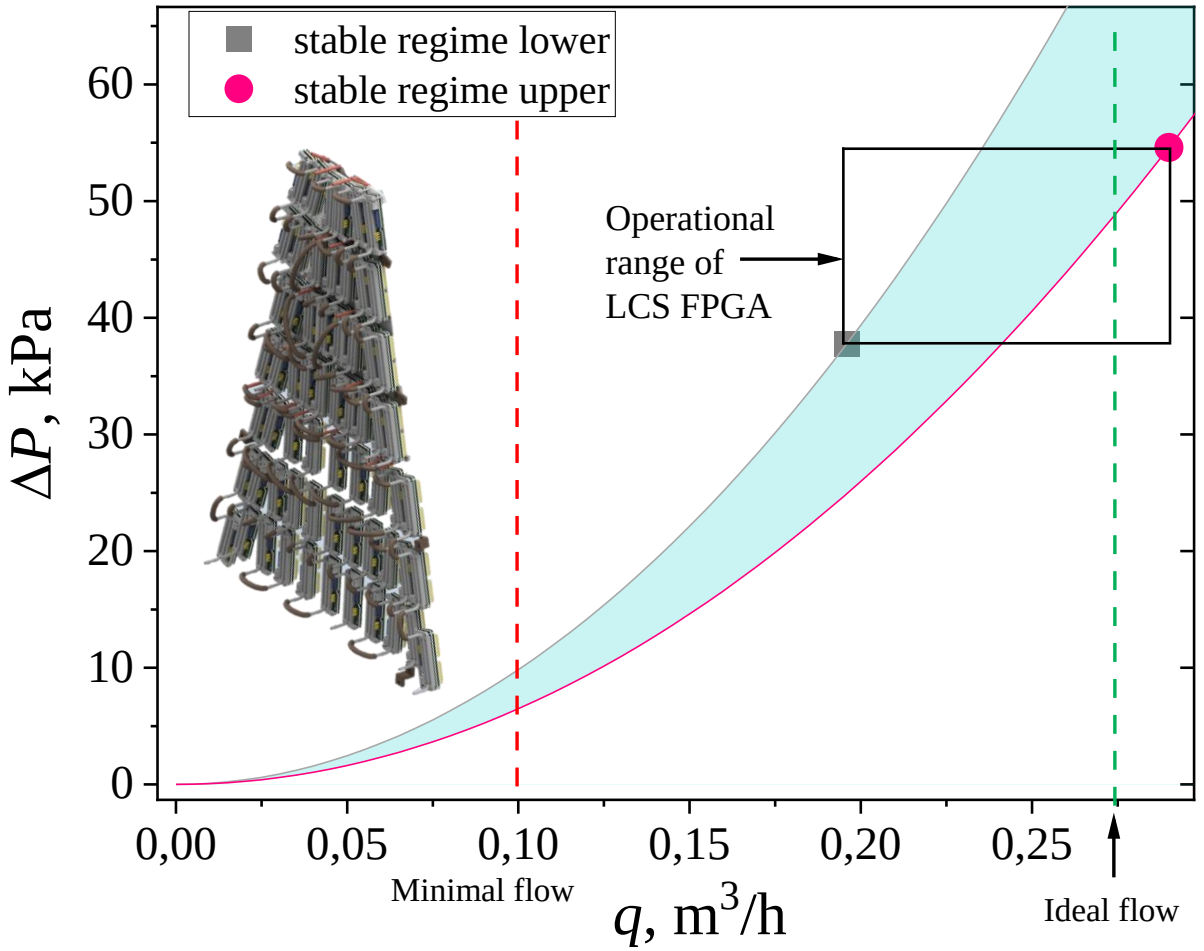




The upper LVDB positions are OK, but the lowest position shows 0.22 m³/h instead of 0.26 m³/h due to pressure losses in the extended (x2) pipeline. A tank pressure adjustment may be required

Frontal thermal screen is great for all positions

Pressure-flow characteristics



FPGA radiators: flow is acceptable (upper position better)

- Upper position (Chamber 12) shows hydraulic performance exceeding expectations, with no signs of cavitation;
- Lower position (Chamber 6) shows flow rates up to 25% lower than the upper position due to the 2× longer pipelines;
- Flow rates are mostly acceptable. Fine-tuning the pressure in the vacuum tank will increase the pressure budget for the lower circuits, while decreasing it for the upper ones.

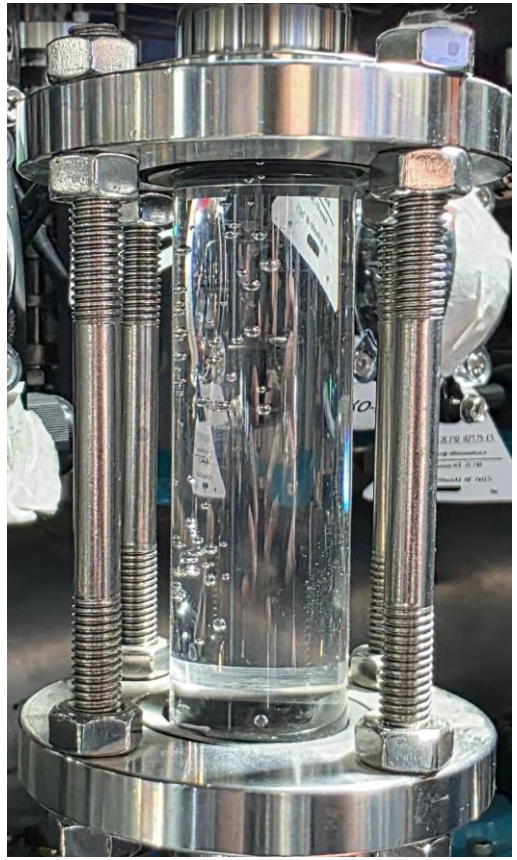
Air in pipelines

Air in pipelines

Air is not tolerated in watching windows



Very bad



Not good



good

- Loss of hermeticity is indicated by bubbles with a diameter of about one-fifth of the sight tube diameter, and/or by bubbles moving with the flow;
- The latter is associated with a rapid increase in hydraulic resistance;
- In such cases, the pipeline must be resealed.

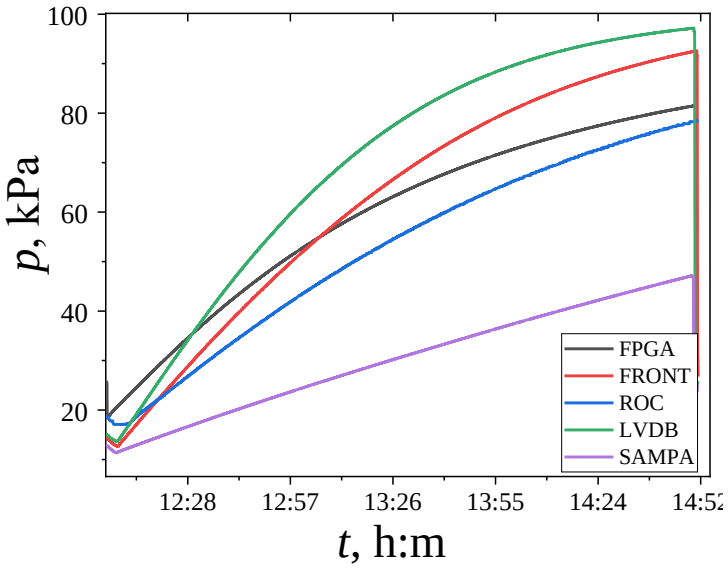
Testing procedure

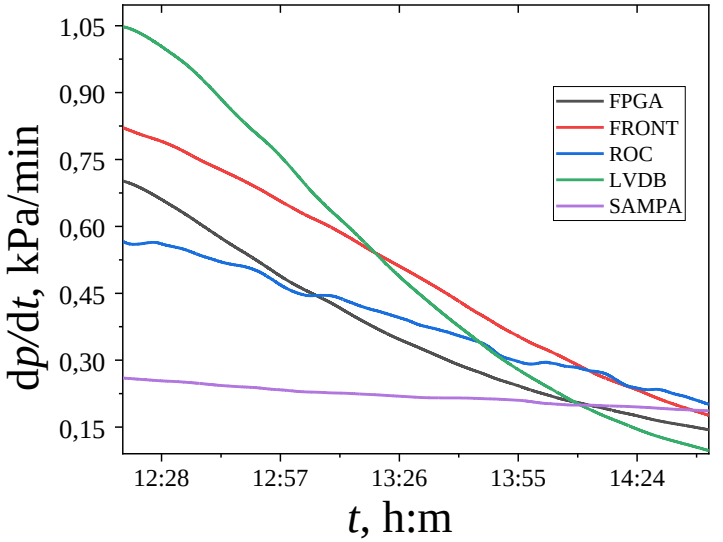
How can we verify that the pipeline is properly sealed?

1) Fill the pipeline with air at a low pressure, p ≈ 0.2 atm;
2) Close the automatic valves at the outlet and at the end of the pipeline;
3) Monitor how quickly the pressure rises over time due to air ingress from the atmosphere or leakage;
4) If the pressure rises too quickly, fill the circuit to an absolute pressure of p ≈ 2.5 atm, apply a soap solution to locate leaks, and reseal the pipeline.

The procedure should be applied separately to the TPC manifolds and the LCS system pipes before and after the connection.

Acceptable rates of pressure change in isolated pipelines





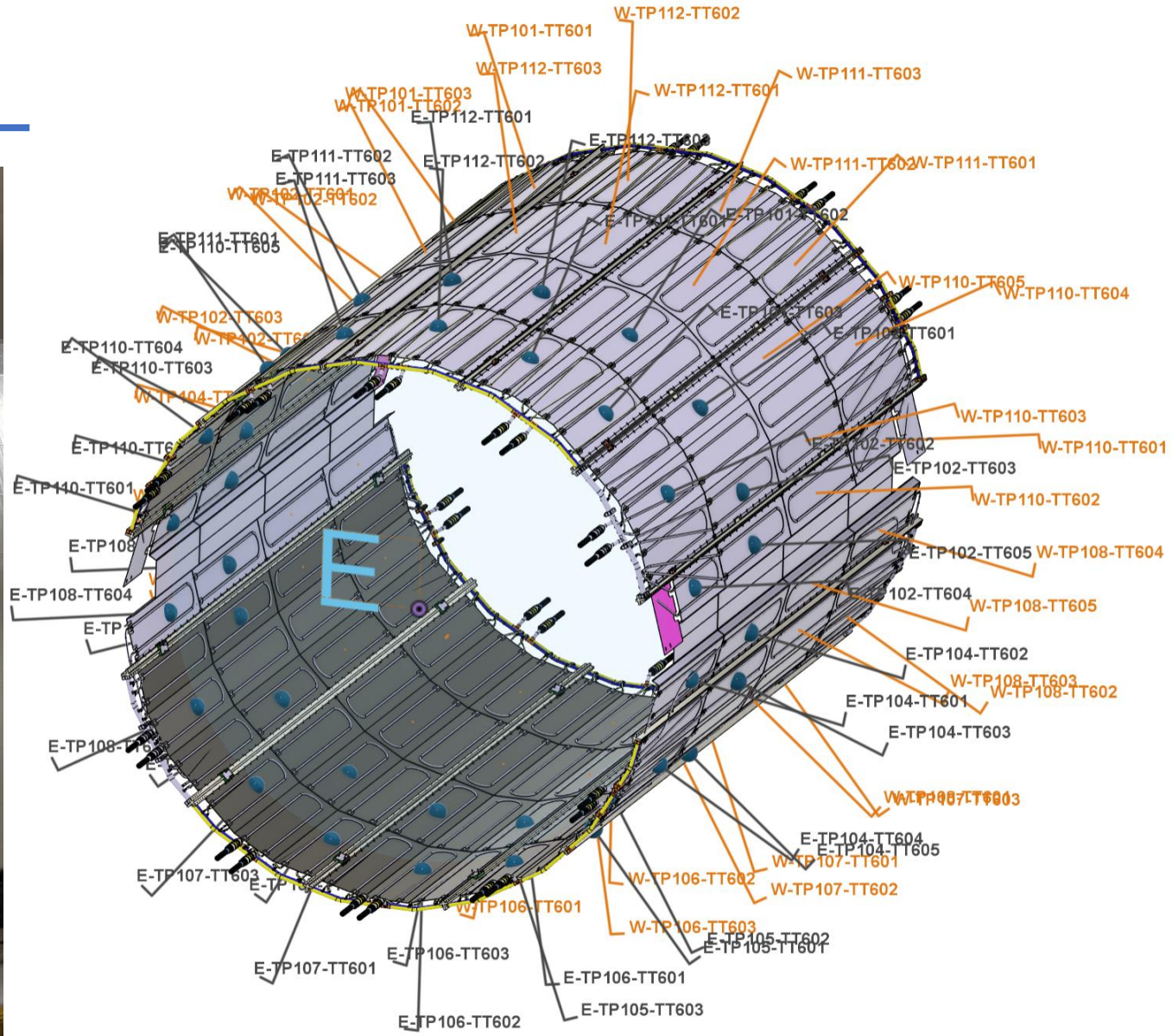
Thermometry progress

Installation of sensors

Installation of the TPC thermometry sensors has started

- 76 calibrated Pt100 AA sensors in aluminum housings are being glued to C4 with epoxy (thermal conductivity: 1.1 W/(m·K));
- A 3D map of the temperature sensors on the C4 shell of the TPC (under the outer thermal screen) has been prepared.





Conclusions

- **Five main TPC cooling circuits** were tested in the highest and lowest possible positions;
- All tested circuits demonstrated **leakless operation**, with **no cavitation** observed;
- In the **upper** position (ROC 12), the radiators performed better that expected, while in the lower position (ROC 6) they still operated within an acceptable range, though additional vacuum tank pressure tuning is foreseen;
- **The air-based sealing** and leak detection procedure was tested and shown to be effective;
- **Installation of the C4 thermometry sensors** has started, and half of them are now in place.

Thank you

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