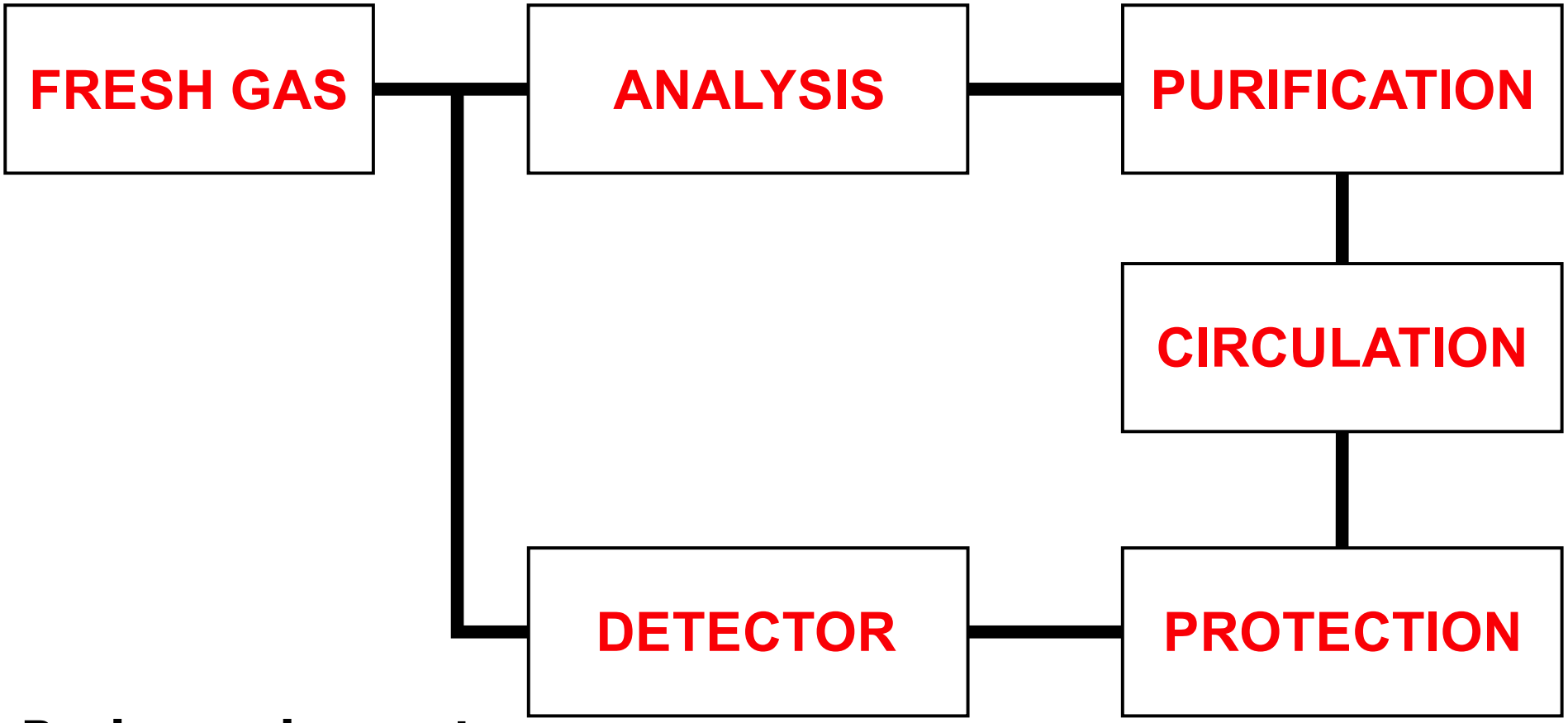
Газовые системы для ядерно-физических детекторов

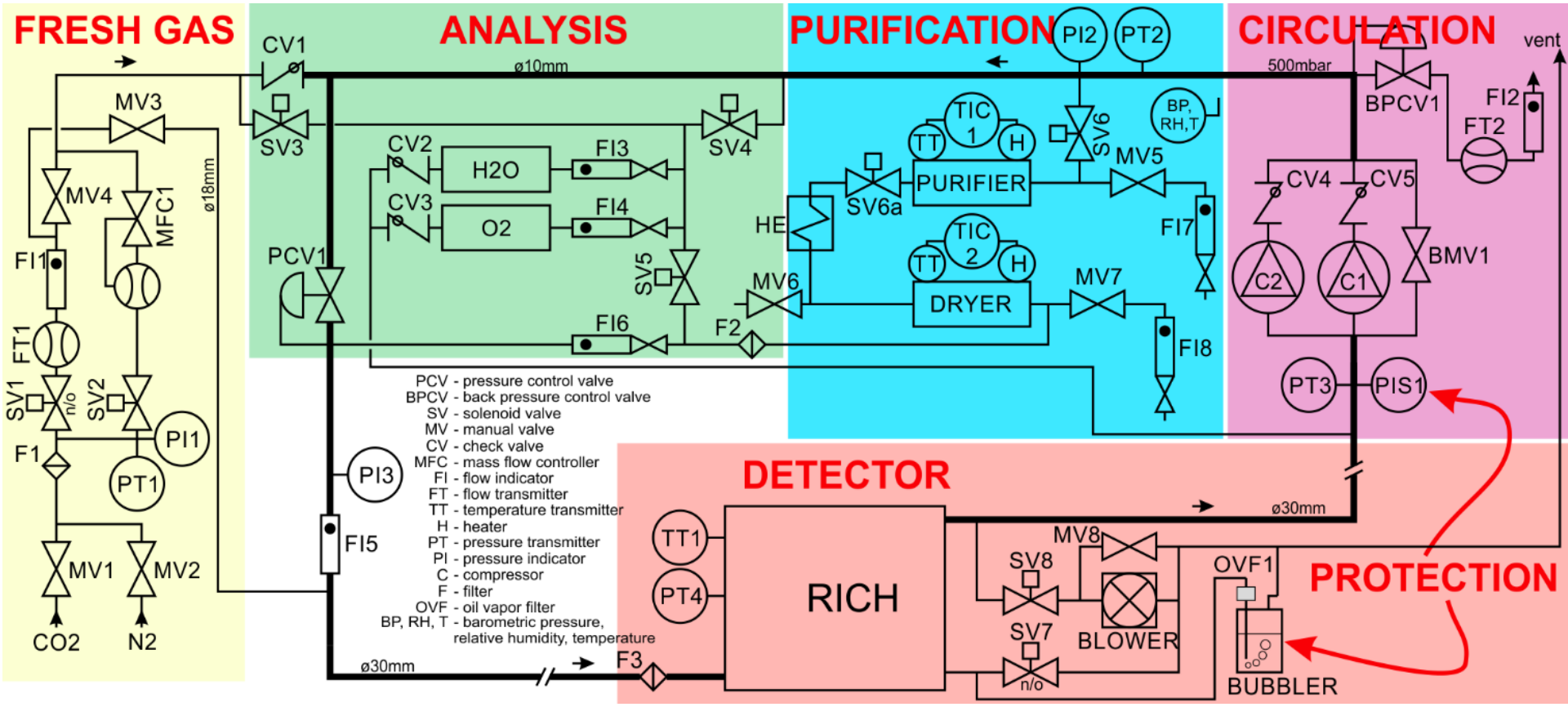
Gas systems principles



Basic requirements:

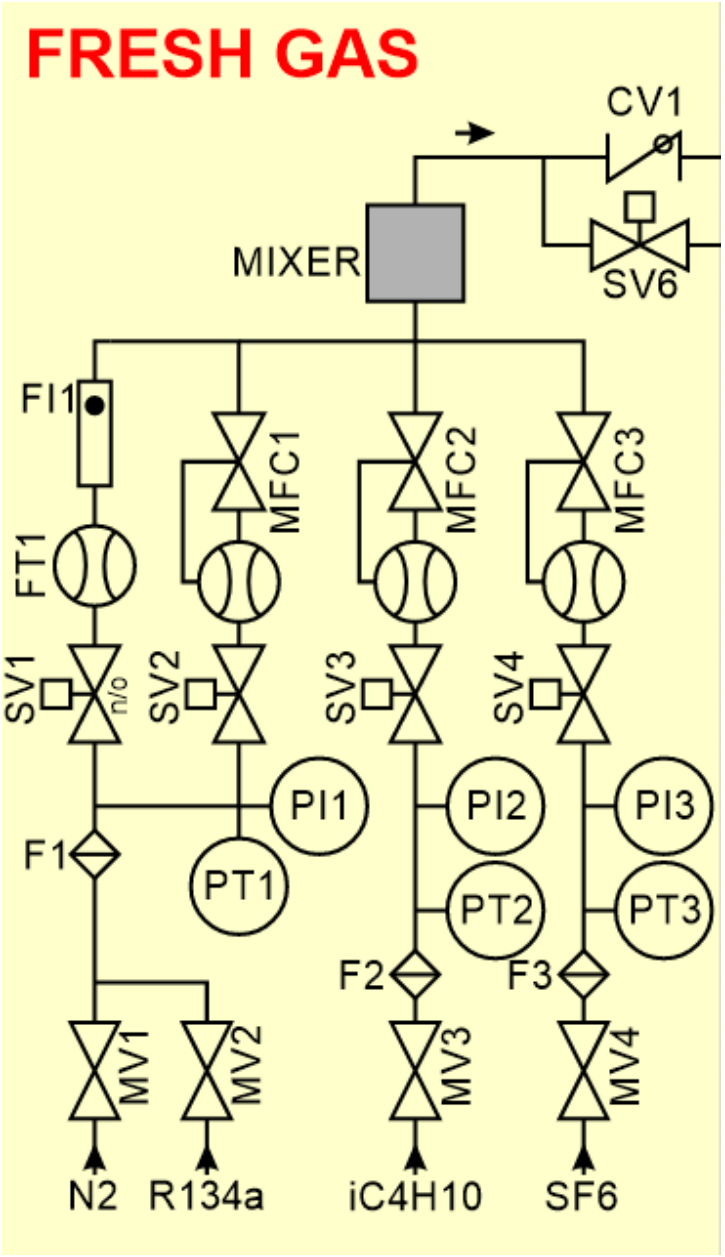
- ❑ Pressure stabilization + detector protection
- ❑ Gas mixture circulation to minimize fresh gas flow
- ❑ Purification of the circulation flow (oxygen and moisture removal)
- ❑ Impurities and content analysis
- ❑ Leak detection

CBM RICH gas system



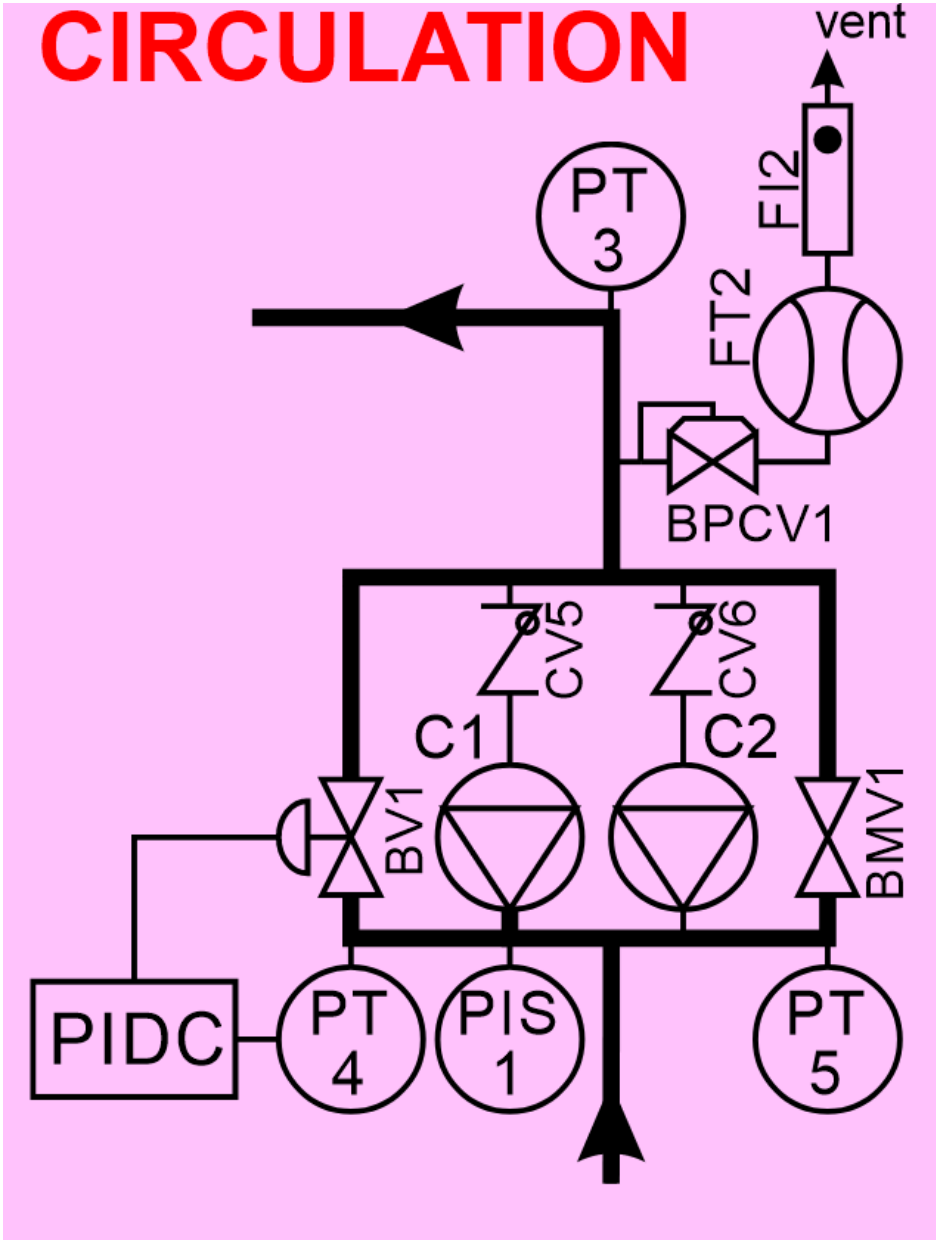
Detector protection : Bubbler, PIS1
Pressure stabilization : MFC1
Recirculation flow rate : 40 slpm
Purification flow : up to 40% (16 slpm)
Purging flow rate : 100 slpm (Blower!)
Gas analysis points : Detector, Fresh, Purified

Fresh gas (CBM MUCH RPC)



- Manual flow indicator (FI1) for nitrogen purging
- MFCx work in normal circulation
- Exhaust flow rate is measured with flow transmitter (FT2)
- Inlet fresh gas flow rate is measured with FT1 + MFCx
- Leak rate = FT1+MFCx-FT2

Gas mixture circulation



Recirculation

- Two compressors (one active, one spare)
- Flowrate and pressure adjusted using bypass manual valve
- Exhaust gas flow adjusted using BPCV1 according to fresh gas flow and leak rate of the detector
- Detector protection (PIS1)

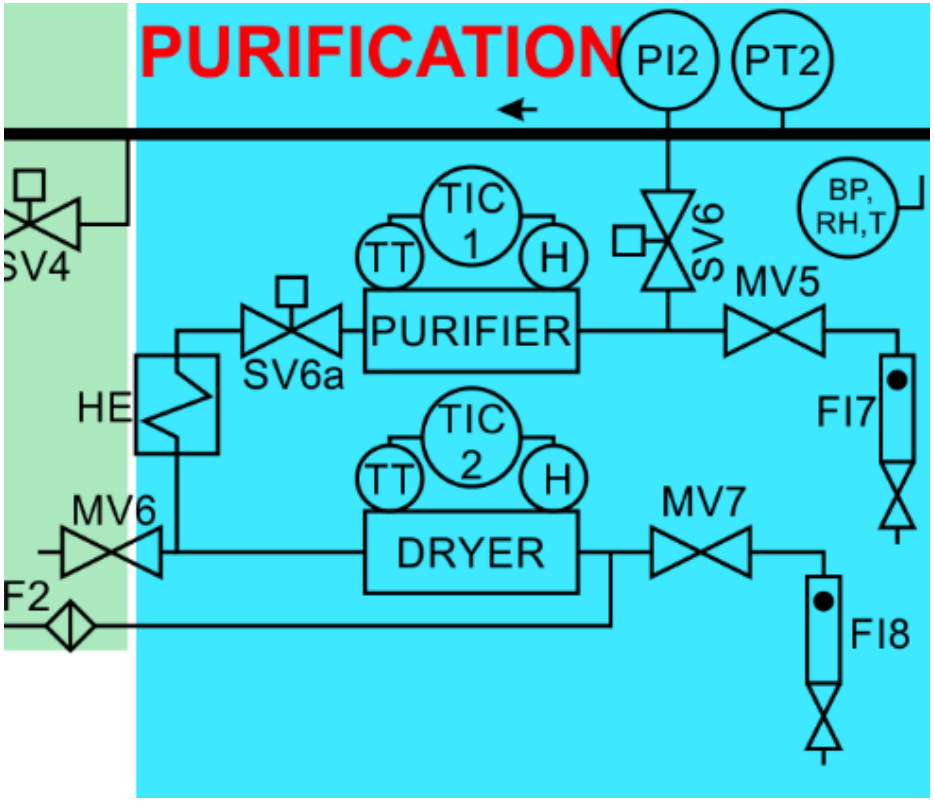
Compressor

- Membrane compressor
- Vortex compressor
- Pneumatic booster
- Cryogenic adsorption compressor

Pressure stabilization

- Fresh gas flow (for simple systems)
- PID controller with pneumatic valve
- Mass flow controller

Purification



Dryer (moisture removal)

NaX Zeolite

- Capacity: ~80g of water (1kg Zeolite)
- Works at room temperature
- Output concentration: <2ppm
- Output concentration (cryo): <1ppb
- Regeneration at 250ºC with pure CO_2

Purifier (oxygen removal)

Active copper

- Capacity: ~100 liters of oxygen
- Works at 200ºC
- Output oxygen concentration: <2ppm
- Regeneration at 200ºC with CO_2+5%H_2

BASF R3-11G

- Capacity: ~100 liters of oxygen
- Works at room temperature and at 200ºC
- Output oxygen concentration: <2ppm
- Regeneration at 200ºC with CO_2+5%H_2

Catalyzer Ni+Cr

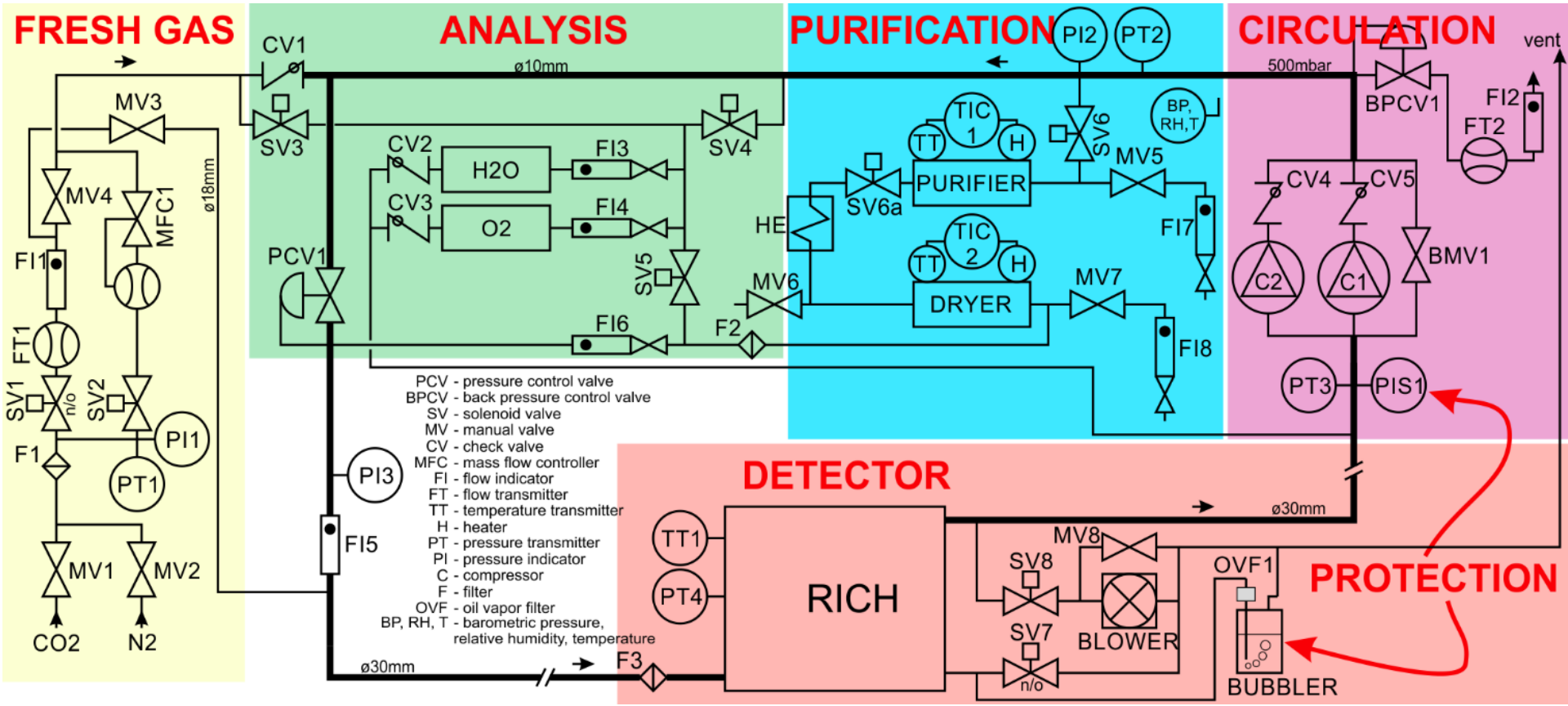
- Produces alcohol from O_2 + CH_4

HF Purifier

Active carbon (200g) + soda lime (500g)

- Works at room temperature
- Regeneration at 150ºC with dry N_2

Gas analysis



Gas analysis

- ❑ Moisture analyzer
- ❑ Oxygen analyzer
- ❑ Mixture analyzers
- ❑ Chromatography (down to 1ppb!)

Analyzers connections

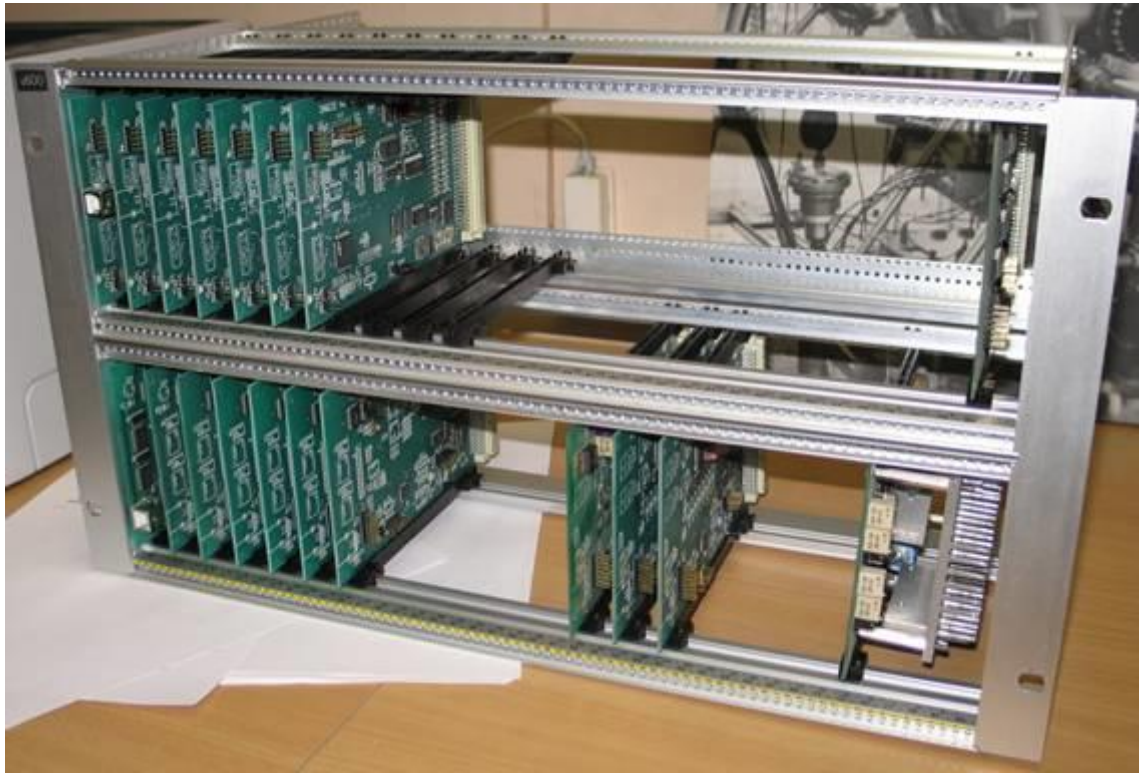
1. Gas flow from the detector
2. Fresh gas
3. Purification unit output

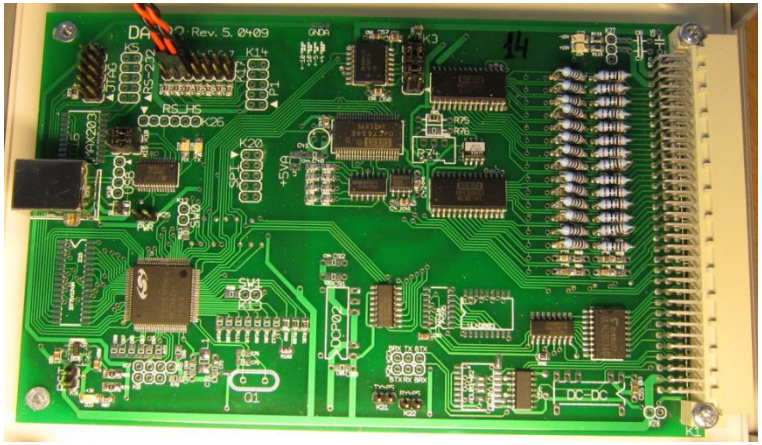
PNPI - NRC KI

PNPI gas systems experience

N	Detector	Volume, standard m3	Pressure, mbar	Mixture	Recirculation flowrate, slpm	Fresh flowrate, slpm	Maximum oxygen content, ppm	Maximum water content, ppm	Year	Control
1	STAR TPC	50	2.00 ± 0.03	Ar + 10% CH4	600	1.5 ÷ 33	25	20	1998	NI SCXI
2	PHENIX TEC/TRD	11.8	0.40 ± 0.01	Ar + 10% CH4	100	1 ÷ 20	10	5	2001	KEITHLEY
3	PHENIX DC/PC	6.6	0.40 ± 0.01	Ar + 50% C2H6	100	1 ÷ 20	20	15	2001	KEITHLEY
4	ATLAS CSC [BNL]	1	0.01 ÷ 0.50	Ar + 30% CO2 + 10% CF4	1 ÷ 15	0.05 ÷ 1	20	15	2001	PNPI
5	PHENIX MuID	50	2.20 ± 0.03	CO2 + 9% iC4H10 CO2 + 25% iC4H10	30	1 ÷ 20	100	10	2002	NI SCXI
6	PHENIX MuTR	3	2.0 ± 0.1	Ar + 30% CO2 + 20% CF4	5 ÷ 15	0 ÷ 0.2	300	10	2005	NI SCXI
7	PHENIX TOF	2	2.5 ± 0.1	R134a + 5% iC4H10	10 ÷ 15	0.2 ÷ 0.4	100	50	2006	NI SCXI
8	PHENIX HBD	0.6	1.0 ± 0.1	CF4	4 ÷ 10	0.1 ÷ 2	2	1	2008	NI SCXI
9	PHENIX RPC	0.6	2.50 ± 0.1	R134a + 4.5% iC4H10 + 0.5% SF6	2.5 ÷ 4.5	0.5 ÷ 2.5	500	40% R.H.	2008	PNPI
10	STAR TOF	3.9	2.50 ± 0.1	R134a + 5% iC4H10 + 5% SF6	5 ÷ 10	0.1 ÷ 0.5	100	20	2009	PNPI
11	MuCAP TPC	0.5	10000 ± 2.5	H2	1 ÷ 5	0	0.005	0.02	2003	PNPI
12	MuSUN TPC	1	5000 ± 2.5	D2	1 ÷ 5	0	0.001	0.001	2008	PNPI
13	ATLAS sTGC	0.2	0.01 ÷ 0.50	CO2 + 45% nPenthane	-	0.34	-	-	2016	PNPI
14	CBM RICH prototype	2	2.00 ± 0.1	CO2	1 ÷ 13	0 ÷ 10	100	100	2010	PNPI
15	CBM RICH	60	2.0 ± 0.1	CO2	40	0 ÷ 20	9000	2000	in progress	PNPI
16	CBM MUCH GEM	0.2	1.0 ± 0.1	Ar + 30% CO2	2	0.1 ÷ 2	10	10	in progress	PNPI
17	CBM MUCH RPC	0.09	(5.0-10.0) ± 0.1	R134a + (3-7)% iC4H10 + (0.2-5)% SF6	0.05 ÷ 1	0.1 ÷ 1	10	10, 40-60%RH	in progress	PNPI
18	NICA MPD TPC	18.5	2.0 ± 0.1	Ar + 10% CH4	200	0 ÷ 50	20	10	2017	PNPI
19	R3B PAS	0.2	2000 ± 20	Ar + 30% C2H6	-	0 ÷ 4	5	5	2021	PNPI
20	Pres TPC+FT	20	20000 ± 5	H2, Ar + 2% CH4	2 x 15	-	10	10	2021	PNPI
21	FISCO	0.01	700 mbara	Ar + 10% CH4	-	0.01	10	10	2023	PNPI

Control system



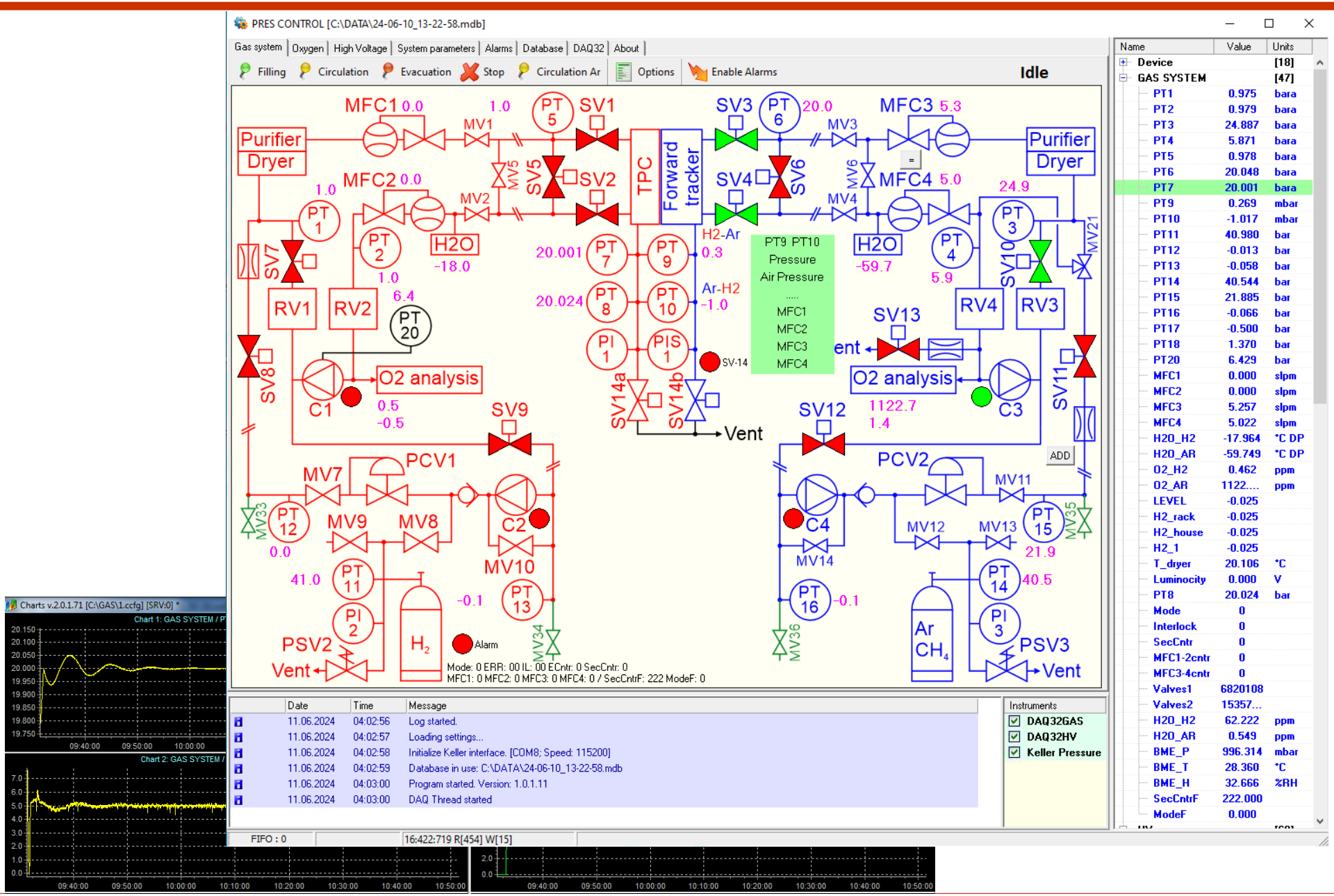


- compact (high channel density)
- integrated controller with interlock
- widely used in our systems over 15 years at

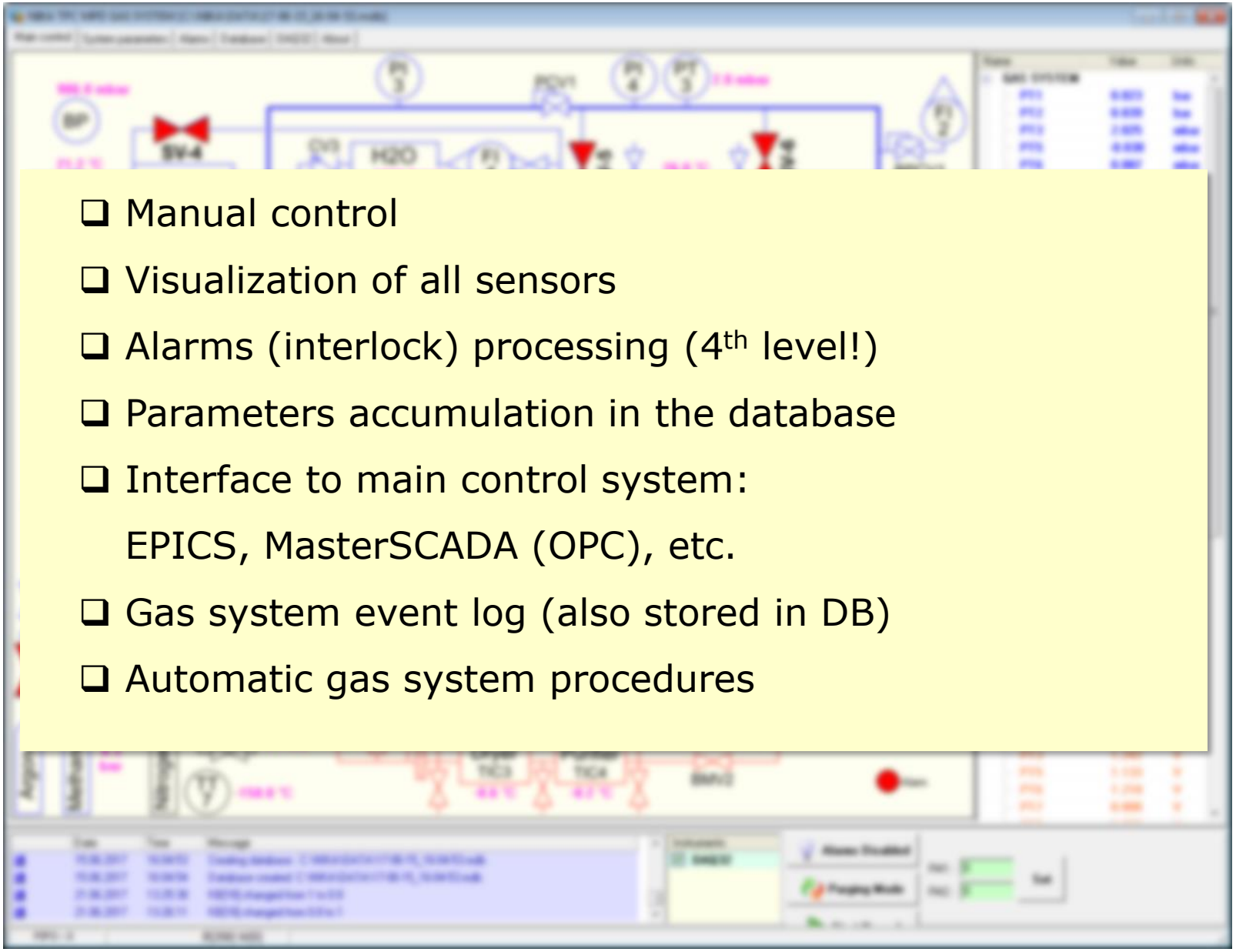
BNL, FZ Juelich, PSI, Dubna and AIRBUS test rig

P.Kravtsov, V.Trofimov. Preprint PNPI-2723, Gatchina (2007)
P. Kravtsov et al., CBM Progress report (2010), p. 32

Control software

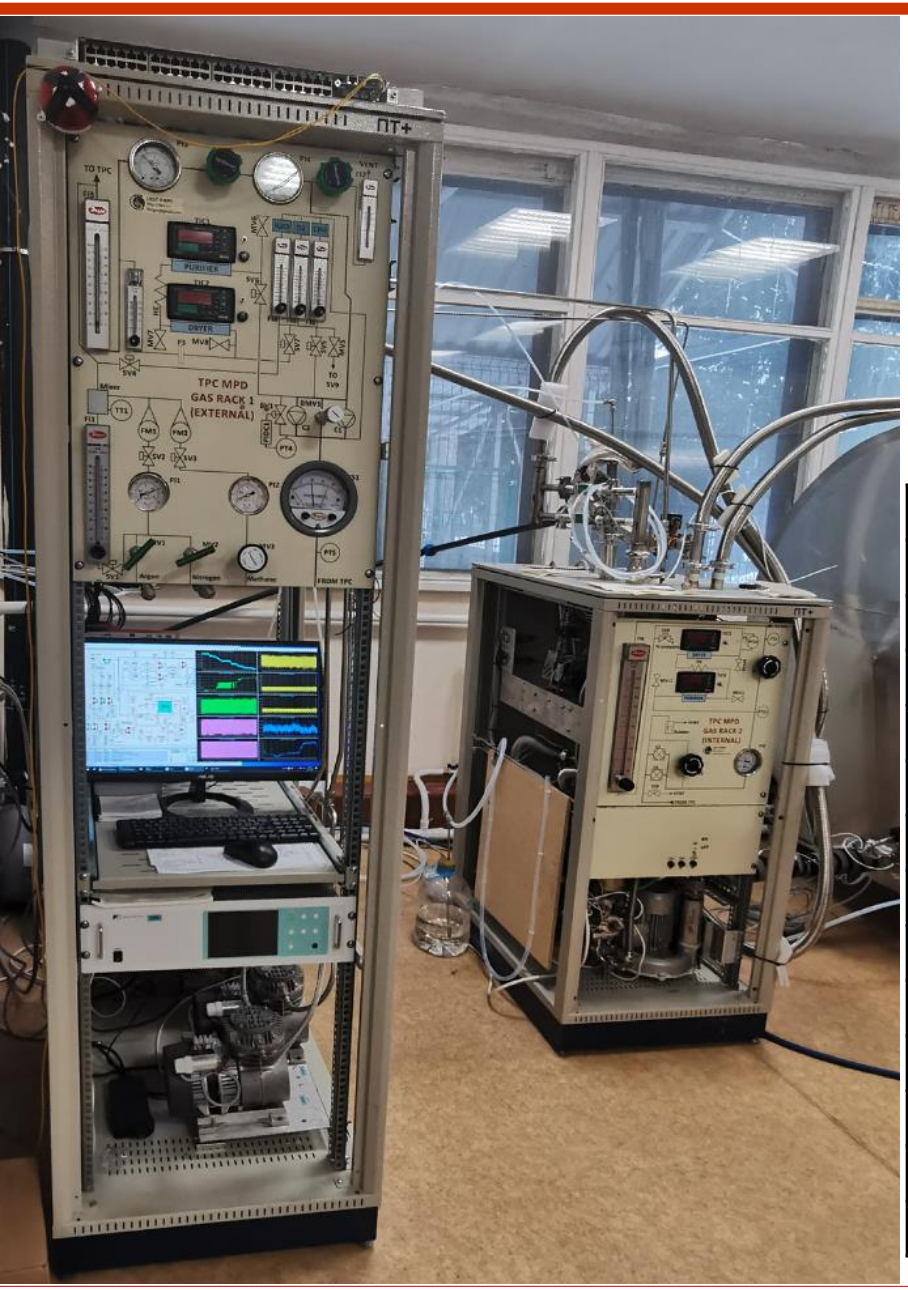


Control software



- Manual control
- Visualization of all sensors
- Alarms (interlock) processing (4th level!)
- Parameters accumulation in the database
- Interface to main control system:

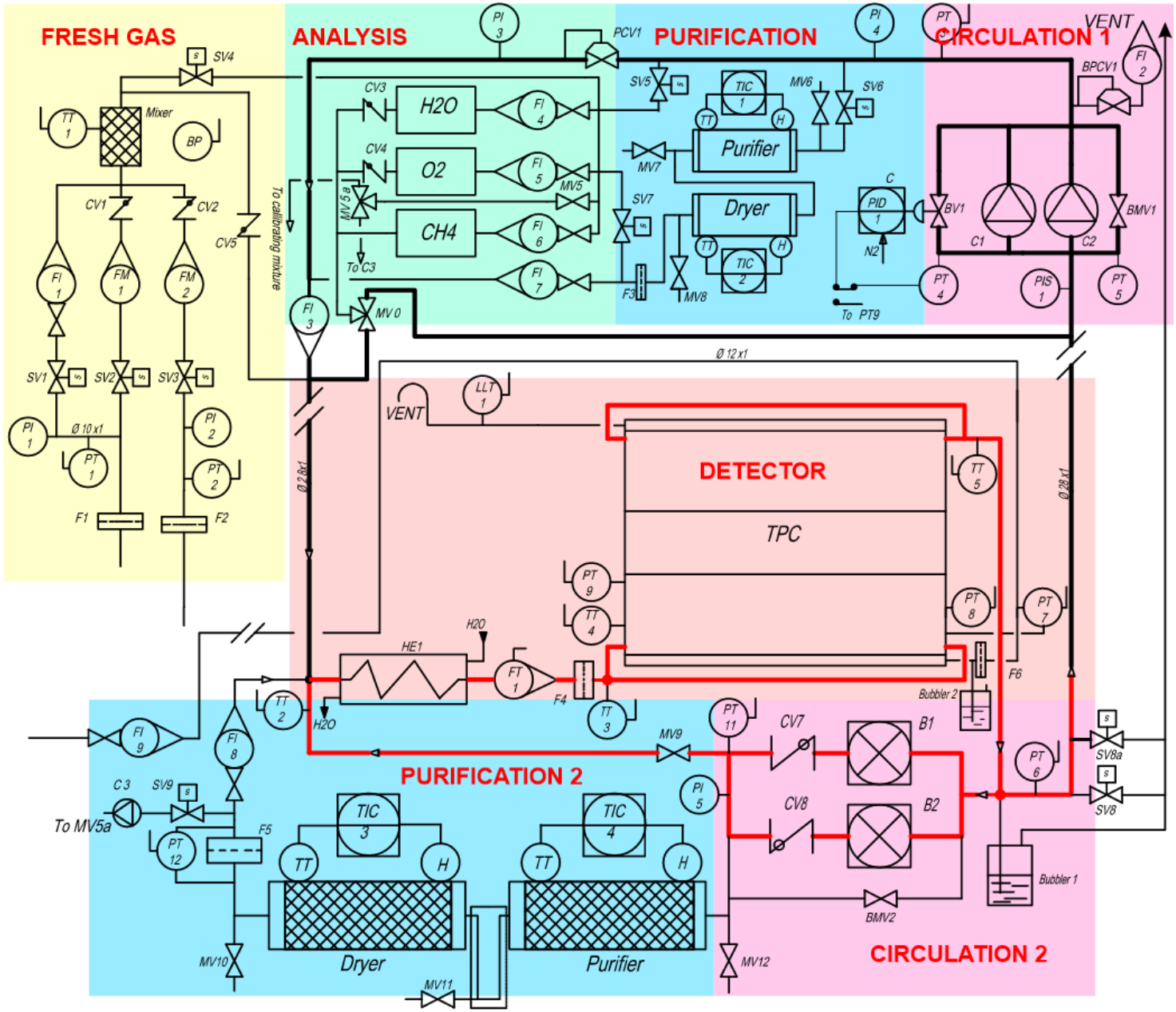
  EPICS, MasterSCADA (OPC), etc.
- Gas system event log (also stored in DB)
- Automatic gas system procedures



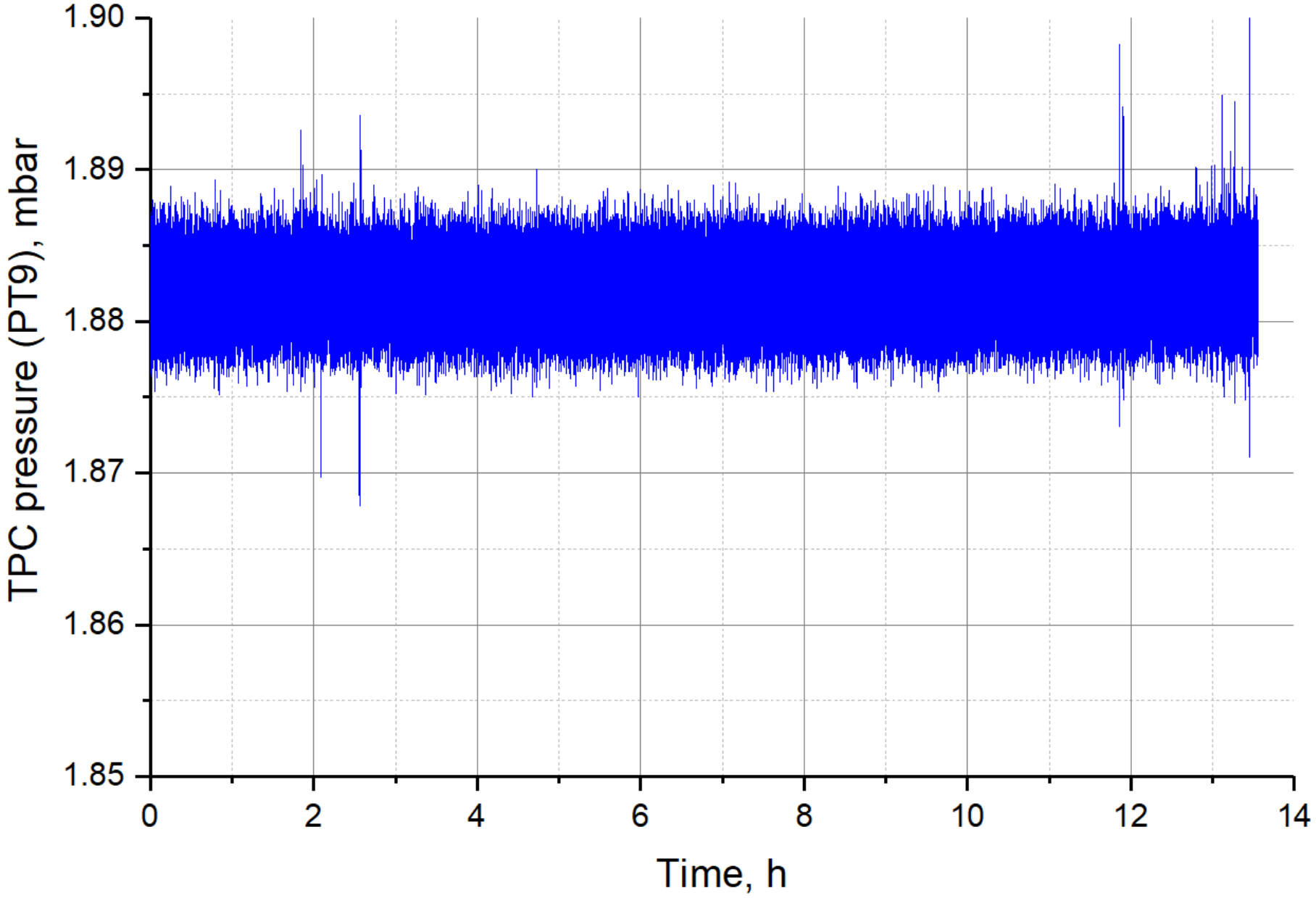
NICA MPD TPC gas system

Parameter	Value
TPC volume	18 500 liters
Mixture (P10)	Ar+(10±0.1%) CH4
Compressors pressure (inner loop)	40-80 mbar
Compressors pressure (outer loop)	100 - 150 mbar
Detector supply pressure	2.1 - 2.2 mbar
Return pressure	0.5 - 1.5 mbar
Internal TPC pressure	2±0.01 mbar
Recirculation flow: inner loop	13 000 l/h
Recirculation flow: outer loop	700 l/h
Purge flow with P10	3 300 l/h
Fresh gas flow	200 - 3 000 l/h
Oxygen content	<20 ppm
Water vapor content	<15 ppm

NICA MPD TPC gas system



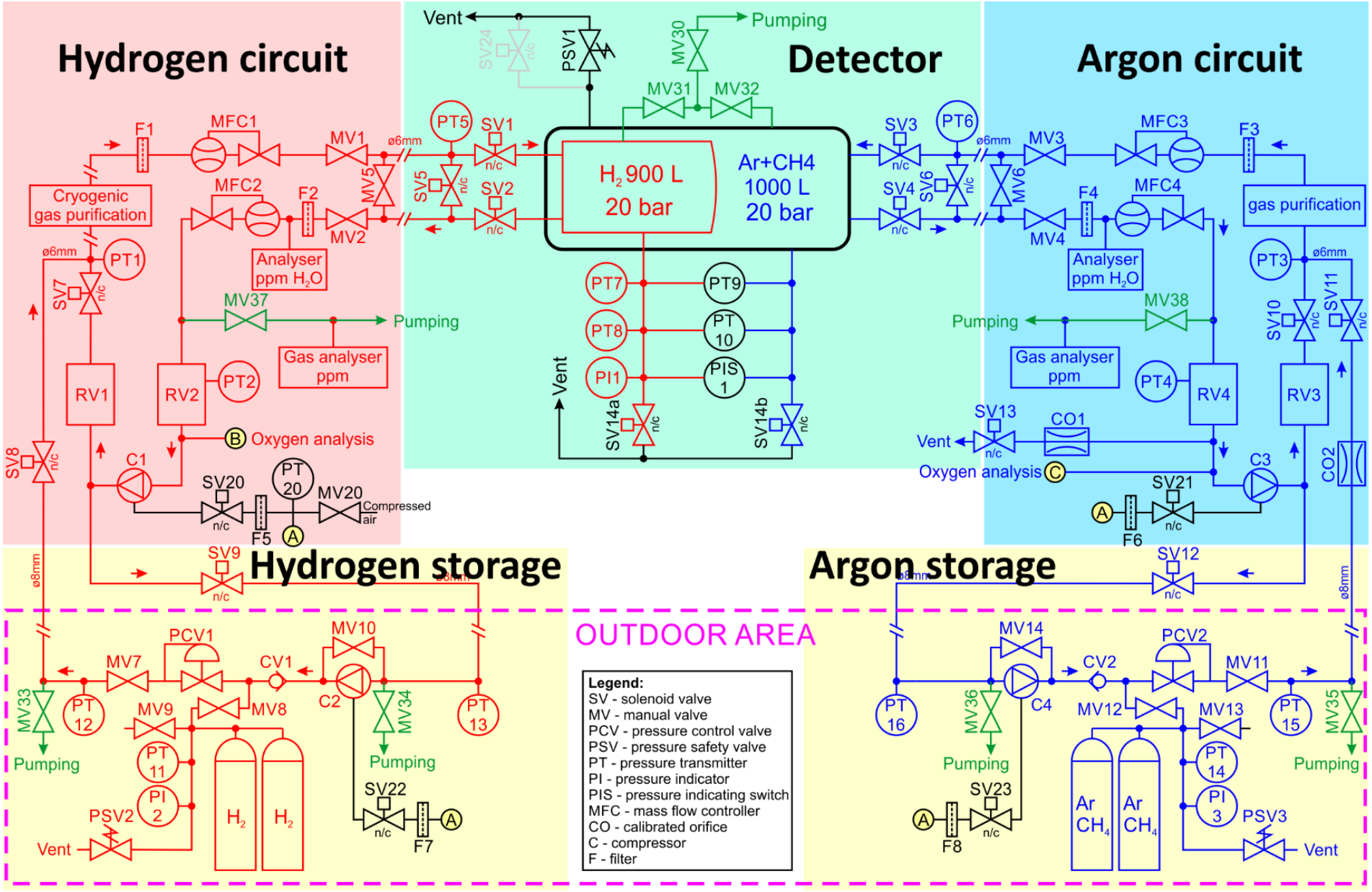
NICA TPC: pressure stabilization



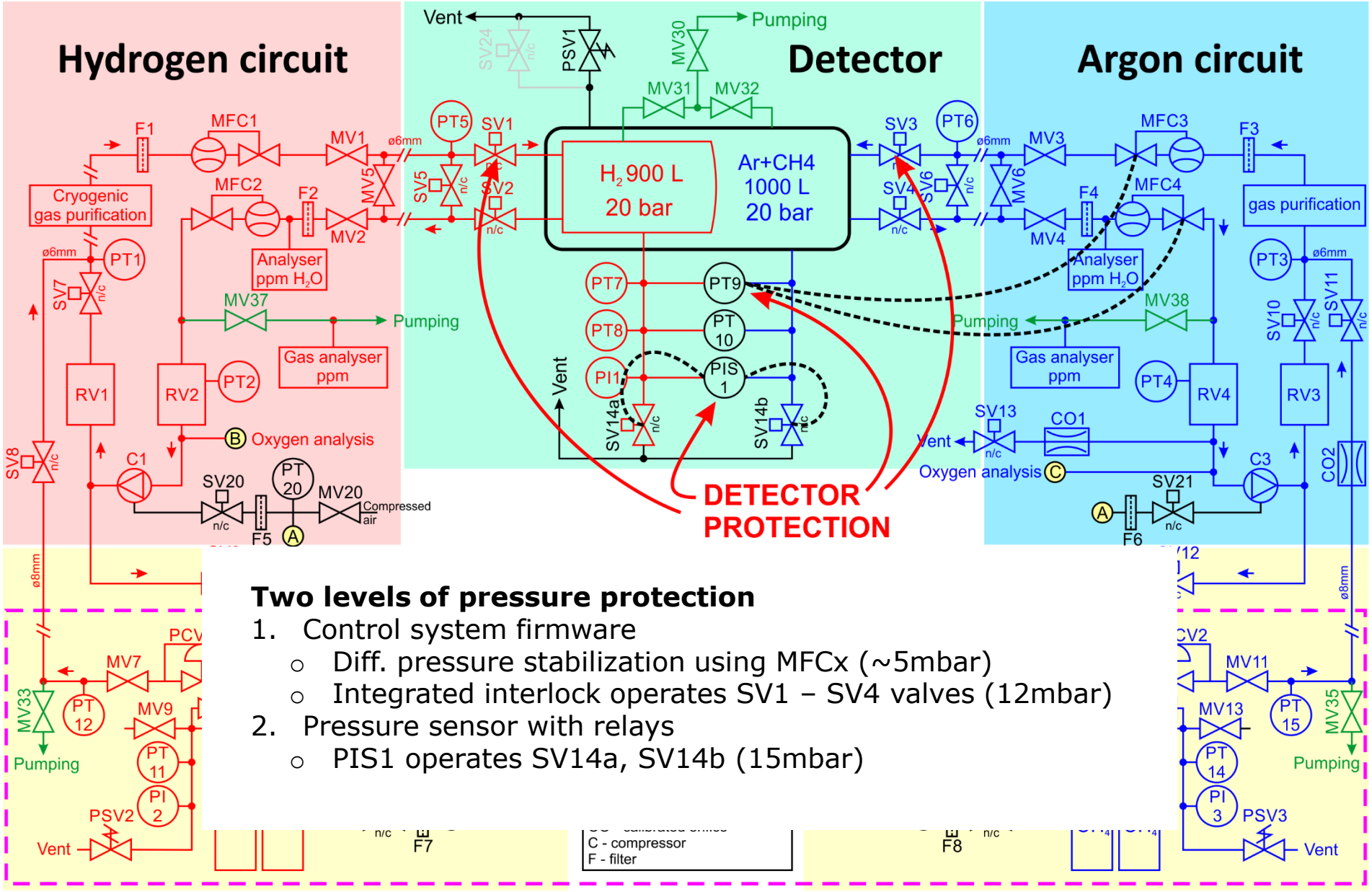
PRES gas system

Parameter	Value
Detector volume (TPC chamber)	~1000 L
Detector volume (PC chamber)	~1000 L
Absolute pressure in the detector	2 – 20 bar
Absolute pressure stability	±5 mbar
Absolute pressure uncertainty	0.01% (2.5mbar)
Maximum differential pressure between TPC and PC chambers	20 mbar
Working differential pressure between TPC and PC chambers	5-10 mbar
Impurity concentration in hydrogen (TPC chamber)	< 100 ppb
Impurity concentration in Ar+CH_4 mixture (PC chamber)	< 10 ppm
Circulation flowrate for each chamber	10-15 slpm
Filling / evacuation flowrate for each chamber	10-15 slpm

PRES gas system



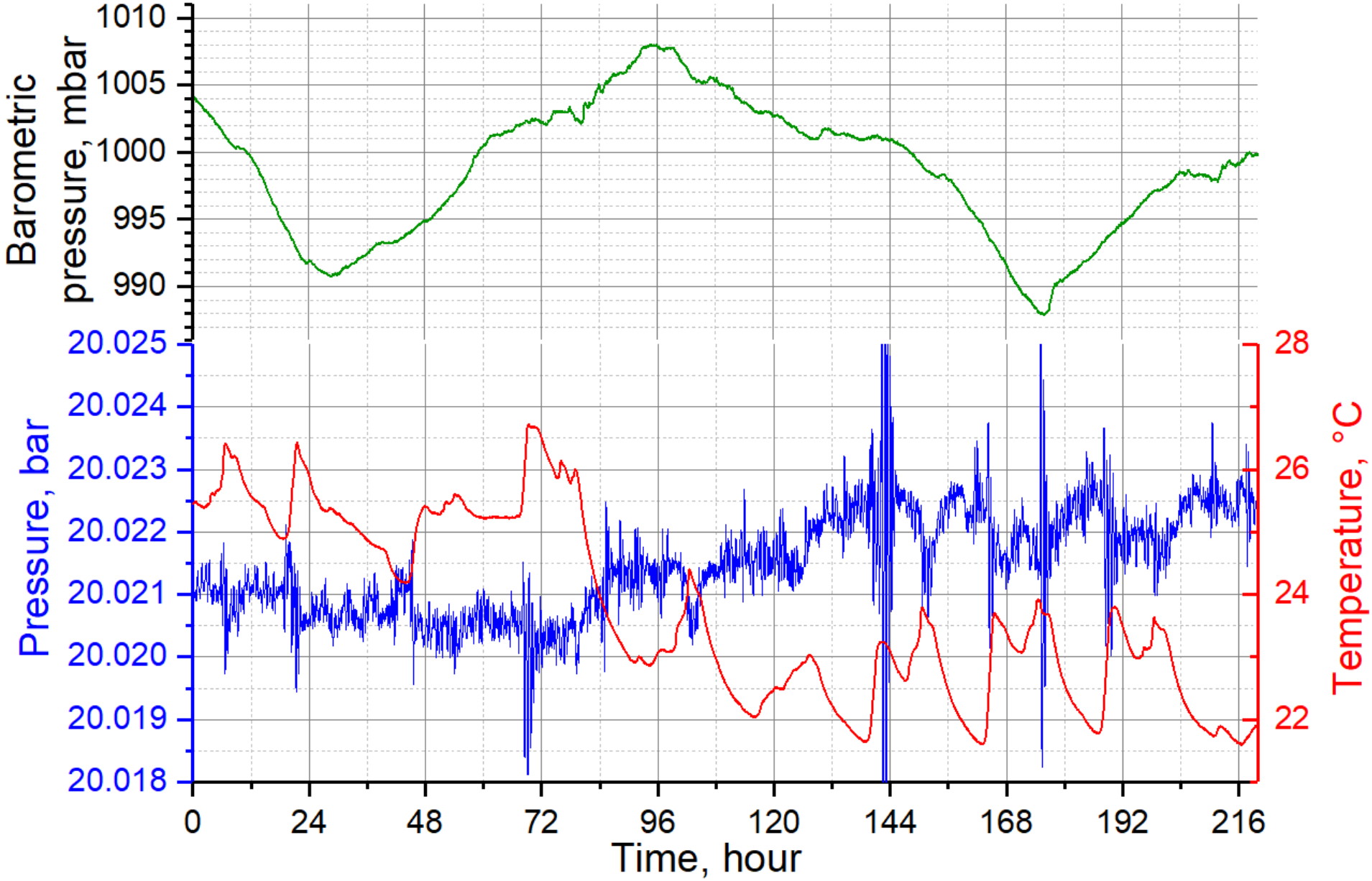
PRES gas system



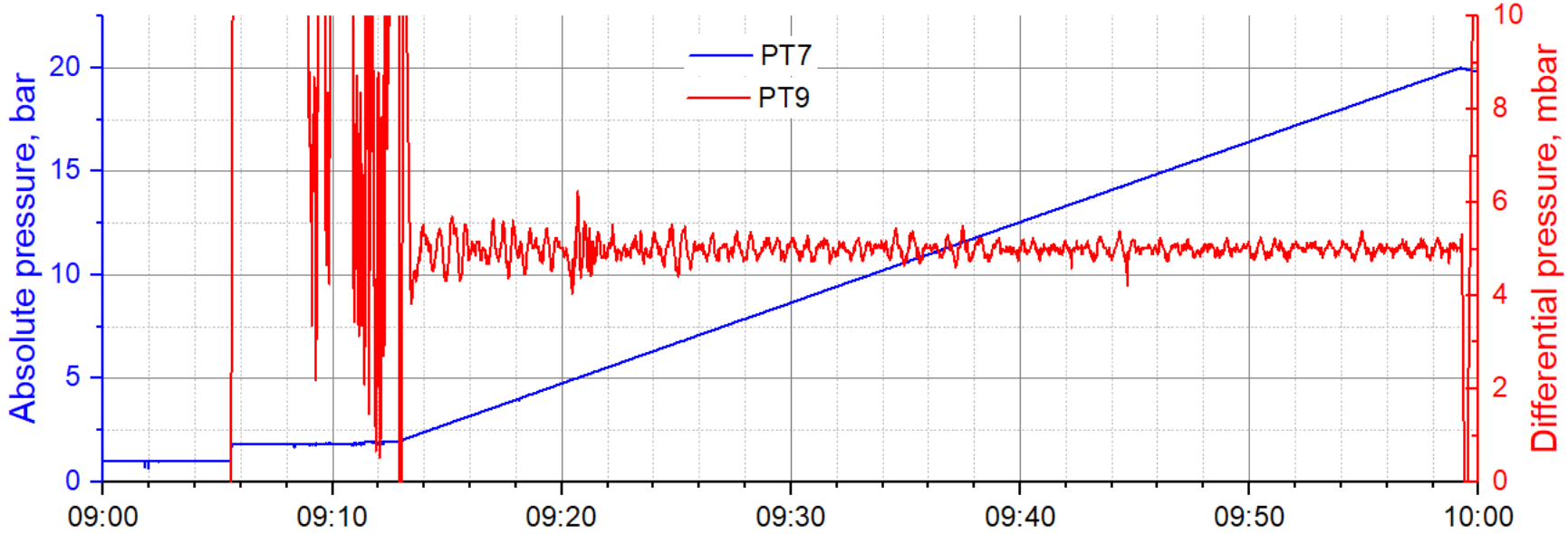
Two levels of pressure protection

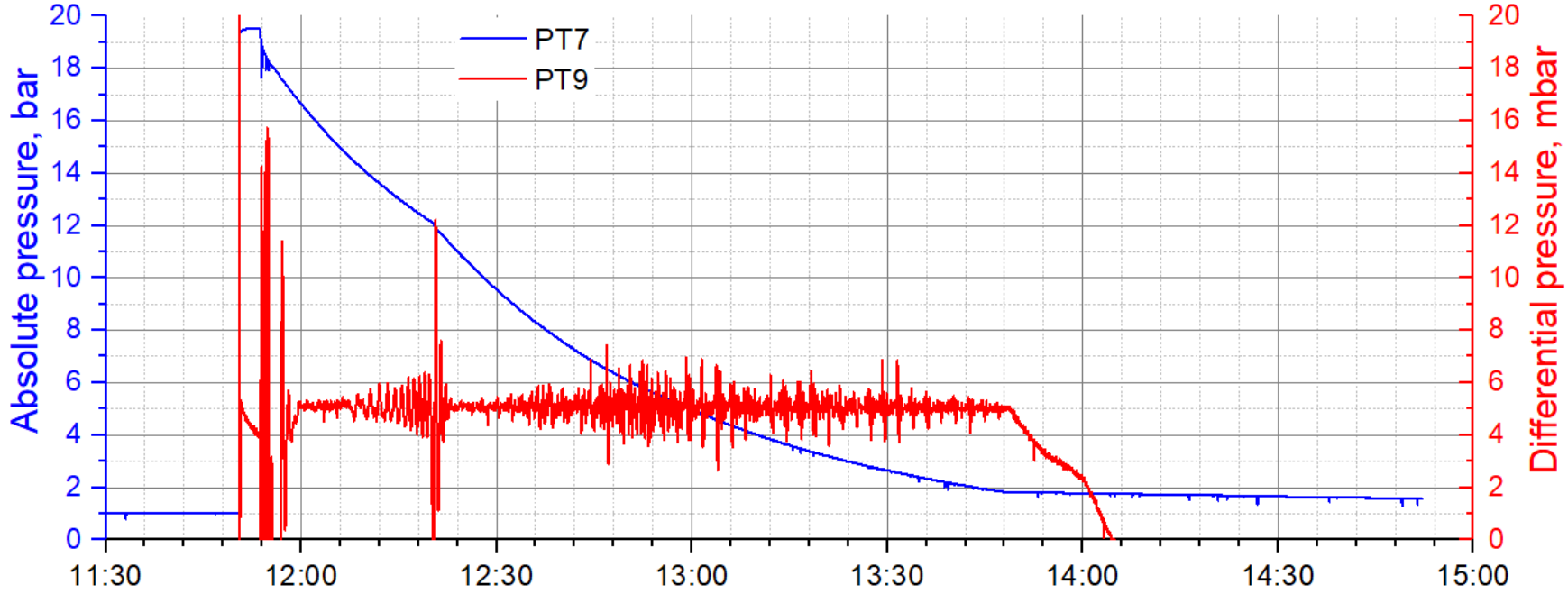
1. Control system firmware
   - Diff. pressure stabilization using MFCx (~5mbar)
   - Integrated interlock operates SV1 – SV4 valves (12mbar)
2. Pressure sensor with relays
   - PIS1 operates SV14a, SV14b (15mbar)

PRES. Pressure stabilization



PRES. Filling and evacuation mode

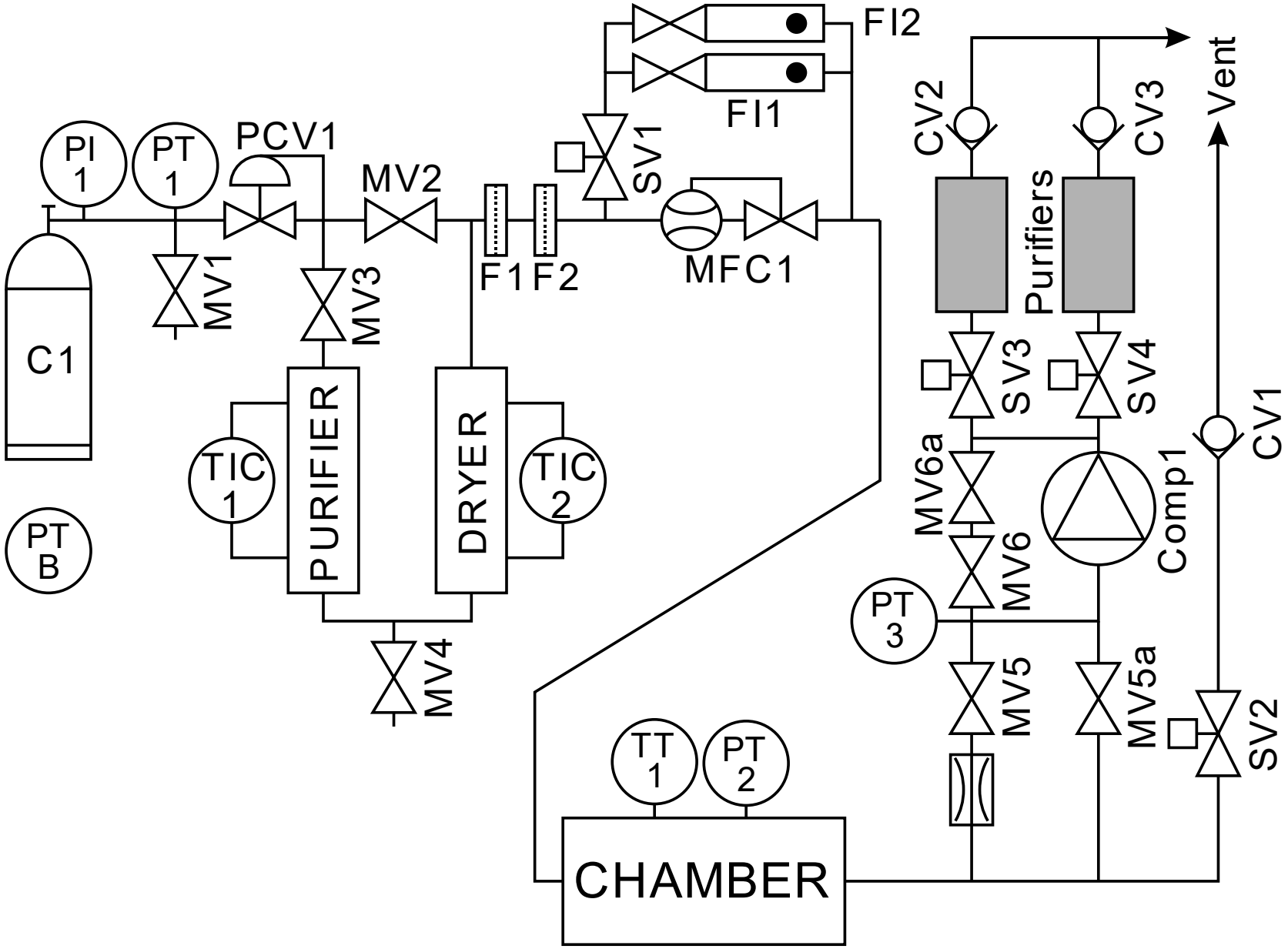




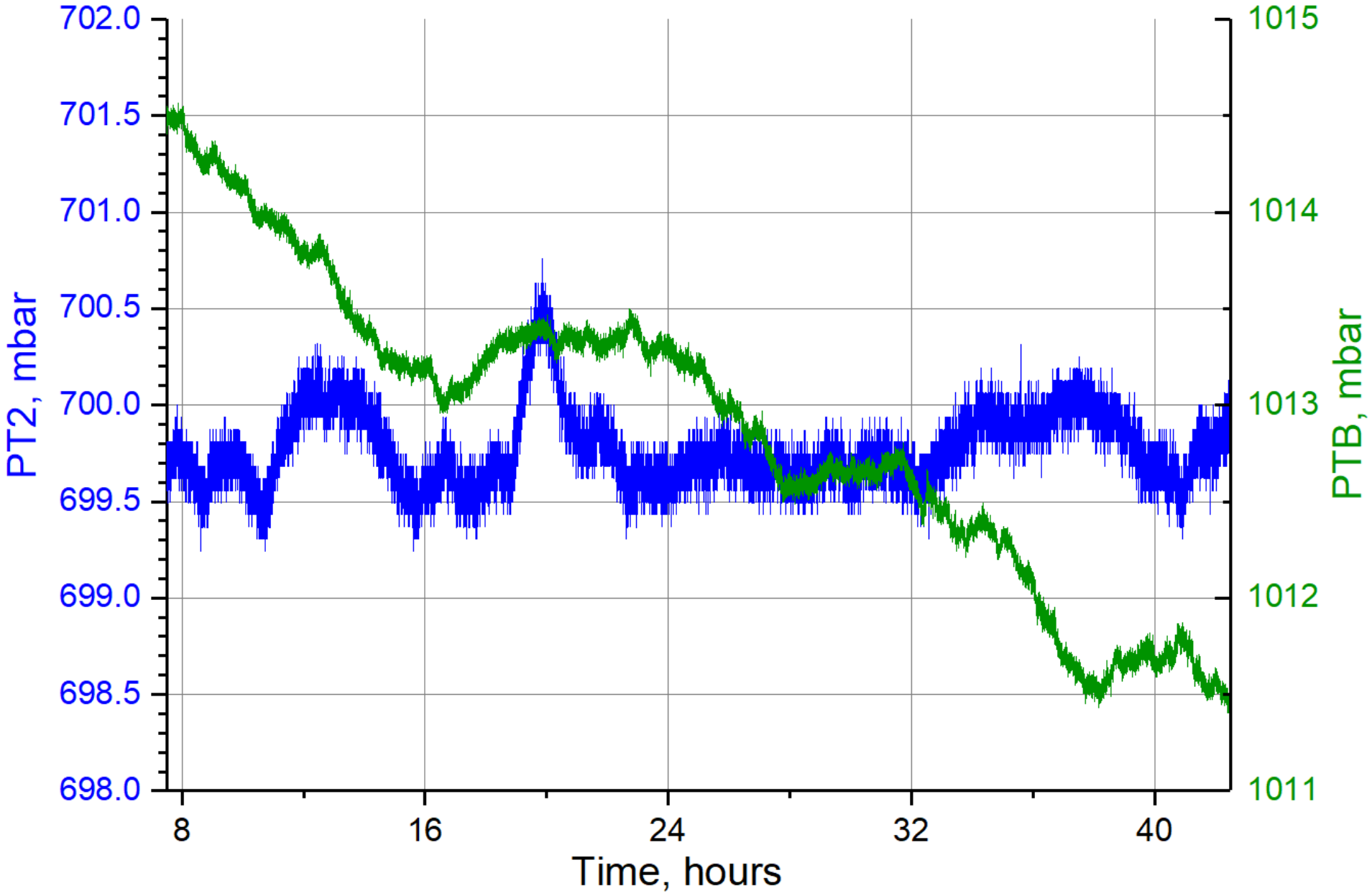
FISCO
gas system

Parameter	Value
Detector volume	3 liters
Mixture (P10)	Ar+(10±0.1%) CH4
Internal TPC pressure	700 - 1200 mbar abs
TPC pressure accuracy	± 3 mbar
Purge flow with P10	20 sccm
Fresh gas flow	10-20 sccm
Oxygen content	<20 ppm
Water vapor content	<15 ppm

FISCO gas system



FISCO. Pressure stabilization



PNPI - NRC KI

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20	Pres TPC+FT	20	20000 ± 5	H2, Ar + 2% CH4	2 x 15	-	10	10	2021	PNPI
21	FISCO	0.01	700 mbara	Ar + 10% CH4	-	0.01	10	10	2023	PNPI

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