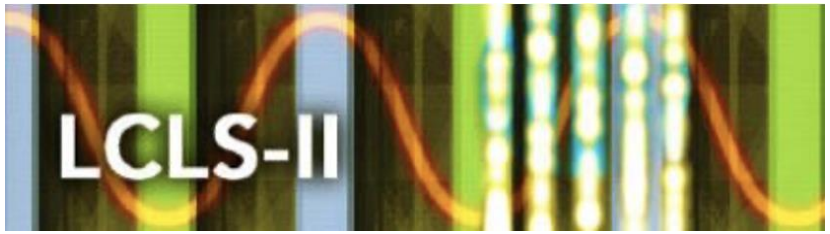

LCLS-II

Helium Refrigeration System Commissioning Tests

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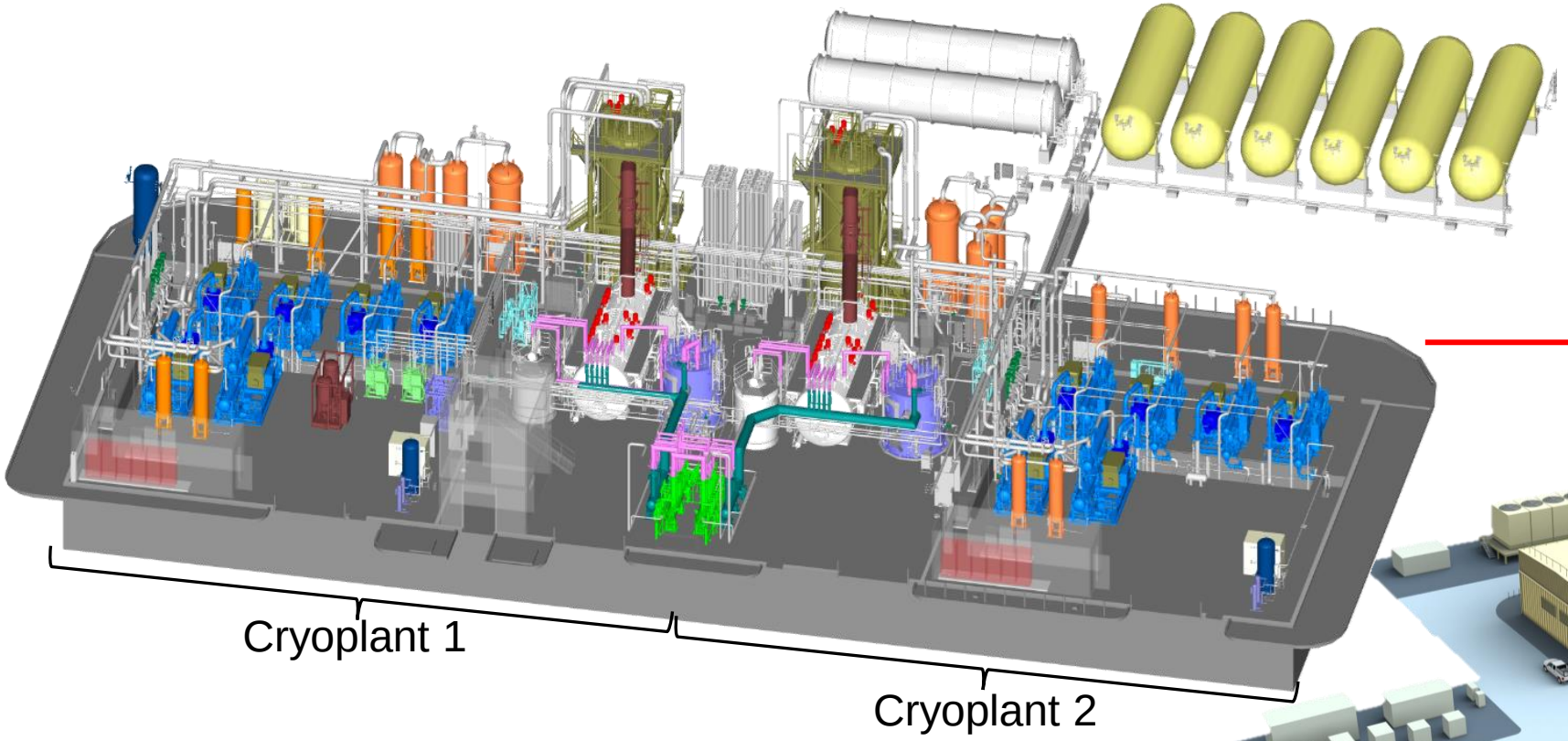
CEC-ICMC23

Outline

- Overview
  - LCLSII Cryogenic system
  - Commissioning Timeline
- LCLS-II Cryoplant Commissioning
  - Recovery and Purifier
  - Warm Compressor
  - 4K Cold Box
- Trip Tests
- Summary

LCLS-II Cryogenic system Overview

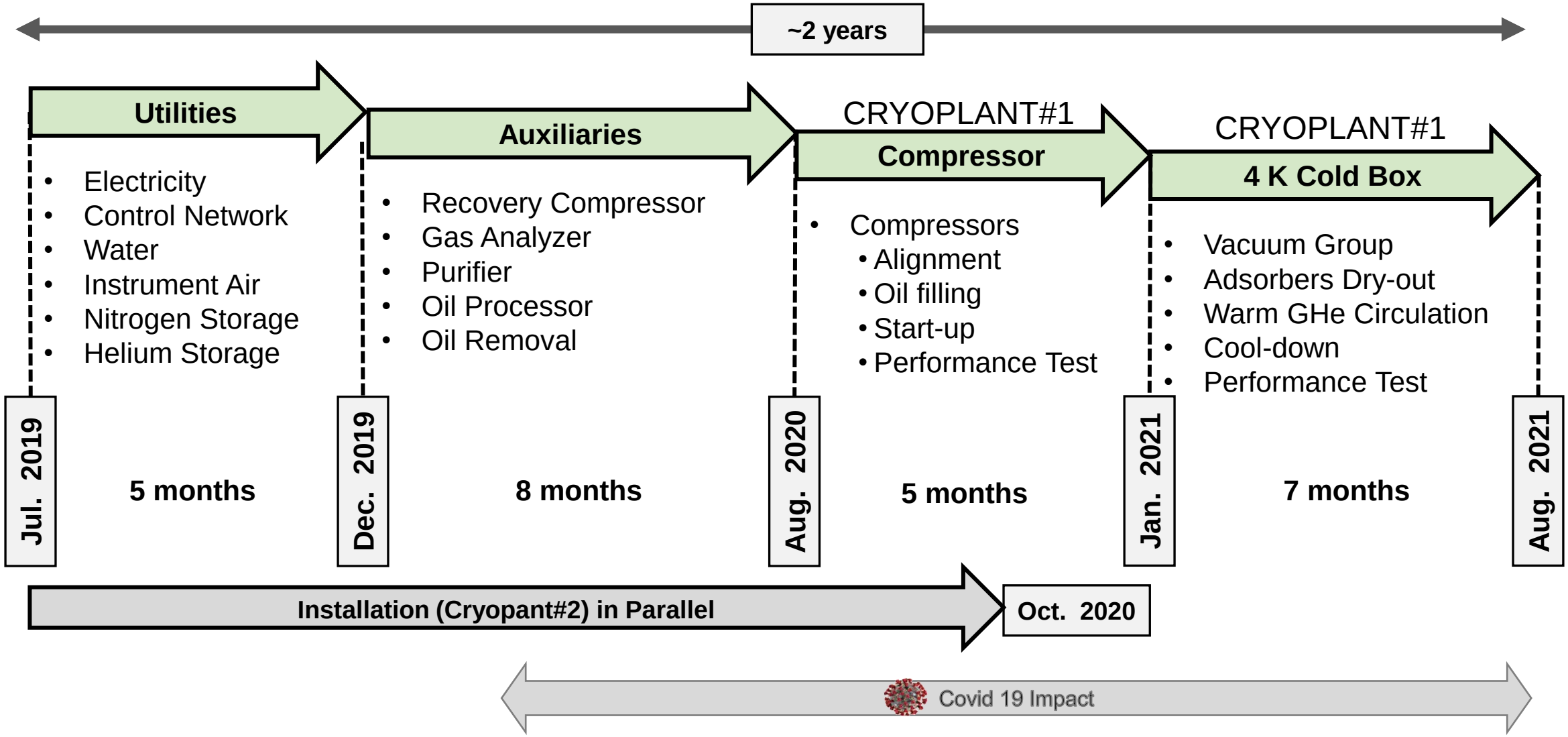


Cryoplant:
- 2x Helium Refrigeration Plant
- Providing ~ 2x 4.0 kW @ 2.0 K

LCLS-II Superconducting LINAC:
- 35x 1.3 MHz Cryomodules
- 2x 3.9 MHz Cryomodules

- ❑ LCLS: Worlds 1st hard x-ray FEL
- ❑ LCLS-II upgrade with superconducting accelerator technology (4GeV):
  - ❑ From 120 Hz to ~1 MHz
  - ❑ 10,000 times brighter beam

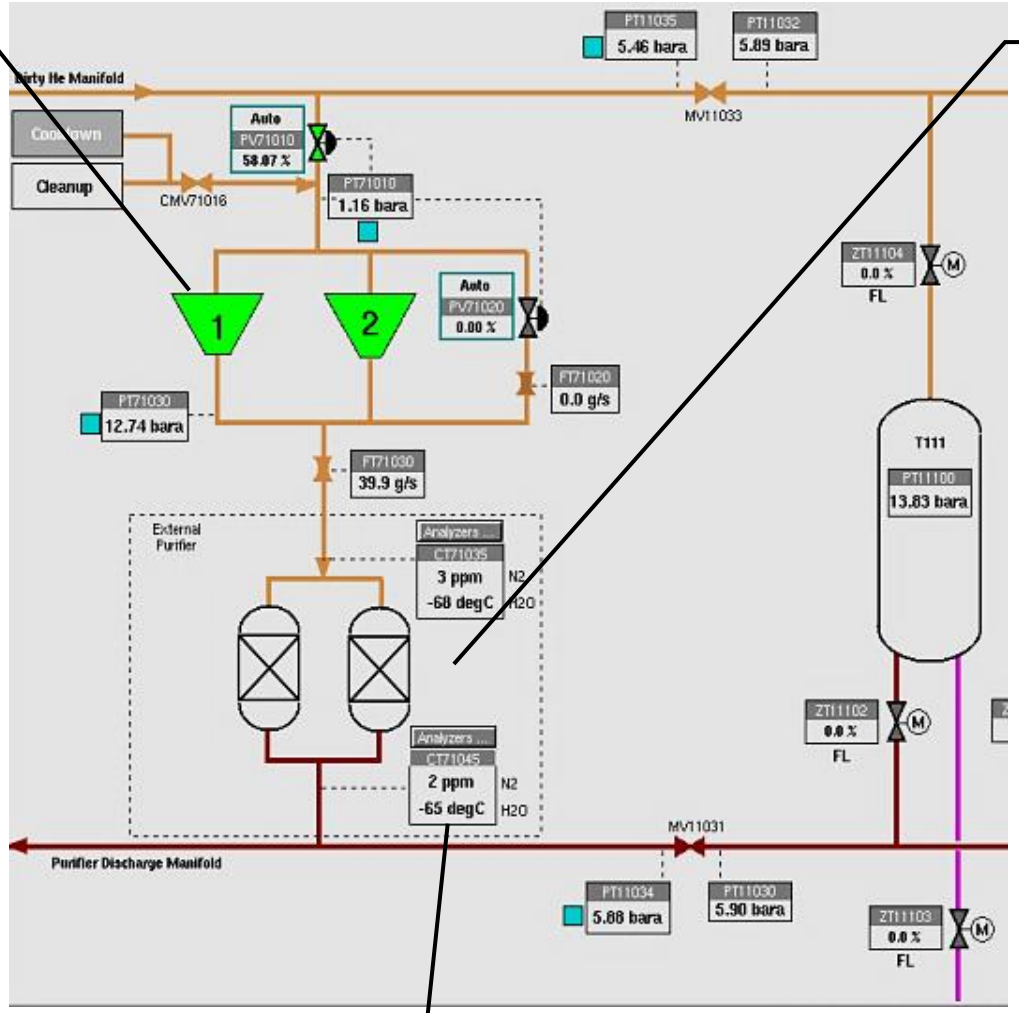
Commissioning Timeline



Recovery & Purifier: Scope

Recovery Compressors

Flow = 2 x 20 g/s
Power = 2 x 134 kW

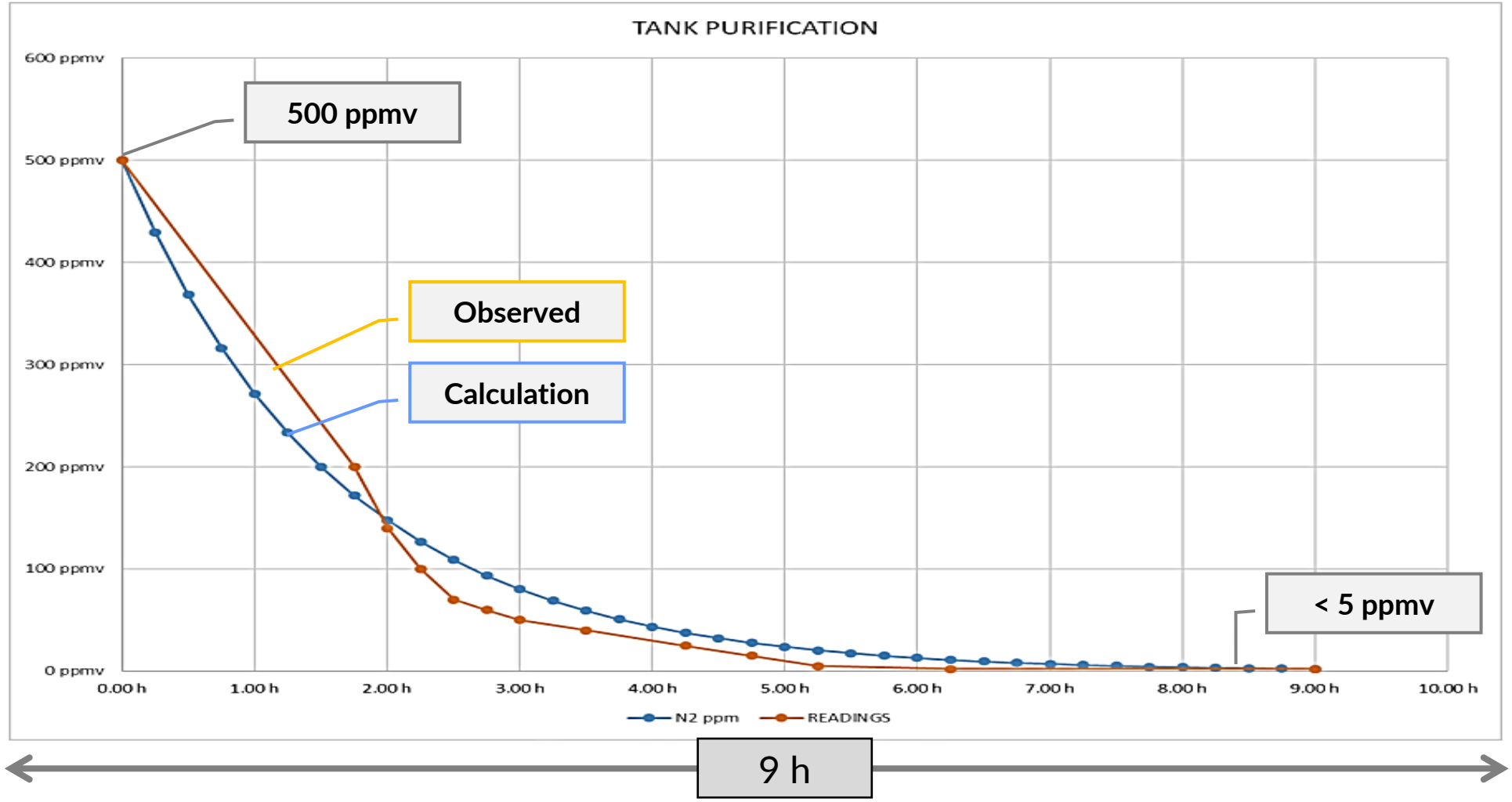


Nitrogen and Moisture Analyzer

Helium Purifier

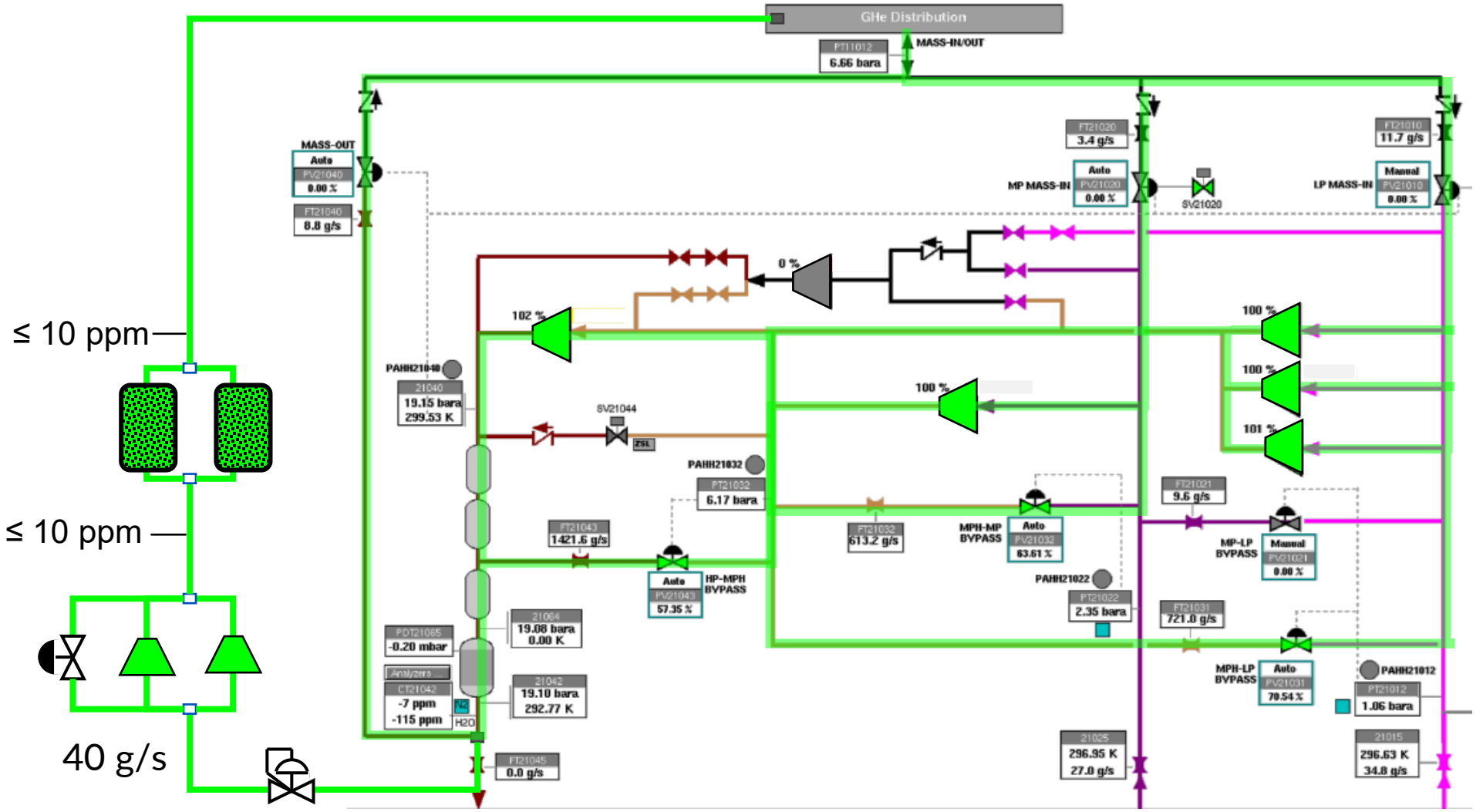
Flow = 40 g/s / Adsorber Bed
Adsorber bed saturation time
30 ppmv → 30 days
400 ppmv → 1 day

Recovery & Purifier: Performance



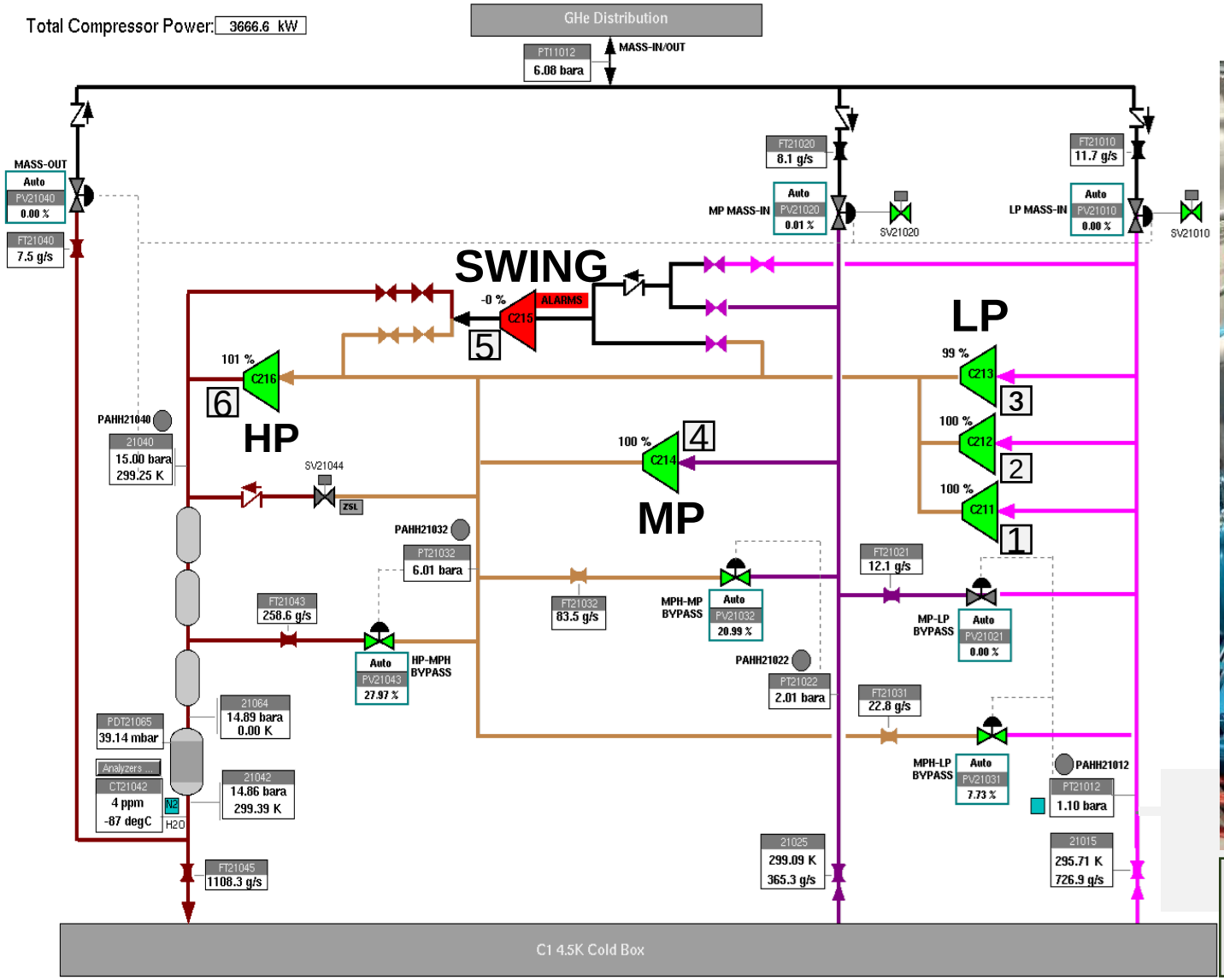
500 ppm (0.5 kg) to < 5 ppm impurity in 9 hours with 1 x 110 m3 @ 6 bara tank connected

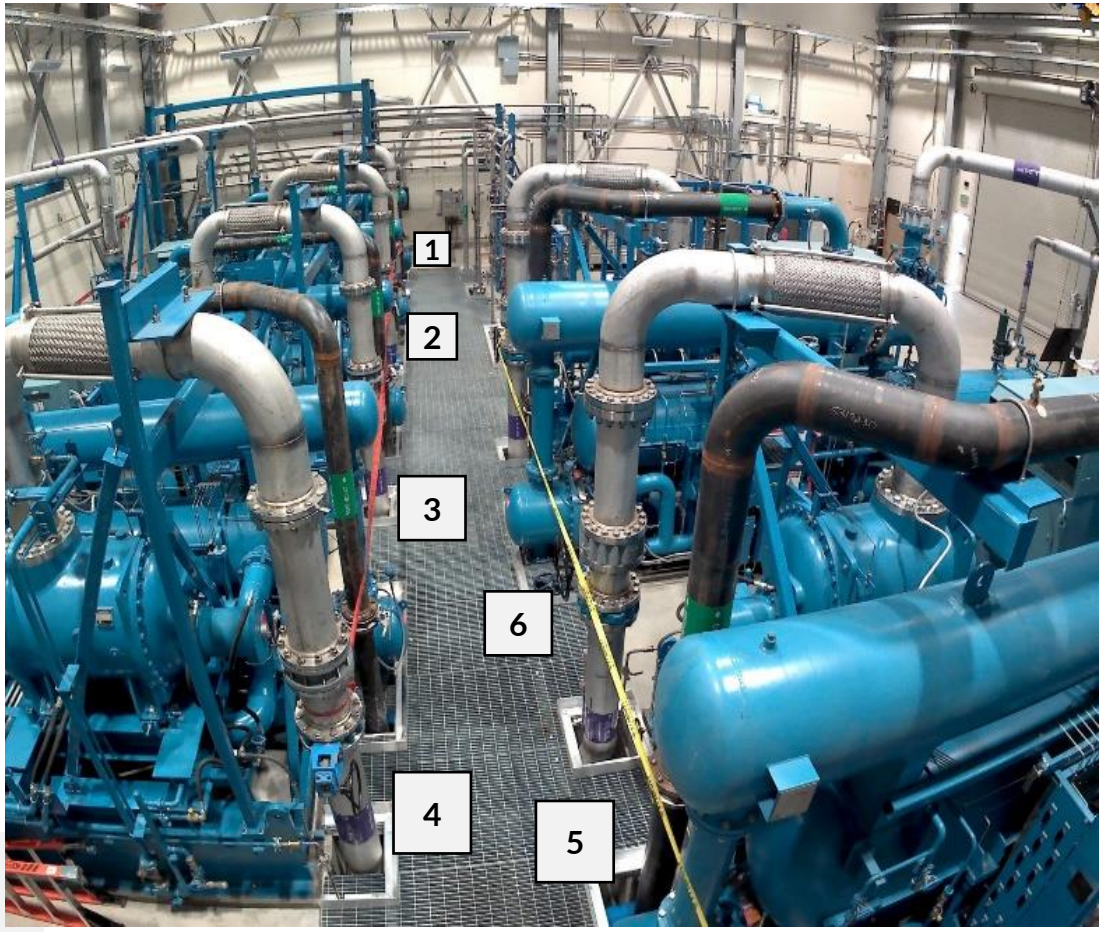
Recovery & Purifier: Performance



System Clean-up using Recovery & Purifier

Warm Compressor: Scope





LCLS-II Compressor Station #1
5 Compressors + 1 Stand-by

Warm Compressor: Performance

Refer V. Ravindranath, et al. CEC/ICMC 2021 for detailed warm compressor commissioning results

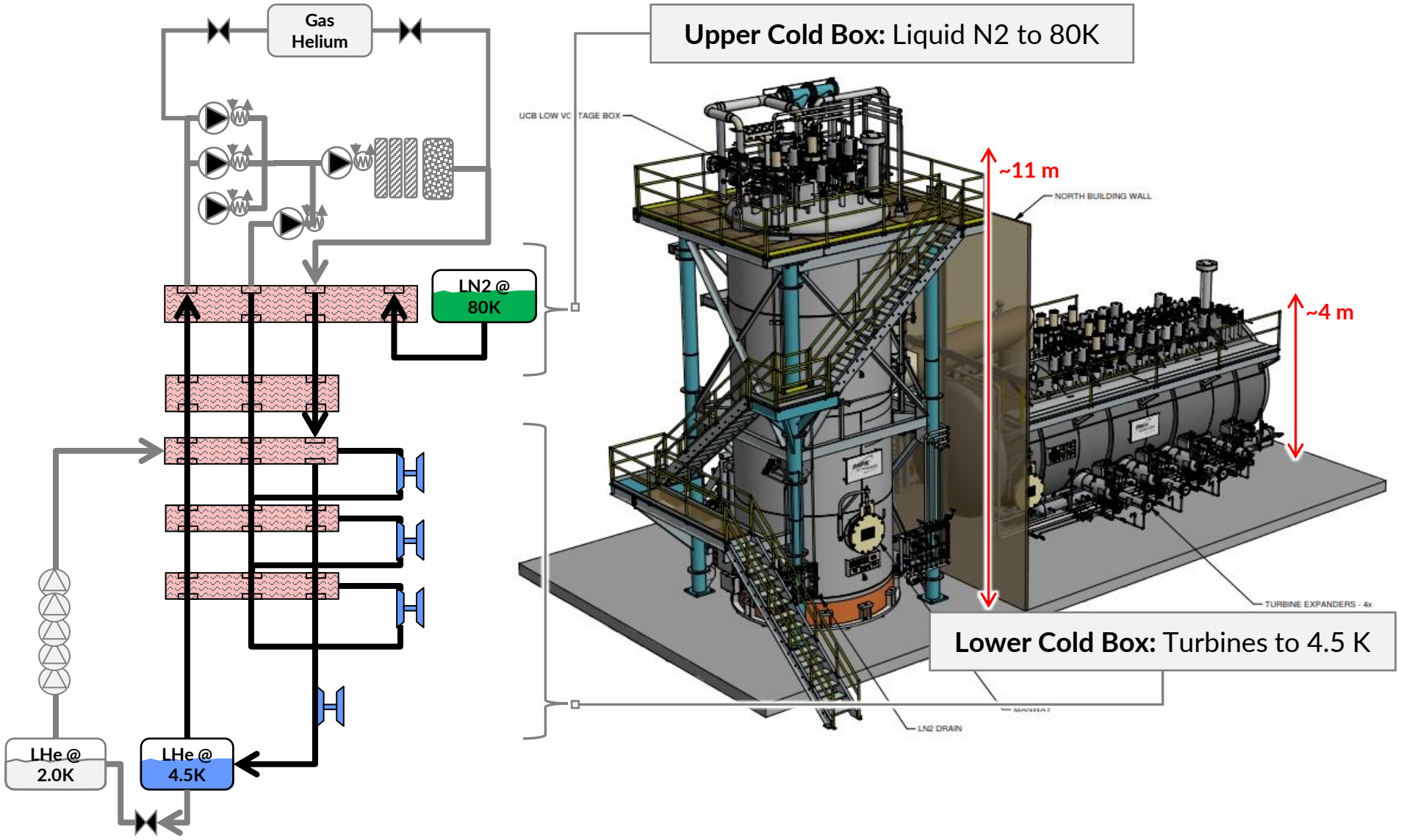
Compressor Performance Test Results						
Compressor Parameters			Expected		Observed	
	Suction Pressure [Bara]	Discharge Pressure [bara]	Flow [g/s]	Power [kW]	Flow [g/s]	Power [kW]
HP	6.15	19.00	1318	1859	1380 [+5%]	1775 [-5%]
MP	2.35	6.15	579	663	613 [+6%]	618 [-7%]
LP	1.05	6.15	757	1817	730 [-4%]	1790 [-1%]
				4339		4183 [-1%]

- Compressor vendor provided data shows +/- 5 % variation in capacity [flow and input power]
- HP and MP compressors efficiency exceeds specification
- LP flow requirement:
  - Process flow required for the Helium Refrigeration System → 730 g/s
  - Bypass flow required for compressor suction pressure controls → ~20 g/s
  - LP stage operates at higher suction pressure → ~1.08 bara

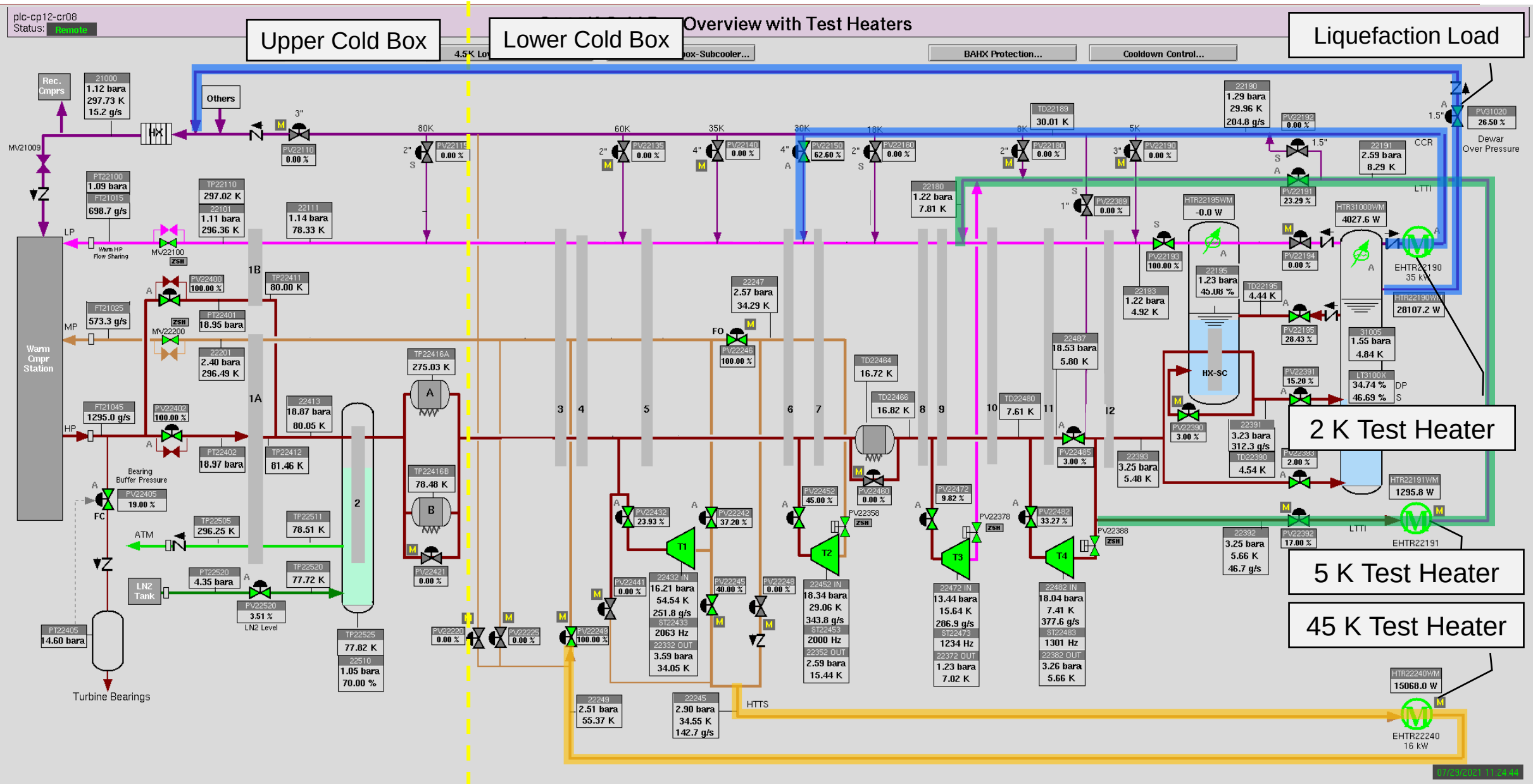
Warm Compressor: Challenges

Significant Vibration on HP Skids: Skid initially reinforced with Timber [For Tests] then with Steel.

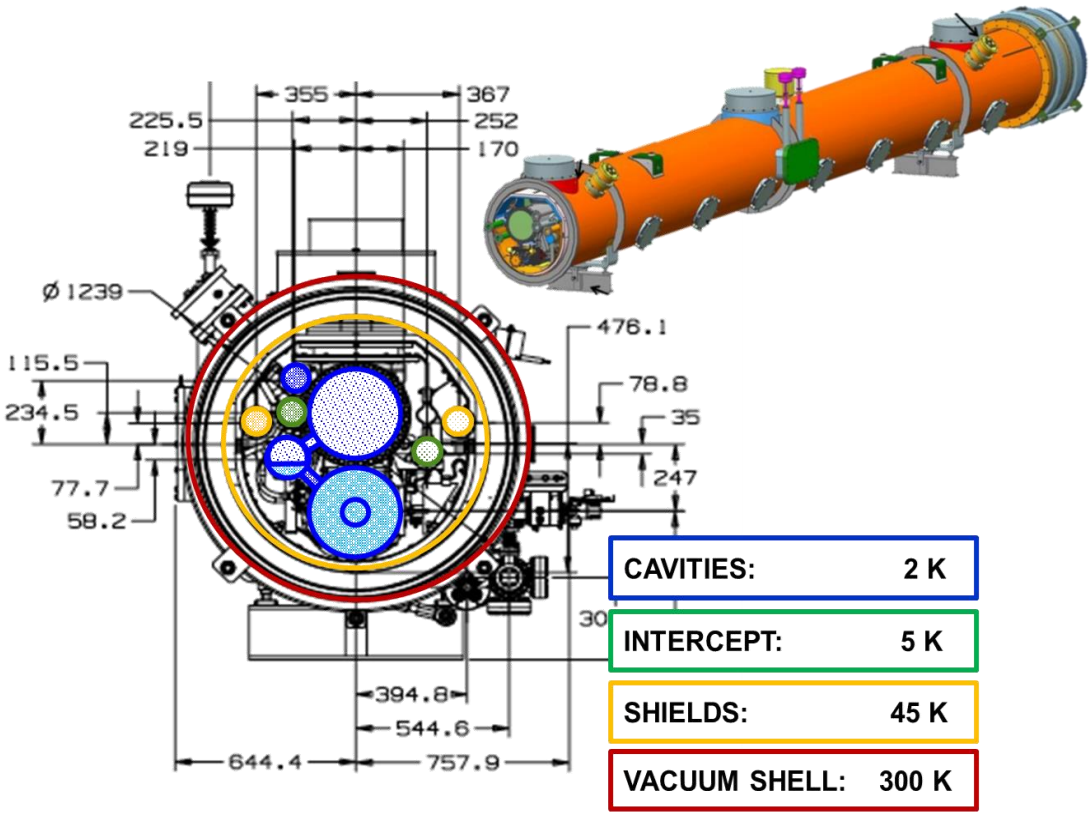
4K Cold Box: Scope



4K Cold Box: Performance



4K Cold Box: Performance – Capacity



	EXPECTED		OBSERVED	
Heat Loads	Flow	Heat	**Flow**	**Heat**
HTTS: SHIELD	146 g/s	15.2 kW	**137 g/s**	**15.0 kW**
LTTI: INTERCEPTS	41 g/s	1.3 kW	**44 g/s**	**1.3 kW**
4.5 Liq.	15 g/s	-	**15 g/s**	**-**
2K Load	200 g/s	4.0 kW	**200 g/s**	**4.0 kW**
Ideal Carnot Work	**1,200 kW**		**1,200 kW**	

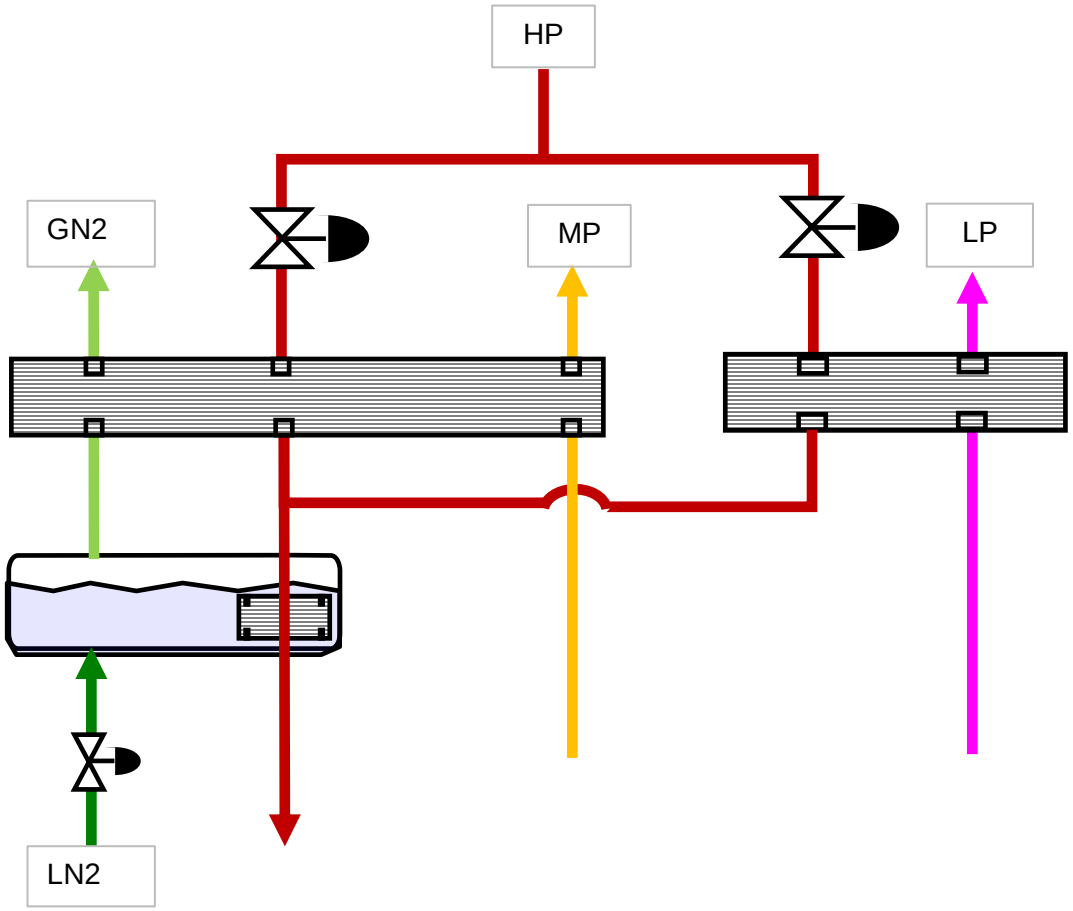
	EXPECTED	OBSERVED
Compressor Power	4,300 kW	4,000 kW
LN2 Flow	104 g/s	109 g/s

4K Cold Box exceeded design specification

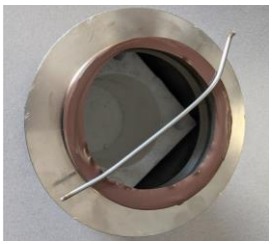
LN2 Consumption: Max Capacity

- LN2 consumption in maximum capacity mode ~ 109 g/s
- LN2 consumption measurement
  - LN2 Dewar level drop
  - Energy balance across the heat exchanger

LN2 CONSUMPTION	
EXPECTED	OBSERVED
104 g/s	109 g/s



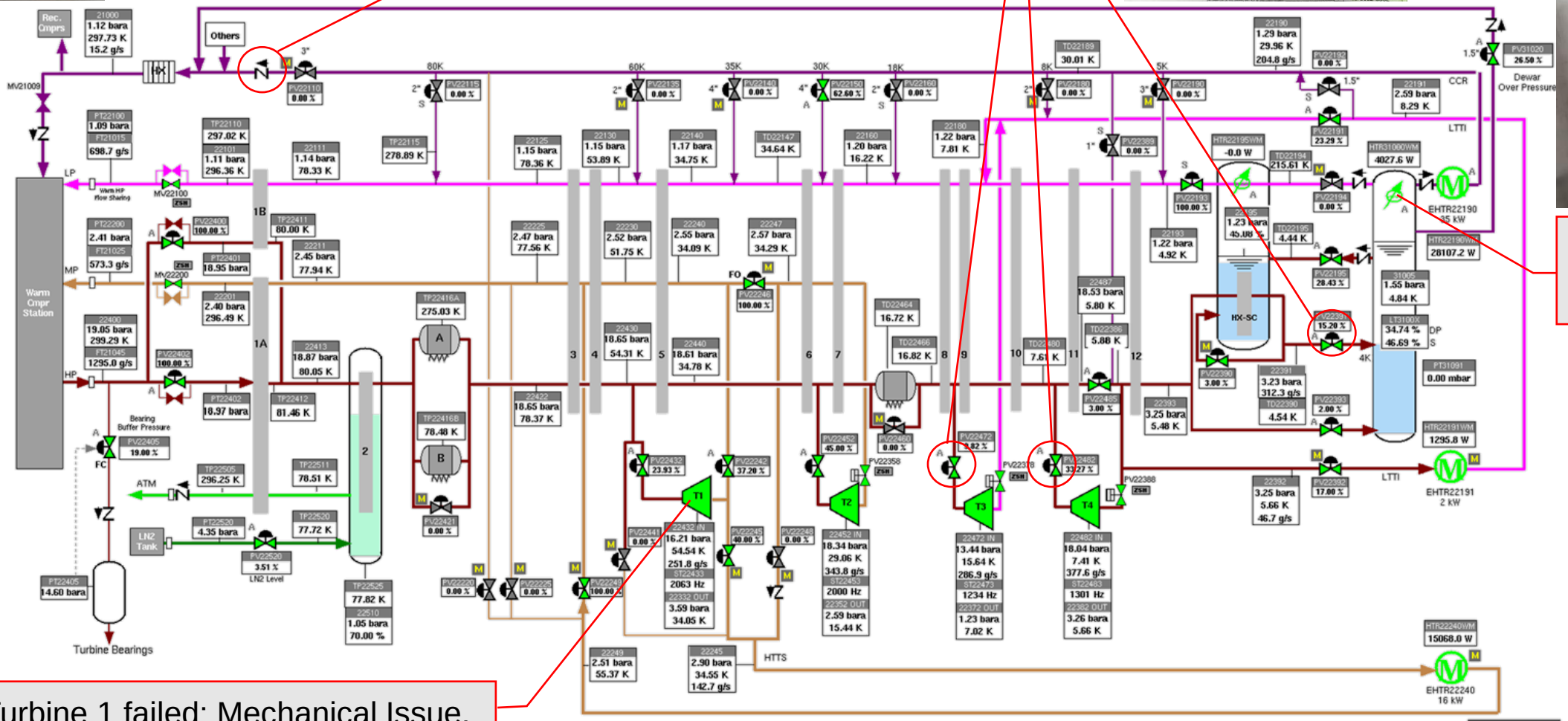
4K Cold Box: Challenges



Blocked Check Valve.

Valves Rangeability: Insufficient

Dewar heater burn-out



Turbine 1 failed: Mechanical Issue.

Trip Test - Scope

Equipment Failure

- Compressor Trip [LP, MP, HP, All]
- Turbine Trip [T1, T2, T3, T4]
- 4K Cold Box Trip

Load Failure

- Loss of 2 K Flow [Cold Compressors]

Emergency

- Emergency stop
  - Loss of Electrical Power
  - Loss of Instrument Air
  - Overall System Controlled STOP

Mitigation

- Well Established Procedures
- Effective Process Controls

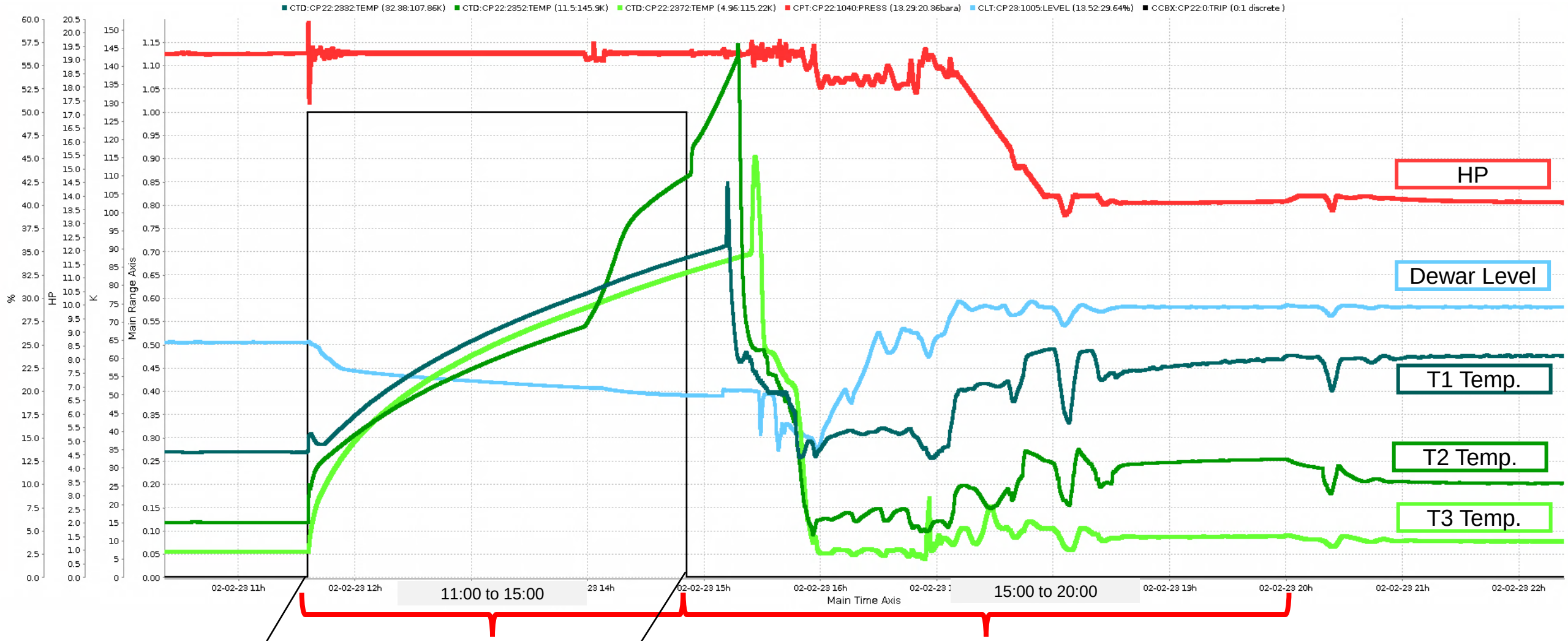
Recovery

- Shorten Recovery Time.
- Minimize Helium Losses

Response

- Continuous Improvement:
  - Improve Procedures
  - Improve Process Control

Trip Test – System Recovery



Summary

- Successful Cryoplant #1 Commissioning:
  - Systematic commissioning approach
  - Compressor capacity adequate for LCLS-II refrigeration demands
  - 4K cold box capacity exceeds design specification

- Trip test carefully planned and executed:
  - Vital for evaluating system robustness/resilience
  - Well established procedures and effective process controls
  - Team is well equipped to handle unexpected failures


Thank you