중이온가속기연구소
Institute for Rare Isotope Science

AFAD 2026

Response and Recovery of the RAON Cryogenic System Following a Momentary Power Outage

13-17 October 2026 / Shanghai, China

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Acknowledgements

1. Introduction

- **SCL3 Cryogenic System for RAON - ① Overview**

RAON : Rare Isotope Accelerator complex for ON-line experiments

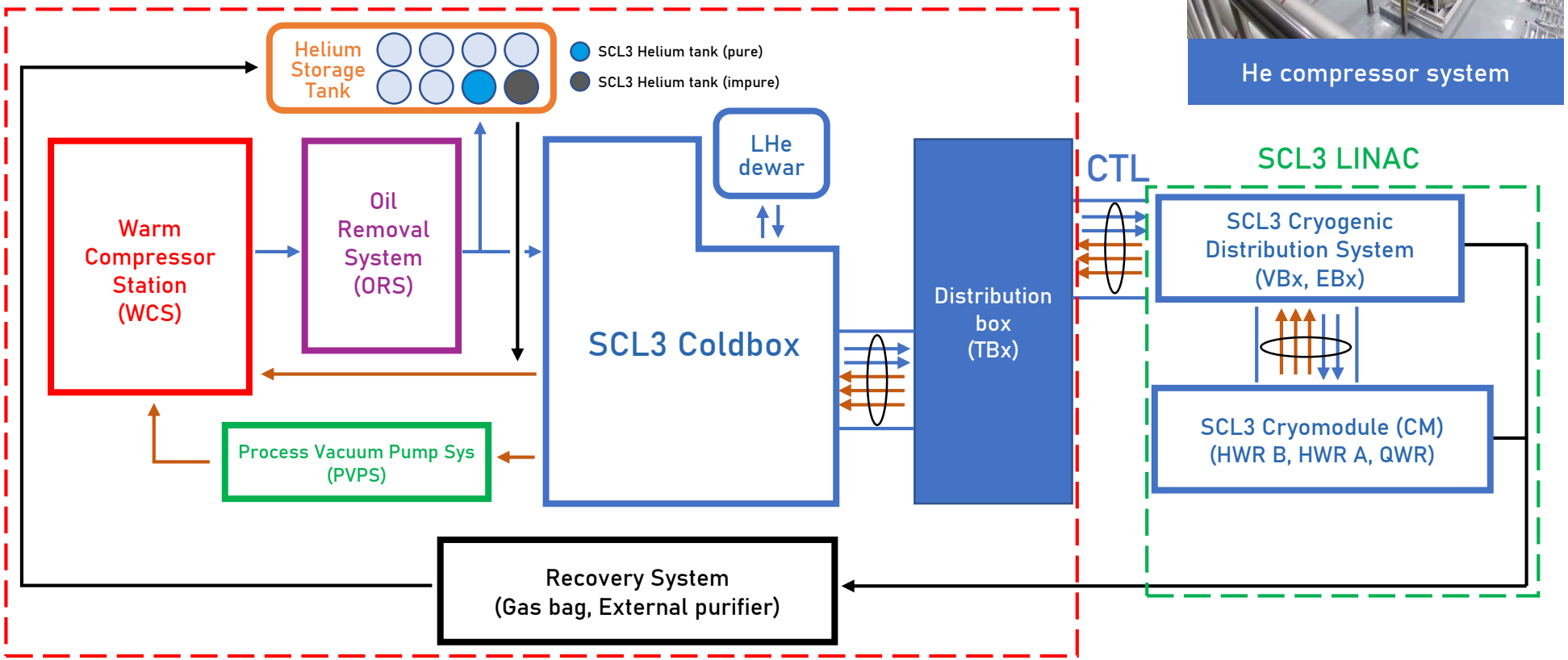
- ISOL + IF methods for rare isotope beams
- SCL3 (~18.5 MeV/u, operation since 2022) + SCL2 (~200 MeV/u, phase 2)



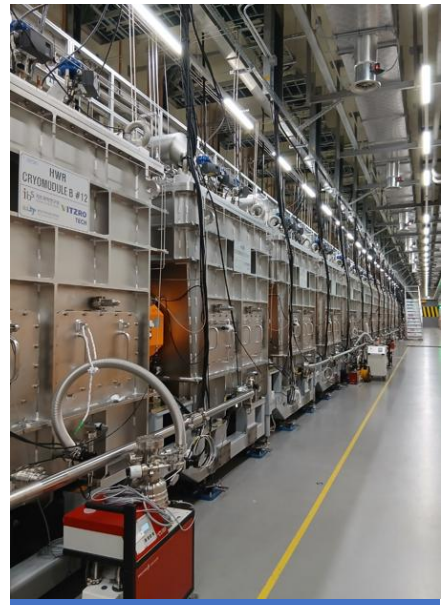
He compressor system



Cryogenic system



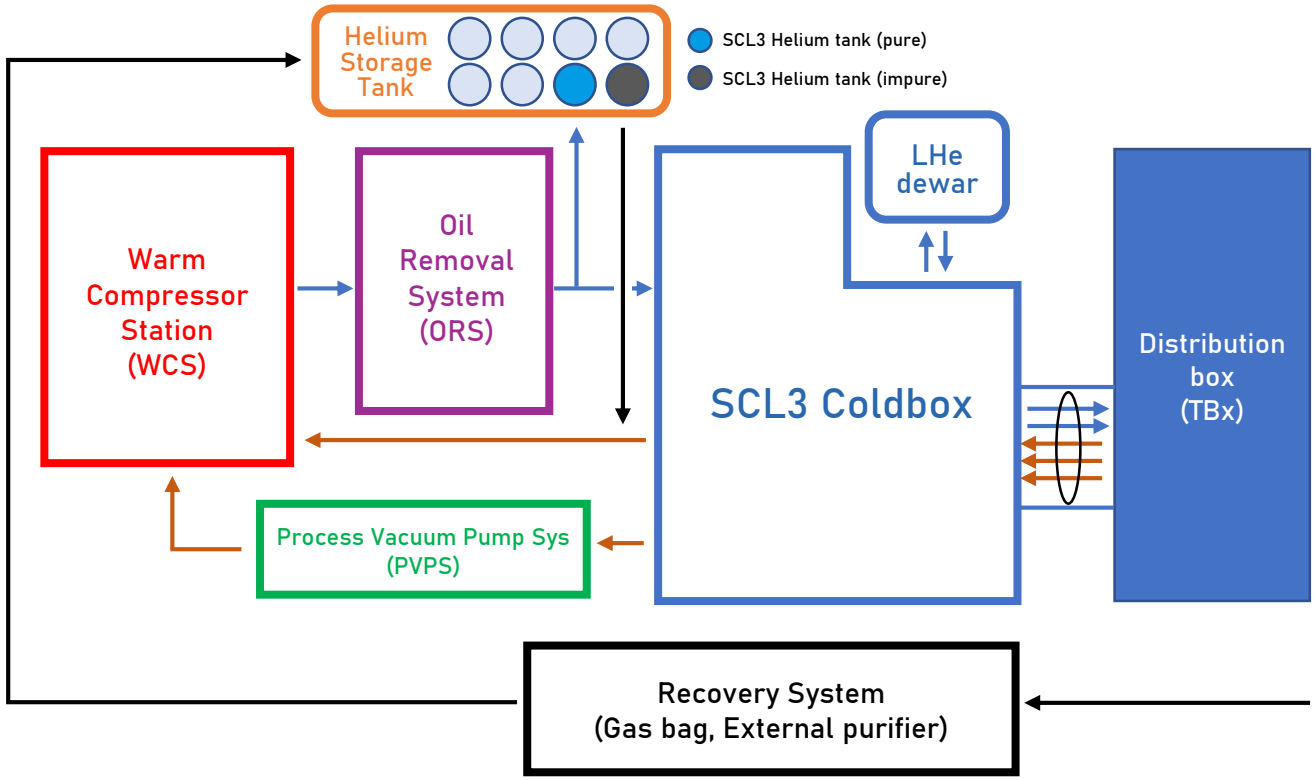
SCL3 Cryogenic plant (Helium compressor , Cryogenic system)



SCL3 LINAC

1. Introduction

- **SCL3 Cryogenic System for RAON - ① SCL3 Cryogenic plant**





Helium Storage Tank

Helium Storage Tank (8 ea.)	
Impure tank (1 ea.)	
SCL3 pure tank (1 ea.)	
Spare pure tank (6 ea.)	
Volume per tank	250 m^3



Process Vacuum Pump System (PVPS)

Process Vacuum Pump System (4 ea.)	
For 2.05 K operation	
Backing pump for Cold Compressors	
HP / LP	1.08 barA / 200 mbarA
VLP	30 mbarA (CCs)
Normal flow rate	41 g/s

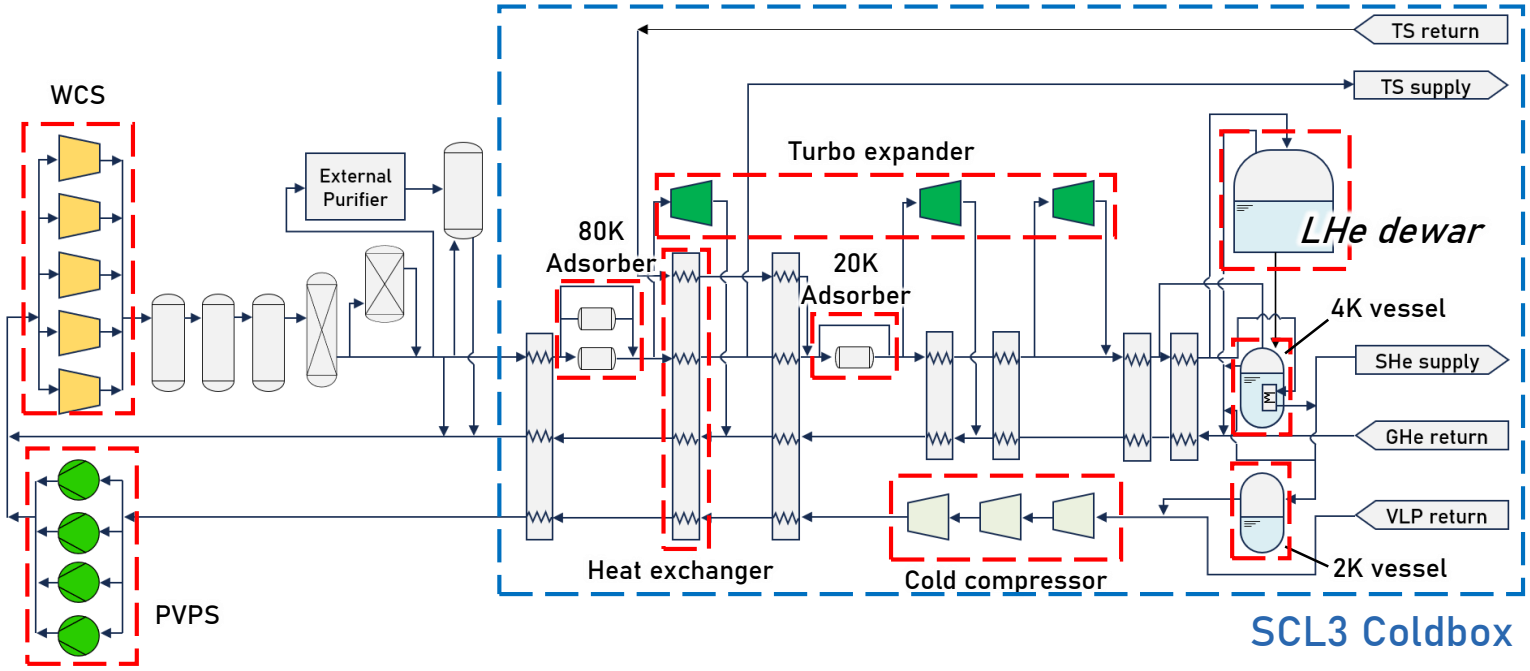


Warm Compressor Station (WCS)

Warm Compressor Station (5 ea.)	
Oil rotary screw compressor	
Maximum operating pressure	15 barA
Minium operating pressure	1.08 barA
Number of compressors	5 units (1 standby)
Nominal flow rate	~310 g/s (TS ~ 107 g/s SHe ~ 85 g/s)

1. Introduction

- **SCL3 Cryogenic System for RAON - ② SCL3 Coldbox**





SCL3 Coldbox (CBx)



Turbo expander



Cold compressor



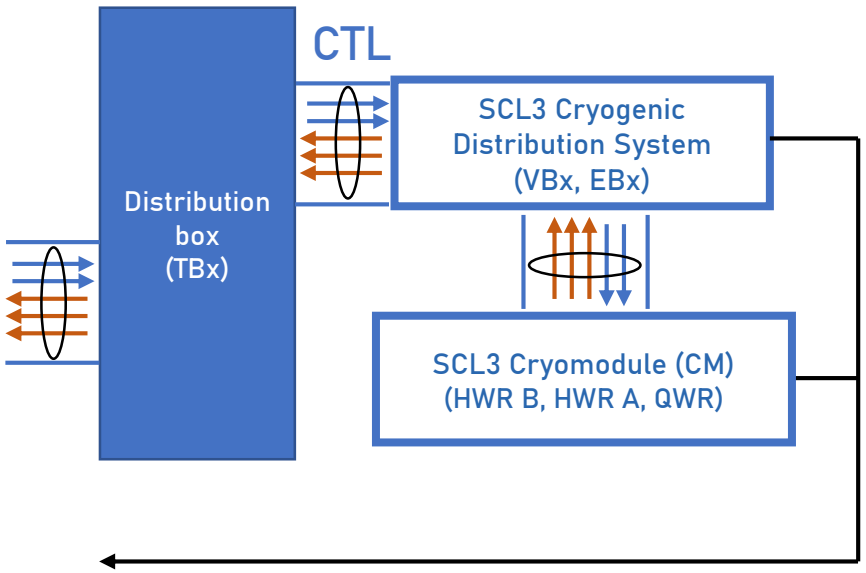
LHe dewar

SCL3 Coldbox	
Maximum cooling capacity*	① 910 W for 2.05K (HWR cavities) ② 1041 W for 4.5K (QWR cavities) ③ 10250 W for 35-45K (Thermal Shield, TS)
Maximum equivalent cooling capacity @ 4.5K	① 2013 W for 2.05K ② 1044 W for 4.5K +③ 1181 W for 35-45K ~4.2 kW @ 4.5K
Equivalent heat load for SCL3 cryogenic system	~2.8 kW @ 4.5K (RF On, 26.04.28)
Number of turbo expander	3
Number of cold compressors	3
Adsorber	80K (2 ea.) 20K (1 ea.)
Supplying pressure	3 barA

* Site Acceptance Test (28 July 2022)

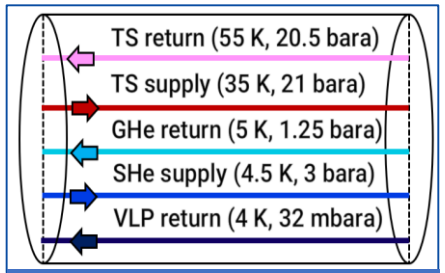
1. Introduction

- **SCL3 Cryogenic System for RAON - ③ SCL3 Cryogenic Distribution System (CDS)**

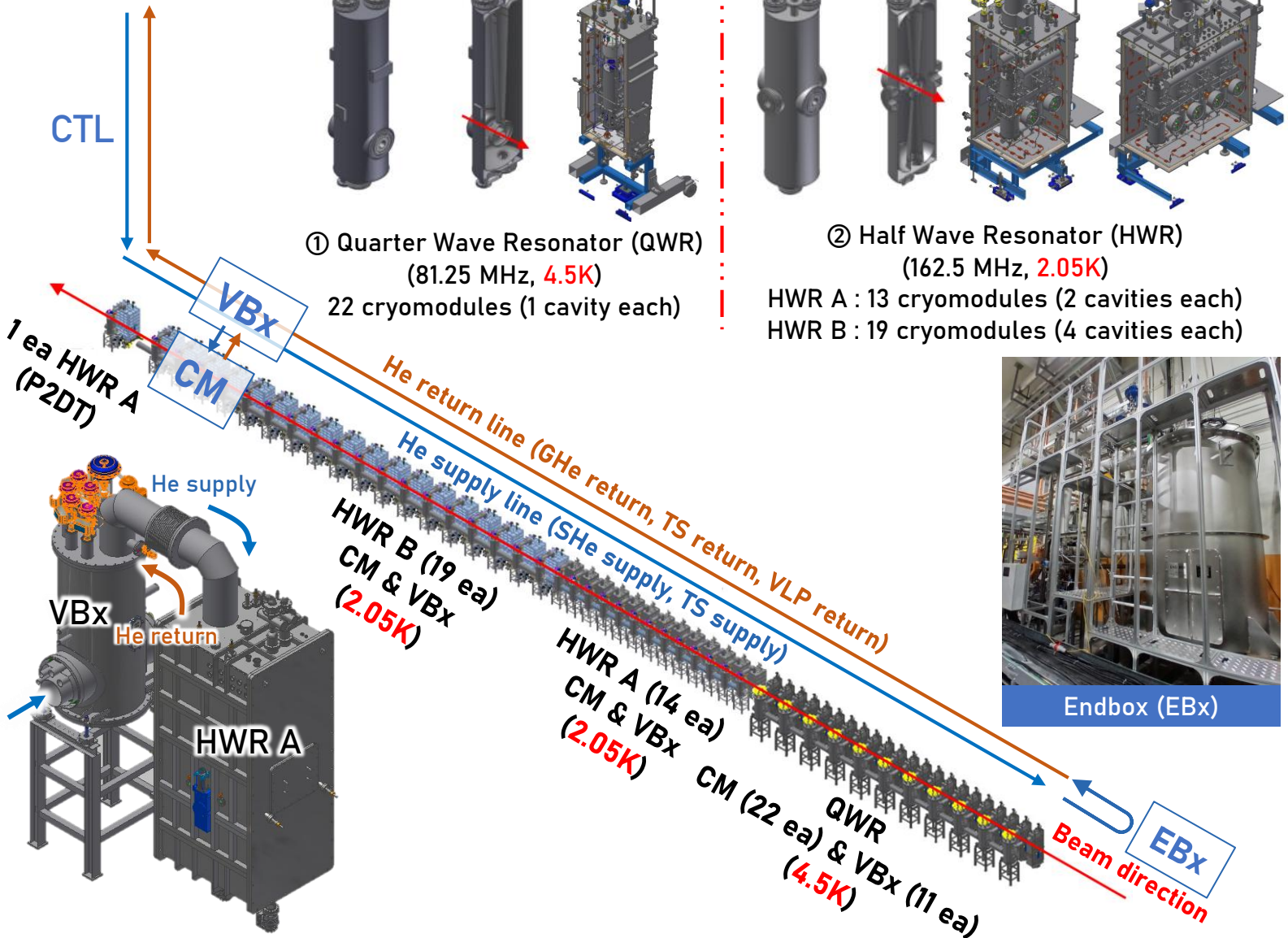




Distribution box (TBx)



Cryogenic Transfer Line (CTL)



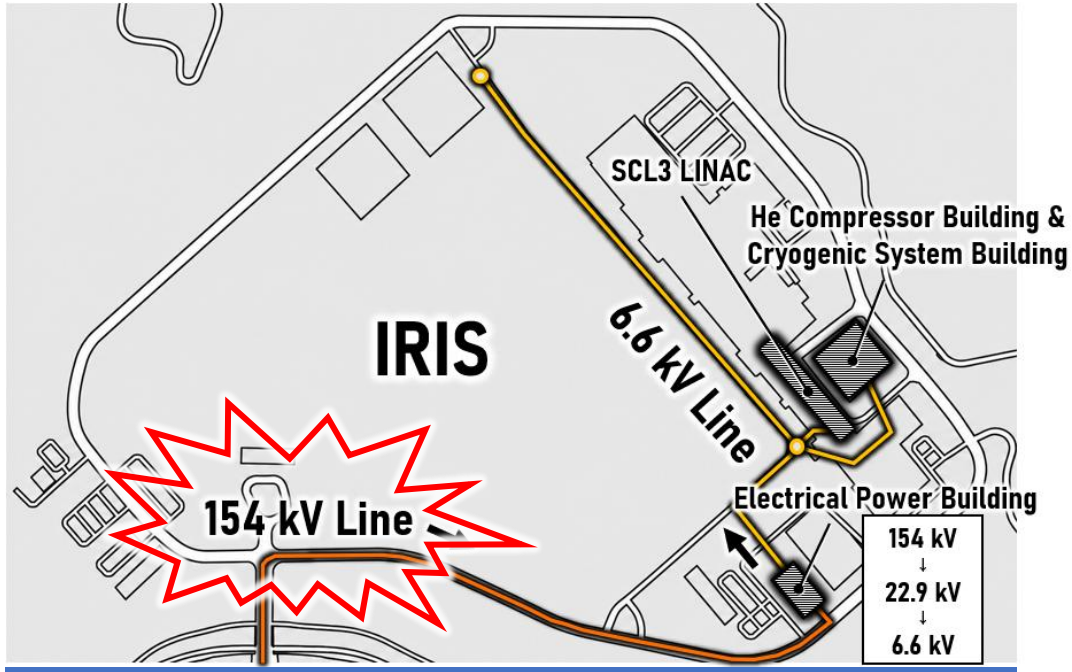
① Quarter Wave Resonator (QWR)
(81.25 MHz, 4.5K)
22 cryomodules (1 cavity each)

② Half Wave Resonator (HWR)
(162.5 MHz, 2.05K)
HWR A : 13 cryomodules (2 cavities each)
HWR B : 19 cryomodules (4 cavities each)

Endbox (EBx)

2. Overview of the power outage

- **Recovery Process Timeline and Overview**
  - On June 8, 2026, a 0.2 second power outage occurred due to an external power system disturbance.
  - The outage caused multiple equipment trips, including the vacuum pumps (TMP, Dry pump).
  - It took 2 days and 7 hours to restore 2 K operation, followed by an additional 1.5 days for control parameter adjustment and equipment inspection.



RAON Power Supply System Diagram

2026.06.08 (Mon.)

- 2K cryogenic system operating normally
- 14:33 — *0.2s power outage*
- 15:13 — 2K operation stopped + Warm up to 4.5K

06.09 (Tue.)

- 04:00 — CTL, EBx vacuum restored to 10^{-8} mbar
- 22:30 — Cryogenic system restored to 4.5K and stabilized

06.10 (Wed.)

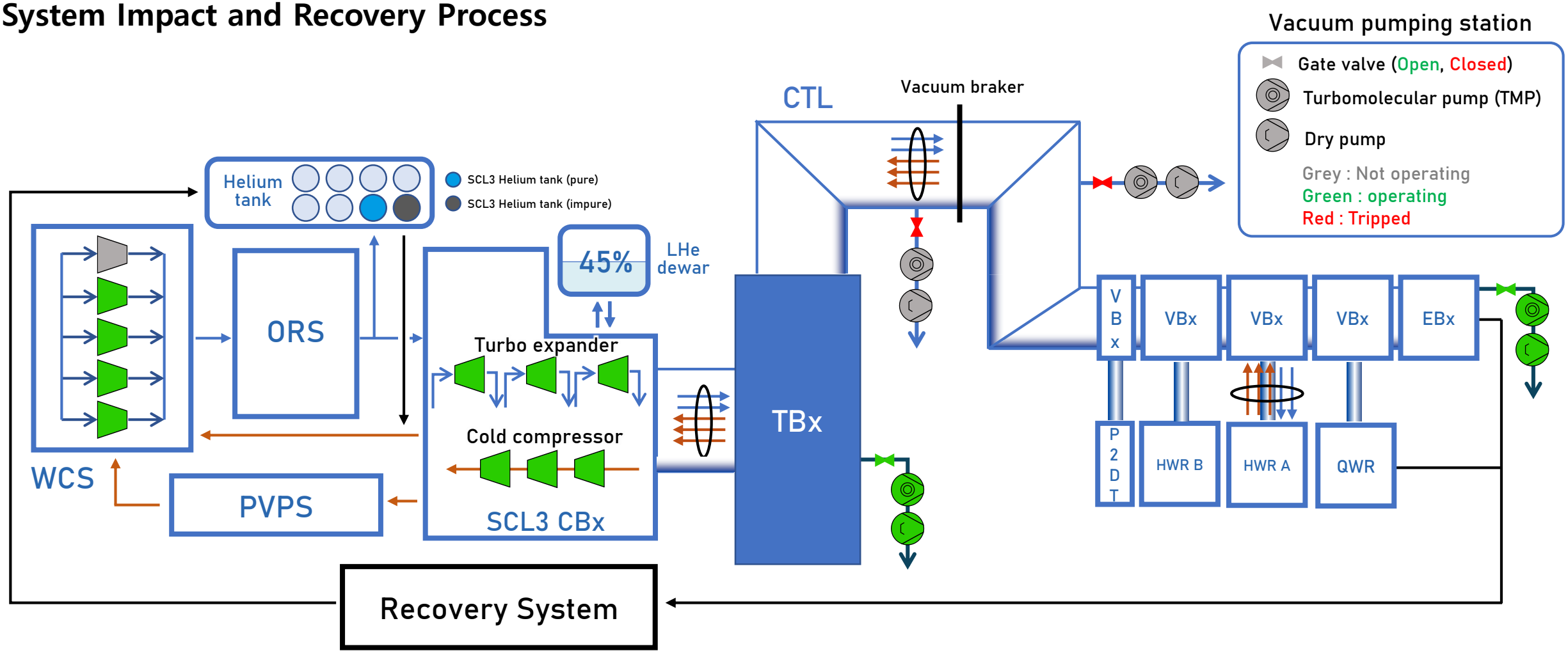
- 10:23 — 2K cool down initiated
- 22:00 — 2K operation restored and stabilized

06.12 (Fri.)

- 13:00 — Control parameter & equipment inspection finished

3. Cryogenic system response and Recovery process

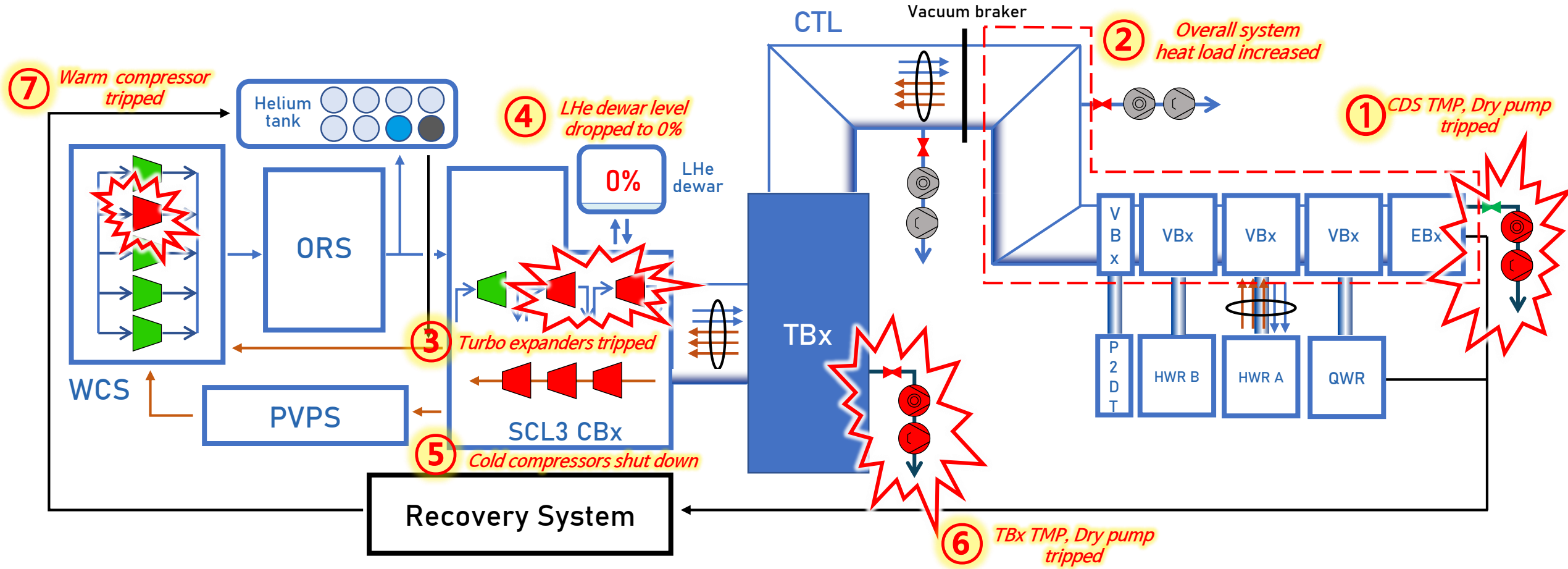
- **System Impact and Recovery Process**



<Before the power outage>

3. Cryogenic system response and Recovery process

- **System Impact and Recovery Process**



<After the power outage>

3. Cryogenic system response and Recovery process

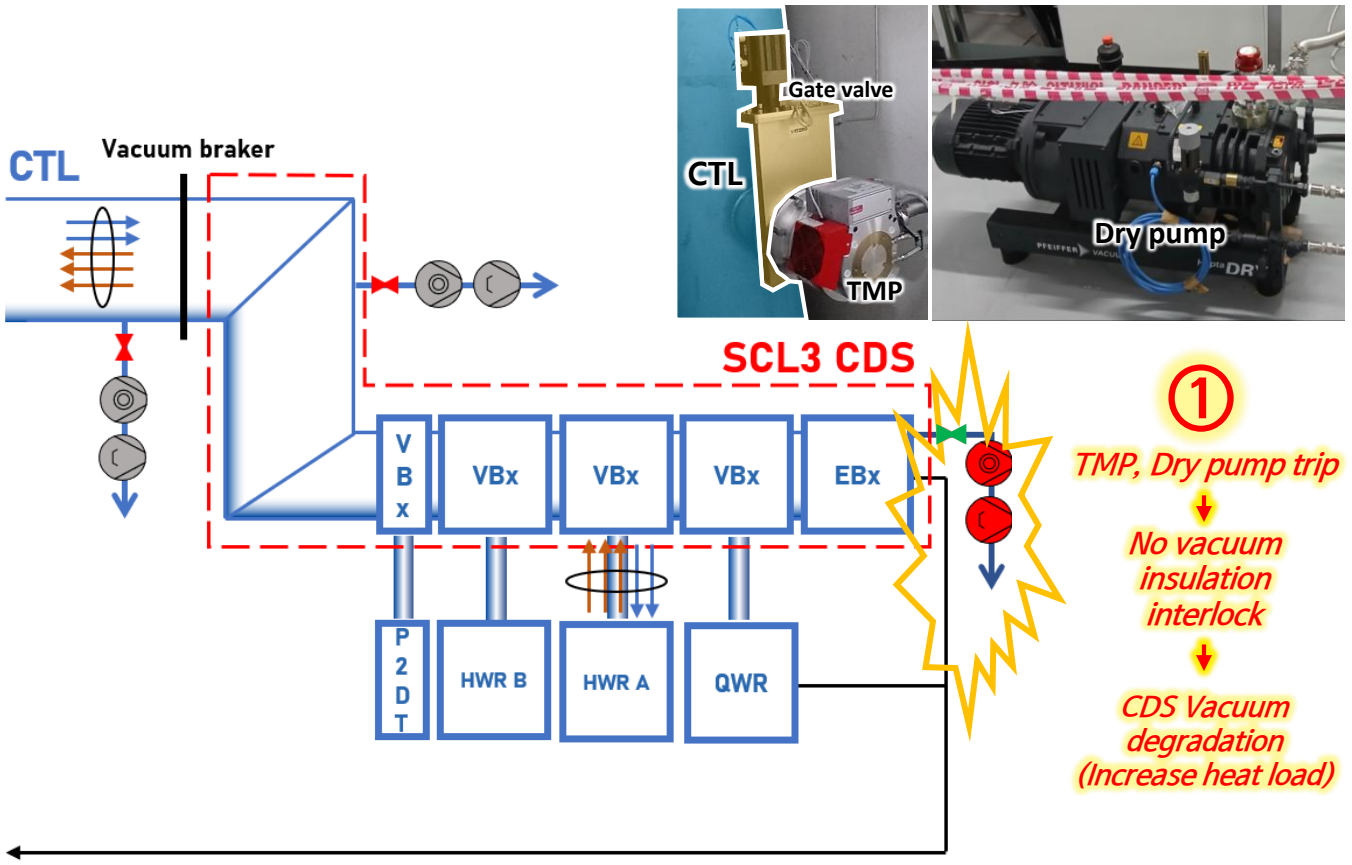
- **System Impact and Recovery Process – Vacuum insulation of CDS**

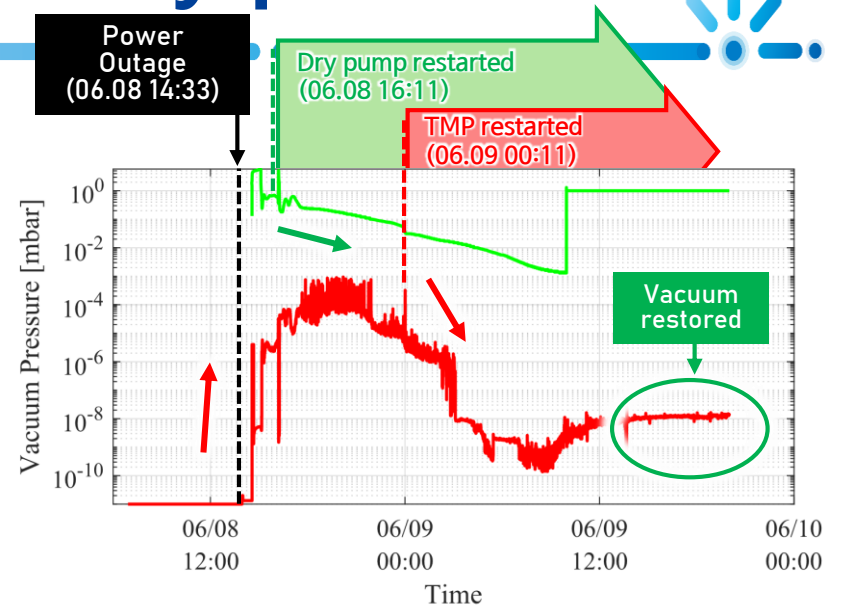
➢ 1) Only a single vacuum pumping station was used

+ 2) No vacuum insulation interlock was installed

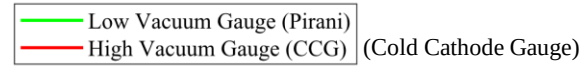
→ CDS vacuum pressure increased from 10^{-8} to 10^{0} mbar.

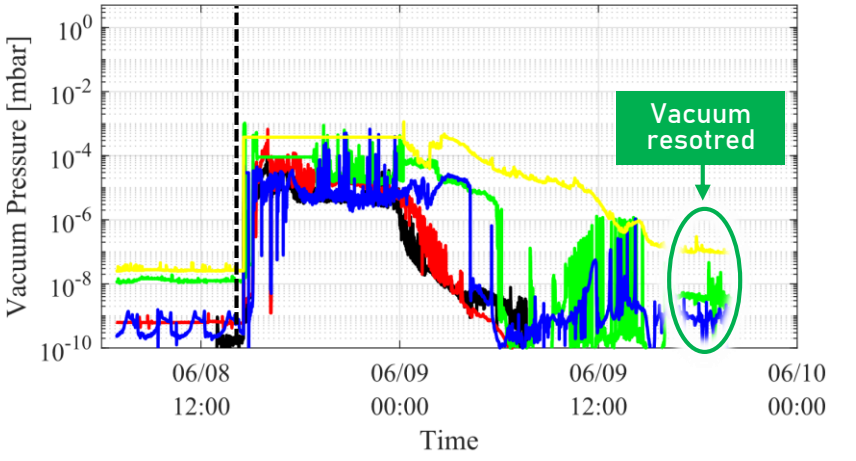
→ Heat load increased!



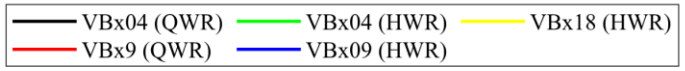


(a)





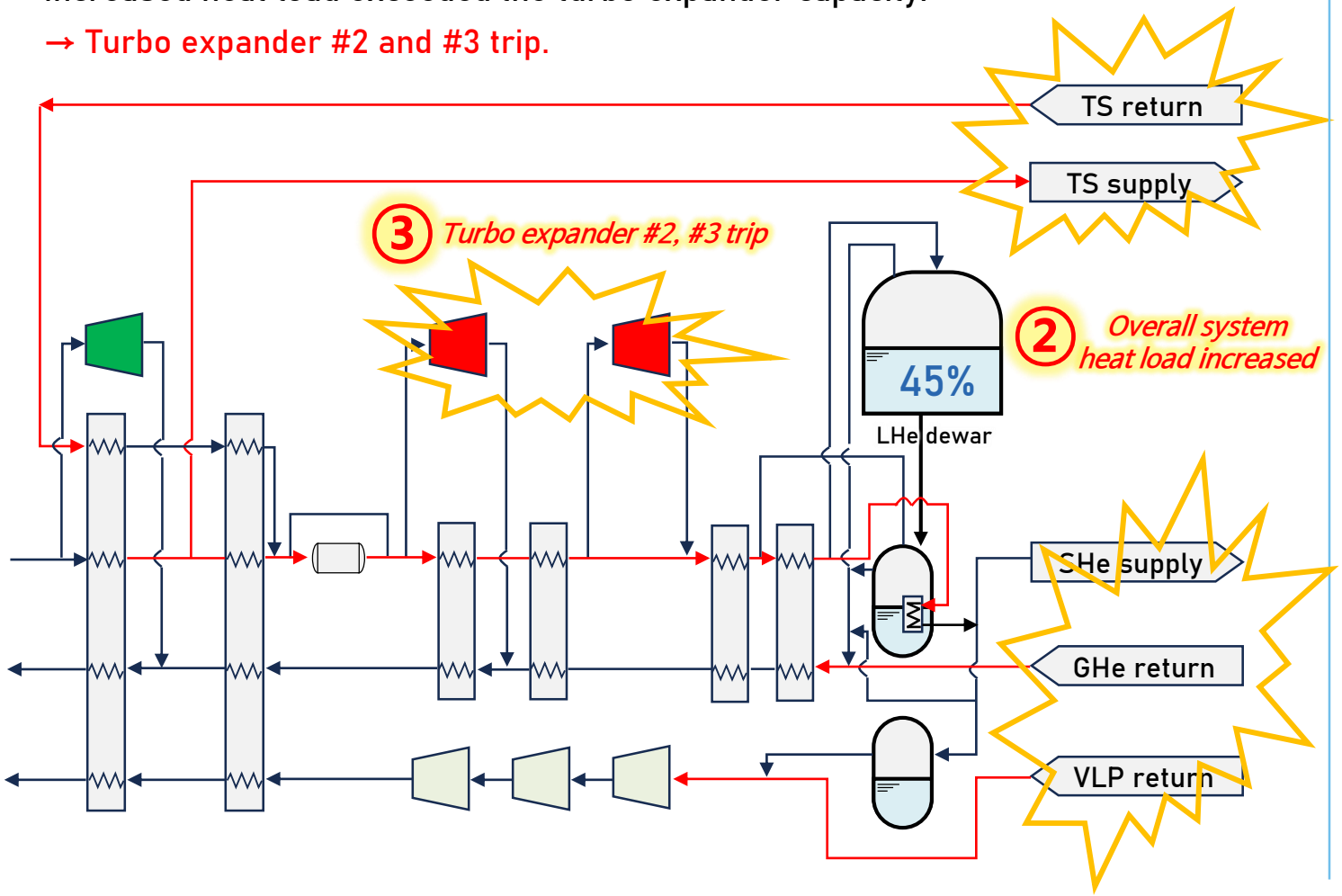
(b)

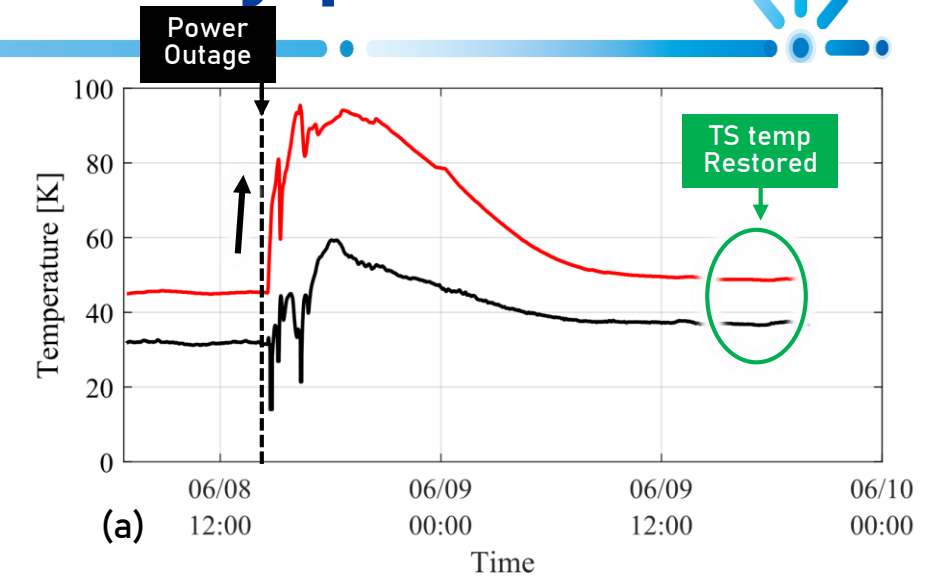


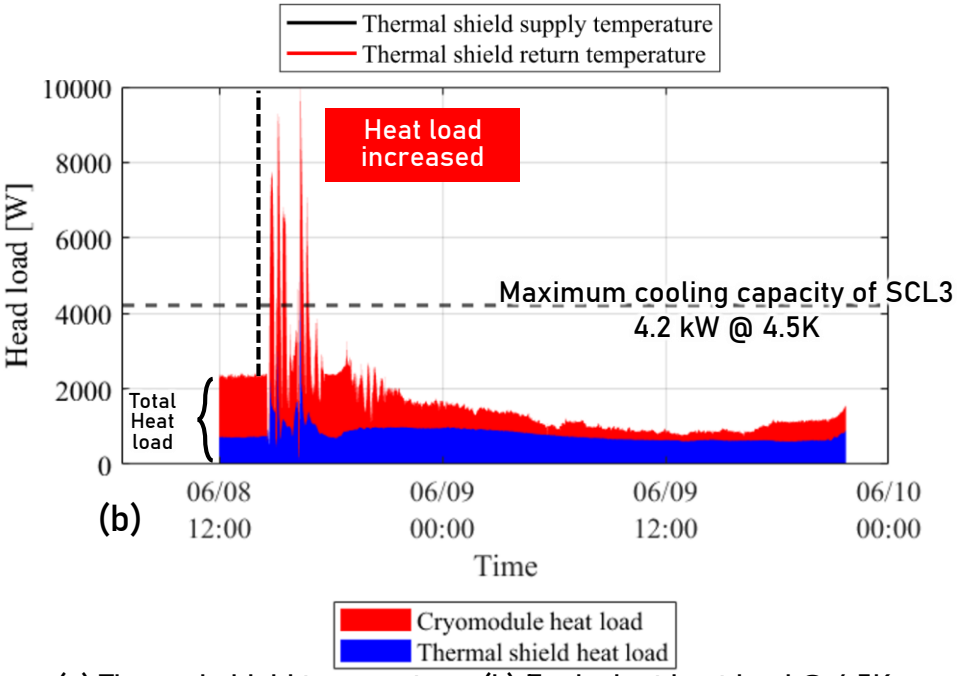
(a) EBx vacuum pressure, (b) VBx vacuum pressure (CCG)

3. Cryogenic system response and Recovery process

- **System Impact and Recovery Process – Turbo expander**
  - ➢ Vacuum degradation increased the heat load up to 10 kW @ 4.5K.
    (Maximum cooling capacity of SCL3 : 4.2 kW @ 4.5K)
  - ➢ Increased heat load exceeded the turbo expander capacity.
    → Turbo expander #2 and #3 trip.



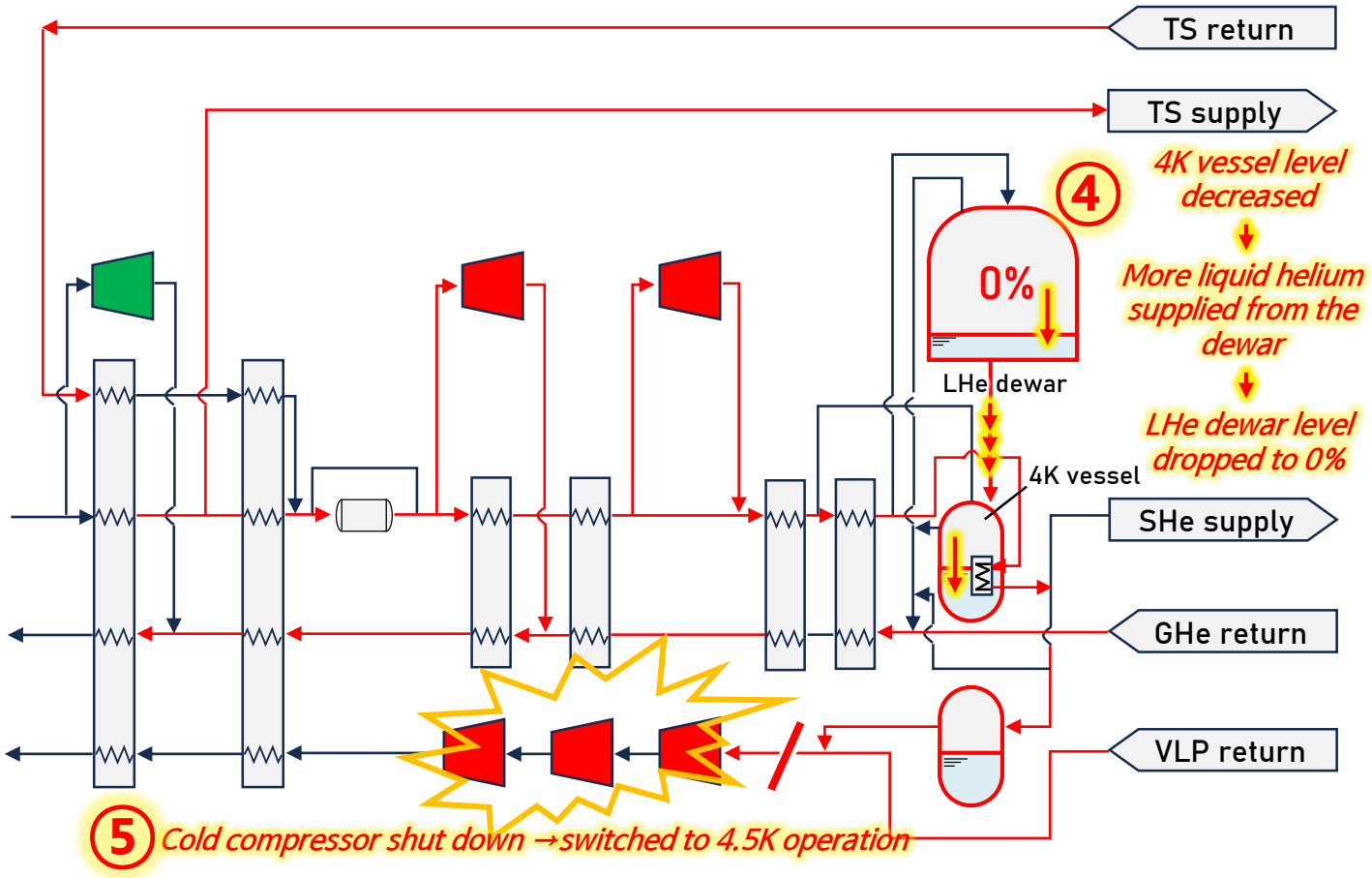


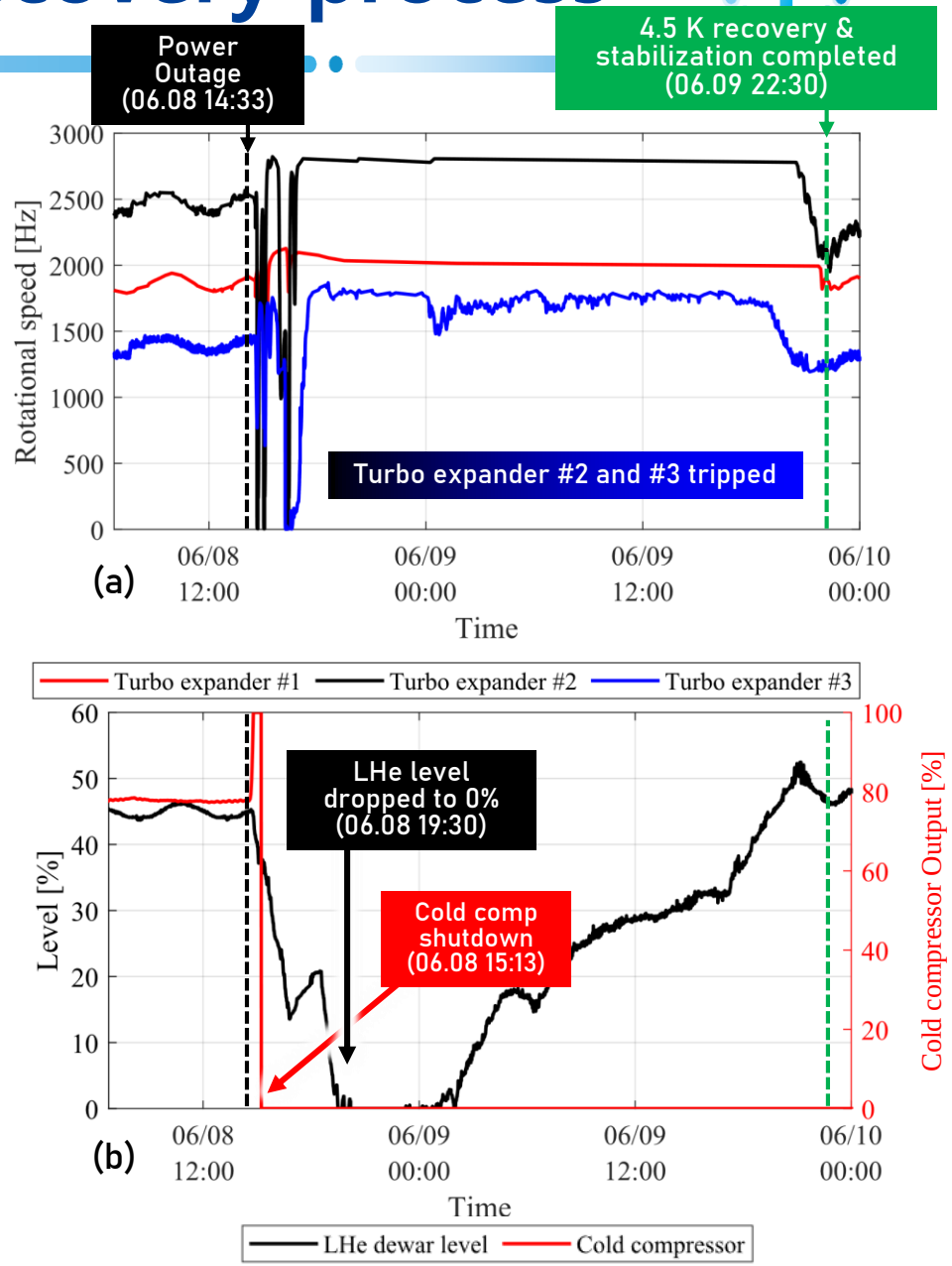


(a) Thermal shield temperature, (b) Equivalent heat load @ 4.5K

3. Cryogenic system response and Recovery process

- **System Impact and Recovery Process – LHe dewar**
  - ➢ All 2,200 L of liquid helium stored in the LHe dewar was used.
  - ➢ 2.05 K operation became unsustainable → Cold compressors were shut down and system was switched to 4.5 K operation mode.

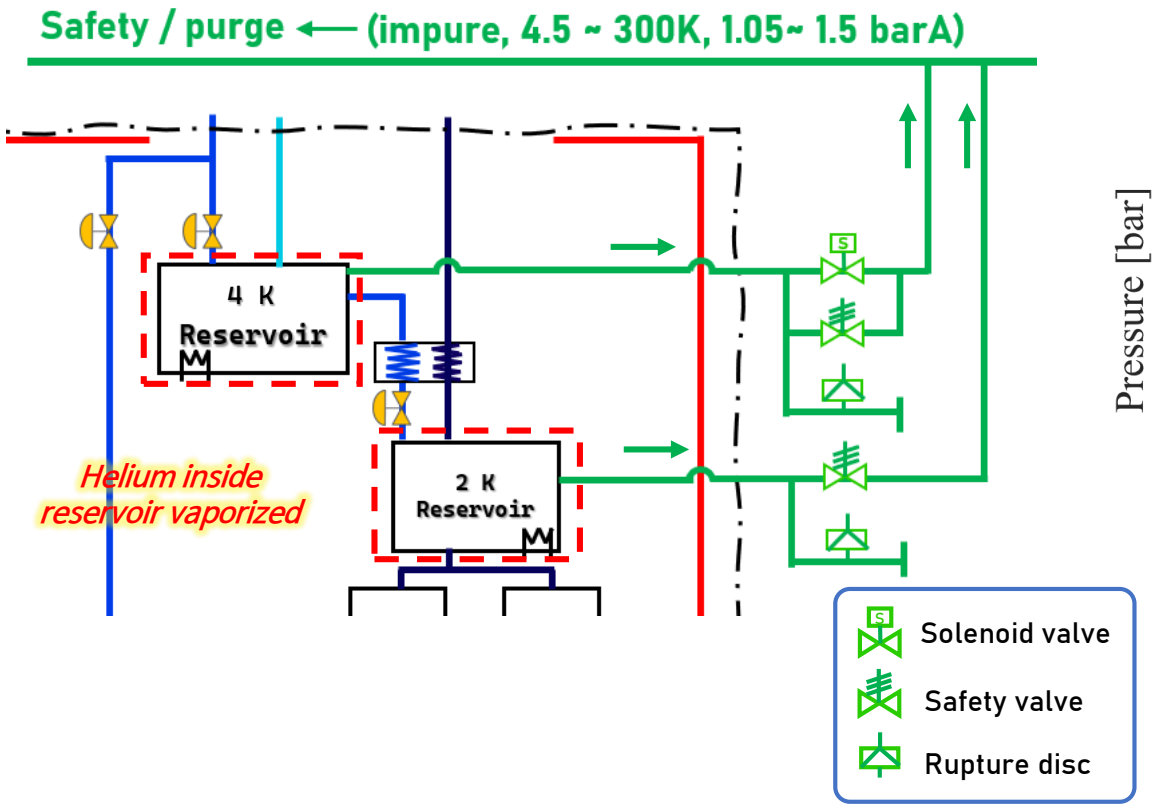


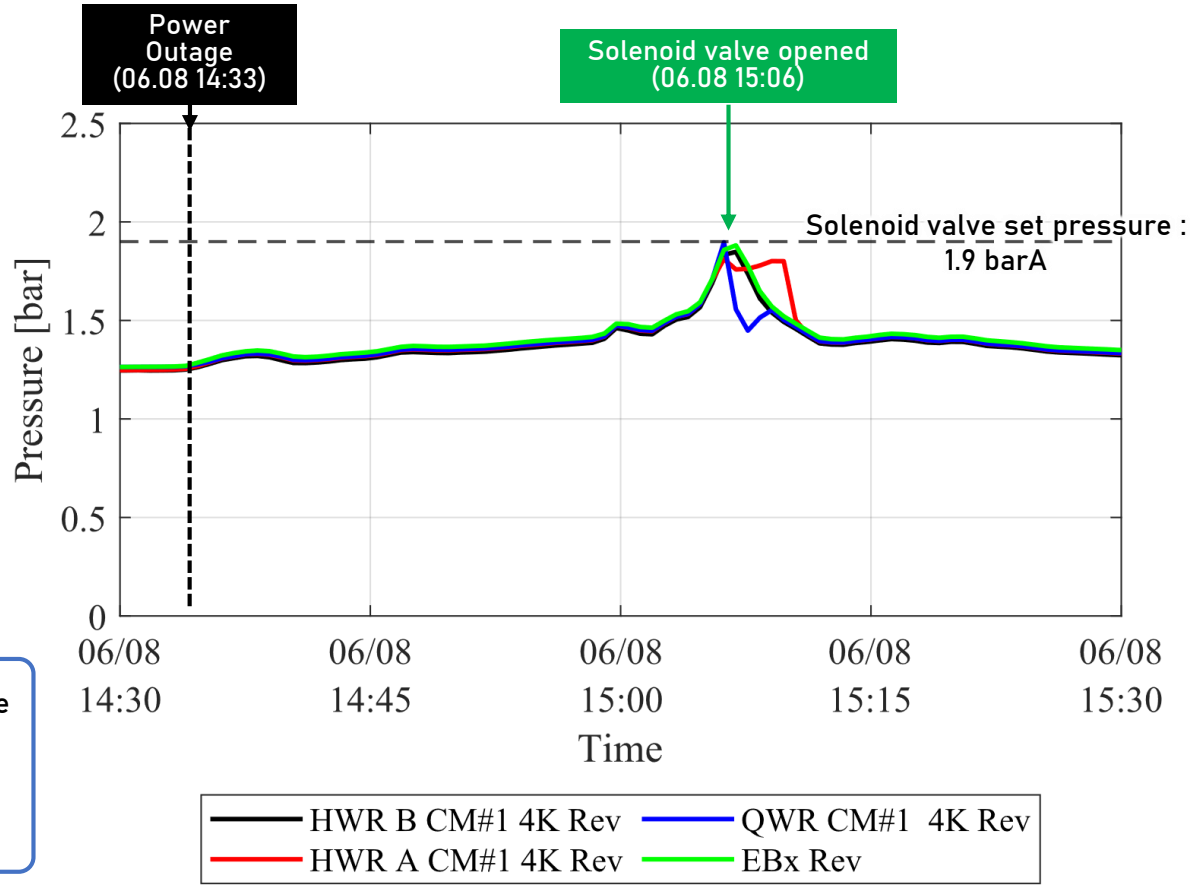


(a) Turbo expander status, (b) LHe dewar level and cold compressor status

3. Cryogenic system response and Recovery process

- **System Impact and Recovery Process – Recovery system**
  - ➢ Helium in the cryomodule reservoirs, cavities, and CDS rapidly vaporized.
  - ➢ Three pressure protection devices are installed: ① Solenoid valve, ② Safety valve ③ Rupture disc
  - ➢ The released helium gas was recovered through the Recovery system.

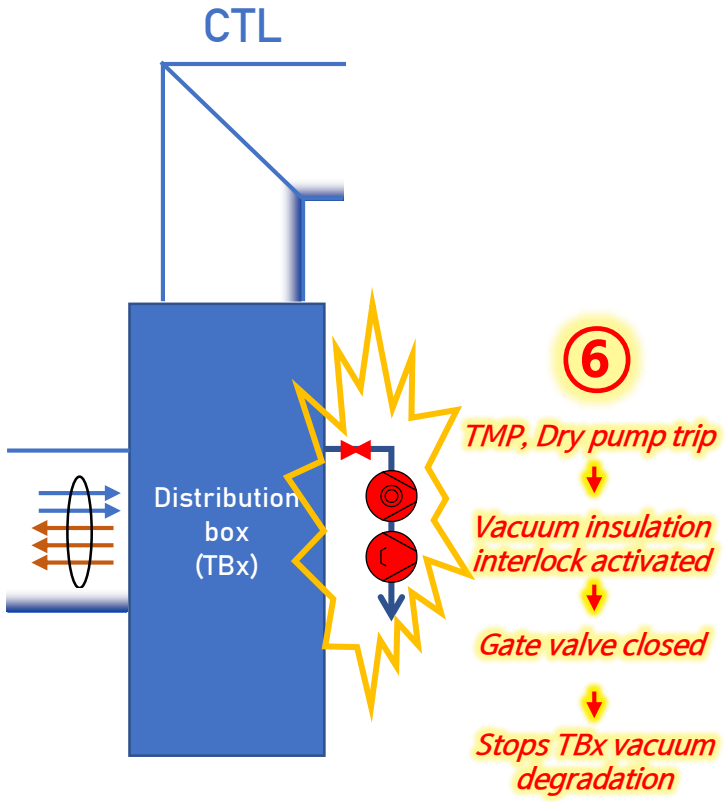


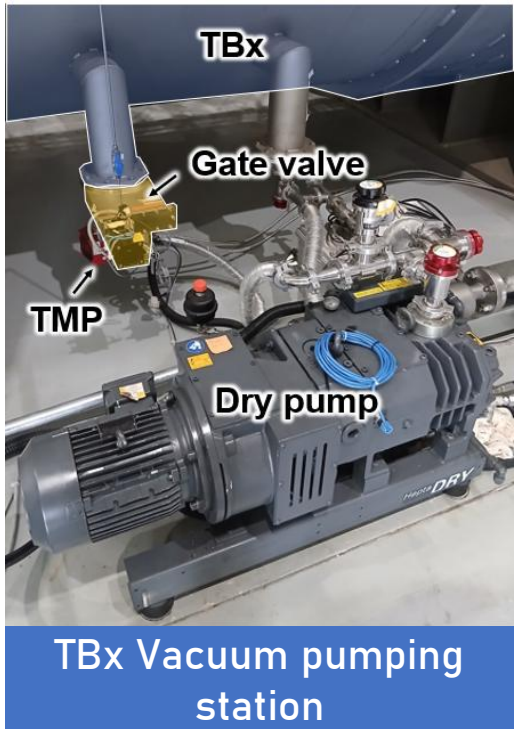


<4K reservoir pressure of selected Cryomodules>

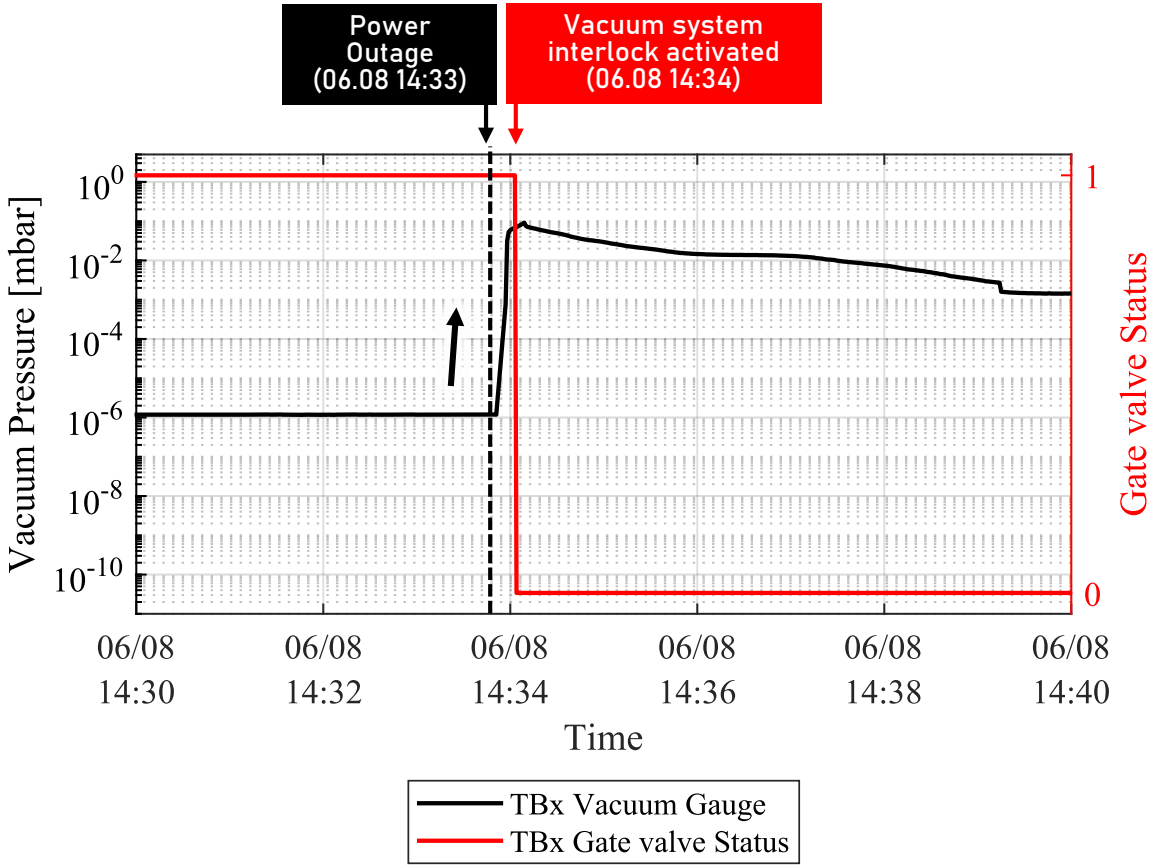
3. Cryogenic system response and Recovery process

- **System Impact and Recovery Process – Vacuum insulation of TBx**
  - For the TBx, the TMP and Dry pump also tripped during the power outage.
  - The vacuum insulation interlock was activated to prevent vacuum degradation.
  - This confirmed the importance of the vacuum system interlock.





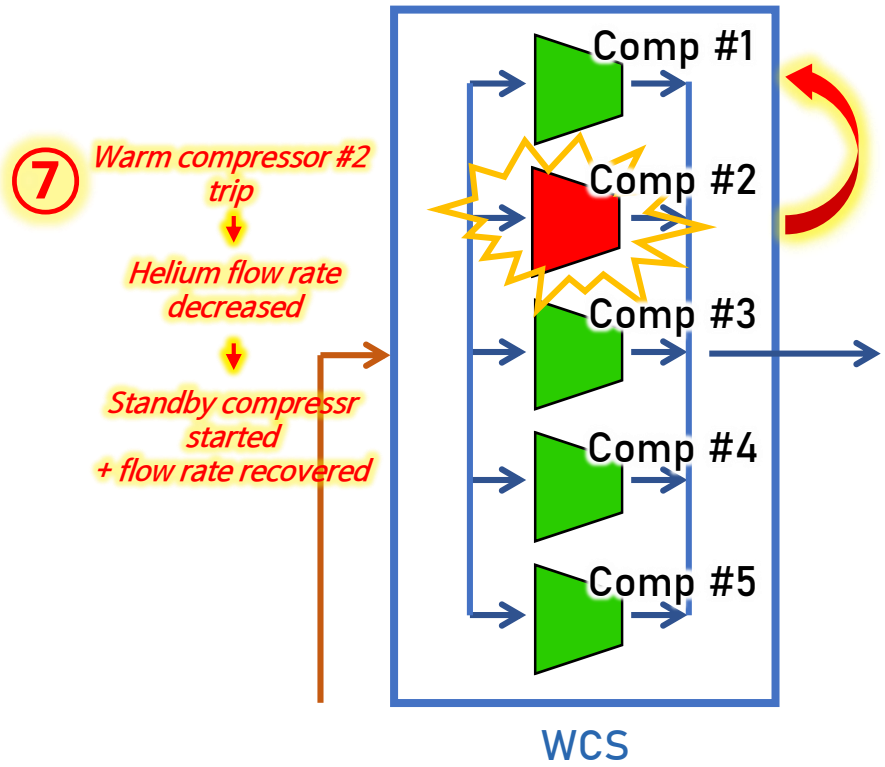
TBx Vacuum pumping station

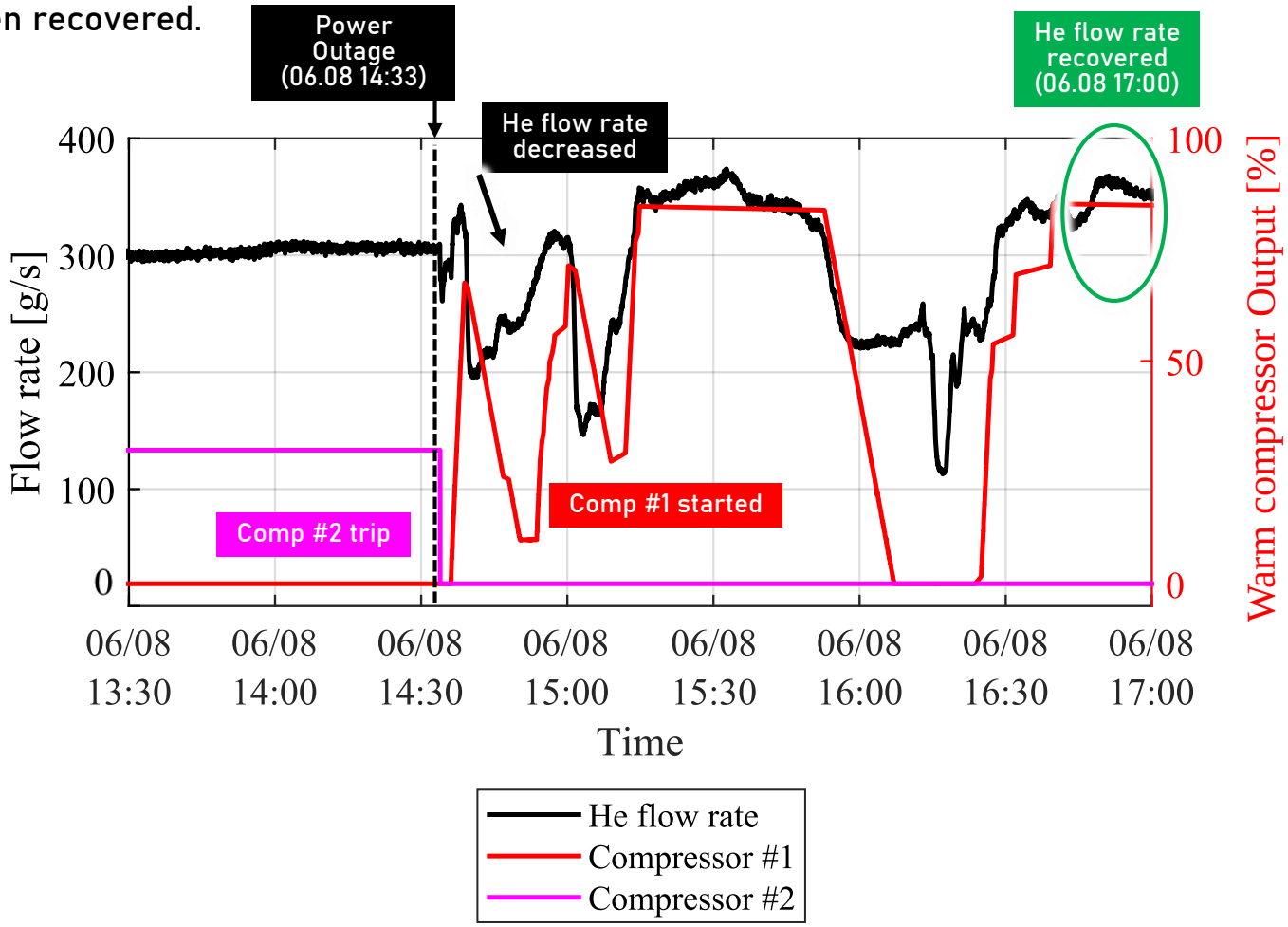


<TBx vacuum pressure and Gate valve status>

3. Cryogenic system response and Recovery process

- **System Impact and Recovery Process – Warm compressor**
  - The SCL3 cryogenic system has five warm gas compressor : 4 in operation and 1 on standby
  - Compressor #2 tripped and failed to restart, So the Standby compressor was started.
  - Helium flow rate decreased from 300 g/s to 150 g/s and then recovered.

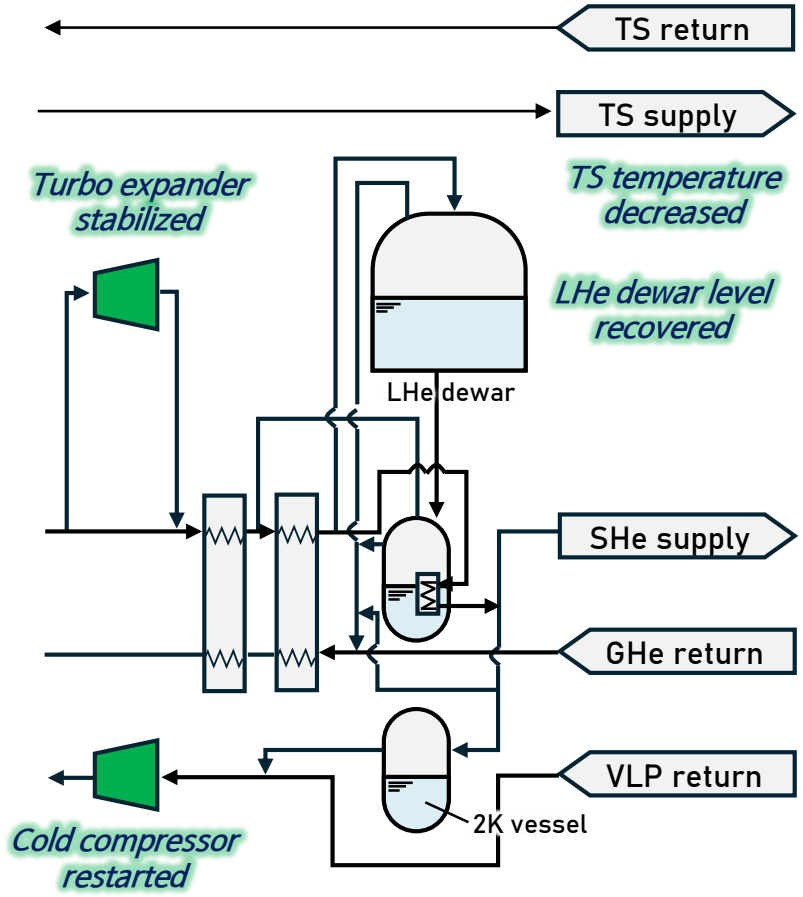


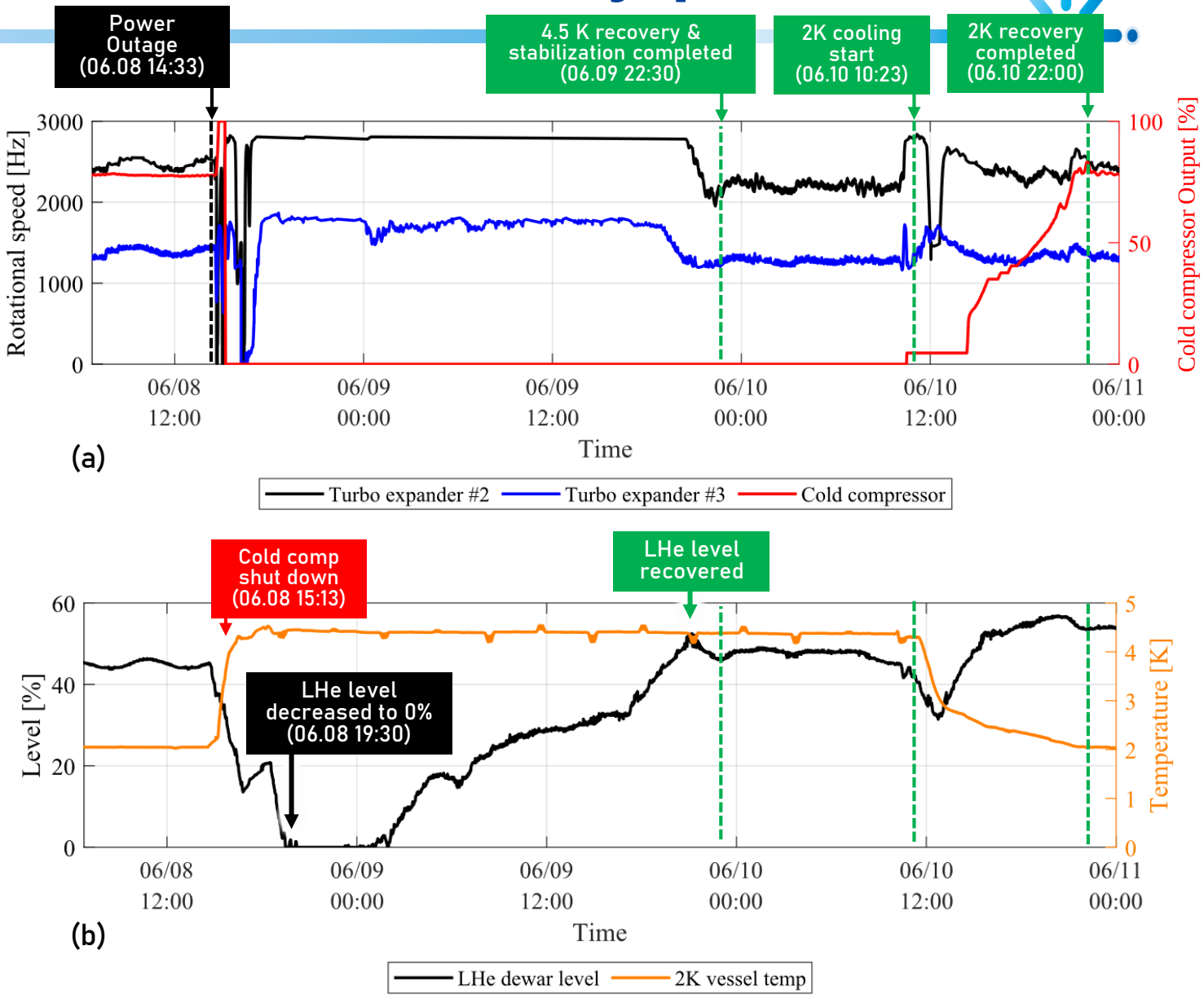


<Helium flow rate and warm compressor status>

3. Cryogenic system response and Recovery process

- **System Impact and Recovery Process**
  - 2.05K operation was restored 2 days 7 hours after the power outage.
  - An additional 1.5 days for parameter tuning, stabilization, and equipment inspection.





(a) Turbo expander & Cold compressor status, (b)LHe dewar level and 2K vessel temperature

3. Cryogenic system response and Recovery process

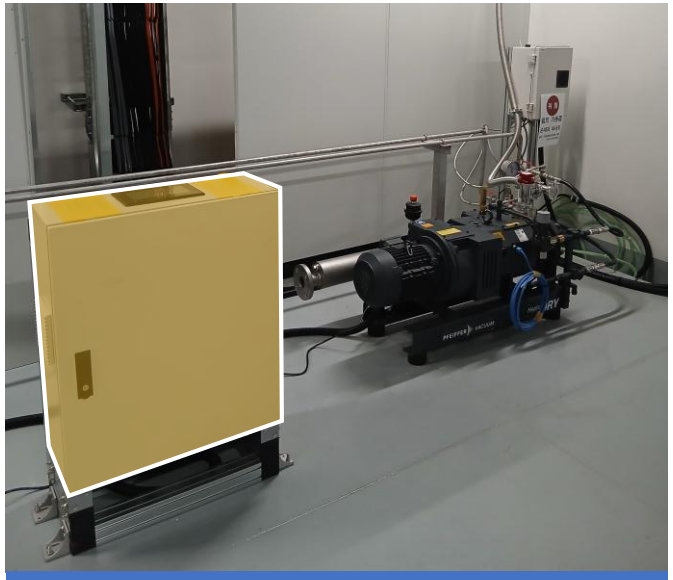
- **Equipment Status and UPS (Uninterruptible Power Supply system) Configuration**

<Equipment status after the power outage and UPS configuration>

Category	Equipment		Status	Power supply	Power	Num of unit	UPS
Cryoplant	Control rack		No effect	1-phase	2 kW/unit	12	O
	EPICS IOC servers		No effect	1-phase		6	O
	Coldbox MCB	Vacuum pumps, Heaters	No effect	3-phase	88 kW	1	X
		Coldbox turbo expander	T#2, T#3 tripped	-	-	3	X
	Cold compressor		No effect	3-phase	15 kW/unit	3	X
	Warm compressor		1 unit tripped	3-phase	315 kW/unit	4	X
	PVPS		No effect	3-phase	22 kW/unit	4	X
CDS	Control rack (Gallery)		No effect	1-phase	3 kW/unit	45	O
	TBx vacuum pumps		Tripped	3-phase	4.8 kW/unit	5	X
	SCL3 Endbox vacuum pumps		Tripped	3-phase	4.8 kW	1	X
	Cryomodule vacuum pumps		No effect	1-phase	240 W/unit	23	X
Others	PCW Pumps		No effect	3-phase	150 kW/unit	2	X
	DIW Pumps		No effect	3-phase	30 kW	1	X
	Control PCs		No effect	1-phase	-	4	X

Conclusion and Future plan

- **Conclusions**
  - On June 8, 2026, the SCL3 cryogenic system experienced a 0.2 second power outage
  - Among the equipment trips, the CDS vacuum pumping station(TMP and Dry pump) had the most significant impact on the system.
  - The vacuum pump trip caused vacuum degradation and a significant increase in heat load, making 2K operation unsustainable.
  - 2K operation was restored 2 days and 7 hours after the power outage, followed by an additional 1.5 days for parameter tuning, stabilization, and equipment inspection.
- **Future plan**
  - Implement vacuum insulation interlock to isolate the vacuum system in case of vacuum pump trip.
  - Consider additional UPS backup for critical equipment currently without UPS protection.



Interlock rack for CTL vacuum pumping station



Interlock rack for EBx vacuum pumping station

중이온가속기연구소
Institute for Rare Isotope Science

Thank You!

Question and Discussion

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Research Fellow, Cryogenic System Team

Acknowledgements

IBS-IRIS Cryogenic System Team

- Jae Hee Shin, Min Ki Lee, Hyun Chul Jo, Sujin Oh, Gyuho Lee, Jinwook Kim, Jaehak Han

MKV Maintenance Team

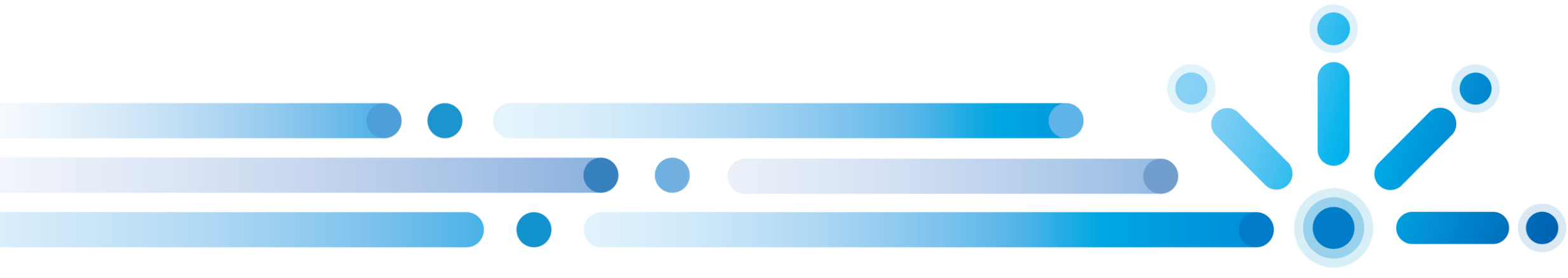
- Jaeho Seo, Youngjae Kim, Deokgi Kim, Jinwoo Park, Dohyun Choi

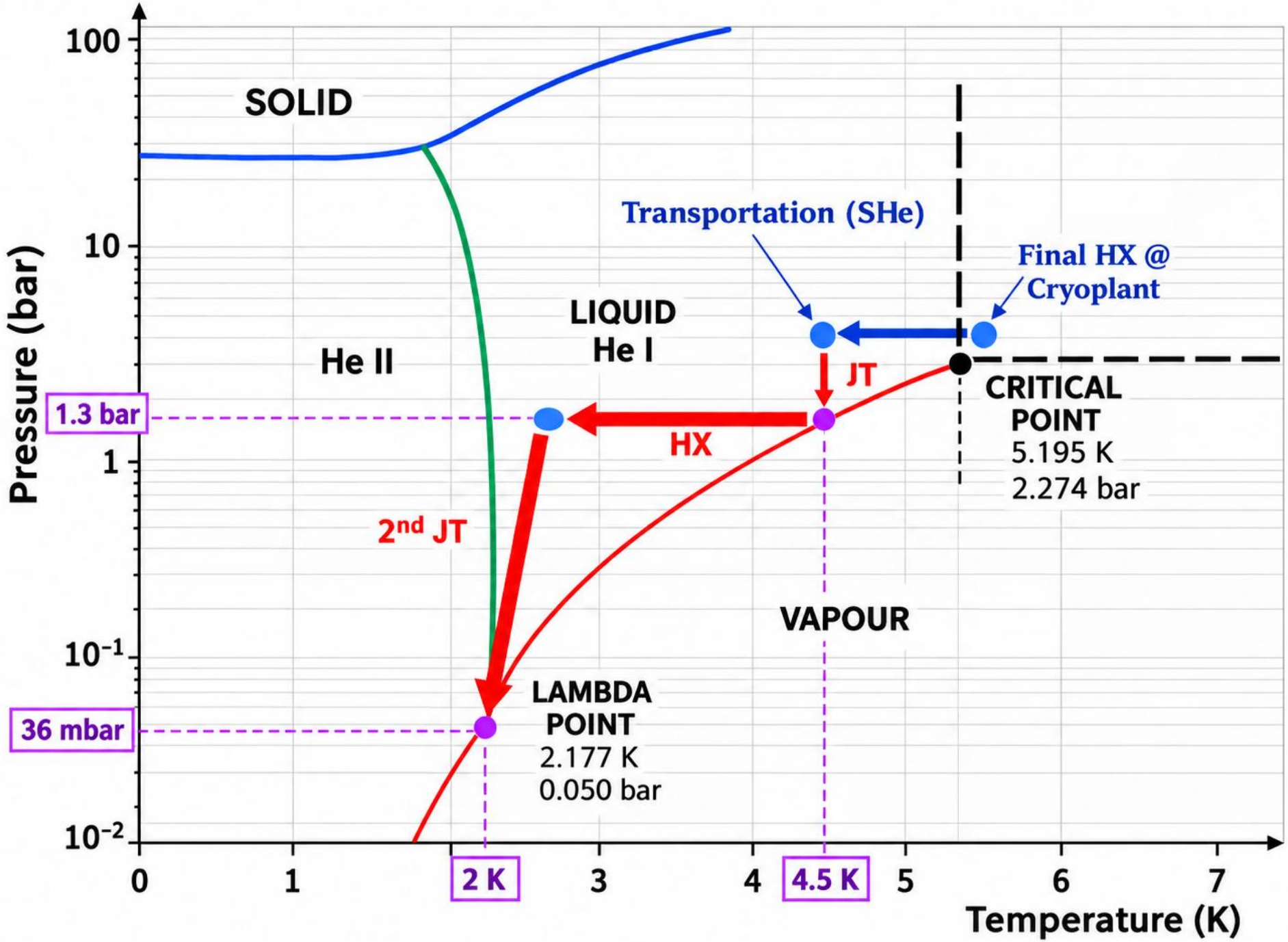
MKV Operation Team

- Jinsoo Park, Chahyun Park, Eunsung Kim, Hanseul Kim, Jiwoo Yoon, Inseong Song, Jihyun Lee, Yoongeon Im, Junho Jang

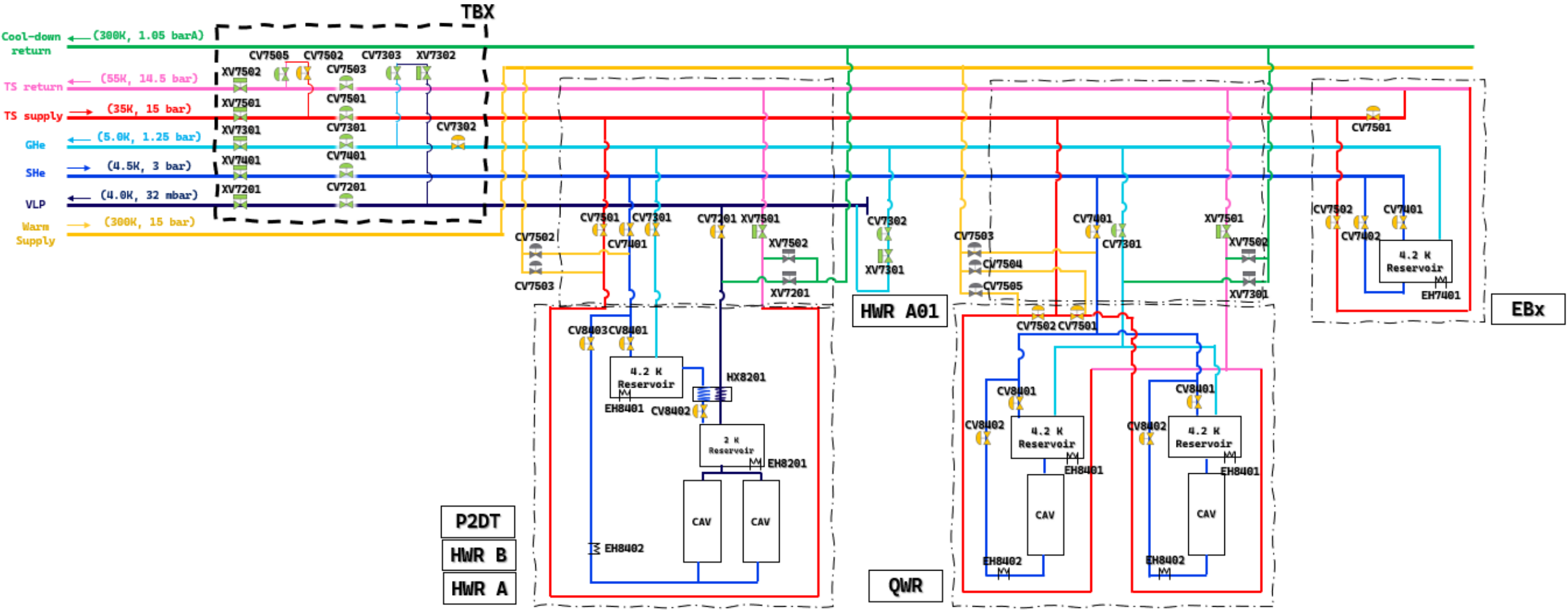
This work was supported by the Institute for Basic Science.

Appendix




SOLID
He II
LIQUID
He I
Transportation (SHe)
Final HX @
Cryoplant
JT
HX
2nd JT
CRITICAL
POINT
5.195 K
2.274 bar
VAPOUR
LAMBDA
POINT
2.177 K
0.050 bar
1.3 bar
36 mbar
2 K
4.5 K
Pressure (bar)
Temperature (K)
100
10
1
10⁻¹
10⁻²
0
1
3
4
5
6
7

P&ID SCL3 LINAC & CDS



SCL2 cryogenic plant vs SCL3 cryogenic plant

	SCL2	SCL3	Remark
Cooling power	13.5 kW	4.2 kW	at 4.5 K equivalant
Power consumption	< 5.2 MW	< 1.5 MW	
Maximum cooling water	< 610 m^3/hr	< 140 m^3/hr	
Maximum operating pressure	21 barA	15 barA	
Medium pressure	O	X	
Number of compressors	5 (HP, LP, VLP comp.)	5 (HP comp.)	1 standby compressor
Number of VFD compressors	1 (LP comp.)	2 (HP comp.)	
Maximum flow rate	1,457.1 g/s	331.3 g/s	
Number of turbines	4 (C5, C4, C3)	3 (C5, C3)	
Number of cold compressors	3	3	
Number of buffer tanks	2 (2* 250 m^3)	1 (1* 250 m^3)	



TMP (Turbomoelcular pump)

Model	Hipace 700
Manufacturer	PFEIFFER
Ultimate pressure	1.0E-07 mbar
Fore vacuum	11 mbar
Pumping speed	655 L/sec



Dry pump

Model	Hepta 100P
Manufacturer	PFEIFFER
Ultimate pressure	1.0E-02 mbar
Pumping speed	36.11 L/sec