Cryogenic Status of J-PARC Neutrino Superconducting Magnet System

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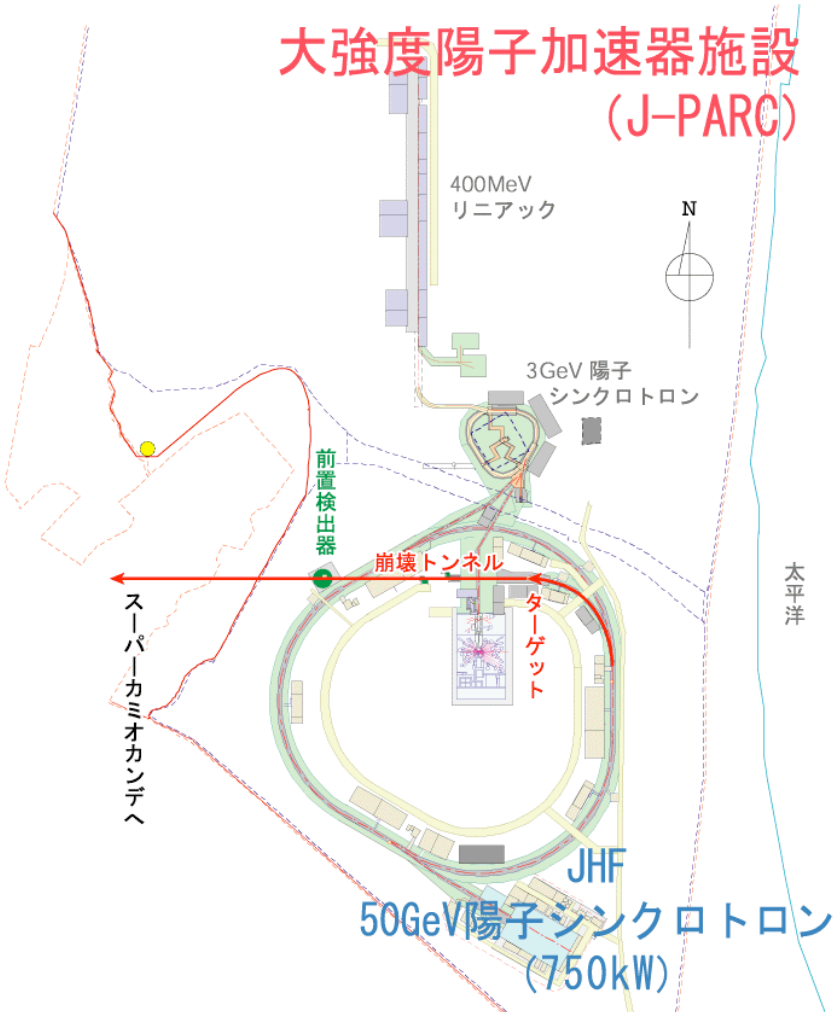
1. Purpose

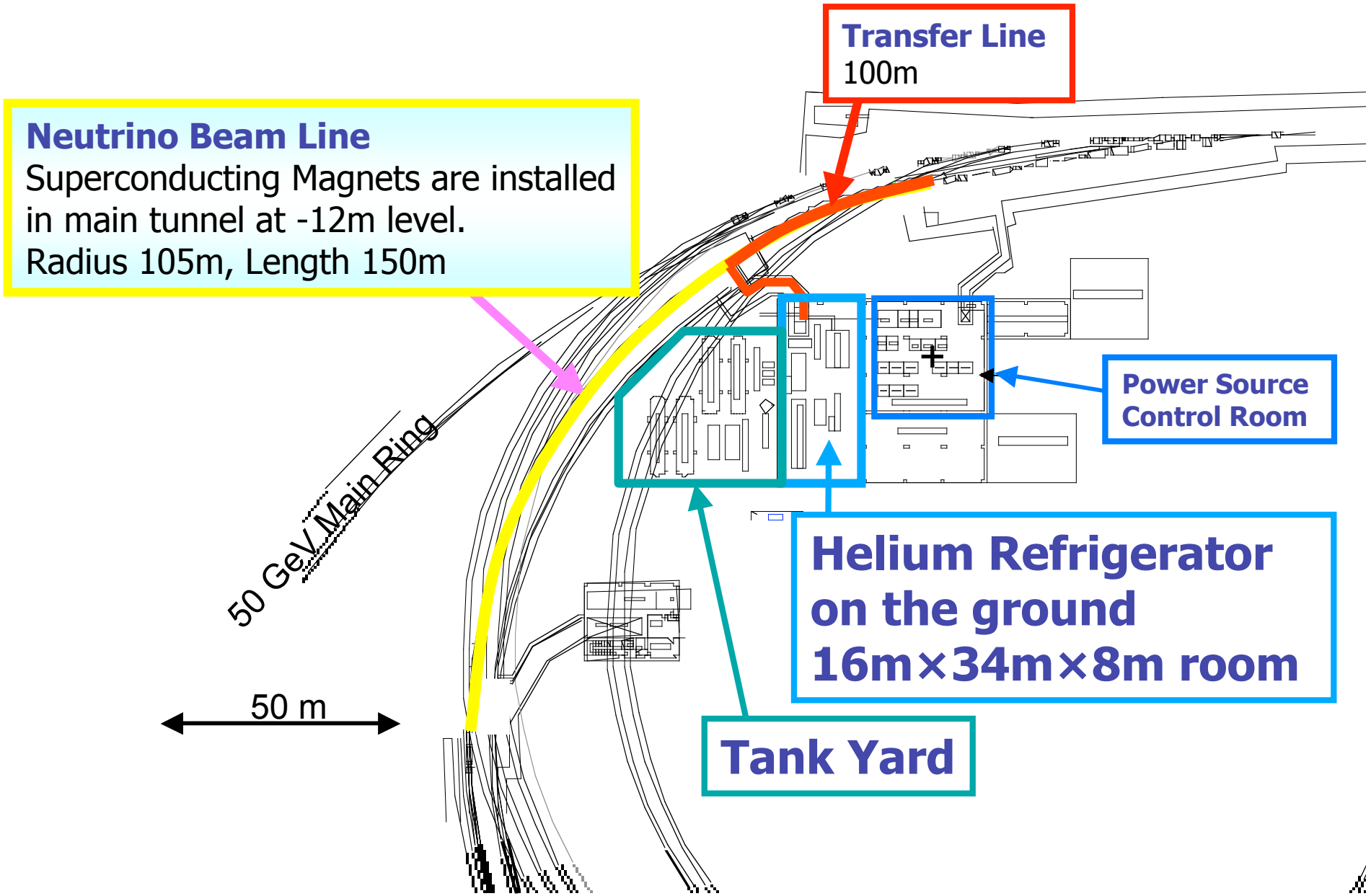
- A neutrino experiment facility using the J-PARC 50 GeV 0.75 kW proton beam is now under construction at Tokai campus of KEK.

- In this project, a superconducting magnet system, which consists of 28 superconducting combined-function magnets, will be installed in an arc section of the primary proton beam line to bend the beam to Kamioka.

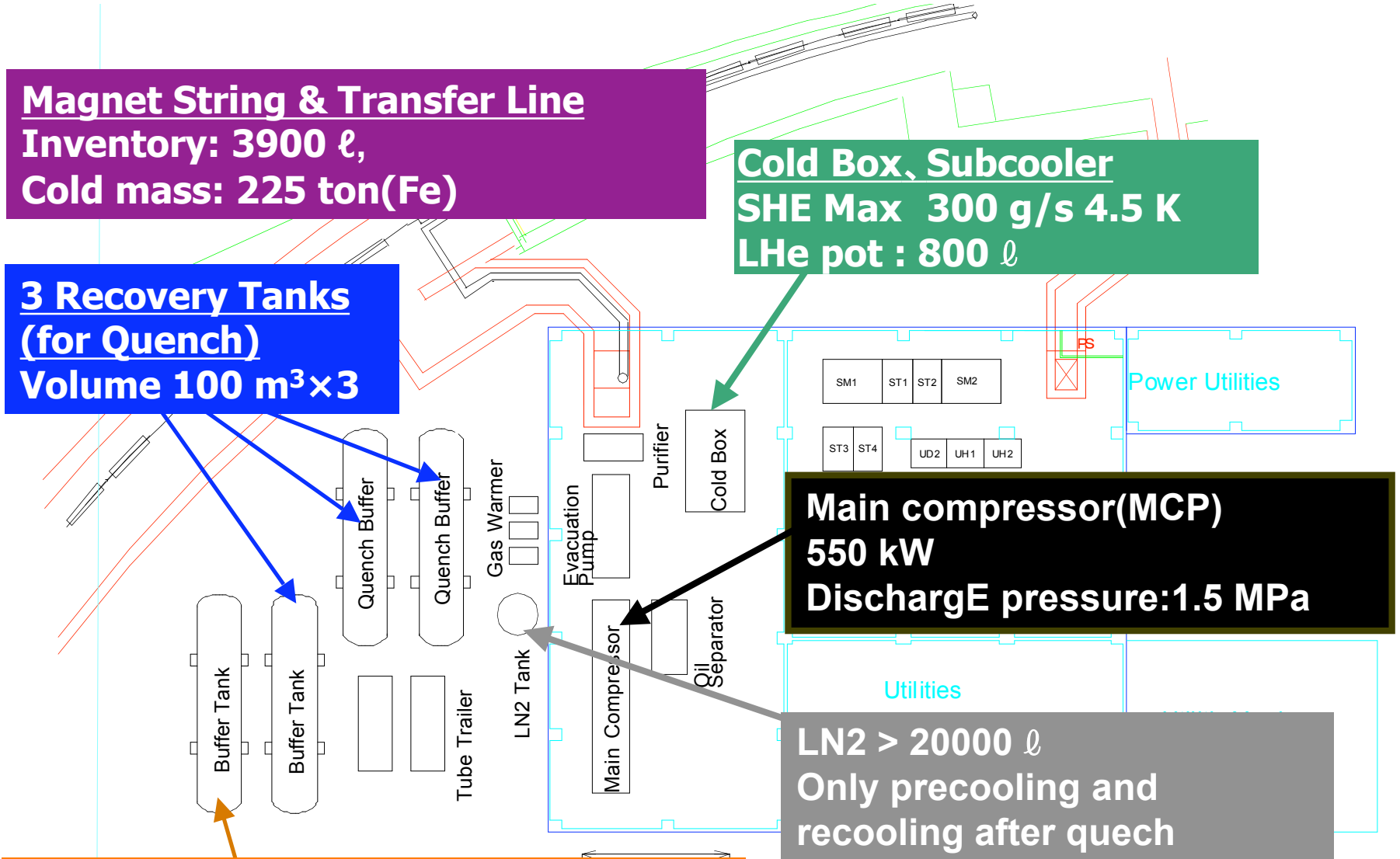
- This cryogenic facility is essential to keep superconducting magnets below 5.0 K



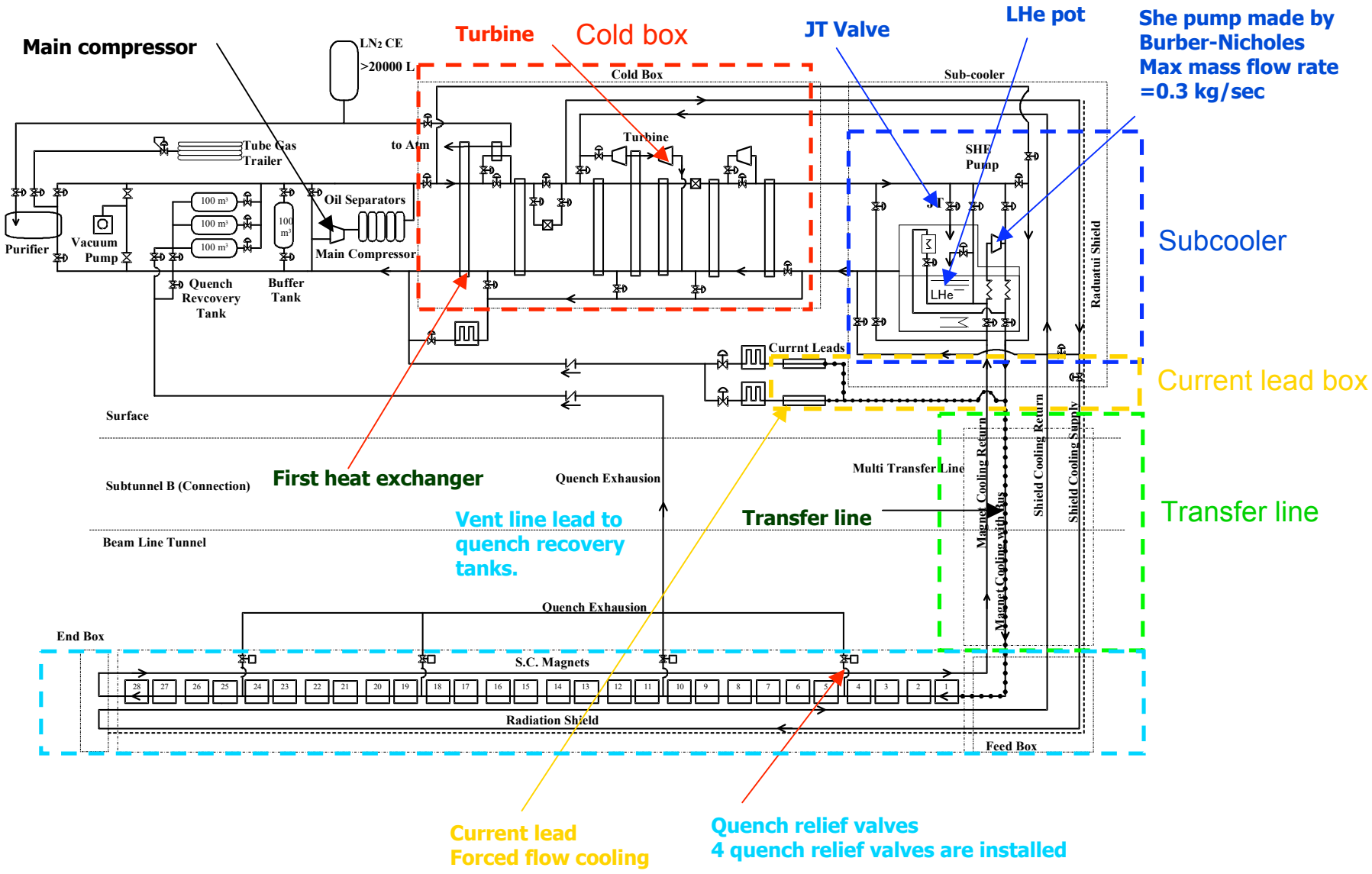
2. Overall Layout



2. Layout of Cryogenic Components



3. Conceptual Flow Diagram



4. Refrigerator Specifications

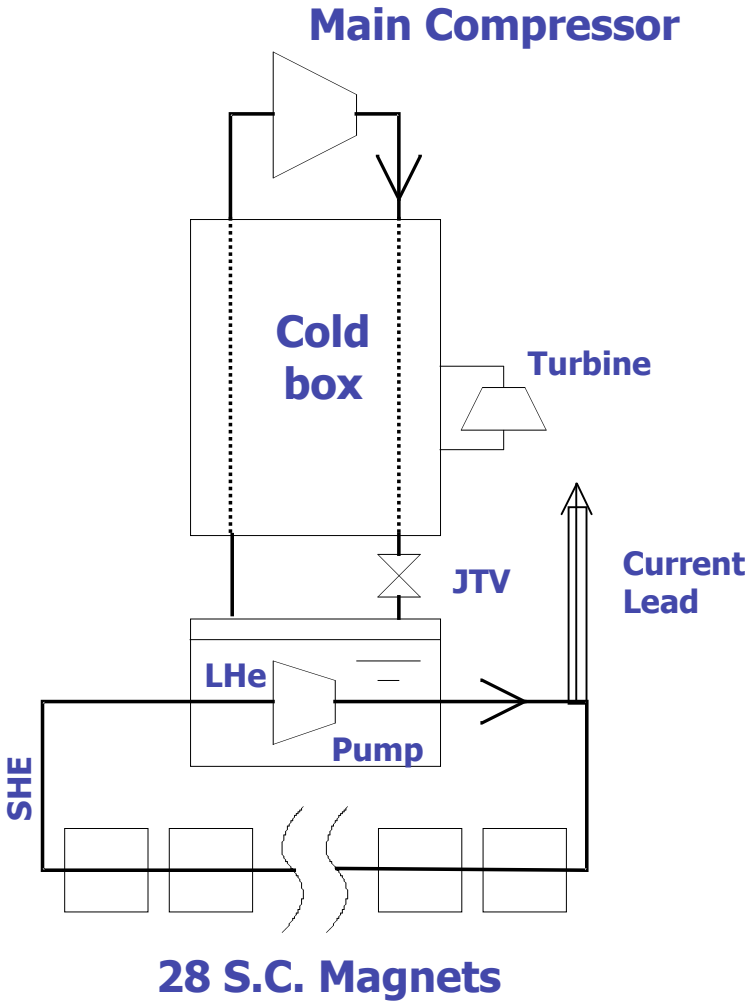
4-1. Summary of Load (Magnet & Transfer Lines) to Cryogenic System

	4.5 K Level	Remarks	80 K Level	Remarks
Coolant	SHE	4.5 K、0.4 MPa	He Gas	60～100 K, 1.2 MPa
Heat Load Estimation	336 W	Including beam loss of 150 W	1419 W	
Current Lead	1.0 g/s	7600A	-	
+ 20 % Contingency	403 W + 1.1 g/s		1703 W	
Cold Mass	204 ton	Iron basis	6.8 ton 2.5 ton	Aluminum basis Iron basis
+ 10 % Contingency	225 ton	Iron basis	7.5 ton 2.8 ton	Aluminum basis Iron basis
Inventory	3550 ℓ		1620 ℓ	
+ 10 % Contingency	3900 ℓ		1780 ℓ	
Pressure Drop	84 kPa	300 g/s, 4.5 K, 400 kPa	36 kPa	40 g/s, 80 K, 1.35 MPa
Design Pressure	>1.8 MPa(G)		>1.8 MPa(G)	

4. Refrigerator Specification

4-2. Required Cooling Capacity

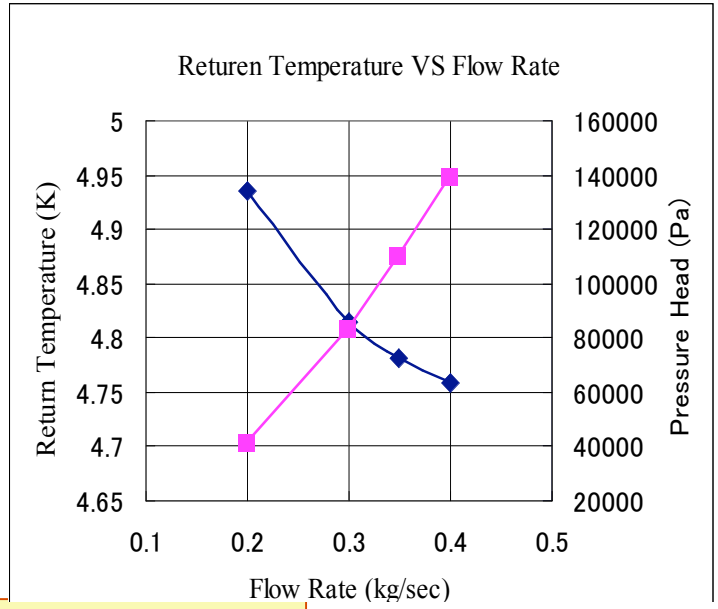
SHE Flow Rate	max 300 g/s
SHE Condition	0.4 MPa(A), 4.5 K
SHE Return	4.9 K
Thermal Load to SHE Flow	410 W
Pressure Head of SHE	85 kPa
Current Lead cooling gas	1.1 g/s (1 pair)
Shield Temperature	60～100 K
Shield Cooling	Cold Helium Gas
Thermal Load to Shield Line	1710 W
Shield Cooling Gas Condition	Not specified
LN2 usage	Only Pre-cooling and re-cooling after quench
Pre-cooling duration	< 20 days
Re-cooing duration	<6 hours (30GeV operation)



Schematic diagram of SHe circulation system

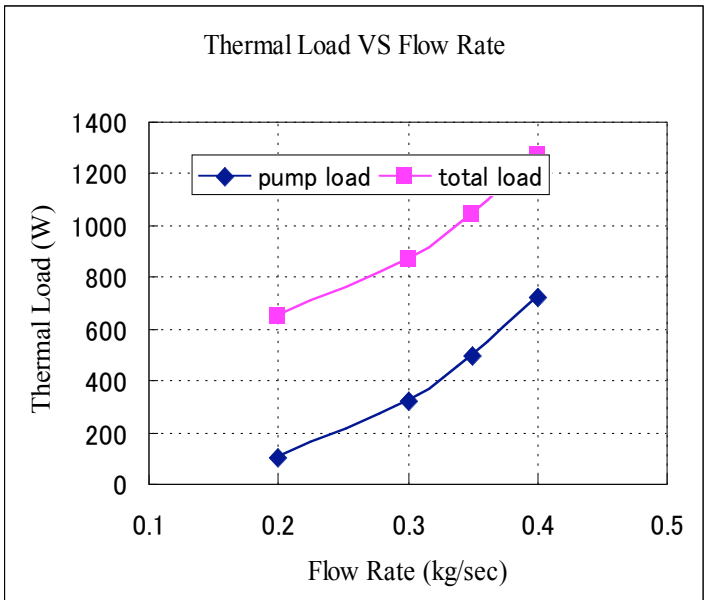
4. Refrigerator Specification

4-3. Required Cooling Capacity - Estimation



$$\Pr essureHead = f\frac{L}{D_h}\frac{\rho u^2}{2}$$

f : Friction Coefficient, L : *Length*,
D_h : Hydraulic Diameter, u : Flow Velocity



$$TotalLoad = [Mag\ \&\ Trans.T + 20\%] + [PumpLoad] + [Sub-coolerLoad : 143W]$$

$$PumpLoad = \frac{\Delta P \dot{M}}{\rho \eta}$$

Expected Operational Flow Rate :
300 g/s → Pump Load : < 300 W
Mag. Temp. : ~ 4.8 K

Mass-flow rate is controlled to be 0.3kg/sec at the maximum. .

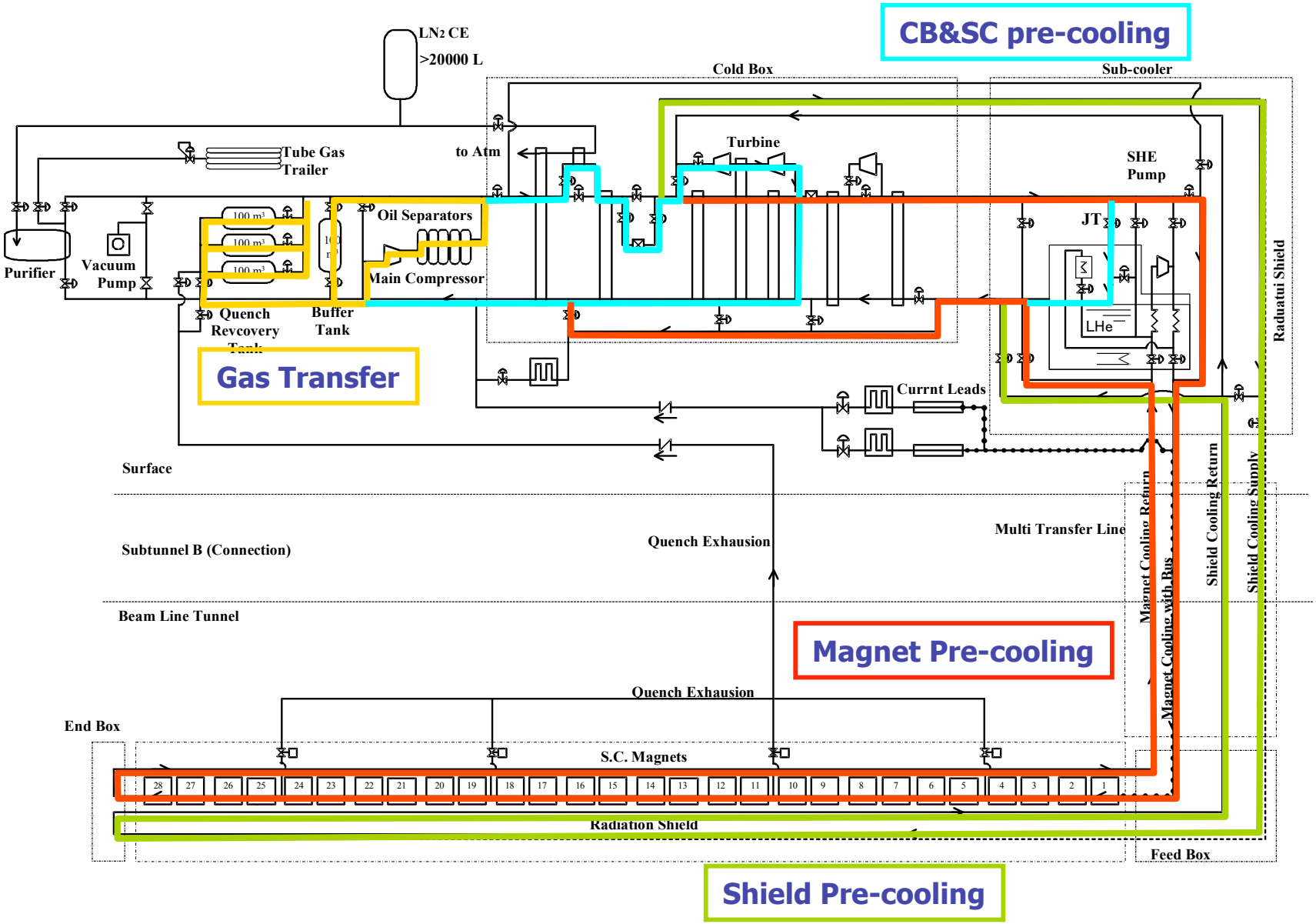
4. Refrigerator Specification

4-4. Required Refrigeration Capacity – Maker Design

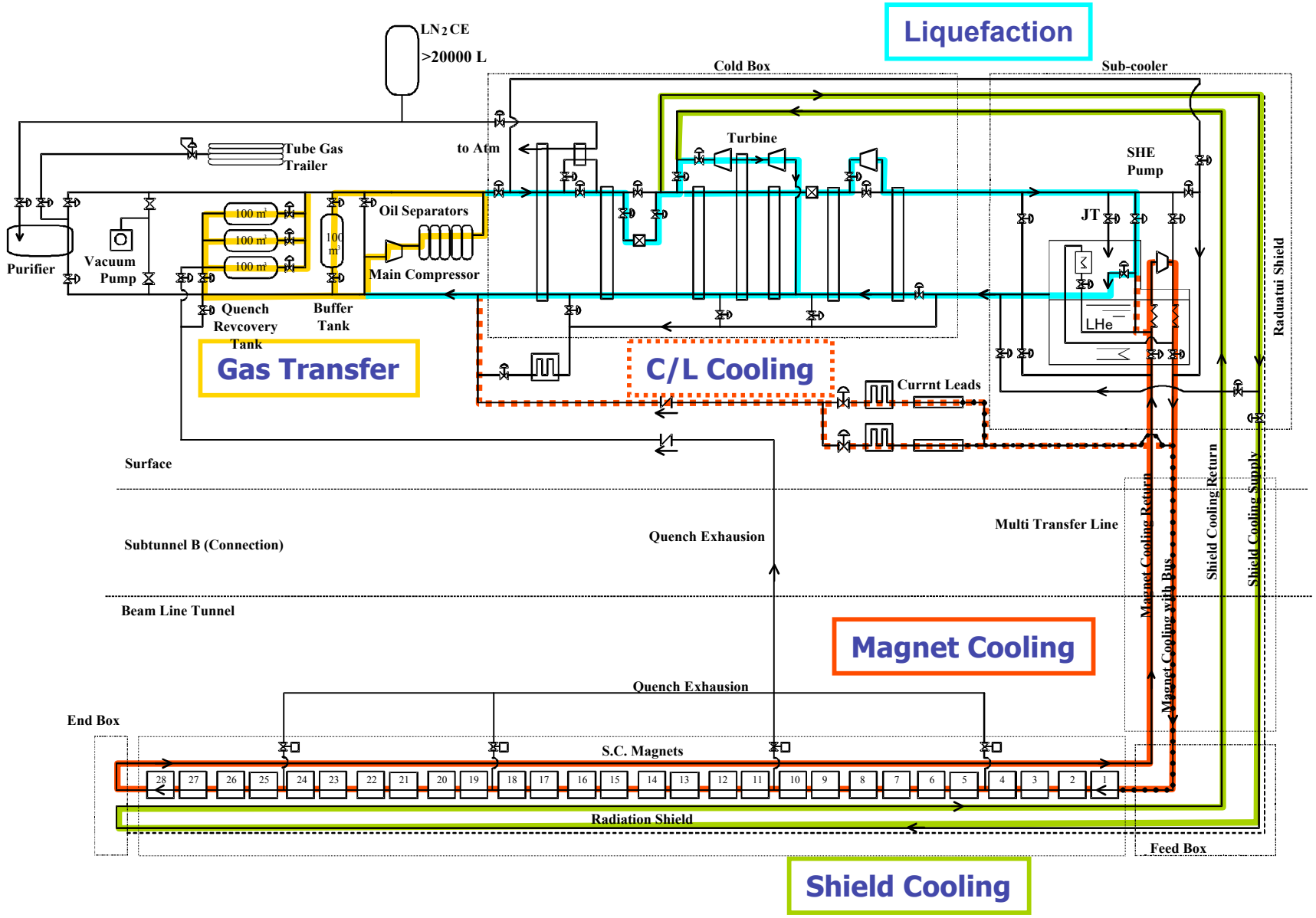
		Thermal Load @4.5 K Level	Thermal Load @shield Level
KEK Requirement	Magnet & Transfer Line	410 W + 1.1 g/s	1710 W
	SHE Flow conditions	Max 300 g/s, 4.5 K, 0.4 MPa Head 85 kPa	
Contractor Design	SHE Pump Load	330 W	
	Sub-cooler, Transfer Line b/w CB	150 W	250 W
	Required Refrigeration	890 W + 1.1 g/s → 1.0 kW	1960 W → 2 kW
	+ 20 % Margine	1.2 kW	2.4 kW

Taiyo-Nissan Co. in the business collaboration with LINDE won the bid.

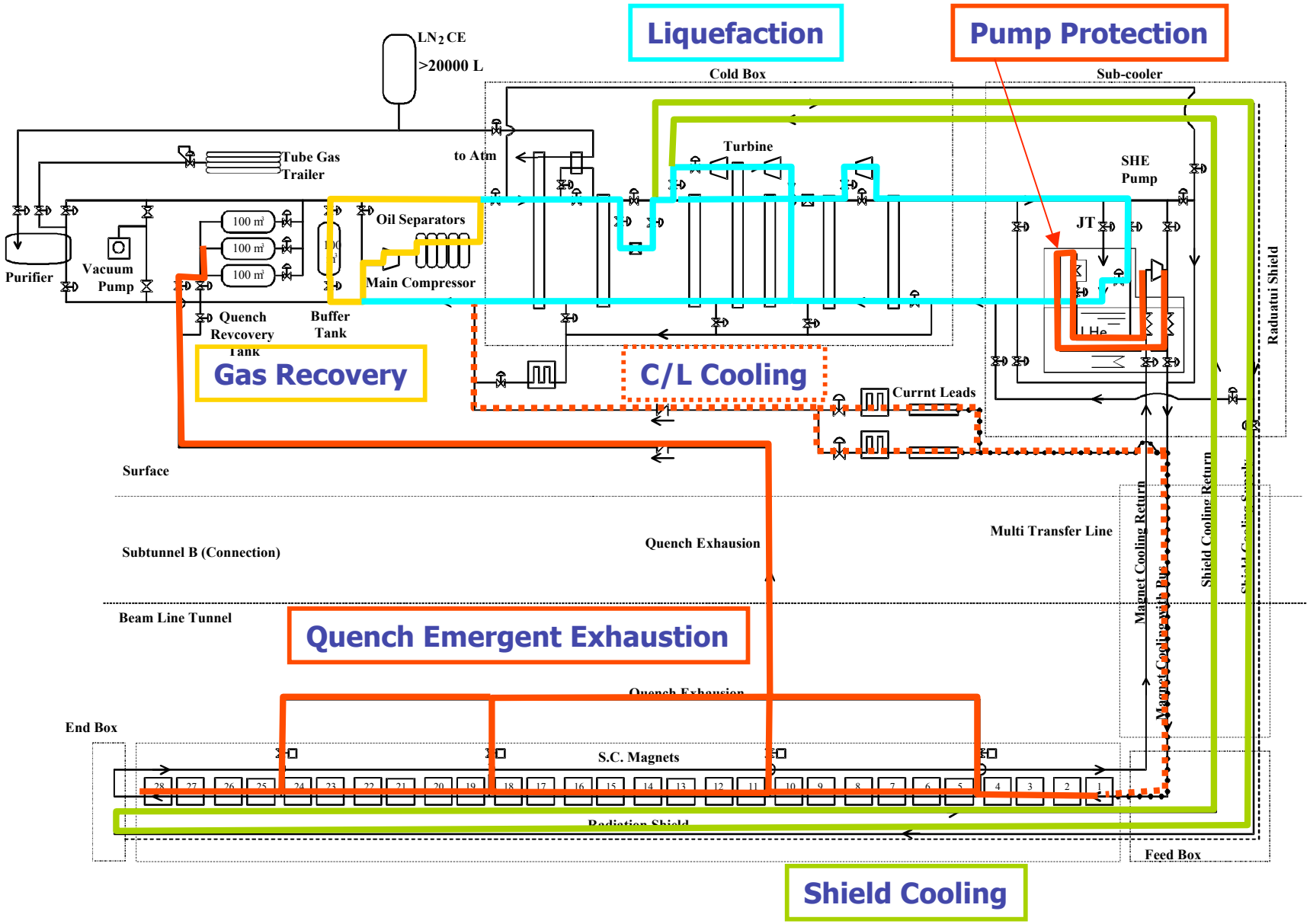
5. Operation – Pre-cooling



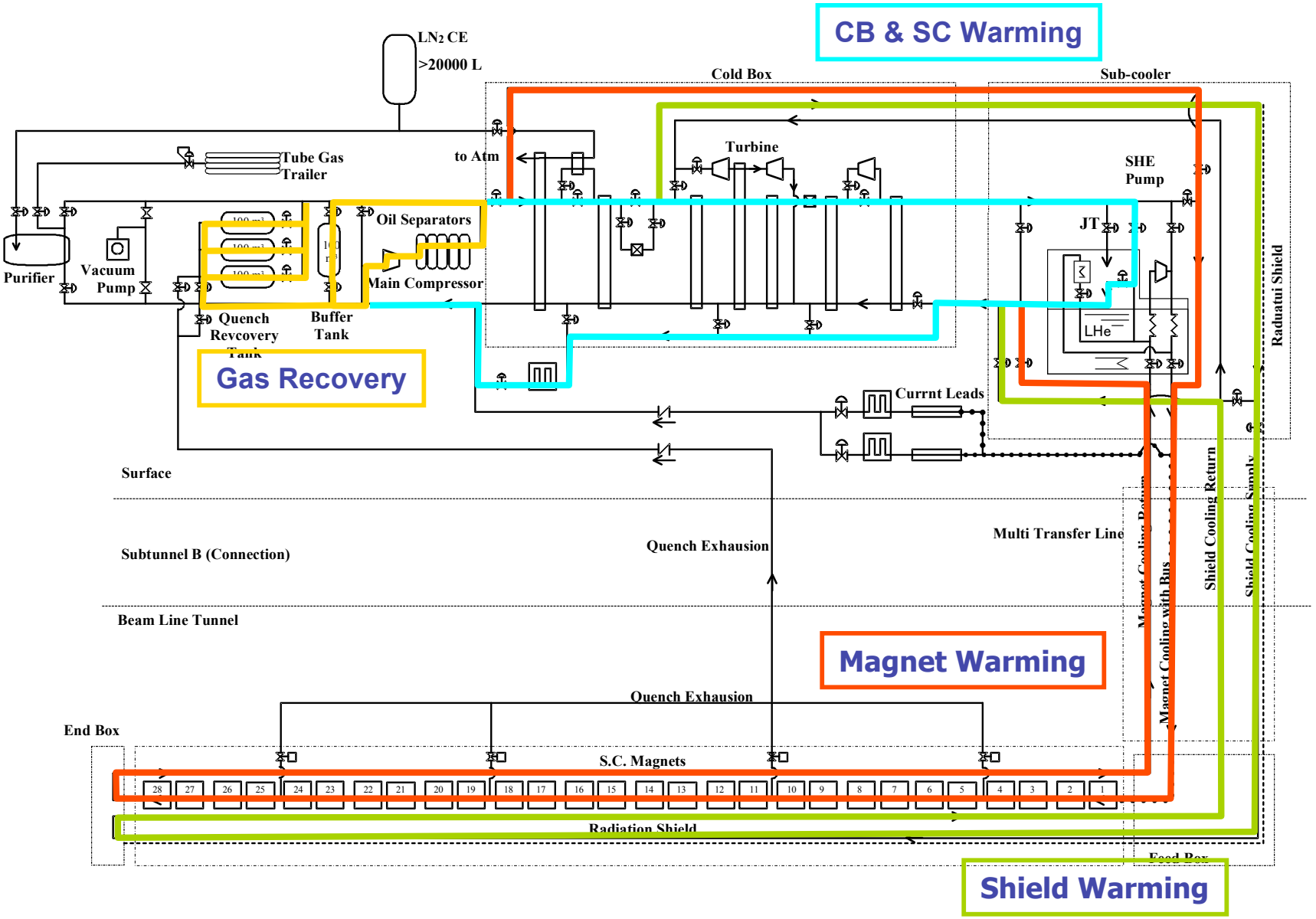
5. Operation – Magnet Excitation (Steady state)



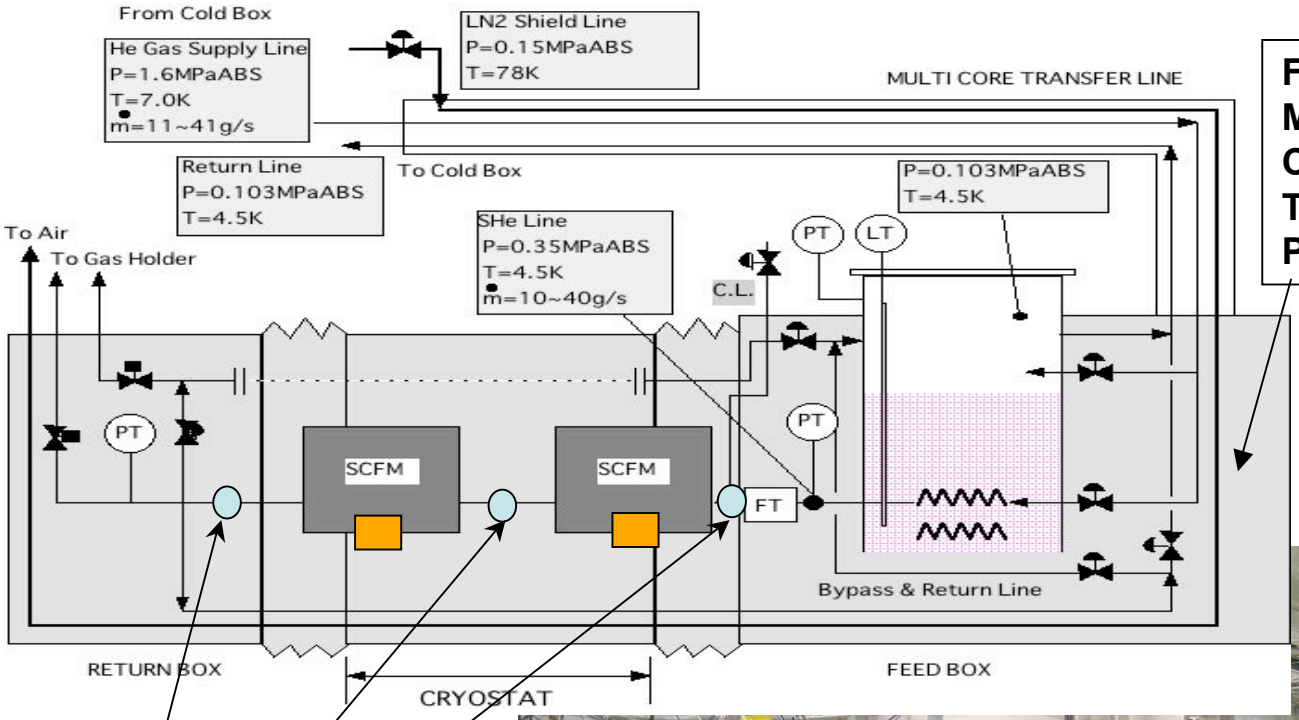
5. Operation - Quench



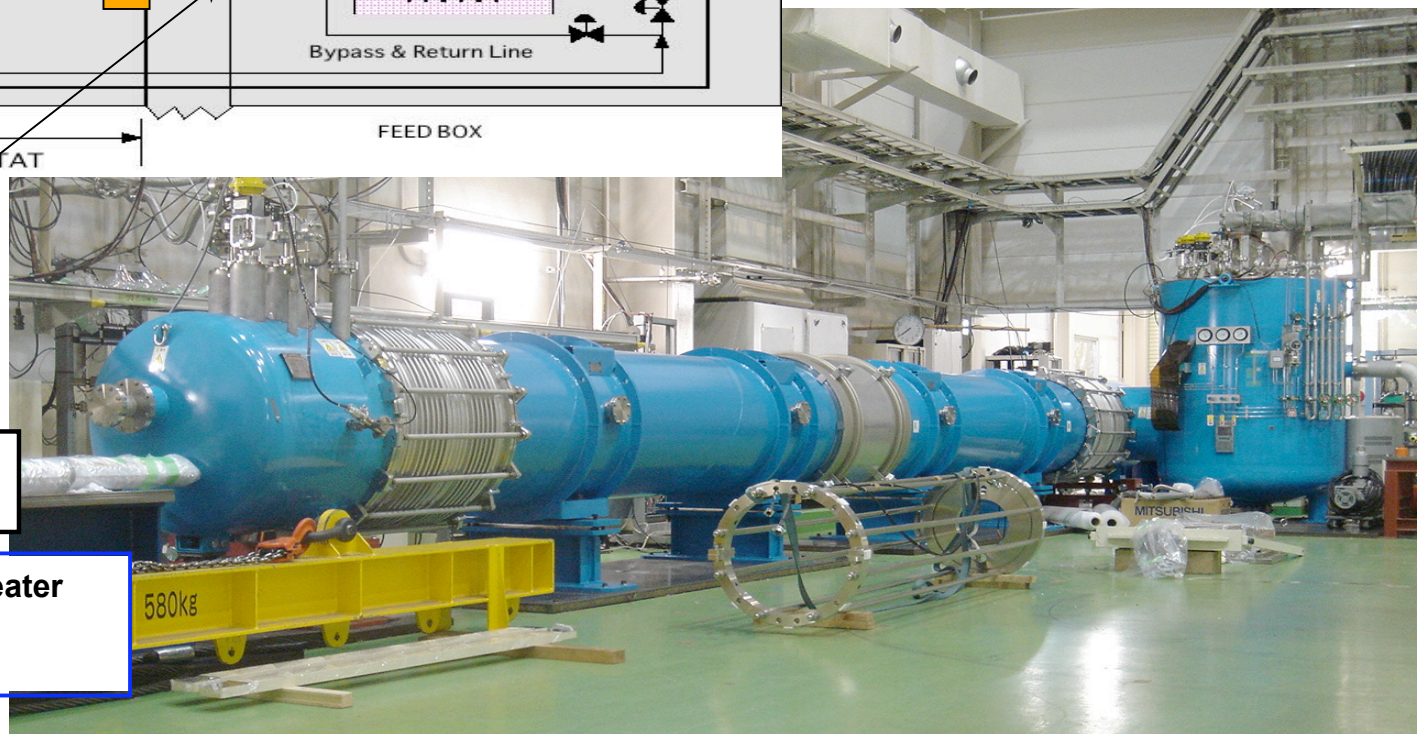
5. Operation - Warming



6. Two in one structure cryostat



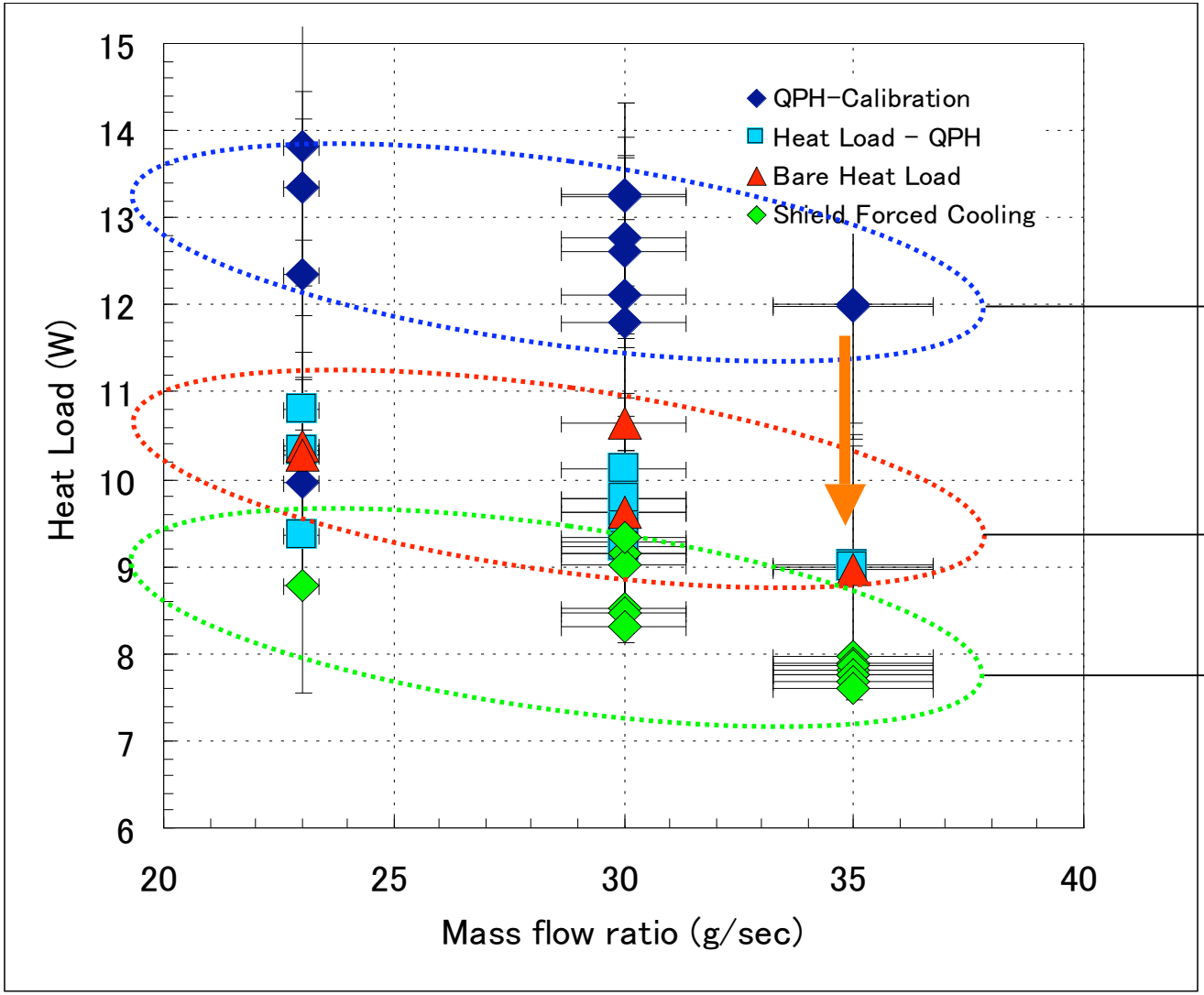
Feed Box
Mass flow rate:20 g/sec~ 40 g/sec
Coolant: SHE
Temperature 4.5
Pressure :0.4 MPa



Cernox temperature censor

Quench protection heater
For calibration
2W, 3W, 4W

6. Results of Heat Load



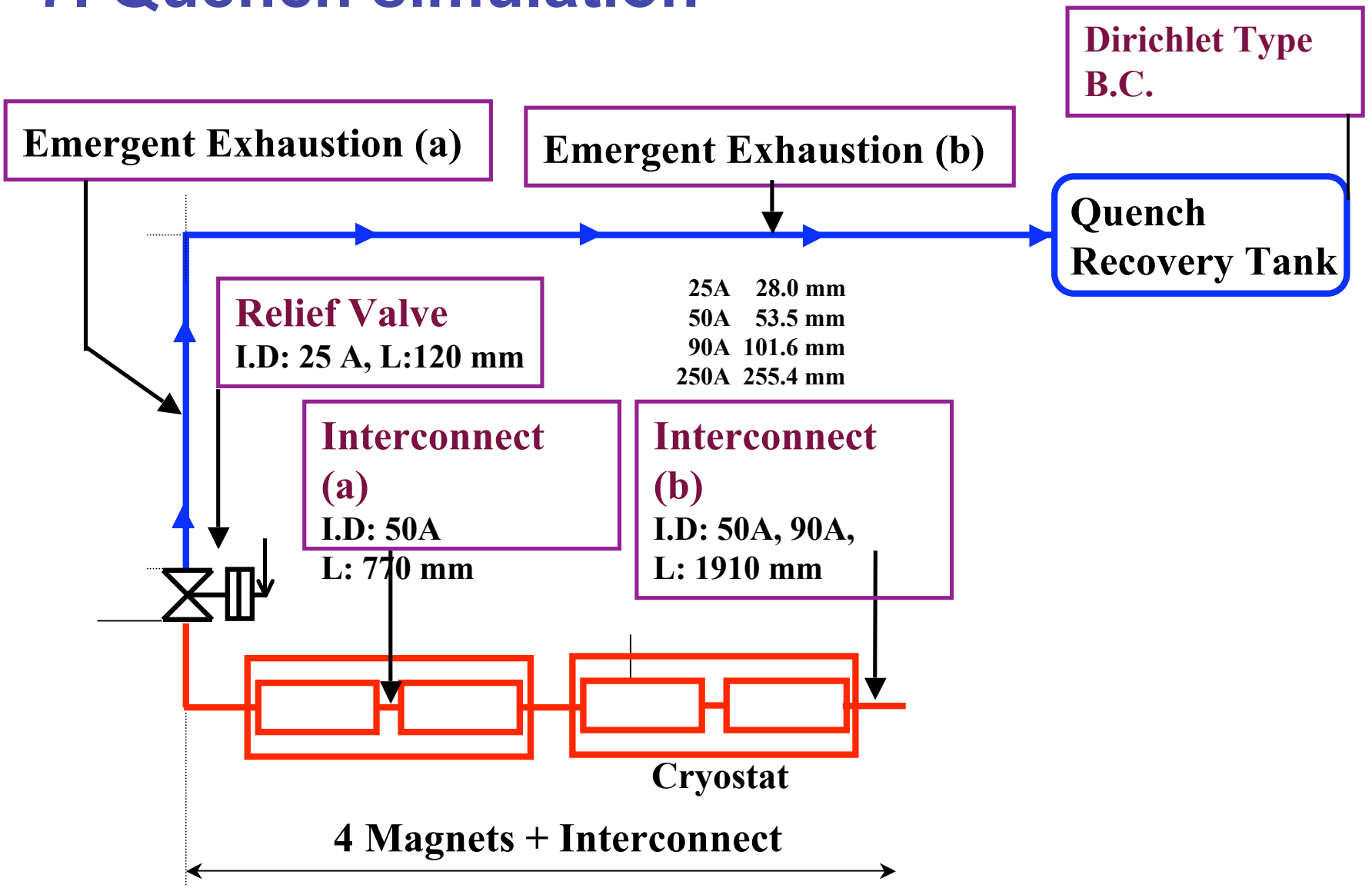
QPH is fired for calibration.

Pure heat load &
Removed QPH Power.

Shield line forced cooling
100K→80K .

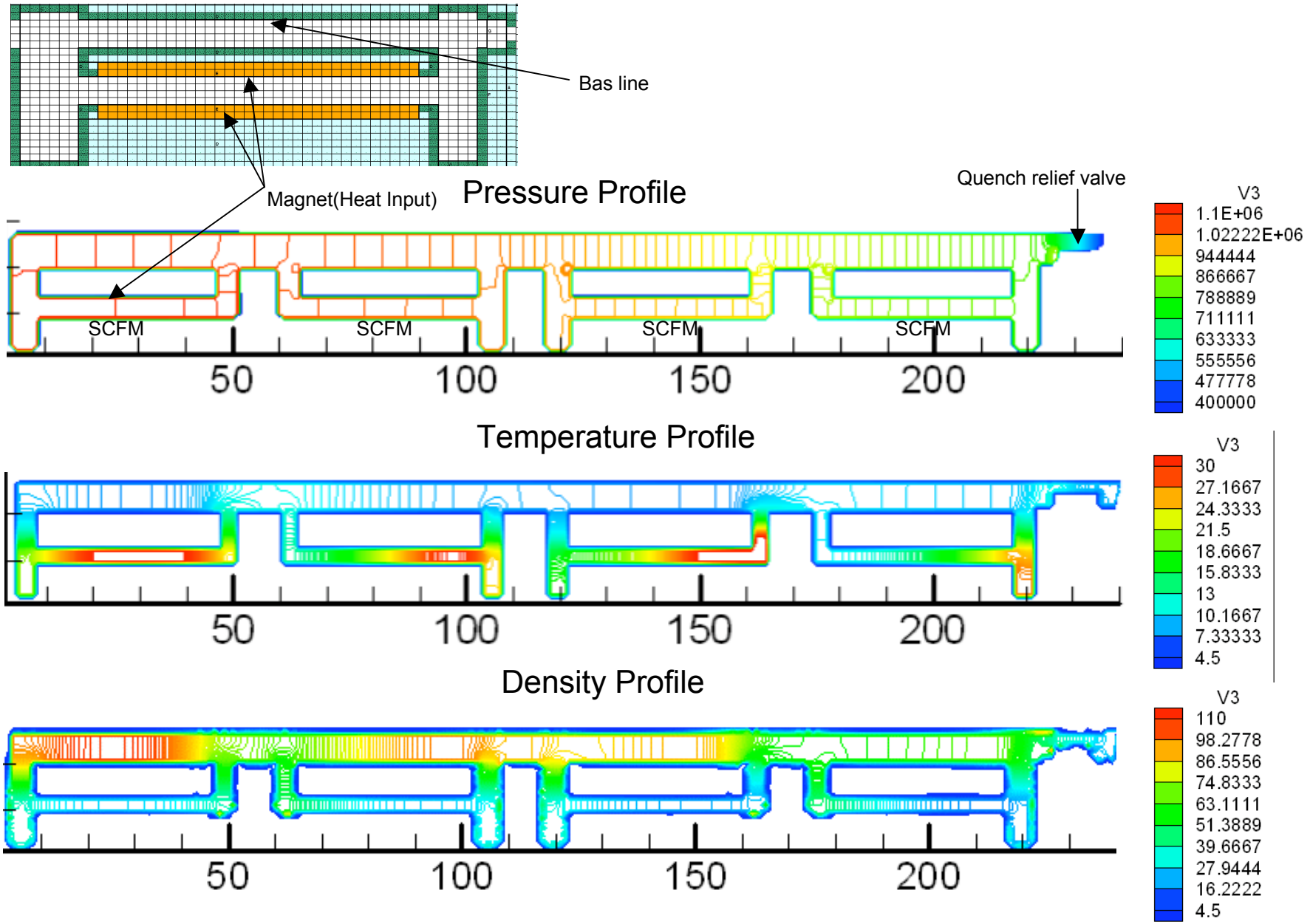
Total heat load to 4.5 K line
8.0W
@Two in one structure cryostat

7. Quench simulation



This model is based on an assumption that flow is Two-dimensional
Numerical simulation is carried out involving four magnets, one relief valve, venting line and buffer tank.

7. Simulation Results at 4/4 Magnets Quench



8. States

- The cold Box is being manufactured by LINDE.
- The compressor is being manufactured by MYCOM.
- The sub-cooler design will be finalized by TN.
- SHE pump is made by Barber-Nichols.
- Tank foundation design, machine room design is in progress by KEK.
- A tender for the control system is being prepared.

- Heat load to 4.5 K level of two in one structure cryostat is 4.0W.

- Quench simulation involving 7 magnets is being prepared.