Cryogenic System of ILC IR

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Overview of cryogenic system for IR

Required Item

Following superconducting magnets are mandatory.

- **ILD + 2QD0s**
- **SiD + 2QD0s**

Undetermined Item

Followings are not decided so far[a].

- **QF1**, (pressurized superfluid He II)
- **CC**, (saturated superfluid He II)
- **DR**, (supercritical He?)
- BDS Cryo (superfluid He II)

[a] **QF1, CC and DR superconducting magnets** should be involved in IR.

Cryo Configuration (ILD,SID,QD0,QF1,CC,DR)

Hybrid A' (All pipes for Helium and cooling water.)

cooling tower for IR compressors including DR.
volume flow rate = 1500L/min per 1 comp.
total volume flow rate = 6000 L/min (4 comps)

sub buffer tanks for comp

main buffer tank

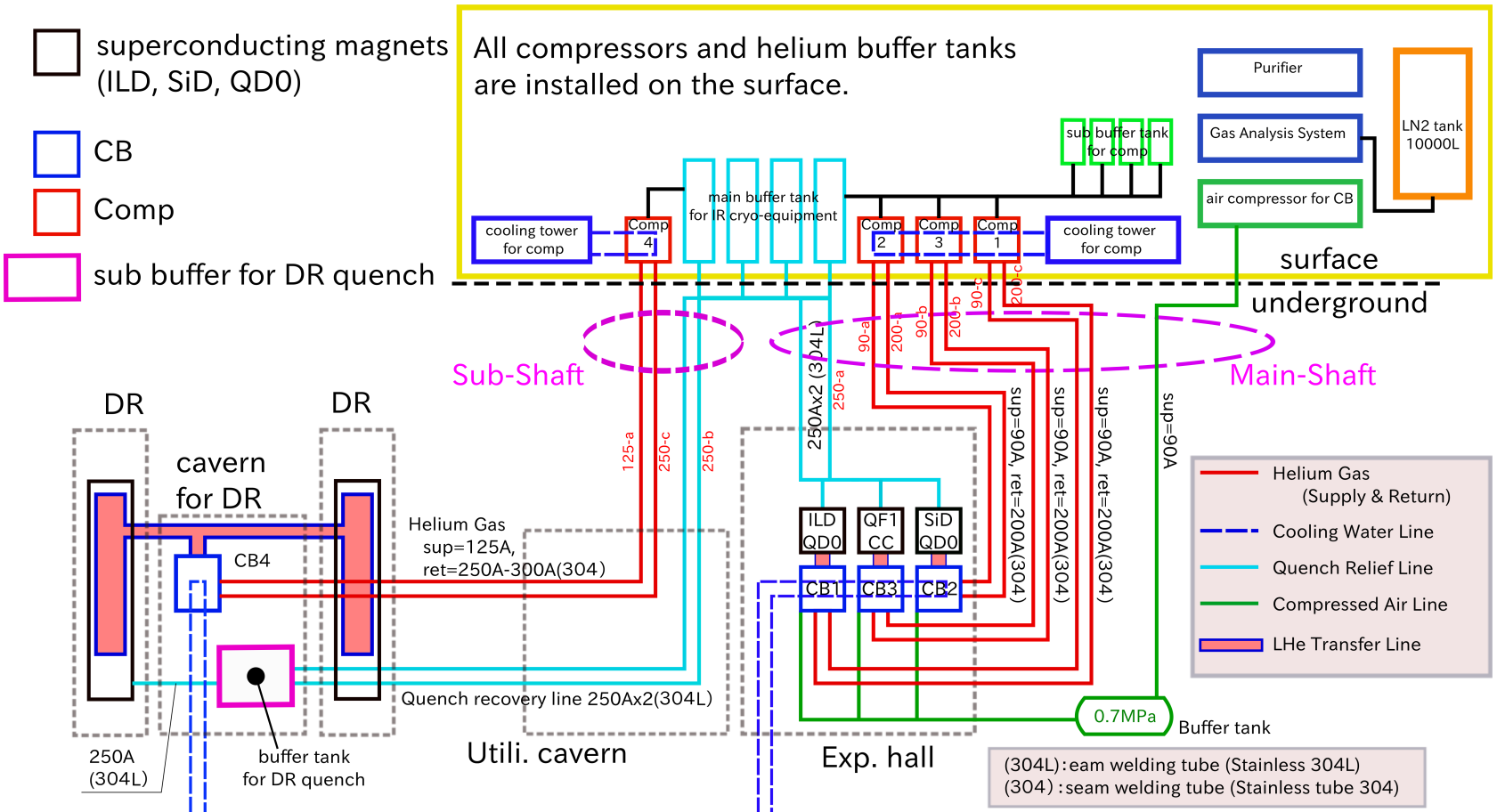
cooling towers

superconducting magnets (ILD, SiD, QD0)

CB

Comp

sub buffer for DR quench



cooling water for turbine is supplied from cooling water system located in the underground
100L/min per one CB.
Inlet temp = 31 deg.

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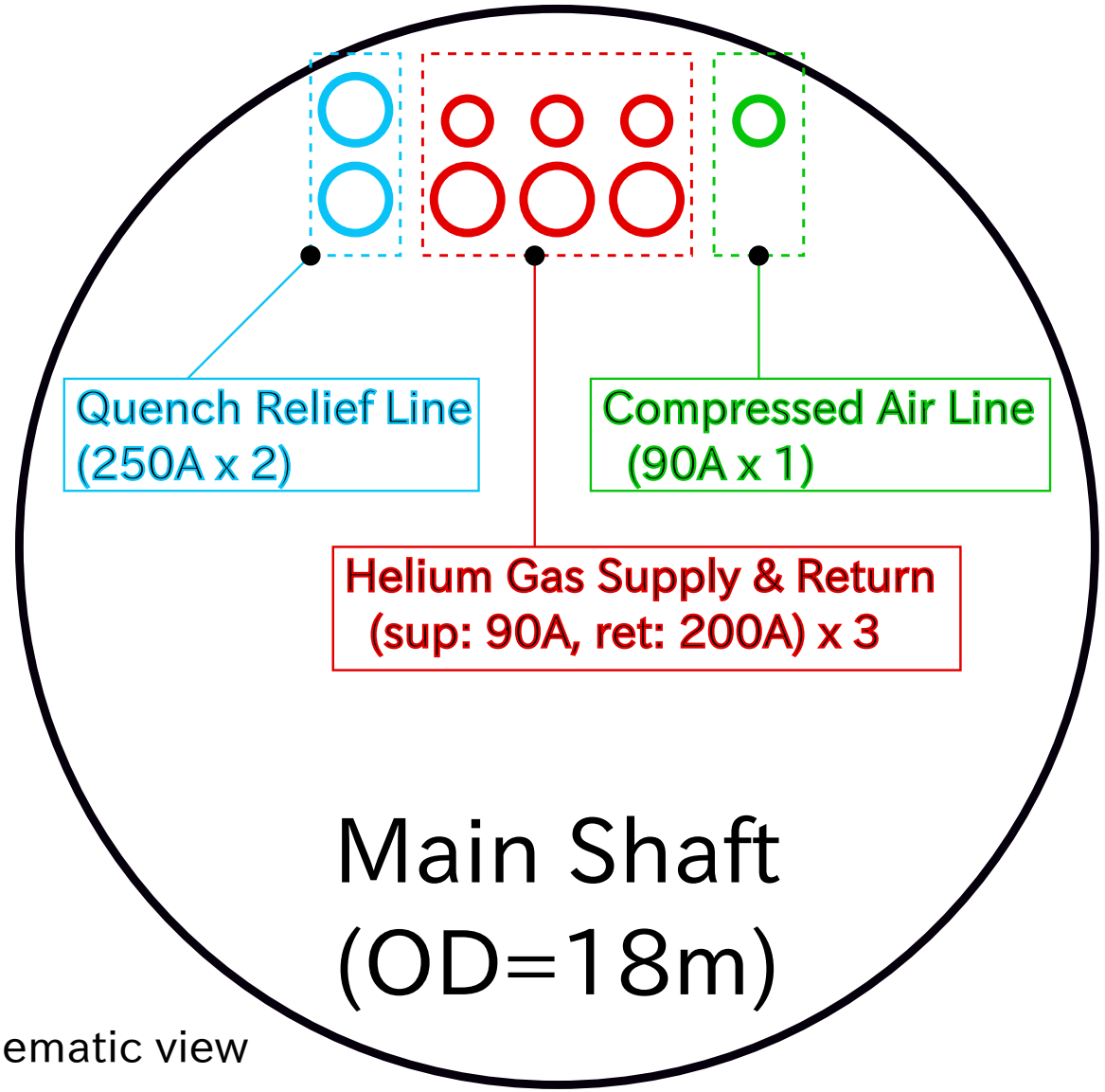
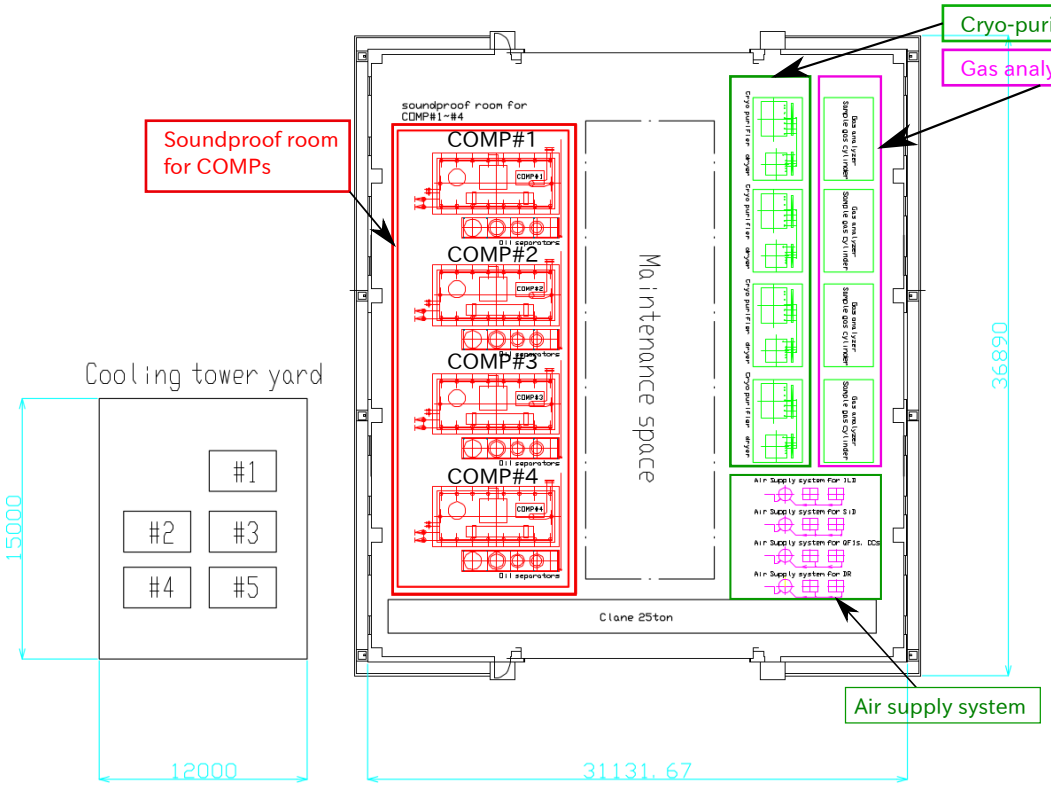
Pipes passed through MS



schematic view

Compressor house (layout example)



Compressor: main specification

COMP #1 : for ILD+QDOs (500 kW)
COMP #2 : for SiD+QDOs (500 kW)
COMP #3 : for QF1s, CCs (300 kW)
COMP #4 : for DR (600 kW?)

Total Cooling water for each compressor

COMP #1 : 1700 L/min (cooling tower #1
COMP #2 : 1700 L/min (cooling tower #2
COMP #3 : 1000 L/min (cooling tower #3
COMP #4 : 2000 L/min (cooling tower #4

Cooling tower #5 is for other equipmen

- 4 helium compressors (in the soundproof room).
- Air supply system, cryo-purifier, dryer and gas analyzer.
- 25 ton crane for installation and maintenance.
- Total ventilation capacity of 40000 m^3/hour.[a]

[a] 40000m^3 is obtained from Japanese High Pressure gas regulation.

Helium Compressor

Helium compressor

- 4 compressors are installed on the surface (in a compressor house).
- Mechanical noise have to be reduced.
  - Bare intensity of mechanical noise is around 100 dB in the case of MYCOM.
  - Noise intensity can be reduced to 70 dB by employing soundproof house (example of J-PARC neutrino cryo-system).
- Required amount of cooling water (after cooler and oil cooler) for 4 compressors are described below.

COMP. No.	Cryo equipment	Shaft Power	Cooling Water
Comp1	ILD+QD0s	~ 500 kW	~ 1700 L/min
Comp2	SiD+QD0s	~ 500 kW	~ 1700 L/min
Comp3	QF1s & CCs	~ 300 kW	~ 1000 L/min
Comp4	DR(RFs & Wigglers)	~ 600 kW	~ 2000 L/min

Necessity of liquid nitrogen tank

♠ **In the underground**

- Liquid nitrogen should not be employed from the view point of safety.

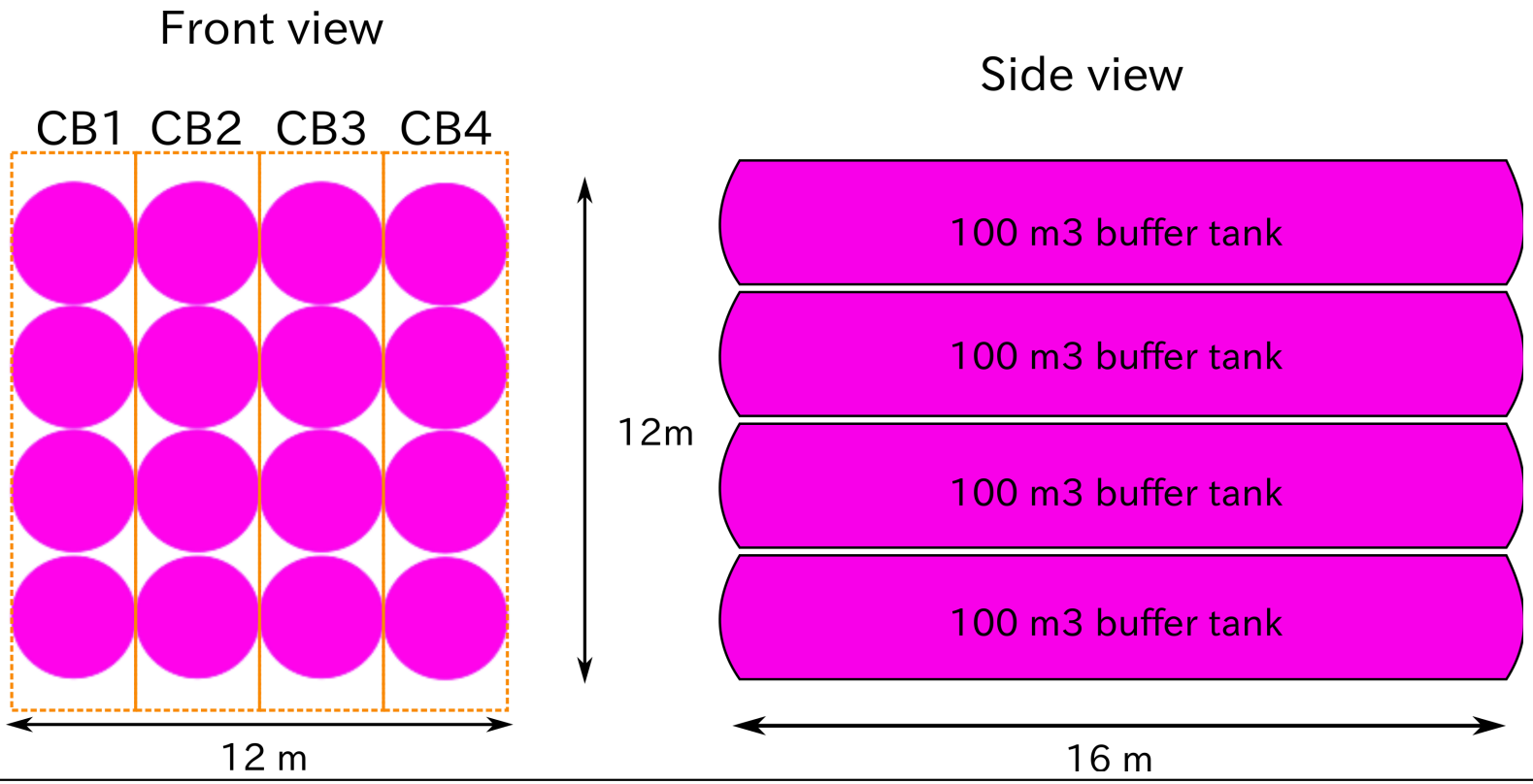
♠ **On the surface**

- Liquid nitrogen should be employed following two operation.
  1. cryo-purifier
     ⇒ Gas analyzer and cryo-purifier are also installed in the compressor house.
  2. charcoal baking process [a] during maintenance season.
     ⇒ LN2 Evaporator also should be prepared in this case.

[a] Charcoal (volume ∼ OD=1.5m, height=3.5m) should be employed for oil separator.

Liquid nitrogen tank with the size of ∼ 10000 L had better be employed proximity to comp. house.

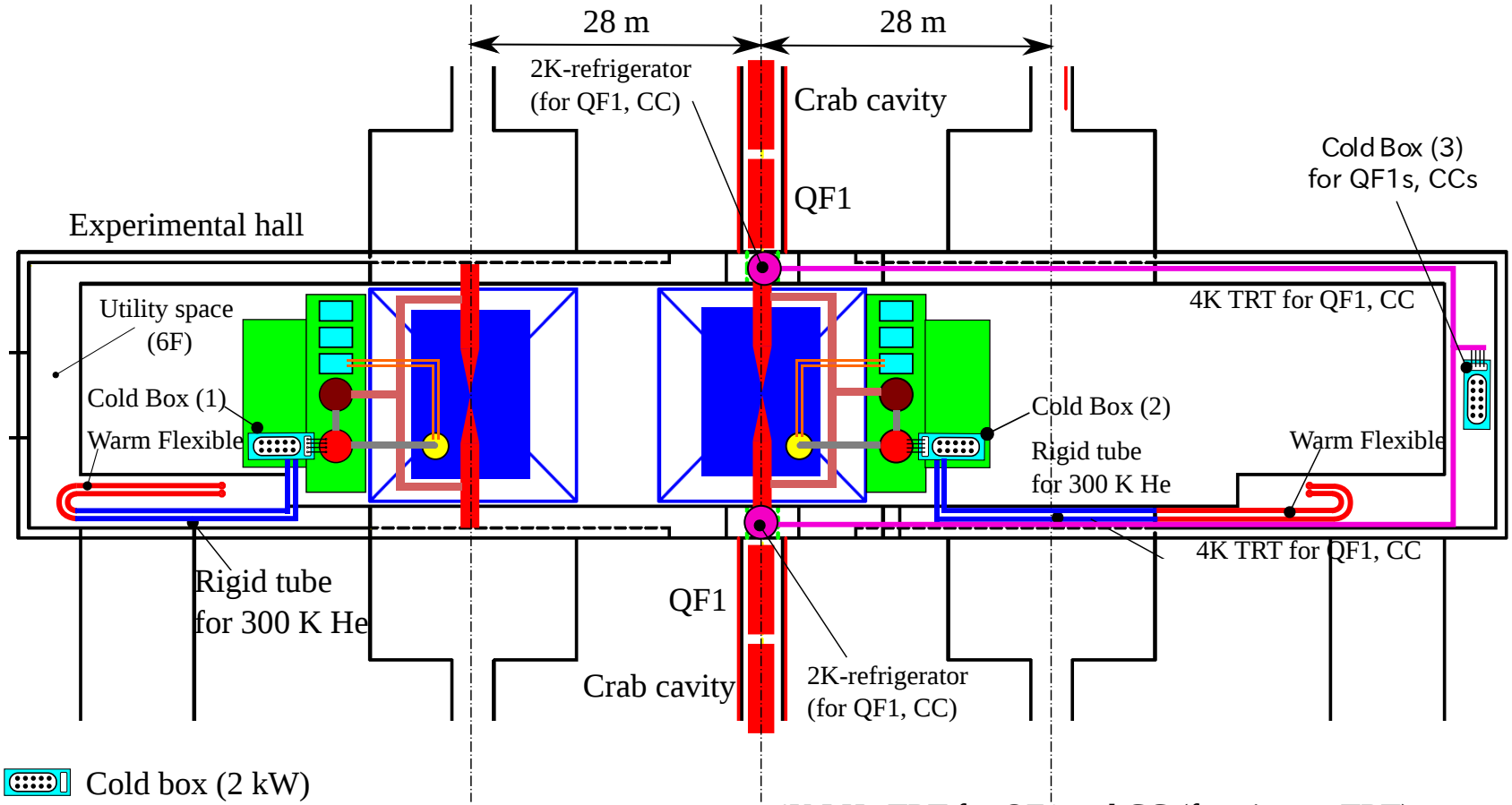
Helium buffer tank yard



Total volume $\sim$ 1600 m^3, Allowable pressure$\sim$ 2.0 MPa

- ILD : 400 m^3
- SiD : 400 m^3
- QF1,CC,DR : 800 m^3

Layout example in DH (ILD,SiD,QD0,QF1,CC)



Cold box (2 kW)

2K refrigerator for QF1 and CC

4K distribution box

2K refrigerator for QD0

Chimney and current lead box for detector

Power supply for detector and QD0

4K LHe TRT for QF1 and CC (four in one TRT)

Fixed 300K Helium gas line (supply and return)

Fixed TRT for 4.2 K liquid helium (Four in one)

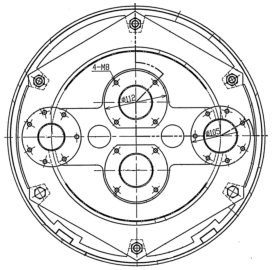
Fixed TRT for superfluid helium (2K, 4K 70K shield).

Flexible 300 K helium gas line (supply and return)----

Bus bar for detector between PS and chimney.

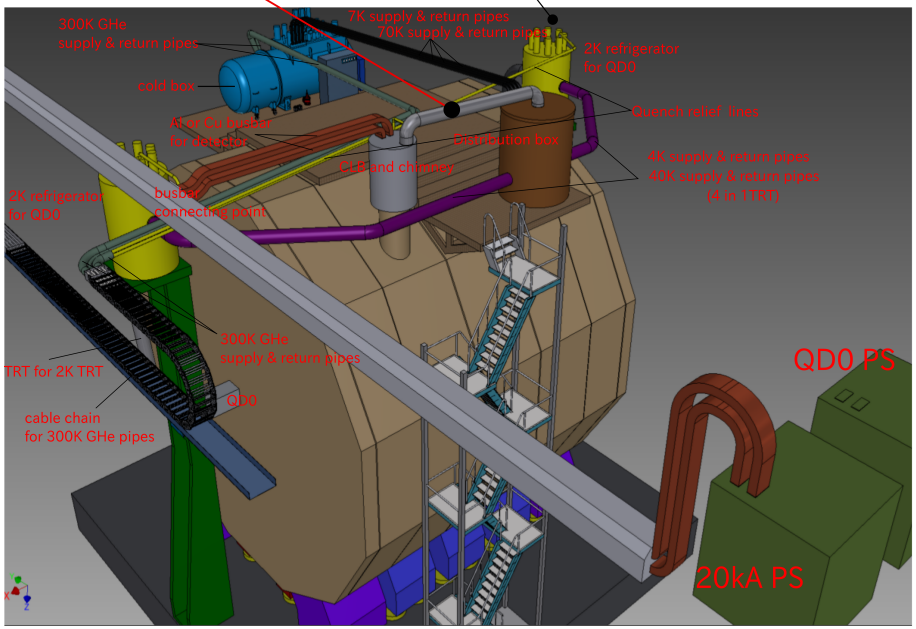
Layout example for ILD

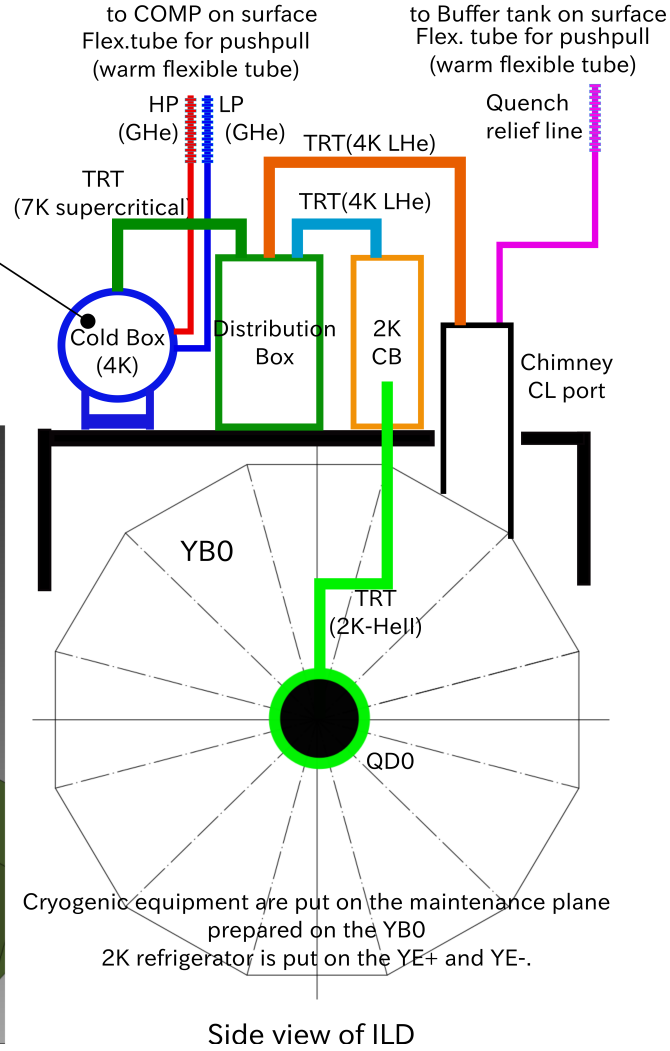
Cross section of TRT
(7K supercritical, 4K LHe)



2K refrigerator
(BNL)

4K cold box





Side view of ILD

Most of the cryo-equipment should be located on the YB0 platform in order that ILD detector should be divided into 5 sectors as easy as possible.

During push-pull and maintenance

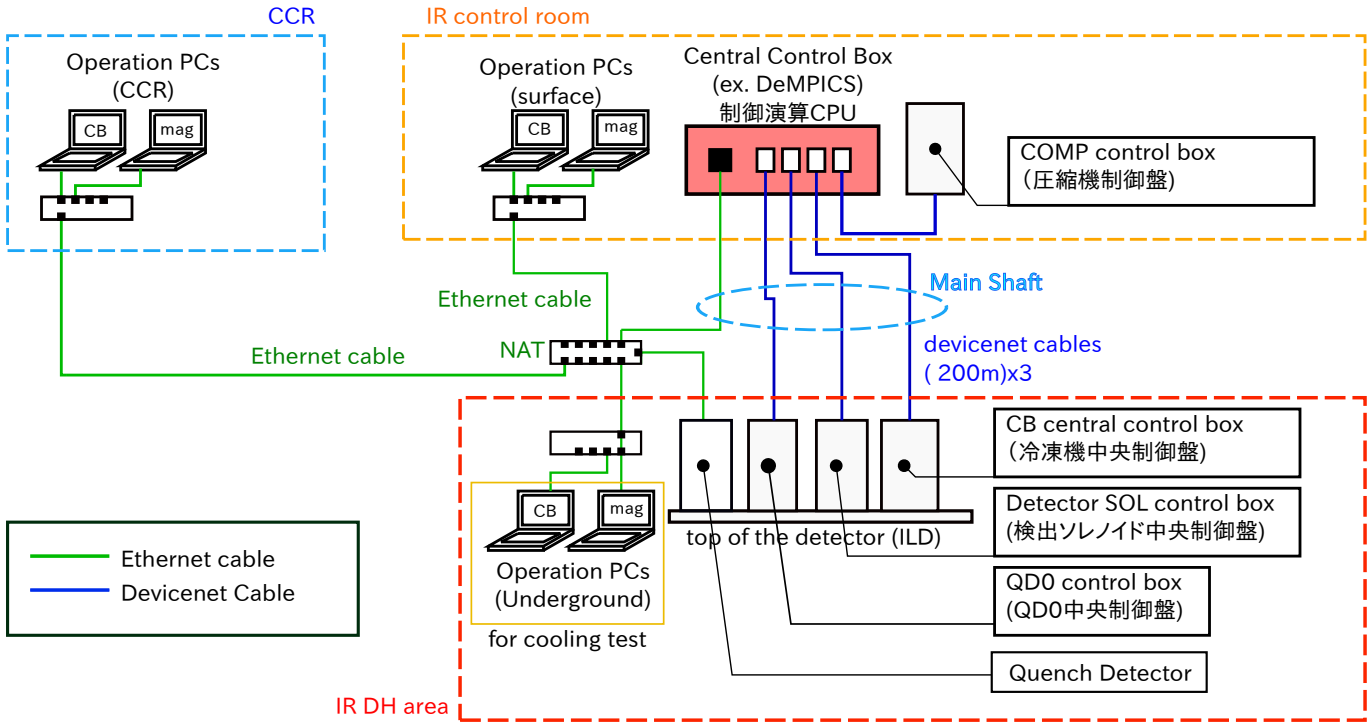
During pushpull

- without breaking up all kinds of tubes.
- Al bas-bar should be disconnected during push-pull.
  $\Rightarrow$ Excitation can not be done.
  - 20kA P.S will be installed on the utility area.

During ILD maintenance

- End cap (YE+,YE-) are only moved existing gap between end cap and support post.
  - CB, 2K-refrigerator and all kinds of tubes don't have to be divided and removed.
- All iron yokes are divided into 5 sectors.
  - TRT,CB, 2K refrigerator have to be decomposed.

Control System (1) overview



- Each control boxes should be located proximity to each equipment to reduce a lot of signal cables length.
- All signals obtained from each control box are concentrated in a CCB.
- Connection method between each control box and CCB are performed by a few devicenet cables.
- Connection method between operation computers and CCB is performed by Ethernet cables.

Control System (2) for quench protection

- Sampling time for control the IR cryogenic system is 1 sec.
- Characteristic time for magnet quench is msec order which is completely different from cryo control characteristic time (sampling time $\simeq$ 1 sec.). So we have to prepare dedicated quench detector system near the magnet control box.
- Magnet control box for detector and QD0s is located on the each detector. All signal of superconducting magnet (such as voltage between selected two taps) are concentrated in the box.
- The quench detector has a rule in magnet slow down, fast down if it detects magnet quench.
- We can know the quench signal and origin of the quench by operation computer.
- The connection way between quench detector and operation computer is performed by Ethernet.

Japanese High Pressure Gas Regulation

- There are two regulations in Japan. Which is better?
  - 一般則 [1]
  - 冷凍則 which is better than 一般則. [2]
- We have to prepare ventilation system in following 3 buidings.[3]
  - Detector hall. (capacity = 28000m3/h) [4]
  - Assembly hall. (capacity = 28000m3/h)
  - Compressor house. (capacity = 40000m3/h) [5]

[1] 一般則 is applied to general equipment with high pressure gas. 冷凍則 is dedicated regulation which is applied to refrigeration system with any kinds of coolant.

[2] In case of 冷凍則, without overhaul inspection every year.

[3] according to 冷凍則.

[4] Capacity is the summation of ILD, SiD, QD0, CC, QF1.

[5] Capacity is the summation of ILD, SiD, QD0, CC, QF1 and DR.

Summary

♣ **on the surface**

- compressor house {p7,8,9}
  - 4 helium compressors (SiD,ILD,QD0,QF1,CC)
  - air compressors
  - purification system, gas analyzers, dryer
- cooling tower for compressors {p8}
- liquid nitrogen tank (10000 L) {p9}
- Helium gas buffer tank {p10}

♣ **in the DH**

- 3 Cold boxes. {p11,12,Appendix(C)}
- power supply for magnet excitation. {p11,12,Appendix(E)}
- 2K cold boxes for QD0, {p11,12,Appendix(E)}
- 2K cold boxes for QF1, CC {p11}
- chimney, distribution box(6000 L dewar). {p11,12,Appendix(E)}
- cooling water for turbines (for brake cooler).

Appendix

- Appendix(A) : Cryogenic Configuration
- Appendix(B) : Compressor house specification
- Appendix(C) : Role of the cold boxes
- Appendix(D) : 3D view of ILD cryo structure
- Appendix(E) : 3D view of ILD cryo structure
- Appendix(F) : 2D view of ILD cryo structure

Appendix (A) : Cryogenic Configuration

- **Helium Compressor**
  - All compressors (4 compressors) are installed on the surface.
  - Cooling towers for comps are also installed on the surface.
- **Helium Cold Box**
  - All CBs (4 cold boxes) are installed in the underground.
    - CB1:ILD+QD0, CB2:SiD+QD0, CB3:QF1+CCs, CB4:DR[a]
    - CB1, CB2 and CB3 are located in the DH[b]
    - CB4 is installed in the DR cavern.
- **Cryogenic Pipes ($\stackrel{\text{def}}{=}$ HP, LP, magnet quench line)**
  - Cryogenic pipes for CB1,CB2 and CB3 are laid through main shaft.
  - Cryogenic pipes for CB4 are laid through sub-shaft.
- **Helium gas storage method**
  - Gas storage $\Rightarrow$ Buffer tanks should be installed on surface.

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[a] DR: Damping Ring
[b] DH: Detector Hall

Appendix (B) : Compressor house specification

Brief Specification of Compressor House

- House size is L=37m, W=32m, H=10m $\sim$ 15m.
- 4 comps (COMP1 to COMP4) are installed in the house.
- House has 25 ton crane for installation and maintenance.
- Total ventilation capacity of compressor house is 40000 m^3/hour (from the Japanese High Pressure Gas Safety Law).
- In order to reduce noise of compressor ~ 100 dB, soundproof room should be employed in the house.[a]
- Air supply systems are also installed in the house.
- Gas analyzer and cryo-purifier are also installed in the house.

  $\rightarrow$ Liquid nitrogen tank with the size of $\sim$ 10000 L had better be employed near the comp. house[b]

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[a] By employing soundproof room, noise of compressor can be reduced from 100 dB to 70 dB.

[b] P13 shows necessity of liquid nitrogen tank.

Appendix (C) : Role of the cold boxes

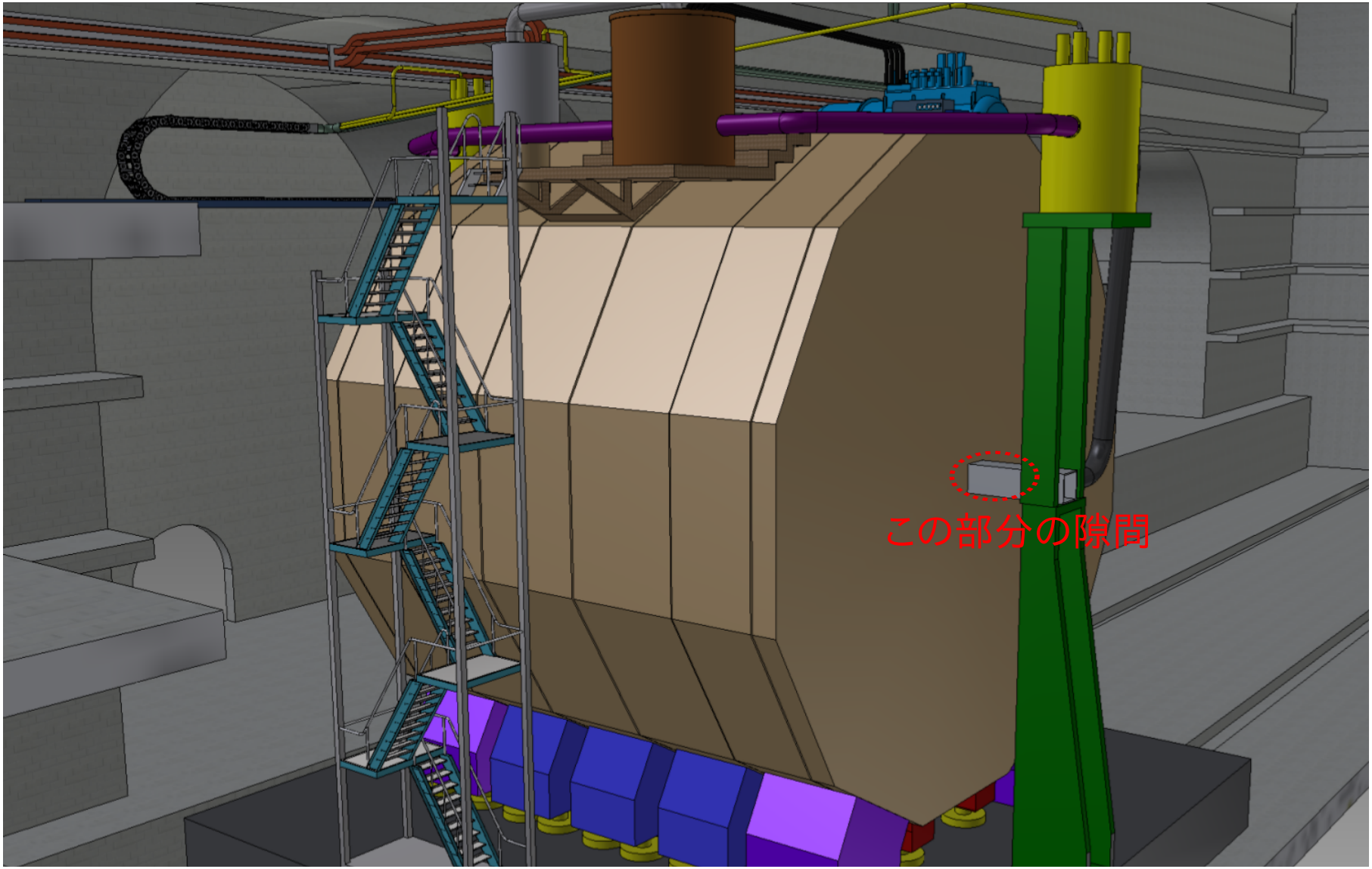
Cold box for detector should be installed on the platform (on the detector) if vibration, magnetic field, radiation problem don't occur.

- CB1: for ILD and QD0s cooling
  - installation on the platform if vibration problem does not occur.
- CB2: for SiD and QD0s cooling
  - installation on the platform if vibration problem does not occur.
- CB3: for QF1s and CCs cooling
  - installation on the utility floor in the DH.
- CB4: for Wiggler and RF cooling
  - installation in the DR cavern.

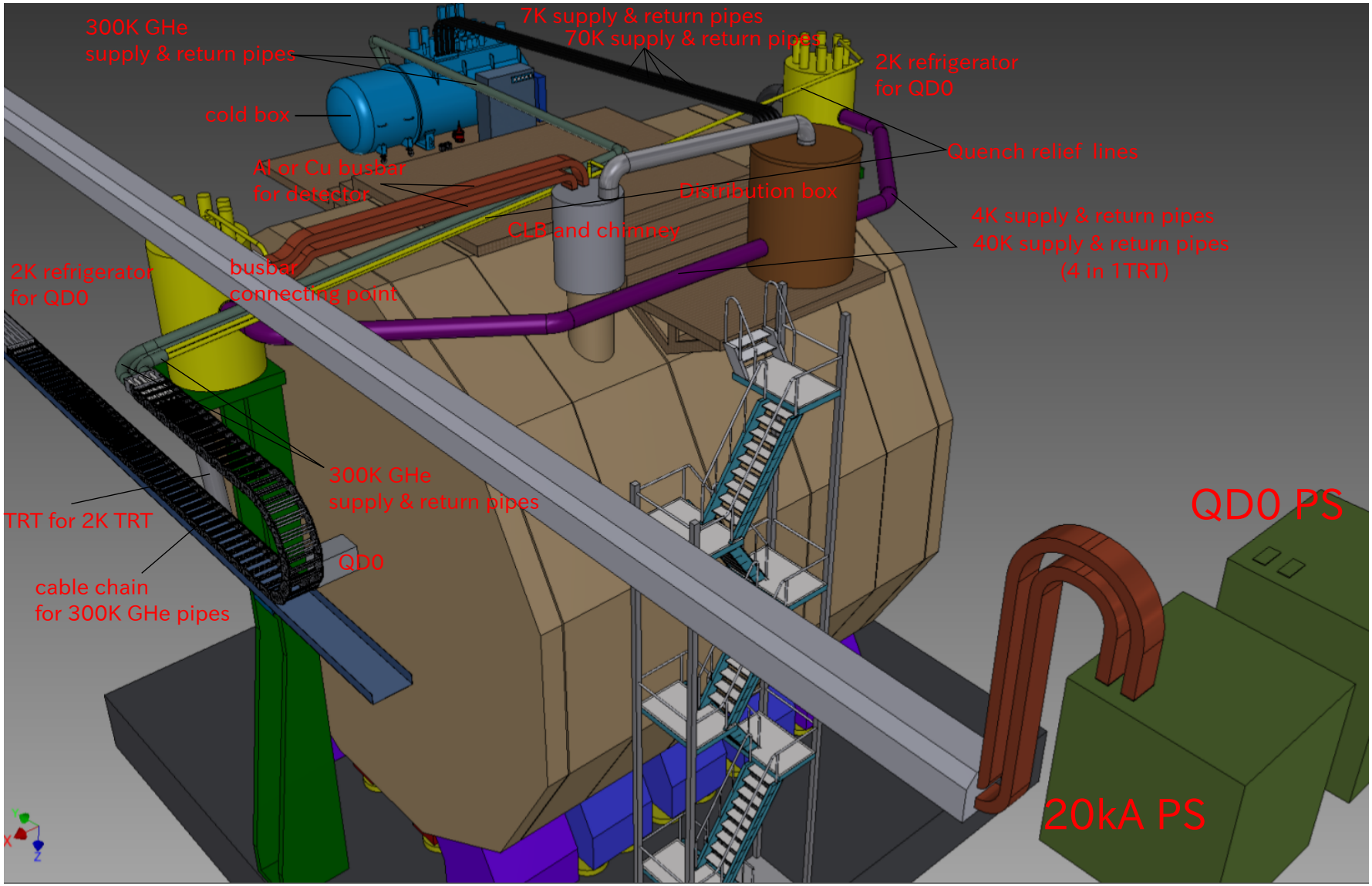
Utilities for cold box

- Cooling water for expansion turbines installed in the CBs are supplied from dedicated cooling water system for the underground.
- Air supply system for control valves should be installed in the underground.

Appendix (D) : 3D view



Appendix (E) : 3D view



Appendix (F) : 2D view