Conceptual Design Study
- Cryogenic Requirements

- How to decide the layout of ILC cryogenic system
- Conceptual design of cryogenic system
- Layout of cryogenic system for site A & B
- Helium inventory
- Cooling water for cryogenic system
- Summary & Future Plan

May 31, 2010

K. Hosoyama

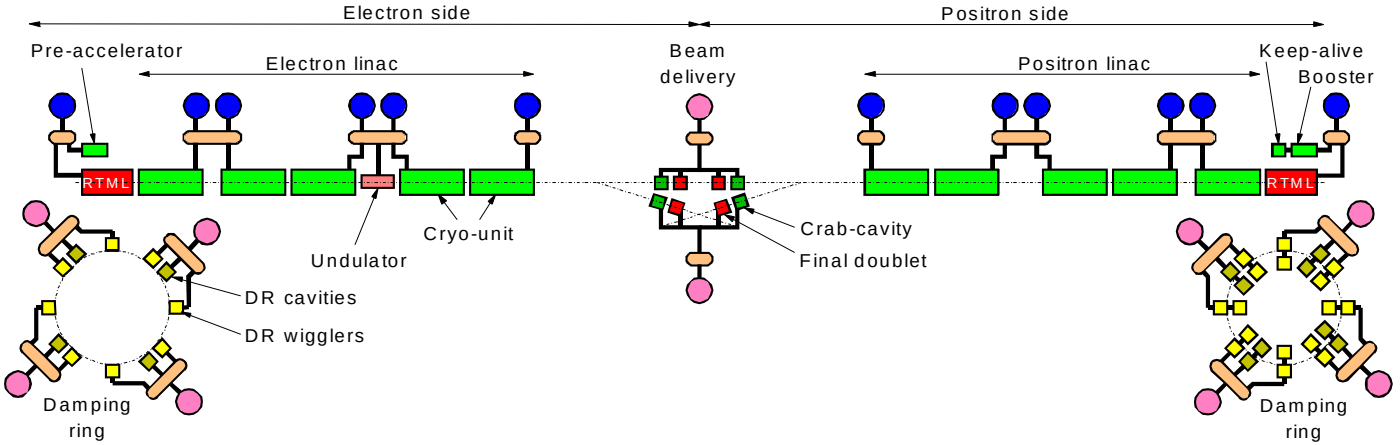
How to decide the layout of cryogenic facility ?

Key Issues

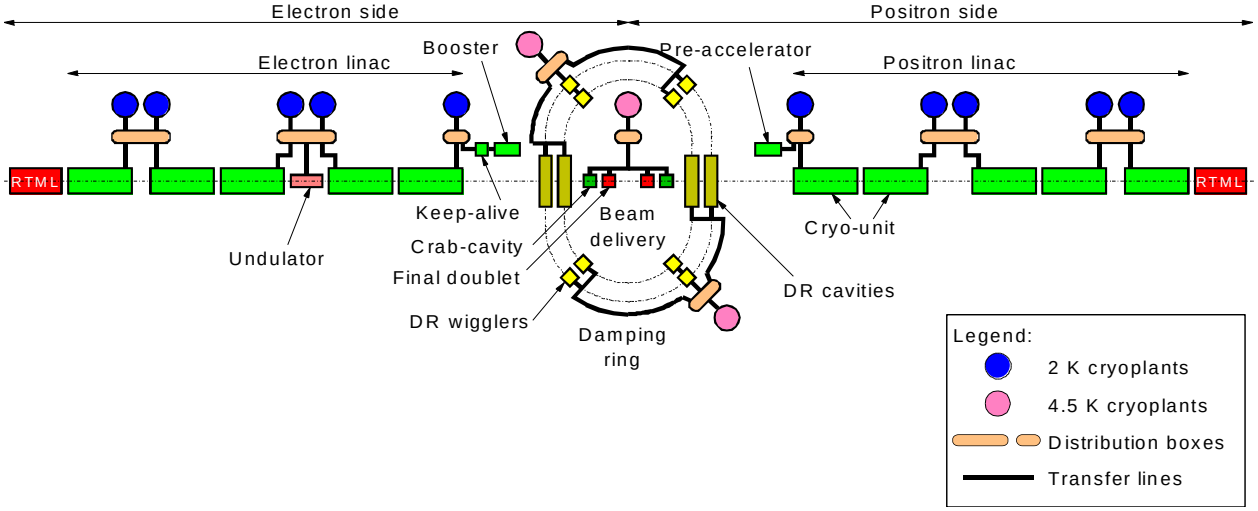
- 2K cold boxes must be installed in the tunnel at 5 km intervals
- Installation, maintenance & repair
  of large components: compressor unit, cold box
- Safety in case of helium gas leakage
- Construction & operation cost
- Use the access tunnel and assembling area of TBM effectively !

Cryogenic plant arrangement / Reference design

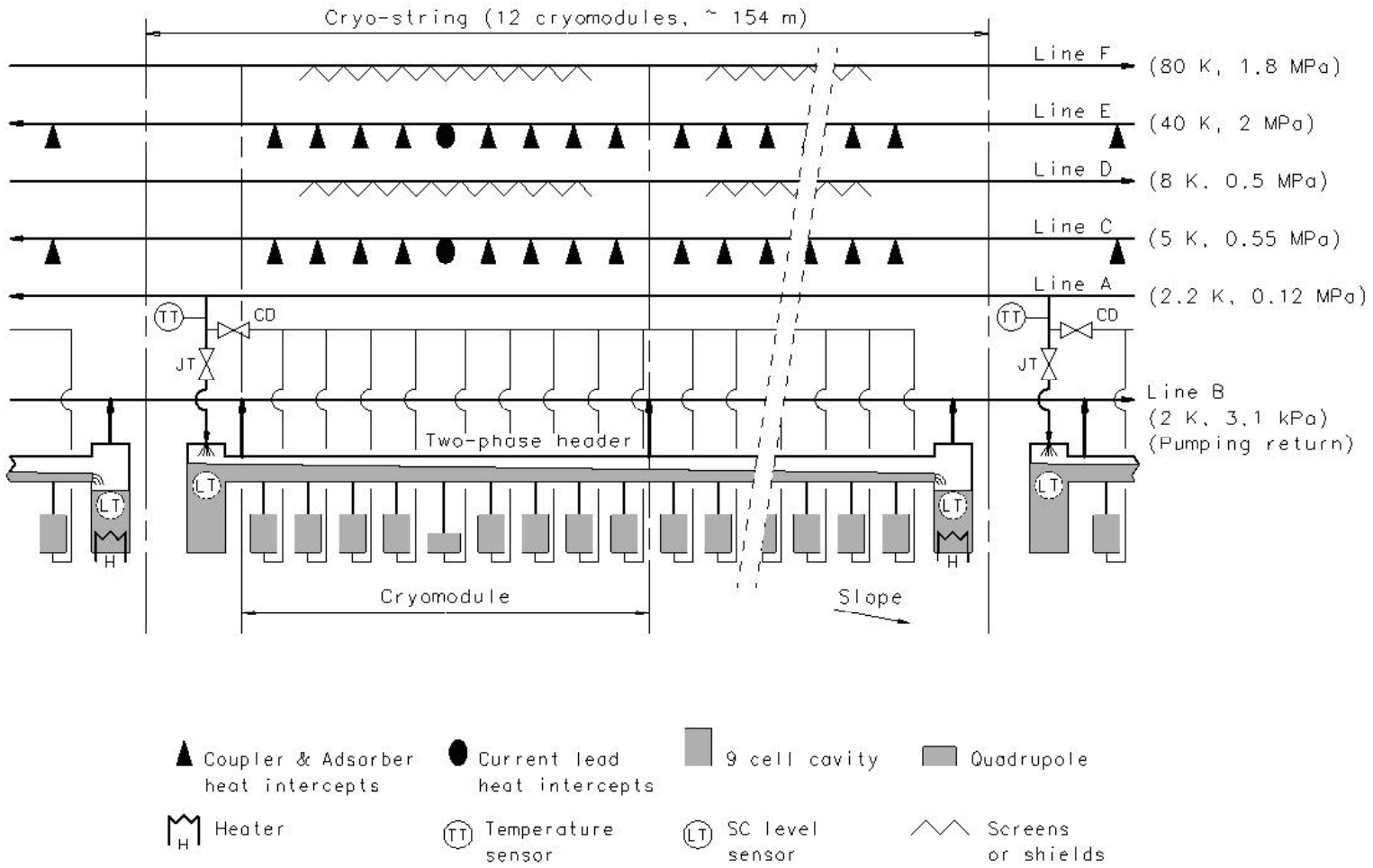
Baseline Configuration Layout



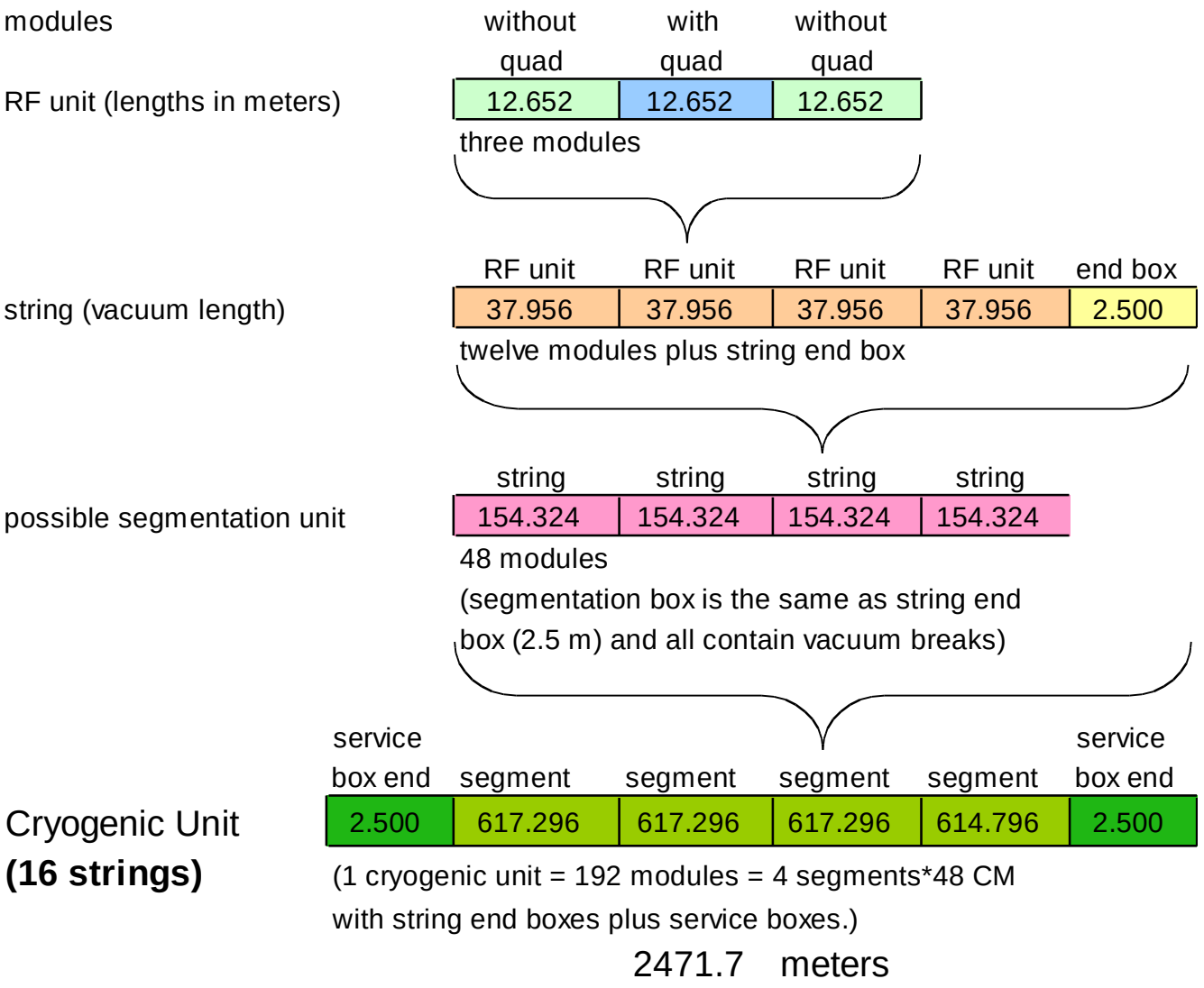
Reference Design Layout



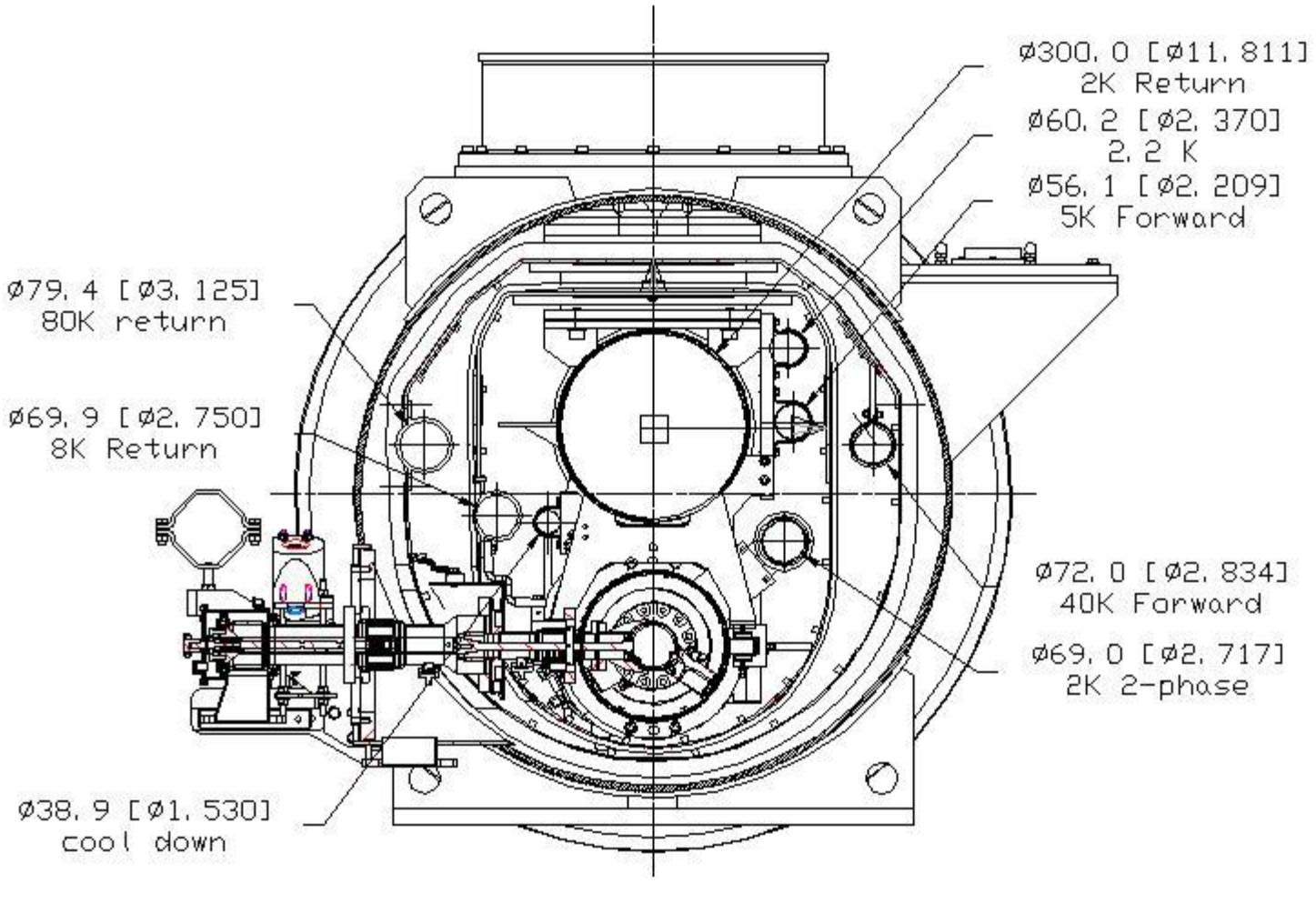
A cryogenic “string”



Main Linac Layout - 1

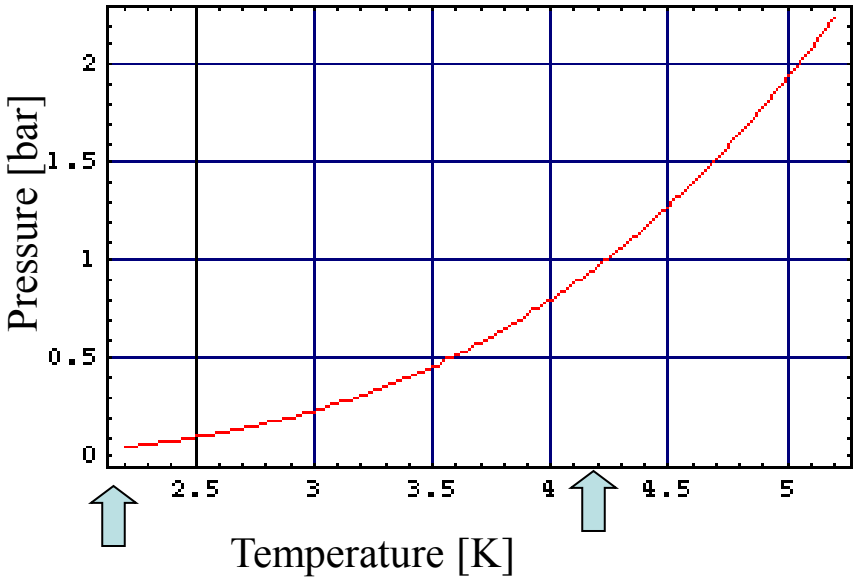


Type 4 cryomodule pipe sizes



Properties of Helium

Vapor Pressure of Saturated Helium



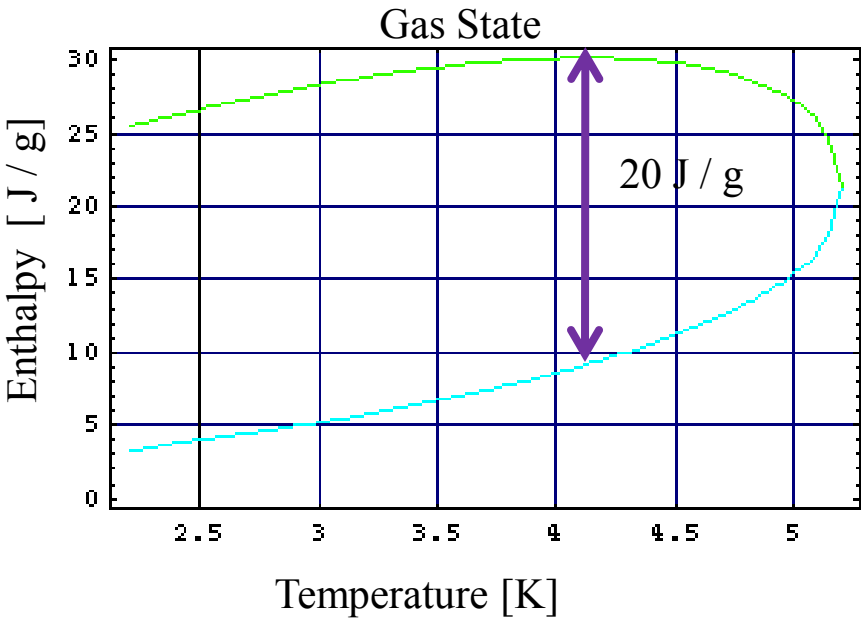
2.0 K ⟺ 0.031 bar

4.2 K ⟺ 1 bar

Ratio of Gas Volume

1 / 0.031 = 32

Enthalpy of Helium



1 W

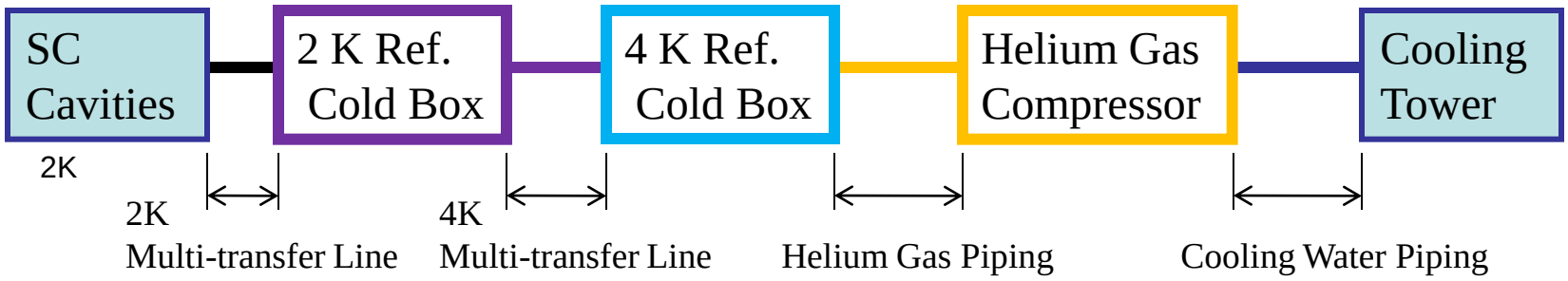
Cooling Power

1.4 *l* / hr

Liq. He Consumption

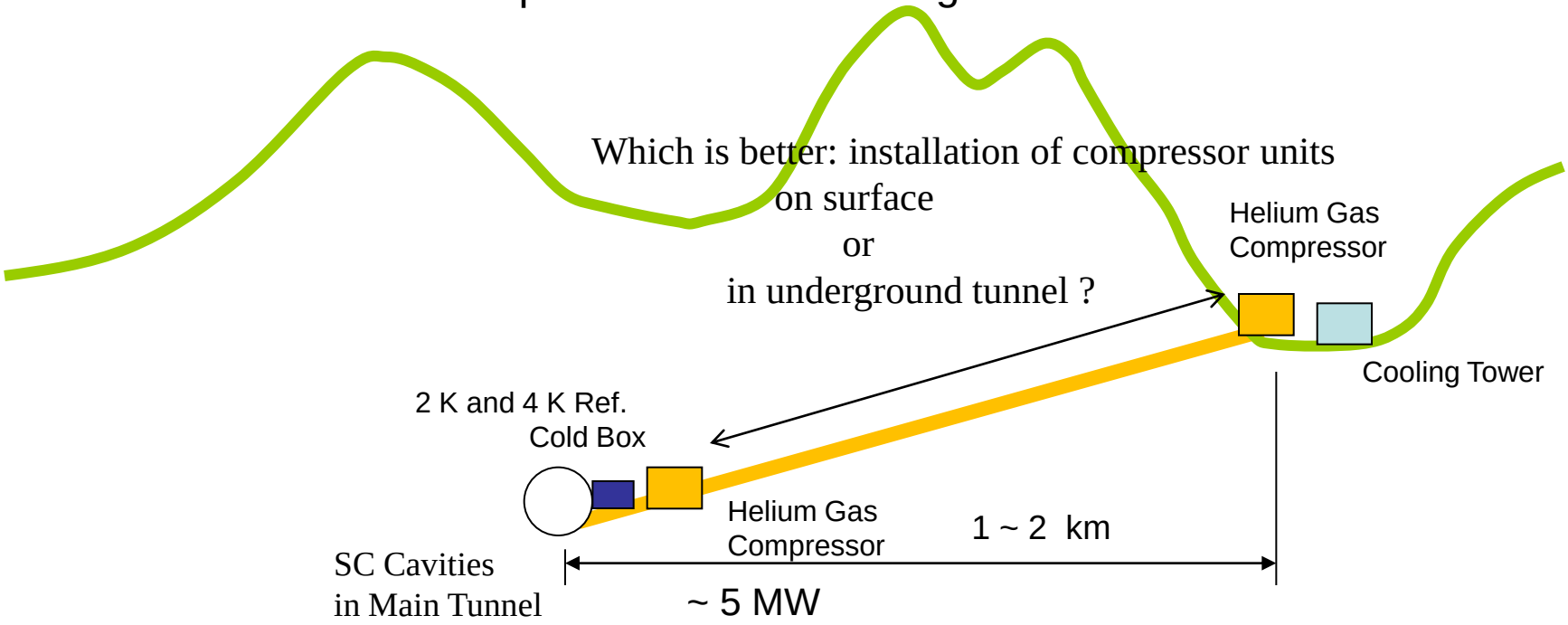
2K cooling power is limited
by pressure drop Δp at cold pumping pipe.

Conceptual Design of Cryogenic System 1



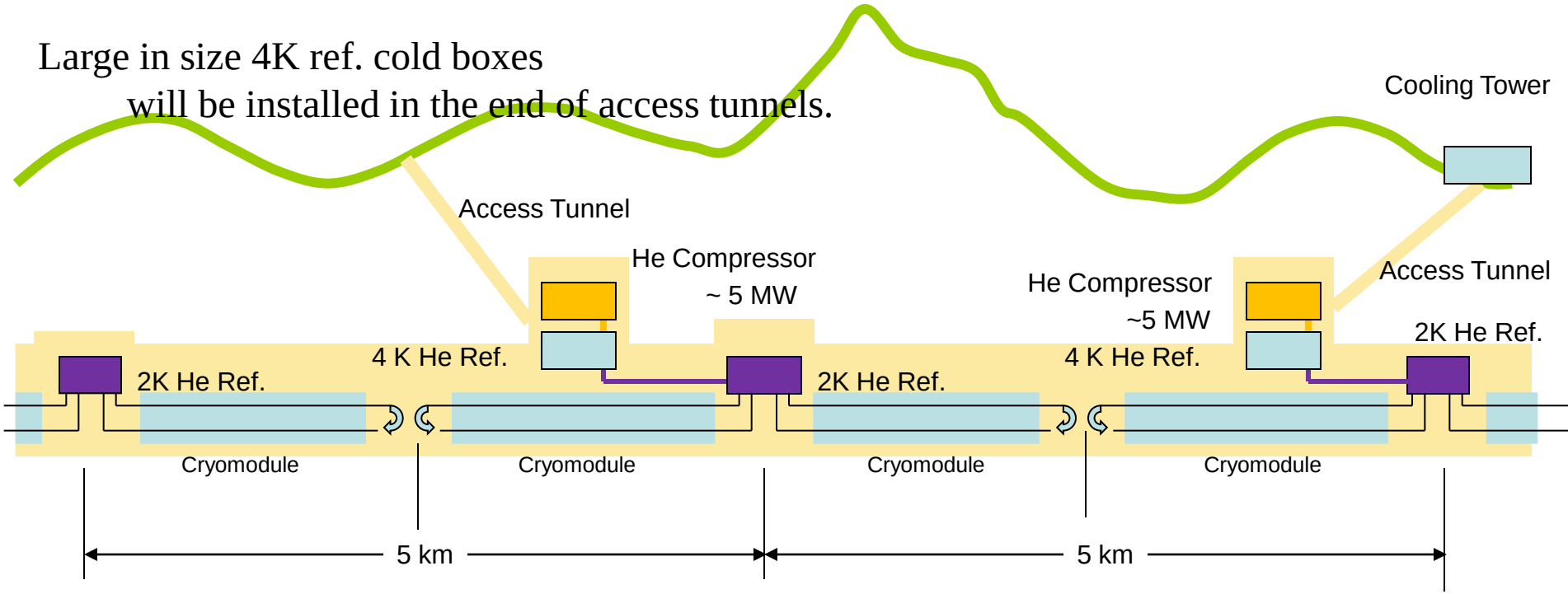
There are m a n y options for layout of cryogenic system , but

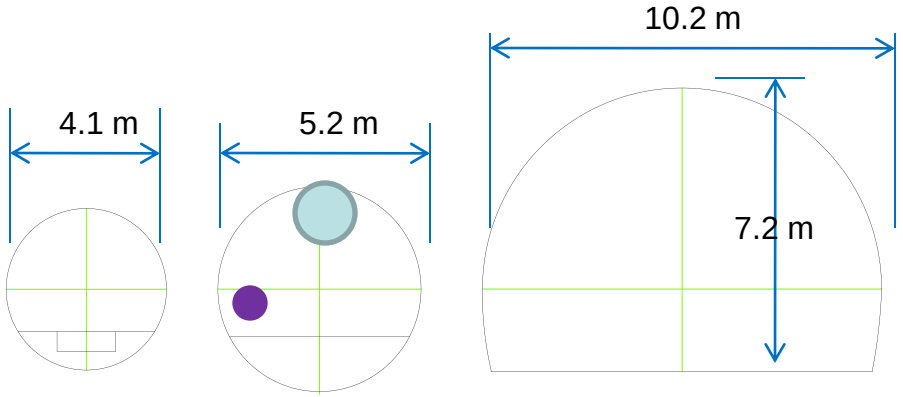
1.the helium ref. cold boxes must be installed in the tunnel,
2.Installation of the compressor units in underground tunnel looks reasonable.

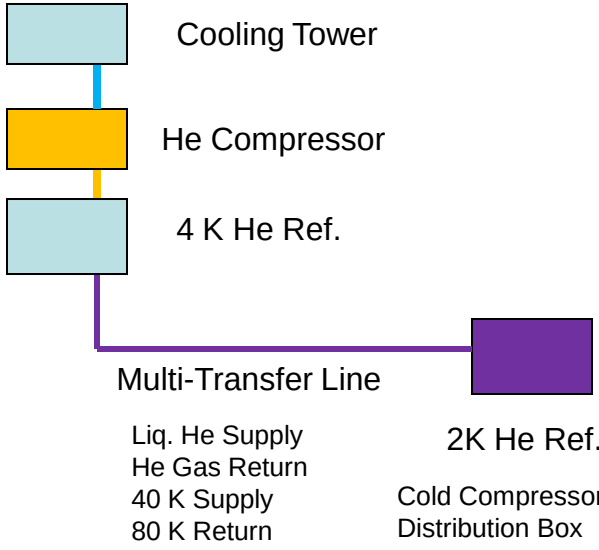


Conceptual Design of Cryogenic System 2

Large in size 4K ref. cold boxes
will be installed in the end of access tunnels.





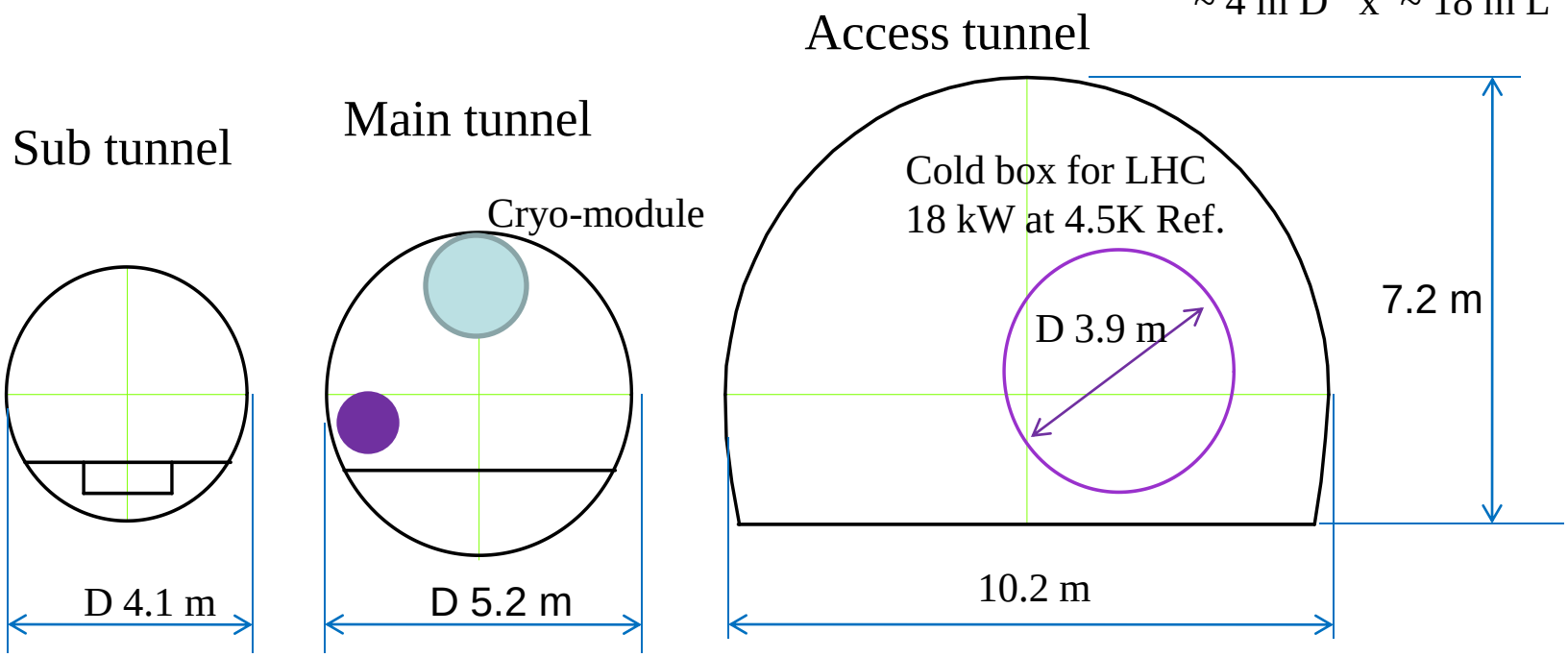


Cross section of tunnels

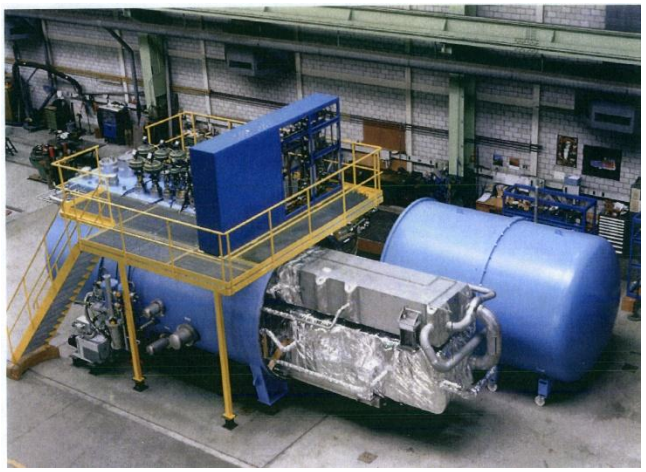
1. The 4K cold box will be carried through the access tunnel and installed in the cavern at the end of access tunnel.
2. The 2K cold box must be carried through main tunnel.

Cold box for LHC
18 kW at 4.5K Ref.

~ 4 m D x ~ 18 m L



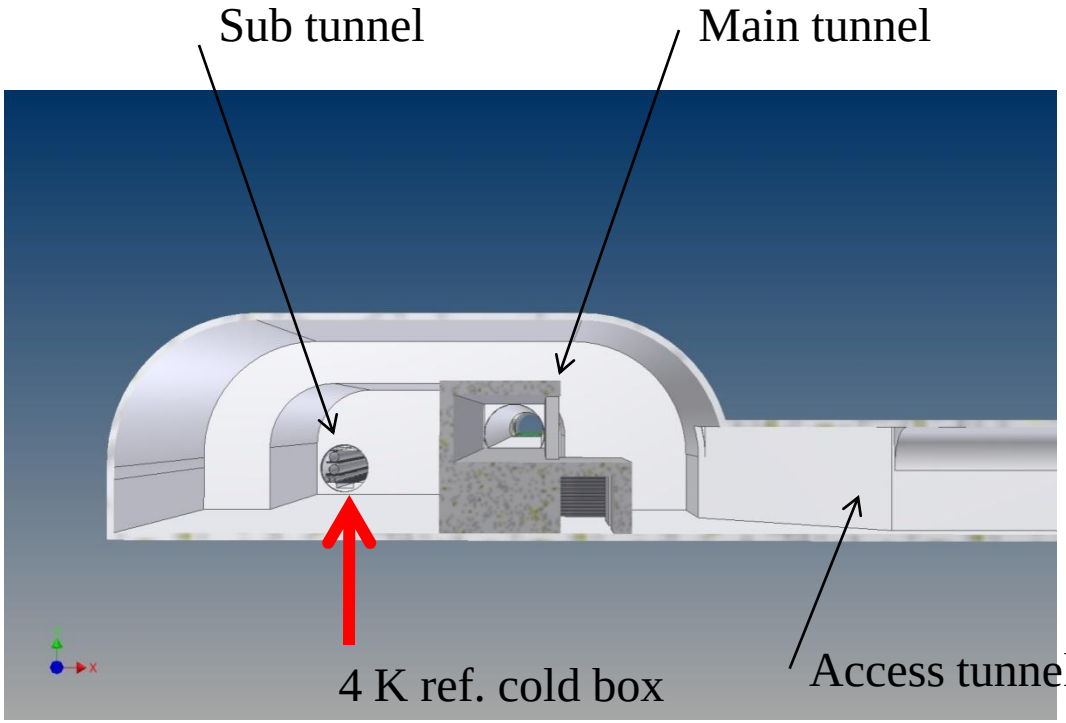
4K Helium Ref. Cold box



18kW Helium Ref. Cold box
/ CERN LHC

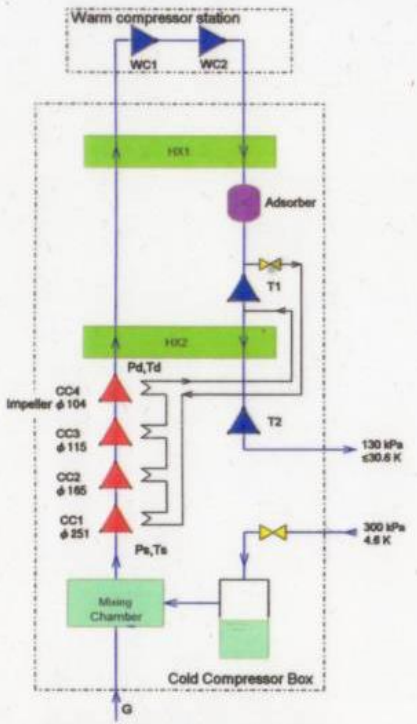
Transportation of the cold box

- The 4K ref. cold box can be installed in cavern prepared for assembling TBM.
- The size of the cold box will be limited by transportation on road from factory to the site.

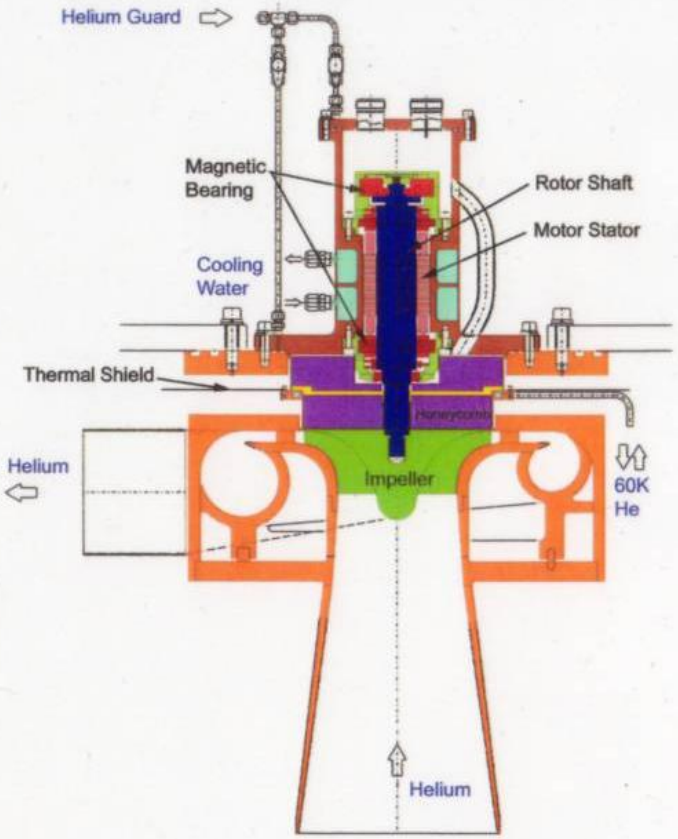


Cavern at the end of access tunnel: used for assembling TBM for the tunnels

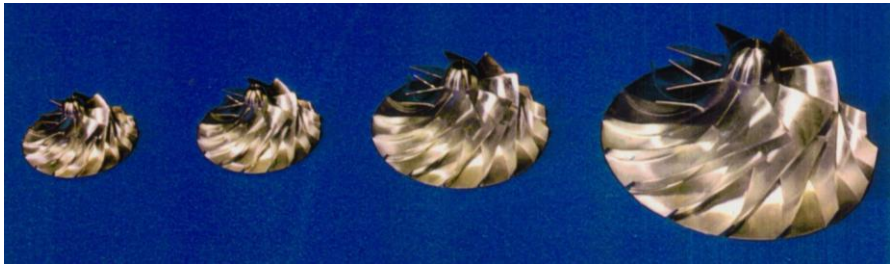
Cold Compressor for LHC 2K Refrigerator



Mode	Installed	Normal	Low intensity
Ps kPa	1.40	1.46	1.47
Ts K	3.96	3.95	4.20
Pd kPa	62.2	42.2	33.2
Td K	27.35	21.83	20.77
G g/s	125.7	84.69	63.89



IHI's four-stage cold compressor system fulfills the various operation modes required in 1.8K refrigeration unit of LHC



Size of Impeller

ϕ 104

ϕ 115

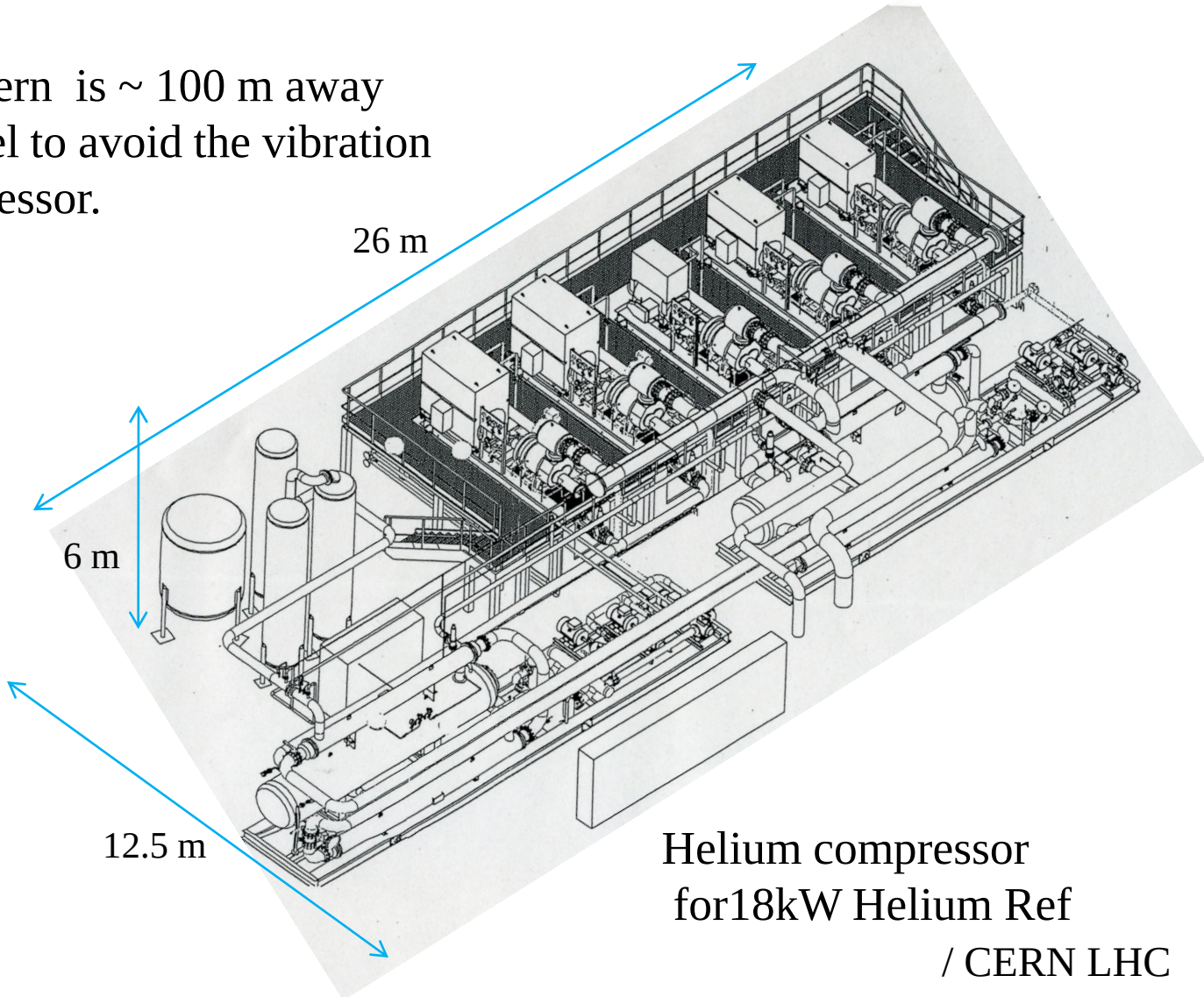
ϕ 165

ϕ 251

Helium Compressor

- The helium compressor is installed in the cavern constructed near by the access tunnel.
- Location of the cavern is ~ 100 m away from the main tunnel to avoid the vibration issues by the compressor.

Compressor + Motor
5 m x 1.9 m x 2 m H

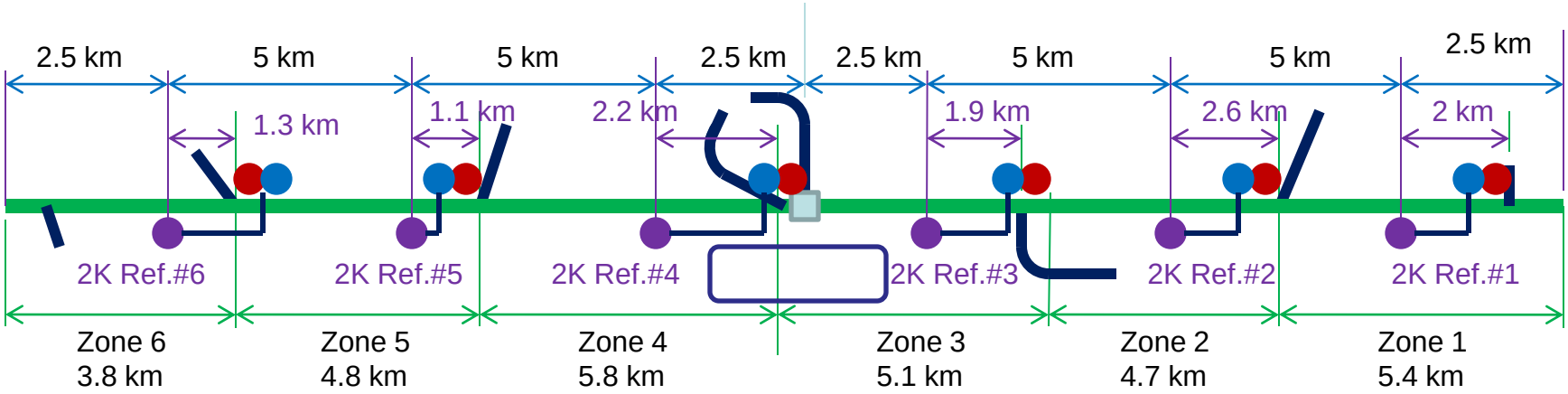


Helium compressor for18kW Helium Ref / CERN LHC

He Refrigeration System for Main Linacs (site-B)

2K cold boxes
4.4 K cold box & compressors

Main Tunnel
Access Tunnel



2K Ref. cold box (+ cold compressor)

4.4 K Ref. cold box

He Compressor

Comment :

1) Need high performance multi-transfer line.
2) End of access tunnel a large space will be prepared for assembling a TBM. This space can be used f o r a 4.4 K cold box.
3) Compressor unit will be installed far away from main tunnel in the cavern near by access tunnel.
4) Helium will be recovered as liquid in the Dewar installed near by 4.4 K refrigerator cold box.

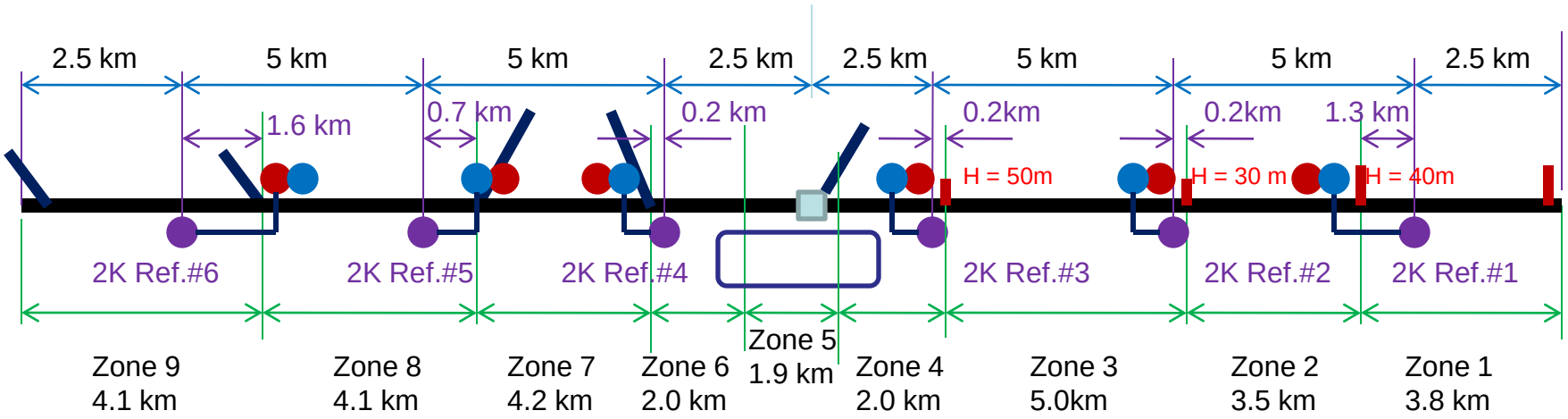
He Refrigeration System for Main Linacs (site-A)

2K Cold Box
4.4 K Cold Box & Compressor

Main Tunnel
Access Tunnel or Shaft

Access Tunnel

Shaft



Comment :

1) Need high performance multi-transfer line.
2) End of access tunnel and shaft a large space will be prepared for assembling a TBM. This space can be used for a 4.4 K cold box.
3) Compressor unit will be installed ~100m away from main tunnel in the cavern near by access tunnel.
4) Helium will be recovered as liquid in the Dewar installed near by 4.4 K refrigerator cold box.

2K Ref. Cold box (+ cold compressor)

4.4 K Ref. cold box

He compressor unit

Helium Inventory

ILC Cryogenic Systems Reference Design
T.J. Peterson et al.
CEC Vol. 53

Required Liquid Helium ~ 650,000 L

Recovery of helium during shutdown?

1) Gas Helium Storage ~ 100 m^3 / unit x 250 units

Standard Gas Storage Tank 100 m^3 (D3 m x L15 m)

1L Liq. Helium ---- 0.7 Nm^3 Gas Helium
100 m^3 x 18 = 1800 ---- ~ 2600 L

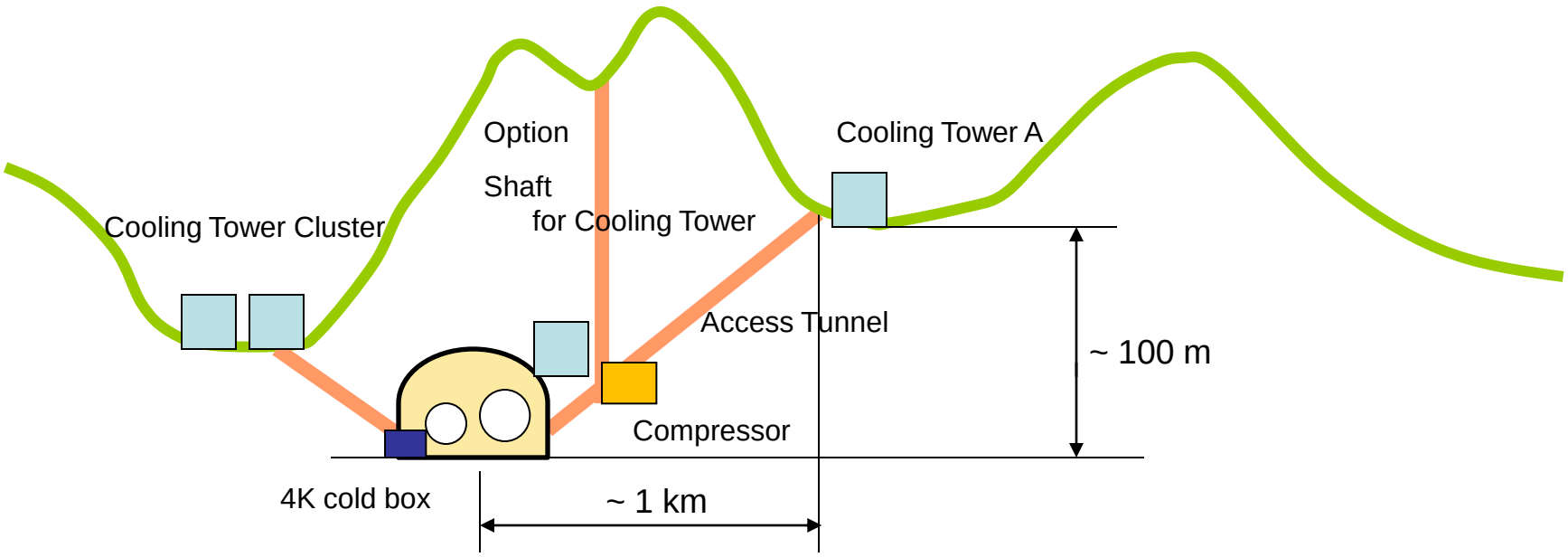
2) Liquid Helium Storage ~ 50,000 L / unit x 12 units

Liq. Helium Dewar ~ 50,000 L (D2.5 m x L10 m)

Vaporization loss:
50,000 L x 0.5%/day = 250 L / day ~10 L/hr

Small refrigerator can be used as “Baby-Sitter”

Conceptual Design of Water Cooling System

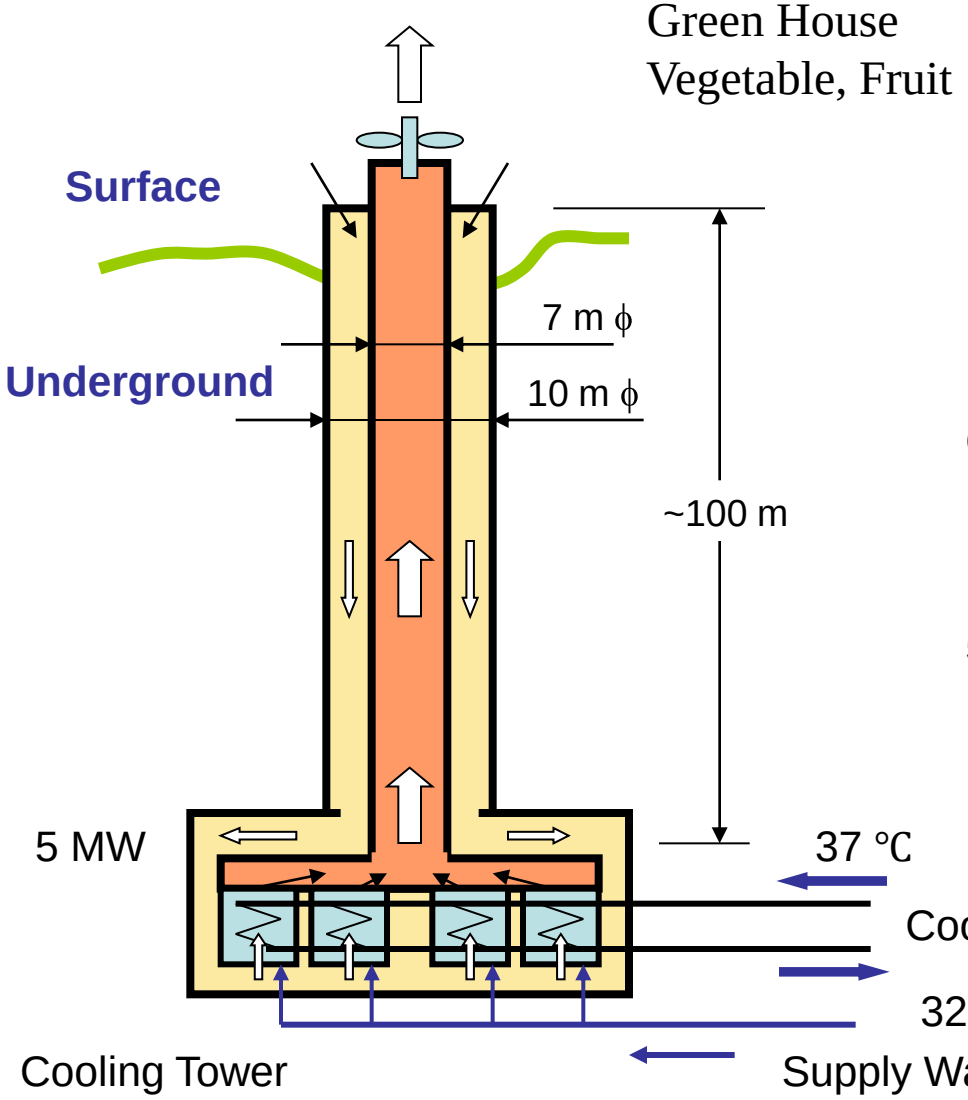


Comment :

1) Cooling tower A can support cooling of local heat load.
2) Cooling tower cluster can support cooling of ~ 8km long distributed heat load. The cooling water circulate in 900 mm in diameter pipe.
3) By installation of the cooling tower in the tunnel, we can eliminate heat exchanger which need to cut the head pressure.

Cooling Tower in the Tunnel

Utilization of Heat :
Agriculture
Green House
Vegetable, Fruit



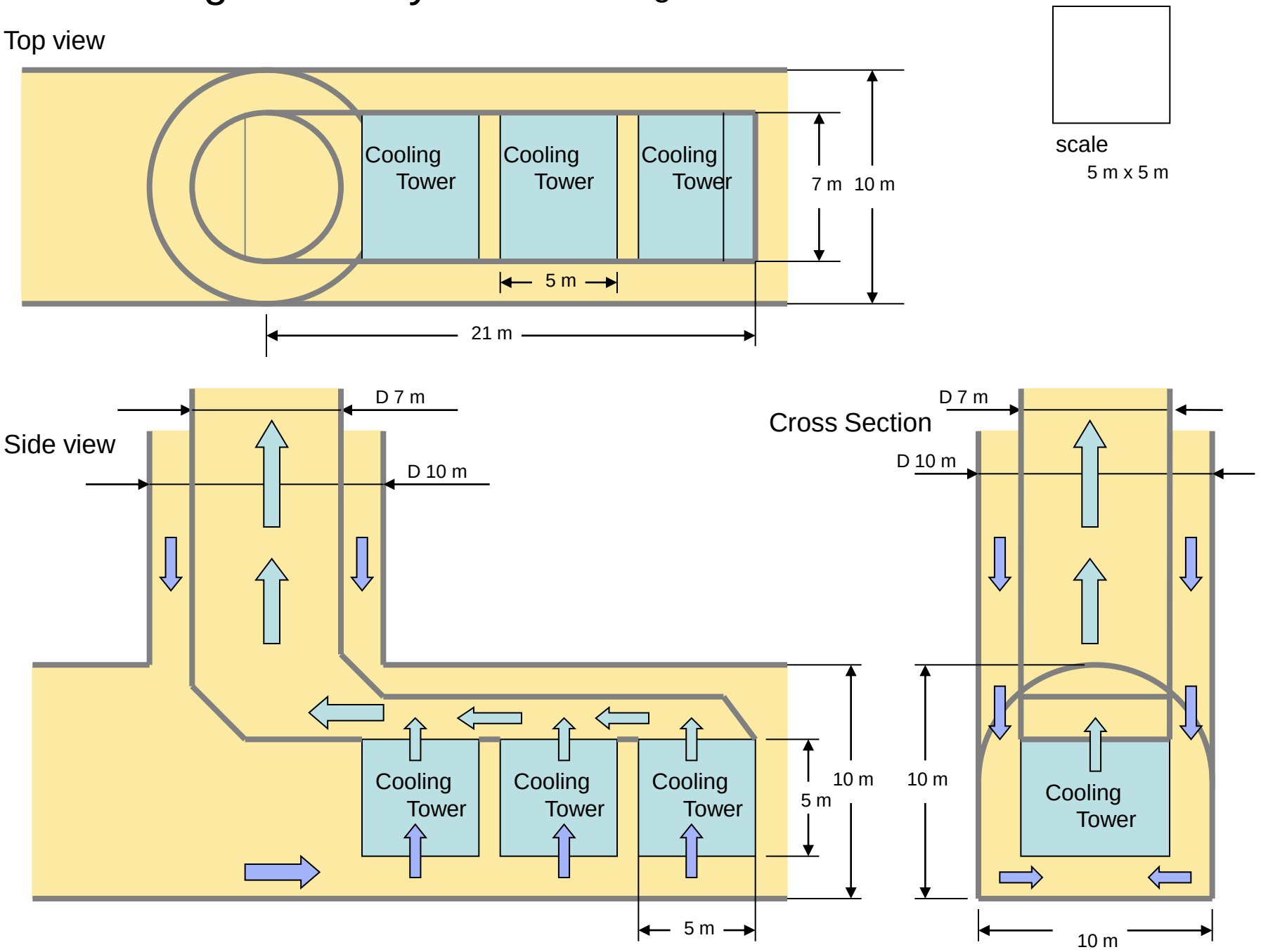
1 L / sec = 539 kcal / sec
= 2253 kW
1 MJ = 0.44 L / sec = 1.6 m3 / hr

Cooling Tower

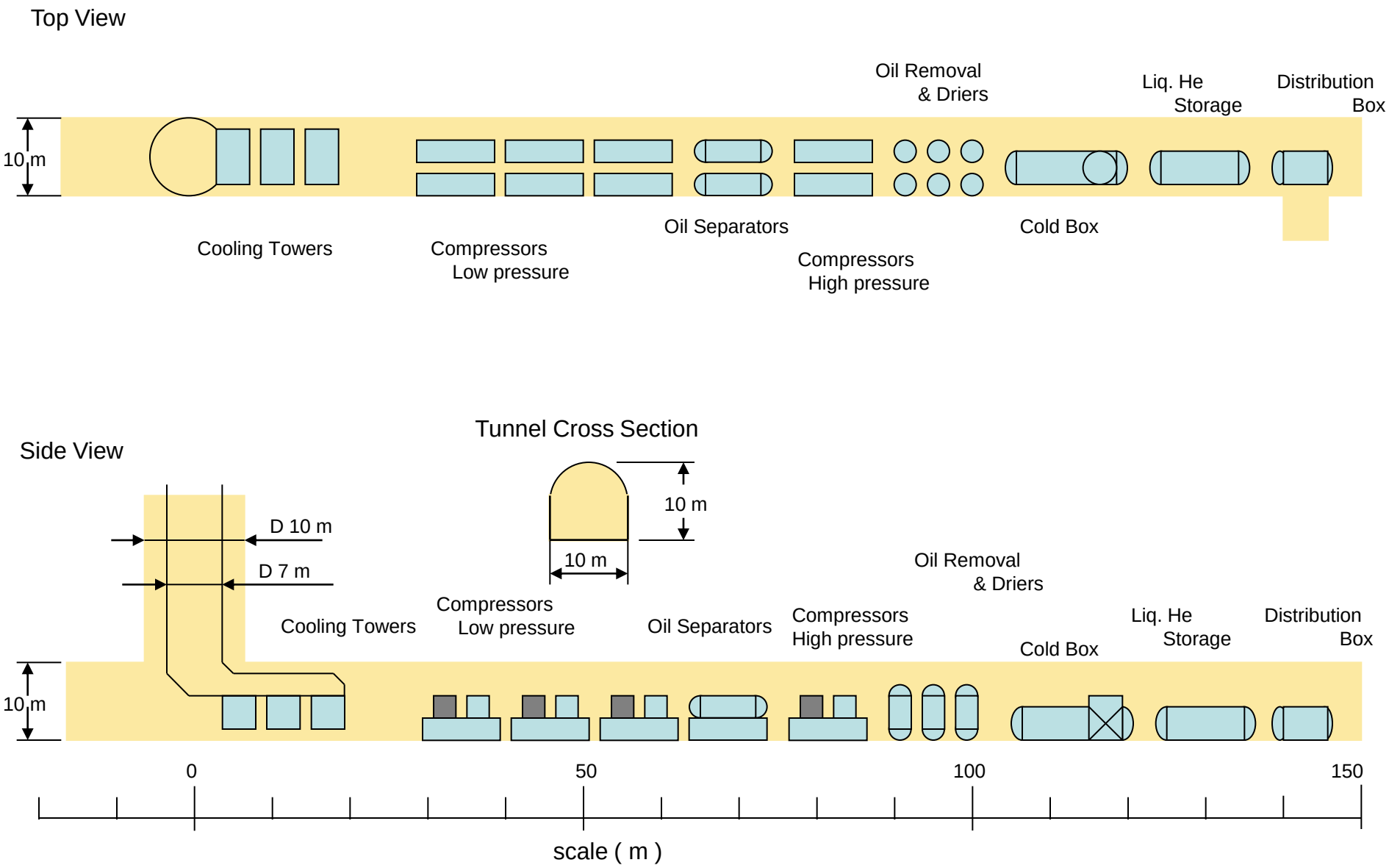
Fan 2 m ϕ ~ 3 m² 0.5 MW

5 MW 30 m2 60 m2 ~ 9 m ϕ

Helium Refrigeration System Cooling Tower in Tunnel

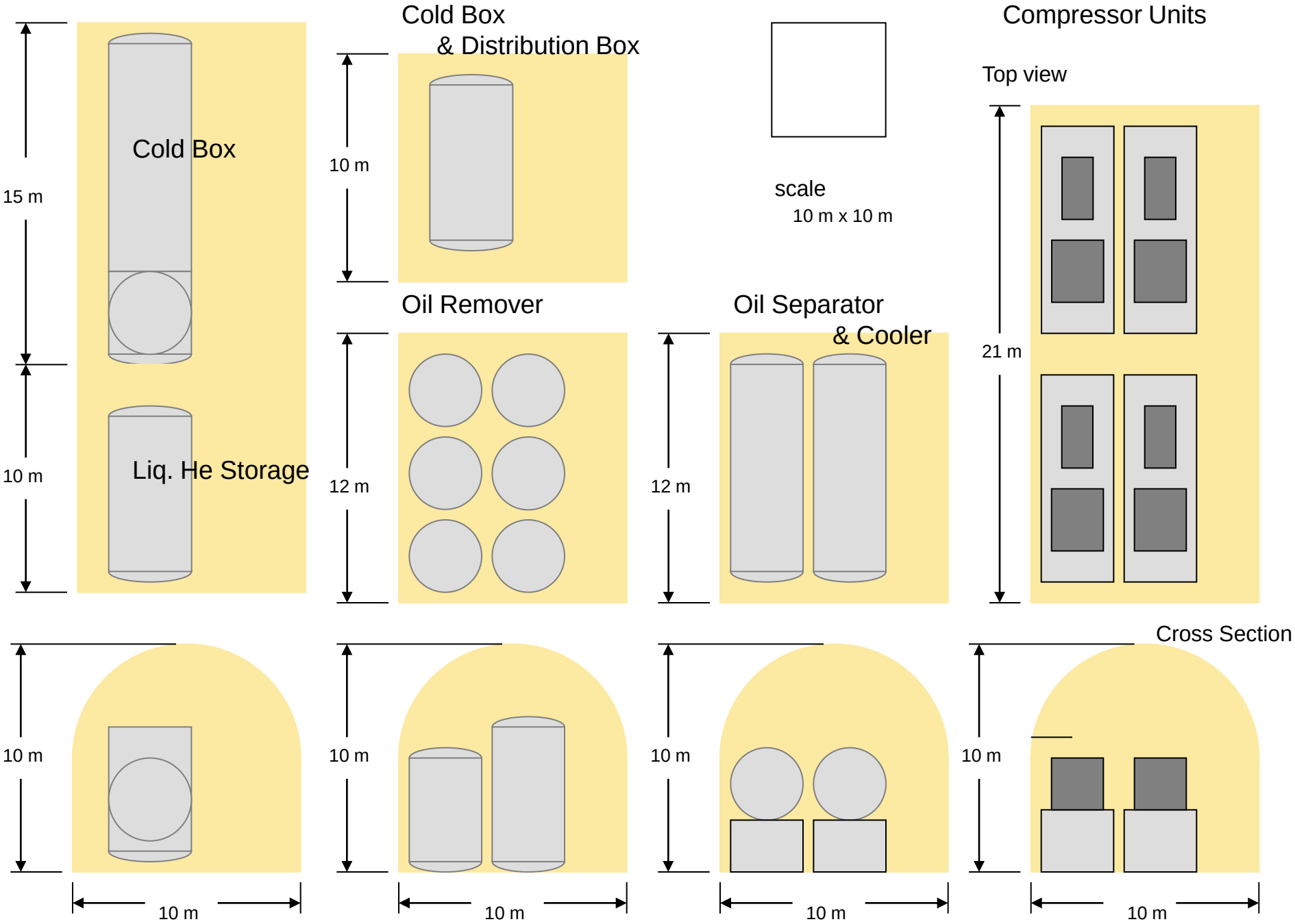


Helium Refrigeration System in Tunnel



Helium Refrigeration System

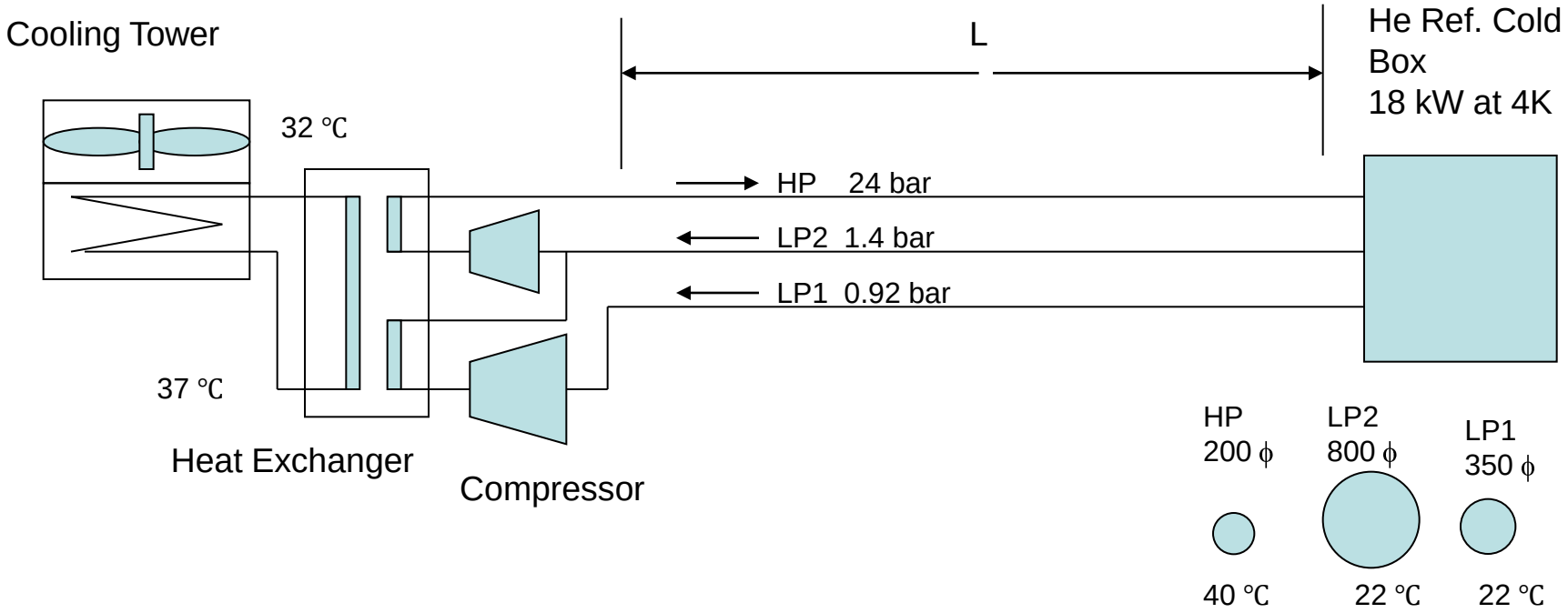
Cold Box / Compressor



Summary & Future Plan

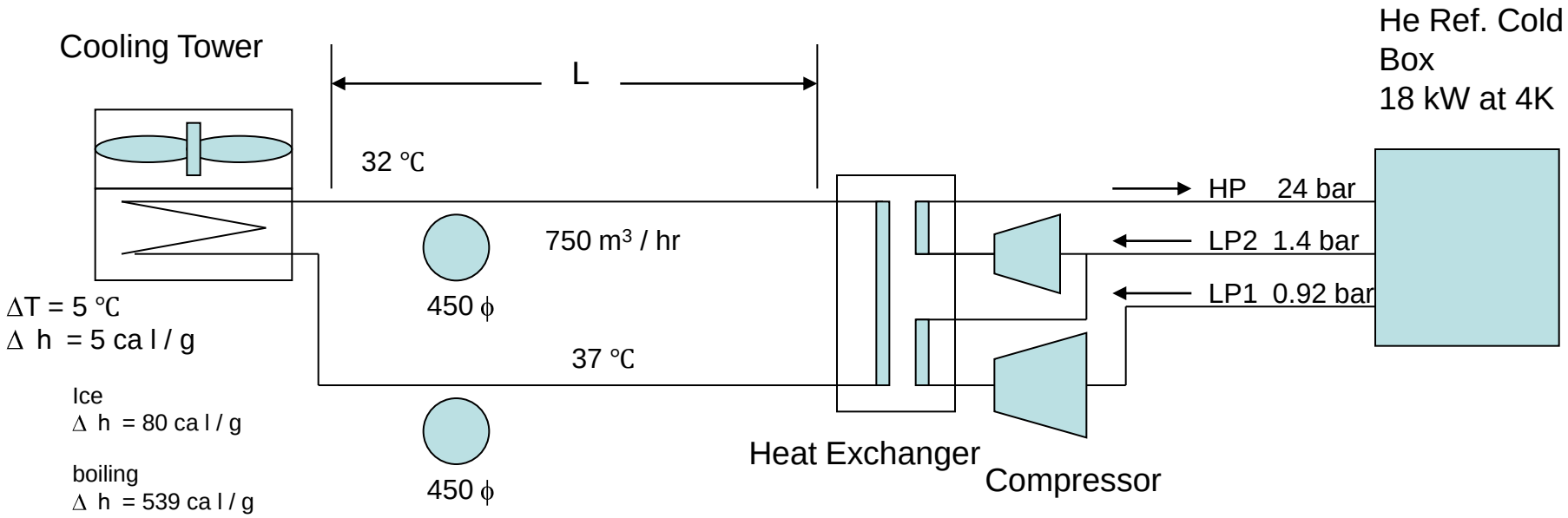
- **The 2K cold boxes will be installed in the small caverns in main tunnel at 5 km intervals.**
- **The 4K cold boxes will be installed in the large caverns at the end of access tunnels prepared for assembling the TBM.**
- **The 2K cold box with cold compressor and the 4K cold box is connected by multi-transfer line installed in the main tunnel.**
- **The compressors will be installed in the caverns constructed alongside the access tunnels.**
- **Large amount of helium inventory will be reserved as liquid helium during shutdown of cryogenic system.**
- **The cooling water used in the compressors will be supplied by local cooling tower or cluster of cooling towers trough 900mm in diameter piping.**
- **We need the engineering design study of cryogenic system collaboration with industry.**

Appendix 1: Pressure Drop and Power Loss in He Pipes



	ΔHP	ΔLP2	ΔLP1 (bar)	Power
L = 10 m	0.007	0.000	0.000	4.3 MW
L = 1000 m	0.695	0.008	0.017	+1.2 %
L = 2000 m	1.389	0.017	0.034	+2.4 %

Appendix 2: Pressure Drop and Power Loss in Water Pipes



	ΔP pipe	ΔP total (bar)	Power	
L = 10 m	0.000	3.02	125.0 kW	6.7 %
L = 1000 m	1.55	4.57	187.1 kW	6.9 %
L = 2000 m	3.04	6.06	245.3 kW	7.1 %