*CFS Two Day Workshop at CERN/20150727*

# *ILC Japan Cryo System*

LINEAR COLLIDER COLLABORATION

Designing the world's next great particle accelerator

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*in collaboration with*

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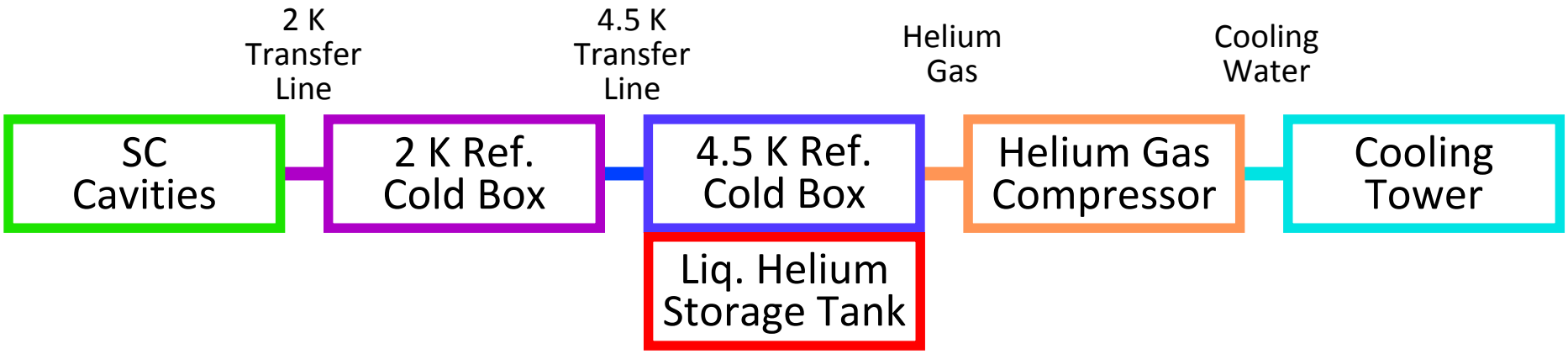
*and Thomas PETERSON, FNAL*

Rev. 0:

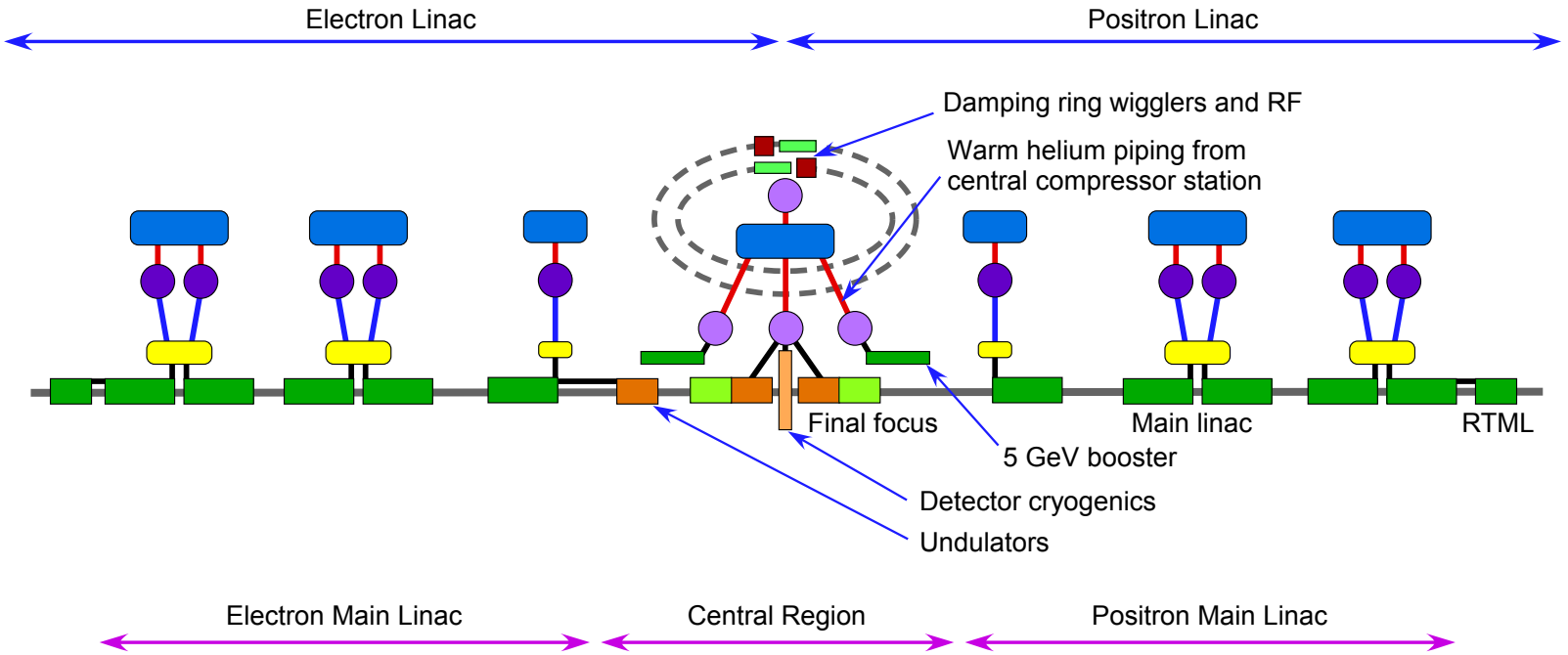
# Basic Components of Cryogenic Systems




- Superconducting cavities installed in underground tunnel
- 2 K refrigerators required for keeping of 1.3 GHz cavities at or below 2 K
- Cooling at or below 2 K requires 4.5 K refrigerators
- Most of electric power for cryogenic systems consumed by helium compressors
- Heat removal necessary for heat generation at helium compressors as much as consumed electric power (cooling water, cooling towers)

# Overall Layout for Cryogenic Systems

## DKS Cryogenic Plant Arrangement (Mountainous Topography)




- Small 2 K and 4.5 K cryoplants
- Large 2 K cryoplants
- Helium compressor stations
- Cryogenic distribution boxes
- 1.3 GHz cryomodule strings
- Other SRF (damping ring and crab cavities)
- Superconducting magnets (wigglers, undulators, final focus)

# Cryogenic Systems of ILC

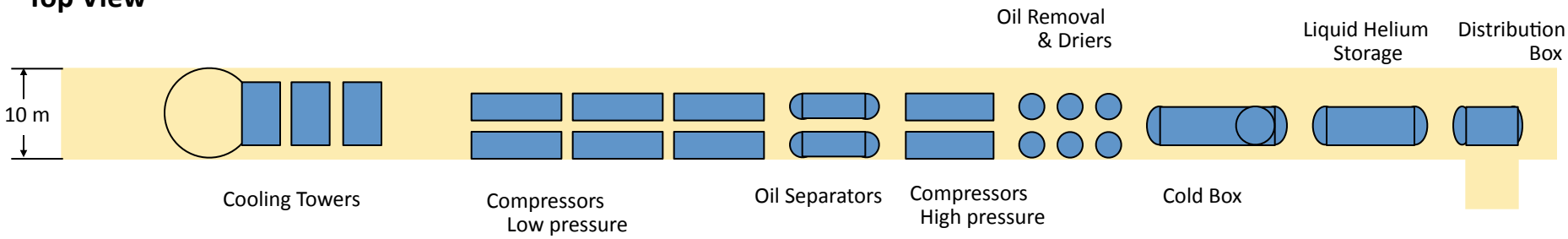
- Cryogenic Systems
  - Detectors (SiD, ILD)
  - Focus magnets (QD0, QF1)
  - Damping rings
  - Crab cavities
  - Main linacs (electron, positron)
- Cryogenics groups (current proposal)
  - Interaction region (IR)
  - Main linacs
- Helium compressors for IR cryogenic systems clustered in one place (Central Compressor Station)

# Points of Consideration

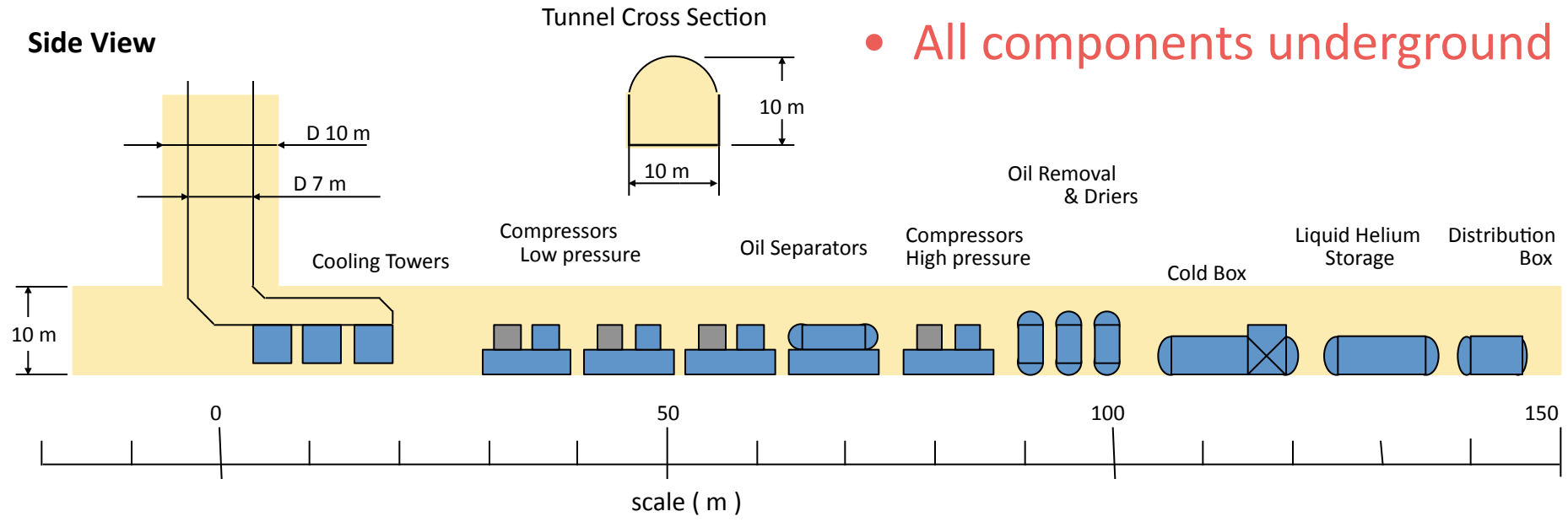
- Scenic conservation and environment protection (noise and mechanical vibration)
- Storage of liquefied gas underground prohibited (CERN and FNAL)
- Mechanical vibration of helium compressors affect beams
- Shorter 2 K transfer lines preferred
- No liquid nitrogen employed for 4.5 K helium refrigerators
- Liquid helium storage tanks close to 4.5 K helium refrigerators
- Heat removal from helium compressors (cooling towers)
- helium delivery as gas (because of circumstance in Japan)
- Helium buffer tanks required for stable operation of cryogenic systems)
- Radioactivation of helium can be ignored (from past measurements at CERN and FNAL)
- Accessibility for daily checks and accidents response
- Construction costs

# Cryogenic Component Configuration (1)

**Top View**



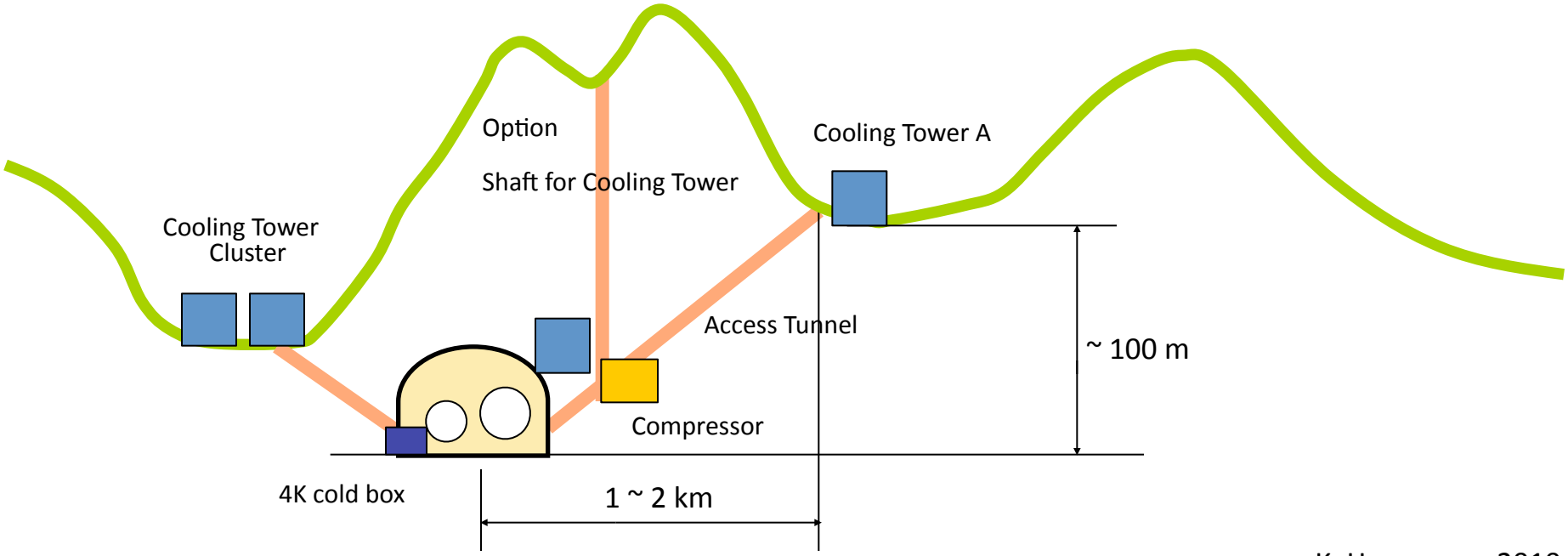

**Side View**




- All components underground

K. Hosoyama, 2010

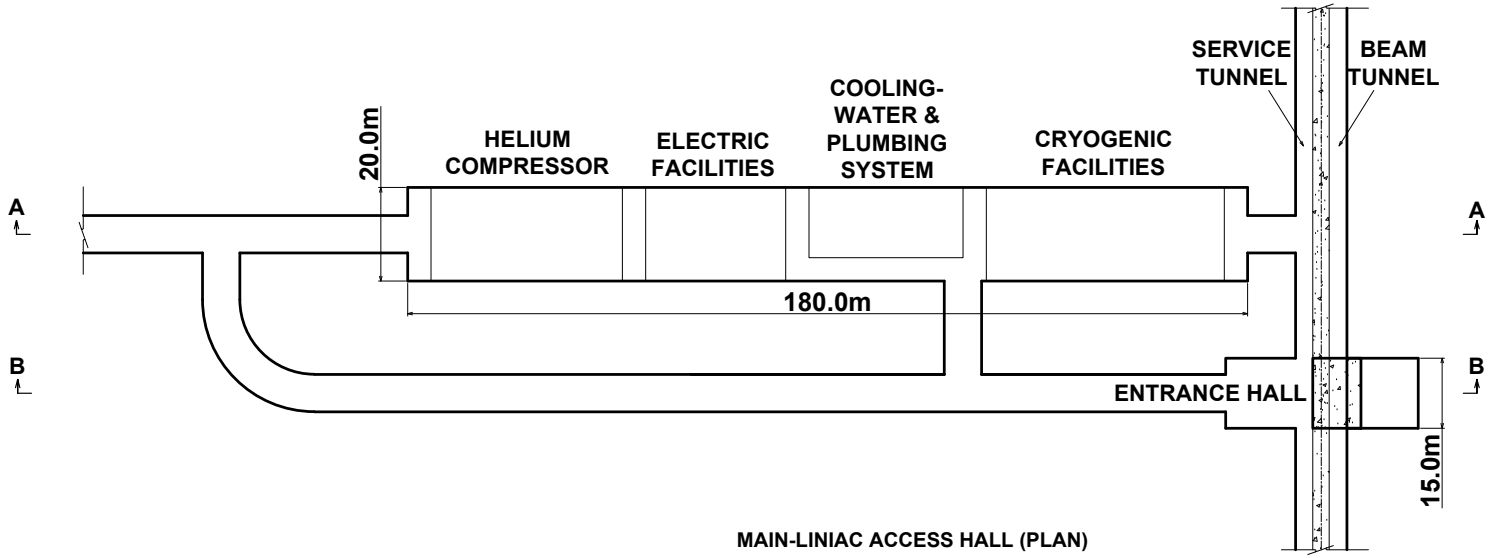
# Cryogenic Component Configuration (2)



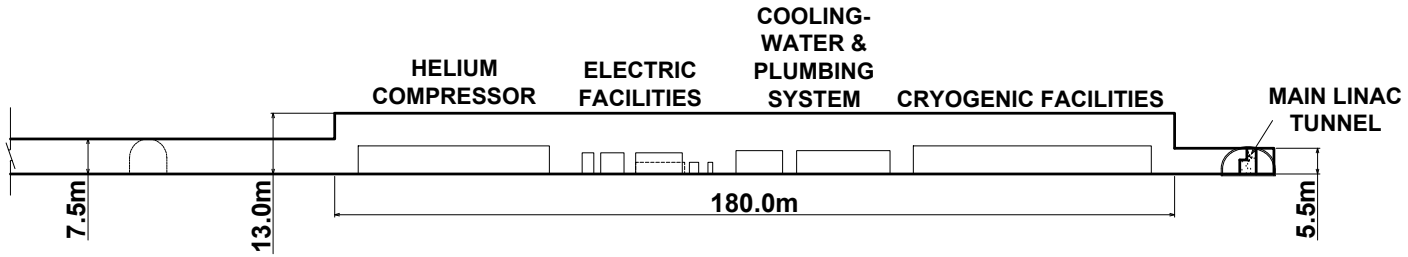

K. Hosoyama, 2010

- Only cooling towers on surface for effective heat removal, and others underground
- Do noise and water vapor from cooling towers may affect environment?

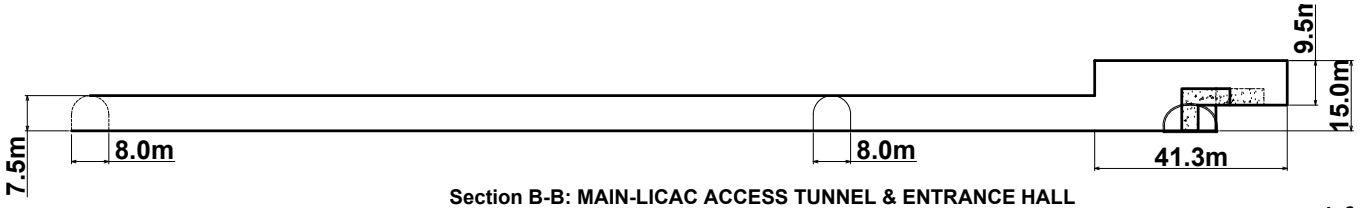
# Typical Access Hall (Cryogenic Cavern)




MAIN-LINIAC ACCESS HALL (PLAN)



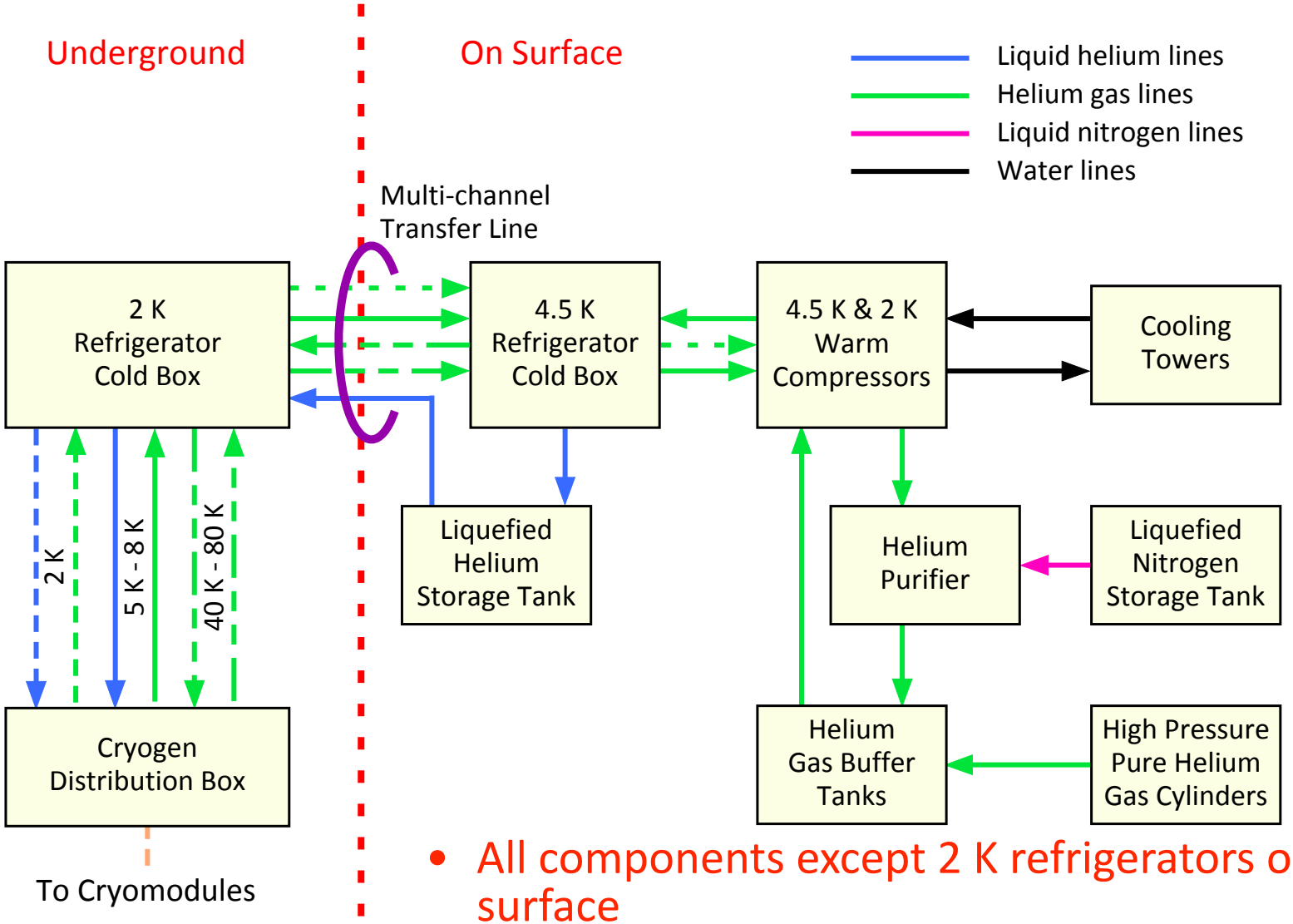

Section A-A: ELECTRICAL & MECHANICAL SERVICE HALL




Section B-B: MAIN-LICAC ACCESS TUNNEL & ENTRANCE HALL

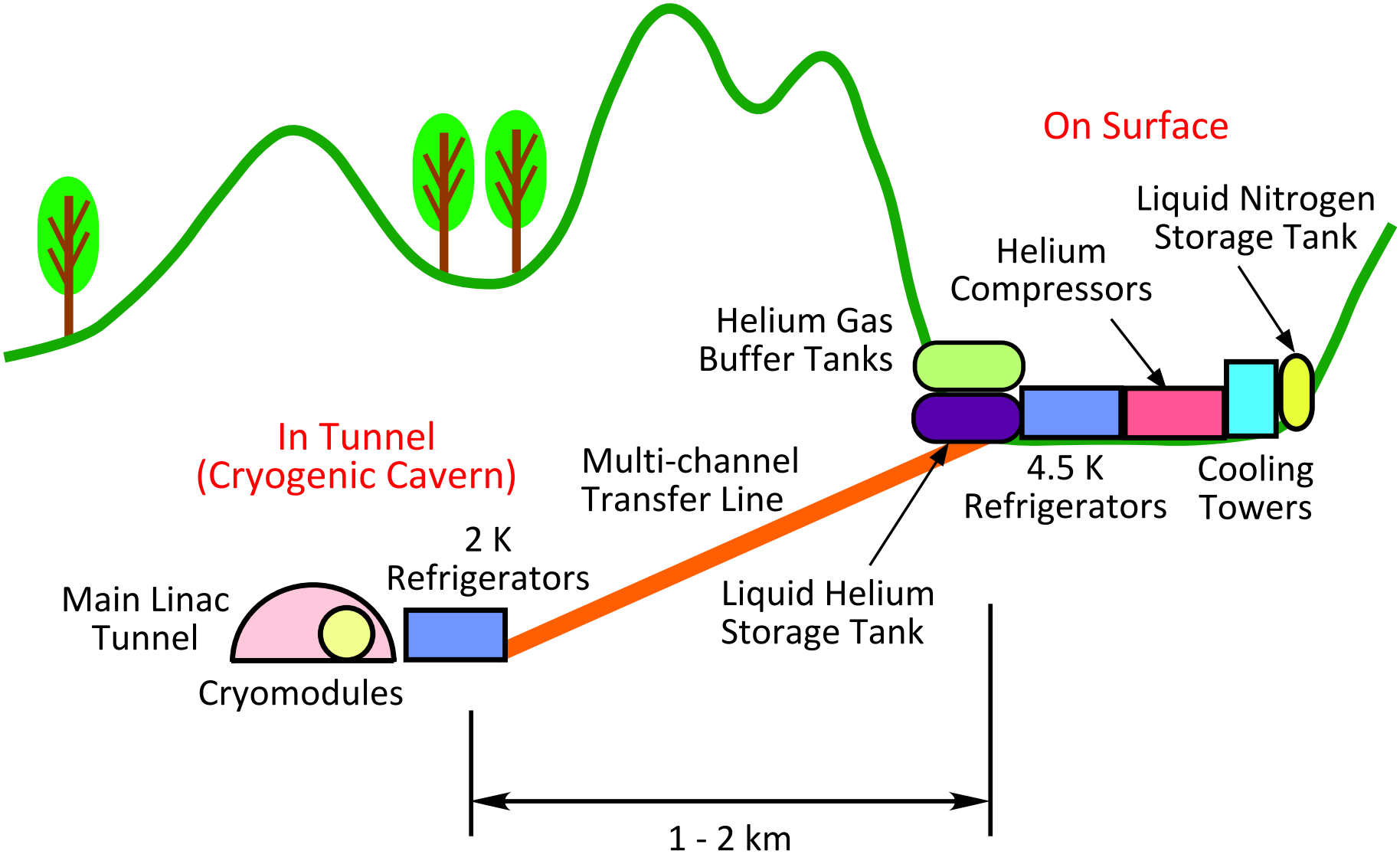
Cited from ILC-TDR

# Current Cryogenic System Configuration

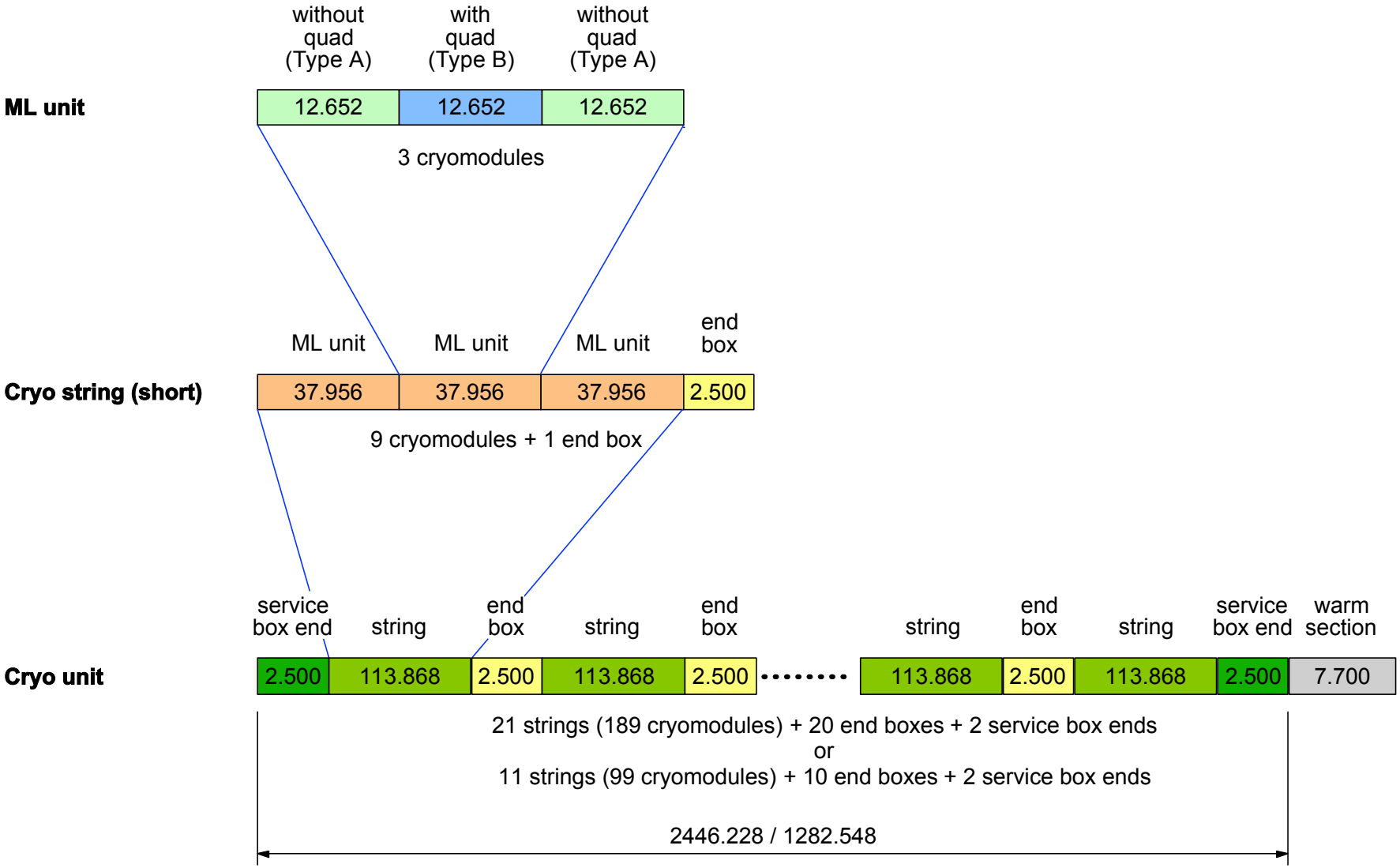



- All components except 2 K refrigerators on surface

# Current Cryogenic Component Configuration

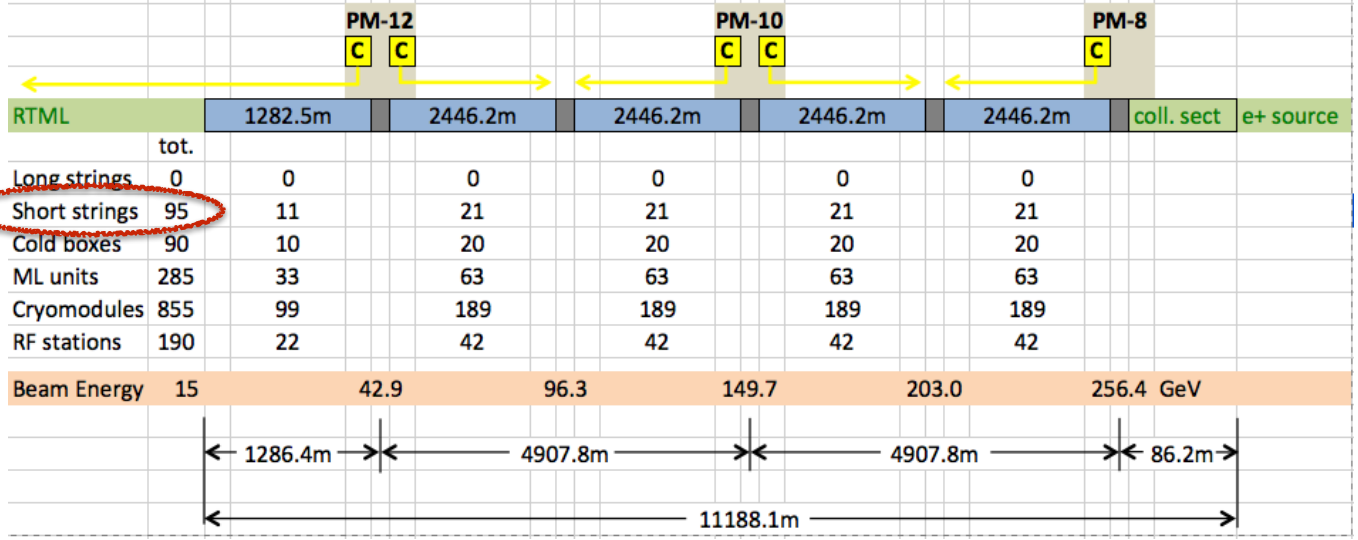


# Cryo Unit Configuration



# Linac segmentation (TDR)

**Electron Linac**

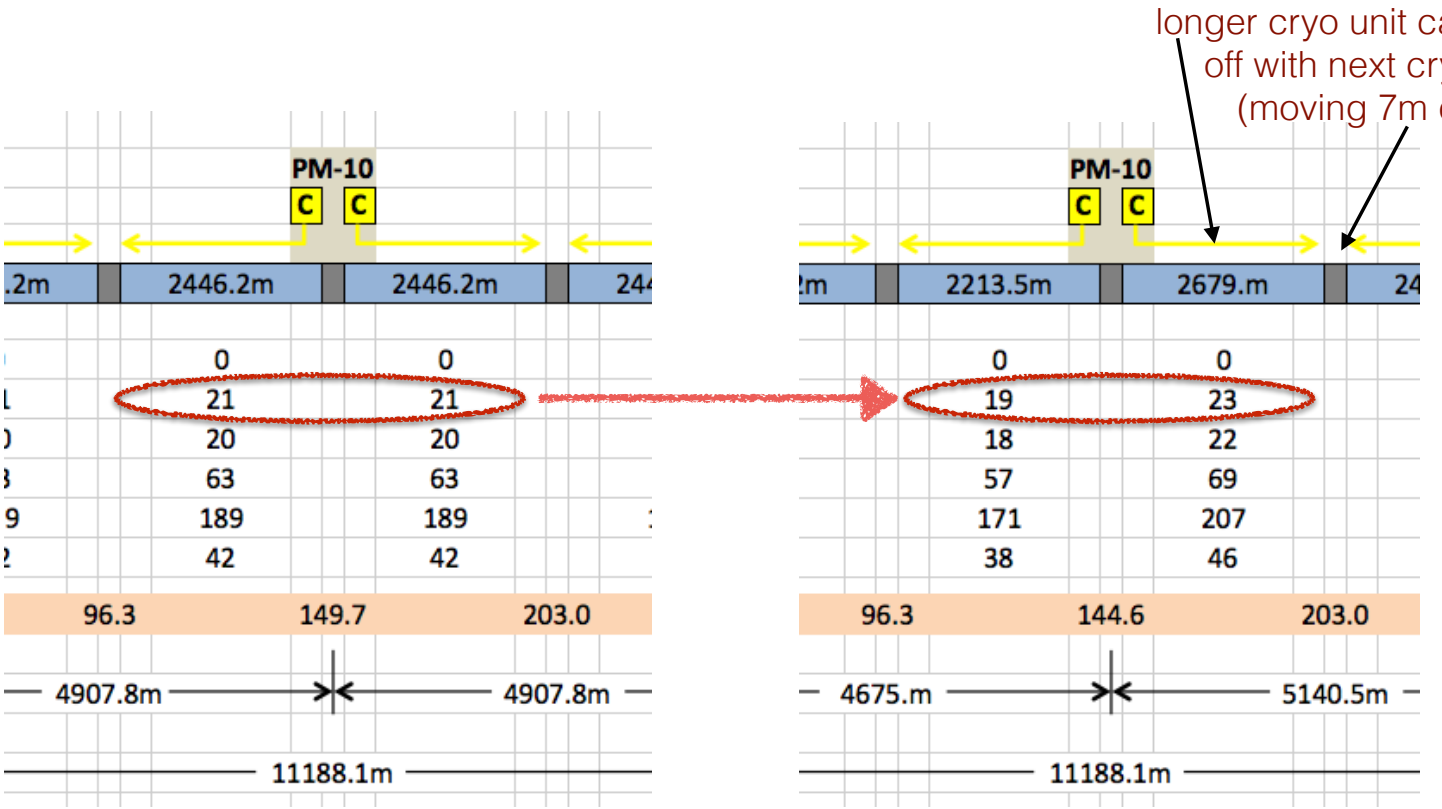



| | tot. | | | | | |
|---|---|---|---|---|---|---|
| Long strings | 0 | 0 | 0 | 0 | 0 | 0 |
| Short strings | 95 | 11 | 21 | 21 | 21 | 21 |
| Cold boxes | 90 | 10 | 20 | 20 | 20 | 20 |
| ML units | 285 | 33 | 63 | 63 | 63 | 63 |
| Cryomodules | 855 | 99 | 189 | 189 | 189 | 189 |
| RF stations | 190 | 22 | 42 | 42 | 42 | 42 |
| Beam Energy | 15 | 42.9 | 96.3 | 149.7 | 203.0 | 256.4 GeV |

- Easiest "unit" is a short string
  - 9 cryomodules (2 DKS RF units) + cold box
  - Maintains standard RF waveguide configuration and linac lattice.
- Length: 116 m
- Straightforward for PM±10 and PM±12
  - Every ±116m shift changes cryo-unit length by ±1/21 ~ ±5% (~ cryo-plant load) [see example next slide]
- PM±8 special case

N. Walker, 2015

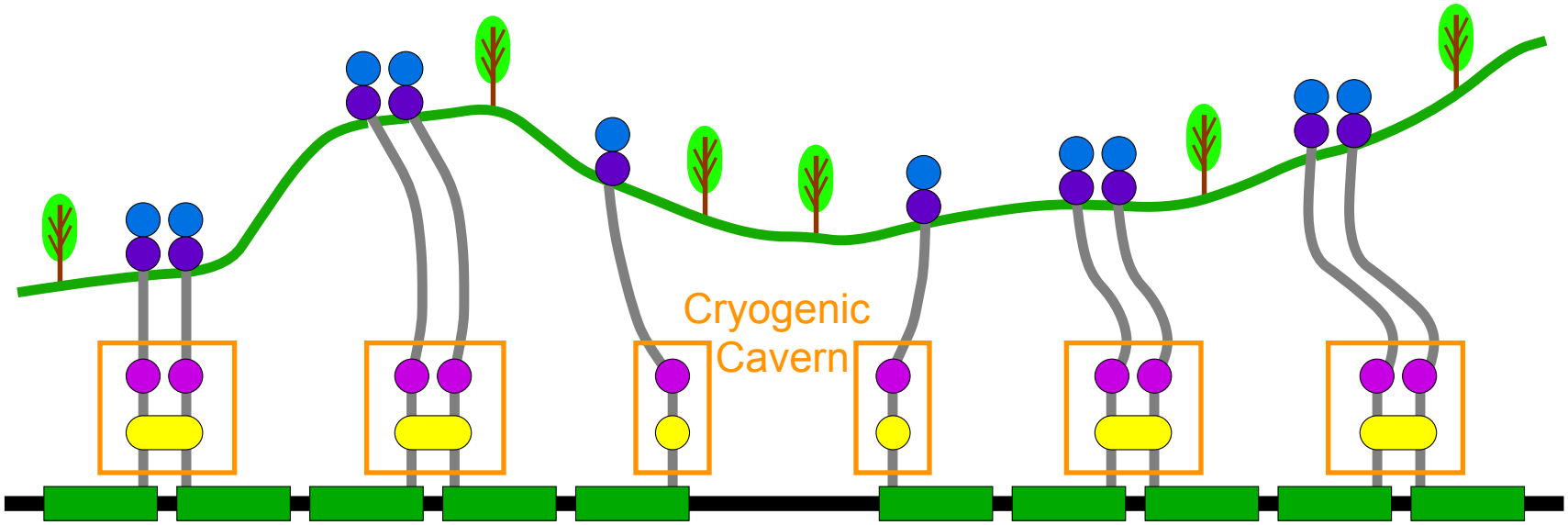
# Example: moving PM-10 by 2×116m




What is the limit on cry-unit lengths from cryogenics standpoint?
(Available cryo-plant power is one main limit)

N. Walker, 2015

# Current Cryogenic Plant Configuration




- Helium compressors
- 4.5 K helium refrigerators (cold boxes)
- 2 K helium refrigerators (cold boxes)
- Cryogenic distribution boxes
- Cryogenic distribution boxes (interconnected)
- Multi-channel transfer lines
- Cryo units

# Dimensions of Cryogenic Components

## Cryogenic Plant Components (per 1 cryogenic plant)

20150716

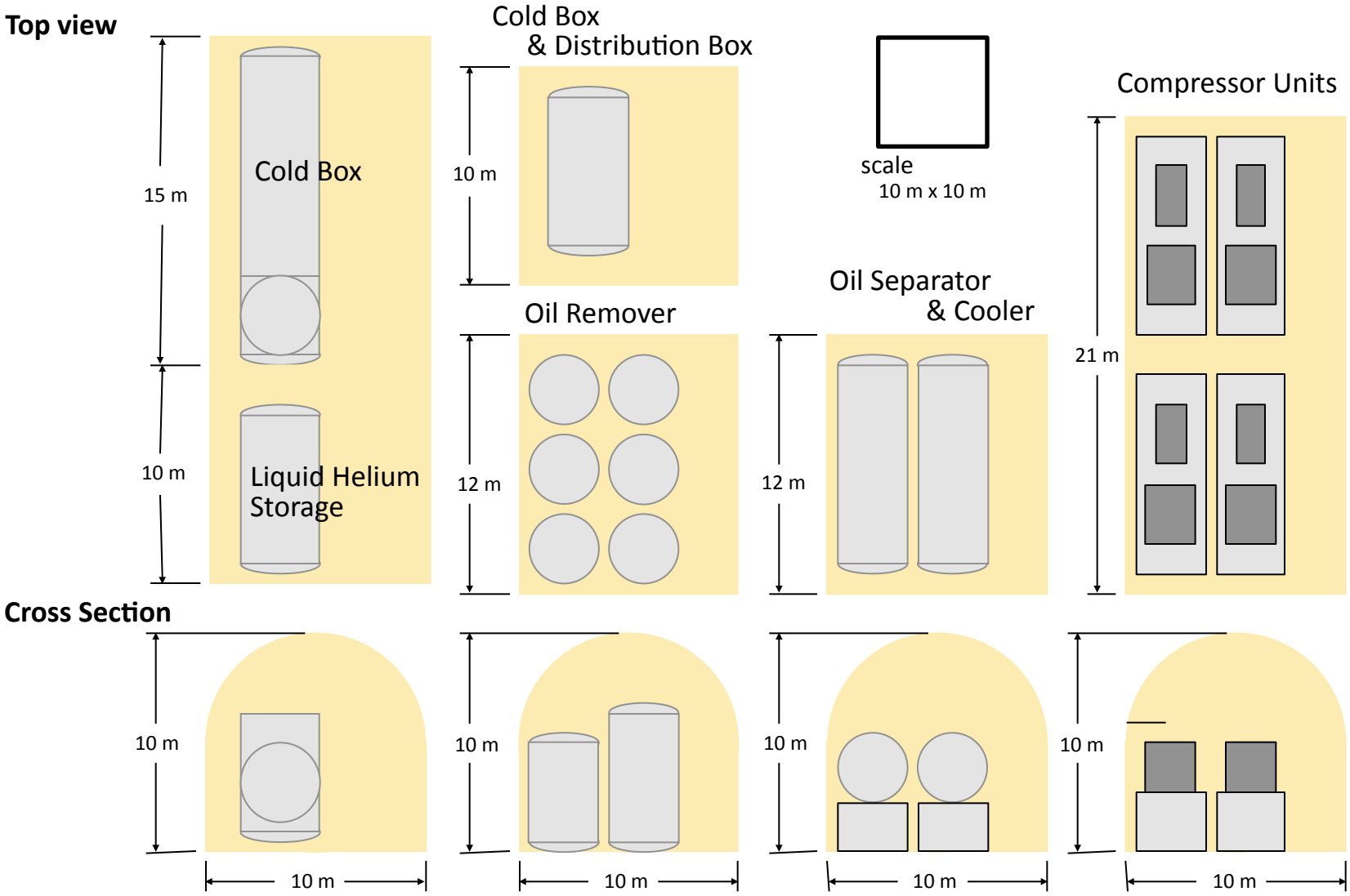
| Component | Dimensions (Width x Depth x Height) | Specifications | Place |
|---|---|---|---|
| 4.5K Refrigerator | 20 m x 8 m x 8.5 m | 19 kW x 1 | Surface |
| Helium Compressors | 15 m x 12 m x 6 m | 1500 g/s | Surface |
| LHe Storage Tank | ϕ3.5 m x 13 m x 5 m** (Horizontal) | 65000 L x 1 | Surface |
| LN2 Storage Tank | ϕ3.5 m x 5 m x 10 m x 2 (Vertical) | 50000 L x 2 | Surface |
| Helium Buffer Tank | 30 m x 16 m x 8 m (Horizontal) | 250 m3 x 1, 1 MPa | Surface |
| | ϕ3 m x 15 m x 3 (Horizontal) | 106 m3 x 3 = 318 m3 | |
| Cooling Towers | 40 m x 22.5 m x 10 m | 10 MW/tower | Surface |
| Helium Purifier | 5 m x 3 m x 5 m** | | Surface |
| HP Gas Cylinders | 2 m x 5 m x 3 m** (Horizontal) | | Surface |
| Air Compressors | 3 m x 2 m x 1 m x 3** | | Surface |
| 2K Refrigerator | 10 m x 8 m x 4.5 m | 2.3 kW x 1 | Cavern |
| Distribution Box | 8 m x 4 m x 5 m* (Horizontal) | | Cavern |

Dimensions cited from Delikaris (no mark), Hosoyama(*) and others(**)

| | | |
|---|---|---|
| Cold Box Building | 25 m x 10 m x10 m | 40 kW, 20 m3/h, 85 dBA |
| Compressor Building | 15 m x 45 m x 9 m | 4.5 MW, 500 m3/h 105 dBA |
| GHe Storage | | 250 m3, 2 MPa, 58 tanks |
| | | 80 m3, 2 MPa, 40 tanks |
| | ϕ3 m x 15 m* | 100 m3 |
| LHe Storage | | 120000 L, 0.1 MPa, 6 tanks |
| | ϕ2.5 m x 10 m* | 50000 L |

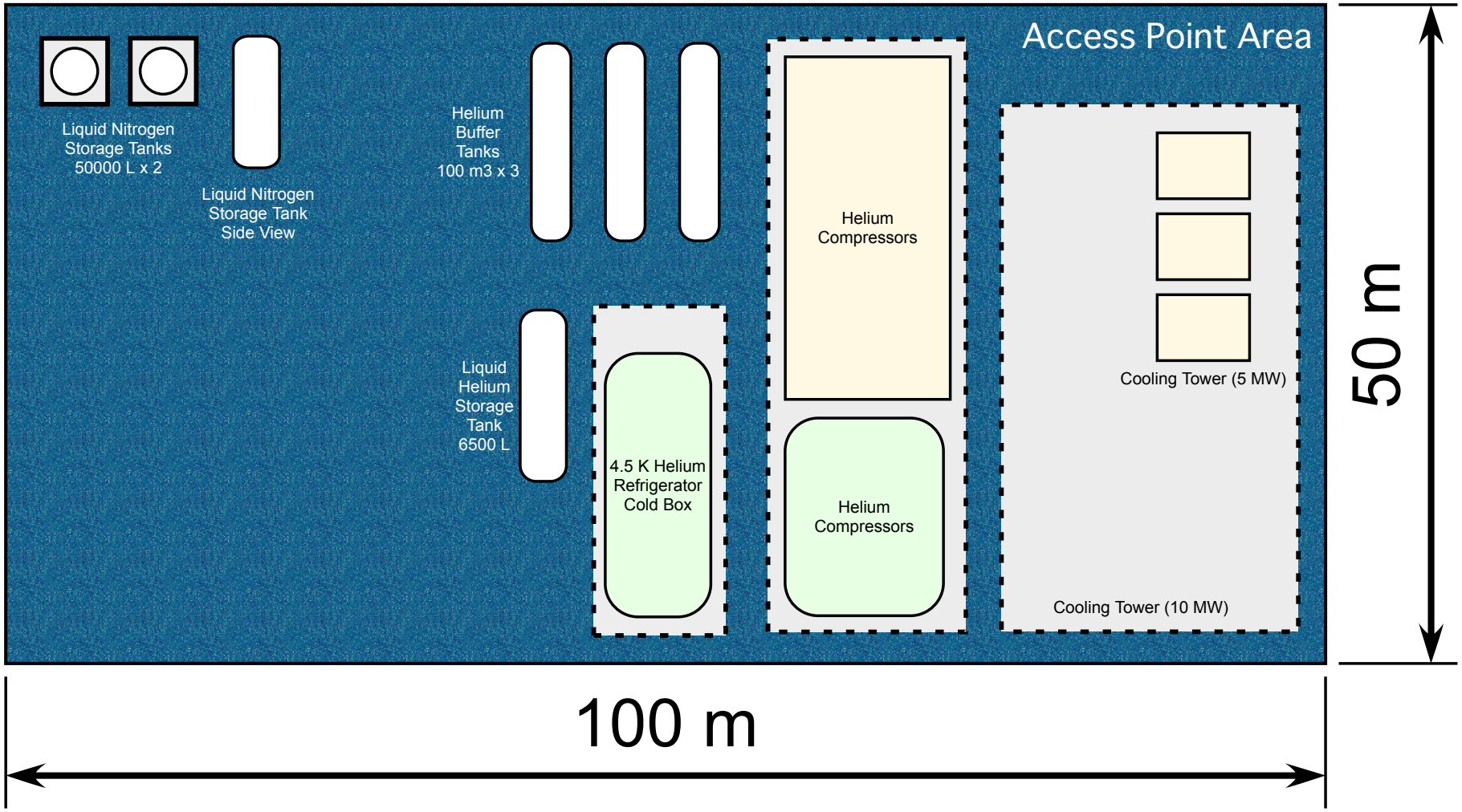
Dimensions cited from Claudet (no mark) and Hosoyama(*)

# Cryogenic System Components

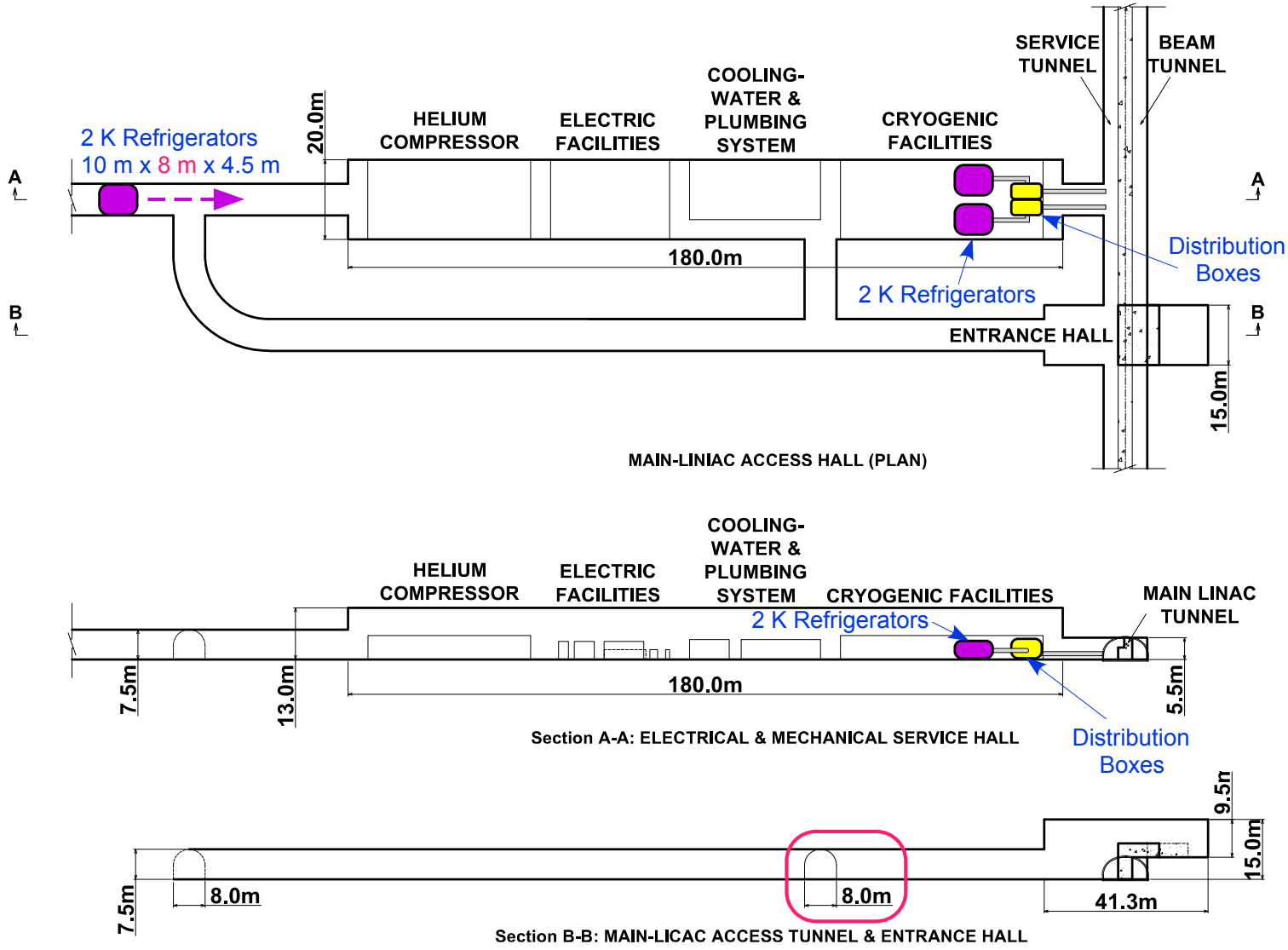



K. Hosoyama, 2010

# Cryogenic Components on Access Point Surface



# Cryogenic Components in Cryogenic Cavern



# Summary

- All cryogenic components except 2 K refrigerators and distribution boxes will be installed on surface
- Cryogenic components on surface and underground will be connected with multi-channel transfer lines
- Consideration of scenic preservation for cryogenic components on surface is necessary
- Cost can be reduced by constructing 10 identical cryogenic plants for main linacs
- Distribution boxes of two adjacent cryogenic plants may be interconnected for redundancy (but higher cost)
- Number of cryo strings for 1 cryo unit should be fixed to 21
- Total length of multi-channel transfer lines differs according to location
- Construction cost should be re-evaluated as cryogenic configuration change

# Open Discussions

- Width of access tunnel defined in TDR and that of 2 K refrigerator cold box of CERN-LHC are both 8 m
  - Impossible to install 2 K refrigerator cold boxes in cryogenic caverns through access tunnels
  - Modification of 2 K refrigerator cold box design possible?
- Cryogen storage tanks prohibited in a tunnel but cryomodules not
  - Multi-channel transfer lines are expensive and major heat loads to cryogenic systems
  - High pressure gas pipes are much less expensive and not heat loads to cryogenic systems
- Distribution boxes of two adjacent cryogenic plants may be interconnected for redundancy (but higher cost)
  - Interconnected or not?
- Total length of multi-channel transfer lines differs according to location
  - Multi-channel transfer lines longer than 1 km acceptable?