LCWS2016, Morioka, Dec. 5 - 9, 2016

Scheme Change of Cryogenics Layout

NAKAI Hirotaka, KEK

OKAMURA Takahiro, KEK

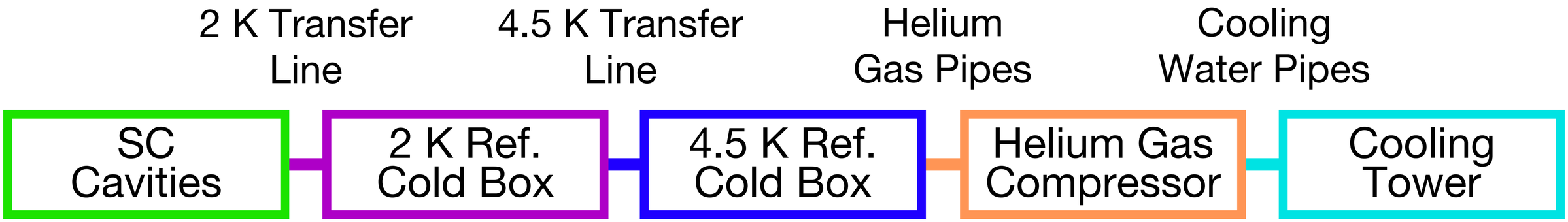
YAMAMOTO Akira, KEK and CERN

in collaboration with

Dimitri DELIKARIS, CERN

Thomas PETERSON, FNAL

Introduction



Major Cryogenic Components

- A 4.5 K helium refrigerator cold box
- A 2 K helium refrigerator cold box
- Helium gas main compressors
- Cooling towers for cooling water

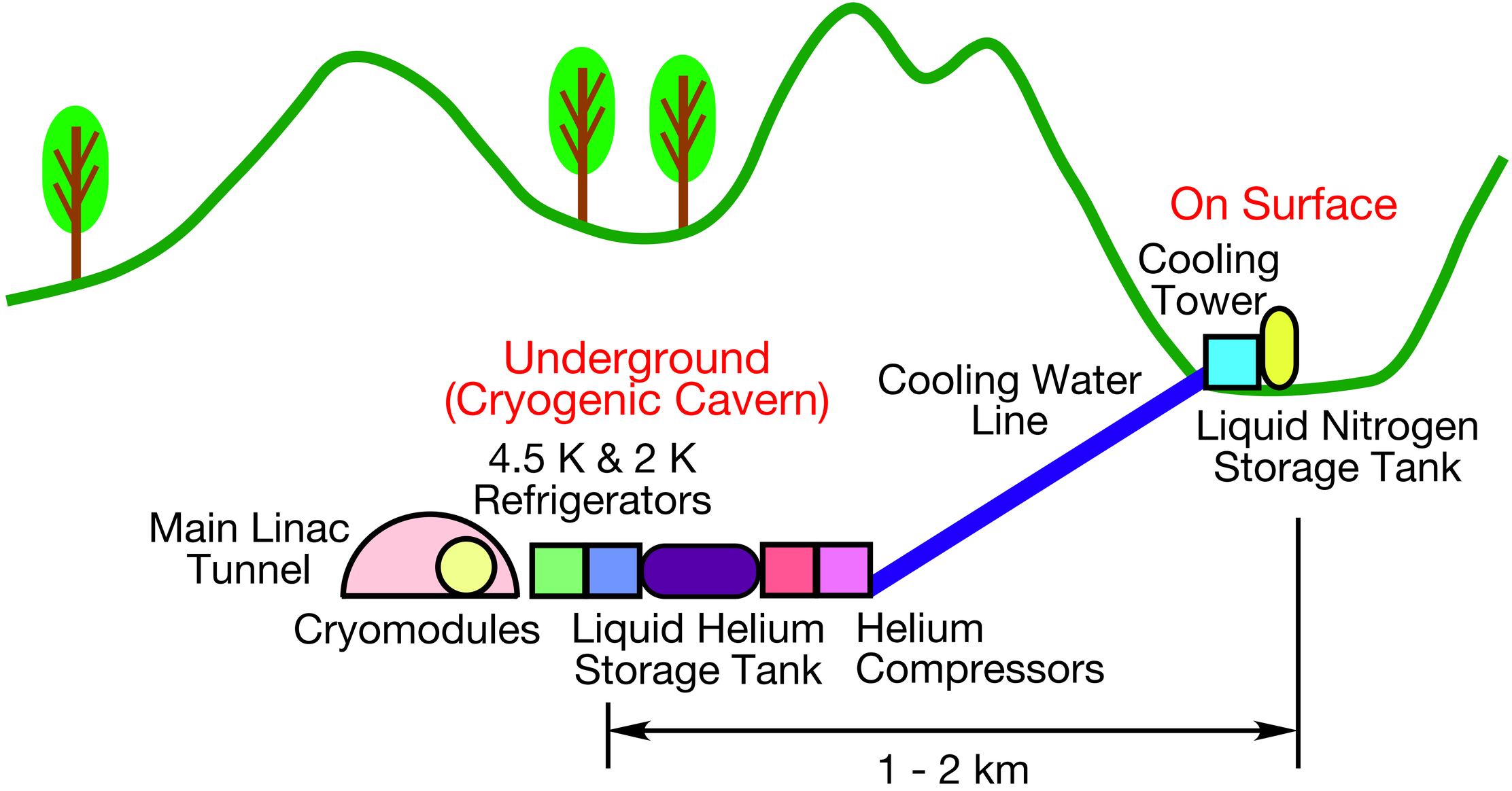
Layout of Cryogenic Components

- Access point on surface
- Cryogenic cavern underground

Outline

- Original cryogenic layout described in TDR
- Modification of layout submitted as Change Request CR-0009
- Further modification of layout submitted as Change Request CR-0014

Layout Described in TDR



Cryogenic Layout in TDR

Pros

- Scenic and environment conservation

Cons

- Larger necessary area in cryogenic caverns underground
- Mechanical vibration from helium compressors may affect beams
- Mass storage of cryogens underground restricted because of safety reason
- Inconvenience for daily checks and machine failure response (especially in radiation-controlled areas)

Change Request 0009 for Cryogenic Layout

On Surface

- **Storage tanks**
  - A liquid helium storage tank for long-term shutdowns
  - A liquid nitrogen storage tank
  - Helium gas buffer tanks (also as helium gas storage tanks if necessary)
- **Helium gas main compressors**
- **A "baby-sitter" helium liquefier for reliquefy evaporated helium gas from the liquid helium storage tank**

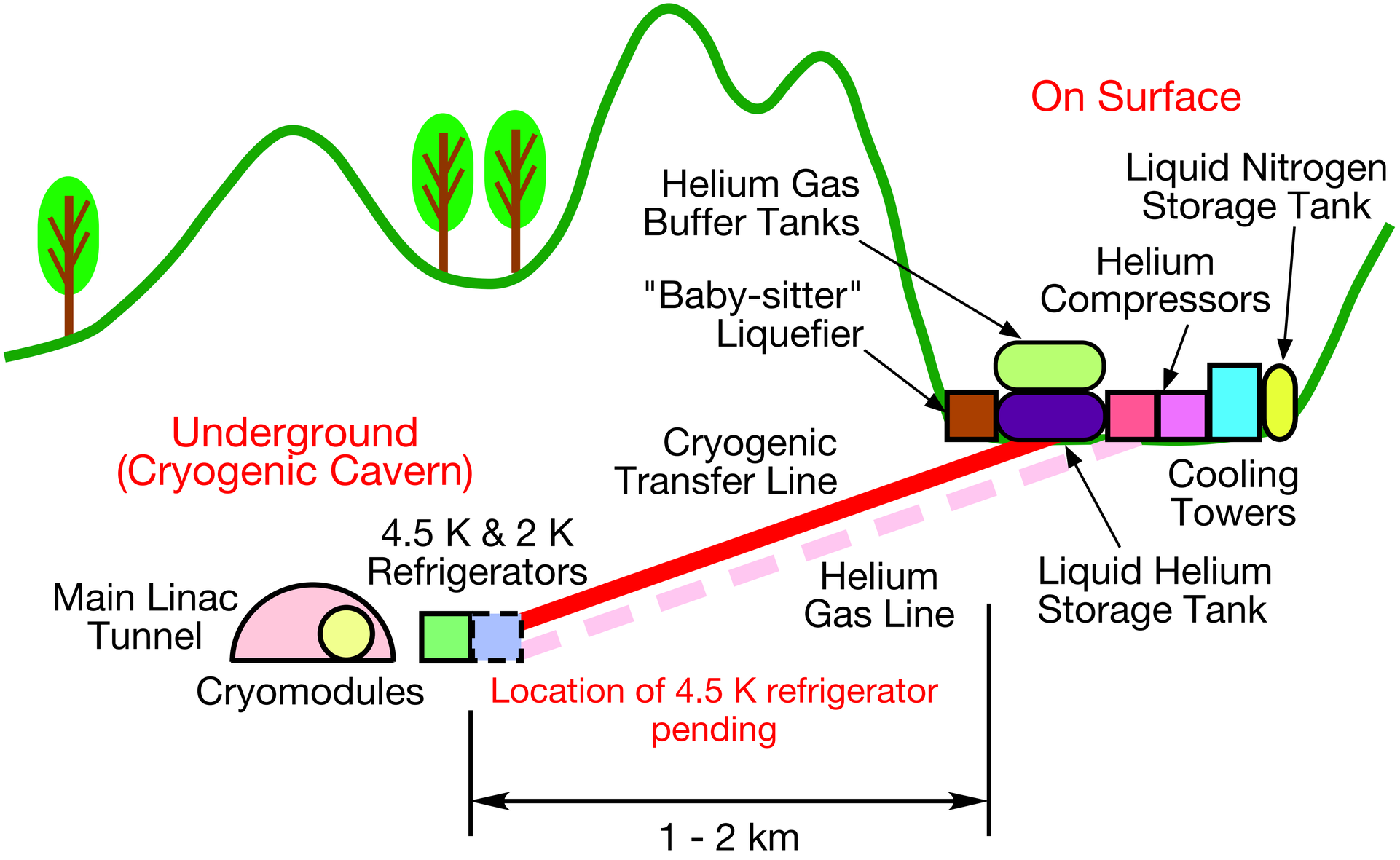
In Cryogenic Cavern Underground

- **A 2 K helium refrigerator cold box**

Pending location of 4.5 K Helium Refrigerator Cold Boxes

- **Further consideration required for fix the location**

Cryogenics Layout Suggested in CR-0009



Cryogenic Layout in CR-0009

Pros

- Beams free from mechanical vibration of helium gas compressors
- Safe storage of cryogens
- Smaller necessary area in cryogenic cavern underground

Cons

- Larger necessary area at access points on surface
- Less scenic and environment conservation
- Location of 4.5 K refrigerator cold boxes is still pending

Discussions After CR-0009

- 4.5 K refrigerator cold boxes may be installed underground to eliminate expensive long cryogenic transfer lines
- Helium recovery process in emergency situations, such as sudden blackouts and machine failures, should be well considered
- Helium inventory procedure should be carefully prepared for long-term shutdowns

Location of 4.5 K Refrigerator Cold Box

- Liquid helium storage tanks not utilized as liquid buffer tanks for stable supply of liquid helium to 2 K refrigerators
- 4.5 K refrigerators and liquid helium storage tanks can be installed separately
- 4.5 K refrigerators should be installed underground to eliminate expensive and long cryogenic transfer lines to 2 K refrigerators in cryogenic caverns
- More sophisticated and effective design can be expected, since 4.5 K and 2 K refrigerators installed together in cryogenic caverns

Helium Recovery in Emergency Situations (1)

- **Helium loss should be minimized even in any emergency situations, because helium is fully imported in Japan**
- **The maximum recovery time from the power failure to normal operation is assumed to be shorter than 24 hrs:**
  - Check of cryoplants before restart
  - 6 hours estimated to resume 10 cryoplants distributed over 30 km
  - Sufficient contingency should be considered (6 hrs x 4 = 24 hrs)
- **A helium recovery compressor should be added on the surface to allow continuous evaporation of liquid helium in cryoplants and cryomodules during 24 hours after blackouts**

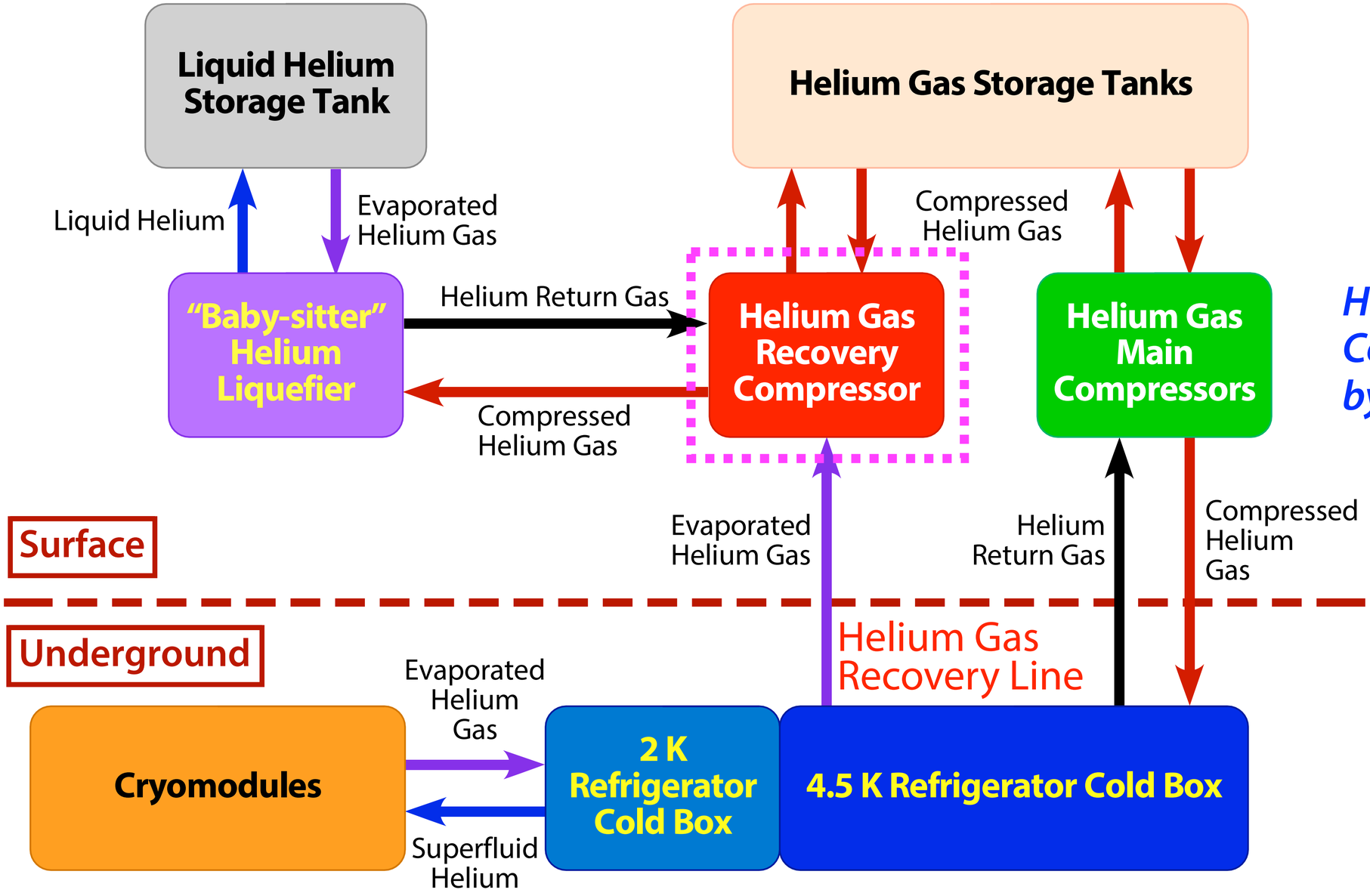
Helium Recovery in Emergency Situations (2)

- A gas/oil emergency power generator of ~1 MW capacity will be equipped at each cryoplant to operate the helium gas recovery compressor and its associated devices such as a cooling water system, an air compressor for valve operation and so on
- Part of evaporated cold helium gas can be used (bypassed) to keep thermal shield and intercept temperature of the cryomodule low enough, and it may result in the liquid helium evaporation rate in the cryomodules can be suppressed
- Thermal insulation of the cold helium gas recovery lines may be needed to minimize excessive liquid oxygen production or ice formation on the helium recovery lines
- A passive heat exchanger will be also needed to warm up the evaporated helium gas before the recovery compressors

Helium Inventory During Long-Term Shutdowns

- Large amount of helium should be stored as either gas or liquid during long-term shutdowns
- Gas storage requires a number of large helium gas storage tanks (~ 6 x 250 m^3), which may affect scenic preservation
- Liquid storage requires only one liquid helium storage tank, but a "baby-sitter" helium liquefier is needed to reliquefy evaporated helium gas from the liquid helium storage tank
- Further investigation is needed to optimize the ratio of gas and liquid storages of helium during long-term shutdowns

Cryogenic Layout for Emergency Situations



Helium Gas Recovery Compressor : powered by Generator

Change Request 0014 for Cryogenic Layout

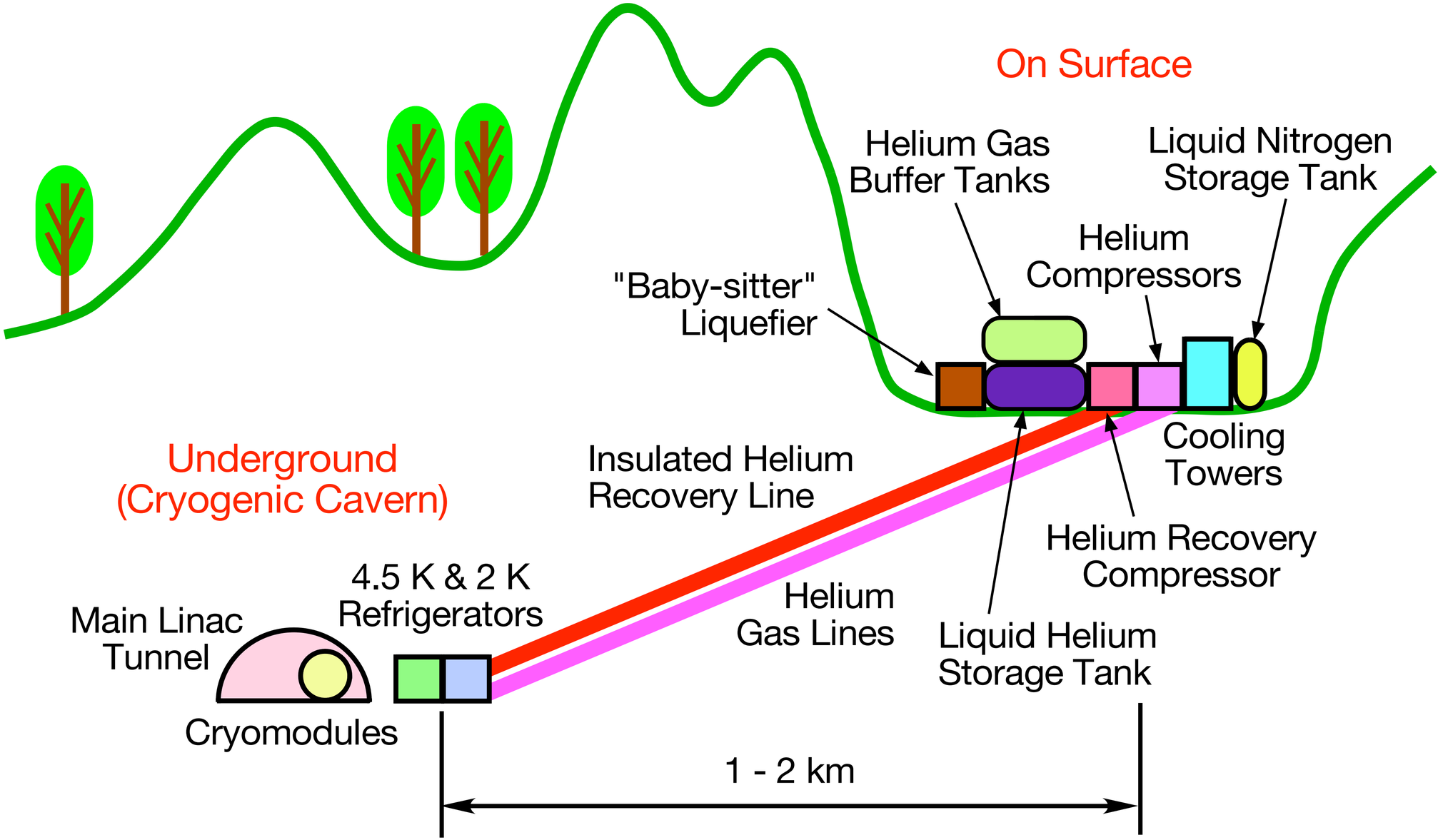
On Surface

- A "baby-sitter" helium liquefier
- Helium gas main compressors
- A helium gas recovery compressor
  - Powered by generator in emergency situation for helium gas recovery
  - Powered by ordinary power line for the "baby-sitter" helium liquefier
- Storage tanks
  - Helium gas buffer tanks (also as helium gas storage tanks)
  - A liquid helium storage tank for long-term shutdowns
  - A liquid nitrogen storage tank

In Cryogenic Cavern Underground

- A 2 K helium refrigerator cold box
- A 4.5 K helium refrigerator cold box

Cryogenics Layout Suggested in CR-0014



Cost Balance

Cost Saving:

- Long cryogenic transfer lines can be eliminated between the cryogenic caverns underground and the surface cryogenic components

Cost Increase:

- Recovery helium gas compressors on the surface inevitably required
- Insulated helium recovery lines (not cryogenic transfer lines) between the cryogenic caverns and the recovery compressors on the surface

- Costs of "baby-sitter" helium liquefiers on the surface and helium gas lines between the 4.5 K refrigerator cold boxes in the cryogenic caverns and helium compressors on the surface have been already included in last change request CR-0009

Summary

Location of 4.5 K Refrigerator Cold Boxes

- 4.5 K refrigerator cold boxes installed in cryogenic caverns underground
- Long cryogenic transfer lines can be eliminated

Emergency Situations Included in Consideration of Cryogenic Layout

- Helium recovery compressors introduced to recover evaporated helium gas from cryomodules
- Helium recovery compressors powered by generators during blackouts

Helium Inventory Stored as Gas or as Liquid During Long-Term Shutdowns

- “Baby-sitter” liquefiers and liquid helium storage tanks needed for liquid storage
- No “baby-sitter” liquefiers needed if 100% storage as gas, but more helium gas storage tanks
- Ratio of liquid and gas storage requires further consideration