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Cool-down Logic for Cryogenic Distribution System of RAON SCL3

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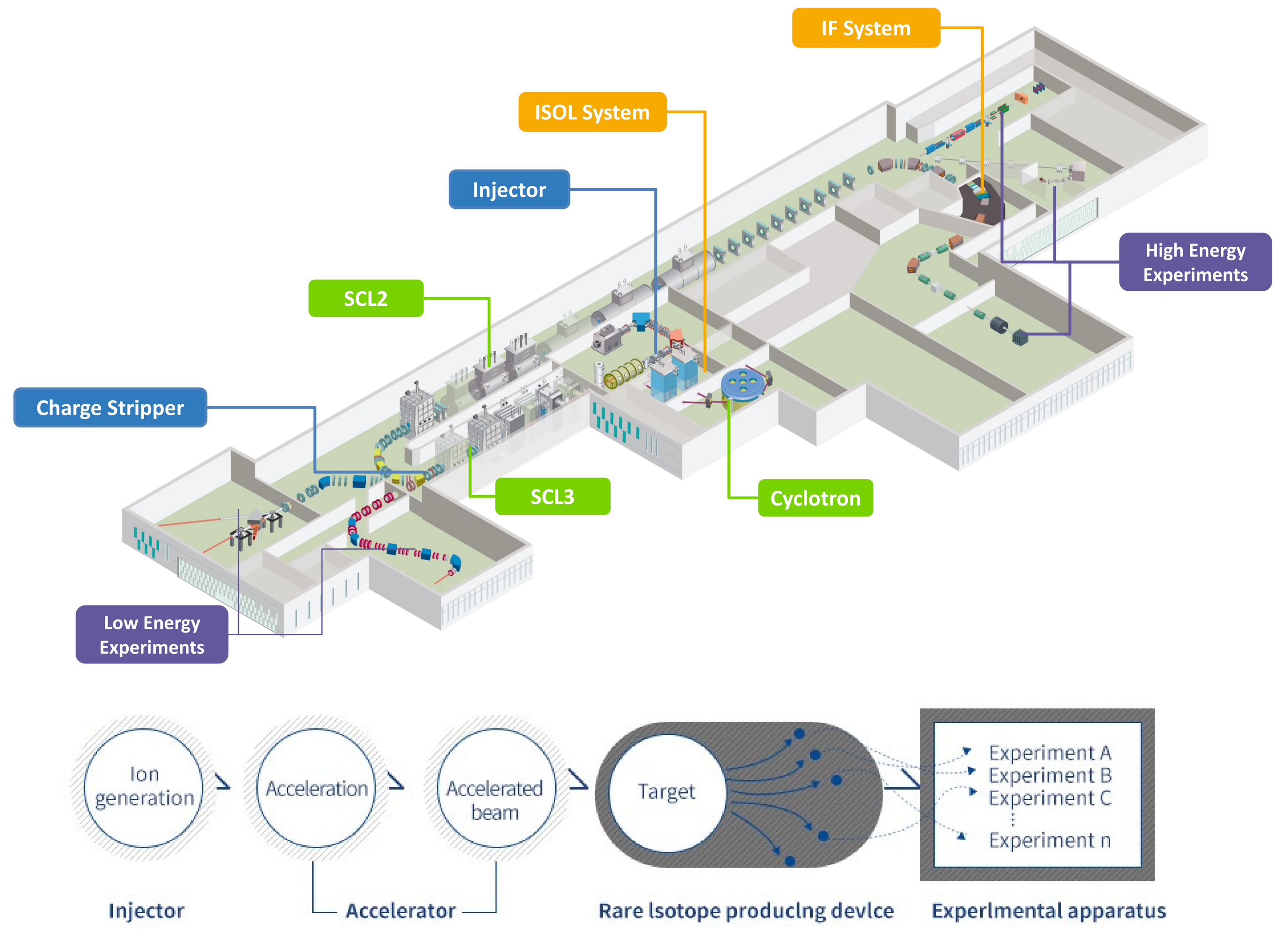
RAON

Introduction

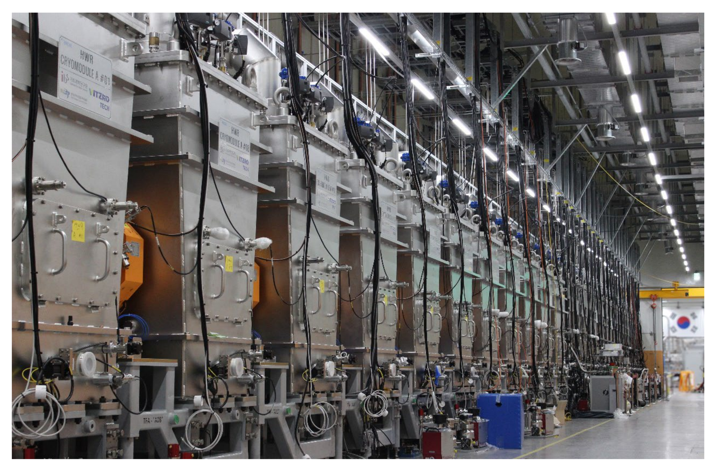
RAON (Rare isotope accelerator complex for on-line experiments)

- The RAON project aims to complete the construction of heavy ion linear accelerators in Daejeon, Korea.
- RAON consists of SCL3 and SCL2 linear accelerators.
- Passing through SCL3 (low energy section) and SLC2 (high energy section), uranium ions accelerate to 200 MeV/u, and hydrogen ions accelerate to 600 MeV/u.



Cryogenic System

- RAON cryogenic system consists of two helium liquefaction systems, SCL3 and SCL2 cryogenic distribution systems (CDS) and the cool-down targets, such as the cryo-modules, the LTS magnets, and the HTS magnets.
- The SCL3 cryo plant has the maximum cooling capacity of 894 W @ 2.05 K, and 1035 W @ 4.5 K; the SCL2 cryo plant has the maximum cooling capacity of 4115 W @ 2.05 K, and 1309 W @ 4.5 K.
- The CDS includes a helium distribution box (DBx), the main transfer lines, the sub transfer lines, the valve boxes (VBxes), and an end box (EBx).

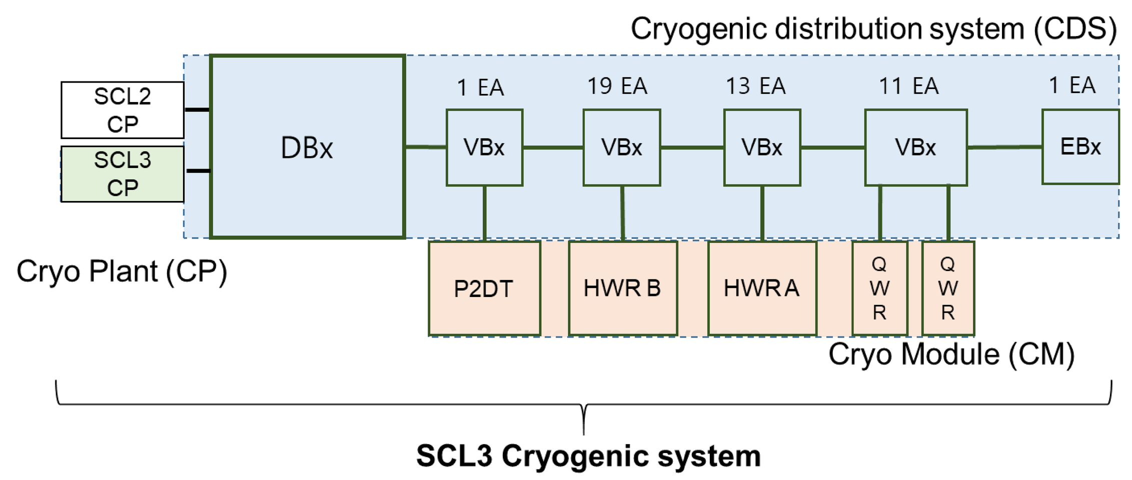


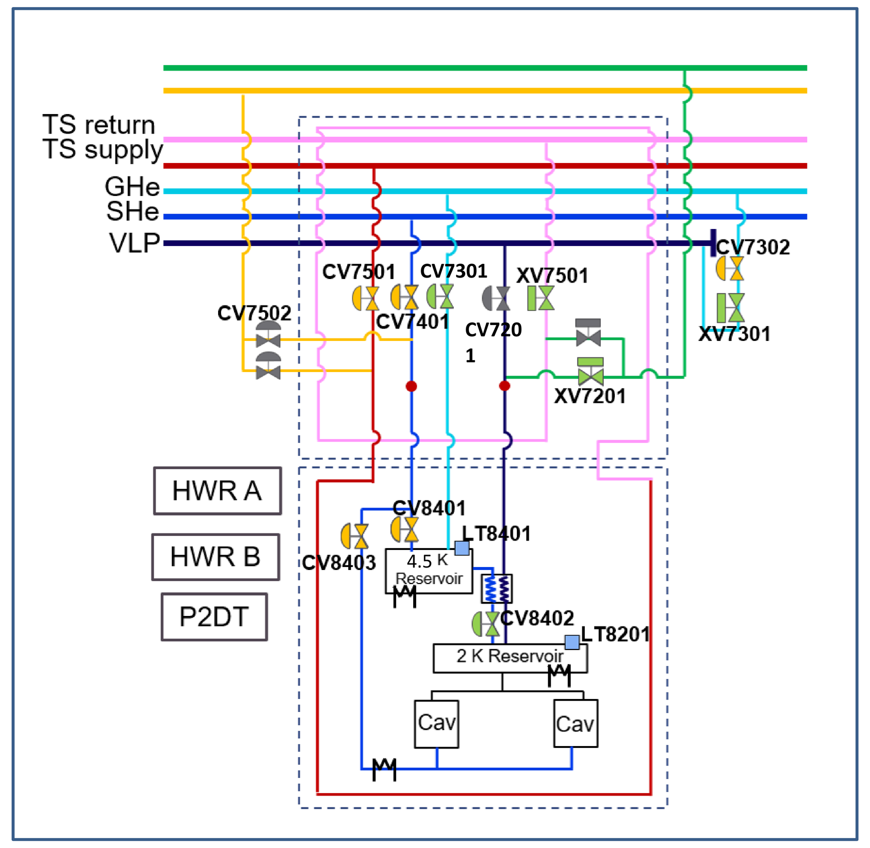
Helium Liquefaction System ----- Cryogenic Distribution system ----- Cryo-module

Operation Logic of SCL3 Cryogenic System

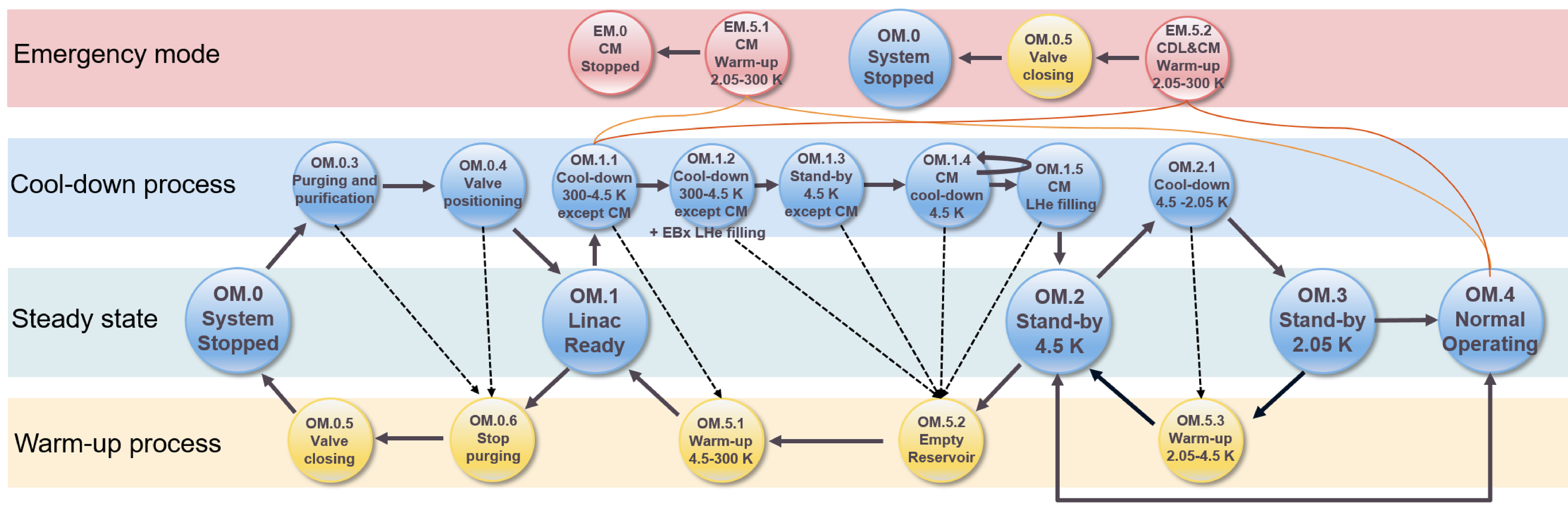
SCL3 Cryogenic System

- SCL3 accelerates beams with 22 quarter-wave resonators (QWRs) and 104 half-wave resonators (HWRs) which need to maintain 4.5 K and 2.05 K, respectively, in operation by helium bath cooling.
- In order to operate the SCL3 cryogenic system, the operation modes, operation sequences, the actuator control logic, and the protection logic including the alarm & interlock and emergency mode are designed.



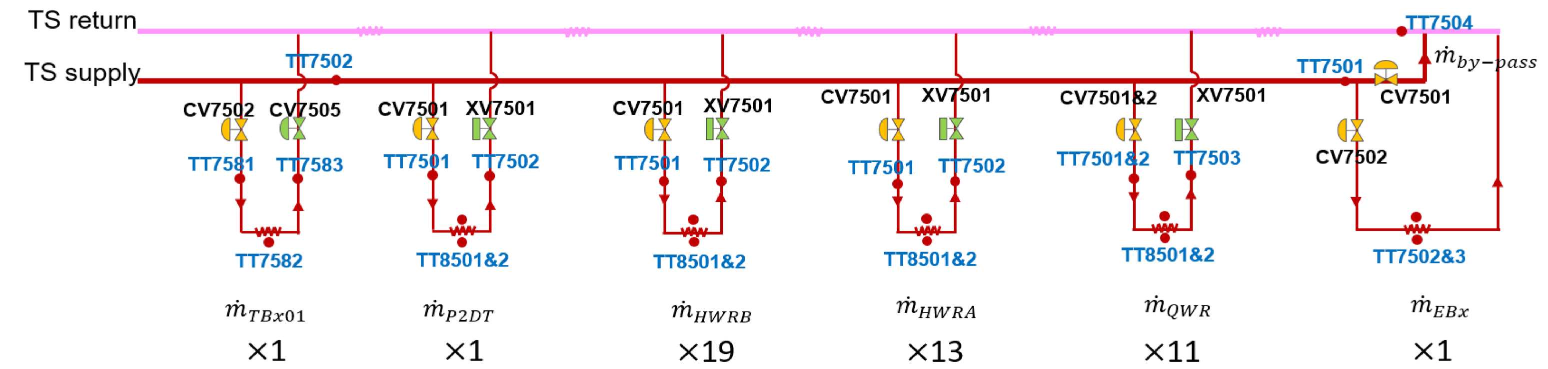


Operation Mode



TS Line Cool-down

Thermal Shield Structure of SCL3



Thermal Shield Cool-down Strategy

T_out – T_in > 50 K : INTERLOCK

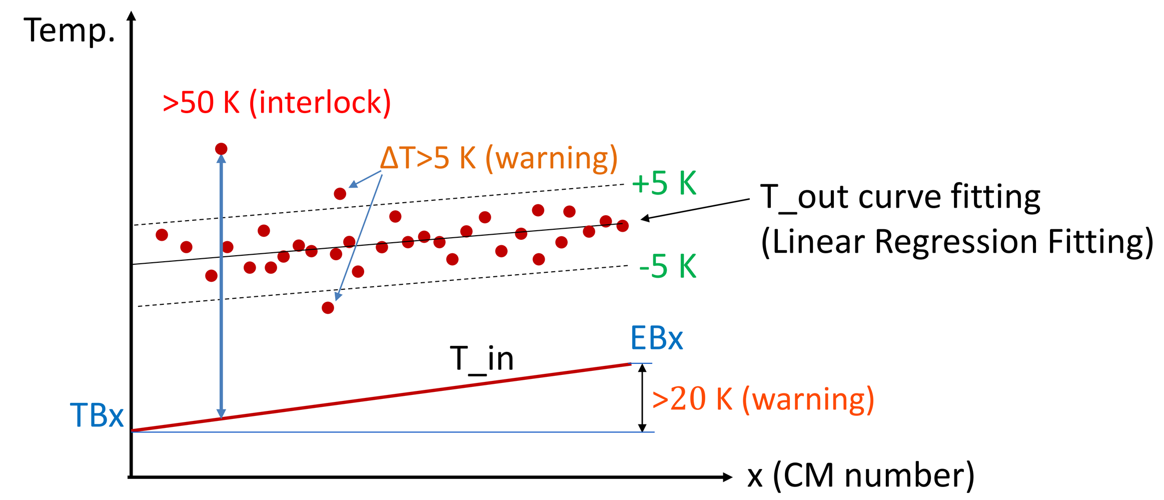
- Close the inlet valve (TBx, P2DT, HWRB, HWRA-CV7501; QWR-CV7501&2; EBx-CV7502)
- Cryogenic plant: Stop decreasing the temperature of the coolant

T_in_EBx – T_in_TBx> 20 K : warning

- Increase the valve opening of EBx-CV7501

ABS.(T_out – T_out_curve fitting) > 5 K: warning

- Regulate the valve opening of the inlet valve



CM Cool-down

4.5 K Cool-down Strategy

T_Cavity 300 K ~ 150 K (slow cool down):

- Cool down speed: 10 K/hour
- T_target [K]=280-10/3600× $t(s)$
- Cool-down valve control:
  if T_cavity_min > T_target + 5 K, cool-down valve open
  if T_cavity_min < T_target - 5 K, cool-down valve close
  if else, cool-down valve keep the state

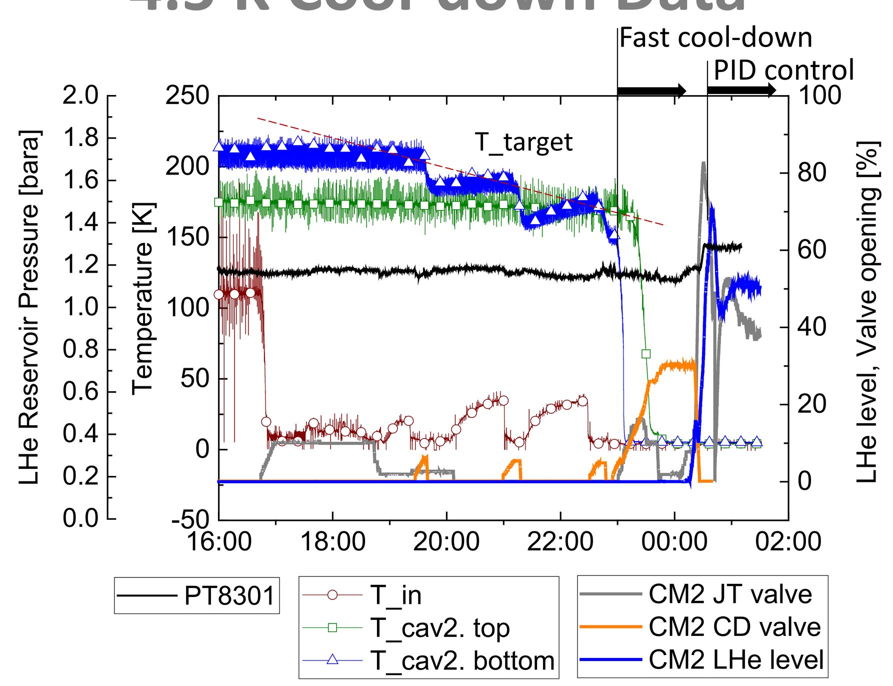
T_Cavity 150 K ~ 4.5 K (fast cool down):

- Cool down valve keep opening (0.01%/s)

Liquid helium filling:

- Close the cool down valve
- Open the JT valve
- When Helium level>60%, turn to PID control

4.5 K Cool-down Data



2 K Cool-down Strategy

Pump down to 36 mbar:

- Main CDS pumping
- Connecting to the VLP line by minimum valve opening
- Increasing the return valve opening when the cold compressor speeds down
- Keep communication with the cryo plant engineer

Superfluid helium filling

- Note the helium level decrease at Lambda point (2.17 K)
- When Helium level>50%, turn to PID control

2 K Cool-down Data