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E01: 110 – Large scale refrigeration

SCL3 cryoplant process design for RAON

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Rare isotope Accelerator complex for ON-line experiments

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Rare Isotope Science Project
RISP and RAON

Rare Isotope Science Project

- RISP belongs institute for basic science.
- RISP is the name of our project.
- The project was launched in Dec. 2011 and the target date for the project is 2021.
- The goal of the project is to construct a **heavy ion linear** accelerator.
- The name of our accelerator is “RAON”.

Rare isotope Accelerator complex for ON-line experiments

- RAON is pure Korean word meaning “delightful”
- RAON has three superconducting linear accelerators.
- First Linac(SCL1) will usually accelerate the **stable** ion beams.
- Third Linac(SCL3) will usually accelerate the **stable** and **unstable** ion beams.
- Second Linac(SCL2) will reaccelerate all ion beams.
- Rare isotope ion beams are produced by ISOL* and IF separator**.

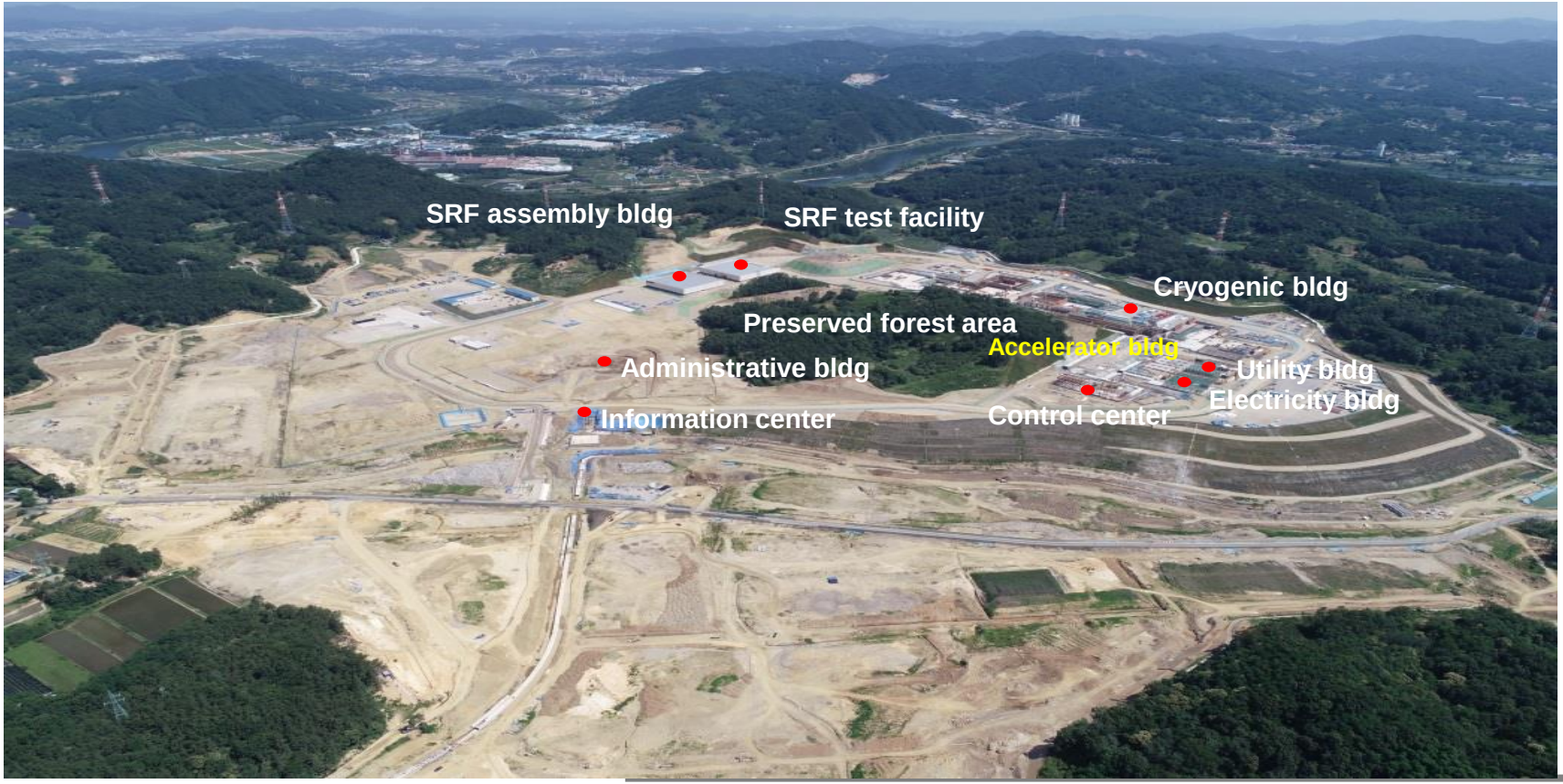
*** Isotope Separator On-Line**
**** In-Flight separator**

Rare Isotope Science Project

RAON facility

Rare Isotope Science Project

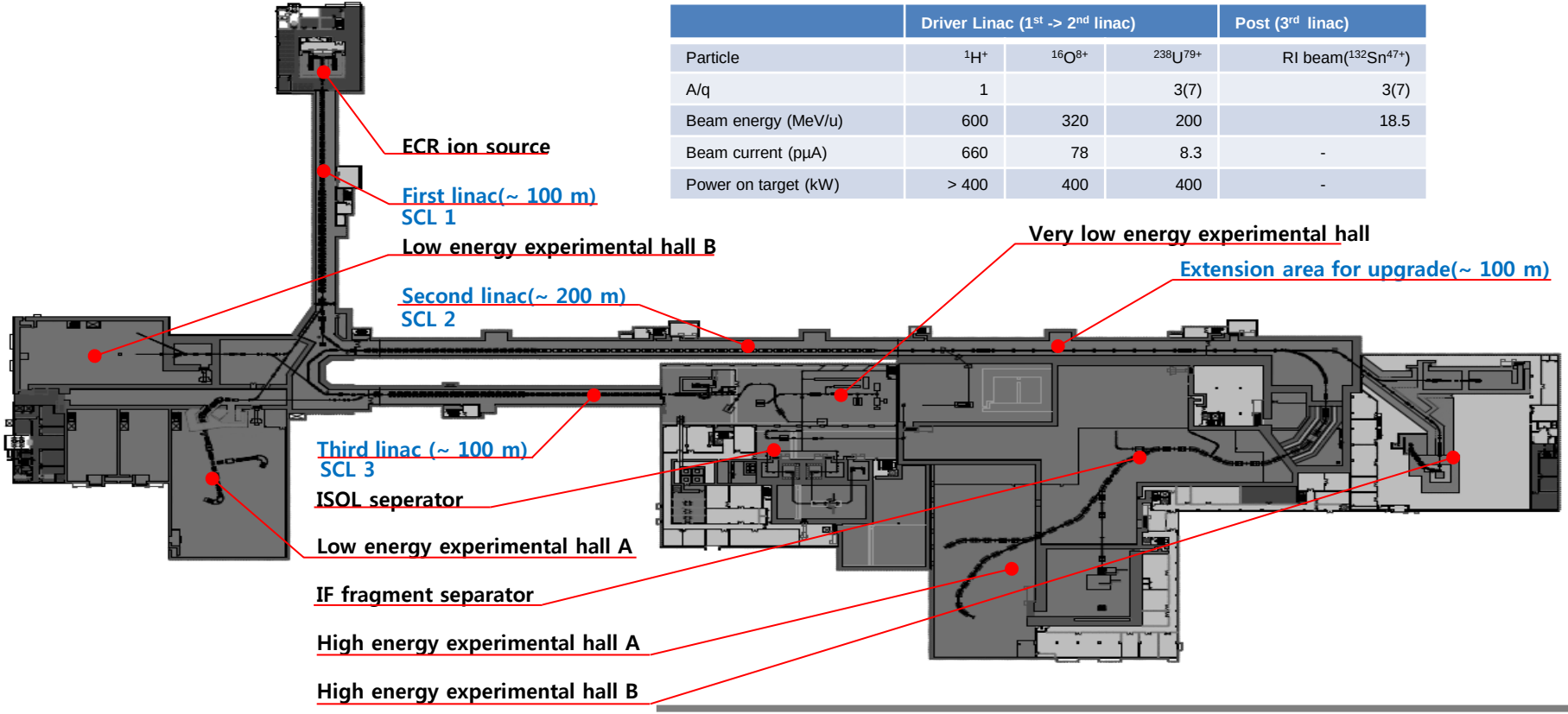
RAON facility(16 June, 2018)



Rare Isotope Science Project

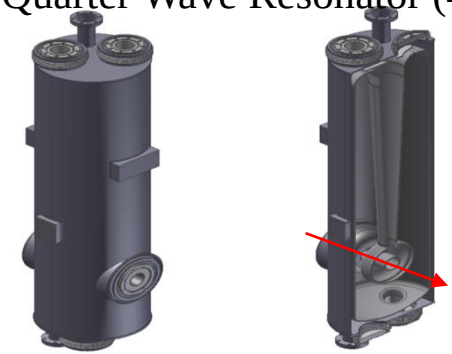
RAON layout

	Driver Linac (1st -> 2nd linac)			Post (3rd linac)
Particle	$^{1}H^{+}$	$^{16}O^{8+}$	$^{238}U^{79+}$	RI beam($^{132}Sn^{47+}$)
A/q	1		3(7)	3(7)
Beam energy (MeV/u)	600	320	200	18.5
Beam current (pμA)	660	78	8.3	-
Power on target (kW)	> 400	400	400	-

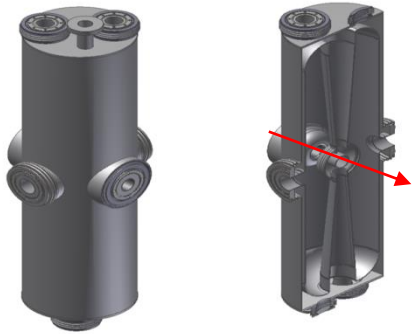


SCL3 requirements
Superconducting cavities and cryomodules

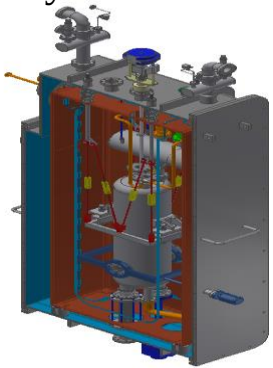
Quarter Wave Resonator (4.5 K)



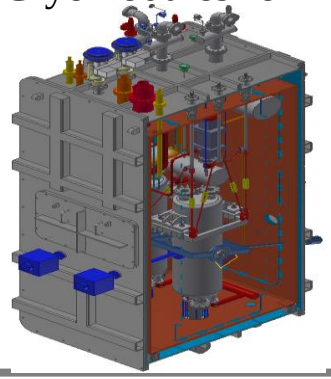
Half Wave Resonator (2.05 K)

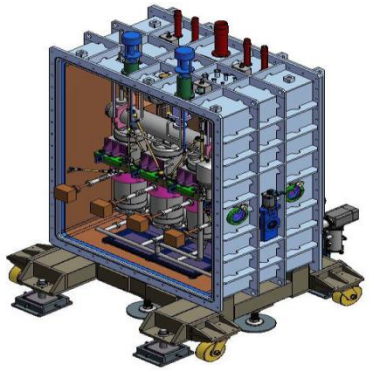


Cryomodule for QWR



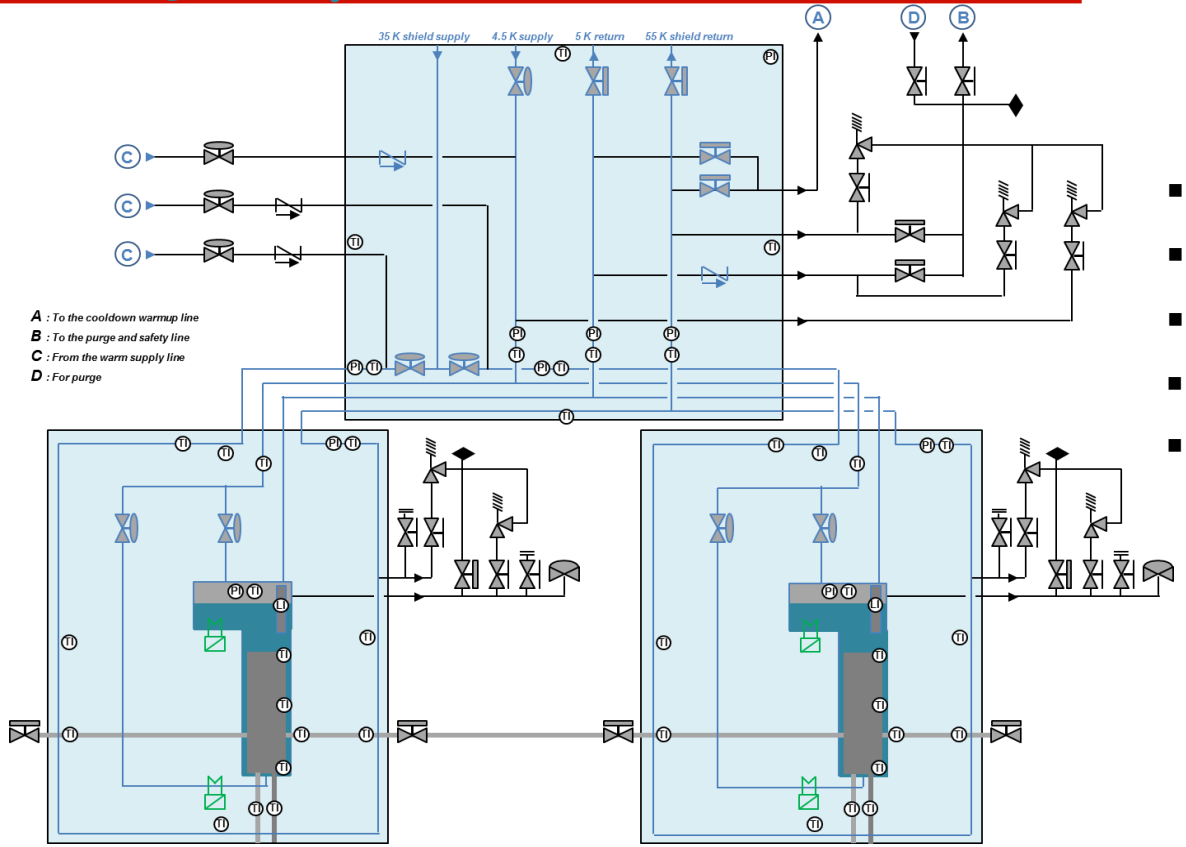
Cryomodules for HWR





SCL3 requirements

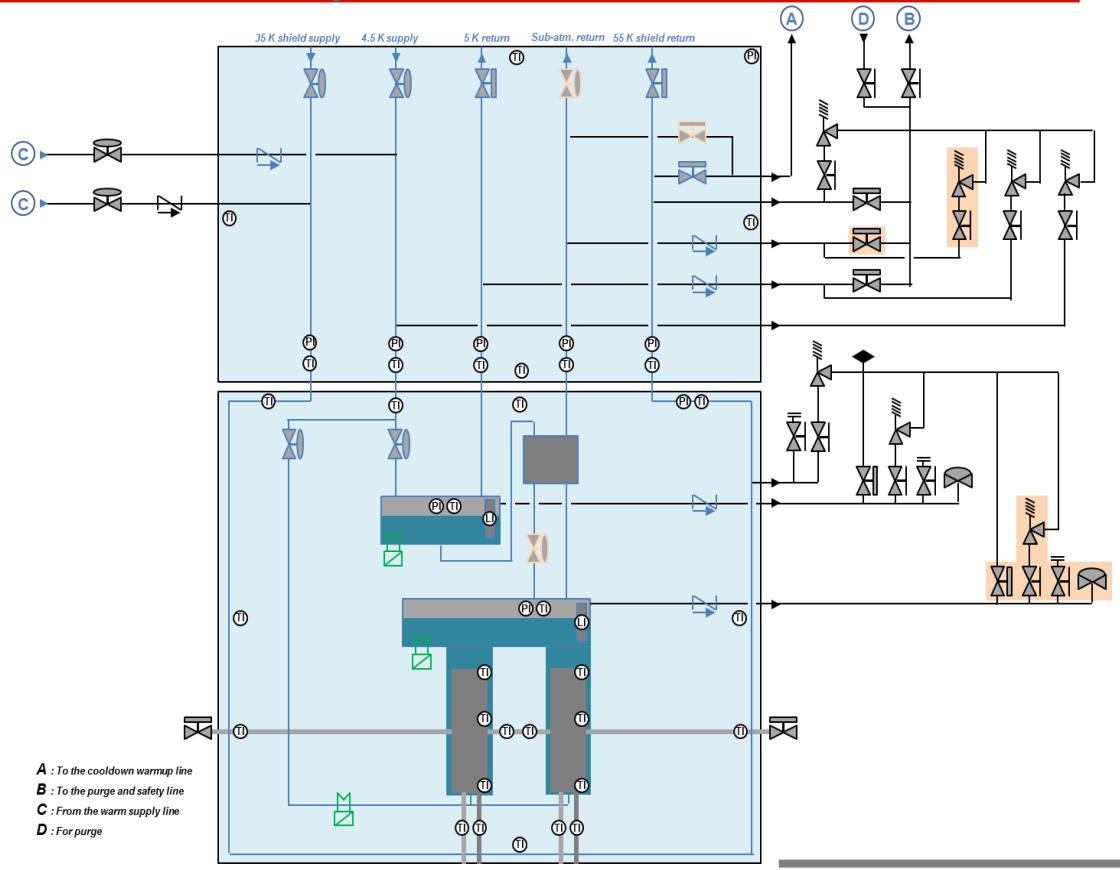
PFD - QWR cryomodules and valve box



- One valve box for two modules
- Sub-cooled SHe supply
- 1st J-T valve in each module
- 4.5 K, 1.3 bara LHe
- Warm GHe for cooldown/warm-up

SCL3 requirements

PFD - HWR cryomodule and one valve box



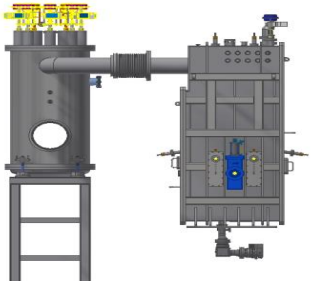
- One valve box for one module
- Sub-cooled SHe supply
- 1st J-T valve in each module
- 2K-4K heat exchanger in each one
- 2nd J-T valve in each module
- Warm GHe for cooldown/warm-up

SCL3 requirements

SCL3 assembly

HWR Cryomodule A with its valve box

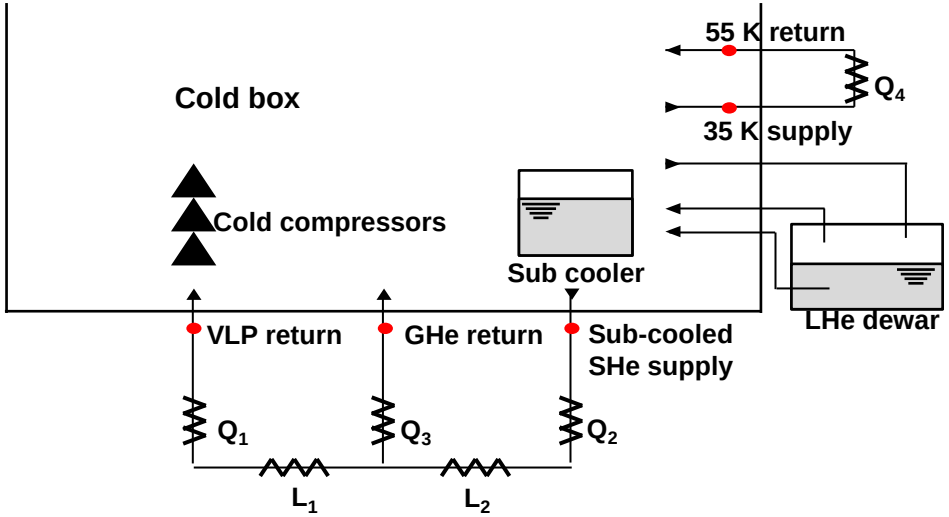
HWR cryomodule B with its valve box



QWR cryomodule with its valve box

SCL3 requirements

Heat loads of SCL3



- Isothermal : L_1 and L_2
- Bath cooling for L_1 and L_2
- L_2 including thermal interceptors
- Non-isothermal: Q_1 ~ Q_4
- Forced helium cooling for shield

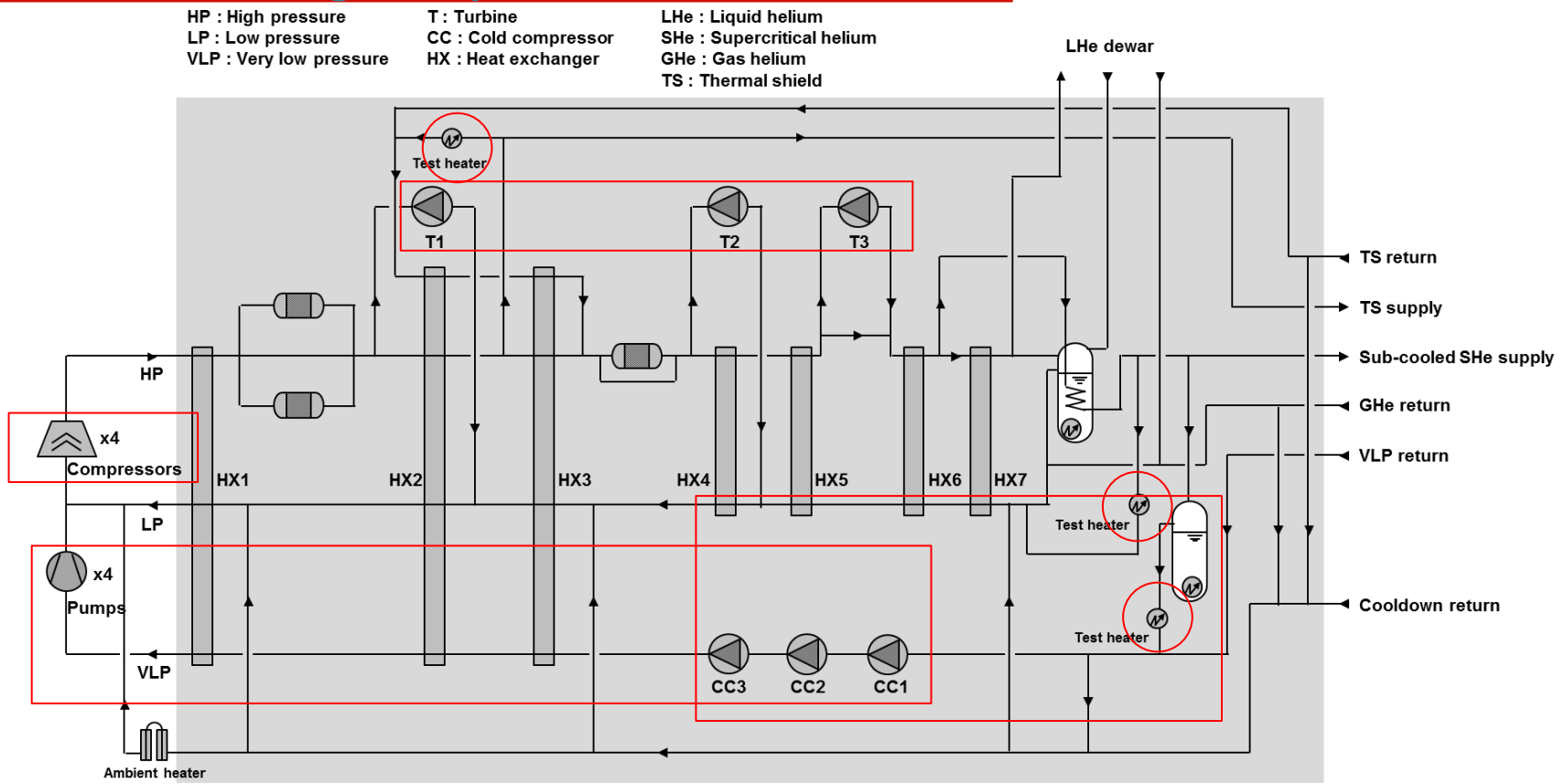
Mode (w/ margin)	2.05 K [W]			4.5 K [W]			35 – 55 K [W]	Remark
	Isothermal		Non-isothermal	Isothermal		Non-isothermal	Non-isothermal	
	Static	Dynamic		Static	Dynamic			
Nominal	199	519	176	378	401	259	10,172	
Beam commissioning	199	191	176	378	113	259	10,172	
Turndown	199	-	176	378	-	259	10,172	
4.5 K standby mode	-	-	-	577	-	435	10,172	
TS standby mode	-	-	-	-	-	-	10,172	

SCL3 requirements
Cold end conditions

		Unit	Mode	2.05 K	4.5 K	35 – 55 K	Remark
From cold box	Pressure	bar	Nominal	-	3.0	Max. 15	
			Beam commissioning	-	3.0	Max. 15	
			Turndown	-	3.0	Max. 15	
			4.5 K standby	-	3.0	Max. 15	
			TS standby	-	-	Max. 15	
	Temperature	K	Nominal	-	4.5	< 35	
			Beam commissioning	-	4.5	< 35	
			Turndown	-	4.5	< 35	
			4.5 K standby	-	4.5	< 35	
			TS standby	-	-	< 35	
	Mass flow rate	g/s	Nominal	-	**82.4**	> 95.3	
			Beam commissioning	-	51.5	> 95.3	
			Turndown	-	36.4	> 95.3	
			4.5 K standby	-	37.8	> 95.3	
			TS standby	-	-	> 95.3	
To cold box	Pressure	bar	Nominal	**< 0.032**	1.25	ΔP > 0.5	
			Beam commissioning	< 0.032	1.25	ΔP > 0.5	
			Turndown	< 0.032	1.25	ΔP > 0.5	
			4.5 K standby	-	1.25	ΔP > 0.5	
			TS standby	-	-	ΔP > 0.5	
	Temperature	K	Nominal	**> 4.5**	> 4.8	ΔT > 20	
			Beam commissioning	> 5.3	> 4.9	ΔT > 20	
			Turndown	> 7.1	> 5.0	ΔT > 20	
			4.5 K standby	-	> 5.5	ΔT > 20	
			TS standby	-	-	ΔT > 20	
	Mass flow rate	g/s	Nominal	**33.7**	**48.7**	> 95.3	
			Beam commissioning	18.3	33.2	> 95.3	
			Turndown	**9.3**	27.1	> 95.3	
			4.5 K standby	-	37.8	> 95.3	
			TS standby	-	-	> 95.3	
Power		W	Nominal	894	1,038	10,172	
			Beam commissioning	566	750	10,172	
			Turndown	375	637	10,172	
			4.5 K standby	-	1,012	10,172	
			TS standby	-	-	10,172	

SCL3 cryogenic plant

Brief PFD designed by ALAT



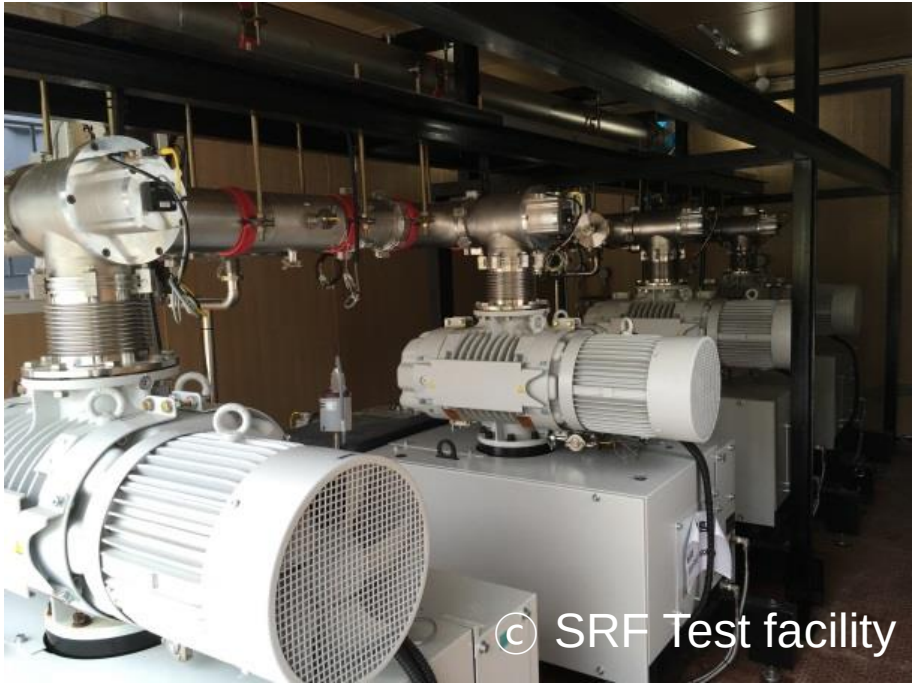
SCL3 cryogenic plant

Warm compressors

- 5 Keaser standard compressors in parallel
- FSD575(3ea) and FSD575 SFC(2ea)
- Including one back-up compressor
- Maximum operating mass flow rate: 331.3 g/s
- Maximum power consumption: 1038 kW
- To save CAPEX and OPEX

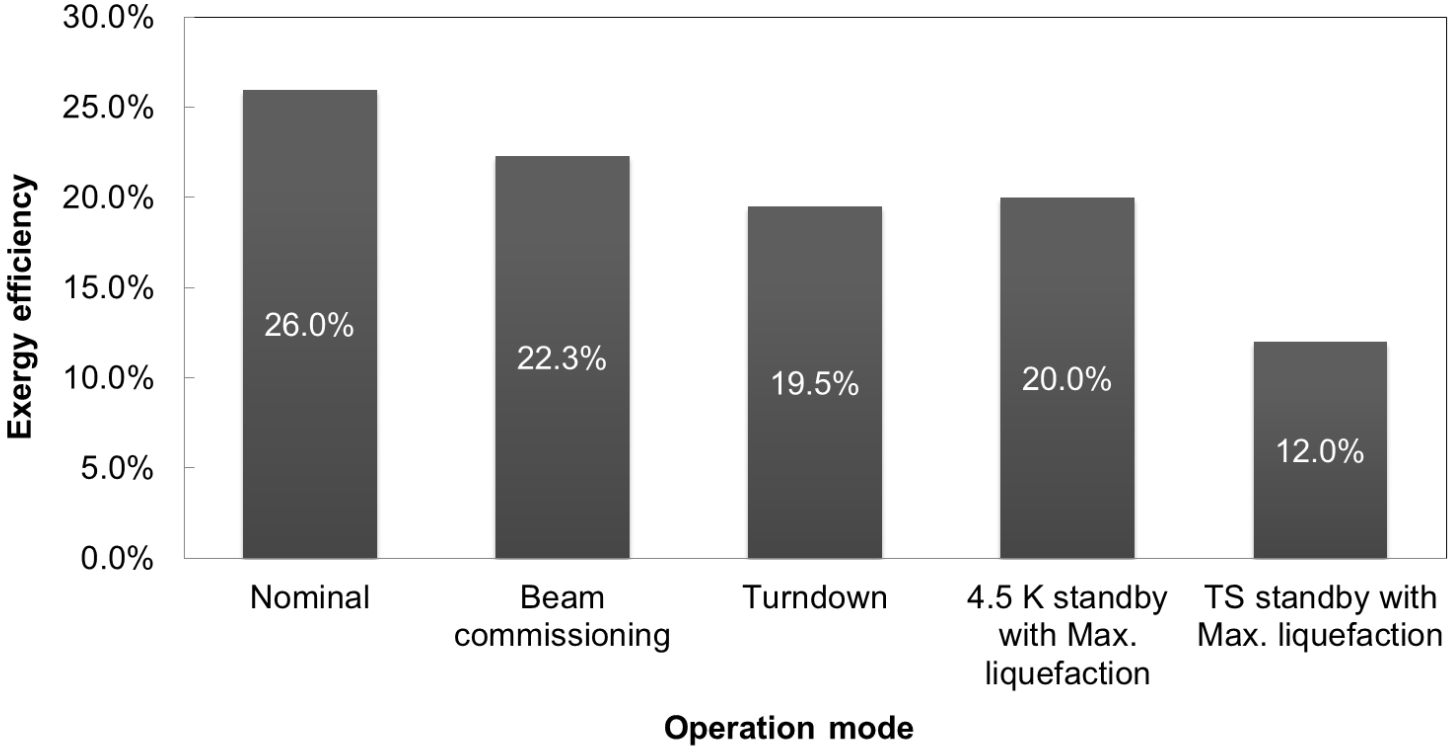
SCL3 cryogenic plant

Process vacuum pumps

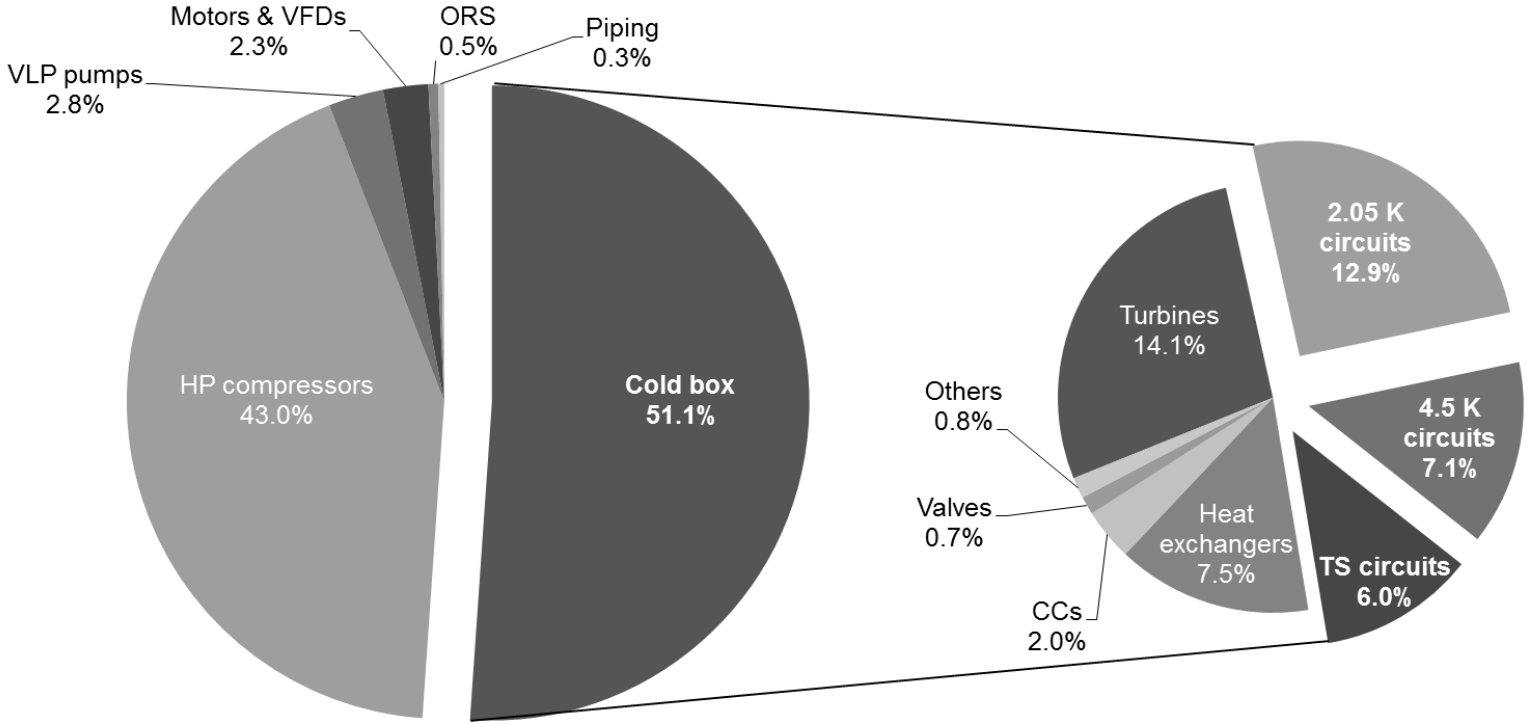


- 4 oil sealed rotary vane pumps in parallel
- Model SV630(Leybold) including one backup
- Same oil as compressors'
- Maximum operating $\dot{m}$: 34.7 g/s at 0.37 bara
- Maximum power consumption: 55.5 kW
- To save CAPEX and OPEX

SCL3 cryogenic plant
Exergy efficiency



SCL3 cryogenic plant
Exergy destruction at nominal mode



SCL3 cryogenic plant
Schedules

- Kick off meeting was held in the middle of this January.
- There were two basic design reviews in the end of this April and June.
- There will be a detail design review in the end of this year.
- The compressors will be delivered until the middle of the next year.
- The cold box will be delivered until the early of 2020.
- The site acceptance test will be finished until the middle of 2020.

Summary

- RAON is a facility for rare isotope beams in Korea.
- RAON has three SC linear accelerators and three cryogenic plants
- “Mixed” compression cycles are chosen for variable 2.05 heat loads.
- SCL3 cryogenic plant will be designed and manufactured by ALAT.
- The plant has five standard compressors including a back-up compressor.
- It has four process vacuum pumps including a back-up pump.
- The exergy efficiency at the nominal mode is about 26.0%.
- Installation of the plant will be finished until the middle of 2020.