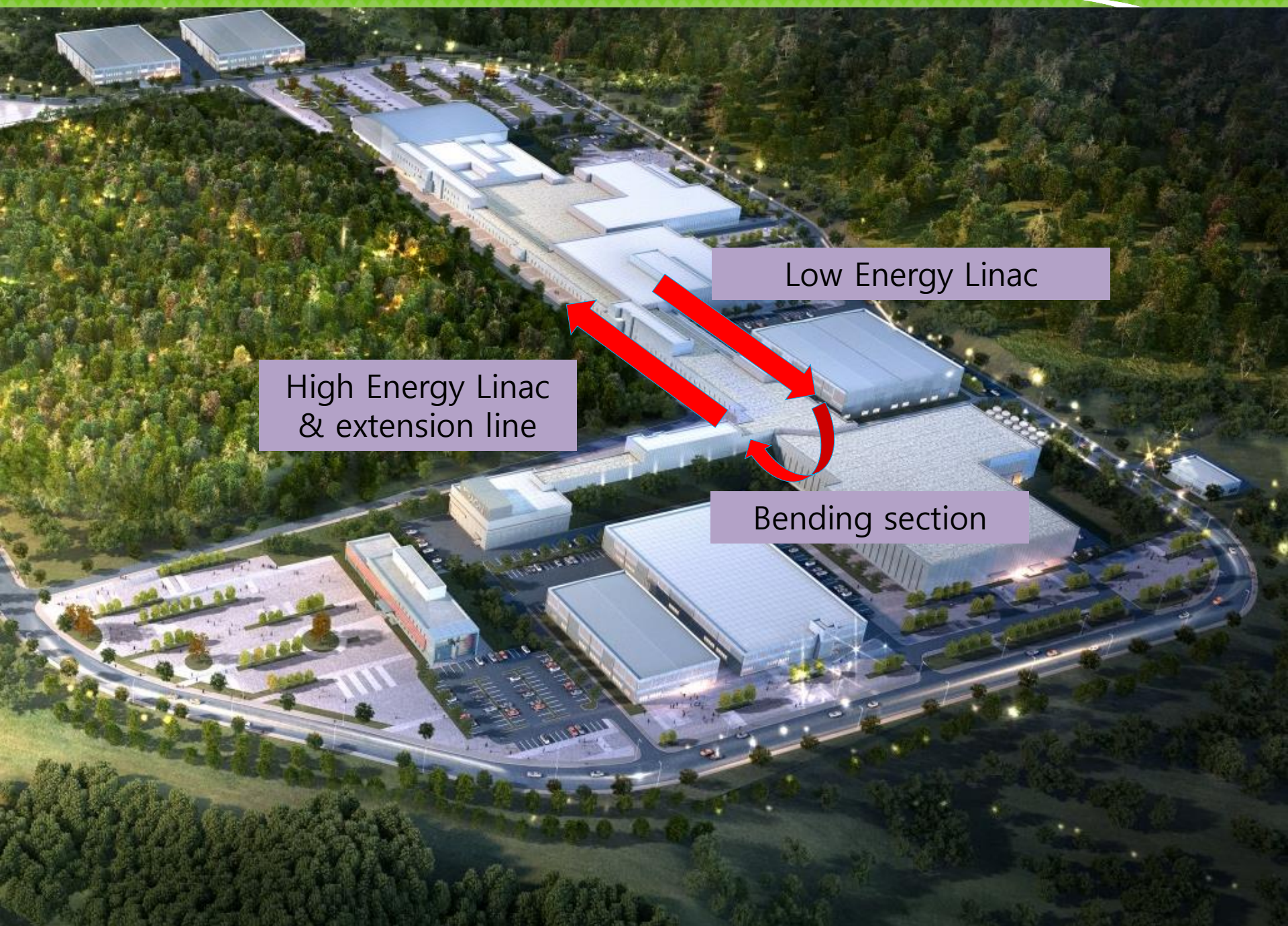


Current status cryomodule development for Low Energy Linac of RAON

**Accelerator systems Team
2018. 1. 29
Lee Min Ki**

- ◆ Introduction
- ◆ Requirements for cryomodule
- ◆ Cryomodule development
- ◆ Conclusion & Future Works

Introduction

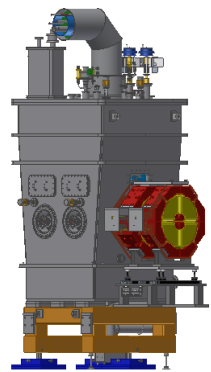


Low Energy Linac

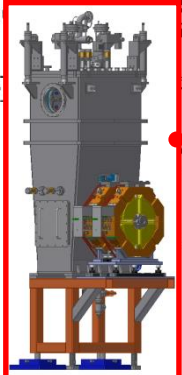
High Energy Linac
& extension line

Bending section

Cryomodules for RAON



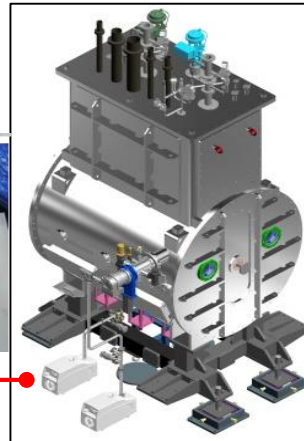
HWR CM



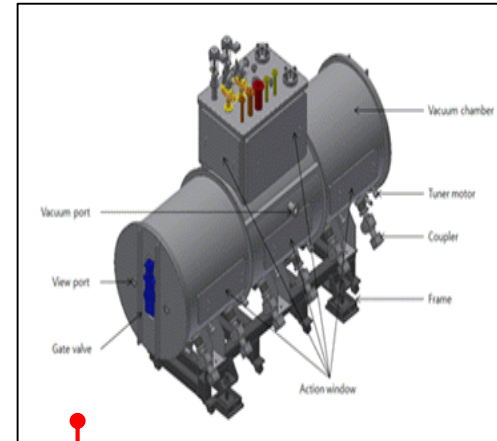
QWR CM



SSR1 CM

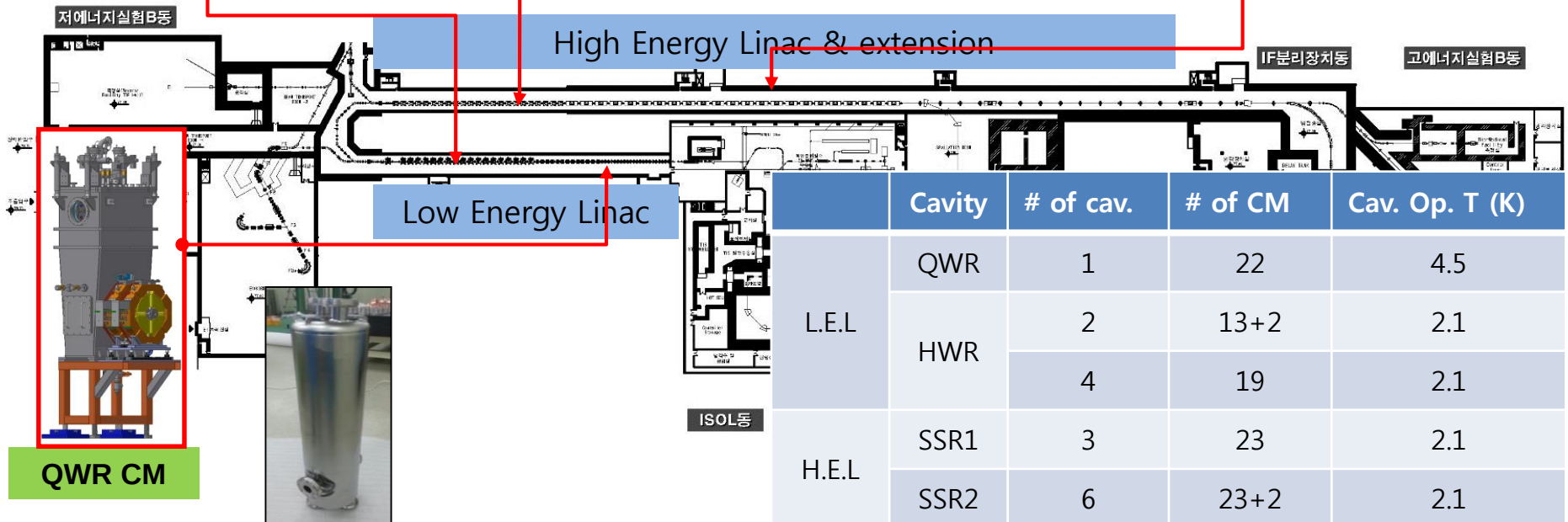


SCL2 CM



High Energy Linac & extension

Low Energy Linac



	Cavity	# of cav.	# of CM	Cav. Op. T (K)
L.E.L	QWR	1	22	4.5
	HWR	2	13+2	2.1
		4	19	2.1
H.E.L	SSR1	3	23	2.1
	SSR2	6	23+2	2.1

Requirements for cryomodule

Technical specification

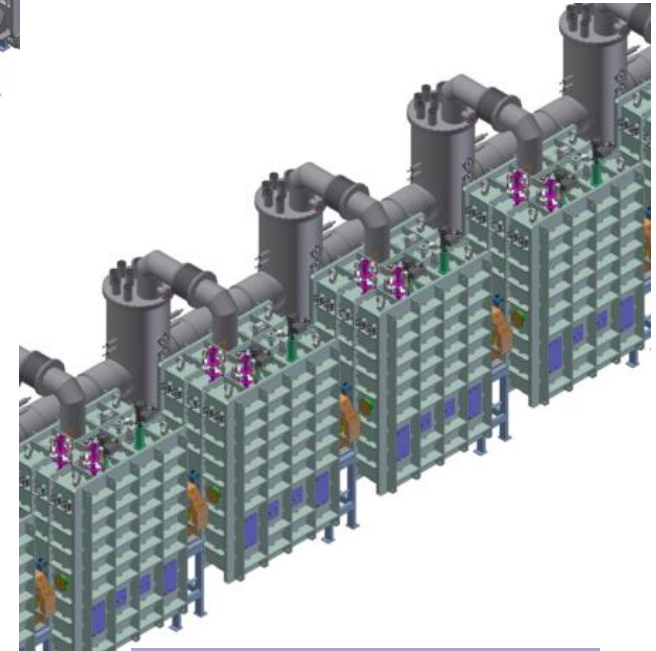
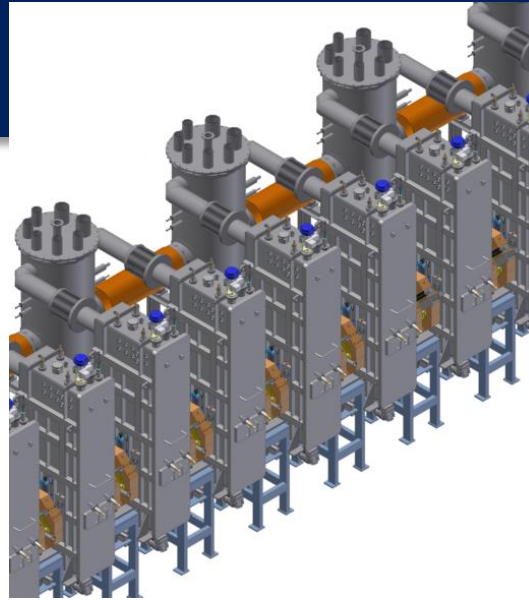


		QWR	HWR1	HWR2	SSR1	SSR2
Size	Width	Less than 1.6 m				
	Length, mm	610	1130	2010	1852	4390
	Height	Less than 3.5 m				
Operating Temp.	Thermal shield	40 K				
	Pipe lines	4.5 K or 2.1 K				
	Cavity	4.5 K	2.1 K			
Align ment	Position error (z : beam direction)	<± 1 mm				
	Rotation error	<± 0.28 °				
Pressure ratings	Helium jacket / reservoir	Room temp.: 2 bar(a) internal Cold temp.: 4 bar(a) internal				
	THS cooling line	20 bar(a) internal				
	Vacuum vessel	1 bar (a) external				

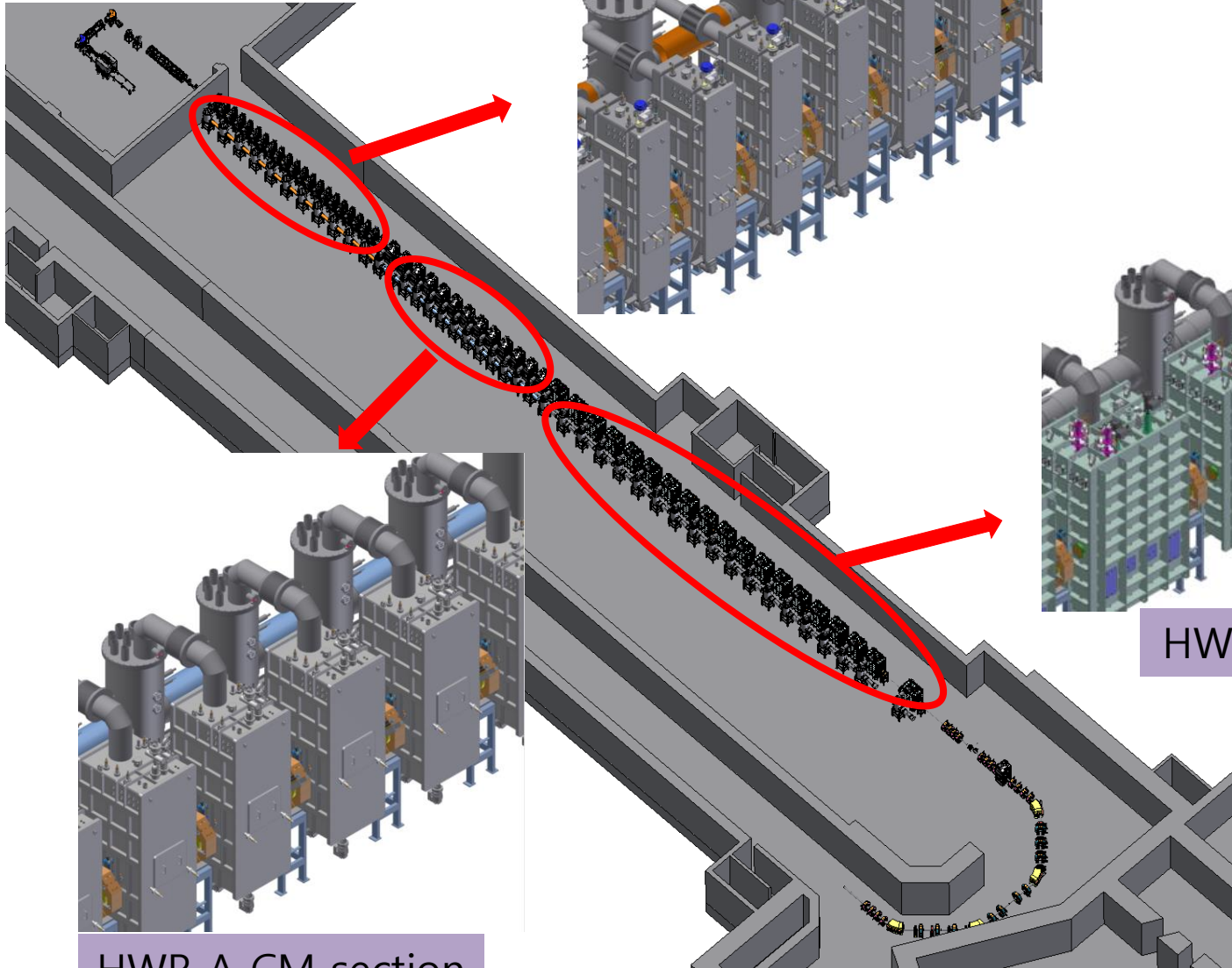
		QWR	HWR1	HWR2	SSR1	SSR2
Magnetic shield		15 mG				
Vacuum	Cavity	Less than 10^{-9} mbar at cold				
	Vacuum vessel	Less than 10^{-5} mbar at cold				
Assembly	Cavity, coupler, vacuum line	Class10 cleanroom				
Static thermal load	40 K (W)	55.5	78.6	121	48.8	92.3
	4.5 K (W)	5.0	3.0	5.0	8.1	12.7
	2.1 K (W)	-	3.0	4.5	5.0	9.2

Layout of SCL3

QWR CM section



HWR B CM section

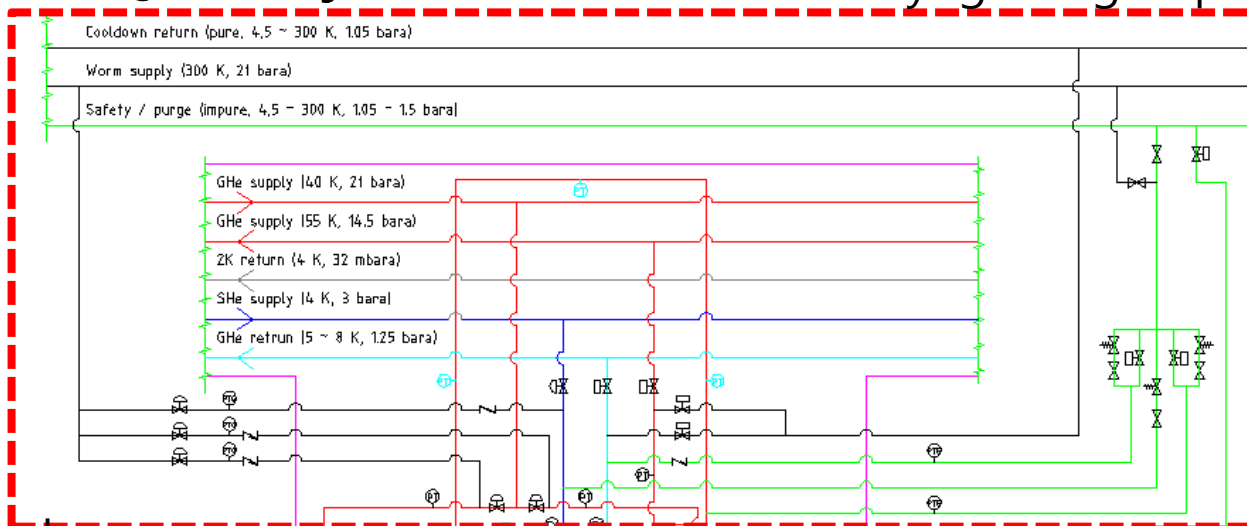


HWR A CM section

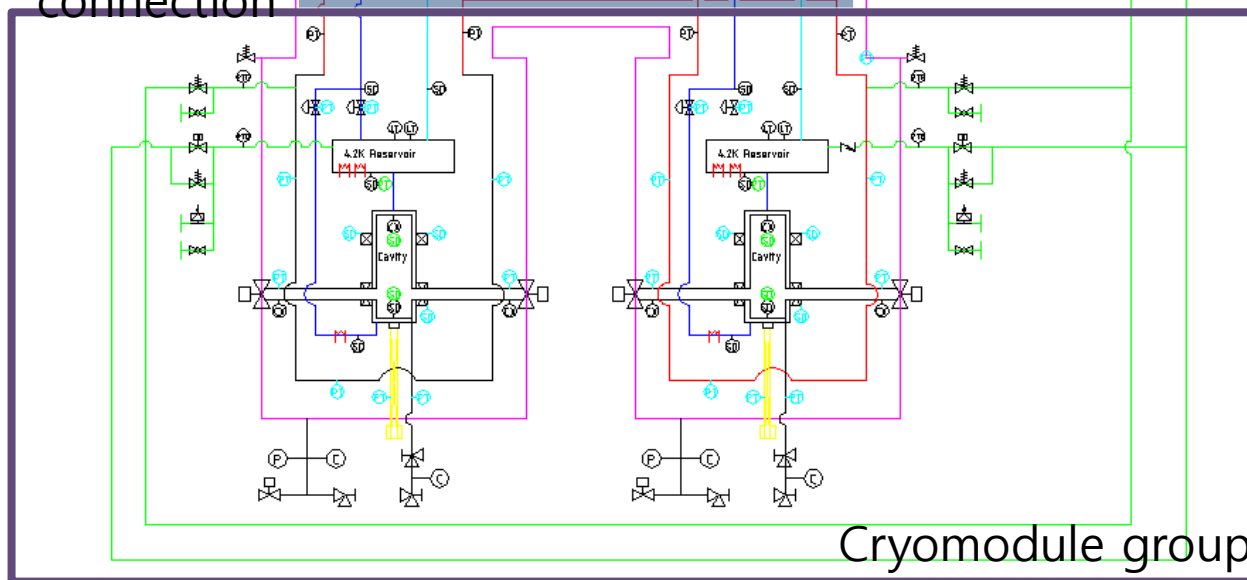
Cryomodule P & ID

◆ QWR cryomodule P&ID

Cryogenic group

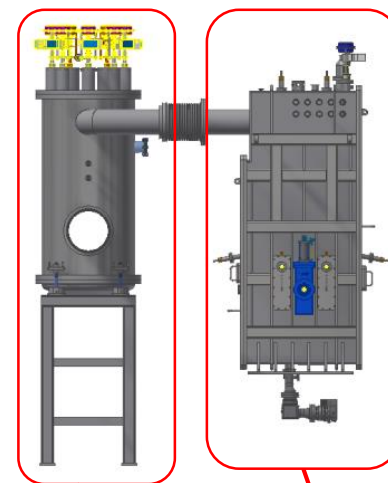


Jumper connection



Cryomodule group

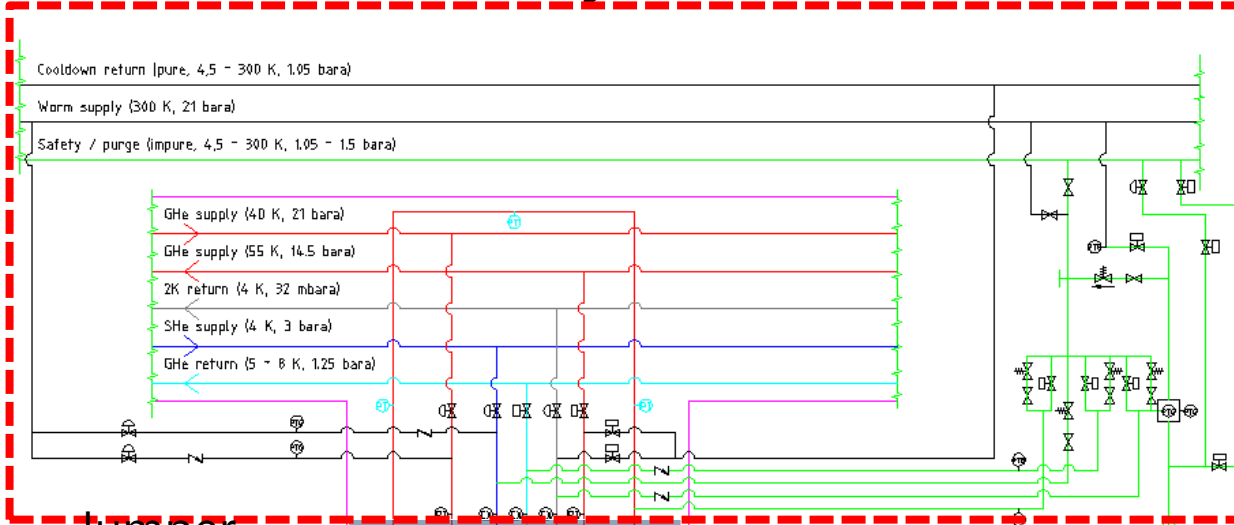
- 4.5 K operation
- 2 cryogenic valves
- 4.5 K reservoir
- 40 K thermal shield
- 2 CM for 1 valve box



Valve box

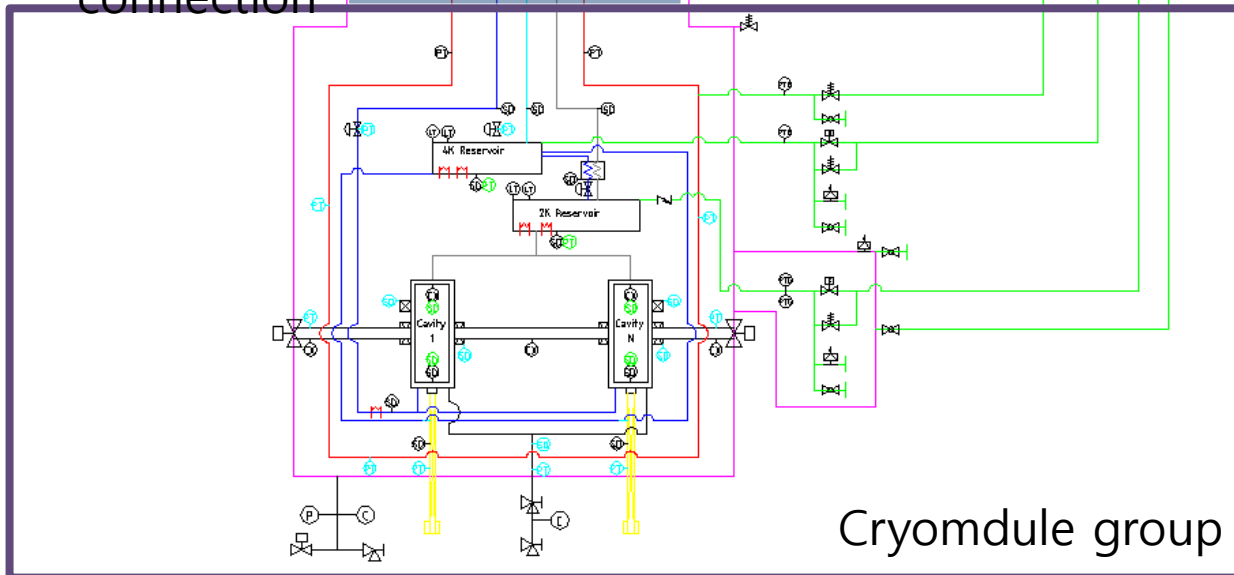
cryomodule

◆ P&ID of other cryomodules Cryogenic group



Jumper connection

- 2.1 K operation
- 3 cryogenic valves
- 4.5 K, 2.1 K reservoir
- 40 K thermal shield
- Heat exchanger for 2.1 K
- 1 CM for 1 valve box



Cryomodule group



Cryomodule development

◆ 1st Prototyping of cryomodules

- 5 types of cryomodule
- Dummy cavities, couplers, tuners in the cryomodule
- Had been fabricated by two domestic vendors from 2014
 - QWR / HWR A / SSR2 : **Vitzro Tech.Inc**
 - HWR B / SSR1 : **SFA.Inc**
- Were tested by RISP: thermal load, alignment

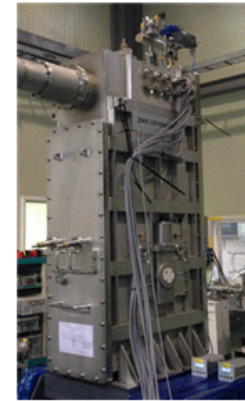
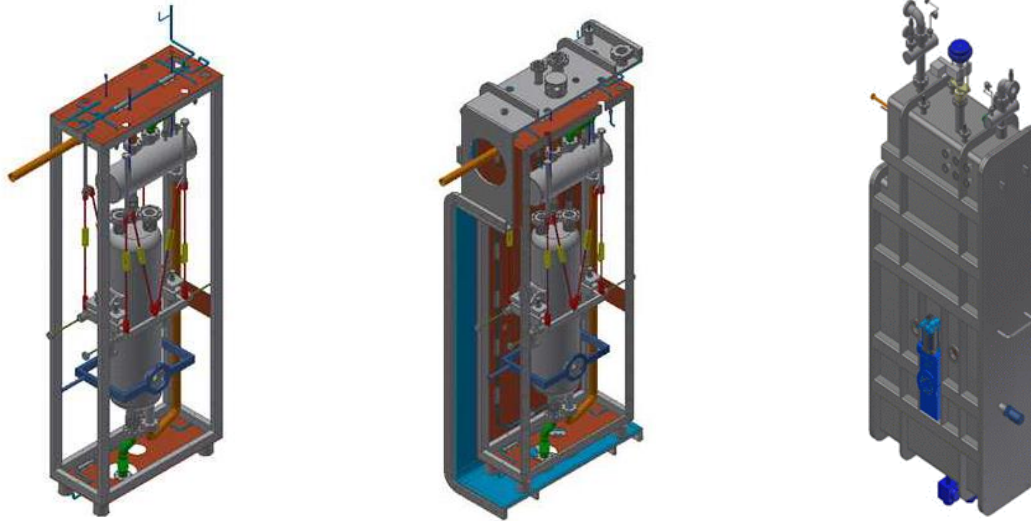
◆ 2nd Prototyping of cryomodules

- 3 types of cryomodule for SCL3 (QWR / HWR A / HWR B)
- being done by two domestic vendors from 2016
 - QWR / HWR A : **Vitzro Tech.Inc**
 - HWR B : **KAT(Kiswire.co.Ltd) & HNE**
- Integration test with cavity, coupler, tuner will be done
- Main changes
 - Bayonet connection → jumper connection
 - 2 cryogenic valves → 3 cryogenic valves (cool-down valve)
 - Vacuum chamber modification for top-loading assembly

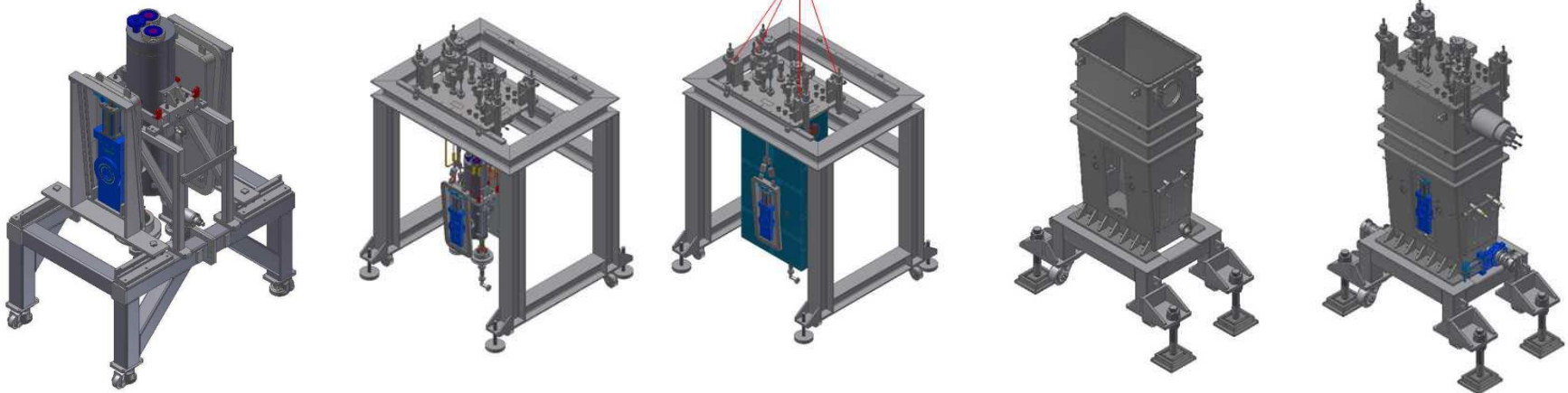
Vacuum chamber modification

◆ Cryomodule modification

Before



After : To prevent form external contamination



Class 10 clean room

CM dedicated assembly area

Vacuum chamber modification

◆ Cryomodule modification



QWR Cryomodule



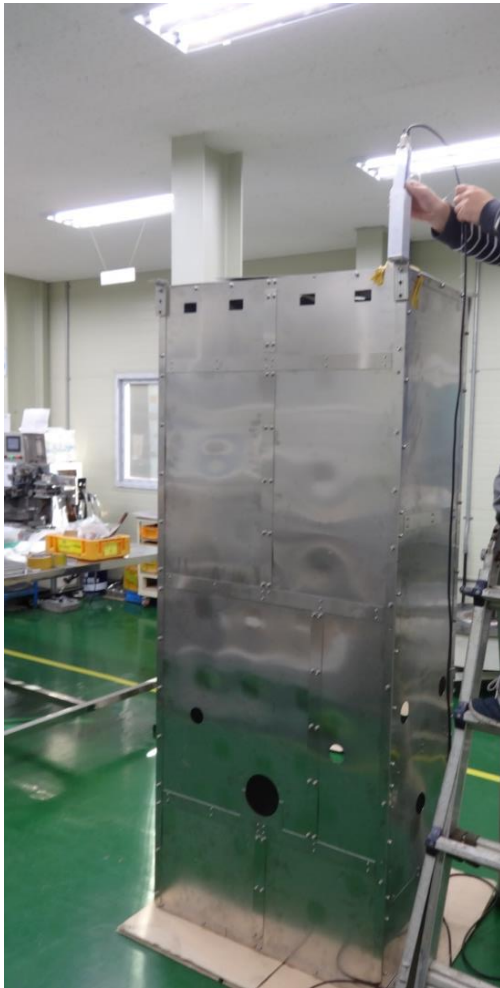
HWR A Cryomodule



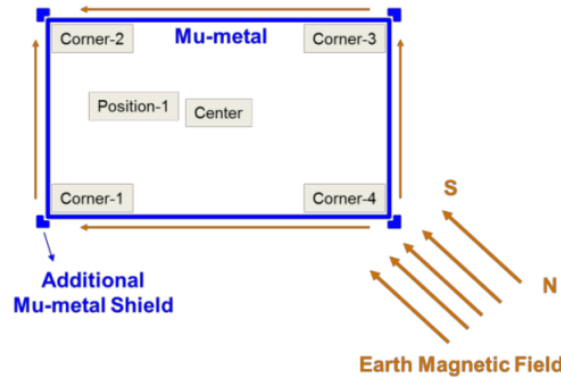
HWR B Cryomodule

Magnetic shield performance

◆ Global shield with 2 mm mu-metal



QWR



HWR A



BARTINGTON instruments(UK).

-> Mag-03 3-axis Magnetic field sensor

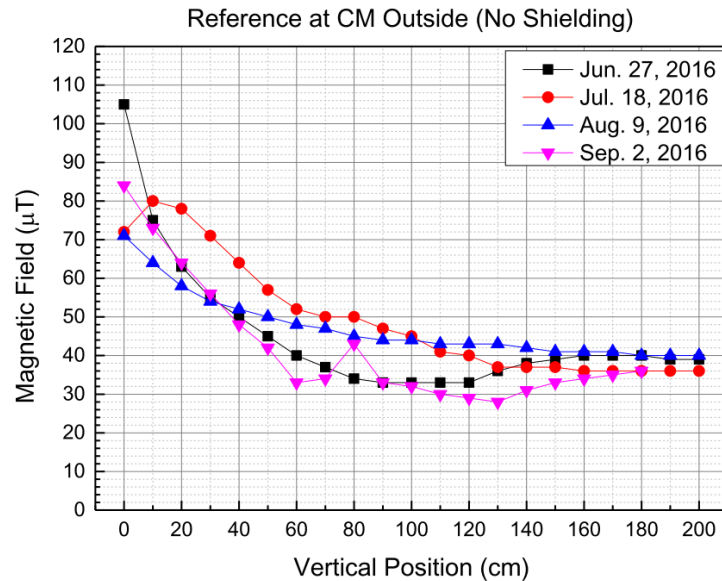
-> Range : $\pm 100\mu\text{T}$



HWR B

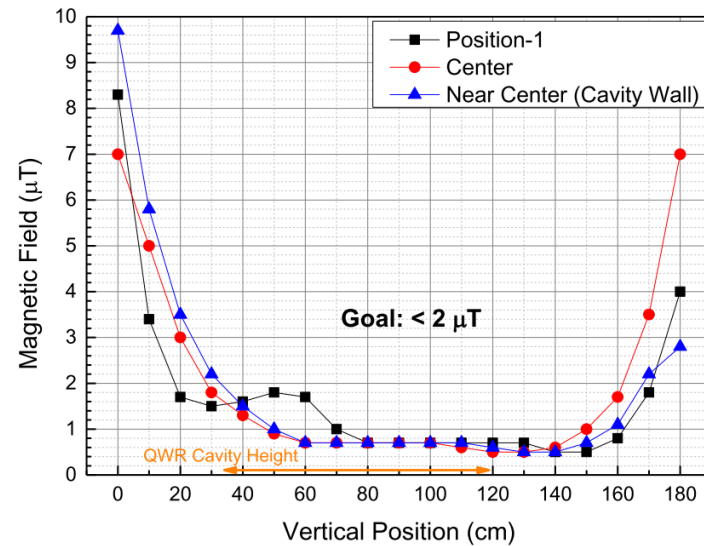
Magnetic shield performance

◆ QWR cryomodule : 2 mm mu-metal



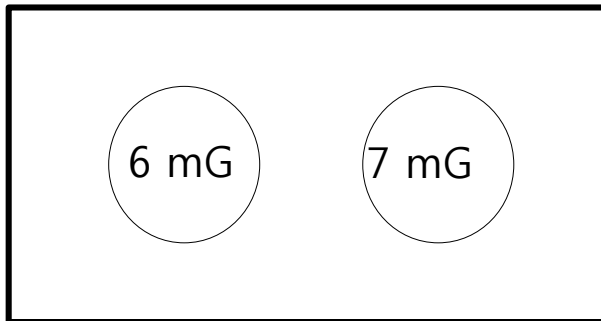
Without magnetic shield ($40 \mu\text{T} = 400 \text{ mG}$)

Mu-metal Box Positioned at the Height of 105 cm (Supposed Tunnel)



With magnetic shield (Less than 10 mG)

◆ HWR cryomodule : 2 mm mu-metal



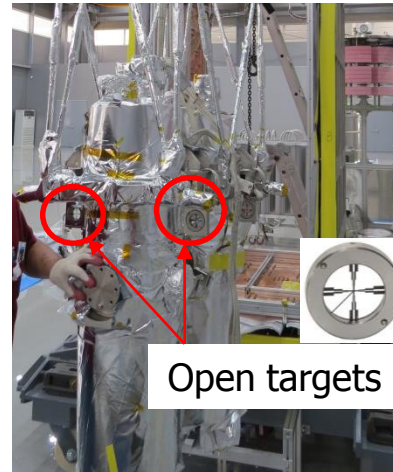
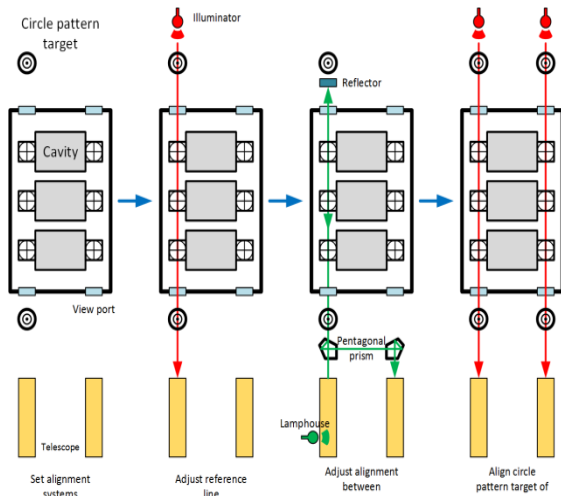
HWR A



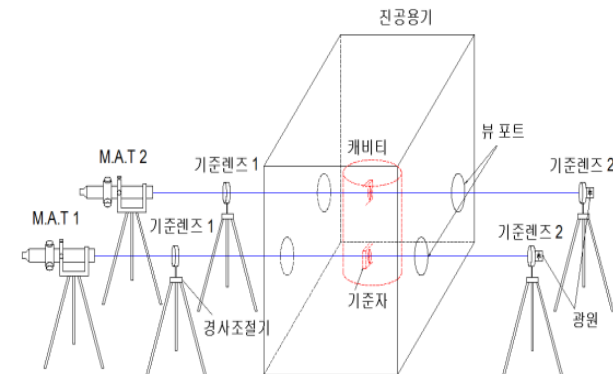
HWR B

Cavity alignment test

◆ Displacement of cavities after vacuum and cool-down



MAT + open target



Alignment test of a cryomodule



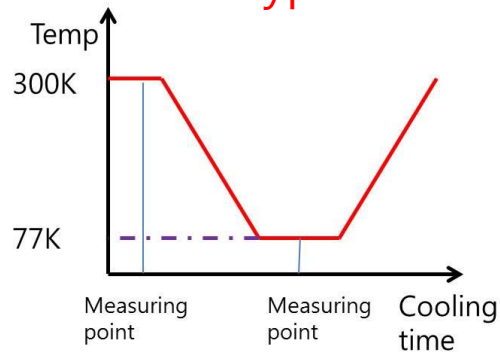
Cavity alignment test

Right

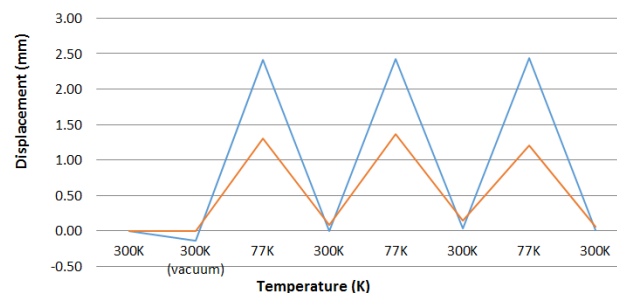
Left



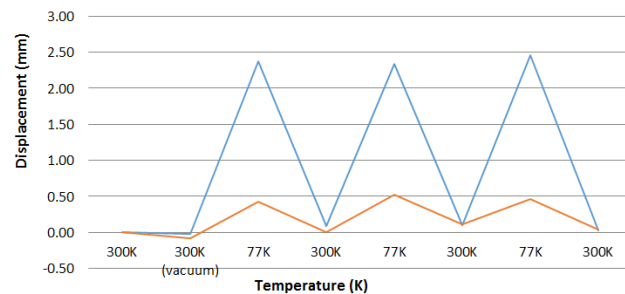
1st Prototype test result.



LN2 Cooling test (3 cycle)



Left



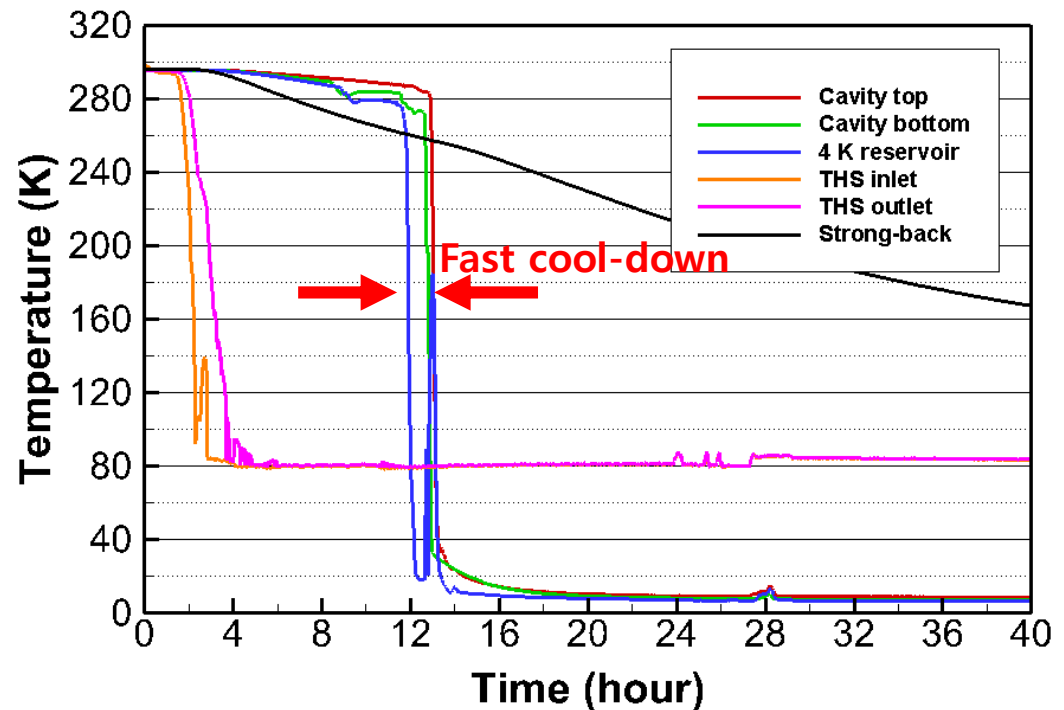
Thermal load measurement

Test : 2017. 5.



Fast cool-down for Q_0

- To prevent Q-disease, fast cool-down took within an hour from 150 K to 50 K.



QWR cryomodule : 24 min.

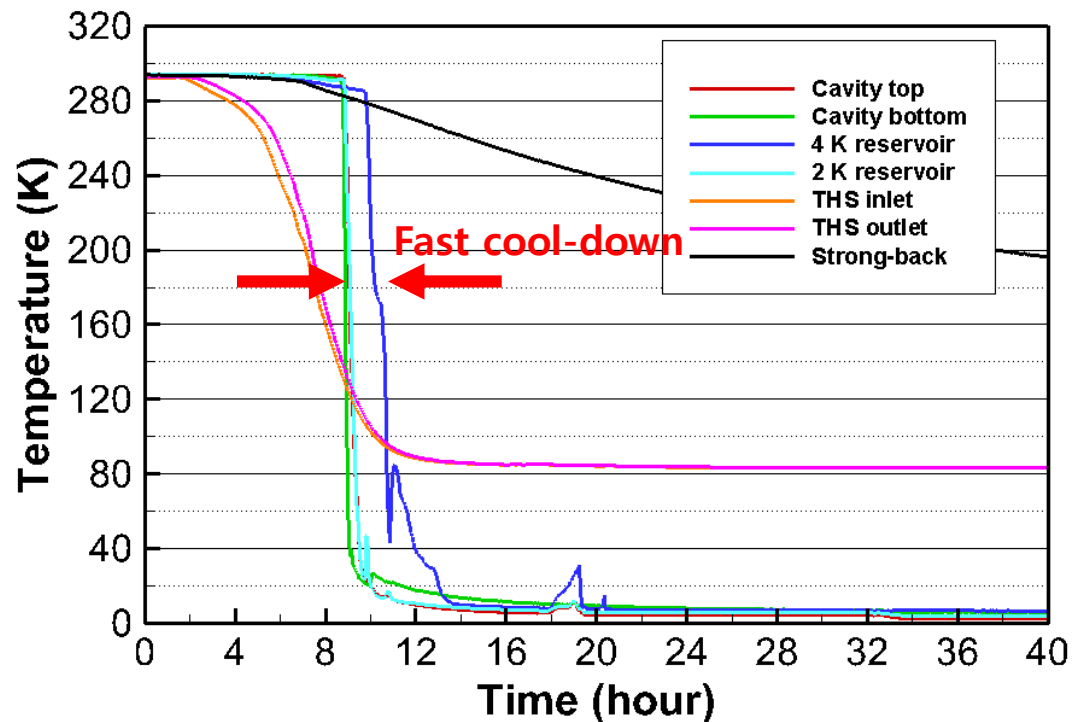
Thermal load measurement

Test : 2017. 10



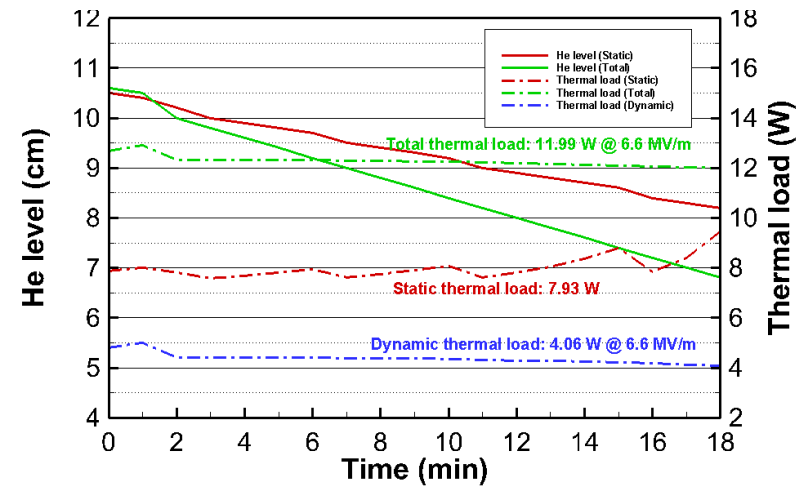
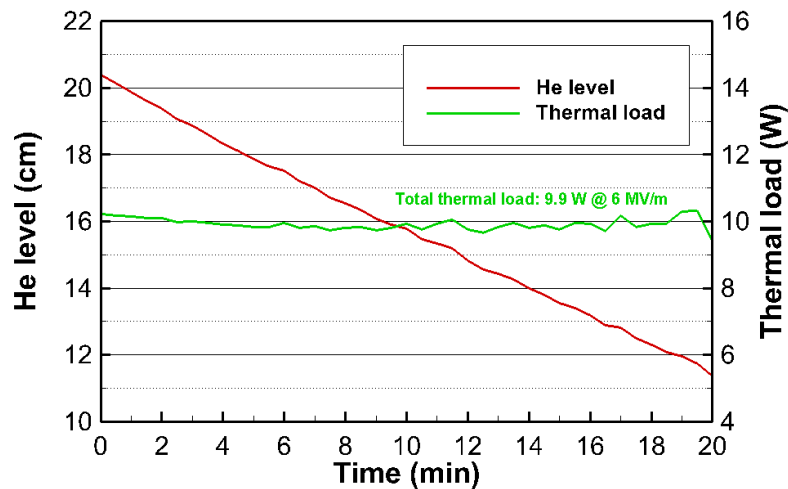
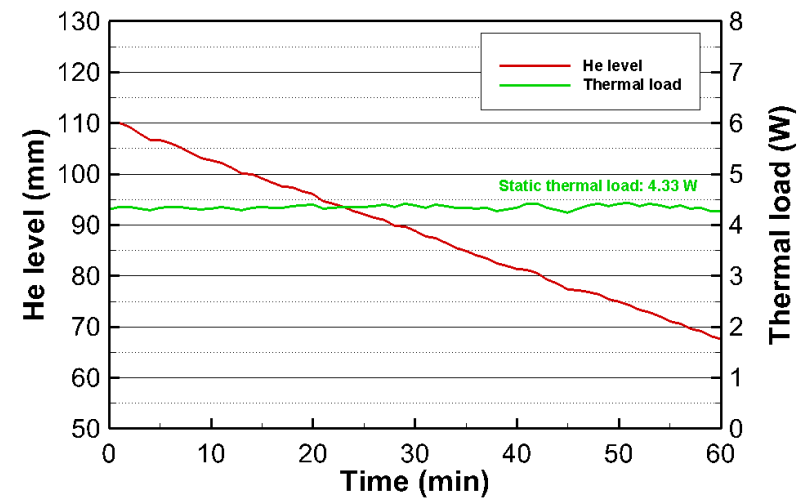
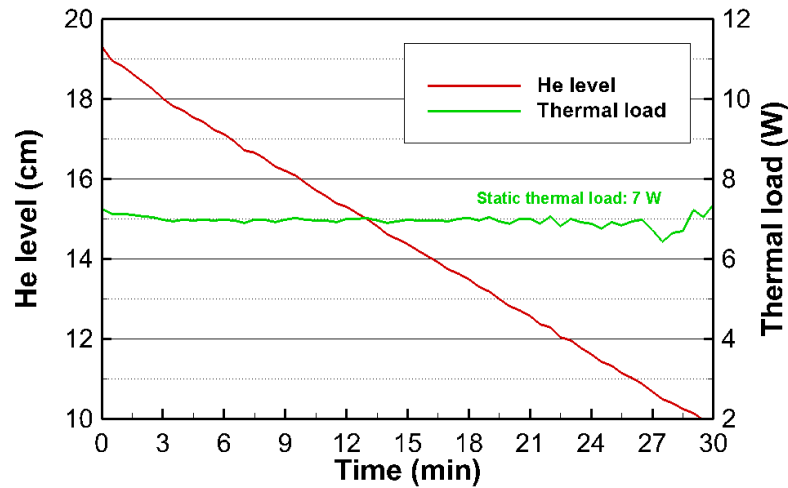
Fast cool-down for Q_0

- To prevent Q-disease, fast cool-down took within an hour from 150 K to 50 K.



HWR A cryomodule : 36 min.

Thermal load measurement



QWR cryomodule

HWR A cryomodule

Condition of experiment

Contents	QWR cryomodule		HWR A cryomodule	
	Design value	Measured value	Design value	Measured value
Magnet filed shielding	15mG	8.2mG	15mG	7mG (HWR A) 9.8mG (HWR B)
Resonant frequency of cavity	81.25 MHz	81.25 MHz	162.5 MHz	162.5 MHz
Static thermal load	< 7.5 W @ 4.2 K	7 W	< 4.5 W @ 2.1 K	4.3 W
Dynamic thermal load	< 17.5 W @ 4.2 K	2.9 W	< 4.8 W @ 2.1 K	4.1 W
Total thermal load	< 25 W @ 4.2 K	9.9 W	< 9.3 W @ 2.1 K	8.4 W

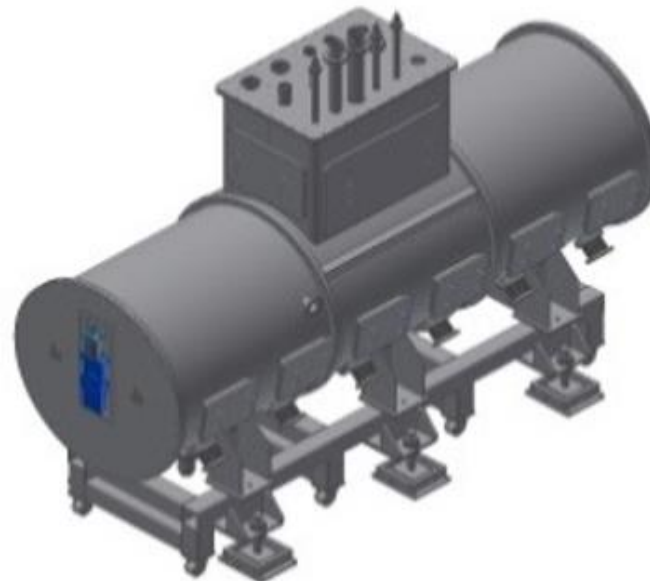
◆ QWR cryomodule for Low Energy Linac

- Mass production is in progress.

◆ Fabrication and test of HWR cryomodule

- HWR A : Fabrication will be done 2018. February.
- HWR B : Fabrication will be done 2018. March.

◆ 2nd prototype of cryomodule for High Energy Linac



Thank you!