

# Sensors in the S1-G Cryomodules

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# Measurements of cryomodule thermal characteristics (static and dynamic conditions)

- Heat loads of the system
  - Heat load at 2K
    - Evaporation of 2K LHe
      - Mass flow rate, Pressures and Temperatures at cavity jacket and pump discharge
  - Heat load at 5K
    - Temperature rise after stopping flow of 5K helium to the 5K shield
      - Temperatures of 5K shield
  - Heat load at 80K
    - Temperature rise after stopping flow of liquid nitrogen to the 80K shield
      - Temperatures of 80K shield
- Heat loads of the components
  - Thermal calculation of the measured temperature profile in the components
    - Temperatures of the components
      - Input couplers, Support posts, Thermal anchors, Thermal shields, RF cables
- Cool-down effect on the cavity alignment
  - Measurement of the cavity-jackets and GRPs positions during cool-down by WPMs

# List of temperature sensors (Module-A)

Cernox	(calibrated from 1.4K to 100K)	PtCo	(from 4K to 300K)	CC thermocouples	(from 70K to 300K)
#1 Cavity	Helium Vessel	#1 Cavity	Helium Vessel	#1 Cavity	80K thermal anchor of input coupler
	Connection area of input coupler with beam pipe	#2 Cavity	Helium Vessel		80K thermal anchor of input coupler close to cooling pipe
	5K thermal anchor of input coupler	#3 Cavity	Helium Vessel		Warm input coupler connection flange
	HOM coupler in the input coupler side-top	#4 Cavity	Helium Vessel	#2 Cavity	80K thermal anchor of input coupler
	HOM coupler in the input coupler side-bottom	5K Shield	0 degree in the side of mocule-C		80K thermal anchor of input coupler close to cooling pipe
	HOM coupler in the non-input coupler side-top		90 degree in the side of mocule-C		Warm input coupler connection flange
	HOM coupler in the non-input coupler side-bottom		180 degree in the side of mocule-C		#3 Cavity
#2 Cavity	Helium Vessel		270 degree in the side of mocule-C		80K thermal anchor of input coupler close to cooling pipe
	Connection area of input coupler with beam pipe		90 degree at fixed support post		Warm input coupler connection flange
	5K thermal anchor of input coupler		180 degree at fixed support post		#4 Cavity
	HOM coupler in the input coupler side-top		0 degree at shield center		80K thermal anchor of input coupler
	HOM coupler in the input coupler side-bottom		90 degree at shield center		80K thermal anchor of input coupler close to cooling pipe
	HOM coupler in the non-input coupler side-top		180 degree at shield center		Warm input coupler connection flange
	HOM coupler in the non-input coupler side-bottom		270 degree at shield center		Fixed support post
#3 Cavity	Helium Vessel		90 degree at movable support post		80K anchor at the 0 degree
	Connection area of input coupler with beam pipe		180 degree at movable support post		80K anchor at the 180 degree
	5K thermal anchor of input coupler		270 degree at movable support post		Room temp. area
	HOM coupler in the input coupler side-top		0 degree in the side of end flange		Movable support post
	HOM coupler in the input coupler side-bottom		90 degree in the side of end flange		80K anchor at the 0 degree
	HOM coupler in the non-input coupler side-top		180 degree in the side of end flange		80K anchor at the 180 degree
	HOM coupler in the non-input coupler side-bottom		270 degree in the side of end flange		Room temp. area
#4 Cavity	Helium Vessel		5K anchor at the 0 degree		80K Shield
	Connection area of input coupler with beam pipe		5K anchor at the 180 degree		0 degree in the side of mocule-C
	5K thermal anchor of input coupler		5K anchor at the 0 degree		90 degree in the side of mocule-C
	HOM coupler in the input coupler side-top		5K anchor at the 180 degree		180 degree in the side of mocule-C
	HOM coupler in the input coupler side-bottom		Connection area to the fixed support post		270 degree in the side of mocule-C
	HOM coupler in the non-input coupler side-top		Connection area to the movable support post		0 degree in the center
	HOM coupler in the non-input coupler side-bottom				90 degree in the center
GRP	Upstream-top (Module-C connection side)				180 degree in the center
	Upstream-bottom (Module-C connection side)				270 degree in the center
	Center-top				0 degree in the side of end flange
	Center-bottom				90 degree in the side of end flange
	Downstream-top (end flange side)				180 degree in the side of end flange
	Downstream-bottom (end flange side)				270 degree in the side of end flange
	Beam Pipe				Position inside of 80K thermal anchor
				GRP	
				Upstream-top (Module-C connection side)	
				Upstream-bottom (Module-C connection side)	
				Center-top	
				Center-bottom	
				Downstream-top (end flange side)	
				Downstream-bottom (end flange side)	

**CERNOX: Total 39**  
(1.4K~100K)

Four cavities : 32  
GRP : 6  
Beam pipe : 1

**PtCo: Total 28**  
(4K~300K)

Four cavities : 4  
5K shield : 18  
Support posts : 4  
GRP : 2

**CC: Total 37**  
(70K~300K)

Four cavities : 12  
Support posts : 6  
80K shield : 12  
Beam pipe : 1  
GRP : 6

# List of temperature sensors (Module-C)

Cernox	(calibrated from 1.4K to 100K)	PtCo	(from 4K to 300K)	CC thermocouples	(from 70K to 300K)
#1 Cavity	Helium Vessel	#1 Cavity	Helium Vessel	#1 Cavity	80K thermal anchor of input coupler
	Connection area of input coupler with beam pipe	#2 Cavity	Helium Vessel		80K thermal anchor of input coupler close to cooling pipe
	5K thermal anchor of input coupler	#3 Cavity	Helium Vessel		Warm input coupler connection flange
	HOM coupler in the input coupler side-top	#4 Cavity	Helium Vessel	#2 Cavity	80K thermal anchor of input coupler
	HOM coupler in the input coupler side-bottom	5K Shield	0 degree in the side of valve box		80K thermal anchor of input coupler close to cooling pipe
	HOM coupler in the non-input coupler side-top		90 degree in the side of valve box		Warm input coupler connection flange
	HOM coupler in the non-input coupler side-bottom		180 degree in the side of valve box	#3 Cavity	80K thermal anchor of input coupler
	Piezo		270 degree in the side of valve box		80K thermal anchor of input coupler close to cooling pipe
#2 Cavity	Helium Vessel		90 degree at fixed support post	#4 Cavity	Warm input coupler connection flange
	Connection area of input coupler with beam pipe		180 degree at fixed support post		80K thermal anchor of input coupler
	5K thermal anchor of input coupler		270 degree at fixed support post		80K thermal anchor of input coupler close to cooling pipe
	HOM coupler in the input coupler side-top		0 degree at shield center		Warm input coupler connection flange
	HOM coupler in the input coupler side-bottom		90 degree at shield center	Fixed support post	80K anchor at the 0 degree
	HOM coupler in the non-input coupler side-top		180 degree at shield center		80K anchor at the 180 degree
	HOM coupler in the non-input coupler side-bottom		270 degree at shield center		Room temp. area
	Piezo		90 degree at movable support post	Movable support post	80K anchor at the 0 degree
#3 Cavity	Helium Vessel		180 degree at movable support post		80K anchor at the 180 degree
	Connection area of input coupler with beam pipe		270 degree at movable support post		Room temp. area
	5K thermal anchor of input coupler		0 degree in the side of module-C	80K Shield	0 degree in the upstream side
	HOM coupler in the input coupler side-top		90 degree in the side of module-C		90 degree in the upstream side
	HOM coupler in the input coupler side-bottom		180 degree in the side of module-C		180 degree in the upstream side
	HOM coupler in the non-input coupler side-top		270 degree in the side of module-C		270 degree in the upstream side
	HOM coupler in the non-input coupler side-bottom	Fixed support post	5K anchor at the 0 degree		0 degree in the center
	Piezo		5K anchor at the 180 degree		90 degree in the center
#4 Cavity	Helium Vessel	Movable support post	5K anchor at the 0 degree		180 degree in the center
	Connection area of input coupler with beam pipe		5K anchor at the 180 degree		270 degree in the center
	5K thermal anchor of input coupler	GRP	Connection area to the fixed support post		0 degree in the downstream side
	HOM coupler in the input coupler side-top		Connection area to the movable support post		90 degree in the downstream side
	HOM coupler in the input coupler side-bottom				180 degree in the downstream side
	HOM coupler in the non-input coupler side-top				270 degree in the downstream side
	HOM coupler in the non-input coupler side-bottom			Beam pipe	Position inside of 80K thermal anchor
	Piezo			GRP	Upstream-top (valve box connection side)
GRP	Upstream-top (valve box connection side)				Upstream-bottom (valve box connection side)
	Upstream-bottom (valve box connection side)				Center-top
	Center-top				Center-bottom
	Center-bottom				Downstream-top (module-C connection side)
	Downstream-top (module-C connection side)				Downstream-bottom (module-C connection side)
	Downstream-bottom (module-C connection side)				
Beam Pipe	Position inside of 5K thermal anchor				

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**PtCo: Total 28**  
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5K shield : 18  
Support posts : 4  
GRP : 2

**CC: Total 37**  
(70K~300K)

Four cavities : 12  
Support posts : 6  
80K shield : 12  
Beam pipe : 1  
GRP : 6

# WPM

WPM	ID Number	Location (mm)	
CM-A GRP	#1	-1123.5	z axis: the origin is the fixed post
	#2	226.5	
	#3	1576.5	
	#4	2926.5	
	#5	4276.5	
CM-A: Cav-#1	#1		
	#2		
CM-A: Cav-#2	#1		
	#2		
CM-A: Cav-#3	#1		
	#2		
CM-A: Cav-#4	#1		
	#2		

On the GRP in Module A, five WPMs will be assembled.

Two WPMs on each KEK cavity jacket are planned to be assembled.

WPM	ID Number	Location (mm)	
CM-C GRP	#1	-1200	z axis: the origin is the fixed post physical center of GRP
	#2	0	
	#3	1600	
	#4	3200	
	#5	4600	
CM-C: Cav-#1	NA		
	NA		
CM-C: Cav-#2	NA		
	NA		
CM-C: Cav-#3	NA		
	NA		
CM-C: Cav-#4	NA		
	NA		

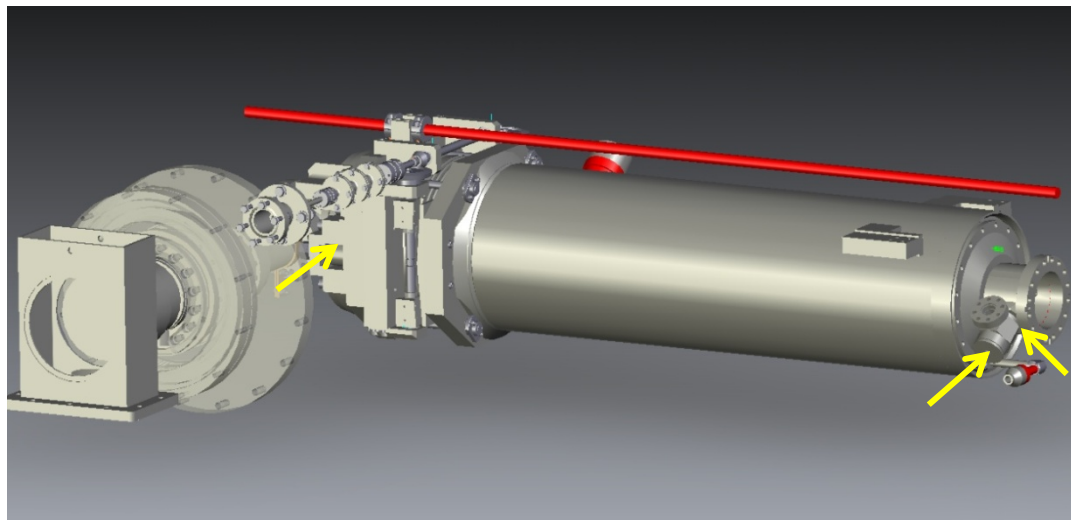
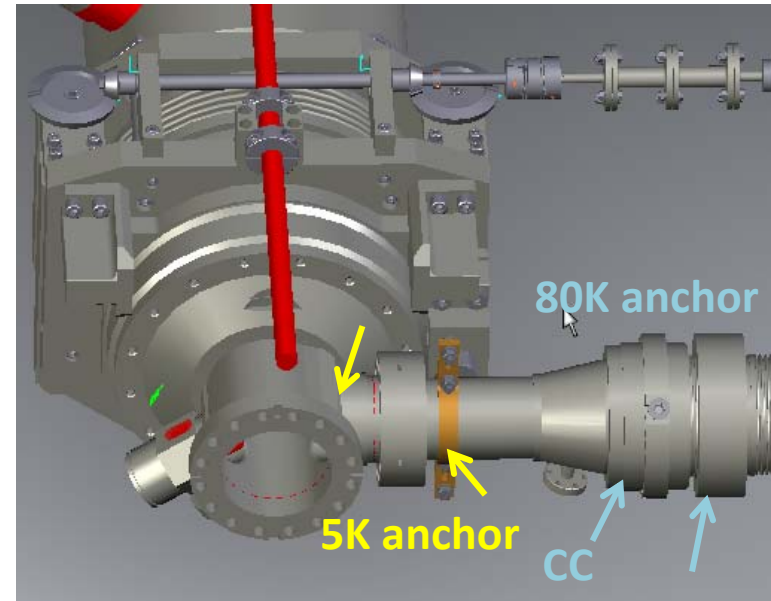
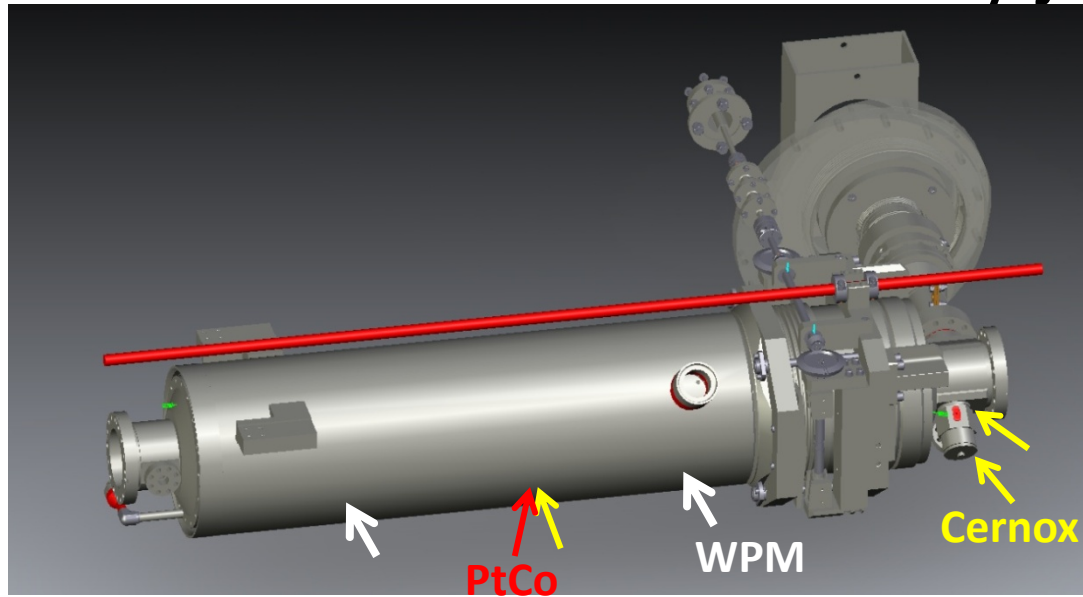
On the GRP in Module C, five WPMs will be assembled.

WPMs on DESY and FNAL cavity jackets are not planned to be assembled.

# Pressure sensors, etc

<b>Pressure Sensors</b>			
GRP	CM-A	Absolute pressure sensor (Hitachi)	0~27kPa
	Connection pipe between	CM-A	Absolute pressure sensor (Hitachi)
		CM-A	Absolute pressure sensor (Baratron)
		CM-A	Pressure sensor
2K Cold Box	4K LHe vessel	Pressure sensor (Hitachi)	-0.1 MPa~0.5 MPa
	2K LHe vessel	Absolute pressure sensor (Baratron)	0~13.3kPa
	5K shield return gas line (cold)	Pressure sensor (Hitachi)	-0.1 MPa~0.5 MPa
5K shield piping	5K shield return gas line (room	Pressure sensor	-0.1 MPa~0.5 MPa
Pump system	Pump discharge pressure	Pressure sensor	-0.1 MPa~0.5 MPa
Vacuum vessel	CM-A	CCG	
	CM-A	Pirani gauge	
<b>Mass flow meter</b>			
Pump system	Pump discharge	Volume flow meter	0~65 Nm <sup>3</sup> /h
	Pump discharge	Volume flow meter	0~10 Nm <sup>3</sup> /h
5K shield piping	5K shield return gas line (room temperature)	Volume flow meter	0~65 Nm <sup>3</sup> /h
<b>Temperature sensor</b>			
2K Cold Box	4K LHe vessel	Cernox, PtCo	1.5K~40K, 4K~300K
	2K LHe vessel	Cernox	1.5K~40K
Pump system	Pump discharge (near mass flow meter)	CC	80K~320K
5K shield piping	5K shield return gas line (near mass flow meter)	CC	80K~320K
<b>LHe level sensor</b>			
2K Cold Box	4K LHe vessel	Superconducting level sensor (AMD)	
	2K LHe vessel	Superconducting level sensor (AMD)	

# KEK- cavity jacket



## Cernox

Helium Vessel
Connection area of input coupler with beam pipe
5K thermal anchor of input coupler
HOM coupler in the input coupler side-top
HOM coupler in the input coupler side-bottom
HOM coupler in the non-input coupler side-top
HOM coupler in the non-input coupler side-bottom
Piezo

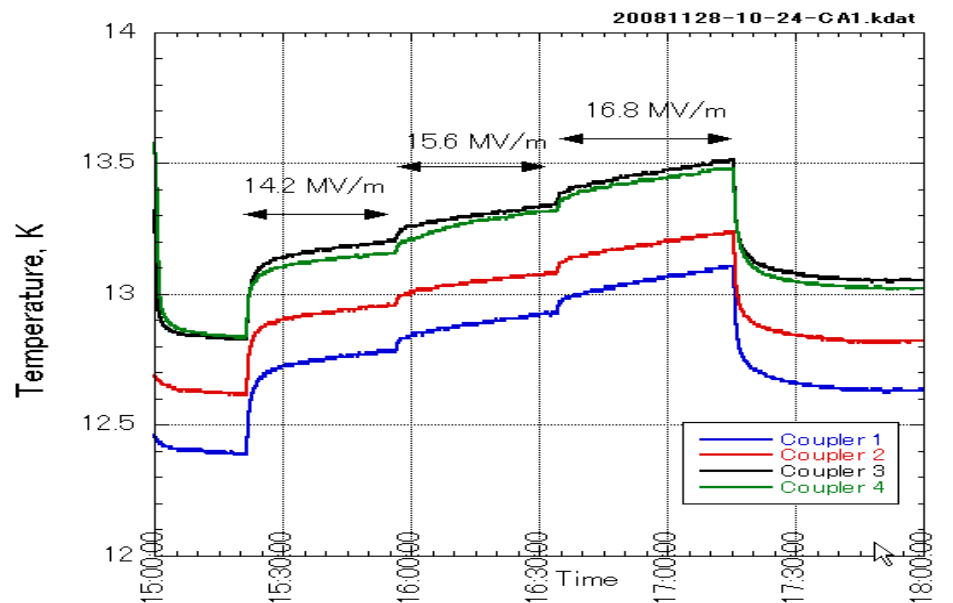
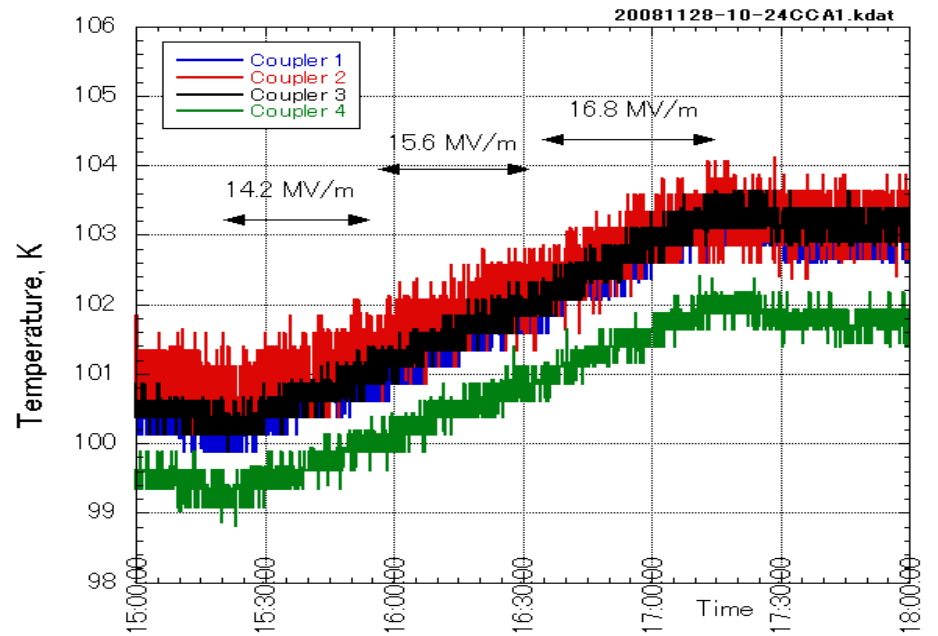
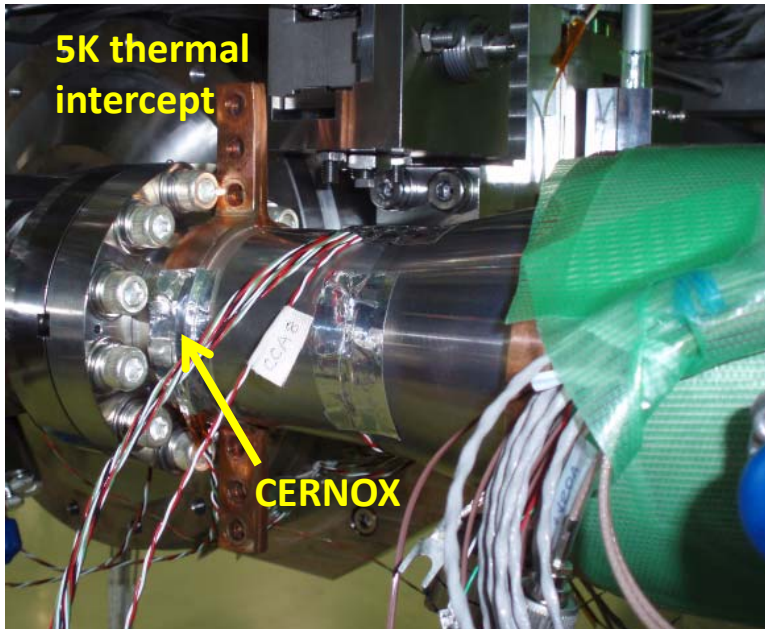
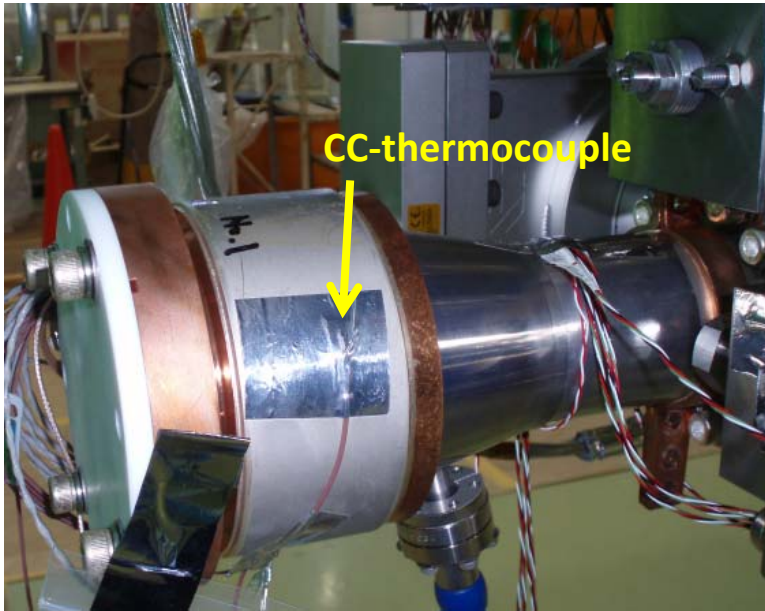
## PtCo

Helium Vessel
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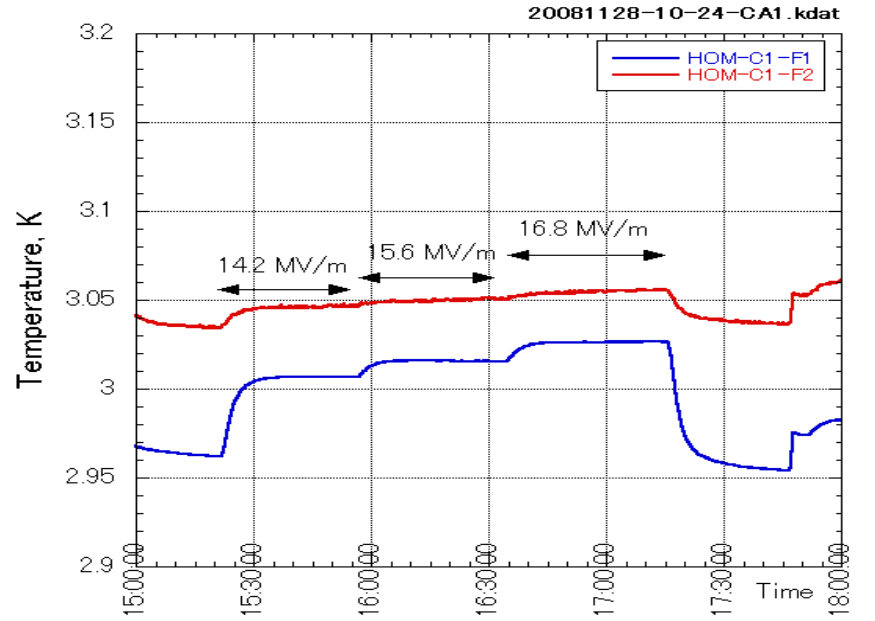
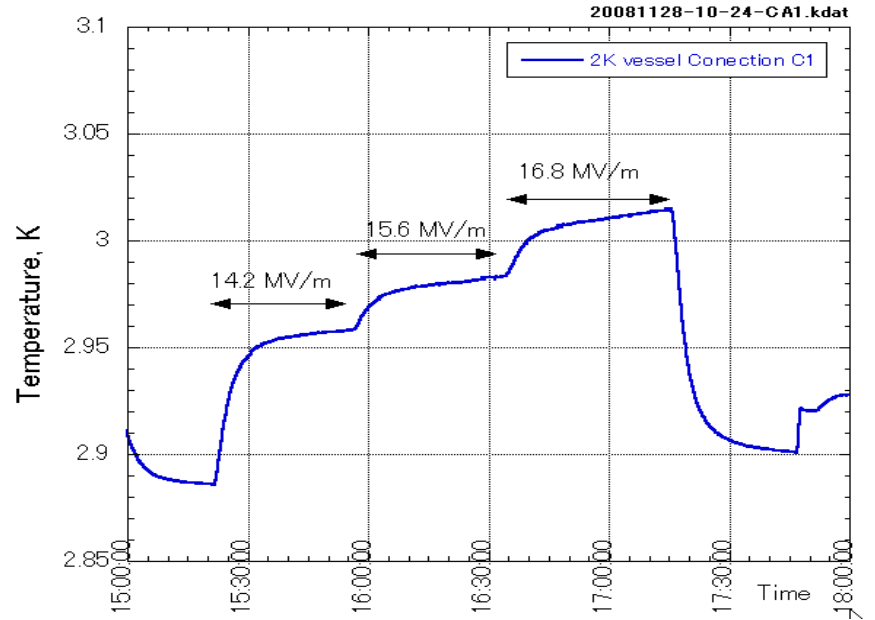
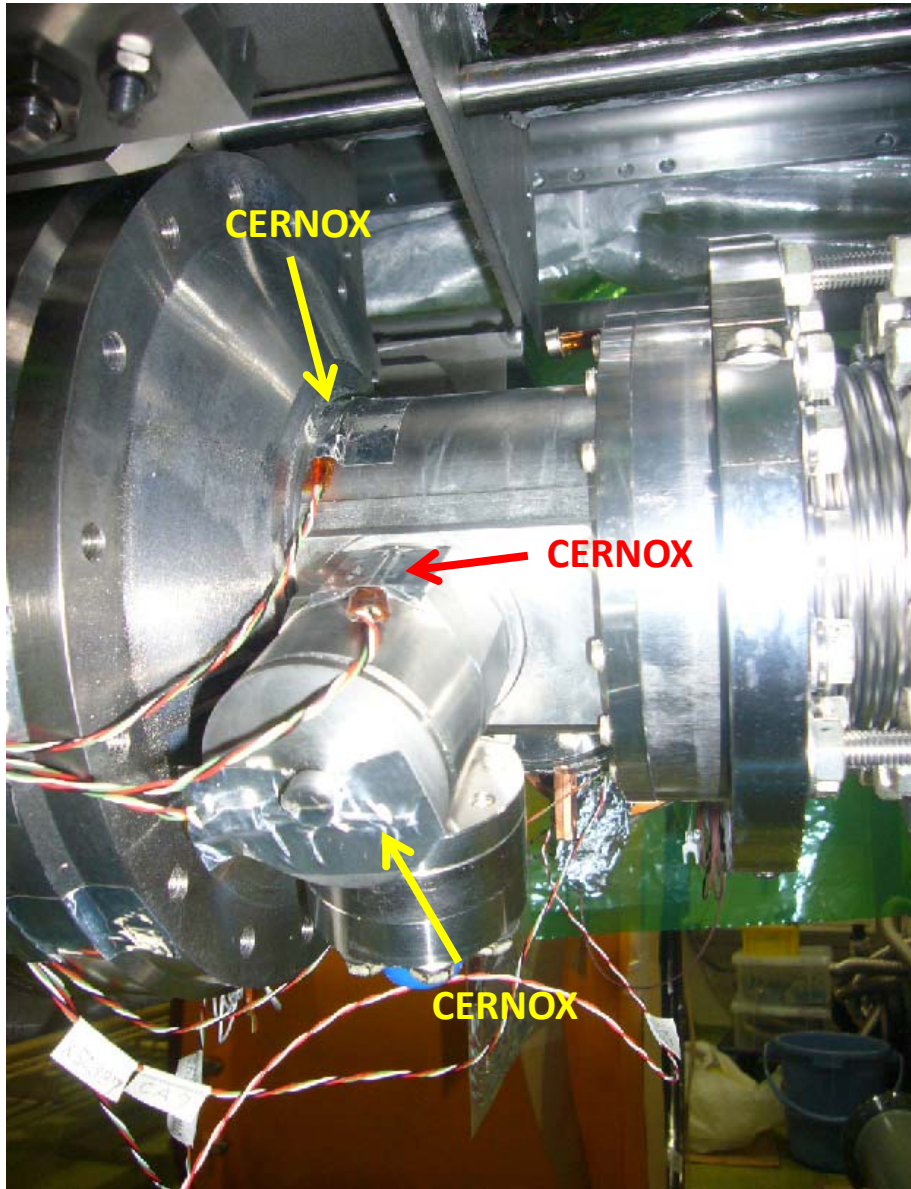
## CC

80K thermal anchor of input coupler
Warm input coupler connection flange

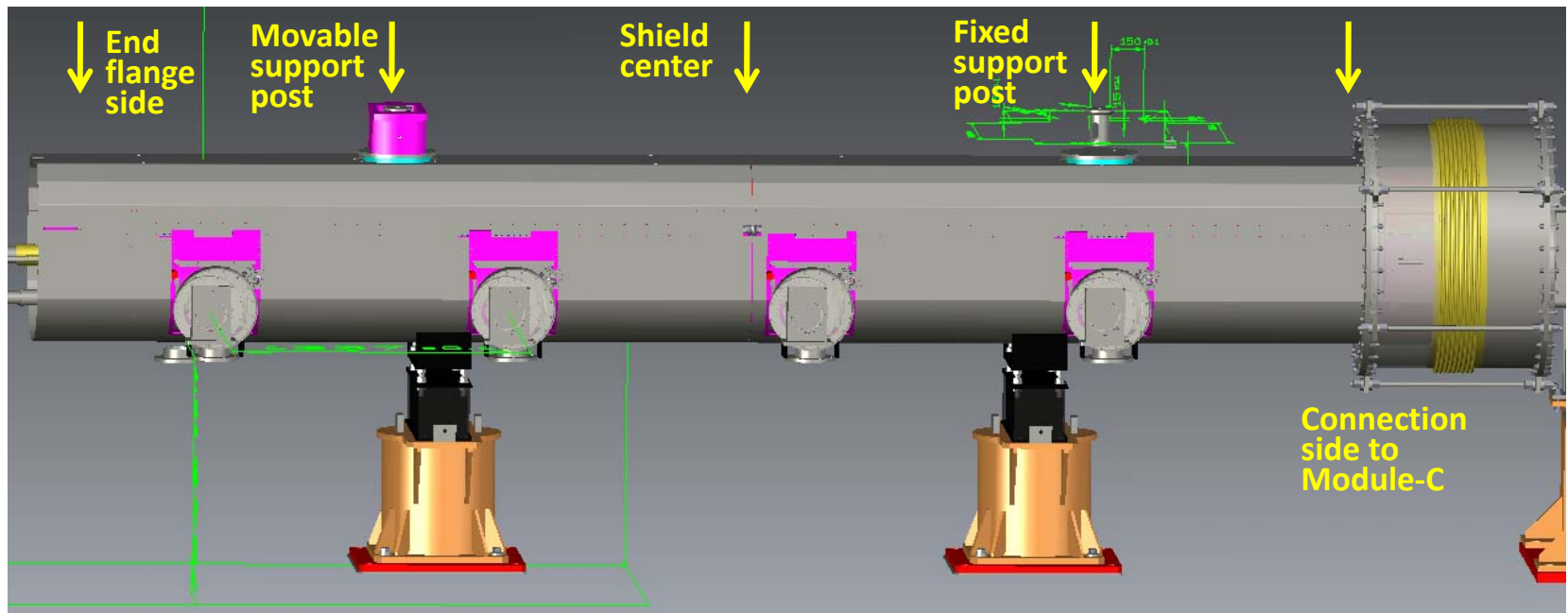








# Thermal shields for Module A



## 5K shield (PtCo)

Connection side to Module-C

0, 90, 180, 270 degree

Fixed support post

90, 180, 270 degree

Shield center

0, 90, 180, 270 degree

Movable support post

90, 180, 270 degree

End flange side

0, 90, 180, 270 degree

## 80K shield (CC)

Connection side to Module-C

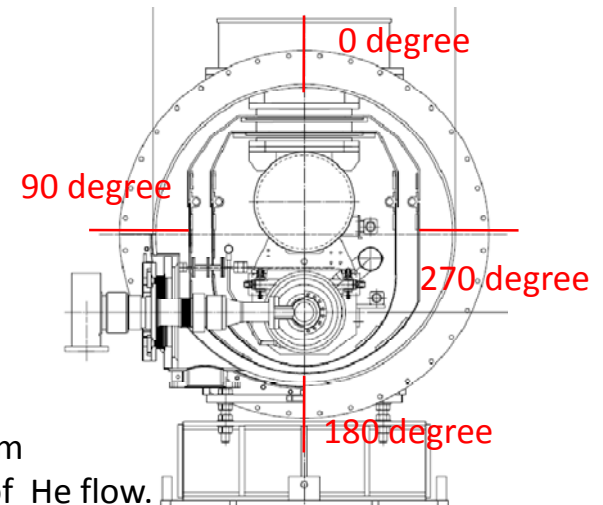
0, 90, 180, 270 degree

Shield center

0, 90, 180, 270 degree

End flange side

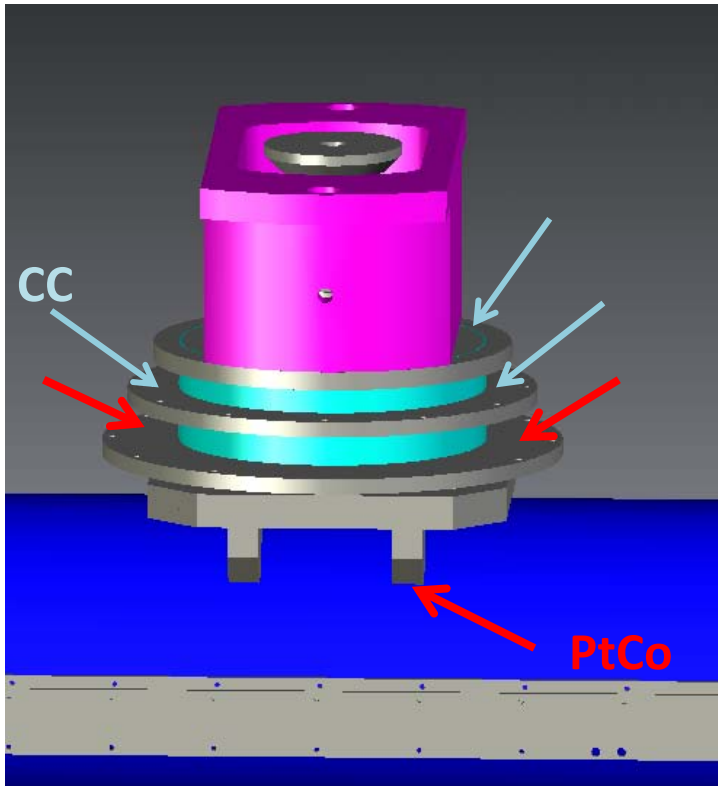
0, 90, 180, 270 degree



Viewed from  
upstream of He flow.

# Support Post

## PtCo

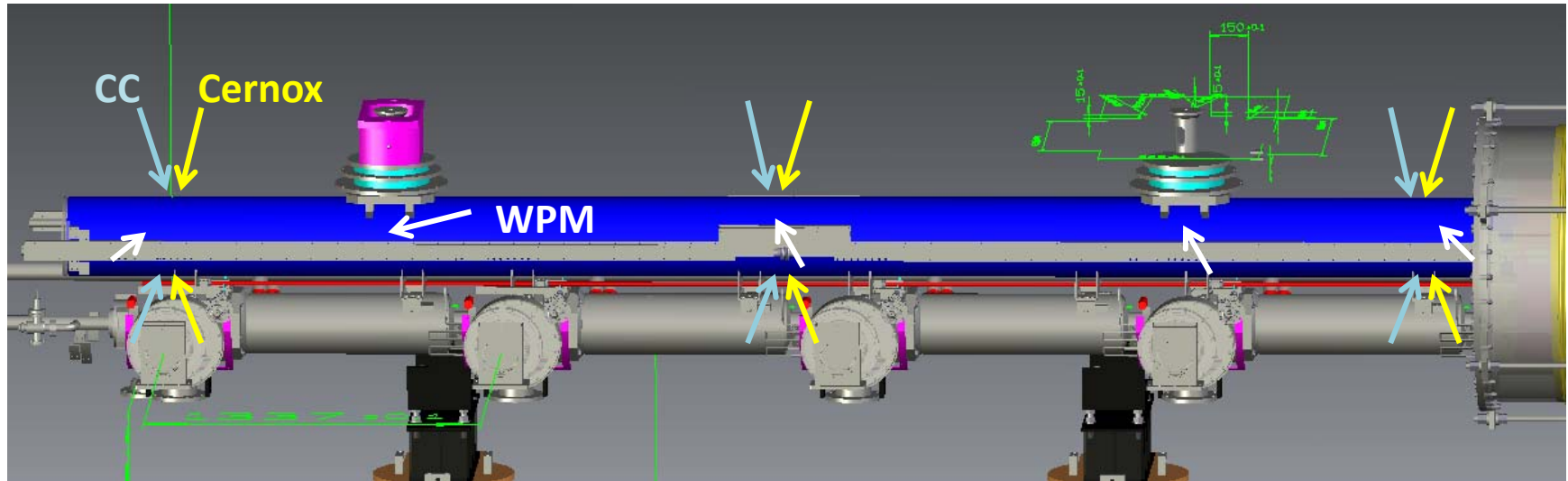


Fixed support post	5K anchor at the 0 degree
	5K anchor at the 180 degree
Movable support post	5K anchor at the 0 degree
	5K anchor at the 180 degree
GRP	Connection area to the fixed support post
	Connection area to the movable support post

## CC

Fixed support post	80K anchor at the 0 degree
	80K anchor at the 180 degree
	Room temp area
Movable support post	80K anchor at the 0 degree
	80K anchor at the 180 degree
	Room temp area

# GRP



## Cernox and CC

GRP	Upstream-top (Module-C connection side)
	Upstream-bottom (Module-C connection side)
	Center-top
	Center-bottom
	Downstream-top (end flange side)
	Downstream-bottom (end flange side)

## WPM

CM-A GRP	#1	-1123.5	z axis: the origin is the fixed post
	#2	226.5	
	#3	1576.5	
	#4	2926.5	
	#5	4276.5	

CM-C GRP	#1	-1200	z axis: the origin is the fixed post physical center of GRP
	#2	0	
	#3	1600	
	#4	3200	
	#5	4600	

# Summary

- Cryomodules
  - Thermal sensor: 208
  - Pressure sensor: 6
  - WPM: 18 (GRP: 10, KEK-cavity: 8)
- Cryogenics
  - Thermal sensor: 4
  - Pressure sensor: 5
  - LHe level sensor: 2
  - Mass flow meter: 3