# S1-G Cryomodule Thermal Tests (Proposal)

KEK, Norihito Ohuchi

# Measurements of thermal characteristics of Module A and C

- Scheduled test period for thermal measurements
  - 1 week before summer shut down
    - Preparatory measurement of the static heat load of the Module-A and C
  - 3 weeks after summer shut down
- Heat load measurements
  - Heat loads of the modules are mainly measured by the mass flow rate of evaporated 2K LHe.
  - Static heat load of Module A and C
  - Dynamic heat load of DESY, FNAL and KEK cavities at the average gradient of 31.5 MV/m
  - Heat loads at 4K are measured during the cool-down of modules (back-up measurement).
- Temperature profile
  - The temperature profiles of the components are automatically measured during all test period.
    - Cool-down and warm-up stages (two times)
    - Operating conditions of cavities.
  - Temperature measurement by Cernox, PtCo and CC.
- Position change of cavities and GRP during cold test
  - Positions of KEK cavities by Wire Position Monitor (WPM)
  - Positions and deformations of GRPs of Module A and C by WPM and strain gauges
  - Positions of GRP of Module A by Laser Position Monitors
    - The measurement will be performed in the first experimental term. In the second term, the holes on the vacuum vessel and 80K shield are closed for the heat load measurements.

# Heat load measurements-1

- Mass flow rate of evaporated 2K LHe is measured by the volume flow meter at room temperature and atmosphere pressure after the pump units.
  - The precision of the measurement is in the range of 0.2 W from the STF experiment .
  - The measuring range of the volume flow meter is 0-3.2g/s. The smaller size flow meter will be prepared.
- Static heat load measurement of Module A and C
  - The static heat load of Module A and C is measured at the same time, not separated.
  - Measuring period at 2K: 1 week in the second test term
    - Two days: static heat load measurements
    - Two days: the calibration of these measurements by the heater
    - One day: preparation of the measurements
    - The measurement will be scheduled after the cavity performance tests in the second term.
  - Preparatory measurement of static heat load during the last week in the first term: 1 week
    - The Module-A has holes for measuring the movement of the gas return pipe by the laser position monitors.
    - The static heat load measurements and the calibration by the heater will be done for two days, respectively.
  - Heat load measurements at 4K during the cool downs in the first and second terms.
    - Three days: before cooling the system down to 2K and after keeping the level of 4K liquid helium at the operating condition, the heat loads of two modules and 2K cold box will be measured.
    - This measurements are required for confirmation of system soundness in the thermal performance.

# Heat load measurements-2

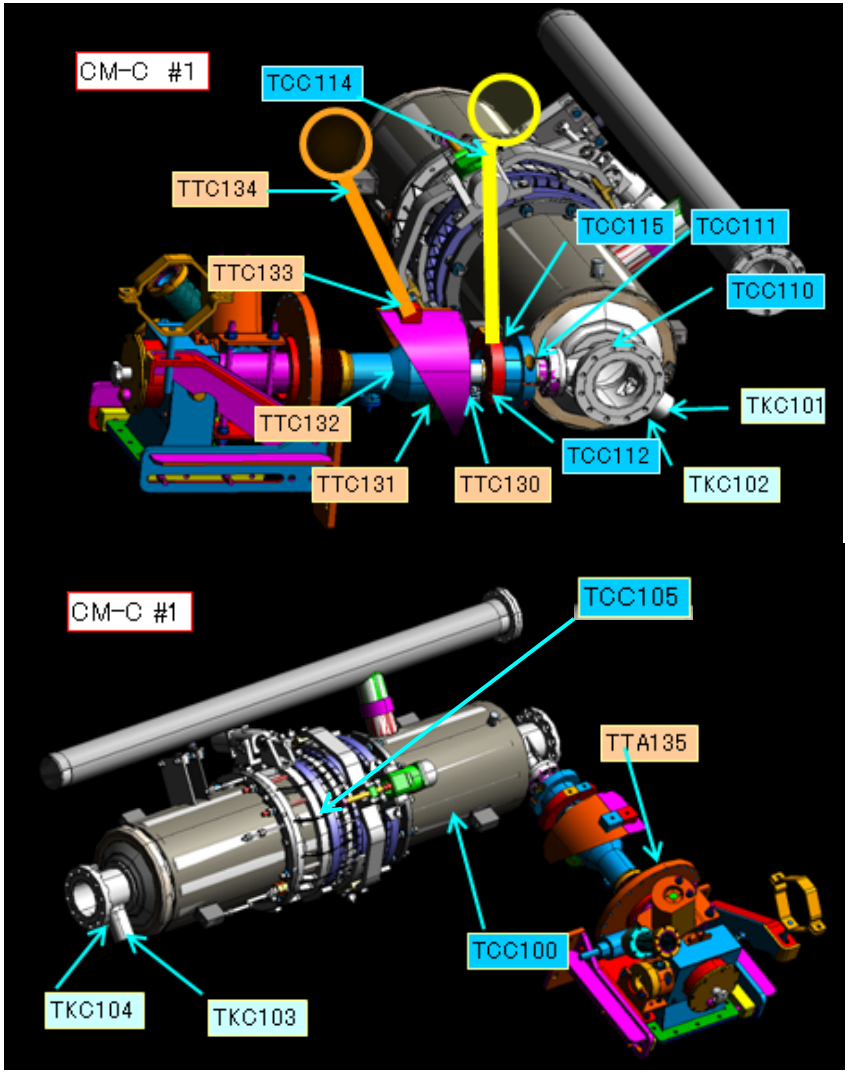
- Dynamic heat load measurement of DESY, FNAL and KEK cavities at the average field gradient of 31.5 MV/m
- At the first stage:
  - Dynamic heat load measurement of each cavity at its maximum operating field.
    - Heat load of each cavity in the detuned condition should be measured in the same day after the dynamic measurement.
    - One day for measuring one cavity in the maximum field and the detuned conditions is required.
    - In total, the period of 8 days should be scheduled.
- At the second stage:
  - Dynamic heat load of eight cavities, all together at the average field gradient of 31.5 MV/m.
    - Two days will be requested.

- For these measurements, the cryogenic system need to be a stable condition thermally. For one parameter change, it takes two hours for the system to be stable.

# Temperature profiles of the components

- Temperature profiles of the components are measured during the cool-down and warm-up, and in parallel with the heat load measurements.
- The measured temperature profiles are compared with thermal calculation results of the components.
- Temperature sensors for Module-A and C:
  - Cernox (2K – 100K) : 50
  - Calibrated carbon resistor (2K – 100K) : 32
  - PtCo (2K – 300K) : 51
  - CC thermocouple (70K – 300K) : 68

# Temperature sensors on cavity jacket and input coupler




| Tag No | Position of measurement |
|---|---|
| TCC100 | Helium Vessel |
| TKC101 | HOM coupler in the input coupler side-top |
| TKC102 | HOM coupler in the input coupler side-bottom |
| TKC103 | HOM coupler in the non-input coupler side-top |
| TKC104 | HOM coupler in the non-input coupler side-bottom |
| TCC105 | Piezo |
| TCC110 | Connection area of input coupler with beam pipe |
| TCC111 | 5K thermal intercept of input coupler (beam pipe side) |
| TCC112 | 5K thermal intercept of input coupler (body) |
| TCC114 | 5K thermal intercept of input coupler (cooling pipe side) |
| TCC115 | 5K thermal intercept of input coupler (intercept side ) |
| TTC130 | 80K thermal intercept of input coupler (beam pipe side) |
| TTC131 | 80K thermal intercept of input coupler (body) |
| TTC132 | 80K thermal intercept of input coupler (vacuum vessel side) |
| TTC133 | 80K thermal intercept brade of input coupler (coupler side) |
| TTC134 | 80K thermal intercept brade of input coupler (cooling pipe side) |
| TTC135 | Input coupler (room temperature and in the vacuum vessel) |

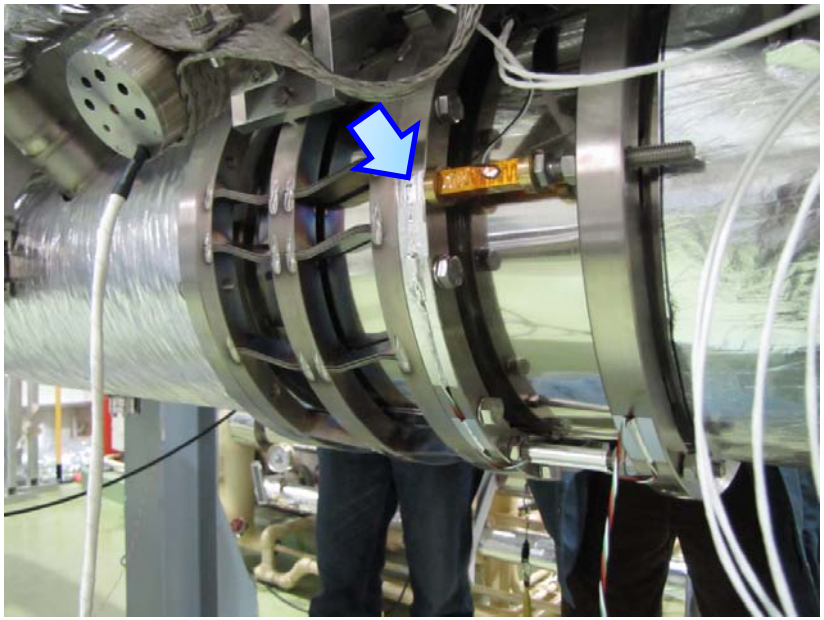
Cernox:7, Carbon resistor:4, CC: 6

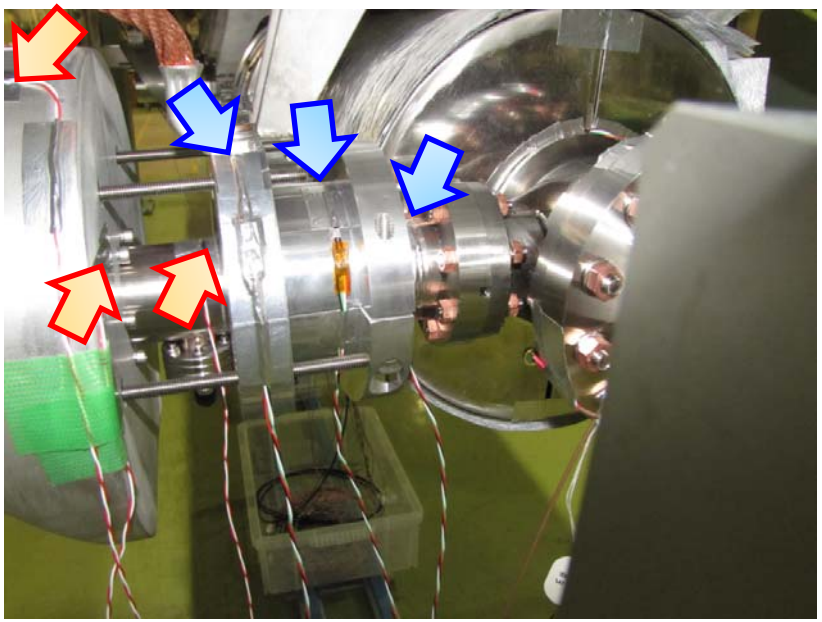
Cavity vessel= 1

Input coupler= 11 (including thermal intercepts)

HOM coupler= 4

Piezo= 1

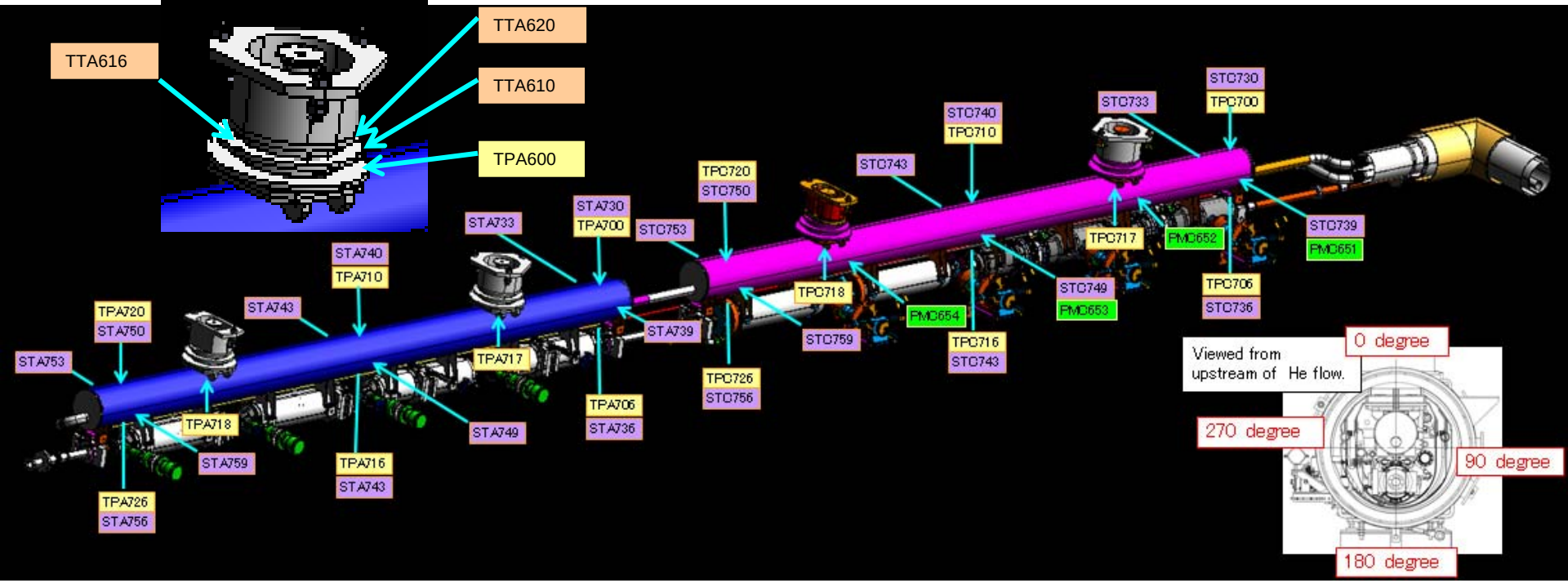





AES004
TKC104
TKC103


AES004 TCC100

# Sensors on GRP and support posts




PtCo : 20, CC thermocouples : 12
GRP= 16
Support Post= 20

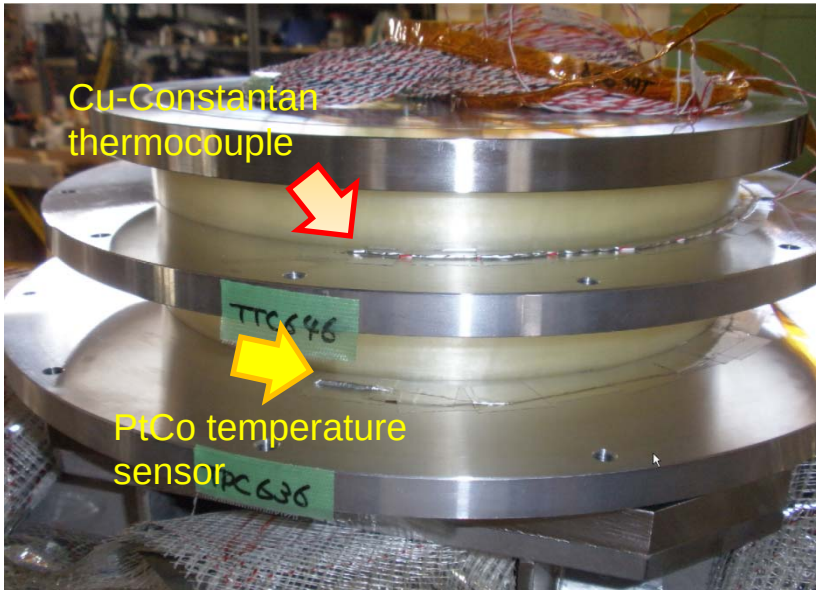
For measuring the GRP deformation
Strain gauge: 24 positions
(3 positions along the GRP axis, and 4 azimuthal positions for one GRP)

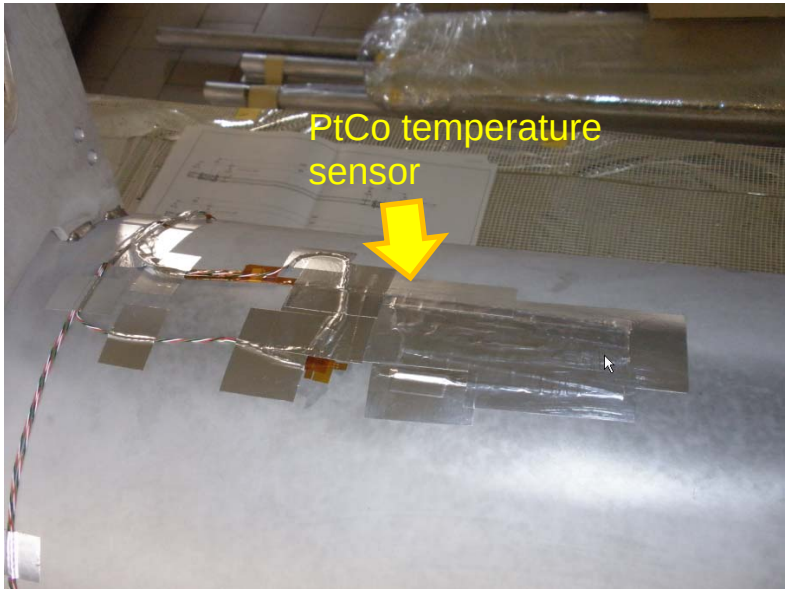
Module-A GRP

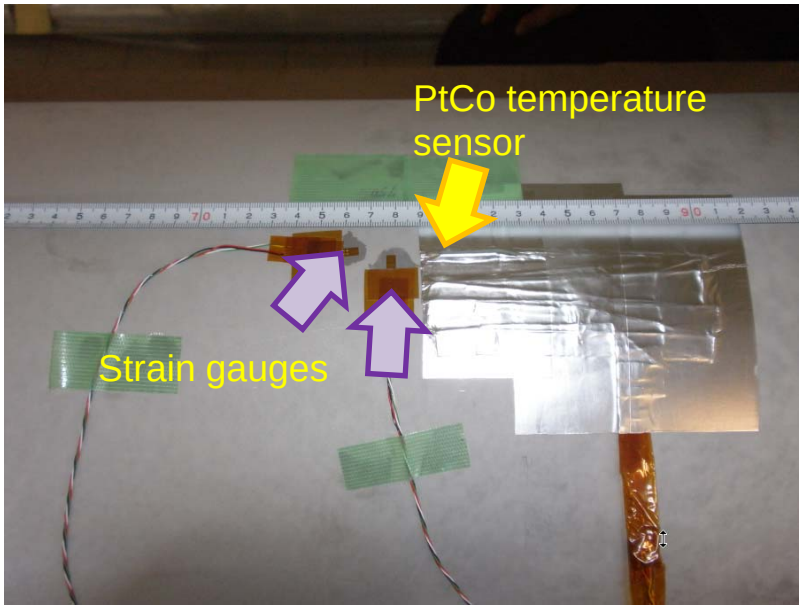
| Tag No | Position of measurement |
|---|---|
| TPA700 | Upstream-top (Module-A connection side) |
| TPA706 | Upstream-bottom |
| TPA710 | Center-top |
| TPA716 | Center-bottom |
| TPA717 | Connection area between S.P and GRP(F) |
| TPA718 | Connection area between S.P and GRP(M) |
| TPA720 | Downstream-top (end flange side) |
| TPA726 | Downstream-bottom |
| STA730 | 0 degree in the side of Upstream |
| STA733 | 90 degree in the side of Upstream |
| STA736 | 180 degree in the side of Upstream |
| STA739 | 270 degree in the side of Upstream |
| STA740 | 0 degree in the center |
| STA743 | 90 degree in the center |
| STA746 | 180 degree in the center |
| STA749 | 270 degree in the center |
| STA750 | 0 degree in the side of end flange |
| STA753 | 90 degree in the side of end flange |
| STA756 | 180 degree in the side of end flange |
| STA759 | 270 degree in the side of end flange |

Module-C GRP

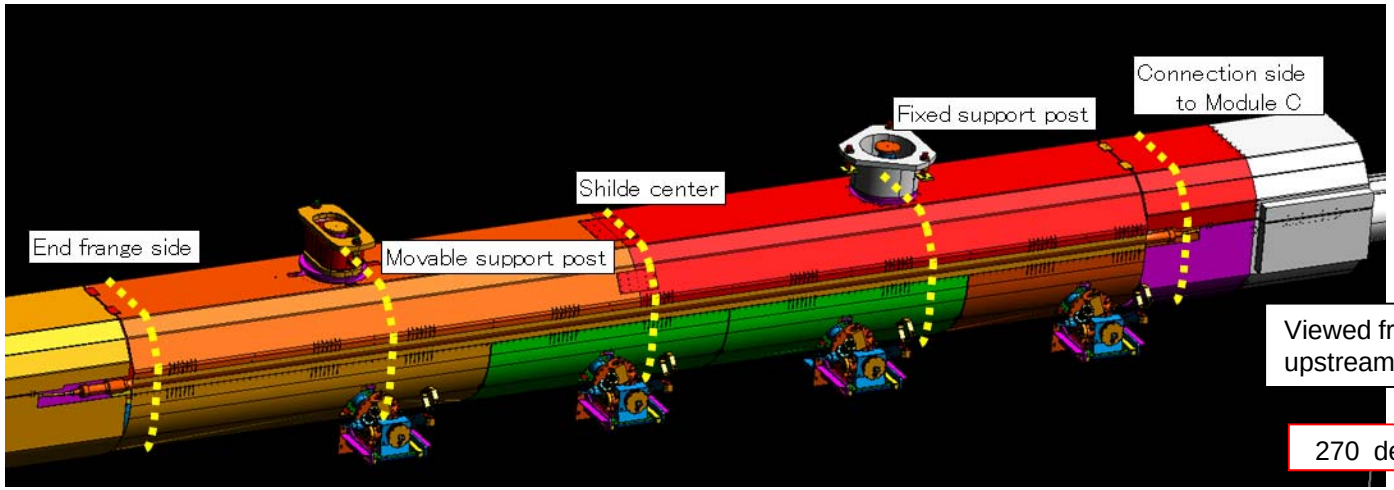
| Tag No | Position of measurement |
|---|---|
| TPC700 | Upstream-top (Module-C connection side) |
| TPC706 | Upstream-bottom |
| TPC710 | Center-top |
| TPC716 | Center-bottom |
| TPC717 | Connection area between S.P and GRP(F) |
| TPC718 | Connection area between S.P and GRP(F) |
| TPC720 | Downstream-top (end flange side) |
| TPC726 | Downstream-bottom |
| STC730 | 0 degree in the side of Upstream |
| STC733 | 90 degree in the side of Upstream |
| STC736 | 180 degree in the side of Upstream |
| STC739 | 270 degree in the side of Upstream |
| STC740 | 0 degree in the center |
| STC743 | 90 degree in the center |
| STC746 | 180 degree in the center |
| STC749 | 270 degree in the center |
| STC750 | 0 degree in the side of end flange |
| STC753 | 90 degree in the side of end flange |
| STC756 | 180 degree in the side of end flange |
| STC759 | 270 degree in the side of end flange |

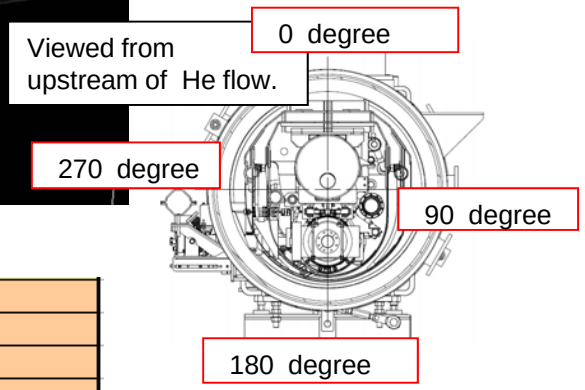

Cu-Constantan
thermocouple
PtCo temperature
sensor


PtCo temperature
sensor


PtCo temperature
sensor
Strain gauges

# Temperature sensors on thermal shields



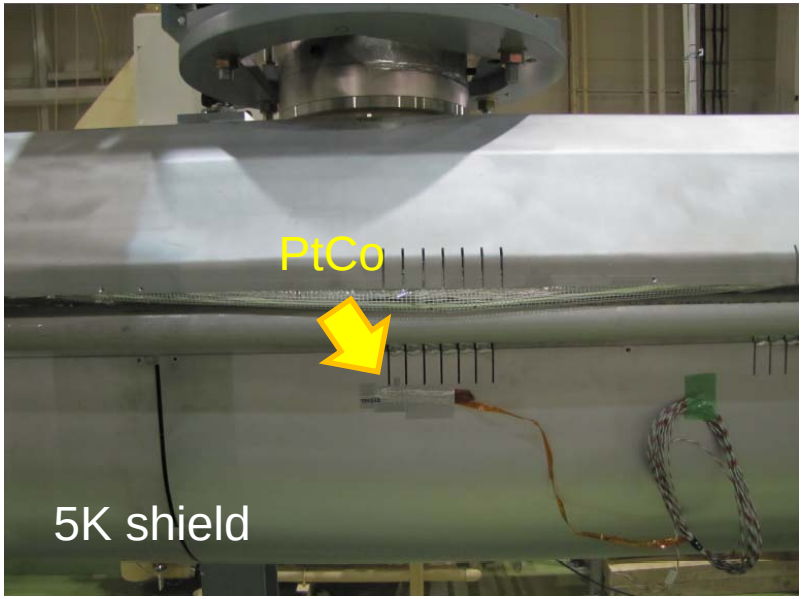

| Tag No | Position of measurement |
|---|---|
| TPC510 | 0 degree in the side of module-C |
| TPC513 | 90 degree in the side of module-C |
| TPC516 | 180 degree in the side of module-C |
| TPC519 | 270 degree in the side of module-C |
| TPC529 | 90 degree at fixed support post |
| TPC533 | 90 degree at shield center |
| TPC536 | 180 degree at shield center |
| TPC539 | 270 degree at shield center |
| TPC549 | 270 degree at movable support post |
| TPC550 | 0 degree in the side of end flange |
| TPC553 | 90 degree in the side of end flange |
| TPC556 | 180 degree in the side of end flange |
| TPC559 | 270 degree in the side of end flange |

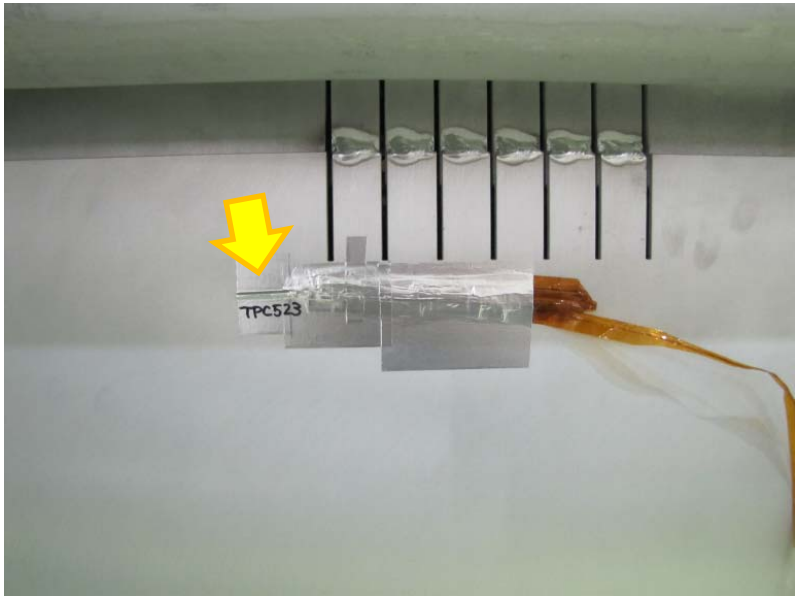
Module-C:
PtCo 13

| | |
|---|---|
| TTC810 | 0 degree in the side of module-C |
| TTC813 | 90 degree in the side of module-C |
| TTC816 | 180 degree in the side of module-C |
| TTC819 | 270 degree in the side of module-C |
| TTC830 | 0 degree in the center |
| TTC833 | 90 degree in the center |
| TTC836 | 180 degree in the center |
| TTC839 | 270 degree in the center |
| TTC850 | 0 degree in the side of end flange |
| TTC853 | 90 degree in the side of end flange |
| TTC856 | 180 degree in the side of end flange |
| TTC859 | 270 degree in the side of end flange |

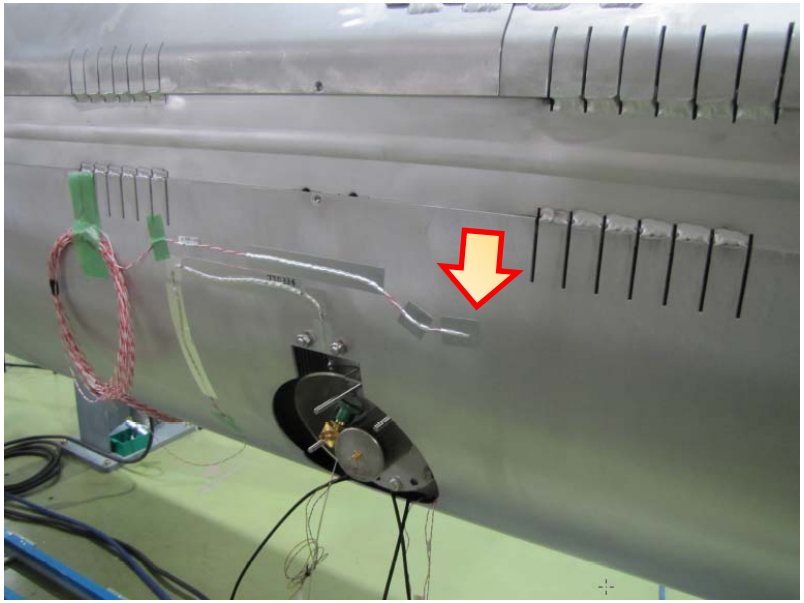
Module-C:
Cu-Constantan thermocouple 12

For Module-A and -C
5K shield
PtCo : 27
80K shield
CC : 24


PtCo
5K shield


TPC523

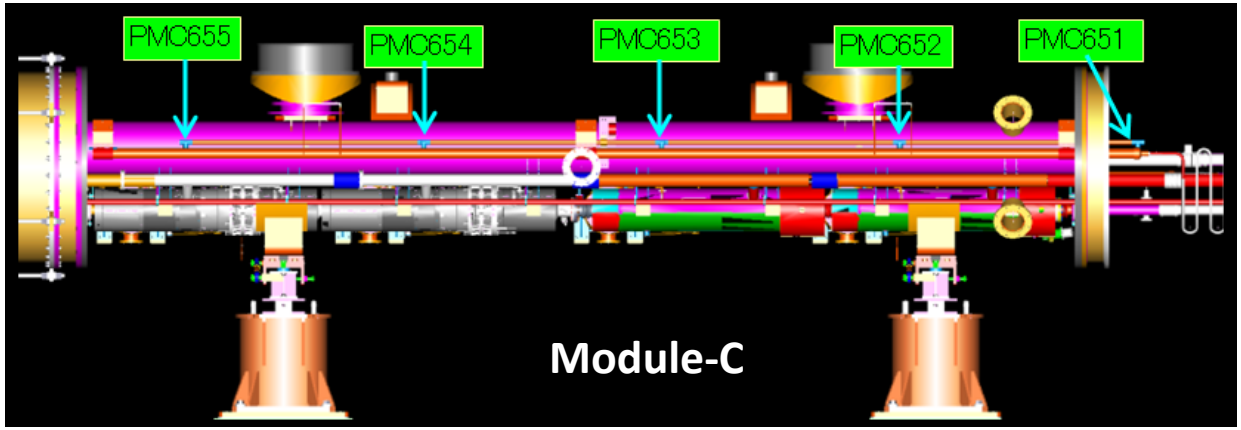

80K shield

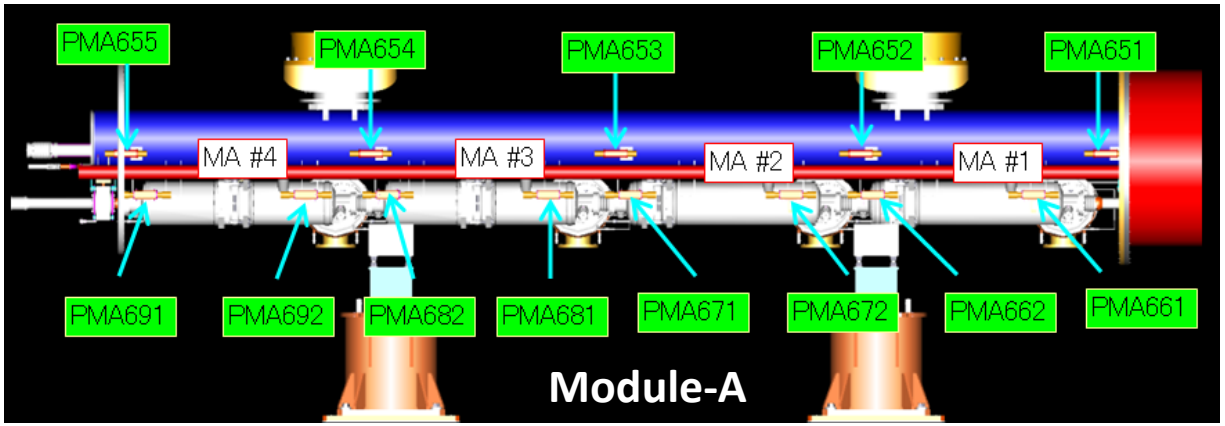


# Position measurement of cavities and GRP

## Measurement of position of cavities and GRP by WPM

- Module-C
  - 5 WPMs are assembled on the GRP.
- Module-A
  - 5 WPMs on the GRP and 2 WPMs for each cavity are assembled. In total, 13 WPMs.



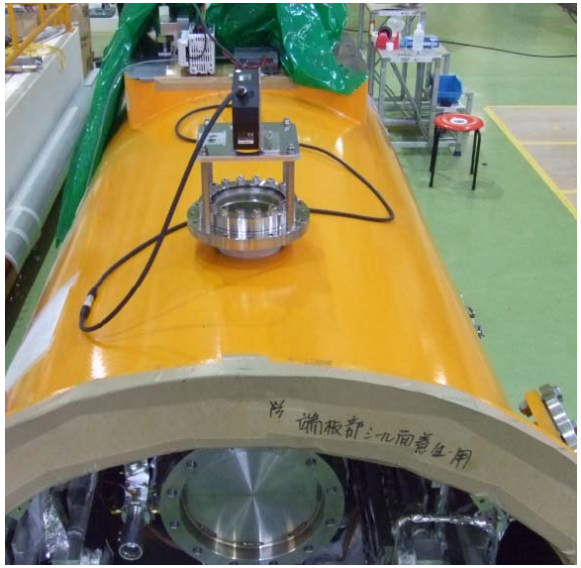



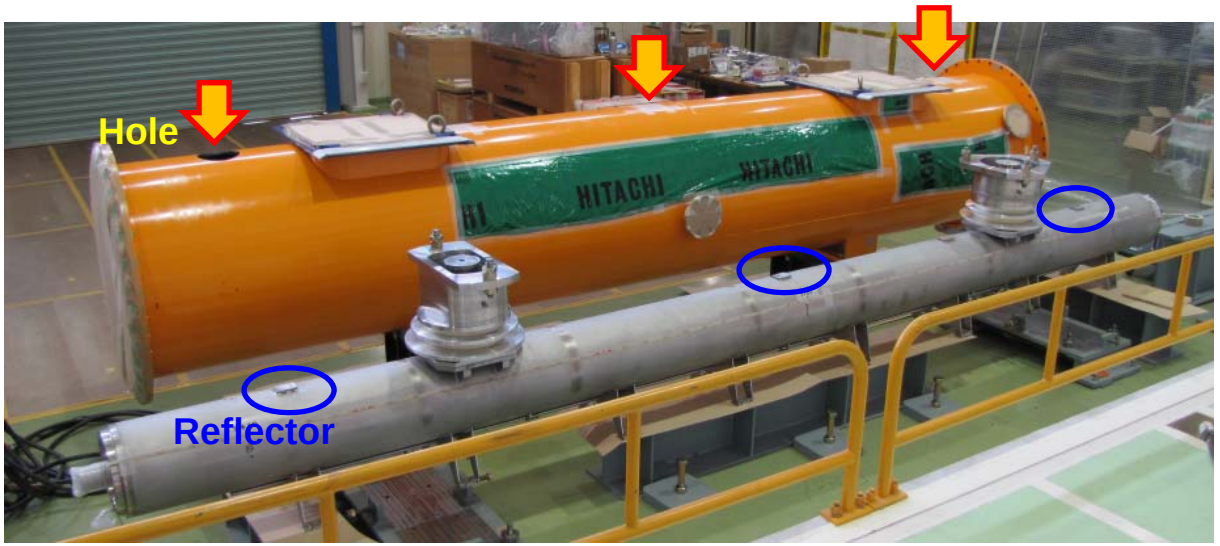
# Measurement by laser position monitor

The laser position monitors were applied for measuring the change in the GRP shape of Module-B.

3 laser position monitors are used for measuring the GRP deformations of Module-A during the cold test before summer shut-down. Precision of the measurement is in the level of a few micro-meter.

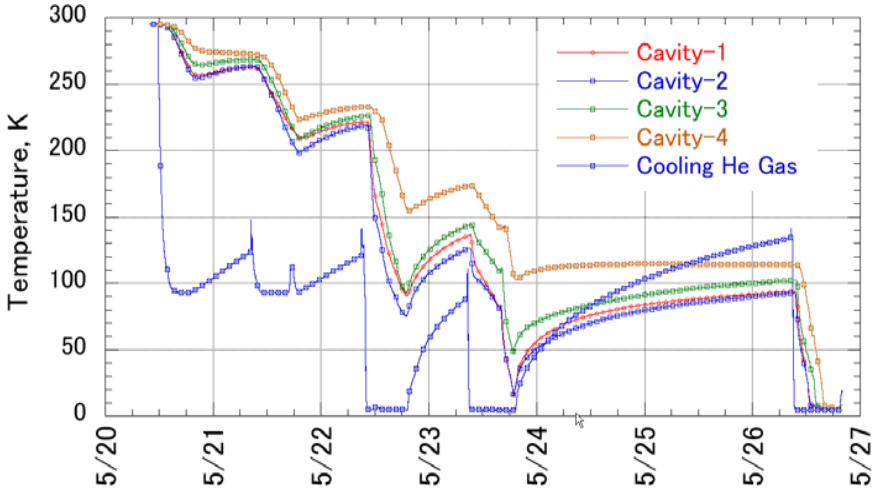
- For this measurement, the thermal radiation shields need to have holes to introduce laser to the GRP.
- Measurement with these monitors are scheduled in the first test term.
- In the second term, the windows on the vacuum vessel and the holes on the 80K shield are closed with the flanges and the Super Insulation.






Laser position monitors for measuring the GRP positions

# Cool-down of Module-A by STF cryogenic system




## Cooling was performed during the normal working time:

1. **The first step of cool-down of the Module-A with four cavities**
   - **In the first two days, four cavities and the GRP were cooled to 200 K by helium gas at 90 K.**
   - **The total mass flow rate was 1.0 g/s, and the typical cooling speed of the cavities was 7.3 K/h.**
2. **Cool-down from 200 K to 4K**
   - **Liquid helium at 4 K was directly transferred from the liquid helium Dewar of 2000 L on the ground level to the cryomodule in the tunnel.**
   - **In the cooling process, the cooling speed of cavities was 12.5 K/h.**
   - **The total time for cooling four cavities from room temperature to 4K was 49 hours.**

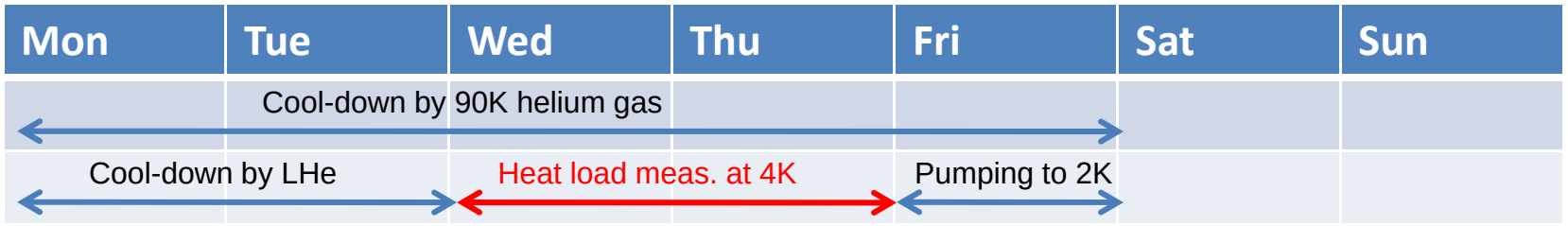
## During the thermal tests of S1-G cryomodules:

- **Cooling 80 K thermal shields will be kept for 24 hours.**
- **Supplying and pumping LHe will be performed from 8:00 to 22:00 or for 24 hours.**

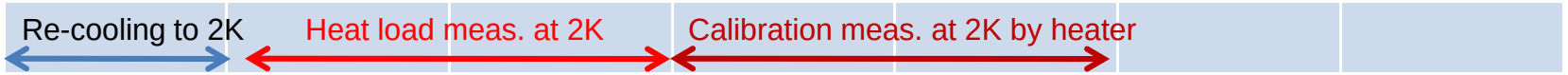
# Time schedule for the thermal test of S1-G modules

## In the first test term

### Cool-down and thermal test at 4K




### Thermal test at 2K




## In the second test term

Cool-down and thermal test at 4K are same as in the first term

### Thermal test at 2K