Cryomodule Technical Specification

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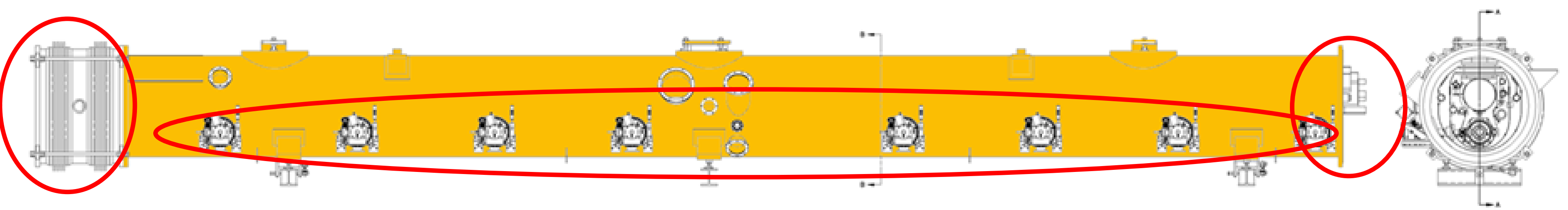
1. Specifications of cryomodule (Proposed)

Vacuum Vessel

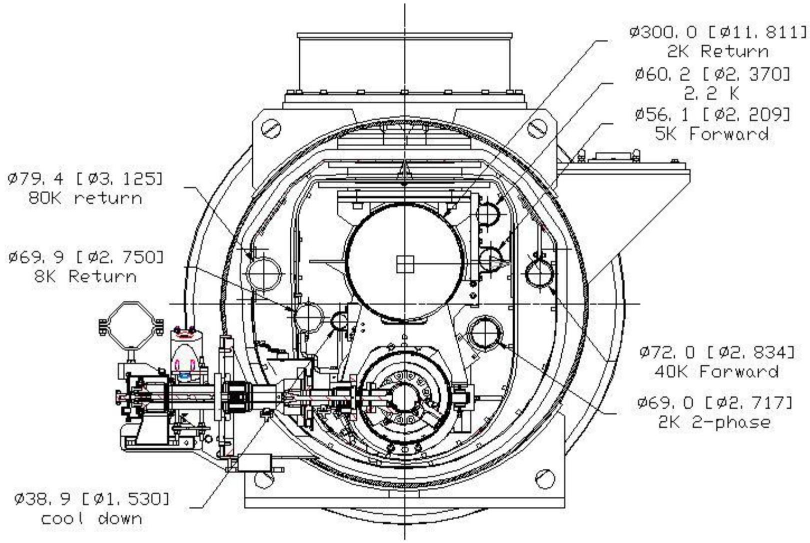
Vacuum vessel	Cryomodule slot length	12679.6	12679.6
	Material (demagnetized)	Carbon Steel	Carbon Steel
	Length (+ vacuum bellow length)	11829.6 (+850)	11829.6 (+850)
	tolerance of length	± 3	± 3
	Outer diameter	965.2	965.2
	Inner diameter	955.7	955.7
	Height of vessel center axis from the support base level	832	832
	Input coupler port	8	9
	Main Coupler #1 z position	-4744.1	-4744.1
	Main Coupler #2 z position	-3417.4	-3417.4
	Main Coupler #3 z position	-2090.7	-2090.7
	Main Coupler #4 z position	-764	-764
	Main Coupler #5 z position	(Quadrupole PKG)	562.7
	Main Coupler #6 z position	1889.4	1889.4
	Main Coupler #7 z position	3216.1	3216.1
	Main Coupler #8 z position	4542.8	4542.8
	Main Coupler #9 z position	**5869.5**	5869.5
	(Tuner driver-shaft port)	8	9
	Port for current leads	1	0
	current lead terminals (quadrupole, 2 dipoles)	6	0
	Port for signal wires	2	2
	Port for vacuum	2	2
	Residual magnetic field on the beam line	< 0.1 Gauss	< 0.1 Gauss

Interface

1. Connection flange and vacuum bellow (T4-CM design)
2. Main coupler flanges on the vessel



Cross section of crymodule



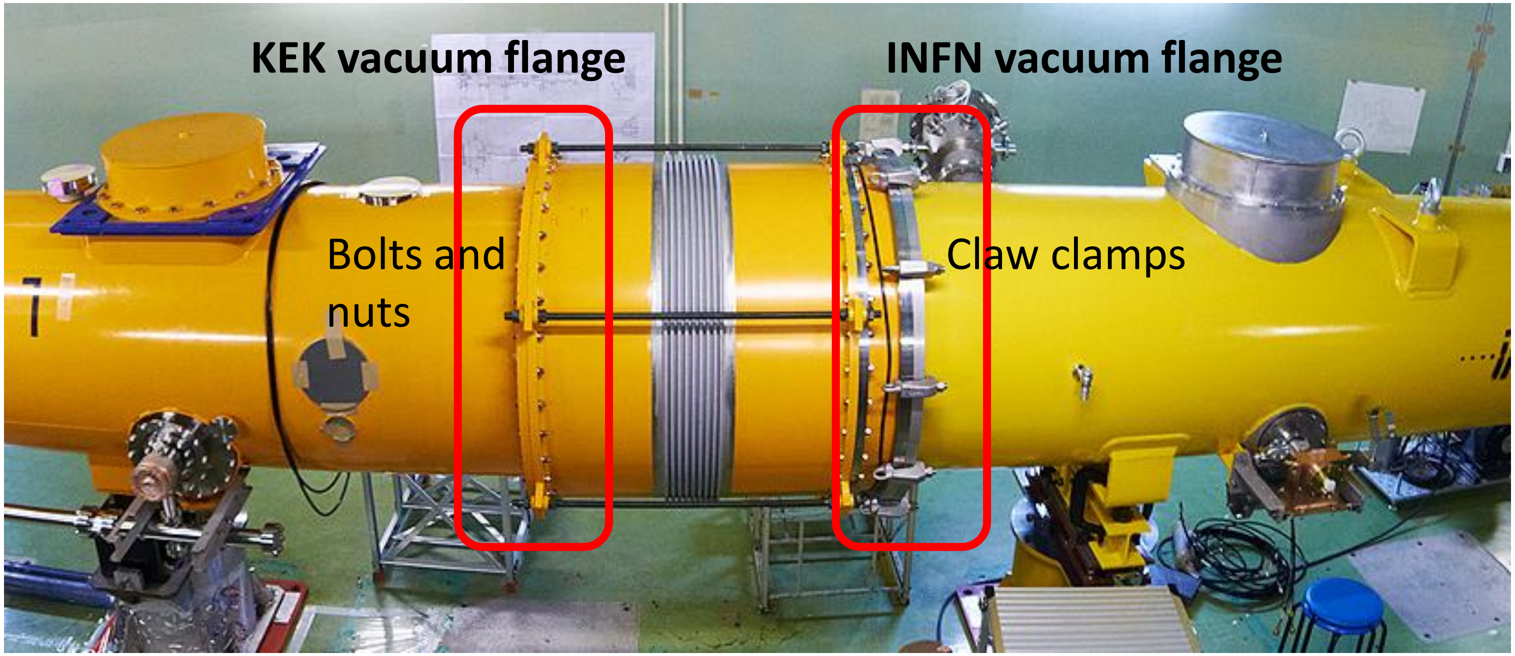
Design of 9 cooling pipe and 2 thermal shields: based on the design of the DESY TTF-III cryomodule . Pipe diameters and design pressures are proposed by the ILC-GDE cryogenic group.

	Material	Inner diameter mm	Design pressure bar
2.2 K subcooled supply pipe	Stainless steel	60	20
Major return header pipe (GRP)	Stainless steel	300	2 at warm (4 at cold)
5 K pipe (forward)	Al1050 or equi.	56.1	20
8 K pipe (return)	Al1050 or equi.	70	20
40 K-80 K pipe (forward)	Al1050 or equi.	72	20
40 K-80 K pipe (return)	Al1050 or equi.	80	20
2-phase supply pipe	Ti	72.1	2 at warm (4 at cold)
Cooldown and warmup pipe	Stainless steel	38.9	2 at warm (4 at cold)
Helium jacket to 2-phase pipe cross connect	Ti	54.9	2 at warm (4 at cold)

2. Plug-compatible interface of cryomodule (with examples in S1-G)

- Vacuum vessel flange and vessel support
- Input coupler connection flange
- Support lags of cavity jackets
- Cooling pipes

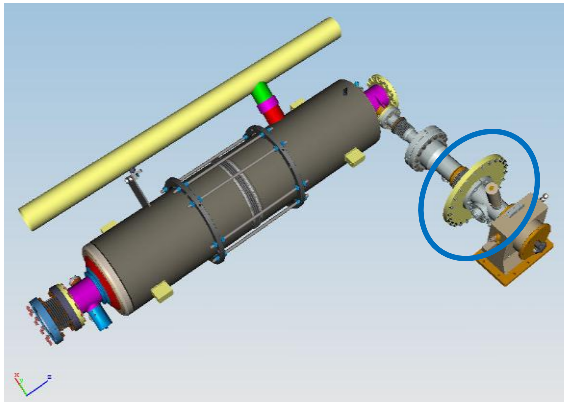
Vacuum vessel flange and vessel support



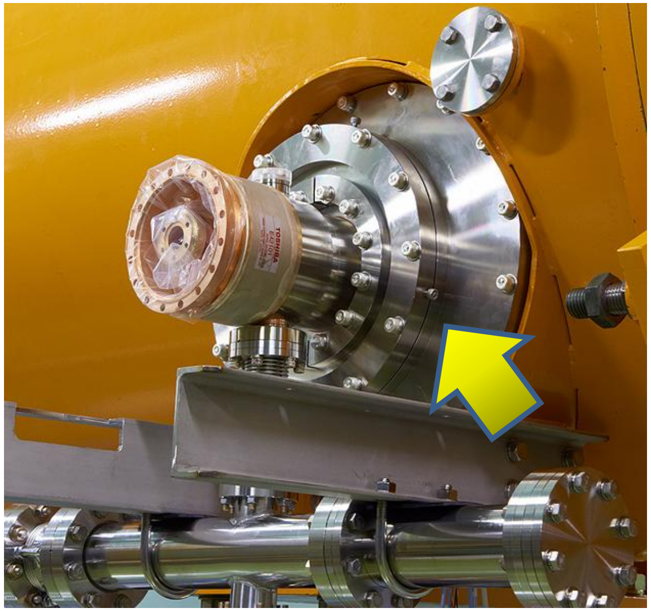
KEK vessel support

INFN vessel support

Input coupler connection flange to vacuum vessel



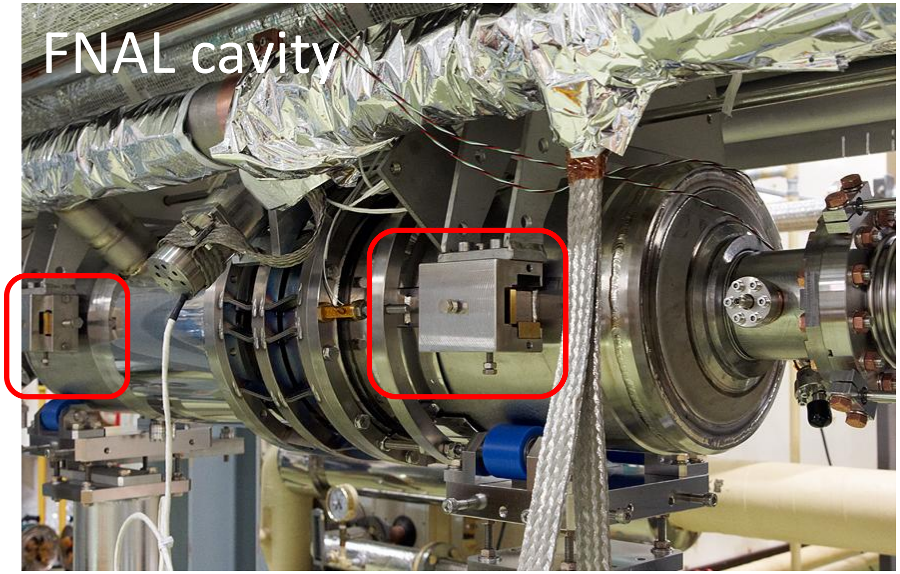
Connection flange of KEK input coupler

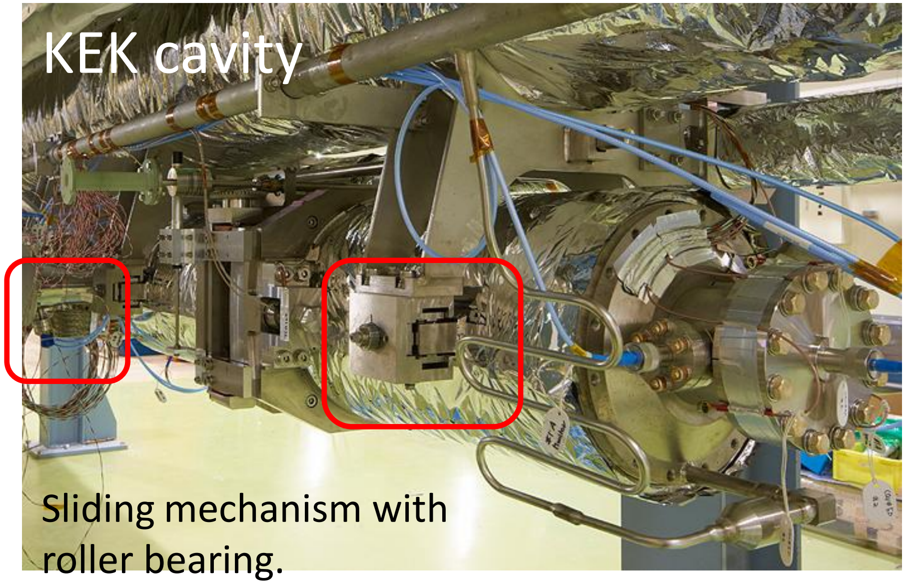


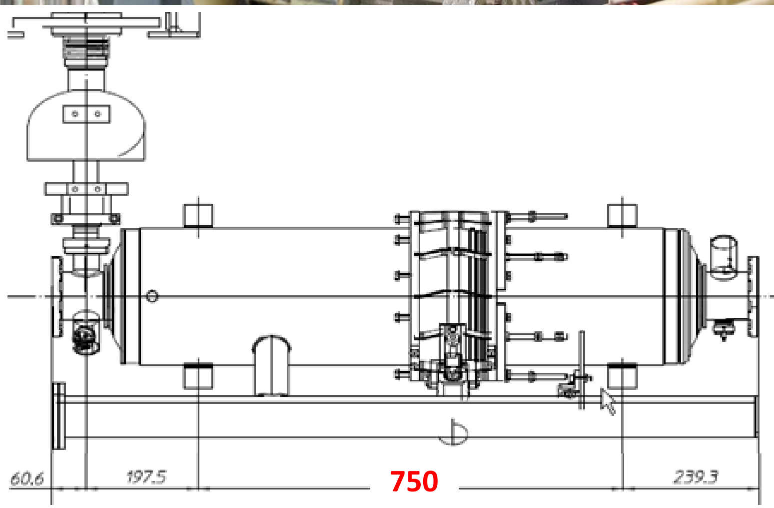
Connection flange of DESY input coupler

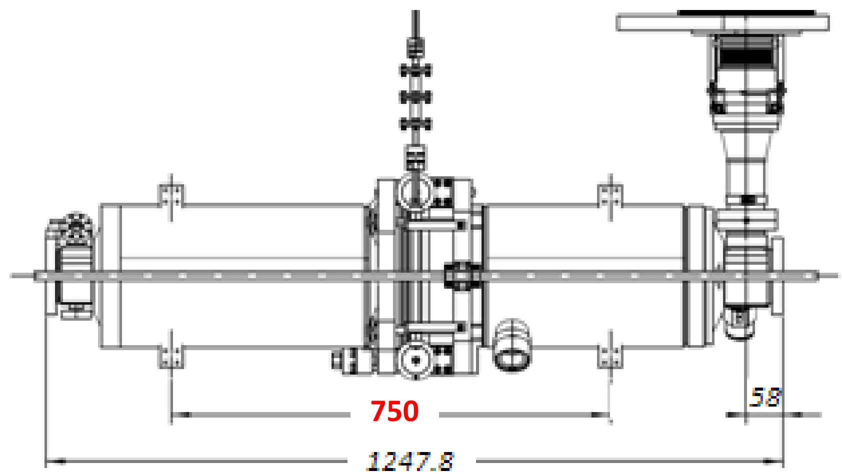
The connection flange design is dependent on the input coupler design.
For accommodating both types of input coupler, the additional intermediate flange is necessary.

Support lags of cavity jackets







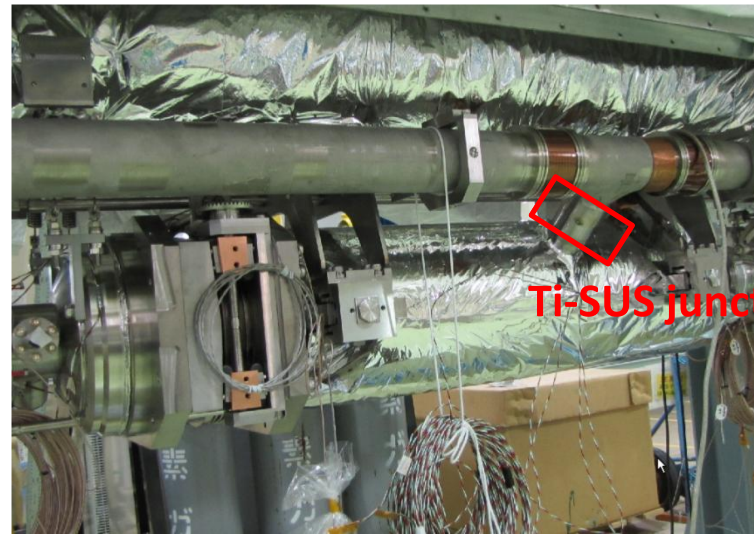


Support configuration of cavity jacket should be common between different cavities.

Cooling pipes

2K LHe supply pipe (Ti)

- DESY pipe : O.D.= 76.1mm, I.D.= 72.1mm, t=2.0
- FNAL pipe : O.D.= 73.02mm, I.D.=66.9mm in the middle, I.D.=69.0mm at the welding part
- Between DESY and FNAL pipes, Ti short pipe was used for welding in S1-G cryomodule.

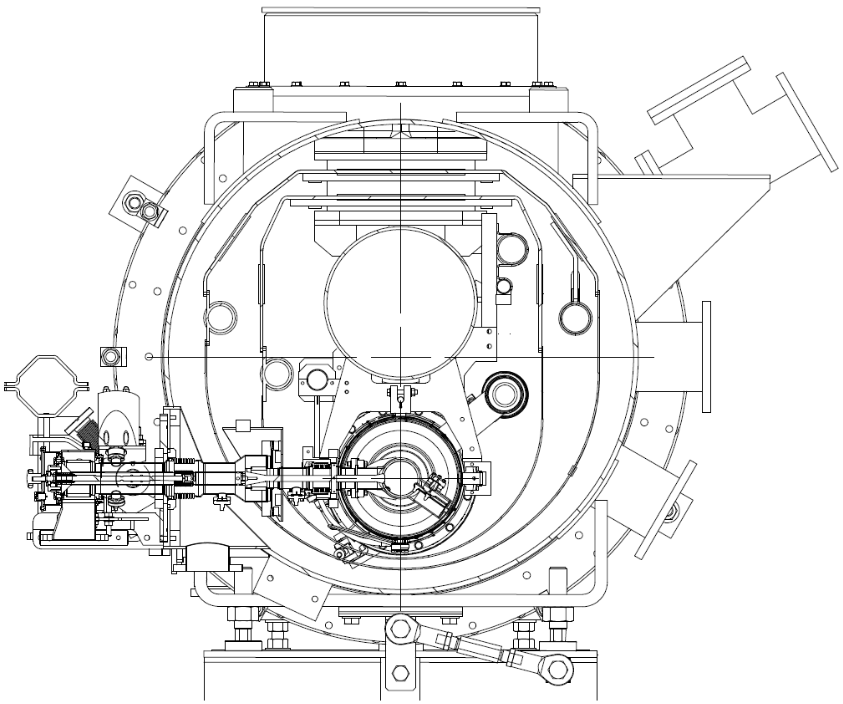


- KEK pipe (Stainless steel) : O.D.= 76.3mm, I.D.= 72.1mm, t=2.1
- KEK used the Ti-SUS junction between Ti jacket and 2 K LHe supply pipe.

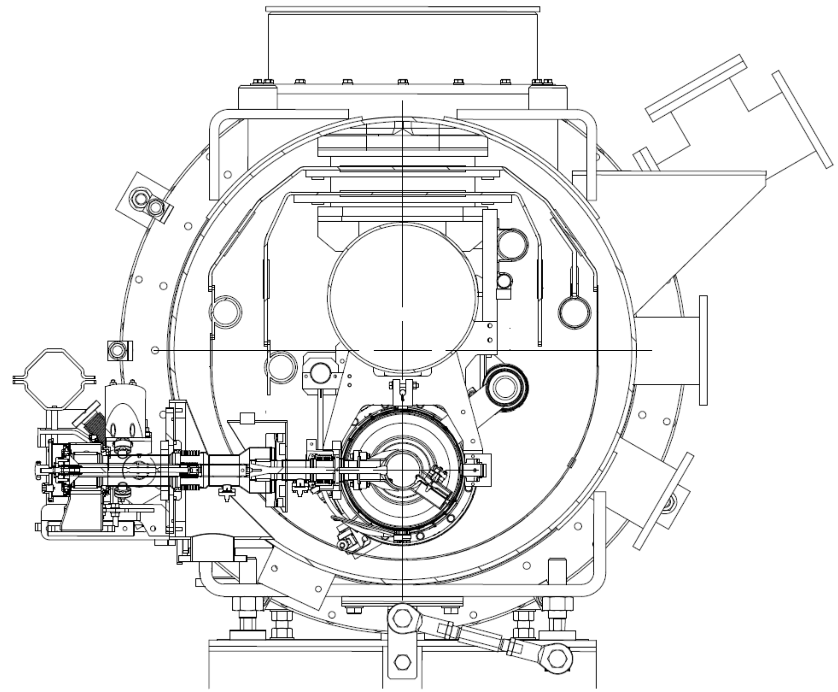
For introducing auto-welding machines, precise common dimension and material of cooling pipes are necessary.

3. Study items for cryomodule components

3.1 5K shield



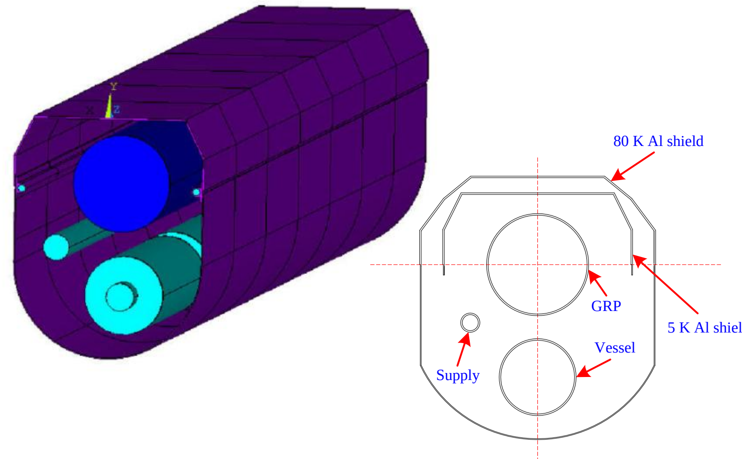
Cross section of S1-G Module-C.



- Removing the lower part of 5 K shield with keeping the design of cross section.
- 5 K cooling pipe is left for cooling input couplers, support posts and current leads.
- Cost estimation including assembly of the cryomodule components.

Thermal study of 5 K shield in KEK

Thermal calculation by ANSYS



Difference of measured heat losses at 2K with and without the lower part of 5 K shield = 0.8 W

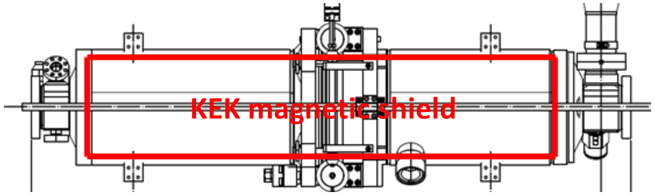
- The measurement was performed by evaporation of 2K LHe in four dummy jackets.
- 5 K shield temperature = 4.5 K, 80 K shield temperature = 84 K

Calculation of heat load with and without 5 K shield

- With 5K shield
  - Heat load to four jackets=0.01 mW
- Without 5 K shield (Temp. of 80 K shield = 84K)
  - Heat load to four jackets=0.79 W
- Without 5 K shield (Temp. of 80 K shield = 84K + SI)
  - Heat load to four jackets=0.17 W
- Without 5 K shield (Temp. of 80 K shield = 46K + SI)
  - Heat load to four jackets=0.02 W

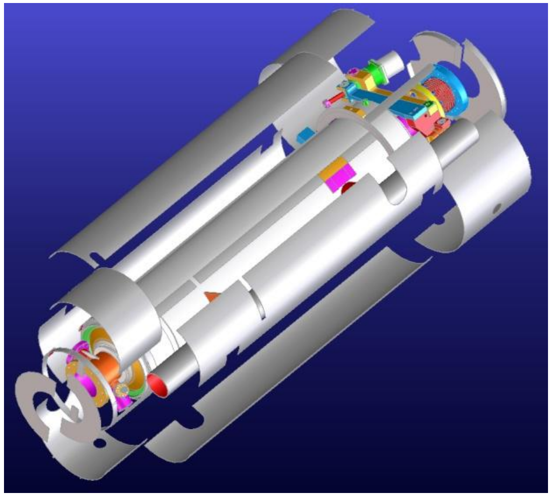
3.2 Magnetic shield

- DESY/FNAL magnetic shield: assembled outside of jacket
- KEK magnetic shield: assembled inside of jacket
  - KEK cavities with inner magnetic shield have shown good performance in S1-G module test.

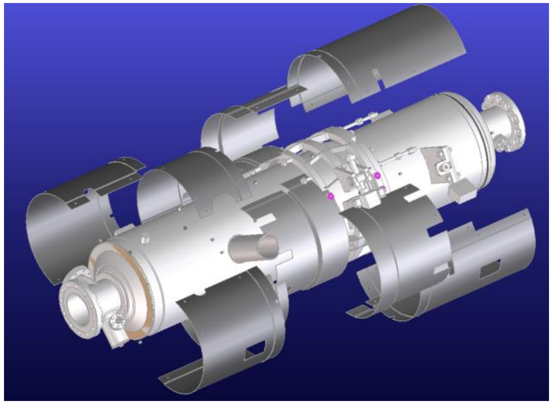


DESY magnetic shield = 24 pieces
FNAL magnetic shield = 10 pieces
KEK magnetic shield = 6 pieces

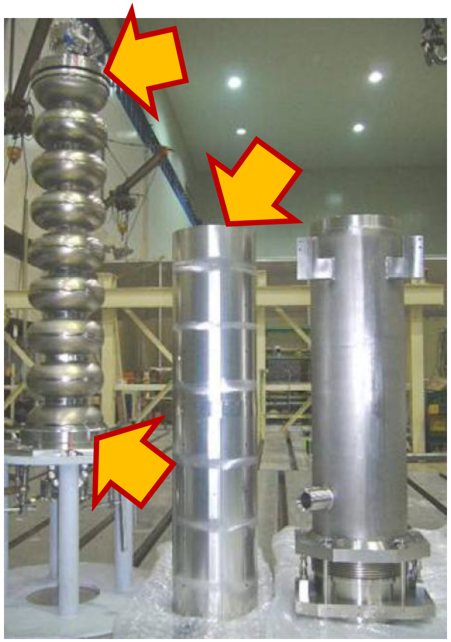
→ Need to estimate the man-hour for manufacturing and assembling components.



DESY magnetic shield



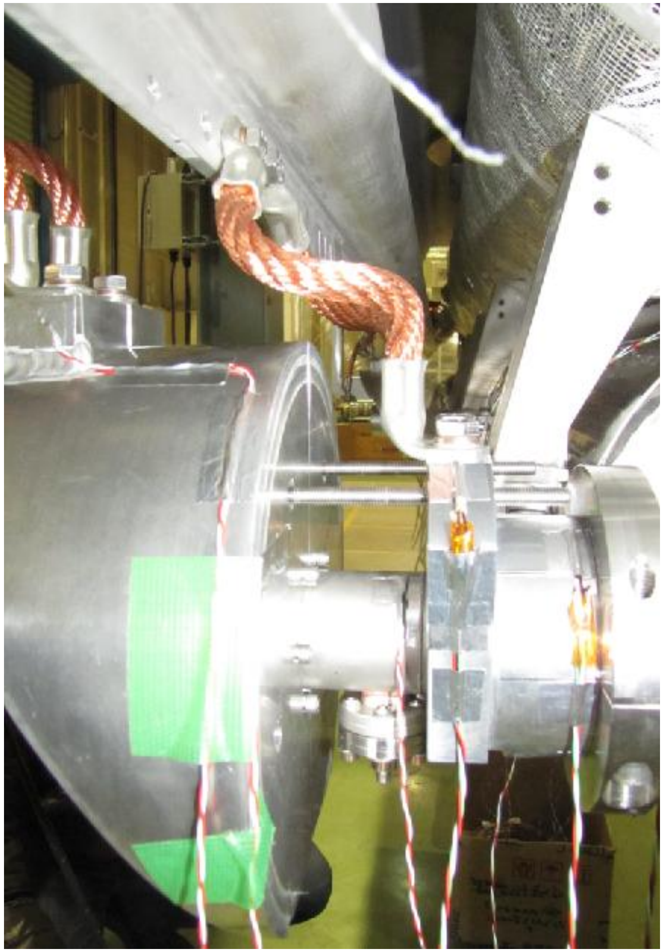
FNAL magnetic shield



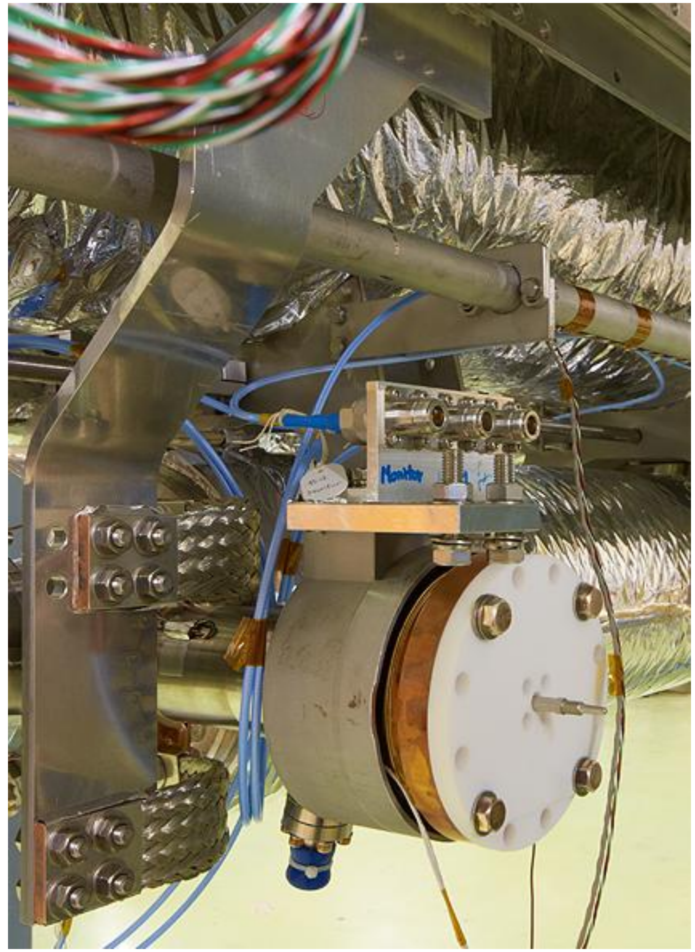
KEK magnetic shield
Number of pieces can be reduced to 3.

3.3 Thermal intercept for input coupler

Thermal intercepts for DESY/FNAL input coupler



Thermal intercepts for KEK input coupler



Temperature profiles of input couplers will be presented in the S1-G session.

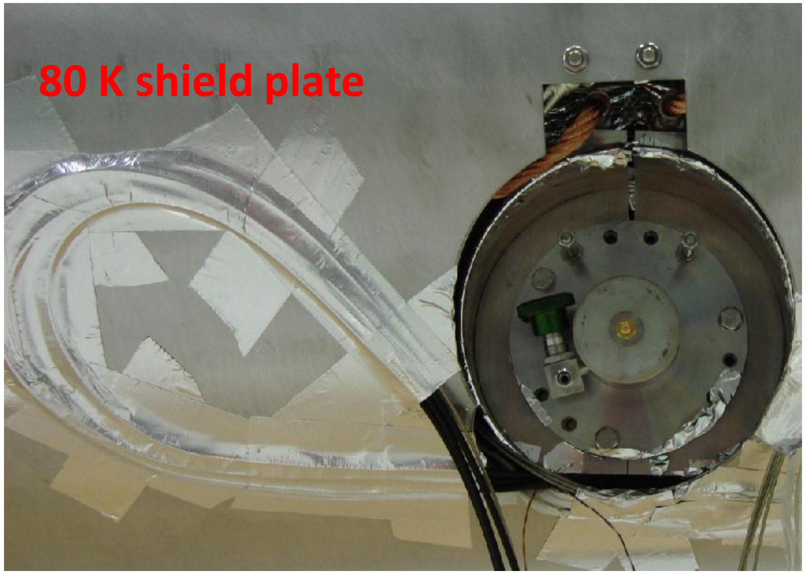
These intercepts should be designed with including the heat transfer capacity of the coolant in the pipe and the contact resistance between the terminal and the fin of shield pipe.

3.4 RF cable material and its thermal intercept

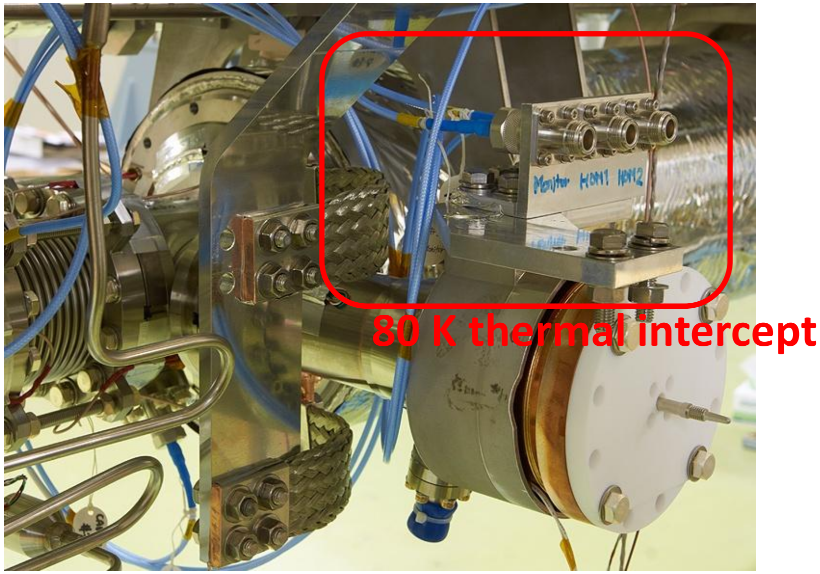
- DESY/FNAL RF cable : HUBER+SUHNER K_03252_D-06, conductor material=Fe
- KEK RF cable : HUBER+SUHNER SUCOFLEX103, conductor material=Cu
- For the ILC operation, the RF cable should be optimized.
  - Thermal conductivity of Fe is 25 % of that of Cu.
  - RF parameters of the cable for 5Hz operation.

Thermal intercepts should be optimized including the assembly process.

DESY/FNAL RF cables are thermal anchored on 80 K shield plate.



Thermal intercept of KEK RF cable



4. For mass production

- Big tools should have common basic design between three region .
  - Insertion machine of cold mass into the vacuum vessel.
  - Cold mass assembly stand.
- Assembly and alignment of cavities and cryomodules
  - Same procedures and tools
    - Alignment of cavities in the clean room.
    - Fiducialization of cavity string to the targets on the cold mass.
- CAD data of cryomodules
  - Strategy of controlling CAD data of cryomodules between laboratories and companies.
- High pressure gas regulation

Summary

1. As the cryomodule technical specification, vacuum vessel and cooling pipes are described.
2. For requirement of the plug-compatible concept of cryomodule, examples in S1-G cryomodule were shown.
3. Before and for the mass production, items which should be studied and discussed are listed.
   - 5 K shield
   - Magnetic shield
   - Thermal intercepts
   - RF cables
   - Tooling
   - Assembly and alignment procedures
   - CAD data
   - High pressure code