Cryostat / Cryogenics Summary and (Proposed) Conclusions

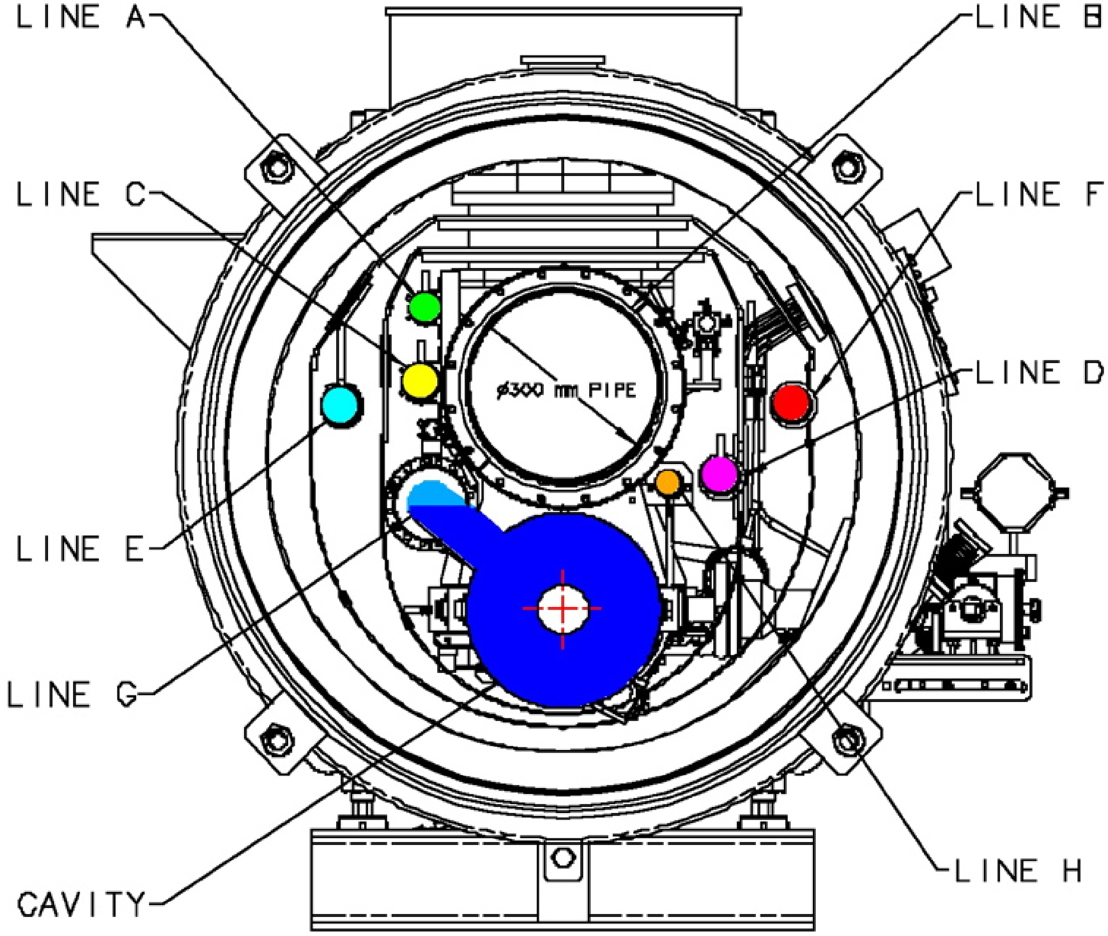
T. Peterson

25 April 2008

Cryomodule design pressures

Pipe function	BCD name	TESLA TDR nominal operating pressure (bar)	XFEL TDR nominal operating pressure (bar)	**Proposed ILC design pressure (bar)**
2.2 K subcooled supply	A	1.1	1.1	**20.0**
Gas helium return header, structural support	B	0.0275	0.0275	**2.0 warm** **4.0 cold**
5 K shield and intercept supply	C	5.5	5.5	**20.0**
8 K shield and intercept return	D	5.0	5.4	**20.0**
40 – 80 K shield and intercept supply	E	16.0	18.0	**20.0**
40 - 80 K shield and intercept return	F	14.0	17.0	**20.0**
2-phase pipe	G	0.0275	0.0275	**2.0 warm** **4.0 cold**
Cooldown/warm-up line	H	?	?	**2.0 warm** **4.0 cold**
Helium vessel to 2-phase pipe cross-connect		0.0275	0.0275	**2.0 warm** **4.0 cold**

Cryomodule pipe labels



"Crash" tests provide important data!

- Loss of vacuum to air
  - **"Safety Aspects for the LHe Cryostats and LHe Containers," by W. Lehman and G. Zahn, ICEC7, London, 1978**
    - "3.8 W/sq.cm. for an uninsulated tank of a bath cryostat"
    - "0.6 W/sq.cm. for the superinsulated tank of a bath cryostat"
  - **"Loss of cavity vacuum experiment at CEBAF," by M. Wiseman, et. al., 1993 CEC, Advances Vol. 39A, pg 997.**
    - Maximum sustained heat flux of 2.0 W/sq.cm.
  - **LEP tests and others have given comparable (2.0 to 3.8 W/sq.cm.) or lower heat fluxes**
  - **New! "Crash" tests at CMTB at DESY**

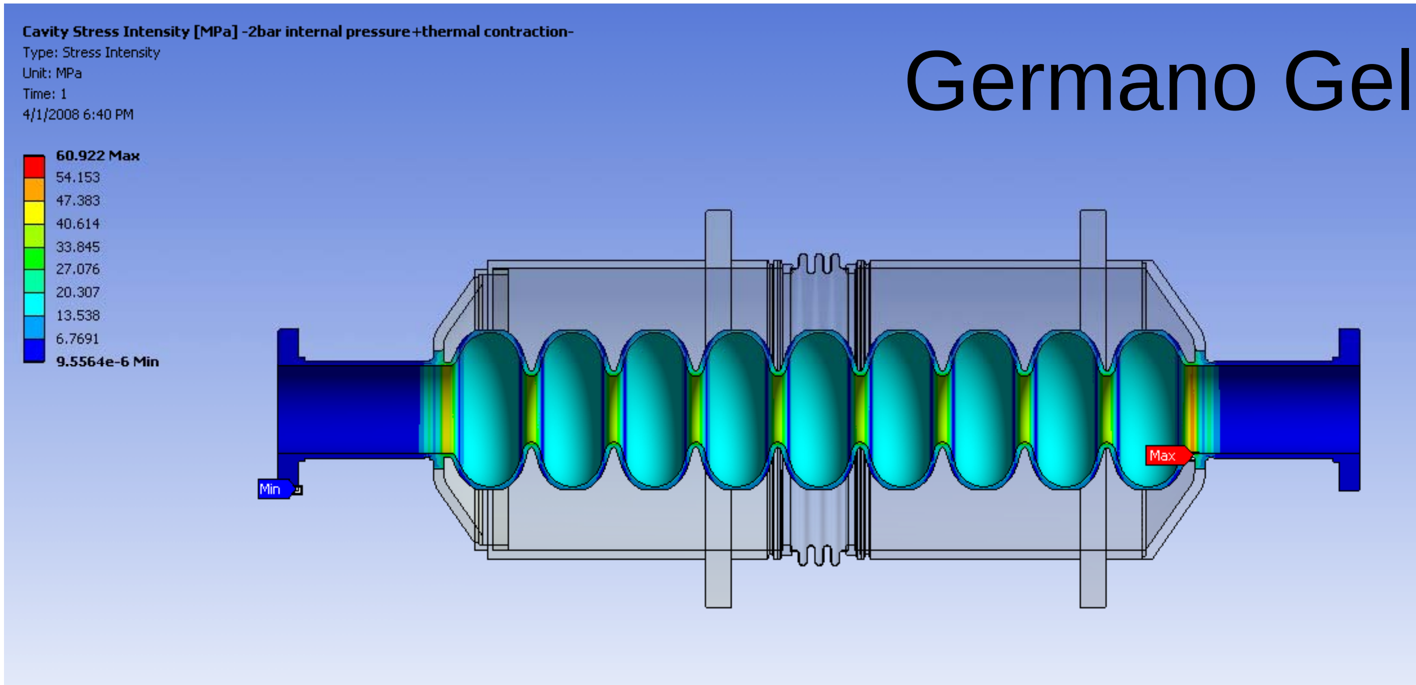
QuickTime™ and a
decompressor
are needed to see this picture.

“Crash” test at CMTB -- News from Lutz Lilje

Dressed cavity vessels as pressure vessels

- Helium vessels (generally) fall under the scope of pressure vessel codes
- Standard pressure vessel codes are difficult to apply
  - **Non-standard materials**
  - **Various heat and chemical treatments**
  - **Non-standard weld/braze joints**
- Each region, in fact each lab, is still developing its methods to comply with standards
- Materials tests, pressure tests, “crash” tests, and analysis are all important input
- Regions/labs should eventually share compliance documentation
  - **Find common elements in the work**
  - **Inter-lab pressure vessel safety approvals**

Cryomodule and helium vessel design pressure issues



Germano Gelasso

- 3rd Harmonic Dressed Cavity Pressure Vessel Engineering Note: Figure A20 - 3rd Load Case: Niobium Cavity. Stress Intensity Map
  - **Maximum Stress Intensity 61MPa**

Jlab helium vessel features

- Ed Daly of Jefferson Lab reported on some features of the 12 GeV upgrade helium vessels
  - **Stainless steel vessel**
  - **Nb - stainless braze joint in end group**
- Jlab (and Fermilab) must comply with US federal law (called 10 CFR851) which says we must conform to pressure vessel and piping codes except
  - **"When national consensus codes are not applicable (because of pressure range, vessel geometry, use of special materials, etc.), contractors [to DOE] must implement measures to provide equivalent protection and ensure a level of safety greater than or equal to the level of protection afforded by the ASME or applicable state or local code."**
  - **And there are various other requirements regarding reviews, documentation, etc.**

Request for information

1. What room-temperature yield stress, ultimate stress, and/or "allowable" stress, do we use in analysis and documentation for dressed SRF cavities, and based on what sources of information?

2. Similarly, what low temperature mechanical properties do we use for the various materials, and based on what sources of information?

3. How do we address the uncertainties in niobium properties that result from the various heat and chemical treatments?

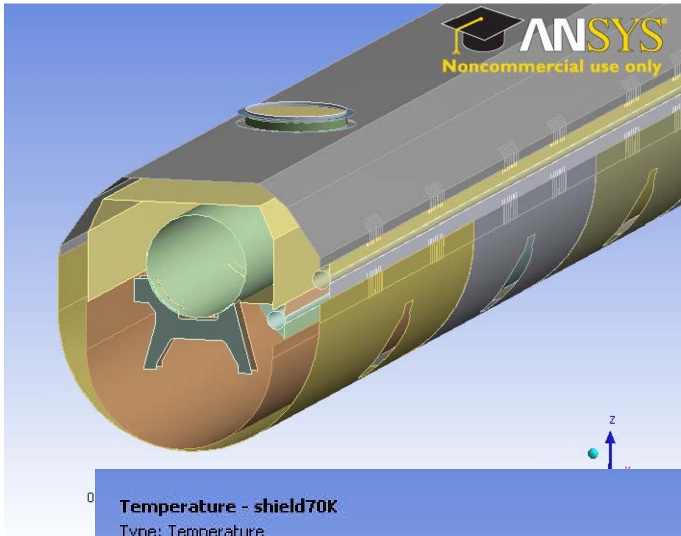
4. How will we qualify joint designs, such as welds and/or braze joints, including welds between dissimilar materials.

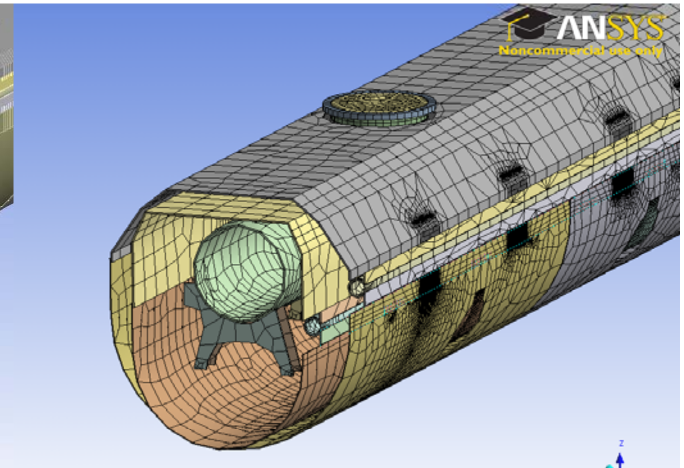
Cryomodule thermal optimization

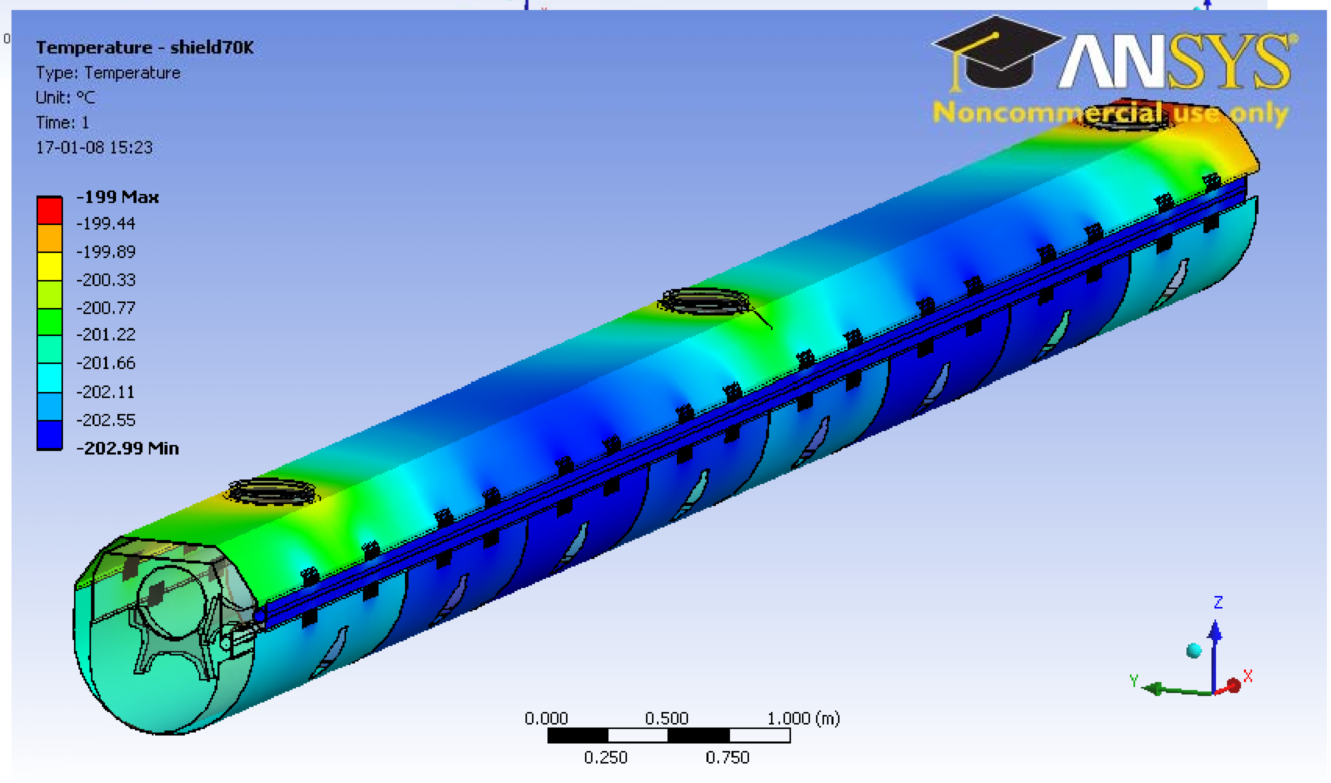
- Cryogenic systems work package #9.
  - **Cryomodule thermal optimization.**
  - **A joint task with cryomodule design.**
- Costs of the cryomodules per meter are much larger than the costs of the cryogenic system per meter.
  - **Optimization studies for capital and operating costs should consider tradeoffs of cryomodule complexity with heat loads.**
  - **For example, thermal shields, thermal intercepts, and MLI can perhaps be simplified for efficient production.**

Paolo Pierini

Validating model results







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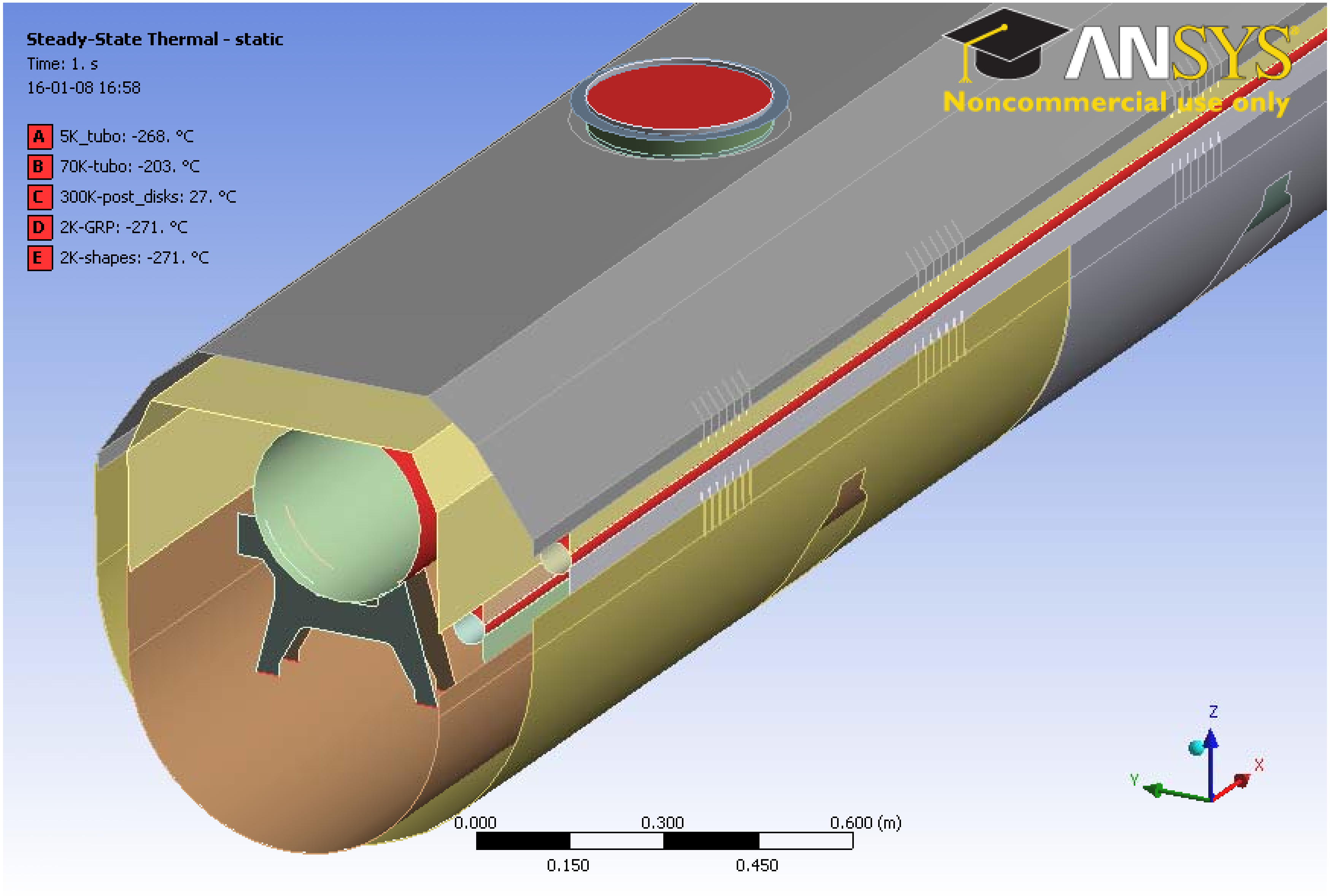
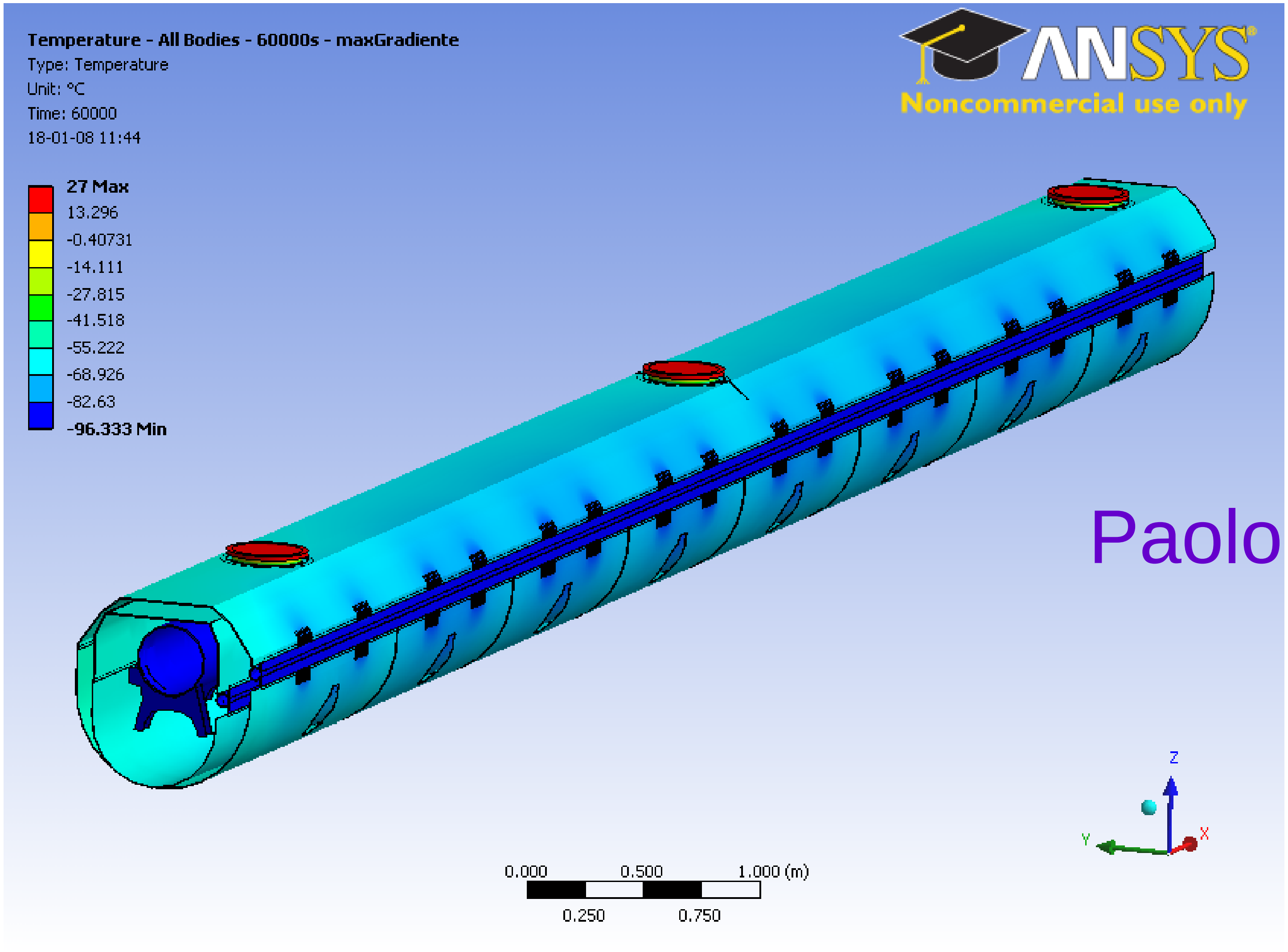
Thermal loads and boundaries



Exploring max gradient during cooldown



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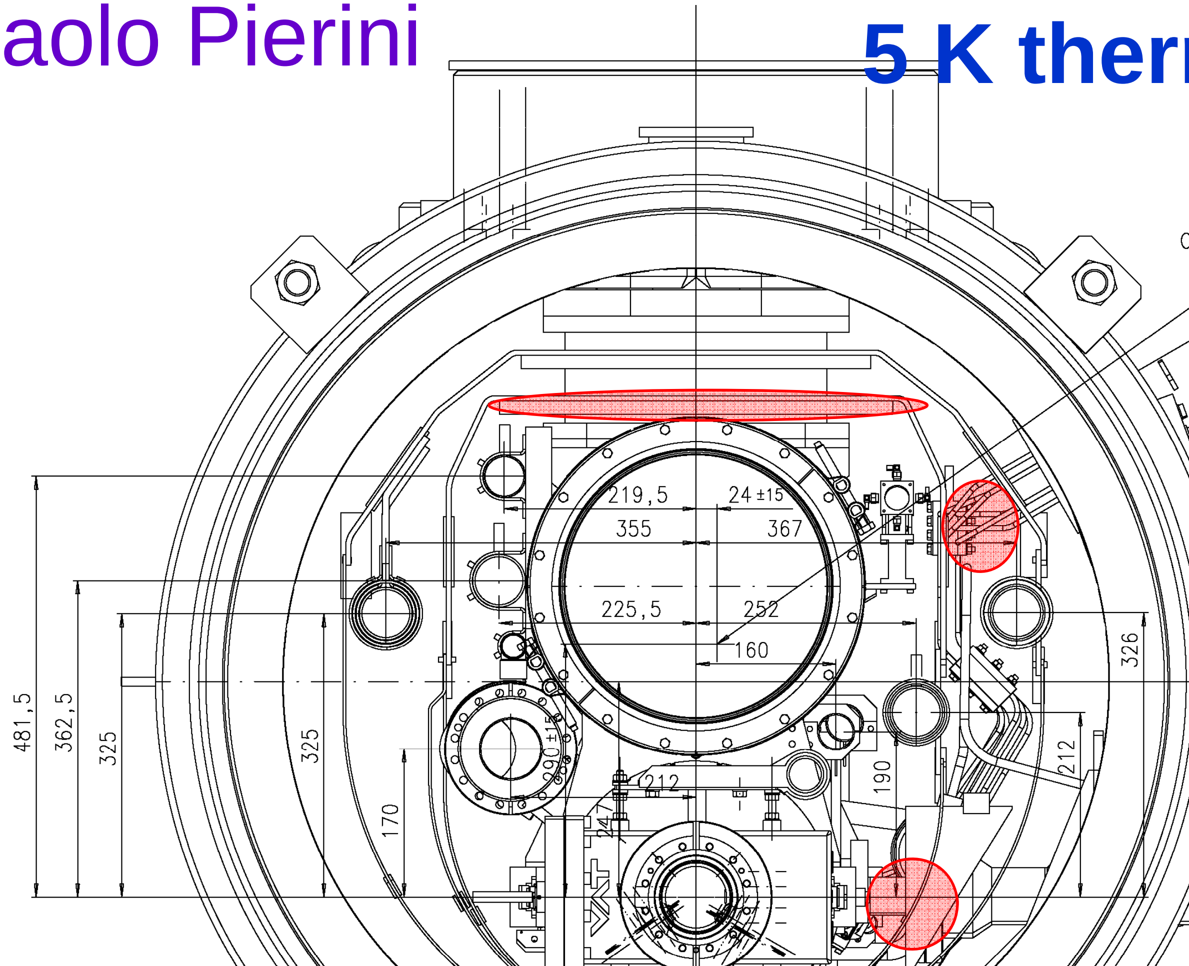
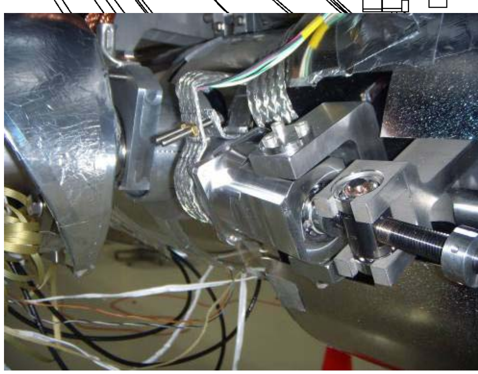
5 K thermal anchors





Heat loads of STF cryomodule for Case1

Norihito Ohuchi

Heat Load @ 2 K

	Static (w./w.o. 5K shield)	Dynamic
RF load	NA	7.46
Radiation	0.00 / 1.34	NA
Supports	0.32	NA
Input Coupler	0.095	0.26
Current Leads	0.28	0.28
Others	0.27	1.76
Total	0.97 / 2.31	9.76

Heat Load @ 5 K

	Static (w./w.o. 5K shield)	Dynamic
Radiation	1.32 / 0.00	NA
Supports	2.06	NA
Input Coupler	4.27	1.73
HOM Coupler (cable)	0.29	1.82
HOM Absorber	3.13	0.76
Current Leads	0.47	0.47
Diagnostic Cable	1.39	NA
Total	12.93 / 11.61	4.78

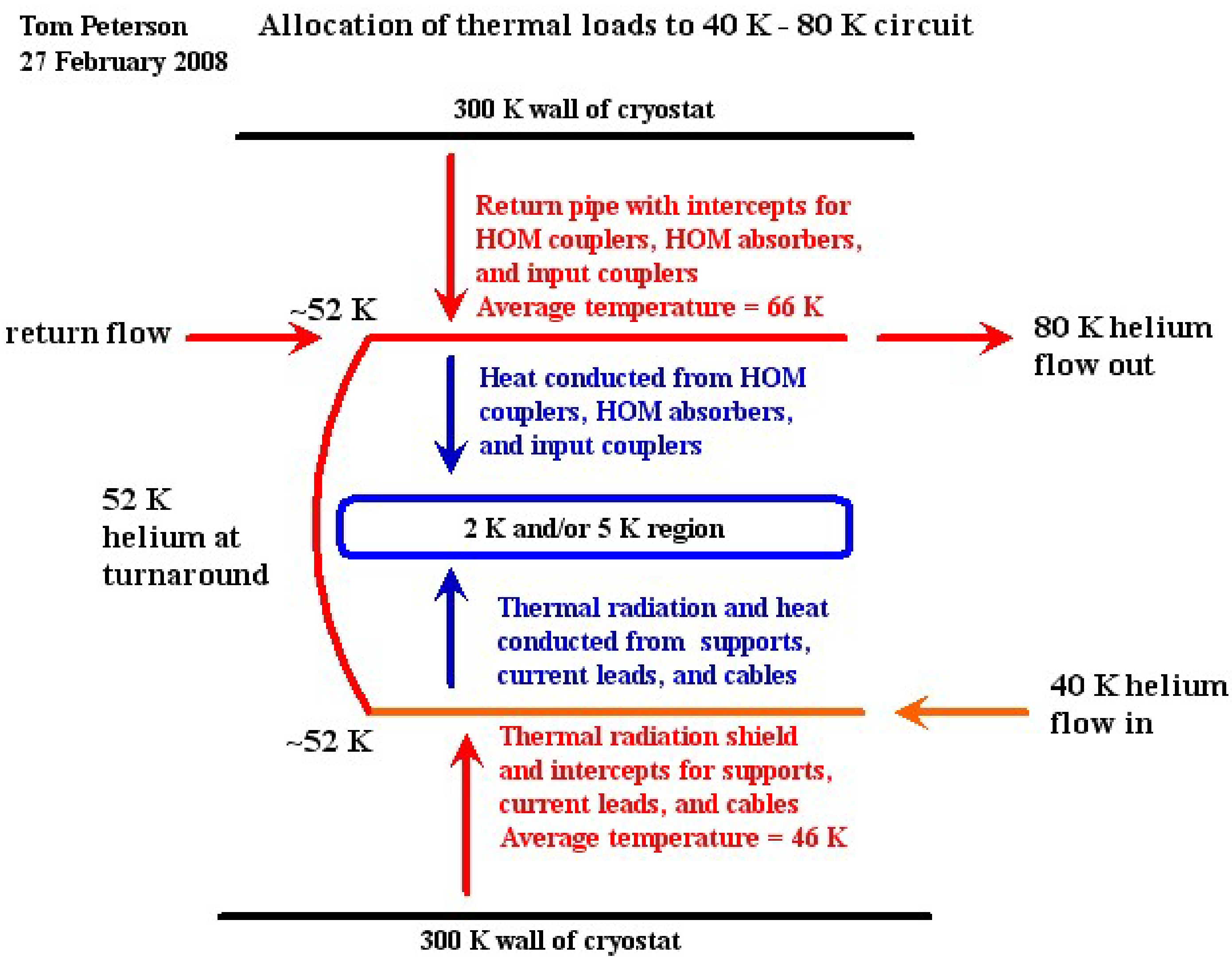
Heat Load @ 40 K

	Static (w./w.o. 5K shield)	Dynamic
Radiation	32.5	NA
Supports	16.62	NA
Input Coupler	28.18	26.01
Others	5.2	28.2
Total	82.5	54.2

Heat load for Case 1

	With 5K shield	Without 5K shield	Original
2K	10.73	12.07	11.36
5K	17.71	16.39	14.9
40K	136.7	136.7	153.5

2.5 km cryogenic unit



Heat loads of STF cryomodule for Case2

Norihito Ohuchi

Heat Load @ 2 K

	Static (w./w.o. 5K shield)	Dynamic
RF load	NA	7.46
Radiation	0.00 / 0.22	NA
Supports	0.23	NA
Input Coupler	0.12	0.26
Current Leads	0.28	0.28
Others	0.27	1.76
Total	0.90 / 1.12	9.76

Heat Load @ 5 K

	Static (w./w.o. 5K shield)	Dynamic
Radiation	0.20 / 0.00	NA
Supports	1.06	NA
Input Coupler	6.24	1.73
HOM Coupler (cable)	0.29	1.82
HOM Absorber	3.13	0.76
Current Leads	0.47	0.47
Diagnostic Cable	1.39	NA
Total	12.78 / 12.58	4.78

Heat Load @ 40 K

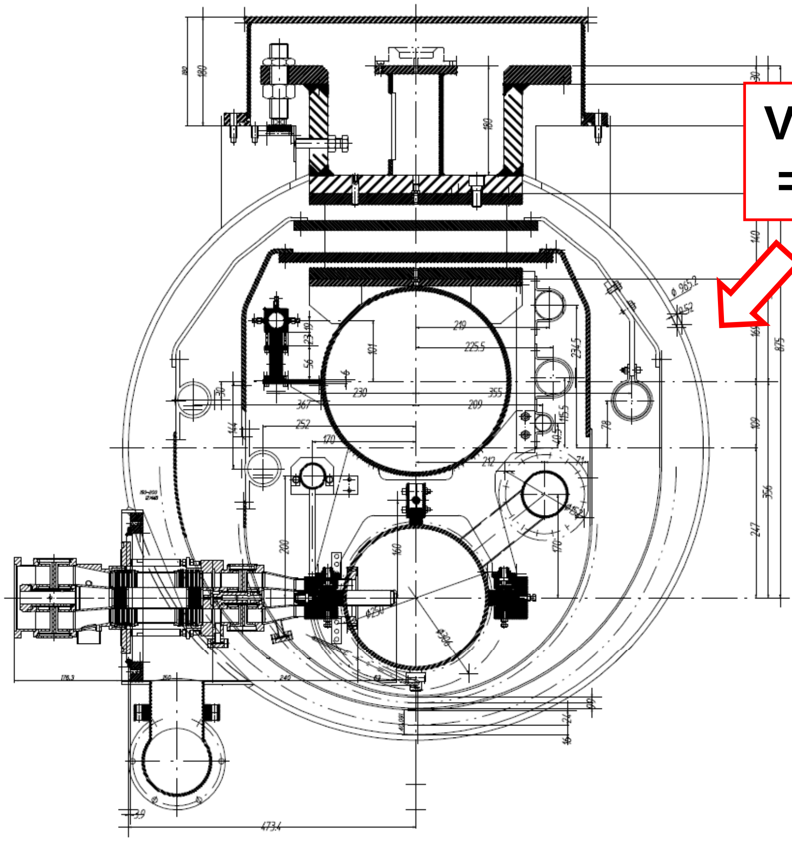
	Static (w./w.o. 5K shield)	Dynamic
Radiation	32.5	NA
Supports	19.04	NA
Input Coupler	24.97	26.01
Others	5.2	28.2
Total	81.7	54.2

Heat load for Case 2

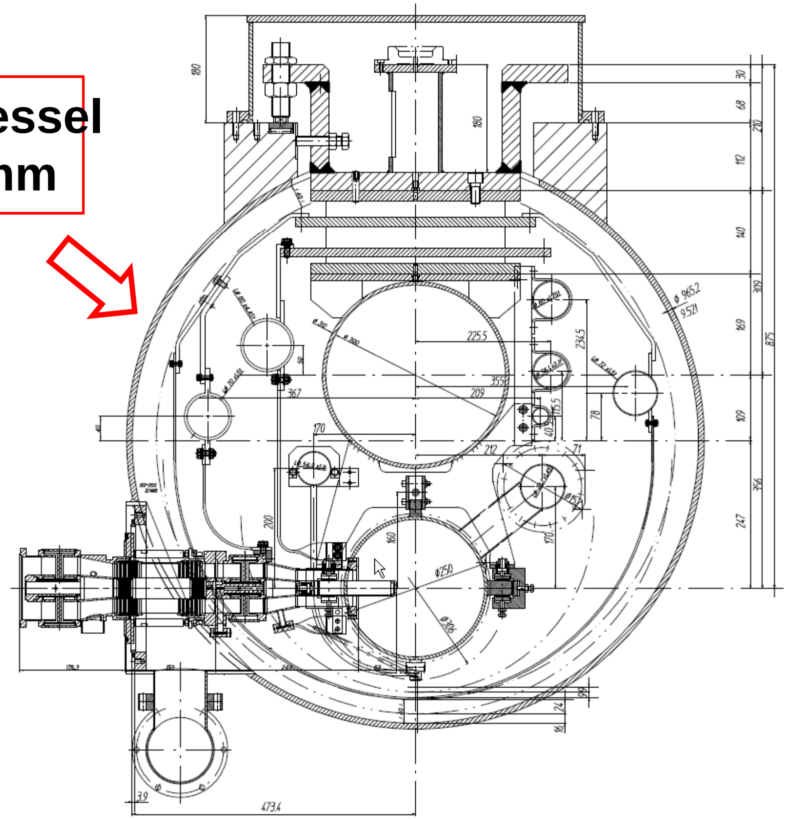
	With 5K shield	Without 5K shield	Original
2K	10.66	10.88	11.36
5K	17.56	17.36	14.9
40K	135.9	135.9	153.5

Study of the cryomodule cross-section (1)

Norihito Ohuchi



Vacuum vessel
= ϕ 965.2mm



Two shields model based on TTF-III with KEK input coupler

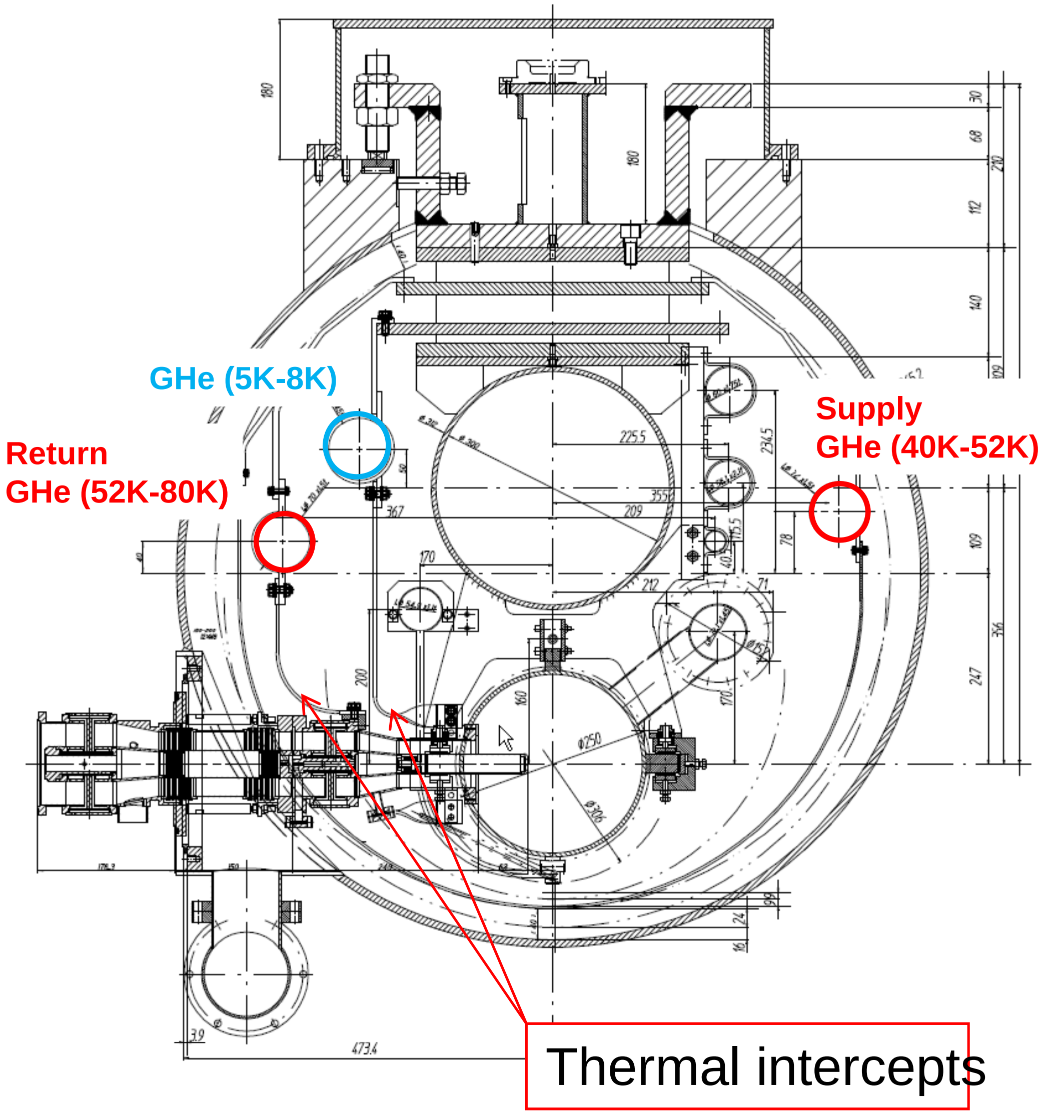
1. 40K-80 K shield with 30-layer-SI
2. 5K-8K shield with 10-layer-SI
3. 5-layer-SI around cavity jacket, GRP and LHe supply pipe

One shield model

1. 40K-80 K shield with 30-layer-SI
2. 5-layer-SI around cavity jacket, GRP and LHe supply pipe
3. 5K cooling pipe support

Study of the cryomodule cross-section (2)

Norihito Ohuchi



- **Thermal interceptors**
  - **Requirement of the design modification in the thermal interceptors**
  - **The interceptors for input couplers and the RF cables are directly connected to the terminals which are fabricated on the return cooling pipe.**
- **By this modification, assembly of the thermal shields and the interceptors will be simple.**
  - **Reduction in labor cost**

Thermal shield conclusions

1. At a minimum, the 5-8 K thermal shield bridges at interconnects can be left out.
   - **These are not needed as thermal intercept conduction paths, and scaling from length would imply that about 10% of the thermal radiation below the 40-80K shield would go down to 2 K without these shield bridges. The simplification at the interconnects and removal of potential interferences will be a large benefit.**

Thermal shield conclusions

2. With or without a 5-8 K thermal shield, we should optimize the deposition of heat on the 40-80 K circuit by careful use of forward and return lines.
   - **Use of the forward line for the 40-80 K thermal radiation shield helps to minimize overall heat reaching the 5 K or 2 K level.**
   - **Use of the 40-80 K forward line for support post intercepts combined with the 80 K return line for the largest dynamic heat loads will help to minimize the temperature variations on the support post intercepts due to dynamic heating.**
   - **These considerations require coordination of cryomodule design, cryogenic system design, and orientation with respect to cryogenic flow in the accelerator tunnel.**

Thermal shield conclusions

3. Cryomodules without a 5-8 K thermal shield may be plug-compatible with those containing a 5-8 K thermal shield.
   - **But be careful -- thermal intercepts from tuners and input couplers should have compatible attachments to whatever thermal strap is used.**
     - We should remember the interfaces for thermal intercepts as a plug-compatibility requirement, in any case.
   - **Compatibility assumes no 5-8 K thermal shield bridge in the interconnect.**
   - **We could decide to not incorporate a 5-8 K thermal radiation shield later**

Thermal shield conclusions

4. A 5 K thermal shield may be very basic and simple.
   - **Gaps are not too important.**
   - **Shaping the shield around interferences is not necessary.**