Cryomodule RDR Review and WP plan in Asia

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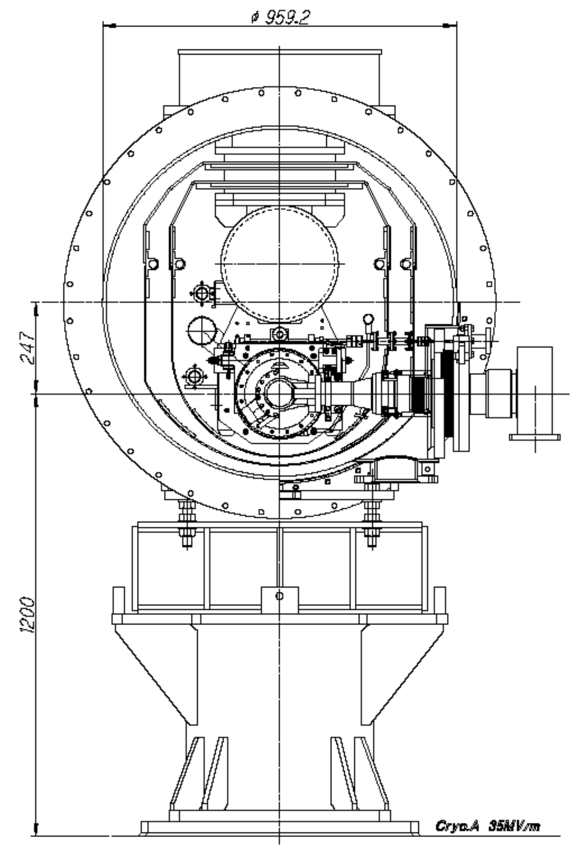
Cryomodule RDR Review in Asia

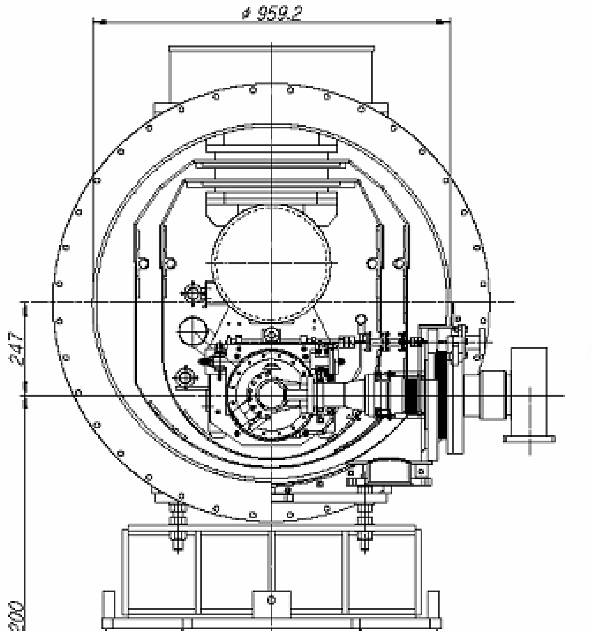
- Works during the RDR phase in KEK (Asia)
  - **Cryomodule cost estimate**
    - 2 Japanese companies (Hitachi and Toshiba) studied the costs for the manufacturing components and assembling the cryomodule.
    - KEK estimated the costs of the cryomodule test facility, man-power for the tests and transportation from KEK to the site.
  - **STF construction and R&D components**
    - KEK constructed the cryomodule and test system in STF.
      - Hitachi manufactured the STF cryostats and this experience was included in the cost estimation.
    - Cryomodule R&D components
      - Ti-SUS junction and magnetic shield studies
  - **3-D CAD works for the STF cryomodule**
    - KEK completed the 3-D CAD of the STF cryomodules.

- Strategies of the cost study of the ILC-cryomodule
  - **Study models for the cost estimation of the ILC-cryomodule**
    - Hitachi
      - Cost estimation based on the STF cryomodule and its construction experience.
      - The STF cryomodule design is based on the TTF-III.
    - Toshiba
      - Based on the TTF-III cryomodule (8 cavi.)
    - In this study, the cavity package and input coupler are not included. They were studied in the cavity components.



STF-Cryomodule
Cross Section-BL cavity

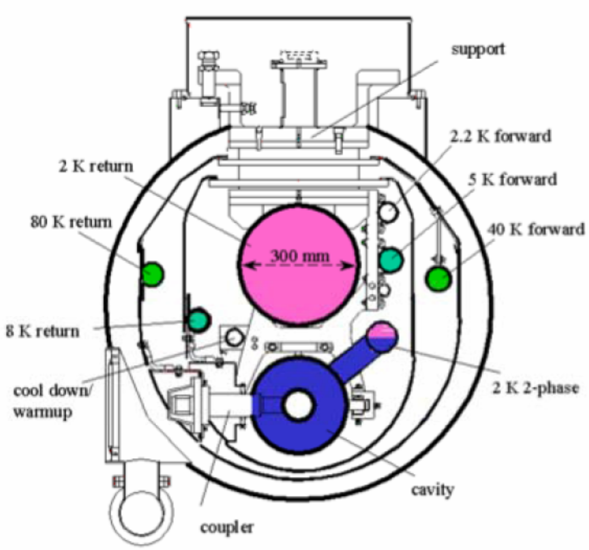
- Comparison between the cryomodules for the cost estimation



STF-Cryomodule
Cross Section-BL cavity

Hitachi cost estimation model

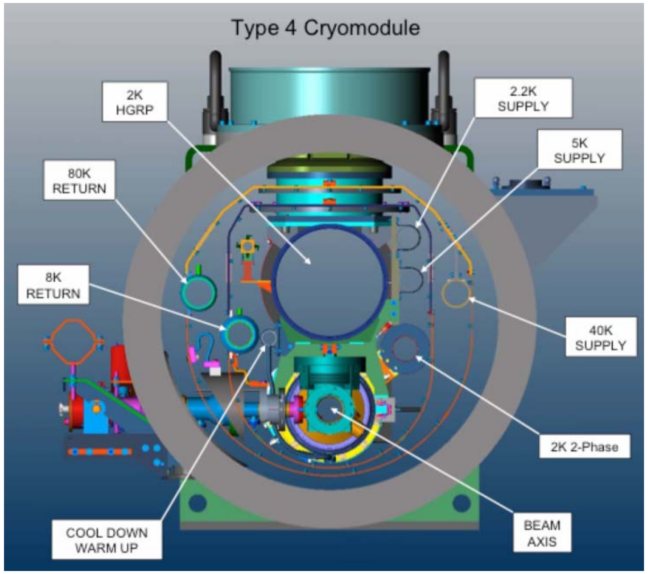
Length of the cryomodule=12.4m
(including a large vacuum bellows)



Tesla Type 3-Cryomodule

Toshiba cost estimation model

Length of the cryomodule=11.4m
(8 cavity cryo.)



Type 4-Cryomodule

Cost Study of Cryomodule-3 (Hitachi-meth.)

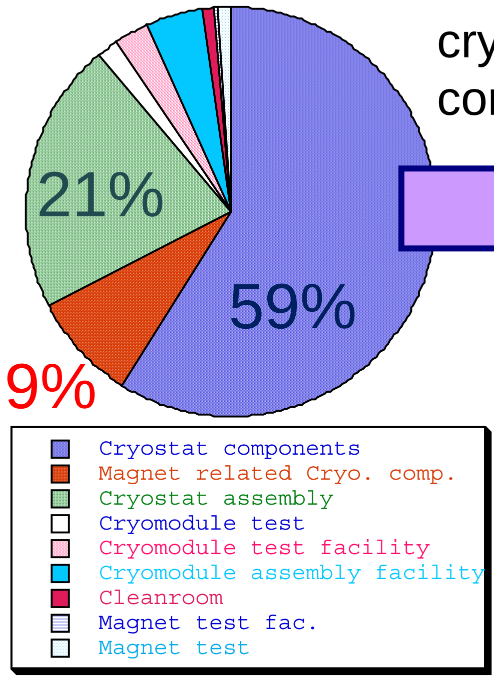
- Cost estimation of the 2100 cryomodules (HITACHI)
  - **Evaluating the cost of the STF cryomodule hardware**
    - Manufacturing cost of the STF cryomodule components
      - raw material cost + man-power cost for processing components
      - The process hours of the components were studied from the actual works.
  - **Assembly cost of the cryomodule inside and outside a clean room**
    - The man-hour at each assembly step was estimated, with reference to the DESY #6 cryomodule.
  - **Quadrupole package cost estimation**
    - The number of the magnet package: 700
  - **Learning ratio for the mass production**
    - Learning ratio of raw material: X1, component process and assembly: X2
    - Hitachi engineer comment
      - the learning ratio < 90 % is expected only for semi-conductors and household electric articles.

Cost Study of Cryomodule-4 (Toshiba-meth.)

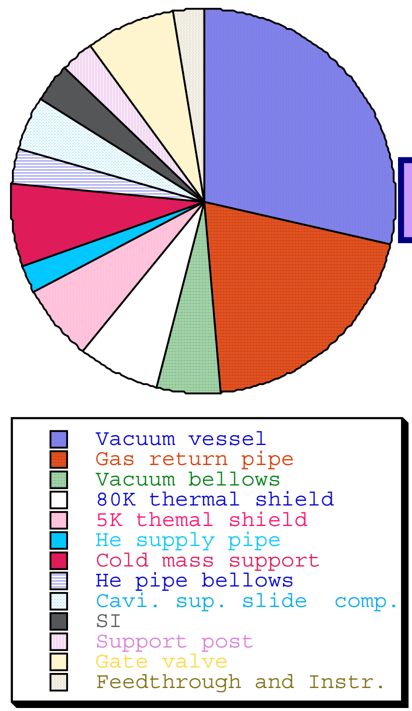
- Cost estimation of the 2100 cryomodules (TOSHIBA)
  - **Toshiba studied the cost of the first cryomodule in the mass production**
    - Cryomodule hardware cost estimation without quadrupole package
      - The cost estimation of the cryomodule components was done from the TTF III cryomodule design.
      - The cost includes the raw material and the machine process.
    - Mass production study
      - The learning ratio of HITACHI was applied on the mass production of the 2100 cryomodules for calculating the cost. (by KEK)

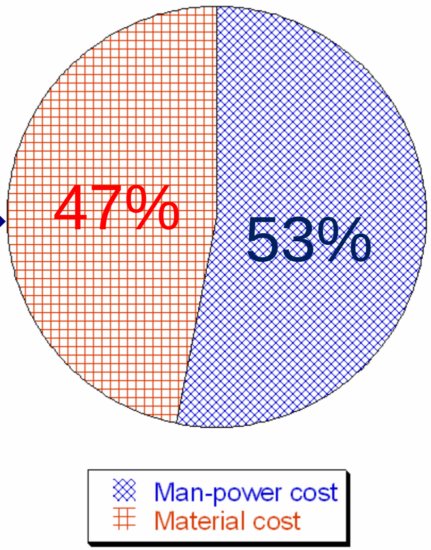
- Assembly and test facilities (estimated by Hitachi and KEK)
  - **Cryomodule assembly building including the clean room: 5400m^2**
  - **Cryomodule test facility and tests**
    - Test and compressor buildings, and tank area: 1820m^2
    - Cold box: 1.6 kW @ 4.2 K
    - 700 cryomodule tests for 5 years
  - **Magnet test facility**
    - The facility in KEK can be allowable. No cost is estimated for the test building.
    - The test stands and the instrumentations were included.
    - 700 magnet tests for 3 years
  - **Cost and Learning ratio**
    - The costs were calculated with the charge of the Hitachi technician.
    - Learning ratio: X2 for man-hours.

Cost profile of the cryomodule (based on the HITACHI data)



cryostat components





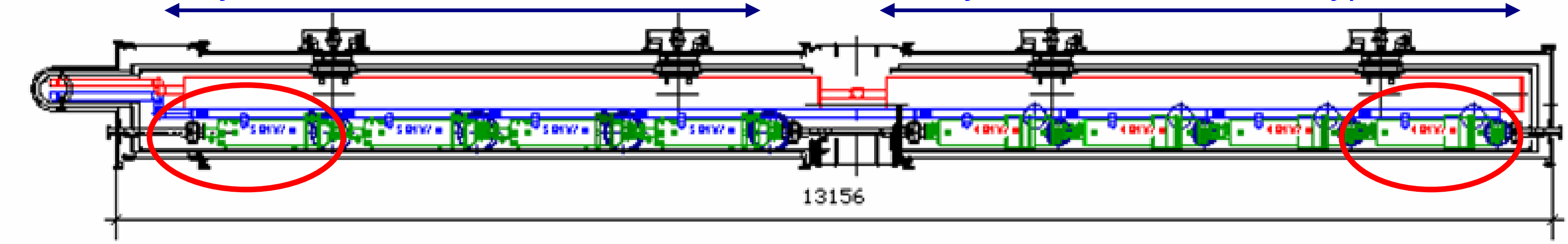
In the material cost, the costs of the gate valves, vacuum vessel bellows and feed-through terminals are included.

The cost of the cryostat components, magnet and assembly is **89 %** of the total cost.

More than 50% of the total cost is man-power cost.
For the cost reduction, out-sourcing is the key point.

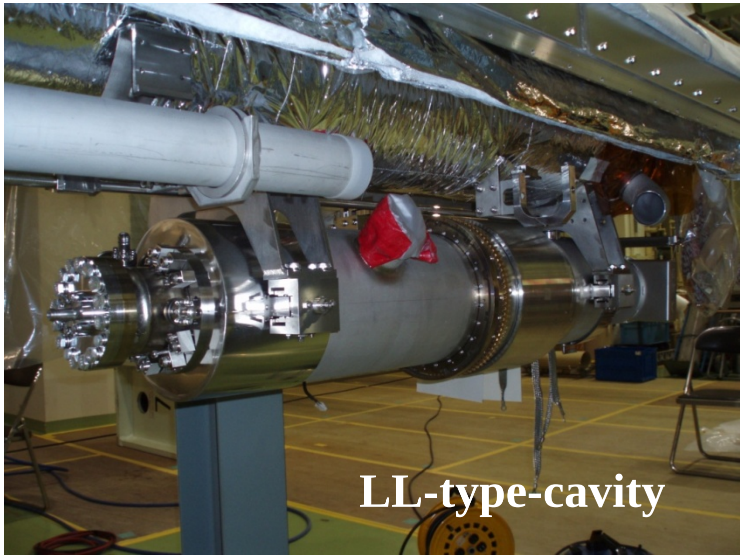
STF cryomodule construction and R&D studies-1

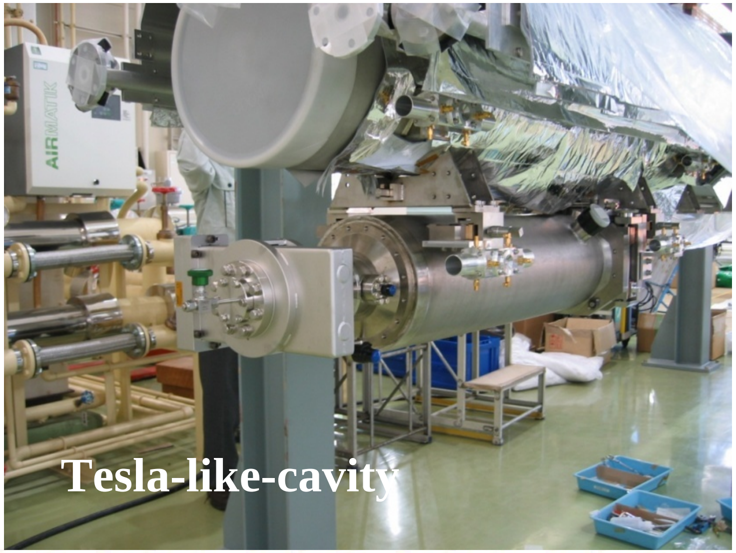
- STF cryomodule design and construction:
  - **KEK started the design work of STF cryomodule at January 2005.**
  - **Hitachi started the engineering design work of STF cryomodule at September 2005.**
  - **The engineering design had been completed at March 2006.**
  - **Ordering materials and manufacturing components started at November 2005.**
  - **Assembly of the cryomodule started at November 2006, and installation of the two cryomodules for the BL cavity and the LL cavity was completed in the tunnel at February 2007.**
    - One cavity for each type was installed into the cryomodule.



Cryomodule RDR Review in Asia

STF cryomodule construction and R&D studies-2

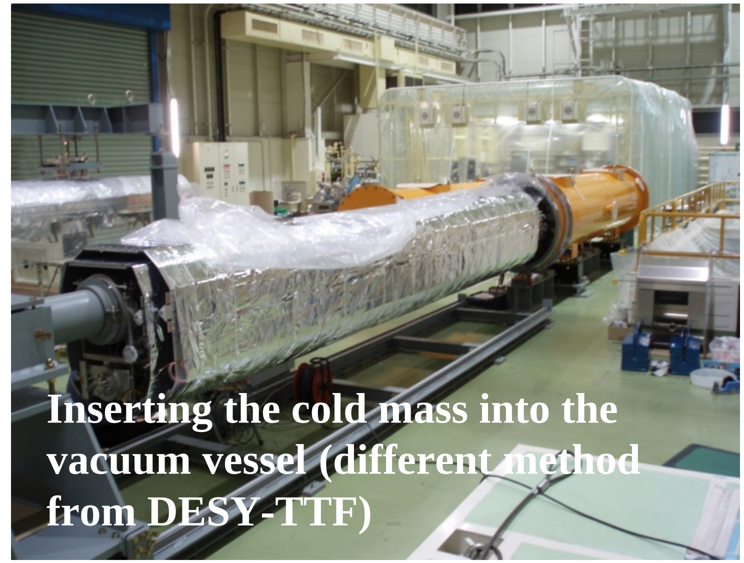


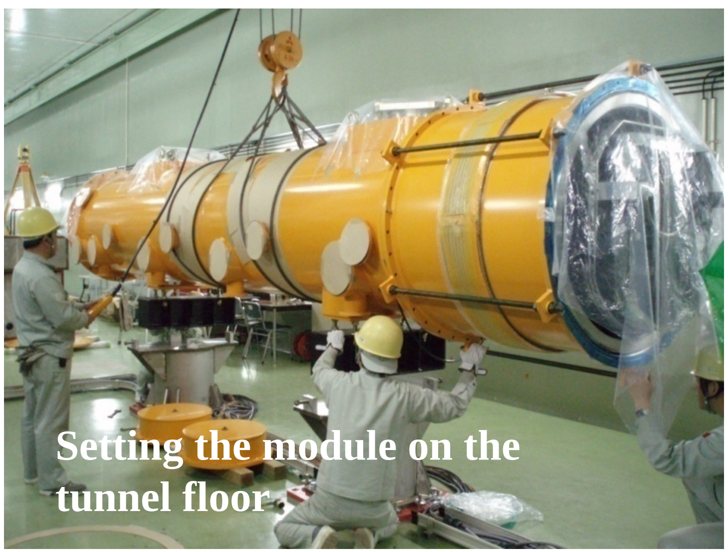


Cryomodule RDR Review in Asia

STF cryomodule construction and R&D studies-3

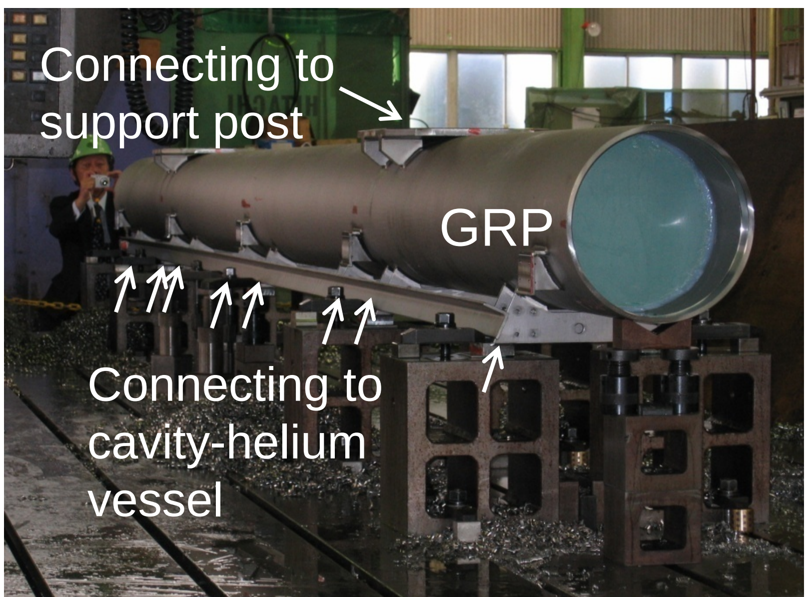

Cold mass hanged under the assembly tool

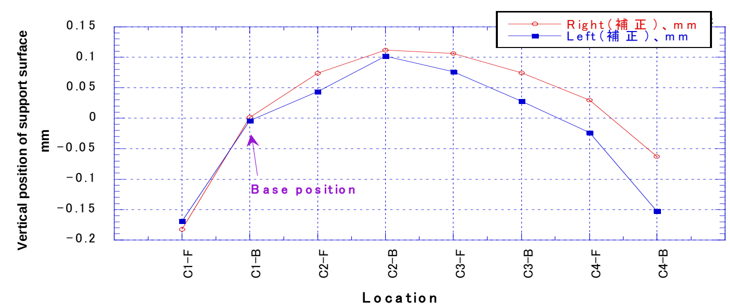

Inserting the cold mass into the vacuum vessel (different method from DESY-TTF)

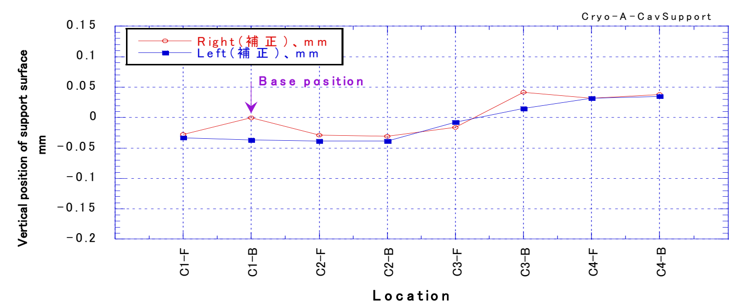

Setting the module on the tunnel floor


2 cryomodules are connected and aligned in the tunnel

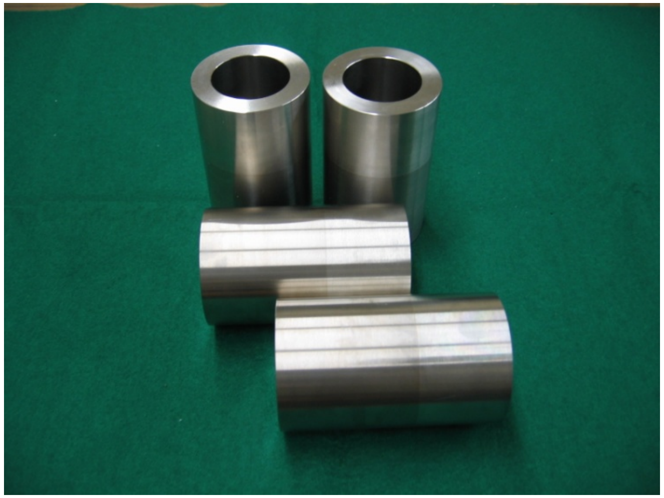
- **Cryomodule construction experience**
  - **Manufacturing cold mass component with some tolerance, assembly and alignment process of cryomodules were studied.**
  - **One of the results**
    - Connecting surfaces on the GRP with the support posts and cavity helium vessels were machined with the design tolerance of 0.05mm.







- Ti-SUS junction:
  - **Ti-SUS Junctions were made by the methods of Hot Iso-static Pressing and Friction Pressing Welding**
    - The strengths of the samples were measured at room temperature and liquid nitrogen temperature.
      - Tensile test: strength was almost same as Ti material.
      - V-notch impact test: 3~5 J/cm^2 at LN_2 (Ti>100 J/cm^2 at LN_2)
    - For the BL cavity helium vessel, 12 junctions were made by HIP.

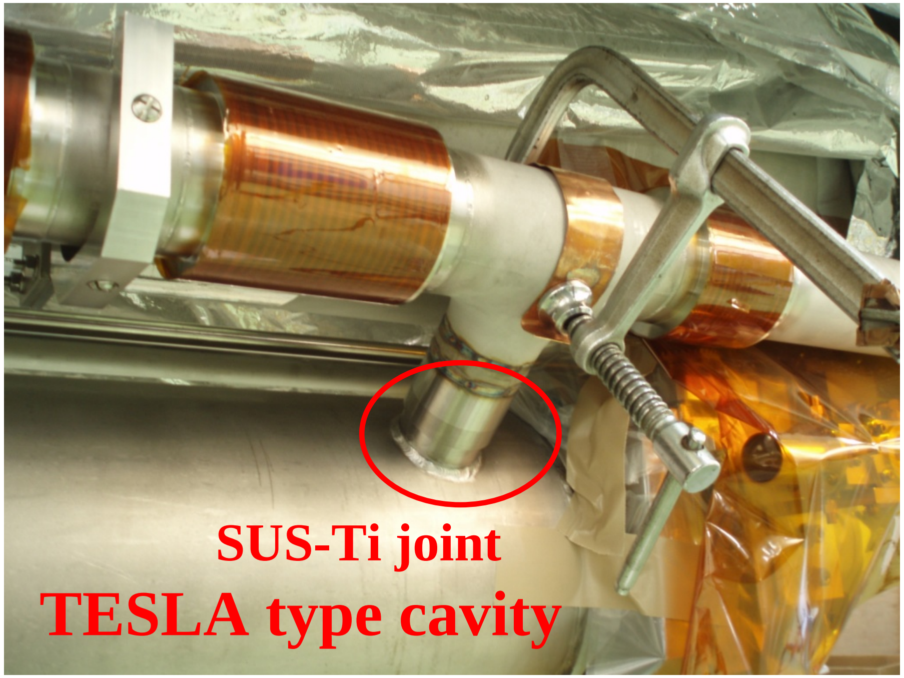


Junctions for BL cavity helium vessels

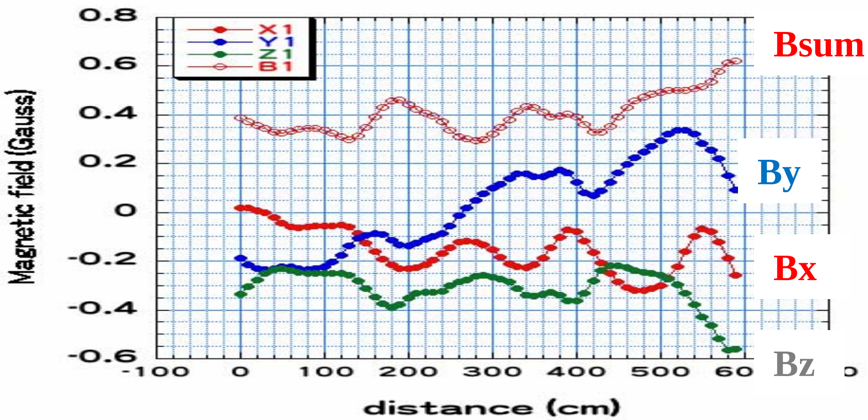
Tensile test of SUS-Ti junction by HIP

– **All junctions were leak-tested at 2K (in He II).**
  - The junctions were used for the helium supply tube and the pre-cooling tube of the TESLA type cavity helium vessel.

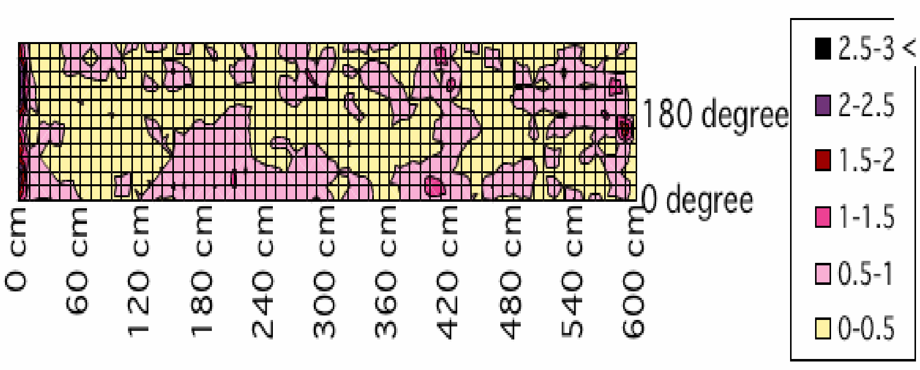
SUS-Ti junction He-leak-test stand



- Magnetic shield studies:
  - **KEK is studying the magnetic shield system**
    - Vacuum vessel
      - Measurement of the field profile in the tunnel and inside the vacuum vessel.
      - De-magnetization of the vacuum vessel and its effect.
    - Magnetic shield of cavities inside the helium vessel
      - Two type cavities have the inner magnetic shield.
    - Measurement of the shield material property
    - Evaluation of the shield shape by calculation



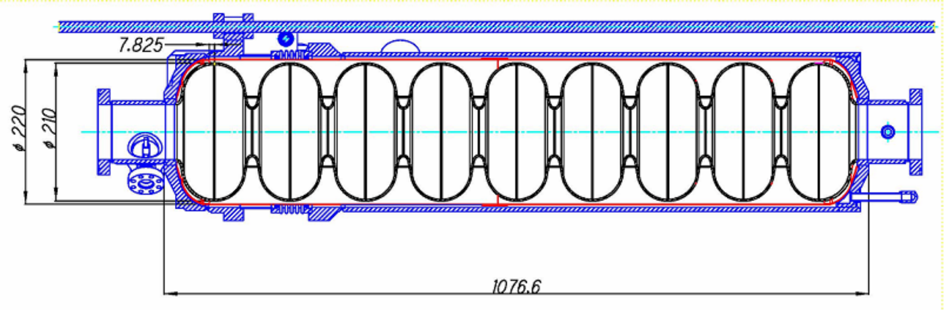
Field profile inside vacuum vessel

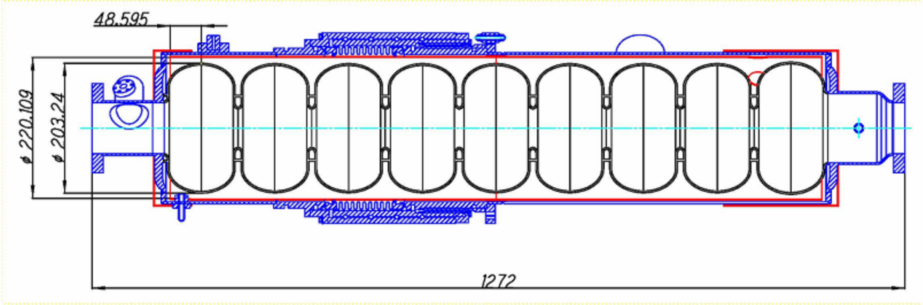


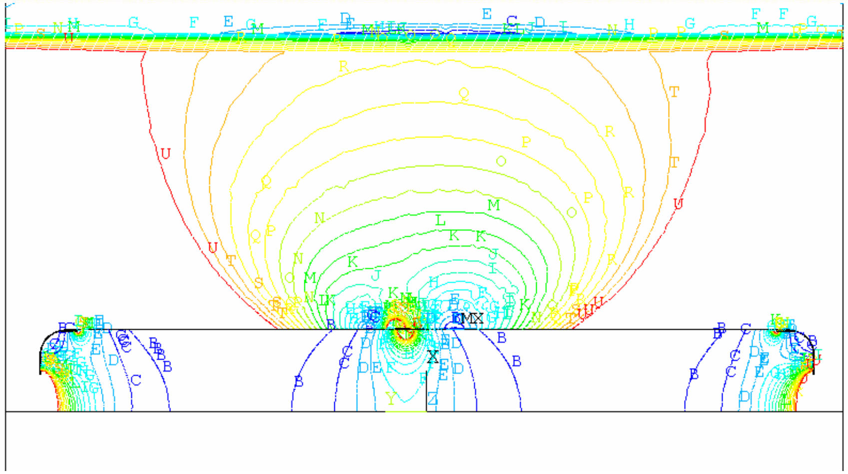
Field profile on the inner surface of the vacuum vessel

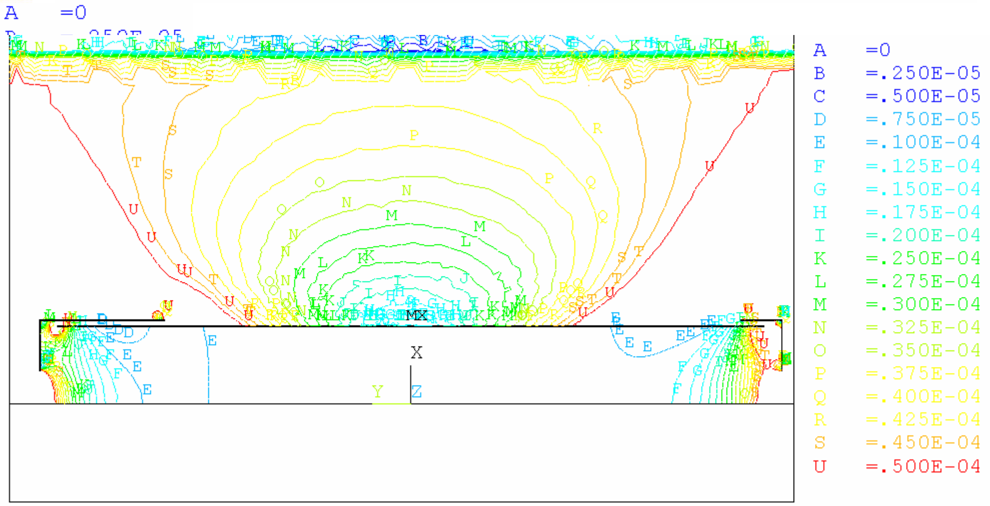
Tesla-type-cavity and shield

LL-type-cavity and shield







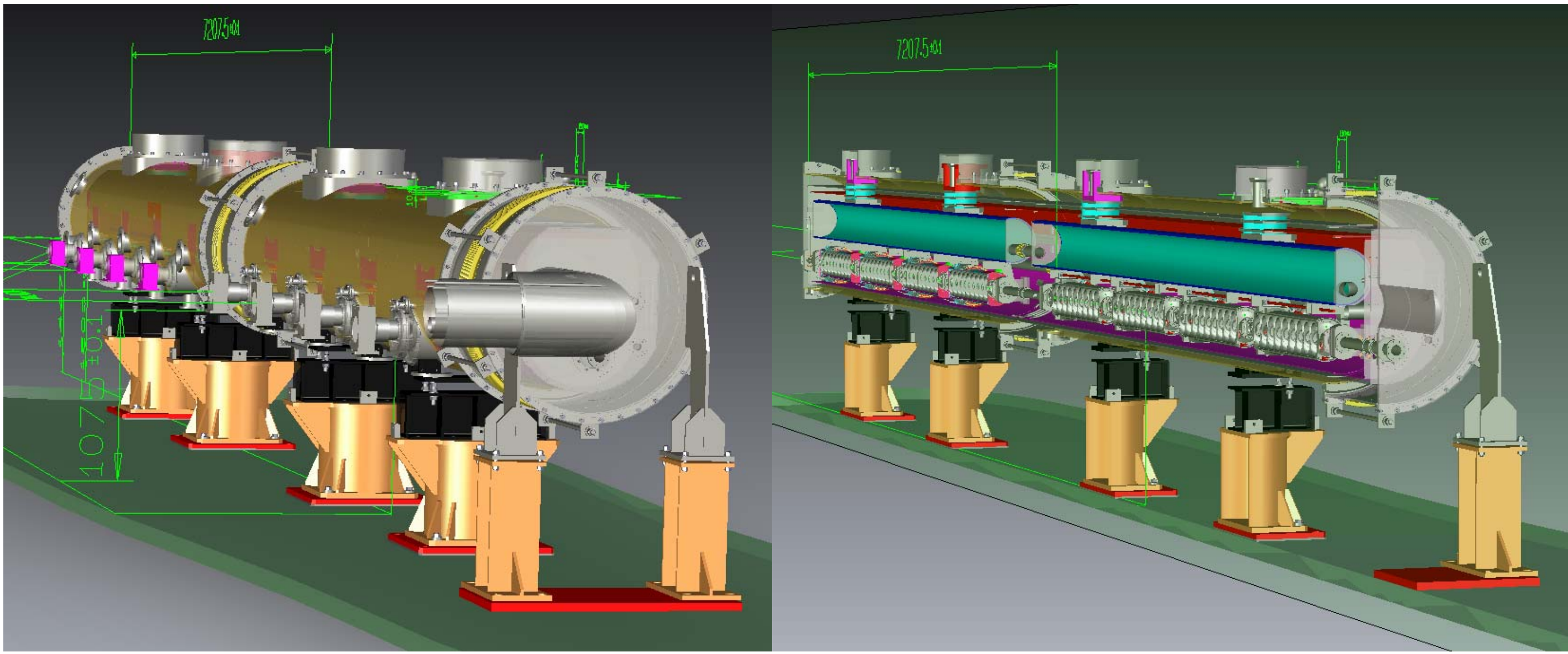


Contour plot of the magnetic field profile inside the magnetic shield .
The plotted lines are from 0 to 0.5 Gauss.
For the calculation, solenoid field of 0.5 Gauss was applied on the calculation model.

3D-CAD for the STF cryomodule-1

- 3D-CAD of the STF cryomodule is now completed:
  - **3D-CAD software: One Space Designer**
    - CAD data can be transferred to I-deas (EDMS)
      - CAD drawings can be viewed on the I-deas, however, the transferred data is not completely functioned on the I-deas.
  - **For designing the STF-2 cryomodule, the CAD work will be done with the I-deas and the CAD data will be transferred into the EDMS.**
    - The component CAD data of the STF-1 can be used for the design work of the STF-2.

- STF-1 cryomodule 3D-CAD



Cryomodule Work Package Plan

- For planning the EDR work package in KEK, we take the construction of STF-2 into consideration.
- Cryomodule -1
  - **As the basic concept, the thermal design is based on the TTF-III.**
    - Cold mass is hanged from the vacuum vessel via support posts.
    - Cavities are supported from the large gas return pipe.
  - **Designing the cooling pipe**
    - The pipe sizes are now given by the cryogenics group (in the presentation of T. Peterson).
    - Calculation of the pressure drops for these pipes after designing the complete cooling channels in the cryomodule.

Cryomodule Work Package Plan

- Cryomodule -2
  - Defining the maximum pressure for these channels. The cavity limits the maximum pressure for the helium vessel and the connected cooling pipes.
    - This pressure influences the pressure tests.

– **5K thermal radiation shield**

  - Making the thermal design without 5 K thermal radiation shield.
    - The thermal radiation system of LHC dipole cryostat consists of the 80 K thermal radiation shield and the radiation screen.
    - The detailed thermal calculation for this model.
    - Need to discuss the heat load change with the cryogenic group.
  - Re-arranging the pipe location in the cryomodule.
  - Cold test for the cryomodule without 5 K thermal radiation shield by the STF-1 cryomodule.
  - For the STF-2 cryomodule, the cryomodule without 5K thermal radiation shield should be tested.

Cryomodule Work Package Plan

- Cryomodule -3
  - **Quadrupole package**
    - Designing the nested quadrupole magnet with corrector coils.
      - Magnetic design of the quadrupole, and the physical magnet design.
        - Operation temperature: 2K or 4K
        - Specifying the field errors induced by the magnetization change coupled with the corrector coils.
    - Deciding the corrector type
      - At present, the normal and skew dipoles are considered to be assembled into the magnet package.
      - By the skew quadrupole, the allowable alignment error will be relaxed.
    - Development of the feed-through and HTS current lead.
    - Specifying the movement of the magnet from the gas return pipe by cool-down.
      - By the actual system, the movement should be measured.
  - **Development of cheap gate valve**
  - **High pressure gas regulation**

Cryomodule Work Package Plan

- Cryomodule -4
  - **2D and 3D-CAD work**
    - The type-4 cryomodule for STF-2 has started with based on the STF-1 cryomodule CAD work.
    - For designing the cryomodule, EDMS and I-deas will be used.
    - After completing the design of the cavity, the cold mass and the quadrupole, the 2D and 3D-CAD drawings will be finalized.
      - With this CAD work, the vibration study and the thermal analysis should be performed.
        - Vibration study by 3D-model
        - Calculation of heat loss of the components by 3D-model-> total heat loss.

Cryomodule Work Package Plan

- Cryomodule -5
  - **Horizontal test stand (CHECHIA)**
    - For pushing the cavity R&D forward and performing the pre-test of the cavity package before installation into the cryomodule, this system should be designed and constructed.

Cryomodule Work Package Plan

- Cavity and cryomodule -1
  - **Selection of the cavity shape**
    - Tesla type or Low-loss type
  - **For the selected cavity, designing the magnetic shield inside the helium vessel**
    - Specifying the leak field value on the cavities.
    - Design of the whole magnetic shield system including the inner magnetic shield, the outer magnetic shield between the helium-vessels and the vacuum vessel.
      - Establishing the method of demagnetization of the vacuum vessel.
      - Getting data of the magnetic properties for the magnetic shield material.
    - After completing the magnetic shield system, the helium vessel design should be finalized.

Cryomodule Work Package Plan

- Cavity and cryomodule -2
  - **Design of the helium vessel**
    - Selection of the material
      - Ti or SUS
    - Development of the junction between different materials
      - SUS helium vessel: Nb-SUS junction
      - Ti helium vessel: Ti-SUS junction
    - Design of the tuner (driving motor location: inside or outside of the vacuum vessel, detailed thermal calculation)
  - **High pressure gas regulation**
    - For the high pressure gas regulation, material property data and the mechanical calculation should be prepared.
    - The material property; Nb, Ti and junctions.
    - The difference of the regulations between three regions should be well understood.

Cryomodule Work Package Plan

- Cost estimation-1
  - **For the cost estimation, the following items should be clarified and re-studied**
    - Required specification of the cryomodule components
      - Process tolerance of the components for machining
        - Especially, the cavity support and the accessory elements, flanges of the vacuum vessel.
        - To make this tolerance clear, alignment method and alignment tolerance of the cavity and quadrupole package should be clear.
      - After construction of cryomodule in three regions, construction errors should be reviewed.
  - **Cryomodule assembly process**
    - Studying the assembly process including the clean room work during STF-1 and STF-2.
    - Improving assembly tools to make assembly time short.
      - Tooling information is very important, and the information should be exchanged between three region.

Cryomodule Work Package Plan

- Cost estimation-2
  - **Study of the cost reduction component in the cryomodule**
    - 5 K thermal radiation shield (Al plate and SI) >> radiation screen
    - etc.
  - **Cost estimation of the cryomodule tests from the experience of STF-1 and STF-2**
    - Test items as the cryomodule final test.
    - Required test period and man-power.
    - Required capacity of the test stand including the cold box.
  - **With these information, the cryomodule cost should be estimated again.**

Situation of STF-1 and Future Plan

- STF-1
  - **The assembly of two STF cryomodules with one cavity and 2K cold box were completed in March.**
    - However, in the final test, it was found that the 2K cold box and the LL cavity helium vessel had helium leak.
      - LL cavity helium vessel : tuner bellows
      - 2K cold box : VCR joint
    - The 2K cold box was disconnected from the cryomodules, and it was repaired on the ground floor.
      - The VCR joints were removed, and the pipes were connected by welding.
      - After repairing, the 2K cold box was successfully cooled down to 1.67K at August 29.
    - The LL cavity cryomodule is being disassembled and the precise helium leak test for the helium vessel will be performed.
    - Cool-down test of one cryomodule with one Tesla type (BL) cavity will be performed.

Situation of STF-1 and Future Plan

- STF-1
  - **After the cool test of the cryomodule with one BL cavity:**
    - The cool-down test of the one BL cavity and one LL cavity.
    - The system will be disassembled for preparing the cold test of 4 BL cavities and 2 LL cavities.
    - The 4 BL cavities will be assembled in a string.
    - The BL cavity string and two LL cavities will be installed into two STF cryomodules.
    - Cold test of the two cryomodules.
      - Low-power and high-power tests of the cavities.
      - Thermal performance tests of the two cryomodules.

Situation of STF-1 and Future Plan

- STF-2 (future plan)
  - **One cavity shape will be selected for constructing STF-2 cryomodules.**
  - **Cavities are processed by new STF-EP, HPR clean-room, and STF-VT.**
  - **3 full-size cryomodules (13m length each, ILC-type cryomodule).**
  - **1 ILC RF unit demonstration.**
    - 26 selected-shape cavities + 1 Quad-steer-BPM package. powered by 10MW MB-klystron with linear distribution.
  - **RF gun and two capture cavities are installed for ILC beam generation and beam loading test for cavities.**
  - **Proof of existence for ILC cryomodule fabrication capability in KEK.**
  - **Industrialization of the cryomodule should be done during STF-2.**

Situation of STF-1 and Future Plan