Study Results of KEK-STF Cryomodule Magnetic Shields

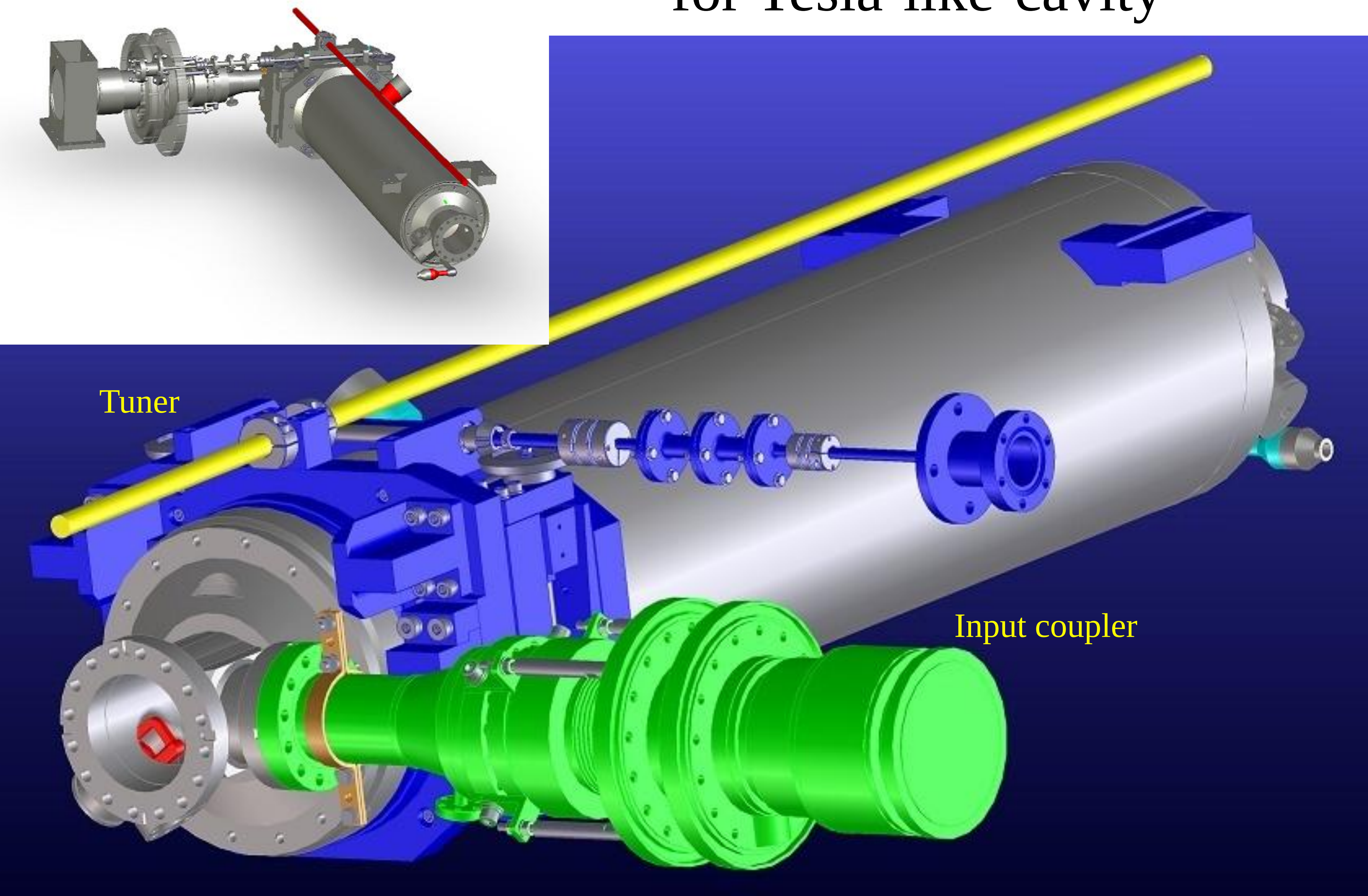
KEK

N. Ohuchi, M. Masuzawa, K. Tsuchiya,

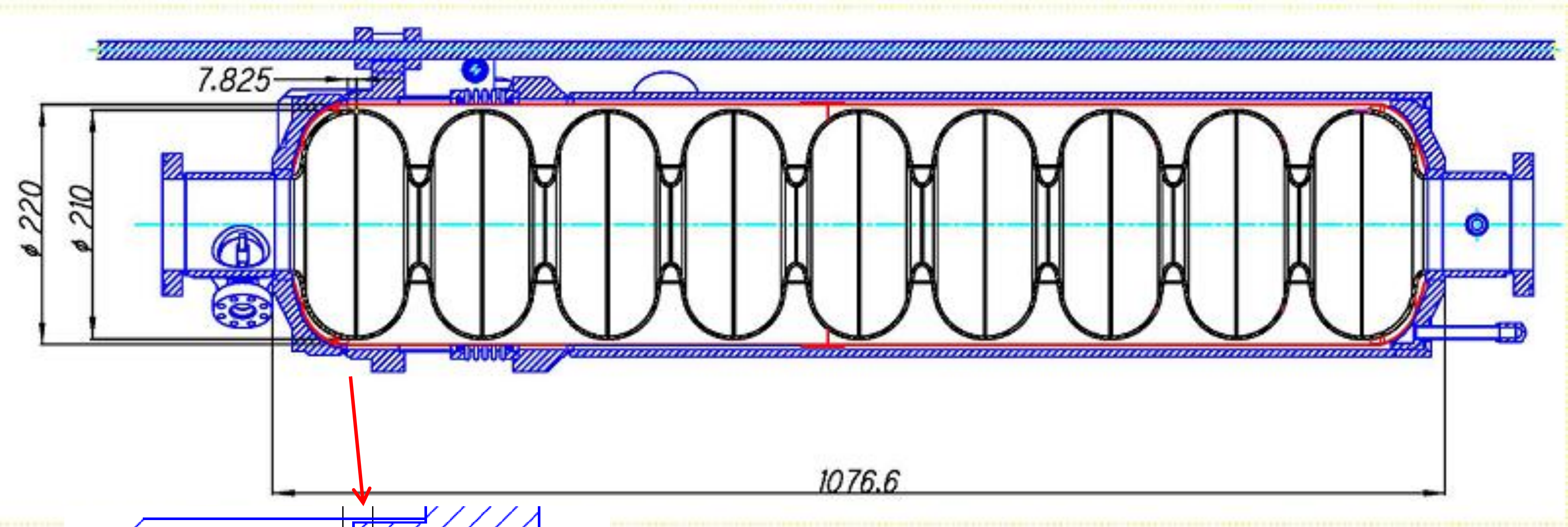
A. Terashima, K. Saito and S. Noguchi

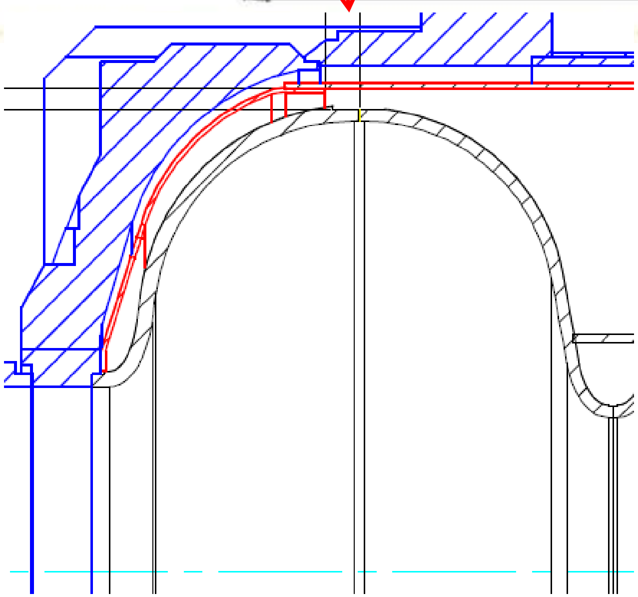
1. Configurations of magnetic shields for KEK-STF cryomodule
2. Field Measurements in the vacuum vessel
3. Field calculation inside the shields
4. Summary

Configuration of the helium vessel for Tesla-like-cavity



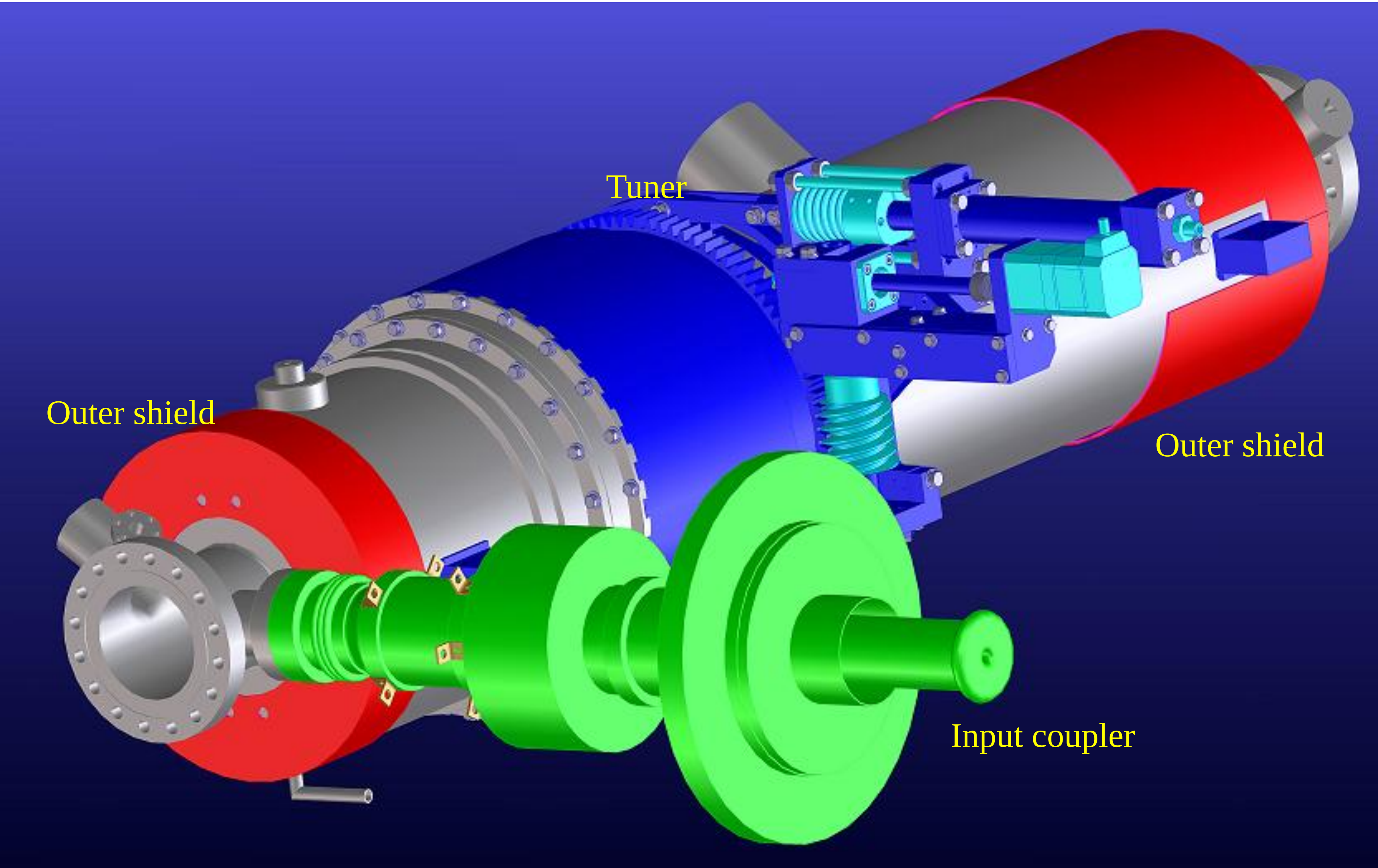
Magnetic shield for Tesla-like-cavity



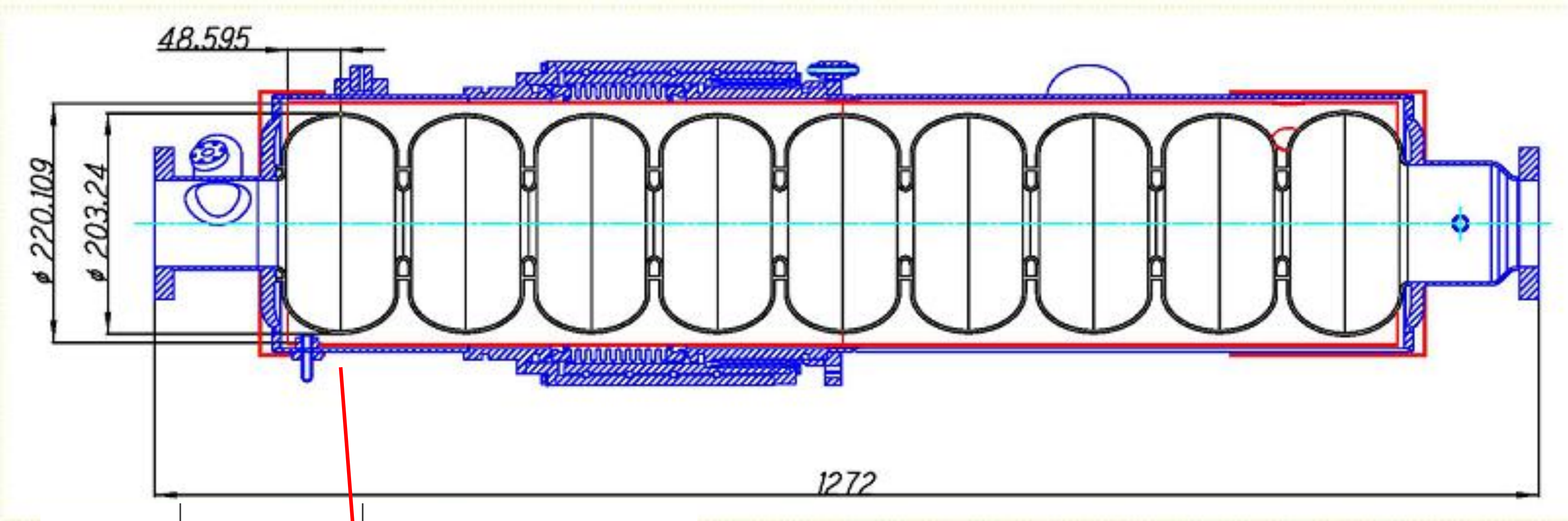


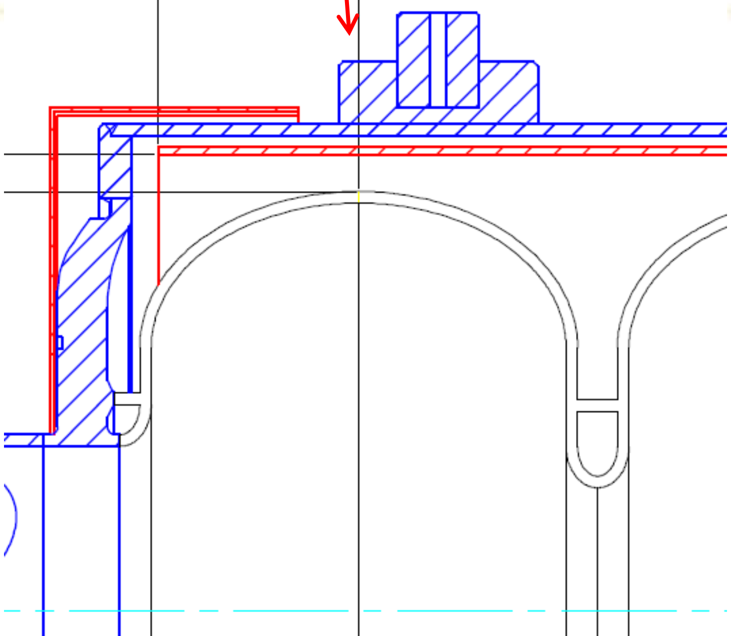
- The magnetic shield system consists of the inner cylinder and the inner ends.
- The thickness of the shield is 1 mm.
- The shield is one layer.
- The length of the cylinder is 978 mm, and the inner diameter is 220 mm.

Configuration of the helium vessel for Low-Loss type cavity



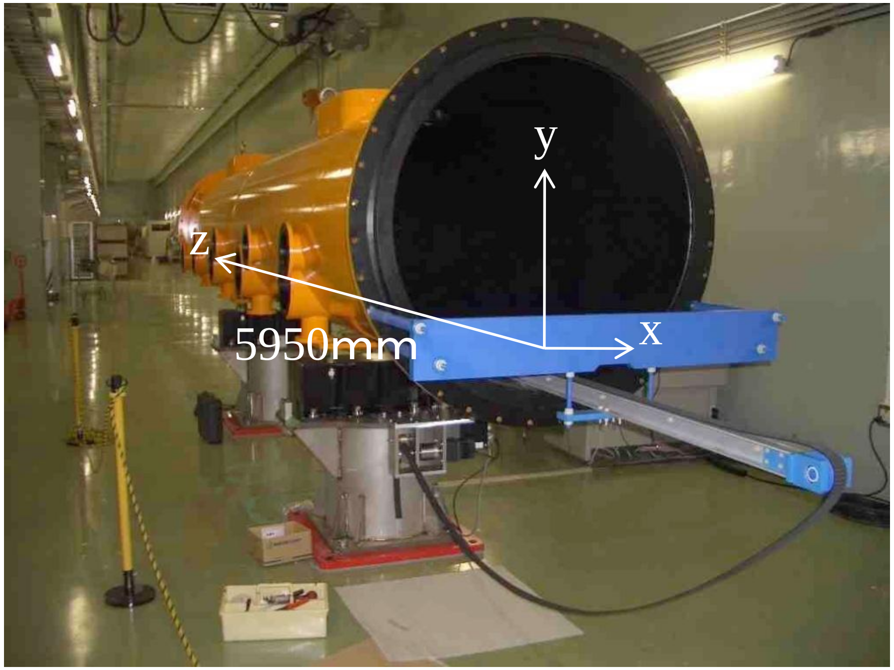
Magnetic shield for Tesla-like-cavity

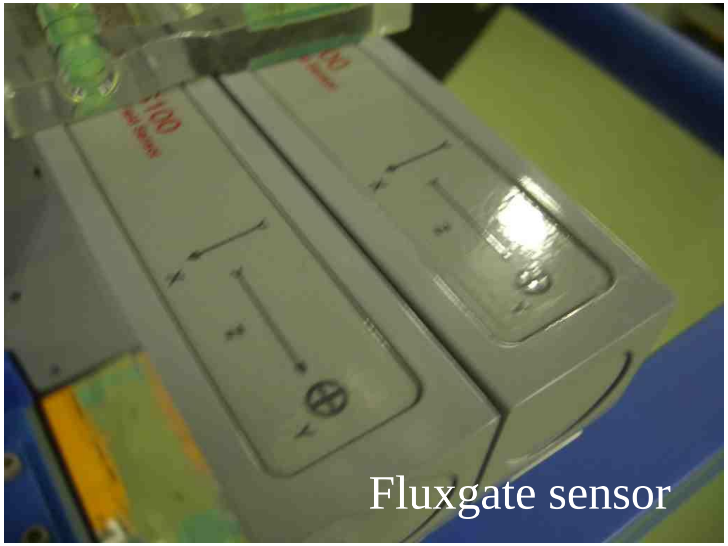




- The magnetic shield system consists of the inner cylinder and the outer ends.
- The thickness of the shield is 1 mm.
- The shield is two layers.
- The length of the cylinder is 1020 mm, and the inner diameter is 220 mm.

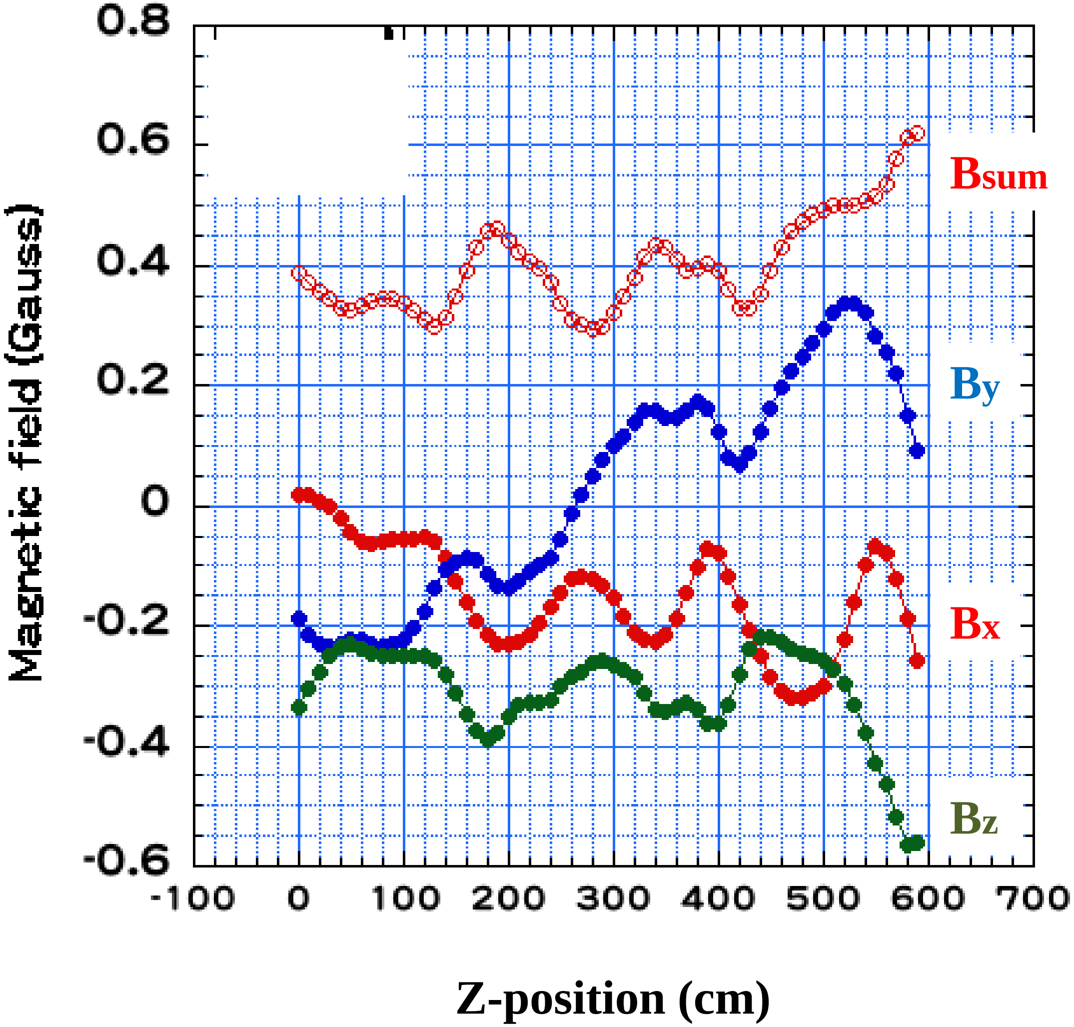
Field Measurements in the vacuum vessel





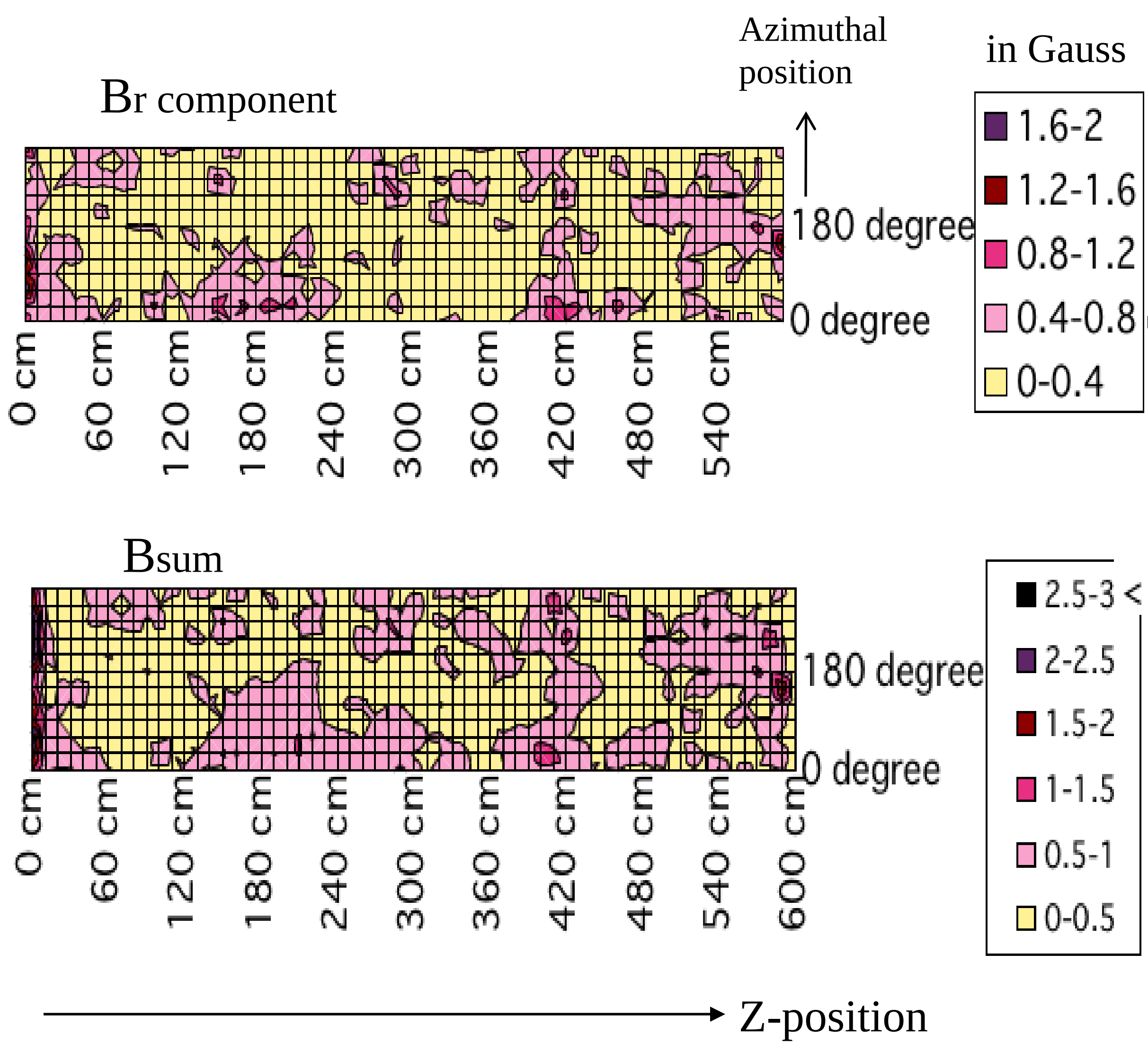
- **In order to estimate the performance of the magnetic shield:**
  - Magnetic field profile in the STF tunnel was measured.
  - Magnetic field profiles inside the vacuum vessel (iron) and at the inner surface of the vacuum vessel were measured.
  - Magnetic field inside the permalloy shield has been measured.
  - Magnetic performance (as material characteristics) of the permalloy at low temperature was measured.
- **The vacuum vessel was demagnetized.**
  - Magnetic field profile in the vessel was measured after demagnetization of the vessel.

Magnetic field profiles inside vacuum vessel



- Field measurements inside the vacuum vessel were performed without closing the end flanges.
- The measured locations were on the beam line.
- The magnetic field strength on the beam line was in the range of from 0.3 Gauss to 0.6 Gauss.
- The magnetic field strength was reduced to 0.2 Gauss by the first demagnetization test.

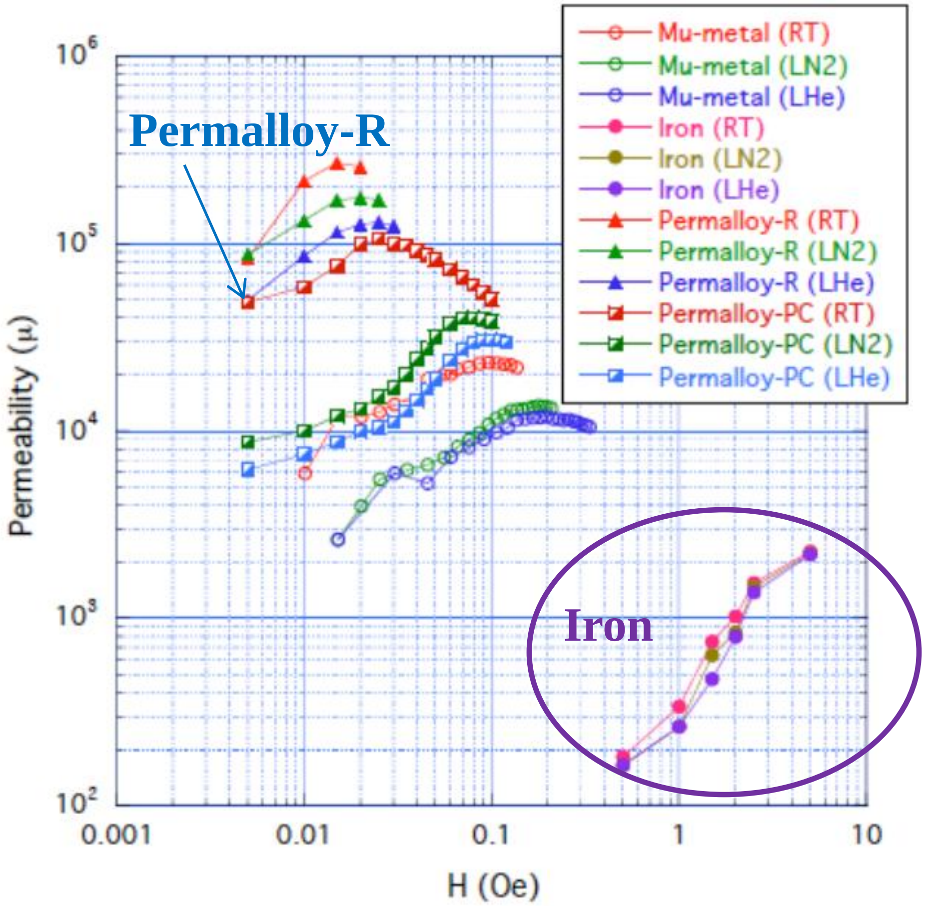
Magnetic field profiles at the inner surface



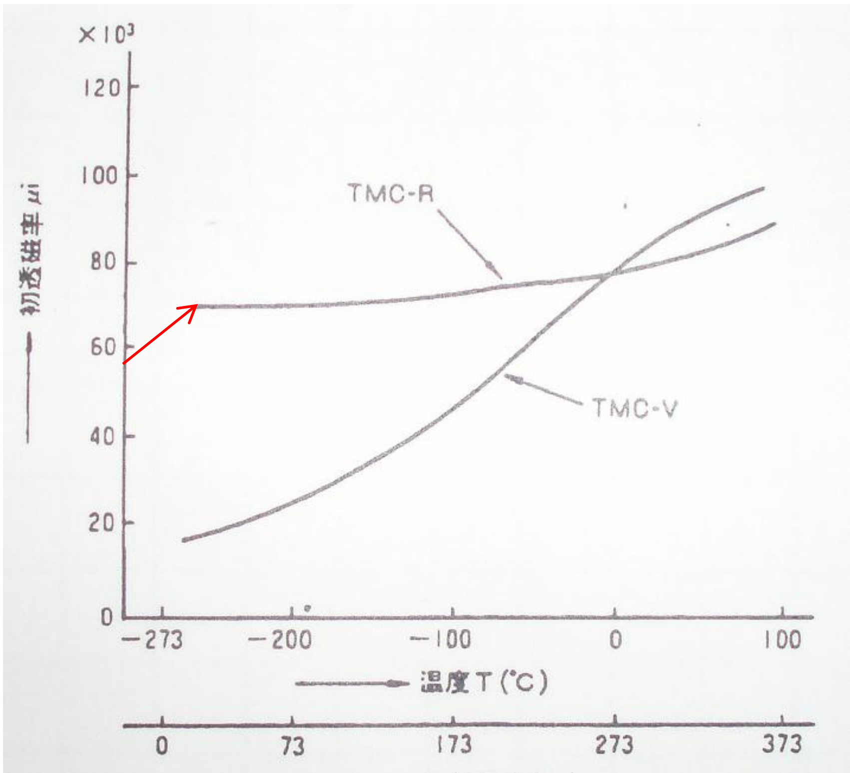
- The vessel is magnetized, rather strongly in places. The magnetized spot has around 3 Gauss locally.
- The strong spots correspond to holes, welds and edges.
- There are some strong spots which do not correspond to any obvious structural differences.
  - Magnetized while being processed at the factory?
  - Magnetic hook?

Note: The vacuum vessel did not undergo any treatment, such as annealing, after being put together.

Magnetic shield material



Permalloy-R has the permeability of 50000 at the temperature of LHe.



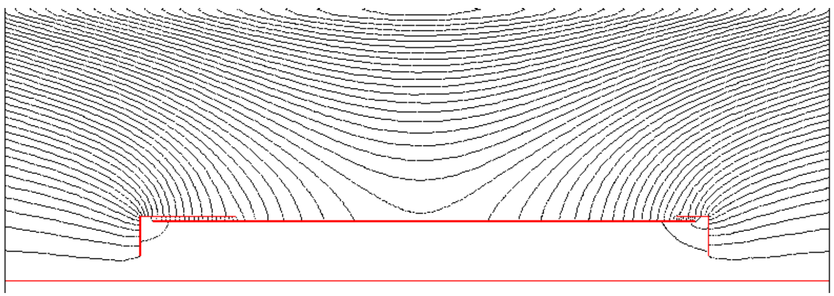
The magnetic property of TMC-R by TOKIN. The typical permeability at the temperature of LHe is 70000. The Curie temperature of the material is 450℃. TOKIN is the metal company in Japan.

The magnetic field calculations in the magnetic shields for the STF cryomodules

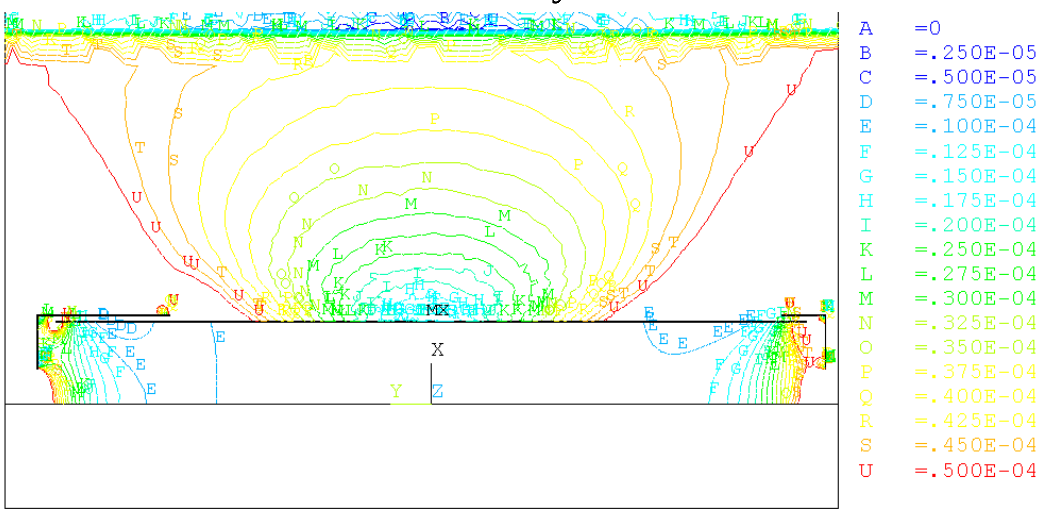
- The magnetic field calculations have been done for the magnetic shields of the Tesla-type-cavity and Low-loss-type cavity in the STF cryomodules.
  - For the calculation conditions, the solenoid field of 0.5 Gauss was applied to the two types of cavities. The magnetic field profiles for the two types were compared.
  - The permeability of the material was 40000 in the calculation.

- For the simplified model of the magnetic shield of Tesla-type-cavity
  - The effects of the demagnetization of the vacuum vessel on the field profile were studied by changing the solenoid field.
  - The effects of the different permeability on the field profile were studied.
  - In the beam pipe area, where two cavities are connected, the magnetic shield was modeled outside the helium vessel and the calculation of the magnetic field was done.

Magnetic field calculation for the LL cavity



Magnetic flux profile for the magnetic shield of the LL cavity

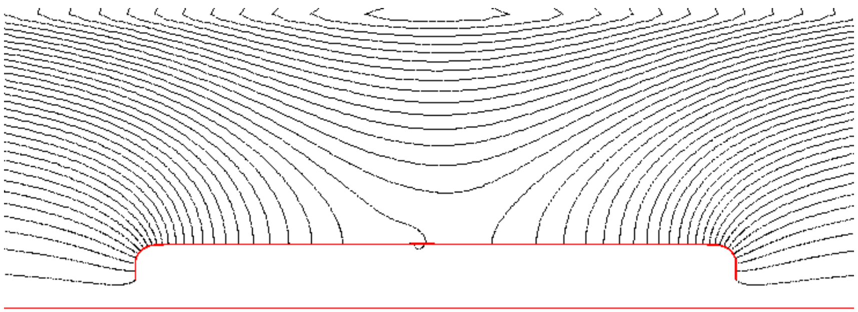


Contour plot of the magnetic field profile for the shield of the LL cavity.
The plotted lines are from 0 to 0.5 Gauss.

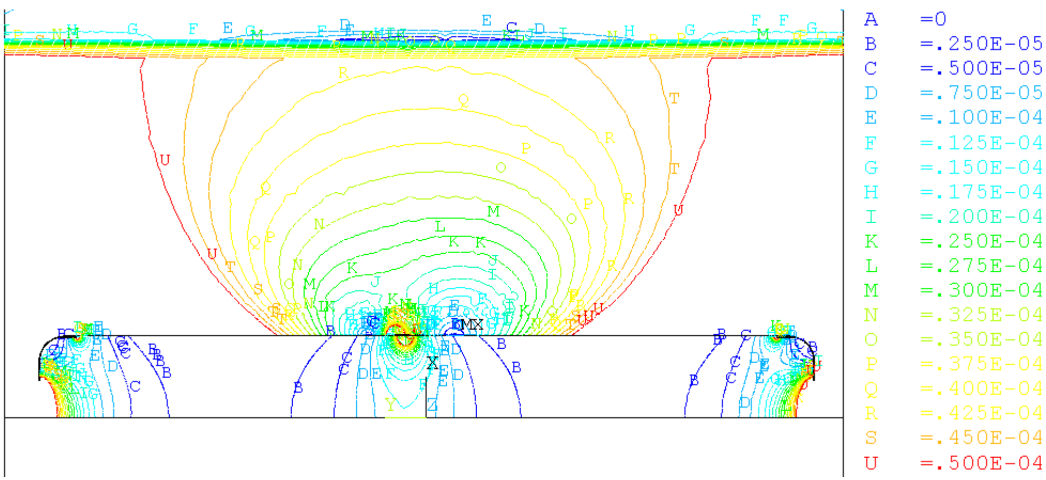
Calculation model for the LL cavity

- The shields has the following configuration;
  - The cylinder part is mounted inside the helium vessel.
  - The end parts are mounted outside the helium vessel.
  - Between the cylinder part and the end parts, there are gaps of 7.5 mm.
- The shield are located in the solenoid field of 0.5 Gauss.
- The permeability of the material is 40000.
- At the center of the shield, the magnetic field was calculated to be less than 0.1 Gauss, and at the right end, the magnetic field on the cavity equator is 0.3 Gauss.

Magnetic field calculation for the Tesla-type cavity



Magnetic flux profile for the magnetic shield of the Tesla-type cavity

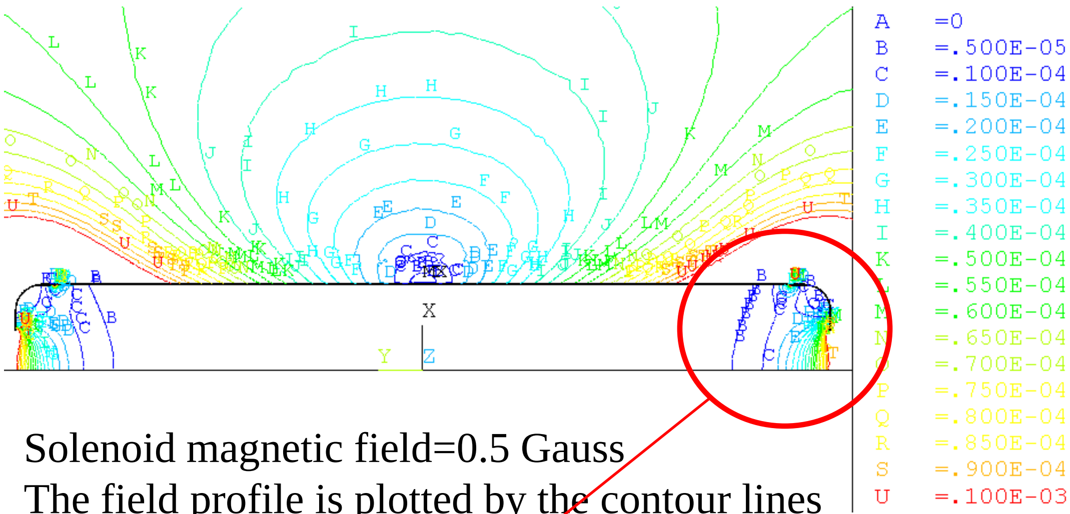


Contour plot of the magnetic field profile for the shield of the Tesla-type cavity.
The plotted lines are from 0 to 0.5 Gauss.

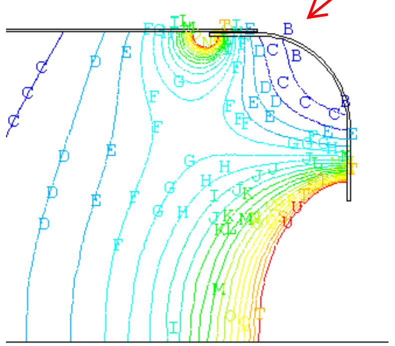
Calculation model for Tesla-type

- The whole shields are mounted inside the helium vessel.
  - The shield system consists of the two cylinder and two ends.
  - The cylinder is separated into two parts. This separation is due to the size of the hearth in the company.
  - The gaps between the components are assumed to be 0.5 mm.
- The shield are located in the solenoid field of 0.5 Gauss.
- The permeability of the material is 40000.
- Since there is separation of the cylinder shield in the model, the leak field in the middle part is higher than the field for the LL type.
- In the ends, the leak field is much less than the field for the LL type.

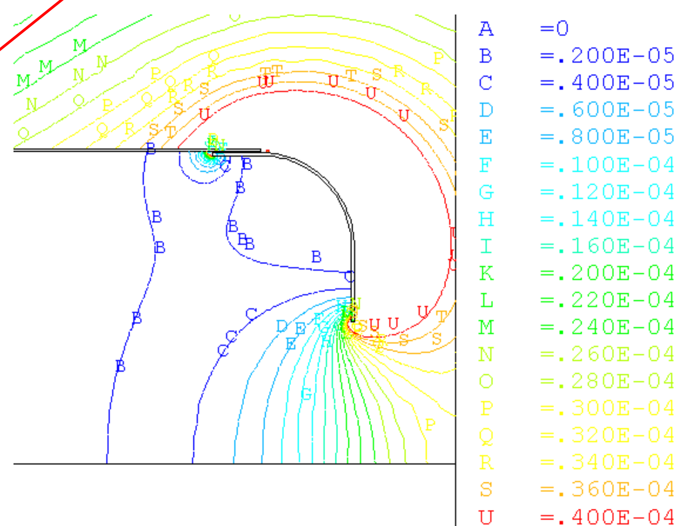
Demagnetization effects of the vacuum vessel



Solenoid magnetic field=0.5 Gauss
The field profile is plotted by the contour lines from 0 to 1 Gauss.



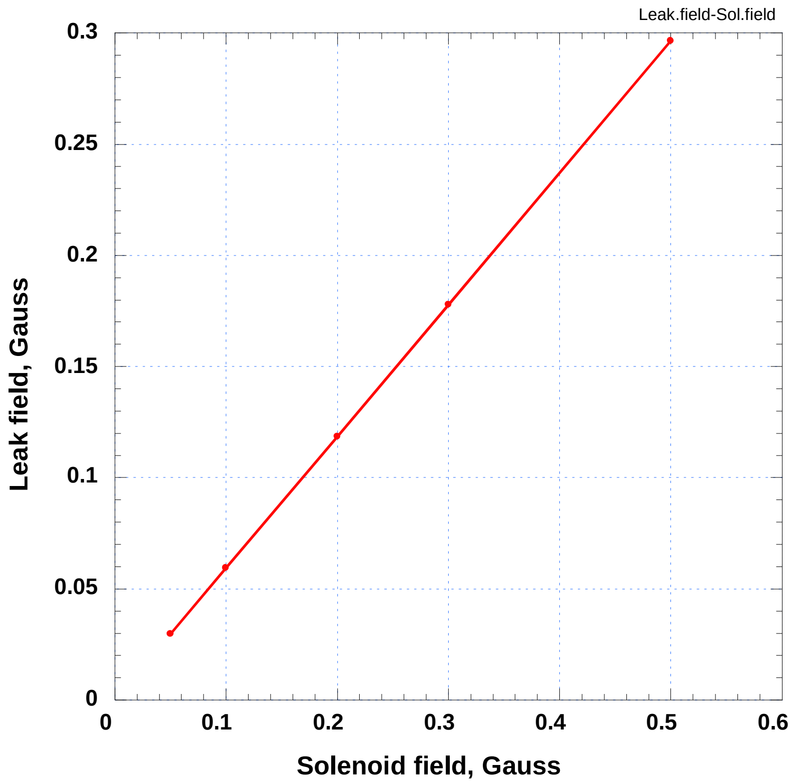
Solenoid field=0.5 Gauss
Contour lines from 0 to 0.4 Gauss

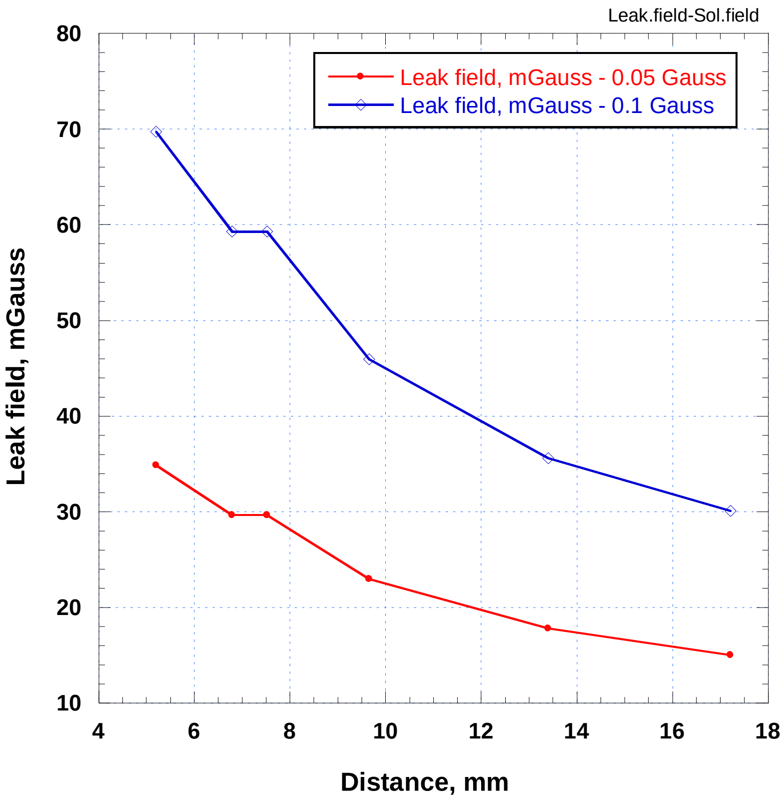


Solenoid field=0.1 Gauss

- Demagnetization effect of the vacuum vessel on the magnetic field profile was studied with changing the solenoid field for the simplified shield system of the Tesla-type cavity.
  - There is no separation in the shield cylinder. There are gaps of 0.5 mm between the cylinder and the end shields.
  - The permeability of the shield material is 40000.
  - In this model, the magnetic field strength in the middle section of the cavity is less than 20 mGauss for the solenoid field of 0.5 Gauss.
- From the calculated field profile in the end region, the leak field at the equator of the end cell can be reduced from 0.4 Gauss to 0.06 Gauss for the solenoid field of 0.1 Gauss.

Leak field characteristics in the ends



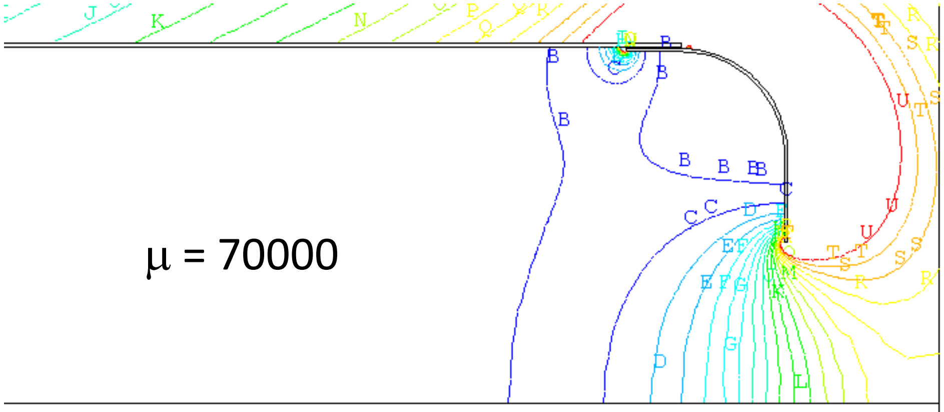


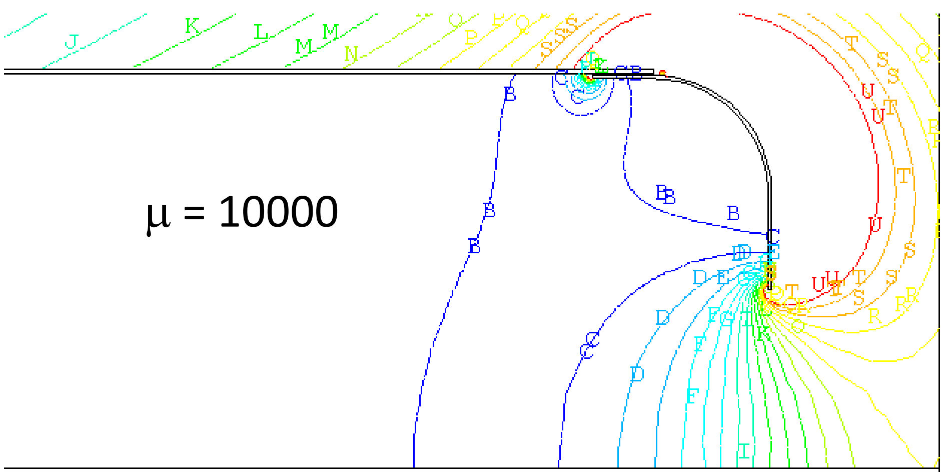
- Leak field on the equator of the end cell changes linearly with the outer solenoid field.
- For this calculation model, in order to reduce the leak field less than 30 mGauss, the outer field should be reduced to 50 mGauss by demagnetization of the iron vacuum vessel.

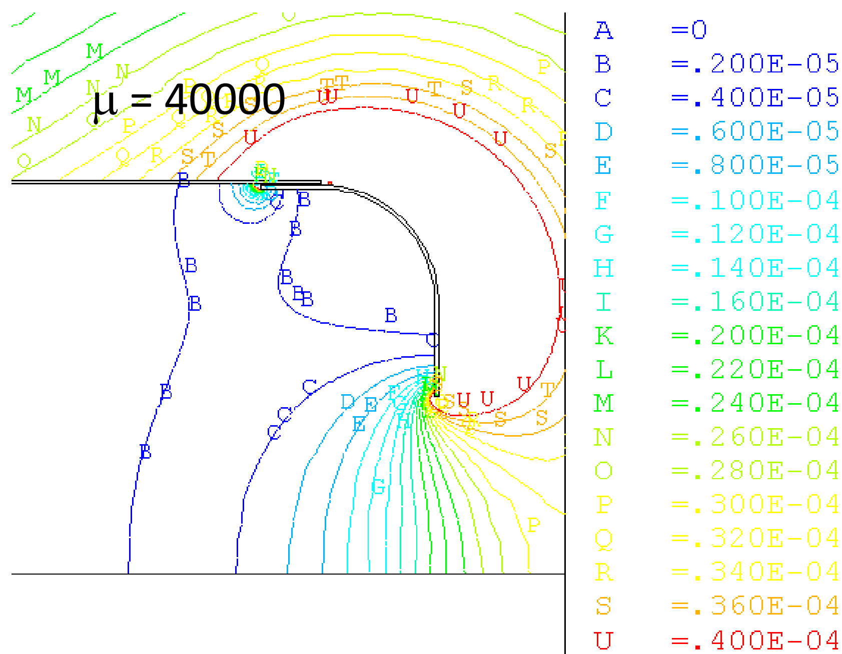
- The relation between the leak field and the distance from the gap at the end to the specific location.

Effects of permeability of the shield material on the field profile

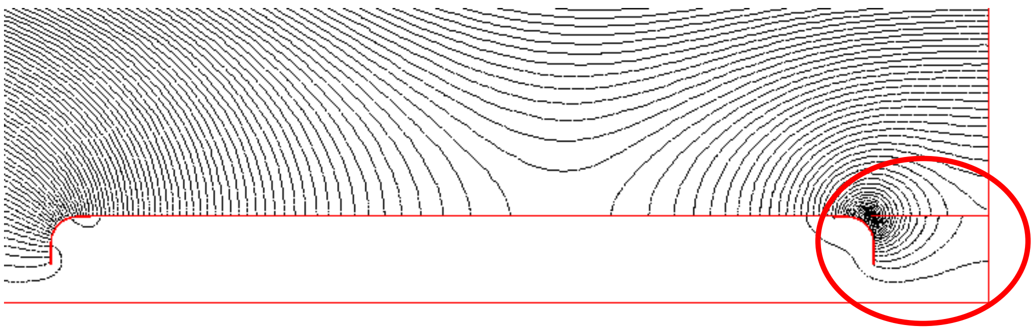
- From the calculation of the demagnetization effect on the leak field, the magnetic field inside the vacuum vessel should be less than 0.1 Gauss.
- The field profile is studied for the solenoid field of 0.1 Gauss by changing the permeability of the shield material.



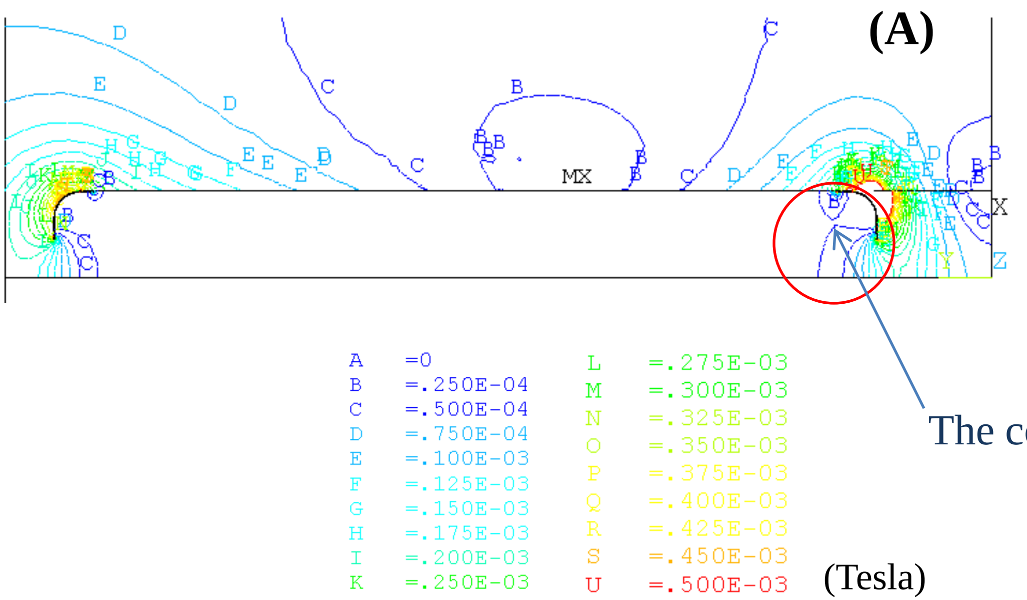




Outer shield between the cavity vessels (1)



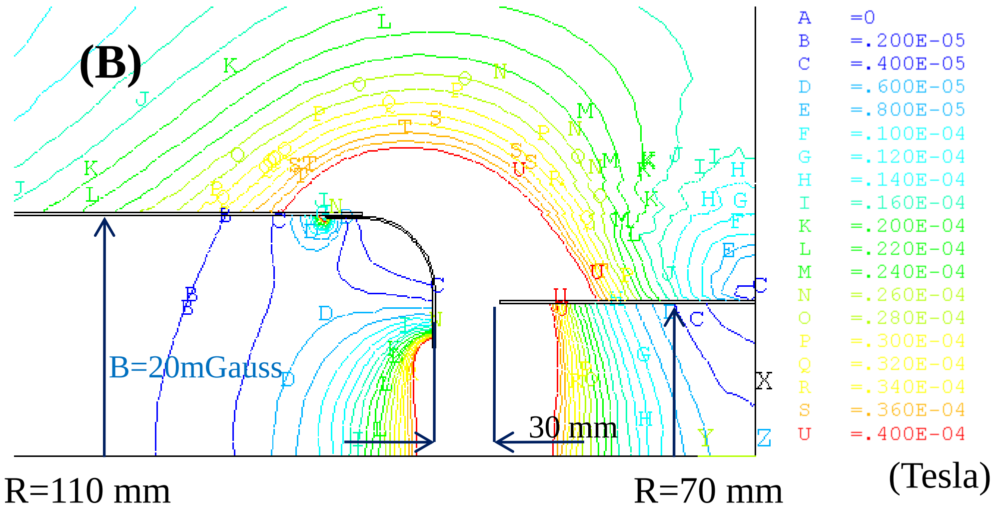
Additional shield between cavities out of the helium vessel



The contour line B corresponds to 0.25 Gauss.

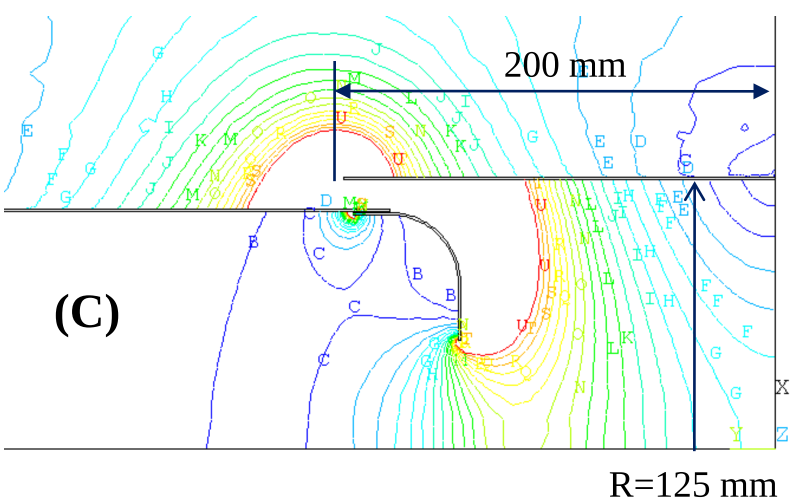
- The calculation condition;
  - Outer field: 0.5 Gauss
  - μ = 40000
  - The additional shield diameter is the same as the cylinder section in the helium vessel. The distance between the inner shield and the additional shield is 30 mm.
- The additional shield absorbs the magnetic flux. Between the inner shield and the additional shield, the magnetic field is over 5 Gauss.
- By the concentration of the magnetic flux, the magnetic field inside the shield is increased.

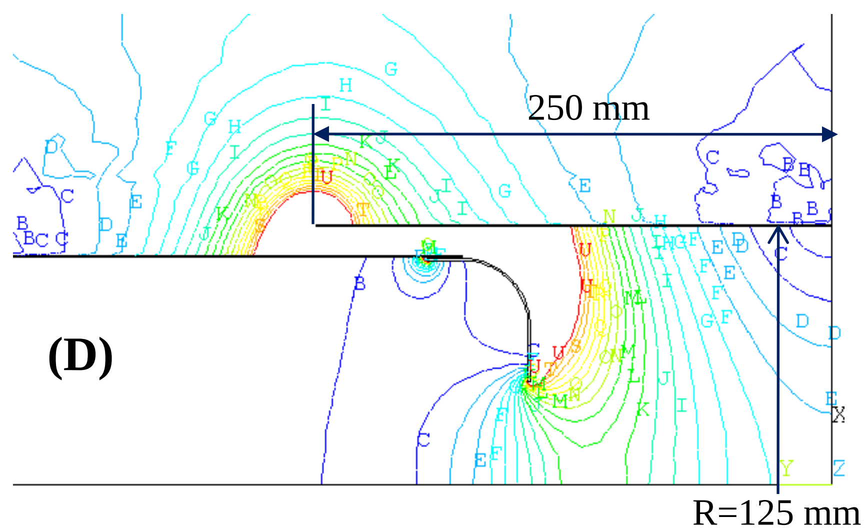
Outer shield between the cavity vessels (2)



Calculation conditions:
Solenoid magnetic field =0.1 Gauss
μ= 40000

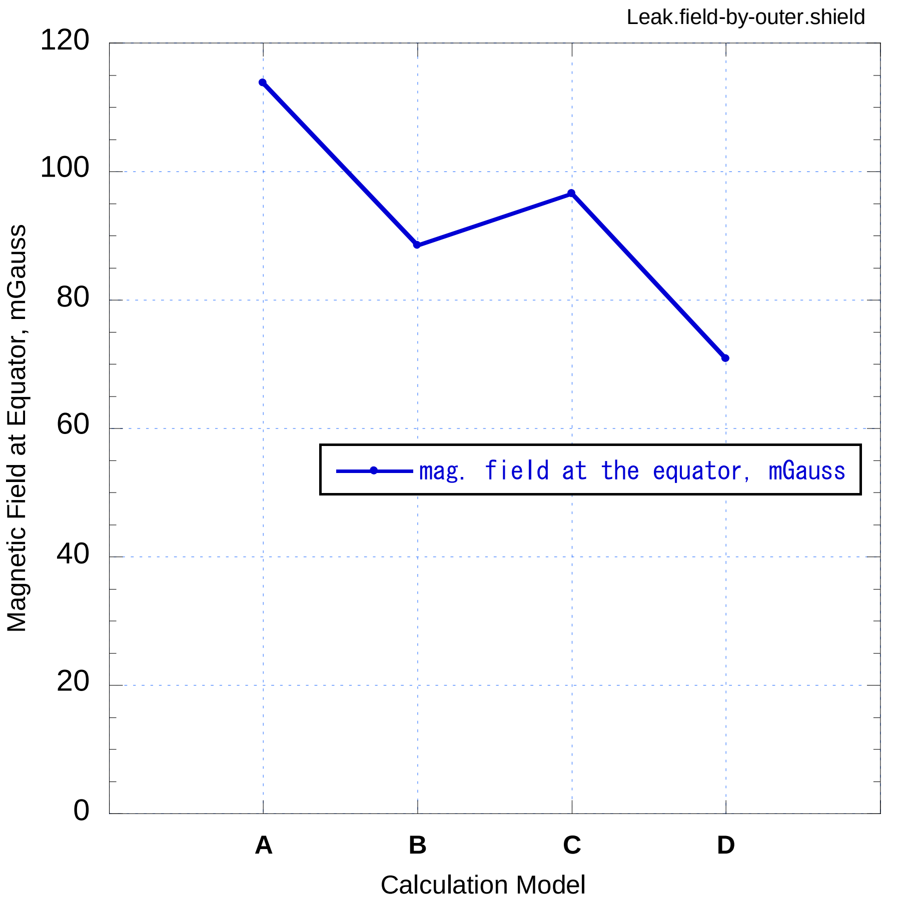
(1) Additional shield radius = 70 mm, distance between the inner shield and the additional shield = 30 mm.
(2) Additional shield radius = 125 mm, the half length of the additional shield = 200 mm.
(3) Additional shield radius = 125 mm, the half length of the additional shield = 250 mm.





Outer shield between the cavity vessels (3)

- The outer shields at ends are necessary for reducing the flux penetration from the beam pipe.
- The outer shield absorbs the magnetic flux, and as the result, the magnetic field of the area between the inner shield and the outer shield increases.
- From the present calculation, the outer shield needs the longer length than 50 mm from the gap between the cylinder and the end shields.
  - The leak field strength for the model A is almost same as that for the model without outer shield.
  - The optimization of the outer shield length should be done.



Calculated leak field on the equator of the cavity cell in the end for the model A to D.

Summary

- The magnetic shield design is required to be done with demagnetization of the iron vacuum vessel.
  - Demagnetization < 0.1 Gauss ??
  - The target leak field<10mGauss ?? (dependent on Q value)
- The location of the gap between the cylinder shield and the end shield has a strong influence on the field profile.
- The change of permeability in the shield material from 10000 to 70000 does not show a large change in the field profile.
- The additional shield between the cavities absorbs the magnetic flux, and introduction of this shield can easily increase the magnetic field around the ends.
  - The geometry and location of the shield should be well designed.
  - From the point of design view of the magnetic shield system, the tuner should locate in the middle of the helium vessel.
- After completing the design of the magnetic shield, the design of the helium vessel can be finalized.