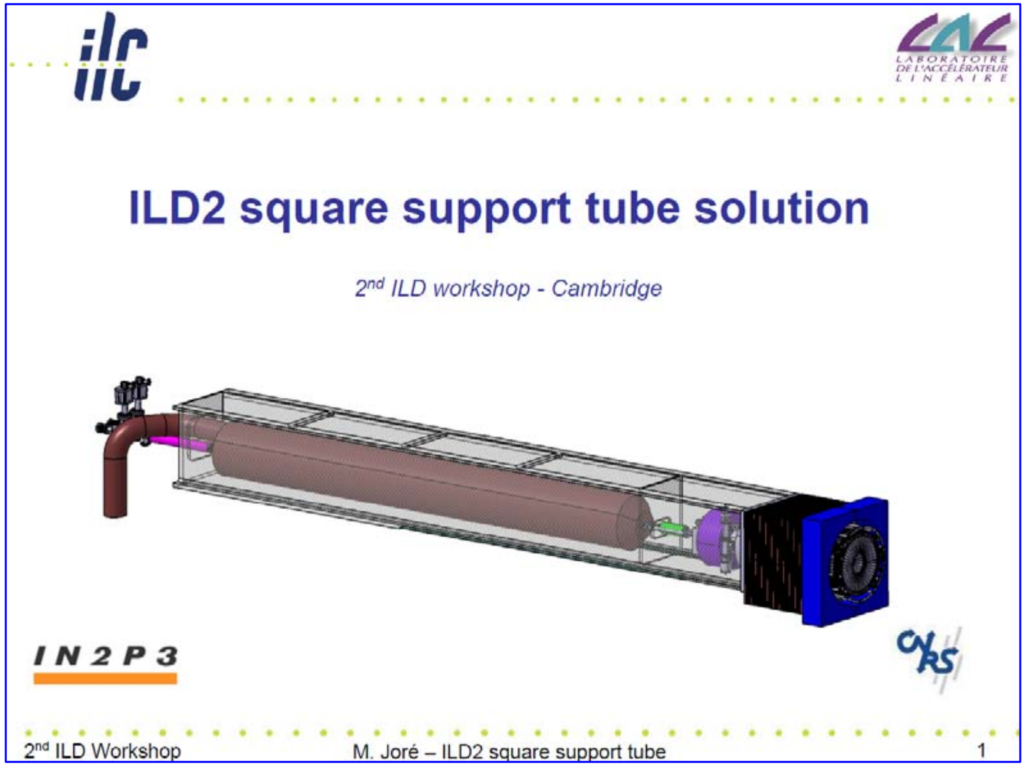
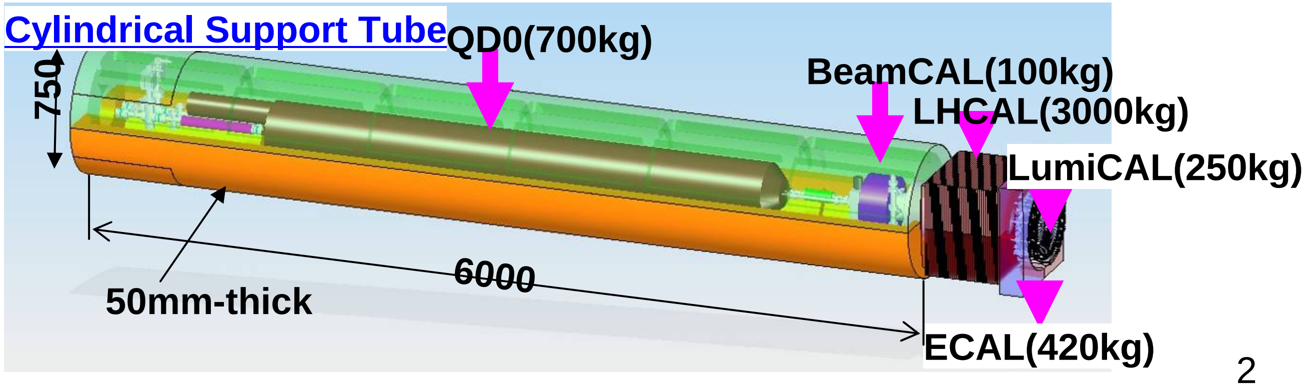
Cylindrical and rectangular support tube properties

KEK Hiroshi Yamaoka

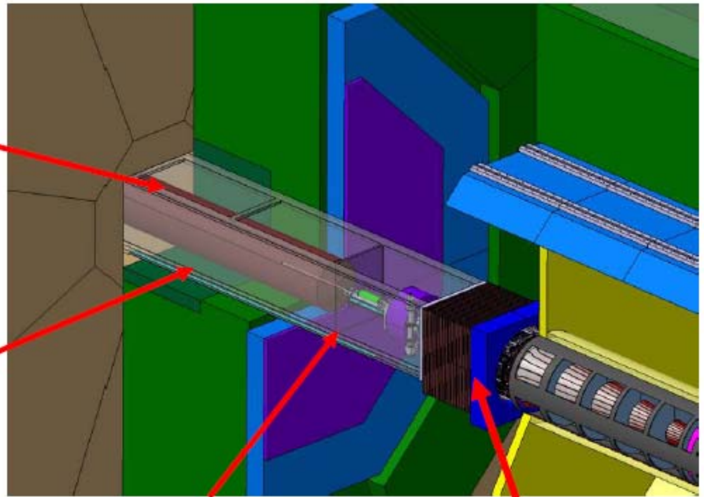
Two types of support tube has been studied.

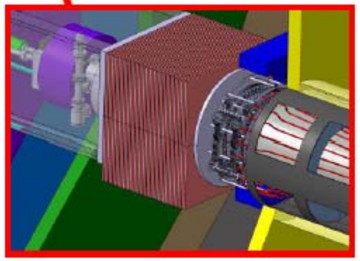




Forward region

- Description





Forward Cals

- Requirements on support tube
  - **Support all the forward components**
  - **Good vibration performance (QD0 stability)**
  - **Allowable amplitude**
    - Few mm in static load
    - About 50nm for ground motion (IR interface document)
  - **Alignment system is needed (in a mm range)**

Boundary conditions;

-FEM analyses

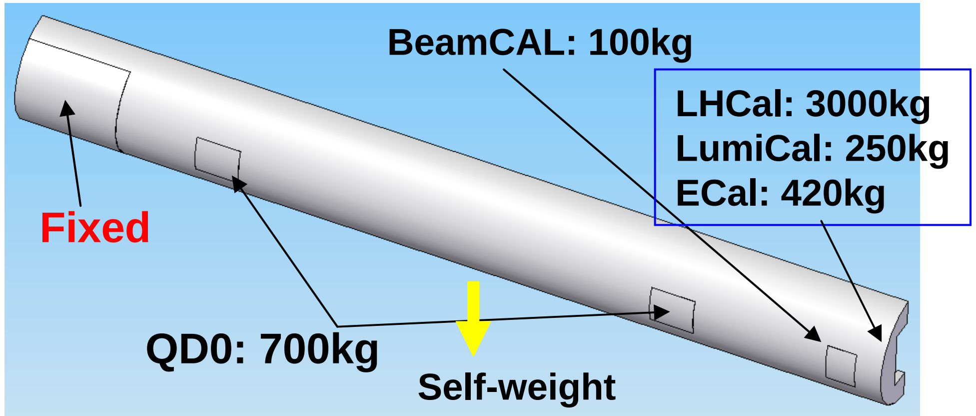
・Static analysis
・Modal analysis
・Dynamic load such as ground motion

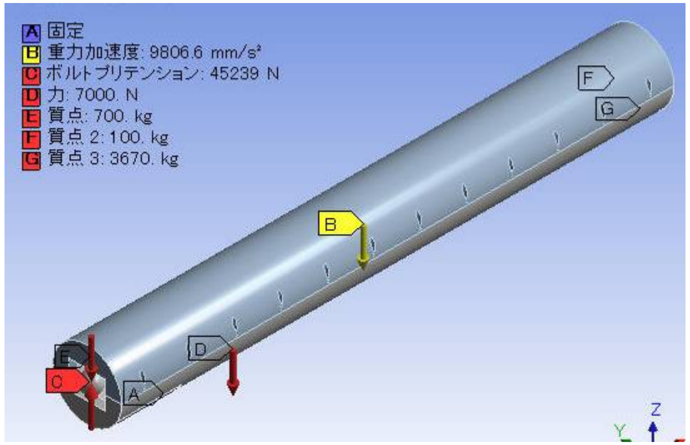
- Materials

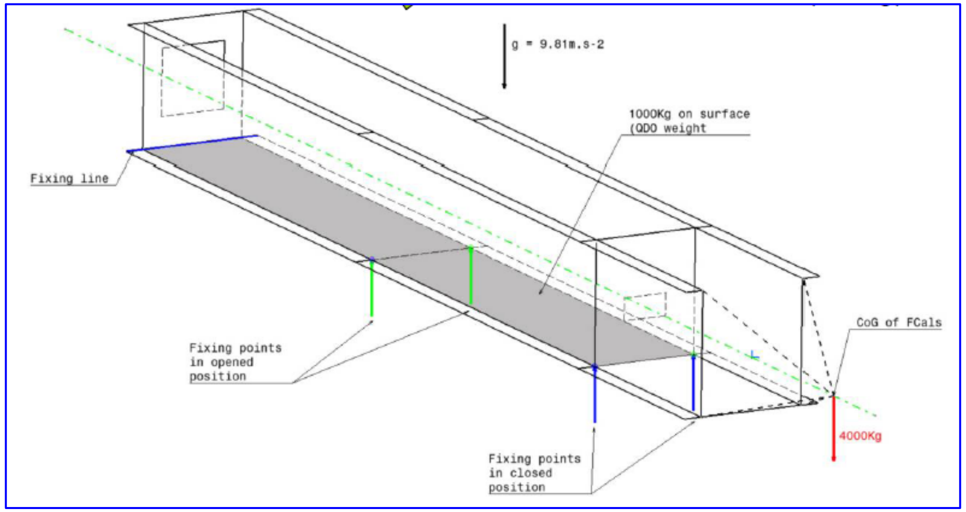
- Stainless steel

-Load condition

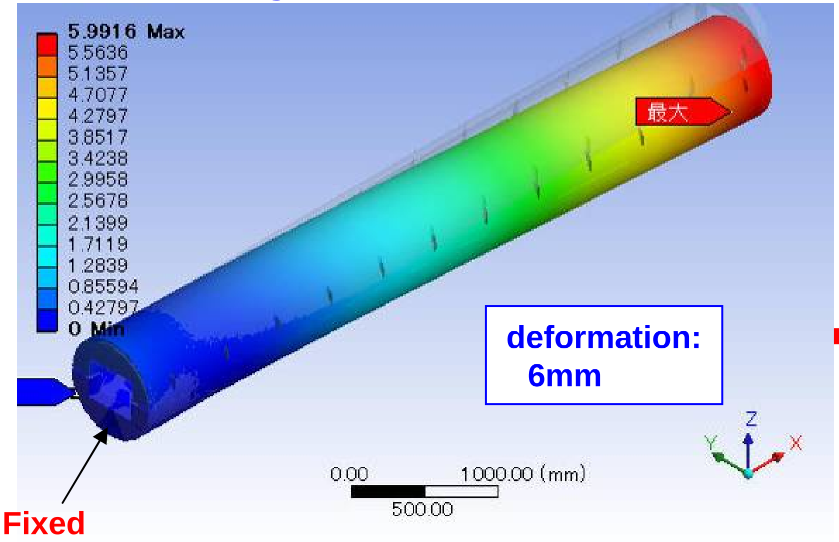
See: right-upper







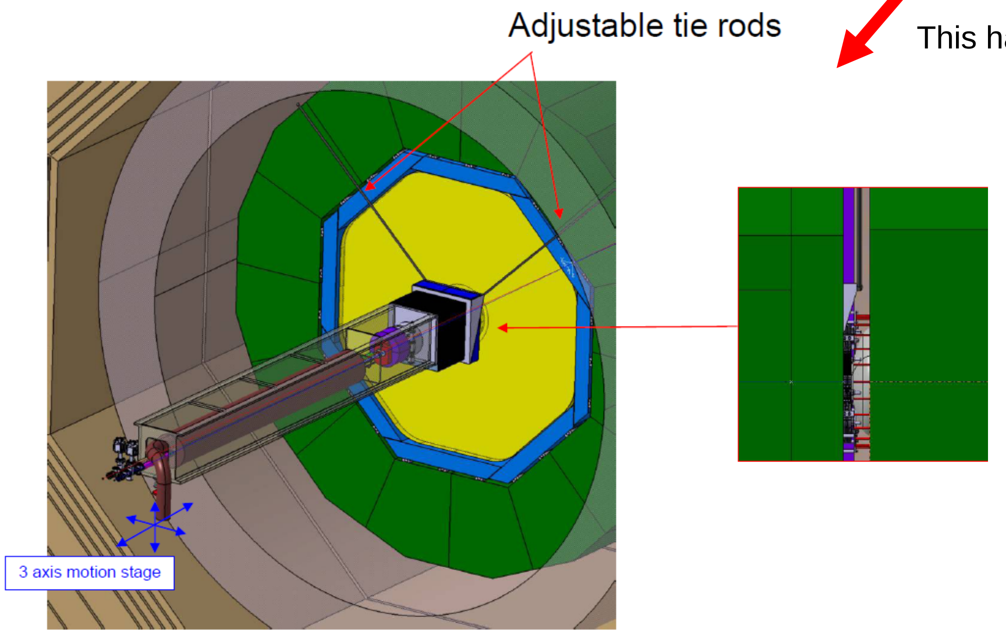
Results: Cylindrical tube



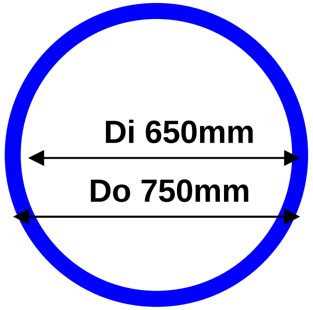
Cantilever type is not good to support the support tube.
Unknown movement will occurs.

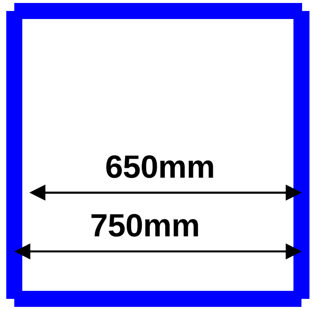
Support tube should be supported at two positions.

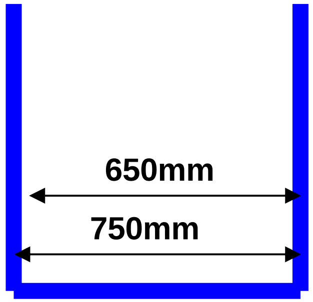
This had been already proposed at the square tube.



Strength comparison with various shape

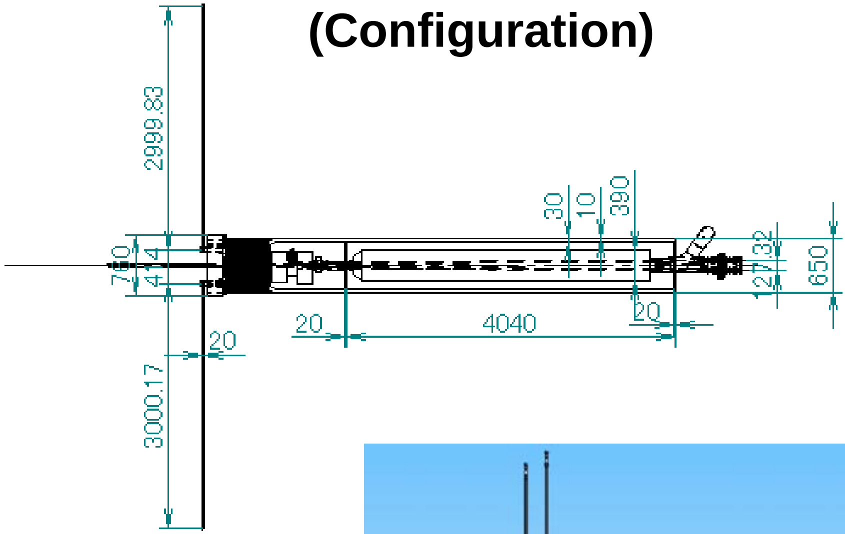


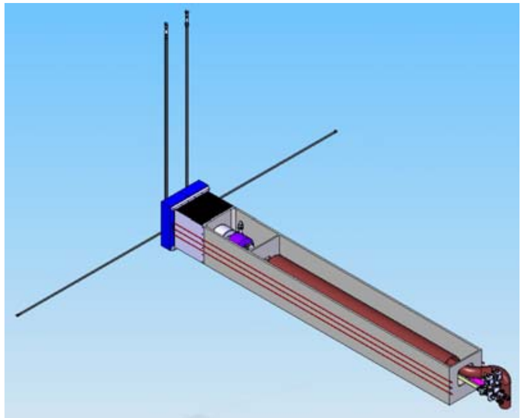


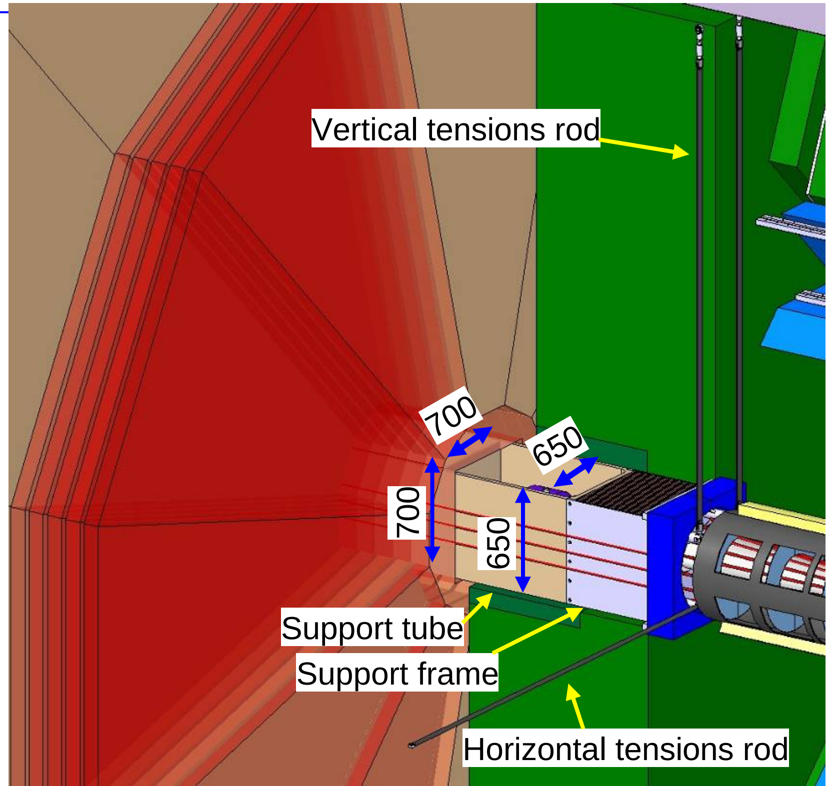


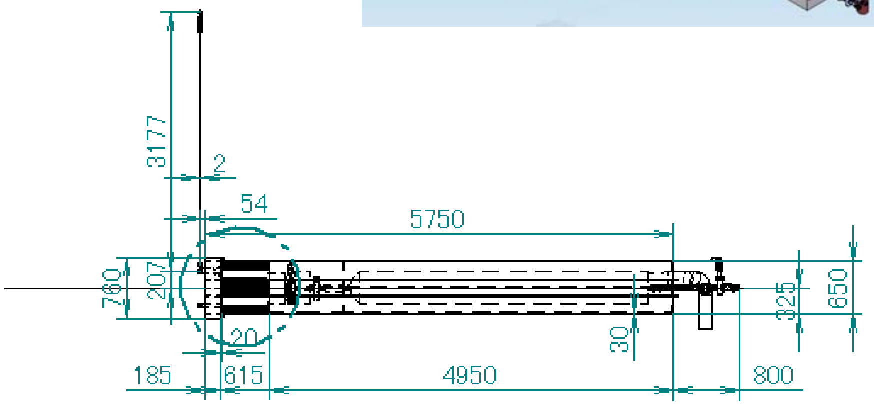
Bending D_B=ExI E: Young's modulus I: Moment of Inertia	$I=\frac{\pi\left(D_O^4-D_i^4\right)}{64}$ I = 6.77e9mm^4 1	$\frac{D_O^4-D_i^4}{12}$ I = 11.5e9mm^4 1.4	I = 6.3e9mm^4 0.93
Tension D_A=ExA E: Young's modulus A: Area	$I_A=\frac{\pi\left(D_O^2-D_i^2\right)}{4}$ A = 1.1e5mm^2 1	$D_O^2-D_i^2$ A = 1.4e5mm^2 1.3	A = 1.08e5mm^2 0.98
Torsion D_t=ExI$_p$ E: Young's modulus I: Polar moment of inertia	$I_p=\frac{\pi\left(D_O^4-D_i^4\right)}{32}$ I$_p$ = 13.5e9mm^4 1	$\frac{2.25\cdot(D_O^4-D_i^4)}{16}$ I$_p$ = 19.4e9mm^4 1.4	$D\cdot t^3$ I$_p$ = 9.4e7mm^4 0.01

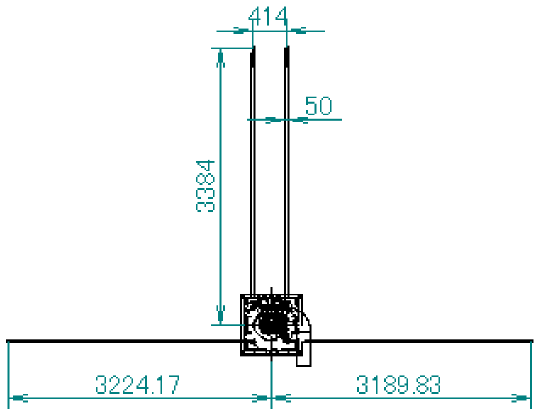
(Configuration)





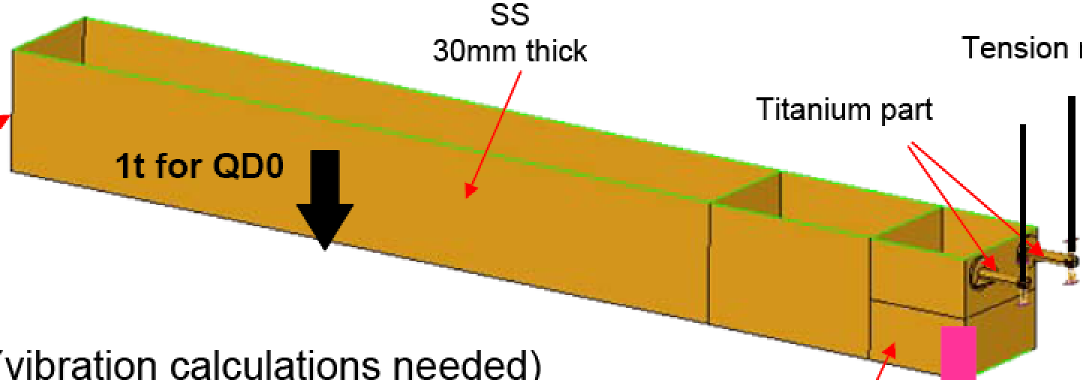






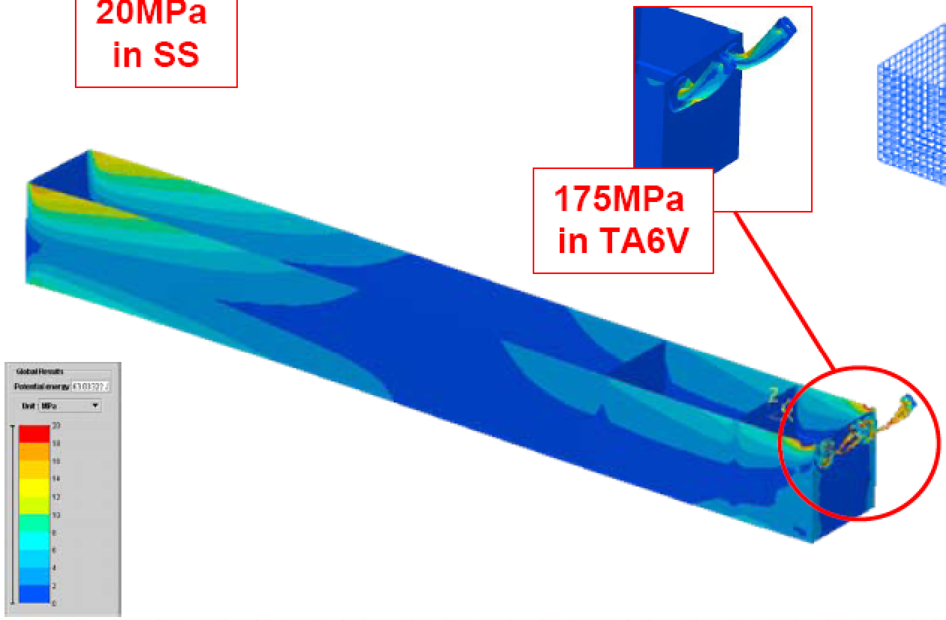
FEA calculations

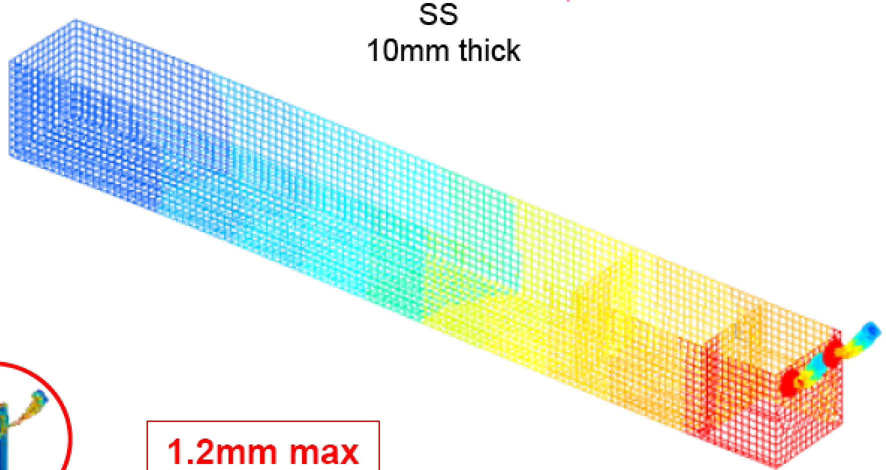
- Model



- First results (vibration calculations needed)

20MPa in SS

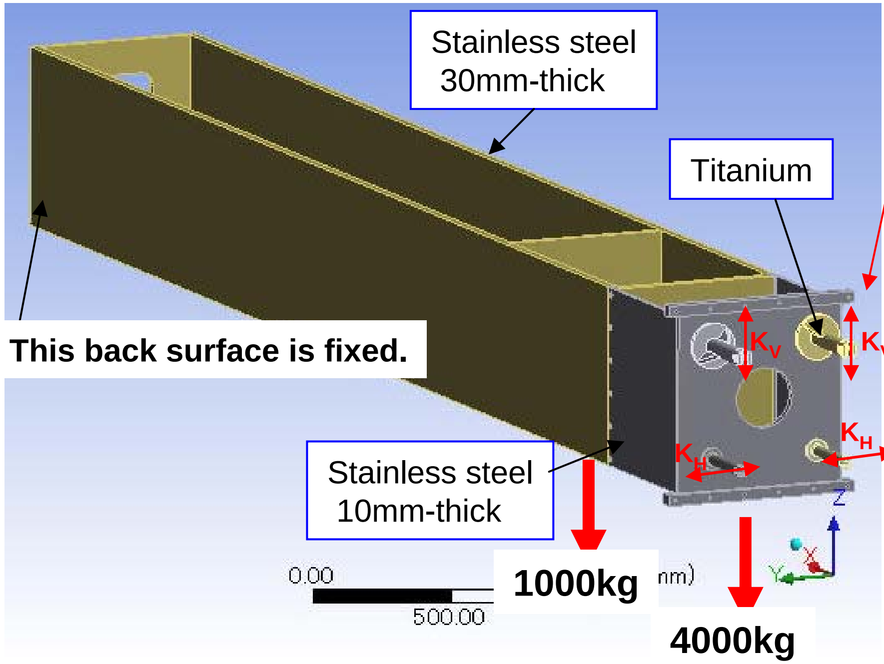


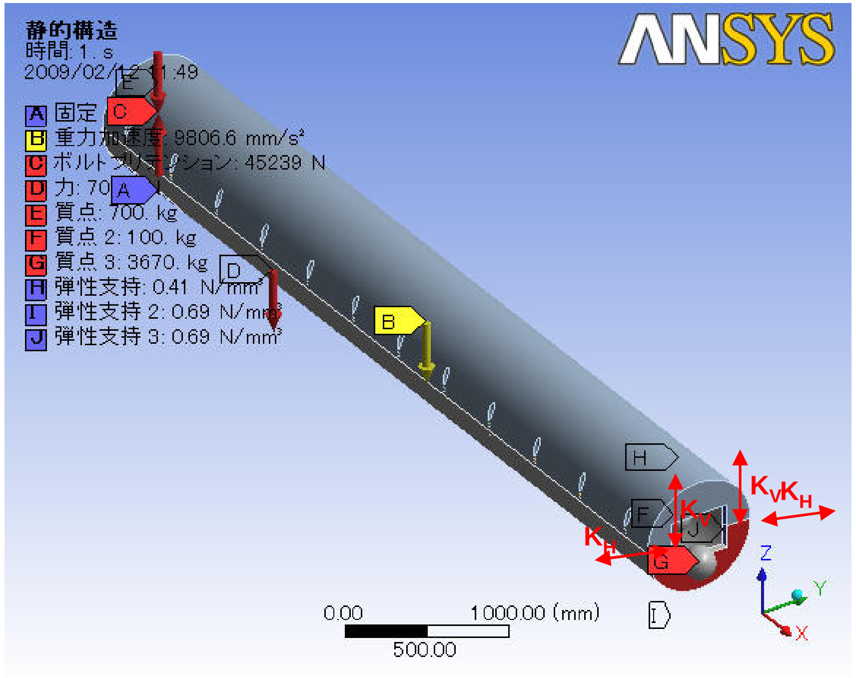


1.2mm max

Corrected with tension rods length

(Modeling)





Calculation of spring constant of the tension rods.

For the modeling of tension rods, spring constants are defined on the top of support rods.

Tension rods; CFRP
E=130GPa
Density: 1.5e-6kg/mm^3

$$\sigma = \varepsilon \cdot E$$

$$P/A = \frac{\Delta l}{l} \cdot E$$

$$P = \frac{\Delta l}{l} \cdot E \cdot A$$

When Δl is $1mm$, P shows the spring constant.

$$P_{vertical} = \frac{1}{3180} \cdot 1.3 \times 10^4 \cdot (50 \times 2)$$

$$= 410kg$$

$K_V = 410\,kg/mm$: Spring constant of the vertical tension rods.

$$P_{horizontal} = \frac{1}{3000} \cdot 1.3 \times 10^4 \cdot \pi (20^2 - 18^2)$$

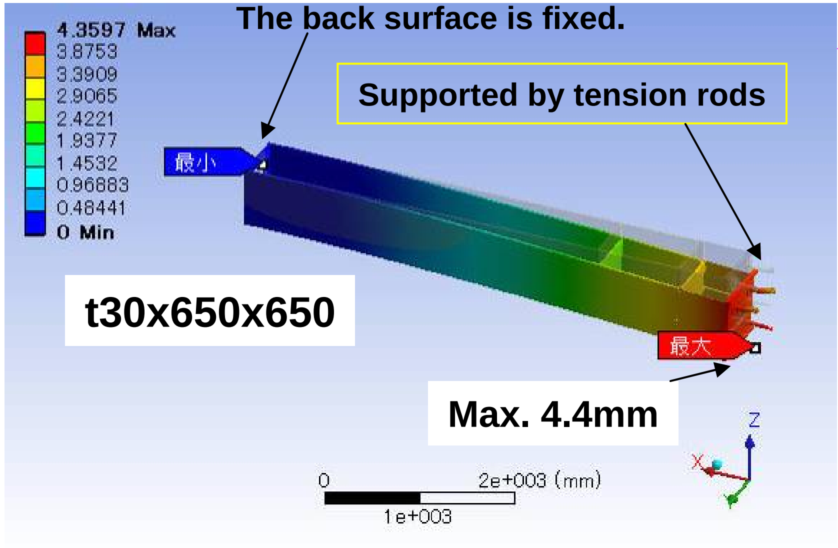
$$= 1035kg$$

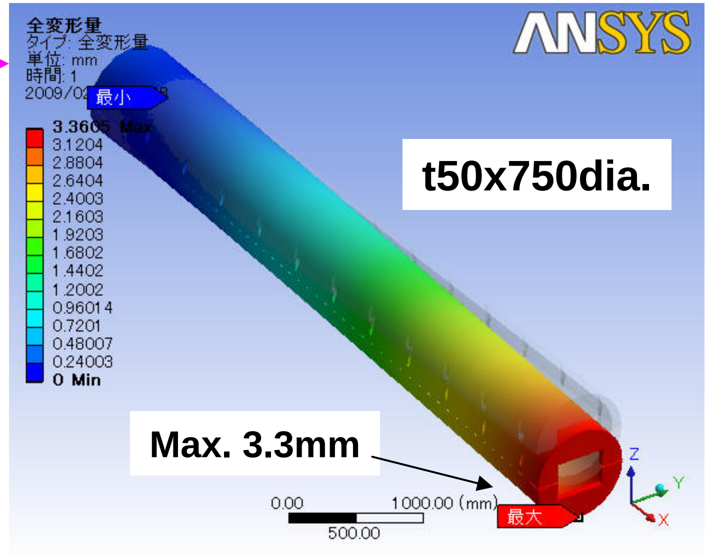
$K_H = 1035\,kg/mm$: Spring constant of the horizontal tension rods.

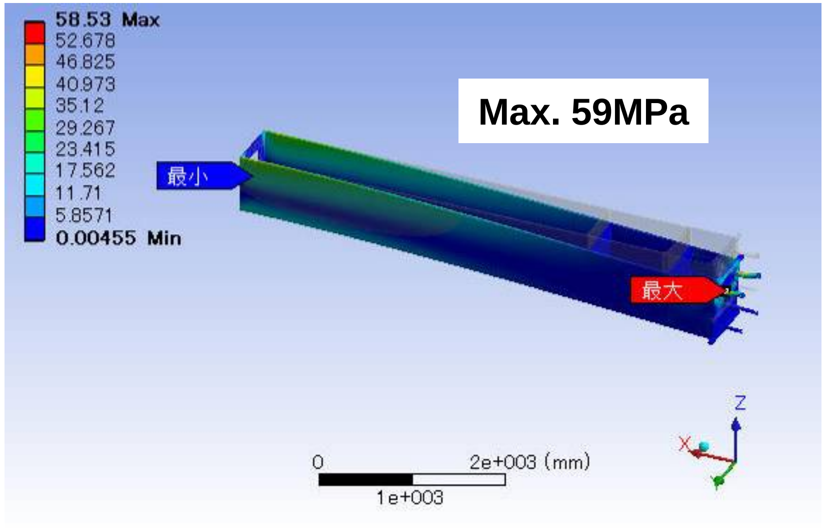
Results of static analysis

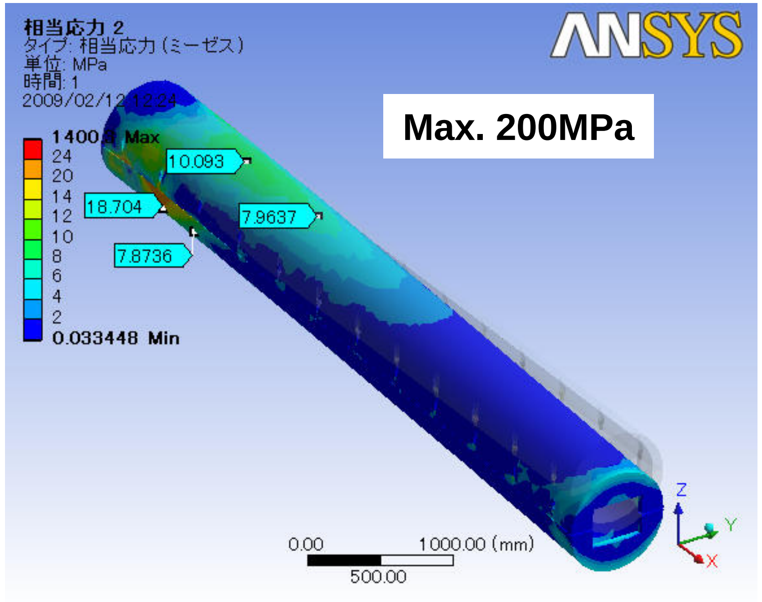
(Supported by tension rods)

*) Size of the tube is not same!



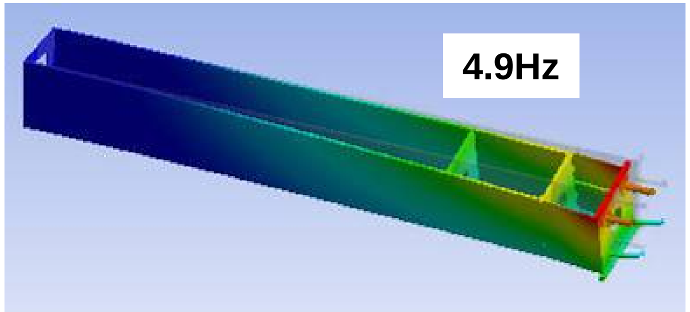


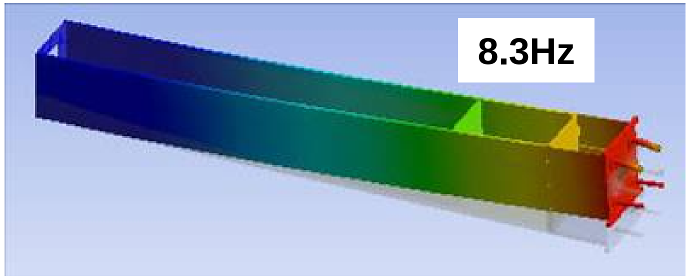


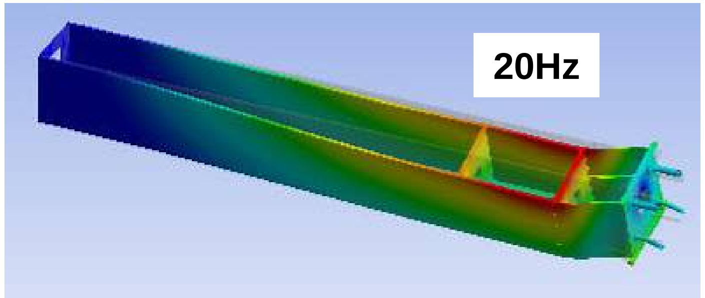


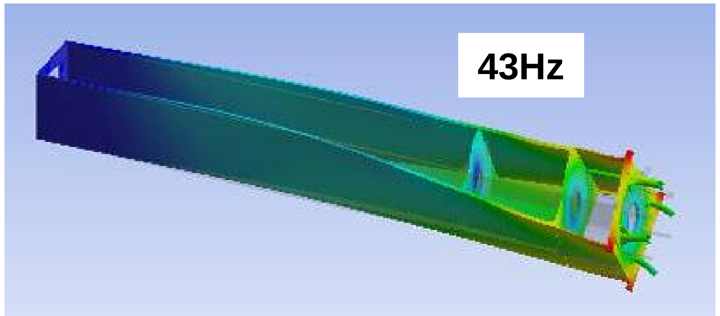
Results of modal analysis

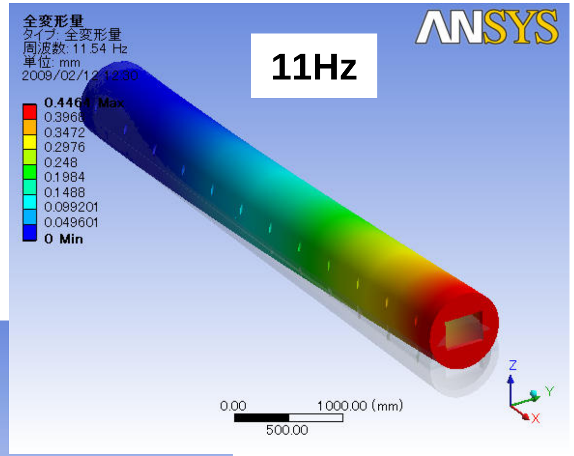
*) Size is not same!

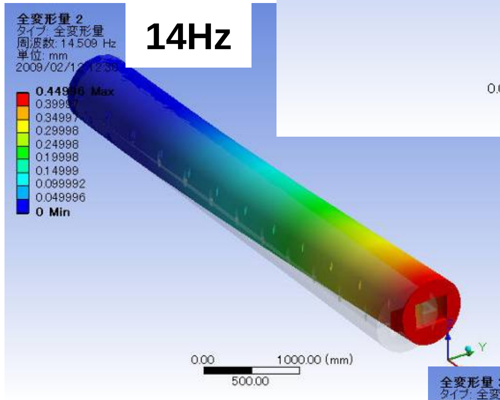


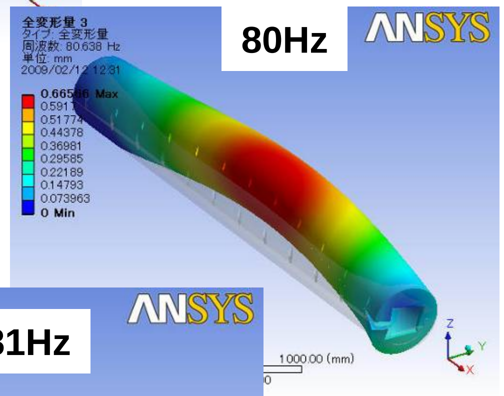


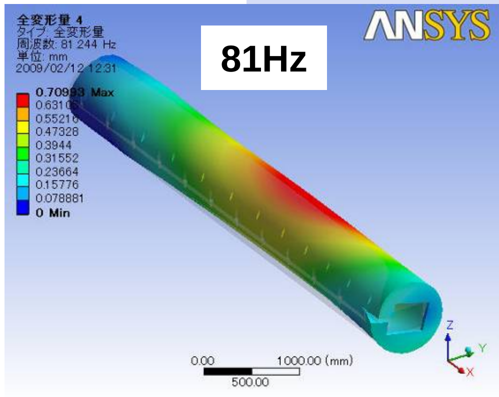




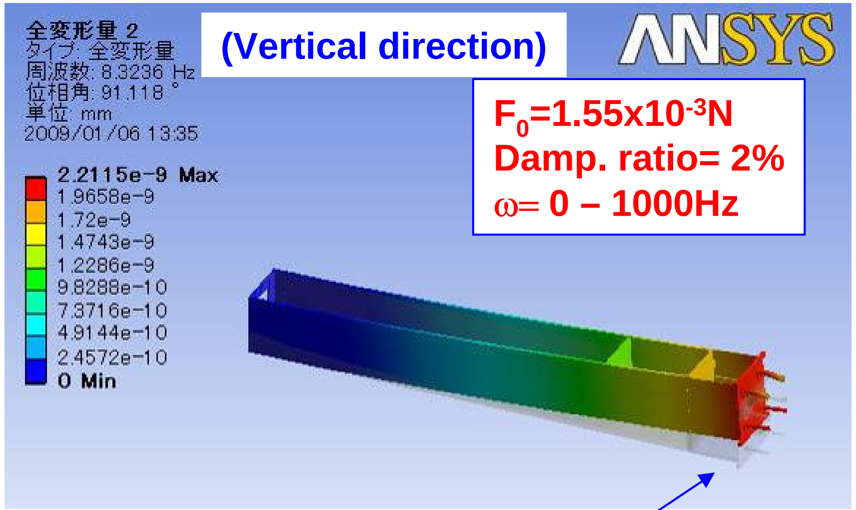


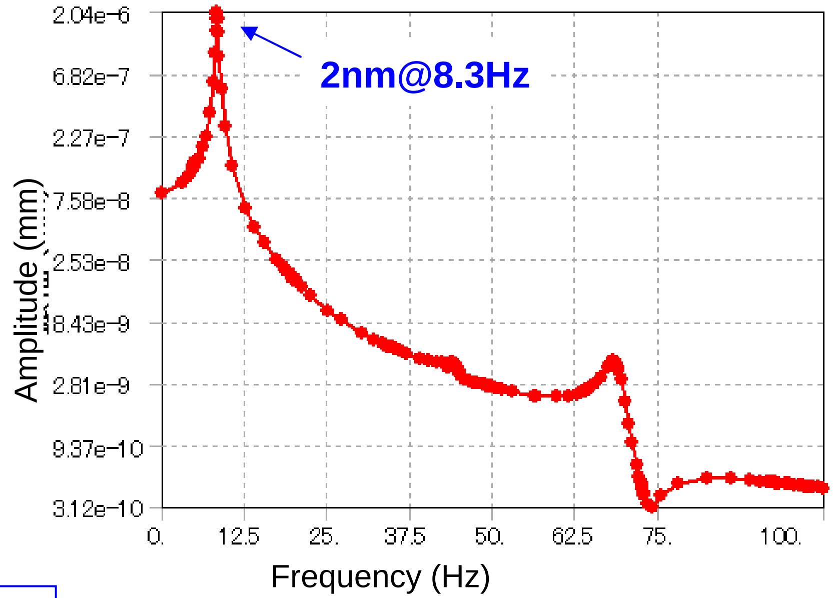




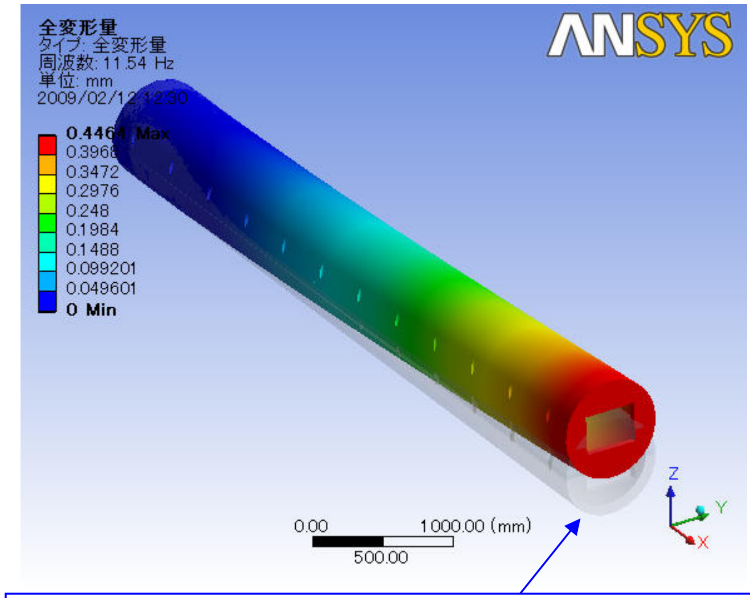


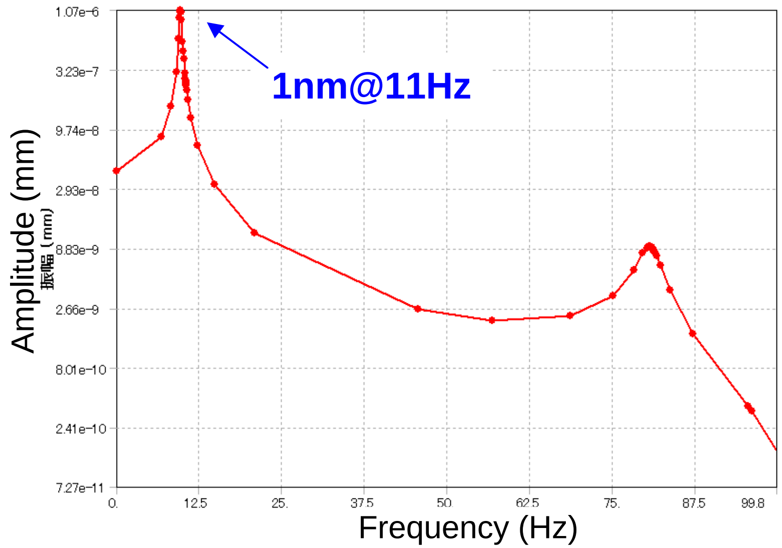
Amplitude due to ground motion



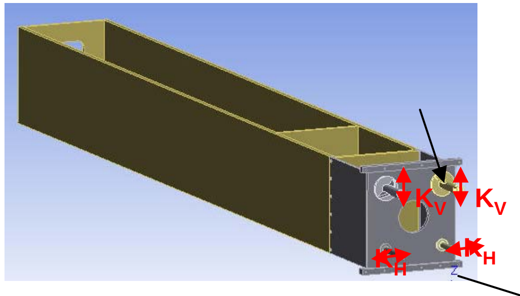


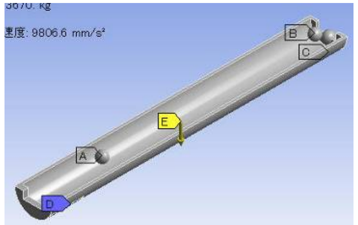
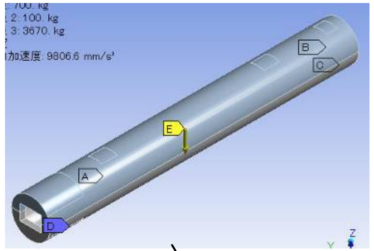
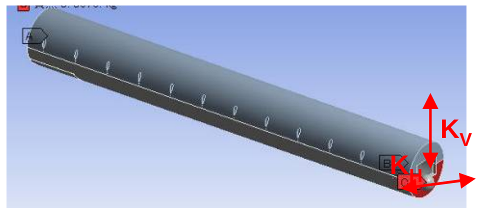
→ **Amplitude: 2nm< 50nm @8.3Hz (Vetical direction)**





→ **Amplitude: 1nm < 50nm @11Hz (Vetical direction)**



	Type	Square	Square	Half Cylinder	Full Cylinder	Assembled with Thred bolts	Assembled with Thred bolts
	Support conf.	Cantilevar	With tension rods	Cantilevar	Cantilevar	Cantilevar	With tension rods
	HxB/Diamter(mm)	650x650	650x650	750dia.	750dia.	750dia.	750dia.
Size	Thickness(mm)	30.0	30.0	50.0	50.0	50.0	50.0
	Length(mm)	5565	5565	6000	6000	6000	6000
Load conditions	QD0(kg)	1000.	1000.	700.0	700.0	700.0	700.0
	BeamCAL(kg)	4000.0	4000.0	100.0	100.0	100.0	100.0
	LHCAL(kg)			3000.0	3000.0	3000.0	3000.0
	LumiCAL(kg)			250.0	250.0	250.0	250.0
	ECAL(kg)			420.0	420.0	420.0	420.0
	Self-Weight(kg)	2400	2400	2685.5	5371.0	5371.0	5371.0
Static analysis	Stress(MPa)	53	59	83.4	38.4	--	200
	Deformation(mm)	6.3	4.4	19.7	3.2	6.0	3.4
Natural Frequency	1st mode(Hz)	3.5	4.9	3.7	9.5	--	9.7
	2nd	6.9	8.3	5.7	78.9	--	80
	3rd	19	20	20.2	122.5	--	110
Harmonic analysis	Inp. force (N)	2.0E-03	2.0E-03	2.0E-03	2.0E-03	--	2.0E-03
	Amp.(nm)	3.5	2.0	7.8	2.7	--	1.1

3D magnetic calculation is necessary

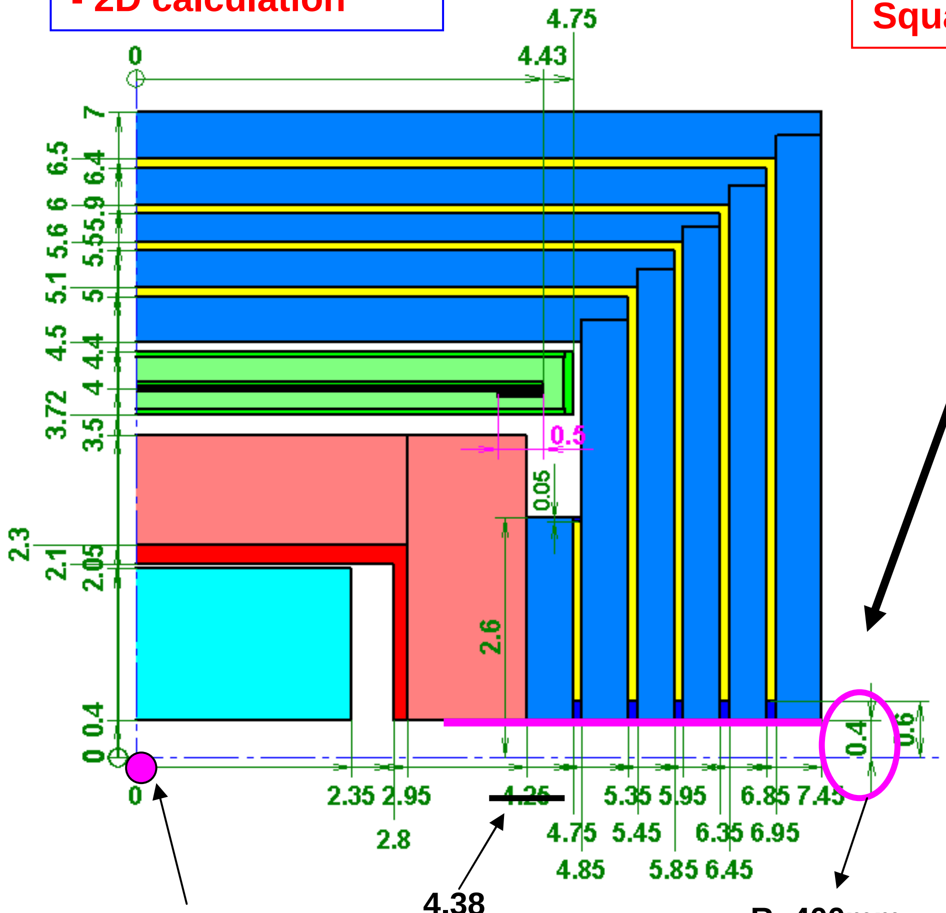
END

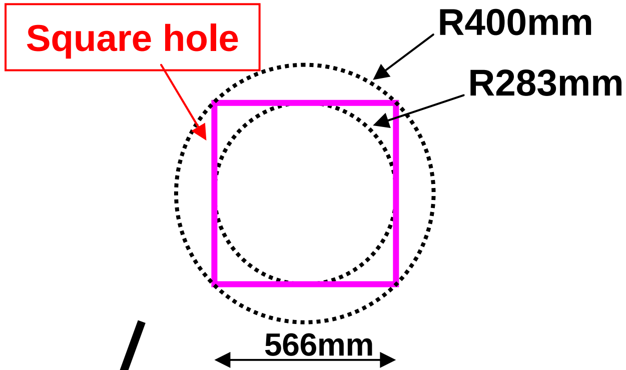
Ref.

Influence of E.Y. square hole on the magnetic field

Not Current model!!
- GLD model
- Bc: 3T
- 2D calculation

Rough estimation of the phi-direction magnetic filed distribution due to the square hole.





2D-Magnetic filed calculation
- R= 400mm
- R= 283mm
have been calculated.

Approach

By 2D magnetic field calculation, the difference of magnetic field distribution in the phi-direction was roughly estimated.

When the above square support tube is installed to the square hole of End Yoke, the size of an inscribed circle is to be R283mm and a 400mm-radius of circumscribed circle.

So the magnetic field calculation in case of R400 and R283 has been performed, respectively.

And from each calculation,

- Field uniformity in the TPC volume

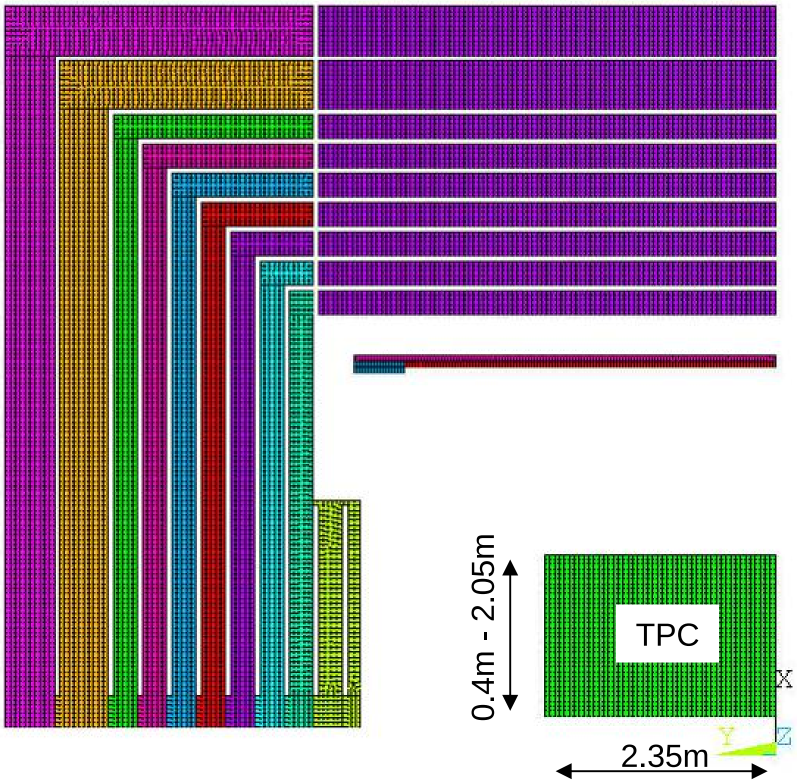
- Magnetic field along the beam line

were compared.

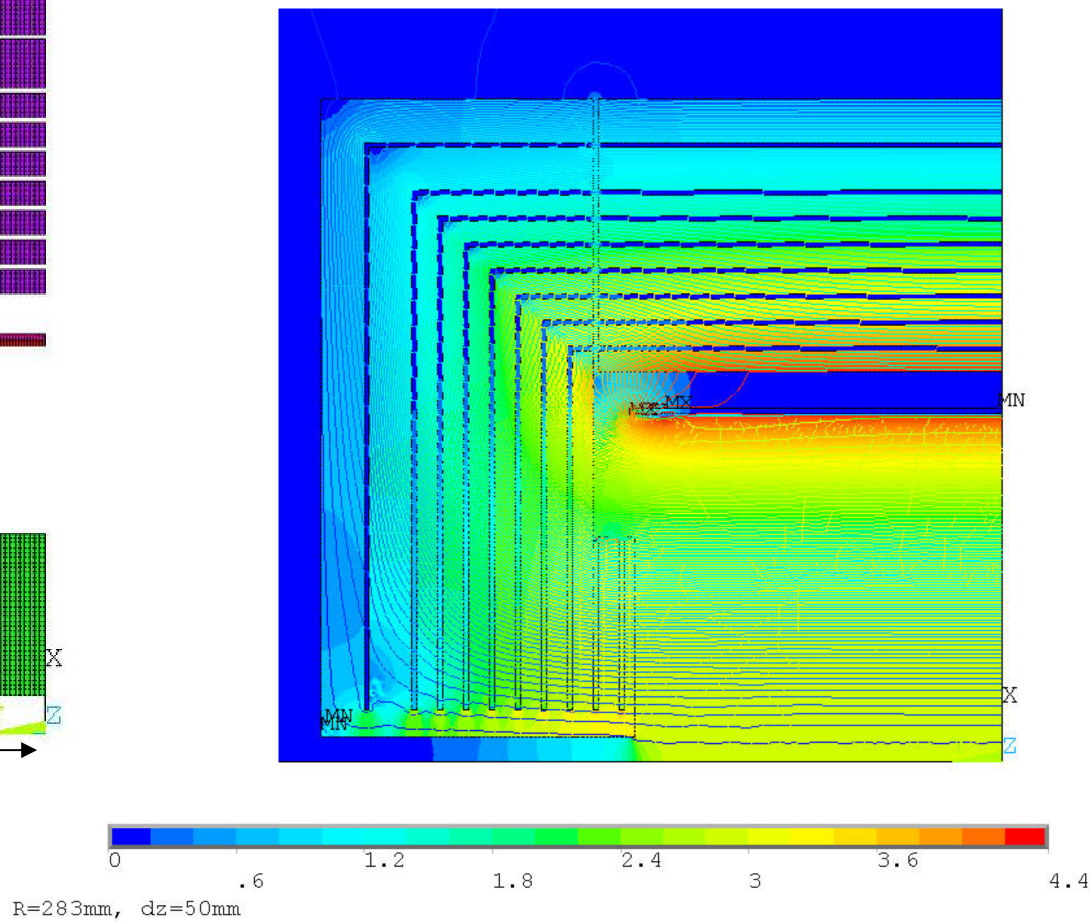
The FEM model for this calculation was used an old GLD iron yoke model shown in left figure.

Magnetic field density (@Bc=3T)

(FEM model: ANSYS)

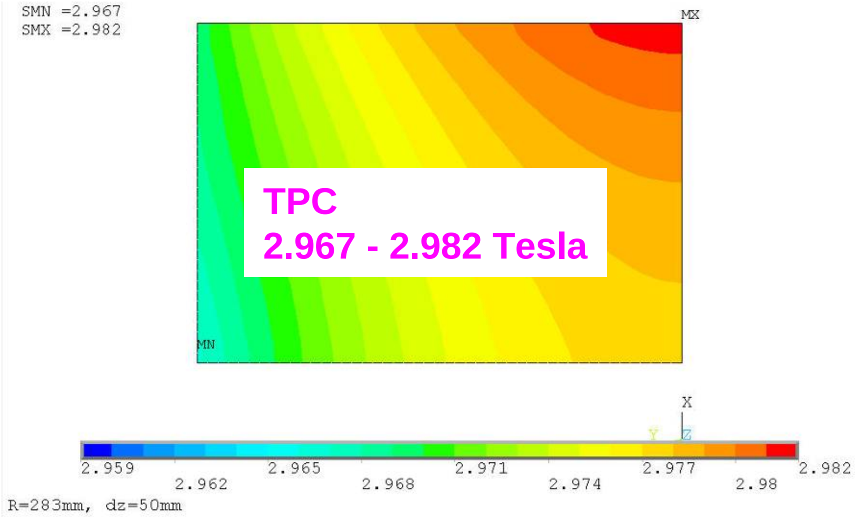


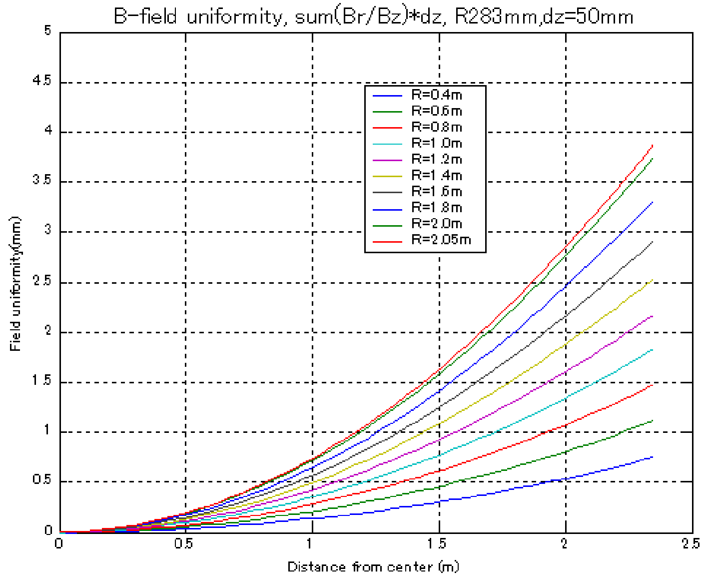
(Magnetic field density: R283mm)



Magnetic field uniformity in TPC volume

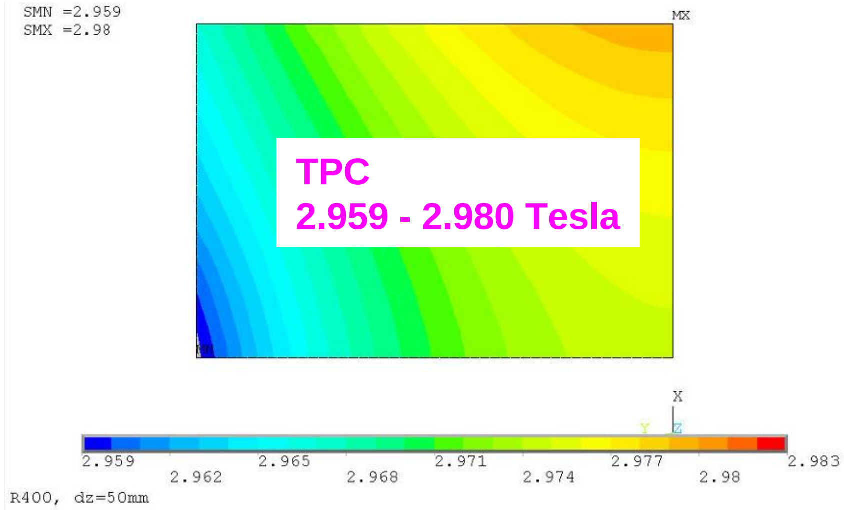
(In case of R283mm)

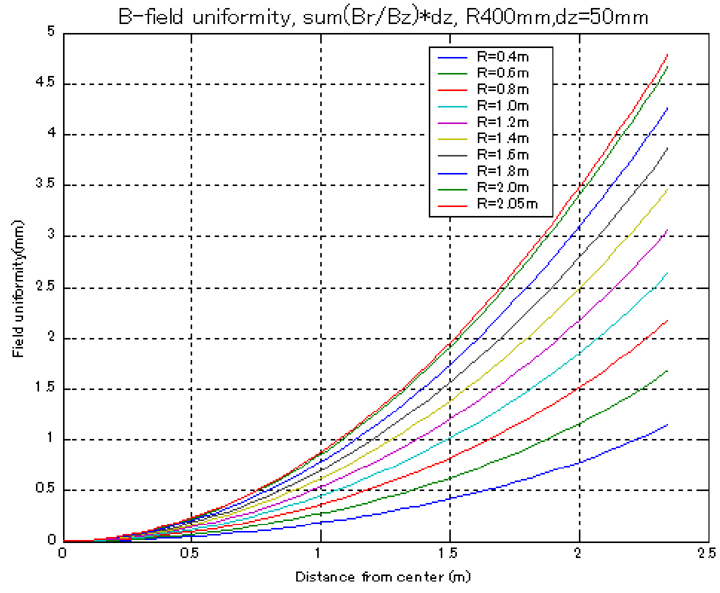




Uniformity= Max. 3.8mm

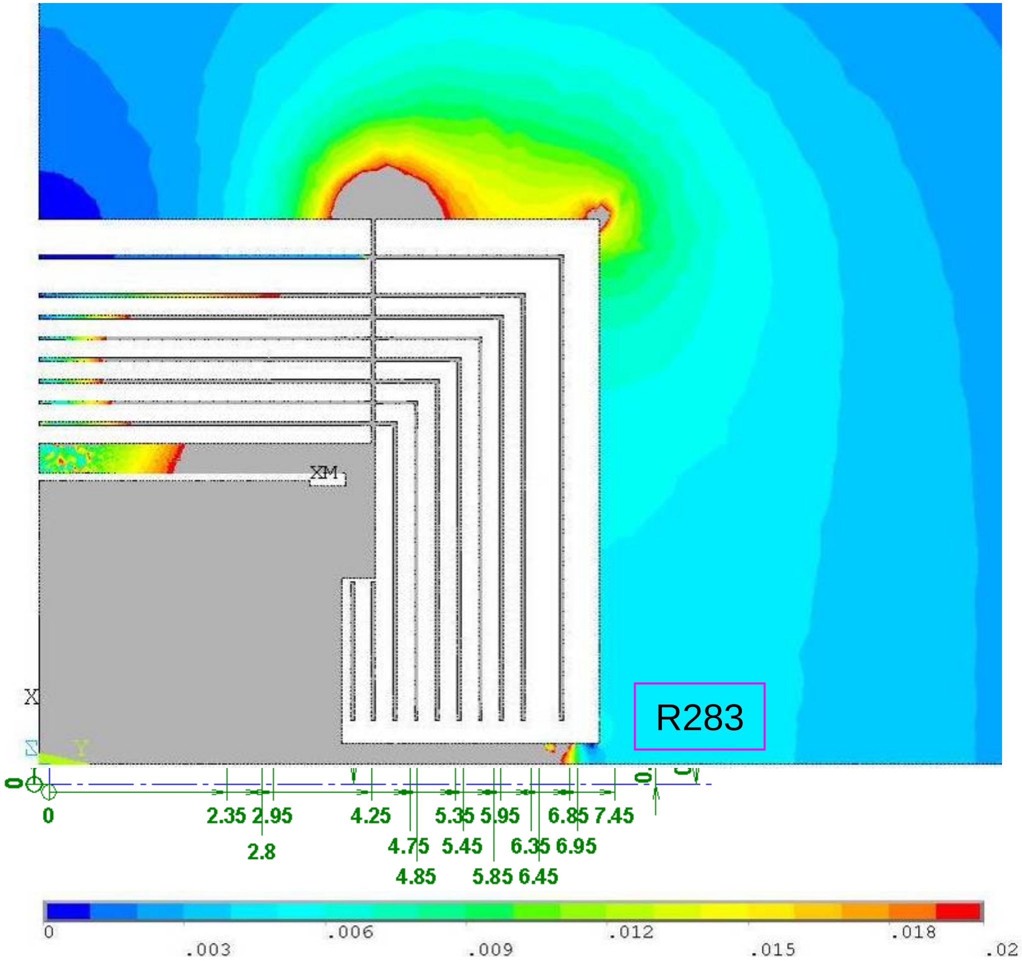
(In case of R400mm)

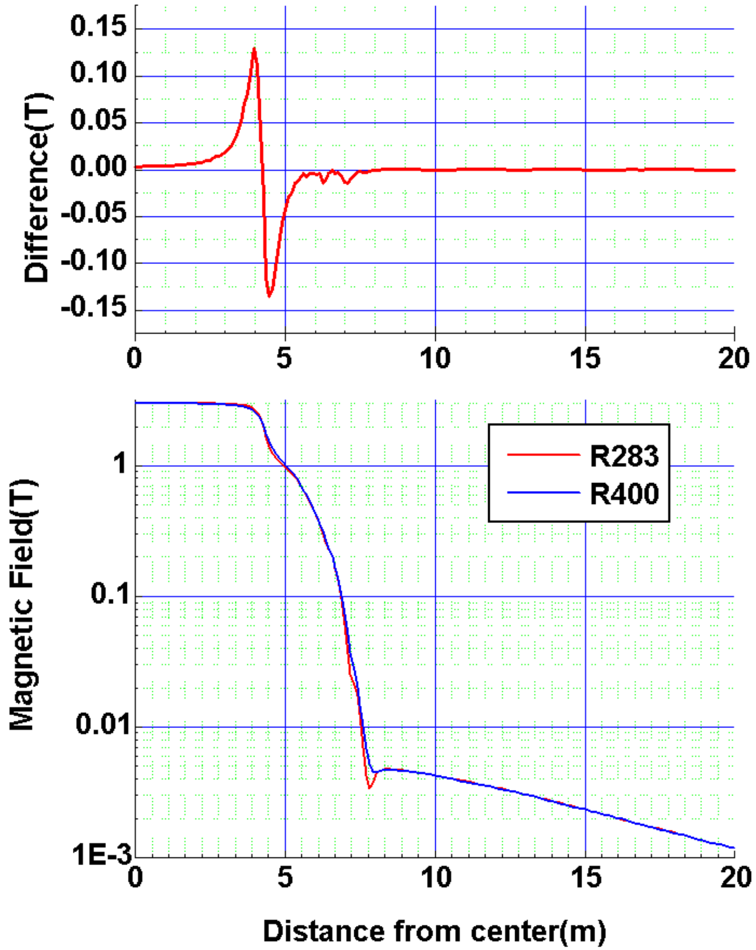




Uniformity= Max. 4.8mm

Magnetic field along the beam line





Although 3D magnetic field calculation should be carried out because the FEM model is different from the present configuration and the central magnetic field is stronger than this calculation.

- **Difference of field uniformity between R400 and R283.**
  ~1mm (~20% different)
- **Difference of magnetic field.**
  ~ Max. 0.13T(Bc=3T)

END