Design of the coil and SC cable for the CBM magnet

Alexey Bragin, Vassily Syrovatin
Budker Institute of Nuclear Physics, Novosibirsk, Russia

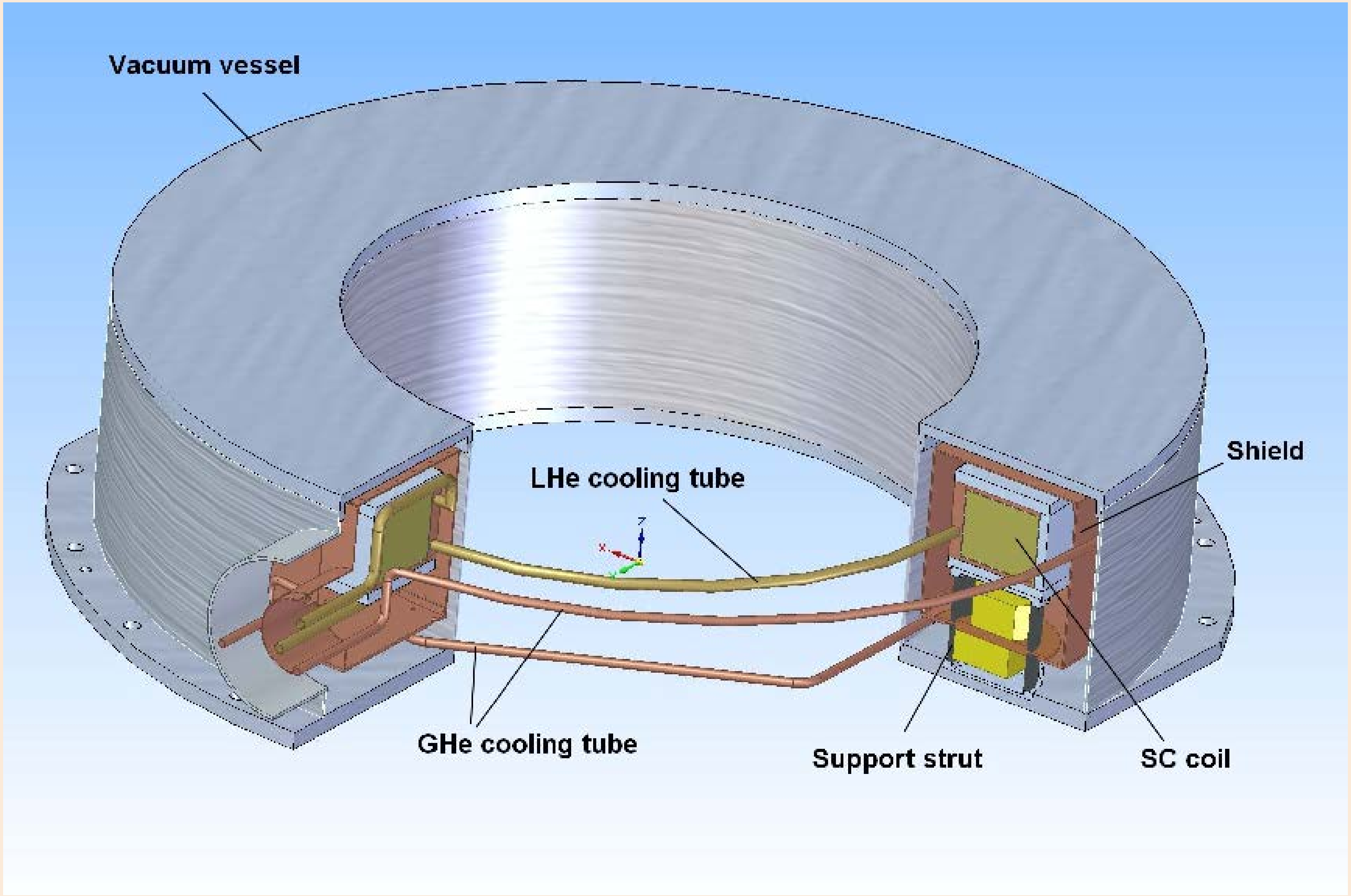
April 2018

Main parameters of the coil

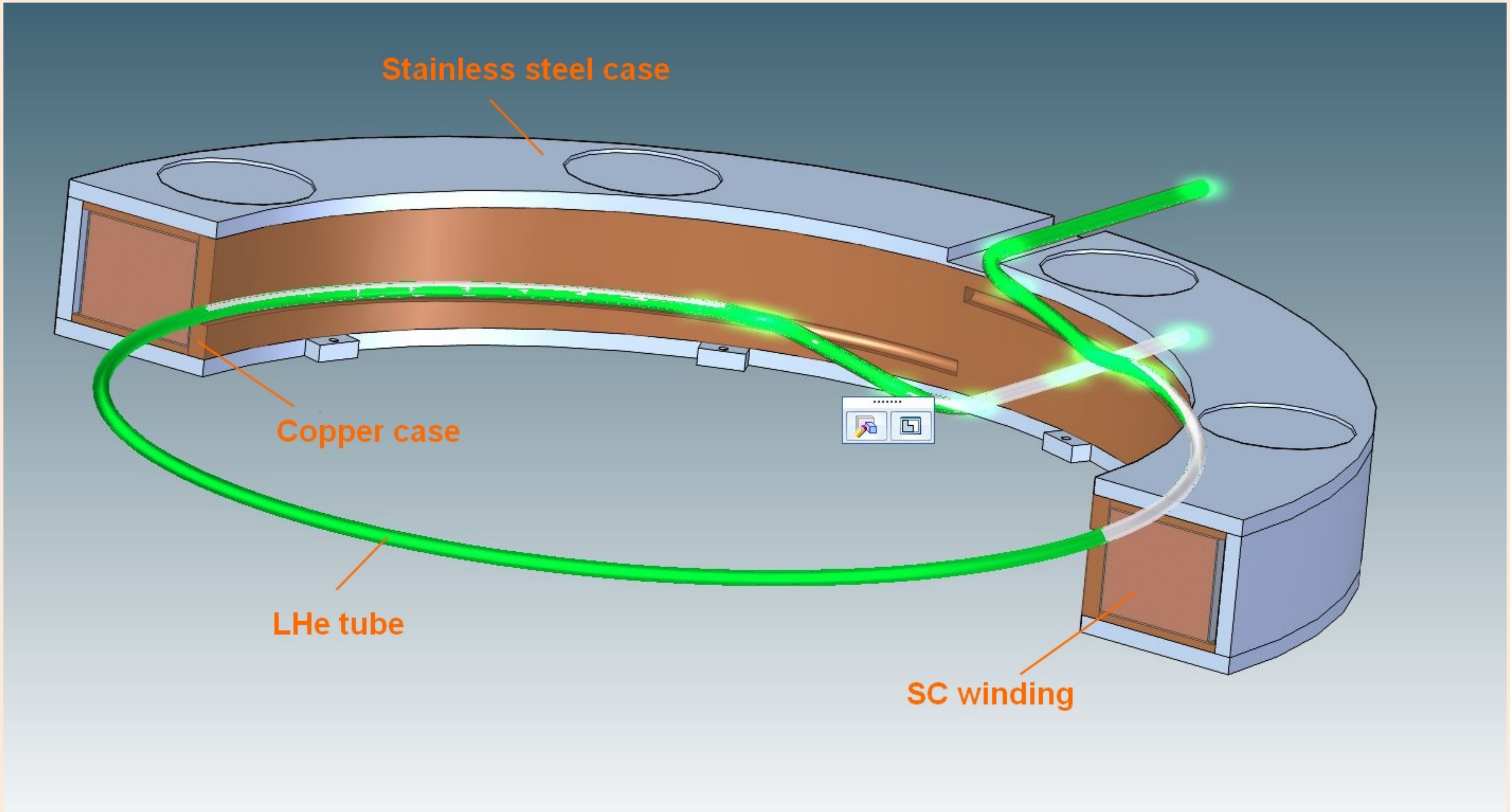
Table 1 Superconducting coil parameters

Coils parameters	Values
Inner diameter of the winding, mm	1390
Cross section sizes of the winding:	
height, mm	131
radial thickness, mm	160
Number of turns in one coil	1749
Number of layers in one coil	53
Interlayer insulation, mm	0.3
Operating current Io, A	686[1]
Test current, Io*1.05, A	720
Magnetic field on the coil Bmax, T	3.9
Io/Ic ratio along the load line, %	57
Io/Ic at fixed B, %	25
Operating temperature, K	4.5
Temperature of current sharing, K	6.8
Stored energy of the magnet, MJ	5.1
Cold mass of one coil, kg	1800
Cold mass of one coil winding, kg	790
Inductance of the magnet at full current, H	21.2
E/M ratio for two windings, kJ/kg	3.2
Mutual inductance between the coils, H	0.21
Vertical force on one coil toward the yoke, MN	3.1

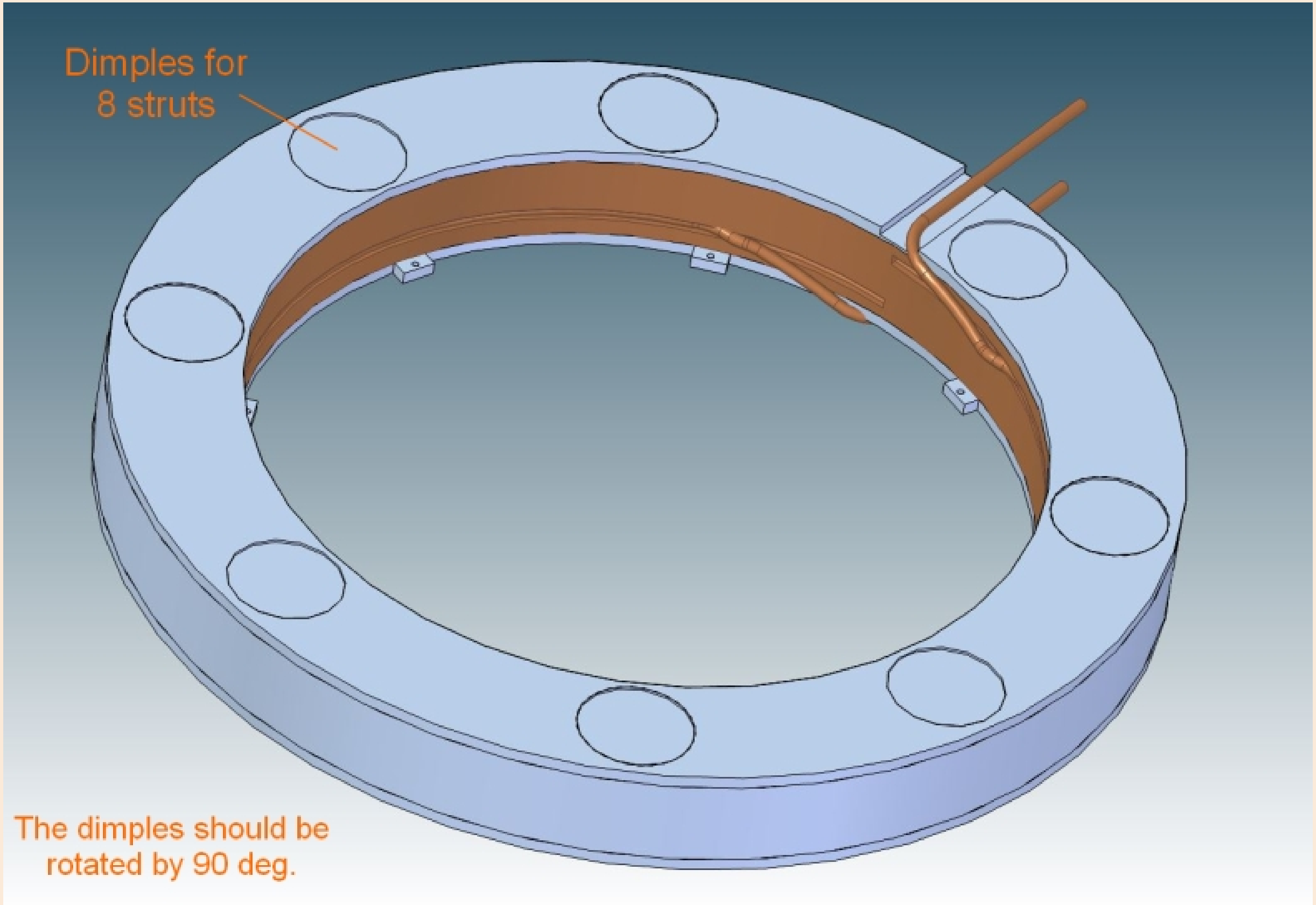
Coil design


Vacuum vessel
Shield
LHe cooling tube
GHe cooling tube
Support strut
SC coil

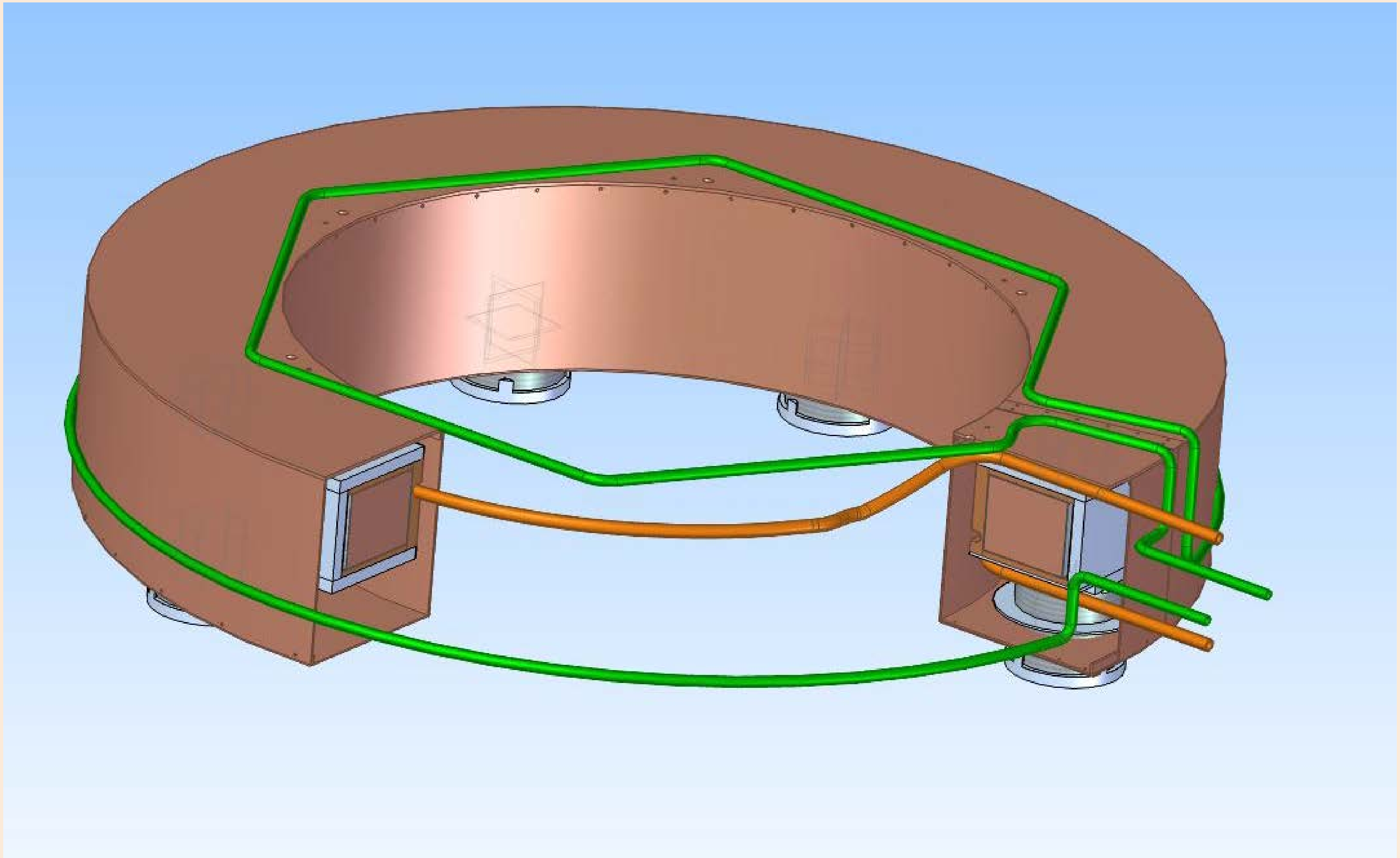
Coil as a cold mass



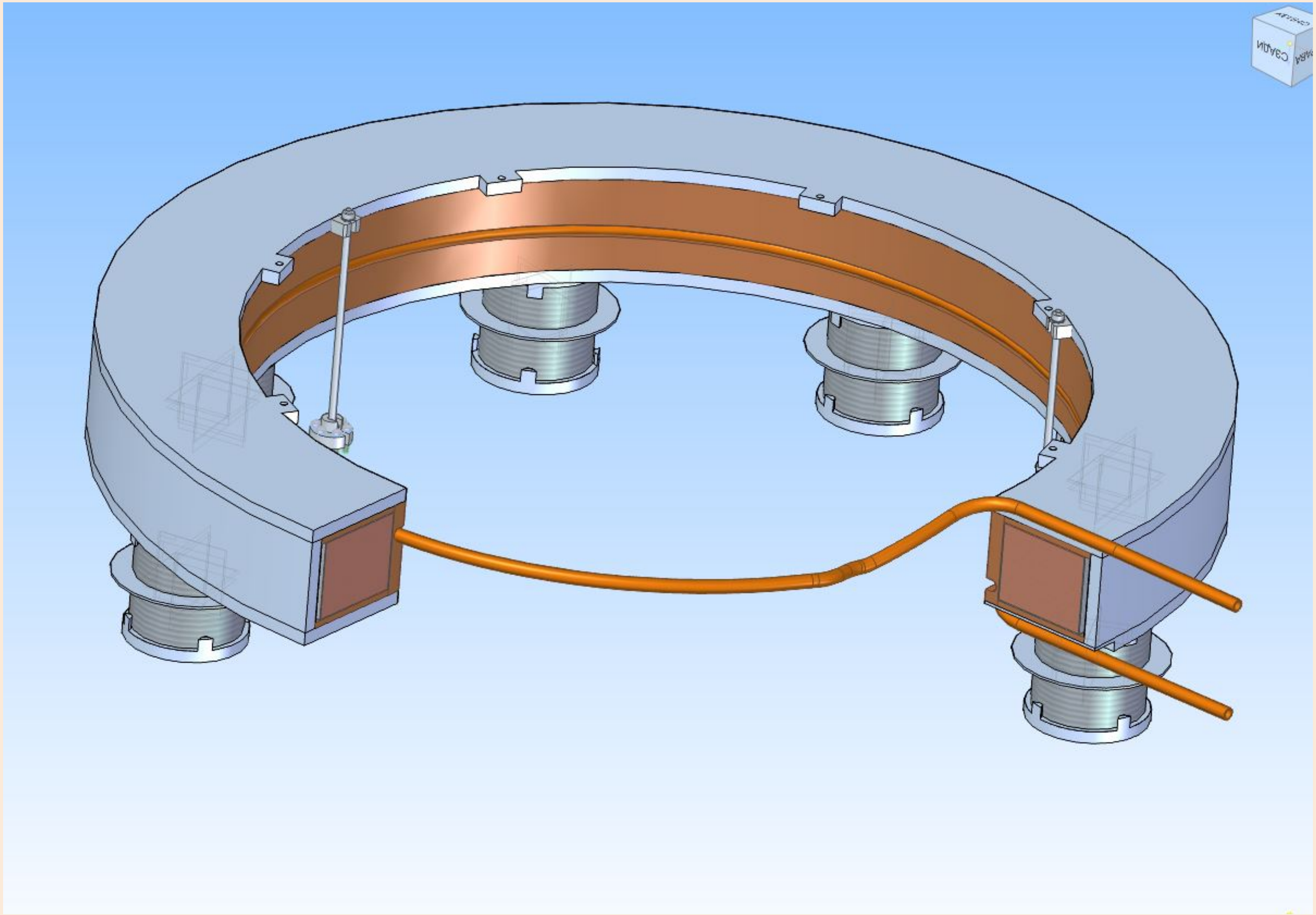
Coil total view



Radiation shield



The coil with the support struts and titanium rods



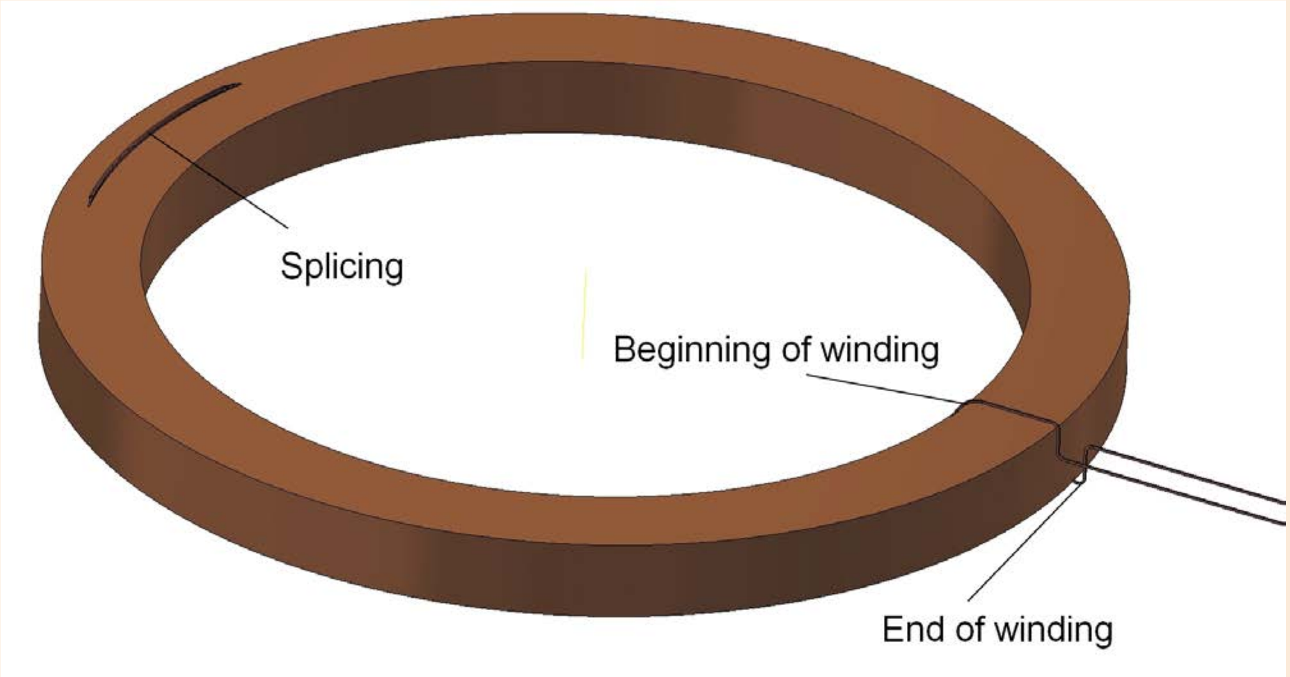
Superconducting winding

The winding will be wound of two pieces of SC cable. The length of one half is ~ 4.6 km.

Dry process of winding.

Impregnation by epoxy compound with fine BN powder. Grain size of the powder < 2 um.

Epoxy also should contain additives increasing its elasticity.

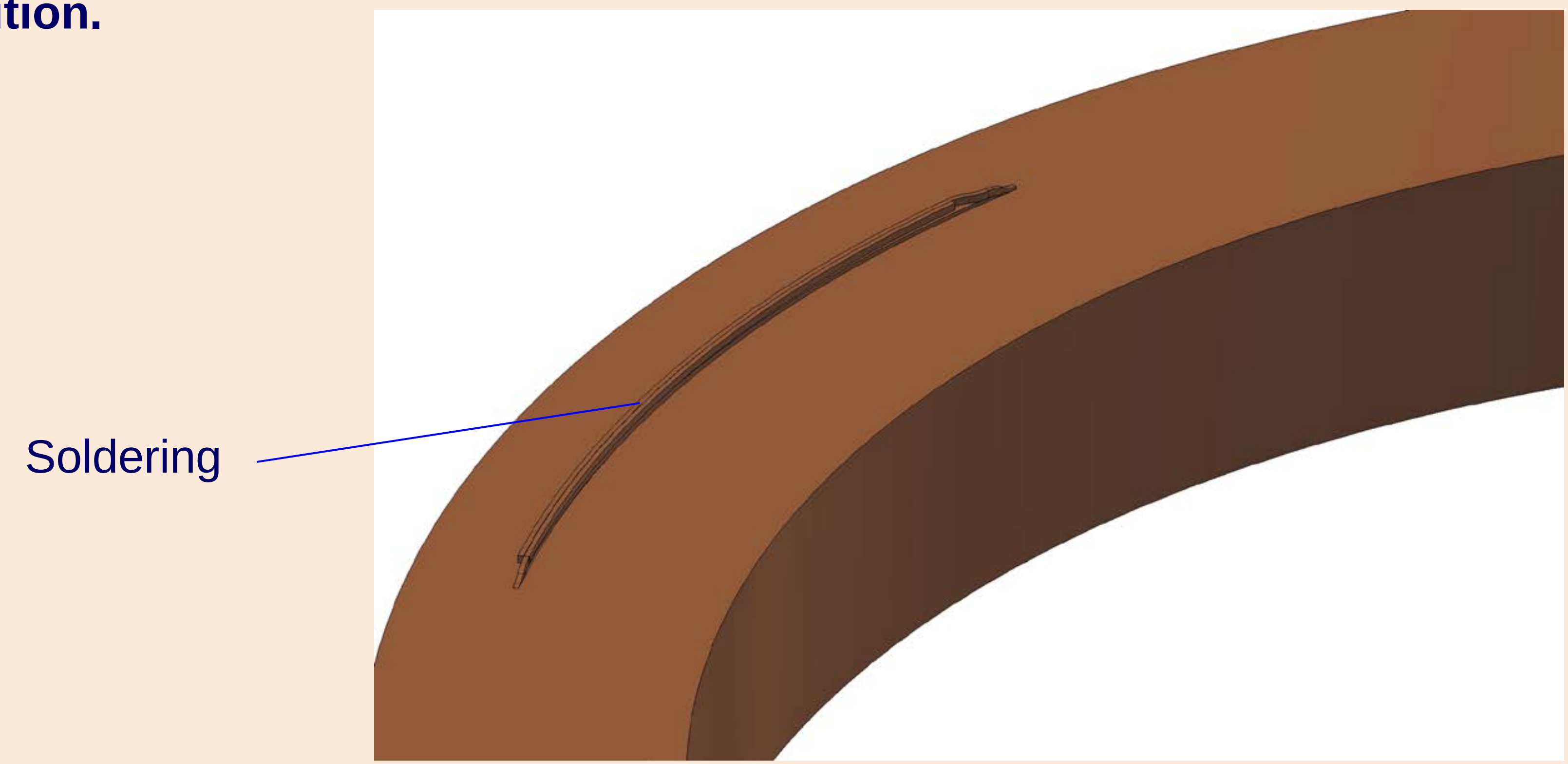


Close view of the splicing

The splicing of the cable will be hidden in the groove of the wall of the copper case.

The thickness of the wall is 8 mm.

The length of the splicing will be more the 10 cm in the place opposite to the support struts position.



Support struts

The support struts are among of critical components of the coils.

Total number if the struts is 8.

Nominal force on the 8 struts is 3.3 MN (maximal). Design breaking force should be ~ 7 MN.

Heat flow from the struts to the 4.5 K coil should be < 0.2 W per strut.

Several designs of the struts are being developed.

The final design decision will taken after testing at loads and heat flow measurements at low temperatures.

Support strut with “G-10” cylinders

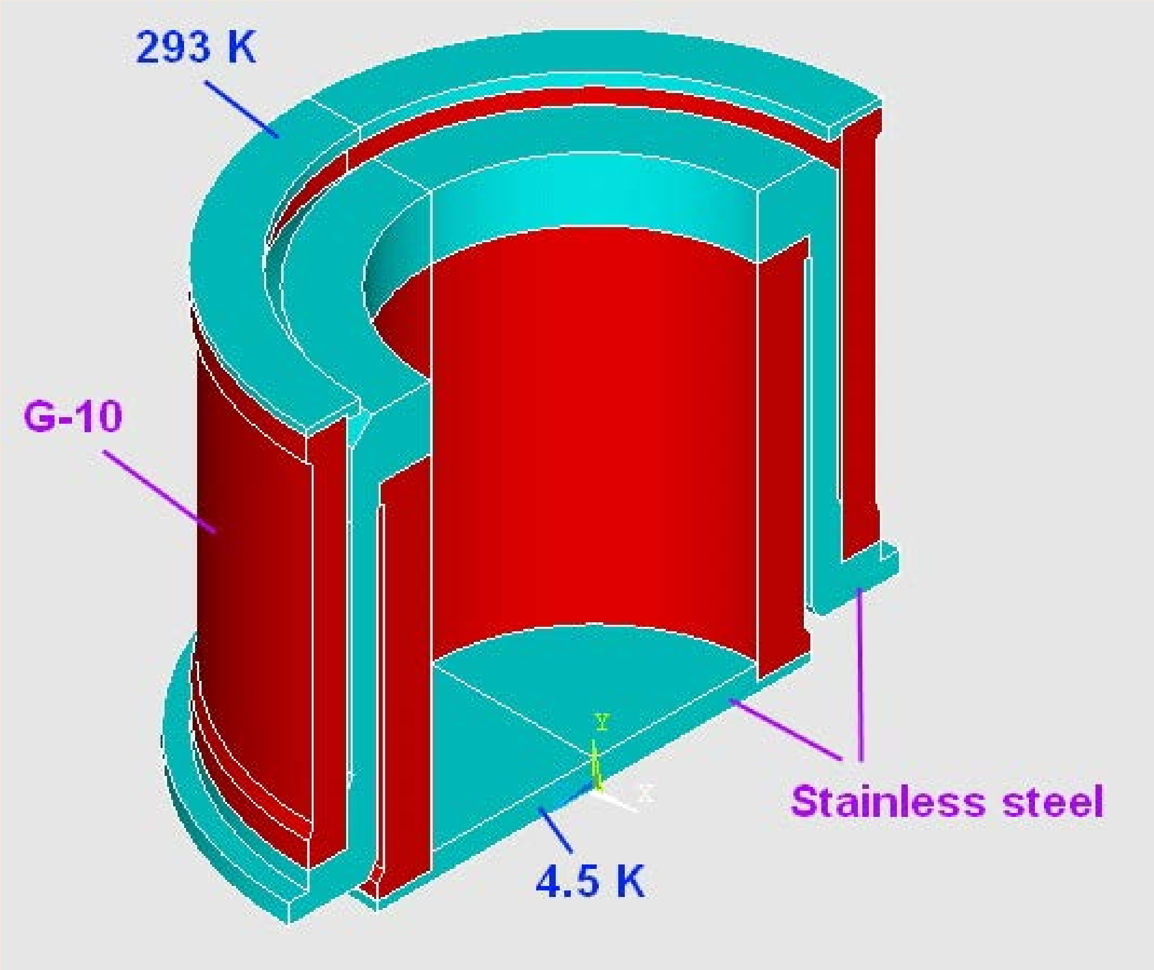
This design has two G-10 cylinders.

These cylinders should have low thermal conductivity in axial direction.

They can be made of rings with low conductivity in vertical direction.

PEEK material is considered instead of G-10.

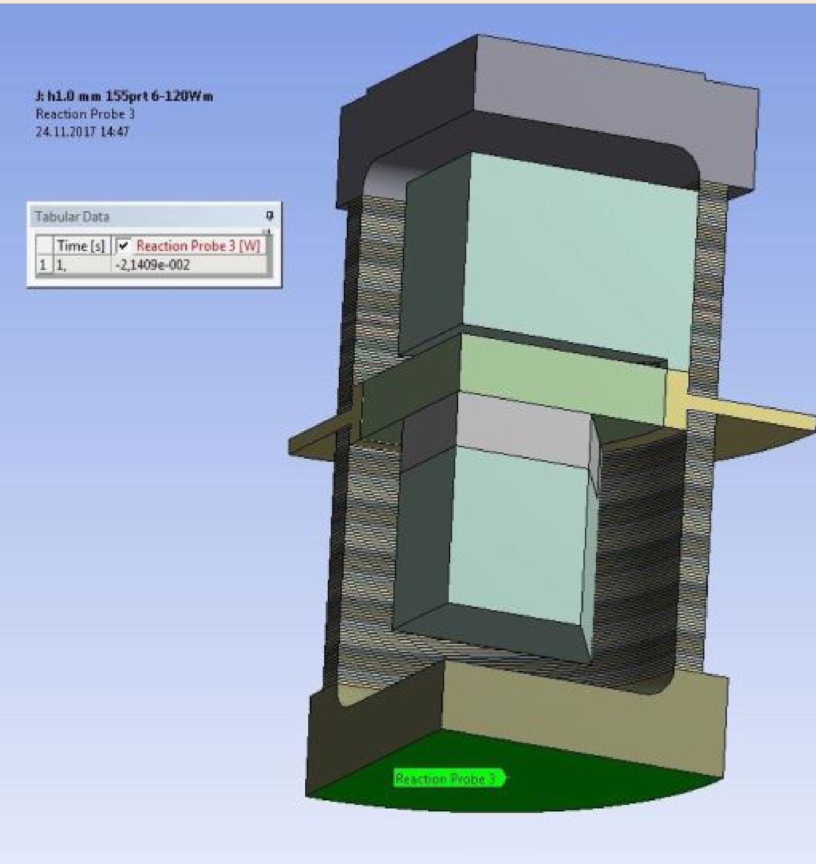
(“PEEK is used for wear and load bearing applications, such as, valve seats, pump gears, and compressor valve plates”)

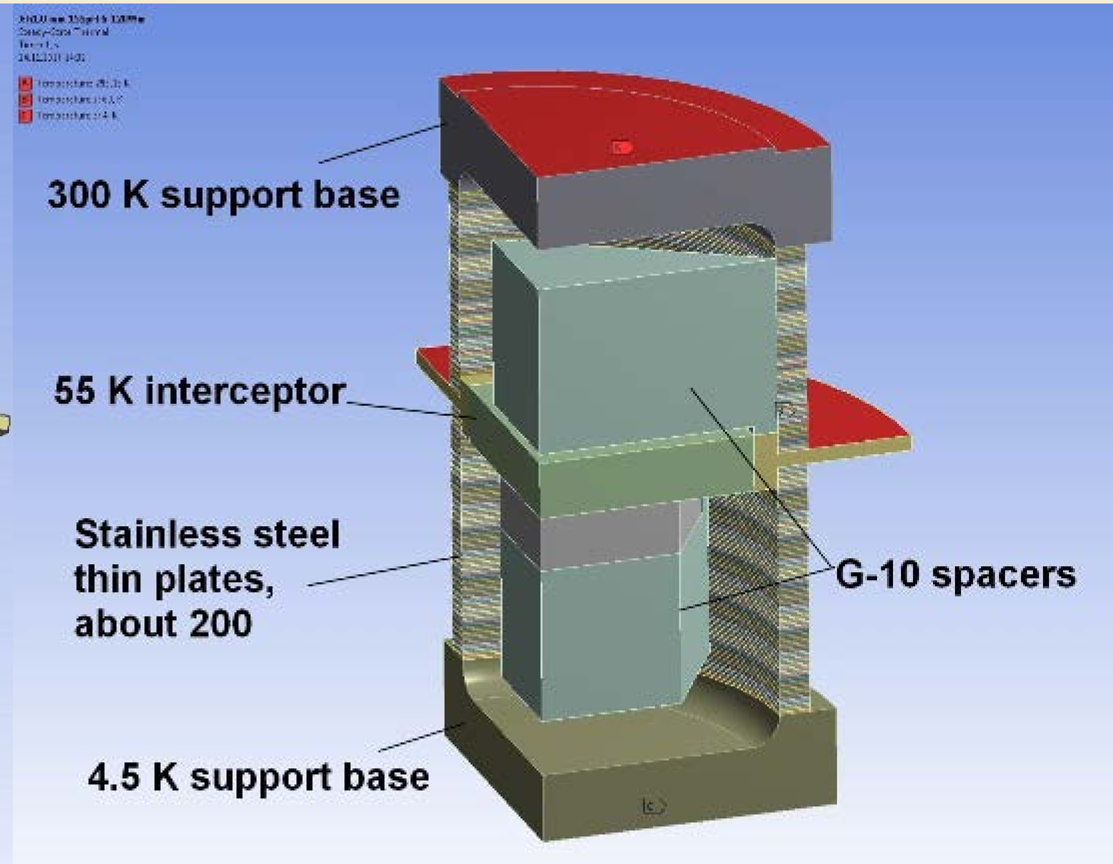


Support strut with stainless steel plates

It has ~ 200 stainless steel plates -> thermal many resistances -> low heat load. Stainless steel has yield strength at 4.5 K ~ 600 MPa.

Thermal and stress tests are necessary. Unaxial force rigidity?

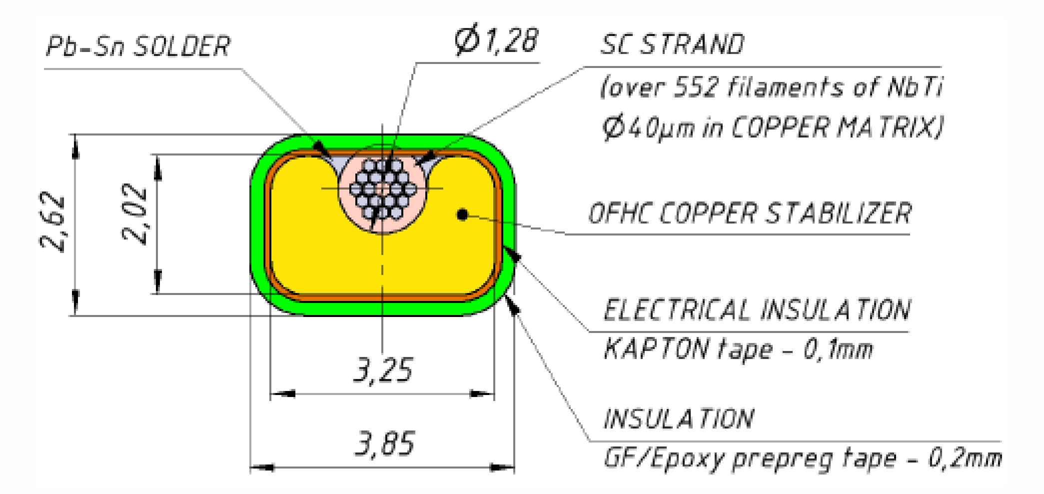




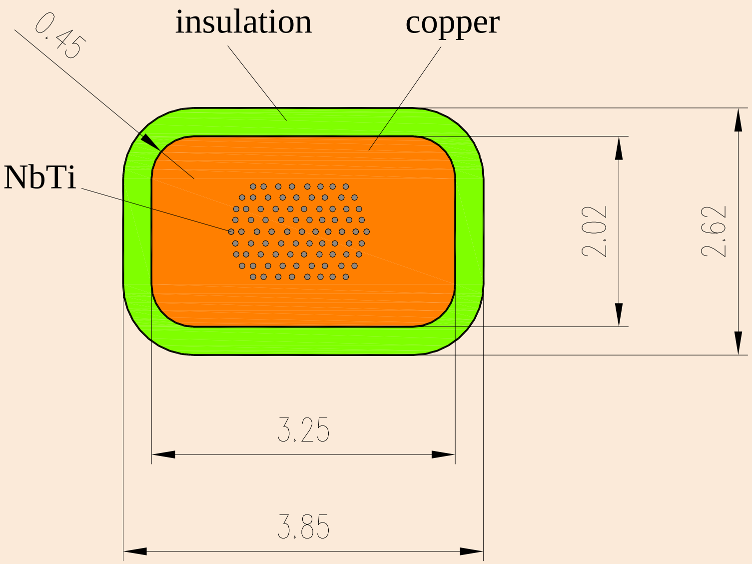
Heat load ~ 0.08 W at 4.5 K per strut.

SC cable

TDR



New cable, already ordered



Parameters	TDR cable	New cable
Total area: copper + NbTi, mm^2	6.188	6.342
Cu area, mm^2	5.575	5.587
NbTi area, mm^2	0.613	0.755
Cu/NbTi ratio	9.1	7.4

NbTi area was increased in the new cable with the solder area of the TDR cable.

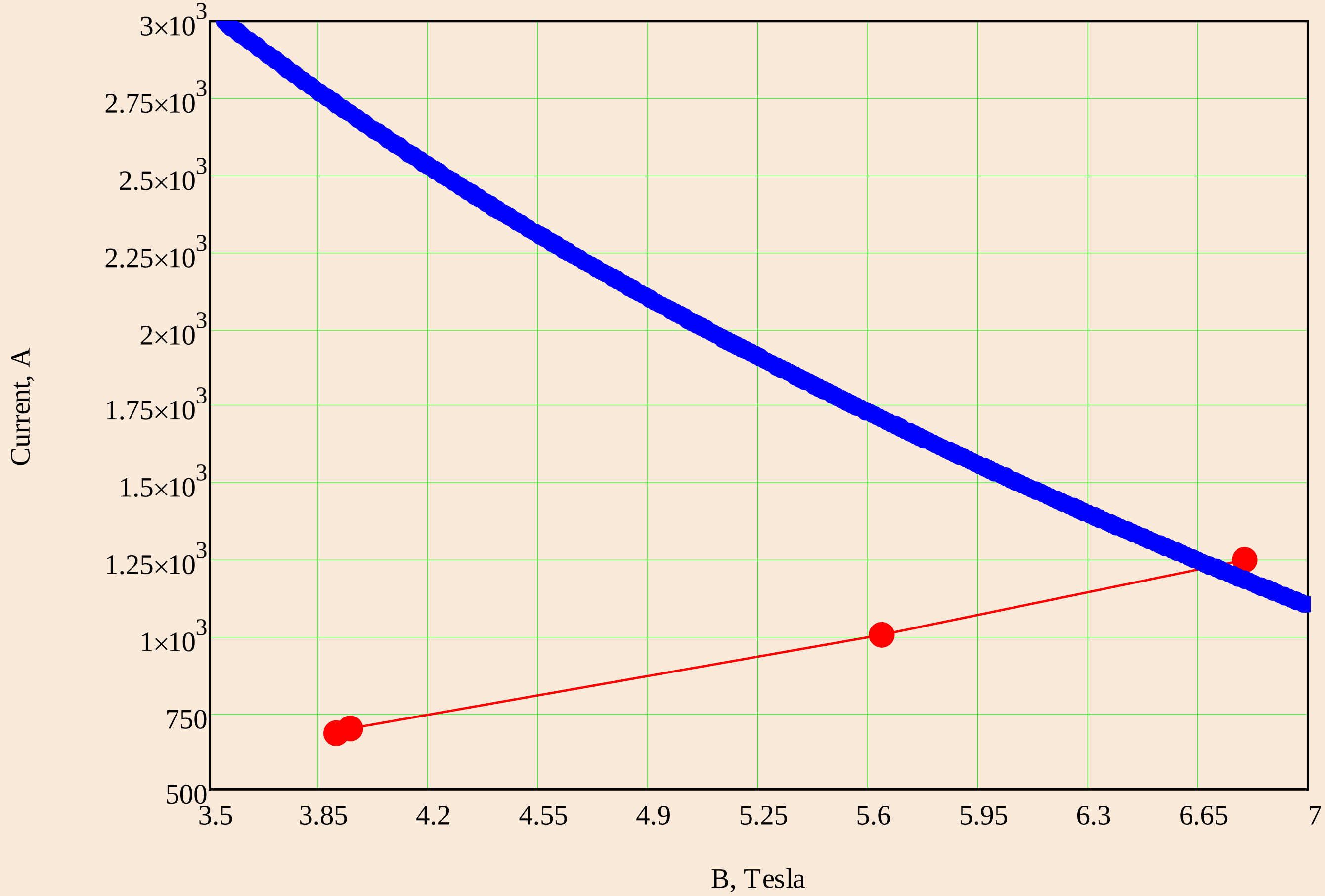
Cross section of the ordered SC cable for the CBM magnet. The cable will be covered by insulation of total thickness 0.3 mm. It will include Kevlar insulation with thickness 0.1 mm, the rest will be fiber glass cloth.

RRR of raw copper material for the cable production will be 200.

SC cable parameters

SC wire parameters	Values
Rectangular bare/insulated sizes:	
a, mm	2.02/2.62
b, mm	3.25/3.85
facets radius, mm	0.45
Cable total length per one coil, km	8.6
One piece of the cable length, km	5
Cu/NbTi ratio	≥7.4
RRR	>100
Filament diameter, μm	39±1
Number of filaments	651
Filament twist pitch, mm	<45
Cu+NbTi cross section area, mm^2	6.342
NbTi cross section area, mm^2	0.755
I_c (5 T, 4.2 K), min A/	2270
I_c (4.5 K, 3.9 T), min A	2700

Load line ratio at 4.5 K



Results

The conceptual design of the CBM magnet coils is presented.

The design of the coils, winding and epoxy impregnation technology was discussed in BINP workshop. No principal problems was revealed.

The support struts should be manufactured and tested as soon as possible.

The superconducting cable is ordered. First part will be supplied to BINP in November 2018.