Cryostat design – preliminary heat loads to the magnet. Thermosyphon cooling.

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

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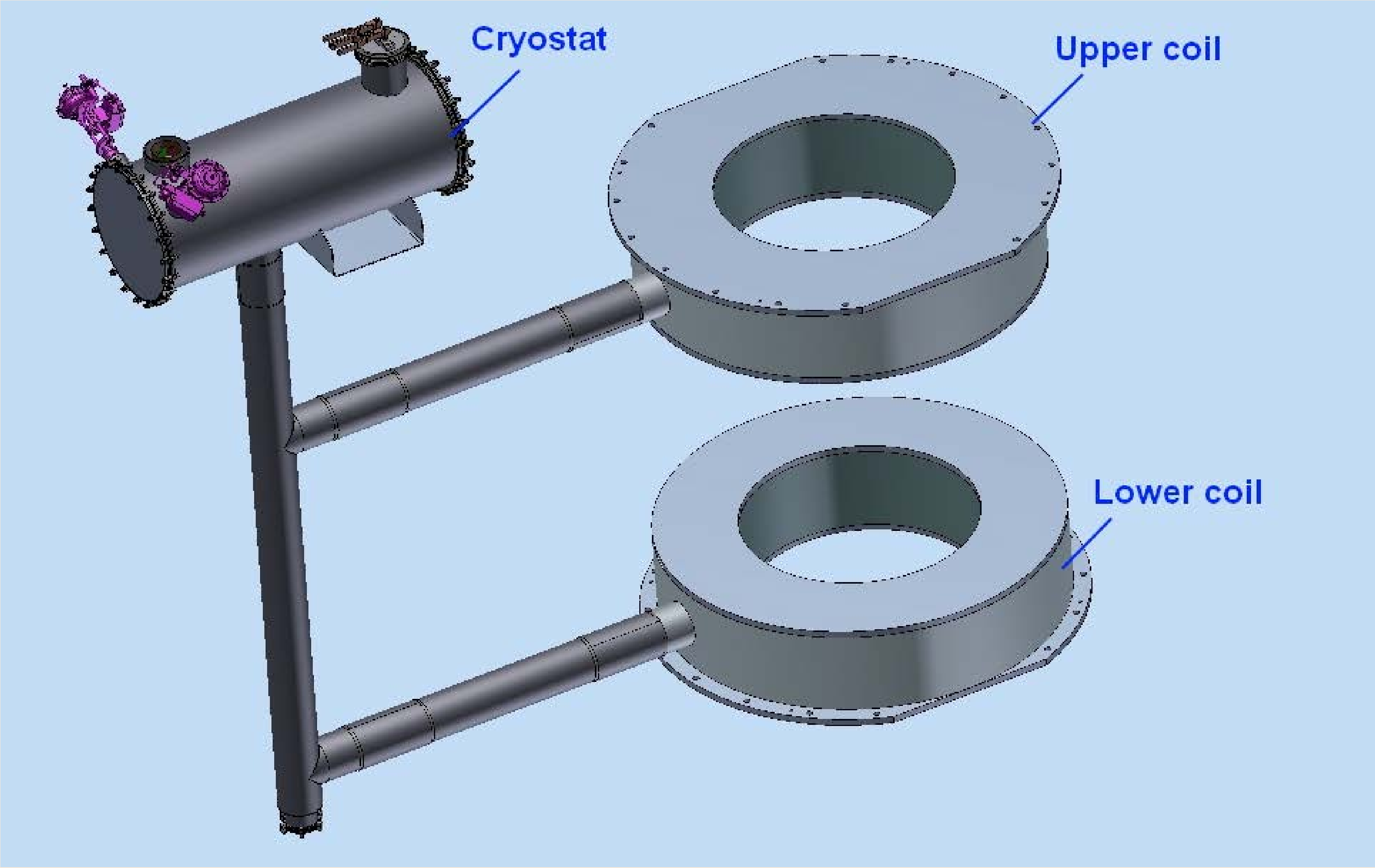
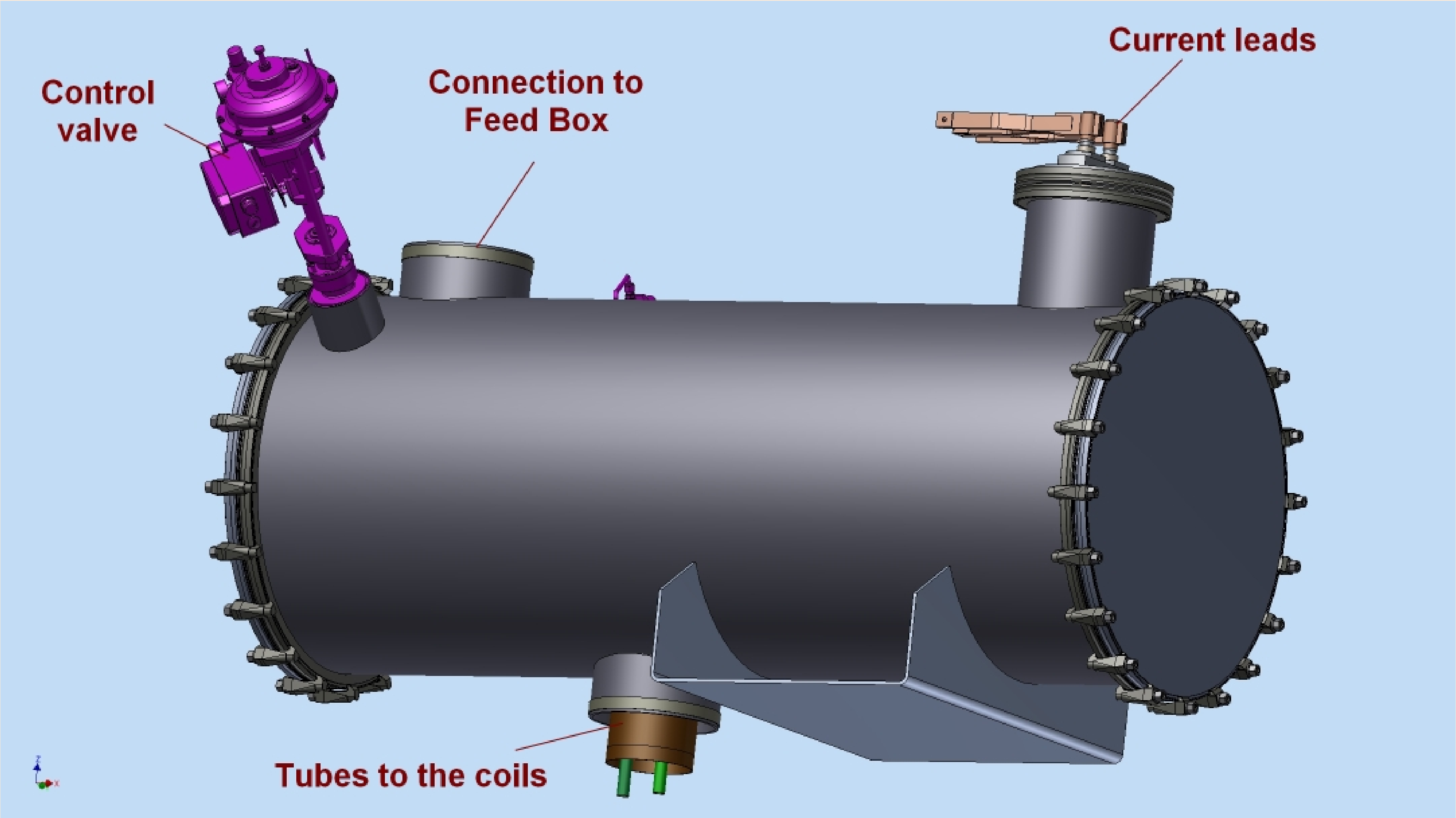
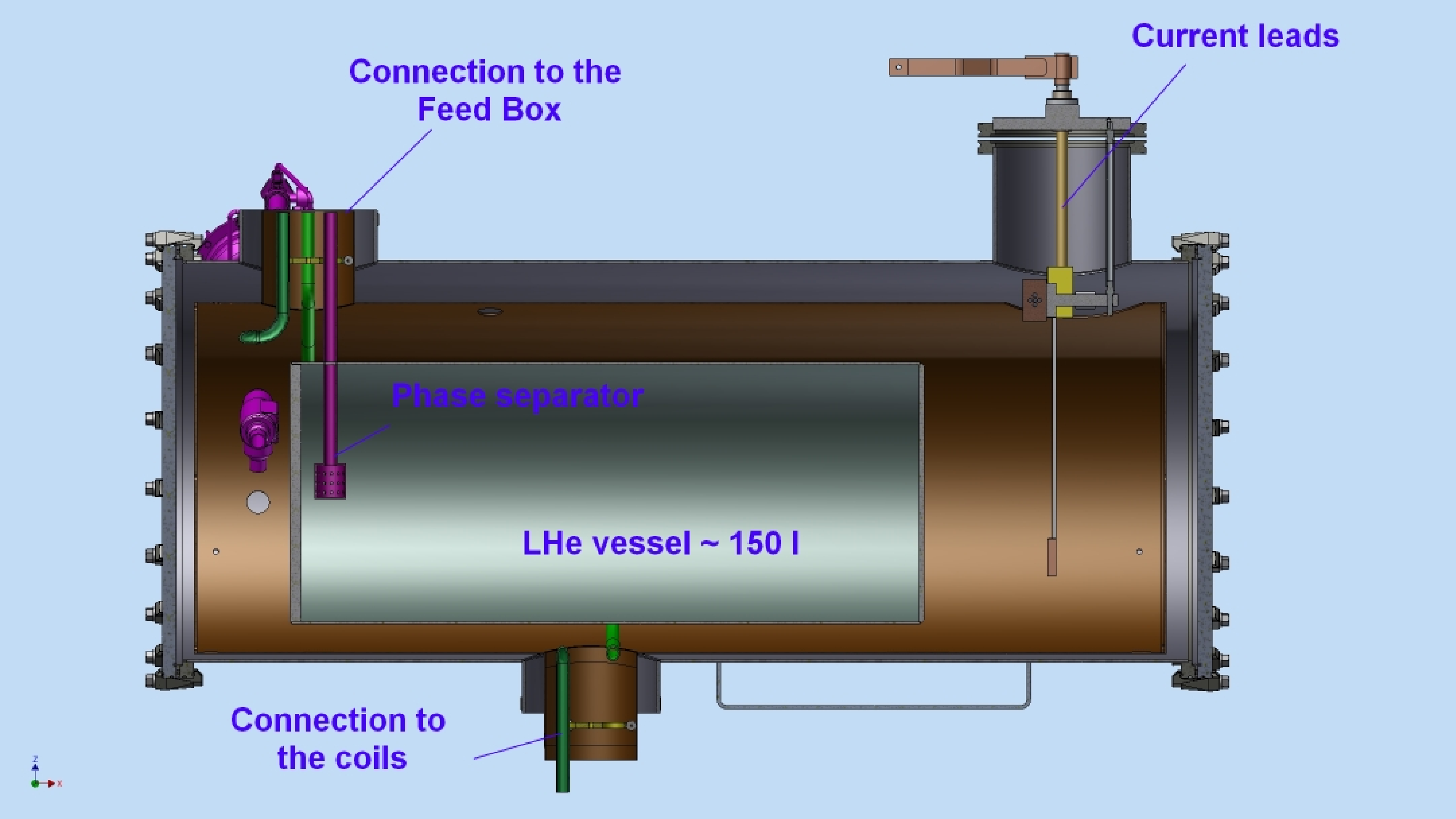
Total view of the cryostat



View of the cryostat



Cryostat view 2



In BINP tests liquid nitrogen will go through the 50-60 K tubes in the cryostat.

Current leads

The current leads are being developed on the base of HTS insertions.

HTS protection will be calculated.

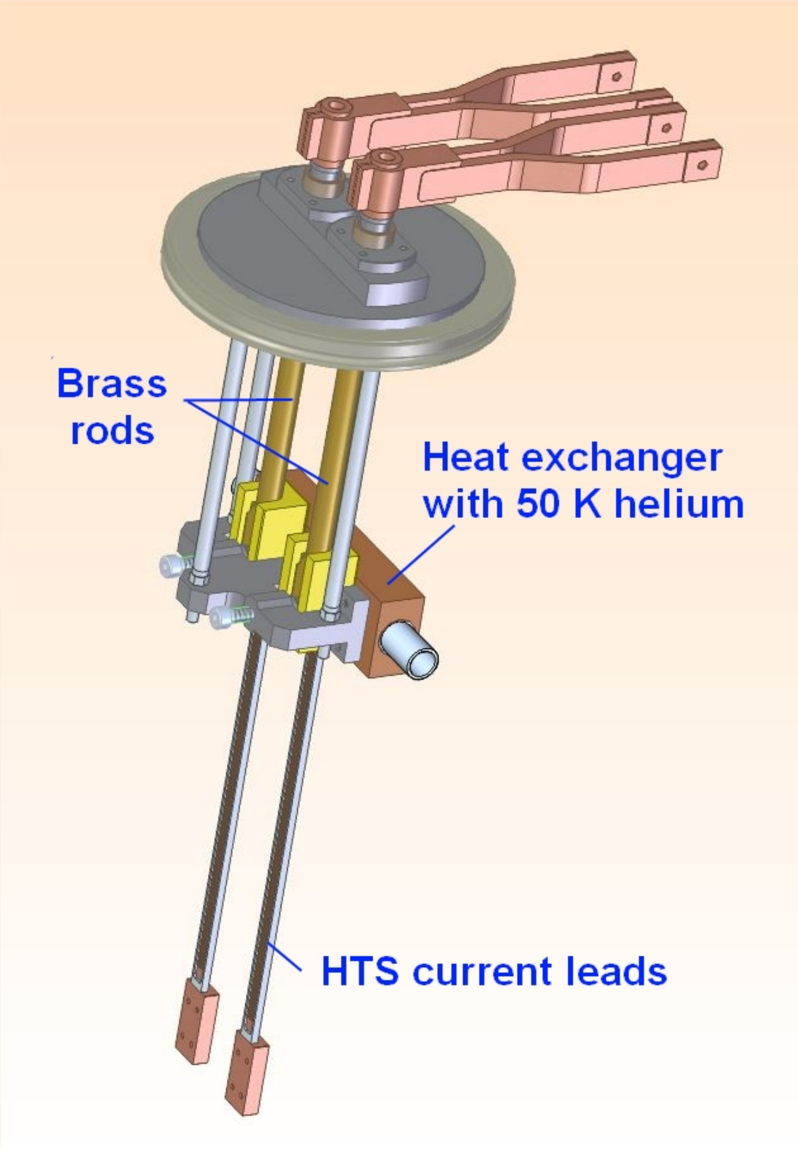
Heat exchanger is important.

Thermal contact via sapphire plates.

HTS terminals will be adopted to the sizes of the CBM cable.

Temperatures will be controlled.

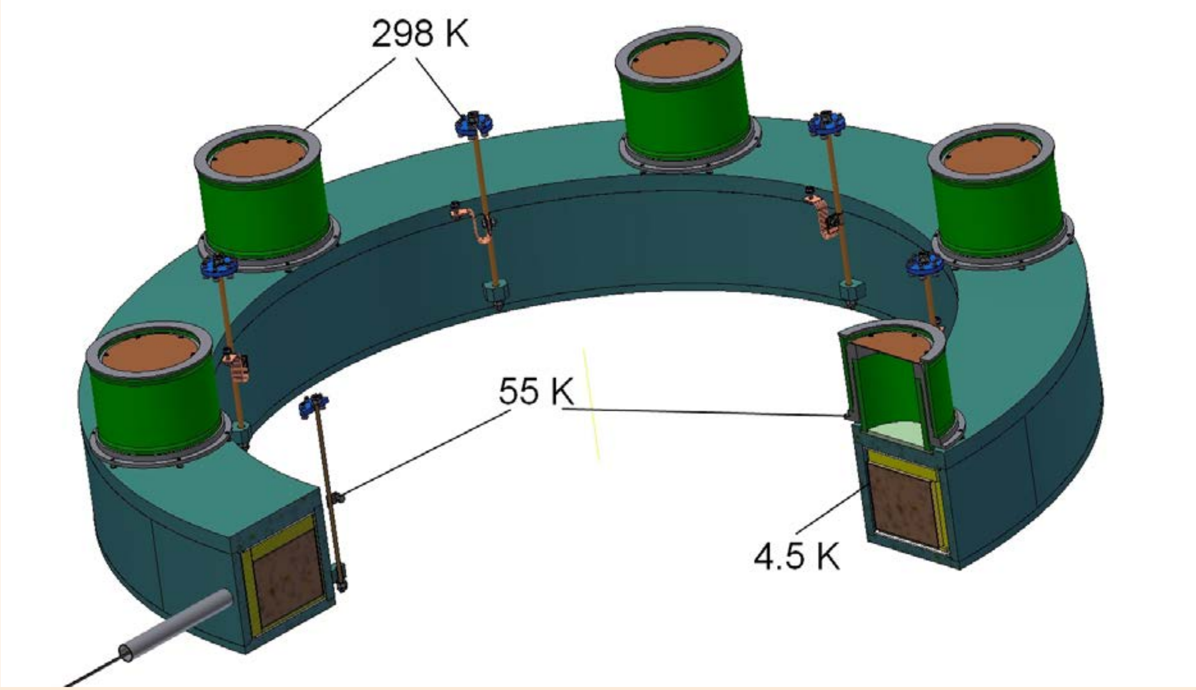
In BINP tests the cryostat will be modified to install a cryocooler to keep the current leads at design temperatures.



Heat loads

Heat loads were estimated for 4.5, 4.6 K helium surfaces and for 50-60 K surfaces.

The major heat in-leaks will be from the support struts and from the current leads.



Heat loads on the cryostat with coils at 4.5 K

Table 6 Heat loads on 4.5 K helium from both coils and the cryostat.

Heat load sources	**Values**
Thermal radiation on the LHe case, W	0.12
Support struts, W	< 3.6 expected
Tie rods, W	0.05
Soldering connection of the cable (at least 6 short splices), W	0.12
Thermal radiation on the cryostat, W	0.015
Cryostat suspension, W	<0.1
Current leads, W	0.5
Measurements wires, W	<0.1
Heat bridges of the cryostat neck and others connections, W	<0.1
Total, W	***~ 4.71***

Table 8 Heat loads on 4.6 K helium from the Branch Box, the Feed Box and the transfer line

Heat load from	**Values**
Thermal radiation on 4.5 K surfaces from the shields on the FB and BB, W	0.15
Supports and suspensions, W	< 2
Control Valves, W	15.2
Check Valves, W	0.9
Measurement wires, W	< 0.01
Heat bridges of the cryostat neck and others connections, W	< 1
Total, W	19.26

Heat loads on the cryostat with coils at 50 K

Table 7 Heat loads on 50 K helium from both coils and the cryostat

Heat load from	**Values**
Thermal radiation on the shields from the vacuum vessel, W	10
Support struts, W	49.5
Tie rods, W	0.5
Thermal radiation on the cryostat shield, W	1.5
Cryostat suspension, W	2
Current leads, W	120*
Measurements wires, W	0.5
Heat bridges of the cryostat neck and others connections, W	1
Total, W	~ 185

*) It will be corrected after detailed design of the current leads

Table 9 Heat loads on the 60 K helium (return line) from the Branch Box, the Feed Box and the transfer line

Heat load from	**Values**
Thermal radiation on the shields from the vacuum vessel, W	7
Support and suspensions, W	20
Control valves, W	38
Check valves, W	11
Measurement wires, W	< 1
Heat bridges of the cryostat neck and others connections, W	5
Total, W	82

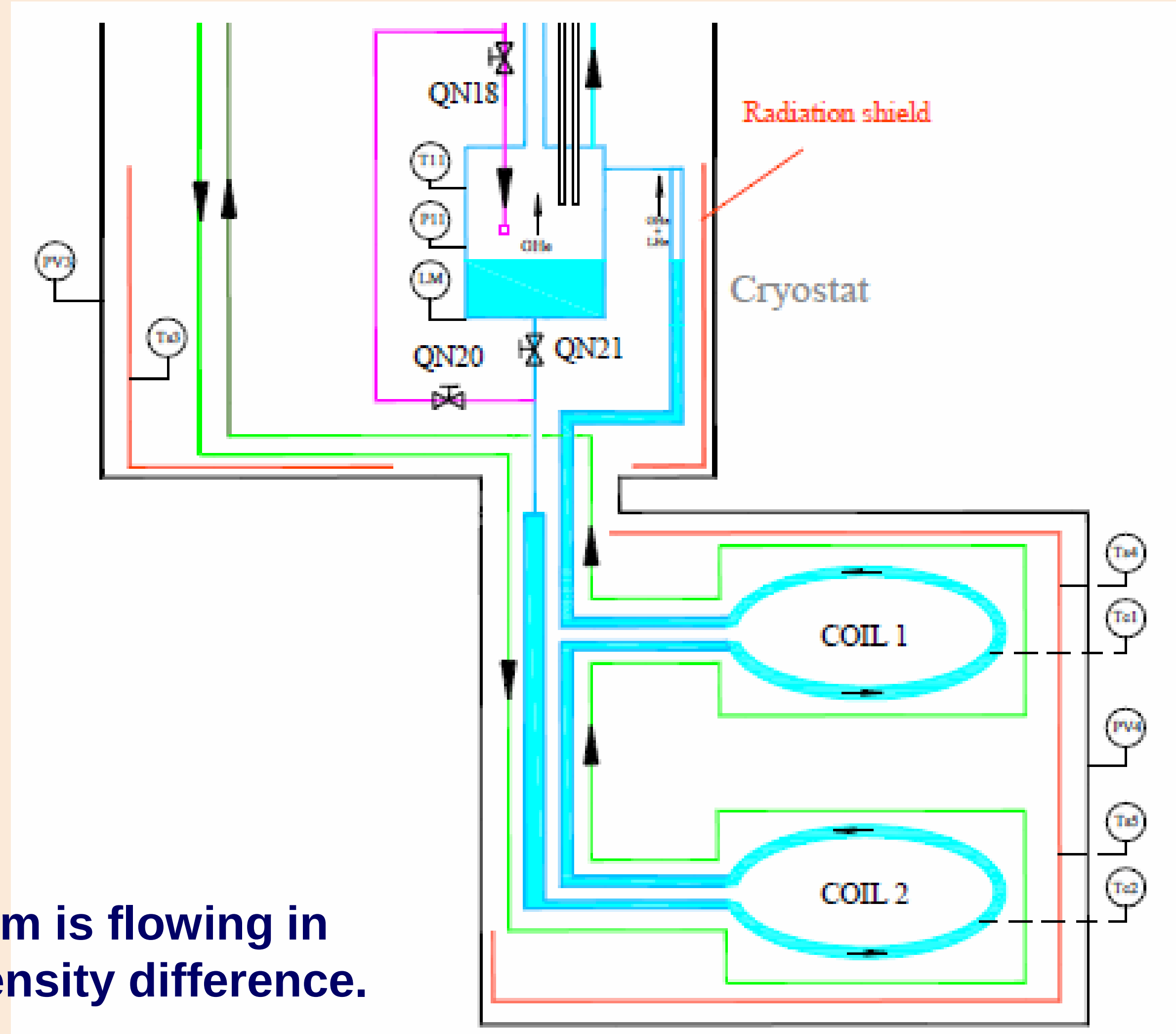
Thermosyphon

Thermosyphon is a cooling method based on natural convection of cooling fluid without external pumps.

Two mechanisms of flows:

- bubbles buoyancy, go out faster than liquid;

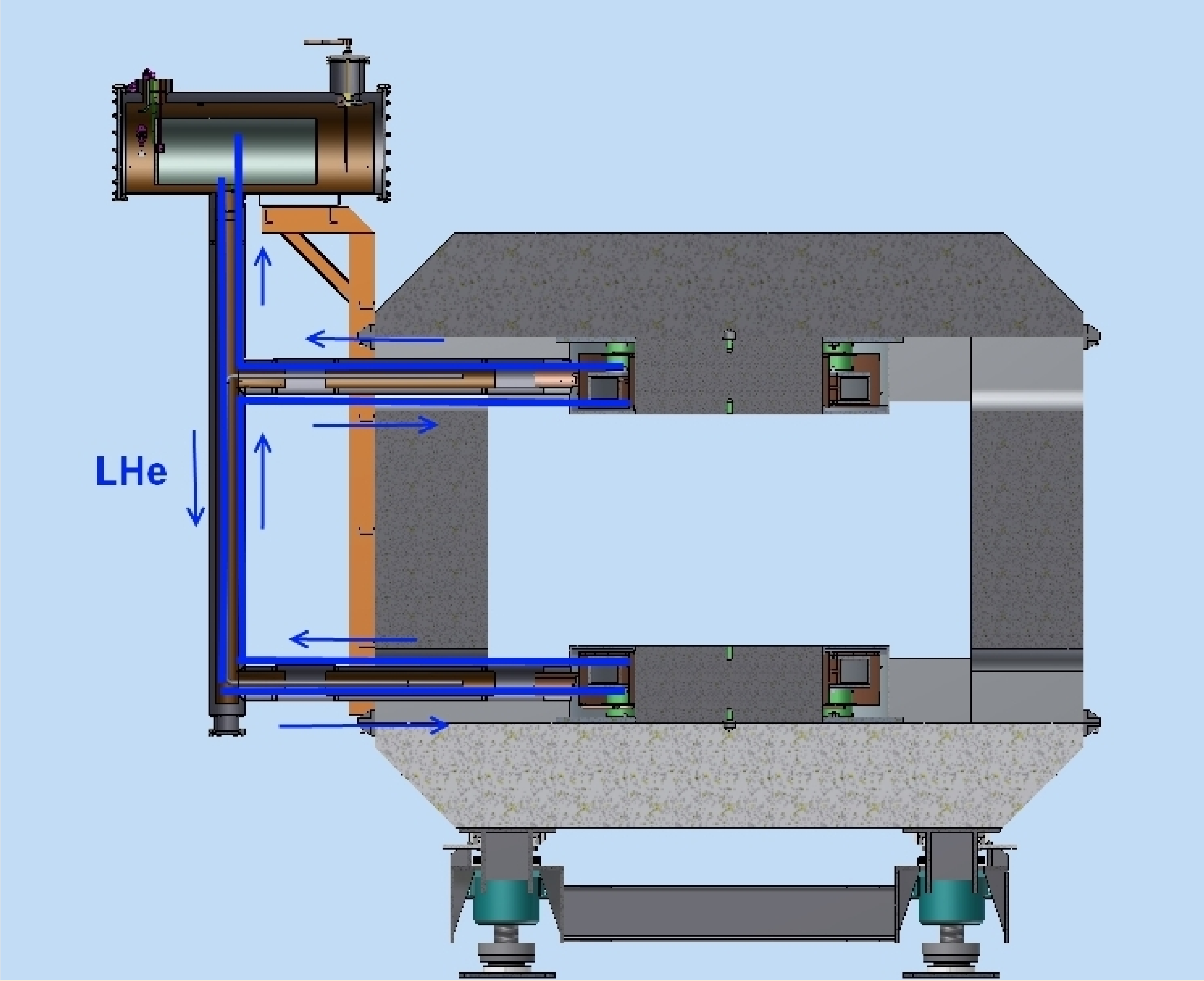
- total mass flow driven by density difference between the vertical channels.



In the CBM magnet helium is flowing in loop driven mostly by density difference.

Two almost horizontal channels will be in this loop. The length of these channels is ~ 14 m.

Thermosyphon circulation



Heat transfer estimations

The heat transfer estimations are based on pool boiling of helium in "large volumes".

The "large volume" is treated as volume with dimensions much higher than bubble diameters which are 0.08-0.16 mm.

The cooling tube of the coils has the diameter of 16 mm.

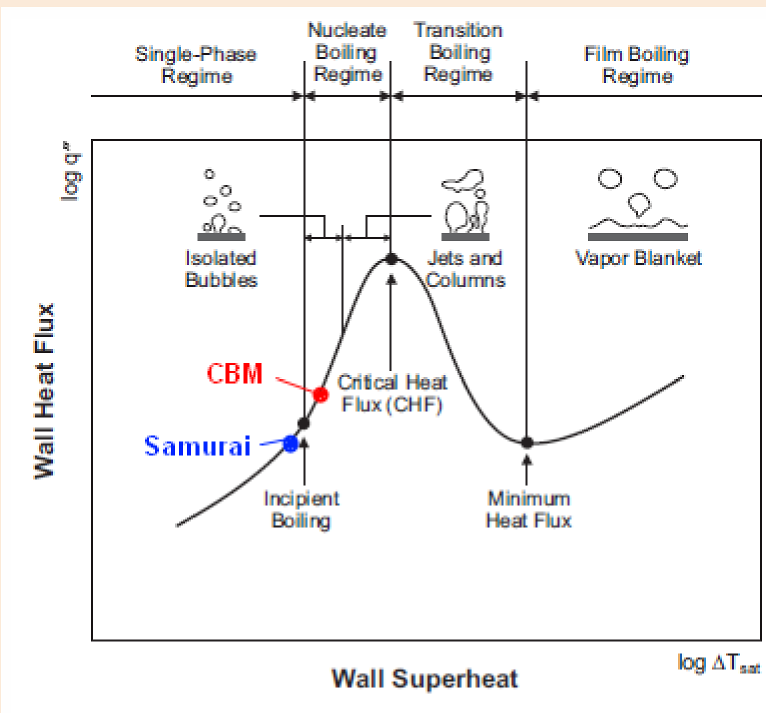
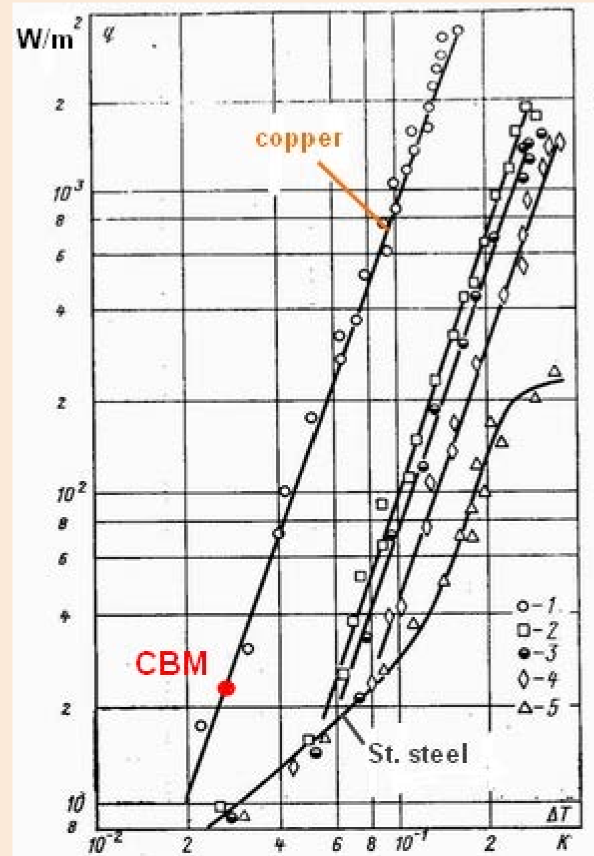


Fig. 1. Pool boiling curve.



The working point for the CBM magnet is close to single phase heat transfer. The critical heat flux is by 100 times higher.

Estimations and experimental data

1. Bubbles velocity due to buoyancy:

$$v = \frac{2}{9} \cdot \frac{g \cdot R^2(\rho_L - \rho_V)}{\eta},$$

v_b = 1.7 m/s – not high value.

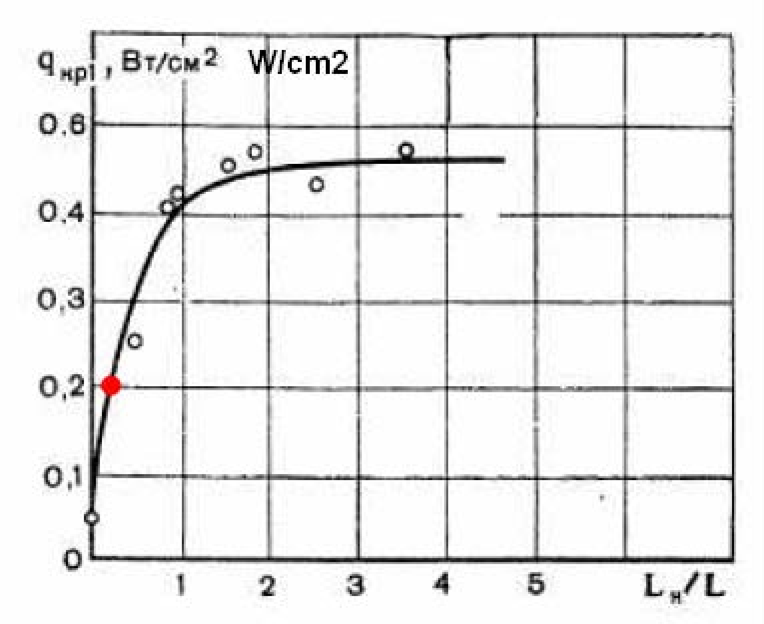
2. The forced flow will be in the helium tube when the density difference will grow up when the bubbles be accumulated in the cooling tubes.

$$\Delta\rho_2 = \Delta p/(g*H)$$

$$\Delta p = \xi \frac{8G^2}{\pi^2 \rho} \cdot \frac{L}{d^5}$$

The Δp ~ 32 Pa at G ~ 2.5 g/s – total mass flow in tubes.

v_g = 0.65 m/s. The bubbles will go faster than the gas-liquid mixture.



Experimental data for critical heat flux on heated horizontal channel (L) and unheated vertical channel (L_H). The red point marks the length ratio for the CBM magnet.

Conclusions

- The preliminary design of the cryostat is presented.
- The HTS current leads are being developed.
- The cryostat designs for BINP tests and in GSI operation will be different.
- The thermosyphon evaluations are presented