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Cryogenic sample environment systems at instruments at the IBR-2 reactor

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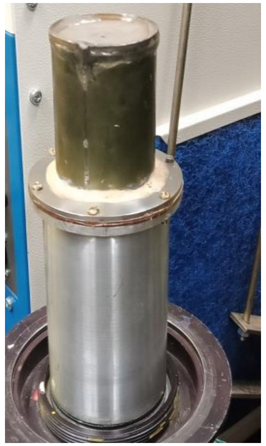
Sample environment and cryogenic research group

Currently, for work in the field of experimental physics of low temperatures, cryogenic equipment is produced by a number of companies, for example, Oxford Instruments, Janis and others. However, here we are dealing with standard equipment, which, as a rule, is not suitable for specific conditions and tasks, and it needs to be adapted or modernized. In this regard, we are developing unique original equipment for problems that are solved using thermal neutron beams. This report is devoted to the development of: cryostats with ultra-low temperatures, cryostats with cooling by closed-cycle cryocoolers, shaft cryostats with vertical and horizontal loading, cryogenic system for cooling HTSC magnets and technology aspects of HTSC magnets



CONTENTS OF THE REPORT

1. Shaft cryostat based on GM cryocooler at spectrometer NERA (neutron beam 7)

powder time-of-flight neutronoscopy

Fig.1 the photograph of a cryostat

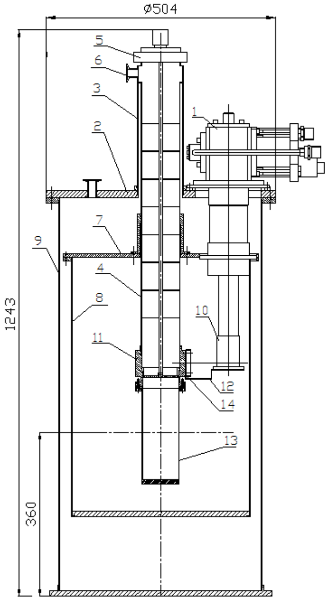


Fig. 2 a drawing of the cryostat. 1 - SRDK415D, 2 – gate, 4 – SS tube 78 mm id, 11 – heater, 12 – thermal bridge, 13 – Al sample chamber

Fig. 3 an insert

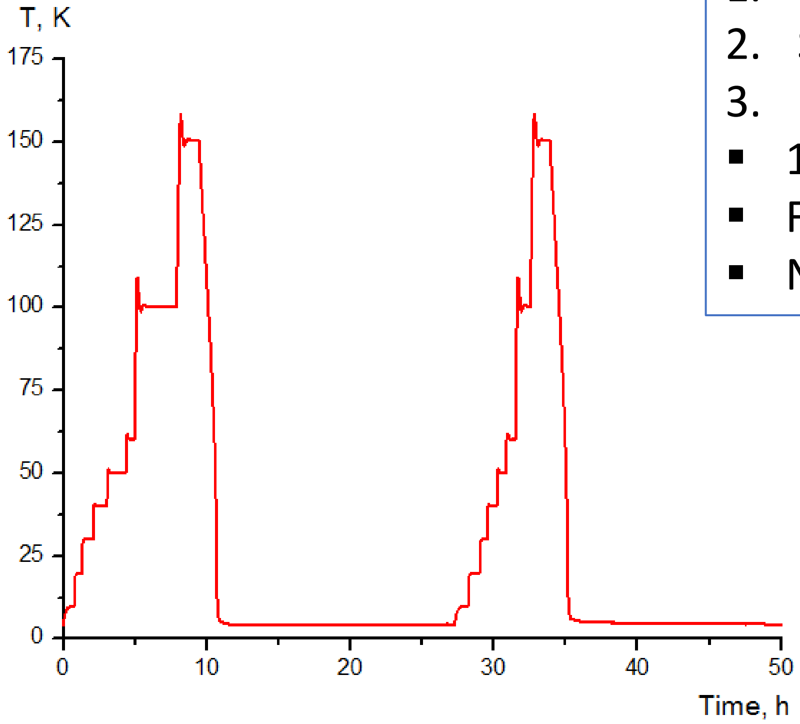


Fig.4 temperature of a sample versus time

1. Final temperature -5 K
2. Shaft – 78 mm id
3. Dimensions

- 1243 mm height
- F 504 mm of main flange
- Neutron position 360 mm

2. Horizontal cryostat based on GM cryocooler at diffractometer DN-6 (neutron beam 6)

High pressure

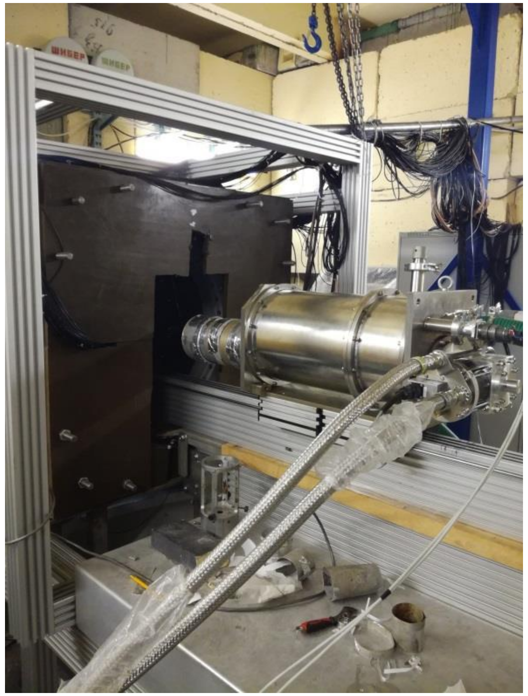


Fig.1 photograph of a cryostat at DN-6

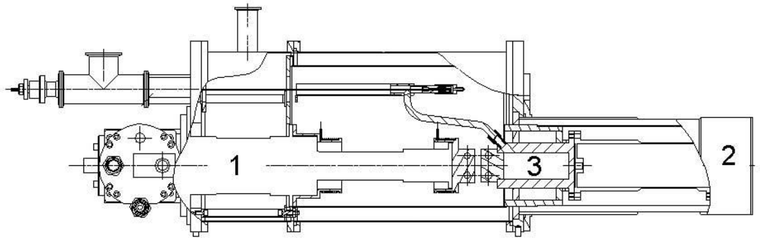


Fig.2 drawing of the cryostat
1 – SRDK415 D, 3 - Thermal bridge,
2 – sample chamber zone

Fig.3 High pressure chamber with sapphire anvils (weight - 3 kg)

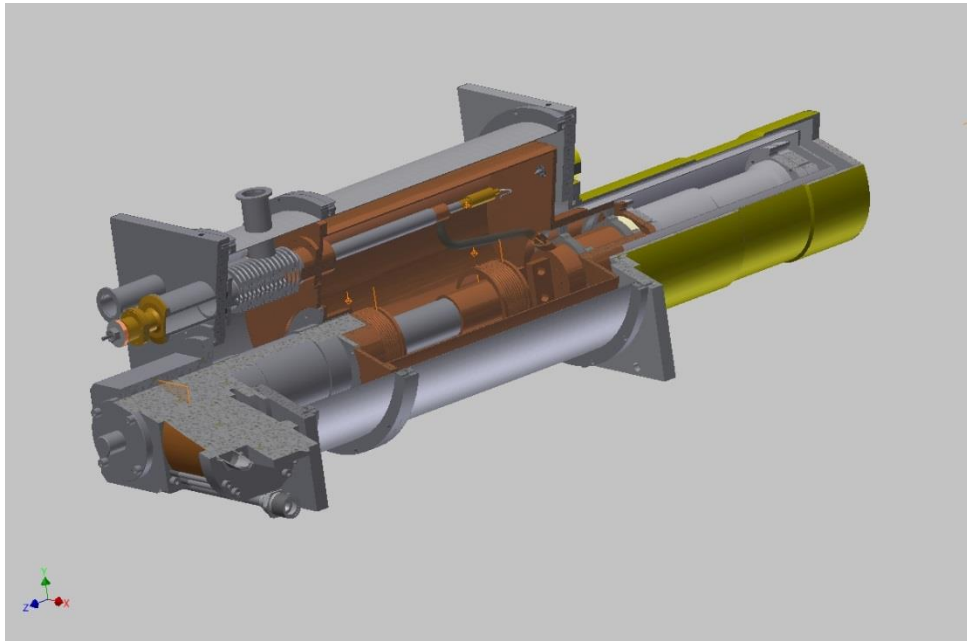


Fig.4 3-D drawing of the cryostat.

3. Horizontal cryostat based on GM cryocooler at diffractometer DN-12 (neutron beam 12)

High pressure

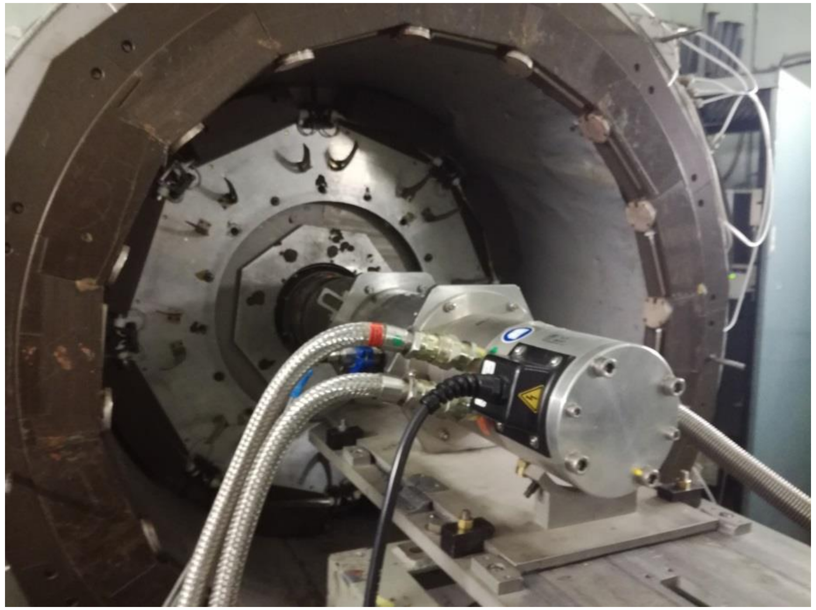


Fig.1 photograph of the cryostat at DN-6

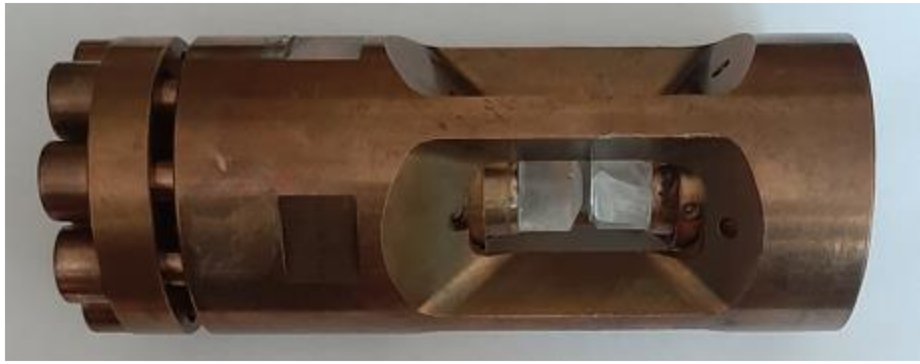


Fig.2 High pressure chamber with sapphire anvils (weight - 3 kg)

4. HTSC Magnet horizontal shaft cryostat based on GM cryocooler at diffractometer DN-12 (neutron beam 12)

High pressure

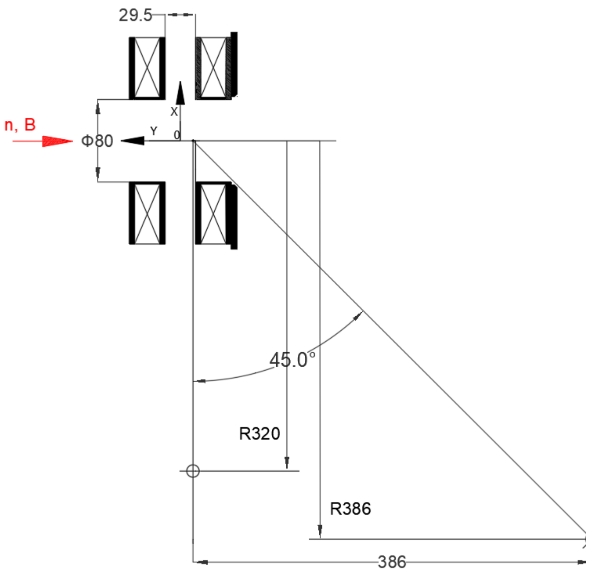


Fig.1 - DN-12 aperture and a magnet. A sample with a characteristic size of 1x1x1 mm3 is shifted from the center to the edge of the magnet frame. The distance in the frame for conducting scattered neutrons is at least 29.5 mm. 1 – sample position. 2 and 3 - detector rings. (R=320mm and R=386mm – distance from the magnet axis to detectors)

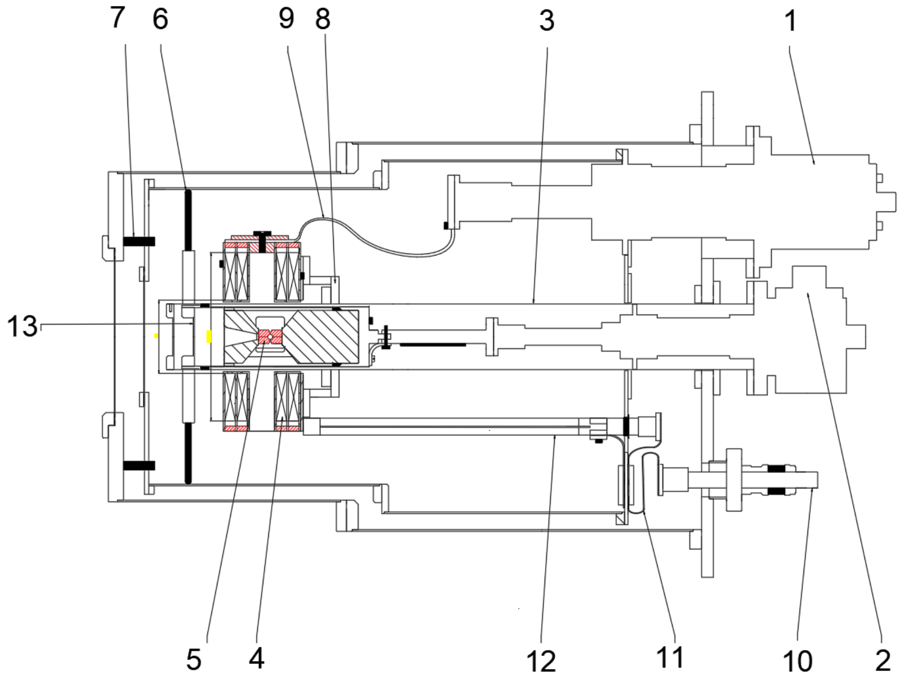


Fig. 2 – cryostat.1 – cryocooler, cold head SRDK 408S; 2 – insert - cold head SRDK 101D with heater; 3 - shaft with an internal diameter of 78 mm; 4 – magnet coils; 5 – container with a high-pressure chamber; 6, 7 – fiberglass limiters; 8 –holders; 9 – flexible aluminum heat conductor; 10 – 300A feedthroughs; 11 – copper current leads; 12 – HTSC current leads; 13 – neutrons input window

Fig.3 Cryostat-insert,
temperature 3.6 -150 K and press on 10 GPa

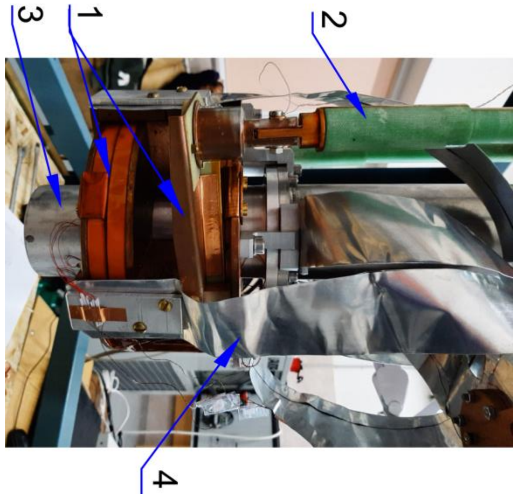


Fig.4 1 – HTSC double pun-cacke coils by Tape 12 mm width and 0.095 mm thickness
2 – HTSC current leads
3 – Al sample chamber
4 – Al thermal bridge

SUPERPOWER
HTSC Tape 12 mm
width
0.095 mm thickness

5. Calculation of Magnetic field of Helmholz pair by HTSC 12 mm tape

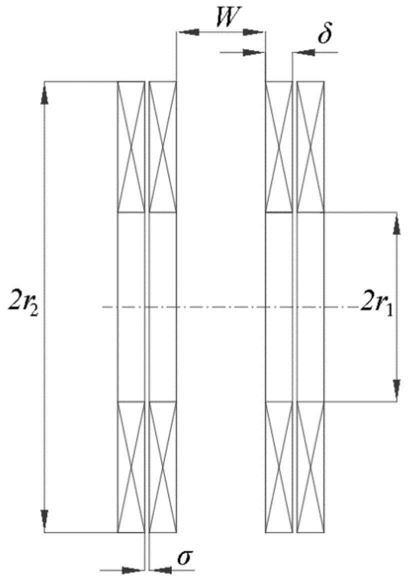


Figure 1 – Drawing of a Helmholz magnet for DN-12. Here *W* is the distance between the coils. *δ* is the width of a tape =12 mm, *σ* is the distance between the spiral windings, $2r_1$ is the diameter of the first winding layer, $2r_2$ is the diameter of the outer winding layer.

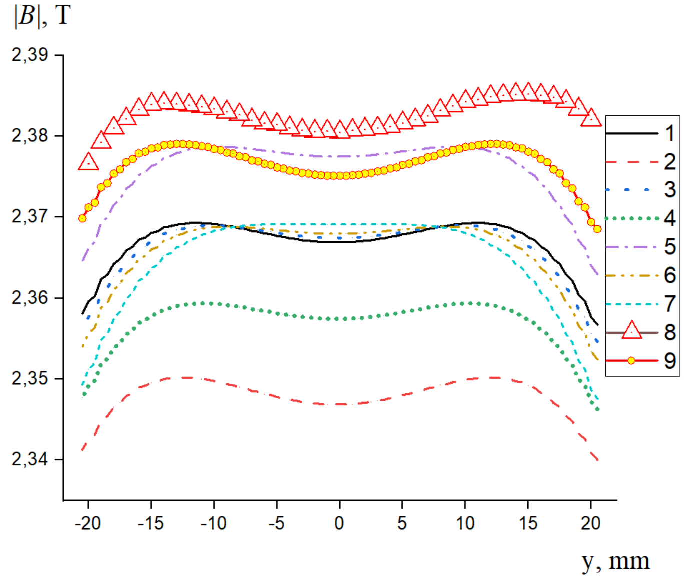
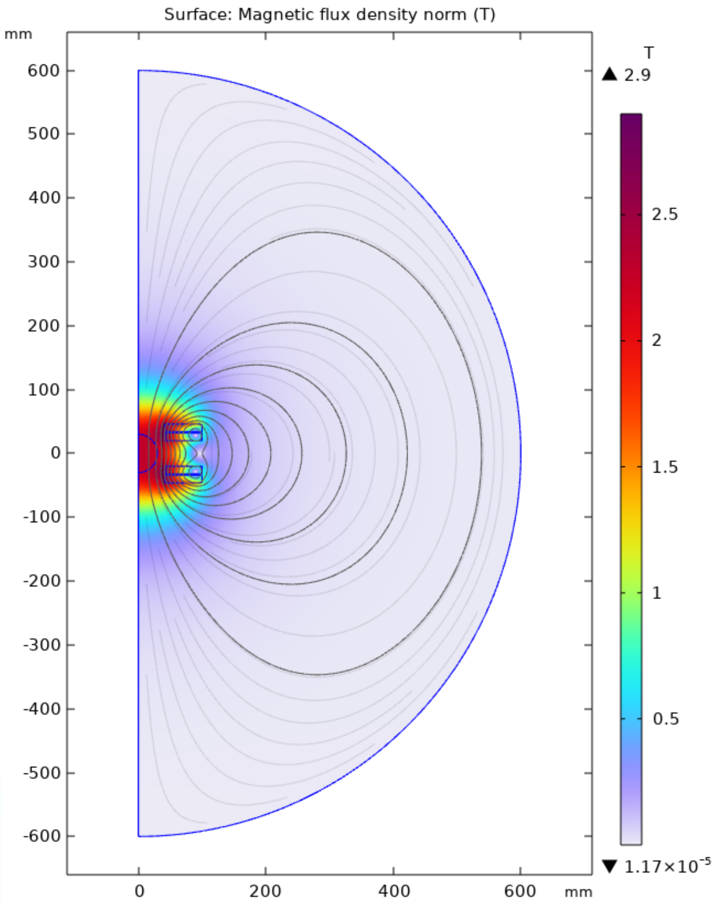


Figure 2 - Magnetic induction value |*B*| on the magnet axis, current 150 A. n - number of layers. λ - tape thickness

1, 2, 3, 4, 5, 6, 7, - calculation, *n*= 604, λ = 0.1 мм. 1 - (*W*=40 мм, σ=2 мм); 2 - (*W*=40 мм, σ=3 мм); 3 - (*W*=39 мм, σ=3 мм); 4 - (*W*=39 мм, σ=3.5 мм); 5 - (*W*=39 мм, σ=2.5 мм); 6 - (*W*=38 мм, σ=4 мм); 7 - (*W*=36 мм, σ=6 мм);

8 – experiment;

9 – calculation, *n*= 610, λ = 0.095 мм, (*W*=40 мм, σ=2 мм)



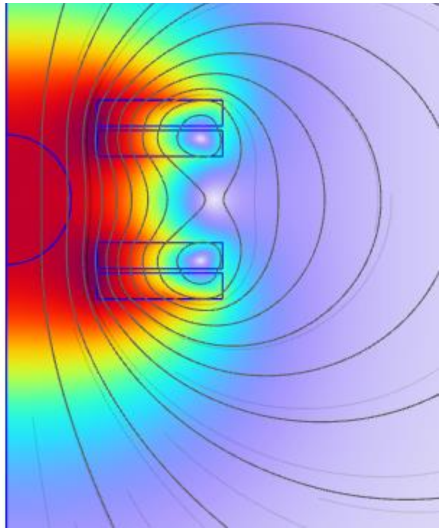


Figure 3 and 4 – Calculation In COMSOL Multiphysics

6. Helium Cryostat ORANGE50 with asymmetrical Helmholtz pair by LTSC (NiTi) at reflectometer REMUR (neutron beam 8)

polarized neutrons reflectometry

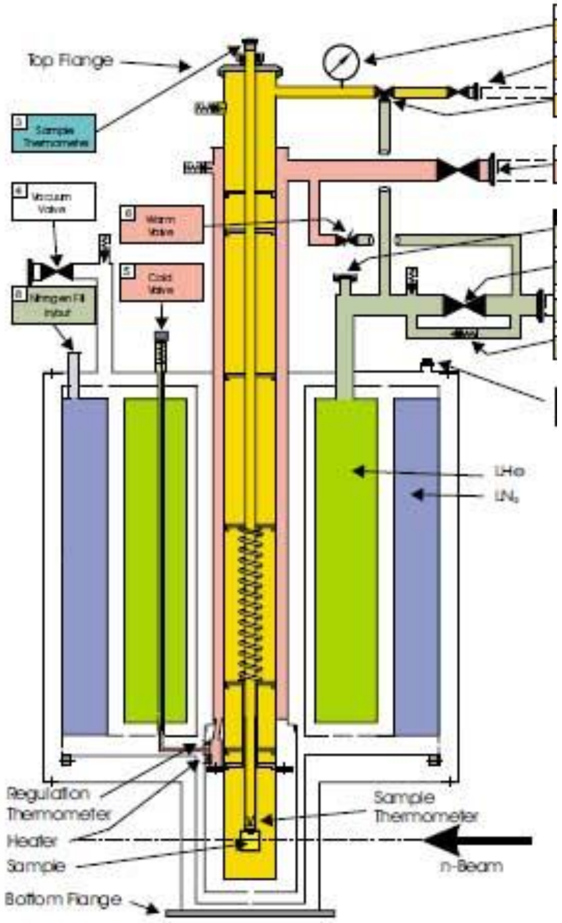


Fig.1 cryostat diagram

Fig.2 photograph of the cryostat

Range - below 300 K
Final temperature 1,5 K
Magnetic field – 2.5 T
Vertically directed

7. HTSC vector magnet for reflectometer REMUR and shaft 3He/4He dilution refrigerator

polarized neutrons
Reflectometry
New project

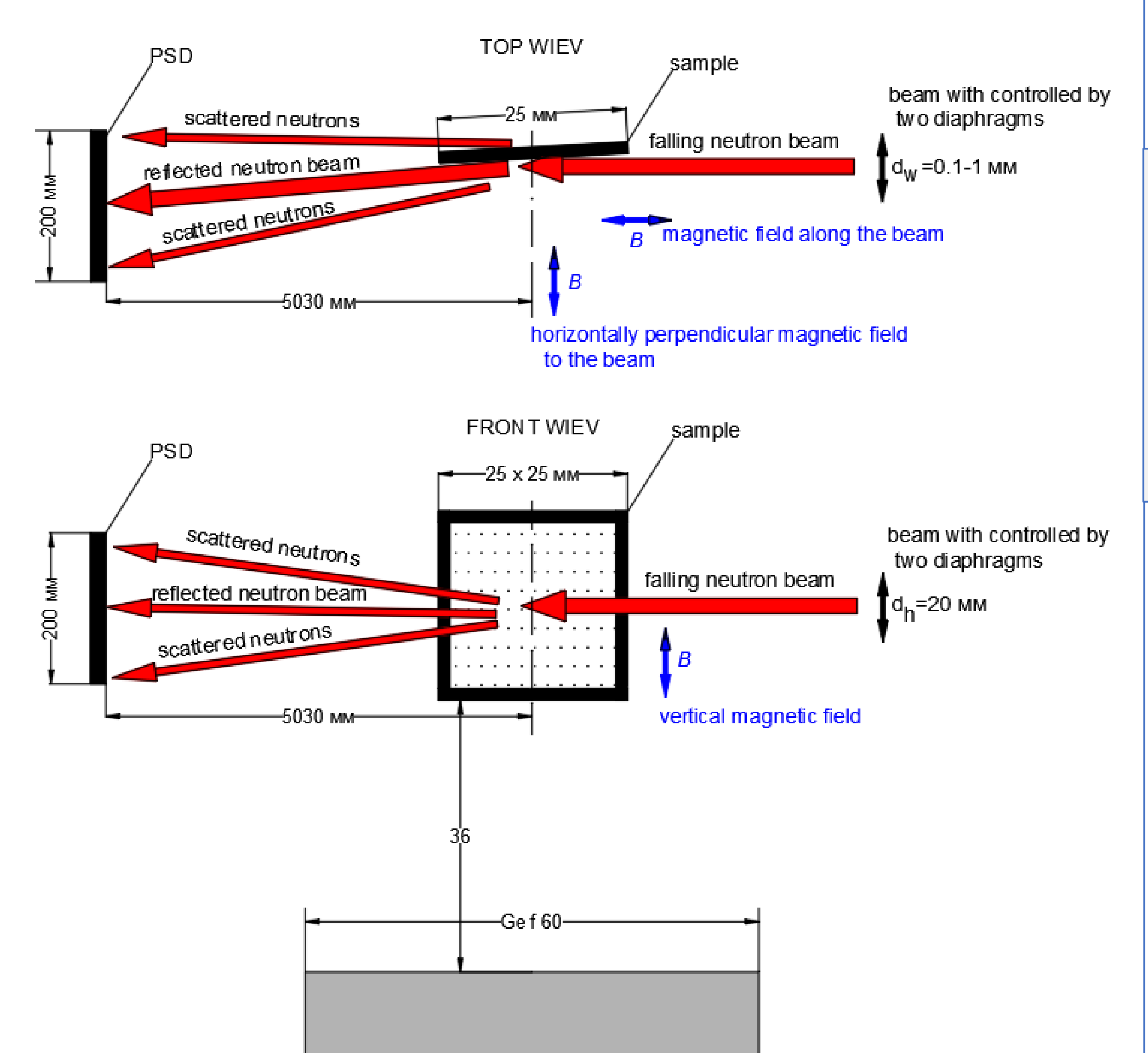


Figure 1. Experimental conditions: sample dimensions, sample position, beam dimensions, scattering aperture, *Ge γ*- detector, magnetic field direction.
Size of crystal of *Ge γ*- detector and its cryostat set minimal sizes of magnetic system.
The sample size determines the minimum diameter of the cryosystem loading shaft (stainless steel tube 35 mm in diameter)

Magnetic field:
Vertically – 3 T
Horizontally - 1 T
Current – 120 A
Material HTSC tape – 4 mm width
0.05 mm thickness
Temperature
Final 100 mK
Method – dilution 3He/4He

8. REMUR Magnetic system design, project. C-innovations 4 mm 50 microns thickness HTSC tape

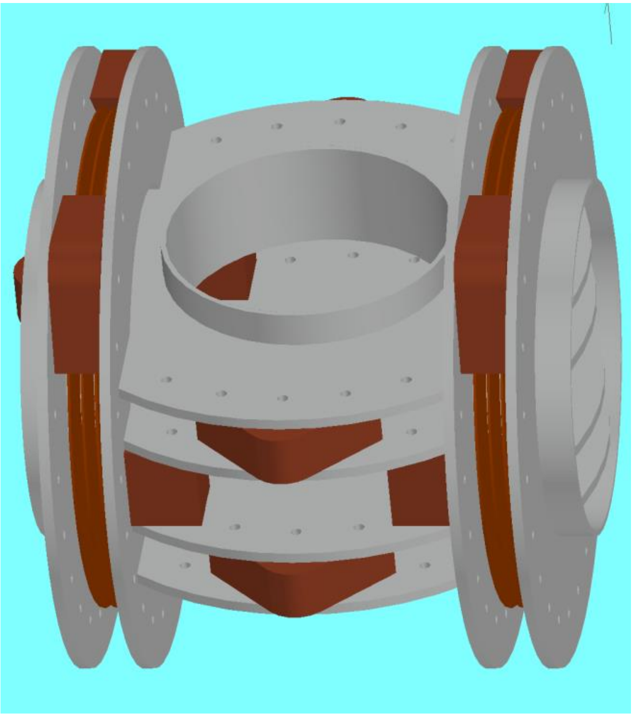


Fig.1 3D model

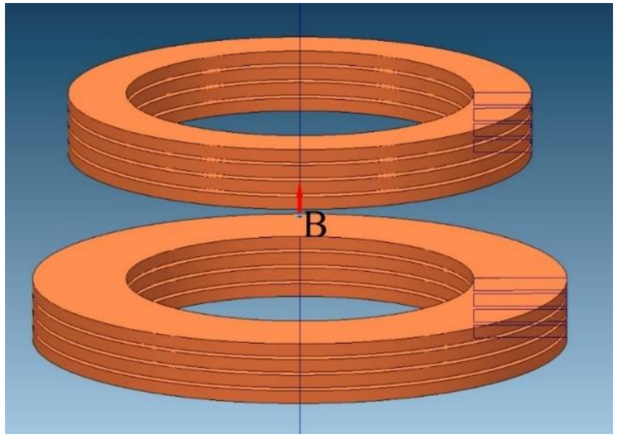


Fig.2 Model of a coil creating a **vertical field**.
The diameter of the first layer is 108 mm.
Lower groups of winding - Two double pub-cacke coils with 527 layers each.
Upper group of windings - Two double pun-cacke coils with 297 layers.
The distance between groups of biscuits is 40mm.

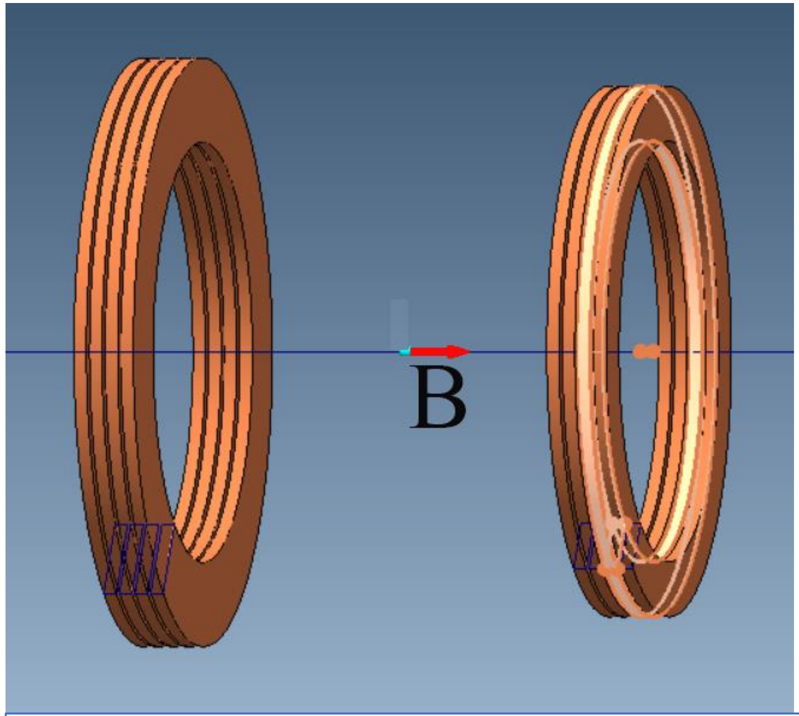


Fig.3 Model of a coil creating a **horizontal** field.
The diameter of the first layer is 130 mm.
Left group of windings - Two double pub-cacke coils with 473 layers each.
Right group of windings - Two double pun-cacke coils with 310 layers.
The distance between groups of biscuits is 130 mm

9. Calculation of REMUR magnetic system

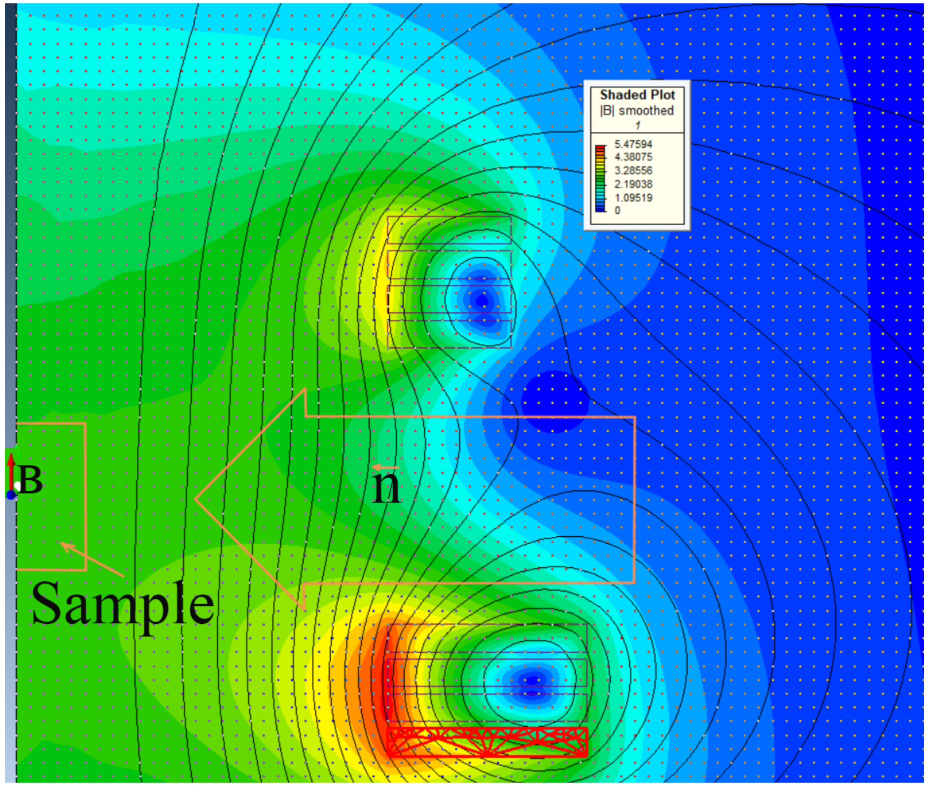


Fig.1 Map of the magnetic field of a vertical coil. Field in the center is 3 T. The grid is indicated with a pitch of 2 mm. Dimensions of the sample are 25x25. The beam dimensions are shown too.

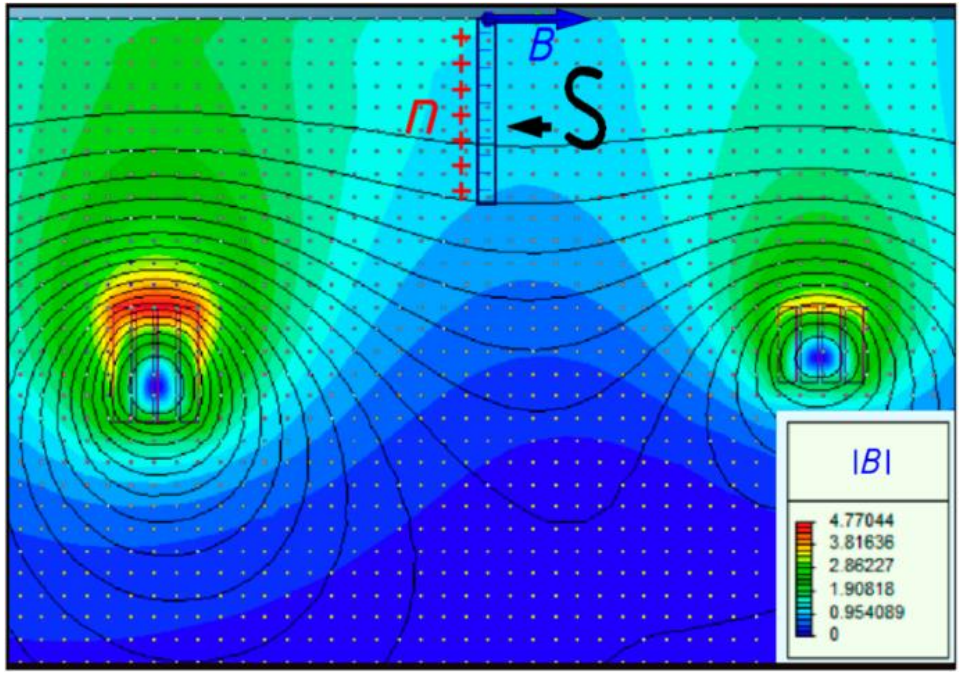


Fig.2 Map of the magnetic field of a horizontal coil. Field in the center is 1 T. The grid is indicated with a pitch of 5 mm. The sample is located symmetrical in the center, thickness of the sample is 2 mm.

10. Technology with 4 mm HTSC tape for REMUR vector magnet

To manufacture the magnet, tape produced by c-innovation (Russia) will be used.

1. The tape is supplied in pieces from 100 to 300 meters long
2. To obtain pieces of the required length, it is necessary to develop a technology for soldering pieces of tape (status 90 %)
3. It is also necessary to develop a machine for rewinding tape from reel to reel (status 100 %)
4. to wind a magnet, it is necessary to develop a machine for winding coils (status 90 %)

Machine for rewinding tape from reel to reel, 4 mm wide
Tape from c-innovation on the reel

Machine for soldering of pieces of tape

Winding machine

To solder pieces of tape we use Solder POS 60 (Sn 60 %, Pb 40 %) doped with Cd 18 %)
For soldering we use a slightly acidic flux, a temperature of 180 degrees Celsius and a pressure of 100 bar
We connect the pieces of tape using a bridge from the same tape
This technology gives us a connection with an electrical resistance of 10^{-9} ohms

11. Cryostat with HTSC magnet and dilution 3He/4He refrigerator for reflectometer REMUR

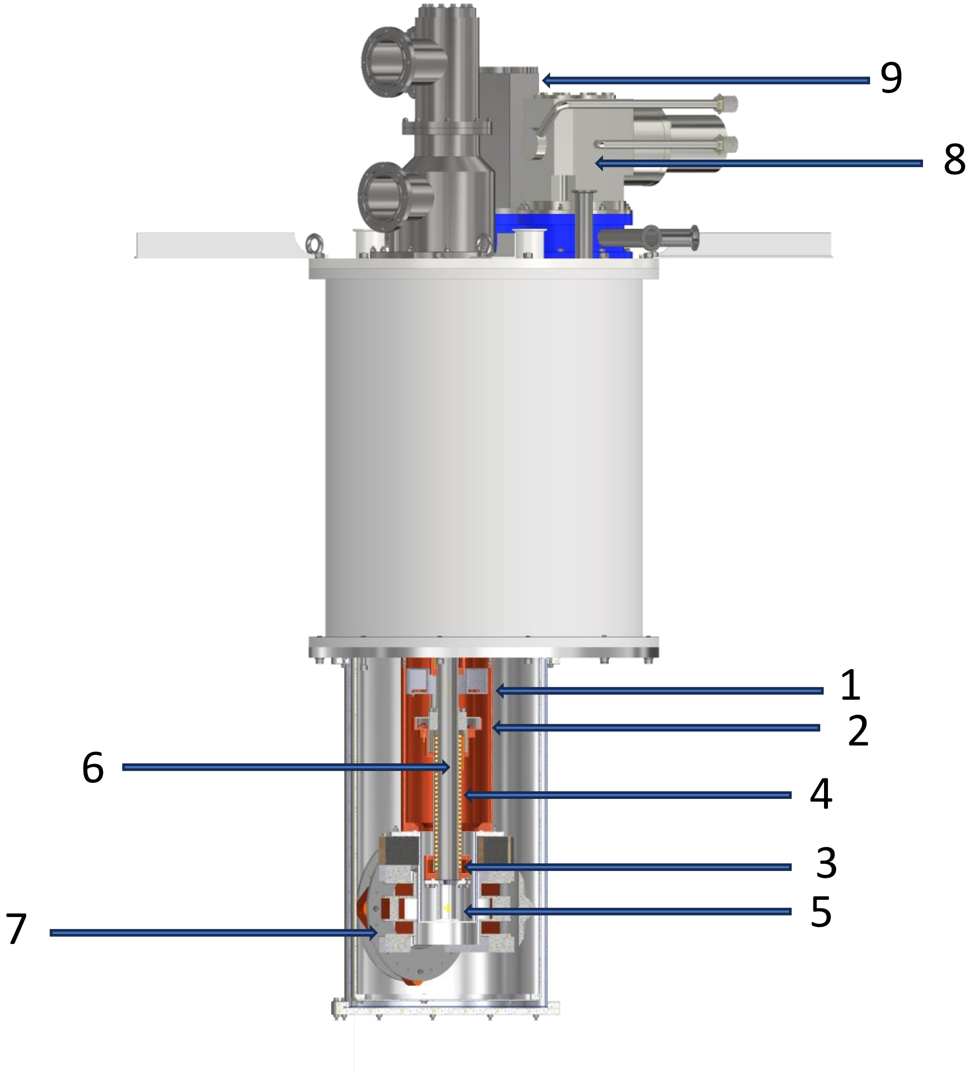


Fig1. Design model of REMUR cryostat.

1 – 1 K bath,

2 – still,

3 – mixture chamber,

4 – heat exchangers of the dilution refrigerator,

5 – sample chamber,

6 – shaft - tube of 34 mm in diameter for loading the sample into the neutron beam zone,

7 – vector magnet,

8 – pulse tube cryocooler for cooling dilution refrigerator,

9 – pulse tube cryocooler designed for cooling the vector magnet.

12. Refrigerator 3He based on closed-cycle cryocooler cooling (cryogenic stand, building 119)

3He purification for neutron detectors

Fig.1 Cryostat

Fig.2 Gas communications

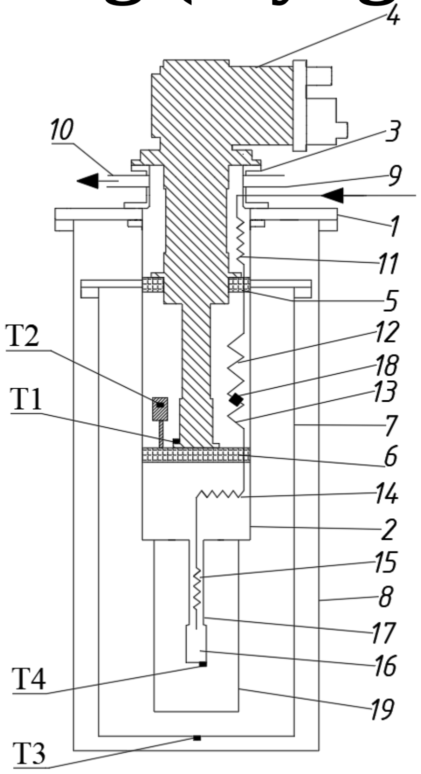
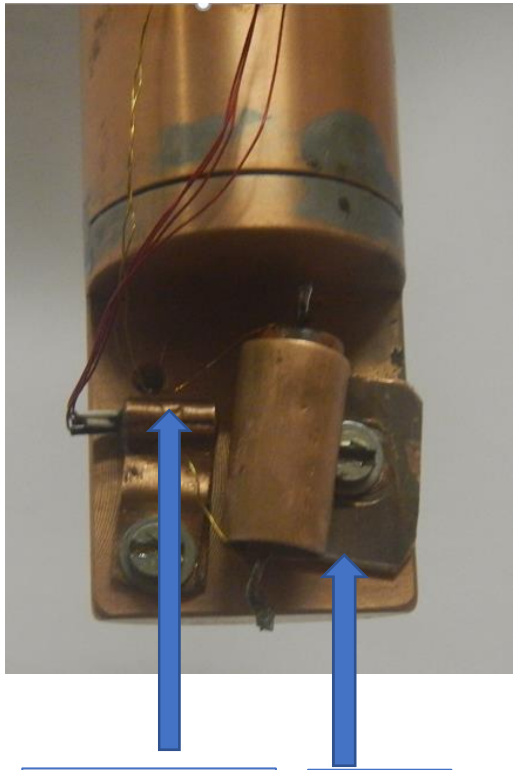


Fig.3 Drawing of cryostat

1-main flange; 2- container – thin-walled SS pipe Φ150 mm and 390 mm long; 3 - gas manifold; 4 – cold head 1.5 W at 4.2 K; 5,6,11,12,13,14 - heat exchangers; 7 – 77K heat shield; 8 – Cryostat housing; 9 – inlet tube for 3He; 10 – pumping tube 3He; 15 – throttle, 16 – evaporator; 17 – thin-walled tube SS Φ 12 mm 60 mm long; 18 - activated carbon filter; T1, T2, T3 – silicon diodes, T4 – thermistor, 19 – 2.3 K thermal shield.

Fig.4 L3He camera



Thermistor T4

Heater

SUMMARY

Thus, we note several main points of the report.

Firstly. Cryostats with GM and Pulse Tube cryocooling are being developed.

Secondly. Strong magnetic fields by high-temperature superconductivity are being developed.

Third. Ultra-low temperatures 3He cryostats are being developed.

And fourth. Vertical and horizontal loading cryostats are being developed.

THANK YOU FOR YOUR ATTENTION