

SPD solenoid



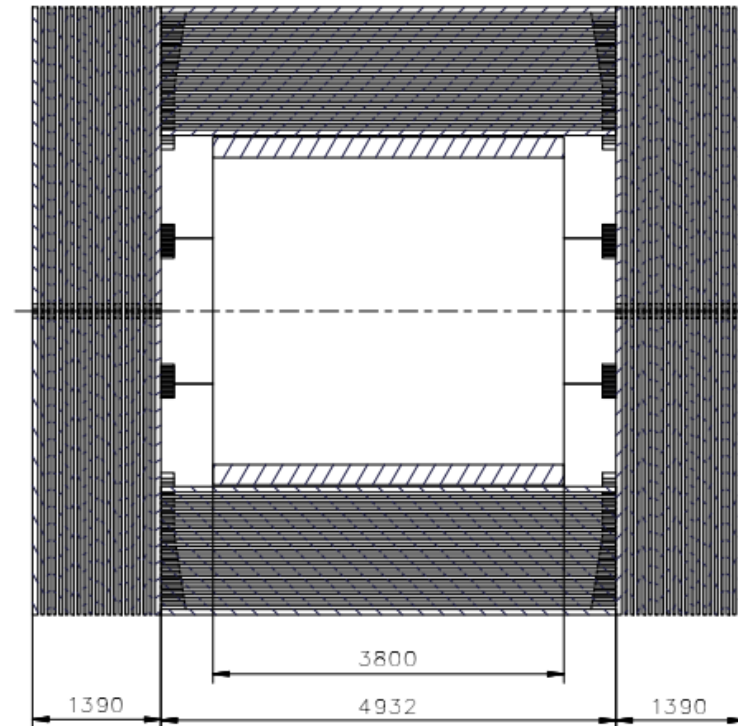
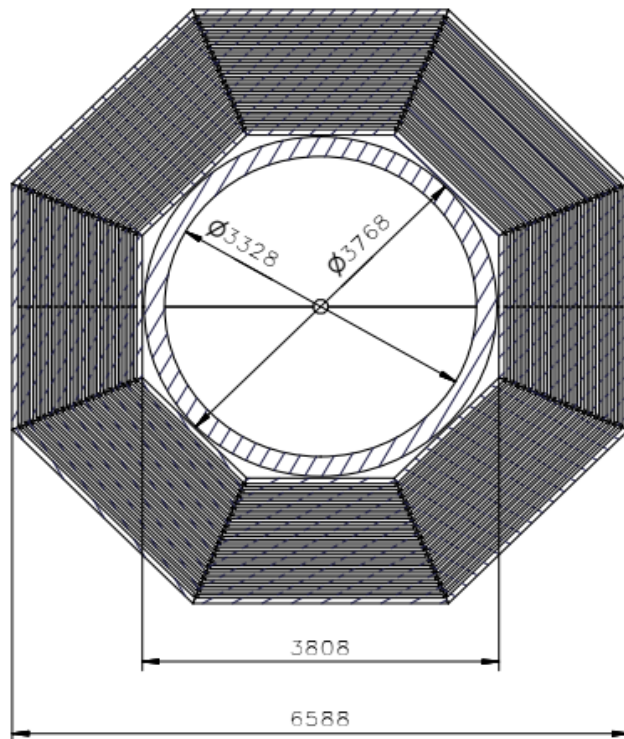
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BINP, Novosibirsk

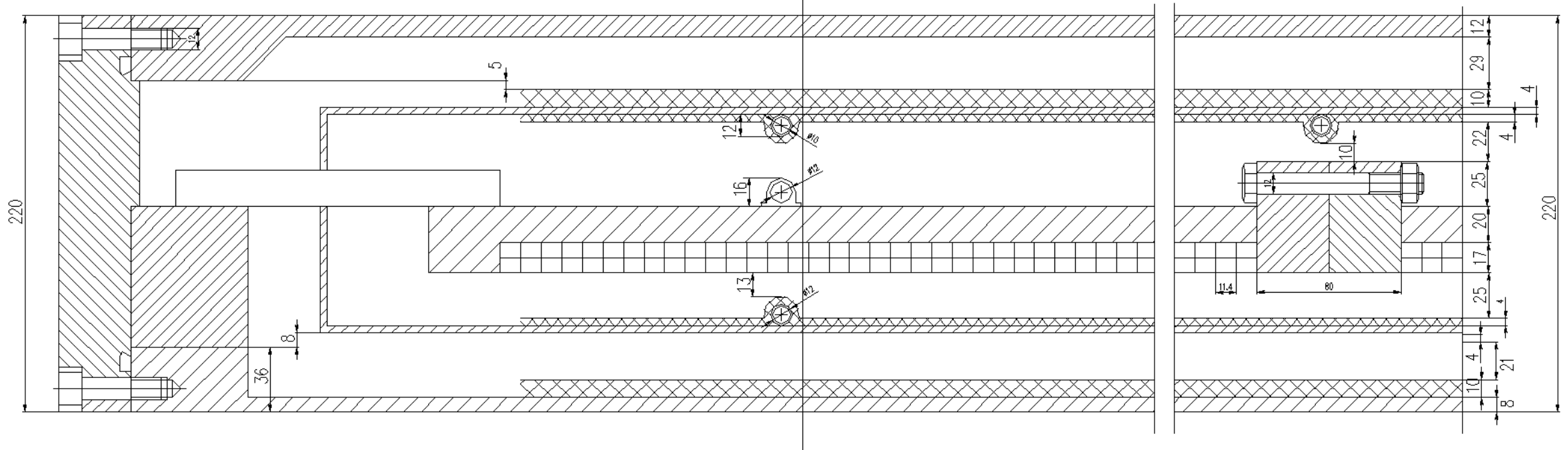
SPD yoke and solenoid

The cryostat of the magnet with the coils, cold mass and thermal shields is located inside the yoke.

The overall dimensions are driven by the space planned for the detectors of SPD and the magnetic field parameters. Outside diameter of the cryostat is 3768 mm and a gap between the yoke and the cryostat about 20 mm. Radially a free diameter of 3228 mm is left for the SPD detectors. The length of the magnet is 3800mm and the magnet should be installed symmetrically inside the yoke



SPD solenoid



Cryostat: OD -3668 mm; ID - 3228 mm;

Length - 3800 mm; Thickness - 220 mm;

Coils (3 pc.): Horizontal winding PANDA conductor - 2 layers; Turns = 552.

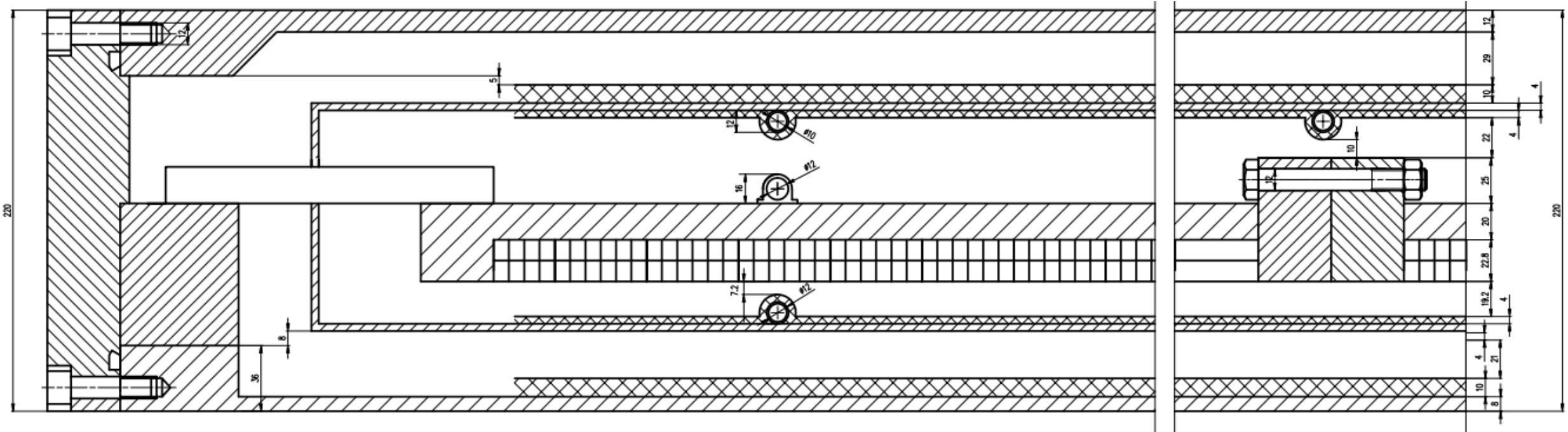
Weight: - cryostat about 9500 kg

- thermos shields - 850 kg

- coils about 3800 kg

Total: ~15 ton

SPD solenoid



Cryostat: OD -3668 mm; ID - 3228 mm;

Length - 3800 mm; Thickness - 220 mm;

Coils (3 pc.): Vertical winding PANDA conductor - 2 layers; Turns = 750.

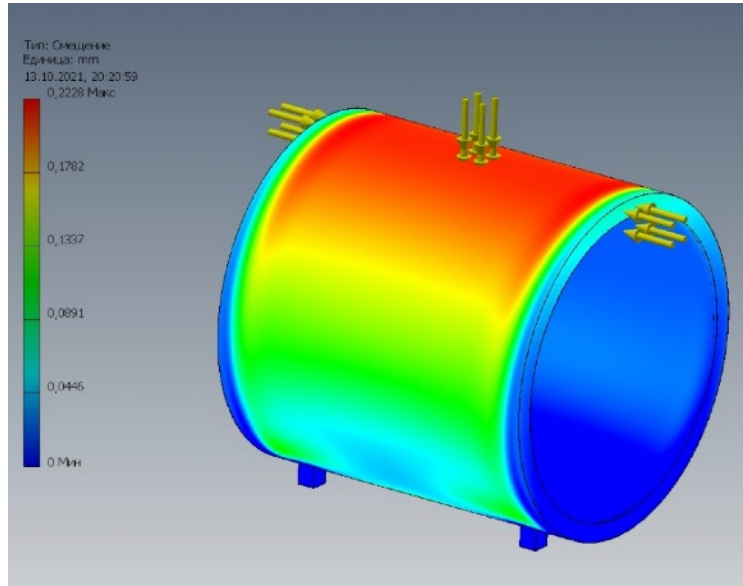
Weight: - cryostat about 9500 kg

- thermos shields - 850 kg

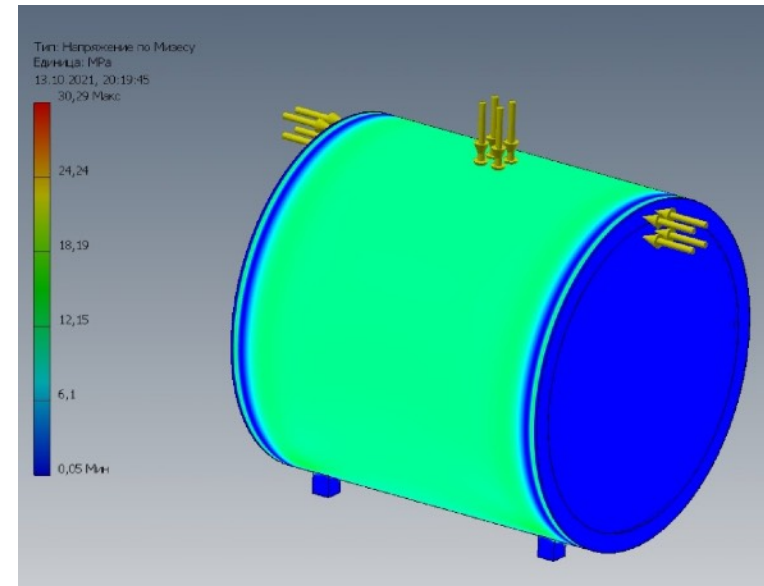
- coils about 4200 kg

Total: ~15 ton

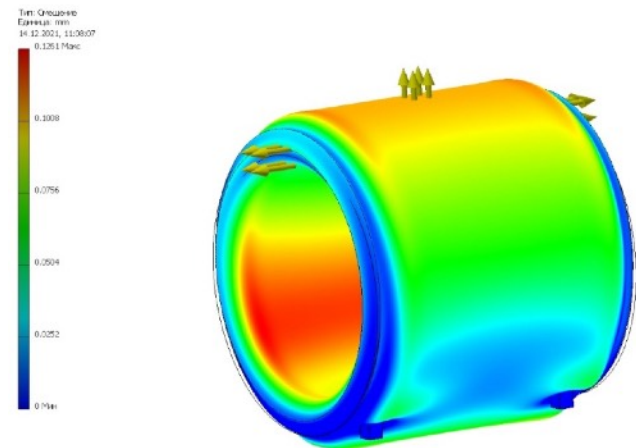
SPD solenoid



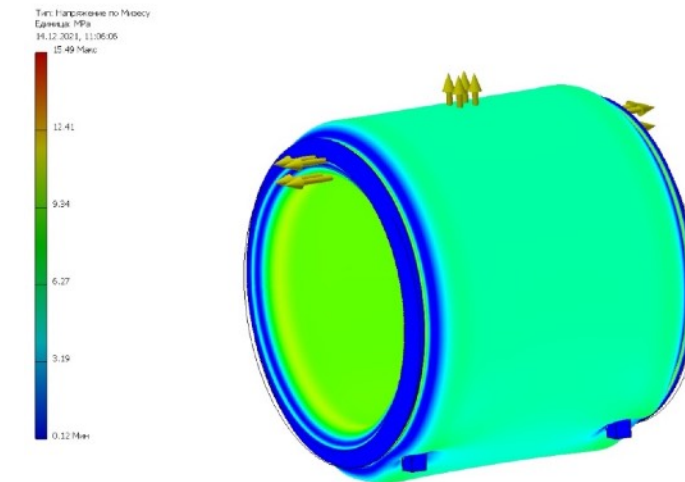
SPD Magnet
(Deformation,
 $p=0,1\text{MPa}$)



SPD Magnet
(Stress, $p=0,1\text{MPa}$)



SPD Magnet
(Deformation,
 $p=0,05\text{MPa}$)



SPD Magnet
(Stress, $p=0,05\text{MPa}$)

SPD solenoid

BINP suggest to use a superconducting NbTi/Cu wire based Rutherford cable co-extruded with a high purity aluminum-stabilizing matrix. This type of conductor was used for production larger detectors such as CELLO, CDF, TOPAZ, VENUS, ALEPH, DELPHI, CLEO, SDC, BELLE, ATLAS CS, ATLAS ECTs, ATLAS BT, CMS, Mu2e solenoids and PANDA.

The SPD solenoid is designed to operate at a current of 6,3 kA for vertical position of the conductor, i.e. about 32% of its critical current at 4.5 K and 2,0 T peak magnetic field.

The conductor is The insulated conductor dimensions at 4.5 K are 10.90 mm in width and 7.90 mm in height. The Rutherford cable is composed of 8 strands with a diameter of 1.40 mm and a Cu/SC ratio of 1.0. The critical current density of the superconductor at 4.2 K and 5 T shall be larger than 2800 A/mm² to ensure a temperature margin for quench well above 2.0 K. The same type of the conductor is produced in Russia and used for the PANDA solenoid, FAIR, Darmstadt.

At the case a horizontal position of the conductor a current is about of 8,3 kA and we need to use a Rutherford cable with 12 wires and the conductor dimensions should be at 4.5 K are 17,7 mm in width and 7.90 mm in height.

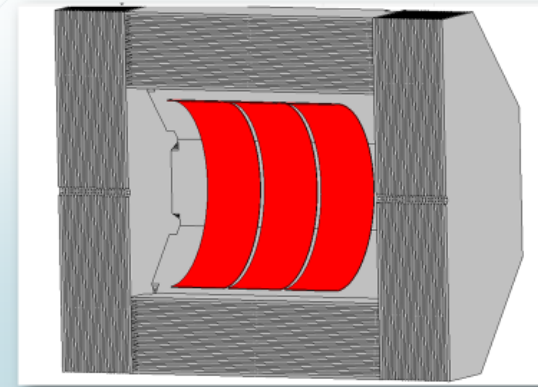
SPD solenoid

Common conditions.

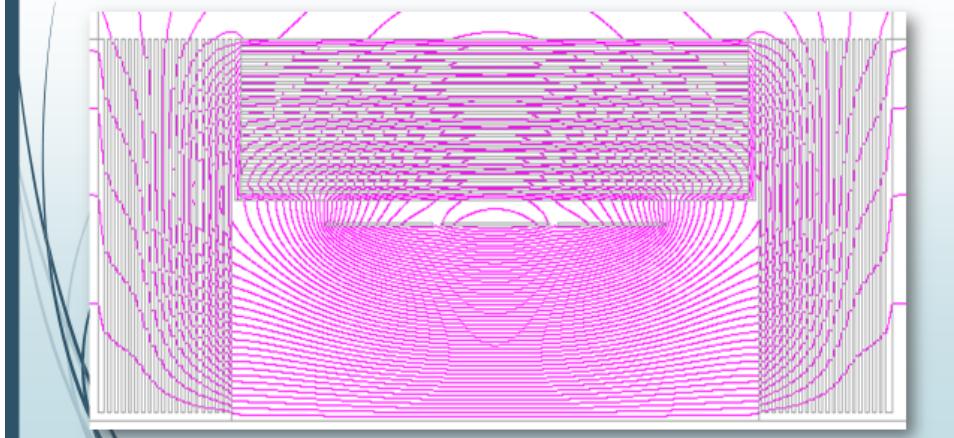
- soft- MERMAID (kGs)
- Type symmetry – axially symmetric model
- Coils – 3
- Size coils - 22.8 mm/250.
- Yoke material – Steel 3.

Magnetic Analysis

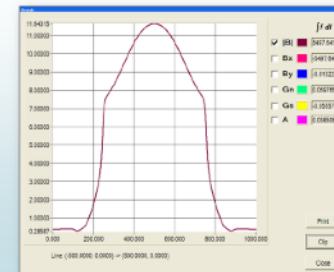
Common view of the solenoid.



View with magnetic field lines.

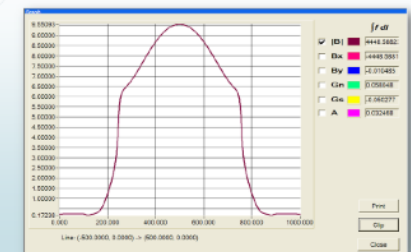


Поле на оси для варианта 250 витков, 6300 А



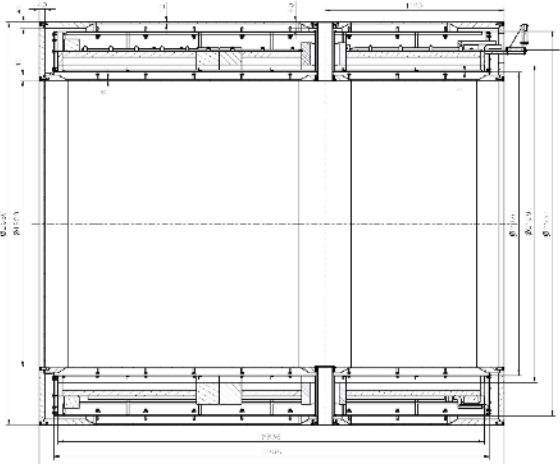
Maximal field in the coil is 2.0 T

Поле на оси для варианта 250 витков, 5000 А

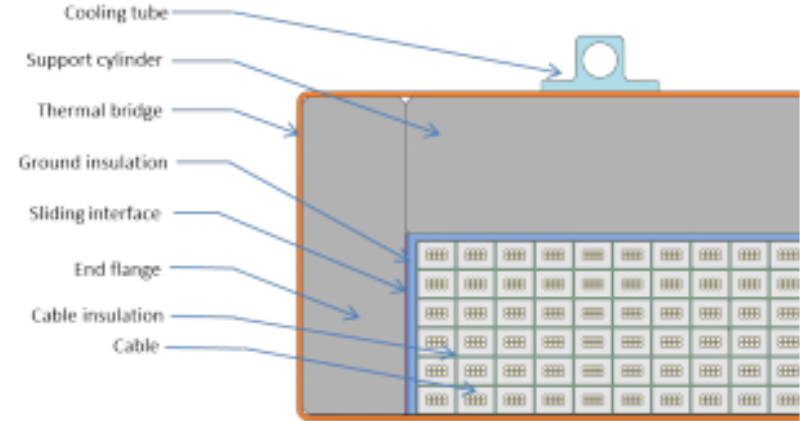


PANDA conductor

Rutherford cable, 8 strands, extruded in Al matrix



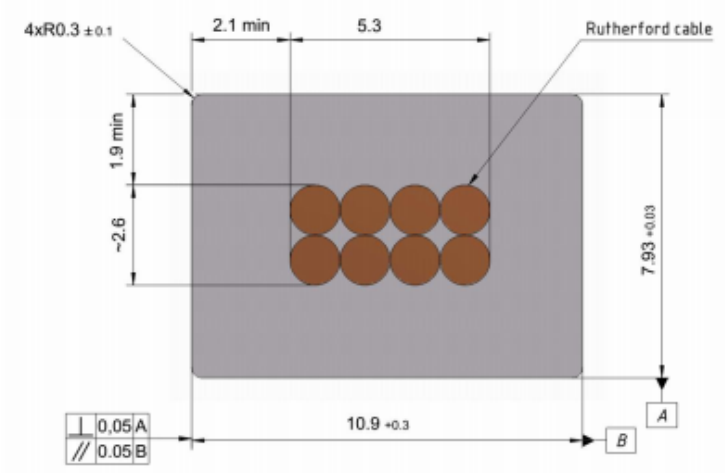
Longitudinal section of the cryostat with cold mass.



Cold mass cross-section.

Thickness (after cold work) at 300 K	mm	7.93	± 0.03
Width (after cold work) at 300 K	mm	10.95	± 0.03
Critical current (at 4.2 K, 5 T)	A	> 14690	
Critical current (at 4.5 K, 3 T)	A	> 16750	
Overall Al/Cu/sc ratio		10.5/1.0/1.0	
Aluminum RRR (at 4.2 K, 0 T)		> 1000	
Al 0.2% yield strength at 300 K	MPa	> 30	

Conductor mechanical and electrical parameters.



Cross-section of the conductor.

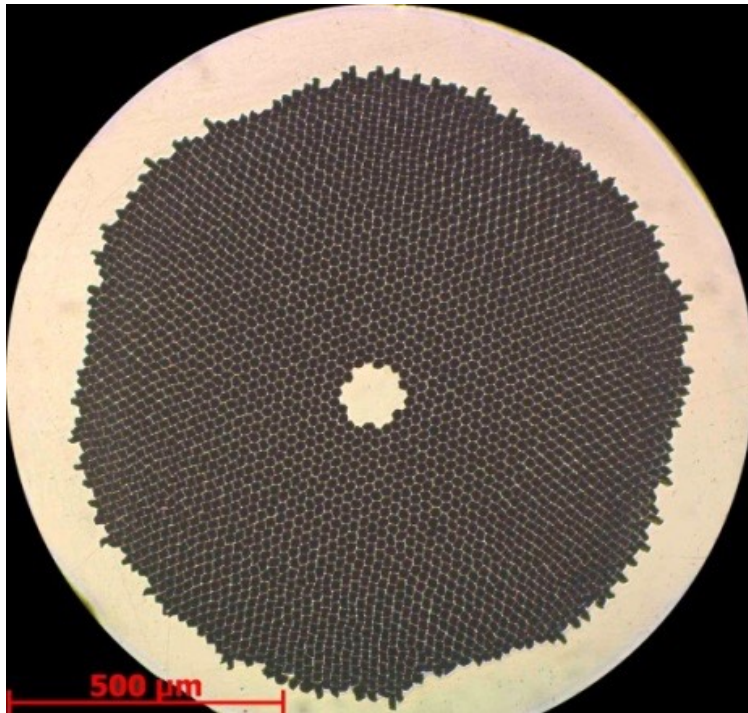
Conductor.

Production strands

Producer: "A.A. Bochvar High-technology Research Institute of Inorganic Materials" (JSC "VNIINM").

Protocol measurements 01-400/423 from 29.09.2021/18.10.2021

Superconductive NbTi strand PANDA solenoid



Strand cross section

Parameter	Unit	Certified		1-C2-1P-1-21/1 > 1400 m	1-C2-1P-1-21/2-1-1-2 > 200 m
		Value	Tolerance		
Diameter filament	μm	< 20	-		
Diameter strand	mm	1.400	± 0.005		
Cu/SC ratio	-	.50/.50	± 0.05	/0.5187	/0.5132
Surface coating	-	none	-	none	none
NbTi J_c (at 4.2 K, 5 T)	A/mm ²	> 2800	-		
Critical current (at 4.2 K, 5 T)	A	> 2160	-	2220	2175
n-value (at 4.2 K, 5 T)	-	> 30	-	71*	70*
Conductor RRR	-	> 100	-	196	191
Twist direction	-	left	-	left	left
Twist pitch	mm	25	± 5	22	21

*Magnetic field value is 6 T

Table 1 NbTi/Cu strand mechanical and electrical specifications.

Conductor.

Production strands

Batch number / strand piece number	Diameter, mm (1,400 ± 0,005 mm)	Cu/SC ratio NbTi, %	Twist pitch		RRR
			begin	end	
1-C2-1P-1-21/1	1,4	0,5187	22	22	196
1-C2-1P-1-21/2-1-1-1	1,4	0,5140	21	22	207
1-C2-1P-1-21/2-1-1-2	1,4	0,5132	21	21	191
1-C2-1P-1-21/2-1-2	1,4	0,5126	22	22	205
1-C2-1P-1-21/2-2	1,4	0,5122	22	24	205

Table 2 Technical parameters

Batch number / strand piece number	Sample	Measurement	Mechanical properties	
			Ultimate resistance, MPa	Yield strength, MPa
1-C2-1P-1-21/1	1n	1	903	838
		2	897	836
		3	909	845

Table 3 Mechanical properties

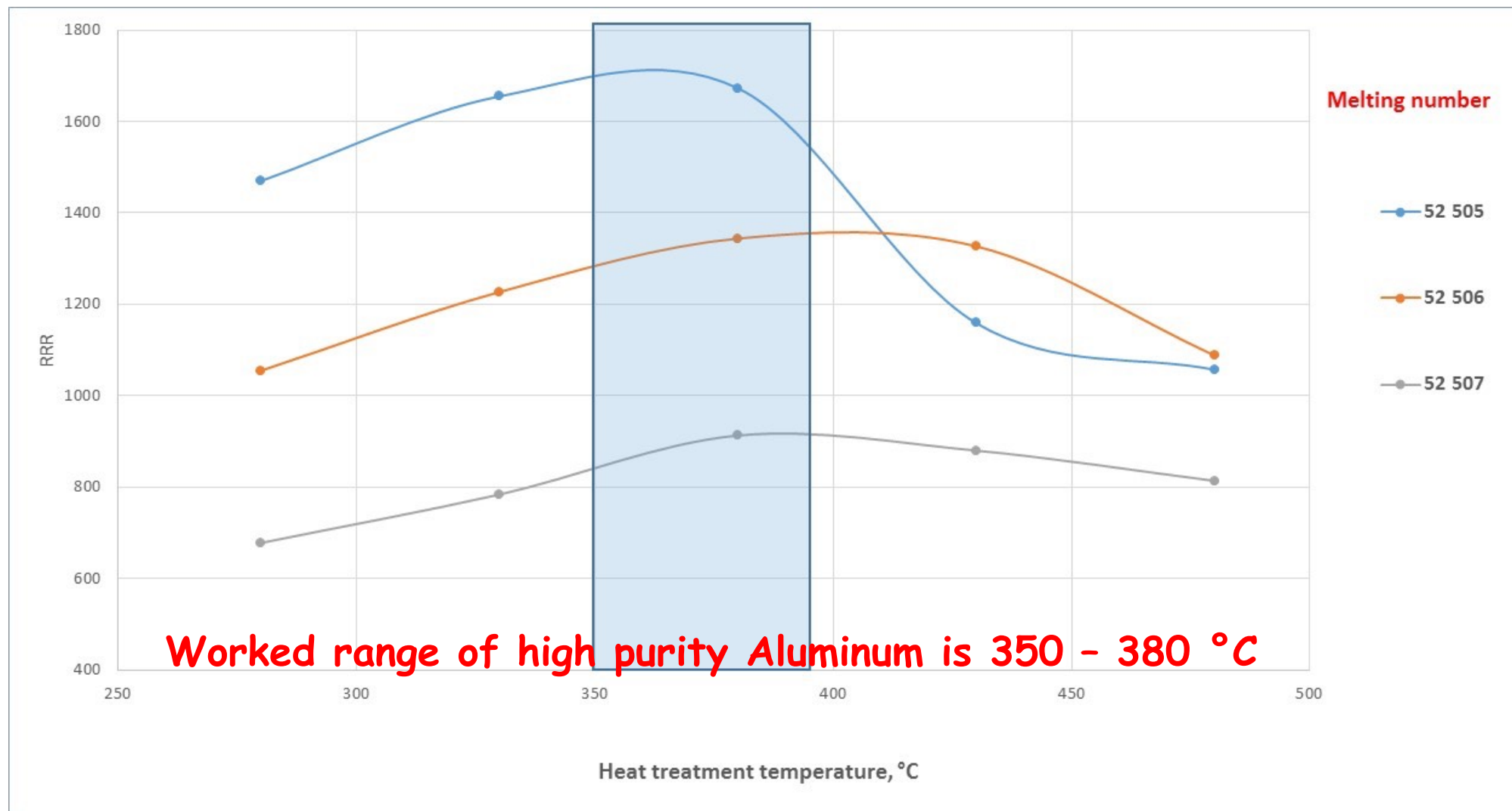
Batch number / strand piece number	Field, T	I_c , A (4,2 K; 0,1 mkV/sm)	n-value
1-C2-1P-1-21/1	8	789	35
	7	1253	52
	6	1746	71
	5	2220 (calc.)	-
1-C2-1P-1-21/2-1-1-1	8	750	35
	7	1208	53
	6	1694	71
	5	2175 (calc.)	-
1-C2-1P-1-21/2-2	8	750	36
	7	1200	50
	6	-	-
	5	2165 (calc.)	-

Table 4 Critical current (at 4.2 K) and n-value (at 4.2 K) vs magnetic field.

Conductor.

Status of the PANDA conductor development/ procurement

BINP/ VNIINM Bochvar/ VNIIKP/ Saransk cable optic (SarKO)



Worked range of high purity Aluminum is 350 - 380 °C

SPD heat loads

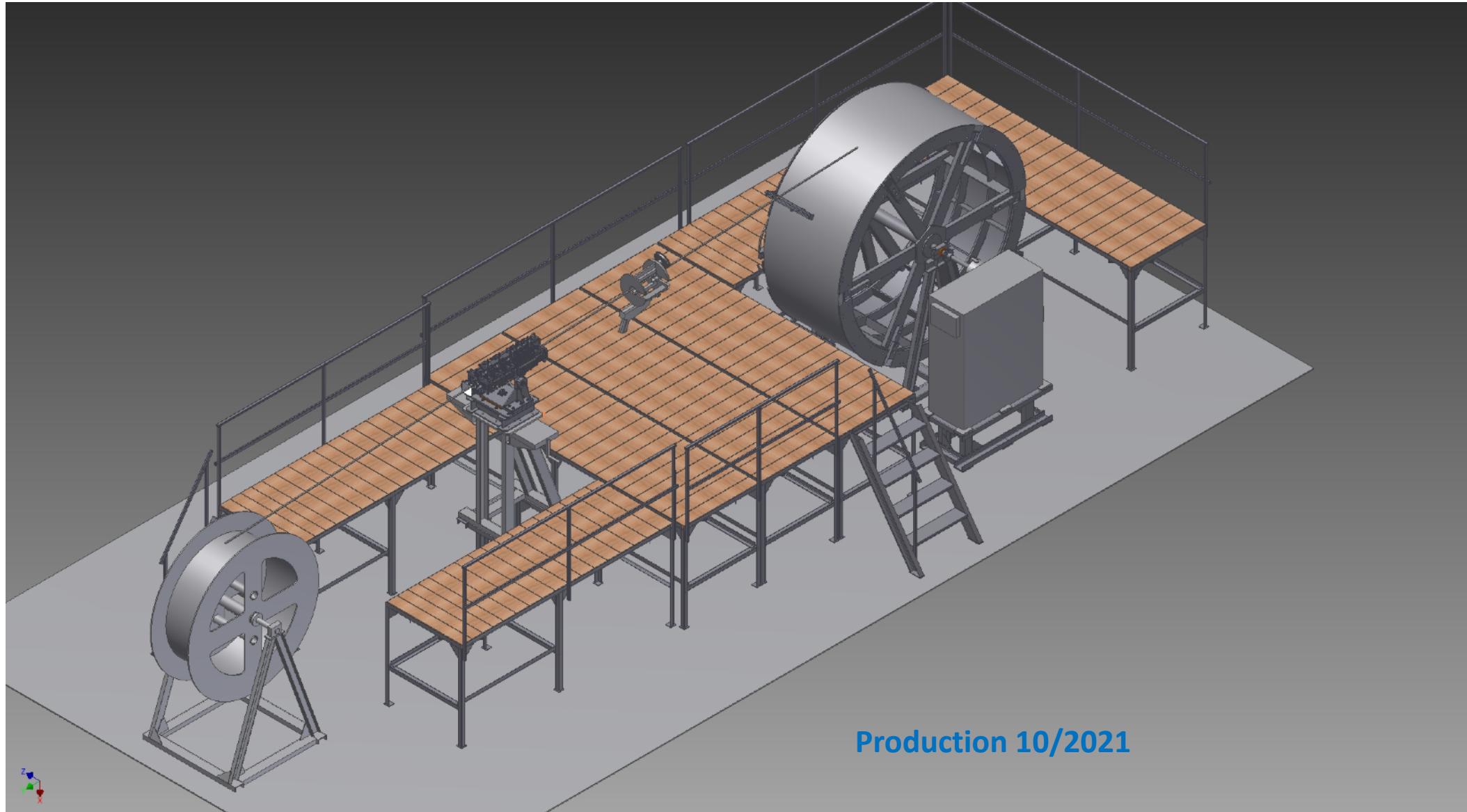
Table 1. Estimated heat loads of the SPD solenoid

T = 4,5 K	Heat loads		
	Worked condition	Without m.f.	With m.f.
Cryostat			
Radiation	7.8	7.8	7.8
Supports	5*	5*	5*
Eddy current loss in casing	-	-	11.50**
Eddy current loss in conductor	-	-	0.09**
Current leads, 6.5kA B=1.25T	15	9	9
Distribution box**			
Radiation	0.45	0.45	0.45
Supports of the LHe vessel	0.26	0.26	0.26
Cold control valves	1.05	1.05	1.05
Safety relief valves	3,22	3,22	3,22
Vacuum barrier	0.35	0.35	0.35
Transfer line**			
Radiation	0.06	0.06	0.06
Supports	0.20	0.20	0.20
Total	33,39	27,39	44,98

* Data of ATLAS central solenoid

** Data of PANDA solenoid

Drawing of the Devices for winding coil (scheme).



Photos of the tolling production



14.12.2021

E.Pyata, BINP

SPD solenoid

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Thank you for your attention