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DEVELOPMENT AND PRODUCTION OF SUPERCONDUCTING AND CRYOGENIC EQUIPMENT AND SYSTEMS FOR ACCELERATORS BY IHEP

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SC magnets and cryogenic equipment produced by IHEP for accelerators

1978 – 1994 Development of UNK SC magnets. Production of a pilot batch of 25 SC dipoles and 4 SC quadrupoles, Russia

1995 – 1997 Large helium vacuum heat exchanger for DESY, Germany

1998 – 2000 HTS current leads, CERN, Switzerland

2000 – 2002 HTS dipole, Rosatom, Russia

1999 – 2004 Tevatron Electron Lens SC magnetic systems #1 and #2 for Fermilab, USA

2001 – 2007 Production of Multi-Layer Insulation

2003 – 2004 Cabling machine for production of SC flat cable from 42 strands for Fermilab, USA

2004 – 2007 42 Cryogenic electrical feed boxes for LHC, CERN, Switzerland

2000 – 2007 Cryogenic system cooling SC RF cavities for IHEP, Russia

K-meson beam-line by superfluid helium (1.8 K, 300 W)

2003 – at present Development of fast ramping magnets and cryogenic system for SIS300 (FAIR), Germany

At present – Cryogenic feed boxes and holders for XFEL, Germany

Equipment for production and test of superconducting magnets at IHEP

UNK superconducting dipole

UNK superconducting magnets

Parameters	Dipole	Quad
Magnetic field, T	5.11	
Field gradient, T/m		97.4
Operating current, kA	5.25	5.25
Field ramp rate, T/s	0.11	
Number of layers	2	2
Strand number in cable	19	19
AC losses, W	5.5	2
Stored energy, kJ	570	180
Inductance, mH	45	13
Coil inner diameter, mm	80	80
Length of the coil, mm	5800	3100
Length of the cryostat, mm	6420	4165
Mass of magnet, kg	6000	1600

Cryogenic helium vacuum heat exchanger

(10g/s helium flow, 300-2 K temperature range)

LHC Cryogenic Electrical Feed Boxes

(2600 HTS current leads from 25 to 12500A)

Multi-Layer Insulation (MLI)

Multi-Layer Insulation (MLI) blankets is high efficiency insulation for cryogenic equipments and lines, superconducting devices.

IHEP manufactured MLI for 2000 m² of ATLAS BT magnet, 1000 m² for LHC DFB and 6000 m² for LHC magnets interconnections.

The MLI blankets are composed by a layers of 6 μm thick Mylar film which both sides coated by 700 A aluminium and layers of 40 μm thick Mylar net. The external layers of blankets was composed of Teril53™ reinforced reflective film.

Parameters of MLI blankets

Measured heat loads at 77 – 300 K range	1,3 W/m²
Out gassing rate after 100 hours pumping	less $1*10^{-7}$ Pa m s^{-1}
Tensile strength	≥80 MPa

Tevetron Electron Lens (TEL)

TEL SC magnetic system in tunnel of Tevetron

Parameters of TEL SC magnetic system

Magnet	B, T	I, A	Di, mm	L, mm
SC solenoid	6.5	1800	152	2500
SC central dipole	0.2	50	200	1940
SC end dipole	0.8	200	200	250
Gun, collector solenoid	0.4	357	250	300
Bending solenoid	0.19	357	390	72

600 A HTS current leads

Nominal current	600 A
Heat load to liquid helium at 600 A	0.08 W
HTS	Bi-2223
Material of matrix	Ag+1at.%Au
HTS tape dimension	4.6*0.25 mm^2
Number of HTS tapes	14
Length of HTS tapes	400 mm
Resistive part length	500 mm
Diameter of copper wires	0.13 mm
Tube inner diameter	11 mm
Packaging density	35 %

HTS dipole magnet

Magnetic field	1 T
Nominal current	25 A
Operating temperature	65 K
Aperture	21*70 mm^2
Magnet dimension	280*345*590 mm^2
Inductance	0.85 H
Turn number	712
HTS	Bi2223
HTS tape dimension	3.8*0.25 mm^2

Superfluid cryogenic system of 21 channel

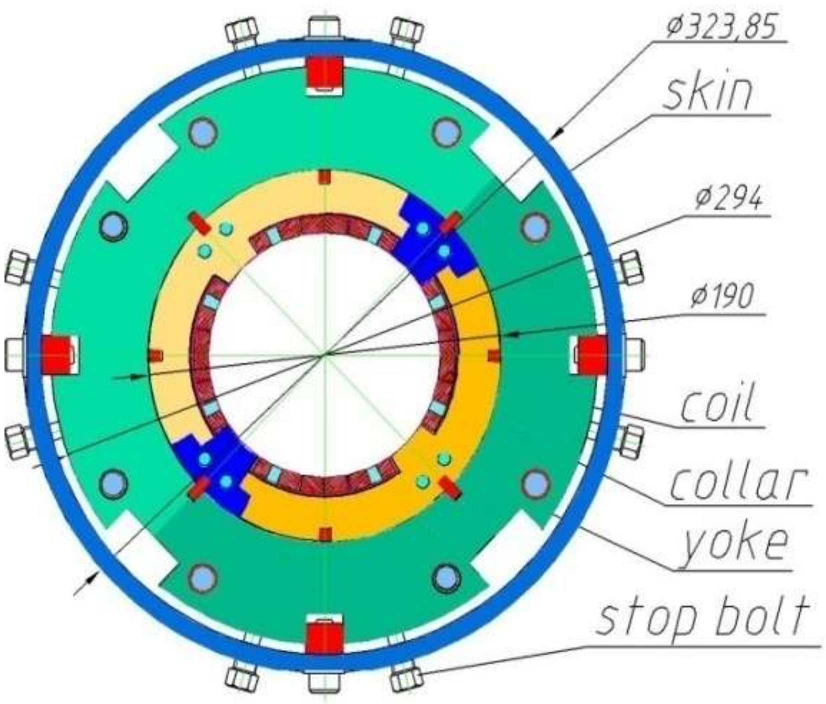
(250 W at 1.8 K)




SIS300 superconducting high field fast cycling dipole model

Dipole magnet	SIS300	UNK
Magnetic field, T	6	5.1
Operating current, kA	6.72	5.22
Field ramp rate, T/s	1	0.11
Number of layers	2	2
Cable strand number	36	19
AC losses, W/m	4.7	0.95
In coil, W/m	3.4	0.6
In iron yoke, W/m	1.3	0.35
Stored energy, kJ	260	570
Inductance, mH	11.7	45
Coil inner diameter, mm	100	80
Length of SC coil, m	1	5.8
Mass of magnet, ton	1.8	6

SIS300 fast cycling quadrupole prototype

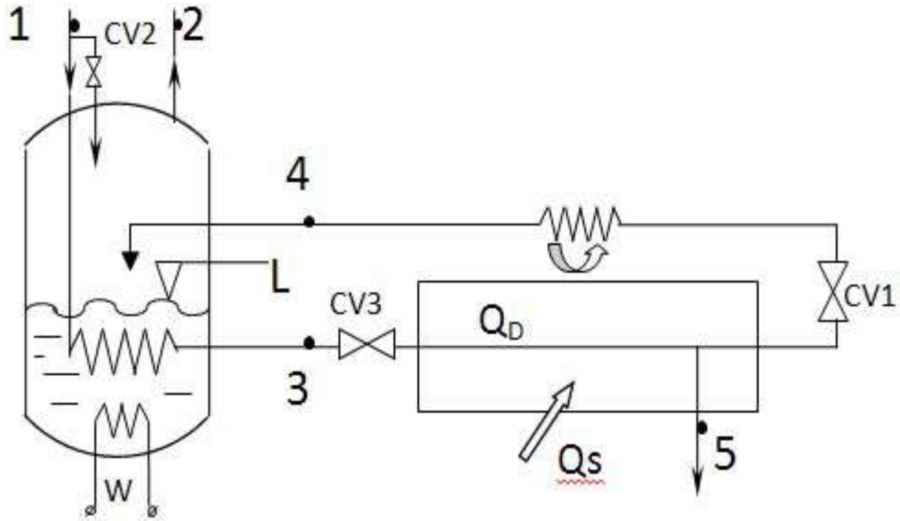


Quadrupole magnet	SIS300	UNK
Field gradient, T/m	45	97
Operating current, kA	6.26	5.22
Ramp rate, T/m/s	10	2
AC losses, W/m	1	0.67
Coil inner diameter, mm	125	80
Length of SC coil, m	1	3.1
Number of layers	1	2
Cable strand number	19	19
Strand diameter, mm	0.825	0.85
NbTi filament diameter, µm	3	6
Step pitch, mm	8	12
J_C (5 T, 4.2 K), A/mm^2	≥2700	≥2300

Requirements to SIS300 fast cycling corrector magnets

Type of corrector	Force	Coil length, m	Powering time, s
Chromaticity sextupole	130 T/m^2	0.78	0.21
Resonance sextupole	325 T/m^2	1	0.5
Steering magnet:			
Vertical dipole	0.5 T	0.65	2.27
Horizontal dipole	0.5 T	0.65	2.27
Multipole:			
Quadrupole	1.8 T/m	0.65	2.25
Sextupole	60 T/m^2	0.65	2.18
Octupole	767 T/m^3	0.65	2.24

SIS300 cryogenic system



SIS300 helium flows	parameters
Length of SIS300 ring	1.1 km
Magnet string number	2
T_1	4.6 K
T_3	4.35 K
P_3	3 bar
P_4	1.105 bar
T_4	4.3 K
x_4	≤95%

Total SIS300 heat load	T=4.5 K
AC losses	2472 W
Ambient heat leak	1367 W
Beam pipe RF mirror current heat release	450 W
Total heat load	4289 W
Liquid helium for cooling the current leads	4.53 g/s

Results of calculation

- **4 additional helium heat exchangers in SIS300 ring;**
- **Temperature of helium, which cools the SIS300 magnets, will not exceed 4.7 K;**
- **Cooling down time of SIS300 SC magnets will be about 60 hours.**

Conclusion

- **IHEP has meaningful experience and equipment for development and production of accelerator magnets on basis of Low Temperature Superconductors and High Temperature Superconductors as well as cryogenic system for cooling superconducting devices and systems.**

- **At present IHEP develops superconducting fast cycling magnets and cryogenic system for cooling these magnets.**