DESIGN AND CONSTRUCTION OF THE MAGNET-CRYOSTAT IN THE SUPERKEKB INTERACTION REGION

Norihito Ohuchi, Zhanguo Zong, Hiroshi Yamaoka, Yasushi Arimoto, Xudong Wang, Masanori Kawai, Yoshinari Kondo, K. Tsuchiya: KEK, Tsukuba, Ibaraki, Japan
T-H, Kim: Mitsubishi Electric Corporation, Kobe, Japan

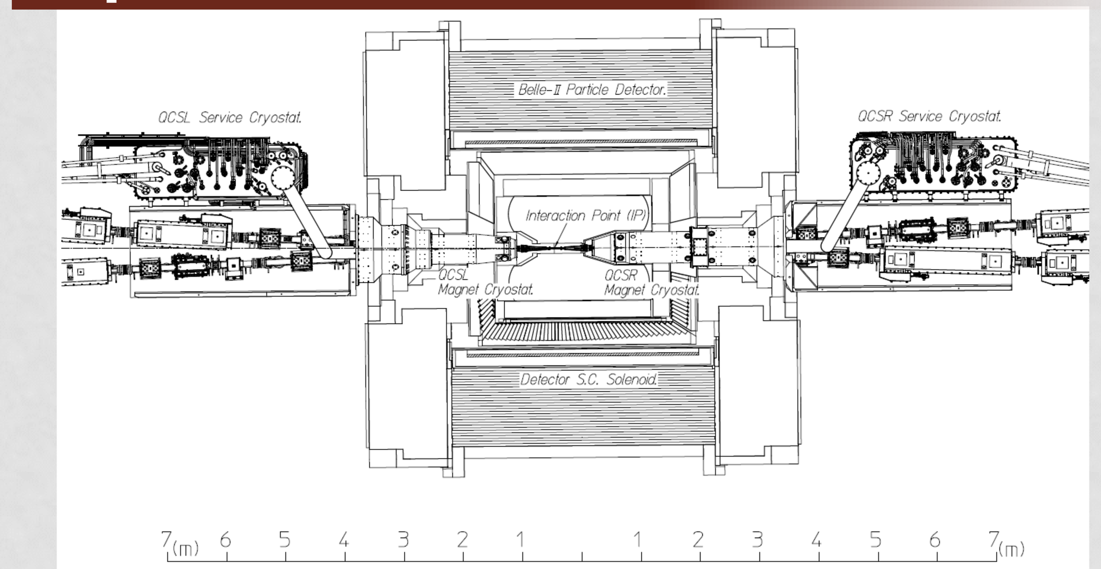
Introduction

SuperKEKB is the upgraded accelerator of KEKB, and it has been designed to explore new physics phenomena beyond the standard model of particle physics in the B meson regime. SuperKEKB is the asymmetric-energy, two-ring collider with 7 GeV electron and 4 GeV positron beams and the machine target is 40 times higher luminosity than the KEKB peak luminosity at 2.1 $\times 10^{34}$ cm^{-2} s^{-1} with 8 GeV electron and 3.4 GeV positron. In order to reach the extremely high luminosity, the beam final focusing system was designed with 55 superconducting magnets, and these magnets were assembled in the two cryostats. In this paper, we report the thermal and mechanical designs and the construction of the cryostats.

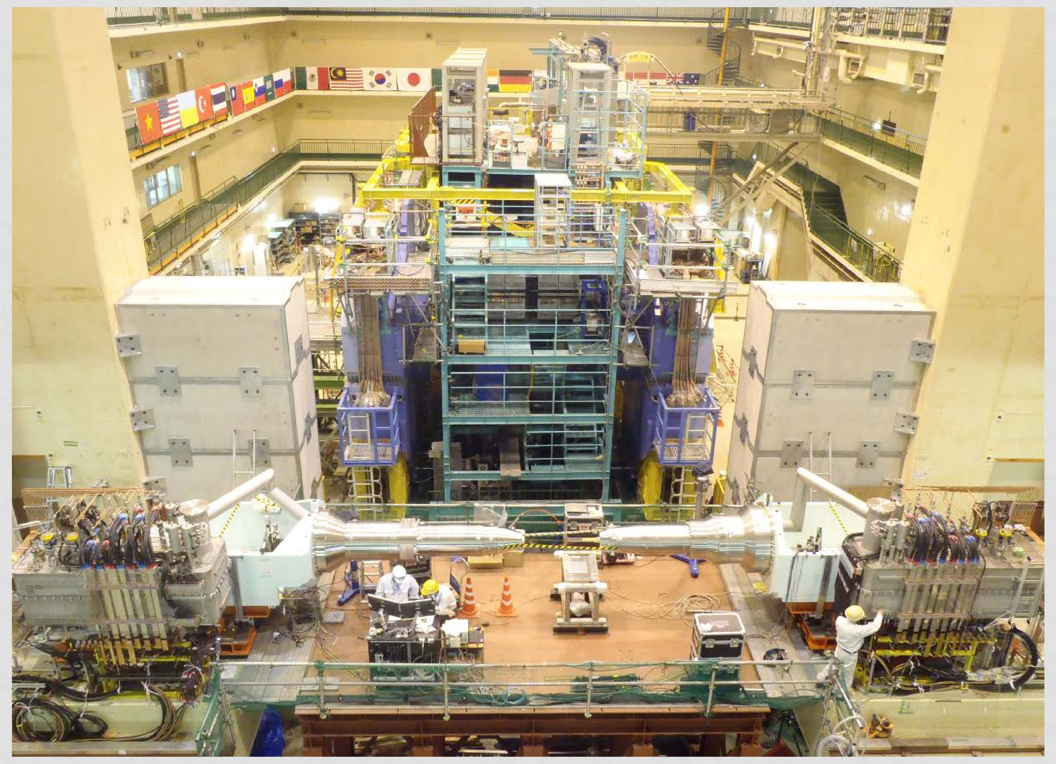
Conclusion

1. Two magnet-cryostats for the beam interaction region of SuperKEKB designed and constructed. The designs of the cryostats were started from 2010, and the cryostat for the left side to IP, QCSL was completed at Dec. 2015, and the QCSR cryostat was completed at Feb. 2017. These two cryostat were already installed in the interaction region of SuperKEKB.
2. Two magnet-cryostats were successfully cooled to 4 K and the all magnets were excited to the nominal operation currents. The thermal performances and mechanical characteristics have been measured.
3. After commissioning the final focus system of SuperKEKB, the system will be prepared for the Phase-II commissioning of SuperKEKB from Feb. 2018.

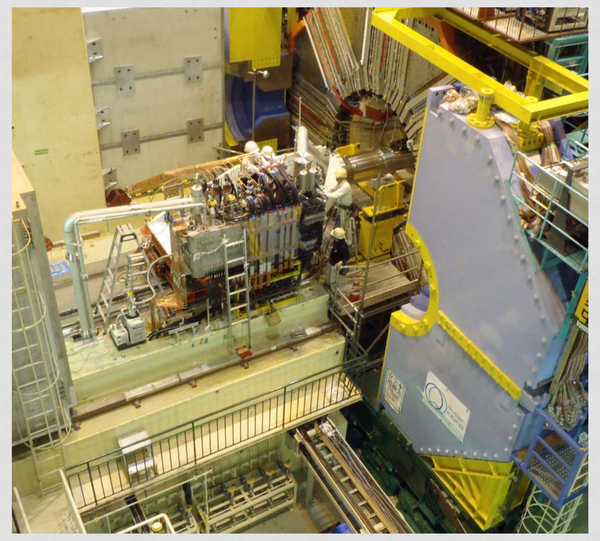
SuperKEKB INTERACTION REGION



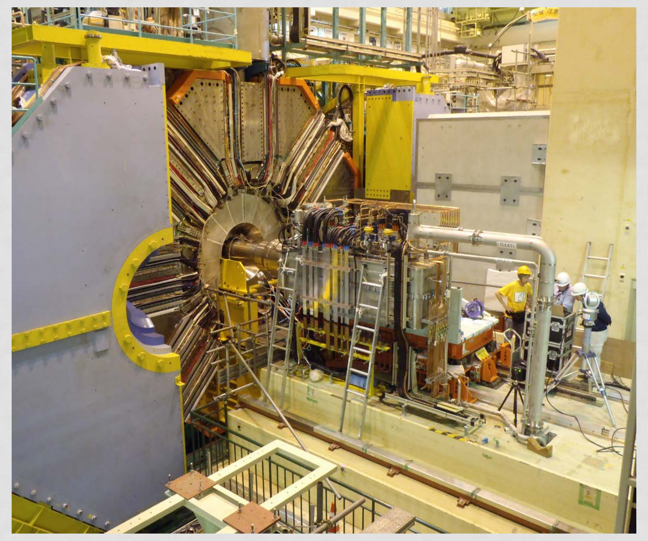
SuperKEKB Beam Interaction Region



Completed Two Magnet-Cryostats and Belle-II Particle Detector

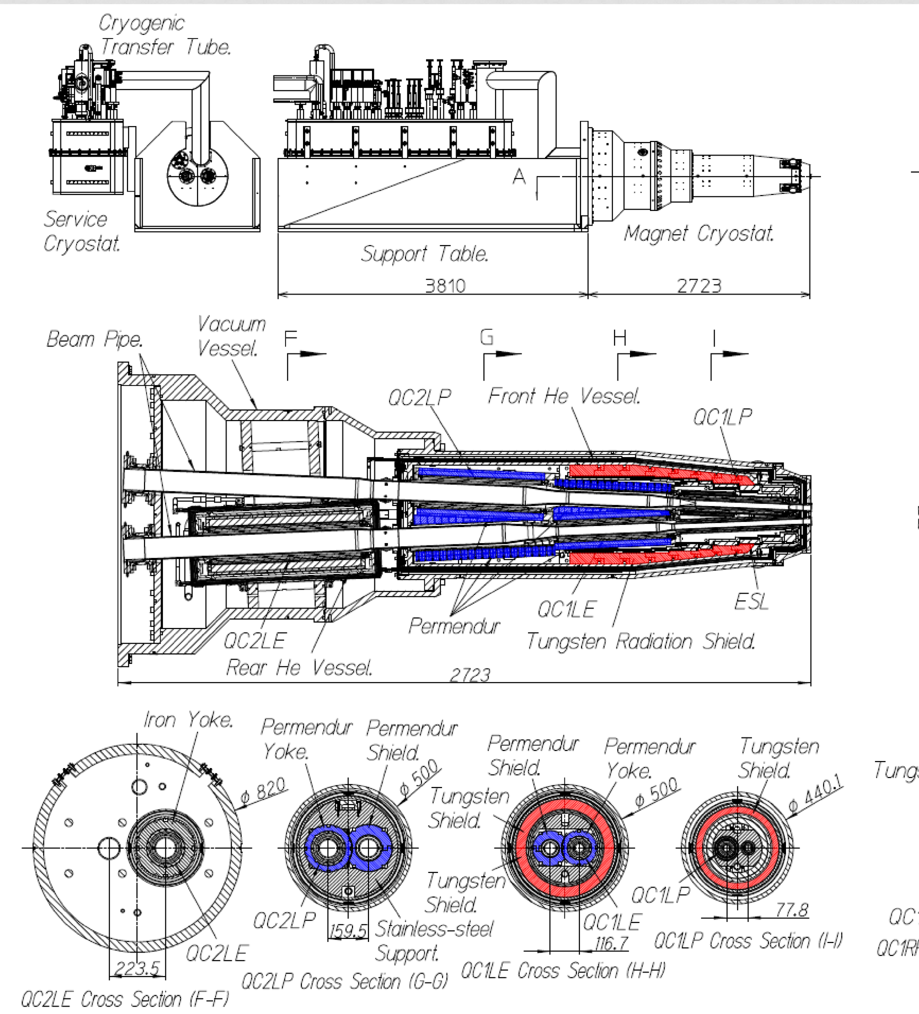


QCS-R cryostat with Belle-II

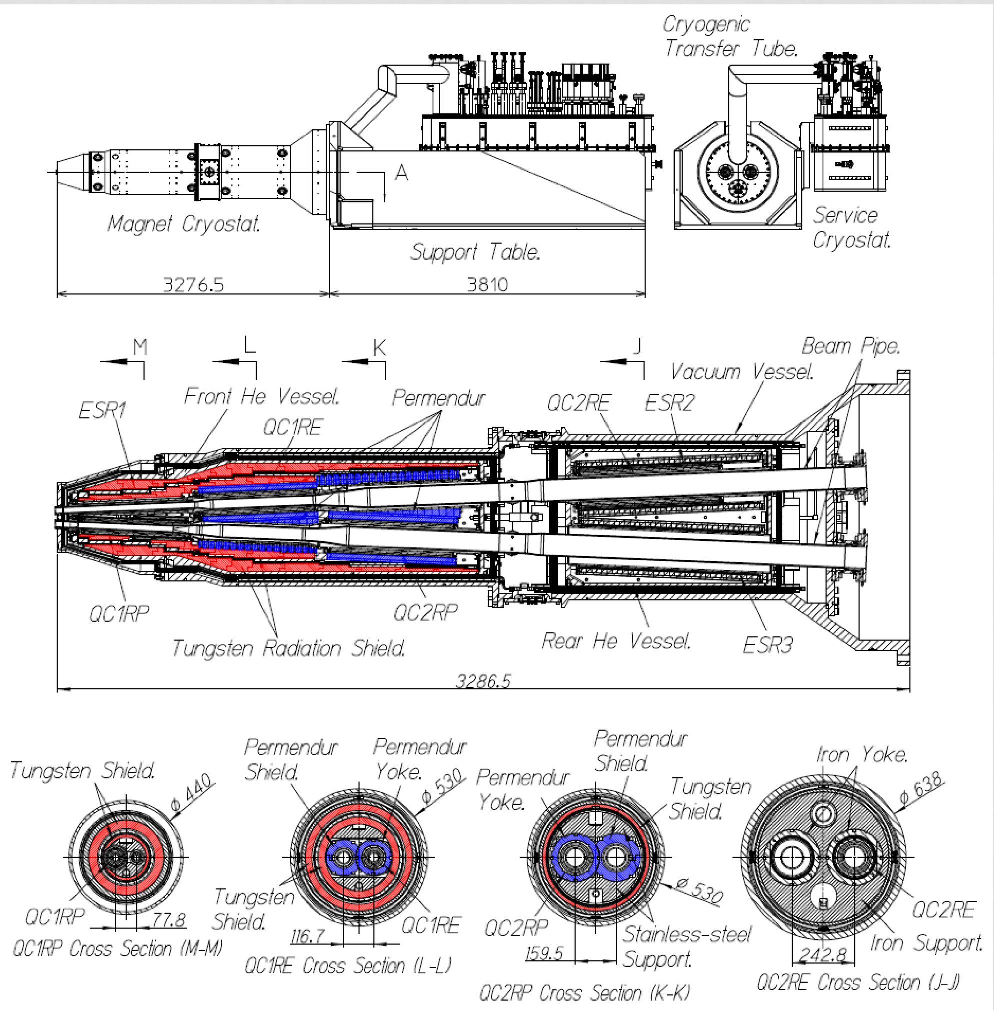


QCS-L cryostat with Belle-II

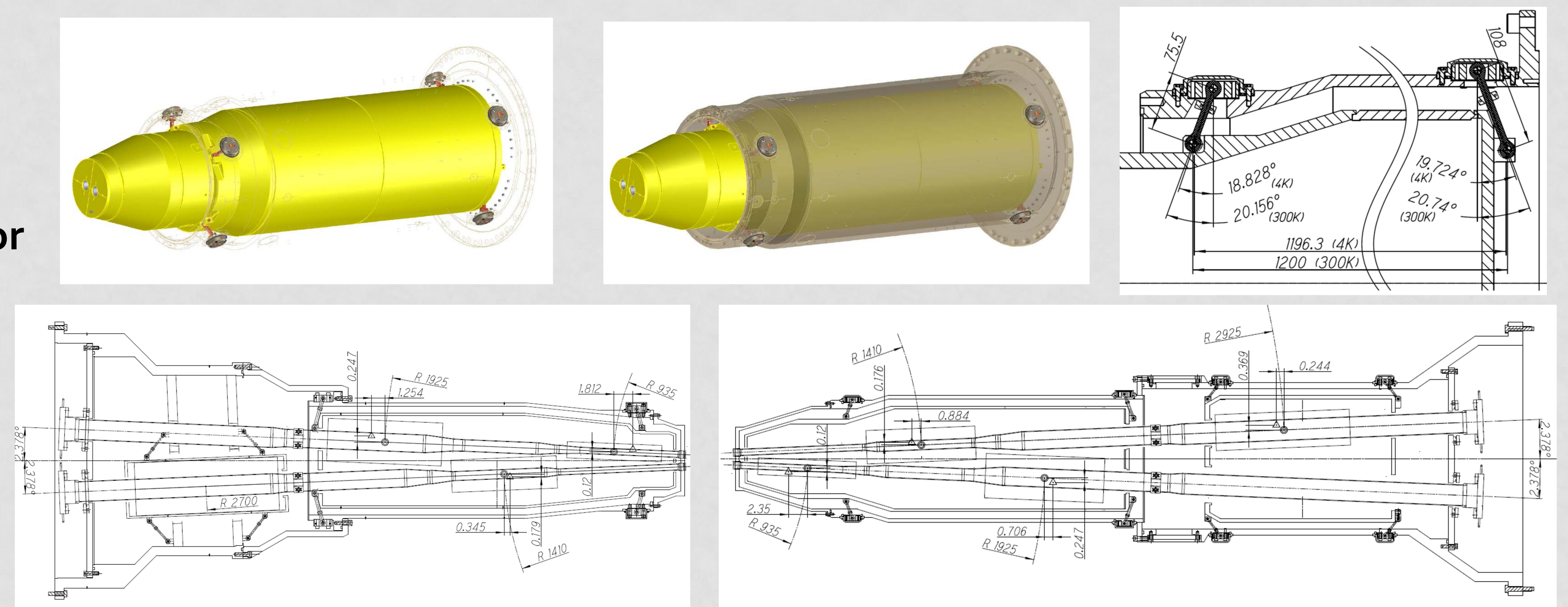
CRYOSTAT DESIGN



QCS-L Cryostat Cross Section Design



QCS-R Cryostat Cross Section Design



8-rod support system of the LHe vessel

The magnet positions at room temperature are designed with including the thermal contraction by cool-down to 4K.

Magnet-Cryostat Design

1. Cryostat system design
   - The cryostat system consists of the magnet-cryostat, the service cryostat, cryogenic transfer tube and the support table.
   - The magnet-cryostat is supported in a cantilever way by the support table.
   - Two cryostats were designed for the superconducting magnets for each side of the beam interaction point, IP.
2. Magnet-cryostat design
   - In the QCSL and QCSR magnet-cryostats, 25 and 30 superconducting magnets are assembled in the two helium vessel, respectively.
   - Two beam pipes at room temperature pass completely through the helium vessel at 4K.
   - The helium vessels, in which the SC magnets are assembled, are supported by the 8 Ti-Al-V alloy rods from the vacuum vessel.
     - ✓ The magnet-cryostats are operated in the Belle-II solenoid field at 1.5 T, the electro-magnetic forces from 20 to 60 kN act on the vessel.
     - ✓ The support rods are designed to withstand the EMF.
   - The magnet components in the cryostats are designed to make the magnet positions after cool-down the nominal positon for the beam operation.
3. Service-cryostat design
   - The service cryostats are interface between the magnet-cryostat and the power supplies and the cryogenic system.

Cryostat Parameters

	QCS-L	QCS-R
Magnet Cryostat		
Vacuum Vessel		
Length and max. dia. in the body, mm	2724/ϕ1100	3287/ϕ638
Weight, kg	1570	1471.7
Cold Mass (total), kg	1522	3139
Front He vessel	1180	2076
Magnet components and others	(949)	(805)
W alloy radiation shield	(231)	(1271)
Rear He vessel	342	1063
80 K thermal radiation shield (SS304), kg	45	36
Service Cryostat		
Vacuum vessel and pipes		
Vessel length, height and wide, mm	2757/917/900	2757/917/863
Weight, kg	2523	2501
80 K thermal radiation shield (Al), kg	79	76.4
Current leads		
He gas cooled conventional leads	10 pairs	10 pairs
Compact 8 terminal leads	5 units	7 units
Control valve	2	2
Support table (SS400)		
Length and weight, mm/kg	3810/6279	3810/6061
Total length and weight, mm/kg	6533/12550	7087/15000

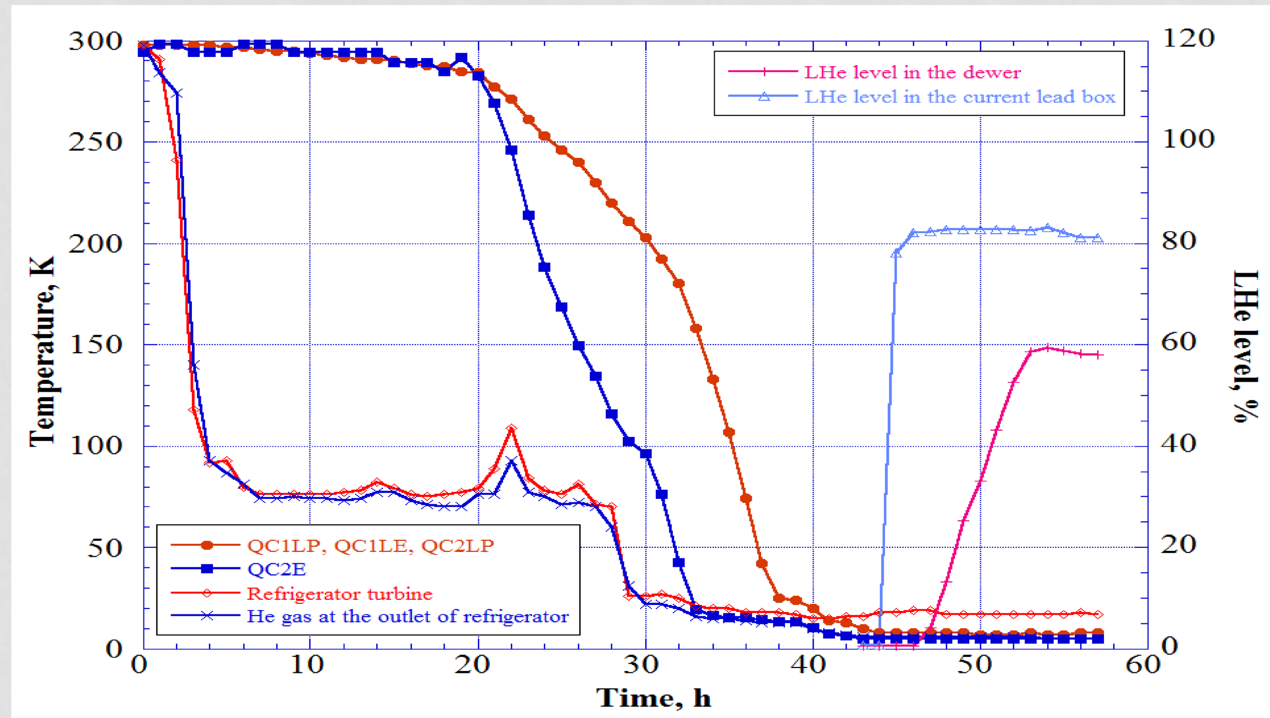
Design Heat Loads of the Cryostats

	QCS-L			QCS-R		
	Mag. Cryo.	Serv. Cryo.	Total	Mag. Cryo.	Serv. Cryo.	Total
Support rod, W	9.72	–	9.72	5.76	–	5.76
Thermal radiation, W	6.62	1.94	8.56	10.06	2.10	12.16
Current lead pipes, W	–	11.49	11.49	–	12.47	12.47
TRT + valves, W	–	6.00	6.00	–	6.00	6.00
Instrument wires, W	0.87	3.80	4.67	0.87	3.42	4.29
Cooling He gas for CL, L/h	–	28.73	28.73	–	29.59	29.59
Total	17.21 W	23.23 W + 28.73 L/h	40.44 W + 28.73 L/h	16.69 W	23.99 W + 29.59 L/h	40.67 W + 29.59 L/h

Electro-magnetic forces and stress in the support rods

	QCS-L Front He Vessel		QCS-R Front He Vessel	
	Weight	EMF	Weight	EMF
With ESL /ESR Excitation (outwatd from IP)	1260 kg	52.6 kN	2076 kg	35.7 kN
Max. stress in the rods	161 MPa		206 MPa	
Without ESL /ESR Excitation (inward to IP)	1260	57.3 kN (to IP)	2076	23.5 kN (to IP)
Max. stress in the rods	174 MPa		152 MPa	

MAGNET-CRYOSTAT CONSTRUCTION



Cool-down of QCS-L Magnet-Cryostat

Magnets were cooled down with the He refrigerator (250 W @ 4.4 K)

Presented at MT-25 , 2017 Aug. 28 – Sept.1, Amsterdam; Session: Cryogenic for Magnet Cooling ; Program I.D. number: Mon-Af-Po1.11