The 2022 international workshop on the high energy Circular Electron-Positron Collider (CEPC)

Cryomodule Design for CEPC Collider and Booster

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On behalf of the CEPC cryogenics team(IHEP)
Oct. 24th, 2022

Outline

1. Introduction of SRF cryogenic system
2. 650MHz cavity formal cryomodule for CEPC collider
3. Design and experiment of 650MHz cavity test cryomodule
4. Fabrication of 1.3GHz cavity cryomodule for CEPC booster
5. Conclusion

1. Introduction of SRF Cryogenic system

1. Cryogenic system

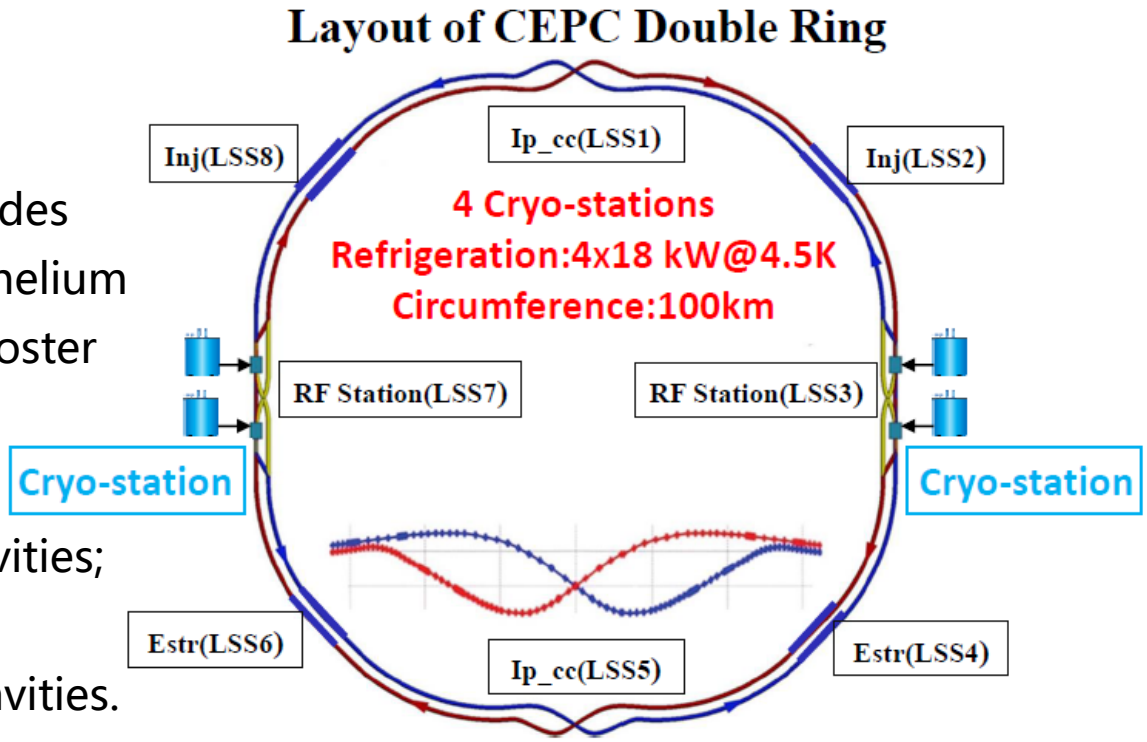
- 4 cryogenic station in the CEPC cryogenic system;
- Each cryogenic station lies besides the RF station, which provides helium for the collider ring and the booster ring.

2. Collider ring

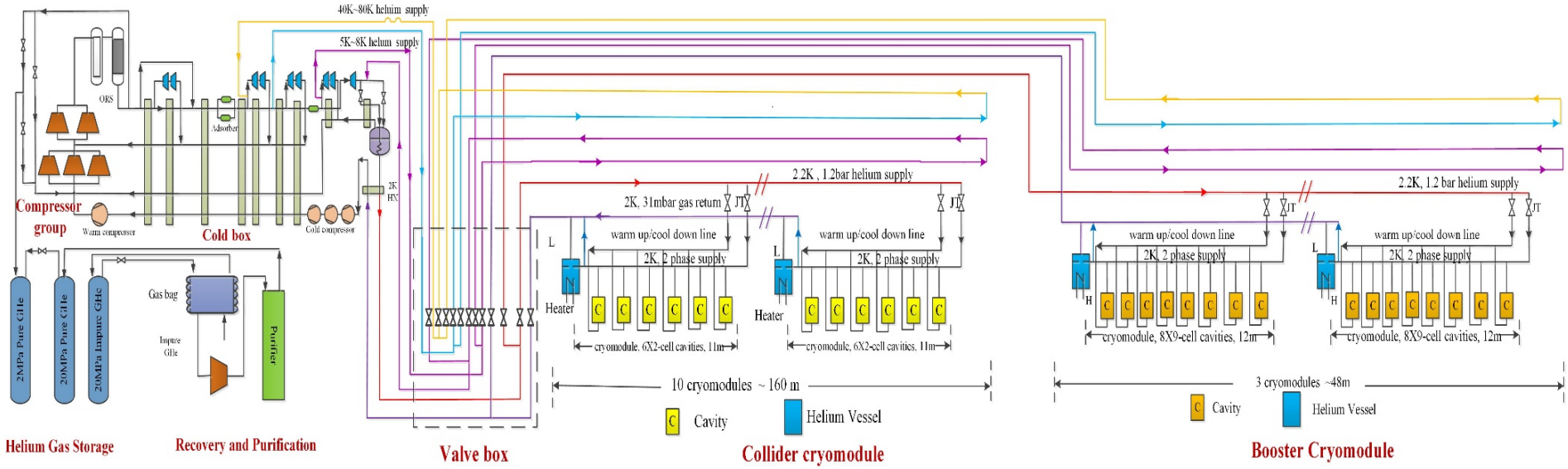
- 650MHz 2-cell cavities, 336 cavities;
- 40 (4*10) cryomodules;
- Each cryomodule includes 6 cavities.

3. Booster ring

- 1.3 GHz 9-cell cavities, 96 cavities;
- 12 (4*3) cryomodules ;
- Each cryomodule includes 8 cavities.



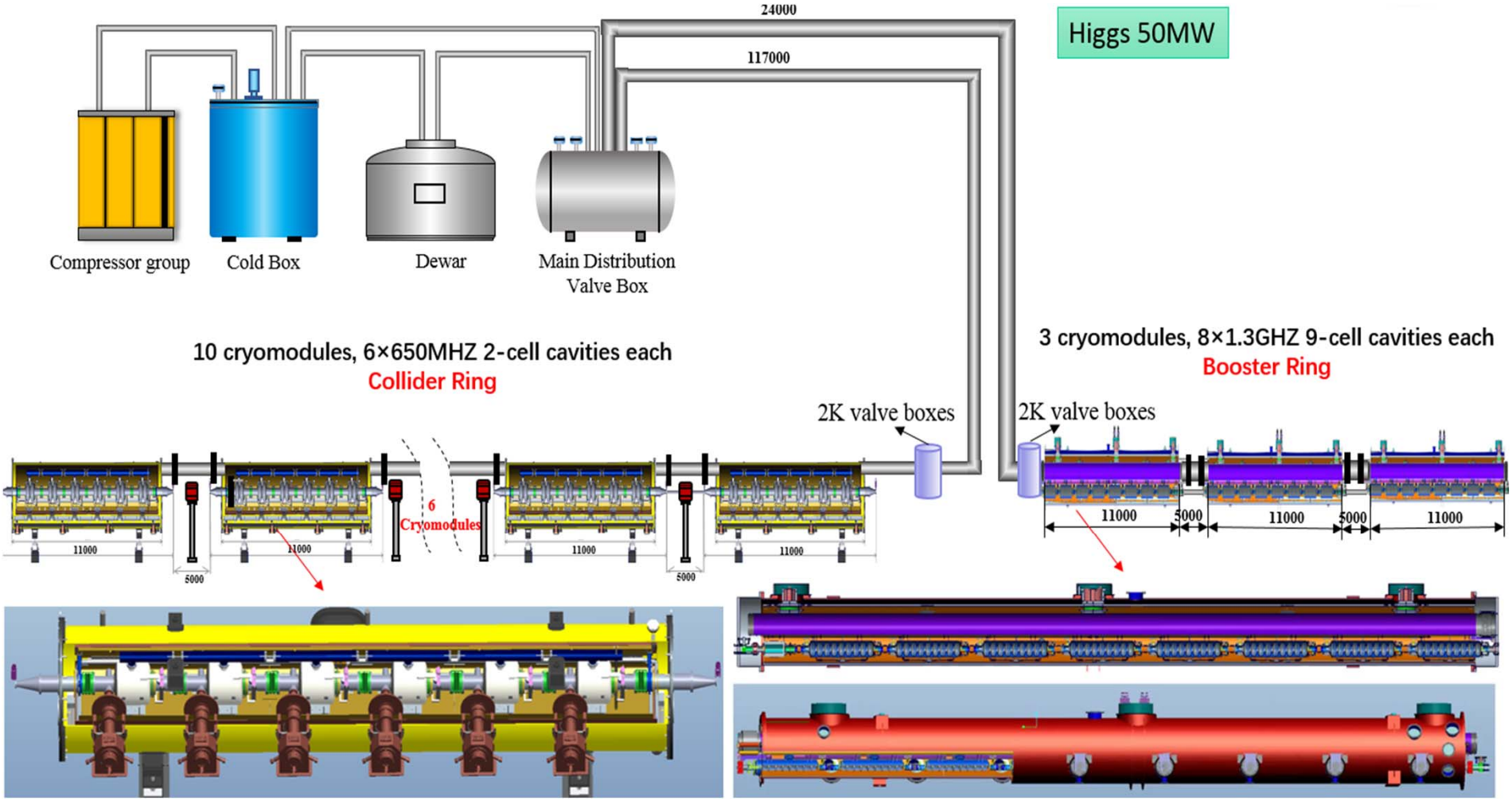
Cooling diagram for SRF cavities



- One Cryogenic station will supply the cooling for 10 collider cryomodules and 3 booster cryomodules;
- Each cryomodule has two thermal shields, a 40K shield and a 5K shield;
- A 2.2K@1.2bar subcooled helium will be supplied for the cryomodules, and the 2K helium gas return to the cold box by the cold compressors .

Cooling diagram for SRF cavities

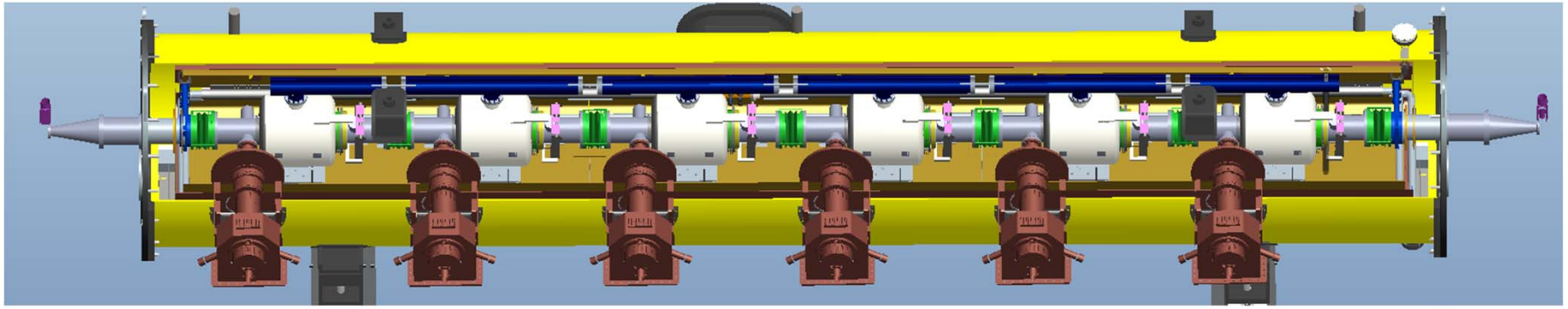
One cryogenic station : 10 collider cryomodules and 3 booster cryomodules

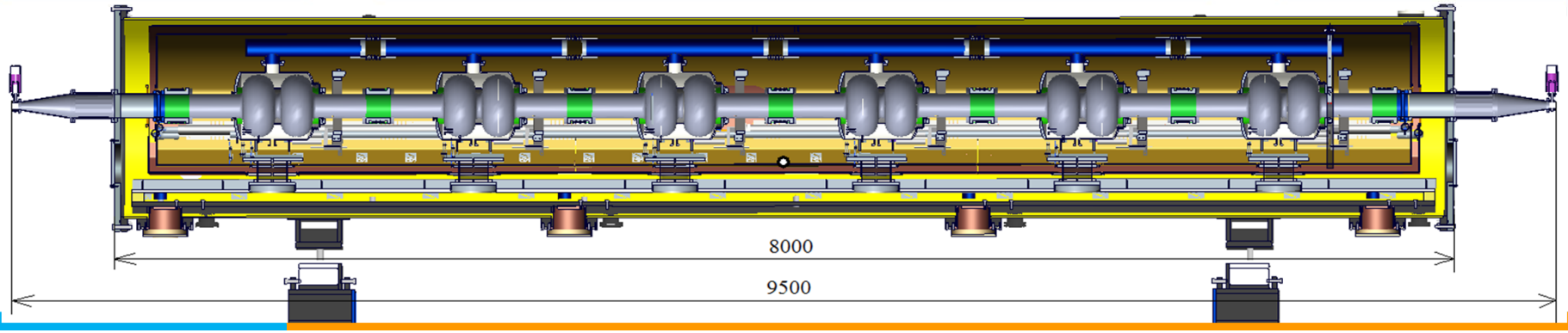


2. 650MHz cavity formal Cryomodule

Six 2-cell Cavities Cryomodule	
Overall length(flange to flange, m)	8.0
Diameter of Vacuum vessel ,m	1.3
Beamline height from floor, m	1.5
Cryo-system working temperature, K	2
Number of cavities	6
Number of coupler	6
HOM absorber	2
Number of 200-POST	6

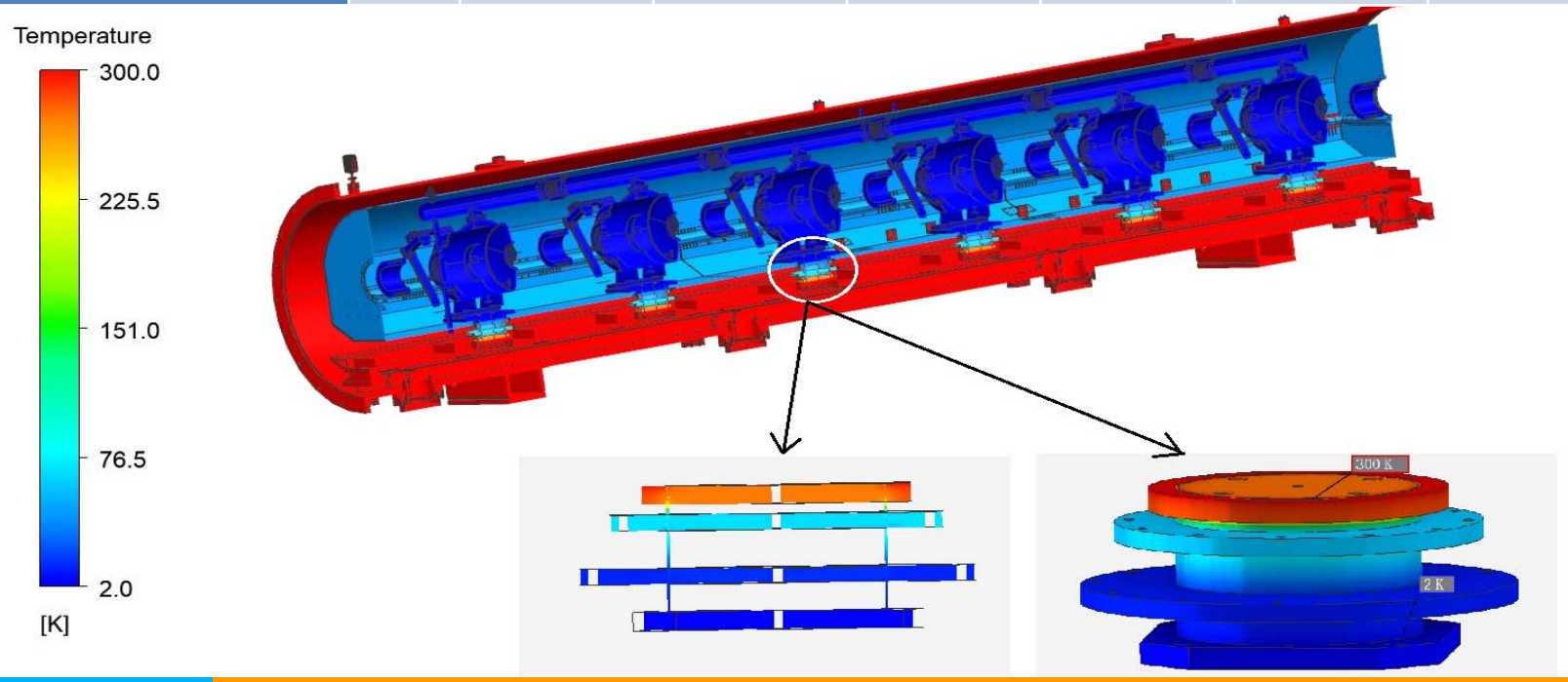
Cryomodule performance		Specification
RF gradient [MV/m]		13.8(H), 9.4(W), 9.6(Z)
Dynamic heat loads at 2K (Q_0=1E10)		19.0(H), 8.7(W), 9.2(Z)
Static heat loads at 2K (Max. Operation)		<5W
Number of leakage	He →insulation	<1E-9 Pa.m^3/s
	He →beam pipe	<1E-9 Pa.m^3/s
	Insulation →coupler	<1E-9 Pa.m^3/s
	Insulation →beam pipe	<1E-9 Pa.m^3/s
	Coupler →beam pipe	<1E-9 Pa.m^3/s
Alignment x/y inside (Cavities)		within ±0.5mm
Alignment z inside		within ±2 mm
Coupler antenna design z		within ±2 mm





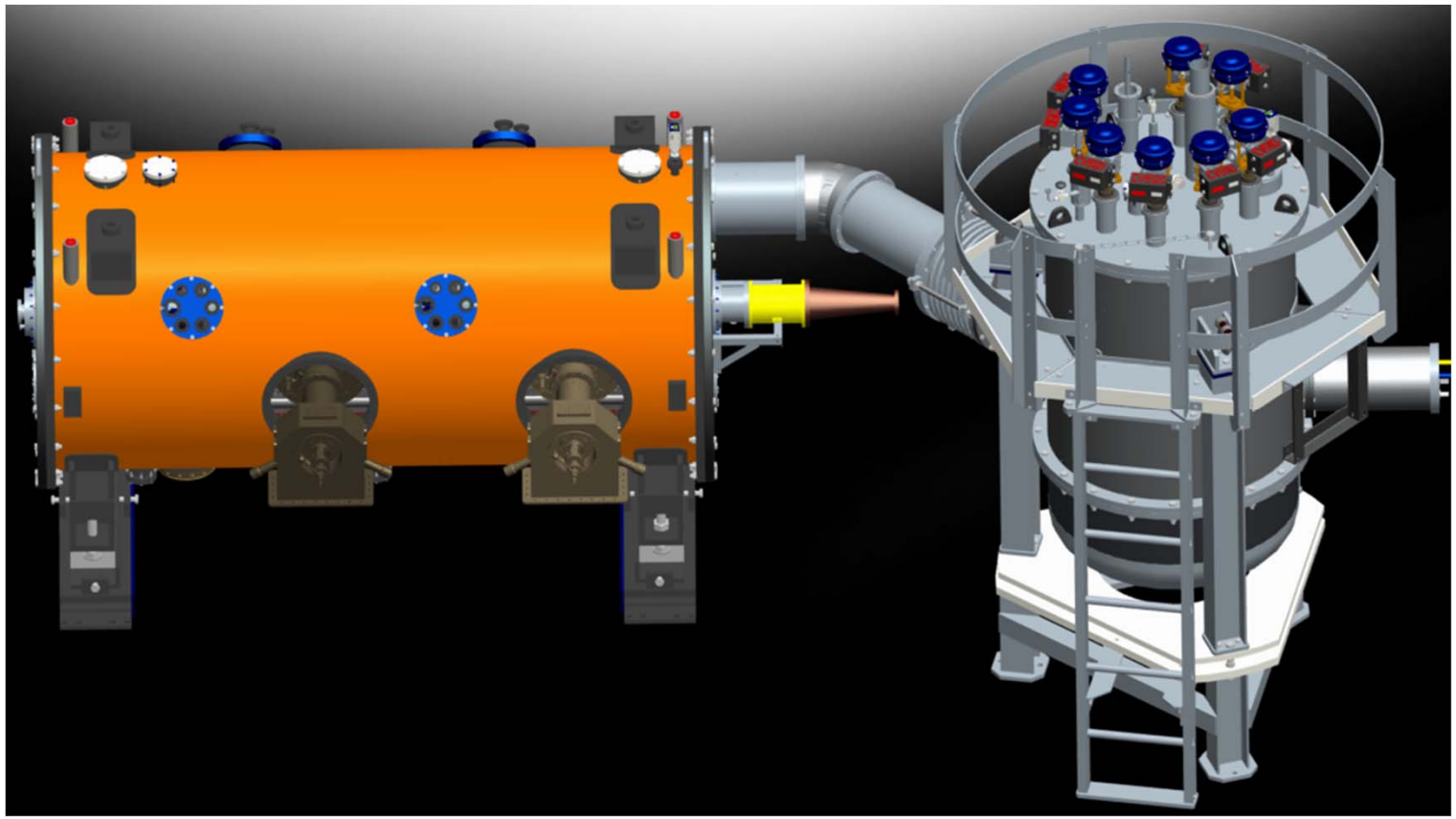
Heat Load of formal cryomodule

Heat source	N	Static/W			Dynamic/W		
		80K	5K	2K	80K	5K	2K
Cavities	6	/	/	/	/	/	114(H)
Input Couplers	6	36.00	18.00	2.10	60.00	36.00	6.00
HOM couplers	12	/	/	/	/	/	6.00
200-POSTs	6	44.37	6.81	2.10	/	/	/
Instrumentation Cables	/	/	/	0.54	/	/	/
Radiation	/	32.50	1.28	/	/	/	/
Beam pipes	/	1.00	0.30	0.20			
Summary		113.87	26.49	4.94	60	36	126

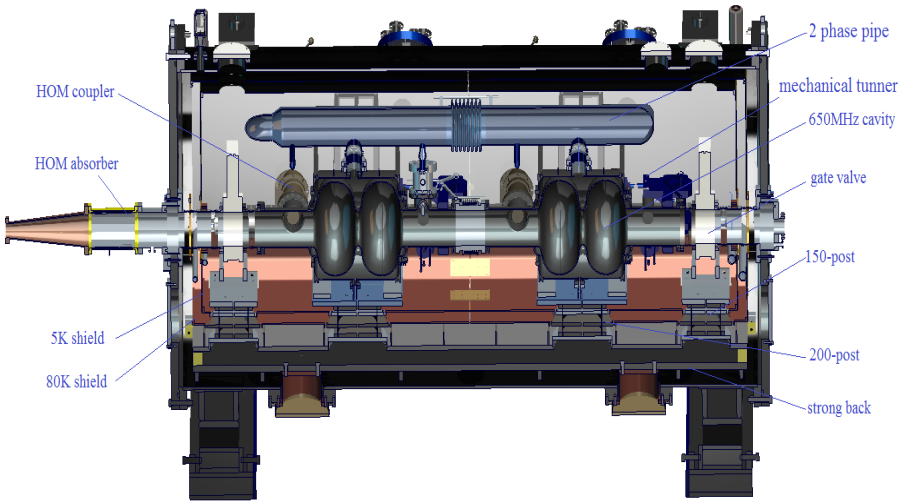


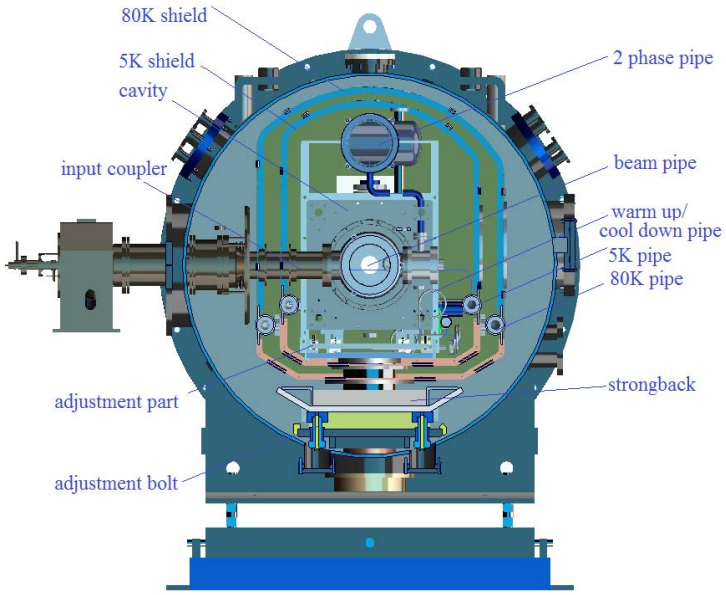
3. Design and experiment Test Cryomodule

- To verify the feasibility and performance of the 650MHz cavity cryomodule design, a test cryomodule (TCM) was constructed.
- A test cryomodule (TCM), housing two 650 MHz 2-cell cavities was designed, fabricated and commissioned before the formal cryomodules since the beginning of 2017.



Design of Test Cryomodule

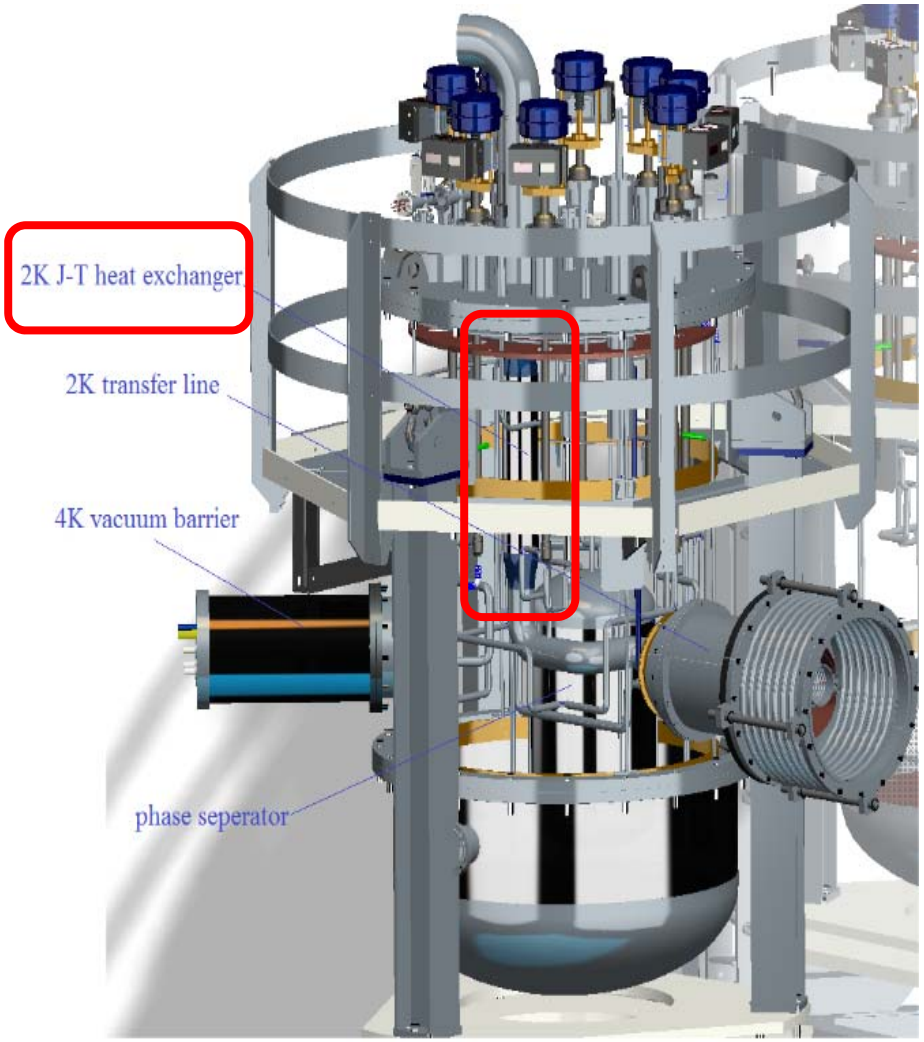


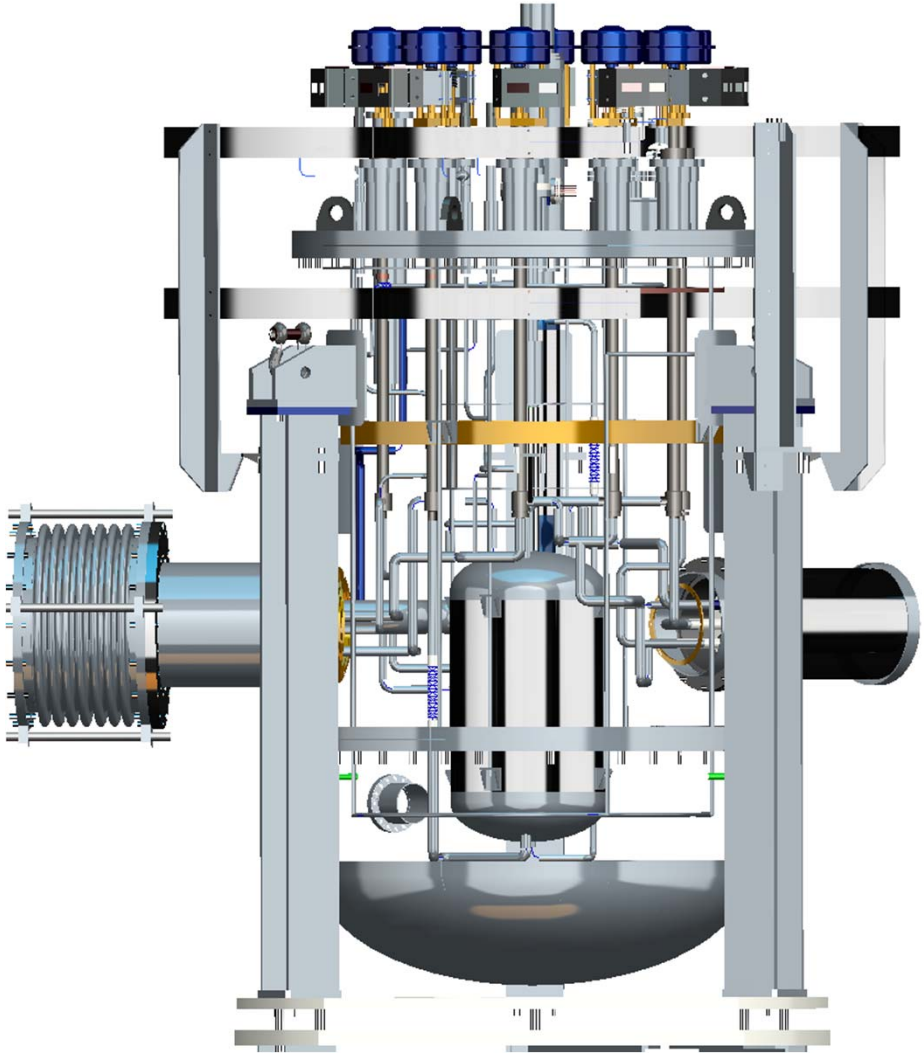


- Two 2-cell 650 MHz superconducting cavities;
- Two high power couplers
- Two mechanical tuners
- Three HOM couplers
- High Q_0
- Fast cool-down is introduced

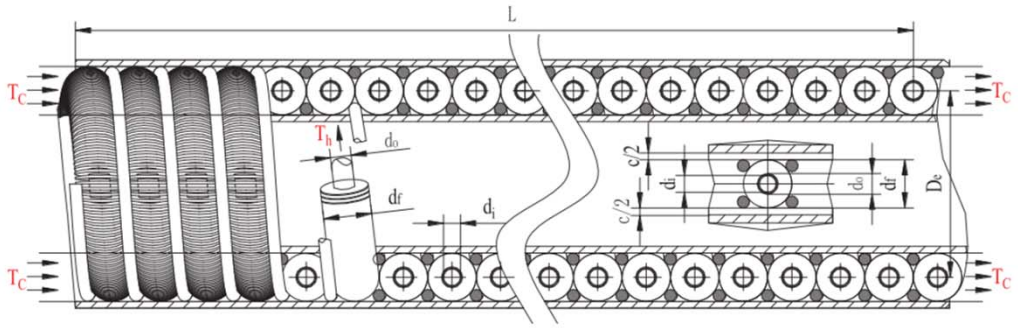
•Vacuum vessel
– Material:316L stainless steel
–Outer diameter = 1424mm
– Length=3000mm
•Support post
–Supporting the all cold mass in the vacuum vessel
–Supporting Cavities： Diameter is 180mm
–Supporting RF-Gate Valve： Diameter is 150mm
–Number:2+2=4
–Material： FRP(G-10)
•Thermal radiation shield
–Aluminum plate ＋Muti-layer insulation of aluminum-evaporated film(Super Insulation)
–40K-70K Nitrogen gas, 5K-10K helium gas
•Strongback
–Stainless steel
–Room temperature

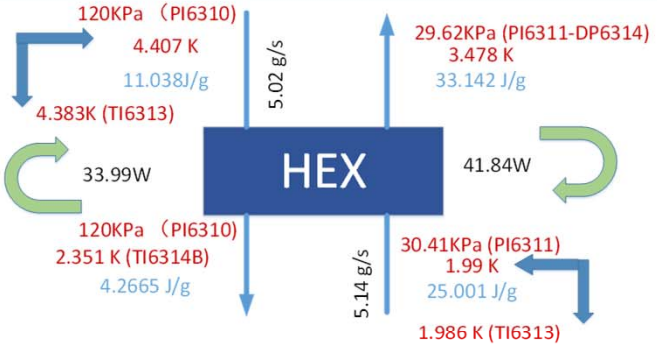
Distribution Valve Box

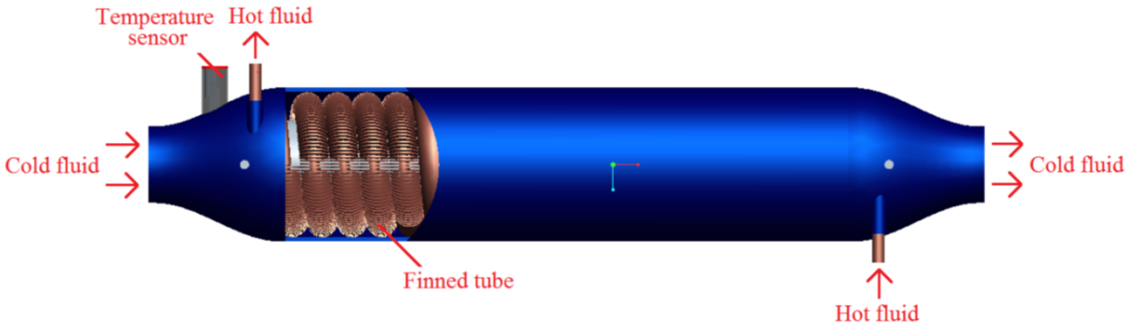


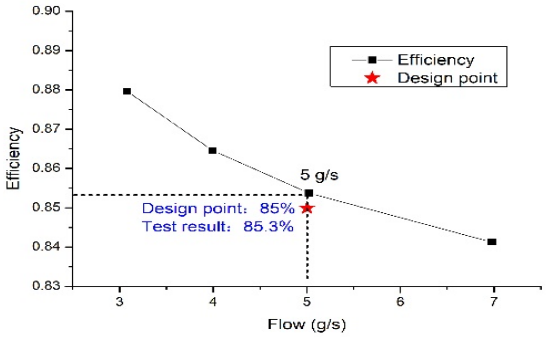


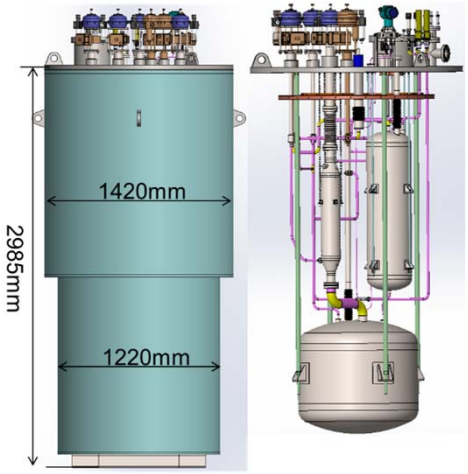
2K J-T Heat Exchanger

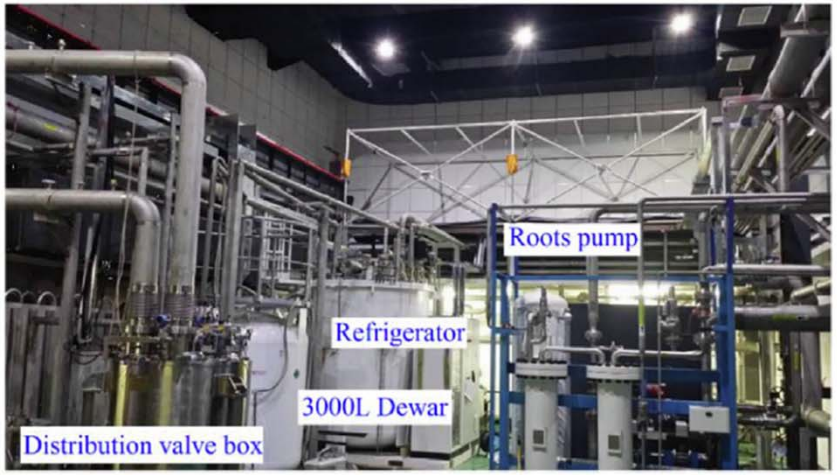










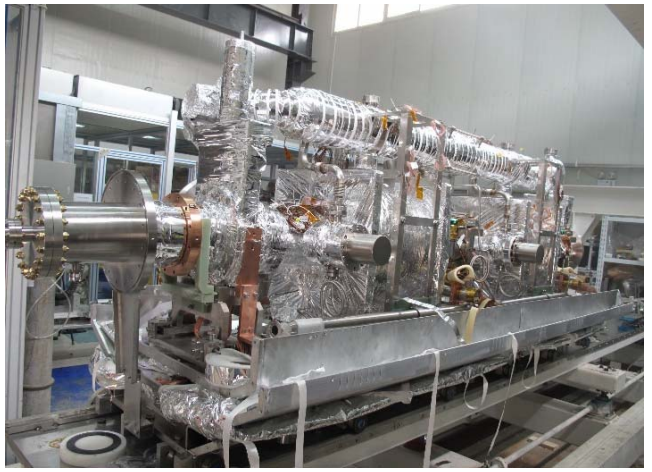


Assembly of Test Cryomodule

March. 2021-May 2021, it takes two months to assemble, transport and integrate to the accelerator system.

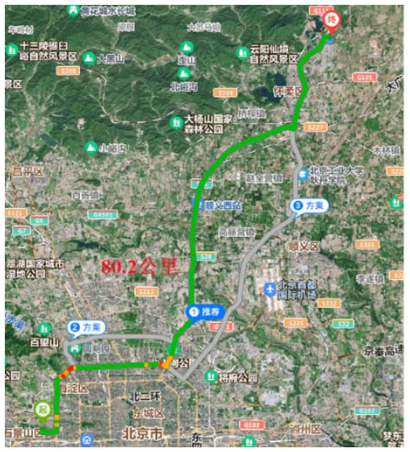
合肥聚能电物理高技术开发有限公司
Hefei Juneng Electro Physics High-tech Development Co., Ltd

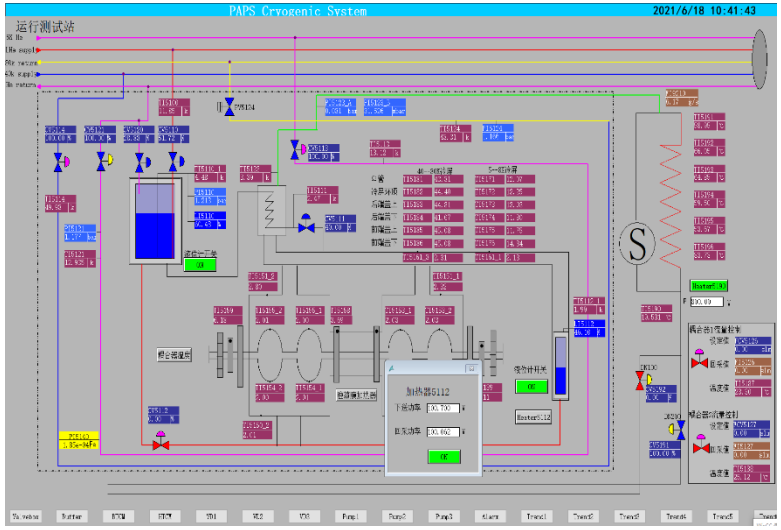





Transport of Test Cryomodule

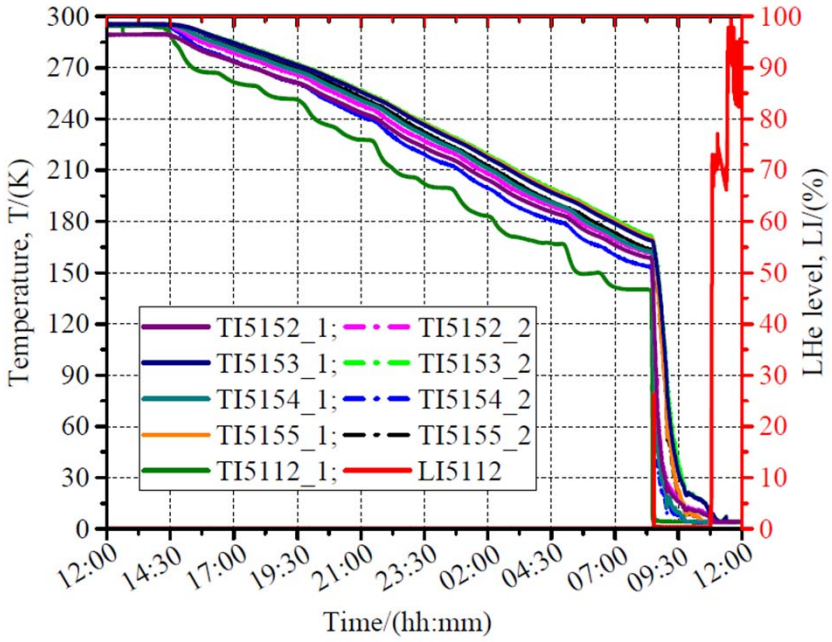
- First case for cryomodule long-distance transportation at IHEP;
- The cryomodule has been installed in the tunnel, connected with the 2 K distribution valve box and cryogenic transfer line.



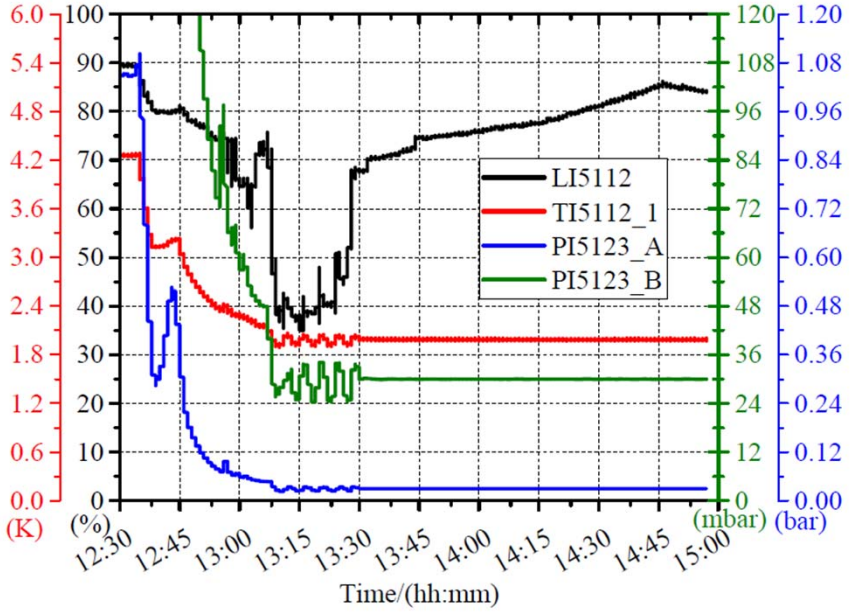


Cool down of test cryomodule

- The first cool down of the TCM started at the middle of June, 2021;



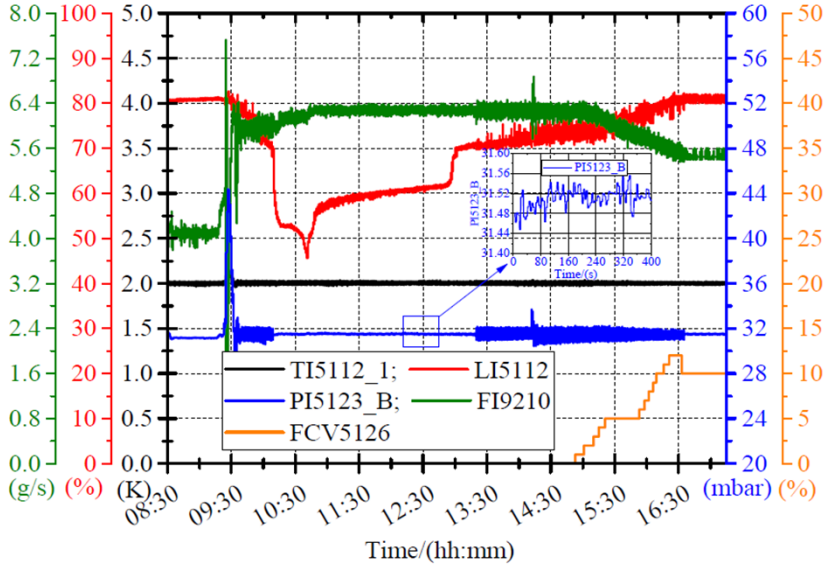
- 300 K to 4.2 K cool down curves is shown as figure;
- cooling process was lasted about 24 hours.



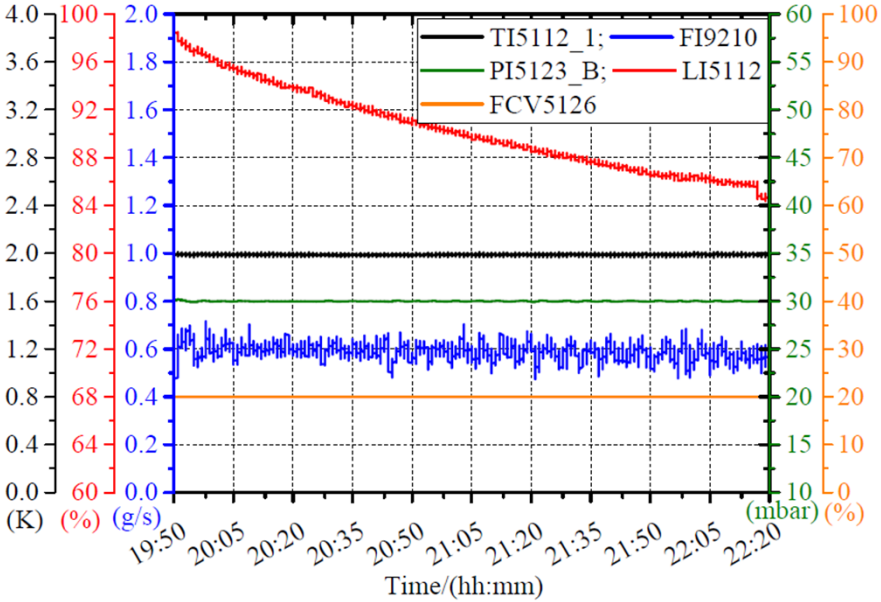
- 4.2 K to 2 K cool down curves is shown as figure;
- cooling process was lasted about 2.5 hours

Operation and Heat load experiment

- Because TCM has not realized operation with beam, and in order to simulate the steady state operations with beam in the cryogenic system, the electrical heater with 100W power is loaded in the helium vessel.
- The pressure in the helium vessels are 31mbar±10 Pa .

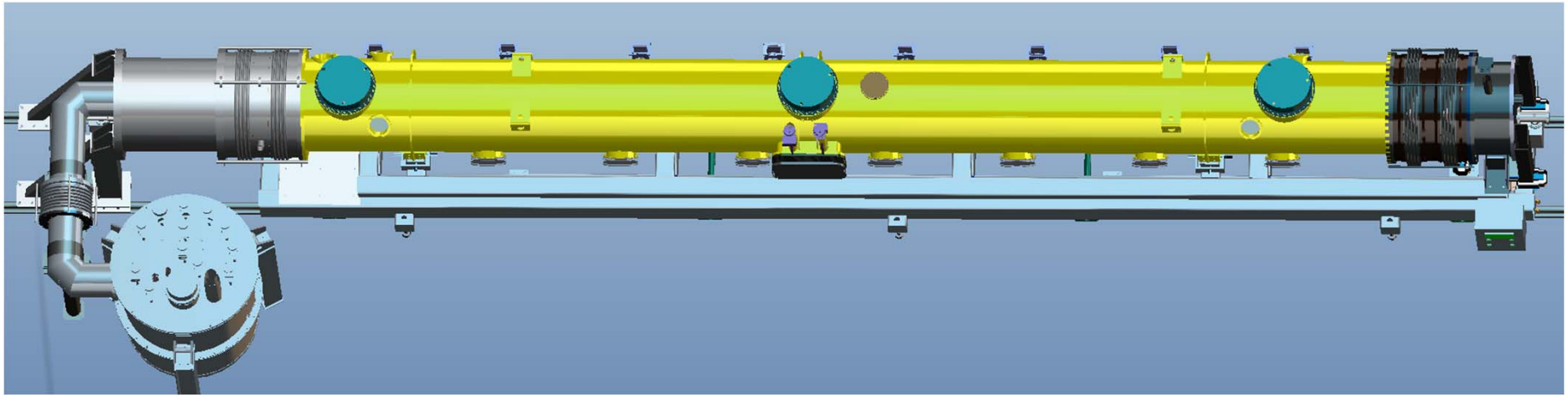


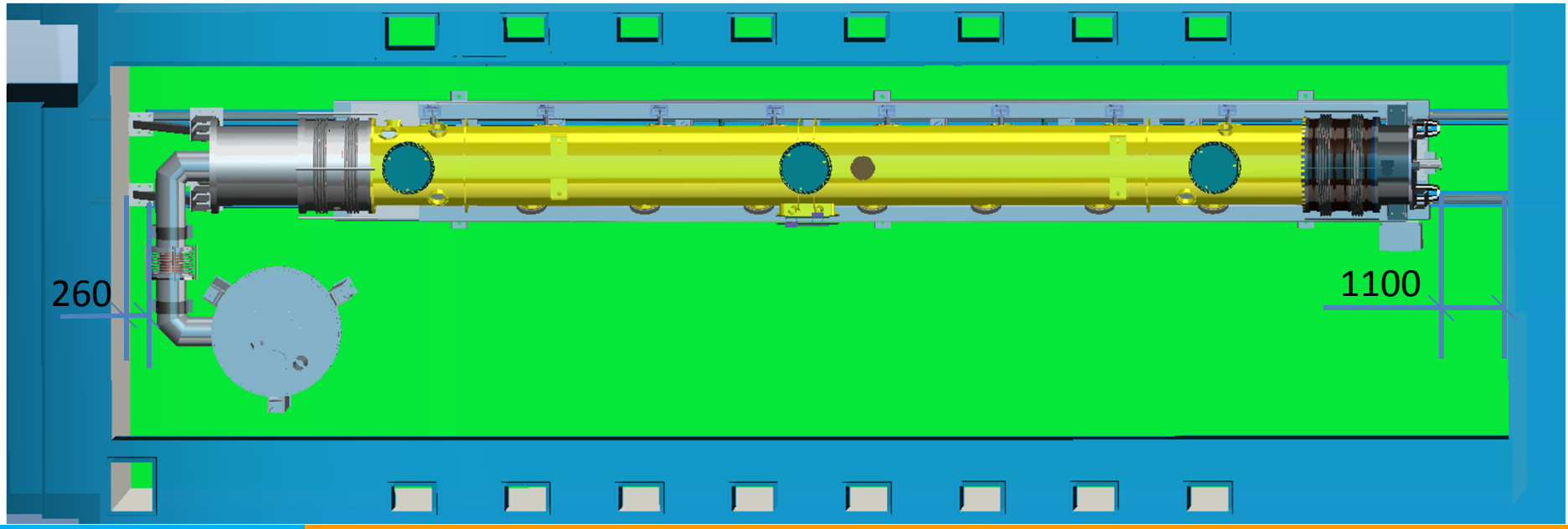
- The average mass flow rate is 0.59g/s;
- The static heat load is 13.8W at 2K temperature.



4. Fabrication of 1.3GHz Cavity Cryomodule

HT station: Cryomodule+Valve box+Feedcap+Endcap+Platform



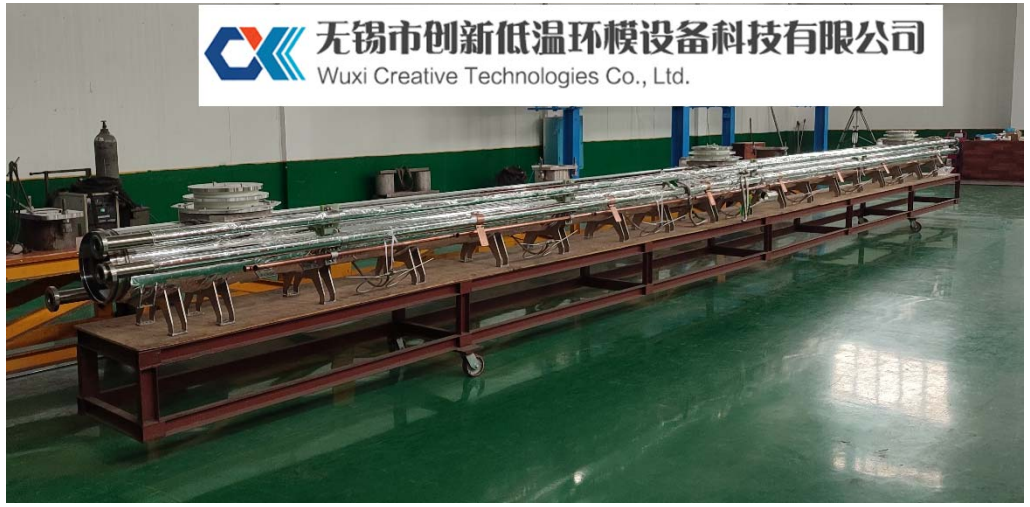


Fabrication of vacuum vessel

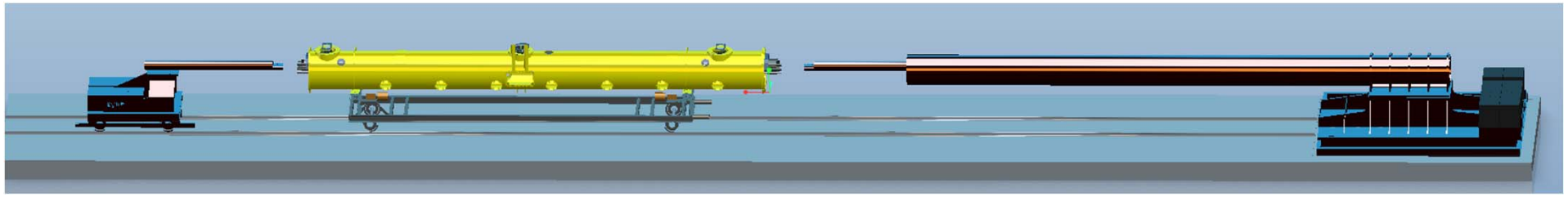
Fabrication of vacuum vessel in manufacture company.

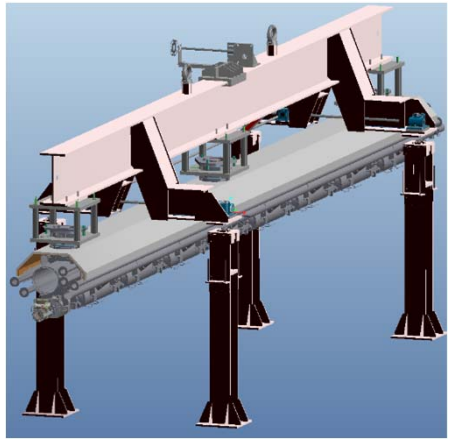
Fabrication of cold mass

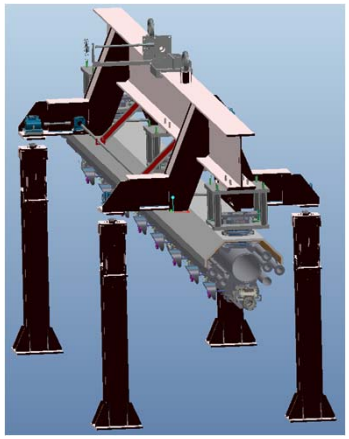
Fabrication of cold mass in manufacture company.

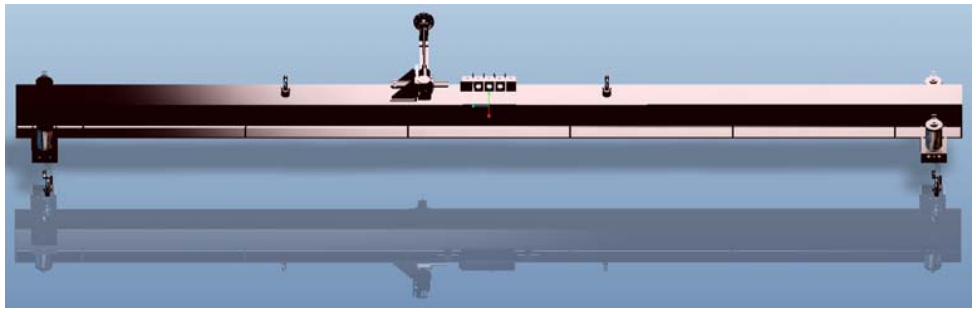


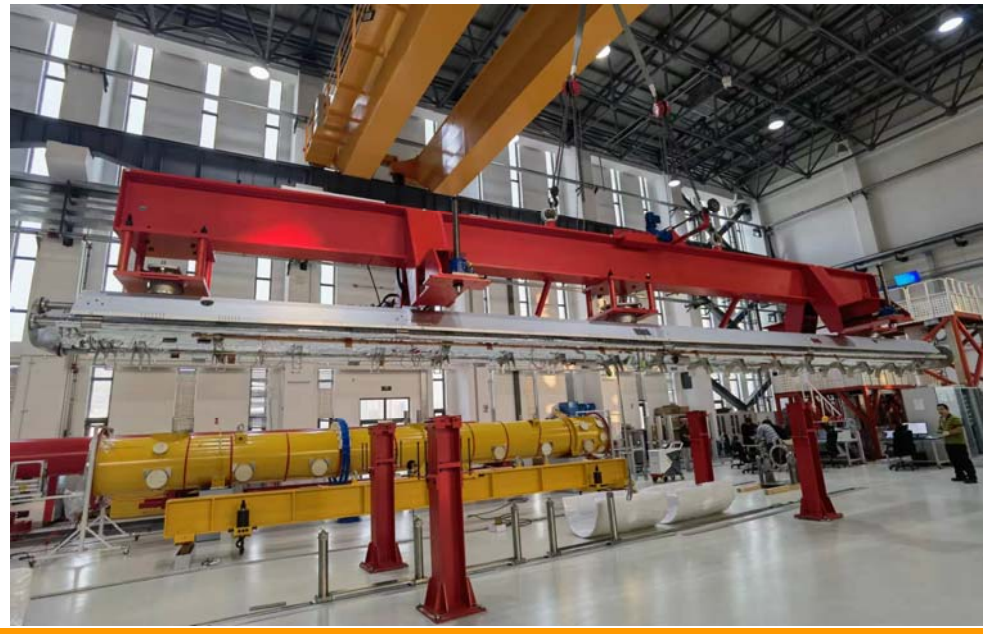
Fabrication of assembly tool











Horizontal test facility at PAPS (Huairou)

PAPS (Huairou, Beijing)
Platform of Advanced Photon Source Technology R&D

cryogenic hall

RF hall

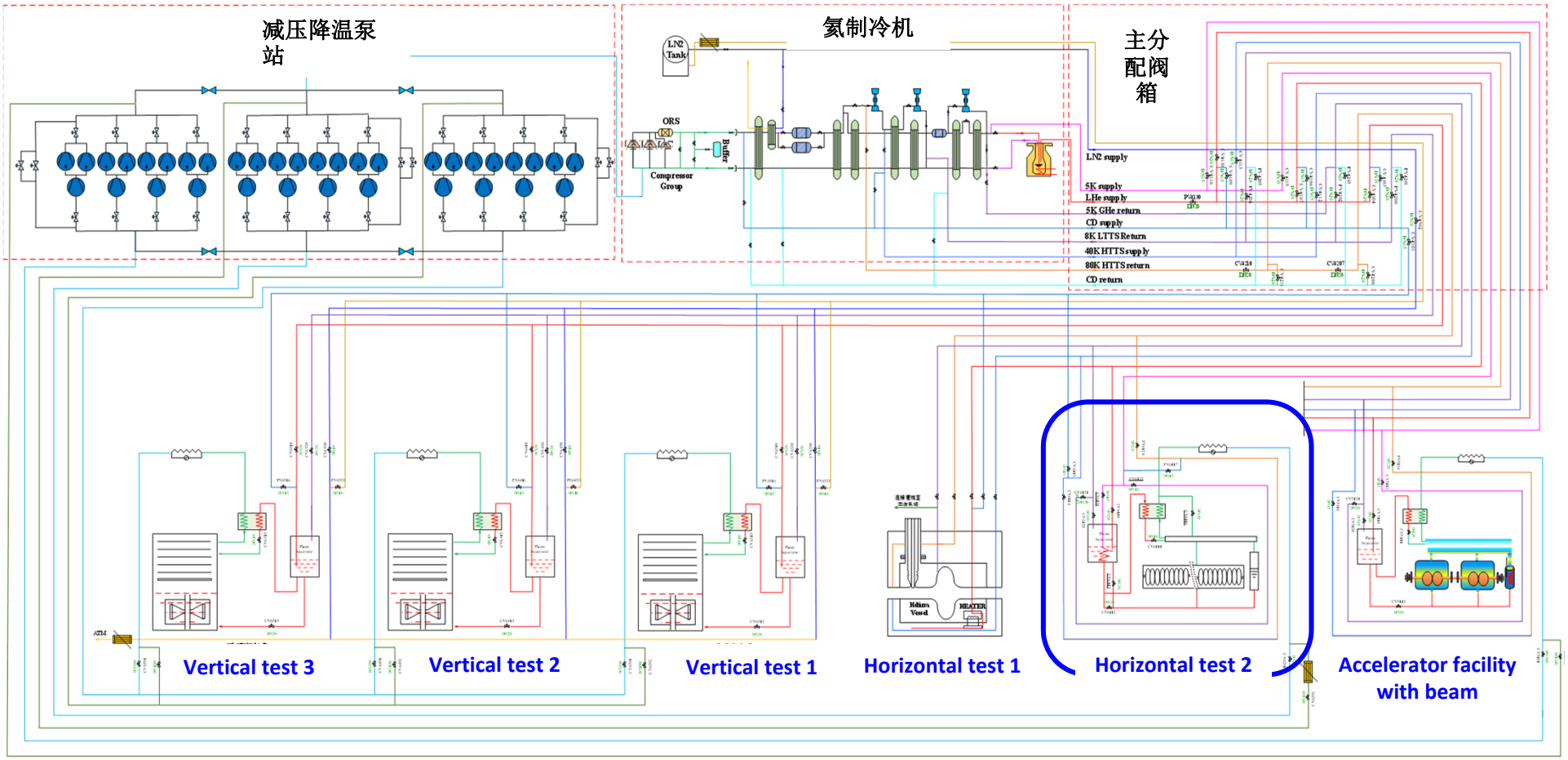
Tanks zone

VT stands

HT test stand

Beam test stand

PAPS cryogenic system diagram



Conclusion

- Conceptual design of 650MHz cavity formal cryomodule have been completed.
- Design, assembly and experiment of the 650MHz cavity test cryomodule were introduced.
- 1.3GHz cavity cryostat and assembly tools have been fabricated.
- Next, 1.3GHz cavity cryomodule will be assembled and horizontal tested at the end of 2022.
- 650MHz cavity test cryomodule will be commissioned at the end of 2022.

Thanks for your attention