环形正负电子对撞机
Circular Electron Positron Collider

IHEP

2022 HongKong IAS HEP workshop

CEPC Cryogenic System R&D

Rui Ge / Mei Li

On behalf of CEPC cryogenic system

Jan., 14th, 2022

OUTLINE

- Introduction
- Layout of the cryogenic system
- Discussion and Comparison on CEPC SRF cryogenic system
- Discussion and Comparison on SC magnets cryogenic system
- Summary

CEPC Cryogenic System Brief Introduction

Booster ring:

- 1.3 GHz 9-cell cavities, 96 cavities
- 12 cryomodules
- 3 cryomodules/each station
- Temperature: 2K

Collider ring:

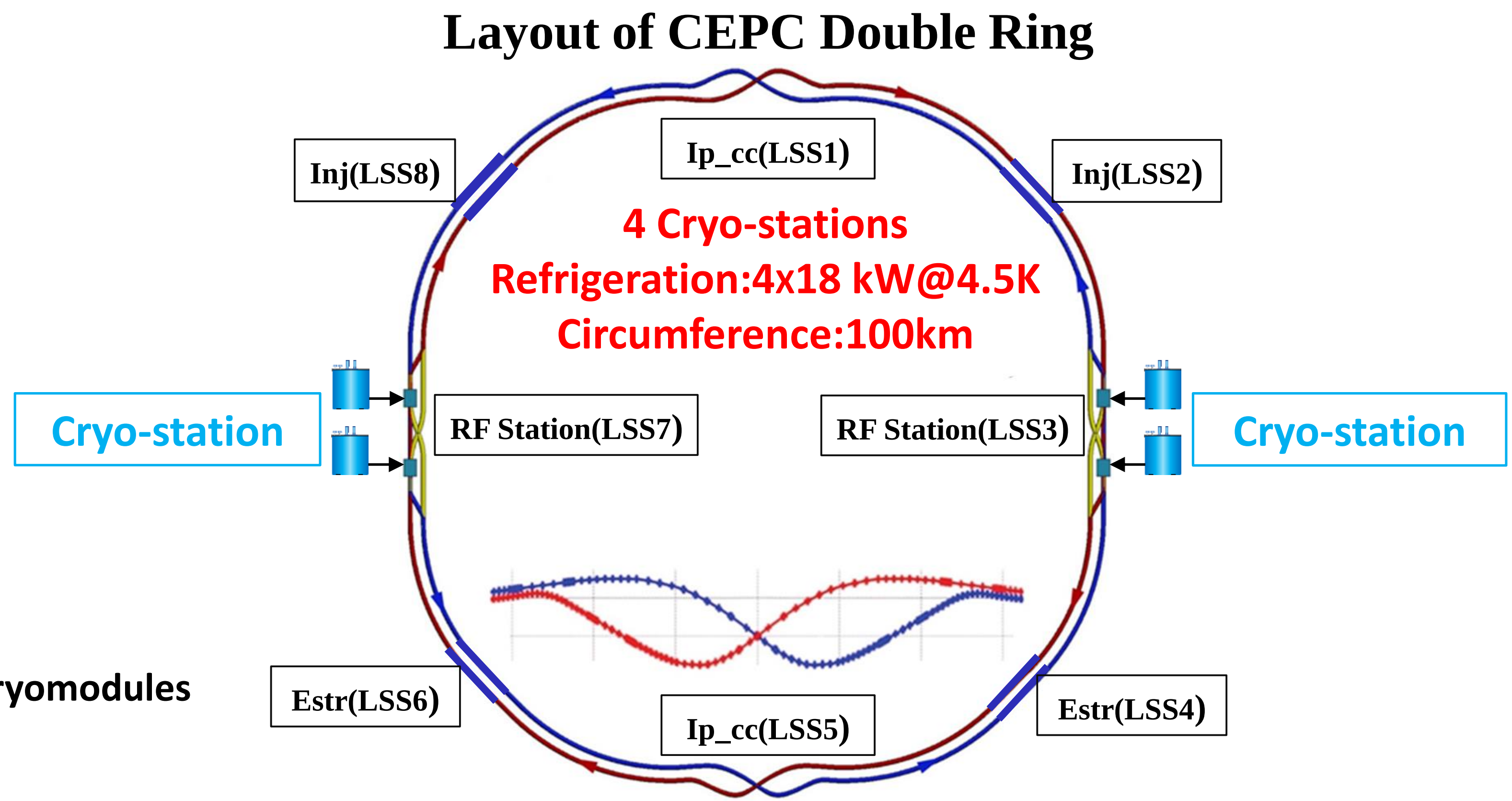
- 650MHz 2-cell cavities, 240 cavities
- 40 cryomodules
- 10 cryomodules/each station
- Temperature: 2K

IR magnets:

- 4 IR magnets, 32 Sextupole magnets, 36 cryomodules
- 18 cryomodules/each station
- Temperature: 4.5K

Detectors:

- 2 detector magnets
- Thermosiphon cooling



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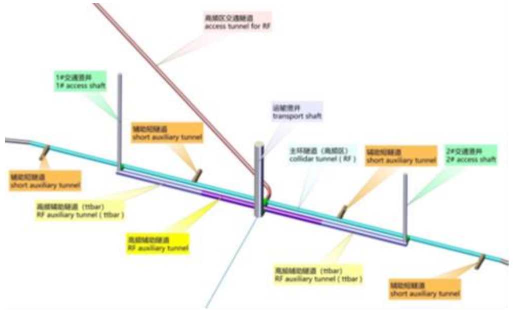
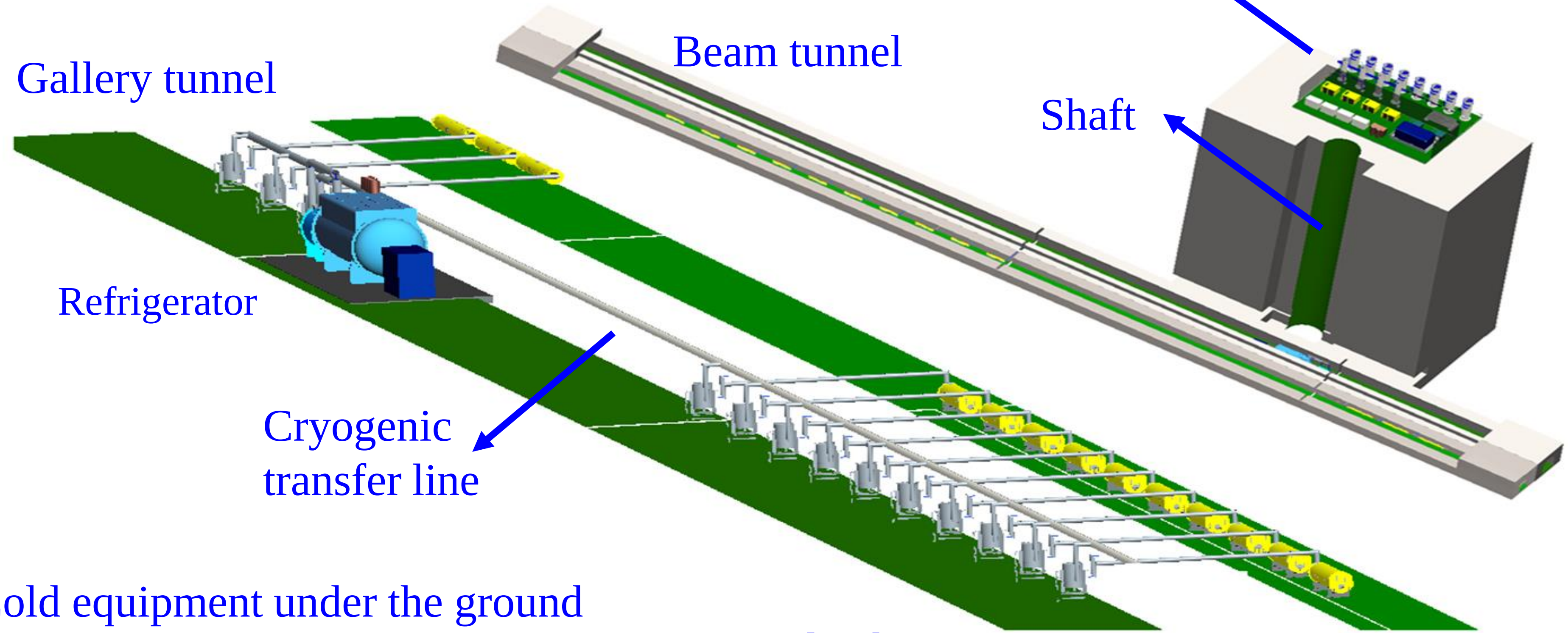
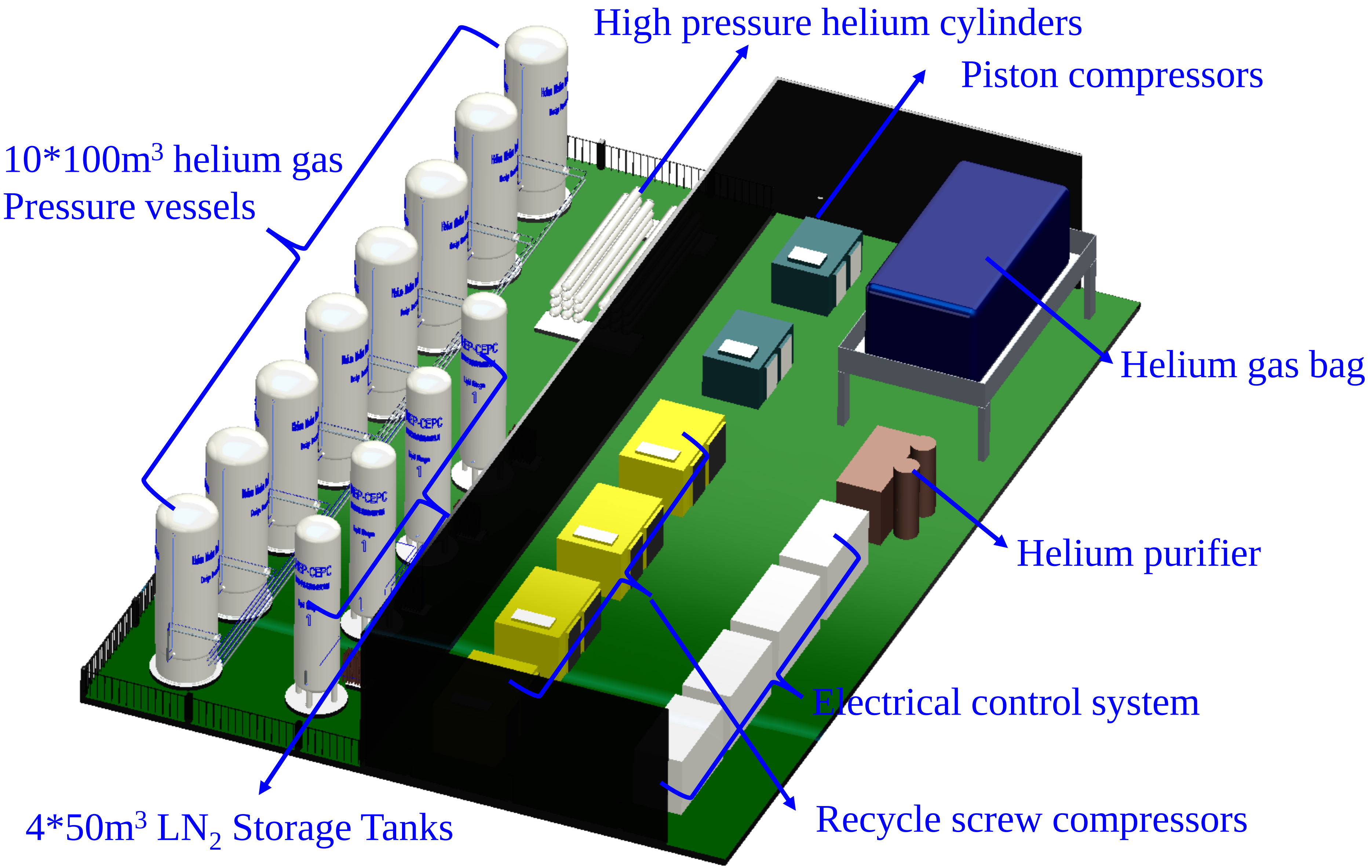
Layout of CEPC cryogenic system

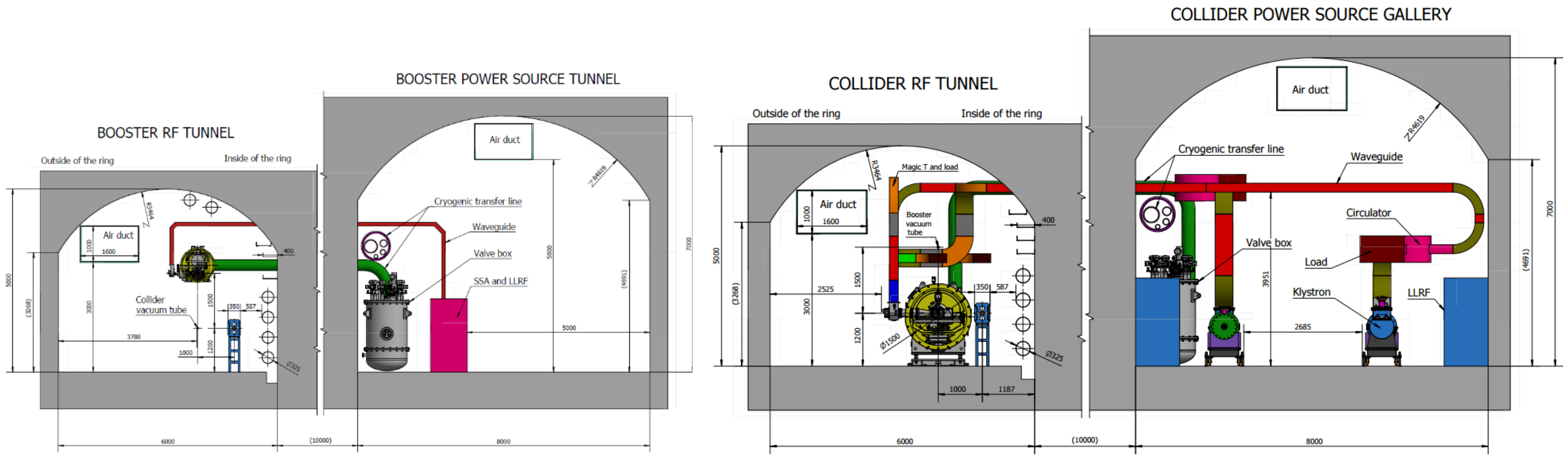


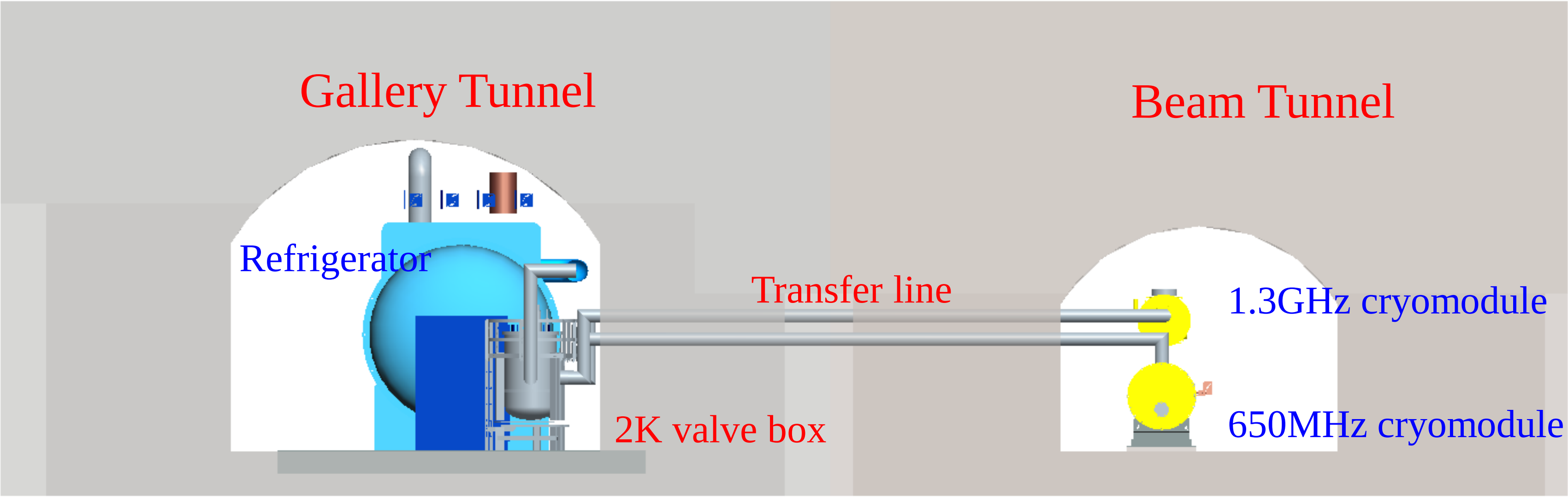


Layout of CEPC cryogenic hall

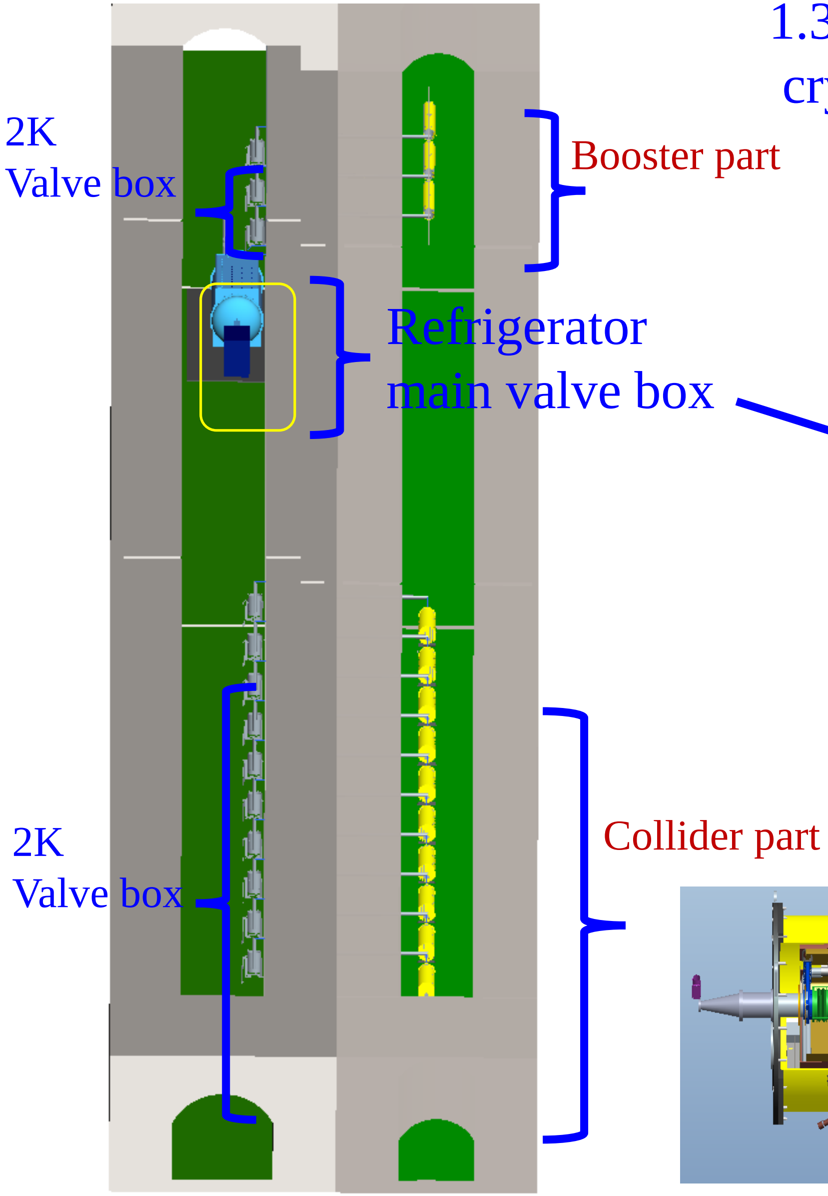


Tunnel Cross section

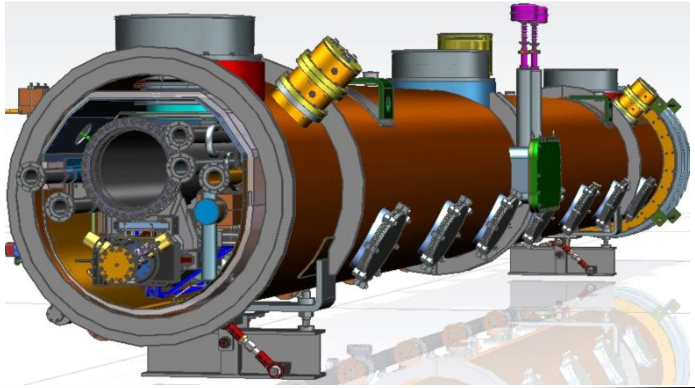


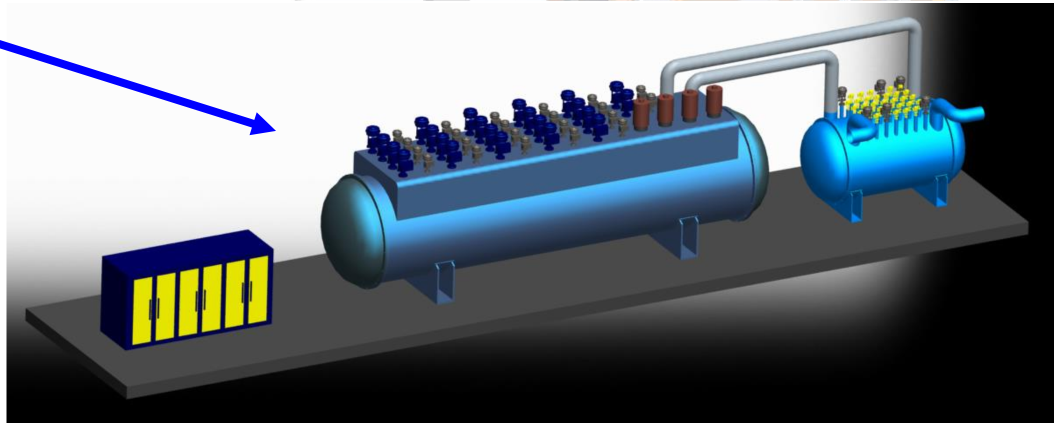


Layout of CEPC cryogenic system

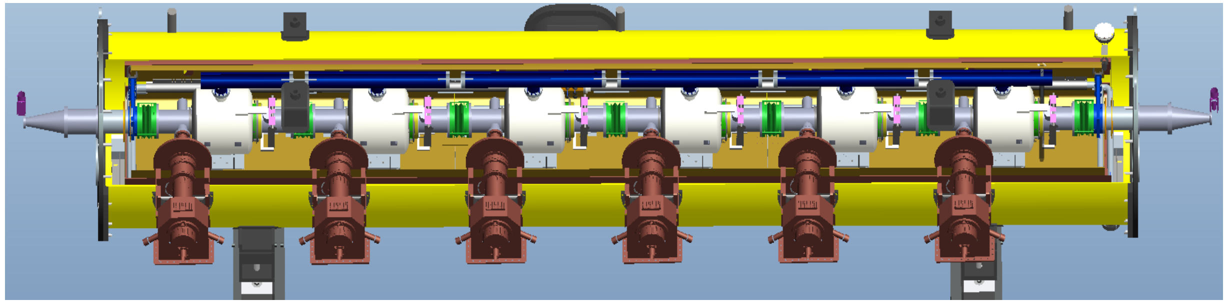


1.3GHz cavity cryomodule





650MHz cavity cryomodule



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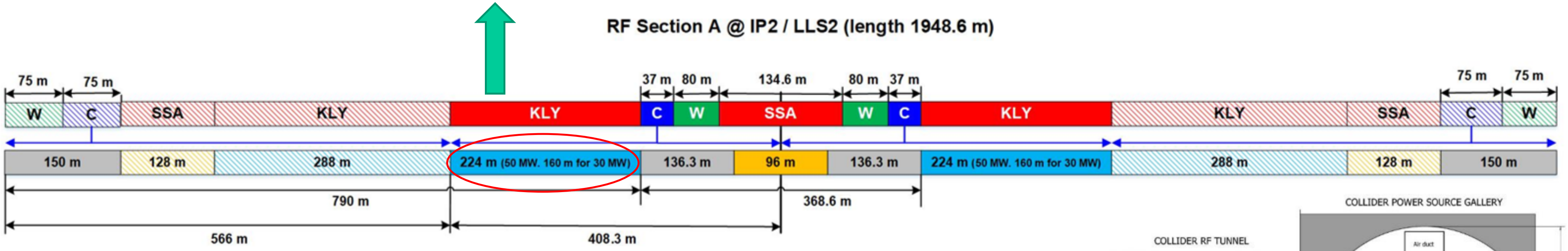
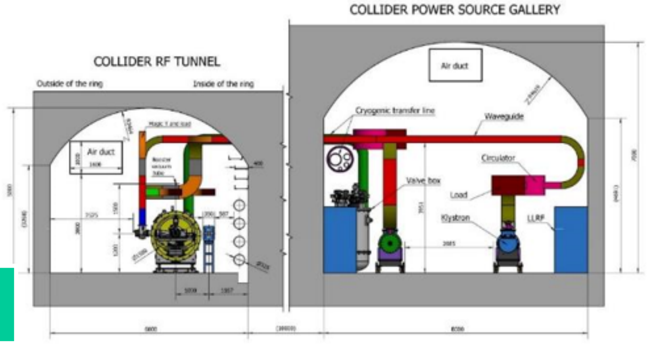
Difference for H50MW and H30MW modes

CEPC SRF Layout

Multi-transfer lines length: H30 MW 160m → H50MW 224m



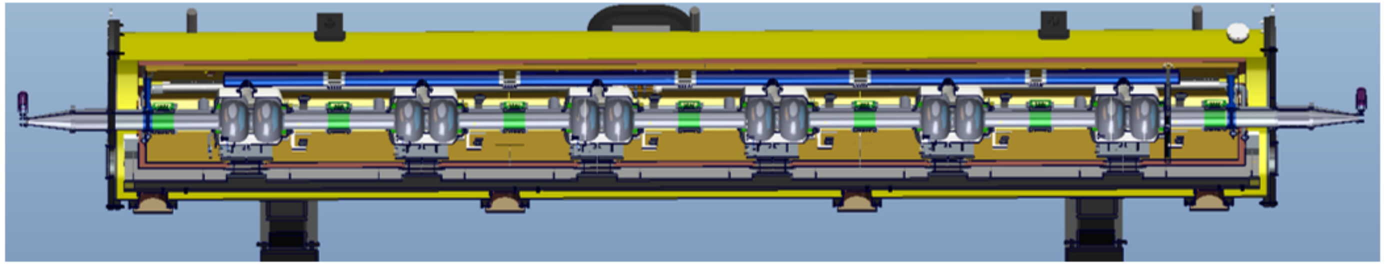


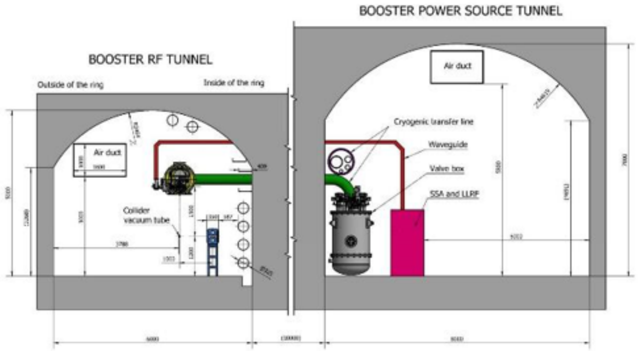
30 MW Higgs:

Collider: 240 650 MHz 2-cell cavities in 40 cryomodules (6 cav./ module).

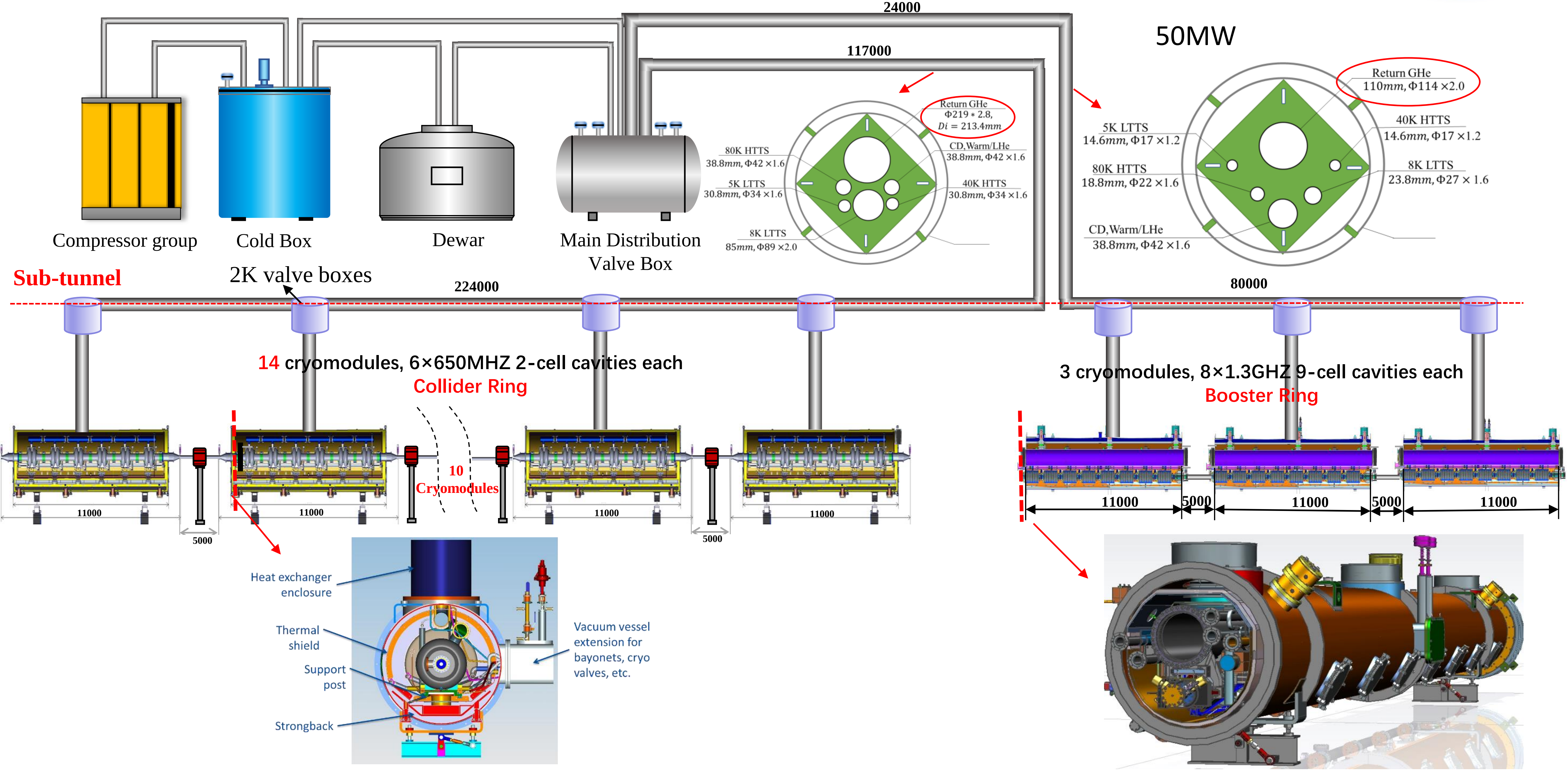
Booster: 96 1.3 GHz 9-cell cavities in 12 cryomodules (8 cav. / module).

50 MW Higgs upgrade: add 16 Collider modules. → 56 collider modules

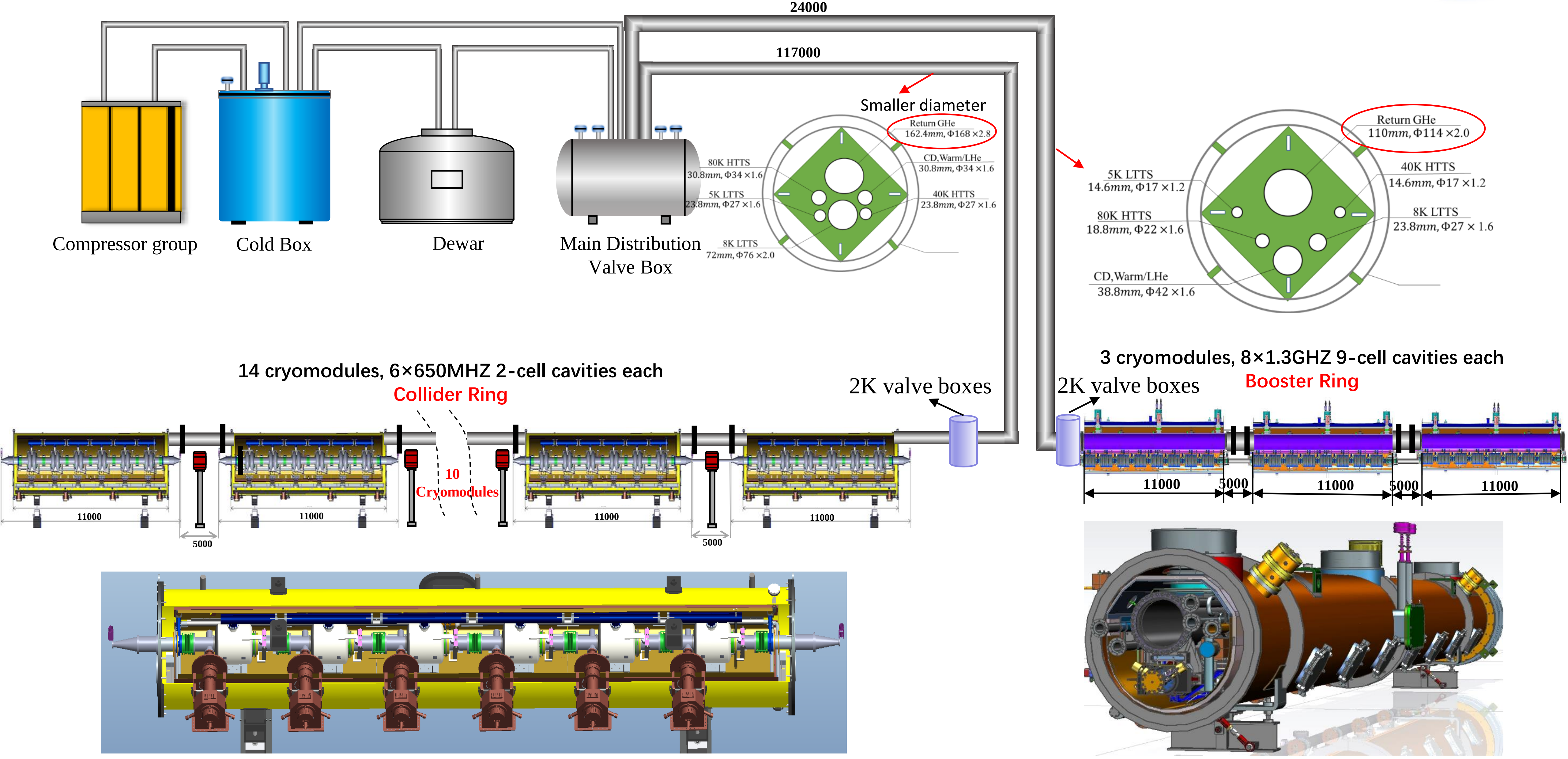




Flow chart of SRF CDR Scheme



Flow chart of SRF Modif. Scheme



Estimated heat loads for SC cavities-CDR Scheme

Higgs Mode 50MW	Unit	Collider			Booster		
		40-80K	5-8K	2K	40-80K	5-8K	2K
Predicted static heat load per cryomodule	W	300	60	12	140	20	3
Cavity dynamic heat load per cryomodule	W	0	0	153.59	0	0	13.98
HOM dynamic heat load per cryomodule	W	20	12	2	2	1	1
Input coupler dynamic heat load per cryomodule	W	60	40	6	40	3	0.4
Module dynamic heat load	W	80	52	161.59	42	4	15.38
Each Module total heat load	W	380	112	173.59	182	24	18.38
Cryomodule number	-	56	56	56	12	12	12
EVB heat loss	W	50	10	10	50	10	10
EVB number	-	40	40	40	12	12	12
MDVB heat loss	W	50	30	30	50	30	5
MDVB number	-	4	4	4	4	4	4
Total cryogenic transfer line length	m	1924	1924	1924	536	536	536
cryogenic transfer line heat loss per meter	W/m	2	0.5	0.3	2	0.5	0.3
Total cryogenic transfer line heat loss	W	3848	962	577.2	1072	268	160.8
Total heat load	kW	27.328	7.754	10.81824	4.056	0.796	0.52136
Total predicted mass flow	g/s	82.42	152.26	373.72	13.34	12.73	18.324
Overall net cryogenic capacity multiplier		1.54	1.54	1.54	1.54	1.54	1.54
4.5K equiv. heat load with multiplier	kW	3.16	10.80	53.32	0.47	1.11	2.58
4.5K equiv. heat load with multiplier	kW	67.29			4.15		
Total 4.5K equiv. heat load with multiplier	kW	71.44					

Total:2460m

- Four individual refrigerators (4 × 18kW@4.5K) will be employed for the CEPC cavity cryogenic system.

Estimated heat loads for SC cavities-Modif. Scheme

Higgs Mode 50MW	Unit	Collider			Booster		
		40-80K	5-8K	2K	40-80K	5-8K	2K
Predicted static heat load per cryomodule	W	300	60	12	140	20	3
Cavity dynamic heat load per cryomodule	W	0	0	153.59	0	0	13.98
HOM dynamic heat load per cryomodule	W	20	12	2	2	1	1
Input coupler dynamic heat load per cryomodule	W	60	40	6	40	3	0.4
Module dynamic heat load	W	80	52	161.59	42	4	15.38
Each Module total heat load	W	380	112	173.59	182	24	18.38
Cryomodule number	-	56	56	56	12	12	12
EVB heat loss	W	50	10	10 Total:2460m	50	10	10
EVB number	-	40	40	40	12	12	12
MDVB heat loss	W	50	30	30 Total:864m	50	30	5
MDVB number	-	4	4	4	4	4	4
Total cryogenic transfer line length	m	728	728	728	136	136	136
cryogenic transfer line heat loss per meter	W/m	2	0.5	0.3	2	0.5	0.3
Total cryogenic transfer line heat loss	W	1456	364	218.4	272	68	40.8
Total heat load	kW	24.936	7.156	10.45944	3.256	0.596	0.40136
Total predicted mass flow	g/s	82.42	152.26	373.72	13.34	12.73	18.324
Overall net cryogenic capacity multiplier		1.54	1.54	1.54	1.54	1.54	1.54
4.5K equiv. heat load with multiplier	kW	2.89	9.97	51.56	0.37	0.83	1.98
4.5K equiv. heat load with multiplier	kW	64.41			3.19		
Total 4.5K equiv. heat load with multiplier	kW	4 × 16.85 kW 67.60 **Can reduce 4.04kW heat load compared scheme1**					

•Four individual refrigerators (4 × 18kW@4.5K) will be employed for the CEPC cavity cryogenic system.

Large Helium Refrigerator Market Research

◆Foreign refrigerator / liquefiers, features: mature and stable industry chain, wide range of users

➢ Linde refrigerator / liquefier series

- BEPCII: 2*500W@4.5K（IHEP）
- PAPS: 2.5kW@4.5K（**IHEP**）
- HEPS: 2.0kW@4.5K+150L/h（**IHEP**）

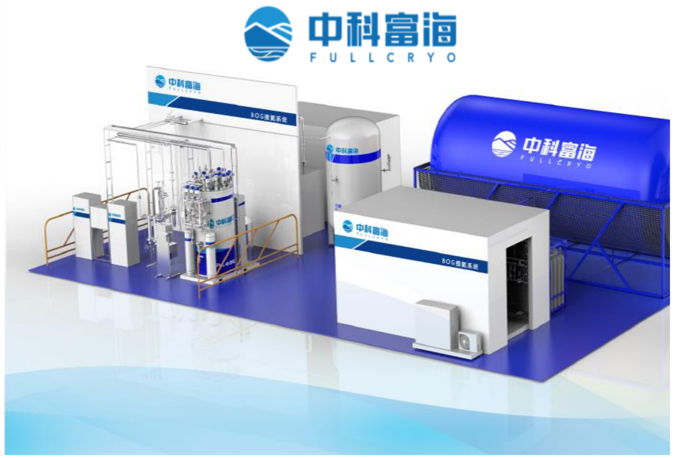
➢ Air Liquide refrigerator/liquefier series

- ADS injector I: 1kW@4.5K or 100W@2K

◆Domestic refrigerator / liquefier

➢ Institute of physics and Chemistry, CAS (FULL CRYO) has: 2kW@20K，10kW@20K, etc.; 2.5KW@4.5K or 500W@2K Has been successfully developed; **10kW@4.5K has planned**

➢ Institute of Plasma Physics, CAS: existing 500W@4.5K or 150L / h, 2.2kW@4.5K , planned 5kW@4.5K




【中国科学报】我国研发成功-271℃超流氦大型低温制冷装备

中国科学报

4月15日，由财政部支持、中国科学院理化技术研究所承担的国家重大科研装备研制项目“液氦到超流氦温区大型低温制冷系统研制”通过验收及成果鉴定，标志着我国打破发达国家的技术垄断，具备了研制液氦温度（零下269摄氏度）千瓦级和超流氦温区（零下271摄氏度）百瓦级大型低温制冷装备的能力，将可满足大科学工程、航天工程、氦资源开发等国家战略高技术发展的迫切需要。

液氦温度低至-269℃，是深低温区最重要的低温源。液氦到超流氦温区大型低温制冷装备是航空航天、氢能源、国家大科学装置等战略领域不可或缺的核心基础平台。但是越往低温推进，制冷技术难度、成本、功耗都呈几何级数上升。核心技术的缺失，使我国大型低温制冷装备全部依赖进口，关键核心部件以及用于特殊领域的专用制冷装备国外对我禁运。

中科院理化所具有几十年低温技术的深厚积累，在洪朝生院士、周远院士带领下，通过一代代低温科技工作者的不懈努力，坚持走自主创新道路，经过五年多的拼搏奋斗，……温度（零下253度）制冷机的基础上，自主研制出了技术指标为2500W@4.5K……W@2K的大型氦制冷机。

https://mp.weixin.qq.com/s/mNQJin9pgKc9wkowtQA4PA

https://mp.weixin.qq.com/s/Twz8Kk4AUwkvB456RWeuqQ

National refrigerator company status research

中科富海制冷机关于万瓦级大型氦制冷机的研制情况：

Development status of 10kW@4.5K or 18kW@4.5K (CEPC) large helium refrigerator of FULL CRYO company:

- 先导专项已立项，科技部重大专项都有相关工作部署，预计三年将开发出10kW@4.5K大型制冷机，为cepc做好充分准备;

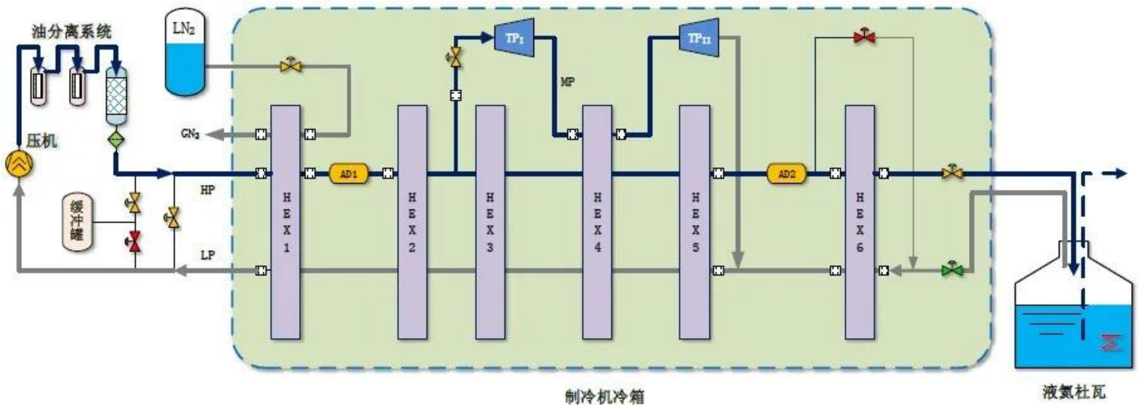
The pilot project has been approved, and the major projects of the Ministry of science and technology have relevant work deployment, which is expected to be developed in three years 10kW@4.5K Large refrigerator, fully prepared for CEPC.

- 2.5kW@4.5K已经通过验收，是理化所的工作成果;

2.5kW@4.5K or 500W@2K refrigerator has passed the acceptance this year, and it is the work achievement of the Institute of physics and chemistry.

- 10kW也是理化所牵头联合富海公司共同研制开发的下一代产品。

10kW@4.5K large helium refrigerator is also the next generation product jointly developed by the Institute of physics and chemistry (TIPC, CAS) and FULL CRYO company.



The main specification of large refrigerator

Designed by TIPC

Operating temperature	Required capacities		Design capacities		
	Pressure（bar）	Heat load（W）	Pressure（bar）	Heat load（W）	Equiv. heat load(@4.5K)
4.5K	----	----	1.25	500	500
2.0K	0.03	3950	0.03	4895	12191
40~80K	18.5	10300	18.5	10587	672
5~8K	5	2720	5	3000	1877
Total equiv. heat load at 4.5K					15240

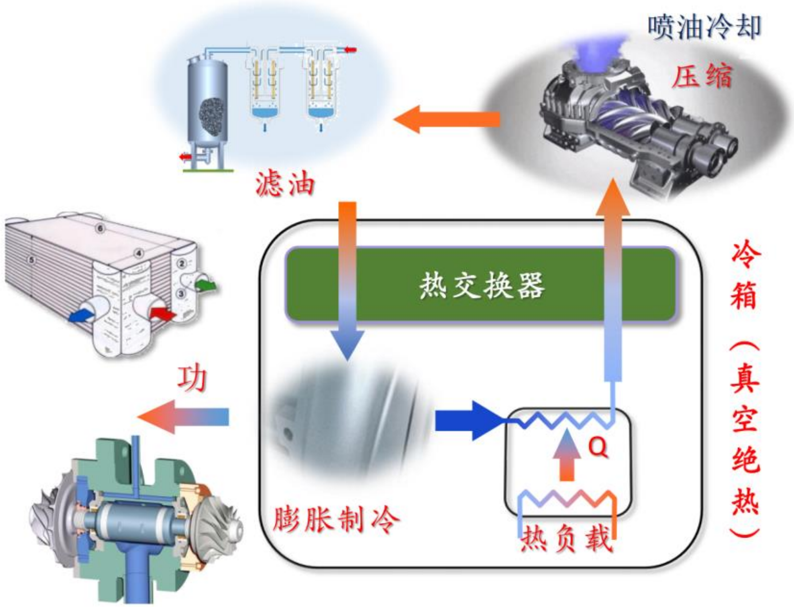
Other parameters	Precooled by Turbin expanders	Precooled by liquid nitrogen
The consumption of the Liquid Nitrogen	0g/s (0L/h)	428.7g/s(2043L/h)
Gas flow for precooling	100g/s	0g/s
Gas flow（g/s）	1668g/s	1551g/s
Power Consumption（KW）	3935.13	3721.3

Factor of merit: 258W/W* 245W/W*

Designed by TIPC

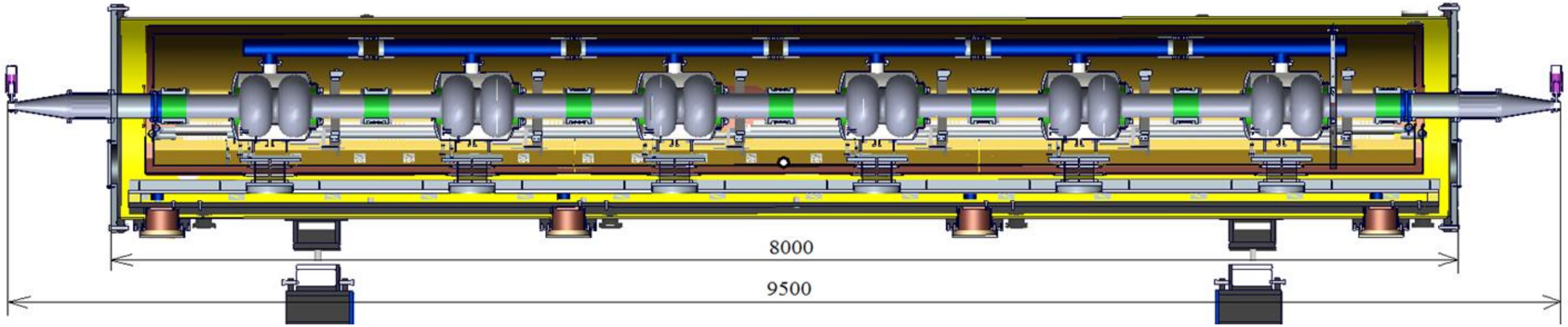
Cold compressor

Parameters	2K refrigeration units		
	The first stage	The second stage	The third stage
Gas flow (g/s)	230.7	230.7	230.7
Temperature of the inlet (K)	3.387	6.073*	10.53*
Pressure of the inlet (kPa)	3.00	8.00*	20.00*
Temperature of the outlet (K)	6.073*	10.53*	17.01*
Pressure of the outlet (kPa)	8.00*	20.00*	44.0
Adiabatic efficiency (%)	60.0	60.0	60.0
Power consumption (W)	3208	5323	7765



Cryomodule for 650MHz 2-cell cavities

- **Including six 2-cell 650 MHz superconducting cavities, six high power couplers, six mechanical tuners and two HOM absorbers**

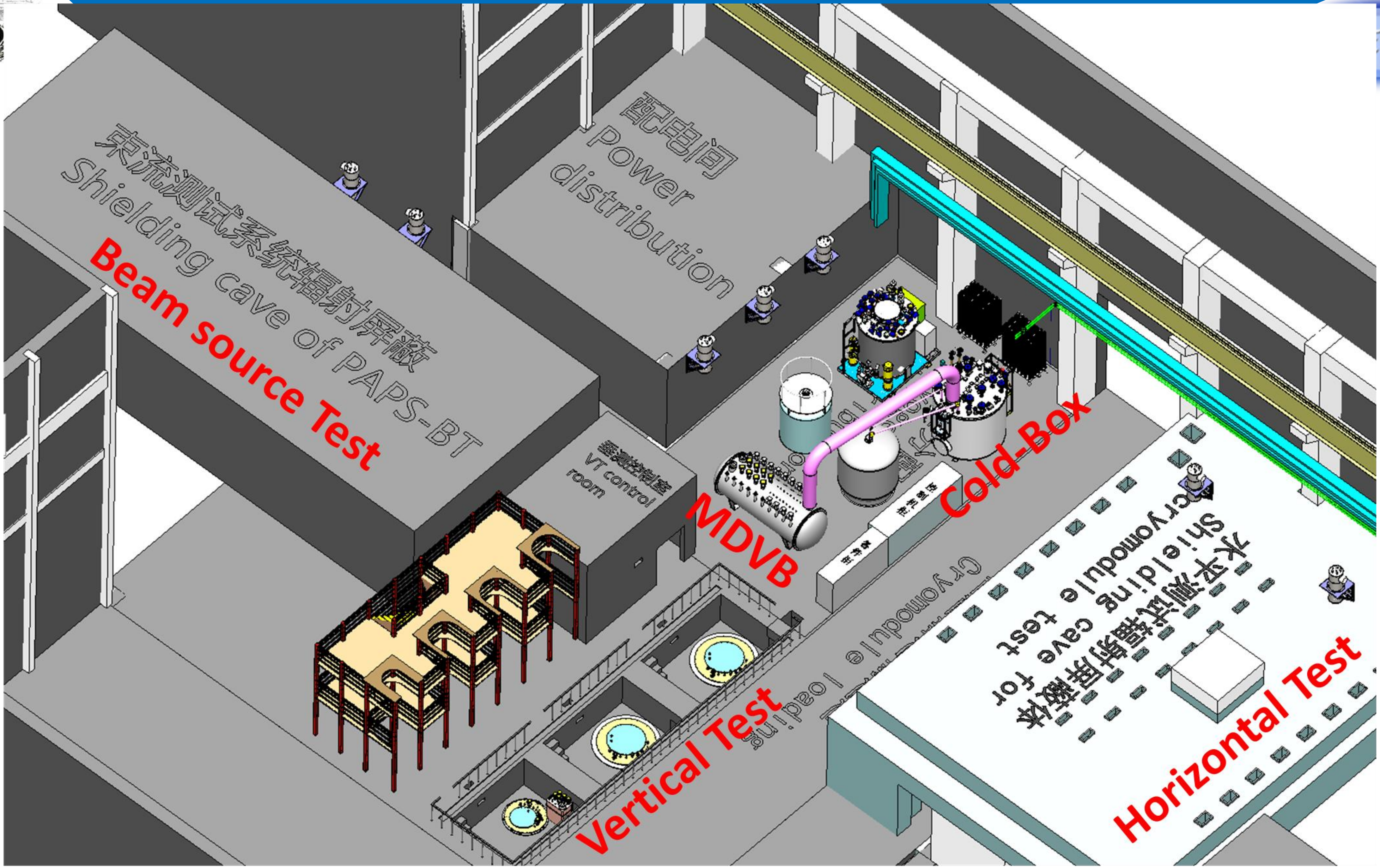


Six 2-cell Cavities Cryomodule	
Overall length(flange to flange, m)	8.0
Diameter of Vacuum vessel ,m	1.3
Beamline height from floor, m	1.5
Cryo-system working temperature, K	2
Number of 200-POST	6

Cryomodule performance		Specification
Number of leakage	He →insulation	0
	He →beam pipe	0
	Insulation →coupler	0
	Insulation →beam pipe	0
	Coupler →beam pipe	0
Alignment x/y inside (Cavities)		±0.5mm
Alignment z inside		within 2 mm
Coupler antenna design z		within 2 mm


Magnet building
Beam test building
SRF building
X-ray building
Cryogenic building
NO.2 A
NO.3
NO.1


热烈庆祝中国共产党成立100周年
高能同步辐射光源首台科研设备安装
先进光源技术研发与测试平台试运行
主办单位：中国科学院高能物理研究所 北京怀柔科学城管理委员会
综合性国家科学中心
21年6月28日

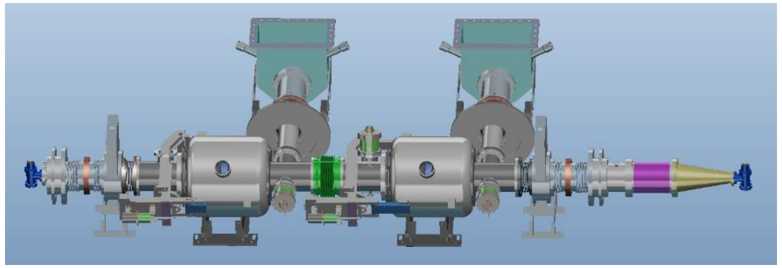

束流测试系统辐射屏蔽
Shielding cave of PAPS-BT
Beam source Test
配电间
Power distribution
VT control room
MDVB
Cold-Box
Cryomodule loading
Vertical Test
水平测试辐射屏蔽体
Shielding cave for cryomodule test
Horizontal Test

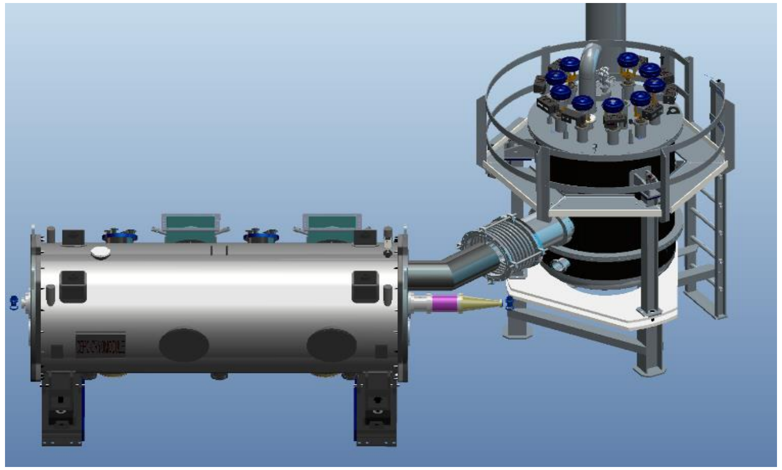
PAPS cryogenic hall

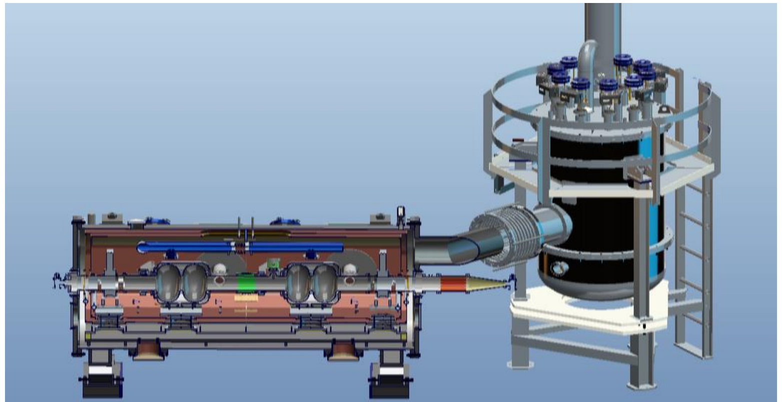
PAPS RF hall

Cryomodule for 650MHz 2-cell cavities

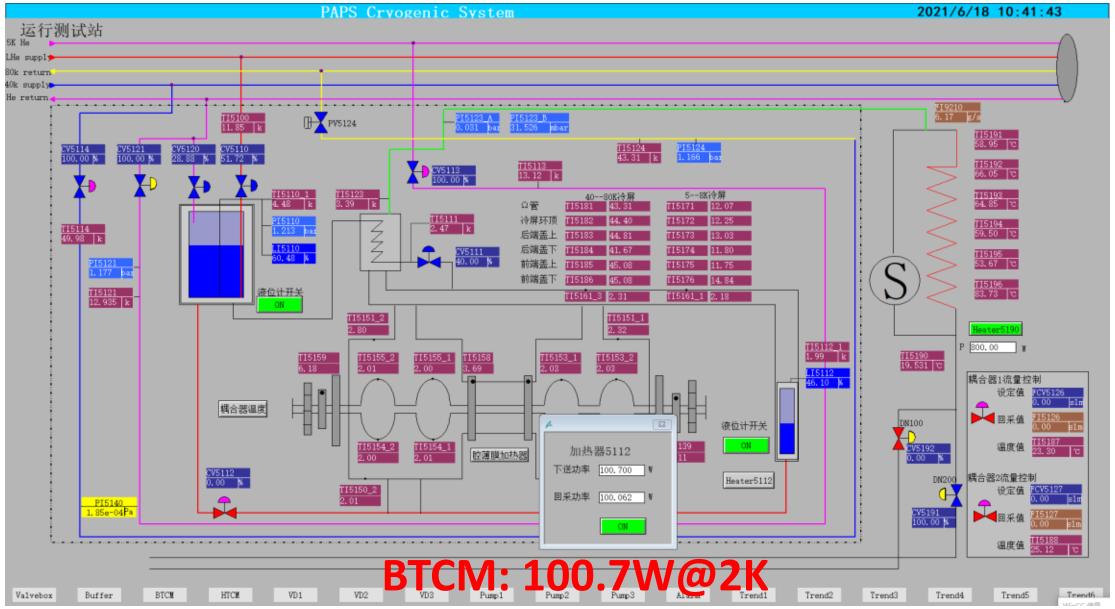
- A test cryomodule with two 2-cell 650 MHz superconducting cavities has been operated in the PAPS system this year.

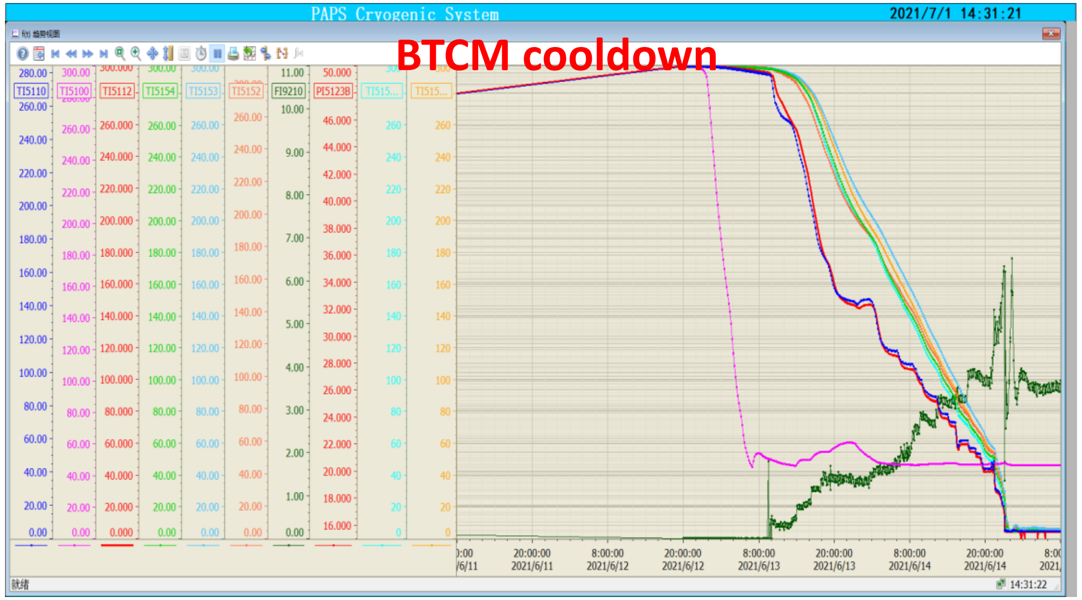


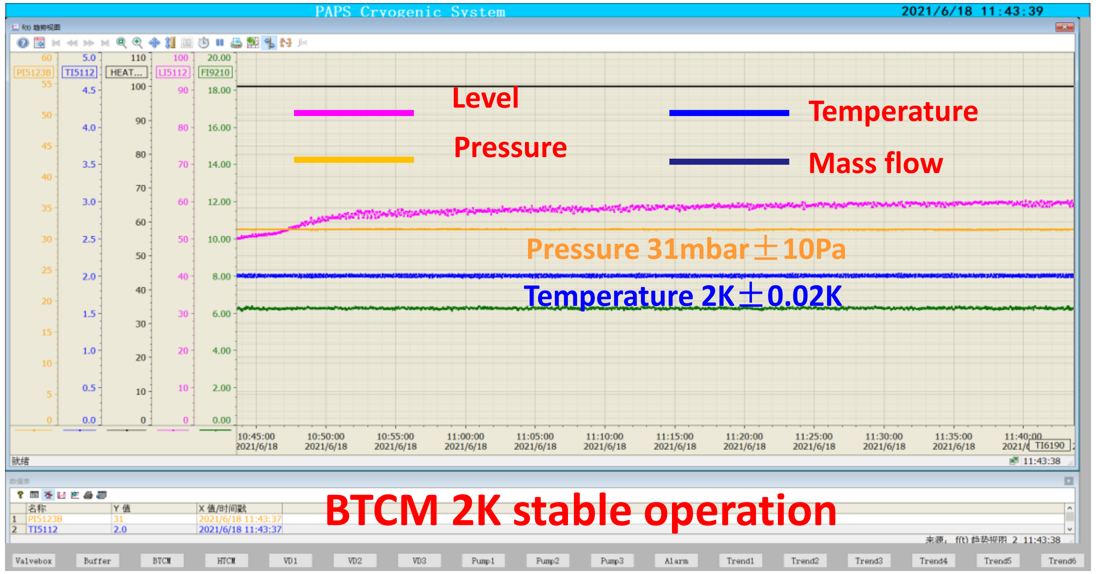


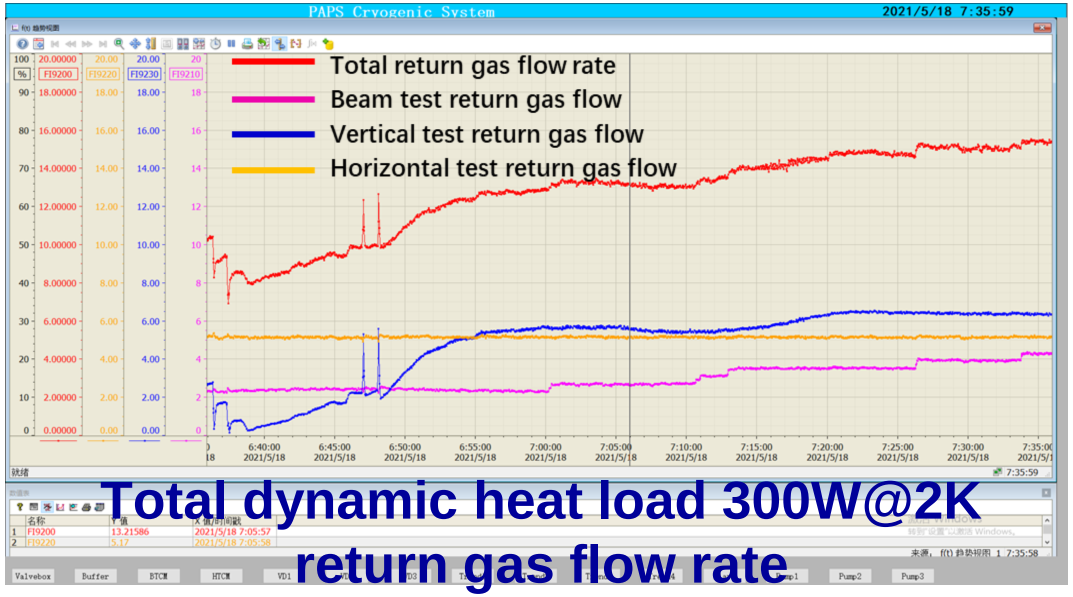


Operation test for 650MHz 2-cell cavities

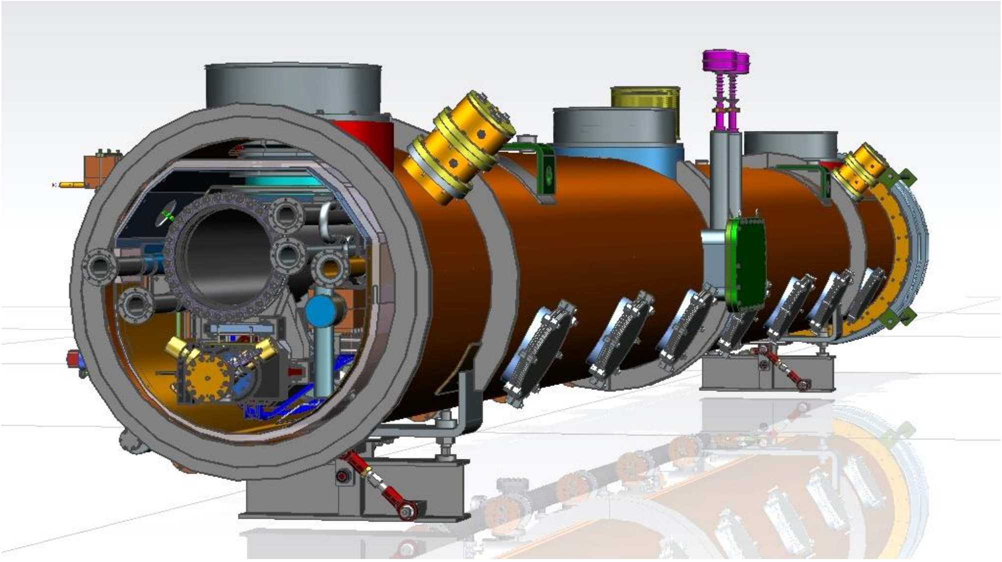








Cryomodule for 1.3GHz 9-cell cavities



XFEL / LCLS-II type Cryomodule for High Q Cavity

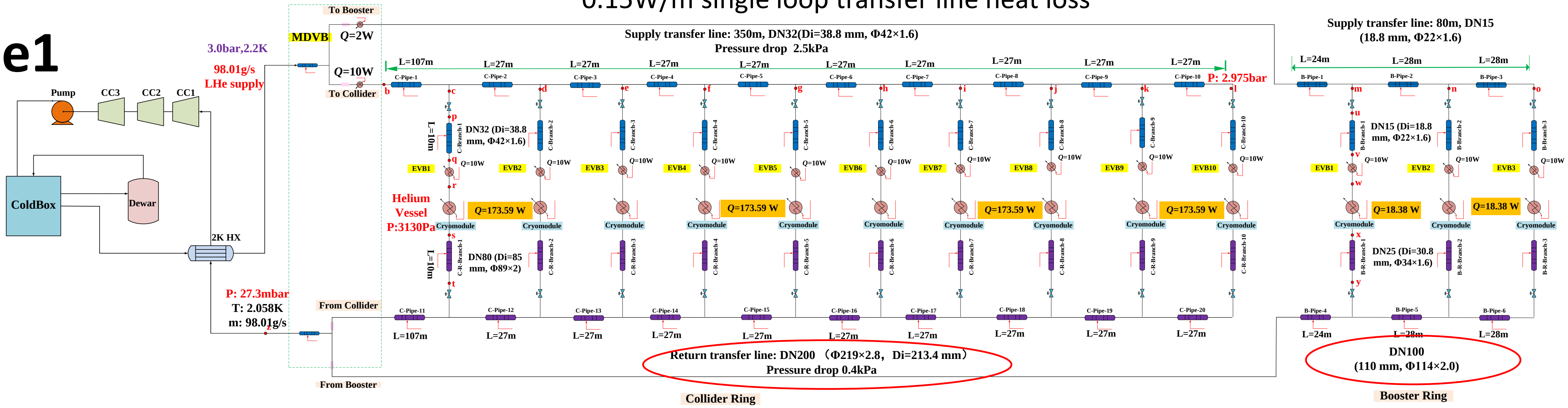
Design Goals:
- Low heat loss
- Fast cool down

- Cryogenic Group in IHEP has manufactured 58 1.3GHz 9-cell Cryomodules for EXFEL cooperated with local companies.
- It's a good foundation for the optimization design for the CEPC cryomodules.

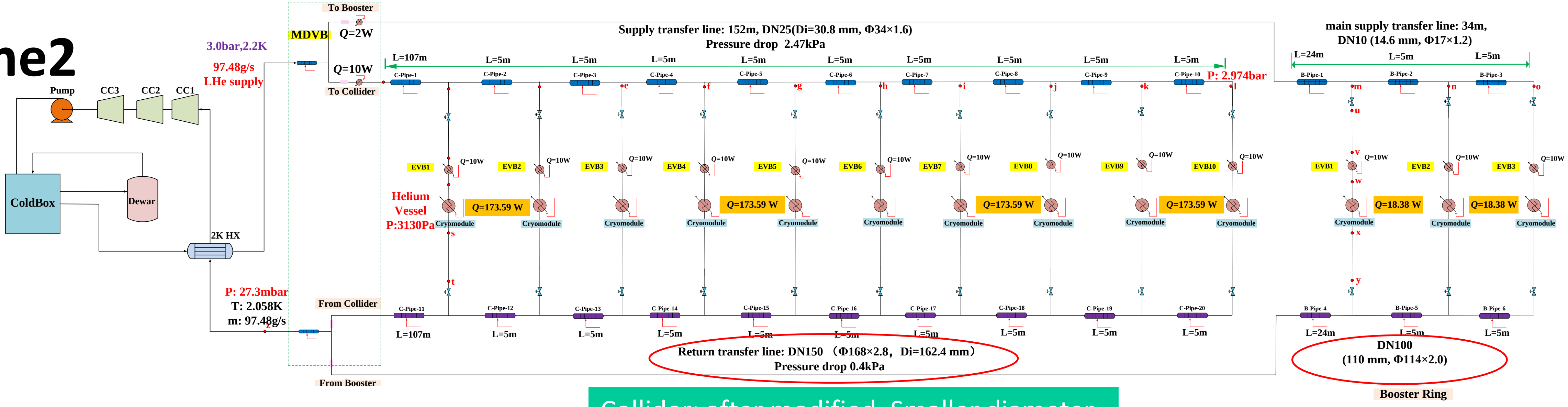
RF detailed Process calculation

0.15W/m single loop transfer line heat loss

Scheme1



Scheme2

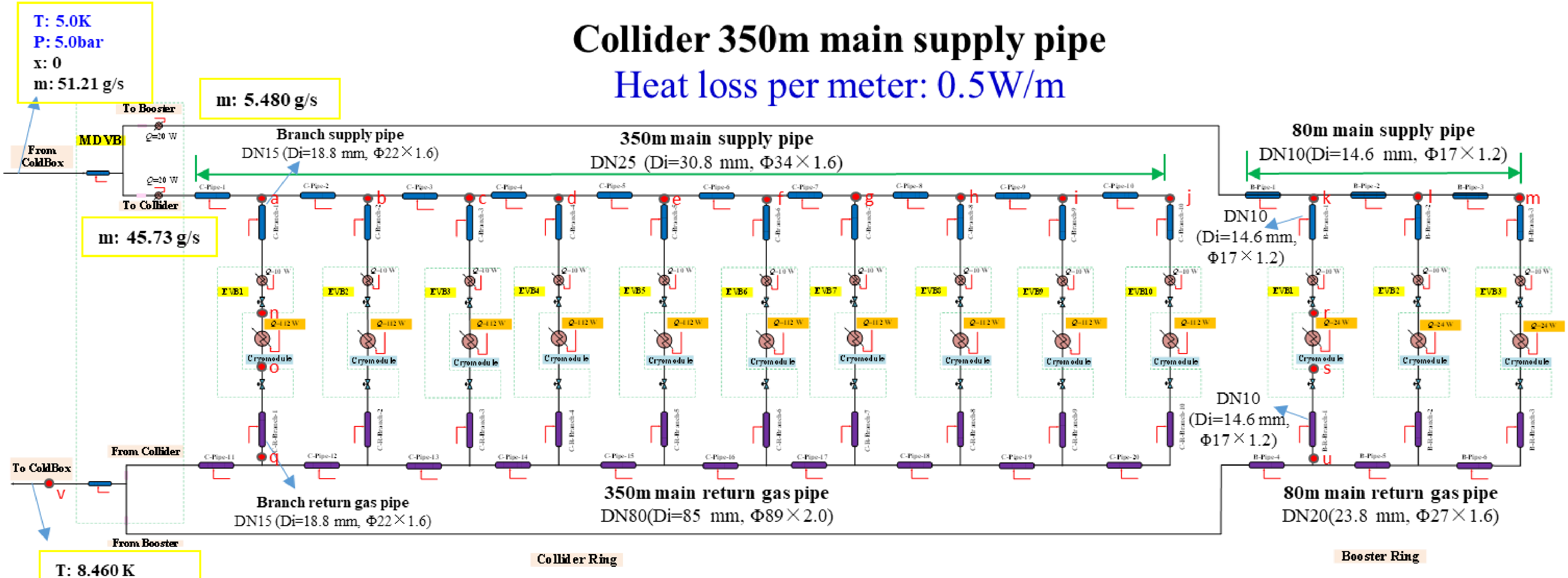


Collider: after modified, Smaller diameter

5K~8K TS calculation

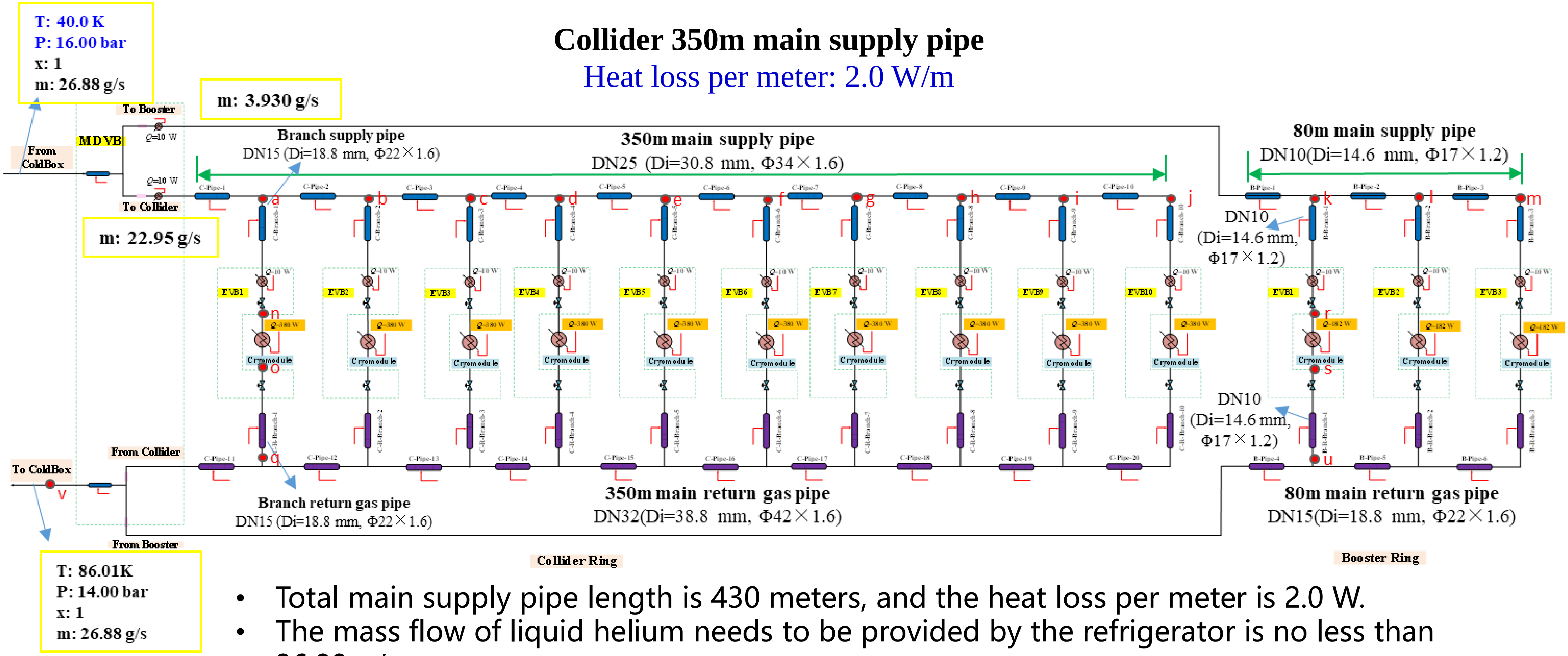
Collider 350m main supply pipe

Heat loss per meter: 0.5W/m



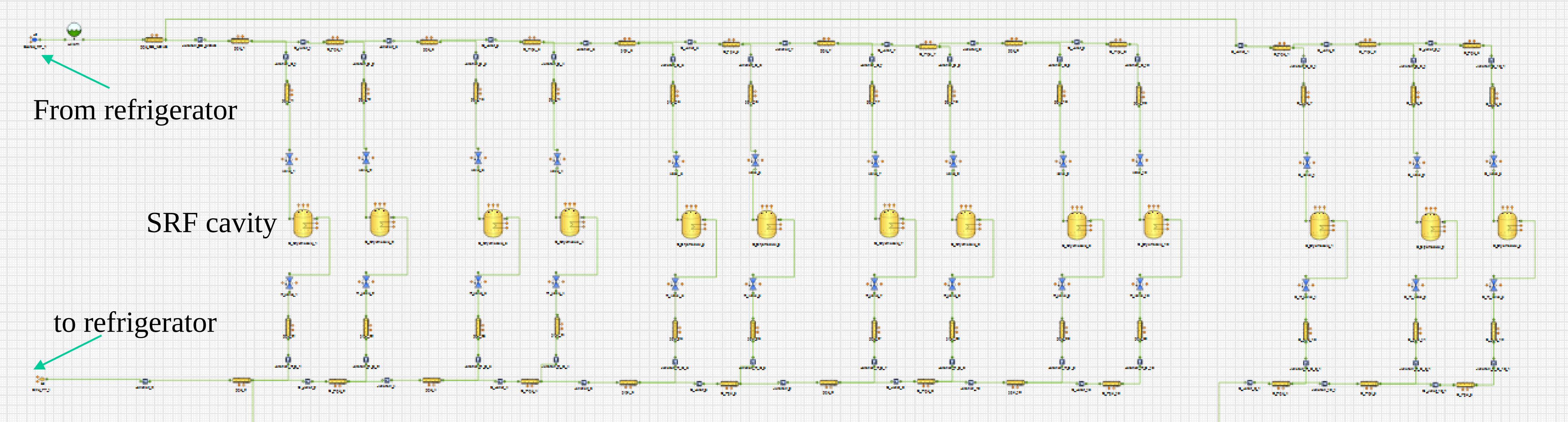
- Total main supply pipe length is 430 meters, and the heat loss per meter is 0.5 W.
- The mass flow of liquid helium needs to be provided by the refrigerator is no less than 51.21 g/s .
- Main supply pipe sizes: collider- Di=30.8 mm, Booster-Di=14.6 mm.
- Main return gas pipe sizes: collider- Di=85 mm, Booster-Di=23.8 mm.
- Branch supply pipe sizes: collider- Di=18.8 mm, Booster-Di=14.6 mm.
- Branch return gas pipe sizes: collider- Di=18.8 mm, Booster-Di=14.6 mm.

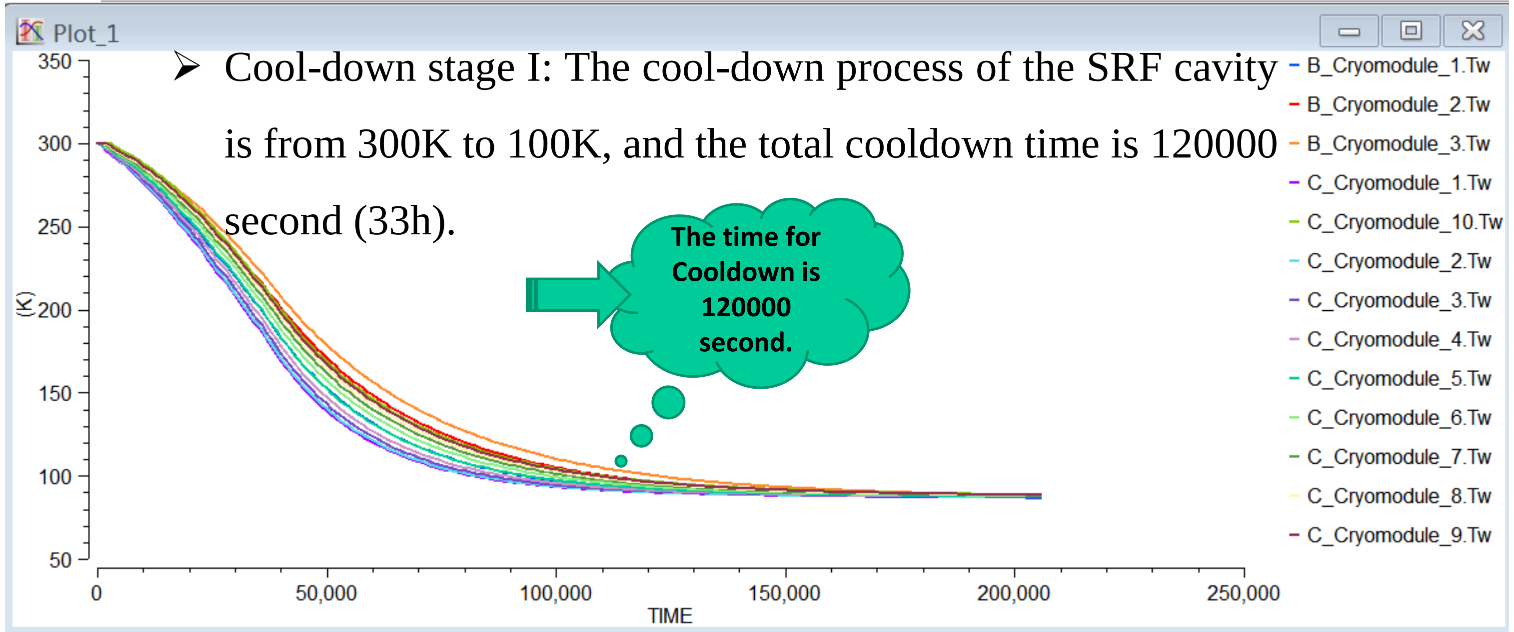
40K~80K TS calculation



- Total main supply pipe length is 430 meters, and the heat loss per meter is 2.0 W.
- The mass flow of liquid helium needs to be provided by the refrigerator is no less than 26.88 g/s .
- Main supply pipe sizes: collider- Di=30.8 mm, Booster-Di=14.6 mm.
- Main return gas pipe sizes: collider- Di=38.8 mm, Booster-Di=18.8 mm.
- Branch supply pipe sizes: collider- Di=18.8 mm, Booster-Di=14.6 mm.
- Branch return gas pipe sizes: collider- Di=18.8 mm, Booster-Di=14.6 mm.

Unsteady-state simulation for the RF cavity cooldown

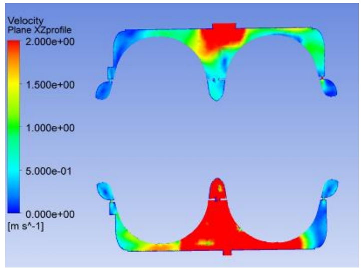




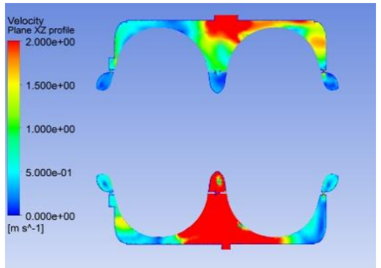
- Cool-down stage I: The cool-down process of the SRF cavity is from 300K to 100K, and the total cooldown time is 120000 second (33h).

Unsteady-state simulation for the RF cavity cooldown

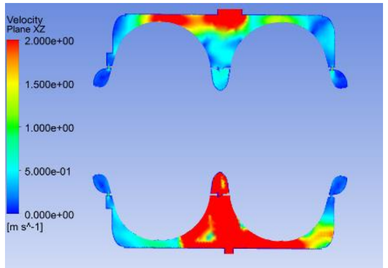
- The cooling rate of the superconducting cavity needs to be strictly controlled, and a three-dimensional flow field non-stationary numerical simulation of the cooling process of the 650 2-cell superconducting cavity is performed.
- A certain simulation basis is laid for the subsequent automatic cooling.



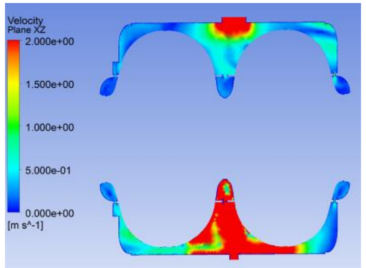
a) 260K



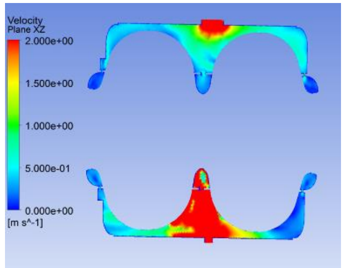
b) 220K



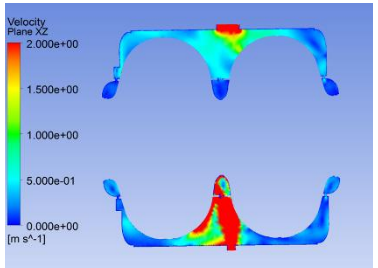
c) 180K



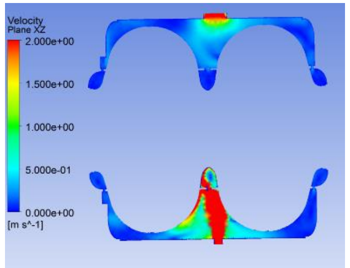
d) 140K



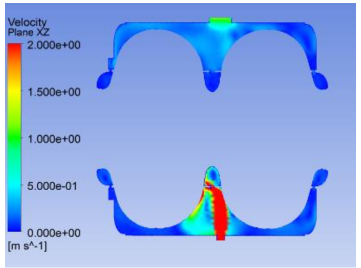
e) 100K



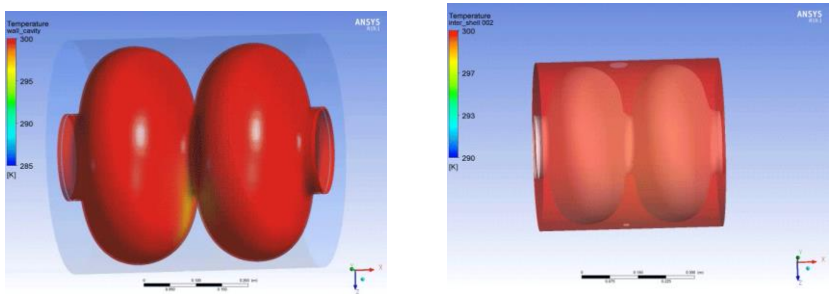
f) 60K



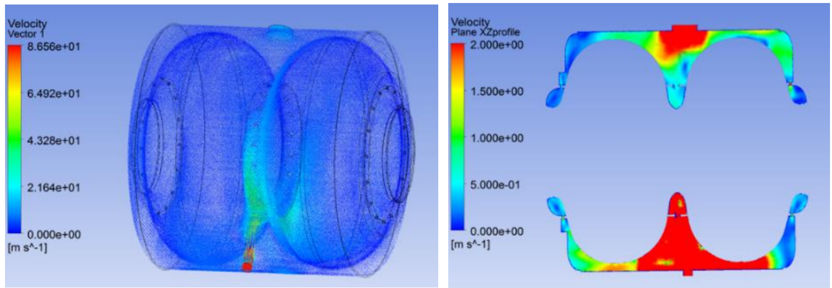
g) 40K



h) 20K



Non-stationary analysis of superconducting cavity cooling process



Global velocity distribution

Summary of CEPC RF cryogenic system design

◆ 接下来，超导腔侧还需要确定以下事情：

Next, the following things still need to be determined on the superconducting chamber side.

- 进行低温系统更为详细的流程计算和优化，以回气△P=0.4kPa压降为条件进行管径优化；

  More detailed process calculations and optimization of the cryogenic system, optimization of the tube diameter in terms of return gas ΔP = 0.4 kPa pressure drop.
- 恒温器结构设计优化（接口尺寸、走向等），恒温器之间常温磁铁的结构确认，与高频组、磁铁组一起协商对接方案

  Cryostat structure design optimization (interface size, orientation, etc.), the structure of the room temperature magnet between the cryostat needs to be confirmed with RF group, magnet group .
- 高性能的多通道低温传输管线的设计与测试研究

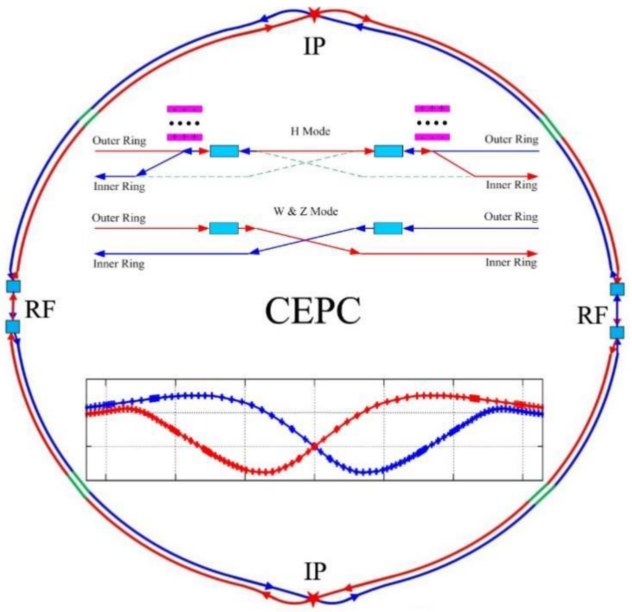
  Design and testing study of high performance multi-channel cryogenic transfer lines.
- 多通道低温管线真空隔断的优化设计

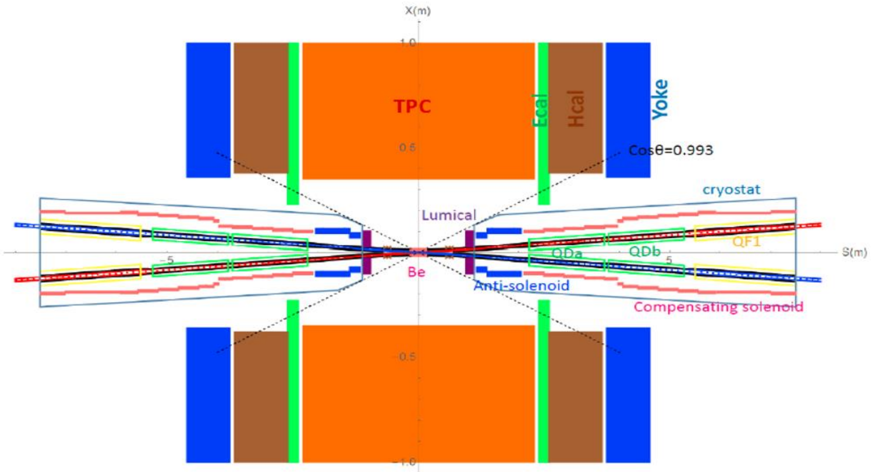
  Optimization of the design of vacuum isolation for multi-channel cryogenic pipeline
- ……

OUTLINE

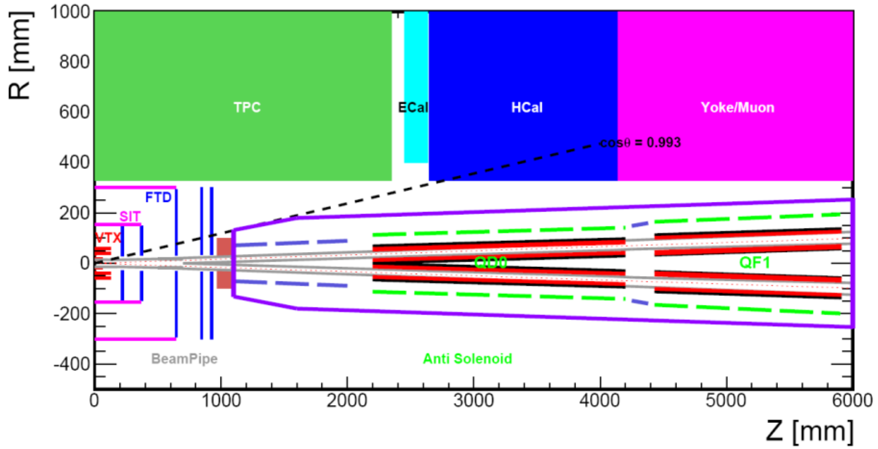
- Introduction
- Layout of the cryogenic system
- Discussion and Comparison on CEPC SRF cryogenic system
- Discussion and Comparison on SC magnets cryogenic system
- Summary

SC magnets cryogenic system overview



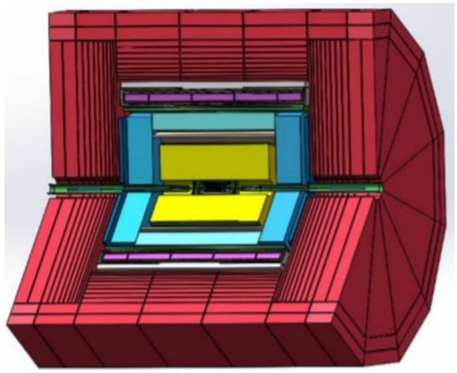


Schematic layout of QD0, QF1, and anti-solenoid



From Zhu Ying-shun

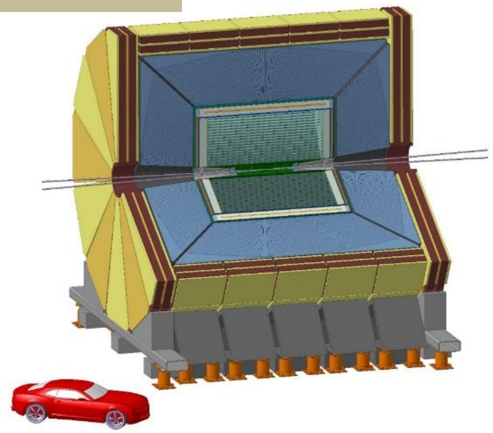
LTS Solenoid



LTS Solenoid：
- Solenoid located outside calorimeter
- Inner diameter 7.2 m, length 7.4 m
- Central field：3 T
- Superconductor：NbTi
- Operation temperature：4.2 K

IDEA detector

HTS Solenoid



HTS Solenoid：
- Solenoid located inside calorimeter/less material
- Inner diameter 4 m, length 6 m
- Central field：2 T
- Superconductor：YBCO
- Operation temperature：20 K

Zhu Zian，Wang Meifen

Estimated heat loads for SC IR magnets

		4.5K main loop			Thermal Shielding 40~80K		
Name	Unit	No.	Heat load for each	Heat load	No.	Heat load for each	Heat load
IR SC sextupole magnet	W	32	10	320			
Valve Box of IR SC sextupole magnet	W	32	20	640			
Current lead heat load of IR SC sextupole magnet	W	32	——	——			
IR SC magnet	W	4	30	120			
Valve Box of IR SC magnet	W	4	30	120			
Current lead of IR SC magnet	g/s	4	0.5	2			
Main distribution valve box	W	4	50	100			
Cryogenic transfer-line	W	4000	0.3	1200	3424	1.5	5136
Total heat load @4.5K	W			2500			5136
Total heat load @4.5K	W			2500W+2g/s			5136
Total heat load @4.5K	W			2523.45			5136
Coefficient				1			0.05
Total heat load @4.5K	W			2523.45			**256.8**
Total equiv. heat load @4.5K	W	2780.25					
Total equiv. heat load @4.5K with multiplier 1.5	W	4170					
Cooling capacity of refrigerator@4.5K	W	**2**	**4kW@4.5K**	**8kW@4.5K**			

•Two individual refrigerators (2 x 4kW@4.5K) will be employed for the CEPC SC magnets cryogenic system.

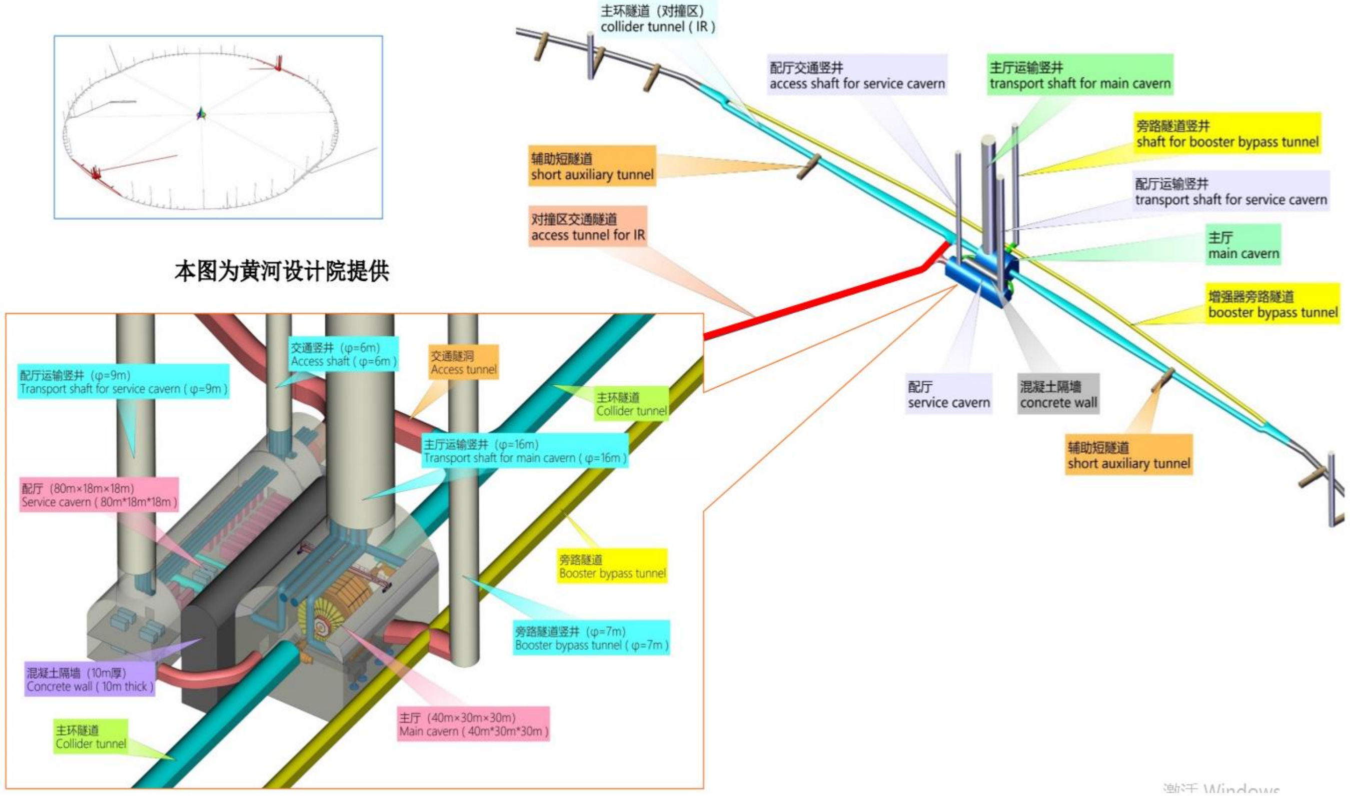
Heat loads and layout for detector magnet

Zhu Zian，Wang Meifen

Items	Parameters
Radiation heat load at 60~80K	1000W
Supports	500W
Radiation heat load	**40W**
Others(Holdings&junctions&valves&pipes)	170W （pipes 100W）
Current lead LHe mass flow rate	2.5g/s----250W
Dynamic heat loads due to field ramping	**240W**
Valve Box of Detect Solenoid Magnet	**20W**
Cryogenic transfer-line	**150W**
others	**30W**
Equiv. heat load @4.5K	**975W**
Cooling capacity of refrigerator@4.5K	**1500W**
Installed power (COP(300W/1W))	**0.45MW**

Refrigerator selection	
Liquefaction	430L/h
Refrigeration	2×1.5kW@4.5K
Liquefaction/Refrigeration	1kW@4.5K & 150L/h

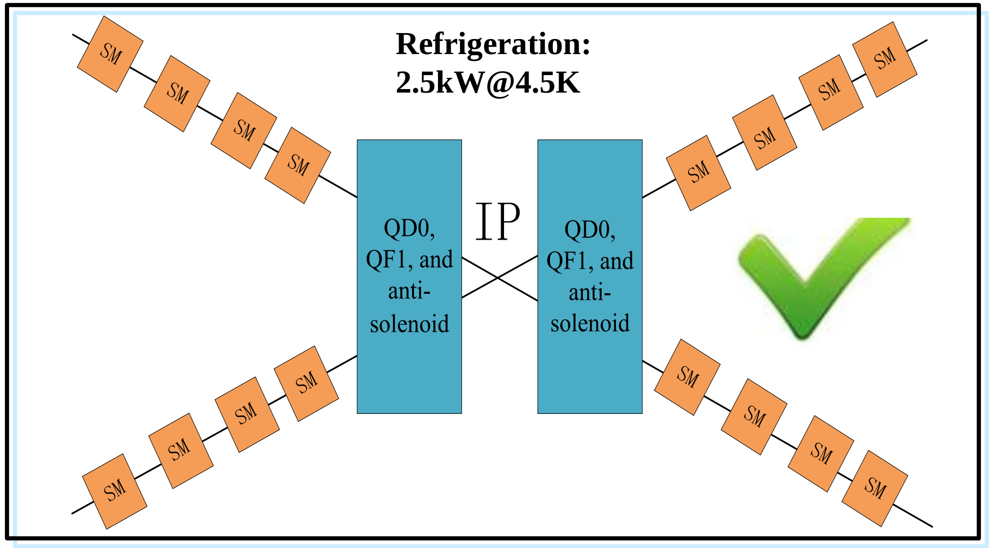
layout for detector magnet



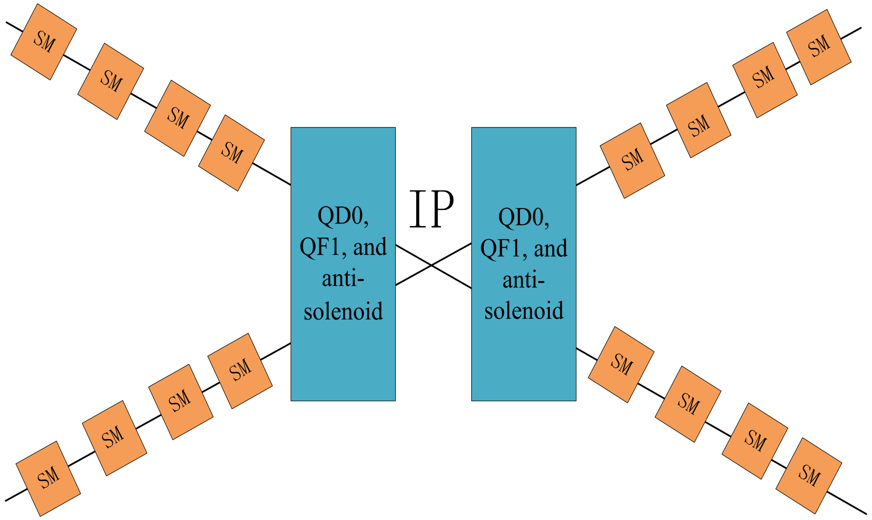
SC magnets cryogenic system

- 2 IPs in CEPC Interaction Region, there are 4 QD0 magnets, 4 QF1 magnets, 4 anti-solenoids and 32 sexupole magnets.

Plant A. Large refrigerator



Plant B. GM refrigerator



- ◆ The GM refrigerator's vibration is unacceptable, besides the electricity power consumption is very high.
- ◆ The maintenance of the GM refrigerator is very difficult, and failure rate is many times that of a single large refrigerator.
- ◆ Compressor takes up space and produces vibration and noise in tunnel.

Power consumption comparison

Name	Unit	4.5K main loop			Thermal Shielding 40~80K		
		No.	Heat load for each	Heat load	No.	Heat load for each	Heat load
IR SC sextupole magnet	W	32	10	320			
Valve Box of IR SC sextupole magnet	W	32	20	640			
Current lead heat load of IR SC sextupole magnet	W	32	——	——			
IR SC magnet	W	4	30	120			
Valve Box of IR SC magnet	W	4	30	120			
Current lead of IR SC magnet	g/s	4	0.5	2			
Main distribution valve box	W	4	50	100			
Cryogenic transfer-line	W	4000	0.3	1200	3424	1.5	5136
Total heat load @4.5K	W			2500			5136
Total heat load @4.5K	W			2500W+2g/s			5136
Total heat load @4.5K	W			2523.45			5136
Coefficient				1			0.05
Total heat load @4.5K	W			2523.45			256.8
Total equiv. heat load @4.5K	W	2780.25					
Total equiv. heat load @4.5K with multiplier 1.5	W	4170					
Cooling capacity of refrigerator@4.5K	W	2	4kW@4.5K	8kW@4.5K			

GM refrigerator

KDE415SA

技术参数		KDE415SA	
	最低温度	< 3.5K	
	制冷量 (50Hz)	一级	二级
		35W @ 50K	1.5W @ 4.2K
	降温时间（二级）	< 60min（4.2K）	
	重量	冷头	压缩机
		19 kg	118kg
	对接压缩机	KDC6000V	
	功耗50Hz	稳态	降温
		6.5kW	7.2kW
	冷却方式	水冷	
	水冷却流量	> 7 L/min	
	标准软管	20A×20m	
	维护周期	10000hrs	

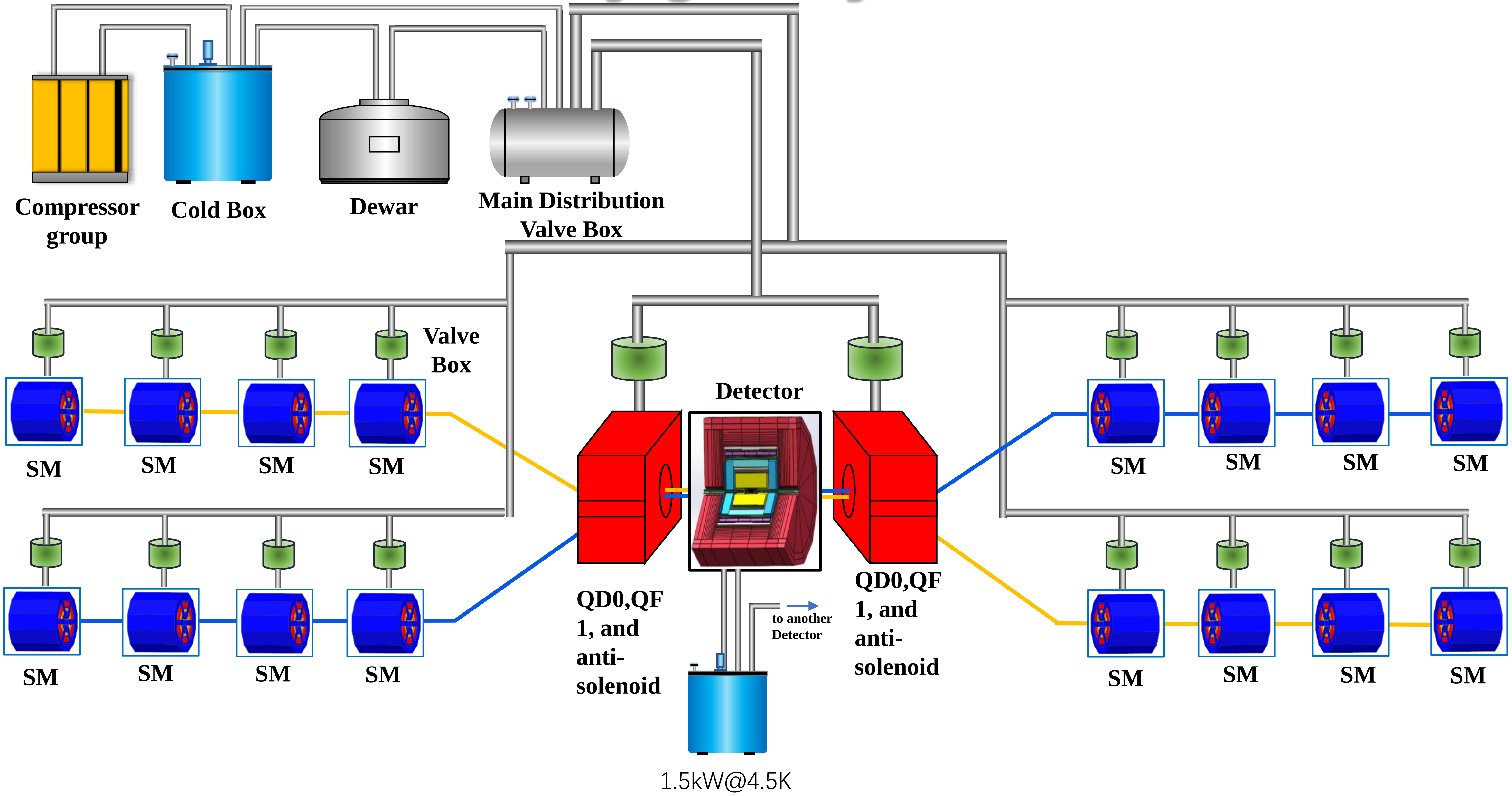
环境要求	项目	运行	储存
	环境温度要求	4-40 ℃	-20-65 ℃
	相对湿度	30%-70%	10%-90%(不结露)
	环境压力要求	70kPa~110kPa	20kPa~110kPa

SC magnet:

- 10W heat load of each SC magnet
- 1.5W@4.2K GM refrigerator, needs 8 sets of GM refrigerators/each SC magnet, **total 16*8=128 sets**
- power consumption 7.2kW/each GM refrigerator
- 16 SC magnets power consumption: **16*8*7.2=921kW**
- **If adopts a large refrigerator, power consumption ~800kW**
- Therefore, the small GM refrigerator scheme has no advantage in the power consumption aspect.

Considering the operation stability and power consumption of the system, the large refrigerator scheme is selected.

Flow scheme of Traditional SC magnets cryogenic system

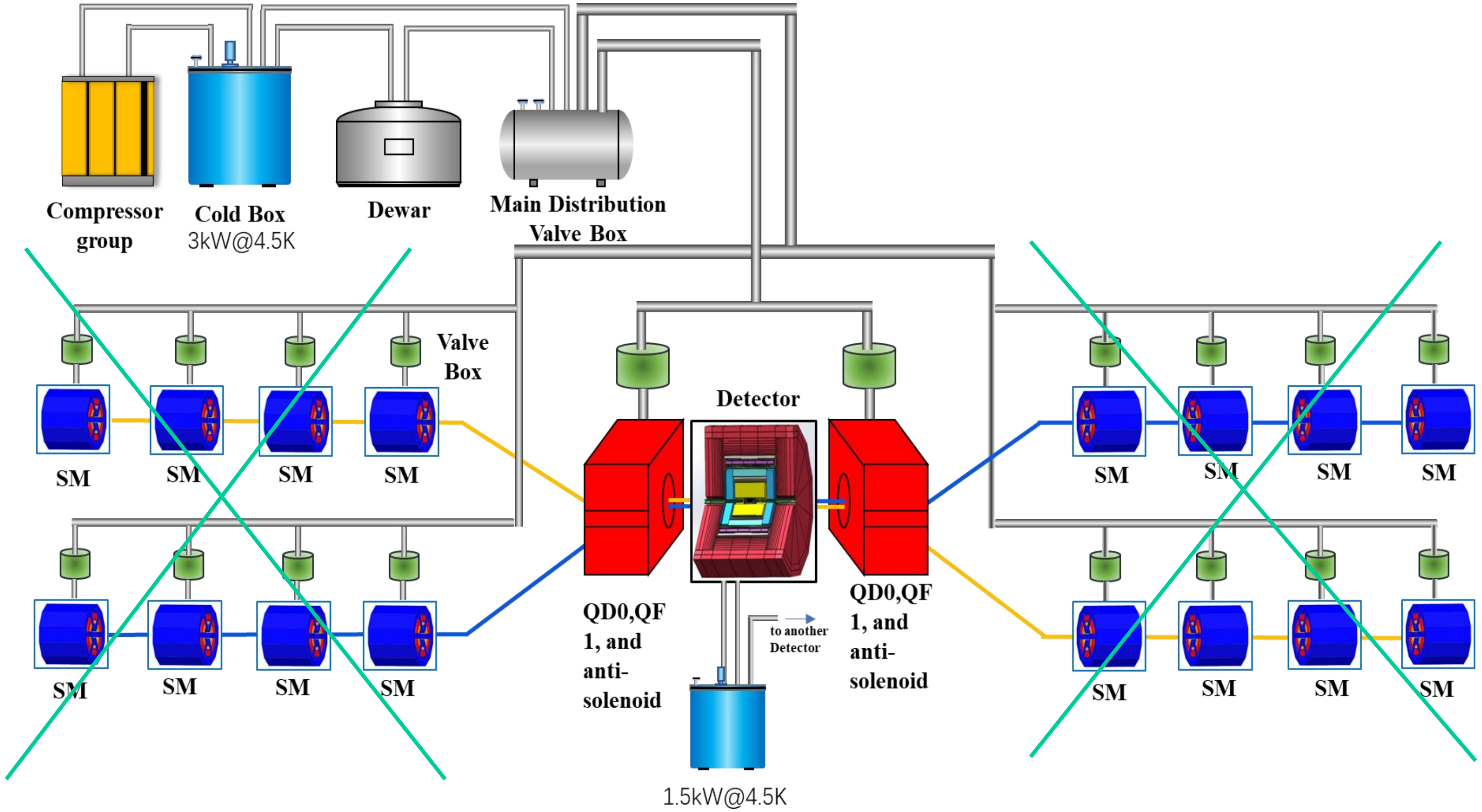


Flow scheme of Modified SC magnets cryogenic system

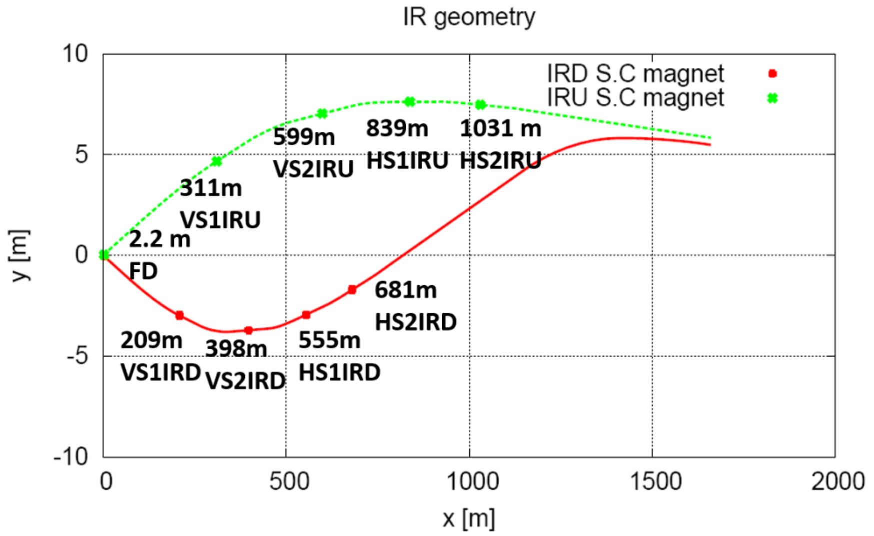
J. Gao

- The requirement for IR sextupole magnets is updated.
- The magnet bore and pole field is reduced.
- Conventional sextupole magnet technology can be used (FeCoV pole). Max strength 3886T/m^2 is achieved with bore aperture 42 mm. **Max current < 200A.**

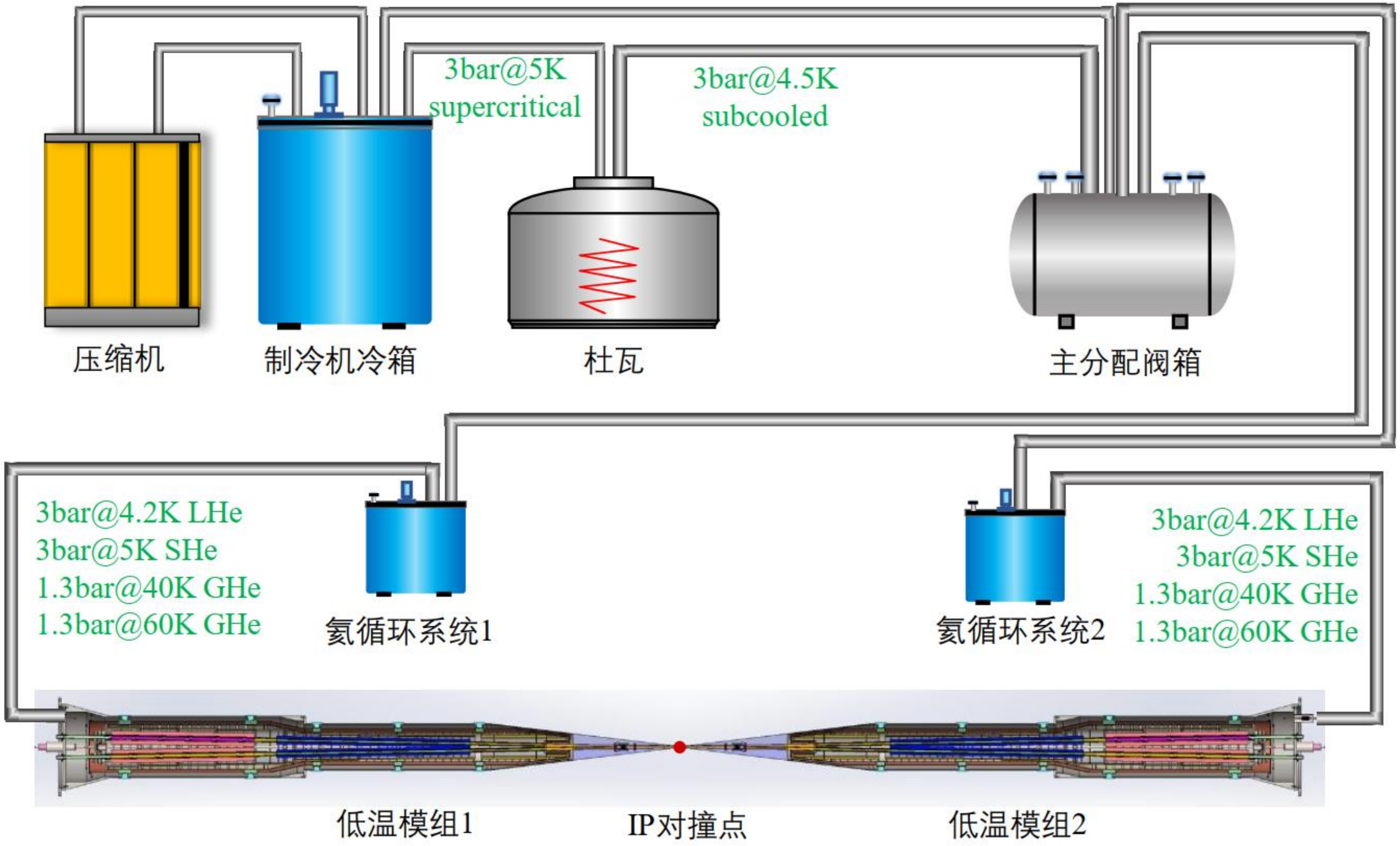
IR sextupoles have been changed from SC magnets to normal conducting ones and cryogenic system for sextupoles can be eliminated.



Y.W. Wang

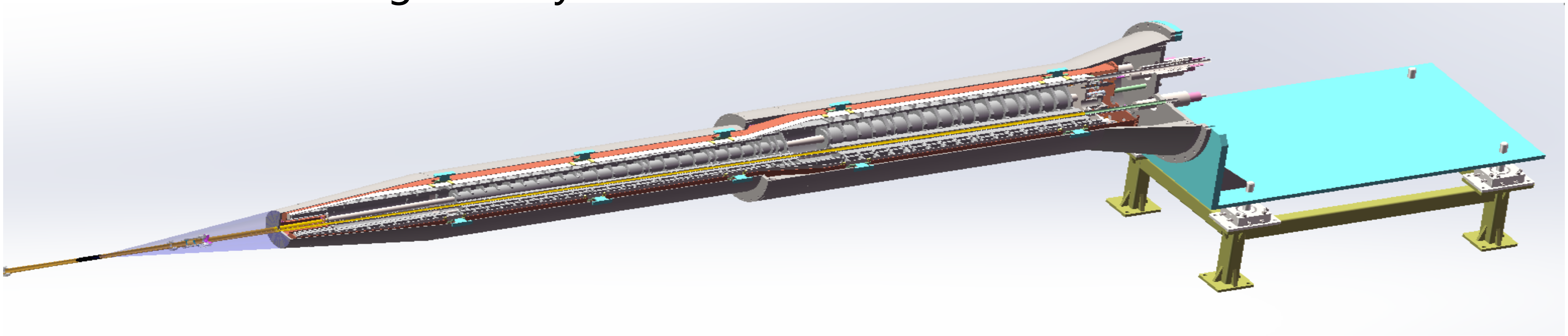


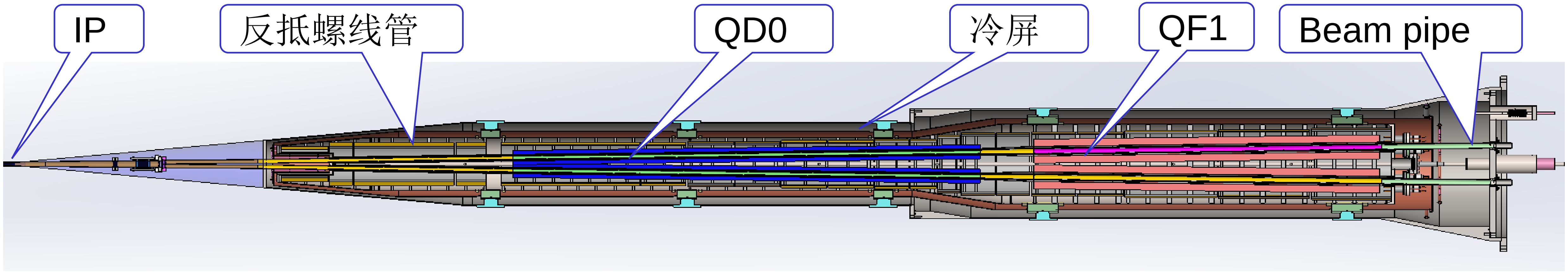
Flow Chart for CEPC MDI Cryostat (one site)



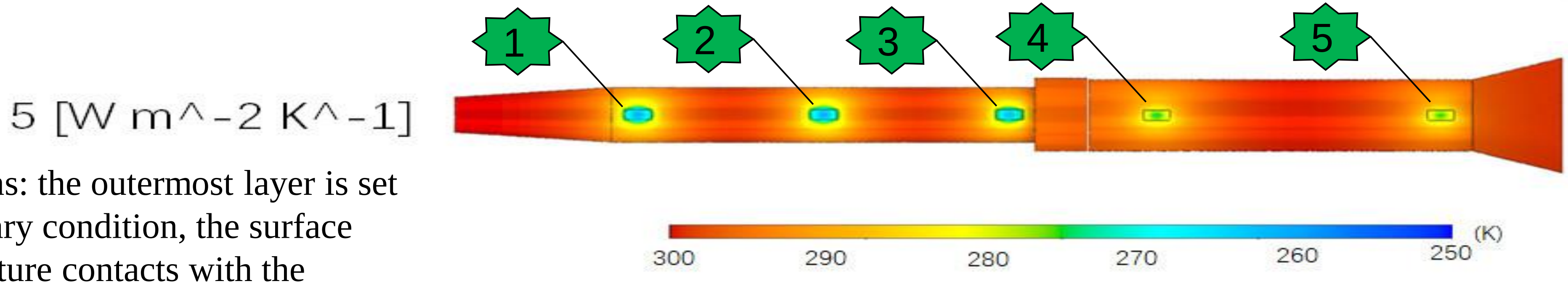
Mechanical Design of CEPC MDI Cryostat

- The total weight of cryostat is about 2.5 T

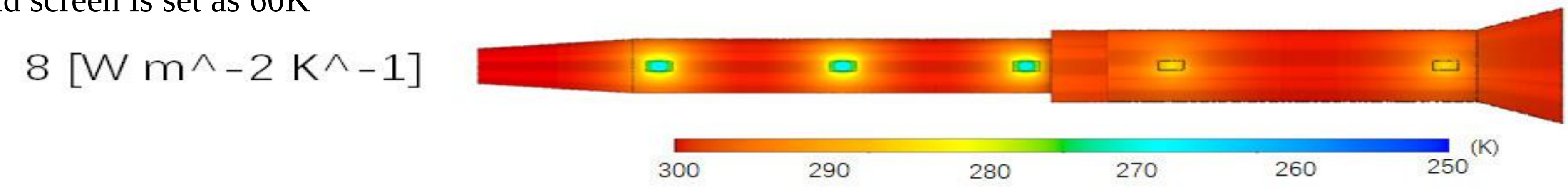




Vacuum chamber---temperature field

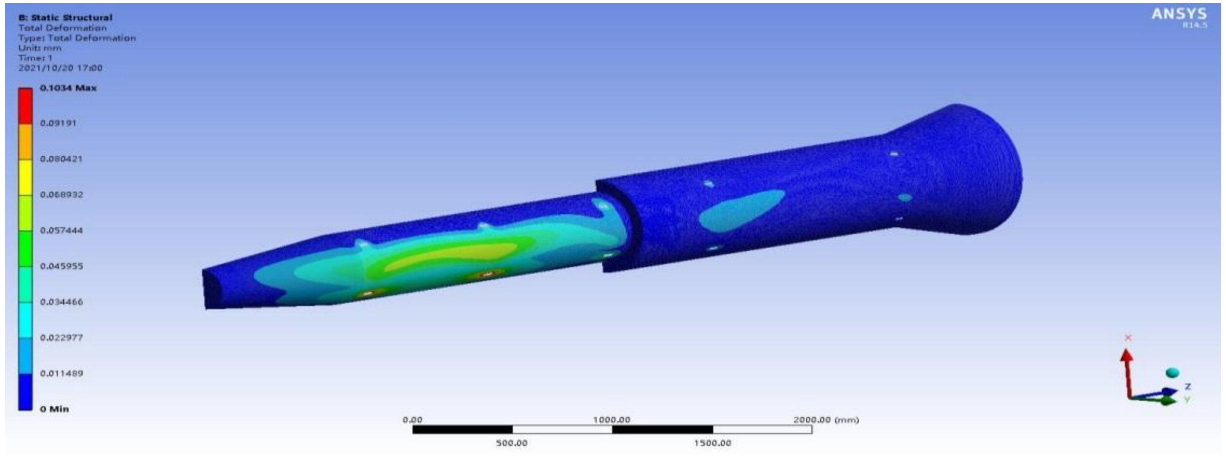


Calculation conditions: the outermost layer is set as convective boundary condition, the surface that the support structure contacts with the helium pool is set as 5K, and the surface that contacts with the cold screen is set as 60K

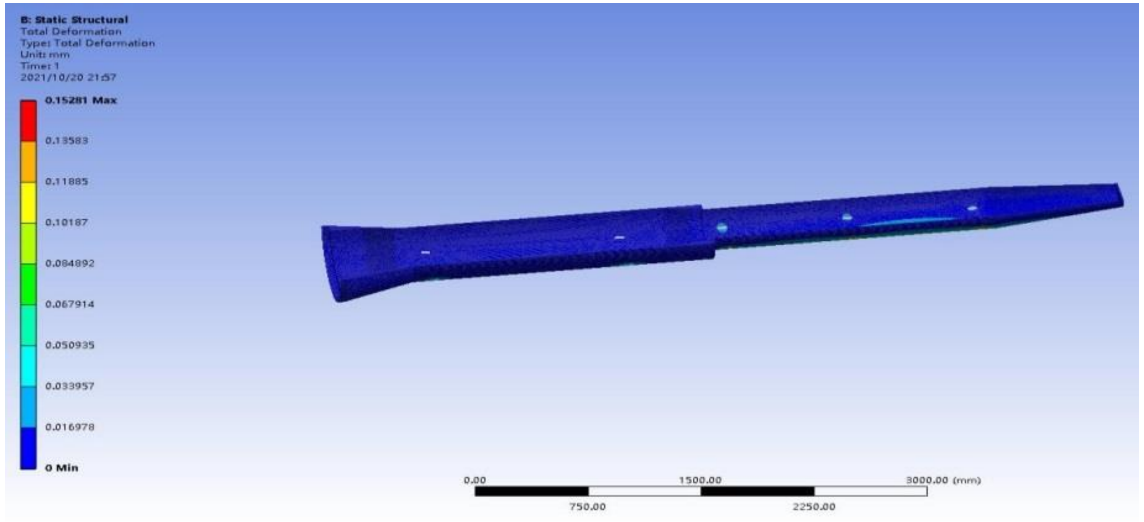


Support numbers					
convective heat transfer coefficient	1	2	3	4	5
5W m^-2 K^-1	268.97 K	268.98 K	270.52 K	282.76 K	283.32 K
8W m^-2 K^-1	273.14 K	273.14 K	274.09 K	285.34 K	286.65 K

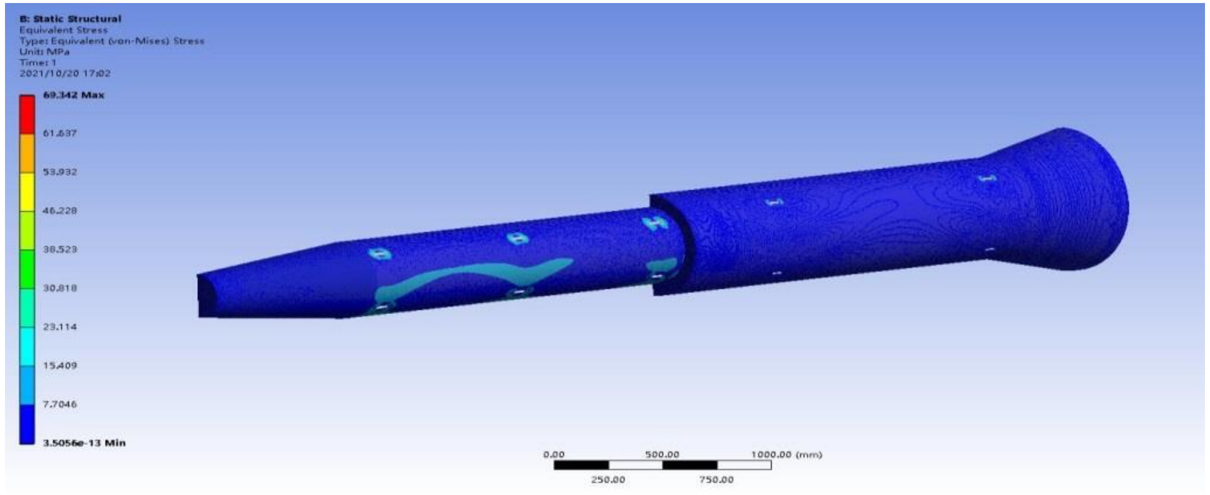
Vacuum chamber--stress analysis



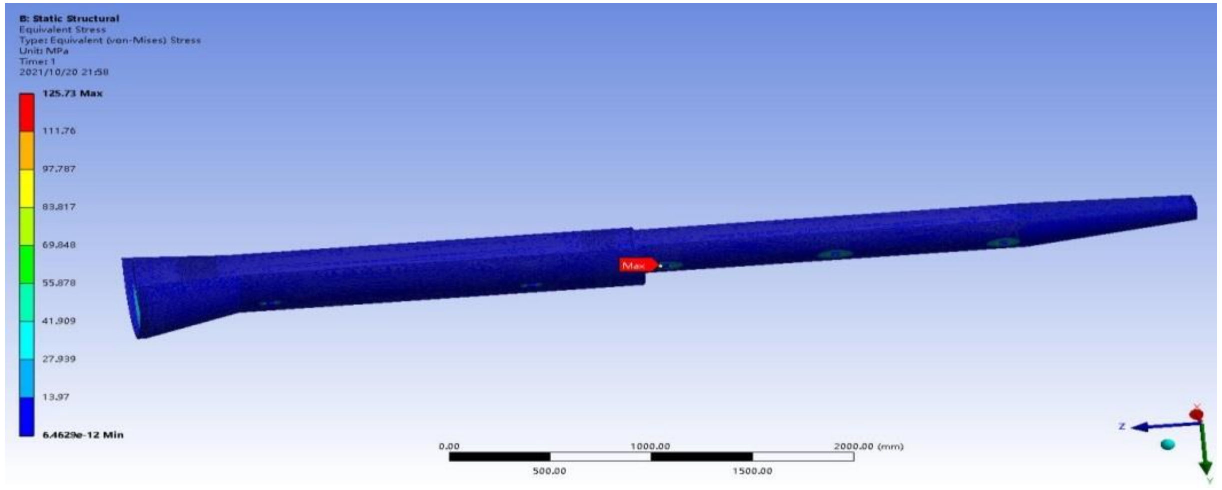
最大变形0.1mm@外压1Bar



最大变形0.15mm@内压1.2Bar



最大应力69.343MPa@外压1Bar



最大应力125.73MPa@内压1.2Bar

Summary of CEPC SC magnets cyogenic system

◆ 接下来，超导磁体侧还需要确定以下事情：

Next, the following things still need to be determined on the superconducting magnet side.

- 需跟进磁铁机械设计，方案确定后可进行更为详细的低温系统设计

  Need to follow up on the progress of multiple technology routes for the magnets, and more detailed design of the cryogenic system can be done after the program is determined.

- 超导磁铁低温恒温器进行更为详细的结构设计，以及针对低温恒温器进行多维度的流动传热仿真计算，分析流场进而指导优化结构设计，形成闭环设计思路。

  More detailed structural design of the superconducting magnet cryostat, as well as multi-dimensional flow and heat transfer simulation calculations for the cryostat, analyze the flow field and then guide the optimization of the structural design to form a closed-loop design idea.

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Summary

- Previous CDR and TDR works have laid a good foundation for the further design.
- For the CEPC cryogenic system TDR design, relevant aspects have been considered , including process scheme, layout, and key equipment design.
- Several key technologies (JT heat exchanger platform/cryo-circulating pump/multi-channel Transfer line test platform/Virtual system establishment and automatic control strategy research) are introduced.
- Further TDR design is going on. Now it‘s just at the stage of scheme comparison, and there is still a long way to complete the whole TDR design. In the later time, the project team members need to work together to greatly push forward the work, and complete the TDR design on time.

Thanks for Your Attention !