Cryogenic for the CEPC Superconducting Magnets

Shaopeng Li, Tongxian Zhao, Miaofu Xu, Mei Li

CEPC DAY (March 27, 2020)

Outline

- Introduction
- Cryogenic for SC magnets
- The main parameters impacting on the cryogenic system
- Heat loads for SC magnets
- Cryogenic system design considerations
- Cryogenic system schematic
- The Cryostat of CEPC-MDI
- Precision Thermometry
- Summary

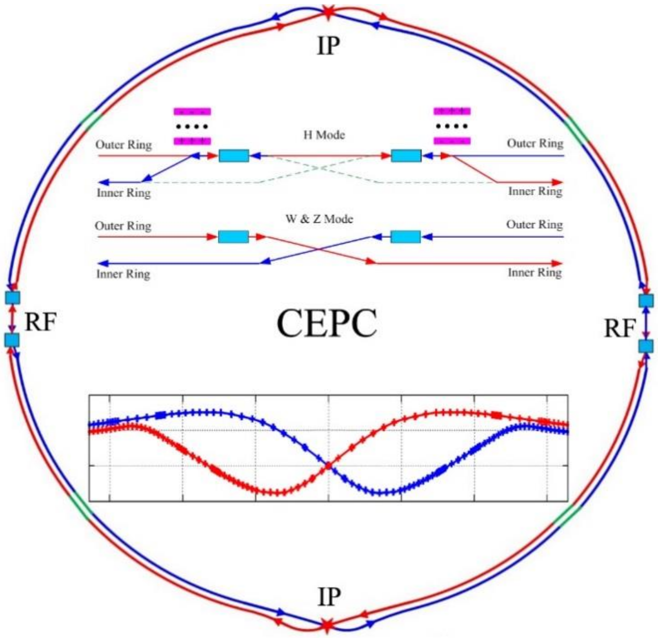
Introduction

IR magnets:

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

Detector solenoid magnet

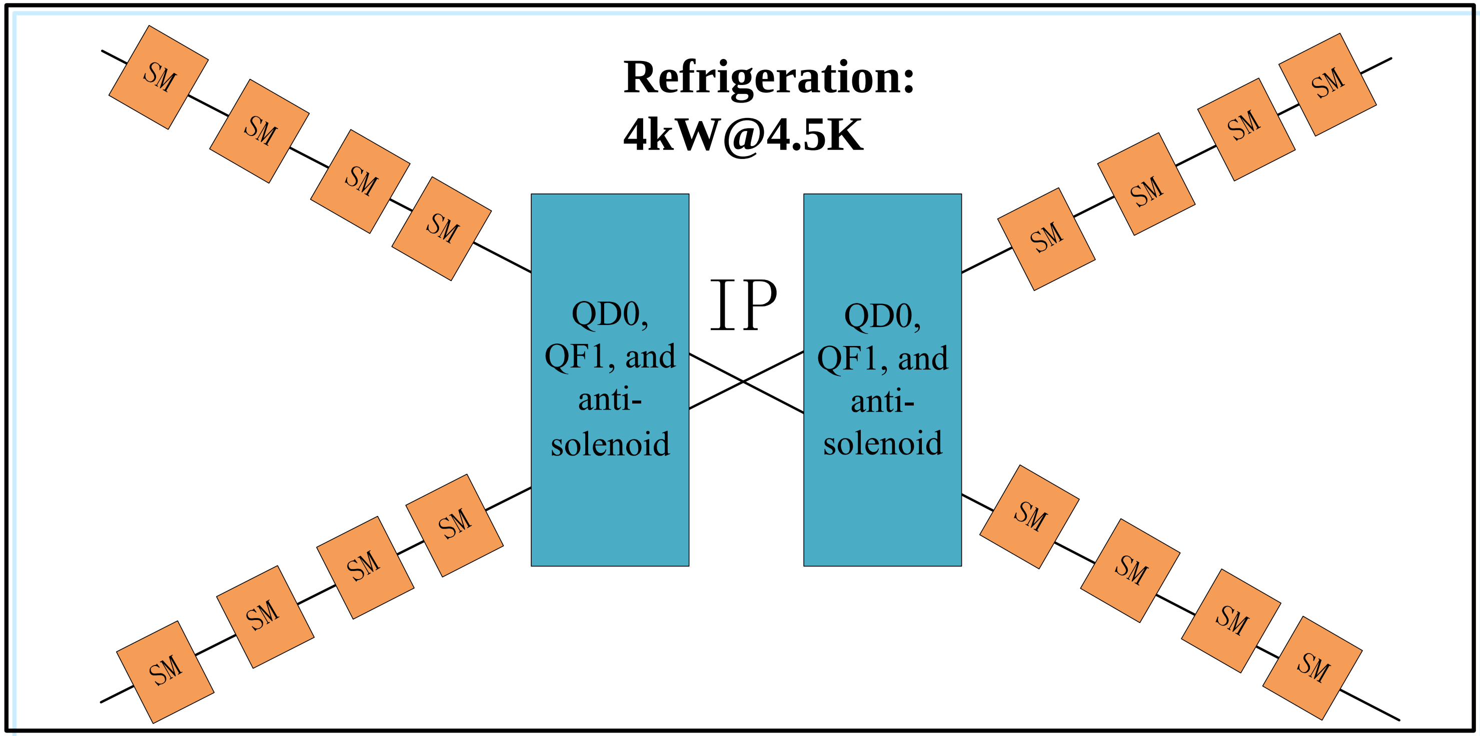
- 2 detect solenoid magnet
- 2 cryomodules
- Temperature:4.5K



Sketch of CEPC Collider ring

Cryogenics for SC magnets

- **Two interaction region in CEPC ring**
  - **2 Detector solenoid magnet**
  - **2 IR magnets and 16 sextupole magnets**
- **Refrigerator with the cooling capacity of 4kW@4.5K will be employed for each cryo-stations.**



The main parameters impacting on the cryogenic system

Interaction Region quadrupole magnets for Higgs

Magnet	Central field gradient (T/m)	Magnetic length (m)	Width of GFR (mm)	Minimal distance between two aperture beam lines (mm)
QD0	136	2.0	19.6	72.6
QF1	110	1.48	27.0	146.20

CEPC MDI SC Magnets R&D

Yingshun Zhu*, Xiangchen Yang, Ran Liang, Miaofu Xu

Detector solenoid magnet

The solenoid central field(T)	Coil radius(m) Inner/outer	Coil length(m)	Working Current(A)	Stored energy(GJ)	Cold mass weight(t)
3	3.6/3.828	7.39	16796	1.3277	125

From: Wang Meifen , Zhu Zian

Heat loads for SC magnets

Name	Unit	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 of IR SC sextupole magnet	g/s	32	0.1	3.2
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	2	50	100
Cryogenic transfer-line	W	4000	0.5	2000
Total equiv. heat load @4.5K*	W	/	/	3820
Total equiv. heat load @4.5K with multiplier 1.5	W	/	/	5730
Cooling capacity of refrigerator@4.5K	W	2	3000	6000
Installed power (COP(300W/1W))	MW	/	/	1.8

***No contingency**

Heat loads for SC magnets

Name	Unit	No.	Heat load for each	Heat load
Detect Solenoid Magnet	W	2	240	480
support @40~80K	W	2	25	50
Radiation heat load@40~80K	W	2	50	100
Valve Box of Detect Solenoid Magnet	W	2	20	40
Current lead of Detect Solenoid Magnet	g/s	2	2.5	5
Ithers	w	2	60	120
Cryogenic transfer-line	m	300	0.5	150
Total heat load		2	720	1440
Equiv. heat load @4.5K	W			1440
Equiv. heat load @4.5K* with multiplier 1.5	W			2160
Cooling capacity of refrigerator@4.5K	W	2	1080	2160
Installed power (COP(300W/1W))	MW			0.648

*No contingency

20200310 CEPC DETECTOR SOLENOID CRYOGENIC SYSTEM Interface parameters , Wang Meifen, Zhu Zian

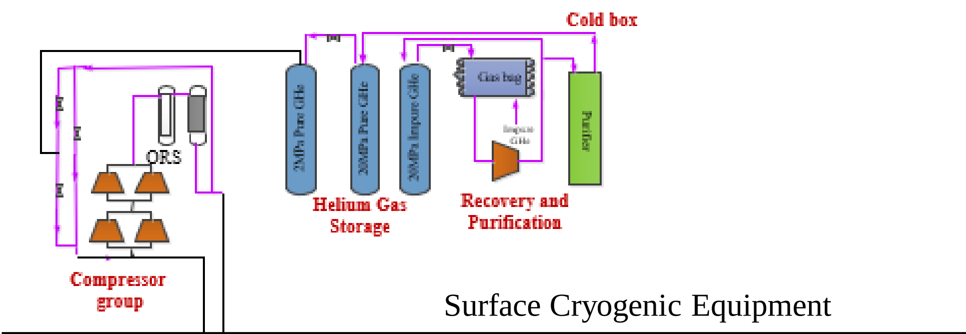
Cryogenic system design considerations

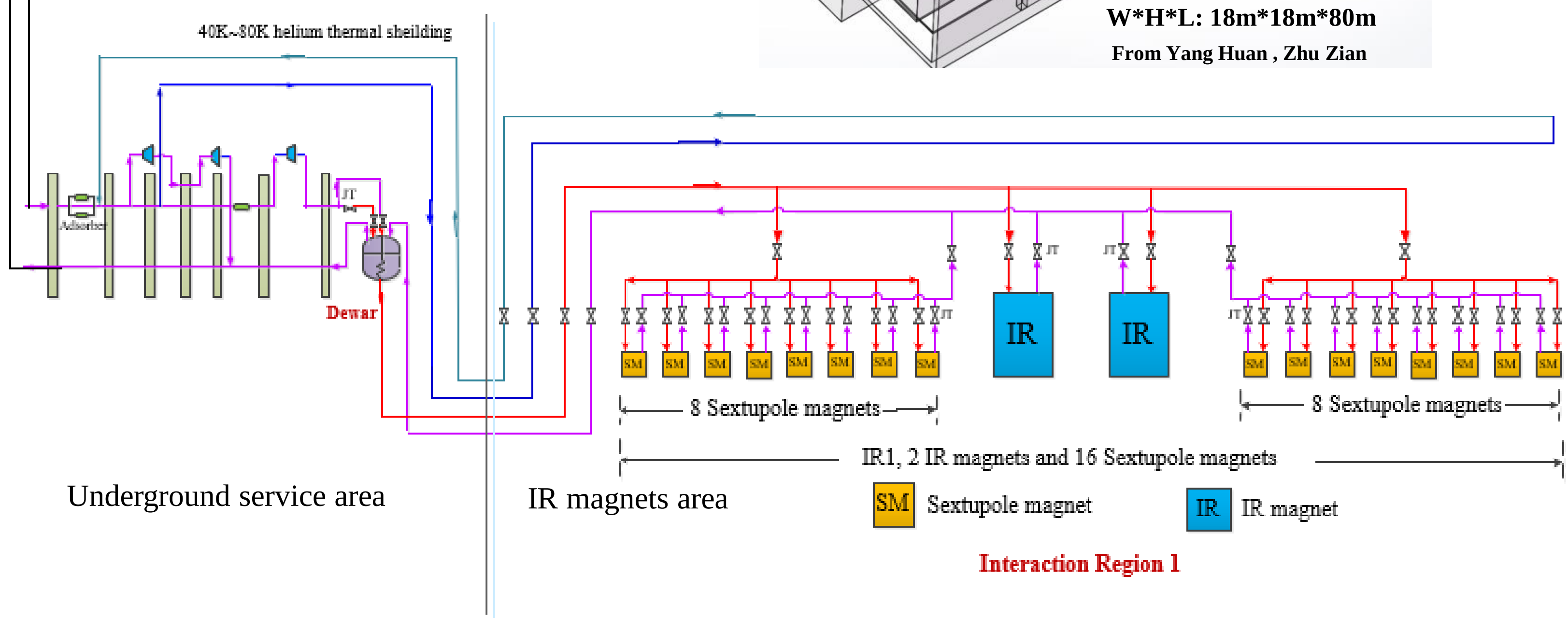
- The cryogenic systems incorporate high efficiency helium refrigeration ,produced by industry, (liquefaction) at 4.5 K, a distribution system with low heat-in leaks ,a large helium inventory (storage) and the cryogenic users (cryostat).
- The design of the cryostat and cryogenics system allowed the prior testing of the full cryogenic loop without magnet.
- CEPC cryogenic system should allow for rapid cool-down and warmup of limited lengths of the strings, e.g. for repairing or exchanging a defective unit.
- To ensure reliable operation, it should provide reasonable redundancy of functions among its components and sub-systems
- Personnel and equipment safety

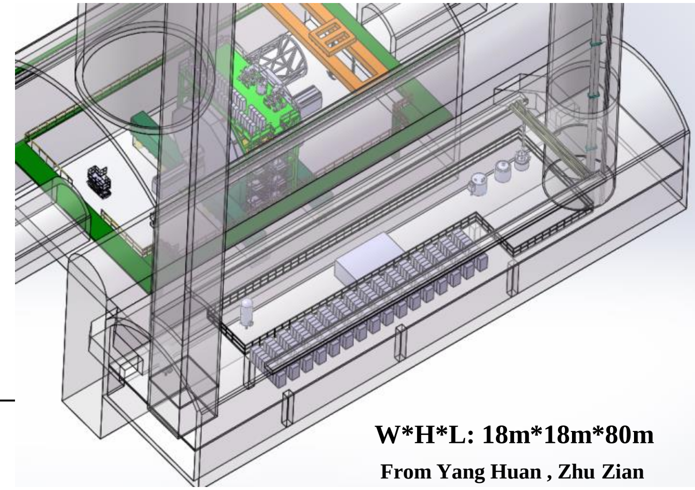
The temperature levels

- 40K to 80K for thermal shield protecting the cold masses.
- 4.5K to 20K for low temperature interception and for cooling the beam screens.
- 4.5K normal saturated helium or subcooled helium for cooling magnets and lower sections of the current leads.
- 20K to 300K cooling for resistive upper of the current leads.

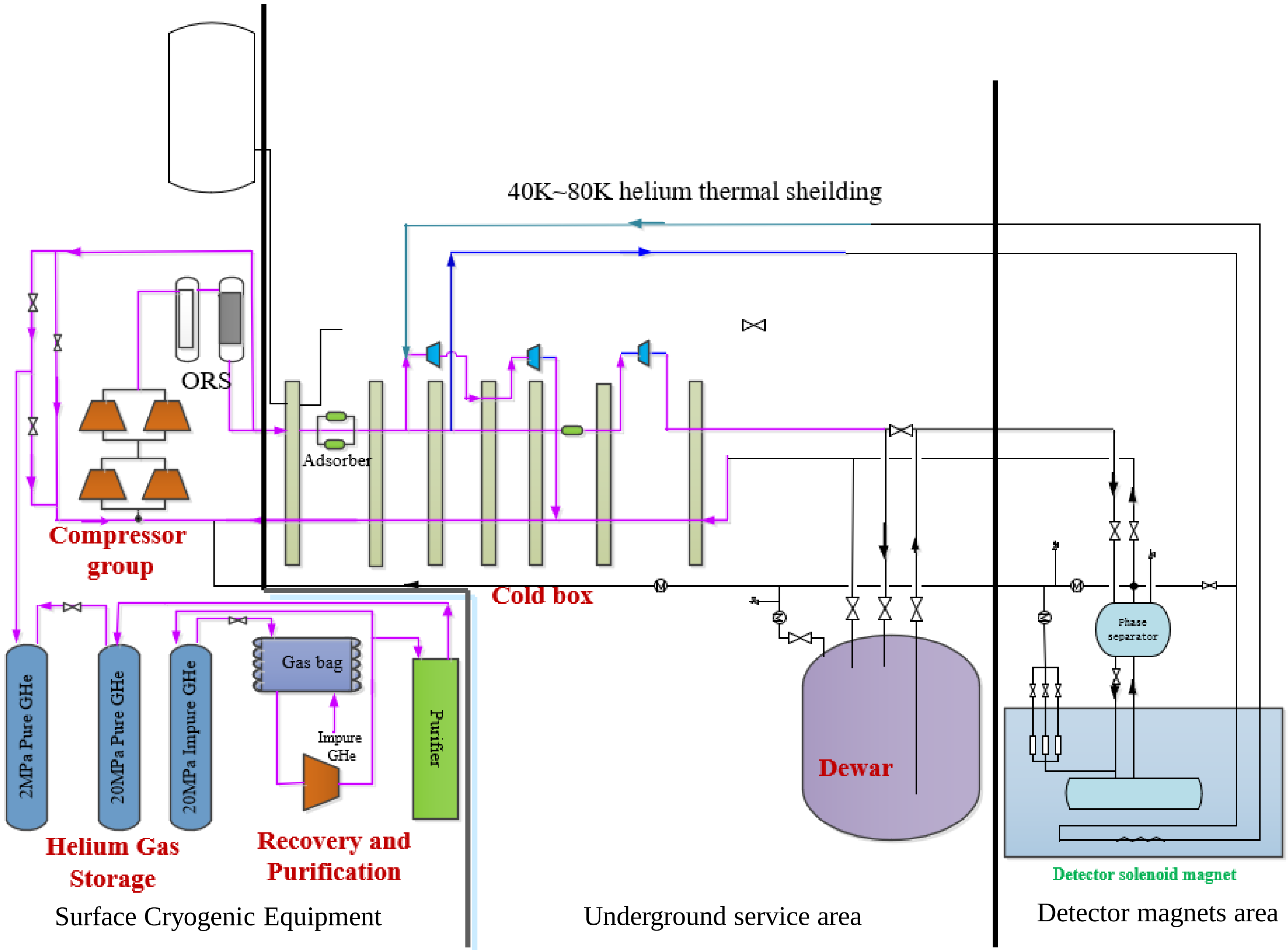
Cryogenic system schematic



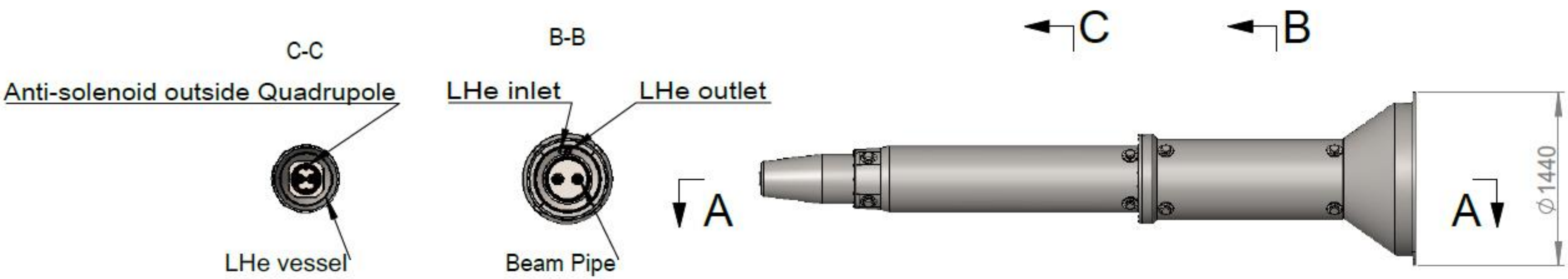




Cryogenic system schematic

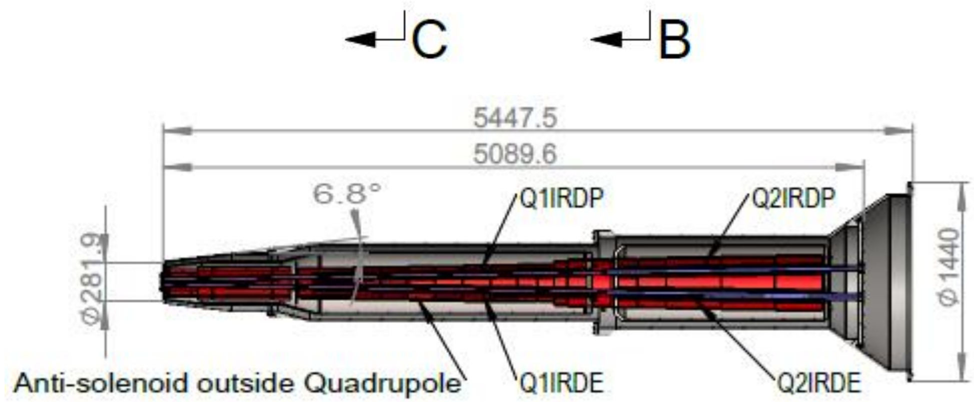


The Structure of Cryostat



Magnet-cryostat design:

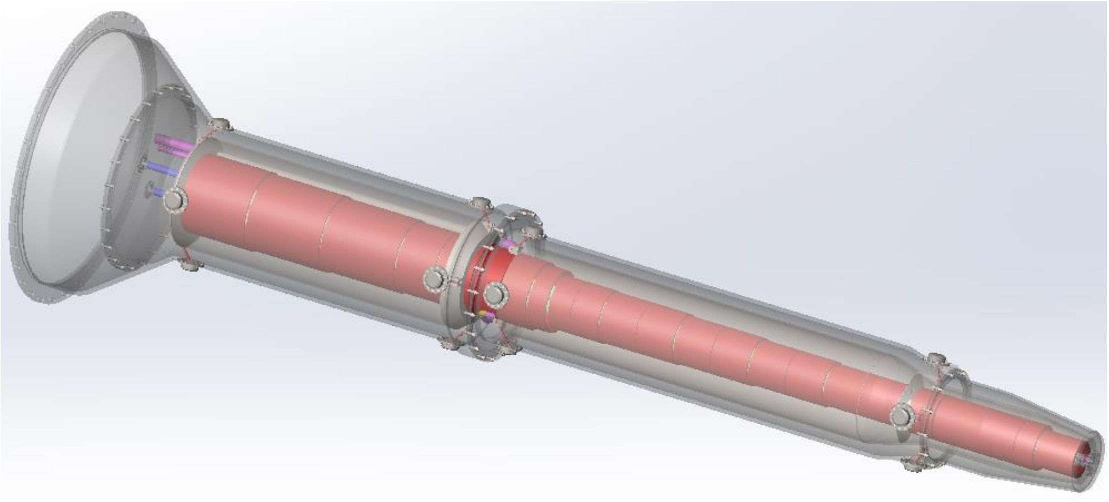
- superconducting magnets are assembled in the two helium vessel, respectively.
- Two beam pipes at room temperature pass completely through the helium vessel at 4K.
- Self-centered supports are designed to make the magnet positions after cool-down the nominal positon for the beam operation.

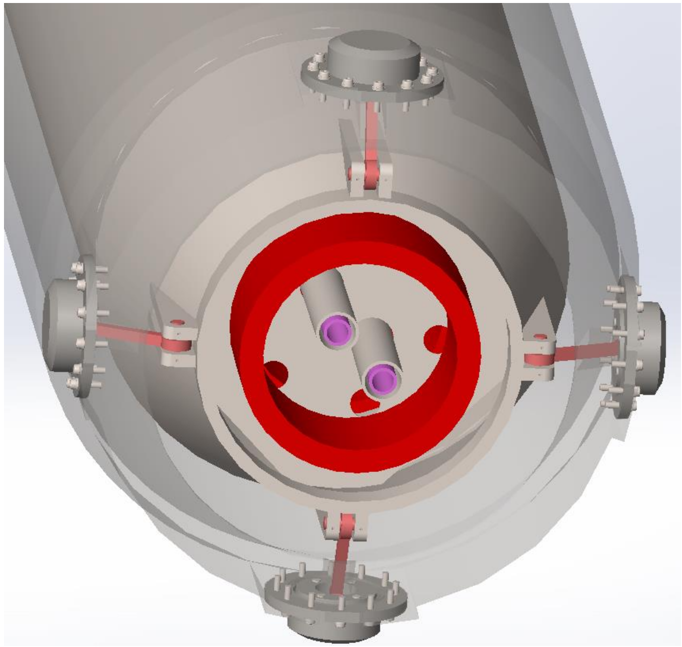


Magnet cryostat	Weight(Kg)
Total cold mass	1057.77
Front Lhe vessel	248.81
Rear Lhe vessel	248.96
Magnet	560

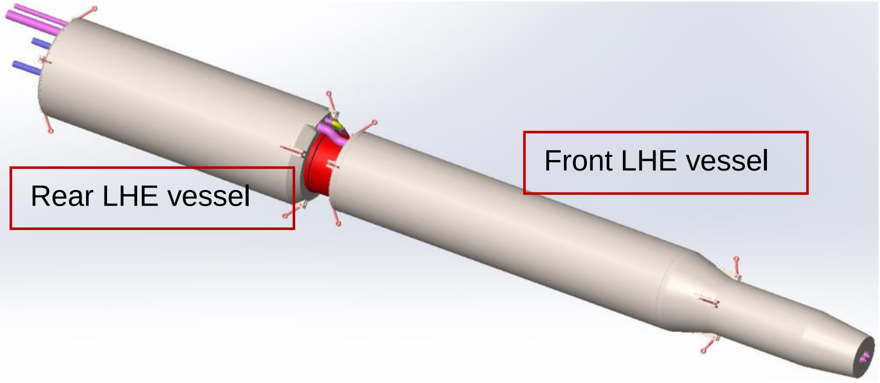
From Miaofu Xu

The Structure of Cryostat



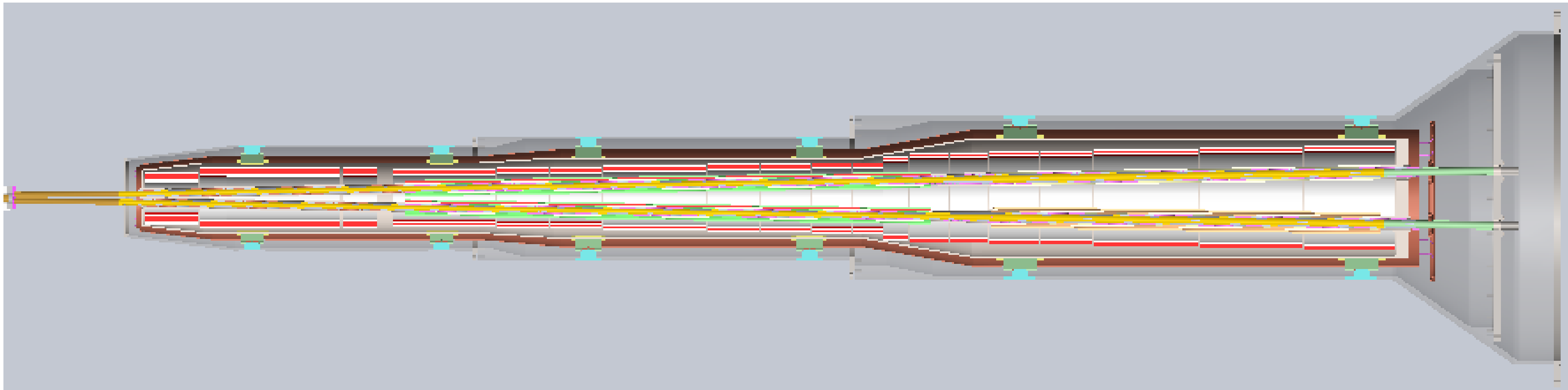


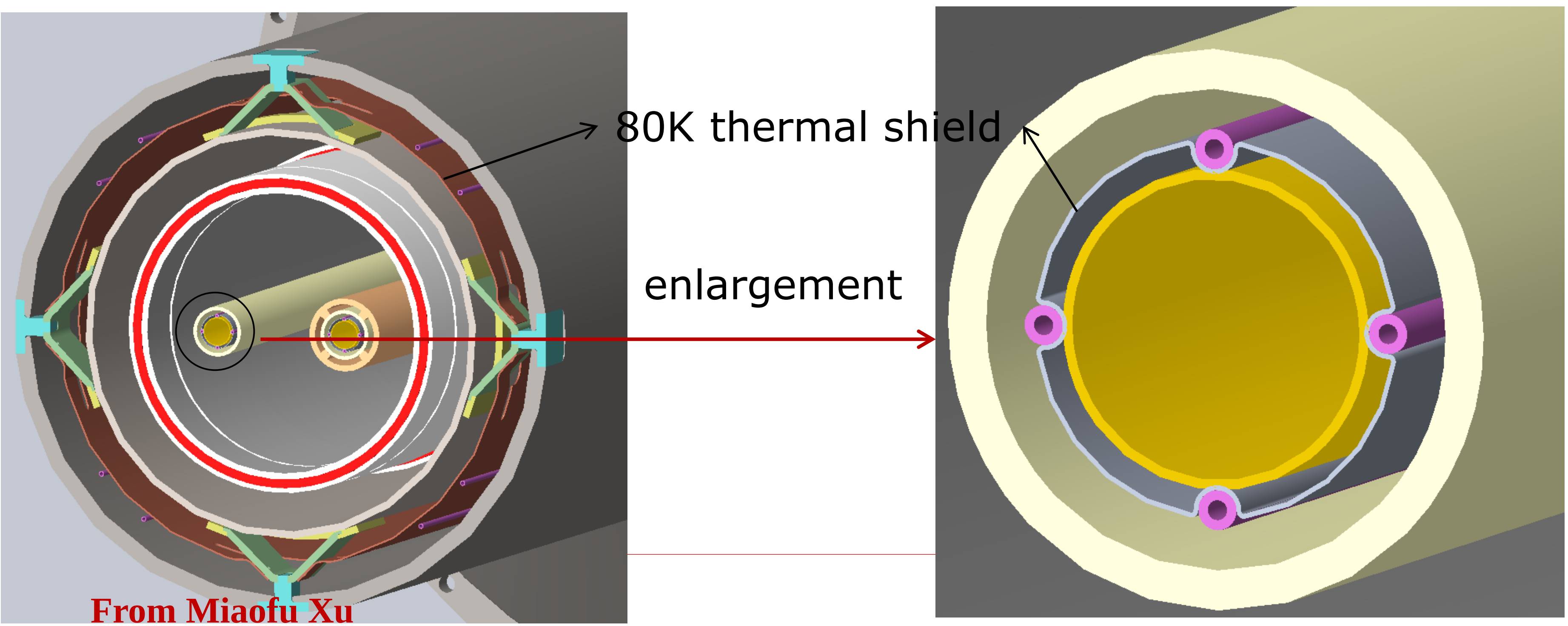
- The helium vessels, in which the SC magnets are assembled, are supported by the 8 rods from the vacuum vessel.
- To be made of non-metallic materials such as Carbon fiber (CFRP, T300)
- The multilayer insulation material and it's dressing process is very important to decrease the heat load



From Miaofu Xu

The Structure of Cryostat





Precision Thermometry

- The cryogenic system in the CEPC require to implement precision cryogenic thermometry on an industrial scale with long term robustness and reliability.
- The calibration of the series sensors will be performed by lakeshore or TIPC.
- Temperature calibration platform at IHEP.
- Collaboration R & D.

summary

- We started the design of the cryostat and cryogenic flow, and are gradually optimizing , next, we will start the cryogenic lines layout design。
- Refine temperature level and heat loads
- Calculation of the cryogenics process
- Simulation of the cryogenics process
- Simulation of magnet cryostat
- Research on precise temperature measurement